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RUSSIAN ACADEMY OF SCIENCES
JOINT INSTITUTE FOR NUCLEAR RESEARCH
PETERSBURG NUCLEAR PHYSICS INSTITUTE
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LXV INTERNATIONAL CONFERENCE

«NUCLEUS 2015»

NEW HORIZONS IN NUCLEAR PHYSICS, NUCLEAR ENGINEERING, FEMTO- AND NANOTECHNOLOGIES

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BOOK OF ABSTRACTS
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LXV INTERNATIONAL CONFERENCE «NUCLEUS 2015». NEW HORIZONS IN NUCLEAR PHYSICS, NUCLEAR ENGINEERING, FEMTO– AND NANOTECHNOLOGIES (LXV MEETING ON NUCLEAR SPECTROSCOPY AND NUCLEAR STRUCTURE). BOOK OF ABSTRACS.
Editor A.K. Vlasnikov

The scientific program of the conference covers almost all problems in nuclear physics and its applications such as: neutron-rich nuclei, nuclei far from stability valley, giant resonances, many-phonon and many-quasiparticle states in nuclei, high-spin and super-deformed states in nuclei, synthesis of super-heavy elements, reactions with radioactive nuclear beams, heavy ions, nucleons and elementary particles, fusion and fission of nuclei, many-body problem in nuclear physics, microscopic description of collective and single-particle states in nuclei, non-linear nuclear dynamics, meson and quark degrees of freedom in nuclei, mesoatoms, hypernuclei and other nuclear exotic systems, double beta-decay and neutrino mass problem, interaction of nucleus with electrons of atomic shell, verification of theories of elementary particles interaction and conservation laws, physics of nucleus and particles in application to astrophysical objects, theory of direct and statistical nuclear reactions, theory of multiple scattering, theory of reactions with clusters and heavy ions, theory of relativistic nuclear collisions, theory of polarization phenomenon in nuclear reactions, theories of proton, two-protons and cluster radioactivity and fission of nuclei, application of the theory of few-particle systems to nuclear and atomic physics (application of Faddeev and Faddeev-Yakubovsky equations, application of hyperspherical and adiabatic hyperspherical methods, application of asymptotic methods for investigation of few-particle wave functions asymptotics, three-body Coulomb problem, few-particle systems on the lattice, few-particle systems with reduced dimensionality), instruments and methods of nuclear-physical experiment, analysis of measurements, accelerators, radio-ecology, application of nuclear-physical experimental methods to astrophysics, medicine and other fields of research, fundamental problems of nuclear power and nuclear technologies.

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IN MEMORY OF KONSTANTIN ALEKSANDROVICH GRIDNEV (08.02.1938—10.06.2015)

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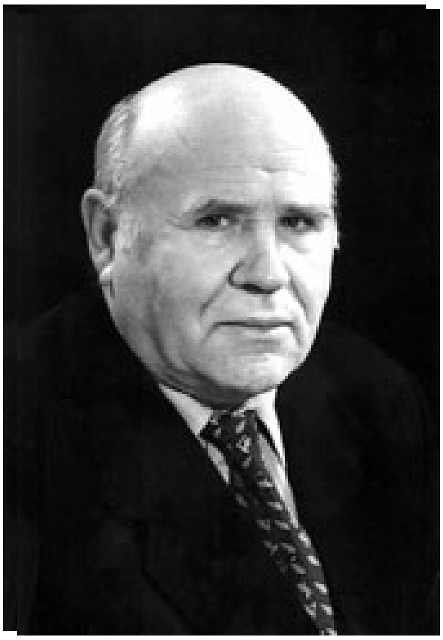

On June 10, 2015 Konstantin Aleksandrovich Gridnev had passed away. He was a prominent scientist, an outstanding organizer of International Conferences on Nuclear Physics and Nuclear Structure, Professor, Doctor of Science. All his active life was connected with the physical faculty of Saint-Petersburg State University, where he advanced from a student to the department head. K.A. Gridnev always endevoureded to develop the most promising research areas in nuclear physics. While still a post-graduate student, he understood the opportunities provided by the newborn computers and developed the program packages for calculations of direct nuclear processes. These programs were widely used in the major nuclear physics centers. Later K.A. Gridnev focused on theoretical studies of nuclear structure and nuclear reaction mechanisms. He got a lot of new interesting results, among which one might mention investigation of transfer reactions to unbound states in nuclei, application of the nonlinear Schrödinger equation to nuclear physics. Konstantin Aleksandrovich made a great contribution to the studies of neutron drip line, Bose condensation and clustering processes in atomic nuclei. He was the author of more than 150 publications. These works were highly appreciated by scientific community and are often cited in the literature.

For more than 25 years Konstantin Aleksandrovich headed the Department of nuclear physics. During this time he prepared 5 Doctors of Science and 37 PhD’s. His lectures were attended by students and professionals in more than 10 countries.

Konstantin Aleksandrovich has played an important role in the development of scientific relations between Russia and international nuclear centers in the United States, Germany, Italy, Spain, Japan and other countries. For many years he represented Russia in the Board of the Nuclear Physics Division of the European Physical Society, was a member of the editorial boards of several international journals. His friends, colleagues and students will always remember him.

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ON MICROSCOPIC THEORY OF RADIATIVE NUCLEAR REACTION CHARACTERISTICS

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A survey of some results in the modern microscopic theory of properties of nuclear reactions with gamma-rays is given. First of all, we discuss the impact of phonon coupling (PC) on the photon strength function (PSF) because the most natural physical source of additional strength, that was found for Sn isotopes in the recent Oslo group experiments [1] and could not be explained within the microscopic HFB+QRPA approach [2], is the microscopic PC effect. In order to check this statement, the self-consistent version of the Extended Theory of Finite Fermi Systems [3] in the Quasiparticle Time Blocking Approximation, or simply QTBA, was applied (see Ref. [4]). It uses the HFB mean field and includes both the QRPA and PC effects. Only the known parameters of the Sly4 force were used in the calculations. With our microscopic *E*1 PSFs in the EMPIRE3.1 code, the following properties have been calculated for many stable and unstable even-even Sn and Ni isotopes [4–7]: 1) neutron capture cross sections, 2) corresponding neutron capture gamma-spectra, 3) average radiative widths of neutron resonances. In all the considered properties, the PC contribution turned out to be significant, as compared with the QRPA one, and necessary to explain the available experimental data. The very topical question about the M1 resonance contribution to PSFs is also discussed.

Secondly, as in order to calculate the above-mentioned properties it is necessary to use the nuclear level density models, we also discuss the modern microscopic models based on the self-consistent HFB method, for example, see [8], and show their better applicability to explain experimental data as compared with the old phenomenological models.

The use of these self-consistent microscopic approaches is of particular relevance for nuclear astrophysics and also for double-magic nuclei.

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QUANTUM CHAOS IN NUCLEAR PHYSICS

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Contrary to numerous guesses concerning quantum chaos, the definition is given of both classical and quantum chaotic systems as a consequence of Liouville-Arnold theorem [1–3]. Thus quantum chaotic system with N degrees of freedom should have $M < N$ independent first integrals of motion (good quantum numbers) defined by the system's Hamiltonian symmetry.

Therefore any nuclear system besides deuteron is in principle chaotic. However in each case one should look for the approximate integrals of motion and the symmetries of the model Hamiltonian H_0 generating these integrals. The degree of chaos in each case is defined by the dimensionless parameter

$$\kappa = \Gamma_{\mathrm{spr}} / D_0 ,$$

where Γ_{spr} is the spreading width of the model Hamiltonian eigenfunctions over the eigenstates of the actual Hamiltonian, while D_0 is level spacing of the model Hamiltonian.

For $\kappa < 1$ the traces of the H_0 symmetries are quite obvious (soft chaos — quantum analogue of the classical KAM theorem). A good example is given by the maxima of the neutron strength function which are the traces of the symmetries of the nuclear mean field which are destroyed by the nucleon-nucleon residual interactions.

For $\kappa \geq 1$ all the traces of the H_0 symmetries are lost (hard chaos). An example is given by the black nucleus model and by Wigner's random matrix approach.

For the shell-model Hamiltonian κ increases with the system's excitation energy E^* as $\Gamma_{\mathrm{spr}} \approx 2W$, where W is the magnitude of the imaginary part of the optical model potential. However κ remains smaller than unity even for E^* about 50 MeV. Therefore the shell-model basis serves a good first approximation in many calculations of the nuclear properties. Actually κ is the main (if not the only) small parameter which makes possible the majority of numerical calculations in nuclear physics.

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CENTRALITY AND MULTIPARTICLE PRODUCTION IN ULTRARELATIVISTIC NUCLEAR COLLISIONS

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Understanding of the initial conditions of nucleus-nucleus and proton-nucleus collisions at high energies is important for any analysis and characterization of the expected quark-gluon plasma formation. Measurements of fluctuations and correlations of global observables allow studying a broad region of QCD phase diagram. Interpretation of experimental data requires information about impact parameter and the number of participating nucleons. In this report we present the critical review of widely applied methods of centrality determination based on the Glauber model.

Using MC simulations we analyze the consistency of the concept of centrality in the cases of pA and AA collisions for heavy and light ions and present a method for the numerical qualification of the centrality estimators. This allows to select the classes of events where background fluctuations related to event-by-event variance in the impact parameter and/or the number of nucleons-participants are minimized.

This approach is checked in non-Glauber Monte Carlo model with string fusion [1] by studying the dependence of multiplicity fluctuations and correlations on the width of the centrality class.

By model calculations [1, 2] we also obtained that the account of the energy-momentum conservation in soft particles production leads to noticeable decrease in the number of nucleon collisions (N_{coll}) in Pb-Pb and p-Pb interactions relative to Glauber model values. Similar effects are intrinsically present in the models [3, 4] which aim to describe consistently the collisions of small (pp) and large (AA) systems. We conclude that the decrease in N_{coll} is important for low transverse momentum phenomena, contrary to rare processes where approximate Glauber scaling remains applicable. Overall, the results suggest reconsidering the general use of Glauber normalization of the multiplicity yields in experimental studies.

The authors acknowledge Saint-Petersburg State University for a research grant 11.38.193.2014.

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EXOTISM OF NUCLEI

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Exotic states of the nuclear matter i.e., of the nuclei in extreme states (with high spin, large deformation, high density and temperature, the neutron- or proton-rich nuclei on the boundary of nucleon stability) play an important role in studies of fundamental nuclear properties, which bring us closer to deducing the equation of state of the nuclear matter. This is undoubtedly of great significance for extrapolating microcosm characteristics to the macro world that presents our Universe.

Synthesis and study of neutron-rich isotopes have two main goals: finding the position of neutron stability boundaries and obtaining data on properties of exotic nuclei near these boundaries. The development of accelerator technology has made it possible to obtain the accelerated beams of secondary radioactive nuclei. In this connection, new vast opportunities have opened up for studying both the structure of light exotic nuclei themselves. It is extremely important to obtain new information regarding nuclei near the nucleon stability boundary because considerable deviations of properties of such nuclei from the widely known regularities may be expected (and are already observed). Here the nuclei in a range of small Z serve as convenient objects for investigation.

At present the most sophisticated physics experiments, which are carried out at large-scale accelerator facilities and require enormous financial investments, can be realized only through the combined efforts and cooperation of the leading scientific centers. As an example, the heavy ion accelerators at the Joint Institute for Nuclear Research (Dubna) which count about 20 member-states. Thus, the research is being done in collaboration of the research centers of several countries. Each country makes its financial and intellectual contribution to the creation of the large-scale facilities, allowing to penetrate deeply into the mysteries of matter and to obtain new information not only for nuclear physics, but also for other scientific fields such as astronomy, condensed matter physics and up-to-date technologies.

The present work reviews the properties of the super neutron-rich isotopes. The changes in nuclear structure appearing as one goes away from the β-stability line are discussed in detail. Information is presented on the mass (hence, on the separation energy of nucleons and on nuclear stability), the radii of nucleon distributions, the momentum distributions of fragments from the break-up of neutron-rich nuclei, on the possibility of halo formation as well as on the deformation and quantum characteristics of the ground states of different isotopes. The location of the neutron drip line and questions about the stability of nuclides are considered in connection with the weakening or even vanishing of the shell effects at the magic numbers 20 and 28, and the discovery of the new neutron magic number.

DISTRIBUTED COMPUTING AND BIG DATA AT JINR

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The report presents the concept and the evolution of the global computing infrastructure for storage, processing and analysis of experiments at the Large Hadron Collider at CERN. Brief information about the participation of Russia in this process is given. An overview of projects in the field of distributed computing and Big Data, performed at the Laboratory of Information Technologies (LIT JINR) in Russia, CERN, USA, China and JINR member states is presented.

Special attention is paid to the creation of the center of the Tier1 level in Russia for storage and data processing of experiments at the Large Hadron Collider, the development of cloud and hybrid infrastructure, as well as of the computing model of megaproject NICA at JINR. The results and plans for the development of a platform for Big Data management are presented.

SEARCHING FOR NEW KIND FISSION ISOMERS IN ACTINIDE NUCLEI

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Conventional fission isomers are due to the specific double humped structure of the fission barrier with rather deep second well for some of the actinide nuclei. The barrier can be called "the binary one" keeping in mind that binary fission appears to occur during the descent of the system from this barrier. Evidently, a dumbbell-like shape of the system is expected in the vicinity of the scission point. Ternary prescission configurations leading to the delayed ternary fission have been also considered from the theoretical point of view [1]. We discuss first experimental results demonstrating delayed fission after emitting of the light ion. By analogy with known "beta delayed fission" such phenomenon can be called "**L**CP delayed **F**ission of **I**somer (LFI)". Schematic scenario of the process is presented in Fig.1.

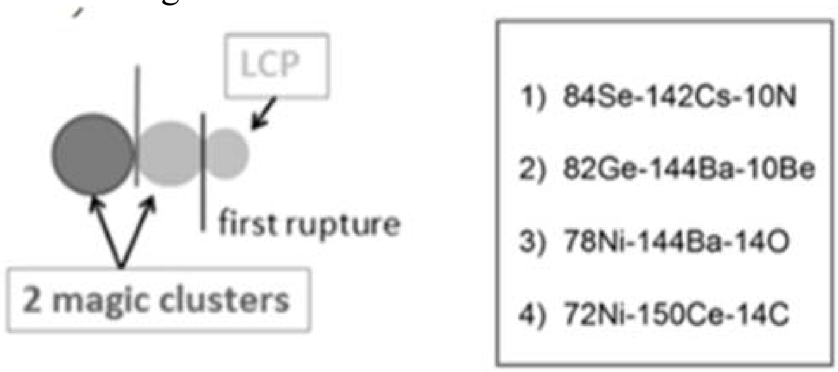

Fig. 1. Schematic illustration of the scenario of LCP delayed fission of isomer (LFI) and ternary prescission configurations decisive for the effect observed.

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DOUBLE-NEUTRON CAPTURE REACTION AND NATURAL ABUNDANCE OF ^{183}W, ^{195}Pt, AND ^{199}Hg ISOTOPES

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Recently, the formation of ^{195m}Pt isomer has been detecte in our experiments at Dubna reactor IBR-2. A high cross section is established for the double-neutron capture reaction through the consequence: ^{193}Ir(n,γ)^{194}Ir(n,γ)^{195m}Ir(3.8h) → ^{195m}Pt. The latter step of β^- decay from isomer to isomer is characterized by the probability of 44% according to the Nuclear Data Sheets. The values observed for ^{195m}Pt must be increased multiplying them by a factor of about 2.3, and for the ^{194}Ir(n,γ)^{195m}Ir(11/2$^-$) reaction, the measured parameters are deduced as σ_{th} =11700 barn; I_γ =670 b. Decay scheme of the low-spin ^{195}Ir(3/2$^+$) makes no contribution into the ^{195m}Pt(13/2$^+$) yield, but the cross-section branch to this 2.5 h-lived nuclide is great. The latter branch exceeds by orders of magnitude the population of the isomeric ^{195m}Ir(11/2$^-$) state due to the known spin restrictions for the yields of (n,γ) products. Thus, a total capture cross section by the short-lived ^{194}Ir(19.3 h) appears to be extremely high and is expressed in a value on the scale of 10^5 barn. Both *m* and *g* species of ^{195}Ir reach the ^{195}Pt ground state after β^- decay and the abundance of stable ^{195}Pt must include the production in double-neutron capture by ^{193}Ir. Over the same work, the ^{nat}Ta targets were also irradiated and the second-step ^{182}Ta(n,γ)^{183}Ta→^{183}W reaction was characterized by the great values of σ_{th} = 25300 b and I_γ = 16600 b. The given here numerical values (except the estimate of 10^5 b) are obtained with a standard inaccuracy of about 10% including the errors due to the calibration and recalculations. Remind in addition a high value of σ_{th} = 25100 b known [1] for the neutron capture by radioactive ^{198}Au leading then to ^{199}Au β^- decayed to ^{199}Hg. Finally, one must account the great cross-sections for neutron capture by odd-odd radioactive nuclides, like ^{182}Ta, ^{194}Ir, and ^{198}Au. The natural abundances of ^{183}W(14.3%), ^{195}Pt(33.8%), and ^{199}Hg(16.9%) include a contribution from the double-neutron capture on the way of *s*-process. In general, the double-neutron capture way differs from scenarios of the standard *s*- and *r*-processes. The second neutron capture happens prior the β^- decay of a first capture product, while the capture of third and further neutrons is improbable.

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MEASUREMENTS OF THE ^{195m}Pt ISOMER YIELD IN IRRADIATIONS OF ^{193}Ir TARGETS WITH NEUTRON FLUX

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The ^{195m}Pt isomer activity is known to be the best for radio-therapeutic applications in a view of the convenient halflife, 4.02 d, the great yield of soft gamma and Auger-electron radiation, and absence of radioactive pollutions past the decay. The possibility of production due to the double-neutron capture was indicated in literature [1], but the details were yet unknown. We suppose the path from initial ^{193}Ir target to ^{195m}Pt through the following intermediate nuclides: $^{193}\mathrm{Ir}(n,\gamma)^{194}\mathrm{Ir}(n,\gamma)^{195m}\mathrm{Ir} \xrightarrow{\beta^-} {}^{195m}\mathrm{Pt}$. The looked for isomer is populated via β^- decay of ^{195m}Ir (3.8 h) in 44% events, while the decay of ^{195}Ir ground state (2.5 h) feeds only the stable ^{195}Pt. At the first neutron capture, the population of ^{194g}Ir is preferred because of productive cross section — 108 b, while the branch leading to ^{194m}Ir is obviously closed since its high spin ($J \approx 11$). Oppositely, the isomeric ^{195m}Ir state could be populated in (n,γ) reaction due to the lower spin, $J^{\pi} = 11/2^{-}$, as follows from the data [2]. The intermediate isotopes and their halflives are defined now, but the σ_{th} and I_{γ} values for the production must yet be distinguished and specified. The method of Cd-difference was applied when the enriched ^{193}Ir (98.5%) targets were exposed at the vertical channel of the IBR-2 reactor in FLNP, Dubna. The targets with and without Cd shielding were irradiated during the 17 d reactor-run. The metal foils of Ta served as spectators. The Ir samples were dissolved with electrochemical method for consequent isolation of the Pt fraction using the chromatography. Gamma spectroscopy with HP Ge detector is used for the activity measurements. The dissolving yield was calibrated by the ^{192}Ir activity (present due to the ^{191}Ir admixture), while the Pt isolation method was tested elsewhere. Finally, the gamma lines of ^{195m}Pt decay have been measured with a good statistical accuracy, and the production process, $^{194}\mathrm{Ir}(n,\gamma)^{195m}\mathrm{Ir}\rightarrow{}^{195m}\mathrm{Pt}$, is characterized by the following values: $\sigma_{th} = 2270$ b and I_{γ} =190 b. Such a great cross section of the ^{195m}Pt production promises the efficient application of this isomer for radiotherapy of patients.

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CONTROVERSIES ON COLD FUSION

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Cold nuclear fusion excites an interest and stimulates the discussions initiated, in particular, due to the publication [1]. The performed studies comprise attempts of experimental observation in atomic collisions, in electric sparks, or even in the macroscopic processes. Nevertheless, many specialists trust that nuclear reactions at so low energies violate the basic principles of physics. There is yet a hope for reliable observation of the claimed effects after a progress in the sensitivity of experimental methods. The explanations of cold fusion in recent publication [2] and in others could not iron out inconsistencies in the process mechanism. The successful d + D fusion was supposed [1, 2] for the deuterium atoms ensconced in the Pd crystal. Palladium is capable to absorb a lot of hydrogen to form the solid solution. The radius of H atom is comparable to the Bohr radius equal 0.529 Å. Heavier atoms are more compact and their interaction is characterized by the Thomas-Fermi screening parameter. In the Pd atom, 46 electrons are confined within the radius of 0.125 Å. Therefore, the electron cloud around each Pd nucleus provides an electron density greater than in H atom by a factor of 3400. Such clouds in principle may serve as electric lenses to attract and to confine the individual ^{1}H, or ^{2}H atoms. The Coulomb field of a deuteron appears to be almost screened within the high-density electron cloud. Two such screened deuterons could obviously fuse with the reduced Coulomb barrier. There arises definitely a point, how great is the reduction of the Coulomb barrier for two deuterons localized within one Pd atom. A probability for two deuterons confinement in the same electron cloud could be very low. Another heavy problem takes place [2], how to be with the release of 23.8 MeV energy due to d + D fusion. The standard D(d,n)^{3}He reaction was not detected in the experiments. A direct emission of the 23.8 MeV photons seems improbable. However, within the discussed here scheme, two deuterons and Pd may form a sort of compact molecule, which splits past d + D fusion with the energy release mostly to electrons, or to the phonon mode. The scheme meets both requirements for explanation of Coulomb barrier penetration and of energy transfer to the crystal. Additional studies are requested, but low yield of the process hardly supports the proofs presented on today.

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DANSS – DETECTOR OF THE REACTOR ANTINEUTRINO BASED ON SOLID SCINTILLATOR

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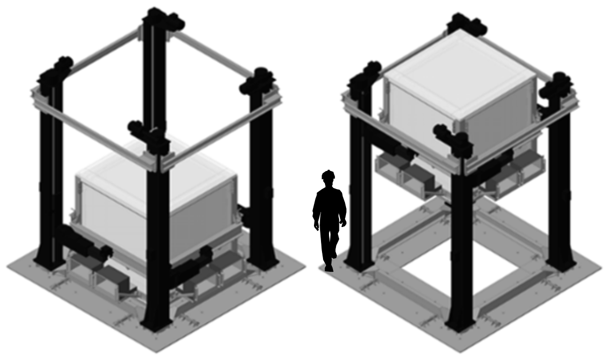
The DANSS project performed within JINR (Dubna) – ITEP (Moscow) collaboration is aimed at creating a relatively compact neutrino spectrometer which does not contain any flammable or other dangerous liquids and may therefore be located very close to the core of an industrial power reactor. As a result, it is expected that a high neutrino flux would provide about 15000 inverse beta decay interactions per day in the polystyrene-based scintillator with a sensitive volume of 1 m^3. High segmentation of the plastic scintillator allows background suppression down to a 1% level. Numerous tests performed with a simplified pilot prototype DANSSino under a 3 GW_{th} reactor WWER-1000 of the Kalinin nuclear power plant have demonstrated operability of the chosen design [1, 2].



The DANSS detector surrounded with a composite shield is movable by means of a special lifting gear, varying the distance to the reactor core in a range from 9.7 m to 12.2 m. Due to this feature, it could be used not only for the reactor monitoring, but also for fundamental research including short-range neutrino oscillations. Thus, we expect to confirm or disprove "sterile" explanation of the reactor neutrino anomaly within few weeks of data taking [3]. Supposing a one-year measurement, the sensitivity to the oscillation parameters could reach a level of $\sin^2(2\theta_{new}) \sim 5\cdot 10^{-3}$ with $\Delta m^2 \in (0.02 - 5)$ eV^2.

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ANNIHILATION OF ANTINUCLEONS WITH NUCLEONS AND NUCLEI

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The annihilation of $\overline{\mathrm{p}}$ and $\overline{\mathrm{n}}$ with nucleons and nuclei are important properties in the interaction of matter with antimatter. Pomeranchuk suggested that $\sigma_{\mathrm{ann}}(\overline{\mathrm{n}}-\mathrm{p})$ is equal to $\sigma_{\mathrm{ann}}(\overline{\mathrm{p}}-\mathrm{p})$ at high energies [1]. On the other hand, from the naive quark model of counting the number of quark-antiquark pairs of the same flavor, $\sigma_{\mathrm{ann}}(\overline{\mathrm{n}}-\mathrm{p})$ would be (4/5) $\sigma_{\mathrm{ann}}(\overline{\mathrm{p}}-\mathrm{p})$. We have re-examined the nucleon-antinucleon annihilation cross sections, taking into account the nuclear and $\mathrm{p}-\overline{\mathrm{p}}$ Coulomb interactions, and found that the Pomeranchuk's suggested equality at high energies appears to be a reasonable concept, as shown in Fig. 1. On the basis of the elementary $\sigma_{\mathrm{ann}}(\overline{\mathrm{n}}-\mathrm{p})$ and $\sigma_{\mathrm{ann}}(\overline{\mathrm{p}}-\mathrm{p})$ cross sections as input, we extended the Glauber model for high-energy collisions [2] to both high and low energies, after taking into account effects of the nuclear interaction, the Coulomb interaction, and the change of the antinucleon momentum inside a nucleus [3]. The extended Glauber model captures the main features of the experimental antinucleon-nucleus annihilation cross sections [3]. At high energies, they exhibit the granular property for the lightest nuclei and the black-disk limit for the heavy nuclei. At low energies, they display the effect of antinucleon momentum increase due to the nuclear interaction for light nuclei, and the effect of focusing due to the attractive Coulomb interaction for antiproton annihilation for heavy nuclei, as shown in Fig. 2 for $\overline{\mathrm{p}}$-nucleus annihilation cross sections.

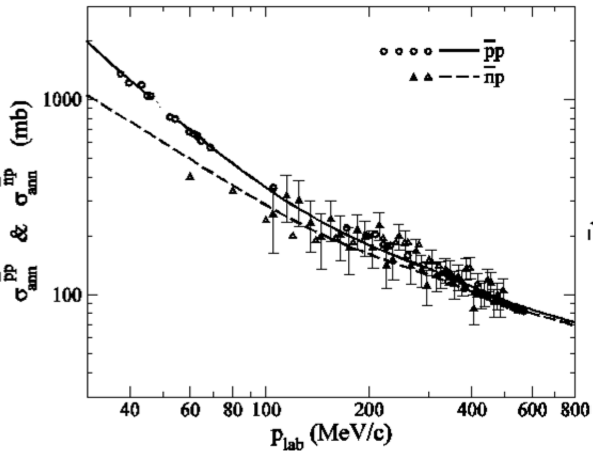

Fig. 1. Comparison of theoretical $\sigma_{\mathrm{ann}}(\overline{\mathrm{p}}-\mathrm{p})$ *and* $\sigma_{\mathrm{ann}}(\overline{\mathrm{n}}-\mathrm{p})$ *curves with data.*

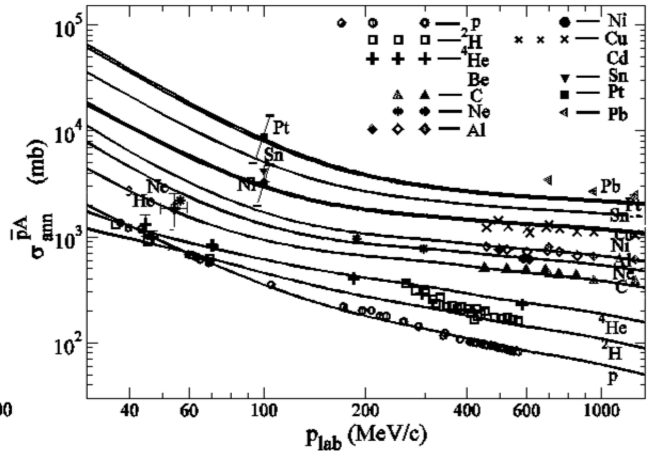

Fig. 2. Comparison of theoretical $\sigma_{\mathrm{ann}}(\overline{\mathrm{p}}-\mathrm{A})$ *curves with data.*

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THE NEW INNER TRACKING SYSTEM OF THE ALICE EXPERIMENT: PHYSICS, DESIGN AND PERFORMANCE

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The ALICE detector at the LHC is specifically designed to investigate the properties of the strong interacting matter at extreme conditions of temperature and density, which lead to the deconfinement of quarks and gluons (QGP). Ultra-relativistic heavy-collisions are well suited to achieve these conditions and to study the properties of such a medium. The physics results achieved by ALICE during RUN 1 have confirmed the nature of the QGP as an almost perfect liquid and have demonstrated the experiment's excellent capabilities to measure high-energy nuclear collisions at LHC.

Despite this success there are several frontiers, including high precision measurements of rare probes over a broad range of transverse momenta, for which the current experimental setup is not yet fully optimized. ALICE is therefore preparing a major upgrade of its apparatus, planned for installation during the second long LHC shutdown in 2018–2019, which will enhance its physics capabilities enormously.

In the proposed upgrade plan, the ALICE detector will exploit the expected significant increase of Pb-Pb luminosity reading-out all interactions up to a rate of 50 kHz and accumulate more than 10 nb^{-1} of Pb-Pb collisions, corresponding to about 10^{11} interactions. One of the key detector to enhance the ALICE physics capabilities is the new Inner Tracking System, whose focus is on the improved performance for detection of heavy-flavour hadrons produced in the collisions and traversing the QGP medium. The greatly improved features of the new ITS in terms of determination of the distance of closest approach to the primary vertex, tracking efficiency at low transverse momenta, and read-out rate capabilities will be illustrated in this contribution. The R&D activities over the last four years, the technical implementation of the main detector components, and the detector and physics performance will be discussed. The plan for the construction of the new ITS will also be presented.

NUCLEAR SIZE ISOMERS

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Isomerism is a well-known phenomenon in nuclear physics. Besides widely spread "normal" isomers (excited states with much larger time-of-life comparatively that of the corresponding ground states) there are known shape and fission isomers. The recently developed methods of measuring the radii of nuclei in their short-lived states led to the observation of the effect of size isomerism, that is, significant enhancement of nuclear radii in some excited states relatively those in the corresponding ground ones. Two classes of size isomers were identified: some alpha-cluster states (e.g., the famous Hoyle state (0^+, E^* = 7.65 MeV) in ^{12}C and its analogs in the neighbor nuclei) and the excited states with neutron halos. These findings resulted in critical reconsideration of many settled ideas about nuclear structure.

THE ASYMMETRIES WITH VARIOUS *P*- AND *T*-PARITY IN THE ANGULAR DISTRIBUTIONS OF THE PRODUCTS OF BINARY AND TERNARY FISSION OF ORIENTED NUCLEI BY COLD POLARIZED NEUTRONS AND *T*-INVARIANCE

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In products angular distributions for binary and ternary fission of oriented target-nuclei by cold polarized neutrons *P*-even, *T*-even $\left(\vec{k}_n,\vec{k}_{LF}\right)$, $\left(\left[\vec{I},\vec{\sigma}_n\right],\left[\vec{k}_n,\vec{k}_{LF}\right]\right)$, $\left(\left[\vec{I},\vec{\sigma}_n\right],\left[\vec{k}_3,\vec{k}_{LF}\right]\right)$; *P*-odd, *T*-even $\left(\vec{\sigma}_n,\vec{k}_{LF}\right)$, $\left(\vec{I},\vec{k}_{LF}\right)$; *P*-even, *T*-odd $\left(\vec{\sigma}_n,\left[\vec{k}_n,\vec{k}_{LF}\right]\right)$, $\left(\vec{I},\left[\vec{k}_n,\vec{k}_{LF}\right]\right)$, $\left(\vec{\sigma}_n\left[\vec{k}_3,\vec{k}_{LF}\right]\right)$, $\left(\vec{I},\left[\vec{k}_3,\vec{k}_{LF}\right]\right)$ and *P*-odd, *T*-odd $\left(\left[\vec{\sigma}_n,\vec{I}\right],\vec{k}_{LF}\right)$, $\left(\left[\vec{\sigma}_n,\vec{I}\right],\vec{k}_3\right)$ asymmetries, where $\vec{k}_n$, $\vec{k}_{LF}$ and $\vec{k}_3$ – the wave vectors of the incident neutron, light fission fragment and the third particle, $\vec{I}$ and $\vec{\sigma}_n$ – the polarization vectors for the target-nucleus and incident neutron, are found. Let us assume that analyzed types of fission have two-step character, when on the initial step polarization of the target nucleus and capture of polarized incident neutron by this nucleus occur simultaneously with formation of polarized compound fissile nucleus and on the final step emissions of fission fragments and third particle from indicated compound nucleus occur simultaneously. In this case conditions of T-invariance [1] for named above asymmetries are realized if these asymmetries don't change itself for inversion of vectors $\vec{I},\vec{\sigma}_n,\vec{k}_n$, $\vec{k}_{LF}$, $\vec{k}_3$ and simultaneous for permutations of moments (spins) of particles participating in initial and final steps. But then asymmetries $\left(\vec{\sigma}_n\left[\vec{k}_3,\vec{k}_{LF}\right]\right)$; $\left(\left[\vec{\sigma}_n,\vec{I}\right],\vec{k}_{LF}\right)$; $\left(\left[\vec{\sigma}_n,\vec{I}\right],\vec{k}_3\right)$; $\left(\left[\vec{I},\vec{\sigma}_n\right],\left[\vec{k}_n,\vec{k}_{LF}\right]\right)$; $\left(\vec{I},\left[\vec{k}_3,\vec{k}_{LF}\right]\right)$ violate *T*-invariance conditions [1], although these asymmetries were obtained by usage of *T*-invariant Hamiltonians of nuclear systems.

Analyzed asymmetries are *T*-invariant if fission process has multistep sequential character. It means that the polarization of the target nucleus and absorption of the incident polarized neutron by the target nucleus must be viewed as two following one after another in time processes as well as the flight of the third particle from the compound nucleus occurs earlier then flight of fission fragments. For this case, it's necessary to go to generalized conditions of *T*-invariance [2], when the transition to the time reversed asymmetries requires not only the inversion of moments and spins of all the particles appearing at different steps of fission process, but simultaneously the permutation of moments (spins) of particles, appearing in various following one after another steps of the processes. Then the vector products $\left[\vec{I},\vec{\sigma}_n\right]$ and $\left[\vec{k}_3,\vec{k}_{LF}\right]$ change signs for permutations vectors $\vec{I}$, $\vec{\sigma}_n$ and $\vec{k}_3,\vec{k}_{LF}$, correspondently, so that all named above asymmetries satisfy the *T*-invariance condition.

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MYSTERY OF ^{9}He, EXOTIC NEUTRON RICH LIGHT NUCLEI, AND A WAY TO STUDY THESE THROUGH THEIR ISOBAR ANALOG STATES

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The original interest to the ^{9}He spectrum is evidently related with an unusual *N* to *Z* ratio which is 3.5. Beginning with ^{9}He, all heavier isotopes of He are unstable to neutron decay. During the last 25 years the properties of the lowest states in ^{9}He were under intensive experimental and theoretical investigation. It appears that the nuclear structure of these states ($1/2^+$ and $1/2^-$) can't be explained on the ground of our knowledge of conventional nuclei. The most evident problem is the width of the $1/2^-$ resonance, which (naively) should be expected to be a shell model $p1/2$ state. Indeed, different experiments (see [1] for the history of the theoretical and experimental studies), including a recent one [1] of well studied (d,p) reaction induced by a rare ^{8}He beam, claimed a narrow (~100 keV) $1/2^-$ first excited state. Various model calculations and even recent *ab initio* approaches [2] could not reproduce experimental results giving ten times larger widths for the $1/2^-$, as would be naive expectations. This clear contradiction between experiment and contemporary theory could be a sign of an unusual nuclear structure at the border of nucleon stability.

Therefore we used a relatively novel experimental technique of obtaining information on neutron rich exotic nuclei through their analog states in neighboring nuclei populated in resonance reactions with rare beams. We have made measurements of the ^{8}He+p resonance elastic scattering to obtain information on T=5/2 levels in ^{9}Li. We used ^{8}He beam with energy of 4MeV/A and intensity ~10^4 pps provided by the TRIUMF facilities. The measurements of the excitation function were made by Thick Target Inverse Kinematics method [3–5] (TTIK). The approach and the high quality of the TRIUMF beam enable us to study the isobaric analogs of the ^{9}He states even if ^{9}He was barely unbound or even bound by few tens of keV.

As a result, our high resolution and high counting statistics study of the excitation functions for the ^{8}He+p elastic scattering did not reveal any narrow structures which could be related with the claimed states in ^{9}He. However we observed a strong Wigner cusp at the threshold of decay of ^{9}Li into the ^{8}Li(T=2,0^+) + n channel. This finding gave evidence for the presence of a l=0 resonance as the isobar analog of the ^{9}He ground state. Evidently, these results show for a new binding energy of ^{9}He as well as different properties of its ground state. However, the accurate data should be provided in a framework of a developed R matrix approach in which the contribution of unknown $T_<$ resonances at ^{9}Li high excitation energy is addressed by an optical model potential [6]. This work should be finished soon.

I'll present the results of this work and its consequences for the considerations on some very exotic nuclei, like ^{10}He and ^{7}H. I'll consider the perspective of the present experimental approach for future studies.

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QUANTITATIVE CHARACTRISTICS OF CLUSTERING IN MODERN MICROSCOPIC NUCLEAR MODELS

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Modern studies of the clustering phenomena are dividable into two groups. Typical investigations of the first type are the antisymmetrized molecular dynamics [1] and the fermionic molecular dynamics [2]. In these approaches clustering properties of some low-laying nuclear states are qualitatively confirmed to emerge directly from *NN*-interactions. The cluster structures turn out to be visible as humps in the density distribution in the body-fixed coordinate frame.

Another type of the approaches to clustering explores the quantitative concepts such as the cluster spectroscopic amplitudes, form factors spectroscopic factors, etc. These values provide possibilities to investigate various processes of cluster decay, resonance cluster scattering, cluster break-up and transfer of composite particles. The discussed characteristics are calculated in various versions of the shell model. Binary cluster channels are described in the framework of simple two-body or advanced orthogonality conditions model. In near future one might expect that high-quality resonating group model would be involved.

The present talk demonstrates methods of calculation of the cluster characteristics in modern shell-model approaches such as configuration interaction technique [3] and no-core shell model [4]. The compatibility of the resulted wave functions and two-body channel wave functions is discussed. The cluster decay properties of multitude of low-laying and highly excited states of nuclei are investigated in one and the same procedure with the excitation energies, electromagnetic moments and other characteristics of these states [5,6].

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SYSTEMATIC COMPARISON OF HEAVY-ION FUSION BARRIERS CALCULATED WITHIN THE FRAMEWORK OF THE DOUBLE FOLDING MODEL USING TWO VERSIONS OF NUCLEON-NUCLEON INTERACTION

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It was shown in Refs. [1, 2] that the high energy parts of the heavy ion fusion excitation functions can be successfully reproduced within the framework of the double folding approach. The major ingredients of this approach are the nuclear densities and the effective nucleon-nucleon interaction [3]. In [1, 2] the well-known M3Y *NN* forces [4, 5] were used. However sometimes in the literature the Migdal *NN* forces [6] are used to calculate the nucleus-nucleus potential [7, 8]. The question is to what extent the fusion barrier heights are different when calculating interaction potentials within the double folding approach with two options of the nucleon-nucleon interaction: the M3Y and the Migdal ones.

In the present work we address this question performing systematic calculations of the fusion barrier height for zero angular momentum, U_{B0}. In our calculations the nuclear densities came from the Hartree-Fock approach with the SKX coefficient set [9, 10]. The charge densities obtained within these calculations are shown to be in good agreement with the experimental data [11, 12]. The values of U_{B0} are calculated in the wide range of the value of the parameter $B_Z = Z_P Z_T / \left(A_P^{1/3} + A_T^{1/3} \right)$: it varies from 10 MeV up to 150 MeV. Only spherical nuclei from ^{12}C up to ^{208}Pb are considered.

Our calculations make it possible to draw definite conclusions about the applicability of the Migdal *NN* forces for describing the nucleus-nucleus collision.

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PROMPT NEUTRON CHARACTERISTICS IN THE SPONTANEOUS FISSION OF HEAVY AND SUPERHEAVY NUCLEI

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The generalized model of the prompt fission neutron emission [1, 2] was applied to neutron energy and multiplicity distributions in the spontaneous fission of heavy and superheavy nuclei. For accurate calculations of nucleon composition and excitation energy of the fissioning nucleus at the scission point, the time-dependent statistical model with inclusion nuclear friction effects was used. The neutron emission during the saddle-to-scission descent time may be important in the spontaneous fission of the heavy nuclei with $Z > 96$. For each member of the compound nucleus ensemble at the scission point, the primary fission fragment characteristics: kinetic and excitation energies and their yields are calculated using the scission-point fission model with nuclear shell and pairing effects. The charge distribution of the primary fragment isobaric chains was considered as a result of the frozen quantal fluctuations of the isovector nuclear matter density at the finite scission neck radius. The post-scission neutron spectra are calculated as the result of the equilibrium emission from the fully accelerated heated fission fragments with calculated primary fission fragment parameters. Results of calculation in the spontaneous fission of heavy and superheavy nuclei with $100 \le Z \le 118$ will be presented.

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PROPERTIES OF NUCLEI FOR WIDE RANGE OF *Z* IN THE NEIGHBORHOOD OF NEUTRON AND PROTON DRIP LINES

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The theoretical investigation of the ground state properties of even-even nuclei for $2 \leq Z \leq 8$ and $86 \leq Z \leq 132$ with extreme neutron and proton excess stable against one neutron and proton emission have been made. Also the investigation included nuclei beyond the drip line. The calculations are based on the Hartree-Fock (HF) method with Skyrme forces (SkM*, SkI2, SLy4) taking into account axial deformation and the BCS pairing approximation. It is shown that the isotopes ^{18}He and ^{40}C form the peninsulas of nuclei stable against one neutron emission beyond the neutron drip line. The restoration of the stability beyond the drip line for ^{18}He and ^{40}C can be explained by full filling of neutron sub-shells with large angular momentum and by intrusion of corresponding neutron levels into the region of discrete bound states.

For neutron deficient nuclei in the neighborhood of neutron number $N = 184$ and $Z \sim 120$ we have analyzed the potential energy curves as the function of the mass quadrupole parameter deformation $E(\beta_m)$ using the constrained HF with SkM*. The same analysis of the potential energy curves were made also for neutron rich nuclei $N = 258$ and $86 \leq Z \leq 132$. The energy curves for this range of nuclei show the growth of stability of spherical shape with the growth of Z from the $Z = 86$ and decrease stability of spherical shape at the end of examined range. These calculations are the continuation of our investigations of nuclei with extreme neutron excess [1] for the isotone chain at the neutron number $N = 258$ beyond the neutron drip line which forms the peninsula of nuclei stable to emission of one neutron.

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STRUCTURE OF $2^+_{1,2}$ STATES IN ^{132,134,136}Te

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Low-lying quadrupole isovector excitations of the valence shell of heavy nuclei represent a unique laboratory for studying the balance between collectivity, shell structure, and the isospin degree of freedom. These excitations, so-called mixed-symmetry (MS) states, have been predicted in the proton-neutron (pn) version of the interacting boson model (IBM-2). An unbalanced pn-content of the wave functions can be interpreted as configurational isospin polarization (CIP) which denotes varying contributions to the 2^+ states by the active proton and neutron configurations due to subshell structure [1]. *M*1 transitions between low-energy quadrupole excitations of the valence shell are often used as signature for states of MS-character. Starting from a Skyrme interaction we study the properties of the low-energy spectrum of quadrupole excitations. The coupling between one- and two-phonon terms in the wave functions of excited states is taken into account [2]. We use the finite-rank separable approximation [3, 4] which enables one to perform the QRPA calculations in very large two-quasiparticle spaces. After the approach has been proven to be sufficiently good to reproduce characteristics of the well-known low-energy spectrum of quadrupole excitations of stable nuclei in the mass range $A \approx 90$ [5], we study the evolution of first and second quadrupole excitations of ^{132,134,136}Te. Using the Skyrme interaction f^- in conjunction with the volume pairing interaction, our calculations describe well the dramatic reduction of the experimental E2 excitation strength to the 2_1^+ state when going from ^{132}Te to ^{136}Te. For ^{132}Te, we identify the 2_2^+ state as a fully developed one-phonon MS state. We observe a dominance of the neutron configurations in the wave function of the 2_1^+ state of ^{136}Te. The 2_2^+ state of ^{136}Te is a proton-dominated state, corresponding to a MS state with substantial CIP. Nevertheless, the $B(M1;2_{\mathrm{MS}}^+ \rightarrow 2_1^+)$ value of ^{136}Te is larger than that of ^{132}Te due to the subtle mechanism based on the near-degeneracy of the proton single-particle states near the Fermi level [6]. These results suggest the f^- parameter set for the description of MS states and CIP in neutron-rich isotopes.

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FEATURES OF THE NUCLEAR MANY-BODY DYNAMICS: FROM PAIRING TO CLUSTERING

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Atomic nuclei are remarkable mesoscopic systems where single nucleon excitations coexist and interact with numerous collective features such as pairing correlations, clustering, shape dynamics, and superradiance [1–3]. Theories such as BCS, RPA, and algebraic models have been successful in addressing nuclear collectivities especially in the macroscopic limit. However, limited overlap between these theories makes it difficult to grasp the whole complex picture involving interplay between collective and non-collective components. Recently, the nuclear shell model has transformed into a powerful configuration interaction tool allowing for these questions to be studied microscopically.

In this work we advance the reach of the nuclear shell model approach towards clustering and other collective many-body phenomena. We explore the alpha spectroscopic factors of low-lying states, study the distribution of clustering strength, and discuss the structure of effective 4-body operators describing the in-medium alpha dynamics in multi-shell configuration spaces. We address interplay of clustering, pairing, collective particle-hole excitations, and decay processes, exploring both model and realistic examples.

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CLUSTERING FEATURES OF LIGHT NEUTRON-DEFICIENT NUCLEI IN NUCLEAR FRAGMENTATION

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Nuclear track emulsion (NTE) is still retaining its exceptional position as a means for studying the structure of diffractive dissociation of relativistic nuclei owing to the completeness of observation of fragment ensembles and owing to its record spatial resolution. Separation of products of fragmentation and charge-exchange reactions of accelerated stable nuclei make it possible to create beams of radioactive nuclei. A unification of the above possibilities extends the investigation of the clustering phenomena in light radioactive proton-rich nuclei. Conclusions concerning clustering features are based on the probabilities for observing of dissociation channels and on measurements of angular distributions of relativistic fragments.

At the JINR Nuclotron exposures of NTE stacks of (NTE) are performed at energy above 1 *A* GeV to the beams of isotopes Be, B, C and N, including radioactive ones [1–3]. In general, the results confirm the hypothesis that the known features of light nuclei define the pattern of their relativistic dissociation. The probability distributions of the final configuration of fragments allow their contributions to the structure of the investigated nuclei to be evaluated. These distributions have an individual character for each of the presented nuclei appearing as their original “autograph”. The nuclei themselves are presented as various superpositions of light nuclei-cores, the lightest nuclei-clusters and nucleons. Recent data on pattern of diffractive dissociation of the nuclei ^{9}C, ^{10}C, ^{11}C and ^{12}N will be discussed in this context.

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SEARCH FOR LIGHT NEUTRON-RICH ISOTOPES IN STOPPED PION ABSORPTION

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Study of light neutron-rich nuclei is a principal line in the development of modern views on the properties of nuclear forces and determination of nuclear properties near the drip line. The present method of investigation relies on precise measurements of energy of charged particles emitted after stopped pion absorption by nuclei. Important advantages of this method are the practically accurate initial state energy and momentum, as well as the possibility to study a wide range of excitation energies.

In this work the analysis of results deduced from the pion absorption on level structures of the superheavy hydrogen isotopes $^{4-6}$H [1,2], heavy helium isotopes ^{6}He [3], ^{7}He [4] and lithium isotopes $^{7-9}$Li [5] and $^{10-12}$Li [6] is presented. The experiment was carried out in meson facility LAMPF using the two-arm semiconductor spectrometer of charged particles [7].

Search for nuclear states was performed in the inclusive and the correlation measurements of missing mass spectra. It follows from the phenomenological analysis of the experimental data that sizeable contribution to pion absorption by nuclei is brought about by quasi-free processes where the nucleons of residual nucleus do not immediately take part in the reaction. This favors a formation of loosely bound and quasi-stationary states in three-particle channels of the reaction. A wide range of excitation energies which can be obtained in correlation measurements provides the possibilities to study isobar-analog states and cluster resonances.

Our data were compared with theoretical and experimental results obtained up to now.

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FIRST MEASUREMENT OF THE PROTON SPIN POLARIZABILITIES

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The spin polarizabilities of the nucleon are fundamental structure constants describing the response of the nucleon spin to an incident polarized photon. The most model-independent way to measure these values is through the Compton scattering with polarization degrees of freedom. Three Compton scattering asymmetries on the proton has been measured in the Δ(1232) energy region using circularly and linearly polarized photon beams from Mainz Microtron and a transversely/longitudinally polarized proton target. Fits to asymmetry data were performed using a dispersion model calculation and a baryon chiral perturbation theory calculation, and a separation of all four proton spin-polarizabilities in the multipole basis was firstly achieved. The analysis based on a dispersion model calculation yields $\gamma_{E1E1} = -\,3.5 \pm 1.2$, $\gamma_{M1M1} = 3.16 \pm 0.85$, $\gamma_{E1M2} = -\,0.7 \pm 1.2$, and $\gamma_{M1E2} = 1.99 \pm 0.29$ (in units 10^{-4} fm^4).

INFLUENCE OF NUCLEAR REACTION MECHANISMS ON POPULATION OF EXCITED NUCLEAR STATES AND ISOMERIC RATIOS

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In recent years, mechanisms of fusion and transfer reactions at low energies have been of growing interest due to problems in synthesis of superheavy transuranic elements and other nuclei near the border of the nuclear stability. The purpose of this paper is to obtain, analyze, and summarize experimental data on cross sections of such reaction channels using beams of radioactive nuclei with halo structure and loosely coupled cluster and stable nuclei. Their interrelation with excitation of collective and single-particle states in nuclei formed as reaction products is also to be investigated. In this paper, the author also analyzes the results of experiments carried out with stable (^{6}Li) and radioactive beams (^{6}He) accelerated at the FLNR DRIBs complex and with extracted beams of deuterons and ^{3}He at the U-120M cyclotron of the Institute of Nuclear Physics (Academy of Sciences of the Czech Republic). The experiments and obtained results are described in [1–3].

The analysis of the results and their comparison with data obtained earlier leads to the following conclusions. Subbarrier fusion reactions with cluster and weakly bound light nuclei (^{6}Li and ^{3}He) are sufficiently described within simple evaporation models, taking into account Q reactions and coupled channels. In nuclei with halo structure, their peculiarity becomes apparent through reactions at energies below and near the Coulomb barrier. In this energy range, mere interaction of two structureless nuclei does not describe all the characteristics of fusion reactions. One should also take into account structural features of nuclei (^{6}He) and coupling with other reaction channels. Neutron transfer is observed with high probability in interactions between all weakly bound nuclei and light and heavy stable nuclei, the reaction Q-value being positive. Cross sections of reaction channels with a positive Q-value and their isomeric ratios (IR) differ drastically for stripping and pickup nucleon reaction channels owning to difference in population of excited single-particle states.

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DATA FOR PHOTONEUTRON REACTIONS FROM VARIOUS EXPERIMENTS

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Two different methods were used for determination of cross sections for partial photoneutron reactions, primarily (γ,1n), (γ,2n) and (γ,3n). One (Livermore (USA), Saclay (France) and some others) was based on the using of quasimonoenergetic annihilation photons and various methods of direct neutron multiplicity sorting. The second method (Moscow (Russia), Melbourne (Australia) and some others) was based on using of bremsstrahlung and obtaining of reaction yield (γ,*S*n) = [(γ,1n) + 2(γ,2n) + 3(γ,3n) + …] cross section from which the contribution of (γ,1n) reaction was estimated by statistical theory correction and those of (γ,2n) and (γ,3n) reactions by using appropriate subtraction procedures. Experimental conditions were noticeably different and therefore significant discrepancies between the results were obtained. The most impressive were the well-known large (up to 100 % of value) systematic disagreements between Livermore and Saclay data – generally σ(γ,1n) are larger at Saclay but σ(γ,2n) in turn at Livermore.

The situation was investigated for many nuclei using proposed objective physical criteria for data reliability: F_i = σ(γ,*i*n)/σ(γ,*x*n) = σ(γ,*i*n)/σ[(γ,1n) + 2(γ,2n) + 3(γ,3n) + …]. By definition F_1 should not be larger 1.00, F_2 – 0.50, F_3 – 0.33, etc.: larger values mean erroneous experimental neutron multiplicity sorting or yield reaction cross section correction and therefore unreliable data. It was found out that data under discussion for many nuclei (^{63,65}Cu, ^{80}Se, $^{91–96}$Zr, ^{115}In, $^{112–124}$Sn, ^{133}Cs, ^{159}Tb, ^{181}Ta, $^{186–192}$Os ^{197}Au, ^{207,208}Pb) are not reliable because of large systematic errors of procedures used.

Experimentally–theoretical method [1–3] was proposed for evaluation of data satisfied to proposed physical criteria: σ^{eval}(γ,*i*n) = $F^{theor}{}_i \cdot \sigma^{exp}$(γ,*x*n). The competition between partial reactions was in accordance with combined model of photonuclear reactions [4, 5] and their sum σ^{eval}(γ,*S*n) is equal to σ^{exp}(γ,*S*n). Partial reaction cross sections evaluated for many nuclei differ noticeably from experimental data obtained using neutron multiplicity sorting or statistical theory correction but agree with modern data obtained using activation method. The deviations of evaluated data from experimental ones are noticeably large and therefore many important physical problems should be reanalyzed.

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INTENSIVE HARD NEUTRINO SOURCE ON THE BASE OF LITHIUM. VARIANTS OF CREATION AND ACCELERATOR CONCEPTION

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An intensive antineutrino source with a hard spectrum ($E_{\tilde{\nu}}^{\max}$ = 13 MeV and $\langle E_{\tilde{\nu}} \rangle$ = 6.5 MeV) can be realized on the base of β^--decay of short living isotope ^{8}Li ($T_{1/2}$ = 0.84 s). The ^{8}Li isotope (generated in (n,γ)-activation of ^{7}Li isotope) is a prime perspective antineutrino source (or lithium converter) owing to the hard $\tilde{\nu}_e$-spectrum and square dependence of cross section on the energy ($\sigma \sim E_{\tilde{\nu}}^2$) [1–4]. Up today nuclear reactors are the most intensive neutrino sources with spectra formed by ^{235}U, ^{238}U, ^{239}Pu and ^{241}Pu isotopes which cause large uncertainties in the summary antineutrino spectrum at $E_{\tilde{\nu}} >$ 6 MeV. Use of ^{8}Li isotope allows to decrease sharply the uncertainties or to exclude it completely. The installations on the base of nuclear reactors (of steady-state or pulse neutron fluxes) plus ^{7}Li converter can be an alternative for nuclear reactors as “traditional” neutrino sources. It is possible creation of neutrino sources another in principle: on the base of beam-dumps of large accelerators plus ^{7}Li converter [1]; on the base of tandem of accelerators, neutron generating targets and ^{7}Li converter [3]. Different realizations of lithium antineutrino sources are discussed: static regime (i.e., without transport of ^{8}Li isotope to the neutrino detector); dynamic regime (transport of ^{8}Li isotope to the remote detector in a closed cycle); an operation of lithium converter in tandem of accelerator with a neutron-producing target (W, Pb, Bi) [4]. It were considered the schemes which allow to minimize the converter sizes that is urgently for oscillation analyses. Different chemical compounds of lithium (as converter substances) are investigated. An alternative to high-pure ^{7}Li in a metallic state is the heavy water solution of LiOD, which allows to decrease the requested mass of expensive purified lithium in about three hundred times. The converter efficiencies for proposed variants are calculated as yield of created ^{8}Li isotope per source neutron (proton). Today the conception of the proposed lithium converter [1–4] in the “tandem” scheme is included to the project of the powerful neutrino source and proposed for neutrino investigations [5].

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COMBINED SCHEMES OF THE MAGNETO-INERTIA CONFINEMENT OF HIGH TEMPERATURE PLASMA

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Two options to create the initial magnetic field in the combined scheme of magneto-inertial fusion (MIF) [1–10] are discussed:

1) the generation of the initial (seed) field at the beginning in the standard (laser driven and plasma jet driven) MIF, provided an increase of the external magnetic field at the same rate as compressed field inside the target. In this case, the time of thermonuclear burning is very close to that of inertial confinement fusion (ICF);

2) the initial magnetic field in the target is equal to zero and formed only after irradiation, then the plasma confinement time can be longer than in traditional ICF.

Dynamic magnetic trap is a trap with two current sources generating a magnetic field (electromagnetic coils in the conventional trap). Unlike standard magnetic trap, these coils shrink themselves and compress the magnetic field. Compression is carried out, for example, by the freezing of magnetic field lines by *Z*-pinch or nonsymmetric *Z*-pinch (they all compressed to its axis of symmetry). The target is located in the center of the dynamic magnetic trap and can be irradiated with laser energy in the direct drive configuration or indirect drive system (conventional hohlraum) or ion beams/plasma jets.

This paper discusses the new horizons of nuclear fusion energy and hybrid technology related to the high-temperature plasma.

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A NOVEL METHOD FOR DETERMINING THE MEAN-FIELD DIRECTLY FROM THE SINGLE PARTICLE MATTER DENSITY: APPLICATION TO THE MEASURED CHARGE DENSITY DIFFERENCE BETWEEN THE ISOTONES ^{206}Pb – ^{205}Tl

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We present a novel method, using the single particle Schrodinger equation, to determine the central potential directly from the single particle matter density and its first and second derivatives. As an example, we consider the experimental data for the charge density difference between the isotones ^{206}Pb – ^{205}Tl, deduced by analysis of elastic electron scattering measurements and corresponds to the shell model $3s_{1/2}$ proton orbit, and determine the corresponding single particle potential (mean-field). We also present results of least-square fits to parametrized single particle potentials. The $3s_{1/2}$ wave functions of the determined potentials reproduce fairly well the experimental data within the quoted errors. The fair agreement with fitted potentials may be an indication that effects of short range correlations on charge distributions due to shell model wave functions are not significant. More accurate experimental data, with uncertainty smaller by a factor of two or more, may answer the question how well can the data be reproduced by a calculated $3s_{1/2}$ wave function.

GAMOW-TELLER RESONANCES IN THE COMPOUND-NUCLEUS ^{118}Sb: PUZZLES OF THE SAROV'S EXPERIMENT

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More than 30 years ago, two rather narrow ($\Gamma \approx 1$ MeV) resonance structures have been observed in the excitation function of the ^{117}Sn (pn_{tot})-reaction [1]. The use of the methods successfully exploited early by the Guzhovskii's group (Sarov) in experimental studies of IAR allowed this group to deduce with a high accuracy the parameters of the mentioned structures associated by the authors with the Gamow-Teller resonances (GTRs) in the compound-nucleus ^{118}Sb. Up to now these unique experimental results are not reasonably explained. This point, and intention to essentially extend experimental studies of excitations functions of the (pp')- and (pn_{tot})-reactions with a number of tin target-nuclei [2] stimulate us to come again to experimental and theoretical studies of the GTR in antimony isotopes. We plan to discuss: (i) a comparison of the results of Ref. [1] with the corresponding data obtained by means of the direct (^{3}He,t)-reaction [3]; (ii) attempts to understand the mentioned experimental results from the theoretical point of view with inclusion into consideration of the specific structure effect – the GTR splitting in antimony isotopes near $A = 118$ [4,5]. A number of open questions and possible theoretical studies are planned to be discussed. The main puzzle is the noticeable difference the GTR total width deduced from the direct and resonance reactions. The small GTR total width might be a signature of an approximate spin-isospin SU(4)-symmetry conservation in nuclei.

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SUPERHEAVY NUCLEI SYNTHESIS IN HIGH INTENSIVE PULSED NEUTRON FLUXES

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Synthesis of heavy and superheavy (SH) nuclei in intensive pulsed neutron fluxes described using adiabatic model [1, 2] based on the astrophysical theory of *r*-process nucleosynthesis [3]. The nature of neutron pulses may be astrophysical and artificial one. So the pulse duration time may vary from microseconds (nuclear/thermonuclear explosion) to some seconds (star explosion). In the middle of this interval are pulsed reactors with milliseconds impulses duration time. For calculating heavy and SH nuclei yields we must know the parameters of neutron fluxes, their dependence in time and properties of short lived nuclei involved in this process. In the very shot-prompt process of thermonuclear explosion to produce SH nuclei the initial isotope composition should include transuranium elements [4]. The calculations were performed and for the super extreme neutron fluxes much higher than in "Hutch" test [5]. In nuclear pulsed reactors the duration time of neutron impulse may differ strongly that is principally influence on the heavy nuclei yields. We have considered nucleosynthesis for conditions reached in pulsed reactors. New data predictions for heavy nuclei from self-consistent microscopic approach [6] were used.

When duration of neutron exposition $t >> 10^{-6}$ s in explosive processes and free number density is higher than in artificial explosions, the answer to the question "whether SHE can be formed?" [7] strongly depends on predictions of the beta-delayed and spontaneous fission rates, mass and fission barriers values. All these questions are analyzed in this work and different problems of heavy and superheavy nuclei production in intensive neutron fluxes of explosive processes are discussed.

The work is partly supported by the Russian Foundation for Basic Research grants no. 13-02-12106 ofi-m, 14-22-03040 ofi_m and SNF SCOPES project № IZ73Z0_152485.

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NRV WEB KNOWLEDGE BASE ON LOW ENERGY NUCLEAR PHYSICS

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The NRV web knowledge base on low-energy nuclear physics [1] was developed at FLNR, JINR to allow quick access to the up-to-date experimental data on nuclear structure and cross sections of nuclear reactions as well as analysis of the data and modeling of the processes of nuclear dynamics within well-established physical approaches.

There are several unique advantages of the NRV web knowledge base compared to other nuclear databases.

As a rule, the nuclear databases supply users with ordinary text information. Thus, to obtain even the simplest systematics the user must manually prepare a separate file with all the necessary data and then use a separate graphical package to plot it. The NRV web knowledge base contains special programs for graphic representation of the data, their comparative analysis and obtaining systematics of all kinds either over a group of nuclei or the whole nuclear map.

Our databases on experimental cross sections of nuclear reactions allow quick processing, easy graphical comparison and analysis of the data within different theoretical models. All this is performed just in a window of the web browser without downloading and installation of any additional computational or graphical software. The computational programs for modeling low-energy nuclear dynamics are the significant part of the NRV web knowledge base.

Other advantages include simplicity of use, the interactive graphical interface allowing to adjust the parameters of theoretical models, detailed descriptions, graphical representation of the results, easy access via the Internet, etc.

The NRV web knowledge base contains most of the available experimental data on properties of nuclei as well as data on the cross sections of different nuclear reactions including fusion, evaporation and elastic scattering.

The available codes include the nuclear map, the shell model, the optical model, the CC model, the DWBA approach, reaction kinematics, etc.

The NRV web knowledge base is now widely used not only for scientific purposes, but also as a valuable tool in the education process in the field of nuclear physics [2].

This work was supported by grant 15-07-07673-a of the Russian Foundation for Basic Research (RFBR).

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EXPERIMENTAL INVESTIGATIONS OF ATOMIC NUCLEUS PROPERTIES

SEARCH FOR NUCLEAR STABLE MULTINEUTRONS IN THE TERNARY FISSION OF ^{232}Th INDUCED BY ACCELARATED α-PARTICLES

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One way of searching for stable neutron nuclei is the induced fission of actinide isotopes. Previously, we reported the results of our measurements where possible emission of multineutrons from the fission ^{238}U was observed by characteristic 1384 keV γ-rays from the ^{88}Sr(^{x}n,(x–4)n)^{92}Sr→^{92}Y process in the activated strontium sample [1]. Recently, we started new series of experiments to search for light multineutrons among of products of the ^{232}Th ternary fission induced by α-particles accelerated on the NRC cyclotron up the energies of 50 and 62 MeV. The identification of neutron nuclei was done by the activation method by measuring of γ-rays from β-radioactive nuclei ^{28}Mg produced in the transfer reactions: ^{27}Al(^{x}n,(x–2)np)^{28}Mg, ^{27}Al(^{x}n,(x–3)nd)^{28}Mg and ^{27}Al(^{x}n,(x–4)nt)^{28}Mg. The choice of ^{28}Mg was defined by the fact that the very intensive γ-rays 1342 keV (52.6%) and 1778 keV (100%) are emitted by the radioactive nuclei from the chain ^{28}Mg→^{28}Al→^{28}Si and half-life of ^{28}Mg is acceptable for the offline measurements ($T_{1/2}$=20.91 h).

The irradiation time was about 8 h at the beam current of 2 μA. Gamma spectra were measured after cleaning of the irradiated samples from ^{24}Na isotope which was produced in the ^{27}Al(n,α) background reaction. The cleaning was done by the method of thermal diffusion in an electrostatic field.

Analysis of the experimental data with the ^{232}Th target is in progress. This measurement could confirm the results of our early work [1].

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ISOBAR ANALOGUE STATES (IAS), DOUBLE ISOBAR ANALOGUE STATES (DIAS), CONFIGURATION STATES (CS), AND DOUBLE CONFIGURATION STATES (DCS) IN HALO NUCLEI. HALO ISOMERS

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The IAS of the halo nuclei may also have a halolike structure [1]. In [2] it is shown that the IAS of the ^{6}He ground state (two-neutron halo nucleus), i.e., the 3.56 MeV 0^{+} state of ^{6}Li, has a neutron-proton halo structure. In the general case [3] the IAS is the coherent superposition of the excitations like neutron hole–proton particle coupled to form the momentum $J=0^{+}$. The IAS has the isospin $T=T_z+1=(N-Z)/2+1$, where $T_z=(N-Z)/2$ is the isospin projection. The isospin of the ground state is $T=T_z=(N-Z)/2$. When the IAS energy corresponds to the continuum, the IAS can be observed as a resonance. CS are not the coherent superposition of such excitations and have $T=T_z=(N-Z)/2$. One of the best studied configuration states is the antianalog state (AIAS) [4]. The DIAS has the isospin $T=T_z+2$ and is formed as the coherent superposition of the excitations like two neutron holes–two proton particles coupled to form the momentum $J=0^{+}$. For the IAS, CS, DIAS, and DCS the proton particles have the same spin and spatial characteristics as the corresponding neutron holes. When the parent state is a two-neutron halo nucleus, IASs and CSs will have the proton-neutron halo structure, DIASs and DCSs will have the proton-proton halo structure. For nuclei with enough neutrons excess IASs and CSs can have not only the pn halo component but also the nn halo component, DIASs and DCSs can have both pp, nn, and pn components [4]. Such excited states and resonances as IAS, DIAS, CS, and DCS in halo nuclei can also have a halolike structure of different types (nn, pp, pn). IAS, DIAS, CS, and DCS can simultaneously have nn, np, and pp halo components in their wave functions [4]. When the halo structure of the excited and ground states are different than the isomers are able to be formed. From this point of view some CS and DCS depending on theirs halo structure, may be observed as isomers (halo isomers).

Structure of the excited states with different isospin quantum numbers in halolike nuclei is discussed. Special attention is given to the nuclei for which ground state does not have a halo structure but excited states may have a halo structure. $B(M\lambda)$ and $B(E\lambda)$ values for γ-transitions in ^{6,7,8}Li, ^{8,9,10}Be, ^{8,10,11}B, ^{10,11,12,13,14}C, ^{13,14,15,16,17}N, ^{15,16,17,19}O, and ^{17}F are analyzed.

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SEARCH FOR CLUSTER ROTATIONAL BANDS IN ^{11}B

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New experimental data on differential cross-sections of the ^{11}B + α inelastic scattering at $E(\alpha)$ = 65 MeV leading to the most of the known ^{11}B states at the excitation energies up to 14 MeV was obtained [1]. The data analysis was done by two methods: DWBA and Modified Diffraction Model [2], which allows determining the radii of the excited states. The radii of the low-lying excited states (excitation energy less than ~ 7 MeV) practically coincide with the radius of the ground state. This result is consistent with the traditional view of the shell structure of the low-lying states in ^{11}B.

Most of the observed high-energy excited states (excitation energy more than ~ 7 MeV) are distributed among four rotational bands:
K = $3/2^-$: 8.56 ($3/2^-$) – 10.34 ($5/2^-$) – 11.60 – 13.14 ($9/2^-$) MeV,
K = $1/2^+$: 6.79 ($1/2^+$) – 9.88 ($3/2^+$) – 11.60 ($5/2^+$) – 13.16 ($7/2^+$) MeV,
K = $3/2^+$: 7.98 ($3/2^+$) – 9.27 ($5/2^+$) – 10.60 ($7/2^+$) – 12.63 ($9/2^+$) MeV,
K = $5/2^+$: 7.29 ($5/2^+$) – 9.19 ($7/2^+$) – 11.27 ($9/2^+$) MeV.

The moments of inertia of these band states are close to the moment of inertia of the Hoyle state of ^{12}C. The determined radii, related to these bands, are 0.7 – 1.0 fm larger than the radius of the ground state, these values are close to the radius of the Hoyle state. Above-mentioned results are in agreement with existing predictions about various cluster structure of ^{11}B at high excitation energies [3, 4].

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SEARCH FOR STATES WITH ABNORMAL RADII IN ^{13}C

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In our previous experiment on the inelastic scattering ^{13}C (α,α') at E(α) = 65 MeV [1] we claimed the observation of three excited states whose radii differed from that of the ground state: 3.09 MeV ($1/2^+$), 8.86 MeV ($1/2^-$) and 9.90 MeV ($3/2^-$). In this paper we continued the analysis including in it some other data. The evaluation of radius of the 3.09 MeV state was performed by three independent methods, Modified diffraction model (MDM) [2], Nuclear rainbow method (NRM) [3, 4] and method using the asymptotic normalization coefficients (ANC) [5, 6]. The radius occurred to be enhanced in good agreement with theoretical predictions [7] demonstrating the existence of a neutron halo in this state. All three approaches gave similar values verifying the validity of the used methods. Application of MDM and NRM to the 8.86 MeV state showed that the latter also has an enhanced radius close to that of the Hoyle state (7.65 MeV, 0^+) of ^{12}C [2]. The radius value of the 9.90 MeV remains an open question. The estimates done both by MDM and NRM methods gave the value less than that of the ground state. As this state is considered to be the head of the $3/2^-$ rotational band [8], and its enhanced radius is predicted [9] a more elaborate analysis of the problem is required. Because of the importance of the obtained result new measurements of the inelastic scattering ^{13}C (α,α') at E(α) = 90 MeV were performed. The analysis is in progress.

