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Abstract Book

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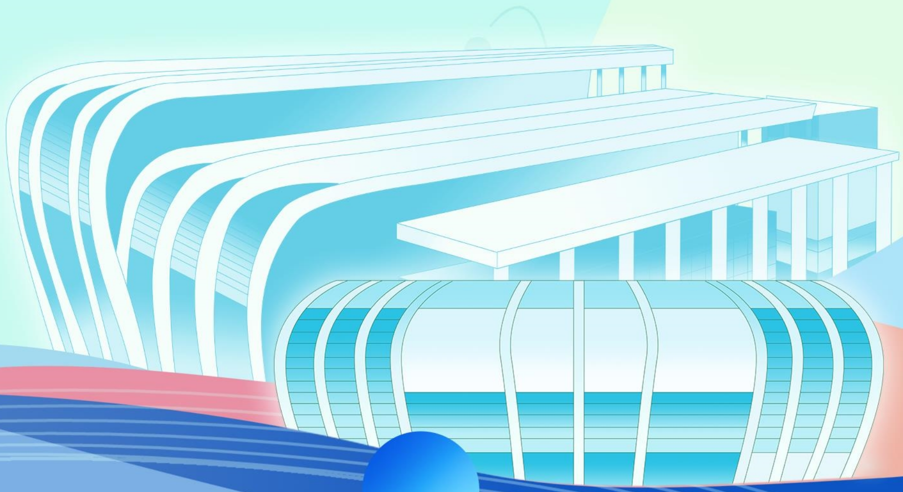

31st International Seminar on Interaction of Neutrons with Nuclei: Fundamental Interactions & Neutrons, Nuclear Structure, Ultracold Neutrons, Related Topics (ISINN-31)

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Book of Abstracts

Contents

Plenary Session

Setting Up High-Energy Polarized Neutron at the China Spallation Neutron Source

Author: Tianhao Wang[1]

[1] *CSNS*

Polarized neutrons serve as a critical probe in nuclear physics to investigate spin-dependent interactions and nuclear dynamics. Polarized neutron enables precise studies of nuclear forces, include probing nuclear structure, analyzing reaction mechanisms and resolving nucleon internal spin-quark distributions via deep inelastic scattering. Challenges persist in achieving high polarization stability, measuring low cross-section reactions, advancing our understanding of spin-mediated nuclear phenomena and QCD in dense matter.
We present our recent effort on setting polarized neutron at the China Spallation Neutron Source Back-n beamline, as well as the polarization technique available for future research. Key instrument development in polarized ^{3}He neutron spin filter, guide fields and spin flippers shall be presented, and the corresponding method for designing experiment will be discussed.

Acknowledgment
Present study was supported by the Guangdong Provincial Key Laboratory of Extreme Conditions (2023B1212010002), and the Government-to-Government International Science and Technology Innovation Cooperation Programs (2024YFE0110000)

The Neutrino Electron Correlation Coefficient in Neutron Beta Decay

Author: Stefan Baessler[1]

[1] *University of Virginia, USA*

One of the current problems of the Standard Model of Elementary Particle Physics is the about three sigma failure of the first-row unitarity test of the Cabbibo-Kobayashi-Maskawa matrix. A long-standing goal of the study of free neutron beta decay is a better determination of its upper left element ("Vud"). That is possible with measurements of the neutron lifetime and a correlation coefficient: the beta asymmetry "A" or the neutrino electron correlation coefficient "a". In this talk, I will present a recent measurement of the neutrino electron correlation coefficient with aSPECT, and I will present commissioning data from a next generation experiment, Nab. The Nab collaboration is working on an improvement in the accuracy of neutrino electron correlation coefficient that - if achieved - is substantial enough to base the determination of Vud on neutron beta decay data alone.

Project of High-Brilliance UCN Source at FLNP JINR

Author: German Kulin[1]

Co-authors: Alexander Frank [1]; Maxim Zakharov [1]; Alexander Popov [1]; Valerii Shvetsov [1]; Vladimir Kurylev [1]; Victoria Shpilevskaya [1]

[1] *FLNP, JINR*

The report presents a project of a high brilliance ultracold neutron (UCN) source, which is planned to be constructed at FLNP JINR. It details the concept of the proposed source, the progress made in designing its key components, and the challenges that need to be overcome. A potential research program on this source is also discussed.
As part of this project, it is initially planned to construct a test VCN channel to carry out methodical experiments essential for development of the future source. The report includes the design of this test facility and a brief overview of the research plan for it.

Modeling the Neutron Whispering Gallery to Search for New Short Range Forces

Author: Jason Pioquinto[1]

Co-authors: Stefan Baeßler [2]; Pierre Cladé [3]; Valery Nesvizhevsky [4]; Serge Reynaud [3]; Katharina Schreiner [5]; Mingyu Shi [6]; Alexei Voronin [7]; Anran Zhao [2]

[1] *University of Virginia, USA; Institut Laue Langevin, France*

[2] *University of Virginia, USA*

[3] *Laboratoire Kastler Brossel, Sorbonne Université, CNRS, ENS-PSL Université, Collège de France, France*

[4] *Institut Laue Langevin, France*

[5] *Institut Laue Langevin, France; Laboratoire Kastler Brossel, Sorbonne Université, CNRS, ENS-PSL Université, Collège de France, France; University of Vienna, Austria*

[6] *Institute for Quantum Electronics, Eidgenössische Technische Hochschule (ETH) Zürich, Switzerland*

[7] *P.N. Lebedev Physical Institute, Russia*

New short-range forces (SRF) are predicted in many theories beyond the Standard Model of particle physics in the form of weakly interacting scalar or pseudo-scalar bosons. For example, dark matter could be explained by the existence of a weakly interacting boson, and some theories with extra spatial dimensions predict such a particle. Neutrons are useful tools in searches for these SRFs due to their neutrality and small electric polarizability. These properties minimize false effects in experimental searches for new interactions. Precision studies of the neutron whispering gallery effect, or the confinement of neutron matter waves along a smooth curved surface, is a particularly promising method to search for these new forces.

By sending a cold neutron beam with a grazing incidence angle into a cylindrical cut of a MgF_2 single crystal, intricate interference patterns have been observed during recent experiments at the Institut Laue Langevin. If new SRFs exist and interact with the neutrons in the whispering gallery through the nuclei in the crystal, these interference patterns will be perturbed. To look for those perturbations in the latest measurements, and to constrain SRF models, a theoretical model was developed to describe the observed interference patterns as a superposition of quasi-stationary states in a finite potential well. The potential well is formed by the optical potential of the crystal and the centrifugal force experienced while propagating along the surface of the cylinder. To incorporate the effects of the roughness of the mirror and the SRFs on the quasi-stationary states and their energies, logarithmic perturbation theory was used. A description of this model will be presented as well as the first analysis of the most recent experimental campaign.

Two-Wave Acceleration Effect and Ultra-Sensitive UCN Spectrometry

Author: Alexander Frank[1]

[1] *FLNP, JINR*

The Acceleration Effect (AE), the existence of which was recently predicted in [1], is a generalization of the previously discovered of optical Accelerating Matter Effect (AME) [2]. It consists in the fact that the result of the interaction of a wave with an accelerating object is a change in its frequency. The effect is proportional to the acceleration of the object and the time delay caused by this interaction. The existence of AE in macrophysics, for example, when transmitting a signal to an accelerating transceiver, is beyond doubt, since in this case it can be interpreted simply as a differential Doppler effect. The same interpretation is valid in the case of AME, when a wave passes through an accelerating layer of matter, experiencing Doppler frequency shifts of various magnitudes on the input and output surfaces of the sample. Verification of the validity of the AE concept in the quantum sector [3], when its relationship with the Doppler effect is not obvious, is still awaiting its experimental confirmation.
A special case of AE, which occurs when a wave passes through an accelerating sample of a birefringent substance, was considered in [4]. In neutron optics, the phenomenon of birefringence is usually associated with the different spin states of the two waves. The difference in the refractive index for these two waves leads to a difference in their propagation times in the sample and, as a result, to a difference in the magnitude of the frequency shift of these two waves passing through the accelerating sample. The interference of these two waves, which have changed frequencies by a different amount due to the AE, leads to periodic oscillations of the polarization of the resulting state, which can easily be transformed into oscillations of the counting rate. Thus, it is possible to register a very small difference in the energies of two spin states, and the sensitivity of the measurement increases with decreasing neutron energy. In the case of UCN, it is possible, in principle, to register the energy difference of two waves on the order of 10-15 eV.
The project of the UCN source currently under discussion at JINR makes it necessary to consider the two-wave Acceleration Effect as one of the important fields of research with this source. The report is devoted to discussing this possibility. The aim of future work will be to demonstrate the validity of EC in neutron scattering on quantum objects with a characteristic interaction time of the order of 10^{-7}s, as well as measurements of the spin-dependent neutron-nuclei scattering amplitudes. The high sensitivity of the method makes it possible to carry out such measurements with samples characterized by very low, up to 10^{-7}, polarization of nuclei, because of which there is no need for a complex and expensive technique for preparing a polarized nuclear target.

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Review of Recent Activities on the Tagged Neutron Method at FLNP JINR

Author: Yuri Kopatch[1]

[1] *FLNP, JINR*

The tagged neutron method (TNM) is currently being implemented at the Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, for neutron-nuclear physics research. This method utilizes the reaction $d + t \to \alpha + n$ to produce neutrons with an energy of approximately 14 MeV, which are emitted simultaneously with α-particles in nearly opposite directions. Neutron tagging is achieved through detecting the associated α-particles. The ING-27 neutron generator, equipped with a built-in position-sensitive α-particle detector consisting of 9, 64, or 256 pixels, serves as a source of tagged neutrons. These generators are manufactured by the Dukhov All-Russia Research Institute of Automatics (VNIIA).

The report will outline various experimental setups developed at FLNP for experiments involving tagged neutrons. It will also provide an overview of the results obtained, including the determination of differential cross-sections for elastic and inelastic neutron scattering on atomic nuclei, measurement of angular correlations between neutrons and gamma-rays, non-destructive elemental analysis utilizing the TNM, and its application for determining carbon content in soil.

Acknowledgment
The present study was supported by the Russian Science Foundation (RSCF grant No. 23-12-00239).

Experimental Study of Parity and Time-Reversal Symmetries in Polarized Epithermal Neutron Optics

Author: Hirohiko M. Shimizu[1]

[1] *Nagoya University, Japan*

The parity violating effects in nuclear interactions is extremely enhanced in resonant neutron absorption processes via compound nuclear states for some of medium-heavy nuclei. The enhancement is explained as a result of the interference between parity-unfavored partial amplitudes of the compound nuclear process, which is referred to as "s-p mixing". The "s-p mixing" is expected to enhance the visibility of the effect of the breaking of both parity and time-reversal symmetry (P-odd T-odd). Based on these considerations, an experimental approach to search for the P-odd T-odd effects to activate a novel type of new physics search beyond the standard model is in progress using the pulsed neutron beam from the pulsed spallation neutron source of Japan Proton Accelerator Research Complex (J-PARC) under the collaboration "Neutron Optical Parity and Time-Reversal Experiment (NOPTREX)" as the program number J-PARC E99. P-odd T-odd effects will be studied in neutron optics in which fake T-violating effects can be controlled, with the enhanced sensitivity biased to chromo-EDM. We discuss the studies of the "s-p mixing" in ^{139}La$(n,\gamma)^{140}$La and the plan of T-violation search with polarized lanthanum target.

Experimental Infrastructure of the Frank Laboratory of Neutron Physics for Research

Author: Egor Lychgain[1]

[1] *FLNP, JINR*

The Frank Laboratory of Neutron Physics (FLNP) of the Joint Institute for Nuclear Research (JINR) is one of the leading centers for neutron physics in the JINR Member States. FLNP scientists conduct research in the fields of condensed matter physics and nuclear reactions with neutrons, as well as to solve a wide range of applied problems using nuclear physics techniques. The basic facility of the Laboratory is the unique periodic pulsed reactor IBR-2. Most modern research methods using neutron scattering are realized at neutron beams of the reactor, as well as neutron activation analysis and studies of radiation effects from neutrons and gamma-rays. FLNP has accumulated a significant amount of state-of-the-art laboratory equipment, which provides information, supplementary to neutron investigations, about the studied samples using various physical methods. This makes it possible to obtain comprehensive information about objects under study. The User Program implemented in the Laboratory provides a unique opportunity for scientists from all over the world to gain access to the research infrastructure of the IBR-2 reactor.
The source of resonance neutrons based on the IREN electron accelerator and the EG-5 electrostatic generator, as well as fast neutron generators, expand the range of possible studies with neutrons in both fundamental and applied research.
The report will provide information about the experimental infrastructure available at FLNP, including examples of research, as well as information on how to access the infrastructure through the User Program.

Laser-Driven Compact High-Flux Ultrafast Neutron Sources

Author: Tongpu Yu[1]

[1] *NUDT, China*

Neutron sources have been widely applied in numerous fields, ranging from detection technology to medicine and laboratory astrophysics due to their unique features of electrical neutrality and deep penetration capability. Currently, there are two main mechanisms for the generation of neutrons assisted by lasers, i.e., photonuclear reactions (γ, n) and beam-target nuclear reactions. Compared with traditional spallation neutron sources like CSNS, the laser-driven neutron sources have several advantages like high brightness, relatively low cost, compactness, and short duration. Here we show one of the typical laser-driven neutron sources based on ion acceleration via Target Normal Sheath Acceleration with the help of the pitch−catcher model. Cascade simulation results using PIC simulations and Geant4 will be presented and the recent experimental results at SILEX-II and Xingguang will be released. Some potential applications and planned experiments will be discussed.

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Present study was supported by the NSFC (12375244 and 12135009).

Development of In Situ Sample Environment Technology for Neutron Scattering at CSNS

Author: Haitao Hu[1]

[1] *CSNS*

As one of the important auxiliary devices for neutron scattering instruments, sample environment provides various experimental conditions to enhance the research capabilities of the instruments. The sample environment at the Chinese Spallation Neutron Source (CSNS) has been providing in-situ experimental services since the commissioning of the instrument in 2018. It has evolved from initially serving as a cryostat to now supporting a wide range of sample environments, including low temperature, high temperature, high pressure, and magnetic field, catering to different user needs. The development has enabled the transition from single-sample environment experiments to multiple-sample environment experiments, showcasing the progress from 0 to 1 and from 1 to many in terms of experimental applications. This article primarily introduces the operation and usage of the sample environment at CSNS. It also highlights recent developments and optimizations in sample environment. Additionally, some experimental applications conducted in collaboration with users are also presented.

Acknowledgment
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Recent Advances of the (n, cp) Reaction Measurements

Author: Guohui Zhang[1]

[1] *Peking University, China*

Abstract: Nuclear data of the (n, cp) reactions are important in the development of nuclear energy, the application of nuclear technology and the research of nuclear reaction theory. Based on the neutron sources of the 4.5 MV Van de Graaff accelerator of Peking University, EG-5 Van de Graaff accelerator of JINR, FLNP, HI-13 tandem accelerator of CIAE, and the CSNS Back-n, we have extended our measurements of the (n, cp) reactions from solid samples to gas samples, from GIC to TPC, and from binary fissions to ternary fissions. Recent advances in these three aspects are illustrated.

Progress in Advanced Accelerator Driven Nuclear Energy System

Author: Yuan He[1]

[1] *IMP, CAS, China*

Accelerator Driven Subcritical system is believed to be the best candidate for nuclear waste transmutation. In the design scheme of ADS plant with one target, high-intensity external neutrons are concentrated in the center of the core which will result in a high power peak factor. To solve the challenges, a Multi-Beam Accelerator Driven Subcritical(MB-ADS) system is proposed. The spallation target is designed as a unit similar to the fuel assembly. The accelerated beam is split into multi-beams by the radio frequency cavity in the beam line. The spaces between neighbor beams are furtherly enlarged by a duodecuple. The high current proton beam is split into multiple parts and injected into different targets located in the core to improve the beam efficiency and flatten the spatial power distribution of the core. Compared with the results of one target ADS scheme, the reasonable MB-ADS scheme have advantages in both beam efficiency, core power flattening and transmutation.

Current Status and Experiments of the Back-n White Neutron Facility

Author: Ruirui Fan[1]

[1] *CSNS*

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 BaF_2 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.

Introduction to Neutron Activation Analysis at the IBR-2 Reactor, FLNP JINR

Author: Inga Zinicovscaia[1]

[1] *FLNP, JINR*

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 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.

Poster Session

The "Polar Lights" and the Structural γ-Quanta in Neutron Radiative Decay Experiments

Author: Rashid Khafizov[1]; Kolesnikov I.A. [1]; Nikolenko M.V. [1]; Tarnovitsky S.A.[1]; Tolokonnikov S. V.[1]; Torokhov V.D. [1]; Trifonov G.M. [1]; Solovei V.A. [1]; Kolkhidashvili M.R.[1]; Konorov[2]

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

[2] *Technical University of Munich, Munich, Germany*

The report considers the time spectra of double and triple coincidences of the neutron radiation decay products - electron, recoil proton, and γ-ray. The peak in the spectrum of triple coincidences is used to identify neutron radiative decay events. However, there is an effect that competes with the sought-after neutron radiative decay effect, which is the emission of γ-quanta caused by β- decay electrons in the residual chamber atmosphere. This phenomenon can be observed in the form of polar lights caused also by ionization of the air at the edge of the atmosphere, the density of which is comparable to the density of the residual gas in the experimental chamber. Both radiative neutron decay and γ-quanta produced by the ionization should give comparable two peaks on the spectrum of triple coincidences. However, whereas the radiative γ-quanta are formed at the moment of decay, the γ-quanta emitted by the inertial process of ionization of the rarefied atmosphere molecules

should be delayed on 1 µs, which we have found on the spectrum of triple coincidences. The value of one time channel was 25 ns, which allow separating the two peaks from each other and excluding their mutual influence. This allowed us to identify radiative decay events and to measure for the first time the relative intensity of neutron radiative decay B.R. = (3.2±1.6)10^{-3} (where C.L. = 99.7% and γ-energy more 35 KeV) [1]. But the Standard Model calculations give a one-and-a-half times smaller value B.R.=2.1*10^{-3} [2], thus we have registered additional γ-quanta, which are structural γ-quanta emitted by the neutron structure. It follows from the above that at registration of only double coincidences of an electron and a γ-quantum only one peak of the "polar light" will appear, and the radiative peak of triple coincidences of an electron, a γ-quantum and a recoil proton will merge with fluctuations of the background since it appears only when the third particle - a recoil proton - is also registered. The spectrum of double e-γ coincidences with a single "polar light" peak is presented in articles [3, 4], and authors positioned this peak not after but before electron registration.The placement of the peak looks extremely ridiculous because for 1 µs gamma-quantum passes several hundred metres, whereas the size of their entire experimental setup is only 0.5 meters, and for this peak there is simply no room to emerge from!

