LV NATIONAL CONFERENCE
ON NUCLEAR PHYSICS

FRONTIERS IN THE PHYSICS OF NUCLEUS

June 28–July 1, 2005
Saint-Petersburg
Russia

BOOK OF ABSTRACTS

SAINT-PETERSBURG
2005

ST. PETERSBURG STATE UNIVERSITY
V.A.FOCK INSTITUTE OF PHYSICS
RUSSIAN ACADEMY OF SCIENCES
PETERSBURG NUCLEAR PHYSICS INSTITUTE
JOINT INSTITUTE FOR NUCLEAR RESEARCH

LV NATIONAL CONFERENCE ON NUCLEAR PHYSICS

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LV NATIONAL CONFERENCE ON NUCLEAR PHYSICS «FRONTIERS IN THE PHYSICS OF NUCLEUS».
BOOK OF ABSTRACS.

The scientific program of the conference presented in the book of abstracts highlights almost all modern achievements in nuclear physics such as: drip-line nuclei, high-spin and super deformed states in nuclei, multiphonon and multiquasiparticle states in nuclei, many-body problem in atomic nuclei, effective interactions in nuclei, nonlinear nuclear dynamics, neutron-rich nuclei, neutron halo, cluster radioactivity, quark associations and nucleon-nucleon forces, mesons and quarks in nuclei, hyper nuclei, synthesis of new super heavy elements, application of methods of nuclear physics in investigations of metallic clusters, reactions with nucleons and deuterons, reactions with heavy ions and nuclear fission, photo-nuclear reactions and reactions with electrons, radioactive nuclear beams, reactions with polarized particles, reactions with elementary particles, direct nuclear reactions, compound nuclei, statistical approach to the nuclear reactions theory, theory of relativistic nuclear collisions, double beta-decay and problem of neutrino mass, tests of theories of elementary particles interactions and conservation laws, nuclear spectroscopy of astrophysical objects, interactions of nucleus with electronic shell, mesonic atoms. accelerator techniques, nuclear instruments and methods, methods of analysis of nuclear experiments, application of experimental methods of nuclear physics to astrophysics, nuclear power engineering, ecological studies, medicine and other fields of investigations.

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CAPTURE CROSS SECTIONS IN VERY HEAVY SYSTEMS

N. Rowley[1], N. Grar[2], S.S. Ntshangase[3,4], R.A. Bark[3], S.V. Förtsch[3], J.J. Lawrie[3], E.A. Gueorguieva[3], S.M. Maliage[3,5], L.J. Mudau[3,5], S.M. Mullins[3], O.M. Ndwandwe[4], R. Neveling[3], G. Sletten[6], F.D. Smith[3], C. Theron[3]

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In intermediate-mass systems, strong couplings to collective excitations (rotational and vibrational states) of the target and projectile greatly enhance the sub-barrier capture cross section by giving rise to a distribution of Coulomb barriers [1]. For such systems, capture essentially leads directly to the formation of a compound nucleus (CN), which then decays to a stable or relatively long-lived evaporation residue (ER) through the emission of light particles (neutrons, protons and α-particles). Thus in such cases, the ER cross section is effectively the same as the capture cross section.

For very heavy systems the experimental situation is significantly more complicated due to the presence of quasi-fission (QF) (the rapid separation into two fragments before the CN is even formed) and by fusion-fission (FF), that is fission of the compound nucleus itself. This means that three cross sections need to be measured in order to reconstruct the total capture cross section. Although the ER essentially recoil along the beam direction, QF and FF fragments are scattered to all angles and require the measurement of angular distributions at many energies in order to obtain the excitation function (and barrier distribution) for capture. One may, however, try to obtain this quantity by exploiting unitarity and measuring instead the flux of particles coming from quasi-elastic (QE) scattering at the Coulomb barrier [2, 3].

Some new QE results obtained for the ^{86}Kr+^{208}Pb system at iThemba LABS in South Africa will be presented. The effect of channel couplings in this case will be discussed, as will the possible effects in "Dubna-style" reactions leading to superheavy elements. It will be shown that for these very high Z_1Z_2 systems, the Coulomb couplings can lead to a suppression of the capture cross sections at high energies, in a way that leads to an effective "extra-push" phenomenon [4]. However, at energies sufficiently below the nominal Coulomb barrier, where the fission probability of the CN will be smaller, enhancements can still persist.

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SYNTHESIS OF SUPERHEAVY ELEMENTS AT SHIP

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The experimental program at SHIP was concentrated on the synthesis of heavy elements using fusion reactions with Pb and Bi targets. Cross-sections were measured, which revealed a continuous decrease by about a factor of ten per two elements. For the synthesis of $^{277}112$ a cross-section of 0.4 pb was measured. For element 113 an upper limit of 160 fb was obtained during a total measuring time of 12 weeks. However, the isotope $^{278}113$ was successfully produced in a recent experiment at RIKEN. There, a cross-section of 55 fb was measured in a 20 weeks experiment. This experiment and the recent studies at SHIP demonstrated that a further upgrade of the experimental set-up is needed in order to reduce the necessary beam time at low cross-section values. As a first and important step of improvements at the UNILAC a new 28 GHz ECR ion source will be built and the first RFQ accelerator section will modified so that a 50% duty factor can be obtained by using the higher ionic charge states extracted from the ECR source. From the improvements we expect an increase of beam intensity by a factor of ten. In order to use these high beam intensities we already performed target test using chemical compounds of high melting point and a proper, more homogenous distribution of the beam intensity across the target. Based on the recent positive results obtained at FLNR-Dubna on the synthesis of superheavy elements using actinide targets, we presently prepare an irradiation of an UF_4 target with ^{48}Ca ions in order to study neutron rich isotopes of element 112. First results should be available at the date of this conference. It is planned to systematically study the synthesis of superheavy elements by irradiation of targets of uranium isotopes with beams of titanium, chromium etc., which are produced with high intensity at the UNILAC.

EXTENDED THEORY OF FINITE FERMI SYSTEMS FOR MAGIC AND NON-MAGIC NUCLEI

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A short review of results, status and perspectives of the Extended Theory of Finite Fermi Systems (ETFFS), which has been applied to collective excitations in the past 15 years, is given. The theory is an extention of the standard TFFS by A.B.Migdal to include in a consistent way the single-particle continuum and more complex $1p1h\otimes$phonon or $2qp\otimes$phonon configurations beyond the RPA or QRPA ones, i.e. the ETFFS takes into account three known mechanisms of giant resonance damping.

To a largest extent, the ETFFS was developed and applied to nuclei without pairing, see the review [1]. Quantitative explanation of the giant resonance widths was obtained, the complex configurations being given a half of the width. In addition , a large fraction of the observed gross and fine structure can be directly traced back to the specific complex configurations and the recent results of the (α,α') experiments in ^{40}Ca, ^{58}Ni were explained (see [1]).

In the past 5 years the ETFFS has been developed and applied actively to even-even and odd mas nuclei with pairing [2-6]. Recent calculations of the E1 pygmy resonance in Ca [5] and Sn [3,6] isotopes were shown that this resonance, which is important for (n,γ) and (γ,n) reactions, can not be explained without the inclusion of complex configurations.

Consistent use of the Green function method allowed to include and calculate some effects which have not been practically studied earlier.These are ground state correlations induced by complex configurations [1] and the second (or quasiparticle-phonon) mechanism of pairing [2]. Both of them can be studied in modern experiments.

Taking the single-particle continuum into account and the practical universality of the interaction parameters allow us to use the ETFFS for calculations of unstable nuclei. Perspectives and status of the necessary development of a self-consistent ETFFS as well as an application to nuclear data [6] are discussed too.

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MASS MEASUREMENTS AT THE STORAGE RING OF GSI

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Over last decade the systematic direct measurements of nuclear masses from a very broad range of exotic nuclides have been performed at SIS-FRS-ESR facility of GSI. Two pioneering methods: Schottky mass spectrometry (SMS) for cooled ions and Isochronous Mass Spectrometry (IMS) for hot ions have been invented to measure new masses in the beams of relativistic ions circulating in the storage ring. The IMS method [1] allows to measure the masses of nuclides with half-lives in the μs-region, whereas the SMS is much slower and nuclides with half-life longer than 1 s are only accessible [2]. In the IMS the storage ring is tuned in an isochronous mode. The specific property of IMS is that single ions are favorably detected in the storage ring.

Last measurements by IMS cover the vast mass regions of products from ^{70}Zn-fragmentation and from ^{238}U-fission [3]. Mass resolving power achieved was $2*10^5$ and typical mass uncertainties are 200-300 keV.

Many products of Zn-fragmentation measured by IMS are situated at the possible astrophysical r-process path, which can be developed at the relatively weak stellar conditions. Some of the products of relativistic fission (with Z~30-35 and Z~51 and 52) are also situated or are very close to the robust r-process path.

About half of masses measured directly by IMS for neutron-rich nuclides [3] are in disagreement with the mass evaluation AME-2003 [4]. Some differences exceed 2σ-values. The perils of indirect mass determination from β-decay spectroscopy, which was used so far for the most of neutron-rich heavy nuclides, are discussed. To revise the mass surface of this region of nuclear chart, new direct measurements are needed.

Future trends of mass measurements of very exotic nuclides are related to the new project ILIMA (Isomeric beams, LIfetimes and MAsses) which is proposed within the framework of new FAIR-facility at GSI [5]. Due to expected dramatic increase (by a factor of 10^4-10^5) of the production yields of nuclides in reactions (fission) with relativistic beams, about 1500 new mass values can be measured. The measurements are proposed to be done in two storage rings (one of them dedicated specifically to IMS and the other to SMS). Production of very high spin pure relativistic beams is also foreseen.

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RECENT RESULTS ON THE VERY HEAVY NUCLEAR SYSTEMS OF HYDROGEN AND HELIUM

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In a survey of clustering structures revealed in the halo nuclei ^{6}He and ^{8}He by means of direct reactions, new experiments realizing the quasi-free α,2α scattering (QFS) will be discussed in more detail. QFS occurring with α core bound in ^{6}He and ^{8}He was detected when helium target nuclei were bombarded by 25–30 MeV ^{6}He and ^{8}He projectiles. Correlated distributions obtained for the momentum values characteristic to the $\tilde{\alpha}$*nn* and *nn* subsystems obtained for ^{6}He from these experiments are discussed along with the possible specific limitations on the assumption of a pole mechanism for the α knock-out reaction in this specific case.

Beams of the lightest radioactive nuclei available nowadays allow us to gain a better understanding about superheavy hydrogen nuclei. The importance of taking into account competing reaction channels will be considered by the example of experiments aimed at the study of ^{4}H and ^{5}H nuclei produced in transfer reactions. Search for the resonance states of these nuclei is also complicated by the fact that the low-lying resonances are broad and overlapping. Correlation study made for the decay products of these resonance states turns out to be sometime indispensable condition for the identification of such resonance states. The observation of ^{5}H resonance states populated in the ^{3}H$(t,p)^5$H reaction will be discussed as a typical example of such study.

The ^{7}H nucleus most likely possesses unique decay dynamics: the four-neutron emission (or 5-body decay). The estimated ^{7}H decay energy has a large uncertainty making possible a very small decay width of the ground state resonance of this unknown nucleus. In an attempt to observe a long living quasi stable ^{7}H, produced in the reaction ^{2}H(^{8}He,^{7}H)^{3}He, we set an upper limit of 3 nb/sr for the reaction cross section. This corresponds to a ^{7}H lifetime less than 1 ns and allows us to estimate a lower limit of 50–100 keV for the ^{7}H decay energy in ^{3}H+4n.

EXPERIMENTAL STUDIES OF THE NUCLEAR SPATIAL STRUCTURE OF NEUTRON-RICH He AND Li ISOTOPES

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The nuclear spatial structure of neutron-rich He and Li isotopes has been studied by different methods. Thus, interaction cross sections and differential cross sections for elastic nucleus-nucleus and proton-nucleus scattering have been measured, momentum distributions of the nuclear fragments appearing in nuclear fragmentation and Coulomb dissociation reactions have been studied, laser spectroscopy experiments have been performed. Some results obtained in these investigations are discussed in the present talk with an emphasis on the studies performed by proton elastic scattering at intermediate energy [1,2]. The results of experimental studies are compared with theoretical predictions.

The performed investigations have shown that the ^{6}He, ^{8}He and especially ^{11}Li nuclei have a well developed halo structure. The data on small-angle proton-nucleus elastic scattering allow one to receive information both on the core and halo sizes. By combining the results obtained from the differential proton elastic scattering cross sections [1,2] with those obtained by the laser spectroscopy experiments [3] and experiments on Coulomb dissociation [4] it is possible to receive detailed information on the spatial structure of the studied nuclei. In particular, in the case of the ^{6}He nucleus, the values of the proton, neutron and total matter rms radii are correspondingly R_p=1.91(2) fm, R_n=2.68(14) fm and R_m=2.45(10) fm, the halo radius being R_h=3.32(31) fm. The radius of the proton distribution in the centre of mass of the core is R^*_p=1.55(10) fm, while the size of the di-neutron halo cluster is R^*_h=2.45(48) fm. The data on proton scattering from ^{11}Li are consistent with significant core polarization in this nucleus. The determined rms matter radii of the He and Li isotopes are shown in Fig. 1.

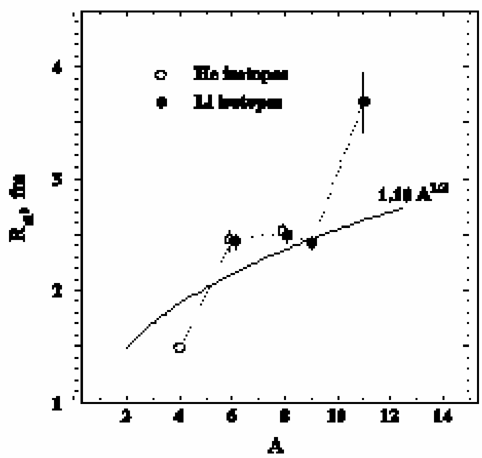

Fig. 1. Nuclear matter radii of the He and Li isotopes determined from the data on intermediate-energy proton elastic scattering (hollow and filled circles) as a function of the atomic number A. The dotted line is drawn to guide the eye. The solid line -- A $^{1/3}$ – dependence

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A DOORWAY TO BORROMEAN HALO NUCLEI: THE SAMBA CONFIGURATION

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We exploit [1] the possibility of new configurations in three-body halo nuclei - Samba type - (the neutron-core form a bound system) as a doorway to Borromean systems. The nuclei ^{12}Be, ^{15}B, ^{23}N and ^{27}F are of such nature. The Samba configuration is to be contrasted with the Tango one [2] seen in, e.g., the hypertritron, where the two subsystems, Λ-*n* and Λ-*p*, are not bound, whereas the *n*-*p* subsystem is bound. In fig. 1 we show our calculation of the radii of the nitrogen and fluorine isotopes using the three body model of Ref. [3]. The nucleus ^{23}N with a half-life of 37.7 s and a halo radius of 6.36 fm is an excellent example of Samba-halo configuration.The two neutron separation energy in Samba halo nuclei is larger than the one neutron separation energy, making the transfer of two neutrons at very low energy less likely than in Borromean halo nuclei. The fusion below the barrier of the Samba halo nuclei with heavy targets could reveal the so far elusive enhancement and a dominance of one-neutron over two-neutron transfers, in contrast to what was found recently for the Borromean halo nuclear reaction ^{6}He + ^{238}U.

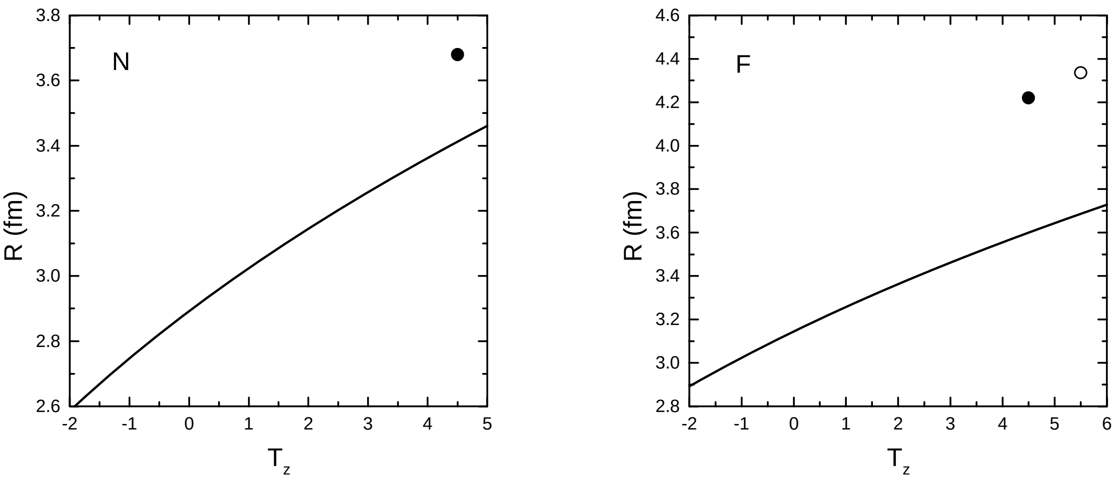

*Fig. 1. Halo radii of our candidates for two-neutron halo nuclei in nitrogen and fluorine isotopes. The full circles are the Samba type nuclei (*See ref. [1] for details*) and the open circles are the Borromean nuclei. The solid line represents the isotope radii calculated assuming a normal nature of the isotope. T_z = (N-Z)/2 is the isospin projection.*

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SEARCH FOR NEUTRINOLESS DOUBLE BETA DECAY WITH NEMO-3 AND SUPERNEMO

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Since February of 2003 the NEMO-3 detector is operating in the LSM (Modane, France, 4800 m.w.e.) searching for neutrinoless double-beta decay ($0\nu\beta\beta$), which would be an indication of new physics beyond the Standard Model. After analysis of data collected during 2003-2004 no evidence (see Fig.1) of $0\nu\beta\beta$ was found neither in ^{100}Mo, nor in ^{82}Se with the corresponding limits (90% CL):

$$T_{1/2}^{0\nu\beta\beta}(^{100}\mathrm{Mo}) \geq 4.6 \cdot 10^{23}\ \mathrm{y} \quad \Rightarrow \quad \langle m_\nu \rangle \leq 0.6\text{-}1.0\ \mathrm{eV},$$

$$T_{1/2}^{0\nu\beta\beta}(^{82}\mathrm{Se}) \geq 1.9 \cdot 10^{23}\ \mathrm{y} \quad \Rightarrow \quad \langle m_\nu \rangle \leq 1.3\text{-}3.6\ \mathrm{eV},$$

which are better ones in comparison with current limits for these nuclei [1-2]. The best world limit for $\beta\beta$-decay with Majorona emission was also obtained:

$$T_{1/2}^{\beta\beta\chi}(^{100}\mathrm{Mo}) > 1.8 \cdot 10^{22}\ \mathrm{y}\ (90\ \%\ \mathrm{of\ CL}) \Rightarrow \chi < (5.3\text{-}8.5) \cdot 10^{-5}.$$

A sensitivity $\langle m_\nu \rangle \sim (0.2\text{-}0.35)$ eV on ^{100}Mo will be reached by NEMO-3 collaboration in 2008.

R&D program of next generation SuperNEMO project was started in 2004. The main goal of SuperNEMO is to reach $T_{1/2}^{0\nu\beta\beta} \sim 2 \cdot 10^{26}$ y level with ~100 kg of ^{82}Se, which corresponds $\langle m_\nu \rangle \sim 50$ meV sensitivity. The advantages of SuperNEMO are successful experience with NEMO-1/2/3, relatively small mass of $\beta\beta$-source, unique $0\nu\beta\beta$-information from tracko-calometric method, and ultra low background. The main R&D directions for SuperNEMO are the improvement of energy resolution of the calorimeter up to 5-7% at 3 MeV (against 11% in NEMO-3), production, and purification of $\beta\beta$-source, as well as design of SuperNEMO detector.

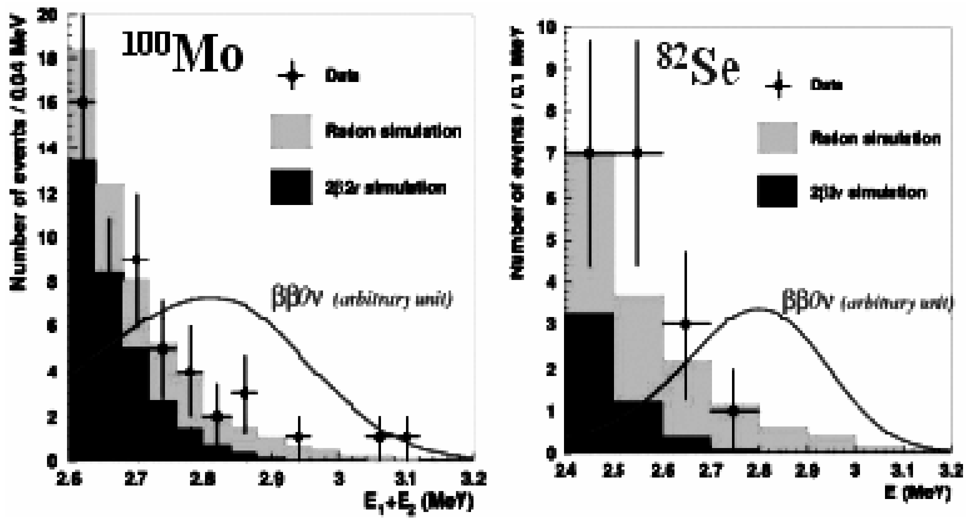

Fig. 1. Tail-zoomed spectrum of the energy sum of the two electrons from ^{100}Mo (left) and ^{82}Se (right). Points are experimental data; solid lines and painted regions are simulations.

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LIQUID-FOG AND LIQUID-GAS PHASE TRANSITIONS OF HOT NUCLEI

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Thermal multifragmentation is a new multibody decay mode of very hot nuclei characterized by the copious emission of the intermediate mass fragments (IMF).The hot nuclei are produced as target spectators in the collisions of light relativistic ions with heavy targets. The 4π-setup FASA on the Nuclotron beam (Dubna) is used in this study. This process is considered as the "liquid-fog" phase transition which takes place at the temperature T_t =(5-7) MeV. The hot nucleus expands by the thermal pressure and enters the phase-unstable spinodal region. Due to density fluctuations, a homogeneous system is converted into a mixed state consisting of liquid droplets (IMF) and nuclear gas interspersed between them. So, the final state of this transition is a nuclear fog, which explodes due to Coulomb repulsion to be detected as multifragmentation. The liquid-fog phase transition is a specific nuclear phenomenon because it is highly influenced by the Coulomb field. This scenario of the spinodal decomposition is proved by the observations given in this talk.

Top of the spinodal region corresponds to the critical temperature T_c for the liquid-gas phase transition, at which surface tension vanishes. The critical temperature is found to be T_c = (17±2) MeV from the best fit of the calculations within the statistical model of multifragmentation (SMM) to the data for fragment charge distribution in *p*(8.1GeV)+Au collisions.

Further analysis of the data results in conclusion that there are two characteristic volumes of the system in this process. The first one, V_t=(2.6 ± 0.3)V_o, corresponds to the "transition state" on the top of fragmentation barrier, at which pre-fragments are actually formed but still interact by nuclear force. The second one, V_f = (5.0 ± 1.0) V_o, is the freeze-out volume filled by well separated fragments. In the terms of ordinary fission, it corresponds to the multi-scission point. The corresponding mean densities are ρ_t= (0.38± 0.04)ρ_o and ρ_f= (0.2± 0.04)ρ_o, where ρ_o is normal nuclear density.

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DIRECT AND SEMIDIRECT PHOTONUCLEON REACTIONS IN THE VICINITY OF THE ISOVECTOR GIANT DIPOLE AND QUADRUPOLE RESONANCES

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In this summary talk some results of recent theoretical studies of the direct+semidirect and semidirect (DSD and SD) photonucleon reactions [1-3] are supposed to be presented. We attempt to describe in a semimicroscopic way (i) the cross sections of the DSD (γ,n)- and (n,γ)-reactions in the vicinity of the isovector giant dipole resonance (IVGDR) [1]; (ii) the cross sections of the DSD and SD (γ,p)-reactions accompanied by excitation of, respectively, the $T_<$ - and $T_>$-component of the IVGDR in not-too-heavy nuclei [2]; (iii) the asymmetry (relatively 90°) of the angular distribution of the products of the DSD+SD photoneutron reactions in the vicinity of the isovector giant quadrupole resonance (IVGQR) [3]. In our studies we use a semimicroscopic approach based on both the continuum-RPA method and a phenomenological treatment for the spreading effect. Within the approach a realistic phenomenological mean field and the (momentum-independent) Landau-Migdal particle-hole interaction bound by some selfconsistency conditions are used, as input quantities with parameters taken from independent data. As applied to description of isoscalar giant resonances, a modern version of the approach is formulated in Ref. [4]. At first, abilities of the approach have been checked by description of the strength functions of the IVGDR and its charge-exchange partners. As a result, we are able to describe the isospin splitting of the IVGDR in not-too-heavy nuclei. Two specific model parameters are fixed for each considered nucleus from a comparison of the calculated and experimental photoabsorption cross sections. They are: (i) the intensity of isovector momentum-dependent forces (taken effectively into account); (ii) the intensity of the energy- and radial-dependent smearing parameter. Then, other properties of the IVGDR and its charge-exchange partners, the main properties of the IVGQR and, that is most impotant, the cross sections of the above-mentioned DSD and SD photonucleon reactions are calculated without the use of free model parameters. The calculation results obtained for a number of singly- and doubly-closed-shell nuclei are compared with available experimental data.

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NUCLEAR CLUSTERS AND COVALENT NUCLEAR MOLECULES

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It has been recognised that in neutron-rich light nuclei very strong clustering phenomena appear due to the predominance of weakly bound states. The same feature appears in excited states close to the decay thresholds. Recent interest in nuclear clustering has reemerged with many studies of molecular structure in loosely bound states. Experimental and theoretical works show that extreme deformations occur in these cases, which in the deformed shell model are referred to as super- and hyper-deformation. Evidence for molecular structure in Beryllium isotopes (dimers) and in isotopes of Carbon (trimers) will be discussed. The chain states in the carbon isotopes are the first examples of deformed structures with an axis ratio of 3:1 (hyperdeformation). The description of these structures is, however, not possible in the shell model. Another feature related to clustering is the development of octupole deformations, or nuclei with intrinsically asymmetric shapes. Asymmetric nuclear molecular states give rise to rotational bands as inversion parity doublets, as observed for rotational bands in isotopes of $^{13\text{-}14}$C and $^{20\text{-}21}$Ne. These states must be described by molecular models, based on clusters and neutrons in covalent orbits. Strongly deformed molecular shape-isomeric states consisting of clusters and covalent neutrons are expected in many nuclei with multi-centre features at or below the cluster thresholds. The observed structures go well beyond the shell model structures described by the mean field approach.

ALPHA-PARTICLE CONDENSATION IN NUCLEI: EXPERIMENTAL PROBLEMS

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Recently it was supposed [1] that *n*α light nuclei may have structures resembling the diluted gas of α-particles which could be considered as Bose-Einstein condensate (αBEC) in nuclear systems. If found it would constitute a new form of nuclear matter. At present time the only more or less definite candidate for αBEC state predicted by theory is the second 0^+ - state of ^{12}C (Ex = 7.65 MeV) located near the threshold $^{12}C \rightarrow 3\alpha$. Getting evidence that this particular level really possesses of some properties of αBEC is of vital importance to the whole hypothesis of the possibility of BEC formation in nuclear systems and would stimulate the search of other examples in different nuclear mass regions.

We discuss several possible experimental approaches to study the properties of interest of the 7.65 MeV level of ^{12}C. Among them are:

* Shift of the positions of the rainbow minima in the inelastic scattering to this level (as it was originally proposed in [2]).

* Extraction of the empirical inelastic form-factor from the α- and ^3He-scattering and comparison it with theoretical predictions.

* Getting information on the ^8Be transfer reactions form-factor.

We used some of existing data for the analysis. However, we came to the conclusion that new measurements of $^{12}C(\alpha,\alpha')^{12}C(7.65)$ inelastic scattering at ~ 120 MeV in the full angular range would be most adequate to solving of the problem. Such proposal was submitted to JYFL cyclotron laboratory.

The possibility of observation of αBEC effects in heavier *n*α nuclei is also discussed. In particular, ^{112}Ba is of great interest due to possible existence of alpha-particle "halo" outside $Z = N = 50$ core [3].

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PHENOMENOLOGICAL DESCRIPTION OF α-DECAY HALF-LIVES OF HEAVIEST NUCLEI

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As most of known superheavy nuclei decay by α emission, it is important to have a realistic model for description of this process. Two observables are to be described: decay energy Q_α and half-life T_α. The energy Q_α is presently described rather well (cf. e.g. [1,2]). A more complex problem is the description of T_α .

The objective of this paper is to discuss the quality of description of T_α by presently used phenomenological models. Some improvements of the models are proposed. The idea is to have rather simple models with a rather small number of adjustable parameters.

A reasonable model is found which uses 6 adjustable parameters to describe relatively well T_α of about 210 heaviest (above lead) known α emitters. These are even-even, odd-even, even-odd and odd-odd nuclei. Another model, with only 5 parameters, leads to results of a similar quality. Some problem is with inclusion to the models effects of shell structure, which are not contained in Q_α .

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SEARCH FOR SCISSION NEUTRONS USING SPECIFIC ANGULAR CORRELATIONS IN ^{235}U FISSION INDUCED BY SLOW POLARIZED NEUTRONS

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The experimental data concerning scission or pre-fission neutrons are very contradictory - the relative part of this neutrons in the prompt fission neutrons is vary from 1% till 35% due to arbitrary assumptions made in different analysis [1]. To solve this problem we've used new alternative method to search for the scission neutrons. Firstly we've searched for the left-right asymmetry of the prompt fission neutron emission in ^{235}U fission induced by polarized thermal neutrons. The correlation can be described by expression:

$$W = (1 + B\, \boldsymbol{P}_{scn}\, [\boldsymbol{P}_{in}, \boldsymbol{\sigma}]),$$

where $\boldsymbol{P}_{in}$ and $\boldsymbol{\sigma}$ - are the momentum and spin of incident thermal neutron, $\boldsymbol{P}_{scn}$ - the momentum of prompt fission neutron, B - the correlation coefficient.

The magnitude and sign of B depends on the quantum numbers of initial and final states of the transition and therefore it should be washed out for neutrons evaporated by excited fragments due to summation or averaging over all huge number of fragments states. But it does not the case for scission neutrons because the number of initial states for their emission should be not so large. We have found that $B = (-5.8 \pm 1.4)\cdot 10^{-5}$ for the angle 90^0 between $\boldsymbol{P}_{scn}$ and the fission axis [2].

The second experiment have been performed on the polarized cold neutron beam of the reactor BER-II of Hahn-Meitner Institut. We've measured the P-odd asymmetry of prompt fission neutrons emission. The correlation that we've searched is $W(\theta) = \text{Const.}\,(1 + A\, \boldsymbol{P}_{scn} \bullet \boldsymbol{\sigma}) = \text{Const.}\,(1 + A \cos\theta)$, where θ is the angle between $\boldsymbol{P}_{scn}$ and $\boldsymbol{\sigma}$. The fission axis was orthogonal to the $\boldsymbol{P}_{scn}$. We've found that coefficient A is equal to $(2.7 \pm 0.8)\cdot 10^{-5}$ [3]. The measurement of the dependence of A on the angle between $\boldsymbol{P}_{scn}$ and fission axis is in progress. The results will give us the relative part of scission neutrons in the total number of the prompt fission neutrons.

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BIMODAL FISSION IN BINARY AND TERNARY SPONTANEOUS FISSION OF ^{252}Cf

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The hot bimodal fission of ^{252}Cf is re-examined with new high statistics data. We constructed a γ-γ-γ coincidence cube for binary fission and an LCP-gated γ-γ matrix for ternary fission. By identifying the secondary fission fragments from their γ-ray transitions, we measure the yields for various fission splits. The normal neutron yield distribution is found to be Gaussian as expected for Xe-Ru. However, the binary fission split of Ba-Mo is found to exhibit a bimodal neutron distribution with the "hot" mode corresponding to ~5% of the total yield. In α-ternary fission, the first measurements of yields for specific fission splits are presented. The Te-α-Ru and Xe-α-Mo neutron yields are fit well with a single mode, but the Ba-α-Mo split shows evidence for an enhanced hot mode with an intensity of ~15% of the normal mode.

QUANTUM AND THERMODYNAMICAL QUALITIES OF BINARY AND TERNARY FISSION OF NUCLEUS

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In the frame of the quantum theory of binary and ternary fission [1] the quantum and thermodynamical characteristics of different fission stages are investigated. The effect is analyzed of Coriolis interaction which mixes the nuclear spin's projections *K* for highly-exited states of deformed nuclei because of dynamical enhancement effect [2]. It is shown that A. Bohr's concept [3], based on principal role of transitional fission states for fission widths and fission fragments angular distributions, is compatible with the properties of Coriolis interaction only if the fissile nucleus near scission point is cold (or not thermalized) in spite of the nonadiabatic character of nuclear collective deformation motion. This conclusion contradicts the traditional fission models, which use the evaporational mechanism of fission fragments and of third particle (for ternary fission) formation.

The remarkable role of superfluid and pairing nucleon-nucleon correlations in the formation of fission products and in classification of fission transitions is demonstrated. It is shown that the thermalization processes for two primary fragments go independently, which leads to different temperatures of fission fragments. For thermalized primary fission fragments the distributions are constructed of their spins and spin projections *K,* which define the characteristics of prompt neutrons and gamma-quanta emitted by these fragments.

The nonevaporational mechanism of third particle formation in ternary fission is discussed, which generalizes the mechanism proposed for alpha-particle [4]. This mechanism is connected with the third particle transitions from cluster states of fissile nucleus neck into continuous spectrum states induced by shake-off effects following from nonadiabatic character of nuclear collective deformation motion. The superfluid correlations and nonevaporational mechanism give the possibility to explain even-odd charge and mass effects in the third particle yields for ternary fission as well as the energy and angular distributions of the third particles (by taking into account time-dependent Coulomb barrier defined by the sum of the Coulomb and nuclear potentials of interaction between the third particle and heavy fission fragments).

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NUCLEAR LEVEL DENSITIES NEAR FILLED SHELLS FROM NEUTRON EVAPORATION SPECTRA IN (*p,n*) REACTION

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Nuclear level density is an area of considerable interest in nuclear physics being very important for the creation of consistent theoretical description of excited nucleus properties and in making nuclear reaction cross-section calculations in the framework of statistical model. The general features of nuclear level density are known, but the existing data are differed often in 1.5 times, and its isotopic dependence, knowledge of which is very important for astrophysical nucleosynthesis calculations, are studied poorly for lack of the experimental information. The experimental data on the nuclear level densities for many nuclei are derived, in the main, from the analysis of low-lying level and neutron resonance data. But this information is limited to rather narrow ranges of excitation energy, spin and (*N-Z*) value, and its extrapolation can lead to essential errors both in absolute value of nuclear level density and its energy dependence, especially, in transition field from well-identified discrete states to continuum part of excitation spectrum. Obviously, it is necessary to attract other experimental methods of nuclear level density determination with scope of more wide ranges of excitation energy, spin and (*N-Z*) value. Such method has been the study of the spectra of particles emitted in nuclear reactions. In this case the type of reaction and the energy of incident particles should be chosen so that the contribution of nonequilibrium processes was minimum. For the middle and heavy nuclei these conditions are best satisfied with (*p,n*) reaction at proton energy up to 11 MeV. In the present work the differential neutron emission cross-sections in (*p,n*) reaction on isotopes of tin, lead and bithmuth in proton energy range of (7-11) MeV have been measured and analysed in the framework of statistical theory of nuclear reactions. The absolute values of the nuclear level densities of ^{116}Sb, ^{118}Sb, ^{122}Sb, ^{124}Sb, ^{204}Bi, ^{206}Bi, ^{207}Bi, ^{208}Bi, ^{209}Po, their energy dependences and model parameters have been determined. In energy dependences of nuclear level density between well-known low-lying levels and continuum part of excitation spectrum is displayed the structure connected with shell unhomogeneties of a single-particle state spectrum for nuclei near filled shells. Isotopic dependence of nuclear level density is found out and explained. It is shown also that the obtained data differ essentially from predictions of nuclear level density model systematics.

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ON DE-EXCITATION OF β- AND γ- ROTATIONAL BANDS IN NONSPHERICAL EVEN-EVEN NUCLEI

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The multipole-mixing parameters of dipole and quadrupole radiation δ have been considered by us before for γ - transitions in even-even spherical nuclei [1, 2]. These parameters were determined for many γ-transitions of 25 isotopes in our experiments with reactor fast neutrons.

Some regularities in the behavior of δ as a function of the neutron number were revealed and opposite signs of δ were established for $(2^+_2 – 2^+_1)$ and $(2^+_3 – 2^+_1)$ transitions.

In the past few years we investigated parameters δ for γ-transitions in nonspherical even - even nuclei $^{148, 150}$Nd, $^{148, 154}$Sm, ^{158}Gd, ^{162}Dy, $^{166, 168, 170}$Er, ^{176}Yb, $^{182, 186}$W. Analyzing our results and information of Nuclear Data Sheets we have found that in the most of cases the next regularities take place:

- opposite signs of δ for $(2^+_\beta – 2^+_1)$ and $(2^+_\gamma – 2^+_1)$ transitions,
- the same signs of δ for $(2^+_\beta – 2^+_1)$ and $(4^+_\beta – 4^+_1)$ transitions,
- the same signs of δ for $(2^+_\gamma – 2^+_1)$, $(3^+_\gamma – 2^+_1)$, $(3^+_\gamma – 4^+_1)$ and $(4^+_\gamma – 4^+_1)$ transitions,
- exceptions to these regularities are observed in the regions where the sign succession of δ for $(2^+_\beta – 2^+_1)$ and $(2^+_\gamma – 2^+_1)$ transitions changes.

The results obtained in (^{32}S, 4*n*γ) reaction showed that besides the quadrupole momentum in rotational band with ΔJ = 1 magnetic properties change weakly too (*g*-factor changes slightly and sign of δ for intraband transitions is invariable). Therefore sign conservation of δ can be expected for "crossover" transitions to which belong transitions from β- and γ-rotational bands to ground state rotational band.

M1 components in considered transitions are forbidden because of ΔK=2 for $(2^+_\gamma – 2^+_1)$ transitions and two-quasiparticle nature of $(2^+_\beta – 2^+_1)$ transitions. Because of these reasons and the collective nature of *E2* transitions |δ| values as a rule are large. M1 components can arise through allowed transitions between magnetic substates, for example, between ones corresponding to projections of magnetic momentum of $1i_{13/2}$ neutron state on the nuclear symmetry axis. Existence of these states with ΔJ =1 at low energy excitation can be established using excited level schemes of neighbouring nonspherical odd nuclei.

Considering spherical nuclei we have paid attention to the role of neutron $1h_{11/2}$ subshell in appearance of negative δ for $(2^+_2 – 2^+_1)$ transitions in the region of *N*=58 – 74 through of negative magnetic momentum for neutron in $1h_{11/2}$ state. The similar situation can be expected in the region of *N*=90– 112 because of neutron in $1i_{13/2}$ and $2f_{7/2}$ subshells. According to Nilsson's scheme the states *n*[523]5/2, *n*[660]1/2, *n*[651]3/2, *n*[642]5/2 in the region of *N*=90 – 96 and the states $n[633]7/2$, $n[624]9/2$ at N=100-106 define appearing $\delta < 0$ for γ-transitions (the state $n[615]11/2$ disposes higher N~110 and far from $n[624]9/2$ state). Different essential contributions of these states into 2^+_β and 2^+_γ excited levels result in different signs of δ for $(2^+_\beta - 2^+_1)$ and $(2^+_\gamma - 2^+_1)$ transitions. As a support of this proposal the correlation of large (≥50%) contribution of $1i_{13/2}$ components into one-phonon states 0^+_1, 0^+_2 and 2^+_2 [5] with negative sign of δ for transitions from these states to the ground rotational band are observed. Thus, sign of δ gives experimental information about two-quasiparticles structure of excited states for even-even non-spherical nuclei involved in γ-transition.

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MULTIPOLE MIXTURES IN ^{154}Sm γ-TRANSITIONS FROM THE $(n,n'\gamma)$ REACTION

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The angular distributions of γ - quanta from the ^{154}Sm $(n,n'\gamma)$ reaction with respect to the fast neutron beam were measured on IR-8 of Russian Research Center "Kurchatov's Institute" reactor. A scheme of levels and γ - transitions of ^{154}Sm nucleus was constructed, the new data about the levels, their characteristics and multipole mixtures δ in the γ - transitions were determined. A part of level scheme with found values δ up to 2 MeV energy is presented in Table.

For γ-transitions 1095.86 keV and 1070.68 keV it is necessary to select the $\delta > 0$ variant because the first one-phonon excitation in ^{154}Sm is determined in mainly proton two-quasiparticles configurations: *pp*413↓413↓ and *pp*532↑532↑.

E_i, keV	$J_i^\pi K$ - $J_f^\pi K$	E_γ, keV	I_γ, rel. units	δ, Δδ
1177.81(4)	2^+0 - 2^+0	1095.86	36.3	+56 *+130 –25* or –0.42±*2*
1286.24(10)	2^+0 - 2^+0	1204.30	29.0	+0.8 *+15 –6*
1337.53(5)	4^+0 - 4^+0	1070.68	11.8	|δ| >50 or –1.1 ± *3*
1440.07(4)	2^+2 - 2^+0	1358.09	32.4	–8.5±*15* or –0.59±*3*
1539.22(5)	3^+2 - 2^+0	1457.23	29.7	–7.5±*10*
1664.86(7)	4^+2 - 4^+0	1398.00	11.2	–2.5 *+10 –25*
1805.21(15)	5^+2 - 4^+0	1538.35	5.5	0.00±*2* or –9±*2*
1878.94(22)	2^+ - 2^+0	1796.96	4.1	–1.5 *+8 –70*

STRUCTURE OF EXCITED STATES OF NEUTRON-RICH CARBON ISOTOPES

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The structure of the neutron-rich carbon isotopes ^{15}C, ^{16}C and ^{17}C has been studied using the three-neutron transfer reaction (^{12}C,^{9}C) on ^{12}C, ^{13}C and ^{14}C targets, respectively. Excited states up to 16 MeV, 17 MeV and 19 MeV have been observed in the three isotopes, respectively. The thirteen states observed in ^{17}C above the neutron threshold (S_n=0.73 MeV) were previously unknown. The measurements have been performed at the magnetic spectrograph at the Hahn-Meitner-Institut, Berlin.

For ^{17}C the lower-lying states are expected to have a three-neutron $(2s1d)^3$ configuration on a ^{14}C core. The chosen three-neutron transfer reaction is therefore the optimum reaction to populate states with this structure. Particle-hole excitations of the ^{14}C core, which has a closed (1*p*) neutron shell, would require high excitation energies. The large reaction *Q*-value of -46.93 MeV leads to a strong mismatch between grazing angular momenta of entrance and exit channels, therefore states with large spin and stretched configurations are preferentially populated. Accordingly, the strongest states in the spectrum could be identified as the lowest-lying $9/2^+$ and $11/2^+$ states. The observed states are compared to shell-model calculations using the code OXBASH [1], and tentative assignments could be made.

The level scheme of ^{16}C states populated in the (^{12}C,^{9}C) reaction [2] shows a striking similarity to the observed level scheme of ^{17}C**:** with a constant shift of -5.82 MeV the excitation energies of ^{16}C agree with those of ^{17}C within ±0.17 MeV for almost all states. A similar agreement is also found for ^{15}C states populated in the three-neutron transfer reaction, but the deviations are slightly larger. It is concluded, that all these states must have a common $(sd)^3$ structure populated in the three-neutron transfer, and the holes in the (1*p*) neutron shell, which are present from the ^{12}C and ^{13}C cores, respectively, introduce in ^{15}C and ^{16}C only a global shift of the corresponding levels with respect to ^{17}C.

A consistent decay scheme could be deduced from the analysis of the observed widths of the resonances assuming a one-neutron decay.

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NUCLEAR CHARGE RADII OF NEUTRON DEFICIENT TITANIUM ISOTOPES ^{44}Ti and ^{45}Ti

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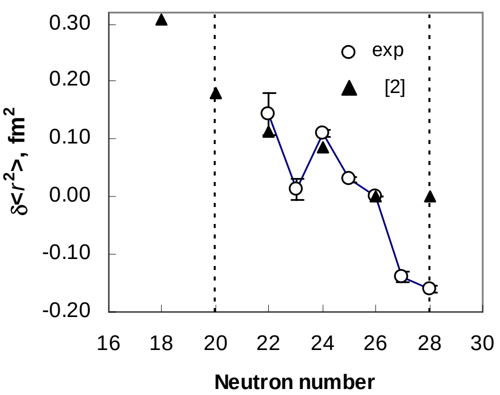
The aim of this work was to re-investigate the nuclear charge radii of ^{44,45}Ti and to obtain improved information on the charge radii changes in the isotopic sequence $^{44-50}$Ti. The new data set on Ti, in combination with the known charge radii of Ar, K and Ca in the $\nu f_{7/2}$ shell, offers an opportunity to obtain more complete overview on nuclear charge radii in the poorly investigated Ca-region. The already observed differences among the charge radii trends of neighbouring elements include the symmetry of the charge radii evolution, amplitude of the mid-shell maximum and the odd-even staggering [1]. From the point of view of the gross nuclear radii systematics such large structural differences are very unusual.



Experiments were performed using the online ion guide isotope separator (IGISOL) facility at the Cyclotron Laboratory, University of Jyväskylä. The results of the isotope shift measurements have been expressed in the corresponding nuclear radii. The charge radii evolution in the $f_{7/2}$ shell is characterised by (i) a non symmetric parabola-like trend; (ii) a "normal" well pronounced odd-even staggering effect and (iii) a continual increase in the charge radius of Ti going from $N = 28$ to the $N = 20$ shell closure. Various theoretical models have been compared to the experimental results and the predictions of the RMF theory [2] appear to most closely reproduce the experimental trends (see the Figure).

The data are compared with the known radii trends in the Ca-region. Four characteristics features of the isotopic and isotonic nuclear radii evolution in this region are observed and discussed.

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EXCITAION OF 135.5 keV ISOMERIC LEVEL OF ^{92}Nb NUCLEUS IN PHOTONUCLEAR REACTIONS

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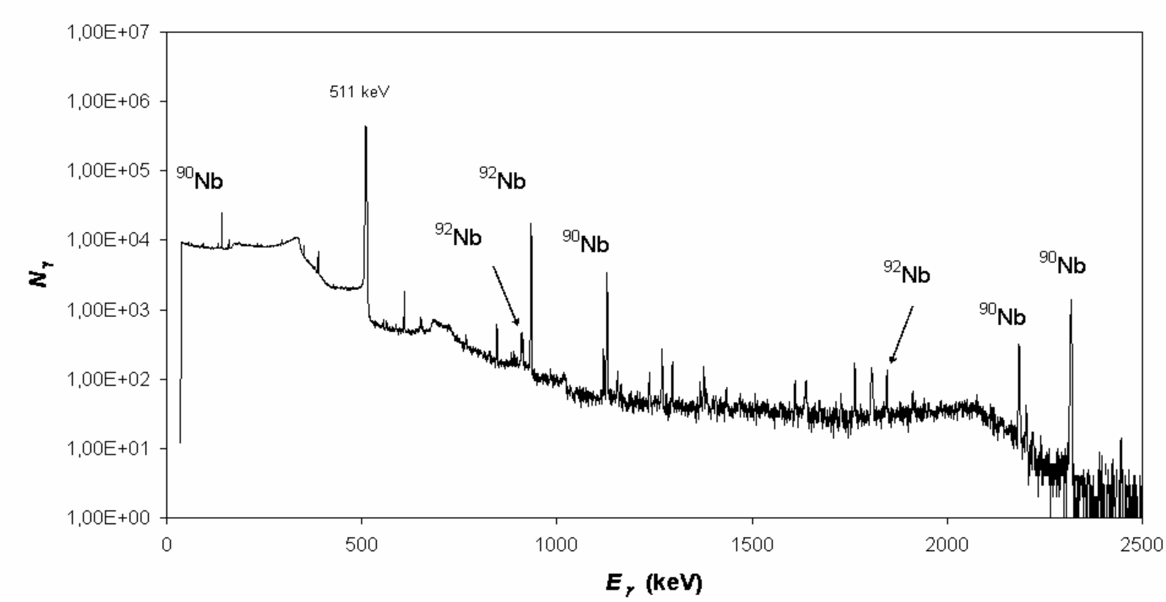
Skobeltsyn Institute of Nuclear Physics, Moscow State University

The ratio of photonuclear reaction yields in ^{93}Nb was experimentally determined, and 135.5-keV isomer of ^{92}Nb was excited.

The ^{92}Nb^m activity was produced by the ^{93}Nb$(\gamma,n)^{92}$Nb^m reaction with bremsstrahlung from the electron racetrack microtron RTM-70 with electron energy of 50 MeV in Skobeltsyn Institute of Nuclear Physics, Moscow State University. The spectrum of residual activity of irradiated sample of ^{93}Nb was recorded by HPGe detector with the efficiency of 30%.



According to experimental data it was found that the ratio of photonuclear reaction yields $Y_m(\gamma,n)/Y(\gamma,3n)$ in ^{93}Nb is 63 ± 1. The reaction yields of (γ,n), $(\gamma,3n)$ were estimated by 934 kev and 1129 keV lines correspondingly. Theoretical estimates based on evaporation model give $Y(\gamma,n)/Y(\gamma,3n) = 97$.

The ground state of ^{92}Nb formed in the (γ,n) reaction is rather long living ($t_{1/2} = 3.47\cdot10^7$ y) and its decays can not be observed. Thus experimental data allows to calculate only the reaction yield for isomeric level.

Good agreement of experimental value with theoretical estimates for the ratio of reaction yields point out that in case of (γ,n) reaction the considerable part of final nuclei ^{92}Nb are formed in isomeric state.

The energy of isomeric level of ^{92}Nb is 135.5 keV, half-life is 10.15 days. The experimental spectrum contains 912 keV, 934 keV, 1874 keV lines corresponding to the decay of this state.

COLLECTIVE BANDS IN ^{104,106,108}Mo

E.F. Jones[1], P.M. Gore[1], S.J. Zhu[1,2,3], J.H. Hamilton[1], A.V. Ramayya[1], J.K. Hwang[1], R.Q. Xu[2], L.M. Yang[2], K. Li[1], Z. Jiang[2], Z. Zhang[2], S.D. Xiao[2], X.Q. Zhang[1], W.C. Ma[4], J.D. Cole[5], M.W. Drigert[5], I.Y. Lee[6], J.O. Rasmussen[6], Y.X. Luo[1,6], and M.A. Stoyer[7]

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We have used our analyses of γ-γ-γ data (5.7×10^{11} triples and higher folds) from prompt γ-rays emitted in the spontaneous fission of ^{252}Cf taken with Gammasphere to study the collective bands in ^{104,106,108}Mo. We have investigated the high-spin states in neutron-rich ^{104,106}Mo and extended the one-phonon and two-phonon γ-vibrational bands and known two-quasiparticle bands to higher spin. The one- and two-phonon β-vibrational bands have remarkably close energies for transitions from the same spin states and identical moments of inertia. Several new bands are observed and are proposed as quasiparticle bands in ^{104,106}Mo, along with the first β-type vibrational band in ^{106}Mo. The possible configurations for the quasiparticle bands will be discussed. These quasiparticle bands have essentially constant moments of inertia near the rigid body value that indicate blocking of the pairing interaction. Candidates for chiral doublet bands in ^{106}Mo are strong. These are the first reported chiral vibrational bands in an even-even nucleus. In ^{104}Mo, the odd-spin level energies are closer to the next higher even-spin level than to the next lower even-spin level, so there is marked staggering. In ^{106}Mo, the level-energy differences increase with increasing spin up the band.

MEASUREMENT OF LIFETIMES OF SOME ^{156,158,160}Ho LEVELS BY DELAYED COINCIDENCE METHOD

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Joint Institute for Nuclear Research, Dubna, Russia

Lifetimes of some levels intensively populated by electron capture have been measured to elucidate the structure of low-lying states of odd-odd transition holmium nuclei (A = 156, 158, 160) and to explain so-called f-forbidden transitions. Parent erbium nuclides were produced at the YaSNAPP-2 ISOL complex. Measurement was carried out with a time spectrometer comprising two HPGe detectors with thin Be windows. A time-to-height converter operating in range 0–500 ns was used in the time channel. The measured three-dimensional matrix $N(E_1, E_2, t)$ was used for analysis of time distributions of γ-quanta E_1 and E_2. To this end, “windows” corresponding to the γ-transitions of interest and closely lying background “windows” were selected on the energy axes of the matrix. Those time distributions were compared with the reference “prompt” ones.

Earlier we found intensive (≈100% per decay) low-energy *E1* transitions of 7.13 and 7.70 keV in the decay of ^{160}Er and ^{158}Er respectively. Measuring delayed coincidences *Kx*(Ho)-γ7.1 in the ^{160}Er decay and γ71.9-γ7.7 in the ^{158}Er decay, we determined for the first time the lifetimes of the 1^+, 67.1 keV state in ^{160}Ho ($T_{1/2}$=30±8 ns) and the 2^+, 74.9 keV state in ^{158}Ho ($T_{1/2}$=60±10 ns). Additional measurement of γ24.3-γ341.6 coincidences in the ^{158}Er decay yielded the lifetime $T_{1/2}$=140±25 ns for the 99.2 keV (2^+) state de-excited by the 24.3 keV *M1* transition. From measurement of the *Kx*(Ho)-γ35.4 (*E1*) coincidences in the ^{156}Er decay the lifetime of the 1^+, 117.6 keV level in ^{156}Ho was found to be $T_{1/2}$=58.0±3.0 ns.

The 7.1, 7.7, 24.3 and 35.4 keV transitions are found to be highly hindered ($F_{hindr} \approx 10^3 \div 10^4$).

Probabilities of electromagnetic transitions between low-lying levels in odd-odd holmium nuclei are analyzed within the independent quasiparticle model.

The work was supported by the RFBR.

STRUCTURES AND ELECTROMAGNETIC TRANSITIONS RATES IN ODD-ODD HOLMIUM ISOTOPES

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Energies and transition probabilities (hindrance factors) in the odd-odd isotopes of Ho with A=156, 158, 160 were calculated within the model of the independent quasiparticles using the Woods-Saxon potential as a mean field and the BCS pairing interaction. The theoretical results are compared with experimental data [1]. The hindrance factor *Fw(calc/exp)* is equal 1 W.u./B (calc/exp).

The experimental ground states of ^{158,160}Ho have the momentum and parity $I^{\pi}=5^{+}$ and the structure $p7/2^{-}[523]+n3/2^{-}[521]$. Moreover, there is the low-lying $I^{\pi}=2^{-}$ isomer in these nuclei with the energy 60-70 keV which decays to the ground state through the *E3* transition with *Fw(exp)*=10^{4}-10^{5}.

The results of the calculations are presented for ^{158}Ho. The calculated excited quasiproton-quasineutron states with $I^{\pi}=2^{-}$ up to energy 450 keV are shown in the table. Under assumption that the γ-decay probability for *K*-forbidden states, when the transition involves the changes of the quantum numbers of both the quasiparticles, are much less than for *K*-allowed states, when the quantum numbers of one quasiparticle only is changed, it is seen from the table that the structure of the first excited state with $I^{\pi}=2^{-}$ has to be $7/2^{-}[p523]-3/2^{+}[n651]$ with the small admixture of $S^{+}[p411]+3/2^{-}[n521]$ configuration. It is also possible to have the small admixture of the complex configuration of the type "(quasiproton-quasineutron) plus phonon".

Energy	*Structure*	*Fw(calc)*
40	$7/2^{-}[p523] - 3/2^{+}[n651]$	5 10^{6}
257	$5/2^{-}[p532] - 1/2^{+}[n660]$	*F*-forbidden
392	$3/2^{+}[p411] + 1/2^{-}[n530]$	*F*-forbidden
410	$1/2^{+}[p411] + 3/2^{-}[n521]$	200

The work was supported by the RFBR.

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SHAPE AND CHARGE RADII OF THE Pb ISOTOPES AT NEUTRON MIDSHELL ($N = 104$) BY SIMULTANEOUS LASER AND NUCLEAR SPECTROSCOPY

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The study of Pb isotopes has been extended to very neutron-deficient isotopes at the neutron mid-shell (N = 104): the isotope shifts and hyperfine structure (for the odd isotopes) measurements have been carried out for $^{183\text{-}190}$Pb chain. The measurements were performed at the ISOLDE (CERN) facility, using the laser in-source spectroscopy technique. Mean-square charge radii and magnetic moments for ^{183,183m,184,185,185m,186,187,187m,190}Pb have been deduced. In Fig.1 the charge radii for the lead isotopes are shown down to A = 183, including our data, along with the even-Z neighbours Hg (Z = 80) and Pt (Z = 78) [1,2,3]. The charge radii of the Pb isotopes follow rather closely the linear trend predicted by the spherical droplet model confirming their spherical nature. The magnetic dipole moments of $13/2^+$ isomers also follow a smooth trend from A = 197 to A = 183.

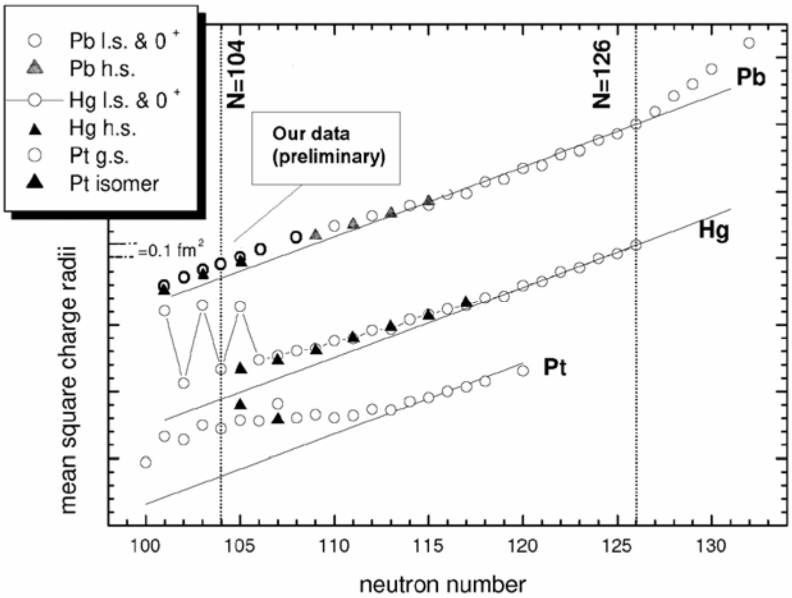

Fig. 1. Mean squared charge radii for the lead, mercury and platinum isotopes, compared to the predictions of the spherical droplet model.

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TRANSFER AND NEUTRON CAPTURE REACTIONS TO ^{194}Ir

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New nuclear spectroscopy results are obtained for a highly complicated odd-odd transitional nucleus ^{194}Ir. A study using (d,α) and (d,p) reactions, via 22 MeV deuterons, (n,γ) and (n,e-) reactions via thermal neutrons was performed. Recently measured deuteron reaction data, up to 765 keV for (d,α), and to 965 keV for (d,p), help to place transitions into the level scheme with a considerable degree of confidence. The (d,α) reaction using polarized deuterons allows to evaluate spins-parities for 36 levels. An extended evaluation for the (n,γ) and (n,e^-) spectra higher than 500 keV is used to develop the level scheme up to about 800 keV, with 60 levels now, including additionally checked 35 earlier known levels [1].

Model interpretation is refined using improved approaches of geometric and algebraic models. A use of Nilsson configurations with associated rotational bands, probably , represents the heaviest nucleus in the rare-earth region where such approximation gives really interesting results. Algebraic models – IBFFM and supersymmetry – allow comparisons between levels of ^{194}Ir and ^{196}Au, which from these viewpoints are similar both in energy values and spins-parities.

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GAMMA SPECTROSCOPY OF TRANSFERMIUM ELEMENTS AT THE VASSILISSA SET UP

A.G. Popeko[1], A.V. Belozerov[1], Ch. Briancon[2], V.I. Chepigin[1], O. Dorvaux[3], K. Hauschild[2], A.P. Kabachenko[1], A. Korichi[2], A. Lopez-Martens[2], O.N. Malyshev[1], Yu.Ts. Oganessian[1], R.N. Sagaidak[1], A.V. Shutov[1], A.I. Svirikhin[1], A.V. Yeremin[1]

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A JINR – IN2P3 collaboration project aimed at the study of nuclear spectroscopy of transfermium elements using high intensity heavy ion beams of the U400 cyclotron, exotic targets and the modernized recoil separator VASSILISSA (FLNR JINR) was launched last year in Dubna.

The set-up was named "GABRIELA" - Gamma Alpha Beta Recoil Investigations with the Electromagnetic Analyser.

GABRIELA was tested using complete fusion reactions: $^{48}Ca+^{164}Dy \rightarrow ^{212}Rn^*$, $^{40}Ar+^{174}Yb \rightarrow ^{214}Ra^*$ and $^{40}Ar+^{181}Ta \rightarrow ^{221}Pa^*$.

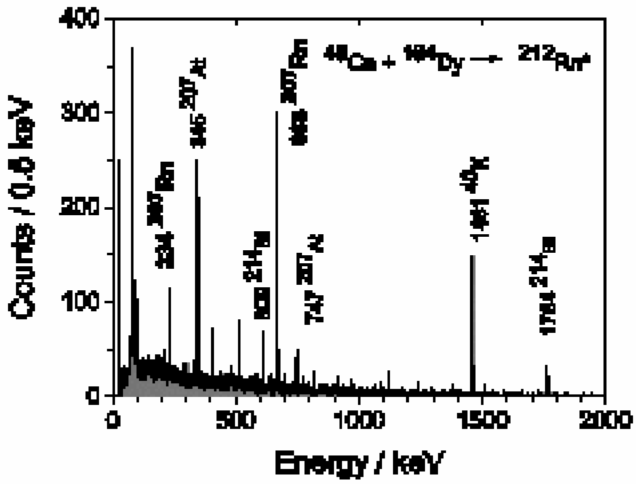

Fig. 1. The raw γ-spectrum recorded in reactions $^{164}Dy(^{48}Ca,xn)$. The γ-transitions with E_γ=234, 665 keV from 181 мs isomeric state of ^{207}Rn are well pronounced.

During the first full-scale experiment in September – October 2004, No and Lw isotopes produced in $^{48}Ca+^{207,208}Pb \rightarrow ^{255,256}No^*$, $^{48}Ca+^{209}Bi \rightarrow ^{257}Lr^*$ reactions were studied. The analysis of the data is in progress.

In the next campaign, more neutron rich No isotopes will be produced using a radioactive ^{210}Pb target. The investigations of heavier Rf- or Db-isotopes as well as Recoil Decay Tagging prompt γ-ray spectroscopy are under discussion.

MODEL-FREE DETERMINATION OF LEVEL DENSITY, RADIATIVE STRENGTH FUNCTIONS AND GENERAL TENDENCY NUCLEAR STRUCTURE CHANGING BELOW B_n

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Recent experimental data on population of nuclear levels below excitation energy of 3-5 MeV allowed [1] direct estimation of discrepancy between the energy dependences of the radiative strength functions for the primary and secondary transitions with equal energy depopulating levels with different energy E_{ex}. In the other words, we obtained for the first time of the realistic experimental information on the function $k(E1)+k(M1)=f(E_\gamma, E_{ex})$.

Accounting for its probable form within the method [2] for simultaneous estimation of level density ρ and strength functions *k* showed that the calculation with equal energy dependence of strength functions of primary and secondary transitions of the cascade gamma-decay regularly overestimates the obtained level density. The value ρ estimated according to method [2] and new function $f(E_\gamma, E_{ex})$ for 21 nuclei demonstrate at least two “step-like" structures in all these nuclei. Corresponding strength functions are practically constant at $E_\gamma<0.3\ B_n$, increase up to the maximum value for the excited levels from the region of “step-like structure" and somewhat decrease for higher values of E_γ.

The totality of these data allows one to conclude that the structure of wave functions of excited levels for any nucleus considerably changes as the excitation energy changes over the whole interval $E_{ex} < B_n$ and strongly influences to the cascade gamma-decay process. Within the model ideas [3] this change in the wave function structure should be related to a break of least two Cooper pairs of nucleons below neutron binding energy B_n.

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^{111}Cd-TDPAC STUDY OF HFIP UNDER HIGH PRESSURE UP TO 8 GPa

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To study the HFI parameters in condensed matter we have developed a method and have been made a number of experiments concerning γγ-correlations (TDPAC) by high pressure. For the probe nuclide we used ^{111}In(^{111}Cd) and the high pressure was up to 8 GPa. In our measurements we used the 4 detectors TDPAC spectrometer [1]. The experimental complex included 4 columns hydraulic press, with the force up to 300 t. The strength and construction of the press admits to use a complicated high pressure chamber so-called “matreshka” [2]. This chamber allows creating the pressure up to 30 GPa. For creating the pressure up to 8 GPa we used a chamber, which is a basic part from the “matreshka” and it is the modification of the so-called “toroid” [2]. The diameter of its work cell is 15mm. The sample has been enveloped in monocristallic NaCl and then it has been pressured.

We have made test measurements with ^{111}Cd in metallic Zn using the pressure 3 GPa. Other authors [3] were measured ^{111}Cd in Zn too, using the chamber piston in cylinder type and the sample has been enveloped in metallic Indium. The comparison of our and their results gives good agreement. In our experiment we measured ν_Q=112.5(10) and in work [3] ν_Q=113.4(7). The line dependency of quadrupole frequency on pressure in case of Zn allows using the measurements of ^{111}In in metallic Zn for calibrating of the pressure.

To study an influence of High pressure on the HFI we measure ^{111}In in $YbAl_2$ up to 8GPa. The results illustrated that the high pressure has a very strong influence of HFI parameters in this medium (look the table).

Pressure P, GPa	0.0(1)	3.0(1)	5.5(1)	8.0(1)
Quadrupole frequency ν_Q, MGz	14(1)	30(1)	49(1)	55(1)

Financial support received from the RFFI - projects 03-03-32120, 04-02-16061.

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INVESTIGATION OF GAMMA-TRANSITION'S ICC IN ^{115}In, ^{117}Sn AND ^{125}Te NUCLEI WITH A HIGH PRECISION

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Institute for Nuclear Research of NAS of Ukraine

Internal conversion coefficient on *K*-shell (α_K) of *l*-forbidden *M1*-transitions with 35 keV energy in ^{115}In, *M4*-transitions with 156.0 keV energy in ^{117}Sn and 109 keV energy in ^{125}Te as well as the full ICC of *M4*-transitions with 156.0 keV energy in ^{117}Sn were measured. Measurements were carried out with a high precision by using gamma-spectroscopy.

Investigations were held on a fast-slow coincidence system. Relative yield of the gamma-transitions (I_γ) and K_X-radiation (I_{K_X}) which go with a process of the internal conversion of gamma-rays were measured. Measurement were carried out on the ^{115}Cd ($T_{1/2}$=2.3 days), ^{117m}Sn ($T_{1/2}$=12.6 days) and ^{125m}Te ($T_{1/2}$=58 days) nuclei. Coefficients α_K were defined using expression $\alpha_K = I_{K_\alpha} / I_\gamma \cdot \omega_K$, where ω_K is fluorescence yield. As a result were obtained $\alpha_K = 8.68 \pm 0.16$ for *M1* - transition in ^{115}In, $\alpha_K = 31.8 \pm 0.8$ in ^{117}Sn and $\alpha_K = 181.3 \pm 3.6$ in ^{125}Te.

^{125m}Te decay by a cascade of γ156 keV (*M4*) and γ158.6 keV (*M1*)-transitions. Energy nearness of these transitions and low probability of the internal conversion of the *M1*-transition allow measuring of γ156 full ICC to within 0.1%. It is found $\alpha_{tot} = 46.44 \pm 0.05$.

The obtained data are discussed.

THE RATIO OF ^{135m}Xe AND ^{135m}Xe YIELDS IN THE PHOTOFISSION REACTIONS OF HEAVY NUCLEI

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The values of isomeric ratios in the fission fragments are much more, as a rule, than the same values in another types of reactions. Some theoretical calculations appear last time to explain this phenomenon [1,2,3].

We have performed the systematic measurements of the isomeric ratios for ^{135}Xe photofission fragments. This isotope was produced at the irradiations of some heavy element targets by bremsstrahlung of microtron with cutoff energy of 25 MeV. The used method of the gas flow transportation allow to separate noble gases Kr and Xe from another fission fragments. The yield of ^{135}Xe in the isomeric and ground states was determined by the measurements of they gamma-spectra. The obtained by a such way isomeric ratios are presented in the table 1.

Table 1.

target	^{232}Th	^{238}U	^{243}Am	^{248}Cm
^{135m}Xe/^{135g}Xe	0.75±0.15	0.65±0.10	5±1	2.0±0.3

For the comparison the isomeric ratios in the reaction ^{134}Xe(n,γ) is 0.013(2) and in the reaction ^{136}Xe(γ,n) is 0.110(9).

We have measured the ratio of the independent yield of ^{135}Xe and of cumulative yield of ^{135}J in the photofission of the same nuclei (table 2).

Table 2.

target	^{232}Th	^{238}U	^{243}Am	^{248}Cm
$^{135m+g}$Xe/^{135}J	0,02	0,07	0,7	0,19

The calculations of isomeric ratios were performed and the values of angular moments for ^{135}Xe fission fragments were obtained.

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THE DECAY OF THE ^{148}Tb ($T_{1/2}$ = 60 min)

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[2]Joint Institute for Nuclear Research, DLNP, Dubna, Russia
[3]Faculty of Physics, Kharkov State University, Kharkov, Ukrainian Republic
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The even-even 84-neutron nuclei are of particular interest since they lie near by the 88–90- neutron transition at the beginning of the region of deformed nuclei 150 < *A* < 190. Mereover, the ^{148}Gd nuclide provides an opportunity to study the effective interactions of two neutrons added to the $^{146}_{64}Gd_{82}$ core belived to have relatively strong shell structure [1].

In the present work, the *X*- and γ-rays, γ-γ coincidences, conversion electrons and positrons from the decay of 60 min ^{148g}Tb were measured by means of the Ge(Li) detectors and magnetic spectrometers. The radioactive isotopes have been produced by spallation reaction on tantalum or erbium targets using the internal proton beam of JINR phasotron. The chemical and subsequent mass separations were used to select the ^{148}Tb isotope and to prepare the sample for different nuclear spectroscopic studies. The 129 γ-rays were assigned to the decay of ^{148g}Tb. Multipolarities of 14 transitions in ^{148}Gd were determined. Significantly modified and supplemented decay scheme of ^{148g}Tb which contains 39 exited states up to 5.4 MeV is proposed.

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NUCLEAR ORIENTATION OF THE ^{148}Tb ($T_{1/2}$ = 60 min) IN Gd HOST

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The X- and γ-rays, γ-γ coincidences, conversion electrons and positrons from the decay of 60 min ^{148g}Tb were measured [1]. Considerably enriched decay scheme of ^{148g}Tb was proposed. In this work directional distributions of γ rays following the decay of ^{148g}Tb oriented in gadolinium host were measured using SPIN facility [2] at JINR and multipole mixing ratios of γ-transitions in ^{148}Gd were determined. The radioactive isotopes have been produced by spallation reaction on tantalum or erbium targets using the internal proton beam of JINR phasotron. The chemical and subsequent mass separations and implantation were used to select the ^{148}Tb isotope and to prepare the sample for the nuclear orientation study. Hyperfine interactions of implanted ^{148}Tb isotope into Gd host at low temperatures have been used to orient radioactive terbium nuclei. The low temperatures were achieved by top-loading ^{3}He–^{4}He dilution refrigerator capable of maintaining a base temperature of 10.5 mK. High resolution Ge(Li) detectors were used to record simultaneously γ ray spectra at 0° and 90° with respect to the external magnetic field of 2 T on the sample.

The anisotropies of γ-rays following the decay of ^{148}Tb were measured, and the *E2/M1* and *M2/E1* multipole mixing ratios were determined for many transitions linking ^{148}Gd levels. Unambiguous spin-parity assignments were made for a number of levels in ^{148}Gd. The magnitudes of the *E0/E2* mixing ratios, $|q(E0/E2)|$ were evaluated for $\Delta I = 0$ transitions and corresponding probability ratios, $X(E0/E2)$, were determined. In particular, the $|q|$ and X values were firstly determined for transition between the negative parity levels $3^- \rightarrow 3^-$, in ^{148}Gd and these values are consistent with the systematics made for transitions of the β-vibrational bands.

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NUCLEAR ORIENTATION STUDY OF THE ^{152}Tb DECAY

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The directional distribution of γ rays following the decay of oriented ^{152}Tb has been studied using SPIN facility [1] at JINR. Appreciable *E0* admixtures in *M1/E2* transitions between the levels of identical non-zero spin in ^{152}Gd are observed. The experimental data on the magnitude and particularly on the sign of the multipole mixing ratios provide a good and sensitive test of different theoretical phenomena in nuclear structure studies [2]. Obtained results together with the results of previous investigations of the conversion electron spectra and ^{152}Gd level scheme studies [3] allow to make detailed analysis of the structure of ^{152}Gd.

The radioactive rare earth isotopes have been produced by spallation reaction on tantalum or erbium targets using the internal proton beam of JINR phasotron. The chemical and subsequent mass separations and implantation were used to select the ^{152}Tb isotope and to prepare the sample for the nuclear orientation study. Hyperfine interactions of implanted ^{152}Tb isotope into Gd host at low temperatures have been used to orient radioactive nuclei. The low temperatures were achieved by top-loading ^{3}He–^{4}He dilution refrigerator capable of maintaining a base temperature of 10.5 mK. High resolution Ge(Li) detectors were used to record simultaneously γ ray spectra at 0° and 90°with respect to the external magnetic field of 2 T.

The γ-ray anisotropies of transitions in ^{152}Gd were measured to determine multipole mixing ratios δ of electromagnetic transitions and spin-parities of the levels in ^{152}Gd. The results related to the investigation of the *E0* multipolariry admixtures, which were observed in many ΔI=0 transitions of ^{152}Gd, are presented. Among them the *E2/M1* mixing ratios for 2 → 2 and 4 → 4 transitions from the β-vibrational (K^π=0$^+$) and γ-vibrational (K^π=2$^+$) bands to the ground-state band were observed, and the *E0/E2* probability ratios, *X(E0/E2)*, were determined.

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NUCLEAR ORIENTATION OF THE ^{155}TbGd

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The $^{155}_{64}$Gd nucleus is situated in the shape transition region at the on- set of nuclei exhibiting a deformed equilibrium shape. Thus, one might expect states in ^{155}Gd with mixed-symmetry features. Detailed investigations of the directional distribution of γ rays following the decay of oriented nuclei give the excellent possibility to determine multipole mixing ratios of electromagnetic transitions including *E0* admixtures. The experimental data on the magnitude and particularly on the sign of the multipole mixing ratios provide also a good and sensitive test of different theoretical phenomena in nuclear structure studies [1].

The results of the investigations of the decay of oriented ^{155}TbGd with the aim to obtain precise information on the levels and transitions in ^{155}Gd are reported. The radioactive rare earth isotopes have been produced by spallation reaction on tantalum or erbium targets using the internal proton beam of JINR phasotron. The chemical and subsequent mass separations and implantation were used to select the ^{155}Tb isotope and to prepare the sample for the nuclear orientation study. Hyperfine interactions of implanted ^{155}Tb isotope into Gd host at low temperatures have been used to oriented radioactive nuclei. The low temperatures were achieved by top-loading ^{3}He—^{4}He dilution refrigerator capable of maintaining a base temperature of 10.5 mK. High resolution Ge(Li) detectors were used to record simultaneously γ-ray spectra at 0˚ and 180˚ with respect to the external magnetic field of 2 T on the sample [2]. The directional distributions of 27 gamma--rays were measured and the *E2/M1* and *M2/E1* multipole mixing ratios deduced for 24 gamma–transitions in ^{155}Gd, fifteen of them for the first time. The present mixing ratios for both *E2/M1* and *M2/E1* transitions are compared to the results of the other measurements and with the theoretical results obtained in the framework of the nonadiabatic quasiparticle–phonon model including a Coriolis interaction.

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LASER SPECTROSCOPIC STUDIES OF NEUTRON DEFICIENT EUROPIUM AND GADOLINIUM ISOTOPES

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The laser ion source has been used for the study of the isotope shifts of neutron deficient Eu and Gd isotopes at the IRIS facility. The region of the applicability of the method by using the γ- and β- radiation detection has been extended. The isotope shifts of the europium optical line 576.520 nm for $^{137–139, 141, 142m, 143, 144}$Eu and the gadolinium optical line 569.622 nm for $^{145, 145m, 143m}$Gd have been measured. To increase the laser ion source efficiency an axial magnetic field (350 Gauss) was applied. Nearly a twofold rise of the ionization efficiency for Eu was observed. By using the effect of optical ion bunching an increase of the selectivity was obtained. For Gd atoms investigation resonance ionization directly inside the target has been applied for the first time.

The isotope shift data for $^{139, 141, 142m, 143, 144}$Eu are in agreement with the previously measured isotope shifts for these nuclides. Changes in mean square charge radii $\delta\langle r^2\rangle_{A,A'}$ for $^{145, 145m, 143}$ Gd and ^{137}Eu and magnetic moments for ^{145,145m}Gd have been determined for the first time. The new data for ^{137}Eu and refined data for ^{138}Eu point to a gradual increase of the deformation for these isotopes rather than the jump-like behavior predicted by the microscopic-macroscopic calculations [1]. The value of the quadrupole deformation parameter β for ^{137}Eu coincides within the limits of errors with the value of β for the core nucleus ^{136}Sm [2]. The stabilization influence of the proton sub-shell closure Z=64 on the $\delta\langle r^2\rangle_{A,A'}$ (i.e. on the deformation) behaviour at N<82 has not been observed in contrast with the region at N>82 [3]. Comparisons with microscopic-macroscopic calculations and calculations in the framework of Hartree-Fock model were performed.

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DECAY OF ^{160}Ho (3s)

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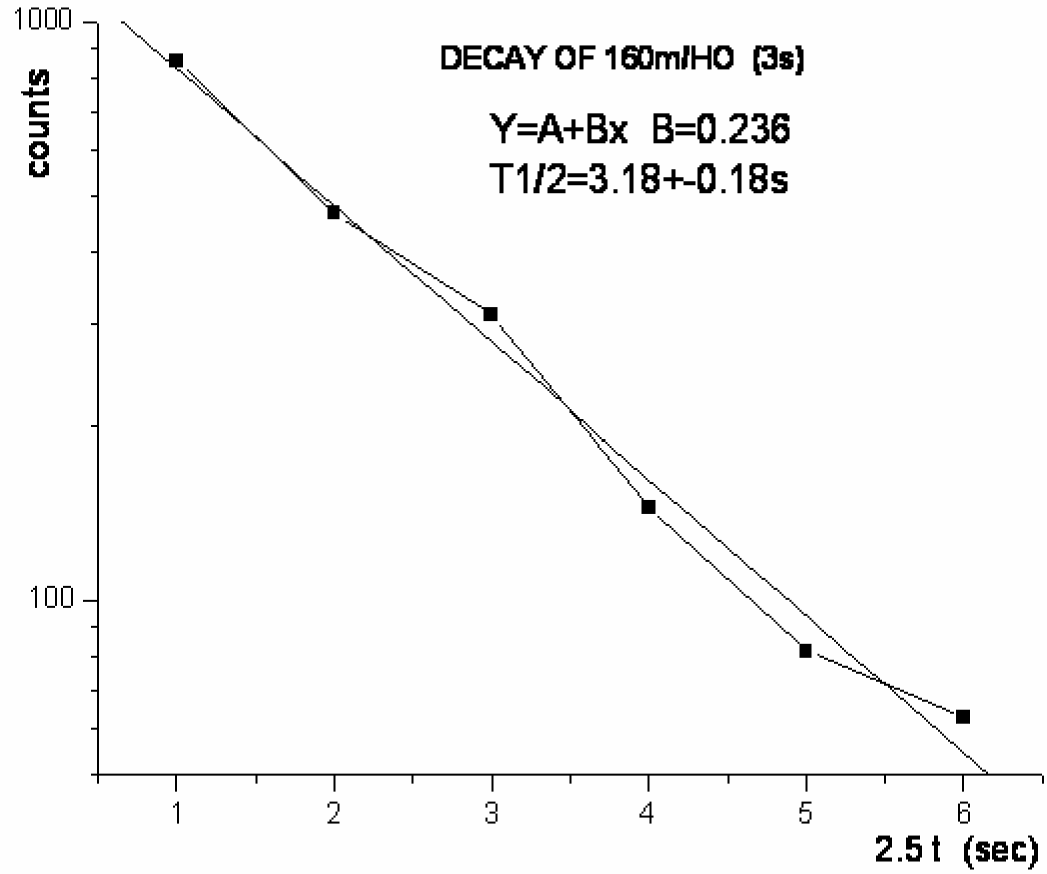
Spectra of gamma-rays and gamma-gamma-coincidences in the decay of the ^{160}Ho isomer (9^+) are measured in the on-line mode of the YASNAPP setup. The half –life of the isomer is found from the decrease in the 118.4 kev gamma - line intensity and it is $T_{1/2}$ = (3.2±0.2) s.



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PRELIMINARY RESULTS OF MEASURING HALF-LIFE AND OTHER NUCLEAR CHARACTERISTICS OF NUCLEI WITH LIFETIME ABOUT 1S AT THE YASNAPP SET-UP

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Study of nuclei beyond the stability lines is an experimental-methodological problem which is not so simple to solve because of abundance of physical information. It is necessary to comprehend theoretically the processes occurring in nuclei off the stability lines. Their half-life ($T_{1/2}$) decreases while the decay energy (Q) increases.

In order to measure the characteristics of nuclei whose half-life is about 1 s, we have to solve a number of technical, methodological and program problems associated with development and modernization of the YASNAPP project:

1. Production of isotopes with short lifetime in the ion-source of the mass-separator.
2. Transportation and collection of isotopes with short lifetime in the detector part of the measuring set-up.
3. Effective registration of these isotopes in the detector.
4. Availability of fast electronics for the quick collection of spectrometric information.
5. Availability of fast software for information transfer an PC and methodological support of the experiment.

In 2003-2004 efforts were made to solve the above mentioned problems[1] Experiments were performed to study gamma-ray spectra and gamma-gamma-rays coincidence spectra in isobars A=155, 156, 157, 158 and 160. The mass-separator target was bombarded with protons for 3, 5 and 20 s, the measurement time was divided in to intervals of 0.5 and 1.0s.

Preliminary results for the isobar chain nuclei A=160, 158, 157, 156, 155 are obtained. For example, the half-life of the ^{160}Ho isomer (9^+) was refined and found to be $T_{1/2}$=(3.2±0.2) s.

The work was supported by the RFBR.

