ISINN-10 **X International Seminar on Interaction of Neutrons with Nuclei**

Neutron Spectroscopy, Nuclear Structure, Related Topics

Dubna, 2002 **Abstracts**

JOINT INSTITUTE FOR NUCLEAR RESEARCH

NEUTRON SPECTROSCOPY, NUCLEAR STRUCTURE, RELATED TOPICS

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NEUTRON DYNAMICS IN MAGNETIC TRAP AND EXPERIMENTAL DATA ANALYSIS

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The experimental data of the first experiments on neutron storage in a magnetic-gravitational trap have been newly processed and its results are considered. The ITEP facility on ultra-cold neutron storage in the magnetic field is described and a system for neutron injection, neutron trapping and neutron registration during the storage and after it on a prearranged schedule is explained in particular. Special features of neutron dynamics in the trap with mounds on the magnetic bottom are mentioned. The possibility to monitor leakage of neutrons being out of the storage conditions turned out to be an unsurpassed peculiarity of that trap. Continuous neutron registration provides conditions to normalize the neutron counts fixed after the magnetic shutter opening to the count numbers of neutrons penetrated through the closed shutter. In a new round of experimental data processing all the possibilities built in the experimental procedure of the last performance of 1985-1986 years were taken into account for the first time. Oscillations of neutron flow from the trap were discovered in the data processing. The storage time obtained from the experimental data taking into account the oscillations is of 860 ± 40 s.

How to explain parity violation effect in lead?

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The effect of parity violation in lead was firstly found by B.Heckel et al. [1] when authors were observing spin rotation of polarized thermal neutrons passing through the natural lead target. The absence of s- and p-resonances near the "thermal point" makes the explanation of this effect a difficult task. Further, it was experimentally shown by O. Ermakov et al [2] that the effect is connected with the isotope of ^{204}Pb. However, it did not answer the question because it requires the presence of very strong "negative" resonance near the "thermal point". The measurements of dependence of radiative neutron capture cross section on energy can be used to found such resonance. This dependence differs very much for s- and p-waves.

Such measurements are being carried out on pulse neutron source IBR-2 by means of COCOS device, which includes combination HPGe detector and BGO scintillators. Energy dependence of the cross section is being observed by means of registration of gamma-quanta of direct transition from the excited state of compound nucleus to the ground state.

The results of the measurements will be presented in the paper.

1. B. Heckel, N.F. Ramsey et al. Phys. Lett, 119B, № 4,5,6 pp. 298-302, (1982)
2. O.N. Ermakov, R. Golub, I.L. Karpikhin, P.A. Krupchitsky, V.V. Vasiliev, "Neutron spin rotation in ^{204}Pb current experimental results", Proc. of ISINN-8 (JINR, Dubna, 2000), p. 377

Violation of fundamental symmetries in resonance neutron induced fission

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It is considered the multimode fission via neutron resonances (NR) as a unique possibility to observe and to study interference phenomena in nuclear fission or quantum mechanical aspects of the process. The P-even and P-odd angular correlations of fission fragments (FF) are discussed in terms of formal theory of (n,f) reaction in helicity representation developed recently by authors. Due to the proper account of total space parity in FF channels and specific advantages of the helicity representation for these channels it becomes possible to calculate the reduced fission amplitudes and to sum the general expression for the differential cross section of (n,f) – reaction over all non observed characteristics of FF. After the summation it is possible to express observed angular correlations via the reduced S-matrix defined with aid "integral" fission amplitudes specified for the $J^{\pi}K$ (A.Bohr's) fission channels. The conditions necessary for "survival" (after summation over huge number of FF channels) of the FF angular correlations are discussed in connection with a spontaneous violation of the shape symmetry of fissioning nucleus on the way from normal to scission deformation. In all consideration it is assumed that space parity violation in fission process takes place at the stage of compound nucleus before an "exit" to the transition state of fission.

Some examples of theoretical analysis of experimental data relevant to the subject under discussion are presented. The results show possibility to study a dependence of fission barriers on parity and to get more deep insight in the nature of transition states of fissioning nuclei. It means that such approach provides some new tool to study nuclei at extremely high deformation.

The work was supported by the grant of INTAS #99-0229.

CULTIVATION OF SPIRULINA PLATENSIS BIOMASS WITH SELENIUM AND CHROMIUM LOADING

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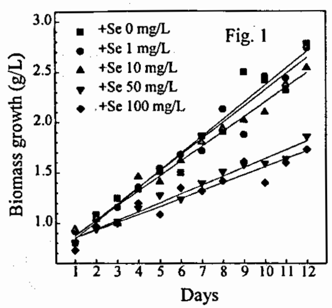
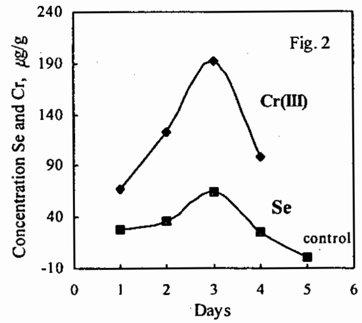
A technology for the cultivation of a *Spirulina platensis* biomass enriched in Se and Cr in the form of stable biocomplexes has been developed. The effect of different selenium and chromium doses on the growth of Spirulina cells, chlorophyll contents, and on the total protein content is studied. It is shown that an increase of Se and CrIII concentrations in an optimal range 0.5-10 mg/L) does not practically affect the growth of *Spirulina platensis* biomass and its natural properties (Fig. 1). However, at large doses a decrease in the chlorophyll and total protein contents in Spirulina biomass was observed.





Invesigations of spirulina cultivation in a nutrient medium with simultaneous Se and CrIII loading were carried out. The results obtained are illustrated in (Fig. 2). Optimal Se and Cr concentrations for pharmaceutical purposes are suggested.

THE TOTAL INTENSITIES OF THE TWO-STEP CASCADES FROM THE $^{182,183,184,186}W(n_{th},\gamma)$ REACTION

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Intensity of the two-step cascades between the capture state i and low-lying levels f depends on the radiative strength functions of cascade γ-transitions and density of their intermediate levels. This allows one to verify [1,2] different model ideas concerning these parameters and, in limits of some realistic assumptions, directly estimate [3] their values. It is obvious that all results of analysis [1-3] strongly depend on the precision in the determination of the experimental cascade intensity.

Fine enough energy resolution and high efficiency of the $\gamma-\gamma$ coincidence spectrometer in Řež [4] provide determination of the two-step cascade intensities after the thermal neutron capture with very high accuracy. Combined measurements of the $\gamma-\gamma$ coincidences and single γ-spectra allowed us to obtain a bulk of independent, very precise values of intensities of γ-quanta following thermal neutron capture in $^{184,186}W$ and, to some less extent, in $^{182,183}W$. Large information was obtained for the ^{185}W compound nucleus — the total intensity of two-step cascades to the final levels with $E_f < 1$ MeV amounts to 60(2)% of the total intensity of its primary γ-transitions. Combination of the data on the peak areas in the sum coincidence spectrum and extrapolation of the mean efficiency of the registration of the cascades provide the probable total intensity of all two-step cascades in $^{185,187}W$ terminating at final levels below 2.2 and 1.9 MeV, respectively. The probability p_n of decrease in the peak areas in the sum coincidence spectrum caused by registration of the residual portion of energy of γ-quanta depopulating level E_f was determined from the equation

$$S(E_{if}) = I_1\epsilon(SE)\epsilon(511)\Psi p_n. \qquad (1)$$

Here, $\epsilon(SE)$ and $\epsilon(511)$ are the efficiencies of registration of the single-escape and annihilation quanta peaks, respectively, related with the registration of primary transition $E_{if} = B_n - E_f$ with the intensity I_1 in different detectors. Ψ is the number of neutrons captured in the target. Energy dependence for efficiency $\epsilon(SE)$ of registration in the single-escape peak was determined independently. For the ground state $p_n = 1$, therefore, Eq.(1) for any excited final level of cascades transforms into the equation with one unknown for independent determination of the intensity I_1:

$$S(E_{if})/I_1 = const\ p_n. \qquad (2)$$

The total cascade intensity found in this way for $^{185,187}W$ equal 70(3) and 55(4)% per decay, respectively.

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Asymmetries in ternary fission induced by polarized neutrons and the fission mechanism

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We are presenting the review of experimental results of measuring various asymmetries of charged particle emission in ternary fission induced by polarized neutrons, namely parity non-conserving asymmetries (PNC), left-right asymmetries (LRA) and triple time-odd (TRI) correlations. We demonstrate what kind of new information about the mechanism of ternary fission can be obtained from their analysis.

In the theoretical paper [1] the analysis was given of the PNC asymmetries $\alpha_{\rm LF}^{\rm PNC}$ of fission fragments and the corresponding asymmetry $\alpha_{\rm TP}^{\rm PNC}$ of ternary particles caused by the correlations $(\vec{\sigma_n}\cdot\vec{p}_{\rm LF})$ and $(\vec{\sigma_n}\cdot\vec{p}_{\rm TP})$, respectively (here $\vec{\sigma_n}$ stands for the spin of the neutron inducing the (n,f) reaction while $\vec{p}_{\rm LF}$ and $\vec{p}_{\rm TP}$ mean the momenta of the light fission fragment and the ternary particle, respectively). It was predicted that in the case of simultaneous fission fragments and ternary particle emission $\alpha_{\rm LF}^{\rm PNC} = \alpha_{\rm TP}^{\rm PNC} \le \alpha_{\rm bin}^{\rm PNC}$ (here *bin* index means binary fission.) In the case of double neck rupture , when the ternary particle is emitted from the neck remnants, which are still protruding from the pre-fragments $\alpha_{\rm LF}^{\rm PNC} = \alpha_{\rm bin}^{\rm PNC}$ $\quad \alpha_{\rm TP}^{\rm PNC} \approx 0$. The experimental data of [2] proved that the latter case is true. This was supported by the similar experimental results on the left-right asymmetry in binary and ternary fission [3]. It was also shown that the values of both, the PNC and RL effects are independent of the ternary particle energy.

However, quite different results were obtained with the same experimental setup [4] while measuring the T-odd triple correlation $\vec{\sigma}_n\cdot[\vec{p}_{\rm LF}\times\vec{p}_{\rm TP}]$. The corresponding asymmetry coefficient D, obtained by reversing any of the 3 vectors, turned out to be of the order of 10^{-3} and markedly increasing with increasing final energy of ternary particles (α or t). The review of those experimental results is given as well as the latest attempts of their theoretical interpretation.

The work was supported by grants of INTAS (project 99-0229) and RFFI (project 99-02-17275).

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Modeling the detector count rates in the Yaguar nn-scattering experiment

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An experiment to measure the nn-scattering length at the Yaguar reactor at the All-Russian Research Institute of Technical Physics in Snezhinsk was first proposed in /1/. The Yaguar reactor's high neutron flux of 10^{18} cm^2/s in an open cylindrical through channel makes it an especially promising facility. A preliminary experiment is described in /2/ and pertaining calculations in /3,4/. We report on modeling calculations of the neutron production rate in the direction of the detector with a full account of the resulting angular distribution of the nn-collision events. Results of modeling calculations of an effective detector solid angle that links the average neutron density (an experimentally measurable quantity) to the detector count rate are also reported.

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2. B. G. Levakov, V. I. Litvin, A. E. Lyzhin, W. I. Furman, E. V. Lychagin, A. Yu. Muzichka, G. V. Nekhaev, A. V. Strelkov, E. I. Sharapov, V. N. Shvetsov, C. R. Howell, G. E. Mitchell, W. Tornow, C. D. Bowman, B. E. Crawford, S. L. Stephenson, JINR report E3-2001-192 (Joint Institute for Nuclear Research, Dubna, 2001), p. 27.
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AIR POLLUTION STUDIES IN CENTRAL RUSSIA (TULA REGION) USING MOSS BIOMONITORS TECHNIQUE, NAA AND AAS

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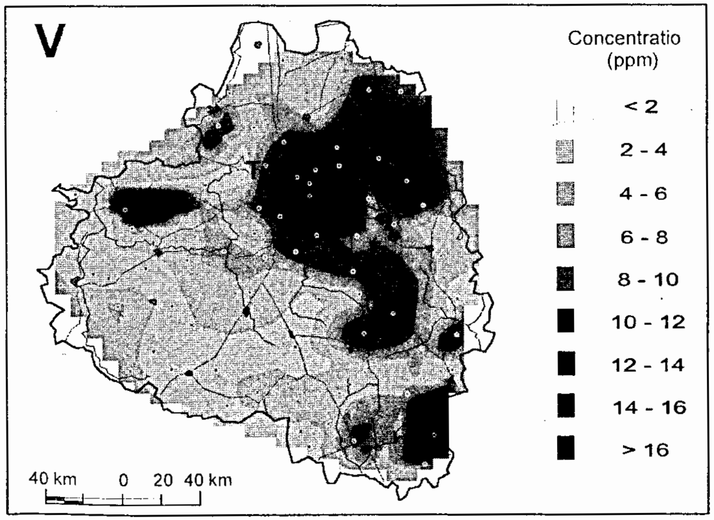
For the first time the moss biomonitors technique was used in air pollution studies in Central Russia (Tula Region) employing NAA, AAS and the GIS technology. The investigated area is located to the south of Moscow. The Tula Region is well known for clustering machine-building, iron and steel works, chemical and coal-mining enterprises. There are several thermal power stations in the Tula Region. Moss samples were collected at 83 sites in accordance with the sampling strategy adopted in European projects on biomonitoring of atmospheric deposition. A wide set of trace elements in mosses was determined. The method of epithermal neutron activation at IBR-2 reactor of FLNP (JINR Dubna) has made it possible to determine the concentration of 33 elements (Na, Mg, Al, Cl, K, Ca, Sc, V, Cr, Mn, Fe, Co, Ni, Zn, As, Br, Rb, Sr, Mo, Sb, I, Cs, BA, La, Ce, Sm, Tb, Yb, Hf, Ta, W, Th, U) over a large-scale range, from 10000 ppm for K to 0.001 ppm for Tb, Ta. In addition to NAA, flame AAS was applied to determine Cd, Cu and Pb in the Norwegian Institute of Science and Technology, Trondheim. A graphical technique and principal component analysis were applied to separate plant, crustal and general pollution components in the moss. The obtained data are used to construct maps of elements distribution over the investigated territory. This allows us to estimate the extent of impact from the pollution source in the nearby area. As an example, the map of vanadium distribution is presented.



