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

Dubna, 2024

Abstracts

Joint Institute for Nuclear Research

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Levels of Heavy Metals in Pregnant Women with Fetal Central Nervous System Anomalies Using ICP-OES

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Central nervous system (CNS) anomalies are the second most common type of fetal anomaly. Heavy metal toxicity and deficiency of trace elements can be a cause for fetal anomalies. This work aimed to assess the possible association between Al, Cd, Co, Cu, Fe, Mn, Pb, Se, Zn and fetal CNS anomalies. Research was conducted in Kasr Alainy Maternity Hospital, Cairo University in the period between March 2021 and October 2022 and included 40 pregnant women, which were divided into two groups (20 women in each group). The first group included pregnant women with normal fetal anatomy sonographic scan and the second group included pregnant women with confirmed sonographic fetal CNS anomalies. Pregnant women with known risk factors for fetal anomalies were excluded. From each woman four grams of hair were collected. In both groups content of Al, Cd, Co, Cu, Fe, Mn, Pb, Se, Zn in all samples was assessed using Inductively Coupled Plasma Optical Emission spectroscopy.

There was no significant statistical difference in the mean age between the two groups. The levels of Al, Cd, Co, Cu, Fe, Mn, Pb, Se, Zn in group 2 (Patients) were 385±3.44 mg/kg, 0.68±0.01 mg/kg, 0.63±0.02 mg/kg, 51±0.4 mg/kg, 152±1.3 mg/kg, 9.2±0.09 mg/kg, 7.5±0.084 mg/kg, 1.8±0.3 mg/kg, 356±3.1 mg/kg, respectively while in the group 1 (control) their levels were 373±2.0 mg/kg, 0.16±0.002 mg/kg, 0.26±0.02 mg/kg, 67± 0.4 mg/kg, 92±0.8 mg/kg, 4.4±0.04 mg/kg, 5.4±0.05 mg/kg, 1.3±0.15 mg/kg, 273±2.5 mg/kg, respectively. Mann-Whitney U test proved highly significant statistical difference between the two groups ($p < 0.001$) just for three elements, Cd, Co and Se. ROC curves showed that the best cut off level for the association of Al, Cd, Co, Fe, Mn, Pb, Se, Zn and fetal CNS anomalies were > 260 > 0.13 > 0.322 >68 > 3.7 > 4.2 >1.4 > and 151, respectively.

Our study is a red flag. Thus, during pregnancy high levels of Cd, Co and Se can be responsible for fetal CNS anomalies. Further studies on a larger number of cases and with extensive studies of the environmental factors are strongly needed.

Neutronic Behavior of SMART-ATFs Nuclear Fuel

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Managing nuclear fuel through the operation of nuclear power reactors is an important step of the nuclear fuel cycle till it is discharged from the reactor core. The operational conditions affect the cycle length of nuclear fuel. As Small Modular Reactors are designed to operate at high burn up to support energy supplies. SMR technology has improvement in the economics achieved through system simplification, component modularization, construction time reduction, and increased plant availability. One of SMRs types is the Korean design named System-Integrated Modular Advanced Reactor (SMART).

SMART is a small-sized integral type PWR with a rated thermal power of 330 MW_{th}; its design characteristics contributing to safety enhancement through utilizing an advanced nuclear fuel designs such as Accident Tolerance Fuels and advanced cladding materials such as High-performance Alloy for Nuclear Application into the reactor core.

Accident Tolerance Fuels (ATFs) was manufactured to improve fuel performance during normal operation, transient conditions, and accident scenarios. Also, to increase fuel cycle length, to reduce oxidation and hydrogen generation, to reduce the fuel cycle cost and its accommodation of fission products is high. High performance Alloy for Nuclear Application (HANA) was developed by Korean Atomic Energy Research Institute (KAERI) and Korean Nuclear Fuel Company (KNFC) and tested to sustain high discharge burn up to more than 70GWd/MTU at Halden research reactor .

The neutronic behavior for SMART-ATFs with HANA cladding alloy will be studied for an average nuclear fuel assembly through its criticality, inventory and radioactivity using MCNP 6.1 code and the enhanced safety features will be reviewed.

Use of Neutrons for Plants Breeding

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For the last ten years interest to the neutron irradiation in plant science has been increasing. According to the IAEA and the Food and Agriculture Organization of the United Nations (FAO) fast neutrons are more suitable in case of producing higher damage in genetic material of plants [1]. Neutrons show good perspective not only in mutagenesis but also in improving agronomic traits and yield parameters of the plants. In comparison with other physical mutagenes neutrons show better relation between LET and RBE [2]. Despite the fact that the relative genetic efficiency of fast neutrons (FN) is 10 times higher than gamma radiation, the share of studies on gamma-induced mutagenesis is about 85% of all studies of physical mutagens, while neutron mutagenesis is only 10–11% [3, 4].

Research over the last ten years has shown the effectiveness of using FN for plants such as rice, wheat, cotton, soybeans, peas, peanuts, tomatoes. Irradiation with fast neutrons affects the structure of DNA, damaging nitrogenous bases, promoting standard breaks; in addition, the repair of DNA damage is greatly slowed down compared to gamma or X-rays. Also, compared to gamma rays, fast neutrons have a higher frequency of double strand breaking. Other studies have shown signs of changes in grain quality. Using the example of rice (Oryza sativa), a change in amylose content was found in some mutant lines. Irradiation with fast neutrons caused changes in the FRO1 gene, which is responsible for increased tolerance and higher accumulation of iron in grains. Also, there are studies showing positive effect of the neutron irradiation on the germination energy and germination of wheat and cotton seeds.

For plant irradiation fast neutrons are mostly used with wide range of energy (1–15 MeV). Installation EG-5 is suitable for conducting such types of research.

References

1. Mutation induction in plants | IAEA (https://www.iaea.org/topics/mutation-induction)
2. Imaging Physics, Chapter 14, Editor(s): Ralph Weissleder, Jack Wittenberg, Mukesh G. Harisinghani, John W. Chen, Primer of Diagnostic Imaging (Fifth Edition), 2011, pp. 690-746, https://doi.org/10.1016/B978-0-323-06538-2.00014-7
3. V.E. Viana, et al. Mutagenesis in Rice: The Basis for Breeding a New Super Plant // Frontiers in Plant Science, 2019.
4. Plant Mutation Breeding and Biotechnology/ Q. Y. Shu, B. P. Forster, H. Nakagawa, Food and Agriculture Organization of the United Nations (FAO) and International Atomic Energy Agency (IAEA), 2011, pp. 595.

Elemental Composition Analysers Based on the Tagged Neutron Method

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Currently, the tagged neutron method (TNM) is actively used to determine the elemental composition of various substances: sinter, coal, iron and phosphate ores. The tagged neutron method consists in irradiation of the substance under study by fast neutrons with an energy of 14 MeV and registration of the induced characteristic gamma radiation. Neutron tagging is carried out by an alpha detector built in a neutron generator.

The results of operation of conveyor analysers of TNM for determination of elemental composition of matter on the conveyor in real time mode without sampling are discussed. The analyser provides the results of the elemental analysis of sinter each 40-60 s without taking the probe. It gives possibility to correct elemental content of the sinter to provide its stability. Large penetrating power of the 14 MeV neutrons provides information of the elemental content of large layer of the substance up to 300 mm.

Interesting results are obtained on stationary TNM analysers that determine the elemental composition of slurry samples required for proper quarrying.

New applications of TNM for the separation of iron ores and the sorting of used refractories using neural networks have also been developed.

Geochemical Characterization of Egyptian Red Sea Mangrove Sediments: Composition, Pollution Sources, and Environmental Implications

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The present study was conducted to assess the elemental composition and pollution sources of mangrove sediments along the Egyptian Red Sea coast. Using inductively coupled plasma–mass spectrometry (ICP–MS) and atomic emission spectrometry (ICP-AES), 26 samples from Sharm El Madfea, Sowmaa Mangrove, and Abu Fasi were analyzed for 58 major and trace elements. Statistical analyses identified trace metal origins. Common geochemical traits with shale, UCC, and marine sediments were revealed. Ratios suggested proximity to continental island arcs (CIA), and sediment recycling was explored. Principal Component Analysis (PCA) clustered elements with similar geochemical traits, indicating contamination from crustal influences, marine weathering, and anthropogenic sources. Enrichment Factor (EF) analysis highlighted significant to extremely high enrichment for Mg, As, Se, P, Cu, Cd, Sn, U, Ca, and Sr, indicating a mixed origin of contamination. The study's findings offer a valuable tool for managing anthropogenic impacts on mangrove ecosystems and serve as a baseline for ongoing monitoring and future environmental predictions.

Keywords: *elemental content; mangrove sediments; ICP-MS; pollution indices; multivariate statistical analysis*

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GEM-Based Detectors for Thermal Neutrons with a VMM3 ASIC Readout

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Gas Electron Multiplier, or GEM, is a modern gas-filled coordinate detector which becomes very popular in High Energy Physics experiments. Used for charged particle detection, GEM can provide high spatial and time resolutions and high rate compatibility. It can be extremely radiation hard and can be made with large active area. A triple GEM, implementing three amplification stages, provides a charge amplification at the level of 10000. A standard triple GEM with an input window made of thin metallized mylar with B4C coating can be operated in both the nominal detection mode and in neutron registration mode.

Custom Application Specific Integrated Circuits (ASICs) VMM3 and VMM3a developed by Brookhaven National Laboratory (BNL) are capable of simultaneous precise measurements of both the charge and time characteristics of signals in gaseous detectors. Their flexibility makes them attractive as a readout electronics solution for a wide range of applications, including readout systems of nGEM-detector in Neutron Physics experiments.

Neutron detection capability of the modified triple GEM operated with the VMM3-based readout is presented in the talk.

Source of Radiation Emission with a Plasma-Physical Accelerator of a Linear Configuration

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The possibility of creating technical means for controlling the processes of accumulation and conversion of the energies of thermal and epithermal neutrons into the energy of monoenergetic photons emission due to neutron pumping of an active medium consisting of nuclei with long-lived isomeric states is studied in this work. The system under study consists of an external pulsed source of D–T neutrons based on an extended gas-dynamic magnetic trap (denoted in [1] as Plasma Source Neutrons, PSN) and a subcritical blanket [1], which includes a variable-geometry neutron-collimation beam-shaping assembly (variable neutron-collimation Beam-Shaping Assembly, vBSA) and an active medium. The vBSA is a sophisticated configuration that consists of moderating blocks and selective plates, which are specifically designed to confine and shape a pulsed neutron flux. The objective of the vBSA is to convert the millisecond signature of the neutron flux into a monoenergetic photon emission, which is crucial for many scientific and medical applications. Gadolinium oxide (Gd_2O_3) enriched in ^{155}Gd isotope is used as the active medium; as the main pump scheme, the channel of ^{156}Gd isotope formation in the inverse state is studied, the de-excitation of which is accompanied by the emission of an intense gamma line with a wavelength of ~10^{-4} nm (~12.4 MeV) [2]. To facilitate a comprehensive feasibility study regarding this possibility, our work focuses on modeling and investigating the neutronic, thermophysical, and hydraulic properties of the system. The primary objective of this simulation is to optimize the temperature conditions for effectively cooling the blanket and the PSN. Additionally, we aim to construct accurate temperature fields, identify any shifts in the power release field, and pinpoint temperature extremes in the region housing the Gd_2O_3. By successfully achieving the project goal, the potential of the developed models and codes in creating a sophisticated "blanket - PSN – vBSA" system is demonstrated.

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1. Bedenko S.V., Lutsik I.O., Prikhodko V.V., et al., Progress in Nuclear Energy, 154, 104477 (2022).
2. Shamanin I.V. and Kazaryan M.A., Bulletin of the Lebedev Physics Institute, 44, 215–217 (2017).

Study of Quaternary Spontaneous Fission of ^{252}Cf

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This work presents the results of experiment on quaternary fission (QF) in spontaneous fission of ^{252}Cf. QF can arise from two primary pathways: "pseudo" QF via the decay of unstable species within ternary particles (LCPs, e.g., ^{7}Li*, ^{8}Be*, ^{9}Be*) and "true" QF through the independent emission of two LCPs [1, 2]. Previous studies faced limitations in acquiring high statistics and pricisely measuring angular correlations between particles from decaying LCPs (e.g., ^{7}Li*(α, t) and ^{8}Be*(α, α)) [1, 2, 3]. This work overcomes these challenges by employing a particle telescope comprising 15 μm and 150 μm ΔE detectors and a 600 μm Timepix detector. This setup enables efficient identification of (α, α) and (α, t) decay pairs from excited LCPs. The detection system geometry was restricted and covered an angular range between 0°–50° and 130°–180° for the mutual opening angles (θ) between two measured LCPs. The geometry of detection system had to be simulated in order to make correction on obtained experimental results.

The observed angular distribution of α-particles from (α, α) coincidences aligns well with calculations simulating the decay kinematics of ^{8}Be from its ground and first excited states. Despite limited statistics, the energy spectrum of (α, t) pairs from the second excited state of ^{7}Li, detected on a single detector, was analyzed and compared to data from ternary Li particles. Additionally, results involving (α, α) and (α, t) pairs detected in opposite detectors are presented. Particle yields and energies were determined per 10^4 ternary alphas and reported.

1. Ahmadov, G.S. Detection of ternary and quaternary fission fragments from ^{252}Cf with a position-sensitive ΔE-E telescope based on silicon detectors / G.S. Ahmadov, Yu.N. Kopatch, S.A. Telezhnikov [et al.] // Phys. Part. and Nuclei Lett., - 2015, vol. 12, p. 542–549.
2. Jesinger, P. New experimental studies on the quaternary fission of ^{233,235}U(n_{th}, f) and ^{252}Cf(sf) / P. Jesinger, Yu.N. Kopatch, M. Mutterer [et al.] // Eur. Phys. J A, -2005, vol. 24, -p. 379–388.
3. Tishchenko, V.G. Study of ternary and quaternary spontaneous fission of ^{252}Cf with the NESSI detector // Report HMI-B 588, 2002.

Measurement of Cross-Section of the p + ^{7}Li, d + Li, p + ^{11}B, and d + B Reactions at Ion Energies up to 2.2 MeV

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The interaction of a deuteron beam with lithium is characterized by a high yield of neutrons, their high energy and a large variety of reactions. The interaction of a proton with boron-11 is considered a promising reaction for neutronless fusion energy. Reliable data for these reaction cross-sections are important for many applications, including radiation testing of advanced materials and equipment, neutron yield, neutronless fusion, astrophysics and hadron therapy. Experimental data on cross-sections differ greatly from one author to another; for a number of reactions there is no data on the cross-section in the databases. Measurements of the reaction cross-section were carried out at the accelerator-based neutron source VITA at the Budker Institute of Nuclear Physics (Novosibirsk, Russia) using a HPGe γ-spectrometers, an α-spectrometers, and a diamond neutron spectrometers. The ^{7}Li(p,p'γ)^{7}Li, ^{7}Li(p,α)^{4}He, ^{6}Li(d,α)^{4}He, ^{6}Li(d,p)^{7}Li, ^{6}Li(d,p)^{7}Li*, ^{7}Li(d,α)^{5}He, ^{7}Li(d,nα)^{4}He, ^{7}Li(d,n)^{8}Be, ^{11}B(p,α_0)^{8}Be, ^{11}B(p,α_1)^{8}Be*, ^{10}B(d,α)^{8}Be, ^{10}B(d,p)^{11}B, ^{11}B(d,α)^{9}Be, and ^{11}B(d,p)^{12}B reaction cross-sections at ion energies up to 2.2 MeV have been measured. Measurements of the differential cross section of the reactions were carried out for two angles, which made it possible to determine the angular distribution of emission of reaction products and calculate the total reaction cross section. The results obtained are distinguished by their reliability. The report will present and discuss the results obtained, and declare plans.

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Possible Experiments to Search for Singlet Deuteron and the Problem of the Existence of Neutral Nuclei

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The existence of the dineutron has been predicted 75 years ago, but the question of its existence has not yet been finally resolved. Currently, a number of experimental studies indicate the existence of the dineutron, as well as other lightest neutral nuclei (for example, tetraneutron). If a dineutron exists, then, according to the principle of isotopic invariance, a $^1S_0-$ state of two nucleons must also exist. The possibility of describing the neutron-proton interaction in the $^1S_0-$ state at low energies as the excitation of a quasi-stationary level lying below the deuteron decay threshold (singlet deuteron) is discussed. The position, neutron and radiative widths of the level are determined by the scattering length, effective radius and cross section for radiative capture of neutrons by protons. Contemporary status and new possible experiments to search for this level in the radiative capture of neutrons by protons and in the resonant scattering of gamma quanta by deuterons are discussed. The discovery of a singlet deuteron would be confirmation of the existence of the dineutron.

Distribution of Radionuclide Impurities in Irradiated Topaz

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Irradiation is one of the most efficient techniques to enhance gemstones, and color enhanced topaz is the best example of commercial application of neutron irradiation. After irradiation the color of topaz turns into deep blue resulting in so-called London blue topaz. However, neutron irradiation induces radionuclides of different half-life time and thus causes radioactivity of the gemstones. For color enhanced topaz it may take up to several months for residual radioactivity to reach a safe level. This period depends on several factors, such as chemical composition of the topaz and the type of irradiation. The residual activity may significantly vary among topaz samples even if they have originally been obtained from the same deposit.

We present results of spectroscopic analysis of about 400 irradiated topaz samples. Large variation in residual activity measured in several months after the irradiation is observed. Different types and different concentration of radionuclides are identified. To optimize the color enhancement procedure and to reduce the storage time required to reach the safe level of residual activity, a post-irradiation sampling is proposed.

Enhancement of the Fundamental Symmetry Breaking Effects in Neutron Resonances: Kinematic or Resonance?

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As an example of P-violation in polarized neutron transmission through the sample we consider the longitudinal asymmetry:

$$P_{\exp} = \frac{N_+ - N_-}{N_+ + N_-} \approx \frac{\Delta^P_{tot}}{\sigma_{tot}},$$

where $N_\pm$ is the number of neutrons with opposite helicities transmitted through the target sample, while the corresponding total cross-section for such neutrons is

$$\sigma^\pm_{tot} = \sigma_{tot} \pm \frac{\Delta^P_{tot}}{2}. \qquad .$$

There are two different theoretical approaches to the problem. One of them (see, e.g. [1, 2]) claims that the quantity $P_{\exp} \approx 2\sqrt{\frac{\Gamma^n_s}{\Gamma^n_p}}\frac{W_p}{D}$ in the vicinity of the p-wave resonance contains a "kinematical" enhancement factor $\sqrt{\frac{\Gamma^n_s}{\Gamma^n_p}} \approx \frac{1}{kR}$, where $\Gamma^n_{s,p}$ are s- or p-resonance neutron widths (W_p is the weak interaction matrix element between the s- and p-resonance wave functions, D is the spacing between the neighboring s- an p-levels of the compound nucleus).

Another approach (see, e.g. [3, 4]) gives the expression:

$$P_{\exp}(E) \approx \frac{4\pi}{k^2\sigma_{tot}(E)}\frac{W_p}{D}\frac{\sqrt{\Gamma^n_s\Gamma^n_p}\cdot\Gamma_p}{(E-E_p)^2 + \Gamma^2_p/4},$$

containing "resonance" enhancement factor

$$\frac{\Gamma_p}{(E-E_p)^2 + \Gamma^2_p/4} = \frac{T(E)}{\hbar},$$

where $T(E)$ is the "delay time" spent by the neutron in the weak field of the target nucleus. It might give a factor of $(D/\Gamma)^2$ enhancement in the maxima of p-resonance.

Analysis is given of both approaches showing that the former one might lead to quite meaningless conclusions. Similar enhancements are present in all the quantities revealing parity or time invariance violation in polarized neutron transmission.

1. O. Sushkov, V. Flambaum. JETP Lett. **32**, 353 (1980).
2. V.V. Flambaum , A.J. Mansour. Phys. Rev. C **105**, 015501.
3. V. Bunakov, V. Gudkov. Nucl. Phys. A 401, 93 (1983).
4. V. E. Bunakov, L.B. Pikelner. Prog. Part. Nucl. Phys. **39,** 337 (1997).

Analyzing the Accumulation of Trace Elements in Moss Samples from Agricultural and Mountainous Environments

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Georgia is characterized by its mountainous terrain and vast diversity in landforms. To understand the impact of agricultural lands and mountainous areas on the accumulation of trace elements in mosses, the concentrations of selected metals in mosses across these environments was compared. Hypnum cupressiforme was selected as the biomonitor species for this study, focusing on samples collected from 2019 to 2023. Samples from urban or industrial areas were excluded, with 24 samples from agricultural zones and 30 from mountainous areas were analyzed. The Mann-Whitney U test revealed no significant difference in levels of Cd, Co, Fe, Mn, Ni, Sr, and Zn between the two groups. However, Al, Ba, Cr, Cu, Pb, and V showed significant differences. Comparative analysis of samples from Moldova, which is a predominantly agricultural country, with moss samples collected near agricultural areas of Georgia, showed significant variances in Cd, Cu, Ni, Pb and Zn, but when compared to Georgian mountain areas, all elements except Co, Fe, Mn and V showed significant differences.

Median concentrations of Al, Ba, Sr, and Zn were higher in Moldova, while all other elements were higher in Georgia. The lowest median concentrations were observed in mountainous areas, except for Co, Ni, and Pb, which were lower in Moldova. The nearly identical Cr concentrations in agricultural areas suggest that fertilizers, often containing Cr, are a significant source of this element.

The findings indicate that pollutants are more easily spread in open areas than in mountainous ones. Georgia and Moldova have slightly different geochemical compositions, with slight differences in the distribution of elements like nickel and zinc between agricultural and mountainous areas in Georgia, but significant differences from Moldova. Additionally, the impact of transport on the environment in Georgia is noticeable. These results are valuable for biomonitoring studies in areas with varying physical and geographical conditions, suggesting further research to uncover more connections between element distribution and environmental conditions.

Measurement of the $^{235,238}U(n, f)$ Cross-Section Relative to n-p Scattering from 10 to 70 MeV at CSNS Back-n

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Neutron-induced fission cross sections of U-235 and U-238 are ones of the most important nuclear data since they are fundamental to nuclear energy. Fission cross sections of ^{235}U and ^{238}U have been evaluated as standard data up to 200 MeV and they are always used as references for other cross section measurements. However, the experimental data in high neutron energy region are scarce. Especially above 30 MeV of neutron energy, there are only a few measurements with obvious discrepancies. Thus conducting a measurement in high energy region is quite necessary meaningful.

The back-streaming neutron facility (Back-n) at China Spallation Neutron Source (CSNS) is a newly built neutron beamline started commissioning since 2018. Back-n provides neutrons from 0.5 eV to 300 MeV with an achievable flux of 1.6×10^7 n/cm^2/s at 55 meters away from the spallation target. It is therefore a good platform for nuclear data measurement. We performed an experiment at Back-n for measuring the fission cross sections of ^{235}U and ^{238}U relative to n-p elastic scattering. The ^{235}U and ^{238}U samples are sealed in an ionization chamber for measuring their fission reactions. A polythene (PE) foil and recoiling proton telescopes (RPT), consisting of silicon detectors and cesium iodide scintillators, are setup in a vacuum chamber located at the downstream of the fission chamber. The proton events are selected by the ΔE-E identification. We will firstly introduce the CSNS Back-n facility. Then we will go to details of the data analysis of fission chamber and RPT. Finally the preliminary results of fission cross section of ^{235}U and ^{238}U from 10 to 70 MeV will be shown.

Neutron Spectrum Unfolding Method Based on Shifted Legendre Polynomials, Its Application to the IREN Facility

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The paper presents a method for unfolding the neutron energy spectrum from the results of measurements with a Bonner multi-sphere spectrometer. The method is based on solving the system of the Fredholm integral equation of the 1st kind using Tikhonov regularization and decomposing the spectrum into shifted Legendre polynomials. To obtain an optimal solution, an algorithm for selecting the regularization parameter and the number of polynomials is proposed. Spectra were reconstructed for rooms near the Intense Resonance Neutron Source (IREN) facility at JINR in the energy range from 10^{-8} to 63.1 MeV. The effective dose rate and ambient dose equivalent rate were estimated for the obtained spectra. Results are compared with the statistical regularization method (the RECONST software).

Measurements of the $^{6}Li(n,\alpha)^{3}H$ Reaction in the Neutron Energy Range E_n=3.3-5.3 MeV

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We have measured the cross sections of the $^{6}Li(n,\alpha)^{3}H$ reaction at E_n=3.9; 4.3; 4.5; 4.8; 5.1 and 5.3 MeV. Experiments were performed at the Van de Graaff Accelerator EG5 of Frank Laboratory of Neutron Physics, JINR. Fast monoenergetic neutrons were obtained from the reaction $D(d,n)^{3}He$ using a gaseous deuterium target. The gridded ionization chamber was used as an alpha particle detector. The absolute neutron flux was determined in the $^{238}U(n,f)$ reaction, the neutron flux was monitored using both a long ^{3}He counter and an additional fission chamber placed inside the ionization chamber. The data we obtained were compared with those available in EXFOR and data libraries.

The Influence of Organic and Inorganic Chemical Compounds on Elemental Content, Bioactive Compounds and Morphological Parameters of Some Field-Grown Winter Wheat Genotypes

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Wheat (*Triticum aestivum L.*) is one of the most important food ingredients worldwide. However, wheat is not only a source of basic nutrients, such as carbohydrates, proteins, and vitamins, but also a source of antioxidants, such as flavonoids and phenolic acids. The present study investigates the effect of two different treatments applied to eight winter wheat genotypes with different origin grown in field conditions. Both treatments, first using synthetic phytohormone -2,4-dichlorophenoxyacetic acid and the second one consisting of the mixture of microelements as Fe, B, Mn, S and Mg, were applied to wheat leaves at the intensive growth stage (stem elongation-Zadoks stage 31-32) for stimulating growth, development and adaptability. Content of flavonoids, total polyphenols and leaf pigments as well as eighteen micro and macroelements (Na, Mg, Al, Cl, K, Ca, Sc, Mn, Fe, Zn, Br, Rb, Sr, Mo, Sb, Cs, Ba, Th) was determined in leaf plant randomly harvested after 10 days of foliar application. Antioxidant activity of the plants and such morphological parameters as (ear length, number of grains/ear, grain weight/ear, moisture, protein, gluten content of the grains, Zeleny sedimentation value and hectolitre mass) were investigated. Basic mineral fertilization applied in autumn after plant emergence was considered as control treatment. Differences between impact of different treatmets was revealed.