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Development and Performance Testing of Liquid Detector Array for Investigation of Prompt Fission Neutron Emission

Authors: Afag Madadzada[1]; Gadir Ahmadov[1]; Daniyar Berikov[1]; Mahdi Nasrabadi[2]; Sabuhi Nuruyev[1]; Olga Sidorova[1]; Shakir Zeynalov[1]

[1] *FLNP, JINR*

[2] *University of Isfahan, Iran*

The measurement of fast neutron emission in nuclear reactions plays a critical role in studying nuclear fission processes, reaction dynamics, and their applications in nuclear energy and astrophysics [1,2]. To facilitate such studies, an experimental setup consisting of liquid neutron detector array and an ionization chamber, ENGREN, has been developed at the Joint Institute for Nuclear Research (JINR) in Dubna, Russia. The experimental setup consists of 16 EJ-309 liquid scintillator (LS) neutron detectors arranged in a cylindrical configuration around a gas ionization chamber (GIC), which can be replaced with a twin Frisch grid ionization chamber. Each neutron detector, with a diameter of 76 mm and a thickness of 50 mm, is coupled to a 76 mm ETL-9821 photomultiplier tube (PMT) to enable time-of-flight (ToF), pulse shape discrimination (PSD), and pulse height (PH) measurements. The GIC, filled with P-10 counting gas (90% Ar + 10% CH_4), is continuously flowing and contains a ^{235}U fission target to detect fission events. The detectors are positioned 51 cm from the fission source. Data acquisition was performed using digital signal recorder (DSR-32) (32 channels, 200 MHz, 11 bit) developed at JINR, which controlled using Romana software developed under the TANGRA project [3]. Additionally, CAEN digitizers N6742 and N6725 were also tested.
To characterize the detector response, measurements were conducted using point calibration gamma and PuBe neutron sources, placed at the position of the ionization chamber. The energy calibration of LS, which is typically challenging due to Compton scattering effects, was performed by comparing the experimental detector response with Monte Carlo-generated spectra. Furthermore, the pulse shape neutron/gamma discrimination (PSD) was evaluated using PuBe neutron source, and PSD performance was analyzed as a function of applied voltage. Preliminary test measurement with a ^{235}U target were performed at the Intense Resonance Neutron Source (IREN), Frank Laboratory Neutron Physics, JINR [4, 5]. This work focuses on the calibration and optimization of the ENGREN setup, including scintillator calibration, neutron-gamma discrimination, timing performance and validation of detector response through simulations and experimental data.

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Theoretical Description of Angular Distribution of Gamma Radiation of Neutron-Nuclear Reaction Products

Authors: Alexander Andreev[1]; Nikita Fedorov[1]; Yuri Kopatch[1]; Tatyna Tretyakova[1]

[1] *FLNP, JINR*

Within the framework of the TANGRA (TAgged Neutrons and Gamma RAys) project at the Frank Laboratory of Neutron Physics (JINR, Dubna), systematic measurements of cross-sections and angular distributions of gamma quanta in reactions with fast neutrons are being conducted. Over the course of its existence, the collaboration has accumulated a large dataset on angular distributions and cross-sections of gamma-ray emission in reactions with 14.1 MeV neutrons, which requires theoretical investigation [1-3].

When neutrons scatter on nuclei, excited states of the reaction products are formed. They decay through the emission of gamma quanta of various multipolarities. The angular distributions obtained in such processes can be theoretically described using the formalism outlined in work [4]. The formula for the angular distributions of gamma quanta includes elements of the scattering S-matrix, which are related to the population of nuclear levels during inelastic neutron scattering. These S-matrix elements in this work were obtained from calculations using the ECIS code [5], which allows for the computation of differential neutron scattering cross-sections and scattering S-matrix elements on nuclei using the optical model, coupled-channel methods, and DWBA. From the data on angular distributions of gamma quanta, important characteristics of excited nuclear states, such as spin-tensor orientation of the nucleus and the ratios of matrix elements for mixed transitions, can be extracted [6]. This work is devoted to the theoretical description of angular distributions of gamma quanta in $(n, n'\gamma)$ reactions for various incident neutron energies and different multipolarity of gamma radiation.

Acknowledgment

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LUE-200 SLED System Effect on the Electrons Energy Spectrum

Author: Kirill Mikhailov[1]

Co-authors: Anatoliy Sumbaev [1]; Igor Zhironkin [1]; Aleksey Levichev [2]

[1] *FLNP, JINR*

[2] *BINP SB RAS*

This report presents the results of a study on the SLED (SLAC Energy Doubler) system effect installed on the first accelerating section feeder of the LUE-200 of the IREN facility on the energy spectrum of electrons. This work is based on analytical calculations of the LUE-200 accelerator beam dynamics conducted by BINP SB RAS specialists in 2020.

Neutron Detectors Based on Microchannel Plates

Author: Andrey Churakov[1]

[1] *FLNP JINR*

A microchannel plates (MCPs) is an vacuum electron amplifiers with a wide range of applications. Their principle of operation is based on the avalanche-like strike multiplication of electrons inside tiny (d~10 microns) tubes (microchannels) when an external electric field is applied. Exceptionally good time characteristics and precise spatial localization make them very promising for use in radiation detectors. This report provides an overview of some existing MCP-based neutron detectors. Various designs and their characteristics are described. A new detector design variant is also proposed for consideration.

Assessment of Toxic Elements in Atmospheric Deposition in Azerbaijan Using Moss Biomonitored Methods

Author: Shahla Nuhuyeva[1]

[1] *Azerbaijan State Agricultural University*

Information from existing studies on heavy metal concentrations in mosses is an invaluable resource for international negotiations on heavy metal pollution. Results from moss studies help investigate both spatial and temporal trends of heavy metals in atmospheric sediments. Besides, these studies allow the identification of places with high levels of atmospheric pollutants that spread over large distances and heavy metals emitted from local sources. For this purpose, air pollution in the Goygol, Gedabey and Dashkasan regions of Azerbaijan was studied by moss biomonitoring using the moss species Pleurozium Schreberi and Hylocomium splendens. The presence of 44 elements was determined by neutron activation analysis (NAA), atomic absorption spectroscopy (AAS) and Particle-induced X-ray emission (PIXE). The main element associations were identified using factor analysis. Four factors were determined. Research methods are based on the application of mosses as indicators, the amount of elemental pollutants in atmospheric sediments and their suitability in mosses. Besides, it reflects the general state of atmospheric pollution in the studied areas. Distributional maps were prepared to point out the regions most affected by pollution and to relate this to the known sources of contamination.

Beside the anthropogenic influences, the lithology and the composition of the soil also play an important role in the distribution of the elements.

Concept of the Bragg Monochromator for Very Cold Neutrons

Authors: Victoria Shpilevskaya[1]; German Kulin[1]; Alexander Frank[1]

[1] *FLNP, JINR*

A new high-brilliance ultracold neutron source at the IBR-2 pulsed reactor is currently being developed at the FLNP JINR. Work on the project of a new type of UCN source requires conducting of a series of methodical experiments with very cold neutrons, which are currently not feasible at JINR. Therefore, at the first stage of work on the project, it is planned to create a test VCN channel. It is assumed that one of the main components of this VCN facility will be a monochromator, which allows to produce a monochromatic neutron beam with a velocity of v = 20 ± 1 m/s.

In this work, an optical Bragg monochromator for very cold neutrons is considered. The monochromator consists of two multilayer titanium-nickel mirrors arranged to preserve the initial beam direction. The necessary requirements for such a monochromator were analyzed and compared with a mechanical velocity selector. It has been shown that the Bragg monochromator allows for higher transmissivity with a better degree of monochromatization.

About the Role of Injections Timing of an Electron Beam into the Accelerating Structure of the LUE-200 Accelerator when Using an RF Power Compression System

Author: Igor Zhironkin[1]

Co-authors: Anatoliy Sumbaev [1]; Valerii Kobets [1]; Aleksey Levichev [2]

[1] *FLNP, JINR*

[2] *BINP SB RAS*

The results of measurements of the energy characteristics of the electron beam with a change in the time of beam injection into the accelerating structure of the LUE-200 accelerator - the driver of the IREN facility, a pulsed photoneutron source of the Joint Institute for Nuclear Research (Dubna) are presented. It is shown that when using a microwave power compression system of the SLED type, the choice of the moment of beam injection into the accelerating structure is an important means for forming and optimizing acceleration modes.

Study on a Gas Target Deuterium-Tritium Fusion Neutron Source

Author: Qiaoyue Jiang[1]

Co-authors: Zeen Yao [1]; Zheng Wei [1]; Yu Zhang [1]; Junrun Wang [1]; Kang Wu [1]

[1] *Lanzhou University, China*

With the continuous development of neutron sources in various fields, achieving efficient miniaturization of accelerator-based neutron sources has become a research hotspot. Traditional large-scale neutron sources devices are limited by their large size and high energy consumption, restricting their feasibility in small laboratories and field applications. Therefore, designing a compact and neutron source with low-energy consumption holds significant scientific and practical value. This research proposes a novel design for a deuterium-tritium (D-T) neutron source, which employs a

ring-shaped gas target structure combined with 16 uniformly arranged deuteron beams to enhance neutron yield and uniformity in energy distribution. Neutron field data were extensively simulated using the Geant4 Monte Carlo program. The results show that, under a unit milliampere beam current, the neutron yield at the center of the ring target reaches the order of 10^{14} neutrons per second, with good monoenergetic characteristics and a relatively concentrated energy distribution, indicating potential as a quasi-monoenergetic neutron source. Additionally, the angular distribution of the neutron field inside the ring target is stable with minor fluctuations, demonstrating good spatial uniformity. Furthermore, to reduce tritium gas consumption, two design schemes are proposed to optimize gas usage efficiency. This design provides a new approach to the miniaturization and efficiency improvement of accelerator-based neutron sources.

Application of Two-Dimensional Organic-Inorganic Hybrid Perovskites in Fast Neutron Detection

Authors: Yang Li[1]; Xinlong Shang[1]; Xue Du[2]; Liang Chen[1]; Jinlu Ruan[1]; Yapeng Zhang[1]; Xiaoping Ouyang[1]

[1] *NINT, China*

[2] *Tsinghua University, China*

Neutron radiation fields frequently coexist with γ-rays, posing a significant challenge to ensure the accuracy of neutron detection. Two-dimensional (2D) organic-inorganic hybrid perovskites (OIHP) have been proven to be potential fast neutron scintillators due to their high light yield, fast response time, high density of hydrogen, and linear energy response. Here we find that the decay time of 2D OIHP to heavy charged particles is significantly faster than that to γ-rays. The unique characteristic endows 2D OIHP with good n/γ discrimination capability, with a figure of merit of 0.86 in Deuterium-Deuterium fusion reactions. Furthermore, we demonstrate the use of 2D OIHP as a next-generation scintillator for neutron imaging. It exhibits a record resolution of 2.00 lp/mm for fast neutron imaging, which is the highest resolution among perovskites so far. The research not only advances the application of perovskites in the field of neutron detection, but also provides a new alternative for the development of neutron detection technologies.

Current Status of Ultracold Neutron Source at the PIK Reactor

Authors: Vitaliy Lyamkin[1]; Anatolii Serebrov[1]; Alexey Fomin[1]; Artem Koptyukhov[1]; Dmitriy Prudnikov[1]; Grigoriy Borodinov[1]; Andrey Nedolyak[1]; Alexey Sirotin[1]; Pavel Hazov[1]; Sergey Ivanov[1]

[1] *NRC "Kurchatov Institute" - PNPI, Russia*

The work is devoted to the creation of a new ultracold neutron source based on superfluid helium for researches in the field of physics of fundamental interactions at the PIK reactor. This source is aimed at obtaining a world record UCN density of 2200 cm^{-3}.
For this source we have developed and implemented the whole scope of technologies allowing us to make UCN sources based on superfluid helium: production and maintenance of superfluid helium at low temperature under reactor heat inflows conditions, development of technological complex to maintain its operating parameters, production of UCN neutron guides with high neutron reflection rate, design of heat exchangers for ultra-low temperatures and production of isotope-pure helium-4. At the first stage of the source operation, it is planned to install a nEDM spectrometer and two neutron lifetime measurement experiments, one with a gravitational and one with a magnetic trap.

Study of Fundamental Interactions in the Neutrino4+ Experiment at the SM-3 Reactor: Status and Perspective

Authors: Rudolf Samoilov[1]; Anatolii Serebrov[1]

[1] *NRC "Kurchatov institute" - PNPI, Russia*

The Neutrino-4 collaboration improved the detector in the first neutrino laboratory at SM-3 reactor. Also, we have been creating a new neutrino laboratory at the same reactor to study light sterile neutrinos. In the Neutrino-4 experiment, an oscillation effect was observed at a confidence level of 2.7σ, which is in good agreement with the gallium anomaly and the result of the BEST experiment, however, contradicts the latest constraints on the oscillation parameters obtained in the STEREO and PROSPECT experiments. The stages of the setup preparation and further prospects are presented.

Development of a Monitoring System Using Modern Technologies for the IREN Facility at JINR

Author: Ivan Ponomarev[1]

[1] *FLNP, JINR*

The IREN facility at JINR is a two-section linear electron accelerator with a neutron-producing target, requiring reliable monitoring to optimize its performance. This work presents a monitoring system for IREN that tracks key parameters: neutron flux intensity, target temperature, and section temperature. The system is built using the Proxmox virtual machine management system, LXC and Docker containerization technologies, with backups stored on a NAS ($n$etwork Attached Storage). It employs Prometheus for metrics collection and storage, and Loki for logs. Grafana is used for visualization, Alertmanager for sending notifications, Nginx as a web server, Promtail for log collection, and custom Golang agents for gathering the three main metrics. Data analysis has already revealed correlations, enabling improvements in the facility's operation. Currently, efforts are underway to incorporate additional signals, such as beam current, beam shape, and vacuum level, which will allow for more detailed control and optimization of the facility in the future.

Preliminary Measurement of Neutron Energy Spectrum of the White Neutron Beam Line at CYCIAE-100

Authors: Xu Ma[1]; Tongpu Yu[1]; Jie Bao[2]; Zijia Zhao[1]

[1] *NUDT, China*

[2] *CIAE, China*

China Institue of Atomic Energy (CIAE) has built a 100 MeV compact high-intensity proton cyclotron (CYCIAE-100), the largest compact high-intensity proton cyclotron in the world with both the higher energy and a maximum current intensity of 520 μA. As two of several beam lines designed for multi-application purposes, both white neutron beam lines based on the proton beam injected by CYCIAE-100, located at 0° and 15° angles from the center of the neutron generating target are constructed. In this work, we report a preliminary measurement of the 0° neutron energy spectrum by means of the time-of-flight method. In the measurement, pulse shape discrimination (PSD) method utilizing double scintillators (scattering detector and main detector) is employed to reduce the amount of gamma-ray radiation background in the TOF spectrum. The CYCIAE-100 proton beam can generate neutrons with energies up to 100 MeV by spallation reaction and elastic scattering, but only a neutron

energy range of 1.75-12.0 MeV is studied due to the detectors linear-response dynamics and the short flight distance between the two detectors.

The "Neutron Beta Decay" Installation for the Reactor PIK

Authors: Anatolii Serebrov[1]; Alexey Fomin[1]; Oleg Zherebtsov[1]; Georgy Klyushnikov[1]; Artem Koptyukhov[1]; Vitaliy Lyamkin[1]; Alexander Murashkin[1]; Dmitriy Prudnikov[1]

[1] *NRC "Kurchatov Institute" - PNPI*

The neutron instrument complex "Neutron Beta Decay" will be located on the beam of polarized cold neutrons on the GEK-3 N0 channel. The installation is designed to measure the asymmetries of neutron beta decay with a relative accuracy of 0.1%. The basis of the installation is a superconducting solenoid that creates a magnetic field in a uniform region of 0.35 T. Electrons and protons appeared during neutron decay move in a magnetic field along magnetic force lines. To select a given angle of electron emission, the magnetic mirror effect is used by creating an area with a stronger magnetic field with an induction value of 0.88 T. The area with high field homogeneity is formed by protons, which can be additionally accelerated by an electric field. An electrostatic system is used for this purpose, which allows raising the voltage in the decay area to 30 kV. Detectors at the input and output of the neutron beam are used to register electrons and protons. To detect electrons, the magnetic field created by the solenoid is deflected downwards to remove electrons from the beam region. A magnetic circuit mounted under the solenoid will be used for this purpose. To deflect protons, the effect of proton drift in crossed electric and magnetic fields is used. At the input of the solenoid are located: a supermirror polarizer, a collimator and a spin-flipper. At the output of the solenoid are located: a polarization analyzer, a neutron detector for beam monitoring, and a neutron beam trap.