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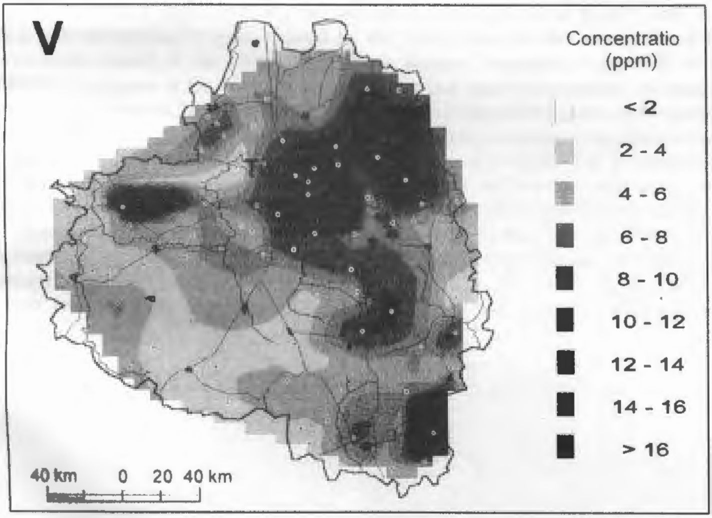

Search of Correlation between Polluted Environment and Health State of Population.

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The combination of epithermal and conventional activation analysis on IBR-2 reactor, supplemented by atomic absorption spectrometry was determined 40 elements in 86 sampling of mosses collected from different parts in Slovakia [1]. Information about the air pollution status is essential for a better understanding of environmental stresses, for example the influence to the health state of population.

Sudy of health state of population is the object of interest of many scientific fields. In general it is expected that the environment influences the health state of population from aproximaately 20 %. Most important influence, aproximately 50 %, represent life style (life and work), genetic factor represent 20 % and level of health care influences from 10 %. In region with markedly polluted environment the influence of environment may be significantly increased. Therefore, relationships between geochemical enviroment and human are much closer than is being commonly assumed.

Preliminary results show that correlation relation between distribution of some chemical elements and occurrence of individual indicators of health state. For example, distribution As and Hg versus percentage of hildren with low birh weight under 2,5 kg, distribution of Cu versus number of potential years of lost life and others.

Reference:

1. M. Florek, et al., Air Polution with Heavy Metals and Radionuclides in Slovakia Studied by Moss-biomonitoruing Technique. Preprint JINR E3-2001-155

RADIOANALYTICAL INVESTIGATIONS IN FLNP: CONTRIBUTION TO THE LIFE SCIENCES AT JINR

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Among the broad spectrum of the constituent trends of the Life Sciences at JINR such as nuclear medicine and pharmacy, radiation biology, radioecology, radioisotope production, radioanalytical investigations play a special role due to the long-term experience in multi-element instrumental neutron activation analysis (INAA) using thermal, resonance and fast neutrons of the reactor IBR-2. The analytical complex based on the pneumatic system REGATA installed at the reactor IBR-2 is widely used for conventional, epithermal and cyclic neutron activation analysis, and has a great potential for radiation research in material sciences.

INAA is presently being used in several projects on **air pollution studies,** supported by the International Atomic Energy Agency and the Plenipotentiaries of the country-members of JINR, that involve moss biomonitoring technique and GIS technologies for constructing geographical maps of atmospheric deposition patterns for a large set of elements. Results for some selected areas of Central Russia, South Urals, Kola Peninsula and countries of Eastern Europe (Bulgaria, Bosnia, Poland, Romania, Serbia, Slovakia, Western Ukraine) are reported to the European Atlas of Heavy Metal Atmospheric Deposition edited under the auspices of the Environmental Commission of the United Nations.

The analytical possibilities of NAA are favourably used in **biotechnologies, in the development of new pharaceuticals** based on blue-green algae *Spirulina platensis*. This is an example of a new interdisciplinary activity on the borderline of the traditional analytical investigations in a nuclear center involving biochemists and biophysicists from a JINR member-state, namely, Georgia. Along with practical applications, a fundamental feature of these algae was discovered: their ability to selectively accumulate non-toxic Cr III as compared to toxic Cr VI.

The third main direction of the radioanalytical investigations at FLNP, JINR is connected with a 2-year international project initiated by the Dubna team on **the occupational health and environmental impact** of the phosphate fertilizer industry financially supported via the INCO-COPERNICUS program of the European Union. To this end, monitoring studies are being carried out at several plants in Russia, Uzbekistan, Poland and Romania (the co-ordinators of the project are from the Netherlands and Denmark). The main goal of this project is to assess how human bio-substrates can be used to follow the rate of the pathological changes in the organism as it is exposed to intense technological impact. The results of the first year activity will be delivered at the International conference on Nuclear Analytical Methods in the Life Sciences (NAMLS-2002) in Turkey.

Postgraduate and undergraduate students from Russia, Poland and Romania are involved in the realization of these intensive and extensive investigations. Experimental material obtained in the Department serves as the basis of their MS and PhD theses. The analytical complex REGATA at IBR-2 is used for **practicals of the special course** «Nuclear and related analytical techniques for environmental studies».

Atmospheric deposition of heavy metals in Serbia studied by moss biomonitoring, neutron activation analysis and GIS technology

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The results of a pilot study on atmospheric deposition of heavy metals and other trace elements using the moss biomonitoring technique in the Northern part of Serbia and some areas of Bosnia are presented. Samples of *Hypnum cupressiforme* along with some other moss types were collected at 92 sites during the summer of 2000. A total of 44 elements were determined by instrumental neutron activation analysis using epithermal neutrons. The observed levels of Cu, Zn, As, Ag, Cd In, Sb, etc in the area surrounding the town of Bor are comparable to those reported from similar industrial areas in other countries such as the Copper Basin in Poland and the South Urals of Russia. In the same region the maximum Se and Mo concentrations are the highest ever recorded in biomonitoring studies using mosses. High median concentrations of Fe and Ni in Serbian mosses are associated with a crustal component as apparent from factor analysis of the moss data. This component could be a result of windblown soil dust (most of the samples were taken from agricultural regions) or deposition of ash from coal-burning power stations. Some specific elements such as Cl and V may originate from known industrial sources, but at certain places high values in the moss samples are suspected to be associated with fires in oil refineries damaged during the 1999 NATO military action.

A HEAVY METAL ATMOSPHERIC DEPOSITION STUDY IN THE SOUTH URAL MOUNTAINS

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Samples of the mosses *Hylocomium splendens* and *Pleurozium schreberi*, collected in the summer of 1998, were used to study the atmospheric deposition of heavy metals and other toxic elements in the Chelyabinsk Region situated in the South Urals, one of the most heavily polluted industrial areas of the Russian Federation. Samples of natural soils were collected simultaneously with moss at the same 30 sites in order to investigate surface accumulation of heavy metals and to examine the correlation of elements in moss and soil samples in order to separate contributions from atmospheric deposition and from soil minerals. A total of 38 elements (Na, Mg, Al, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Zn, As, Se, Rb, Sr, Zr, Mo, Sb, Cs, Ba, La, Ce, Nd, Sm, Eu, Gd, Tb, Dy, Yb, Hf, Ta, W, Au, Th, U) in soil and 33 elements Na, Mg, Al, Cl, K, Ca, Sc, V, Cr, Mn, Fe, Co, Ni, Zn, As, Se, Br, Rb, Ag, Sb, Cs, Ba, La, Ce, Sm, Tb, Yb, Hf, Ta, W, Au, Th, U) were determined by epithermal neutron activation analysis. The elements Cu, Cd and Pb (in moss samples only) were obtained by atomic absorption spectrometry. The element concentrations were compared to those for copper basins in Poland and Serbia as well as to baseline concentrations in Norway. VARIMAX rotated principal component analysis was used to identify and characterise different pollution sources and to point out the most polluted areas.

The reactor YAGUAR pulse shape and neutron density measurements

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The proposed /1,2/ nn-scattering experiment at the pulsed reactor YAGUAR (Snezhinsk, Russia) is intended for the first direct measurement of the neutron-neutron scattering length A_{NN}. It will allow, by comparison with the proton-proton scattering length, to draw conclusions on the issue of charge symmetry of the nuclear force. The international collaboration DIANNA (Direct Investigation of A_{NN} Association) is created for performing this task. Recently measurements of neutron densities and the reactor pulse shapes have been carried out at Snezhinsk. This report summarises the obtained results in comparison with the MCNP modeling.

1. C. D. Bowman, B. G. Levakov, A. E. Lyzhin, E. V. Lychagin, E. P. Magda, A. Yu. Muzichka, A. V. Strelkov, E. I. Sharapov, and V. N. Shvetsov, ISINN-VIII, JINR report E3-2000-192 (Joint Institute for Nuclear Research, Dubna, 2000), p. 245.

2. B. G. Levakov, V. I. Litvin, A. E. Lyzhin, W. I. Furman, E. V. Lychagin, A. Yu. Muzichka, G. V. Nekhaev, A. V. Strelkov, E. I. Sharapov, V. N. Shvetsov, C. R. Howell, G. E. Mitchell, W. Tornow, C. D. Bowman, B. E. Crawford, S. L. Stephenson, JINR report E3-2001-192 (Joint Institute for Nuclear Research, Dubna, 2001), p. 27.

Investigations of the Space Parity Violation and Interference Effects in the Fragment Angular Distributions of ^{239}Pu Fission by Resonance Neutrons

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Investigations of the space parity non conserving (PNC) asymmetry of emission of fission fragments (FF) from ^{239}Pu(n,f)-reaction and the parity conserving (PC) interference effects of left-right and forward-backward asymmetries of FF yields were carried out with aid of the neutron beams of the IBR-30 over neutron energy range from 0.02 eV up to 100 eV.

All experimental results obtained were processed and analyzed on the basis of the modern theoretical concepts on the mechanisms of formation of PNC and PC effects in nuclear fission induced by slow neutrons [1,2]. In case of the PC interference effects the well-marked irregularities in their dependence on neutron energy up to 100 eV were observed. As a remarkable result of the PNC effect measurements a resonance-like behavior of the P-odd asymmetry coefficient in the vicinity (0.02 – 0.6) eV was observed. Unfortunately, in general the statistical accuracy of the PNC effect measurements is not enough for reliable observation of these effects in more wide energy interval.

Interference effects investigated in case of ^{239}Pu(n,f)-reaction present a specific interest as the compound level density in this nucleus is well below than for ^{235}U(n,f)- or ^{233}U(n,f)-ones. Beside that only JπK combinations 0^+0 and 1^+0 and may be 1^+1 give contribution in s-wave neutron induced fission of ^{239}Pu target nucleus having $J\pi=1/2^+$. So the theoretical analysis of the data involves less free parameters and its results could be more informative. The preliminary results of simultaneous analysis of all three asymmetry effects performed in the framework of theoretical approaches [1, 2] are presented. The satisfactory combined description of the experimental data is obtained. As a result of this analysis of the main p-wave resonance parameters were extracted for neutron energy range below 20 eV where a satisfactory energy resolution allows one to separate distinct neutron resonances. Nuclear matrix elements of the weak interaction were estimated only in the low energy range.

This work was supported by RFBR Grant 93-02-3979, 97-02-16846, and INTAS Grant 99-0229.

[1] O.P. Sushkov and V.V. Flambaum, Usp. Fiz. Nauk **136** (1982) 3 [transl. Sov. Phys. Usp. **25** (1982) 1]
[2] A.L. Barabanov, V.I. Furman, In Proc. International Conference on Nuclear Data for Science and Technology, May 19-24, 1997, Trieste, Italy, p. 190-193

To the Question of the ^{234}U Thermal Fission Cross-section

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It is presented the experimental estimate of the ^{234}U thermal neutron induced subbarrier fission obtained in the course of the PNC-effect measurements at the cold polarized neutron beam of the ILL high flux reactor. Known experimental values for that cross-section are very scattered from 650 mb [1], (300±20) mb [2], (210±30) mb [3] up to (68±14) mb [4].

Our experimental set-up represented the plane multi-plate ionization chamber with seven double-sided ^{234}U (235U admixture about 0.08%) and one double-sided ^{233}U targets on the thin Al foils 0.1 mm thickness. Total amounts of fissile materials were about 40.1 mg (^{234}U) and 70 μg (^{233}U) with the average covering density 0.14 mg/cm^2 and 2.3 μg/cm^2, respectively.

Under the target irradiation by the well-collimated neutron beam, being much smaller than the target sizes and orthogonal the target planes, the figure (1.200±0.006) was obtained for the ratio of ^{234}U and ^{233}U counting rates.