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SEARCH FOR RARE CLUSTER CONFIGURATIONS IN THE NUCLEUS ^{14}C IN THE REACTION ^{14}C(π^-,pd)X

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Search for rare cluster configurations in the ^{14}C nucleus was made in the correlation measurements of stopped pion absorption reaction ^{14}C(π^-,pd)X via previously used method [1–3].

For our analysis we took the data obtained in the experiment on the low energy pion beam of the LAMPF using the two-arm semiconductor spectrometer of charged particles [4]. The contribution of impurities in the ^{14}C target was taken into account by means of the experimental data, obtained on the isotopically-pure ^{12}C target during one experimental run.

The analysis of the 2-dimensional energy distribution (Dalitz' diagram) of the registered particles allowed the extraction of two- and three-body reaction mechanisms.

The kinematic area which corresponds to the pion absorption on the intranuclear ^{3}p cluster was found in the three-body channel. This fact indicates on the occurrence of the rare cluster structure in the ^{14}C nucleus: ^{11}Li + ^{3}p. In the mentioned region the ^{11}Li momentum is about $p_F \approx 150$ MeV and the ^{11}Li isotope is a "spectator".

Two-body reaction channels were studied for $\pi^- + {}^{14}\mathrm{C} \rightarrow \mathrm{d} + {}^{12}\mathrm{Be}$ and $\pi^- + {}^{14}\mathrm{C} \rightarrow \mathrm{p} + {}^{13}\mathrm{Be}$. In the $\pi^- + {}^{14}\mathrm{C} \rightarrow \mathrm{p} + {}^{13}\mathrm{Be}^* \rightarrow \mathrm{p} + \mathrm{d} + {}^{11}\mathrm{Li}$ reaction an indication on the appearance of the highly excited state of the ^{13}Be (the resonance energy $E_r > 20$ MeV) was obtained for the first time.

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THE STUDY OF THE PHENOMENON OF "DISSOLUTION" OF ALPHA-CLUSTERS AND THE FORMATION OF THE MEAN FIELD IN THE TRANSITION FROM LIGHT TO MEDIUM NUCLEI

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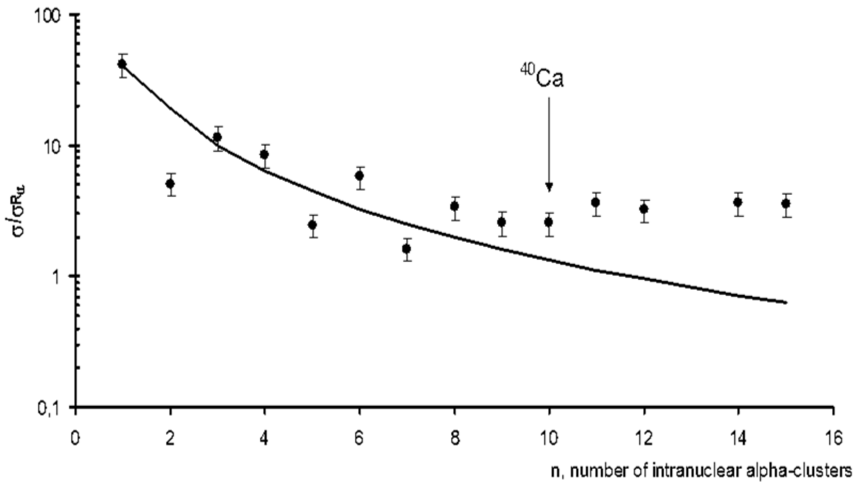
Historically, alpha-cluster structure of nuclei was the first and was first used by the founders of nuclear physics E.Rutherford and L.Meitner [1]. However, the effect of a sharp rise in the differential cross sections of Rutherford at small angles, understood recently authors [2], allowed to find the desired method.

The figure shows the evolution of the "disappearance" of the raising the cross sections for the 4n-nuclei at energies comparable probing particles of 10 MeV/*A*, which clearly points to the phenomenon of "dissolution" of alpha-clusters. The x axis represents the number of hypothetical intranuclear alpha clusters. The ordinates represent the ratio of quasi-integrated cross sections (differential cross sections integrated from Coulomb angle, that is, to the trajectory tangent to the surface of angle, to 90 deg. in which the ends of the Fraunhofer diffraction pattern) to the cross section of Rutherford on alpha-particles. Points – collisions with the nucleus as a whole. The solid curve – collisions with intranuclear alpha clusters. The coincidence of the theoretical solid curve with the experimental data clearly indicates the existence of spatially separate alpha-clusters (cross section of the Rutherford on alpha-particles is much smaller than the nucleus as a whole). The discrepancy between the theoretical curve and the experimental points in the area comes from the region ^{40}Ca nuclei, which begins the formation of the average nucleon field.



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EVOLUTION OF $N = 40$ NEUTRON SUBSHELL AT $20 \leq Z \leq 30$ WITHIN THE DISPERSIVE OPTICAL MODEL

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Experimental data support the closure of N = 40 subshell in ^{68}Ni. Such data are not yet available for ^{60}Ca. The calculation within HFB+generator-coordinate-based method [1] indicates the tendency to increase of $E(2_1^+)$ and decrease of $E(4_1^+)/E(2_1^+)$ in the neighbor isotone ^{62}Ti and also a spherical shape of ^{60}Ca and ^{68}Ni. Neutron single-particle energies of isotones with N = 40 at $20 \leq Z \leq 30$ were calculated with the dispersive optical potential (DOP) (see Fig. 1). According to these calculations, the evolution of N = 40 gap is determined by the evolution of $1f_{5/2}$ level. This level is located between the $2p_{1/2}$ and $1g_{9/2}$ levels at $Z \leq 26$, so that $1g_{9/2}$–$1f_{5/2}$ gap reaches a minimum in ^{64}Cr. The evolution of the single-particle spectrum is consistent with the growth of collectivity of ^{64}Cr nucleus [1]. Such evolution also results in N = 40 subshell closure in ^{68}Ni. In this nucleus, $1g_{9/2}$–$2p_{1/2}$ gap reaches a maximum, neutron energy $E_{1g_{9/2}}^{DOP}$ is close to neutron separation energy (with the opposite sign) $-S_{\rm n}(N+1,\, Z)$ from (N+1, Z) nucleus and neutron energy $E_{2p_{1/2}}^{DOP}$ is close to $-S_{\rm n}(N,\, Z)$. In ^{60}Ca, $1g_{9/2}$–$1f_{5/2}$ gap increase up to 2.8 MeV in comparison to 2.03 MeV in ^{62}Ti. This result is consistent with the expectation of semi-double magicity of ^{60}Ca.

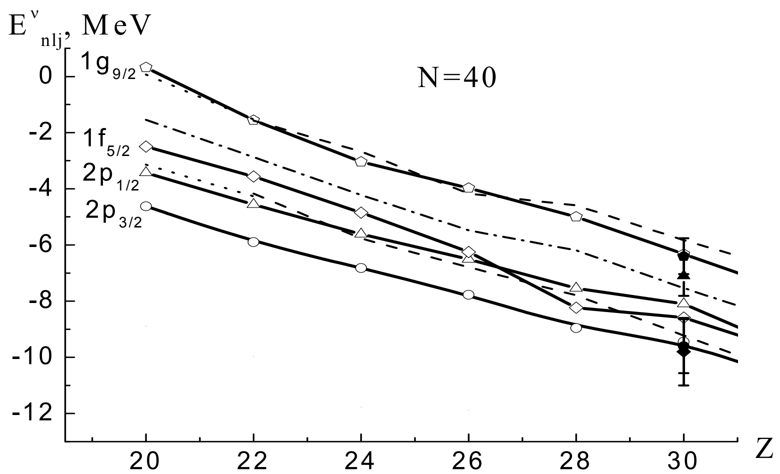

Fig. 1. Neutron single-particle energies of N=40 isotones. Solid symbols – experimental data, open symbols connected with the lines – calculation with DOP, dashed and dotted lines – energies –S_n(N+1,Z) and –S_n(N,Z), dashed-dotted line – the Fermi energy.

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NEUTRON SINGLE-PARTICLE STRUCTURE OF Mo ISOTOPES WITHIN THE DISPERSIVE OPTICAL MODEL

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Experimental neutron differential elastic scattering cross sections and total interaction cross sections for stable Mo isotopes were analyzed by the dispersive optical model. Imaginary part of the dispersive optical potential was fixed in accordance with the global parameters [1]. Achieved good agreement between calculated and experimental data (see Fig. 1 for ^{100}Mo as an example) allowed using the global parameters [1] to calculate the dispersive component and then the neutron single-particle spectra of near spherical Mo isotopes with N near 82. Hartree-Fock type component of dispersive optical potential was found from the condition of agreement between summed number of neutrons in bound states and N number of the isotope. The dynamics of neutron single-particle spectra is shown in Fig. 2. Spectrum of nucleus ^{124}Mo with magic number N=82 stands out among other. In that case, N=82 energy gap achieves a maximum, the Fermi energy is located between $1h_{11/2}$ and $2f_{7/2}$ levels which are close to the neutron separation energy $S_{\rm n}$ (with the opposite sign) from (N,Z) and (N+1,Z) nuclei correspondingly.

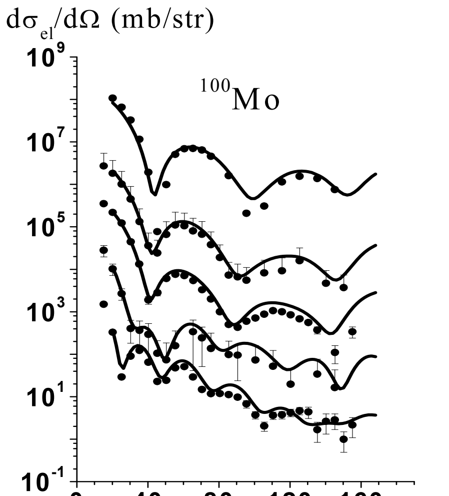

Fig. 1. Neutron differential elastic scattering cross sections for ^{100}Mo at 26, 20 (x10), 11 (x100), 9 (x1000) and 7 MeV (x50000).

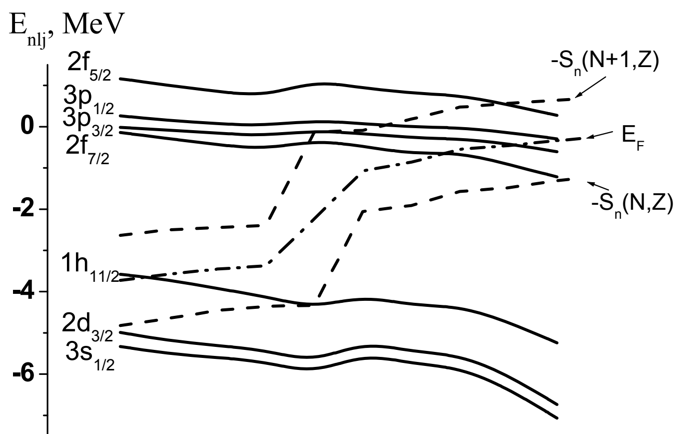

Fig. 2. Single-particle energies of Mo isotopes near N = 82.

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INVESTIGATION OF ^{164}Dy IN (n, n'γ) REACTION

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Gamma-ray spectra and γ-ray angular distributions relative to the reactor fast neutron beam were measured in ^{164}Dy (n, n'γ) reaction with use of fast neutron facilities on the IR-8 reactor at the NRC "Kurchatov Institute". About 500 γ-lines corresponding to γ-transitions in ^{164}Dy with energy of up to 2.7 MeV were singled out in obtained spectrum. Measured angular distributions enabled to determine multipolarity or multpole mixture ratio for 65 γ-transitions. The levels and γ-transitions scheme of ^{164}Dy was constructed. The previously unknown levels were supplemented in this scheme and levels introduced erroneously in some published works were established. The $J^{\pi}K$ quantum characteristics for many levels and multipole mixture ratios for many γ-transitions were defined unambiguously. The obtained results allow to conclude that presented ^{164}Dy scheme of levels with angular momentum J from 0 to 4 is complete for excitation energy of up to ~1.9 MeV.

Influence of respective Nilsson's quasiparticle states of $1i_{13/2}$ subshell on the rotational band parameters was considered. The systems of nonrotational states of ^{162}Dy, ^{164}Dy, ^{166}Er and ^{168}Er were compared and it was established that the levels 1796.65 keV in ^{164}Dy and 1703.11 keV in ^{166}Er with $J^{\pi}=2^{+}_{2}$ do not contain quasiparticle states of $1i_{13/2}$ subshell with high orbital momentum (l_{ν}=6). This conclusion lets us to assume these levels to be "spherical". Violation of band construction rules of rotational bands with $K^{\pi}=0^{+}_{2}$ and 1^{+}_{1} in these nuclei may be occasioned by the interaction of respective close-lying rotational states of these bands with the "spherical" 2^{+}_{2} state. Another possible explanation of observed peculiarities of band structure in ^{164}Dy and ^{166}Er because of superconductor-type pare vibrations was given in [1].

The complete system of nonrotational levels with J from 0 to 4 in ^{164}Dy is listed for excitation energy of up to ~1.9 MeV in the table below.

E_{lev}, keV	0.00	761.815	976.917	1588.097	1654.71	1674.95
$J^{\pi}K_{\mathrm{n}}$	$0^{+}0_{g}$	$2^{+}2_{1}$	$2^{-}2_{1}$	$4^{-}4_{1}$	$0^{+}0_{1}$	$1^{-}1_{1}$
E_{lev}, keV	1779.15	1796.68	1809.57	1840.66	(1883.55)	1933.65
$J^{\pi}K_{\mathrm{n}}$	$0^{+}0_{2}$	2^{+}_{2}	$1^{+}1_{1}$	$1^{-}1_{1}$	$(0^{+}0_{3})$	$4^{-}4_{2}$
E_{lev}, keV	1949.78	1978.82	1985.65	2049.13	2053.62	
$J^{\pi}K_{\mathrm{n}}$	$3^{-}3_{1}$	$3^{+}3_{1}$	2^{-}, 3^{-}	$(2^{+}2_{2})$	$1^{(-)}$	

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THE IMPROVED ENERGY OF THE 21.5 keV *M*1+*E*2 TRANSITION IN ^{151}Eu

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According to the last compilation [1], the first excited state 21.541(3) keV $7/2^+$ in ^{151}Eu is depopulated to the $5/2^+$ ground state by the 21.542(3) keV *M*1+*E*2 nuclear transition with the *E*2 admixture parameter $|\delta(E2/M1)|=0.029(1)$. Energies of 21.501(10) and 21.517(13) keV were obtained for the above first excited state and the nuclear transition, respectively, from the electron capture decay of the parent ^{151}Gd isotope. The most precise energy value of $21543.2\pm0.3^{\text{stat}}\pm$about 3^{syst} eV was measured [2] for the nuclear transition in question using the Si(Li) and HPGe detectors. Having to our disposal a high-resolution combined electrostatic electron spectrometer [3] and a ^{151}Gd source prepared by vacuum evaporation on a polycrystalline carbon foil, we performed the energy determination for this transition by means of the internal conversion electron spectroscopy. The only *L*-21.5 conversion electron line group was measured at the 7 and 14 eV absolute instrumental resolution. From the obtained conversion electron line energies and the corresponding electron binding energies [4], a preliminary value of 21541.6±1.1 eV was determined for the nuclear transition. This value agrees well with the abovementioned data [1, 2] but it is substantially more accurate. Moreover, a preliminary value of 0.030(1) for the *E*2 admixture parameter $\delta(E2/M1)$ was derived from our *L*-subshell conversion line intensity ratios 40.7(4) : 5.3(3) : 2.6(2) using the relevant internal conversion coefficients for the *M*1 and *E*2 multipolarities calculated in the present work by means of the computer code NICC [5] using the potential [6] for a neutral europium atom and the europium electron binding energies [4]. This value is in very good agreement with the above adopted *E*2 admixture [1].

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ON THE NECESSITY OF THE PRECISION INVESTIGATION OF THE EXCITED STATES IN THE Ho AND Dy NUCLEI FROM THE ^{156,158,160}Er DECAY

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A necessity of performing precision (ΔE~0.01 keV, ΔI~0.1 rel. un.) investigations of excited states in the dysprosium and holmium nuclei with A = (156, 158, 160) belonging to the transition deformation region is discussed. New data on the (γ-γ) coincidences and gamma rays are reported. The results of processing the ^{158}Dy gamma spectrum in the range up to 4 MeV are presented. Gamma spectra of the ^{156,158}Dy nuclei that have high decay energy (Q_β = 5060 and 4240 keV) feature a high density of gamma transitions and a lot of double gamma lines. The decay schemes of these nuclei in the region above 3 MeV have almost not been studied, and gamma transitions with energies higher than 3 MeV have not been placed [1, 2].

A=156. New data on γ-γ coincidences in ^{156}Dy: (window, keV) (response, keV)
(138 keV): (2757, 2780, 2825, 2846, 2905, 2911, 2926, 2980, 2985, 2993, 3047, 3148, 3152, 3208, 3229, 3418, 3644, 3657, 3678, 3823, 3993 et al.). *(266 keV):* (2846d, 2891, 2924, 2980, 3118, 3127, 3210, 3257, 3278, 3428, 3556, 3556, 3643, 3661, 3670, 3825, 4023, 4032 et al.) *(366 keV):* (1494, 1499d, 1585, 1634d, 1769, 1953, 2570, 2614, 2669, 3021, 3049, 3188, 3257, 3428 et al.). *(445 keV)*: (642, 1617); *(3566 keV)*: (138, 266); *(d3665 keV)*: (138, 266).

A=158. Investigating the γ-γ coincidence spectra, we found the following coinci-dence cascades in the ^{158}Ho nucleus: (131.7 keV, 204 keV), (93.9 keV, 204.2 keV), (50.7 keV, 336 keV) and (93.8 keV, 131.7 keV).

The coincidence cascades (874.4 keV, 1678.0 keV), (846.6 keV, 1460.6 keV), (406.2 keV, 1627.1 keV), (517.3 keV, 990.0 keV), (218.2 keV, 2396.4 keV) and (320.5 keV, 2076.1 keV) observed in the decay of the ^{158}Ho nucleus allowed us to introduce the following levels in the ^{158}Dy nucleus: 2634.3 keV, 261.0 keV and 2713.7 keV.

In the γ-γ coincidence spectra with the higher-intensity gamma transitions of 218.2 keV, 320.5 keV (and 839.0 keV) we observed new gamma transitions at 1159.2 keV, 839.0 keV (and 732.5 keV), which allow establishing additional decay channels of the high-spin 9^+ isomer to low-lying states.

A=160. The problems of the upper part [3] of the ^{160}Dy decay scheme can be solved when good-quality electron-gamma and γ-γ coincidences are observed.

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EFFECT OF METALLIC MATRIX ON PROBABILITY OF 910 eV TRANSITION IN ^{154}Eu NUCLEI

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Effect of the metallic atomic surroundings (matrix) on the probability of nuclear conversion transition was studied previously when nuclear isomers ^{235m}U (transition energy ΔE = 76 eV) and ^{99m}Tc (ΔE = 2.17 keV) were implanted into matrix of various materials. It was shown that after implanting of these nuclei into a metal the probability of the conversion transitions becomes smaller than for the nuclei inside dielectric: $\delta P \sim 1000$ % for ^{235m}U [1] and $\delta P \sim 0.1$ % for ^{99m}Tc [2]. This effect is not caused by atomic shells deformation of isomeric nuclei inside matrix or by conversion electron scattering on atoms of matrix, but it can be explained as screening (by metal) of the electromagnetic interaction causing conversion transitions of isomeric nuclei inside metal [3]. Such explanation supposes that the effect should decrease with increasing transition energy.

We studied the conversion transition ΔE = 910 eV between the exited states of ^{154}Eu nucleus which occur after decay of ^{154m}Eu isomer ($T_{1/2}$ = 46 min.). Previously observed variation $\delta P \sim 10$ % of the transition probability for ^{154m}Eu nuclei inside various matrices [4] can be measured using yield variation of 31.8, 68.2 and 100.9 keV ^{154m}Eu gammas that can be detected directly from matrix containing ^{154m}Eu nuclei. This experimental method is easier-to-use than ^{235m}U method when it is possible to detect conversion transition only for nuclei on the backing surface or than ^{99m}Tc method when the matrix effect is very small.

In the present work we found that for ^{154m}Eu nuclei implanted inside metallic alloy of Sm and Sn the 910 eV transition probability is 17 ± 6 % less than for ^{154m}Eu nuclei inside Sm chloride matrix. Finding the matrix effect for 910 eV transition at the level of tens of percent opens the possibilities of systematic study of the effect of various matrices on the conversion transition probability.

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ON THE DECAY SCHEME OF ^{234}Th NUCLEUS β-DECAY

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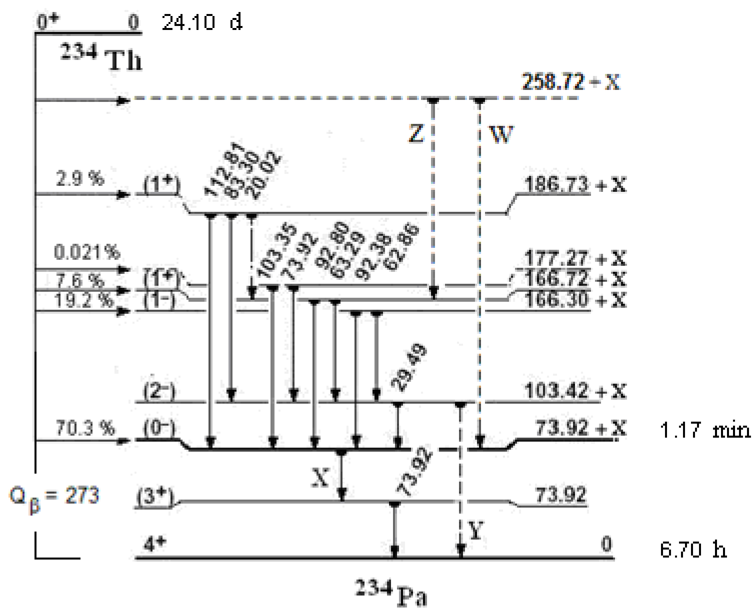
Decay scheme of the excited ^{234}Pa nucleus formed after β-decay of ^{234}Th is still not completely clear. For energy of isomeric transition X it were reported only the upper limit of 10 keV [1] and theoretical estimate $X \approx 20$ eV [2]. The weak γ-lines of ^{234}Th β-decay 57.75, 87.02, 92.00, 103.71, 108.00, 132.9 and 184.8 keV are not ascribed to definite nuclear levels [1]. The decay scheme still has to be extended using some extra levels.

In ref. [3] ^{234}Th γγ-coincidence spectrometry showed the emission of gammas $Y = 106.0 \pm 0.5$ keV in cascade with 63.29 keV gammas that gives $X = 2.6 \pm 0.5$ keV. Also in cascade with 63.29 keV gammas, the emission of gammas 92.2 ± 0.5 keV was observed. Identification of this γ-line with unidentified in [1] γ-line $Z = 92.00$ keV initiate a need for introduction of new level 258.72 + X in ^{234}Th decay scheme. Using this level it is possible to explain emission of another γ-line $W = 184.8$ keV which is known but is not identified [1]. More accurate energy measurement is necessary to improve reliability of the γ-line identification.



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W, Z-transitions and 258.72 level are introduced in the present work.

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INVESTIGATION OF DOUBLE BETA DECAY OF ^{58}Ni

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Investigation of double beta decay processes (β^+EC, EC/EC) of ^{58}Ni was performed at the Modane underground laboratory (LSM, France, 4800 m w.e.) using ultra low-background HPGe detector OBELIX with sensitive volume of 600 cm^3 [1]. The objects of analysis were γ-rays with energies of 511 and 811 keV. The β^+EC decay to the ground 0^+ and first 2^+ excited states of ^{58}Fe will be accompanied by emission of positron, which creates two correlated annihilation γ-quanta with energies of 511 keV. The β^+EC decay to the first 2^+ excited state of ^{58}Fe will be accompanied by additional γ-quantum with energy of 811 keV emitting in de-excitation of this excited state. EC/EC decay of ^{58}Ni to the first 2^+, 811 keV excited state of ^{58}Fe will be accompanied with 811 keV γ-rays. All these γ-quanta can be detected by the OBELIX detector with high efficiency.

A sample of natural nickel, containing ~68% of ^{58}Ni, was prepared in a shape of a Marinelli beaker. It looked like a cylinder with an external diameter of 192 mm and a height of 130 mm having an internal hole with a diameter of 126 mm and a depth of 106 mm. The total mass of the sample was ~21.7 kg. Test measurement of the sample was started in the middle of October 2014 and lasted 47.5 days. The goal of this measurement was to obtain contaminations of short-living cosmogenic isotopes in the sample. Their activity was found to be high for a long-term measurement of ^{58}Ni. The main run will be started in approximately one year after decreasing the activity of short-living isotopes to a few percent. Basing on the data accumulated in the test measurement new experimental limits on β^+EC decay of ^{58}Ni to the ground 0^+ and excited 2^+, 811 keV excited state of ^{58}Fe, and EC/EC decay of ^{58}Ni to 2^+, 811 keV excited state of ^{58}Fe were obtained. They are: $T_{1/2}(\beta^+\mathrm{EC}, 0^+ \to 0^+) \geq 3.7\cdot10^{21}$ y; $T_{1/2}(\beta^+\mathrm{EC}, 0^+ \to 2^+) \geq 3.1\cdot10^{21}$ y and $T_{1/2}(\mathrm{EC/EC}, 0^+ \to 2^+) \geq 1.4\cdot10^{21}$ y. All limits are at 90% CL. Previous experimental limits for these decay modes were $T_{1/2}(\beta^+\mathrm{EC}, 0^+ \to 0^+) > 7.0\cdot10^{20}$ y (68%CL) [2], $T_{1/2}(\beta^+\mathrm{EC}, 0^+ \to 2^+) > 4.0\cdot10^{20}$ y (68%CL) [2] and $T_{1/2}(\mathrm{EC/EC}, 0^+ \to 2^+) > 4.0\cdot10^{19}$ y (90%CL) [3].

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NEW LIMITS OF MAJORANA NEUTRINO MASS FROM COMBINED ANALYSIS OF ^{76}Ge, ^{136}Xe, ^{130}Te AND ^{100}Mo NEUTRINOLESS DOUBLE BETA DECAY SEARCHING FOR EXPERIMENTS

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Now in the particle physics is question about absolute neutrino mass and neutrinoless double beta decay (0νββ) could presented information on this issue.

We have performed combined analysis of results the last ^{76}Ge, ^{136}Xe, ^{130}Te and ^{100}Mo neutrinoless double beta decay (0νββ) searching for experiments[1–6] namely in connection with that problem.

For 0νββ mediated by the majorana neutrino, the half-life is given by

$$\frac{1}{T_{1/2}^{0\nu}} = \left|m_{\beta\beta}\right|^2 G^{0\nu} M_{0\nu}^2,$$

where $G^{0\nu}$, $M_{0\nu}$ and $m_{\beta\beta}$ the phase space factor, the NME and effective majorana mass $\left|m_{\beta\beta}\right| = \sum_{i=1}^{3} \left|U_{ei}\right|^2 m_i$, where U_{ei} is the mixing matrix of eigenvalues m_i.

The result energy spectra of these experiments together with their experimental parameters such as exposure, energy resolution and efficiency were used as input parameters for Bayesian calculation of the 0νββ signal. For the analysis so it were used the nuclear matrix elements which have calculated simultaneous ones as for ^{76}Ge so as for ^{36}Xe [7, 8]. This gave us a reduction of systematic errors connected with nuclear matrix element calculation techniques.

It were obtained $m_{\beta\beta}$ < [80.5 – 89.2] meV, what excludes quasidegenerate mass hierarchy.

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MEASUREMENT OF NEUTRINO MAGNETIC MOMENT WITH THE LOW-BACKGROUND GERMANIUM SPECTROMETER GEMMA-II

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The magnetic moment is the fundamental parameter of the neutrino and its measurement in a laboratory experiment may lead to results beyond the Standard Model. The antineutrino-electron scattering is investigated in GEMMA («Germanium Experiment for measurement of Magnetic Moment of Antineutrino»). As a result of the first experiment (GEMMA-I) within the framework of the project the world best upper limit for the neutrino magnetic moment (NMM) was found to be $\mu_\nu < 2.9 \cdot 10^{-11} \mu_B$ (90% CL).

The experimental setup of GEMMA-II is located under the reactor №3 of KNPP where the distance from the centre of the core is 10 m. In this way we obtain an enormous antineutrino flux that is equal to $5.4 \cdot 10^{13}$ 1/cm^2/s. The γ-background conditions in the new room are much better (by an order of magnitude), the climate conditions are more stable if compared with GEMMA-I. Furthermore, being equipped with a special lifting mechanism the spectrometer is moveable. It gives us an opportunity to vary on-line the antineutrino flux significantly and thus suppress the main systematic errors caused by the possible long-term instability and uncertainties of background knowledge. The mass of the detector is 6 kg (two detectors with a mass of 3 kg each). To avoid the “Xe-problems” the internal part of the detector shielding will be gas tight. A special U-type low-background cryostat is used in order to improve the passive shielding and thus reduce the external background in the region of interest down to ~ 0.5 – 1.0 (keV kg day)$^{-1}$. A special care is taken to improve antimicrophone and electric shielding. We also reduce the effective threshold from 2.8 to 1.5 keV. As a result of all the improvements we will be able to suppress the systematic errors and expect the experimental sensitivity to be at the level of (1–1.5) 10^{-11} μ_B and thus to reach the region of astrophysical interest.

In 2018 8–10 kg of point contact detectors will be used for an upgrade of the experimental setup. In this case new NaI active shielding consisting of 12 parts will be used to suppress the background down to 0.2–0.5 (keV kg day)$^{-1}$. In this way we will be able to work on the $10^{-12}\mu_B$ level that is of astrophysical interest. As a result of the last step the experimental sensitivity will be improved to the level of ~ 5 10^{-12} μ_B after several years of data taking.

APPLICATION OF NEUTRINO-CAPTURE BETA DECAY IN TRITIUM FOR MEASURING THE SPECTRUM OF SOLAR NEUTRINOS

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The mass of the daughter nucleus of He^3 in beta decay of tritium is smaller than that of the nucleus of tritium. Therefore, the reaction

$$\nu_e + {}^3\mathrm{H} \rightarrow {}^3\mathrm{He}^+ + e^- \quad (1)$$

will take place even if the neutrino energy is $E_{\nu_e} \rightarrow 0$.

The cross section of this reaction has been calculated in [1, 2].

The electron energy in reaction (1) equals $E_e = Q_\beta + E_{\nu_e} + m_\nu c^2$, where Q_β is the final point energy, i.e. the maximum electron energy in beta decay of tritium given that the neutrino has zero mass, E_{ν_e} is the energy of the incident neutrino, and $m_\nu c^2 \leq 0.1$ eV is the neutrino mass.

By measuring the spectrum of generated electrons, one can determine the spectrum of solar neutrinos.

In the paper, we demonstrate the possibility in principle of measuring the spectrum of solar neutrinos and getting data on all neutrino reactions in the Sun, except for the hep and ^{17}F reactions.

We show that the use of ~10 MCi (~1 kg) of tritium as a target will allow detecting a statistically significant number of neutrino-capture beta decay reactions for all reactions, except hep and ^{17}F, in a year of measurements; and that statistically significant quantities can also be obtained for the energy range from 100 to 200 keV of the pp reaction.

Under normal conditions, 10 MCi of tritium occupy a sphere of radius ~1 m.

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ON NEW ELECTRON CONVERSION LINES FROM EXISTING γ-TRANSITIONS IN ^{160}Dy

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Two photo plates derived with spectrograph LNP JINR with constant magnetic field [2] have been investigated using the Automatic Scanning Microscope MAS-1 [1]. Electron internal conversion (ICE) spectrograms of two erbium (Er P-2, Er P-8) and one Ho fractions has been measured. More detailed analysis gave us the possibility to obtain some new lines (see table) in addition to many earlier existing lines in ^{160}Dy [3]

E_γ (ΔE_γ) [3] (keV)	I_γ(ΔI_γ) [3] (rel. units)	I_κ [this tesis] (rel. units)
673.09(7)	2.7(3)	< 0.015
748.,8(1)	4.5(3)	< 0.05
791.5(2)}	4(1)}	}< 0.04
792.0(2)}	3.0(5)}	}
828.13(15)	3.2(4)	< 0.046
986.15(11)	2.63(12)	< 0.001
987.9(11)	3.64(17)	< 0.001
989.75(5)	7.7(3)	< 0.002
994.76(13)	4.0(5)	< 0.002
1058.25(4)	2.96(15)	< 0.01
1067.9(1)	3.5(4)	< 0.01
1077.25(6)	3.6(4)	< 0.01
1083.70(5)	3.6(5)	< 0.006
1091.1(3)	3.6(5)	< 0.005
1102.60(4)	9.3(4)	< 0.01
1111.11(18)	2.7(6)	< 0.005
1208.28(12)	3.2(2)	< 0.005
1211.71(6)	2.9(2)	< 0.004
1754.32(8)	1.25(8)	< 0.004
1871.5(2)	1.58(8)	< 0.002

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SINGLE-PARTICLE CHARACTERISTICS OF ^{208}Pb WITHIN THE DISPERSIVE OPTICAL MODEL

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Experimental data on neutron and proton single-particle energies of the bound nucleon states including deep lying states as well as differential elastic scattering, total interaction, and total reaction cross sections for ^{208}Pb were analyzed by the mean field model with dispersive optical potential (DOP) [1]. The obtained DOP was used to calculate single-particle characteristics of ^{208}Pb (single-particle energies, spreading widths, spectroscopic factors, neutron and proton (charge) density distributions). Good agreement with available experimental data was achieved.

The neutron and charge density distributions of ^{208}Pb, its rms radii, are attracting sufficient interest due to the connection between neutron skin thickness Δr_{np} and nuclear symmetry energy. In [2], authors studied neutron skin thickness Δr_{np} of ^{208}Pb which were calculated according to the various mean-field models of nuclear structure. We calculated neutron and proton (charge) density distributions using the solutions of the Schrödinger equation with the real part of DOP as single-particle wave functions and the occupation probabilities which were determined by a formula of the Bardeen-Cooper-Schrieffer theory with the single-particle energies. The resulting charge and neutron density distributions of ^{208}Pb are shown in Fig. 1 in comparison with the experimental charge density. The corresponding value Δr_{np} =0.321 fm is close to that obtained by the relativistic model NL1 [2].

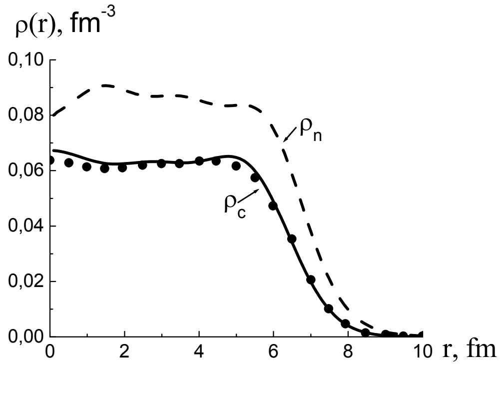

Fig. 1. Charge and neutron density of ^{208}Pb.

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CLUSTERING FEATURES OF THE ^{7}Be NUCLEUS IN RELATIVISTIC FRAGMENTATION

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Stacks of pellicles of nuclear track emulsion provide a special opportunity to explore clustering of light nuclei (reviewed in [1]). The presented results on dissociation of ^{7}Be nuclei are demonstrate the progress in research carried out by the BECQUEREL Collaboration [1–3]. The ^{7}Be nucleus is a source for the study of the states ^{3}He + ^{4}He, ^{3}He + ^{3}He + n, ^{6}Li + p and ^{6}Be + n. The pattern of fragmentation is important for understanding of the structure features of the nuclei ^{8}B, ^{9}C and ^{12}N because the ^{7}Be nucleus plays the role of a core in them.

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STUDY OF ^{11}C FRAGMENTATION IN NUCLEAR TRACK EMULSION

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Featuring an excellent sensitivity and spatial resolution nuclear track emulsion (NTE) maintains the position of a universal and inexpensive detector for survey and exploratory research in microcosm physics. Use of this classical technique on the beams of modern accelerators and reactors turns out highly productive. In a number of important tasks the completeness of observations provided in NTE can not be achieved for electronic detection methods. In particular, in the last decade clustering of a whole family of light nuclei including radioactive ones was investigated in the processes of dissociation of relativistic nuclei in NTE [1, 2]. Recent data on pattern of diffractive dissociation of the nuclei ^{9}C, ^{10}C, ^{11}C and ^{12}C will be discussed in this context.

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EXPERIMENTAL INVESTIGATIONS OF NUCLEAR REACTIONS MECHANISMS

MODERN METHODS OF TOTAL REACTION CROSS SECTION STUDIES, FEATURES, RESULTS AND PERSPECTIVES

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A total reaction cross section (σ_R) belongs to one of the most fundamental and important parameter of nuclear physics which is reflecting the properties both of nucleus-nucleus interaction and nuclear matter. The total nuclear reaction cross sections measurements have long been of interest since 1985 year when the applying of a transmission method for discovery the properties of nuclei with a neutron halo [1] firstly provide the clear indication of the existing the nuclei with abnormally large sizes.

The present work reviews the properties and futures of the modern methods (particularly, the methods which have been developed at JINR, Dubna [2–5]) which allow carry out a direct and model-independent σ_R measuring.

In the past years, the application of the modified transmission method or so-called "multilayer telescope" enabled to make a considerable progress in the experiments where total reaction cross sections have been measured [2,3]. The "multilayer telescope" method is based on the direct counting of the number of particles I_0 hitting the target and the number of the reaction events ΔI_R. One should note that this method is based on "event-by-event" counting and has high precision and effectiveness for low intensity secondary beams. The ΔI_R events are mostly separated by target energy loss value dE_{TARG}; it turned out that this method had some limitations caused both by the technology of manufacturing of telescope detectors (choice of target nuclei is limited by elements Si, Ge and C, limited thickness and detector counting response, etc.) and by principal one of the main disadvantages of the method: inability to separate elastic and inelastic scattering channels in the backward hemisphere, etc. These limitations can be easy removed by using a multilayer telescope in combination with a 4π-geometry n-γ spectrometer [4,5]. This experimental method was based on detection of the prompt neutrons and γ-quanta by 4π-technique applied in event-by event mode. A high efficiency γ-spectrometer has to be used for the γ-ray detection to minimize γ-multiplicity dependence.

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STUDY OF THE pd- AND dd- REACTION MECHANISMS IN THE DEUTERIDES OF METALS IN ASTROPHYSICAL ENERGY REGION

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Investigation of the pd- and dd-reactions in the ultralow energy (~keV) range is of great interest in the aspect of nuclear physics and astrophysics for developing of correct models of burning and evolution of stars. This report presents compendium of experimental results obtained at the pulsed plasma Hall accelerator (TPU, Tomsk). Most of those results are new, such as:

- temperature dependence of the neutron yield in the $D(d,n)^3He$ reaction in the ZrD_2, Ta_2D TiD_2;
- potentials of electron screening and respective dependence of astrophysical *S*-factors in the dd-reaction for the deuteron collision energy in the range of 3÷6 keV, with ZrD_2, Ta_2D temperature in the range of 20 ÷ 200 °C [1];
- characteristics of the reaction $d(p,\gamma)^3He$ in the ultralow collision proton-deuterons energy range of 4÷13 keV [2, 3] in ZrD_2, Ta_2D and TiD_2;
- observation of the neutron yield enhancement in the reaction $D(d, n)^3He$ at the ultralow deuteron collision energy due to channeling of deuterons in microscopic TiD_2 with a face-centered cubic lattice type $TiD_{1.73}$, oriented in the [100] direction [4].

The report includes discussion and comparison of the collected experimental results with the global data and calculations. We discuss an agenda of further planned research of the reactions between light nuclei at astrophysical energy range.

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ANGULAR CORRELATIONS IN ^{27}Al(p,$\alpha_1\gamma$)^{24}Mg REACTION AT E_p = 7.4 MeV

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Double-differential cross sections of the reaction ^{27}Al(p, $\alpha_1\gamma$)^{24}Mg at E_p = 7.4 MeV were measured for the front hemisphere of the alpha emission angles on the SINP MSU 120-cm cyclotron. The angular correlation functions $W(\theta_\gamma, \varphi_\gamma; \theta_\alpha)$ (ACF) were carried out on a three planes φ_γ of γ-rays registration that allowed to restore all density matrix spin-tensor even components of the final nucleus ^{24}Mg(2^+, 1.37 MeV) for each angle θ_α.

Else the cross section of the ^{27}Al(p, α)^{24}Mg reaction for the formation of the ^{24}Mg nucleus ground and first excited states were measured in the α-particles angle range from 25° to 160° (lab.).

Experimental data were compared with theoretical results, obtained for the compound nucleus statistical mechanism (CNSM) (cod CNDENSY [1]) and for the triton cluster pickup mechanism by the coupled-channel method (FRESCO and CHUCK codes [2, 3]). The spectroscopic factor amplitudes of vertex ^{27}Al $\rightarrow$^{24}Mg + t were calculated in the 1*d*–2*s*-shell model with the nucleus wave functions in the Nilsson model, which takes into account the deformation of the nucleus and the spin-orbit interaction of nucleons [4].

The comparison of experimental and calculated ACF for the CNSM shows that the calculation qualitatively describes the experimental ACF, but the latter has stronger depend on the angle θ_γ than estimated. The account of the pickup mechanism improves the agreement, but shows a strong dependence of the results on the choice of optical potential parameters in the output channel.

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DOUBLE DIFFERENTIAL AND INTEGRAL CROSS-SECTIONS OF (p,*x*p) AND (p,*x*α) REACTIONS ON Co NUCLEUS AT E_p = 30 MeV

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The role of new nuclear-physics experiments in the creation of nuclear databases and development of theoretical models in accordance with modern approaches is key in both fundamental and applied researches related in particular to the development of electro-nuclear plants (Accelerator Driven System, ADS) for the nuclear transmutation of long-lived radioactive nuclear waste and energy production [1]. Correct simulation of the neutron flux requires data on the spectral composition and angular distributions of secondary protons and light charged particles that result from the quenching of the primary beam in a target in the incident proton energy range of several to tens and even hundreds of MeV.

The experiment with the protons, accelerated to energy of 30 MeV was performed at the isochronous cyclotron of Institute of Nuclear Physics (Almaty, Republic of Kazakhstan).The double-differential cross-sections of (p,*x*p) and (p,*x*α) reactions on ^{59}Co nucleus were measured in angular range 30–135° with the step 15°. The reaction products were detected and identified by a two detector telescope consisting of a thin detector and a total absorption detector. The spectrometers were calibrated in energy using the kinematics of the states of residual nuclei in the ^{12}C(p,x) reaction and recoil protons.

The experimental data have been analyzed within the framework of the phenomenological exciton model of preequilibrium decay [2,3] and microscopic theory of the multi-step direct and multi-step compound processes [4]. A satisfactory agreement between experimental and calculated values has been achieved. The contribution of the preequilibrium mechanism to the (p,*x*p) reaction dominates and that is in agreement for both the exciton model and the quantum-mechanical theory calculations.

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SPECTRA OF LIGHT PARTICLIES FROM INTERACTION OF 50.5 MeV ^{3}He IONS WITH ^{27}Al

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New experimental nuclear data on the double differential and integral cross sections of reactions initiated by stable isotopes of helium is essential for researches in fields of nuclear physics, nuclear energy, radiation safety of the nuclear industry, new nuclear technologies such as Accelerator Driven System (ADS). Of particular interest is the measurement of the inclusive spectra of the reactions induced by ^{3}He ions. Experimental information about these reactions is extremely small.

The experiment with the ions of ^{3}He, accelerated to energy of 50.5 MeV was performed at the isochronous cyclotron of Institute of Nuclear Physics (Almaty, Republic of Kazakhstan). Self-supporting foil of ^{27}Al with 3.65 mg/cm^2 thickness was used as the target. The reaction products were registered by ΔE-E telescope. The double-differential cross sections of the reactions were measured in the angular range 30–150° with angle increments of 15°. The energy distributions integrated over angle were determined on the base of these experimental results.

The analysis of experimental cross-sections of reactions is carried out in accordance with exciton model [2, 3] for pre-equilibrium nuclear reactions that describes the emission of particles from an equilibrating composite nucleus. Additional components are calculated semi-empirically to account for direct nucleon transfer reactions and direct knockout processes involving cluster degrees of freedom. A satisfactory agreement between experimental and calculated values has been achieved.

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ANALYSIS OF NEPTUNIUM AND PLUTONIUM TRACER CROSS SECTIONS IN THE p AND ^{3}He INDUCED REACTIONS

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The proton and ^{3}He induced reactions with ^{235,236,238}U and ^{237}Np are promising tool for production of neutron-deficient heavy nuclides which are particularly great of interest as tracers in the environmental studies. The excitation functions for ^{234,236,237}Pu and ^{234,235,236m}Np nuclides have been earlier obtained [1, 2]. The experimental data were analyzed in the framework of the theoretical model with inclusion pre-equilibrium processes and the nuclear friction in fission channel [3]. The direct reaction contributions were also estimated.

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THE USE OF $d(d,n)^3He$ REACTION AS A TOOL FOR NEUTRON DETECTORS EXAMINATION

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The response of various hydrogen-containing scintillators irradiated by neutrons was investigated. The monoenergetic neutrons were obtained in the $d(d,n)^3He$ reaction using different angular configurations of experiment with coincidental registration of neutron and ^3He. In the experiment, the target of deuterated polyethylene was irradiated by deuteron beam with energy of 15 MeV at U-120 accelerator of Skobel'tsyn Institute of Nuclear Physics, MSU. Changing the angles of neutron and ^3He detection allowed us to obtain the spectral light response of various neutron detectors on monoenergetic neutrons in the energy range of 6–14 MeV. We obtain also the values of the neutron detection efficiency for different detectors in this energy range.

SETUP FOR STUDYING pp-CORRELATION EFECTS IN d + ^{2}H→(nn)+(pp) AND ^{3}He+^{2}H→^{3}H+(pp) REACTIONS

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Existence of a diproton as quasi-bound state of pp-pair inside the proton-rich nucleus is considered in many works on diproton radioactivity (see, for example, [1]). In [2] it was proposed that even in ^{3}He-nucleus (p+p+n system) the additional correlation of two protons in the neutron field leads to an effective "weakly bound pp-state". Therefore, we can assume that if the neutron will be quickly removed from ^{3}He, the observed character of momentum distributions of "remaining" pp-pair will be not changed, and it is expected that the measured pp-correlations, in particular the energy of quasibound state, will differ from that which is inherent to the free pp-system.

We propose to investigate the effects of *pp*-correlation in different reactions with two protons in the final state: d+^{2}H→(pp)+(nn) and ^{3}He+^{2}H→^{3}H+(pp). To perform these measurements, an experimental setup with possibility to simultaneously detect two protons from the breakup of a quasi-bound state and the third particle (neutron or ^{3}H, respectively) was created.

To register two protons at small opening angles (determined by the energy of quasi-bound state, being very close to the breakup threshold) we use a detector consisting of a matrix (4x4) of 2*2*10 mm^3 LYSO scintillators mounted at the surface of MAPD-3N photodiodes. Energy and timing characteristics of all detectors were investigated. Test measurement of the reaction d+^{2}H→(pp)+(nn) with registration of two protons and a neutron was performed.

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STUDY OF THE $d(^4He,\gamma)^6Li$ REACTION AT ULTRALOW COLLISION ENERGY REGION

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The problem of the cosmological lithium exists more than 20 years. Abundances of nuclei ^6Li and ^7Li which are defined by means of observational astronomy do not converge with the predictions of Big Bang Nucleosynthesis (BBN) model by orders of magnitude [1]. Only in 2014 a direct information about the reaction cross-section of $d(^4He,\gamma)^6Li$ ($\sim 10^{-35}$ cm^2) in the cosmological area of energy (94 keV) appeared, which confirmed the status of the problem [2]. In the present experiment, we assume to measure the reaction cross-section of $d(^4He,\gamma)^6Li$ in the energy range of 20÷35 keV in the laboratory coordinate system.

The pulse plasma accelerator of ions (TPU) and highly effective facility for registration of γ-rays are used for measurements [3]. Preliminarily, the background conditions arising when the studying of reaction of $d(^4He,\gamma)^6Li$ were researched. As a result it was shown that it is possible to optimize background conditions by refusal of using in the target chamber and around it: lead, brass, copper, stainless steel, hydrogenous materials.

Research of reaction is begun at ion energy of ^4He is equal to $E_\alpha = 31$ keV in the laboratory coordinate system. During the experiment through the target of deuterated titanium TiD2 (texture [100]) $1.2 \cdot 10^{19}$ ions of ^4He passed. Abnormally high yield of γ-rays with energy of $E\gamma = 1.49$ MeV was found out, which gives a reaction cross-section assessment $\sigma \sim 10^{-35}$ cm^2 which is 5 orders of magnitude greater than the theoretical estimate. Such a large cross-section could solve a problem of the cosmological ^6Li. The direct method of measurement of a background was developed, assuming that abnormally high yield of γ-rays was caused with the background processes. Measurements are continuing and the results will be reported at the conference.

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ELASTIC AND INELASTIC SCATTERING OF DEUTERONS ON ^{7}Li NUCLEI AT 25 MeV ENERGY AND MECHANISM OF THE ^{7}Li(d,t)^{6}Li REACTION

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The differential cross sections for elastic and inelastic scattering with excitation of the 0.478 MeV (1/2^{-}) state of ^{7}Li as well as the cross sections of the ^{7}Li(d,t)^{6}Li reaction with transitions to the ground (1^{+}) and exited (E_x = 2.186 MeV, 3^{+}) state of ^{6}Li have been measured at the deuteron beam with the 25 MeV energy in the angular range 8^{o} – 169^{o} (Lab).

The experiment was performed at the U-150 isochronous Cyclotron of Institute of Nuclear Physics (Almaty, Kazakhstan).

The experimental angular distributions were analyzed in the framework of the coupled reaction channels (CRC) [1] with taking into account the exchange mechanism ^{7}Li(d,^{6}Li)t with α-particle transfer. It was shown that the channel coupling affects the triton emission cross sections only at angles greater than 40^{o}. In the main maximum of the angular distributions for the ^{7}Li(d,t)^{6}Li reaction, the CRC and DWBA give an equivalent description of the experimental data. It was established that the mechanism of the one-step neutron pick-up dominates at angles up to 40^{o} and the reaction occurs on the surface of a nucleus.

The values of spectroscopic factors for ^{7}Li → ^{6}Li + n and ^{7}Li → ^{6}Li* + n systems were obtained by comparison of the calculated angular distributions with experimental data. The results are close to the theoretical predictions [2].

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ELASTIC AND INELASTIC SCATTERING OF DEUTERONS FROM ^{11}B NUCLEI

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Angular distributions for the elastic and inelastic scattering of deuterons from ^{11}B were measured at isochronous cyclotron U-150 M INP RK. The extracted deuterons beam has been accelerated to energies 14.5 MeV and then directed to ^{11}B target of thickness ~ 398 μg/cm^2. The measurements were carried out in a vacuum volume of the special multi-purpose scattering chamber, which included two independent ΔE-E telescopes. Each telescope consisted of two silicon semiconductor detectors. The first telescope covered angular range of small angles up to 20º, whereas the second telescope covered angular range of 20º–150º in laboratory system.

Angular distributions for elastic scattering and for inelastic scattering leading to 2.125 MeV $J^\pi = 5/2^-$, 4.445 MeV $J^\pi = 5/2^-$ states were obtained within angular range of 10º–150º in laboratory system. The behavior of differential cross sections for these states has noticeable diffraction pattern. The experimental results for elastic scattering were analyzed within the framework optical model. The theoretical calculations for the abovementioned excited states were performed using the coupled channel method implemented in computer code FRESCO [2].

In addition to our experimental data for d+^{11}B scattering at energy 14.5 MeV, we also analyzed the experimental data for this nuclear system at other energies 13.6 MeV [3] and 27.2 MeV [4].

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STUDY OF INTERNAL STRUCTURE OF Be AND B ISOTOPES IN ^{3,4}He + ^{9}Be REACTIONS

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A study of inelastic scattering and single-particle transfer reactions was performed by α and ^{3}He beams on a ^{9}Be target at energy about 50 MeV.

Angular distributions of the differential cross sections for the ^{9}Be(α,α)^{9}Be*, ^{9}Be(α,^{3}He)^{10}Be, ^{9}Be(α,t)^{10}B, ^{9}Be(^{3}He,^{6}Li)^{6}Li and ^{9}Be(^{3}He, ^{6}Be)^{6}He reactions were measured and compared with the previous data [1, 2]. Experimental angular distributions of the differential cross sections for the ground state and a few low-lying states were analyzed in the framework of the optical model, coupled channels and distorted-wave Born approximation. The comparison of the angular distributions of the differential cross sections for the isobaric analog states of ^{10}Be and ^{10}B was done (Fig. 1). The information on the cluster structure of the reaction products are obtained. The value $9/2^{-}$ was assigned to the spin and parity of the 11.28 MeV state in ^{9}Be. An analysis of the obtained spectroscopic factors was performed.

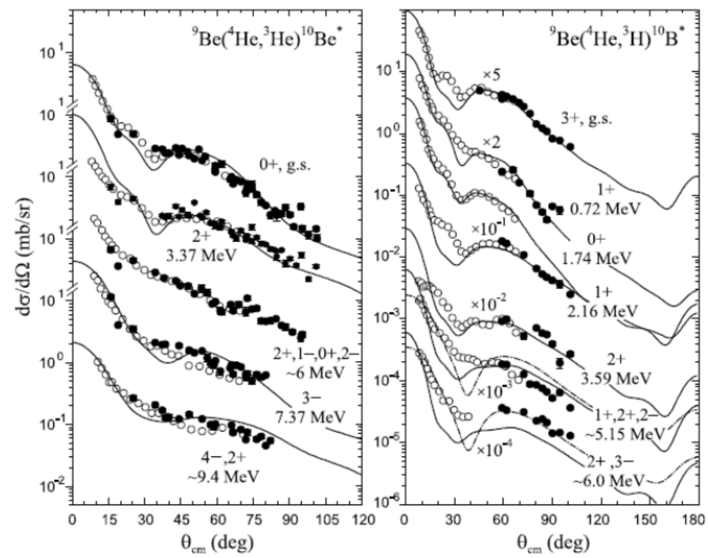

Fig. 1. Angular distributions of the differential cross sections for the isobaric analog states of ^{10}Be and ^{10}B.

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EXPERIMENTAL AND THEORETICAL INVESTIGATION OF SCATTERING OF ALPHA PARTICLES FROM ^{13}C NUCLEI

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^{13}C is a good example of a “normal” nucleus well described by the shell model. Its level scheme is reliably determined up to the excitation energies ~ 10 MeV. In the earlier work [1] the results of experimental and theoretical studies for the elastic and inelastic scattering of α-particles from ^{13}C target nuclei in a wide energy range, including the new experimental data obtained from the cyclotron JYFL Jyvaskyla (Finland) at energy 65 MeV are presented. Theoretical analysis of the angular distributions for $\alpha+^{13}C$ inelastic scattering:$1/2^-$ (8.86 MeV) and $1/2^+$ (3.09 MeV) ^{13}C excited states performed in the framework of the distortedwave method and the modified diffraction pattern showed a significant increase in the radius for these excited states in comparison with the value obtained for the ground state. In the current work we continue the investigation of the nature of ^{13}C excited states at low energies.

The experiment of the scattering α-particles on ^{13}C was carried out at the isochronous cyclotron U-150M in Institute of Nuclear Physics (Almaty, Kazakhstan) at energy E_α=29 MeV. Sets of ΔE-E telescopes for detection of the α-particles were used in the experiments.

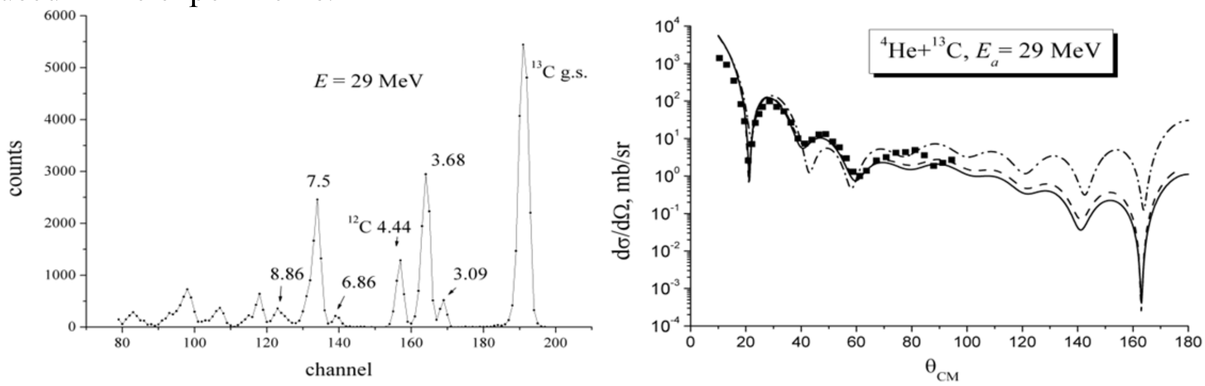

Fig. 1. Left: A sample spectrum (θ =32°) for the $\alpha+^{13}C$ scattering at E(α) = 29 MeV. Right: Differential cross sections for elastic scattering of α particles on ^{13}C at energies E = 29 MeV. Solid and dashed lines are the calculations within the framework of optical model, dash-dotted line is calculations using double folding model.

In addition to our experimental data at E_{lab}=29 MeV, $\alpha+^{13}C$ elastic scattering was analyzed at different energies from literature; 65 MeV [1], 54.1 and 48.7 MeV, 35 MeV and 26.6 MeV. The comparison between the experimental data and the theoretical predictions is fairly good overall the whole angular range.

Analysis of data on inelastic scattering (excited states of 3.09 and 8.86 MeV) is planned to done with the use of the obtained parameters of optical potentials in the following papers.

1. A.S.Demyanova *et al.* // Int. Nucl. Phys. Conf. INPC2013: Firenze. Italy. NS 051.

INVESTIGATION OF SCATTERING PROCESSES OF HELIUM IONS ON ^{28}Si NUCLEUS AT 50–60 MeV

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The study of elastic and inelastic processes of particles and nuclei with nuclei interaction remains one of the priority areas of nuclear physics, since they provide the information on structural characteristics of nuclei and the mechanisms of colliding systems interaction. The main task is to determine the effective potential of nucleus-nuclear interactions, the knowledge of which is required to understand the nature of nuclear transformations involving the particles of different types in the input and output channels of the reaction.

The differential cross-sections of elastic and inelastic scattering of ^{3}He and ^{4}He ions with E = 50 – 60 MeV on ^{28}Si nucleus in angular range of 11–170º were measured on the U-150M Kazakh isochronous cyclotron.

The analysis of cross-sections of elastically scattered helium ions on studied nucleus was performed using standard optical model (code SPI-GENOA [1]) with Woods-Saxon potential of separated form-factors of real and imaginary parts. The optimal values of inter-nuclear interaction potentials are obtained. As a criterion for matching the results of theoretical calculations with experimental data the minimization of the χ^2 values and the values of the volume integrals of the real part of the optical potential were used.

Analysis of cross sections of inelastic scattered helium ions on ^{28}Si nucleus was carried out using the distorted wave Born approximation (by code DWUCK4 [2]) with form-factor of a macroscopic collective excitation using optimal optical potential parameters obtained from elastic scattering.

One of the ways to improve the method for analysis of experimental data on inelastic scattering is the generalized optical model or the method of coupled channels. The calculations of the angular distributions of elastic and inelastic-scattered helium ions were performed using the rotary approximation within the framework of the ECIS-88 code [3].

The work was supported by the Program of Grant funding of scientific researches under Ministry of Education and Science of Republic of Kazakhstan - Grant 0335/GF4.

1. F.G.Perey // NBI version. 1976.
2. P.D.Kunz // University of Colorado, Boulder, USA (unpublished).
3. J.Raynal. ECIS-88 (unpublished).

TOTAL REACTION CROSS SECTIONS FOR ^{6,8}He AND ^{8,9}Li NUCLEI AT ENERGIES of (25–45) *A* MeV ON ^{nat}Al AND ^{nat}Pb

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Preliminary results of measurements of the total reaction cross sections (σ_r) for weakly-bound ^{6,8}He and ^{8,9}Li nuclei at energies in the interval (25-45) *A* MeV on ^{27}Al (small isospin) and ^{208}Pb (high isospin) targets (reaction targets) are presented. A secondary beams of ^{6,8}He and ^{8,9}Li were produced by bombardment of the ^{11}B (33 *A* MeV) primary beam on Be (89 mg/cm^2) target and separated by COMBAS fragment-separator [1]. In dispersive focal plane a horizontal slit defined the momentum acceptance as 1% and a wedge degrader of 200 μm Al was installed. The *B*ρ of a second section of fragment-separator (after *F* dispersive focal plane) was adjusted for measurements in energy range 25–45 *A* MeV. The position of secondary beams at the reaction targets (^{27}Al and ^{208}Pb) was determined by parallel-plate avalanche counters and diaphragm (Ø15 mm). After the reaction targets the scattered particles were detected by two Si Δ*E* detectors 300 μm (32 *X*-stripes, 64×64 mm^2) and 1000μm (32 *Y*-stripes, 64x64 mm^2) and *E*-detector from scintillation CsI/Tl wall (64×64 mm^2), which consisted of nine CsI/Tl granules.

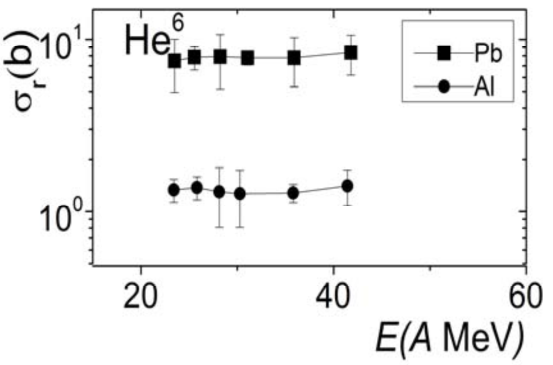

Fig. 1 Total reaction cross sections for He^6.

Also 2*n*-removal cross sections σ_{-2n} of ^{4,6}He and ^{7,8,9}Li on Si, were determined. As example measured ^{6}He total cross sections as a function of energy for Al target (circles) and Pb target (squares) is shown in Fig. 1.

1. A.G.Artukh *et al.* // Instruments and Experimental Techniques. 2011. V.54. P.668.

SOURCE VELOCITY AT RELATIVISTIC BEAMS OF ^{4}He

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Multifragmentation of Au nuclei induced by 4–14.6 GeV ^{4}He has been studied with the 4π setup FASA of Dubna Nuclotron.

To check whether break-up of the emitting system is close to thermal equilibrium, the plot of the fragment invariant probability distribution in terms of the longitudinal versus transversal velocity components were analyzed. Source velocities ($\beta = v/c$) extracted from rapidity plots is presented in Fig. 1. The mean values of source velocity are close to estimates with the INC [1] + SMM [2] model for ^{4}He(14.6 GeV) + Au.

It was found transition from broad range source velocity (Fig. 1) distribution in case of ^{4}He(4 GeV + Au) to fixed source velocity in case of ^{4}He(14.6 GeV + Au).

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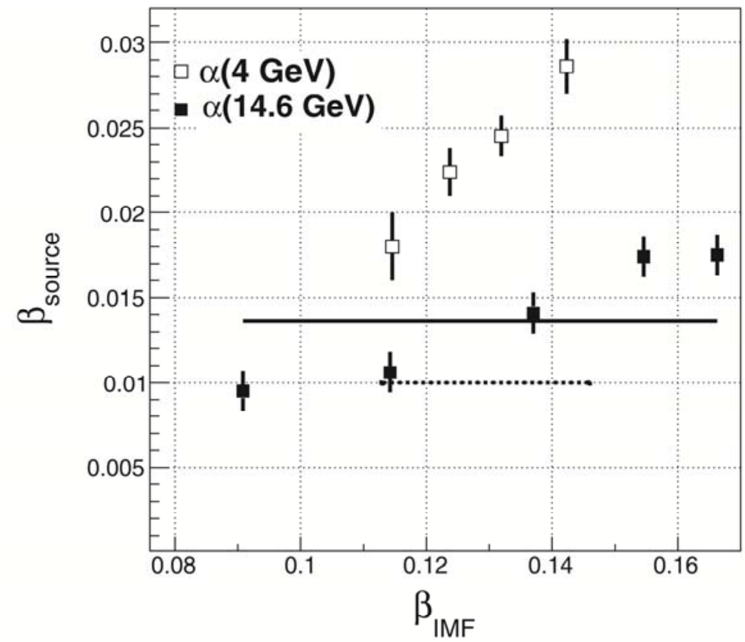

Fig. 1. Source velocity as a function of IMF velocity. Symbols – experiment. Lines – INC+SMM calculations (Solid line – 14.6 GeV, doted line – 4 GeV).

1. V.D.Toneev *et al.* // Nucl. Phys. A. 1990. V.519. P.463.
2. J.Bondorf *et al.* // Phys. Rep. 1995. V.257. P.133.

COLLECTIVE EFFECTS IN SMALL QCD SYSTEMS AT RHIC COLLIDER

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It has been established that strongly interacting quark-gluon plasma (sQGP) is created in heavy ion collisions at RHIC and LHC energies [1]. One of the most interesting features of this new state of matter is long-range angular correlations which are studied experimentally by measuring azimuthal anisotropy between particles well separated in rapidity [2]. In heavy ion collisions appearance of such correlations was attributed to collective flow that develops on the early partonic stage of the interaction. Recently evidence of the long range angular correlations has been observed at the LHC in high multiplicity p+p collisions at 7.0 TeV and p+Pb collisions at 5.02 TeV and then at RHIC in d+Au and ^{3}He+Au collisions at 200 GeV. These observations raise doubts about the paradigm that such collisions are only suitable for studying of the cold nuclear effects not associated with formation of the hot and dense matter.

In this talk, we present the most recent PHENIX results for d+Au and ^{3}He+Au collisions at 200 GeV. Obtained results are compared to model predictions; implications for collective effects in small systems are discussed.

1. K.Adcox *et al.* // Nucl. Phys. A. 2005. V.757. P.184.
2. S.Huang // Nucl. Phys. A. 2014. V.932. P.342.

PARTICLE PRODUCTION IN Cu+Au AND U+U COLLISIONS IN PHENIX EXPERIMENT AT RHIC

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The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Lab allows nuclear matter to be studied at extremely high temperatures and energy densities [1]. RHIC is uniquely capable of colliding asymmetric Cu+Au nuclei and irregularly shaped nuclei such as U+U, providing the possibility to produce systems that have different initial energy density profiles for the same number of participating nucleons. This allows for systematic investigation of the effects of initial geometry and density on particle production. For example, in U+U collisions the slightly elongated nuclei overlap in a variety of different ways such that, even at zero impact parameter, distinct configurations exist. In central Cu+Au collisions the Cu nucleus is completely embedded within the Au. Such geometries present an opportunity to measure the wide range of initial energy densities of these systems. They also allow the study of some unique features arising from these configurations [2].

In this talk we will present the results on particle production from Cu+Au and U+U datasets in PHENIX such as global particle production and elliptic flow variables.

1. A.Adare *et al.* // Phys. Rev. Lett. 2008. V.101. 232301.
2. R.Hollis // J. Phys.: Conf. Ser. 2013. V.458. 012007.

STUDY OF COHERENT DISSOCIATION OF ^{10}C NUCLEUS AT ENERGY 1.2 GeV PER NUCLEON

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The charge topology in the fragmentation of ^{10}C nuclei in a track nuclear emulsion at energy of 1.2 GeV per nucleon is studied [1]. In the coherent dissociation of ^{10}C nuclei, about 82% of events are associated with the channel $^{10}C \rightarrow 2\alpha + 2p$ [2]. The angular distributions and correlations of product fragments are presented for this channel. It is found that among $^{10}C \rightarrow 2\alpha + 2p$ events, about 30% are associated with the process in which dissociation through the ground state of the unstable $^9B_{g.s.}$ nucleus is followed by $^8Be_{g.s.}$ + p decays.

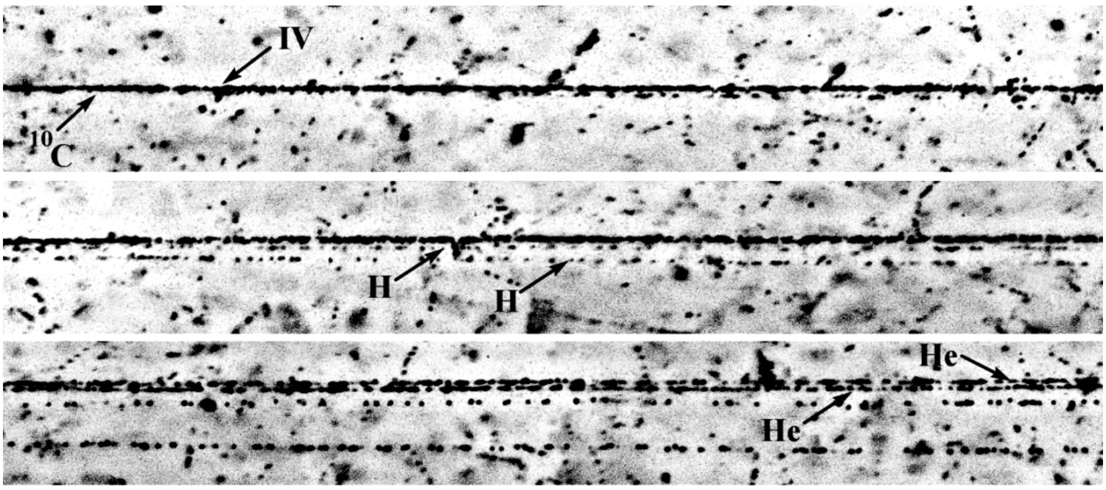

Fig. 1. Successive microphotographs of an event involving the dissociation of ^{10}C nucleus at energy of 1.2 GeV per nucleon. The arrows indicate the track of a beam ^{10}C nucleus, an interaction vertex (IV; at the top), and tracks of H and He fragments.

1. The BECQUEREL Project. http://becquerel.jinr.ru/
2. R.R.Kattabekov, K.Z.Mamatkulov *et al.* // Phys. At. Nucl. 2010. V.73. P.2110.

