ISINN-27

XXVII International Seminar on Interaction of Neutrons with Nuclei

Fundamental Interactions & Neutrons, Nuclear Structure, Ultracold Neutrons, Related Topics

Dubna, 2019 **Abstracts**

Joint Institute for Nuclear Research

FUNDAMENTAL INTERACTIONS & NEUTRONS, NUCLEAR STRUCTURE, ULTRACOLD NEUTRONS, RELATED TOPICS

XXVII International Seminar on Interaction of Neutrons with Nuclei

Dubna, Russia, June 10–14, 2019

Abstracts

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Фундаментальные взаимодействия и нейтроны, структура ядра, ультрахолодные нейтроны и связанные вопросы: Тезисы докладов XXVII Международного семинара по взаимодействию нейтронов с ядрами (Дубна, Россия, 10–14 июня 2019 г.). — Дубна: ОИЯИ, 2019. — 90 с.

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20:00 Welcome party in DUBNA hotel

June 11, Tuesday

8:30 – 9:00 Registration in International Conference Hall

9:00 - 17:25

UCN, VCN, neutrons properties

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4.	**10:25 – 10:45**	**Goryunov S.** Search for UCN upscattering on artificially generated SAW.	**20 min**
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June 12, Wednesday

International Conference Hall

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June 13, Thursday

International Conference Hall

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13:30 – 15:30 Poster session

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International Conference Hall
9:00 - 16:30
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17:00 – 17:30 Coffee final

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1.	Kopatch Yu.N., Novitsky V.V., **Ahmadov G.S.**, Gagarsky A.M., Berikov D.B., Danilyan G.V., Hutanu V., Klenke J., Masalovich S., Deng H. Reanalysis of the data on T-odd angular correlations in the emission of prompt gamma rays and neutrons in fission of uranium by polarized cold neutrons.
2.	**Aliyev F.A.**, Madadzada A.I., Aliyev C.S., Huseynov D.A., Duliu O.G., Pavlov S.S., Dmitriev A.Yu., Hramco C., Fedorov N.A., Grozdanov D.N., Kopatch Yu.N., Ruskov I.N., Skoy V.R. Application of x-ray fluorescence and instrumental neutron activation analysis to studies of geological samples.
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7.	**Lan Changlin** A Method for determining d–T neutron energies using cobalt activation at high flu and long-time irradiation.
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Application of X-ray Fluorescence and Instrumental Neutron Activation Analysis to Studies of Geological Samples

F.A. Aliyev[1,2*], A.I. Madadzada[1,3], C.S. Aliyev[2], D.A. Huseynov[2], O.G. Duliu[4], S.S. Pavlov[1], A.Yu. Dmitriev[1], C. Hramco[1,5], N.A. Fedorov[1,6], D.N. Grozdanov[1,7], Yu.N. Kopatch[1], I.N. Ruskov[1,7], V.R. Skoy[1]

[1]Joint Institute for Nuclear Research, Joliot Currie 6, 141980 Dubna, Moscow region, Russia
[2]Institute of Geology and Geophysics, Azerbaijan National Academy of Sciences, H. Javid av., 119 Baku, AZ1143 Azerbaijan
[3]National Nuclear Research Center, Inshaatchilar ave. 4 Baku, AZ1073 Azerbaijan
[4]University of Bucharest, Department of Atomic and Nuclear Physics, P.O. Box MG-11, 077125, Magurele (Ilfov), Romania
[5]Institute of Chemistry of the Academy of Sciences of Moldova Academiei str., 3; MD-2028 Chisinau, Republic of Moldova
[6]Lomonosov Moscow State University, Leninskie Gory, 119991 Moscow, Russia
[7]Institute for Nuclear Research and Nuclear Energy of Bulgarian Academy of Sciences, Tsarigradsko chaussee 72, blvd., 1784 Sofia, Bulgaria

Geological samples of different stratigraphic age were analyzed by Instrumental Neutron Activation Analysis (INAA) and X-ray Fluorescence (XRF) in order to determine the elemental content. Sedimentary rocks such as: clay, sandstone, argillite, marl, were collected from the south-east end of the Greater Caucasus from the geological outcrops. By the INAA and XRF were determined of concentrations of 9 major, REE and trace elements in geological samples at the Joint Institute for Nuclear Research (JINR) in Dubna.

In this work the obtained results were interpreted in the framework of the Upper Continental Crust model in order to determine the origin of the sediments. The content of trace elements, including REE, confirmed an average rock composition close to the Upper Continental Crust.

Keywords: activation analysis; x-ray fluorescence analysis; major elements; REE, trace elements; geological samples.

* Corresponding author Tel.: + 7-496-216-2131; fax: +7-496-216-5085.
email: fuad.aliyev107@gmail.com

Martensitic Phase Transition in Yttrium-Stabilized ZrO_2 Nanopowders by Adsorption of Water

E.B. Asgerov[1,2], A.S. Doroshkevich[1,3], A.I. Beskrovnyy[1]

[1]*Joint Institute for Nuclear Research, Dubna, Russia*
e-mail: beskr@nf.jinr.ru;

[2]*National Center for Nuclear Research, Baku, Azerbaijan*
e-mail: elmar.asgerov@gmail.com

[3]*Donetsk Institute for Physics and Engineering named after O.O. Galkin, Kiev, Ukraine*
e-mail: doroh@jinr.ru

Abstract: The present study was aimed at revealing the influence of the mechanical stress induced by surface absorbed water molecules on the composition of crystalline phases in the ZrO_2 – 3mol% Y_2O_3 – nanoparticles. Neutron diffraction methods have been used to determine the phase transition. The fact of phase-structural $\beta \rightarrow \alpha$ transformation and the simultaneous presence of two polymorphic structural modifications (β is the phase of the tetragonal syngony and α is the phase of monoclinic syngony in nanoscale particles (9 nm)) under normal physical conditions is established by these methods.

Biomonitoring of Air Metal Pollution Using Plants by Means of Neutron Activation Analysis – Egypt

W.M. Badawy[1,3], H. El Samman[2], A. El-Morsi[2], Marina V. Frontasyeva[3], Y. Sarhan[2]

[1]*Radiation Protection & Civil Defense Dept., Egyptian Atomic Energy Authority (EAEA), Nuclear Research Center, 13759 Abu Zaabal, Egypt*

[2]*Menoufia University, Faculty of Science, Department of Physics, Shibin El-koom, Egypt*

[3]*Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, 6, Joliot Curie str., 141980, Dubna, Russian Federation*

The present work was conducted to give a comprehensive description of the biomonitoring of heavy and trace elements for air pollution assessment using two kinds of plants (*Eucalyptus Globulus* and *Ficus Nitida*) in two different regions in Egypt (Cairo and Minoufia). The concentrations (mg/kg) of thirty-two elements were determined in 30 leaves samples. The collected samples were subjected to neutron activation analysis NAA at REGATA, in the pulsed reactor IBR-2 in Dubna, Russian Federation. The obtained concentrations were compared with those published worldwide. The results are in line with those published in the literature except for Na, Al, Cl, Ca, Sc, Ti, V, Cr, Fe, Co, Ni, As, Se, Br, Sr, Sb, La, Sm, Tb, Hf, Ta, Th, and U are significantly high. The descriptive statistics of the obtained concentration revealed that the aforementioned concentrations in Minoufia are significantly higher than, those in Cairo, in spite of the intensely population, heavy traffic, and vehicles waste disposed in Cairo. The remarkable increase of metals in Minoufia region is most probably due to the uncontrolled of industrial and domestic waste disposal. In addition, the study shows the *Ficus Nitida* plant responsiveness to metals is higher than *Eucalyptus Globulus.*

Keywords: plants biomonitoring/ air pollution/ NAA/heavy and trace elements

Numerical Simulation on the Temporary Evolution of Defects in p-Type Si Irradiated by Neutrons

X.Y. Bai, Y. Liu, C. Chao, X.M. Jin, and G.Z. Wang

State Key Laboratory of Intense Pulsed Radiation Simulation and Effect, Northwest Institute of Nuclear Technology, P. O. Box 69-10, 710024, Xi'an, China

High fluence pulse neutron irradiation can introduce a myriad of defects in bulk Si, which subsequently anneal. The essence of the so called early-time annealing can be understood by considering the reactions of primal interstitials and vacancies with dopants and impurities. The temporary evolution of defect species in p-type Si irradiated by neutrons was presented in this paper. The influence of ionization enhanced diffusion on the early-time annealing was mainly discussed. Continuum equations were used to simulate the density evolution of defect species. Here diffusion and drift items were ignored with the assumption of the primal interstitials and vacancies generated uniformly in space. The theory of diffusion-limited reactions was used to estimate reaction rates. The athermal diffusivities for interstitials calculated on the Bourgoin mechanism have an approximate linear correlation with were the density of electron-hole pairs (Fig.1). Fig.2 gives the simulated concentrations of the principal defect species versus time when the total density of electron-hole generated during the pulse was taken to be 3×10^{18} cm^{-3} and the irradiation pulse was supposed to be 40 ns. It was clearly indicated that the production velocity for B_I was significantly faster than the velocity for VO, mainly due to the rapid migration of interstitials.

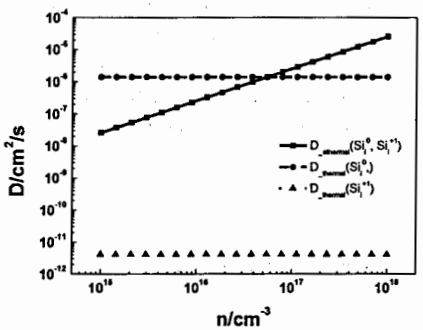

Fig.1. Diffusion coefficients versus the electron density

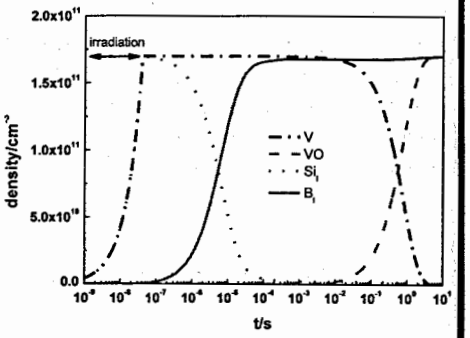

Fig.2. Temporary evolution of defect species

ANGULAR ANISOTROPY OF FRAGMENTS FROM NEUTRON-INDUCED FISSION OF HEAVY NUCLEI AT ENERGIES UP TO 200 MeV: MEASUREMENT DATA AND THEIR THEORETICAL INTERPRETATION

A.L. Barabanov[1], A.S. Vorobyev[2], A.M. Gagarski[2], O.A. Shcherbakov[2], L.A. Vaishnene[2]

[1]*NRC "Kurchatov Institute", Moscow 123182, Russia*

[2]*NRC "Kurchatov Institute", B.P. Konstantinov Petersburg Nuclear Physics Institute, Gatchina 188300, Leningrad district, Russia*

The angular anisotropy of the nuclear fission fragments carries an information on the deformation of the nucleus at the barrier, as well as on the contributions of channels with different values of K to the fission cross section, where K is the projection of the nuclear spin on the deformation axis. In the early stage of fission studying, extensive data on the angular anisotropy of fragments were obtained in neutron-induced fission of a number of fissile isotopes at energies up to 20 MeV. Later, some studies were carried out in this area at the neutron energies above 20 MeV (see, in particular, [1]). However, recently the results appeared of systematic measurements performed for a number of isotopes at incident neutron energies from 1 to 200 MeV. It is about a natural mixture of Pb isotopes (nat-Pb), and on nuclei ^{209}Bi, ^{232}Th, ^{233}U, ^{235}U, ^{238}U, ^{239}Pu (see [2,3] and references therein).

In Ref. [1], where data on the angular anisotropy of fragments from the fission of ^{232}Th and ^{238}U isotopes by neutrons with energies from 20 to 100 MeV were first presented, an attempt was made to interpretate these data in the framework of a combined model that takes into account equilibrium and pre-equilibrium processes. However, to describe all the details of the fission process of spin-oriented nuclei, both additional parameters and additional assumptions, in particular, on the role of pre-equilibrium processes, are required. Therefore, the conclusions of the authors of [1], grounded on a number of assumptions and based on a limited amount of data, can be considered only as preliminary.

In this work, we analyze a more complete amount of data on the angular anisotropy of fragments. This allows us to establish correlations between the angular anisotropy, on the one hand, and the partial cross sections, in particular, the cross sections of pre-equilibrium processes, on the other hand, and to narrow the range of uncertainties embedded in the model. For calculating the cross sections and angular anisotropy of the fragments, the modified TALYS program [4] is used. Our modification of TALYS makes possible the calculation of the spin orientation of the states of all residual nuclei formed from the initial compound states in the process of multiple emission of particles, which allows us to establish contributions to the angular anisotropy from isotopes formed at all stages of the decay of the compound nucleus. As a result, our analysis provides additional information on the ratio of equilibrium and nonequilibrium processes in reactions at intermediate energies.

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Experimental Investigation on n/γ Discrimination of Several Scintillators

Chen X., Han H.T., Zhang Z.C., Lu Y., Li G., Yi Y.C.

State Key Lab of Intense Pulsed Radiation Simulation and Effect, Northwest Institute of Nuclear Technology, Xi'an, China

Abstract

To accurately obtain the characteristics of specific particles in a mixed radiation field, the detection system must have enough n/γ discrimination ability. It is no doubt that scintillation detectors have been the dominating type in detecting neutron and gamma rays for several decades. Based on earlier theoretical simulation, n/γ discrimination ability of some scintillators is experimentally investigated in this paper with the Cockcroft-Walton Accelerator and ^{60}Co radiation instrument. Scintillators contain inorganic (such as Lu_2SiO_5, BaF_2, CeF_3) and organic materials (such as ST401, a kind of plastic crystal). The results confirm that n/γ discrimination of these four crystals are 0.26 (LSO, Ø50×5 mm^2), 0.29 (BaF_2, Ø50×10 mm^2), 0.31 (CeF_3, Ø50×10 mm^2) and 1.99 (ST401, Ø50×10 mm^2), respectively. This is in good accordance with the foregoing theoretical simulations, which can provide strong experimental supports for the design and improvement of detection system in mixed radiation field.

Software for the Quantitative Determination of Elements Mass Fractions in Samples by the Absolute Method of Neutron Activation Analysis

A.Yu. Dmitriev*[,1], S.B. Borzakov[1,2], V.V. Lobachev[1], A. Zhomartova[1]

[1]*Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna, Moscow Region, Russian Federation*

[2]*Dubna State University, Dubna, Moscow Region, Russian Federation*

*e-mail: lobachev@jinr.ru

Basic facilities of the Frank Laboratory of Neutron Physics (FLNP), Joint Institute for Nuclear Research (JINR), the IBR-2 reactor and the IREN facility, are actively used for carrying out of neutron activation analysis (NAA). The determination of elements content is performed by the comparative method of NAA using the software previously created at FLNP JINR. Sometimes, there is a necessity to check or complement the obtained results, for example, in the case of absence of the required element in the used SRMs or in the case of determining of the elements mass fractions with a large uncertainty, etc. To solve such problems, software was created that allows calculating the elements content in the samples by the absolute method of NAA.

A text file with nuclear constants was created. The file contains cross sections, resonance integrals, isotopic abundances, and half-lives of the isotopes to be determined.

The software uses report files with the results of the spectra of induced activity processing. These are report files for flux monitors, SRMs and investigated samples created by the Genie-2000 program.

At the first stage, thermal and resonance neutron fluxes are calculated. The created software calculates fluxes in two ways – by the cadmium difference method and by two zirconium isotopes – ^{95}Zr and ^{97}Zr.

Further, the elements mass fractions of the samples are calculated by the absolute method using isotopes activities from the report files. Calculations are performed by two significant energy lines for each isotope and by maximum of four spectra measurements for each sample. The results of calculations for each sample are saved in text files. A summary table of results for whole sample set is created using these files. It is possible to save the created summary table to a file with MS Excel format for further work.

The developed software allowed to get rid of routine long-term manual calculations, to increase productivity, significantly reduced the possibility of errors due to the human factor.

New Aspects of Ultracold Neutron Scattering in Condensed Deuterium and on Material Surfaces

Stefan Döge (Doege)[1,2], Juergen Hingerl[1,2], Christoph Morkel[1], Peter Geltenbort[2], Nicolas Hild[3], Andreas Frei[4], Winfried Petry[4], Stephan Paul[1]

[1]*Physik Department, Technische Universität München, Garching, Germany*
[2]*Institut Laue-Langevin, Grenoble, France*
[3]*Paul Scherrer Institut, Villigen, Switzerland*
[4]*Forschungsneutronenquelle Heinz Maier-Leibnitz, Technische Universität München, Garching, Germany*

Abstract

Ultracold neutrons (UCNs) are a versatile tool for fundamental physics experiments, such as the determination of the lifetime of the free neutron and the search for a possible non-zero neutron electric dipole moment.

The precise knowledge of UCN cross sections of solid deuterium is pivotal to the design and improvement of new UCN sources throughout the world, which promise to provide significantly higher UCN densities than the UCN facility PF2 called "Turbine" at Institut Laue-Langevin (ILL) in Grenoble, France.

A novel sample container for cryogenic liquids and solids featuring highly polished transparent silica windows is presented. Using this sample container, the total UCN cross sections of liquid and solid deuterium for UCNs were measured in transmission geometry with a time-of-flight (TOF) setup at the PF2-EDM beamline at ILL. The talk will feature velocity-dependent cross section data for UCN scattering in liquid and solid deuterium. It will also discuss the importance of UCN scattering from rough surfaces and from deuterium crystal defects, the concentrations and scattering cross sections of which were determined quantitatively for the first time.