We had obtained following estimate for the ^{234}U fission cross section:

$$\sigma_f = (0.93\pm0.30) \text{ barns.}$$

To confirm neutron flux value, total amount of the ^{233}U and justice the 1/v law, used under the data evaluation, we have measured neutron flux by the method of Au foils and neutron energy spectra by the time-of flight method for two different average energies. Neutron beam intensity obtined with a gold foil is $\Phi=3.9\cdot10^8$ n/(cm^{2}s) (with 10% accuracy). The ^{234}U fission cross section estimate, obtained with this flux value and certified total amount of studied fissile material, was found to be equal

$$\sigma_f = (0.96\pm0.30) \text{ barns.}$$

References

1. *J. Mughabghab*. **Neutron Cross Sections**, Academic press, New York (1984)
2. *C. Wagemans, J. Wagemans, P. Getlenbort, O. Zimmer*. Nucl. Sc. And Eng. 132 (1999) p.308
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P-odd Asymmetry of the Light Fragment Fly out in the ^{234}U Subbarrier Fission by the Cold Polarized Neutrons

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Parity violating effect of the ^{234}U fission fragment emission relative to the cold neutron polarization was measured for the first time at the ILL High Flux Reactor.

Polarized neutron beam has flux at the fissile target position of about $4\cdot10^8$ n/(cm$^2\cdot$s) and longitudinal polarization about 95%.

We used in that experiment the ^{234}U target with approximately the following isotope composition (99.84%, 0.082%, 0.046%, and 0.03% of 234, 235, 236, and 238 U-isotopes respectively). The total amount 40.1 mg of this material (determined by alfa-spectroscopy method with accuracy about 5 %) was coated on two sides of seven Al foils (0.1 mm thickness, 70 mm diameter, active spot 52 mm diameter). As a reference in the ^{234}U PNC-effect measurements, we used ^{233}U (68 μg, 98.99% enrichment), coated on two sides of one Al foil-backing being similar to ^{234}U ones. Each target foil, placed in between two anodes and made of the same Al foil, formed two independent fast ionization chambers. Sixteen such chambers were operating in joint volume (about 8 l.) of CF_4 gas. Longitudinally polarized neutron beam ($4\cdot10^8$ n/(cm$^2\cdot$s), 4 Å) hits on the targets at the right angle. Under such experimental conditions the ratio the $^{234+235}$U and ^{233}U fission count rates was about 1.2 with a good homogeneity over the targets surface.

After all experimental data evaluation we had obtained following figures for the PNC asymmetry coefficients:

With the ^{233}U target: $\alpha=(3.82\pm0.15)\cdot10^{-4}$ (our preceding value $\alpha=(3.67\pm0.06)\cdot10^{-4}$ [1])

With the $^{234+235}$U target: $\alpha = (0.74\pm0.09)\cdot10^{-4}$ (in ^{235}U: $\alpha=(0.80\pm0.06)\cdot10^{-4}$ [2]).

To extract value of ^{234}U PNC-asymmetry coefficient from the asymmetry coefficient measured in experiment for the isotope mixture, one need the exact magnitude of ^{234}U fission cross-section. Because this cross-section is not well known nowadays, we used the estimation of this quantity obtained in our experiment relatively ^{233}U fission cross-section $\sigma_f=(1.0\pm0.3)$ barns. In this case the PNC-effect in subbarrier fission of pure ^{234}U was found as follows:

$$\alpha=(0.71\pm0.14)\cdot10^{-4}$$

References:

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CROSS SECTION MEASUREMENTS FOR THE REACTION $^{10}B(n,\alpha)^7Li$ FROM 1 TO 4 MeV.

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Abstract

A new powerful technique for the spectrometry of light charged particles has been developed and successfully operated for the measurement of (n,α) reactions on boron-10 at the 7 MV Van de Graaff accelerator of IRMM. The basic elements of the new method are a gridded ionisation chamber (GIC), a fast waveform digitizer for signal sampling/storage and advanced off-line analysis. Much more information can be extracted from the fully digitized signals compared to the classical GIC spectrometer, which only records signal amplitudes. The topology of each charged particle event is effectively used to suppress backgrounds, especially those produced in the detector gas. A background reduction by a factor of 30 has been achieved for the reaction $^{10}B(n,\alpha)^7Li$ using as detector medium an Ar(90%)CH4(10%) gas mixture. In this way high quality energy and angular distributions for the $\alpha 0$ and $\alpha 1$ particle groups have been measured in the energy range 1.5-2.8 MeV. Cross sections and $\alpha 0/\alpha 1$ ratios have been obtained between 1.5 and 3.8 MeV by using as detector medium a Kr(97%)CO2(3%) gas mixture. The data show a satisfactory agreement with the JENDL-3.2 and strong deviations from the ENDF/B-VI evaluation respectively. With the new method we have also obtained preliminary results for the nuclear reaction Ni(n,α)Fe at En=5.2 MeV. The $\alpha 0$, $\alpha 1$, $\alpha 2$ and $\alpha 3$-$\alpha 4$ particle groups of the reaction $^{58}Ni(n,\alpha)^{55}Fe$ have been clearly resolved and identified. The overall angular distribution is in good agreement with results published by other groups.

EXPERIMENTAL STUDIES OF SECONDARY FRAGMENTS IN INTERMEDIATE ENERGY NEUTRON-INDUCED FISSION

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At LANSCE/WNR, the unique combination of a broad-range continuous-energy neutron beam and the high-resolution gamma-ray detection capabilities of the Germanium Array for Neutron-Induced Excitations (GEANIE) is being exploited to collect data on fission with isotopically-enriched uranium targets.

The yields of prompt gamma-rays and x-rays emitted from de-exciting fission fragments have been measured for uranium 238. For x-ray detection, a thin, fission sensitive target was especially designed.

Charge yields as well as some individual nuclei production as a function of neutron energy are extracted from these data. The study of the relative intensity of high-spin state de-excitations in odd nuclei may provide information on the evolution of the fissioning system's angular momentum with neutron energy. Preliminary results will be presented.

Study of a Resonance Structure of the Neutron Cross Sections and the α-Value of ^{239}Pu for Different Temperatures

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The time-of-flight spectra for γ-ray multiplicities from 1 to 15 were measured on the 122 m flight path of the IBR-30 pulsed neutron booster using the 16-section liquid scintillation detector with the 80 l total volume [1] for thin metallic ^{239}Pu radiator-sample (0.3 mm) at the presence of ^{239}Pu filter-sample with one thickness 0.5 mm by two temperatures (100^0 and 293^0) in the neutron beam and without them.

Multiplicity spectra and alpha values $\alpha = \sigma_\gamma / \sigma_f$ were obtained from time-of-flight spectra after subtracting background components for the energy group over the range of 2.15-2150eV with and without filter- samples of ^{239}Pu.

From the time-of-flight spectra of 3-rd and sum of the 6-9th multiplicities were determined the self-indication functions in capture and fission cross-sections for foregoing temperatures and the Doppler-coefficient in the alpha values.

Analogous values were calculated by the GRUCON code with using of the ENDF/B-6, JANDL-3 evaluated data libraries.

Investigation of a Resonance Structure of the Neutron Cross Sections for Nb, Mo, Pb in Energy Range 0.02 – 100 keV

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The neutron total and capture cross sections for the natural Nb, Mo and Pb have been measured at the 501 m and 1006m flight paths of the IBR-30 by means of the batteries with the ^3He counters and the 16-section NaI(Tl) crystal scintillation detector with volume of 36 l. The metallic disks with different thickness and 80 mm diameter of Nb,Mo,Pb saved as samples-filters for measurement of transmitions. The group total cross sections and them self-shielding factors were obtained from transmitions in energy range 0,02 – 100 keV. The group capture cross sections of Nb and Mo were obtained from the sum time-of-flight spectra of 1-7 gamma-ray multiplicities in energy range 0,02 – 10 keV. The group ^{238}U capture cross sections were used as the standard ones. The experimental uncertainties of group cross sections and self-shielding factors are 2-10%

Analogous values were calculated by the GRUCON code with using of the ENDF/B-6, JENDL-3 evaluated data libraries.

Investigation of (n-n) – Interaction by Method of Overtaking Neutrons

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The new method of measurement of the total and partial (n-n)-interaction cross sections was described . Usually, neutron sources with moderators have the wide neutron spectra, therefore the low energy neutrons are proposed to use as the neutron sample, which might interact more fast overtaking neutrons with. The mathematical expressions for calculation of neutron density at the different distances from the neutron source and anything moment after the neutron burst for pulse source was presented here. It was presented also the test results, which was measured at flight path of IBR-30 and First Atomic Station

On the Geometry of Configuration Space of an Atom Core

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We determine the configuration space of the atom core in the coordinates of neutron and proton mass centers and in the vektor field of equally probable displacement of proton and neutron mass centers. Thus, each of the elementary particles of the atom core corresponds to a domain in the form of a sphere. Let the spheres of protons and neutrons differ in colour.

The problem of geometric connection of monochrome spheres is considered. The existence conditions for strong and loose connections of monochrome spheres are determined. If is proved that all monochrome configurations of the spheres have a loose connection at a time. The monochrome configurations with a strong connection are also local in the large. But if one of the monochrome configurations possesses a strong connection in the large, all other monochrome configurations exhibit only a loose connection.

Interaction of Photons with Aqueous Solutions of Some Organic

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The linear attenuation coefficients of aqueous solutions of 1,4 Dioxane, Formamide and N,N Dimethyl Formamide have been determined at 356, 511, 662, 1173 and 1332 keV energies by gamma ray transmission method in a narrow beam good geometry set-up. From the precisely measured densities of these solutions, mass attenuation coefficients were then obtained, which were found to decrease with the increase in the weight fraction of the corresponding organic compound. Also these coefficients were found to depend energy of the incident photons. In addition to this, the experimentally determined values of mass attenuation coefficients of these compounds were used to determine the effective atomic numbers and electron density of these solutions. Excellent agreement is observed between experimental and theoretical values.

Measurements of nuclear level densities and γ-ray strengths and its interpretations

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The Oslo Cyclotron Group has established a method to extract primary γ-ray spectra at excitation energies up to the neutron binding energy. From these energy distributions, the level density and γ-ray strength function can be extracted [1,2]. In this group report we focus on the experimental technique and the interpretation of thermodynamical quantities obtained within the microcanonical and canonical ensemble theory.

The high nuclear level density is due to the many ways nucleons can add up to a certain excitation energy. Each valence nucleon, i.e. nucleons not coupled in Cooper pairs, carries a single-particle entropy of $S_1 \sim 1.7k_B$. Thus, a broken Cooper pair contributes significantly to the total entropy and heat capacity [3]. Observed structures in the caloric curve and heat capacity may therefore be fingerprints of the breaking of Cooper pairs. Using the canonical $C_V(T)$ quantity as thermometer [4], a local maximum is found at $T_C \sim 0.5$ MeV, indicating the breaking of Cooper pairs and quenching of pair correlations.

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FIRST MEASURMENT OF THE ^{233}Pa FISSION CROSS SECTION

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The past few years have witnessed a renewed and vigorously increasing interest in the thorium fuel cycle in connection with transmutation of nuclear waste. A well-known proposal to combine nuclear waste transmutation and inherently safe nuclear reactors is the Energy Amplifier (EA) suggested by Carlo Rubbia [1]. This is a ^{232}Th-fueled sub-critical reactor driven by a high-energy proton accelerator. Any successful development and implementation of this concept rely strongly on accurate neutron reaction data. However, it is evident from a comparison of different evaluated data libraries that cases of major discrepancies exist for some cross section values, even in the well-studied region of neutron energies up to 20MeV.

The neutron-induced fission cross section of ^{233}Pa is a conspicuous example of discrepant data in the accepted evaluations. This protactinium isotope is important for the thorium fuel cycle as a relatively short-lived intermediate nuclide between the ^{232}Th source material and the ^{233}U fuel material. The reactions involving ^{233}Pa are responsible for the balance of nuclei as well as the average number of prompt fission neutrons in a contemplated reactor scenario [2]. The very presence of the intermediary protactinium in a ^{232}Th fueled reactor gives rise to what is known as the protactinium effect [3]. When a ^{232}Th fueled reactor is stopped the ^{233}Pa continues to decay into ^{233}U. This will increase the reactivity and may cause criticality in the reactor. In order to calculate the amount of protactinium in the reactor fuel, and thus estimate the importance of the protactinium effect, it is vital to know the reactions competing with the natural decay of ^{233}Pa.

In a IAEA report from 1999 [4], it is stated that there is a need to know the ^{233}Pa(n,f) cross section with an accuracy of 20%. However, in different neutron data libraries there is a difference of a **factor two** for this cross section. There are some technical difficulties involved in measuring the ^{233}Pa(n,f) cross section, e.g. its short half-life, high radioactivity and the in-growth of the daughter product ^{233}U. Hence, it has previously been deemed not feasible to measure this reaction directly. The entries in the neutron libraries are thus based on theoretical predictions, which explains the large discrepancies.

A sophisticated detector system for fission cross section measurements was used for efficient background suppression. With a very well performing neutron source, and the preparation of a highly purified ^{233}Pa sample, the ^{233}Pa(n,f) cross section was successfully measured for the first time at four well-defined neutron energies at the Van de Graaff accelerator facility at IRMM in 2001. The data analysis and achieved results will be presented together with some problems caused by the fact that also the ^{233}U fission cross section is not very well known.

A new campaign of measurements is presently underway, with the intention to extend the data to higher neutron energies covering the second chance fission threshold. This eventually satisfies the demands for thorium-fuel based technologies.