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CONCERNING THE $J^{\pi} = 0^{+}$, 1577 keV STATE IN ^{158}Gd

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13 excited states up to 3.1 MeV were observed in deformed nucleus ^{158}Gd in ^{160}Gd(p,t)^{158}Gd reaction [1]. Moreover new 0^{+} level 2023.85(4) keV was found in [2]. Then there were published theoretical works with interpretation of some of 0^{+} states [3,4]. Checking the reliability of new states we made the conclusion that the state 1577 keV, 0^{+} does not exist in the level scheme of ^{158}Gd and should be excluded. There are several reasons for such conclusion:

1. According to [1] 4 transitions from (n,γ)-reaction depopulate the level 0^{+} and sums of transition energies and final states energies are equal. From our analysis it follows that differences in the sums are about 0.2 keV with errors 0.03 keV.
2. According to [1] the strongest transition 600.08 keV has intensity 0.6 units. From systematic of reaction (n,γ) the expected value is 50 units.
3. The primary transitions to this 0^{+} level from capture states in the ($\tilde{n}$,γ)-reaction (E($\tilde{n}$) = 2 keV) were not found. Their expected intensity is 2-3 times larger than that in experimental spectrum in the neighboring region of energy.
4. The intensity of transition 1497 keV, $0^{+} \rightarrow 2^{+}_{gsb}$ in reaction (n,n'γ) [5] is I_{γ} = 0.05 units. Statistical model predicts I_{γ} = 1.5 units. Transitions 600 and 389 keV [1] were not found too.
5. Rotational satellite $J^{\pi} = 2^{+}$ is expected in the region 1660(40) keV. The nearest 2^{+} level is 1791.7 keV.

The observing of line 1577 keV in ^{160}Gd(p,t)^{158}Gd reaction spectrum may be fully explained by presence of impurity ^{154}Gd in the target material. Authors [1] accepted that impurity was 0.33% and it gave line 1577 keV. They consider that only 40% of the line intensity was due to transition 1577 keV in ^{158}Gd. If impurity is about 0.6%, then all intensity of the line could arise from ^{154}Gd.

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ELECTRIC AND MAGNETIC PROPERTIES OF ^{178}Hf

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There are many experimental data on deformed nucleus ^{178}Hf [1,2]. We have investigated the depopulation of excited levels of $K^{\pi} = 1^{-}$ octupole band based on the head state 1310.068 keV, 1^{-}. The properties of intraband transitions were deduced supposing the quadrupole moments of octupole band and ground state band are the same $Q = 6.7$ e b. In the table 1 the giromagnetic ratios ($g_K - g_R$) of *M1*-transitionsin the $K^{\pi} = 1^{-}$ are presented.

Transition	$2 \rightarrow 1$	$4 \rightarrow 3$	$5 \rightarrow 4$
$g_K - g_R$	0.79(25)	≤1.4	≤1.4

Table 2 contains matrix elements *M* of *E2* transitions and values ($g_K - g_R$) for *M1*-transitions between $K^{\pi} = 1^{-}$ and $K^{\pi} = 2^{-}$ bands (head states 2^{-} 1260.250 keV). There is difference between ($g_K - g_R$) –values of the transitions to final levels with odd and even spins.

Transition	$2 \rightarrow 2$	$3 \rightarrow 3$	$3 \rightarrow 2$	$4 \rightarrow 4$	$4 \rightarrow 3$	$5 \rightarrow 5$	$5 \rightarrow 4$
M e b	<26	<3	6.1(7)	<2.7	3.2(12)	<10	2.8(9)
$g_K - g_R$	<1.5	<0.3	0.67(7)	<0.4	1.1(4)	≤0.17	1.3(4)
F_h	$6\ 10^4$	$4\ 10^5$	$1.2\ 10^5$	$9\ 10^5$	$1.8\ 10^5$	$1\ 10^5$	$1.2\ 10^5$

From the table 2 it follows that hinderance factors F_h of *E1*-transitions to γ- and gsb are approximately the same. Only $3^{-} \rightarrow 4^{+}$-transition has larger value F_h.

From calculations of Coriolis interaction between levels of $K^{\pi} = 1^{-}$ and $K^{\pi} = 2^{-}$ the value of parameter $B = 10.578$ keV was obtained.

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QUADRUPOLE MOMENTS AND INERTIONAL PARAMETERS OF EVEN-EVEN HAFNIUM ISOTOPES

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The internal quadrupole moments Q_0 and inertional parameters $A = \hbar^2/2\Im$ are specific for ground state rotational bands in even-even deformed nuclei. In the frames of adiabatic model it is possible to calculate the values of Q_0 by formulae $X = B(E2;J \rightarrow J\text{-}2) = (5/16\pi)\ Q_0^2\ \langle J_i\ K_i\ L\ K_f - K_i \mid J_f\ K_f\rangle^2$, where X depends on γ-partial half-time T_γ (s) and transition energy E_γ (MeV): X=(5.66 10^{-14} / (T_γ E_γ^5). Table contains the results of calculations being used data from [1].

	^{168}Hf		^{170}Hf		^{178}Hf		^{180}Hf	
	A, keV	Q_0, e^2b^2	A, keV	Q_0, e^2b^2	A, keV	Q_0, e^2b^2	A, keV	Q_0, e^2b^2
2	20.67	6.50(13)	16.80	7.30(15)	15.53	6.9(7)	15.55	6.9(7)
4	18.69	6.4(5)	15.80	7.1(5)	15.24	-	15.38	7.1(7)
6	16.88	6.6(5)	14.59	6.7(4)	14.80	6.45(23)	15.10	6.5(5)
8	15.22	6.6(5)	13.35	7.5(5)	14.21	6.6(9)	14.77	7.1(8)
10	13.74	6.6(8)	12.16	6.3(6)	13.49	6.8(14)	-	-
	^{172}Hf		^{174}Hf		^{176}Hf			
2	15.87	6.6(4)	15.16	6.7(3)	14.73	7.4(3).		

It is possible to make following conclusions.

1. There are experimental data on quadrupole moments of 2^+-10^+ states in four hafnium nuclei, (A = 168. 170. 178. 180).
2. The values Q_0 are known in three other nuclei, (A = 172-176).
3. The Q_0 values are the same for all levels in each nucleus.
4. Value Q_0 = 6.7(1) e^2b^2 is the same in limits of errors for four nuclei. The same value Q_0 = 6.7(2) e^2b^2 have states 2^+ in isotopes ^{172}Hf and ^{174}Hf.
5. Only ^{176}Hf has $Q_0(2^+)$ = 7.4(2) e^2b^2 which is different. May be we here have the experimental error in measurement of half-time of the 2^+ level.

We have not found the correlation between inertional parameters A that go down rather strong in dependence from spin J of levels, and quadrupole moments Q_0, that are constant. We also did not noticed the dependence of Q_0 from the energies of the first exited level $E(2^+)$, $E(2^+) = 6\ A$.

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ISOMER EXCITATION IN INELASTIC ELECTRON AND PHOTON SCATTERING REACTIONS

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Observed high efficiency of ^{178m2}Hf triggering with low-energy X-rays stressed all models, which might have been able to predict such the effect. And though the experimental investigation of ^{178m2}Hf triggering phenomenon has been continued using not only portable X-ray machine, but Synchrotron Radiation sources as well [1], significant efforts are still being applied to find both proper explanations and correct mechanisms responsible for such an unexpected high efficiency of the triggering. The idea that atomic electrons could be involved in the triggering process taking away the necessary quantity of quantum momentum from the nuclei did happen to be very useful, so if not the direct mechanism then either NEET or Inelastic Electronic Bridge mechanism (or even some combination of them) is surely responsible for the experimentally observed accelerated decay of ^{178m2}Hf isomers induced by low-energy photons.

Further theoretical analysis is obviously needed otherwise one can hardly expect that the research of ^{178m2}Hf triggering phenomenon might be extended quite easily to other *K*-isomers. Even in the case of ^{177m}Lu and ^{179m}Hf nuclear isomers, the next ones after ^{178m2}Hf suitable for such research, the triggering effect can be completely covered by intense spontaneous decay of these isomers, saying nothing that their excitation energies are much lower, than in the event of ^{178m2}Hf.

On the other hand, due to the key role of atomic electrons in the triggering process other long-lived nuclear isomers, not necessarily high-energy *K*-isomers, can also be perspective for such research. The first observations of ours on the accelerated decay of ^{180m}Ta nuclear isomer induced by electrons with the energy about 3 MeV are presented in [2]. Moreover, an idea that electrons could be more effective for isomer triggering looks very interesting also. ^{180m}Ta deexcitation and ^{176m}Lu excitation cross-sections have been measured at the new linac of Kiev Institute for Nuclear Research at the energy of electrons up to 3 MeV and electron currents up to 1 μA/cm^2. It is quite surprising that nuclear isomer excitation can be experimentally detected at such low currents of electron beam. Either atomic electrons do play the key role in the nuclear isomer triggering or not, electrons look to be much more efficient than bramstahlung photon for nuclear isomer excitation research. This experimental observation can be of great importance for the understanding of ^{178m2}Hf triggering phenomenon.

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LOW-SPIN MIXED PARTICLE-HOLE STRUCTURES IN ^{185}W

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A comprehensive level scheme of ^{185}W has been established using one-nucleon transfer reactions supplemented by thermal neutron capture results. Polarized deuteron beams provided the spin-parity determination for almost all levels observed below 3 MeV. Also an essentially complete set of $1/2^-$, $3/2^-$ states has been obtained in this energy region. A large number of observed levels can be interpreted in terms of rotational bands associated with Nilsson configurations. That reflects the validity of the axially symmetric deformation in this transitional nucleus. Low-spin levels below 1 MeV are assigned to rather pure quadrupole and octupole vibrations coupled to the quasiparticle states closest to the Fermi level. Other old and newly established states around 1 MeV offer an example of structures with mixed one-quasiparticle and vibrational components. The established band structures slightly above this region indicate a progressively greater degree of mixing. A number of angular and asymmetry distributions can not be fitted with DWBA calculations because they would require additional multi steps to the simple one-step direct transfer mechanism. These 'anomalous' shapes mostly appear in transitions to moderately high rotational band members. This leads in some cases to worse agreement with simple Nilsson model predictions.

An obvious fact of significant fragmentation of one-quasiparticle strength and their quantitative evaluation is provided predominantly from the (*d,t*) and (*d,p*) DWBA analysis. It is in particular interesting that both particle- and hole-type configurations are almost equally involved into the observed band structures although some hints for the preference of this effect in the negative-parity system continue to be more obvious. This statement would be of importance for the theoretical interpretation since its presence might indicate that the extra exchange by vibrational phonons across the Fermi surface has an enormous effect of breakdown of the individual properties of Nilsson states. The observation of (*d,p*) hole states might indicate that inner shells are only partially occupied. This empirical feature can be partly understood as a clear experimental evidence of the importance of configurational ΔN=2 mixing that embraces N=5, 7 together with N=4, 6 orbits. Finally, the significance of configurational mixing and compression of the spectra in a transitional nucleus such as ^{185}W are a straightforward indication of the loss of quadrupole deformation at the peak of the hexadecapole deformation.

TWO-STEP CASCADES OF THE ^{187}W COMPOUND STATE GAMMA-DECAY

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Two-step cascades from the ^{186}W(n_{th}, γ)^{187}W reaction were studied in $\gamma\gamma$ -coincidence measurement. Their total intensity is estimated up to excitation energy near 1.9 MeV for the first time.

The decay scheme of ^{187}W, which include 386 cascades, was established up to the excitation energy ~3 MeV. It contains data about 196 excited levels for this nucleus with probably spins 1/2 and 3/2.

The excitation spectrum of intermediate levels of most intense cascades, as in early studied nuclei, was found to be harmonic.

OCTUPOLE TWO PHONON STATES IN DEFORMED NUCLEI

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The excitation spectrum of 0^+ states in ^{158}Gd [1], ^{228}Th, ^{230}Th and ^{232}U has been studied by means of the (*p,t*) reaction using the Q3D magnetic spectrometer facility at the Munich tandem accelerator. For 27 MeV (and 25 MeV) proton beams the 0^+ transfer angular distributions have very large cross sections for small reaction angles and distinct angular distribution, a feature that allows to identify and to assign these states in otherwise very complicated and dense spectra. We resolved for each of these nuclei typically 13 excited states with safe 0^+ assignments. The studied excitation energy range was up to 3.1, 2.3, 3.3 and 2.1 MeV, respectively.

For ^{158}Gd Zamfir et al. [2] compare calculated 0^+ states from the conventional *sd* boson IBA (*sd*-IBA) with those from *spdf*-IBA, including in addition *p* and *f* bosons. The parameters are chosen to reproduce the low lying spectrum, in the latter case this includes the states of negative parity. In the energy ranges considered, the *spdf*-IBA for ^{158}Gd predicts three more 0^+ states in addition to five excited 0^+ states from the *sd*-IBA, and three more at somewhat higher energies. These six additional states have two bosons in the *pf* boson space, they are related to - or represent - octupole two phonon excitations (OTP). Analysing the ^{228}Th, ^{230}Th and ^{232}U data accordingly, we obtain for these cases again the five excited 0^+ states from the *sd*-IBA, but for ^{228}Th and 230Th six and for ^{232}U four states of OTP nature. This different behaviour of OTP excitations is related to the different excitation energies $E_x(1^-,^{158}\mathrm{Gd}) = 977.1$ keV, $E_x(1^-,^{228}\mathrm{Th}) = 328.00$ keV and $E_x(1^-,^{232}\mathrm{U}) = 563.2$ keV of the respective lowest states of negative parity, which represent to some extent the strength of octupole collectivity in deformed nuclei.

This (*p,t*) study provides evidence that a considerable part of the 0^+ states are of octupole two phonon nature. If one succeeds to enclude in the calculation also the hexadecupole (*g*-boson) degree of freedom accordingly and the monopole pairing vibration, one might expect to account for all of the observed excited 0^+ states within a collective model description.

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NUCLEAR *g*-FACTORS OF HIGH-SPIN ISOMERS IN ^{190,192,194}Pt AND ^{196,198}Hg

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The integral perturbed angular distribution (IPAD) method in an external magnetic field of 2.8 T has been used to measure the *g*-factors of isomers in the ^{190,192,194}Pt and ^{196,198}Hg nuclei. The isomers were populated and aligned in the ^{188,190,192}Os(α,2n) and ^{194,196}Pt(α,2n) -reactions at energy 27 MeV. Osmium enriched up to 99% targets of about 40 mg/cm were prepared by depositing metallic powder on a thick bismuth backing. Colloidal graphite was used to glue the powder to the backing. Self supporting platinum targets enriched up to 98% were used in the experiment. The logarithmic derivatives used in the analysis of the experimental data were obtained by measuring the γ-spectra by two HPGe-detectors shifted for $\theta = \pm 9^o$ with respect to the position 135^o used at the measurement of the perturbed angular distribution. The results of the preliminary analysis of the experimental data are as follows:

	^{190}Pt	^{192}Pt	^{194}Pt	^{196}Hg	^{198}Hg
7^-	0.33(12)	0.25(9)	0.16(5)	-0.043(15)	-0.036(20)
10^+				-0.21(6)	-0.16(5)
12^+	-0.21(15)	-0.23(9)	-0.09(3)*		
10^-	-0.003(3)	-0.002(1)			

* The value is not corrected for the prompt side feeding from the assumed missing 12^+ state.

The intrinsic structure of the isomers is discussed. The 12^+ states in platinum isotopes and 10^+ states in mercury isotopes have the rotational-aligned ($\nu i_{13/2}{}^{2}$) structure. The missing rotation-aligned ($\nu i_{13/2}{}^{-2}$)12^+ state is suggested to be isomeric in ^{194}Pt (instead of the 10^+ state as believed in previous works) and to which the *g*=-0.13(5) value has to be attributed. From the *g*-factors of the 10^- states in ^{190}Pt and ^{192}Pt with the configuration ($\nu 9/2^-[505]$¤$\nu 11/2^+[615]$) the anomalous orbital *g*-factor for neutrons has been derived as *g* = - 0.030(6). The positive values of the *g*-factors of the 7^- states in platinum isotopes indicate a change in the intrinsic structure of the negative-parity bands from mainly ($\nu i_{13/2}{}^{-2}$) as in Hg-isotopes to mainly ($\pi h_{11/2}{}^{-2}$) in going from the Hg isotopes to those of Pt.

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THE INVESTIGATION OF e_0 ELECTRON YIELDS FROM THE SURFACE OF DIFFERENT TARGETS UNDER BOMBARDMENT BY α- PARTICLES FROM ^{226}Ra DECAY

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Registration probabilities R_{e_0} of near zero electrons e_0 ($E_{e_0} \approx 1$ eV) emitted from the surface of targets with different Z under irradiation by α- particles from ^{226}Ra radioactive source are measured by (eα)- coincidence method [1,2]. e_0- electron yields Y_{e_0} are derived from measured values of R_{e_0}. Targets from vacuum- evaporated Al, Ge, Cu, Ru, Er, Hf, and Au on Al or Mylar foils were used. Electrons were detected by assembly of two microchannel plates (MCP) in the form of a chevron, α- particles – by the surface-barrier n-type Si detector.

Yields of e_0- electrons Y_{e_0} are changed in the range of 15% for targets with different Z. Ratios of yields for α- lines of ^{226}Ra (energies of α- particles – in brackets) were obtained:

$$Y_{e_0}(4708\text{ keV}) : Y_{e_0}(5414\text{ keV}) : Y_{e_0}(5926\text{ keV}) : Y_{e_0}(7611\text{ keV}) =$$
$$((1.29 \pm 0.02) : (1.21 \pm 0.01) : (1.13 \pm 0.02) : 1)$$

These ratios are well described by $E_\alpha^{-1/2}$ dependence on its energies, which in our case are equal to

$$1.27 : 1.19 : 1.13 : 1$$

Comparison of obtained experimental e_0- electron yields with the quantum theoretical treatment of the atomic excitation by α- particle [3] allows to evaluate the energy of the transition from bound state to continuum as ~70 eV, which is comparable with known energies of Auger electron in gold – 69.8 eV and in aluminum – 63.2 eV.

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THE INVESTIGATION OF e_0-ELECTRON YIELDS Y_0 FROM THE SURFACE OF THIN FILMS AFTER β-PARTICLE IRRADIATION FROM THE ^{152}Eu, ^{154}Eu AND ^{226}Ra DECAY

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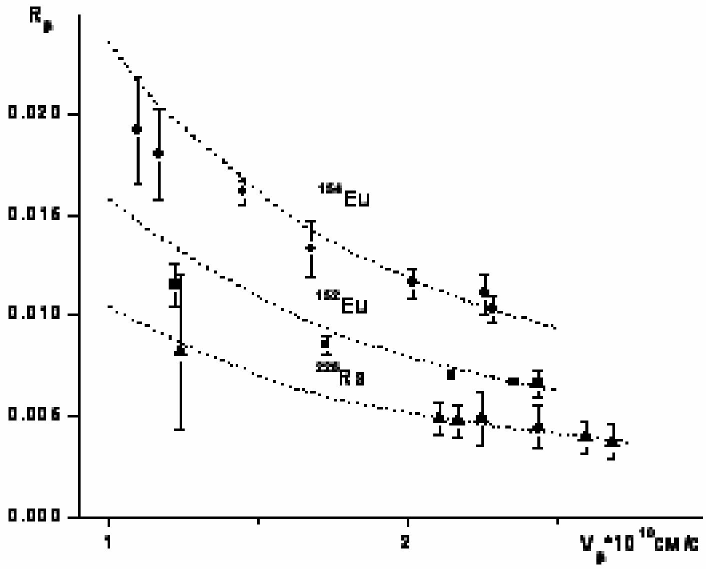
Registration probabilities R_0 of near-zero-energy electrons emitted from the surface of thin films under irradiation by β^--particles with different endpoint of β-spectra were measured by ($e\gamma$)-coincidences method. R_0's are approximately proportional to e_0-electron yields Y_0 and can be used in some arbitrary units for representation of dependence R_0 on mean energy of β-particles for different β-branches.

β-branches from the decay of ^{152}Eu, ^{154}Eu and ^{226}Ra were investigated. To avoid the influence of self-ionization of atoms under β- decay on yields Y_0 the sources of ^{152}Eu and ^{154}Eu were covered with organic film 2 μm thickness with vacuum- evaporated on it transparent layer of aluminum. The source of ^{226}Ra is covered with thin film of TiO_2 constructively. Different branches of β-decay have different mean energy of β-particulates $\overline{\mathrm{E}}_{\mathrm{B}}$. It enables to establish dependence Y_0 on $\overline{\mathrm{E}}_{\mathrm{B}}$ or mean velocity $\overline{\mathrm{v}}_{\mathrm{B}}$.

Dependence R_0 on $\overline{\mathrm{v}}_{\mathrm{B}}$ for investigated β-sources is shown on fig. Dotted lines indicate $R_0 \sim \overline{\mathrm{v}}_{\mathrm{B}}^{-1}$ dependences. Experimental points agrees satisfactorily with $\overline{\mathrm{v}}_{\mathrm{B}}^{-1}$- curve.



THE EVALUATION OF ^{242}Cm AND ^{244}Cm DECAY DATA

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This evaluation of decay characteristics of two even-even curium isotopes takes into account experimental data and other information (compilations, calculations, evaluations) published until January 2005. The evaluated values have been obtained using the approaches, programs and procedures adopted by the Decay Data Evaluation Project working group [1]. The decay characteristics of ^{242}Cm and ^{244}Cm have been evaluated as follows: half-life, decay energy, energy and probability of alpha-transitions, energy and probability of gamma-transitions, internal conversion coefficients of gamma-transitions, energy and absolute emission probability of gamma-rays, energy and absolute emission probability of *X*-rays, energy and absolute emission probability of electrons.

The half-lives of ^{242}Cm and ^{244}Cm have been evaluated as 162.86(8) days and 18.11(3) years, respectively. Below the evaluated energies and probabilities of alpha-particle groups are given for ^{242}Cm and ^{244}Cm.

^{242}Cm	
$E(\alpha)$ keV	Probability × 100
6112.72(8)	74.06(7)
6069.37(9)	25.94(7)
5969.24(9)	0.034(2)
5816.39(11)	0.0046(5)
5607.76(16)	2×10^{-5}
5517.75(11)	$2.5(5)\times10^{-4}$
5462.47(14)	$1.3(3)\times10^{-5}$
5186.95(12)	$3.5(7)\times10^{-5}$

^{244}Cm	
$E(\alpha)$ keV	Probability × 100
5804.77(5)	76.7(4)
5762.65(5)	23.3(4)
5665.41(5)	0.0204(15)
5515.29(6)	0.00344(9)
5315.3	4×10^{-5}
5217.24(7)	$5.4(9)\times10^{-5}$
4958.20(9)	$1.49(16)\times10^{-4}$
4919.24(7)	$5.2(8)\times10^{-5}$

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ALPHA- AND GAMMA-ANISOTROPY IN THE DECAY OF ORIENTED ^{254}Es AND ITS DAUGHTER NUCLEUS ^{250}Bk

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Angular anisotropies of ^{254}Es α-emission and ^{250}Bk γ-radiation have been measured using the low temperature (T < 100 mK) nuclear orientation technique at the ^{3}He – ^{4}He dilution refrigerator of the Leuven University. Es activity was obtained by neutron irradiation of ^{252}Cf targets in high flux reactor of RIAR (Dimitrovgrad) with subsequent radiochemical separation and purification. The sources for the experiment were prepared using the ion implantation of this activity into pure iron foils at the electromagnetic isotope separator of the Bonn University.

The observed quantity in this experiment is the angular distribution function $W(\theta)$ which is derived from the normalized radiation intensity at the emission angle θ:

$$W(\theta) \approx 1 + fA_2U_2B_2Q_2P_2(\cos\theta) + fA_4U_4B_4Q_4P_4(\cos\theta).$$

Parameters A_k, U_k, B_k, Q_k, P_k are defined, e.g., in [1]. From the analysis of experimental α-anisotropy of ^{254}Es the directional distribution coefficients A_k were obtained and the corresponding mixing ratios δ_{0L} of α-waves with different angular moments L as well as the L=2 intensity for the favored α-transition in the decay of ^{254}Es were determined. The latter is the main factor responsible for the observed α-anisotropy. ^{254}Es nuclear magnetic moment was firstly extracted from the experimental data.

The analysis of the 1031keV ($E2$) γ-ray angular anisotropy for ^{250}Bk provided the effective fraction f of nuclei that are oriented by hyperfine interactions in Fe foil. Contributions of L = 0, 1, 2 angular moments for the first forbidden $2^- \rightarrow 2^+$ β-transition of ^{250}Bk were also extracted and $E2/M1$ mixing ratio for 988 keV γ-rays of ^{250}Bk was estimated.

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AN UNIVERSAL CURVE FOR NUCLEON AND NUCLEAR PHOTOPRODUCTION CROSS–SECTIONS AT THE BARYON RESONANCE REGION OF 200-800 MeV

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Nuclear Sum Rules(*SR*) play an important role at a study of nuclear physics problems. Similar to *SR* for photonuclear reactions[1], *SR* for total photo-production cross-sections are used as a check for solving many aspects of the electromagnetic interaction physics at the baryon resonance region.

Higher meson threshold, already at $A \geq 6$ total photo-production cross sections are described by so called universal curve [2], in which the total photo-absorption cross sections are $\sigma / A \approx const$, i.e. approximately proportional to mass number *A*, sum of protons or neutrons. Along the periodic table from Li to U cross sections, divided by *A*, are equal with accuracy order of 5-7%, depending from systematic errors at different labs.

However, an essential difference in values and shapes of total photo absorption cross sections is observed between the proton and other nuclei at baryon resonance region at 0.2-1.2 GeV [2,3]. Distinct resonances are seen at the proton curve at 320(P_{11}), ~ 720(D_{13}), ~ 1000(*F*) MeV photon energies and others, which are not resolved at experiments. For deuteron the cross section of theΔ - resonance is smaller and broader than for the proton, and the D_{13} one looks as shoulder of the Δ-resonance. For few body nuclei as $^{3,4}He$ the 2nd resonance gradually disappears.

A schematic model [4] explains a larger broadening of *D*- and *F*-resonances comparatively with Δ-resonance by Fermi motion, propagation and interaction of the Δ and some other effects, which broaden a width of resonances.

At this work it is shown, that the average cross-sections for nucleons are the same as predicted by the universal curve. With this purpose the integral cross-sections (*ICS)* were calculated at the energy region 200 – 800 MeV [5] from most accurate data [1] and compared with results for the proton, deuteron and complex nuclei [3]. Although parameters of resonances visibly change or disappear, *ICS* is almost constant in error limits at the abovementioned resonance region. Its value is ~ 157±5 MeV-mb for the proton, nuclei with *A*=2-4 and complex nuclei starting from *A*=6 (with error ± 7 Mev mb).

So the strength is kept at this energy region and only its redistribution is going on with increasing mass number *A*.

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HIGHLY HINDERED *M2*-TRANSITION IN ^{90}Nb

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The properties of 2.3 keV *M2*-transition from 124.67 keV (4^-) isomeric state to 122.37 keV (6^+) state in ^{90}Nb are considered. The γ-partial half-life $T^{\gamma}_{1/2}$ = (1.9÷6.2)·10^7 s is deduced from $T_{1/2}$ = 18.8 s using the value of total internal conversion coefficient $\alpha(M2)$ = (1.0÷3.3)·10^6 [1,2], the range of values is due to inaccuracy (±0.4 keV) [3] of determination of transition energy and to its nearness to binding energies of electrons on *L*-subshells in Nb atom. The single particle value is $T^{\gamma}_{1/2}(M2)$ = 6.4·10^3. That means that this *M2*-transition is highly hindered, the hindrance factor being F_H = 3000 ÷ 1.3·10^4. This value is unusually large for the nucleus having numbers of protons (41) and neutrons (49) close to the magic numbers but can be understood if one ascribes proton-neutron configurations $(\pi 2p_{1/2}\nu 1g_{9/2}^{-1})4^-$ and $(\pi 1g_{9/2}\nu 1g_{9/2}^{-1})6^+$ to states 124.67 keV and 122.37 keV respectively. Then 2.3 keV *M2*-transition proceeds between $\pi 2p_{1/2}$ and $\pi 1g_{9/2}$ components of these states and is *L*-forbidden (and Δj is large here, $|\Delta j| = 4$).

The possible admixture of *E3*-mulpipolarity in this transition could make *M2*-hindrance factor even more large. But it is worth noting to say that even so small admixture as 0.1% *E3* corresponds to enchantment factor of *E3*-component F_E = 20 - 50, which is high enough. So *E3*-admixture to *M2*-multipolarity probably is very small in 2.3 keV transition.

In [4] two variants 2.334 keV and 2.439 keV for energy of the transition considered were proposed. Any of them leaves the conclusion about high forbiddance of this *M2*-transition unchanged.

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ESTIMATION OF FRENEL DIFFRACTION DE BROGLIE'S WAVES RANGE ON THE NUCLEI FOR INCIDENT PARTICLES WITH *Z* FROM 0 to 8.

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Experimental obtaining of values and signs of deformation of nuclear surface is one of the central problems of modern nuclear physics. Such information was derived before from the experimental data on electric quadrupole moments which defined only deformation of charge component of nucleus. Later A.Yushkov has developed an experimental method for extraction of values and signs of mass component of nucleus according to the method of Blar's phases shift. This method has three disadvantages: 1) necessity to measure inelastic scattering of accelerated ions in couple with elastic scattering; 2) impossibility to make experiments in heavy nuclei sector (especially for rare earth elements), which have huge nuclear deformations and short energy interval between collective level 2^+ and ground state; 3) impossibility to measure quadrupole deformation of odd-mass nucleus with collective level 2^+ decomposed by valence nucleon for energy multiplet. And shift of phases disappeared. That's why we need to search experimental methods for accurate measurements of values and sings of nuclear deformations in heavy and super heavy nuclei area, and also nuclei that have no excited rotary collective states necessary for methods of shift of Blar's phases, for example, odd-odd nuclei.

Main purpose of this work is to develop experimental method of accurate measurements of absolute value and sign of nucleus deformation for ground state with help of elastic scattering of light and heavy ions. Theoretical works by Kotlyar and Shebeko premised to development of such method and revealed that Frenel diffraction also is sensible for sign of nuclear deformation as in the method of Blar's phases shift founded on Fraungopher's diffraction of de Broglie's waves. Using two conditions in the experiment simultaneously: condition of strong absorption of incident particles by nucleus and high value of Sommerfeld's parameter, in 1968 V.Gonchar and others discovered apparent Frenel oscillations in angular distribution of differential cross-section of elastic scattering. Extremums of these oscillations shift to the zone of small or high angles depending on sign of deformations; and angular value of the shift depends on absolute value of nonsphericity parameter.

Some experiments of measurements of differential cross-section of elastic scatering of protons with the energy from 350 keV to 1000 keV for the light nuclei made on linear accelerator UKP-2-1. Using other sources we analyzed the received data of angular distributions in the limits of Kotlyar's and Shebeko's theory of Frenel diffraction. The received shifts of the Frenel phases allowed estimation of values and signs of nuclear nonsphericity of some light and medium nuclei. These values coincide with data received from Fraungopher's diffraction by method of Blar's phases shift rather well.

DEEPER INSIGHT INTO MECHANISM OF BAND SPECTRA GAP FORMATION AND POSSIBLE NEW VIEW ON THE NUCLEAR SHELL MODEL

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We introduce the notion of the possibility of exact coincidence ('permanent' resonance) of external fixed periodic potential and wave spatial oscillating frequencies for continuous energy values on a whole finite energy interval. It results in exponential increase/decrease of wave swinging amplitudes and resonance destruction of physical solutions inside the spectral gaps (forbidden zones) for waves in periodical structures. The break of the continuous spectra for free wave motion by periodic perturbation and band spectra formation has analogy in separation of shell model multiplets in nuclei. The solutions in allowed zones can be understood as alternation of increasing/decreasing regimes (wave beating) when exact resonance is violated. These wave beatings can explain some shape deformations.

NUCLEAR STRUCTURE DERIVED FROM INTERQUARK CORRELATIONS OF BOUND NUCLEONS

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Starting with a quark model of nucleon structure, elaborated by one of the authors [1], in which the valence quarks are strongly correlated with one another within the nucleon, the smallest nuclei, ^{2}H, ^{3}H, ^{3}He and ^{4}He can be constructed by assuming similar correlations with the quarks in neighboring nucleons. Applying the model to larger collections of nucleons reveals the emergence of symmetries at the nuclear level that are implied by the quark-quark interaction – specifically, geometrical shells and subshells that are isomorphic with those known from the independent-particle (~shell) model [2]. Significantly, the nuclear texture implied by the strong correlations in the quark model is not a nucleon "gas" or independently orbiting nucleons, but rather a nucleon lattice in which local (quark) interactions are responsible for all aspects of nuclear binding. By constructing large nuclei in this way, the quark-based lattice model reproduces the main features of the shell and liquid-drop models in a fully self-consistent manner. Because of the predominance of three– , four– , and many–body effects in the quark model, medium and heavy nuclei have transient tetrahedral nucleon aggregates that correspond to the alpha configurations of the cluster model. In general, lattice arrangements of nucleons lead in natural way to nuclear deformations, even though nuclei with closure shells are not spherically symmetric.

It is shown that quark–quark interactions of adjacent nucleons are responsible for formation of the nuclear configurations that correspond to the exotic (borromean) nuclei. According to the model loosely bound halo neutrons are arranged in triangular configurations bound to one proton of the core nucleus.

We therefore claim that the many liquid-drop, shell and cluster characteristics of nuclear structure are manifestations of interquark correlations. The model has been developed on a qualitative rather than quantitative level, but indicates ways in which the long-standing internal contradictions of nuclear structure theory (long or short mean-free-path, strong or weak nuclear force, solid/liquid/gaseous nuclear phase, etc.) can be resolved on the basis of quark effects.

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QUASILOCAL DENSITY FUNCTIONAL THEORY

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We propose a generalization of the conventional (local) density functional theory (DFT) [1,2] to deal with the non-local case overcoming the limitations encountered previously [3]. Our new theory leads to single-particle equations of motion with a quasi-local mean-field operator. This operator contains a quasi-particle position dependent effective mass and a spin-orbit potential which are essential ingredients in nuclear structure theory. The energy density functional is constructed using the Thomas-Fermi approximation to the one-body density matrix [4]. The ground-state properties of doubly magic nuclei are considered in the framework of this approximation. Calculations are performed using the finite range Gogny D1S force and the results are compared with the exact Hartree-Fock (HF) ones [5].

We also have explored the ability of this quasi-local DFT to describe a particular excited state: the isoscalar giant monopole resonance [6]. This study is done using the scaling approach and performing constrained calculations to obtain the cubic and inverse energy moments (sum rules) of the RPA strength. The numerical calculations are performed using the Gogny forces and an excellent agreement is found with the HF+RPA results reported in earlier literature.

Finally we briefly describe the extension of the DFT to include pairing correlations and its connection with Hartree-Fock-Bogoliubov theory is discussed. Our quasi-local DFT including pairing correlations allows to obtain equations of motion which are more simple for numerical calculations than the equations corresponding to the non-local case [7].

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TWO UNRESOLVED PROBLEMS OF SUPERDEFORMATION

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Since the experimental discovery of superdeformed (*SD*) bands twenty years ago several unexpected phenomena have been observed. The discovered bands have so regular rotational structure that the *SD* nuclei represent a best quantum rotor known in nature. The regularity helped to uncover two fine effects, identical bands and the ΔI=4 bifurcation, which have been not fully understood in terms of our knowledge of nuclear structure. It is not unlikely that an adequate solution of these problems leads to new insights into nucleus as a finite many-body system.

The identical bands in neighbouring *SD* nuclei have the nearly equal γ-ray energies E_γ. The accuracy of the coincidence is of order 10^{-3} which is much smaller that the expected variation of 10^{-2} due to the mass difference. The finding of the identical bands in *SD* nuclei was followed by the discovery of similar bands at normal deformations. The last effect is more puzzling owing to the pairing correlations which increase the variation to 10-15%.

The ΔI=2 transition energy staggering or the ΔI=4 bifurcations is the other mysterious phenomenon in the physics of superdeformation. It is observed as regular deviations of the γ-ray energy differences ΔE_γ from the smooth behaviour. In spite of having the energy scale of tens of electron-volts (compared with $E_\gamma \approx$ 1MeV), the phenomenon is a topic of considerable interest. The motivation is furnished by a period of oscillations, ΔI=4, that is unusual for nuclear physics, and by their long and regular character.

The common feature of these two phenomena is the strong dependence on the detailed property of the single-particle structure of a band. The feature allows to find active orbitals and to establish the systematization, which give an opportunity for solving the problems.

MULTICLUSTER STATES IN NUCLEI AND THE STATISTICS OF ALPHA-PARTICLES

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How does many-fermion system give rise to substructures (clusters) in it? Are they stable or fluctuating? What is the interrelation between the cluster structure and an observation process? To answer these questions the microscopic (A-nucleon) model of multi-alpha-particle (MAP) states of nuclei basing on the Hamiltonian of broken *SU(3)* symmetry is proposed and the classification of these states taking into account Pauli principle is built. Due to the properties of the Hamiltonian at the proper boundary conditions a system behaves as MAP one although its constituents are nucleons. The memory about the fermion structure of such a system is kept in the specific selection rules only. As a consequence of these rules the allowed number of alpha-particles at a certain energy level is limited and is not a constant. The model provides a rather good description of qualitative and quantitative characteristics of the multicluster spectra. It seems to be promising to describe quasimolecular and superdeformed spectra, may find use in nuclear astrophysics, etc.

A system described by the Hamiltonian looks like MAP condensate at normal density. The statistics of alpha-particles is not precisely Bose-Einstein one, it is also neither Fermi-Dirac nor parastatistcs; and this property is model independent for MAP phase of a system. The number of alpha-particles at a certain level is limited due to the antisymmetry of the wave functions of fermions comprising a system. However occupation numbers of alpha-particles grow rapidly with the increasing of the size of a system thus Bose-Einstein statistics appears. The statistics of arbitrary bosons composed by fermions (mesons, electronic subsystems of atoms with an even Z, etc.) are qualitatively the same as the alpha-particle one.

BOSON STRUCTURE OF THE LOW-LYING STATES OF 1*p*0*f*-SHELL NUCLEI

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Many attempts have been made to establish a connection between the interacting boson model (*BM*) and the shell model (SM). In general, main difficulties in these attempts consist in finding the transition from the fermion space of the SM to the collective boson subspace.

In the IBM calculations the boson space is customary formed by the *s* and *d* bosons, but for majority cases this is too small for the description of the basic features of the low-lying spectra of collective nuclei. Therefore, in order to reproduce results obtained in large SM spaces it is necessary to consider boson spaces of correspondingly large dimensions, but expanded in terms of set of bosons as small as possible.

We report a method which immediately indicates bosons dominating in the low-lying states of 1*p*0*f*-shell nuclei. This method based on the mapping procedure of Ref. [1] consists in constructing and diagonalizing the boson image of the SM Hamiltonian in the space expanded in terms of bosons corresponding to collective pairs which expand the complete SM space. Thus, having expanded the SM eigenfunctions in terms of all bosons allowed in the major 1*p*0*f* shell we can find their population in examined nuclear states and implicitly select a small set of dominating bosons which suffices to reproduce the SM spectra in the reduced boson space.

As an example we present in Fig.1 the boson's population in the lowest T=0 states of A=44 nucleus while the BM energy spectrum of the same nucleus calculated in spaces expanded in terms of *s, d, d', g, g', i* and *i'* bosons, i.e. bosons most intensively populated in the 1*p*0*f* shell is compared in Fig.2 with the SM energy spectrum.

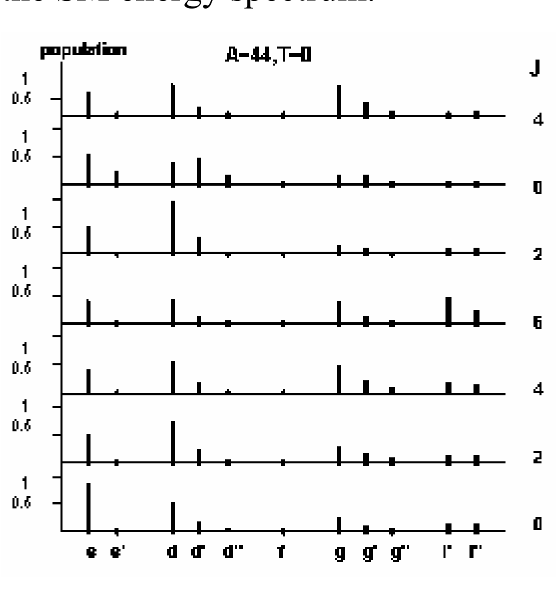

Fig.1

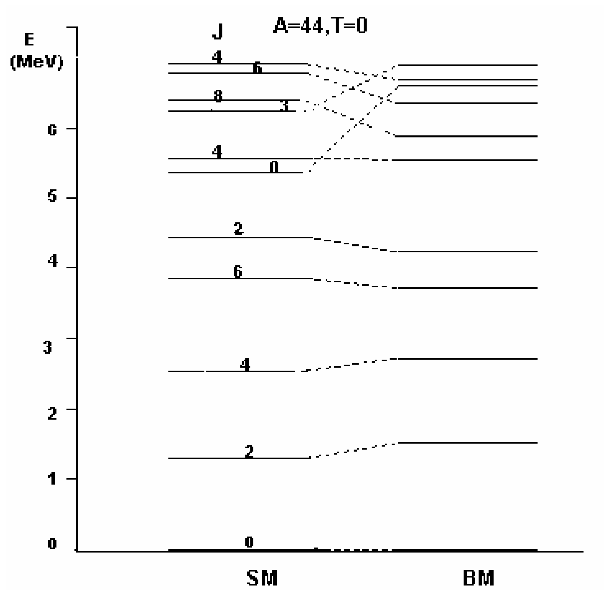

Fig.2

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STUDIES OF PHASE TRANSITIONS AND QUANTUM CHAOS RELATIONSHIPS IN EXTENDED CASTEN TRIANGLE OF IBM-1

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The precise solution for the classical energy functional $E(N,\eta,\chi;\beta)$ minimum of extended Casten triangle [1], following from the corresponding cubic equation

$$A(N,\eta,\chi)\cdot\beta_0^3 + B(N,\eta,\chi)\cdot\beta_0^2 + C(N,\eta,\chi)\cdot\beta_0 + D(N,\eta,\chi) = 0\,, \qquad (1)$$

has been obtained. The first order phase transition lines and critical points $X(5)$, $\overline{X(5)}$, $E(5)$ have been analyzed with respect to roots β_{01}, β_{02}, β_{03} of Eq.(1). The obtained results were compared with the approximate ones of Ref.[1], following from the application of Landau theory of phase transitions to the energy functional $E(N,\eta,\chi;\beta)$.

The solutions of the corresponding quantum Hamiltonian of IBM-1 for Casten triangle case, obtained using values of parameters (η,χ) in the neighbourhood of phase transition lines and critical points, have been employed for the calculations of statistical (level spacing distributions) and dynamical (wave function entropy [2] and level fragmentation width [3]) criterions of quantum chaos. It was found that the behaviour of quantum chaos criterions is correlated with the positions of parameters (η,χ) in the Casten triangle, showing the relationship with phase transition lines and critical points.

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PSEUDOSPIN SYMMETRY IN FINITE NUCLEI

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The notion of pseudospin symmetry (PSS) has been introduced in nuclear physics about 40 years ago, but only very recently, different explanations for its origin based on the relativistic description of nuclei have been proposed. In the present report the current status of the problem of the PSS will be discussed. In particular, the following points will be emphasized:

1. The PSS is an important feature of the nuclear structure. At present, most of the authors, working in this field consider the PSS as a dynamical symmetry, although there exist certain differences of opinions about the particularities of its realization. We have shown that the PSS in the nucleus is strongly related to the spin-orbit interaction and, consequently, to the spin symmetry (SS).

   Although the relativistic formalism of the SS and the PSS shows many common features, it also reveals essential differences arising from the different behavior of the term breaking the corresponding symmetry.

2. The PSS is realized as an approximate symmetry in nuclei. Its accuracy has been related by us, in particular, to the number of nodes of the small component F of the Dirac spinor (the degree of pseudospin-orbit degeneracy and of the degree of similarity between their respective F functions increase rapidly with the number of nodes of F).

3. The relativistic framework enables one to investigate also the special status of the intruder states in finite nuclei.

SPIN CUT-OFF PARAMETER OF NUCLEAR LEVEL DENSITY

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Recently extensive level schemes have become available which are complete in a given energy and spin range and which contain reliable spin and parity assignments. This level scheme together with neutron resonance data represents an ideal prerequisite in order to test statistical theories and to determine statistical parameters about the neutron binding energy. In our study the energies, spin and parities of large number of nuclei from ^{12}B to ^{247}Cf are applied to determine the spin cut-off factor for low lying levels as a function of mass number A. Balanced number of even-even , even-odd and odd-odd , light, medium heavy and heavy, spherical and deformed nuclei are considered in the investigation. We have used the traditional Bethe formula in the analysis of the experimental data. The preliminary results are presented at the APS meeting [1]. We have found that unlike the claims made by some authors, the spin cut-off factor does not follow a smooth A-dependence and deviates substantially from their corresponding rigid body values.

We have initiated similar analysis of the data using the microscopic theory of the BCS model. This model takes into account the pairing interaction as well as the shell effect. The results of calculation will be presented and discussed. The dependence of spin cut-off factor on energy and deformation will also be presented.

Level density parameter has also been obtained using the same data. It is found that the level density parameter near the major shell is very different from their corresponding Fermi gas values. This can be accounted for by considering pairing interactions and shell effect as well. These results will also be presented.

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INCOMPRESSIBILITY AND SINGLE PARTICLE POTENTIAL FOR ASYMMETRIC NUCLEAR MATTER USING SKYRME POTENTIAL

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The incompressibility and the single particle potential of asymmetric nuclear matter have been investigated in the framework of the Skyrme potential. These parameters have been studied as functions of the density ρ, the neutron excess parameter α_τ and the temperature *T*. The ratio of the isothermal incompressibility $K^T(\alpha_\tau, T)$ of hot asymmetric nuclear matter to the incompressibility $K^0(\alpha_\tau,0)$ of cold asymmetric nuclear matter for different values of α_τ is calculated as a function of temperature (Fig.1). It is observed that this ratio decreases with increasing the temperature for different values of α_τ where $0 \leq \alpha_\tau < 1$. For $\alpha_\tau = 1$ (pure neutron matter) the ratio starts to increase with increasing the temperature. The symmetry incompressibility has been calculated as a function of density for different values of temperature.

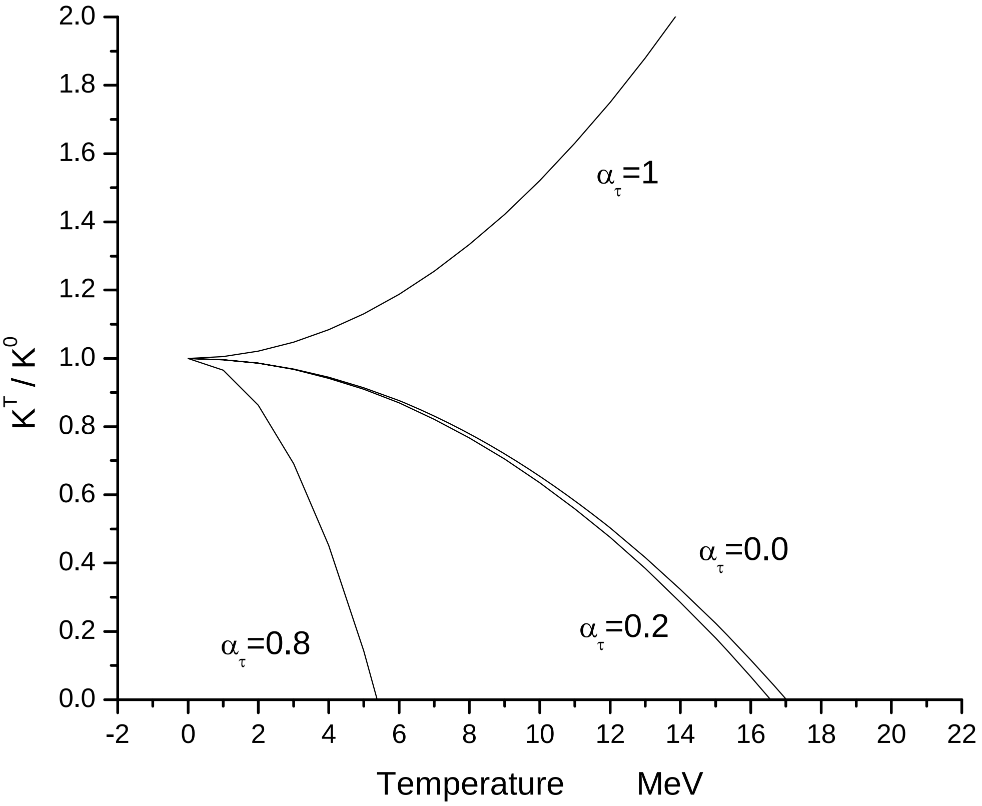

Fig.1. The ratio of the incompressibility of hot nuclear matter to that of cold nuclear matter as a function of temperature

SIGNATURE OF PAIRING PHASE TRANSITION IN THE THERMAL PROPERTIES OF $^{96\text{-}97}$Mo

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The nuclear level density is an essential quantity in the determination of the thermodynamic properties of nuclei such as entropy, temperature and heat capacity. Unfortunately, it is difficult to obtain these quantities experimentally as well as theoretically. Recently the Oslo Cyclotron group has extracted the nuclear level densities for ^{96}Mo and ^{97}Mo nuclei from primary γ spectrum using (^{3}He,$\alpha\gamma$) and (^{3}He, ^{3}He$'\gamma$) reactions on ^{97}Mo target [1].

The basic aim of the results of this work is to investigate the signature of a pairing phase transition in the entropy of $^{96\text{-}97}$Mo nuclei. The entropy is a fundamental quantity in the description of many-particle system.

The nuclear level densities of $^{96\text{-}97}$Mo nuclei are calculated in the framework of BCS theory [2]. The parameters of nuclear level density are so chosen that the saddle point conditions are satisfied and also the best fit to the experimental data yields. Then using these parameters the energy and the entropy are calculated as a function of temperature.

As it will be presented and demonstrated the dip in the caloric curve reflects the structural change. Besides, the entropy curve exhibits an *S*-shape. This is a signature of the transition from strongly paired states at low temperature to unpaired at higher temperature.

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ANTIFERROMAGNETISM OF NUCLEAR MATTER IN THE MODEL WITH EFFECTIVE GOGNY INTERACTION

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The possibility of ferromagnetic and antiferromagnetic phase transitions in symmetric nuclear matter is analyzed within the framework of a Fermi liquid theory with the effective Gogny interaction. It is shown that at some critical density nuclear matter with the D1S effective force undergoes a phase transition to the antiferromagnetic spin state (opposite directions of neutron and proton spins). The self-consistent equations of spin polarized nuclear matter with the D1S force have no solutions corresponding to ferromagnetic spin ordering (the same direction of neutron and proton spins) and, hence, the ferromagnetic transition does not appear. The antiferromagnetic (AFM) spin polarization parameter is found both at zero and finite temperatures. It is shown that the AFM spin polarization parameter of partially polarized nuclear matter for low enough temperatures increases with temperature. The entropy of the AFM spin state for some temperature range is larger than the entropy of the normal state. Nerveless, the free energy of the AFM spin state is always less than the free energy of the normal state and the AFM spin polarized state is preferable for all temperatures below the critical temperature.

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ON THE PARTIALLY SELF-CONSISTENT MEAN FIELD

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The mean field concept is widely used in nuclear physics. Usually the field consists of the isoscalar and isovector central parts (U_0 and U_1 , respectively), the isoscalar spin-orbit term (U_0^{so}) and the mean Coulomb field (U_C). Recently fully phenomenological mean field with inclusion also of a rather small isovector spin-orbit term (U_1^{so}) has been used to describe the experimental single-quasiparticle spectrum in doubly-closed-shell nuclei ^{208}Pb, ^{132}Sn, ^{48}Ca [1]. Most levels has been satisfactory described (better, then 0.3-0.4 MeV) except of one-two levels near the Fermi energy (the difference was found about 1-1.5 MeV).

It is well known, that within the single-particle model the fundamental symmetries of the nuclear Hamiltonian are broken. They can be restored within the RPA with the use of a particle-hole interaction. In particular the isospin-selfcosistency condition, which relates U_1 to the isovector (i.e. neutron-excess) density, should be used to describe correctly the Fermi and other types of the isovector excitations (see, e.g., Refs. [2,3]). In these references the isospin-selfconsistent mean field has been used with inclusion also of the self-consistent mean Coulomb field. The use of such a mean field leads, in particular, to the single-quasiparticle spectra, which are close to those obtained in Ref. [1].

In the present work we extend the number of consistently calculated terms in the mean field. Namely, we calculate consistently also the isoscalar and isovector spin-orbit terms which are supposed to be proportional to smoothed derivative of, respectively, the isoscalar and isovector nuclear density. In such a version of the mean field all "small" terms (U_1 , $U_{0,1}^{so}$, U_C) are linear in the corresponding combinations of the neutron and proton densities and can be calculated selfconsistently. The use of this partially selfconsistent mean field allows us to reduce the large differences between the calculated and experimental energies in the single-quasiparticle spectra of the above-mentioned nuclei. Other possible applications of the presented version of the partially selfconsistent mean field are also discussed.

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ON MICROSCOPIC CALCULATIONS OF ODD DEFORMED NUCLEI STRUCTURE

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The quasiparticle-plus-phonon model (QPM) and the axially-symmetric particle-plus-rotor model (PRM) including Coriolis mixing [1] is used to describe odd deformed nuclei. Nilsson potential parameters κ_N and μ_N, deformation parameters ε_2 and β_4, pairing gaps Δ_p and Δ_n, even-even core quadrupole and octupole vibrational energies and moments of inertia of individual experimental bands are the only free parameters fitted to experimental energies. We should emphasize that no additional adjustment of model quasiparticle, intrinsic QPM or PRM band head energies was necessary. Preliminary results for ^{161}Tm and ^{161}Er are presented in Table:

^{161}Tm band heads			^{161}Er band heads		
exp. E[keV]	theor. E[keV]	$K[Nn_z\Lambda]$	exp. E[keV]	theor. E[keV]	$K[Nn_z\Lambda]$
0	0	7/2[404]	0	2	3/2[521]
7	7	1/2[411]	172	170	5/2[523]
19	18	5/2[402]	213		5/2[642]
23	23	3/2[411]	369	368	3/2[651]+3/2[402]
78	76	7/2[523]	396	397	11/2[505]
			463	448	3/2[402]+3/2[651]
			481	498	7/2[400]
			725	723	3/2[532]
			843	841	5/2[512]

ε_2	β_4	$\Delta_{p[}$[MeV]	Δ_n[MeV]	ε_2	β_4	Δ_p[MeV]	Δ_n[MeV]
0.245	0.010	0.821	0.921	0.265	-0.046	0.906	0.888

κ_{2p}	κ_{3p}	κ_{4p}	κ_{5p}	κ_{6p}	κ_{3n}	κ_{4n}	κ_{5n}	κ_{6n}	κ_{7n}
0.107	0.0653	0.0950	0.0499	0.0679	0.0837	0.0788	0.0644	0.0715	0.0441
μ_{2p}	μ_{3p}	μ_{4p}	μ_{5p}	μ_{6p}	μ_{3n}	μ_{4n}	μ_{5n}	μ_{6n}	μ_{7n}
0.0164	0.2497	0.6885	0.6124	0.4148	0.2312	0.4536	0.5521	0.3983	0.2447

vibrational state energies [keV]											
0^+	2^+	0^-	1^-	2^-	3^-	0^+	2^+	0^-	1^-	2^-	3^-
790	1030	1200	1320	1360	1310	780	1180	1320	1180	1300	1220

One can see remarkable agreement between experimental and theoretical band head energies for reasonable fitted model parameters.

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EFFECT OF QUDRUPOLE AND OCTUPOLE VIBRATIONAL STATES ON NUCLEAR LEVEL DENSITY

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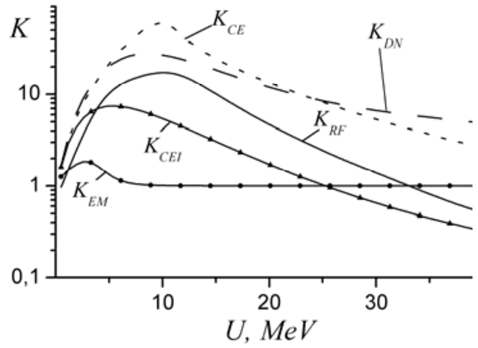

The effect of the quadrupole and octupole vibrational states on level density is studied with the use of different phenomenological approaches [1-4] and theory-based response function method [5]. The ratio (K) of nuclear level densities with and without allowing for vibrational states is studied as a function of the excitation energy. The change of the partition function due to the vibrational state effect is equal to $\Delta Z(T) = \exp\left(-\left(\Delta\Omega(T) - \Delta\Omega(T=0)\right)/T\right)$ with T for the temperature and $\Delta\Omega$ for addition to the thermodynamic potential due to vibrational states. The component $\Delta\Omega$ with allowance for vibrational state of multipolarity L is calculated by the relation $\Delta\Omega_L = \frac{2L+1}{2\pi}\int_0^k \mathrm{d}k' \int_{-\infty}^{+\infty} \frac{-\hbar}{\exp(-\beta\hbar\omega)-1} \mathrm{Im}\left(\chi_{k',L} - \chi_{0,L}\right)\mathrm{d}\omega$ within response function method [5]. Here $\chi_{k,L}$ is collective nuclear response function on external field of multipolarity L, k - strength of residual separable interaction. The dependence of the enhancement factor K on excitation energy is shown for ^{56}Fe on the figure. The contributions of quadrupole 2^+ and octupole 3^- states are taken into account; solid curve denotes calculation by the response function method $K = K_{RF}$ with relaxation time due to the kinetic theory [6]; – – - $K = K_{DN}$ from [2]; –·– - $K = K_{CE}$ is calculated as a ratio $\Delta Z_{CE} = Z_B(\omega_L)/Z_B(\omega_{0,L})$ of partition functions of bosons with complex energies; ▲ - $K = K_{CEI}$ from [1]; ● - $K = K_{EM}$ within method from code EMPIRE II[3]. The calculations within methods based on the partition function of bosons with the complex energies and attenuated occupation numbers can be used to simulate theory-based response function approach.

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COMPARISON AND TESTING OF METHODS FOR *E1* STRENGTH CALCULATIONS

V.A. Plujko[1,2], O.A. Bezshyyko[1], L.O. Golinka-Bezshyyko[1], O.I. Davidovskaya[2], I.M. Kadenko[1], R.V. Yermolenko[1]

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The radiative strength functions (RSF) are an important ingredient of statistical theory of nuclear reactions. Electric dipole gamma-transitions tend to dominate in nuclear processes. The nuclear reaction calculations are as a rule time consuming and simple closed-form expressions are preferable in evaluation of gamma-ray strengths. Recent analytical expressions for dipole transition gamma-ray strength functions provide reasonably reliable results for description RSF over a relatively wide range of gamma-ray energies (from zero to above the GDR energy) in middle and heavy nuclei on the beta-stability line [1-4]. These expressions are based on RSF description in the approximation of an symmetric nucleus (with the same numbers of neutrons and protons). It can lead to an underestimate of a total width of the RSF as well as to a distortion of the RSF shape, specifically in the range of gamma-ray energies close to the neutron separation energy (the pygmy dipole resonance region). An exact treatment of the centre of mass motion (c.m.) associated with dipole excitations of neutron-proton asymmetric nuclei is given in methods [5-7] in the absence of collision damping.

In this work the large-scale comparisons of E1 strength calculations within framework of the methods [1-7] are performed to study an effect of the c.m. motion conservation on the RSF shape in asymmetric nuclei. Photoabsorption cross-sections and average radiative widths are calculated and compared with experimental data to test both RSF models and different sets of the giant dipole resonance parameters. New version [8] of the Empire II (v.2.19) is used for calculations of the gamma-widths.

This work is supported in part by the IAEA(Vienna) under IAEA Research Contract № 12492.

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EFFECT OF NEUTRON EXCESS ON ISOVECTOR DIPOLE RESPONSE OF HEAVY NUCLEI

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The isovector dipole response of neutron-rich spherical nuclei is studied by using a semiclassical approach based on the solution of the linearized Vlasov equation for two-component systems with moving-surface boundary conditions. By using a separable approximation for the isovector and isoscalar residual interactions, an analytical expression is obtained for the dipole response function of neutron-proton asymmetric systems. It is shown that, by taking into account the surface degrees of freedom, the spurious center of mass motion is excluded from the isovector dipole response of asymmetric systems. This fact is essential for the study of the low-energy dipole strength (a pygmy dipole resonance) that is observed recently in neutron-rich spherical nuclei. Calculations of the isovector dipole strength function show that neutron excess leads to a smooth strength in the energy region of the pygmy dipole resonance. In the present study effects of neutron skin in the equilibrium state of system have been neglected. Taking into account these effects may bring to a low-energy resonance structure in our semiclassical approach.

ON DIRECT PROTON DECAY OF THE ISOVECTOR SPIN-FLIP GIANT MONOPOLE RESONANCE

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The charge-exchange (in the β^--channel) isovector spin-flip giant monopole resonance (IVSGMR$^{(-)}$) is the next vibration mode relative to the well-known Gamow-Teller resonance and, therefore, it is located at a large excitation energy. For this reason, one can expect the IVSGMR$^{(-)}$ to be strongly coupled to the single-proton continuum and, as a result, to have a large (i.e. of order of unity) total direct-proton-decay branching ratio b_{tot}. Such a prediction for the IVSGMR$^{(-)}$ in ^{208}Bi has been done in Ref. [1] within a semimicroscopic approach. This prediction has been experimentally confirmed by joint studies of the ^{208}Pb(^{3}He,*t*)- and coincident ^{208}Pb(^{3}He,*tp*)-reactions [2]. However, the distribution of the total decay probability over the decay channels was found in a sharp disagreement with predictions of Ref. [1]. In particular, strong population of the deep neutron-hole states in ^{207}Pb was unexpectedly found in Ref. [2]. This fact was one of the reasons to extend the experimental studies for other target nuclei, the results are expected to be available soon [3].

In the present work the partial and total direct-proton-decay branching ratios for the IVSGMR$^{(-)}$ are evaluated within a semimicroscopic approach. The approach is based on the continuum-RPA method and a phenomenological treatment for the spreading effect. As applied to description of isoscalar giant resonances, a modern version of the approach is formulated in Ref. [4]. We have extended the study of Ref. [1] in the following directions: (i) the spreading effect is taken into account in calculations of the proton continuum-state wave functions; (ii) the refined phenomenological mean field is used within the approach (it is especially concerns the spin-orbit term); (iii) possible contribution of the isovector momentum-dependent forces to formation of the IVSGMR$^{(-)}$ is effectively taken into account; (iv) properties of the IVSGMR$^{(-)}$ in singly- and doubly-closed parent nuclei ^{90}Zr, ^{120}Sn and ^{208}Pb are analyzed. The preliminary results for the b_{tot} values obtained with the use of the unit reduced spectroscopic factor for one-hole states in the corresponding product nuclei are the following: 72% (^{90}Zr), 65% (^{120}Sn) and 64% (^{208}Pb, $b_{tot}^{exp} = (52 \pm 12)\%$ [2]). Nevertheless, the disagreement with experimentally found in Ref. [2] distribution of the partial direct-proton-decay branching ratios for the IVSGMR$^{(-)}$ in ^{208}Bi still remains. For this reason, a comparison of the calculated branching ratios with the coming results of Ref. [3] has a great importance.

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QUASIPARTICLE TIME BLOCKING APPROXIMATION AND ITS APPLICATION TO THE CALCULATIONS OF THE ISOVECTOR *E1* RESONANCE IN NON-MAGIC NUCLEI

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A generalization of the model of Ref. [1] is presented. This model had been originally developed for the normal Fermi systems without pairing to describe excited states of the even-even doubly magic nuclei taking into account $1p1h$ plus $1p1h\otimes$phonon configurations. Within the present generalization the pairing correlations are also included. Thus, the range of the model [1] is extended to non-magic nuclei. The extended version of the model is based on the generalized Green function formalism (GGFF) which is very close to one employed in Ref. [2]. Within the GGFF normal and anomalous Green functions are treated in a unified way in terms of matrix elements of the generalized Green functions in a doubled space. Modification of the GGFF is considered in the case when many-body nuclear Hamiltonian contains two-, three-, and other many-particle effective forces. The physical content of the model is determined by the quasiparticle time blocking approximation (QTBA) which allows to keep the contributions only of the two-quasiparticle ($2q$) and $2q\otimes$phonon configurations excluding (blocking) more complex intermediate states.

The QTBA have been applied to calculations of the isovector *E1* resonance in the tin isotopes. The single-particle continuum is taken into account by making use of the method described in Ref. [3]. The results are compared with the QRPA calculations and with available experimental data. It has been obtained that the $2q\otimes$phonon configurations provide noticeable fragmentation of the resonance resulting in appearance of significant spreading width.

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INERTIA AND FRICTION IN SEMICLASSICAL NUCLEAR COLLECTIVE DYNAMICS

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For a semiclassical description of the nuclear low-energy collective dynamics, the periodic orbit theory (POT) was suggested in [1]. The multipole vibrations of a nuclear surface with radius $R(t) = R\,[1+Q(t)Y_{L0}(\theta)]$, $Q(t)$ is the time-dependent deformation of nucleus, were considered by applying the Strutinsky shell correction method for response functions. In the present work we deal with transport coefficients, the stiffness C, friction γ and inertia M, within the response theory in terms of sum of their smooth components, given by Strutinsky's averaging procedure, and shell corrections.

In the high temperature limit, the smooth components of transport coefficients are dominating. For a smooth friction $\tilde{\gamma}$ we derived the well-known "wall formula" by using the semiclassical trajectory expansion for one-body Green function, but with accounting for the two-body dissipation. The corresponding Thomas-Fermi inertia parameter $\tilde{M}$ is much smaller in order of the semiclassical parameter $k_F R \sim A^{1/3}$ than the hydrodynamic inertia of irrotational flow M_{irr}, $\tilde{M} \propto M_{irr}/A^{1/3}$ (k_F is the Fermi momentum, A the particle number). With the macroscopic stiffness $\tilde{C}$ of the liquid-drop model, for instance for quadrupole vibrations, one arrives at the A-systematics of low excitation energies $\hbar\omega = \hbar\sqrt{\tilde{C}/\tilde{M}} = D/A^{1/3}$, $D \approx \hbar^2\sqrt{2b_S/E_F}/mr_0^2 \approx 30$ MeV for typical realistic nuclear parameters**,** in contrast to the too low $A^{-1/2}$ behavior found in the liquid-drop model ($b_S = 17$ MeV for the surface energy constant, $E_F = 40$ MeV for the Fermi energy**,** m is the nucleon mass, $r_0 = R/A^{1/3} = 1.2$ fm). The smooth reduced friction $\tilde{\gamma}/\tilde{M} \approx 2E_F/\pi\hbar \approx 40\cdot 10^{21}\,\mathrm{sec}^{-1}$, valid at too high temperatures, overestimates the known experimental data on fission. We emphasize importance of the shell corrections δC, δM and $\delta\gamma$ to the transport coefficients at smaller temperature $T \ll E_F$. We obtained them analytically in terms of the periodic orbit sums, approximately as $\delta M \propto \delta F$, $\delta C \propto -\delta F$ and $\delta\gamma \propto -\delta F$, where δF is the shell correction to the free energy. These shell components exponentially disappear at temperatures $T \approx T_{cr}$, $T_{cr} \sim 3-4$ MeV. Due to these shell components, our POT results for the collective reduced friction γ/M and excitation energy parameter $\hbar\omega$ are largely in agreement with some experimental data and theoretical calculations.

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INTERACTING VECTOR BOSON MODEL ANALYSIS OF THE ^{160}Dy ROTATIONAL BANDS ENERGIES

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Written in terms of the (λ,μ) labels facilitates together with the decomposition rules the energy spectrum produced by the IVBM Hamiltonian are as follow [1]:

$$E((\lambda,\mu);L;T_0) = \alpha N+\alpha_1 N(N+5)+\beta_3 L(L+1)+\alpha_3(\lambda^2+\mu^2+\lambda\mu+3\lambda+3\mu)+cT_0^2 \qquad (1)$$

From the energy spectrum (1) we can determine the expressions for the rotational bands energies as follow:

$K^\pi = 0^+$ **ground state band** $\{\lambda = 0, \mu = 2L\}$ and $T = 0$, $T_0 = 0$

$$E_{gr} = 4\alpha L + \beta_3 L(L+1) + 4\alpha_1 L(5+4L) + 2\alpha_3(6L+4L^2) \qquad (2)$$

$K^\pi = 0^+$ ***S*** **band** $\{\lambda = 4, \mu = 2L-2\}$ and $T = 2$, $T_0 = 1$

$$E_s = c_s + 4\alpha L + \beta_3 L(L+1) + 4\alpha_1 L(5+4L) + 2\alpha_3 (6L+4L^2) \qquad (3)$$

$K^\pi = 1^-$ **octupole vibrational band** $\{\lambda = 2, \mu = 2L-1\}$ and $T = 1$, $T_0 = 1$, $L \geq 1$

$$E_{oct\,1}^- = c_1^- +4\alpha L+\beta_3 L(L+1)+4\alpha_1 L(5+4L)+\alpha_3\{10+5(2L-1)+(2L-1)^2\} \qquad (4)$$

$K^\pi = 2^+$ γ **vibrational band** $\{\lambda = 4, \mu = 2L-2\}$ and $T = 2$, $T_0 = 1$, $L \geq 2$

$$E_\gamma = c_\gamma + 4\alpha L + \beta_3 L(L+1) + 4\alpha_1 L(5+4L) + \alpha_3\{28+7(2L-2) + (2L-2)^2\} \qquad (5)$$

$K^\pi = 2^-$ **octupole vibrational band** $\{\lambda = 2, \mu = 2L-1\}$ and $T = 1$, $T_0 = 1$, $L \geq 2$

$$E_{oct\,2}^- = c_2^- + 4\alpha L + \beta_3 L(L+1) + 4\alpha_1 L(5+4L) + \alpha_3\{10+5(2L-1) + (2L-1)^2\} \qquad (6)$$

Previous calculations of rotational bands energies with the different forms of nuclear density shapes [1] had shown that the moment of inertia depends on number of monopole bosons n approximately as: $I(n) \approx I(0)(1+xn)$, where x is connected with the diffuseness parameter s, compressibility coefficient C_0, one-phonon energy E_0 and nuclear half-radius R as:

$$\boldsymbol{x} = ((E_0 R^2((-3+20\pi)R^4+30(-1+4\pi)R^2 s^2+45(-1+4\pi)s^4))\times$$
$$\times(8C_0\pi^2(R^6+13R^4 s^2+45R^2 s^4+45s^6))^{-1})$$

We use this approximation in our calculations of the energies of rotational bands determined by (2-6). It is important to point out that all these bands are calculated with the same set of parameters :

α	α_1	α_3	x	β_0
0.00568396	-0.0274276	0.05485516	0.0020997	0.23, $\boldsymbol{\beta_3} = 1/2I(n) = \boldsymbol{\beta_0}/(1+n\boldsymbol{x})$

The agreement between calculated and experimental energies [2,3] is very good and average energy deviation $<|E_{expt}-E_{calc}|>$ for all bands under consideration is less than 9 keV per point.

The investigation was supported by the RFBR.

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APPLICATION OF BOGOLUBOV TRANSFORMATION TO IBM

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Many transitional nuclei exhibit quasirotational bands in which the distance between levels gradually increase with the spin I and intraband *B(E2)* values are much more than single-particle estimates. Such spectra can be described by the Interacting Boson Model (IBM) with parameters intermediate between the SU_5 and O_6 limits of IBM. Though the energies could be reproduced only in the frame of the SU_5 limit conserving the number (n_d) of the IBM *d*–bosons, effective charges *e** in this limit turn out noticeably higher than microscopical RPA estimations (*e** is a scale factor to connect empirical and theoretical *E2*-matrix elements). This drawback is removed by keeping those terms in the IBM Hamiltonian which mix *d*-boson numbers. This enhances theoretical *E2* matrix elements and consequently decreases *e**. To comprehend the role of such terms we have applied the boson Bogolubov Transformation (BT), $d^+_\mu = uc^+_\mu + vc_{\bar\mu}$, to a simplified IBM Hamiltonian allowing for basic SU_5 and O_6 terms

$$\widehat{H} = e\hat{n}_d - k\sum\nolimits_\mu \left(d^+_\mu d^+_{\bar\mu} ss + h.c.\right) \approx e\hat{n}_d - k\sum\nolimits_\mu \left[d^+_\mu d^+_{\bar\mu}\left(\Omega - \hat{n}_d\right) + h.c.\right] \quad (1)$$

Ω being the maximum *d* – boson number. A similar approach was used in [1] and showed its efficiency. After BT the exclusion of terms $P^+ + P$ ($P^+ = \sum c^+_\mu c^+_{\bar\mu}$) in the transformed Hamiltonian it is reduced to the form $\hat{h}_n = E_{On} + \omega_n(\hat{n}_d + 5/2)$, so its eigenfunctions for yrast states are $\sim (c_2^+)^n \mid 0>_n$. The vacuum and one–quasiboson energies (E_{On}, ω_n) and also the vacuum function $\mid 0>_n$ depend on *n*, that is caused by the boson "blocking" and that has to be taken into account at calculations of *E2* matrix elements. The only parameter determining E_{On}, ω_n and *u, v* – coefficients is $z = 2\kappa/\varepsilon$, $\kappa = k(\Omega - <\hat{n}_d>)$, $\varepsilon = e + 4\,k\,u\,v\,(n + 2.5)$, $0 \le z \le 1$; it is found as a solution of a nonlinear equation $z=(2k/e)\{\Omega+2.5+(n+2.5)[(1-z^2)^{0.5}-2(1-z^2)^{-0.5}]\}$. The comparison of the energies and *B(E2)* values obtained by the BT method and after the exact diagonalization of $\widehat{H}$ (1) indicates that the exactness of the BT method improves with increasing of Ω (the discrepancy is $\le 3\%$ for $\Omega = 6$ and $\le 1\%$ for $\Omega = 12$). Since empirical data manifest that observed maximum spins in long bands are frequently much more than the number of valence particles or holes (as it is adopted in IBM), the BT method can find practical application for analyzing such bands.

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IKEDA DIAGRAM IN THE FRAME OF THE MODEL OF BINDING ALPHA-PARTICLES

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In the light nuclei, the correlated nucleons show a cluster structure. This fact is well expressed in the Ikeda diagram [1], which demonstrates cluster states in $N=Z$ nuclei and their thresholds for the decomposition into clusters. We assume that atomic nuclei might be considered as tightly packed alpha-particles [2]. The base of the suggested model is the assumption that binding energy can be expressed as a sum of energies coming from interactions between alpha-particles and their self-energies. We have two conditions for the distribution of alpha-particles in nuclei:

1. Alpha-particles are confined in the volume, which is approximately equal to the volume of nucleus.
2. The certain configuration of the alpha-particles corresponds to the minimum of the potential energy.

According to these conditions we can calculate the coordinates of alpha-particles in the nucleus. For the calculation of decomposition energy, we should take into account interaction between alpha-particles. For our calculations we have used the following potential:

$$V_{\alpha\alpha}=V_{nucl} + V_C$$

where V_{nucl} is the nuclear part of the αα potential and V_C is Coulomb potential. The Fig. 1 shows the result of the calculation for different kinds of nuclear potentials. There is a good agreement between experimental and theoretical data. We have approximately the same binding energies for the wide class of the potential wells, that are frequently used in the molecular and nuclear physics.

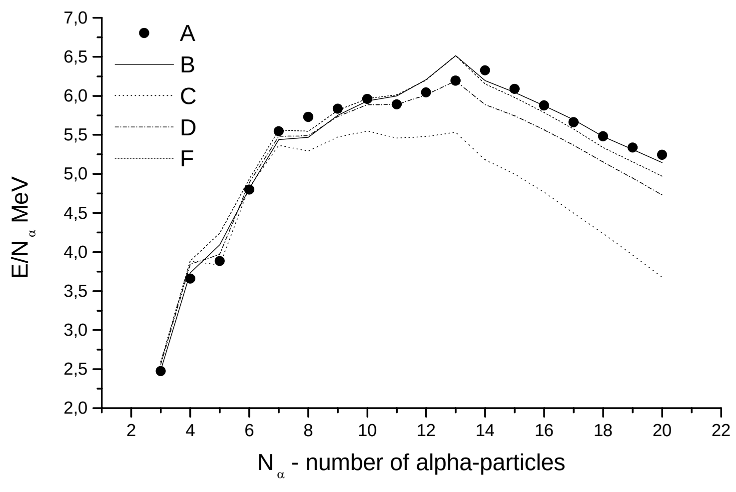

Fig. 1. The energy threshold for decomposition into alpha-particles per alpha-particle as a function of alpha-particles number. A -the experimental data, B - Ali-Bodmer potential, C - Yukawa potential, D - Bohr potential, E - Morse potential.

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ON THE GLOBAL PROPERTIES OF THE *A*=48 ISOBARS

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The basic properties of the *A*=48 isobars, from the neutron excess doubly magic ^{48}Ca up to the mirror-symmetrical proton excess nucleus ^{48}Ni are considered by using two methods: the concept of isobaric symmetry and the self-consistent HF+BCS calculations.

By now, the data on the value of the binding energy of ^{48}Ni are still not complete and final. The chance to use the isobaric chain with the complete set of mirror nuclei with the fixed mass number (*A*=48 in our case) leads to the unique opportunity when the deficiency of experimental information on the very exotic nuclei ^{48}Ni may be filled up by use of the isobaric relations that are fulfilled with a good reliability. As a result we obtain the value of the binding energy of ^{48}Ni equal to B_{emp}=348.2(0.5) MeV. This may be compared with the limitation on the B_{exp} that may be deduced from the lower limit (0.5 μs) [1] for the half-life of ^{48}Ni: $B_{exp}(^{48}\text{Ni}) \geq 348.2$ MeV. We also defined the values of the root-mean-square (*rms*) radii for the excited isobaric states for some *A*=48 nuclei that happened to be systematically more than those for the ground states.

Self-consistent HF+BCS calculations of binding energies and charge radii for the whole isobaric chain with *A*=48 were performed by using the Skyrme III and constant pairing interactions with account of blocking effect in cases of odd-odd nuclei. Together with the exchange Coulomb energy, that was considered in the Slater approximation, the contribution of the correlation Coulomb energy [2] was included as well. By account of all effects we obtained $B_{th}(^{48}\text{Ni})$=349.0 MeV. The calculations show the existence of small pairing correlations ($\Delta B_{th} \approx 1$ MeV) in ^{48}Ni. These correlations lead to a rather strong increase of the rms charge radii for the ground states of ^{48}Co and ^{48}Ni, the effect arises due to admixtures of the proton quasi-stationary states of the 28 ÷ 50 shell to the ground-state wave function of ^{48}Ni. The experimental confirmation of this effect would testify to the smearing of magicity in the proton system of ^{48}Ni.

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OPTIMAL-ROTATING-FRAME METHOD WITH CONSTRAINT CONDITIONS BETWEEN NUCLEON VARIABLES

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The method based on the Mikhajlov transformation from the laboratory to a body-fixed frame (see [1] and ref. therein) is developed for the description of deformed rotating nuclei. The structure of many-body angle operators describing the nucleus orientation is investigated, and it is shown that essential matrix elements of these operators between quasiparticle states may be approximately expressed via an effective single-particle operators. Equations for the effective operators are determined by minimization of the nuclear Hamiltonian transformed to the rotating frame. The nucleus wave functions and energies are found within the framework of the self-consistent independent-quasiparticles approximation. The constraints between nucleon variables are taken into account by the following two ways.

In the first manner, the usual cranking-model constraint fixing an average value of angular momentum projection is used. Calculations for rotational energies of nuclei with odd neutron number have been performed in the framework of this simple version. The developed model describes the energies of positive parity bands considerably better than the self-consistent cranking model while for negative parity bands the quality of both models is approximately the same.

A more correct manner to take into account quantum constraints is considered. This method, developed by Bes et al. [2], is based on a hamiltonization of the theory with the Faddeev path integral. It is shown that difficulties of the method appearing because of divergent matrix elements may be removed if for each such matrix element an appropriate sequence of loop diagrams is summed.

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SPHERICAL LATTICE FOR NUCLEAR SHAPE MODELING

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It is known, that the stability of radioactive atoms depends on the shapes of nuclei [1]. Root-mean-square (RMS) radii and deformation of nuclei are the parameters in half-life and decay energy calculations [2] which may occur experimentally inaccessible, especially in the case of superheavy elements not synthesized yet. Thus the mathematical modeling of nuclear shape dependence on its structure has theoretical and practical meaning.

Lattice models have been developed as computational techniques to calculate several properties of nuclei, see for example [3-5]. The correspondence between the lattice symmetries, lattice sites and the IP model eigenvalues and energy states of nucleons [6], allows to assume that despite lattice models have no strictly physical substantiation yet, the accuracy of calculations is close to fundamental nuclear models and the simplicity of computation have perspectives for nuclear shape modeling by lattices.

In our researches we develop the *spherical lattice model* (*SL-model*) and the computer program *Statgraf_01* for the investigations of the spatial properties of heavy nuclei. The main difference between our lattice model and previous ones consists in nuclear building-up procedure which has included some features from liquid drop and from independent particles models.

For model approbation the root-mean-square radii of nuclei with atomic number $115 \leq Z \leq 240$ were calculated. Only one adjustable parameter – the radius of lattice unit cell- was fitted and the average convergence between experimental and theoretical RMS has turned out to be 0,4 % rel. This good convergence was achieved due to the lattice substructures variations that could be fulfilled in frame of *SL-model*. Also it was found that when several lattice substructures are taken into calculations a few RMS values could be obtained for nuclei with *A*-nucleons and they differed on the same manner as experimental RMS for isotones with this *A*. It was assumed that the exchange of lattice substructures may be caused by various proton/neutron distribution in isotones.

Thus the first approbation of *SL-model* by RMS-calculations has shown its sensitivity and applicability to researches of the spatial properties of heavy nucleus.

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DOUBLE REVERSAL THE PARITY SIGN IN ROTATION BAND WITH ALTERNATIVE PARITY

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The presence of strong octupole correlations in nuclei of actinide region is reflected in a significant lowering of the excitation energies of the negative parity states. The energies of the octupole excitations fall into the levels of ground rotational band and form together with them an alternating parity band characterized by spin-parity sequence $I^{\pi} = 0^{+}, 1^{-}, 2^{+}, \ldots$ In such a unified band, the energy gap in each doublet of the parity is referred to as energy of the parity splitting.

Within the framework of the collective model of octupole motions, it was found [1] that the parity splitting decreases exponentially with angular momentum.

The model successfully described experimental data known at that time. But new experimental data has appeared and it became known that the parity splitting energy decreases to negative values with increasing angular momentum. As a result the effect of the parity sign reversal is observed in the alternative parity band.

To describe the reversal of the parity sign in the light isotopes of radium $^{220\text{-}226}Ra$ we applied the rotational model with high-spin approximation to Coriolis interaction between states exhibit parity splitting and alignment of intrinsic angular momentum [2].

The effect of angular momentum alignment as an energetic profitable effect leads to decreasing the energy of the state and to negative value of the splitting energy. The effect of parity sign reversal described within the framework of our phenomenological model by crossing of positive- and negative-parity rotational bands.

At high spins in some nuclei the reversal of the parity sign is developed second times. To describe that we introduce two more states with different values of alignment angular momentum into basis of unperturbed states. The Coriolis interaction gives rise to mixing of these states and as a result the second crossing of positive- and negative-parity rotational bands observed. The model explains this crossing by changing angular momentum alignment of the bands with opposite parity. The calculated values and experimental data comply very well.