Determining the Relative Efficiency of HPGe and $LaBr_3$ Gamma-Ray Detectors Using ^{60}Co, ^{152}Eu, ^{228}Th and $^{35}Cl(n,\gamma)^{36}Cl$

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The primary goal of the TANGRA project at the Frank Laboratory of Neutron Physics (FLNP) of the Joint Institute for Nuclear Research (JINR) in Dubna, Russia, is to conduct comprehensive studies on the inelastic scattering of 14.1 MeV neutrons on atomic nuclei using the tagged neutron method (TMN). As part of this ongoing research program, we measured the relative photo-peak efficiencies of the HPGe and LaBr3 detectors within a newly constructed experimental facility. We utilized standard gamma-ray point sources including ^{60}Co, ^{152}Eu, and ^{228}Th, as well as the $^{35}Cl(p,\gamma)^{36}Cl$ reaction. Additionally, we determined these efficiencies using Monte Carlo simulation with the GEANT4 program. The simulations demonstrated very good agreement between the results obtained from Monte Carlo calculations and the experimental data. The findings of our research may prove useful for processing and analyzing data obtained during experiments within the TANGRA project, as well as for scientists utilizing HPGe and LaBr3 detectors for gamma-ray spectroscopy.

The Problem of Verification and Attestation of Computer Programs Used for Research Reactor Calculations

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The design of a new pulsed fast neutron reactor "NEPTUN" is being developed in JINR. A large number of calculations are required for the correct operation of the reactor and validation of its safety. In accordance with the requirements for the content of the report on safety justification of research nuclear facilities (NP-049-17 par. 16) [1], the programs used must be verified and attested. Since May 23, 2018, amendments to Article 26 of Federal Law No. 170-FZ of November 21, 1995, "On the Use of Atomic Energy" [2], have stipulated that the development of calculation models must exclusively rely on software programs (SPs) that have undergone thorough expertise.

Creating calculation models using computer programs has its own limitations in applicability. The validity of such models in the Russian Federation is carried out by the Scientific and Engineering Centre for Nuclear and Radiation Safety (SEC NRS), which since 2018 is an official scientific and technical support organization of Rostechnadzor and carries out expert expertise of computer programs [3]. There were over 300 software programs in the Attestation Certificate Database as of 2023, but less than 10% of them have been attested for use at nuclear research reactors (NRRs) [4]. Factors that complicate the attestation of NRRs software programs include the following:

- Specificity of NRRs' characteristics:

NRRs have some unique characteristics and parameters that do not always correspond to the standard models and methods adopted for commercial reactor calculations. It requires the use of specialized software programs, which must be adapted and verified for the specific conditions of a particular NRR.

- Insufficiency of experimental data:

In some cases, the insufficient amount of experimental data on the operation of a NRR may make it difficult to develop and verify software programs Insufficient experimental data may make it difficult to properly model the processes occurring in the reactor facility and reduce the accuracy of the calculations.

- Increased safety requirements for NRRs:

NRRs are generally subject to more stringent safety requirements, due in part to the experiments conducted at these facilities.

Neutron-physical calculations are central to the safety justification of NRRs, as the results of neutron-physical calculations are the basis for making judgments about the safe operation of NRRs. In this work, SPs for neutron-physics calculations (MCNP, MCU, PRIZMA-2017, OpenMC, Serpent, SCALE, SAPFIR 95.1, etc.) were analyzed in order to select the most suitable SP for attestation and further calculations.

1. The requirements for the content of the report on safety justification of research nuclear facilities (NP-049-17) - The Federal Service for Environmental, Technological and Nuclear Supervision, Moscow, 2018.
2. Federal Law No. 170-FZ of November 21, 1995, "On the Use of Atomic Energy". base.garant.ru, 22 -01-2024, URL. https://base.garant.ru/510105506/
3. Bogdan S. N., Zhylmaganbetov N. M., Kozlova N. A., Ponizov A. V., Sharafutdinov R. B., Shevchenko R. A., Shevchenko S. A., Yashnikov D. A. Current issues of review of computer codes used for safety analysis of nuclear facilities. Nuclear and Radiation Safety, 2022, no. 2 (104), pp. 31–49. DOI: 10.26277/SECNRS.2022.104.2.002 [in Russian].
4. SEC NRS. "List of Attestation Certificate of computer programs (as of 09.11.2023)". www.secnrs.ru, 18.01.2024, URL. https://www.secnrs.ru/expertise/software-review/

Experimental Measurement of TOF Histogram in High Energy Part of the Neutron Spectrum

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An increase of the detector's and data acquisition system's performance, made it possible for TOF spectrometer to distinguish the initial part of the histogram, corresponding to cascade and fast neutrons.

The work presents experimentally measured initial parts of TOF spectra, obtained using samples-radiators of Au-197, Ho-165, In-115 and other subjects as target materials. The possibility to reconstruct neutron target station's fast neutron spectrum, using experimental histograms, is discussed.

Measurements were carried out with a channel duration of the data acquisition system 100 nanoseconds and proton linear accelerator operating with parameters: proton energy 267 MeV, pulsed current 10 mA, proton beam duration 250 nanoseconds at half-maximum current amplitude, flash frequency 50 Hz.

Instrumental Neutron Activation Analysis of River Sediments of Danube (Romania), Nile (Egypt) and Zarafshon (Tajikistan): A Comparative Investigation

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The Instrumental Neutron Activation Analysis (INAA) proved to be one of the most sensitive elemental analytical technique that permit the determination of mass fraction of more than 40 elements with an accuracy of the order of mg/kg and less. Moreover, INAA does need any preliminary processing of investigated material, avoiding in this way any systematic errors inherent to any sample digestion procedure, as the case of ICP-MS, -AES or OAS.

Beside the major, rock forming elements Na, Mg, Al, Si, K, Ca, Ti, Mn and Fe, INAA gives excellent results in determining the mass fraction of the most important incompatible elements such as the High-field-strength elements (HFSE) Sc, Zr, eight Rare Earth Elements (REE), Hf, Ta, W, Th and U. Although different from HFSE, a large category of trace elements closely related to the human activity, better known as Presumably Contaminating Elements (PCE) which includes V, Co, Cr, Ni, Cu, Zn, As, Se, Sn, Sb represents excellent proxies for any anthropogenic contamination.

As a direct consequence of this fact, INAA can simultaneously furnish confident data to be used on one hand in elucidating the nature of investigated material which can be equally sediments, soils, a wide variety of rocks or, in quantifying the degree of local contamination.

Given the great volume of date, only an appropriate multivariate statistical analysis can derive confident conclusions. Accordingly, cluster, principal component or discriminant analysis together with a variety of graphic bi- and ternary plots were systematical used in investigating soil and sediments from different geological formation located on three continents, e.g. Nile Valley and Delta of north-east Africa, Danube river and delta, eastern Europe or Zarafshon river, central Asia.

Our investigation allowed evidencing a close similarity between soil and sediments collected along the Nile sector between Aswan lake and Mediterranean Sea, or along entire Zarafshon river. In this regard is wort mentioning the presence of mafic components in Nile sediments and soils, peculiarity well explained by the High Ethiopian Plateau origin of Blue Nile which transports about 80% of the Nile water. Opposite to this was the situation of Danube and Zarafshon river sediments and soil of which mineral material is almost felsic, in concordance with the Neogene orogeny of their catchment basins.

At the same time, given the reduced industrial activity along Nile and Zarafshon rivers, excepting some local contaminated hotspots, the rest of river seemed less or almost uncontaminated with PCE. A similar situation was noticed in the case of Danube river and specially in the Danube Delta, there the vertical profile of some PCE presented a certain tendance of diminishing towards the sediment surface, a consequence of the active measure taken by the EU state to reduce the environmental contamination.

4D Neutron Imagining for Textured Samples

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Neutrons are important and powerful tool for studying materials as it is considered to be a unique of probe for important details on the behaviour and structure of different alloys. Neutron imaging has undergone notable advancement in recent years due to the creation of neutron spallation generators that produce beamlines with brighter pulsed neutrons. However, research on crystallographic phase mapping using neutron imaging was limited to the spatial and temporal resolution of the current detectors [1]. Additionally, identification of the crystallographic phases in a textured materials is typically a complex process since the texture influences the thermal neutron cross-section, resulting in a different neutron spectrum compared to an isotropic sample [2–4]. The phase determination was studied using neutron imaging and confirmed with neutron diffraction for a textured sample (Figure 1).

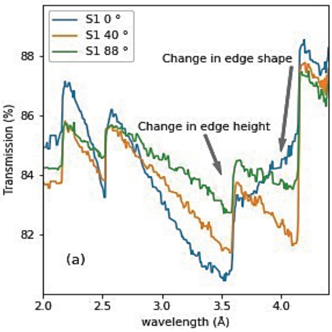

Figure 1. The texture of the sample appears at different rotation angle.

[1] A. Steuwer, P.J. Withers, J.R. Santisteban, and L. Edwards, "Using pulsed neutron transmission for crystalline phase imaging and analysis," *J. Appl. Phys.*, vol. 97, no. 7, p. 074903, Apr. 2005, doi: 10.1063/1.1861144.

[2] R. Woracek, J. Santisteban, A. Fedrigo, and M. Strobl, "Diffraction in neutron imaging—A review," *Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip.*, vol. 878, pp. 141–158, 2018, doi: 10.1016/J.NIMA.2017.07.040.

[3] F. Malamud *et al.*, "Texture analysis with a time-of-flight neutron strain scanner," *J. Appl. Crystallogr.*, vol. 47, no. 4, pp. 1337–1354, Aug. 2014, doi: 10.1107/S1600576714012710.

[4] J.R. Santisteban, L. Edwards, and V. Stelmukh, "Characterization of textured materials by TOF transmission," *Phys. B Condens. Matter*, vol. 385, pp. 636–638, Nov. 2006, doi: 10.1016/j.physb.2006.06.090.

Design and Implementation of Protective Layer for Protecting Cultural Heritage Wooden Artifacts

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The cultural heritage of Egypt is well known with its richness and diversity; besides the numerous archaeological and historical sites allover Egypt. The preservation of cultural heritage is of concern both in Egypt and globally.

In this presentation we are going to point out the efforts done in our project in the field of cultural heritage. We believe that this field needs several efforts from scientist in different fields of science and technology.

So that, in this presentation an attempt is presented to determine the efficiency of nano-metals oxides to act as protective layers. Molecular modeling using density functional method level indicated that both silicon dioxide and magnesium oxide could act as protective layer against light and moisture. Later on, bimetallic SiO_2/MgO structure was prepared as powder and colloids following co-precipitation method. Then the physical and surface properties of the material are characterized with different characterization tools. The prepared samples were tried as protective layers for aged Coptic icons indicating the ability to be applied for wooden artifacts.

Keywords: Cultural Heritage; Molecular modeling; Nano metal Oxides; Protective layers,; Coptic Icons.

Proposed New Different Coincidence Neutron Detection Systems Using Monte Carlo Simulation

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The worldwide community faces significant and difficult challenges in safeguarding nuclear material. This work proposed new designs for coincidence neutron detection systems with different neutron detectors (^{3}He, Ar and BF_3) and calculations. The simulated systems include special nuclear material (SNM) with changing the neutron sources such as; AmLi, AmBe and ^{252}Cf. This work aims to determine the coincidence system efficiency and neutron distribution fluence for each proposed system in active mode. The results of the proposed systems were studied and compared to the active-well neutron coincidence counter (AWCC) employed in uranium testing using the code Monte Carlo N-Particle eXtended (MCNPX).

Key Words: MCNPX, Active Well (AWCC), ^{3}He-Gas Detectors, Ar and BF_3 gas filled detectors.

Operation and Experimental Introduction of the CSNS Back-n White Neutron Facility

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The Back-n white neutron facility is a comprehensive experimental platform that serves a wide spectrum of research goals, including nuclear data measurement, experiments in nuclear physics and astrophysics, calibration of neutron detectors, investigation of neutron radiation effects, and applications in archaeology, among others. Operational since 2018, this beamline has facilitated over 300 varied experiments involving international collaborations with China, Russia, and the USA, afford more than 30,000 hours of beam time.

In 2023, the Back-n started employing boron nitride (BN) absorber sheets as a substitute for conventional cadmium sheets, thereby significantly reducing the cutoff energy for low-energy neutrons. This strategic enhancement has broadened the beamline's capacity to include accurate measurement of thermal neutron reaction cross-sections. The substantial neutron flux and extensive beam time have been crucial in securing high-quality statistical data in energy regions that were previously unattainable, leading to notable physical discoveries. These advancements are highlighted by the recently published measurements of the ^{232}Th fission cross-section, which illustrate the improved capabilities of the beamline.

Moreover, Back-n's involvement in the NOPTREX international collaboration has facilitated the conduct of advanced polarized neutron physics experiments, leveraging the SEOP neutron polarization apparatus. The use of polarized neutrons in the eV energy range has enabled a series of fundamental physics experiments, including CP violation experiment etc.

The facility has also experienced significant enhancements in its detection technology. Recent developments include the commissioning of leading-edge detection systems such as a BaF2 detector array (GTAF) for capture cross-section measurements, a Multipurpose Time Projection Chamber (MTPC) for the charged particles and fission cross-sections, and a boron-doped Microchannel Plate detector (BMCP) for total cross-section measurements and neutron resonance radiography. These detectors are among the most advanced neutron detection technologies in the world. Their integration into the Back-n beamline is expected to lead to a wave of pioneering scientific results from the white neutron experiments.

Angular Correlation (n', γ) in the Reaction of Inelastic Neutron Scattering on ^{12}C

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The knowledge about (n, γ) and $(n, n'\gamma)$ correlations is very useful for understanding the process of inelastic neutron scattering and for estimation of the influence of the direct and compound nucleus (CN) mechanisms on the nuclear reaction. A detailed review of the CN approach is presented in [1], the direct mechanism is described in [2]. The formalism reported in [1] works quite well for low-energy particle scattering, but it fails to describe 14 MeV neutron scattering [3]. There are not too many experiments measuring $(n, n'\gamma)$ correlation with 14 MeV neutrons, and the largest part of them was carried out more than 40 years ago with rather poor accuracy [4,5]. In recent years $(n, n'\gamma)$-correlation in the reaction of inelastic neutron scattering on ^{12}C was measured in work [6], but their results don't generally agree with previous experiments. Thus, it is interesting to obtain data on $(n, n'\gamma)$-correlation with small errors and higher angular resolution.

In Dubna, at the TANGRA setup, an experiment is being carried out to measure angular correlations $(n, n'\gamma)$ in the inelastic scattering of neutrons with an energy of 14.1 MeV on ^{12}C using the tagged neutron method. We use 12 long (1 meter) plastic scintillation detectors with two PMTs. Ten of them are placed around the target in the plane of reaction and two detectors are placed perpendicular to the plane of reaction. These detectors have time resolution about 3ns and space resolution about 20cm that helps us to obtain better angular resolution and separate gamma-rays from neutrons by the time-of-flight.

This paper proposes a theoretical approach to describing the differential probability of gamma ray emission in the reaction of inelastic neutron scattering depending on the directions of the initial neutron, scattered neutron and gamma quanta for both direct and CN reaction mechanisms. This approach is based on invariant spherical functions of several vectors - see, for example, [7]. Our formula for angular correlations includes elements of the S-matrix, which can be obtained from the TALYS program, which calculates cross sections for nuclear reactions.

1. E. Sheldon. Rev. Mod. Phys. 1963. V.35 P. 795.
2. A.B. Clegg and G.R. Satchler. Nucl. Phys. 1961. V. 27. P. 431.
3. N.A. Fedorov. Studying of 14.1 MeV neutrons scattering on light nuclei. Master thesis. MSU, Moscow, 2017.
4. B.A. Benetskii and I.M. Frank, Soviet Physics JETP, 1963, V. 17/2, P. 309
5. J. Zamudio, L. Romero, R. Morales. Nuclear Physics. 1967. V. A96. P. 449.
6. K.J. Kelly, M. Devlin, J.M. O'Donnell, E.A. Bennett. Phys. Rev. C, 2021, V. 104, 064614.
7. L.C. Biedenharn and J. D. Louck. Encyclopedia of Mathematics and its Application; Ed. G.C. Rota, V. 8. - Addison-Wesley Publishing Company Reading, Massachusetts, 1981.

Simulation of the Experiments with Ultracold Neutrons at the PIK Reactor

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Monte Carlo simulation of the complex of research with ultracold neutrons at the PIK reactor (Gatchina, Russia) is carried out. The complex is being built on the basis of a high-intensity source of ultracold neutrons at the GEK-4 channel. Superfluid helium is used as a converter of cold neutrons into ultracold ones. A Monte Carlo model has been developed, which includes a source, a neutron guide system and experimental installations, taking into account their real location in the main hall of the reactor [1,2]. Based on the simulation, it was found that, in a closed source chamber at a superfluid helium temperature of 1 K and a loss factor for the coating material of the inner walls of the chamber of $3 \cdot 10^{-4}$, a UCN density of $3.5 \cdot 10^3$ n/cm^3 can be obtained.

The sensitivities of measuring installations for the search for the electric dipole moment of the neutron and for the measurement of the neutron lifetime at the PIK reactor were obtained. For the experiment on the search for neutron electric dipole moment using a two-chamber magnetic-resonance spectrometer, it was found that the ultracold neutron density in the spectrometer chambers can be 200 n/cm^3, which is 50 times better than that in the ultracold neutron source at the Institute Laue-Langevin (Grenoble, France). At this density, a measurement sensitivity of $1 \cdot 10^{-27}$ e·cm/year is achievable, which will improve the existing neutron electric dipole moment measurement limit by more than an order of magnitude. For the experiment on measuring the neutron lifetime at the facility with a big gravitational trap, it was found that the counts of the neutron detector during emptyings are 50 times larger compared to that in the experiment at the Institute Laue-Langevin reactor, which is an indicator of the possibility of achieving a statistical accuracy of the measurement result of 0.1 s at equal duration of measurements.

1. A.K. Fomin, A.P. Serebrov, Technical Physics **67** (2022) 259.
2. A.K. Fomin, A.P. Serebrov, Journal of Surface Investigation **16** (2022) 1012.

Direct Measurement of the Neutron Velocity in a Refractive Medium and Test of the Dispersion Law for UCN

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It is well known that the dispersion law of slow neutrons in matter is described with high accuracy by the ratio [1]

$$k^2 = k_0^2 - 4\pi\rho b, \tag{1}$$

where k is the wave number in the medium, k_0 is the wave number in vacuum, ρ is the number of nuclei per unit volume, and b is the coherent scattering length. This dependence corresponds to the effective potential, $U = \left(2\pi\hbar^2/m\right)\rho b,$ where m is the neutron mass. For this reason, dispersion law (1) is often referred to as a potential law. From formula (1) it follows directly that the refractive index of a neutron in a medium is determined as

$$n(k) = \left[1 - \left(4\pi\rho b/k_0^2\right)\right]^{1/2}. \tag{2}$$

For a long time, it was considered obvious that from the fact of the existence of a refractive index different from unity, it directly follows that the speed of a neutron in a matter is $V{=}nV_0$. In fact, the refractive index $n{=}k/k_0$ is the ratio of wave numbers in a vacuum and a medium, and not the ratio of velocities V/V_0. As to the neutron speed in the medium it is determined by the quantity $V = \frac{\hbar k}{m^*}$, where m is the effective mass of the neutron in the medium, the value of which depends on the dispersion law. It is equal to the inertial mass of the neutron only in the case of the potential dispersion law [2].

The difference between the speed of neutrons in a refractive medium and the vacuum value was first demonstrated in a direct experiment [3], which consisted of measuring the precession phase of the spin of neutrons passing through samples of various thicknesses. The relatively low accuracy of these measurements, about 10%, did not allow us to draw any significant conclusions about the neutron dispersion law in the medium.

This report is devoted to the proposal of an experiment to directly measure the speed of ultracold neutrons in a refractive medium with percentage accuracy. The experimental approach consists of measuring the time delay in the time of flight of the UCN, caused by the presence of a refractive sample neutron on its path. Measuring the time delay for neutrons with a well-known and variable energy will make it possible to verify the dispersion law of UCNs in matter with an accuracy of the order of a percent.

References

1. L.L. Foldy. Phys. Rev **67**, 107 (1945), M. Lax. Rev. Mod. Phys. **23,** 287 (1951).
2. A.I. Frank. Physics-Uspekhi, **61**, 900 (2018).
3. A.I. Frank, I.V. Bondarenko, A.V. Kozlov, et.al. Physica B: Cond. Matter **297**, 307 (2001).

To the UCN Source at Periodic Pulsed Reactor

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Work continues on the creation of the concept of an intensive source of ultracold neutrons (UCN) on a pulsed reactor of moderate power. The source under consideration is based on F. L. Shapiro's idea of pulsed filling of the UCN trap [1], as well as deceleration by a local device of very cold neutrons (VCN) to energies typical for UCN. An adiabatic spin-flipper designed for high magnetic fields is considered as such a device. At a sufficiently large value of energy taken away from the neutron, the flux of VCN, which after deceleration are converted into UCN capable of being stored in a trap, has a pulsed structure [2]. Using a spin-flipper together with a time lens will allow to obtain a neutron flux density in a bunch significantly exceeding the average value.

The report will be considered in detail the current concept of the source, as well as the status of work on the design of its main elements.

1. F.L. Shapiro, PEPAN 2 (4) (1971) 975–979.
2. A.I. Frank, G. V. Kulin, M. A. Zakharov. Phys. Part. Nuclei Lett. 20 (2023) 664–667.

Atmospheric Deposition of Cosmic Dust Studied by the Moss and Trepel Analysis

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It is well established phenomenon that extraterrestrial dust particles and micrometeorites survive atmospheric entry and reach the Earth's surface. Collection of extraterrestrial dust for research focuses on the environments where terrestrial sedimentation rates and input of artificial particles of anthrogenic origin is minimal, including deep-sea sediments, Antarctic ice and snow, as well as natural planchettes of mosses and peat-bog cores. Experimental observations of particles considered as cosmic dust are presented in moss samples (*Sanionia uncinata*) collected in King George Island [1], *Pleurozium Shreberi* in highlands of Georgia [2], the same in Tver Region of Russia, and newly obtained results on cosmic dust in Arctic, as well as trepel (a loose or weakly cemented fine-porous opal sedimentary rock composed of diatom and radiolarian skeletons) from the lowlands of Belarus [3] are presented. Microanalysis of moss samples showed the presence of clastic, anthropogenic particles and particles of cosmic dust. The identification of particles as micrometeorites is achieved on the basis of their compositional, mineralogical, and texture analyses using SEM microscopy/EDAX techniques and neutron activation analysis (NAA). The majority of particles undergo melting during their passage of the atmosphere. Most abundantly, particularly at large sizes, cosmic spherules (i.e. completely melted droplets) were observed. These spherical particles provide a useful proxy for the total flux of cosmic dust because they are relatively easy to identify. They are the background magnetic component of cosmic dust, mainly microspheres and particles of native metals. Most often, it was possible to detect native Fe, Fe-Ni and Fe-Cr minerals.

Keywords: cosmic dust, SEM microscopy/EDAX techniques, neutron activation analysis

References

1. Mróz T., Szufa K., Frontasyeva M.V., Tselmovich V.A., Ostrovnaya T.M, Kornaś A., Olech M., Mietelski J.W., K. Brudecki. (2017). Determination of atmospheric deposition of trace elements across King George Island (Antarctica) using reactor neutron activation analysis and scanning electron microscopy. Environ Sci Pollut Res, 25(1):436-446. doi: 10.1007/s11356-017-0431-2.
2. Shetekauri S., Chaligava O., Shetekauri T., Kvlividze A., Kalabegishvili T., Kirkesali E., Frontasyeva M.V., Chepurchenko O.E., Tselmovich V.A. (2017). Air pollution biomonitoring with moss in Georgia. Accepted by Pol. J. Environ. Stud.
3. Tselmovich V.A., Maxe L.P. Comparative analysis of microstructure and composition of space-origined particles from trepel and desert sand. Experiment in GeoSciences, 2021, Vol.21, No. 1, p. 21-25. (in Russian).

Review of FLNP JINR Cooperation on Environmental Research in Egypt

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Thirty years of cooperation connects Egyptian and FLNP JINR scientists in the field of the environmental research in Egypt. The first work in this direction began in 1994 in collaboration with the National Center for Nuclear Safety and Radiation Control in Nasr City, Cairo, on assessment of air pollution with trace elements based on analysis of air filters from the radiation monitoring network of stations in Egypt. In 2009, in the framework of the Agreement between the Joint Institute for Nuclear Research and the Ministry of Higher Education and Scientific Research of ARE, an ambitious project of Sector of NAA and Applied Research of FLNP with several Egyptian institutions (Menoufia University, Tanta University, South Valley University, EAEA) was launched: “Nuclear and related analytical techniques used to study environmental situation in the Nile River Basin (Project # 405). More than 1000 samples of soil, bottom sediments and vegetation were collected and subjected to INAA at the reactor IBR-2 of FLNP JINR in Dubna. Geochemistry of sediments and surface soils from the Nile delta and lower Nile valley studied by epithermal neutron activation analysis was investigated. Never before has such a set of elements been obtained, including heavy metals, rare earth elements, uranium and thorium for this area. Along with the Nile River Basin, which includes the upper Nile and its delta, similar studies were carried out in the Siwa oasis in the Sahara Desert, in Egypt’s Central Nile Valley and in the city of Sadat, allocated in the outskirts of Cairo. Together with Cairo University, the Red Sea corals from several locations (Suez Gulf, in the vicinity of the Suez City) as biomonitors of trace metal pollution have been investigated. Up to 45 elements of Periodic Table were determined. Modern statistical analyses were applied to the results obtained to extract maximal information about the sources of elevated mass fractions of the determined elements. In addition, ratio scores and discrimination charts were implemented to determine the origin of the studied samples. To characterize the regions under study, multiple pollution indices were calculated. As a result of the study, it was established that the elemental composition of the studied samples does not pose a significant hazard to the environment and humans in comparison with those given in the literature. However, there are some areas that require more attention to get rid of significant contamination. The research results of our studies can serve as a baseline data on the elemental background of Egypt and be used as a scientific justification for taking measures to control the environmental situation in Egypt.

Measurement of Fission Cross Section and Angular Distribution of Fission Fragments from Neutron-Induced Fission of ^{242}Pu in the Energy Range 1–500 MeV

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The fission cross section and angular distribution of fission fragments from the neutron-induced fission of ^{242}Pu were measured in the energy range 1–500 MeV using the GNEIS neutron time-of-flight spectrometer and the pulsed neutron source based on the 1 GeV proton synchrocyclotron of the NRC KI - PNPI (Gatchina). A description of the original experimental setup, consisting of two MWPC counters with ^{242}Pu and ^{235}U targets, is given, as well as some basic details of the experimental data processing.