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On the Geochemistry of the Western Black Sea Euxinic Sediments as Determined by Neutron Activation Analysis

O.G. Duliu[a,b], Carmen I. Cristache[c], Ana-Voica Bojar[d,e], G. Oaie[f], Otilia A. Culicov[b,g], Marina V. Frontasyeva[b], E. Constantinescu[h]

[a]*University of Bucharest, Department of the Structure of Matter, Earth and Atmospheric Physics and Astrophysics, P.O. Box MG-11, 077125, Magurele (Ilfov), Romania*
[b]*Joint Institute of Nuclear Research, 6, Joliot Curie str. 141980 Dubna, Russian Federation*
[c]*National Institute of Research and Development for Physics and Nuclear Engineering "Horia - Hulubei", P.O. Box MG - 6, 077125 Magurele (Ilfov), Romania*
[d]*Salzburg University, Geographie und Geologie, Geologie, Salzburg, Austria*
[e]*Studienzentrum Naturkunde, Universalmuseum Joanneum, Weinzöttlstraße 16, A-8045 Graz, Austria, (5) Mass Spectrometry*
[f]*National Institute of Marine Geology and Geoecology, 23-25, Dimitrie Onciul str., 024053 Bucharest, Romania*
[g]*National Institute for Research and Development in Electrical Engineering, 313 Splaiul Unirii, 060032 Bucharest, Romania*
[h]*University of Bucharest, Department of Mineralogy, 1, Nicolae Balcescu Blv., 010041Bucharest, Romania*

The marine euxinic environment, due to the total absence of bioturbation organisms, represents ideal media to conserve past events. At the same time, the hydrogen sulfide confers to euxinic media a redox character which, in its turn, determines some redox-sensitive elements such as Fe, Re, Se, Mo and U to precipitate from the water column and accumulate in sediments.

To get more data concerning the origin of sedimentary material deposited on the Western Black Sea Continental Platform slope as well as the evolution of the euxinic environment, both Epithermal Neutron and Prompt Gamma Activation Analysis were used to determine the content of eight major, rock forming, and about 22 trace elements in a sedimentary column collected at a depth of 600 m, *i.e.* well below the chemocline.

The Black Sea was chosen as it represents the greatest meromictic basin in the world, its water being stratified into two unmixed layers, a surface, oxygenated one with a thickens varying between 120 and 180 m and a significantly thicker layer, saturated with hydrogen sulphide and filling the rest of Black Sea volume up 2100 m depth.

Investigated sediments were extracted from a 50 cm core which maximum age determined by ^{135}Cs and ^{210}Pb geochronology, was estimated at 1 ky. For a better understanding of the sedimentary material origin, the content of both major and some representative trace elements were compared with the corresponding elements from the Upper Continental Crust (UCC) and North American Shale Composite (NASC).

The seven major elements showed contents slightly lower than the UCC ones excepting Fe as a redox sensitive element, Na due to the sea water presence and especially Ca which content was significantly higher, mainly due to the presence of *Emiliania huhleyi* coccolithophore algae. In spite of this, a ternary diagram of main major elements as oxides showed a remarkably similarity with both UCC and NASC one, suggesting a terrigenous origin of sedimentary material. This hypothesis was further confirmed by the experimental data concerning the content of some incompatible or insoluble elements such as Sc, Zr, REE, Hf, Th and U.

At the same time, all sediments showed an increased content of redox sensitive elements Fe, Se Mo and U which content normalized to Sc showed a relative steadiness of the euxinic environment in the past 1 ky, *i.e.* along the entire sedimentary column.

Cross Section Measurement of the Sb(n,xγ) Reactions on the "TANGRA" Setup

N.A. Fedorov[1,2*], T.Yu. Tretyakova[3], Yu.N. Kopatch[1], V.M. Bystritsky[1], D.N. Grozdanov[1,4], F.A. Aliyev[1,5], I.N. Ruskov[1,4], V.R. Skoy[1], C. Hramco[1,6], A. Kumar[7], A. Gandhi[7], D. Wang[8], E.P. Bogolyubov[9], Yu.N. Barmakov[9], and TANGRA collaboration

[1]*Joint Institute for Nuclear Research (JINR), Dubna, Russia*
[2]*Faculty of Physics, Lomonosov Moscow State University (MSU), Moscow, Russia*
[3]*Skobeltsyn Institute of Nuclear Physics (SINP), MSU, Moscow, Russia*
[4]*Institute for Nuclear Research and Nuclear Energy (INRNE), Sofia, Bulgaria*
[5]*Institute of Geology and Geophysics, Baku, Azerbaijan*
[6]*Institute of Chemistry, Academy of Science of Moldova, Chisinau, Republic of Moldova*
[7]*Banaras Hindu University, Varanasi, India*
[8]*Xi'an Jiao Tong University, Xi'an, China*
[9]*All-Russia Research Institute of Automatics (VNIIA), Moscow, Russia*

The project "TANGRA" (TAgged Neutrons & Gamma-RAys) aimed at experimental investigations of important for nuclear science and engineering nuclear reactions induced by fast neutrons, is realized at JINR. The main purpose of the TANGRA [1,2] is the detailed studying the ~14 MeV neutron inelastic scattering on atomic nuclei using tagged neutron method (TNM).

The neutron generator ING-27 is used as a neutron source. The maximal intensity of the "tagged" neutron flux in 4π geometry is 5×10^7 c^{-1}. The α-particles are registered by a 64-pixel α-detector with a sensitive pixel dimensions 6×6 mm^2. The detector is located at a distance of 100 mm from the tritium-enriched target. To perform precise investigation of the γ-ray spectra emitted in (n, xγ)-type reactions an ORTEC GMX3083PLS HPGe detector was used. The number of the emitted neutrons was counted; neutron fluxes inside the target were calculated using Geant4.

The tagged neutron method gives two main advantages in this type of experiments: it reduces significantly the background from the reactions of neutrons with surrounding materials (shielding, the detector itself, etc.), and it allows to unambiguously identify those gamma-ray peaks which are originated from the investigated target by comparison of spectra taken inside and outside the coincidence time window.

Impact of the gamma-quanta and neutrons scattering inside the sample and detector's case has to be taken into account because it can significantly change the efficiency of γ-quanta registration. Moreover, sizes of the sample have to be optimized to obtain more accurate results.

The results of the measurements, as well as Geant4 Monte Carlo simulations used for applying geometrical corrections will be presented.

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*Corresponding author Tel.: +7-496-216-2131; e-mail: na.fedorov@physics.msu.ru

Measurements of Response Function of an BC501A Organic Liquid Scintillator for Neutron Energy Range from 100 to 250 MeV

Jindong Wang

Xi'an Jiaotong University, China

Neutron response functions of 101.6 cm diameter by 101.6 cm long BC501A organic liquid scintillator have been measured for energy range from 100 MeV to 250 MeV continuously with the TOF method on the CSNS back streaming white neutron beam line in china. The measured response functions were compared with Monte Carlo calculations using some codes which are widely used. Finally, the new response matrix which covered from 100 to 250 MeV based on the measured data was constructed by the help of calculation data.

Measurements of Angular Distributions and Anisotropy of Fission Fragments from Neutron-Induced Fission of ^{232}Th, ^{233}U, ^{235}U, ^{238}U, ^{239}Pu, ^{237}Np, ^{nat}Pb and ^{209}Bi in Intermediate Energy Range 1–200 MeV

A.M. Gagarski[1], A.S. Vorobyev[1], O.A. Sh cherbakov[1], L.A. Vaishnene[1], A.L. Barabanov[2]

[1]*B.P. Konstantinov Petersburg Nuclear Physics Institute of National Research Ceneter "Kurchatov Institute", Gatchina, Leningrad district, 188300, Russia*
[2]*National Research Center "Kurchatov Institute", 123182, Moscow, Russia*

Angular distributions of fission fragments from the neutron-induced fission of ^{232}Th, ^{233}U, ^{235}U, ^{238}U, ^{239}Pu, ^{237}Np, ^{nat}Pb and ^{209}Bi have been measured in the energy range 1–200 MeV at the neutron TOF spectrometer GNEIS based on the spallation neutron source at 1 GeV proton synchrocyclotron SC-1000 of the PNPI (Gatchina). Recently, the list of nuclei to be studied within the framework of present investigation was filled with isotope ^{237}Np. Neptunium is a major component of spent nuclear fuel, therefore an accurate knowledge of its fission cross-section and fragment properties is needed for waste transmutation and advanced nuclear facilities (reactors, ADS, etc.) studies.

A description of the experimental equipment and measurement procedure is given. The anisotropy of fission fragments deduced from the data on measured angular distributions is presented in comparison with experimental data of other authors, first of all, the recent data from LANSCE (Los Alamos) and n_TOF (CERN). The data on anisotropy and angular distribution of fission fragments in neutron energy range above 20 MeV for ^{233}U, ^{239}Pu, ^{nat}Pb and ^{209}Bi have been obtained for the first time. The underlying ideas of the theoretical approach developed for analysis of the obtained experimental data are briefly discussed.

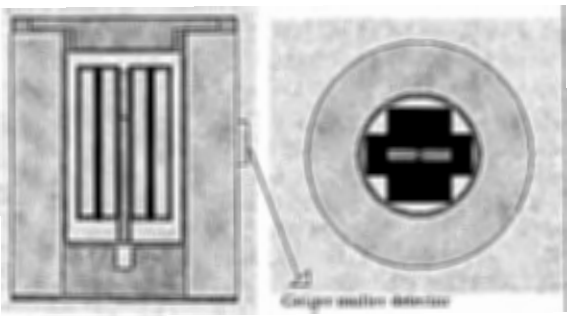
DUAL PURPOSE TRANSPORT CASK DESIGN FOR TEHRAN RESEARCH REACTOR SPENT FUEL TRANSPORTATION

Gholamzadeh Z., Jozvaziri A., Abedi E., Mirvakili S.M.

Reactor and Nuclear Safety Research School, Nuclear Science and Technology Research Institute (NSTRI), Tehran, Iran

Abstract

Spent nuclear fuel which is generated in the operation of nuclear reactors needs to be safely managed following its removal from the reactor core. Reactor storage pools were designed on the assumption that after a short period of time spent nuclear fuel would be removed for reprocessing, disposal or storage elsewhere [1]. Some factors should be regarded for designing the transport casks of the spent fuels consist of the cask effective multiplication factor, the gamma dose rates at the cask surface, the cask fixed and non-fixed contaminations and so on. In the present study, a dual-purpose dry storage and transport cask was designed and the pervious parameters were calculated using MCNPX computational code when the cask involves the 5-year and 10-year cooled spent fuels. The required carbon-steel wall thickness was determined to keep the standard values of the gamma dose rates at the cask surface.



Simulation of the Dual purpose cask using MCNPX code.

1. Dual Purpose Casks for Spent Nuclear Fuel, International Workshop - May 2014.

Super-Asymmetric Fission

F. Goennenwein[1], E. Chernysheva[2], J.M. Itkis[2], M.G. Itkis[2], G. Knyazheva[2], and E. Kozulin[2]

[1]*Uni Tubingen, Germany*

[2]*Flerov Lab, JINR, Dubna, Russia*

The super-asymmetric fission mode of fissile nuclei is a shell driven asymmetric mode of mass distributions. It is steered by shell properties in the light fragment group with fragment charge numbers $Z_L = 28$ and neutron numbers $N_L = 50$. Generally, it contributes with much smaller yield to mass distributions compared to the more common yields of modes due to shell effects in the heavy mass group. This makes the identification of the super-asymmetric mode more difficult.

A review of experiments ranging from fission in the pre-actinides up to super-heavy elements is presented. It allows to discuss the properties of the super-asymmetric mode and compare it with properties of fast quasi-fission. The two decay modes have often been confounded in the past.

BIOACCUMULATION OF RARE-EARTH ELEMENTS IN MOSSES

Gorelova S.V.[1], Frontasyeva M.V.[2], Vergel K.[2]

[1]*Department of Biology, Institute of Natural Sciences, Tula State University, Tula, Russia*
[2]*FLNP JINR, Dubna, Russia*

The results of neutron activation analysis of more than 70 moss samples sampled in different areas of the Tula region showed that the medium content of rare-earth elements in moss ranges from 0.065 to 3.60 mg/kg in dry matter. Such rare earth elements as Ce > Nd > La are dominant in moss of Tula Region. Their minimum concentrations range from 0.25 to 0.4 mg/kg; maximum concentrations range from 10.9 to 27.5 mg/kg in samples from contaminated areas of the region. Average concentrations are characteristic for such elements as Sm > Gd > Yb > Eu. Their minimum concentrations range from 0.01 to 0.05 mg/kg; maximum concentrations range from 0.56 to 2.13 mg/kg. Minimum concentrations are characteristic of such elements as Tb and Tm: from 0.005 to 0.355 mg/kg.

Accumulative ability of different species of mosses in relation to rare-earth elements differs by more than 10 times. The maximum accumulation ability characterizes such species of mosses as *Eurhynchium angustirete, Oxyrrhynchium hians, Plagiomnium ellipticum* (11.7–2.5 mg/kg Ce; 5.6–12.5 mg/kg La; 5–10.9 mg/g Nd; 0.8–2.1 mg/kg Sm; 0.25–0.56 mg/kg Gd; 0.15–0.31 mg/kg Tb; 0.07–0.17 mg/kg Tm; 0.61–1.08 mg/kg Yb). The minimum accumulation ability characterizes such species of mosses as *Climacium dendroides, Rhytidiadelphus triquetrus, Sphagnum angustifolium* (0.42–1.51 mg/kg Ce; 0.11–0.27 mg/kg La; 0.67–1.71 mg/kg Nd; 0.02–0.16 mg/kg Sm; 0.02–0.04 mg/kg Gd; 0.01–0.02 mg/kg Tb; 0.01–0.08 mg/kg Tm; 0.07–0.09 mg/kg Yb).

The concentration of rare-earth elements Ce and Sm in the atmospheric depositions of Tula region, studied using the moss-biomonitor method was higher than in other regions of Russia in 1.7–4.7 times for Ce and in 1.4–8.3 times for Sm.

Correlation analysis of the results revealed the interrelationship between the bioaccumulation of element-pollutants of the industrial origin deposited from atmosphere and absorbed from the soil: La, Ce, Nd, Sm with Sc, Ti, Cr, Mn, Fe, Ni, Co, As, S, Ba, Cs and high degree of correlation with the other rare-earth elements which may indicate the formation of conglomerates of these elements. Factor analysis clearly identified 4 factors that can be attributed to technogenic soil pollution. Factor 1: Na, Mg, Al, Sc, Ti, Cr, Ni, Co, As, Rb, Zr, Ba, Cs, *La, Ce, Nd, Sm*, Eu, *Tb, Yb,* Hf, Ta, Th, U associates with soils, industrial pollution of soil and weathering processes.

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Angular Distributions of Gamma Rays from the Inelastic Scattering of 14 MeV Neutrons on Some Light Nuclei

Grozdanov D.N.[1,2*], Kopatch Yu.N.[1], Bystritsky V.M.[1], Fedorov N.A.[1,3], Aliyev F.A.[1,4], Hramco C.[1,5], Skoy V.R.[1], Ruskov I.N.[1,2], Bogolyubov E.P.[6], Yurkov D.I.[6], and TANGRA collaboration

[1]*Joint Institute for Nuclear Research, Joliot Currie 6, 141980 Dubna, Moscow region, Russia*
[2]*Institute for Nuclear Research and Nuclear Energy of Bulgarian Academy of Sciences, 72 Tsarigradsko chaussee, blvd., 1784 Sofia, Bulgaria*
[3]*Lomonosov Moscow State University, Leninskie Gory, 119991 Moscow, Russia*
[4]*Institute of Geology and Geophysics, Azerbaijan National Academy of Sciences, H. Javid av., 119 Baku, AZ1143 Azerbaijan*
[5]*Institute of Chemistry of the Academy of Sciences of Moldova Academiei str., 3; MD-2028 Chisinau, Republic of Moldova*
[6]*All-Russia Research Institute of Automatics (VNIIA), Sushchevskaya 22, 127055 Moscow, Russia*

At the Joint Institute for Nuclear Research (JINR), in the frame of TANGRA-project, we continued investigating the inelastic scattering (INS) of 14-MeV "tagged" neutrons on a number of isotopes. The 14-MeV neutrons were produced in d(t, α)n-reaction by VNIIA ING-27 portable neutron generator, which has a 64-pixel Si charge particle detector, incorporated in its vacuum chamber. By registering the alpha-particles, we "tagged" the corresponding neutrons, which according to the reaction kinematics are irradiated in directions nearly opposite to those of the neutrons.

We used an array of 18 cylindrical BGO crystals for spectrometry of the coincided with the α-particles characteristic γ-rays following the INS-reaction.

The outputs of BGO gamma-detectors were fed to a computerized 32-channel data acquisition system (DAQ) from JINR AFI electronics, which was used for digitizing the analog signals from the detectors and storing the waveforms on the PC computer hard-drive for further off-line analysis.

We succeed to measure the angular distributions of gamma-rays from the INS of 14-MeV neutrons on the nuclei of important for nuclear science light elements. Here we report and discuss the results from several measurements.

Keywords: ING-27, tagged neutron method, inelastic neutron scattering, gamma-rays, angular distributions

* Corresponding author Tel.: + 7-496-216-2785; fax: +7-496-216-5085.
email: dimitar@nf.jinr.ru.

Dependence of the ROT effect on the energy of light charged particles and on the neutron energy in ternary fission of ^{235}U induced by polarized neutrons

I. Guseva[1], A. Gagarski[1], F. Gönnenwein[2], Yu. Gusev[1]

[1]*Petersburg Nuclear Physics Institute of National Research Centre "Kurchatov Institute", 188300 Gatchina, Russia*
[2]*Physikalisches Institut, Universität Tübingen, D-72076 Tübingen, Germany*

For the first time ROT effect was detected in 2005. It corresponds to a shift of the angular distribution of light charge particles (LCPs), which was observed in the ternary fission of ^{235}U induced by polarized neutrons [1]. This experimentally detected shift was explained by the presence of rotational states in the level structure of the deformed compound nucleus. The size estimation of this effect was given by modified trajectory calculations [2, 3].