Light Ions Accompanied Break-Up of the Medium Heavy Fission Isomers

Author: Dmitry Kamanin[1]

Co-authors: Yuri Pyatkov [1]; Alexey Solodov [1]; Vladimir Zhuchko [1]; Zoya Goryainova [1]; Oleg Strekalovsky [1]; Elena Kuznetsova [1]; Alena Zhukova [1]

[1] *FLNP, JINR*

In series of the photo-fission reactions, namely, ^{235,238}U(γ, f), ^{232}Th(γ, f), ^{242}Pu(γ, f) we have found that some part of the fission fragments (FFs) are presumably born in the state of the fission isomer with the yield Y ≈ 10^{-3} fission and with the lifetime τ_{isom} > 400 nsec [1, 2]. A binary break-up of such fragments was observed when they pass through a solid-state foil. The effect takes place also for the FFs from ^{252}Cf(sf). In the proposed presentation we discuss the mode of the break-up with forming light ions in the mass range (3-20) u as one of the resultant decay products. The link of such events with known polar emission of the light charged particles is analyzed.

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Thermal Hydraulic Simulation Analysis of Liquid Metal Neutron Generating Target

Author: Yuzhao Li[1]

[1] *Key Laboratory of Nuclear Data, China Institute of Atomic Energy, China*

In order to explore the fluid flow and heat transfer process in the liquid metal neutron production target and provide theoretical basis for the design of the liquid metal neutron production target, the 2.5MeV 1mA particle beam was taken as an example to carry out theoretical analysis on the flow and heat transfer process of the liquid metal neutron production target, and the system design of the entire liquid metal neutron production target was carried out. The three-dimensional model of the liquid metal neutron production target is established, and the thermal and hydraulic simulation is carried out by using fluid software, and the theoretical and engineering analysis is carried out. The results show that the thermal hydraulic design parameters can meet the requirements of fluid flow and heat transfer when the particle beam bombards the liquid film, and can be used as the parameters of the liquid metal neutron generation target, and the liquid metal neutron generation target is feasible in theory and engineering. The above results provide a theoretical basis for the thermal-hydraulic design of liquid metal neutron production targets and fill the research gap in related fields in China.

The Study for the 4D Detector Based on AC-LGAD Silicon Sensors

Author: Yunyun Fan[1]

[1] *IHEP, CAS, China*

The AC-LGAD technology is chosen to be used as the time of flight detector and out track for the Circular electron-positron collider (CEPC). As suggested by the CEPC board, the time of flight is urgent for the flavor physics in CEPC, especially for the K/p and K/π separation in the low-energy part. The AC-LGAD based ToF & out tracker would be located between the TPC and ECAL which would cover 90 m^2 area. The expected performance is the 50 ps time resolution and 10 μm spatial resolution. This study will show the current test results with the strip AC-LGADs. The time resolution is ~37 ps and the spatial resolution is ~8.5 μm.

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

Authors: Liang Sheng[1]; Xiaodong Zhang[1]; Zhongming Wang[1]; Xinjian Tan[1]; Minwen Wang[1]; Baichuan Wang[1]; Liu Xiao[1]; Xin Zhuo[1]; Yufu Yang[1]; Xiufeng Weng[1]; Bo Tang[1]; Ge Ma[1]; Jingtao Xia[1]; Bin Sun[1]; Hongqiao Yin[1]; Haoqing Li[1]; Faquan Wang[1]

[1] *NINT, China*

The high repetition rate and short pulse neutron source based on 3 MeV proton accelerator has the characteristics of high single pulse neutron number, narrow pulse width ($n$anosecond level), wide neutron spectrum coverage and high repetition frequency (40 kHz). The neutron source is mainly composed of 100 mA ECR ion source, low energy transmission line (LEBT),100 mA continuous wave RFQ, medium energy transmission line (MEBT),330 kW continuous wave power source and high current and strong neutron target station. The ECR ion source can generate 110 mA, 80 keV proton beam; LEBT is used to match the beam parameters of the ion source to RFQ, and the 110 mA DC proton beam can be chopped into 40 kHz, 100 ns wide macropulses by using a slow beamformer; RFQ is used to accelerate the high-frequency macro pulse proton beam to 3 MeV, and to generate

a dozen micropulses with a distance of 6ns and a pulse width of 1ns, each of which is larger than 1 E10 p/pulse. MEBT is used to match the beam parameters of RFQ to the neutron target station, and a single micropulse in the macro-pulse cluster is selected by using a fast chopper, so that the generated 40 kHz and 1ns micro-pulses are incident to the neutron target station; the neutron target station is used to produce 40 kHz and 1ns pulsed neutrons with a yield of more than 1E9 n/s and a neutron spectrum range of 0.1 ~ 1.2 MeV, and three beams are planned on the neutron target station. Slow neutron and fast neutron experiments. The performance index of the device is very special, reaching the international advanced level, and the neutron with high energy resolution can be obtained at close range, which is an ideal platform for studying the neutron-related technology. Based on its high-quality, high-intensity neutron beam and proton beam, the basic fields of fast neutron physics, neutron (proton) photography, anti-nuclear reinforcement, nuclear data, nuclear detection technology and so on can be studied. Currently, the development of ECR ion source, LEBT, RFQ, MEBT and neutron target station is under way, and construction of the device is expected to be completed by the end of this year.

Deep Learning-Based Attempt for Multi-Type Particle Discrimination

Authors: Yulong Wang[1]; Xiufeng Weng[1]; Xiao Liu[1]

[1] *NINT, China*

Due to the heterogeneous composition of space radiation and the differential response characteristics exhibited by distinct particle species across various detector configurations, it is experimentally challenging to fully calibrate waveform responses of all particle types in detection systems. This study employs an autoencoder (AE) method from deep learning to perform discrimination and classification of particle waveform signals with limited prior information, establishing critical data infrastructure for space particle identification research. Furthermore, convolutional neural networks (CNNs) were implemented to achieve high-efficiency particle discrimination. The results demonstrate that the AE method effectively enables particle classification in both standalone CLYC+SiPM detectors and composite scintillator-configured CLYC+SiPM detection systems. Specifically, five characteristic signal categories were identified in standalone CLYC+SiPM detectors, while three distinct signal types were observed in composite scintillator systems. Leveraging CNN algorithms, precise discrimination of the two dominant signal types (cumulative proportion >99.8%) in composite scintillator-based CLYC+SiPM detection systems was achieved, with a figure of merit reaching 3.17. This study conclusively validates the efficacy of unsupervised deep learning methodologies in particle discrimination, providing a solid foundation for deploying advanced algorithmic architectures to achieve refined particle identification in complex space radiation

Key words Neutron/Gamma discrimination, Pulse shape discrimination, Deep learning, Space radiation

Analysis of Experimental Data on Neutron Decay for the Possibility of the Existence of the Right Vector Boson $W_\mathbf{R}$

Author: Anatolii Serebrov[1]

[1] *NRC "Kurchatov Institute" - PNPI, Russia*

In connection with the assumption that sterile neutrinos are right neutrinos, an analysis of the current experimental situation in neutron decay for right currents was performed. As a result of the analysis, it was found that there is an indication of the existence of a right vector boson W_R with a mass $M_{W_\mathrm{R}} = 304^{+24}_{-20}$ GeV, and a mixing angle with W_L : $\zeta = -0.039 \pm 0.014$. It is shown that this

result does not contradict the collider experiments to search for a hypothetical vector boson. This circumstance is the basis for discussing the possibility of expanding the Standard Model with an additional gauge vector boson W_{R} with little mixing with the left vector boson W_{L}. In addition, there are grounds for considering the possibility of the existence of right neutrinos. It can be assumed that sterile neutrinos are, in essence, right neutrinos. In this regard, the possibility of explaining dark matter in the Universe by right neutrinos is analyzed. Various aspects of this approach to the problem of dark matter are discussed: the dynamics of the origin of dark matter and the stability of dark matter consisting of right neutrinos.

Fission Neutrons Multiplicity Distribution Reconstruction Techniques

Author: Roman Mukhin[1]

Co-authors: Igor Izosimov [1]; Andrey Isaev [1]

[1] *FLNP, JINR*

Nuclear fission is one of the most important phenomena in nuclear physics, with broad practical applications. While it is well-studied for applied needs, numerous open questions remain in fundamental research. Spontaneous fission (SF) is one of the primary decay modes in the transfermium ($Z \geq 100$) and super-heavy element (SHE) regions. However, most available experimental data have been collected for isotopes up to californium ($Z \leq 98$), while data for heavier nuclei remain scarce.

Experimental studies of SF properties in the SHE region face multiple obstacles, such as short half-lives requiring online measurements and extremely low formation cross-sections necessitating highly efficient setups due to limited data yields. The primary SF characteristic—mass or isotopic distributions of fission fragments—cannot yet be measured with high efficiency. Other critical properties include total kinetic energy (TKE) and prompt neutron multiplicity distributions (PNMD). Most existing detector setups for SHE studies rely on silicon strip detectors, which struggle to measure TKE accurately due to the amplitude deficit effect. In contrast, PNMD can be measured with relatively high efficiency using large arrays of ^{3}He counters or similar solid-body neutron detectors.

The single-neutron detection efficiency for such detectors typically ranges near 50% and rarely exceeds 70%. This sub-100% efficiency distorts the measured PNMD shape compared to the true distribution, requiring a reconstruction procedure. Currently, the most widely used method is the simple yet powerful Tikhonov regularization technique, which incorporates prior information via a linear operator and regularization parameter. However, optimal selection of the regularization parameter remains a topic of debate. Monte Carlo methods offer a second approach, enabling the incorporation of arbitrary nonlinear detection efficiencies and potentially outperforming traditional methods for low-statistics data.

This talk addresses the optimal strategy for selecting regularization parameters in Tikhonov methods, discusses previously unreported technique artifacts, and proposes solutions. Additionally, it explores the often-overlooked impact of detection efficiency uncertainties on results. Finally, Monte Carlo methods are examined for their applicability to induced fission studies, where PNMD measurements are limited by low, energy-dependent neutron detection efficiencies but collected statistics are high.

Prompt Fission Neutron Spectra of ^{241}Am, ^{242}Am, and ^{243}Am(n, F) Reactions

Author: Vladimir Maslov[1]

[1] *Minsk, Belarus, Slobodskoj proezd 4, 220025*

Prompt fission neutron spectra (PFNS) of ^{241}Am(n,F), ^{242m}Am(n,F) and ^{243}Am(n,F) are obtained at 10^{-5} <En <20 MeV. The methods of analysis of integral PFNS for americium nuclides were elaborated via comprehensive analysis of ^{233,235,238}U(n,F) and ^{239,240}Pu(n,F) PFNS data [1, 2]. Average PFNS energies of ^{241,242m,243}Am(n,F) are strictly correlated with fission chances contributions ^{241,242m,243}Am(n,xnf) of observed fission cross sections and average prompt fission neutron numbers. The strongest influence on PFNS is predicted in case of ^{243}Am(n,F) and ^{243}Am(n,nf)1 reactions at En ~6 to 8 MeV (Fig. 1). The largest relative amplitude of pre-fission neutrons is predicted for ^{243}Am(n,xnf)1 reaction at En ~6.0 to 6.25 MeV. In case of ^{241}Am(n,F) reaction influence of pre-fission neutrons on and PFNS is much weaker but is of similar shape. In case of ^{242m}Am(n,F) reaction at Ennf <En<En2nf is quite different (Fig. 2). It depends mostly on Ennf and En2n reaction thresholds and excitation energies of fission fragments. Exclusive pre-fission neutron spectra ^{241,242m,243}Am(n,xnf)1,..x are consistent with σ(n,F) of ^{241,242m,243}Am(n,F), ^{241}Am(n, $2n$) and ^{243}Am(n, $2n$)^{242g}Am reaction cross sections. Average total kinetic energies TKE for fission fragments and products, partial contributions of ^{241,242m,243}Am(n,xnf)1,..x reactions of prompt fission neutrons number and observed fission cross section are predicted and compared with evaluated data [3, 4].

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Determination of Partial Neutron Widths of p-Wave Resonance of ^{35}Cl Nuclei at the 397.8 eV Energy

Authors: Valery Kuznetsov[1]; Alex Oprea[1]; Almat Yergashov[1]; Constantin Hramco[1]; Yuri Kopach[1]; Ludmila Mitsyna[1]; Christina Oprea[1]; Natalia Rebrova[1]; Pavel Sedyshev[1]

[1] *FLNP, JINR*

Angular distributions of emitted gamma quanta during the neutron capture process, in the region of the p-wave resonance by ^{35}Cl nuclei were measured. Corresponding expressions, for the forward-backward asymmetry effect and anisotropy in the angular distribution of gamma quanta for a target nucleus with a spin of 3/2, were obtained in the frame of the mixing states of compound nucleus with the same spin and opposite parities formalism. Using experimental data and theoretical evaluation of forward-backward asymmetry effect and anisotropy of gamma quanta, partial neutron widths Γnp,1/2 and Γnp,3/2 were obtained.

Coming Back to the Problem of True Ternary Fission - Actual View

Author: Yuri Pyatkov[1]

Co-authors: Dmitry Kamanin [1]; Vladimir Zhuchko [1]; Zoya Goryainova [1]; Elena Kuznetsova [1]; Yuri Sereda [1]; Alexey Solodov [1]; Oleg Strekalovsky [1]; Alena Zhukova [1]

[1] *FLNP, JINR*

In the past, there were multiple attempts to find the so-called "true ternary fission" i.e. ternary fission with comparable masses of the fragments. So far, it has not been done, at least not in the frame of the traditional experimental approaches. In a series of our experiments, we have observed ternary partition of the heavy nuclei [1, 2] when one of the fragments of binary fission undergoes a break-up while passing through a solid-state foil. Among such events, there is a fraction of them with comparable masses of the resultant fragments. It should be stressed that the fragment undergoing a break-up is born in the shape isomer state [3]. In our presentation, we discuss a possible mechanism of the ternary partition leading to comparable masses of the fragments.

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Design of the Birdcage Coil for a Gradient Spin-Flipper in a Strong Magnetic Field

Author: Vladimir Kurylev[1]

Co-authors: German Kulin [1]; Alexander Popov [1]; Alexander Frank [1]; Maxim Zakharov [1]

[1] *FLNP, JINR*

The FLNP JINR is currently working on the development of an ultracold neutron (UCN) source with pulsed neutron accumulation in a trap. The concept is based decelerating very cold neutrons (VCNs) to the UCN energy using a gradient spin flipper, in which the neutron spin flip occurs under the action of a high-frequency magnetic field perpendicular to a stationary but coordinate-dependent strong magnetic field.
In this report, we present a preliminary design for an RF resonator, specifically 8-legged high-pass birdcage coil. This resonator design not only provides the desired magnitude and frequency of the alternating magnetic field with sufficient homogeneity, but also has cylindrical symmetry, which allows for the use of a most convenient, solenoidal geometry for the magnet forming stationary gradient magnetic field. In this configuration, neutrons traveling through the magnetic system would not meet any matter in their path.

Modelling of the Forward-Backward Effect in (n, p) Reaction with Slow and Resonance Neutrons on ^{35}Cl

Authors: Igor Chuprakov[1]; Yuri M Gledenov[1]; Cristiana Oprea[2]; Ioan Alexandru Oprea[1]; Enkhbold Sansarbayar[1]

[1] *FLNP, JINR*

[2] *High School Lucuan Blaga Oradea Romania*

In nuclear reaction induced by slow and resonant neutrons on ^{35}Cl nucleus followed by proton emission, the forward–backward effect was investigated. In the frame of the model of mixing states of compound nucleus with the same spin and opposite parities, cross sections, angular correlations and asymmetry coefficients were evaluated. Using theoretical calculations, measurement of forward–backward effects were simulated taking into account target properties like dimensions, temperature and proton energy loss in the target. From protons spectra, the modeled forward–backward coefficient was obtained and compared with the experimental effect. From theory the highest value of forward–backward effect is about 0.3 but the measured one is about 30-50% lower than expected.

The difference should come from the influence of temperature, target properties, background produced by a pulsed neutron source and other factors.
Forward–backward effect together with other asymmetry coefficients represent an important tool in the analysis of symmetry breaking process in the nuclear reactions induced by slow and resonance neutrons generated by weak non-leptonic interaction between nucleons in compound nucleus. In early researches the authors had demonstrated the possibility to obtain only from experimental asymmetry and spatial parity violation effects, the matrix element of the weak non-leptonic interaction.

Ternary Fission of Actinides Induced by Thermal Neutrons with Light Particles Emission

Author: Larisa Titova[1]

Co-authors: Stanislav Kadmensky [1]; Egor Belousov [1]

[1] *Voronezh State University, Russia*

In [1-3] the virtual mechanism of ternary fission of the compound nucleus (A, Z), formed by the capture of the thermal neutron by target-nucleus $(A-1, Z)$ as the two-stage process was suggested. At the first stage light particle $(A-A_{LP}, Z-Z_{LP})$ with kinetic energy close to the Coulomb barrier height is emitted from the nucleus (A, Z) with the forming of the virtual state of the intermediate nucleus having internal energy lower than its ground state energy and undergoing binary fission at the second stage. The yield N_{LP} of the light particle and the energy distribution $W(T_{LP})$ related to one act of the binary fission are defined as [1-3]
$W(T_{LP}) = \frac{1}{2\pi}\frac{(\Gamma^A_{LP}(T_{LP}))^{(0)}}{(Q_{LP}+B_n-T_{LP})^2} = \omega_{LP}\frac{\hbar c\sqrt{2T_{LP}}}{2R_{neck}\sqrt{\mu c^2}}P(T_{LP}), N_{LP} = \int W(T_{LP})dT_{LP} = \frac{\Gamma_{LPf}}{\Gamma_f}$,
where Γ_{LPf} and Γ_f are the widths of the ternary and binary fission of compound nucleus (A, Z), correspondingly, $\Gamma^A_{LP}(T_{LP}))^{(0)}$ is the width of the virtual decay of the nucleus (A, Z) with light particle emission from the deformed transition fission state corresponding to the configuration (0) of these nuclei with the neck radius R_{neck} between two fission prefragments, Q_{LP} is the heat of the decay of the nucleus (A, Z) with light particle emission, B_n is neutron binding energy in (A, Z), $P(T_{LP})$ is light particle penetrability factor of the Coulomb barrier formed by the sum of the non-spherical nuclear and Coulomb potentials of the light particle interaction with nucleus $(A - A_{LP}, Z - Z_{LP})$, ω_{LP} is the probability of light particle formation in the neck of the nucleus (A, Z), μ is the reduced mass of light particle and nucleus $(A - A_{LP}, Z - Z_{LP})$. Using the experimental energy distributions $W(T_{LP})$ [4 - 6], the estimations of the R_{neck} [7] and taking into account that penetrability factor $P(T_{LP}) \approx 1$ at the maximal energies of the emitted light particles $(T_{LP})_{max}$ the estimations of the probability ω_{LP} of the light particle formation were obtained for the target-nuclei ^{233}U, ^{235}U, ^{249}Cf, ^{251}Cf, in fission induced by thermal neutrons.