The fission cross section of ^{242}Pu is determined by the ratio method using ^{235}U as a reference. Of particular interest is the angular distribution of fission fragments in the energy range 1–500 MeV. There are currently no other experimental data in this field, despite growing interest stimulated by the development of new nuclear technologies. This measurement is a part of our investigations of neutron-induced fission of the plutonium isotopes ^{239}Pu, ^{240}Pu and ^{242}Pu at intermediate energies.

Unlocking the Interfacial Synergy of 2D/2D CuO/Reduced Graphene Oxide (rGO) Nanocomposite for Reduction of Cr(VI)

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Nano-sized copper oxide (CuO) and graphene oxide (GO) have promising characteristic properties. A composite of copper oxide and reduced graphene oxide (CuO/rGO) nanocomposites was synthesized by mixing CuO and GO under probe sonication at 600 W. The synthesized compounds were characterized by X-ray powdered diffraction (XRD), Field Emission Scanning Electron Microscope (FESEM) and High-Resolution Transmission Electron Microscope (HRTEM). The structural parameters such as lattice constant, crystallite size and strain have been studied. The electron microscopes indicated the formation of nanosheets of both CuO and rGO. The optical bandgap of CuO and CuO/rGO composite have been determined. The photocatalytic reduction of the toxic Cr(VI) as model of radioactive form to Cr(III) by CuO/rGO nanocomposite was investigated. The results showed that, the photo-reduction efficiency has reached 75% by adding rGO to the CuO. A mechanism of photoreduction process has been suggested.

Keywords: 2D nanocomposite, CuO nanosheets, Graphene, Chromium (VI) reduction

On Estimating the Loss Rate of Ultracold Neutrons in Material Traps

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The accurate estimate of loss rate of ultracold neutrons (UCN) by the absorption inside the walls of material traps is important for precise measurements of neutron lifetime and for other UCN experiments. The typical difference between the measured UCN storage time τ_{st} and the neutron beta-decay time τ_n exceeds 20 seconds, while the systematic error of τ_n measurements is less than 1 second. Such a high precision is achieved by the accurate estimate of UCN loss rate using the geometry and temperature extrapolation. The standard geometry extrapolation to extract the neutron lifetime from the measured storage time is complicated by the energy dependence of the effective collision frequency and by the effect of Earth gravity field. The latter is, usually, taken into account via the dependence of neutron kinetic energy on its height above the trap bottom, with a subsequent integration over the trap surface.

However, the gravity field changes not only the neutron kinetic energy but also its angular velocity distribution, because only the vertical velocity component is affected by gravity. The assumption of uniform angular distribution of UCN velocity is no more valid. This changes the UCN absorption rate inside trap walls, because the latter depends on the normal-to-wall component of neutron velocity, i.e. on the incidence angle of neutrons reflected from the wall in addition to its kinetic energy. Usually, this change of UCN angular distribution is disregarded, but it may modify the estimates of UCN losses in material traps and shift the measured τ_n.

We analyze how the change of angular distribution of UCN velocity by gravity affects the UCN loss rate from the absorption inside trap walls and the accuracy of τ_n measurements.

The work is supported by the Russian Science Foundation grant No. 23-22-00312.

Measuring the Angular Distributions of 14.1-MeV Neutrons' Scattering on Carbon Nuclei

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The study of neutron-induced nuclear reactions on carbon is of interest both from the point of view of improving experimental data on its excitation levels and for determining the parameters of the model used to describe the mechanism of neutron-nuclear interactions. According to F. Hoyle, carbon plays an important role in the process of nucleosynthesis in the Universe and, in particular, that life on Earth is possible due to the existence of a level in carbon with energy of 7.65 MeV [1].

As part of the TANGRA project [2, 3], using the Tagged Neutron Method (TNM), we measured the angular distributions of 14.1-MeV neutrons scattered on a carbon sample. To apply the TNM, we used an ING-27 neutron generator with a built-in 256-pixel alpha particle detector (APD). The sample used was a graphite plate measuring 44×44×2 cm, located at a distance of 27 cm from the front end of the neutron source. The neutron flux from ING-27 incident on the sample was determined by counting alpha particles from the d(t, α)n reactions using the APD. Scattered neutrons with energy of 14.1 MeV were measured using 20 plastic scintillation detectors located around the sample at a distance of ~2 m from it. The energy of scattered neutrons was determined by the time-of-flight (TOF) method. The angular distributions of elastically scattered neutrons, as well as inelastically scattered neutrons for excited states of the carbon nucleus at energies of 4.44 MeV, 7.65 MeV, 9.64 MeV, 10.33 MeV and 10.84 MeV were measured. The data obtained are compared with the results of previous experiments on the scattering of neutrons with energy of 14.1 MeV on ^{12}C.

The work was carried out with support from the Russian Science Foundation grant №23-12-00239.

1. Hoyle F., On Nuclear Reactions Occurring in Very Hot Stars. I. The Synthesis of Elements from Carbon to Nickel, Astrophys. J. Suppl. **1** (1954) 121–146, https://doi.org/10.1086/190005.
2. TANGRA, https://flnp.jinr.int/en-us/main/facilities/tangra-project-en.
3. I.N. Ruskov, Yu.N. Kopatch, V.M. Bystritsky, et al., TANGRA-Setup for the Investigation of Nuclear Fission Induced by 14.1 MeV Neutrons, Physics Procedia 64 (2015)163–170, https://doi.org/10.1016/j.phpro.2015.04.022.

Estimation of the Magnitude and Sign of the ROT Effect for ^{239,241}Pu, ^{241}Am and ^{245}Cm Nuclei at Low Neutron Energy Inducing Their Fission

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The advisability of performing experiments to determine the ROT effect during ternary fission induced by polarized resonant neutrons with the energy of about 0.3 eV in the isotopes ^{239,241}Pu and ^{241}Am is discussed. Theoretical estimates made using modified trajectory calculations [1] show that at these energies one can expect significantly larger effects for plutonium isotopes compared to the ROT effects previously discovered in experiments performed on a beam of polarized neutrons from an ILL reactor with the energy of 4.5 meV.

The ^{241}Am isotope target, which has not previously been used to study the ROT effect, may be interesting in that when used it is expected not only an effect of significant magnitude, but also of the opposite sign with respect to the effects for all four isotopes previously studied at cold neutron energies [2]. Experimental confirmation of the negative sign of the effect will mean the dominant rotation of the compound nucleus of this isotope around the neutron polarization axis counterclockwise.

The negative sign effect can be observed in experiments studying the ROT effect during the ternary fission of the ^{245}Cm nucleus by cold or thermal neutrons.

It can be expected that for the isotopes under consideration, the values characterizing the ROT effect during the emission of γ-quanta or neutrons in binary fission induced by polarized neutrons with $E = 0.3$ eV will be greater than those already found in binary fission for the ^{235}U target.

References:

1. I.S. Guseva and Yu.I. Gusev, ISINN-14, JINR, Dubna, 2006, p. 101; AIP Conf. proc. 2009, vol. 1175, p. 355.
2. A. Gagarski, F. Goennenwein, I. Guseva, P. Jesinger, Y. Kopatch, T. Kuzmina, E. Lelievre-Berna, M. Mutterer, V. Nesvizhevski, G. Petrov, et al., Phys. Rev. C **93**, 054619 (2016).

Efficiencies and Characterization of Hexagonal Scintillator Detector

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Most scintillation gamma-ray detectors currently are formed from inorganic materials, that have relatively high densities of electrons and can be employed to build bulky array detectors with large-scale light output. The degree of gamma-ray detector performance work included the efficiency of the detector as a main function depending on the crystal geometry and its surfaces that deal with the radioactive source positions. Besides it works to obtain an energy resolution in good shape by allowing the maximum number of photons to be recorded within the actual real volume of the detector itself. In the current study, the scintillation hexagonal detector design efficiency and resolution are investigated to improve the detector response function to gamma-ray radiation, based on the source position related to the detector surface, which is considered all the time as an essential element in the characterization and optimization of scintillation detectors. This factor is one of the high-significance parameters for the hexagonal type of scintillation detectors, in which scintillation pulses are induced within the crystal by the interaction of the photons with enough high energy. This study gives an exceptional about the energy resolution manners using the response from the scintillation channels. The output features build a good idea about the measurement setup geometrical conditions that can be chosen in the scientific experiment with good ability to the detector response based on the position, where a certain geometric parameter, such as a geometric solid angle improves the efficiency of the hexagonal scintillation crystal.

Keywords: Scintillation Hexagonal Detector, Geometrical Solid Angle, Detector Efficiency and Energy Resolution.

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Optimization of the Main Parts of the New Pulsed Nuclear Reactor NEPTUNE

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A new pulsed high flux nuclear reactor is currently being developed within the Frank Laboratory of Neutron Physics (FLNP) to replace the current IBR-2M reactor after the end of its service life. One of the proposed options is the NEPTUNE reactor (average power of 12–15 MW, pulse duration of 210 μs and an average neutron flux of 1.6×10^{14} n/cm^2/s and at the peak power of 3.8×10^{17} n/cm^2/s), which will use fuel based on the isotope Np-237 for the first time.

Np-237 is a threshold isotope with a fission threshold of 0.4 MeV, lower than the fission threshold of uranium-238 of 2 MeV. This gives it a greater advantage in terms of the possibility of using as the new nuclear fuel in pulsed reactors to obtain a short neutron pulses, have a low background power between pulses and use a new, more effective reactivity modulator and control rods based on neutron moderation (also for the first time in fast reactors).

The report and presentation will explain the principle of operation of the reactor, its most important properties and some of the features that were discovered during the developing stage, while presenting proposed solutions:

- illustrate the possibility of partially using high enriched uranium (90% U-235 enrichment) or low-enriched uranium (with U-235 enrichment less than 20%) fuel with the possibility of using anew stationary reflector around the reactor core to enhancing the safety parameters of the reactor by increasing the generation life time of the neutron;
- a new proposal for a reactivity modulator will be presented in order to reduce the thermal load on the titanium hydrate material to increase its service life;
- also review the results of comparing the use of three materials, namely liquid para hydrogen, solid methane, and mesitylene, at temperatures of 20 K, in order to increase the percentage of cold neutrons extracted in the neutron channels.

Development of Novel Scintillation Detectors

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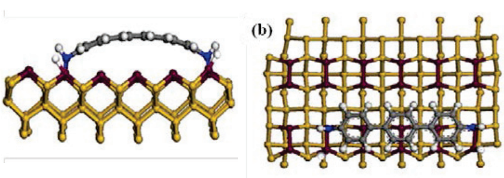
Nano organic molecules have attracted much of my interest to fabricate novel functional devices. Interfaces between organic semiconductors have crucial roles in determining the electronic properties of devices ranging from field-effect transistors (FETs) to photovoltaics and scintillations, which is a flash of light produced in a transparent material by an ionization event; the process of scintillation is one of luminescence whereby light of a characteristic spectrum is emitted following the absorption of radiation. Interface and fabrication an ultrathin film play important roles in the scintillation efficiency, this condition has been achieved in my study by depositing 4,4″-diamino-p-terphenyl (DAT Figure 1(a)) on the Si (001), DAT is a good candidate for a silicon substrate. DAT has been employed for electroluminescence (EL) devices prepared by vapor deposition polymerization. So, the thicknesses of devices using DAT can be easily controlled at molecular level in the vapor polymerization process.

Fig.1. (a)



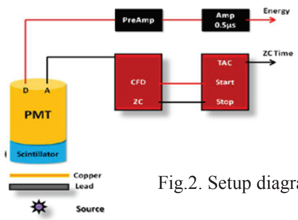


Fig.2. Setup diagram.

Organic composite scintillators such as *p*-terphenyl can be compared with the organic liquid scintillators, composites are solids and less flammable; flash point for *p*-terphenyl is 207 °C and for stilbene over than 112 °C. Composite scintillators are sensitive not only to fast neutrons, but also to γ-rays; however, the signals from these events can be well separated. The composite scintillators can also be obtained in larger diameter than organic single crystals, but they must be thin enough to achieve the performance which is the key of issue.

A simplified diagram of the setup shown in Figure 2, samples attached to photomultiplier tube PMT, the pulse shape discrimination (PSD) performed by means of a zero−crossing (ZC) method. The anode pulse as a start signal was taken by constant fraction discriminator (CFD) and a stop signal using ZC of a bipolar-shaped pulse. The time difference was registered by a time-to-amplitude converter (TAC). It is well known that various charged particles produce scintillations with different decay constants, depending on their mass and charge, which results in differences in ZC time. The large differences in amplitudes of the slow component decay time are crucial for separation of fast neutrons from γ-rays. The estimation of the number of photoelectrons per energy unit (phe/MeV) will be done by using the Compton edge of γ-rays from a 137 Cs source and a single photoelectron spectrum from the PMT. The response of the composite scintillators to fast neutrons measured by means of a neutron source. The detector shielded by 10 cm of lead to reduce the intensity of high-energy γ-rays from the neutron source and 3 mm of copper to reduce the X-rays from lead.

In conclusion, it is expected that the new material have a scintillation properties in addition to use fascinating molecular characteristics, compact, light and environmental-friendly novel devices can be supplied at reasonable costs.

Heat Producing Elements and Microfossils in the Polonnaruwa Meteorite: "Wet Panspermia" and the Cosmic Distribution of Biospheres

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Where, when and how life originated represent some of the most perplexing questions of Science. The widely accepted paradigm that Earth-life arose on Earth is based on the ancient Aristotelean doctrine of spontaneous generation dating back to the 3rd century BCE. It was revived into its modern context by Haldane and Oparin at the turn of the 20th century, and its empirical basis rests on the 1952 Miller-Urey Experiment which showed simple racemic amino acids (D/L=1)could form by electric arc discharge into a simulated prebiotic, early Earth atmosphere. At the time, the incredible complexity of polymeric biomolecules (e.g. DNA, RNA, proteins, enzymes) comprised of homochiral amino acids, sugars and other metabolites required for life was unknown. The fact that life appeared on Earth soon after the crust cooled enough to permit liquid water Oceans was not understood. It was thought that full details of the first appearance *in situ* of living cells would soon be revealed and the "Panspermia" hypothesis advanced in 1903 by Arrhenius and re-introduced by Hoyle and Wickramasinghe in the 1980's in a modern astronomical context would be finally rejected. Evidence for biomolecules in interstellar and cometary dust led Hoyle and Wickramasinghe to revive the Panspermia hypothesis that life originated elsewhere in the Cosmos and was delivered to Earth from Space. This is consistent with the Vernadsky concept of the eternity and cosmic status of life and the Biosphere even on the cosmological level. Discoveries since the early 1960's have provided evidence for microfossils and complex biomolecules in carbonaceous meteorites, but those were often attributed to abiotic processes or terrestrial contaminants. Recent SEM studies in the US, UK and Russia have revealed well-preserved diatoms, cyanobacteria, prasinophytes and magnetotactic bacteria in the Polonnaruwa (Low-Density Ungrouped), Murchison (CM2) and Orgueil (CI1) carbonaceous meteorites that are thought to be remnants of comets or low-density carbonaceous asteroids such as 162173 Ryugu (Cb-type) and 101955 Bennu (B-type). EDS measurements of N<0.5% and O/C ~ 0.1 to 0.2 for cyanobacterial filaments and diatoms in these stones indicates diagenetic conversion to kerogen and establishes that these forms are indigenous and ancient and consequently cannot be interpreted as modern biological contaminants. This provides direct observational evidence for the existence of extraterrestrial life and support for the "cometary panspermia" model. The James Webb Space Telescope (JWST) recently detected Dimethylsulfide (DMS) in the Hycean Exoplanet K2-18 b. DMS is a biogenic cleavage product of Dimethylsulfoniopropionate (DMSP) released only by complex metabolic pathways using the DMSP lyase enzyme that is found in diatoms, cyanobacteria and many other marine phytoplankton. DMS has been detected on Mars in the Orgueil meteorite and samples returned from asteroid Ryugu. Extraterrestrial purine and pyrimidine nucleobases and chiral amino acids have been found in the Orgueil, Murchison and many other carbonaceous meteorites. Our recent ENAA analysis at JINR of the fossil-rich Polonnaruwa meteorites has revealed Rare Earth Elements and astonishingly high levels of Heat Producing Elements (^{40}K, ^{238}U, ^{242}Th) HPE's Radiogenic HPE's with half-lives of billions of years are responsible for heating the crust of the Earth. Planetary HPE's provides a "Wet Panspermia" mechanism in which water can be maintained in liquid state for billions of years beneath the icy crust of Pluto and rogue planets in deep space far away from a star or giant planet. On these distant sites replication, growth and death of living organisms could continue just as has occurred in deep oceans of Earth for ~ 3.8 billion years. Unicellular and even multicellular life could exist on an astronomical scale and thrive beneath the icy crusts of Moons, Comets, Exoplanets or Rogue Planets and the interplanetary, interstellar or intergalactic tranfers of intact Biospheres may be the inevitable consequence of the dynamical evolution of galaxies.

Determination of the Parameters of Multisectional Liquid Scintillation Spectrometer and of Prototype of "Gamma" Installation at the IREN Facility

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On the flight bases of the 3rd (60 meters) and 4th (11 meters) channels of the IREN facility, neutron flux density measurements were performed in the neutron energy range from 0.4 eV to 1500 eV. The neutron fluxes (thermal and resonance) were determined using gold foils, applying the coincidence technique and the neutron activation analysis technique. The parameters of the resolution function have also been determined and their values, obtained from experimental measurements for several neutron energies, are in good agreement with the calculations.

The Measurement of PFNS in CIAE

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China Nuclear Data Center, China Institute of Atomic Energy

The Prompt Fission Neutron Spectrum (PFNS) data of heavy nuclear induced by neutrons is the fundamental data of nuclear reactions. In response to the current deviation of PFNS data and the poor experimental data, the experimental research on PFNS relied on white neutron source was carried out in the Chinese Spallation Neutron Spectrum (CSNS).

Using the double neutron time of flight method, a series of PFNS data of different neutron energy points can be obtained with only one successful measurement. These data can serve as experimental samples for super calculations of nuclear devices, and can also provide a large amount of experimental data for theoretical research on nuclear structure, nuclear reactions, and so on. The Cf-252 fragment source was placed in a Parallel Plate Avalanche Counter (PPAC), and the neutron detective efficiency of 48 liquid scintillator detectors used in the experiment was calibrated by measuring the neutron time of flight spectra between the PPAC and the liquid scintillator detectors. The Monte Carlo simulation of the background of the PFNS experiment in CSNS Back-n experiment hall for PFNS experiment has been completed with Geant4 and some improvements of the experimental arrangement have been adopted according to the simulation results. The experimental PFNS measurement was accomplish at Back-n and the reasonable neutron spectra have been obtained after the experiment. The time resolution between the liquid scintillation detector and the PPAC is 1.9 ns. The work lays the foundation for further research on PFNS for a series of important nuclides in the future.

Exploring Materials at Molecular Modeling and Spectroscopy Laboratory, National Research Centre, NRC, Egypt

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Molecular Modeling and Spectroscopy Laboratory is part of the Centre of Excellence for Advanced Science, at the National Research Centre. The aim of the laboratory is providing professional technical consultations and designing molecular models for environmental; biological interactions and electronic properties of matter.

This could be achieved throughout studying the electronic; molecular behavior of smart and nano-materials. Furthermore, molecular structure of these models could be supported by experimental verifications.

Application example will be given for modified carbon based materials as bio and gas sensors. Graphene based systems were modified with several nano metal oxides to produce some efficient sensors for sensing volatile organic compounds VOCs as well as moisture.

Another application will be presented for the modification of natural resources for possible remediation of pollutants from environment. The idea is to control wastewater with eco-friendly and cost effective methods.

A device designed and implemented in our lab based on 3D printing technology will be presented. This device is adapted to produce mass production microsphere for multiple application.

Keywords: Molecular Spectroscopy; Gas Sensor, 3D printing; Wastewater control and Molecular Modeling.

Estimate of Radiation Damage Using the Stopping and Range of Ions in Matter

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The localized disruption of a solid crystal lattice caused by high-charged and neutral elementary particles traveling through it is referred to as radiation damage. When an energetic particle interacts with a lattice, kinetic energy is transferred to the lattice atom, resulting in primary knock on (PKA) that causes the atom to be displaced from the lattice site (vacancy). Later, secondary knock on (SKA) is created during the passage of (PKA), which causes the production of a displacement cascade of point defects. We must quantify the path length the particle takes through the material from the point at which it started moving and compute the energy lost by the moving particle as it traveled through the medium (stopping power) in order to characterize the radiation damage. This work aims at evaluating the effects of changes/variations in TRIM input damage related parameters on the obtained damage calculation results, which will lead to the most suitable recommendations with regard to these parameters; for the best practices of TRIM damage calculations. The input parameters which have been covered are: the threshold displacement energy, the lattice binding energy, and the number of incidents ions. The effects were tested in the two major damage calculations mode of TRIM. I.e. the quick damage calculation and the detailed calculation with full damage cascade.

It is usually stated that in SRIM calculations, it is recommended to set the binding energy value to zero. We used both the default (3 eV) and the recommended value (i.e. 0 eV) to examine the effect of this parameter on the calculated damage results. The results obtained in KP calculation mode are shown below. It was discovered that changing the binding energy has no strong effect.

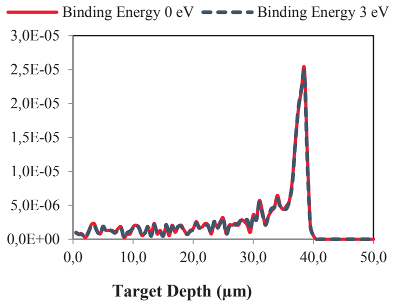

Fig.1.10 MeV H ions in Zr target (K-P mode)

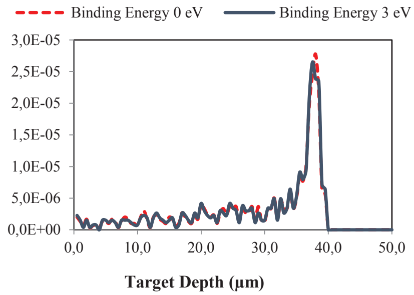

Fig.2.10 MeV H ions in Zr target (F-C mode)

Our findings provide valuable insights into the relationship between binding energy, displacement energy, ion energy, ion type, and the resulting radiation damage. Understanding these factors is crucial for predicting and mitigating radiation damage in various materials and applications.

The SFiNx Detector System

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A new detector system SFiNx (Spontaneous Fission, Neutrons and X-rays) for on-line investigation of the SF properties of short-lived heavy nuclei synthesized in complete fusion reactions was created in FLNR (Fig. 1). The neutron registration efficiency is (55 ± 1) %.

As a result of an experimental series on SHELS separator, the prompt neutrons yield data from spontaneous fission obtained for heavy nuclei with Z = 100 – 106. The prompt neutron yields for ^{250,254}No, ^{256}Rf and ^{260}Sg isotopes obtained for the first time and significantly refined for the isotopes ^{244,246}Fm and ^{252}No (Fig. 2).

Using the SFiNx system and the GRAND gas-filled separator at the JINR Superheavy Elements Factory, it will be possible for the first time to obtain data on the emission of prompt neutrons from the heaviest nuclei.

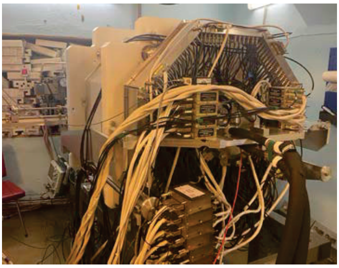

Fig. 1. The SFiNx detector system.

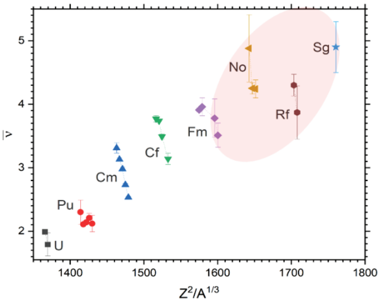

Fig. 2. Systematics of the average number of neutrons per spontaneous fission decay. The oval marks the data obtained with the SHELS separator.

Trace Analysis of Uranium by Laser Spectroscopy and ICP-MS

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State of the art laser spectroscopy (Resonance Ionisation Mass Spectrometry, Time Resolved Laser Inuced Fluorescence, Time Resolved Laser Induced Chemiluminecence,) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) can be very efficient for elemental and isotope composition analysis of various samples, as well as for the determination of the molecular and valence forms of uranium (speciation analysis) [1–5].

A series of RIMS measurements of reference materials with various isotope compositions ranging from depleted and natural to enriched uranium have been previously reported by our collaboration [1, 2]. Simple sample preparation process not involving any chemical separation, pre-concentration or need for chemical reactions is employed. Highly selective and efficient uranium photoionisation schemes were applied. For samples of depleted uranium the $^{235}U/^{238}U < 0.003$ ratio was determined with < 7% precision (2σ errors) for the total uranium concentrations not exceeding ~80 fg per sample [1]. The details of multi-step excitation of species and time-resolved detection of resulting luminescence (TRLIF) and chemiluminescence (TRLIC) have been evaluated and applied for analysis of biological samples. Typical concentration of uranium [4] in blood plasma for different regions is ranging $0.05 ng \cdot ml^{-1}$–$0.5 ng \cdot ml^{-1}$, and in urine is $0.2 ng \cdot ml^{-1}$–$5 ng \cdot ml^{-1}$. Without mineralization, the limit of uranyl detection (LOD) by TRLIF in blood plasma has been determined $0.1 ng \cdot ml^{-1}$. After mineralization, a lower LOD ranging $0.008 ng \cdot ml^{-1}$–$0.01 ng \cdot ml^{-1}$ has been evaluated. The limit of uranyl detection in urine in our TRLIF experiments was up to $0.005 ng \cdot ml^{-1}$. This LOD is sufficient to allow for studies the dinamics proccesses and behaviour of the of uranium in biologicas objects [3,4]. However, actinides in various valence states do not all exhibit luminescence properties. The use of chemiluminescence methods (TRLIC) for detection of actinides in solutions allows the sensitivity to reach the limit of detection (LOD) from 10^{-6} M to 10^{-13} M depending on chemical form of actinide in a solution [2–5]. TRLIC methods were applied for detection of the molecular and valence forms of uranium.

In a separate experiments, ICP-MS methods has been used for analyses [6] of the elemental and isotope composition (64 elements) of bones of dinosaurs, South mammoths, prehistoric bear and archanthropus as well as the samples of surrounding soils; everything collected in different parts of Uzbekistan. A high concentration of uranium we detected in the bones of dinosaurs (122mg/kg), South mammoth (220mg/kg), prehistoric bear (24mg/kg) and archanthropus (1.5mg/kg) compared to surrounding soils (3.7–7.8 mg/kg) and standard bones (< 0.01mg/kg) was established. The standart ratio $^{235}U/^{238}U = 0.007$ was detected for all samples, but the ^{234}U concentration differ from secular equilibrium value.