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ESTIMATION OF CRITICAL TEMPERATURE FOR THE NUCLEAR LIQUID-GAS PHASE TRANSITION USING SMM

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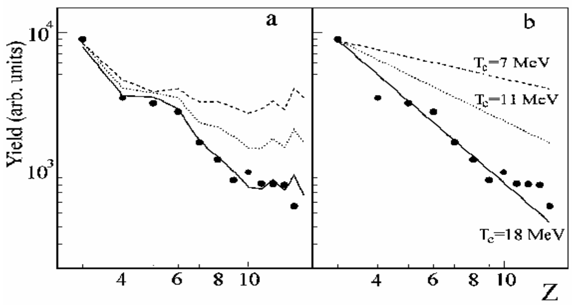
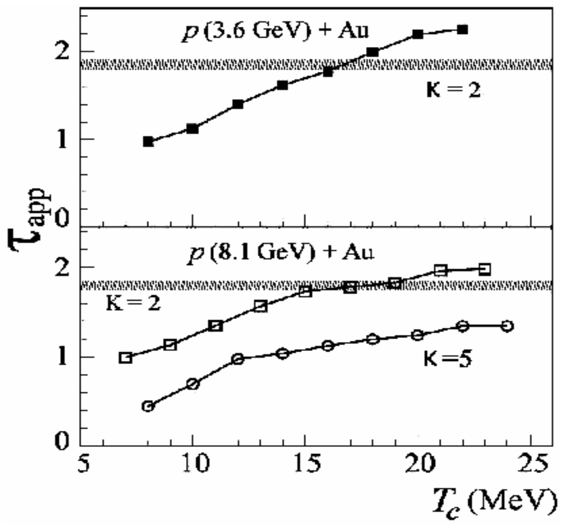
The critical temperature for the nuclear liquid-gas phase transition T_c (at which the surface tension vanishes) is estimated by using the statistical multifragmentation model. For that purpose, the IMF charge distribution for *p*+Au collisions at 3.6 and 8.1 GeV have been analyzed within the SMM with T_c as a free parameter. The value T_c = (17±2) MeV obtained from the best fit to the data should be considered as some effective value of T_c averaged over all the fragments produced in the collision. Although our value for T_c is model dependent, as is any other estimate of the critical temperature, the analysis presented here provides strong support for a value of T_c >15 MeV.



Fragment charge distribution for p + Au at 8.1 GeV (dots): a) the lines are calculated by INC+SMM model, assuming T_c = 7 MeV, 11 MeV and 18 MeV; b) the power-law fits.



Power-law exponents for the IMF charge distribution. The measured τ_{app} value (shown by the band) is compared to the model predicted ones with T_c as a free parameter.

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TEST OF INTERNAL CONVERSION THEORY THROUGH COMPARISON WITH PRECISE EXPERIMENT

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The question of allowing for the hole in the atomic shell after conversion is still an open question. Theoretical values of internal conversion coefficient (ICC) calculated with and without regard for the hole considerably differ (by ~15% and larger) when the conversion electron energy E_k is low (several keV and lower). On the one hand, when the time required to fill the hole is compared with that required for the electron to escape from an atom, it is apparent that the hole should be considered. On the other hand, in doing so wave functions of the initial and final states are no longer orthogonal functions of the same Hamiltonian as assumed in the conversion theory.

An extensive comparison [1] of various ICC calculations with a large body of experimental data did not reveal a clear preference for either of these two models ("hole" or "no hole"). Among 100 transitions listed in [1], the lowest conversion-electron energy is for the 80.2-keV *M4* transition in ^{193}Ir, where E_k=4.088 keV for conversion in the *K*-shell. In this case the difference between the "hole" and "no hole" calculations exceeds 10%. However, the two existing measurements of ICC α_K^{M4} were inconsistent with one another, one value being closer to ICC obtained in the "hole" model and other agreeing with the "no hole" model.

This situation gave impetus to the new precise experiment. The value obtained is α_K^{M4} =103.0(8) [2]. Calculations were performed in the framework of the Dirac-Fock method with and without regard for the hole which was taken into account using the self-consistent field of the ion (SCF) as well as the ion field with frozen orbitals (FO).

Model	α_K^{M4}	Δ,%
"no hole"	92.01	10.7
"hole", FO	103.3	-0.3
"hole", SCF	99.55	3.3

As seen, ICC calculated with regard to the hole are in good agreement with the experimental value. Here Δ is the difference in the experimental and calculated ICC.

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BOSONIC TREATMENT OF PAIRING CORRELATIONS IN A SOLVABLE MANY-LEVEL MODEL

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Developing reliable microscopic approaches for the description of correlations in quantum many-body systems is a field of active research in various branches of physics. A preeminent role in this field has been traditionally played by the Random Phase Approximation (RPA). This theory represents, in fact, the simplest theory of excited states which admits the possibility that the ground state is not of a purely independent character but may contain correlations. As is well known, however, this theory suffers of important limitations which have stimulated in the past an intensive work aimed at improving it [1-3].

We discuss an extension of the RPA based on a boson formalism and show some applications of it within an exactly solvable many-level pairing model (the so called "picket-fence model", also known in the condensed matter community as "reduced BCS model"). We preliminary discuss the boson mapping technique which is used to set up the boson operators (the Marumori technique) and show how it is possible to re-derive the Richardson's equations (which define the exact eigenvalues of the pairing Hamiltonian) in terms of a simple two-body hermitian boson Hamiltonian. We therefore make use of the boson formalism so defined to construct RPA-like equations in correspondence with different expansions of the boson operators (both the Hamiltonian and the phonon operators). The standard RPA equations are obtained in correspondence with the first order boson truncation. Two higher-level approximations are defined by resorting to a truncation of the boson operators at the second order. These two approximations differ for the choice of the ground state wave functions, one being cleared of some spurious components. We test the validity of the approximations by comparing their predictions with the exact results as well as with RPA and Self-Consistent RPA calculations. We show that it is possible to improve considerably upon RPA by still keeping the formalism simple enough to be used in realistic cases without a too serious computational effort.

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NEW METHODS FOR THE EXACT SOLUTION OF THE NUCLEAR EIGENVALUE PROBLEM BEYOND MEAN FIELD APPROACHES

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We have developed a new algorithm for diagonalizing the shell model Hamiltonian which consists of an iterative sequence of diagonalizations of sub-matrices of small dimensions [1]. The method, apart from being easy to implement, is robust, yielding always stable numerical solutions and free of ghost eigenvalues. Subsequently, we have endowed the algorithm with an importance sampling [2] which leads to a drastic truncation of the shell model space, while keeping the accuracy of the solutions under control. Applications to typical nuclei how that the sampling yields also an extrapolation law to the exact eigenvalues.

Complementary to the shell model algorithm is a method we are developing for studying collective and non collective excitations. To this purpose we solve the nuclear eigenvalue problem in a space which is the direct sum of Tamm-Dancoff n-phonon subspaces (n=0,1,..,N). The multiphonon basis is constructed by an iterative equation of motion method, which generates an overcomplete set of n-phonon states from the (n-1)-phonon basis. The redundancy is removed completely and exactly by a method based on the Choleski decomposition. The full Hamiltonian matrix comes out to have a simple structure and, therefore, can be drastically truncated before diagonalization by the mentioned importance sampling method.

The phonon composition of the basis states allows to remove naturally and maximally the spurious admixtures induced by the centre of mass motion.

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THEORETICAL INVESTIGATION OF *E2*- TRANSITIONS IN ^{172}Yb

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There are some known positive parity rotary bands in ^{172}Yb. In it the rotational structure of bands is developed, and some of them include levels with large enough spin. Experimental and theoretical works are devoted to investigate the properties of rotational levels these nuclei. The significant amount of them is devoted to study characteristics of electromagnetic transitions [1-4]. During last years, there intensively spent experiments an definition of low-lying collective states $K^{\pi}=1^{+}$ in the deformed nuclei, in particular in isotopes ^{172,174,176}Yb, promote development of their theoretically investigation.

In this work the properties of positive parity states of nuclei ^{172}Yb and the influence of $K^{\pi}=1^{+}$ states on the characteristics of low-lying levels are investigated. For calculations we have proposed the phenomenological model [4] which takes into account the Coriolis mixture of the ground $0_1^+(gr)$, $0_2^+(\beta_1)$-, $0_3^+(\beta_2)$-, $2_1^+(\gamma_1)$-, $2_2^+(\gamma_2)$- and 1^+ rotational bands.

Energy levels, reduced probabilities of *E0*-, *E2*- transitions and *M1*-transitions, as well as their ratio $X_I(E0/E2)$, $\delta(E2/M1)$ are calculated. In particular, the influence of nuclei rotation on parameters X_I and δ, the influence of states $K^{\pi}=1^{+}$ bands on electromagnetic characteristics low-lying levels are also investigated. The calculated values of the reduced probabilities of matrix elements *E2*- transitions from 0_2^+, 2_1^+ bands are compared with the experimental data [2]. As it is shown in table, the present model clearly reproduces experimental reduced matrix elements of *E2*- transitions (*eb*).

$I_iK_i \to I_fK_f$	Exp.[2]	Theor.	$I_iK_i \to I_fK_f$	Exp.[2]	Theor.
$2\gamma_1 \to 0gr$	$0.208^{+0,010}_{-0,040}$	0.164	$2gr \to 0gr$	2.45±0.12	2.50
$2\gamma_1 \to 2gr$	$0.250^{+0,016}_{-0,018}$	0.212	$4gr \to 2gr$	3.76±0.19	4.0
$2\gamma_1 \to 4gr$	$0.063^{+0,009}_{-0,004}$	0.050	$6gr \to 4gr$	5.34±0.27	5.05
$4\gamma_1 \to 4gr$	$0.46^{+0,08}_{-0,13}$	0.260	$8gr \to 6gr$	5.90±0.30	5.91
$4\gamma_1 \to 2gr$	$0.22^{+0,07}_{-0,05}$	0.112	$10gr \to 8gr$	6.71±0.34	6.66
$3\gamma_1 \to 2gr$	0.326(11)	0.316	$12gr \to 10gr$	7.01±0.35	7.33
$3\gamma_1 \to 4gr$	0.235(6)	0.212	$14gr \to 12gr$	$8.12^{+0,63}_{-0,43}$	7.95
$2\beta_1 \to 0gr$	$0.090^{+0,009}_{-0,009}$	0.124	$2gr \to 2gr$	$-2.63^{+0,28}_{-0,27}$	-2.98
$2\beta_1 \to 2gr$	$0.162^{+0,071}_{-0,008}$	0.143	$4gr \to 4gr$	$-3.54^{+0,84}_{-0,18}$	-3.81
$2\beta_1 \to 4gr$	$0.27^{+0,02}_{-0,08}$	0.212	$6gr \to 6gr$	$-4.31^{+0,22}_{-0,62}$	-4.54
$4\beta_1 \to 4gr$	-	0.162	$8gr \to 8gr$	$-4.49^{+0,23}_{-0,77}$	-5.17
$0\beta_1 \to 2gr$	$0.166^{+0,018}_{-0,018}$	0.127	$10gr \to 10gr$	$-6.32^{+0,74}_{-0,32}$	-5.74
			$12gr \to 12gr$	$-6.15^{+0,64}_{-0,74}$	-6.25

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NON-ADIABATIC *E1*- TRANSITIONS IN ^{170}Er

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In the given work the calculations for ^{170}Er are conducted within the phenomenological model [1], which takes into account Coriolis mixing of octupole bands. The parameters of inertia of rotating core J_0 and J_1 (Harrice parameterisation) are obtained from ground state band with $I \leq 10$. We have obtained analytical expressions for negative parity wave functions. The *E1*- and *E2*- transions probabilities from the states of $K^{\pi}=1^{-}$ bands are calculated.

In the table the theoretical values of ratio $R_{IK}=B(E1;IK\rightarrow(I+1)gr)/B(E1;IK\rightarrow(I-1)gr)$ are compared with the experimental ones [2] and with the values calculated in the adiabatic approach (Alaga). These calculations and the analysis of known experimental data show, that for improvement of theoretical description it is necessary to consider mixture of states of $K^{\pi}\geq 2^{-}$ bands.

E1- transitions ratio from the states of $K^{\pi}=1^{-}$ band

I	Exp. [3]	Alaga	Theory
1	?0.15	0.5	0.13
3	0.34	0.75	0.37
5	<1.18	0.83	0.47
7	-	0.87	0.52
9	-	0.90	0.54

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STRUCTURE OF ^{15}C NUCLEUS

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In recent years interest to the neutron-excess isotopes of ^{12}C nucleus has increased [1]. In present work on the basis of the particle-hole formalism within the multi-particle shell model the structure of ^{15}C nucleus has been treated. In accordance with Pauli principle the excess neutron of this nucleus in nine ones should be in $2s-1d$ shell. The positive parity of low-lying states in ^{15}C [1] proves the last statement.

In calculations of characteristics of ^{15}C nucleus states like two-proton holes in magic nucleus ^{16}O plus one neutron have been used as basis functions. In LS-coupling scheme these functions have the form

$$\left|(1p^{-2})^{(2T_1+1)(2S_1+1)}L_1, 2s :^{(2T+1)(2S+1)} L\right\rangle \text{ and } \left|(1p^{-2})^{(2T_1+1)(2S_1+1)}L_1, 1d :^{(2T+1)(2S+1)} L\right\rangle.$$

The energies and wave functions of low-lying states were calculated by diagonalization of nuclear Hamiltonian taking into account both central and spin-orbit interactions. Central interaction was taken as paring one. Our calculations reproduce the correct order of states, so the ground state is those one with quantum numbers $J^\pi, T = 1/2^+, 3/2$ and the first excited state $J^\pi, T = 5/2^+, 3/2$ which according experiment is laying on 0,740 MeV higher [2]. But theoretical value of excited state level exceeds the ground state only on 0,4 MeV. Ground state wave function (WF) consists of 8 components, while WF of the first excited state has 10 components. In the ground state s-components dominate in WF (their input is $\sim 98\%$), and in the first excited state d-components dominate practically with the same weight.

On the basis of obtained WF probability of β-decay to the ground and some excited states of ^{15}N nucleus have been calculated, as well as neutron spectroscopic S_n-factors in channel $n + {}^{14}$C with formation of ^{15}C both in the ground and first excited states. Our estimations of S_n-factors may be recommended for the experimental search in (d, p) stripping reactions on ^{14}C nucleus.

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SPECTROSCOPIC CHARACTERISTICS OF ^{6}Li+*n* CLUSTER CHANNEL OF ^{7}Li PRESENTED AS *αt*–SYSTEM

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Modern cluster models of light nuclei like $^6Li, ^7Li, ^9Be$, i.e. binary and multi-cluster dynamic models with Pauli projection (MDMP) proved to be quite adequate as they reproduce a lot of available experimental information on the static and dynamic nuclear characteristics.

It is well known that cluster wave functions (WF) are not orthogonal to each other. So, it is possible to construct different relative motion WF within the chosen presentation of initial nucleus. In [1] $2\alpha n$ WF of ^9Be nucleus was projected onto two-cluster channels with lithium isotopes $^{6,7,8}Li$. Following the same procedure in present paper αt-cluster WF of ^7Li [2] was projected on ^6Li+n channel. MDMP wave functions for ^6Li ground and excited states were used [3]. As a result, the relative motion radial WF $R_{6n}(r) = \left\langle {}^6Li, n \middle| {}^7Li \right\rangle$ have been obtained, and spectroscopic S_n-factors have been calculated. The comparison of present results with theoretical calculations done in multi-particle shell model [4] and experimental data [5] is given in the Table.

$^6Li: J^\pi;T$	$1^+;0$	$3^+;0$	$0^+;1$	$2^+;0$	$2^+;1$	$1^+;0$
E_x, MeV	0	2,19	3,56	4,31	5,37	5,65
S_n^{theor} [4]	0,804	0,593	0,285	0,086	0,208	0,017
S_n^{theor}	0,941	0,586	0,280	0,2175	0,1686	0,0267
$S_n^{\exp}$ [5]	0,87	0,67	0,24	(0,05)	0,14	–

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CORRELATION STUDIES OF THE ^{5}H SPECTRUM

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The spectrum of ^{5}H was studied using the $t(t,p)^5$H transfer reaction with 57.7 MeV triton beam delivered by the U400M cyclotron of Flerov Laboratory of Nuclear Reaction in JINR (Dubna, Russia). The high statistics of the data allowed complete kinematical reconstruction of energy and angular correlations among the ^{5}H decay fragments. Due to very expressed angular correlation picture we were able to unambiguously identify the broad structure in the missing mass spectrum above 2.5 MeV (with typical width of several MeV) as a mixture of $3/2^+$ and $5/2^+$ states.

The correlation picture at E < 2.5 MeV gives a strong evidence for interference of the low-energy wing of $3/2^+$ -$5/2^+$ doublet with the ground $1/2^+$ state of ^{5}H. We show that the results of this work are consistent with our previous studies of this reaction [1]. Our results for the ground state are also in a good agreement with the experimental observations [2] finding the ^{5}H g.s. at 1.7(3) MeV with width 1.9(4) MeV.

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DIAGNOSTICS OF THREE-BODY BORROMEAN HALO CONTINUA
RNBT (Russian-Nordic-British Theory) COLLABORATION

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General properties of the ground and three-body scattering states of Borromean halo nuclei are explored in a core + *n* + *n* three-body model using realistic binary interactions, for the testbench nuclei ^{6}He and ^{11}Li. Some criteria for resonances in three-body continua are discussed in Ref. [1].

Amplification of continuum cross-sections may be caused by,

i) True three-body resonances, which are caused by interaction of all three particles in the interior spatial domain;

ii) A long lived binary resonance in one of the constituent pairs;

iii) The response of an extended system to long-range transition operators;

iv) Resonances due to strong coupling between channels (CC resonance in few channels) or parametric resonance in quantum diffusion with complex coefficients.

The resonance criteria have strong similarity with those of the two-body case:

(a) a concentration of the wave function in the interior region (except for barrier top and virtual-state cases), and

(b) the existence and properties of any intrinsic resonant state should not depend on the excitation mechanism.

We have developed methods of continuum diagnostics:

i) Analysis of the multi-channel three-body effective 'mean field' to explore existence of possible 3-body bound and resonant states;

ii) Search for resonance behavior in interior norms of the continuum wave functions revealed in transitions to continuum states in nuclear reactions;

iii) Analysis of eigenphases of *S*-matrix for 3->3 scattering.

Progress in theoretical and experimental studies is being made by exploring the structure of the halo continuum in terms of two-dimensional energy and angular-energy correlations of constituents, from inelastic and charge-exchange reactions and electromagnetic dissociation of Borromean nuclei. General analytic properties of three-body scattering and transition amplitudes as well as analysis of spatial correlations [2] give helpful unique signature of the three-body resonance nature of the bumps in excitation functions. The intrinsic correlated structures of the continuum reveal three-body 2^+_1, 2^+_2, 1^+_1 resonances in ^{6}He, 0^+_1, 0^-_1 resonant structure in ^{11}Li, and a lack of resonant structure in soft dipole and monopole excitations in ^{6}He and in the ^{11}Li dipole response.

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CHARGE AND MATTER RADII OF BORROMEAN HALO NUCLEI: THE ^{6}He NUCLEUS RNBT (Russian-Nordic-British Theory) COLLABORATION

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A semianalytic connection between matter and charge radii for Borromean halo nuclei is derived. It is based on the three-body core + N + N cluster structure of such halo nuclei and knowledge of corresponding radii for the constituents from general properties of their ground states [1]. In stable nuclei the charge and matter sizes are close to each other, while in the neutron halo nuclei they are strikingly different. Traditionally, the charge radius is studied by electron scattering, isotope-shift measurements etc., involving the well-known electromagnetic interaction. Extracting the matter radius is more model-dependent, since in addition to ambiguities of the nuclear structure, supplementary assumptions on the reaction mechanism and effective nucleon-nucleon interactions are involved. Recently, a precise measurement of the charge radius of the ^{6}He Borromean nucleus, 2.054 ± 0.014 fm, was performed [2] by the method of laser spectroscopy.

Using the experimental value for the ^{6}He point-proton charge radius 1.912 ± 0.0018 fm, and the point-proton charge/matter radius 1.45 fm of ^{4}He (derived from the charge radius 1.672±0.025 fm), we obtain with our semianalytic formula that r.m.s. matter radius of ^{6}He is equal to 2.59±0.05 fm. Comparing this with r.m.s. radii extracted from nuclear reactions we may conclude, that Glauber type methods using core + valence neutron density [3] or granularity of the ^{6}He structure with quantum interference [4], are gratifyingly consistent with our reconstructed value.

The charge form factor of ^{6}He which is subject of future experiments at GSI and RIKEN is also predicted.

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FEW BODY IMPULSE AND FIXED SCATTERER APPROXIMATIONS FOR HIGH ENERGY SCATTERING

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One of the major complexities associated with the study of halo nuclei is the interplay between the structure and the scattering framework. When describing the scattering of stable from halo nuclei it is crucial to handle its many-body character in order to extract reliable structure information about the halo system.

We will review and compare several approaches for the scattering of a nucleus by a weakly bound composite, based on the multiple scattering expansion of the total scattering amplitude, namely, Factorized Impulse and Fixed Scatterer/Adiabatic Single scattering Approximations.

The effect of these different approximations to the scattering formalism on the calculated elastic scattering cross sections are studied for proton scattering from ^{6}He at 700 MeV/u. Higher order multiple scattering effects are also analyzed.

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STRUCTURE OF THE WEAKLY-BOUND ^{8}He VIA DIRECT REACTIONS ON PROTON TARGET

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Angular distributions of the elastic and inelastic scattering to the first 2^+ state of the ^{8}He exotic nucleus on a proton target were measured at E_{lab} =15.7A.MeV, using an ^{8}He beam produced by the Spiral facility at GANIL. Other direct reactions ^{8}He(*p,d*)^{7}He$_{gs}$ [1] and (*p,t*) were measured simultaneously at the same incident energy. The light charged particles (*p,d,t*) were unambiguously identified and measured in the MUST telescope array.

The (*p,d*) cross sections are large compared to the elastic ones [1]. To include the strong coupling effects of the ^{8}He(*p,d*)^{7}He$_{gs}$ on the ^{8}He(*p,p'*), the data were analyzed within the framework of the coupled-reaction-channel (CRC) method [2]. The ^{8}He(*p,p'*) and transfer ^{8}He(*p,d*) reactions were included in the channel coupling scheme of the continuum discretized coupled channel calculations. The entrance channel potential and transition form factor from ground state (gs) to 2^+ state were calculated within the framework of the microscopic complex JLM [3] nucleon-nucleus potential using the microscopic ^{8}He gs and transition densities, generated by the no-core shell model [4]. Including explicitly the coupling to the (*p,d*), the (*p,p'*) reactions are well reproduced. It is shown that this coupling changes deeply the features of the entrance potential and strongly affects the extraction of the structure information. From the (*p,p'*) analysis within CRC framework, we have extracted the features of the density profile for the gs and transition densities of ^{8}He, and compared it to the structure models. These results recall that, in general, it is essential to measure the (*p,d*) reaction and include it explicitly in the analysis of the (*p,p'*) scattering if correct information on structure is to be drawn.

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STRUCTURE OF THE ^{11}Li CONTINUUM FROM BREAKUP ON PROTON TARGET

RNBT (Russian-Nordic-British Theory) COLLABORATION

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Breakup reactions with fast beams of exotic nuclei are powerful tools for investigations of halo nuclei. We consider ^{11}Li breakup on proton target at *E/A* = 68 MeV, studied experimentally in Ref.[1] by correlation measurements of the emitted particles. In the present paper we probe the ^{11}Li inelastic scattering using the four-body distorted-wave reaction model [2] which allows calculations of all observables in processes leading to the low-energy 3-body continuum excitations of Borromean two-neutron halo nuclei.

The calculations of inelastic scattering show accumulation of dipole and monopole excitations of ^{11}Li near the three-body threshold and describe well the observed peak in the experimental energy spectrum of ^{11}Li. Also, the theory reproduces the corresponding experimental angular distribution and confirms a dominance of the dipole excitation. To reveal clearly the monopole excitation, experimental data at small angles are needed.

Investigations of a variety of angular and energy correlations between constituents are necessary to explore in detail the nature of halo nuclei. Various correlations are sensitive to different aspects of reaction mechanism and nuclear structure. To unravel the nature of halo excitations and establish their character, two-dimensional plots of energy correlations of fragments have shown to be useful. We investigated ridges in the calculated two-dimensional energy plots for ^{11}Li and obtained an indication, that while the monopole excitation is a `true' three-body resonance, a deviating behavior of the cross section ridge in the case of the dipole excitation provides new and additional evidence that this is not a `true' three-body resonance. Furthermore, angular correlations are sensitive to the partial orbital composition of halo excitations. Our calculations of angular correlations in the ^{11}Li inelastic scattering show that a mixture of angular momenta with different parities in the ^{9}Li + n + n continuum leads to asymmetry in the case of the dipole excitation.

Thus, simultaneous analysis of a variety of observables within the same theory is used to reduce ambiguities of model assumptions related to the reaction dynamics.

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NEUTRON-NEUTRON CORRELATION APPROACH FOR ^{11}Li HALO STRUCTURE INVESTIGATION

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It was predicted in ref. [1] that, due to the very large radius of ^{11}Li, and due to the very low binding energy of the halo neutrons, one may expect that in a fusion process on a light target, the halo neutrons may not be absorbed together with the ^{9}Li core, but may be emitted in the early stage of the reaction. Indeed, the experimental investigation of Si(^{11}Li, fusion) has shown that a fair amount of fusion events [2] are preceded by the pre-emission of one or two halo neutrons. In ref. [2] was also found that in the position distribution of the halo neutrons, a very narrow forward neutron peak is present. Considering that this peak may be due to neutron pairs, it was decided to investigate the neutron pre-emission in condition of much higher statistics by means of an array detector [3]. Indeed within the narrow forward peak (9 msr) a large number of *n-n* coincidences was found. Trying to built the n-n correlation function, a serious discrepancy was found between the experimental [4] and the theoretical ones [5]. This is shown in Fig. 1, in which the experimental points are significantly lower than predictions of $COSMA_1$ and $COSMA_2$ models. A possible explanation could be the residual correlation of the halo neutrons [6]. In ref.[6] has been proposed an iterative calculation to compensate for the residual correlation. But in ref [4,7] was shown that the iterative calculation is considerably increasing the error so that is no more possible to draw any conclusion concerning the theoretical predictions. In ref [4] was proposed an experiment for getting the intrinsic correlation function by using ^{11}Li and ^{11}Be beams. The halo nucleus ^{11}Be would be ideal for the denominator of the correlation function construction, because it has only one halo neutron and therefore no residual correlation can be possible.

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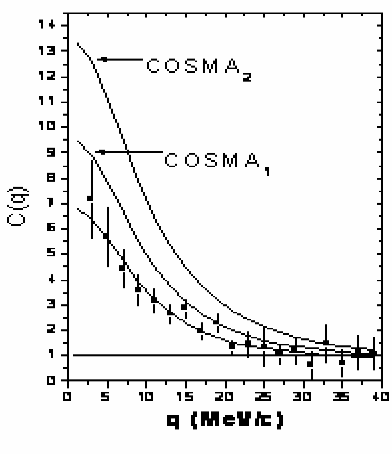

Fig. 1

SEARCH FOR 4-NEUTRON RESONANT STATE IN THE INTERACTION OF ^{11}Li WITH LIGHT TARGETS

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At the EXON-2001 Symposium, three events of 4-*n* coincidences fulfilling the 96% criterion of cross-talk (c-t) rejection have been presented [1]. Reanalyzing the events, was found that two of them satisfy also the 99% c-t rejection criterion. In table, the 4-*n* event #59, is exemplified. For c-t rejection formula 1 of ref. [2] (quoted in the following as *F1*) was used. The columns in table, are containing: the event number, the detector number (see Fig. 1, of next contribution in this vol.), neutron time of flight *T*, the neutron energy *E*, the light output *A* and the minimum energies E_m calculated in 4 variants, subtracting from t_1, up to 3 σ_t.The resolution σ_t = 0.4 ns was estimated from the γ-time-of flight peak [1]. At present, appears to be possible the investigation of 4-*n* coincidences at a level of much higher statistics, by using the pre-emission effect on C instead Si target [3], [4]. The number of expected 4-*n* events in an experiment ^{11}Li+C, can be estimated in the following way: Assume the number of *n-n* coincidences will increase ~7 times [4] by working with C target (s=3.5 times due to less target-screening and 2 times due larger number of carbon nuclei in the target). Considering that 4-*n* scales with s^2, one may expect up to 50 4-*n* events. The observation of 4-*n* coincidences would be an evidence for a 4-*n* resonant state appearing in the early interaction of ^{11}Li with the target, probably in the channel ^{7}Li + 4-*n*, for which the separation energy S_{4-n} is only 6.5 MeV. In the next contribution (in this vol.), the obtained P_{4-n} probability, with a new method (derived from ref [3]), supporting the data of table, is presented.

Ev	Nr. Det	*T* (ns)	E_n (MeV)	A (ch)	E_m MeV *F1*	E_m MeV *F1*-σ_t	E_m MeV *F1*-2σ_t	E_m MeV *F1*-3σ_t
#59,	8	.3948E+02	.6333E+01	115	150.5	78.5	48.1	32.4
#59,	23	.3941E+02	.6357E+01	82	69.1	34.6	20.8	13.8
#59,	70	.3978E+02	.6239E+01	5	239.4	142.0	93.9	66.6
#59,	76	.3844E+02	.6679E+01	104	–	–	–	–
#59,	8	.3948E+02	.6333E+01	115	4748.4	105.3	30.7	14.4
#59,	70	.3978E+02	.6239E+01	5	4450.8	1027.7	445.1	247.2
#59,	23	.3941E+02	.6357E+01	82	–	–	–	–
#59,	70	.3978E+02	.6239E+01	5	3570.7	655.8	265.8	142.8
#59,	8	.3948E+02	.6333E+01	115	–	–	–	–

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METHOD FOR CROSS-TALK DETERMINATION IN 4-NEUTRON COINCIDENCE EXPERIMENTS

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In this contribution, a new method derived from ref [1], allowing to determine quantitatively the cross-talk (c-t) in 4-neutron coincidences, is described. Implicitly, this method gives the $P_{4\text{-}n}$ probability characterizing the validity of the 4-*n* event as a true coincidence one. In ref [1] was observed that $t = t_2 - t_1$ distribution of c-t (t_1 being the arrival time of the first neutron in detector 1 and t_2 the arrival time of the neutron in detector 2) presents at low t values, a window in which c-t is very low. This window has been denoted by TC. For example in Fig. 2 (i) corresponding to the second order coincidence between detectors 76 and 23 (denoted in the following a, b respectively), the probability for c-t is very low indeed 10^{-3}. It follows that the probability for the experimental point shown with horizontal error bars, to be a true coincidence one, is P_{ab}=0.999. Figure 2 (ii) presents the coincidence between detectors 8 (denoted *c*) and 70 (denoted *d*) which according to Fig. 1 is a 4th order coincidence (detectors, separated by 3 detectors). As can be seen in Fig.2 (ii) the probability P_{cd}=0.994. It follows that the probability ${}^1P_{4\text{-}n}$ = 0.999*0.994=0.993. The other combinations are ${}^2P_{4\text{-}n} = P_{ad}*P_{bc}$=0.989 and ${}^3P_{4\text{-}n} = P_{ac}*P_{bd}$ = 0.991. The total probability $P_{4\text{-}n} = 1/3({}^1P_{4\text{-}n} + {}^2P_{4\text{-}n} + {}^3P_{4\text{-}n})$=0.991. The c-t points in Fig.2 were generated by Program MENATE [2]. The obtained data confirm also validity of analysis in ref. [3].

54	53	52	51	50	81	80	79	78
55	29	28	27	26	49	48	47	77
56	30	12	11	10	25	24	46	76
57	31	13	3	2	9	23	45	75
58	32	14	4	1	8	22	44	74
59	33	15	5	6	7	21	43	73
60	34	16	17	18	19	20	42	72
61	35	36	37	38	39	40	41	71
62	63	64	65	66	67	68	69	70

Fig. 1 The 4-n event #59.(see previous contribution in this volume (ref. [3])

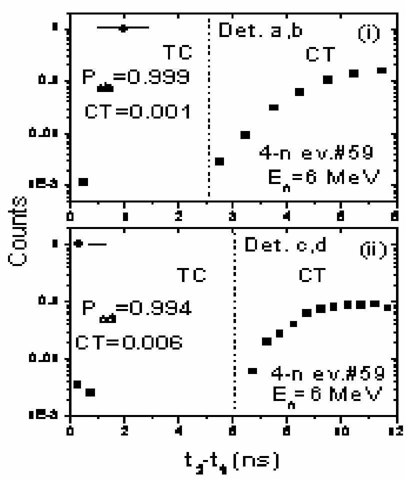

Fig.2 Det a,b are 76 and 23; Det, c,d are 8 and 70.

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ON POSSIBILITY TO STUDY A TWO-PROTON HALO IN ^{17}Ne: COULOMB DISSOCIATION AND NUCLEAR FRAGMENTATION

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The ^{17}Ne nucleus was studied theoretically in a three-body ^{15}O+p+p model [1,2]. We demonstrate that the experimental question of the proton halo existence in ^{17}Ne, formulated as in [3], is largely defined by *s/d* configuration mixing. The exact *s/d* ratio in ^{17}Ne is difficult to obtain unambiguously by theoretical calculations. To derive it from experimental data it is necessary to know the sensitivity of various observables to this aspect of structure. We calculate several observables for ^{17}Ne system and its isobaric mirror partner ^{17}N. We study also the Coulomb dissociation and nuclear fragmentation processes for this system. We show that currently available experimental data are insufficient to determine reliably the structure (and possible halo properties) of ^{17}Ne. It is possible, however, to find out which kind of experimental data is required to resolve the puzzling issues of the ^{17}Ne structure.

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NEUTRON-RICH NUCLEI NEAR THE DRIP-LINE FOR $6 \le Z \le 16$

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We present our results of searching for highly neutron-excessive stable nuclei that are distant from the conventional nucleon stability line. This investigation is based on the Hartree-Fock approximation with the Skyrme forces accounting for deformations (DHF). Sly4 parameterizations [1] of the Skyrme forces have been widely used for recent years. However in our previous paper [2] we have shown that for the deformed nuclei ^{25}Mg and ^{29,31}Si the most satisfactory description of observed spectra comes with the set of parameters Ska [3]. For this reason we investigated the phenomenon with both types of interaction. Pairing effects were included in the frame of the BCS approximation [4] with the pairing constant equal $G = 19/A$ for the protons and neutrons. Our DHF calculations of drip-line with the Ska forces predict the existence of a stability peninsula which rests on the isotope ^{40}O (see fig.1). As it is seen nuclear drip-line can have more complicated structure than it is commonly supposed to have [5,6].

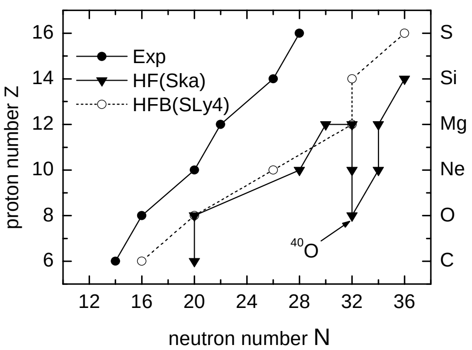

Fig.1. The part of neutron drip-line. For each value of Z the heaviest stable isotope has been presented for experimental data [7], Sly4 calculations [5], and our Ska calculations.

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COLLECTIVE EXCITATIONS IN EXOTIC NUCLEI

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Nuclei at extreme values of isospin are characterized by unique ground state properties: weak binding of outermost nucleons, closeness of the Fermi surface to the particle continuum, formation of the neutron skin and halo structures. These phenomena are also reflected in multipole response of unstable nuclei, leading to new modes of excitations. The excitation phenomena in nuclei towards the neutron and proton drip-lines are studied in the framework of the fully self-consistent relativistic quasi-particle RPA (RQRPA) based on the Relativistic Hartree-Bogoliubov model (RHB) [1,2]. The effective interaction is described by a Lagrangian density which includes new interactions with density-dependence that is explicitly included in meson-nucleon vertex functions. The properties of the low-lying excitations are studied in neuron-rich nuclei, indicating the appearance of a genuine exotic mode of excitation where the neutron skin oscillates around the rest of nucleons: pygmy dipole resonance (PDR). Within the Ni, Sn, and Pb isotopic chains, PDR is already at moderate proton-neutron asymmetry located above the neutron emission threshold, resulting with implications for the future photon scattering experiments and r-process calculations [3]. In nuclei towards the proton drip-line, recent RHB+RQRPA studies indicate the existence of a new exotic mode: proton electric pygmy dipole resonance, where loosely bound protons coherently oscillate against the proton-neutron core [4]. Furthermore, a method is suggested for determining the size of the neutron skin, based on the difference of the excitation energies of the Gamow-Teller resonance and the isobaric analog state [5]. The RHB+RQRPA model is also employed in the studies of beta-decay half-lives of nuclei of the relevance for the r-process [6].

An alternative approach to the studies of collective excitations is ab-initio framework based on realistic nucleon-nucleon interactions. Fully self-consistent Hartree-Fock + RPA model (UCOM-RPA) is formulated on the basis of the nucleon-nucleon Argonne V18 interaction, with explicit treatment of interaction-induced short-range and tensor correlations via the unitary correlation operator method [7].

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TERNARY FISSION FROM HYPER-DEFORMED STATES IN ^{60}Zn

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We have studied the binary and ternary cluster decay of ^{60}Zn using a unique charged particle detector set-up for the registration of binary coincidences (BRS, the Binary Reaction Spectrometer) in the reaction $^{36}Ar+^{24}Mg$ at energies of E_{lab}=195. The BRS measures the reaction angles in- and out-of-plane with a resolution of 0.2°, and gives through Bragg-curve and range spectroscopy a complete coverage of the charge yields for different final channels. The yields of the binary channels and the non-binary channels with definite values of missing charges and masses up to A=16 are determined. We observed very narrow out-of-plane angular correlations for binary but also for those ternary events, where the third missing charge is a multiple of α-particles (ΔZ= 4, 6). Energy distributions and differential cross sections are determined for the narrow and wide components of the fission yields. The two-dimensional diagrams for the events in the (energy/out-of-plane angle)-distributions give clear evidence, that the ternary decays originate from the highest angular momenta and from hyper-deformed shapes in ^{60}Zn. The relative yields of the fission events are described using the statistical approach (Extended Hauser-Fehsbach-model ETHF). The ternary fission decay and the formation of highly excited hyper-deformed nuclei in ^{60}Zn is supported by the shell-corrections which are shown in Ref. [1].

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EXPLORING THE REGION OF SHE – NUCLEAR STRUCTURE AND REACTION MECHANISM

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The search for superheavy elements has yielded exciting results for both the “cold fusion” approach with reactions employing Pb and Bi targets and the “hot fusion” reactions with ^{48}Ca beams on actinide targets [1-4]. In recent years the accelerator laboratories in Berkeley, Dubna and Darmstadt have been joined by new players in the game in France with GANIL, Caen, and in Japan with RIKEN, Tokyo. At RIKEN, in particular, very encouraging results have been obtained for the reactions on Pb/Bi targets. The results from GSI were confirmed [5] and in a ≈140 days experiment the new isotope $^{278}113$ has been successfully synthesized. Beyond the successful synthesis interesting features of the structure of the very nuclei like the hint for a possible *K*-isomer in ^{270}Ds [7] or the population of states at a spin of up to 22 ħ in ^{254}No [8] give a flavour of the exciting physics we can expect in the region at the very extreme upper left of the nuclear chart. Nuclear structure investigations and the study of reaction mechanism are necessary ingredients for a successful progress in synthesizing ever heavier elements in order to reach the predicted region of increased stabilisation by the next closed shell in neutron and proton number. Apart from more recent approaches like the investigation of partial wave distributions via γ-multiplicities [9], fusion excitation functions are the classical tools to study the features governing the fusion process. To complete and extend the existing body of data for reactions leading to nuclei with Z > 102, ^{54}Cr+$^{207,\ 208}$Pb excitation functions have been measured recently. An extensive program to study the nuclear structure using evaporation residue-α-γ(-γ) correlations after separation has successfully been pursued at SHIP throughout the last years (see e.g. [10]). Many isotopes up to Dubnium have been studied so far. The existence of *K*-isomers has been predicted to a general feature for many heavy isotopes [11] what supports our possible observation for ^{270}Ds. To get additional evidence we are presently performing a series of experiments to search for this behaviour in ^{260}Sg where two *K*-isomers are predicted [11] and`43 higher production cross sections should facilitate their observation. To continue successfully with these systematic investigations as well as with the synthesis of new elements a considerable increase in sensitivity is demanded from future experimental set-ups.

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TRAJECTORY ANALYSIS FOR FUSION PATH IN SUPERHEAVY-MASS REGION

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We propose an effective method for the precise investigation of the fusion-fission mechanism in the superheavy-mass region, using the fluctuation-dissipation model. The trajectory calculation with friction is performed in the nuclear deformation space using the Langevin equation. In the reaction $^{48}Ca+^{244}Pu$, the trajectories are classified into the fusion-fission process, the quasi-fission process and the deep quasi-fission process. By analyzing the time evolution of each trajectory, the mechanism of each process is clearly revealed, i.e., it is explained why a trajectory takes a characteristic path in this model. We discuss, in particular, the condition under which the fusion path is followed, which is crucial in the discussion of the possibility of synthesizing superheavy elements.

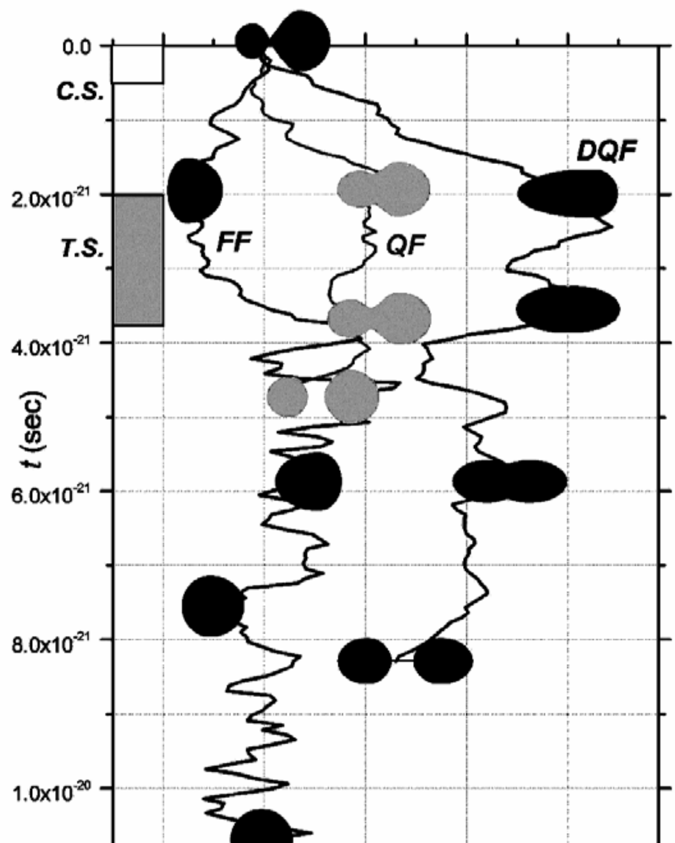

Fig. 1. The time evolutions of parameter δ and the nuclear shapes at several points for the trajectories, in reaction $^{48}Ca+^{244}Pu$ at $E^{*}=50$ MeV. The process is indicated by QF, DQF and FF. The blocked areas indicated by C.S. and T.S. are the critical stage and the turning stage, respectively.

After passing the critical stage, each process takes a different value of δ. Only the trajectory of the FF process takes a negative value of δ, and it is very important for the fusion process to maintain the oblate fragment deformation until the relaxation of δ.

Y.Aritomo and M.Ohta // Nucl. Phys. A. 2005. V.753. P.152.

THE SEARCH FOR THE SUPERHEAVY HYDROGEN ISOTOPE ^{7}H IN THE REACTION ^{9}Be(π^{-}, *pp*)*X*

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For the dripline nuclei the traditional magic numbers disappear and are replaced with new ones [1]. In particular, experimental data on the spectroscopy of the neutron-rich isotopes of He, Li and Be show that $N = 8$ magic number is replaced by $N = 6$. On this assumption one would expect that ^{7}H is most bounded among the superheavy hydrogen isotopes.

Recently the first experimental indication on the observation of the ^{7}H has been obtained in the reaction $p(^{8}\text{He},pp)X$ with the ^{8}He beam at 61.3*A* MeV [2]. The experimental missing mass spectrum increases near the t+4n threshold more sharply than phase-space distributions. However, the authors did not determine the resonance parameters of this state because of the large background.

In the present work the experimental search for the isotope ^{7}H is performed in the reaction of stopped pion absorption $^{9}\text{Be}(\pi^{-},pp)X$. The experiment was carried out at the Low Energy Pion channel of the Los Alamos Meson Physics Facility with a multilayer semiconductor spectrometer [3].

In the missing mass spectrum we obtained evidence for two states of ^{7}H with following parameters - $E_{r1} = 16\pm1$ MeV, $\Gamma_1 \cong 2$ MeV and $E_{r2} = 21\pm1$ MeV, $\Gamma_2 \cong 5$ MeV (E_r - resonance energy above the unbound 4n+t mass; Γ - is the FWHM of the peak). Some feature in the spectrum is observed near t+4n threshold, but statistics in this region is very poor.

The work was supported by the CRDF (grant MO-011-0) and the program "Russian Universities".

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STUDY OF THE MOMENTUM DISTRIBUTION OF ^{4}He FROM BREAKUP OF ^{6}He

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Momentum distributions of ^{4}He from breakup ^{6}He on carbon and gold nuclei were measured. Studying of the properties of ^{6}He by measurement of the momentum distribution of the ^{4}He core (or two neutrons) is of great interest and has been performed by many scientific groups around the world [1,2].

The beam of exotic nuclei ^{6}He with energy E=60.3±0.4 MeV and intensity $I=5\bullet10^{6}$ pps was produced by the acceleration complex for radioactive beams DRIBs. The size of the beam was not bigger than 7x8 mm. Reaction products were analyzed by the magnetic spectrometer MSP-144 [3] and were identified using a position-sensitive focal-plane detector.

As a result parallel momentum distributions of ^{4}He from the breakup of ^{6}He on gold (Fig. 1a) and carbon (Fig. 1b) were measured. The distributions were fitted by a Gaussian function. The widths of the momentum distributions were found to be narrow and equal to σ = 28-29 MeV/c. If ^{6}He were an ordinary nucleus this value should be approximately 100 MeV/c [4], but, as we see, in our experiment it is much less, a fact that confirms the existence of a halo in ^{6}He.

A series of measurements for the study of the breakup of ^{6}He and its isobar-analog ^{6}Li at different energies and on different target nuclei is planned.

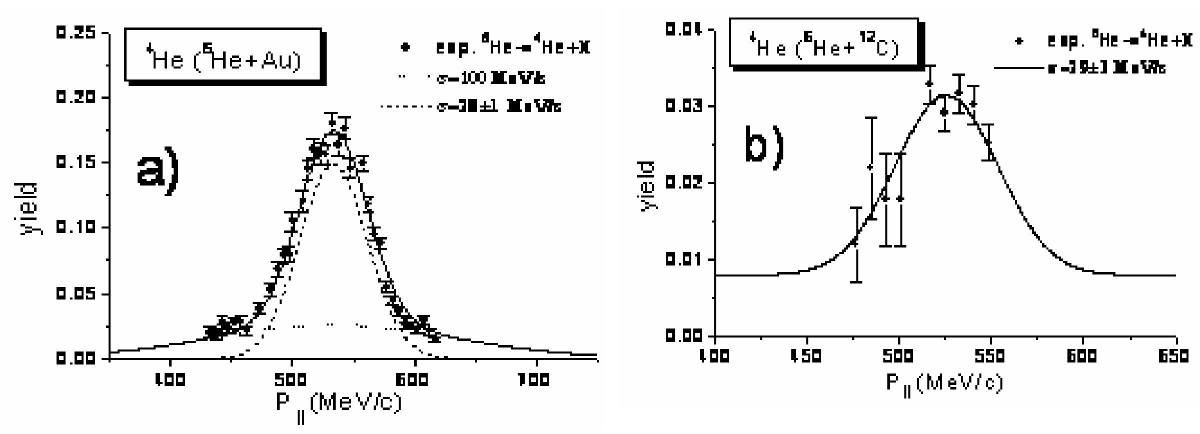

Fig. 1. Momentum distribution of ^{4}He from breakup of ^{6}He on carbon and gold target nuclei.

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CLUSTER POTENTIAL APPROACH TO DESCRIPTION OF ^{9}Be(γ, t_0)^{6}Li REACTION

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The ground-state cross sections (differential and total) measured in the energy range $E_\gamma = 21-34$ MeV and angular distributions of $^9Be(\gamma,t_0)^6Li$ reaction are reported in [1]. Energy distribution of outgoing tritons at $\theta_t = 125^o$ shows the pronounced resonance structure what may be interpreted by strong interactions in final scattering states.

Firstly, the relative motion ^6Li+t wave function (WF) was constructed by the overlapping of $^9Be_{gs}$ WF in $2\alpha n$-model [2] and ^6Li WF calculated in αnp-model [3]. As a result $R_{6t}(r) = \left\langle {}^6Li,t \middle| {}^9Be \right\rangle$ has a node behavior what is in agreement with 3*P*-wave function of shell model. Spectroscopic S_t-factors have been calculated under various assumptions on α-particle structure and compared with both theoretical calculations done in shell model and experimental data.

Following amplitudes have been taken into account: $P \xrightarrow{E1} s(1/2^+) + d(3/2^+, 5/2^+)$ and $P \xrightarrow{E2} p(1/2^-, 3/2^-) + f(5/2^-, 7/2^-)$. It was found that d-waves have the resonances at $E_{c.m.} \approx 5{,}5$ and 6,8 MeV and f-waves – at $E_{c.m.} \approx 10{,}3$ and 14,3 MeV. Angular distributions at $E_\gamma \le 23$ MeV are determined practically by *E1*-multipole. Then, at higher E_γ energies *E1-E2* interference leads to preferable outgoing of tritons into backward hemisphere what is qualitative agreement with experimental data [1].

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CLUSTER POTENTIAL APPROACH TO DESCRIPTION OF ^{9}Be (γ, p_{0+1})^{8}Li REACTION

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There are two sets of exclusive experimental data on photo-proton emission from ^9Be when ^8Li is registered in the ground state $(J^\pi, T = 2^+, 1)$ and 1-st excited state ($J^\pi, T = 1^+, 1; E^* = 0{,}9808$ MeV). Measured energy distribution for the (γ, p_0) process at $\theta_p = 125^o$ in the energy interval $E_\gamma = 18 - 28$ MeV as well as angular distributions integrated by the energy range $E_\gamma = 22 - 22{,}5$ MeV are given in [1]. Differential cross sections of the process (γ, p_{0+1}) at $\theta_p = 90^o$ are presented in [2]. Both measurements show the pronounced resonance structure of $\frac{d\sigma}{d\Omega}(E_\gamma)$ at $E_\gamma(E_{cm}) = 20{,}75(3{,}65)$; 21,66 (4,57) and 23,33(6,44) MeV. The analysis of photo-proton angular distributions [2] expanded by Legendre polynomials shows the comparable input of *E1*- and *E2*-multipoles. So, the goal of our investigations was to reproduce these specific features of the processes $^9Be(\gamma, p_{0+1})^8Li$.

Relative motion $^8Li + p$ wave function (WF) was obtained by the overlapping of $^9Be_{gs}$ WF in $2\alpha n$-model [3] and ^8Li WF calculated in αtn-model [4]. As a result $R_{8p}(r) = \left\langle {}^8Li, p \middle| {}^9Be \right\rangle$ WF has no node what is in agreement with $1P$-wave function of shell model.

Following amplitudes have been taken into account: $P \xrightarrow{E1} s(3/2^+) + d(1/2^+, 3/2^+, 5/2^+)$ and $P \xrightarrow{E2} p(1/2^-, 3/2^-, 5/2^-) + f(3/2^-, 5/2^-, 7/2^-)$. Theoretical calculations of (γ, p_0) and (γ, p_{0+1}) channels are in good agreement with experimental data [1,2]. It was found that the resonance structure of differential cross sections is conditioned by the resonance behaviour of $f(3/2^-, 5/2^-, 7/2^-)$ partial waves.

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CLUSTER STRUCTURE OF THE ^{12}Be NUCLEUS

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For analyzing cluster structure of light nuclei on the basis of the multi-channel version of the resonating-group method, it is appropriate to invoke a superposition of generating functions corresponding to various binary clusterings of the nucleus under study. As a result, it is possible to describe collision between light nuclei accompanied by formation of compound nucleus and its subsequent decay into different binary channels. Generator parameters of the generating functions represent complex-valued Jacobi vectors defined in the Fock-Bargmann space. Each cluster configuration is matched by a definite Jacobi tree. Vectors belonging to the latter tree serve as independent variables of both internal cluster functions and wave function of their relative motion. The superposition of generating functions generates a complete basis of the harmonic-oscillator states allowed by the Pauli principle of a multi-channel nuclear system. Within such an approach the shell-model wave function turns out to be a linear combination of terms corresponding to a distinct channels of deformation of a nucleus or its break-up. Each term is the result of transformation of the wave function realized by means of transition from single-particle vectors to the Jacobi vectors belonging to a certain tree. The shell-model is not adapted for describing deformation of a nuclear system or its break-up into various directions. For this purpose, it is necessary to invoke a wealth of specially selected configurations.

It is possible to reveal leading SU(3) branches among the variety of basis states, i.e., those which are matched by the maximum eigenvalues belonging to the Pauli-allowed states. Besides, there is one more characteristics of leading branches – their content depending on the type of clustering to which they belong to. The content of leading branches changes, as the number of quanta increases. Furthermore, the influence of the Pauli principle on the kinetic energy of cluster relative motion causes an effective cluster-cluster interaction, with the range and the strength being dependent on the type of clustering.

As an example of nuclear system which is able to decay into several binary channels (^{11}Be+n, ^{10}Be+2n, ^{6}He+^{6}He and ^{8}He+^{4}He), the ^{12}Be nucleus has been considered. Numerical calculations performed for ^{11}Be+n and ^{10}Be+2n clusterings demonstrated that in the ^{11}Be+n channel the 0^+ bound state is formed by the attraction owing its origin to antisymmetrization effects. The latter attraction appears to be strong enough to ensure the existence of the state with the energy about 0.8 MeV below the $^{12}\text{Be}\rightarrow{}^{11}\text{Be}+n$ threshold even without an interaction between valence neutron and the ^{11}Be cluster. *S*-matrix elements have been calculated for each clustering. The eigenphases have been demonstrated to be formed mainly by the kinetic-energy operator modified by the Pauli principle. Their behavior in the low-energy region reveals an attraction between clusters at small distances between them induced by the Pauli principle.

SCATTERING ON NUCLEI OF TWO-CLUSTER NUCLEI WITH ALLOWANCE FOR THE COULOMB INTERACTION

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The theory of diffraction interaction with atomic nuclei of weakly-bound nuclei with two charged clusters is developed taking into account the Coulomb interaction. The divergences (first of all logarithmic) of the integrals in the amplitudes of processes arising thus in the terms with double scattering in the standard diffraction theory, were eliminated by the precise allowance for the law of conservation of the momentum.

The differential cross sections of elastic scattering of nuclei $^{6}\mathrm{Li}(d+\alpha)$, $^{7}\mathrm{Be}(^{3}\mathrm{He}+\alpha)$ and $^{8}\mathrm{B}(p+{}^{7}\mathrm{Be})$ on nuclei are calculated at medium energies taking into acount the Coulomb interaction of both clusters with the nuclear target. It is shown, that the elastic scattering gives the main contribution to the measured cross sections of scattering [1–3], where can yield the small contribution as well inelastic processes. Is is shown, that the offered method at simple generalization can be used for calculations of the cross sections of elastic scattering and diffraction dissociation of incident weakly-bound nuclei with arbitrary number of charged clusters.

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THREE-BODY RESONANT RADIATIVE CAPTURE REACTIONS IN ASTROPHYSICS

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The reactions of the three-body radiative capture may play a considerable role in the rapid nuclear processes which take place in stellar media under the conditions of high temperature and density. We develop the formalism based on the *S*-matrix for 3 → 3 scattering to derive the direct three-body resonant radiative capture reaction rate [1]. Within this formalism the states, which decay only/predominantly directly into three-body continuum, should also be included in the capture rate calculations. The results obtained indicate that some theoretical calculations are incomplete. Basing on the derivation, as well as on the modern experimental data and theoretical calculations concerning ^{17}Ne nucleus, we significantly (up to 6-9 orders of the magnitude in the certain energy range, see Fig. 1) update the reaction rate for ^{15}O(2p,γ)^{17}Ne process in explosive environment. We also discuss possible implementations for the ^{18}Ne(2p,γ)^{20}Mg, ^{38}Ca(2p,γ)^{40}Ti, and ^{4}He($n\alpha$,γ)^{9}Be reactions.

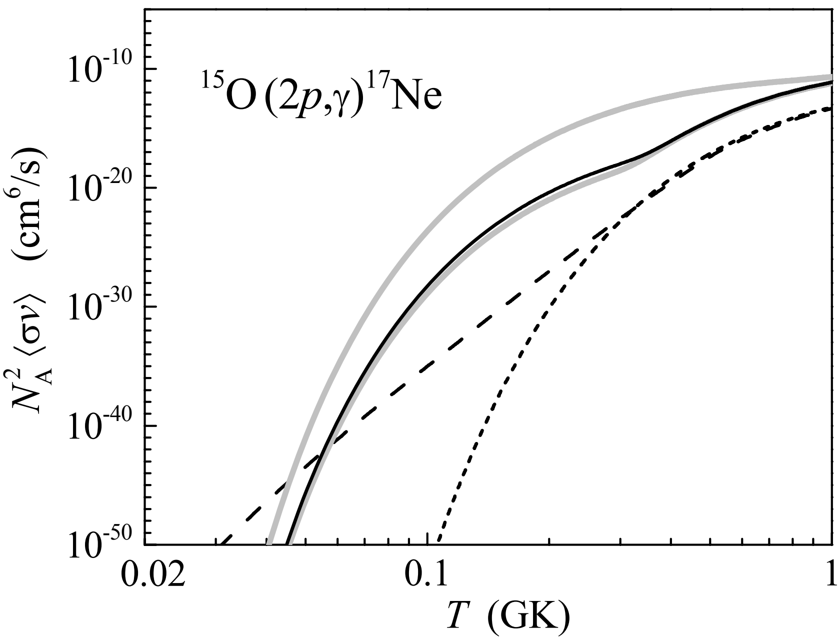

Fig. 1. Reaction rate for ^{15}O(2p,γ)^{17}Ne reaction. Solid curve shows calculations of our work. Gray curves indicate boundaries due to uncertainties in the input. Dashed and dotted curves show full result from Ref. [2] and resonance contribution to it respectively.

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DETERMINATION OF CROSS-SECTIONS OF A RADIATIVE CAPTURE ^{6}Li(p,γ)^{7}Be REACTIONS FOR THE ASTROPHYSICAL APPLICATIONS

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The reaction of a radiative capture ^{6}Li(p,γ)^{7}Be has large value for building of an ^{7}Li isotope, which is a result of an electron capture by a final ^{7}Be nucleus. The values of the astrophysical S-factor for this reactions were obtained at $E_p > 150$ keV with an error 30 % in low-energy area [1]. The calculated rates of this reaction for temperature $T_9 \leq 1.5$ have appeared of above recommended values, given in work [2]. This discrepancy can be connected with large experimental errors and uncertainties of a procedure of an extrapolation of cross-sections and S-factors in the area of low energies. The problem is, that the bound energy of ^{7}Be nucleus in a channel ^{6}Li+p is rather great (E = 5.609 MeV), therefore, reaction ^{6}Li(p,γ)^{7}Be descends not only in surface area, but also in all volume of a nucleus. It is needed computational method of the S-factors evaluation, which one correctly would allow to describe the contributions to total cross-section of formation ^{7}Be both area small and large relative intervals of colliding fragments.

In the present work the calculations of cross-sections of reaction ^{6}Li(p,γ)^{7}Be in an energy range from 0.16 MeV up to 1.2 MeV were carried out. The calculations were conducted with using of optical potentials with radiuses 1.1 fm and diffusivity 0.75 fm. The calculated values of total cross-sections of ^{6}Li(p,γ)^{7}Be reaction have appeared on 10 % of above experimental literary values. The given difference can be connected with none accounting of the spectroscopic factor of a channel ^{7}Be$\rightarrow^{6}$Li+p, which one relied to equal unit, because of absence in the literature of its any experimental estimations. The estimations is conducted by us, demonstrate, that it is determined by a channel spin 3/2 and is approximately equal to C = 0.9.

The estimation of the astrophysical factor on the basis of theoretical cross-sections was carried out with using of a parabolic function. The following parameters S (0) = 92 eV*b were obtained, which one are between an estimation S (0) = 65 eV*b of work [1] and estimation S (0) = 106 eV*b of work [3].

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TOTAL NUCLEAR REACTION CROSS SECTION AND FORWARD SCATTERING AMPLITUDE OF 10-1000*A* MeV LIGHT STABLE AND HALO NUCLEI

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The Glauber approach to analysis of reaction cross section data in the energy range below 100*A* MeV needs theoretical substantiation owing to an increase in noneikonal corrections and growth of influence of collective excitations. Recently [1], calculation of total cross section σ_R for reactions induced by nucleus-nucleus collisions were performed in the first approximation of eikonal expansion within the framework of optical model with phenomenological optical potentials (OP). In this paper we calculated σ_R and scattering amplitude on zero angle for nucleus-nucleus collisions using microscopic OP for energy range of incident particle 10-1000*A* MeV. The first order OP includes some versions of parameters of nucleon-nucleon scattering amplitude both for free nucleons and for nucleon-nucleon collisions in medium.

The density distributions of point nucleons in a target-nucleus and in a light stable projectile-nucleus have been parameterized in accordance with Charagi-Gupta prescription [2] and for the neutron halo projectile–nucleus according to COSMA model [3].

It is shown that in the case of nuclear density of Gaussian shape the noneikonal corrections have essentially smaller values in comparison with ones calculated in the framework of phenomenological optical model with Woods – Saxon OP. At the same time uncertainties of input parameters of nucleon-nucleon amplitude result in disagreement between calculated values σ_R, exceeding a correction to eikonal result for σ_R both for light stable and for radioactive halo nuclei.

Similar conclusions one can make for real part of forward scattering amplitude.

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ON MECHANISM OF $^{18}O+^{181}Ta$ AND $^{18}O+^{9}Be$ REACTIONS IN FERMI ENERGY DOMAIN

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In order to study the production mechanisms of exotic nuclei in the Fermi energy domain (E_F=38 MeV) we measured in [1,2] zero–angle velocity distributions and yields of quasi-projectiles with $2< Z <11$ from the collisions of the ^{18}O beam with energy of 35 MeV/u bombarding the ^{181}Ta and ^{9}Be targets. Charges, masses and beam-parallel velocities of collision products have been identified using in-flight separator COMBAS in the spectrometry mode. In the present work we perform theoretical analysis of the velocity distributions and yields of those products of the above reactions, which have $Z< 9$ and $A< 18$.

The analysis is based on the hypothesis of a two-step mechanism of which the first step is stripping of few nucleons from the projectile during its motion through the target and the second step is particle-emission decay of the many-hole states originated in the projectile in the first step. The Pauli blocking does not forbid us to overlap the densities of two interacting nuclei if the beam velocity exceeds the Fermi velocity. The stripping rate is described in terms of classical trajectories of the projectile constituent nucleons and the imaginary part of the optical potential responsible for the absorption of these nucleons in the target. The post collision decay is treated within the Fermi breakup model, using Botvina's code RAZVAL.

Taking $\Delta N_0=\Delta Z_0=3$ for the maximal numbers of neutrons and protons removed from the projectile in the first stage of the collision enabled us to reproduce zero-angle yields for $^{13\text{-}16}$O, $^{12\text{-}17}$N, $^{9\text{-}16}$C, $^{8,10\text{-}15}$B, $^{7,9\text{-}12,14}$Be, and $^{6\text{-}9,11}$Li isotopes in both reactions of study. This implies that our hypothesis on production mechanism of these nuclei is correct. Significant overestimation of experimental yields that we found for ^{17}N and ^{16}C nuclei may be attributed to the fact that these nuclei are mainly populated by direct stripping of few nucleons from ^{18}O. In our approach, it is impossible to describe the probabilities of such processes because we use a pure shell-model for ground states of all nuclei involved, and do not take into account the deviation of the mean field parameters in quasi-projectiles from those of the projectile nucleus.

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SEARCH FOR NEUTRON NUCLEI FROM TERNARY FISSION OF URANIUM BY ACTIVATION METHOD WITH ^{130}Te

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A search for nuclear stable ^{x}n (^{6}n, ^{8}n and so on) clusters in the ternary fission of ^{238}U induced by fast protons was suggested at low-background γ-spectrometer with HPGe detector and anti-Compton system. It is known that in ternary fission all neutron-rich isotopes of hydrogen, helium and lithium have been observed. Therefore if the ^{x}n are stable then one could expect that they will be produced in the ternary fission too. In interaction with nuclei they will activate the isotopes which are adjacent with target through the *k*-neutron transfer reactions. As activated sample the enriched ^{130}Te isotope is suggested. In this case radioactive isotopes of tellurium and iodine will be produced in the ^{130}Te (^{x}n, $(x-k)n$) $^{130+k}$Te (β^{-})$^{130+k}$I reaction.

The choice of ^{130}Te is important and is determined by the following.

i) Registration of characteristic г-quanta occurs in the $^{130+k}$Te → $^{130+k}$I →$^{130+k}$Xe double β-decays chain and half-life's of $^{130+k}$I isotopes are within 1-100 hours. It is very convenient for their radiochemical extraction from the irradiated tellurium. This allows to bring down sharply the background of γ-rays caused by many of side reactions and first of all (n,p), (n,np), $(n,2n)$ and so on.

ii) The melting point temperatures of TeO_2 и I are not so high (720^{o} и 113^{o}). Iodine is well sublimated and its extraction from the irradiated TeO_2 samples does not represent the serious problem. The chemical reactions (for example, I + Ag → AgI) as well as the iodine collection on the cooled surface can be used.

iii) The γ-rays energies and intensities are very suitable for their registration by the Ge detector. For example, in case of the ^{132}Te (78 h) → ^{132}I (2.3 h) → ^{132}Xe* chain for the two-neutron transfer channel they are equal to $E_{г}$=667.7 keV (98.5%) and 772.6 keV (76.0%). It is also important that γ-quanta with E_{γ}=364.5 keV from the ^{130}Te(n,γ)^{131}Te→^{131}I →^{131}Xe* side reaction do not contribute to the Compton spectrum for γ-rays from decay of $^{132\text{-}135}$I.

At present a vacuum chamber for the samples irradiation by neutral clusters from uranium fission was assembled in the geometry close to π. The target of enclosed type has been fabricated. It is a uranium plate covered with nickel of 20 mkm thickness by electrolysis. The set-up for melting of the Te and TeO_2 in argon atmosphere and for the iodine collection on the absorption foils was assembled. The tests with the Te и TeO_2 pellets irradiated by the ^{252}Cf source showed that the ^{131}I atoms which are produced in the ^{130}Te(n,γ) reaction are collected with ~35% effectiveness. In the nearest time we intend to perform experiments on search for ^{x}n at cyclotron using proton beam.

The work was supported by RFBR (project № 04-02-16365).

THE MECHANISM, PREREQUISITE AND REALIZATION OF SUPERHEAVY NUCLEI SYNTHESIS IN THE PROCESS OF CONTROLLED ELECTRON-NUCLEAR COLLAPSE OF CONDENSED TARGET

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The problem of stability of condensed target in particular and stability of "usual" atomic form of matter in general in relation to the process of self-squeezing up to the collapse state and full-range laboratory nucleosynthesis is studied.

It was shown for the first time that for a neutral atom compressed by external forces, a threshold electron density is shown to exist [1]. If such a density is reached, a self-organizing process of "electron downfall to the nucleus" starts. This process is exoenergic and leads to the formation of a supercompressed electron-nuclear cluster. The higher is the charge of a nucleus, the lower is the threshold of the external compression. The method of realization of such requirement was studied.

It is shown that the maximum binding energy shifts during such a self-organizing collapse of the electron-nuclear system from $A_{\text{opt}} \approx 60$ (for uncompressed substance) to the area of high mass numbers $A_{\text{opt}} \geq 200 ... 5000$ and could render the synthesis of superheavy nuclei to be energy efficient [1]. The synthesis proceeds through the absorption of other nuclei by the collapsed nucleus. It is theoretically proved that the synthesis efficiency is ensured by both the width reduction and increased transparency of the Coulomb barrier in the extremely compressed electron-nuclear system. The release of binding energy through the absorption of nuclei by the electron-nuclear collapsed clusters may result in the simultaneous emission of lighter nuclei.

Such mechanism takes place in any nuclei in the collapse area. The mechanism of formation and evolution of an annular self-controlled electron-nucleus collapse up to state of nuclear substance at the center of condensed targets is also discussed [2].

It is assumed that such mechanism of synthesis can explains the formation of electron-nuclear collapse, the creation of stable superheavy and other anomalous nuclei, and the process of transmutation of radioactive nuclei to different stable isotopes in the collapse zone observed in 10000 experiments with electron driver carried out at the Kiev Electrodynamics Laboratory "Proton-21" during 2000-2005.

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MASS AND HALF-LIFE MEASUREMENTS AT FRS-ESR FACITILITIES AT GSI

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FRS-ESR facilities at GSI provide unique experimental conditions for experiments with stored highly-charged exotic nuclei at relativistic energies. Masses are measured with Schottky (SMS) and Isochronous (IMS) Mass Spectrometry.

This contribution will concentrate on the experimental results, present status, and the perspectives of the SMS.

SMS requires electron cooling of the stored beam and has a lower limit for lifetimes of the order of a few seconds. Masses of 114 neutron-deficient nuclides were measured recently with an accuracy of $\sim 1.5 \cdot 10^{-7}$ (30 μu). A new experiment was performed to measure neutron-rich ^{238}U projectile fragments.

The time-resolved SMS is well suited for half-life measurements. Prolongations of the half-lives of neutron-deficient nuclides were measured in the absence of orbital electrons. New decay mode in the neutron-rich nuclides, bound-state beta decay, was measured in $^{207}Tl^{81+}$ ions. The branching ratio to the continuum beta decay was determined which is in good agreement with theoretical predictions. The stochastic pre-cooling provides access to nuclides with half-lives of the order of one second, which was proven by measuring the half-life of the ^{207m}Tl isomeric state ($T_{1/2}$=1,33 s).

DISTRIBUTIONS OF PARTICLES AND HOLE PAIRS OVER SINGLE-PARTICLES LEVELS GENERATED BY THE PAIRING CORRELATIONS

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Pairing superconducting correlations in systems with a finite particle number (nuclei and clusters) can generate excitations of several zero spin pairs from levels below the Fermi surface (*F*) to levels above *F*. Therefore the ground state comprises these excitations and the Hartree-Fock state. For many applications it is of interest to find the probability distribution of these excitations as a function of n, i.e. the number of particle pairs (above *F*) or the number of hole pairs (below *F*) since these pairs are created simultaneously.

For calculations of these probabilities we have employed the Projected BCS theory (PBCS). Fig.1 demonstrates that for small pairing strengths *G* results of this theory for the correlation energy practically coincides with first order perturbation theory. For relatively small numbers (N_p) of particles participating in the pairing and realistic values of *G* the differences in Bogolubov parameters of PBCS and BCS are noticeable and so the probability distributions calculated with BCS and PBCS parameters are distinguished (Fig. 2, N_p = 60). However for $N_p \geq 300$ (that can occur in nanoclusters) the probabilities are calculated with BCS parameters as they inessentially defer from PBCS ones. The results are displayed in Fig. 3 for wider range of N_p then it was considered in Ref. [1].

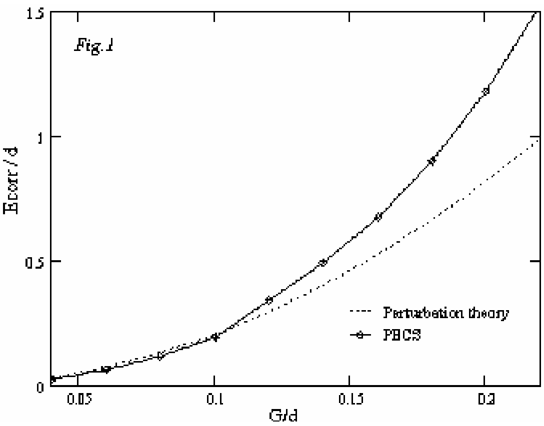
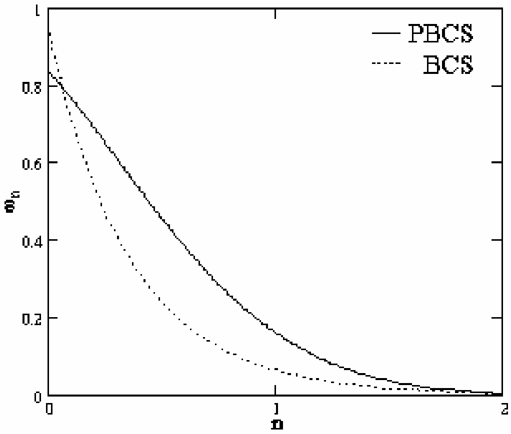


Fig.1 The correlation energy E_{corr}/d as a function of G/d (d is interlevel distance).



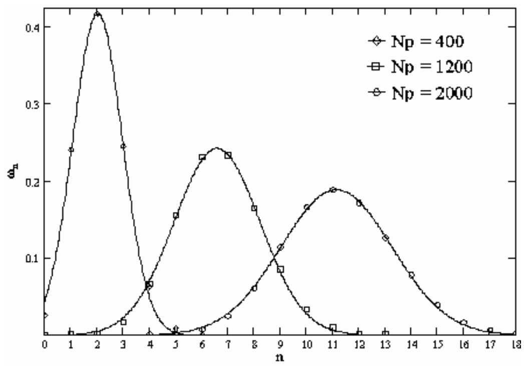


Fig.2 Fig.3

The particle-hole probabilities ω_n ws. number of particles or holes n.

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VARIATION OF THE SUPERCONDUCTING GROUND STATE WITH INCREASING ROTATIONAL OR LARMOR FREQUENCIES

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The pair correlations in nuclei and atomic clusters are destroyed by the rotation or the external magnetic field respectively. With increasing ω, the rotational or Larmor frequency, the energy of an excited state with two or several broken pairs can turn out lower than the correlated ground state. We have considered which values of the pairing strength G and ω have to lead to the first crossing of the g.s. and the state with $\nu \geq 2$ unpaired particles in even systems. With increasing ω the new g.s. including ν particles crosses a state with ν + 2 particles and so on. In our calculations the equal level spacing model (the interlevel distance is d) is employed and only spin momenta are taken into account. For small particle numbers (nuclei) the projected BCS theory is used (the version of Ref. [1]). For clusters we apply the BCS theory with blocking those levels which are occupied by unpaired particles. In this case for preliminary estimates we have obtained a new expression for the pairing gap Δ when ν unpaired particles are on the levels nearest to the Fermi level (2Ω is the number of the particles participating in the pairing)

$$\frac{\Delta}{d} = \frac{\Omega - 0.5}{sh\left(d/G\right)} \sqrt{\left(e^{d/G} - \frac{\nu+1}{2\Omega-1}\right) \cdot \left(e^{-d/G} - \frac{\nu+1}{2\Omega-1}\right)}$$

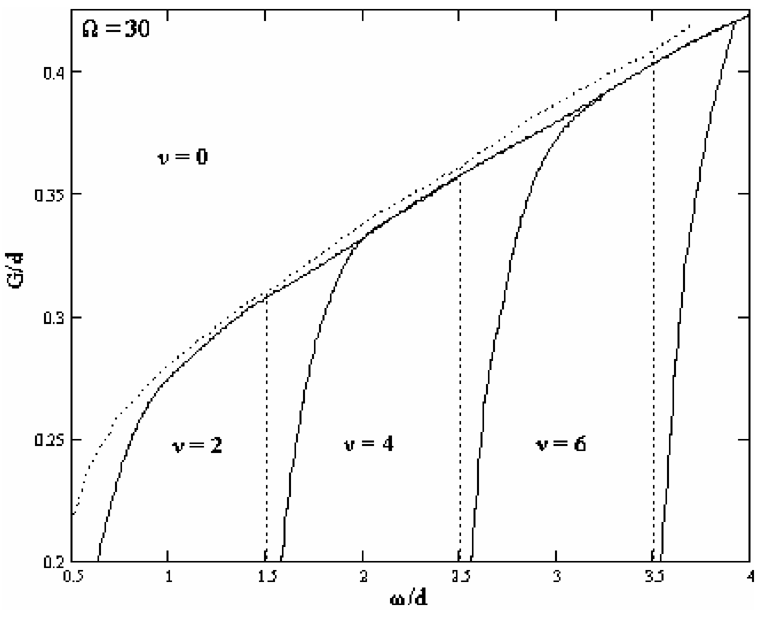

Fig. shows the boundaries in the plane (G/d, ω/d) of areas inside which the g.s. is the state with ν = 0, (the upper part of Fig.), with ν = 2, (the left part of Fig. below the lines), and, to the right, with ν = 4, 6. The solid and dotted lines correspond to the projected BCS and BCS with blocking. On the boundaries of the areas there takes place degeneration of states with ν and ν + 2. The crossing points are the three fold degeneration points.

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${}^{6}_{\Lambda\Lambda}$He AND THE PROBLEM OF ΛΛ–INTERACTION

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Up to now it was reported about the observation (with different degree of confidence) of six double hypernuclei: ${}^{6}_{\Lambda\Lambda}\mathrm{He}$, ${}^{10}_{\Lambda\Lambda}\mathrm{Be}$, ${}^{13}_{\Lambda\Lambda}\mathrm{B}$ (or ${}^{10}_{\Lambda\Lambda}\mathrm{Be}$), ${}^{10}_{\Lambda\Lambda}\mathrm{Li}$ (or ${}^{11}_{\Lambda\Lambda}\mathrm{Li}$) and ${}^{32}_{\Lambda\Lambda}\mathrm{Si}$. Among them ${}^{6}_{\Lambda\Lambda}\mathrm{He}$ is considered to be the most appropriate for an analysis of the ΛΛ-interaction, but there are two quite different measurements for its binding energy $B_{\Lambda\Lambda}$ and so the combined analysis including all known ΛΛ-hypernuclei is necessary. In this report two version of ΛΛ-interaction are considered based on the supposition that (a) $B_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He})$=10.9±0.4 MeV [1] and (b) $B_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He})$=7.25±0.2 MeV [2]. In both cases ${}^{6}_{\Lambda\Lambda}\mathrm{He}$ is calculated as six particle system bounded by semirealistic Λ*N* and *NN*-potentials [3] under supposition that ΛΛ-potential $V_{\Lambda\Lambda}$ has the same radial dependence as the singlet Λ*N*-potential $V^{s}_{\Lambda N}$ [3]. The solution of an inverse problem leads to the ΛΛ-potential $V_{\Lambda\Lambda} = 0.653 V^{s}_{\Lambda N}$ in the case (a) and to $V_{\Lambda\Lambda} = 0.095 V^{s}_{\Lambda N}$ in the case (b). The reliability and accuracy of six-particle calculations are assured by calculation of upper (E_U) and two lower (E^{T}_{L} and E^{Q}_{L}) bounds of energy (see [3]), that is demonstrated for the case (a) in Fig. 1 for different number of trial functions *n* (indicate by figures near corresponding pints).

The calculations of ${}^{10}_{\Lambda\Lambda}\mathrm{Be}$ (as system ααΛΛ) and ${}^{13}_{\Lambda\Lambda}\mathrm{B}$, ${}^{10}_{\Lambda\Lambda}\mathrm{Li}$ and ${}^{32}_{\Lambda\Lambda}\mathrm{Si}$ (as system ΛΛ+core) with Ali-Bodmer αα-potential and folded potential Λ-core show that in the case (a) they agree better with calculations of ${}^{6}_{\Lambda\Lambda}\mathrm{He}$, than in the case (b). Note that in the case (a) the nuclei ${}^{5}_{\Lambda\Lambda}\mathrm{H}$ and ${}^{5}_{\Lambda\Lambda}\mathrm{He}$ are found to be particle stable, but not ${}^{4}_{\Lambda\Lambda}\mathrm{H}$, whereas in the case (b) all these hypernuclei are instable.

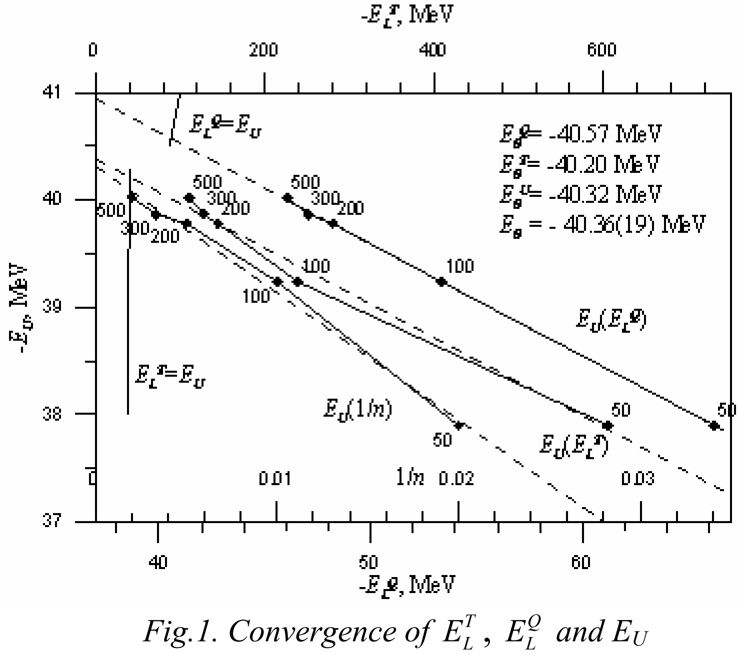

Fig.1. Convergence of E^{T}_{L}, E^{Q}_{L} and E_U

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POTENTIAL Λ-CLUSTER FROM 3, 4 AND 5-PARTICLE CALCULATION OF HYPERNUCLEAR AND NUCLEAR SYSTEMS

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In order to understand what are the effects of deformation of a core and correlation in hypernuclei (neglected in the model Λ+core) and to find by that way a realistic potential Λ-cluster we calculate 2, 3, 4 and 5-particle hypernuclei and corresponding nuclei as few-body systems. For this purpose the *NN*-potential of paper [1] was used, that describes sufficiently well the binding energies and electric form-factors of ^{2}H, ^{3}H, ^{3}He and ^{4}He. We use also Λ*N*-potential that reproduces in the limits of experimental errors the binding energies B_Λ of ${}^{3}_{\Lambda}\mathrm{H}$, ${}^{4}_{\Lambda}\mathrm{H}$, ${}^{4}_{\Lambda}\mathrm{H}^*$, ${}^{4}_{\Lambda}\mathrm{He}$, ${}^{4}_{\Lambda}\mathrm{He}^*$ and ${}^{5}_{\Lambda}\mathrm{He}^*$ as well as cross sections of Λ*p*-scattering [2]. The calculations show that the addition of Λ-particle results in reduction of interparticle spaces (Λ-particle squeezes a core). The coefficient of compressibility turns out to be 10.4%, 9.5%, 7.7%, 10.4%, 8.5% and 3.9% for respectively ${}^{3}_{\Lambda}\mathrm{H}$, ${}^{4}_{\Lambda}\mathrm{H}$, ${}^{4}_{\Lambda}\mathrm{H}^*$, ${}^{4}_{\Lambda}\mathrm{He}$, ${}^{4}_{\Lambda}\mathrm{He}^*$ and ${}^{5}_{\Lambda}\mathrm{He}^*$. An account of deformation of a core in accordance with two-body (Λ+core) model leads for last five above systems to the binding energies B_Λ equal to 0.75, 0.34, 0.96, 0.54 and 2.48 MeV instead of 0.47, 0.21, 0.58, 0.30 and 2.16 MeV for undeformed core. In order to reach the correct value of B_Λ in the frame of the model Λ+undeformed core it would be necessary for all six mentioned above hypernuclear states to augment $V_{\Lambda N}$ by, correspondingly 49%, 26%, 18%, 27%, 18% and 8%. The presence of Λ-particle results also in correlation of nucleonic density $\rho(\vec{r})$ with remoteness of Λ-particle from center of the core (moreover $\rho(\vec{r})$ becomes angular dependent). Averaging $V_{\Lambda N}$ over density of nucleon in the core one can find the "correlational" potential. However it does not take into consideration that the probability of finding Λ-particle strongly changes with its distance from core. Taking this factor into account we arrive at an "effective" potential Λ-cluster (Λ*d*, Λ-*t*, Λ-^{3}He, Λ-α) that leads practically to the same results for B_Λ as exact *A*-particle calculation, and this can be grounds to consider it as most realistic potential Λ-cluster. Note that the use of this "effective" potential in calculation of ${}^{9}_{\Lambda}\mathrm{Be}$ (as system α+α+Λ) with Ali-Bodmer αα-potential d_0 leads to B_Λ almost equal to experimental value (6.61 MeV instead of 6.71(4) MeV).