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7. S.G. Kadmensky, D.E. Lyubashevsky, P.V. Kostryukov, A.A. Pisklyukov PEPAN 21, 1114 (2024)

Growth Optimization and Ce Doping Engineering in CLLB/CLLBC Scintillators for Enhanced Neutron-Gamma Discrimination

Authors: Zhuochen Cai[1]; Xianggang Zhang[1]; Jinbo Liu[1]; Keing Liu[1]; Zhe Kang[1]; Ziang Yin[1]; Qinghua Zhao[1]; Tao Wang[1]

[1] *Northwestern Polytechnical University, China*

Elpasolite scintillators notably $Cs_2LiLaBr_6$:Ce (CLLB) and $Cs_2LiLa(Br,Cl)_6$:Ce (CLLBC), play a critical role in neutron-gamma detection for homeland security and nuclear monitoring. In this work, high-quality CLLB crystals were grown using both the vertical Bridgman (VB) and traveling heater (THM) methods, guided by a constructed Cs_2LaBr_5-LiBr phase diagram. Focusing on performance tuning through Ce doping, detailed investigations revealed that the scintillation properties of CLLB-particularly energy resolution and neutron/gamma discrimination-are highly sensitive to the Ce concentration. Specifically, an energy resolution of approximately 3.0-3.5% at 662 keV was achieved once the effective Ce concentration exceeded 2%, with optimal neutron/gamma discrimination observed near 3% Ce doping. The effective segregation coefficient of Ce in CLLB was determined to be 1.59, and the THM process contributed to a homogenized Ce distribution, which is critical for performance control.
Further, CLLBC crystals grown via the VB method with Ce concentrations of 2-4% exhibited enhanced scintillation performance, including improved energy resolution, increased light yield and reduced decay times. Notably, the figure of merit (FOM) for pulse shape discrimination-a key metric quantifying the ability to distinguish between neutron and gamma events-increased from 1.6 to 2.0. This FOM enhancement underscores the improved pulse shape differentiation in CLLBC, which is essential for reducing misidentification in mixed radiation fields. These findings offer valuable insights into Ce doping optimization and growth methodology, paving the way for advanced neutron and gamma radiation detection technologies.

Measurement of Arsenic Contamination in Soil and Groundwater in Pabna, Bangladesh, Using JINR FLNP Neutron-Producing Facilities

Author: Pretam Kumar Das[1]

[1] *Pabna University of Science and Technology, Pabna-6600, Bangladesh*

In regions such as Pabna, Bangladesh, where groundwater is the primary source of drinking water, arsenic contamination in both soil and groundwater poses a significant threat to human health.
Neutron Activation Analysis (NAA) is a highly sensitive and precise analytical technique capable of detecting and quantifying trace levels of arsenic, even at concentrations as low as parts per billion (ppb). This method allows for the assessment of both total and bioavailable arsenic fractions in soil samples, as well as analysis of dissolved arsenic in groundwater samples. The World Health Organization (WHO) has established a guideline threshold of 10 μg/L for arsenic concentrations in drinking water, which serves as a critical benchmark for evaluating contamination levels in affected environments.
Arsenic concentrations in soils are expected to exhibit significant spatial variability, with elevated levels likely in areas historically subjected to intensive agricultural practices and irrigation using arsenic-contaminated groundwater. This report emphasizes the urgent need for immediate mitigation strategies, including the development of alternative water sources and the implementation of soil remediation techniques, to address the widespread arsenic contamination in Pabna. Additionally, it highlights the severe health risks associated with prolonged exposure to arsenic.
Neutron Activation Analysis (NAA) conducted at the IBR-2 reactor or the IREN facility at the Frank Laboratory for Neutron Physics, Joint Institute for Nuclear Research (JINR), Dubna, Russia has proven to be a highly effective technique for analyzing the elemental composition of environmental samples. This method is proposed for assessing arsenic contamination levels in affected regions.
The findings from this research will contribute to initiatives aimed at ensuring access to clean drinking water and promoting sustainable agricultural practices. Furthermore, this study will enhance the

existing understanding of arsenic pollution in Bangladesh and support efforts to mitigate its impact on public health and the environment.

Keywords: Neutron Activation Analysis (NAA), IBR-2 reactor, IREN facility, Arsenic contamination, groundwater, soil samples.

Parallel Session 1: Fundamental interactions & symmetries in neutron induced reactions/Properties of compound states, nuclear structure/Intermediate and fast neutron induced reactions/Nuclear fission

Progress in the Measurement of the Neutron-Induced Fission Cross-Section at CSNS Back-n

Author: Yonghao Chen[1]

[1] *CSNS*

China Spallation Neutron Source (CSNS) is a newly built large scale facility in 2018. It is generating neutrons by bombarding 1.6 GeV protons into a tungsten target for multidisciplinary research. A back-streaming neutron beamline (Back-n) at CSNS is built at the reverse direction regarding to the proton beam mainly for the nuclear data measurement. Back-n is characterized by its wide energy range (from thermal to 300 MeV), high flux (up to 10^7 n/cm^2/s at 77 m) and good energy resolution (less than ~1% below 1 MeV), which stands as one of the state-of-the-art white neutron source in worldwide. Fission cross-section of a series of isotopes, such as ^{232}Th, ^{235}U, ^{236}U, ^{238}U, ^{239}Pu, has been measured in wide energy ranges since 2018, and more isotopes (such as minor actinides) are planned to be measured in the near future. In this presentation, the CSNS Back-n facility and the campaigned fission cross-section measurement will be reviewed. Then the challenges and perspectives of the fission cross-section measurement at CSNS Back-n will be highlighted.

Application of Tagged Neutron Technology for Applied and Fundamental Nuclear Problems

Authors: Anton Maznitsyn[1]; Alexey Presnyakov[1]; Maxim Karetnikov[1]; Vyacheslav Batyaev[1]; Sergey Belichenko[1]

[1] *FSUE All-Russian Scientific Research Institute of Automation, Russia*

A nanosecond tagged neutron technology (NTNT) is based on the space-time analysis of events produced by the 14 MeV neutrons which time of escape, energy, and direction of movement is known by the recording of the accompanying alpha-particle. The development by FSUE VNIIA of the high-intensity generator of tagged neutrons promoted the extension of the applications of tagged neutrons. Currently, the NTNT is used for the neutron activation analysis as well as for applied and fundamental nuclear problems due to the following advancements:

• Measuring the neutron flux with the absolute inaccuracy less than 5% and relative inaccuracy less than 1% in the high range of neutron generator intensity.
• Directional reading of the angle of the tagged neutron escape with the accuracy up to 0.02 rad, and measuring the coordinates of nuclear reactions stipulated by tagged neutrons.
• High effect/background ratio provided by the space-time discrimination of events stipulated by interaction of "untagged" neutrons and secondary radiation with the matter.
• Possibility of gamma-detector calibration while measurement by special object-calibrators when tagged neutrons are passing through them, the emitted gamma-lines can be easily interpreted on the NTNT spectrum (alpha-gamma coincidences);
• Possibility of gamma-detector calibration while measurement by reference isotope sources, the gamma-lines can be defined by the gamma-spectrum without coincidences and they practically do not affect the NTNT spectrum.

The several applications of NTNT are considered in the report:
• Precise 14 MeV neutron flux generation for nuclear detector calibration;
• Determination of gamma-detectors response to 14 MeV neutrons;
• Measuring the angle distribution and Doppler effect of gamma-rays emitted at the inelastic neutron scattering.
The experimental technique and results are considered. The obtained data are in a good agreement with the numerical calculations and experimental data by other authors.

Measuring $B_{nat}(n$, tot) Reaction as an International Standard

Author: Ignacio Durán[1]

[1] *Universidad de Santiago de Compostela, Spain*

The final accuracy of the evaluations relies on the quality of the experimental datasets being used. But, conversely, the quality of the experimental datasets relies on the quality of the standards used as reference. Big improvements have been done in the last decade, after the IAEA launched an international project for the "Maintenance of the Neutron Cross-Sections Standards", adopting the upgraded version of the GMAP code from ENDF/B. Present Nuclear Data Standards (IAEA NDS) are those collected by A.D. Carlson et al in [1], where it is explained how the short table of principal international standards –the so-called Thermal Neutron Constants (TNC) together with the specific neutron cross-sections of light elements (H, ^{6}Li and ^{10}B)- play a relevant role in the whole NDS evaluation by adopting the upgraded version of the GMAP code from ENDF/B. Mention must be made of the fact that these TNC –which include (n,f), (n,g) and (n,el) reactions– cannot be directly measured as "absolute", trailing so an USU (Unknown Systematic Uncertainty) [see 2] that cannot be removed by statistical analysis. New inputs are needed to increase the quality of this international effort and one of the most sensitive points is the standard value at thermal point of the ^{10}B(n,α) reaction, which experimental uncertainty depends on the acknowledge of the flux of the used neutron source.The interest in measuring the B_{nat}(n,tot) reaction as a way to improve the ^{10}B(n,$alpha$) standard is discussed in this work. Looking for an absolute Standard around thermal an near-epithermal energy region, the B_{nat}(n,tot) cross section is well suited because it can be accurately obtained from a neutron transmission experiment by using cumulative thin samples, and based on integrating the cross section function over a wide energy interval. The method and a possible experimental setup will be presented in this work.

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A New Method for Determining the Transverse Vibration Energy of Fission Prefragments

Authors: Dmitry Lyubashevsky[1]; Pavel Kostryukov[2]

Co-authors: Sherbina Julia [1]; Klyuchnikov Stanislav [1]; Volokhin Nikita [3]

[1] *Voronezh State University, Russia*

[2] *Voronezh State University of Forestry and Technologies / Voronezh State University, Russia*

[3] *Novovoronezh NPP, Russia*

The study of the dynamics of heavy nuclei fission remains a relevant problem in modern nuclear physics. One of the key questions in this field is the identification of the mechanism of spin formation of the fission fragments, which is still insufficiently studied. In this work, based on studies [1,2], a modelling of the potential energy of the compound fissile system has been performed to analyse the role of transverse oscillations in the spontaneous fission process of the ^{252}Cf nucleus. The focus of the study was directed towards wriggling and bending oscillations, which may play a role in the final spin distribution of the fission fragments.

The calculation method is based on the use of an effective nucleon-nucleon potential [3] to estimate the potential energy of the transverse oscillations. Furthermore, the concept of a "cold" nucleus [4] has been used, which implies that all excitation energy is converted into non-equilibrium deformation energy during the entire fission process, simplifying the analysis of collective oscillations and their influence on the spin distribution. The proposed model includes a number of parameters, including charge and mass asymmetry, distance between fragments, and quadrupole deformations. The frequencies of the oscillations and the stiffness coefficients are calculated numerically, allowing the contribution of each type of oscillation to the final distribution [5,6] of the spins of the fission fragments to be determined. The validity of the model has been verified with experimental data [7] on spin distributions.

The analysis of the results obtained confirms that mentioned types of oscillations make a significant contribution to the process of fission fragments spins formation. Nevertheless, the ratio between the energies of wriggling and bending oscillations remains approximately constant, which is consistent with theoretical predictions for symmetric fission path described in [8]. The findings of this study indicate that the outcomes obtained within the framework of the hydrodynamic approach [9] are more closely aligned with the observed spin values. This confirms the importance of considering collective effects in describing the fission mechanism of heavy nuclei.

In addition, the influence of the initial deformation conditions of the nucleus on the nature of the transverse vibrations and the final distribution of the spins of the fragments has been considered. The inclusion of non-equilibrium deformations allows a more accurate prediction of fission parameters, especially near the scission point. Important correlations between transverse oscillations and angular momentum redistribution processes have been identified, confirming their key role in the formation of fission fragments. Further analysis can be directed towards studying the influence of temperature effects and interactions between fragments in the final stages of fission.

This study contributes to the refinement of the mechanisms of energy and angular momentum transfer in the process of nuclear fission. The results obtained can be used to improve theoretical models and to predict the characteristics of the fission products of other actinide nuclei. In the future, it is planned to extend the research to other heavy nuclei and to use more detailed quantum mechanical models to describe the dynamics of the collective oscillations in the fission process.

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Rotation Effect of a Fissile Nucleus (ROT Effect) for Prompt γ-Rays in Binary Fission of ^{235}U by Polarized Neutrons of Different Energies

Authors: Daniyar Berikov[1]; Afag Madadzada[1]; Gadir Ahmadov[1]; Gevorg Danilyan[2]; Yuri Kopatch[1]; Sabuhi Nuruyev[1]

[1] *FLNP, JINR*

[2] *Institute for Theoretical and Experimental Physics of National Research Centre "Kurchatov Institute", 117218 Moscow, Russia*

The present work provides a detailed examination of a series of studies [1,2] dedicated to investigating the effect of rotation of the fissile nucleus of the isotope ^{236}U in the ^{235}U(n,f) process induced by monochromatic polarized neutrons with energies of 62 meV and 270 meV. The main focus is on the analysis of the anisotropic angular distribution of γ-rays emitted by the excited fission fragments and its shift by a small angle relative to the deformation axis of the fissile nucleus when the neutron beam polarization direction is reversed.

The studied effect represents an important aspect in understanding the dynamics of the nuclear fission process, especially near the rupture point. The shift in the angular distribution of γ-rays can provide valuable information about the internal structure of fissioning nuclei and the mechanisms governing the fission process. This, in turn, may contribute to the development of a more comprehensive quantum-mechanical model of fission, which has yet to be established.

All experiments were conducted at the Heinz Mayer Leibniz Research Neutron Source (FRM II reactor) at the Technical University of Munich, located in Garching. A beam of polarized neutrons from the POLI facility was used for the measurements.

Additionally, the work includes a comprehensive analysis of results obtained in previous studies by the ITEP group [3] concerning ROT effects for fission γ-rays, which were obtained using cold neutrons. Furthermore, the results obtained by the PNPI group [4] for thermal neutrons are presented, allowing for a comparative analysis and the identification of common trends in the behavior of γ-rays under different experimental conditions.

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Double (n-γ) and Triple (n-$n'\gamma$) Angular Correlations in Neutron Inelastic Scattering on ^{12}C

Authors: Polina Filonchik[1]; Alexey Barabanov[2]; Dimitar Grozdanov[1]; Yuri Kopatch[1]; Pavel Prusachenko[1]; Nikita Fedorov[1]; Tatyana Tretyakova[1]; Ivan Ruskov[1]; Vadim Skoy[1]; Constantin Hramco[1]

[1] *FLNP, JINR*

[2] *NRC "Kurchatov Institute", Russia*

Understanding (n-γ) and (n-$n'\gamma$) correlations is crucial for analyzing inelastic neutron scattering processes and assessing the impact of direct and compound nucleus mechanisms on nuclear reactions. However, there are few experiments measuring (n-n'γ) correlations with 14 MeV neutrons, and most of these studies, conducted over 40 years ago, suffer from poor accuracy and limited angular range [1-5]. Recent measurements of (n-$n'\gamma$) correlations in the inelastic neutron scattering on ^{12}C [6] show discrepancies with earlier results. Therefore, obtaining data with better statistics and higher angular resolution is of great interest.
At the TANGRA facility in Dubna, an experiment is underway to measure angular correlations (n-$n'\gamma$) in the inelastic scattering of 14.1 MeV neutrons on ^{12}C using the tagged neutron method. The setup includes twelve 1-meter-long plastic scintillation detectors, each equipped with two photomultiplier tubes (PMTs). Ten detectors are positioned around the target in the reaction plane, while two are placed perpendicular to it. These detectors offer a time resolution of approximately 3 ns and a spatial resolution of about 20 cm, enhancing angular resolution and enabling the separation of gamma rays from neutrons based on their time-of-flight.
A theoretical approach is proposed to describe the double differential cross section of gamma radiation in inelastic neutron scattering. This approach considers the directions of the incident neutron, scattered neutron, and gamma quantum. It uses rotationally invariant functions of three vectors, as described in [7]. Our formula for angular correlations includes S-matrix elements, which can be obtained using the TALYS program for calculating nuclear reaction cross sections. Theoretical calculations were performed using the TalysLib library [8] to optimize the optical potential parameters. This was done to accurately describe the angular distribution of inelastically scattered neutrons.

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Cross Sections of the ^{148}Sm(n, α)^{145}Nd Reaction in the 4.8–5.3 MeV Neutron Energy Region

Authors: Igor Chuprakov[1]; E. Sansarbayar[1]; Guohui Zhang[2]; Yu.M. Gledenov[1]; G. Khuukhenkhuu[3]; L. Krupa[1]; Jie Liu[2]; Haofan Bai[2]; Cong Xia[2]; Zepeng Wu[2]; Wenkai Ren[2]

[1] *FLNP, JINR*

[2] *Peking University, China*

[3] *Nuclear Research Center, National University of Mongolia, Mongolia*

Cross sections for the ^{148}Sm(n,α)^{145}Nd reaction were measured at neutron energies of 4.8, 5.1, and 6.3 MeV, performed at the EG-5 Van de Graaff accelerator at the Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research. A double-section gridded ionization chamber was employed to detect the emitted alpha particles. Samples of ^{148}Sm2O3 were positioned back-to-back on the common cathode plate of the chamber. Monoenergetic neutrons were produced via the D(d,n)^{3}He reaction in a deuterium gas target. The neutron flux was monitored with a ^{3}He long counter, and the absolute flux was determined using a ^{238}U3O8 sample. The experimental results are compared with evaluated data and calculations from the TALYS-1.96 nuclear reaction code.