1. I. Strashnov, et al., *J. Anal. Atom. Spectroscopy*, **34**,1630(2019).
2. I. Strashnov, et al., *J. of Radioanalytical and Nuclear Chemistry*, **322**, 1437(2019).
3. I.N. Izosimov, *Procedia Chemistry*, **21**, 473(2016).
4. I.N. Izosimov, *Environmental Radiochemical Analysis VI*, pp. 115-130, Royal Society of Chemistry Publishing, 2019. DOI: 10.1039/9781788017732-00115
5. I.N. Izosimov, *J. of Radioanalytical and Nuclear Chemistry*, **304**, 207(2015).
6. I.N. Izosimov, et al., *Czech Chemical Society Symposium Series,* **20**, 116(2022).

Cross-Section Measurement of $^{14}N(n, p)^{14}C$ Reaction

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Accurate cross sections and differential cross sections of the $^{14}N(n, p)^{14}C$ reaction are of significant importance for research in Boron Neutron Capture Therapy as well as astrophysical element synthesis. From the last century to the present, several measurements have been conducted, and cross sections have been obtained. However, on one hand, present experimental measurements show considerable discrepancies in the keV neutron energy region; on the other hand, there is a severe lack of differential cross sections for the $^{14}N(n, p)^{14}C$ reaction across the entire energy spectrum, with a shortage of measurement results. Based on the Back-n white neutron beamline at China Spallation Neutron Source, this research utilized wide-spectrum neutrons and employed charged particle detectors for experimental measurements. Through simulation and multiple beam test experiments, the experimental conditions and methods were explored, and a successful 400-hour beam time experiment was conducted. For the first time internationally, the differential cross sections of the $^{14}N(n, p)^{14}C$ reaction in the 0.1–6MeV neutron energy range was measured, and differential cross sections as low as 0.1mb in the 0.1–0.45MeV neutron energy range were provided, which are expected to clarify the discrepancies in previous measurements and different evaluation databases in this energy region.

Investigation of Spectroscopic Properties of ^{108}Ag via the ^{107}Ag(n,2γ) Reaction

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In low-energy nuclear physics, the precise determination of gamma transitions, level scheme, nuclear level density, and radiative strength function holds paramount importance. These accurate experimental values play a crucial role in various scientific domains, including astrophysical reactions, medical isotope production, rare isotope beams, and reactor technology. The two-step gamma cascade method, involving the detection of gamma-gamma coincidences after thermal (cold) neutron capture (i.e., the (n_{th},2γ) reaction), has demonstrated effectiveness in providing spectroscopic data and insights into level density and radiative strength functions.

This study focuses on the investigation of the spectroscopic properties of the ^{108}Ag nucleus, utilizing an enriched (99.07%) ^{107}Ag target. The experimentation took place at the PGAA station of the Budapest Neutron Centre in Budapest, Hungary, employing a cold neutron beam, 3 HPGe detectors with appropriate shielding, and an acquisition system for coincidence measurements. This presentation offers a concise overview of the methodology employed, highlighting the spectroscopic results for the ^{108}Ag nucleus obtained through the ^{107}Ag(n_{th},2γ) reaction, with a specific emphasis on gamma transitions and the level scheme.

References

1. David Knezevic et al, *Study of gamma transitions and level scheme of ^{94}Nb using the ^{93}Nb (n_{th}, 2γ) reaction*, Nuclear Physics A, volume 993, 121645, January 2020, https://doi.org/10.1016/j.nuclphysa.2019.121645
2. David Knezevic et al, *Study of gamma ray transitions and level scheme of ^{56}Mn using the ^{55}Mn (n_{th}, 2γ) reaction*, Nuclear Physics A, volume 992, 121628, December 2019, https://doi.org/10.1016/j.nuclphysa.2019.121628
3. N. Jovančević et al, *Study of Nuclear Structure Parameters by Using the (n_{th}, 2γ) Reaction*, Journal of the Korean Physical Society, volume 75(2), July 2019, pages 100-116, DOI: 10.3938/jkps.75.100.

Artificial Neural Networks for Unfolding Procedures in Neutron and Photon Activation Measurements

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Activation methods play a crucial role in measuring cross-sections for neutron and photon induced nuclear reactions. In this study, we propose the utilization of artificial neural networks (ANNs) for the unfolding procedure in these measurements [1,2,3]. Traditionally, unfolding techniques such as SANDII, GRAVEL, and MAXED algorithms have been employed to obtain cross-section values from saturation activity measurements via gamma spectroscopy [4,5,6]. Here, we explore the potential of ANNs as an alternative approach for unfolding. Preliminary results from tests conducted on the measurement of neutron and photon-induced reactions on indium are presented, demonstrating the efficacy of ANNs in this context.

1. N. Jovancevic, L. Daraban, and S. Oberstedt, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 739, 68 (2014).
2. N. Jovančević, L. Daraban, H. Stroh, S. Oberstedt, M. Hult, C. Bonaldi, W. Geerts, F.-J. Hambsch, G. Lutter, G. Marissens, et al., The European Physical Journal A 52, 148 (2016).
3. S. Ilić, N. Jovančević, L. Daraban, H. Stroh, S. Oberstedt, M. Hult, C. Bonaldi, W. Geerts, F.-J. Hambsch, G. Lutter, G. Marissens, M. Vidali, and D. Knežević, The European Physical Journal A 56, 202 (2020).
4. M. Reginatto and P. Goldhagen, Health physics 77, 579 (1999)
5. W. N. McElroy, S.Berg, and T. Crockett, Los Alamos National Laboratory report, AFWL-TR-67-41 I-IV (1967).
6. M. Matzke, Report PTB-N-19 I-IV (1994).

Fundamental Differences in Theoretical Approaches to Describing of the Observed Characteristics of Spontaneous and Induced Binary and Ternary (with the Emission of Nucleons and Light Nuclei as Third Particles) Nuclear Fission

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Widely used theoretical approaches [1] to the description of the observed energy, spin and angular distributions of the products of spontaneous and induced binary fission of compound fissile nuclei (CFN), although they take into account quantum mechanical concepts associated, for example, with the use of transition fission states of these nuclei [2], are largely macroscopic in nature, associated with hydrodynamic (liquid drop model of the nucleus taking into account shell corrections) and thermodynamic (Gibbs distributions taking into account various temperatures) characteristics of fission fragments. The developed in [3–4] approach, based on quantum mechanical consideration [5] of collective transverse bending and wriggling vibrations for prescission configurations of CFN, makes it possible to successfully describe the observed characteristics of binary fission products of these nuclei. The practical value of this approach is due to the fact that it allows one to calculate the characteristics of nuclear fission reactions with thermal neutrons used in nuclear power plants.

To describe the observed characteristics of spontaneous and induced ternary fission of nuclei, the presentations are used about the mechanisms of the emission of the third light particle from the CFN, both due to the influence of the nonadiabatic motion of fission fragments in the prescission configuration of this nucleus [6], and due to taking into account the three-particle interaction potentials of fission fragments and third particle [7]. In [8–11], the virtual mechanism of ternary fission was proposed, considered as a two-stage process, when in the first stage the third light charged particle with kinetic energy T_3, close to the height of its Coulomb barrier, is emitted from the CFN, with the formation of the virtual state of the intermediate nucleus, which at the next stage undergoes binary fission. This mechanism made it possible to successfully describe the observed characteristics of ternary nuclear fission.

1. J. Wilson et al., Nature, 2021. **590**. 566.
2. A. Bohr and B. Mottelson, Nuclear Structure (W.A. Benjamin, NY, Amsterdam, 1969).
3. V.E. Bunakov, S.G. Kadmensky, D.E. Lyubashevsky, Phys. of At. Nucl. 2016. **79**. 198.
4. S.G. Kadmensky, V.E. Bunakov, D.E. Lyubashevsky, Phys. of At. Nucl. 2016. **80**. 441.
5. J. R. Nix and W. J. Swiatecki, Nucl. Phys. A. 1965. **71**. 1.
6. O. Tanimura, T. Fliessbach, Z. Phys. 1987. **328**. 475.
7. A.L. Barabanov, Symmetries and spin-angular correlations in reactions in reactions and decay (FML, Moscow, 2010).
8. S.G. Kadmensky, L.V. Titova, D.E. Lyubashevsky, Phys. of At. Nucl. 2020. **83**. 581.
9. S.G. Kadmensky, L.V. Titova, Bull. Russ. Acad. Sci., Phys. 2021. **85**. 732.
10. S.G. Kadmensky et. al., Bull. Russ. Acad. Sci., Phys. 2022. **86**. 1332.
11. S.G. Kadmensky, D.E. Lyubashevsky, Bull. Russ. Acad. Sci., Phys. 2022. **86**. 991.

Observation of Fission Isomers among Fragments of Spontaneous and Induced Fission of Heavy Nuclei

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In three different experimental approaches, it was consistently found that part of the fission fragments from the reactions $^{235,\,238}U(\gamma, f)$, $^{232}Th(\gamma, f)$, $^{235}U(n_{th}, f)$ and $^{252}Cf(sf)$ are presumably born in the state of the fission isomer (with yield $Y \approx 10^{-3}$/binary fiss.) with lifetime $\tau_{isom} >$ 400 nsec. A binary break-up of such fragments was observed when passing through foils made of Ti, Cu, Ni, Al_2O_3 due to inelastic Coulomb scattering on the foil nuclei. At least one of the three resultant products of the splitting of the mother nucleus in this channel is a magic or near-magic nucleus. The effect was observed for the first time.

References

1. D.V. Kamanin et al., Bulletin of the Russian Academy of Sciences: Physics, V. 87 (2023), p. 1238.
2. D.V. Kamanin et al., Journal of Physics: Conference Series, V. 2586 (2023) 012043.

Manifestation of the Fission Dynamics in Muon-Induced Prompt Fission

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In muonic atoms of ^{238}U, the nuclei can undergo prompt fission through non-radiative transitions [1] of the muon: *2p – 1s, 3p – 1s, 3d – 1s etc*. Main features of the fission dynamics are studied in prompt fission: augmentation of the barrier, dynamics of the saddle-to-scission descent, muonic conversion and characteristic X-rays from fission fragments supply information on the multipolarity of electromagnetic transitions and charge distribution, structure of nuclear transition currents. Revision of the non-radiative transition probabilities comprises my present purpose.

It is commonly accepted that the probability of the non-radiative nuclear excitation in the muonic transition $i \to f$ can be expressed in terms of the photoexcitation cross-section and resonance internal conversion coefficients [2]. In this way, satisfactory agreement is attained with experiment [3] for non-radiative transition widths for the 2*p*–1*s* transitions in ^{238}U. However, the 3*p*–1*s* radiative transition width turns out to be by a factor of 15 larger that experimental one. I undertake detailed analysis of this circumstance on the basis of Ref. [4]. First, this broadening is not only due to the additional contribution of the non-radiative transition, but also the admixed GDR nuclear width gives a contribution. And that width is of the order of MeV. Second, there is level doubling due to the non-radiative interaction, with the related broadening of the second radiative component within MeV scale due to the GDR total width. Moreover, the nucleus gets excited, properly speaking, not in the 3p–1s transition, but rather in the preceding cascade transition to this state, like 4d–3p, even 3d–3p (virtually) or similar. Correspondingly, some missing intensities should manifest themselves in these transitions.

References

1. M.Ya. Balatz, L.N. Kondrat'ev, L.G. Landsberg, P.I. Lebedev, Yu.V. Obukhov, B. Pontecorvo. Zh. Exp. Teor. Fiz. 38, 1715 (1960); 39, 1168 (1961).
2. Karpeshin F.F. and Nesterenko V.O.J. Phys. G: Nucl. Part. Phys. **17**, 705 (1991).
3. H. Haenscheid, P. David, H. Foiger, J. Konijn et al., Z. Phys. A – Hadrons and Nucl **342**, 111 (1992).
4. F.F. Karpeshin, I.M. Band, M.B. Trzhaskovskaya and M.A. Listengarten, Phys. Lett. B **372**, 1 (1996).

Digital System for Signal Processing from a Position-Sensitive Detector Based on a Digitizer with Open FPGA

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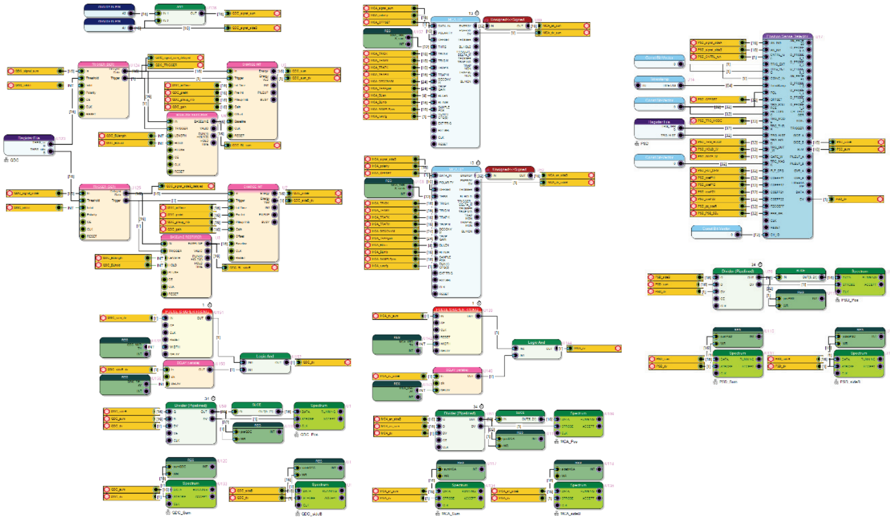
Signal preprocessing plays an important role in the interpretation of experimental data obtained with different types of neutron detectors. Since in most experiments information is collected digitally, FPGAs are increasingly used for signal processing as part of the data acquisition system. For this purpose, it is convenient to use a digitizer, an electronic device that continuously receives analog pulses passing through an analog input signal conditioning stage, performs analog-to-digital conversion using fast ADCs, and stores the digitized samples as event data in digital memory, from which they can be read by a host computer via fast communication interfaces (USB, VMEbus, Optical Link, Ethernet). To accelerate and facilitate the development of firmware for such devices, Nuclear Instruments in cooperation with CAEN has developed Sci-Compiler software, which instead of standard VHDL/Verilog programming languages uses a set of ready-made libraries for further code generation.

The main stages of creating custom firmware for a digitizer with Open FPGA are presented. The algorithms of high-level IP library blocks are discussed in detail and three methods of signal processing of a gas one-dimensional position-sensitive detector with a resistive filament are compared. Figure 1 shows the main blocks of the project comparing the three methods - QDC, MCA HP and PSD. The first results obtained using a neutron source are also presented.



a) b) c)

Figure 1: Graphical diagram of the three detector data processing methods in the Sci-Compiler project a) QDC, b) MCA HP and c) PSD.

Characteristic Features of Double and Triple Coincidence Spectra Coupling in Radiative Neutron Decay

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The paper uses the example of radiative neutron decay, which we discovered in 2005 at the TUM (Technical University of Munich) reactor [1], to examine the coupling of double and triple coincidence spectra. To this end, special attention is paid to the electronic system for collecting and processing information received from the electron, proton, and gamma-ray detectors. As demonstrated, in the presence of a significant background gamma-ray, the spectrum of triple coincidences will have, apart from the peak of triple coincidences of the beta electron, proton, and gamma-ray quantum, additional peaks which represent responses to the peaks in the spectra of double coincidences of beta electron with proton and beta electron with gamma quantum. After processing the spectra using the response function method, we measured the main characteristic of the radiative beta decay of the neutron, namely its branching ratio. Thus, in this experiment we were the first to measure the branching ratio (B.R.) of radiative neutron decay B.R. = (3.2±1.6)10-3 (where C.L. = 99.7% and gamma quanta energy threshold is equal to 35 Kev) [1]. On the other hand, theoretical calculations of this value according to the Standard Model give 1.5 times lower value [2], so we recorded additional gamma quanta which are structural gamma quanta emitted by the quarks that a neutron consists of.

1. R.U. Khafizov et al. JETP Letters, v. 83(1), 2006, p. 5.
2. Yu.V. Gaponov, R.U. Khafizov. Phys. Lett. B 379 (1996), p. 7.

Retention of Liquid Helium Films by an Electric Field in Ultracold Neutron Traps

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A film of liquid helium on the surface of material traps for ultracold neutrons protects the neutrons from being absorbed by the trap walls [1–3]. The main problem with this idea is that the thickness of the ^{4}He film on the side walls is too thin. This problem is solved by applying a potential difference between the side wall of the ultracold neutron trap and the electrode, which leads to an enhancement of the electric field near the roughness of the wall. By using surface roughness and an electrostatic field, a helium film of sufficient thickness can be held over the entire height of the trap. We calculated the field distribution near the tip of such wall roughness of the trap and estimated of the influence of this field on the retention of helium.

We investigated how the transition from two-dimensional artificial roughness of the equipotential surface in the form of periodically arranged triangular grooves to three-dimensional roughness in the form of periodically arranged square pyramids enhances the electric field near the pyramid vertices. Two-dimensional roughness corresponds to diffraction gratings, the production of which has long been developed and which are available for purchase. Three-dimensional roughness in the form of quadrangular pyramids is not much more complicated to produce, but still requires costs, so the transition from two-dimensional to three-dimensional wall roughness is justified only if the gain is noticeable. Our calculations showed that the gain from such a transition is significant, only if the angle of the pyramid vertex is small enough and the distance to the vertex is not too large. Otherwise, roughness in the form of a diffraction grating is almost as effective as the more complex three-dimensional roughness in the form of periodically arranged pyramids.

The proposed full coverage of the walls of ultracold neutron traps with liquid ^{4}He can lead to the emergence of a new generation of traps for ultracold neutrons with a very long storage time. This can significantly improve the accuracy of neutron lifetime measurements and other experiments with ultracold neutrons.

1. P.D. Grigoriev, A.V. Sadovnikov, V.D. Kochev, and A.M. Dyugaev, *Improving ultracold neutron traps coated with liquid helium using capillarity and electric field*, Phys. Rev. C **108**, 025501 (2023).
2. P.D. Grigoriev, A.M. Dyugaev, *Superfluid helium film may greatly increase the storage time of ultracold neutrons in material traps*, Phys. Rev. C **104**, 055501 (2021).
3. P.D. Grigoriev, A.M. Dyugaev, T.I. Mogilyuk, A.D. Grigoriev, *On the Possibility of a Significant Increase in the Storage Time of Ultracold Neutrons in Traps Coated with a Liquid Helium Film*, JETP Letters, **114**, 493 (2021).

Applications of the Tagged Neutron Method for Fundamental and Applied Research

Yu.N. Kopatch and TANGRA collaboration

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The tagged neutron method (TNM) consists in irradiating the object of study with fast neutrons with an energy of about 14 MeV, which are formed in the reaction d+t→α+n. Neutron tagging is carried out by registering an alpha particle with a special position sensitive detector built into the neutron generator. The use of TNM in experiments studying nuclear reactions with fast neutrons provides a number of important advantages, in particular, a decrease in the background due to the registration of events coinciding with α-particles. The study of the spectra of gamma rays produced in the reactions of inelastic neutron scattering makes it possible to carry out an elemental analysis of the irradiated object. Currently, TNM technology is widely used in various practical applications for remote non-destructive analysis of the elemental composition of a substance.

The TANGRA (TAgged Neutrons and Gamma Rays) project at JINR is aimed at investigations of the neutron-nuclear reactions using the tagged neutron method, finding new ways to use neutron methods in fundamental and applied research, improving existing and creating new approaches for processing the data collected in nuclear physics experiments.

A brief overview of recent activities in the framework of the TANGRA project will be presented with an emphasis on the measurements of the gamma-ray emission cross sections and angular distributions from (n,xγ) reactions with 14.1 MeV neutrons using the tagged neutron method, as well as on the development and use of the TNM for non-destructive elemental analysis of various objects.

Moderated and Fast Neutrons Dosimetry Using Radiometric Gafchromic™ EBT3 Film

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The dosimetric response of the Gafchromic™ EBT3 film upon exposure to moderated neutrons and fast neutrons were investigated. The moderated neutrons are from two Am-Be sources with an average flux of 2.3×10^4 $cm^{-2}s^{-1}$ while the fast neutrons were obtained by direct exposure to the neutrons from Am-Be source having standard spectral emission probability with neutron yield of 1.1×10^7 s^{-1}. EBT3 radiochromic films were irradiated in both the moderated and fast neutron fields for different durations. Thereafter, Gafchromic™ EBT3 films were scanned with flatbed scanner and the resulted RGB images were separated to color channels Red, Green, Blue. The dynamic ranges of the EBT3 Gafchromic™ films irradiated with moderated neutrons are approximately equal to, 136 ± 3, 125 ± 2, 89 ± 2, and 26 ± 6 for red, green, grey, and blue color respectively, while in the case of fast neutrons irradiation, the dynamic ranges are 83 ± 2, 73 ± 3, 40 ± 1, and 37 ± 3, in their respective order. UV-Vis absorbance spectra at the two characteristic peaks of 632 ± 2 nm and 580 ± 2 nm of irradiated Gafchromic™ EBT3 film show a wider dynamic range but lower sensitivity comparing with flatbed scanner. The results reveal that the response of Gafchromic™ EBT3 film to both moderated neutrons and fast neutrons is almost the same. The indirect and direct energy band gaps of the Gafchromic™ EBT3 films irradiated with moderated neutrons and fast neutrons in the range of applied irradiation time exhibit insignificant change. By contrast, Urbach's energy shows a continuous decrease with the increment of irradiation time.

Keywords; Moderated neutrons, Fast neutrons, Gafchromic™ EBT3 film, Flatbed scanner, UV-Vis spectrophotometer, Radiation dosimetry.

Phytoremediation of Contaminated Urban Soils Using Two Ornamental Plants

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The phytoremediation method (the removal of contaminants using plants) is especially relevant in urban areas where soils are polluted with heavy metals and other toxic elements. Some ornamental plants not only serve an aesthetic function, but can also efficiently accumulate pollutants and therefore remediate contaminated soils. This study aimed to evaluate the phytoremediation capacity of *Coleus* sp. and *Petunia* sp. which are widely used in urban landscape design. The plants were planted in the soils containing high concentrations of V, Cr, Mn, Fe, Co, As, Br, Cs, Zr and Th, and after 30 days the content of the elements in the soil, roots and aboveground parts of the plants was determined using neutron activation analysis. The concentrations of Cr, Fe, Co, As, Cs and Th in soils decreased by 11–29%. To assess the ability of plants to accumulate elements from soils and transfer them from roots to shoots, the bioconcentration and translocation factors, respectively, were calculated. It was observed, that both plant species had low values of bioconcentration factors (< 1) for all elements except Br, which indicates limited ability of elements' accumulation by these plants. However, the values of translocation factors greater than unity were determined for several elements. *Petunia* sp. was more effective in translocating V, Cr, Br, Cs, Mn, Fe and Zr with the translocation factors ranging from 1.1 to 12. Among the species studied *Petunia* sp. can be considered as the most promising species for phytoextraction of heavy metal-contaminated soils. Phytoremediation potential of *Coleus* sp. and *Petunia* sp. needs to be investigated in a long-term experiment.

Mechanical and Temperature Calculations of the Reactivity Modulator Construction of the Research Pulsed Reactor NEPTUN

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The NEPTUN reactor is a pulsed periodic research reactor under development with a sodium coolant and a core based on neptunium nitride fuel. The reactor is designed for experiments using extracted beams. Average thermal power is 10–15 MW, pulse half-width is 200 μs, pulse frequency is 10 Hz, time-average thermal neutron flux density is $\sim 10^{14}$ $cm^{-2} \cdot s^{-1}$. The reactor vessel and its core are divided into two parts. A reactivity modulator (RM) is located in the space between parts of the core.

The pulsed operating mode of the reactor is achieved by the reactivity modulator. The RM is a disk which rotates in a vertical plane with a box-shaped rim, in the cavity of which there are blocks of titanium hydride (TiH2). The disk diameter is 3000 mm, thickness is 50 mm, rotation frequency is 10 Hz. The rim contains a «window» 440 mm high, which has no titanium hydride. When the «window» passes through the core, a neutron pulse is generated.

The power pulse (therefore the stability and safety of the reactor) is sensitive to such parameters as the reactivity and the rate of change of reactivity. The above parameters depend on the stability of the reactivity modulator. RM is a non-standard design, not used on serial types of reactors. Therefore, there is a need for research of the reactivity modulator construction.

The report presents the results of numerical calculations of a reactivity modulator construction:

- Natural frequencies and oscillation shapes of the reactivity modulator disk. Obtained during modal analysis in the Modal Analysis of the ANSYS software;
- Distribution of stresses, strains and displacements in the RM construction during its rotation at idle mode of the reactor. Also, the safety factor of the RM during its rotation is estimated. The results were obtained during mechanical calculations in the Explicit Dynamics module of the ANSYS software;
- Temperature distribution in the RM "window" area at nominal capacity mode of the reactor. The calculations were carried out for two versions of the RM: with and without nickel inserts. The results were obtained during thermal calculations in the CFX module of the ANSYS software.

Monte-Carlo Evaluations of Low-Energy Neutron Radiative Capture in ^{93}Nb Nucleus and γ-Quanta Forward-Backward Asymmetry Caused by Geometry and Kinematics

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A study of forward-backward asymmetry of γ-quanta emitted at the radiative decay of nuclei at a capture of neutrons with energies near low-energy p-wave resonances allows obtaining their parameters – the neutron $\Gamma_{n1/2}$ and $\Gamma_{n3/2}$ partial widths. For this purpose the trial experiment already started by the time-of-flight method at 10-m flight-path of the IREN facility (FLNP, JINR) with ^{93}Nb nucleus.

For a correct experimental determination of forward-backward asymmetry of γ-quanta from ^{93}Nb(n,γ) reaction in the energy region of the 35.8, 42.3 and 94.3 eV p-wave resonances, it is necessary to define a compromise between a desirable high yield of gammas (i.e. the target must be thick enough) and minimization of an undesirable distortion of the required forward-backward γ-asymmetry which demands a thin target.

To define this compromise Monte-Carlo calculations were made. The results are presented for 4×4 cm^2 niobium plate-targets of three thicknesses (400 mcm, 2 mm and 6 mm). The asymmetries caused by a multiple scattering of neutrons in the target before their capture as well as by finite thickness of target, which distort counts of the detectors and inevitably contribute to the required spatial γ-anisotropy, were established by Monte-Carlo calculations for taking them into account.

Angular Correlation Analysis in the Neutrons Capture Process by ^{109}Ag Nucleus

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Angular distributions in the ^{109}Ag(n,γ)^{110}Ag reaction were evaluated in the framework of Flambaum-Sushkov's approach and the two-levels approximation. The angular correlation is a pondered sum of Legendre polynomial with coefficients that depend on the energy of the incident neutrons, the partial reduced widths of the incident neutrons, and the emergent gamma. These coefficients are of interest in the evaluation of asymmetry and parity-breaking effects in neutrons induced processes.