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ACCURATE CALCULATION OF ENERGIES BY EXTRAPOLATION OF UPPER AND LOWER BOUNDS FOR NUCLEAR 3-6-PARTICLE SYSTEMS

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A knowledge of lower bound of energy (E_L) together with upper bound (E_U) not only fix the limits inside of which the exact value of energy (E_0) is located, but procure also a new opportunity for extrapolation to E_0. Among different versions of estimation of energy from below (according to Temple (E_L^T) [1], to Romberg (E_L^Q) or Weinstein (E_L^W), see [2], or else Hall and Post (E_L^H) [3]) the better approach to E_0 is assured by E_L^T and E_L^Q. The matrix elements of H and H^2 required for their calculation are known in the case of Gaussian basis functions (see [4]) and are used in our calculations. We would like to note that for short-range (nuclear) interactions the dependencies of E_L^T on E_U and E_L^Q on E_U are close to the linear ones for systems of 3, 4, 5 and 6 particles. This is illustrated in Fig. 1 for four-particle system ^{4}He and in Fig. 2 for five-particle system ${}^5_\Lambda\mathrm{He}$. The values of E_0^T, E_0^Q and E_0^U calculated correspondingly by extrapolation of dependencies $E_L^T(E_U)$, $E_L^Q(E_U)$ and E_U (as function of number of basis functions n) allow to find the energy E_0 as $\frac{1}{3}(E_0^T + E_0^Q + E_0^U)$ and also rms deviation from it. The similar results were obtained for 3, 4, 5 and 6-particle systems ^{3}H, ^{3}He, 3α, ${}^3_\Lambda\mathrm{H}$, ${}^4_\Lambda\mathrm{H}$, ${}^4_\Lambda\mathrm{He}$, ${}^9_\Lambda\mathrm{Be}$ (as system ααΛ), 4α, ${}^{10}_{\Lambda\Lambda}\mathrm{Be}$ (as system 2α+2Λ), ${}^5_{\Lambda\Lambda}\mathrm{He}$, ${}^5_{\Lambda\Lambda}\mathrm{H}$ and ${}^6_{\Lambda\Lambda}\mathrm{He}$ (see [4]).

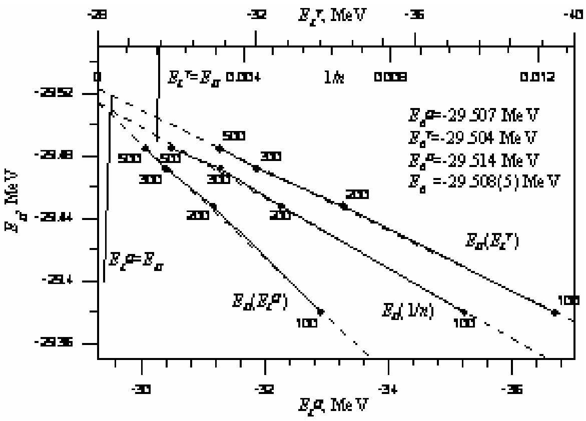

Fig. 1. Convergence of upper and lower bounds of energy for ^{4}He

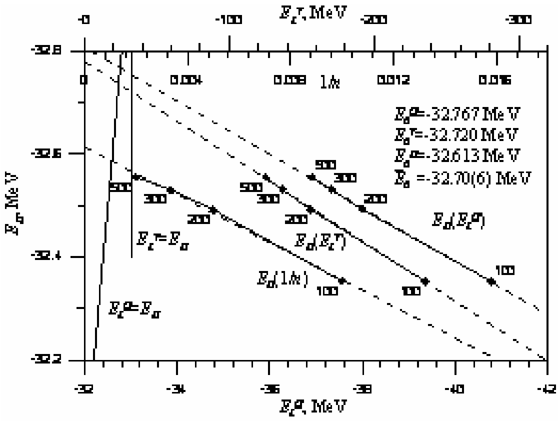

Fig. 2. Convergence of upper and lower bounds of energy for ${}^5_\Lambda\mathrm{He}$

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BINDING ENERGIES OF HYPERNUCLEI AND ΛN-INTERACTION

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A detailed analysis of experimental data on binding energies of hypernuclei (both light and heavy) as well as energetic and angular dependence of Λ*p*-scattering leads to a conclusion that (i) the Λ*N*-potential $V_{\Lambda N}$ is spin and charge-dependent, (ii) that it has a short range and changes the sign and (iii) it weakens for heavy (A > 4) hypernuclei. So $V_{\Lambda N}$ can be presented in the form $V_{\Lambda N} = \alpha V^c(r)(1+\lambda T_3) + V^\sigma(r)(\vec{\sigma}_\Lambda \vec{\sigma}_N)$, where T_3 is the projection of isospin. If the radial dependence of $V^c(r)$ and $V^\sigma(r)$ is chosen in the gaussian form $V^{c,\sigma}(r) = V_r^{c,\sigma} e^{-\mu_r r^2} + V_a^{c,\sigma} e^{-\mu_a r^2}$ and the numeric values of parameters are fixed as follows: V_r^c= 517 MeV, V_a^c= –297 MeV, V_r^σ= –500 MeV, V_a^σ= 152 MeV, $\mu_r = 6.0$ fm^{-2}, $\mu_a = 2.5$ fm^{-2}, λ = 0.054, α =1 for A<5 and α = 0.854 for $A \geq 5$, then the potential $V_{\Lambda N}$ assures the description (in the limits of experimental errors) both the cross sections of Λ*p*-scattering and binding energies B_Λ of all hypernuclei, that is illustrated in the table for the regions $A \leq 5$.

	^{2}H	$^3_\Lambda$H	^{3}H	$^4_\Lambda$H	$^4_\Lambda$H*	^{3}He	$^4_\Lambda$He	$^4_\Lambda$He*	^{4}He	$^5_\Lambda$He
B_Λ^{exp}		0.13(5)		2.04(11)	1.00(12)		2.39(3)	1.21(5)		3.12(2)
B_Λ^{calc}		0.15(2)		1.99(2)	0.93(2)		2.37(2)	1.23(2)		3.10(6)
B^{exp}	2.224		8.48			7.719			28.29	
B^{calc}	2.226		8.46			7.77			29.51	

In the table the binding energies of Λ-particle (B_Λ) and corresponding nuclei-core (B) are given in MeV. The calculations of all 3, 4 and 5-particle systems were performed by variational method. High precision of calculations (see the table) is achieved owing to determination of not only upper but also lower bounds of energy. The semirealistic *NN*-potential of paper [1] was used, that assures sufficiently good description of binding energies B of ^{2}H, ^{3}H, ^{3}He and ^{4}He (as it is seen in the table) and their sizes. For all considered hypernuclear and nuclear systems the rms distances from center of mass and interparticle distances were calculated. Considered Λ*N*-potential at volume integral Ω=203 MeV·fm^3 and rms radius R=0.953 fm assure for heavy nuclei (A>5) an adequate description of binding energies B_Λ in the frame of the model Λ+core.[2]

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EXPERIMENTAL INVESTIGATIONS OF NUCLEAR REACTIONS

NEW DATA FOR PHOTONUCLEAR REACTIONS AND NUCLEAR STRUCTURE FROM THE MODERN DATABASES

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Modern advanced nuclear reaction and nuclear spectroscopy databases [1] developed in the frame of wide international cooperation gives to possibility for obtaining any nuclear data in accordance with practically unlimited queries. Those can be used for carrying out systematical various experiments results analysis in many cases resulted in a new physical information.

Systematical analysis [2] of photonuclear reaction cross sections obtained in experiments with bremsstrahlung (BR) and quasimonoenergetic annihilation (QMA) photon beams resulted in solving several well-known problems of significant disagreements between various experiments results. Using the method of reduction it was shown that Giant Dipole Resonance intermediate (width ~ 100 keV) structure seen in majority of BR-cross sections has been lost in QMA-experiments because of poor real energy resolution. Typical procedure of obtaining difference in cross section excluds effects of photon spectrum bremsstrahlung tail but does not help to achieve high energy resolution because subtraction of two values with poor resolution leads to large errors. Structure lost could be restored by taking into account effective photon spectrum shape. Significant discrepancies in absolute values of various experimental total and especially partial photonuclear reaction cross sections were overcame on the basis of systematical analysis of experimental conditions, first of all, photoneutron multiplicity sorting procedures.

Combined analysis of nucleon stripping and pick-up reactions information using special method [3] for putting both types of data into accordance to each other (based on re-normalization of both kinds of spectroscopic strength sums in accordance with quantum mechanical rules) gave possibility to increase significantly nuclear spectroscopy information accuracy and reliability. New accurate various sub-shells energies and occupation probabilities were obtained and gave possibility to predict many new data on spins of levels, explain well-known disagreements between experimental and shell model sequences of sub-shells population, etc. Among new data obtained the most impressive is unpredictable forming of the closed $2d_{5/2}$ shell in ^{96}Zr (similar to $1f_{7/2}$ shell in double-magic nucleus ^{48}Ca). So $N = 56$ looks like a magic number for $Z = 40$.

The work is partially supported by grants of President of Russia N SS-1619.2003.2 and RFBR NN 03-07-90431, 04-02-16275.

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PHOTONUCLEAR REACTIONS: ASTROPHYSICS IMPLICATIONS

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Brief review on astrophysical aspects in photonuclear studies is presented. Main attention is paid on the two kind experiments. The first one was performed at ESRF by the GRAAL collaboration [1] using the back scattering laser photons technique to study the light speed anisotropy with respect to the dipole of the Cosmic Microwave Background (CMB) radiation. This is the modern analog of the Michelson–Morley experiment. The results obtained are not only methodically different from those of the abovementioned experiments but also provide stronger constraints on the light speed anisotropy in CMB frame. Second subject is related to the electron scattering on exotic nuclei which can play significant role in explosive phenomena such as novae, supernovae and neutron stars. Such approach may be considered as the alternative to traditional low energy accelerator experiments. Exotic nuclei for this purpose can be obtained at GSI (ELISe project) [2]. The experiment is foreseen to be installed at the New Experimental Storage Ring (NESR) at FAIR where cooled secondary beams of radioactive ions will collide with an intense electron beam circulating in a small electron storage ring.

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ABOUT HIGH EXCITED STATES OF THE LIGHT NUCLEI WITH A=6 POPULATED IN $\alpha+t$ INTERACTION

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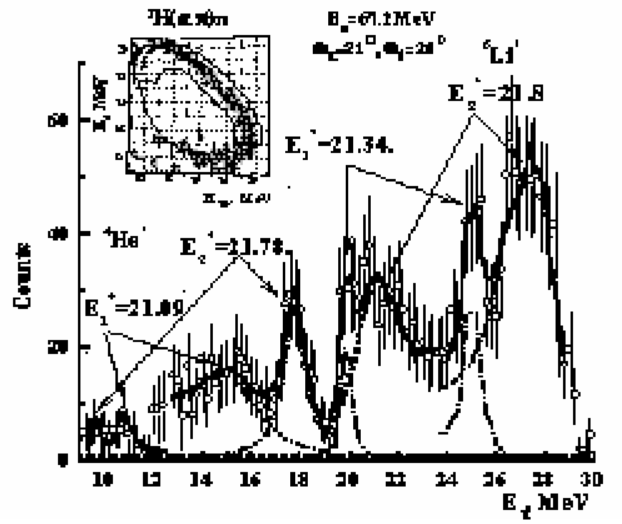
In excitation schemes of light nuclei with A=6 for excitation energies higher than threshold of decay on $t+\tau$ (15.98MeV) for ^{6}Li and $t+t$ (12.203MeV) for ^{6}He, which were represented in different compilation publications [1,2] one can see substantial difference. For example, in energetic region from the threshold to 27 MeV for ^{6}Li there are six excited levels in [2] and only four excited levels in [1]. To determine values of excitation energies of high-excited levels of ^{6}Li and ^{6}He, which is inherent 3+3 cluster structure, and to specify the excitation schemes of these nuclei one can get from experimental kinematically complete investigations of three-body ^{3}H(α,τt)n and ^{3}H(α,tt)p reactions. These reactions were investigated at E_α=67.2MeV .



The experimental data were analyzed by using the Monte Carlo method, which allow excepting the ambiguities, related with no point experimental geometry.

Figure represents two-dimensional spectrum of τt- coincidences and projection of selected upper branch on axis of τ-particle energy from ^{3}H(α,τt)n reaction.

Using the Breit-Wigner procedure of fitting the values of excitation energy and width for two excited states of ^{6}Li were obtained. There are E^*_1=21.34(0.30); Γ=0.3(0.2); E^*_1=21.80(0.30); Γ=0.4(0.2). At the same time parameters of two excited states of ^{4}He, decayed on $\tau+n$ were determined and equal E^*_1=21.09(0.20); Γ=0.48 (0.30); E^*_1=21.78(0.30); Γ=0.4(0.2). The obtained values are in accordance with [1,2] and confirms authenticity of results for ^{6}Li. From similar analysis of two-dimensional tt-coincidence spectra energy positions (14.7(0.2); 15.7(0.2) MeV) and widths (0.63(0.17); 0.3(0.2) MeV) were obtained for two excited states of ^{6}He.

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EXCITATION SPECTRA OF ^{6}He FROM ^{3}H(α,$p\alpha$)2n REACTION

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In inclusive proton spectra, measured in ^{3}H(α,p)^{6}He reaction at E_α=27.2 MeV, the first excited state with E^*=1.8MeV and the resonance structure with energy excitation near 3 MeV and width 2.4 MeV were observed [1]. In order to except the proton contributions due to decay of other unbound states from $\alpha+t$ interaction the $p\alpha$-coincidences spectra from few-body ^{3}H(α,$p\alpha$)2n reaction were got and analyzed. The experiments were carried out by using the titan-tritium targets and incident alpha-particle beams with E_α=27.2 and E_α=67.2MeV. The projections on the axis of proton energy of selected part of $p\alpha$-spectra, which corresponded the excitation of ^{6}He are represented on Fig. 1, 2. The excitation energy of ^{6}He is indicated on the upper abscissa. In spectrum got at less energy interaction (Fig.1) besides the first excited state of ^{6}He a bump with corresponding maximum near 3 MeV was observed.At higher energy interaction (Fig.2) one can see three excited states: the first excited state of ^{6}He and two resonance structures with maximums near 3 MeV and 5.5 MeV, respectively.

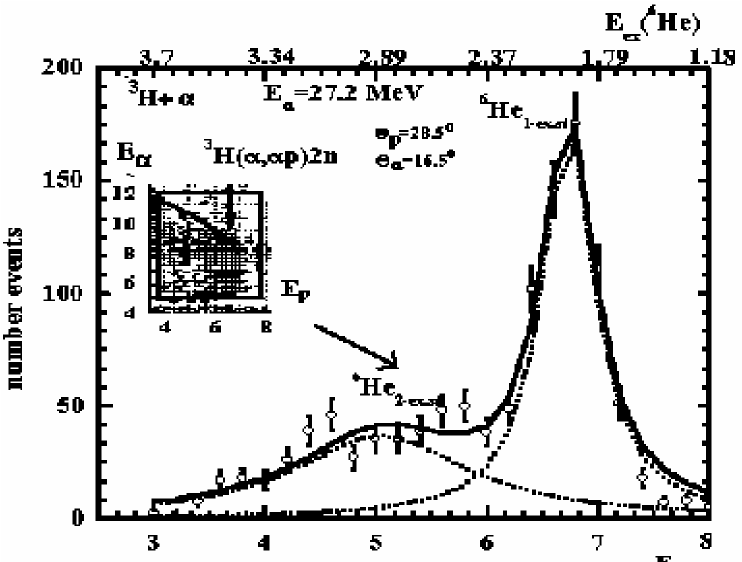

Fig.1

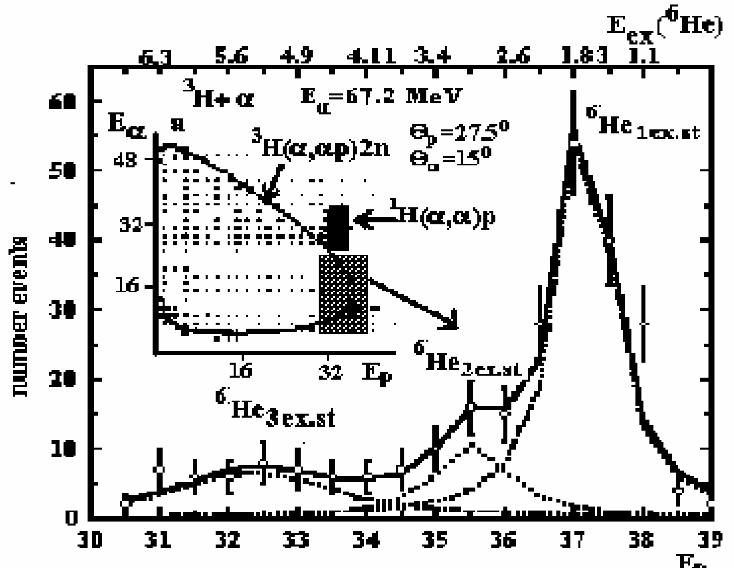

Fig.2

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TRANSFER, SEQUENTIAL AND QUASI-FREE REACTIONS INDUCED BY 18 MeV ^{6}He BEAM ON ^{6}Li, ^{7}Li AND ^{12}C

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The ^{6}He nucleus with its exotic Borromean structure is an ideal building block for similarly exotic molecular structures in beryllium and carbon isotopes [1]. The rapid improvement of the low energy ^{6}He radioactive beam enables studies of different ^{6}He-induced reactions and of unusual structures in other light nuclei. We have studied the ^{6}He scattering and reactions on ^{6}Li, ^{7}Li and ^{12}C using a 18 MeV beam at the Louvain-la-Neuve facility. Outgoing charged particles were detected in three large silicon strip detector arrays covering the angular range 4^{o}-12^{o}, 20^{o}-65^{o} and 115^{o}-160^{o}.

A number of states in light nuclei were studied in two different ways [2-5]: by analyzing obtained partial angular distributions for their production and by investigating their sequential α-decay. An example of the first approach is the $^{6}He+^{6}Li \to \alpha+^{8}Li$ reaction where direct transfers of $2n$ and d allow comparison of the $\alpha+2n$ configuration in ^{6}He with the $\alpha+d$ configuration in ^{6}Li. The α-particle pick-up has also been studied; the large values of the obtained α-spectroscopic factors for some states indicate their well-developed $\alpha+^{6}He$ cluster structure [3]. The two-proton pick-up reaction (^{6}He, ^{8}Be) was observed for the first time in this experiment and shown to be a useful spectroscopic tool [4]. Quasi-free scattering of ^{6}He on deuteron and α-particle in ^{6}Li was also observed.

Several reactions with three (or more) particles in the exit channel were studied [5]: $^{6}He+^{6}Li \to 2\alpha+t+n$, $^{6}He+^{6}Li \to ^{6}He+\alpha+d$ and $^{6}He+^{7}Li \to ^{6}He+\alpha+t$. These were found to mainly proceed sequentially via well-developed cluster states in ^{6,7}Li and $^{8-10}$Be. The decay of the $5/2^{-}$ state at E_x= 2.43 MeV in ^{9}Be and the 2^{+} state at E_x= 7.54 MeV in ^{10}Be was thus studied [5]. Furthermore, angular correlation analysis for the 10.2 MeV state in ^{10}Be suggests the 4^{+} assignment [5], thus supporting the existence of molecule-like rotational band in ^{10}Be with a very large moment of inertia [1,5]. Similar structures were found for the ^{14}C nucleus from the $^{6}He+^{12}C \to ^{10}Be+2\alpha$ reaction [2].

To conclude, the ^{6}He beam was found to be an excellent choice for studies of exotic light nuclei. Final results of all observed phenomena will be summarized with only a part of them being published earlier.

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STRUCTURE EFFECTS ON REACTION MECHANISMS IN RIB INDUCED COLLISIONS

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Effects on the fusion cross-section at energies around the Coulomb barrier, enhancement or hindering depending upon the theoretical model, have been predicted in reaction induced by halo nuclei. Several experiments have been performed to clarify this issue. In the present talk an overview of the available experimental results will be performed, with particular attention to the $^{6}He+^{64}Zn$ reaction.

At energies above the barrier a reduction of fusion cross-section has been predicted in reactions induced by weakly bound nuclei. The $^{13}N+^{9}Be$ fusion reaction, where both projectile and target are weakly bound, will be discussed.

METHOD OF STUDY OF HALO-NUCLEUS STRUCTURE USING NEUTRON TRANSFER REACTION

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One of the brightest results of application of radioactive nuclear beams was a discovery of exotic structure for light neutron-rich nuclei - neutron halo. The first nuclei with such exotic structure, existence of which was established experimentally, were ^{11}Li and ^{6}He. The problem of more detail study of such neutron halo structure and, in particular, of correlations of valence neutrons, has not been experimentally solved till now.

To estimate the probability of two-neutron configuration in halo nuclei, we propose an experimental method of studying neutron-neutron correlations at periphery of such nuclei by measuring two-neutron transfer reaction. The experimental study of $^{6}\text{He}+A \rightarrow {}^{4}\text{He}+B$ and $^{11}\text{Li}+A \rightarrow {}^{9}\text{Li}+B$ reactions for various targets is performed using radioactive nuclear beams of Flerov Laboratory of Nuclear Reactions (JINR, Dubna) at energy of about 15 MeV/u. The theoretical analysis shows that simultaneous registration of recoil nucleus *B* and ^{4}He(^{9}Li)-nucleus allows one to obtain information on relative momentum distribution of two halo neutrons in the region of small values of this variable.

Secondary particles ^{4}He(^{9}Li) and *B*-nuclei are detected by the technique of nuclear photoemulsions. Thus, the nuclei of photoemulsion (^{12}C, ^{14}N, ^{79,81}Br, ^{107,109}Ag) are used as target nuclei. One of the important problems is a separation of the events caused by two-neutron transfer from those of one-neutron transfer. The simulation performed has shown that these reactions can be separated by the difference in their kinematics (different *Q*-values, presence of neutron in the case of one-neutron transfer) studying the energy and angular dependencies of emission of secondary ^{4}He(^{9}Li) nuclei. Searching for events of two-nucleon transfer reaction and their processing is performed using the PAVICOM-setup at P.N.Lebedev Physical institute. This automatic setup allows one to considerably speed up the processing of bulk of measurements in nuclear photoemulsions. Now, the first version of the software package, allowing one to recognize nuclear tracks in photoemulsion and determine the kinematic characteristics of secondary particles, is developed and debugged. First experimental data on $^{6}\text{He}+A \rightarrow {}^{4}\text{He}+B$ reaction are obtained and processed.

PECULIARITIES OF NEUTRON-TRANSFER AND FUSION IN ^{6}He-INDUCED REACTIONS ON ^{197}Au (FIRST EXPERIMENTS AT THE ACCELERATOR COMPLEX DRIBS, DUBNA)

Yu.E. Penionzhkevich, S.M. Lukyanov, V.I. Zagrebaev, R.A. Astabatyan, N.A. Demekhina, S.P. Lobastov, A.A. Kulko, R. Kalpakchieva, V.A. Maslov, E.R. Markaryan, N.K. Skobelev, T.K. Zholdybaev[1], J. Vincour[2], Z. Dlouhy[2], V.Yu. Ugryumov

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The first experiment at the accelerator complex for radioactive beams DRIBs at the Flerov laboratory of Nuclear reactions (JINR) was carried out using a ^{6}He beam in December 2004. The beam of accelerated ^{6}He ions was produced by simultaneously operating two accelerators. At the U400M accelerator a beryllium target was irradiated with a ^{7}Li(32-MeV/A)-beam in order to produce ^{6}He ions, which diffused out of a hot stopper and after ionization were transported with an energy of 20 keV to the second accelerator U400, where they were accelerated. The radioactive ^{6}He beam had an energy of 60.3±0.4 MeV, the size of the beam spot was $\sim 10\times 10$ mm^2 and the intensity – up to $5\cdot 10^{6}$ pps.

The aim of the experiments was to study the fusion of ^{6}He with ^{197}Au-target nuclei, as well as reactions involving the transfer of neutrons. After the irradiation of a stack of gold foils, we could observe fusion reaction products, viz. the residue nuclei after the evaporation from the compound nucleus of 2-7 neutrons. It was found out that the $2n$-evaporation channel had a higher cross section than expected according to the statistical model of the decay of compound nuclei. In addition, the excitation function for the reaction ^{206}Pb(^{6}He,$2n$)^{210}Po was measured and at its maximum it also showed a considerably higher cross section. This allowed us to draw the conclusion that for the systems ^{6}He + ^{197}Au and ^{6}He + ^{206}Pb the Coulomb barrier is lower than in the case of interaction of a stable nucleus (such as ^{4}He or ^{7}Li) with the same target nuclei. This may mean that the fusion process of ^{6}He with the given target nuclei takes place in a different way, in particular, by an intermediate sequential neutron transfer to the target, followed by its fusion with the rest of the projectile [1].

In the same energy range the cross sections of neutron transfer reactions in the interaction of ^{6}He with ^{197}Au were also measured. At energies close to the Coulomb barrier for the ^{6}He + ^{197}Au reaction, we observed a rather high yield of the ^{198}Au isotope. With the increase of the bombarding energy, some decrease in the cross section takes place, which turns into a plateau. At the same time the cross section for the pick-up by ^{197}Au of two neutrons with the formation of ^{199}Au in its ground state was found to be very low. The excitation function for the ^{196}Au isotope, produced by the stripping from ^{197}Au of one neutron, does not show any special features.

In this way, the experiments have clearly shown a strong enhancement of the sub-barrier fusion of ^{6}He, which confirms our earlier results [2], as well as the peculiar behavior of the one-neutron transfer reactions.

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PROJECTILE FRAGMENTATION OF ^{40}Ca AND ^{48}Ca AT 140MEV/*U*

L. Andronenko[1], M. Andronenko[1], M. Mocko[2], M.B. Tsang[2], M. Famiano[2], M.-J.van Goethem[2], W. Lynch[2], O. Tarasov[2], G. Verde[2], M. Wallace[2], Hua Hui[3]

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Projectile fragmentation has been widely used to produce radioactive isotopes far from stability around the world (GSI, RIKEN, GANIL, NSCL). At the National Superconducting Cyclotron Laboratory at Michigan State University, we measure the fragmentation cross sections of neutron rich nuclei using ^{40}Ca and ^{48}Ca beam with two targets: ^{9}Be and ^{181}Ta. More than 100 isotopes have been obtained from the fragmentation of ^{40}Ca while nearly 200 isotopes have been measured with the neutron rich ^{48}Ca beam. These cross-section measurements will be used to extract excitation energy information of the fragmenting nuclei, to optimize configuration for further studies of nuclei far from stability, to improve empirical models for cross section (e.g. EPAX2) and to provide better parameterizations to the Abrasion-Ablation model

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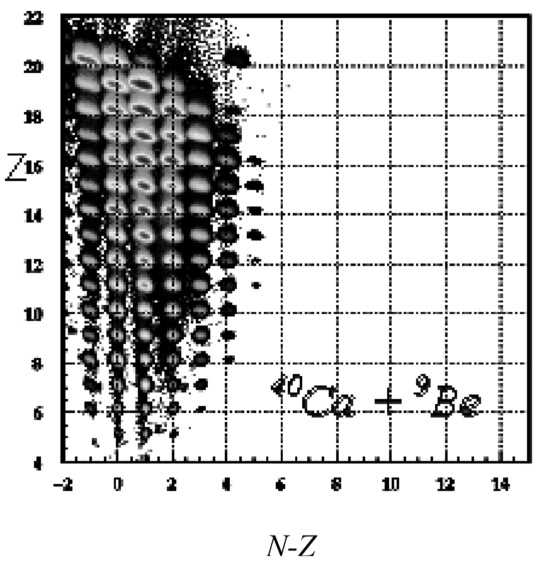

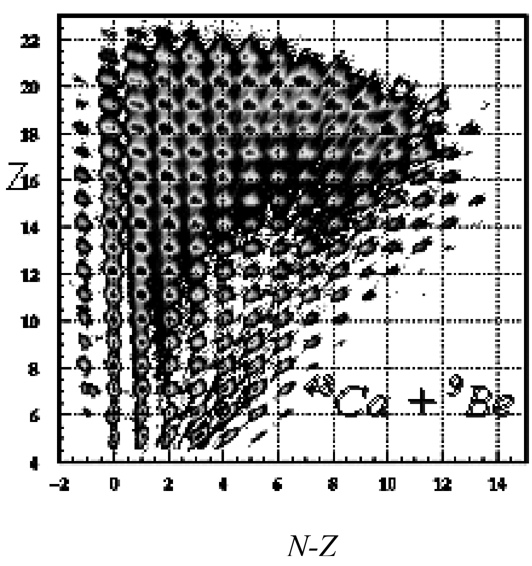

EVIDENCE OF COMPLETE FUSION IN THE SUB-BARRIER $^{16}O + ^{238}U$ REACTION

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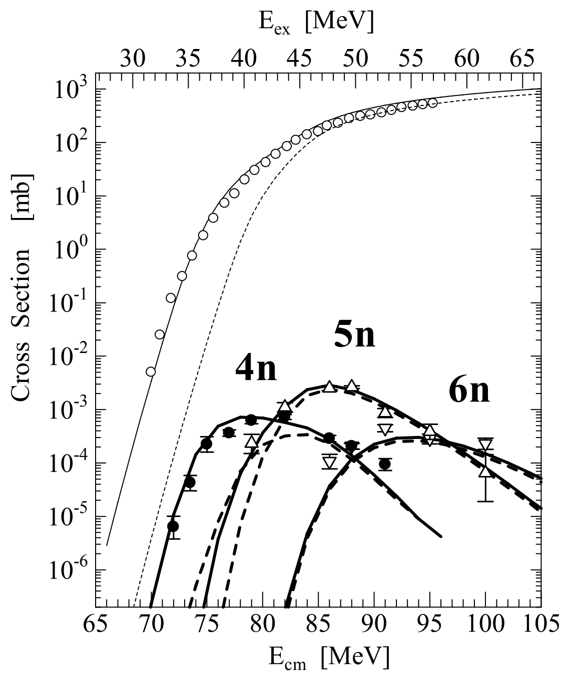
Recently, there has been much interest in the fission fragment angular distribution in sub-barrier heavy-ion reactions using actinide targets [1]. This is because of the observation that the angular anisotropies in the sub-barrier region show much larger values than the prediction of the standard transition state model (TSM) [2]. In the reaction of $^{16}O+^{238}U$, the large anisotropy is explained by assuming the quasi-fission to be dominated in the sub-barrier region [1], where the interaction of the projectile is restricted to the tips of the prolately deformed target.



In order to investigate the fusion process for $^{16}O + ^{238}U$, we have measured the evaporation residue (ER) cross sections from above to extreme sub-barrier energy. The ^{16}O beams were supplied by the JAERI-tandem accelerator. The fusion products were transported by an aerosol-loaded He-gas jet system to a rotating wheel apparatus, where the α decays were detected to determine the production rates. Figure shows the results of the ER cross sections. The thin curve is the fusion cross section calculated by the couple channel model, which reproduces the fission cross section (open circle;[1]). The thick solid curves are the corresponding ER cross sections calculated by a statistical model (HIVAP). The calculation reproduces the experimental data from above to sub-barrier region. The dashed curves are the calculation that the tip collision does not result in complete fusion. This fails to reproduce the sub-barrier ER cross sections.

We conclude that complete fusion is the main process after the projectile is captured to the tips of ^{238}U, and the quasi-fission is not the reason for the anomalous behavior of the fission fragment angular distribution.

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STUDY OF THE $^{28}Si + ^{208}Pb$ EXTREMELY DEEP SUB-BARRIER FUSION

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Investigation of deep sub-barrier fusion of the products of the cluster decay $^{236}Cm \rightarrow {}^{28}Si + {}^{208}Pb$ has been performed. The aim of the experiment is to get new information on the mechanisms of heavy-ion fusion and cluster radioactivity. The experiment was done using the Jyväskylä University cyclotron (Finland) and the array of solid-state track detectors (mica). The employed method allows one to investigate deep sub-barrier fusion-fission reactions down to the cross section level of 10^{-36} cm^2. The fission cross section of the ^{236}Cm compound nucleus has been measured down to 10^{-5} mb that is less by 4–5 orders in comparison with traditional experiments. For this combination of projectile-target nuclei the measured contribution of evaporation residues (ERs) is small, and fission cross sections practically exhausted the fusion ones. The analysis of the data was performed in the framework of the HIVAP code using the potential barrier penetration model (PBPM) [1]. PBPM is coupled with the standard statistical model for the calculation of fission and ER cross sections. The best fit to the data was obtained with the exponential nuclear potential and fluctuating fussion barrier. The selected potential well reproduces the empirical barrier distribution determined as $d^2(\sigma E)/dE^2$.

This experiment allowed us to propose a new approach to study of the mechanism of fusion reactions. It is based on the combined study of the extremely deep sub-barrier fusion using SSTD and cluster decay of the corresponding compound nucleus. This approach seems to be most efficient for the projectiles with A = 20–40 and Pb, Bi targets due to exhausting of fusion cross-sections by those of fission and availability of cluster radioactivity data (experimental or predicted with good reliability). In particular, the problem of the transition between sudden (cluster, or alpha-decay-like) and adiabatic (fission-like) potentials, being in common both for cluster decays and fusion dynamics is in scope of this approach. Basing on the $^{242}Cm \rightarrow {}^{34}Si + {}^{208}Pb$ decay data [2] and some cluster radioactivity systematics, the conclusion was done that this transition can be expected for clusters with A = 30–40.

This work has been supported by the Academy of Finland under the Finish Center of Excelence Programme 2000 - 2005 (Project N 44875. Nuclear and Condensed Matter Phesics Programme at JYFL).

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LIGHT-PARTICLE-ACCOMPANIED QUASI-FISSION IN SUPERHEAVY COMPOSITE SYSTEMS

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The quasi-fission process is the main competitive channel in heavy ion reactions which are used to synthesize the superheavy nuclides [1, 2]. The dynamics of the quasi-fission is determined by the properties of the di-nuclear system (DNS) formed in heavy ion reactions. The neutron and light-charged particles are the valuable probes for determination of the time scale and the temperature of these DNS on the way to the formation of a compact compound nucleus. The dynamics of the excited superheavy system with Z=118 in the reaction ^{86}Kr + ^{208}Pb at E_{Kr} = 600 MeV was investigated in our work [3] where the first indication for the б-particle-accompanied quasi-fission process was obtained. Additional measurements were made at the two energies E_{Kr} = 460 and 500 MeV to determine the energy dependence of the reaction characteristics. Mass and kinetic energy of binary fragments were measured by the time-of-flight method. The double differential distributions of neutrons, protons and α-particles were measured in coincidence with fragments. The neutrons, protons and α-particle double differential spectra have been analyzed within a multiple-source model which includes 4 sources: the two fragments, the compound nucleus and the neck region between fragments. The properties of two-dimensional fragment mass-total kinetic energy distributions show that quasi-fission is the dominant channel in the fragment mass interval A_F = 100 – 194. It was established that the α-particles accompanied quasi-fission process for excited superheavy system with Z = 118 occurs at bombarding energy around 500 MeV and its probability increases with the energy.

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COMPETITION BETWEEN FUSION-FISSION AND QUASI-FISSION IN THE REACTIONS WITH HEAVY IONS

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The work presents new results of the study of characteristics of the fusion-fission and quasi-fission of heavy nuclei ($Z = 82 – 122$), produced in the reactions with heavy ions. The major part of these experiments has been performed at the U-400 accelerator of the Flerov Laboratory of Nuclear Reactions (JINR, Dubna); at the TANDEM-ALPI accelerator of the LNL (INFN, Legnaro, Italy) and at the Accelerator Laboratory of University of Jyväskylä (JYFL, Finland) using a time-of-flight spectrometer of fission fragments CORSET (CORrelation SET-up), gamma and neutron detectors.

Mass-energy distributions (MED) of the fragment in the reactions with ^{12}C, ^{16}O,^{24}Mg, $^{40,48}Ca$, ^{56}Fe,^{64}Ni projectile on a wide number of targets at energies near and below the Coulomb barrier (i.e. when the influence of the shell effects on the fusion and characteristics of the decay of the composite system is considerable) have been measured.

It was found that the quasi-fission dominates as the reaction products in the reactions with the transuranium elements, whereas in the reaction with double-magic ^{208}Pb the contribution of the quasi-fission process into the capture cross-section does not exceed the value of 3-4%. At the same time in the reactions with rare-earths like ^{154}Sm, $^{168,170}Er$, $^{174,176}Yb$ the yield of quasi-fission increases again and its contribution into the capture cross-section reaches the value of ~30-40%. Obviously, such a behavior of the quasi-fission yield can be explained by the influence of nuclear shells and deformation .

It was established that gamma quantum and neutron emission from the fissioning compound nucleus is a criterion for distinguishing the physically close processes of fission and quasi-fission, which permits more exactly determining the characteristics of those two processes.

TOTAL CROSS SECTION OF ^{9}Be(p,α)^{6}Li*(3.56MeV) REACTION AT E_p=3.1-5.24 MeV

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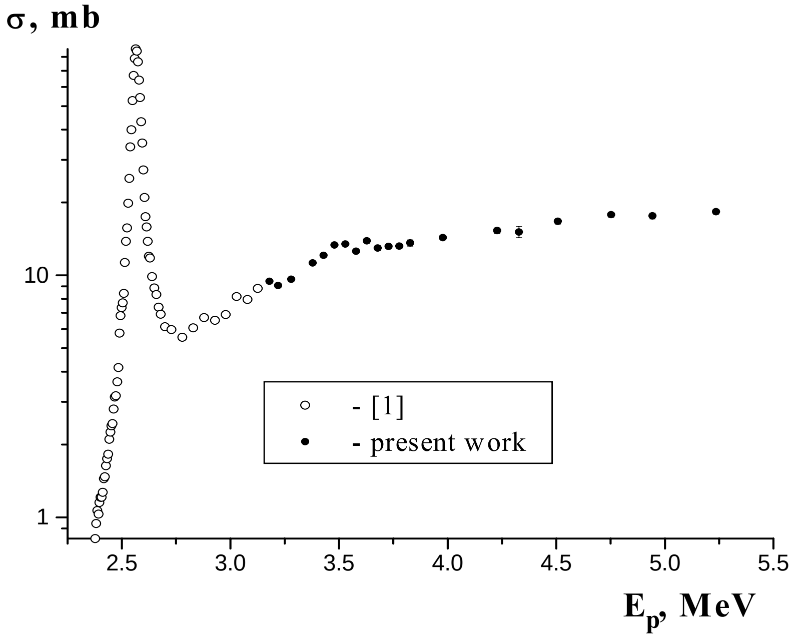
^{9}Be(p,α)^{6}Li*(3.56 MeV) reaction is of interest for γ-ray diagnostics of plasma in controlled thermonuclear fusion [1]. In [1,2] the reaction cross-section is investigated at $E_p \leq 3.1$ MeV up to the threshold. In the present work the measurements cover the interval E_p =3.1-5.24 MeV (fig.). First, the relative energy dependence of γ-rays production was studied with E_γ=3.56 MeV, which was then normalized to the cross-section absolute values [1].



In the report the possible mechanisms of the nuclear reaction are discussed.

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INVESTIGATION OF THE EXCITATION FUNCTION OF $^{11}B(t,p)^{13}B$ REACTION

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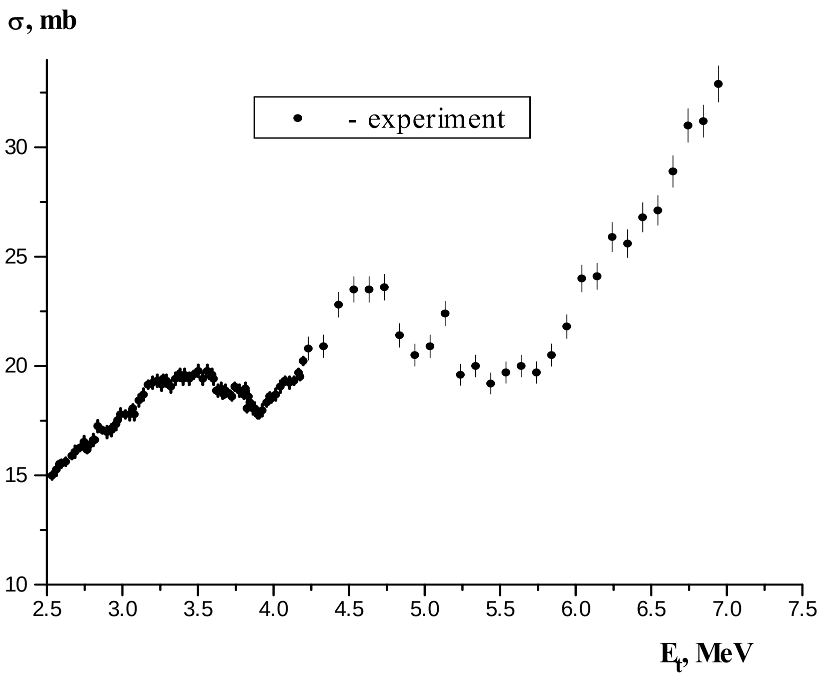
On the triton beam of an electrostatic accelerator in the interval E_t=2.6-7 MeV there has been measured the excitation function of $^{11}B(t,p)^{13}B$ reaction (fig.). The measurements have been carried out to detect γ-rays with E_γ=3.685 MeV, that emerge after β-decay of ^{13}B. In the interval E_t=2.6-4 MeV the measured curves of ^{13}B β-decay can be described with the half-life of (16.59±0.02) ms, that essentially differs from the presently accepted value (17.33±0.17) ms [2].

The relative energy dependence of the excitation function at E_t=2.6-4.2 MeV has been already published [1].



In the report the resonance and threshold structure of the excitation function is discussed.

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RESONANCE-LIKE STRUCTURE OBSERVED IN ^{38}Ar(p,γ)^{39}K REACTION

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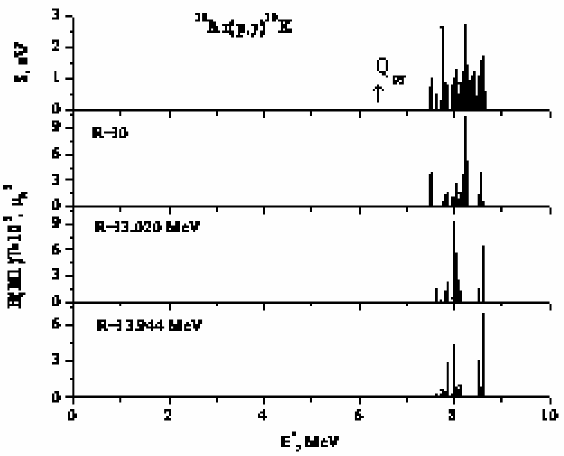
The gamma decay of the resonance-like structure (RLS), observed in the ^{38}Ar(p,γ)^{39}K in the region of excitation energies of 7–9 MeV was studied. The analysis of the excitation function of this reaction [1,2,3] has allowed for the first time to identify RLS of similar themes, that were investigated in ^{23}Na, ^{27}Al, ^{31}P, ^{35}Cl and ^{37}Cl nuclei by us earlier [3]. The analysis of spectrums and angular distributions of photons appeared at decay of resonance's comprising this RLS together with the analysis of the excitation function has allowed to receive a probability distribution for magnetic dipole γ – transitions on a ground state and states with energies 3.020 and 3.944 MeV in ^{39}K. The obtained distributions of the strength of $M1$ – transitions in ^{39}K have resonance character (Fig.). The position of the center of gravity ($E_{cog}=\Sigma_k E_k B_k(M1)/\Sigma_k B_k(M1)$) of the magnetic dipole resonance (MDR) on the ground state in ^{39}K are equal to 8.3±0.9 MeV, and are situated in the region of excitation energies expected for the odd nuclei with closed $d_{5/2}$ – subshell. In other words the nn or pp – pair from $d_{5/2}$ – subshell in these nuclei takes part in formation of the MDR, therefore the magnitude of nn (pp) – pairing in $d_{5/2}$ – subshell affects on the position of the center of gravity MDR in these nuclei.As a result of the investigation it is possible to state, that the states RLS belong to the both states of a MDR on the ground state, and states of a MDR built on excited states in ^{39}K.



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PARTIAL CROSS-SECTIONS OF REACTION $^{54}Cr(p,\gamma)^{55}Mn$

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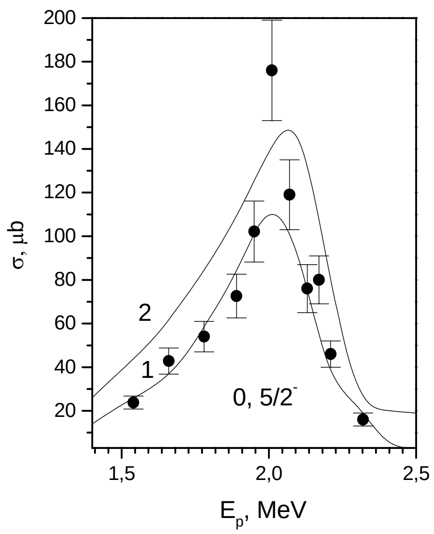
The analysis of partial cross-sections (PCS) of proton capture reaction by nuclei ^{54}Cr is carried out within the framework of a statistical model for transitions in basic (0, $5/2^-$) and low-lying excited states ^{55}Mn (126 keV, $7/2^-$), (1528 keV, $3/2^-$), (2253 keV, $3/2^-$), (2564 keV, $3/2^-$). The measurements were fulfilled in NSC KIPT using a Van de Graaf accelerator in an interval of energy of the accelerated protons from 1.5 up to 2.5 MeV. The spectra of high-energy γ-rays corresponding to primary transitions were measured by a binary spectrometer consisting of a Ge(Li) detector of volume 63 sm^2 surrounded by a four section annular NaJ(Tl) detector.

The calculation PCS of the reaction $^{54}Cr(p,\gamma)^{55}Mn$ is carried out within the framework of the statistical theory with attracting of various theoretical estimations for calculation E1-RSF. As it is visible from a figure, the best exposition of the measured PCS manages to be reached if to use for calculation of a radiative strength function (RSF) the statistical approach proposed by Sirotkin [1] (the curve 1). At the same time, E1-RSF calculated as an extrapolation GDR (the curve 2) in field E_γ<10 MeV, noticeably upraises experiment for all explored states. Captured as a result of the analysis of the PCS the gang of parameters of statistical model was used for the solution of an inverse problem. The data on quantity and energy dependence RSF for nuclei ^{55}Mn in an energy rang of γ-quantums from 6 up to 9.5 MeV were obtains the method of one-parametric optimization.



Obtained RSF were compared with calculated within the framework of the various theoretical approaches. It is exhibited, that without attracted modern theoretical models, which are taking into account temperature and structure of the lower excited states of a daughter nucleus, it fails to describe RSF in all an explored energy rang of γ-quantums. The made earlier guess about necessity of a reformulation of a known Brinck' hypothesis is reconfirmed [2].

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INVESTIGATION OF (*p*, γ)-REACTION IN ^{120}Sn NUCLEUS

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Measurements of the single and γγ-coincidence spectra were carried out in the ^{120}Sn (*p*, γ) ^{121}Sb reaction on a tandem-generator's beam. We irradiated the tin target enriched by ^{120}Sn to 98%. The resolution of used Ge-detectors is 1.8 keV on ^{60}Co γ-lines and efficiency of these detectors is 30% in comparison of 3"x3" Na(J)Tl detector.

An energy of protons was 4 MeV. The gamma-transitions were identified as a result of our measurements. These transitions are related to decay of excited states of ^{121}Sb. More then 20 new transitions were identified in γγ-coincidences. The scheme of ^{121}Sb levels were extended using data obtained.

Relative population of numerous states was defined directly from (*p*, γ) reaction. It allows to define the quasi-particle configurations cleanly because of in (*p*, γ) reaction the states are excited mainly by *S*- and *P*-waves.

The obtained data are discussed.

ISOMERIC RATIOS OF CROSS SECTIONS IN THE PROTON- AND DEUTERON- NUCLEAR REACTIONS

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Samples from enriched tin isotopes ^{112,118,120,124}Sn were irradiated on the nuclotron and the synchrophasotron of the LHE JINR by protons and deuterons with the energy 3.65 GeV/nucleon. The duration of the irradiation was 6.42 h in the case of protons and 1.083 h in the case of deuterons. The cross section of the deuteron beam had the shape of an ellipse, its axes being 3 and 2 cm. The diameter of the proton beam, which was round in shape, was 2 cm. For beam monitoring we employed the reactions ^{27}Al(d,3p2n)^{24}Na and ^{27}Al(p,3pn)^{24}Na, their cross sections being 14.2±0.2 and 10.6±0.8 mb respectively. On the basis of this monitoring we obtained the following beam intensities: 1.33×10^{13} *d/h* (^{112}Sn), 0.768×10^{13} *d/h*(^{118,120,124}Sn), 2.35×10^{13} protons (0.366×10^{13} *p/h*) (^{112}Sn) и 0.73×10^{13} protons (0.114×10^{13} *p/h*)(^{118,120,124}Sn). The induced-activity method was used to explore the yields of radioactive residual nuclei formed in the targets. The gamma spectra of residual nuclei were measured by HPGe detectors at the LNP JINR during the year after the irradiation. The residual nuclei formed in the targets were identified by the characteristic gamma lines and by the respective half-lives. The measured spectra were evaluated by the DEIMOS code.

In this work the isomeric ratios of formation cross sections of a few isomeric pair in the proton- and deuteron-nuclear reactions were investigated. Were studied:

a) The dependence of isomeric ratios of cross sections (R) for the proton-nuclear reactions on the proton energy for E_p= 0.66; 1.0; 3.65; 8.1 GeV;

b) The dependence of R on the number of emitted neutrons;

c) The dependence of R on the type of projectile (p, d, γ).

The following results we obtained:

a) The R ratios do not depend on the primary energy of the projectile within the experimental errors;

b) for the direct reactions R<1 (^{112}Sn→ ^{110m,g}In) and increase with the increasing of ΔA ($\Delta A=A_t-A$), and become constant by the some value of ΔA. For the other reactions R was constant within the experimental errors;

c) The value of R for the deuteron-nuclear reactions (^{86m,g}Y) was considerably greater than for the proton-nuclear reactions, and for the ^{99}Rh, ^{95}Tc, ^{44}Sc do not depend on the type of projectile (p, d, γ).

RECOIL STUDIES IN THE REACTION OF PROTONS WITH THE ENRICHED ISOTOPE ^{118}Sn

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[2]*Joint Institute for Nuclear Research, Dubna, Russia;*
[3]*Nuclear Physics Institute, Řež, Czech Republic*

The recoil properties of the residual nuclei from interaction of 3.65 GeV protons with ^{118}Sn target have been studied by the method of catching foils in the LHE JINR. The target consists a stack of the 15 foils of enriched isotope each sandwiched between two pairs of mailar foils. The thicknesses of the targets and catchers allowed to make a measurements by using "thick target - thick catcher" method. The induced activity in targets and catching foils were measured after irradiation on HPGe detectors.

The relative quantities of the forward- and backward- (relative beam direction) emitted nuclei were calculated from relations:

$$F=N_F/(N_t+N_F+N_B),\quad B=N_B/(N_t+N_F+N_B)$$

where N_F , N_B , N_t are the numbers of nuclei emitted in forward and backward catchers and formed in target foils respectively.

The mathematical formalism of the standard two step vector model [1] was used for analyses of experimental results. The reaction product ranges (R) and the velocities transferred to residuals on the first (v) and second (V) steps of reaction have been calculated by using following expressions :

$$\eta = \frac{v}{V},$$

$$F/B=(1+\eta)^2/(1-\eta)^2$$

$$R=4WF/(1+\eta)^2=kV^n$$

where W is the target thickness in mg/cm^2, k and n are the parameters obtained by the fitting the range dependence on energy of accelerated ions within the region from 0.25 to 60 MeV/nucleon.

The kinematical characteristics for ~20 residuals were obtained. The F/B ratios changed from values ≤ 2 for light fragments to > 2 for heavier nuclei.

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EXPERIMENTAL STUDY OF RESIDUAL NUCLIDE PRODUCTION IN PROTON REACTIONS ON Pb ISOTOPES AND Bi

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[2] *RSC Kurchatov Institute, 123182 Moscow, Russia*

The ITEP U-10 proton synchrotron has been used to make 55 irradiations of thin ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{nat}Pb and ^{209}Bi targets exposed to 0.04, 0.07, 0.1, 0.15, 0.25, 0.4, 0.6, 0.8, 1.2, 1.6 and 2.6 GeV protons with the view of determining the cross sections for production of radioactive residual nuclides.

The radioactive product nuclide yields are determined by direct gamma-spectrometry using a high-resolution Ge detector. 5600 independent and cumulative yields of radioactive residual product nuclides with halflives from 8 minutes to 32 years have been determined.

A number of discrepancies in the absolute quantum abundances of some radionuclides (^{188}Pt, for instance) have been found in identifying the gamma-spectra obtained. Besides, the gamma-spectra measured show the gamma-lines that cannot be identified by the present-day nuclear decay databases and belong to still unknown isomeric states of nuclei.

The radioactive residual nuclide production cross sections are presented as plots of excitation functions.

The research has been carried out under the ISTC Project#2002.

ON THE EXCITED STATES OF ^{5}He IN THE REACTIONS ^{6}Li(d,^{3}He)^{5}He AND ^{7}Li(d,^{4}He)^{5}He

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Both kinematically complete and incomplete experiments were performed at a deuteron laboratory energy of 37 MeV for the study of ^{5}He excited states in the exit channels of the reactions ^{6}Li(d,^{3}He)^{5}He and ^{7}Li(d,^{4}He)^{5}He. Due to high Q-value the reaction ^{7}Li(d,^{4}He)^{5}He has been intensively studied predominantly at the low deuteron energy [1]. Experimental data for ^{6}Li(d,^{3}He)^{5}He reaction were obtained early only at E_d = 14.5 MeV [1].

The experiments were performed at cyclotron U-240 (Kyiv). The charged reaction products were detected by three ΔE-E_1-E_2 telescopes of detectors with the thickness of 50, 600 and 2000 μm, respectively. Fourth telescope consists of two segmented ΔE-E detectors with the thickness of 50 and 600μm. The inclusive spectra of ^{3}He and α-particles were measured in the angular range of Θ_{lab}=15–62°. Coincidence spectra were also obtained for more than 10 sets of two particle detection angles.

The main contribution to the inclusive spectra of ^{3}He and ^{4}He at all angles is caused by the formation and decay of unbound states of ^{4}He*, ^{5}He, ^{6}He*, ^{5}Li, ^{6,7}Li*, ^{8}Be in accompanied three and four particle reactions. Most of these resonances were observed in coincidence spectra of different pairs of detected particles. Only ~ 15% of ^{3}He and ^{4}He yields corresponds to the population of different states of residual ^{5}He nucleus. ^{3}He and ^{4}He spectra were analysed taking into account all accompanied processes, that made it possible to extract the cross sections of formation of the ground and excited states (E_x<25 MeV) of ^{5}He and to determine their resonance parameters. In particular, the values (2.3±0.3) MeV and (2.9±0.6) MeV for the excitation energy and width of the first excited state of ^{5}He were obtained, respectively.

The first excited state of ^{5}He was observed also in coincidence αα-spectra measured at some sets of angles. From their analysis the values E_x=(2.5±0.3) MeV and Γ=(2.9±0.4) MeV are found for this state. The possible reasons of discrepancies in the data obtained for a broad resonances from inclusive and coincidence spectra are discussed in the present work. Also the influence of the energy of incident particles and reaction type on the parameters of short lived nuclear states [2,3] are considered.

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A SEARCH FOR EXCITED STATES OF ^{3}He BY THE REACTION ^{7}Li(d,^{6}He)^{3}He

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V.O. Kyva, I.N. Kolomiets

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The reaction ^{7}Li(d,^{3}He)^{6}He has been studied at a deuteron laboratory energy of 37 MeV with the aim to determine the main reaction mechanisms [1]. The differential cross sections of this reaction were determined in usual way from inclusive spectra of ^{3}He and ^{6}He nuclei measured at different angles. Besides the peaks connected with population of the ground state of ^{3}He all ^{6}He spectra reveal some structure at energies corresponding to the excitation of ^{3}He recoil nuclei in the range of E_x = 6–18 MeV.

According to review [2] of experimental and theoretical investigations there are no unambiguous evidence for the existence of excited states of ^{3}He and ^{3}H. Recently resonance-like structure of α-particle spectrum was observed in reaction ^{1}H(^{6}He,α)^{3}H [3]. This is in agreement with earlier study of this reaction [4], where the excited state of ^{3}H with a width Γ = 0.6 MeV and excitation energy E_x = 7 MeV was observed. To some extent these results obtained for ^{3}H have initiated the present study.

The interaction of deuterons with ^{7}Li at the energy of 37 MeV is characterized by lots of opened reaction channels in which different stable and unstable nuclei are produced. It is known that in many cases the main contribution to inclusive spectra of reaction products is connected with formation and decay of unbound nuclear states in accompanied reaction channels.

The inelastic scattering of deuterons as a process with large cross sections and the reactions ^{7}Li(d,2p)^{7}He are considered in the present work as a possible ways of ^{6}He production. The Monte-Carlo simulation of inclusive spectra of ^{6}He from decay of ^{7}Li* and ^{7}He into ^{6}He+p and ^{6}He+n channels, respectively, have been performed. Calculated spectra are in agreement with experimental one within their statistical errors. So, the structure of ^{6}He spectra observed in reaction ^{7}Li(d,^{6}He) can be explained as the contribution of the processes mentioned above without the assumption about existence of ^{3}He excited states.

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THE YIELDS OF ^{186}Re IN REACTION ^{186}W(*d,2n*)

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St. Petersburg State University

By method "of target of stacked foils" has been investigated the energy dependence and yields of ^{186}Re in reaction ^{186}W(*d*,2*n*) in the energy range of deuterons 12.8/5.9 MeV (the threshold energy of reaction - 3.58 MeV).

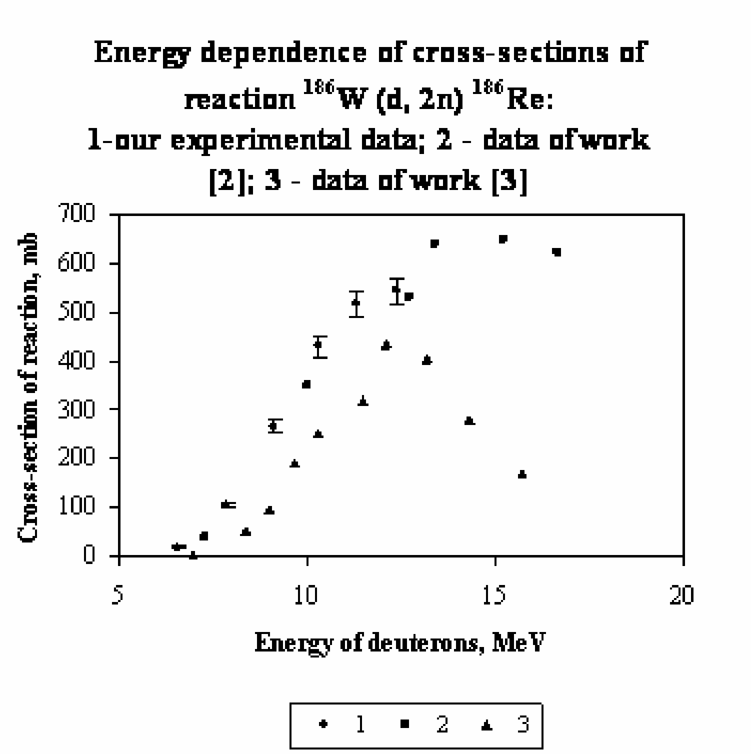
The cyclotron targets have been prepared from the foils of naturally metal tungsten by thickness of 20 microns (surface density - 38.6 mg·cm^{-2}), chemical purity - 99.95 %. For definition of an integrated current of a beam of deuterons were used copper monitors which were placed on a course of a particle beam ahead and behind of the tungsten foils.

The study of yields of nuclear reactions it was made with use of high-precision gamma- spectrometry. For research of radioisotope composition of the irradiated targets, definition of energy dependence of yields of ^{186}Re semiconducting detector GX1018 (Canberra, Inc., U.S.A.) was used. The activity of the targets radionuclide was determined on photopeak 0.1372 MeV, quantum yield - 9.47%. The bias of activity was not more than 5 %.

The energy dependence of yields of ^{186}Re (for EOB) is given in the table below.

Energy of deuterons, MeV	12.8/11.9	11.9/10.8	10.8/9.7	9.7/8.5	8.5/7.3	7.3/5.9
Yields of ^{186}Re, MBq·mcA^{-1}·h^{-1}	0.917	0.874	0.726	0.447	0.175	0.033

Ground above mentioned yields of target radionuclide energy dependence of cross-sections of reaction of production of ^{186}Re in the picked energy range of deuterons (see fig. on which besides experimental results received by us the literary data known today [1, 2]) is designed. The integrated yield ^{186}Re over the range energies 12.8/5.9 MeV has made 3.17 MBq·mcA^{-1}·h^{-1}.



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COMPARATIVE ANALYSIS OF THE ^{178m2}Hf ISOMER YIELD AT REACTIONS WITH DIFFERENT PROJECTILES

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The triggered release of the energy stored in nuclear isomers is promising for the creation of pulsed sources of gamma-radiation. For instance, the high-spin $K^{\pi}=16^{+}$ ^{178m2}Hf isomeric state stores a specific energy of about 1.3 MJ/mg with a half-life of 31 years. For applicative purposes and extensive studies on the trigger mechanisms one needs to produce isomers in an amount of milligrams, or even more in extreme. As is known up to now, the largest quantity of the ^{178m2}Hf material was produced in Los-Alamos with 800 MeV protons at the high-current accelerator. The advantage of this method was a possibility to accumulate the isomer as by-product in a massive Ta beam-dump during the operation of the accelerator for other experiments. However, the produced isomeric material contains very high activity of other radionuclides, and the background radiation remains high even after chemical isolation of the Hf fraction. The productivity of the spallation reactions with protons at intermediate energies has been systematically studied for the Ta, W and Re targets at Dubna 660 MeV synchrocyclotron in Ref. [1]. Some recommendations, how to optimize the spallation method have been worked out. However, basic disadvantage of a high contaminating activity is not yet overcome.

The ^{176}Yb (^{4}He,2*n*)^{178m2}Hf reaction was investigated in Ref. [2], and much better quality sources were produced using a 36 MeV ^{4}He-ion beam and the following chemical processing of the irradiated Yb targets with the mass-separation of ^{178}Hf nuclides at the end. The problem of isomer separation from the stable ^{178}Hf is not yet solved. The method of (^{4}He, 2*n*) reaction has still the disadvantage of much lower productivity as compared to the spallation. So, it can be used for the high-preciseness physical experiments with the ^{178m2}Hf source, but not for the applications. There is known in literature also the producer reaction of ^{179}Hf(n, 2*n*)^{178m2}Hf at a 14 MeV neutron beam. The cross-section of the latter reaction is reasonably good, but the flux of fast neurons generated in the ^{3}H(^{2}H, *n*)^{4}He reaction is typically not high. Neutron energies of E_n>10 MeV are requested for (*n*, 2*n*) reaction and they are represented in the reactor spectrum with very low yield. Recently, we made an attempt to detect the production of ^{178m2}Hf in the reactor irradiations of the ^{nat}Hf target assuming some reasonable yield due to the ^{178}Hf(n,n') reaction with the neutrons of fission spectrum. However, only upper limit of the cross-section is deduced today because of high activity of other products. More sensitive measurements are expected after longer cooling time. The production of ^{179m2}Hf in (n, n') reaction is nevertheless detected.

The yield of ^{178m2}Hf has been successfully observed [3] in the Ta target exposed to a 4.5 GeV bremsstrahlung at Yerevan synchrotron and newly analyzed using the γ-spectroscopy technics at Dubna. At optimum irradiation scheme, the evaluated productivity turns out to be higher than at the (^{4}He, 2n) reaction and lower than at the spallation. However, for definite conclusion, the total cost and radiational safety conditions should also be compared, as well as the technical restrictions on the maximum beam current of electrons or protons.

The yields of all known reactions are compared in their productivity for the accumulation of the ^{178m2}Hf isomer. However, the general conclusion can be formulated that extraordinary high cross-section is not found for any reaction among investigated. This means, that the idea to accumulate grams of the ^{178m2}Hf isomer requires for realization the special high-power systems for the production and use of very dense fluxes of nuclear projectiles. Parameters of the standard research facilities are not enough for this purpose.

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COUPLED CHANNELS DESCRIPTION OF α-PARTICLES SCATTERING FROM ^{11}B

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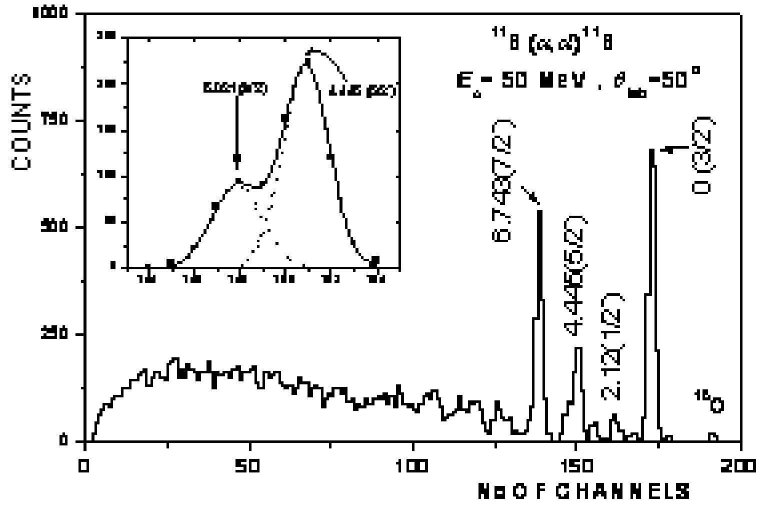
As the ^{11}B nucleus belongs to the middle of *p*-shell it has extremely high quadrupole deformation. Therefore the low-lying states of this nucleus with energies 2.125 MeV ($1/2^-$), 4.445 MeV ($5/2^-$), 5.021 MeV ($3/2^-$) and 6.743 MeV ($7/2^-$) are usually interpreted as members of two rotational bands built on the ground ($3/2^-$) and the first excited ($1/2^-$) states with $K = 3/2$ and $K = 1/2$ respectively. In this case the coupled channels effects become essential. Their neglect can be responsible both for non-physical values of potential parameters derived from optical model phenomenological analysis of elastic scattering and for incapacity to reach the acceptable data description with folding potentials.



The main purpose of the present work was extraction of quadrupole and hexadecapole deformation parameters of ^{11}B nucleus from elastic and inelastic scattering of *α*-particles at energies of 40 and 50 MeV using the coupled channels method. The typical spectrum of scattered *α*-particles is shown in the figure. The angular distributions which are measured for the members of the ground state rotational band of the ^{11}B nucleus (E_x = 0.0 MeV ($3/2^-$), 4.445 MeV ($5/2^-$) and 6.743 MeV ($7/2^-$)) were analyzed by the coupled channels method in the frame work a collective model where ^{11}B nucleus is represented as a symmetric rotator. In calculations we neglected effects of *K*-band mixing. Results of our analysis gives an evidence in favour of the negative sign for the quadrupole deformation parameter ($\beta_2 = -0.6 \pm 0.15$). The hexadecapole deformation ($\beta_4 = 0.1 \pm 0.2$) is small and could not be determined with the best accuracy in the present analysis. The additional DWBA calculations demonstrate that the cross sections enhancement observed in the large angle scattering is connected with the heavy cluster (^{7}Li) transfer mechanism in the ^{11}B (α, ^{11}B) α reaction.

THE REFRACTIVE, ELASTIC $^{16}O+^{12,13,14}C$ SCATTERING AT E_{lab}=132 MeV

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In our previous investigations of elastic $^{16}O+^{12}C$ scattering prominent rainbow structure was detected [1]. It was demonstrated a preference of the energy 132 MeV for the deepened investigation of the refractive effects. Herewith some pronounced Airy minima of the high orders were observed. With energy increase absorption increases and Airy structure is damped.

Till now the prominent rainbow structure was displayed only for heavy ions ^{16}O and ^{12}C. But it is important to search it for the other light nuclei with the different structure in particular for carbon isotopes.

No distinctive Airy structure was observed in the earlier investigations of elastic $^{16}O+^{13,14}C$ scattering. But the structure of ^{14}C is similar one of ^{16}O (2 "holes" in *p*-shell) and ^{13}C -^{12}C (odd neutron). One can suppose the rainbow structure can be observed for carbon isotopes if a right choice of the energy and the pair of colliding nuclei will be made.

Differential cross-sections of elastic $^{16}O+^{12,13,14}C$ scattering at E_{lab}=132 MeV were measured. The experiments were carried out at the cyclotron of Kurchatov Institute (Moscow, Russia). For registration of reaction products 3 telescopes *dE-E* with solid angles 0.15 mster were used.

Angular distributions span the range (7 –170) c.m. deg. for $^{16}O+^{12}C$ and (7-90) c.m. deg. for $^{16}O+^{13,14}C$. The forms of 3 curves are similar. There are Frauenhover oscillations at the forward angles and two pronounced minima at 80^o and 60^o. The minima are located at nearly the same angles. There is the small smooth shift about 5^o from ^{12}C to ^{14}C. The minima depth decreases with increasing of the target mass. Differential cross- sections value at the range 7^o-90^o are almost equal. Thus isotopic effects observed are insignificant.

Optical model analysis was carried out. Angular distributions at the large angles are described well by the far component of scattering amplitude that confirms their refractive nature. Minima observed were identified as Airy minima of the third and the fourth order. This means the energy 132 MeV ensures high sensitiveness to nuclear potential at small distances. Using of the known L_{cut} procedure results in the value 2-2.5 fm. This is essentially less RSA.

The volume integrals of the real and imagine parts of optical potential are close. Taking into consideration the same position of Airy minima one can suppose refractive properties are defined by some general ones of nuclear medium. The close values of cross-sections and volume integrals of the imagine part of optical potential testify to approximately identical absorption. Therefore carbon isotopes structure influences on reaction mechanism faintly.

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CONSTRAINING NEUTRON STAR MATTER WITH LABORATORY EXPERIMENTS

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While measurements of nucleus-nucleus collisions have provided significant constraints on the equation of state of symmetric nuclear matter [1], there are currently no good constraints on the asymmetry term in the nuclear EOS. These constraints are relevant to the understanding of neutron rich astrophysical objects. Heavy ion collisions, which create nuclear matter over a range of densities provide an opportunity to study the density dependence of nuclear symmetry energy. The status of present investigations with heavy ion beams will be reviewed. With the development of new facilities for producing energetic rare isotope beams especially those with extreme isospin composition, prospects for future measurements in this area will also be explored. This work is supported by the NSF Grant No. NSF-PHY-01-10253, INT-PHY-02-18329.

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THE ^{4}He(^{3}He,γ)^{7}Be REACTION STUDIED VIA THE ANC METHOD: PRELIMINARY RESULTS

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Angular distributions of the ^{6}Li(^{3}He,*d*)^{7}Be transfer reaction were measured at the Catania 3.5 MV HVEE Singletron Accelerator at energies near the Coulomb Barrier (E_{lab}(^{3}He)=5 and 3 MeV) for the transitions to the ground and first excited state of ^{7}Be.

The measurement was performed in order to get information on the Asymptotic Normalization Coefficients(ANCs)[1] for the $^7\mathrm{Be}\rightarrow{}^3\mathrm{He}\oplus{}^4\mathrm{He}$ process, in turn related to the astrophysical relevant ^{4}He(^{3}He,γ)^{7}Be radiative-capture reaction.

The data were preliminarily analyzed in the framework of the DWBA method. Both the p-transfer and alpha-transfer reaction channels were taken into account in the calculations. The analysis showed up the presence, in this energy range, of a dominant compound contribution, which actually does not allow the extraction of the ANCs.

It is planned to extend the measurements at sub-Coulomb energies; experimental hints at such low energies and the astrophysical implications of the ^{4}He(^{3}He,γ)^{7}Be radiative-capture reaction will be also discussed.

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INELASTIC INTERACTION OF NUCLEI OF GOLD AT 100–10200 MeV/NUCLEON WITH NUCLEI OF PHOTOEMULSION

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Within the bounds of this work experimental investigation and theoretical study of passing process heavy nuclei of gold at 100–10200 MeV/nucleon through homogeneous medium are continued in conditions of overall experiment an opportunity are given by method nuclear emulsion [1,2].

Experimental measuring the plurality of charged particles, resulting from inelastic interaction of nuclei of gold with nuclei of photoemulsion, is passed. The dependence of plurality of charged particles on flying nucleus energy and mass is analyzed. For the first time have found out an effect of heavy nuclei of target finite. The distribution of power of initial particles took part in inelastic interaction with nuclei of photoemulsion NIKFI BR-2 is received in the work. Also charge state of nuclei of gold fragment and charge distribution of second fragments are investigated on interaction of nuclei of gold with nuclei of photoemulsion.

Theoretical calculation within the bounds of cascade-evaporating model (for 1000 inelastic interaction of nuclei of gold with nuclei of hydrogen – H, carbon – C, nitrogen – N, oxygen – O, bromine – Br, silver – Ag) is made. A sequential comparison fundamental experimental characteristic of the process results with results of calculation by cascade-evaporating model is made. To achieve the agreement in experimental dates and theoretical calculation it is necessary to take into account in using model the process nuclear shell fission and (or) multifragmentation, which are considerable in experiment.

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SURVEY OF GROUND STATE NEUTRON SPECTROSCOPIC FACTORS FROM Li TO Cr ISOTOPES

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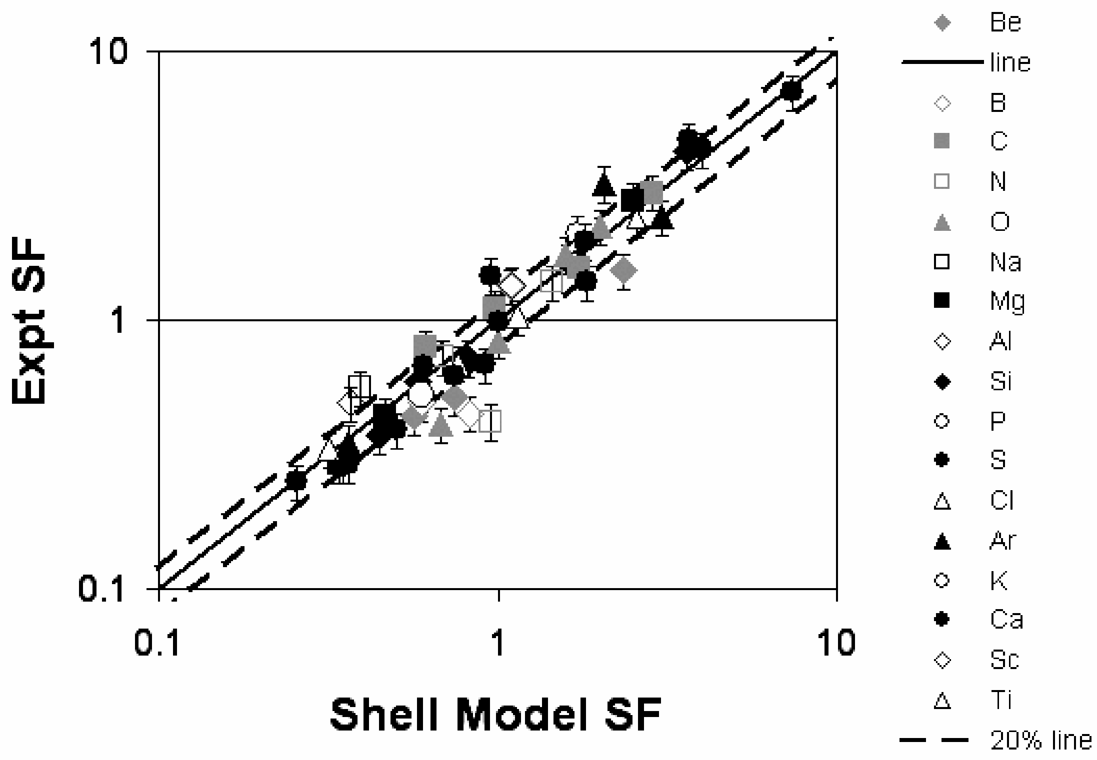
The success of the Shell Model has prompted many measurements to extract the spectroscopic factors, which describe the configuration of single particle orbitals. We have extracted the ground state to ground state neutron spectroscopic factors (SF) for 78 nuclei ranging in Z from 3 to 24 by analyzing the past measurements of the angular distributions of (*d,p*) and (*p,d*) reactions in a systematic and consistent manner [1]. For the Ca isotopes from ^{40}Ca to ^{48}Ca, the spectroscopic factors follow the predictions of the single particle model predictions as well as predictions from shell model suggesting Ca isotopes have good spherical cores with well defined valence nucleons. For the 59 nuclei where modern shell model calculations [Oxbash] are available, with the exception of the deformed F and Ne isotopes, the experimental spectroscopic factors for most nuclei agree with predictions from modern day shell model to within 20% as shown in the figure below. This work is supported by the NSF Grant No. NSF-PHY-01-10253, INT-PHY-02-18329 and SURE.



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TEXTBOOK EXAMPLE OF THE NEUTRON SPECTROSCOPIC FACTORS OF $^{40\text{-}48}$Ca ISOTOPES

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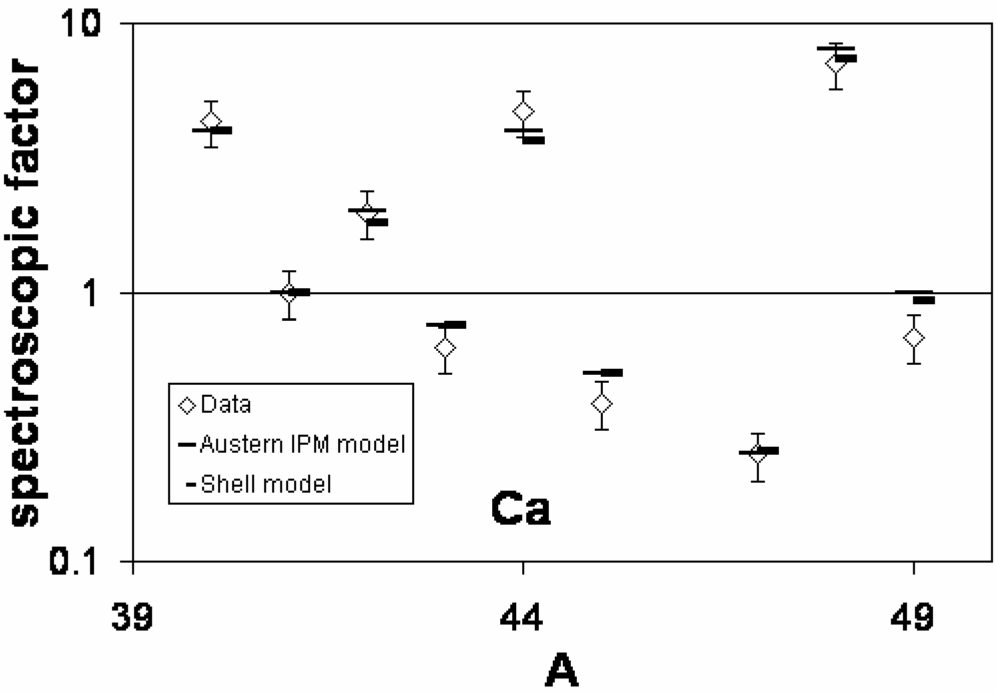
We have analyzed the angular distributions of the ground-state to ground-state transitions from (*d,p*) and (*p,d*) transfer reactions on different Ca isotopes thus obtaining the spectroscopic factors (SF) of the valence neutron for ^{39}Ca, ^{40}Ca, ^{41}Ca, ^{42}Ca, ^{43}Ca, ^{44}Ca, ^{45}Ca, ^{47}Ca, ^{48}Ca, ^{49}Ca isotopes. In our analysis, we used the Johnson-Soper adiabatic and distorted-wave theories and a standard set of parameters including global optical potentials [1]. The extracted spectroscopic factors are plotted as symbols in the bottom figure as a function mass number of the Ca isotopes. This figure serves as a textbook example for the independent particle model which includes only the pairing effect. For example, on page 291 in Austern's book [2], an example for j=7/2 which corresponds to the $f_{7/2}$ orbits of the $^{41\text{-}48}$Ca is given; SF=1, 2, 0.7, 4, 0.5, 6,0.25, 8 for n=1,2,3,4,5,6,7,8 where n is the number of valence nucleons. These predictions are shown as thin red bars on the left of the symbols and the blue bars are shell model predictions. The apparent contradictions of the extracted ^{40}Ca neutron SF value with the proton SF value obtained from (*e,e'p*) measurements will be discussed. This work is supported by the NSF Grant No. NSF-PHY-01-10253, INT-PHY-02-18329 .



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FRONTIERS IN STUDIES OF INVERSE KINEMATICS RESONANCE SCATTERING INDUCED BY RADIOACTIVE BEAMS

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Resonance scattering of radioactive beams on hydrogen, using Thick Target Inverse Kinematics Method (TTIK) [1], became a powerful and a conventional tool to study nuclear structure of drip line nuclei as well as processes of astrophysical interest.