TEMPERATURE PARAMETERS FOR CARBON FRAGMENTATION AT 0.6 GeV/N

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Momentum distributions of nuclear fragments from ^{12}C fragmentation on a Be target were measured at 3.5^{o} in the FRAGM experiment [1] at the ITEP TWA heavy ion accelerator. The fragments were selected by correlated time of flight and dE/dx measurements with a magnetic spectrometer with scintillation counters. The main attention was drawn to the high momentum region where the fragment velocity exceeds the velocity of the projectile nucleus. At energy 0.6 GeV/nucleon the momentum spectra of fragments span the region of the fragmentation peak as well as the cumulative region. The differential cross sections cover three-six orders of magnitude depending on the fragment. The shapes of the momentum spectra are compared to the predictions of four ion-ion interaction models: INCL++, LAQGSM03.03, QMD and BC. The kinetic energy spectra of the fragments in the projectile rest frame are fitted with the sum of two exponents with different slope parameters. The temperatures of the source extracted from the slope parameters are 5–8 MeV for a soft component and 15–30 MeV for a hard component. For each fragment the temperatures are compared with the predictions of the above mentioned models as well as with those measured at 1 GeV/nucleon in Au+Au interactions [2]. A dependence of these temperatures on the fragment type is discussed.

1. B.M.Abramov *et al*. // JETP Lett. 2013. V.97. P.439; Kulikov *et al*. // POS 2015. Baldin ISHEPP XXII. P.079.
2. T.Odeh *et al*. // Phys. Rev. Lett. 2000. V.84. P.4557.

SPALLATION REACTIONS ^{197}Au (^{11}B, *X*n *Y*p) AT ENERGY 24 MeV/N

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Spallation reactions were measured on ^{11}B beam (Dubna, Russia U-400M accelerator cyclotron) at incident energy 24 MeV/*N* in ^{197}Au. The target stacks method was used for energy distribution over the energy range from 264~137 MeV. The presented data are the isobaric residual distributions in mass region near target mass number 205–188 u, produced in complete and incomplete fusion with ^{11}B and with different parts produced in the decay throw projectile inelastic scattering ($^{11}B \rightarrow {}^{7}Li + \alpha$; $2\alpha + {}^{3}He$) in the target Coulomb or nuclear field. The thresholds of these break up reactions are high enough in comparison with weekly bound nuclei, but taking into account the energy of the incident ^{11}B beam and the *Q* value of α-particle separation equal to 8.664 MeV we suppose that ^{11}B is stable but weekly decaying nucleus [1]. The mass distributions of the reaction products in different Au-plates were compared with PACE-4 calculation. This model, presented evaporation code, considers the complete fusion only without other type interaction as projectile break up and transfer processes. The disagreements calculated and experimental data can be related to contribution of the incomplete fusion not considered in frames of model. In Fig. 1 (a, b) are shown experimental and calculated data at two extreme energy values 234.64±3.5MeV and 137.5±4 MeV. The presented data are shown that heavy reaction products from ^{11}B+^{197}Au reactions at both energies include substantial components from incomplete fusion as well as complete fusion. At high energies the incomplete fusion differs the mass yield distribution more essentially. The similar conclusion was made within framework at break up fusion model with other kind projectiles near and above Coulomb barrier [2].

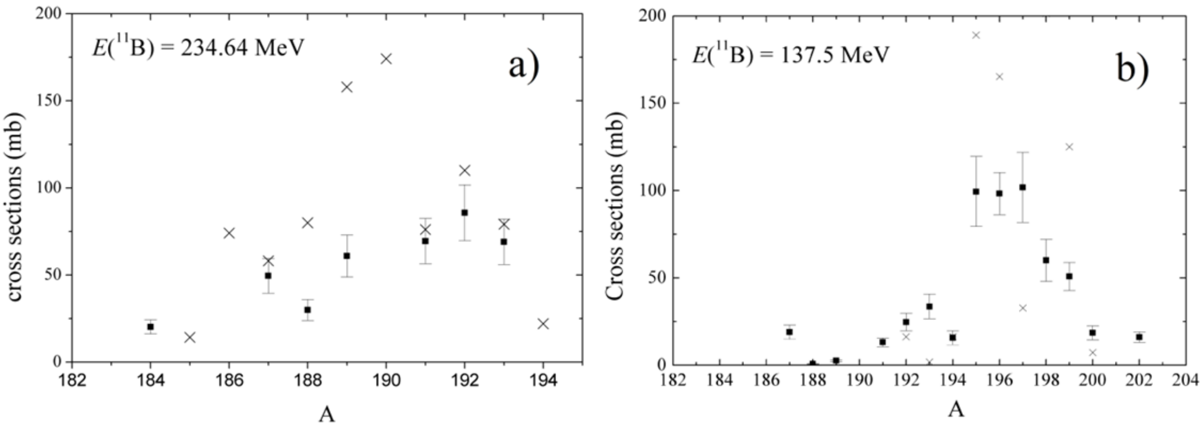

Fig. 1.

1. L.R.Gasques, D.J.Hinde *et al.* // Phys. Rev. C. 2009. V.79. 034605.
2. D.P.Singh *et al.* // Phys. Rev. C. 2009. V.80. 014601.

MULTINUCLEON TRANSFER REACTIONS IN ^{18}O+Ta

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Alternative method for the production of the exotic nuclei is the multinucleon transfer. Multinucleon transfer reactions occurring in low-energy collisions of heavy ions are currently considered to comprise the most promising method for the production of new heavy neutron-rich nuclei, which could be not obtainable by other reaction mechanisms.

The aim of this study is a measuring of production cross section in the case of the ^{18}O projectile. In order to use opportunity of utilizing of secondary beams, knowledge of the relevant production cross sections is essential. The experiments with ^{18}O beams of energies E = 15 MeV/A were carried out at the U400 cyclotron of the Flerov Laboratory of Nuclear Reactions (JINR) using the high resolution magnetic separator MSP-144. During the experiment, identification of products were determined by measuring of energy loss ΔE and residual energy E_r delivering by the Si-Si(Li) telescope, located in external focal plane of the MSP-144 spectrometer.

The experimental differential cross sections for producing oxygen isotopes was analyzed as a function of Q_{gg} for different target-projectile combinations at various projectile energies. Making use of the Q_{gg} systematics, it was possible to estimate the yields of nuclei lying far from the stability line. We estimated the differential production cross section for ^{24}O by linear regression of the Q_{gg} systematics. The obtained value is much less than predicted in [1]. The reaction channels ($-x$p, $\pm$ nx) are preferable comparing with pure neutron pick-up channel. Additionally, the production cross sections in the reaction ^{18}O+Ta are compared with the reaction ^{22}Ne+Ta, leading to the production of neutron rich oxygen isotopes. The use of a beam of ^{22}Ne gives larger value of cross section for the O isotopes due to higher probabilty of the ($-x$p, $\pm$ nx) channels.

1. V.I.Zagrebaev *et al.* // Phys. Rev. C. 2014. V.89. 054608.

TENSOR ANALYSING POWER COMPONENTS OF THE NEGATIVE PION PHOTOPRODUCTION ON DEUTERON

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The results of simultaneous measurements of T_{20}, T_{21}, and T_{22} components of the tensor analyzing power are shown for the exclusive negative pion photoproduction on deuteron, provided at the energy range 250–750 MeV [1]. The experiment was performed using internal polarized deuterium target at the VEPP-3 electron storage ring with coincidence final proton registration.

We compare the obtained dependencies with the theoretical predictions have been made within the framework of the spectator model and the impulse approximation with FSI. It follows from this comparison that for pion photoproduction at large proton momenta, it is required to take into account in addition to πN and NN interactions, more complicated mechanisms of reaction, in particular, ΔN interaction in the intermediate states.

This work was supported by the Russian Foundation for Basic Research (grant № 15-02-00570-a).

1. V.V.Gauzshtein *et al*. // Physics of Atomic Nuclei. 2015. V.78. N.1. P.1.

NEGATIVE PION PHOTOPRODUCTION ON A DEUTERON BY QUASI-REAL PHOTONS AT LARGE PROTON MOMENTA

Dmitriev V.F.[1], Dusaev R.R.[2], Gauzshtein V.V.[2], Loginov A.Yu.[2], Nikolenko D.M.[1], Rachek I.A.[1], Stibunov V.N.[2], Shestakov Yu.V.[1], Toporkov D.K.[1], Zevakov S.A.[1]

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Experimental differential cross sections of photoproduction of negative pions on a deuteron have been obtained. A special feature of the experiment reported here is the detection of both proton in the final state of the reaction, and with large values of the momenta. The experiment was performed on an internal target of the VEPP-3 electron storage ring. In the approximation of zero scattering angles of the electrons, we investigate the reaction of photoproduction of π^- mesons by quasi-real photons. Coincidence detection of two protons with large momenta suppresses the mechanism of quasi-free photoproduction by increasing the relative contribution of more complex reaction mechanisms. The kinematics of pion photoproduction on a deuteron is fully reconstructed from the measured energies and proton emission angles. The calculated photon energies are in the range 300 – 1200 MeV. The theoretical model [1] lying at the basis of the generation of events takes into account the contribution of the diagrams of the impulse approximation and the diagram of pion-nucleon and nucleon-nucleon rescattering. The satisfactory agreement of the experimental data with the theoretical predictions arrived within the traditional framework of the impulse approximation with πN and NN rescattering speaks about the fact that the contributions of all the most important resonances from second resonance region are taken into account in the elementary amplitude of pion photoproduction on a nucleon.

This work was supported by the Russian Foundation for Basic Research (grant № 15-02-00570-a).

1. A.Yu.Loginov *et al.* // Yad. Fiz. 2000. V.63. №1. P.478.

CROSS SECTIONS OF THE REACTIONS $^{14}N(\gamma,2n)^{12}N$, $^{14}N(\gamma,2p)^{12}B$, $^{13}C(\gamma,p)^{12}B$

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The reactions $^{14}N(\gamma,2n)^{12}N$, $^{14}N(\gamma,2p)^{12}B$, $^{13}C(\gamma,p)^{12}B$ are used in photonuclear method under development for detection of hidden explosives (see, e.g., [1]). The cross sections of these reactions determine feasibility, sensitivity and reliability of the method. We compiled existing experimental data and results of model calculations of these cross section as from literature as fulfilled by us using the codes TALYS [2] and EMPIRE [3] and analyzed all these data.

For the reaction $^{13}C(\gamma,p)^{12}B$ there are the experimental cross sections from three independent experiments with acceptable for a case level of agreement between them. But there are the only experimental results for each of the reactions $^{14}N(\gamma,2n)^{12}N$ and $^{14}N(\gamma,2p)^{12}B$ which were obtained at high levels of background and with rather pure accuracies and not for the cross sections themselves but for integral values, connected with these cross sections.

The codes for modeling nuclear reactions were developed in time and now at least for TALYS and EMPIRE the model cross sections for all three reactions are in agreement with each others but they are lower than corresponding experimental ones on about one order of magnitude. It is interesting, that in recently published work [4] from CERN it was pointed out on similar underestimations of model cross sections obtained with the codes TALYS and EMPIRE.

We concluded that there is strong necessity to make new measurements of the cross sections for $^{14}N(\gamma,2n)^{12}N$- and $^{14}N(\gamma,2p)^{12}B$- reactions. That is why we took serious attention to analysis of the details of used earlier experimental techniques.

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2. TALYS-1.6. http://www.talys.eu/.
3. M.Herman *et al.* EMPIRE–3.1 Rivoli. User's Manual. February 8, 2012.
4. P.Žugec *et al.* // Phys. Rev. C. 2014. V. 90. 021601.

POSSIBILITIES TO SEPARATE IVE1 & IVE2 GIANT RESONANCES BY FORWARD-TO-BACKWARD ASYMMETRIES MEASURED WITH NEUTRON THRESHOLD DETECTORS

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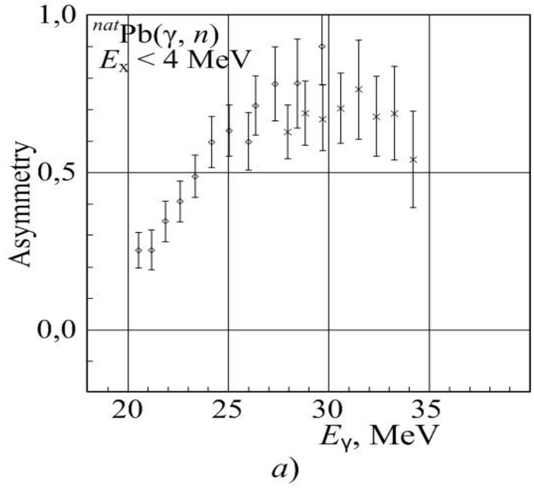
There are serious problems and connected with them contradictions of data at separation of the isovector electric quadrupole (IVE2) from the prevailing isovector electric dipole (IVE1) giant resonances (GR) (see, e.g., [1]). To solve these problems it is necessary to use some ways for enlarging relative contributions connected with IVE2 GR. In [1] there was used for it method based on measuring of the forward-to-backward asymmetry of fast neutron emission in (γ,n)-reactions $[(d\sigma/d\Omega)_\theta - (d\sigma/d\Omega)_{\pi-\theta}]/[(d\sigma/d\Omega)_\theta + (d\sigma/d\Omega)_{\pi-\theta}]$, where θ is an angle of fast neutron emission with respect to a direction of incident photons. In [1] there were used tagged bremsstrahlung photons and time-of-flight neutron spectrometers (see on Fig. (*a*) the values of this asymmetry obtained in [1] for lead in dependence on photon energies E_γ).

It is suggested here to use for these purposes high intensity total bremsstrahlung together with high efficiency neutron threshold detectors, based, e.g., on the reaction $^{16}O(n,p)^{16}N$ (see on Fig. (*b*) [2] its cross section in dependence on neutron energies E_n). Taking into account the thresholds of (γ,n)-reactions on lead (7–8 MeV) we may expect for electron energies >~ 40 MeV the analogous asymmetries of (γ,n)-reaction yields connected with IVE2 GR to be about tens of percents with better statistical uncertainty levels.



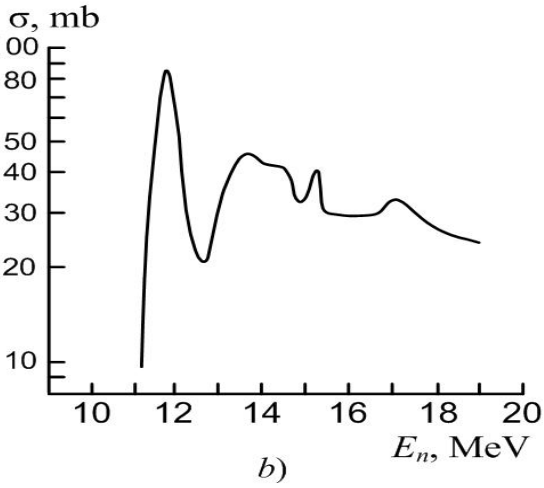


Fig. Forward-to-backward asymmetry in (γ, n)-reaction for lead [1] (a) and the cross section of the $^{16}O(n, p)^{16}N$ - reaction [2] (b).

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PARTIAL PHOTONEUTRON REACTION CROSS SECTIONS DATA FOR ^{63,65}Cu AND ^{80}Se RELIABILITY

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Experimental data on photodisintegration of a large number of medium and heavy nuclei (^{91,94,96}Zr, ^{115}In, $^{112–124}$Sn, ^{159}Tb, ^{181}Ta, ^{197}Au, ^{208}Pb) obtained primarily at Livermore (USA) and Saclay (France) using quasimonoenergetic annihilation photons and the neutron multiplicity sorting based on its energy measurement were analyzed in [1–3]. It was shown that many data under do not satisfy to proposed objective data reliability criteria: in various energy ranges of initial photons the ratios F_2 = σ(γ, 2n)/σ(γ, xn) = σ(γ, 2n)/σ[(γ, 1n) + 2(γ, 2n) + 3(γ, 3n) + …] have physically unreliable values larger 0.50 and at the same time ratios F_1 = σ(γ, 1n)/σ(γ, *x*n) have physically forbidden negative values. That means that experimental neutron multiplicity sorting has been done erroneously because of large systematic uncertainties. A very noticeable disagreements between experimental and physical criteria based cross section energy dependences were found out for ^{159}Tb, ^{116}Sn, ^{94}Zr, ^{65}Cu, ^{80}Se.

Therefore new data free of systematic uncertainties under discussion were evaluated for two isotopes ^{63,65}Cu [4] data obtained at Livermore and ^{80}Se [5] data obtained at Saclay. New experimentally–theoretical method [2] was used for evaluation: – σ^{eval}(γ, in) = $F^{theor}{}_{i} \cdot \sigma^{exp}$(γ, *x*n). It means that competition between partial reactions is in accordance with combined model of photonuclear reactions [6, 7] and their sum σ^{eval}(γ, *x*n) is equal to σ^{exp}(γ, *x*n) free from neutron multiplicity sorting problems mentioned above.

New cross sections were evaluated for (γ, 1n) and (γ, 2n) reactions for isotopes ^{63,65}Cu and ^{80}Se. Using evaluated partial reactions cross sections new data for total photoneutron reaction σ(γ, Sn) = σ[(γ, 1n) + (γ ,2n) + (γ, 3n) + …] were obtained also. Large deviations of evaluated partial reactions cross sections from experimental ones are discussed in details. It is shown that those deviations are the results of unreliable and erroneous redistribution of many neutrons between the channels with multiplicities “1” and “2”.

The work is partially supported by the RFBR Grant 13–02–00124.

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6. B.S.Ishkhanov *et al.* // Physics of Particles and Nuclei. 2007. V.38. P.232.
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SEARCHING FOR RARE TERNARY DECAYS USING "DOUBLE-HIT" APPROACH

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Studying of the new ternary decay channel in the low excited nuclei called "collinear cluster tri-partition (CCT)" proves to be very complicated methodical task [1, 2]. According to our experiments already performed the angular divergence of the CCT partners flying in the same direction does not exceed 1–2°. It means that the bulk of the ternary events are linked with pile-up signals in the "stop" PIN diodes of the mosaic used. Such events cannot be interpreted properly and must be rejected. Using of the fast flash-ADC let us to obtain the digital image of the current impulses from the two CCT partners hitting the same PIN-diode or timing detector during registration gate. Instead of rejection such pile-up "doublet" can be resolved off-line (”double-hit" technique). We discuss first results of applying this approach to investigation of the CCT channel in ^{252}Cf (sf). Typical pile-up event in the "stop" timing detector is shown in Fig. 1. The event is presumably caused by ternary decay of mother nucleus.

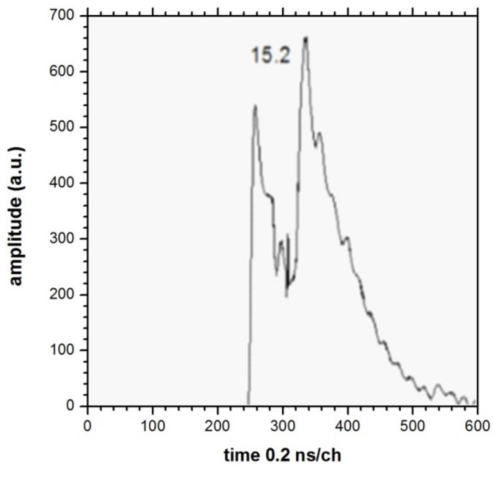

Fig. 1. Pile-up event in the "stop" timing detector. It is presumably connected with ternary almost collinear decay of ^{252}Cf (sf). Time delay between the signals does not exceed 15.2 ns.

1. Yu.V.Pyatkov *et al.* // Eur. Phys. J. A. 2012. V.48. P.94.
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PRIMARY PARTICLES IN STOPPED PION ABSORPTION REACTIONS

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Results on the investigation of spectra and yields of p, d, t formed in the reaction of stopped pion absorption by atomic nuclei are presented. The study is based on the experimental results obtained on the pion channel of PNPI synchrocyclotron using semiconductor spectrometer [1]. Unique data on charged particle formation after pion absorption on 17 isotopes have been obtained in wide mass range ($6 < A < 209$). The spectra have been measured in energy range from 10 MeV to the kinematic thresholds (~ 100 MeV).

Phenomenological model developed by us [2, 3] is used for data analysis and separation of different stages contributions: primary pion absorption on intranuclear clusters, preequilibrium processes (pick-up, knock-out, coalescence, scattering of primary particles) and evaporation. Contributions of these stages in yields are defined. It is shown that high-energy region is populated mostly with primary particles.

Assuming dominating role of two-particle absorption mechanisms we successfully describe A-dependence of primary proton yields (with 10–15% precision). This result allows us to estimate the ratio of the elementary absorption widths on the pp- and pn-pairs $R' = 3.3 \pm 0.5$ and to confirm its constancy in the wide range of mass numbers.

It is shown that pion absorption on more heavy clusters needs to be taken into account in order to explain the formation of compound primary particles.

1. M.G.Gornov *et al.* // Nucl. Inst. and Meth in Phys.Res. A. 2000. V.446. P.461.
2. L.Yu.Korotkova *et al.* // Bull. of RAS: Phys. 2012. V.76. P.446.
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STATUS OF νGeN EXPERIMENT AT THE KALININSKAYA NUCLEAR POWER PLANT FOR DETECTION COHERENT NEUTRINO Ge NUCLEUS ELASTIC SCATTERING

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Aim of νGeN project is observation of neutrino coherent scattering on Ge nuclei. In the project the scattering will be searched using unique low-threshold germanium detectors developed by JINR (Dubna) [1]. The detectors will be placed into low-background setup that will provide an energy threshold of ~300 eV. The existing possibility to perform the experiment at Kalininskaya Nuclear Power Plant (KNPP) provides us with the antineutrino flux greater than $5.4\cdot10^{13}$ $(cm^2\cdot sec)^{-1}$. This opens up a new unique possibility to perform the first experimental search of neutrino-nucleus coherent scattering within next 3-5 years. The sensitivity level is expected to be sufficient for observation of this process. Up to date the realization of the project is in the phase of experimental infrastructure creation and parts of the setup development as well as commissioning of the detectors. In particular, the systems of active shielding against cosmic rays (muon veto) and anticompton shielding based on 12 NaI(Tl) scintillators were designed and created. The analysis of low-threshold HPGe detectors (4 detectors 450 g each) characteristics were carried out in the deep underground low background laboratory (LSM, Modane, France) using infrastructure of the EDELWEISS experiment [2]. These low threshold point contact HPGe detectors are the basis of the νGeN setup. Measurements of own background of the νGeN cryostat were also accomplished. The complex measurements of gamma, neutron and cosmic backgrounds were carried out on the territory of Kalinin Nuclear Power Plant in the laboratory under the reactor where the measurements on search for coherent scattering of neutrino will be performed. The software for test and methodic measurements was created as well.

This work is conducted under the RNF grant N 14-12-00920.

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2. E.Armengaud *et al.* // Phys. Lett. B. 2011. V.702. №.5. P.329.

STATUS AND FIRST RESULTS OF THE EDELWEISS-III DARK MATTER SEARCH EXPERIMENT

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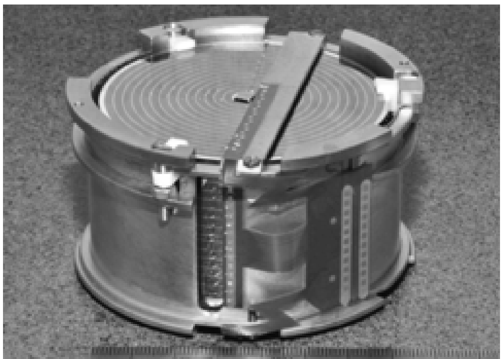
The EDELWEISS program [1, 2] searches for evidence of direct WIMPs from Milky Way galaxy scattering of Ge nuclei within cryogenic Ge crystals. The EDELWEISS detectors are cryogenic (work temperature is about 20 mK) HPGe bolometers with simultaneous measurement of phonon and ionization signals. The comparison of the two signals provides an efficient event-by-event discrimination between nuclear recoils (induced by WIMPs) and electrons. The experiment is located in the LSM deep underground laboratory to reject background caused by cosmic radiation. The new phase (EDELWEISS-III) of the experiment was started in 2014. The EDELWEISS-III consists in an upgrade of cryogenic system, shielding, data acquisition and detectors of the EDELWEISS-II setup. Physics data taking with 24 new 800 g FID detectors (all surfaces of detectors are covered by ring electrodes — fully interdigitized detectors) has been started in June of 2014. The detectors (Fig. 1, left) show world leading suppression for the surface background. After one year of running 3000 kg.d with no surface background events at nuclear recoil band above 15 keV threshold expected to be accumulated. This will provide the sensitivity to WIMP-nucleon SI cross-section of better of the $4x10^{-45}$ cm^2 for a M_{WIMP} ~100 GeV/c^2 in successful competition with other world leading Dark Matter search experiments. Low energy WIMP mass (M_{WIMP} below of 30 GeV/c^2) analysis with the analysis threshold for several detectors at 1.5 keV_{ee} shows competitive results, and will be presented in the conference talk.

This work has been partly supported by RFBR.



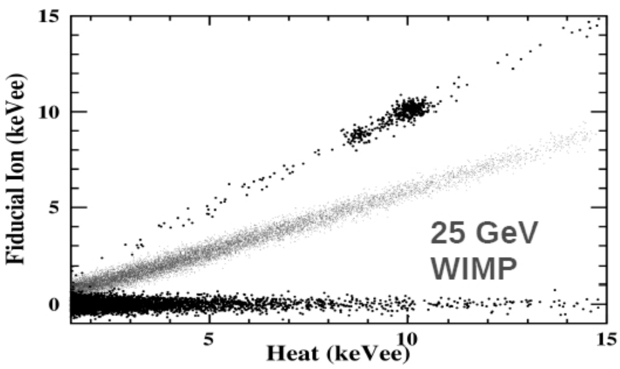


Fig. 1. Left: Photo of FID800 detector. Right: Ionization and heat for events registered with EDELWEISS-III (30 kg.d) – black dots, and expected event band (MC) for light WIMPs (for M_{WIMP} 25 GeV/c^2) – tiny gray dots.

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STUDY OF ELASTIC SCATTERING PROTONS FROM ^{14}N NUCLEI AT ENERGIES NEAR THE COULOMB BARRIER

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The purpose of this study is experimental and theoretical study of the elastic scattering of protons from ^{14}N nuclei at energies close to the Coulomb barrier.

Experiments were carried out on a linear accelerator UKP-2-1 at INP (Almaty). The accelerated protons energies were 700–1100 keV. Measurements of the differential scattering cross sections were made in the angular range of 20º–170º in laboratory system. The particles were detected by silicon detectors with sensitive layer 200 microns thick. The employed targets were thin films made of titanium nitride with thickness of 60–70 μg/cm^2. Thicknesses of targets were defined with an accuracy within 5%. In general, the absolute error of the data does not exceed 10%. As an example, the cross sections for elastic scattering of protons from ^{14}N nuclei at energies 990 and 1100 keV are shown on Fig. 1.

The experimental data were analyzed within the framework of standard phenomenological optical model and semi-microscopic folding model.

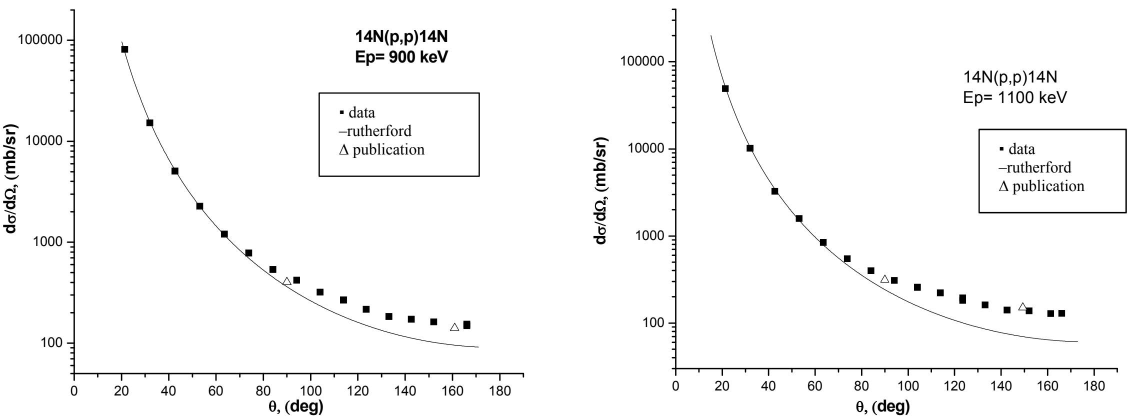

Fig. 1. Differential cross sections for elastic scattering of protons by nitrogen nuclei (E_p= 900 keV and 1100 kev).

GLOBAL FEATURES OF SHELL STRUCTURE OF THE Z = 20 – 50 NUCLEI

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Single-particle energies and occupation numbers of the Z = 20 – 50 nuclei were obtained from the experimental data by the method of joint analysis [1]. Some global features of shell structure of these nuclei were discovered. So, the tensor forces do the important contribution to the evolution of shells. In particular, trends of $1f_{7/2}$ energy changing prove it (see dashed arrows in Fig. 1). We calculate monopole two-body matrix elements from data obtained and, again, the tensor forces appear. Two different types of the filling of the neutron orbitals when N increasing are discovered: the simultaneous many orbitals filling and the 'one orbital' one. In some cases, the shell evolution gives rise to new magic numbers, such as 56, 64 etc.

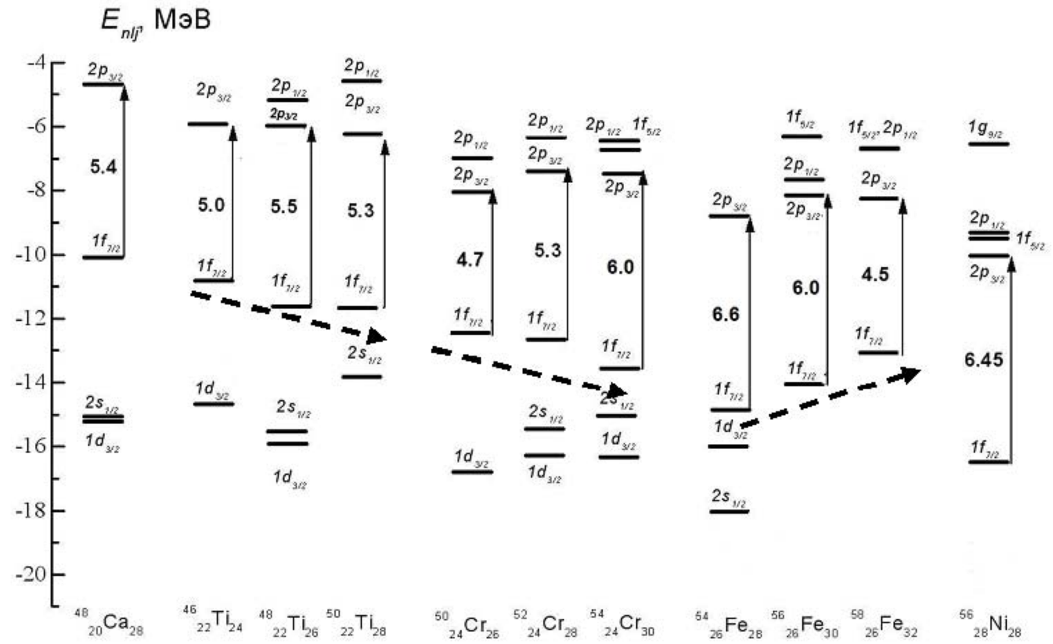

Fig. 1. Neutron single - particle energies in the Z = 20 – 28 nuclei.

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INVESTIGATION OF ISOMERIC STATES IN THE REACTION d + ^{197}Au AT 4.4 GeV ENERGY

Balabekyan A.R.[1], Demekhina N.A.[2,3], Karapetyan G.S.[4], Drnoyan J.R.[2], Adam J.[2], Solnyshkin A.A.[2], Tyutyunnikov S.I.[2], Zavorka L.[2], Zhemenik V.I.[2]

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In reactions induced by deuteron beam at energy 4.4 GeV different isomeric states were measured by using spectroscopic analysis if the activated target foils. The measured radioactive products can be belong to different reaction mechanisms as fission, spallation, multifragmentation. Among measured products were obtained ^{44m,g}Sc isotope, that can be produced in multifragmentation process. ^{95m,g}Nb and ^{95m,g}Tc can be refer to target fission probable at measured energy. Products as ^{84m,g}Re, ^{148m,g}Pm, ^{121m,g}Te, ^{102m,g}Rh can be considered as a results of target spallation. Particular attention was devoted to the high spin states of Hf isotopes as ^{177m}Hf, ^{179m}Hf with spins values $37/2^{-}$ and $25/2^{-}$ correspondingly. Cross sections of the nuclei ^{179m}Hf and ^{177m}Hf indicates that when the several nucleons are emitted from the compound nuclei the initial high transferred angular momentum results in the more likely the high-spin state isotope of the residual nucleus. Unfortunately the ground states in these nuclei were unmeasurable by means our methods.

On the other hand very interesting were the measurement the isomeric states of the near target isotopes as ^{196m,g}Au and ^{197m}Hf, ^{193m}Hf.

^{197m}Hg formed with a cross-section of 2.63 ± 0.2 mb probably in the surface interaction. The proton interaction from deuteron with the quasi-free neutrons of target surface in reaction type (p, n) formed in these cases residual nuclei in high spin state.

In production of last isotopes the direct and transfer reactions should be play the essential role in the understanding of the reaction mechanism. In several latest works [1, 2] was considered the excitation of the high spins states production of the Hg isotopes in direct and transfer processes at different energies.

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PROTON INDUCED FISSION OF ^{232}Th AT INTERMEDIATE ENERGIES

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[3] *Heavy Ion Laboratory of Warsaw University, Warsaw, Poland;*
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The multi-parameter correlation study of the reaction ^{232}Th(p,f) at E_p=7-55 MeV has been carried out. The fission fragment mass, total kinetic energy distributions have been measured. The three humped shape has been observed in the mass distributions up to higher proton energy. Shell structure effects were observed in fission fragment mass distributions even at high excitation energy. Some indications on the existence of the nuclear shell Z = 30 near fragment mass A_{fr} = 78 will be presented.

Experiments were carried out at the proton beam of the K-130 cyclotron of the JYFL Accelerator Laboratory of the University of Jyväskylä and U-150m cyclotron of the Institute of Nuclear Physics, of Ministry of Energy of the Republic of Kazakhstan. The mass-energy distributions and cross sections of proton-induced fission of ^{232}Th have been measured at the proton energies of 7, 13, 20, 40 and 55 MeV. For all proton energies three fission modes are quite clearly seen in the Mass-TKE distributions: symmetric and two asymmetric ones. The symmetric contribution grows up with increasing proton incident energy, although even at 55 MeV of proton energy the shoulders in the mass energy distribution clearly indicate the asymmetric fission peaks.

This work was partially supported by the program "Development of nuclear power in the Republic of Kazakhstan".

SOME FEATURES OF ISOMERIC RATIOS IN NUCLEAR REACTIONS INDUCED BY p, d, AND α

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For checking how some regularities noticed in nuclear reactions are displayed in models we did some calculations using TALYS 1.4 code. We chose (p,n), (d,2n), and (α,p3n) type reactions in which targets and products had the same mass numbers. We did the calculation and obtained excitation function for ground and isomeric states of products in energy region below 80 MeV (the energy step was 1 MeV). Then we calculated isomeric ratios *R* (*R* is cross sections ratio of high and low spin state). In all cases *R* was calculated at the maximum of the excitation function of the high spin state. The following features were noticed.

1. The *R* for (p,n) and (d,2n) reactions grow up to ~ 20–30 MeV and then remain almost constant (Fig. 1) because at high energies the role of direct and semi direct processes become significant. At low energies (below 15 MeV) calculated data are in good agreement with experimental one taken from data base EXFOR. For higher energies we didn't find experimental data.

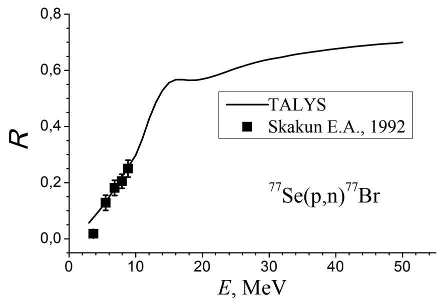

Fig. 1. Dependence of R on energy for $^{77}Se(p,n)^{77}Br$ reaction.

2. According to the calculated data the *R* grow with the increase of mass number of the incident particle. On Fig. 2 the dependence of *R* normalized to R_p for (p,n) reactions on particle mass number is present (for different nuclei with high spin state $8^{\pm}$). We notice the same dependence for product with high spin state of $8^{\pm}$, $7^{\pm}$, $6^{\pm}$ and $5^{\pm}$. The increase is steeper for the highest spin ($8^{\pm}$) and become smoother with the decrease of spin.

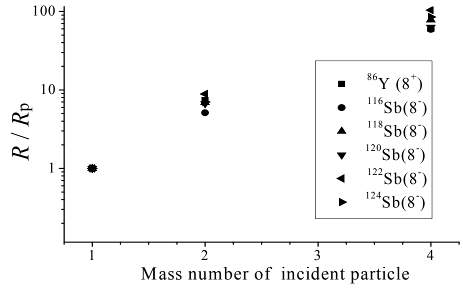

Fig. 2. Dependence of R/R_p on incident particle mass number.

3. In some cases the experimental and calculated data differ significantly (Fig. 3) (for example $^{86m}Y(8^+)$, $^{94m}Tc(7^+)$, $^{89m}Zr(9/2^+)$, $^{96m}Tc(7^+)$, $^{106m}Ag(6^+)$ etc.). Probably, the reason of it is the existence of high-spin yrast lines for the indicated nucleus.

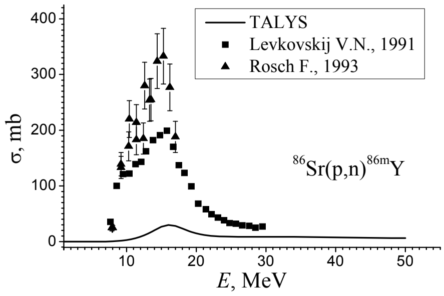

Fig. 3. Excitation function of $^{86}Sr(p,n)^{86m}Y$ reaction.

INVESTIGATION OF CLUSTER STRUCTURE ^{12}N NUCLEI IN A COHERENT DISSOCIATION

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A track nuclear emulsion was irradiated with a mixed beam of relativistic ^{12}N, ^{10}C, and ^{7}Be nuclei at a beam momentum of p_0 = 2 GeV/c per nucleon. The beam was formed upon the charge-exchange process involving primary ^{12}C nuclei and their fragmentation. An analysis of the charge topology in the coherent dissociation of these nuclei confirmed the dominance of the isotopes ^{7}Be and ^{10}C in the beam and the presence of ^{12}N nuclei there [2].

The identification of tracks by charge permits reconstructing the charge topology of white stars generated by ^{12}N nuclei (Table 1). On the basis of these data, the contribution of ^{12}N nuclei to the beam was estimated at a level of 14% (without allowance for H and He nuclei). According to the accumulated sample of white stars generated by ^{10}C and ^{7}Be nuclei, the contribution of each of these isotopes is about 43%. For $Z_{fr} > 2$ isotopes, the mass number A_{fr} is also determined from Z_{fr}. For a further selection of coherent-dissociation events featuring only fragments of ^{12}N nuclei (not involved in the interaction process), the condition for the angular cone was toughened to become $\theta_{fr} < 6^o$. The value on the right-hand side of this inequality was determined by a lenient constraint on the momentum of the Fermi motion of nucleons. In the distribution of 45 selected events (Table 1), the fraction of channels involving $Z_{fr} > 2$ heavy fragments reaches about 2/3, but the contribution of channels featuring only light fragments (He and H) remains quite significant. The sample of events associated with the 2He + 3H channel proved to be unexpectedly large. Taking into account the fact that, in the dissociation of the ^{7}Be nucleus, the branching fractions of the 2He and He + 2H channels are approximately equal to each other and assuming the ^{7}Be core in the ^{8}B and the ^{9}C nuclei, one would expect an approximate equality of the branching fractions of the 2He + 3H and 3He + H channels for the ^{12}N nucleus.

Channel	He+5H	2He+3H	3He+H	^{7}Be+3H	^{7}Be+He+H	^{8}B+2H	^{8}B+He	C+H	$\sum$
$\theta_{fr} < 11^0$	9	24	2	10	9	11	3	4	72
$\theta_{fr} < 6^0$	2	12	2	5	8	9	3	4	45

Table 1. Distribution of the number of white stars (N_{ws}) among the dissociation channels where the total charge of fragments is Z_{fr} = 7 and where the measured charge of the beam track is Z_{pr} = 7.

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EXPOSURES OF NUCLEAR TRACK EMULSIONS TO NEUTRONS AND HEAVY IONS

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Nuclear track emulsion (NTE) stays to be a versatile and inexpensive technique for forefront researches [1–3]. In JINR samples of reproduced NTE have been exposed to thermal and fast neutrons and 1.2 *A* MeV Kr and Xe ions.

NTE enriched with boron is exposed to thermal neutrons at the reactor IBR-2 allow one to extend range calibration for the ^{7}Li nucleus using events n_{th} + ^{10}B → ^{7}Li + (γ) + α. Angular and energy correlations of the reaction products are studied.

Correlations of α-particles ^{12}C → 3α are studied in NTE exposed to 14.1 MeV neutrons of the apparatus DVIN. Energy distributions $Q_{2\alpha}$ and $Q_{2\alpha}$ indicate on superposition of the ^{8}Be 0^+ and 2^+ states in the ^{12}C ground state at that $^8Be_{2+}$ is dominating.

There is a prospect of an NTE application in physics of a ternary fission. It is necessary to perform range calibrations and to estimate of angular resolution for an available variety of heavy ions. NTE samples without light protection paper are exposed to ions $^{86}Kr^{+17}$ and $^{132}Xe^{+26}$ at the cyclotron IC-100. Ranges of Kr and Xe ions correspond to the primary energy value. Scatterings of ions degraded in NTE to 300 *A*·keV with a visible recoil nucleus are measured. Progress of analysis of NTE exposure to a ^{252}Cf source will be presented.

Number of events analyzed in these pilot studies is a small part of available statistics. NTE provides a basis for the application of automated microscopy and image recognition software, allowing one to rely on unprecedented statistics. Thus, a synergy of classical nuclear technique and modern technology can be achieved. The report is illustrated by microphotographs of the discussed events.

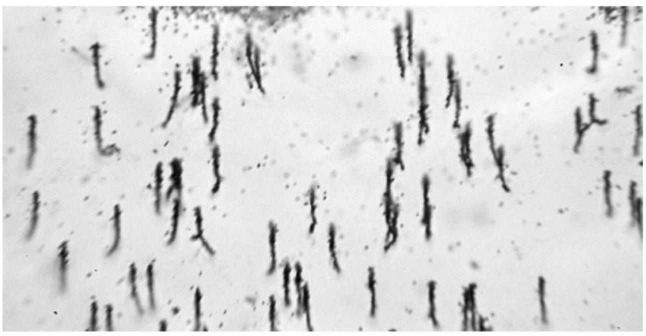

Fig. 1. Microphotograph of NTE exposed to 1.2 A·MeV Xe ions.

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INVESTIGATION OF THE EXCITATION OF THE $11/2^-$ ISOMERIC STATE IN THE $(\gamma,n)^m$ REACTIONS ON THE ^{138}Ce NUCLEUS IN THE 10 – 20 MeV REGION

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This work is dedicated to the studies of the $11/2^-$ isomeric state excitation processes in the $^{138}Ce(\gamma,n)^{137m}Ce$ reaction using the isomeric ratios method. The experiments were carried out with the Bremmstrahlung gamma-quanta beam produced by an M-30 microtron at the IEP, UNAS. The measurements were carried out with the ΔE=0.5 MeV step in the 10–20 MeV energy region. Close to the reaction threshold $(\gamma,n)^m$, the above step was 0.25 MeV.

In this experiment, the activation technique was applied. The experimental reaction threshold of the $^{138}Ce(\gamma,n)^{137m}Ce$ reaction was determined to be 11.0±0.2 MeV, which is about 1.4 MeV above the (γ,n) reaction threshold. The $(\gamma,n)^m$ reaction cross section has a single-humped shape with a maximum at 15.5 MeV.

The resulting experimental cross sections are compared to theoretical calculations carried out using the TALYS-1.6 code. According to the program manual, below the daughter nucleus excitation energy E = 3 MeV, a spectrum of discreet levels was used from the RIPL-3 database [1]. At higher energies the spectrum of the excited states of the daughter nucleus was considered continuous described by the level density $\rho(E, J, \pi)$.

A satisfactory agreement between the theoretical and experimental results was reached by introducing an additional level with $J^\pi = 7/2^-$ and E=1.4 MeV to the discrete level scheme.

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ON THE CONTRIBUTION OF THE PARTIAL CROSS SECTIONS OF THE (γ,n) AND (γ,2n) REACTIONS INTO THE TOTAL PHOTO-NEUTRON CROSS SECTION FOR THE ^{142}Ce ISOTOPES

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The main array of the most accurate data on the total and partial experimental cross sections of the (γ,n), (γ,2n) and (γ,3n) photo-neutron reactions has been obtained by using the quasi-monochromatic gamma-quanta beams at Saclay and Livermore for a wide class of atomic nuclei [1]. Later on, a certain systematic disagreement between the above data has been found. It has been stated that the σ(γ,2n) cross sections measured in Saclay were essentially underestimated, while the σ(γ,n) ones above the (γ,2n) reaction threshold – overestimated. In [2,3], this discrepancy was suggested to be explained by the difference in the 1n and 2n event detection using the spectroscopic methods.

In this paper, we made an attempt to check the possible contribution of the (γ,2n) reaction into the Saclay data on the (γ,n) reaction at the ^{142}Ce nucleus by the spectroscopic technique using the ^{140}Ce (γ,n) ^{139}Ce reaction as a monitor. The ^{140}Ce and the ^{142}Ce nuclei are very convenient for this purpose. First, identification of the (γ,n) reactions for these nuclei is made according to the close gamma-lines 165 keV and 145 keV minimizing the error related to the detector photoefficiency. Second, the (γ,2n) reaction thresholds for these nuclei differ significantly (i.e. by 3 MeV) and this gives a chance to determine precisely the values of the 2n event contribution to the (γ,n) reaction yield.

In our paper, we have carried out the measurement of the $f_{\rm exp}=Y(140)/Y(142)$ relative yields for the ^{140}Ce (γ,n) ^{139}Ce and ^{142}Ce (γ,n) ^{140}Ce reactions within the 9–18 MeV maximal energy range of the Bremsstrahlung spectrum. This work was carried out with the Bremsstrahlung gamma-quanta beam produced by an M-30 microtron at the IEP, UNAS. The microtron magnetic field strength was controlled by the nuclear magnetic resonance method. We have recalculated the σ(γ,n) cross sections for the ^{140}Ce and the ^{142}Ce nuclei obtained at Saclay [4] into the Y yields and found their ratio $f_{\rm Sacl}=Y(140)/Y(142)$. A comparison of the $f_{\rm exp}(E_{\gamma\max})$ and $f_{\rm Sacl}(E_{\gamma\max})$ curves shows that they reproduce each other with high accuracy. However, the $f_{\rm Sacl}$ curve is shifted with respect to our curve by approximately 300 keV towards the lower energies. Taking into account the above shift, our spectroscopic data and those obtained at Saclay coincide with a 2–3% accuracy.

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EXCITATION OF ^{179m2}Hf

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Studies of nuclear isomers allow to obtain various and very important information concerning nuclear structure, at the same times some of nuclear isomers have an enormous amount of excitation energy. One of such nuclear isomers is ^{179m2}Hf and therefore the goal of our work is to investigate both the cross-section and isomeric yields ratios of ^{179m2}Hf creation in reactions in alpha-particles and bremmsstrahlung photons with energy in the broad range.

Measurements of cross-section and isomeric yields ratios of ^{179m2}Hf ($T_{1/2}$ = 25 d., J^{π} = $25/2^{-}$, E^{*}=1.1 MeV) creation were carried out on the targets of natural isotopic composition both lutetium after their irradiation by alpha-particles with energy near 26.0 MeV and hafnium after their irradiation by bremmsstrahlung γ-rays at end-point energy about 15.1 and 17.5 MeV. The irradiation by alpha-particles has been completed at U-120 cyclotron in the Kyiv Institute for Nuclear Research of NASU, while the irradiations by bremmsstrahlung γ-rays were done on the M-30 microtron of the Laboratory of Photonuclear Reactions at Uzhgorod Institute of electronic physics. The measurement of activity has been performed in a separate laboratory by Ge-spectrometers with energy resolution 1.8–2 keV for the 1332-keV γ-line of ^{60}Co and detection efficiency of 15–40% in comparison with a 3″×3″ NaI(Tl)-detector.

The next cross-section and isomeric yields ratios have been obtained: $\sigma = (1.1\pm0.11)\cdot10^{-27}$ cm^2 for nuclear reaction ^{176}Lu(α,p)^{179m2}Hf and $Y_{m2}/Y_g = (6.1\pm0.6)\cdot10^{-6}$ and $(3.73\pm0.37)\cdot10^{-6}$ for nuclear reaction ^{180}Hf(γ,n)^{179m2}Hf at end-point energy of bremmsstrahlung photons about 15.1 and 17.5 MeV, appropriately. In addition we measured the cross-section for nuclear reaction ^{175}Lu(α,2n)^{177}Ta which is equal $\sigma = (366\pm18)\cdot10^{-27}$ cm^2.

While the excitation functions for nuclear reactions ^{180}Hf(γ,n)^{179g}Hf and ^{176}Hf(γ,n)^{175}Hf are the same that both ^{179g}Hf and ^{175}Hf yields have the near values in our experimental conditions. So, the yields of ^{175}Hf are used as Y_g after accounting of the corrections induced both the different contributions ^{180}Hf and ^{176}Hf in the natural isotopic composition of hafnium and different thresholds of the corresponding (γ,n)-reactions. As the isomeric yields ratios are decreasing with increasing the energy of bremmsstrahlung photons that the hypothesis is put forward about the single-humped type of excitation function for nuclear reaction ^{180}Hf(γ,n)^{179m2}Hf. Experimental values of the cross-section and isomeric yields ratios are compared with the theoretical values, which are calculated by using TALYS-1.4 and EMPIRE-3.2 codes.

The discussion concerning obtained results is carried out.

STUDY OF SPECTROMETRIC CHARACTERISTICS OF THE DIAMOND DETECTOR AT THE BEAM OF HEAVY IONS

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The experiment aimed at studying of the spectrometric characteristics of the diamond detector at the IC-100 accelerator beam was performed in the Flerov Laboratory (JINR, Dubna, Russia). Secondary beams used for the measurements were produced by the scattering of the initial Xe beam at different metal foils. Knocked-out ions pass through the degraders of three different thicknesses in order to increase energy range under study. The shapes of the detector signals were measured using fast flash-ADC (sampling frequency is 5 GS/s). Velocities of the ions were measured event-by-event with a help of two micro-channel plate based timing detectors. The results are compared with those for the Si PIN diode tested in the same experiment.

TESTING OF THE Si PIN DIODE ON HEAVY IONS

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Reconstruction of the heavy ion masses in the time-of-flight spectrometry using PIN diodes is known to be a complicated task due to distortions both in timing ("plazma delay-PD") and measuring of the ions energy ("pulse height defect-PHD"). The experiment aimed at testing of the spectrometric characteristics of the Si PIN diode at the IC-100 accelerator beam was performed in the Flerov Laboratory (JINR, Dubna, Russia). Secondary beams used for the measurements were produced by the scattering of the initial Xe beam at different metal foils. The shapes of the detector signals were measured using fast flash-ADC (sampling frequency is 5 GS/s). The results obtained are compared with known parametrization of both PHD and PD effects.

DETERMINATION OF NEUTRON AND PROTON COMPONENTS OF NUCLEAR SUBSTANCE FOR WEAKLY BOUND NUCLEI FROM A COMPARATIVE ANALYSIS OF (ee')-SCATTERING AND MEASUREMENT OF TOTAL REACTION CROSS-SECTIONS

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In studies of weakly bound (exotic and cluster) nuclei and their cores scientists pay special interest to the comparison of radial parameters, deformation lengths and ratios of neutron and proton components (M_n/M_p) in the ground and low-lying states of nuclei. Such data can be obtained from the comparative analysis of the experimental values of cross sections (elastic and inelastic scattering) and total reaction cross sections (TCS, σ_R) for different types of particles on the same target nucleus. This is due to the fact that scattering of electrons [1] is more sensitive to the proton distribution (ρ_p), whereas the experimental values of σ_R, measured on a proton target [2, 3] at low energies, are more sensitive to the neutron distribution (ρ_n). In [4] and in our earlier papers it was shown that α-nuclear scattering is equally sensitive to proton and neutron distributions, i.e., to the mass distribution (ρ_m).

For a comparative analysis and determination of ρ_p we used (ee')-scattering data from [5] and other papers. To determine ρ_n we analyzed systematic energy dependence of TCS on the proton target, and to obtain ρ_m we used σ_R data for ^{12}C and ^{28}Si in a wide range of energies. Using ρ_m, ρ_p and ρ_n density distributions, we determined the M_n/M_p.

To obtain ρ_m, ρ_p and ρ_n density distributions to analyze experimental cross-sections, a (semi-) microscopic folding model was used. The objects of investigations were light weakly bound (cluster and exotic) nuclei, in particular, $^{6–9}Li$ and ^{11}Li.

In this paper we present new quantitative results on radial parameters, deformation lengths and relationships of multipole matrix elements M_n/M_p for the ground and low-lying states of studied nuclei. We compared our results with the predictions of the simple collective model.

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MEASURING SHIFTS BLAIR AND FRESNEL PHASES IS AS A METHOD FOR DETERMINING THE MAGNITUDES AND SIGNS OF DEFORMATION EVEN-EVEN AND ODD NUCLEI

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Group of Kharkov Institute of Physics made the discovery phase shifts Blair at Fraunhofer diffraction in the medium angles and phase shifts Fresnel nuclear diffraction at small angles [1, 2]. In the experimental determination Blair phase shift problem was only in increasing the experimental angular resolution of the spectrometer and the precision step in the corner. A significant problem was the experimental determination of the Fresnel shifts. The fact that the Fraunhofer diffraction there exists a reference point shift angle. The reference point is extremum of elastic scattering, measured at the same time inelastic scattering. But Fresnel diffraction such obvious reference point is not visible.

In this paper, the authors propose the comparison Fresnel diffraction extrema for the nucleus as a "reference" point of use Fresnel diffraction theory calculations [2] under the assumption that this nucleus is spherical nucleus ($\beta_2 = 0$). Deviation of the experimental angular distributions of the differential cross sections for elastic scattering of alpha particles in the nucleus with respect to this theoretical curve to the right or to the left will give a phase shift on which determines β_2 and sign(β_2).

On the other hand, and Fraunhofer elastic oscillations have been used as reference in the following procedures. Experimental oscillations described theoretically by the parameterized phase analysis. Then, the theoretical calculation applies to the Fresnel region. And finally, such theoretical Fresnel extremes compared with the experimental, which gives the desired changes to the deformed nucleus.

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STRANGE MESONS IN P+P, d+Au, Cu+Cu AND Au+Au COLLISIONS AT 200 GeV IN PHENIX EXPERIMENT

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Strongly coupled quark gluon plasma (QGP) was discovered in heavy ion collisions at Relativistic Heavy Ion Collider (RHIC) [1]. Unlike up and down quarks, strange quarks are not present in colliding nuclei and are formed in collisions between constituents of the QGP. Therefore measurements of particles that contain strange quarks is an effective way to compare with hadrons that contain only light quarks and investigate the properties of the hot and dense matter formed in heavy ion collisions. Particles with strangeness content cover a wide range of masses and include mesons and baryons which makes them a perfect tool to study such features of hadron production as radial flow and recombination at intermediate p_T and energy loss flavor dependence at high p_T.

In this talk we present the latest PHENIX results on production of $K^{\pm}$, K_S, K^* and φ mesons in p+p, d+Au, Cu+Cu and Au+Au collisions at 200 GeV. While p+p collisions provide a baseline and are used for precision tests of pQCD calculations, for heavier colliding systems such as d+Au, C+Cu and Au+Au the nuclear modification factors are studied at different centralities. These systematic studies enrich our understanding of the strange meson production and their difference from light quark hadrons. The role of radial flow and coalescence in particle production is discussed.

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ELASTIC SCATTERING CROSS SECTION MEASUREMENT OF ^{13}C NUCLEI ON ^{12}C AT ENERGY 22.75 MeV

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Elastic scattering cross section of the ^{13}C at nuclei ^{12}C have been measured (heavy ion accelerator DC-60, Astana, Kazakhstan) at 22.75 MeV energies, in the laboratory system.

Experimental data shows that for the $^{13}C+^{12}C$ reaction is observed the rise of elastic differential cross sections at large angles. Previously anomalous scattering of the system $^{12}C + ^{16}O$ at energies near the Coulomb barrier has been systematically investigated [1]. A significant rise of the elastic scattering cross sections for backward angles was shown. It is completely determined by the alpha cluster transfer mechanism between the interacting nuclei. The experimental data in the framework of the phenomenological and semi-microscopic (potential convolution) optical model were analyzed. Optimal parameters of the interaction potential for the system $^{12}C + ^{13}C$ were found. Experimental data reproduce by the parameters for the forward hemisphere. Anomalous behavior of ion scattering of ^{13}C on ^{12}C can be described by nucleon exchange mechanism [2] between the interacting nuclei calculated by DWBA. Figure 1 shows the experimental data of the elastic scattering cross section of the accelerated ions ^{13}C to ^{12}C at 22.75 MeV and result of the analysis. Differential cross sections can be describes by Rutherford scattering only for the front angles.

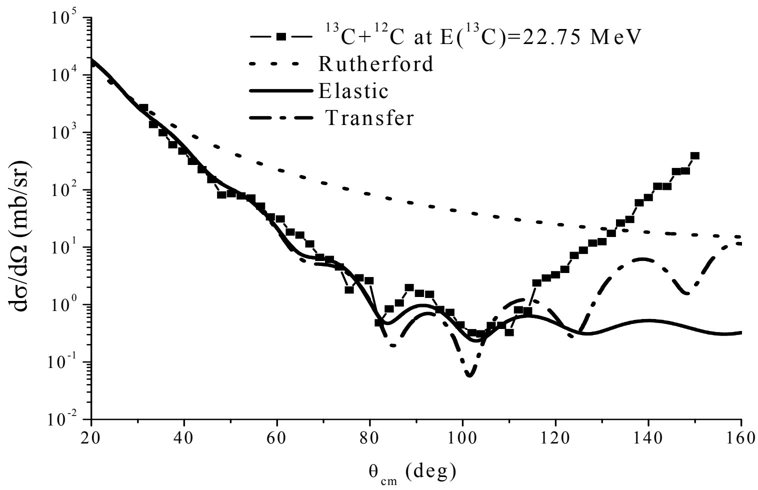

Fig. 1. The differential cross section of elastic scattering ^{13}C to ^{12}C nuclei at energy of 22.75 MeV.

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EXCITATION OF ISOMERIC STATES IN THE REACTIONS (γ,n) AND (n,2n) ON $^{85,87}Rb$

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The method of the induced activity measured the isomeric yield ratios and cross-sections ratios of reactions (γ, n) and (n, 2n) on nuclei $^{85,87}Rb$. Samples of natural Rb have been irradiated in the bremsstrahlung beam of the betatron SB-50 of Institute of Applied Physics of National University of Uzbekistan in the energy range of 10 – 35 MeV with energy step of 1 MeV. For 14 MeV neutron irradiation we used the NG-150 neutron generator of Institute of Nuclear Physics.

The gamma spectra reactions products were measured with a spectroscopic system consisting of HPGe detector CANBERRA with energy resolution of 1.8 keV at 1332 keV gamma ray of ^{60}Co, amplifier 2022 and multichannel analyzer 8192 connected to computer for data processing. The filling of the isomeric and ground levels was identified according to their γ lines. Values Y_m/Y_g at $E_{\gamma\max}$ = 25 MeV for the reaction (γ, n) on nuclei ^{85}Rb and ^{87}Rb are respectively: 0.33±0.02 and 0.087±0.004.

Cross-sections of reactions $^{85}Rb(\gamma,n)^{84m,g}Rb$ and $^{87}Rb(\gamma,n)^{86m,g}Rb$ in the energy range 12 – 25 MeV with a step of 1 MeV are determined. The experimental received sections of reactions are compared to results of other works and the calculated data which were carried out with use of a software package of TALYS-1.6 [1]. The isomeric ratios of cross-sections of reactions at $E_\gamma=E_m$ are also estimated. The experimental results have been discussed, compared with those of other authors as well as considered by the statistical model [2]. Theoretical values of the isomeric yield ratios have been calculated by using code TALYS-1.6 [3].

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INVESTIGATION OF THE EXCITATION OF ISOMERIC STATES IN THE REACTIONS (γ,n) AND (n,2n) ON ^{45}Sc, ^{82}Se AND ^{81}Br

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This work presents work results of investigation of the isomeric yield ratios Y_m/Y_g of the $^{45}Sc(\gamma,n)^{44m,g}Sc$, $^{45}Sc(n,2n)^{44m,g}Sc$, $^{82}Se(\gamma,n)^{81m,g}Se$, $^{82}Se(n,2n)^{81m,g}Se$, $^{81}Br(\gamma,n)^{80m,g}Br$ and $^{81}Br(n,2n)^{80m,g}Br$ reactions. The isomeric yield ratios were measured by the induced radioactivity method. Samples of natural Sc, Se and Br have been irradiated in the bremsstrahlung beam of the betatron SB-50 in the energy range of 10 – 35 MeV with energy step of 1 MeV. For 14 MeV neutron irradiation we used the NG-150 neutron generator.

The gamma spectra reactions products were measured with a spectroscopic system consisting of HPGe detector CANBERRA with energy resolution of 1.8 keV at 1332 keV gamma ray of ^{60}Co, amplifier 2022 and multichannel analyzer 8192 connected to computer for data processing. The filling of the isomeric and ground levels was identified according to their γ lines. Values Y_m/Y_g at $E_{\gamma\max}$ = 30 MeV for the reaction (γ, n) on nuclei ^{45}Sc, ^{82}Se and ^{81}Br are respectively: 0.21±0.02; 0.56±0.02 and 0.46±0.02. In the range 26 – 35 MeV the isomeric yield ratios Y_m/Y_g of the reaction (γ,n) on ^{45}Sc, ^{82}Se and ^{81}Br are obtained at first. Using the isomer yield ratio and the total cross section of the (γ, n) reaction on ^{45}Sc, ^{82}Se and ^{81}Br [1] received the cross sections of $(\gamma, n)^m$ and $(\gamma, n)^g$ reactions. The cross section isomeric ratios at E_γ=E_m are estimated.

The isomeric cross-section ratios σ_m/σ_g was determined in the case of the reaction (n, 2n). In order to obtain the absolute values of the cross sections for the ground state and for the isomeric state, use was made of methods based comparing the yields of the reaction under study and the monitoring reaction. The reaction $^{27}Al(n,\alpha)^{24}Na$ ($T_{1/2}$ = 15 h, E_γ = 1368 keV), whose cross section σm was 118 ± 2 mb at E_n = 14.4 MeV [2], was taken for a monitoring reaction.

The experimental results have been discussed, compared with those of other authors as well as considered by the statistical model [3]. Theoretical values of the isomeric yield ratios have been calculated by using code TALYS-1.6.

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THEORY OF ATOMIC NUCLEUS AND FUNDAMENTAL INTERACTIONS

CONTRACTION LIMITS OF THE PROTON-NEUTRON SYMPLECTIC MODEL

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Two contraction limits of the fully microscopic proton-neutron symplectic model are considered. As a result, two simplified macroscopic models of nuclear collective motion are obtained in simple geometrical terms. The first one is called $U(6)$-phonon model with a semi-direct product structure $[HW(21)]U(6)$, and the second one, is the two-rotor model with a $ROT_{\mathrm{p}}(3) \otimes ROT_{\mathrm{n}}(3) \supset ROT(3)$ algebraic structure. The latter, in contrast to the original two-rotor model, is not restricted to the case of two coupled axial rotors. The full range of low-lying collective states can then be described as two-rotor model states, renormalized by coupling to the giant resonance vibrations.

GREEN'S FUNCTION METHOD IN THE THEORY OF NUCLEAR MATTER AND ATOMIC NUCLEI

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The Green's function method in Kadanoff-Baym (KB) version is capable of describing dynamical and statistical properties of quantum many-body systems in a comprehensive way with specific application to nuclear matter. As declared in [1], "it can be now conclusively stated that self-consistent spectral functions should (and perhaps equally important now can) be included in any serious consideration of nuclear properties being it in ground state, excited state or in a state of nonequilibrium". In the frame of this method the correct approximation to the spectral function which takes into account the widths of energy levels was found [2]. It was shown that: a) self-consistent approximations used in the Bruckner theory and in KB method lead to almost coinciding values of binding energy in nuclear matter [2]; b) the Landau-Silin (LS) kinetic equation for a normal Fermi liquid is valid in the case when the widths of one-particle energy levels are taken into account [3], provided the correct expression for the spectral function is used. The LS kinetic equation allows to analyse the collective excitation spectrum of a nuclear matter, considering that it is, in a good approximation, a collection of strongly interacting nucleons wandering solo in all directions.

The application of the KB formalism to finite atomic nuclei which demands a generalization of the method on the case of spationally nonhomogeneous systems is performed. The usage of the Born-Oppenheimer adiabatic approximation is justified provided a long-standing problem of the choice of proper nuclear collective coordinates is taken into account. The exciton particle-hole state densities which are required to calculate the cross sections of pre-equilibrium nuclear reaction models discussed in [4] are considered. The influence of a schematic particle-hole residual interaction on the values of the excitation energy of the vibrational state, the self-energy shift and the transition matrix elements is discussed. It appears that the excited state properties can be treated in a proper way in the frame of the generalized KB method despite the fact that the high order corrections to the effective interaction in the diagrammatic approach, which demand phonon insertions in the self-energy diagrams, turned to be pointless to make [5].

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COLLECTIVE STATES OF NUCLEAR IN THE NUCLEON PAIR APPROXIMATION AND GENERALIZED SENIORITY

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In order to study the properties of low-lying states, one really has to truncate the shell-model space. Pair approximation is one of the ideas along this line. The physics of the *SD*-pair approximation is well recognized. Attractive pairing interacting and quadrupole correlations favour configurations constructed to a large extent by pairs with spin zero and spin two *S* and *D* pairs. As an approximations the *SD* pairs are used to construct the model space. In the interacting boson model (IBM) *SD* pairs are approximated to sd-bozons [1].

The generalized seniority or broken pair approximations [2] has long been proposed as a truncation scheme for the nuclear shall-model. The generalized seniority scheme has also been proposed as a microscopic foundation for the phenomenologically successful IBM. A shell-model calculations for the ground state and low-lying states can then be carried out in a truncated space, consisting of states built from a condansate of collective *S* pairs together with a small number ν the generalized seniority of nucleons not forming part of an *S* pair.

Although the generalized approach has long been applied in various contexts it has not been systematically benchmarked calculations carried out in the full shell model space with realistic interactions. Extensive previous studies with generalized seniority basis have instead compared the seniority results with experiment. Such comparisons do not disentangle the question of how accurately the truncated calculation approximates the full-space calculations and model space are for description of the particular set of experimental data.

The purpose of the present work is to establish a benchmark comparison of the results obtained in a generalized seniority truncated model space against those obtained in the full shell model space with realistic interaction. We consider the Pd even isotopes (N = 54–72) in pfg-shell model space and truncated calculations to one broken particle pairs (ν_p, ν_n=2). These calculations should be viewed as a baseline in that, they are based on the most restricted generalized seniority truncation.

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NUCLEAR SHAPE PHASE TRANSITION AT THE NUCLEON STATE AND BOZON MAPPING APPROACH

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There exist phase transitions a many modes of collective motion and geometric shapes such as vibrational, rotational and exotically deformed shapes, which have attracted great attentions in recent years [1]. Most of the investigation were carried out in the interacting boson model (IBM) and one has shown that the U(5), SU(3), O(6) symmetry corresponds to the shape phase a spheroid, axially prolate and γ-soft rotor respectively.

The IBM is phenomenological model of nuclear structure. Along-standing significant question is then to identify directly the shape phase structure in fermion space. Recently there have been studies on nuclear shape phase transitions and their critical point symmetries in the framework of shell model [2].

In this framework we take a general shell Hamiltonian to study the dependence of the shape phases on each of the microscopic monopole-pair and quadrupole-quadrupole interactions.

To avoid the difficulties in shell model calculations with large valence nucleon space, we employ the Otsuka-Arima-Iachello (OAI) mapping method. In a boson mapping process a fermion space is mapped onto an ideal boson space and every fermion operator can be exactly transformed into a corresponding boson operator.

The purpose of this work is to study the dependence of nuclear shape phases on the microscopic interactions between nucleons. The investigation shows that there exist shape phase transitions driven by these interactions. For example the transition from the vibrational to the axially prolate rotational can be induced by the quadrupole-pair interaction as the critical point. The OAI mapping method has been used in describing the spectroscopic properties of low-lying states and nuclear shape phases in isotopes nuclear ^{74,76,78}Se. The dependence of the shape phase on the strength of each of the three interactions is calculated.

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COMBINING RPA WITH IBM IN ^{114}Xe

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The standard Random Phase Approximation (RPA) cannot be employed for description of transitional nuclei with developed quadrupole collectivity because of considerable ground state (GS) correlations. To overcome this shortcoming we use (see e.g., [1]) a combination of RPA and the Interacting Boson Model in its first version (IBM), parameters of which and their renormalizations under the influence of noncollective phonons are calculated in the RPA frame. In our method GS is treated as a superposition of the boson vacuum (BV) and states with several quadrupole boson (in $^{114}\mathrm{Xe}$ their average quantity is ~ 2.6). As in the fermion space such boson GS corresponds to the RPA vacuum (RPAV) and several RPA two quasiparticle phonons, the fermion GS includes, therefore, essential admixture of four and greater numbers of quasiparticles though RPAV can insignificantly differ from the quasiparticle vacuum (QV). To regulate the difference between RPAV and QV and contributions of many boson states to GS, the special term X is introduced in the energy functional, variations of which give a set of equations determining Bogolubov's and phonon amplitudes and also boson compositions of wave functions. $\mathrm{X} \sim \chi\,(1+r)/(1-r);\quad r = \Sigma\varphi_{ik}^2 / \Sigma\psi_{ik}^2,\ \psi_{ik}, \varphi_{ik}$ are RPA phonon two-quasipaticle amplitudes. The Lagrange multiplier χ is fitted so to fix the quantity of r which should be ≈ 1 to employ the standard RPA. Apart from this purpose term X impacting on ψ, φ and hereby on the IBM parameters allows them to be consistent with boson expectation values on which these parameters also depend. Optimal quantities of r can be found at consideration of the GS energy E_0 as a function of r (earlier [2] we established that r can be in a range $0.02 \div 0.07$). E_0 comprises the QV energy (with allowing for QV blocking by phonons (bosons) attending in GS), the RPAV energy and the IBM collective boson energy. The function ΔE vs r, $\Delta E = E_0 - E$ (Independent particle model) is depicted in Fig.1 that shows a shallow minimum at $r = 0.03$. Nevertheless, the energy ΔE of the "pure" RPA (without IBM, i.e. at $\chi = 0$) is 4.5 MeV higher. The energies of yrast states (up to spin $I = 10$) and of two known collective excited states calculated at $r = 0.03$ for $^{114}\mathrm{Xe}$, as seen in Fig. 2, are in reasonable agreement with experiment.