Several computer simulations have been done to evaluate the impact of experimental conditions on the angular distribution coefficients and asymmetry effects. The computer evaluation took into consideration the target's dimensions, the attenuation of neutrons and gamma rays, the flux of incident neutrons, and other parameters. Additionally, the analytical expression of the polar angle was obtained by the Direct Monte-Carlo method. Computer analyses have shown that more than 10% of the gamma quanta are lost in the target of a thickness of 1 mm and a transverse area of 1 cm^2. In the case of a 10% forward-backward asymmetry coefficient, edge effects can be neglected. For asymmetry and parity breaking effects, gamma attenuation, edge effects and target dimensions become significant at values below 0.1.

For neutrons' energy near 30 eV in the ^{109}Ag(n,γ)^{110}Ag process, where the forward-backward effect is approximately 0.2, the coefficient corresponding to the second-order Legendre polynomial is approximately 0.05. Absolute errors of the forward-backward effect and second order Polynomial Legendre coefficient were also derived under various experiment settings and cross-section experimental precisions.

The results of the simulations are helpful for future measurements of the angular distribution and related asymmetry and parity violation effects, which will be carried out at the neutrons source IREN, the FLNP JINR basic facility.

REFERENCES

1. V.V. Flambaum, O.P. Sushkov, Physics Letters, vol. 94B, no. 3, pp. 377–379 (1980).
2. V.V. Flambaum, G.F. Gribakin, Prog. Part. Nucl. Phys., vol. 35, pp. 423–503 (1995).
3. A.L. Barabanov, E.I. Sharapov, V.R. Skoy, C.M. Frankle, Phys. Rev. Lett., vol. 70, pp. 1216–1219 (1993).
4. J. Boettcher, E.A. Golubkov, V.A. Egorov, Y.K. Zaytseva, V.N. Zamrij, A.S. Kayukov, V.V. Kobets, A.Z. Korokin, V.S. Minashkin, V.G. Pyataev, et al., Phys. Part. Nucl. Lett., vol. 11, pp. 665–671 (2014).

Pressure-Induced Phase Transitions in VdW Magnets

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Van der Waals compounds are currently one of the most interesting objects of research in the field of condensed matter physics due to the recently discovered magnetic properties in their two-dimensional forms. The structural features lead to a significant sensitivity of the physical properties in these compounds to external influences, which can cause many unusual phenomena: charge, orbital and spin ordering, superconductivity, various phase transitions, also important for the development of a wide range of spintronic devices.

High pressure is a direct method of controlled change in magnetic interactions due to variations in interatomic distances and angles. Performing studies at high pressures provides a unique opportunity to study the relationship of changes in the structural parameters of the crystal with changes in the magnetic structure, which is necessary to understand the nature and mechanisms of physical phenomena observed in the studied objects.

This work is devoted to the investigation of the crystal, magnetic structure and vibrational properties of vdW $CrBr_3$ in wide temperature and pressure ranges using neutron diffraction at DN-6 diffractometer of the IBR-2 reactor (FLNP, JINR, Dubna), also using X-ray powder diffraction and Raman spectroscopy. A negative thermal volume expansion in $CrBr_3$ below $T_C = 37$ K was observed, associated with spin-lattice coupling. The effect of high pressure leads to the suppression of magnetic ordering, and the transition from the initial FM state is expected at P~8.4 GPa to AFM or to PM state. Our results also demonstrate an isostructural phase transition in a $CrBr_3$ ferromagnet (2.5 –7 GPa). With a further increase in pressure to 38 GPa, significant changes are observed in the behavior of the frequencies of the vibrational modes, which is associated with the transition to a metallic state above 26 GPa.

Classification of Mortars from the St. George Cathedral of the Yuryev Monastery (Veliky Novgorod, Russia) Based on Neutron Activation Analysis Data at the IREN Facility (JINR, Russia) and the WWR-K Reactor (INP, Kazakhstan)

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One of the important components of architectural monuments are mortars, which were used as the main binding material in creating of stone or brick masonry. Over time, the compositions of mortars have changed significantly. This fact can serve as a basis for mortar classification.

The subject of this study is the mortars from the St. George Cathedral of the Yuryev Monastery. The Cathedral is one of the most important architectural monuments in Veliky Novgorod. It is of federal significance and included in the UNESCO World Heritage List. The St. George Cathedral was built in the pre-Mongolian era, in the first half of the 12^{th} century and restored in the 1830s.

In the present work, eleven mortar samples from the St. George Cathedral were studied. Five of them date back to the 12^{th} century, and four – to the 19^{th} century. The research aim is the classification of mortars with unknown dating based on the elemental composition.

Neutron activation analysis was used to determine elemental composition of the mortars. The samples were irradiated using the IREN facility at the Joint Institute for Nuclear Research and the WWR-K reactor at the Institute of Nuclear Physics. Therefore, the mass fractions of 35 elements were obtained.

Statistical treatment (Hierarchical cluster analysis and Principal component analysis) using the R programming language was carried out for sample classification. As a result, the authors assumed, that samples with unknown dating presumably belong to the 19^{th} century mortar group.

Ultracold Neutron Source for Research in Fundamental Physics at the PIK Reactor

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In 2020, a Federal Program was implemented for creating experimental facilities for the PIK reactor. One of the main facilities to be constructed within this Program is a new superfluid helium based UCN source for research in fundamental physics [1]. The projected UCN density in the chambers of a neutron EDM spectrometer connected to the source by a UCN guide is expected to be 200 cm^{-3} [2].

This UCN source will be installed on the thermal neutron beam channel GEK-4 with its inner diameter of 220 mm. Our plan is to create a 1-meter-wide aperture in the outer PIK biological shielding. This hole is large enough to host the entire UCN source, with a graphite reflector, a liquid deuterium pre-moderator and the superfluid helium converter, everything included in an outer vacuum vessel. The thermal neutron flux density in the convertor is expected to be 6.6×10^{10} $cm^{-2}s^{-1}$.

UCN source manufacturing is at the final stage right now: all the elements of the entire UCN source part and the technological complex have already been manufactured. More than 40 m^3 of isotopically pure helium-4 with a helium-3 content below 10^{-8} was produced. Work is underway to assemble the entire complex at PNPI for cryogenic testing and confirm the operating parameters of the facility.

In general, a broad research program is planned. The UCN guide system has been designed to feed up to four experimental facilities. At the start of its operation, it is planned to equip the UCN source with experimental setups already available at PNPI: an nEDM spectrometer and two neutron lifetime experiments, one with a gravitational and one with a magnetic trap.

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Keywords: ultracold neutron, PIK reactor, superfluid helium, neutron EDM

References

1. M.V. Kovalchuk et al., Crystallography Reports **66** (2021) 195. DOI: 10.1134/S1063774521020061
2. A.K. Fomin and A.P. Serebrov, Technical Physics **92** (2022) 327. DOI:10.21883/JTF.2022.02.52025.261-21

Relation of Transuranium Isotopes Yields as Indicator of the Achieved Neutron Fluences at the Pulse Nucleosynthesis

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The possible perspective way for production of transuranium isotopes is the artificial rapid nucleosynthesis (in the nature the *r*-process and the next decays of neutron rich nuclei are responsible for isotope abundance) realized under explosive conditions. The process is the consistent multiple neutron capture by irradiated target (manufactured from the ^{238}U or more heavy/mixture isotopes as ^{232}Th, ^{237}Np, ^{238}U, ^{242}Pu, ^{243}Am). An intensive synthesis is ensured by extremely high neutron fluence (several units of 10^{24} neutrons/cm^2) during the short time exposition (~10^{-6} s). The first time the creation of isotopes with neutron excess up to mass A=255 was obtained and discovered in the Mike experiment [1]. During the Plowshare program and some next nuclear tests (as Anacostia, Kennebec, Par, Barbel, Tweed, Cyclamen, Kankakee, Vulcan and Hutch) the transuranium isotopes up to A=257 was registered [2–5].

In the realized pulse nucleosynthesis model it were considered the sequential (n,γ)-neutron captures by mono isotope ^{238}U target and binary (^{238}U + ^{239}Pu)-variant for case of ^{239}Pu injection [6,7]. The model includes the temperature decrease during the adiabatic expansion with index γ = 1.5 at the initial temperature ~20 keV and linear velocity ~190 km/s. Here we simulated the isotope yields for Mike, Anacostia, Barbel, Par and Vulcan experiments. The obtained results indicated on the roughly linear dependence of the isotope Y-yield relations from the neutron fluence [8]. Namely we considered the next pairs of neighboring isotopes with atomic masses A=245 and 244, A=246 and 245, A=247 and 246. The relation 246/245 (i.e., yields with masses A=246 and 245) depending on the fluences is the most strong demonstrator of the linear dependence. The results allow to consider these relations as indicators of the achieved neutron fluences in the experiment.

References

1. Dorn DW. Phys Rev 1962;126:693
2. United States Nuclear Tests. July 1945 through September 1992. DOE/NV-209-REV 16. September 2015.
3. Hoff RW, Dorn DW. Nucl Sci Eng 1964;18:110.
4. Dorn DW, Hoff RW. Phys Rev Lett 1965;14:440.
5. Balagna JP, et al. Los Alamos Radiohemistry Group. Phys Rev Lett 1965;14:962.
6. Lutostansky YuS, Lyashuk VI, Panov IV. Bull Russ Acad Sci: Phys 2010;75:533.
7. Lyashuk VI. Bull Russ Acad Sci: Phys 2012;76:1182–6.
8. Lyashuk V.I., Results in Physics 2024; 56:107234.

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Research with Neutrons at FLNP JINR

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Since its foundation in 1957, the Frank Laboratory of Neutron Physics of the Joint Institute for Nuclear Research realizing research programs with neutrons in the field of nuclear physics and solid-state physics. The scientists of the lab successfully used methods of neutron physics and other nuclear techniques to solve scientific and applied problems in different field of research. There are several neutron sources in the laboratory now: a periodic pulsed reactor IBR-2, a source of resonant neutrons based on the electron accelerator IREN, and a (D-T) neutron generator to realize the research programs. The experimental infrastructure around the sources is constantly being developed. Around IBR-2 the complex of instruments with different sample environment devices have been developed to use practically all possible methods of neutron scattering for research. The set of additional laboratory equipment constantly updated with new ones. It makes possible perform additional study of the samples by different non-neutron methods. Most instruments are included in the user program and are available for use through the experiment proposal system.

The report will provide information about the neutron sources and experimental infrastructure of the Laboratory of Neutron Physics of the Joint Institute for Nuclear Research, actual directions of research and plans of the infrastructure developments.

Methodology for Simulating the Properties of Nanostructured Reflectors for Very Cold Neutrons

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At the moment, many neutron research centers around the world are aiming to increase the range of useful neutrons while lowering their energy. Such neutrons are very promising for fundamental research and condensed matter studies. However, progress in this field is limited by the relatively small fraction of low-energy neutrons in the total flux and the low efficiency of their delivery to research facilities. Once the wavelength of neutrons reaches the interatomic distance, they begin to interact less efficiently with homogeneous media, pass through reflectors, and are not delivered to the facilities. The use of nanodispersed media, consisting of particles a few nanometers in size, solves this problem. Cold (CN) and very cold neutrons (VCN) are reflected from such materials due to intense coherent elastic scattering on an ensemble of nuclei, the individual nanoparticles [1].

Unique nanostructured reflectors of CN and VCN based on detonation nanodiamonds (DNDs), which have no effective analogs in the world, are being developed in the JINR FLNP. However, applications of such nanostructured reflectors and further optimization of their properties require the development of adequate models of both the nanopowders themselves and the propagation of slow neutrons in them [2]. The JINR FLNP has been engaged in the related studies for the last 20 years, and its results will be presented in the report.

For a quantitative analysis of neutron scattering on DNDs and their clusters, we developed the following model of discrete-size diamond nanospheres. We simulated both the DNDs and their clusters with diamond nanospheres. We assumed a discrete set of nanosphere sizes, in which the next generation nanosphere radius is larger than the previous one by a certain factor. In the calculations presented below, the radii are uniformly distributed on a logarithmic scale, with 20 values of the radius by an order of magnitude.

We adjusted populations of DNDs/clusters of each generation to fit the experimental data of small-angle neutron scattering. The fitting procedure is stable with respect to the parameter choice of the model (the initial populations of cluster generations, the step of increasing the mass of clusters of the next generation, the boundaries of the mass range if it sufficiently broad).

The obtained distribution of scatterers' sizes provides the differential cross-section of single elastic neutron scattering. We used this cross-section to simulate the multiple scattering of low-energy neutrons in a nanodispersed medium. Moreover, it does not matter in this case what method, exact or approximate, to use for the calculation of scattering cross-sections on a spherical particle. It is important that it be used for the simulation of neutron diffusion.

Models' benchmarking, various results of simulation of CN and VCN scattering on different nanodiamond powders will be presented.

References

1. Chernyavsky S.M. et al. "Enhanced directional extraction of very cold neutrons using a diamond nanoparticle powder reflector." *Rev. Sci. Instrum.* 93 (2022): 123302.
2. Frei, A., et al. "Fluorination of Diamond Nanoparticles in Slow Neutron Reflectors Does Not Destroy Their Crystalline Cores and Clustering While Decreasing Neutron Losses." *Materials* 13 (2020): 3337.

Spin Distributions of Fragments in Binary Asymmetric Nuclear Fission

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Within the framework of quantum fission theory, the spin distributions of the primary fragments of low-energy binary fission of nuclei were considered, which expand the understanding and shed light on the most important dynamic characteristics of this process. The obtained values are crucial for the interpretation of experimental data on the multiplicity and distribution of neutrons and γ-quanta that arise as a result of the fission of actinide nuclei, as well as delayed neutrons emitted from the final fission fragments.

The modern understanding of the occurrence of large values of fragment spins is associated with two collective transverse modes of the fissile nucleus near scission point: wriggling- and bending- vibrations [1]. Based on the concept of the fissile nucleus coldness in the vicinity of its scission point and using the wave functions of wriggling- and bending-vibrations in the ground state in the momentum representation, along with determining the moments of inertia of fission fragments within the framework of the superfluid model of atomic nuclei [2], analytical formulae were obtained for the first time, describing spin distributions and average spin values of fission fragments:

$$P\left(J_{1,2}\right) = 2J_{1,2}d_{1,2}\exp\left(-J_{1,2}^2 d_{1,2}\right), \quad \overline{J_{1,2}} = 1/2\sqrt{\pi/d_{1,2}},$$

where $d_{1,2}$ are coefficients depending on the momenta of fission pre-fragments, rigidity and mass parameters, as well as the energies of wriggling- and bending-vibrations.

The calculated spin distributions and their average values are in reasonable agreement with the experimental values [3] observed in the low-energy stimulated fission of ^{238}U and ^{232}Th by neutrons and in the spontaneous fission of ^{252}Cf.

1. J.R. Nix *and* W.J. Swiatecki, Nucl. Phys. A 71, 1 (1965).
2. A.B. Migdal, JETF 37, 249 (1959).
3. J. Wilson *et al.*, Nature 590, 566 (2021).

Orbital Momenta of Fragments in Binary Asymmetric Fission of Actinide Nuclei

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The question of describing the orbital momenta of fission fragments (FDs) requires the use of quantum concepts about the dynamics of the fission process. This process always begins with the formation of thermalized excited states of a fissile compound nucleus in the first well of its deformation potential. The multiquasiparticle wave functions of these states include components associated with collective deformation vibrations of the fissile nucleus and the corresponding O. Bohr's transition fission states. It was demonstrated that during spontaneous and low-energy induced binary fission FDs near the scission point should be in cold nonequilibrium states. For the construction of FDs angular distributions, it is necessary to take into account only zero transverse wriggling – and bending – vibrations of the fissile nucleus [1]. The directions of FD emission from the fissile nucleus, according to O. Bohr's hypothesis, are close to the symmetry axis of the nucleus, which makes it possible to represent the amplitude of the angular distribution of fragments in the form of a smeared delta function determined by the coherent superposition of large relative orbital momenta of these fragments. The appearance of this superposition can be associated with the occurrence of zero collective transverse vibrations of pre-fragments in the vicinity of the scission point of the fissile nucleus, which leads to large values of the relative orbital momenta of the FD. It was obtained an analytical formula for estimating the average value and distribution of orbital momentum:

$$\overline{L} = 1/2\sqrt{\pi C_w}\,, \quad P(L) = (1/\pi C_w)\exp\left(-L^2/C_w\right),$$

where C_w is the coefficients of wriggling -vibrations [1]. Comparison of the distributions and average values of orbital momenta with the results of [2] gives reasonable agreement for the spontaneous fission of ^{252}Cf nuclei.

1. J.R. Nix *and* W.J. Swiatecki, Nucl. Phys. A 71, 1 (1965).
2. A. Bulgac, *et al.*, Phys. Rev. Lett. 128, 022501 (2022).

Determination of the Electrical Parameters of the GaS Thin Film

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In this work, the electrical conductivity, volt-ampere characteristics of GaS thin film obtained by thermal evaporation on clean glass were studied before and after gamma irradiation, thermal annealing temperature, and their electrical parameters were determined. The changes in the values of the electrical parameters were compared.

Key words: thin film, electrical conductivity, radiation, charge carrier, volt-ampere characteristic

Soft Rotator Multiband Optical Model Parameters for Fissile Actinides

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The recently developed multiband dispersive optical model with soft rotator nuclear model couplings is used to build a regional potential for fissile actinides. The model allows coupled-channel calculations for odd-A targets considering rotational bands built on vibrational states. Those complex vibrational states are characterized by a coupling of single-particle excitations with the vibrational states of the corresponding even-even core.

We studied fissile targets U-233, U-235, Pu-239, and Pu-241 and derive optical model parameters to predict “optical” cross section data. For U-233, the ENSDF database identifies two bands (beta- and octupole vibrations), one band for Pu-239 and one band for Pu241 (octupole). For U235 no such bands are found, however the new model can predict cross sections in this case due to the inclusion of the centrifugal stretching effect across the ground state rotational band.

Experimental data on nucleon scattering from U-233, U-235 and Pu-239 are described using this model as implemented in the OPTMAN code with four nuclear deformations as fitting parameters. Optical predictions for U-235m and Pu-241 are also studied.
Derived optical model potentials are being used elsewhere for on-going INDEN evaluations of neutron induced reactions on Pu-239 and U-233 targets.

Prompt Fission Neutron Spectra of ^{233}U(*n,F*)

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Prompt fission neutron spectra (PFNS) are produced for incident neutron energies from thermal up to 20 MeV. Simultaneous analysis of measured and calculated data for ^{235}U(*n,F*), ^{239}Pu(*n,F*) [1] and ^{233}U(*n,F*) maintains stronger justification for the predicted PFNS of ^{233}U(*n,F*). For the latter the reliable measured PFNS data are available at $E_n \sim E_{th}$ only. Pre-fission neutron spectra influence the partitioning of fission energy between excitation energy and total kinetic energy of fission fragments. For the reactions ^{233}U(*n,F*) and ^{235}U(*n,F*) shape of prompt fission neutron spectra (PFNS) strongly depends on the fissility of composite and residual nuclides (Fig.1). The correlation of these peculiarities with emissive fission contributions (*n,xnf*) to the observed fission cross section and competition of the reactions (*n,nγ*) and $(n,xn)^{1,..x}$ is established. Exclusive neutron spectra $(n,xnf)^{1,..x}$ are consistent with fission cross sections of ^{235}U(*n,F*), ^{234}U(*n,F*), ^{233}U(*n,F*) and ^{232}U(*n,F*) reactions, as well as neutron emissive spectra of ^{235}U(*n,xn*) at ~14 MeV. Initial model parameters for ^{233}U(*n,F*) PFNS are fixed by description of PFNS of ^{233}U(n_{th},*F*). We predict the ^{233}U$(n,xnf)^{1,..x}$ exclusive pre-fission neutron spectra, exclusive neutron spectra of ^{233}U$(n,xn)^{1,..x}$ reactions, total kinetic energy TKE of fission fragments and products, partials of average prompt fission neutron number and observed PFNS of ^{233}U(*n,F*). PFNS of ^{233}U(*n,F*) are harder than those of ^{235}U(*n,F*) PFNS, but softer than those of ^{239}Pu(*n,F*). Difference of average energies of PFNS <E> of ^{233}U(*n,F*) and ^{235}U(*n,F*) amounts to 1~3 %. At incident energies higher than (*n,2nf*) reaction threshold the observed PFNS may seem similar, though the partial contributions of ^{233}U(*n,xnf*) and ^{235}U(*n,xnf*) to the observed PFNS are quite different.

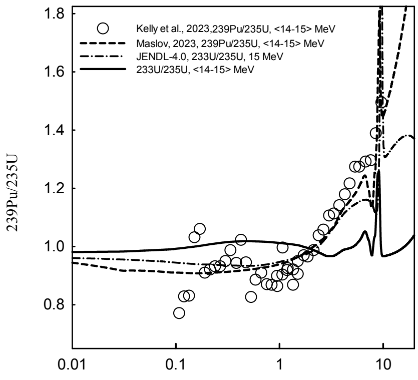

Fig.1. ^{235}U(*n,F*), ^{233}U(*n,F*), ^{239}Pu(*n,F*) PFNS ratios.

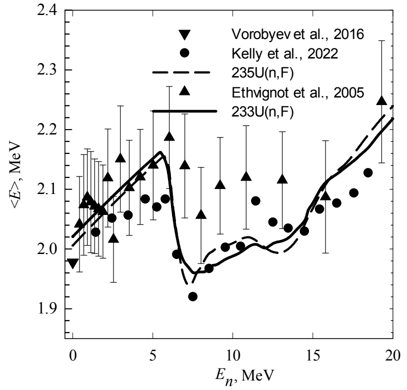

Fig.2. ^{235}U(*n,F*) and ^{233}U(*n,F*) <E> of PFNS.

1. V.M. Maslov, Physics of Atomic Nuclei, 2023, vol.86, No. 5, pp. 627–629.

Prompt Fission Neutron Spectra of ^{240}Pu(*n*,*F*)

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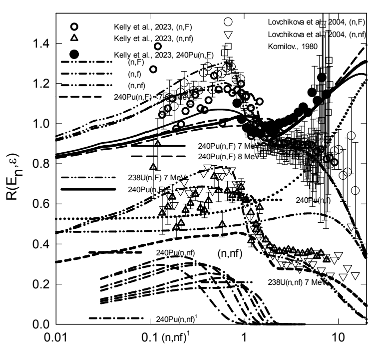
Pre-fission neutron spectra influence the partitioning of fission energy between excitation energy and total kinetic energy of fission fragments. For incident neutron energies up to E_n ~20 MeV prompt fission neutron spectra (PFNS) of ^{240}Pu(*n,F*) are predicted as described in [1]. Simultaneous analysis of measured data for ^{238}U(*n,F*) and ^{240}Pu(*n,F*) allows extract sensitivities of PFNS shape near (*n,xnf*) reaction thresholds to the exclusive pre-fission neutron spectra. Those for ^{238}U(*n,F*) PFNS [1] are strongly supported by the data of [2,3]. The disclosed data [3] on average energies <E> of ^{240}Pu(*n,F*) PFNS support the approach pursued in [1], though the lowering of <E> in [3] is inconsistent with predicted contribution of ^{240}Pu(*n,2nf*) to the observed PFNS and fission cross section. In case of ^{238}U(*n,F*) the various influence of ^{238}U(*n,nf*)^1 excusive neutron spectra on PFNS at E_n ~7 MeV and E_n ~7–8 MeV is demonstrated, while it is predicted for the ^{240}Pu(*n,F*) and ^{240}Pu(*n,nf*)^1 (Fig. 1). The largest amplitude of excusive neutron spectra at E_n~6–6.25 MeV is envisaged. For the reactions ^{238}U(*n,F*) and ^{240}Pu(*n,F*) shape of PFNS strongly depends on the fissility of composite and residual nuclides (Figs. 1 and 2). The ^{240}Pu(*n,F*) shape is rather close to that of ^{239}Pu(*n,F*), though the contribution of pre-fission neutrons is a bit higher, as predicted in [1]. Exclusive neutron spectra (*n,xnf*)$^{1,..x}$ are consistent with fission cross sections of $^{237–240}$Pu(*n,F*), as well as neutron emissive spectra of ^{239}Pu(*n,xn*) at ~14 MeV. Initial model parameters for ^{240}Pu(*n,F*) PFNS, fixed by description of PFNS of ^{240}Pu(*sf*) are consistent with ^{240}Pu(*n,F*) PFNS at E_n ~1–2 MeV. We predict the ^{240}Pu(*n,xnf*)$^{1,..x}$ exclusive pre-fission neutron spectra, exclusive neutron spectra of ^{240}Pu(*n,xn*)$^{1,..x}$ reactions, total kinetic energy TKE of fission fragments and products, partials of average prompt fission neutron number and observed PFNS of ^{240}Pu(*n,F*). PFNS of ^{240}Pu(*n,F*) are harder than those of ^{238}U(*n,F*), but softer than those of ^{239}Pu(*n,F*).



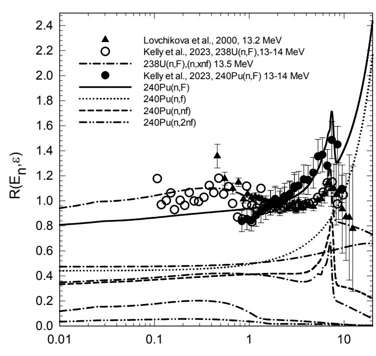


Fig.1. ^{238}U(*n,F*) and ^{240}Pu(*n,F*) PFNS, E_n~7–8 MeV. Fig.2. ^{238}U(*n,F*) and ^{240}Pu(*n,F*) PFNS, E_n~13–14 MeV.

1. V.M. Maslov, Physics of Particles and Nuclei Letters, 2023, vol.20, No. 4, pp. 565–576.
2. K.J. Kelly, M. Devlin, J.M. O'Donnel et al., Phys. Rev. C, 108, 024603 (2023).
3. K.J. Kelly et al., https://indico.bnl.gov/event/18701/contributions/82692/(2023).