Recently more exotic applications of the Thick Target Inverse Kinematics Method (TTIK) were made [2,3]. These were the observations of resonance yield of neutrons and γ rays in reactions leading to the population of the states which are Isobaric Analogs of the neutron rich nuclei.

Several laboratories are working on investigations of resonance reactions induced by radioactive beams in helium. Apart from the nuclear structure interest these reactions are also important for the understanding of nucleosynthesis. The high efficiency and the precision of the TTIK makes the method very useful for different applications with low intensity beams.

We'll review new activities in this field together with possible limitations of the method. We intend also to consider some analysis problems, related with identification of several overlapping resonances in the excitation functions. This situation should became conventional in the resonance reaction studies of drip line nuclei [3].

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COLLINEAR THREE-BODY NUCLEAR FISSION INDUCED IN TUNGSTEN NUCLEI BY 1 GEV PROTONS

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The majority of the collinear disintegrations induced in heavy nuclei by relativistic protons are the result of peripheric interactions with small momentum and energy transfer. Such an energy transfer is enough to overcome the low fission barrier in heavy nuclei. However, in some events two collinear fission fragments were accompanied by large nucleon losses [1], which meant high nuclear excitation at low momentum transfer. In order to continue the experimental study of this effect at a 1 GeV proton beam an experiment was carried out with a tungsten target enriched with ^{184}W isotope with ($2E$,$2V$) measurement technique, similar to that used in [1]. The medium-heavy nuclear target with high fission barrier was used in order to eliminate the low energy fission events. Fig. 1a shows a bidimensional (P_1,P_2) momentum plot for calibration ^{252}Cf fission events as well as for events of disintegrations induced in tungsten by 1 GeV protons (the background events are rejected). The same events are shown in Fig. 1b in a bidimensional (M_1,M_2) mass plot. Squares refer to collinear disintegrations with fragment folding angles within $177.5^{\circ} \leq \theta \leq 180^{\circ}$. The events below the dashed line belong to the 3-body disintegrations into fragments of comparable masses. The measured TKE values of two detected fragments were used [2] to determine a parameter $\eta = e^2 Z^2{}_0 / D_3$ which contains an initial distance between outward fragments of the collinear 3-body configuration as a function of the relative mass $\xi = M_3/M_0$ of the inner slowly moving fragment.

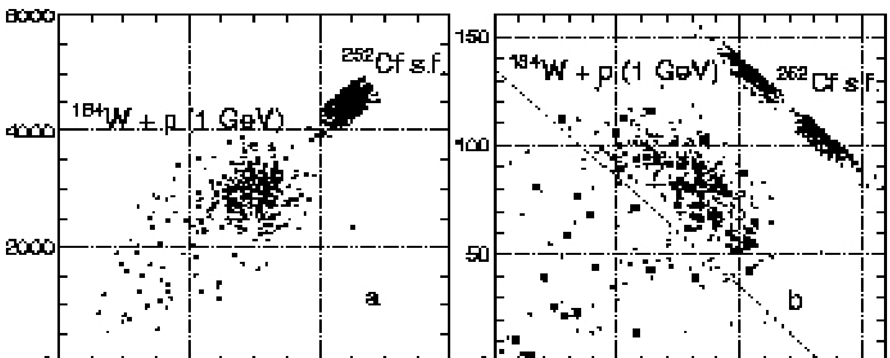

Fig. 1

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EXPERIMENTAL EVIDENCES FOR THE INDUCED SINGLE-STAGE NUCLEAR FISSION

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The binary fission of ^{238}U, ^{232}Th and ^{197}Au at the 1 GeV incident proton energy was investigated with use of the double-arm time-of-flight spectrometer at PNPI [1]. In the processing of the experimental results, there were obtained convincing evidences for the single-stage nuclear fission by the transverse nucleon flows, induced by a recoil nucleon after the incident proton quasi-elastic scattering and by the double-nucleon absorption of a produced π-meson. The mean multiplicities of those flows are equal to ~ 10 and ~ 20 nucleons, respectively. The collective interaction of those flows with the average nuclear potential of nucleon-spectators deforms the residual nucleus to the saddle-form of its fission-barrier that results in the immediate direct nuclear fission [2]. Single-stage fission events are distinguished from two-step fission events by less deviations from the exact oppositely directions of the complementary fragments emission and the other kinematical peculiarities. The induced single-stage fission cross-section of ^{238}U at proton energy E_p = 1 GeV is found to be ~ 500 mb (the summary cross-section for the both channels).

A heavy doubly magic cluster-formation within a heavy deformed nucleus results in immediate expulsion of this cluster, because the clusterization energy is very great. This single-step reaction was called recently cluster-fission [3]. There are presented experimental evidences for the cluster-fission of ^{238}U and ^{232}Th by 1 GeV protons with the ^{132}Sn cluster as the heavy fission fragment. Such clusters and another core-like fragments are emitted sometimes both in the quasi-elastic and in the π-meson single-stage fission channels. The cross-section of such reaction at E_p = 1 GeV are found to be ~ 100 mb for the both nuclei.

On the basis of the concept of the two-step and single-stage nuclear fission coexistence it is proposed a new approximation of the total fission cross-section energy dependence for the target nuclei ^{238}U. It is the sum of three exponential functions of the first order.

The first function decreases, as the incident proton energy is increased from $E_p \approx$ 50 MeV to ~ 30 GeV. It corresponds to the two-step fission [4].

The second function increases from threshold energy $E_p \approx$ 200–270 MeV to its maximum value at ~ 3 GeV. It corresponds to the single-stage fission.

The third function decreases between $E_p \approx$ 3 GeV and ~ 30 GeV. It reflects decreasing of the single-stage nuclear fission cross section in this energy range.

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NEUTRON AND PROMPT GAMMA RAY EMISSION IN THE PROTON INDUCED FISSION OF ^{239}Np AND ^{243}Am AND SPONTANEOUS FISSION OF ^{252}Cf

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Average preequilibrium $<M_n^{preeq}>$, average statistical prescission $<M_n^{stpre}>$ and postscission $<M_n^{post}>$ neutron multiplicities as well as average γ-ray multiplicity $<M_\gamma>$, average energy $<E_\gamma>$ emitted by γ–rays and average energy per one gamma quantum $<\varepsilon_\gamma>$ as a function of mass and total kinetic energy (TKE) of fission fragments were measured in proton induced reactions p+^{242}Pu→^{243}Am, p+^{238}U→^{239}Np (at proton energy E_p=13, 20 and 55 MeV) and spontaneous fission of ^{252}Cf. The solid angle aberration and the Doppler shift in the laboratory angular distribution of γ-ray emission were utilized to obtain the number and energy of γ-rays as functions of single fragment mass. The results in the case of ^{252}Cf, for both average number and average energy as functions of single fragment mass, are characterized by a sawtooth behavior similar to that which is well known for neutron emission. The similar behavior one can see for proton induced fission of ^{239}Np and ^{243}Am. The fragment mass dependence $<M_n^{post}>(m)$ and $<M_\gamma>(m)$ shows a clear sawtooth structure that is gradually washed out with increasing proton energy E_p or with decreasing TKE. Using the response matrix technique we were able to distinguish between the statistical dipole (*E1*) and collective quadrupole (*E2*) γ-ray emission of single fission fragments.

YIELDS OF PRODUCT NUCLEI IN RADIOACTIVE ^{129}I, ^{237}Np, ^{238}Pu AND ^{239}Pu SAMPLES EXPOSED TO THE SECONDARY NEUTRONS OF THE U/Pb-ASSEMBLY OF THE SETUP "ENERGY PLUS TRANSMUTATION" IRRADIATED BY 1 GeV PROTONS FROM NUCLOTRON (JINR, DUBNA)

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Collaboration "ENERGY PLUS TRANSMUTATION"

Results of the radioactive sample exposed to the field of the secondary neutrons on the surface of a four-section blanket (206.4 kg of natural uranium) generated in its lead target (Ø8.4x48 cm) irradiated by 1 GeV protons from the JINR Nuclotron accelerator are presented [1]. Simultaneously, ^{127}I and threshold detectors were exposed, which allowed us to take into account the stable I contribution (17.1% in the ^{129}I sample). The samples contained: ^{129}I ─ 0.521 g of ^{129}I and 0.1075 g of ^{127}I; ^{237}Np ─ 1.011 g; ^{238}Pu ─ (0.051 g: 72.9% of ^{238}Pu and 16.8% of ^{239}Pu) and ^{239}Pu ─ 0.44 g. Spectra of the induced activity were measured by the HPGe gamma-spectrometers and analyzed using the methods described earlier [1, 2]. Reaction rates R (per sample's atom per incident proton), i.e. partial yields for all (n,γ), (n,f), (n,α) and (n,xn) observed channels were calculated. The results are given in the Table, where absolute and relative product yields are presented for irradiations with energies of 1 and 2 GeV [3].

Transmutation (burning-up) estimation with consideration of all the reaction channels on the assumption of 10 mA proton current and 1 (or 2) GeV proton energies during 720 days amounts to (in percent):

^{129}I - 1.44(3.65); ^{237}Np - 28.3(67); ^{238}Pu - 4.6(27); ^{239}Pu - 26.4(100).

Ratio of the product nuclei yields at the two incident proton energies above is close to 3.5.

The work was supported by the grants FZJ (Jülich, Germany), ISTC-1372 and Committee on Collaboration of Czechia Institutes and Universities with JINR.

Table. Absolute and relative yields of product nuclei

Target	Product isotope	$T_{1/2}$	R 1 GeV	R 2 GeV	Reaction	R (2GeV) / R (1GeV)
^{239}Pu	Na-24	14,958h	3,55(10)E-29	1,01(5)E-28	*n*,α	2,84
	Kr-88	2,840h	1,16(13)E-27	2,59(33)E-27	*n*,*f*	2,23
	Sr-91	9,630h	2,14(8)E-27	6,92(63)E-27	*n*,*f*	3,23
	Sr-92	2,710h	2,20(34)E-27	5,15(58)E-27	*n*,*f*	2,34
	Y-92	3,540h	5,91(58)E-27	1,51(12)E-26	*n*,*f*	2,55
	Zr-97	16,900h	3,24(30)E-27	1,41(10)E-26	*n*,*f*	4,35
	Mo-99	2,748d	5,38(22)E-27	1,70(18)E-26	*n*,*f*	3,16
	Ru-103	39,260d	5,26(25)E-27	2,43(37)E-26	*n*,*f*	4,62
	Ru-105	4,440h	4,93(20)E-27	1,71(25)E-26	*n*,*f*	3,47
	Sb-128	9,010h	1,29(16)E-28	4,64(63)E-28	*n*,*f*	3,58
	Sb-129	4,400h	1,19(12)E-27	4,0(9)E-27	*n*,*f*	3,36
	Te-132	3,204d	3,45(14)E-27	1,72(41)E-26	*n*,*f*	4,98
	I-131	8,021d	2,80(14)E-27	1,28(8)E-26	*n*,*f*	4,58
	I-132	2,295h	2,67(63)E-27	9,57(16)E-27	*n*,*f*	3,59
	I-133	20,800h	6,08(21)E-27	2,11(15)E-26	*n*,*f*	3,46
	I-135	6,570h	4,86(12)E-27	1,52(4)E-26	*n*,*f*	3,12
	Xe-135	9,140h	7,67(89)E-27	4,84(47)E-26	*n*,*f*	6,31
	Ce-143	33,040h	3,23(13)E-27	1,42(13)E-26	*n*,*f*	4,40
	Ba-140	12,752d	4,2(13)E-27	1,53(18)E-26	*n*,*f*	3,61
	La-140	1,678d	5,88(70)E-28	1,30(24)E-27	*n*,*f*	2,21
^{238}Pu	Na-24	14,958h	3,11(10)E-29	1,18(7)E-28	*n*,α	3,80
	Zr-97	16,900h	3,20(30)E-27	1,77(22)E-26	*n*,*f*	5,53
	Sb-129	4,400h	6,6(34)E-28	-	*n*,*f*	-
	I-132	2,295h	3,24(39)E-27	7,5 (32)E-27	*n*,*f*	2,32
	I-133	20,800h	2,28(54)E-27	6,5(24)E-27	*n*,*f*	2,86
	Xe-135	9,140h	2,58(52)E-27	1,50(13)E-26	*n*,*f*	5,80
	Ru-105	4,440h	-	2,36(59)E-26	*n*,*f*	-
^{237}Np	Na-24	14,958h	3,24(7)E-29	-	*n*, α	-
	Sr-91	9,630h	1,57(12)E-26	-	*n*,*f*	-
	Zr-97	16,900h	6,30(35)E-28	-	*n*,*f*	-
	Te-132	3,204d	5,27(67)E-28	-	*n*,*f*	-
	I-133	20,800h	7,75(67)E-28	-	*n*,*f*	-
	I-135	6,570h	7,48(67)E-28	-	*n*,*f*	-
	Np-238	2,117d	5,41(11)E-26	1,73(32)E-25	*n*,γ	3,2
^{129}I	Na-24	14,958h	2,67(9)E-29	8,2(4)E-29	*n*, α	3,07
	I-123	13,270h	2,20(43)E-29	4,31(75)E-29	*n*,7*n*	1,96
	I-124	4,176d	3,25(86)E-29	4,36(54)E-29	*n*,6*n*	1,34
	I-126	13,110d	9,67(43)E-29	2,48(49)E-28	*n*,4*n*	2,57
	I-130	12,360h	3,47(13)E-27	8,93(36^E-27	*n*,γ	2,58

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INDUCED FISSION TIMES OF HEAVY NUCLEI AS A PROBE OF THE NUCLEAR MATTER VISCOSITY

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We present the results of the uniform analysis of the large set of experimental data on the induced fission times - τ_f obtained by the crystal blocking technique [1]. Among the data our own τ_f values for the ^{232}Th,^{235,238}U + *p*, *d*, ^{3}He, α reactions [2], measured at the cyclotron U-120 of the Institute of Nuclear Physics, Moscow State University (Russia), at the beam energies in the range from 4 to 7.8 MeV/nucleon, and also for the ^{28}Si + ^{nat}Pt reaction [3], investigated at the Tandem-XTU accelerator of the LNL Laboratories (Padova, Italy), at the silicon beam energies from 140 to 170 MeV. We also performed the comparative analysis of the τ_f values for the Pb-like ($Z = 82 \pm 1$) and U-like ($Z = 92 \pm 1$) nuclei formed in the ^{208}Pb + ^{28}Si and ^{238}U + ^{28}Si reactions [4, 5], measured at the GANIL facility (France), at the lead and uranium beam energies 29 MeV/u and 24 MeV/u, respectively. Analyzed τ_f values fall in the range from 10^{-14} to 3×10^{-19} s and cover the wide range of the initial excitation energy from 5 to 250 MeV. Analysis was carried out within the novel stochastic approach based on Langevin equations taking into account neutron, light charged particle and γ-quantum emission from the hot fissioning systems. Also phenomenon of the damping of shell effects with increasing of nuclear temperature (responsible to the transformation of double-humped fission barrier with two classes of excited nuclear states realized in the first and second potential wells into a single-humped one) was considered by the self-consistent way. Simultaneous description of the analyzed energy dependences of τ_f and respective experimental data on the total neutron multiplicities for the investigated reactions allows us to obtain the nuclear dissipation magnitudes and the shell effect damping function. The possible temperature and deformation dependences of the nuclear matter viscosity predicted by the different authors [6, 7] are considered. It was demonstrated that τ_f values for the Pb-like nuclei lie significantly below than ones for the U-like nuclei and far beyond the low limit of the crystal blocking technique.

This work was supported in part by the State Program "Russian Universities" (grant No. UR. 02.02.513/05).

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MASS YIELD MEASUREMENT OF ^{239}Pu FISSION PRODUCTS BY NEUTRONS OF DIFFERENT ENERGIES

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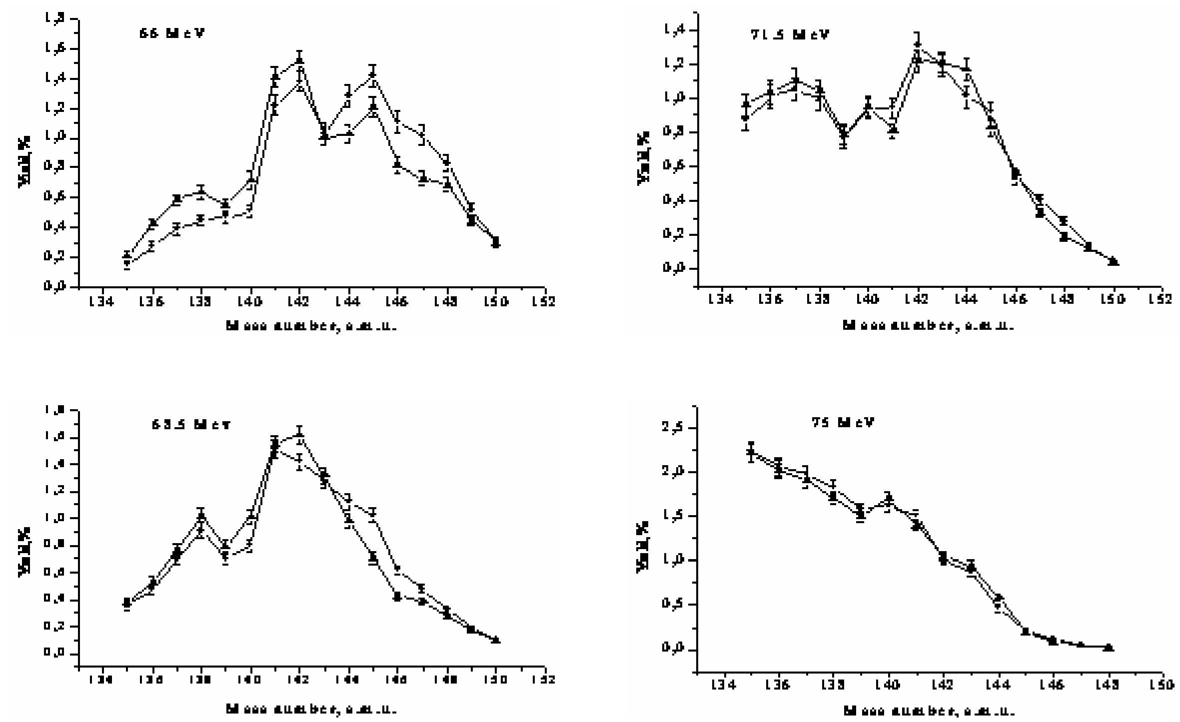
Measurements of fission fragments (FF) mass yield for different parts of spectrum of reactor neutrons using various filters were carried out. The neutron flux in a horizontal channel was previously measured at power of the reactor 10 MWt with help of Cu and Au foils, which served detectors. After irradiation the measurements of their activity were conducted and the neutron flux in the target location at reactor neutrons N_r=8·10^{12} neutron / cm^2·c. was determined. Through the samarium filter with 0.25 mm thickness pass neutrons above 0.2 eV energy, the neutron flux has constituted N_{Sm}= 6.5·10^{11} neutron /cm^2·c. Through the cadmium filter thickness of 0.75 mm pass neutrons above 0.4 eV energy. Their neutron flux has constituted N_{Cd} = 2.6·10^{11} neutron / cm^2 ·c. A procedure of such measurements was elaborated and tested. Relative mass distributions Y_A FF at fixed values of kinetic energies $E_к$ = 66.0, 68.5, 71.5 and 75.0 MeV at fission by reactor neutrons are shown in the Fig. Physical interpretation of the obtained results with further applications and development are given. The work was supported under the STCU grant Uzb-96.



Relative yields of FF at different E_k, (•- without filter, Δ-with filter)

RECENT MULTI-PARAMETER STUDIES ON THE PARTCLE-ACCOMPANIED FISSION OF ^{252}Cf (*sf*) AND ^{235}U(n_{th}, *f*)

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For a previous multi-parameter study on spontaneous ^{252}Cf(*sf*) ternary fission (TF), a compact and highly efficient detector system "CODIS" was developed for detecting fission fragments (FFs) and ternary light charged particles (LCPs) and measure their mutual energy and angular correlations. CODIS was placed inside a 4π-NaI(Tl) Crystal Ball spectrometer which was used for the coincident detection of prompt fission neutrons and γ-rays. The novel experimental approach has brought out a wealth of new information on the ternary fission process [1-3], having prompted us to project supplementary studies. A new setup "CODIS2" was constructed and successfully applied in two recent experiments. Compared to CODIS, some technical modifications have been made to accept high fission rates in the twin-IC and improve LCP detection efficiency and particle discrimination.

In a first measurement performed at the GSI Darmstadt [4] a 4π ^{252}Cf sample of 2.5×10^4 fissions/s was used and high-resolution γ-ray spectroscopy in binary and ternary fission was accomplished with a pair of large-volume segmented Super Clover Ge detectors. Here, the main topics of interest have been the prompt fission γ-decays from both, the FFs and LCPs, and γ-ray anisotropy. A second experiment was carried out at the ILL on ^{235}U(*n,f*) induced by cold neutrons of the PF1 facility [5]. With dedicated pile-up rejection a high fission rate of 2.5×10^5 fissions/s was handled successfully with the FF-IC without compromising its high resolution. Thus, reliable FF-LCP correlation data for ^{235}U(*n,f*) ternary fission with LCPs up to Be became accessible and, in addition, first of such correlation data for the still rarer α-α and α-*t* quaternary fission processes.

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EXPERIMENT AIMED AT THE STUDY OF ^{252}Cf BINARY AND TERNARY FISSION

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New experiment devoted to the binary and ternary fission of ^{252}Cf and to nuclear spectroscopy of neutron-rich nuclei far off the beta-stability produced by spontaneous fission is described. Our knowledge about fission phenomena was substantially enriched during the last years, as a consequence of experiments performed by using triple-gamma coincidences in the Gammasphere. The fragments were identified by their gamma-ray spectra. Among other new aspects of the fission process seen for the first time with this new technique, one should mention α and ^{10}Be accompanied cold fission, the double fine structure, and the triple fine structure in binary and ternary fission. A particularly interesting feature, observed in ^{10}Be accompanied cold fission of ^{252}Cf is related to the width of light particle gamma-ray spectrum.

An assembly of a ^{252}Cf source with a detector array was installed in the center of Gammasphere. The detector assembly is shown schematically in Fig. 1. Fragments emitted in binary and ternary fission of ^{252}Cf reached the silicon detectors, and their energies were measured with a resolution of ~2.5 %. The atomic masses of the two complementary secondary fragments were determined within five mass units. In the experiment made in January 2005, ~10^9 events were detected. The great majority of detected events are due to the binary fission. In half of this statistics, clusters with $Z \geq 2$ emitted in ternary fission were also detected in coincidence with fission fragments. One of the principal objectives of the present experiment – the search for long-lived scission point configurations with light clusters emitting their characteristic γ rays from nearly the quiescent state – implies the observation of gamma rays, which did not experience Doppler shift. Correction for Doppler shift will be made for γ rays emitted in flight. First results of data analysis will be presented.

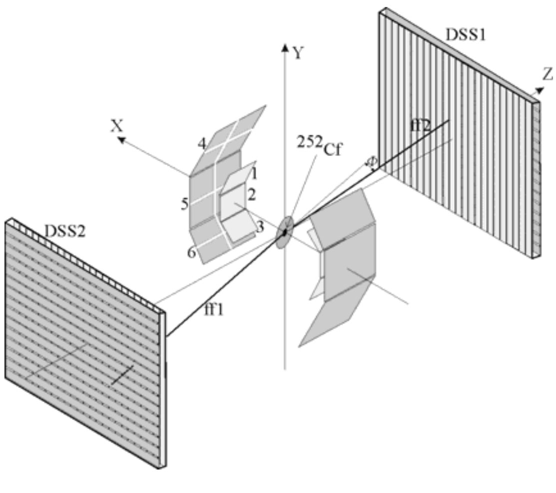

Fig. 1. The source of ^{252}Cf is in the center. Fission fragments ff1 and ff2 hit detectors DSS1, DSS2. Telescopes installed along X axis detect ternary fission light clusters.

ELASTIC AND INELASTIC ELECTRON SCATTERING BY TENSOR POLARIZED DEUTERON

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The method of utilizing of 2 GeV electron storage ring VEPP-3, Novosibirsk for the nuclear experiments with internal targets is described. The most attention is paid to experiments with tensor polarized deuterium target [1]. The descriptions of the construction of the target, its parameters and the detector system for the scattered and recoil particles are given.

Tensor analyzing power components T_{20} and T_{21} in elastic electron-deuteron scattering have been measured at the momentum transfer range 8.4 - 21.6 fm^{-2}. The new data determinate the deuteron form factors G_C and G_Q in important range of momentum transfer where the first node of the deuteron monopole charge form factor is located [2].

The measurement of photodisintegration of tensor polarized deuteron recently completed for the photon energy range 40 - 500 MeV and covered proton emission angles of 20 - 100 degrees.

The results of these experiments and comparison to existing theoretical predictions will be given.

The nearest planned experiments on coherent neutral pion photoproduction on tensor polarized deuteron and determination of two photon exchange diagrams contribution to elastic *e-p* scattering will be discussed briefly.

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QUASIELASTIC SCATTERING IN THE ENERGY REGION OF GIANT RESONANCES IN (*e,e′*) SPECTRA

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The results of the investigation of giant resonances (GR) by means of the inelastic electron scattering depend strongly from the quasielastic (QE) background, which should be extracted before analyzing the strength and multipolarity of GR. At the same time the energy dependence of pure QE cross section is interesting in itself as an object for verification of different theoretical models of QE electron scattering. Up to now the energy dependence of QE cross section at the energy region of GR is unknown because of impossibility to separate QE part of the spectrum from the resonance part. All testing of different theoretical QE scattering models were carried out at high excitation energies where there are any resonances.

We first propose the method to divide an electron scattering spectrum into resonance and QE parts. This method is based on the so-called "bin" technique, which has been successfully tested in the energy region where the QE process is absent [1]. We have applied this method to electroexcitation of ^{65}Cu.

The experiment was carried out at the LINAC-300 of NSC KIPT. The details of experimental technique being used, methods of scattered electron spectra measuring and obtained data processing can be found in [2].

As a result the transition probability $B(E\lambda)$ energy dependence was obtained for each multipolarity λ. There are any resonances at high excitation energy (>50 MeV) and we see here the energy dependence of QE reduced probability. So we consider reduced probability energy dependence for each multipolarity as a sum of GR and much more broad high-energy maximum corresponding to QE process. The Gaussian function was fitted to each experimental maximum by least square method.

The obtained Gaussian shape of the high energy maximum for each multipolarity gives us energy dependence of the QE process. The momentum transfer energy dependence is given by Helm formfactor. So the QE cross section now can be represented as a sum of Helm formfactors with Gausian amplitudes.

The QE peak was obtained for 11 spectra of inelastic electron scattering within the transferred momentum range from 0.5 to 1.4 fm^{-1}. The accuracy of QE curve determination in all excitation energy intervals up to 80 MeV is better than 15%.

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PHOTOPRODUCTION OF η-MESONS ON QUASI-FREE PROTON AND NEUTRON

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The ratio of η-meson photoproduction cross-sections on the quasi-free neutron and quasi-free proton have been measured. The data have been obtained by the GRAAL collaboration [1] using the liquid deuteron target. Gamma beam was obtained by the back scattering laser technique in the energy range from 0.7 to 1.5 GeV. Exclusive measurement of η-mesons and recoil nucleons was done in coincidence. The response function and neutron detection efficiency of the GRAAL detector [2] have been studied and compared with the GEANT-based simulation. Experimental results show that neutron/proton ratio is increasing vs the gamma energy up to 1.5 at $E_{\gamma} = 1$ GeV. The obtained results are compared with the literature data. It is seen that the neutron/proton cross section ratio measured in [3] at 0.8 GeV (0.68±0.06) is in agreement with our data.

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LIGHT FRAGMENT KNOCK OUT FROM ^{12}C AND ^{16}O BY INTERMEDIATE ENERGY PIONS

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The quasielastic deuteron and triton knock out has been studied on pion beam in full kinematics on ^{12}C and ^{16}O. The experiment was performed at the ITEP Proton Synchrotron with the 3-m magnet spectrometer at an incident pion momenta of 0.72, 0.88 and 1.28 GeV/c. Momentum and angles of forward going deuteron/triton as well as of beam and backward scattered pions were measured. The momentum distributions of the internal motion of the quasideuteron clusters, the excitation energy spectra and quasideuteron effective numbers for ^{12}C and ^{16}O were obtained. These results are discussed together with our previous measurements on Lithium isotopes [1]. Parameters of quasideuteron internal motion and quasideuteron effective numbers are in a reasonable agreement with the measurements made at proton and electron beams demonstrating independence from reaction mechanisms and supporting cluster model approach. Excitation energy distributions are compared with calculations in simple models of quasielastic scattering.

Triton knock out from ^{12}C and ^{16}O together with our measurements on ^{6}Li and ^{7}Li [2] made it possible to estimate *A*-dependence of the reaction and to predict cross section for the backward pion triton elastic scattering not measured yet at so high momentum transfer.

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SYSTEMATICAL MACROSCOPIC AND SEMIMICROSCOPIC ANALYSIS OF (^{4}He, ^{4}He) ELASTIC SCATTERING AT ENERGY UP TO 100 MeV

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In present work the systematical analysis of seven experimental angular distributions of elastic scattering $^{4}He(\alpha,\alpha)^{4}He$ at the energy up to 100 MeV was performed by the first time. Energy and mass dependencies of macroscopic optic and semimicroscopic folding-model were received and their errors were estimated.

EXPERIMENTAL ENERGY DISTRIBYTIONS OF ^{4}He-PARTICLES WITH STABLE NUCLEI ^{28}Si AND ^{90}Zr

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We have studied the experimental energy distributions of α-particle elastic scattering at the energies in range from 14 up to 240 MeV on nuclei ^{28}Si, ^{90}Zr at different angles with interval $(5 – 10)^{0}$. On the basis of macroscopic optic and semi-microscopic folding models it is observed the amplifying of diffraction minimums and maximums with rising of α-particle energies in range (20–100) MeV in excitation functions of reactions $^{4}He+^{90}Zr$ in medium angle region $(40 – 70)^{0}$ s.c.m. Also, it is observed more sharp maximums in excitation functions in angle region $(60 – 90)^{0}$ at energies (20 – 35) MeV.

EMPIRIC ENERGY DEPENDENCES OF PHENOMENOLOGICAL OPTIC AND SEMI-MICROSCOPIC FOLDING-MODEL PARAMETERS FOR REACTIONS ^{4}He+ ^{28}Si

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Differential and total reaction cross sections for α-particles in region of low and medium energy for nuclei from *A*=12 – 208 have been calculated and their systematic analysis has been carried out firstly within the framework of the macroscopic optic (MOM) [1, 2] and semi-microscopic folding model (SFM) [3]. In a density functional method the effective nucleon - nucleon forces, proton and neutron densities of the colliding nuclei are taken into account.

In order to construct a global dependence of MOM and SFM parameters for α-particles with energy up to and above 80 MeV the analysis of experimental angular distribution of elastic scattering and total reaction cross section on the ^{90}Zr nuclei was carried out. In the range of energies up to and above 80 MeV the mass dependence of MOM and SFM parameters is investigated for α-particles with an energy ~ 50 MeV and ~ 140 MeV on the nuclei ^{12}C, ^{24}Mg, ^{28}Si, ^{40}Ca, ^{48,50}Ti, ^{58}Ni, ^{68,70}Zn, ^{90,94}Zr, ^{120,124}Sn, ^{208}Pb [1, 2, 3].

In present work the systematic analysis of experimental angular distributions of elastic scattering ^{4}He(^{28}Si, ^{28}Si)^{4}He (and total reaction cross sections) at the energy from 14.7 to 240 MeV was performed. Energy dependencies of MOM and SFM model parameters were received and their errors were estimated. A comparison between the obtained results and the energy dependencies of parameters for nucleus ^{90}Zr is carried [1, 2, 3].

The optimum MOM and SFM parameters were searched so that to achieve the best agreement within the framework of the joint analysis differential cross-section of scattering and data on total reaction cross sections, tendency of a values change of a volume integral from a real part. One should mention that at the joint analysis of differential and total reaction cross sections the SFM parameters are determined uniquely.

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CENTRALITY OF THE COLLISIONS AND CLUSTER FORMATION IN THE NUCLEAR-NUCLEAR INTERACTIONS

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The appearance of the strongly interacting matter mixed phase (MP) has been suggested to understand qualitatively the regime change existence in the behavior of some centrality depending characteristics of events. The MP has been predicted by QCD for the temperatures around the critical temperature T_c and could be formed as a result of nucleon percolation in the density nuclear matter. Our main goal is to get a new experimental confirmation of the percolation cluster formation as an accompanying effect of the MP formation. To reach the goal, the experimental data on Kr+Em - reaction at 0.95 GeV/nuc. And Au+Em – reaction at 10.6 GeV/nucl. with a number of target fragments $N_h > 8$, have been analyzed. The behaviors of the distributions of the target and the projectile fragments have been studied. The experimental data have been compared of the data coming from the cascade-evaporation model.

We can conclude that:

-- the centrality of the collision could be defined as a number of the target *g*-fragments in Kr + Em reactions at energies 0.95 A GeV/nucl. and as a number of projectile *F*-fragments with $Z \geq 1$ in Au + Em reactions at energies 10.6 *A* GeV/nucl.;

-- the formation of the percolation cluster sufficiently influences the characteristics of nuclear fragments;

-- there are points of the regime changes in the behavior of some characteristics of *s*-particles as a function of centrality which could be qualitatively understood as a result of the big percolation cluster formation.

EXPERIMENTAL STUDY OF ENERGY DEPENDENCE OF PROTON INDUCED FISSION CROSS SECTIONS FOR ^{nat}Pb, ^{209}Bi, ^{233}U, ^{235}U, ^{238}U IN THE ENERGY RANGE 200-1000 MeV

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The results of the total fission cross sections measurements for ^{nat}Pb, ^{209}Bi, ^{233}U, ^{235}U, ^{238}U nuclei at the energy proton range 200-1000 MeV with step 100 MeV are presented. Experiments were carried out at 1 GeV synchrocyclotron of PNPI RAS with the updated beam system that allows one to have proton beams with intensity up to 10^7 protons/s in all energy range. The measurement method is based on the registration in coincidence of both complementary fission fragments by two gas parallel plate avalanche counters, located at a short distance and opposite sides of investigated target. The insensitivity of parallel plate avalanche counters allowed us to place the counters together with target between immediately in the proton beam thereby providing a large solid angle acceptance for fission fragment registration and reliable identification of fission events. The proton flux on the target to be studied was determined by direct counting of protons by scintillation telescope and using secondary reaction of elastic proton scattering by $(C_2H_2)_n$ target. Obtained results are compared with other experimental data and show that the fission cross sections do not depend strongly on the incident proton energy over this entire energy range.

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THE MECHANISM OF PHOTODISINTEGRATION OF CARBON NUCLEUS IN THE $^{12}C(\gamma,n)^{3}He2\alpha$ AND $^{12}C(\gamma,p)^{3}H2\alpha$ REACTIONS AT E_{γ}^{max}=150 MeV

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Differential cross sections for the “mirror” reactions $^{12}C(\gamma,n)^{3}He2\alpha$ and $^{12}C(\gamma,p)^{3}H2\alpha$ have been measured over several energy ranges. The asymmetry parameter of nucleon angular distributions (β_N) relative to 90° was determined. In the $^{12}C(\gamma,n)^{3}He2\alpha$ reaction, the β_N value is small at energies up to 38 MeV, but in the 38-40 MeV range it increases abruptly. At energies above 40 MeV, the β_N value increases with the γ-quantum energy. The variation of the asymmetry parameter in the 38-40 MeV range is due to a change in the mechanism of interaction between the electromagnetic radiation and the nucleus. The data obtained at energies up to 40 MeV are explained in terms of the direct mechanism model. In the electric dipole approximation, the angular distributions having the $d\sigma/d\Omega \sim \sin^2\Theta$ form suggest the conclusion that the excited states of the nuclei ^{11}C and ^{11}B have the quantum numbers $J^p=1/2^+$ [1]. A high excitation energy of the intermediate nucleus and the shape of angular distributions give evidence that nucleons are ejected from the *s*-shell. At energies above 40 MeV the present results are in agreement with the predictions by the model of photon absorption by the nucleon pair with a dominant contribution from meson exchange currents [2].

Previously, we have indicated the dependence of the asymmetry parameter on the excitation energy of intermediate nucleus at a constant γ-quantum energy [3]. The present experimental results confirm the tendency for the asymmetry parameter to decrease with excitation energy increasing.

The distributions in the relative energy carried away by n^3He and p^3H pairs have been analyzed. The quasi-α-particle model prediction [4] about the transfer of the substantial γ-quantum energy portion to these pairs lacks support from the factual evidence.

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THE β-DELAYED ALPHA-PARTICLES EMISSION FROM THE PHOTOFISSION FRAGMENTS OF ^{238}U

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Beta-decay of the some fission fragments can lead to the daughter nucleus with excitation energy, sufficiently large to alpha-particle emission. However, usually the neutron is evaporated in such a case, because a reasonably long time must be spend for alpha-particle formation and penetration of the Coulomb barrier.

The experiments for detections of β-delayed alpha-particle emission from ^{238}U photofission fragment were performed, using FLNR JINR MT-25 microtron as the bremsstrahlung radiation source. Fission fragments, stopped into the gaseous catcher, were delivered to the detector using aerosol gas flow through the capillary. Capillary length is of 9 m, inner diameter is of 2 mm. The nitrogen was used as a buffer gas. The nitrogen pressure into the reaction chamber was 2 atm, and the detector chamber was pumped by the forevacuum mechanical pump with 16 l/s output. Delay for fragments transportation from the targets to the detector was about 0.9 s.

The solid-state track detector was used for the alpha-particles registration. It was placed against the aerosol collector, at distance of 1 cm. Tracks, corresponded to the alpha-particles with energy of 8 MeV and more, were selected among the registered ones. Such particles can appear in the natural conditions from the ^{214}Po decay only, and as a background from a cosmic rays, but last events are rare. The ^{214}Po isotope is on the ^{222}Rn decay chain, so one can expect that it will decay with 3.7 d halflife into the ^{222}Rn-isolated environment.

In the our preliminary experiments were registered the high-energy alpha-activity, which exceed background at ~10 events per hour. It corresponds to the probability of the alpha-particle emission of $\sim 3\cdot10^{-9}$ per fission.

The accuracy of the preliminary data is enough pure, because of high background. The experiments with much lower background will be performed soon.

EXTRAPOLATION OF ^{2}H AND ^{4}He RESPONSE FUNCTION BY POWER FUNCTION

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The important trend of nuclear investigation is the study of response function moments represented as

$$S^{(k)}_{T/L}(q) = \int_0^{\infty} R_{T/L}(q,\omega)\omega^k d\omega, \qquad (1)$$

where k is an integer number, q and ω are the 3-momentum and the energy transferred to the nucleus, respectively, $R_{T/L}(q,\omega)$ are transverse (T) and longitudinal (L) response functions (here sort of R-functions are as in paper [1]). The experimental testing of $S^{(k)}_{T/L}(q)$ calculations requires the response functions extrapolation in the region of large transverse energies, where the measuring isn't impossible. The extrapolation function, which is written as $R^t(q,\omega) = C(q)\ \omega^{-\alpha}$, is propose in [1,2].

In the present work the ^{2}H and ^{4}He response functions were received from the data obtained at the KIPT electron accelerator LUE-300 in the range of $q = 0.9\times1.35$ fm^{-1}. The values of α_T and α_L were found from the fitting of R^t-function to the experimental data of $R_T(q,\omega)$ and $R_L(q,\omega)$, respectively.

It was found that:

1) for either of the two nuclei $\alpha_T \cong \alpha_L$;

2) $\alpha(^2\mathrm{H}) = 2.95\pm0.15$;

3) $\alpha(^4\mathrm{He}) = 2.0\times2.3$.

The received for $q = 0.9\times1.35$ fm^{-1} experimental α lead to conclusions:

a) the received values of $\alpha_L(^2\mathrm{H})$ are in good agreement with the calculation of [1] given $\alpha_L(^2\mathrm{H}) = 3\times4$;

b) parameter α depends on atomic number of nucleus;

c) if for ^{2}H and ^{4}He response functions are extrapolated by power function, the finite values of $S^{(k)}_{T/L}$ can be obtained to the integer number $k \leq 1$.

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TWO-NEUTRON (γ, 2n) REACTION IN THE GDR ISOSPIN SPLITTING CONCEPTION

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Detailed study of parameters of giant dipole resonance isospin splitting has been carried out [1 - 3]. Data on both various photonuclear reaction cross sections and spectroscopic information about levels with various isospin values in target nuclei and neighbor nuclei of isospin multiplets have been used for analysis (^{22}Ne, ^{63,65}Cu, ^{58,60,62}Ni, ^{90}Zr ^{208}Pb).

It was obtained that both isospin splitting energy values ΔE and two isospin component ratios R are quite different from predictions of traditional model [4, 5]. The reason is that simple geometric model developed mainly for heavy nuclei does not take into account some features of reactions on medium and light nuclei. The point is that in those nuclei: 1) Coulomb barrier is not too high and does not forbid completely $T_<$-states proton decay and 2) excitation energies of $T_>$-states in $(N - 1)$ nuclei are not high enough and $T_>$-states neutron decay also is not forbidden. Therefore the clear separation ($T_>$ - (γ, p) and $T_<$ - (γ, n)) does not realized – GDR states with different isospins are mixed and could be separated only using special methods. Nevertheless on the whole [4, 5] $T_>$-states primarily forming (γ, p) reaction are lying at higher energies in comparison with $T_<$-states primarily forming (γ, n) reaction.

The most interesting result of analysis carried out is the specific role of the two-neutron reaction (γ, 2n). In many cases absolute cross section values of those reaction are of the same order as of (γ, p) reaction but thresholds are much more higher and energy thresholds for excitation of $T_>$-states in (N-2) nuclei are very high (~ 30 MeV) also. Therefore because $T_0(N) = T_0(N - 2) + 1$ at the GDR energies two-neutron reaction can occur only through $T_<$-states decay. So the picture of GDR isospin splitting became quite different from simple conception scheme: $T_<$-states dominates at energy ranges of (γ, n) and (γ, 2n) reactions, but $T_>$-states between them – at energy range of (γ, p) reaction. Therefore the total GDR width increased but ΔE is not the difference between of (γ, p) and (γ, n) reaction cross section centers of gravity – the contribution of (γ, 2n) reaction cross section must be included.

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(γ,3n) REACTION CROSS SECTION DATA VERIFICATION BASED ON VARIOUS EXPERIMENTS RESULTS

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The detailed combined analysis of the (γ,xn), (γ,n) and (γ,2n) reaction cross section data obtained using quasimonoenergetic annihilation photon beams at Livermore (USA) and Saclay (France) have been carried out [1] for 19 nuclei ^{51}V, ^{75}As, ^{89}Y, ^{90}Zr, ^{115}In, ^{116,117,118,120,124}Sn, ^{127}I, ^{133}Cs, ^{159}Tb, ^{165}Ho, ^{181}Ta, ^{197}Au, ^{208}Pb, ^{232}Th, ^{238}U. It has been shown that: 1) (γ,xn) cross sections obtained at Livermore have in general absolute values smaller then that obtained at other various laboratories and therefore must be corrected - multiplied by appropriate individual coefficients $R^{int}(\gamma,xn) = R^{int}(\gamma,n) = \sigma^{\mathrm{int}}{}_{\mathrm{S}}(\gamma,n)/\sigma^{\mathrm{int}}{}_{\mathrm{L}}(\gamma,n)$ ($<R^{int}{}_{syst}> =$ 1.12), where S denotes Saclay and L - Livermore; 2) partial photoneutron reactions (γ,n) and (γ,2n) cross sections obtained at Saclay because of incorrect neutron multiplicity sorting procedure are not correct and consistent each other and must be recalculated using special method [1, 2]: Saclay (γ,n) reaction cross section part $1/2(\sigma(\gamma,n)_{\mathrm{S}} - R\sigma(\gamma,n)_{\mathrm{L}})$ must be removed and added (“transmitted back”) to Saclay (γ,2n) reaction cross section $\sigma(\gamma,2n)_{\mathrm{S}}$.

The results obtained were used for system analysis of existed data for (γ,3n) reaction cross sections. Because all of those cross sections were measured as a rule for very narrow energy ranges on the high-energy tail of giant dipole resonance with poor statistics the analysis was based on the expression connected more accurately measured reaction cross sections $\sigma^{\mathrm{eval}}(\gamma,3n) = 1/3[\sigma(\gamma,xn) - (\gamma,n) - 2\sigma(\gamma,2n)]$. The analysis confirms additionally the correctness of procedure used in [1]: $\sigma^{\mathrm{eval}}(\gamma,3n)$ are consistent with Livermore experimental data directly but with Saclay data only after recalculation introduced before [1].

The jointly corrected data of Livermore and Saclay were used for evaluation of new (γ,3n) reaction cross sections for ^{117}Sn, ^{118}Sn, ^{119}Sn, ^{124}Sn, ^{127}I, ^{133}Cs, ^{159}Tb, ^{165}Ho, ^{181}Ta, ^{197}Au, ^{208}Pb. The reliability of analysis carried out is supported by the comparison of data obtained for with ^{181}Ta(γ,3n)^{178}Ta reaction with published data obtained using induced activity method in experiments with bremsstrahlung [3, 4].

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CROSS-SECTIONS OF (γ, n) REACTION IN ^{81}Br AND ^{121}Sb NUCLEI

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Excitation cross-sections of isomeric states of ^{80m}Br ($T_{1/2}$ = 4.42 hours, J^{π}=5$^-$) and ^{120m}Sb ($T_{1/2}$ = 5.76 days, J^{π}=8$^-$) were measured in photoneutron reactions of ^{81}Br(γ, n) ^{80m}Br and ^{121}Sb(γ, n) ^{120m}Sb. The reaction products are odd-odd nuclei. The spins of their metastable states are formed both proton and neutron shells. In the case of ^{80}Br nucleus they are $2p_{1/2}$ and $1g_{9/2}$ correspondingly. Whereas in ^{120}Sb nucleus they are $2d_{5/2}$ and $1h_{11/2}$.

Measurements are carried out in the range of 9-18 MeV with the 0.5 MeV step of measurements (ΔE=0,5 MeV). An identification of excitation of metastable states was performed by γ-lines with following energies: 0.037 MeV for ^{80m}Br nucleus and 1.023 MeV for ^{120m}Sb. Cross-sections were calculated by the Penfold-Liss method. The obtained cross-sections were approximated by Lorentzians. This table represents parameters of these Lorentzians:

Nuclei	σ_0, mb	Γ_0, MeV	E_0, MeV
^{81}Br	77.6±2.1	4.31±0.23	16.8±0.07
^{121}Sb	28.8±1.2	4.18±0.21	16.6±0.06

Data of full photoneutron cross-sections (σ_n) for stibium isotopes [1] allow to calculate an isomeric ratio of σ_m and σ_n cross-sections (σ_m/σ) for ^{121}Sb. This ratio is equal 0.32±0.03 at the 17 MeV energy of gamma quanta. The obtained results are considered.

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EXCITATION OF ^{113m}In, ^{195m}Pt AND ^{199m}Hg ISOMERS IN THE REACTIONS OF INELASTIC GAMMA SCATTERING

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The yields curves have been measured and reaction cross-sections have been obtained for the reactions ^{113}In (γ, γ') ^{113m}In ($T_{1/2}$ = 1.7 h, $J^{\pi} = 1/2^{-}$), ^{195}Pt (γ, γ') ^{195m}Pt ($T_{1/2}$ = 4.1 d, $J^{\pi} = 13/2^{+}$) and ^{199}Hg (γ, γ') ^{199m}Hg ($T_{1/2}$ = 42.6 min., $J^{\pi} = 13/2^{+}$). The irradiation has been conducted at the microtron M-30 in the energy range of bramstahlung photons from 4 up to 12 MeV with a step of ΔE = 0.5 MeV. The targets of natural isotope composition have been used. The measurements have been carried out using HPGe detector and yield statistical uncertainty happened to be decreasing from 3-2% at 4-5 MeV to 0.3-0.2% at higher energies.

The reaction cross-sections have been calculated by Penfold-Liss method and cross-section values σ_m obtained for a number of energies are presented in the Table.

E, MeV		4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
σ_m, mb	^{113}In	-	0.07	0.28	0.53	0.97	1.35	0.80	0.18	0.25
	^{195}Pt	0.09	0.16	0.48	0.10	0.05	-	-	-	-
	^{199}Hg	0.027	0.12	0.23	0.25	0.045	0.10	-	-	-

The cross-section for ^{113}In (γ, γ') ^{113m}In reaction reaches a maximum at the energy about 9.0 MeV, while in the case of the reactions ^{195}Pt (γ, γ') ^{195m}Pt and ^{199}Hg (γ, γ') ^{199m}Hg it happens at the energy around 6.6 MeV. The resonance locations for all mentioned above nuclei coincide with the corresponding (γ, *n*) reaction thresholds.

The obtained cross-section values σ_m have been used to calculate the isomeric ratios $\sigma_m/\sigma_{tot.}$. As for the total photoabsorption cross-sections $\sigma_{tot.}$, extrapolated Lorentzian values in the energy range 4-12 MeV for the investigated nuclei have been taken [1]. The experimental isomeric ratios are compared with calculations in the frame of statistical Fermi gas theory [2].

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PHOTOEXCITATION STUDY OF ^{157m}Gd AT ENERGIES BELOW 5.2 MeV

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Photoexcitation of ^{157m}Gd (11/2-, 426 keV, $T_{1/2}$ =18,5 μs) has been studied at the pulse non-ferromagnetic betatron with fixed electron energy equal to 5.2 MeV under the conditions as previously presented [1]. The yield of reaction ^{181}Ta(γ,γ')^{181m}Ta [2] has been measured under the same conditions for a comparison. This allowed to exclude some uncertainties related to bremsstrahlung. This procedure has a physical significance if we take into account the latest results on interpretation of the second reaction in the framework of the quasiparticle-phonon model of nuclei [3] and closely related structures both nuclei at low excitation energies at least.

We used as a target a piece of irregular shape of natural gadolinium oxide with mass equal to 360 g (abundance of ^{157}Gd equals to 15.5%). The yield of reaction ^{157}Gd(γ,γ')^{157m}Gd was obtained via registration of gamma-line 245 keV from the decay spectrum of isomer in 50 μs periods delayed by 40 μs after the *X*-ray pulses.

In view of the expected low counting rate and very large cross-sections of reactions ^{155}Gd (*n*,γ) and ^{157}Gd (*n*,γ) for thermal neutrons (in this case the diffusion time constant of neutrons is of the order of 50 μs) much efforts were made to protect the target and the detectors from neutrons flux emerging in some parts of electromagnet of betatron exposed to bremsstrahlung from inner target.

The normalized yield of reaction of photoexcitation (def. see [1]) of ^{157m}Gd turned out to be of the order of 0.2 of the yield of reaction ^{181}Ta (γ,γ') ^{181m}Ta with large uncertainty up to factor of three.

The experiment on photoexcitation of ^{157m}Gd is novel. In future we'll likely fulfil it within some energy range of the bremsstrahlung endpoint energy with the more fitted gadolinium target.

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IZOMERIC YIELD RATIOS AND CROSS SECTION RATIOS OF THE (γ,n) REACTION ON ^{85,87}Rb

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In the present work results of investigation of the isomeric yield ratios Y_m/Y_g and cross-section ratios σ_m/σ_g of the photoproton reactions ^{85}Rb(γ,n)^{84m,g}Rb and ^{87}Rb(γ,n)^{86m,g}Rb in the energy range of 13÷35 MeV with energy step of 1 MeV are presented.

The isomeric yield ratios were measured by the induced radioactivity method. Samples of natural Rb have been irradiated in the bremsstrahlung beam of the betatron SB-50. The induced activities were examined by detecting and analyzing γ-rays with help of a 63 cm^3 Ge(Li) semiconductor spectrometer equipped with a 4096 channel pulse height analyzer. The counting system had a resolution of ~3,5 keV for the 1332 keV γ-line of ^{60}Co.

The yields of the metastable state decays were evaluated by using the 216,2 keV (^{84m}Rb, J^{π}=6$^+$, $T_{1/2}$=20,5 m) and 555,6 keV(^{86m}Rb, J^{π}=6$^-$, $T_{1/2}$=1,02 m) γ-rays. The yields of the ground state decays were evaluated by using the 881,6 keV(^{84g}Rb, J^{π}=2$^-$, $T_{1/2}$=32,9 d) and 1078,8 keV(^{86g}Rb, J^{π}=2$^-$, $T_{1/2}$=18,6 d) γ-rays .

The results of calculation are given in the table below(22÷25 MeV).

$E_{\gamma max}$, MeV	Y_m/Y_g	
	Target nucleus, J^{π}	
	^{85}Rb, 5/2$^+$	^{87}Rb, 3/2$^+$
22	0,33(1)	0,084(4)
23	0,32(1)	0,092(4)
24	0,33(1)	0,086(4)
25	0,33(1)	0,087(4)

For the ^{85}Rb the results are in good agreement with the date of ref.[1]. The isomeric yield ratios of the reaction (γ,n) on ^{87}Rb are obtained at first.

The results are compared with the calculations made in the statistical Fermi-gas theory. The experimental results are in agreement with the calculated ratios for values of spin cut-off parameter σ between 2 and 3.

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TIME SCALE OF THE THERMAL MULTIFRAGMENTATION IN *p*+Au COLLISIONS AT RELATIVISTIC ENERGIES

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The relative angle correlation of intermediate mass fragments has been studied for *p*+Au collisions at 3.6 and 8.1 GeV. Strong suppression at small angles is observed caused by IMF-IMF Coulomb repulsion. Experimental correlation function is compared to that obtained by the multi-body Coulomb trajectory calculations with the various decay time of fragmenting system. The combined model including the empirically modified intranuclear cascade followed by statistical multifragmentation was used to generate starting conditions for these calculations. The model dependence of the results obtained has been carefully checked. Model analysis of the data made with two characteristic volumes of the system in this process [1]. The first one, $V_t=3\cdot V_o$, corresponds to the "transition state" on the top of fragmentation barrier, at which pre-fragments are actually formed but still interact by nuclear force. The second one, $V_f=5\cdot V_o$, is the freeze-out volume filled by well separated fragments. In the terms of ordinary fission, it corresponds to the multi-scission point. The mean decay time of fragmenting system is smaller than the Coulomb interaction time [2] $\tau_c \approx 10^{-21}$ s (300 - 400 fm/*c*), and that is in accordance with scenario of the "simultaneous" multi-body decay of a hot and expanded nuclear system.

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NEUTRON EMISSION FROM DINUCLEAR SYSTEM

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Using the statistical approach, we study the dependences of de-exitation of dinuclear systems [1] formed in heavy-ion reactions on the isotopic configurations of the entrance channel. Different ways of taking into account the distribution of the excitation energy between two fragments are considered.

We estimate neutron emission from DNS cross sections in $^{62-73}$Ni+^{208}Pb reactions and propose an experiment for the observation of this process.

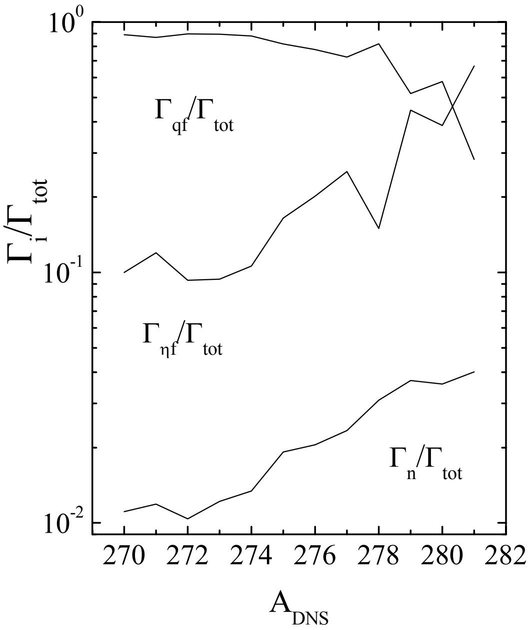

Fig. 1. The dependences of contributions of different de-excitation channels (neutron emission, quasifission and decay in mass asymmetry coordinate) on mass number of dinuclear systems formed in $^{62-73}$Ni+^{208}Pb reactions.

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ON THE DIAGRAM OF THE "SQUARE WITH A DIAGONAL" TYPE FOR NUCLEAR PROCESSES

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Investigation of singular points of Feynman diagrams for nuclear processes allows one to obtain important information on characteristics of that processes. In paper [1], the analysis was performed of singularities of triangle diagrams (as well as of generalized triangle diagrams containing inner loops) contributing to the form factor for the vertex of the virtual decay $a \rightarrow b+c$. This analysis resulted in establishing the existence of the `anomalous` asymptotics of the wave function of the nucleus a in the $b+c$ channel. This asymptotics differs markedly from the usually adopted asymptotics determined by the binding energy of the a nucleus in the $b+c$ channel. In paper [2], information on the positions of singularities of the simplest Feynman diagrams, along with the equations of the inverse scattering problem, was used to construct effective local potentials describing interactions between the lightest nuclei.

In the given work, the singularities of a more complicated diagram of the "square with a diagonal" type is investigated using the method of paper [3]. The positions of the singularities of the various diagrams of that type are calculated for the partial amplitudes of elastic scattering and transfer reactions in the collisions $d + t$, $d + {}^6\mathrm{Li}$ and ${}^6\mathrm{Li} + {}^7\mathrm{Li}$. In the cases when the diagram can be described as a sequence of processes occurring in a three-body system, the results coincide with those obtained using the approach of paper [4]. The calculated singularities are compared with the singularities of the simpler pole and triangle diagrams. Some general formulas are obtained relating positions of singularities of diagrams of different types. The singularities of the diagram of the "square with a diagonal" type are considered also for the form factor of the virtual two-fragment decay of a nucleus, which determines the asymptotic form of the corresponding wave function.

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CORRELATIONS BETWEEN LOW-ENERGY PARAMETERS OF *Nd* AND *Nα* SCATTERING AND VERTEX CONSTANTS OF VIRTUAL DISSOCIATION (SYNTHESIS) OF ^{2}H AND ^{4}He NUCLEI

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Recently the new analytic approach to constructing operators of effective interactions in nuclear reaction theory has been proposed [1]. In this approach, effective local potentials are constructed on basis of the information on discontinuities of partial-wave amplitudes on dynamical cuts. In many processes of scattering off the lightest nuclei, discontinuities of partial-wave amplitudes on dynamical cuts, which are the nearest to the physical region, are determined by the vertex constants (VC) of the virtual dissociation of these nuclei. For example, in *Nd* and *Nα* scattering these cuts are determined by the VC's $^4\mathrm{He}\leftrightarrow T+N$ ($G_{\alpha TN}$) and $d\leftrightarrow p+n$ (G_{dpn}), T denoting ^{3}H or ^{3}He. Note that the VC G_{abc} for the $a\leftrightarrow b+c$ process is proportional to the asymptotic normalization coefficient (ANC) c_{abc} of the a nucleus wave function in the $b+c$ channel [2]. Nowadays VC's and ANC's are widely used in analyses of nuclear reactions, in particular, of the astrophysical nuclear reactions (see, e.g., [3]). The approach suggested predicts strong correlations between the low-energy scattering characteristics (scattering lengths, effective radii) and the quantities determining the nearest to the physical region dynamical cuts. These correlations result from the analytic structure of partial-wave scattering amplitudes and are model-independent. In the present work, the correlations between the VC's G_{dpn} and $G_{\alpha TN}$ and the low-energy parameters in the S wave quartet *Nd* scattering and the S wave *Nα* scattering are investigated. When calculating the discontinuities of the partial-wave amplitudes of *pd*- and *pα*-scattering, the Coulomb effects in two- and three-particle states as well as in the vertex functions are taken into account. Using the data on *Nα* scattering, the information on the $G_{\alpha TN}$ has been obtained. It should be stressed that the known values of the VC $G_{\alpha TN}$ and of the corresponding ANC $c_{\alpha TN}$ are characterized by the wide dispersion [2,4] and therefore the accurate determination of these quantities is the burning problem.

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HIGH-ENERGY APPROACH FOR HEAVY-ION SCATTERING WITH EXCITATIONS OF NUCLEAR COLLECTIVE STATES

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We study effect of the multistep excitation of rotational nuclear states on the heavy ion scattering from nuclei at energies about a hundred MeV/nucleon. The phenomenological spherical optical potential originally fitted in elastic channel is generalized to include the Coulomb and nuclear interactions caused by the rotational degrees of freedom of a target-nucleus. In the high-energy approach (see e.g. [1]), the analytic expressions for elastic and inelastic scattering amplitudes are obtained where the all orders of their expansions in the deformation parameters are taken into account. Calculations of the respective differential cross-sections for the ^{17}O ions scattered on different nuclei are made and compared with the experimental data from [2]. The effects of the real and virtual internuclear multistep transitions are estimated and analyzed.

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FIRST OBSERVATION OF NUCLEAR RAINBOW SCATTERING IN $^{16}O + ^{40}Ca$ SYSTEM

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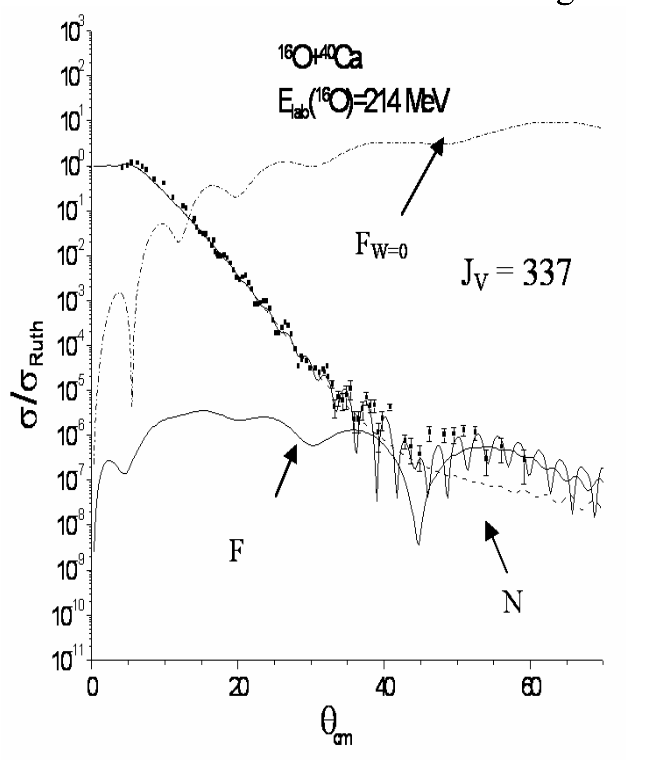
The differential cross-section of the $^{16}O + ^{40}Ca$ elastic scattering was measured at the ^{16}O energy 214 MeV. The aim of the work was searching for the signatures of rainbow scattering in such heavy projectile-target (P-T) combination. As nuclear rainbow phenomenon corresponds to deep interpenetration of the colliding nuclei it is expected that the region of nucleon densities overlap must contain significantly more nucleons in comparison with the systems studied before (the heaviest P-T system for which rainbow patterns were observed until now was $^{16}O + ^{16}O$). Consequently, this would provide some important new information on the dynamics of nucleus-nucleus interaction at small distances and properties of nuclear matter. Several attempts to identify nuclear rainbow scattering in $^{16}O + ^{40}Ca$ were unsuccessful due to extremely strong absorption resulted in domination of diffraction scattering.

The experiment was done at Jyvaskyla cyclotron with the use of Large Scattering Chamber. Two types of detector systems were employed in different angular ranges: $\Delta E - E$ telescopes and kinematical coincidence method. The angular distribution was measured up to 60° cm, and the cross-section level of 10^{-4} – 10^{-5} mb/sr was reached. Though the data demonstrate huge diffraction scattering coming from the interference of near (*N*) and far (*F*) components of the differential cross-section there are some definite indications of the presence of nuclear scattering:



* quite definite change of slope at $\theta > 40°$;
* the existence of a minimum (at 45°), which is repeated by *F*-component;
*predominance of the latter at larger angles;
* the existence of a minimum in *F* – component with the turned-off absorption ($F_{W=0}$) at the same angle.

The preliminary analysis shows that 45^o- minimum is a supernumerary one (probably, of 2^{nd} or 3^d order). It corresponds to the distance of closest approach ~ 3 fm. The volume integrals of the real part of potential lie in the range 290 – 340 MeV*fm^3 in agreement with the existing systematics and normal values of the effective nucleon-nucleon interaction.

$^{12}C+^{12}C$ SYSTEM AT LOW ENEGIES

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The fusion of the $^{12}C+^{12}C$ system at very low energies is important to understand the carbon burning nucleosynthesis that occurs for massive stars in the late stages of stellar evolution (the most recent experimental data at $E_{c.m.}$ = 4.475 - 6.5 MeV was obtained in ININ, Mexico [1]). The fusion cross section at very low energies of astrophysical interest, ~ $E_{c.m.}$ = 1 MeV (this limit is not achieved at the present time), is estimated approximately by 10^{-10} mb. The most prominent feature of the fusion and the elastic scattering excitation functions for the $^{12}C+^{12}C$ system at energies above and below the Coulomb barrier is a structure of some 0.2 to 1.5 MeV width, which is associated with quasimolecular doorway states.

Our theoretical analysis showed that the strong energy dependent structure of the fusion excitation function for the $^{12}C+^{12}C$ system within the energy region $E_{c.m}$ = 1.5 -9. MeV can be successfully reproduced in the framework of the optical model with variable geometry and an energy dependent imaginary strength *W(E)* (Fig.1). The astrophysical *S*-factor obtained from the fusion experimental data also is reproduced successfully.

The developed phenomenological optical potential allowed us to reproduce individual elastic angular distributions and the main features of the 90^o elastic-scattering excitation function in the energy region $E_{c.m}$ = 3 - 37.5 MeV.

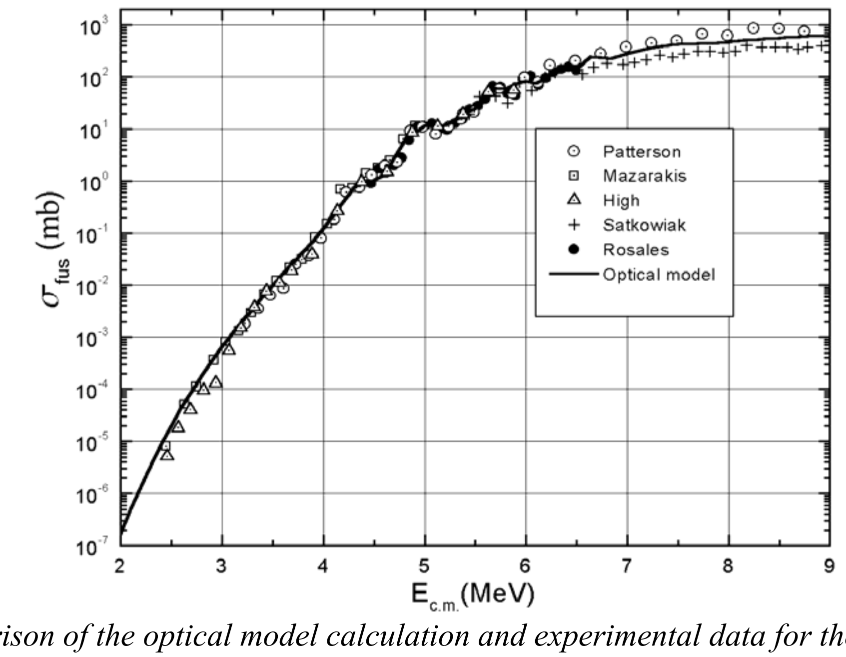

Fig.1. Comparison of the optical model calculation and experimental data for the $^{12}C+^{12}C$ fusion excitation function.

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MICROSCOPIC OPTICAL POTENTIALS AND THE HIGH-ENERGY APPROACH FOR THE NUCLEUS-NUCLEUS SCATTERING

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The brief review is presented which includes results of the microscopic calculations of the real and imaginary parts of nucleus-nucleus potentials where the realistic Fermi type nuclear density distributions are used [1,2]. Then, in the high-energy approach (see e.g. [3]), these potentials are used to calculate the differential elastic [1,2] and total reaction cross sections [4,5]. Effects of the nuclear medium and the trajectory distortion of colliding nuclei on cross sections are estimated. Besides, the effect is considered of the internal collective structure of nuclei on mechanisms of their elastic and inelastic scattering. Comparisons with experimental data [6-8] are made and the fitting method based on constructing the co-called semi-microscopic potentials are discussed.

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NON-CLASSICAL FEATURES OF ^{50}Cr PROTON STRUCTURE

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One-nucleon occupation probabilities N_{nlj} as well as single-particle energies $-E_{nlj}$ of the proton subshells in nuclei of ^{50,52}Cr were determined using the method [1] of putting one-nucleon pick-up and stripping experiments data in accordance to each other. The results are presented in a Table. Uncertainties within the brackets take into account both statistical uncertainties of the relative spectroscopic factors and uncertainties of some states of the final nuclei.

One-nucleon occupation probabilities N_{nlj} and single-particle energies $-E_{nlj}$ of the proton subshells in nuclei of ^{50,52} Cr.

n,l,j	^{50}Cr				^{52}Cr	
	N_{nlj}	$-E_{nlj}$	N_{nlj}	$-E_{nlj}$	N_{nlj}	$-E_{nlj}$
$1f_{5/2}$	-	-	0.22(2)	4.46(44)	0	< 0.36
$2p_{1/2}$	-	-	-	-	0	< 1.65
$2p_{3/2}$	0.05(2)	2.02(23)	0.03(2)	2.11(21)	0.17(3)	3.47(42)
$1f_{7/2}$	0.39(6)	6.29(77)	0.35(4)	6.07(61)	0.50(9)	7.51(116)
$1d_{3/2}$	0.98(2)	11.22(128)	0.99(1)	11.42(142)	0.96(3)	13.16(136)
$1s_{1/2}$	0.94(3)	11.17(115)	0.94(3)	11.16(116)	-	-

The results obtained were analyzed in the frame of the dispersive optical model (DOM) [2], and dispersive optical potentials sets determined allow achieve good agreement of $-E_{nlj}^{exp}$ and $-E_{nlj}^{DOM}$ values.

Two kinds of the results were obtained for ^{50}Cr. They differ by various assumptions for the final states spin values that are unknown. For the first kind, the sum value of the pick-up and stripping spectroscopic factors is insufficient to determine N_{nlj} and $-E_{nlj}$ for $1f_{5/2}$ proton subshell. In the second, the final states spin value assumptions allow to do that, and very interesting results were obtained - N_{nlj} = 0.22(2), $-E_{nlj}$ = 4.46(44) MeV for $1f_{5/2}$ proton orbital. This orbital is populated following the $1f_{7/2}$ orbital: the positions of $1f_{5/2}$ and *2p3/2* orbitals are inverted in comparison of traditional shell-model predictions. This inversion of proton orbitals in ^{50}Cr explains well-known ^{51}Mn ground state spin-parity values $J^{\pi} = 5/2^{-}$.

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^{84,86,88}Sr NEUTRON SUBSHELLS: NON-PURE MAGICITY OF ^{88}Sr

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Determination of both one-nucleon occupation probabilities N_{nlj} and single-particle energies $-E_{nlj}$ of the neutron subshells in the stable even-even isotopes of $^{84,86,88}{}_{38}$Sr is very important for testing different nuclear structure models. In $^{88}{}_{38}Sr_{50}$ the closure of the $1g_{9/2}$ orbital corresponds to the magic number $N = 50$. So, it is interesting to study the filling of the neutron subshells in Sr isotopes, because values of N_{nlj}^{exp} allow to evaluate the degree of agreement of these nuclei single-particle structure and predictions of the shell model as well as the Dispersive Optical Model (DOM) [1] developed at last years. The method [2] of putting one-nucleon pick-up and stripping experiments data in accordance to each other was used. Values of N_{nlj}^{exp} and $-E_{nlj}^{exp}$ (in MeV) are presented in Table.

One-nucleon occupation probabilities N_{nlj} and single-particle energies $-E_{nlj}$ of the neutrons subshells in $^{84,86,88}{}_{38}$Sr.

nlj	^{84}Sr		^{86}Sr		^{88}Sr	
	N_{nlj}	$-E_{nlj}$	N_{nlj}	$-E_{nlj}$	N_{nlj}	$-E_{nlj}$
$3s_{1/2}$	-	-	0	< 6.00	0	4.42(44)
$2d_{5/2}$	0	6.87(69)	0	6.35(64)	0.04(2)	5.91(60)
$1g_{9/2}$	0.58(6)	10.50(100)	0.78(8)	10.83(110)	0.97(3)	11.18(132)
$2p_{1/2}$	0.72(7)	11.09(110)	0.90(5)	11.80(120)	0.98(1)	12.80(130)
$2p_{3/2}$	0.85(8)	12.18(122)	-	-	1	14.29(143)
$1f_{5/2}$	1	12.61(126)	-	-	1	14.52(145)

The results obtained can be described in the frame of DOM.

The typical for magic nuclei increasing of the energy gap is seen – in this case between $1g_{9/2}$ and $2d_{5/2}$ orbitals. As a rule, the last close subshell in magic nucleus is characterized by one-nucleon occupation probability value of $N_{nlj} = 1.00$, and for the higher subshells $N_{nlj} = 0.00$. Very interesting feature of $^{88}{}_{38}Sr_{50}$ is that noticeable quantity of neutrons (~ 0.2 - 0.3) is placed on $2d_{5/2}$ subshell in spite of quite considerable gap.

Research was supported by the President of Russia grant N SS-1619.2003.2.

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GLOBAL HARTREE-FOCK COMPONENT OF NUCLEON DISPERSIVE OPTICAL POTENTIAL FOR NUCLEI WITH 40 < *A* < 208 AT –65 < *E* < 65 MEV

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Dispersive optical potential (DOP) is successfully used to describe single-particle features of the nucleon bound states in nuclei. Global parameters of the Hartree-Fock component of the DOP has been presented in the previous paper [1] for the spherical and near-spherical nuclei with 40 < *A* < 208 at –65 < *E* < 65 MeV. The results were obtained by the dispersive optical model analysis of the single-particle energies of the neutron and proton bound states E_{nlj} in ^{40}Ca, ^{90}Zr, and ^{208}Pb. The Hartree-Fock component was expressed by Woods-Saxon shape with the strength parameter which depended on *A*, *(N - Z)/A*, and *E*. Energy dependence was chosen of exponential form. The geometrical parameters were unique for all the nuclei.

In the present work new data on the single-particle energies $-E_{nlj}$ of the neutron and proton bound states near the Fermi energy for the systems *n,p* + ^{92,94,96}Zr,^{58,60,62,64}Ni were additionally included into the data base for the dispersive optical model analysis. The energy values $-E_{nlj}$ were determined by the joint evaluation of the nucleon stripping and pick-up reaction data for the same nucleus. Global parameters of imaginary part of the most modern traditional optical potential [2] were used to calculate the dispersive component of DOP. As a result, an updated set of the global parameters of the Hartee-Fock component was obtained. With the updated set, the better description of the available single particle energies of the bound nucleon states was achieved.

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DEUTERON SIZE AND NUCLEAR POTENTIAL DEPENDENCE OF CROSS SECTIONS FOR DEUTERON-NUCLEUS DIFFRACTION INTERACTION PROCESSES

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In many works the diffraction interaction of deuterons and other weekly bound systems with nuclei was studied in a three-body model with optical potentials acting between projectile constituents and a target, the eikonal and adiabatic approximations being used (see e.g. [1]). On the basis of this approach the diffraction theory of deuteron (or two-body halo nucleus) scattering was improved recently by taking into account both noneikonal and nonadiabatic effects [2]. The use of a strong absorption condition and small diffuseness of a nuclear surface gives the unique possibility to perform analytic calculations of cross sections for deuteron induced reactions and thus to reveal their dependence on theory parameters in a wide range of energies [2, 3].

In the present work made in the framework of the potential three-body model we obtained analytic expressions for integrated cross sections for stripping reactions σ_p, σ_n, diffraction dissociation σ_d, and deuteron absorption σ_a. These expressions include a linear dependence on geometrical characteristics of the deuteron, in particular on the mean distance between nucleons $\langle r\rangle$ and mean value $\langle 1/r\rangle$ calculated with Hulthen's wave function. They include also a linear and quadratic dependence on the diffuseness parameter of a nucleon-nucleus potential of Woods-Saxon type and on the strong absorption radius which is determined easily through the imaginary strength and geometrical parameters of this potential. It can be seen from our results that a potential diffuseness leads to the substantial decrease of the cross section for deuteron diffraction dissociation. The total noneikonal and nonadiabatic correction to $\sigma_r=\sigma_p+\sigma_n+\sigma_a$ is proportional to the ratio of real to imaginary strength parameter and is positive for an attractive nuclear potential. Corresponding correction caused by Coulomb interaction is negative. Numerical calculations made at some energies demonstrate an applicability of our formulae for analysis of deuteron induced reactions.

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METHOD OF CALCULATION OF TWO PROTON DECAY CHARACTERISTICS WITH TAKING INTO ACCOUNT STRONG CHANNEL COUPLING

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The partial width amplitude for the favored deep subthreshold two proton decay of the nucleus with taking into account three-body kinematics is presented as [1] $\sqrt{\Gamma_\alpha} = \sum_\beta e^{i\delta_\beta} N_{\alpha\beta} \sqrt{\Gamma_\beta}$, where $N_{\alpha\beta}$ is the real unitary matrix, which reduces *S*-matrix of the potential scattering of two proton decay products to the diagonal form with δ_β phase [2],

$$\sqrt{\Gamma_\beta} = \sqrt{2\pi} \sum_{\alpha'} \left\langle \frac{U_{\alpha'}^{JM} f_{\alpha'\beta}(\rho)}{\rho^{5/2}} \right| V \left| \varphi(\rho,\varepsilon) \right\rangle, \tag{1}$$

at that U_α^{JM} is channel function with channel index $\alpha \equiv l\lambda$, which includes spin and orbital functions of protons and normalized Yakobi polynomial $\tilde{P}_{\lambda l}(\varepsilon)$:

$$U_\alpha^{JM} = \left\{ Y_{lm}(\Omega_{\mathbf{R}}) Y_{l-m}(\Omega_{\mathbf{r}}) \right\}_{00} \tilde{P}_{\lambda l}(\varepsilon) \left\{ \Psi_{1/2m_1}(\mathbf{y}_1) \Psi_{1/2m_2}(\mathbf{y}_2) \right\}_{00}, \tag{2}$$

and $\varphi(\rho,\varepsilon) \equiv \left\langle \Psi_i^{JM} \middle\| \Psi_f^{JM} \right\rangle$ is finite form-factor, describing the behavior of two flying out protons in internal shell region of parent nucleus with taking into account the superfluid correlations, Ψ_i^{JM} and Ψ_f^{JM} are wave functions of the parent and daughter nuclei respectively. Real form-factors $f_{\alpha\beta}(\rho)$ describing elastic scattering of decay products are determined by the solution of the system of equations coupled by matrix elements $V_{\alpha\alpha'} \equiv \left\langle U_\alpha^{JM} \middle| V \middle| U_{\alpha'}^{JM} \right\rangle$ of the effective potential V of two proton and daughter nucleus interaction without taking into account nuclear potentials between two proton and daughter nucleus. In order to find the solution of this system the method based on the use of the basis functions defined in internal and external regions of the elastic scattering problem has been suggested. The analysis of matrix elements $V_{\alpha\alpha'}$ structure with taking into account the symmetry of potential V demonstrates sufficiently fast convergence of mentioned method under the enlargement of channel function basis. Application of form-factors $\varphi(\rho,\varepsilon)$ allows to achieve the quick convergence of used method of calculation of partial width amplitudes $\sqrt{\Gamma_\alpha}$ and angular and energy distributions for two protons determined by $\sqrt{\Gamma_\alpha}$. The proposed method has higher stability than the method [3] based on the procedure of sewing for the internal and external components of fissile nucleus wave function in configuration space (ρ,ε).

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ABOUT DISSOCIATION OF DEUTERON IN THE FIELD OF NUCLEUS

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In the work [1]*) the general formula for the differential cross section $d\sigma / d\Omega_p d\Omega_n dE_p$ of dissociation in the Coulomb field of the nucleus of an incident deuteron of arbitrary energy is obtained. Since the formula contains three-dimensional integral on products of degenerate hypergeometric functions of composite arguments, in [1], the authors restricted themselves to examination of process only at small energies E_d, when the Coulomb parameters $n_d = Ze^2 / \hbar v_d$ and $n_p = Ze^2 / \hbar v_p$ are considerably exceed 1. Independently in [2] with the usage of a perturbation theory the same process is investigated, but at high energies, when $n_d << 1$.

In the present work, the precise calculations of the cross section are carried out [1] on the computer for the process $^{12}C(d, pn)^{12}C$ at different energies E_d (including, when $n_d \sim 1$) and angles of emission of nucleons θ_p and θ_n and, in particular, at 56 MeV ($n_d \approx 0.2$) and $\theta_p = \theta_n = 0^0$. At such energy E_d and zero angles of emission of nucleons the experiment was earlier carried out [3], which is well described in the work [4] with the usage of the diffraction approach both on the shape of energy distribution of emitted protons E_p and the magnitude of the cross section. The present precise calculation has confirmed occurrence in [4] of a minimum at $E_p = \frac{1}{2}(E_d - \varepsilon)$, where ε – the binding energy of a deuteron, and two adjacent maxima in the distribution, but height of maxima has appeared more than 3 times overstated, than in [3, 4], as it should be, since here , as well as in [1], the nuclear interaction (absorbtion) was not regarded, but which was taken into account in [4] alongside with the Coulomb interaction and their interference.

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*) We note, that the factor of 2 is missing in the cross section in [1]

MICROSCOPIC THEORY OF WINDOW-LIKE FRICTION

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The window formula for dissipation rate $\dot{Q}$ proposed by Randrup and Swiatecki [1] is based on the two assumptions: 1) sharp change of mass flow while crossing the window and 2) complete randomization of nucleon trajectories. In this work we construct the microscopic theory of window-like dissipation, free of these limitations. The key expression for calculationg the window-like dissipation rate $\dot{Q}^{(u)}$ is given by

$$\dot{Q}^{(u)} = -\int_0^\infty dt(1-\Gamma t)e^{-\Gamma t}\int \frac{d\vec{r}d\vec{p}}{(2\pi)^3} F^{(u)}(\vec{r}_t,\vec{p}_t)F^{(u)}(\vec{r},\vec{p})\frac{\partial f(H)}{\partial H}, \tag{1}$$

$$F^{(u)}(\vec{r},\vec{p}) = \sum_{\alpha,\beta} m^{-1}p^\alpha p^\beta \frac{\partial u^\alpha(\vec{r})}{\partial r^\beta}. \tag{2}$$

Here $\vec{r}$, $\vec{p}$ are the coordinate and momentum of the particle, Γ is the nucleon-nucleon collision rate, $f(H)=1/(1+\exp((H-\mu)/T)$ is the Fermi-gas occupation probability of particle state with energy $H=p^2/2m+V(\vec{r})$, $\vec{u}(\vec{r})$ denotes the mass flow at point $\vec{r}$ differing from zero due to collective motion. The phase space point $(\vec{r}_t,\vec{p}_t)$ is the solution of Hamilton's equations with the Hamiltonian H, satisfying the initial condition $(\vec{r}_0,\vec{p}_0)=(\vec{r},\vec{p})$.