The experimental results were obtained without accurate identification of the ternary particle type. Originally the calculations were performed with α-particles as LCPs, since they dominate in ternary fission. The evaluated angular shift averaged over the energy of α-particles was in a good agreement with experimental result. But the detailed distribution of the calculated ROT effect values depending on the energy of LCP deviated from the experimental results. This discrepancy was explained by the fact that not only α-particles were detected in the experiment. Taking into account the presence of tritons, which contributes about 7% to the LCP yield, it was possible to approach the calculated results to the experimental data [4].

However, besides α-particles and tritons there are ^{5}He ternary particles with a sizable contribution to ternary fission [5]. It was therefore decided to start a new version of trajectory calculations taking ^{5}He into account. Although the lifetime of ^{5}He is approximately 1×10^{-21}s and this ternary particle decays very rapidly into ^{4}He and a neutron, both helium isotopes are involved in the formation of the ROT effect, and this phenomenon should be considered when estimating its dependence on the LCP energy.

In addition, the behavior of the ROT effect value depending on the incident neutron energy was investigated. Taking into account the ratio changing for partial fission cross sections with neutron energy, it was shown that in the neutron resonance region with E_n=0.274 eV the ROT effect can be expected half as much as in the thermal region but for the resonance with E_n=1.134 eV this effect would be on the contrary more than twice as strong.

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Spallation and Reactor Neutron Radiation Effects on SRAM-Based FPGA

X.M. Jin, C. Qi, J.L. Li, Y. Liu, X.Q. Guo, W. Chen

State Key Laboratory of Intense Pulsed Radiation Simulation and Effect, Northwest Institute of Nuclear Technology, P. O. Box 69-10, 710024, Xi'an, China

Abstract

Radiation effects of SRAM (static random access memory)-based FPGA (field programmable gate array) are studied due to spallation and reactor neutrons respectively. The spallation neutron radiation experiment is carried out at CSNS (China spallation neutron source) and the reactor neutron radiation experiment at XAPR (Xi'an pulse reactor) in China. The devices under test are fabricated by CMOS technology. A testing system for FPGA is designed to simultaneously measure two samples. These two samples are initialized by the same data configuration before neutron irradiation. During neutron irradiation, one sample is exposed to neutron beam and the other one is out of the neutron radiation field. The function error, CSRAM (configuration SRAM) upset, BSRAM (block SRAM) upset and static power current are monitored every 30 seconds by the testing system. By comparison of the tested results between the two samples, the neutron radiation effects for the irradiated FPGA are clearly identified.

The experimental results show the SRAM-based FPGA is very sensitive to neutron-induced SEU (single event upset). Neutron-induced SEU cross-section in CSRAM is much higher than that in BSRAM. Therefore, the SEU in CSRAM is identified as the dominant failure mode for FPGA exposed to neutron irradiation. The memory cell of SRAM-based FPGA is a six-transistor SRAM. The SEU mechanism in FPGA can be analyzed by the ionizing effects in the vulnerable regions of the MOS (metal-oxide-semiconductor) transistors in this structure. The drains of the off-state MOS are the sensitive regions to collect charges to cause an upset in a single memory cell of a SRAM. Incident neutrons transfer energy to the lattice and they can produce recoil and spallation products, which are highly ionizing and generate electron-hole pairs in the sensitive regions. For each primary neutron, upset occurs in SRAM when the cumulated ionizing energy exceeds the critical SEU energy, which is the threshold energy to produce enough charge to cause one upset.

Interestingly, the SEU cross-section from logic 0 to 1 is much higher than that from logic 1 to 0. Moreover, the static power current of the irradiated FPGA increases almost linearly with the neutron fluence. This current increase is primarily due to driver contentions resulting from the SEU of the SRAM. After neutron irradiation, the irradiated FPGA can regain its functionality after reloading the initial configuration program. This test result indicates neutron radiation induces soft errors in FPGA and these temporary failures are restorable by reconfiguration.

THE ν-BALL PROJECT AT IPN ORSAY

N. Jovančević[1,2], M. Lebois[1,2], J.N. Wilson[1,2], D. Thisse[1,2], D. Etasse[3], R. Canavan[4,5], M. Rudigier[4,5], R.-B. Gerst[6]

[1]IPN Orsay, 15 rue Georges CLEMENCEAU, 91406 Orsay, France
[2]Université Paris-Saclay, 15 Rue G. Clémenceau, 91406 Orsay Cedex, France
[3]Laboratoire de Physique Corpusculaire de Caen, 6 Bvd du maréchal Juin, 14050 CAEN CEDEX 4, France
[4]Department of Physics, University of Surrey, Guildford, GU2 7XH, UK
[5]National Physical Laboratory, Teddington, Middlesex, TW11 0LW, UK
[6]Institut fur Kernphysik, Zülpicher Strasse 77, 50937 Köln, Germany

The nu-ball was high efficiency hybrid spectrometer establised at IPN, Orsay, France. It was consist 24 clover Ge detectors and 10 coaxial Ge detector (with BGO shield) as well as up to 20 $LaBr_3$ detectors or PARIS detectors. This configuration of spectrometer provides optimum energy and timing resolution. The nu-ball geometry allows coupling with the LICORN directional neutron source on the ALTO facility at the IPN, Orsay [1]. That was excellent possibility for precision spectroscopy of neutron induced reactions as well as heavy ion induced reactions. The experimental campaign was done between November 2017 and Jun 2018 [2–5]. Description of performed experiments with some preliminary results will be presented.

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TRUE QUATERNARY FISSION CHANNEL IN $^{235}U(n_{th}, f)$ REACTION

D.V. Kamanin[1], Yu.V. Pyatkov[2,1], A.A. Alexandrov[1], I.A. Alexandrova[1], Z.I. Goryainova[1], V. Malaza[3], E.A. Kuznetsova[1], A.O. Strekalovsky[1], O.V. Strekalovsky[4,1], A.V. Tomas[2,1] and V.E. Zhuchko[1]

[1]*Joint Institute for Nuclear Research, 141980 Dubna, Russia*
[2]*National Nuclear Research University "MEPHI", 115409 Moscow, Russia*
[3]*University of Stellenbosch, Faculty of Military Science, Military Academy, Saldanha 7395, South Africa*
[4]*Dubna State University, 141980 Dubna, Russia*

In our previous publications [1, 2] we discussed possible physical scenario standing behind rectangular–like structures in the fission fragments mass-correlation distributions from $^{252}Cf(sf)$. The rectangle is bounded by the known magic nuclei such as ^{68}Ni, ^{84}Se and others. The fission events aggregated in the rectangle show extremely low total kinetic energies. Special cinematic analysis of the experimental observables allowed us to come to conclusion that the mother nucleus undergoes true quaternary fission. Such decay channel is observed for the first time. Similar fission events were observed as well in $^{235}U(n_{th}, f)$ reaction. Their properties are discussed in this report.

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Some Features of the Data Processing in the Time-of-Flight Mass-Spectrometry of Heavy Ions

D.V. Kamanin[1], Yu.V. Pyatkov[2,1], Z.I. Goryainova[1], V.E. Zhuchko[1], A.A. Alexandrov[1], I.A. Alexandrova[1], V. Malaza[3], E.A. Kuznetsova[1], A.O. Strekalovsky[1], O.V. Strekalovsky[4,1]

[1]*Joint Institute for Nuclear Research, 141980 Dubna, Russia*
[2]*National Nuclear Research University "MEPHI", 115409 Moscow, Russia*
[3]*University of Stellenbosch, Faculty of Military Science, Military Academy, Saldanha 7395, South Africa*
[4]*Dubna State University, 141980 Dubna, Russia*

Experimental studies of the rare multibody decays of the low excited heavy nuclei carried out in our group [1] put forward specific requirements to the methodic. Need for registration of the pairs of fission fragments with a short follow-up interval, principal possibility of the detailed analysis of the shapes of the spectrometer signals related to the events of interest caused the formation of short detector signals and using fast multichannel digitizers such as flash-ADC DT5742. Data processing algorithms are an integral part of the experimental technique. Two of these algorithms provided respectively energy and time spectrometry of heavy ions using PIN diodes are considered in this report. The algorithms were tested recently in the special experiment at the beam of the IC-100 accelerator in FLNR of the JINR.

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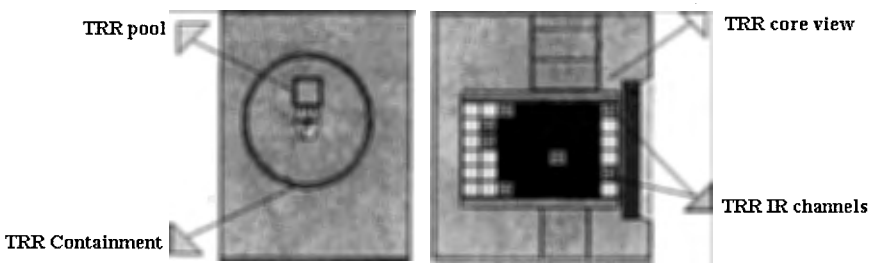
EVALUATION OF GAMMA SOURCE OF TEHRAN RESEARCH REACTOR AFTER THE CORE SHUTDOWN

Kardan M., Gholamzadeh Z.

Reactor and Nuclear Safety Research School, Nuclear Science and Technology Research Institute (NSTRI), Tehran, Iran

Abstract

Spent nuclear fuel of a research reactor emits many gamma rays which is much proficient to be used for different goals when the reactor is shutdown between its operation schedule. The present study discusses the gamma flux distribution inside the Tehran Research Reactor and its irradiation channels when the research reactor is shutdown. MCNPX computational code was used to simulate the TRR core. Axial and radial gamma flux of the core was calculated using the code and integrated gamma dose rated the irradiation channels was calculated during the shutdown hours. Gamma dosimetry films were used to measure the gamma dose rates of the different irradiation channels. A comparison between the simulation data and the experimental ones was conducted to benchmark the obtained theoretical data. The obtained results showed there is very fine conformity between the measured and modeled gamma dose rates.



Simulation of the Tehran Research Reactor using MCNPX code.

Monte Carlo Simulation of Ions in the Radiative Neutron Decay Experiment

Khafizov R.U.[a], Kolesnikov I.A.[a], Nikolenko M.V.[a], Tarnovitsky S.A.[a], Tolokonnikov S.V.[a], Torokhov V.D.[a], Trifonov G.M.[a], Solovei V.A.[a], Kolkhidashvili M.R.[a], Konorov I.V.[b]

[a]NRC «Kurchatov Institute», Russia
[b]Technical University of Munich, Munich, Germany

khafizov_ru@nrcki.ru

This report is dedicated to Monte Carlo simulation of the ions inside our experimental chamber for radiative neutron decay investigation and the measurement of its branching ratio (B.R.). Our methodology is focused on measuring the spectra of triple coincidences of radiative gamma-quantum, beta electron, and recoil proton and double coincidences of beta electron and recoil proton. The peak on the spectrum of triple coincidences shows the number of radiative neutron decays, while the peak on the spectrum of double coincidences shows the number of regular neutron beta-decays. This methodology enabled us to become the first team to measure the branching ratio of radiative neutron decay B.R. = $(3.2\pm1.6)10^{-3}$ (where C.L. = 99.7% and gamma quanta energy exceeds 35 Kev) [1] in 2005 on our old experimental equipment.

We have now prepared a new experiment on radiative neutron decay with the aim of measuring B.R. with a high degree of precision. The precision of branching ratio measurement is determined using the value of the ion background. The spectrum of double coincidences obtained in our experiment shows a fairly significant ion background, the fluctuations of which indicate the precision of measurement for the number of recoil protons [1,2]. Because the ion background specifically is quite significant, it appears even under super deep vacuum as beta electrons ionize the highly rarified air inside the chamber. The value of the ion background very slowly decreases with decreasing density of air inside the equipment. For example, our experimental data lead to the conclusion that the value of the ionic background is significant when compared with the value of the proton peak and on the other hand decreases only by 5–6 times if the pressure within the chamber goes down by 2 orders of magnitude. Besides, we discovered an additional wide peak on the spectrum of triple coincidences. This peak consists of delayed gamma quanta created during the ionization of rare gas by beta-electrons.

Thus, this experiment allows us to study another important phenomenon, the ionization of rarified gas by beta electrons with emission of gamma quanta. Our last experiment showed that these two phenomena, radiative neutron decay and ionization with gamma quanta emission, are distinguishable in the case of high time resolution and can be studied separately. This is another important result of our last experiment and in this report we mention that the authors of articles [3,4] registered namely the ionization with gamma radiation events.

This report is dedicated to a discussion of the computer experiment we conducted using the well-known GEANT4 software package. As a result of these calculations, we demonstrated that the value of the ionic background is proportional to the cubic root of the rarefied air density within the equipment, i.e. it changes very smoothly in relation to the pressure within the chamber. Besides, the report presents a comparison of our measurements of double coincidences [2] and triple coincidences [3,4], with two other experimental groups.

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Statistical Model Analysis of (n,t) Cross Sections for 14–15 MeV Neutrons

G. Khuukhenkhuu, J. Munkhsaikhan, M. Odsuren, Ch. Saikhanbayar, and B. Batchimeg

Nuclear Research Center, National University of Mongolia, Ulaanbaatar, Mongolia

Yu.M. Gledenov, E. Sansarbayar, and M.V. Sedysheva

Frank Laboratory of Neutron Physics, JINR, Dubna, Russia

Fast neutron-induced (n,t) reactions lead to enhancement of tritium in structural materials of fusion reactors. However, experimental data of the (n,t) reaction cross sections are scarce and their available values for the same isotopes are varied in the wide range. So, a systematical analysis of known (n,t) cross sections is a useful to estimate those for nuclides where no experimental data are available. On the other hand, from the systematical regularity of the known cross sections it can be concluded that which value is a probably correct.

In this work, we carried out a systematical analysis of known (n,t) cross sections for 14–15 MeV neutrons and observed some dependence of the reduced (n,t) cross sections on the proton-neutron relative numbers of the target nuclei. In the framework of the statistical model of nuclear reactions these obtained results are analyzed and discussed.

Reanalysis of the Data on T-Odd Angular Correlations in the Emission of Prompt Gamma Rays and Neutrons in Fission of Uranium by Polarized Cold Neutrons

Kopatch Yu.N.[1], Novitsky V.V.[1,2], Ahmadov G.S.[1,6], Gagarsky A.M.[3], Berikov D.B.[1,7], Danilyan G.V.[1,2], Hutanu V.[4], Klenke J.[5], Masalovich S.[5], Deng H.[4]

[1]*Joint Institute for Nuclear Research, 141980 Dubna, Russia*
[2]*Institute for Theoretical and Experimental Physics of National Research Centre "Kurchatov Institute", 117218 Moscow, Russia*
[3]*Petersburg Nuclear Physics Institute of National Research Centre "Kurchatov Institute", 188300 Gatchina, Russia*
[4]*Institut für Kristallographie, RWTH Aachen and Jülich Centre for Neutron Science at Heinz Maier-Leibnitz Zentrum (MLZ), Lichtenbergstr. 1, 85748 Garching, Germany*
[5]*Forschungs-Neutronenquelle Heinz Maier-Leibnitz, D-85747 Garching, Germany*
[6]*National Nuclear Research Centre, Baku, Azerbaijan*
[7]*L.N.Gumilyov Eurasian National University,* 010000 *Nur-Sultan, Kazakhstan*

Study of the T -odd three-vector correlation in the emission of prompt neutrons from ^{235}U fission by polarized cold neutrons has been measured at the facility MEPHISTO of the FRM II reactor (Technical University of Munich). Although these experiments were done in 2010-2012, till now the results were published only for several angles to the fission axis. The aim of this work is to show the results for all angles at which measurement done. There were used 4 NaI and 8 plastic scintillators in the experiments. NaI detectors were placed at angles $\pm45^0$ and $\pm135^0$, while plastic scintillators at angles $\pm22.5^0$, $\pm67.5^0$, $\pm112.5^0$, and $\pm157.5^0$ relative to direction of registration of the fragments. As a target it was used an oxide-protoxide of ^{235}U with a thickness of 500 $\mu g/cm^2$ deposited on both side of a 1-mm-thick zirconium plate. The results for the ROT-effect correlation in the emission of prompt fission neutrons and gamma-rays are presented for plastic scintillators at given angles. The magnitude and the sign of the angle of rotation of polarized nuclei is determined and compared with the values for the ternary fission.

Measurement of the ROT-Effect in Fission of ^{235}U Induced by Monochromatic Cold Polarized Neutrons with the Energy of 60 meV

Yu.N. Kopatch[1], V.V. Novitsky[1,2], G.S. Ahmadov[1,6], A.M. Gagarsky[3], D.B. Berikov[1,7], G.V. Danilyan[1,2], V. Hutanu[4], J. Klenke[5], S. Masalovich[5], H. Deng[4]

[1]Joint Institute for Nuclear Research, 141980 Dubna, Russia
[2]Institute for Theoretical and Experimental Physics of National Research Centre "Kurchatov Institute", 117218 Moscow, Russia
[3]Petersburg Nuclear Physics Institute of National Research Centre "Kurchatov Institute", 188300 Gatchina, Russia
[4]RWTH Aachen University and JCNS at Maier-Leibnitz Zentrum, 85748 Garching, Germany
[5]Forschungs-Neutronenquelle Heinz Maier-Leibnitz, D-85747 Garching, Germany
[6]National Nuclear Research Centre, Baku, Azerbaijan
[7]L.N.Gumilyov Eurasian National University, 010000 Nur-Sultan, Kazakhstan

Abstract. An experiment studying T-odd effects in binary fission of ^{235}U induced by monochromatic cold polarized neutrons was performed at the POLI instrument of the FRM2 reactor in Garching. In particular, triple correlations between the spin of the incoming neutrons and the emission directions of fission fragments and prompt γ-rays/neutrons were investigated. The neutrons were polarized using ultra compact SEOP (Spin Exchange Optical Pumpning) based ^{3}He polarized. The anisotropy parameter A determined from the experimental data for prompt gamma-rays and neutrons was established at the level of 10^{-4}. In spite of the smallness of the effects, the results are in agreement with the most modern theoretical model prediction.