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Study of Gamma-Ray Photon Interactions with Barium Borate Glasses

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Mass attenuation coefficients, effective atomic numbers, I nteraction cross-sections and effective electron densities of the glasses of x BaO -(1-x) B2O3 (x = 0.24, 0.30, 0.34, 0.40 and 0.44), were determined at 356, 511, 662, 1173 and 1332 keV photon energies by using a narrow beam transmission method. Glass samples were prepared by melt quenching technique. Appreciable variations in these coefficients were observed with changes in the chemical composition of glass samples. Also mass attenuation coefficients were found to increase with increase in the chemical composition of Ba and decrease with increase of incident photon energy for a fixed composition. The effective atomic numbers were found to decrease with the increase in the chemical composition of the heavy element. Effective electron densities and the interaction cross-sections were also calculated for these glass samples. Good agreement was observed between experimental and theoretical values.

The Quantum-Mechanical Description of Nuclear Binary and Ternary Fission

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On the basis of the open Fermi-systems theory [1], Bohr's concept of fissional transitional states [2] and the adiabatical approximation for asymptotical region of fissioning nuclei [3] the structures of partial fission widths and fission phases for spontaneous and low energy induced binary and ternary fission of nuclei have been investigated. The different stages of nuclear fission have been analysed. The orientation pumping mechanism [4] connected with nonspherical nuclear and Coulomb interactions between fission fragments has been generalized to the case of taking into account the relative orbital moments of fission fragments. The influence of coherent effects connected with the adiabatical approximation to the fission partial widths and to the angular distributions of fission fragments has been analysed. The dynamical dependences of fissional phases and partial widths from structure of parent nucleus and fission fragments and from orientations of internal axises, spins and relative orbital moments of binary and ternary fission fragments have been built. The fragments angular distributions for binary fission of polarized nuclei and ternary fission of nonpolarized nuclei have been investigated.

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CALCULATIONS OF THE WEAK *P*-ODD SINGLE-NUCLEON HARTREE-FOCK POTENTIAL FOR ^{208}Pb AND ^{40}Ca WITH THE ACCOUNT OF SURFACE TERMS

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Apart from the main term ~ $(\sigma_1 \hat{\mathbf{k}}_1)$, investigated in [1], the weak single-nucleon Hartree-Fock potential V_W^{HF} [1] includes also, in both the Hartree and Fock parts, terms with the density (density matrix) gradient and the meson formfactor gradient inside the integrals. All these Hartree terms and zero-order Fock terms ($\exp(i\,\mathbf{r}\hat{\mathbf{k}}_1) \to 1$), having the surface character, are proportional to the factor $i(\sigma_1 \mathbf{e}_{r1})$ ($\mathbf{e}_{r1} = \mathbf{r}_1 / r_1$) – just as the surface term of phenomenological weak nucleon-nucleus potentials V_W^{ph} [2] with the density gradient.

Thus, we have: $V_W^{HF} \approx W^{HF}(1, \hat{\mathbf{k}}_1)(\sigma_1 \hat{\mathbf{k}}_1) + i(\sigma_1 \mathbf{e}_{r1})(V_{sf(1)}^{HF}(1) + V_{sf(2)}^{HF}(1))$, where $V_{sf(1)}^{HF}$, $V_{sf(2)}^{HF}$ are the respective total contributions of terms with the density (density matrix) gradient and the meson formfactor gradient; $1 \equiv (\mathbf{r}_1, \tau_{1z})$, $\tau_{1z} = +1$ (n) and -1 (p).

The calculations for ^{208}Pb and ^{40}Ca, performed in the general scheme of [1], have shown that the radial dependences of the total isoscalar and isovector parts (as well as partial meson components) in the main term ~ $(\sigma_1 \hat{\mathbf{k}}_1)$ and those of the surface terms $V_{sf(1)}^{HF}$, $V_{sf(2)}^{HF}$ are close to the radial dependences of the main and surface terms in V_w^{ph} [2], respectively. For isovector Fock terms, where the π-meson component strongly prevails, the Fermi function radius $R \le 1.05\, R_A$ differs most noticeably from the density radius R_A.

Below, the calculated values of the isoscalar (V_{sf}) and isovector ($\tilde{V}_{sf}$) components of $V_{sf(1)}^{HF}(1)$, $V_{sf(2)}^{HF}(1)$ and the total surface term $V_{sf}^{HF}(1)$ at $r_1 = R_A$ ($R_A = 1.1A^{1/3}$) are presented (in the units of eV), with the demonstration of Hartree and Fock contributions.

^{208}Pb: $V_{sf(1)}^{HF} = -0.99$ ($V_{sf(1)}^{H} = -0.14$, $V_{sf(1)}^{F} = -0.85$); $V_{sf(2)}^{HF} = 1.31$ ($V_{sf(2)}^{H} = 0.56$, $V_{sf(2)}^{F} = 0.75$); $V_{sf}^{HF} = 0.32$ ($V_{sf}^{H} = 0.42$, $V_{sf}^{F} = -0.10$);
$\tilde{V}_{sf(1)}^{HF} = 0.52$ ($\tilde{V}_{sf(1)}^{H} = 0.05$, $\tilde{V}_{sf(1)}^{F} = 0.47$); $\tilde{V}_{sf(2)}^{HF} = -0.59$ ($\tilde{V}_{sf(2)}^{H} = -0.20$, $\tilde{V}_{sf(2)}^{F} = -0.39$); $\tilde{V}_{sf}^{HF} = -0.07$ ($\tilde{V}_{sf}^{H} = -0.15$, $\tilde{V}_{sf}^{F} = 0.08$).

^{40}Ca: $V_{sf(1)}^{HF} = -0.93$ ($V_{sf(1)}^{H} = -0.14$, $V_{sf(1)}^{F} = -0.79$); $V_{sf(2)}^{HF} = 1.28$ ($V_{sf(2)}^{H} = 0.56$, $V_{sf(2)}^{F} = 0.72$); $V_{sf}^{HF} = 0.35$ ($V_{sf}^{H} = 0.42$, $V_{sf}^{F} = -0.07$);
$\tilde{V}_{sf(1)}^{HF} = 0.55$ ($\tilde{V}_{sf(1)}^{H} = 0.08$, $\tilde{V}_{sf(1)}^{F} = 0.47$); $\tilde{V}_{sf(2)}^{HF} = -0.71$ ($\tilde{V}_{sf(2)}^{H} = -0.32$, $\tilde{V}_{sf(2)}^{F} = -0.39$); $\tilde{V}_{sf}^{HF} = -0.16$ ($\tilde{V}_{sf}^{H} = -0.24$, $\tilde{V}_{sf}^{F} = 0.08$).

In each of the terms $V_{sf(1)}^{HF}$, $V_{sf(2)}^{HF}$, $\tilde{V}_{sf(1)}^{HF}$, $\tilde{V}_{sf(2)}^{HF}$ the Fock component essentially enhances the Hartree one. However, in all cases the contributions $_{(1)}$ and $_{(2)}$ have the opposite signs. As a result, the total surface terms V_{sf}^{HF}, $\tilde{V}_{sf}^{HF}$ are small; the total Hartree component prevails over the total Fock one, having the opposite sign. It should be also noted that the total isovector value $\tilde{V}_{sf}^{HF}$ for ^{40}Ca is in good accordance with the values of isovector surface term in V_w^{ph} [2] for ^{40}Ca at $r_1 = R_A$ (($-0.32 \div +0.18$) eV).

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INFORMATION POSSIBILITIES OF EXPERIMENTAL INVESTIGATION OF THE CASCADE γ-DECAY OF HEAVY COMPOUND NUCLEI

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The spectra of the primary γ-transitions [1] and two-step γ-cascades [2] after the decay of compound nuclei with high level density are the only sources of the data on the probability of γ-quanta emission and number of levels excited by them. The observables in such experiments are the folding of these two parameters. Therefore, determination of these parameters is seriously made difficult. The energy dependencies of the intensity of the primary transitions and two-step cascades are quite different. As a result, one spectrum of primary transitions can be reproduced in calculation with the using of partial γ-widths and level densities varying from $-\infty$ to $+\infty$. Reliability of this parameters what it is simultaneously extracted from several spectra at different energies E_i of decaying levels together is very doubtful. Hence, one can obtain reliable information on, for instance, radiative strength functions from the spectrum of primary transitions only using [1] the model values of level density.

In the case of two-step cascades the variations of mentioned parameters can be limited by very narrow [2] interval of values at any energies of γ-quantum (or excitation energy). In the case of cascades, one can simultaneously estimate the narrow enough intervals which contain infinity numbers of possible values of both parameters. This was done [2], however, under assumption of equal energy dependence of strength functions for the primary and secondary transitions. Of course, this results in some systematical error.

Therefore, one can hope to obtain the more reliable data on the level density and radiative strength functions from the joint analysis of the spectra of the primary transitions and two-step cascades measured in different experiments but in the same nucleus. The performed tests show that the maximum change in the level density and radiative strength functions in this analysis is close to the uncertainty of data obtained in [2].

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Scissors mode and two-step cascades from the (n,γ) reaction

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Some of the 1^+ states of deformed nuclei was interpreted as "scissors mode" in the nuclear resonance fluorescence (NRF) experiments. These states can be excited and by the two-step γ-cascades following thermal and resonance neutron capture if the J^π compound states are lying in the region $0^- - 2^-$. It is of interest is to compare populations of these states and any levels $J^\pi = 1^+$ with other components of their wave functions.

This comparison was done according to the method [1] (Table) for the $^{156,158}Gd$, ^{164}Dy, ^{184}W, ^{190}Os, and ^{196}Pt compound nuclei. Such analysis is necessary, for example, for verification of the appeared information that the scissors mode states, built on the excited states of a nucleus, to the high extent determine the properties of levels of deformed nuclei above $\simeq 3$ MeV and, correspondingly, intensities of cascades.

The comparison of the intensities of the two-step cascades populating all possible intermediate levels with the analogous parameter for scissors mode states did not reveal noticeable difference between them. If the scissors mode levels built on the excited states really exist at the neutron capture then their contribution to the γ-decay process should be insignificant (by analogy with the role of vibrations of other types).

Table. Total experimental $I_{2\gamma}^{exp}$ and expected [1] $I_{2\gamma}^{cal}$ for zero detection threshold L_c intensity of two-step cascades (% per decay); I_{sm}^{exp} is the population of the scissors mode states by γ-transitions (% per decay). $N_{2\gamma}^{exp}$, $N_{2\gamma}^{cal}$ and N_{sm}^{exp} are the number of the observed intermediate levels of cascades, their expected number and the number of states identified as the scissors mode, respectively.

Nucleus	$\Delta E, MeV$	$I_{2\gamma}^{exp}$	$N_{2\gamma}^{exp}$	$I_{2\gamma}^{apr}$	$N_{2\gamma}^{apr}$	L_c	I_{sm}^{exp}	N_{sm}^{exp}
^{156}Gd	2-3.3	8.4	77	9.8	206	0.02	< 0.24	≥ 10
^{158}Gd	2-3.3	4.2	41	5.9	186	0.035	< 0.4	≥ 13
^{164}Dy	2-3.3	7.5	61	10.5	150	0.045	< 0.8	≥ 7
^{184}W	2-3.7	15.9	142*	15.9	302*	0.02	< 1.5	≥ 20
^{190}Os	1.1-3.5	27.6	68	32.2	340	0.1	< 4.1	≥ 29
^{196}Pt	2.2-3.3	13.6	42	24.1	146	0.08	< 1.8	≥ 10

*) Preliminary data. More precise data on possible multiplet structures may change number of levels by several percent.

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RESEARCH OF TERNARY FISSION OF ^{252}CF

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ABSTRACT

For reseach of ternary nuclear fission a spectrometer based on double Frisch-gridded ionization chamber and crystal CsI(Tl) was constructed. The digital signals processing allows to obtain the information on energies, masses, emission angles of the fission fragments and on energy and type of light particles. The first measurement of the spontaneous ternary fission of ^{252}Cf was carry out. Analysis on the charged particles type showed existence of an events group with unusually low specific energy losses (between protons and electrons). We consider these events as indication on the ternary nuclear fission with charged meson emission. In the future we suppose to use this spectrometer for investigation of this phenomenon. In particular the investigation of time correlation between pulses allows to organize the search of mesons decay sequences.

Capture Cross Section Measurements of ^{161}Dy, ^{162}Dy, ^{163}Dy, and ^{164}Dy in the Energy Region Between 10 keV and 90 keV

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The neutron capture cross sections of Dy isotopes (^{161}Dy, ^{162}Dy, ^{163}Dy, and ^{164}Dy) have been measured in the neutron energy region of 10 to 90 keV using the 3-MV Pelletron accelerator of the Research Laboratory for Nuclear Reactors at the Tokyo Institute of Technology. Pulsed keV neutrons were produced from the ^{7}Li(p,n)^{7}Be reaction by bombarding the lithium target with the 1.5-ns bunched proton beam from the Pelletron accelerator. The incident neutron spectrum on a capture sample was measured by means of a TOF method with a ^{6}Li-glass detector. Capture γ-rays were detected with a large anti-Compton NaI(Tl) spectrometer, employing a TOF method. A pulse-height weighting technique was applied to observed capture γ-ray pulse-height spectra to derive capture yields. The capture cross sections were obtained by using the standard capture cross sections of ^{197}Au. The present results were compared with the previous measurements and the evaluated values of ENDF/B-VI.