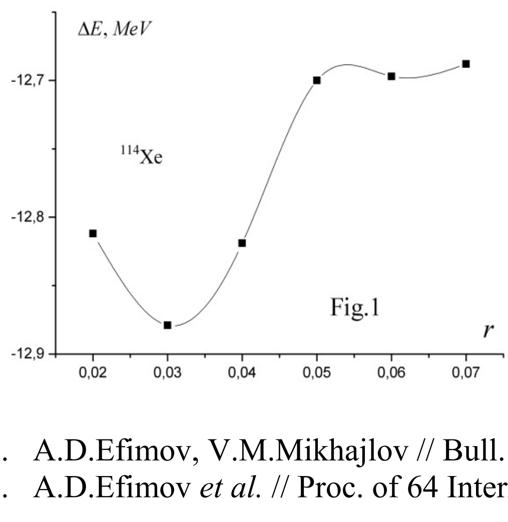

Fig.1

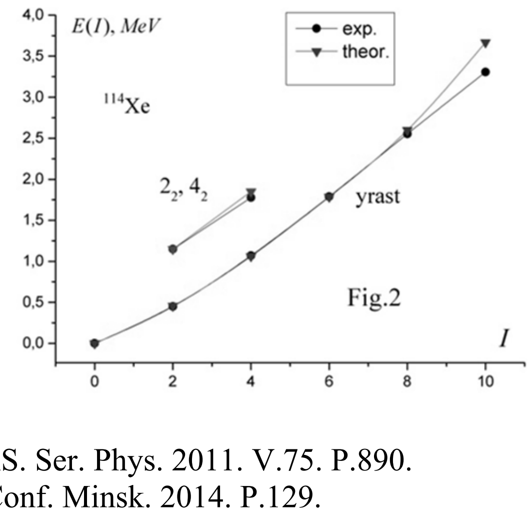

Fig.2

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EXACT AND APPROXIMATE SOLUTIONS TO THE EFFECTIVE BCS HAMILTONIAN FOR ^{124}Te

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Eigenvalues of the BCS Hamiltonian are found in Te (Z = 52, N = 72), for proton and neutron states with zero seniority (s) (i.e. for the ground states and monopole (0^+) excitations) and for states with s = 2 described as a rule as states with two Bogolubov quasiparticles. Calculations have been performed with Saxon-Woods single-particle spectra in which the pairing cuts out the energy layer of $\sim 2\hbar\omega_D \simeq 14.7$ MeV with the center on the Fermi level. Pairing strengths G_p = 0.245 MeV, G_n = 0.182 MeV approximately correspond to smoothed dependencies of G on mass numbers obtained from empirical pair energies in the frame of the BCS theory. The same values are employed in quasiparticle calculations. Exact excitation energies (as differences of energies with $s = 2$ and ground states in protons and neutrons) are displayed in the table together with corresponding BCS two-quasiparticle energies (BCS 2qp.) and values calculated in the strong pairing approximation (SPA) [1] for neutrons. For protons SPA cannot be applied as the proton pairing is weak. The table shows that all proton $s = 2$ excitations and the first excited level $E_\mathrm{p}(0^+)$ = 3.8 MeV lie above doubled proton pairing gap ($2\Delta_\mathrm{p}$=2.5 MeV). Besides, the transfer amplitude $\left\langle N-2 \,|\, \sum_s a_{\bar{s}} a_s \,|\, N \right\rangle$ turns out to be equal to zero. At the same time in neurtons the strong pairing (caused by a higher level density) reveals itself in low lying $s = 2$ states and $E_\mathrm{n}(0^+)$ = 2.74 MeV which are below $2\Delta_\mathrm{n}$=2.80 MeV. Though BCS and SPA give comparable deviations from the exact energies, SPA, lowering energies, nevertheless, reproduces positions of first s = 2 states below $2\Delta_\mathrm{n}$. The work is supported by the SPbSU grant No. 11.38.648.2013.

protons (MeV)			neutrons (MeV)			
$s = 2$ configurations	exact	BCS 2qp.	$s = 2$ configurations	exact	BCS 2qp.	SPA
$(4g\,7/2)^2$	2.93	3.24	$5h\,11/2, 4s\,1/2$	2.71	2.80	2.69
$4d\,5/2, 4g\,7/2$	3.62	3.76	$4s\,1/2, 4d\,3/2$	2.74	2.82	2.72
$4d\,5/2, 4d\,5/2$	4.30	4.29	$(5h\,11/2)^2$	2.75	2.80	2.69
$4g\,9/2, 4g\,7/2$	5.69	5.32	$(4d\,3/2)^2$	2.84	2.84	2.75
$4g\,7/2, 4d\,3/2$	5.73	5.71	$4d\,5/2, 4s\,1/2$	4.21	4.06	3.98
$4g\,9/2, 4d\,5/2$	6.20	5.84	$4d\,5/2, 4d\,3/2$	4.23	4.08	3.98
$4d\,5/2, 4d\,3/2$	6.42	6.23	$4g\,7/2, 4s\,1/2$	4.39	4.26	4.18

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MAGNETIC CHARACTERISTICS OF THE Yb ISOTOPES

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The energy and wave function structure of excited states are calculated. The finding reveals that the bands mixing have been found to have considerable impact on the wave function of low-lying states β_υ^+ and γ_υ^+ bands. In addition, the probabilities of $E2$- and $M1$- transitions have been calculated. The values from calculations of $B(E2)$-transitions and coefficients of the multipole mixture $\delta\left(E2/M1\right)$ from β_1^+, β_2^+, γ_1^+ and γ_2^+ bands are compared with the experimental data. Finally, it is noteworthy that these are an obvious inverse relation between g_R– factor and angular momentum I of the ground band states. This has been explained by a mixing ground and $K^\pi = 1_\upsilon^+$ bands which have a strong $B\left(M1\right)$ to ground state band.

In adiabatic approximation of the equation of reduced probability of M1 – transition follows as

$$B\left(M1;11_\upsilon^+ \rightarrow 00_1^+\right) = \frac{3}{4\pi}\times 0.02\left(m_{1_\upsilon}^{'}\right)^2 \mu_N^2. \qquad (1)$$

From the known experimental values of the probability of $M1$– transitions can calculate $m_{1_\upsilon}^{'}$. The values of parameter $m_{1_\upsilon}^{'}$ were calculated by the formula (1), using the experimental data of *B(M1)* [4] which are presented in Table. However, formula (1) does not allow to define sign of the parameters $m_{1_\upsilon}^{'}$.

	^{172}Yb				^{174}Yb			
ν	E_{1_ν} (MeV)	E_{11_ν}	$B(M1)\uparrow\left(\mu_N^2\right)$	$m'_{1_\nu}\left(\mu_N\right)$	E_{1_ν} (MeV)	E_{11_ν}	$B(M1)\uparrow\left(\mu_N^2\right)$	$m'_{1_\nu}\left(\mu_N\right)$
1	2.010	1.06±0.14	$1.27\cdot10^{-2}$	+1.63	1.625	2.31±0.28	$3.1\cdot10^{-2}$	–0.80
2	2.573	0.51±0.09	0.93·0.10	–8.06±0.87	2.037	0.64±0.40	0.15±0.11	–3.24±2.38
3	2.612	0.70±0.13	0.33·0.09	–4.80±1.31	2.068	0.67±0.34	0.20±0.12	–3.83±2.30
4	3.002	0.51±0.10	0.34·0.09	–4.87±1.29	2.338	0.74±0.20	0.28±0.10	–4.34±1.55
5	3.096	0.46±0.12	0.11·0.04	+2.77±1.01	2.500	0.60±0.16	0.35±0.11	–5.01±1.58
6	3.253	0.46±0.12	0.09·0.03	+2.51±0.84	2.581	0.46±0.14	0.21±0.08	+3.83±1.5
7	3.604	0.76±0.13	0.49·0.12	–5.85±1.43	2.815	0.90±0.38	0.16±0.001	–3.24±1.62
8	3.863	1.14±0.24	0.45·0.14	–5.61±1.75	2.920	0.41±0.07	0.44±0.11	+5.61±1.4

Here E_{1_ν} are energy levels, branching ratio $E_{11_\nu} = \dfrac{B(M1;11_\upsilon \rightarrow 20_1^+)}{B(M1;11_\upsilon \rightarrow 00_1^+)}$.

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NUCLEAR HAMILTONIAN PARAMETERS FOR EVEN-EVEN ACTINIDES IN SOFT-ROTATOR MODEL

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Low-lying collective states of deformed even-even nuclei are known to be rather well described by the soft-rotator mode [1]. This model considers dynamic nonaxial quadrupole, octupole, and static axial hexadecapole deformations of nuclear shape and builds rotational bands on the lowest vibrational states [2].

Nuclear wave functions of the model are successfully applied for sophisticated coupled channel optical model calculations. Nevertheless for heavy actinides such parameters had been determined only for ^{232}Th and ^{238}U.

Present work demonstrates reasonable coincidence between the energies of model-predicted and experimental level data for 14 even-even actinides, measurements for which are available.

Hamiltonian parameters for these nuclei had been determined and their isotopic dependencies were analyzed.

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ENERGY SPECTRA OF LOW-LYING STATES IN EVEN-ODD NUCLEI WITH Z = 96 – 108

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The calculated equilibrium deformations, energies, and structure of the low-lying states are presented for neutron odd transuranium nuclei. Because the experimental information for this nuclear region is still score to fix all parameters of the theoretical approaches, in the present work we analyze the dependence of the results of the Quasiparticle-Phonon Model [1] on the parameters used for the Woods-Saxon mean-field potential and residual interaction. The calculated spectra of the low-lying nonrotational states in nuclei ^{243,245,247,249,251}Cm, ^{245,247,249,251,253,255}Cf, ^{249,251,253,255,257,259}Fm, ^{251,253,255,257,259}No, ^{255,257,259,261}Rf, ^{259,261,263,265}Sg, and ^{263,265,267,269}Hs are compared with available experimental data and other calculations [2–4].

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THE 2*p*-2*h* STUDY OF LOW-ENERGY DIPOLE STATES IN NEUTRON-RICH *N* = 80, 82 AND 84 ISOTONES

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The new spectroscopic studies of pygmy dipole resonances (PDR) [1] in neutron-rich nuclei stimulate a development of the nuclear models. One of the successful tools for describing the PDR is the quasiparticle random phase approximation (QRPA) with the self-consistent mean-field derived by making use of the Skyrme effective nucleon-nucleon interaction [2]. Such an approach describes the properties of the low-lying states less accurately than more phenomenological ones, but the results are in a reasonable agreement with experimental data. Due to the ahnarmonicity of vibrations there is a coupling between one-phonon and more complex states. The main difficulty is that the complexity of calculations beyond standard QRPA increases rapidly with the size of the configuration space, so one has to work within limited spaces. Using a finite rank separable approximation for the residual interaction obtained from the Skyrme forces that has been suggested in [3–5] one can overcome this problem. We study the properties of the low-lying dipole states in the even-even nuclei $^{126\text{-}130}$Pd, $^{128\text{-}132}$Cd, $^{130\text{-}134}$Sn, $^{132\text{-}136}$Te, and $^{134\text{-}138}$Xe. Effects of the shell structure and the neutron skin are studied in a systematic way. This reveals a number of characteristic features of the low-energy *E*1 modes. In particular, we find the impact of the shell closure on the low-energy *E*1 strength.

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LOCAL-EXCHANGE APPROXIMATION FOR THE VELOCITY-DEPENDENT TERMS OF THE SKYRME INTERACTION

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The random phase approximation (RPA) and its extended versions are an efficient tool for the description of nuclear excitations. One of the widely used models of this kind is the self-consistent RPA based on the Skyrme energy density functional (see, e.g., Ref. [1]). From a theoretical point of view, the fully self-consistent (FSC) RPA is most preferable since it provides unambiguous predictions of nuclear properties and solves the problem of the so-called spurious states. However, the RPA+FSC calculations are quite cumbersome in the case of the Skyrme particle-hole interaction, especially if the RPA equations are solved in the coordinate representation to include the single-particle continuum [2]. The main difficulties in this case are connected with the velocity-dependent terms of the Skyrme force. To avoid these difficulties, the different versions of the local approximation for these terms were proposed (see, e.g., Ref. [3]). In our work we present the approximate method of the treatment of the velocity-dependent terms based on their decomposition into the direct and exchange parts [4]. In this method, the direct term is included exactly, while the exchange term is taken into account in the local approximation. On the one hand, this allows us to use the advantages of the coordinate representation in the treatment of the single-particle continuum. On the other hand, this method (which we call the local-exchange approximation: LXA) improves the pure local approximation [3]. The LXA was used in our calculations of the giant dipole resonances in ^{16}O, ^{40}Ca and ^{208}Pb [5]. In the present work the method is analyzed in the comparison of the RPA+LXA and the RPA+FSC calculations of the giant resonances in magic nuclei.

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THE PECULIARITIES OF *E*1 RESONANCES IN ^{28}Si AND ^{30}Si NUCLEI

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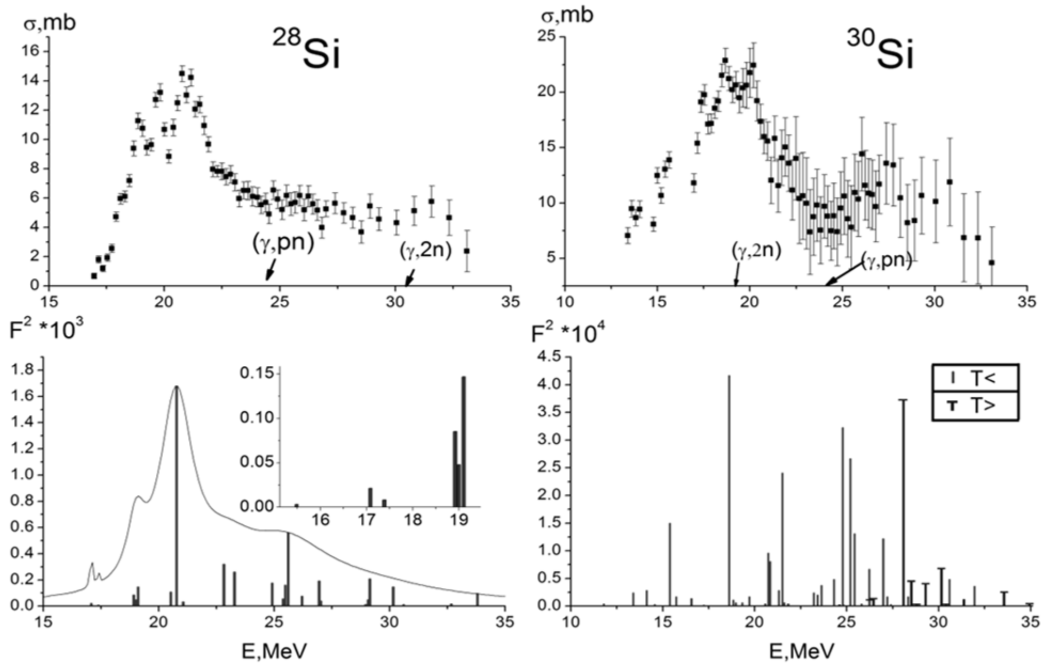
Microscopic description of dipole giant resonances was obtained for ^{28}Si and ^{30}Si in the "particle-core coupling" version of the multiparticle shell model (PCC SM) [1]. The spreading of hole configurations among the states of daughter nuclei was taking into account with help of pick-up reaction spectroscopy.

The ^{30}Si nucleus in comparison with ^{28}Si has two additional neutrons, which in the extreme single particle shell model (ESPSM) occupy 2s subshell. But the real spectroscopic factors' distributions in both nuclei [2] show considerable fragmentation of all nucleon states involved in the forming of *E*1 resonance. E.g. transitions from $1d_{3/2}$ states seems to be very important in dipole excitations for both nuclei in the energy area lower than main *E*1 peak. In *E*1 in ^{30}Si these transitions dominate at $E < 17$ MeV. In the figures are shown calculated form factors of *E1*excitations for ^{28}Si and ^{30}Si together with experimental distributions of (γ,n) cross sections from [3]. For *E*1 in ^{28}Si and ^{30}Si the main peaks correspond mostly to $1d_{5/2}\rightarrow 1f_{7/2}$ transitions. The *E*1 states with $T = 2$ in ^{30}Si dominate at $E > 26$ MeV. The energy splitting of hole states revealed in the pick-up reaction spectroscopy is the main source of *E*1 resonance fragmentation in ^{28}Si and ^{30}Si nuclei.



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UNITARITY OF THE PARTICLE-HOLE DISPERSIVE OPTICAL MODEL

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Within a recently developed particle-hole dispersive optical model (PHDOM) the main relaxation modes of high-energy particle-hole-type nuclear excitations are commonly taken into account [1]. In connection with the description of isoscalar monopole (ISM) excitations within the PHDOM (first results are obtained in [2]) the question of violation of the model unitarity arises. The source of the violation is the use of the optical-model Green functions. The latter satisfy equations that contain an optical-model energy-dependent term (having the imaginary and real parts) which is added to the nuclear mean field. The signatures of violation are: (i) a non-zero value of the calculated strength function $S_1(\omega)$, corresponding to the "spurious" external field $V(r)=1$ (the general expression for an ISM external field is $V(\vec{r})=V(r)Y_{00}(\vec{n})$; (ii) negative values of the strength function $S_{r^2}(\omega)$ at high excitation energies ω, that leads to underestimation of the corresponding energy-weighted sum rule. To restore unitarity of the model, we properly modify the energy-averaged ISM double transition density by adding to it a term involving the ground-state density normalized to unity. As a result, we get: (i) the zero value for the modified "spurious" strength function; (ii) the modified ISM strength functions, which are now evaluated for the modified external field $V(r)-\langle V\rangle$ with averaging over the ground-state density. Illustrative calculations based on the results of [2] are performed for ^{208}Pb.

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SOME UNIVERSALITIES IN PROPERTIES OF THE DENSITY MATRICES FOR FINITE NUCLEI (BOUND SYSTEMS)

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The intrinsic one-body and two-body density matrices in coordinate space and corresponding Fourier transforms in momentum space have been studied for a nucleus (a nonrelativistic system) that consists of A nucleons (particles) [1-2]. There shown how these quantities of primary concern can be expressed through expectations values of the A-particle multiplicative operators $\hat{\rho}^{[1]}_{\text{int}}$ and $\hat{\rho}^{[2]}_{\text{int}}$ sandwiched between intrinsic nuclear states. Our consideration is translationally invariant since the operators depend on the relative coordinates and momenta (Jacobi variables). To avoid a cumbersome multiple integration, we have developed an algebraic technique based upon the Cartesian or boson representation, in which the Jacobi variables are the linear combinations of the creation and destruction operators $\vec{a}^{+}$ and $\vec{a}$ for oscillator quanta in the three different space directions. In the framework of the subsequent operations the normal ordering of the operators involved in $\hat{\rho}^{[1]}_{\text{int}}$ and $\hat{\rho}^{[2]}_{\text{int}}$ plays a central role in getting both the general results and the working formulae [1].

In the course of such a procedure the own “Tassie-Barker” (TB) factors stem directly from the intrinsic operators (not the intrinsic wave functions (WF’s)). In other words, their appearance is not an exclusive property inherent in the harmonic oscillatory model used in the original calculation of the charge FF after Tassie and Barker. Each of them is a Gaussian whose behavior in the space of variables is governed by a size parameter and particle number *A* for a given finite system (nucleus) and does not depend upon the choice of the g. s. WF. The latter can be a simple Slater determinant, embody SRCs or not, be CMM corrected or not, etc. After separation of the TB factors we propose additional analytic means in order to simplify subsequent calculations (including the well-known cluster expansions for remaining many-body operators). Our calculations [2] of the density and momentum distributions for nuclei ^{4}He and ^{16}O, which have been carried out in this framework, will be shown together with the available data.

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β-DECAY RATES OF $^{54,56}Ca$

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The experimental studies of the β-decay properties of $^{54,56}Ca$ are presently the object of very intensive activity [1–3]. The low-energy spectrum of the Gamow-Teller (GT) states is a key character in the presence of the tensor correlations [4]. One of the successful tools for the studies of GT strength distributions is the quasiparticle random phase approximation (QRPA) with the self-consistent mean-field derived by the Skyrme interaction. These QRPA calculations allow one to relate the properties of the ground states and excited states through the same energy density functional. Making use of the finite rank separable approximation (FRSA) [5–7] for the residual interaction enables one to take into account the effects of the tensor correlations and the 2*p*–2*h* fragmentation on the GT transitions [8]. In this report the β-decay rates of $^{54,56}Ca$ are studied within the approach. Taking into account these effects results in a dramatic reduction of β-decay half-lives. The 2p-2h impact on the half-lives comes inherently from the $[1^+_1 \otimes 2^+_1]_{QRPA}$ term of the wave function of the 1^+_1 state.

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β-DECAY $^{65}Zn \rightarrow ^{65}Cu$

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β^+-decay $^{65}Zn \rightarrow ^{65}Cu$ has been described by means of the method offered in [1]. Quasiparticle and multy-phonon states (up to ten phonons) of main band of even-even core, as well as influence of vacuum fluctuations of quasiparticles to reduced probabilities of beta-transitions are taken into account.

The β transitions with maximum intensity and probability occur from the ground state of ^{65}Zn, the main contribution in which gives neutron one-particle state $f_{5/2}$, to $3/2_1^-$ and $5/2_1^-$ states of ^{65}Cu, the main contributions in which give the proton one-particle states $p_{3/2}$ and $f_{5/2}$ accordingly.

The comparison of experimental and calculated $\lg ft$ are present in the table.

I^π	$3/2_1^-$	$5/2_1^-$
E	0	1115.6
I,%	49.4	50.6
$\lg ft$, exp.	7.5	5.9
$\lg ft$, cal.	7.49	6.0

The renormalization of weak interaction constants in this calculation was the same as for the nuclei with $31 < A < 231$. Hence, it does not depend of Fermi surface of nuclei, so and from Fermi and Gamow-Teller resonances.

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BETA HALF-LIVES PREDICTIONS FOR NEUTRON-RICH SHORT-LIVED NUCLEI

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Beta-decay rates is one of the main nuclear parameters of neutron-rich nuclei. It is very important for astrophysical r-process nucleosynthesis. These characteristics for extended number of neutron-rich nuclei, important for the heavy nuclei formation were calculated.

For beta-decay rates predictions for neutron-rich nuclei models of beta strength-function are usually used [1, 2]. In this work for the beta-decay rates calculations we used the beta-strength function model derived in the framework of approach, based on the finite Fermi-systems theory. On the basis of the model the consequent calculations of neutron emission and beta-delayed fission probabilities were derived recently for actinides [3]. The consistent calculations of beta-decay rates based on the same model are needed for predictions of heavy and superheavy nuclei abundances in the *r*-process nucleosynthesis.

When it was shown [4] that the values of beta-decay rates strongly depend on abundances of rare earth elements, forming in nucleosintesys in very high neutron environment, more exact calculations became actual. After the comparison with other predictions and experimental data was done it was shown that accuracy of beta-decay half-lives of short-lived neutron rich nuclei is increasing with increasing of neutron excess that is sufficiently good for modeling of nucleosynthesis of heavy nuclei in the *r*-process.

The new calculations confirm the proposition [4], that beta-decay rates of translead nuclei are significantly shorter, than half-lives predicted earlier [2]. That is even more important for the *r*-process in the region beyond lead where the half-lives of neutron-rich nuclei systematically 10 times in average less, than by other predictions [2]. Some of our results mentioned here were also summarized in [3].

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EFFECT OF INTENSELY HEATED MEDIUM ON BRANCHING COEFFICIENTS FOR MULTIBETA-DECAY NUCLEI

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The aim of this paper is to investigate how the ionization of an atomic *K* shell in a high-temperature field varies the δ branching coefficients for the multibeta-decay nuclei. The δ branching coefficient determines the fraction of the electron beta-decay in the total decay rate for multibeta-decay nucleus. In the mass-number range between 74 and 196 there are 33 of such nuclei: ^{74}As, ^{78}Br, ^{80}Br, ^{84}Rb, ^{92}Nb, ^{94}Nb, ^{96}Tc, ^{98}Tc, ^{102}Rh, ^{106}Ag, ^{108}Ag, ^{110}Ag, ^{112}In, ^{114}In, ^{120}Sb, ^{124}I, ^{126}I, ^{130}Cs, ^{132}Cs, ^{136}La, ^{138}La, ^{144}Pm, ^{152}Eu, ^{156}Tb, ^{158}Tb, ^{162}Ho, ^{164}Ho, ^{168}Tm, ^{174}Lu, ^{180}Ta, ^{184}Re, ^{190}Ir, and ^{196}Au. The branching coefficients received in the terrestrial conditions are well-known [1]. In the extremely heated medium the atomic ionization multiplicity, including the *K* shell, is high and the capture of atomic electrons by multibeta-decay nucleus is hindered. This effect for multi-decay nuclei with anomalously small values of the branching coefficients can significantly increase the contribution of their electronic beta-decay [2].

The range of nuclear temperatures from 0.2 to 0.5 MeV in energy units which corresponds to the stages of the oxygen and silicon layer burning in massive star was considered. The ionization degree of atomic *K* shell is calculated by using the Saha-Boltzmann formula. The following maximal temperatures of the substance of a massive star, *T* are used: $3{\cdot}10^9$ K for the stage of oxygen burning and $5{\cdot}10^9$ K for the stage of silicon burning.

The action of the high-temperature field on beta processes and the suppression of the electron *K* capture change substantially the δ coefficients in the relation to their terrestrial values. The calculated values of the δ branching coefficients may be of interest not only as it is but also for the models intended for describing the synthesis of *p*-nuclei at various stages of massive-star evolution.

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IONIZATION DEGREE OF ATOMIC *K*-SHELL AND RATE OF *P*-NUCLEUS SYNTHESIS IN MASSIVE STAR INTERIOR

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The *p*-nucleus abundances are calculated from the set of kinetic equations written for the chain of the beta-decays, (A; Z)→(A; Z+1)→(A; Z+2). Here under terrestrial conditions the progenitor nucleus, (A; Z), and the *p*-nucleus, (A; Z+2), are stable but they have become beta active in extremely heated substance. The intermediate odd-odd nucleus, (A; Z+1), is multibeta-decay. Our model considers the quasi-equilibrium stages of massive-star evolution. We investigated the high temperature stages of oxygen and silicon burning in massive stars when the temperature of the substance reaches the "nuclear" values of 0.2–0.5 MeV in energy units. In these calculations it is significant to take into account all the modes of thermal nuclear beta-transitions (electron capture, electron and positron transitions) and nuclear photobeta-decay. For the final abundance, $N(T, \tau)$, of the *p*-nucleus, (A; Z+2), the analytical solution of kinetic equations was previously received [1] (T is the substance temperature, τ is the stage duration of star evolution). It is necessary to make preliminary calculations of the total rates of electron beta-transition, (A; Z)→(A; Z+1), reverse beta-transition, (A; Z+1)→(A; Z) (it includes the positron beta transition and electron K capture) and the electron beta transition, (A; Z+1)→(A; Z+2). All these rates depend on medium temperature. In addition it is necessary to know the initial abundance of the progenitor nuclei, (A; Z).

We estimated the ionization degree of atomic K shell in the substance of a massive star heated up to the "nuclear" temperatures of 0.2–0.5 MeV in energy units. The ionization degree of atomic shell is calculated by using the Saha-Boltzmann formula. The following maximal temperatures of the substance of a massive star, T are used: $3\cdot 10^9$ K for the stage of oxygen burning and $5\cdot 10^9$ K for the stage of silicon burning. The ionization degree of atomic K shell has an effect on the electron K capture rate and the total rates of reverse beta-transition, (A; Z+1)→(A; Z). The final abundances, $N(T, \tau)$, of the p nuclei, (A; Z+2), are calculated for the quantities of the τ parameter equal to 5 months or 1 day for the stages of oxygen or silicon burning respectively. The initial abundances of the progenitor nuclei, (A; Z), are taken from Ref. [2]. The nuclear matrix elements are obtained by focusing on the typical values of lg*ft* = 4.5–5.5 for unfavored allowed transitions. As a result, the "solar" abundances of the 27 from 33 p isotopes can be received at the stages of the oxygen and silicon burning in massive stars.

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ACTIVATION OF NUCLEAR ISOMERIC STATES BY SYNCHROTRON RADIATION

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The excitation probability of nuclear isomeric states in nuclei with two low-laying excited states by a synchrotron radiation is calculated. The lower one is an isomeric state having the energy, E^*, and the total spin, J^*. The higher one is an excited state with the energy less than 250 keV. Besides, the total spin, J, of this state is such that the electromagnetic transitions of the low multipolarity to the ground state and to the isomeric state are allowed.

Radiation from the synchrotron of the third generation (Spring-8, Japan) is considered [1]. This synchrotron produces electromagnetic waves with the photon energies up to 300 keV. Such radiant energy range assumes a research of the direct effect of the radiation onto characteristics of the nuclear states. In addition, the synchrotrons of the third generation produce a high-intensity radiation of the frequency continuous spectrum (from a wiggler) or even a higher-intensity radiation of the quasi-discrete frequency spectrum (from a magnetic undulator).

Our model includes the resonant transition from the ground state of the nucleus under consideration to the second excited state and then the natural electromagnetic transition from this state to the isomeric one. This transition involves spontaneous component and induced component. The time dynamics of the energy level population in the synchrotron radiation field is estimated from a set the kinetic equations. Nuclei with the reliable values of the experimental characteristics are investigated. These are ^{58}Co, ^{94}Nb, ^{96}Tc, ^{144}Pr, ^{169}Lu, ^{171}Lu ^{191}Os, and ^{235}U. The rates of the excitation processes of the nuclear isomeric states are calculated by using the well-known form of the electromagnetic spectra of the Spring-8 synchrotron (from the wiggler) [1].

It is obtained that the values of nucleus yields in the isomeric states are in the (10^4–10^8) s^{-1} range. Only ^{169}Lu and ^{171}Lu isotopes with very small energies of the $5/2^- \rightarrow 1/2^-$ transitions, when the probability of conversion process is large, are the exception. In these cases the yields of the isomeric state excitations are 0.66 s^{-1} and 0.54 s^{-1}, respectively. For ^{58}Co and ^{144}Pr nuclei the experimental widths of the radiation transitions are known from experiments. The rates of the excitation processes of the isomeric states calculated by using these widths differ from those obtained with the single-particle widths by less than an order of the magnitude.

1. http://www.spring8.or.jp

NUCLEAR-OPTICAL TECHNOLOGIES OF THE NEW GENERATION

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Of great interest are nuclides, in which there are excited state with extremely low energies, within the scale of e few eV or keV [1]: ^{201}Hg, ^{189}Os, ^{237}Np, ^{235}U, ^{229}Th and other nuclides. Such levels are isomeric owing to small their energies. They effectively mix up with close atomic levels, forming resonances in the optical domain [2]. This gives the chance to operate with the lifetimes of these isomers in a resonant field of laser radiation. Unlike the atomic spectra, the nuclear lines are stable against influence of external fields and environment. They possess rather narrow widths. These advantages do their use attractive in many aspects, including creation of reference points of frequency in the optical range. This gives basis for development new nuclear technologies, founded on application of lasers for mastering nuclear processes. From such standpoint, one of the most perspective looks ^{229}Th, in which nucleus the splitting of the basic and excited levels is minimum and makes less than 10 эВ [3]. There are projects of creation of an atomic clock on this transition with an uncertainty within 10^{-21} [4].

Topical issues of study of this isomer are considered: experimental determination of exact energy of this isomer and optical pumping the isomeric atoms through one- and two-photon absorbgtion. It is shown that in both cases the decisive contribution occurs still from the resonant *8s–7s* electronic transition. Details of the optimum scheme of experiment in neutral atoms and ions are discussed. Estimated time of the two-photon pumping in single ions of ^{229}Th^{II} makes about 1.5 s with at intensity of the fields of each laser of 1 V/cm.

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THE BOHR-WEISSKOPF EFFECT IN THE HYPERFINE SPLITTING AND THE NUCLEAR STRUCTURE

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For twenty years research into the anomalies in the hyperfine spectra was going in a wrong direction, based on fighting the Bohr-Weisskopf effect. This effect in the hyperfine structure is defined as arising due to distribution of the nuclear magnetization over the finite nuclear size. As way out, we propose the constructive model-independent way, allowing one to extract information about the nuclear structure from the data. The way is based on analogy of hyperfine splitting to internal conversion coefficients, and the Bohr-Weisskopf effect — to the anomalies in the internal conversion coefficients. It is shown that the parameters which can be extracted from the data are the even nuclear moments of the magnetization distribution. The method enables the nuclear moments to be determined, only if the higher QED effects are properly taken into account. Therefore, the proposed method offers a strict test of both QED and atomic calculations, on one hand, and experimental data – on the other hand. Experimental recommendations are given, aimed at retrieving data on the HFS values for a set of few-electron configurations of various atoms.

The radii R_2 and, for the first time, R_4 are obtained in this way by experiment fit of the HFS values for the H- and Li-like ions of ^{209}Bi. The momenta radii determined as a result of experiment fit are R_2 = 6.12 fm, and R_4 = 6.78 fm. The critical prediction is made concerning the HFS for the $2p_{1/2}$-state: 0.25753 eV.

PROBABILITY OF THE SINGLE-QUANTUM ANNIHILATION OF POSITRONS AVERAGED OVER ATOMIC ELECTRONS

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The processes of positron – atomic electron annihilation studied well enough [1]. In some cases the necessity to find the total probability of the process of positron annihilation with electrons of the different atomic shells is appears. In this case the probability of annihilation for each electron is calculated and then summarize these probabilities.

The more simple method is suggested instead of this laborious work. This method enables to calculate approximately the probability of the single-photon annihilation of positron averaged over all atomic electrons. The statistical Thomas-Fermi method is used for that. In this method the averaged atomic electron density is calculated as function of coordinate. Usually this density is used for calculation of the atomic energy of ionization. At the present work this method is used for the calculation of cross sections of the positron-electron annihilation averaged over all atomic electrons. For this purpose Tietz approximation [2] for the average potential in which electrons move is used. The average density of the atomic electrons $n(r)$ as function of coordinates r can be calculated in this potential analytically. With this density we can calculate the average cross sections of single-photon annihilation of positron and electron σ_{av} in a case of the small positron energies ($p_+ \cdot m$, where p_+ and m are the momentum and mass of positron). This cross section is compared with the total for all electrons cross section which calculated approximately in the framework of quantum mechanic σ_{qm} at the same energies. The ratios of the cross sections $\sigma_{av} / \sigma_{qm}$ for different charges *Z* are presented in the table:

Z	85	88	90	93	95	100
$\sigma_{av} / \sigma_{qm}$	1.34	1.19	1.1	0.98	0.91	0.76

Thus the suggested method provides a possibility to calculate approximately the total for all atom the cross section of single-photon annihilation of positrons for a big charges Z.

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UNUSUAL TEMPERATURE DEPENDENCE OF THE HEAT CAPACITY AT SMALL PAIRING STRENGTHS

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The effective Hamiltonian of Bardeen, Cooper, Schriffer H_{BCS} is applied to calculations of thermodynamic properties of superfluiding or superconducting systems such as atomic nuclei or nanometer metallic clusters. Both the well-known standard variational method with H_{BCS} (SVMBCS) and the employment of the exact solutions to H_{BCS} (ESBCS) predict the appearance of only one maximum in the temperature (T) dependency of the heat capacity (C) if single-particle spectra of systems are either equidistant or near the Fermi level there are two solitary levels (filled by N particles) with degeneracies $(2\Omega_1, 2\Omega_2)$ and the lower one is completely filled by particles at $G = T = 0$, G is the pairing strength, i.e. $N = 2\Omega_1$. However, calculations of C_{can} for the canonical ensemble with ESBCS show that single-particle level structure can cause appearance of two maxima of C_{can} if the degenerate Fermi level is unfilled. The explanation of this phenomenon lies in that at the beginning imparted heat is used up for particle excitations inside the Fermi level – this gives the first maximum. A further rise in T transfers particles to the upper level, i.e. both levels work simultaneously that gives the second maximum. Nevertheless, increase of $G/\Delta\varepsilon$ ($\Delta\varepsilon$ is the level spacing) leads to merge of two maxima in one. The work is supported by the SPbSU grant № 11.38.648.2013.

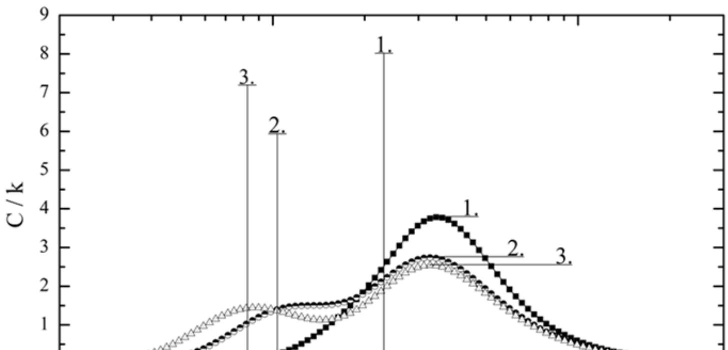

Figure displays C_{can} for two solitary levels. Values of C_{can} at T=G=0 are identical for a) – the lower level (Ω_1 = 2) is occupied by two particles, the upper one (Ω_2 = 6) is vacant; b) – the lower level (Ω_1 = 6) is completely occupied by 12 particles and the upper one (Ω_2 = 2) is half empty, i.e. in case b) the particle number on two levels is equal to 14. Numerals1.,2.,3., relate to G/ε = 0.2; 0.125; 0.1 respectively. The vertical lines in the figure show corresponding critical temperatures (T_c) of SVMBCS, their lengths amount to the maximum values of C_{BCS} at T_c.

ON THE POSSIBLE PRESENCE OF NEUTRAL (ANTI)LEPTONS OF ALL GENERATIONS IN THE SOLAR NEUTRINO FLUX

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In the present work, a development [1], the flavor structure of the solar neutrinos (SN) is investigated. The prediction that part of the electron neutrino flux from Sun undergo conversion into neutral (anti)leptons of other families is considered.

If the helicity ν_e is retained, their conversion into neutral leptons of the second and third generation is allowed within the left-polarized (left) neutrino concept. When the helicity changes, the right-polarized (right) neutral particles can be considered as the muon and tau antineutrinos. Consequently, it is possible, that the "solar messengers" can reach an electron target in the $\{\nu_e^L, \nu_\mu^L, \nu_\tau^L\}$ (I) and $\{\nu_e^L, \tilde{\nu}_\mu^R, \tilde{\nu}_\tau^R\}$ (II) states of the wave (anti)neutrino packet. In the framework of the four-component theory representation about right muon neutrino the preserving (changing) of the SN helicity corresponds to the state $\{\nu_e^L, \tilde{\nu}_\mu^L, \nu_\tau^L\}$ (III) ($\{\nu_e^L, \nu_\mu^R, \tilde{\nu}_\tau^R\}$ (IV)).

The summary spectra of recoil electrons from the elastic scattering on an electron, in particularly, for the states (I) and (II) are described as

$$\frac{d\sigma_{tot}}{dT} = P(\nu_e)\frac{d\sigma(\nu_e^L e)}{dT} + (1 - P(\nu_e))\frac{d\sigma(\nu_{\mu,\tau}^L e)}{dT}, \quad \text{(I)}$$

$$\frac{d\sigma_{tot}}{dT} = P(\nu_e)\frac{d\sigma(\nu_e^L e)}{dT} + (1 - P(\nu_e))\frac{d\sigma(\tilde{\nu}_{\mu,\tau}^R e)}{dT}, \quad \text{(II)}$$

where T is the electron kinetic energy, $P(\nu_e)$ is the survival probability of the SN.

The quantitative analysis and the graphic description of the standard electroweak summary spectra are presented for the scattering of beryllium SN (E_ν = 0.862 MeV) with $P(\nu_e) = 0.51 \pm 0.07$ [2].

The possibility of the SN transformation in related antineutrino is also considered, the electron spectrum containing admixture $\tilde{\nu}_e$ component is obtained and analyzed. The spectrum $\frac{d\sigma(\tilde{\nu}_e^R e)}{dT}$ sharply decreases with an increase in the electron kinetic energy from a limit value 0.59 (in units $\sigma_0 = \left(2G_F^2 m_e\right)/\pi \cong 1.712\cdot10^{-48}$ m$^2\cdot$MeV^{-1}) to zero at $T_{\max}$ = 0.67 MeV. The characteristic feature of the predicted spectrum can facilitate detection on the electron antineutrinos in the SN flux.

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STANDARD LENTONS AND NEXT LEPTON IN THEORY OF BYUON

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Physics of lepton masses nature is shown on the base of theory of byuon (TB).This theory is the “life” of special unobservable discrete objects – byuons from which the surrounding space (physical space, fundamental constants: h, e, c etc.) and the world of elementary particles (masses of basic ultimate particles, 4 fundamental interactions and new force, etc.) are formed [1–3].An essential distinction of that theory from the modern models in the classical and quantum field theories is that the potentials of physical fields (gravitational, electromagnetic, asf.) gain exactly fixable measurable values.The theory of byuons predicts the existence of a next lepton (80.4 GeV).TB give the following values for the lepton massesfromonly three constants: $\tilde{x}_0 \approx 2.78\cdot10^{-33}$cm; $\tau_0 \approx 0.927\cdot10^{-43}$ s and the module of new fundamental constant – cosmological vector-potential $A_g \approx 1.95\cdot10^{11}$ Gs·cm (defining theproperties of the byuon):

1. $m_e c^2 = m_{4\delta_e} c^2 \cdot \frac{ct^*}{x_0} \approx 0.51$ MeV; $\quad m_{4\delta_e} c^2 = \frac{|A_g|^2 \cdot \tilde{x}_0^3}{2c^2 \cdot \tau_0^2}$
2. $m_\mu c^2 = m_{4\delta_\mu} c^2 \cdot \frac{ct^*}{2x_0} \approx 105$ MeV; $\quad m_{4\delta_\mu} c^2 = \frac{|A_g|}{ct^*} \cdot \frac{A^0}{2x_0} \cdot \frac{2x_0}{ct^*} \cdot 2x_0^3$; $A^0 = \frac{2\sqrt{3}\cdot e_0}{\sqrt{x_0 ct^*}}$
3. $m_\tau c^2 = m_{4\delta_\tau} c^2 \cdot \frac{ct^*}{8x_0} \approx 1779$ MeV; $\quad m_{4\delta_\tau} c^2 = \frac{|A_g|}{ct^*} \cdot \frac{A_\tau^0}{2x_0} \cdot \frac{2x_0}{ct^*} \cdot 24 \cdot 8x_0^3$; $A_\tau^0 = \frac{2\sqrt{3}\cdot e_0}{\sqrt{2x_0 \cdot ct^*}}$
4. $m_{nx} c^2 = m_{4\delta_{nx}} c^2 \cdot \frac{ct^*}{512x_0} \approx 80.4$ GeV; $m_{4\delta_{nx}} c^2 = \frac{|A_g|}{ct^*} \cdot \frac{A_{nx}^0}{2x_0} \cdot \frac{2x_0}{ct^*} \cdot 1536 \cdot 512x_0^3$

$$A_{nx}^0 = \frac{2\sqrt{3}\cdot e_0}{\sqrt{4x_0 \cdot ct^*}}$$

Here: $x_0 = k\tilde{x}_0 \approx 0.89\cdot10^{-17}$cm; $ct^* = kN\tilde{x}_0 \approx 1{,}38\cdot10^{-13}$cm; k, N – are calculated periods of interaction of byuons ($k = 3.2\cdot10^{15}$; $N = 1.54\times10^4$).
It is discussed the last results of collaborations (CDF I, DO I, CDF II) of W^+-boson mass (80.4 GeV) and ATLAS (birth of couple $W^+ W^-$) measurements and a connection of these results with TB and next lepton.

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DIRAC MATRICES AS ELEMENTS OF SUPERALGEBRAIC MATRIX ALGEBRA

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Clifford extension $M(\Lambda_n)$ of Grassmann algebra Λ_n [1, 2] has been analyzed. The vector of state for operators of the algebra $M(\Lambda_n)$ is a sum of monoms (product of Grassmann variables θ^α) of all possible ranks: $\Psi = \psi_0 1 + \psi_\alpha \theta^\alpha + \psi_{\alpha\beta}\theta^\alpha\theta^\beta + \ldots + \psi_{\alpha\beta\ldots\eta}\theta^\alpha\theta^\beta\ldots\theta^\eta$.

It has been shown that the matrix M of arbitrary linear transformations of elements θ^β can be mapped to an element $\hat{M} = m_\alpha{}^\beta \hat{\theta}^\alpha \frac{\partial}{\partial\theta^\beta}\hat{P}_1$ of the algebra, where $\hat{P}_1$ is a projector on the space ${}^1\Lambda$ of monoms of rank 1 (a linear space with basis elements θ^α). The operator $\hat{P}_n = \hat{\theta}^1\hat{\theta}^2\ldots\hat{\theta}^n \frac{\partial}{\partial\theta^n}\ldots\frac{\partial}{\partial\theta^2}\frac{\partial}{\partial\theta^1}$ is a projector on the space ${}^n\Lambda$ of monoms of rank n, the operator $\hat{P}_{n-1} = \hat{\theta}^{\alpha_1}\hat{\theta}^{\alpha_2}\ldots\hat{\theta}^{\alpha_{n-1}} \frac{\partial}{\partial\theta^{\alpha_{n-1}}}\ldots\frac{\partial}{\partial\theta^{\alpha_2}}\frac{\partial}{\partial\theta^{\alpha_1}}(\hat{1}-\hat{P}_n)$ is a projector on the space ${}^{n-1}\Lambda$ of monoms of rank $n-1$, and so on. The element transposed to $\hat{\theta}^\alpha$ is defined as $(\hat{\theta}^\alpha)^T = \frac{\partial}{\partial\theta^\alpha}$, and $(\frac{\partial}{\partial\theta^\alpha})^T = \hat{\theta}^\alpha$, $(AB)^T = B^T A^T$.

It has been found that such a subalgebra of $M(\Lambda_n)$ is isomorphic to the usual matrix algebra. It is referred to as $\mathrm{Mat}(\Lambda_n)$. However, the algebra $M(\Lambda_n)$ has extra operators $M({}^k\Lambda, {}^l\Lambda) = m_{\beta_1\ldots\beta_l}{}^{\alpha_k\ldots\alpha_1}\hat{\theta}^{\beta_1}\ldots\hat{\theta}^{\beta_l}\frac{\partial}{\partial\theta^{\alpha_k}}\ldots\frac{\partial}{\partial\theta^{\alpha_1}}\hat{P}_k$ that transform the monoms of rank k (elements of the subspace ${}^k\Lambda$) into the monoms of rank l (elements of the subspace ${}^l\Lambda$).

The column-operator, which corresponds to the matrix of a single column, is a generalized matrix $m_\alpha\hat{\theta}^\alpha\hat{P}_0$ which transforms ${}^0\Lambda$ to ${}^1\Lambda$, and the row-operator, which corresponds to the matrix of the single row, is a generalized matrix $m^\beta\frac{\partial}{\partial\theta^\beta}\hat{P}_1$ which transforms ${}^1\Lambda$ to ${}^0\Lambda$.

The conclusion is made that the Dirac matrices can be constructed as operators of the generalized matrix algebra $\mathrm{Mat}(\Lambda_n)$. This allows us to treat the Dirac matrices not as some unrelated elements to odd variables of supersymmetric theories, but as natural elements of a generalized matrix algebra, and the operators $M({}^k\Lambda, {}^l\Lambda)$ as an extension of spin-tensors to superspace.

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ENERGY CHARACTERISTICS OF RELATIVISTIC CHARGED PARTICLE IN A CIRCULARLY POLARIZED PHASE-FREQUENCY MODULATED ELECTROMAGNETIC WAVE AND IN THE CONSTANT MAGNETIC FIELD

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We consider the dynamics of a relativistic electron in a strong phase-frequency modulated electromagnetic field of circular polarization and in constant magnetic field. The interaction of charged particles with ultrashort femtosecond laser pulses with intensities of radiation to 10^{22} W/cm^2 is one of the main areas of laser physics at the moment.

In this paper, we assumed that a plane monochromatic electromagnetic wave modulated by phase-frequency [1]. We obtained the following result for the average kinetic energy of the particle over the period of vibration:

$$\overline{\varepsilon} - mc^2 = mc^2\left(h + \sigma^2 \sum_{n=-N}^{N} \tilde{Z}_n^4 \frac{\left(S_n^2 + 8\delta^2 N_n\right)}{32(1+h)} \right). \quad (1)$$

where

$$\tilde{Z}_n = J_n(\mu) / \left((1+n\eta)^2 - \delta^2\right),\ N_n = (1+n\eta)^2 + \delta^2,\ S_n = (1+n\eta)^2 - \delta^2,$$
$$h = \frac{\sigma}{4}\sum_{n=-N}^{N} \tilde{Z}_n^2 T_n,\ T_n = (1+n\eta)^2 + 3\delta^2, \sigma = \frac{q^2 b^2}{m^2 c^2 \omega^2} = \frac{2q^2}{\pi m^2 c^5} I\lambda^2. \quad (2)$$

Here $I = cb^2/8\pi$ – the intensity of a circularly polarized electromagnetic wave; $\lambda = 2\pi c/\omega$ – wavelength; mc^2 – the rest energy of a charged particle; $q > 0$ the absolute value of the electron charge; δ – frequency ratio of ω_c and ω and besides $\delta \in [0;1)$; $\eta = \omega'/\omega$; $\mu = \Delta\omega_m/\omega'$ – modulation index equal to the ratio of frequency deviation to the frequency of the modulating wave; ω' – frequency modulation; $J_n(\mu)$ – the *n*-th Bessel function.

In the absence of phase-frequency modulation and constant magnetic field, we obtain formula for the case of circular polarization [2].

The resulting formula for contains an explicit dependence on the initial data: the amplitude of the electromagnetic wave, frequency carrier wave and modulation frequency, intensity and polarization. It allows to carry out practical calculations.

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GAMMA-DECAY TRANSITION RATES AND CONFIGURATION SPLITTING IN THE TWO-GROUP SHELL MODEL

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In our previous paper [1] we considered intershell beta- and gamma-decay transition rates between the two-group configurations, specifically between the configurations $\left\{ j_1^{n_1}(s_1\alpha_1J_1)\, j_2^{n_2}(s_2\alpha_2J_2)\right\}$ and $\left\{ j_1^{n_1-1}(s_1'\alpha_1'J_1'),\, j_2^{n_2+1}(s_2'\alpha_2'J_2')\right\}$. Here, we consider gamma-transitions within the configuration $\left\{ j_1^{n_1}, j_2^{n_2}\right\}$, as well as configuration splitting conditioned by the two-body interaction. For this aim, we use the formalism of the two-group fractional parentage expansions, that takes account of antisymmetrization, and the Racah algebra. The obtained formulas may be strongly simplified in case of odd-odd nuclei, if we consider multiparticle states with lowest values of seniorities. In this way, we obtain simple analytical expressions for transition rates, as well as for electric quadrupole and magnetic dipole moments. The formulas are applied for description of experimental data in nuclei close to ^{90}Zr. We obtained a good agreement with the experiment over the data on the *E*2 transition rates, values of quadrupole and dipole moments, as well as over data on energy spectra of odd-odd isotones with N = 51. When calculating energy spectra, we employed effective interaction used by us before [2, 3].

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ON THE PROPERTIES OF *N*=50 EVEN-EVEN ISOTONES FROM ^{78}Ni TO ^{100}Sn

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By now, basic efforts in experimental nuclear physics are concentrated on investigation of nuclei far from the stability line. In papers [1, 2], we performed calculations of basic properties of nuclei in the long chains of isotopes of Ni (Z=28), from proton excess ^{48}Ni up to neutron-excess ^{78}Ni, and of isotopes of Sn (Z=50), from ^{100}Sn to ^{132}Sn. Here, we study the chain of N=50 isotones, from neutron-excess ^{78}Ni, up to proton-excess ^{100}Sn. We calculate binding and one-nucleon separation energies, density distributions of protons and neutrons, root-mean-square radii, as well as excitation energies and transition rates. Below, we show excitation energies and corresponding transition rates of the lowest quadrupole states in even-even nuclei with N=50.

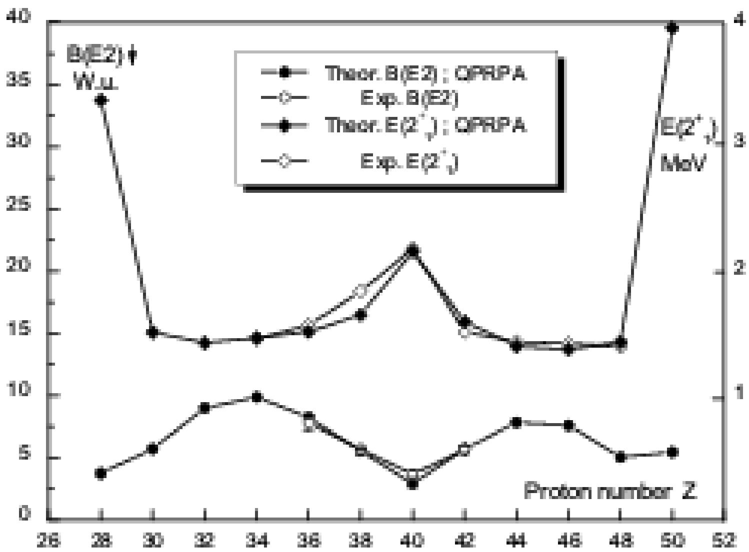

Fig. 1. Energies of the 2^+_1 levels and transition rates in the sequence of N=50 isotones, from ^{78}Ni to ^{100}Sn.

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PROBABILITIES OF MAGNETIC TOROIDAL MONO-FIELDS IN THE NON-STATIONARY PROCESSES OF RADIOACTIVE LUTETIUM OXIDE

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The issues of magnetism, its nature have been recently discussed in large extent by Ginzburg V.A. [1] and Kopaev Yu.V. [2]. In contrast to us, they reviewed not the radioactive materials of other chemical content, but as we are they extremely focused on the toroidal polarization of the discussed material. In general, our approaches for solving the problems are simply not compatible and our decision to consider and provide other theoretical interpretations than those considered by them in their problems is quite objectively justified. The methods of nuclear electron spectroscopy are quite effective in solving the various complex problems.

It is interesting, that the super-strong magnetic field, observed in the process of toroidal polarization, providing the line splitting of the *M* and *N* - shells of nuclear states, agitates the assumption relating to the features of toroidal magnetic mono-fields formation, which different versions have not recently deny the various theories.

It is undisputable, that the serious explanation for the observed experimental data should lead to the important theoretical conclusions, and possibly to the major proposals to consider some options of their practical use based on them.

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STUDY OF PENETRATION EFFECTS IN 69.7 keV *M*1-TRANSITION IN ^{153}Eu

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Study of penetration effects in *M*1-transitions gives a unique opportunity to estimate the value and the sign of spin-multipole force. Note, that except for *E*1-transitions this is the only way to obtain such an information for other multipolarities.

Penetration effects for M1-transitions are described by the expression $\alpha_K^{exp} = \alpha_K^{tab}(1 + B_1\lambda + B_2\lambda^2)$, where α are table and experimental values of internal conversion coefficients on *K*-shell, B_i are electronic parameters given in corresponding tables.

Penetration effects contribution is usually about few percents, so α_K^{exp} should be measured with the accuracy of (1–2)%.

We performed measurement of α_K of 69.7 keV transition by comparison of intensity of its γ-rays (I_γ) and characteristic radiation (I_{Kx}) accompanying internal conversion process $\alpha_K = I_{Kx} / (I_\gamma \cdot \omega_K)$, where ω_K is fluorescence yield.

Measurements were performed with ^{153}Gd source ^{153}Gd ($T_{1/2}$ = 241.6 days). The source was produced at KINR research reactor. Via electron capture ^{153}Gd is decayed on excited states of ^{153}Eu. The state with energy 173 keV ($I^\pi = 5/2^+$) is decayed by inhibited *M*1-transition (F_W=4.5) with energy 69.7 keV. We carried out the measurement using Ge-spectrometer with 500 eV resolution in 70 keV energy region. Intensity of triple summation peaks ($I_{\gamma 103} + I_{Kx} + I_{Kx}$) and ($I_{\gamma 103} + I_{\gamma 69} + I_{Kx}$) was measured. From these data $\alpha_K^{exp} = 4.31 \pm 0.09$ value has been determined. Statistical error was about (0.3–0.5)%. The accuracy of relative registration efficiency is within 0.5% due to proximity of K_X-radiation and γ 69.7 keV. However, because of large (up to 30%) contribution of accidental coincidences the total error was found to be (1.5–2)%. The table value is α_K^{tab}= 4.51 taking into account 1.9% admixture of *E*2-component.

From these data we found penetration parameter value $\lambda = -1.9 \pm 1.1$ corresponding to penetration effects in 69.7 keV transition of ^{153}Eu. Obtained results are under discussion.

DAMPING OF DEEP-HOLE STATES IN MEDIUM-HEAVY-MASS SPHERICAL NUCLEI

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Experimentally found the anomalously large excitation energy and total width of deep-hole states in the ^{90}Zr and ^{208}Pb parent nuclei [1] motivates us to apply a recently reformulated single-quasiparticle dispersive optical-model (SQDOM) [2] to the description of these states. In most Hartree-Fock calculations exploited different versions of Skyrme-type forces the energy of $1s_{1/2}$-states in ^{208}Pb is strongly underestimated [3]. The same conclusion is obtained with the use of phenomenological partially self-consistent mean-field exploited in [2]. Starting from this mean field, we apply the dispersive relationship of [2] to evaluate an energy-dependent addition to the mean field via an energy-dependent imaginary part of the optical-model potential. The parameters of this part are adjusted to reproduce via an iterative procedure the observable total width and excitation energy of a number of deep-hole states. Such a procedure, allowing us to describe at least qualitatively the deep-hole states in the ^{90}Zr and ^{208}Pb parent nuclei, demonstrate abilities of the SQDOM in phenomenological description of the spreading effect on properties of high-energy single-quasiparticle excitations in medium-heavy-mass spherical nuclei.

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ASYMPTOTIC MODELS FOR STUDYING KINETICS OF FORMATION OF COMPACT OBJECTS WITH STRONG INTERNAL BONDS

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An asymptotic method [1] has been developed for investigation of kinetics of formation of compact objects with strong internal bonds. The method is based on the uncertainty relation for a coordinate and a momentum in space of sizes of objects (clusters) with strongly pronounced collective quantum properties resulted from exchange interactions of various physical nature determined by spatial scales of the processes under consideration. The proposed phenomenological approach has been developed by analogy with the all-known ideas about coherent states of quantum mechanical oscillator systems for which a product of coordinate and momentum uncertainties (dispersions) accepts the value, which is minimally possible within uncertainty relations. With such an approach the leading processes are oscillations of components that make up objects, mainly: collective nucleon oscillations in a nucleus and phonon excitations in a mesostructure crystal lattice. This allows us to consider formation and growth of subatomic and mesoscopic objects in the context of a single formalism. The proposed models adequately describe characteristics of formation processes of nuclear matter clusters as well as mesoscopic crystals having covalent and quasi-covalent bonds between atoms.

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BOUND FERMION STATES IN THE FIELD OF THE SOLITON OF THE NONLINEAR *O*(3) σ-MODEL

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The (2 + 1)-dimensional nonlinear *O*(3) σ-model whose *n*-field is coupled to the fermion field by the Yukawa interaction has been examined. The cases of the isosinglet and isodoublet fermion fields with respect to the internal symmetry group have been considered. It has been shown that bound states of the fermion in the *n*-field of the soliton [1] of the nonlinear *O*(3) σ-model exist for some variants of the Yukawa interaction. The absence of zeroth fermion modes in the *n*-field of the soliton has been established. The properties of the ground state of the fermion have been numerically studied. In particular, it has been shown that an increase in the spatial size of the soliton results in a decrease in the energy of the ground state. This leads to the instability of the soliton in a certain region of the parameters of the model.

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QUADRUPOLE DEFORMATION PARAMETER OF EVEN-EVEN NUCLEI IN THE RANGE OF $58 \le A \le 250$ AND THE COUPLED CHANNEL OPTICAL MODEL

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Earlier, we analyzed experimental data on the interaction of low energy neutrons (0.04–3.0 MeV) with even-even isotopes over a wide range of mass numbers with $58 \le A \le 246$ in the context of the coupled channel optical model (CCOM). The aim of analyzing the neutron data for a large number of nuclei, differing considerably in their properties, is to obtain a uniform description of the whole set of the data, to find shell effects in neutron cross sections, and to search for nontraditional magic nuclei.

Our consideration involved a variety of options of Woods-Saxon potential. The CCOM parameters for each nucleus were found from the best description of the considered data. The use of this approach allowed us to obtain a good description for even-even nuclei over a range $58 \le A \le 246$ with common CCOM parameters [1]. For magic (both traditional and non-traditional) and non-spherical nuclei diffuseness parameter value was different from the average value of 0.65 fm. These deviations are well described by the behavior of the N_pN_n product, where N_p and N_n – number of valence protons and neutrons.

The values of the quadrupole deformation parameters, determining the matrix elements of channel coupling in the CCOM, were chosen equal to values, which were obtained mainly from electromagnetic processes (e.g. [5]).

However, experimental studies of inelastic scattering of protons and neutrons on near magic nuclei [3] show the difference in nuclear and electromagnetic parameters of deformation. At a neutron energy of several MeV a good phenomenological description of elastic scattering and total cross sections for deformed nuclei was obtained for values β_2, substantially lower (~ 30%) than the values determined from Coulomb excitation (e.g. [4]).

We attempted to obtain an optimal description for "ambiguous" nuclei in terms of a unified approach by changing the core values β_2, derived from data on electromagnetic processes, and analyze these changes in terms of NpNn systematic.

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PRODUCTION OF STRANGE PARTICLES IN THE FRAMEWORK OF MULTI-POMERON EXCHANGE MODEL

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We propose an extension of multi-pomeron exchange model [1–3] by accounting the production of strange particles. The model [1–3] describes consistently multiplicity, transverse momentum and their correlation in pp and ppbar collisions in a wide energy range (from ISR to LHC) by introducing string interaction in an effective way. The particles species differentiation is implemented according to Schwinger mechanism [4].

The results on strange particles yields, their transverse momentum and correlations are presented and compared to the experimental data. We discuss also the influence of higher resonances on these observables.

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ZERO-SOUND EXCITATIONS IN THE ASYMMETRIC NUCLEAR MATTER

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The particle-hole polarization operator $\Pi(\omega,k)$ for the asymmetric nuclear matter (ANM) in the Fermi-liquid theory is constructed in accordance with [1]. The ANM is characterized by the asymmetry parameter $\beta=(\rho_n-\rho_p)/(\rho_n+\rho_p)$, where ρ_n (ρ_p) – is the neutron (proton) density. To obtain $\Pi(\omega,k)$ we should investigate the different intervals for the momentum k. Here the interval $p_{Fn} - p_{Fp} < k < p_{Fp}$ is taken, p_{Fn} (p_{Fp}) – is the neutron (proton) Fermi momentum. The values of k in this interval correspond to the momenta of giant dipole resonances in nuclei [2].

In our method [2] we calculate the complex solutions, $\omega_s(k,\beta)$, to the dispersion zero-sound equation. The imaginary part of $\omega_s(k,\beta)$ corresponds to the emission width of excitations in nuclei, when one particle (proton or neutron) is emitted. In ANM the solutions $\omega_s(k,\beta)$ are different in the proton and neutron decay channels. Dependence of $\omega_s(k,\beta)$ on β is shown in Fig. 1.

Function $D(k,\beta)=\mathrm{Re}[\omega_s(k,\beta) - \omega_s(k,\beta=0.01)]$ is presented for the ANM density $\rho_0=\rho_n+\rho_p = 0.17$ fm^{-3}, $p_0 = 268$ MeV. The dispersion equation includes the isovector part of particle-hole interaction [1] with the constant parameter F'=2.0.

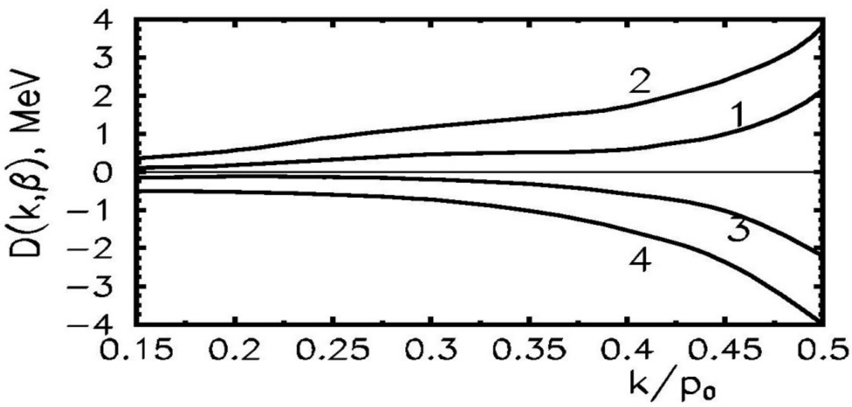

Fig. 1. Dependence of D(k,β) on the asymmetry parameter β. Curves 1 and 2 (3 and 4) are obtained for the solutions with the neutron (proton) emitted. Curves 1 and 3 (2 and 4) are calculated for β=0.1 (0.2).

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ON DOUBLE POLARIZATION ASYMMETRIES IN THE ELASTIC ELECTRON-PROTON SCATTERING

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In the work [1] we considered two types of polarization asymmetries in the elastic scattering of the longitudinally polarized $(\zeta = \pm 1)$ electron off the polarized $(\vec{s})$ proton target. These were $A_p^{\parallel}(\zeta; E, q^2)$ and $A_p^{\perp}(\zeta; E, q^2)$ – asymmetries for the target proton spin orientation with respect to incident electron moment $\vec{s} \parallel \vec{k}$ and $\vec{s} \perp \vec{k}$, keeping only weak-electromagnetic interference corrections.

Now we extend previous results to include as well pure weak contributions to the cross section:

$$\frac{d\sigma}{d\Omega} = \frac{\sigma_{Mott}}{1+\tau}\frac{1}{f_-(\omega,\tau)}\left\{a_t + \zeta a_t^h + (\vec{n}\vec{s})\left(b_t + \zeta b_t^h\right) + (\vec{m}\vec{s})\left(c_t + \zeta c_t^h\right) + \left(\vec{m}[\vec{n}\vec{s}]\right)\left(d_t + \zeta d_t^h\right)\right\},$$

where correlation functions $f = a, b, c, d$ are given by expressions $f_t = f_{em} - 2\delta_{0\text{p}}\tau f_{int} + \delta_{0\text{p}}^2\tau^2 f_{weak}$, with $\delta_{0\text{p}} = \frac{G_F m_\text{p}^2}{\pi\alpha\sqrt{2}}$, $\tau = -\frac{q^2}{4m_\text{p}^2}$, ω is incident electron energy in the proton mass; $\vec{n}$ and $\vec{m}$ are unit vectors along the incident and scattered electron moments.

Single spin correlation terms, proportional to a_t^h, b_t, c_t, determine spatial parity violating asymmetries A_{RL} and A_p [2], while the triple vector correlation term $\sim d_t$ is responsible for the time reversal violation due to electric dipole G_{2p} form factor of the proton. Corresponding asymmetry with account of the double spin correlation functions d_t^h and b_t^h, is given by the expression

$$A_p^{\perp} = \frac{d_t + \zeta d_t^h}{a_t + \zeta a_t^h + (\vec{n}\vec{s})\left(b_t + \zeta b_t^h\right)}.$$

The benefit of this formula in searching for the time reversal violation due to proton electric dipole moment lies in the fact, that its contribution to d_t is proportional to $G_{1p}G_{2p}$, i.e. to proton anapole moment, while its main contribution to d_t^h is proportional to $G_{Mp}G_{2p}$, i.e. to proton magnetic moment, and thus, is at least $1/\delta_{0\text{p}}$ times stronger.

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BOOST GENERATORS IN THE CLOTHED-PARTICLE REPRESENTATION AND THEIR EMPLOYMENT IN RELATIVISTIC NUCLEAR CALCULATIONS

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Starting from the instant form of relativistic quantum dynamics for a system of interacting mesons and nucleons, where amongst the ten generators of the Poincar´e group (Π) only the Hamiltonian H and the boost operator $\vec{B}$ carry interactions, we have proposed [1] a constructive way of ensuring the RI in field models with cutoffs in momentum space. In contrast to the Lagrangean formalism, in which the generators of Π are expressed via the Noether theorem through the energy-momentum tensor density, our purpose is to find these generators as elements of the Lie algebra of Π for a typical situation where the total Hamiltonian interaction density $H_{\mathrm{I}}(x)$ in the Dirac picture includes a Lorentz-scalar part $H_{\mathrm{sc}}(x)$. Using purely algebraic means, we show that the $\vec{B}$ can be decomposed into the Belinfante operator built of $H_{\mathrm{sc}}(x)$ and the operator which accumulates the chain of recursive relations in the second and higher orders in $H_{\mathrm{nsc}}(x) = H_{\mathrm{I}}(x) - H_{\mathrm{sc}}(x)$. Moreover, in combination with the method of unitary clothing transformations [1] the proposed approach enables us to get the interactions between the clothed particles (in particular, physical mesons and nucleons) simultaneously in H and $\vec{B}$. The derived interactions are hermitean and energy independent including the off-energy-shell and recoil effects (the latter in all orders of the $1/c^2$-expansion). Explicit expressions for the boosts need in relativistic calculations when the center-mass-motion of a system is not separated from its internal degrees of freedom. Then, for example, the dipole magnetic moment of a nucleus in the state with the total angular momentum J and its projection $M_J = J$ is determined by the expectation

$$\mu = \frac{1}{2}\left\langle \vec{0};J \right| \left[\vec{B} \times \vec{J}(0) \right]^z \left| \vec{0};J \right\rangle .$$

In the rest frame, where $\vec{J}(0)$ is the current density operator at the time-space point $x = (t,\ \vec{x}\,) = 0$. We would like to show applications [2] of the approach when calculating the deuteron dipole magnetic and electric quadrupole moments.