The details of the experimental setup on beamline POLI, as well as the results of the experiment and the future plans will be presented.

Using XRF to Determine the Elemental Composition of Dyes in the Painting of Medieval Eastern Faience

V.Yu. Koval[1], A.Yu. Dmitriev [*,2], V.S. Smirnova[2,3], V.V. Lobachev[2]

[1] *Institute of Archeology of the Russian Academy of Sciences, Moscow, Russian Federation*
[2] *Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna, Moscow Region, Russian Federation*
[3] *Dubna State University, Dubna, Moscow Region, Russian Federation*
*e-mail: andmitriev@jinr.ru

An X-ray fluorescence analysis (XRF) of the glaze of a glazed medieval eastern ceramics batch was carried out in the NAA group of the IREN research facility of the Frank Laboratory of Neutron Physics, JINR, to determine the marker elements characteristic of various types of raw materials used to manufacture of dyes. 13 samples were obtained from the Institute of Archeology, RAS. Each sample was examined from the glazed sides.

A portable device Bruker Tracer 5i was used for carrying out the X-ray fluorescence analysis. The design features of the device are the ability to install interchangeable collimators and the availability of a built-in video camera. A collimator with a diameter of 3 mm was used for the study. The built-in video camera made it possible to position the sample under investigation relative to the place of the X-ray beam penetration. These features of the device allowed to study the elemental composition of not only the glaze itself, but also to carry out a unique non-destructive researches of various decorative elements with dimensions of more than three millimeters.

Samples were grouped as follows:

a) turquoise transparent glazes without additional decor;
b) white and greenish covered with tin glazes, including luster painting;
c) transparent colored glazes with overglaze colorful and luster decor;
d) colorless glazes of vessels decorated with polychrome underglaze painting.

A comparative analysis was carried out among the groups.

The following conclusions were made based on the results:

1. The turquoise color in the group of turquoise transparent glazes without additional decor is caused by a high content of copper oxide in the mixture. An iridescent view was obtained by iridescence.
2. A large amount of tin, as well as lead and arsenic, which are not dyes but serve as technological additives, is noticed in white glazes muffled with tin. There is an interesting sample in this group. A green and gold painting is applied on this sample. The color of the painting is based on the addition of silver to the mixture.
3. The group of transparent glazes with overglaze colorful and luster decor is represented by samples with multi-colored patterns (blue, brown, green, turquoise). The blue color everywhere in the group is due to the presence of cobalt in the dye, which has a strong coloring effect. Turquoise color, as in group 1, was obtained by adding copper to the dye. Green one is also due to the presence of copper. Brown one is formed by iron. Tin, lead and arsenic are noted in some samples.
4. The study of colorless glazes with underglaze painting was complicated by the fact that X-ray fluorescence analysis is a superficial method. This fact limited the ability to fix the elements under the glaze. However, some elements of the dyes were found: manganese, causing brown color, chrome – green one, copper – turquoise one.

The study can serve as the basis for the formation of a database of archaeological glazed ceramics.

Elemental Analysis of the Molding Paste of Medieval Eastern Faience

V.Yu. Koval[1], A.Yu. Dmitriev[2], O.E. Chepurchenko[2], Yu.G. Filina[2], V.S. Smirnova[2,3], V.V. Lobachev[2], N.N. Chepurchenko[2], A.Zh. Zhomartova[2]

[1] *Institute of Archeology of the Russian Academy of Sciences, Moscow, Russian Federation*
[2] *Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna, Moscow Region, Russian Federation*
[3] *Dubna State University, Dubna, Moscow Region, Russian Federation*
e-mail: andmitriev@jinr.ru

Neutron activation analysis (NAA) of the ceramic paste of a batch of glazed medieval Kashin ceramics was carried out by the NAA group at the IREN facility of the Frank Laboratory of Neutron Physics, JINR. The batch was transferred from the Institute of Archeology of the Russian Academy of Sciences and included 13 samples.

Ceramics made of Kashin (this material is called "quartz-frit" or "stonepaste" in Europe and the United States), is a specific kind of Oriental glazed wares produced from the XI century. Stonepaste is a quartz sand ground into powder, sometimes with the addition of glass powder, fluxes (a small amount of white clay, lime), mixed with an aqueous solution of glue (animal or vegetable origin) and fused at a temperature of 1000-1200 °C. On the territory of the Russian Federation stoneware (dishes and decorative tiles) were made for a short time in the middle of the XIV – early XV centuries, in the Golden Horde cities of the Lower Volga. In addition, stoneware from Iran, Syria, Egypt, and Central Asia were brought to Eastern Europe. The chemical composition of stonepaste was studied using materials of Central Asia, Iran and the Lower Volga region.

As far as we know, NAA has not previously been used to study the composition of stonepaste. In addition, for the first time, the task was to comparatively study stonepaste of wares produced in different countries of the East. Among the studied samples, there were undoubtedly Iranian stoneware (vessels with luster painting over white glaze), uniquely Golden Horde wares with polychrome underglaze painting (parts of vessels produced in the cities of the Lower Volga region), as well as vessels whose origin is controversial. In particular, vessels with ultramarine (and turquoise) glaze and overglaze polychrome painting, are considered to be produced in Iranian workshops, as well as several samples with polychrome underglaze painting, which are similar to Iranian wares in their decor. All the studied samples came from the excavations at the Bolgarian settlement and belonged to a narrow chronological group of the middle of the XIV century, i.e. they were produced at the same time.

Studies have shown that silicon oxide was the basis of the stonepaste material – from 57 to 82%, for most samples – 64-74%. However, data in modern scientific literature are often presented that are normalized to 100% of basic oxides. If you use this technique, the proportion of silica in the studied samples will be from 87 to 93%, which is fully consistent with data from previous studies.

For the other main components of the stonepaste (oxides of aluminum, calcium, magnesium, sodium), whose fractions are from 1 to 5%, there were no discrepancies with the data of the predecessors. The only slight difference is observed in iron oxide (0.3-0.7%), which, according to NAA data, in some cases is about 2 time less than that was recorded by other methods in previous studies.

The obtained data on traces are unique and there is nothing to compare with it, since traces in the stonepaste were not previously studied. However, there is a promising way of research in this direction – comparing data on stonepastes with data on ancient glass and glazes, since the main component of those and others is quartz sand, which had features in its elemental composition in different regions of the planet.

Ceramics of Bolgar: The First Results of Usage of Neutron Activation Analysis

V.Yu. Koval[1], A.Yu. Dmitriev*[,2], S.B. Borzakov[2,3], O.E. Chepurchenko[2], Yu.G. Filina[2], V.S. Smirnova[2,3], V.V. Lobachev[2], N.N. Chepurchenko[2], M.V. Bulavin[2]

[1] *Institute of Archeology of the Russian Academy of Sciences, Moscow, Russian Federation*
[2] *Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna, Moscow Region, Russian Federation*
[3] *Dubna State University, Dubna, Moscow Region, Russian Federation*
*e-mail: andmitriev@jinr.ru

The work is devoted to the first attempt to use neutron activation analysis (NAA) to determine the chemical composition of archaeological ceramic paste. 15 fragments of medieval vessels from the city of Bolgar, the capital of Volga Bulgaria (now the territory of Tatarstan, Russian Federation) were provided for investigation by the Institute of Archaeology of the Russian academy of sciences. NAA was carried out by the NAA group of the IREN research facility in the Frank Laboratory of neutron physics at the Joint institute for nuclear research.

The analytical study of the chemical composition of the Bolgar ceramics made it possible to obtain such data that were not previously known to researchers of medieval ceramics.

The main conclusion obtained as a result of these studies is that all the studied ceramic samples, including obviously imported, did not have significant differences neither in the main components (silicon, aluminum, iron, magnesium), nor in traces. So, at the first stage of research, it is difficult to indicate the signs by which pottery products similar in external appearance could differ. Differences cannot be traced between the dishes made in different eras, which in general should not be surprising, since the same clay was probably used for production. The coincidence of the elemental composition of clays of different geographical origin (from the Bolgar, the Lower Volga region, and the unknown center) is most surprising. However, the singleness of the comparative material allows us to assume that such coincidences are random. To check them, additional studies will be required on a wider series of samples.

The accumulation of data, new series of analyzes can significantly promote knowledge of the ancient ceramic industry, providing information that cannot be obtained by other methods.

Determination of the Air Pollution Sources Using Neutron Activation Analysis and Moss Biomonitoring in the Upper Silesia Region

Krakovská A.[1,2], Svozilík V.[1,2], Jančík P.[1,2]

[1]*Joint Institute for Nuclear Research, Dubna, Russia, email: krakovska@jinr.ru*
[2]*VŠB – Technical University of Ostrava, Czech Republic*

Moss biomonitoring in the upper Silesia region is applied on areas of a small scale unlike the whole country researches. A regular network of sampling points was created for improvement of the monitoring system in the industrial region. In the years 2015/2016, 85 moss-sampling points were used. The samples were analysed by neutron activation analysis in Frank Laboratory of Neutron Physics in Department of Neutron Activation Analysis and Applied Research. As results, 46 elements were determined.

The factor analysis was used for grouping the elements. Cattell's scree test shows an ideal scenario for three and a less ideal but acceptable one for four factors. In the case of three factors, six elements constitute factor 2 (Zn, As, Br, Sb, I, Ba). The most significant samples that are considered in factor 2 are situated around mining cities with plenty of power plants and above the underground brines in Poland. Factor 3 is composed of four elements (Ca, Se, Mo, Cd). The research works with an assumption that Ca, Se and Mo are of a vegetation origin. The distribution of significant samples in factor 3 contributes to the previous assumption. All these samples are situated in unpolluted localities, even in a nature reserve.

Calculating the contamination factor ensures better result interpretation. (Fernandez, Carballeira, 2000; Hakanson, 1980). The contamination factor determines whether a specific element indicates pollution or not.

The contamination factors were calculated by dividing each value by the corresponding background level of that element. The simplest way of doing this is to calculate contamination factors (CFs) for each element, i.e., the ratio between the concentration of an element in moss samples and its background level in that moss (Gonçalves et al. 1992). Background values were calculated on data from moss survey 2015, 2016 and 2017. Finally, the background level was defined as a concentration average of the 5% of samples. First, the contamination factor (CF) was calculated for each element, further, the contamination factor was calculated for individual samples.

Elements with high uncertainty of determining the concentration were eliminated and those with determined contamination level were used for further factor analysis. Factor 2 is significant especially around mining cities with plenty of power plants. Following elements: Br, Sb, I, Ba were excluded from factor 2 compare to previous analysis. It is possible that implicated elements are those present in the inversions. In the inversion period these elements can be highly concentrated especially in the southern parts of both industrial areas in Poland and Moravská brána. Factor 3 can be affected by traffic and partly the domestic heating systems. Factor 4 is situated mainly in the valleys and road surroundings. Domination of Cl and K indicates that the contamination is caused by covering the roads with salt during the winter period.

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Formation of Transient Layers after Ion Irradiation of $TiO_2/SiO_2/Si$ Multilayer System

M. Kulik[1,2*], E.B. Asgerov[1,3], A.I. Madadzada[1,3], D. Kołodynska[4], K. Pyszniak[3]

[1]*Joint Institute for Nuclear Research, Joliot Currie 6, 141980 Dubna, Moscow region, Russia*

[2]*Institute of Physics, Maria Curie-Skłodowska University, Lublin Poland*

[3]*National Nuclear Research Center, Gobu settlement of Absheron district, Baku-Shamahi hw 20 km, Baku, AZ 0100 Azerbaijan*

[4]*Faculty of Chemistry, Maria Curie-Skłodowska University, Lublin Poland*

The studied systems find a wide range of applications in optoelectronics, in particular in the production of solar batteries. The multilayer systems were irradiated with ions beams of Ne^+, Ar^+, Kr^+ and Xe^+. The energy and fluencies were 250 keV and 1×10^{16} cm^{-2}, respectively. The all samples after ion implantation were measured using two methods, RBS and SE. It is noted that at the interface between TiO_2 and Si layers, a transitional layer is formed in the process of ion implication. This is related to the displacement of the Ti and O atoms. It was found, that thicknesses of transition layers can be described by the phenomenological function of ion mass. The results of the ellipsometric studies have shown that as the ion mass increases, the extinction coefficient values increase faster compared to the refractive index spectra. These effects can be attributed to the formation of a homogeneous mixture of the transient layers.

Keywords: $TiO_2/SiO_2/Si$, nuclear methods, transition layers, RBS, ellipsometry

* Corresponding author Tel.: + 7-496-216-59-24
email: mkulik@hektor.umcs.lublin.pl

The Measurement of the Neutron Beam Background of the First Channel of the IBR-2 by Means of Transmission Method

V.L. Kuznetsov[1,2], E.V. Kuznetsova[1], and P.V. Sedyshev[2]

[1]*Institute for Nuclear Research, Russian Academy of Sciences, Moscow, 117312 Russia*
[2]*Joint Institute for Nuclear Research, Dubna, Moscow oblast, 141980 Russia*

A new method for measuring the neutron lifetime was proposed in [1]. It also notes the need for accurate measurement of the neutron background, especially the background of the delayed neutrons of the IBR-2 reactor, and formulated a proposal for experiments to measure the neutron background. The ratio of the background neutron count to the slow neutron flash must be less than 10^{-6}. According to [2], about 7 percent of the IBR-2 reactor power is released between the pulses of the reactor power, and since the number of neutrons is proportional to power, the background from delayed neutrons will also be 7%.

As a detector for measuring time-of-flight spectra, we used SNM-18, mounted on a span of ~ 29.6 m, as well as an ionization chamber with a layer of ^{235}U. When working with the SNM-18 counter, a reduction in the intensity of the neutron beam was required. To do this, using a lead collimator coated with cadmium and set to 12 m, a narrow, 2 mm wide, neutron beam was formed. At the 26-meter span of the base was installed 10 mm gap of borated polyethylene. The signals from the neutron detector were sent to a fast preamplifier, then to a fast amplifier (1501), and then to the discriminator pulse shaper in the NIM standard. The time analysis of signals, the collection and accumulation of experimental spectra were carried out using the "TIMECODER" system developed at the FLNP JINR [3].

The measurements of the transmission spectra with various samples were carried out, and the background magnitude and its measurement accuracy were estimated.

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Measurement of D-T Neutron-Induced Cross Section of ^{124}Xe (n,2n)^{123}Xe

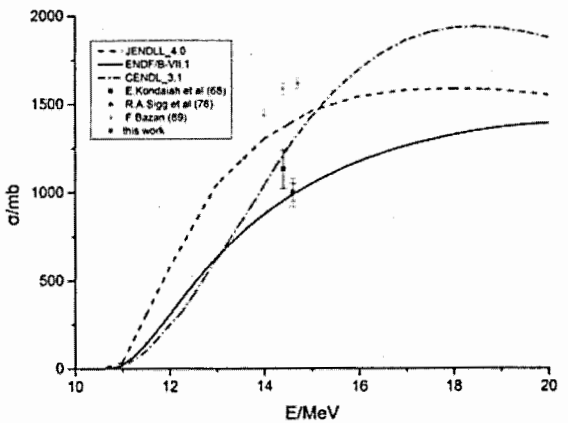
Liang Jianfeng[1], Xie Feng[1], Li Xuesong[1], Shang Jianbo[1], Shi Quanlin[1], Chen Xiongjun[2]

[1]*Northwest Institute of Nuclear Technology,Xi'an 710024, China*

[2]*Key Laboratory of Nuclear Data, China Institute of Atomic Energy, Beijing 102413, China*

Abstract: Nuclear reactions play an important role in understanding the inner dynamics of inertial confinement fusion (ICF) plasma. For various reasons, ^{124}Xe, which undergoes both (n,2n) and (n,γ) reactions, is one of the most prominent nuclide for such research. The threshold of $^{124}Xe(n,2n)^{123}Xe$ reaction is about 10.6MeV, and its cross section is definitely important for the ICF plasma diagnose. Experimental measurements of the cross section have been completed by several institutions. However, the discrepancy of these results is rather evident. In order to provide more accurate experimental data, the $^{124}Xe(n,2n)^{123}Xe$ cross section was measured with monoenergetic neutrons at 14.6MeV by using the activation method. The experiment was carried out using the Cock-croft Walton Accelerator at China Institute of Atomic Energy. Monoenergetic neutron beams were produced via the $^{3}H(d, n)^{4}He$ reaction (Q = +17.6MeV). Typically, the deuteron beam current was about 250μA, producing the neutron yield of 3×10^{10}/s. The ^{124}Xe gas, enriched to purity of 99.5% , was contained in a PMMA cylinder with inner diameter of 20mm and height of 10mm, and the pressure was about 1atm, resulting in a ^{124}Xe mass of approximate 16mg which was weighted accurately. In addition, two high-purity thin ^{93}Nb foils of the same diameter were attached to the front and back faces of the ^{124}Xe gas cylinder for incident neutron flux determination. The distance between the ^{3}H target and the center of the ^{124}Xe cylinder was typically 10mm. After irradiation, the activity of ^{123}Xe and ^{92m}Nb was determined by using a high-purity germanium (HPGe) detector with calibrated efficiency in 10cm thick Pb shield. A Monte Carlo code was written to correct the neutron flux because of the short distance between the ^{3}H target and the ^{124}Xe gas. The cross section result is 1.00 b at 14.6MeV energy, and the uncertainty is about 5.0%. Our data is in excellent agreement with ENDF/B-VII.1 and the data of Sigg et al.