^{242m}Am Isomer Yield in ^{243}Am(n,2n) Reaction

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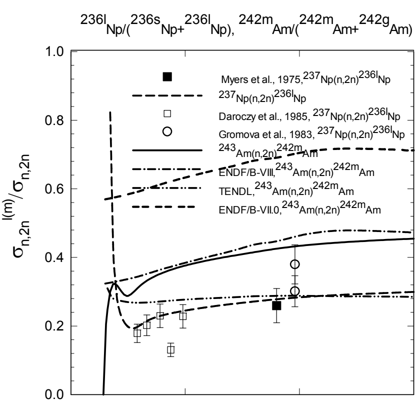
The reaction ^{243}Am(n,2n) populates either the $T_{1/2}$=16h ground state ^{242g}Am with $J^{\pi}=1^{-}$ or the ^{242m}Am isomer state $J^{\pi}=5^{-}$ with $T_{1/2}$=141y. The former state ^{242g}Am mostly β^{-}-decays to ^{242}Cm [1] or goes to ^{242}Pu via electron capture. The yield of the ^{243}Am(n,2n)^{242g}Am(β^{-}(ε)^{242}Cm(^{242}Pu) influences the α–activity and neutron activity of the spent fuel due to emerging nuclides ^{242}Cm and ^{238}Pu. The yield of the ^{242m}Am long-lived isomer state, which due to large and odd value of $J^{\pi}=5^{-}$ may decay to ^{242g}Am via isomeric transition only, gives a path for the ^{244}Cm yield via ^{242m}Am(n,γ)^{243}Am(n,γ)^{244m}Am(β^{-}(ε) ^{244}Cm(^{244}Pu) or ^{242m}Am(n,γ)^{243}Am(n,γ)^{244g}Am(β^{-}) ^{244}Cm. If not the forbidden β^{-}-decay of ^{242m}Am state, the major path for the ^{244}Cm accumulation would not exist. A number of discrepancies are observed in Fig. 1 and Fig. 2.

Calculated yields of ^{242g}Am and isomer ^{242m}Am states of the residual ^{242}Am nuclide are applied to predict the branching ratio $R(E_n)=\sigma^{m}_{n2n}(E_n)/(\sigma^{g}_{n2n}(E_n)+\sigma^{m}_{n2n}(E_n))$ (Figs. 1, 2). The branching ratio defined by the ratio of the populations of the lowest states. These populations defined by the γ-decay of the excited states, described by the standard kinetic equation. The absolute yield of ^{242g}Am is compatible with the measured data [1]. The ordering of the low and high spin states is different in case of ^{236}Np and ^{242}Am, that explains different shapes of $R(E_n)$ near the (n,2n) reaction threshold, though the excitation energy dependences are similar.



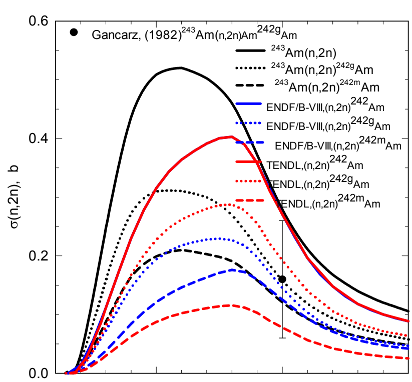


Fig.1. Relative yield of long-lived (5^{-}) ^{242m}Am state in ^{243}Am(*n,2n*) reaction.

Fig.2 Cross sections of ^{243}Am(*n,2n*), ^{243}Am(*n,2n*) ^{242m}Am and ^{243}Am(*n,2n*) ^{242g}Am.

1. T.L. Norris, A.J. Gancarz, D.W. Efurd, R.E. Perrin, G.W. Knobeloch, P.W. Oliver, G.F. Grisham, R.J. Prestwood, I., Binder, G.W. Butler, W.R. Daniels, and D.W. Barr. 14-MeV (n,2n) Neutron Cross Sections of ^{241}Am and ^{243}Am. In: Irradiations at the Rotating Target Neutron Source-II, p. 69. UCID-19837-83.

The Elemental Content of Seawater and Algae Collected from the Red Sea, the Arabian Gulf, and the Gulf of Oman: Preliminary Study

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The content of Na, Mg, Al, Ca, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Sr, Cd, Ba, and Pb in 24 samples of algae and 9 samples of water collected from 5 stations in the Red Sea, 2 stations in the Gulf of Oman and 2 stations in the Arabian Gulf were determined using ICP-OES. For all water samples, it was found that the concentrations of Cr, Co, Ni, Cd, and Pb were below the detection limits. Meanwhile, the predominant elements found in all water samples were Na, Mg, and Ca. Except for Ba, which attains its peak concentration at the Kalba station in the Gulf of Oman, the highest levels of all examined elements were detected in water samples from the Red Sea. Al, Ca, Mn, Fe, and Sr exhibit their maximum concentrations in water samples collected from the Al-Ain Al-Sukhna station in the Red Sea, demonstrating signatures indicative of geogenic origins in this area. On the contrary, the highest content of most of the elements was reflected in algae samples collected from the Gulf of Oman. The study revealed that different algae species collected from the same location exhibited a remarkable variance in elemental concentrations, which can be attributed to different accumulation capacities. Notably, the highest content of Pb was found in *Sargassum sp*. collected from Zaafrana station (The Red Sea) with a value of 19.4 mg/kg, which is 18 times higher than the average Pb content in all collected samples, revealing a possible Pb contamination in this area. The highest values of Fe, Co, Ni, and Cu were found in *Callithamnion corymbosum sp*. collected from Diba Fujairah station in the Gulf of Oman. While Cr and Mn showed their highest content in *Corallinalis sp*. collected from Kalba station in the Gulf of Oman.

The Accumulation Features of Plants and Bivalves near the Natural Sources of Strontium (Tula Region, Russia)

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The natural sources of elements create a specific ratio in biota even in protected areas. The key task of biomonitoring studies is to define the background levels of elements in order to define areas with the excess of elements associated with presumed sources of pollution. In the case of unusual high levels of selected elements in specific regions it is important to assess the intensity of their effect on biological objects, which could be used as biomonitors.

The study was conducted in three different zones in Tula region, Russia. The samples of water, Bivalvia molluscs, aquatic vegetation, soils and bottom sediments were collected at 12 sites on the floodplains of rivers in the vicinity of suggested sources of natural strontium deposition: near Sebino village on the Morkaya Tabola river, near Beryozovka village on the Nepryyadva river and Strikino village on the Ista river. In addition, the two types of samples water, soils and bottom sediments) were collected as the background at anthropogenically modified and pristine sites: rivers Don and Moskva, respectively. The concentrations of 30 microelements were determined by using ICP-OES in FLNP.

The creeping buttercup (*Ranunculus repens*) was chosen as a typical aquatic plant, which could accumulate elements from soils in the vicinity of considered rivers and springs. The plants near the outcrops of celestine on the Mokraya Tabola river (Sebino village) contained high levels of Al, P, S, V, Cr, Mn, Fe, Co, Ni, Cu with the highest levels of Sr and S among all studied samples. The highest levels of Al, Co, Pb, V, Cr, Fe, Mn, Ni were found in samples collected in an agricultural zone 300 m down the river. This could be explained by the influence of the agricultural practice, pollution by waste and fuel products, machine oil from the quarry of celestine limestones.

In other zone, the highest levels of strontium were found in the water of spring near the village Beryozovka, which is connected with the swamp and Nepryadva river. However, down the river near this site, the water contained three-four times lower levels of strontium in comparison with the initial source.

The levels of other microelements in plants and Bivalvia shells depending on strontium concentrations in water will be further discussed.

In addition, result of this study could be used for a better understanding of and the mechanisms of elements accumulation in biota of wild and anthropogenic areas with attention to the possible natural inputs and minimal background of selected element.

Testing the Effect of Nanodiamond Fluorination on the Efficiency of Reflection of Very Cold Neutrons

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Neutron reflectors are important in neutron physics and the nuclear industry. They reduce neutron losses and redirect fluxes of neutrons with different energies.

Intense fluxes of very cold neutrons (VCN) with velocities between 20 and about 200 m/s are of great interest for a variety of applications in both fundamental research and neutron scattering. However, the absence of efficient VCN reflectors was one of the most significant problems for developing intense VCN sources for a long time. The promising solution to the issue of VCN reflectors is detonation nanodiamonds (DND). In a series of previous works, it was experimentally shown that DND powders could be used as an effective diffuse reflector of VCN. The possibility of contamination, mostly by hydrogen (H), in raw DNDs causes neutron losses and reduces the reflection efficiency. In previous studies, the concentration of H was reduced by 30–60 times using the chemical treatment of DNDs in F_2 gas. The reduction of H impurities by the fluorination of DNDs improves the VCN albedo and the probability of quasi-specular reflection of cold neutrons [1].

Now, it is useful to compare the efficiency of DND reflectors relevant for 2018 (fluorinated DND powder produced in Snezhinsk, F-DND) and 2008 (commercial DND powder of *ultradiamond90*).

In this report, the results of a Monte Carlo simulation of VCN scattering on the F-DND are compared against existing experimental data for backward and forward scattering of VCN on the *ultradiamond90* layers of different thicknesses [2]. The VCN albedo for F-DND is higher up to 46, 27, and 28% for layers with thicknesses of 0.4, 2.0, and 6.0 mm, respectively, compared to the same for *ultradiamond90* powder.

References

1. Nesvizhevsky, V.V.; Dubois, M.; Gutfreund, P.H.; Lychagin, E.V.; Nezvanov, A.Y.; Zhernenkov, K.N. Effect of nanodiamondfluorination on the efficiency of quasispecular reflection of cold neutrons. Phys. Rev. A 2018, 97, 023629.
2. Nesvizhevsky, V.V.; Lychagin, E.V.; Muzychka, A.Y.; Strelkov, A.V.; Pignol, G.; Protasov, K.V. The reflection of very cold neutrons from diamond powder nanoparticles. Nucl. Instrum. Methods Phys. Res. Sect. A 2008, 595, 631–636.

Neutron Flux Density Spectral Parameters of the Pulse Neutron Source IREN

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IREN neutron Facility consists of the electron linear accelerator LUE-200 as a specialized accelerator driving system, and a non-multiplying neutron generating target with the W converter, placed inside a water moderator [1]. Up to now, this pulse neutron source has not only been used for the neutron activation analysis area, but also utilized for experiments measuring the reaction cross section of thermal neutron capture and resonance integral. For these applications, we have to understand the characteristics of the neutron spectra produced in this facility. In this study, neutron flux spectra were calculated by using the Monte-Carlo simulation code MCNP. Thereby, parameters such as the Maxwellian-temperature T for the thermal neutron distribution, and the shape-factor α of the epithermal neutron distribution were investigated [2]. In addition, we used the method of simultaneously activating two standard samples [3] of ^{197}Au and ^{94}Zr to determine experimental value of the α parameter and make comparisons.

Keywords: IREN facility, neutron flux distribution, neutron activation analysis, neutron cross sections, resonance integrals, Monte Carlo calculations.

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Reference:

1. A. Sumbaev et al, JINST 15 (2020) T11006.
2. H. Harada et al, J. Phys. Commun. 4 (2020) 085004.
3. F. De Corte et al, J. Radioanal. Chem. 62 (1–2) (1981)209.

Mosses as Bioindicators of Air Pollution with Potentially Toxic Elements in Karaganda Region, Kazakhstan

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Air pollution is one of the main problems which society faces during last several decades. Among compounds released into the atmosphere as a result of anthropogenic activity special attention is given to potentially toxic elements (PTEs), including heavy metals. The control of atmospheric air quality requires, primarily, a multi-element analysis of the aerosol particles and determination of the concentrations of elements considered as toxic for living organisms.

For the first time, moss biomonitoring was carried in Karaganda region, Kazakhstan. In October 2019, 38 moss samples were collected on the territory of the Karaganda region. Sampling was carried out within the framework of the United Nations Air Program in Europe (UNECE ICP Vegetation**)** in accordance with the manual. Most of the samples were collected on the territory of the Karkaraly National Park, which is one of the specially protected natural areas of Kazakhstan. The high conservation value of the park is attributable to the exceptional diversity of landscapes for Central Kazakhstan. Moss samples were also collected in the village of Akzharyk (Aktogay district) located in the close vicinity to the Karagaily mining and processing plant, the Kentobe deposit and town Karkaralinsk. The studied area covered two territories with different level of anthropogenic load: the Karkaraly National Park and the Akzharyk settlement.

A total of 39 elements were determined in mosses collected at 38 sites using neutron activation analysis and atomic absorption spectrometry. The values of potentially toxic elements were higher for samples collected near Akzharyk settlement. To reveal any associations of elements and to match them with possible emission sources factor analysis was applied. Four factors were determined, of which two of mixed geogenic–anthropogenic origin and two of anthropogenic origin. To assess the level of studied area pollution and the impact of elements on human health, the contamination factor, pollution load index and environmental risk were calculated. According to the calculated values, studies region can be characterized as unpolluted to slightly polluted, with low potential ecological risk. Maps of the spatial distribution of elements were compiled using ArcGIS. The obtained data were compared with the results of the 2015/2016 moss survey reported for neighboring countries. The content of Pb in analyzed samples was the highest relative to neighboring countries, while the content of other elements was lower or comparable. Mining, ore processing, metallurgy and transport can be considered as main source of air pollution in Karaganda region.

SiPM-Based Gamma Spectrometer for Nuclear Spectroscopy

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This study presents the results of a scintillation gamma spectrometer detector developed using a 16-element SiPM matrix. The matrix was coupled with different scintillator crystals, including GaGG, YSO, and BGO. Each SiPM element had a sensitive area of 3×3 mm², a pixel density of 1440 pixels/mm², a photon detection efficiency of 40% at 470 nm wavelength, and an operating voltage of 55.5 V. The characteristics of the gamma detector were evaluated using gamma rays from Am-243, Co-60, Cs-137, Na-22, and Th-228 sources.

The detectors coupled with GaGG and YSO crystals exhibited a perfectly linear relationship between detected signal amplitude and gamma-ray energy from 26.3 keV to 1.33 MeV. The BGO scintillator crystal demonstrated a 1 MeV longer linear range for gamma-ray energy but exhibited low sensitivity for energies below 300 keV. The energy resolutions for the 662 keV gamma-ray peak were 8.17%, 9.3%, and 10.2% with GaGG, YSO, and BGO scintillator crystals, respectively.

The Dynamics of Oscillation Instability of the IBR-2M Reactor. The Noise Analysis

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The main results of the study on noise dynamics of the pulse energy in the IBR-2M for period from 2012 at the power of 2 MW until the middle of 2021 are presented. The frequence ranges, level of the fluctuations and the possible causes of the fluctuations in the noise energy pulses are also presented. It is shown that with an increase in fuel burnup, the power spectral density of the pulse energy noise becomes more complicated and the amplitude of low frequency oscillations grows.

Optimization of Automatic Power Control System of the IBR-2M Pulsed Reactor

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The IBR-2M pulsed reactor has been in operation in Dubna (Russia) since 2012. The IBR-2M is an upgraded version of the IBR-2, which was decommissioned in 2006 due to the end of its service life. Studies of the IBR-2M pulsed reactor showed that high (up to ~50 %) fluctuations of pulse energy correspond to a complex frequency spectrum of oscillations. In addition to the white noise component and a number of harmonic oscillations, it includes a significant low-frequency component with a period of 10 s. The low-frequency oscillations are interpreted as self-oscillations associated with the attenuation of the fast power feedback (PF) during reactor operation. One way to reduce the amplitude of self-oscillations is to optimize the parameters of automatic power control (AC). Optimization of the AC parameters is based on a model representation of the reactor dynamics as a pulsed AC system. The mathematical model of the IBR-2M dynamics makes it possible to analyze both power transients and noises in self-regulation (without AC) and automatic regulation (with AC) modes. To optimize the AC parameters, it is necessary to simulate the reactor operation when the AC system and the fast PF system work together. Optimization of parameters of the IBR-2M AC system made it possible to significantly reduce both the influence of random and deterministic reactivity fluctuations on pulse energy noises of the reactor. The work presents the main results of the study of the optimization of the AC system of the IBR-2M pulsed reactor.

Verification of an Available Cross-Section Library for Neutron Interaction with Solid Deuterium Using Monte Carlo Simulation

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The calculation of neutron transport plays an important role in the development of neutron sources. The certainty of the calculation depends mainly on the choice of nuclear data library, particularly the neutron cross-sections. Nowadays, there are various types of nuclear data, and libraries already exist, such as the Japanese Evaluated Nuclear Data Library (JENDL), the Evaluated Nuclear Data Files (ENDF), the Joint Evaluated Fission and Fusion File (JEFF) organization, the TALYS Evaluation Nuclear Data Library (TENDL), the evaluated neutron data library (BROND), the ACE Application Nuclear Data Libraries, and others.

In our research, we have studied the neutron data library for solid ortho-deuterium (sD_2) at 5 K. It is one of the most effective materials that might be used in the design of very cold neutron (VCN) and ultracold neutron (UCN) sources as a converter of such neutrons. The library was developed in ACE format by the Spallation Physics Group at the European Spallation Source. It is based on the neutron scattering kernel for sD_2 proposed by Granada J.R. [1]. The main characteristics of Granada's model are contained in the mathematical formalism, including the lattice's density of states, the Young-Koppel quantum treatment of the rotations, and the internal molecular vibrations. Moreover, the elastic processes involving coherent and incoherent contributions are fully described, as are the spin-correlation effects.

To verify the library for sD_2 at 5 K, a Monte Carlo code was used to simulate the experimental cross-sections directly. Calculations were conducted, including: 1. Total cross-section for neutrons interacted with a flat layer of sD2 of a thickness of 1 cm. The initial energy range was from 10^{-2} to 10^{3} meV. The simulation results show a similarity to the measured cross-section. 2. The differential inelastic cross-section of energy transfers due to the interaction of neutrons with the initial energy of 20.4 meV. In this case, the sD2 was a sphere with a radius of 5 cm with a point isotropic neutron source at its centre. The neutron scattering data was compared with the results published by A. Frei [2], showing agreement for the range of energy loss of sub-thermal neutrons in the sD_2 converter material.

Based on the results of the calculations mentioned above, we have calculated the cross section for generating VCN with velocities from 50-200 m/s.

Moreover, for simulations relating to the production and transport of UCN, the library shows a lack of necessary data. The limitation applies to the range of neutron energies from 10^{-2} to 10^{3} meV. In the next stage of our research, we will focus on using the neutron scattering kernel for sD_2 that was proposed by Granada J.R. for the development of a data library for Geant4 extended to the UCN energy region.

1. Granada, J.R. "Neutron scattering kernel for solid deuterium." *Europhysics Letters* 86.6 (2009): 66007.
2. Frei, A., et al. "Understanding of ultra-cold–neutron production in solid euterium." *Europhysics Letters* 92.6 (2011): 62001.

Existing Developments and Directions for Further Development of Thermal-Neutron Detectors at the IBR-2 Department of Spectrometers Complex

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The Joint Institute for Nuclear Research (JINR) is one of the most important scientific centers in Russia and the world thanks to the existing experimental facilities distributed throughout the laboratories of the JINR.

For the Frank Laboratory of Neutron Physics (FLNP), the IBR-2 reactor is the main research facility. The rated power of the reactor is 2 MW, and the pulse half-width is 320 µs. The density of the thermal neutron flux from the surface of the thermal moderator is 10^{13} n/(cm^2 s).

The IBR-2 reactor has 14 research channels for extracting neutron beams, designed to conduct studies of condensed matter and biological systems by neutron scattering methods. Neutron beams are formed in the extraction channels, which are directed to specialized facilities, each of which is equipped with a neutron radiation detection system adapted to the measurement technique used at the facility.

The Department of Spectrometers Complex (DSC) of IBR-2 plays an important role in maintaining the efficiency and development of the experimental facilities. One of the most important activities of DSC is the development and creation of detector technologies, on the basis of which detectors for experimental installations are created.

This report will present the existing developments of Sector No. 1 of the DSC IBR-2 in the field of detectors for neutron detection and electronics for data collection and accumulation, as well as possible directions for future development.

Dynamics Model for the "Neptune" Reactor

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In the Frank Laboratory of Neutron Physics is working on developing a project for a new neutron source – periodically pulsed reactor "Neptune" –, which will replace the IBR-2 reactor by the end of 2030s. The new facility may be the first in the world to use neptunium nitride as fuel. This will increase the neutron flux by approximately ten times compared to the existing reactor and will provide new technological possibilities in neutron research.

This poster will present current status of the dynamics program for the Neptune periodically pulsed reactor, as well as possible directions for future development.

Stationary Magnet of Neutron Flipper-Decelerator for the UCN Source at a Periodic Pulsed Reactor

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The main idea of the UCN source in pulsed reactors is the pulsed accumulation of UCN in a trap [1]. The neutron density accumulated in the trap depends on many factors. They include: the duration of the bunch at the entrance to the trap, the efficiency of transportation, absorption by the walls of the trap itself, etc. In the absence of special steps, the necessary distance of the trap from the place where UCN were produced leads to the spreading of neutron bunches during the transportation of UCN to the trap. As a result, the pulse structure of the beam disappears, which makes the idea of pulse accumulation impossible.

In work [2], it was shown that in the case of large deceleration of very cold neutrons (VCN) by some local device, which can be an adiabatic spin flipper operating in high magnetic fields, the flux of VCNs, which after deceleration are converted into the UCN, has a pulse structure. In this case, the duration of neutron bunches can be significantly less than their repetition period. Accordingly, the density of the neutron flux in the bunch will significantly exceed the average value.

The report is devoted to the design of an adiabatic spin-flipper with a magnetic field of about 20 T.

1. Shapiro F.L., PEPAN 2 (4) (1971) 975–979.
2. Frank A.I., Kulin G.V., Zakharov M.A. “On a New Possibility of Pulsed Accumulation of Ultra Cold Neutrons in a Trap”. Phys. Part. Nuclei Lett. 20, (2023) 664–667.

The Measurement of the $^{6}Li(n, t)^{4}He$ Reaction Cross-Section in the Energy Range of 4.25–7.50 MeV

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The measurement of the total cross-section of the $^{6}Li(n,t)^{4}He$ reaction was carried out over the energy range of 4.25–7.50 MeV by a time-of-flight method relative to the cross-section of the ^{235}U fission. The Cs_2LiYCl_6:Ce based scintillation detector was used as a lithium containing target. The scintillation detector was placed in an axially symmetrical geometry relative to a monitor fission chamber containing ^{235}U layers. The pulsed quasi-monoenergetic neutron beam from the $^{2}H(d,n)^{3}He$ reaction was used as a neutron source. The total systematic uncertainty in the experiment was 4.6–6.7% with the statistical uncertainty of 2.0–3.7%. The obtained data do not support the evaluated cross-section of the $^{6}Li(n,t)^{4}He$ reaction from the ENDF-B/VIII.0 library. At the same time, the average difference between the evaluated cross-section from the JENDL-5.0 library and the experimental data obtained in this work also exceeds the total systematic uncertainty of the measurements.

Progress in Neutron Resonance Imaging Experiments Using MCP at CSNS Back-n

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Neutron resonance imaging (NRI) has shown great potential in the field of archaeology. This technique, which exploits the resonant absorption of neutrons by specific isotopes, has been refined using boronized microchannel plates (MCP) detectors to achieve higher contrast and spatial resolution than traditional neutron imaging methods. In this presentation, we will discuss the latest progress in neutron resonance imaging experiments using boronized MCP at the China Spallation Neutron Source (CSNS) Back-n facility. The results of the test experiment have demonstrated the capability of boronized MCP for high-resolution imaging and its potential for enhancing the sensitivity and efficiency of NRI.

Interaction of 14-MeV Neutrons with ^{75}As

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Two novel experimental setups have been commissioned to explore 14-MeV neutron-induced scattering and activation nuclear reactions on various isotopes and elements as part of the TANGRA (TAgged Neutrons & Gamma RAys) project conducted at FLNP JINR (Dubna, Russia) [1]. Such investigations are crucial for advancing both fundamental and applied neutron-nuclear physics research. The TANGRA-GeLa system comprises a portable 14.1 MeV neutron generator (ING-27, VNIIA, Moscow) and an array featuring two HPGe and four $LaBr_3(Ce)$ gamma-ray spectrometers. The TANGRA-PSA experimental setup is equipped with a plastic scintillator array (PSA) to distinguish the contributions of reaction products (scattered neutrons and gamma-quanta), using time-of-flight (TOF) and pulse-shape discrimination (PSD) techniques in addition to the tagged-neutron method (TNM). This study aims to use both setups for conducting a feasibility study on the cross-sections of 14-MeV-neutron-induced reactions and the angular distributions of gamma rays for ^{75}As nuclei [2, 3]. Accurate nuclear data regarding ^{75}As are essential to perform elemental analyses of substances and materials through nondestructive determination of arsenic content in soil, water, plants, food, and pharmaceuticals. They are critical for identifying chemical warfare agents containing arsenic, such as Lewisite ($C_2H_2AsCl_3$), which consists of 51% Cl, 36% As, 11% C, and 1% H. The nuclear data acquired could enhance the existing nuclear databases for the ^{75}As isotope [4].

References

1. TANGRA project, https://flnp.jinr.int/en-us/main/facilities/tangra-project-en.
2. Fei Tuo, Toujie Ji, Junhua Luo, et al., Cross section measurements for ^{75}As isotope at neutron energies from 13.5 to 14.8 MeV, Nuclear Instruments and Methods in Physics Research, SectionB, Volume 264, Issue 2, 2007, Pages 235-239, https://doi.org/10.1016/j.nimb.2007.06.031.
3. Ugo Abbondanno, Ferruccio Demanins, Maria Rosa Malisan, Giancarlo Nardelli, A study of the ^{75}As(n, n'γ)^{75}As reaction, Nuclear Physics A, Volume 305, Issue 1, 1978, Pages 117-143, ISSN 0375-9474, https://doi.org/10.1016/0375-9474(78)90167-7.
4. Keiichi Shibata, Go Chiba, Akira Ichihara & Satoshi Kunieda (2010), Evaluation of Neutron Nuclear Data on Arsenic-75 for JENDL-4, Journal of Nuclear Science and Technology, 47:1, 40–46, https://10.1080/18811248.2010.9711925.

Interaction of 14-MeV Neutrons with ^{9}Be

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Within the framework of the JINR project TANGRA (TAgged Neutrons & Gamma RAys) [1], a comprehensive investigation into the characteristics of nuclear reactions induced by 14-MeV neutrons is currently underway, focusing on elements crucial for both fundamental and applied neutron-nuclear physics. These elements lack sufficient or accurate data. The research program also includes a series of measurements using beryllium-containing samples, employing two multi-detector systems to detect gamma rays and neutrons generated in reactions between "tagged" neutrons from ING-27 and beryllium nuclei.

Beryllium, renowned for its distinctive structural, chemical, atomic, and neutron absorption cross-section properties, finds widespread applications in aerospace, automotive industries, rockets, nuclear weapons, medical X-ray devices, agriculture, food processing, oil and gas exploration, mining, robotics, and safety products. Additionally, it has proven successful as a neutron reflector in three generations of nuclear fission reactors.