Measurement Thermal Neutron Capture Cross Section and Resonance Integral of ^{94}Zr(n, γ)^{95}Zr Reaction using Intense Resonance Neutron Source "IREN"

Author: Le Tran Minh Nhat[1]

[1] *FLNP, JINR*

The thermal capture cross section and resonance intergal for the ^{94}Zr(n,γ) reaction were measured relatively to that of ^{197}Au(n,γ)198Au by activation method using IREN facility of the Joint Institute for Nuclear Research (JINR) [1]. Neutrons are produced via the interaction of electron beam with a tungsten target. The induced activities in activated samples were measured by a high-resolution HPGe gamma spectrometer. The necessary correction factors including neutron thermal and epithermal self-shielding effects, the γ-ray self-absorption and other were taken into account to improve the accuracy of the results [2]. Our obtained value of thermal neutron cross-section for ^{94}Zr(n,γ)^{95}Zr reaction is 0.0516 ± 0.00395 barn. The differences between this value and most of that listed in the international nuclear data libraries JENDL-4.0, JEFF-3.2, ENDF/B-VII.1 are less than 4%. The value of the resonance integral measured by us is 0.2764 ± 0.084 barn, which is 14% difference from the mean of previously reported data.

The Precise Measurement of Triton-Producing Three-Body Breakup Reaction of ^{7}Li Nucleus Induced by Fast Neutrons with the Multi-purpose Time Projection Chamber at CSNS

Authors: Han Yi[1]; Ruirui Fan[1]

[1] *CSNS*

Tritium is important in fusion facility and one of the main ways to realize tritium production is the triton-producing reaction of lithium nucleus induced by neutrons. Generally the cross section of neutron induced triton-producing reaction of ^{6}Li has a large value in a wide range of neutron energy, while in the energy range of fast neutron the triton production is dominant by the reaction of ^{7}Li nucleus. In the research of Molten Salt Reactor (MSR) the cross section data of triton-producing reaction of ^{7}Li will significantly influence the estimation of tritium production and the design of reactor. The cross section data of triton-producing reaction induced by fast neutrons is important for the calculation of tritium yield and tritium breeding rate In the research of fusion facility. The triton-producing reaction of ^{7}Li is a three-body reaction, including the sequential decay, the quasi-elastic scattering and the direct breakup processes. The double differential cross section data and integral craoss section data are necessary for the theoretical model construction and fitting parameters constraint. Currently the data of ^{7}Li triton-producing reaction are mainly the integral cross section data and double differential data of secondary neutrons, and the double differential data of secondary charged particles are scarce, limiting the further research of reaction theory. The precise measurement of triton-producing reaction of ^{7}Li is limited by the technology of detection and measurement. Considering the latest developed Multi-purpose Time Projection Chamber (MTPC) at CSNS, it is possible to measure the kinetic process of triton-producing reaction of ^{7}Li by the momentum and energy reconstruction of the secondary particles. And the systematic measurement of the reaction will be conducted at the Back-n white neutron source to provide more data sets in details for theoretical model construction and data evaluation.

Test of the T-Invariance with Polarization-Asymmetry Theorem in Mirror Reflection of the Slow Neutrons

Author: Vadim Skoy[1]

[1] *FLNP, JINR*

A possibility of the test of T - invariance violation in neutron - nuclear interaction in the multiple mirror reflections of slow neutrons is considered. The reflections are assumed in a "whispering gallery" mode. It is shown that an expected effect may exceeds in magnitude a correspondent effect near p - wave resonance. The methodical features of such experiment are considered.

Faddeev-AGS Calculation of Neutron Induced Nuclear Reaction on Deuteron within Wave-Packet Continuum Discretization Approach

Authors: Wendi Chen[1]; Danyang Pang[1]; O. A. Rubtsova[2]

[1] *Beihang University, China*

[3] *Lomonosov Moscow State University, Russia*

The n+d reaction is one of the most fundamental three-body nuclear reactions, which is an important platform for examining the nucleon-nucleon interaction. The wave-packet continuum discretization approach is developed to solving three-nucleon scattering equations within a modified Faddeev-AGS equation framework, which is based on the discretization representation of the three-body continuum states and lattice representation of all scattering operators in momentum space. As an application, calculations were performed for n+d reactions with realistic nucleon-nucleon interactions. The calculated results, including the elastic scattering angular distributions, triple differential breakup cross section, double differential cross sections of the emitting neutrons and protons and so on, were in fair agreements with the experimental data as well as the evaluated data in CENDL-3.2, ENDF/B-VIII.0, JENDL-5 and JEFF-3.3.

Measurement of Neutron Total Cross Section of ^{169}Tm at Back-n

Authors: Jie Ren; Jieming Xue; Haolan Yang

CIAE

The neutron total cross sections (σ_{tot}) are of great value in nuclear reactor design, nuclear theory models, nuclear applications and other fields. Thulium (^{169}Tm) is a crucial neutron absorbing material, and the σ_{tot} of ^{169}Tm are highly useful for nuclear reactor design. However, there are only a few experimental σ_{tot} of ^{169}Tm in EXFOR and no data in the energy between 10 keV and hundreds keV. Besides, the evaluated σ_{tot} of ^{169}Tm in ENDF/B-VIII.1, JENDL, and TENDL show significant discrepancies within the 10 keV and 100 keV energy region. To determine the σ_{tot} of ^{169}Tm in the energy between 10 keV and 100 keV, a wing-shaped lithium glass detector was designed in this work, and a measurement was carried out with this lithium glass scintillation detector at the Back-n facility. The experimental backgrounds induced by gamma rays were measured with lithium-7 enriched scintillator and "black resonance filter" method. The corrections for dead time, beam stability, and self-shielding were taken into consideration in the data analysis. The σ_{tot} of ^{169}Tm in the energy between 5 keV and 100 keV was obtained and compared with the evaluated data from ENDF/B-VIII.1, JENDL, and TENDL. The comparison result indicated that the σ_{tot} of ^{169}Tm measured by this work is more consistent with the evaluated data of JENDL-5.

Primary Gamma Transitions in ^{176}Lu and ^{177}Lu after Resonance Neutron Capture

Authors: Gadir Ahmadov[1]; Daniyar Berikov[1]; Costa Hramco[1]; Walter Furman[1]; Wei Jiang[2]; Sabuhi Nuruyev[1]; Sergei Telezhnikov[1]; Gaole Yang[3]

[1] *FLNP, JINR*

[2] *CSNS*

[3] *Sun Yat-sen University, China*

$^{175,\,176}$Lu (n,γ) $^{176,\,177}$Lu reactions were studied via radiative capture of resonance neutrons at the CSNS Back-n White Neutron Source. Using the time-of-flight (ToF) technique, gamma-ray spectra for isolated resonances were measured. The experiment was conducted with a coaxial HPGe gamma detector equipped with an anti-Compton system, positioned 20 cm from the target. A 60 g sample of metallic natural lutetium (^{nat}Lu) with 99.9% purity (dimensions: 60 × 2.2 mm) was used as the target, located 76 m from the spallation target in the ES#2 experimental hall. The ToF spectrum was measured in the 1–700 eV energy range, with sufficient γ-ray statistics up to 100 eV. The measurement time was approximately 200 hours. The ToF resolution enabled the extraction of gamma-ray spectra from 16 neutron resonances for the ^{175}Lu (n,γ) ^{176}Lu reaction. Due to the low natural abundance of ^{176}Lu (2.6 %), gamma-ray spectra were obtained from 10 resonances for ^{176}Lu (n,γ) ^{177}Lu reaction. In total, 40 primary gamma transitions were identified for ^{176}Lu, but 15 for ^{177}Lu. Resonance spins were also deduced from the analysis of gamma-transition intensities for both reactions.

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We thank the staff members of the Back-n white neutron facility (https://cstr.cn/31113.02.CSNS.Back-n) at the China Spallation Neutron Source (CSNS) (https://cstr.cn/31113.02.CSNS), for providing technical support and assistance in data collection and analysis.

Investigation of Properties of Low-Level p-Wave Neutron Resonances at the IREN Facility (FLNP, JINR, Dubna)

Authors: Constantin Hramco[1]; Alex Oprea[1]; Natalia Rebrova[1]; Sergey Borzakov[1]; Ludmila Mitsyna[1]; Pavel Sedyshev[1]; Kuznetsov Valery[1]; Almat Yergashov[1]; Kopatch Yuri[1]

[1] *FLNP, JINR*

At the 11-m flight path of the IREN facility the measurements of the differential cross sections of the Br (n,γ) and Cl (n,γ) reactions were carried out in region of the low-lying p-wave resonances of bromine at the 0.88 eV incident-neutron energy and chlorine at 398 eV, correspondingly. The purpose of the experimental γ-quanta angular distributions obtaining is search of the asymmetry of their forward-backward recording. Monte-Carlo calculations were also made to evaluate an asymmetry of γ-quanta due to kinematics and real geometry of the experiment, as neutrons are scattered in the target before capture, with considering multiple scattering in the targets. The results of investigation of the p-wave resonances are presented.

A New Scheme of Space-Based Measurement of Neutron Lifetime

Author: Baohua Sun[1]

[1] *Beihang University, China*

How long neutrons survive plays a key role in particle physics and cosmology. However, conflicting results with a deviation of about 9 second have been found over years in neutron lifetime measurements. Different ideas have been proposed to solve such deviations. We proposed a new scheme based on CubeSat to determine neutron lifetime. In this talk, after a short overview on the lifetime puzzle, I will show the principle of our proposed measurement, the challenges and also the progress in payload development.

Prompt Fission Neutron Spectra and Angular Distributions Measured in Narrow Windows of Fragment Masses and Total Kinetic Energies: A Puzzling Result and a Possible Explanation

Author: Nicolae Carjan[1]

Co-authors: Alf Gook [2]; Stephan Oberstedt [3]

[1] *FLNR, JINR*

[2] *Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden*

[3] *European Commission, JRC Directorate G, Nuclear Safety and Security, Geel, Belgium*

A previous experiment performed at JRC-Geel on prompt fission neutrons (PFN) in correlation with fragments from spontaneous fission of ^{252}Cf was repeated using an improved setup and much better statistics. The experiment lasted 3 months and 68×10^6 coincident events were collected. In this new experiment PFN spectra and angular distributions (in the laboratory system) are selected in a narrow window of fragment masses and total kinetic energies around AL=109 and TKE=184 MeV, AL=120 and TKE=193.5 MeV, AL=109 and TKE=184 MeV. In this way we have isolated (as good as possible) certain fission paths which makes comparisons with theoretical models easier.

Clear deviations from a Maxwellian spectrum were found from 0.5 to 6 MeV. They consist in structures, more pronounced around the most probable energy ($\simeq$1 MeV). There is a resemblance with the deviations predicted by the dynamical scission model, which assumes that PFN are emitted during the separation of fragments at scission. Concerning the angular distribution, deviations from a smooth curve are observed in the form of fine structures. They could be the sign of scattering of neutrons on the just born fragments.

Finally, oscillations are shown to be present also in the inclusive angular distribution since the sample of events over which the summation is done is not large enough to completely wash out the structures.

At first look, these identified structures in the data are not compatible with the traditional hypothesis that PFN are evaporated from fully accelerated fragments, because this hypothesis predicts smooth distributions

Recent Progress of Neural Networks in Nuclear Structures

Author: Amir Jalili[1]

[1] *Zhejiang Key Laboratory of Quantum State Control and Optical Field Manipulation, Department of Physics, Zhejiang Sci-Tech University, Hangzhou 310018, China*

In the burgeoning age of artificial intelligence (AI) and advanced technologies, neural networks have emerged as powerful tools, revolutionizing various scientific domains. This lecture, "Recent Progress of Neural Networks in Nuclear Structures," explores the intricate workings of these algorithms and their transformative impact on nuclear physics.

We begin by examining the fundamental principles that underpin neural networks and their learning processes, drawing from seminal works such as V. Vapnik's "The Nature of Statistical Learning Theory" [1]. This foundational understanding sets the stage for our exploration into the application of neural networks in nuclear physics. The lecture introduces recent advancements in machine learning (ML) techniques tailored for nuclear physics, as discussed in Boehnlein et al.'s comprehensive review, "Colloquium: Machine Learning in Nuclear Physics" [2]. We highlight how these ML algorithms accelerate complex calculations, offering unprecedented efficiency and accuracy. A significant portion of the lecture is dedicated to the application of ML in predicting nuclear masses, a critical area of research. We reference Mumpower et al.'s work on "Physically Interpretable Machine Learning for Nuclear Masses" [3], which highlightes the potential of ML in enhancing our understanding of nuclear structures.

Furthermore, we extend our discussion to the prediction of ground-state charge radii using support vector regression, as demonstrated by Jalili and Chen [4]. Additionally, we explore the application of ML in predicting alpha and beta decay, with research on "Nuclear Beta-Decay Half-Life Predictions and r-Process Nucleosynthesis Using Machine Learning Models" [5]. Through these discussions, the lecture underscores the pivotal role of neural networks in advancing nuclear physics, paving the way for future innovations and discoveries.

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Energy Distributions and Absolute Yields Measurements of the Long-Range Alpha Particles and the Tritons in Thermal Neutron-Induced Ternary Fission of ^{235}U Using a Twin-Gridded Ionization Chamber

Authors: Zepeng Wu[1]; Jie Liu[1]; Haofan Bai[1]; Cong Xia[1]; Wenkai Ren[1]; Guohui Zhang[1]

[1] *Peking University, China*

The energy distributions and absolute yields of the long-range alpha particles and the tritons in thermal neutron induced ternary fission of ^{235}U were measured using a twin-gridded ionization chamber. The experimental result shows that the long-range alpha particles and the tritons can be separated obviously in the cathode amplitude vs anode amplitude two-dimensional spectrum, and the absolute yield of the long-range alpha particles can be obtained accurately by selecting the event region, and the yield is $(1.84 \pm 0.10) \times 10^{-3}$. For the tritons, the tritons can be distinguished from the long-range alpha particles in the anode amplitude vs anode rime time two-dimensional spectrum, but the yield of the tritons needs to be corrected after considering the influence of the long-range alpha particles. The absolute yield of the tritons is $(1.13 \pm 0.06) \times 10^{-4}$. The energy distributions of the long-range alpha particles and the tritons were determined by adjusting the mean energy and the FWHM of these particles to make sure that the simulated energy distributions are in good agreement with the experimental result. These results are discussed and compared with previous data.

Measurements of the Gamma-Ray Emission Cross Sections and

Angular Distributions from $(n, x\gamma)$ Reactions with 14.1 MeV Neutrons

Authors: Dimitar Grozdanov[1]; Nikita Fedorov[1]; Yuri Kopatch[1]; Pavel Prusachenko[1]; Ivan Ruskov[1]; Vadim Skoy[1]; Tatyana Tretyakova[1]; Petr Kharlamov[1]; Aleksandr Andreev[1]; Polina Filonchik[1]; Constantin Hramco[1]; Grigorii Pampushik[1]

[1] *FLNP, JINR*

The study of inelastic scattering of fast neutrons by atomic nuclei is of great importance for both fundamental and applied neutron-nuclear physics. Reactions induced by neutrons provide a unique source of information for describing the processes of strong interaction between nucleons. Inelastic scattering processes are utilized to study the characteristics of excited states of target nuclei [1]. The practical application of the $(n, n'\gamma)$ reaction necessitates the expansion and refinement of experimental data on this process. Research on the inelastic scattering of fast neutrons has recently become more active, driven by new prospects for nuclear energy production using fast neutron reactors. The purpose of this experiment was to refine the available data on emission cross sections and angular distributions from the inelastic scattering of 14.1 MeV neutrons by certain light nuclei. This work was conducted within the framework of the international TANGRA (TAgged Neutrons and Gamma RAys) project at the Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research in Dubna, Russia. Inelastic scattering was studied using the Tagged Neutron Method [2], in which neutrons with an energy of 14.1 MeV, produced in the $d(t, \alpha)n$ reaction, are "tagged" by detecting alpha particles. Gamma quanta from the $(n, n'\gamma)$ reaction were recorded using a new multidetector system [3]. The experimental data are presented and discussed in comparison with previously published results.

Acknowledgment
This work was conducted with financial support from the Russian Science Foundation (grant no. 23-12-00239).

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Research on Neutron Flux Measurement of CSNS Back-n

Author: Yijia Qiu[1]

[1] *CSNS*

The Back-streaming neutron beamline (Back-n) at the China Spallation Neutron Source (CSNS) is a newly built time-of-flight facility that provides white neutrons. The neutron flux of Back-n is of crucial importance for the feasibility studies and data analysis of experiments conducted utilizing this resource. In particular, the accurate flux is a prerequisite for conducting high-precision nuclear data measurement. The energy region of Back-n is exceptionally broad, spanning 10 orders of magnitude, and includes two endstations (ES#1 and ES#2) with various beamline configurations to accommodate different beam requirements. Consequently, systematic and comprehensive research is essential.
The flux from 0.3 eV to 150 keV was measured using a Li-Si monitor, while the flux from 150 keV to 300 MeV was measured using a fission ionization chamber. Experiments revealed and confirmed spectral differences between ES#1 and ES#2, with discrepancies reaching up to 20% in the 0.3 eV to 150 keV range, thereby clarifying longstanding inconsistencies in neutron capture cross-section

measurements. Additionally, it was observed that the shape of the energy spectrum remained unchanged despite the increase in CSNS accelerator power from 20 kW to 125 kW between 2018 and 2022. However, with the power expected to reach 170 kW in 2024, adjustments in the beam window structure have led to changes in the energy spectrum shape. Furthermore, it was found that the shape of the energy spectrum varies with the beam profile; the large beam spot (60-60-60) in ES#2, exhibits a consistent spectrum shape with the combined beam spot (60-30-30), yet it significantly differs from the small beam spot (30-30-30).