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GEOMETRY-PHYSICS ASPECTS OF SPATIAL ANISOTROPY INVESTIGATIONS

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Results of some theoretical and experiment investigations of space-time anisotropy of Galactic gamma-rays angular distribution [1] (with addition of the theory with the vacuum spontaneous breaking symmetry in the fermion system with the gravitation interaction [2]) within the frame of the space rays generation mechanism on a method of direct transformation of intergalactic gamma-rays (and so masers and X-ray bursters) to the current on spin shock-waves are presented (curve in Fig. 1). This is done within the frame of the "eight spin-flip shock wave" model, which is based on an accurate solution of the Maxwell equations for a dust-like medium of charged particles in the flat space (and which are identical to the spin conservation low). It is shown with dates [3, 4], that the Galactic gamma-ray angular anisotropy axis has following Galactic coordinates: longitude (exactly) l = 96°, latitude ≈ 20°, that corresponds in the second equatorial coordinate system: right ascension α = 271°, declination δ ≈ 40°. These results are in accordance with those of some experiments [5] on determining the direction of a cosmological vector-potential A_G.

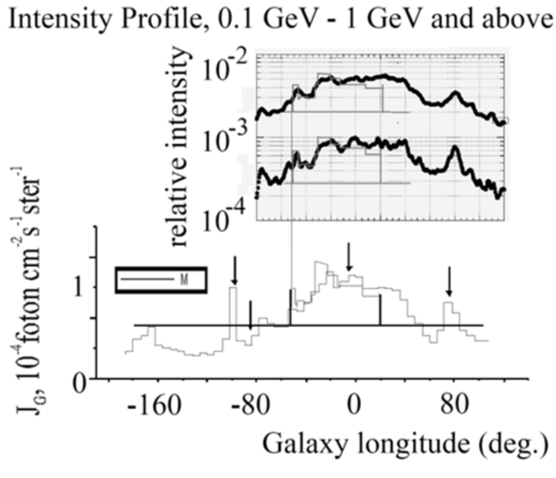

Fig. 1. The longitudes distributions of Galactic Gamma-radiation [3] J_G (energy more than 70 MeV) in the latitudes ± 10° (line across the range of longitudes) in relation to the distribution of Galactic currents on basic model of 8 spin-flips, built (thin line ascending from the upper ends of two bold vertical line segments beginning with the horizontal line middle level) from the average level of gamma-radiation in comparison with data [4]. At the top there is a clear peak near longitude -50° in accordance with the theory. Its position is indicated by a vertical line.

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DECAY OF THE QUASI-MOLECULAR STATES IN ^{26}Mg

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Resonance like structures were observed in the excitation function for the ^{14}C+^{12}C elastic and inelastic scattering [1]. We have made an experimental study of the ^{14}C(^{12}C,^{10}Be)^{16}O reaction at the center of mass energies of 21.1, 23.5 and 24.6 MeV to test the nature of these structures. The angular distributions obtained at these energies were analyzed in the framework of a quasi-molecular approach and also as a result of the transfer reaction. The parameters of the optical potential were founded, and DWBA calculations were performed.

It was shown that polynomial character of the angular distribution agrees with the 12^+ resonance for the ^{10}Be+^{16}O system. While the authors [2] could explain the behavior of the cross-section assuming the α-transfer, we found that this channel has much smaller amplitude than the 2*p*-transfer.

On the other hand, the strong oscillations of the cross-section for the ground-state exit channel showed that there were no strong admixture of the resonances with random angular momenta and phases. In this case, it is possible to consider the resonance-like cross-section as a shape resonance in the exit channel.

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PAIRING INTERACTION IN THE $f_{7/2}$ SHELL NUCLEI

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The nucleon-nucleon interaction properties in medium mass region isotopes are discussed on basis of the excited states structure. Nucleon paring leads to formation of ground state multiplets (GSM), which splitting is estimated on nuclear masses [1, 2]. GSM in nuclei near 20 and 28 magic numbers with identical nucleons over filled $Z = N$ core ^{40}Ca are considered on the basis of delta-interaction. The 7/2 shell nuclei give the unique possibility to track behavior of analog states outward from the magic number [5].

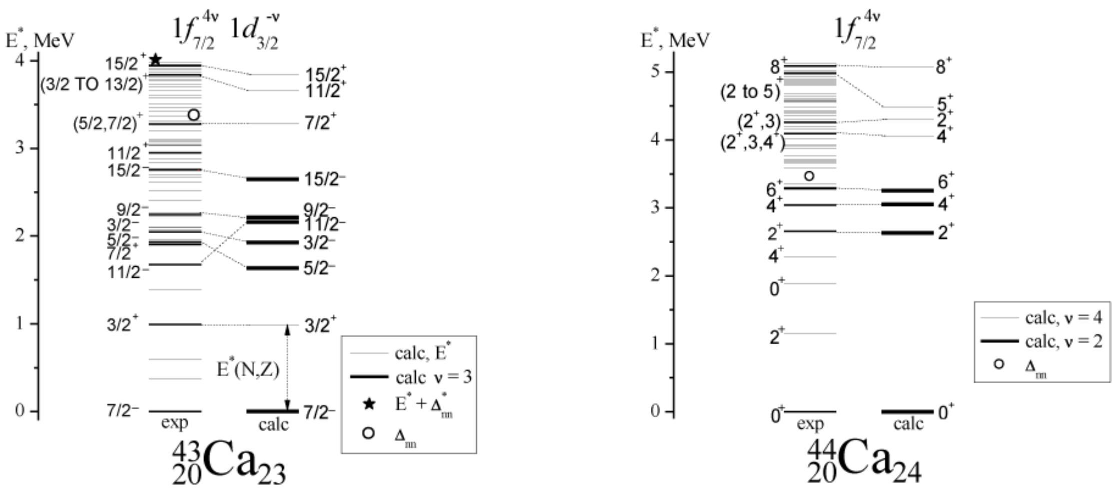

Fig. 1. GSM with v=3 and with v=2 multiplet, based on excited state E(3/2$^+$)=0.99 MeV in ^{43}Ca (left) and GSM with with v=4 and 2 in ^{44}Ca (right) . Experimental data are from [3, 4].

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RELATIVISTIC INTERACTIONS IN MESON-NUCLEON SYSTEMS: APPLICATIONS IN THE THEORY OF NUCLEAR REACTIONS

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Starting from the primary Yukawa-type couplings between "bare" fermions (nucleons and antinucleons) and bosons (π -, η -, ρ -, ω - mesons, etc.) with the help of the method of unitary clothing transformations (UCTs), developed for the Dubna-Kharkov cooperation [1] and extended by the Kharkov-Padova group [2], we have built up a new family of the interactions ("quasipotentials") between “clothed” particles, responsible for physical processes in meson-nucleon systems. These quasipotentials are hermitian and energy independent that make them attractive in practical calculations. The corresponding four-operator interactions for the 2 ↔ 2 processes (such as NN ↔ NN and antiN+N ↔ π+π) the five-operator interactions for the 2 ↔3 ones (such as NN ↔ BNN) are derived along the chain: bare particles with bare masses, bare particles with physical masses and physical (observable) particles.

Further, in order to avoid ultraviolet divergences typical of local field theories, we prefer to handle the regularized contributions to the interaction Hamiltonian density by introducing some covariant cutoff functions in momentum space. Our consideration is compatible with the relativistic invariance requirements being fulfilled in the framework of an original procedure proposed to meet the Poincaré-Lie algebra [3]. When describing the N-N scattering below the pion production threshold, we have compared [4] our results with those by the Bonn group [5] and obtained a fair treatment of the data. The corresponding values of the meson-nucleon coupling constants and cutoff parameters differ (sometimes considerably) from those extracted for the analysis [5]. In addition, we will show to what extent these distinctions become apparent in studying the electromagnetic interactions with nuclei (in particular, the electron-deuteron scattering).

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INVESTIGATION OF TWO SPIN STATES RELATIVISTIC AMPLITUDE'S ROLE IN DESCRIPTION OF ELASTIC p-p SCATTERING DATA IN ENERGY RENGE 2–7000 GeV IN MATHEMATICAL EIKONAL METHOD

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Recently in the work [1,2] there were shown the description of the elastic p-p scattering data at energy 62 GeV [1] and 7000 GeV [2]. The results of differential and total cross section's computations were obtained in the mathematical eikonal method (MME) [3] with two relativistic amplitudes

The singlet amplitude MME defined as

$$N(t) = i\,\beta_1\,\sqrt{\pi}\int_0^\infty d^2r_\perp\;\omega^2(\vec{r}_\perp,\,\beta_1)/[1-\omega(\vec{r}_\perp,\,\beta_1)]\;\ln[[1-\omega(\vec{r}_\perp,\,\beta_1)]]\times \\ \times J_0(r_\perp\,\sqrt{-t})\;F_p^2(\sqrt{-t}) \tag{1}$$

and the triplet so

$$R(t) = i\,\beta\,\sqrt{\pi}\int_0^\infty d^2r_\perp\;\omega^2(\vec{r}_\perp,\,\beta)/[1-\omega(\vec{r}_\perp,\,\beta)]\;\ln[[1-\omega(\vec{r}_\perp,\,\beta)]]\times \\ \times J_0(r_\perp\,\sqrt{-t}) \tag{2}$$

The eikonal profile functions in (1) and (2) have the same form as for the triplet so singlet $\omega(\vec{r}_\perp,\,\beta) = \exp[-(A+i\,B)\,(\nu\, r_{\wedge})^3\;K_3(\nu\, r_{\wedge})/8\,\beta]$-1 but with different sets of values A, B, ν and mathematical eikonal parameter β. F_p is the best analytic fitting for the experimental proton form-factor in e-p scattering.

This report has been presented the results of the elastic p-p scattering differential cross section's calculations with amplitudes (1)–(2) at energies 2, 23.5, 30.7 and 52.8 GeV. These results are in a good agreement with the experimental data [4] at wide region $|t|$. There are obtained the profile function parameter's values at these energies too. The analysis of these results displays that forming diffraction cone triplet amplitude is the complex potential scattering in MME one and the MME singlet amplitude describing enough good experimental data behind the cone includes proton's structure.

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ELASTIC PROTONS SCATTERING ON ^{9,10}B ISOTOPES AT INTERMEDIUM ENERGY WITHIN THE DIFFRACTION THEORY

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Currently, the important area in the field of fundamental nuclear physics is the study of nuclear reactions take place in the nuclear reactors of new generation at protons energies of about 1 GeV. The most urgent tasks are the nuclear reactions with atomic nuclei of the reactor structural elements, fissile materials and moderators. Theoretical analysis of the experimental results during their interaction with protons and neutrons at high energies can significantly broaden the base of nuclear data. This stocking of experimental and evaluated data banks on the cross sections of nuclear reactions opens a new level of information support for fundamental and applied research and sets up new requirements for the experiment and theory in the field of nuclear energy.

Selecting boron (B) isotopes for research is not accidental, since many of them due their basic structure are the main absorber of neutrons and the structural element in the nuclear fusion reactors of latest generation. The beams of radioactive isotopes $^{8,12-15}$B with E = 790 MeV/nucleon were first produced in Bevalac (USA) [1]. The experiments on ^{9,10}B isotopes were held in Indiana University Cyclotron Facility (USA) [2] at E = 197 MeV, in the National Superconducting Cyclotron Laboratory, Michigan (USA) [3] at E = 15−53 MeV/nucleon, in the Lawrence Berkeley Laboratory (USA) [4] at E = 200−400 MeV/nucleon, Laboratori Nazionali del Sud INFN (Italy) [5] at E = 22.3−55.6 MeV.

In this paper the calculation of the differential and total cross sections of the scattering is presented within the Glauber theory of multiple diffraction scattering. For nuclei description we used the wave functions in the 2αN-model (for ^{9}B) and in the shell model (for ^{10}B nucleus). The formalism was developed for analytical calculating of the p-^{9,10}B scattering amplitudes. The analysis of the calculated cross sections was made with the contribution of structural (depending on wave functions) and dynamic (depending on the operator of multiple scattering) components in the amplitude. The calculations have shown the sensitivity of p^{9}B- and p^{9}Be- scattering to the nuclei structure and to the contribution of the multiple collisions.

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ISOSPIN AND ANGULAR DEPENDENCIES OF SPIN-TRANSFER PROBABILITIES D_{ls} IN UNNATURAL-PARITY $(\vec{p},\vec{p}')$ REACTIONS AT INTERMEDIATE ENERGIES

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In this paper, our primary purpose is to demonstrate that the observables D_{ls}, based on a set of polarization-transfer measurements, and their analysis within the framework of the model of Bleszinski *et al.* (see our other abstract in this book) can be applied for the systematic evaluation of the role of spin-orbit interactions in nucleon inelastic scattering on a number of light-weight nuclei.

Accordingly, numerous research data have proven that at intermediate energies the isovector spin-orbit interaction is consistently weak. However, the isoscalar spin-orbit component of the effective interaction is large. In agreement with that, we observe large quantities D_{ls} for T = 0 and small quantities for T = 1. Hence, the corresponding spin-transfer probabilities D_{ls} appear to be primarily driven by the strengths of spin-orbit amplitudes (Fig. 1).

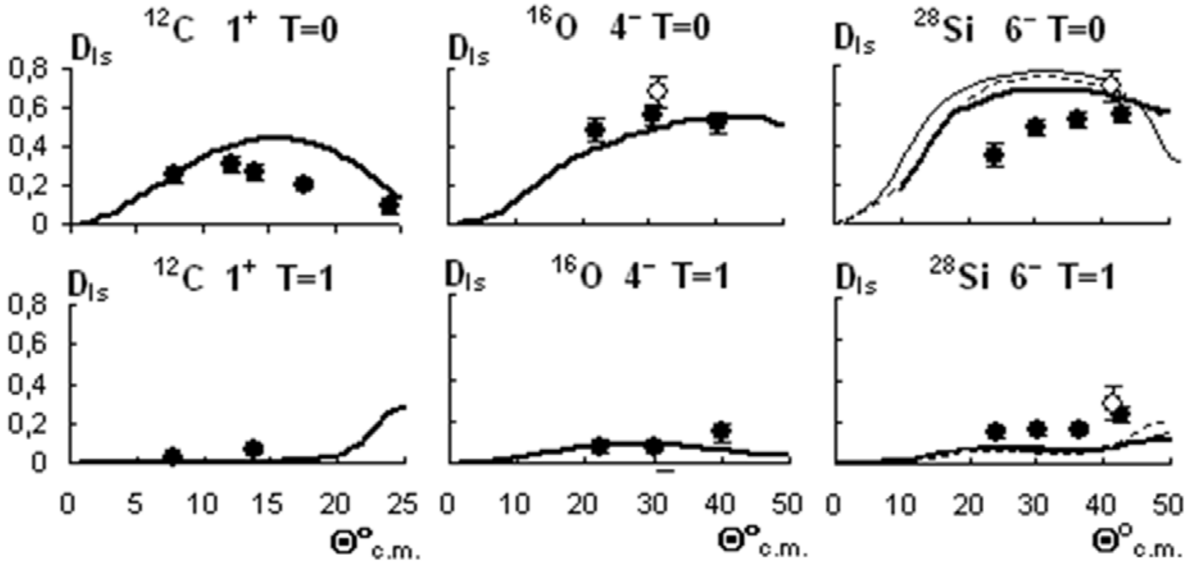

Fig. 1. The systematized experimental and DWIA predicted data, D_{ls}, for $(\vec{p},\vec{p}')$ scattering on ^{12}C, ^{16}O and ^{28}Si to the T = 0 and T = 1 excitations. We based the represented experimental results D_{ls} on the $(\vec{p},\vec{p}')$ spin-observable measurements at 200 MeV from [1] for ^{12}C, and from [2] for ^{16}O and for ^{28}Si (solid points); at 350 MeV, the data were taken from [3] (open point – ^{16}O), and at 500 MeV from [4] (open points – ^{28}Si). Due to the difference in energies E_p, we introduced certain kinematic corrections. All the calculated data (curves) refer to 200 MeV, except the dashed curves (^{28}Si) that refer to 500 MeV.

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TRANSVERSE- AND LONGITUDINAL-SPIN-TRANSFER PROBABILITIES FOR UNNATURAL-PARITY $(\vec{p},\vec{p}')$ REACTIONS AT INTERMEDIATE ENERGIES

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Here we present systematized angular distributions of two spin (polarization)-transfer probabilities D_K (Fig. 1), based on the available complete $(\vec{p},\vec{p}')$ measurements at E_p = 200 MeV (solid points), as well as at E_p = 350 MeV, E_p = 500 MeV (open points for ^{16}O and ^{28}Si, respectively), for the unnatural-parity $T = 1$ levels in a set of light-weight nuclei. Instead of measured and calculated polarization transfer coefficients, Fig. 1 shows their combinations, which, as probabilities D_K, are associated in the PWIA prediction with the squares of particular amplitudes in the *NN* effective interaction. The given D_K are polarization observables introduced by the model of Bleszinski et al. (see our other abstract in this book).

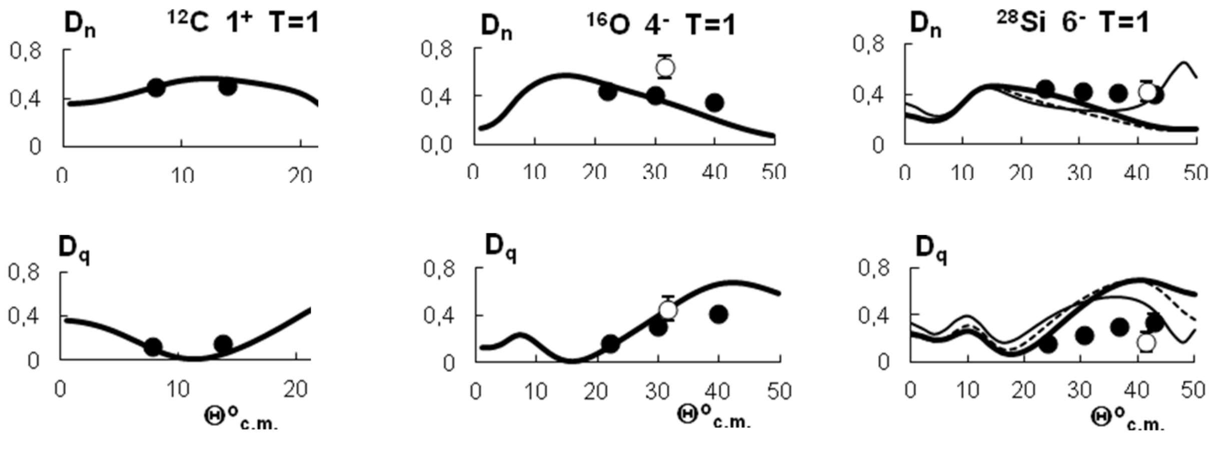

Fig. 1. Systematized angular distributions of the spin-transfer probabilities, D_n and D_q, for the indicated isovector levels in ^{12}C, ^{16}O and ^{28}Si, based on the measured $(\vec{p},\vec{p}')$ quantities at 200 MeV [1, 2], as well as at 350 and 500 MeV. The measurements at 350 MeV (^{16}O) were performed in [3], and at 500 MeV (^{28}Si) – in [4]. The calculations applied to 200 MeV were as follows. In the case of ^{12}C, we used DWIA calculations, based on the DBHF interaction [1]. For ^{16}O, we employed the DWBA 91 program from Raynal and G-matrix (DD) from Geramb. For ^{28}Si, all our calculations were made using the DWBA 91 program with three types of interactions: G-matrix from Geramb (thick solid curve) and two variations of the Idaho interaction (thin solid and dashed curves) [5].

A distinctive feature of the $T = 1$ excitations is that the isovector spin-orbit interaction is weak at intermediate energies. The smallest quantity of D_{ls}, both in experiments and in our calculations, confirm this fact (see our other abstract in this book). As a rule, normal spin-transverse D_n quantities exceed D_{ls} values.

Consequently, the spin-observable combinations D_n that depend on the isovector spin-spin interaction and the transverse spin-matrix element are generally well described by calculations for the excitations represented in Fig. 1: 1^+ (15.11 MeV) in ^{12}C, 4^- (18.98 MeV) in ^{16}O, and 6^- (14.35 MeV) in ^{28}Si.

The contrasting term D_q is a spin-longitudinal component of the spin-transfer probability. The D_q depend on the spin-spin interaction, namely on the pion-dominated isovector $(\sigma_1 \cdot \hat{q}\ \sigma_2 \cdot \hat{q})$ piece of the *NN* interaction, as well as on the longitudinal spin-matrix element.

Different q dependences of D_n and D_q can be explained by the fact that the transverse and longitudinal axial formfactors have a different q dependence. The qualitative features of such a relative behavior of D_n and D_q can be understood from Fig. 2, which represents the isovector transverse (T) and longitudinal (L) parts of the t-matrix interaction at 210 MeV (see [6]). Whenever θ_{cm} in Fig.1 varies from 20° to 40°, this corresponds to q, changing from 1 to 2 fm^{-1} (Fig. 2).

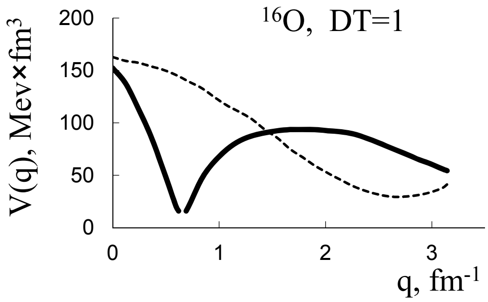

Fig. 2. Transverse and longitudinal isovector parts of the t-matrix interaction at E_p = 210 MeV V_T (---) and V_L (—), respectively from Love and Franey.

Let us apply these results to the 4^-, $T = 1$ state in ^{16}O. Thus, near 1.5 fm^{-1}, where $V_T \sim V_L$ (Fig. 2), D_n and D_q have similar quantities (Fig. 1), as the transverse and longitudinal transition densities are also comparable for the stretched 4^-, $T = 1$ excitations [6]. Near 0.7 fm, where V_L is very small, D_q becomes roughly equal to 0. The D_n, however, acquires its maximum value, since here V_T is large and dominant. At larger q, where V_L becomes bigger than V_T, D_q acquires larger values as compared to D_n. At 0° ($q = 0$), when V_T and V_L are practically the same (Fig. 2), we also observe similarity of D_n and D_q in our calculated data (Fig. 1).

Although isoscalar spin-dependent forces present a different picture, they could be analyzed in a similar manner. Accordingly, the relation between the isoscalar D_n and D_q probabilities appear to be entirely different for the $T = 0$ states (see our other abstract in this book). However, we still observe a unique sensitivity of the nucleon to the longitudinal spin response of the nucleus, which cannot be detected in the e- and π-nucleus interactions.

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UNNATURAL-PARITY $(\vec{p},\vec{p}')$ REACTIONS IN A FACTORIZED IMPULSE-APPROXIMATION MODEL FOR POLARIZATION TRANSFER (PT) AND SPIN RESPONSES

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Four polarization observables, D_K, introduced by Bleszynski *et al.* [1], are expressed in terms of linear combinations of the Wolfenstein parameters [2], or analogous complete PT coefficients (D_{ij}), for the $(\vec{p},\vec{p}')$ reaction. In PWIA with optimal factorization approximation, the combinations D_K are given as:

$$D_{ls} = [1 + D_{NN} + (D_{SS} + D_{LL})\cos\theta - \delta\sin\theta]/4,$$

$$D_q = [1 - D_{NN} + D_{SS} - D_{LL}]/4,$$

$$D_n = [1 + D_{NN} - (D_{SS} + D_{LL})\cos\theta + \delta\sin\theta]/4,$$

$$D_P = [1 - D_{NN} - D_{SS} + D_{LL}]/4,$$

where $\theta \equiv \theta_{\mathrm{c.m.}}$ (deg.) is a scattering angle, and $\delta = D_{LS} - D_{SL}$.

The D_{ls} is associated with spin-orbit term in the *NN* effective interaction. The other three D_K are associated with the tensor terms for each axis, as D_q with the momentum transfer $\vec{q} = \vec{k}_{in} - \overleftarrow{k}_{out}$, and as D_n – with normal $\vec{n}$ to the reaction plane, and as D_p – with $\hat{p} = \hat{n} \times \hat{q}$.

As an example, the Figure shows experimental and calculated dependences for all four D_K data for the 1^+, $T = 1$ levels in ^{12}C and ^{28}Si.

The novelty of the present work is that the range of the measured spin-observable combinations, D_K, has been extended to 0°, which allowed, for the first time, to evaluate the validity of the analytical results at extremely forward angles (at and near zero degrees). Moreover, the measured D_K for the 1^+, $T = 1$ state in ^{12}C at 0° have been completed by similar data for the 1^+, $T = 1$ level in ^{28}Si (Fig. 1).

The above-mentioned combinations, D_K, become simpler at small scattering angles since $\delta \approx 0$, $\cos\theta \approx 1$ and $\sin\theta \approx 0$. According to [5], in the case of 0° for the isovector ($\Delta T = 1$) *M*1 transition, we have $D_{SS} = D_{NN} \approx D_{LL} \approx -1/3$. If these quantities are inserted into the simplified expressions D_K, we will easily get the following set: $D_{ls} = 0$, and $D_q = D_n \approx D_p \approx 0.3$. Furthermore, these quantities appear to be approximately equal to the measured values and to our DWIA calculations, using the FL (Franey and Love) interaction and the program code LEA from Kelly.

As for the description of the D_K data at other angles, the program code LEA, used here for the first time, turned out to be more effective overall than some other programs, proceeded from nonrelativistic and relativistic calculations that were previously employed for such purposes [3].

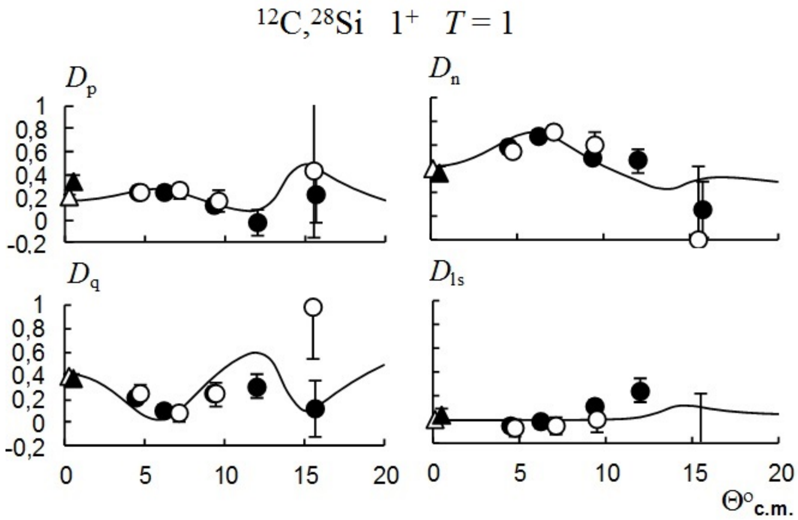

Fig. 1. Systematized angular distributions of the spin-transfer probabilities, D_K, for the isovector 1^+ (15.11 MeV) level in ^{12}C, and 1^+ (11.5) level in ^{28}Si, based on the measured $(\vec{p}, \vec{p}')$ quantities at 500 MeV (filled circles [3]), open circles [4]), and at ~400 MeV [5] (open triangle – ^{12}C, filled triangles – ^{28}Si). Our calculations (curves) are described in the text.

As is seen in the Fig. 1, the angular distributions of the transverse- and longitudinal spin-transfer probabilities, D_n and D_q, respectively, are considerably different in shape, as it is in the case of lower energy (E_p = 200 MeV). This phenomenon can be explained by a significant difference in the momentum dependence of transverse- and longitudinal axial formfactors (see our other abstract in this book).

At the same time, the angular distributions, D_n and D_q, in calculations and experiments, have similar smooth shapes, both at E_p = 400–500 MeV and at E_p = 200 MeV, for the isoscalar 1^+ (12.71 MeV) state in the ^{12}C $(\vec{p},\vec{p}')$ ^{12}C reaction (not shown). This is in good agreement with the fact that the moduli of the isoscalar interaction components of the free nucleon-nucleon *t*-matrix for 140-MeV (and 800-MeV) nucleons from Love and Franey, responsible for transverse and longitudinal transitions, respectively, are similar in value and are rather flat as functions of q [6].

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TEST OF TIME-REVERSAL INVARIANCE IN A DOUBLE-POLARIZED pd-SCATTERING

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Time-reversal invariance will be tested in proton-deuteron transmission experiment at COSY [1]. The integrated cross section $\tilde{\sigma}$ will be measured for transverse polarized proton beam (p_y) and tensor polarized deuterium target (P_{xz}). This observable provides a real null test of time invariance violating but *P*-parity conserving (TVPC) forces which do not arise in the Standard model as a fundamental interaction. This signal is not affected by the initial and final state interaction and therefore its observation would directly indicate time-invariance violation, like in case of neutron EDM. The differential spin observables of the elastic *pd* scattering and total *pd* cross sections for polarized proton and deuteron are calculated within the spin-dependent Glauber theory [2] at the energy of the planned experiment [1] 135–200 MeV. We use the formalism of [3] and develop it for inclusion of *T*-odd *pN*-scattering amplitudes and to calculate on this basis the energy dependence of the null-test observable in terms of unknown TVPC coupling constants. The results of our calculations [2] for unpolarized differential cross section, vector and tensor analyzing powers and spin correlation parameters with *T*-even *P*-even interactions are in a reasonable agreement with the existing data at 135 MeV and 200 MeV in forward hemisphere.

We show that only double scattering mechanism generates the $\tilde{\sigma}$ observable. Furthermore, we find that the contribution from the lowest-mass meson allowed in the TVPC interaction, i.e. the charged ρ-meson [4], to the null-test signal $\tilde{\sigma}$ vanishes. It means that the TVPC signal $\tilde{\sigma}$ will be weaker than usually expected since it is caused only by heavy mesons exchanges which contribution is suppressed due to a nucleon-nucleon repulsive core. On the other hand, we show for the first time that the Coulomb interaction does not lead to divergency of the $\tilde{\sigma}$ observable. Analytical formulas are derived in the *S*-wave approximation for the $\tilde{\sigma}$ observable and its energy dependence is calculated for several types of phenomenological TVPC *NN*-interactions. This dependence differs from that found in [5] where only a breakup mechanism was taken into account in the impulse approximation.

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PHOTONUCLEON CHANNELS OF ^{7}Li, ^{7}Be NUCLEI AT ULTRALOW ASTROPHYSICAL ENERGIES

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In the present work within the dynamic potential cluster model the investigation and comparative analysis of characteristics of photonucleon channels for ^{7}Li and ^{7}Be nuclei such as $^6\mathrm{Li}+\mathrm{n}\to{}^7\mathrm{Li}+\gamma$, $^6\mathrm{He}+\mathrm{p}\to{}^7\mathrm{Li}+\gamma$, $^6\mathrm{Be}+\mathrm{n}\to{}^7\mathrm{Be}+\gamma$, $^6\mathrm{Li}+\mathrm{p}\to{}^7\mathrm{Be}+\gamma$ were performed. These channels are interesting due to the several reasons: first of all these channels are isobar-analogous, and investigation of isobar-analogous nuclei (in our case $^6\mathrm{He}\text{-}^6\mathrm{Li}\text{-}^6\mathrm{Be}$, $^7\mathrm{Li}\text{-}^7\mathrm{Be}$) is of interest from the point of view of charge independence of nuclear forces, in addition, within the isobar multiplets some features of the nuclei structure can be revealed. From the other hand, the processes with participation of these nuclei, occurring at low and astrophysical energies, are of particular interest for Nuclear Astrophysics. It is caused by that these nuclei are parts of the chain of element synthesis in the Universe, so the processes with $^{6,7}\mathrm{Li}$, $^7\mathrm{Be}$ nuclei have a significant influence on the abundance of elements in the Universe.

Earlier, in [1] the calculation and comparative analysis of the spectroscopic characteristics of $^7\mathrm{Li}\to{}^6\mathrm{Li}+\mathrm{n}$, $^7\mathrm{Li}\to{}^6\mathrm{He}+\mathrm{p}$, $^7\mathrm{Be}\to{}^6\mathrm{Be}+\mathrm{n}$, and $^7\mathrm{Be}\to{}^6\mathrm{Li}+\mathrm{p}$ virtual disintegration channels have been performed. In [2] the total cross-sections and yields of $^6\mathrm{Li}+\mathrm{n}\to{}^7\mathrm{Li}+\gamma$, $^6\mathrm{He}+\mathrm{p}\to{}^7\mathrm{Li}+\gamma$ nucleon radiative capture reactions and the astrophysical *S*-factor for $^6\mathrm{He}(\mathrm{p},\gamma)^7\mathrm{Li}$ reaction have been calculated at ultralow astrophysical energies ($E_{cm}\le 1$ MeV).

We reported the total cross-sections and yields of $^6\mathrm{Li}(\mathrm{p},\gamma)^7\mathrm{Be}$, $^6\mathrm{Be}(\mathrm{n},\gamma)^7\mathrm{Be}$ reactions and the astrophysical *S*-factor for $^6\mathrm{Li}(\mathrm{p},\gamma)^7\mathrm{Be}$ reaction have been calculated at low astrophysical energies ($E_{cm}\le 1$ MeV). The comparative analysis of the obtained results with available theoretical and experimental data has been carried out.

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COMPARISON OF π-MESONS AND PROTONS SCATTERING ON ^{6,8}He ISOTOPES WITHIN THE GLAUBER THEORY

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Elastic and inelastic scattering of $\pi^{\pm}$-mesons on nuclei is the main source of information to understand the pions induced nuclear reactions and the opportunities for research of nuclear structure with their help. The basic properties of $\pi^{\pm}$-mesons such as small mass, the zero spin, three charge states, make them a link between the short- and long-range field of nuclear forces.

The purpose of this paper is to compare the structural and dynamic features of He isotopes under scattering of pions and protons on them. Scattering characteristics (differential cross sections and analyzing powers) of protons on ^{8,6}He nuclei in inverse kinematics are well known in two energy ranges: at E = 70 MeV/nucleon [1] and E = 700 MeV/nucleon [2, 3]. The wave functions of nuclei are calculated for various models: shell, two- and three-clusters, MRG. Due to high degree of clustering the dominant channels are α+n+n (for ^{6}He, $E_{св.}$= 3.47 MeV) and α+4n (for ^{8}He, $E_{св.}$= 2.46 MeV). This paper, in the framework of the Glauber theory with the wave functions of three-particle cluster model for ^{6}He (α2N-model) [4] and in the shell model with a large basis (LSSM) for ^{8}He [5], provides the calculated differential cross sections of $\pi^{\pm}$-^{6,8}He scattering. We compare the results of calculations for the differential cross sections of $\pi^{\pm}$-^{8,6}He scattering with the previous calculations [6] on protons scattering on ^{8,6}He nuclei at the same energy. In particular, a comparison of particle scattering contribution to the differential cross sections on the α-core and the valent neutrons have shown that the main contribution to the cross section is provided by the scattering on the valent neutrons at small angles (corresponding to small momentum transfers), and on the core at high angles.

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THE *S*(*E*)-FACTORS FOR PROTON CAPTURE BY ^{6}Li AT THE ENERGIES OF ASTROPHYSICAL INTEREST

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The astrophysical *S* factors for the radiative capture reaction ^{6}Li(p,γ)^{7}Be in the region of extremely low energies have been calculated on the basis of the modified *R*-matrix approach [1]. The total width and the strength of the $E_{c.m.}$= 140 keV resonance were determined by fitting the new experimental data [2,3]. The total widths of the J^{π}=($1/2^{+}$, $3/2^{+}$) resonance states were found as even and equal to Γ_{tot}=160 ± 40 keV, and the resonance strengths values for the radiative transitions into the ground (J^{π}= $3/2^{-}$) and first excited (J^{π}= $1/2^{-}$; 429 keV) states have been obtained to be equal w_{γ}=6.93±0.01 eV. The contribution of direct radiative capture to the bound states of ^{7}Be nucleus was determined using the asymptotic normalization coefficients obtained from an analysis of the reaction ^{6}Li(^{3}He,d)^{7}Be [4] with including three-body Coulomb effects. A value of *S*(0) = 81.0 ±10.0 eV b was obtained for the total astrophysical *S* factor.

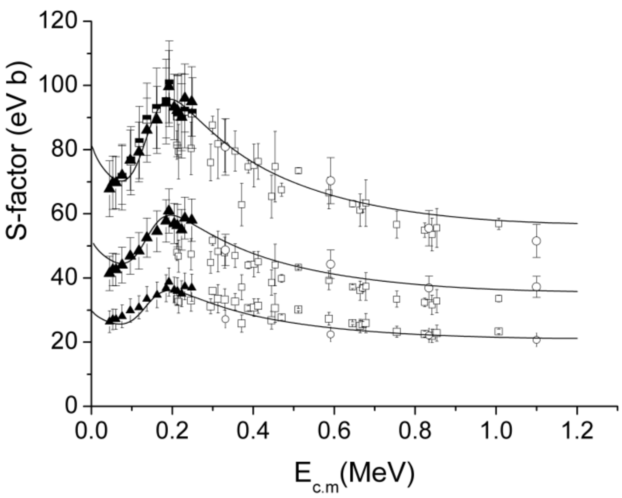

Fig. 1. The astrophysical S –factor of the ^{6}Li(p,γ)^{7}Be. The solid points are the experimental data from [2], empty points are the experimental data from [3] and references therein. The curves correspond to captures into first excited and ground states and their sum, bottom-up.

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MANIFISTATION OF ^{9}Be STRUCTURE IN DIRECT NUCELAR REACTIONS

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We studied the inelastic and transfer reactions induced by the helium isotopes ^{3,4}He with the ^{9}Be target, which were investigated early experimentally in details [1–3]. The projectiles such as ^{3,4}He ones are very suitable for study the target properties since the projectile's structure is simplest one. It is assumed generally that in light exotic nuclei (like the ^{9}Be ones) the nucleons tend to group into clusters, whose relative motion mainly defines the properties of these nuclei. This assumption leads to great advantages for models employing the cluster concept for both the structure and the reactions involving light exotic nuclei. In this work we treat the ^{9}Be nuclei as the three-cluster system ($\alpha + \alpha + n$) or the two-body one (^{5}He + α). The corresponding ground state wave functions are calculated within the hyperspherical harmonics method and then applied to calculate the folding potentials. Obtained interaction potentials are used to calculate the angular distributions for the nucleon transfer, and inelastic scattering in ^{3,4}He + ^{9}Be reaction using the distorted wave Born approximation. The different folding potentials are compared with the optical potentials known from the literature. The cross sections are compared with available experimental data. The good agreement with data is demonstrated.

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SPATIAL PERIPHERY STRUCTURE OF NEUTRON-EXCESS ^{9,11}Li ISOTOPES

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The distinction of structure of the neutron periphery of nuclei ^{9}Li and ^{11}Li represents the greatest interest. The ^{9}Li nucleus is rather compact system, despite excess of neutrons. The ^{11}Li differ significantly from isotope ^{9}Li. The addition of two neutrons to the compact nucleus ^{9}Li turns it into a Borromean weakly bound nucleus ^{11}Li. To understand the distinction reason we calculated the angular dependence of the cross section of the (t, p) reaction at ^{7}Li and ^{9}Li with the initial energy 7–10 MeV/nucleon for dineutron stripping mechanism within the method, developed by us in [1]. On that basis we determined the spatial distribution of probability densities of in ^{9,11}Li for dineutron $W_{\rm nn}(r_{\rm nn})$ together with potentials of a dineutron and core interaction (Fig. 1, 2).

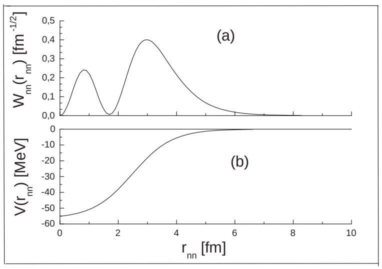

Fig. 1. The dependence dineutron W(nn) of nucleus ^{9}Li (a) and nn-^{7}Li potential (b) from r_{nn}.

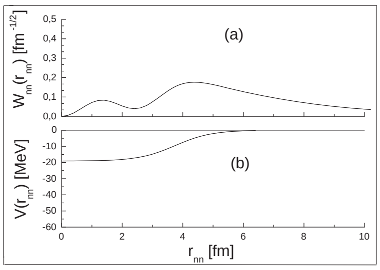

Fig. 2. The dependence dineutron W(nn) of nucleus ^{11}Li (a) and nn-^{9}Li potential (b) from r_{nn}.

As can be seen from Fig. 1*a*, the $W_{\rm nn}(r_{\rm nn})$ in ^{9}Li has a node at $r_{\rm nn} \approx 2$ fm leading to formation quit rigidly system from dineutron and core. nn-^{7}Li potential (Fig 1*b*) is rather deep, so $W_{\rm nn}(r_{\rm nn})$ (99%) is located inside potential almost completely. Compactness of the structure of ^{9}Li is caused by strong *jj*-pairing forces at completely filled neutron $p_{3/2}$-subshell. Radial dependence of $W_{\rm nn}(r_{\rm nn})$ in ^{11}Li (Fig. 2*a*) differs from similar dependence in ^{9}Li cardinally. Full overlapping of dineutron and a core ^{9}Li doesn't take place even inside the nn-^{9}Li interaction potential (Fig. 2*b*) which is more than twice smaller, than nn-^{7}Li potential. Thus only 60% of $W_{\rm nn}(r_{\rm nn})$ is located inside potential and 40% makes extensive (up to $r_{\rm nn}$ = 18–20 fm) asymptotic. Such structure of ^{11}Li is due to the fact that two external nucleon in ^{11}Li filled completely $p_{1/2}$-subshell and *jj*-pairing forces pull together these neutrons to dineutron. Majorana exchange forces [2] are pushing away subshells $p_{3/2}$ and $p_{1/2}$. In result dineutron in ^{11}Li is weakly bonded with the core ^{9}Li and has extensive asymptotic. These results testify that existence of a tetra neutron configuration is problematic.

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MECHANISMS OF NEUTRONS TRANSFER AT ^{9}Be(t, p)^{11}Be REACTION

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Recently, there are many theoretical and experimental works with great interest for the structure of ^{11}B. It is associated with the predictions of the existence at ^{11}B the cluster configurations of various types especially dineutron configuration. The existence of such configuration allows to clarify the large value of root-mean-square radius of ^{11}Be nucleus. It is about 3 fm, thus the ^{11}B nucleus size concedes in the size of its isotope analogue ^{11}Li only. In previous work [1], we used the reaction (t, p) at lithium isotopes with the initial energy 7–10 MeV/nucleon to study the contribution of various mechanisms. In this paper a similar procedure for (t, p) reaction at ^{9}Be was realized to evaluate the parameters of optical potentials and potentials of bound states.

We calculated the angular dependence of the reaction cross section within one- and two-step mechanism [2] (Fig. 1). The calculation results together with experimental data [3] are presented in Fig. 2.

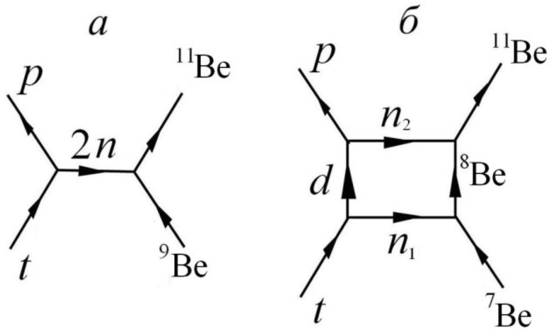

Fig. 1. Diagrams of two neutrons transfer mechanisms at ^{9}Be(t, p)^{11}Be reaction: a – dineutron stripping, b – consecutive neutron transfer.

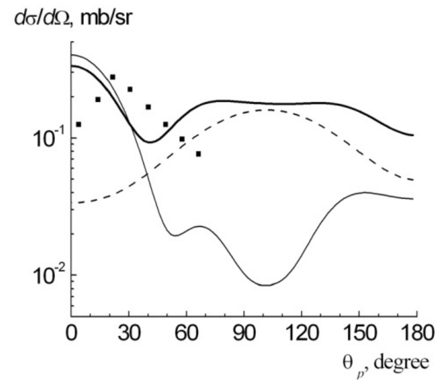

Fig. 2. Differential cross section of ^{9}Be(t, p)^{11}Be reaction. Fine solid line – dineutron stripping; dashed – consecutive transfer of neutrons; bold solid line – coherent sum of both mechanisms.

As can be seen from Fig. 2, the agreement between theoretical and experimental cross section is only qualitative character. But even such agreement was obtained in case of a significant increase of the geometrical parameters of all potentials (r_0 = 1.8 fm, a_0 = 0.65 – 0.85 fm). This parameters increase may be associated with abnormally large root-mean-square radius of ^{11}Be nucleus.

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LONGITUDINAL MOMENTUM DISTRIBUTIONS IN STRIPPING REACTIONS WITH HALO NUCLEI

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In the work [1] a nucleon stripping reaction of a halo nucleus was considered on the basis on the simple diffraction theory [2] using the black disk model for description of the interaction between a target nucleus and constituents of the weakly bound nucleus. An improved version of the approximation [3] of a small target-radius (compared to the size of the halo nucleus) was proposed. Simple analytic expressions obtained for the differential cross section and the longitudinal momentum distribution of core particles could be useful in analyses of experimental data.

The present work is a continuation of studies of stripping reactions due to diffraction interaction between the halo nucleus having the core + nucleon structure and the target nucleus. In particular a good accuracy of the approximate formulas mentioned above for calculations of the nucleon stripping observables is demonstrated by several examples. The small target-radius approximation is shown to be applicable also to calculations of the differential (in the longitudinal nucleon momentum) cross section for the core stripping reaction of the halo nucleus. In this case a general relationship of the diffraction theory between the differential cross section for the nucleon stripping and core stripping reactions must be used.

The nucleon stripping reaction is considered also in the large-radius approximation, a longitudinal momentum distribution of core particles being obtained in an analytic form. The results of calculations within both approaches are discussed using concrete examples.

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DESCRIPTION OF THE RADIATIVE CAPTURE REACTIONS WITHIN THE ALGEBRAIC VERSION OF THE ORTHOGONALITY CONDITIONS MODEL

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Interaction of composite particles (clusters) is one of the most important problems of nuclear physics. The effects of nucleon exchange are basic features of this interaction. The exchange modifies the form of various terms of equations of motion. Accurate approaches for taking all that into account are the resonating group model (RGM) [1] and the algebraic version (AV) of it [2–5]. Various types of the exchange terms play different roles in the cluster dynamics and these roles vary drastically depending upon the masses of the fragments, collision energy, etc. At the same time the exchange effects make fully microscopic calculations very complicated and in fact unrealizable for sufficiently heavy clusters. Therefore the analysis of the exchange effects is necessary for the construction of various reliable approximations which make the problem of composite particle interaction solvable. One of the promising approaches is the algebraic version of the orthogonality conditions model [6] (AVOCM) developed in [7–9].

In the present work we apply the AVOCM to study deep sub-barrier processes of the radiative capture. The mirror ^{4}He + ^{3}H and ^{4}He + ^{3}He colliding systems are considered. The radiative capture reactions in these systems at low energies are very important for investigations of the big bang nucleosynthesis and the stellar core [10, 11]. The exchange terms entering into the expressions for the exchange kernel, kernel of the kinetic energy, the matrix elements of the Coulomb and nuclear interactions are studied in detail. The formalism that allows to treat the first two terms exactly in the AVOCM is presented. The approximations for the other two terms are built. Prospects of the approach applications in the studies of heavier systems are discussed.

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PROJECTILE FRAGMENTATION OF ^{40,48}Ca IN A TRANSPORT APPROACH

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The fragmentation at low energies is of interest in the production of exotic nuclei, but the detailed mechanism is not completely understood. Here we calculate isotope and velocity distributions for reactions of ^{48}Ca and ^{40}Ca with heavy (^{181}Ta) and light (^{9}Be) targets at 140 A·MeV incident energy, for which also data exist in the literature [1]. The characteristics of primary fragments are calculated in a transport approach, namely the Boltzmann-Nordheim-Vlasov (BNV) approach, e.g. [2]. We evaluate the excitation energies of the primary fragments in a consistent way with the same interaction as in the transport calculations. To take into account the de-excitation of the primary fragments we use the Statistical Multifragmentation Model (SMM) of Bondorf, et al. [3]. The secondary decay is necessary to be able to compare to the experimental data [1]. Isotope distributions are described reasonably well, but velocity distributions are generally too narrow. Comparing the two projectiles we can obtain information on the nuclear symmetry energy. The yield ratio of ^{40}Ca and ^{48}Ca determines the isoscaling parameters [4], which are proportional to the symmetry energy in the decaying system. In the figure we compare the calculated yield ratios with the experiment. The slopes, which determine the isoscaling coefficients, are very similar, however, there are stronger deviations for the very neutron-rich isotopes, perhaps due to the treatment of the secondary decay.

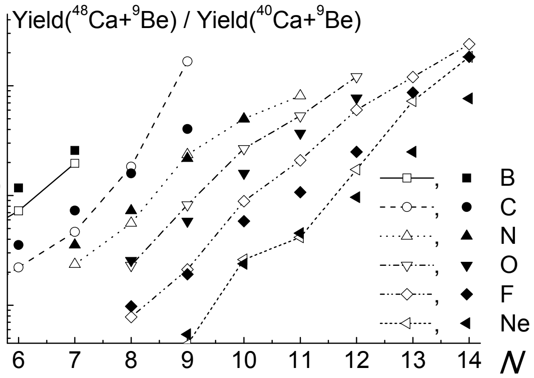

Fig. 1. Yield ratios for different elements for the reactions ^{48}Ca and ^{40}Ca on ^{9}Be at 140 MeV / nucleon. The closed symbols are the experimental results, while the curves with open symbols are the calculations.

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NON-EQUILIBRIUM EQUATION OF STATE IN HEAVY-ION COLLISIONS AT INTERMEDIATE ENERGIES

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In the development of our approach [1–4], we proposed to find the distribution function of nucleons $f(\vec{r},\vec{p},t)$ (where $\vec{r}$ is the spatial coordinate, $\vec{p}$ is the momentum, t is the time) in heavy-ion collisions from the solution of a kinetic equation by taking the moments with the weights $1,\vec{p},p^2$, and $p_x^2-(p_y^2+p_z^2)/2$. The obtained equation of state relates a non–equilibrium component $f_1(\vec{r},\vec{p},t)$ corresponding to the form of a Fermi-ellipsoid, and the equilibrium component $f_0(\vec{r},\vec{p},t)$ corresponding to the equilibrium Fermi-sphere, where $f(\vec{r},\vec{p},t)=f_1\cdot q+f_0\cdot(1-q)$ (here q is a relaxation factor). These equations were used in the calculation of the hydrodynamic evolution of a hot spot produced in heavy-ion collisions, including into a description of compression, decompression, and expansion stages.

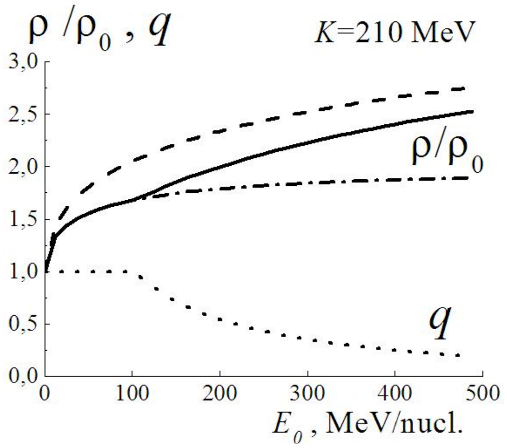

Fig.1. The energy dependence of the maximum compression ratio ρ/ρ0 of nuclear matter in the central collisions of Ar and Ca nuclei at the compression module K=210 MeV (the solid line corresponds to the general case, the dashed line corresponds to the case of q=0, the dashed–dotted line corresponds to the case of q=1), and the energy dependence of the relaxation factor q in the general case (the dotted line).

In this paper we have shown that our approach to the hydrodynamic description of the heavy-ion collisions at medium energies and, in particular, to the description of the hot spot evolution with using of a non-equilibrium equation of state has been more successful in calculation of the proton spectra in collisions of the nuclei Ar + Ca, than those given in [5] based on the Vlasov-Uehling-Uhlenbeck (VUU) kinetic equation.

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SEMI-EMPIRICAL MODEL OF NEUTRON REARRANGEMENT IN QUANTUM CHANNEL-COUPLING APPROACH

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The significant enhancement of sub-barrier fusion cross sections owing to neutron rearrangement with positive Q-values was found for many combinations of colliding nuclei. The empirical channel-coupling (ECC) model with neutron rearrangement has already been successfully used in several papers (e.g., [1, 2]) to describe and predict cross sections for sub-barrier fusion reactions of stable nuclei. It is rather difficult to include nucleon transfer channels in the rigorous quantum channel-coupling (QCC) approach [3, 4].

In this work the QCC approach was combined with the empirical model to add neutron rearrangement channels to vibrational and rotational excitations. The probability of the transfer of x neutrons with the given Q-value was estimated in the semiclassical approximation [1]. The partial penetration probability through the multidimensional potential barrier was obtained in the QCC approach using the calculated partial wave functions (Fig. 1a). The model was applied to the analysis of the sub-barrier fusion cross sections for ^{40}Ca+^{90,96}Zr (Fig. 1b) and ^{32}S+ ^{90,92,96}Zr reactions.

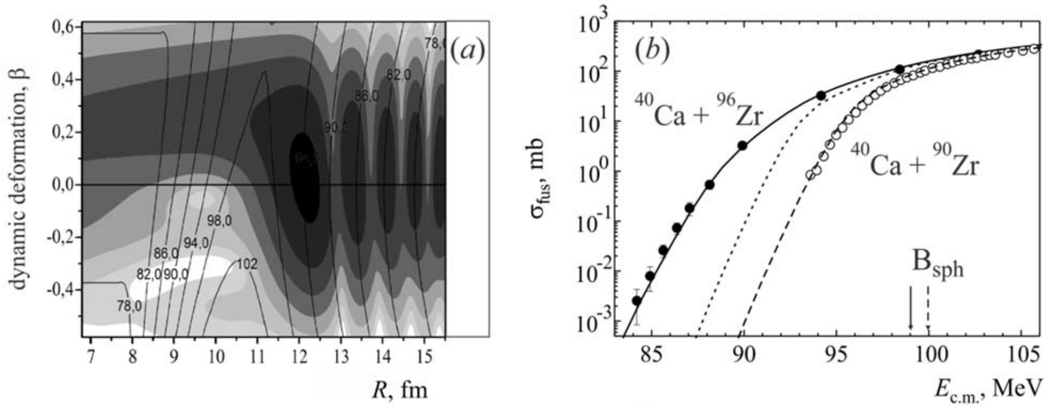

Fig. 1. (a) The partial (L=0) probability density $|\Psi(R, \beta)|^2$ flow through the multidimensional potential barrier $V(R, \beta)$ for the reaction ^{40}Ca+^{90}Zr ($E_{c.m.}$= 96 MeV). (b) Fusion excitation functions for ^{40}Ca +^{96}Zr [5] (filled circles) and ^{40}Ca + ^{90}Zr [6] (open circles). The solid and dotted curves are the calculations with and without neutron rearrangement for ^{40}Ca +^{96}Zr. The dashed curve is the calculation without neutron rearrangement for ^{40}Ca +^{90}Zr.

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NEAR-BARRIER NEUTRON TRANSFER IN REACTIONS WITH ^{3,6}He

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Experimental excitation functions for near-barrier neutron transfer in ^{3,6}He+^{197}Au reactions [1, 2] and cross sections for production of Sc isotopes in ^{3,6}He+^{45}Sc reactions [3, 4] have been analyzed. To calculate the probabilities of neutron transfer and the transfer cross sections the time-dependent Schrödinger equation (TDSE) [5, 6] and the coupled channel (CC) equations [6] for external neutrons of ^{3,6}He and ^{45}Sc, ^{197}Au nuclei have been solved numerically. The contribution of fusion and subsequent evaporation to the experimental data is negligible in case of ^{3,6}He+^{197}Au reactions, whereas in case of ^{3,6}He+^{45}Sc reactions it is quite large. The fusion-evaporation was taken into account using the PACE code [7]. Results of calculation demonstrate overall satisfactory agreement with the experimental data including the sub-barrier region for ^{3,6}He+^{197}Au reactions (Fig. 1). The used realization of the TDSE and CC methods may also be applied for calculation of reactions with cluster nuclei.

This work is partially supported by grant 15-07-07673-a of the Russian Foundation for Basic Research (RFBR).

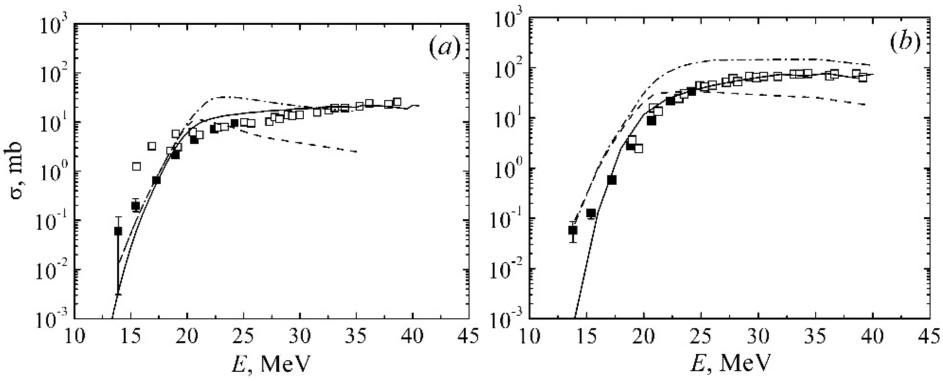

Fig. 1. a) The excitation function for the reaction $^{197}Au(^{3}He,^{4}He)^{196}Au$. b) The excitation function for the reaction $^{197}Au(^{3}He,2p)^{198}Au$. Symbols are the experimental data from Ref. [1] (filled squares) and Ref. [8] (empty squares), dash-dotted and dashed curves are the results of the TDSE calculations with two different approximations for the probability of neutron transfer, solid lines are the results of combining CC and TDSE methods.

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ROLE OF NEUTRON TRANSFER IN FUSION REACTIONS AT SUB-BARRIER ENERGIES

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The nuclear deformation and neutron-transfer process have been identified as playing a major role in the magnitude of the sub-barrier capture and fusion cross sections [1, 2]. It is generally thought that the sub-barrier capture (fusion) cross section increases because of the neutron transfer. However, as shown recently in Ref. [3], the neutron transfer channels with positive *Q*-value weakly influence the capture (fusion) cross section in the ^{60}Ni +^{100}Mo (Q_{2n} = 4.2 MeV) reaction. The effect of transfer channels on the capture (fusion) of ^{132}Sn,^{130}Te + ^{58,64}Ni at energies above and a few MeV below the Coulomb barrier is demonstrated to be very weak with no significant differences observed in the reduced excitation functions [4]. These measurements are in contrast to a number of previous measurements with lighter systems that showed large enhancements of the capture (fusion) in correlation with transfer channels with an increased positive *Q*-value.

The purpose of our investigation is the theoretical explanation of the recent experimental data. We try to answer the question why the influence of neutron transfer is strong in some capture reactions and is weak in others. The reactions with radioactive ion beams are of particular interest because they can be used to gain larger production cross sections of superheavy elements. Our results can have important consequences for nuclear reactions of astrophysical interest as well as in the newly growing field of interactions with light radioactive beams.

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MICROSCOPIC TIME-DEPENDENT DESCRIPTION OF ALPHA-CLUSTER TRANSFER AND INCOMPLETE FUSION IN REACTIONS NEAR COULOMB BARRIER

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The cluster structure of the nucleus ^{20}Ne has often been cited as the best example of clustering in light nuclei, e.g. [1]. The time-dependent Schrödinger equation was numerically solved for alpha-cluster wave functions in reaction ^{20}Ne+^{122}Sn [2] at energies near the Coulomb barrier. The alpha-cluster potential energy determined from alpha particle scattering data [3] was used. The potential had the minimum in the center of ^{20}Ne [4, 5] and in the surface region of the heavy target ^{122}Sn [6, 7]. The used alpha-cluster potential had imaginary part as in the optical model [8]. The evolution of the alpha-cluster probability density was calculated for the complete and incomplete fusion and transfer channels (Fig. 1a). The impact parameter distributions for three channels of the reaction ^{20}Ne+^{122}Sn (Fig 1b) are similar to the phenomenological approximation distribution [2]. This approach was applied to the calculation of the transfer and incomplete fusion cross sections in the ^{20}Ne+^{122}Sn reaction. The model may also be applied for analysis of reactions with nuclei having other cluster structures

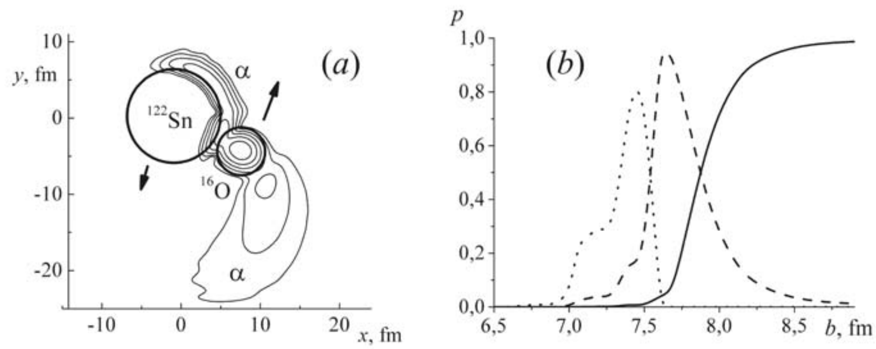

Fig. 1. a) Probability density (in logarithmic scale) for alpha-clusters at the distance of the closest approach in the collision ^{20}Ne+^{122}Sn with the impact parameter b = 7.7 fm and E_{CM} = 150 MeV; b) Probabilities of channels (^{20}Ne,^{20}Ne), (^{20}Ne,^{16}O), (^{20}Ne,^{12}C) in the collision ^{20}Ne+^{122}Sn with E_{CM} = 150 MeV are shown by solid, dashed and dotted lines, respectively; b is the impact parameter.

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TWO-PARTICLE CORRELATION FUNCTION: THE FORWARD-BACKWARD VS DI-HADRON CORRELATION APPROACH

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Two methods of determination of two-particle correlation function are compared. The first one is based on the measurements of the correlation between multiplicities in two separated small acceptance windows, in accordance with the definition of the two-particle correlation function C_2 by double and single inclusive cross sections. It is connected with the so-called forward-backward correlation approach [1–3]. The other is known as di-hadron correlation approach [4]. It determines the two-particle correlation function C through the ratio of the "signal", S, to the "background", B. In S one takes into account all possible particle pairs with given pseudorapidity and azimuth differences, produced within one wide acceptance window. The B is obtained by similar way using the event mixing procedure, when the pair particles are taken from different events to imitate uncorrelated particle production.

It is known that in the mid-rapidity region, where the translation invariance in rapidity takes place and hence the particle distribution in rapidity is flat, the both methods lead to the same result, if the proper normalization procedures were applied for S and B [2]. In the absence of translation invariance, when the particle distribution is not flat, as e.g. in the case for wide rapidity intervals or for asymmetric nuclear interactions, such as ultra relativistic pPb and dAu collisions at LHC [5–7] and RHIC [8], the correlation function C, obtained by the di-hadron correlation approach, does not reproduce the canonical two-particle correlation function C_2, defined through inclusive cross sections.

Using the simple string model for pA and dA interactions we show that the unjustified application of the di-hadron correlation approach in this case can lead to appearance of phantom short range correlations in C, which were not introduced for the sources (strings) of the model. Whereas the method based on the studies of the forward-backward correlations between multiplicities in two small windows enables to find the correct value of the two-particle correlation function C_2 in all cases. We also show the difference between C and C_2 in the case of pPb interaction basing on the results of MC event generator simulations.

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THE GLUON DISTRIBUTION AT SMALL *X* FROM PHOTOPRODUCTION OF ψ(2S) MESONS IN ULTRAPERIPHERAL COLLISIONS AT THE LHC

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The gluon distributions in the proton ($g_p(x)$) and nuclei ($g_A(x)$) are fundamental quantities of Quantum Chromodynamics (QCD) playing a key role in analysis of hard processes with nucleons and nuclei. At small values of the momentum fraction x, $g_p(x)$ and $g_A(x)$ are known with significant uncertainties; the program of ion ultraperipheral collisions (UPCs) at the Large Hadron Collider (LHC) [1] aims to better constrain these quantities.

Using the leading order perturbative QCD (pQCD) predicting that the cross section of charmonium photoproduction is proportional to the gluon density squared, we show [2] that pQCD provides the good description of photoproduction of J/ψ and ψ(2S) mesons in proton–proton UPCs at 7 TeV measured by the LHCb collaboration at the LHC [3]. This analysis allows one to place additional constrains on $g_p(x)$ at small x down to $x = 5 \cdot 10^{-6}$.

We also examine the contribution to the photon flux of the p $\rightarrow \Delta\gamma$ transition and its effect on the theoretical interpretation of the LHCb measurement.

Applying leading order pQCD to charmonium photoproduction on nuclei and using for $g_A(x)$ predictions of the leading twist theory of nuclear shadowing and results of QCD fits to nuclear parton distributions, we obtained [4,5] the good description of the ALICE data on J/ψ photoproduction in Pb-Pb UPC at 2.76 GeV [6,7]. Our analysis gave first direct evidence of the large nuclear gluon shadowing (suppression of $g_A(x)$) at $x = 0.001$. Extending this framework to the case of ψ(2S) photoproduction in Pb-Pb UPCs, we predict [8] that the nuclear shadowing suppression is very similar in the J/ψ and ψ(2S) cases. This prediction is to be compared with the preliminary ALICE data which does not favor large nuclear shadowing suppression of ψ(2S) photoproduction at the central rapidity in Pb-Pb UPCs at 2.76 TeV.

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MONTE CARLO EVENT GENERATORS FOR NICA/MPD AND CBM EXPERIMENTS

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New experiments with relativistic heavy ions are planned now – NICA/MPD at JINR (Russia) and CMB at GSI (Germany). The NICA/MPD experiment is going to study nucleus-nucleus collisions at $E_{\mathrm{cms}} = 4 - 11$ GeV and search for the mixing phase (mixture of hadronic gas and quark-gluon-plasma). The CBM experiment at $E_{\mathrm{cms}} = 3 - 10$ GeV is aimed to create the condensed baryonic matter and study its phase diagram. The experiments are now at the design stage. Thus many Monte Carlo simulations are required: estimations of particle production rates, yield of nuclear fragments, generation of neutrons, penetration of particles through detectors and so on. We will consider the central part of the simulations – simulation of particle production.

There are a lot of generators – DCM, Fritiof, UrQMD, QGSM, PHSD, GiBUU and FTF of Geant4. Some of them are based on the Glauber theory. The theory is using for calculations of reaction cross sections and general properties of interactions – impact parameter distributions, multiplicities of participating nucleons, multiplicities of binary nucleon-nucleon collisions and so on. Recently, we proposed a code [1] for calculations of the properties in the desired energy range. A unified systematic of nucleon-nucleon elastic scattering data [2,3] is in the core of the program. A short description of the code and its results will be presented.

The generators will be shortly considered in the second part of our report. There will be also given calculations results – densities of particles in rapidity space, ratios of particles yields, distributions of particles on kinematical variables in dependence on collision centralities.

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NUCLEAR EFFECTS IN DIFFRACTION SCATTERING PROCESSES OF PROTONS ON NUCLEI AT HIGH ENERGIES

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Differential diffraction cross-section of the reaction pA→pX for the nuclear target Al simulated with Monte-Carlo event generator HARDPING 3.0[1].

HARDPING 3.0 allows to describe hadron production in p-A interaction. It takes into account the following effects: initial hadrons and their constituents energy losses and multiple rescattering inside the nucleus, energy losses and multiple rescatterings of the hadrons and their constituents produced in the interaction. Also the formation length of the hadrons produced in hard scattering is taken into account. The parameters of multiple soft rescattering, energy loses and hadron formation inside the nucleus were fixed in previous versions.

This paper gives differential diffraction cross-section $d\sigma/dt$ of p+Al→p+X reaction as function of squared transferred momentum t for ^{13}Al nucleus.

Results of simulation are compared with data from HELIOS experiment at 450 GeV (Fig. 1) [2]. As the Fig. 1 shows, results of simulation are in agreement with the experiment. Solid markers represent results from HELIOS, blank markers represent results from HARDPING simulation. Only protons with $xF > 0.925$ were selected for the analysis of experimental and simulation data.

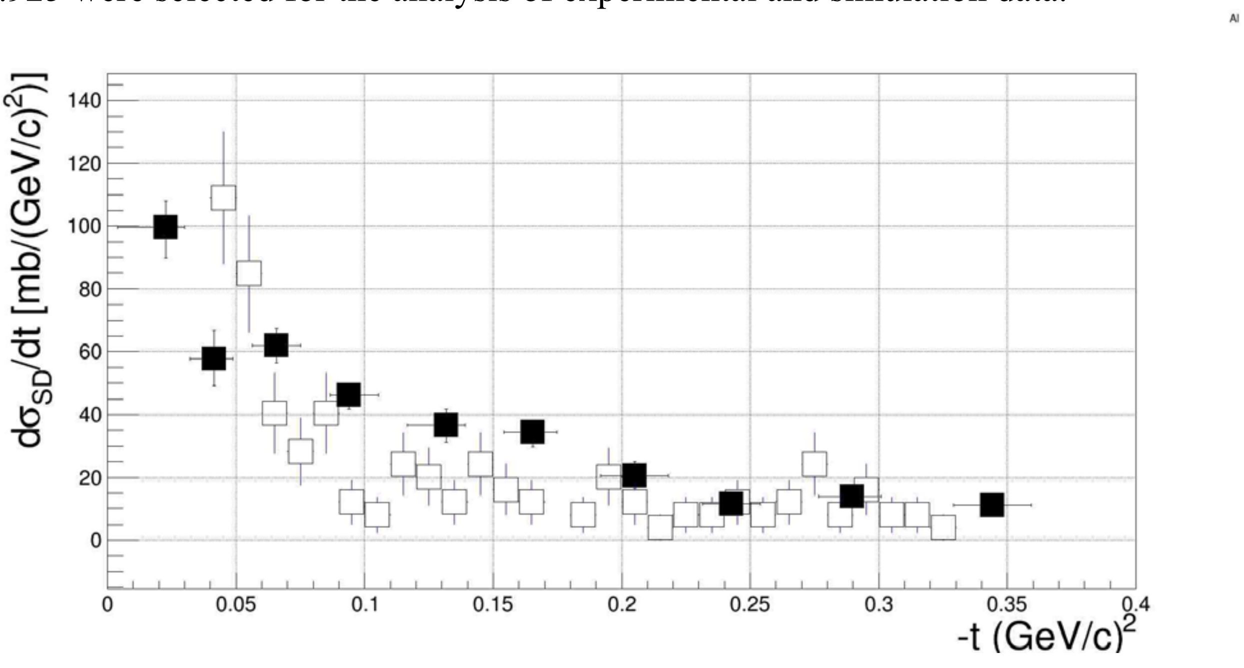

Fig. 1. Differential diffraction cross-section of the reaction pA→pX for the nuclear target Al.