The cross-section for the $^{9}Be(n,t_1)^{7}Li^* \to {}^{7}Li + \gamma$ (0.477 MeV) reaction [2] can be determined by registering gamma rays at various scattering angles. The significance of the $^{9}Be(n,2n)$ reaction lies in fusion reactor development, as it involves neutron multiplication and exhibits a relatively large cross-section around 14 MeV, providing insights into the nuclear mechanism of the (n,2n) process, where different nuclear reactions may contribute. Nuclear data for this reaction directly influences the neutronic characteristics of the solid breeder blanket for the fusion reactor ITER. The time-of-flight (TOF) technique serves to differentiate gamma rays from the neutron background. A more precise understanding of the interaction between 14-MeV neutrons and beryllium nuclei could also enhance the quality of existing libraries containing evaluated nuclear data [3, 4].

References

1. TANGRA project, https://flnp.jinr.int/en-us/main/facilities/tangra-project-en
2. F.S. Dietrich, L.F. Hansen & R.P. Koopman (1976), Cross Section for the $^{9}Be(n, t_1)^{7}Li$ Reaction Between 13.3 and 15 MeV, Nuclear Science and Engineering, 61:2, 267–268, http://dx.doi.org/10.13182/NSE76-A27361
3. Simakov S. P., Pavlik A., Vonach H., et al., Status of Experimental and Evaluated Discrete Gamma-Ray Production at E_n=14.5 MeV, IAEA, Vienna, Austria. 1998, https://inis.iaea.org/collection/NCLCollectionStore/_Public/29/062/29062821.pdf
4. Zhenpeng Chen, Yeying Sun, Qianghua Wu, A primary evaluation for n+^{9}Be, https://www-nds.iaea.org/index-meeting-crp/CM-INDEN-LE/docs/File%201.pdf

Interactions of 14-MeV Neutrons with ^{40}Ca

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Two novel experimental setups have been commissioned to explore 14-MeV neutron-induced scattering and activation nuclear reactions on various isotopes and elements as part of the TANGRA (TAgged Neutrons & Gamma RAys) project conducted at FLNP JINR (Dubna, Russia) [1]. Such investigations are crucial for advancing both fundamental and applied neutron-nuclear physics research. The TANGRA-GeLa system comprises a portable 14.1 MeV neutron generator (ING-27, VNIIA, Moscow) and an array featuring two HPGe and four $LaBr_3$(Ce) gamma-ray spectrometers. The TANGRA-PSA experimental setup is equipped with a plastic scintillator array (PSA) to distinguish the contributions of reaction products (scattered neutrons and gamma-quanta), using time-of-flight (TOF) and pulse-shape discrimination (PSD) techniques in addition to the tagged-neutron method (TNM). This study aims to utilize both setups to conduct a feasibility study on the differential and angle-integrated cross-sections of 14-MeV neutron-induced reactions and the angular distributions of gamma rays for ^{40}Ca nuclei [2]. Calcium, along with fluorine and chlorine, is one of the most important materials in the molten salt reactor (MSR), a Generation IV nuclear power reactor that intends to use molten fluorides or chlorides as fuel mixtures or coolants. Our measurements can improve the quality of experimental and evaluated nuclear data for ^{40}Ca [3], whose reactions with 14-MeV neutrons remain among the most extensively studied due to the variety of reactions and decays.

References

1. TANGRA project, https://flnp.jinr.int/en-us/main/facilities/tangra-project-en
2. Ophoven, N., Ilic, Z., Mauerhofer, E. et al., Fast neutron induced gamma rays from (n,n'), (n,p) and (n,α) reactions on $CaCO_3$, J. Radioanal. Nucl. Chem. **331**, 5729–5740(2022). https://doi.org/10.1007/s10967-022-08594-6.
3. Jun Chen, Nuclear Data Sheets for A=40, Nuclear Data Sheets, Volume 140, 2017,Pages 1–376, https://doi.org/10.1016/j.nds.2017.02.001.

Preliminary Conceptual Design of the High-Intensity Ultracold Neutrons Source at the WWR-K Reactor

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Because of their unique feature, ultracold neutrons (UCN) are used as a sensitive instrument in fundamental physics experiments where high-precision measurements are required. Various UCN measurements are especially aimed at solving unanswered questions in fundamental physics, astrophysics and cosmology. These include the verification of fundamental theories, such as the search for the electric dipole moment of the neutron, the measurement of the neutron lifetime and the search for new types of interactions at short distances, the search for neutron-antineutron oscillations, etc.

However, the solution of these problems is limited by the intensity of the UCN source, so the development and construction of a high-intensity UCN source is extremely important, which will make measurements more comprehensive and minimize statistical errors. In this regard, it is proposed to develop high-intensity UCN source in the thermal column of the WWR-K research reactor.

The thermal column of the 6 MW WWR-K reactor is available for construction of the UCN source with record UCN density for fundamental studies. The large diameter (1 meter) of the thermal column makes it possible to place a lead shield 10 cm thick to reduce the heat load; room temperature graphite will moderate neutrons to thermal energy range; 19 K low-temperature converter will produce cold neutrons, and superfluid helium at a temperature of 0.8–1.25 K will convert cold neutrons into ultracold neutrons. The estimated volume density of UCN in the source chamber of 35 *l* is about $1.6 \cdot 10^5$ n/cm^3 at a helium temperature of 0.8 K, which is more than 1000 times higher than the maximum achievable UCN density at the ILL source.

Exploring the Role of Nuclear Structure Effects in Photofission Mechanism of ^{237}Np

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The photofission process is important for various nuclear applications and presents a multifaceted and complex phenomenon that demands exact and perfect investigations. Photofission, characterized by the excitation and subsequent fission of a nucleus induced by photon absorption, holds critical importance in fields such as nuclear energy production, nuclear medicine, and fundamental nuclear physics research. However, its complexity arises from the complicated interplay of various factors, including nuclear structure, excitation mechanisms, and reaction dynamics. By seeking the theoretical underpinnings of photofission, we attempt to know the inherent complexities of the process and clarify the underlying mechanisms governing ^{237}Np photofission. In this study, it is shown that the effects of nuclear structure such as the nuclear level density (NLD) at saddle points and fission barrier parameters play an essential role in determining the probability and characteristics of photofission reactions. By employing advanced theoretical models and nuclear reaction codes, we investigate the complicated interplay between these key factors and the photofission cross section of ^{237}Np. Theoretical calculations will be validated by the experimental data giving us a deeper understanding of the underlying mechanisms governing ^{237}Np photofission dynamics.

Keywords: Nuclear photofission, Nuclear level density, Saddle points, Fission barriers, Neptunium 237

Development of a Project for a Universal Trap for Storing Ultracold Neutrons

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The project proposes the development of a universal trap for storing UCNs. In one installation, 2 traps are installed on the same axis: material and magnetic. The material trap is made of copper and coated with hydrogen-free fomblin oil. The magnetic trap is an assembly of NdFeB permanent magnets. By rotating the trap system around an axis, it is possible to carry out gravitational capture of UCNs either into a material or into a magnetic trap. Thus, on one installation it is possible to carry out measurements with both a material and a magnetic trap, i.e. it is possible to compare the material and magnetic storage of UCNs under the same conditions. It is also important to note that these two measurement methods differ methodically: in a material trap, the neutron lifetime is obtained as a result of extrapolation, while in a magnetic trap it is measured directly. Such a measurement scheme will make it possible to get rid of a number of systematic uncertainties in measurements with different traps and is proposed for the first time. The gravitational capture of UCNs in a magnetic trap proposed in the project is a fundamentally new approach that has never been implemented before. One of the factors influencing the systematic error of the experiment will be the process of neutron depolarization in a magnetic field. Therefore, an important problem that needs to be solved in this project is the development of a magnetic system that minimizes the probability of neutron depolarization [1]. It is also important to consider the so-called turbine effect, which can manifest itself in a change in the UCN energy during rotation due to interaction with the flat faces of the trap [2].

The study has been carried out with the support from the Russian Science Foundation, grant no. 23-22-00169, https://rscf.ru/project/23-22-00169/.

1. G.N. Klyushnikov, A.P. Serebrov, JETP **137** (2023) 316.
2. A.K. Fomin, A.P. Serebrov, Instruments and Experimental Techniques, in press.

Neutron Slowing Down as a Random Walk Problem

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In this report-poster author asserts that the names of Pierre-Simon Laplace, Gian-Carlo Wick, Enrico Fermi, Karl Pearson and Paul Langevin happened to be directly related to the historical problems of the random walk in the statistical theory and slowing down of fast neutrons to thermal energy in the physics. Their works have been instrumental in solving these problems by developing the exact mathematical expressions for the probability density of the sum of independent random variables. Several approaches to obtaining these expressions will be shown. There were most problematic difficulties with getting the result in the form of an analytical formula for energy distribution of neutrons, which are slowed down by a fixed numbers of impacts with protons. The author's simplest way to deduce such formula is shown also, for the pedagogical reasons, for students interested in neutron physics.

References:

1. E. Amaldi, O. D'Agostino, E. Fermi, B. Pontecorvo, F. Rasetti, and E. Segre. *Artificial Radioactivity produced by neutron bombardment II*. Proc. Roy. Soc. **A149**:522–558 (1935).
2. G.C. Wick. *On the slowing down of neutrons*. *Phys. Rev*. **49**:192–193 (1936).
3. E.U. Condon, G. Breit G. *The energy distribution of neutrons slowed by elastic impacts*. *Phys. Rev*. **49**:229–231 (1936).
4. Pierre-Simon Laplace. *Theorie Analytique des Probabilities*, *Troisieme Edition, Paris (1820)*. In: Oeuvres complete de Laplace. Tome **7**:253–263, Paris (1878).
5. Karl Pearson. *The problem of the Random Walk.* Nature **72(**1865):294, **72(**1867):342 (1905).
6. Paul Langevin. *Sur les chocs entre neutrons rapides et noyaux de masse quelconque*. Ann. Phys, Paris, **17**:303–317 (1942).

The Ecological-Geochemical Assessment in Recreational Zones of Moscow Based on the Study of Three Environmental Components (Soil, Vegetation, Atmospheric Air)

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The study was performed from June to September 2018 on the territory of seven Moscow parks (Losiny Ostrov, Sokolniki, Ostankino, Izmailovo, Tsaritsyno, Kuzminki-Lublino, Victory Park) to examine the level of potentially toxic elements in recreational areas. To assess atmospheric deposition of elements active biomonitoring or moss bag technique was applied. In addition, sampling of soil and vegetation was carried out at three locations in each park with varying degrees of anthropogenic impact. Elemental composition of samples was determined by instrumental neutron activation analysis at the reactor IBR-2 of FLNP, JINR. Such elements as Cd, Cu and Pb were determined by atomic absorption spectrometry. The total pollution index was calculated for the assessment of the levels of pollution. The highest pollution was characteristic for soils, which is associated with its depositing capacity and long period of pollutants impact. Comparing parks, the highest concentrations of elements were determined for sites located close to roads in Elk Island, Izmailovo, Tsaritsyno and Kuzminki-Lublino.

Computer Simulation Process of Neutron Transport in Liquid Scintillator Filled Multi-Module Neutron Detector

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Investigation of (Prompt Fission Neutrons) PFN is important in study of process of scission of nuclei, due to PFN multiplicity carry information on nucleus excitation energy. For detailed study of fission fragments mass and excitation energy distributions in along with properties of prompt fission neutrons in reactions ^{235}U(n,f), ^{237}Np(n,f), ^{239}Pu(n,f), induced by resonance neutrons and in spontaneous fission of ^{252}Cf, the neutron detector, consisted of 32 PFN detectors modules manufactured by SIONICS (Netherlands) company was located in resonance neutron beam of IREN Facility of JINR in Dubna (Russian Federation). PFN emitted in fission, induced by the neutrons in the resonance energy range irradiated the U-235 target, located on the common cathode of a double Frisch-gridded ionization chamber (IC). Exited fission fragments emitted PFNs, which were detected PFN detector modules. Fission fragments were detected in IC, where their kinetic energies and emission angles were measured. For each fission event the following information was obtained: event time stamp, fission fragment (FF) emission angle, its kinetic energy and pulse shape information. PFN detector was able to separate PFN from background gamma radiation. Multi-module structure of PFN detector gives the advantage of high detector efficiency value, from the one hand and the multiple scatterings creates drawback of false multiplicity of events. In that situation we need to determine the share of events created by multiple scattering, using computer simulation of process neutron travelling inside the detector body. To do that we developed computer program, generated 20 scenarios with 500000 events with PFN emissions in each scenario. In these calculations we determine the possible systematic errors level connected with multiple scattering does not exceed the level of 5%. In our calculations we took into account the share of neutrons reflected from surroundings, especially from the floor.

$N^{real} \sim 0.95 \cdot N^{visible}$, where $N^{visible}$ is the number of events registered by neutron detector, N^{real} is the actual number of neutrons detected in the system.

Non-Destructive Investigation of Fragment of Leggings (4th Century BCE) Using Neutron Resonance Capture Analysis

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Neutron resonance capture analysis is a state of the art method for elemental identification. It is based on registration neutron resonances in radiative capture and measurement the yield of reaction products in these resonances. The method is in particular highly valuable in the determination of the composition of archaeological objects.

As part of this direction, joint work is being carried out with the Institute of Archeology of the Russian Academy of Sciences (RAS) for various samples. One of these samples is a fragment of leggings. This archeological object was found during excavations of the Scythian mound Gorki-I, carried out by senior researcher at the Institute of Archeology of RAS Savchenko E.I. in 2003. The burial mound was located in the Krasnyansky district of the Belgorod region, in the burial mound No. 13, dating from the mid-second half of the 4th century BCE. A pair of bronze leggings was found there, one of which was so poorly preserved that only one could be reconstructed [1].

The bronze leggings, which are leg armor that protects not only the shin, but also the knee, are extremely rare in the burials of the Scythian nobility; they are found only in the richest (royal) Scythian burial mounds. In view of such rarity fragility of the artifact, the determination of element and isotope composition by non-destructive Neutron Resonance Capture Analysis is particularly relevant.

REFERENCES

1. Gulyaev V.I., Savchenko E.I., 2004. A new monument of the Scythian era on the Middle Don // Archeology of the Middle Don in the Scythian era. Proceedings of the Potudan archaeological expedition of the Russian Academy of Sciences. 1993–2000 Digest of articles. Rep. ed. V.I. Gulyaev. M.: Institute of Archeology RAS. pp. 35–52.

Structural Studies of Greek Alabaster Vases: Data from X-Ray Tomography and Diffraction, Raman Spectroscopy

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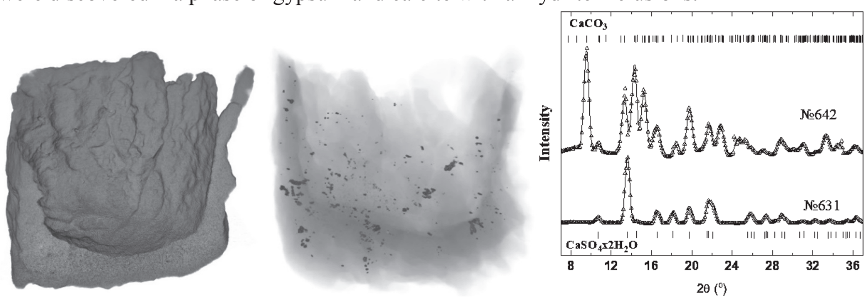
There is still no reliable petrographic indicator of the geographical origin of homogeneous gypsum and limestone rocks [1]. Usually, assumptions are made about the origin of raw materials based on the stylistic indications of artifacts or on the geographical proximity of quarries. Currently, a search is underway for structural prerequisites for a comparative analysis of archaeological finds, and on the basis of this, identifying sources of raw materials or locations of ancient workshops [2]. Since the supposed alabaster material of the vases contains mainly light atoms of calcium, sulfur, carbon and oxygen, this makes X-ray imaging methods preferable and effective.

In our work, we present structural studies of alabaster vases from archaeological excavations of the Volna 1 soil burial ground of the 4th-6th centuries, located on the Taman Peninsula. The vases under study are fragments of white and grayish vessels, the differences in their mineral composition and internal volumetric features were studied using X-ray tomography, X-ray diffraction and Raman spectroscopy. Two phases of the vases' material were discovered – a phase of gypsum and calcite with anhydrite inclusions.



(a) (b) (c)

Fig.1. A section of a fragment of a gypsum vase reconstructed from tomographic data (a) and its representation with segmented grains of inclusions (b), X-ray diffraction data on the phase analysis of the material of two vases (c). Experimental points, the profile calculated using the Rietveld method, and the positions of the Bragg peaks for the gypsum and calcite phases are presented.

1. Amin, A.T.A., Elkholy, D.M., Khamis, H.A. et al. Structural and geochemical processes controlling the formation of Egyptian Alabaster at Wadi Mawathil area, Eastern Desert, Egypt. Arab J Geosci 15, 1190 (2022).
2. Bakirov, B.; Smirnova, V.; Kichanov, S.; Shaykhutdinova, E.; Murashev, M.; Kozlenko, D.; Sitdikov, A. Structural Features of the Fragments from Cast Iron Cauldrons of the Medieval Golden Horde: Neutron Tomography Data. J. Imaging 2023, 9, 97.

Innovative Neutron Activation Approach for Analysis of Liquid Samples Based on Short-Lived Radionuclides

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Flowing sample neutron activation analysis (FSNAA) is a subclass of NAA, which has been developed for analysis of liquid samples [1]. It involves continuous pumping of a large volume of the sample, in a tube, between the irradiation site and the γ-ray detector [1]. Analysis of large volume of a sample improves the detection limits, while continues pumping allows better measurement of short-lived radionuclides. The set-up was previously tested with ^{252}Cf as a neutron source [1, 2]. The purpose of the present work is to install FSNAA at a research reactor to take the benefit of its high flux. Irradiation durability test was performing to select a suitable tubing material. Samples of different types were irradiated for different periods and then a simple bending test was performed [3]. The FSNAA set-up was constructed using the selected tube. The general procedures including: placing the sample in a sample tank, pumping it to the irradiation site, and then record a γ-ray spectrum with HPGe. A run with de-ionized water was carried out for leakage test and to check the performance of the set-up components as well as for background measurements. FSNAA was tested for analysis of tap and river waters samples. The analyzed sample volume was ~1l and the flow-rate was 30 ml/min. However, irradiation durability test showed that all tested tubes have acceptable radiation resistance; TYGON was used for constructing the system due to its excellent radiation durability. Nine elements were detected and quantified (Al, Mn, Mg, V, Na, K, Cu and Ca), while Cl, Br, I, and ^{18}O were detected but not quantified due to the lack of reference standard. The detection limits obtained from this preliminary study are satisfied in comparison to conventional NAA and other techniques. Levels of the quantified elements in the tap water are below the WHO guidelines [4].Under the current experimental conditions, the decay time (the travelling time between the irradiation site and HPGe) was ~ 3.5 min. This relatively long decay time hinders the analysis of several elements (those with shorter half-lives isotopes ex: ^{20}F, ^{46m}Sc, ^{77m}Se, ^{107m}Pb,…). Also, it adversely affects the detection limits of ^{28}Al, ^{52}V, and ^{66}Cu due to the decay of major fraction of their radioactivities before reaching the HPGe. As a future plan, use of powerful pump will be considered to reduce the decay times; and hence it is expected to increase the number of measured elements and improves the detection limits for some elements like Al, V, and Cu. The capability of FSNAA to measuring ^{18}O reveals its potential for determining past climate temperatures using, for example, water samples collected from ice cores.

REFERENCES:

[1] M. Soliman *et al.*, J. Radioanal. Nucl. Chem., **295** (2013) 245–254.
[2] M. Soliman *et al.*, J. Radioanal. Nucl. Chem., **299** (2014) 89–93.
[3] H. Kikunaga, et al., KURRI Progress Report 2013, PR10-3, (2014)
[4] Dinelli et al., L. Geochem. Explor. 112 (2012) 54–75.

Neutron Activation Analysis Lab at ETRR-2: Achievements and Future Work

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The presentation will cover the following topics:

1- Brief description of neutron activation analysis laboratory;

2- Current experiments performed at neutron activation laboratory at Egypt Second Research Reactor.

3- Planned experiments which include

   i. Designing and installing a loop irradiation facility for analysis of circulating liquid samples. It requires insertion of irradiation tube close to the reactor core. I installed this facility at Kyoto University Reactor, and I am working on installing it at our reactor, ETRR-2.

   ii. Installing a sub-cadmium irradiation facility outside the core of ETRR-2 in order to perform epithermal neutron activation analysis.

Fundamental Information from Combined Analysis of Nuclear Data and Particle Masses

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Empirical observations of the Standard Model parameters which are unexpectedly manifested simulteniousely in the prominent maxima in spacing distributions of nuclear excitations (see Table 2 in [1], Fig. 2, bottom, in [2]) and stable intervals in total distribution of particle mass differences allow us to conclude that their combined analysis demonstrate the universal character of the parameters $\delta = 16m_e$ and m_e.

Additionally the equation (1) is considered, where m_τ, m_μ and m_e are the lepton masses.

$$m_\tau = 2m_\mu + 2m_\omega \approx 2 \cdot 13 \cdot 16m_e - 2m_e + 2 \cdot 96 \cdot 16m_e \tag{1}$$

The manifestation of lepton masses demonstrates the fundamental character of correlations in nuclear data and particle masses.

1. S.I. Sukhoruchkin, Z.N. Soroko, D.S. Sukhoruchkin. *Analysis of nuclear excitations in different elements*. Proc. ISINN-27. JINR-E3-2020-10. p. 40.
2. S.I. Sukhoruchkin, Z.N. Soroko, M.S. Sukhoruchkina. *Grouping of neutron resonance positions*. Proc. ISINN-29. JINR-E3-2023-58. p. 129.

Fine and Superfine Structures in Neutron Resonance Positions

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Parameters of fine and superfine structures were introduced empirically in 1971 [1] from the analysis of maxima in distributios of neutron resonance positions, nuclear excitations and binding energies of wide range of nuclei. Recently, particle masses distributions were added [2]. Some maxima values were noticed to be in relations close to the QED radiative correction to the magnetic moment of the electron $\alpha/2\pi = 115.9 \cdot 10^{-5}$ applied to the electron mass. This value is of a fundamental character and reflects the influence of the physical condesate, vacuum [3].

$$\alpha/2\pi = 115.9 \cdot 10^{-5} = \varepsilon'' : \varepsilon' = \varepsilon' : 2m_e = m_e : M_q = m_\mu : M_Z = M_q : 3M_{H^\circ}. \quad (1)$$

In this equation (1) there are parameters of superfine and fine structures ε''=1.34 eV and ε'=1.2 keV, as well as the constituent quark mass M_q, Z boson mass M_Z and the scalar boson mass M_{H°=125 GeV.
A large amount of information on neutron resonances of heavy nuclei with Z=90-96 allows us to perform the analysis of the levels positions and spacings to check the distinguishing character of the superfine structure parameter. There is a system of stable energy intervals that are multiples of each other [4]. The superfine structure parameter ε''=1.34 eV was found in spacing distribution of neutron resonances of compound nucleus ^{238}Np: maximum at 1.1 eV. This value is close to the position of the first strong resonance at E_n=1.321 eV in this nucleus. The next strong resonance at E_n=5.777 eV is four times larger than the position of the first strong resonance and is close to the parameter 5.5 eV observed in even-even target nuclei of U: 5.98 eV ^{232}U, 5.1570 eV ^{234}U, 5.45 eV ^{236}U [5]. The intervals 5.5 eV=4ε'' and ε', as well as intervals that are multiples of them, were found in many heavy nuclei as maxima in spacings distributions of neutron resonances.

1. S.I. Sukhoruchkin. *Statistical Properties of Nuclei.* Pl. Press, 1972, p. 215.
2. S.I. Sukhoruchkin. Nucl. Part. Phys. Proc. **318 - 323** (2022) 142.
3. V. Belokurov, D. Shirkov, *Theory of Particle Interactions* AIP, 1991.
4. S.I. Sukhoruchkin, Z.N. Soroko, M.S. Sukhoruchkina. Proc. ISINN-29. JINR-E3-2023-58. p. 129.
5. S.I. Sukhoruchkin, Proc. Conf. Nucl. Data for Reactors, Paris, 1966. V. 1. p. 159. IAEA Vienna. 1967.

Progress in the Simulation of the Energy Resolution Function for CSNS Back-n Facility

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The Back-n facility at the China Spallation Neutron Source (CSNS) is a newly-built white neutron beam based on the time-of-flight technique. The Energy resolution function (ERF) is essential for the data analysis, particularly in the neutron resonance energy region. The ERF represents the inherent broadening effect for the measured resonance peaks, primarily caused by the process of the neutron production and moderation in the spallation target, which cannot be directly acquired with experimental method. The Geant4 Monte-Carlo toolkit can be used for investigating the ERF distribution of Back-n facility, as its flexible capabilities of particle tracking and information recording. The spallation target model has been built, the moderation distance (ΔL) is defined as the product of the velocity and moderation time of neutrons in the target. The back-streaming neutrons' parameters at the spallation target surface are recorded, the distributions of ΔL at different energies are obtained. Furthermore, the neutrons that can reach experimental stations are selected by reconstruction method, and the very low statistics require a novel technique to enhance the weight of the neutrons that we are interested in.

Using Carbon Stable Isotope to Evaluate Water Efficiency Following Seasonal Variation in Coffee Leaf

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Improper water management, indiscriminate water use, and climate change are the major factors reducing the global freshwater resources, and the major challenges facing many parts of the world. This study aims to determine the water use efficiency (WUE) index based on the carbon isotope discrimination ($\delta^{13}C$) to investigate the relationship between carbon absorption and water loss in coffee plants. The contents consist of the followings: (1) The design of the sampling area, collecting coffee leaf samples corresponding to the design of irrigation season and regime; and measuring temperature, rainfall, and humidity parameters in the area; (2) Testing and optimizing the procedure for analysis of $\delta^{13}C$ stable isotope in coffee leaf samples on the EA-IRMS system at the Dalat Nuclear Research Institute; (3) Analyzing $\delta^{13}C$ stable isotope in coffee leaf samples in Lam Dong (about 90 samples); (4) Using this stable isotope data for the water use efficiency index calculation of coffee plants and the. The results showed that the accuracy of the procedure with $\delta^{13}C$ is ≤ 0.3‰, and the precision (absolute standard deviation) with $\delta^{13}C$ is ≤ 0.2‰ in coffee leaf samples. And water use efficiency index and $\delta^{13}C$ were positively correlated with temperature (T°C), humidity (H%), and annual precipitation (Rmm) while carbon content was negatively correlated. In the data observed, the results showed that in the rainy season, the water use efficiency index was nearly 14% higher than that in the dried season; in the dry season WUE was 0.19 whereas in the rainy season, the amount of water in plants increased with the WUE index (0.22) and p-value = 0.017.