Keywords: ^{124}Xe, (n, 2n), Neuron induced cross-section, ^{123}Xe, ICF



$^{124}Xe(n,2n)^{123}Xe$ cross section data of ours and others.

Epithermal Neutron Activation Analysis of Soil and Sedimentary Rocks Samples from Azerbaijan

A.I. Madadzada[1,2*], F.A. Aliyev [1,3], J.A. Naghiyev[2], S.S. Pavlov[1], M.V. Frontasyeva[1]

[1]*Joint Institute for Nuclear Research, Joliot Currie 6, 141980 Dubna, Moscow region, Russia*
[2] *National Nuclear Research Center, Gobu settlement of Absheron district, Baku-Shamahi hw 20km, Baku, AZ 0100 Azerbaijan*
[3]*Institute of Geology and Geophysics, Azerbaijan National Academy of Sciences, H. Javid av., 119, Baku, AZ1143 Azerbaijan*

Epithermal neutron activation analysis (ENAA) has found its usage in many fields of science. ENAA also is an increasingly important tool in trace element studies of geological materials. In the territory of Azerbaijan over 400 mud volcanoes are present, making Azerbaijan top in the world in the number of mud volcanoes characterized by exceptionally high natural radioactivity. Those deposits in the Caucasus and Transcaspian are associated with large deposits of uranium and rare earth metals. In this study instrumental epithermal neutron activation analysis (ENAA) was applied at the IBR-2 reactor of the FLNP JINR to study soils and geological materials collected in Azerbaijan the south-eastern part of the Greater Caucasus. The 43 samples (15 soils, 24 sedimentary rocks and 4 mud volcanoes) were collected. Soil sampling sites were chosen in ten different locations characterized in the interval of altitudes of 200-650 meters above the sea level, at depth of 20-30 cm in the area not affected by any mining and industrial activity. Sedimentary rocks such as clay, sandstone, argillite, marl, were collected from the geological outcrops. A total of 45 elements including lanthanides and actinides (Th and U) were determined in soils. In sedimentary rocks (clay, sandstone, argillite, marl, mica) and mud volcanoes, were determined 35 (major, REE and trace) elements.

Keywords: Instrumental Neutron Activation Analysis; Azerbaijan; major elements; trace elements; soils, clay, sandstone, argillite, marl

* Corresponding author Tel.: + 7-496-216-34-38
email: madadzada@jinr.ru

Investigation of Atomic Composition and Optical Properties in Multilayer Systems of $SiO_2/TiO_2/Si$ after Ion Implantation with Ions of Noble Gases

A.I. Madadzada[1,2], M. Kulik[1,3*], E.B. Asgerov[1,2], D. Kołodynska[4], M. Turek[3], A.P. Kobzev[1]

[1]*Joint Institute for Nuclear Research, Joliot Currie 6, 141980 Dubna, Moscow region, Russia*

[2]*National Nuclear Research Center, Gobu settlement of Absheron district, Baku-Shamahi hw 20 km, Baku, AZ 0100 Azerbaijan*

[3]*Institute of Physics, Maria Curie-Skłodowska University, Lublin Poland*

[4]*Faculty of Chemistry, Maria Curie-Skłodowska University, Lublin Poland*

The all samples were implanted with Ne^+, Ar^+ and Kr^+ with the same fluence 3×10^{16} ions/cm^2 and the energy was 250 keV. With the help of RBS and SE methods were obtained the depth profiles of elements and the optical properties of the samples. It was noticed that mass of ions increase the dielectric function of all layers have been changed. It was noticed that transient layers between the SiO_2 and TiO_2 are formed. The atomic composition of these layers indicates that they are a mixture of Si, Ti and O elements. The dielectric functions of the study layers. The dielectric function of these layers confirms that the interaction of ions with the atoms of the target creates a layer that describes the EMA model well. Layer thicknesses determined on the basis of RBS and SE are in good agreement. The results of these studies indicate that the use of these measurement methods gives precise measurements.

Keywords: SiO_2TiO_2/Si, nuclear methods, ion implantation, RBS, ellipsometry

* Corresponding author Tel.: + 7-496-216-59-24
email: mkulik@hektor.umcs.lublin.pl

TOTAL KINETIC ENERGIES IN ^{232}Th(n,F) AND ^{238}U(n,F)

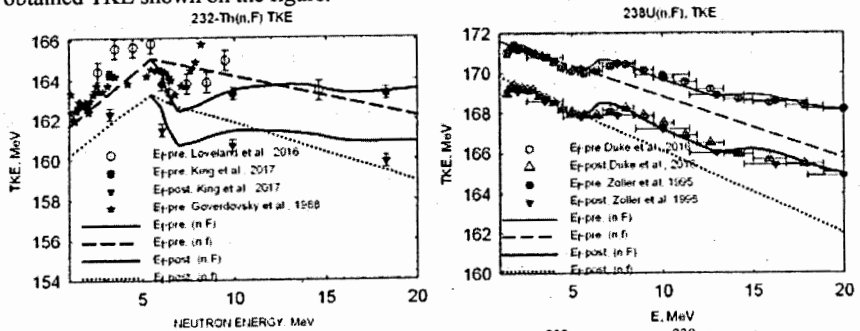
V.M. Maslov

Joint Institute of Nuclear and Energy Research, 220109, Minsk-Sosny, Republic of Belarus

Local minimum in TKE of fission fragments in ^{232}Th(n,F) around ^{232}Th(n,nf) threshold was first observed by Goverdovsky et al. in 1988. In 1995 Zoller et al. observed local maxima in TKE in ^{238}U(n,F) reaction around ^{238}U(n,xnf) thresholds. These variations are due to pre-fission (n,xnf) neutrons, which are pronounced in observed cross sections, prompt fission neutron spectra (PFNS) and mass distributions as well. Contribution of the (n,xnf) reaction to the $\sigma_{n,F}$ of ^{232}Th(n,F) around E_n ~7 MeV is ~1.5 higher than in case of ^{238}U(n,F), which is pronounced in TKE also. Partial contributions of (n,xnf) were fixed in [1–3] and seem to reproduce TKE variations. TKE values E_f^{pre} (E_f^{post}) before (after) prompt neutron emission from fission fragments were calculated as

$$E_f^{pre}(E_n) = \sum_{x=0}^{X} E_{fx}^{pre}(E_{nx}) \cdot \sigma_{n,xnf} / \sigma_{n,F}, \qquad E_{nx} = E_n + B_n - \sum_{x=0,1\le j\le x}^{X} \left(\left\langle E_{n,xnf}^{j} \right\rangle + B_x \right).$$

TKE E_f^{post} were de-defined as $E_f^{post} \approx E_f^{pre}\left(1 - \nu_{post} / \left(A - \nu_{pre}\right)\right)$, $\nu_p = \nu_{post} + \nu_{pre}$. Components ν_{post} and ν_{pre} of ν_p are defined via ν_p and PFNS analysis at E_n ~2–20 MeV. Assuming $E_f^{pre}(E_n)$ for $^{233-x}$Th, $^{238-x}$U are similar to those of ^{233}Th and ^{239}U (note TKE of ^{232}Th(γ,F)) we obtained TKE shown on the figure.



TKE shown on the figure is consistent with observed ^{232}Th+n and ^{238}U+n data on cross sections and PFNS. Straight lines are approximations of TKE values for non-emissive fission. The (n,xnf) neutrons influence on TKE values E_f^{pre} and E_f^{post} is much more pronounced in case of ^{232}Th(n,F) reaction. That is due to the transition states structure of ^{232}Th and competition of ^{232}Th(n,nγ) and ^{232}Th(n,nf) at $E_n \le 6.5$ MeV. For both ^{232}Th(n,F) and ^{238}U(n,F) (n,nf) neutrons influence on PFNS at E_n ~6.5 MeV and E_n ~7 MeV are quite different, which is due to the (n,2n) reaction neutrons competition to the (n,nf) reaction.

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Peculiarities of Elemental Accumulation in Molluscs from the Coastal Zones of South Africa

P.S. Nekhoroshkov[1], J. Bezuidenhout[2], M.V. Frontasyeva[1], I.I. Zinicovscaia[3], N.S. Yushin[1]

[1]*Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Russian Federation*
[2]*School for Science and Technology, Faculty of Military Science, Stellenbosch University, South Africa*
[3]*Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering, 30 Reactorului Str. MG-6, Bucharest - Magurele, Romania*

p.nekhoroshkov@gmail.com

Molluscs accumulated several trace elements in high amounts in correspondence with the environmental ratios. The neutron activation analysis was used as the main technique for determination of 40 elements in soft tissues of 90 natural molluscs from 6 stations along the South African coast. The procedure of NAA was carried out at the REGATA facility of the reactor IBR-2, in FLNP, JINR. For comparative analysis, the ratios of key elements-markers of anthropogenic and terrigenous component were estimated in the model zone of Saldanha Bay.

The model stations with constant anthropogenic impact of the routine coastal city emissions were chosen and corresponded to two different types of water areas in region of Saldanha Bay (which were studied earlier). The obtained concentrations in all other stations were compared with values from model stations to demonstrate the level of anthropogenic influence at the current conditions.

Preliminary results demonstrated that such elements as Ti, Cr and others (V, Sc, Th etc), which were taken as a markers of terrigenous matter reached high values at the almost all stations along African coast in comparison with model polluted station at the Saldanha Bay. But elements which can be used as markers of matter of anthropogenic origin (Zn, Se, As, Br) reached higher or close level of values at the Hout Bay and Waterfront stations in the Cape Town water area. The samples from Durban contain the highest level of terrigenous component, which was indicated by such elements as Ti, Cr, Fe, etc. This trait was characteristic of other coastal station but in a smaller scale. This can be reason for increasing of concentrations of several elements, which were connected with resuspended terrigenous particles accumulated by molluscs in and after storm seasons.

The study will be proceed in the frame of the "Mussel Watch" project which expanded to new areas of the African coast, and other species of molluscs.

Fast Neutrons Processes on Molybdenum Isotopes

C. Oprea, A.I. Oprea

Frank Laboratory of Neutron Physics (FLNP), Joint Institute for Nuclear Research (JINR), 141980 Dubna, 6 Joliot Curie str., Moscow Region, Russian Federation

Abstract. Molybdenum nucleus has many natural and artificial isotopes important for fundamental and applicative researches. Cross sections, angular correlations and isomer ratios in fast neutrons induced reactions up to 30 MeV were evaluated using codes realized by authors as well as dedicated software. Contributions of different nuclear reaction mechanisms in the cross sections were also determined. Parameters of nuclear optical potential, density levels and radius channels were extracted. Theoretical evaluations were compared with existing experimental data.

The results of present work were realized in the frame of the fast neutrons scientific program at FLNP basic facilities (IREN and EG5) and are necessary for future experiment preparation.

Asymmetry and Spatial Symmetry Breaking Effects Modeling in (n,p) Reaction

C. Oprea, A.I. Oprea

Frank Laboratory of Neutron Physics (FLNP), Joint Institute for Nuclear Research (JINR 141980 Dubna, 6 Joliot Curie str., Moscow Region, Russian Federation

Abstract. Asymmetry and spatial parity breaking effects in nuclear reaction induced by slow and resonant neutrons on ^{35}Cl nucleus followed by protons emission were analyzed. Effects were obtained applying Flambaum–Sushkov formalism using two-level approximation. In the computer simulation different types of target and neutrons incident flux were considered. Obtained results are compared with existing experimental data. Some differences between theoretical evaluation, computer modeling and experimental data are explained considering contributions of other open channels.

The present evaluations are realized in the frame of the scientific program of FLNP dedicated to the investigation of symmetry breaking effects in slow neutrons induced processes. The results will be used in the future experiments planned at IREN, the FLNP neutron source and other neutrons facilities from abroad.

Elemental Analysis of Human Remains of XV–XVII Centuries from the Moscow Kremlin Necropolis (Part 2)

T.D. Panova[1], A.Yu. Dmitriev*[,2], S.B. Borzakov[2,3], O.E. Chepurchenko[2], Yu.G. Filina[2], V.S. Smirnova[2,3], V.V. Lobachev[2], N.N. Chepurchenko[2], M.V. Bulavin[2]

[1]*Moscow Kremlin State Historical and Cultural Museum and Heritage Site, Moscow, 103132 Russia*
[2]*Frank Laboratory of Neutron Physics, JINR, Dubna, Moscow Region, Russian Federation*
[3]*Dubna State University, Dubna, Moscow Region, Russian Federation*
*e-mail: andmitriev@jinr.ru

Studies of the elemental composition of unique historical samples of human remains of the XV – XVII centuries from the Moscow Kremlin necropolis by the NAA method were continued in the neutron activation analysis group at the IREN research facility of the Frank Laboratory of Neutron Physics, JINR. Among the samples obtained for analysis were a fragment of the rib of Grand Princess Maria Borisovna (died in 1467, the first wife of Ivan III); fragments of the brain and organic matter from the skull of Grand Princess Elena Glinskaya (died in 1538, mother of Ivan the Terrible); the small bone of the Princess Feodosia (died in 1594 at the age of 1.5 years, daughter of Fyodor Ivanovich and Irina Godunova); three fragments of the rib of Tsaritsa Maria Nagaya (died in 1611, the last, sixth, wife of Ivan the Terrible); as well as the vertebrae (two) from the two monastic burials of the second half of the 15th – early 16th centuries (without epitaphs, A-905 and A-906). First of all, historians were interested in the mass fractions of mercury and arsenic in the remains – elements that were actively used as part of drugs, cosmetics and poisons in the Middle Ages.

High mercury content was found in fragments of the brain and organic matter from the Elena Glinskaya 's skull in the course of the research. An increased arsenic content was found in the fragment of the rib of Maria Borisovna. The reason for the unexpected and early death of these two young women is beyond doubt - it was poisoning. They could not accumulate toxic elements at such young age using medicines and cosmetics. Both women became victims of the power struggle in the Russian state in the second half of the XV and in the first half of the XVI centuries; there were many such situations in its history.

The increased content of toxic elements in the remains of two monks is explained by the fact that they most likely performed paintings in the Chudov monastery of the Kremlin – they painted frescoes and icons. Anthropologists have identified serious injuries of the hands of both monks, so they could not do the hard work (for one of them, the right hand even dried out, it was 5 cm shorter than the left one!). Medieval paints were made from minerals containing mercury, arsenic, antimony, lead, sulfur, copper and other toxic elements. They entered the body of painters through the pores on the skin. It led to chronic (like in any harmful production!) poisoning. Both monks survived to a solid age, but they undoubtedly had many health problems. Modern paint has the same effects on humans.

The obtained results give possibility to clarify the circumstances of life and death of some representatives of the highest nobility of the Russian state, as well as to enter into scientific circulation and replenish the database of the elemental composition of human remains from the graves of not only Russian historical figures of the second half of the XV – beginning of the XVII century, but also the ordinary population from medieval Moscow.

Programs for the R-Matrix Description of Neutron Cross-Section Structure

A.B. Popov

Frank Laboratory of Neutron Physics,
Joint Institute for Nuclear Research, Dubna, 141980, Russia

popov_ab@nf.jinr.ru

Abstract

A study of neutron fission and non-fission cross sections, performed during many years in the Frank Laboratory of Neutron Physics, allowed to accumulate a significant experience in the analysis of resonance structure of the cross section as well as of correlation effects in fission using R-matrix formalism. We present a detailed description of the mathematical approach used for the analysis of experimental data with the help of least square method (FUMILI minimization) in order to extract the parameters of structure of cross section or correlation coefficients. The obtained results of the fits for the total, fission and capture cross sections of ^{235}U, in the energy range up to 10 eV, and for the total cross section of ^{181}Ta, in the energy range up to 50 eV, are presented.

The calculations were performed in Fortran-codes at JINR using the FLNP and LIT computer clusters.

NEW SIDES OF THE COLLINEAR CLUSTER TRI-PARTITION SCENARIO

Yu.V. Pyatkov[1,2], D.V. Kamanin[2], A.A. Alexandrov[2], I.A. Alexandrova[2], Z.I. Goryainova[2], V. Malaza[3], E.A. Kuznetsova[2], A.O. Strekalovsky[2], O.V. Strekalovsky[4,2], V.E. Zhuchko[2]

[1]National Nuclear Research University "MEPHI", 115409 Moscow, Russia
[2] Joint Institute for Nuclear Research, 141980 Dubna, Russia
[3]University of Stellenbosch, Faculty of Military Science, Military Academy, Saldanha 7395, South Africa
[4]Dubna State University, 141980 Dubna, Russia

In our recent publication [1] we have proposed possible scenario of the collinear cluster tri-partition (CCT) in ^{252}Cf(sf). Under our model, one of the most populated CCT modes giving rise to the so called "Ni-bump" occurs as a two-stage breakup of the initial three body chain like the nuclear configuration with an elongated central cluster. The model gave answers to many critical questions on the CCT scenario. Nevertheless, it's needed in further clarification. The updated version is discussed in this report.

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Neutroneum

Yu.L. Ratis

Institute of power engineering for special applications, Samara, Russia

Many puzzles of the low-energy nuclear physics one can solve in the framework of the approach based on the hypothesis of the exotic electroweak resonance state "neutroneum" [1].

The easiest neutrino's exoatom "neutroneum" in Ref. [1–2] interpreted as "the quasi-bound state of a quasi-neutron and a quasi-neutrino". The prefix "quasi" in this work means that the metastable compound system can be considered as exoatom in which neutrino moves near a neutron [2].

A little-known property of the neutrino is used for this purpose, namely: the boundary condition a "zero at infinity" for the neutrino's wave function. It is not forbidden by any physics laws if the neutrino exoatom can decay to the residual atom and the electron. At the same time the exoatom decay channel with neutrino emission is closed by the energy conservation law (not by the attractive νN-force).