The upper script u in $\dot{Q}^{(u)}$ and $F^{(u)}$ is to indicate that we deal with that type of dissipation, which accompanies relaxation of spatial inhomogeneities of the mass flow $\vec{u}(\vec{r})$. For proving eqs. (1), (2) we assume that $u \ll m^{-1}p$ and use Zubarev's non equilibrium statistical operator technique to calculate the entropy rate. Elementary derivation of eqs. (1), (2) may be obtained by calculating linear response of the system to perturbation of H equal $\vec{p}\vec{u}(\vec{r})$.

Adopting the Randrup-Swiatecki anzats for $\vec{u}$ and reducing the time integral in (1) to the moments of first collision of the particle with the boundary, we recover from (1), (2) their window formula. The Monte Carlo calculations of $\dot{Q}^{(u)}$, eq.(1), that we performed for Cassini shapes, using the Werner-Wheeler flow for $\vec{u}$, in the range of the mean free path $\lambda = (m\mu/2)^{1/2}\Gamma^{-1} = 20 \div 50$ fm, show significant deviations of microscopic friction coefficients from the window formula of Randrup and Swiatecki.

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DEPENDENCE OF ISOMER RATIOS ON PARAMETERS OF NUCLEAR MODELS

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The investigation of independent yield of isomer states with different spin (isomer ratio, σ_m/σ_g) in evaporation residues of reaction products is one of the most simple and rather reliable method to deduce information on spin distribution *P(I)* and on value of mean angular momenta $\langle I \rangle$. It is necessary to fix many characteristics of nuclear structure and decay (densities of nuclear levels, shape of radiative strength functions, peculiarities of gamma de-excitation of nuclear low-lying levels, and so on) for correct calculations of isomer ratios.

In this work the simple approaches for calculations of isomer ratios are tested. An effect of the model simplifications on the value of isomer ratio is studied. An extension of the nuclear reaction model code Empire II [1] is used for calculation of isomer ratios and to study dependence of results on characteristics of nuclear structure and decay. It shown that some model modifications are needed to obtain reasonable agreement with experimental data [2]. The role of gamma-ray multiplicity and shape of radiative strength function in the low energy region is discussed.

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NON-EVAPORATING MECHANISM OF TERNARY PARTICLES FORMATION AND *T*-ODD ASYMMETRIES IN TERNARY FISSION

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It was shown in the framework of quantum fission theory [1] that *P*-odd, *P*-even and *T*-odd correlations in the angular distributions of fission fragments might exist only in the absence of thermalisation for the fissioning nuclei states (which are excited in the non-adiabatic collective motion of the nucleus) at all the stages ending with the emission of the separated fragments. This gave rise to the idea of the non-evaporative "shake-off" mechanism of the ternary particles emission. The Coriolis interaction V_{Cor} of the ternary particle angular momentum l_3 with the spin J of the rotating fissioning nucleus was shown [2] to be the source of the *T*-odd asymmetries in ternary fission. This interaction was considered in [2] as the perturbation in tthe fission widths' amplitude which caused the transition between the internal (shell-model) and external (cluster) components of the fissioning nucleus wave function.

In the present work we continue studies of *T*-odd asymmetries in ternary fission with the consistent use of the "shake-off" mechanism for the ternary particles formation and emission. In this modified approach the interaction V_{Cor} was considered as a perturbation affecting the wave functions of the ternary particles c.m. motion in the field of the axially-symmetrical fissioning nucleus with considerable octupole deformation caused by the strong charge and mass asymmetry of the fission fragments. This allowed to express the coefficient D_t of *T*-odd asymmetry as a ratio of the Coriolis interaction matrix element (which mixes the "single-particle" cluster excited states of ternary particles with the projections K_3=0 and $K_3 = \pm 1$ of its angular momentum l_3 on the symmetry axis) to the energy difference ΔE of these states. The comparison of D_t with the corresponding experimental value D shows that $\Delta E \approx 0.5$ Mev, in good agreement with the "single-particle" cluster nature of the ternary particle excited states. This excludes the hypothesis of thermal equilibrium and evaporation mechanism of ternary particles emission.

Using the results of [3], we were able to explain the experimentally observed independence of the ternary particle emission angle for the *T*-odd asymmetry *D*. We were also able to explain the experimentally observed increase of $|D|$ with the increase of the ternary particle energy E_3 by the fact that the more compact configurations of fissioning nucleus cause both the increase of E_3 and the increase of the V_{Cor} values.

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MANIFESTATION OF STRUCTURE EFFECTS IN QUASI-FISSION REACTIONS

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Nucleon transfer between the nuclei in a DNS is statistical in nature [1,2], and there is a possibility that the system may reach and overcome the B.G. point, and thus a compound nucleus will be formed. An alternative to that process is the break-up of the system into two fragments (quasi-fission). In order to calculate the probability of proton transfer from one nucleus to another in a di-nuclear system we used an expression from ref. [3] and assumed that the macroscopic nucleon transfer probability P_z can be expressed in terms of the microscopic probability λ_z and the level density ρ_z as $P_z=\lambda_z\ \rho_z$.. The level density can be written using the DNS potential energy. $\rho_z = \rho(E^*)$, where E^* is the excitation energy of the di-nuclear system. Knowing relative $(P^+ + P^- = 1)$ probabilities and using a random value uniformly distributed over the interval between 0 and 1, we randomly chose the direction for the DNS to move: either the direction to a symmetric system or the direction to the compound nucleus. The procedure may be repeated as many times as necessary for obtaining the necessary statistics. Fig.1 presents the calculation of the mass distribution of quasi-fission products in the reaction $^{48}Ca + ^{244}Pu$. From Fig.1 it can be seen, that our model reproduces an enhanced yield of fragments with mass numbers 208 and 132 observed in the experiment. However, the yield of nuclei with closed shells appeared to be rather high in the model. During the DNS evolution to the symmetric form its excitation energy grows substantially. It leads to the weakening of the influence of shells effects and accordingly to decreasing the maxima in the mass spectrum. In reactions of warm synthesis of SHE there are indications for the influence of the nuclear structure of the DNS nuclei on the probability of the system disintegration observed in the mass distribution of quasi-fission products - nuclear fragments with closed shells have

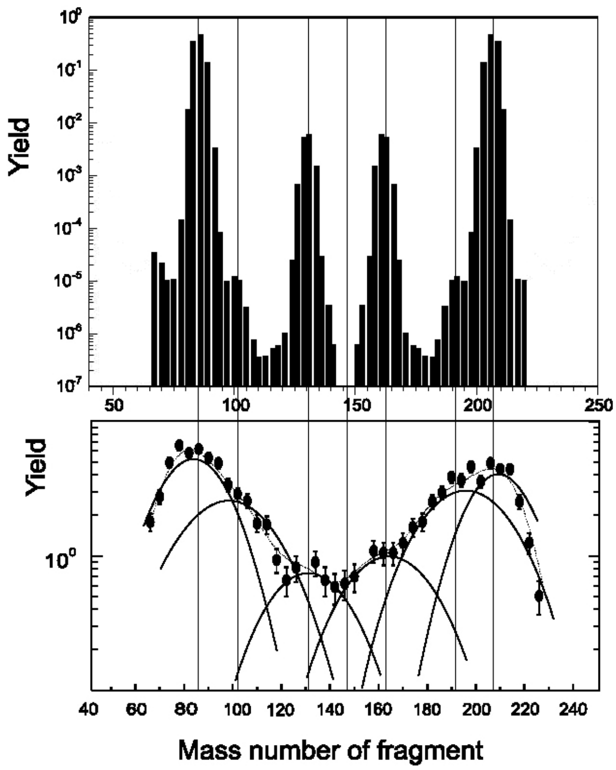

Fig.1. Calculations of the QF mass distribution in the reaction $^{48}Ca+^{244}Pu = ^{292}114$ (upper); the fragment mass distribution for the same reaction measured experimentally (bottom) [4].

the greatest yield. Our model offers a clear and realistic interpretation of the quasi-fission process and occurrence of shell effects in the mass distributions. The model based on this concept allows one to reproduce the shell effects in experimental mass distributions of quasi-fission products.

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DEPENDENCE OF YIELD OF LOW-LYING HIGH- SPIN STATES ON THE PROJECTILE NEUTRON NUMBER AND THE BOMBARDING ENERGY

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At the moment the development of investigations of nuclear isomers is expected in the context of the use of unstable nuclear beams. In the present paper we discuss the probability of low-lying high-spin states production in the reactions with light neutron-rich (halo) projectiles.

The ratio of cross sections of a certain pair of isomeric states (high-spin and low-spin respectively) in one and the same nucleus allows to obtain an information on angular momentum dynamics of a preceding reaction and spin dependence of nuclear level density. This dynamics depends on the properties of a target, projectile and emitted particles. It is important to find out optimal reaction parameters to populate high-spin isomer. In the present work we investigate the dependence of its yield on the projectile neutron number and the bombarding energy.

Measurements of isomeric cross-section ratios (ICSR) in the reactions ^{110}Pd(αp)^{113mg}Ag, ^{108}Pd(^{6}He,p)^{113mg}Ag and ^{106}Pd(^{8}He,p)^{113mg}Ag in the energy range 17-29 MeV were carried out by us earlier using off-beam measurements of induced activity of the isomeric pair [1]. The activation method is a reliable tool for identification of reaction products. Here we present for the first time our results improved through the handling of the activation data with the use of the optimal extraction formula from [2].

Calculations of ICSR for the indicated reactions are performed using the upgraded program EMPIRE-II-19 [3]. This code is based on Hauser-Feshbach version of the statistical theory of nuclear reactions [4]. The field of application of the model is placed over the area of 10 – 50 MeV excitation energy of a compound nucleus, where the widths of resonance are greater than the distances between them.

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POSSIBLE EVIDENCE FOR NONHADRONIC DEGREES OF FREEDOM IN SPECTRA OF KAONS, PRODUCED IN RELATIVISTIC NUCLEUS-NUCLEUS COLLISIONS

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The experimental energy spectra of heavy mesons produced at different energies and different combinations of colliding nuclei were described within the framework of relativistic nuclear fluid dynamics model [1]. In our approach it is possible also to take into account consider the renormalization of kaon mass in accordance with the experimental data [2].

Now the great interest appears caused by manifestation of nonhadronic degrees of freedom, connected with quark-gluon plasma production. In paper [3] it was pointed of the discrepancies between microscopic calculations with UrQMD model and experimental data for kaon spectra. These discrepancies are seen beginning from energy 4 GeV/nucleon for collisions of heavy nuclei Au + Au, Pb + Pb. The experimental temperature is almost two times greater then the calculated one. It may be interpreted as a two-fold decrease of the number of degrees of freedom at the stage of the kaon formation ("freezout" stage). In contrast with UrQMD model and other microscopic approaches one may simplify the calculations and use our macroscopic approach [1,2]. This consideration allows one to reproduce the increase of kaon temperature at energies greater than 4 GeV/nucleon in accordance with the experimental data [4].

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OPTICAL POTENTIALS FROM INVERSION OF THE 1340 MEV ALPHA-PARTICLE SCATTERING DATA

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The data of elastic scattering α-^{12}C, α-^{40}Ca at E_{lab}=1370 MeV are analyzed within model-independent approach. In WKB approximation we construct optical potentials using model-independent complex phase shifts as input data. The details of the inversion procedure can be found in [1]. The method demands of continuation of phase shifts into complex λ-plane. Phase shifts have been expanded by complete set of functions. The coefficients of expansion have been determined from the fit to experimental differential cross section of elastic scattering. It should be noted that at the considered energy WKB approximation is in fact exact method.

For analysis of scattering data at energies of several hundred MeV/*N*, the Glauber model, optical limit of the model and so-called t_{cc} approximation are widely used. They provide simple connection between densities of colliding nuclei and total reaction cross section which is often an only available observable quantity at high colliding energy.

Model free analysis can serve as the test of the optical limit and t_{cc} approximation. Also we compare real parts of found potentials with double folded potentials calculated with *t*-matrix parametrization of free *NN* interaction.

The calculations show that t_{cc} limit is a rather poor approximation in the considered cases. Constructed potentials are also different from folded potentials even at radii close to strong absorption radius. It indicates that the medium modification of *NN* interaction must be important at considered energy.

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POLARIZATION OF SCATTERED NUCLEONS IN STOCHASTIC DIFFRACTION NUCLEAR MODEL

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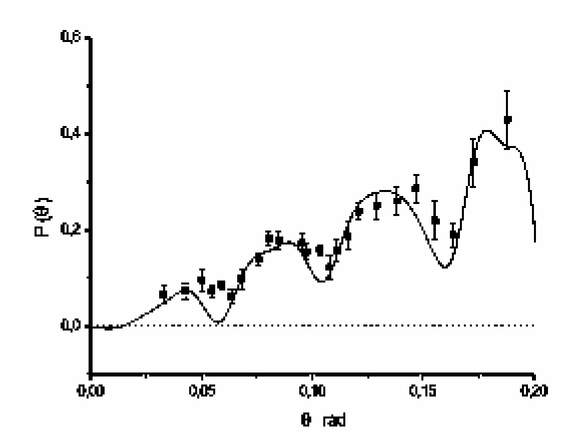
The amplitude [1] $f = (f_C + f_L + f_{L_S}) + (\vec{\sigma}\,\vec{n}) f_{L_\sigma}$ (where f_L is related to full nucleons absorption domain and f_{L_S}, f_{L_σ} – to surface spherical layer of the nucleus, where spin-orbit inte-raction exists) describes the elastic diffraction scattering of nucleons by non-diffuse surface nuclei.



The nuclear parts of the amplitude for calculating of differential cross-section σ and polarization $\vec{P}$ are being avera-ged on corresponding partial wave angular momentum inter-vals of uncertainty. Let us define dispersion DZ of complex-valued stochastic function of real argument $Z(\tau)$ as mathematical expectation of function $\left|Z(\tau) - \langle Z(\tau)\rangle\right|^2$. Then expression for polarization is the following

$$\left\langle \vec{P}(\vartheta)\right\rangle_{L,L_S} = \vec{n}\,2\,\mathrm{Re}\left[\left\langle f_C(\vartheta) + f_L(\vartheta) + f_{L_S}(\vartheta)\right\rangle_{L,L_S} \left\langle f_{L_\sigma}(\vartheta)\right\rangle^*_{L_S}\right] \Big/ \left\langle \sigma(\vartheta)\right\rangle_{L,L_S},$$

where

$$\left\langle \sigma(\vartheta)\right\rangle_{L,L_S} = \left|\left\langle f_C(\vartheta) + f_L(\vartheta) + f_{L_S}(\vartheta)\right\rangle_{L,L_S}\right|^2 + \left|\left\langle f_{L_\sigma}(\vartheta)\right\rangle_{L_S}\right|^2 +$$
$$+ Df_L(\vartheta) + Df_{L_S}(\vartheta) + Df_{L_\sigma}(\vartheta).$$

The typical result of the calculation and comparison with the experiment [2] corresponds to proton scattering with energy 1 GeV by nucleus ^{208}Pb is shown on figure.

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RESONANCE STATES OF COMPOUND SUPERHEAVY NUCLEUS AND EPPP IN HEAVY NUCLEI COLLISIONS: ENERGY APPROACH

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A great interest to this topic has been, in particular, stimulated by inaugurating the heavy-ion synchrotron storage cooler ring combination SIS/ESR at GSI. It is known a discovery (ORANGE & EPOS collabor.) of the existence of a narrow and unexpected e+ line in the positron spectra, obtained from heavy ions collisions near the Coulomb barrier. Here a consistent unified energy approach, based on QED, is developed and applied for studying the electron- positron pair production (EPPP) process in the heavy nuclei (ions) collisional problem [1,2]. Resonance phenomena in the nuclear system lead to the structurization of the positron spectrum produced. The variation of parameters of the inter-nuclear potential within the reasonable limits leads to changes of the positron spectra. All the spontaneous decay or the new particle (particles) production processes are excluded in the zeroth order. Upon collisions of atomic ions or nuclei with energy E>1 MeV the EPPP is allowed. To calculate the EPPP cross-section, a modified versions of the QED energy approach, based on the S-matrix Gell-Mann and Low formalism, is used [1]. The calculation is carried out for the cases of U-U and U-Ta collisions. The calculation with two-pocket potential leads to principally the same physical picture as a calculation with one-pocket potential, besides the appearance of some new peaks [2]. In fig. 1 calculation results for the differential cross-section $d\sigma$ (es,E_1)/des (plotted against $e(1s)$ - es, in B/MeV$^{)}$ for the nuclear subsystem collision energies E_1: (a) E_1 = 162.0 keV (3rd s-resonance), (b) E_1 = 247.6 keV (the 4th s-resonance), are presented.

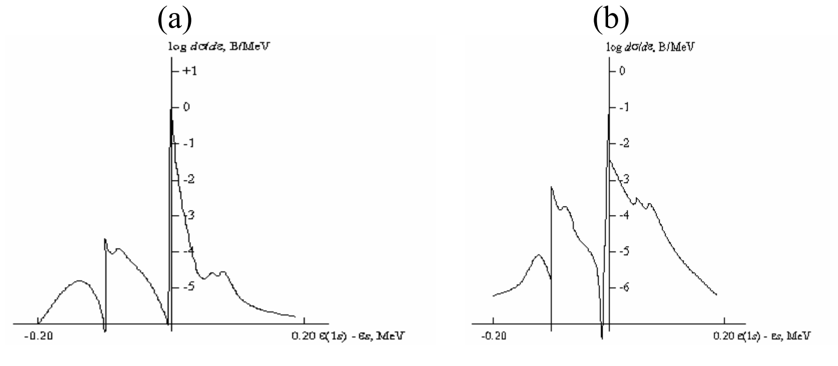

Fig.1.The differential cross-section $d\sigma(\varepsilon s, E_1)/d\varepsilon s$ plotted against $\varepsilon(1s)$-εs (in B MeV^{-1}) for the nuclear subsystem collision energies: (a) E_1 = 162.0 keV; (b) E_1 = 247.6 keV.

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SOME NEW PUZZLES OF $^{12}C + ^{12}C$ SCATTERING

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The $^{12}C + ^{12}C$ excitation function attracted much attention in the 60 – 70^{ties}. The low energies narrow resonances were attributed to formation of quasimolecular states. The broad resonances at E_{cm} > 30 MeV could not find explanation for a long time, and finally were identified as the rainbow structures. It was claimed that the scattering characteristics (positions of Airy minima Θ_{min}, the values of real volume integrals J_V) were determined unambiguously (see, e.g., [1]). However, we analyzed the scattering of the neighbor projectile – target combinations $^{16}O + ^{16}O$ [2] and $^{16}O + ^{12}C$ [3] and showed that the energy dependences $\Theta_{min} - 1/E_{cm}$ for $^{12}C + ^{12}C$ system differ from those of the two other ones stronger than it was possible to expect from rainbow systematics. This analysis led us to the conclusion that $^{12}C + ^{12}C$ real potential could be deeper than it was thought before (it is worth to mention that some authors [4] proposed originally the values $J_V \sim 450$ MeV*fm^3 at E_{cm} = 5 MeV but later adopted more convenient from theoretical point of view $J_V \sim 350$ MeV*fm^3.

Permissibility of our suggestion is supported by the fact that there exist no measurements of $^{12}C + ^{12}C$ scattering cross-section extended to large enough angles. The situation is illustrated by Fig.1. The experimental data [5] in the limited angular range are reproduced equally well with potentials with J_V = 283 (curve 'b') and J_V = 344 (curve 'c'). The deeper potential 'c' predicts an additional rainbow minimum at $\Theta_{min} \sim 60^o$, which would be the main one.

If $^{12}C + ^{12}C$ potential really occur deeper this would strongly influence current understanding of nucleus – nucleus interaction mechanism.

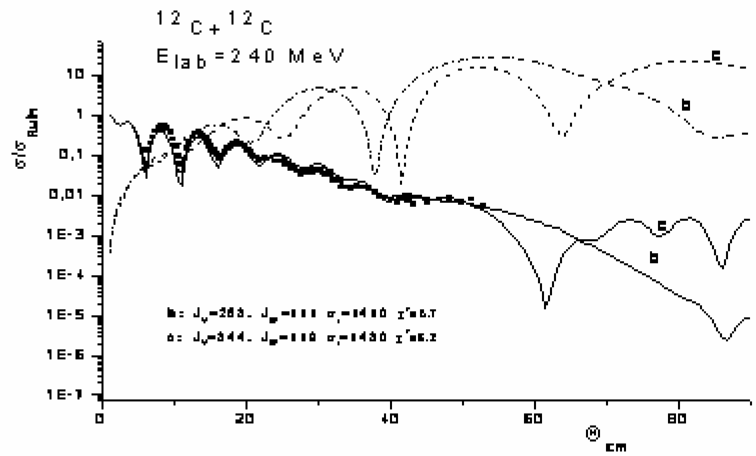

Fig.1. Differential cross-sections of $^{12}C + ^{12}C$ scattering fitted with two different optical model potentials with J_V = 283 (curve 'b') and J_V = 344 (curve 'c')

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COULOMB BREAK-UP ON TWO CHARGED PARTICLES. CALCULATION FOR REACTION ^{90}Zr(^{3}He, *dp*) ^{90}Zr AT E_L=90 MeV

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In author's work [1] the analytical representation for the matrix element of the transition operator T_{fi} for Coulomb break-up of the loosely bound light nucleus scattering with the heavy one with an outgoing of two charged particles has been received. The method of the distortion waves and zero range approximation for the interaction between clusters in the light nucleus has been used for the derivation. In this approach T_{fi} is expressed as a limit on regularizing parameter from a derivative by the same parameter from integral of overlapping $X_{(\omega)}$ of three Coulomb scattering functions of the light nucleus participating in break-up reaction. Expression for $X_{(\omega)}$ looks like a double series of almost hypergeometrical type with a weight multiplier in a form of product of two hypergeometrical Gauss functions depending on the arguments similar to arguments of hypergeometrical function in a similar expression of known Landau formula [2] for the deuteron break-up. Calculations have showed, that series through which the derivative from $X_{(\omega)}$ is represented, converges due to decreasing of power functions whereas hypergeometrical functions, decreasing, tend to some limiting values. The entrance parameters at that has been determined by three particles nonrelativistic kinematical relations.

In the present work the calculations of three times differential cross-sections [3] are executed in initial approximation of the account of finite range interaction between particles from break-up. That is supposed, that confluent hypergeometrical functions which are included in the scattering functions of these particles in the Coulomb field of the target nucleus, do not depend on their relative coordinates. For calculation of Fourier-image *D(k)* of the form-factor of break-up of the three-particle nucleus ^{3}He the method that has been developed in works [4, 5] is used. As against these works, the author applies alternative representation *D(k)* through two elementary functions. Here *k* is the wave number for the transferred moment. In this case $X_{(\omega)}$ is multiplied on *D(k)* whereas in zero range approximation $X_{(\omega)}$ is multiplied on *D(0)*. The results of calculations confirm the small contribution of the Coulomb break-up in the cross section of the investigated reaction and specify strong dependence of the Coulomb break-up cross section on the corner between the particles from the break-up.

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ON THE NUMERICAL SOLUTION OF FADDEEV'S EQUATIONS FOR THE *nd* SYSTEM

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In our recent paper [1], we have proposed the new approach allows us to solve three body problem for continuum. In particular, it has been shown that full wave function for *nd* system can be constructed as

$$\Psi = \Phi + \sum_{K,n_K} B_{K,n_K}(\rho) u_{K,n_K}(\Omega), \tag{1}$$

where $\Phi = \varphi_d(r)\exp(i\vec{p}\vec{\rho})$ is the asymptotic wave function ($|\vec{\rho}| \to \infty$), $\varphi_d(r)$ is the intrinsic deuteron wave function, $\vec{p}$ and $\vec{\rho}$ are the relative *nd* momentum and radius-vector correspondingly. The second term in (1) is the expansion in series of hyperspherical harmonics $u_{K,n_K}(\Omega)$, which has rapid convergence due to failing of the Coulomb interaction. The functions $B_{K,n_K}(\rho)$ can be found from numerical solution for the set of bounded Faddeev's integral equations. In simplest case $K = 0$ and $B_{0,0}(\rho) = B_{0,0}^{(1)} + B_{0,0}^{(2)} + B_{0,0}^{(3)}$ we have

$$B_{0,0}(\rho) = f(\rho) + \lambda \int_0^\infty d\rho' \mathrm{K}(\rho,\rho') B_{0,0}(\rho'), \tag{2}$$

where $f(\rho)$, λ and equation kernel $\mathrm{K}(\rho,\rho')$ were taken from [1]. Using Hülten *NN*-potential, we got the set of tabular data for $B_{0,0}(\rho)$ as the result of numerical solution (2). Differential cross sections $d\sigma/d\Omega = |\mu(2\pi)^{-1}\langle\Phi|V_{nn} + V_{np}|\mathrm{X}\rangle|^2$ were calculated at neutron energy $E_n = 3.28$ MeV for cases $d\sigma/d\Omega|_{\mathrm{X}=\Phi}$ and $d\sigma/d\Omega|_{\mathrm{X}=\Psi}$. From comparison with the experimental data [2] it follows that values $d\sigma/d\Omega|_{\mathrm{X}=\Psi}$ reach better fitting than $d\sigma/d\Omega|_{\mathrm{X}=\Phi}$.

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NUCLEAR STRUCTURE IN $^4He + {}^4He$ COLLISIONS

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During last thirty years the microscopic calculations for the reactions with ^4He nuclei suppose invariable structure of this nucleus especially at moderate energy. Such conviction is based on calculation [1]. At present time in spite of considerable number of publications concerning in particular α-α scattering a satisfactory detailed describing of existing experimental data is not obtained. In this connection, the present work proposes a new version of RGM basis, which supposes a structural interdependence of the colliding nuclei. A RGM formalism taking into account the spatial dependence of the size parameter $b = (\hbar / m\omega)^{1/2}$ of the nuclear shell model potential is developed for α-α scattering. Introducing of the dependence $b(r)$, where r is the internuclear distance, essentially complicates the mathematical form of integrodifferential RGM dynamic equation. For numerical calculation a simple approximate two-level form of $b(r)$ is used which provides a practically complete describing of the scattering phase shifts with $L = 0$, 2, 4, 6 in the one-channel energy region when at the internuclear distance $r_t \approx 2$ fm $b(r)$ in the internal region receives the decrement $10 - 20\%$ comparatively with phenomenological $b(r)$ value at large r. External and internal $b(r)$ values are connected by smooth curve within a narrow interval centered at r_t. The calculation result depends weakly on the variation of the transitional region width from 0.04 fm up to 0.24 fm. As the nucleon-nucleon potential is used a slightly modified Volkov potential which provides exact binding energy value for ^4He at phenomenological nuclear radius value taking into account the Coulomb interaction of the nucleons. Concerning nucleon-nucleon scattering data the modified potentials are practically equivalent to theirs original forms. Good describing for the energy dependence of the scattering phase shifts shows that the calculation correctly reproduces position and width at least of three low-lying ^8Be states. These results are obtained with modified first form of Volkov potential. Thus proposed concept of the RGM even with very simple radial dependence of the shell model size parameter reflects a basic evolution trend for the structure of the colliding ^4He nuclei, and used variant of nucleon-nucleon potential adequately reproduces effective interaction in the considered system. There is reason to expect that such approach will be an essential resource also in the microscopic calculation of the reaction with heavier nuclei.

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ABOUT THE POSIBILITY OF DEFINITION OF THE HAMILTONIAN OF THE NUCLEAR SYSTEM IN THE PROBLEM OF THE QUANTUM SCATTERING PARTICLES

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In the 1920s W.Heisenberg [1], when developing the matrix theory of the interaction in the quantum mechanics, expressed his idea relating to the fact that from experimental data of the matrix of collisions one can determine the quantum system's Hamiltonian.

This idea was confirmed by the problem of two bodies scattering [2] where the possibility of recovering of scattering potential by scattering phases in the energy range $(0,\infty)$ was proved. Strict microscopic theories of nuclear reactions [3] reproduce adequately the dependence of the interaction cross-section on the energy. However, integrals of wave functions overlap defining the matrix of collisions can not be calculated theoretically due to both the reason of imperfect knowledge of nuclear interactions as well as complicity of solution of many-body problem. One can determine their values from the experimental data near the reaction thresholds where theoretical dependence on the energy in the analytical form is well known. The integrals of wave functions overlap defining the matrix of collisions can be determined numerically when approximating of the experimental excitation function by the theoretical function. That is why a study of thresholds specific features [4] is of the most interest in the nuclear interaction research. In the last 80 years the nuclear physics and physics of elementary particles have made a great progress in the nucleus cognition and development of experiment technique, instrument making and mathematics methods of scattering theory for quantum-mechanical many-body systems. At present there exist many premises for possibilities for recovering of Hamiltonian of atomic nucleus and the system of elementary particles. This report bases on the papers which are most suitable for calculations of Hamiltonian [3-5].

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THE FINITE SIZE EFFECTS IN FUSION OF DEFORMED NUCLEI AT INCIDENT ENERGIES NEAR THE BARRIER

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At the end of seventies it was demonstrated experimentally that near-barrier heavy ion fusion cross sections depend crucially upon the static deformations of the colliding nuclei. About 10 years ago the precision of cross-section measurement was increased up to 1%. This allowed the measured cross sections to be converted into experimental fusion barrier distributions (see [1] and references therein). In the experimental analysis the barrier distributions were analyzed using a Woods-Saxon shape for the nuclear part of the bare nucleus-nucleus potential. This potential was defined along the line joining the centers of the two nuclei, and is referred to here as a "simplified potential". For deformed nuclei of finite size, this approach seems not to be in accordance with the short range character of nucleon-nucleon (*NN*) nuclear interaction. We present in this contribution the results of our theoretical study of the significant deviations of the simplified potential from a "realistic" nuclear potential. The finite size effects on the potential for deformed nuclei have been first investigated in a geometrical way, accounting for the minimum distance between the nuclear surfaces and for the surface curvature correction to the nucleus-nucleus potential. These finite size effects have been found to be significant for near-barrier fusion cross sections and the shape of the barrier distribution [2]. This geometrical way of incorporating finite size corrections is approximate in itself. A more rigorous approach might be to calculate the nucleus-nucleus potential using a semi-microscopic double folding model. Thus we developed a computer code that realized the double folding model, initially for two colliding spherical nuclei. Using this code, bare nucleus-nucleus potentials have been calculated with the Reid and Paris M3Y effective *NN* forces. The exchange part of the interaction was taken to be of finite range and the density dependence of the NN interaction was accounted for. The calculated fusion barrier energies and fitted diffusenesses of the potential were compared with those extracted from experimental data [3]. Then the code was modified to obtain the bare nucleus-nucleus potential for heavy-ion fusion reactions involving deformed target nuclei. The angle-dependent fusion barriers calculated with a simple delta function-like exchange term of the *NN* interaction are very similar to those calculated with a finite range expression [4]. This circumstance enables us to perform rather quick calculations of the fusion cross sections and the corresponding barrier distributions. Results obtained for seven reactions confirmed the conclusion made on the basis of the purely geometrical approach described above: the finite size effects are substantial and can not be ignored in a quantitative analysis of experimental fusion cross sections and barrier distributions.

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TIME-DEPENDENT SCHRÖDINGER EQUATION ANALYSIS OF NEAR-BARRIER FUSION ENHANCEMENT CAUSED BY COLLECTIVIZATION OF VALENCE NEUTRONS

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The process of "sequential fusion" [1] of heavy nuclei at near-barrier energies, in which the intermediate transfer and collectivization of valence neutrons play a significant role, was analyzed for the first time by numerical solution of 3-body and 3-dimensional time-dependent Schrödinger equation. It was found that neutron transfer with zero projection of angular momentum onto the inter-nuclear axis dominates at initial reaction stage. Neutron collectivization (spreading of the neutron wave function over the volumes of two colliding nuclei) starts just before approaching the Coulomb barrier and affects the fusion probability. Typical density of the ^{6}He valence neutron wave function is shown in Fig. 1 at the distance of R=12 fm from ^{206}Pb target (logarithmic scale). Before contact of two nuclei, 1p neutrons of ^{6}He with a large probability populate the two-center (quasi-molecular) states (with m=0) arising from the 3d, 4s and 2g states of the isolated Pb nucleus. Occupation probabilities P for these states are shown in Fig. 2 depending on the inter-nuclear distance at near-barrier collision energy. The corresponding energies of the quasi-molecular terms, $\varepsilon(R)$, are shown in Fig. 3.

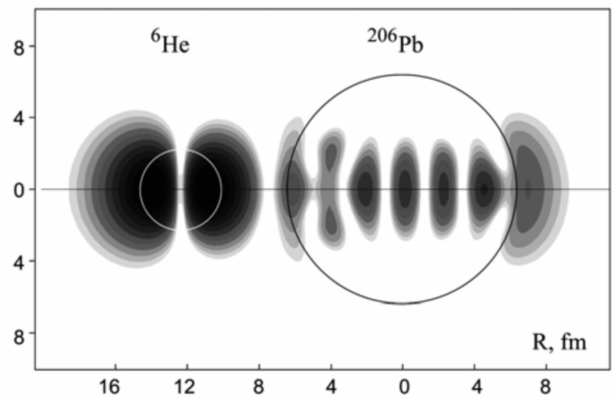

Fig. 1

The intermediate neutron motion and its influence on the near-barrier fusion of heavy nuclei were analyzed in details within the model and will be discussed in the talk.

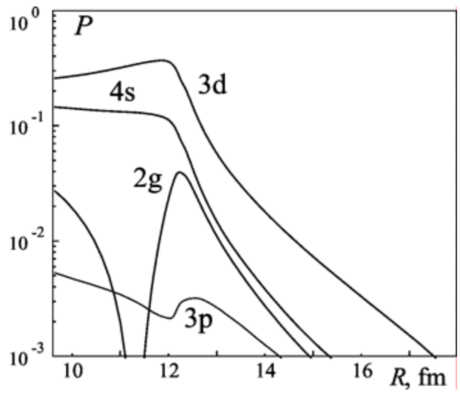

Fig. 2

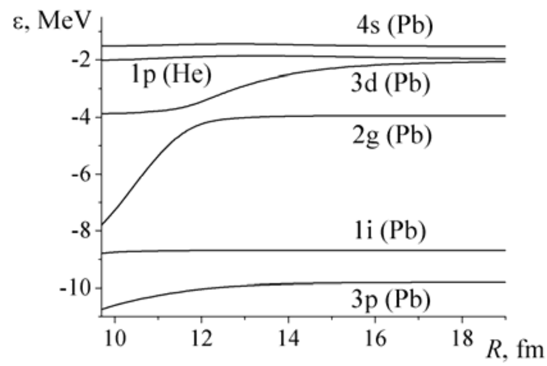

Fig. 3

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QUANTUM-MECHANICAL METHOD OF CALCULATION OF ANGULAR AND ENERGY FRAGMENT'S DISTRIBUTIONS FOR BINARY AND TERNARY FISSION

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In the framework of quantum theory of binary fission [1] the asymptotic of fissile nucleus wave function which defines angular distributions of fission fragments is presented as $\Psi^{JM} \rightarrow \sum_{\alpha} U_{\alpha}^{JM} \left[\exp\left(i\left(kR - \frac{L\pi}{2} + \delta_{\alpha} \right)\right) \Big/ R \right] \sqrt{\Gamma_{\alpha}}$, where U_{α}^{JM} is channel function depending on channel index $\alpha \equiv \sigma_1 \sigma_2 J_1 J_2 L$ and the wave functions of the fission fragments with quantum numbers σ_1, σ_2 and spins J_1, J_2 and orbital angular function of relative fragments motion with orbital momentum L. The real radial form-factors $f_{\alpha\beta}(R)$, which describe elastic scattering of fission fragments on their interaction potential $V(\mathbf{R})$ and define the amplitude $\sqrt{\Gamma_{\alpha}}$ [1], and fission phases δ_{α} can be found from the solution of the system of connected equations. In order to solve this system the method of basis functions with asymptotic $\sin(kR + L\pi/2 + \delta_{\beta})$ providing the high accuracy of calculations [2] can be applied. The carried out analysis of the structure of matrix elements $\left\langle U_{\alpha'}^{JM} \middle| V \middle| U_{\alpha}^{JM} \right\rangle$ for the potentials $V(\mathbf{R})$ of strongly deformed fragment interaction giving channel coupling show the quick convergence and stability of the method under the enlargement of the channel function basis.

Developed method of calculations is generalized in the framework of the quantum theory of ternary fission [3] for the calcuation of amplitudes $\sqrt{\Gamma_{\alpha}}$ and angular and energy distributions of ternary fission products under the transition from two-body to three-body kinematics and with use of hyperspherical coordinates (ρ, ε). With application of the condition that ternary fission fragments fly out predominantly along the symmetry axis of fissile nucleus the method of $f_{\alpha\beta}(\rho)$ calculation was developed for the solution of connected equation system. This method conserves all advantages of the mentioned above method for binary fission.

The work is supported by INTAS (03-51-6417), RFBR (03-02-17469), Dynasty Foundation and International Center for Fundamental Physics in Moscow.

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ANGULAR DISTRIBUTIONS OF BYNARY FISSION FRAGMENTS

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In the framework of the quantum theory of binary fission [1] with use of radial real form-factors $f^J_{\alpha\beta}(R)$, which describe elastic scattering of fission fragments and satisfy to the system of connected equations defined in paper [2], the calculations of fragments angular distributions for binary fission were carried out. In order to find form-factors $f^J_{\alpha\beta}(R)$, phases δ_β [2] the method based on the procedure of logarithmic sewing together the basis functions determined in internal and external regions of the scattering problem has been used. The analysis of the structure of Coulomb V^c and nuclear V^n interaction potentials for deformed fragments of binary fission demonstrates that symmetry axes of fission fragments coincide with symmetry axis of fissile nucleus, and the nonsphericity of fragments interaction potentials leads to the mechanism of pumping of big values of relative orbital moments L and fragment's spins [1]. The calculation of form-factors $f^J_{\alpha\beta}(R)$ and phases δ_β with use of the V^c and V^n potentials from the paper [3] for the two most likely fragments of ^{252}Cf spontaneous fission – ^{148}Ba и ^{104}Mo – with their parameters of deformation $\beta_2 = 0.22$ and $\beta_2 = 0.35$ respectively [3], shows that values of phases δ_β for the all channels with $L \le L_m$, where L_m is maximal value of fragments relative orbital momentum, are close to each other and coincide with Coulomb scattering phase. This fact has lead to the coherent addition of the partial fission width amplitudes in the formation of fission fragments angular distributions and to the fragments flight predominantly along or against the direction of the fissile nucleus symmetry axis in the cone with corner angle $\Delta\theta \sim 1/L_m$. This result gives the possibility to explain the success of O. Bohr's formula for the angular distributions of fission fragments, which defines itself by the condition that fission fragments fly strictly along or against the symmetry axis of fissile nucleus. Values $L_m \approx 25$, which were found in calculation, are in good agreement with values obtained earlier on the base of pumping mechanism and with values L_m from analysis of angular distributions of fragments for subthreshold photofission [1].

The work is supported by INTAS (03-51-6417), RFBR (03-02-17469), Dynasty Foundation and International Center for Fundamental Physics in Moscow.

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QUANTUM-MECHANICAL ANALYSIS OF ANGULAR DISTRIBUTIONS OF THE THIRD PARTICLES FOR TERNARY FISSION OF NUCLEUS

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Angular and energy distributions of the third particles for ternary fission usually are described on the base of the quasiclassical methods of three-body trajectory calculations [1]. For the quantum-mechanical description of mentioned distributions it is necessary to solve Shrödinger equation with quantum-mechanical boundary condition obtained in the paper [2] for the wave function $\Psi(r,R,\theta)$, where θ is angle between vectors $\mathbf{r},\mathbf{R}$ describing relative motion of ternary fission products in external region where their interaction potential $V(\mathbf{r},\mathbf{R})$ is only Coulomb potential and fission fragments fly out along the symmetry axis of fissile nucleus.

Potential $V(r,R,\theta)$ with taking into account mass and charge asymmetry of fragments $\delta=(A_2-A_1)/(A_2+A_1)\approx(Z_2-Z_1)/(Z_2+Z_1)$ is practically independent on the fragment's deformation and has minimum at the angle $\theta=\theta_m$, where $\theta_m=0$ for $r<\delta R/2$, which analytically transits to the minimum at $\cos\theta_m=\delta R/2r$ for $r>\delta R/2$. For angles θ in vicinity of angle θ_m the potential $V(r,R,\theta)$ can be reduced to oscillatory form: $V(r,R,\theta)=V_0(r,R)+$ $+(1/2)C(r,R)(\theta-\theta_m)^2$, where $C(r,R)$ is stiffness coefficient.

The solution of Shrödinger equation at fixed coordinates r,R gives possibility to obtain wave functions $\Psi_m(r,R,\theta)$, depending on projections m of the third particle orbital momentum onto symmetry axis of fissile nucleus, in form which connected with Gauss functions, that corresponds to Coulomb focusing of the third particle flight in the direction of the angle θ_m. These functions practically don't change at the transition from $m=0$ to $m=1$. With use of the mean value theorem it is possible to select such values $r=r_0$, $R=R_0$ when function $\Psi_0(r_0,R_0,\theta)$ efficiently describes experimental angular and energy distributions of the third particle. Obtained values r_0,R_0 qualitatively correspond to physical picture of ternary fission, when the higher energy of the third particles are achieved at more compact configurations of the fissile nucleus at the moment of it's scission. Therefore the increase of the third particle energy leads to the approaching of the angle θ_m to $\pi/2$ and to widening of the third particle angular distribution, and the increase of asymmetry δ leads to angle θ_m decrease, when the width of angular distribution of the third particle practically doesn't change.

The work is supported by INTAS (03-51-6417) and RFBR (03-02-17469).

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ANGULAR ANISOTROPY OF NEUTRONS EVAPORATED FROM FISSION FRAGMENTS

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The probability estimates for the emission of scission neutrons (those emitted in the vicinity of the scission point) were done several times. The main method used in these estimates was the comparison of the experimental and theoretical energy and angular distributions of neutrons accompanying fission. The basic assumption of the method was the isotropic emission of neutrons in the c.m. system of each fission fragment.

The present work takes into account the anisotropy of such an emission which results [1] from the large fragments' spins, which appear at scission and are perpendicular to the line of the fragments' relative motion. Contrary to the majority of previous works the sequential emission of neutrons was calculated in the framework of the standard evaporation model by Monte-Carlo method. The angular distribution of neutrons in the fragment's c.m. system was defined in [2] as:

$$W = \sum P_{lm} \,|\, Y_{lm}(\theta,\phi)\,|^2$$

Here θ is the angle between the neutron momentum and the line of the fragments' motion. P_{lm} is the emission probability of a neutron with angular momentum l and magnetic number m, defined with the aid of vector addition coefficients for vectors $\vec{\ell}$, $\vec{J}_f$ (final fragment spin), $\vec{J}_i$ (initial fragment spin). The initial spin distribution of the fragment was taken not only in the "standard" form $(2J+1)\exp[-\frac{(J+\frac{1}{2})^2}{2\sigma^2}]$, but also in the form $\sum_{J=0}^{J_{\max}}(2J+1)$ resulting from the quantum theory of fission [3].

It is shown that the anisotropy $[\frac{W(0^o)}{W(90^o)}-1]$ in the fragment c.m. system depends only on the average value $\langle J_i \rangle$ but is insensitive to the form of the initial spin distribution and is about 10% for both heavy and light fragments. In the laboratory system this anisotropy is much smaller than the one arizing from the fragments' relative motion and practically should not affect the estimates of the scission neutrons yield.

We appreciate the support of INTAS (ref. No. 03-51-6417).

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REARRANGEMENT OF ATOMIC ELECTRONS IN THE β-DECAY OF THE ATOM

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Using the time-depending formalism describing one-step decay of prepared state of quantum system [1] it is shown that the rearrangement of atomic electrons structure in contrast to traditional concepts [2] is not a secondary process with respect to β-decay of atom and is directly connected with the formation of partial and total widths of atom β-decay. It is demonstrated that total widths of atom β-decay differs from widths of "bare" nucleus β-decay Γ_0 which is in agreement with representation of "quantum paradox of Zenon" theory [3]. The formulae is given for calculations of atom β-decay widths for all orders of perturbation theory in the potential V_1 connected with change of charge of nucleus during it's β-decay (which leads to shake-off of atomic electrons mechanism) and in the potential of Coulomb interaction of β-particle with atomic electrons V_2 (which governs the direct collisions mechanism).

The partial and total widths of light and heavy atoms' β-decays are analyzed taking into account the rearangement of atomic electrons structure both for the internal and for the external atomic shells. The analysis of experimental data shows that partial widths of β-decay of heavy atoms with $Z >> 1$ connected with the transition of atomic electrons system from ground state of parent atom to ground state of daughter atom and giving sufficient contribution to atomic β-decay total widths are sensitive both to the shake-off and to the direct collisions mechanisms.

The improved formulae allowing to describe the changes of atomic β-decay total widths relatively to Γ_0 are obtained which are useful because of precisional measurements methods creation [4]. The approaches developed for taking into account the shake-off mechanism for atom β-decay can be used for the description of analogous mechanism defined in quantum theory of fission [5] the yields of binary and ternary fission products and the energy distributions of the ternary particles.

The work is supported by INTAS (03-51-6417) and by the grant «Universities of Russia» (УР-01.02.013).

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STOCHASTIC MODEL OF THE TILTING MODE IN NUCLEAR FISSION

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The untangling of the complex time evolution problems associated with heavy-ion reactions requires a good understanding of the relevant degrees of freedom, among which the angular momentum degrees of freedom plays a central role. The present work is aimed at a study of the tilting mode associated with the projection ***K*** of the total angular momentum ***J*** onto the symmetry axis of deformed fissioning nuclei. This mode controls angular distributions [1] and spins of fission fragments [2]. Usually these observables are described within the statistical model of the transition states. There exist two versions of the model, which identify the transition states with either the saddle point [1] or the scission point [3] of the fission barrier. However for heavy ion induced reactions the experimental anisotropies of fission fragments are spread in between the predictions of these models [4]. In addition, it is expected that the saddle point model loses its validity for very high angular momenta and heavy fissioning nuclei, namely, when the angular momentum reduces the fission barrier to a value similar or smaller then the nuclear temperature [4]. In this work, we consider a new dynamical model of fission of hot and rotating heavy nuclei. It should be noted that the conception of the transition states at any specific point of the potential energy surface is not used in our approach. The model takes into account the thermal fluctuations of the tilting mode. These fluctuations lead to jumps between different orientations of the deformed fissioning system with respect to ***J***. Time evolution of such processes is controlled by the relaxation time of the tilting mode. Dynamics of induced fission is simulated in the frames of the Langevin approach [5] considering the ***K***-dependence of the fission barriers. In the frames of the model we analyzed the experimental data on angular distributions, spins of fission fragments and prescission neutron multiplicities for a set of the ^{16}O, ^{12}C, ^{4}He induced reactions on the Pb-Cm targets at the energies, when a validity of the standard models is questionable. This analysis allowed us to determine the relaxation time of the tilting mode. The possible deformation and/or energy dependences of the relaxation time are considered.

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TIME AND KINEMATIC CHARACTERISTICS OF NUCLEAR DEEXCITATION PROCESS AS A PROBE OF THE LEVEL DENSYTY MODELS

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Approach based on the statistical theory of nuclear reactions and Monte-Carlo method is used for evaluations of excited nuclear system characteristics like probability of decay channel (light particle, γ-quanta emission or fission), energy, emission angle of decay products and time characteristics of deexcitation processes. This method permits the direct simulation of experimental situation, in particular, nuclear lifetime measurements by the crystal blocking technique. In previous works [1, 2] this method was used in analysis of the time characteristics of compound nucleus decay in the $^{12}C+^{28}Si \rightarrow ^{40}Ca$ and $^{19}F+^{28}Si \rightarrow ^{47}V$ reactions. In the frames of our approach the pronounced deference between production times for even Z and odd Z evaporation residue was detected. This effect certainly connected with the even – odd deference in the nuclear level densities. In the present work the influence of different models of nuclear level densities on estimation of production times for even Z and odd Z evaporation residue is analyzed. In this way most attention has been concentrated on the next problems: models of yrast band description, influence of nuclear shape symmetry and so on.

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ROLE OF TWO NEUTRONS INDEPENDENT TRANSFER MECHANISM IN ELASTIC α-^{6}He SCATTERING

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In the theoretical works on research of a configuration of a neutron-rich-nucleus ^{6}He the presence of two strongly differing spatial component is predicted: dineutron and cigar like. Dineutron component has strongly pull together neutrons which center of mass is removed enough from α-particle. In elastic α - ^{6}He scattering this component causes the exchange cluster mechanism that leads the existence of back up maximum in elastic α-particles section.

The second component is characterized by the greater distance between neutrons and small - between the center of mass of two neutrons and α-particle. In elastic α-^{6}He scattering such configuration caused the mechanism of consecutive neutrons transfer with formation of virtual system ^{5}He-^{5}He. The specified mechanism is described by the quadrangular diagram, in the perturbation theory it corresponds to the second order members and, depending on a direction of arrows in the diagram, is a correction member or to the mechanism of potential scattering, or to the mechanism of virtual α-particle exchange.

The method of calculation of amplitudes of quadrangular diagrams, realized in code QUADRO, was used for an estimation of contributions of mechanisms of independent transfer of neutrons in elastic α-^{6}He scattering. The executed calculations and their comparison with experimental sections allow to evaluate the contribution of cigar like components in a spatial configuration of neutron-rich- nucleus ^{6}He.

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STUDY OF THE MECHANISM OF INELASTIC DEUTERON SCATTERING ON ^{12}C NUCLEI USING THE ANGULAR *dγ*-CORRELATION TECHNIQUE

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The double differential cross sections for the reaction $^{12}C(d, d\gamma)^{12}C(2^+,$ 4.44 MeV) have been measured for 24 deuteron emission angles from 22° to 160° using 15.3 MeV deuteron beam of the 120-cm cyclotron of the Institute of Nuclear Physics of Moscow State University. From these cross sections the angular dependence of even components of the density matrix spin-tensor of ^{12}C nucleus state 2^+(4.44 MeV) has been determined for the first time. The angular dependence of magnetic sublevel populations and of components of the angular momentum orientation tensors where obtained also. In addition, the angular and energy dependences of differential cross sections of elastic and inelastic deuteron scattering have been measured.

The analysis of the experimental characteristics of the reaction is carried out assuming collective excitation (the computer code CHUCK) and heavy cluster stripping (the code OLYMP). Also the contribution of the mechanism of sequential particle exchange with delayed interaction (the code QUADRO) is analyzed. The contribution of the mechanism due to the compound nucleus intermediate stage is estimated using the computer code CNCOR.

The results show that collective effects and heavy cluster stripping provide main contribution to the scattering cross section. Taking into account the sequential particle exchange with delayed interaction results in some improvement of agreement with the experimental results. In the analysis of the reaction using the coupled channel approach, the value of ^{12}C nucleus deformation parameter turns out to be close to the values for other reactions obtained in analysis of our previous measurements using the same angular correlations method. From our study it can be concluded that, even qualitatively, the model of compound nucleus does not provide a satisfactory description of experimental results.

The fulfilled analysis concerns also the comparison of the obtained dynamical characteristics of the state 2^+ (4.44 MeV) with similar characteristics found earlier for inelastic scattering of ^{3}He and ^{4}He on ^{12}C nucleus.

This work was supported by the Foundation of Russian Universities (02.02.506) and by the Foundation of Scientific Schools (1619.2003.2).

EFFECT OF NUCLEAR STRUCTURE ON VECTOR ANALYZING POWER OF π^+ SCATTERING FROM ^{7}Li IN THE REGION OF THE Δ_{33} –RESONANCE

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In this paper we have calculated the vector analyzing power iT_{11} in framework of the Glauber theory for three π^+ -meson energy values: 134, 164, and 194 MeV. These energy values lie into the Δ_{33}- resonance of $\pi^{\pm}N$ – interaction with the maximum at 180 MeV. The resonance is characterized by strong $\pi^{\pm}$- absorption through the elastic channel that leads to predominant interaction in the surface nucleus layer. In order to find out how sensitive are the characteristics of π^+-^7Li scattering in respect to structural features of a target nucleus we have calculated iT_{11} using several model wave functions (WFs) of the ^7Li nucleus: WFs obtained in αt-cluster and shell models

Fig. demonstrates results of iT_{11} calculations for E_π=134 MeV together with experimental data [1]. Curves solid and dash illustrate calculations using WFs with different potentials of αt-interaction: 1- Woods-Saxon potential; 2- Buck potential. Dot curve represents calculations using shell WF with harmonic oscillator potential. Although their first minimum all curves is near the value θ~70^o however absolute values and nicety behavior of the curves appreciably differ. Dot curve differs from the first two curves in the whole angular range: its maximums are higher and minimums are deeper and shifted to the region of lower scattering angles. The dependence of iT_{11} on the choice of model WFs can be explained by the difference of WF asymptotics and the neglecting nuclear correlations in oscillator WF. The comparison of experimental data with calculated values visually demonstrates the advantages of cluster WFs obtained in deep attracting potentials with the forbidden states.

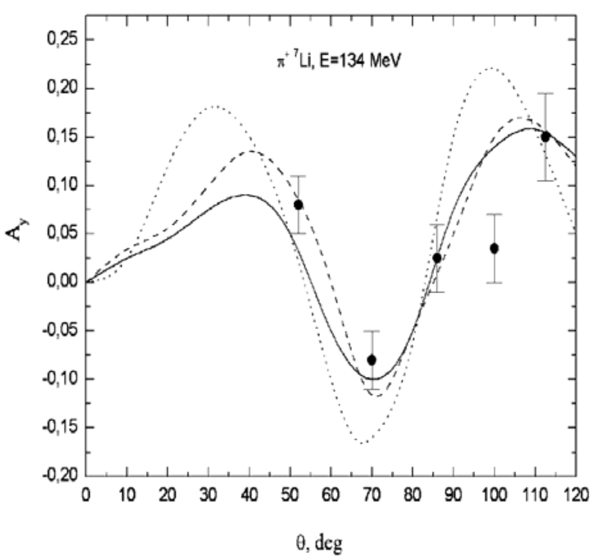

Fig. Vector analyzing power iT_{11} (b) at E_π=134 MeV.

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LONGITUDINAL ELECTRON SCATTERING RESPONSE FUNCTIONS OF ^{3}H AND ^{3}He NUCLEI

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Trinucleon longitudinal response functions $R_L(q,\omega)$ are studied in the momentum transfer range of q = 175 - 700 MeV/c and in the whole range of the energy transfer ω. Both three-nucleon (*NNN*) and Coulomb forces are fully included. Two realistic *NN* interactions (BonnA, AV18) and two *NNN* potentials (Urbana IX, Tukson-Melburn) are employed. Complete final state interactions are taken into account with the help of the method of integral transforms [1]. With this approach one deals solely with localized quantum mechanical states. Calculating final state continuum states and summation over their contributions to the inclusive cross section are thus avoided.

It is found that the *NNN* forces give effect of between 5% and 10% in the peak region and of 15% in the threshold region at the lowest considered momentum transfer. In the ^{3}He case one finds a much improved agreement with experiment both in the peak region and in the low-q-low-ω region when *NNN* forces are included.

We study effects of first-order relativistic corrections to the nuclear charge operator. Another relativistic effect we consider is the following. One may calculate the response in any reference frame transforming the results into the lab frame. This would not make any difference if the calculation is based upon relativistic dynamics. But this makes a difference in our case since we adopt conventional non-relativistic nuclear dynamics. These effects become of importance at q>400 MeV/c, especially for high ω values.

To extend the applicability range of non-relativistic dynamics calculations we suggest the use of a fast nucleon plus rest nucleus model to correct for breakup relativistic kinematics. With this model, responses obtained from calculations in various reference frames become close to each other even at high q values.

In comparison with experimental data rather good agreement is generally found. Exceptions are the data for responses at q=487 MeV/c and low ω values (excitation energies up to 15 MeV) where we observe large discrepancy with experiment. Similar results were obtained in Ref. [2] below the three-nucleon breakup threshold in the excitation range of 2.26 MeV. In the considered regime rather high momentum components in the initial and final state are probed. The conventional theory of nucleus thus seems to fail at such momenta.

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ENERGY LOSS OF QUARKS IN HADRON-NUCLEUS COLLISIONS

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The energy loss of fast quarks, a process which affects proceeding of hadron-nucleus collision, takes a great interest last years. There are a lot of models trying to describe such an effect (see, e.g. Ref. [1]). Much of the problem originates from impossibility of direct measurements of the partonic energy loss rate *dE/dz*. The energy loss in the initial state (before hard collision) is usually measured from the data on *A*-dependence of the Drell-Yan (DY) lepton-pair production in proton-nucleus collisions (e.g., E866 Collaboration at FNAL [2]).

In this work to study the effect of quark energy loss in nuclei we used our HARDPING Monte Carlo event generator. The HARDPING procedure to simulate quark energy loss uses two parameters: energy loss rate *dE/dz* (free parameter), and length of a quark path in a nucleus *L*, which was calculated according to the approach of Ref. [3]. The obtained results are shown in Fig. 1 in comparison with the data of E866 Collaboration in proton-nucleus collisions at 800 GeV.

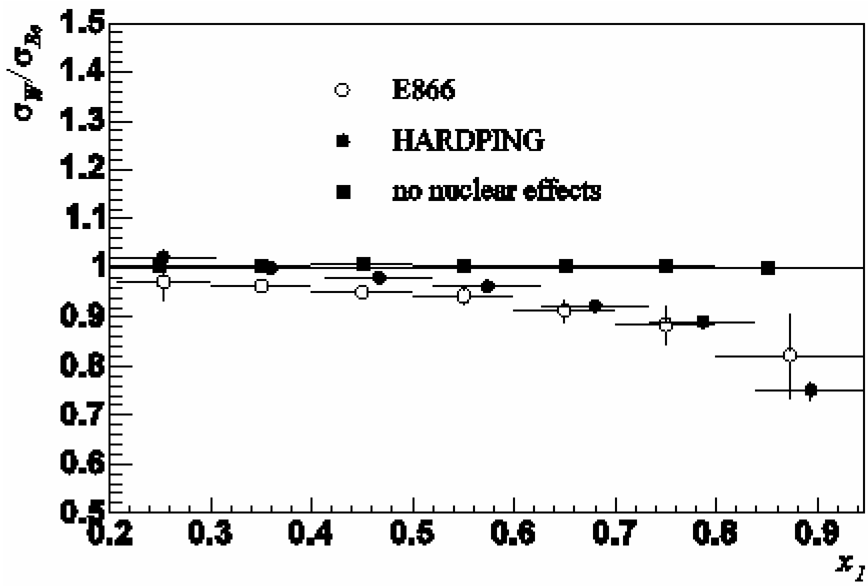

Fig. 1. Ratio of the cross sections for DY events on different nuclei versus x_1. To calculate the ratio obtained by HARDPING it has been used dE/dz = 3 Gev/c.

It is clear that taking into account the quark energy loss effect allows to significantly improve agreement with the experimental data [2] on *A*-dependence of the DY lepton-pair production.

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HARDPING: A MONTE CARLO EVENT GENERATOR FOR *hh*, *hA*, AND *AA* COLLISONS

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Despite the success in theoretical explanation of nuclear effects in high-energy hard collisions there is no an adequate implementation of nuclear effects in Monte Carlo (MC) event generators. Because of event complexity of collision involving nucleus, MC generators are widely used for phenomenological studies as well as at all stages of physical experiments, from project design to experimental data analysis. So, it is very important to have a MC event generator with correct treatment of nuclear effects. In this paper we present a new MC event generator, HARDPING (Hard Probe Interaction Generator). It is based on HIJING generator [1], an extension of PYTHIA [2] for hadron collisions on jet production in nuclear collisions. We have essentially modified and extended HIJING code on some important nuclear effects. The main features of the present version of HARDPING are as follows:

(1) Multiple soft rescatterings of incident quarks in nucleus. This effect has been implemented according to Ref. [3];

(2) Energy loss of incident quark propagating through the nucleus. This effect was included following Ref. [6];

(3) The Drell-Yan (DY) lepton pair production. The DY lepton pair production is very informative for study of initial state effects before hard parton collision.

(4) Small-x shadowing of nuclear parton distributions. We have included flavor and scale dependent EKS98 shadowing parametrization [4] because scale and flavor independent nuclear shadowing parametrization used in HIJING leads to contradiction with data (see Ref. [5] for details).

Apart from the above features we did some other modifications to the standard HIJING, e.g., a nucleus now consists from Z protons and $(A - Z)$ neutrons.

The obtained HARDPING version reasonably reproduces the latest data on the DY pair production in hadron-nucleus collisions obtained by E772 and E866 Collaborations (see Ref. [7] and references therein). It allows to extract from the data such important parameters as energy loss in nuclear medium per length unit, etc.

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MULTIPLE SOFT RESCATTERINGS OF QUARKS IN HADRON-NUCLEUS COLLISIONS

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New experimental results from the Relativistic Heavy Ion Collider (RHIC; BNL, USA) raised a new problem in clarifying the observable nuclear (A) dependence [1], namely strong suppression of high-p_t hadrons yield in central Au + Au collisions at $\sqrt{s} = 130$, 200 GeV per nucleon. Such a behavior contradicts Cronin effect (anomalous A-dependence for production of hadrons with $p_t \geq 2$ GeV/c, which was observed in fixed target proton-nucleus (pA) collisions at energies 200, 300 and 400 GeV) [2].

The anomalous A-dependence can be affected by initial- and final-state effects, i.e., the effects before and after hard scattering. The results of Ref. [3] shown that the observed Cronin effect in pA-collisions can be explained by multiple soft rescattering of incident quarks before hard scattering. A unique tool for studying such initial-state effects is the Drell-Yan (DY) lepton-pair production in pA-collisions.

We studied one of the important initial-state nuclear effects– multiple soft rescatterings of incident quarks in pA-collisions, which was taken into account according to Ref. [3]. The analysis was performed using our HARDPING Monte Carlo event generator. The obtained results and the results by the standard version of HIJING generator without quark rescatterings were compared with E866 Collaboration data at 800 GeV [4] (Fig. 1).

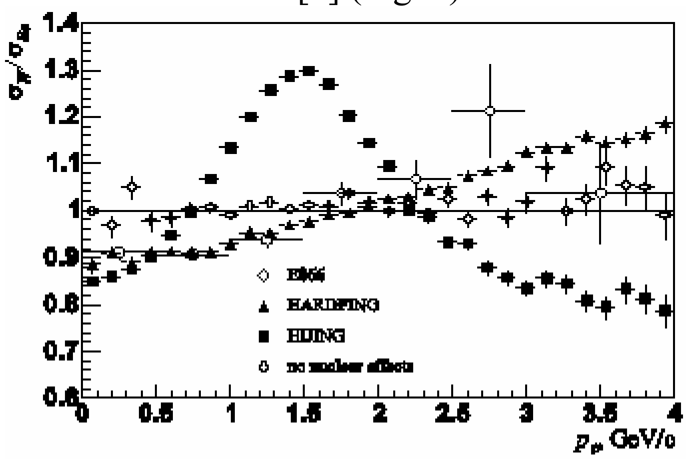

Fig. 1. Ratio of the DY cross sections on different nuclei versus p_t.

In Fig. 1 one can see that a proper treatment of multiple soft rescattering effect according to approach of Ref. [3] allows to improve significantly agreement with the experimental data [4].

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SCATTERING OF ELECTRONS AND NEUTRINOS ON ORIENTED NUCLEI IN THE FRAMEWORK OF ELECTROWEAK THEORY

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The behaviour of the scattering of electrons and neutrinos by some light oriented nuclei and the influence of orientation effects on the process are studied. The currents of nuclear transition, which composed of the electromagnetic, vector and axial ones, were expanded into multipole components and as a result the scattering cross section is expressed in terms of the multipole form factors [1, 2].

The influence of orientation is described by the ratio $\Delta\sigma/\sigma_o$, where σ_o is the cross section without target orientation and $\Delta\sigma$ - the contribution to the cross section from nuclear orientation. It is interesting to compare the contributions from orientation to the scattering cross section of polarized electrons and neutrinos by this ratio. At energies of the order a few GeV the influence of weak interaction on the electron scattering may be neglected and although electrons and neutrinos interact with nuclei in quite different ways, one can find the similarity in these two contributions. For the nuclei with equal numbers $N = Z$ these ratios for the scattering of electrons and of neutrinos completely coincide.

As examples for illustration the calculations of the ratio $\Delta\sigma/\sigma_o$ for the scattering on the nucleon and on some lightest nuclei ^{2}H, ^{3}H, ^{3}He, ^{6}Li, ^{7}Li and ^{7}Be are performed. The magnitude of $\Delta\sigma$ at many values of scattering angle is of the same order as the cross section without orientation σ_o. This proves the possibility of determining separately the multipole form factors of the nuclear transition not only in electron experiments, but also in neutrino experiments.

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DISPERSION OF ELECTRONS OF HIGH ENERGY BY PROTONS IN THE FIELD OF BINOMIAL POTENTIAL

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Earlier we have shown [1, 2], that interaction of electron with a proton occurs under the law $V = -\frac{e^2}{r} + \frac{\Gamma}{r^2}$. In the same place it has been shown, as thus decisions of a classical problem of Kepler and equation of Schrödinger change.

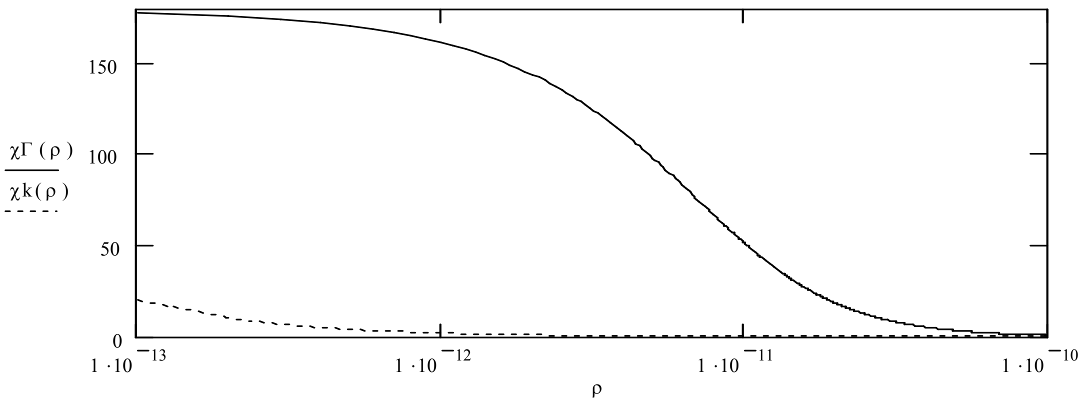
In the present work a process of dispersion of electrons on protons in a field of binomial potential will be considered.

It is known, that the formula of dispersion with Coulomb potential gives satisfactory results only at energy of electrons about several tens *eV*. At hundreds, thousand and more *eV* such formula of dispersion does not correspond

$$e := 4.80298 \cdot 10^{-10} \qquad \Gamma := 6.10356 \cdot 10^{-28} \qquad E := 6.4076 \cdot 10^{-6}$$

$$\gamma(\rho) := \left[2 \cdot \mathrm{acos}\left[\frac{1}{\sqrt{1 + \frac{4 \cdot E^2 \cdot (\rho)^2}{e^4}}}\right]\right] \qquad \psi(\rho) := 2 \cdot \sqrt{\frac{E \cdot (\rho)^2}{E \cdot (\rho)^2 + \Gamma}} \cdot \mathrm{acos}\left[\frac{1}{\sqrt{1 + \frac{4 \cdot E \cdot \left(E \cdot \rho^2 + \Gamma\right)}{e^4}}}\right]$$

$$\chi k(\rho) := 180 - \frac{180}{\pi} \cdot \gamma(\rho) \qquad \chi\Gamma(\rho) := 180 - \frac{180}{\pi} \cdot \psi(\rho)$$



to experiment any more.

In figure formulas with Coulomb's *γ (ρ)* and binomial *Ψ (ρ)* in potentials are shown. (In the same place other data are given so that the reader could reproduce these formulas in program Mathcad 2001 and calculate variants with other energies of electron). Curves in the figure correspond to energy 400 *MeV*.

Calculations show, that the formula of dispersion of electrons in a field of binomial potential well represents process within the limits of aim distances down to 10^{-13} for energy of electron from units *eV* up to hundreds *MeV*.

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CLUSTER KNOCK-OUT REACTIONS ON LIGHT NUCLEI

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The deuteron, α-particle and ^{3}He knock-out reactions from 1*s*- and 1*p*-nuclei by protons at medium energies (30-150 MeV) are studied. The analysis of available coplanar experiments has shown that the main processes contributing to the (*p,px*) reaction mechanism at medium energies are: quasi-elastic knock-out of a cluster by the incident proton; two-step processes (the first stage is inelastic scattering of the proton with formation of an excited nucleus; in the second stage the excited nucleus emits particle *x*); exchange processes (the (*p*,*x*) replacement reactions followed by emission of the proton by the excited nucleus). Therefore, the amplitude of the reaction under consideration must be calculated as a coherent sum of the amplitudes of the above processes.

Formerly, calculation of quasi-elastic knock-out of clusters was as a rule made using the distorted-wave impulse approximation. For the study of the (*p,px*) reactions at medium energies the impulse approximation cannot be applied, since factorisation of the matrix element and substitution of the free *px*-scattering cross-section cannot be properly justified at the energy range, where distortion of the wave-functions is significant. For the study of these reactions we use the distorted wave *t*-matrix approximation. The amplitudes of all processes contributing to the reaction mechanism are calculated within a unified approach, and a comparison of the results of the calculation with experimental data may lead to a conclusion as to which processes make contribution to the mechanism of a certain reaction. The parameters used in our calculations were found independently of the main calculation. For example, the distorted wave parameters were determined from an analysis of elastic and inelastic scattering; parameters of the wave function of the relative movement of the cluster in the nucleus were determined from the cluster separation energy; parameters of the wave function of the proton in the initial nucleus were determined from the description of rms radii. The approximation of final relative energy for quasi-two-particle *px*-interaction was used. Comparison of calculation results with experimental data shows that as a rule the main process in (*p,px*) reactions at medium energies is a quasi-elastic knock-out. In some cases two-step and exchange character of the reactions shows distinctly in coplanar experiments, for example the reaction ^{14}N(*p*,*pd*)^{12}C at proton energy 44 MeV, which first stage is a (*p*,*d*) reaction. Taking into account two-step and exchange processes enabled us to achieve good agreement of calculated results with experimental data.

DYNAMICAL EFFECTS IN THE APPROACH PHASE OF THE NUCLEAR FUSION

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The central collision of ^{40}Ar and ^{208}Pb is studied in the framework of the elastoplastic model [1]. The ellipsoidal deformations (parameter) and isovector dipole mode of motion in the approaching ions are included in the equations of motion. The emory effects are taken into account considering the Fermi-surface deformations as kinematically independent mode of motions. The potential energy surface is examined in its dependence on the distance between the ions and their deformation parameters. It is found that the inertia forces hinder strongly the “creeping” motion of ions along the potential energy valley (Fig. 1). The formation of long-living compact configurations (“fusion”) and quasi-elastic collisions of ions turn out to be separated by a particular trajectory in the collective phase space (“separatrix”) leading at ∞ to the saddle point in the potential energy surface. The saddle point corresponds to the configuration of two strongly deformed ions barely touching each other and is situated at the “ridge” in the potential energy surface establishing the barrier between the compact configurations and the states of independently moving fragments.

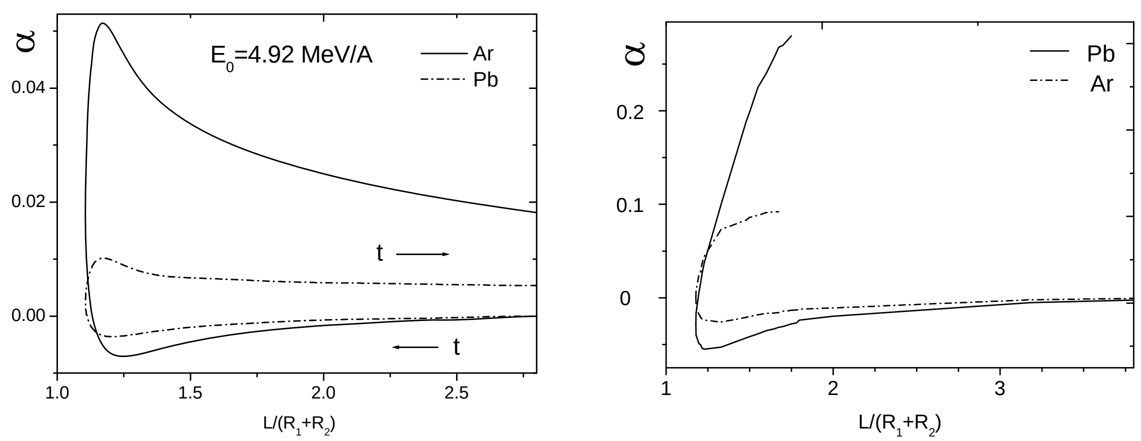

Fig. 1. Trajectories of ions in the -L (L distance between the centers of two ions) plane: left figure, the trajectory close to separatix calculated withing the elasto-plastic approach, right one – deformations, strictly following the potential valley of two approaching ions

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ASYMPTOTIC NORMALIZATION COEFFICIENTS FOR MIRROR NUCLEI ^{27}Al, ^{27}Si AND NUCLEUS ^{28}Si FROM ANALYSIS OF ONE NUCLEON TRANSFER REACTIONS

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The experimental differential cross sections of one nucleon transfer reactions ^{27}Al(d,t)^{26}Al, ^{27}Al(^{3}He,d)^{28}Si and ^{28}Si (d,^{3}He)^{27}Al at beam energy about several MeV/nucleon have been analyzed by method combining DWBA and Dispersion theory [1,2] to obtain the values of vertex constants (VC) $|G^2|$ of single particle bound states ^{27}Al→^{26}Al+n, ^{28}Si→^{27}Al+p. In the frame of DWBA VC is defined by square asymptotic coefficient of bound state function b_{lj}^2 multiplied by spectroscopic factor. The shell model spectroscopic factors C^2S of proton and neutron bindings in mirror nuclei as well as spectroscopic factors of bindings of proton and neutron in nuclei with $N=Z$ are supposed to be equal. So the relation between the VCs of corresponding states is to be defined by the relation of values of their b_{lj}^2, which have been found together with parameters of single particle bound state potential of Woods –Saxon form V_0, r_0, a in independent research on base of pn-pairs interaction approach [3] with using Shrödinger equation [4]. With the empirical values of VC of bindings ^{27}Al→^{26}Al+n, ^{28}Si→^{27}Al+p and values of b_{lj} obtained in the analysis the values of VCs of the other states ^{27}Si→^{26}Al+p, ^{28}Si→^{27}Si+n and values of S have been calculated.

Nucleus A	V_0 [MeV], r_0 [Fm], a [Fm]	b_{lj}, [Fm$^{-1/2}$]	$\|G^2\|$ [Fm]	$C^2 S$
^{27}Al→^{26}Al+n ^{27}Si→^{26}Al+p	-47.405 1.355, 0.55	7.44 12.2	6.54[7]; 5.65÷7.33[5,6] 17.6; 15.2÷19.7	0.79;0.68÷0.89
^{28}Si→^{27}Si+n ^{28}Si→^{27}Al+p	-50.381 1.393, 0.55	14.3 23.4	56.0[11], 57.8[10]; 64.5[12],65.3[8], 66.8[9] 150., 155., 173.,175., 179.	1.8 ÷ 2.2

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TESTING OF DIFFERENT COMPONENTS OF NUCLEON-NUCLEON INTERACTION IN INELASTIC SCATTERING OF POLARIZED PROTONS FROM ^{12}C

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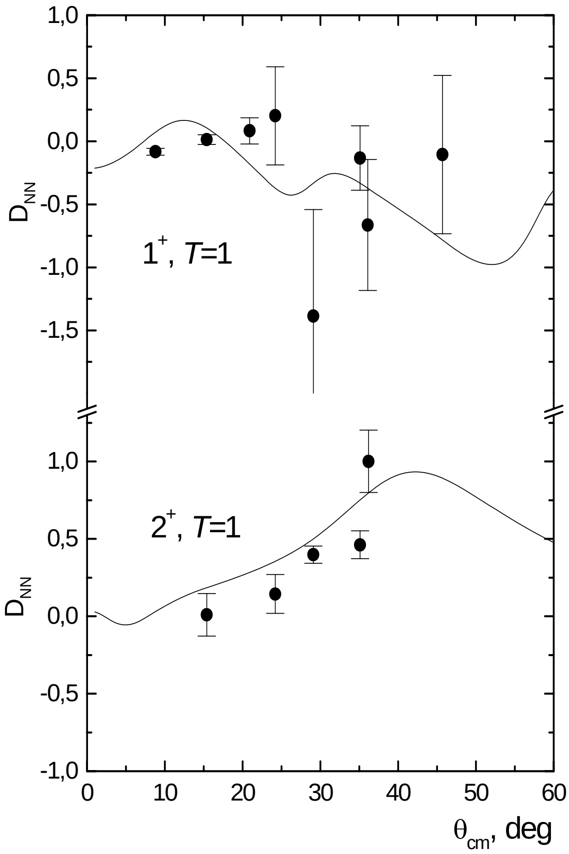
The polarization transfer coefficient D_{NN} is determined by its simple (linear) dependence on the spin-flip probability and is characterized by week sensitivity to the details of the transition density. Hence, D_{NN} appears to be an effective tool for testing the effective *NN* interaction. The excitation of the 2^+ and 1^+ states with $T = 0$ and 1 in ^{12}C by protons in inelastic scattering is used for this purpose [1]. We have analyzed the experimental data for the coefficient D_{NN} obtained from [2] and [3] in order to test the density dependent forces of Geramb [4] and Nakayama and Love [5]. The Figure illustrates comparison of the 150 MeV energy protons experimental data for D_{NN} with our calculations using the code DWBA91 of Raynal. These calculations are based on the density dependent forces of Geramb and the Cohen-Kurath wave functions for the indicated isovector excitations. The agreement with the experimental data is rather satisfactory compared with poor agreement at 397 MeV[1], where density dependence is not taken into account. In testing the density-dependent *NN* interaction in inelastic scattering, we also used the polarization (*P*), the analyzing power (*A*), the difference between *P* and *A*, and the differential cross-sections data for the above states.



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THE NUCLEON-DEUTERON SYSTEM AT LOW ENERGIES IN THE TWO-BODY POTENTIAL MODEL

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Recently, (see [1, 2] and references therein), low-energy characteristics of the doublet $N+d$ system have been calculated in the frame of the two-body model with different potentials by the use of the Lippmann-Schwinger integral equation. In the case of the *pd* system, the Coulomb difference for the ^{3}He–^{3}H binding energies was estimated by the use of the Yukawa form for the nuclear potential and for the screened Coulomb potential up to macroscopic values for the screening radius.

In this report, we apply the Schrödinger equation instead, which is better suited to taking the Coulomb interaction into account. We calculate the wave functions for the bound ^{3}He and ^{3}H and the corresponding asymptotic normalization constants. Furthermore, we calculate the doublet *S*-wave *Nd* scattering phase-shifts $\delta(E)$ as the functions of energy E. In the past the well known generalized effective-range approximation in the form $K(k^2) = (1+ +k^2/\kappa_0^2)^{-1}\,(-\,1/a+C_2k^2+C_4k^4)$ (1) was used to estimate $\delta(E)$. It was shown earlier [1, 2] that the convergence region of the expansion (1) in k^2 is limited to the complex energy area with a radius of up to $E_d=\varepsilon_d/3$ where ε_d is the deuteron binding energy. This is because the position of the nearest scattering amplitude singularity is due to a one nucleon exchange Feynmann diagram. In the case of the potential model, E_d = (s) $(\hbar^2/m)\,(1/2R)^2$ (m is the nucleon mass) if the potential decreases as const $r^{-n}\exp(-r/R)$. The potentials proposed in [3] have the biggest R value ($\cong$ 6 fm). As a result, E_d has the smallest value (< 0.2 MeV), so the approximation (1) may not be a good one already at $E_{\rm lab}$> 0.3 MeV.

The results of the Schrödinger equation solution in the continuum are the following. The functions $K(k^2)$ for *Nd* scattering are very close to each other for the Hulthen and Yukawa potentials with the parameters fitted by the experimental data for the triton binding energy and the doublet *nd* scattering length. The corresponding functions $K(k^2)$ are situated slightly below the three-body calculation results with the 3*N*-force taken into account and for the *pd* scattering the function $K(k^2)$ is in an agreement with the experimental data at $E_{\rm lab}$=2, 2.5 and 3 MeV. In the case of the oscillating effective nuclear *Nd* potential suggested by Tomio et al. [3] (variant B), these functions are situated at $E_{\rm lab} \geq 1$ MeV above the Faddeev results for the same *NN* potential without 3*N*-force. So we show that the two-body potential model is quite applicable to a description of the *Nd* system at low energy.

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THE VIRTUAL STATE IN CONFIGURATIONAL SPACE

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In the past, (see [1] and references therein) the resonance state calculation method was developed, based on the analytical continuation of the Lippmann-Schwinger integral equation onto the unphysical sheet of energy. It was applied successfully to different physical systems. Unfortunately this method can not be used directly in the case of charged particles.

In this report, we consider the Schrödinger differential equation method to calculate the energy of the virtual (antibound) state in the framework of a two-body model with a short-range nuclear potential with asymptotics $V_N(r) \to \text{const } r^{-n} \exp(-r/R)$ but without the Coulomb interaction. The main problem here is an exponential increase of the radial wave function $\Psi(r)$ when r is large for the Gamov state. One can write the asymptotic form of $\Psi(r)$ in the continuum S-state as $\Psi^{as}(r) = C_1(k) \exp(-ikr) + C_2(k) \exp(ikr)$. The condition for the virtual pole existence at $k = -i\kappa$ ($\kappa > 0$) is a zero coefficient $C_1(-i\kappa)$. The coefficients C_1 and C_2 are found from the set of equations $\Psi(r_1) = \Psi^{as}(r_1)$, $\Psi(r_2) = \Psi^{as}(r_2)$ where both the neighboring points r_1 and r_2 should be situated in the asymptotic region. In our calculation program, we choose as an example $r_1 = 0.5\, R_{max}$, $r_2 = 0.7\, R_{max}$, where $R_{max} = N\, R$. The N value should be big enough to fulfill the condition that $\Psi(r_1)/\Psi^{as}(r_1) =$ const. The main obstacle lies in the fact that for a resonance the first term in $\Psi^{as}(r)$ is much smaller than the second one. So, one should obtain a solution with a very high precision to calculate $C_1(-i\kappa)$, which is a quite small difference between very big figures. In our calculations, the virtual state energy $|E_v(N)|$ occurs to be a smooth decreasing function while N increases in the asymptotic region but at some $N > N_{max}$ the energy exhibit a sudden change to larger value of $|E_v(N)|$. It means that for a too big radius precision is not good enough to calculate $C_1(-i\kappa)$ accurately so one should take the result $E_v(N_{max})$. The method is applied to the virtual (singlet) deuteron and virtual triton with different potentials. The results of this calculation are compared with the corresponding results obtained earlier by the integral equation method. As a test, we use the Hulthen potential when the problem has analytical solution.

To normalize the resulting Gamov wave function, one can use the generalized effective-range approximation or calculate the Fourier transform of $\Psi(r)$ for which the normalization procedure is given in [1]. To do this, the nuclear vertex function expression with $V_N(r)$ in the integrand (see (87) in [2]) can be used.