Keywords: Water use efficiency (WUE), elemental analyzer-isotope ratio mass spectrometry (EA-IRMS), coffee leaves, $\delta^{13}C$, and carbon content.

Nuclear Structure Investigations in Light Nuclei

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The investigation of light nuclei along the N=Z line is of considerable interest since it addresses directly the charge symmetry of the nuclear forces and the role of the Coulomb effects on nuclear structure.

Excited states in the mirror nuclei ^{31}P and ^{31}S were populated in the 1p and 1n exit channels of the reaction ^{20}Ne + ^{12}C, at a beam energy of 33 MeV. The ^{20}Ne beam was delivered for the first time by the Piave-Alpi accelerator of the Laboratori Nazionali di Legnaro. Angular correlations of coincident γ -rays and Doppler-shift attenuation lifetime measurements were performed using the multi-detector array GASP in conjunction with the EUCLIDES charged particle detector. In the observed B(E1) strengths, the isoscalar component, amounting to 24% of the isovector one, provides strong evidence for breaking of the isospin symmetry in the A = 31 mass region. The comparison of the B(E1) strengths in the two mirror transitions indicates a violation of the isospin symmetry manifested by the presence of a large induced isoscalar component. Self-consistent calculations using the NNLO*sat* and the Equation of Motion Phonon Method reproduce well the experimental findings, confirming the breaking of the isospin symmetry originating from the violation of the charge symmetry of the two- and three-body parts of the potential. The result provides evidence for a coherent contribution to isospin mixing, probably involving the isovector giant monopole resonance [1].

Second experiment represents DSAM lifetime measurements which were carried out with the multidetector array EUROBALL [2]. The results of the analysis, partly achieved with a precise procedure [3], provide valuable information on the transition strengths in the yrast cascades of the mirror nuclei ^{47}Cr and ^{47}V. The behavior of the transition strengths with spin is well described by full pf shell model calculations. In this way, a test of the isospin symmetry in mirror nuclei is performed on the basis of the determined $B(E2)$ values.

New experimental results for the N=Z nucleus of ^{30}P will be presented for the first time.

Some experimental findings in both mirror couples with A=31 and A=47 will be compared and discussed in the presentation.

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References:

1. D. Tonev et al., Phys. Rev. Lett. B 821, (2021) 136603.
2. P. Petkov et al., Nucl. Instrum. Methods A 437, (1999) 274.
3. D. Tonev et al., Phys. Rev. C 65, (2002) 034314.

Assessment of Environmental Gamma Dose Rate in Ho Chi Minh City, Vietnam

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Assessment of environmental gamma dose in air and radioactivity in surface soils in Ho Chi Minh city, Vietnam has been conducted to establish a baseline data of gamma dose rate in air, natural activity concentrations and associated radiological hazards in the city. Soil samples were collected at 120 locations distributed widely in the city and the gamma dose rate at 2245 locations using a portable dosimeter installed on a motorbike with GPS integrated and positioned 1 m above the ground surface. The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K are within the range of 9.6 – 48.5, 14.8 – 59.6 and 10.9 – 637 Bq kg^{-1}, with the average values of 21.1 ± 1.3, 36.6 ± 1.3 and 279 ± 29, respectively.

Radium equivalent activity varies from 48.2 to 142 Bq kg^{-1}, with the average value of 94.9 Bq kg^{-1}. Cumulative gamma dose rates have also been measured using the TLD dosimeters located at 20 fixed locations around the city to evaluate the total component and the contribution of cosmic rays in the rainy and dry seasons. The gamma dose rates in the city were found in the range of 0.05 – 0.18 μSv/h with the average value of 0.10 μSv/h. The cumulative gamma dose in the dry season is greater than that in the rainy season by about 15%.

Spatial and Temporal Variations in the Distribution of Multiple Elements in Sediments within the Iron Gate I Reservoir along the Danube River

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Iron Gate I, situated in the Đerdap Gorge and extending over 117 km, stands as the largest hydropower dam and reservoir system along the Danube River. The environmental impact of this dam encompasses alterations to the hydrological regime of both surface and groundwater, as well as changes to sediment patterns. Notably, the sedimentation rate within the Iron Gate I Reservoir is remarkably high, estimated at approximately 23.3 cm per year, suggesting a significant potential for accumulation and, consequently, the preservation of pollutants. Monitoring efforts have been focused on evaluating pollution levels in the River Danube, with particular attention given to emerging contaminants such as metals and metalloids (Hg, As, Ni, Zn, Cu, Cr, Pb, and Cd). This study aims to determine major and trace elements in Danube River sediment using instrumental neutron activation analysis (INAA) and to identify possible contamination.

The concentrations of 40 major and minor elements were measured at 8 locations along the Danube River, spanning from 1141 to 864 km, to monitor the spatial and temporal quality of sediment. Sediments were collected from the surface of the river bottom at the central and the deepest part using an Ekman grab sampler in April and September 2016, April 2017, April and July 2018. All samples are analyzed applying the INAA. The major elements (Al, Ca, Fe, K, Na, Ti, Mg, and Mn), trace elements (Ba, Zn, Cr, Sr, V, Rb, Ni, Cu, Co, As, Sc, Th, Cs, Hf, Sb, U, W, Ta), and lanthanides (La, Ce, Nd, Sm, Eu, Gd, Tb, Dy, Tm, Yb) were quantified. Irradiations of the samples were performed at the pulsed reactor IBR 2 (Frank Laboratory of Neutron Physics - FLNP, Joint Institute of Nuclear research—JINR, Dubna, Russian Federation) using thermal or epithermal neutrons.

The concentrations of the investigated elements varied significantly among the sample locations, with relative standard deviations ranging from 18 to 90%. The contamination factor (CF) was calculated by comparing the concentration of the target element in sediment from the sampled location to values from a reference sample, denoted as background. A sediment sample collected from the depths of the River Danube, specifically at a depth of 7 meters, and displaying the lowest concentrations of nearly all elements, served as the reference sample.

We found a contamination factor (CF) exceeding 6, signaling exceptionally high levels of contamination for Zn, As, and Sb in the sample gathered from location Smederevo. CF values for Zn, As, and Sb varied between 1 and 6, indicating low to moderate contamination levels across all examined samples. The sediment sample from the River Danube in Smederevo serves as a focal point for contamination with Zn, As, and Sb, likely stemming from anthropogenic sources, possibly linked to a nearby steel processing plant in the vicinity of Smederevo.

Study of the Native Oxide Layer on the Surface of Semiconductor Material GaAs before and after Hot-Implanted Al Ion by RBS/NR Method

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When semiconductor materials are exposed to air, a thin oxide layer known as the native oxide layer grows on their surface. The electrical characteristics and functionality of semiconductor devices are greatly influenced by this native oxide layer. Gallium arsenide (GaAs) is a semiconductor material widely used in electrical and optoelectronic applications. Therefore, studying the formation and growth of the native oxide layer on GaAs surfaces is crucial for improving the performance, reliability, and integration of GaAs-based devices [1]. This work examined the native oxide layer on the GaAs material's surface both before and after hot-implanted aluminum (Al) ions. For the purpose of research, the GaAs samples were subjected to irradiation with 100 keV-Al ions at a fluence of 4×10^{16} ions/cm^2. Ion implantation was performed at temperatures of 25^0 C (room temperature), 300^0 and 500^0 Celsius. Rutherford backscattering spectroscopy with nuclear reaction analysis (RBS/NR) method was used to determine the thickness and atomic composition of elements in the samples [2]. The nuclear reaction $^{16}O(^4He^+,^4He^+)^{16}O$ exhibits elastic resonance at around 3.05 MeV. This resonance provides a useful method for expanding RBS techniques to investigate the concentration of oxygen in oxides [3]. This represents a distinct resonance that exhibits a backscattering cross-section close to the resonance energy, which is up to 25 times larger than the Rutherford cross-section. The RBS/NR approach's conclusion indicates that the surface of GaAs samples contains an oxygen-enriched layer. It has also been demonstrated that when the temperature of the Al-implanted process rises, the thickness of this layer decreases.

Keywords: hot-implanted, GaAs, RBS/NR
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Reference:

1. A.G. Baca, C.I.H. Ashby, Fabrication of GaAs Devices, The Institution of Engineering and Technology, London, 2005.
2. W.K. Chu, J.W. Mayer, M.A. Nicolet, Backscattering Spectrometry, Academic Press, New York, San Francisco, London, 1978.
3. J.R. Cameron, Elastic scattering of alfa-particles by oxygen, Phys. Rev. 90 (1953) 839–844.

Cement-Polymer Composites Containing PANI/B_4C: Neutron Shielding Performance by Monte Carlo Simulation

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Neutron radiation requires special protection provided by shielding materials due to its high penetration ability. Cementitious materials are common neutron shielding materials due to their cost-effective and reliable shielding performance. Therefore, enhancing the radiation shielding capabilities of cementitious materials is essential for ensuring the safety of neutron radiation facilities. We investigated using cement composites containing PANI and B_4C to find an innovative solution for neutron shielding purposes. Boron carbide (B_4C) is a highly efficient neutron shielding material due to its high ^{10}B content. However, its use is limited in cementitious materials because of the formation of boric acid, which reduces durability. To offer an alternative solution to this problem, polymers are widely used because of their low cost, versatility, precise controllable synthesis, and availability, making them an excellent option for radiation shielding. Polyaniline (PANI) is a conductive polymer that is stable in the environment, easy to synthesize, has stable electrical conductivity, and is a low-cost monomer. Because of its high hydrogen content, PANI may be a good neutron shielding material. A simulation study for thermal (0.025 eV), intermediate (1 keV), and fast (10 MeV) neutrons was performed by Geant4 for Ordinary Portland Cement (OPC) with the water-to-cement ratio of 0.3 and cement composites incorporating 4 wt.% PANI, 4 wt.% B_4C, and 4 wt.% PANI/B_4C relative to OPC. The macroscopic cross-section (Σ) values were calculated by Geant4 simulations (Table 1). Adding PANI and B_4C has increased neutron attenuation at different neutron energies. Therefore, the addition of PANI/B_4C to cement can be functional when shielding is required for neutrons of various energies. Ongoing studies are being conducted to prepare composites and investigate their radiation shielding properties experimentally.

Table 1. Macroscopic cross-section (cm^{-1}) values of materials at different neutron energies.

Material	0.025 eV	1 keV	10 MeV
OPC	1.181	0.830	0.119
OPC + 4 wt.% PANI	1.185	0.861	0.117
OPC + 4 wt.% B_4C	3.266	0.827	0.124
OPC + 4 wt.% PANI/B_4C	2.256	0.863	0.120

Keywords: cement, polyaniline, boron carbide, neutron shielding, attenuation, Geant4

Assessment of Air Pollution in the Vicinity of Industrial Enterprises Using Moss Bags Technique

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Moss bags biomonitoring technique using the species *Sphagnum girgensohnii* was used to examine atmospheric deposition of heavy metals and trace element around the industrial enterprises: oil refinery plant "Slavneft'" in Yaroslavl and metallurgical plant "Electrostal" and machine-building plant "Elemash" in Electrostal. Moss for bags was collected in pristine area in Tver region, Russia. In Yaroslavl moss-bags were exposed for 2-month period (June – August 2022) at eight representative sites, while in Electrostal exposition period was June – August 2023 and bags were exposed at eleven sites. The concentrations of 16 elements: Al, Cu, Cd, Co, Pb, Zn, Ba, Cr, Mn, Fe, Sr, V, Ni, S, P and Hg were determined using ICP-OES and direct mercury analyzer. At some exposure sites significant accumulation of elements compared to the control was observed. In Yaroslavl content of V and Ni increased up to 5 times, depending on wind direction. In Electrostal industrial zone level of certain metals increased up to 70 times. Moss bags biomonitoring proved to be a cheap and efficient tool to assess heavy metal pollution in industrial zones.

Keywords: biomonitoring, moss bags, oil refinery plant, metallurgical plant

Tritium Activity Concentration Study in Seawater Samples in the Gulf of Tonkin, Vietnam

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This work presents measurements of the activity concentration of Tritium (^{3}H) in seawater samples in the Gulf of Tonkin, Vietnam, using electrolytic enrichment and liquid scintillation counting. Three sites were investigated Tra Co (Quang Ninh Province), Bach Long Vi (Hai Phong Province), and Ky Anh (Ha Tinh Province), from December 2018 to October 2020 with six surveys. The ranges of ^{3}H radioactivity in seawater at three sites were 1.25 ÷ 1.74 TU (0.15 ÷ 0.21 Bq/L), 1.12 ÷ 1.65 TU (0.13 ÷ 0.20 Bq/L), and 0.99 ÷ 1.47 TU (0.12 ÷ 0.17 Bq/L), with the average values of 1.47 TU (0.17 Bq/L), 1.42 TU (0.17 Bq/L), 1.16 TU (0.14 Bq/L), respectively. The reliability of the analytical results was validated through interlaboratory comparisons - the proficiency test for Tritium in seawater organized by the International Atomic Energy Agency (IAEA). The results of the ^{3}H activity concentrations obtained in the study were in correspondence with the value range of other studies in Vietnam and Asia–Pacific. These values show that the ^{3}H radioactivity in seawater in the survey area is low and mainly generated from natural processes through fallout.

Keywords: *Tritium, Seawater, Liquid scintillation counting.*

Radiation Effects on CCDs Induced by Neutron Beams at Atmosphere Neutron Irradiation Spectrometer of CSNS

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Charge coupled devices (CCDs) exhibit many merits as solid imaging devices and are widely used in the radiation environments such as particle detection, space mission, medical imaging, and nuclear industry. However, the CCDs used in the radiation environments are sensitive to radiation damage. The neutron radiation effects on CCDs are still one of the major concerns of displacement radiation damage. The neutron radiation experiments were carried out at atmosphere neutron irradiation spectrometer (ANIS) of China spallation neutron source (CSNS) are presented. The CCDs were irradiated at the fluence of 1×10^{10}, 1×10^{11}, and 1×10^{12} n/cm^2. The degradations of the sensitive parameters such as the dark current, dark signal non-uniformity (DSNU), saturation output, dynamic range (DR), and signal to noise (SNR) induced by ANIS neutron beams at ANIS are analyzed. The degradations versus neutron fluence are presented. The annealing tests after irradiations are also performed. The degradation mechanisms of the sensitive parameters induced by neutron radiation damage are demonstrated. The research will provide the theories and experimental techniques for radiation damage evaluation of the array CCDs induced by neutron beams at ANIS of CSNS.

Measurements of Spectral and Dose Characteristics of Neutron Fields behind Biological Protection at the IREN Facility at the Electron Energy of 110 MeV

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Radiation fields behind the shields of JINR nuclear facilities are formed mainly by neutrons of a wide energy spectrum. Radiation monitoring in fields of mixed (neutrons and gamma rays) and scattered radiation is a complex task, especially in cases where the upper neutron energy exceeds 15–20 MeV. This is due to the fact that the mechanisms of interaction of neutrons with matter (and, accordingly, the sensitivity of neutron dosimeters) change greatly with an increase in their energies from thermal to tens and hundreds of MeV. The most adequate method for determining the values of the effective dose of neutrons is associated with measuring their energy distribution and using the conversion factors of the fluence-effective dose in the geometry of human irradiation, typical for the measurement site. To measure the spectrum of scattered neutrons in a wide energy range, a multisphere spectrometer is used, based on the readings of which the neutron spectrum at the measurement point is then reconstructed.

This article and is a direct continuation of work already done, currently in print, and describes the results of measuring neutron spectra at several points at the Resonant Neutron Source (IREN) of the Laboratory of Neutron Physics of JINR. The characteristics of the IREN facility have changed significantly, so this work clarifies and updates previous results. Based on the obtained spectra and calculated effective neutron dose rates at measurement points, it will be possible to assess the radiation situation at IREN facility.

Modeling the Impact of High and Thermal Energy Neutron Flux on Semiconductor Film Heterostructures

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In this scientific study, we conducted extensive numerical modeling of the impact of neutrons of various energies on semiconductor films using Geant4 software. Our research covers the full spectrum of reactions that can occur in the material when exposed to neutrons, including both elastic collisions and inelastic processes.

An important aspect of our work was the detailed study of the influence of neutron energy on the reactions occurring in the semiconductor. Our results include data on various types of secondary particles formed during the interaction of neutrons with semiconductors.

This research project is significant for understanding the physical processes occurring in semiconductors when irradiated with neutrons and may lead to the development of new methods for controlling and manipulating the properties of semiconductor materials. The obtained data will be used for comparison with the results of irradiating samples in a reactor with a specific neutron spectrum, allowing for more accurate prediction of the electro-physical characteristics of the semiconductor and its behavior under different conditions.

Furthermore, our study may find applications in various fields, including nuclear energy, electronics and medical technology, and the aerospace industry, where understanding the impact of neutrons on semiconductor materials plays a crucial role.

Investigations of Low-Energy P-Resonances in (n,γ) Reaction on ^{93}Nb Nucleus

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Investigations of the angular distributions of reaction products, as shown in reference [1], allows one to determine the type of resonance (s, p, d, f,...). There are very few experimental works on the measurement of angular distributions in the (n,γ) reaction. Experiments on the evaluation of the partial neutron widths on ^{113}Cd and ^{117}Sn nuclei were carried out at FLNP JINR Dubna in the 90s years of the last century [2]. In the capture process of resonant neutrons, angular distributions and contribution of the interference of s- and p-wave amplitudes were analyzed using formulas for nuclei with spin ½ given in [3,4].

Our work presents the first results of the study of low-lying p-wave resonances in the (n,γ) reaction on ^{93}Nb nucleus, obtained at the pulsed neutron source IREN from FLNP [5].

Double differential cross sections were processed applying Blatt - Biedenharn approach with coefficients of angular distribution calculated for ^{93}Nb nucleus with a 9/2 spin value. Further, from the analysis of angular distribution an estimation of partial neutron widths was also obtained.

REFERENCES

1. J.M. Blatt, L.C. Biedenharn, Review of Modern Physics, vol. 24, no 4, pp. 258–272 (1952).
2. V.R. Skoy, E.I. Sharapov, Physics of Elementary Particles and Atomic Nuclei, vol. 22, no. 6, pp. 1400–1432 (1991).
3. V.V. Flambaum, O.P. Sushkov, Physics Letters, vol. 94B, no. 3, pp. 377–379 (1980).
4. V.V. Flambaum, G.F. Gribakin, Prog. Part. Nucl. Phys., vol. 35, pp. 423–503 (1995).
5. V.N. Shvetsov, Quantum Beam Sci., vol. 1, no. 6 (2017).

Effect of Neutron Irradiation on the Electronic and Optical Properties of AlGaAs/InGaAs-Based Quantum Well Structures

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The effect of neutron irradiation on the structural, optical, and electronic properties of doped strained heterostructures with AlGaAs/InGaAs/GaAs and AlGaAs/InGaAs/AlGaAs quantum wells was experimentally studied. Heterostructures with a two-dimensional electron gas of different layer constructions were subjected to neutron irradiation in the reactor channel with the fluence range of 2×10^{14} cm^{-2} ÷ 1.2×10^{16} cm^{-2}. The low-temperature photoluminescence spectra, electron concentration and mobility, and high-resolution X-ray diffraction curves were measured after the deactivation. The paper discusses the effect of neutron dose on the conductivity and optical spectra of structures based on InGaAs quantum wells depending on the doping level. The limiting dose of neutron irradiation was also estimated for the successful utilization of AlGaAs/InGaAs/GaAs and AlGaAs/InGaAs/AlGaAs heterostructures in electronic applications.

Keywords: InGaAs; two-dimensional electron gas; neutron irradiation; photoluminescence; electron concentration; mobility; high resolution X-ray diffraction

Cyanobacteria *Arthospira platensis* as an Effective Tool for Gadolinium Removal from Wastewater

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For the first time, cyanobacteria, namely *Arthrospira platensis*, were applied for biosorption and bioaccumulation of gadolinium ions from batch solutions. In biosorption experiments, the effect of the most important parameters, such as gadolinium concentration, time, pH and temperature, on the biomass biosorption capacity was investigated. The maximum biosorption of gadolinium of 101 mg/g was achieved at pH 3.0 and temperature of 20 °C, and it was significantly higher than the values reported in the literature. Gadolinium removal was shown to be a very quick process – three minutes were enough for maximum metal removal. The kinetics of the biosorption was better described by pseudo-first-order kinetic model, while equilibrium data were better presented by the Freundlich model, suggesting biosorption on the heterogeneous surface. From a thermodynamic point of view, the process of gadolinium biosorption was spontaneous and exothermic in nature. In the bioaccumulation experiments, gadolinium ions were almost completely accumulated from the cultivation medium and stimulated biomass growth. The obtained data showed that cyanobacteria *Arthrospira platensis* can be applied for gadolinium removal from wastewater through biosorption and/or bioaccumulation processes.

Numerical Study of the Non-Stationary Quantum Phenomena with Ultra-Cold Neutrons in 2D Dimension

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The report presents the results of theoretical study dedicated to the problem of ultra-cold neutron interaction with cylindrical potential well oscillating in space or moving with acceleration. A wave packet with parameters specific of ultra-cold neutrons was considered as a particle. The evolution of wave function was studied by numerically solving the time-dependent Schrödinger equation using the method of splitting the evolution operator. The spectra of the resulting state after the interaction of the packet with object were obtained.

In the case of an oscillating object, the calculation results show a pronounced splitting of the energy spectrum of the scattered state. The probability dependence of an energy quantum transfer on the direction of motion of scattered wave is demonstrated.

In the case of an accelerating object, calculations demonstrate a distinct change in the energy of the scattered wave, according to the description of the acceleration effect formulated as a general phenomenon in the work of A. I. Frank [1]. The obtained results can be the beginning of an approach to the theoretical study the problem of UCN dispersion in a medium moving with acceleration.

References:

1. A.I. Frank, Physics-Uspeckhi, 63, 500–502 (2020).

PFN Investigation at IREN Resonance Neutron Energy Range

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Investigations of prompt-fission neutron (PFN) emission are important in understanding of the sharing excitation energy between the fission fragments. Experimental activities on PFN emission at JINR are underway for more than 20 years with main focus on investigations of the reactions ^{252}Cf(sf) and ^{235}U(n,f) in the region of the resolved resonances. Resonance region of neutron energies is interesting for testing nuclear scission model. For the ^{235}U(n,f) reaction, strong fluctuations both in the mass of the fission fragments and their mean total kinetic energies, depending on incident neutron energy, were observed. In addition, fluctuations of PFN multiplicity also were observed according to the literature. The goal of the present research is to verify the current knowledge of PFN multiplicity fluctuations and to verify their correlations with properties of fission fragments. The measurements of PFN multiplicity variations in the resonance-neutron induced fission of ^{235}U nuclei revealed a surprising result, which stimulates a new investigation of PFN multiplicity at IREN with new high-efficiency experimental setup.

Research Progress of High Repetition Frequency and Ultrashort Pulse Neutron Source Based on 3 MeV Proton Accelerator

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In order to solve the problem of accurate calibration of energy spectrum response of neutron measurement system, the high repetition frequency and ultrashort pulse neutron source based on 3 MeV proton accelerator is constructed. For the device, the maximum proton energy is 3 MeV, the number of micro bunch particles is more than 1×10^{10}, the length of micro bunch is 1 ns, the repetition frequency is more than 40 kHz, the neutron yield is greater than 1×10^{9} n/s, the length of pulse neutron is 1 ns, and the range of neutron energy spectrum covering 0.1 ~ 1.2 MeV interval. The time-of-flight method can be used to calibrate the neutron response sensitivity of the whole energy range in experiment, so the neutron calibration efficiency can be greatly improved. This report will introduce the technical route, the latest research progress and the application prospect of this neutron source. The performance index of the device is very special and has reached the international advanced level. It will be an ideal platform for the research of neutron-related technology.

Keywords: High repetition frequency, ultrashort pulse, 3 MeV proton accelerator, neutron source, neutron application

Fission Induced by High Energy Particles and Energy Release in Massive Fissionable Targets Applied for ADS

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External driven systems (EDS) use accelerators for the generation of a high energy neutrons flux. These neutrons irradiate the nuclear fuel and the long lived high radiotoxic nuclear waste and deposit their energy by interacting with the fissionable nuclei. The neutron flux and plutonium production are calculated by using nuclear models and cross sections. The MCNP transport code is the most widely applicable software for this purpose. Most of the available cross sections data are defined up to 20 MeV, but some are up to 200 MeV (TENDL 2015 [1], JEDNL40he [2,3] and JENDL5 [4]) and 1000 MeV (ADS-II IAEA [5]). The extended cross sections data contain inaccuracies. When used for EDS calculation additional estimations of the energy deposition and high energy neutron interactions have to be done. Some of the inaccuracies are in the primary ENDF files. There are no spallation cross sections for all of the nuclides and the (n,f) reaction for Pb, Bi isotopes is nor present and the (n,xn) reactions are defined up to 30 MeV and for the energies above that the cross sections are zero. There are other inaccuracies in the ACE files. Some versions of the NJOY and FRENDY software do not process correctly the cross sections data above 20 MeV [6]. The article presents the differences in the total neutron production, fission, ^{239}Pu production and fission energy deposition in a cylindrical target made of depleted uranium irradiated by 1 GeV proton beam calculated by MCNP6 with above cross section data.

Keywords: Transmutation, ADS, MCNP6

REFERENCES

1. https://tendl.web.psi.ch/tendl_2015/tendl2015.html
2. https://www-nds.iaea.org/exfor/endf.htm
3. https://rpg.jaea.go.jp/main/en/ACE-J40HE/
4. https://rpg.jaea.go.jp/main/en/ACE-J50/
5. https://www-nds.iaea.org/ads/adshe.html
6. P. Zhivkov, Importance of high energy neutron cross sections for neutron induced reactions for infinite fissionable targets, "*in AccApp2021*", Washington DC, doi.org/10.13182/T125-37232 2021, pp. 88–92.

Nuclear and Related Analytical Techniques in Environmental and Nanotechnological Studies

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Neutron activation analysis due to its high accuracy, reproducibility and nondestructive nature is a technique widely used in the environmental, material, archeological, geological and nanotoxicological studies. Favorable features of neutron activation analysis will be highlighted in the presentation and the principal of its realization on the installation REGATA of the IBR-2 reactor will be presented. Examples of application of neutron activation analysis as well as complimentary technique, ICP-AES, for the assessment of heavy metal deposition using active and passive moss biomonitoring, water biomonitoring and development of the approaches for wastewater treatment, medicinal plants analysis will be given. Besides, the effects of metal nanoparticles on different living organisms will be discussed. The information is addressed to researchers interested in the applications of neutron activation analysis or to those who are searching for an analytical technique suitable for environmental, biomedical, geological, etc. studies.

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Abstracts

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