Measurement of Total Cross Sections for Dy, In and Cu at Pohang Neutron Facility

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The Pohang Neutron Facility consists of an electron linac, a water–cooled Ta target, and a 10.8 m long time–of–flight path. The electron linac consists of a thermionic RF–gun, an alpha magnet, four quadrupole magnets, two SLAC–type accelerating sections, a quadrupole triplet, and a beam–analyzing magnet. The beam energy is 75 MeV, and the measured beam currents at the entrance of the first accelerating structure and at the end of the linac are 100 and 40 mA, respectively. The length of electron beam pulses is 1 μs and the pulse repetition rate is 10 Hz. The diameter of electron beam is about 20 mm at the beam profile monitor in front of the target.

In 2001 – 2002 years the neutron beam line of Pohang Neutron Facility was essentially improved. The new combined collimator was installed. The neutron guide now is equipped with a combined collimator system. It consists from the sequence of iron, H_3BO_3 and lead rings. The inner diameters of the rings are varying simultaneously from 100 mm to 50 mm.

As a neutron detector, we have used a BC-702/5 (Bicron Corporation) scintillation detector. The detector is 6.35 mm in thickness and 40 mm in diameter. It incorporates a matrix of a lithium compound enriched to 95% ^{6}Li dispersed in a fine ZnS(Ag) phosphor powder. BC-702/5 is an efficient scintillation detector for thermal and epithermal neutrons which provide also discrimination against gamma–ray backgrounds because the last one leaves a small portion of their initial energy. However, because of high rate of Bremsstrahlung gamma–rays and that from a neutron capture, the total contribution of gamma – rays to the detector count rate is sufficient. To prevent this contribution we designed a new electronic system for neutron–gamma separation that improves the measurement abilities of the whole neutron facility. The separation system are designed from the standard EG&G Ortec electronic blocks.

We have reported the total cross sections of Dy, In and Cu samples measured at Pohang Neutron Facility.

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Neutron spectroscopy with a fast waveform digitizer

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The rapid growth of computer performance, the size of hard disks and compact disk storage, and the rapid increase in performance of flash ADCs stimulated the development of the use of waveform digitizers as a new technique for nuclear experiments. Now one may connect a detector with a waveform digitizer and record its complete output signal during an experiment. This method has obvious advantages in comparison with the traditional technique when separate electronic units are applied for selection, and storage of the information:

- it is possible to record all information available from the output of a detector;
- it is possible to apply any method for signal processing/data evaluation. The choice is limited only by the imagination of the experimentalist, and the useful information in the signal.
- it is possible to increase count rate while maintaining successful discrimination and full determination of events separated by a few tens of nanoseconds;

Some advantages of this method were presented in Ref. [1]. There, the LeCroy digitizer with 12.5 ns sampling time was applied to a gridded ionization chamber and a CsI detector. In this report, we present the application of this method for an organic scintillator coupled with a fast photomultiplier tube (PMT) in the field of fast neutron spectroscopy.

The last advantage mentioned above is a unique one that is ideal for spectroscopy of secondary neutrons (also ν-prompt for fissile isotopes) produced by neutron-induced reactions in the energy range from 10 to 100 MeV at a white high-intensity neutron source such as nTOF [2]. In such an experiment the incident neutron energy is estimated by time of flight but the secondary neutron spectra are calculated by unfolding of the measured pulse height distribution of a neutron detector with well-known response function. In the case of nTOF, the low frequency of the input burst and the high intensity provide very high instantaneous count rates and complicate the application of an organic neutron detector with the traditional method.

In this work we used a DP111 (Acqiris) waveform digitizer (WFD) with bandwidth 500 MHz (minimum rise time ~0.7 ns). This WFD samples the detector signal at rates of 1 giga sample per second (1 GS/s) to 8 bits. In our case the input voltage was +0.1 V to –0.4 V.

Various stilbene crystals and photomultilpliers (PMTs, RCA8575, FEU-143, XP2041) were tested. The RCA8575 PMT had the best response function and was used for most of the tests. We have demonstrated comparable pulse height response and timing characteristics compared with conventional techniques. It was verified that proton induced signals in stilbene have three components in agreement with those mentioned in Ref. [3]. More interestingly it was observed that the relative contribution of the three components is proton energy dependent, while the pulse shape is constant for electron-induced events.

Two methods of particle type identification were compared. First, the traditional method based on the comparison of "fast" and "total" charge components. The second one uses the correlation of a detected event with a standard pulse-shape that corresponds to electron-induced signals. The correlation method significantly improved particle type discrimination in particular for saturated pulses.

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Analysis of neutron emission spectra from ^{232}Th

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Model calculations were performed to interpret neutron emission spectra from ^{232}Th. Measured neutron emission spectra from ^{232}Th for incident neutron energies from 1 MeV to 18 MeV (Baba et al., 1989, 1991, Miura et al, 2001) are described. Structures evident in measured emission spectra for incident neutron energies in the range of 1 - 6 MeV are correlated with excitation of levels of $K^{\pi}=0^-$ and $K^{\pi}=0^+, 2^+$ bands. The coupled channel optical model potential is obtained which fits total cross section data as well as angular distribution data. Direct excitation cross sections for $\gamma(\beta)$-vibration ($K^{\pi}=0^+, 2^+$) as well as octupole ($K^{\pi}=0^-$) band levels are calculated with a soft rotator model. The direct scattering parameters for octupole and hexadecapole bands were defined by fitting collective levels structure as well as inelastic scattering data. Collective level structures of ^{232}Th and ^{238}U are compared. Measured inelastic data are described in terms of Hauser-Feshbach approach. Prompt fission neutron spectra data in a broad incident neutron energy range are analyzed, since measured emission neutron spectra are inclusive of both fission and scattered neutrons. Neutrons emitted in (n,xnf) reactions are included.

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Prompt fission neutron spectra of U and Th

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Prompt fission neutron spectra data in a broad incident neutron energy range are analyzed with statistical model calculations. The low energy component due to pre-fission neutrons strongly influences on the PFNS shape. The calculated spectra for ^{232}Th(n,f) and ^{238}U(n,f) reactions are compatible with measured data by Boykov et al. (1993) and Lovchikova et al. (2000). In the domain of emissive fission similar tendencies are observed for both reactions. For ^{232}Th(n,f) reaction the contribution of pre-fission neutrons from (n,nf) reaction to the observed PFNS in fission neutron energy range $E_{th}\sim E_n - B_f$ is much more pronounced than in case of ^{238}U(n,f) reaction. Actually the energy dependence of ^{238}U(n,f) and ^{232}Th(n,f) PFNS for prompt fission neutron energies $E_n < E_{th}$ resembles the shape of fission probability of ^{238}U or ^{232}Th nuclide, respectively. Fission probabilities of ^{232}Th and ^{238}U were defined by fitting measured fission cross sections above (n,nf) emissive fission reaction thresholds. The contribution of ^{232}Th(n,nf) reaction cross section to the observed fission cross section for E_n<10 MeV is higher than in case of ^{238}U target. For incident neutron energy of ~14.6 MeV (n,nf) contribution produces much stronger peak in ^{232}Th(n,f) PFNS around ~8 MeV energy of the secondary neutrons than in case of ^{238}U(n,f) reaction. More flat energy dependence of ^{238}U fission probability fits observed ^{238}U(n,f) reaction cross section. Consequently, fission probability for ^{238}U is of more flat shape above fission threshold. Prompt fission neutron spectra for ^{232}U(n,f) reaction are predicted based on the analysis of emissive fission contributions to the observed fission cross section. Relative contribution of ^{232}U (n,nf) reaction is lower than in case of ^{232}U (n,nf) reaction for E_n<9 MeV. At the other hand, relative contribution of ^{232}U(n,nf) reaction is much higher than in case of ^{238}U(n,nf) reaction for En>9 MeV. For ^{232}U(n,f) reaction the contribution of pre-fission neutrons from (n,nf) reaction to the PFNS in fission neutron energy range $E_{th}\sim E_n - B_f$ should be less pronounced than in case of ^{238}U(n,f) for E_n <9 MeV and more pronounced for higher E_n. The latter peculiarity is a direct consequence of high ^{232}U target nuclide fissility with neutrons and consequent high non-emissive fission contribution to the observed fission cross section.

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Neutron-Induced Fission of ^{232}U

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High α-activity of the ^{232}U sample has hindered extensive measurements of its neutron-induced reaction cross sections. Only one total cross section measurement by Simpson et al. (1967) and a few fission cross sections measurements exist, which are rather discrepant with each other. ^{232}U target nuclide undergoes substantial thermal neutron fission and exhibits a non-threshold behavior at low incident neutron energies in contrast with the other even-even U isotopes. Neutrons excite only one spin state in ^{232}U up to ~200 eV, so Reich-Moore resonance parameters, fitting total and fission data, could be easily provided. We demonstrate how Reich-Moore parameter set, corresponding to two fission channels, proposed in BNL-325, could be modified to improve fit of total and fission data by Auchampaugh et al. (1968). Improved fission data description in the valleys between resonances might be obtained changing the character of interference between resonances. It is possible to reconcile the data by Auchampaugh et al. with data by Fursov et al. (1968) at higher energies using statistical model calculation. Fission threshold is not observed in the reaction $^{232}U(n,f)$, nonetheless we argue that step-like irregularity in fission cross section around ~1 MeV incident neutron energy also might be attributed to the step in the level density of fissioning nuclide, as it was done in case of $^{238}Pu(n,f)$ reaction cross section [1].

In the domain of emissive fission rather different contribution of (n,nf) reaction for the $^{232}U(n,f)$ reaction, than in case of $^{238}U(n,f)$ reaction is observed. Relative contribution of ^{232}U (n,nf) reaction is lower than in case of $^{238}U(n,nf)$ reaction for $E_n < 9$ MeV, but much higher for $E_n > 9$ MeV. These peculiarities are direct consequence of high ^{232}U target nuclide fissility with neutrons and consequent high non-emissive fission contribution to the observed fission cross section. Data on fission probability of ^{232}U, measured in transfer reaction (Gavron et al.,1978) are compared with calculated fission probability of ^{232}U for the reaction $^{231}U(n,f)$. The decreasing trend of $^{232}U(n,f)$ above E_n~7.5 MeV is correlated with the absorption reaction cross section.

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Fragments of Fission at Low Kinetic Energies

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Mass, charge and energy distributions of the fragments have been measured for the fission reaction U235 (nth ,f), using the Cosi Fan Tutte spectrometer at the high flux reactor of the Institute Laue Langevin of Grenoble.

At high kinetic energies, fission fragments are emitted cold; without excitation energy. At very low kinetic energies, where the analysis of experimental data is very delicate because of the poor charge resolution of the spectrometer and the low statistics[1] some autors[2] suggest that the naissants fragments are cold and heavily deformed; the excitation energy recuperated by the compound nucleus in its transition from saddle to scission point is transformed into energy of deformation. Aour analysis at vey low kinetic energies is in desageement with hypothesis.

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Chaos and Symmetry Breaking in Nuclei

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Abstract

Complete spectroscopy has been performed on the nuclide ^{30}P from the ground state to 8-MeV excitation energy — the angular momentum J, parity Π, and isospin T are known for 103 of the first 107 levels. For this N = Z = odd nuclide the two isospins (0 and 1) coexist throughout the spectrum. This provides the opportunity to measure the effect of symmetry breaking on the fluctuation properties. The small symmetry breaking (a few %) has a large effect on the eigenvalue distribution. The Brody parameter ω is about the same as obtained from our earlier measurement on ^{26}Al. The distribution of the electromagnetic transition strengths deviates from the Porter-Thomas distribution. Again there is qualitative agreement with our earlier measurements in ^{26}Al. Although the results disagree with the standard heuristic argument (that the Porter-Thomas distribution should be observed), recent theoretical (random matrix) predictions are consistent with the experimental observations.

ON POSSIBLE DIFFRACTION EFFECT IN n,e-SCATTERING EXPERIMENT

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An analysis of the known results of Khorn and Ringo [1] was fulfilled under influence of the made long ago prediction of Akhieser and Pomeranchuk [2] on the neutron diffraction in single-atom gas. A small forward-backward asymmetry of neutron scattered by gas can be caused not only by n,e-scattering but also by the interference of neutron waves scattered by neighbouring atoms. The value of diffraction effect is proportional to the gas pressure while the n,e-scattering effect is not dependent on pressure, so a certain addition to the n,e-scattering effect of amount $(34\pm20)\cdot10^{-5}$ for krypton and $(27\pm14)\cdot10^{-5}$ for xenon was found. However, theoretically predicted diffraction effect is 4 – 6 times less than one obtained from Khorn and Ringo data.

Is there diffraction in single-atom gas or is not, the answer can be received from the special experiments only, fulfilled using monoenergetic neutrons (or time-of-flight method) and higher gas pressures.

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Heavy metals in *Hypnum cupressiforme* collected in the surroundings of the petrochemical centers Ploiesti and Slovnaft

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The terrestrial moss *Hypnum cupressiforme* was collected in the surroundings of the petrochemical centers Slovnaft (Slovakia) and Ploiesti (Romania) to monitor atmospheric deposition of the heavy metals. Sampling was carried out according to the guidelines of the UNECE ICP Vegetation [1, 2]. Epithermal neutron activation analysis (ENAA) and atomic absorption spectrometry (AAS) methods were used to determine the concentration of vanadium, chromium, iron, cobalt, nickel, copper, zinc, arsenic, bromine, silver, cadmium and lead in moss samples. A comparative evaluation of heavy metal atmospheric deposition recorded on the two impact areas versus a background area in Europe (Norway) is presented. The highest concentrations were observed for V, Cr, Fe, Co, Ni and As at Ploiesti and for V, Cr, Fe, Co, and Ag at Slovnaft. The bioindication index (here, ratio of maximal/minimal concentration) ranging from 2 to 20 reflects the variability of heavy metal content in the moss *Hypnum cupressiforme*. The correlation factor between vanadium and nickel is 0.87 and 0.98 in Ploiesti and Slovnaft areas, respectively, and is related to distinct characteristics of the local sources concerned. The crustal enrichment factors were calculated on the basis of local soil data. They were further used to provide a differentiation between the atmospheric pollution associated with the local industry and the possible incidence of soil contamination of moss samples. It is concluded that *Hypnum cupressiforme* can be used as biomonitoring organism to indicate and characterize deposition of atmospheric pollutants nearby the petrochemical centers.