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THE 2 REGGEONS TO 2 REGGEON + PARTICLE EFFECTIVE VERTEX ($A_+ A_+ A_- A_- V_\nu$) IN THE LIPATOV EFFECTIVE ACTION IN THE REGGE KINEMATICS

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The vertex $A_+ A_+ A_- A_- V_\nu$ is constructed for gluon production in interaction of two reggeons coupled to projectiles and two reggeons coupled to targets. The vertex can be used to build cross-sections for collisions of two pairs of nucleons in AA scattering.

To study this process we use the Lipatov effective action [1], which provides a powerful and constructive technique for the calculation of all Feynman diagrams in the Regge kinematics.

The effective Lagrangian is local in rapidity and describes the self-interaction of gluons at a given rapidity by means of the usual QCD Lagrangian L QCD and their interaction with reggeons. It has the form:

$$L_{eff} = L_{QCD}(V_\mu^y + A_\mu^y) + 2\mathrm{Tr}\Big((A_+(V_+^y + A_+^y) - A_+^y)\partial_\perp^2 A_-^y + (A_-(V_-^y + A_-^y) - A_-^y)\partial_\perp^2 A_+^y \Big),$$

where $A_\pm(V_\pm) = \sum_{n=0}^{\infty} (-g)^n V_\pm (\partial_\pm^{-1} V_\pm)^n = V_\pm - gV_\pm \partial_\pm^{-1} V_\pm + g^2 V_\pm \partial_\pm^{-1} V_\pm \partial_\pm^{-1} V_\pm + \ldots$

Some of the full and induced vertices derived from this action have been already found in [2]. The induced vertex RP→RP is new and will be derived here.

In my talk I would like to speak about the effective vertex $A_+ A_+ A_- A_- V_\nu$ and show it's calculation. Also I will talk about poles at zero values of longitudinal momenta that appear in this case and I will show that their behavior is different from the case of a single projectile.

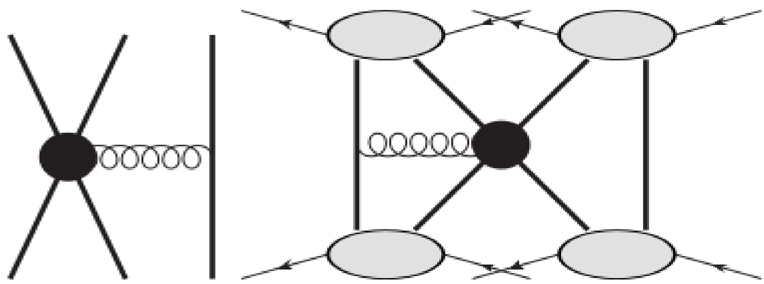

Fig. 1. $A_+ A_+ A_- A_- V_\nu$ effective vertex (left); process of interaction of two quark pairs (right).

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ON THE UNDERTHRESHOLD PHOTONUCLEOSYNTHESIS PHENOMENA

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Phenomena of the underthreshold photonucleosynthesis was theoretically predicted [1, 2] and experimentally proved [3].

Gaseous deuterium in the X-ray-transparent stainless steel cylinder was irradiated by «cobalt gun» γ- quanta $E_\gamma = 1.1$ MeV. Target irradiation time was 15 days [3].

Experimental installation includes:

1) The cylindrical chamber with the "cobalt gun": diameter 130 mm, height 210 mm.
2) Ten tubes of 30 sources by activity $0.58 \cdot 10^{12}$ Bq around chamber.
3) Each source is the cylinder: diameter 11 mm, height 81 mm
4) Cylinder with deuterium V = 50 ml, the walls thickness 2 mm, pressure 110 bar.

The tritium concentration was measured by liquid scintillation method (TriCarb 2810 TR). The exposed cylinder contains $\nu_D \approx 0.65$ mol of deuterium or $N_0 \approx 7.8 \cdot 10^{28}$ atoms. After deuterium oxygenation we received approximately 13 g of heavy water with tritium.

The increasing of the tritium quantity was significant. We interpret this result by only one way: the direct "experimentum crucis" on tritium photoproduction in gaseous deuterium confirmed the theoretical predictions of the dineutroneum existence [1, 2]. This result is in a qualitative agreement with the data on carbon photoproduction in dense helium [4, 5].

The alternative explanation of tritium and carbon photoproduction is absent.

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ANGULAR DISTRIBUTIONS OF PROTONS EMITTED AT TWO-PROTON DECAYS OF SPHERICAL NUCLEI

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The angular distribution of emitted protons in the case of a two-step facilitated two proton decay of spherical nuclei [1] using the conversion from the LCS S to the coordinate system S' associated with the first proton momentum $\vec{k}_1$ when $Y_{lm_l}(\theta'_{\vec{k}_1}=0)=\sqrt{(2l+1)/4\pi}\delta_{m_l 0}$, can be reduced to the formula for the angular distribution of the second proton in S':

$$\frac{\partial\Gamma}{\partial\Omega'_{\vec{k}_2}}=\frac{1}{2\pi}\int_0^{Q_0} dT\sum_{ll'L} B(l,l',L,T)C^{L0}_{l0l'0}Y_{L0}(\theta'_2) \quad (1)$$

Equation (1) contains the terms, that symmetric and antisymmetric towards to angle $\theta'_2=\pi/2$, respectively, for even L (taking into account the interference of the orbital angular momenta $\theta'_2=\pi/2$ of the proton of the same parity) and for odd L (taking into account the interference of l,l' different parity).

The experimental angular distribution [2] of the second proton relative to the direction of emission of the first proton for two-proton decay of nucleus ^{45}Fe is asymmetric towards to the angle $\theta'_2=\pi/2$. This situation is possible in the case of contributions' proximity to the total width of the parent nucleus proton states with different parities and taking into account the interference of these states, for example, states $1f_{7/2}$, $2p_{3/2}$ and $2s_{1/2}$.

Note that the experimental distribution [2] has been described in article [3]. This concept is based on the idea of the simultaneous emission from the parent nucleus of two protons and the daughter nucleus and realized by using the method of hyperspherical functions. However, only the states of emitted protons $1f_{7/2}$, $2p_{3/2}$, having the same parity were taken into account.

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THE THEORY OF MULTISTEP STATISTICAL DECAYS IN CHAINS OF GENETICALLY RELATED NUCLEI

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On the framework of methods of paper [1] the width of the n-step statistical decay $r_0 \to b$ of the resonance state r_0 of the parent nucleus with spin I_{r_0}, energy E_{r_0} and total $\Gamma^{I_{r_0}}$ and partial widths $\Gamma_b^{I_{r_0}}$, that occurs as $r_0 \to b_1 + r_1 \to b_1 + b_2 + r_2 \to \ldots \to b_1 + \ldots + b_n + B$, where $r_1, r_2, \ldots, r_{n-1}$ are resonance states and final channel b is defined by only stable particles $b_1, \ldots, b_n, B$ with internal energies $E_{b_1}, \ldots, E_B$, is presented as

$$\Gamma_b^{I_{r_0}} = \sum \int \frac{dT_{b_1} \ldots dT_{b_{n-1}}}{(2\pi)^{n-1}} \sum \frac{\Gamma^{I_{r_0}}_{I_{r_1} j_{b_1} l_{b_1}} \Gamma^{I_{r_1}}_{I_{r_2} j_{b_2} l_{b_2}} \ldots \Gamma^{I_{r_{n-1}}}_{I_B j_{b_n} l_{b_n}}}{\left((T_{b_1} - Q_{b_1})^2 + \Gamma^2_{r_1}/4\right) \ldots \left((T_{b_{n-1}} - Q_{b_{n-1}})^2 + \Gamma^2_{r_{n-1}}/4\right)}, \quad (1)$$

where l_{b_1} and j_{b_1} – orbital moment of relative motion of particles b_1, r_1 and the total spin of particle b_1, T_{b_1} – the kinetic energies of relative motion of particles (b_1, r_1) and $Q_{b_k} = (E_{r_{k-1}} - E_{b_k} - E_{r_k})$ – heat for decay $r_0 \to b_1 + r_1$. In cases when all heats have values $Q_{b_1} > 0$, …, $Q_{b_{n-1}} > 0$ and connect only with open decay channels of resonance states r_1, r_2, …, r_{n-1} formula (1) after integration on T_{b_1}, ..., $T_{b_{n-1}}$ transits to the formula for the width of sequential n-step statistical decay:

$$(\Gamma_b^{I_{r_0}})^{\text{seq}} = \sum \frac{\Gamma^{I_{r_0}}_{I_{r_1} j_{b_1} l_{b_1}} \Gamma^{I_{r_1}}_{I_{r_2} j_{b_2} l_{b_2}} \ldots \Gamma^{I_{r_{n-1}}}_{I_B j_{b_n} l_{b_n}}}{\Gamma^{r_1} \ldots \Gamma^{r_{n-1}}}, \quad (2)$$

which is agree with analogous width obtained for kinetic equations of decays in chains of genetically related nuclei [2]. If one or several heats have negative values for the virtual multistep transitions appear in formula (2). For example for case $Q_{b_k} < 0$, when $Q_{b_{k+1}} > 0$ and $T_{b_k} + T_{b_{k+1}} = Q_{b_k} + Q_{b_{k+1}} > 0$ in (2) instead sequential transitions $r_{k-1} \to b_k + r_k \to b_k + b_{k+1} + r_{k+1}$ the twostep virtual transition $r_{k-1} \to b_k + b_{k+1} + r_{k+1}$ appears.

Formulae of type (1) are obtained for the cases when all particles $b_1, b_2, \ldots, b_n$ don't interact each with other. This situation is realized if these particles flight in remarkably different moments of time. It can be shown that the interactions between particles (b_k, b_{k+1}), (b_k, b_{k+1}, b_{k+2}) etc. must be taken when these particles form new resonances $\overline{b_k b_{k+1}}$, $\overline{b_k b_{k+1} b_{k+2}}$ etc., flighting from resonance r_{k-1} with the creation of resonances r_{k+2}, r_{k+3} etc. On following steps new resonances $\overline{b_k b_{k+1}}$, $\overline{b_k b_{k+1} b_{k+2}}$, etc. decay with the creations of particles (b_1, b_2), (b_1, b_2, b_3) etc. in continuous spectra. The same situation is realized for two proton decays and quasitrue quaternary fission of nuclei.

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CONDITIONS OF THE *T*-INVARIANCE FOR SEQUENTIAL MULTISTEP STATISTICAL NUCLEAR REACTIONS

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Consider the sequential three-step statistical nuclear reaction $a \to b$, that occurs as $a+A \to r_0 \to b_1 + r_1 \to b_1 + b_2 + B$, where the particle $A(a)$ with spin $I_A(I_a)$ and internal energy E_A (E_a) appears in the initial channel a, the final channel b is associated with the appearance of three stable particles b_1, b_2 and B, the resonance state r_0 (r_1) with spin I_{r_0} (I_{r_1}), energy E_{r_0} (E_{r_1}) and the width Γ_{r_0} (Γ_{r_1}) is formed by collision of particles a, A (b_2, B). Using the methods of [1,2] the amplitude $f^{(3)}_{b,a}$ of this reaction is represented as:

$$f^{(3)}_{b,a} = \sum_{r_0, r_1} \frac{g\left(I_B I_{b_2} l_{b_2} \leftarrow I_{r_1}\right) g\left(I_{r_1} I_{b_1} l_{b_1} \leftarrow I_{r_0}\right) g\left(I_{r_0} \leftarrow I_A I_a l_a\right)}{\left(E - E_{r_0} + {}^{i}\!/_{2}\Gamma_{r_0}\right)\left(Q_{b_1 r_1} - T_{b_1 r_1} + {}^{i}\!/_{2}\Gamma_{r_1}\right)},$$

where $Q_{b_1 r_1} = E - E_{b_1} - E_{r_1}$ and $T_{b_1 r_1}$ – energy of the relative motion of the particles b_1 and r_1. The amplitude of the time reversed reaction $f_{-a,-b}$ has the structure:

$$f^{(3)}_{-a,-b} = \sum_{r_0, r_1} \frac{g\left(\overline{I_A I_a l_a} \leftarrow \overline{I_{r_0}}\right) g\left(\overline{I_{r_0}} \leftarrow \overline{I_{r_1} I_{b_1} l_{b_1}}\right) g\left(\overline{I_{r_1}} \leftarrow \overline{I_B I_{b_2} l_{b_2}}\right)}{\left(E - E_{r_0} + {}^{i}\!/_{2}\Gamma_{r_0}\right)\left(Q_{b_1 r_1} - T_{b_1 r_1} + {}^{i}\!/_{2}\Gamma_{r_1}\right)},$$

where $\overline{K}$ – the time reversed arbitrary state K.

Taking into account the T-invariance conditions for the g-amplitudes included in the formulas for $f^{(3)}_{b,a}$ and $f^{(3)}_{-a,-b}$: $g\left(I_B I_{b_2} l_{b_2} \leftarrow I_{r_1} m_1\right) = g\left(\overline{I_{r_1} m_1} \leftarrow \overline{I_B I_{b_2} l_{b_2}}\right)$, the analogous condition for the amplitude $f^{(3)}_{b,a}$ is represented as $f^{(3)}_{b,a} = f^{(3)}_{-a,-b}$. It means that T-invariant amplitude $f^{(3)}_{b,a}$ doesn't vary for inversions of moments and spins of all particles, appearing at the various steps of considered reaction, and simultaneously for the permutation of moments (spins) of the particles lying in continuous spectrum of reactions in accordance with the transition from the moment sequence $\vec{p}_{b_2}$, $\vec{p}_{b_1}$, $\vec{p}_a$ for reaction $a \to b$ to the different sequence $\vec{p}_a$, $\vec{p}_{b_1}$, $\vec{p}_{b_2}$ for the reversed reaction $b \to a$.

It's demonstrated that the T-invariance condition for the amplitude of sequential n-step statistical nuclear reaction is similar T-invariance condition for analogous three-step reaction. It allows without contradictions to confirm the T-invariance of all found asymmetries in the angular distributions of products of binary, ternary and quaternary fission of nuclei.

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THE SEQUENTIAL CHARACTER OF LOW-ENERGY TERNARY AND QUATERNARY NUCLEI FISSION

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In the series of papers, for example [1, 2], it is presented arguments that the low-energy ternary nucleus fission is not sequential two-step process for which the moments of third particle formation and the fission fragments are well separated but is one-step process in which these fission products appear simultaneously. As it will be present below, these arguments are unconvincing.

Firstly, the evaporation mechanism of third particle emission from the fissile nucleus or from fission fragments on the fission steps close in time to scission of fissile nucleus does not realize. It is connected with the fact that for the indicated steps the fissile nucleus and fission fragments stay cold, that leads to absence of the dynamic enhancement of Coriolis interaction and to the possibility to have different anisotro-pies in angular distribution of fission fragments. Therefore, the flight of third particle from the fissile nucleus is defined by nonevaporational mechanism, which is connected with non-adiabatic character of collective deformation motion of fission nucleus on the previous it's scission steps.

Secondly, on the all steps of binary and ternary fission the axial symmetry of deformed compound fissile nucleus is saved and the axis of this symmetry determines one of selected vectors of compound nucleus direction of which coincides with the direction of vector of light fission fragment moment $\vec{p}_{LF}$. This vector can appear together with the other selected vector of the compound nucleus [2], which appears for the polarized compound nucleus and coincides with it's vector polarization. Therefore for cases with the parity conservation the angular distribution of third particle depends only from the correlator ($\vec{p}_3, \vec{p}_{LF}$), where $\vec{p}_3$ – the moment of third particle.

Finally, the analyze of the T-odd asymmetry $(\vec{\sigma}_n,[\vec{p}_3,\vec{p}_{LF}])$, which was experimentally detected in the ternary fission of non-orientation nucleus-target by cold polarized (with polarization $\vec{\sigma}_n$) neutrons, leads to the conclusion [4], that the indicated asymmetry satisfies the condition of *T*-invariance in case of the sequential two-step character of ternary fission process. At the same time this asymmetry is not T-invariant in the case of simultaneous flight of the third particle and fission fragments from fissile nucleus for ternary fission.

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THE CLASSIFICATION *T*-ODD ASYMMETRY FOR PRESCISSION AND EVAPORATIVE LIGHT PARTICLES IN REACTIONS TERNARY AND QUATERNARY FISSION BY COLD POLARIZED NEUTRONS

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The coefficients $D(\theta)$ of *T*-odd asymmetries in angular distribution of α-particles emitted in ternary fission reactions by cold polarized neutrons are represented [1] as $D(\theta) = D_{ROT}(\theta) + D_{TRI}$. The coefficient D_{ROT} for ROT-asymmetry caused by the influence of collective rotation of polarized fissile system to the unperturbed α-particle angular distribution $W^0(\theta)$ is represented as $D_{ROT} = a_{ROT}[W^0(\theta)]^{-1} dW^0(\theta)/d\theta$. The coefficient D_{TRI} for TRI-asymmetry is practically independent from the angle θ and is caused by the influence of catapult and Coriolis forces connected with presented above rotation to nucleons of fissile nucleus neck participating in the formation of α-particles. Coefficients $D_{ROT}(\theta), D_{TRI}$ and $D(\theta)$, proposed in [1] have dynamical character and therefore must be close for neighboring target nuclei ^{233}U, ^{235}U, ^{239}Pu. But measured coefficients $D(\theta)$ for these nuclei change in the irregular manner. For the explanation of these result it was proposed [2] the unified mechanism for ROT- and TRI-asymmetries associated with different influences of the Coriolis interaction to even $A^0_{ev}(\theta)$ and to odd $A^0_{odd}(\theta)$ amplitudes of α-particles angular distributions, when $D_{ROT}(\theta) = a_{ev} \dfrac{dA^0_{ev}}{d\theta} \Big/ A^0(\theta)$; $D_{TRI}(\theta) = a_{odd} \dfrac{dA^0_{odd}}{d\theta} \Big/ A^0(\theta)$ where the coefficients a_{ev} and a_{odd} are defined by phase differences for amplitudes of ternary fission from different *s*-neutron resonance states of the fissile nucleus which strongly fluctuate for neighboring target nuclei. These coefficients $D_{ROT}(\theta)$ and $D_{TRI}(\theta)$ successfully explain the experimental dependences of $D(\theta)$ for nuclei ^{235}U, ^{239}Pu at all angles θ and for the nucleus ^{233}U in the region of $60^\circ < \theta < 110^\circ$. It is necessary the additional testing of experimental results for nucleus ^{233}U in remaining area of angles.

The appearance of the *T*-odd asymmetries for angular distributions of the evaporation neutrons and γ-quanta can be caused, firstly, by the anisotropy of named above distributions and, secondly, by the influence of the polarized fissioning system rotation to fission fragments angular distributions. Since these anisotropies are connected with the even orbital angular momentum of neutrons and quanta, the *T*-odd asymmetry for them must have the character of ROT-asymmetry, which is consistent with the experimental dependences of $D(\theta)$.

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THE ANGULAR AND SPIN DISTRIBUTIONS OF THE FISSION FRAGMENTS WITH TAKING INTO ACCOUNT THE FISSILE NUCLEUS TRANSVERSE OSCILATIONS NEAR IT'S SCISSION POINT

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The angular distribution $W(\theta')$ of fissile fragments in internal coordinate system of fissile nucleus is localized in the narrow region near the conserved in fission process direction of symmetry axis of name above nucleus. This localization is defined [1] by zero transverse wriggling-vibrations of fissile nucleus near it's scission point which led to the distribution of relative orbital angular moments of prescission fragments $W_w(L) = L/C_w \exp[-(2C_w)^{-1}L^2]$ [2]. For actinide nuclei the value C_w is equal 132 and average value of orbital moments L is equal $\bar{L}_w = 14.4$. Distribution $W_w(L)$ coincides with the analogous distribution of fission fragments for conditions $\bar{L}_w \gg J_0$ and $\bar{L}_w \gg \Delta L$, where J_0 – the spin of the fissioning compound nucleus and $\Delta L \leq 2$ – the change of orbital moment L of fragments connected with the nonsphericity of it's Coulomb interaction. With usage of the distribution $W(\theta')$ as the spread δ-function, which is constructed by the replacing of L-distribution $W_w(L)$ into $W_0(L) = 2L/L_m^2$, where $L \leq L_m$, the comparison of calculated [3] angular distributions of photofission fragments $W(\theta)$ in the laboratory coordinate system with analogous experimental distributions leads to the value $L_m \approx 30$. Using the found above values $\bar{L}_w$ and the relation $L_m = 3/2\,\bar{L}$ for distribution $W_0(L)$ it can be get the value $L_m = 21.6$, which has the essential deviation from found above value $L_m \approx 30$. It is interesting to understand the reasons of this deviation.

The fission fragment spin distribution coincides with the prefragment spin distribution $W(J) = 4J/(C_w + C_b)\exp[-2J^2(C_w + C_b)^{-1}]$ of, constructed with usage [2] of zero transverse wriggling- and bending-vibrations of the fissile nucleus. For actinide nuclei the value C_b is equal 57.3 and the average value of spin $\bar{J}$ is equal 8.6, which agree with experiment values of $\bar{J}$. At the same time, the alignment of the fission fragments spins relatively of the symmetry axis caused by transverse wriggling- and bending-vibrations give possibility to explain the anisotropies angular distributions of the evaporation neutrons and γ-quanta.

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APPLICATION OF FOUR-DIMENSIONAL LANGEVIN DYNAMICS TO STUDY DIFFERENT FEATURES OF HEAVY-ION-INDUCED FISSION

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The four-dimensional dynamical model (4D) [1], which has been proposed and developed on the basis of the three-dimensional model (3D) by incorporating the tilting degree of freedom (*K*-mode) into Langevin dynamics, was applied to the analysis of experimental observables from fusion-fission reactions induced by heavy ions. In the present study we investigate the reaction ${}^{20}\mathrm{Ne}+{}^{232}\mathrm{Th}\rightarrow{}^{252}\mathrm{Fm}$, ${}^{24}\mathrm{Mg}+{}^{208}\mathrm{Pb}\rightarrow{}^{232}\mathrm{Pu}$, ${}^{16}\mathrm{O}+{}^{184}\mathrm{W}\rightarrow{}^{200}\mathrm{Pb}$, for which experimental data on the mass-energy distribution, multiplicity of prescission light particles, fission probability P_f and anisotropy of angular distribution are available.

Three collective shape coordinates plus the tilting coordinate were considered dynamically from the ground state deformation to the scission into fission fragments. In the present study we investigate the effect of the various deformation dependences of the friction parameter γ_K(q), which controls the coupling between the orientation degree of freedom *K* and the "heat bath" [2], on the experimental observables at different values of a reduction coefficient from the contribution from the "wall" formula k_s [3].

The 4D calculations for light and heavy nuclei allow to obtain a consistent description of the mass-energy distributions parameters, prescission neutron multiplicity, fission probability, and anisotropy. Using the constant k_s coefficient from the interval $0.25 < k_s < 0.5$ and deformation-dependent coefficient $k_s(q)$ obtained from chaos-weighted "wall" formula [4] provides a good description of experimental observables in 4D calculations. To reproduce the experimental data on the anisotropy for light nucleus, the friction coefficient γ_K with respect to the orientation degree of freedom should be increased up to 0.4 $(\mathrm{MeV\cdot zs})^{-1/2}$ (its value is dependent on the k_s used). The calculated results demonstrate that the influence of the k_s and γ_K parameters on the calculated quantities can be selectively probed. The friction parameter γ_K affects the angular distribution of fission fragment only. At the same time reduction coefficient k_s affects mass-energy distribution, multiplicity of prescission light particles, fission probability P_f and anisotropy of fission fragment distribution. The 4D dynamical calculations predict independence of the anisotropy of the fission fragment angular distribution on the fission fragment mass, and it is in agreement with the experimental data.

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POST-SCISSION DISSIPATIVE MOTION AND FISSION-FRAGMENT KINETIC ENERGY

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Theoretical description of the fission fragment (FF) kinetic energy distribution is a longstanding and still unresolved problem [1, 2]. When describing theoretically this distribution it is usually thought that the values defining it are frozen at the scission point [2, 3]. In this work we focus on the question whether the post-scission motion can influence the FF kinetic energy. For this aim we calculate the energy dissipated during the flying-off of the FFs.

As the first step we develop an algorithm approximating the dumbbell prescission shape by two separated fragments just after scission. The quadrupole and octupole deformations of FF are taken into account, the FF configuration is supposed to possess axial symmetry (the FF are positioned pole-to-pole).

Then we model the FF post-scission motion using the trajectory model with surface friction developed by us in [4]. The nucleus-nucleus potential which is the core quantity in this model is calculated within the double-folding model with M3Y *NN* forces [5]; the Coulomb energy is calculated using the double-folding approach as well. The dissipative force is constructed according to the method proposed in [6]. Our calculations show that depending on the initial pole-to-pole distance the dissipated energy can reach up to 10% of the experimental FF total kinetic energy.

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PRECISE MULTIDIMENSIONAL POTENTIAL ENERGY SURFACES FOR ALPHA-CLUSTERING, BINARY AND TERNARY FISSION

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The microscopic description of fission process involving different cluster formation is presented. The comparison with other modern theoretical approaches to nuclear potential energy calculations (PES) aimed to describe the nuclear clustering is done [1, 2]. The non-restricted axial shape parameterization used [3] displays the effect of the strong magic shells formation on the nuclear potential energy landscape. The internal structure of nucleus is assumed to be equilibrium at each step of the collective motion so the internal degrees of freedom are described within the adiabatic approximation. It is the shell-correction part of the nuclear energy that is responsible for the multi-modal structure of the PES in the deformation space of high-dimension.

In [1], the minima of the PES are found by variation of the charge and mass numbers of two fragments out of the three constituents and the distances between them. The calculations agree with the recent experimental results on the collinear cluster tri-partition [4, 5]. There are the ruptures of two necks separating the middle cluster belonging to the nearly ternary nuclear system and two outer magic fragments. In [2], the alpha-decay process was described as the evolution of the system in the collective coordinates of the mass asymmetry and relative distance between the center of mass of clusters. The strong relationship between the reflection asymmetry and alpha-clustering was obtained.

In our model collective parameters of the system such as neck radius and asymmetry value are not used in the shape parameterization, they are determined only after calculation of the resulting shape by minimization in ten deformation parameters. The choice of the collective parameters gives us a unique possibility to describe various fission processes such as conventional multimodal binary fission, different ternary type configurations [1,4,5] and effects of the alpha-clustering in heavy nuclear by means of general high-dimensional PES consisting of the several sheets. Each sheet of the PES is responsible for the strongest shell correction effect.

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COLLINEAR NUCLEAR FISSION INTO THREE COMPARABLE FRAGMENTS

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Ternary fission is usually understood as the nuclear fission on two normal fragments accompanied with emission of the third light charged particle, usually alpha particles. Long time it was considered that at low energies of the fissile nuclei under tens MeV, division into three comparable fragments is extremely improbable. Only rather recently, the idea of collinear fission into three fragments gained distribution. Purposeful searches of this mode resulted in experimental values of relative probability about 10^{-3} in comparison with binary fission [1]. This revives old interest in the question.

Usually two mechanisms are considered which can realize this type of fission. One of them is, at first sight, obvious: this consecutive nuclear fission, at first on two fragments, one of which in turn undergoes fission into two others. Both events can be considered occurring in a random way, independently from each other. The other mechanism is usually called real ternary fission. However, for a long time this mechanism was not concretized. In work [2] it is shown that this mode can be related with the corresponding doorway states. In the report it is shown that this mechanism is caused by hexadecapole deformation of the nuclear surface, whereas binary fission occurs through the quadrupole oscillations. Estimates on the mass relations of splinters are received as 1:1.87:1. Dynamics of formation and scattering of collinear splinters is shown. The calculated probability of truly threefold division of $P_{3f} \approx 10^{-3}$ corresponds to the observed values.

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EFFECT OF THE ELECTRON SCREENING ON NUCLEAR REACTIONS

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Effect of the electron screening on the alpha decay rate of typical nuclei is considered. To this end, the adiabatic approach is exploited, which consecutively takes into account the adiabaticity of the motion of the alpha particle through the shells [1]. The results of the calculation are presented in the Table. The effect is found to be of the order of one tenth to one hundredth of a percent for the considered representative nuclei. The method can be applied to description of nuclear reactions of synthesis, which take place in stellar plasma or at laboratory. The effect is expected to be much stronger in the nuclear reactions at small energies, ~ 30 keV and lower.

Nuclide	Q (MeV)	$T_{1/2}$	Y (%)
^{144}Nd	1.905	$2.29 \cdot 10^{15}$ yr	0.24
^{214}Rn	9.208	0.27 μs	0.02
^{226}Ra	4.871	1600 yr	0.23
^{252}Cf	6.217	2.645 yr	0.28
^{241}Es	8.320	9 s	0.12
^{294}118	11.81	0.89 ms	0.27

Table. Results for the relative change in half-periods in bare nuclides (last column).

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ONE-STEP MECHANISM CONTRIBUTION TO THE NEUTRON TRANSFER IN THE (p,d) AND (d,t) REACTIONS ON ^{11}B NUCLEUS

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Differential cross sections of deuterons elastic and inelactic scattering as well as the (d,t) and (d,^{3}He) reactions on ^{11}B nucleus have been measured at the energy E_d=14.5 MeV. The experiment was carried out at the beam of U-150M cyclotron of the INP (Almaty). The semiconductor ΔE-E technique and enriched boron targets were used.

The optical model analysis of the elastic scattering of deuterons within wide energy range of deuterons (~11÷30 MeV) have been fulfilled. The obtained now and published earlier our experimental data on the reactions (d,t) with excitation of four lowest states of ^{10}B nucleus and (d,^{3}He) to the ^{10}Be in ground state as well as suitable literature information have been analyzed in the framework of modified DWBA [1,2]. It was shown that the nucleon transferring in these reactions is peripheral process at the whole mentioned energy interval at least within the region of main pick-up maximum. The obtained values of the asymptotical normalization coefficients (ANC) for configurations $^{11}B\rightarrow{}^{10}B_{g.s}$+n and $^{11}B\rightarrow{}^{10}Be_{g.s}$+p are equal 30.0 ± 2.2 and 24.0 ± 1.0 fm^{-1}, respectively .The empirical ANCs extracted at the energy E_d=11.8 MeV [3] exceed more than twice the values obtained at the higher energies. The reason of the discrepancy is discussed.

The ANC for $^{11}B_{G.S}\rightarrow{}^{10}B$+n obtained from the analysis of not peripheral reaction ^{11}B(p,d)^{10}B [4] depends on the geometry parameters of Wood-Saxon bound state potential. It is found equal to 19.2 fm^{-1} at r_0=1.25 fm and a=0.65 fm and becomes close to that from the reaction ^{11}B(d,t)^{10}B if the geometry parameters taken on the values r_0=1.12 fm and a=0.65 fm. So, the appropriate value of spectroscopic factor $S_{11B\rightarrow10B+n}$=1.17 is to become well-defined.

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DEUTERON SCATTERING FROM ^{12}C AND ^{16}O NUCLEI IN THE α-CLUSTER APPROACH

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The polarization observables for the elastic 400 and 700 MeV deuteron scattering from ^{12}C and ^{16}O nuclei have been analyzed in framework of the multiple diffraction scattering theory and α-cluster model with dispersion. The rigid projectile approximation (RPA) with "effective" d-α scattering amplitude as well as the three-body (TBA) n+p+A model, which uses nucleon-*A* scattering amplitudes and deuteron ground state wave function with both *S* and *D* waves are applied for the calculations. Both approaches are compared with each other and with the available experimental data. The results obtained for 700 MeV deuteron scattering from ^{16}O nuclei are given in Fig. 1.

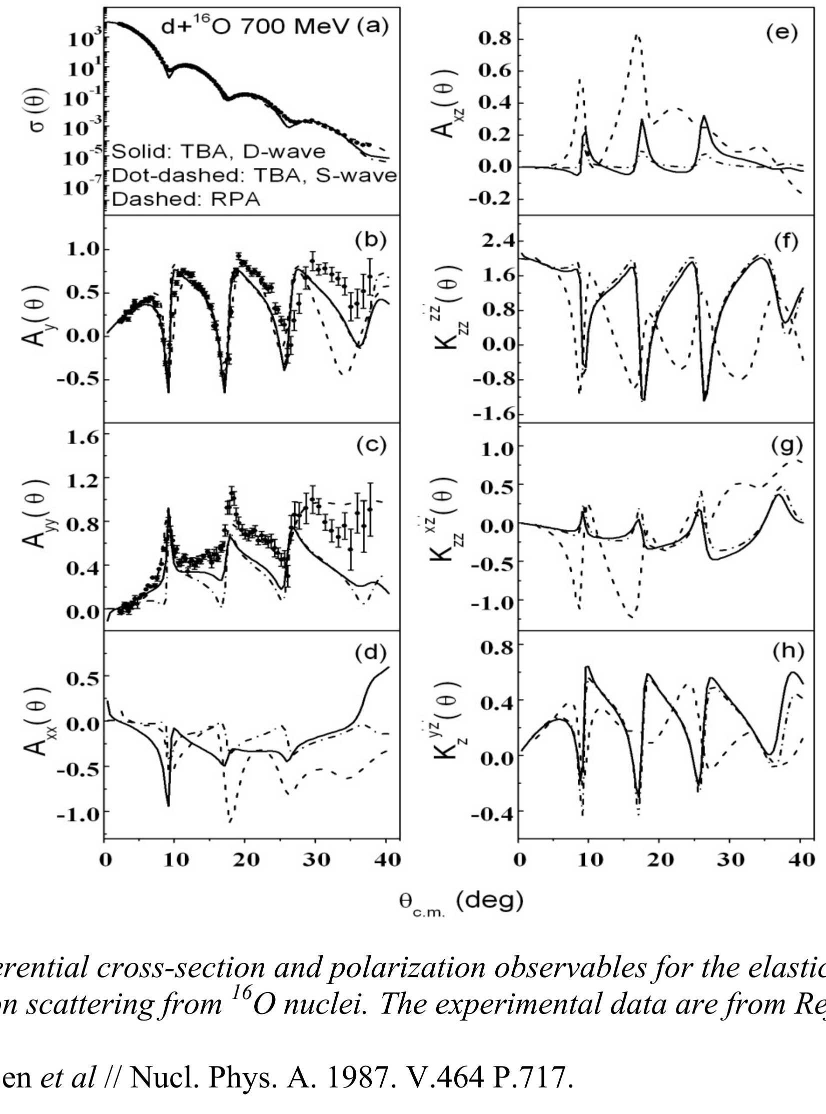

Fig. 1. Differential cross-section and polarization observables for the elastic 700 MeV deuteron scattering from ^{16}O nuclei. The experimental data are from Ref. [1].

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ALPHA-DECAY: EMPIRICAL RELATIONS FOR ALPHA-DECAY HALF-LIVES AND UNIFIED MODEL FOR ALPHA-DECAY AND ALPHA-CAPTURE

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Alpha-decay is very important process in nuclear physics. The alpha-decay process involves sub-barrier penetration of alpha-particles through the barrier, caused by interaction between alpha-particle and nucleus. The fusion (alpha-capture) reaction between alpha-particle and nucleus proceeds in the opposite direction to the alpha-decay reaction. However, the same alpha-nucleus interaction potential is the principal factor to describe both reactions. Therefore it is natural to use data for both the alpha-decay half-lives and the around barrier alpha-capture reactions for determination of the alpha-nucleus interaction potential. The alpha-decay half-lives and the alpha-capture cross-sections are evaluated in the framework of unified model for alpha-decay and alpha-capture (UMADAC) [1,2].

The experimental data on the alpha-decay are expanded and refined continually. The alpha-decay half-life data have been updated in January 2015 [4]. The ground-state masses and spins of nuclei have been updated in 2012 [5]. Therefore, it is reasonable to use extended and updates the data for description of the alpha-decay half-lives for the ground-state-to-ground-state transitions in the framework of the UMADAC. The updated data for the alpha-decay half-lives for the ground-state-to-ground-state transitions and the alpha-capture cross-sections of ^{40}Ca, ^{44}Ca, ^{59}Co, ^{208}Pb and ^{209}Bi are used in the UMADAC now.

It is very important to have simple and accurate expressions for evaluation the alpha-decay half-lives, which can be used very easy. The first empirical formula for alpha-decay half-lives was presented by Geiger and Nuttall in 1911. Sets of simple relations for evaluation of the half-lives of alpha-transitions between the ground states of parent and daughter nuclei are proposed [3]. The new extended data for the alpha-decay half-lives [4], atomic masses and spins [5] give possibility to improve the empirical relations introduced in [3].

The alpha-decay half-lives and the alpha-capture cross-sections reevaluated in the framework of UMADAC agree well with the updated experimental data. The updated alpha-decay half-life values are well described by the empirical relations.

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THE MINIMAL BARRIER HEIGHT FOR SYMMETRIC AND ASYMMETRIC NUCLEUS-NUCLEUS SYSTEMS

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Nuclei can deform at small distances between them due to interaction between nucleons in interacting nuclei. Therefore a barrier height of nucleus-nucleus potential depends on the deformations of the nuclei and the mutual orientation of them. We search the minimal barrier height between nuclei with spherical ground-states. The minimal value of barrier height is related to the nose-to-nose orientation of prolate nuclei. The full nucleus-nucleus potential energy consists of Coulomb, nuclear parts and energy related to deformation of each nucleus. The ground-state shape of interacting nuclei are spherical, therefore the energy of deformation should be added.

The interaction potential of symmetric and asymmetric systems of two nuclei is studied with an account of quadrupole, octupole, and hexadecapole deformations of the nuclei. The influence of different types of deformations on the barriers heights and the interaction energies of two nuclei is considered in detail for various systems, see, for example Fig. 1. The height of the minimal barrier of the interaction potential and the corresponding deformation parameters are evaluated.

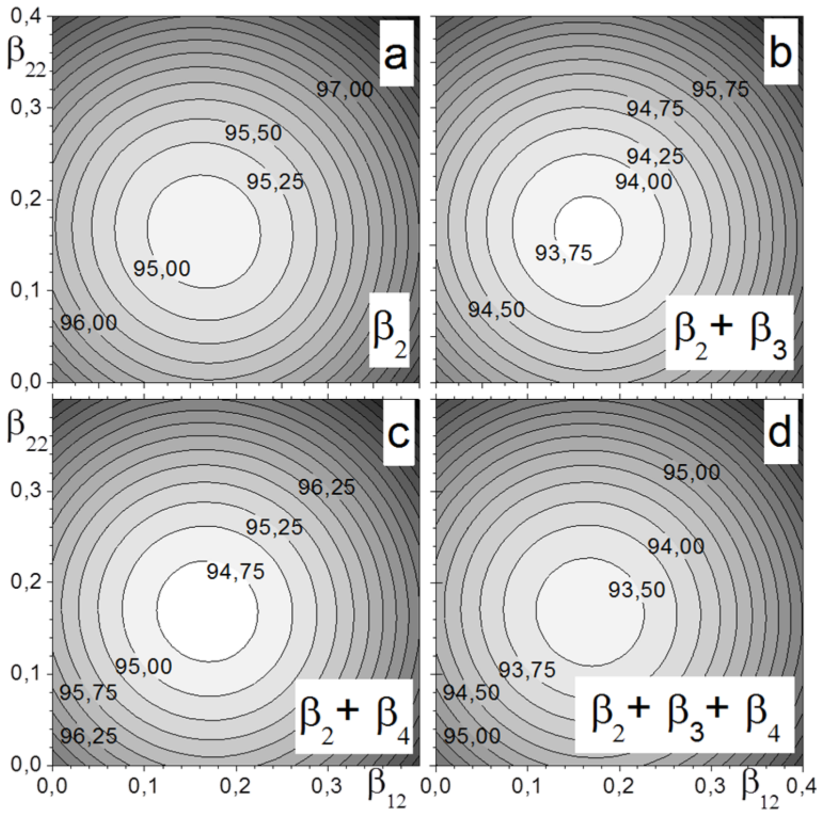

Fig. 1. Dependence of barrier height on nuclear deformation of $^{64}Ni + ^{64}Ni$, when the deformations of higher multipolarities are taken into account.

NUCLEUS-NUCLEUS POTENTIAL WITH SHELL-CORRECTION CONTRIBUTION: BARRIERS AND SUBBARRIER FUSION

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The full energy of nucleus consists of the sum of macroscopic and microscopic contributions according to the shell-correction method proposed by Strutinsky. The contribution of the shell structure to the nucleus-nucleus potential has been ignored in phenomenological approaches. Therefore, it is desirable to find the improved phenomenological nucleus-nucleus potential which takes into account the contributions of shell-correction energies of the interacting nuclei. Such full potential should take into account both gross and individual properties of the specific nucleus-nucleus system and be more accurate than a global macroscopic potential.

The phenomenological relaxed-density nucleus-nucleus potential with the shell-correction contribution is discussed in detail [1]. The macroscopic part of the potential is related to a nucleus-nucleus potential obtained in the framework of the extended Thomas-Fermi approach with the Skyrme and Coulomb forces and the relaxed-density ansatz for evaluation of proton and neutron densities of interacting nuclei. The shell-correction energy contribution to the potential is connected to inner structure of nuclei which is disturbed by the nucleon-nucleon interactions of colliding nuclei. A simple approach for the evaluation of the shell correction contribution to the full potential is proposed. The shell-correction contribution shows how the full potential for the specific nucleus-nucleus system deviates from the global macroscopic potential. The shell-correction contribution to the full potential is very important at distances smaller than the barrier radius. The parameters of the shell correction and macroscopic parts of the relaxed-density potential are found by fitting the empirical barrier heights of the 89 systems of spherical or near spherical nuclei as well as the macroscopic potentials evaluated for 1485 nucleus-nucleus systems at 12 distances around touching points. The phenomenological relaxed-density nucleus-nucleus potential with the shell-correction contribution can reproduce the empirical barrier heights with the value of the root mean square error of 0.879 MeV.

It is shown that the deep sub-barrier fusion hindrance takes place for nucleus-nucleus system with the strong negative shell-correction contribution into the full heavy-ion potential, while the strong positive shell-correction contribution into the full potential leads to weak enhancement of the deep sub-barrier fusion cross section [2]. The fusion cross sections for reactions $^{16}O+^{208}Pb$, $^{48}Ca+^{48}Ca$, and $^{58}Ni+^{54}Fe$ are well described in the approach [2].

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ASTROPHYSICAL *S*-FACTOR OF THE PROTON RADIATIVE CAPTURE ON ^{14}C AT LOW ENERGIES

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To continue the study of the radioactive capture processes [1] in the frame of the modified potential cluster model (MPCM) with forbidden states (FSs) the reaction $p^{14}C \rightarrow {}^{15}N\gamma$ was considered at low energies. For the bound states (BSs) and ground states (GSs) of nuclei, formed by the capture reaction, in the cluster channel, which coincides with the initial particles, intercluster potentials are constructed based on the description of the binding energy of the particles in the final nucleus and based on certain fundamental characteristics of such states [1].

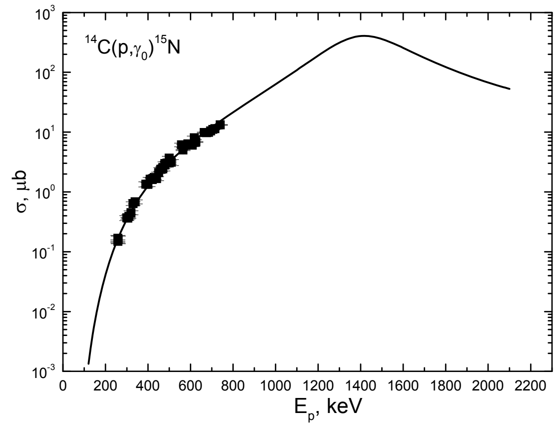

Fig. 1. Total cross-section of the proton radiative capture on ^{14}C on the GS of ^{15}N. Experimental data are taken from [3].

For the potential of the resonance $^2S_{1/2}$ wave at 1.5 MeV with FS the following parameters of the Gaussian potential can be used: $V_0 = 5037.0$ MeV, $\alpha = 12.0$ fm^{-2}. This leads to the scattering phase shifts the with resonance at 1500 keV in l.s. and with the width of 530 keV in c.m.s., which agrees with available experimental data. For the $^2P_{1/2}$ potential of the GS of ^{15}N without FS in the $p^{14}C$ cluster channel the following parameters were obtained: $V_0 = 221.529718$ MeV, $\alpha = 0.6$ fm^{-2}. That leads to the mass radius of $R_m = 2.52$ fm, charge radius of $R_{ch} = 2.47$, binding energy of –10.207400 MeV at the accuracy of the finite-difference method equals 10^{-6} MeV. The asymptotic constant (AC) value of 1.80(1) in the dimensionless form [2] $\chi_L(r) = \sqrt{2k_0} C_w W_{-\eta L+1/2}(2k_0 r)$ was calculated at the range of 3-10 fm. We could not find data about the AC in this channel obtained in other works by independent methods. Experimental data for total cross-sections of the proton radiative capture on ^{14}C on the GS of ^{15}N for the energy range of 260–740 keV were measured in work [3]. For their description the cross-section to the GS of the $E1$ transition from the resonance of the ^2S scattering wave with described previously potentials has been considered. The results of calculations of the total cross-section are shown in Fig. 1 by the solid line, which properly describes the available data marked by points.

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LOW ENERGY α+^{16}O SCATTERING IN ORTHOGONALITY CONDITION MODEL

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In the present work elastic scattering α-particles on ^{16}O at E_{lab}<10 MeV is investigated. The Pauli principle plays substantial role in nuclei scattering at low energies (near the Coulomb barrier). As a consequence, the total interaction potential is non-local. In the framework double-folding optical model the potential is calculated as folding of nuclei densities with effective NN interaction. In this method only single-particle exchange is taken into account with local approximation for exchange part of the potential. This approach is a good approximation only for sufficiently high relative energies.

We use one-channel equation of Orthogonality Condition Model (OCM) which is the equation with non-local exchange part of the potential taking into account the Pauli principle. But unlike strict microscopic description direct (local) potential in OCM is treated phenomenologically.

Some states of intermediate system ^{20}Ne group into rotational bands $K^{\pi} = 0_1^+, 0_1^-$ which are commonly interpreted as α–^{16}O cluster bands. These states are observed as low energy resonances. Low energy α +^{16}O scattering was analyzed in [1, 2] within OCM with Wood-Saxon type potential as the direct one. Good description of experimental data was achieved but with different direct potentials for the bands of different parity. We use the folding potential with M3Y NN interaction [3] as direct OCM potential. This allowed us successfully describe both intermediate cluster states and differential cross section. The method (OCM plus direct folding potential) can be considered as an alternative to strict microscopic approach.

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HIGH PRECISION OPTICAL-MODEL PROGRAM CODE "OPTMODEL"

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A high precision optical-model program code OptModel [1] is aimed at solving standard optical-model tasks on elastic scattering of n, p, d, t, ^{3,4,6}He, ^{6}Li on spherical nuclei (or nuclei close to them). A phenomenological optical potential on the basis of Woods-Saxon form is used. To solve Schrodinger radial equation the technique of the 12th order precision (this technique was developed in 2004 in the Shanghai University, China [2]) complemented with a lot of innovations and supplements was implemented. The orbital moment maximum value is not fixed in advance. The Coulomb functions calculation is performed by the RCFWN program code [3] with a relative accuracy of 10^{-10}. Coulomb phases are defined with a relative accuracy not worth than 10^{-6} on the basis of Γ-function presentation through the Euler integral [4]. The programming language is C^{++}.

Mathematics used in the program code is described in details in [5]. In submitted paper modern state of the program code is presented. The main innovation is related to an opportunity of simultaneous analysis of unrestricted amount of experimental data on elastic scattering that makes it possible to obtain the energy dependence of optical potential parameters in automatic mode. OptModel program code has got a state registration [6].

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DEUTERON STRIPPING ON NUCLEI AT INTERMEDIATE ENERGIES

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A general analytical expression for the double differential cross section of deuteron stripping reaction on nuclei at intermediate energies of incident particles was obtained in the diffraction approximation [1]. Nucleon-nucleus phases were calculated in the framework of Glauber formalism and making use of the double-folding potential. The exact wave function of deuteron with correct asymptotics at short and long distances between nucleons [2] was used. The calculated angular dependencies of cross sections (Fig. 1) are in good agreement with corresponding experimental data [3].

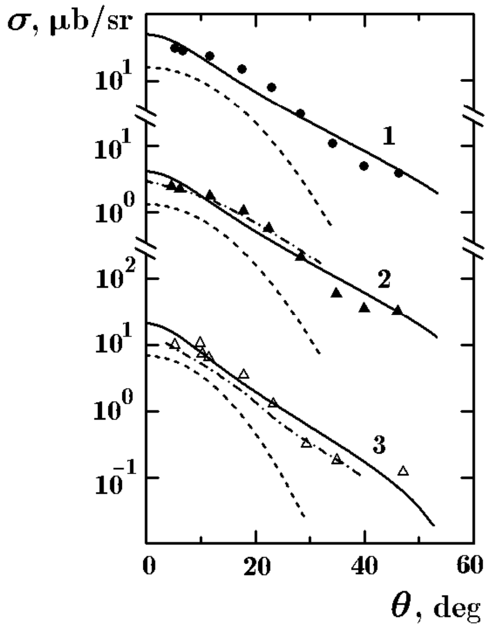

Fig. 1. Angular distributions of released neutrons in the reaction $^2H(d, n)^3He$ at 787 (1), 858 (2), and 1242 MeV (3). Experimental data were taken from work [3].

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QUASIELASTIC SCATTERING OF ^{6}He, ^{7}Be, ^{8}B NUCLEI FROM ^{12}C NUCLEI

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Using the nuclear diffraction model and the high-energy approximation with double-folding potential based on CDM3Y6 interaction [1], the observed quasi-elastic scattering cross sections of nuclei ^{6}He, ^{7}Be and ^{8}B nuclei ^{12}C at intermediate energies were described. The calculations performed using realistic nucleon density distribution for target nuclei [2]. Moreover the Coulomb interaction and the inelastic scattering with excitation of low-lying collective states of the target [3] were taking into account. As an example, Fig. 1 shows the calculation results for the ^{6}He ions scattering from ^{12}C nuclei at 82.3 MeV per nucleon.

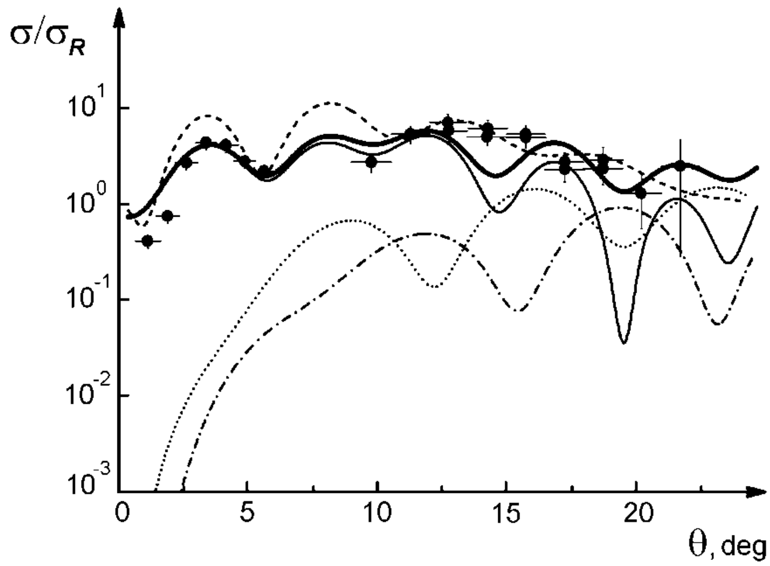

Fig. 1. Angular distributions of cross sections ratio σ/σ_R for the quasielastic scattering of $^{6}He+^{12}C$ at 82.3 MeV/nucleon. Types of curves are denoted as follows: the dot and dash-dot curves are the contributions of 2^+ and 3^- exitation levels of ^{12}C target, correspondingly; the thin solid curve is the elastic scattering; the bold solid curve is the non-coherent sum of elastic and non-elastic scattering; the dashed curve is the calculations results [4] based on the coupled channel method with the double-folding potential. Experimental data were taken from work [4].

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SUB-BARRIER FUSION REACTIONS OF ^{6}He WITH LIGHT STABLE NUCLEI AND THEIR ASTROPHYSICAL ASPECT

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Fusion reactions involving light weakly bound nuclei attract considerable interest. In these reactions an increase of the fusion cross section at energies below the Coulomb barrier is observed. The processes of rearrangement of valence neutrons with positive *Q*-values (which leads to a gain in the kinetic energy of the colliding nuclei) may substantially increase the sub-barrier fusion cross section. Moreover, a similar mechanism of neutron rearrangement may significantly increase the fusion cross sections of light stable nuclei such as ^{7}Li, ^{10}B, ^{12}C, ^{14}N, etc. Note, that deep sub-barrier fusion of light nuclei (including exotic ones) may also be important for astrophysical nucleosynthesis [1]. In case of strong neutron flux a considerable number of light neutron-rich nuclei far from the drip line (^{6,8}He, ^{8,9,11}Li, etc.) may be formed. Their lifetimes are long enough to allow the production of heavier elements in collisions with stable nuclei. This scenario may be realized during *r*-process nucleosynthesis in supernovae.

The aim of this work is to study the mechanism of neutron rearrangement in the fusion reactions of the radioactive neutron-rich isotope of ^{6}He with light stable nuclei from Li to Mg. The predictions of fusion cross sections are made within the empirical coupled-channel (ECC) model with neutron rearrangement [2, 3]. Stable light nuclei are mainly formed in the Universe in radiative capture reactions. Cross sections for reactions of radiative capture are investigated on the basis of the potential model [4]. Differences between fusion and radiative capture reaction rates are discussed.

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TOWARDS GAUGE-INDEPENDENT TREATMENT OF RADIATIVE CAPTURE IN NUCLEAR REACTIONS: APPLICATIONS TO LOW-ENERGY CLUSTER-CLUSTER COLLISIONS

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Our departure point in describing electromagnetic (EM) interactions with nuclei (in general, bound systems of charged particles) is to use the Fock-Weyl criterion and a generalization of the Siegert theorem. It has been shown how one can meet the gauge invariance principle (GIP) in all orders in the charge and construct the corresponding EM interaction operators in case of nuclear forces arbitrarily dependent on velocity (see paper [1] and refs. therein). Along the guideline we have derived the conserved current density operator for a dicluster system (more precisely, the system of two finite-size clusters with many-body interaction effects included). In the context, we are addressing the current clusterization as a first step when accounting for possible cluster excitations Being expressed through electric and magnetic field strengths and matrix elements of the generalized electric and magnetic dipole moments of a system the single-photon transition amplitudes attain a manifestly gauge-independent (GI) form. It makes our approach especially attractive for such situations where one has to deal with approximate many-body wave functions.

Special attention is paid to the cluster structure of the *T*-matrix for radiative process $A+B \rightarrow \gamma+C$, in which a target-nucleus *A* captures a projectile-nucleus *B* that is followed by the single-photon emission and formation of a system $C=A+B$ in a bound or continuum state, e.g., as in case of $\alpha+\alpha \rightarrow \gamma+\alpha+\alpha$ bremsstrahlung. We show the decomposition of *T* into separate contributions from the photon emission induced by each of the colliding nuclei (“clusters”) to be expressed through its charge and magnetic form factors and the interference contribution from the so-called cluster-cluster interaction current. The latter arises every time if one takes into account exchange and nonlocal properties of nuclear forces. Certainly, the obtained formulae are simplified in the long-wavelength approximation when the transition amplitude is determined merely by the total electric and magnetic moments of the dicluster system. Note that some ideas of our approach have been successfully employed when treating the cross sections of the ^{3}He(α, γ)^{7}Be(g.s.) reaction at astrophysical energies [2].

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GIANT DIPOLE RESONANCE FROM FEYNMAN OSCILLATOR POINT OF VIEV

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In development of activity application Feynman oscillator for investigation microscopic mechanism of photoabsorbtion atomic nuclei, [1,2,3], hold out procedure for phenomenological description its photodisintegration. Insignificant difference capability giant dipole resonance even-even and neighbor odd nuclei show clearly that giant dipole resonance is result photoexcitation interior nucleons. Shell model, account for magic nuclei, does not correspond charge-density distribution in nuclei. Improvement shell model by Hartree-Fock method transform effective nucleon localization, that may be described by oscillate wave packets. Oscillator coefficient of elasticity due to internucleonic forces and correspond nucleon binding energy plus single-body energy self-consistent field. Under interaction with cyclic force appear three observable object: wave packets, oscillating with greater amplitude, correspond excited nucleon, nucleus core and hole in the core, oscillating with previous amplitude. Relation between giant dipole resonance width and charge-density distribution in nuclei is deduced. Parametrizing interaction between excited nucleon, nucleus core and hole in the core may be described photonucleon spectra, its evaporating character and statistical correction cross-section on multiple photoneutron output [4, 5].

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THE NEUTRON RADIATIVE CAPTURE ON ^{14}C AT ASTROPHYSICAL ENERGIES

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The total cross sections of the neutron radiative capture on ^{14}C at astrophysical energies have been calculated using the modified potential cluster model [1]. Potential of the $^2S_{1/2}$ ground state (GS) with one forbidden state (FS) should reproduce correctly the GS binding energy of ^{15}C with $J^\pi = 1/2^+$ in the n^{14}C channel at -1.21809 MeV [2]. It also should describe the root-mean-square (rms) radius of ^{15}C, which seems not differ substantially the radius of ^{14}C, that equals 2.4962(19) fm [2]. Consequently, the following parameters were obtained: $V_{\text{g.s.}} = 93.581266$ MeV, $\alpha_{\text{g.s.}} = 0.2$ fm^{-2} for the Gaussian GS potential. This potential leads to the binding energy equals 1.2180900 MeV and the rms radius of $R_{\text{ch}} = 2.52$ fm. For the asymptotic constant (AC) the value of 1.85(1) was calculated at the range of 7–27 fm. In [3] the AC equals 1.13 fm$^{-1/2}$ is given. After recalculation to dimensionless quantity at $\sqrt{2k} = 0.686$ the AC turned to be 1.65. Detailed overview of the values of a constant can be found in one of the latest papers [4] about calculation of the AC using the characteristics of different reactions.

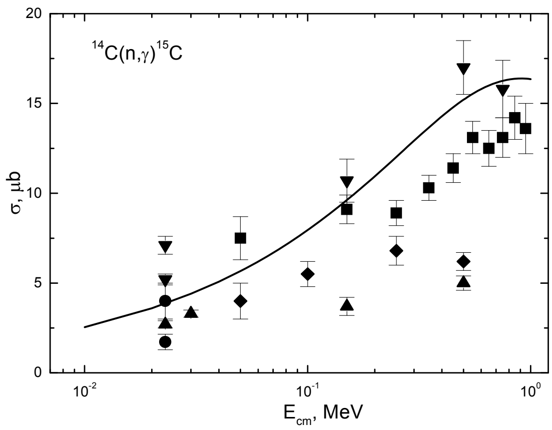

Fig. 1. Total cross section of the neutron capture on ^{14}C. Experiment from [5].

Available experimental data on the total cross sections of the neutron radiative capture on ^{14}C [5] indicate the presence of large ambiguities of measured cross sections presented in different papers. Experimental results from previously mentioned papers for energies 23 keV – 1.0 MeV are shown in Fig. 1. The total cross sections of the neutron radiative capture on ^{14}C with previously described potential of the GS at energies below 1 MeV were calculated and the results are shown in Fig. 1. Comparison of the calculated cross-sections with the experimental data shows the best coincidence with the data from [5]. Thus, the total cross sections completely depend on the shape of the GS potential of ^{15}C in the n^{14}C channel, because the ^2P potentials of the initial channel without FS could be equaled zero at considering energies.

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APPLICATION OF THE THEORY OF FEW-PARTICLE SYSTEMS TO NUCLEAR AND ATOMIC PHYSICS

BOUNDS ON ROTATION OF THE SPECTRAL SUBSPACES OF A FEW-BODY HAMILTONIAN

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We overview the results on the shift of the spectrum and norm bounds for variation of spectral subspaces of a Hermitian operator under an additive Hermitian perturbation. A particular attention is paid to the very recent subspace perturbation bounds. Then we apply the abstract results to few-body Schroedinger operators. In particular, we give a priory estimates on the shifts of binding energies and variation of the corresponding eigensubspaces of a few-body Hamiltonian if an extra interaction is added, provided that positions of the initial binding energies are known. We underline that our estimates are not perturbative in the sense of the conventional perturbation theory. The bounds we give only involve the distances between parts of the spectrum of the unperturbed Hamiltonian and the norms for operators that describe the additional interactions. The bounds described may also be useful in the accuracy control of numerical calculations.

ANALYTIC CONTINUATION OF SCATTERING DATA FOR SYSTEMS WITH TWO OR MORE BOUND STATES

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The analytic continuation of scattering data to the region of bound states [1] was used by the authors to determine vertex constants (VC) and asymptotic normalization coefficients (ANC) for the only bound state of ^{6}Li in the dα channel [2]. The effective range expansion was employed to approximate the scattering function $k\,\mathrm{ctg}\,\delta$.

In the present work, the analytic continuation of dα scattering data to the negative energy region is used for the d+α system possessing two bound states (^{6}Li), the lowest of which is considered as forbidden. The dα interaction is described by the square well potential, for which the exact solution is known. The potential parameters U_0 = 39.185 MeV and R = 3.227 fm are fitted to the values of the binding energy and ANC obtained from the solution of the Faddeev equations [3].

In that case the calculated function $k\,\mathrm{ctg}\,\delta - ik$, which is the denominator in the expression for the scattering amplitude, has two zeroes corresponding to the poles of the scattering amplitude, that is to the bound states with the binding energies 2.409 MeV (ANC=2.29) and 29.033 MeV (ANC=18.00). However, in between these zeroes (at energy E = –14.668 MeV) the function $k\,\mathrm{ctg}\,\delta - ik$ turns into infinity, which corresponds to the zero of the scattering amplitude. Note that in the general case the appearance of each new bound state results in the appearance of both a new zero and a new pole of the function $k\,\mathrm{ctg}\,\delta - ik$.

Using the standard effective range expansion to approximate the scattering function $k\,\mathrm{ctg}\,\delta$ at positive energies is sufficient to analytically continue it to the position of the highest bound state and to found the corresponding VC (ANC). However, to describe the poles of $k\,\mathrm{ctg}\,\delta$ and to continue it to the positions of the low-lying bound states one should modify the approximation form of $k\,\mathrm{ctg}\,\delta$. In the case of two bound states the simplest way is to explicitly include the first-order pole term into that form, which means actually using the Padé approximants. In this case the position of that pole should be considered as an additional fitting parameter. This approach is used to analyze the α + ^{12}C system in the 0^+ channel, which contains two bound states of ^{16}O.

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THEORY OF QUASIELASTIC LASER-ASSISTED ATOMIC REACTIONS

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Laser-assisted coincidence experiments are rather complicated, and the first published results [1] called for a more mathematically developed theory. Of course, the general approaches are formulated [2,3], but many mathematical details remain undiscussed. In particular, this concerns the so-called quasielastic (e,2e) reactions. We remind that these processes are characterized by high energy of the projectile electron (>1 keV), usually equal energy sharing between the final electrons, with their angles being around 45° with respect to the momentum of the incident electron. Such kinematics typically refers to the so-called electron momentum spectroscopy (EMS).

The mathematical basis for the theory of quasielastic (e,2e) reactions is more or less well-established [4]. In particular, it includes the procedure of renormalization of higher Born terms which are presented by formally divergent integrals, if the basis of plane waves is employed. Most of the calculations are carried out within the plane/distorted wave first Born approximations, but divergences of higher Born contributions make such calculations not reliable without the rigorous mathematical theory.

In the case of the (e,2e) laser-assisted reactions, most of calculations are also carried out within the first Born approximation with the Volkov functions instead of plane waves. Nevertheless, a number of issues remain open, when formulating the theory in analogy with the time-independent one. We list the main problems below.

1) Classification of eigenfunctions of the equation

$$\left(i\frac{\partial}{\partial t} + \frac{1}{2}\Delta + \frac{1}{r} - F(t)(\vec{e}\cdot\vec{r}) \right)\varphi_{\beta}(\vec{r},t) = 0$$

and spectral representation of the Green's function for this equation.

2) Probable divergence of the Born perturbation series.

3) Mathematical and physical conditions for the replacement of the continuum eigenfunction as $\left|\varphi_{\vec{p}}(\vec{r},t)\right\rangle \approx \left|\chi_{\vec{p}}(\vec{r},t)\right\rangle$, i.e. by the Volkov function. We discuss these problems in our report.

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ULTRACOLD RESONANT PROCESSES IN 1D AND 2D ATOMIC TRAPS

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Impressive progress of the physics of ultracold quantum gases has stimulated the necessity of detailed and comprehensive investigations of collisional processes in the confined geometry of atomic traps. Here the free-space scattering theory is no longer valid and the development of the low-dimensional theory including the influence of the confinement is needed. In our works we have developed a computational method [1–3] for pair collisions in tight atomic waveguides and have found several novel effects in its application: the confinement-induced resonances (CIRs) in multimode regimes including effects of transverse excitations and deexcitations [2], the so-called dual CIR yielding a complete suppression of quantum scattering [1], and resonant molecule formation with a transferred energy to center-of-mass excitation while forming molecules [4]. Our calculations have also been used for planning and interpretation of the Innsbruck experiment on investigation of CIRs in ultracold Cs gas [5]. Recently, we have calculated the Feshbach resonance shifts and widths induced by atomic waveguides [6].

We plan to discuss the Heidelberg experiment [7], which recently confirmed the mechanism, we predicted in [4], of resonant molecule formation in tight quasi-1D atomic traps, and the prospects to extend the consideration for the quasi-2D geometry of the trap.

In the frame of our approach we have predicted dipolar CIRs in quasi-one dimensional geometry of atomic traps [8]. The exact knowledge of the positions of dipolar CIRs may pave the way for the experimental realization of, e.g., Tonks-Girardeau-like or super-Tonks-Girardeau-like phases in effective one-dimensional dipolar gases. We have also analyzed the collisional dynamics of the polarized as well as unpolarized polar molecules in pancake-like traps [9]. This analysis can resolve the puzzle with the position of the 2D CIR measured recently [5], which is under intensive discussions.

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THE RARE GAS CLUSTERS AND UNIVERSALITIES

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The rare gas clusters represent a typical example of van der Waals systems which unusual properties attracts a lot of attention of many researches recently. In fact, the development of the technology gives a possibility to study ultracold gases with fully controlled interatomic interaction and to find some universal correlations between observables [1]. To investigate Efimov phenomena in three-atomic clusters necessary to have good knowledge of a dimer systems [2]. Here we treat the spectrum of van der Waals dimers of rare gases.

We calculated spectra and wave functions of pairs of atoms He, Ne, Ar, Kr, Xe and Rn. Calculations were performed for all possible homogeneous and heterogeneous pairs of rare gas atoms. The interatomic van der Waals potentials for the these pairs were determined using the Tang-Toennies *et al.* [3], Aziz *et al.* [4] and Lennard-Jones [5] potential models. It is necessary to point out that during purely theoretical *ab initio* computations of potential curves, their authors, as a rule, do not go beyond the presentation of potential values in the form of a table. Such numerical reports are often sufficient, because subsequent application of various parameter-fitting procedures yields fairly simple expressions, but for few-body calculations the analytic expression of potential is needed.

We calculated the Efimov spectra of the 4He trimer and analyzed the universality of the Efimov systems. We have investigated some universality in the ^{4}He trimer system and in the nuclear system ^{3}H, calculated using potential model MT [6].

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MANIFESTATION OF UNIVERSALITY AT THE TWO-BODY THRESHOLD IN THREE-BODY COLLISIONS: THE MODIFIED PHILLIPS LINE

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The linear correlation between the neutron-deutron scattering length and the triton bound state energy is known as the Phillips line [1]. Efimov and Tkachenko have suggested that this correlation is related to nearly universal interaction regime in the three-nucleon system [2]. Here we present a generalization of the Efimov and Tkachenko result for three identical bosons [3].

We propose to rewrite the relationship between the particle-dimer scattering length and the near-threshold three-body bound state energy in terms of dimensionless parameters $\alpha \equiv \alpha_3 \sqrt{-2m_{12}E_2} / \hbar$ and $\omega \equiv 1 / \sqrt{E_3 / E_2 - 1}$.

After this rescaling the observables follow an interaction-independent curve which can be described by a simple formula

$$\alpha = \frac{\alpha_1}{\frac{1}{\omega} - \frac{1}{\omega_0}} + \omega + \alpha_0 .$$

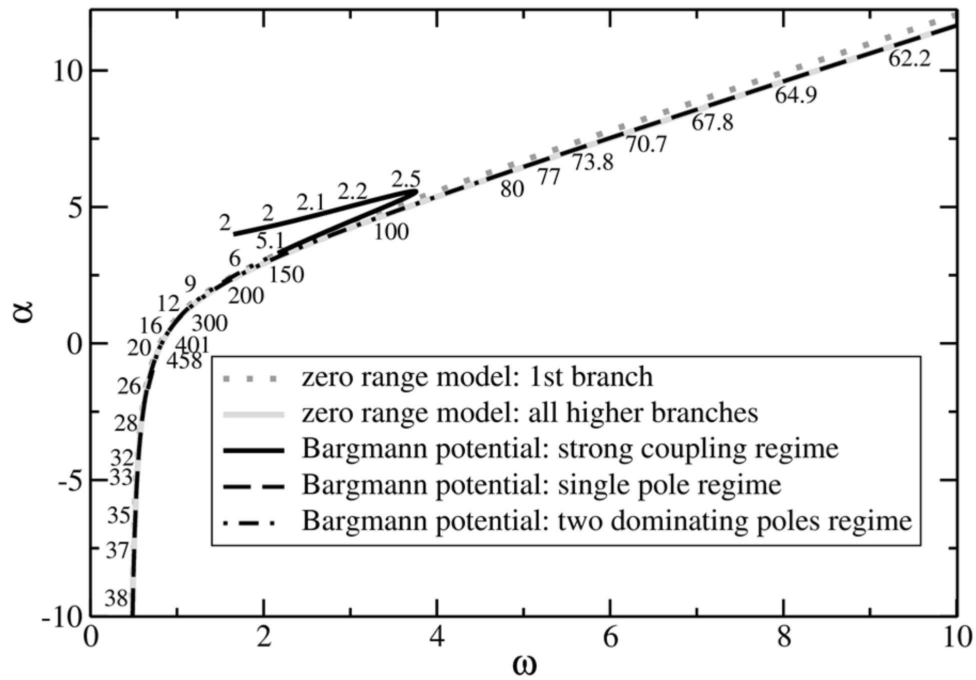

Fig. 1. The modified Phillips line: the universal correlation between the low-energy properties of three-body systems. The numbers along the curve mark the corresponding value of the two-body scattering length.