With the help of the concept of the neutroneum, the results of a paradoxical experiment [3–4] can be naturally explained. In [3–4] there was observed the subthreshold carbon photoproduction in dense helium.

In experiments [3-4], the sequence of processes may be as follows.

Step 1. The exotic electron capture

$$e + {}^{4}_{2}He \rightarrow e' + {}^{4}_{2}He_{\nu} \qquad (1)$$

Index ν means that one of the protons in the α-particle transforms and become "neutroneum".

Step 2. Neutroneum is a source of the time-dependent long-range nuclear forces [5].

Step 3. The result of the step 2 is reaction

$${}^{4}_{2}He_{\nu} + 2{}^{4}_{2}He \rightarrow {}^{12}_{6}C_{\nu} + phonon; \qquad {}^{12}_{6}C_{\nu} \rightarrow {}^{12}_{6}C + e \qquad (2)$$

The reaction (2) takes place only near the chamber walls because in other case this reaction is forbidden. The phonon emission in reaction (2) is a result of momentum transfer to the irradiated chamber walls in conditions of the experiments [3], [4] according to energy-momentum conservation law.

Another consistent explanation of these experiments in the framework of normal physics has not yet been proposed.

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AB INITIO STUDY OF DECAY WIDTHS AND BRANCHING RATIOS OF NEUTRON RESONANCES OF LIGHT NUCLEI

D.M. Rodkin [1,2], Yu.M. Tchuvil'sky[2,3]

[1]Moscow Institute of Physics and Technology, 141701, Dolgoprudny, Moscow Region, Russia
[2]Dukhov Research Institute for Automatics, 127055, Moscow, Russia
[3]Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, 119991, Moscow, Russia

Our previous papers [1,2] were devoted to ab initio description of clustering phenomena in light nuclei. The method used for this theoretical study is based on the basis of translationally-invariant wave functions of cluster and one-nucleon channels.

In the present work the proposed method is extended to ab initio calculations of asymptotic characteristics of low-laying levels of light nuclei – amplitudes, widths, and branching ratios of the decay of resonance states to various channels. Results of ab initio multi-channel calculations of these values for ^{5}He ground state and the lower part of ^{7}Li nucleus spectrum are presented. In the most cases the experimental data turn out to be well-reproduced in the proposed approach.

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Angular Distribution of 1.368 MeV Gamma-Rays from Inelastic Scattering of 14.1 MeV Neutrons on ^{24}Mg

I.N. Ruskov[1,4,*], Yu.N. Kopatch[1], V.M. Bystritsky[1], N.A. Fedorov[1,2], T.Yu. Tretyakova[3], D.N. Grozdanov[1,4], V.R. Skoy[1], F.A. Aliyev[1,5], C. Hramco[1,6], A. Kumar[7], A. Gandhi[7], D. Wang[8], E.P. Bogolyubov[9], Yu.N. Barmakov[9], and TANGRA collaboration

[1]Joint Institute for Nuclear Research (JINR), Dubna, Russia
[2]Faculty of Physics, Lomonosov Moscow State University (MSU), Moscow, Russia
[3]Skobeltsyn Institute of Nuclear Physics (SINP), MSU, Moscow, Russia
[4]Institute for Nuclear Research and Nuclear Energy of Bulgarian Academy of Sciences (INRNE-BAS), Sofia, Bulgaria
[5]Institute of Geology and Geophysics (IGG), Baku, Azerbaijan
[6]Institute of Chemistry, Academy of Science of Moldova, Chisinau, Republic of Moldova
[7]Banaras Hindu University, Varanasi, India
[8]Xi'an Jiao Tong University, Xi'an, China
[9]All-Russia Research Institute of Automatics (VNIIA), Moscow, Russia

In the frame of TANGRA-project at JINR-FLNP (Dubna) we measured the gamma-rays resulting from the inelastic scattering of 14.1 MeV neutrons on magnesium. As a source of neutrons we used ING-27 portable neutron generator of VNIIA (Moscow) where the neutrons are produced in a D-T nuclear reaction T(D,n)^{4}He. The α-particles were registered by a 64-pixel Si charge particle detector embedded in ING-27 vacuum chamber.
The sample tested was a 10cm-thick plastic cube filled with MgO powder. The gamma-rays from the interaction of neutrons with the sample we registered by a Romashka-type Fe-protected array, consisted of 22 hexagonal NaI(Tl) scintillator prisms. The analog signals from all the α- and γ- detectors were collected in list-mode, simultaneously, by a computerized 32-channel data acquisition system (DAQ) from JINR AFI-electronics, which was used, also, for digitizing and storing the waveforms on the computer hard-drive for further off-line analysis with CERN-ROOT modular scientific software toolkit.
Using the time-correlated associated particle method (TCAPM), also known as tagged neutron method (TNM), the influence of the background radiation on the collected gamma-ray spectra was reduced ~200 times.

We obtained the angular distribution of 1.368 MeV gamma-rays from ^{24}Mg(n, n'γ)-reaction in the range from 30° to 150° with a good statistical accuracy.

Here we report the results from our first experiment in comparison with the available data from the other authors. Further experiments are foreseen.

Keywords: ING-27, 14 MeV neutrons, tagged neutron method, inelastic neutron scattering, gamma-rays, gamma-spectrometry, angular distribution

* Corresponding author E-mail: ivan.n.ruskov@gmail.com; ivan@inrne.bas.bg.

Condensation of Ultra-Cold Neutrons in the Light of the Concept of Nuclear Exchange Beta-Forces. About the Possibility of Obtaining of Neutron Substance in Laboratory Conditions

Ryazantsev G.B.[1], Beckman I.N.[1], Lavrenchenko G.K.[2], Buntseva I.M.[1], Nedovesov S.S.[3]

[1]Lomonosov Moscow State University, Leninskie Gory, Moscow, Russia, *anis-mgu@rambler.ru*
[2]LLC «Institute of Low Temperature Energy Technology», POB188, Odessa, Ukraine, *lavrenchenko.g.k.@gmail.com*
[3]Shevchenko National University of Kyiv, Ukraine, *pc.remont.tk@gmail.com*

Today, the neutron matter and neutron stars are already substantially rooted in the nuclear physics and astrophysics, and it is logical to have their consideration of them in terms of chemical properties and principles of general chemistry.

The formation of a neutron substance, in addition to gravitational neutronization, is considered, other mechanisms, such as the condensation of ultracold neutrons (UCN) and neutronization due to a critical increase in the atomic number in the Periodic system of elements (PS). The stability of the neutron substance is substantiated already at the micro level due to Tamm interaction (*exchangeable β-nuclear forces)* [1] and not only at the macro level due to the gravitational interaction, as it is now considered in astrophysics [2].

It should be noted that G.A. Gamow [3] first spoke about the condensation of cold neutrons (1946). Rarely mention this idea, which over time has found application in the theory of neutron stars. Gamow in 1937–38 showed that when a neutron gas is compressed, a new superdense state of matter arises. The possibility of obtaining a neutron substance in terrestrial laboratory conditions is considered.

A neutron substance is a very concrete physical reality, urgently demanding its rightful place in the PS and studying not only physical, but also chemical, and possibly even in the near future, engineering and technical properties. We also consider the possibility of a "chemical" interaction of UCN with molecules of substances with an odd number of electrons.

It is proposed to extend the PS beyond the limits of classical chemical substances and to cover a much wider range of matter in the universe, based on the forgotten ideas of D.I. Mendeleev. Moreover, PS begins with neutron and its isotopes (dineutron, tetraneutrone, etc.) and ends the neutron stellar substance [2].

Keywords: neutron, neutron stars, neutron substance, periodic system of elements, neutronization, Tamm interaction, condensation of UCN.

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TySSA – A Set of Means for Building of Distributed Software Systems for the Automation of Experiments by the User. Part 1. Build Tools and Control Program

Salamatin K.M.[1], Salamatin I.M.[2]

[1]*LAUNJE, Michurina 36, Dubna, Moscow region, Russia*
[2]*FLNP, JINR, Joliot Currie 6, Dubna, Moscow region, Russia*

Modification of software systems for experiment automation requires time comparable to its development due to their uniqueness. So relevant methods and tools that reduce these periods. The paper presents a set of tools that ensures the continuity of the components of such systems at the level of the executable format (.exe) and the integration of components into a distributed system. The development of drivers for individual devices that make up the experimental setup is performed by specialists with the necessary qualifications, and they are presented in an executable format (.exe). The development time for one driver is from several days to a month. If the necessary drivers are available, their integration into the experiment automation system, which corresponds to the planned experiment methodology, is performed by the experimenter and requires 10–20 minutes.

Composition, purpose and properties of the components of the TySSA complex:

1. PSJsupport.db database. Used by driver developers to document driver characteristics.

2. The PSJ program is designed to prepare an experiment task in JSON format, used by the experimenter. PSJ allows, in accordance with the planned experiment methodology, to select the necessary drivers in PSJsupport.db, set the sequence and values of the parameters at their launch, and other data. This information is represented by the PSJ program as JSON text and is an experiment program. The process of composing the task and the results of the program PSJ enters into the database JOBSlist.db.

3. The TySSA program performs an experiment task, composed using PSJ. The search for drivers in the network and the control dialog is carried out according to the protocols implemented in SLP and a specially developed DiCME module. The TySSA program is equipped with means to protect against information loss in case of power failures and experimental equipment failures.

4. Library of device drivers that are part of various spectrometers and more general purpose services. Drivers are used by the TySSA program. Drivers are represented in the .exe format, can be used without change in any experiment whose software is prepared in this technology, can be run (in the local network) on any computer to which the equipment they use is connected.

TySSA – A Set of Means for Building of Distributed Software Systems for the Automation of Experiments by the User. Part 2. Unified Structure of the Complex Services

Salamatin K.M.[1], Salamatin I.M.[2], Tsulaia M.I.[2]

[1]*LAUNJE, Michurina 36, Dubna, Moscow region, Russia*
[2]*FLNP, JINR, Joliot Currie 6, Dubna, Moscow region, Russia*

When changing the composition of drivers in an experiment control program built with the help of a translator as a whole, as a rule, more or less serious changes are needed in programs that have combining the components into the system by means of the translator, use special means of integrating the necessary components into the system. For this purpose, a unified experiment control program (TySSA) and a special driver structure were developed. Both the TySSA control program and the drivers are represented in executable format (.exe). The experiment technique is described with text in JSON format. The control program, in accordance with the implemented experimental method, dynamically accesses the necessary drivers. Such a technology of building a system by ensuring the continuity of the control program and drivers at the level of the executable format provides significant time savings when changing the experiment methodology.

There are 3 parts in the driver structure:

1. A procedure that performs the main function of the driver in accordance with the parameters passed to it.
2. The procedure that performs calculates the time required to perform this function, using the specified parameter values.
3. The interface part that provides interaction with the control program.

The interface part is the same for all drivers in this technology. The interaction is carried out according to the protocols implemented in the SLP and the specially developed DiCME module. If the power supply allows, all the drivers that bring the hardware system to the state in which the data will be recorded can start at the same time. The hardware part of the system can include several computers connected in a local network to which the equipment used in the experiment is connected. In this case, the driver is launched on the appropriate computer and its control program is searched for automatically.

NEW EXPERIMENTAL INVESTIGATIONS OF THE (n,γf)-REACTION: GETTING STARTED

O.A. Shcherbakov, A.S. Vorobyev, A.M. Gagarski, L.A. Vaishnene

B.P. Konstantinov Petersburg Nuclear Physics Institute of National Research Center "Kurchatov Institute", Gatchina, Leningrad district, 188300, Russia

Abstract

The neutron-induced fission after preliminary emission of one or more gamma-quanta, also called as (n,γf)-reaction, first proposed theoretically in 1965, is a "hard nut" for the experimentalists. The pre-fission gamma-rays related to the transitions between highly excited states in compound nucleus are masked by the much more intensive gamma-rays from fission fragments. The only productive experimental method to separate prefission and direct fission gamma-rays is to study variations of multiplicity of fission gamma-rays and neutrons as well as total energy of fission gamma-rays in the resolved resonance neutron energy range and energy spectra of fission gamma-rays. The new measurements of these observables have been initiated at the neutron time-of-flight spectrometer GNEIS of NRC KI – PNPI. The first runs of the measurements carried out for 3^-, 4^- -resonances of ^{235}U in the neutron energy range 0.1 – 200 eV are described. A paralleled-plate ionization chamber containing 9 double-sided targets of ^{235}U (total amount of 1.9g) was used for registration of fission fragments. Two NaI(Tl) scintillation detectors Ø150mm x h100mm and two stilbene scintillation detectors Ø60mm x h45mm were used for registration of fission gamma-rays and neutrons, respectively. A data acquisition system was based on the two 4-input, 500 MS/s, 8 Bit, DC-270 Acqiris waveform digitizers under control of the PC equipped with the 1Tb hard disk memory for the raw data accumulation.

In this report, the preliminary results of the measurements, details of the experimental technique and data analysis, as well as a comparison with the existing database, are presented and discussed. .

EXPERIMENTAL INVESTIGATIONS OF THE (n,γf)-REACTION TO BE OR NOT TO BE?

O.A. Shcherbakov, A.S. Vorobyev, A.M. Gagarski, L.A. Vaishnene

B.P. Konstantinov Petersburg Nuclear Physics Institute of National Research Center "Kurchatov Institute", Gatchina, Leningrad district, 188300, Russia

Abstract

The neutron-induced fission after preliminary emission of one or more gamma-quanta, also known as (n,γf)-reaction, was predicted theoretically in 1965 by Stavinsky & Shaker, and by Lynn. A first stage of experimental studies of the (n,γf)-reaction lasted about 30 years and lead to a conclusion that this two-step fission process has been experimentally observed. Its probability was found to be small as compared with a direct fission. It do not exceeded 0.4% of the average fission width for 4^- - resonances of ^{235}U and 6% for 1^+-resonances of ^{239}Pu. In spite of a great importance of the information about gamma-transitions between highly excited states in compound fissioning nuclei which could be obtained from the studies of the (n,γf)-reaction, a small contribution of this reaction in fission process has "cooled" enthusiasm of the investigators. As a result, during next 20 years there were practically no noticeable achievements in this field. Very recently, a situation changed principally due to the requests of the neutron data evaluators who strictly formulated a necessity to obtain new accurate experimental data on the (n,γf)-reaction, at least for a "big two" fissile isotopes ^{235}U and ^{239}Pu, in the resolved resonance neutron energy range. First, it is necessary to measure pre-fission widths $\Gamma_{\gamma f}$ and spectra of the prefission gamma-rays, which are associated with gamma-transitions in the 1-st well of fission barrier. Next, more difficult experimental task, would be observation of the gamma-transitions in the 2-nd well feeding probable isomeric state at its bottom. One more intriguing problem is a question about the competition between electric and magnetic transitions in prefission gamma-ray spectra. In particular, it would be very interesting to approve or reject a hypothesis about the existence of low-lying M1 "scissors mode" in the gamma strength function for actinides.

In this report, a review of the investigations of the (n,γf)-reaction, both theoretical and experimental, is given. The principal tasks of the new measurements to be done in the nearest future have been formulated.

Numerical Calculation and Experimental Research of 14 MeV Neutron Yields of ^6Li Conversion Target in XAPR

Shi Quanlin, Shang Jianbo, Dai Yihua, Bai Tao, Xu Chenxi

Northwest Institute of Nuclear Technology, Xi'an 710024, China

Abstract: It is significant important to convert thermal neutrons into 14 MeV neutrons by irradiating ^6LiD with thermal neutrons in Xi'an Pulse Reactor (XAPR) in NINT for the irradiation test of materials in the high energy neutron field for both high intensive neutron irradiation effect and nuclear reaction. An approach of numerically calculating of 14 MeV neutron yields of a ^6LiD conversion target is considered as following. Firstly, the energy, position and emission direction of tritium particles between the neutron and ^6Li reaction were determined by tracking the neutron transport process. Then, the energy loss per unit distance of tritium particles during transport was calculated by SRIM program. Finally, the yields of high energy neutrons produced from the reactions of T+D and T+^6Li are calculated according to the cross section data, respectively. Based on the cross section data of ENDF BVII.1, a Monte Carlo simulation had been undertaken to get the high energy neutron yields from the ^6LiD target with a thermal neutron, which were calculated to be 1.54×10^{-4} of T+D reaction, and 7.6×10^{-5} of T+^6Li reaction, with the sum of 2.30×10^{-4}. The result was similar to the yields calculated by Wang Guanbo in 2013, which were 2.15×10^{-4} where the deviation may derived from the careful consideration of tritium energy loss during transportation in our simulation. 2 grams of D $^6LiO.D_2O$ powders were pressed into a circular die of 3.5 cm diameters with 1.5 mm thickness as a conversion target (the atom densities of ^6Li, ^7Li and D in the target were $1.82\times10^{22}/cm^3$, $3.71\times10^{20}/cm^3$, and $5.57\times10^{22}/cm^3$ respectively) to be irradiated in XAPR and its 14 MeV neutron yields were calculated to be 6.76×10^{-5} according to the neutron spectrum of XAPR. The target and a piece of Zr metal were irradiated together in XAPR where the activation ratio of $^{90}Zr(n,2n)^{89}Zr$ were measured to experimentally determine the high energy neutron yields of the conversion target. The experimental results of high energy neutron yields were estimated to be 7×10^{-5}, which is consistent with the MC simulation.

Key Words: Neutron, ^6LiD, Conversion target

Investigation of the Element Composition of Medallion (the 12th – First Half of the 13th Centuries) by Method of Neutron Resonance Capture Analysis

N. Simbirtseva[1,2], A.M. Ergashov[1,2], S.T. Mazhen[1,2], Yu.D. Mareev[1], P.V. Sedyshev[1], V.N. Shvetsov[1], I.A. Saprykina[3]

[1]*Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna, Russia*

[2]*Institute of Nuclear Physics, Almaty, 050032, the Republic of Kazakhstan*

[3]*Institute of Archaeology Russian Academy of Sciences, Moscow, Russia*

Abstract

The analysis of element composition of the medallion was carried at IREN Facility in Frank Laboratory of Neutron Physics by Neutron resonance capture analysis (NRCA).The method is based on the registration of neutron resonances and the measurement of the yield of reaction products in the resonances. The resonance energies are known practically for all stable nuclei and the set of energies does not coincide completely for any pair of isotopes. It allows determining the isotope-element composition.