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CHROMIUM UPTAKE BY *ARTHROBACTER OXYDANS* STUDIED BY NAA

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Environmental pollution by chromium is widespread in soils, sediments and groundwater. As a transition element it occurs in a number of oxidation states, however, only two stable trivalent and hexavalent species are significant in environmental systems. Hexavalent chromium [chromate: Cr(VI)] compounds are highly soluble and toxic, while Cr(III) compounds are less soluble and less toxic. Certain species of bacteria are capable of transforming Cr(VI) to Cr(III).

In this work NAA method was applied to study Cr(VI) and Cr(III) uptake by *Arthrobacter oxydans,* gram-positive endolithic (rock/mineral inhibiting) bacterium, isolated and cultivated from the Columbia basalt samples (USA). Cr(VI) (as K_2CrO_4) and Cr(III) (as $Cr(CH_3COO)_3$) were added into the culture medium at the exponential growth-phase of *A.oxydans*. The concentrations of chromium species were in range of 10-200 μg/ml. NAA measurements confirmed that *A.oxydans* do not accumulate Cr(III) in contrast to Cr(VI) which easily penetrates bacterial cells. The value of Cr(III) uptake by Cr(VI) which easily penetrates bacterial cells. The value of Cr(III) uptake by *A.oxydans* cells is about of an order of magnitude less then uptake Cr(VI). In addition, NAA showed that Cr(VI) uptake is dose-dependent. Chromate uptake is found to be much faster up to 70 μg/ml. These results are well correlated with the kinetics of Cr(V) formation and reduction by *A.oxydans*. Reduction of Cr(VI) to Cr(V) was measured by ESR spectroscopy.

Primary Gamma Transitions in ^{159}Gd after Resonance Neutron Capture

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Abstract

Level states and electromagnetic transitions in this nucleus were studied by means of radiative neutron capture at 12 isolated resonances of ^{158}Gd. The Time of Flight technique was used on an enriched target at the IBR-30 reactor at JINR Dubna. A total of 80 primary γ-rays and their absolute intensities were recorded resulting in the complete observation of levels with $J^{\pi} = 1/2^{\pm}, 3/2^{\pm}$ up to 2400 keV excitation. The sum of the observed γ-ray strength amounts to 30 % of the total gamma width. This result is confirmed the calculation of the remaining γ-ray strength up to the capture state region based on the validity of a Giant Dipole Resonance of Standard Lorentzian Shape in describing the photon strength in terms of the Axel-Brink model. The $E1$ strength function agrees well with a Giant Dipole Resonance of Standard Lorentzian Shape with parameters from ^{159}Tb. The $M1$ strength function exhibits an average constant value of $(1.5 \pm 0.3) \times 10^{-8}$ MeV^{-3} and appears to be energy independent as in the single particle Weisskopf model. Correlations among different partial radiation widths and among neutron widths and different partial radiation widths were studied. Spin-parity assignments were proposed for most populated level states. The neutron binding energy was determined to be (5943.1 ± 0.1) keV.

Measurement of Neutron Capture Cross Sections of Dy-161 and Dy-163 Between 0.002eV and 10 keV using Total Energy Absorption Detector

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The neutron capture cross sections of Dy-161 and Dy-163 have been measured in the energy region from 0.003 eV to several tens of keV by using the neutron time-of-flight (TOF) method with a 46 MeV electron linear accelerator (linac) at the Research Reactor Institute, Kyoto University (KURRI). An assembly of twelve pieces of $Bi_4Ge_3O_{12}$ (BGO) scintillators (each size: 5 cm x 5 cm, 7.5 cm long), which was placed at a distance of 12.7±0.02 m from the neutron source, was employed as a total energy absorption detector for the prompt capture gamma-ray measurement, to obtain the absolute capture cross sections. The enriched samples of Dy-161 and Dy-163 are a form of metallic plate (15 mm in diameter, 0.225 mm in thickness). A natural boron sample (18 mm x 18 mm, 1.10 g/cm^2) was employed to monitor the neutron flux/spectrum of the TOF beam using the standard reference cross section of the ^{10}B(n,α) reaction. The Dy sample or B-10 capture sample was set at the center of the through hole in the BGO assembly.

The current measurement has been compared with the previous measurements and the evaluated data in ENDF/B-VI .

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QUASIPARTICLE RPA WITH FINITE RANK APPROXIMATION FOR SKYRME INTERACTIONS

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Among the great variety of microscopic nuclear models aiming at a description of the properties of nuclear excitations one can distinguish one approach in which the emphasis is put on the consistency of the picture by employing an effective interaction which must describe, throughout the periodic table, the ground states in the framework of the Hartree-Fock (HF) approximation and the excited states in time-dependent HF, or random phase approximation (RPA) or approximations beyond. To this class belong the Skyrme-type interactions [1]. When the residual particle-hole (p-h) interaction is separable, the RPA problem can be easily solved no matter how many p-h configurations are involved. Starting from an effective interaction of Skyrme type, a finite rank separable approximation is proposed [2] for the residual particle-hole interaction with the aim to allow one to perform structure calculations in very large particle-hole spaces.

Now we extend this approach to take into account the pairing paying a special attention for the quadrupole and octupole states in nuclei with very different mass numbers. As an application we present results of calculations for low-lying 2^+ and 3^- states in some O, Ar, Sn and Pb isotopes. As one can see from table calculations are in a reasonable agreement with experimental data.

Table : Energies and B(E3)-values for up-transitions to the first 3^- vibrational states of ^{36}Ar, ^{112}Sn and ^{208}Pb

Nucleus	Energy (MeV)		B(E3↑) (e^2fm^6)	
	Exp.	Theory	Exp.	Theory
^{36}Ar	4.18	4.26	11100 ±1100	16000
^{112}Sn	2.36	2.73	87000 ±12000	97000
^{208}Pb	2.62	2.66	611000 ±9000	860000

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Background modelling for the nn-experiment at the reactor YAGUAR

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Abstract

As a next step in the experimental programm /1,2/ at the reactor YAGUAR, a proof-of-principle of the nn-experiment is planned with the main goal to study background conditions. This experiment will be performed at a continuation of the flight path drilled beneath the concrete floor of the Yaguar experimental hall. We report on the MCNP modeling of the neutron background at this flight path emphasizing the delayed fission neutrons contribution.

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NEUTRON SPIN FILTER BASED ON OPTICALLY POLARIZED ^{3}HE IN A NEAR-ZERO MAGNETIC FIELD

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A test of polarization of ^{3}He nuclei via spin – exchange collisions with optically pumped rubidium atoms in an extremely low applied magnetic field was carried out. Permalloy magnetic shields were used to prevent a fast relaxation of ^{3}He polarization owing the inhomogeneity of a surrounding magnetic field. The whole installation was placed at the neutron beam line of the IBR – 30 facility, and used as a neutron spin filter. Thus, a prototype of new design of neutron polarizer was introduced. We intent to apply this experience for the full – scale KaTRIn facility to test the time reversal violation in neutron – nuclear reactions.

These experiments were supported by Russian Foundation for Basic Research (00-15-96586, 02-02-16980), Federal Program "Integration" (Б-0049) and Alexander von Humboldt Stifftung.

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NEW COMPILATION OF NEUTRON RESONANCE PARAMETERS

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Neutron Resonance parameters Files – NRF [1] contain recent information on individual resonance parameters, including γ-ray spectra as well as RI, thermal and 30 keV cross sections. Standard data presentation makes these compilations useful in bringing together different branches of nuclear research [2]. The high accuracy of data needed in applications (reactor technology, astrophysics etc.) put a question about a role of cross section modulations frequently described as an influence of few-nucleon configurations (door-way states) [3]. A well-known example of such effect is grouping of s-resonances at 500 keV in compound ^{207,208,209}Pb [1]. Grouping of E_n'=A/(A+1)E_n in different Ca isotopes (Table 1) persists in distribution of E_n' in all Z≤28 N-even nuclei (Fig.1, left). Grouping of $E_n'=E^*$-S_n is the result of the tuning effect in both values (E^*,S_n) which is seen directly in spacing distributions of the same nuclei (D and relations between them in Table 1) [3,4]. Two other examples of groupings of E_n' are given in Fig.1 (right):

1) E_n'=84 keV in Z-odd nuclei (^{46}Sc – ^{60}Co) are close to D=85 keV in ^{55}Co, ^{65}Cu [4];

2) The groupings in all light nuclei Z=20-28 at E_n'=61 keV, E_n'=183 keV and at double value E_n'=372 keV. Stable spacings D=123-246-492-1476-3939 keV (1:2:4:12:32) were found in light and near-magic nuclei and were considered as a manifestation of series with n=13 (of period 19 keV/4=4.75 keV seen in spacings). The maximum at D=1477 keV in spacing distribution of N-even Z=21-30 nuclei has 5σ (standard deviations) [5].

Table 1: Positions E_n'=19 keV and spacings D=k×9.5keV in resonances of Ca and ^{61}Ni

Nucl.	^{41}Ca	^{41}Ca	^{43}Ca	^{45}Ca	^{49}Ca	^{49}Ca	^{41,43}Ca	^{61}Ni	^{61}Ni	^{61}Ni	^{61}Ni	^{61}Ni	^{61}Ni
l_n	2	0	1	1	2	≤3	D_{ij} [3]	l_n=0	D_{ij}	D_{ij}	D_{ij}	D_{ij}	D_{ij} [3]
E_n,keV	19.34	20.43	19.06	20.47	19.23	19.23		19.34					
E_n',keV	18.87	19.93	18.62	20.01	18.84	18.84	342	18.87	4.8	9.3	14.1	19.0	23.7
k(8ε′)	2	2	2	2	2	2	2x18	2	1/2	1	3/2	2	5/2
kx8ε′	19.00	19.00	19.00	19.00	19.00	19.00	342	19.00	4.75	9.50	14.25	19.00	23.75

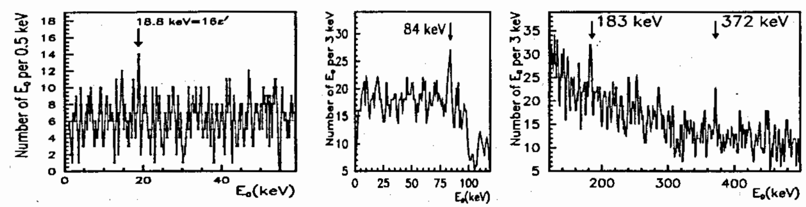

Figure 1: Distribution of resonance positions in all N-even light nuclei (left, region 0-60 keV), in Z-odd nuclei (region 0-90 keV), in all light nuclei (region 100-500 keV).

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Monte Carlo modeling of the neutron field inside the Yaguar through channel

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Experiments have recently been proposed /1-3/ to measure the nn-scattering length at the Yaguar reactor at the All-Russian Research Institute of Technical Physics in Snezhinsk, Russia. The unique design of this pulsed reactor provide a high, 10^{18}cm^2/s, instantaneous neutron flux in a cylindrical through channel at the center of the reactor. We report on Monte Carlo modeling calculations using MCNP to determine characteristics of the neutron field within the through channel. Extensive calculations of the time, velocity, space and angular distributions of neutrons emitted by the inserted thermal neutron polyethylene convertor have been performed. The obtained results and their implications on the neutron-neutron collision rate will be discussed.

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Quasi-Elastic UCN Scattering

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Abstract: Ultracold neutrons (UCN) are lost from traps if they are quasi-elastically scattered from the wall with an energy gain sufficient to exceed the Fermi potential for the wall. Possible mechanisms of a quasi-elastic energy transfer are, for instance, scattering from hydrogen diffusing in an impurity surface layer or on capillary waves at a liquid wall. Using two different experimental methods at the UCN source of the Institut Laue-Langevin we have investigated both the energy-gain and the energy-loss side of quasi-elastic UCN scattering on walls coated with Fomblin grease. For Fomblin oil and similar new types of oil we report up-scattering data as a function of temperature and energy transfer. These low-temperature oils may be used in an improved measurement of the neutron lifetime, which requires a wall coating with extremely low reflection losses.