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RESONANCE STATES OF ^{12}C NUCLEUS IN THE 3α-PARTICLE MODEL FRAMEWORK

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The Hoyle 0^+_2 resonance state plays an important role in stellar nucleosynthesis as the only explanation for the observed abundance of ^{12}C in the universe [1]. While the Hoyle resonance plays the main role in this process, it was noted lately [2] that higher resonance states of ^{12}C can also influence the formation rate. There exist many models of ^{12}C nucleus reproducing its binding energy, Hoyle resonance and matter radii. Higher resonance states, however, appear to be more sensitive to details of the interaction. Furthermore, not all methods used for calculations of bound states and narrow resonances can be used to study broad resonances.

Here, an application of the total angular momentum formalism combined with the complex scaling method is presented. The method allows for accurate calculations of both bound states and resonances with arbitrary widths. This approach is used for the calculation of bound and resonance 0^+ states of ^{12}C nucleus in the framework of the 3α-particle model with various phenomenological potentials [3–6]. The main attention is focused on fair comparison of higher resonances calculated for different models [3–6]. The spatial structure of calculated states is investigated. A set of new wide resonances of the system has been found and analyzed.

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METASTABLE STATES OF COMPOSITE SYSTEM TUNNELING THROUGH REPULSIVE BARRIERS

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The description of quantum tunneling and channeling of composite systems of several identical particles through the repulsive barriers in a coupled-channel approximation of the new symmetrized-coordinate representation of harmonic oscillator basis is presented [1–6].

In this approach a multichannel scattering problem for the Schrödinger equation is reduced to a set of the coupled second-order ordinary differential equations with third-type boundary conditions and solved by the *R*-matrix method.

Efficiency of the proposed approach is demonstrated by analysis of metastable states of composite systems leading to a quantum transparency effect (for example, see Fig.) of the repulsive barriers in dependence on a number of identical particles and type of the permutation symmetry of their states.

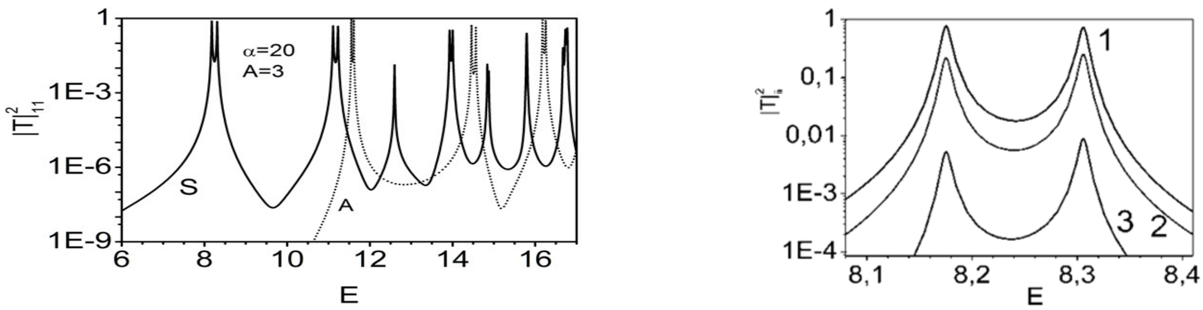

Fig. Left panel: The transmission coefficient $|T|^2_{11}$ vs collision energy E (osc. u.) of symmetric (S) and antisymmetric (A) states for composite system of three identical particles (A=3) tunneling through narrow repulsive Gaussian barrier $V(x_i)=\alpha/(2\pi\sigma^2)^{1/2}\exp(-x_i^2/\sigma^2)$, $\alpha=20$, $\sigma=0.1$. Right panel: The transmission coefficients $|T|^2_{ii}$, in open channels (i=1,2,3) in a vicinity of first double peak of the pair metastable states with energies $E_1=8.17509-i\ 0.00514$, $E_2=8.30607-i\ 0.00502$ (osc. u.).

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PHASE SHIFTS OF AMPLITUDES OF POTENTIAL BARRIER RESONANCE REFLECTION AND TRANSITION OF THE COUPLED PAIR OF PARTICLES

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The report provides the features of resonant transition of the potential repulsive barrier by the beryllium molecule, height and width of which have the scale of the beryllium atom interaction with the crystal surface. Previously [1] the integral contribution of the resonant transition of the molecule in the physical observables has been considered. As a result, the simple formulas to evaluate this contribution have been obtained.

To expand the range of possible applications of the resonance transition effect, this work analyzes the amplitudes of transition and reflection either for elastic and inelastic processes.

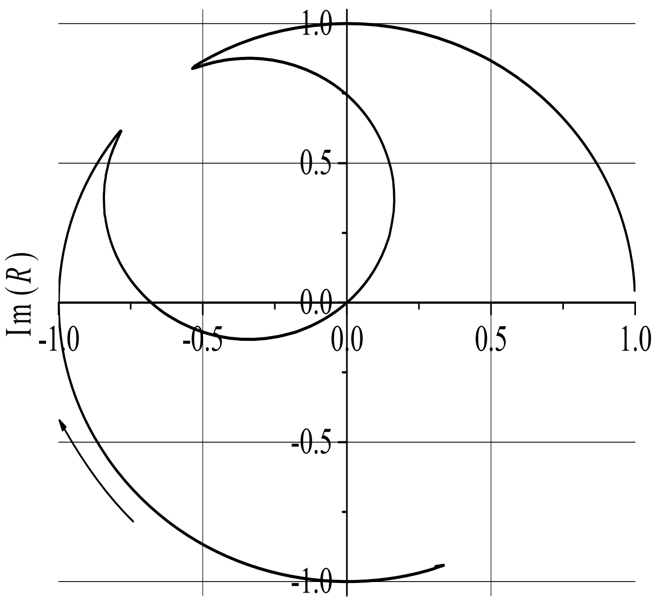

Fig. 1. The behavior of real and imaginary parts of the resonance reflection amplitude R near the resonance depending on the molecule energy. The arrow indicates the direction of the moving with the energy increase.

In particular, it is shown that the contrast of the molecular interference pattern on the crystals surface depends strongly on the energy of the molecules.

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COMPLEX POTENTIAL'S RECONSTRACTION IN SELF-CONSISTENT DESCRIPTION OF PARTICLE-BOUND SYSTEM'S SCATTERING BY UNITARITY'S CONSERVING

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In references [1, 2] there was proposed an asymptotic method of Schrödinger equation's solution with the complex potential for the particle-two particles bound system's scattering. In the Jacobi coordinates: related coordinates in bound system $\vec{r} = \{x, y, z\} = \vec{r}_2 - \vec{r}_3$ and the related scattering particle – center mass of the bound system $\vec{R} = \{X, Y, Z\}$ Schrödinger equation can be written in the form

$$[-\frac{\hbar}{2M}\Delta_{\vec{R}} - \frac{\hbar}{2\mu}\Delta_{\vec{r}} + V_{12}(\vec{R},\vec{r}) + V_{13}(\vec{R},\vec{r}) + V_{23}(\vec{r})]\Psi(\vec{r},\vec{R}) = E\Psi(\vec{r},\vec{R}). \quad (1)$$

Wave function $\Psi(\vec{r},\vec{R})$ was chose in the optical spirit

$$\Psi(\vec{r},\vec{R}) = (2\pi)^{-3/2} e^{if(\vec{R},\vec{r})} \Phi_0(\vec{r}), \quad (2)$$

where $\Phi_0(\vec{r})$ is the interne bound system's wave function and $f(\vec{r},\vec{R})$ is a pure real function to provide the wave function normalization 's conserving. Coordinates of vector $\vec{r}$ differentiating in (1) and using in the asymptotic case $|\vec{R}| >> |\vec{r}|$ the $\vec{r}$ power series expansion for the function $f(\vec{r},\vec{R})$ and two-particle complex potentials $V_{12}(\vec{R},\vec{r})$ and $V_{13}(\vec{R},\vec{r})$ it was obtained [1, 2] the systems of equations respect the expansion's coefficients as for the function $f(\vec{r},\vec{R})$ so for potentials.

In this report is received the interne wave function $\Phi_0(\vec{r})$ averaged equation (1) and the integral Lippmann-Schwinger type equation for averaged T-matrix $\langle \Phi_0 | T | \Phi_0 \rangle = T_{\text{opt}}$ with some two-particle optical potential
$V_{\text{opt}} = \overline{\langle \Phi_0(\vec{r}) | V(\vec{R},\vec{r}) | \Phi_0(\vec{r}) \rangle} = v_{\text{opt}} + iu_{\text{opt}}$

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UNIVERSAL DESCRIPTION OF ROTATIONAL-VIBRATIONAL SPECTRUM OF THREE TWO-COMPONENT PARTICLES WITH CONTACT INTERACTIONS

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The rotational-vibrational spectrum for two non-interacting identical particles of mass m and a distinct particle of mass m_1 with zero-range interaction between different particles is studied. One considers the even total angular momentum L and positive parity if identical particles are bosons and the odd L and negative parity if identical particles are fermions. The present results are obtained by extension of the approach used for $L^P = 1^-$ sector of three two-component fermions to description of an arbitrary L^P sector. Following the analysis for $L^P = 1^-$, an additional three-body parameter b should be introduced for mass ratio above the values $\mu_r(L)$ presented in Table 1. On the other hand, the Efimov effect takes place [1, 2] in each L^P sector for mass ratio above the values $\mu_c(L)$ presented in Table 1.

L	$\mu_r(L)$	$\mu_c(L)$
1	8.61857692	13.6069657
2	32.9476118	38.6301584
3	70.0707750	75.9944943
4	119.731217	125.764636
5	181.866438	187.958355

Tab.1. The mass-ratio values $\mu_r(L)$ and $\mu_c(L)$ for total angular momentum L.

One particular important case $b = 0$ was considered previously (papers [2,3] for different L and [4,5] for $L^P = 1^-$). In these papers it was shown that the bound states exist in each L^P sector for sufficient large mass ratio below $\mu_c(L)$ and a number of states generally increases with increasing L.

In the present report the three-body energies of two-component particles for an arbitrary three-body parameter b and mass ratio in the interval $\mu_r(L) \leq m/m_1 \leq \mu_c(L)$ are calculated by using the method of [2,4]. In particular, for some L^P sectors a number of three-body bound states is presented in the form of a “phase” diagram in the plane of parameters m/m_1 and b.

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DISCRETE SPECTRAL SHIFT FORMALISM FOR SOLVING MULTI-CHANNEL SCATTERING PROBLEMS

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An approach towards the solving for few-body scattering problems on the basis of the complete continuum discretization procedure is presented. The special technique of stationary wave-packets allows to formulate a problem in a discrete L_2 space in which all the scattering wave functions and operators are represented by vectors and matrices [1]. The resulted discrete representation has some evident advantages as compared to the conventional continuous one and leads to new ways in a practical solution of few-body scattering problems.

We discuss here the discrete version of the spectral shift function (SSF) formalism as a part of this general approach. It allows to find the scattering observables in a wide energy region without solving any scattering equations at all using only the discretized spectra of the total and free Hamiltonians [2, 3]. The technique is fully applicable in a multi-channel case where the set of different discrete SSFs corresponding to different branches of the multichannel Hamiltonian spectrum are defined, each of which is directly interrelated to the corresponding eigenchannel phase shift. The elements of the rotation matrix for the transformation from the eigenchannel representation to initial channels can also be found in the approach. Thus, each element of the multi-channel *S*-matrix is evaluated for a wide energy region from a single diagonalization procedure of the Hamiltonian matrix in the multi-channel L_2 basis [2, 3].

The approach is valid in cases of fully realistic complicated interactions, e.g. for non-local or tensor components, also it can be used in a charged particle scattering problem where the so called Coulomb-nuclear phase shifts are found. As an illustration for fruitfulness of the approach, numerical results for several scattering problems in nuclear and atomic physics are presented.

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POTENTIAL SPLITTING APPROACH TO THE THREE-BODY COULOMB SCATTERING PROBLEM

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The complex scaling technique allows one to avoid using the exact boundary conditions when solving the scattering problem. The method was developed for two-body scattering problem with short-range [1] and long-range (but non-Coulombic) [2] potentials. The method was extended to two-body single-channel [3] and multi-channel [4] Coulomb scattering problem using the potential splitting approach. The three-dimensional distorted incident wave for the splitting method is constructed in [5].

In the present contribution the formalism of the potential splitting is extended to the three-body Coulomb scattering problem. The distorted incident wave is constructed and the driven Schrödinger equation is derived. The full angular momentum representation is used to reduce the dimensionality of the problem. The phase shifts for $e^+ - H$ and $e^+ - He^+$ collisions are calculated to illustrate the efficiency of the presented method.

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RELATIVISTIC GENERALIZATION OF THE METHOD OF MULTIDIMENSIONAL ANGULAR COULOMB FUNCTIONS FOR QUANTUM-MECHANICAL MANY-BODY PROBLEM SOLVING

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Methods of multidimensional angular functions (MAF) [1], has been used for description of many-body systems, consolidate a wide class of functions, including employed in nuclear theory well-known hyperspherical functions (HSF).As well as multidimensional angular Coulomb functions used for description many-body atomic systems are particular of MAF. Methods of MAF development is determined by idea of mathematical tool elaboration equally operable in elementary particle theory, nuclear theory, atomic and molecular physics.

The paper presents analytical method of solution to the Dirac equation for Coulomb interacting systems. Working out of the method is performed in the context of methods of MAF development for quantum-mechanical many-body problem solving. Opportunities of the method are demonstrated by the example of transuranium elements ions properties calculation.

Matrix elements calculation technique of various operators of the Dirac equation in 3*A*-dimensional space (*A* – number of electrons) is used for solution the equation. That allows to realize a transition from multidimensional Dirac equation to the system of two first order differential equation. Its solution was analytically found. The obtained analytical wave functions are used for calculation electron density and radial momenta for ions above and so can be applied to specify different properties.

The presented method is relativistic generalization of the method of multidimensional angular Coulomb functions (MACF) [1].

In the paper MAF constructing for solution Dirac equation in zero approximation of the method of MACF by the example of lithium-like ions of heavy elements is demonstrated.

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ASYMPTOTICS OF THE BINARY AMPLITUDE FOR THE MODEL FADDEEV EQUATION

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We study the model equation obtained from the *s*-wave Faddeev equation [1] for three identical bosons by interchanging the inhomogeneous integral term by the known function [2]. The function simulates the asymptotic behavior of the inhomogeneous term of the original Faddeev equation, namely $\sim xV(x)O(y^{-3/2})$ as $y\to\infty$, where $V(x)$ is the known Bargmann potential [3]. Moreover, it allows us to take into account the breakup part of the Faddeev component in the scattering amplitude. For the model equation, the asymptotics of the scattering amplitudes have been obtained by the Green function method. Using this method, we found that the asymptotics of the binary amplitude, corresponding to the binary channel, as $y\to\infty$ is given as

$$a_0(q,y)=\frac{I_x}{2iq}\cdot\left(a-\frac{i}{\left(\sqrt{E}+q\right)}\frac{\exp\left(i\left(\sqrt{E}+q\right)y\right)}{\left(y+y_0\right)^{3/2}}+\frac{i}{\left(\sqrt{E}-q\right)}\frac{\exp\left(i\left(\sqrt{E}-q\right)y\right)}{\left(y+y_0\right)^{3/2}}+O\left(\left(y+y_0\right)^{-5/2}\right)\right),$$

where y_0 is the real constant, a is the complex constant, I_x is the one-dimensional integral of the potential and the wavefunction of the two-particle subsystem. Energy E and the relative momentum q of the third particle are related to the two-particle bound state energy as $\varepsilon=E-q^2$. The found asymptotics describes the oscillations of the binary amplitude as $y\to\infty$, observed in the numerical calculations. The oscillations are caused by the term with relatively small factor $(E^{1/2}-q)$ in the denominator. The precise convergence of the binary amplitude to the constant value a is achieved only at $y>1000$ fm, where this term of order of $y^{-3/2}$ becomes small. For the original *s*-wave Faddeev equation for the neutron-deuteron scattering, the numerically obtained binary amplitude shows similar oscillating behavior. The relatively small oscillations can be achieved only at comparable values of $y>1000$ fm.

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TWO-DIMENSIONAL COULOMB SCATTERING OF A SLOW QUANTUM PARTICLE

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By assumption, a slow charged quantum particle moves in the two-dimensional plane of the three-dimensional configuration space and is scattered by the fixed Coulomb center lying in the same plane.

The wave-function of this particle, the Green function and all radial components of these functions are studied. For the modules of these components the uniform major bounds are derived. The representation of the wave-function in terms of the regular radial Coulomb functions and the representation of the scattering amplitude in terms of the partial phase-shifts are found. For the Green function and its radial components the integral representations are obtained.

It is shown that the radial wave-functions of a quantum particle satisfy the Coulomb equation with half-integer index. The structure of these functions is studied. A special attention is paid to the low-energy limit. The expansions of the wave-function and the radial wave-functions over integer powers of the wave number and the Bessel functions of real order are derived. It is proven that the finite sums of these expansions are the asymptotics of the wave-functions in the low-energy limit.

The main differences of the two-dimensional Coulomb scattering from the three-dimensional one are clarified.

SOLUTION OF THE DISCRETIZED FADDEEV EQUATIONS ON A GRAPHICS PROCESSING UNIT

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A principally new technique for an ultra-fast solution of few-body quantum scattering problems is discussed. We transform multi-dimensional singular integral equations of the Faddeev type describing few-body quantum scattering in momentum space into a fully discrete form utilizing the wave-packet basis of an L_2 type [1]. The pixel-like matrix form for the integral equations resulted from the wave-packet continuum discretization is especially convenient for an effective parallelization of a practical solution. However the ultra-fast parallel solution can be found here with ordinary PC using a graphics processing unit (GPU) framework and without the involvement of any supercomputer facilities [2]. We show that the GPU-acceleration of computations (in comparison with the conventional CPU realization of the same algorithm) reaches from 10 to 50 times for the total solution while the acceleration achieves even two orders of magnitude for separate parts of the whole algorithm for 3*N* system [2]. As a result, the solution of the 3*N* Faddeev equation with a semi-realistic *NN* interaction takes only few seconds on PC using GPU. For the general *N*-d scattering problem with 54 coupled channels in every partial wave for the fully realistic *NN* potential, the execution time takes a few minutes only. It should be contrasted with the time consuming supercomputer realizations using a conventional approach. So, this general novel technique opens a new way for ultra-fast GPU-calculations in few-body quantum scattering theory.

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A QUASI STURMIAN APPROACH TO TWO-ELECTRON CONTINUUM PROBLEMS

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A new type of basis functions is proposed to describe a two-electron continuum which arises as a final state in electron-impact ionization and double photoionization of atomic systems. These two-particle basis functions are obtained, by analogy with the Green's function of two non-interacting hydrogenic atomic systems, as a convolution integral of two one-particle Quasi Sturmian functions [1]. We name these functions Convoluted Quasi Sturmian functions (CQS). By construction, a CQS function (unlike a simple product of two one-particle ones) behaves like a six-dimensional outgoing spherical wave when the hyperradius $\rho \to \infty$. This important property should be useful in solving three-body scattering problems. It is the purpose of this contribution to explore the effectiveness of such CQS as a basis set.

The driven equation [2] describing an (e,3e) process on helium in the framework of the Temkin-Poet model has been solved numerically using an expansion on the proposed CQS basis. The CQS functions asymptotic behavior in the so called three-body region Ω_0 where all three particles are well separated is not correct since it misses out the phase factor [3]:

$$\exp\left(-i\frac{\rho}{\sqrt{2E}}\frac{1}{r_{12}}\ln\left(2\sqrt{2E}\rho\right)\right),$$

corresponding to the Coulomb e–e interaction (at a distance r_{12}). Therefore, the convergence of an expansion on CQS needs to be proven. We examined the scattering solution by increasing the size of the CQS basis set: we found that the solution shows a divergent phase as a function of the basis size, whereas the magnitude seems to converge. This problem of slow convergence (or even perhaps lack of convergence) can be removed by using modified CQS functions equipped with an appropriate phase factor corresponding to the potential $1/r_{12}$. Moreover, such a modification of the boundary condition leads to appreciable change in the magnitude of the solution.

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STUDY OF GROUND STATES OF He NUCLIDES BY FEYNMAN'S CONTINUAL INTEGRALS METHOD

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The wave functions of the ground states of He nuclides were calculated by Feynman's continual integrals method in Euclidean time [1–4]. The results are shown in Fig. 1 in Jacobi coordinates together with the corresponding nucleon configurations. The nucleon-nucleon interaction potentials similar to the M3Y potential [5, 6] were used. In the ^{6}He case the effective neutron-alpha-particle interaction potential included the centrifugal potential for the 1*p* shell orbital. The results may be used for correct definition of the initial conditions in the time-dependent calculations of reactions with He nuclides.

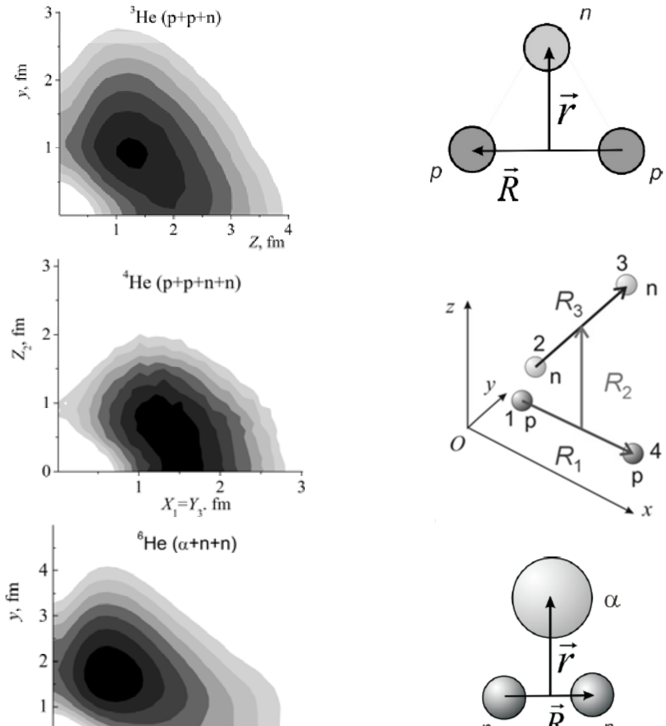

Fig. 1. The probability density of the ground states of He nuclides (on the left) and the corresponding nucleon configurations (on the right).

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ASYMPTOTIC SOLUTION OF THE THREE-BODY SCHRÖDINGER EQUATION FOR THREE PARTICLES IN THE CONTINUUM

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The asymptotic solution of the 3-3 three-body scattering problem for particles interacting by short-range potentials is constructed by the method of successive rescattering. The structure of singularities of the rescattering terms has been studied by the Faddeev equations in the momentum space as it was first proposed in [1]. The large separation asymptotic in the configuration space is obtained by studying the Fourier transform integrals of the momentum space terms by technique developed in [1,2]. In contrast to the study of previous papers [1,3] this contribution is focused on consideration of that configuration of particles where the distance of one particle is much larger than the distance between two remaining particles. Such configurations are referred to as the two-body sectors in the three-body configuration space [1,2]. For such configurations of particles it is shown that besides the standard plain wave and one-scattered wave the asymptotic solution of the three-body Schrödinger equation contains the spherical wave of the special type which previously was unknown. The amplitude of this wave is constructed as the specific integral of the product of the two-body *T*-matrices. The analytic form of the obtained asymptotic solution allows us to analyze critically the field of applicability of the so called multiplicative ansatz, which is used in some papers [4] for description of the leading terms of the continuum three-body wave function. The perspective of application of this result to the continuum three-body Coulomb problem is discussed.

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NUCLEAR PHYSICS EXPERIMENTAL TECHNIQUE AND ITS APPLICATIONS

HIGH-RESOLUTION MAGNETIC ANALYZER MAVR FOR SEPARATION AND IDENTIFICATION OF REACTION PRODUCTS

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A project of the high-resolution magnetic analyzer MAVR is proposed. The analyzer will comprise new magnetic optical and detecting systems for separation and identification of reaction products in a wide range of masses (5–150) and charges (1–60).

The magnetic optical system consists of the MSP-144 magnet and a doublet of quadrupole lenses. This will allow the solid angle of the spectrometer to be increased by an order of magnitude up to 30 msr. The magnetic analyzer will have a high momentum resolution (10^{-4}) and high focal-plane dispersion (1.9 m). It will allow products of nuclear reactions at energies up to 30 MeV/nucleon to be detected with the charge resolution ~1/60. Implementation of the project is divided into two stages: conversion of the magnetic analyzer proper and construction of the nuclear reaction products identification system.

The MULTI detecting system is being developed for the MAVR magnetic analyzer to allow detection of nuclear reaction products and their identification by charge Q, atomic number Z, and mass A with a high absolute accuracy. The identification will be performed by measuring the energy loss (ΔE), time of flight (TOF), and total kinetic energy (TKE) of reaction products. The particle trajectories in the analyzer will also be determined using the drift chamber developed jointly with GANIL.

The MAVR analyzer will operate in both primary beams of heavy ions and beams of radioactive nuclei produced by the U400 – U400M acceleration complex. It will also be used for measuring energy spectra of nuclear reaction products and as an energy monochromator.

STUDY OF (n,*f*), (n,γ), (n,2n) AND (n, spallation) REACTION RATES IN ^{232}Th SAMPLES IRRADIATED BY 4 GeV DEUTERONS AND SECONDARY NEUTRONS AT THE MASSIVE URANIUM TARGET QUINTA

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Uranium target "QUINTA" was irradiation by 4 GeV deuteron beam from the Nuclotron accelerator at the VBLHEP JINR. A set of four ^{232}Th samples were placed inside the uranium assembly at the deuteron-beam axis in four of the six special gaps. The total flux of deuterons on the target was $1.44 \cdot 10^{13}$ particles during the 1157 min. irradiation.

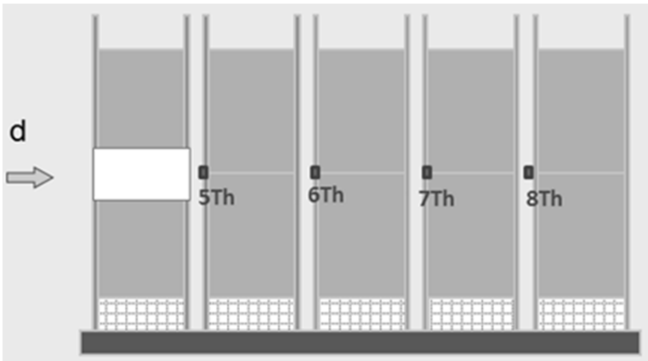

Fig. 1. The position of investigated ^{232}Th sample.

After irradiation, the sample was taken to the spectrometric complex YASNAPP-2 in the JINR DLNP, where the spectra of γ-radiation were measured using HPGe-detectors.

The main channels of the interaction of secondary neutrons with nuclei of thorium are ^{232}Th (n,2n)- reaction with the production of ^{231}Th. The next is ^{233}Th – a product of the (n,γ)- reaction, which decays with a half-life of 22.3 min. in ^{233}Pa, which we have observed. Products of the fission reaction (n,*f*) – for example: ^{85m}Kr, ^{99}Mo, ^{115}Cd, ^{133}I, ^{140}Ba, ^{143}Ce have been observed as well. Moreover, some products of the spallation reactions in ^{232}Th have been detected, such as ^{69m}Zn, ^{120m}Sb, ^{173}Hf, ^{192}Hg.

The experimental data were compared with the results of the MCNPX 2.7. simulations. A good agreement within the statistical uncertainties was observed.

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W-Be PHOTONEUTRON SOURCE OF INR RAS

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W-Be photoneutron source is developed and installed at 8 MeV electron beam of linear accelerator LUE-8-5 of the Institute for Nuclear Research. The source includes tungsten γe-converter, beryllium neutron-generating target, polyethylene moderator, working irradiation chamber, external neutron beam collimator, as well as the neutron shielding made of borated polyethylene. To reduce heating the tungsten converter is equipped with a system of water cooling. The working chamber is designed to irradiate samples, e.g. for neutron activation analysis. Collimator assembly is intended for operation with external neutron beam. The collimator entrance is inserted into the location of the peak thermal neutron flux.

Using neutron activation analysis the thermal neutron flux density inside the working chamber was measured. ^{63}Cu reference samples were irradiated and their activity was measured in a low-background HPGe γ-spectrometer [1]. Independent measurements of γ-spectra from the decay of ^{24}Na by neutron activation analysis of irradiated NaCl samples confirmed the values obtained for thermal neutron flux density. We also measured the neutron flux on the extracted beam of neutron source.

1. A.V.Andreev *et al.* // Nucl. Phys. and Eng. 2013. V.4. P.879.

DIGITAL n-γ PULSE-SHAPE DISCRIMINATION WITH NANOSECOND WAVEFORM DIGITIZER

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In experiments with neutron detection, it is necessary not only to establish the fact of appearance of signal caused by neutron, but also to obtain precise information about the time of neutron interactions in the detector. This means using fast timing scintillators, absence of shaping amplifiers in the registration channel, and application of digital pulse processors (DPP) operating in the nanosecond region. Working with fast signals requires the use of new and modernization of known methods of digital pulse shape analysis.

To compare various methods of n-γ pulse shape discrimination irradiation of fast scintillators by PuBe neutron source was performed. We examined different scintillators: stilbene crystals, hydrogen- and deuterium-containing liquid scintillators. The signals from the photomultipliers were fed to the inputs of DPP CAEN DT5742 (16 + 1 Channel, 12 bit, 5 GSample/s, recorded time of 200 ns per event) [1]. DPP DT5742 allows the digitization of nanosecond pulses with a channel width of 0.2 ns.

Different versions of discrimination methods were examined: Digital Charge Comparison Method, Simplified Digital Charge Collection, Pulse Gradient Analysis, Frequency Gradient Analysis and Wavelet Method. Comparison of methods was carried out by determining the value of figure-of-merit (FOM) parameter. Various optimizations of FOM such as linearization method, the use of two-dimensional information on separation parameters, and coordinate rotation [2] were considered.

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NEUTRON ACTIVATION ANALYSIS OF AEROSOL FILTERS AT PHOTONEUTRON SOURCE OF INR RAS

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Neutron activation analysis (NAA) of clear aerosol filters, intended for sampling of aerosol probes, was performed using W-Be photoneutron source installed at 8 MeV electron beam of linear accelerator LUE-8-5. The examined filters were made of fiberglass and quartz fiber. The goal of this study was to determine background components, which may contribute to subsequent measurements of aerosol probes.

The samples were irradiated by thermal neutrons in the irradiation chamber of the photoneutron source. Activity of the samples was measured in a low-background chamber using HPGe γ-spectrometer [1]. Before the neutron irradiation the natural radioactivity of samples in low-background chamber was measured.

NAA results indicate no significant background contributions for the quartz filters. The fiberglass filters are characterized by the presence of strong lines from the decay of ^{24}Na in γ-spectra. Identification of the isotopes was carried out based on the results of energy and half-life determination for the observed lines and on the NAA results for the reference NaCl samples. The presence of Na in filters will complicate the determination of impurities, so the quartz-fiber filters are more suitable for neutron activation analysis.

According to the analysis of NaCl samples we have obtained independent evaluations of thermal neutron flux density inside the irradiating chamber of the source. This value agrees with that obtained from NAA measurements with reference ^{63}Cu samples.

1. A.V.Andreev *et al.* // Nucl. Phys. and Eng. 2013. V.4. P.879.

INVESTIGATIONS OF THE NEW GENERATION PIXEL DETECTORS FOR ALICE EXPERIMENT AT LHC

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The ALICE (A Large Ion Collider Experiment) detector was constructed to study the properties of extremely hot and dense hadronic matter formed in relativistic nuclear collisions. An excellent performance in particle identification was demonstrated by ALICE in measurements at the LHC beams. The increase of the LHC luminosity, planned in 2018, opens the possibility to expand the program of the physical studies of ALICE, in particular, in the high precision measurements of rare probes like heavy flavor hadrons (particles containing *c* and *b* quarks) and dileptons at low transverse momenta. This goal requires the upgrade of the currently running ALICE vertex detector, the Inner Tracking System (ITS), in order to increase the accuracy of secondary vertices coordinates reconstruction (by a factor of about 3) and to lower the threshold of the particle transverse momentum measurement. The upgrade strategy of the ITS is based on the application of new Monolithic Active Pixel Sensors (MAPS) in 0.18 um CMOS imaging sensor process (from TowerJazz). The 50 um thick chip consists of a single silicon die incorporating 18 um a high-resistivity silicon epitaxial layer (sensor active volume) and a matrix of charged collecting diodes (pixels) with readout electronics.

A wide set of MAPS structures with different read-out circuits, namely the MIMOSA, Explorer and ALPIDE families, was produced and is being studied by the ALICE collaboration for the optimization of the pixel sensor functionality. In this work we present results of our tests of several prototypes of ALPIDE (ALICE Pixel Detector). The chip pALPIDEfs measures 15.3 mm by 30 mm and contains a matrix of 512×1024 sensitive pixels. The pixels are 28×28 um^2. There are four sub-matrices of 512×256 pixels, each matrix being composed by identical pixels differing by the size of the charge collection diode and by the way the diode reset is implemented. The special experimental set-up has been constructed at SPbSU to perform the tests with this chip. The linearity of all voltages and currents generated by a set of 11 on-chip DACs was checked for different temperature of the chip. To investigate the main characteristics of the pixel sub-matrices the threshold scan, noise occupancy scan and radioactive source scan have been accomplished. The threshold behavior was studied using different voltage and current biases generated by DACs. The comprehensive analysis of the hit maps produced by different gamma and beta sources has also been done.

THE RECOVERY OF THE PROPORTIONAL COUNTER OPERATING AGED DUE TO SILICON CONTAMINATION

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Usually the ‘classical’ aging effects in gas discharge detectors appear as a result of the chemical reactions, occurring in avalanche plasma near anode wire, leading to the formation of deposits on electrode surfaces. Silicon is the most frequently detected chemical element in the analysis of the deposits on the wires.

In this paper we present a method of restoring the operating parameters of the proportional counter that degraded due to formation of the silicon compounds on the anode wire surface. Studies of aging effects were carried out under sustained irradiation by an intense ^{90}Sr β-source of straw proportional counters operated with an $60\%Ar+30\%CO_2+10\%CF_4$ gas mixture. To accelerate a rate of degradation the gas mixture was fed to the detector through the polluted by Si-sealant gas tube. This resulted in increasing of the anode wire diameter due to the deposits appearance. A significant drop of the signal amplitude in the detector have been observed already after accumulation of the charge Q = 0.009 C/cm. The recovery stage was done with an $80\%CF_4 + 20\%CO_2$ gas mixture. Cleaning of the anode wire from the silicon precipitation was carried out due the etching in the gas discharge. Thus the signal amplitude of the counter was restored to the original. Analysis of the restored wire surface, conducted by means of a scanning electron microscope and a method X-ray spectroscopy demonstrated a good cleaning from the silicon compounds.

The proposed method allows a multiple restore of the detector performance after aging. The results of multiple "aging-recovering" cycles for one of anode wire are presented in Fig.1.

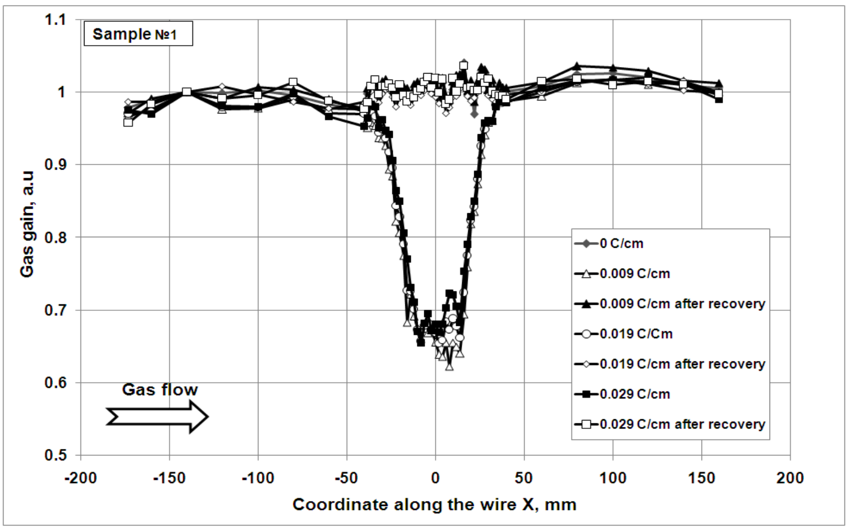

Fig. 1. Gas gain distribution along the straw measured on aged and then on recovered straw in $60\%Ar + 30\%CO_2 + 10\%CF_4$ gas mixture.

ON A POSSIBILITY OF USING CdTe-PIN DETECTORS FOR INVESTIGATIONS OF THE ^{239}Np DECAY

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Measurements using CdTe-PIN detectors are provided for within the program for investigation of physics aspects of the electronuclear power production and nuclear waste transmutation. The experiments are performed at the Nuclotron / JINR Phasotron (Dubna) within the Energy plus Transmutation Project.
The investigation is concerned with the spectrum of ^{239}Np (58 h) resulting from a chain of beta decays: ^{238}U(n,γ)^{239}U (23.54 m) $\beta^- \rightarrow$ ^{239}Np (2.36 d) $\beta^- \rightarrow$ ^{239}Pu.

The yield of the 277.6 keV gamma line is to be measured, and the number of reactions of radiative capture of neutrons by ^{238}U nuclei is to be determined. Thus, the CdTe-based detector has to be able to detect a single gamma line at 277.6 keV in a massive uranium target under an increased background (Fig. 1).

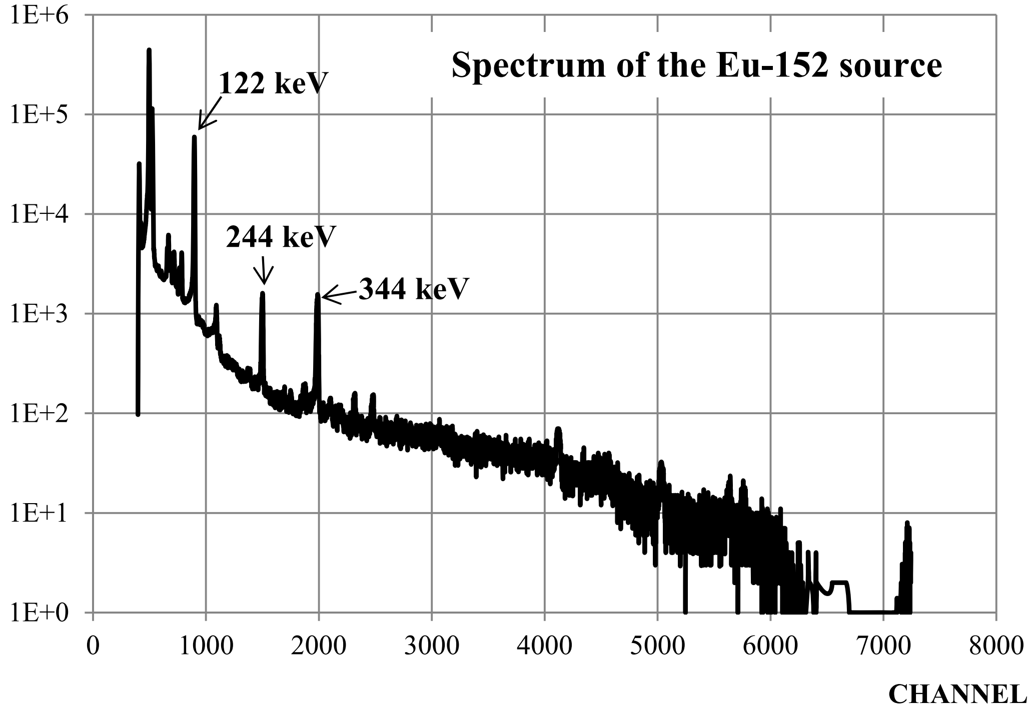

Fig. 1. Gamma spectrum of the Eu-152 source obtained using the CdTe detector with an area of 46 mm^2 and thick ness of 1 mm of a voltage of -300 V.

The research was supported in part State Corporation «ROSATOM» by contract № H.4x.44.90.13.1125 (20.01.2014).

GAS DISCHARGE PROCESSES IN THE STRANDARD AND METAL CHANNEL PMT's

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The effect of the potential different at the focusing chamber electrodes of the FEU-85, FEU-87, and FEU-93 photomultipliers on the intensity of afterpulses resulting from gas discharge processes is investigated. Influence of $V_{\text{ph-m}}$ on intensity of afterpulses is presented on Fig. 1. With appropriately selected potentials, the number of recorded secondary pulses can be decreased. Charge distribution spectra are obtained for this sort of pulses, which gives a qualitative estimate of both the homogeneity of the charge and mass distribution of residual gases and the ion-electron emission coefficients.

A possibility of using metal channel PMTs to search for isomeric states in the nano- and microsecond ranges by the autocorrelation method [1] with detection of secondary pulses in addition to the primary ones is studied. It is found out that the time distribution of secondary pulses up to a few microseconds is governed by ion feedback pulses – Fig. 2. It is shown that the optimum way to search for nano- and microsecond isomers in low-energy isomeric cascades with metal channel PMTs is to equip an autocorrelation spectrometer with double PMT's for detecting radiation in the coincidence mode.

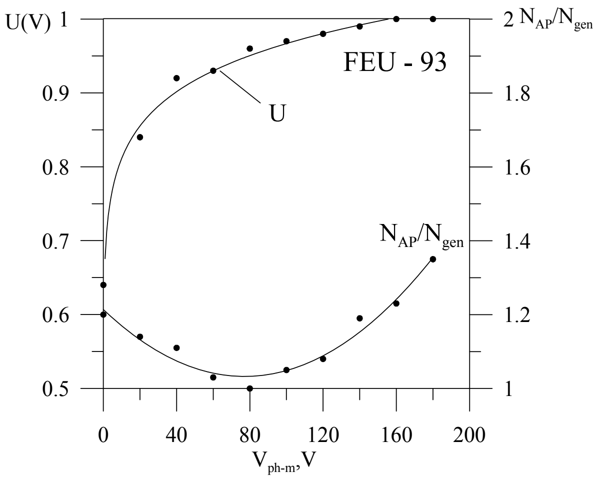

Fig. 1. Drift of ions in FEU-93.

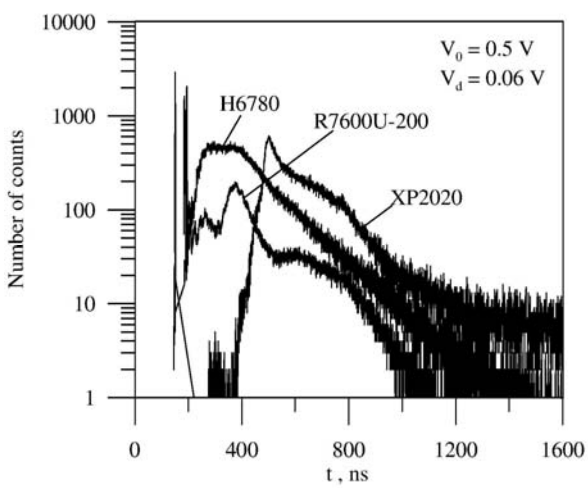

Fig. 2. Time distributions of afterpulses in PMT's of various type.

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STABILITY OF GAMMA-RAY DETECTION BY HPGe DETECTORS IN CONTINUOUS MEASUREMENTS UP TO SIX MONTHS LONG

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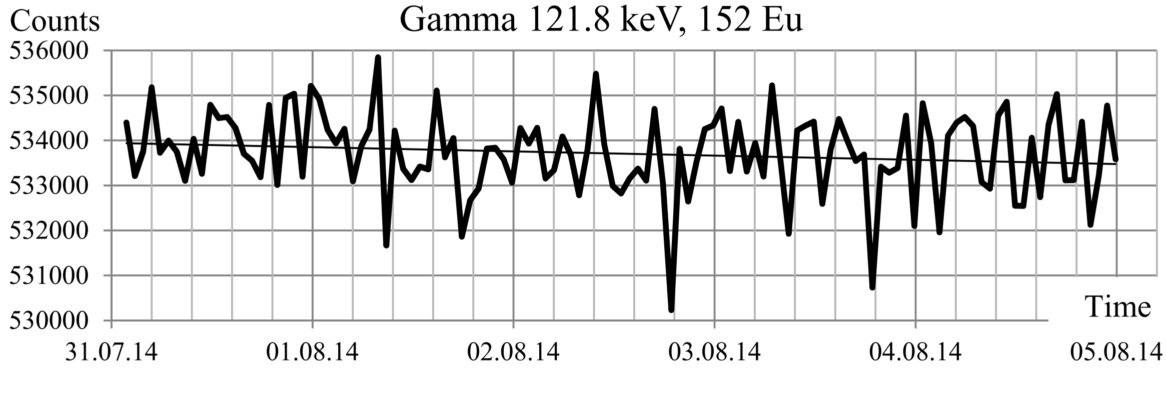
Stability of HPGe detectors in detecting gamma rays accompanying beta decay of ^{152}Eu and ^{22}Na nuclei is investigated.

The spectrometric channel consisting of an HPGe detector with a preamplifier, digital spectrometric device (16k), and personal computer was made at the Joint Stock Company «The Institute in Physical-Technical Problems» (Dubna).

No periodic, hourly or daily, variation in the detection of the beta decay rate was observed in continuous measurements over six months long with the detection time over 10^4 s at one point and integral amplitude-spectrum statistics over $(1–10)\cdot10^6$ events within the area of the peak at 121.8 keV.

We thoroughly investigated and eliminated possible sources of instability, which allowed us to state that the hypotheses [1] of the cosmological effect on nuclear processes on the Earth are groundless.

The figure shows a fragment of the research results that will be analyzed in detail in the report.



The area of the peak at 121.8 keV (120 points, each 1h long), (ΔS/S ~ 0.4%)

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BIAS DEPENDENCE OF THE ENERGY RESOLUTION IN PLANAR HPGE DETECTORS FOR LOW ENERGY *X*-RAYS

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In this work, theoretical consideration of the processes in planar High Purity Ge (HPGe) detectors for low energy *X*-rays was carried out. Using the random stochastic processes formalism, the generating function of the processes of *X*-rays registration with accounting for charge carrier trapping was derived. The power series expansion of the mean amplitude and the variance of the detector's signal in terms of inverse powers of the bias voltage were derived. The coefficients of these expansions allow determining of the Fano factor, electron mobility lifetime product, and other characteristics of the semiconductor material.

FLUCTUATIONS IN THE PROCESSES OF CHARGE INDUCTION IN IONIZATION-TYPE DETECTORS

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The energy resolution of ionization-type detectors, i.e. semiconductor detectors and liquid ionization detectors, is determined not only by the variance in the number of charge carriers produced by X-rays, but also by fluctuations in the process of charge induction on the detector electrodes. The trapping of charge carriers and the resultant decrease in charge collection efficiency degrades the line shape of spectral peaks produced by *X*-ray spectrometers. In this work, the characteristic function of the process of charge induction on electrodes of an ionization-type detector with accounting for charge carrier trapping was derived. This characteristic function allowed deriving the general expression for the moments of the distribution function as well as the formulae for the mean value and the variance of the charge induced on the detector electrodes. These formulae are useful for analysis of the influence of the charge transport on the energy resolution of ionization type detectors.

APPLICATION OF STATISTICAL MONTE CARLO METHOD FOR SPECTROMETER CALIBRATION TO DETERMINE THE SURFACE ACTIVITY OF THE RADIONUCLIDES DEPOSITED ON THE GROUND

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The key tasks at response on radiological emergencies are radionuclide identification and determination of surface activity of the radionuclides deposited on the ground, which can be compared to operational intervention levels.

Traditional method of environmental monitoring on radioactive contaminated areas is environmental sampling and laboratory analysis.

However, for prompt response on emergency situations with a radiation factor it is more reasonable to use the technique of *in situ* gamma spectrometry.

The number of studies [1, 2] shows that the application of *in situ* gamma spectrometry technique allows effective and detailed examination of contaminated areas.

The purpose of this research work was carrying out the efficiency calibration and verification of the *in situ* method with application of handheld gamma spectrometer HPGe detector GR3019 (Canberra) with software «EcoGamma». Geometry of measurements – the detector placed 1 m above ground surface [3]. Conditions of soil contamination – recent and old fallout with various depth distributions.

Experimental methods of calibration for such type of measurements are complicated by reasons of: large volumes of the radioactive material, specific or short-lived radiation sources, inhomogeneous depth distribution of radionuclides, etc. Therefore detector efficiency was simulated by using the statistical Monte Carlo method. MCC MT software [4] was used for modeling.

In our work the model of the detector was simulated and spectra for condition of point sources and surface and volume distributions of radionuclides were generated. Validity of such model was checked by using real reference point sources, volumetric sources and the soil samples which were collected from contaminated areas.

The conducted research shows that the software MCC MT can be applied for efficiency calibration in the energy range from 30 to 1500 keV, with expanded uncertainty (k = 2) up to 22% for measurement of surface activity of the radionuclides deposited on the ground.

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DETERMINATION OF DISTRIBUTION COEFFICIENTS (K_d) OF VARIOUS RADIONUCLIDES ON "UTEVA" RESIN

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The extraction chromatographic resin UTEVA Resin (Uranium and TEtraValent Actinides) is a product provided to us by «TRISKEM INTERNATIONAL SAS». This resin has been used successfully for the separation of actinides. However, the distribution coefficients (K_d) have not yet been determined for a wide range of elements. This data is necessary for the separation of complex mixtures of elements and can also be of interest for the chemistry of elements with 3, 4, 5 and 6 valences. The coefficients are determined in solutions of hydrochloric, sulfuric and nitric acids. Studies were carried out using radioisotopes of the following elements: In, Sn, Sb, Te, Bi, Co, Fe, Nb, Sr, Ba, Ag, Cd, Zr, Hf and Ti, produced at the Phasotron in Dzehelepov Laboratory of Nuclear Problems, Joint Institute for Nuclear Research (DLNP, JINR).

MATHEMATICAL SIMULATION OF RADIATION IMPACT ON HETEROGENEOUS MICROSTRUCTURES

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Evaluation of the radiation hardness of many materials, used in modern atomic and space technology, requires determination of absorbed dose values in the microsized elements of spacecraft construction and on-board equipments, including electronics. For example, to develop next-generation spacecraft and forecast their lifetime one needs to calculate absorbed dose in microchips and even in a separate transistor of the microchip.

To simulate the radiation-induced processes in such microsized elements of various composition and structure it is important to apply different physical models implemented in various existing software codes, and to understand advantages and limits of their usage. This paper presents a generalized scheme of problem-solving methods for calculating the absorbed dose in heterogeneous structures using modern software codes GEANT4 [1], FLUKA [2], RDOSE [3] and others.

As examples of this scheme realization, we demonstrated absorbed dose distributions calculated with GEANT4 and TRIM/SRIM [4] in different microcomposite and multilayer thin-film materials under the impact of electrons and protons with different energies. Effects of the chemical composition and structure of materials on the absorbed dose distribution were analyzed. The role of nuclear interactions in irradiation-induced processes for 1–50 MeV protons was estimated.

Telescopic detectors for registering electrons and protons of Earth's radiation belts can be considered as another example of a multilayered structure. For such a detector we calculated metrological characteristics for correction of measurement results. It was shown that for electron registration a widely used approach to calculate energy boundaries on the base of mean energy losses in detectors, can lead to significant errors. We proposed a more accurate method of determining the telescopic detector metrological characteristics based on the true energy losses of electrons in the detecting elements.

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RESTRICTIONS FOR CRYSTAL UNDULATOR RADIATION

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Channeling of high-energy particles in straight and bent crystals is known since many years. It was supposed that periodic changes of the bending direction may create the oscillating trajectory similar to the path of particles in the magnetic undulator. Respectively, a higher frequency of the undulator radiation could be reached and varied by the choice of the bending period. The efficiency of capture to channeling in bent crystals and critical radius were estimated in [1]. Typically, the efficiency is far from 100% even at the favorable conditions. The smooth sinusoidal configuration of the channel could be prepared [2] by the variation of the atomic content in a super-lattice crystal. Particles must deviate periodically “up and down”, or “left and right”, the same as in the undulator. After each change of the curvature sign, a significant part of captured particles crosses the outer wall of the channel because of the angle exceeding the critical angle of channeling and misses the stable trajectory, as is shown in the scheme of Fig. 1. Therefore, efficient generation of the undulator photons is restricted. The missed particles, in principle could be re-channeled due to the multiple scattering at some distance but the resonance conditions for radiation are missed. Some authors propose the periodic scratches, or smooth hills and valleys at the crystal surface. Such a configuration is useless for the sinusoidal trajectory formation and for the undulator radiation, correspondingly. Different-kind radiation due to periodic perturbations may be emitted, but only for the particles moving near the modulated surface. The yield of photons looks impractical.

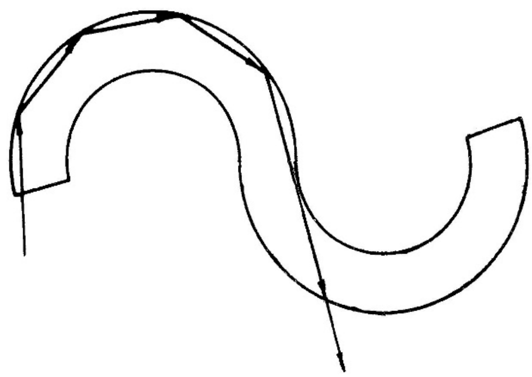

Fig. 1. Missing of regular trajectory due to the changed sign of the channel curvature.

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TWO TYPES OF CHANNELING IN CRYSTALS

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Channeling of charged particles in crystals is typically understood as a periodic motion driven by collective potential of the atomic chains or net planes. There exists an alternative view that channeling is nothing but a consequence of small-angle scattering events for particles moving near the crystallographic direction. One may suppose that both interpretations are almost similar, and the potential of plane is just an approximation convenient for the mathematic simulation. Meanwhile, many years ago, it was experimentally proved the existence of the discrete quantum levels of the transverse energy in the collective potential well. No doubts remained on the reality of the potential. As early as 35 years ago, there was published [1] a discussion about the recoil energy for crystal atoms due to the channeling. A magnitude of recoil energy was estimated in [1] and found to be very low, comparable to that allowing the Mössbauer resonance absorption of gammas. In both cases a particle interacts with the crystal as whole and transfers zero momentum to the body of a great mass. The Mössbauer mechanism is manifested with a finite probability dependent on the crystal temperature. Similarly, the recoil free channeling could be observed at some conditions. The collective potential is formed only by atoms located closely to their equilibrium position in the lattice. Others, shifted enough due to the defects, or thermal vibrations may participate in the consequence of binary collisions. Correspondingly, two different types of channeling are possible. The recoil-free channeling generates perfect sharp reflexes narrow and intense at a zero angle, and binary collisions produce the reflexes which are wider and smooth. Sometimes, both are manifested together. One could not exclude even that the collective potential generates a channeling reflex, while binary collisions create an image of another type. In angular distributions of heavy ions transmitted through the mono-crystalline foils of a μm thickness there are observed [2] narrow channeling peaks at zero angle accompanied with the 3-times wider dips, type of blocking. Both reflexes are manifested independently with different dependence on the exit energy of the particles. Whatsoever, these patterns did not find a trustable explanation in theory. The coexistence of two different-type orientational effects is evident.

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VOLUME CAPTURE TO CHANNELING IN CRYSTALS

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Volume capture was revealed in experiments with heavy-ion beams when the channeling peaks were observed [1] at standard conditions corresponded to the blocking-minimum manifestation, namely at large-angle scattering. Therefore, a deep transformation of the particle flux distribution was evident due to transmission through the crystal matter. Clearly in the geometry of a beam directed closely to the crystal axis or plane, the volume capture to channeling must be even more intense. The volume capture effectively reduces the dechanneling strength and supports the observation of long-range channeling for high-energy protons in bent crystal. No need even to assume the inelastic "cooling" of the transverse energy. The electronic-stopping power reduces simultaneously both the longitudinal and transverse moments of particles without decreasing of the trajectory angle to the net plane. Let us to estimate the yield of volume capture into planar channeling due to the scattering. Initially, the uniform distribution of particles is supposed. The scattering rate is decreased for ions moved at very small angles to the plane due to the channeling and also for great-angle scattering because of normal Rutherford dependence. We suppose that the angles around critical angle: $(0.5–1.5)\psi_{crit}$, are mostly responsible for the capture to channeling past scattering. The integral: $P \approx k\int\sigma_R(\psi, t)d\psi dt$ defines the probability of capture, where the Rutherford cross section σ_R is expressed in cm^2 and the layer thickness t – in atoms/cm^2. The percentage of scattering to right direction, i.e. closer to the plane is accounted with the coefficient k. The numerical example is evaluated assuming the conditions of experiment [1] for Ne ions in Ge crystal. At Ne beam with the energy of 105 MeV, the spatial distribution of ejectiles demonstrates channeling peaks magnifying the flux density by a factor of (1.2–1.5). The calculated probability of constructive scattering for re-channeling is great, near by 100%. The particles deviated out of plane could store the transverse energy in multiple scattering events and form the blocking trajectory, unlike to particles captured by the plane for channeling. The mean multiplicity of scattering is growing proportionally to $\sigma_R \sim (Z_1Z_2)^2E^{-2}$, and in experiments [2], the blocking reflexes were indeed strongly manifested at lower energy E and at higher Z_1Z_2 value.

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HYPERFINE INTERACTION IN HfO_2 STUDIED BY TIME DIFFERENTIAL PERTURBED ANGULAR CORRELATION METHOD USING ^{172}Yb

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Hafnium oxide (HfO_2) is a technologically important material [1], for example, it is applying in: nuclear, chemical, electronic industry.

Our study of HfO_2 has been made through time differential perturbed angular correlation (TDPAC) method with ^{172}Yb. We have measured TDPAC spectra at various temperatures (300 – 1300 K), and we had the samples with implanted isotopes ^{172}Hf and ^{172}Lu.

The essence of method is: a radioactive isotope (^{111}In, ^{44}Ti, ^{172}Lu etc.) has been implanted in the investigated object. The measurements of angular correlation of cascade of γ-quanta give us the information of hyperfine interaction (HFI) between the implanted nucleus and the sample lattice.

Our experimental setup includes: a 4 detectors' spectrometer, a cryogenic system and an oven [2].

We have applied ^{172}Yb in our measurements, because:

1) It has a wide collection of suitable γ-cascades, and high energy γ-quanta, which have a high penetrating ability. This allows to study HFI under various external influences.

2) It has two ways to be implanted in the sample, because ^{172}Yb can be produced by two decay modes (ε-capture): $^{172}Hf \rightarrow ^{172}Lu \rightarrow ^{172}Yb$ or $^{172}Lu \rightarrow ^{172}Yb$. This gives us a possibility to estimate post effects from the radioactive decay.

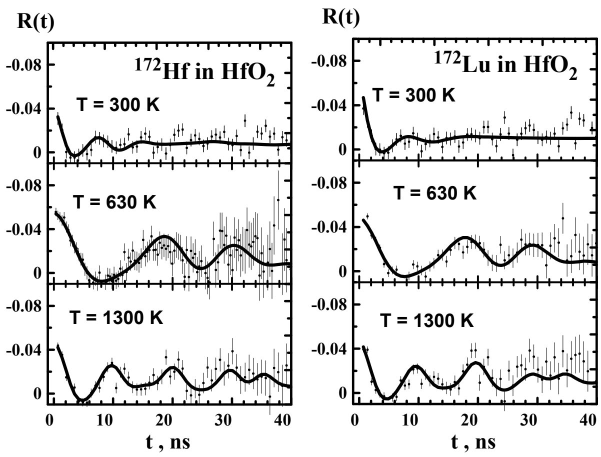

Fig. 1. TDPAC spectra of ^{172}Yb in HfO_2 at some temperatures, with: ^{172}Hf and ^{172}Lu.

3) The ^{172}Hf has a half live time of 1.87 y. So the samples prepared with ^{172}Hf have been useful for measurement for a long time. Then, we can study the same sample under various external influences. Also we can minimize systematical errors from some varieties of conditions concerning with preparing the sample.

On the Fig. 1 the results are presented. The temperature change of spectra helps us to assume that we observe phase transitions.

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EMISSION OF γ-QUANTA, ELECTRONS, POSITRONS FROM CHARACTERISTIC TARGETS AT DECAYS OF PRODUCED IN THE TARGETS ^{12}N AND ^{12}B

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The photonuclear method for detection of hidden explosives in luggage of air-passengers is now under development (see, e.g., [1]). In this method it is supposed to use reactions ^{14}N(γ,2n)^{12}N, ^{14}N(γ,2p)^{12}B, ^{13}C(γ,p)^{12}B and to register γ-quanta, electrons and positrons emitted from luggage at β-decays of radioisotopes ^{12}N and ^{12}B produced in these reactions. So it is important to estimate fluxes and spectra of these particles, emitted from luggage. We calculated such fluxes and spectra using codes GEANT4 [2] and MCNPX-5 [3] for some characteristic spherical "luggage"-targets having ∅20 cm and densities (0.05; 0.10; 0.25; 0.50) g·cm^{-3} and containing equal quantities of H, C, N, O atoms when the sources of ^{12}N and ^{12}B are in the sphere centers (see, e.g., fig.).

The obtained results help to predict important features of the method.

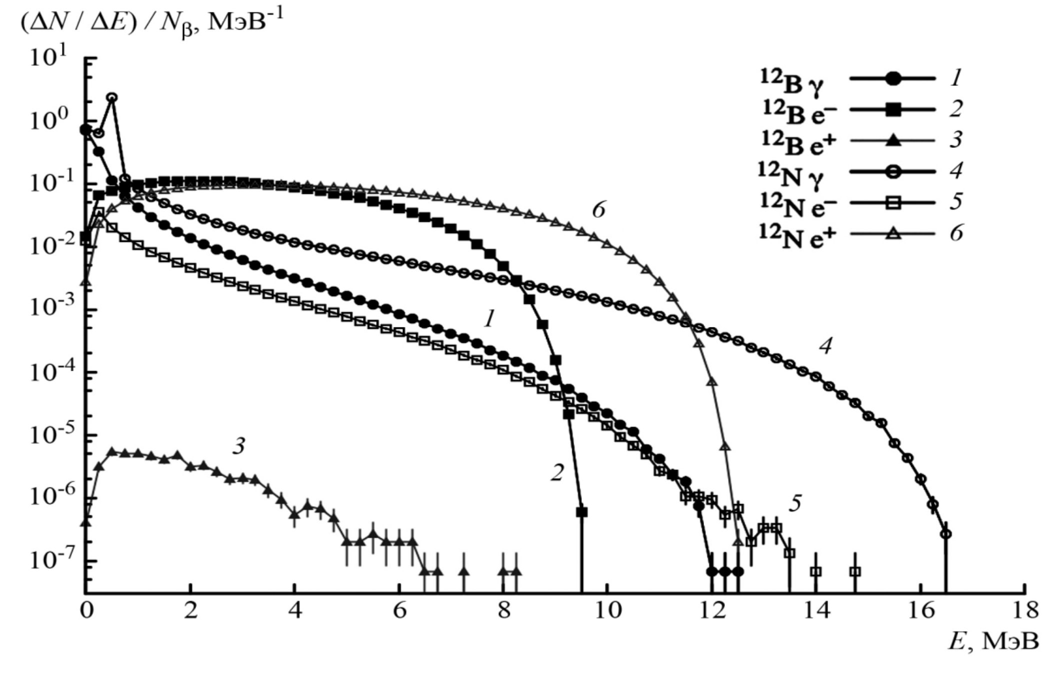

Fig. Calculated spectra of γ-quanta, electrons and positrons from sphere surface at β-decays of ^{12}B and ^{12}N from center of the sphere having ∅20 cm and containing equal quantities of H, C, N, O atoms at the total density 0.25 g·cm^{-3}.

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ELECTRONIC-POSITRON STRUCTURE OF NUCLEAR SUBSTANCE

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For the benefit of a electronic-positron structure the representations about an annihilation of the electronic-positron pairs, formation in substance electronic-positron of pairs under activity action of a gamma radiation, electronic and positron character of a beta radiation in nuclei are worked.

Terminology: positrino, electrino, pairino. The new mechanism of a physical phenomenon, well explored to the present moment, with the conventional interpretation – mechanism of an annihilation of a free positron on electrons of substance is offered. That is the conventional point of view is those, that during annihilation the electron burns down, disappears or is transmuted into a gamma-quantum. In opinion of the author any facts or the proofs of such interpretation do not exist.

The following mechanism therefore is offered: an electron and positron at coming together are discharged by two gamma-quantum and form pairino (unloaded electron-positron state with gravitational mass "m" about 2 eV, with compensation by electric charge, about an electrino by positrino interaction); that is the mechanism “cold” (low, is less than 10 KeV, energies) synthesis of pairino. The given mechanism of phenomenon of annihilation is more realistic.

Decrease or enlargement of the number of pairinos in nuclei and as free nucleons, pairinos, electrinos, positrinos is a factor of destabilization in the matter and or environment.

CESIUM SORPTION BY NANOPARTICLES OF CLINOPTILOLITE

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A variety of practical applications of nanoclinoptilolite are caused by its structural singularities. One of the most remarkable of these singularities is a crystalline skeleton with hollows and channels. In natural clinoptilolite they are filled up with crystalline hydrated water. The three-dimensional crystal of nanoclinoptilolite has a substratified constitution and bidimensional system of channels. The ions of Al^{3+} and Si^{4+} in elemental cell $[(Si,Al)O_4]$ are in tetrahedral coordination relatively of oxygen and isomorphically substitutes Si^{4+}. The hydration of clinoptilolite leads to weakening of electrostatic interaction of cations with a skeleton and, accordingly, to dropping of barriers of their migration. The correct selection of preliminary handling of a mineral is the major factor of rising of cation activation.

The high-silicon natural clinoptilolite out of the Sokirnitsky deposit with high content of SiO_2 (< 70%) and Si/Al ≥ 5 was researched. The dimension of original fine-grained powder of clinoptilolite was ~ 3 mm. Procedure of deriving clinoptilolite in nanosize state was the following: the grinding of clinoptilolite in an agate mortar for a long time, the precipitation of powder in the distilled water with the subsequent centrifugation. In this case the sedimentation by centrifugation was realized for the diameter of clinoptilolite particles from 70 to 110 nanometers.

$CsNO_3$ sample (30 mg) was irradiated by bremsstrahlung with E_{max}=23 MeV, I=700 μA. The nuclear reaction for activating cesium was $^{133}Cs(\gamma,n)^{132}Cs$. The active sample of $CsNO_3$ was dissolved in 250 ml of distilled water.

The sample of nanoclinoptilolite (3.7 mg) was placed in a solution of $^{132}CsNO_3$. The time of sorption was 24 hours. The cesium content in nanoclinoptilolite after 24 hours of a sorption was 55 mg/g. In our case, according to [1] the time of stabilisation of equilibrium at level 0.95 for nanoparticles of clinoptilolite (100 nm) was 8 hours.

According to [2] the modification of lattice parameter of oxides can be observed up to 100 nanometers. The hydrated radius of cesium is less than the hydrated radii of sodium and potassium. Therefore exchange of ions of Na and K of Cs in nanoparticles will be more intense in comparison with exchange in massive material. Abovementioned the properties of nanoparticles promote of higher capacity of cesium in nanoclinoptilolite.

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SORPTION PROPERTIES OF MAGNESIUM-POTASSIUM PHOSPHATE SYSTEMS

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Sorption properties of magnesium-potassium phosphate ceramics ($KMgPO_4{\cdot}6H_2O$) for ^{137}Cs immobilization were researched.

The influence of sorption parameters of magnesium-potassium phosphate ceramics (duration of sorption, pH of solution, dispersity of sorbent, etc.) on the efficacy of extraction of radioisotope ^{132}Cs was studied. The dimension of particles of ceramics did not exceed 1.6 microns. Powder of $CsNO_3$ has been irradiated by bremsstrahlung with E_{max}=23 MeV and I=700 μA within 4 days. Sorption of ^{132}Cs by fine-grained ceramics were studied by the introduction of the given amount ^{132}Cs in a certain volume of a solution with various acidity (pH 4, 7 and 12). γ-lines from ^{132}Cs were being detected by means of Ge(Li)-detector with the energy resolution 3.25 keV in the area of 1333 kev.

The efficacy of the use of fine-grained magnesium-potassium phosphate ceramics for ^{132}Cs extraction from solution is illustrated in Fig. 1.

The increase of pH solution in the dynamics of experiments was noted, apparently, at the expense of a leaching of the mobile potassium out of ceramics. The high chemical stability and radioresistance of the given ceramics (cesium diffusion coefficients were being changed in the course of a leaching from unities 10^{-10} cm^2/s to 10^{-16} cm^2/s) was detected [1].

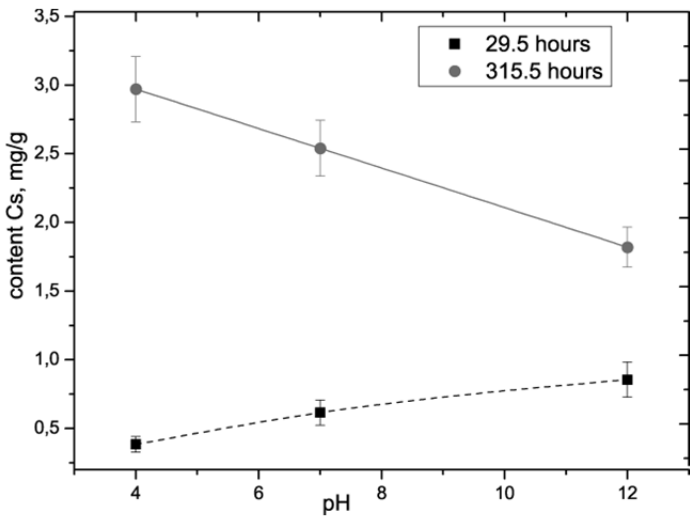

Fig. 1. The concentration of cesium in samples of $KMgPO_4{\cdot}6H_2O$ after ion exchange for 29.5 and 315.5 hours.

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THE STUDY OF THE NUCLEAR REACTIONS FOR THE Sb ISOTOPES PRODUCTION

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The analysis of the biomedical researches showed the advantage of Auger-emitting radionuclides over traditional alpha and beta-emitting radionuclides (^{211}At, ^{212}Bi, ^{213}Bi, ^{90}Y, ^{186}Re) for the therapy of cancer. Auger emitters are capable of delivering a high and localized radiation dose to the target region due to their very short range in biological tissue. Hence, by exploiting Auger electrons we will get a low level of damage to surrounding cells which is important for the idealized targeted therapy. One of the potential nuclide for this targeted radiotherapy is 119Sb. The 119Sb in combination with the 117Sb for patient-specific SPECT-based 3D dosimetry [1] provides excellent treatment results with minimum side effects, combining modern imaging methods and radiotherapy. Therefore the nuclear reactions and methods for production of these radionuclides were investigated in present work.