Geant4 Simulation of the Energy Resolution Function for the CSNS Back-n Facility

Author: Shengda Tang[1]

[1] *SYSU*

The Back-n facility at the China Spallation Neutron Source (CSNS) is a newly-built neutron time-of-flight facility providing white neutrons. It is characterized by the high neutron flux, wide energy range, and good energy resolution. As one of the essential parameters, the Energy resolution function (ERF) has a significant impact on nuclear data measurements and related neutron techniques, such as the neutron resonance analysis. The ERF represents the inherent broadening effects in the determination of neutron energy that are due to the spallation target assembly system. These effects can be studied using the Geant4 Monte-Carlo toolkit, benefiting from its flexible capabilities of particle tracking and information recording. In this simulation work, the model of the Target Moderator-Reflector (TMR) system was constructed. The TMR system primarily consists of 11 tungsten targets encapsulated in tantalum shells, reflector models, and different types of moderators, such as the decoupled water moderator (DWM), decoupled poisoned hydrogen moderator (DPHM), and coupled hydrogen moderator (CHM). The "equivalent moderate distance" (λ), defined as the product of the moderation duration of the neutrons inside the target assembly and their velocity at the target emitting surface, was obtained. The RPI (Researchers at Rensselaer polytechnic Institute, RPI) function was fitted using the parameter λ to derive the ERF, and it demonstrates effective performance within the 1-100 eV range.

Parallel Session 2: Nuclear data for applied and scientific purposes/Neutron detection & Methodical aspects

A Latest Result of the Neutron Capture Yield of ^{197}Au Measured by the C_6D_6 Experimental Set-up System in Back-n

Authors: Zhanqiao Cui[1]; Wei Jiang[2]; Gaole Yang[3]

[1] *SUSTech, China*

[2] *IHEP, CAS, China*

[3] *Sun Yat-sen University, China*

Since the foundation of Back-n beam line in CSNS, the capture cross section of $^{197}Au(\mathrm{n},\gamma)$ had been measured twice. Considering the lower energy zone and high level of background of previous results, however, we aim to process the yield result to 1 MeV, and analyze the resonance parameters: resonance peak, Gamma width and incident neutron width from 1 eV to 2 keV that belongs to the Resolved Resonance Range(RRR), using M6-version SAMMY code.

Direct Neutron Fluence Measurement with a Novel Spherical Long Counter

Authors: Changlin Lan[1]; Gong Jiang[1]

[1] *Lanzhou University, China*

Efficient and practical neutron detectors are crucial in many areas, including national security, medicine, crystallography, and astronomy. As commonly used neutron detectors, ^{3}He-gas-filled proportional counters still play an irreplaceable role in neutron fluence monitoring. ^{3}He tubes are used directly to detect the thermal neutron, but the measurable neutron energy range is often extended by adding moderating materials, so-called long neutron counters. Long cylindrical counters have attracted much attention due to their easy range extension. Nevertheless, the large fluctuation of the energy response due to the neutron incidence direction has not been solved, which directly limits the application of long counters in neutron flux detection. Therefore, it is necessary to conduct innovative research on neutron detectors to measure neutron fluence more accurately and conveniently. We previously reported the physical design of a new spherical long counter for the first time. The spherical long counter has a stable neutron fluence energy response in the energy range from 0.01 eV to 20 MeV, and the angular response difference in 4π space is no more than 16.5%. Here we show the further development of the spherical long counter and the results of its verification using different types of neutron sources., including D-D, D-T quasi-monoenergetic accelerator neutron source, Am-Be, ^{252}Cf isotopic neutron source, reactor thermal neutron source, and spallation neutron source. The angular and fluence responses of the spherical counter are examined, and the maximum angular response difference is 5.86%. The new detector we developed can adapt to the accurate measurement of multi-energy and multi-occasional neutron sources for direct neutron flux measurement.

Compact Time-of-Flight Neutron Spectrometer with Digital Signal Processing

Authors: Nikita Lashmanov[1]; Vladimir Yurevich[1]; Victor Rogov[1]; Sergey Sedykh[1]; Sergey Sergeev[1]; Mikhail Kapishin[1]; Semen Piyadin[1]; Sergey Bazilev[1]; Ilia Slepnev[1]; Valyo Velichkov[1]; Vladimir Tikhomirov[1]; Alexander Timoshenko[1]; Ivan Filippov[1]; Alexey Shutov[1]; Andrey Shchipunov[1]

[1] *FLNP, JINR*

A compact time-of-flight neutron spectrometer was developed as a part of the BM@N setup at the Nuclotron accelerator (JINR). The aim of the spectrometer is study of neutron emission from target spectator decay in heavy-ion collisions at 2 – 4 A GeV. The neutron spectra are measured at large angles in the energy range of 2 – 200 MeV using small flight path of 20 – 30 cm. Neutron detectors are based on stilbene scintillators coupled with four silicon photomultipliers. The time and shape of detector pulses are processed and recorded using TQDC modules developed in JINR. The characteristics of the spectrometer were studied in the last BM@N run with Xe + CsI collisions at 3.8 A GeV. The obtained time resolution of the detectors is $\sigma t \approx 110 - 120$ ps. A high degree of gamma-quanta suppression was achieved by the pulse shape discrimination method with a factor FOM ≥ 2. A careful study of γ-ray and neutron background was an important part of the experiment. It was shown that the developed TOF spectrometer can provide reliable measurement of neutron spectra. An example of neutron energy spectrum obtained for Xe + CsI collisions is shown and discussed.

Progress of Shielding Integral Experiments at CIAE

Authors: Shiyu Zhang[1]; yangbo Nie[1]; Yanyan Ding[1]; Qi Zhao[1]; Kuozhi Xu[1]; Xinyi Pan[1]

[1] *CIAE*

Beryllium, zirconium, and bismuth play crucial roles in nuclear science and technology: beryllium serves as a neutron reflector and moderator, zirconium is widely used in reactor structural materials, and bismuth is essential in accelerator-driven systems and lead-bismuth-cooled reactors. Accurate nuclear data for these materials are critical for shielding, reactor design, and nuclear safety assessments. To assess the reliability of nuclear data libraries, shielding integral experiments were conducted at the CIAE (CIAE) using the 400 kV nanosecond pulsed neutron generator. The experiments were performed on three different thicknesses of each material at six measurement angles, providing valuable benchmark data for the evaluation of CENDL-3.2, ENDF/B-VIII.0, JENDL-5, and JEFF-3.3.
To improve the accuracy of shielding integral experiments, several key optimizations were implemented. SiC detectors were introduced for associated particle detection, enabling simultaneous measurement of D-D and D-T neutron yields, which effectively resolved the issue of D-D reactions induced by deuterium deposition on the target. A monitor detector system was deployed at 0° and 90°, and its neutron time-of-flight spectra were analyzed using the MLEM algorithm, achieving a source neutron pulse time distribution precision better than 10^{-3}. To validate the reliability of the experimental platform, polyethylene benchmark experiments were conducted at 47°, 61°, and 79° to examine the consistency of C/E values across different energy regions.
For beryllium, CENDL-3.2 demonstrated reasonable agreement with experimental data in the elastic scattering region, with minor overestimations observed at small angles. However, in the $(n,2n)$ reaction region, significant deviations in spectral shape were present, particularly at larger angles. ENDF/B-VIII.0 and JENDL-5 provided good agreement at small angles but underestimated neutron spectra at larger angles. JEFF-3.3 consistently underestimated experimental results across all angular ranges, highlighting the need for further refinement in the $(n,2n)$ reaction region.
For zirconium, CENDL-3.2 showed increasing C/E values with angle in the (n,el) region, underestimating at small angles and overestimating at large angles, while the other libraries remained stable but consistently overpredicted. In the (n,inl)D region, CENDL-3.2 and JEFF-3.3 overestimated at all angles, while ENDF/B-VIII.0 was notably lower. In the (n,inl)C region, JEFF-3.3 underestimated at large angles with decreasing cross-section values. In the $(n,2n)$ region, CENDL-3.2 and JEFF-3.3 predicted lower neutron spectra than experimental results, with their cross-sections lower than ENDF/B-VIII.0 and JENDL-5.
For bismuth, CENDL-3.2 showed reliable performance across various scattering regions, particularly at intermediate angles. The discrete inelastic scattering region showed that JEFF-3.3 provided better agreement at small angles, whereas JENDL-5 was more accurate at larger angles. The continuous inelastic scattering region indicated that JEFF-3.3 provided the best overall agreement. ENDF/B-VIII.0 provided the closest agreement in the $(n,2n)$ reaction region, while JENDL-5 demonstrated stable performance across multiple energy regions.
These results highlight the importance of continuous experimental validation for improving nuclear data libraries. The study provides valuable benchmark data for neutron transport simulations, shielding analysis, and nuclear reactor applications. Further refinements in nuclear models, particularly in the $(n,2n)$ reaction region, are necessary to enhance the reliability of nuclear data for beryllium, zirconium, and bismuth.

Dataset Preparation Software for Training a Neural Network to Determine the Boundaries of Full Energy Peaks in Gamma Spectra

Authors: Vladimir Galustov[1]; Dmitrii Grozdov[1]

[1] *FLNP, JINR*

Gamma spectra processing is one of the most time-consuming stages of instrumental neutron activation analysis. Since spectra contain a large number of multiplets, their processing by classical mathematical methods leads to high uncertainty in the areas of full energy peaks. In this case, it is necessary to perform manual fitting of peak boundaries. This process is planned to be automated using a neural network. However, for its training dataset should be created.
The software for the boundaries of full energy peaks dataset preparation was designed. The development was carried out in the object-oriented programming language C# (.NET Framework 4.8.1) using API Windows Forms. To create a dataset, about 70000 gamma spectra were selected. In order to increase spectra processing performance, a flexible control system was introduced, allowing to work in the program in three modes: keyboard only, mouse only and keyboard + mouse. Addition-

ally, vertical and horizontal zoom functions were added for more accurate processing. To access the application, the user authorization system was implemented *via* MS SQL Server, used to record the parameters of processed full energy peaks into the database.

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Analysis of Chlorine Neutron Capture Experiment for Efficiency Calculation Validation

Author: Costa Hramco[1]

[1] *FLNP, JINR*

The TANGRA project is aimed at studying the inelastic scattering of 14.1 MeV neutrons from the ING-27 neutron generator on various atomic nuclei using the tagged neutron method. To register gamma rays from the interaction of neutrons with nuclei, we use HPGe and $LaBr_3$(Ce) detectors. To perform high-precision measurements, the energy calibration and counting efficiency of the detectors were determined using standard point gamma sources and prompt gamma rays from neutron capture on chlorine nuclei. In addition to the experimental data, the dependences of the gamma-quanta registration efficiency on energy for two types of detectors were obtained using Monte Carlo (MC) simulations in GEANT4. In this work we will present the results of efficiency measurements and compare them with calculated data.

Fast-Timing Measurement at CSNS

Author: Guangxin Zhang[1]

[1] *Sun Yat-sen University, China*

Fast-timing measurement of nuclear excited states using $LaBr_3$ detectors has gained a lot of attention in experimental nuclear physics. This is because that the lifetime information is more sensitive to the intrinsic nuclear structure than the level energy. In this talk the speaker will briefly introduce the idea of constructing a fast-timing detector array by $LaBr_3$ detector coupled with digital DAQ system at CSNS and show some preliminary result.

New Measurement of ^{165}Ho Neutron Capture Cross Section Data

Authors: Suyalatu Zhang[1]; Ruirui Fan[2]; Wei Jiang[2]; Dexin Wang[1]

[1] *IMUN, China*

[2] *IHEP, CAS, China*

The neutron capture cross section data for ^{165}Ho were measured at the Back-streaming White neutron beam line (Back-n) of China Spallation Neutron Source (CSNS) using total energy detection systems, which is comprise a set four C_6D_6 scintillator detectors coupled with pulse height weighting techniques.
The resonance parameters were extracted using the multilevel, multichannel R-matrix code SAMMY,

fitting the measured capture yields of the ^{165}Ho(n,γ) reaction in the neutron energy range below 100 eV. Subsequently, the resonance region capture cross sections were reconstructed based on the obtained parameters. Additionally, the unresolved resonance average cross section of ^{165}Ho(n,γ) reaction was determined relative to the standard ^{197}Au sample within the neutron energy range of 2 keV to 1 MeV. The experimental data were compared with the recommended nuclear data from the ENDF/B-VIII.0 library, as well as TALYS-1.9 code calculations. The comparison indicates that the measured ^{165}Ho(n,γ) cross sections are in good agreements with these data. The present results are significant for evaluating the ^{165}Ho neutron capture cross section data, enhancing the quality of evaluated nuclear data libraries, and providing valuable guidance for nuclear theoretical models and nuclear astrophysical studies.

Developing and Optimizing Signals Processing Techniques for the Tangra Project Experimental Setups

Authors: Petr Kharlamov[1]; Nikita Fedorov[1]; Dimitar Grozdanov[1]; Yuri Kopatch[1]; Pavel Prusachenko[1]; Constantin Hramco[1]; Ivan Ruskov[1]; Tatyana Tretyakova[1]; Vadim Skoy[1]; Aleksandr Andreev[1]; Polina Filonchik[1]; Grigorii Pampushik[1]

[1] *FLNP, JINR*

In the scope of the "TANGRA" (TAgged Neutrons and Gamma RAys) project established at the Frank Laboratory of Neutron Physics (JINR, Dubna), several experimental setups of different configurations [1] were devised and employed to study the inelastic scattering of neutrons with an energy of 14 MeV on atomic nuclei using the tagged neutron method [2].
One of "TANGRA" setups utilizes two high-purity germanium (HPGe) semiconductor detectors [3] to measure gamma-radiation resulting from the neutron-induced reactions. The selection of HPGe was made on the basis of its smaller band gap and the lowest energy for formation electron-hole pairs in comparison to other semiconductors.
In the "TANGRA" experiments, customized digitizers are employed, with the resulting signals subsequently fed into the "Romana" software, which was developed as a part of the project. The software is used for recording and processing of signals from the detectors, and it utilizes a specialized approach for acquiring spectrometric information.
Nevertheless, it has been observed that the energy resolution significantly deteriorates as the detector load increases. One potential solution to mitigate this loss of resolution is to expand the processing area of signals. However, this approach may cause the processing system to be unable to maintain the required data processing rate, potentially leading to data loss.
Consequently, alternative digital signal processing techniques were developed, and optimal parameters were identified to achieve the best energy resolution.
The purpose of this report is to present the findings from the latest studies on optimizing parameters for various methods used to process digitized signals from HPGe detectors.

Acknowledgment
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Measurement of CSNS Back-n Neutron Beam Profile with Micromegas

Authors: Yang Li[1]

[2] *CSNS*

The Back-n white neutron beam line, which uses back-streaming white neutrons from the spallation target of the China Spallation Neutron Source, is used for nuclear data measurements. A Micromegas-based neutron detector with two variants was specially developed to measure the beam spot distribution for this beam line. In this article, the design, fabrication, and characterization of the detector are described. The results of the detector performance tests are presented, which include the relative electron transparency, the gain and the gain uniformity, and the neutron beam profile reconstruction capability. The result of the first measurement of the Back-n neutron beam spot distribution is also presented.

The Reconstruction Algorithm for Neutron/Gamma Imaging Detectors Based on Artificial Neural Networks

Authors: Jifeng Han[1]; Penghui Wang[1]; Yiyang Long[1]; Chaoyang Zhao[1]; Chuqi Yi[1]; Zhouhang Duan[1]

[1] *Sichuan University, China*

Gamma and neutron imaging are crucial non-destructive testing techniques which have been widely used in nuclear safety, national security, materials characterization, and cultural heritage preservation. While the hit position reconstruction algorithms are key issues to improve the image fidelity and accuracy. A 2D planar neutron and gamma imaging system based on a monolithic lithium glass scintillator and a silicon photomultiplier (SiPM) array have been developed. To overcome the edge distortion of the traditional Center-of-Gravity (COG) reconstruction method, several distinct algorithms have been studied and compared, which including the Truncated COG (TCOG), the Particle Swarm-Optimized Least Squares Estimator (PSO-LSE) method and artificial neural networks (ANN) including fully connected neural network (FCNN), residual neural network (ResNet), and convolutional neural network (CNN).
The imaging performance have been evaluated using three metrics: flood image uniformity, useful field-of-view, and position linearity response. The result indicates that the ANN methods represent significant advancement over traditional reconstruction method and achieves better metrics values. These methods were used to reconstructed the images of the '720' and 'SCU' models, and the imaging performance were quantitative evaluated by Contrast-to-Noise Ratio, Information Entropy, and Gradient Magnitude. The analysis demonstrates that the FCNN method exhibits best image quality. The spatial resolution were calculated using a knife-edge slit phantom by the modulation transfer function (MTF), and the MTF10 value of 0.45 mm have been achieved for the FCNN method. These methods have been applied on the experimental system, and validated by the flood image and pinhole image, which indicate the ANN models trained by the simulation data can be applied on the experimental data although some artifacts are introduced. This study demonstrates that ANN method significantly enhances both positioning accuracy and computational efficiency, ultimately resulting in superior quality for neutron/gamma imaging.

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Estimation of Cosmic Muon-Induced Neutron Yields via Muon Spallation in Deep Underground Environments Using (e, e'xn) Cross-Section Measurements of ^{181}Ta

Authors: Yuqi Yang[1]; Xiufeng Weng[2]; Yigang Yang[1]

[1] *Tsinghua University, China*

[2] *NINT, China*

Cosmic muon-induced fast neutrons are one of the main sources of neutron background in deep underground environments. Due to the high energy and low flux of cosmic muons, it is challenging to directly measure the neutron yield. According to the Weizsäcker-Williams virtual photon method, when the energy transfer is less than one-tenth of the kinetic energy of the lepton, the Coulomb excitation process of leptons with the same relativistic factor is analogous. Therefore, by measuring the neutron yield produced by electron Coulomb excitation, we can estimate the cosmic muon-induced neutron yields via muon spallation in detectors and provide an estimate of the lower bound of neutron background in deep underground measurements. In this study, the cross sections of the ^{181}Ta$(e, e'xn; x = 1\text{–}8)^{181-x}$Ta reactions induced by electrons with energies ranging from 20 to 110 MeV were measured. Discrepancies between the experimental data and the TALYS code predictions were observed, which were attributed to the nuclear level density model in TALYS not accurately describing the Ta nuclei. Consequently, the model selection and its parameterization were optimized. Based on the measurement results, the neutron yield produced by cosmic muons in detectors—serving as a lower limit for the neutron background in deep underground measurements—was estimated per unit mass of detector material per unit time.