TUNING EFFECTS IN PARTICLE MASSES AND NUCLEAR DATA

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The QED correction to the electron magnetic moment as well as to mass was discussed in [1]. The lepton ratio L=m_μ/m_e becomes closer to an integer after correction m_e^o=$m_e(1-\alpha/2\pi)$, namely L=m_μ/m_e^o=207.008. This fact was combined in [2] with two observations based on analysis of data in nuclear spectroscopic and neutron resonance parameters files:

1) the ratio $\alpha/2\pi$=1.16×10^{-3} can be used as a scaling factor for comparison of stable nuclear intervals ε_o=1.022 MeV, ε'=1.2 keV and $4\varepsilon''$=5.5 eV (seen in neutron resonances);

2) noticed by R.Sternheimer stable intervals in particle masses m_i^S=441 MeV (Table, left) continue this dimensionless relations into higher energies. The corresponding value for the reduced mass m_e^o is $m_e^o(\alpha/2\pi)^{-1}$=440.2 MeV, close to M_q^o=$m_{\Xi^-}/3$=440.44(4) MeV discussed by P.Kropotkin together with m_i^S [2]. The first intervals m_i^S between masses of nucleon m_n and Σ^o-hyperon consists of two parts: hadronic nucleon Δ-excitation (293.7 MeV=2ΔM_Δ=2×147 MeV) and m_s=147 MeV. New relations with $\alpha/2\pi$ are:

3) mass splitting of pion δm_π=4.594(4) MeV forms ratio $\delta m_\pi/m_e^o$=9.000(1) [3];

4) muon and vector boson masses form ratio m_μ/M_Z=105.658/91188(2)=1.159×10^{-3} close to 1.1597×10^{-3}=$\alpha/2\pi$-... It means that M_Z/M_q^o=L=207 (see Table, at right).

5) Close to m_i^S are estimations of constituent quark masses M_q (Table): a) assuming relation m_s=ΔM_Δ=150 MeV calculation of strange baryon masses gives M_d=436 MeV and b) model with Goldstone boson exchange has initial nucleon mass M_N^{GBE}=3M_q=1350 MeV or constituent quark mass (before inclusion of residual interaction) M_q=450 MeV.

Table. Relations between the parameter ΔM_Δ=18·16m_e and particle masses, their differences Δm_i and stable intervals in nuclear binding energies ΔE_B [3,5].

Param. (MeV) J^π	Δm_i^S [2,3] $m_{\Sigma^o}-$ $-m_n$	m_n- $-m_{K^o}$	$m_\eta-$ $-m_\mu$	M_q M_d 1/2$^+$	[3,4] $M_N^{GBE}/3$ 1/2$^+$	ΔE_B [5,6]	ΔE_B [5,6]	M_q^o $m_e^o\times$ $\alpha/2\pi$	M_q^o $m_{\Xi^-}/3$ 1/2$^+$	M_q^o M_Z/L [3,5]
Δm_i	441.1	441.9	441.6	436	450	147.2	441.1	$\boxed{440.2}$	$\boxed{440.4}$	$\boxed{440.5}$
kx18x16m_e	441.5	441.5	441.5	441.5	441.5	147.2	441.5	441.5	441.5	441.5

Parameters of tuning effect in nuclear binding energies ΔE_B [5,6] are included in the Table as additional hadronic values supporting the distinguished character of Δm_i^S=3·ΔM_Δ and ΔM_Δ=18·16m_e. Nuclear physics data on QED correction [2] and long-range correlations with m_e [5,6] are in line with other hadronic data. QCD is a member of Standard Model scheme $SU(3)_{col}\otimes SU(2)\otimes U(1)$. The inclusion of hadronic parameter M_q^o into relations with SM-parameters (m_e, m_μ, M_Z, α) could mean that SM-condensate responsible for masses of fundamental fermions [7] has a discreteness with parameters M_q^o and m_e^o.

The role of neutron data in checking stable hadronic nuclear intervals is discussed [8].

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FINE AND SUPERFINE EFFECTS IN NEUTRON RESONANCES

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Modulations of local neutron strength function was discussed earlier [1] after plotting positions (E_n) of all known relatively strong neutron resonances. The fine structure with period 30 keV was found in light and near magic nuclei. Grouping of E_n was checked [2] by analysis of data in a special table of BNL-325 [3] where ten strong resonances in each nucleus are presented. Grouping at E_n=2ε' and 4ε' were found with parameter of fine structure ε'=1.188 eV determined from the following consideration of the observed by Ohkubo correlations in positions of resonances in compound nuclei ^{82}Br, ^{124}Sb and ^{141}Ce.

Position of strong neutron resonance E_n' (after recoil correction) is a difference between E^* of a state with the relatively simple structure of wave function and S_n. It was noticed [4] that in ^{141}Ce positions of two strongest resonances (marked by * and ** in Table) are in ratio 9:4=2.25 (2.253 in fact). The same ratio (2.237) exists between energies of low-lying excitations of ^{143}Ce (Table, center). The triplet of these closely spaced levels (next E^* is located at 633 keV) is a result of the residual interaction of three valence neutrons. One could notice ratio 1:2 between values E_n' in ^{141}Ce and E^* in ^{143}Ce (ratio 0.505). E_n' of strong s-resonances in some other N=83 nuclei are related to these E_n'. For example, E_n' in ^{142}Pr is close to that of ^{141}Ce (marked as 8ε'=8×1.188 keV) while E_n' in ^{140}La is close to ε' (Table). In near-magic ^{145}Sm (N=83) position of p-wave resonance with largest Γ_n^1 is close to ε' (while stable spacing of its s-wave resonances has D=ε'/3). Stable intervals D=595 eV=ε'/2 and D=294 eV=ε'/4 were found in resonances of ^{134}Cs [2] and ^{128}I [5].

Clustering of strong resonances in ^{82}Br [4] was found to have small (0,03) occasional probability of grouping. Table shows that E_n' of the strongest resonances in ^{80}Br, ^{82}Br and ^{86}Rb are close to ε' and 2ε'. In ^{182}Ta E_n' of two strongest s-resonances are ε' and ε'/2.

Table 1: Positions of strong resonances in some near-magic nuclei and E^* in ^{143}Ce

Nucl.	^{141}Ce		^{142}Pr	^{140}La	^{143}Ce	3/2$^-$	^{80}Br	^{82}Br	^{86}Rb	^{182}Ta	
J_i^π, l_n	l_n=0	l_n=0	l_n=0	l_n=0	7/2$^-$	5/2$^-$	l_n=0	l_n=0	l_n=0	l_n=0	l_n=0
Γ_n^o,meV	660**	3060*	160	54			72.0*	120*	159**	19.5*	17.7**
E_n	9.573	21.57	9.598	1.179			1.201	1.209	2.398	1.192	0.597
E^*,E_n'	$\boxed{9.505}$	21.42	$\boxed{9.530}$	1.170	18.9(1)	42.28	$\boxed{1.186}$	$\boxed{1.194}$	2.370	$\boxed{1.185}$	$\boxed{0.593}$
m(ε')	8	18	8	1	16	36	1	1	2	1	1/2
m×ε'	$\boxed{9.504}$	21.38	$\boxed{9.504}$	1.188	$\boxed{19.0}$	42.77	$\boxed{1.188}$		2.376	$\boxed{1.188}$	$\boxed{0.594}$

The suggested in [6] common approach to the description of excitation and binding energies (E_B) was used here for evaluation of general parameters of interaction of valence nucleons and common parameters determined from stable E^*, D=E_i^*-E_j^* and ΔE_B could be checked by distributions of E_n' (differences between E^* and ΔE_B) in many nuclei.

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A NEW METHOD FOR NUCLEAR-REACTION NETWORK ANALYSIS, ELEMENT PRODUCTION IN S-Cl REGION, DURING THE HE AND C BURNING IN 25 $M_\odot$ STARS

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The results of the calculations of the element overproduction in S-Cl region during the helium and carbon burning in massive stars (25 $M_\odot$) are presented (Fig. 1 & 2) and discussed.

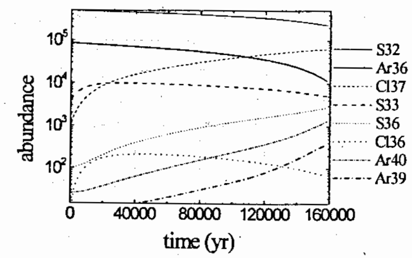

Fig. 1. The time dependence of the isotope abundance during the He burning

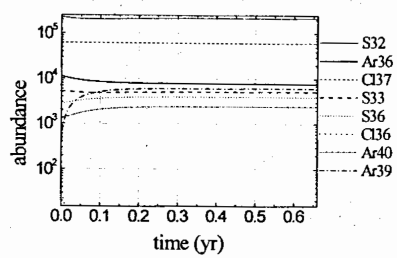

Fig. 2. The time dependence of the isotope abundance during the C burning

The calculations for the given set of the differential equations were performed using integrated mathematical systems. The authors consider that such method may be successfully adopted for other physical problems, in particular for the problem of transmutation of heavy elements and chemical kinetics.

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MEASUREMENT OF THE ELECTRIC HYPERFINE COUPLING CONSTANT

P / k IN RUN CRYSTAL.

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Abstract

The accuracy of electric hyperfine P/k constants received in the end of the fifties for uranium nuclei in the crystal of Rubidium-Uranil Nitrate (RUN) [1-3] usually used for orientation of fissile nuclei [3-5] now turns into a limitation the accuracy of the nuclear fission information that may be extracted from the modern experiment [5]. So the necessity of their independent measurement with more accuracy was appeared. This work is the first step in this direction and is dedicated to the measurement of constant P/k of ^{233}U nuclei in RUN crystal. For the temperature range (293 – 0.3)K the 17 runs was made with statistic on the order of 10^7 events in detector for each run and the sample temperature accuracy about (0.1 – 1.5)%. The obtained data of the temperature dependence of an α-emission at 0°, 45° and 90° directions relatively to the orientation spin axis of ^{233}U nuclei aligned in the RUN crystal were processed by a joint analysis with help the computer code created for analytical expressions for an angular distribution of alpha emission for aligned nuclei and standard procedure MINUIT. Obtained estimation of the value hyperfine constant P/k for ^{233}U nuclei has an accuracy for the present about 30%. To improve more the constant accuracy it is needed to increase more than an order the statistic of useful events, to decrease the sample temperature and to increase the accuracy of temperature to 2 – 3 mK for the low temperature runs.

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THE STUDY OF P-ODD ASYMMETRY $\alpha_{PN}(\vec{s}_n, \vec{k}_\gamma)$ IN THE $^{10}B(n,\alpha)^7LI^* \Rightarrow \gamma \Rightarrow {}^7LI(g.s.)$ REACTION

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The experiment on measurement of the P-odd asymmetry of emitted γ-quanta in the $^{10}B(n,\alpha)^7Li^* \rightarrow \gamma(M1,\ 0.478\ MeV) \rightarrow {}^7Li(g.st.)$ reaction was carried out at polarized cold neutron beam of the PF1B instrument of the ILL reactor, Grenoble, France. Whole neutron beam intensity ($\sim 3 \cdot 10^{10}\ s^{-1}$) was utilized by use an enriched boron sample of respective size, that provide with emitted γ-ray intensity on detector more than $10^9\ s^{-1}$. A system consisted of two NaJ(Tl) detectors operated in the current (integral) mode of event registration. Main measurements with the enriched ^{10}B sample and several background runs were performed. The resulting P-odd asymmetry coefficient is $\alpha_{PN} = +(25.8 \pm 6.5) \cdot 10^{-8}$.

According to the number of theoretical works, a study of the P-odd effects in the neutron reactions with superlight nuclei may be one of the ways for searching of the weak neutral current in the N-N interactions.

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PHOTOFISSION IN MASSIVE URANIUM TARGET

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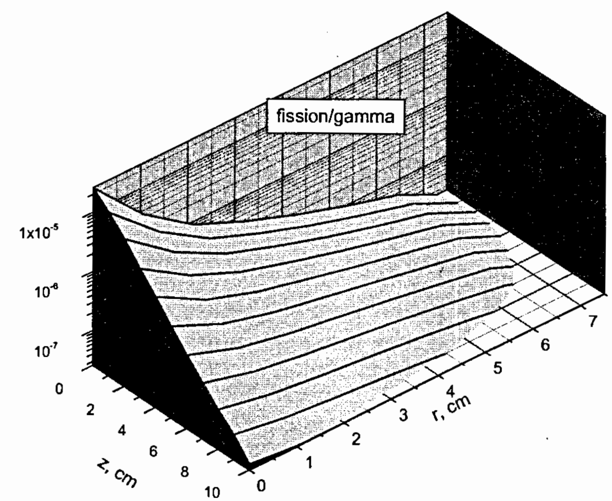
Fission process of heavy nuclei induced by bremshtrahlung gamma rays is interesting from different points of view: transmutation of minor actinides, radioactive beam source, verification of transport codes and data base etc.

We calculated distribution of fission probability in massive uranium target with different abundant and content.

It is obvious the important role of fission by secondary neutrons from the (γ,f), (γ,n), (γ,2n) reactions. To produce cross section library theoretical calculations of cross sections and neutron spectra were done.

Transport calculations were performed with KASKAD and MCNP code to take in consideration all interactions inside massive target. The MCNP code was applied to estimate spatial distribution of the (γ,f) reaction rate. The KASKAD 2D code is intended for transport, criticality and sub-criticality calculations in 2D geometry. It was used to calculate fission densities resulting from the (γ,n), (γ,2n) and (γ,3n) reactions separately. Fission probability distribution is presented in the Figure.



Fission events distribution (fission per one gamma) in massive natural uranium cylindrical target.

DIGITAL SIGNAL PROCESSING APPLICATION TO CHARGED PARTICLE SPECTROSCOPY WITH DOUBLE IONIZATION CHAMBER

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The great potential contained in digital signal processing technology opens new perspectives for particle detectors traditionally used in nuclear physics studies. In the present paper results of investigation of charged particle spectroscopy using Frisch-gridded ionization chamber and digital signal processing technology are presented. We found advantage provided by this technology which made available both alpha-, and fission fragment spectroscopy with more flexibility and better quality in respect to traditional analog technology.