The excitation functions (in particular in maximum) for the reactions with Sb radionuclide formation have not been so extensively studied [2, 3]. According to preliminary estimations to reach the maximum of the excitation function for these reactions one can use the different types of low-energy commercial cyclotrons. Therefore the information about Sb cross-section formation is of interest both fundamental and applied research.

For investigations of the antimony radionuclide production technique the proton-induced reactions on natural tin have been studied in present work. The original target unit included on-line target heating control system was used. Also the experimental studies of monitor reactions on Ti and Cu targets and targets from stainless steel were done for the beam parameters determination. The production cross-sections of the residual radionuclides 119Sb and 117Sb were theoretically calculated using model approximations. We used models based on evaporation mechanism to get the yield of nucleons and light particles evaporated from high-excited compound nuclei. Also the extended Hauser–Feshbach formalism including the parameterization of the transmission coefficients has been exploited.

The reported study was partially supported by RFBR, research project № 15-02-06250 a.

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A NUMBER OF APPLIED ASPECTS OF THERMAL REACTOR THEORY BASED ON THE PARTICLES BIRTH-DEATH MODEL

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In previous scientific works [1–3] in the context of the particles birth-death model in a linear approximation it was broadly formulated the theory of neutrons interaction with multiplying medium which by its parameters is close to a thermal reactor multiplying medium. This theory was adapted for description of the process of time evolution of the system "multiplying medium + neutron". In previous papers it was described a contribution of delayed neutrons to ensuring of a mode of self-sustaining fuel core fission reaction in a thermal reactor. Due to a huge amount of theoretical computations in the above mentioned papers there was no place for exposition of applied aspects of the theory.

This very paper is devoted to non-steady transient processes which run in a physical reactor under regulation of its power during its start-up and shutdown and in case of accidental deviations of power from a nominal one.

Of particular interest is ^{239}Pu production and its contribution to energy generation. To study these processes it is necessary to thoroughly examine the behavior of dependency of neutrons average number in multiplying medium on time, parameters of multiplying medium etc. In this article a number of aspects on ^{239}Pu in thermal reactors is being considered in contrast with previous works [1–3] where insufficient attention was paid to this problem.

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PARTICULATE BEHAVIOR IN NUCLEAR REACTOR COOLANT

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Today sodium is being actively used as a coolant of fast reactors. It has a number of favorable properties which provide high parameters for fast neutrons facility. The presence of impurities in liquid metal coolant reduces its heat-transfer properties and increases corrosion attack on the metal of circuit.

The impurities which are present in the liquid metal coolant at the initial stage and form at the operation period of installation as well. They can exist in two statuses: in the dissolved form and in the form of the suspended polydisperse particulate phase. Initially, the impurity is present in dissolved form and transforms to the solid particulate phase in the "cold" leg of the circuit. In a thermalhydroulic circuit of the reactor mass transfer of impurities from "hot" leg to "cold" one occurs, which results in a number of negative phenomena and the deterioration of heat transfer is one of them.

At the present work the process of particulate formation and its sedimentation on surfaces of a heat hydraulic path is considered. These processes are interesting, because of their essential contribution to the overall balance of impurity mass transfer through the circuit, which consists of the following processes: nucleation, particulate transport, dissolution and deposition of suspended particles. The mathematical description of these processes allows one to evaluate behavior of suspended particles in existing facilities with liquid metal heat transfer, and in projects of advanced nuclear reactor systems, which are under development now.

MODELING OF NITRIDE FUEL UNDER IRRADIATION

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A model of fission product release and phase evolution of mononitride fuel under irradiation was developed on the base of oxide fuel model [1]. According to the model, fission products diffuse through UN grain matrix. Gas phase and precipitates are formed in the pellet intergranular porosity. Phase composition of irradiated nitride fuel was taken from literature [2]. Distribution of chemical elements in chemical compounds and phases was calculated with the help of mass action law. Due to higher value of nitrogen diffusion coefficient in UN matrix than fission product one at temperatures less than 1500 K [3], thermochemical equilibrium of nitrogen at a grain scale during irradiation process was assumed. Condensed phase evolution of the system is shown in Fig. 1. Results of calculation agree with experimental observations of precipitates in irradiated nitride fuel [4, 5].

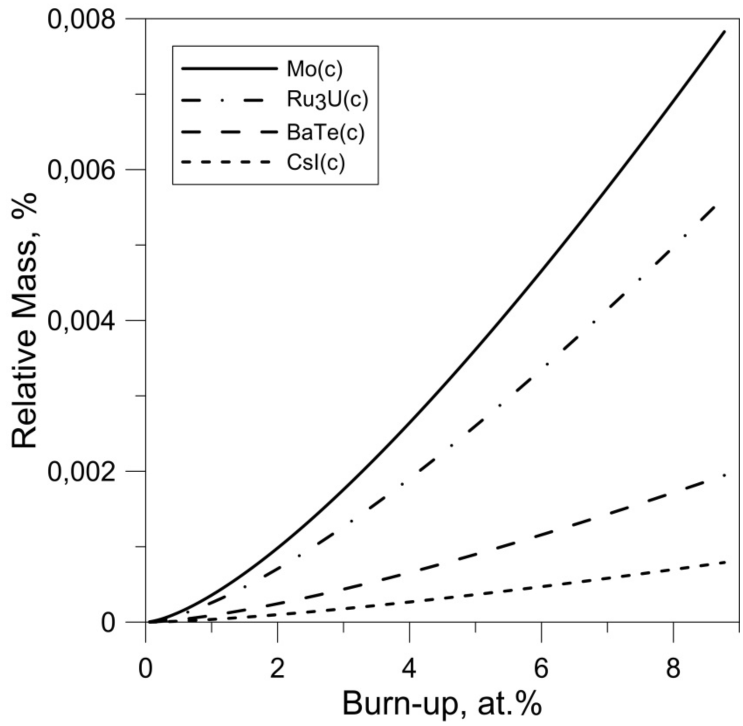

Fig. 1. Evolution of Mo(c) and Ru_3U(c) phase during irradiation of UN fuel at T = 1200 K.

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ADAPTATION AND SOLUTION OF RADIATIVE TRANSFER PROBLEM IN MULTI-GROUP DIFFUSION APPROXIMATION USING THE «FEniCS» OPEN SOURCE PROJECT

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The Fenics Project set out with the idea to automate the solution of mathematical models based on differential equations. By dint of current complex to finding the solution of tasks on neutron physics of the reactor, provides big perspectives. Thereby, the complex allows to solve problems of heat hydraulics, molecular diffusion and mechanics of a solid body, and it is possible to organize the conjugate solution of these tasks with superimposing of neutron physics, it is the important, modern and actual task [1].

The two-dimensional model (the main option; the standard version three-dimensional model) of big fast-neutron reactor. The prototype of this test: the fast-neutron reactor with oxide-coated fuel and the sodium heat carrier. The result of a task is reached by solution of the diffusion equation for this model. The sizes of geometrical parts, which form a single unit, boundary conditions and compliance between geometrical and "physical" zones (parts of different composition) are given in Fig. 1. [2].

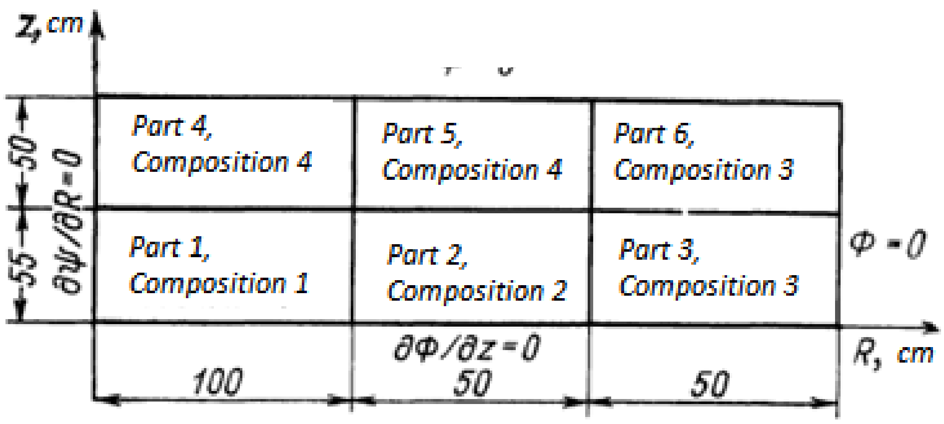

Fig. 1. The geometry of test model.

Results of calculations showed good accuracy and acceptable precision for task. Based on these results gives possibility to continue verification work on diffusion model of neutrons transfer using Fenics open source.

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ON THE POSSIBILITY OF A CHAIN NUCLEAR FUSION REACTION BASED ON THE REACTION p+^{11}B

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The possibility of using ultrashort high-intensity laser pulses to initiate the reaction p + ^{11}B in conditions far from thermodynamic equilibrium is discussed.

Reaction p + ^{11}B has the advantage that further nuclear reactions can generate high-energy protons, maintaining a chain reaction.

The possibility of realizing a nuclear chain reaction p + ^{11}B in the target consisting of boron isotopes ^{11}B and target of naturally occurring boron (80% ^{11}B and 20% ^{10}B) when irradiated target protons with energies of 700 keV. The differential balance equations were resolved for the corresponding possible nuclear reactions.

It is shown that at the use of a solid target of naturally occurring boron the conditions for nuclear chain reactions occur at the times of more than 1 μs (see Fig. 1).

By increasing the target density the dispersal of chain nuclear reaction is accelerated accordingly.

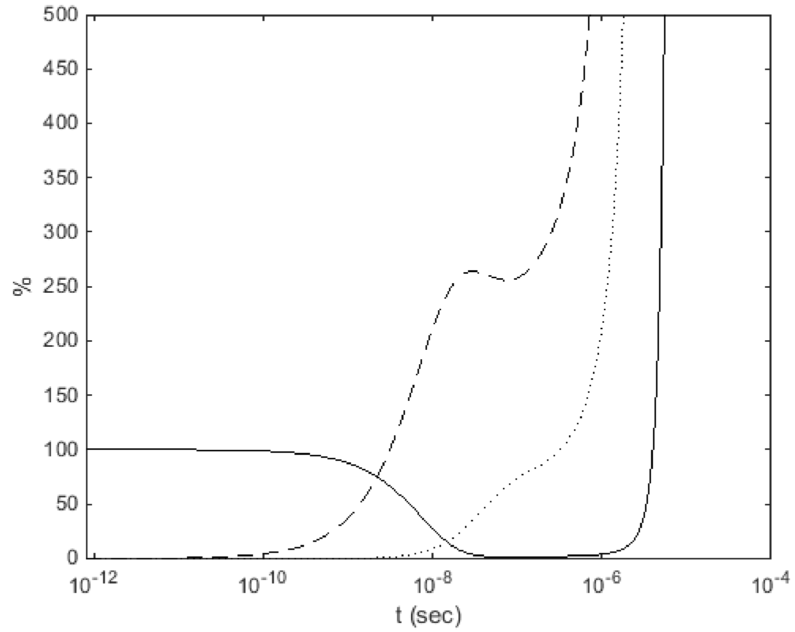

Fig. 1. Number of protons (solid), α-particles (dashed) and neutrons (dotted) versus time (in % from the initial number of protons).

STUDY OF THE FUEL-CONTAINING MATERIALS FROM THE ChNPP SHELTER OBJECT

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As a result of the Chernobyl accident lava fuel-containing materials (LFCM) were formed inside the "Shelter" object. LFCM contain fuel with varying degrees of burnout. The study of these materials provides a unique opportunity to study the reproducing of transuranium nuclides during different periods of irradiation of Fuel elements. In particular, these data can be used for assessments of the reproducing of Cm-244 in fuel. This isotope is one of the key isotopes for evaluation of fuel burnout at operating NPPs. We performed the gamma, beta and alpha spectrometric studies of radionuclide concentration in LFCM containing fuel with varying degrees of burnout. Data for some samples are shown in the table.

Isotope	Fuel element with minimal burnout	Fragment of LFCM
^{134}Cs	0.12	0.11
^{137}Cs	1000	1000
^{154}Eu	4.57	15
^{155}Eu	1.09	3.2
^{90}Sr	949	3292
^{234}U	0.05	0.13
^{235}U	0.001	0.004
^{236}U	0.01	0.02
^{238}U	0.02	0.05
^{242}Pu	0.03	0.10
^{239,240}Pu	14.7	48
^{238}Pu	7.19	29
^{241}Pu*	163	820
^{243}Am	0.05	0.14
^{241}Am	27.8	83
^{243,244}Cm	0.64	1.79
^{242}Am+^{242}Cm	0.03	0.09
^{243}Cm	0.06	0.19

* a discussion of the results is carried out

ENERGY DEPENDENCE INVESTIGATION OF PHOTON RADIATION QUALITY FACTOR

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The energy dependence is investigated for a monoenergetic photon radiation quality factor with energies up to 40 MeV. The conditions of irradiation simulate radiobiological experiments to determine the relative biological effectiveness with photon radiation passing through a thin layer. The irradiated layer (in this case water) of variable thickness simulating a biological object is located on a substrate of polymethyl methacrylate and is irradiated by a wide photon beam. The quality factor is calculated on the basis of data on linear energy transfer of all the particles in the irradiated layer, which are calculated using the Monte Carlo method and GEANT4 code. It has been shown that in considered layers as a result of heavy particles with a high LET photon quality factor significantly (3–15 times depending on the layer thickness) differs from the recommended value of 1.

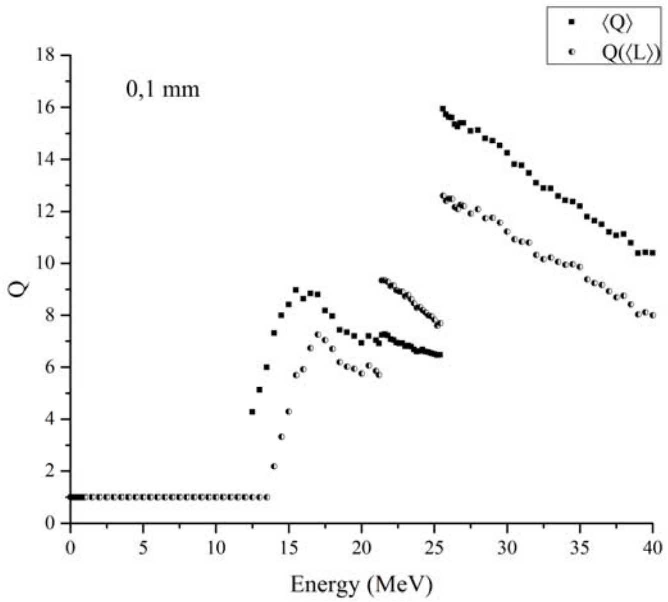

Fig. 1. The dependence of the quality factor of photon radiation on its energy for the 0.1 mm layer.

INFLUENCE OF ELEMENT CONSIST ON A DOSE DISTRIBUTION FROM BRACHYTHERAPY RADIONUCLIDES

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According AAPM TG #43 recommendations for calculations of dose distributions from the closed sources by computer system planning it is necessary to define a set of parameters. Such parameters as radial dose functions and anisotropy function are defined in the water environment, real dose distributions pay off for the objects which element consist mismatch of water. For the characteristics of affinity degrees of dose distributions in different media it is entered concepts water- and tissue-equivalency. According to this conception the matters possessing close values of effective atomic number, have close dose distributions.

The work purpose consists in point dose kernel calculations of the gamma spectrum correspond to spectrum of ^{169}Yb, ^{125}I and ^{137}Cs, widely used in modern brachytherapy. By means of computer modeling on a Monte-Carlo method with use of good known software package and libraries of data GEANT4 distributions of the absorbed energy from a point source are calculated. For some tissue equivalency materials and organs, predefined at GEANT4, the correlation field between effective atomic number and the absorbed dose is constructed. The visual analysis of a correlation field does not allow to draw a conclusion on presence of correlation dependence between these values. Statistical processing of the received data is spent and the H_0 hypothesis about equality to zero of correlation factor is checked.

It is not revealed statistically authentic correlation between effective atomic number and the absorbed energy for the photon radiation with spectrum corresponds to radioisotopes ^{169}Yb, ^{125}I and ^{137}Cs. The maximum deviation of the absorbed energy from average under effective atomic numbers to value can reach ~15%. Thus, at definition of TG #43 parameters it is necessary to enter correction on conditions in which they were defined.

THE SEARCH FOR NEW RADIONUCLIDES FOR A PERMANENT BRACHYTHERAPY

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Brachytherapy is a kind of treatment with ionizing radiation whose source is applied to the surface of the body or within the body a short distance from the area being treated [1]. Certain paper is dedicated to the search for new radionuclide candidates for the therapy that would fit two general criteria. Half-life period has to be less than 90 days and maximum energy in spectrum has to be less than 700 keV.

Selection process included two stages. During first stage, candidates were selected from the Brookhaven National Laboratory NuDat database [2]. Next stage was to calculate point dose kernels for the selected candidates and to compare them with well-known radionuclides that were used in brachytherapy. This was implemented using Monte-Carlo method with a help of CERN Geant 4.9.6 software. ^{183}Re and ^{73}As showed most close results to already used radionuclides.

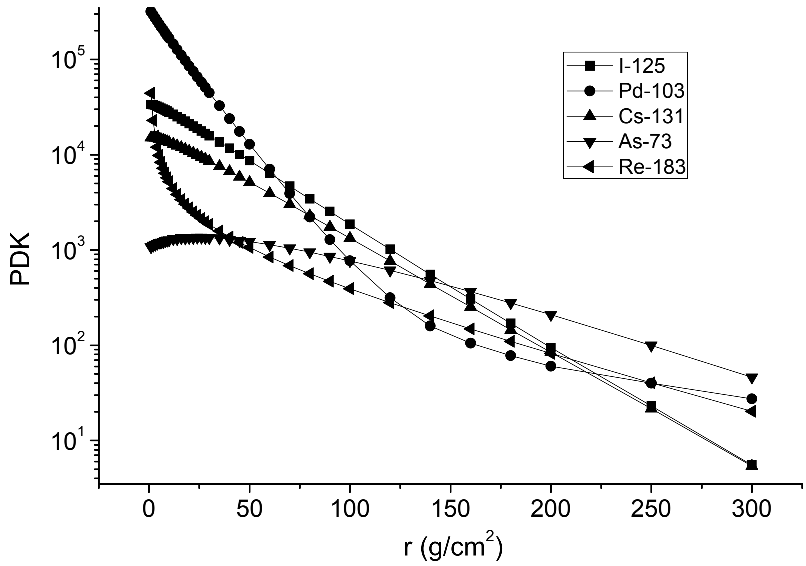

Fig. 1. Point dose kernel calculated for selected radionuclides.

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CALCULATION METHODOLOGY OF HYPOTHETIC ISOMER γ-REACTORS BY THE EXAMPLE OF ^{178m2}Hf

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High specific energy capacity of media consisting of nuclear isomers provides strong impetus to search for methods of this energy release for practical use in stationary and pulse installations – sources of energy and γ-radiation. In scientific literature there are considered many media consisting of different nuclear isomers so that the possibilities of taking energy stored in them are discussed. Particular attention of researches was paid to a medium consisting of nuclear isomer ^{178m2}Hf [1].

In spite of extreme difficulties of isomer γ-reactor implementation it was of special interest to investigate the properties this installation would possess if in actual practice. The present report is dedicated to this problem. This issue was considered before in article [2].

By the example of ^{178m2}Hf isomer there was developed a methodology of describing kinetic and dynamic phenomena in isomer γ-reactors. The consideration of processes in ^{178m2}Hf medium is based on a supposition that as a result of NEET resonance mechanism application it has been possible to convert isomer to trigger state and thereby create conditions for chain reaction of γ-decays similar to chain reaction of fissions in neutron reactors. Consequently there was formulated the condition of γ-reactor criticality, worked out sets of kinetics and dynamics equations and a program of equations numerical solution. There were made calculations for specific γ-reactors of metal ^{178m2}Hf. In particular it was obtained that the pulses of γ-radiation in the reactor under consideration are distinguished by extremely short duration (tens of nanoseconds).

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THE METHOD OF REGISTRATION OF SOLAR COSMIC RAYS BY NEUTRON DETECTION

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To estimate the radiation risk from solar activity during space flights it is necessary to know the chemical composition and spectrum of solar cosmic rays. The method of experimental study of solar cosmic rays (SCR) in the energy range from a few tens of MeV up to maximum energy is presented. The method allows us to measure the intensity and energy of the ionizing component of cosmic rays by determining energy losses of protons and light nuclei in the scintillators and the multiplicity of local generation of neutrons in the converter. For the detection of neutrons in the setup were tested detectors based on liquid scintillators (EJ-301 and EJ-315), stilbene, and lithium glass scintillator and photomultiplier, and solid state neutron detector with dual SiPM readout on ZnS (Ag) / LiF.

Use of combination of these detectors allows us to register fast and slow neutrons with a time resolution from 0.2 to 10 ns in the range of 100 microseconds. For rejection of background events from gamma rays in a measurement system different methods of selection signals: amplitude, time, selection signals by pulse form are used. With this method it is possible to carry out studies of the nucleon component of primary cosmic rays in the near-Earth space using satellites. [1]

Test measurements were performed to check the efficiency of such setup. A compact apparatus was used, which includes the digital signal processor CAEN DPP DT5720 [2], a “top” plastic scintillation detector of charged particles ($30\times20\times15$ cm^3 size), and “bottom” combined detector, described above. Between the "top" and "bottom" detector lead converter of 5 cm thick was set. Fast neutrons generated by cosmic rays in the converter were recorded by the bottom scintillator. The "bottom" detector allows pulse shape discrimination, to separate neutrons, photons and charged particles, and determine the timing structure of neutron detection. All signals are fed to the DT5720 and then digitized. It is possible to register the neutrons in the range of 100 mks at a resolution of 10 ns and measure the energy loss of charged particles in the upper detector. The fast neutrons generated by cosmic-ray protons with energies > 300 MeV have been registered.

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RECOMBINATION COMPENSATION IN SUPERCONDUCTING TUNNEL JUNCTION *X*-RAY DETECTORS

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Cryogenic detectors based on superconducting tunnel junctions (STJ detectors) have high energy resolution and low energy threshold and can be used in the precision *X*-ray, ultraviolet and optical spectroscopy [1]. Unfortunately, the real energy resolution is noticeably worse than the theoretical predictions. One of the main mechanisms of the energy resolution degradation is self-recombination of the excess quasiparticles, generated in superconducting absorber after X-ray quantum absorption [2].

In this work the system of two differential equations describing of the evolution of the excess quasiparticles density in both electrodes of the STJ-detector was analyzed. The conditions of compensation of recombination losses are obtained. Then the detector signals were numerical calculated for different sets of the parameters describing the quasiparticle and 2Δ-phonon movement in STJ-detectors.

Analysis of the data has shown that full compensation of recombination is possible only in the case of a symmetric detector having the same sets of parameters for both electrodes. Unfortunately, these detectors cannot be implemented practically.

Noticeable weakening of recombination effects was observed in cases when the compensation condition was satisfied only for the electrode where the photon has been absorbed. For these detectors dependence of the signal amplitude on the photon energy is almost linear, and recombination broadening of the detector line is significantly weakened.

These calculations can be verified experimentally by changing the thicknesses of the electrodes.

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STUDY OF ^{nat}U(n,*f*), ^{238}U(n,γ) AND ^{59}Co(n,*x*) SPATIAL REACTION RATES IN MASSIVE URANIUM TARGET BY IRRADIATION WITH RELATIVISTIC DEUTERONS AND ^{12}C NUCLEI

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Uranium target (512 kg of ^{nat}U) of assembly QUINTA [1] surrounded by lead blanket was irradiated by deuterons and carbon nuclei with energy of 2 and 4 $A\cdot$GeV at the accelerator Nuclotron (JINR, Dubna). The purpose of irradiations was investigation of nuclear-physical characteristics of neutron fields generated as result of spallation reactions in uranium target. The research was carried out using the activation technique. As activation detectors 30 samples of natural uranium (~1 g) and 10 samples of cobalt (~4 g), which were placed inside the uranium target, were used. After irradiation spectra of gamma-ray of activation detectors were measured with semiconductor high purity germanium detector. Full fluence of accelerated particles incident on the target was also determined using activation technique by measuring yield of ^{24}Na when aluminum and copper monitor foils were irradiated.

In this experiment the reactions ^{nat}U(n,*f*), ^{238}U(n,γ), ^{238}U(n,2n) and ^{59}Co(n,*x*) were investigated. Using information of measured gamma-spectra the number of produced isotopes (^{239}Pu, ^{237}U, ^{143}Ce, ^{131}I, ^{133}I, ^{97}Zr et al.) in uranium was calculated as well spatial distributions of ^{238}U(n,γ), ^{nat}U(n,f) over the assembly were obtained. Moreover using this data spatial distributions of spectral indices, such as $\bar{\sigma}^{238\mathrm{U}}_{(\mathrm{n},\gamma)}\big/\bar{\sigma}^{238\mathrm{U}}_{(\mathrm{n,f})}$, $\bar{\sigma}^{238\mathrm{U}}_{(\mathrm{n,2n})}\big/\bar{\sigma}^{238\mathrm{U}}_{(\mathrm{n,f})}$ and $\bar{\sigma}^{238\mathrm{U}}_{(\mathrm{n,2n})}\big/\bar{\sigma}^{238\mathrm{U}}_{(\mathrm{n},\gamma)}$ over the assembly were received. It is very useful data for researching, because it does not contain error due to error in total intensity of incident particles. Using received data the comparison of obtained experimental results in dependence on the energy of incident beam and type of particles was carried out.

In this work a lot of reactions ^{59}Co(n,x) were investigated using gamma-spectra of cobalt detectors as well dependencies of incident deuteron energy of reaction rates $^{59}\mathrm{Co}(\mathrm{n,x})^{48}\mathrm{V}\big/^{59}\mathrm{Co}(\mathrm{n,p})^{59}\mathrm{Fe}$ and $^{59}\mathrm{Co}(\mathrm{n,x})^{44}\mathrm{Sc}\big/^{59}\mathrm{Co}(\mathrm{n,p})^{59}\mathrm{Fe}$ were obtained. Analysis of this data has shown neutron spectrum hardening. The obtained experimental data was analyzed using the MCNPX transport code, ENDF70 data tables and a combination of the following nuclear models – INCL4, ISABEL, CEM2K, LAQGSM together with an evaporation model ABLA. A comparison of the calculated and experimental values shows the possibilities and limitations of the exploited models.

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SYMMETRY VIOLTION AND LOCALIZED-DELOCALIZED STATES IN DOUBLE QUANTUM WELLS

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Semiconductor heterostructures as quantum wells (QWs), quantum dots (QDs), and quantum rings (QRs) may have energy level structure of hundreds of electron confinement states. The single electron spectrum of the double quantum wells (DQWs) (or DQDs and DQRs) is presented as a set of quasi-doublets. The spectrum of weakly coupled DQW can be separated by three parts: localized states, delocalized states, and states with different probability for localization in each QW of DQW (see Fig. 1, a) [1]. For the last states, the ratio $2W/\varepsilon$ (wave functions overlapping integral W and the electron energy difference ε of isolated left and right QWs) defines a weight coefficients in the expansion of wave function on the basis of wave functions of isolated QWs [2]. In case of quasi-identical QWs in DQW ($\varepsilon \to 0$) the indeterminate form 0/0 takes a place for the coefficient. It is found that small violations of the DQW shape symmetry drastically affects localization of electron. In particular, such violations lead to elimination of the delocalized states of the system (see Fig. 1, b). The same symmetry violation effect happens if an electrical (magnetic) fields are applied and if different material mixing is occurred in QWs. These phenomena could be used to propose a new type of detection based on the high sensitivity of electron localization in weakly coupled double nanostructures on small violations of Left-Right symmetry. This work is supported by the NSF (HRD-1345219) and NASA (NNX09AV07A)

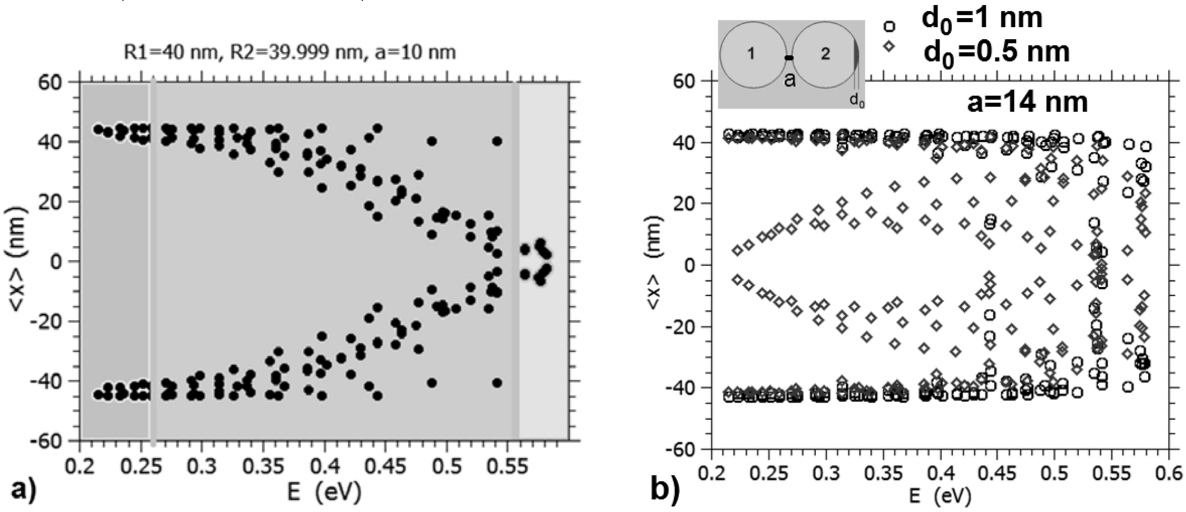

Fig. 1. a) <x> is averaged electron position for each level of spectrum for circle shaped InAs/GaAs DQW (red- localized, blue-transitional, yellow- delocalized states); b) (Upper) DQW symmetry violation by QW shape cut. (Lower) <x> calculated for different depth d_0 of QW shape cut (R_1=R_2=40 nm).

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TIME DIFFERENTIAL PERTURBED γ-γ ANGULAR CORRELATION METHOD AND SOME HIS APPLICATIONS (IN CONDENSE MATTER STUDY AND CHEMICAL RESEARCH)

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Method of time differential perturbed γ-γ angular correlation (γγ-TDPAC), experimental setup and main topics of our investigations have been explained.

The essence of method is as follows: a radioactive isotope (^{111}In, ^{44}Ti, ^{181}Hf, ^{172}Lu etc.) has been implanted in the investigated object (sample). The measurements of angular correlation of cascade of γ-quanta give us the information of hyperfine interaction between implanted nucleus and an electric field gradient or/and magnetic field, that has been produced from the sample lattice.

The experimental setup includes: a 4 detectors' spectrometer, cryogenic system, oven and hydraulic press [1]. This allows to perform measurements at temperatures from 4 K to 1400 K or/and presures from atmosferic to 10^6 at. In addition, the potential of our department gives us a possibility to apply a wide collection of suitable radioactive isotopes.

The main topics of our investigations are:
– a study of hyperfine fields in oxides of Al, Sc, Ti;
– a study of intermetallic compounds of lanthanides with Al, Ge, In [2,3,4];
– a study of behaviour of radioactive isotope in solutions [5];
– developing the method of γγ-TDPAC for the purpose of applying new isotopes.

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TECHNOLOGY BASED ON LOW-ENERGY RADIATION IN THE PRODUCTION OF SEMICONDUCTOR DEVICES WITH MOS STRUCTURE

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The low-energy radiation and technological processes (RTP) of precision adjustment of the MOS parameters of the integrated schemes (IS) are for the first time developed and introduced in a mass production. New RTP are based on the thermostable radiation induced charge in the MOS fine oxide of structure containing phosphorus [1].

For identification of electrophysical parameters, the analysis, sensitive to influence of radiation, the degradation processes in MOS IS, the original test crystals with a set of special test structures which are completely reflecting features of products and technology of their production were developed. The automated subsystem of the statistical analysis of test control was developed for production conditions. For realization of a complex of precision control methods of the MOS parameters of structures, taking into account geometry and planar heterogeneity of superficial potential of the semiconductor, the automated measuring device was developed.

The choice of soft *X*-ray radiation as the most effective influence for formation of a thermostable charge in fine oxide is reasonable. It is established that UV of a near range causes emission of electrons on the periphery of fine oxide and reduces the radiation induced.

Results of successful introduction of RTP in a large-lot production of MOS IS are generalized and analysed. Big economic effect of introduction of low-energy RTP is shown and prospects of their further development are shown.

The MOS model of structure (poli-Si-SiO_2(P) – Si) with own and impurity defects in a layer of SiO_2 (P) and superficial states on border of SiO_2 (P) which is adequately describing the processes happening in MOS structures during realization of RTP is stated [2].

On the basis of model the method of the forecast of radiation degradation of static characteristics of MOS in fields of low intensity is offered. The method is based on the analysis within the offered model of experimental dose dependences of an isothermal relaxation of size of threshold tension of MOS of structures at various temperatures [3].

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LITHIUM-LOADED LIQUID SCINTILLATORS ON THE BASE OF α-METHYLNAPHTHALENE-WATER MICROEMULSION

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The uniformity of an element-containing additive distribution is an important condition for good quality of element-loaded organic scintillators. The methods providing the obtaining of true solution of the element-containing additives in the basic substance of scintillator are the main directions in the field of design of such materials. They are:

– selection of element-containing additives with sufficient solubility in organic solvents;
– search for new liquid and polymeric bases including multicomponent systems.

However, there are natural limitations in this way associated with low solubility in organic solvents of compounds of a number of elements.

The obtaining of element-loaded scintillators on the base of microheterogeneous systems is an alternative solution of this problem. In such systems, element-consisting additives are dispersed as solid particles of nanometer size in a liquid solvent or are dissolved in one of the components of a microemulsion.

The purpose of this investigation is the development and study of the properties of the new stable lithium-containing liquid scintillators for thermal neutrons detection.

α-Methylnaphthalene was selected as the organic component of the microemulsion system. This aromatic compound is available, safe, has high conversional efficiency and a density close to one, which is important to achieve the sedimentation stability of the microemulsion as a whole. The combining of functions of two major components of new scintillator, the surfactant and the lithium-containing additive in a single compound – lithium salt of di-(2-ethylhexyl)-phosphoric acid is the distinguishing feature of its composition. This made it possible to simplify the scintillator composition and achieve its high stability over time.

As a result of this work are new lithium-loaded liquid scintillators with a mass fraction of a natural mixture of lithium isotopes, reaching 0.47%, stable at least during 15 months. The resulting materials are characterized in details. Light output, transmission and luminescence spectra, density and refractive index were measured.

This work has been performed by the joint support of the RFBR (project №14-42-03596) and the Moscow Region Government (contract №141/12-14).

RESEARCH OF "HOT PARTICLES" FROM CHERNOBYL NUCLEAR POWER PLANT 30-KILOMETRE ZONE

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In the present time radioactive contamination of soil is extensively presented in a form of insoluble particles of different size and chemical composition, so called "hot particles". These "hot particles" are mainly fragment of fuel-carrying materials with radionuclide composition that corresponds to composition of irradiated fuel. It is significant that particles with high content of ^{106}Ru (ruthenium particles) and ^{144}Ce (cerium particles) were distinguished in first years after Chernobyl Accident. These radionuclides decayed in the present time. Therefore, they are inaccessible for examination.

For the first time we distinguished americium particles. Samples were got from soils selected on 10 km distance from Chernobyl Nuclear Power Plant. Results are presented in the table. Data obtained by Ge-spectrometer.

Table 1

Radionuclide	^{137}Cs	^{241}Am	^{243}Am	K_x U	^{243}Cm	^{155}Eu	^{154}Eu
Activity, Bq	40.2	207	0.46	4.36	0.40	4.38	20

Error of all activities ≤ 3 %.

As it is seen the activity of ^{241}Am five times larger than the activity of ^{137}Cs. The activity of ^{241}Am is not exceed 10% of ^{137}Cs activity in fuel particles.

Obtained data is discussed.

HIGH THERMO-ELECTRIC EFFICIENCY OF THE NEW NANOSTRUCTURED SUPERIONIC MATERIALS

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The special attention is presently spared – to development and research of new high-efficiency thermo-electric materials. Modern strategy of their synthesis is based on the last achievements of nanotechnologies [1–3].

For creation of high-efficiency thermoelectrics the different nanostructured methods are used. Depending on the group of materials (pellicle, volume, super latticed, nano composite and others) and from a temperature range, the attained record values of thermo-electric efficiency of *ZT* are in limits – from 0.5 to 2.4.

Last year's we are execute an analysis and choice of methods of synthesis of perspective thermoelectrics, their methodologies are worked out, hard chalcogenides is synthesized with the general formula of $Me_xCu_{2-x}S_ySe_{1-y}$ (Me=Ag, Li). Measuring of coefficient of thermo-emf, conductivity, heat conductivity of synthesized binary and some alloyed materials is produced. Most high values of coefficient of thermo-emf about 0.5 mV/gr discovered for lithium-containing sulfides $Li_{0.05}Cu_{1.95-\delta}S$. It is found that over reduction of sizes of grains leads (brings) to the considerable decline (reduction) of electronic conductivity for all investigated samples of material.

With the purpose of increase of thermo-electric efficiency of materials (TEM) we are apply alloying, solid solutions are synthesized on the basis of copper selenide of the compositions $Ag_{0.01}Cu_{1.99}Se$, $Ag_{0.02}Cu_{1.98}Se$, $Ag_{0.03}Cu_{1.97}Se$, $Ag_{0.04}Cu_{1.96}Se$. We investigated influence of nanostructured samples of materials $Cu_{2-x}Li_xS$ и $Cu_2S_yTe_{1-y}$ their thermal properties [4]. Measuring of temperature dependences of coefficient of thermo-emf is executed, conductivity, heat conductivity, and the estimation of TEM is got. Studies of the got materials are undertaken in composition the one factorable modules of Peltier.

Results got by us on TEM with $ZT \geq 1$ – correspond to the world level for the by volume nanostructured thermoelectrics – in the average of temperatures (300 – 600^o C).

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SOLAR RADIATION CONVERSION WITH MESOPOROUS SILICA ACTIVATED BY RARE-EARTH IONS

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In Solar Energy – Semiconductor (SC) components cannot work at peak efficiency over the entire spectral range of solar radiation [1]. Required spectral range of solar radiation for photovoltaic cells (PVC) is determined by the energy band gap of SC (ΔE_g). This area starts from the (the fundamental absorption) semiconductor's photoelectric threshold. Thus, the energy range of PVC used to convert solar energy into electricity is 30% of all solar radiation incident to earth. The remaining part (70%) of PVC is spent on unwanted heating of the PVC material. The efficiency of such PVC ranges from 10% to 12% [2]. To increase the efficiency of PVC different technologies are developed to transform the remaining parts of solar spectrum into the red infrared light for additional electron-hole pairs creation.

In the present study, we investigated the nature of self-luminescence and energy transfer mechanisms in mesoporous silicon particles by introducing Eu^{3+} and Tb^{3+} rare earth ions.

Based on our previous studies [3] and the emission spectra of Eu^{3+} and Tb^{3+} in Luminescent Mesoporous Silica colloid (LMCS-) particles measurements, it is assumed that the emission band at 610 nm in a LMCS – Eu^{3+} and emission band at 543 nm in LMCS – Tb^{3+} is attributed to the intracenter transitions within the Eu^{3+} ions and Tb^{3+}.

The observed emission bands of Eu^{3+} impurities at 610 nm and Tb^{3+} impurities at 543 nm are excited with (350 – 365) nm and (285 – 315) nm, where it is LMCS own matrix particles radiation is excited. With increasing concentration of the impurities, the intensity of intracenter radiation of impurities increases as well, whereas simultaneous intensity reduction of own matrix luminescence is observer. Based on the experimental evidence it is suggested that the energy of the own electronic matrix excitation is transferred by emitters, i.e. impurities Eu^{3+} and Tb^{3+}.

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CHERENKOV RADIATION FROM ELECTRONS PASSING THROUGH HUMAN TISSUE

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The tissues of human body are transparent to visible light in the red and infrared region. This optical property has been used to develop a new method for diagnosing and treating some diseases [1]. The main difficulties of these studies are associated with the large elastic scattering ability of human tissue. In order to determine various optical features it is necessary to use extremely thin layers of tissue, and complex optical systems do not allow “in vivo” measurements of the optical characteristics.

We suggest the use of Cherenkov radiation produced by relativistic electrons in the investigation of optical properties of human tissues. Using of the Cherenkov radiation as a source of light photons has several advantages. For example, it is possible to vary the “position” of the produced Cherenkov light source by changing the electron energy, and to generate short light pulses in order to distinguish the true signal against the background.

A numerical statistical simulation method is used to study the propagation of electrons and photons in human tissues, taking into account multiple electron and photon scattering processes. In order to carry out a statistical simulation of an electron travelling through matter, we use the Moliere theory of multiple scattering [2]. In diffused media, the angular distribution of the scattered photons is given by the Henyey-Greenstein formula [3].

The results demonstrate that the number of transmitted and reflected photons per electron with energy 1–2 MeV range from 1 to 200. Assuming that about 10^5 electrons penetrate into the human tissue, about 10^6 photons will be emitted. This amount will be enough to be detected with high statistical accuracy. It is easy to estimate that 10^5 electrons with average energy 1.5 MeV will create equivalent dose less 20 μGy. This equivalent dose is far less than that annual dose due to natural radioactivity. For this reason the suggested method may be applied for “in vivo” measurements of the optical features of human tissue.

Statistical simulation shows that the number of photons before and after the target is rather highly sensitive to the optical properties of human tissue. Using this fact, it is possible to measure the intensity of the Cherenkov photons produced by relativistic electrons with different energies to determine the optical constants of human tissue, and vice versa.

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SEPARATIONS OF NUMBER OF ELEMENTS ON UTEVA RESIN

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One of the most effective methods for separation of elements is the extraction chromatography technique this technique is primarily used in analytical and radioanalytical chemistry as well as in geology and nuclear medicine. The newly determined distribution coefficients (K_d) for the extraction chromatographic resin “UTEVA Resin” (Uranium and TEtraValent Actinides) were applied. Chromatographic separations with UTEVA were carried out using the previously published data and the numbers from the newly determined K_d. The elements separated are as follows: Zr, Hf, Th, Ra and Ac with decreasing concentration of HNO_3 and Nb, Zr and Y with decreasing concentration of HCl.

IMPLEMENTATION OF THE AUTOCORRELATION METHOD FOR DETERMINATION DECAY MODE OF THE LUMINESCENCE CENTERS OF SCINTILLATORS

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A new method to determine scintillator decay time and space correlation of radiation based on an autocorrelation method [1] has been applied to measure not only the decay time of inorganic and organic scintillators but also to define decay mode of the luminescence centers of scintillators. In this method the decay time constant defined not by expression $N=N_0\cdot\exp(-t/\tau)$ but by expression $E=E_0\cdot\exp(t/\tau)$. Fig.1 and Fig.2 present the results of decay time measurements for different scintillators:

1. Single component of YAG decay time τ = 76(1) ns.
2. Double component (consecutive) of YAP decay times τ_1=26(90%) ns and τ_2=67(10%) ns.
3. Triple component (parallel) of stilben decay times τ_1=4 ns, τ_2=10 ns and τ_3=11 ns.

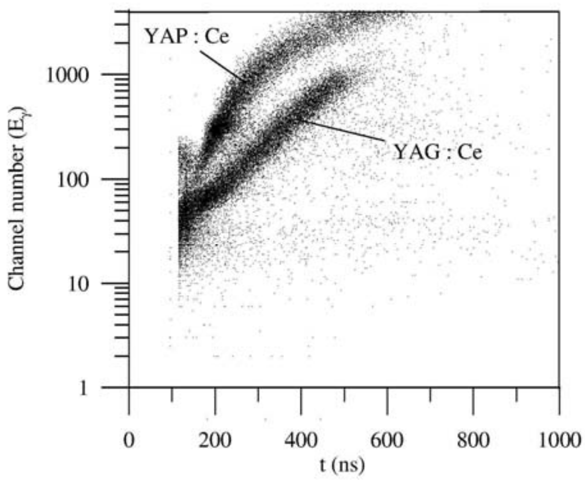

Fig. 1. Decay spectra of the YAP:Ce (double component) and YAG:Ce (single component) scintillators.

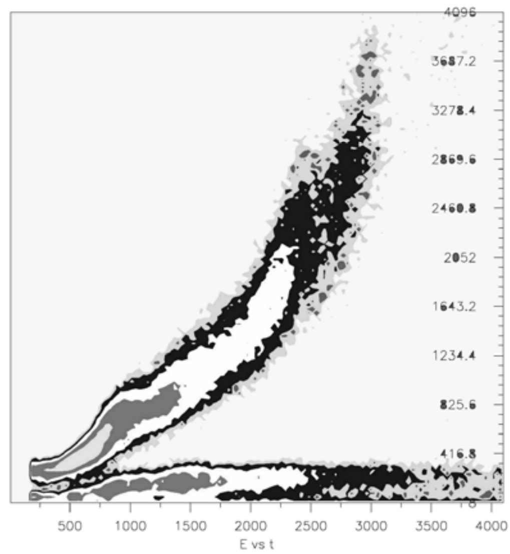

Fig. 2. Decay spectrum of the STILBEN (triple component), E axis is linear.

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DIELECTRIC PROPERTIES AND CHARGE TRANSPORT IN ELECTRON-IRRADIATED $TlGaSe_2$ SINGLE CRYSTAL

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$TlGaSe_2$ single crystals belong to a class of layered wide-band high-resistivity semiconductors and attract a lot of attention due to their interesting physical properties. These properties include strong anisotropy of the electric parameters related to special features in the crystalline structure. $TlGaSe_2$ has a wide range of physical characteristics of practical importance, such as high photo- and roentgeno- sensitivity.

This study presents the results of studying the frequency dependence of real (ε') and imaginary (ε'') components of the complex dielectric permittivity, loss tangent (tan δ), ac-conductivity across the layers of $TlGaSe_2$ single crystals at frequencies from 50 kHz up to 35 MHz and the effect of electron-irradiation on them.

Samples from $TlGaSe_2$ were made in sandwich form with electrodes of silver paste. The thickness of the single-crystal samples of $TlGaSe_2$ was ~270 microns. All measurements were performed at 300 K by the resonance method.

Electron-irradiation of the samples was carried out on the linear accelerator. The energy of electron-irradiation was 4 MeV. Measurements of samples were carried out after each irradiation.

It is shown that electron-irradiation of $TlGaSe_2$ single crystal with doses of $2\cdot10^{12}$–$2.4\cdot10^{13}$ e/cm^2 resulted in a decrease in the real (ε') and imaginary (ε'') parts of the complex dielectric permittivity, loss tangent (tan δ) and ac-conductivity (σ_{ac}) across the layers at all studied frequencies.

The experimental frequency dependence of the dissipation factor tan δ for $TlGaSe_2$ single crystal at f = 50 kHz – 35 MHz is characterized with a maximum. Such tan $\delta(f)$-dependence before and after electron-irradiation is evidence of the fact, that relaxation losses become the main dielectric loss mechanism in the $TlGaSe_2$ single crystal at studied frequency range.

The investigation of the frequency dependences of ac-conductivity of the electron-irradiated $TlGaSe_2$ single crystal made it possible to elucidate the hopping charge-transfer mechanism. We evaluated the density and energy spread of localized states near the Fermi level, the average hopping time and the average hopping length in $TlGaSe_2$ single crystal at various doses of electron-irradiation.

DEVELOPMENT AND RESEARCH OF RADIOPHARMACEUTICALS FOR DIAGNOSIS IN ONCOLOGY

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In recent years the world has been a significant strengthening of interest in the use of radioactive colloidal nanomaterials in medicine. Their use in oncology is based on the possibility of rapid and effective identification of "sentinel" lymph nodes, as well as for tagging autoleukocytes for diagnosis of inflammatory processes. As a label for nanocolloids most popular is the short-lived radionuclide technetium-99m. This is primarily due to its nuclear-physical characteristics: a relatively short $T_{1/2}$ (6.02 h) and γ-radiation energy of 0.1405 MeV, providing a low exposure dose, however, sufficient penetration ability for of radiometric measurements [1,2].

The sizes of the colloidal particles are decisive in the choice of radioactive indicator for research. For example, it is known that the optimum particle size for lymphoscintigraphy of 20–100 nm. Such particles are derived from the tissues at a rate which does not allow them to penetrate into the bloodstream. The particles with sizes less than 20 nm can easily pass into the bloodstream that prevents the visualization of lymph nodes.

This paper presents experimental studies of the processes of causing radioactive label ^{99m}Tc gamma-aluminum oxide in the presence of a reducing agent, tin (II). To increase the yield of nanocolloids with the size of 100 nm and increase the radiochemical purity of preparations were used ascorbic acid, sodium pyrophosphate, and gelatin. Present the results of medico-biological tests of preparations. It is shown that their functional suitability for lymphoscintigraphy (Fig. 1).

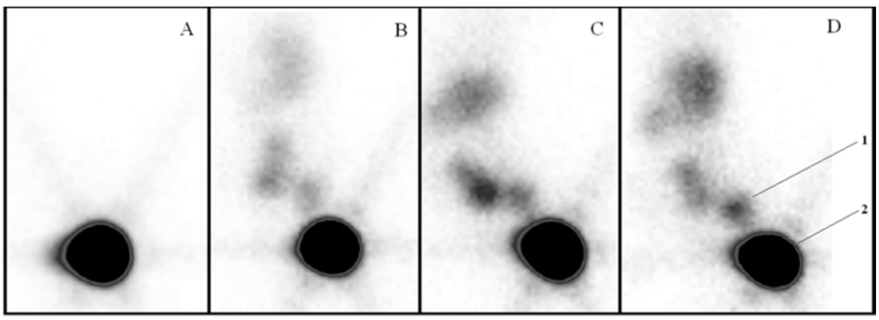

Fig. 1 Distribution of the drug in the organism of the experimental animal (rat) when administered suspensions «Nanokolloid, ^{99m}Tc - Al_2O_3»: A) Immediately after the injection; B) After 30 minutes after administration; C) 60 minutes after the administration; D) After 120 minutes after administration.

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TECHNETIUM-99M GENERATOR: SEARCH SORBENTS FOR ACTIVATION TECHNOLOGY

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The important role that ^{99m}Tc has played in shaping the field of diagnostic Nuclear Medicine has been clearly established and remains undisputed, till date. ^{99m}Tc is routinely produced in $^{99}Mo/^{99m}Tc$ generators. Most commercial technetium-99m generators use column chromatography, in which molybdenum-99 in the form of molybdate (MoO_4^{2-}) is adsorbed onto acidified alumina (Al_2O_3). A typical column contains 2–3g of alumina for fission-based molybdenum and 6–7g for (n,γ) molybdenum-99 with low specific activity.

Must be searched alternate sorbents having higher sorption capacity compared to alumina for development of $^{99}Mo/^{99m}Tc$ generators from (n,γ) ^{99}Mo. Adsorption of molybdenum on alumina samples and different sorbents was studied with the aim of using these sorbents in production of sorption technetium-99m generators. Zinc oxide, titanium dioxide, silicon oxide and samples of alumina for chromatography with varying acidity were studied. Adsorption characteristics and sorption capacity for molybdenum-99 were determinated. The sample of alumina with acidity pH2.5 has been showing better results (specific surface area – 219.1m^2/g, pore volume – 0.36sm^3/g, pore medium size – 65.1A, sorption capacity – 0.88mM/g (curve in Fig. 1)). This work was supported by the Russian Federation represented by the Ministry of Education and Science of Russia (project № RFMEFI57514X0034)

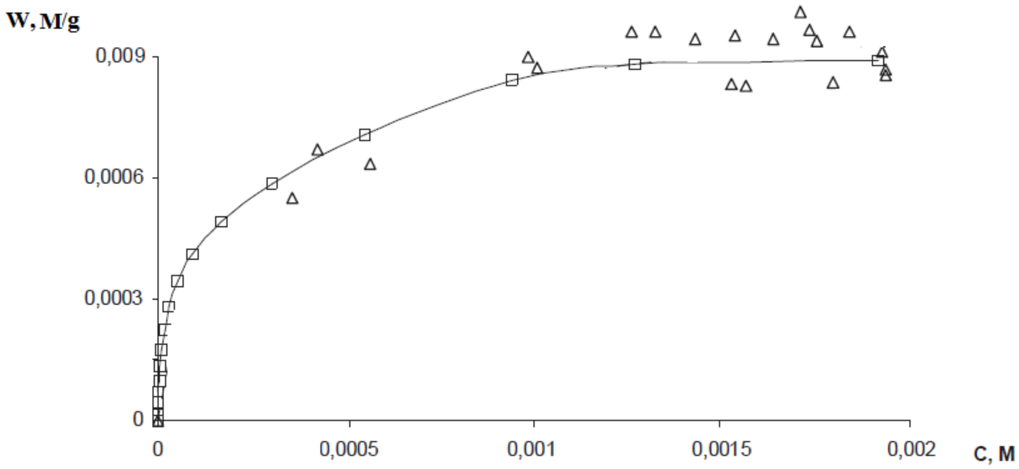

Fig. 1. Langmuir isotherm of dynamic adsorption of molybdate on alumina at 25°C.

1. Non-HEU Production Technologies for Molybdenum-99 and Technetium-99m // IAEA Nuclear Energy Series 2013. No. NF-T-5.4.

DEFINITION OF STANDARD SETS IN ROCK SAMPLES

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The possibility of a new method – a method of standard sets for definition of the age of the samples is considered. The standard set of nuclides is an ordered set of nuclides of one series, genetically-related by mutual decay and formation. The method is based on the measurement of the experimental nuclide spectra of activities of all nuclides of ^{232}Th, ^{235}U, ^{238}U series. As standards (reference standards) for measurement modell (calculated) nuclide spectra is used. To arrive at these spectra, we used our own calculations, based mainly on classical solutions of the Bateman-Rubinson system of differential equations (Bateman 1910; Rubinson 1947), which describe the decay and formation of radioactive nuclei of nuclides. The result of measurement of the experimental nuclide spectra of activities will be the duration of existence of the system ΔT. The resulting value can be interpreted as the duration of existence of the standard set – the time between the event which created this set, and the moment of measurement.

Also we compare our results with the well known method of nuclear chronometers. It is based on the gamma-activity of two nuclides (parent M and daughter D) in the series. A number of assumtions were made to arrive at the expressions for calculating the activities of pairs of nuclides which are based on the Bateman equations.

Comparing the values of ΔT (obtained by method of standard sets), and t (obtained by method of nuclear chronometers), it can be concluded that there is a satisfactory agreement between values obtained by the two dating methods.

RESEARCH DATABASE OF GAMMA-SPECTROMETRIC DATA OF ROCK SAMPLES AND BUILDING MATERIALS OF TRANSCARPATHIA

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Transcarpathia, as is known, was and is the supplier of the basic building materials – stone, crushed stone, gravel, wood, etc. The radioactivity of building materials to a large extent determines the natural background of the environment and, first of all, the background of housing, which began to change. The comparative estimation of building materials on radiating pollution can be carried out according to their chemical composition with use of data under characteristics of some important radioactive isotopes for chemical elements which are included in their structure.

Thus, there is a special importance to gamma-spectrometric control of samples of building materials, as well as to the comparative analysis of the results based on the information that is already there. Therefore a database of natural gamma-activity of samples of the basic building materials, including rock samples of industrial ores Transcarpathia was created and is developed. For research more than 200 rock and building material samples were selected.

The resulting database created by us contains instrumental gamma-spectra of the samples, and the results of their processing by a program complex, as well as specific activity for isotopes ^{232}Th, ^{238}U series and radioactive isotopes ^{40}K та ^{137}Cs. Their further processing includes the creation of nuclide spectra of the samples, the spectra of the sample type; group identification, which does reliable enough factorizing of samples of values.

In the future the given database should increase the number of samples and group them by years for radiation control of building materials, as well as for acquiring the latent information.

ON THE STUDY OF THE DECAY OF THORIUM-229 ISOMER

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Isomeric state Th-229m has the lowest energy among all other nuclides: 7.8(5) eV. Small natural width and location of the transition in the optical range gives us the hope to use this state as an oscillator with a quality factor Q by several orders of magnitude higher than the Q-factor of systems currently in operation. The small moments of the nucleus and the shielding by orbital electrons eliminates the influence of external fields. This creates the possibility of exploiting the oscillator in a dense medium and, as a consequence, the design of solid compact devices. This gives reason to expect for a wide range of applications in technology and fundamental physics.

At this stage it is planned to study internal conversion electrons from the decay of the Th-229 isomer placed on the surface of the sample. Other observables are photons emitted by ions implanted in the crystals which are transparent to ultraviolet radiation. Observation of the decay, determination of energy and time parameters depending on the properties of the environment will let us efficiently and with good background conditions to record population of the isomer by laser radiation. The additional interest to the registration of conversion electrons dealt with the possibility of their use in the circuit of frequency standard based on the ion trap with ions of thorium-229.

In our report the methodological aspects for the preparation of the search for the decay of the isomeric state of thorium-229 will be discussed. We consider the method of forming the beam 1, 2 and 3 charged ions transport scheme, the preparation of a thin source and method of registration of conversion electrons.

STUDY BY POSITRON ANNIHILATION SPECTROSCOPY OF CONDENSED MATTER WITH AN INTERNAL AND EXTERNAL RADIATIONS

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When irradiated by positrons in condensed matter with an internal radiation (eg, radioactive substances, etc.) are negatively charged and neutral point or extended defects with dimensions in angstrom and nanometer ranges, which can serve as scavengers of positrons and positronium atoms. This fact, as shown by experimental data and calculations performed by us, a profound impact on changes in the basic characteristics of positron annihilation spectra, allowing detection of these nanodefects in experiments and to study their effect on the properties of condensed matter with an internal radiation. It is known that positrons effectively probe the free volume of nano-objects with sizes in the nanometer range and angstrom in metals and alloys, as well as in semiconductors [1]. Of particular importance is the possibility of determining the size of nano-objects in condensed matter (materials) with an internal radiation and materials irradiated with protons, neutrons, α-particles and microwave radiation (e.g., giant microwave pulses [2]). This requires comprehensive studies of defect structure in these materials containing nanometer and angstrom cavity size (vacancies, vacancy clusters and pores, as well as dislocation) using different methods of positron annihilation spectroscopy. This allows us to establish links between the experimentally measured parameters of the annihilation spectra and characteristics nanodefects (type, size, density) in the Angular distributions

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THE S^3 AS AN AUXILIARY DETECTOR FOR NEUTRINO MONITORING OF A NUCLEAR REACTOR

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One of the prospective methods of industrial nuclear reactor monitoring could be done by means of neutrino detection.

In order to realize this idea it is necessary to have some relatively simple neutrino detectors, which do not contain any flammable or other dangerous liquids and may therefore be located very close to the core of an industrial nuclear reactor.

In this work we describe design of the S^3 detector developed in JINR. The S^3 is very similar to the big DANSS detector, but has more simple construction and smaller dimensions.

The sensitive volume of the detector (64 l) consists of 80 polysterene-based plastic scintillator plates. To collect light signal 8 photomultipliers and 80 multi-pixel photon counters (MPPCs) coupled to the plates via wavelength-shifting fibers are used.

Each S^3 detector is expected to register that about 500 neutrino events per day with a background less than 10%; and the system consisting of the DANSS detector and two or three S^3 detectors renders it possible to determine the center of fuel burning in the WWER-1000 reactor with the accuracy of 10–20 cm.

MODELLING OF THE INTERACTION OF POWERFUL RADIATION WITH A CONDENSED MATTER TARGET IN A MAGNETIC FIELD

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High energy density systems, such as magneto-inertial fusion devices [1, 2] can be used for a wide range of applications: as a particle source for disposal of radioactive wastes and medical applications of isotopes, as part of the fusion-fission reactor, for experiment with materials and etc. The significant feature of these systems is an ultrahigh magnetic field (~10^4 T during target compression) [3, 4].

It is required to consider the processes of the target compression together with equations of state (thermal and thermodynamic) at various stages, including maximum compression, i.e. for a wide range of density and temperature (temperatures from a few thousands K to a hundred millions K, densities from gas-like up to 10^7 kg/m^3). Obtaining the equations of state in such a wide range of parameters leads to the problem of joining the solutions. Relatively simple and sufficiently accurate option is to use the Thomas-Fermi model at high temperatures and densities (temperature $T > 10^5$ K, the density of the order of solid density and higher) [5–7]. One can use the ionization equilibrium model (Saha model) [5, 8] for lower temperatures and densities.

This paper describes the following subtasks arising from modeling of the interaction of powerful radiation with a condensed target in an external magnetic field: physical context and mathematical formulation of the problem; the calculation of the thermodynamic properties (pressure, specific internal energy and entropy) of plasma on the basis of wide-range equation of state. The calculation results in the temperature-density coordinates are presented. Criteria for the use of each model are obtained.

This work was supported by the Ministry of Education and Science of the Russian Federation (Project № 13.79.2014/K).

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MONITORING SYSTEM OF RADIATION EXPOSURE PROTON LINAC

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A result of the proton beam loss is formed radionuclides, gamma and neutron secondary radiation, which represent danger to the personnel and the population. The main radiation hazard to population is short-lived radionuclides in atmospheric radioactive emissions from the linac.

The monitoring system online controls the neutron radiation from the beam loss, the gamma-activity of radioactive gases and aerosols in the ventilation system of the linac and a dose rate from an external gamma and beta radiation near to urban area. The system consists of neutron detectors in transport channels, gamma detectors in the ventilation system and the distributed network DKS-AT1121 dosimeters placed in territory. The detectors are connected to the server through data cable. The central server performs the storage and processing of data from the sensors, the display card detectors, the spectra and the measurement results, the presentation of the results in text and graphical form on a Web page.

EXPERIMENTAL STUDIES OF THE MEDICAL ISOTOPES PRODUCTION USING SPALLATION NEUTRONS GENERATED IN MASSIVE URANIUM TARGET

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Most of the discussed or projected electronuclear systems (Accelerator Driven Systems) are a hybrid of the subcritical fast reactor (sub-critical core) and external neutron source (spallation target) based on the accelerator. Sub-critical core implemented neutron spectra close to moderated fission neutron spectrum and in these spectra one can produce radionuclides typical for fast nuclear reactor. Neutron spectrum in the spallation target more hard than fission neutron spectrum. This spectrum will allow produce some medical isotopes by spectral neutrons with energy > 10 MeV.

We investigated the production possibility of the therapeutic radionuclides ^{64,67}Cu and alpha emitter ^{225}Ac(^{213}Bi) via ^{nat}Zn(n,x) and ^{232}Th(n,x) reactions induced by fast spallation neutrons generated by 1–8 GeV deuteron and 660 MeV proton beams. Experiments was performed on a massive uranium target (mass of natural uranium ~ 512 kg) of assembly "QUINTA-M" [1] at the accelerators “Nuclotron” and “Phasotron” JINR , Dubna.

It was found that all reaction rates, calculated per unit of beam power, remains approximately constant within our statistical errors for all energies of the deuteron beam in the range from 1 to 8 GeV. During a saturation irradiation, it is possible to produce 2.4 GBq of ^{67}Cu per gram of natural Zn and per 1 MW primary beam power. Saturation yield of ^{64} Cu is 49 GBq/g/MW.

In this work we performed calculation of radionuclide purity depending on the degree of enrichment of the various zinc isotopes and depending on the ‘cooling’ time after irradiation. The main disadvantage of this method is a high ^{64}Cu/^{67}Cu ratio in the final product at EOB. Significantly reduce ^{64}Cu/^{67}Cu ratio is only possible if you use zinc target enriched with ^{68}Zn. Satisfactory result can be expected for the enrichment starting with 50% ^{68}Zn.

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THE USE OF THE 120-CM CYCLOTRON FOR THE STUDY OF COMBINED EFFECT OF IONIZING RADIATION AND HYPOMAGNETIC CONDITIONS ON THE LETTUCE SEEDS

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Study of biological effect of high energy charged particles and hypomagnetic conditions (HMC) is an actual interdisciplinary task that is important for human activities and functioning of the future bioregenerative life support systems (BLSS) for astronauts in deep space and on the Moon.

Using the 120-cm cyclotron we studied the effect of α-particles under conditions of normal and low geomagnetic field on chromosomal damage lettuce seeds Latuca sativa L., belonging to the intended composition BLSS during long distant flights.

Irradiation of seeds carried out in cells with walls made of thin mylar films. The seeds were placed between the two films in a single layer. Irradiation was carried out sequentially on both sides of the cell. Energy of α-particles bombarding seeds was 25.8 MeV. The magnitude of the linear energy transfer (LET) at the same time close to the value of LET relativistic nuclei neon-magnesium galactic cosmic rays, which allows you to simulate their effect on biological objects.

To create HMC conditions used hypomagnetic cylindrical chamber of a soft magnetic material with a working volume of 28 liters, in which the geomagnetic field has been weakened by more than 1000 times.

Irradiated seeds with different values of absorbed doses were germinated in a different attenuation of the geomagnetic field. The result of exposure to ionizing radiation and the HMC was estimated by the number of chromosomal damages in first mitosis of seedling root meristem.

As a result of the experiments there was a trend to increased levels of chromosomal aberrations in irradiated seeds. Under cytogenetic analysis after germination of irradiated and non-irradiated seeds in HMC there was observed a tendency of increase in the percentage of chromosomal aberrations, cells with multiple aberrations, as well as the percentage of chromosomal bridges in comparison with seeds, germinated in the laboratory condition.

The work was performed by using equipment purchased by "Program for Development of Moscow University."

SOFTWARE COMPLEX FOR SIMULATION OF INTROSCOPY AND TOMOGRAPHY SYSTEMS

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Present simulation software of introscopy and tomography. Software complex allows for required mathematical and computer processing and visualization of the results of recognition.

The report is devoted to development and testing of a program complex for an industrial *X*-ray tomography with application of the dual energy method. The purposes of the project also include creation of full-scale realistic modelling (simulator) of an industrial *X*-ray tomography. It is shown, that the analysis, development and application of a dual-energy method of in an industrial tomography will give new quality of the restored tomograms and will allow to obtain a new information about research object.

Dual-energy method allows to obtain the atomic number and density by linear attenuation coefficient examination at two different energies [1].

The possibility of the dual-energy method application in *X*-ray CT was examined with the use of *X*-ray CT simulating. The software complex was developed for full-scale realistic modeling of the *X*-ray tomography from a stage of reception of projective data till restoration of the image of investigated object [2].

The obtained results and the developed software will be used in researches made on the industrial *X*-ray tomography on faculty «Experimental nuclear physics» SPbPU. Also it is possible to use the obtained results in development of other tomography systems for simulation, testing and data processing from corresponding facilities.

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RECORDING SYSTEM OF MULTICHANNEL TEMPORAL DISTRIBUTION SPECTROMETER

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A system of measurement of temporal properties of radiation fluxes has been developed on the basis of a spectrometer consisting of four independent parallel measurement channels, including points of time t_i of arrival from four radiation detectors.

Each channel of a spectrometer version created has a spectrometric amplifier, a differential amplitude discriminator, and a standard signal conditioner. Pulses from each channel are received by a multichannel meter-counter recording the point of time of arrival of pulse sequences.

A software package of buffer memory channel control for channels with FIFO structure has been developed to assure the optimum management of accumulation of sequences t_i arrays. The error of time point determination amounts to $2.5 \cdot 10^{-7}$ s.

The systems allows for the off-line scanning of t_i arrays accumulated and forming of the corresponding arrays of time intervals $\tau_i = t_{i+1} - t_i$ and number $n(\Delta t)$ of particles during interval Δt.

Such approach allows, without losing any information on time characteristics of radiation fluxes, the forming of time series of the required structure for further statistical analysis.

THREE-CHANNEL TEMPORAL SPECTROMETRY OF RADIATION FLUX

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Three-channel measurements of sequences of points of time t_i of generation of semiconductor detector pulses at recording of alpha-radiation from reference source ^{238}Pu have been carried out.

The measurements were performed with the help of a three-channel spectrometer of temporal distributions of t_i. The duration of continuous measurement amounted up to 18 days. The error of determination of t_i did not exceed $2.5 \cdot 10^{-7}$ s. The accumulated arrays of time sequences t_i were off-line formed into the arrays of time serieses $n(\Delta t)$ of the number of pulses during the specified intervals of time $\Delta t > 10^{-1}$ s. The stability of measurement conditions, i.e. stationary state, was monitored as per the parameters of amplitude spectra of alpha particles of each channel.

Time serieses $n(\Delta t)$ obtained with the volume of up to $1.5 \cdot 10^6$ were processed with the help of correlation analysis and spectral Fourier analysis. The autocorrelation function was applied as follows:

$$R(n_i, n_{i+k}) = \frac{\operatorname{cov}(n_i, n_{i+k})}{S(n)},$$

where $\operatorname{cov}(n_i, n_{i+k})$ and S – autocorrelation function and dispersion respectively.

The correlation and spectral Fourier analysis of functions $R(n_i, n_{i+k})$ was carried out with several standard windows – weight functions used. Moreover, the cross-correlation analysis of time serieses of all three channels was performed.

No fluctuations of values of $n(\Delta t)$ with periods of 1 min $\leq T \leq$ 48 hours have been observed for the significance level of 0.95 and 0.99.

FIELD GENERATED BY THE PASSAGE OF GAMMA RAYS THROUGH A LIQUID MEDIUM

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The electromagnetic field generated by the interaction of hard gamma radiation with the liquid media was studied even in beginning of the last century [1, 2].

The general approach to calculation of the field in space-time representation is presented in [3]. Many works were performed in this approach in the frame of the linear current model [4, 5].

Here we calculated the components of electromagnetic field produced with gamma radiation passing through the media as liquid as gaseous for comparison. We summed the fields of the free electrons resulting from interaction of gamma radiation with media.

There is difference in data for total sources of electromagnetic fields at fixed observation's angels in these media. Result decreases with the increasing of pressure of gaseous medium.

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NEUTRINO EXPERIMENTS DATA BASE

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Detection of neutrinos is one of the highest priorities for the scientific community now. Neutrino carries unique information about important processes from the depths of the Earth and out from deep space. Meanwhile there is no database that accumulates the results of a large number of experiments.

The unified database for neutrino experiments is presented. The resulting database allows to add, store, and search for a variety of data, such as general information about the experimental complex, parameters of the detector, purposes of the experiment, characteristics of the neutrino, experimental points, as well as information about the participants of the experiment and related publications.

The adding data interface is implemented so that the user can quickly and easily edit the stored information. Web database interface also enables a flexible search of the stored data and presents the result in the most convenient form. The main tools for implementation of a relational database and control interface are SQL (structured query language), PHP, JavaScript, and JSON (JavaScript Object Notation).

The database and control interface provides the open internet access. The database is running at SINP MSU (Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University) at present, and it is in the process of loading the experimental data now.

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