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DESCRIPTION OF DIPOLE RESONANCE IN ^{27}Al BASED ON DIRECT REACTION SPECTROSCOPY

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The microscopic description of $3/2^-$, $5/2^-$, $7/2^-$ (T=1/2 and 3/2) states in ^{27}Al excited by *E1* photon absorption was obtained in "particle-core coupling" (PCC) version of shell model. The wave functions of excited states in PCC SM [1] were built on the basis

$$\left|J_{f,}T_f\right\rangle = \sum_{(J'),j'} \alpha_f^{(J'),j'} \left|(J'E'T')_{A-1} \times (n'l'j') : J_f, T_f\right\rangle, \qquad (1)$$

where all low-lying states of A=26 nuclei which have non vanishing spectroscopic factors for pick-up reactions [2] were included. The deviation of the ^{27}Al nucleus from closed $1d_{5/2}$ subshell reveals in a wide range of energy spread for the A=26 nuclei states.

On the Fig.1 are shown the distributions of *E1* transverse form factors at photopoint (q= E_{exc}) together with data for (γ,n) cross section [3] . The states with isospin T=3/2 are supplied with arrows. The line corresponds to summed *E1* form factor calculated with account to the decay widths of excited states.

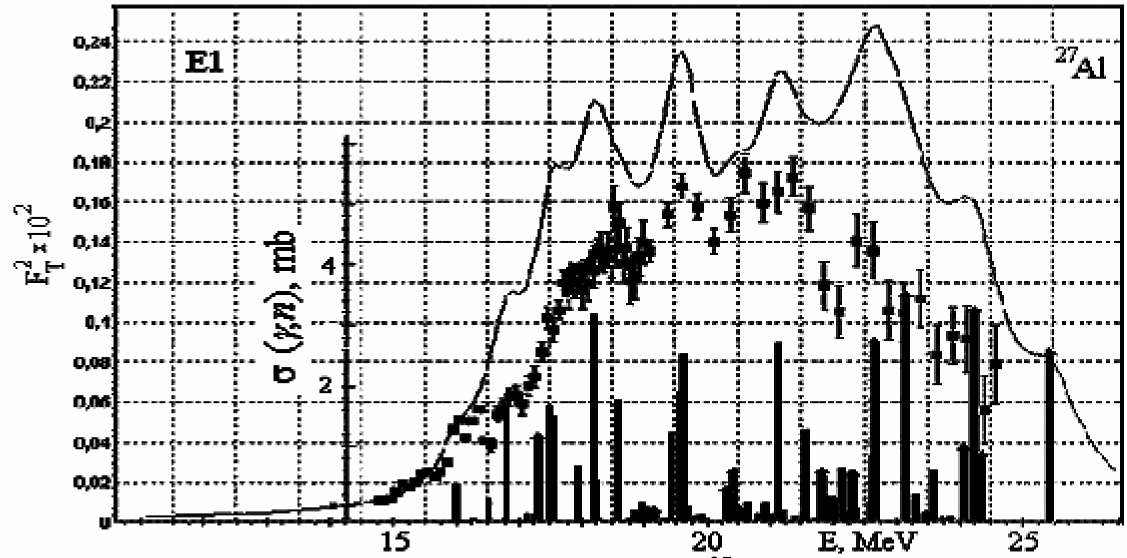

Fig. 1. E1 resonance distribution in ^{27}Al at photopoint

The comparisons of experimental and theoretical results for *E1* resonance in ^{27}Al as well for all open shell nuclei uncover the role of the final nuclei states energy spread in the resonance strengths fragmentation. This factor together with isospin splitting is a main source of observed in ^{27}Al resonance structure.

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MICROSCOPICAL DESCRIPTION OF *E1* RESONANCE IN ^{24}Mg DEFORMED NUCLEUS

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Distribution and values of the multipole resonances (MR) strengths in open shell nuclei, especially in deformed ones, represent a challenge to the theory. Some advance in the interpretation of MR in these nuclei could be achieved in particle - core coupling (PCC) version of shell model [1], where the energy spreading of final nuclei states is taken into account. Transverse form factors for ^{24}Mg excited *E1* states with isospin T=1 were obtained in PCC on the basis where all states of A=23 nuclei with noticeable spectroscopic factors for pick-up reactions [2] are included. In the Fig.1 is shown the isovestor *E1* resonance transverse form factors distribution in ^{24}Mg at photopoint. PCC results for *E1* resonance are in good agreement with experiment [3].

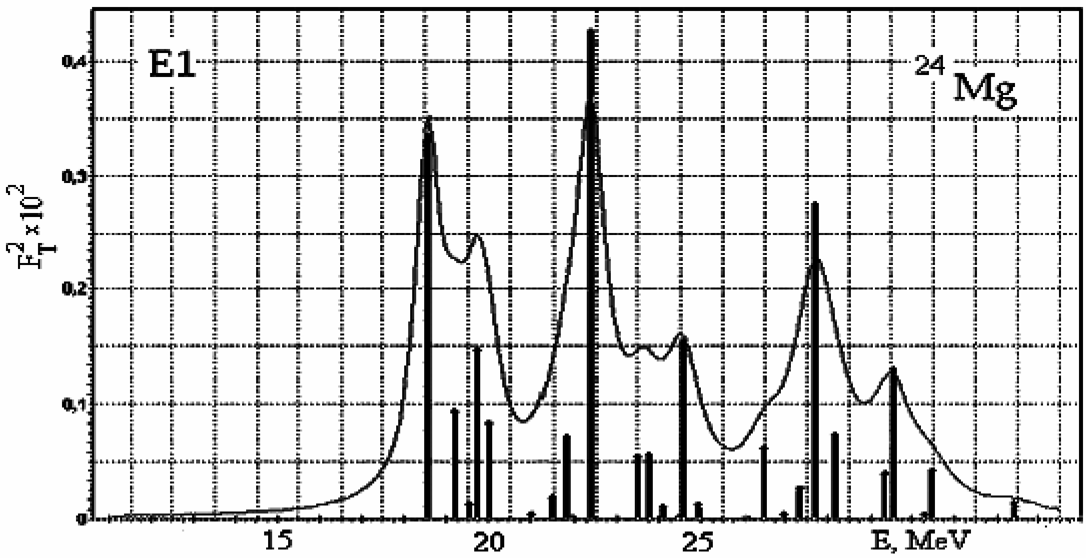

Fig.1. E1 distribution in ^{24}Mg at photopoint.

^{24}Mg as well as ^{23}Mg and ^{23}Na are strongly deformed. The information on deformed open shell nuclei embedded in direct reaction spectroscopy could be used in PCC for satisfactory interpretation of the MR characteristics in these nuclei.

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INVESTIGATION OF SPIN INFLUENCE ON FISSION FRAGMENTS ANISOTROPY BY COUPLED CHANNELS SPIN EFFECT FORMALISM

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An analysis of selected fission fragment angular distribution when at least one of the spins of projectile or target is appreciable in induced fission is made by using SSM. The results of this model predicate that the spins of projectile or target to be effected on nuclear level density of compound nucleus. Also the experimental data analysed with Couple Channel Spin Effect formalism. This formalism suggests that the projectile spin is more effective on angular anisotropies in limit of energy near fusion barrier.

COMPARISON OF THE FLUKA MODELS CALCULATIONS WITH EXPERIMENTAL DATA

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In the present paper, comparison of the FLUKA models [1] calculations with experimental data on separated isotopes $^{112,118,120,124}Sn$ at 1, 8.1 GeV [2,3] energy was made. In the FLUKA Monte Carlo code the hadronic interactions are simulated by different event generators, depending on energy:

- Energy < 20 TeV and > 4 GeV: Dual Parton Model (DPM).
- Energy between 3.5 and 4-5 GeV: Resonance production and decay model.
- Between 0.02 and 3.5 GeV: Pre-equilibrium-cascade model PEANUT.

All three models include evaporation and gamma deexcitation of the residual nucleus. Light residual nuclei are not evaporated but fragmented into a maximum of 6 bodies, according to a Fermi break-up model.

For comparison experimental and theoretical data we used the following parameter [4]:

$$H = 10^{\sqrt{\left\langle \left(\lg\left(\frac{\sigma_{ti}}{\sigma_{\exp i}} \right) \right)^2 \right\rangle}},$$

with standard fluctuation $S(\langle H \rangle) = 10^{\sqrt{a}}$, where $a = \left\langle \left(\left| \lg\left(\frac{\sigma_{ti}}{\sigma_{\exp i}} \right) \right| - \lg(\langle H \rangle) \right)^2 \right\rangle$, $\langle \ \rangle$ is the average of all data comparison ($i = 1 \ldots N_s$, where N_s - number of used experimental and theoretical data).

The results are presented in the table. The data analyses in 67 < A <110 region shows good agreement between experimental and theoretical data, except several nucleus. During formation that nucleus the isotope effect takes important part.

Table

Target	E_p=1GeV		E_p=8.1GeV	
	H	$S(\langle H \rangle)$	H	$S(\langle H \rangle)$
^{112}Sn			1.57	1.28
^{118}Sn	1.44	1.24	1.48	1.29
^{120}Sn	1.62	1.31	1.43	1.23
^{124}Sn	1.63	1.38	1.49	1.28

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DYNAMICS MODEL ANALYSIS OF FORWARD-ANGLE PROJECTILE-RESIDUES WITH 2<*Z*<11 INDUCED IN REACTION ^{18}O (35 MeV/u) WITH ^{9}Be

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The dynamics model calculations of forward-angle fragment production were performed in oxygen (^{18}O) induced reaction on ^{9}Be target with 35 *A*MeV energy (close Fermi energy) [1,2]. The calculations reproduce the general trends of experimental velocity, isotopic and element distributions. Besides the predominant of fragmentation for most of the products, the direct transfer process is still a very strong component for products nearby the projectile. The calculations shows that the reaction time on the dynamic stage at the intermediate energy is very short (up to $0.5 * 10^{-21}$ s). A survival of weakly-bound nuclei including the drip-line isotopes seems shows that the excitation energy of the projectile-like and target-like fragments is far from being shared in proportion to their masses (thermal equilibrium is not reached).

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pQCD PHENOMENOLOGY OF ELASTIC ed SCATTERING

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In recent few years new data from TJINAF on the *ed* elastic scattering were reported. They include the electric structure function, $A(Q^2)$, measured with high precision up to $Q^2=6(GeV/c)^2$ [1,2] and tensor polarization observables, t_{20}, t_{21} and t_{22}, up to Q^2=1.7(GeV/c)^2 [3].

This electron-deuteron elastic scattering data ($A(Q^2)$ and $B(Q^2)$ structure functions and polarization observables , t_{20}, t_{21} and t_{22}) are fit with a model that respects asymptotic properties of pQCD at high momentum transfer. The data analysis shows that pQCD starts from Q^2_{QCD}=3.5(GeV/c)^2. Predictions for the magnetic structure function $B(Q^2)$ (see figure 1)

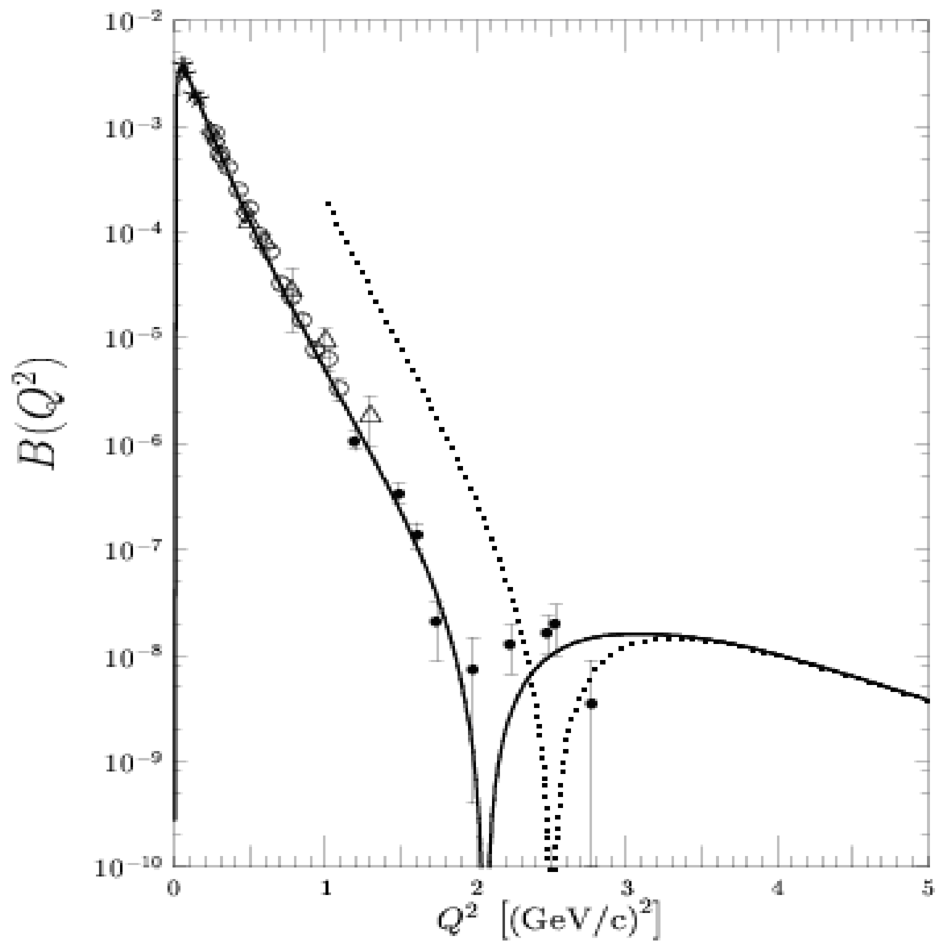

Figure 1.

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TO THE CALCULATION OF PROTON AND NEUTRON DISTRIBUTION IN FISSIONING NUCLEI

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In the frame of approach, developed in [1], were obtained equations for the distribution of protons and neutrons in fissioning nucleus:

$$\rho_p(r) = \frac{Z}{A}\rho_0 + \frac{\rho_0}{8a_{sym}}\left[<\Phi'_C> - \Phi'_C(r) + \delta\right] \tag{1}$$

$$\rho_n(r) = \frac{N}{A}\rho_0 - \frac{\rho_0}{8a_{sym}}\left[<\Phi'_C> - \Phi'_C(r) + \delta\right] \tag{2}$$

where $\rho_p(r)$, $\rho_n(r)$ and ρ_0 are proton, neutron and average material density in nucleus, Z, N and A are charge, neutron and mass numbers accordingly, a_{sym} energy of pair correlations [2], $\Phi'_C(r)$ is Coulomb potential of nucleus and $<\Phi'_C> = \frac{3}{4\pi A r_0^3}\int_0^{R_A}\Phi'_C(r)d^3r$, $R_A = r_0\sqrt[3]{A}$ with $r_0 = 1.2$ fm. More attention was paid to the additional, in compare with results of [1], term δ defined as:

$\delta = 2\alpha\left[<\Im> - div\left(\frac{\partial\overline{U}_\sigma}{\partial\rho_p} - \frac{\partial\overline{U}_\sigma}{\partial\rho_n}\right)\right]$, where $\overline{U}_\sigma$ is normal to the nucleus surface, expressing intensity of nuclear interaction on the nucleus surface, α is phenomenological parameter, describing influence of nuclear surface degrees of freedom on fission processes and $<\Im>$ is equal to: $<\Im> = \frac{3}{4\pi A r_0^3}\int_0^{R_A} div\left(\frac{\partial\overline{U}_\sigma}{\partial\rho_p} - \frac{\partial\overline{U}_\sigma}{\partial\rho_n}\right)d^3r$. Surface term was considered on the base of quantum theory of oscillation of surface degrees of freedom [3,4]. Equations (1)-(2) are solved numerically. Numerical stability of final results was investigated. Results of calculations are presented in tables and figures.

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CLUSTER COMPOSING IN NUCLEAR QUASI-FREE PROCESSES

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Many years passed since first steps were made [1-4] to reconcile clear evidence of the quasifree mechanism of cluster knockout nuclear reactions (*p,pd*), ($p,p\alpha$) and others, with the shell-model character of nuclear structure. Now we go deeper into clustering dynamics in nuclei with more attention to subnucleon aspects of nuclear structure. Taking into account recent progress in coincidence measurements on the quasi-free process ($p,d\pi^+$) [5,6], we investigate the potential of similar reactions with more complicated clusters such as ($p,t\pi^+$), ($p,{}^3\mathrm{He}\pi$), ($p,{}^3\mathrm{He}\eta$) and ($p,\alpha\ \pi$) [7] where α-particle, triton or ^{3}He-cluster is produced (together with a pion or, even, η-meson) as being composed of lighter fragments in the very act of its knock-out from nucleus. At the moment we concentrate on three main aspects of the problem:

a) to stimulate experimental investigations on the new line, a number of typical examples on cluster composing reactions are considered to estimate the order of magnitude of corresponding cross-sections and specific features of expected cluster-meson angular correlation functions;

b) taking into account that such processes as $p+p\to d+\pi^+$, $p+d\to t+\pi^+$, $p+d\to {}^3\mathrm{He}+\eta$ become a subject of growing regular studies in particle and few-body physics [8-11], we put a special attention to investigate possibilities to use complex nuclei as a selector of competing mechanisms in corresponding "elementary" cluster composing processes;

c) in perspective, we orient our study to possible experiments with polarized proton beams or polarized reaction products; this forces us to overcome simplifications of the DWIA approach due to the procedure of factorization of the reaction cross section widely used in practice of performing calculations in physics of cluster knock-out reactions.

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ACTINIDE NUCLEON-INDUCED FISSION UP TO 200 MeV: CROSS SECTIONS, PROMPT FISSION NEUTRON SPECTRA AND MULTIPLICITIES

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Actinide nucleon-induced fission cross sections are analyzed in a fission/ evaporation approximation [1] up to E_n=200 MeV. Influence of the pre-fission neutron emission on the fission observables, i.e., fission cross sections, prompt fission neutron spectra and multiplicities is investigated. Competition of symmetric and asymmetric fission at high intrinsic excitations is analyzed. The symmetric SL-mode and lumped asymmetric (S1+S2)-mode fission cross sections of ^{238}U(*n,f*) reaction are analyzed up to 200 MeV. Ratio of the symmetric to observed neutron-induced fission events probes the contributions of emissive fission chances with high and low number of pre-fission (*n,xnf*) neutrons to the fission observables, i.e. cross sections, yields and neutron multiplicities.

Exclusive pre-fission (*n,xn*f) reaction neutron spectra are calculated within Hauser-Feshbach statistical model for incident neutron energies up to 20 MeV. The prompt fission neutron spectra (PFNS) component due to the pre-fission neutrons is distinguished in shape of the measured PFNS data. Its contribution is compatible with the experimental estimates of the average energies of PFNS [2] for neutron-induced fission. The dependence of the pre-fission neutron contribution on the target nuclide fissility and E_n is shown to be pronounced in PFNS shapes. Pre- and post-fission neutron emission contributions are investigated and compared for neutron-, proton- and heavy-ion –induced fission.

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TENZOR FORCES ACCOUNTING IN THREE PARTICLE CALCULATION OF ^{8}Li NUCLEUS

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In work [1] we have calculated ^{8}Li nucleus in three-body αtn-model. In wave function of ground state three configurations with $\lambda=l=1$, where λ-orbital momentum in αt-system, and l-orbital momentum between neutron and αt-system centre mass, were taken into account. Configurations differ among self by total orbital momentum L and total spin momentum S. As expected, main contribution to wave function of ground state gave configuration with λlLS=1111, because λ=1 correspond to bound state of ^{7}Li nucleus. In spite of theory gave binding energy, spectrum of low lying levels, mean square radius and magnetic momentum reasonable values, it mark down in half as much again quadrupole moment of ^{8}Li-nucleus. In work [2] we have enlarged basis dimension to 7 configurations, by including states with $\lambda=3$, $l=1$ and $\lambda=1$, $l=3$ with various possible values L and S. Difference between Q_{theor}. и $Q_{exp.}$ remained , thou shorten to 30%.

For improvement of agreement between theory and experiment we have included in consideration tensor forces between various pairs of clusters. As known these forces lead to mixture of states with various values of orbital momentum. For example, only with its help it is explained big life time of ^{14}C nucleus relative to β=decay. By inclusion of tensor forces the correct value of deuteron quadrupole moment was obtained and nonadditivity of magnetic moments in deuteron is explained. In a ^{8}Li nucleus tensor forces have increased weight a component with LS=21, which give the considerable contribution to value of the quadrupole moment. Thus the account of tensor interactions in a tn-channel has resulted in deterioration of bound energy and useful increase of the quadrupole moment as contrasted to its experimental value. Vice-versa, the tensor forces between an α-fragment and triton have improved the consent of the theory with experiment both for bound energy, and for the quadrupole moment. Thus the quality of the description of mentioned above other characteristics of a nucleus remained approximately same.

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FUNDAMENTAL INTERACTIONS IN NUCLEAR PHYSICS

REMARK ON STATE VECTOR CONSTRUCTION WHEN FLAVOR MIXING EXISTS

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In the framework of quantum field theory, we consider the way how to construct properly the one particle state (with definite 3-momentum) when the particle mixing exists such as in the case of flavor neutrino.

In the preceding report [1], we have examined the structure of expectation values of the flavor-neutrino charges (at time t) with respect to a neutrino-source state prepared at time t' (earlier than t). When there is no mixing among neutrinos, each of various contributions to the expectation value is equal to the transition probability corresponding to respective neutrino-production process. On the basis of the assumption that such an equality holds also in the mixing case, we can find an appropriate form of one flavor-neutrino state with 3-momentum and helicity.

In the present report, we examine along the same way as in the neutrino case, how to construct the one-boson state when the flavor mixing exists. After finding an appropriate form of the state vector similarly to the fermion case, it is pointed out that a special prescription is necessary for the state vector normalization, i.e. for the inner product of the state vectors at the same time. The inner product for two state vectors of one (pseudo-)scalar particle at different times, which can be calculated by employing the inner product for the same – time state vectors, leads to the typical oscillation formula obtained usually from the quantum mechanical consideration.

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ASTROPHYSICAL FACTOR FOR THE ^{11}B +p REACTION EXTRACTED BY MEANS OF THE TROJAN HORSE METHOD

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Lithium, berillium and boron abundances are among the best probes for primordial nucleosynthesis and stellar mixing mechanisms [1]. For a better understanding of these scenarios, bare astrophysical *S(E)*-factors of several reactions involving these isotopes, are needed. The ^{11}B(p,α)^{8}Be reaction has been studied from 1 MeV down to sub-Coulomb energies by means of the Trojan Horse Method (THM) [2,3] applied to the ^{11}B(d,α^{8}Be)n three body reaction performed at an incident energy of 27 MeV. The astrophysical *S(E)*-factor for this process was extracted from the three body reaction cross section at low spectator momentum and compared with the behaviour of the free two-body reaction data for the energy region where they are available [4]. In the present work updated information on the low energy bare-nucleus *S(E)*-factor are extracted by means of modified plane wave Born approximation [5]. The results are compared with the previous analysis via PWIA [6] and direct measurements [4].

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RESONANCE INTERNAL CONVERSION AS A WAY OF ACCELERATING NUCLEAR PROCESSES

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Theory of resonance conversion is presented. Being a natural extension of the traditional internal conversion into the subthreshold area, resonance conversion in a number of cases strongly affects the nuclear processes. Moreover, concentrating the transition strength on the narrow bands corresponding to the spectral atomic lines, it offers a unique tool capable to accelerate nuclear decay rates. Furthermore, along with the conventional nonradiative process of nuclear excitation through NEET and its reverse, TEEN, resonance conversion offers an appropriate mathematics for consideration of a number of cross-invariant processes involving both nuclei and the electrons: excitation and deexcitation of the nuclei by hyperfine magnetic field, nuclear spin mixing, hyperfine interaction and magnetic anomalies in the atomic spectra, collisional nuclear excitation via ionization of the shells, in the muon decay in the orbit etc. The mechanisms of the optical pumping the isomers are also considered , as well as triggering their energy in the resonance field of a laser. The effect is especially high in the hydrogen-like heavy ions due to practical absence of any damping of the resonance. The theory is also generalized to the case of the discrete Auger transitions.

MEASUREMENT OF THE MUON CAPTURE RATES FOR DOUBLE BETA DECAY

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As it was mentioned in [1], Nuclear Matrix Elements (*NME*) of two different processes - Double Beta Decay and Ordinary Muon Capture - are closely connected. That is why our measurement of the μ-capture rates (especially, partial rates) provides an experimental input to the $NME_{2\beta}$ calculation, precision of which is very important from the point of view of recent 2β results [2] and future 2β projects [3].

The most promising (from the $Q_{2\beta}$-value point of view) candidates for 2β-experiments are: ^{48}Ca, ^{150}Nd, ^{96}Zr, ^{100}Mo, ^{82}Se, ^{116}Cd, ^{106}Cd, ^{130}Te, ^{136}Xe, ^{136}Ce and ^{76}Ge. In addition to ^{48}Ca and ^{48}Ti investigated in our previous works [4], in our 2004' experiment at PSI we have done precise measurements of γ-rays following OMC in isotopic-enriched ^{76}Se and ^{106}Cd, as well as natural Se and Cd targets. Supposing that the main reaction channel is the (μ^-, $x_\mu n$) one, and analyzing time-evolution of well-identified γ-lines, we can extract the total muon capture rates with a precision at the level of 1% separately for each isotope from the natural mixture. Table show our preliminary results for some Se isotopes.

On the other hand, to get partial rates, it is really necessary to analyze the detailed balance of the γ-intensities for the (μ^-, $x_\mu n$) channel not distorted by the presence of (A+1)-isotope in the target. Such analysis of the enriched ^{76}Se and ^{106}Cd data is in progress.

Isotope	γ-line	Total rate [10^3/s]	τ [ns]
^{76}Se	183 keV	6715 ± 66	148.92 ± 1.46
	199 keV	6728 ±25	148.62 ± 0.54
	265 keV	6740 ± 20	148.36 ± 0.45
	279 keV	6748 ± 22	148.18 ± 0.48
^{77}Se	165 keV	6110 ± 53	163.66 ± 1.43
^{78}Se	215 keV	6017 ± 50	166.20 ± 1.39
^{80}Se	100 keV	5278 ± 84	189.45 ± 3.02
	109 keV	5383 ± 59	185.76 ± 2.04
^{82}Se	336 keV	4847 ± 130	206.33 ± 5.54

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SPIN EFFECTS AS TESTS FOR STANDARD ELECTRO-WEAK AND (V - A) – MODELS OF (ANTI)NEUTRINO-ELECTRON SCATTERING (II)

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In the present work, a development of [1], the elastic νe and $\tilde{\nu}e$ scatterings are investigated on the basis on the standard electroweak model (SM) and the low-energy ($V-A$) – mechanism for diagonal lepton processes.

The differential cross sections taking into account the possible interference of the amplitudes of neutral and charge currents are analyzed. Its contribution is estimated by the ratios

$$K_{1(2)} = \left[\frac{d\sigma(\nu_e(\tilde{\nu}_e)e)}{d(\cos\alpha \text{ or } y)}\right]_{SM} \Bigg/ \left[\frac{d\sigma(\nu_\mu(\tilde{\nu}_\mu)e)}{d(\cos\alpha \text{ or } y)}\right]_{SM},$$

$$K_{3(4)} = \left[\frac{d\sigma(\nu_e(\tilde{\nu}_e)e)}{d(\cos\alpha \text{ or } y)}\right]_{SM} \Bigg/ \left[\frac{d\sigma(\nu_e(\tilde{\nu}_e)e)}{d(\cos\alpha \text{ or } y)}\right]_{V-A}$$

Here α is the angle between the initial (anti)neutrino and recoil electron, $y = T/E_\nu$ determines the (anti)neutrino energy fraction transferred to the electron at scattering.

The orientations [2] of the neutral lepton momentum and the final electron along (+;+) or opposite (−;−) to the polarization vector $\vec{\eta}_e(\vec{\eta}_e')$ of the target (recoil) electron and also the case of perpendicular vectors (0; 0) are analyzed. The different versions of the mutual orientation of the vectors have an influence on the angular and y - distributions of the electron (see, for example, fig. 1, 2; $E_\nu = 10 MeV$).

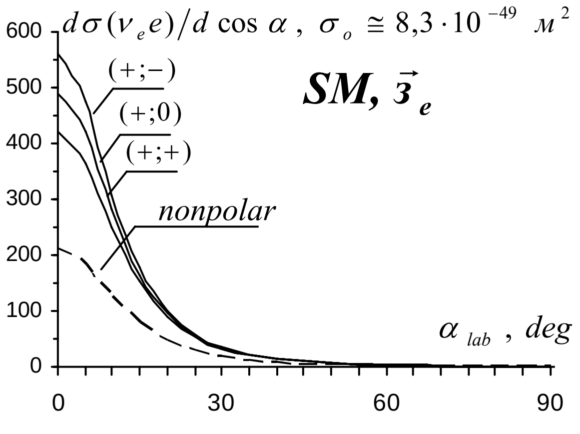
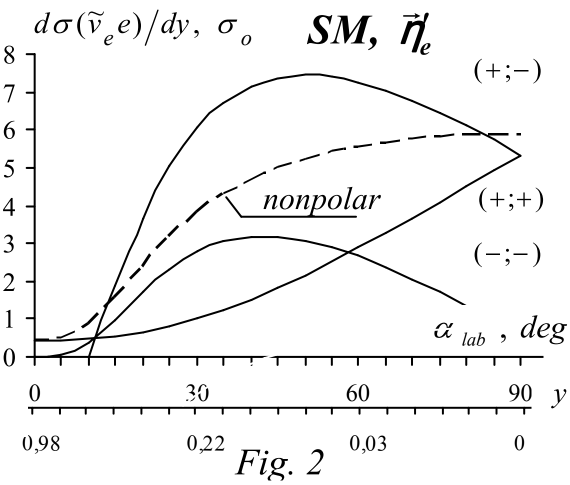


Fig. 1



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ANAPOLE AND NEUTRAL WEAK MAGNETIC MOMENTS OF THE PROTON IN ELASTIC ELECTRON-PROTON ELECTROWEAK SCATTERING

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Study of the parity violation in the polarized electron scattering, especially in the elastic electron-proton scattering, provides unique possibility to obtain new information about fundamental interactions and electroweak structure of the nucleon. Important role here play detailed theoretical and experimental (the SAMPLE, HAPPEX, MAINZ collaborations) investigations of the spin asymmetries which give opportunity to determine the contribution of the strange quark pairs $(\bar{s}s)$ to charge and magnetic moment distributions in the proton.

In this work as a further continuation of [1], we present analytical expressions for right-left polarization asymmetry A_{RL}, and asymmetry A_p on the target proton spin orientation in the elastic electroweak scattering $e^-_{L,R} + p \xrightarrow{\gamma, Z^0} e^- + p$ and $e^-_{L,R} + p(\vec{s}) \xrightarrow{\gamma, Z^0} e^- + p$ with account of electroweak form factors, including anapole moment and neutral weak magnetic (NWM) proton's form factors $G_{1p}(q^2)$ and $f_{Vp}(q^2)$. The latter is connected with strange quark content $(\bar{s}s)$ of the proton.

Particularly, for the asymmetry A_{RL} we have found

$$A_{RL} = A_{RL}^{W\gamma} + A_{RL}^{anapole} = \frac{\delta\omega y}{D(\omega, y)}\left\{ g_{Ae} G_{Ep} g_{Ep}\left(1 - y - \frac{y}{2\omega}\right) + \right.$$

$$\left. + \frac{\omega y}{2} G_{Mp}\left[g_{Ae} g_{Mp}\left(1 - y + \frac{y^2}{2} + \frac{y}{2\omega}\right) + g_{Ve}\left(g_{Ap} + \frac{4}{\delta}\frac{G_{1p}}{g_{Ve}}\right)\left(1 - \frac{y}{2}\right)\left(y + \frac{2}{\omega}\right)\right]\right\}.$$

Here $\delta = \frac{G_F m_p^2}{\pi\alpha\sqrt{2}}$, $D(\omega, y) = \left[G_{Ep}^2\left(1 - y - \frac{y}{2\omega}\right) + \frac{\omega y}{2} G_{Mp}^2\left(1 - y + \frac{y^2}{2} + \frac{y}{2\omega}\right)\right]$, $\omega = E/m_p$ – energy of the incoming electron measured in proton mass; $y = E_k/E$, E_k – kinetic energy of the recoil proton; G_{Ep} and G_{Mp} – electromagnetic proton's form factors; $q^2 = -2m_p^2\omega y$; $g_{Ep} = g_{Vp} + \frac{q^2}{4m_p^2} f_{Vp}$, $g_{Mp} = g_{Vp} + f_{Vp}$.

Asymmetries A_{RL}, and A_p are studied in dependence of the electron scattering angles, as well as parameters of the anapole and NWM form factors of the proton.

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WEAK HADRONIC INTERACTION AS PROBE OF NUCLEAR STRUCTURE

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Many-body systems such as compound nuclei with dense spectrum of excited levels are preferable for the measurements of parity violating (PV) effects because of huge enhancement (up to 10^6) of these effects [1,2]. On the other hand, the complexity of the compound nucleus resonance structure hinders dramatically the interpretation of available experimental data concerning the isospin structure of the weak nucleon-nucleon (*NN*) interaction (strangeness-conserving hadronic weak process). Recent experiments (see review [3]) have demonstrated, for the first time, the non-statistical behavior in the sign of the PV effects.

In this presentation we advance the idea that this non-statistical behavior is a deterministic property for all neutron induced reactions. We found that the sign of PV effects can be solely explained by the signs of the strong interaction amplitudes, which depends on the specific structure of a nucleus (location of *s*-, *p*-resonances and neutron energy, spin-factor, parity of p-resonance, resonance phases [3,4], etc.). That means that the sign associated with the weak interaction is constant for all these cases. This surprising fact does not contradict current experimental data. However, it does require some theoretical explanation.

At low energies, *P*-odd nuclear forces are described by a set of six constants that determine the exchanges of π, ρ and ω mesons between nucleons [5,6]. Such exchanges correspond to weak charged and neutral currents and are governed by the isospin selection rules $|\Delta T|=0, 1, (2)$.

It is well known [7,8] that the contribution of $|\Delta T|=1$ weak neutral currents to *P*-odd nuclear forces is strongly suppressed. According to the estimates presented in [9], the isotensor interaction ($|\Delta T|=2$) makes a small contribution that vanishes upon summation over the nucleon core. It follows that it is the isoscalar component of the weak nucleon-nucleon interaction that predominantly manifests itself in neutron induced reactions [4]. This means that, if the isospin of the neutron resonances being mixed are the same, the formation of the effect is always controlled by the same set of constants, which yields the same sign of weak interaction in agreement with experimental data [3].

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ANALYTICAL APPROACH TO CONSTRUCTING EFFECTIVE NUCLEON-NUCLEON POTENTIALS IN AN ARBITRARY ANGULAR MOMENTUM STATE

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It is now widely believed that QCD is fundamental theory of strong interactions. However, due to formidable mathematical problems raised by the non-perturbative character of QCD at the low and intermediate energies, we are still far from a quantitative understanding of hadron-hadron interactions from this point of view. The path-integral method together with idea of spontaneous violation of chiral invariance leads to effective field theory (EFT), which formulates the problem in terms of meson and baryon (anti-baryon) degrees of freedom. The Lagrangian of EFT is very complicated. Therefore in practice the decomposition of this Lagrangian in power series on relative momentum of particles is used and in this approximation the theory refers to as chiral perturbation theory (ChPT) [1]. Unfortunately ChPT can be applied to description of strong interactions only at very low energies. In our recent work [2] the new relativistic approach to constructing the hadron-hadron effective interaction operators, based on analytic theory of *S*-matrix and the methods of inverse scattering problem, was suggested. For description of dynamics of the NN-interaction we use the relativistic three-dimensional equation of quasi-potential type, which can be obtained by reconstruction of initial Bethe-Salpeter equation. The basic idea of the suggested approach is to define effective potential as such operator in the three-dimensional partial-wave equation, which generates relativistic on-mass-shell scattering amplitude, having required discontinuities on dynamic cuts. Specified discontinuities of the partial-wave scattering amplitudes can be calculated by methods of the relativistic quantum field theory with the help of various dynamic approaches. In the present work the new method to constructing effective nucleon-nucleon interaction operators in an arbitrary angular momentum state, based on the Marchenko type equation [3], is developed. The method is applied to constructing effective nucleon-nucleon potentials in ${}^1P_1$-, ${}^3P_1$- and ${}^3P_0$-partial-wave states. The theoretical predictions for phase shifts are obtained at kinetic energies of incident nucleon up to 1.5 GeV.

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COMBINED STUDY OF NUCLEAR DATA AND PARTICLE MASSES

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Correlation analysis of nuclear binding energies and excitations [1, 2] which enables to determine a common tuning effect was continued. Relations in values of stable energy intervals are compared with the known parameters of the Standard Model (SM) - masses of fundamental fermions, bosons and QED parameters $\alpha=137^{-1}$ and $\alpha_Z=129^{-1}$.

According to Y.Nambu [3] empirical relations in SM-parameters could be helpful at this stage of a theory. A mass problem is a first signal about the unfinished state of SM. It was noticed that a ratio between the SM-parameters $m_\mu/M_Z=1.159\times10^{-3}$ is close to the QED radiative correction $\alpha/2\pi=1.16\times10^{-3}$ and to the ratio between the electron mass m_e and the parameter M_q=441MeV=$3\Delta M_\Delta$ ($m_e/3\Delta M_\Delta=1.159\times10^{-3}$) introduced by R.Sternheimer as 1/3 of the mass of Ξ-hyperon and as equal intervals in particle masses m_η-m_μ, m_η-$m_K{}^o$ and m_Σ-m_n=$3\Delta M_\Delta$, where $2\Delta M_\Delta$ is the nucleon Δ-excitation. The value M_q corresponds to a half of nucleon "stripped" mass ($M_N{}^{strip}\sim$ 880 MeV from the lattice calculations) and to 1/3 of the initial baryon mass ($M_N{}^{init}\sim$1350 MeV close to Ξ^- -hyperon mass 1324 MeV) in the constituent quark models with Goldstone-Boson exchange. The estimation of relations (2:6:9) between the nucleon parameters: Δ-excitation, $M_N{}^{strip}$ and $M_N{}^{init}$ could help in understanding of exact relations in SM-parameters. In Table [2] these values related to each other by $\alpha/2\pi$ and $\alpha_Z/2\pi$ are marked by asterisk.

Fundamental information from files of nuclear data [4] will be discussed.

Table. Representation of parameters of tuning effect in nuclear data and particle masses by expression $(n\mathrm{x}16m_e(\alpha/2\pi)^x)\mathrm{x}m$. Two asterisks mark stable nuclear intervals [1, 2]

x	m	n=1/8	n=1	n=13	n=16	n=17	n=18
-1	1			M_Z = 91.2	M_H = 115		
GeV	3				*$2m_t$ = 348		
0	1	e_0	$16m_e$	$m_\mu+m_e$		$m_\pi-m_e$	147=ΔM_Δ, ΔE_B
MeV	3				$m_\omega/2$	*420=M_q’	*441=M_q,, ΔE_B
1	1	1.2**	9.48**	123**	152**	161**	170**
keV	3			368**	455**	481**	*511=e_0/2=m_e
	8	9.5**	76**	964	1212	1293=D_0	
2	1		11**	143**	176**	187**	
eV	4	5.5**	44**	572**		750**	

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EFFECT OF THE OUTER MAGNETIC FIELD DIRECTION ON THE MÖSSBAUER ABSORPTION OF THE LONG-LIVED ISOMER ^{109m}Ag GAMMA RAYS

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The surplus absorption was observed earlier in several works [1-5] of ^{109m}Ag isomer gamma-rays of 88 keV energy at 4.2K temperature in single crystal silver plates served as gamma-sources and absorbers simultaneously. This surplus self-absorption was ascribed by authors to the Mössbauer effect which revealed itself after cooling of silver. In our work two experiments were performed with single crystal and polycrystalline silver gamma-sources. The effect was observed on the gamma-ray resonant self-absorption of the direction change of magnetic field affected on the gamma-sources. This influence is connected with the dependence of different components of Zeeman hyperfine structure of gamma-ray microspectrum on the angle between the direction of gamma-quantum emission and the magnetic field strength vector. This effect was calculated quantitatively for the ^{109m}Ag case in [6]. The experiment consisted in the intensity measurements of ^{109m}Ag 88 keV and control gamma-source ^{241}Am 59.54 keV gamma-lines at temperatures 295, 77 and 4.2K in horizontal and vertical directions by two Ge-detectors. The periodic switching on and off of a pair of Helmholtz rings was used for compensating of Earth's magnetic field vertical component. The corresponding change of field direction must in accordance with [6] lead to the alteration of resonant absorption cross section by 60 %. The experimentally observed relative changes of 88 keV gamma-ray intensities in horizontal gamma-beam at 4.2 K are equal to $(4.8 \pm 2.5)\times10^{-4}$ for polycrystalline gamma-source and $(6.8 \pm 4.0)\times10^{-4}$ for single crystal one. Such influence was not observed on ^{241}Am gamma-ray yields at all temperatures in both gamma-beams and on ^{109m}Ag gamma-rays at heightened temperatures and at 4.2K in vertical gamma-beam, where resonant absorption is suppressed by gravitation. These data corresponds to the broadening factors of ^{109m}Ag Mössbauer gamma-line equal to 22^{+29}_{-8} for single crystal gamma-source and 22^{+23}_{-7} for polycrystalline one. These results and the data of previous works also tell in favour of anomalously small broadening of gamma-line as compared with theoretical estimate of broadening factor as $\sim 10^5$.

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CO-OPERATIVE NUCLEAR SUPERRADIATION

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According to our previous experimental results[1, 2], the isolated events of *induced gamma emission* (IGE) take place in *M4*-transitions of long-lived nuclear isomers ^{123m2}Te, ^{125m2}Te, and ^{119m2}Sn. This is true when proper radioactive solid matrix is cooled down to a “Mössbauer temperature”. Under these conditions, the additional *M4* γ-quanta come into existence in transitions $11/2 \rightarrow 3/2$, and not just the spontaneously emitted γ-quanta. It is important that an appearance of these super-spontaneous γ-quanta occurs in form of the “clasters” involving up to 10 photons [2]. Examination of experimental data leads us to recognize that appearance of the low-temperature super-spontaneous γ-quanta is a result of *co-operative nuclear superradiation* (CNSR). A mathematical model of the CNSR is presented in [3].

The calculated for a dipole radiation theoretical IGE yield is consistent with experimental IGE yield measured on BeTe matrix but no on the Mg(*Te)O matrix. In the latter case the dipole theoretical yield was found to be less than experimental yield by a factor 10^5-10^7. To eliminate this discrepancy, the IGE theory was corrected in view of a hexadecapole character of the M4 γ-quanta. Other than these, several new experiments were performed in order to exclude any doubt upon the appearance of super-spontaneous γ-quanta in cooled matrix Mg(*Te)O. The essence of these experiments is an immediate measurement of the decay constant, λ, of nuclear isomer *Te in cooled matrix Mg(*Te)O.

1st experiment: radioactive source Mg(^{123m2}Te)O with activity *A*=3MBk. Decay rate in the source the whole time thermostated at 78K is higher by factor 1.018±0.002 than a decay rate in identical source the whole time thermostated at 300K. That is, low temperature increment is equal to $(\Delta\lambda/\lambda) = (1.8 \pm 0.2)\%$.

2nd experiment: the same radioactive source Mg(^{123m2}Te)O, except that its activity is equal to *A*=0.7 MBk. The low temperature increment is equal to $(\Delta\lambda/\lambda) = (0.4 \pm 0.2)\%$

3rd experiment: radioactive source Mg(^{121m2}Te)O with activity *A*=0.8 MBk. The low temperature increment is equal to $(\Delta\lambda/\lambda) = (0.5 \pm 0.2)\%$.

Since increment $\Delta\lambda/\lambda$ is activity dependent, the measured appreciable increase in decay rate constant, λ, can not be a result of low temperature rise of the internal conversion probability. The same conclusion results from the dependence of increment $\Delta\lambda/\lambda$ on the energy of γ-quanta *M4*. It remains to adopt a single reason, namely, CNSR.

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SEARCH FOR THE SOLAR AXION EMITTED IN THE *M1*-TRANSITION OF $^7Li^*$

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The solution to the strong CP problem of QCD proposed by Peccei and Quinn has the consequence that a new pseudoscalar particle, the axion, should be emitted in the nuclear magnetic transitions. One of the main solar reactions $e^- + {}^7Be \rightarrow {}^7Li + \nu$ leads to $^7Li^*$ with 0.1 branching as shown in the inset of fig.1. The flux of axions emitted in the 478 keV *M1*-transition is proportional ^{7}Be-neutrino flux which is $4.8 \cdot 10^9$ $\nu/(cm^2c)$ at the Earth surface. The near-monochromatic axions can excite the same nuclide in a laboratory $\alpha + {}^7Li \rightarrow {}^7Li^* \rightarrow {}^7Li + \gamma$, because the axions are Doppler broadened the hot core of the Sun.

To search for the resonant absorption of the solar axions by nucleus of ^{7}Li leading to the excitation of the first nuclear level the energy spectrum of the 160-cm^3 HPGe-detector surrounded of 3.9 kg with layer LiOH have been measured.The high-resolution HPGe-detector and LiOH target were mounted inside a special low-background set-up consisting passive shielding and active plastic scintillators. Both spectra in a anticoincidence and in a coincidence with active shield were recorded, the late to evaluate $^7Li^*$ production by cosmic radiation. The 450-500 keV interval corresponding 127 days of data taking are shown in figs.1, 2.

The probability of emission (absorption) of the hardronic axion in *M1*-transition is proportional m_a^2. Taking into account this dependence and the intensity of the 477.6 keV γ-peak, the new upper limit on the axion mass $m_a \leq 16$ keV (90% c.l.) was obtained. This result is two times stronger than obtained in the previous works and practically closes the allowed region of axion mass up to *M1*-transition of ^{57}Fe (14.4 keV). Our preliminary results were published in [1].

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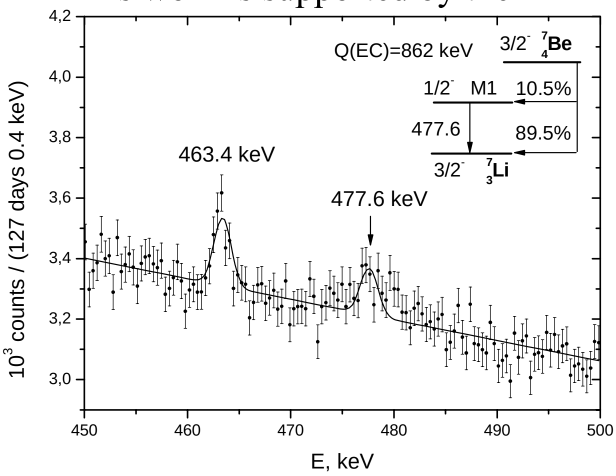

Fig.1 The spectrum measured in coincidence with cosmic veto. In inset decay scheme of ^{7}Be is shown.

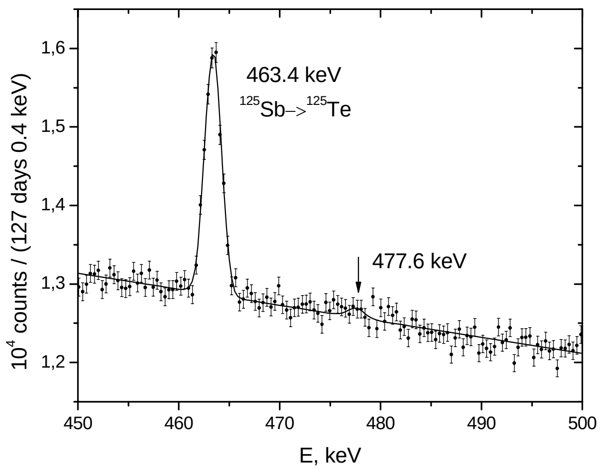

Fig.2 The spectrum measured in anticoincidence with cosmic veto. Intensity 478 keV peak is 630±320 counts.

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STIMULATION OF WEAK PROCESSES BY SYNCHROTRON RADIATION

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The objective of the study is to explore theoretically a possibility of nuclear beta decay stimulation. In contrast with the papers in which the exposure of laser radiation on beta decay was considered the influence of electromagnetic field directly on a nucleus but not on a beta particle is investigated. A sufficiently intensive flow of high-energy photons (with energy above 60 keV) from a modern synchrotron gives this opportunity. Synchrotron radiation parameters of the most powerful source with a wide area of a high-power spectrum (due to Spring-8 synchrotron wiggler (Japan)) are used in our calculation. The rate estimations of the stimulated beta processes are made on a physical mechanism basis of photobeta decay with an exact account of Coulomb field in the final and intermediate lepton states [1].

Two cases are considered here: endothermic beta decays of stable nuclei and natural high-forbidden beta decays of nuclei. In the first case stable nuclei with a relatively moderate energy threshold are taken into consideration (nuclei ^{68}Ga, ^{163}Dy, $^{178, 181}$Ta, ^{179}Hf). Depending on the magnitude of the energy threshold the rate of stimulated beta decay has the magnitude order typical of the second-forbidden beta decays (nucleus ^{163}Dy with a very small energy threshold of 2.5 keV) or for the third-forbidden beta decays (the rest of the nuclei with the energy thresholds from 90 to 190 keV). In the second case the second-forbidden beta decays (nuclei ^{129}I, ^{135}Cs), the third-forbidden beta decay (nucleus ^{87}Rb) and the fourth-forbidden beta decay (nucleus ^{115}In) are investigated. In these cases the synchrotron radiation influence will increase the rate of a natural forbidden beta decay. The beta decay rate of nucleus ^{87}Rb is increased by 2% that is greater than an experimental error (< 1 %) and the beta decay rate of nucleus ^{115}In is increased by nearly two magnitude orders, in particular. For the second-forbidden beta decays the changes of the beta decay rates are slight ($< 2 \cdot 10^{-3}$ %).

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ON ROLE OF WEAK INTERACTION IN *p*-NUCLEUS SYNTHESIS

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The formation process of *p*-nuclei (or bypassed elements) at the quasiequilibrium stage of massive star evolution is investigated. It is known that in *s*-process of standard theory of element synthesis [1] the chain of consecutive beta decays usually comes to a sudden end in the formation of beta-stable nucleus (A, Z) (A and Z are, respectively, its mass and charge numbers). A further beta transition of $(A,Z)\rightarrow(A,Z+1)$ proves to be impossible because the energy threshold divides (A,Z) and $(A,Z+1)$ nuclei. To surmount this the following beta transition of $(A,Z+1)\rightarrow(A,Z+2)$, where $(A,Z+2)$ is beta-stable *p*-nucleus, can, as a rule, be fulfilled in a natural way. Two following physical mechanisms to surmount the above mentioned energy barrier in the heated substance of a star are proposed. One of them is endothermic beta decay of beta-stable nucleus (A,Z) stimulated by the electromagnetic field of Planck frequency spectrum (photobeta decay) [2]. The other mechanism is natural beta transitions between the excited states of (A,Z) and $(A,Z+1)$ nuclei above the energy threshold. The latter process also becomes possible since nucleus excited states will be populated in the medium where the temperature is of the same magnitude order as nuclear temperatures ($T \approx 0.1 \div 0.5$ MeV). The analysis of the energy-level diagrams for the nuclei participating in *p*-element production shows that in both cases the most intensive beta transitions of the allowed type predominate.

The objective of the present study is to investigate the possibility of the 33 *p*-nucleus synthesis within the two indicated above mechanisms. The stage of hydrostatic oxygen combustion in a massive star interior is considered (the matter temperature is $T = 2.5 \times 10^9$ K, the stage duration is about six months). It is established that the indicated physical mechanisms can contribute significantly to the process of synthesis at least to 21 *p*-nuclei. It is essential that the natural β transitions between the excited states of nuclei above the energy threshold usually contribute more to the process of synthesis than the photobeta decay process. This result may be important for a standard theory of nucleosynthesis [1] because in a hot star matter there appear new channels of the allowed beta decays in the chains of kinetic equations. It is especially important in case beta transitions from the ground states of the parent nuclei are high-forbidden transitions.

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NUCLEAR COMPOSITION AND TRANSMUTATIONS IN ULTRAMAGNETIZED ASTROPHYSICAL PLASMAS

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Ultra-magnetized astrophysical objects were invoked to interpret an activity of, e.g., soft gamma repeaters (SGRs) and anomalous *X*-ray pulsars (AXPs). Upon the pioneering discovery [1] of famous 05.03.1979 event, various observations brought numerous evidences in support of such a `magnetar' concept implying, thereby, enormous stellar magnetic fields of a strength ranging up to 10^{18} *G*. As discussed recently [2] such magnetization can dramatically modify the nuclear structure, reactions and, consequently, influence a formation of chemical elements.

In this contribution we consider such magnetic effects in nuclide creation and transmutation processes. The theory of nuclear statistical equilibrium (NSE) is used extremely successfully for the description of abundance of the most tightly bound atomic nuclei (i.e. transition metals of iron group and nearby nuclides) for over half a century. Then the portion Y_i of *i*-ths nuclear spices at a temperature *T* is mainly determined by respective binding energy *B* through the Saha relation [2]. Since shell effects dominate magnetism of atomic nuclei we exploit the field dependence of shell correction energy to examine nucleosynthesis in the ultra-magnetized astrophysical plasma. As demonstrated oscillations of nuclide yields as a function of field strength represent perhaps the most interesting magnetic phenomenon. The magnetic change in nuclear structure results in rather different field dependence of relative abundances for, e.g. ^{44}Ti and ^{56}Ni. At increasing strength *H* in the range of relatively "weak" fields the production of ^{56}Ni is suppressed, while the portion of ^{44}Ti grows. Such a behavior is related to magic-antimagic switching in nuclear shell structure at varying magnetization [2].

The transmutations of chemical elements exposed under a neutron flux are considered to form heavy nuclides beyond iron region. We analyze respective key nuclear reactions represented by neutron radiative capture on ultra-magnetized atomic nuclei. By employing the Hauser-Feshbach statistical model the important magnetic effects are argued to originate from modifications of reaction Q-values and nuclear level densities due to change in nuclear structure discussed above. The magnetic effects in nuclear levels give rise to oscillations of n-capture cross-section around an average value. The magnetic contribution to Q-value is found to speed up nuclear reaction rates [2] and, accordingly, reduces a time for SE establishment. Such properties give rise to magnetic shift of r-process path with increasing portion of heavy nuclides and large magnetic moment.

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POSSIBLE MECHANISM GENERATING GAMMA-RAY BURST

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Gamma-ray bursts (GRBs) are the most energetic phenomena that occur in the universe. GRBs has been identified as being cosmological in origin, implying energy outputs on the order of 10^{51} to 10^{53} ergs released within a time scale of seconds [1]. One of the most popular models for GRBs is the merger of binary neutron stars. The gamma-ray are most likely produced by ultra-relativistic particles electrons and protons that are accelerated in the shock waves.

We suggest a mechanism of the gamma-ray bursts generating dibaryons decay in neutron stars. Neutron stars contain the mixture of neutrons, protons and quarks. Neutron stars have high particle and energy density. Central particle density of the neutron star with mass of 1.4 $M_{\oplus}$ and radius R =10.5 km is about 0.7 fm^{-3}. Energy density of the neutron is about 1.0 fm^{-4} (200 $MeV \cdot fm^{-3}$) [2]. Neutron stars exhibit conditions for generating dibaryons (sixquark states). The possibility of the existence sixquark states was predicted by QCD models. Recently dibaryons with masses M_D=1904, 1926, 1942 MeV were observed in *pd*- scattering [3]. Cross section of dibaryon formation σ_D is about 10^{-3} fm^2. Dibaryon lifetime τ_d is about 10^{-17} s. Dibaryons can be generated at three-nucleon interaction in neutron star. Dibaryons can form dibaryon condensate because they are bosons. Dibaryon generation probability λ_g should be exceed by its decay probability λ_d. Dibaryons form dibaryons condensate at density n above 0.01 fm^{-3} and energy density E_V above 0.1 fm^{-4}. Dibaryon decay into $D \rightarrow \gamma N N$. Nuclear 2*n*- and 4*n*-clusters can be formed in neutron star at density below 0.01. Gamma-rays with energy of the 70 MeV (wave-length λ = 3 fm.) can cause dibaryon condensate decay in range on the order λ. The condensate decay result in gamma radiation in cone with angle $0.5 \cdot 10^{-18}$ sr (for condensate size 10 km). This cone contain 10^{38} dibaryons. Decay of the result in radiation with energy on the order 10^{34}ergs. Gamma radiation energy into 4π angle is 10^{53} ergs. Gamma radiation time (~1s) result in fast rise time of gamma-ray bursts.

Gravity field of neutron star slows down the decay of the condensate (several tens of percent). Peak in the extragalactic gamma-ray spectrum is observed below 70 MeV [5].

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SEARCH FOR DOUBLE ELECTRON CAPTURE OF ^{106}Cd IN THE EXPERIMENT TGV-2

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Investigation of the rare nuclear process – double electron capture (EC/EC) of ^{106}Cd has been performed in the Modane underground laboratory in France (4800 m w.e.) using the low-background spectrometer TGV-2 [1]. The detector part of the spectrometer consists of 32 HPGe detectors with a total sensitive volume of about 400 cm^3 mounted one over another in a common cryostat. Thin foils of cadmium with a thickness of ≈50 μm were inserted between neighboring detectors in the same cryostat. The coincidence between two characteristic KX-rays of palladium detected in neighboring detectors was analyzed in searching for double electron capture of ^{106}Cd. Several long-term measurements were made with 16 samples of natural Cd with a total mass of 14.5 g and without any sample to obtain the background conditions of TGV-2. Three runs were performed in searching for double electron capture of ^{106}Cd. In the first run lasted 1768 hours 13 samples of enriched ^{106}Cd (enrichment about 60%) with a total mass of 11 g and 3 samples of natural Cd with a total mass of 2.4 g were investigated. The second run (3277 hours) was performed with 12 samples of enriched ^{106}Cd (enrichment 68%) with a total mass of 10 g and 4 samples of natural Cd with a total mass of 3.2 g. The third run, lasted at present more than 1000 hours, was performed with 12 samples of ^{106}Cd (enrichment 75%) and the same foils of natural Cd as in the second run. In the first two runs an additional background was observed in the region of interest (20-25 keV) resulting in a low sensitivity for 2нEC/EC-decay ($0^+\rightarrow0^+$, ground state) of ^{106}Cd. The mentioned background was caused by the presence of the radioactive impurity of ^{113m}Cd in foils of enriched ^{106}Cd arising the *KX*-rays of Cd due to this reason. Background in the third run is much lower than in previous two runs, and the limit of $T_{1/2} > 5\times10^{19}$ y (90% CL) was obtained for 2νEC/EC-decay ($0^+\rightarrow0^+$, ground state) of ^{106}Cd from the preliminary calculations of the data accumulated for 900 hours. This value is more than 1 order of magnitude higher than those reached in recent experiments [2,3].

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COLLECTIVE NUCLEAR DECAY IN THE FIELD OF OWN γ-RADIATION

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Collective nuclear decay of isomeric ^{119m}Sn and ^{125m}Te nuclei having intermediate Mössbauer levels is observed and studied recently [1]. The essence of matter consists in the fact that concentration of the radioactive nuclei $\geq 3\cdot10^{14}$ 1/cm^3 and of the stable resonance nuclei $\sim6\cdot10^{19}$ 1/cm^3 (*S*-source) produces the nonexponential (up to oscillations) character of decay. The control source (*C*-source) having a zero contents of the stable isotope behaves in a standard way and satisfies the exponential decay.

Why it is so important the presence in the source (for example, ^{125m}Te) of a high contents of the stable Mössbauer isotope (^{125}Te)? The cross-section of Mössbauer absorption of ^{125}Te is $2.86\cdot10^5$ barn that provides in *S*-source the conditions for γ-radiation of ″absolute dense target″ with a effective area in some cm^2. The *C*-source target, on the contrary, is ″absolute empty″ with a effective area of order the sum of a geometrical dimensions of nuclei ^{125m}Te ($\sim10^{-10}$cm^2). The radiation fluxes of the applied *S*- and *C*-sources were identical ($\sim10^8$ 1/s, E=35.6 keV). Hence, γ-radiation in the *S*-source acts on the isomeric nuclei that did not yet decay (E=145 keV, $T_{1/2}$=58 days) and in the *R*-source this action is absent.

The next hypothesis is proposed: in *S*-source γ-quanta are mainly the waves, and in *R*-source – the particles. The wave character to γ-radiation gives apparently the interaction with nuclei ^{125}Te, the action radius of that differs by an $\sim10^3$ times from the nucleus dimensions. This is equivalent to the corresponding ″expanding″ of γ-quantum in *S*-source by flying of it near the nucleus ^{125}Te. A strong field of the resonance mutual induction covering a major portion of time (~4%) and all volume arises in the *S*-source. This field connects the radioactive and stable nuclei in a common system of the strong (and hence nonlinear) collective interaction. In this system the decay equation transforms to the nonlinear (cubic) form and effects of the decay inhibition, acceleration and oscillation are possible. In the *R*-source, on the contrary, γ-quanta are extremely ″narrow″ and the field of radiation is absent.

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SUPERINTENSE LASER FIELD ACTION ON SURFACE WITH FORMING THE FEMTO-SECOND PLASMA AND LASER SPECTROSCOPY OF NUCLEAR ISOMERS

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It is well known that using the super short light pulses changes principally a character of interaction of the laser radiation with substance (surface) [1]. Under laser radiation intensities more than 10^{15} Wt/cm^2 during the laser pulse electrons get energy of 100-1000eV and it is realized a process of forming the femto-second laser plasma.(FLP). The main mechanism of the hot electrons generation in plasma is provided by oscillation of electron on the border "plasma-vacuum" or resonant absorption of laser radiation. For porous materials one may wait for the sharp increasing the hot electrons generation and *X*-ray radiation. Experimental estimates show that a velocity of the plasma flying of the strongly porous samples Si (I~3x10^{16}W/cm^2) is ~10^8cm·s^{-1}, that is corresponding to energy 2±1 MeV [2]. We carried out the modelling the femto-second laser plasma forming in the porous materials (Si) on the basis of the energy balance equations and Green's function formalism for non-ordered materials and considered possibilities of the laser spectroscopy of nuclear isomers. Special attention is devoted to the modelling the system: nano-structured porous material with clusters, on surface of which there is a great number of bonds with H and OH groups. In a case of the D-and OD group's one can wait for realization of the cluster explosion process and reaction D+D→α+*n* (3,8MeV). One can wait for appearance of the powerful flow of neutrons in plasma under intensity of heating pulse ~ 10^{16} Wt/cm^2. In the high density plasma there is possible an excitation of the low lying isomers (level energy less 20 keV) by means of the channels: photo excitation by own *X*-ray plasma radiation, the electron impact excitation, electron conversion etc. The calculating characteristics (energy, decay channels etc.) of low lying isomers of the stable and long lived nuclei by means of the atomic and nuclear numerical codes [3] is now in progress. Let us note that an experimental measuring properties of these isomers by traditional nuclear spectroscopy methods is connected with known difficulties. In conclusion an observation of effect of the excitation for isomer nuclear level in laser plasma is discussed.

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ADVANCED QUANTUM CALCULATION OF THE HADRONIC ATOMS AND SUPER HEAVY IONS: ENERGY SHIFTS AND WIDTHS, DECAY PROBABILITIES

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A great interest to problem has been stimulated by inaugurating the heavy-ion synchrotron storage cooler ring combination SIS/ESR at GSI. With this facility, which allows to produce, store and cool fully stripped heavy ions beams up to U^{92+}, new ways are opened in atomic and nuclear physics. Paper is devoted to calculation of the spectra, energy shifts and widths, hyper fine structure (fs) parameters for some hadronic (pion, kaon) atoms and super heavy ions. A new, QED perturbation theory [1] allows an accurate account of relativistic, correlation, nuclear, radiative effects. One of the main purposes is establishment of a quantitative link between quality of the nucleus structure modelling and accuracy of calculating energy and spectral properties. Zeroth approximation is generated by the effective functional, constructed on the basis of the comprehensive gauge invariance procedure [1]. The wave functions zeroth basis is found from the Klein-Gordon (pion atom) or Dirac (kaon) equation. The potential includes the effective core potential, electric and polarization potentials of a nucleus (the Fermi and Gauss models of nucleus are used). For low orbits there are important effects due to the strong hadron-nuclear interaction (pion atom). The energy shift is connected with length of the hadron-nuclear scattering (scattering amplitude under zeroth energy). For superheavy ions the correlation corrections of the high orders are taken into account within the Green functions method. There are accounted for all correlation corrections of the “2” order and dominated classes of the higher orders diagrams (electrons screening, particle-hole interaction etc.) [2]. The magnetic inter-electron interaction is accounted in the lowest (on α^2 parameter; α -fine str. constant), the Lamb shift polarization part- in the Uhling-Serber approximation, self-energy part of the Lamb shift is accounted for effectively with using the Green functions method. We carried out calculation :1).$1s(2)2lj$,$3lj$,$4lj$ energy levels, hyperfine structure intervals for Li-like ions in interval Z=36-100 with account of correlation, nuclear size and radiative effects; 2). energy spectrum of the atom Z=118; 3). Shifts and widths of transitions ($2p$-$1s$, $3d$-$2p$, $4f$-$3d$) in some pionic and kaonic atoms (^{84}Kr , K^--^{4}He etc.).

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DISCHARGE OF METASTABLE NUCLEI DURING MUON CAPTURE: ENERGY APPROACH

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A negative muon captures by a metastable nucleus may accelerate the discharge of the latter by many orders of magnitude [1]. For a certain relation between the energy range of the nuclear and muon levels the discharge may be followed by an ejection of muon, which may then participate in a discharge of other nuclei. Within of the Gell-Mann and Low S-matrix formalism we developed effective energy approach (EA) [2] to calculating characteristics for the discharge of nucleus with γ quantum emission and further muon conversion, which initiates this discharge. Traditional processes of the muon capture are in details studied earlier and not considered here [3]. The decay probability are linked with imaginary part of energy of the "nuclear core+ proton +muon" system. Three channels should be taken into account: 1). radiative purely nuclear $2j$-poled transition (probability $P1$; it is calculated by means of standard formula); 2). Non-radiative decay; proton transits to the ground state and muon leaves the nuclei with energy $E=E(p\text{-}N1J1)\text{-}E(i)$, where $E(p\text{-}N1J1)$ is an energy of nuclear transition, $E(i)$ is an energy of bond for muon in $1s$ state ($P2$); 3). A transition of proton into the ground state with excitation of muon and emission of γ quantum with energy $E(p\text{-}N1J1)\text{-}E(nl)$ ($P3$). For condition $E(p\text{-}N1J1)>E(i)$ a probability definition reduces to QED calculating probability of autoionization decay of the two-particle system. Numerical calculation is carried out for Sc nucleus. The probabilities of meso-atom decay for some transitions: $P2(p_{1/2}\text{-}p_{3/2})=3{,}93\cdot10^{15}$, $P2(p_{1/2}\text{-}f_{7/2})= 3{,}15\cdot10^{12}$, $P2(p_{3/2}\text{-}f_{7/2})= 8{,}83\cdot10^{14}$. For these transitions the nucleus must transit the momentum no less than 2, 4 and 2 according to the momentum and parity rules. If a meso-atom is in the initial state $p_{1/2}$, than the cascade discharge occurs with ejection of muon on the first stage and the γ quantum emission on the second stage. To consider the case, when the second channel is closed and the third one is opened, suppose: $E(p_{1/2})\text{-}E(p_{3/2})$=0.92 MeV. Energy of nuclear transition is not sufficient to transit a muon to continuum state and it may excite to $2p$ state. There is proton transition $p_{1/2}\text{-}p_{3/2}$ with muon virtual excitation to states of nd series and γ quantum emission with energy $\hbar\omega=E_p(p_{1/2}) +E_\mu(1s)\text{-}E_p(p_{3/2})\text{-}E_\mu(2p)$. The dipole transition $2p\text{-}1s$ occurs with $P3=1.9\cdot10^{13}$ s^{-1} that is more than probabilities of $p_{1/2}\text{-}p_{3/2}$, $p_{1/2}\text{-}f_{7/2}$ transitions without emission.

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ADVANCED QUANTUM MECHANICAL CALCULATION OF ATOMIC PARITY VIOLATION EFFECT AND THE BETA DECAY PROBABILITIES

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A consistent unified quantum mechanical and QED approach (operator QED perturbation theory) [1] is used in calculating the beta decay characteristics and atomic parity violation effect. As method of calculation of the relativistic atomic fields and electron wave functions we have used the relativistic, gauge invariant Dirac-Fock approach [1]. The potential of Dirac equation includes the core ab initio potential, the electric and polarization potentials of a nucleus (the Fermi model, the gaussian form of charge distribution in the nucleus considered). Approach allows calculating the continuum wave functions with entire account of exchange of considered continuum electron with electrons of the atom. As usually for calculation of the beta decay shape and decay half period one should use tables of the Fermi function and integral Fermi function. Two schemes of calculation are used: i). relativistic electron radial wave functions are calculated on the boundary of the spherical nucleus; ii). values of these functions in zero are used. We have considered the following beta decays: $^{33}P \rightarrow ^{33}S$, $^{35}S \rightarrow ^{35}Cl$, $^{45}Ca \rightarrow ^{45}Sc$, $^{63}Ni \rightarrow ^{63}Cu$, $^{106}Ru \rightarrow ^{106}Rh$, $^{155}Eu \rightarrow ^{155}Gd$, $^{241}Pu \rightarrow ^{241}Am$. Comparison of the Fermi function values is carried out for different approximations with partial and entire account of the exchange, calculation with using wave functions on the boundary of the spherical nucleus and with using squires of the amplitudes of expansion of these functions near zero [2]. Further we present calculation results for energy levels, hyperfine structure intervals, *E1*-, *M*1-transitions amplitudes in heavy atoms of Cs, Sn, Pb. As example we present the result for parity non-conserving 6*s*-7*p* dipole amplitude in Cs. Result of our calculation: $D=\langle 6s|Dz|7s\rangle=-0.92\cdot 10^{-11} i|e|a(-Qw/N)$. For comparison we present other data: $D=-0.91\cdot 10^{-11} i|e|a(-Qw/N)$ by Dzuba et al.; $D=0.935\cdot 10^{-11} i|e|a(-Qw/N)$ by Bouchiat et al. (Paris); $D=-0.935\cdot 10^{-11} i|e|a\,(-Qw/N)$ by Johnson et al. (Indiana) [2]. The comparison of calculated value D with data of the measurement of Noeker et al gives the following results for the weak nuclear charge and Wainberg angle: $(-Qw/N)$=0,918±0,020(exp.)±0,010(theor.); $\sin^2\vartheta_W$= 0,231± 0,007 (exp.)±0,004 (theor.) that is in a good agreement with average world value $\sin^2\vartheta_W$=0,230±0,005.

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BETA-DECAY $^{117}Sb \rightarrow {}^{117}Sn$

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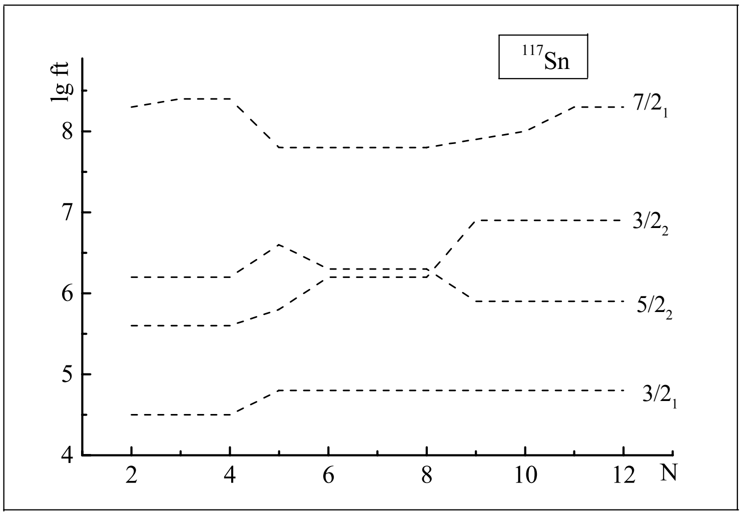
The energy levels, spectroscopic factors, magnetic dipole and electric quadrupole moments of the ground and excited states of ^{117}Sn, as well as reduced probabilities of electromagnetic transitions between them and reduced probabilities of Fermi and Gamow-Teller beta-transitions from ground state of ^{117}Sb to excited states of ^{117}Sn have been calculated in the framework of dynamic collective model [1].

The expression for reduced matrix element of the weak interaction Hamiltonian for β-decay of the U-tipe [2] was used for the calculation of the probabilities of beta-transitions. It consist of 12 addends, related with direct beta-decay, vacuum fluctuations, creation or destruction of one or two phonons (this addends can be represent by the 12 classes of diagrams). Only direct beta-decay was taken into account in other works and creation of one phonon in [3, 4].



Proton $d_{5/2}$ orbital makes the main contribution to the formation of one-quasiparticle ground state of ^{117}Sb, so the beta-decay with great intensity (99%) and probability occur to one-quasiparticle $3/2_1^+$-state of ^{117}Sn: the experimental *lg ft* = 4,9; the calculated *lg ft* = 4,8. The contributions of different classes of diagrams to *lg ft* for the beta-decay to several states of ^{117}Sn are shown in figure.

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BETA-DECAY $^{131}Cs \to {}^{131}Xe$

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The expressions for reduced matrix elements of the weak interaction Hamiltonian for β-decay of the *U*-tipe (β^--decay of odd-neutron nuclei and β^+-decay of odd-proton nuclei) and of the *V*-type (β^--decay of odd-proton nuclei and β^+-decay of odd-neutron nuclei) have been derived [1]. Twelve classes of diagrams which reflect influences of direct beta-decay, vacuum fluctuations, creation or destruction of one or two phonons to the probabilities of β-transitions were taken into account. Only direct beta-decay was taken into account in other works and creation of one phonon in [2, 3].

All spectroscopic characteristics of daughter nucleus, as well as reduced probabilities of Fermi and Gamow-Teller beta-transitions from ground state of ^{131}Cs to ground state of ^{131}Xe have been calculated in the framework of dynamic collective model (DCM) [4].

The main contribution to the formation of one-quasiparticle ground state of ^{131}Cs makes proton $d_{5/2}$ orbital. Decay energy is very little: Q = 352 keV. There is only one suitable state for this decay – ground state of ^{131}Xe, in which main contribution makes neutron orbital $d_{3/2}$. Experimental significance of $lg\,ft$ = 5,5; calculated in DKM $lg\,ft$ = 5,4; calculated in [3] $lg\,ft$ = 3,7. We think that main reason of good agreement of our calculation with experimental significance in this case is that vacuum fluctuations were taken into account. DCM better describe the level scheme of ^{131}Xe than microscopic guasiparticle-phonon model [3] too.

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APPLICATION OF QUANTUM CHROMODYNAMICS METHODS IN NUCLEAR PHYSICS

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Quantum chromodynamics is the modern theory of strong interactions. In the context of this theory we describe Hofstadter experiments of electron–nucleus scattering.

The original results consist in the following:

1) It is shown that differential cross sections for the $e-H^2$ and $e-He^4$ scattering demonstrate Bjorken scaling caused by parton structure;
2) Electric and magnetic formfactors of nucleons are calculated by renormgroup methods.

Derivations of these results are based on the prescriptions:

a) the additivity assumption,
b) the quark count rules,
c) the asymptotic freedom.

As a consequence we obtain the excellent agreement of theoretical data with experimental observables.

EVOLUTION OF POLARIZED ELECTRON-PHOTON SHOWER IN CRYSTALS WITH VARIOUS INITIAL CONDITIONS

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Modern accelerator technology and existing modern electronic and muon detectors allow investigating non-elastic electromagnetic interaction of high-energy electrons, muons and γ-quanta with atoms and nuclei of matter.

When high-energy charged particles ($e^{\pm}, \mu^{\pm}$) and γ-quanta pass trough matter, in addition to separate acts, they give birth to shower structures under certain conditions. These shower structures are continuously directed jets of various particles, such as, charged particles in solid and gas meters, electron (muon)-photon showers in amorphous and crystal environments, nucleon cascades in nuclear matter. Electromagnetic showers resulting from interactions of high energy particles with atom nuclei in crystal environment are main source of electron, positron and photon beams of high energy and also are excellent tool for investigation of matter structure and electromagnetic properties of nuclei.

This article deals with theoretical investigation of polarized electron-photon showers in crystals at two different initial conditions for emergence of shower: 1) shower is created by high energy (E_0) initial lepton ($e^{\pm}$, $\mu^{\pm}$); 2) shower may also be created by initial high-energy γ-quantum (E_0). We were there first who wrote down equations for the evolution of electromagnetic shower in crystals and found solutions to these equations under initial conditions indicated above. Analytical expressions that we obtained for the distribution of shower leptons and γ-quanta are

$$P_{1,2}(t, E_0, E) = F_{1,2}(s, \lambda_1)\exp(sy - \lambda_1(s)t),$$

$$\Gamma_{1,2}(t, E_0, E) = \Phi_{1,2}(s, \lambda_1)\exp(sy - \lambda_1(s)t)$$

here s- is Laplas-Mellin parameter, E_0 , E – are initial and current energies of shower particles, t-is depth of penetration, $F_{1,2}(s, \lambda_1)$, $\Phi_{1,2}(s, \lambda_1)$, λ_1 and y - are some functions depending on s, initial energy of particles and initial conditions.

Detailed analysis of these functions for silicon crystal indicates that initial conditions make strong impact on both distribution function of shower particles and their polarization properties.

LOWER AND UPPER BOUNDS OF ENERGY FOR COULOMB THREE AND FOUR PARTICLE SYSTEMS

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A calculation of lower bound of energy (E_L) and its confrontation with upper bound (E_U) lead to understanding of the accuracy of determination of energy. There exists four versions of lower estimation of the energy: (a) the version of Temple (E_L^T) [1], (b) of Römberg (E_L^Q), Weinberg (E_L^W) [2] and that of Hall and Post [3] from which E_L^T and E_L^Q assure the best approach to the exact value of energy (E_0). This report concern the upper and lower evaluation of E_L^T, E_L^Q and E_U for three-particle Coulomb systems: atom He (both standard model $^\infty$He with infinite mass of nucleus and real system $\alpha e^- e^-$), hydrogen ion H^- ($^\infty H^-$ and pe^-e^-), systems $e^+e^-e^-$, μe^-e^-, $pp\mu$, $\mu\mu e^-$, ppe^- and for four-particle molecular systems H_2 and HeH^+. All three-particle systems were calculated with exponential trial functions and four-particle systems — with gaussians. The results of calculation of E_L^T, E_L^Q and E_U are presented in the table for different number of trial functions n. In addition are given: the energy of first excited level E_1 (required for calculation of E_L^T), the virial index δ_v (defined as $\delta_v = -\lg\left|1+\frac{2\langle T\rangle}{\langle E\rangle}\right|$) and the number of right digits Δ (defined as $\Delta = 1-\lg\left|E_U - \frac{1}{2}\left(E_L^T + E_L^Q\right)\right|$). As it is seen there exists a correlation between δ_v and Δ, that can be expressed roughly by $\delta_v \approx \Delta+2$.

System	E_1	n	E_U	E_L^T	E_L^Q	δ_v	Δ
$^\infty$He	−2.146	10	−2.903 723 6	−2.903 83	−2.903 737	6.0	4.2
		30	−2.903 724 373	−2.903 725 8	−2.903 724 6	8.3	6.8
		100	−2.903 724 377 01	−2.903 724 414	−2.903 724 381	10.4	8.5
		300	−2.903 724 377 033 15	−2.903 724 380 41	−2.903 724 377 47	12.1	9.8
αe^-e^-	−2.146	300	−2.903 304 557 732 27	−2.903 304 561 11	−2.903 304 558 17	12.6	9.6
$^-$H	−0.500	100	−0.527 751 016 400	−0.527 751 66	−0.527 751 033	9.0	6.5
pe^-e^-	−0.500	100	−0.527 445 880 971	−0.527 446 533	−0.527 445 898	9.2	6.8
$e^+e^-e^-$	−0.250	50	−0.262 005 068 6	−0.262 008 7	−0.262 005 220	7.6	5.2
$pp\mu$	−0.450	50	−0.494 386 790	−0.494 391 1	−0.494 387 12	6.8	5.8
μe^-e^-	−0.500	100	−0.525 054 806 098	−0.525 055 501	−0.525 054 827	8.6	6.0
$\mu\mu e^-$	−0.560	50	−0.584 971	−0.594 4	−0.586 55	3.2	2.2
ppe^-	−0.580	50	−0.595 67	−0.618	−0.600 6	3.3	1.8
H_2	−1.145	500	−1.160 2	−4.78	−1.187	2.3	0
HeH^+	−2.9567	300	−2.965 0	−61	−3.053	3.0	1

Energies are given in a.e. for electron systems and in μ.e. for mesonic systems.

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FRACTAL DIFFUSIONAL PROCESSES IN PARTICLE PHYSICS

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The possibility of description of processes of nuclear physics and particle physics directly basing on the notion of possibility and the possibility distribution function by analogy with the macroscopic physics was explored.

It was shown that time series of variables describing the dynamics of a following one by one independent hadron-hadron reactions could be considered as a diffusion in a fictitious space similar to a fractal Brownian motion and defined with a Fokker-Planck equation.

Earlier it was founded by us with a Hurst-Mandelbrot method [1-4] that the experimentally obtained series of kinematic variables for hadron-hadron interactions possess some correlations. Taking into account this fact lets draw an analogy with a fractal Brownian motion and examine distributions of sums of the variables $\Delta\alpha$, $P_t^{\max}$, $b_{\min}^{\max}$, Δy [1] for N following one by one independent events, for example $\Delta\alpha_1+\Delta\alpha_2...+\Delta\alpha_N$. Several thousands of such sums for different N was taken for investigations of the distributions.

It was shown that the larger is N the closer the examined distribution is to the Gaussian curve (Table 1). Also the dependence $ln(D)=a+b\cdot ln(t\text{-}t_0)$ was proved where D is the dispersion of the distribution, $t\text{-}t_0$ is equivalent to N, a is some constant and $b=2H$ where H is the Hurst coefficient (Table 1). Values of a and b were obtained with a least-squares method.

Table 1. χ^2/n for comparison of experimental distributions with different N with the Gaussian curve and parameters a and b.

Value	χ^2/n, N=2	χ^2/n, N=4	χ^2/n, N=8	χ^2/n,N=16	a	b
$\Delta\alpha$	67±3	17±2	3,6±0,5	1,3±0,5	-4,410±0,004	1,248±0,013
$P_t^{\max}$	13±1	3,0±0,6	1,5±0,5	2,0±0,5	-3,500±0,001	1,278±0,001
$b_{\min}^{\max}$	113±12	19±2	4,3±0,8	1,7±0,4	9,903±0,001	1,031±0,003
Δy	26±2	6,0±1,0	2,3±0,5	1,7±0,3	-0,135±0,001	1,030±0,002

This results allow us to conclude the processes under examination to be diffusion-like and so they can be described with a standard Fokker-Planck equation where coefficient of diffusion D must somehow depend on the fractal characteristic of the process H.