MEASUREMENT OF THE THICK TARGET 9Be(p,n) NEUTRON SPECTRA AND ANGULAR DISTRIBUTIONS

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Investigation of white neutron sources is of interest for many applications, such as measurement of the neutron induced cross-sections in a wide energy range simultaneously, accelerator-based boron neutron capture therapy, calibration of the neutron spectrometers, etc. ^{9}Be(p,n) reaction is a preferable high intensity white source of neutron as it has low neutron production threshold, beryllium is a good material for removal of heat and proton produce lesser neutron and gamma background during transport of beam. In the present work the thick target neutron spectra and angular distributions of the ^{9}Be(p,n) reaction have been measured in the range of proton energy from 8.2 MeV to 11.2 MeV for angles of (0-140) degrees. The measurements were performed by time-of-flight spectrometer on the pulsed tandem accelerator EGP-15 of IPPE [1]. Neutrons were detected by the stilben crystal scintillation detector with neutron energy threshold of 0.25 MeV, the efficiency of which was determined by measuring of the ^{252}Cf prompt fission neutron spectrum by the time-of-flight method in the same geometry of the experiment. The energy neutron spectra and the angular distributions are presented.

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NUCLEAR LEVEL DENSITIES FROM NEUTRON SPECTRA IN PROTON-INDUCED REACTIONS ON ISOTOPES OF TIN, LEAD AND BISMUTH

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Excitation functions, neutron spectra and angular distributions in (p,n) reaction on isotopes of ^{116}Sn, ^{118}Sn, ^{124}Sn, ^{208}Pb, ^{209}Bi have been measured in proton energy range of (7-11) MeV. The measurements were performed by time-of-flight fast neutron spectrometer on the pulsed tandem accelerator EGP-15 of IPPE [1]. The high resolution (~0.6 ns/m) and stability of time-of-flight spectrometer allowed to identify reliably the discrete low-lying levels together with continuum part of neutron spectra. Analyses of the measured excitation functions, neutron spectra and angular distributions have been carried out in the framework of statistical equilibrium and pre-equilibrium models of nuclear reactions. The calculations are done with computer code PEAK-98[2] using the exact formalism of the statistical theory as given by Hauser-Feshbach with generalized superfluid model of nucleus [3], back-shifted Fermi-gas model [4] and composite formula of Gilbert and Cameron [5] for nuclear level density. The nuclear level densities of ^{116}Sb, ^{118}Sb, ^{124}Sb, ^{208}Bi, ^{209}Po, their energy dependences and model parameters have been determined. In energy dependences of the nuclear level density between well-known low-lying levels and continuum part of excitation spectra is displayed the structure connected with the shell unhomogeneties of a single-particle state spectrum for nuclei near filled shells. For nuclei of Sb the isotopic dependence of nuclear level density is found out and explained. It is shown also that the obtained experimental data differ essentially from the predictions of nuclear level density model systematics.

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MEASUREMENT OF TOTAL CROSS SECTIONS FOR THE VERY COLD NEUTRON (VCN) INTERACTION WITH A RANK OF MATERIALS IN TEMPERATURE RANGE OF 80-300 K

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The total cross section of interaction of very cold neutron with several types of fluorine substituted oil, polyethylene and sapphire were measured in temperature interval 80-300 K. Results of measurement can be used for different applications in neutron physics.

INVESTIGATION OF POSSIBILITIES TO STORE VERY COLD NEUTRONS (VCN)

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Investigation of possibilities to store very cold neutrons (VCN) was started at the ILL (Grenoble) at 2002 and the first result is now presented. It was experimentally investigated reflection of VCN for samples (teflon, Fomblin grease, graphite powder admixture in Fomblin oil). The existence of a such neutron reflection was observed and can be explained by spatial inhomogeneity of Fermi potential for investigated matters. The probability of neutron losses per one reflection was measured for neutrons with velocity 9 m/s kept in teflon trap and was estimated as 0.0384 ± 0.002.

MEASUREMENT OF SPECTRAL CHANGES OF UCN REFLECTED ON HYDROGEN FREE OIL AFTER WEAK HEATING

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Results of measurement of spectral changes of UCN reflected on hydrogen free oil in the process of weak heating are presented. Measurements were performed for oil temperature of 25, 75 and 100° C with the help of Gravitational Flight Spectrometer of UCN.

Prospects for Investigation of Time Reversal Invariance Violation with the Use of Five-fold Correlation

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Abstract

Large parity non-conserving (PNC) effects have been observed in neutron-nuclei interactions. The values of PNC effects are enhanced by five-six orders of magnitude in some cases [1] as compared to the values of PNC effects in nucleon-nucleon interactions. One can expect [2] an analogous enhancement of time reversal invariance (TRI) violation effects in neutron-nucleus interaction with the use of P-odd and T-odd three-fold correlation $\sigma[\mathbf{pI}]$ (here σ, $\mathbf{p}$ and $\mathbf{I}$ are the neutron spin, neutron momentum and the nucleus spin, respectively). To measure this correlation a polarized nuclear target is needed. The TRI violation effects in neutron-nucleus interaction can be investigated also with the use of P-even T-odd five-fold correlation $\sigma[\mathbf{pI}](\mathbf{pI})$. In this case an aligned target is required. The arguments were advanced in favour of some enhancement of this TRI violation effect as compared to the effect in few nucleon systems [3,4]. The main problem for both three-fold and five-fold correlation experiments is an overcoming of false effects, which can imitate effects under investigation. The second serious problem is a development of appropriate polarized and aligned nuclear targets. Up to now there is no polarized nuclear target with required properties. The method of dynamical nuclear alignment (DNA) proposed in [5] opens a way to produce aligned nuclear targets for five-fold correlation studies in neutron-nucleus interaction. The possibilities of production of target materials for aligned targets are briefly considered. The first experiment on the development of DNA method is in progress [6].

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Optical precession of the cold neutron spin in a noncentrosymmetric crystal

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Abstract

Effect of neutron-optic spin rotation in a noncentrosymmetric crystal was experimentally observed. The effect is caused by Schwinger interaction of neutron, passing through the crystal far from any Bragg condition, with an interplanar electric field of the noncentrosymmetric crystal and depends on a direction and energy of neutron.

For α-quartz crystal it is shown, that the value of resultant electric field affecting on a neutron is $|\mathbf{E}_{sum}| \approx (1-10)\cdot 10^4$ V/cm for broad band of neutron wavelengths and corresponding value of the angle of neutron spin rotation may reach $\pm 2\cdot 10^{-4}$ rad/cm. The measured effect has well coincided with the theoretical one.

Observation of this effect may be interesting for the search of the neutron electric dipole moment. In addition, there is a proposal for searching the T-odd part of nuclear interaction for energies, close to the P-wave neutron resonance, and that can be made only for large deviations from Bragg condition, because it is impossible to observe dynamical diffraction for neutron with energy ~ 1 eV due to crystal imperfection.

Laue diffraction method of a neutron EDM search. Project of the experiment

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Abstract

The project of the experiment of a search for a neutron electric dipole moment (EDM) using Laue diffraction in a noncentrosymmetric crystal is proposed. The method is based on the effect of depolarization of the diffracted neutron beam due to interaction with an interplanar electric field of a noncentrosymmetric crystal. The value of this field can reach $\sim 10^9$ V/cm.

Some features of the proposed method, which give us a hope to exceed the sensitivity of the most precision now magnetic resonance method using ultracold neutrons (UCN method) are the next:

- Existence of a strong electric interplanar field E_g (up to 10^9 V/cm) acting on a neutron, diffracted by crystal without a center of symmetry, during all the time of neutron stay in crystal. This field 10^5 times exceeds field used in UCN method.
- For Bragg angles close to $\pi/2$ the time τ of a neutron passage through the crystal essentially increases and can reach ~ 1 ms for α-quartz crystal.
- The feature of the depolarization effect is an absence of false effect from changing of an exterior magnetic field, because all the components of the vector of neutron beam polarization after the crystal are close to zero and its rotation in a magnetic field does not change the measured values.
- The angle of neutron spin rotation due to interaction of the EDM with the interplanar electric field is increased essentially for $\Theta_B \sim \pi/2$ whereas the angle due to Schwinger interaction does not depend on the Bragg angle at all.
- On-line monitoring of the main parameters of experimental setup, which allows discerning EDM-effect and false effects.
- The relative compactness of the setup.

The calculated sensitivity of the method is $\sim 10^{-25}$e·cm per day for really existing α-quartz crystal. Detail description of the set-up is given.

A PRECISE MEASUREMENT OF THE SPIN-DEPENDENT NEUTRON SCATTERING LENGTH OF ^{3}HE

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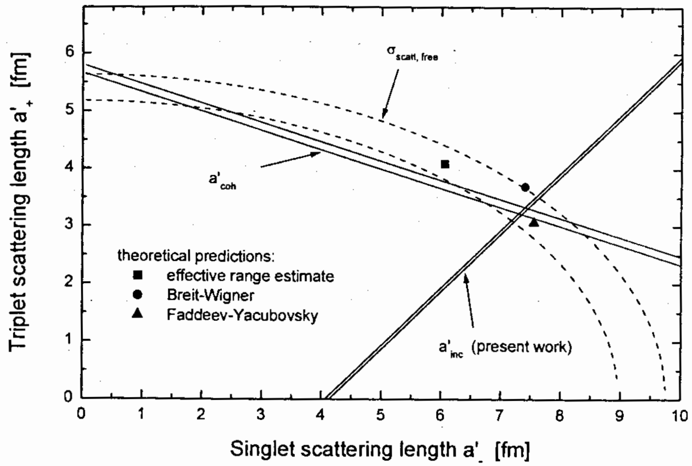
The poor knowledge of the spin-dependent scattering length of ^{3}He has until now handicapped nuclear four body theory and the interpretation of excitations in the quantum liquid. We have measured, for the first time directly, the real part of the bound incoherent neutron scattering length of ^{3}He. A neutron spin echo spectrometer was used to detect pseudomagnetic precession of polarised neutrons passing through polarised ^{3}He gas. Any absolute calibrations of sample and beam parameters were avoided using simple transmission measurements with non-polarised neutrons. The only *a-priory* information required was the spin-dependent neutron absorption cross section of ^{3}He. The result is b'_{inc} = -2.365(20) fm, which reduces the prior uncertainty by a factor 30. The corresponding accurate value of the bound incoherent scattering cross section is σ_{inc} = 1.532(12) barn, enabling an unambiguous interpretation of existing neutron scattering data off liquid ^{3}He. The figure illustrates the gain for the nuclear few body problem (see [1] for further explanations).



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STUDY OF REASONS FOR SMALL CHANGES IN ENERGY OF UCN IN TRAPS

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Annotation

We report the experimental study of reasons for the phenomenon of small changes in UCN energy [1]. The present experiment uses a new cryogenic gravitational UCN spectrometer, which has been recently constructed for these and related studies. We measured the spectra and the temperature dependencies of the upscattered neutrons at metal and nanopowder samples.

The probability of small changes in UCN energy at solid state surfaces (stainless steel, copper) is measured with better accuracy and methodical transparency than earlier. This new measurement confirms our previous results [1, 2]. The shape of the integral VUCN spectrum at stainless steel surface confirms our previous measurements also [1, 2]. The present experiment is precise enough in order to extract for the first time the corresponding differential neutron spectrum. The probability of this effect is measured as a function of the temperature treatment of the stainless steel sample. It revealed extremely well pronounced temperature dependence, which is useful for identification of the nature of this phenomenon.

Besides, we measured for the first time the small changes in UCN energy due to their interaction with nanopowder sample of ultradispersed diamond. The nanoparticles increases the probability by many orders of magnitude. The spectrum of corresponding VUCN is analogous to that produced at stainless steel surface. The temperature dependence for the probability of this effect appeared to be identical to that measured earlier at surfaces of beryllium or copper [3]. VUCN spectra at room temperature of the nanopowder and at the liquid nitrogen temperature of the nanopowder are the same. The experimental data are analyzed within the hypothesis of UCN Doppler shift at surface nanostructures or nanoparticles in the state of permanent thermal motion.

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LIMITATIONS FOR NEUTRON POLARIZATION AND SPIN ANALYSIS WITH THE USE OF SUPERMIRROR BENDER

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The progress in multilayers production makes supermirror bender to be standard instrument for neutron polarization and its analysis. However, the polarizing properties of such bender are strongly angular and neutron wavelength dependent. This geometrical factor limits the averaged polarization achievable for the beam of wide angular divergence and broad wavelength spectrum. Moreover, serious problems rise up in attempts to analyze the beam polarization also using an analyzer based on supermirror bender. We will show how these difficulties could be overcome significantly.

A COMPARATIVE STUDY OF *PSEUDOSCLEROPODIUM PURUM* AND *RHYTIDIADELPHUS SQUAROSUS* IN A MINING DISTRICT OF ROMANIA

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The difficulty of thorough sampling of a particular moss species in biomonitoring studies is well-known. On the scale of a country or even a region it is not always possible to collect samples of one particular species with a sufficiently high density of sampling. In particular, during the summer 2000 in the Baia Mare region it was not always possible to sample moss species in keeping with Scandinavian standards. Nevertheless, samples of the moss *Pseudoscleroposium Purum* and *Rhytidiadelphus Squarosus* were collected during the summer 2000 in the Baia Mare area intensively exploited for non-ferrous metals (Cu, Zn, Pb) and then analyzed by NAA at the IBR-2 reactor in Dubna. A comparison of the elemental compositions of two species from the same sampling site was carried out. The regression equations for the moss concentration data were calculated for the elements of interest from the pollution viewpoint. The eventual phenomenon of saturation is also discussed.

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