The medallion dates back to the 12th – first half of the 13th centuries (the ancient Russian time). It was found in historical part of Tver city near the Tver Kremlin. Analogues of this medallion are in the expositions of the Moscow Kremlin which consist mostly of silver. The result of investigation of element composition of medallion will be presented in report.

Modeling of Photon Strength Function in ^{196}Pt on the Basis of Data Obtained with DANCE Detector

N. Simbirtseva[1,2], F. Bečvář[3], R. Casten[4], A. Couture[5], W. Furman[1], M. Krtička[3], S. Valenta[3]

[1]*Joint Institute for Nuclear Research, RU-141980, Dubna, Russia*

[2]*Institute of Nuclear Physics, Almaty, 050032, the Republic of Kazakhstan*

[3]*Charles University in Prague, CZ-180 00 Prague 8, Czech Republic*

[4]*Yale University, Wright Lab, New Haven, CT 06520 USA and MSU FRIB, E Lansing, MI48823 USA*

[5]*Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, New Mexico 87545, USA*

The ^{195}Pt(n,γ) reaction was measured with the γ-calorimeter DANCE (Detector for Advanced Neutron Capture Experiments) consisting of 160 BaF_2 scintillation detectors at the Los Alamos Neutron Science Center. The cascades of gamma-decay from isolated compound-states of ^{196}Pt nucleus were simulated by the DICEBOX statistical model code and were transformed with the GEANT4 code simulating response of the detector into the form allowing direct comparison with experimental data and the comparison has then been made for several different models of level density (LD) and photon strength functions (PSFs) models.

The comparison confirms the presence of E1 pygmy resonance at 5.6 MeV in photon strength function of ^{196}Pt reported earlier [1, 2].Our simulations indicate that there is a significant contribution of the M1 strength in 3–4 MeV gamma-ray energy region. Our analysis also indicates a constant of the PSF strength at very low energy.

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Modelling of the Influence of the Fast Neutrons Irradiation on the Layered HTc Superconductors Subjected to the Bending Strain

J. Sosnowski

Electrotechnical Institute, Pozaryskiego 28, 04-703 Warsaw, Poland

Superconducting materials, including high temperature superconductors are presently more and more widely used in the nuclear physics power devices. During the work of the superconducting accelerators superconducting coils are exposed to the nuclear irradiation, especially of the fast neutrons, because heavy ions are usually stopped in the metallic shields of accelerators. In the paper have been performed modelling works devoted to the analysis of this effect, it is the influence of the created during nuclear irradiation nano-defects on the current carrying properties of the superconducting tapes, especially suspected to the bending strain process, also creating structural defects in the form of the micro-cracks. Such bending strain defects are created during the preparation of the superconducting coils, so they appear just in the windings of the magnets of the superconducting accelerators. In the paper it will be analyzed in which way fast neutrons creating nano-sized defects influence the current-voltage characteristics and critical current of the high temperature multilayered superconducting materials and in which way this effect will lead to the critical current variation of the bent superconducting tape. An example of the results of the calculations influence of the bending strain on the current-voltage characteristics of the superconducting tape is given in the Fig. 1.

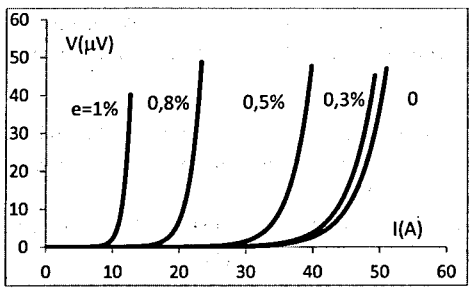

Fig. 1. Calculated influence of the bending strain, e, in percent on the current-voltage characteristics of the HTc superconducting multifilamentary tape with ordered micro-cracks

ANALYSIS OF NUCLEAR EXCITATIONS IN DIFFERENT ELEMENTS

Z.N. Soroko, S.I. Sukhoruchkin, D.S. Sukhoruchkin

B.P. Konstantinov Petersburg Nuclear Physics Institute NRC KI 188300 Gatchina

In this work, we continue the analysis of the unexpectedly accurate relations between the nucleon masses and the electron rest mass m_e, contained in the CODATA evaluation. According to F. Wilczek, such a new aspect of the nuclear spectroscopy ("nuclear chemistry" with very accurate results for energies of nuclear states) can be used in several important applications, for example, in laser technology. This new approach to the development of nuclear physics is based on the observation made in the 1960s that the doubled value of the pion's β-decay energy is close to the period δ=16m_e.

For confirmation of CODATA relations we use the results of the global analysis of nuclear data collected in PNPI and published in Springer Landolt-Boernstein Library New Series. The Editor-in-chief of L.-B. Library W. Martienssen compared data-compilations with the bridges between different branches of Science. Nuclear data files were used for a check of empirical relations in particle masses due to the fact that theoretical models, for example, NRCQM, provide a description of the origin of nucleon masses, and the QCD is a general theory of nuclear excitations and nuclear binding energies. In the analysis of data on energies of all known nuclei, both parameters of the CODATA fine structure ($m_e/3$=170 keV=$\varepsilon_o/6$ and $m_N/8$=161 keV) were found earlier, in a separate analysis. We use a new method of data analysis based on the selection of data for all isotopes of each element. We study the location of the grouping effect in the values of the excitation energies collected among all the isotopes of given element. In the combined E^* distribution for Z=40–72, maximum at 3.072 MeV close to $3\varepsilon_o$=3.066 MeV was found. The random probability of such a grouping is less than 10^{-5}.

Another method of data analysis was to obtain and analyse combined data for isotopes of neighbouring near-magic elements (nuclei with Z=8-9-10, Z=20, 22 etc.). The grouping effect in the values of the excitation energies of different isotopes of a certain element, which was considered earlier, was the first step. The second step was based on the observation of the similarity in the excitations in several near-magic nuclei. For example, it was noticed long ago, that the first excitations of ^{18}O and ^{24}Ne $E_1^*(2^+)$=1982.1(1) keV and $E_1^*(2^+)$=1981.6(4) keV are unexpectedly close to each other. Now we have found that the grouping effect in the sum of ordinary D-distributions in neighboring elements Z=8, 9, 10 at the first excitations of ^{18}O and ^{24}Ne at D=1982 keV (161 intervals with a deviation of 2.4σ over the mean value) can be compared with a maximum at the same value in a similar analysis of the combined spectrum of the same three elements (n=546+804+701=2051, for Z=8, 9, 10). The mean value n=≈1200 in the combined spectrum of all 55 isotopes of these three elements is much larger than the mean value n=126 (the sum of the results of a separate analysis), but the effect of about 160 values (over the mean level, in the combined analysis) is much greater than the effect of 35 values, obtained during the routine analysis of individual data. To explain this effect, we use the AIM-method of data analysis.

This result independently confirms the common parameters of the CODATA relations and has been checked with data for nuclei from other Z–regions.

FISSION FRAGMENTS BRAKE-UP AT CROSSING OF METAL FOILS

A.O. Strekalovsky[1], D.V. Kamanin[1], Yu.V. Pyatkov[2,1], A.A. Alexandrov[1], I.A. Alexandrova[1], Z.I. Goryainova[1], V. Malaza[3], E.A. Kuznetsova[1], O.V. Strekalovsky[4,1], V.E. Zhuchko[1]

[1]*Joint Institute for Nuclear Research, 141980 Dubna, Russia*

[2]*National Nuclear Research University "MEPHI", 115409 Moscow, Russia*

[3]*University of Stellenbosch, Faculty of Military Science, Military Academy, Saldanha 7395, South Africa*

[4]*Dubna State University, 141980 Dubna, Russia*

In our previous publications [1–3] we discussed new original effect appeared at crossing of the metal foils by fission fragments (FFs). In the series of recent experiments we have compared the mass of the FF before (Mtt) and after (Mte) it passes the foil, event by event. In the light of the obtained results, an FF from conventional binary fission is supposed to be born in the shape isomer state which looks like a di-nuclear system consisting of the a magic core and lighter cluster. Comparison of the correlation mass distributions Mtt-Mte for different metal foils is presented and aimed at testing possible models of the effect.

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COMBINED ANALYSIS OF NUCLEAR DATA AND PARTICLE MASSES. II

S.I. Sukhoruchkin , M.S. Sukhoruchkina

B.P. Konstantinov Petersburg Nuclear Physics Institute NRC KI 188300 Gatchina

We consider a role of neutron resonance spectroscopy in the development of nuclear physics and a search for a "new physics", where several unanswered questions of the theory can be considered, among them are the following problems:
1. What is the reason of the mentioned by R. Feynman success of the Nonrelativistic Constituent Quark Model and the origin of the exact relations in the constituent quark mass parameters. Parameters M_q and M_q'' were initially introduced empirically by G. Wick, R. Sternheimer and P. Kropotkin from the stable intervals between many particle masses, namely, M_q=$m_\Xi/3$=1324 MeV/3=441 MeV$\approx m_{K^*}/2$ and M_q''=$m_\omega/2$=782 MeV/2=390 MeV (a half of the vector meson mass and 1/3 of the baryon mass). The pion mass as the parameter of the NRCQM model was found also in ΔM distribution for all known particle masses and in masses of particles containing the charm quark:

$$D^{*\pm} - D^{\pm} = (140.7 \pm 0.3)\,\mathrm{MeV} = m_\pi \quad (1)$$

$$D_s^{*\pm} - D_s^{\pm} = (141.6 \pm 1.9)\,\mathrm{MeV} = m_\pi \quad (2)$$

$$\chi_{C2}(1P) - \chi_{C0}(1P) = (141.2 \pm 1.1)\,\mathrm{MeV} = m_\pi. \quad (3)$$

2. What is the role of physical condensate, considered by V. Belokurov and D. Shirkov, and how QED radiative corrections can be observed in the data on particle masses and nuclear states, including the data on neutron resonances. Empirically observed correlations in spectra of neutron resonances were considered earlier by M. Ohkubo, K. Ideno, F. Belayev, G. Rohr and others. The term "superfine structure" was proposed by I.M. Frank for stable intervals of the order of several eV and larger, similar to the "fine structure" introduced by V. Andreev for stable energy intervals of the order of 170 keV. The unique possibility of neutron resonance spectroscopy to study the "superfine structure" effects in nuclei where the "fine structure" was observed in the analysis of low-lying levels is discussed with the examples of the data for nuclei with Z=45-52 and Z=72.

3. How a unification of different SM-interactions, mentioned by Y. Nambu, could be obtained, and how the role of the vector interaction could be explained and interconnected with the systematic features of the particle mass spectrum. Recent analysis of particle masses confirmed the existence of the period of $\delta = 16m_e$, derived from the ratio between the masses of nucleons and leptons evaluated in CODATA review. The ratio m_n/m_e=1838.6836605(11) and the nucleon mass splitting δm_N=1293.3322(4) keV result in the neutron mass shift from $115{\cdot}16m_e$ - m_e δm_n = 161.6491(6) keV equal to $(1/8)\delta m_N$. The ratio δm_N : δm_n=8×1.0001(1) corresponds to:

$$m_n = 115 \cdot 16m_e - m_e - \delta m_N/8 \qquad m_p = 115 \cdot 16m_e - m_e - 9(\delta m_N/8) \quad (4)$$

The ratio of the δm_n to the pion mass $\delta m_n/m_\pi = 115.86 \cdot 10^{-5}$ is very close the QED radiative correction $\alpha/2\pi = 115.95 \cdot 10^{-5}$. It means a presence of two fine structures in the nucleon mass presentation: the first, connected with the m_e (the shift -m_e/3=170 keV and the period $16m_e = \delta$) and the second, with the period 161 keV=$\delta m_N/8$, both associated by the factor $\alpha/2\pi$ with the NRCQM parameters 147 MeV=$(m_\Delta$-$m_N)/2$ and the pion mass $m_{\pi^\pm}$ itself. Independent, indirect confirmation of the $\alpha/2\pi$ factor can be obtained from neutron resonance data.

Experimental Study of the Gamma-Decay of Compound-States of ^{56}Mn and ^{94}Nb Nuclei in the (n_{th},2γ)-Reaction

Anatoly M. Sukhovoj[1], Liudmila V. Mitsyna[1], Nikola Jovančević[2], David Knežević[3], Aleksandar Dragić[3], László Szentmiklósi[4], Tamás Belgya[4], Zsolt Revay[5], Christian Stieghorst[5], Stephan Oberstedt[6], Miodrag Krmar[2], Dimitrije Maletić[3], and Dejan Joković[3]

[1]*Joint Institute for Nuclear Research, 141980 Moscow region, Dubna, Russia*

[2]*University of Novi Sad, Faculty of Science, Department of Physics, Trg Dositeja Obradovica 3, 21000, Novi Sad, Serbia*

[3]*University of Belgrade, Institute of Physics Belgrade, Pregrevica 118, 11080 Zemun, Serbia*

[4]*Centre for Energy Research, Hungarian Academy of Sciences, Budapest, Hungary*

[5]*Technische Universität München, Forschungsneutronenquelle Heinz Maier-Leibnitz (FRM II), Lichtenbergstr.1, D-85747 Garching, Germany*

[6]*European Commission, Joint Research Centre, Directorate G Nuclear Safety and Security*

When the results obtained from the reactions ^{55}Mn(n_{th},2γ) and ^{93}Nb(n_{th},2γ) analyzing, the experimental-data array on the intensities of two-step gamma-cascades at a decay of compound-nuclei after radiative capture of thermal neutrons was enlarged. As for 44 nuclei in mass region $28 \leq A \leq 200$ investigated earlier, the quanta-energy dependences of two-step cascades $I_{\gamma\gamma}(E_1, E_2)$ in the compound-nuclei ^{56}Mn and ^{94}Nb were determined, where E_1 and E_2 are energies of primary and secondary cascade quanta, and then the dependencies $I_{\gamma\gamma}(E_1)$ were obtained using all spectroscopic information. The empirical Dubna model of the cascade gamma-decay was used for description of $I_{\gamma\gamma}(E_1)$-intensities by parametrical functions of the nuclear level density, $\rho = \varphi(p1, p2...)$, and partial radiative widths, $\Gamma = \psi(q1, q2...)$, and the most probable nuclear parameters were fitted simultaneously with the use of maximum likelihood method. The Dubna model provides a high precision of experimental-data description.

Problems and Possibilities of a Study of the Cascade Gamma-Decay of a Nucleus Excited below the Neutron Binding Energy

Anatoly M. Sukhovoj[1], Liudmila V. Mitsyna[1], Vu D. Cong[1,2]

[1]*Joint Institute for Nuclear Research, 141980 Moscow region, Dubna, Russia*

[2]*Vietnam Academy of Science and Technology, Institute of Physics, Hanoi, Vietnam*

The Dubna empirical model for simultaneous obtaining of the level density, ρ, and partial radiative widths, Γ, when the experimental dependence $I_{\gamma\gamma}(E_1)$ of the two-step gamma-decay intensities on the energy of primary quanta of the cascades is described, was used for reanalyze of the data obtained with γ-calorimeter of the DANCE spectrometer. The experimental spectra of the γ-cascade intensities for gamma-quanta multiplicity of $M \geq 2$ for ~ ten of even-even nuclei measured with the DANCE spectrometer were used by collaboration participants [1] to find among the existing models of the level density and radiative strength functions those which could exactly describe the experimental spectra. But the results of this employment were unsatisfactory.

The Dubna model always guarantees an obtaining of the nuclear parameters which conditioned by χ^2 minimum: $\chi^2 = (I_{\gamma\gamma}^{cal}(E_1) - I_{\gamma\gamma}^{exp}(E_1))^2 / \varepsilon^2$, where $I_{\gamma\gamma}^{cal}(E_1)$ and $I_{\gamma\gamma}^{exp}(E_1)$ are model-parametrized and experimental distributions of intensities, and ε^2 is a dispersion of their difference. Discovering of χ^2 redundancy corrects the initial parameters of iteration process. Our reanalyze of the data of [1] is compared with our analysis of two-step gamma-cascades for the same nucleus measured in Dubna [2].

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UNCERTAINTY PRINCIPLE AND INTERPRETATION OF THE COLLINEAR CLUSTER TRI-PARTITION PHENOMENON

Yu. M. Tchuvil'sky

Dukhov Research Institute for Automatics, 127055, Moscow, Russia
Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, 119991, Moscow, Russia

Features of a new phenomenon – so called collinear cluster tri-partition – are analyzed from various viewpoints. First, limitations on the angular distributions which are imposed by the general principles of quantum mechanics are considered. Second, these limitations together with the experimental data published earlier are used to estimate the total yield of CCT. Third, some confirmation of the large yield of the lightest component of the tri-partition arising from geochemical data is presented.