Measurement of the ^{6}Li$(n, t)^4$He Cross Section with Multi-purpose Time Projection Chamber at the Back-n White Neutron Source of CSNS

Authors: Hongkun Chen[1]; Han Yi[2]; Tianzhi Chu[3]; Haizheng Chen[4]; Yang Li[5]; You Lv[5]; Ruirui Fan[5]

[1] *Sun Yat-sen University, China*

[2] *IHEP, CAS, China*

[3] *Shenzhen University, China*

[4] *Xi'an Jiaotong University, China*

[5] *CSNS*

Neutron-induced reaction ^{6}Li$(n, t)^4$He plays an important role in nuclear energy and nuclear data evaluation. The cross section of ^{6}Li$(n, t)^4$He has been adopted as standard in the energy range of 0.0253 eV–1.0 MeV [1], and is commonly used as reference for other cross section measurements. Previous works have shown non-negligible discrepancies in cross section results [2,3,4], and the angular distribution data in high neutron energy region are scarce.
The multi-purpose time projection chamber (MTPC), which is designed for measuring neutron nuclear data of varied field, has been fabricated in the back-streaming neutron facility (Back-n) at China Spallation Neutron Source (CSNS). The detector is able to measure the charged particles emission from neutron-induced reactions. We have carried out an experiment with MTPC for measuring the total cross section as a function of neutron energy and the differential cross section as a function of the product particle emission angle of ^{6}Li$(n, t)^4$He in the energy range of 0.5 eV–-100 keV. In the experiment, we use a Lithium Fluoride sample with the aluminum substrate as the target, and a gas composition of 93% Argon and 7% Carbon Dioxide is used. Different experimental conditions were set for measuring different emission particles.
In this work, detector design and experiment setup are firstly introduced. Then the data analysis of MTPC is discussed in detailed, and results of total cross section and differential cross section is presented. Finally, an upgrade on the detector is shown as a new measurement of the ^{6}Li$(n, t)^4$He in the energy range of 100 keV–10 MeV is on schedule.

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Characterization of an EJ-200 Plastic Scintillator Array for Experiments with 14-MeV Tagged Neutrons Using Carbon and Polyethylene Samples

Authors: Pavel Prusachenko[1]; Dimitar Grozdanov[1]; Nikita Fedorov[1]; Yuri Kopatch[1]; Vadim Skoy[1]; Ivan Ruskov[1]; Tatyna Tretyakova[1]; Petr Kharlamov[1]; Aleksandr Andreev[1]; Grigorii Pampushik[1]; Costa Hramco[1]; Polina Filonchik[1]

[1] *FLNP, JINR*

The main goal of the TANGRA (TAgged Neutrons and Gamma RAys) project at the Frank Laboratory of Neutron Physics (JINR, Dubna) is to study the interaction of 14.1 MeV neutrons with various nuclei. One of the experimental setups developed within the project consists of an array of 20 EJ-200 plastic scintillators and is designed to study the angular distributions of neutrons and γ-rays resulting from the elastic and inelastic scattering of 14.1 MeV neutrons. The motivation for this work is the problem of computational and experimental determination of the detection efficiency of organic scintillation detectors for neutron energies above 8 MeV. In particular, the issue of simulating the efficiency of EJ-200 scintillators arises from contradictory and insufficient data regarding the light output functions for secondary charged particles emitted during neutron interactions with this scintillator material. Another pressing issue is the development of novel methods for the experimental verification of the detection efficiency of neutron detectors used in tagged neutron beam experiments.
To resolve these issues the energy dependence of the light output for secondary charged particles (protons and α-particles) was measured in the neutron energy range of 1.5 to 14.0 MeV for an array of EJ-200 scintillation detectors. The scattering of a tagged neutron beam with an energy of 14.1 MeV on graphite and polyethylene samples was used to obtain neutrons with known energies at various angles. Based on the obtained data, both the response function and the intrinsic efficiency of the detectors used were simulated in GEANT4. To verify the simulated efficiency, a method based on the measurement of elastically scattered neutrons from the ^{1}H(n,n_0)^{1}H reaction was implemented.

Acknowledgment
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Model of Experiments and a Method of Analysis of Data for Determination of Absorbed Dose of Samples for Applied Research at the NICA Facility

Author: Nelli Pukhaeva[1]

[1] *FLNP, JINR*

Model of experiments for applied research at the Nica facility are developed and manufactured. Model includes two ionization chambers IK-1, IK-2, strip and phosphor chambers for measure profile with coordinate and intensity of beam and various sample holders with different geometry. At those chambers, the materials of electrodes are used different, at the IK-1 it is foil-clad fiberglass, for the IK-2 are taken foil-clad polyimide One of the ionization chambers will be assembled before irradiated samples, other mounted after. The strip chamber will be added for measure the coordinate of beam or it will replace the IK-2 ionization chambers. By the phosphor chambers will be tracked and follow the profile of beam. The chambers IK-1 and IK-2 have been tested on a 60Co gamma source

and a 150 MeV proton beam at the accelerator "Prometheus" at the Tsyba MRRC (Obninsk).
A method for analysis of the intensity and profile data by using the 3.8 GeV/nucleon 124Xe54+ ion beam data is developed. The method is necessary to provide the precise determination of the fluence and absorbed dose for irradiated materials. The beam profile and intensity distributions together with overall intensity and duration of radiation exposure are used for the developing the method of analyzed for the set of samples of different geometry and chemical composition. The analyzed raw data were taken in the long-term exposure mode. Software was developed for investigation of intensity and profile of the beam. Because the data is a sequence of intensity values per short run, each run will be analyzed separately. The intensity will be measured before collision with the target for what were require additional study on how the intensity decreases after passing through each detector and approximation of the intensity, which reaches a particular sample. Distributions of beam intensity and profile versus exact duration of irradiation will be obtained for each investigated sample. Each sample will be at the beam sequentially in series that results in individual profile for particular sample. The distributions will be obtained by the developed software for the input data and further precise calculation of energy losses and absorbed dose in irradiated materials. Those several different parameters necessary to investigate and explore, the uncertainty is under study.
The study is performed within the ARIADNA Collaboration.

Constrained Optimization of Microscopic Nuclear Data via Integral Experiment-Informed Frameworks

Author: Jiahao Chen[1]

Co-authors: Tao Ye [1]; Bo Yang [1]

[1] *Institute of Applied Physics and Computational Mathematics, China*

Current microscopic nuclear data face two major challenges: significant discrepancies among datasets from different sources and missing data points at specific energy levels. To maximize the utilization of existing data, this study proposes constraining differential experimental results through integral experiments, thereby enhancing data consistency and completeness.
Our investigation focuses on two microscopic physical quantities: fission yields and the Prompt Fission Neutron Spectrum (PFNS). In fission yield research, leveraging the analytical strengths of machine learning in complex data processing, we employ a Bayesian Neural Network (BNN) to model experimental data on neutron-induced ^{239}PU fission yields. The objective is to uncover latent energy-dependent correlations and establish an energy dependence framework. For optimizing the PFNS, we developed a random sampling methodology. The proposed methodology begins with generating PFNS candidate sets through randomized sampling that incorporates microscopic experimental measurements and their uncertainty ranges, followed by full-core neutron transport simulations using the JMCT code for critical benchmark configurations under these sampled PFNS conditions. The PFNS is then iteratively optimized through systematic comparison between calculated effective multiplication factors keff and experimental benchmark values, thereby establishing a self-consistent framework bridging microscopic data uncertainties and macroscopic reactor physics.

Acknowledgment
Present study was supported by the National Natural Science Foundation of China (no.12347126)

Measurement of Relative Differential Cross Sections of the ^{1}H(n, n)^{1}H Reaction in the Neutron Energy Range from 0.45 MeV to 8.5 MeV

Author: Kang Sun[1]

[1] *CSNS*

The ^{1}H(n, n)^{1}H reaction is important for fundamental physics research, neutron cross-section standards, and nuclear data evaluation. However, there are few differential cross-section data for this reaction in several MeV neutron energy regions. The relative differential cross sections of the ^{1}H(n, n)^{1}H reaction was measured at the Back-n white neutron source of the China Spallation Neutron Source (CSNS). A 500 nm thick Mylar film was used as the sample for experimental measurements. The charged particles produced by the ^{1}H(n, n)^{1}H reaction were detected using the ΔE–E telescope array and Silicon detector array of the Light-charged Particle Detector Array (LPDA) spectrometer. The relative differential cross sections of the ^{1}H(n, n)^{1}H reaction in the center-of-mass system from 66° to 142° in the neutron energy range from 0.45 MeV to 8.5 MeV were obtained from 8 Silicon detectors in the ΔE–E telescope array and the Silicon detector array. This work is an extension of the previous measurement in the neutron energy range from 6 MeV to 52 MeV. The present results are in good agreement with the previous measurement results and evaluation data.
Keywords: ^{1}H(n, n)^{1}H reaction, differential cross sections, Back-n white neutron source, LPDA

Upgrade Plan for Spallation and Transmutation Reaction Models in ADS Studies

Author: Rong Wang[1]

[1] *IMP, CAS, China*

In accelerator-driven subcritical nuclear system (ADS) simulations, spallation and transmutation reaction models are typically employed due to the lack of the database in medium-to-high energy range. However, some model deviations have been identified, particularly in high-energy neutron-induced reactions on actinide nuclides. This paper presents a comprehensive verification of the current intranuclear cascade model and de-excitation models in terms of the differential cross-section data. Furthermore, we propose an upgrade plan for the spallation and transmutation reaction models by incorporating nuclear medium effects and nucleon-nucleon short-range correlations, which are currently missing in the existing Monte Carlo simulation framework. These model improvements are expected to enhance the accuracy of full-energy range and multi-particle Monte Carlo transport simulations, thereby advancing the ADS research and design and many other simulation studies in medium-to-high energy region.

Progress in Measurement of the Capture Reaction Cross Section of ^{242}Pu Induced by Thermal Neutron Based on Activation Method

Author: Yonggan Zhang-Sun[1]

[1] *NINT, China*

The relative deviation of the thermal capture cross-section of ^{242}Pu in the mainstream nuclear database is more than 10%, and the uncertainty of its capture cross-section in the intermediate and fast neutron region is over 30%. In this paper, the thermal capture cross-section measurement of ^{242}Pu was carried out based on activation method. The irradiation experiment was carried out on the running-rabbit irradiation channel of Xi'an pulse reactor. The neutron flux was measured with the thermal capture cross section of ^{197}Au. The capture reaction product ^{243}Pu was analyzed by the γ energy spectrum, and ^{243}Am was analyzed by mass spectrometry. The thermal capture cross-section obtained by γ energy spectrum analysis are 21.12 ± 2.36 b. Mass spectrometry experiments and data processing are being carried out. The main contributions of the uncertainty of that are the peak counts and branch ratio of 84keV of ^{243}Pu.The next step is to optimize the matrix material and shielding method of

the sample, and to carry out the measurement of ^{243}Pu characteristic ray branch ratio based on the combined analysis of mass spectrometry and energy spectrum, so as to reduce the uncertainty of thermal capture cross-section based on the γ spectrum analysis.

Non-Statistical Effects in (p, γ) Reactions and in β-Decays

Author: Igor Izosimov[1]

[1] *FLNP, JINR*

The characteristics of various nuclear processes are rather simple to calculate in statistical model [1,2]. In particular, the transition-width distribution is described by the Porter–Thomas equation, there are no correlations between different partial widths, the strength function of β-transitions $S_\beta(E)$ depends smoothly on energy, and the ratios of the amplitudes for decay via various spin channels follow the Cauchy distribution.
Deviations from the statistical theory have been observed in $(p, p'\gamma)$ and (p, γ) reactions, β^- and β^+/EC-decays [1-4]. Non-statistical effects are closely related to the symmetry of the nuclear interaction and intermediate resonance structure [3,4].
In this report non-statistical effects manifested in reactions involving low-energy protons and in β-decay are analyzed. In (p, γ) reactions for non-analog resonances in $N > Z$ nuclei non-statistical effects are connected with neutron excess and domination of the simple configuration such as proton-particle neutron-hole in the wave function of nonanalog resonances [1–3]. The association of non-statistical effects in (p, γ) reactions and in the β-decays with spin–isospin $SU(4)$ symmetry are discussed. The non-statistical effects taking into account non-statistical correlations in $E2$ and $M1$ γ-transitions for the γ-decay of the non-analog resonances in (p, γ) reactions are analysed.

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Measurement of the Differential Cross Sections of ^{6}Li$(n, t)^4$He Reaction at CSNS Back-n White Neutron Facility

Authors: Wei Jiang[1]; Xiaohui Sun[2]; Kang Sun[1]; Qiuyue Luo[1]

[1] *CSNS*

[2] *Huzhou University, China*

The cross section of ^{6}Li$(n, t)^4$He reaction is adopted as standards up to 1 MeV due to its relatively high cross-section. However, in the neutron energy above 0.5 MeV, it was indicated that the cross section might be overestimated by evaluated data, such as ENDF/B-VIII.0 and JEFF-3.3 [1]. Besides, due to the high Q value (4.78 MeV), the ^{6}Li$(n, t)^4$He reaction is widely used in neutron detection in various nuclear physics experiment and other applications, for example, tritium production for fusion reactors. However, in few MeV energy region, the experimental data on the ^{6}Li$(n, t)^4$He reaction are quite limited, and discrepancies among different measurements and evaluations were found for an energy range above 3.0 MeV [2]. In addition, the differential cross section of ^{6}Li$(n, t)^4$He reaction could provide information on the excitation levels of the compound nucleus ^{7}Li.

In order to resolve the discrepancies and to improve the accuracy of ^{6}Li(n, t) ^{4}He differential cross section in the 3-6 MeV neutron energy region, the ^{6}Li$(n, t)^4$He reaction was measured at the China

Spallation Neutron Source (CSNS) Back-n white neutron source. The differential cross-sections of the ^{6}Li(n, t)^{4}He reaction at 7 detection angles ranging from 21.4° to 90° are obtained with Si-PIN detectors for neutron energy from 40 keV to 6.8 MeV. The measured cross section will be presented in the talk, the comparison between the present differential cross-sections with existing data and evaluations, as well as R-matrix calculations will be shown.

Parallel Session 3: Neutron detection & Methodical aspects/Physics of ultracold neutrons

Concept of the UCN Source at the WWR-K Reactor (AlSUN)

Author: Kylyshbek Turlybekuly[1]

[1] *FLNP, JINR*

A concept is presented for an ultracold neutron (UCN) source with a superfluid helium converter placed in the thermal column of the WWR-K research reactor (Almaty, Kazakhstan). Similar source designs are employed in the existing TRIUMF project (Vancouver) [1] and the proposed project at the WWR-M reactor (Gatchina) [2]. The main distinguishing features of our concept are more efficient systems for accumulating UCNs in the source and transporting them to experimental facilities. This is achieved by separating the heat and UCN fluxes from the source, as well as by lowering the temperature of the helium converter below approximately 1 K.

In this work, we build on the parameters of UCN source concepts from existing projects that involve accumulating UCNs in superfluid helium, and we aim to refine these parameters for developing a UCN source at the WWR-K reactor. We perform an assessment of the achievable UCN density both in the source and in the experimental setup. We also discuss the challenges that must be resolved to justify the feasibility of such a project and to achieve the highest possible performance of the source.

Acknowledgment
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VCN Test Facility as the Initial Phase of the UCN Facility Development

Author: Alexander Popov[1]

Co-authors: Alexander Frank [1]; German Kulin [1]; Vladimir Kurylev [1]; Victoria Shpilevskaya [1]; Maxim Zakharov [1]

[1] *FLNP, JINR*

A new high-brilliance ultracold neutron (UCN) source is planned to be created for the FLNP JINR pulsed reactor. It is planned to carry out a series of investigations using VCNs, which are essential for the design of the main elements of this UCN source. For this purpose, a test VCN channel at the third channel of the IBR-2M reactor will be built. This will allow us to obtain a VCN beam with a wide range of velocities. It has been estimated that the flux of desired neutrons with velocities of 20 ± 1 m/s will be approximately 10^5 n/s in ideal case. The source will be operational for a relatively

long period of work on the project and will be replaced by the main source at the end. The report is devoted to the design of the VCN test channel.

Optimisation of Bulk Density of Nanodispersed Medium to Maximise Its Reflectivity for Very Cold Neutrons

Author: Alexander Nezvanov[1]

[1] *FLNP, JINR*

Nanodispersed media, such as nanodiamond powders, are efficient diffuse reflectors of low-energy neutrons [1]. This is due to the intense coherent elastic scattering of such neutrons on individual nanoparticles of a few nanometers in size. Such reflectors can be used for quasi-specular reflection of cold neutrons [2] and in the design of very cold neutron sources for their directed extraction [3]. However, the influence of the bulk density of the nanodispersed medium (packing coefficient) on the reflection efficiency has not yet been studied.
The point is that the transport cross-section for very cold neutrons, which determines the reflectivity of the nanodiamond powders of finite thickness, should increase as the packing factor of nanoparticles in the volume increases. Nevertheless, with a significant increase in the packing factor, when the nanoparticles in the medium are so close together that neutrons can no longer scatter on them independently, the transport cross-section should start to decrease [4]. Theoretically, it should fall to almost zero and be determined only by incoherent scattering on individual nuclei in the case where the nanoparticles completely fill the entire available volume, since the fluctuations of the medium density, on which coherent scattering occurs, disappear.
The change in small-angle neutron scattering intensities with increasing media density has previously been observed when studying the fractal structure of unmodified nanodiamond powders produced by detonation synthesis [5-7]. Predominantly diamond nanoparticles in such powders form unbreakable primary clusters up to 100 nm in size, which do not allow achieving significant powder compaction. In practice, the bulk density of unmodified powders reaches $0.2 - 0.3$ g/cm^3.
In our study, to verify the influence of bulk density on the transport cross-section and reflection of very cold neutrons, we used deagglomerated nanodiamond powder, in which the nanoparticle clusters are almost completely destroyed, and the bulk density reaches $0.6 - 0.9$ g/cm^3 [8]. Total cross-sections and small-angle scattering intensities of thermal neutrons were measured at the YuMO small-angle scattering facility of the IBR 2 pulsed research reactor at the Joint Institute for Nuclear Research. The experimental results will be presented and discussed.
The study was initiated under grant ANR-20-CE08-0034, France.