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A SEARCH FOR DEEPLY BOUND PIONIC STATES OF XENON PRODUCED IN THE ^{136}Xe(d, ^{3}He)^{135}Xe$_{\text{p-bound}}$ REACTION

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Bound states of negatively charged pions and nuclei, pionic atoms, have been investigated by detecting *X*-rays emitted in the electromagnetic deexitation of atomic levels. Due to the competition from absorption by the nucleus, however, deeply bound states cannot be studied with this technique. The existence of relatively narrow deeply bound pionic states in heavy nuclei was predicted theoretically by Toki and Yamazaki [1]. At present the existence of the deeply bound pionic states of lead [2, 3] and tin [4] isotopes and also natural xenon [5] was observed experimentally in the (d, ^{3}He) pick-up reaction. The closed shell nucleus ^{136}Xe is suggested, by Umemoto *et al.* [6], to be a particularly good candidate as a target for the study of the deeply bound 1s state.

Here we report on results of a search for deeply bound pionic states of xenon produced in the ^{136}Xe(d, ^{3}He)^{135}Xe$_{\text{p-bound}}$ reaction. The experiment was carried out at the CELSIUS storage ring by letting a 500 MeV electron-cooled deuteron beam interact with the internal cluster-jet target. A high-purity germanium spectrometer [7] was used to measure the energy spectrum of secondary ^{3}He ions emitted at zero degree. The spectrometer covers the ^{3}He energy range up to 420 MeV with the energy resolution ~ 900 keV.

A slightly pronounced peak was observed in the ^{3}He energy spectrum which corresponds to the population of the 1s pionic atom state of ^{135}Xe. The measured reaction cross section of approximately 40 μb/sr is in agreement with predictions [6]. The binding energy of the 1s state, $B = 2.9 \pm 0.5$ MeV, however, is lower than theoretically predicted [6].

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ELECTRON ACCELERATORS ACTIVITY AT SINP MSU

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During last 20 years several electron accelerators having no analogs in Russia were designed and built at SINP MSU. First of these machines was normal conducting (NC) continuous wave (CW) 6.7 MeV electron linear accelerator with low emittance (< 5 mm mrad, normalized), high average current (up to 1 mA), low energy spread (< 0.3 %) beam which was used in fundamental nuclear physics research. Experience in working with NC accelerating structures in CW mode under high heat loading was the basis for development of industrial accelerators series, the latest of which is 1.2 MeV, 60 kW average power compact accelerator operating at 2450 MHz useful for application in different technological processes (polymers modification, industrial gases and sewage cleaning etc) instead of bulky direct current machines.

In 1999-2003 two pulsed racetrack microtrons (RTM) were designed and built at SINP MSU in collaboration with WPT Inc (USA). 70 MeV RTM has several innovations for the first time used in accelerator technique, such as large, high induction, 1 T, high uniformity, 0.3 %, field, rare earth permanent magnets, standing wave electron accelerating structure with quadrupole RF focusing, compact rare earth permanent magnets electron beam phase shifter. This accelerator is now used for fundamental nuclear physics and for applied researches. 35 MeV RTM with high brightness beam has external high energy, 5 MeV, injection from photocathode electron gun. This accelerator was also built with rare earth permanent magnets and is used for coherent radiation study. With its short, 5 ps, high charge, 150 pC, bunches following with 150 Hz and having energy varying in 5-35 MeV range RTM is well suitable for high resolution time-of-flight measurements of particle spectra in photonuclear reactions.

Other direction of accelerator physics which is investigated at SINP MSU during last 5 years is laser acceleration in vacuum with diffraction type accelerating structure. The goal of this study, important for future linear collider projects, is reaching accelerating gradient above 1 GeV/m. This work is now passing from theoretical to experimental stage, specifically technology for accelerating mictrostructure manufacturing is under development.

Two more projects are at the initial stage now at SINP MSU. First is joint with Lebedev Physical Institute project of bi-monochromatic *X*-ray source for non-invasive angiography based on the laser photons scattering from the circulating 35 MeV compact storage ring electrons. Second is miniature RTM with beam energy varied in 4-12 MeV range with dimensions less than 11x20x50 cm and weight less than 60 kg, which can be used in intraoperational radiation therapy complex, in security systems as well as in different radiation technologies research.

PHYSICS ON KHARKOV SUPERCONDUCTING ELECTRON ACCELERATOR ON ENERGY UP TO 730 MeV (PROJECT "SALO")

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It is discussed some perspective directions of fundamental nuclear and hadron physics researches with electromagnetic probes in intermediate energy range (up to 1 GeV) which could be realized at new electron accelerator facility, which is proposed at Kharkov Institute of Physics and Technology [1]. It is planned that the accelerator will have the energy up to 730 MeV, duty factor ~1 and current up to 100 mkA. Three beam line are planned to provide the experiments with real polarized tagged photons, electrons and high intensity photon beams and for neutron production. The facility will be equipped by sources of polarized electrons, linearly polarized photon and polarized targets.

There are following possible perspective topical trends which could be studied [2]: i) test of theoretical predictions of the chiral perturbation theory; ii) many-body processes and influence of nuclear medium on hadron properties; iii) test of the electroweak theory in scattering of polarized electrons on nucleons and nuclei, and the parity violation effects.

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ACCELERATING COMPLEX FOR NUCLEAR PHYSICS IN NSC KIPT - PROJECT "SALO"

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During last two years NSC KIPT and Technische Universiteit Eindhoven in common develop the project recirculator with superconducting accelerating structure on energy up to 730 MeV [1].

The accelerator will be disposed in existing buildings on exit of linac LU2000 (see Fig. 1). It will allow to use for problems on a nuclear physics as an existing hall of magnetic spectrometers and to organize some new workstations for these operations. The source of polarized electrons will allow to receive quasicontinuous beams with energy from 100 up to 730 MэВ and a current up to 100 μA. RF photogun will accelerate continuous and impulse electron beams with a charge up to 1 nC in one bunch and an average current up to 1 мA.

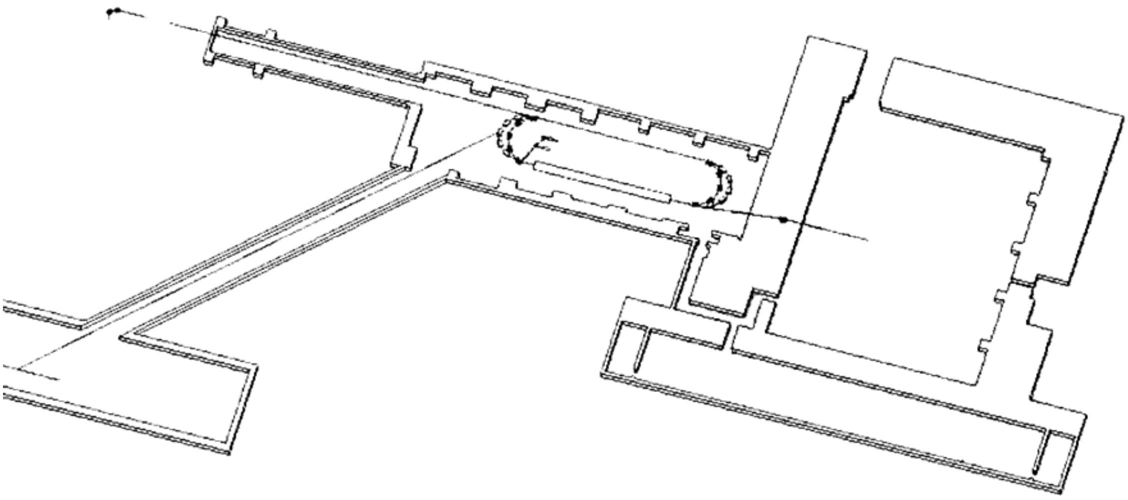

Fig. 1.

Base tasks which are supposed to be solved with the help of new accelerator**:**

1. Problems of fundamental nuclear physics
2. Neutron source and its applications in different fields of science
3. Free electron laser
4. Radiation physics, nuclear physics applications, isotope manufacturing.

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NEUTRON DETECTORS FOR REGISTRATION OF RARE SPONTANEOUS FISSION EVENTS

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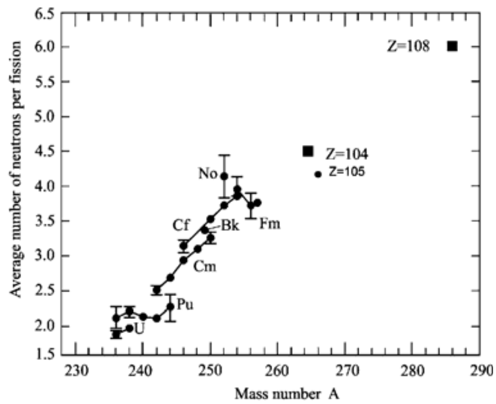
Recent years considerable progress is attained in synthesis of super heavy elements and existence of the "stability island" is experimentally proved. Recently were carried out chemical properties studies for 108, 112 elements [1,2], and the chemical authentication of Db [3]. Experimental information on stability of the elements 108-118 heaved up a question about the SHE existence in natural objects [4]. According to modern experimental data the most long-living can appear the heavy isotopes of a 108 element. This element is a chemical homologue of Osmium, which is a rare element (10^{-8}g/g). So, in a sample of metallic Os its homologue Hs (Z=108) should be present and enriched at the same level. In contrast to stable Os isotopes, the Hs atoms must undergo radioactive decay. In the decay of nuclei with Z=108, spontaneous fission of the initial nucleus or products of its decay (Z=106-104) will always be present.

The number of investigated nuclei are small, so detecting apparatus must have high efficiency of registration. Detectors of spontaneous fission neutrons on the basis of the proportional counters filled ^{3}He are described in the work.

Average neutron number per fission varies from 2 for ^{238}U up to 4.2 for ^{268}Db [3], calculated values for nuclei with Z=104 and 108 are 4.5 and 6.0 resp.

The neutron detectors consist of several tens of counters filled with ^{3}He at 7 bars situated in a polyethylene moderator.



Efficiencies of detectors are 40-60%. Probability of registration of neutrons flash as coincidences of two and more signals from all counters for Z=108 will be about 90%; three and more –74%. Unique natural emitter of spontaneous fission is ^{238}U. It should be possible to estimate background from the spontaneous fission of ^{238}U for our detector less than 5 double coincidences per year. Other source of background is interaction of cosmic radiation with material of neutron detector. To avoid this, the SHIN detector has been installed in LSM laboratory (4000 м on a depth water equivalent), where background of fast muons will give about 5.10^{-2} events per year. The double background coincidences induced by thermal and fast neutrons in LSM will be ~ 0.1/ year. The background measurements are in progress now. Expected limit for contamination of element 108 is 10^{-15}g/g for 1 year experiment with 500 g of Os.

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SUPERCONDUCTING TUNNEL JUNCTION DETECTORS. THE PROBLEMS OF THE ENERGY RESOLUTION

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Superconducting tunnel junction (STJ) detectors have 10 times better energy resolution than semiconductor detectors. Now STJ detectors are used in precise *X*-ray analysis, astrophysics and in some others applications. Nevertheless the energy resolution of real STJ-detectors exceeds the theoretical ultimate values. The main reason of line broadening is the spatial dependence of the detector signal on photo-absorption site (inhomogeneous broadening). In this work the detector line shape was analyzed on the base of the diffusion model taking into account quasiparticle self-recombination and boundary losses. Numerical calculations have shown that recombination losses reduce the amplitude of a signal, induce broadening of the detector line and lead to nonlinearity in energy dependence of the detector signal.

The model spectra were compared with the experimental data for STJ detectors with Ti/Nb/Al/Al_2O_3/Al/Nb/NbN layers structure. There is only one active electrode, Al/Nb/NbN, in this detector. The second one, Ti/Nb/Al, contains Ti-layer at the side opposite to tunnel barrier, Al_2O_3. It works as killed electrode for quasiparticles and 2Δ-phonons [1]. The detectors were tested at T=1.35 K with Co^{57} source. The better results were obtained for detectors with large area. The line width for 6.4 keV *X*-rays was about 100 eV and the electronic noise contribution was about 60 eV. This energy resolution is about 2 times better then for silicon *X*-ray detectors. But it is much more than ultimate theoretical value of about 5-10 eV. The spectra were fitted by the diffusion model. It is shown that the both factors, the quasiparticle self-recombination and the boundary losses, are responsible for detector line broadening.

The detector response on *X*-ray energy was investigated using Co^{57} source and additional fluorescent screens. In the case of Ti screen four *X*-ray lines were simultaneously recorded in the spectrum: 7.04 keV Fe K_β, 6.4 keV Fe K_α, 4.5 keV Ti K_α and 1.8 keV Si K_α. The data show strong nonlinearity of the signal versus absorbed energy. The nonlinearity is caused by self-recombination losses of excess quasiparticles. The recombination losses are intensified in the detectors with killed electrode due to 2Δ-phonons absorption in Ti layer.

In conclusion, the diffusion model can describe the main features of STJ-detector line shape. Possible ways for improving the energy resolution of STJ-detectors will be discussed.

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HIGH RESOLUTION LASER SPECTROMETER FOR FUNDAMENTAL AND APPLIED RESEARCH

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A high resolution tunable laser spectrometer is now being created at the Flerov Laboratory of Nuclear Reactions, JINR (Dubna). The spectrometer is to be used in fundamental and applied research on the structure and properties of the atomic nuclei and clusters, molecular structures, in determining trace amounts of materials in the environment at high sensitivity. It is being created with the support of the Faculty of Physics, the University of Poznan, and with the participation of the Institute of Automation and Electrometry (Novosibirsk) as well as Novosibirsk State University.

The spectrometer includes a continuous wave argon pump laser of the “Inversia” type (Novosibirsk) whose radiation power is 10-12 W in the blue-green range, a ring single-frequency Ti-supphire dye laser with frequency stabilisation - DYE-SF-07 whose linewidth is 0.5 MHz and frequency is smoothly scanning in the 5 GHz range. When pumped from the powerful “Inversia” radiator, the ring dye laser is capable of delivering an output radiation power of up to 1 W in the single- frequency mode.

The “Inversia” argon laser, created in Russia, differs from conventional pump lasers by two features: a large-diameter discharge channel (7mm) and a slow gas flow through the discharge tube. This makes it possible, first, to obtain a large output radiation power with a relatively short tube, second, to make the discharge tube collapsible, which is important in long-term usage. In addition, the slow gas flow lowers the quantity of detrimental impurities in the discharge.

The argon laser has a two-mirror resonator about 130 cm in length. The changeable inner mirrors, 7 mm thick and 20 mm in diameter, are dielectric coated, which allows one to choose between the blue-green and blue generation spectra depending on the dye used.

The laser spectrometer is to be equipped with a radiation frequency doubler to extend its radiation spectrum up to UV, which will significantly expand the range of the nuclei to be studied (measurement of charge radii, nuclear moments and deformation parameters) including radioactive nuclei and fission fragments (Project DRIBs – Dubna Radioactive Ion Beams).

A COMPLEX OF EQUIPMENT FOR PREPARATION OF HIGH-QUALITY RADIOACTIVE SOURCES USED IN PRECISE NUCLEAR SPECTROSCOPY

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Precise investigations of spectra from nuclear radiations are quite sensitive to quality of radiation sources used. In an ideal case a source should introduce no noticeable distortion into registered spectrum. In spectroscopy of low-energy gamma quanta, electrons and alpha particles sample preparation quite frequently turns to be a challenging independent scientific investigation. Source preparation is conventionally performed at two stages – extraction of activity from a target and its uniform distribution over a substrate. A general requirement to such radioactive layer is maximal total and specific activity.

The paper introduces a complex of experimental equipment for preparation of high-quality radioactive sources. This complex is arranges in a well-protected heavy box equipped with master-slave manipulators. Biological protection of the box makes it possible to handle activities up to 10^{11} Bq. Main part of the complex is a special vacuum post that assures works with active samples in the vacuum up to 10^{-7} mm Hg) – the operations include fractional sublimation, thermal evaporation, thermal diffusion, evaporation by electron beam, etc. All units of the vacuum post arranged in the box are designed to work with master-slave manipulators. The post is mainly used for preparation of a high-quality beta sources and extraction of microamounts of radionuclides from reactor and cyclotron targets by the method of fractional sublimation. Another important unit of the complex is an equipment for selective chemiosorption in vacuum. Complex comprises all required auxiliary equipment. The entire complex operated at high rate of reliability.

The paper pays particular attention both to systematization of available data on application of fractional sublimation and to consideration of a range of important issues regarding the mechanism of this process in order to optimize the procedures for preparation of radioactive sources for precise nuclear spectroscopy. Employing the method of fractional sublimation at the complex there were produced the following high-quality sources: ^{101}Pd, ^{105,106,111}Ag, ^{107,111}Cd, ^{131}J, ^{131,136}Cs, ^{194}Au and ^{209,210,211}At. The works on obtaining highly active sources for measurements of important low-intensity spectra of three-electron Auger transitions are in progress [1].

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RECENT RFNC-VNIIEF ACHIEVEMENTS ON INCREASING OF ACTINIDE ISOTOPE ELECTROMAGNETIC SEPARATION EFFICIENCY

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The report presents the scope of works fulfilled in these latter years to increase operational factors of S-2 mass-separator for the purpose of perfecting technology of electromagnetic separation of heavy actinide isotopes.

The applied mass-separator is provided with radiation shielding what makes it possible to operate highly active materials: uranium, plutonium, americium and curium[1-4].

Table. The nomenclature of available isotopes [6].

Main isotope contents (as atoms. %)				
Uranium	Neptunium	Plutonium	Americium	Curium
U-233 99.97	Np-236 <0.01	Pu-238 99.6	Am-241 99.99	Cm-243 99.99
U-234 84.52	Np-237 99.99	Pu-239 99.997	Am-242m 85.6	Cm-244 99.3
U-235 99.9923		Pu-240 >99.9	Am-243 99.998	Cm-245 99.998
U-236 97.81		Pu-241 99.998		Cm-246 99.8
U-238 99.9990		Pu-242 99.99		Cm-247 90.2
		Pu-244 98.9		Cm-248 97.5

Now we are to develop a new ion source and electric power source to increase operation temperature of the source so that the separated materials are used in the form of metals and oxides.

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COINCIDENCE SUMMATION IN γ-RAY SPECTRA. DETERMINATION OF INTENSITY FOR WEAK CROSS OVER γ-TRANSITIONS

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A.A. Smolnikov, V.I. Fominykh, V.G. Chumin

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In γ-spectra of radioactive nuclides are observed peaks which created by summation of pulses from coincident gamma-ray. The influence of this effect on response function of Ge-detectors was investigated in [1,2]. In [3] it is shown that the summation effect is practically equivalent to experiments with γ-γ-coincidences. In present work the intensities of summation peaks in γ-spectra were used for determination an absolute activity of radiation source and determination the intensity per decay for weak cross over γ-ransitions between initial and final levels of cascade coincident γ-transitions.

It is proposed the procedure of measurements and calculations these values taking into account the dead time of experimental installation and decreasing ("washing away") intensity of the peaks of cascade γ -transitions in γ–spectrum due to the coincidences them with photo-peak and compton distribution from γ-transition – partner in cascade. The intensities of cross over γ- transitions for ^{208}Tl, ^{209}Tl, ^{207}Bi and ^{44}Sc are determined. The results for ^{208}Tl are shown in table below.

E_γ, keV	2614,5	1093,8	3197,7	3475,0	3708,5	3960,9
a_γ%, this work	100	0.36(7)	≤0.007	≤0.003	≤0.004	≤0.003
a_γ%, [4]	100	0.37(4)	–	–	–	–

For the first time the upper limits for intensities for γ-rays with energies 3197.7 keV, 3475.0 keV, 3708.5 keV and 3960,9 keV are determined. The observation of summation peaks with energies 2891 keV, 3125 keV and 3377 keV which created by summation of pulses from γ- transitions in triple cascade is in agreement with decay scheme of ^{208}Tl [4].

The method for determination an absolute activities of γ-sources by using summation of peaks is described in work [5]. This work was supported by RFBR grant (№ 04-02-17144).

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DETERMINATION OF CHARGED PARTICLE TRAJECTORIES IN NUCLEAR PHOTOEMULSION

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To study two neutron transfer reaction $^6He+A \rightarrow {}^4He+B$, nuclear photoemulsion (NPE) were irradiated by ^6He beam with energy ~ 15 MeV/u. As target-nucleus (*A*) the elements included in NPE (^{12}C, ^{14}N, ^{16}O, $^{79,81}Br$, $^{107,109}Ag$) were used.

Search of events of transfer reaction and further processing was performed using automated measuring setup PAVIKOM at P.N.Lebedev Physical Institute. In this setup the images of consecutive (with step of several μm) NPE layers using special camcorder and interface were obtained and transferred to computer. At further processing of these images, we select darkening areas (globes) with darkening degree, shape, and size inherent for tracks of given charged particle ($^{4,6}He$). Coordinates (*x, y*) of centers of mass of all globes in each layer (*z*-coordinate) are determined and stored. Then, particle trajectories $X_i(z)$ and $Y_i(z)$ are determined by center-of-mass coordinates in consecutive layers of NPE.

Further the trajectories obtained are processed to determine their parameters. The characteristic trajectory corresponding to the given reaction must consist of: trajectory of primary particle (^6He), bend of trajectory corresponding to the interaction vertex, trajectory of secondary particle emitting from interaction vertex (^4He), and presence or absence of recoil nucleus trajectory in the case of light (^{12}C, ^{14}N, ^{16}O) or heavy ($^{79,81}Br$, $^{107,109}Ag$) target nucleus, respectively. Trajectories before and after interaction are approximated by straight lines, but at the interaction vertex the direction of trajectory (first derivative of trajectory) changes. Therefore, *z*-coordinate of this vertex is determined by the position of extremum in the dependence of second derivative of trajectory on *z*. For trajectories having a bend, the program determines coordinates (x,y,z) of the interaction vertex, angle of emission of secondary particle, range (energy) of the primary particle at the interaction vertex, and range (energy) of the secondary particle. Thus, all data necessary to obtain angular distribution of the reaction studied are determined.

NEUTRON CAPTURE REACTION RATES IN ^{139}La ACTIVATION SAMPLES EXPOSED TO THE SPALLATION NEUTRON FLUENCE OF GAMMA-2 SETUP LEAD TARGET IRRADIATED BY 1, 1.5 AND 2 GeV PROTON BEAMS FROM THE JINR NUCLOTRON

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GAMMA-2 Collaboration
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GAMMA-2 extended setup consisted of an 8 cm in diameter 50 cm long lead target surrounded with a 6 cm thick paraffin moderator was irradiated by 1, 1.5 and 2 GeV Nuclotron accelerator proton beam for the purpose of study of spallation neutron production in thick targets and radioactive waste transmutation rates in conditions similar to those described in [1]. The 15 mm in diameter plastic vials containing about 1 g of ^{139}La in the form of $LaCl_3{\bullet}7H_2O$ each were placed onto the outer surface of the moderator along the beam direction with 5 cm gaps between them.

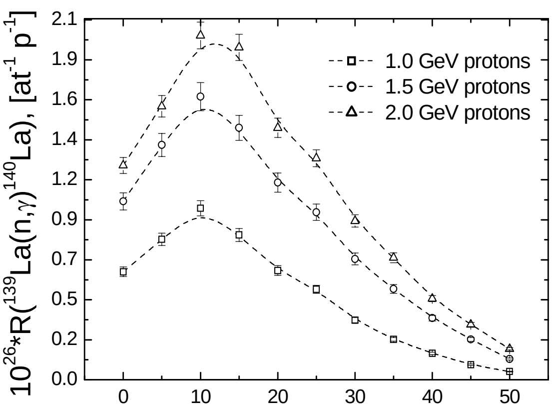

Figure. Reaction rates in the ^{139}La detectors.

Induced γ-activity was measured using a set of HPGe detectors, and the γ-spectra were analysed employing software applying the methods similar to those described in [2].

Dependence of the (*n*,γ) reaction rates obtained on the incident proton energy as well as distance from the beam entrance point are shown in the Figure. The results allow determining the position (10-15 cm from the front) with the maximum fluence of the thermal neutrons for placement of the transmutation samples and threshold detectors, and prove the decrease in the grows of fluence in the region from 1 to 2 GeV, which complies with our previous results obtained on the shorter target.

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TRANSMUTATION RATES IN ^{129}I AND ^{237}Np RADIOACTIVE WASTE SAMPLES EXPOSED TO THE SPALLATION NEUTRON FLUENCE OF GAMMA-2 SETUP LEAD TARGET IRRADIATED BY 1, 1.5 AND 2 GeV PROTON BEAMS FROM THE JINR NUCLOTRON

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GAMMA-2 Collaboration

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GAMMA-2 setup generally described in [1] but extended to 50 cm was irradiated by 1, 1.5 and 2 GeV Nuclotron accelerator proton beam of integral fluence equal to $3 \cdot 10^{13}$ protons for the purpose of study of spallation neutron production in thick targets and radioactive waste transmutation rates [1]. Radioactive waste samples of ^{129}I and ^{237}Np isotopes about 1 g in weight weld-sealed in aluminum containers were placed onto the outer mantle of the moderator. Induced γ-activity of $^{129}I(n,\gamma)^{130}I$ and $^{237}Np(n,\gamma)^{238}Np$ reaction products was measured as described in [2].

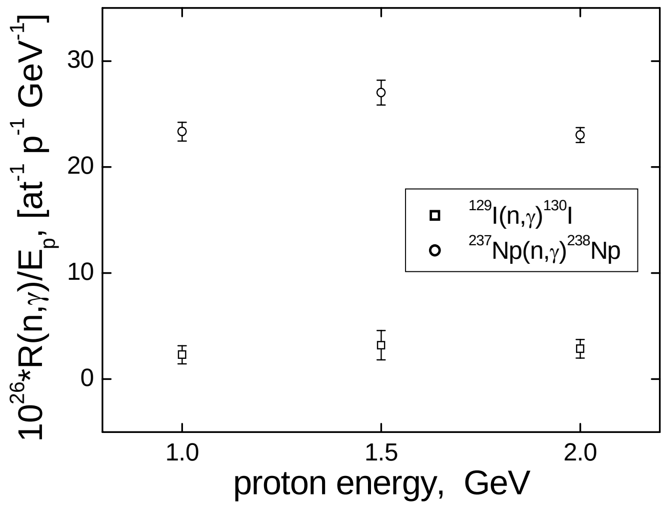

Figure. Reaction rates (n,γ) in ^{129}I and ^{237}Np transmutation samples.

Dependence of the measured transmutation rates per GeV initial proton energy on its energy is given in Figure. The results show that within the energy range under study transmutation rates are almost constant.

This observation complies with our previous results obtained on the shorter target.

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A LASER DESORPTION/RESONANCE ENHANCED PHOTOIONIZATION TOF-SYSTEM FOR THE ANALYSIS OF URANIUM ISOTOPIC RATIOS AT THE TRACE LEVEL

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A method for the direct and spatially resolved trace analysis of Uranium with high sensitivity and selectivity is presented. The modified commercial high resolution time of flight mass spectrometer is combined with a pulsed tuneable dye laser system for resonant ionization. Methodical developments have been performed with particular emphasis on the elements gadolinium and uranium. The applications include selective and direct trace determination of Uranium and other actinides in environmental and technical samples [1].

Fig. 1 shows a schematic view of the modified front end of the experimental setup for postionization. Laser desorption is performed with a nitrogen laser (λ = 337 nm), in order to release the analyte from the target. By means of a pulsed ion repeller, unselectively produced desorption ions are suppressed back to the target. Desorbed neutral atoms are selectively converted to ions by resonant postionization, and finally extracted for mass analysis in the TOF- spectrometer.

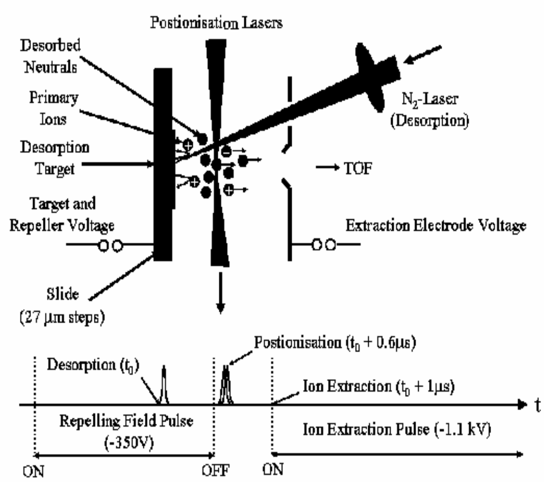

Fig. 1: Experimental setup for resonant photoionisation of laser desorbed neutrals. Explanations are given in the text.

For uranium two resonant transitions, one at a wavelength of 424.23 nm for the first step started from the ground state ([Xe] $5f^3 6d7s^2\ {}^5L_6$, pulse energy ~ 1µJ), and one at a wavelength of 575.42 nm into a high-lying J=6-state @ 40950 cm^{-1} (pulse energy ~ 40 µJ) for the second step as well as a final ionization step with laser light at a wavelength of 1064 nm from the Nd:YAG pump laser (1.3 mJ/pulse) were used. A resonance enhancement of two orders of magnitude was measured with respect to a detuning of about 200 GHz of the blue laser at 424.23 nm.

The isotopic ratio $^{235}U/^{238}U$ in uranium grains (U_3O_8, UO_3) and solutions has been measured without chemical pre-treatment of samples. The concentrations of Uranium was at the trace level (<1 pg).

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XENON NEUTRON-CAPTURE THERAPY

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Neutron-capture therapy (NCT) is a cancer treatment that utilizes nuclear-capture reaction [1]. NCT exploits the high thermal neutron (TN) cross-section of nuclides: ^{10}B (3837 barns), ^{149}Sm (41,000), ^{157}Gd (242,000). The nuclide Gadolinium-157 has the possible advantages over boron-10 typically used as radiation producing isotope in NCT. ^{157}Gd nuclear-capture reaction result in emission of long range prompt gamma-ray, internal conversion electrons, X-rays and Auger electrons with large total kinetic energy (7.94 MeV). Tne TN cross-section of ^{157}Gd is 66 times larger than that of ^{10}B; Gd-NCT may increase the possibility of hitting the target tumor cells with the long-range photons and/or a locally intensive destruction of the tumor site by Auger electrons; it will be possible in the future to integrate Gd-NCT with magnetic resonance imaging (MRI) diagnosis [2]. Gd-NCT use Gd-loaded chitosan nanoparticles (contains 2.4 mg natural Gd), which are injected into solid tumor, 8 h before neutron irradiation. The TN irradiation flux of ~10^9 neutrons cm^{-2} s^{-1} results in tumor-killihg effect. An dose (~ 30 Gy) in the tumor tissue of gamma-ray results from the neutron irradiation with fluence of 6.3×10^{12} neutrons/cm^2 suppress tumor growth. This neutron flux can be obtained from RADEX equipment MMF [3]. The proton beam (current 50 μA, energy 300 MeV) from the Linear Accelerater irradiation W target of the RADEX. Spallation reaction results in emission of fast neutron flux of ~10^{13} neutrons cm^{-2} s^{-1} into the RADEX vertical channel. The TN flux of ~10^9 neutrons cm^{-2} s^{-1} is out the vertical channel.

We propose xenon-135 neutron-capture therapy (Xe-NCT) which exploits the high TN cross-section of ^{135}Xe (3.4×10^6 barns). Xenon-135 isotopes result from the decay of the fission fragments into nuclear reactor [4].

$$^{135}\mathrm{Te} \xrightarrow[2\ \mathrm{min}]{} {}^{135}\mathrm{I} \xrightarrow[6.7\ \mathrm{h}]{} {}^{135}\mathrm{Xe} \xrightarrow[9.2\ \mathrm{h}]{} {}^{135}\mathrm{Cs} \xrightarrow[2\cdot10^6\ \mathrm{y}]{} {}^{135}\mathrm{Ba}$$

^{135}I and ^{135}Xe isotopes are saved into nuclear reactor. Iodine-135 can be injected into solid tumor using the I-labelled acridine method, 11h before neutron irradiation. The Xe-NCT has the possible advantages over Xe-NCT. The TN cross-section of ^{135}Xe is 13.4 times larger than that of ^{157}Gd. Well-designed iodine-loading particulate systems may well integrate Xe-NCT with I-labelled diagnosis in the future. ^{135}I and ^{135}Xe isotopes are product fission fragment into nuclear reactor. Xe-NCT would have great potential usefulness if pharmaceutical optimization of Xe (I) source was performed.

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MAGNET QUALITY ANALYSIS OF THE TASCA SEPARATOR MAGNET USING 3*D* MAGNETIC MEASUREMENTS AND FIELD SIMULATION

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While preparing the new TASCA (TransActinide Separator and Chemistry Apparatus) project at the GSI, 3*D* magnetic field measurements and simulations of the TASCA dipole magnet (*C*-type) were performed.

Measurements were carried out at GSI at coil currents of I=350, 600 and 700 A corresponding to magnetic field levels of B=1, 1.5 and 1.65 T, respectively.

The field calculations were made with the finite-element code KOMPOT [1,2]. KOMPOT simulates various 3*D* stationary field distributions. The code has rich graphic tools for building finite-element models. The postprocessor is capable of producing distributed and integral magnetic characteristics. For example, field maps or magnetic fluxes and EM forces for a given region are created. The graphical interface makes it possible to visualize calculated field distributions in any region of interest and to compare it with data measured at the GSI.

The newly developed KOMPOT postprocessor MOPS allows to calculate optical parameters of the magnet. It can be used for trajectory analysis based on theoretically (KOMPOT) or experimentally (at GSI) determined field map in the working. These parameters contain the field distribution across a beam trajectory, magnetic length, bending angle and slant angles of the magnet, both for the central trajectory and as a function of deviation. Also MOPS gives the edge field distribution along the central trajectory. All the distributions are accessible both as tables and as series expansions.

The KOMPOT model developed for the TASCA *C*-magnet was reduced to one quarter of the magnet bordered by the median plane and the vertical symmetry plane. The mesh had 128 ×63 ×59=475776 nodes. The mesh step in the working zone was taken as 6 mm along the horizontal axis and 4 mm along the vertical axis. More than 30 runs were carried out (i) for currents varying from 50 *A* to 700 *A* for the existing magnet poles shape, (ii) for 700 *A* with different pole shapes to optimize the pole shape, and (iii) with the optimized pole shape for currents up to 850 *A*.

A comparison between measurements and simulations shows only a very small mismatch. Computational model and magnetic measurement data allow calculating magnets with required magnetic field distributions. In addition, the synergism between model calculation and measurement yields much better and much more economic results in any magnet design and optimization. The magnetic field simulations and subsequent optical parameters calculations provided a $3D$ field map in the working area of the TASCA magnet and the corresponding optical characteristics for all required induction (current) regions.

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WHAT DETERMINES THE ENERGY RESOLUTION OF CRYOGENIC IMAGING DETECTORS?

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In this paper, general approach to the energy resolution of cryogenic imaging detectors has been attempted. In detector of this type, primary particles interact with an absorber of a large effective area. Phonons generated by the incident particle in the absorber are registered by arrays of the superconducting tunnel junction (STJ) detectors placed at the perimeter. As signals of STJ detectors depend on position of an incident particle absorption point, so this imaging device provides a two-dimensional position resolution of the events.

This work is intended to describe statistical processes in the cryogenic imaging detectors. The theory of branching cascade processes is applied to the signal formation in an imaging detector and the formula for the energy resolution is derived. It is shown that the energy resolution of an imaging detector is determined by the fluctuations of the phonon absorption probability by STJs, caused by spatial variation of the primary particle absorption point:

$$\eta_\kappa^2 = \sum_{k=1}^{K} \langle m_k \rangle^2 \int_V \tau_k^2(\vec{r}) \cdot \rho(\vec{r}) \cdot dV \Big/ \left(\sum_{k=1}^{K} \langle m_k \rangle \int_V \tau_k(\vec{r}) \cdot \rho(\vec{r}) \cdot dV \right)^2 - 1,$$

where $\rho(\vec{r})$ is the distribution function of the primary particle interaction points with the absorber; $\tau_k(\vec{r})$ is the probability of phonon generated at point $\vec{r}$ to be absorbed by STJ number k; $\langle m_k \rangle$ is the amplification coefficient of the STJ number k.

ENERGY THRESHOLD REDUCTION IN SPECIAL SILICON DETECTORS

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A number of important experiments of modern physic [1-3] require spectrometers with a very low threshold for energy registration. One of the ways for threshold reduction in semiconductor detectors is internal amplification of signals [4]. This work dedicates to investigations of special planar detectors made of *p*-type silicon.

Four quadrants were arranged on a silicon wafer with resistivity 80 Ohm·cm: the pixel diameters were 30 (quadrants I and II), 100 (III), and 1000 (IV). The structure of all pixels was $n^{++}p^{+}pp^{+}$. Charge multiplication occurred in the p^{+} area (between n^{++} and p), because in this area the electric field was enough for avalanche processes. All detectors were fabricated in Research Institute of Material Science and Technology (Zelenograd, Russia).

Registration of X-rays from ^{55}Fe source (energies 5.9 and 6.4 keV) by typical silicon detectors is impossible at room temperature. Detection threshold is about 20 keV even for the best ones. However, we could see the ^{55}Fe X-rays, when we use the investigated structures (Fig. 1). We received similar results for various types of preamplifiers and amplifiers. Amplification coefficient reached the value of 30, energy resolution of amplifying peak > 30%. So spectrometric performances of describing detectors are far from optimal, but the effective reduction of registration threshold could be obtained.

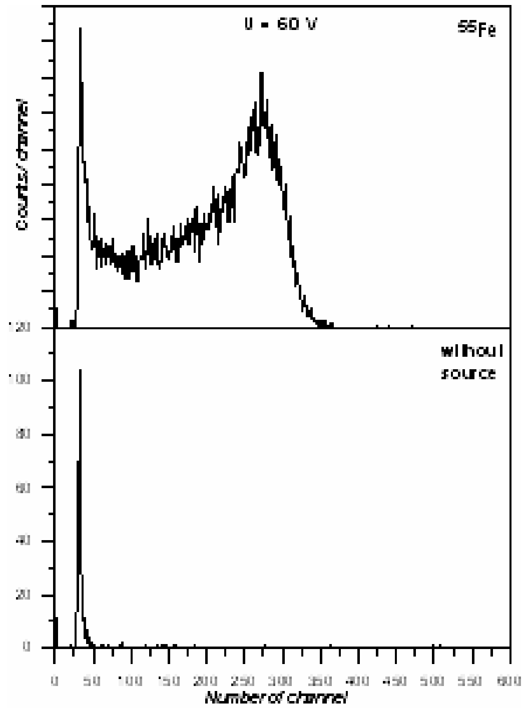

Fig.1. Spectra of X-rays from ^{55}Fe source and without source at room temperature.

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X-RAY FLUORESCENCE DETECTING BY SUPERCONDUCTING TUNNEL JUNCTION

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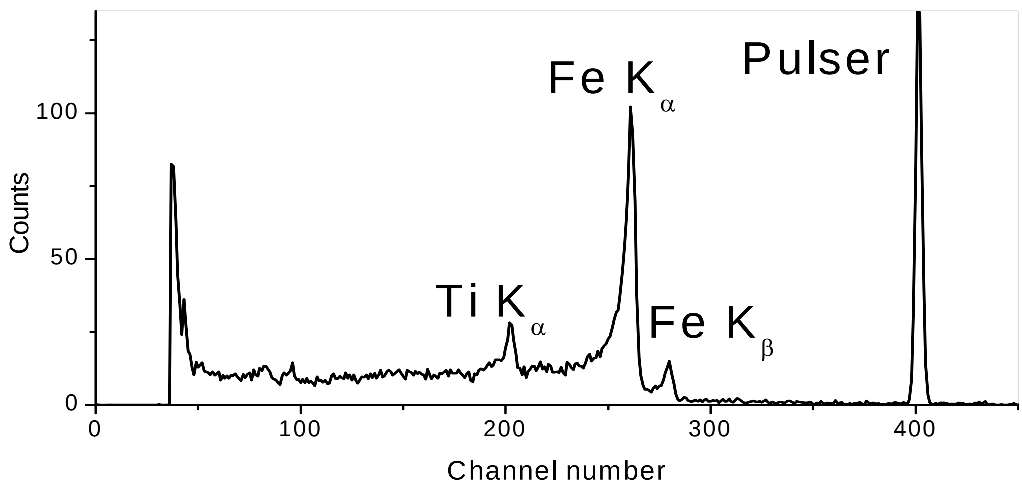
In our studies of low temperature superconducting tunnel junction detectors recently we obtained energy resolution better than that of modern semiconductor radiation detectors [1]. This allows us to investigate the detector response in the soft X-ray energy range (1÷10 keV). Similar work by other groups was carried out with X-rays produced by low-power electron beam impacting a target anode at high voltage [2], tuneable collimated synchrotron beam [3] or X-ray fluorescence excited by synchrotron [4].

In the present study we used less expensive method of fluorescence excitation by a radioactive source. A small cylinder wrapped from Ti foil was placed between the source and detector. A standard ^{55}Fe and Mossbauer ^{57}Co sources were used. In both cases Ti fluorescence was clearly seen. X-ray fluorescence line of Ca from a cylinder made from CaF_2 was also observed.

The result of the ^{57}Co source and Ti foil experiment is shown in the figure. The Mossbauer 14.4 keV line is not registered as a peak in the pulse height spectrum. The consideration of the peak positions shows some nonlinearity with energy. Self-recombination of excess quasiparticles produced after photon absorption is one of the possible reason for this nonlinearity.



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HOW TO FIND EIC OF LOW INTENSITY ON MAS-1 SET UP

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We present in this work a method of finding the low intensity Electron Internal Conversion (EIC) on MAS-1 set up. MAS-1 is a microscopic automatic scanner. This set up was constructed in ITEP in 1997, and after modernization in 2001 it is used for investigations of EIC spectra. MAS-1 set up has CCD-chamber with SONY CCB-M27/CE with CCD matrix having 768 x 576 pixels (sensitive area is 6.46 x 4.83 mm). The system was constructed on firm "Videoscan". The accuracy on all coordinates better than 0.5 mkm.

In the work we investigated a photoemulsion plate with erbium fraction, and only 610-630 keV range was studied. Photoplate R-50 type was exposed on β-spectrometer LNP JINR to electrons from erbium isotopes and their daughter nuclei. In this range of energy at least 12 weak spectral lines were found. Signal/background in this range is 0.02-0.03, and this investigation is not so easy. Only good resolution in our set up (0.07%) gave the possibility to resolve weak lines. For example, we have resolved EIC K672.35 and K673.09 lines.

It is important that first line is E0-transition in ^{160}Dy nucleus between 0^+-states with 1952.33 and 1279.95 keV. In connection with our estimation an intensity of that transition is 0.07±0.01.

MEASUREMENT OF THE ^{57}Fe 14.5-keV STATE HALF-LIFE BY SINGLE-CRYSTAL SCINTILLATION TIME SPECTROMETER

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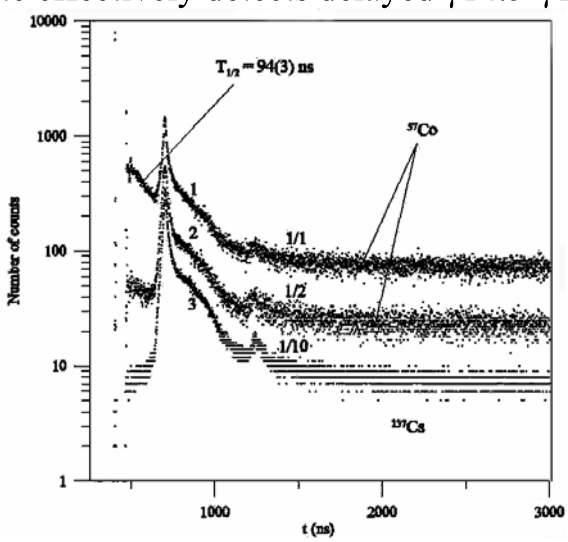
[2]*National Institute for Nuclear Physics and Engineering-HH, Bucharest, Romania.*

This work was carried out to demonstrate that the single-crystal time spectroscopy method may allow the search for isomeric states in the nano- and microsecond region as low-energy γ-radiation is detected by the plastic scintillator. The radioactive source was ^{57}Co produced by irradiating of a natural iron foil (4μm thickness) with a proton beam at the cyclotron accelerator at NIPNE-HH (Bucharest). A photomultiplier, PMT type XP2020, with a low level of noises (≤ 5 keV) and a plastic scintillator type NE104 (∅40×20 mm) was used. The ^{57}Co source was at a distance of 1 mm from the plastic scintillator and was covered with a polyethylene film 40 мm thick on the side facing the detector so that conversion electrons from the 14.5-keV transition were completely absorbed. The results of time measurements at the decay of ^{57}Co are shown by curves 1 and 2 in Fig.1. Curve 2 corresponds to the measurements with the use of 1 mm-thick polyethylene filter. In spite of the rather strong absorption of the 14.4 keV γ-rays (the absorption coefficient equal to 3), the both curves have the same shape, but in the case “2” the counting rate was correspondingly lower. The measured time distribution includes exponential part from the 500th to the 700th channel. The curve 3 corresponds to decay of ^{137}Cs and presents the time spectrum of ^{137}Cs, in fact the distribution of accidental coincidences and afterpulses due to the ion feedback. All these spectra were recorded in the same working conditions with the same counting rates. The processing of data from the exponential distribution leads to the life-time $T_{1/2}$=94(4) ns, in good agreement with well-known life-time $T_{1/2}$=98.1(3) ns of the 14.4 keV isomeric state in the ^{57}Fe. Thus, it is shown that the ASSTS with a plastic scintillator quite effectively detects delayed γ14.5-γ122.3 coincidences.



INVESTIGATION OF ION FEEDBACK AFTERPULSING IN PHOTOMULTIPLIERS

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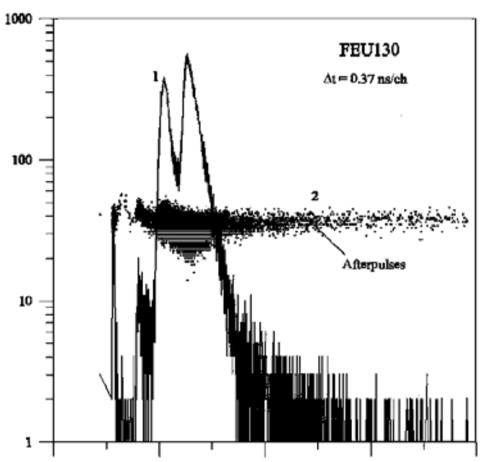
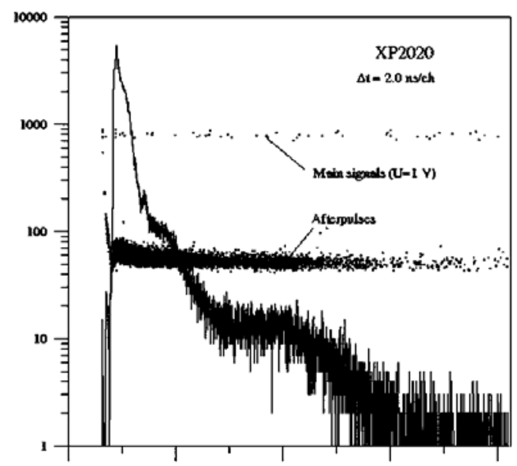
Investigation of ion feedback afterpulsing (IFAP) in the XP2020 and FEU130 photomultipliers was aimed at selecting potentials across the electrodes of the photomultiplier entrance chamber which could provide the minimum intensity level of the detected afterpulsing. Unlike the case in XP2020, in FEU130 the first dynode was coated with GaP and therefore had a higher secondary electron emission coefficient. It was found that in XP2020 a change in the potentials across the electrodes entailed a change in the photoelectron and feedback ion focusing conditions, which was not observed in FEU130. This allows one to get the minimum afterpulsing intensity at the maximum output signal amplitude in photomultipliers with focusing electrodes in the entrance chamber. In FEU130, a photomultiplier without focusing electrodes, this is impossible. In addition, it was found that the afterpulsing intensity in FEU130 is about an order of magnitude larger than the afterpulsing intensity in XP2020. Considering that at a certain voltage applied to the photomultiplier the afterpulsing amplitudes are constant and do not depend upon amplitude of the main signal, criteria for selection of scintillation detectors were formulated such as to provide a low afterpulsing detection level.

Amplitude distributions of IFAP as a function of t are presented on Fig.5 and 6. The main amplitude difference of IFAP is seen in region of the biggest intensities of IFAP and irregularities in this distributions may be explained by the different-types of ion or differences in their charges. It is interesting to see the constancy of the IFAP amplitudes in the microsecond region. Evidently, it is impossible to explain this fact by the drift of ions from the last dynodes of PMT to photocathode. May be it can be explained by the ion interaction with the photocathode material.





INTERACTION OF CHANNELING PARTICLES AT LOW ENERGY

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The interaction of two channeling charging particles has been considered. While using oscillatory approximation for particle-crystal interaction, it is shown that in the case of mass and charge ratios' equality the problem of channeling particles' interaction is solve by description of one particle's behavior on the field of two potentials (1):

$$\left\{-\frac{1}{2\mu}\left(\frac{1}{\rho}\frac{\partial}{\partial\rho}\left(\rho\frac{\partial}{\partial\rho}\right)-\frac{l_z^2}{\rho^2}+\frac{\partial^2}{\partial z^2}\right)+U(r)+\alpha\rho^2\right\}\varphi_2(\rho,z)=E\varphi_2(\rho,z) \qquad (1)$$

where $\alpha\rho^2$ is modified oscillatory potential of crystal-particle interaction, $U(r)$ is between particle interaction potential and μ is reduced mass of two particles.

Analysis of numerical of the equation (1) for the deeply subliminal energy and "head-on collision" show, that in asymptotic ($z\to\infty$), the main part (up to 95%) is carried by the component coinciding to oscillatory level of falling wave. At the same time transmission coefficients equal zero with precision not more than digital. This result is coinciding with analytical solution for one-dimension Coulomb barrier. Therefore the probability of transmission coefficients isn't equal zero may be exist only for non-direct collision. It can be waited that passing of barrier for channeling particles will sufficient differ from three-dimension collision.

The result of this work can be useful for the investigation of opportunity thermonuclear reaction in crystal [1,2].

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CURRENT PRODUSED BY PULSE OF HARD RADIATION

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In this work we consider effects of secondary electrons and photons effects in order to get a better understanding of detector performance for relativistic charged particles registration.

The roles of photo, Compton, and ionization electrons in the formation of the pulse current are discussed. Monte-Carlo method is applied. The program code is developed basing on the GEANT 4 software package [1]. A computer cluster of Department of physics of St.-Petersburg State University is used for the calculations.

The results presented in Table 1 were obtained for 20 – 4000 keV gamma-ray photons propagating through the 4 mm water layer.

Table 1. The contribution of various physical processes in a current pulse formed by the interaction of gamma radiation with the 4 mm layer of water, fixed in the middle of layer (detecting plane on distance of 2 mm from a source of radiation).

Energy	Photo effect	Compton effect	Ionization,	Effect pairing
кeV	%	%	%	%
20	99.9	0.0	0.1	0.0
50	97.5	2.0	0. 5	0.0
100	30.2	69.4	0.4	0.0
200	2.0	97.6	0.4	0.0
300	0.4	98.9	0.7	0.0
500	0. 1	98.9	1.0	0.0
1000	0.0	98.4	1..6	0.0
1500	0.0	97.9	2.1	0.0
2000	0.0	97.3	2.3	0.4
3000	0.0	95.0	2.6	2.4
4000	0.0	92.1	2.8	5.1

It should be noted that the main contribution to the resulting current pulse is given by the electrons of energy greater than 10 keV which are effectively produced if the initial photon energy is higher than 300 keV.

The work is partly supported by the State Program “Russian Universities” (grant № 02.01.300).

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DIRECT EXPERIMENTAL OBSERVATION OF POSITRONIUM ATOM IN POROUS SILICON

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The method of the angular distribution of annihilation photons (ADAP) [1] has been used to investigate the positron annihilation in porous silicon layers formed by the electrochemical method [2] on single crystal silicon wafers, boron-doped, 0.03 Ohm.cm resistivity, (111) surface orientation. The thickness of the porous layers in all samples was 20 μm. The ADAP spectra are well approximated by the parabola (I_p) and two Gaussians (I_{g1}, I_{g2}) (Table 1). Each of these components characterizes a certain channel of the positron annihilation. The most interesting is the narrow Gaussian component I_{g1} caused by the annihilation decay of the para-positronium in the volume of pores. The half-height width of the component is about 0.5 mrad that corresponds to the kinetic energy of the annihilating positron-electron pair of (0,079±0,012) eV, and its intensity is about 1.5%.

Thus, the total yield of the positronium in the porous silicon runs up to the value of 6%. These data are the direct experimental evidence of the existence of the slow quasi-thermalized para-positronium in pores.

Sample characteristics	$I_{g1}=S_{g1}/S_{sum}$	$I_{g2}=S_{g2}/S_{sum}$	$I_p=S_p/S_{sum}$
Porous Si $HF:C_2H_5OH=2:1$, J=20 mA/cm^2	0,015±0,003	0,493±0.052	0,492±0,044
Porous Si $HF:C_2H_5OH=1:1$, J=10 mA/cm^2	0,006±0,003	0,492±0,045	0,502±0,038

Note: The thickness of silicon wafers is ≈ 340-370 μm, $Ig = Sg/ S_{sum}$ is the intensity of the Gaussian component and $I_P = S_p/S_{sum}$ is the intensity of the parabolic component in the ADAP spectra (S_{sum} is the total area of the experimental ADAP spectrum , S_g and S_p are areas of the Gaussian and parabolic components in this spectrum, correspondingly), J is the current density.

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TO THE PROBLEM OF CUSTOM INSPECTION OF NUCLEAR MATERIALS

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The international regime of the nuclear weapon non-prolifiration is a large complex of political, juridical, organizational, scientific and technical measures. The possibility of production or reception of the nuclear weapon by terrorist groups can be prevented only by technical means. That is why a role of systems for the primary proximate detection and identification of nuclear materials by custom inspection of freights, transport facilities and luggage increases. The point is not only in fissile and heavy isotopes but as well as in high-neutron-absorbing and high-neutron-moderative materials like ^{2}D, D_2O, Li, ^{6}LiD, ^{9}Be, BeO, graphite and etc. which can be used for production of nuclear weapon components.

Modern inspectional complexes for nondestructive testing of freight containers and transport facilities function or are created on the basis of 3-15 MeV electron accelerators technology. (For all that the high stability of parameters and the high reproducibility of received bremsstrahlung beams permit to use such accelerators in technological tomography and introscopy). The possibilities of such inspection complexes (in the field of application for the primary proximate detection and identification of nuclear materials) can be considerably expended if it makes using the following circumstances: photofission thresholds of fissile and heavy isotopes are smaller than 6 MeV (but more than 4.0-4.5 MeV), and photoneutron thresholds are smaller than 6 MeV only for ^{2}H(0.015%)-2,23; ^{6}Li(7.4%)-5.67; ^{9}Be(100%)-1.67; ^{13}C(1.1%)-4.95; ^{17}O(0.04%)-4.15; ^{145}Nd(8.3%)-5.76; ^{149}Sm(14%)-5.88; ^{151}Sm(β^-; 81 y.)-5.60; ^{189}Os(16%)-5.93; ^{210}Pb((β^-; 22.3 y.)-5.19; ^{210}Bi(α; $3.04\cdot10^{6}$ y.)-4.87 MeV respectively [1,2,3]. So, by discrete changing of electron energy (i. e. of maximal energy of bremsstrahlung beam up to 6 MeV) it is possible reliably to identify both the nuclide – the photoneutron source and to determine in the inspection object presence of fissile or heavy isotopes (as both as by photofission neutrons and by delayed neutrons between bunches of electrons).

It is presented the estimations of yields of photoneutrons and also photofission neutrons for maximal energy of bremsstrahlung of 5 and 6 MeV (per 1 sec., per 1 m from bremsstrahlung thick W-target, per 1 μA of average target electron current, per 1 gram of testing material).

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POSSIBILITIES FOR INVESTIGATIONS OF IRRADIATED SAMPLES WITH DEPTH SELECTIVE ELECTRON MöSSBAUER SPECTROSCOPY

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Mössbauer spectroscopy is widely used in various nuclear-physical investigations. In particular, non-destructive method of depth selective electron Mössbauer spectroscopy (DSEMS) that enables studies of subsurface nano-layers undergoes now its active development. Precise measurements performed at an installation represented by a combination of beta-spectrometer and nuclear gamma-resonance spectrometer are of particular interest.

Recent years investigations of properties of various irradiated materials including materials containing Mössbauer nuclei attract more attention. In that case DSEMS method faces known obstacles since activated samples radiate considerable number of “interfering” electrons without any relation to discharging of excited Mössbauer levels.. Precise measurements at a combined installation are of particular value since a beta-spectrometer makes it possible to effectively single out electrons in a quite narrow energy interval.

In order to evaluate possibilities of this method application for investigations of irradiated samples there were determined energy and intensity of “interfering” electron radiation in a range of construction materials with various Mössbauer nuclei. In each case there were recommended optimal ways for utilization of specific types of electron radiation due to decomposition of Mössbauer levels – they could be internal conversion electrons, Auger electrons or secondary electrons. There was found decay time for ageing of irradiated samples with the purpose to decrease intensity of the “interfering” electron radiation to acceptable level. In all cases fluence of activating particles was varied.

It has been shown that the most promising and wide possibilities for investigations of irradiated samples are provided by a combined installation with highly effective magnetic sector beta-spectrometer with double focusing equipped with a large area non-equipotential electron source (sample under investigation) and a position-sensitive detector based on microchannel plates [1]. In several cases this spectrometer enables measurements of samples with, for instance, natural mixtures of iron isotopes.

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STUDY OF YIG FILMS LONG-TERM STABILITY UNDER IRRADIATION

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Oscillations and waves of magnetization (or spin waves) in yttrium-iron garnet (YIG) ferrite films have interesting and useful properties such as a high *Q*-factor, a wide variety of dispersion laws dependent on the orientation of the bias magnetic field, and a possibility to tune their frequencies in the range of several GHz by changing the magnitude of the bias magnetic field.

Another important property of ferrite films is low (of the order of several microwatt) power threshold of nonlinear spin wave processes. The nonlinear properties of ferrite films can be used for the development of novel nonlinear microwave signal processing devices based on the parametric interaction of spin wave packets propagating in films with localized electromagnetic fields of microwave pumping.

At the same time, YIG ferrite films are widely used in different electronic and magnetic-electronic devices and equipment that have already found a variety of both space and nuclear applications. So radiation stability investigations of such materials become very important now [1].

The irradiation of YIG films has been performed by electrons and bramstahlung photons with the energy up to 3 MeV and currents about 1 $\mu A/cm^2$ at the new linac of Kiev Institute for Nuclear Research and by reactor neutrons with the fluences up to 10^{19} n/cm^2. The radiation effects have been analyzed using ferro-magnetic resonance method.

At the same time, YIG films have been irradiated by neutrons from radio-isotopic sources and by low-energy electrons with the energy up to 100 keV as well. In order to study the effects of such irradiations different techniques more sensitive than the ferro-magnetic resonance method have been used.

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THE ACCOUNT OF THE EFFECTS OF SELF-ABSORPTION AND TRUE COINCIDENCE SUMMING OF GAMMA-QUANTA IN THE NEUTRON ACTIVATION METHOD

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Semi-empirical method of the account of the effects of self-absorption and true coincidence summing of gamma-quanta for the case of axial-symmetric geometry of spectra measuring is proposed.

Self-absorption correction is calculated by Monte-Carlo method taking into account the non-uniform distribution of activity. The influence of detector edge effect is also included.

True coincidence summing correction is calculated by semi-empirical method. Besides the γ-γ true coincidences the influence of X-rays originating from internal conversion or preceded by electron capture, positron annihilation photons, absorbed and scattered in the sample gamma radiation are considered. Proposed mathematical treatment significantly simplifies the analysis of the decay-schemes of any complexity by means of fragmentation of the whole decay-scheme on the elementary cascades.

Created and tested technique simplifies the analysis of complex decay schemes and gives the opportunity essentially decrease the statistical error in the (n, x) nuclear reaction cross section measurements.

DEAD TIME CORRECTIONS FOR VARIABLE COUNT RATE SOURCES

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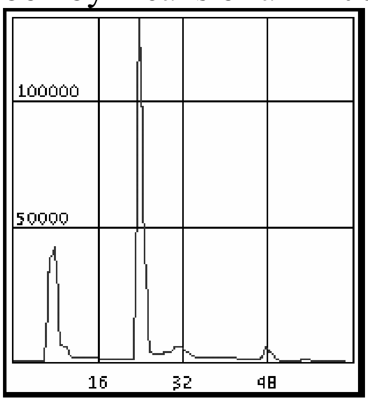
To process correctly spectra having been obtained during measurement of a radioactive source with variable count rate it is necessary to take into account the dead time losses. For instance the determination of the source isotopical mixture by means of studying the decay period of the typical peaks is not possible without knowledge of the dead time losses.

In the framework of the wmonitor [1] data acquisition system, which is used on YASNAPP-2 facility, a special measuring modul has been developed. Two counters and the real time stamp of the moment, when the program is awaked by the interrupt, give the possibility to deduce both the hardware and software processing time.

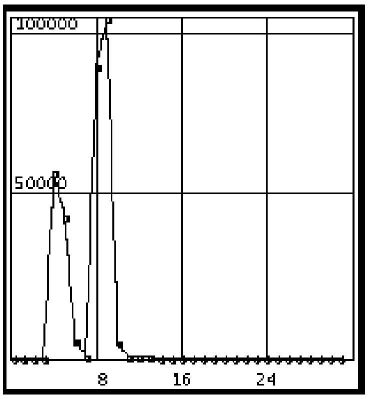
The multi-parameters both on-line and off-line sorting program enables to obtain not only the usual single spectrum with the dead time losses but also the anatomy of the signal processing in detail. Thus the noise and pile-up pulses can be identified and removed.

The ^{152}Eu source giving about 3000/s count rate has been measured with a 20% HPGe detector, an Ortec 673 amplifier, a Canberra 8075 ADC with a proprietary CAMAC interface and two counters. The shaping time was ф=3мs. The CAMAC crate was controlled with an 1.2GHz/256MB Celeron PC linux box by means of a KK009/PK009 controller.



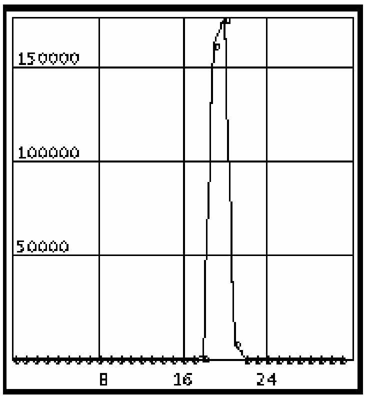
time [мs]

1. amplifier dead time



time [мs]

2. interrupt response



time [мs]

3. program dead time

The picture number one shows the amplifier BUSY signal. The first, second and other peaks correspond to the noise, the typical ~7ф and pile-up pulses, respectively. The picture two displays the estimated PC and OS interrupt response. The first peak corresponds to the noise pulses. The third picture shows the program processing time from the moment when the program has been awaked by the interrupt request.

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INVESTIGATION METEORITE TSAREV ABUNDANCES IN THE CALCIUM BY ACCELERATOR TECHNIQUES

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The mechanism of element synthesis of a Solar system is investigated widely now. The formation of isotopes in range of masses from silicium to titanium depends on mass of a Supernova explosion. It is supposed, that the elements from sulfur to titanium are synthesised as rule in stars of a mass more 25 $M_{\odot}$. Therefore measure of isotopic abundances in calcium of crystalline rocks of the Earth and meteorites allows to investigate evolution of a Solar system and Universe. Let's mark, that the formation $^{42,43,44}Ca$ have substantial contributions from s–process. The nuclides $^{42,43}Ca$ are a product of explosive oxygen and carbon burning, respectively. The nuclide ^{44}Ca appears not be made by explosive and quasi–equilibrium processes in required amounts. The formation ^{46}Ca does not correlate with formation ^{48}Ca. Perhaps, ^{48}Ca is formed during burning silicium with high density of neutrons. It is correspondent to weak–interaction steady state conditions [1].

In this paper the ratio $^{44}Ca/^{48}Ca$ of the Earth rocks and the meteorite Tsarev is obtained (it has fallen in 1922 year in the Volgograd range of Russia) by means of use of a bremsstrahlung radiation of a powerful linac of electrons (energy 23 MeV, current 700 μA). The spectrums of radiation from samples of calcite, fluorite, apatite and the meteorite Tsarev was measured by the low background of arrangement on a basis Ge(Li)-detector. For these geologic samples ratio $^{44}Ca/^{48}Ca$ does not depend on a type of rock and place of bedding. The ratio $^{44}Ca/^{48}Ca$ of the stone meteorite Tsarev (L5) is 14 % high relatively the geologic samples.

It is supposed, that isotope abundances in calcium of calcium-aluminium-rich inclusions (CAI) in the Universe and in Supernova arising substance during explosion can be different. Therefore it is possible to assume that Supernova with low value of ^{48}Ca was present in early stages of evolution of Solar system.

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NUCLEAR SUPERFLUORESCENCE IN ^{178}Hf "GAMMA-OPTICAL" MEDIUM

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The realization of induced emission regime in gamma diapason is the old and very complex problem, which have not been solved so far. It can not be made in traditional "optical" way because:

1) The methods to reach the inversion population of a two-level "gamma-optical" medium are absent;
2) The resonators for steady state regime in gamma diapason are not created.

Such state of art has stimulated the search of alternative approaches to solve the problem of induced amplification of gamma radiation. One of them could be gamma emission under nuclear superfluorescence conditions. For some time this approach has attracted the increased interest due to the recent investigations of metastable states of the nuclei belonging to "stability island" (A~180) [1]. Especially, it have been shown the acceleration under bremsstrahlung influence of electromagnetic transition from metastable state to a short-lived state which is then decaying by a cascade of electromagnetic transitions.

One of the perspective isotopes for the reach of the conditions of nuclear superfluorescence could be ^{178}Hf which possesses the isomer state ^{178m2}Hf with $t_{1/2} \approx 31$ yr. It has been found that accelerated transition of ^{178m2}Hf to upper superfluorescence levels with either $t_{1/2} \approx 78$ ns or $t_{1/2} \approx 68$ μs could be possible under influence of bremsstrahlung of energy $E_\gamma \leq$ 90 KeV. In this work the formation of gamma avalanche due to collective decay of such upper levels in ^{178}Hf "gamma-optical" medium is being theoretically studied.

It is proposed that synchrotron radiation is used as both bremsstrahlung and triggering mechanism of gamma avalanche formation. It could allow, at first, to increase the density of states for collective decay and, at second, to "instantly" populate upper superfluorescence level with $t_{1/2} \approx 78$ ns.

The theoretical modeling of nuclear superfluorescence have been carried out as for unperiodical (forward scattering) "gamma-optical" medium as periodical (nuclear diffraction under Bragg conditions) one. The last case is especially important because inelastic interaction of gamma-quanta with ^{178}Hf atoms is essentially attenuated due to Borrmann effect. The work have been particularly supported by RFBR under grant № 05-02-16567.

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STIMULATION MECHANISMS OF LOW ENERGY NUCLEAR REACTIONS USING SUPERLOW ENERGY EXTERNAL FIELDS

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The review of possible stimulation mechanisms of LENR (low energy nuclear reaction) is represented. We have concluded that transmutation of nuclei at low energies and excess heat are possible in the framework of the modern physical theory – the universal resonance synchronization principle [1] and based on its different enhancement mechanisms of reaction rates are responsible for these processes [2]. The excitation and ionization of atoms may play role as a trigger for LENR. Superlow energy of external fields may stimulate LENR [3]. Investigation of this phenomenon requires knowledge of different branches of science: nuclear and atomic physics, chemistry and electrochemistry, condensed matter and solid state physics. The results of this research field can provide a new source of energy, substances and technologies.

The puzzle of poor reproducibility of experimental data is due to the fact that LENR occurs in open systems and it is extremely sensitive to parameters of external fields and systems. Classical reproducibility principle should be reconsidered for LENR experiments. Poor reproducibility and unexplained results do not means that the experiment is wrong. Our main conclusions:

1) LENR may be understood in terms of the modern theory without any violation of the basic physics.

2) Weak and electromagnetic interactions may show the strong influence of the surrounding conditions on the nuclear processes.

3) Universal resonance synchronization principle is a key issue to make a bridge between various scales of interactions and it is responsible for self-organization of hierarchial systems independent of substance, fields and interactions. We bring some arguments in favor of the mechanism – ORDER BASED on ORDER, declared by Schrodinger in [4], fundamental problem of contemporary science.

4) The universal resonance synchronization principle became a fruitful interdisciplinary science of general laws of self-organized processes in different branches of physics because it is the consequence of the energy conservation law and resonance character of any interaction between wave systems. We have proved the homology of atom, molecule and crystal structures including living cells. Distances of such systems are commensurable with the de Broglie wave length of an electron in the ground state of a hydrogen atom, it play the role of the standard distance for comparison.

"The selective resonant tunneling model" [5], "the superwaves principle" [6], "the tetrahedral and octahedral symmetric condensations" [7], "the lattice resonating group method" [8], "the ion band" [9], "the boundary effects" [10], "transmutations in biological systems" [11],… are consistent with our universal resonance synchronization principle – the common design feature of many modern models for LENR.

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AN ALPHA CLUSTER MODEL BASED ON *pn*-PAIRS INTERACTIONS

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In the phenomenological approach the proton –neutron (*pn*) pair is considered as a basic element of the nuclear structure [1]. The nuclear potentials of proton and neutron of one pair are supposed to be equal (EPN principle). The spins of pairs are taken into account only once to explain that fact that two pairs are bound in a spinless alpha cluster. Also for excess neutrons the spin is mentioned only in connection with explanation why the excess neutrons are bound in neutron-neutron spinless pairs. Such considerations leads to the classical alpha cluster liquid drop model [2] with some addition that short range interactions between alpha clusters refer to thier *pn*-pairs interactions, which helped in obtaining of empirical values of inter clusters nuclear adherence and Coulomb repulsion energies for nuclei in their ground states.

The EPN principle allows one to consider the value of difference between the single particle energies of proton and neutron ΔE_{pn} as the Coulomb energy of the proton interaction with the other protons of the nucleus, which helps in obtaining empirical values of Coulomb energy for nuclei with $Z < 30$ (for nuclei with $22 < Z < 30$ the values of ΔE_{pn} were taken from [3]). In frame of the model root mean square radii $<r^2>^{1/2}$ for nuclei with $8 < Z < 118$ were calculated. The deviation of the values $<r^2>^{1/2}$ from known experimental values is $<\Delta^2>^{1/2} = 0.05$ Fm [4]. In this model charge radius and Coulomb radius of nuclei are defined by the number of proton-neutron pairs.

Energy of excess neutrons stays beyond the consideration, so in the calculations empirical values of energies of excess *nn* - pairs are used. In frame of the model a phenomenological formulae to calculate binding energy of nuclei with integer amount of *pn*-pairs and excess *nn*- pairs is obtained, which gives deviation $|\Delta|$ of the calculated values from experimental data compatible with Weizsacker formula's errors, which is in average less than 0.5%.

To test the formula in independence of excess neutrons binding energy alpha particle and deutron separation energies have been calculated too. An average deviation between the values and experimental ones $|\Delta| = 1$ MeV.

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CHARGE AND MATTER NUCLEAR RADII IN FRAME OF MODEL OF *pn*-PAIRS INTERACTIONS

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In frame of alpha cluster model of nuclear structure based on proton-neutron pairs interactions with using shells (4 or 5 alpha clusters) charge radii R_{ch} of all known nuclei have been calculated on amount of consisted in nucleus proton - neutron pairs (or alpha clusters) disregarding to the number of excess neutrons [1,2]. It is suggested that excess neutron-neutron pairs fill in the space between the charge and matter of the alpha clusters. To calculate radius of nuclear matter R_m nucleus is supposed to consist of a core and a molecule ^{16}O (for nuclei with even Z) or ^{19}F (for odd Z). With the value of radius of one nucleon of alpha clusters of core r_{pn} = 0.945 Fm and radius of one neutron of excess neutron-neutron pairs r_{nn} = 0.84 Fm the values of R_m for the most abundant isotopes have been calculated. The deviation between R_{ch} and R_m for nuclei with $12 \le Z \le 118$ is $\langle\Delta^2\rangle^{1/2}$ = 0.036 Fm. The deviation between the radii R_m and R_{exp} $\langle\Delta^2\rangle^{1/2}$ = 0.048 Fm Fig. 1. [2].

The equivalence of charge and matter radii of nucleus might be one of the conditions needed for long longevity of isotope and as the consequence its big abundance on Earth. If there is not the balance between the radii in the nucleus it causes в - radioactivity. Some even nuclei can have either ^{16}O or ^{20}Ne molecule above their core (for odd nuclei either ^{19}F or ^{23}Na), which give some amount of stable isotopes with close values of $R_m = R_{ch}$. It is illustrated on example of stable isotopes of Calcium.

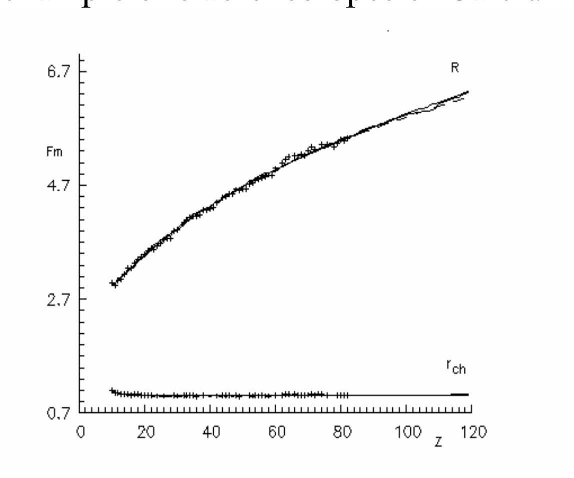

Fig1. Charge and matter radii R and charge radius of one nucleon of α-clusters r_{ch}. Crosses stand for R_{exp}[3], solid lines indicate R_{ch} and R_m. Dashed line indicates $R=1.008(2Z)^{1/3}$ Fm for $Z \geq 2\alpha$. Values of r_{ch} are obtained from $r_{ch}=R_{ch/exp/m}/(2Z)^{1/3}$. Indications of the values r_{ch} correspond to R_{ch}, R_{exp}, R_m. In the scale the lines of r_{ch} merge the dashed line of value r_{ch} =1.008 Fm.

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EXPLANATION OF THE CONSERVATION OF LEPTON NUMBER

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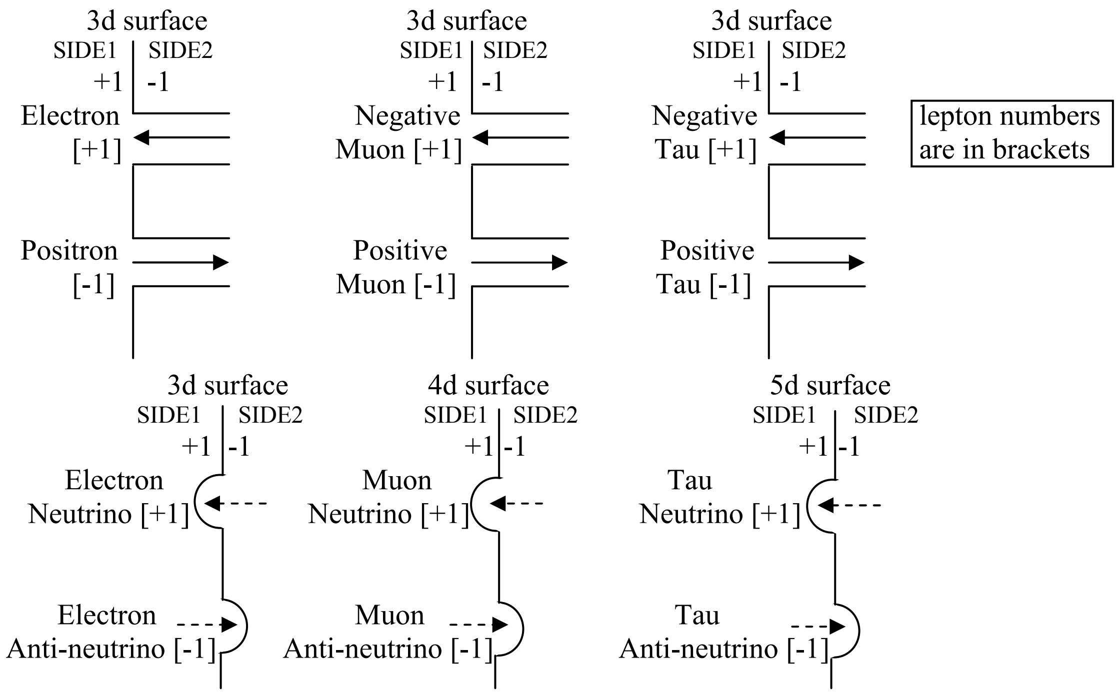
It was proposed that all hadrons and the electron, muon, and tau leptons are three dimensional (3*d*) holes bent into and out of the surfaces of higher dimensional space [1]. These holes are the ends of vortices of space flowing through fourth dimensional space that originally connected them to their anti-particle. As space flows into a 3*d* hole, a positive electrostatic charge is created; as space flows out of a 3*d* hole a negative electrostatic charge is created; while neutral particles are vortices bent into torus configurations [2]. Neutrinos are quantized transverse waves bent out of the 3d surface and anti-neutrinos are bent into the 3*d* surface. Applying this model to the creation and destruction of leptons, a correlation was discovered between lepton number and the direction space is flowing (black arrows) in electrons, muons, taus, their anti-particles and, the direction bent space is oriented within their associated neutrino or anti-neutrino. The 3d surface is drawn as a line. The left side +1 [side1] represents space bent out of the surface; the right side -1 [side2] represents space bent into the surface.



On the diagrams, it can be seen that the direction space is bent corresponds to the lepton number. Observe too that the electron, muon, and tau neutrinos, and their anti-neutrinos are all created upon the surfaces of different dimensions. These dimensions correspond to the higher dimensional holes the vortex theory now proposes to exist within the muon, tau, and their anti-particles.

1. R.G.Moon, V.V.Vasiliev // *Nucleus-2003*, 2003, Book of abstracts. P.251.
2. R.G.Moon, V.V.Vasiliev // *Nucleus-2004*, 2004, Book of abstracts. P.259.

THE POSSIBLE EXISTENCE OF A NEW PARTICLE IN NATURE: THE "TUNNELING PION"?

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Using the principles of the Vortex Theory, it was discovered that when the neutrino collides with the neutron, or when the anti-neutrino collides with the proton, two "tunneling" quarks are released: a neutron releases the down, anti-up quarks; the proton releases the up, anti-down quarks [1].

The down, anti-up quarks create a tunneling negative pion, while the up, anti-down quarks create a tunneling positive pion, when the energy of the collision is high enough these pions do not tunnel, but instead become the pions seen during the decays of nucleons [2].

Both particles travel (tunnel) through fourth dimensional space just beneath the surface of three dimensional space [3]. These two particles are the precursor of a new classification of particle whose mass and energy characteristics are undetectable until colliding with another particle.

1. R.G.Moon // *The Vortex Theory Explains the Quark Theory*, Gordon's Publications of Fort Lauderdale Fla., USA, 2005, P.195.
2. D.R.Lide // CRC Handbook of Chemistry and Physics, P.11-1, CRC Press LLC, 2003-2004.
3. R.G.Moon, V.V.Vasiliev // The bases of the vortex theory, Book of Abstracts. The 53 International Meeting on Nuclear Spectroscopy and Nuclear Structure, St. Petersburg, Russia, 2003, P.251.

THE POSSIBLE EXISTENCE OF A NEW PARTICLE: THE NEUTRAL PENTAQUARK?

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Using the principles of the Vortex Theory [1], it was discovered that when the gamma ray strikes a nucleon, the positively charged pentaquark (and the K^- meson) had to be created by the collision with neutron. This discovery further reveals that if the gamma ray strikes a proton it can create a Neutral Pentaquark (and a D^+ meson).

The neutral pentaquark will consist of an up, up, down, down, and an anti-charm quark, while the D^+ meson will consist of a charm and an anti-down quark [2]. The neutral pentaquark will later decay into a neutron and $D^{\mathbf{0}}$ meson. Because the vortex theory also reveals that the strong force couples a proton to a neutron [3], the neutron that was coupled to the proton in the nucleus will also be found amid the debris particles.

1. R.G.Moon, V.V.Vasiliev // Nucleus-2003, Book of abstracts. P.251.
2. R.G.Moon // *The Vortex Theory Explains the Quark Theory*, Gordons Publications of Fort Lauderdale Fla., 2005, P.195.
3. R.G.Moon // *The Vortex Theory*, Gordons Publications of Fort Lauderdale Fla., 2003, P.45.

THE GENERALIZED KAPUR-PEIERLS FORMULA FOR CROSS-SECTION OF INELASTIC NEUTRON SCATTERING

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For a case of a scatter of a neutron on a core with the moments ℓ =0 and ℓ≠0 the expression for amplitude of an inelastic scatter in a common basis containing a wave functions of bound and continuous conditions of a neutron in a compound nucleus is obtained:

$$\Psi\left(\vec{r},\vec{\xi}\right)=\sum_p [a^p \Psi^{(\partial)p}\left(\vec{r},\vec{\xi}\right)+c^p \Psi^{(H)p}\left(\vec{r},\vec{\xi}\right)] \tag{1}$$

The similar decomposition utilised by the writer in activity [2] at obtaining amplitude of an elastic scatter.
The conditions of a compound nucleus are characterized by a wave function $\Psi^p\left(\vec{r},\vec{\xi}\right)$. Here $\vec{\xi}$ - in-house coordinates A nucleons in a core; $\vec{r}$ - a position vector of a scattered neutron.

For cross-section of an inelastic scatter the formula of a kind is obtained:

$$\sigma_{\alpha\alpha',j}=\frac{\pi}{k^2}\left|\sum_p I_\alpha \left[\frac{u_p^{(\partial)}u_{pj}^{(\partial)}}{w_p^{(\partial)}-E}+\frac{u_p^{(H)}u_{pj}^{(H)}}{w_p^{(H)}-E}\right]\right|^2 \tag{2}$$

The first member marked by of the sum represents the known formula Kapur-Peierls for cross-section of an inelastic scatter if to rename $u_p^{(\partial)}=u_p, u_{pj}^{(\partial)}=u_{pj}$.

The functions $u_p^{(H)}$ also $u_{pj}^{(H)}$ look like:

$$u_p^{(H)}=\left(\frac{k\hbar^2}{M}\right)^{\frac{1}{2}}\frac{1}{\left|\phi_\alpha^+(R)\right|}\int_{E_{00}}^{\infty} c_m^p \phi_m^{(H)} dE_{0m}, \quad u_{pj}^{(H)}=\left(\frac{k\hbar^2}{M}\right)^{\frac{1}{2}}\frac{1}{\left|\phi^{j}{}_{\alpha'}^{+}(R)\right|}\int_{E_{j0}}^{\infty} c_{jm}^p \phi_{jm}^{(H)} dE_{jm} \tag{3}$$

The functions $u_p^{(H)}$ also $u_{pj}^{(H)}$ are resulted in [1].

The expression (3) is obtained under condition of continuity of a wave function of a core and it by logarithmic derivative on border of a core R pursuant to the requirement of activity [1]. The waiving of the last condition yields expression for cross-section of a scatter, which here is not resulted because of its complexity. The formula (2) will allow more precisely to take into account the contribution of the continuous spectrum energy at problem solving of applied character.

1. A.Lein, R.Thomas // *Theory of Nuclear Reactions at Low and Intermediate Energies*, Moscow, 1960. 416 p. (In Russian).
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