1. Yu. V. Pyatkov et al, Phys. Rev. C **96**, 064606 (2017).

Degradation of Array Charge Coupled Devices Induced by Back-Streaming White Neutrons at CSNS

Z.J. Wang[1], Y.Y. Xue[1], H. Ning[2], R. Xu[2], G.T. Dong[1], Z.B. Yao[1], W.Y. Ma[1], B.P. He[1], J.K. Sheng[1]

[1]*State Key Laboratory of Intense Pulsed Irradiation Simulation and Effect, Northwest, Institute of Nuclear Technology, Xi'an, 710024, China*
[2]*School of Materials Science and Engineering, Xiangtan University, Hunan, 411105, China*

wangzujun@nint.ac.cn

Abstract

Charge coupled devices (CCDs) are widely used in the radiation environments as imaging devices. The radiation effects on CCDs are still one of the major concerns of radiation damage. The radiation experiments of array CCDs induced by back-streaming white neutrons are presented. The neutron radiation experiments were carried out at China spallation neutron source (CSNS) (Dongguan, China). The flux of neutron beams was about 1.4×10^6 n/(cm^{2}s), and the ratio of neutrons and the neutron energy spectrum ranges from 1 eV to 200 MeV. The samples used in these experiments are ICX285AL array CCDs manufactured by Sony. The degradations of the array CCDs parameters induced by back-streaming white neutrons are analyzed. The dark current, dark signal non-uniformity (DSNU), and random noise increases with increasing neutron fluences. The saturation output, dynamic range (DR) and signal to noise (SNR) decreases with increasing neutron fluences. The degradation mechanisms of the array CCDs parameters induced by neutron radiation damage are demonstrated in detail. The research will provide the theories and experimental techniques for radiation damage evaluation of the array CCDs induced by back-streaming white neutrons.

Radiation Response of Vacuum Photoelectric Tube and a Temporal Method for Reducing Its Effect

Xingyin Guan

Northwest Institute of Nuclear Technology, Ping Valley Road Lintong District No. 28 in Shaanxi Province, 710024, China

Abstract: Vacuum photoelectric tube is a kind of almost near-ideal light receiver and amplifier so that it is widely in scintillation detectors for converting weak light output to electrical signal than can be measured directly. When in use, the tube is usually placed in the interesting radiation field and inevitably radiated by incident or scattered radiation so that a little unwanted output signal is formed. This signal isn't related to the designed scintillator and possibly affects the designed pulsed radiation performance of whole detector when some scintillator with low light yield is adopted. In the paper, signal formation mechanism of the radiation response is for the first time theoretically analyzed. Then the sensitivity is also estimated and experimentally tested. At last, through well-designed reversed experiment, it is demonstrated that not only Cerenkov emission generally accepted, but also fluorescence emitted isotropically both play primacy role in the radiation response of the tube. In addition, a temporal layout has been designed and proved to be effective for reducing effect of radiation response.

Comparison of Displacement Damage Effects on Bipolar Transistors Irradiated by Spallation Neutrons and Reactor Neutrons

Yan Liu[a,b], Wei Chen[b], Chaohui He[a], Xiaoqiang Guo[a,b], Qiang Zhang[b]

[a] *School of Nuclear Science and Technology, Xi'an Jiaotong University, Xi'an 710049, China*
[b] *State Key Laboratory of Intense Pulsed Irradiation Simulation and Effect, Northwest Institute of Nuclear Technology, Xi'an, 710024, China*

liuyan@nint.ac.cn

Displacement damage induced by neutron irradiation in China Spallation Neutron Source (CSNS) was studied on bipolar transistors with lateral PNP, substrate PNP and vertical NPN configurations, respectively. Based on the ASTM E722 standard, a 1MeV neutron equivalent fluence conversion coefficient of energy above 0.01MeV was calculated according to the CSNS neutron spectra. Comparison of the effects on different-type transistors was conducted based on 1MeV neutron equivalent fluence displacement damage factor, the displacement damage factors based on 1MeV equivalent neutron flux of different transistors are consistent between Xi'an pulse reactor (XAPR) and CSNS. Data shows that the lateral PNP transistor is the most sensitive, the substrate transistor is the second, and the vertical NPN transistor is the least sensitive in this study. The differences were analyzed through minority carrier lifetime calculation and structure analysis. The LPNP transistor has the longest minority carrier lifetime, which is more vulnerable to displacement damage than NPN transistors. On the other hand, the parasitic structure inside the transistors also affect the displacement damage effect, the parasitic transistor structures in LPNP are composed of E(emitter)-B(base)-S(substrate), C(collector)-B(base)-S(substrate), respectively. Under the combined action of two transistors, the excess base current after neutron irradiation could increase significantly. The influence of emitter perimeter was also discussed, the LPNP has a larger bulk base recombination current (due to the largest emitter perimeter) than the substrate PNP and vertical NPN transistors, leading to more severe degradation after neutron irradiation.

The influence of CSNS neutrons irradiation on the lateral PNP transistors was analyzed by gate-controlled method, including the oxide charge accumulation, surface recombine velocity and minority carrier lifetime. Generally, the total ionizing dose effect cause negative drift of gate voltage, and ΔI_B increase with the total dose. Results in this study show that the influence of ionizing radiation caused by different level spallation neutrons is negligible, the surface recombination velocity and oxide trap charge even exhibit slightly decrease. The initial decrease of the ionizing dose factors can be attributed to the reduction of the density of interface states. The natural existing interface traps was passivated by neutron induced defects, upon further irradiation the neutron induced defects increased and the influence of interface state is not so effective any more. The minority carrier lifetime before and after CSNS neutron irradiation is also calculated. The change in the reciprocal of carrier lifetime is linear with the neutron fluence, which is consistent with the literature. The degradation of the transistors was mainly induced by the reduction of the minority carrier lifetime.

TRACE ELEMENT CONCENTRATIONS IN THE PROSTATIC SECRETION OF PATIENTS WITH CHRONIC PROSTATITIS AND BENIGN PROSTATIC HYPERPLASIA INVESTIGATED BY X-RAY FLUORESCENCE

V. Zaichick[1], S. Zaichick[1,2]

[1] *Medical Radiological Research Centre, Korolyev St., 4, Obninsk, 249036, Russia, e-mail: vzaichick@gmail.com*

[2] *Feinberg School of Medicine, Northwestern University, Chicago, IL 60611-4296, USA*

Prostatitis is the most common urologic disease in adult males younger than 50 years and the third most common urologic diagnosis in males older than 50 years. Chronic prostatitis (CP) is functional, somatoform disorder with a high worldwide prevalence estimated in systematic reviews or population studies at 10–32%. However, CP is a more common condition, with 35–50% of men reported to be affected by symptoms suggesting prostatitis during their lifetime. Benign prostatic hyperplasia (BPH) is an internationally important health problem of the man, particularly in developed countries, and represents the most common urologic disease among of men after the age of fifty. Incidence of histological BPH could be over 70% at 60 years old and over 90% at 70 years old.

Thus, the both BPH and CP is the very common urologic disease in adult males. Moreover, use systematic review methods provide the statistical evidence that the association between BPH and CP is significant. This warrants the need of reliable diagnostic tool which has ability not only to diagnose CP reliably but also to differentiate it from the BPH and conversely.

One of the main functions of prostate gland is a production of prostatic fluid with extremely high concentration of Zn and some other chemical elements. In present study it was supposed by us that apart from Zn the levels of some other TE in EPF have to reflect a difference between functional changes of chronic inflamed prostate and hyperplastic prostate.

Prostatic fluid levels of Br, Fe, Rb, Sr, and Zn were prospectively evaluated in 33 patients with CP and 52 patients with benign prostatic hyperplasia. Measurements were performed using ^{109}Cd radionuclide-induced energy dispersive X-ray fluorescent microanalysis.

Mean values ± standard error of means (M±SEM) for concentration (mg/L) of trace element in the prostatic fluid of inflamed prostate were: Br 3.35±0.69, Fe 10.9±2.3, Rb 2.32±0.30, Sr ≤1.57, and Zn 382±48. The concentrations of trace element in the prostatic fluid of hyperplastic prostate were (mg/L): Br 2.32±0.30, Fe 11.5±1.8, Rb 1.70±0.23, Sr 1.41±0.26, and Zn 488±42. No differences between the Br, Fe, Rb, Sr, and Zn concentrations in EPF samples of BPH and CP group were found.

RELATIONSHIP BETWEEN Ca, Cl, K, Mg, Mn, Na, P, AND Sr CONTENTS IN THE INTACT CROWNS OF FEMALE TEETH INVESTIGATED BY NEUTRON ACTIVATION ANALYSIS

V. Zaichick[1], S. Zaichick[1,2]

[1] *Medical Radiological Research Centre, Korolyev St., 4, Obninsk, 249036, Russia, e-mail: vzaichick@gmail.com*

[2] *Feinberg School of Medicine, Northwestern University, Chicago, IL 60611-4296, USA*

The bioaccumulation of chemical elements in human bone and teeth is rather a complex process. Factors that influence bioaccumulation include age, gender, genetic inheritance, dietary habits, environmental quality, and so on. Many chemical elements in human organism act antagonistically and/or synergistically. Some elements in the teeth can be substituted by other elements and, as a result, change biochemical reactions in humans. Variations in relative content of chemical elements in the teeth lead to modulation/dysfunction of teeth metabolism.

To use chemical element composition as estimation of teeth health in clinical, geographical, environmental and occupational medicine, paleoanthropology, and other directions, it is necessary to know normal levels and age- and gender-related changes of chemical element ratios.

This work had three aims. The first one was to determine the Ca, Cl, K, Mg, Mn, Na, P, and Sr mass fractions in the intact crowns of female teeth by instrumental neutron activation analysis with high resolution spectrometry of short-lived radionuclides (INAA-SLR) and to calculate some statistical parameters of Cl/Ca, K/Ca, Mg/Ca, Mn/Ca, Na/Ca, P/Ca, Sr/Ca, Ca/P, Cl/P, K/P, Mg/P, Mn/P, Na/P, Sr/P, Ca/Mg, Cl/Mg, Mn/Mg, Na/Mg, P/Mg, Sr/Mg, Ca/Cl, K/Cl, Mg/Cl, Mn/Cl, Na/Cl, P/Cl, Sr/Cl, Ca/K, Cl/K, Mg/K, Mn/K, Na/K, P/K, Sr/K, Ca/Na, Cl/Na, K/Na, Mg/Na, Mn/Na, P/Na, and Sr/Na mass fraction ratios. The second aim was to evaluate the effect of age on mean values of ratios of chemical element mass fractions in the intact crowns of female teeth. The third aim was to estimate the inter correlations between Ca, Cl, K, Mg, Mn, Na, P, and Sr mass fractions in the intact crowns of female teeth.

In the intact crowns of female teeth it was found a statistically significant age-related decrease of the Sr/Ca, Sr/P, Sr/Mg, Sr/Na, and Cl/Na ratios accompanied an increase of the K/Cl, Na/Cl, and P/Cl ratios.

The positive inter-correlations of P mass fractions with Ca (p <0.001) and Cl (p <0.01), as well as Mn mass fractions with K (p <0.05) and Sr (p <0.01) mass fractions were found in female teeth crowns. If some correlations between the elements were predictable (e.g., Ca–P), the interpretation of other observed relationships requires further study for a more complete understanding.

NEUTRON ACTIVATION ANALYSIS OF Br, Ca, Cl, K, Mg, Mn, Na, AND P CONCENTRATIONS IN HUMAN SALIVA IN HEALTH AND PARODONTOPATHY

V. Zaichick[1], S. Zaichick[1,2]

[1] *Medical Radiological Research Centre, Korolyev St., 4, Obninsk, 249036, Russia, e-mail: vzaichick@gmail.com*

[2] *Feinberg School of Medicine, Northwestern University, Chicago, IL 60611-4296, USA*

Periodontal diseases and dental caries are the most common diseases in the oral cavity. Periodontal diseases are chronic inflammatory disorders encompassing destructive and nondestructive diseases of the periodontal supporting tissues of teeth. Gingivitis is a nondestructive disease ubiquitous in populations of children and adults globally. Aggressive periodontitis is characterized by severe and rapid loss of periodontal attachment often commencing at or after puberty and common among Caucasians. Chronic periodontitis is a common disease and may occur in most age groups, but is most prevalent among adults and seniors world-wide. Approximately 48% of United States adults have chronic periodontitis, and similar or higher rates have been reported in other populations. Moderate and advanced periodontitis is more prevalent among the older age groups, and rates of 70% or more have been reported in certain populations.

However, case definitions and criteria that are used to diagnose periodontal diseases are not yet consistent worldwide. Thus, there are needs to find additional parameters to characterize the periodontal diseases. Salivary main electrolytes and trace element can be involved in the etiology and pathogenesis of periodontal diseases. The objective of this investigation was to estimate the possibilities of using the data about concentrations of main electrolytes and trace element in mixed non-stimulated saliva in the diagnosis of periodontal disease.

The concentrations of Br, Ca, Cl, K, Mg, Mn, Na, and P were determined by the instrumental neutron activation analysis in samples of the mixed non-stimulated saliva of 52 apparently healthy subjects and 60 patients with parodontopathy (gingivitis and periodontitis). The age of the persons examined (80 females and 32 males) was in the range from 17 to 49 years. There were no any metallic oral inclusions or prosthesis in all persons involved in the study. Dental diseases were diagnosed according to the complex data of special clinical examinations (disease anamnesis, inspection assessment of pathological dental and gingival pouch state, panoramic X-radiography). The samples of mixed saliva were cooled in period between 10 a.m. and 12 a.m., then cooled and lyophilized.

It was found that the concentration of almost all elements studied in mixed saliva of patients with parodontopathy was higher than the normal level.

Interaction of Ultracold Neutrons with a Neutron Interference Filter Oscillating in Space

M.A. Zakharov, A.I. Frank, G.V. Kulin

Joint Institute for Nuclear Research, Dubna, Russia

The work presents the results of the study dedicated to the problem of the interaction of ultracold neutrons with a neutron interference filter oscillating in space – Fabry-Perot interferometer. The numerical solution of the non-stationary Schrödinger equation was found by splitting the evolution operator. The spectra of transmitted and reflected states are obtained, depending on the parameters of the interferometer motion.

For the most part, the calculation results correspond to the expectations. The transmitted state is modulated in amplitude, and the state spectrum has a discrete form. At the same time, the essential details of the obtained picture differ from the predictions based on semi-classical ideas. Probably the most significant of the discovered effects is the shift of transmission maxima of the system with increasing frequency followed by the merging of neighboring peaks. As a result, the apparent frequency of intensity modulation is halved. Such behavior of the transmission state cannot be explained on the basis of simple considerations on the temporal intensity modulation due to the variable speed of the interferometer. Apparently, the finite time of state formation in the resonant system represented by a Fabry-Perot interferometer and completely unaccounted effects of its acceleration plays a significant role.

The obtained results are based on the assumption that the description of the interaction of neutrons with matter by means of the effective potential is valid. At the same time, in the case of a medium moving with great acceleration, the validity of such an assumption is not obvious. Therefore, it is very important to conduct an experiment in which it would be possible to verify the theoretical results. Preparations for this experiment are underway.

Measurement of Time-of-Flight Transmission Spectra by the Current Method

Sh. Zeinalov[1], V. Kuznetsov[1,2], E. Kuznetsova[2], P. Sedyshev[1]

[1]Joint Institute for Nuclear Research, Frank Laboratory of Neutron Physics 141980 Joliot-Curie 6, Dubna Moscow region, Russia
[2]Institute for Nuclear Research, Russian Academy of Sciences, 117312 Moscow, 60th Anniversary of October *7a, Russia*

An increase in the intensity of pulsed neutron sources leads to an unprecedentedly large pulsed density of neutron flux, up to 10^{11} n/s and, as a consequence, to the impossibility of using data acquisition systems operating in the counting mode. On the other hand, when operating in stationary reactors, current-mode detectors are often used. This paper presents the results of measuring the time-of-flight neutron transmission spectra of tantalum and indium samples using a neutron counter operating in the current mode.

Neutron Emission in $^{235}U(n_{th},f)$ and $^{252}Cf(sf)$ Reactions

Shakir Zeynalov, *Pavel* Sedyshev, *Valery* Shvetsov, and *Olga* Sidorova

Joint Institute for Nuclear Research, 141980 Dubna Moscow region, Russia

Abstract. The prompt neutron emission in thermal neutron induced fission of ^{235}U and spontaneous fission of ^{252}Cf was investigated by using digital signal electronics. The goal was to check new revised data analysis software with fission fragment (FF) kinetic energy corrections after prompt fission neutron (PFN) emission. The revised software was used to reanalyze old data measured in EC-JRC-IRMM, where $^{252}Cf(sf)$ reaction was investigated. Both measurements were done using similar twin Frisch grid ionization chamber for fission fragment detection with equivalent NE213 fast neutron detector. About $0.5 \cdot 10^6$ FF with PFN coincidences have been analyzed in both measurements. The fission fragment kinetic energy, mass and angular distribution were investigated along with prompt neutron time of flight and pulse shape analysis using a six channel synchronous waveform digitizer (WFD) with sampling frequency of 250 MHz and 12 bit resolution in the $^{235}U(n_{th},f)$ reaction. Similar WFD with sampling frequency of 100 MHz was used for PFN investigation in $^{252}Cf(sf)$ reaction. These two experiments were considered as a reference for further investigations with a new setup composed of position sensitive ionization chamber to detect FF and an array of 32 liquid scintillators recently constructed in Dubna to detect neutrons.

Lithium Biosorption by *Spirulina Platensis* Biomass

Zinicovscaia I.[1,2], Yushin N.[1], Pantelica A.[2], Apostol A.[2]

[1]*Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Joliot-Curie Str., 6, 1419890, Dubna, Russia*
[2]*Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering, 30 Reactorului Str. MG-6, Bucharest - Magurele, Romania*

The biosorption of lithium from batch systems by *Spirulina platensis* biomass was studied. Adsorption capacity of the biosorbent was investigated as a function of contact time, initial metals concentration and pH values. Lithium content in biomass was determined using Proton Induced Gamma Emission technique. The ability of spirulina biomass for lithium biosorption showed a maximum at the pH 11. Equilibrium data fitted well with the Langmuir model with maximum adsorption capacity of 1.75 mg/g, while the kinetic data were best described using the pseudo second-order kinetic model. The pseudo second-order model was found to correlate well with the experimental data. *Spirulina platensis* biomass could be applied as environmentally friendly sorbent for lithium removal from model solution.

Keywords: biosorption, lithium, Spirulina platensis, PIGE technique

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Abstracts

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