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Test of the Performance of an LGAD-Based Zero-Degree Detector on the CSNS Back-n Beamline

Author: Yuhang Guo[1]

[1] *CSNS*

To establish a comprehensive and reliable nuclear database for neutron-induced processes, the development of accelerator-driven system (ADS) technology is essential. Despite many efforts have been made, accurate measurements of light charged ions (LCIs), including protons, tritium, and α particles, at zero degrees in the beam direction remain challenges. Conventional detectors often fail to operate consistently under intense neutron beam fluxes, severely limiting their applications as zero-degree detectors (ZDDs). However, the recent development of low-gain avalanche diode (LGAD) technology, designed to meet the strong demands of the ATLAS experiment during the high-luminosity phase of the Large Hadron Collider (LHC), offers a promising solution. With its ability to withstand 2.5E15 1 MeV neq/cm^2 irradiation, 50-μm active thickness, 30-ps timing resolution, cost-effectiveness, and excellent radiation hardness, the LGAD detector emerges as a strong candidate for ZDD applications in neutron-induced process measurements. This report presents a performance evaluation of the LGAD detector as a ZDD on the back-streaming neutron (Back-n) beamline at CSNS. Through cross-section measurements of the ^{6}Li$(n, t)\alpha$ reaction, the LGAD demonstrates excellent performance, showing strong agreement with data from the evaluated nuclear data file (ENDF).

Parameters of Extracted Neutron Beams of the IREN Resonance Neutron Source at the FLNP, JINR

Author: Almat Yergashov[1]

Co-authors: Sergey Borzakov [1]; Evgenii Golubkov [1]; Costa Hramco [1]; Yuri Kopatch [1]; Valery Kuznetsov [1]; Saltanat Mazhen [1]; Ludmila Mitsyna [1]; Natalia Rebrova [1]; Anatolii Rogov [1]; Pavel Sedyshev [1]; Igor Zhironkin [1]; Artem Zontikov [1]

[1] *FLNP, JINR*

There are several instruments on the flight bases of the IREN facility that are used to carry out measurements on the transmission, capture and scattering of neutrons on samples.
The analysis of experimental data, the assessment of the possibility of conducting, and the planning of experiments with IREN beams require knowledge of the facility parameters: the absolute fluxes of resonance and thermal neutrons at the sample locations, the dependence of the neutron fluxes on the neutron energy, and the energy resolution function of the instruments.
The fluxes of thermal and resonance neutrons, the dependence of the neutron flux on their energy, and the resolution function were determined experimentally for 11-meter and 60-meter bases (on channels 4 and 3) of the IREN facility, JINR. The experimentally determined parameters are compared with the results of Monte Carlo calculations.

Application of Micropattern Detectors from High-Energy Physics for Neutron Detection

Author: Temur Enik[1]

[1] *FLNP, JINR*

The work presents application of the particle detection techniques developed in the field of High-Energy Physics (HEPh) to neutron detection. This area has been growing rapidly over the past decade due to ongoing developments at CERN, JINR and other research centers.

Mictro-Pattern Gaseous Detectors (MPGD), such as GEMs, or Gas Electron Multiplier, Micro-Megas, micro-RWELL, micro-GROOVE, are being produced at CERN and became available for other laboratories. They are used for charged particle detection, operate with the gas gain of about 10,000 and provide good spatial and time resolution. An MPGD detector, which has the entrance window made of a thin neutron-convering foil, turns into a unique detector which is sensitive not only to charged particle, but also to neutrons.

JINR develops the coating technique which allows a thin metalized maylar foil to be covered with a thin layer of B_4C. The coating can be done for a large area with extremely high precision. Depending on the application, the thickness of the B_4C layer can be between 50 nm and 1 um with a variation of about few nanometers over the whole foil area.

Neutron detection capability of a triple GEM with a B4C-covered entrance window is presented in the talk.

Study of SEU Effects and Mitigation Measures for Kintex Ultra-Scale FPGA using CSNS Neutron Beam Lines

Author: Changqing Feng[1]

[1] *USTC, China*

The damage effect caused by high energy particles, especially Single Event Upset (SEU), is one of the major factor of failure in SRAM-based FPGA components, for applications in harsh radiation environments, such as space-borne payloads and ground-based large scale particle experiments. With the advancement of the integrated circuit industry, in nowadays the feature size of high-performance FPGAs has entered the scale of nanometers, making SEU effects increasingly severe.
Traditionally, the evaluation of single-event effects (SEE), as well as the verification of mitigation measures, mainly rely on heavy ion beam testing, which has been regarded as the gold standard in the past years. However, the operation of SEE testing using heavy ion beam is relatively complex and expensive. Moreover, the availability of heavy ion beam facilities is limited, conflicting with the rising demand of chip testing and verification.
During the past several years, the presenter's team has been cooperated tightly with the CSNS Back-n group, to conduct research on radiation-hardening and high-reliability design methodologies for high-performance FPGA devices, using neutron beam lines. We employed neutron time-of-flight (TOF) methodology to characterize the correlation between single-event upset (SEU) cross-section (in BRAM and CRAM) and incident neutron kinetic energy in a Kintex UltraScale FPGA device, which is a representative high performance SRAM-based FPGA with 20 nm CMOS technology. Radiation-hardening measures for SEU mitigation were designed and experimentally validated, as well. The results have been published in the IEEE TNS and JINST journals.
The project will be further extended in future. Our hope is to systematically investigate the energy-dependent correlation between incident neutron kinetic energy and recoil ion's linear energy transfer (LET), both by Monte Carlo simulation for CMOS devices and by carrying out more experiments. We hope providing theoretical foundations for domestic radiation effects evaluation infrastructure development. Our ultimate goal is to establish an effective and systematic methodology for the research and evaluation of SEU in high-performance FPGA devices.

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Novel Neutron Detector Design for Accurate Measurement in Ultra-Iron Nucleosynthesis Study

Authors: Jianqi Chen[1]; Yongce Gong[1]; Junsheng Jing[1]

[1] *Great Bay University, China*

The current polyethylene-moderated ^{3}He neutron detector suffers from low detection efficiency and a dependence on the neutron energy and emission angle, which hinders the accurate measurement of critical data for astrophysical modeling, such as (α, n), (γ, n) cross sections, and β-delayed neutron emission probabilities. To address this, a novel detector design was proposed, using a large spherical heavy water tank, and a layer of "^{3}He+CF_4" gases coupled with surrounding photomultiplier tubes. We used the MCNPX code to calculate detection efficiency dependencies with the neutron energy and emission angle under the different configurations, and obtained an optimal configuration (6 cm thick ^{11}B + 0.2 cm thick Be + 70 cm thick D_2O) that can offer a high detection efficiency (76%), a relatively good efficiency flatness (1.02) up to 10 MeV, and a broad scope of emission angle independency with efficiency. Such a leap in fast neutron detector would advance nuclear astrophysics with more accurate measurements.

A Neutron Detector Designed for ICF Diagnosis

Author: Zhaohui Song[1]

[1] *NINT, China*

With the advancement of science and technology, the field of Inertial Confinement Fusion (ICF) has entered a new era where fusion yields are sufficiently high to enable nuclear measurements to provide multidimensional information encompassing spatial, temporal, and spectral dimensions. Nevertheless, neutron yield remains one of the most critical parameters of concern in the diagnostics of ICF facilities. Currently, neutron yields must be measured across several orders of magnitude, with the upper limit reaching approximately 2×10^{16} neutrons per shot.
To address high-intensity ICF neutron yield measurement, a neutron detector based on fission reactions has been developed. Drawing inspiration from the design of Vacuum Compton Diode detectors, this detector comprises a vacuum chamber, front window, collector, anode, and rear window. Its operational principle is as follows: Fusion neutrons pass through the detector's front window and impinge on the collector, which consists of a fission foil with a beryllium substrate (primarily composed of natural uranium). Neutrons interact with uranium to produce fission fragments. As these fragments escape, they ionize the collector material, generating secondary electrons. On average, each fragment produces approximately 300 secondary electrons. The anode, constructed as a stainless-steel grid, is positively biased. The secondary electrons are accelerated by the anode voltage and ejected from the collector, generating a positive signal and recorded by a digital oscilloscope. This detector exhibits fast temporal response, compact structure, and user-friendly operation, making it suitable for measuring ICF fusion neutron yields. Its measurable range spans from 1×10^{14} to 1×10^{18} neutrons per shot.

Key words:
Inertial Confinement Fusion, Fusion Neutron, Neutron Yield, Fission Fragment, Secondary Electron

Laser Plasma Accelerating Ultra-Short Ultra-Intense Electron Beam for Nuclear Applications

Author: Jie Feng[1]

[1] *SJTU, China*

With the development of ultra-short and ultra-intense laser technology, laser driven plasma electron acceleration is becoming increasingly mature. Compared with traditional RF acceleration, this acceleration method has significant characteristics - an acceleration gradient three orders of magnitude higher. It is precisely because of its ultra-high acceleration gradient that the accelerated beam has characteristics such as ultra-short <10s fs, dense >1e19 cm^{-3}, and high current >10s kA. This talk will introduce our recent experimental progress in laser accelerated ultra-short and high current electron beams, and introduce their ultra-fast and ultra-intense characteristics into nuclear physics research,

exploring their potential applications in ultra-fast and efficient nuclear isomer excitation, ultra-short pulsed neutron source, high energy-resolution neutron resonance absorption spectroscopy.

Investigation of the Inverse Leidenfrost Effect in the Production of Moderating Material for Cold Neutron Sources

Authors: Alexey Galushko[1]; Ivan Litvak[1]; Maxim Bulavin[1]; Roman Chepurchenko[1]

[1] *FLNP, JINR*

The dispersed moderating agent for cryogenic moderators of the IBR-2M reactor is produced by the formation of droplets and subsequent freezing in liquid nitrogen. The heat exchange between the droplet and liquid nitrogen leads to intensive local boiling of the liquid nitrogen, resulting in vapor cushioning and heat exchange. This phenomenon is known as the Leidenfrost inverse effect.

The device that utilizes this effect consists of a cryostat and a dropper. The cryostat, a vertical vessel, is filled with liquid nitrogen and is isolated from the bottom and sides of the outer space by a vacuum jacket.Inside the cryostat, cells ensure the freezing of each drop in a separate volume.During the manufacturing process, beads accumulate at the bottom of the cryostat.

The utilization of a "steam cushion" approach enables analytical calculations to determine the duration of ball formation under specific conditions. These conditions include the quasi-static nature of the process, the spherical shape of the drop, and the uniformity of the crystallization process.While this analysis provides a fundamental understanding of the processes involved, it serves as a solid foundation for further research and the practical application of the obtained knowledge.

Installation of New Wide-Aperture Scintillation Detectors ASTRA-M and BSD on the IBR-2M Fourier-Diffractometers: First Results

Author: Maxim Podlesnyy[1]

[1] *FLNP, JINR*

The Department of Spectrometers Complex (DSC) of IBR-2 plays an important role in maintaining the efficiency and development of the experimental facilities at the IBR-2 reactor. One of the directions of DSC is the development and creation of wide-aperture neutron detectors based on the ^{6}LiF/ZnS(Ag) scintillator. As part of the modernization of the scientific installations of the IBR-2 reactor, the ASTRA-M and BSD detectors were created. At the moment, the detectors have been created and installed on the diffractometers of the IBR-2 reactor.
The report will present the first results obtained from the ASTRA-M and BSD detectors, and provide a comparison with the previous ones.

Development of Polarized ^{3}He at CSNS

Author: Junpei Zhang[1]

[1] *CSNS*

The development of polarized neutron technology is pivotal for advancing studies in material science and fundamental physics, particularly in probing magnetic structures and symmetry violations. At the China Spallation Neutron Source (CSNS), significant progress has been made in the design and implementation of polarized ^{3}He neutron spin filters (NSFs) based on spin-exchange optical pumping (SEOP) [1-5]. An off-situ system demonstrated exceptional performance with 77.4% ^{3}He polarization and a polarization lifetime exceeding 200 hours, making it highly suitable for long-duration experiments [2]. The in-situ NSFs also achieve significant progress, building on the first-generation (70 cm × 70 cm × 60 cm, 74.4% ^{3}He polarization) [3], a compact in-situ system (55 cm × 56 cm × 48 cm) was developed [4], integrating a uniform magnetic field (<1.74×10^{-4}/cm), dual-laser optical pumping, and precise thermal control (±0.15℃) with low-noise NMR monitoring. Validated on the BL-20 beamline, this system achieved 75.66%±0.09% ^{3}He polarization and 96.30% neutron polarization at 2 Å. These advancements have enabled versatile deployment across multiple CSNS beamlines. For instance, the Back-n white neutron source utilizes the in-situ NSF for time-reversal violation studies [5], while a specially designed in-situ NSF for the Very Small Angle Neutron Scattering (VSANS) instrument successfully implemented China's first polarization-analyzed small-angle neutron scattering (PASANS) technique [6].

As an underdevelopment polarized neutron facility, our group poised to enhance system stability and expand the applications in complex magnetic materials with polarized neutron, such as investigations of magnetic skyrmions and beyond-Standard Model physics. Future efforts will focus on optimizing performance for advanced experiments in nuclear weak interactions and exotic symmetry-breaking phenomena.

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Multi-purpose Time Projection Chamber (MTPC) Signal Simulation Method and Experimental Verification

Authors: Haizheng Chen[1]; Han Yi[2]; Ruirui Fan[2]; Hongkun Chen[3]

[1] *XJTU, China*

[2] *CSNS*

[3] *Sun Yat-sen University, China*

The Multi-purpose Time Projection Chamber (MTPC) prototype has been successfully developed and commissioned at the CSNS Back-n white neutron beamline. As a novel detection system, its primary design objective focuses on precise measurement of light charged particle emissions in nuclear reactions, while maintaining versatile capabilities for multiple applications including fission cross-section determination, beam profile characterization, and neutron imaging experiments. Our research team has conducted a series of beam tests with the MTPC prototype, obtaining preliminary yet significant experimental results. These initial findings demonstrate the detector's feasibility for conducting neutron-induced nuclear reaction measurements with satisfactory resolution. To support the development of advanced data analysis algorithms, we have established a comprehensive simulation and analysis framework that integrates the operational principles of MTPC with established open-source tools including Geant4 for particle transport simulations, Garfield++ for drift field calculations, and ROOT for data processing. This integrated framework enables parametric studies through systematic variation of experimental conditions, generating simulation predictions that show strong agreement with actual measurement data. The synergy between experimental validation and computational modeling provides valuable insights for detector optimization and experimental design refinement, particularly in understanding complex signal formation processes within the time projection chamber.

Monitoring Neutron Spectrum of Reactor IBR2 Using New Direct Beam Detection System at Small Angle Neutron Scattering Spectrometer (YuMO)

Author: Ahmed Elmekawy [1]

[1] *FLNP, JINR*

The specific geometry of small angle neutron scattering spectrometer YuMO, a central hole along the neutron beam direction through the two scattering detectors reaching to direct beam detector (DBD) located at 35 meters from moderator [1-3]
DBD importance return to determine the transmittance of the sample as a function of wavelength, due to peculiarities of normalization when the ratio between the scattering values from the sample and the vanadium standard become close to each other. Additional information about the procedure can be found in [1,2]. Also to monitor occurring changes at reactor power on long term.
The new direct beam detector at YuMO is a proportional gas detector with solid state Boron converter [4-8]. Here we present recording for IBR2 neutron spectrum with different reactor power by processing empty beam spectrum on DBD, it was shown that the detector works effectively. Also, comparison between new and old DBD detector showed that both are stably working. However new DBD have higher efficiency.

Modeling and Optimization of Experimental Setup Geometry for Measuring Ultracold Neutron Loss Factors Using Gravitational Spectroscopy

Author: Zhanibek Kurmanaliyev[1]

[1] *FLNP, JINR*

This study presents numerical and analytical investigations aimed at optimizing the measurement of ultracold neutron (UCN) loss factors on various materials using the gravitational [1] spectroscopy method. The optimization of experimental setup geometry was performed through numerical simulations, allowing for the determination of optimal parameters to enhance measurement accuracy. Within the UCN gas [1] model framework, time dependencies of storage, filling, and emptying of neutron vessels were calculated, and measurement uncertainties for UCN loss factors were evaluated for different materials (deuterated polyethylene, diamond-like carbon, and beryllium). Estimated exposure times were obtained, and the dependence of statistical data collection time on the sample surface area was analyzed, enabling the determination of optimal experimental conditions. The results of this study can be utilized to improve the precision and efficiency of experiments investigating ultracold neutron interactions with surfaces.

Experimental Validation and Geant4 Simulation of Spatial Resolution in Fast Neutron Radiography at CSNS Back-n Facility

Authors: Baojun Duan[1]; Dongwei Hei[1]; Ruirui Fan[2]

[1] *NINT, China*

[2] *CSNS*

Fast neutron radiography offers distinct advantages over conventional X-ray radiography, demonstrating significant developmental potential and broad application prospects in strategic fields including national defense, aviation, aerospace, and nuclear energy. As a critical performance indicator for imaging systems, spatial resolution has been extensively studied through theoretical simulations in current research, while experimental investigations remain comparatively limited.
This study develops a comprehensive simulation methodology for system spatial resolution using Geant4 Monte Carlo simulations, complemented by systematic experimental validation at the Back-n white neutron source facility of the China Spallation Neutron Source (CSNS). The experimental results exhibit close agreement with theoretical predictions, thereby establishing crucial technical foundations for advancing fast neutron radiography applications. This work bridges the gap between simulation and experimental research while providing valuable insights for optimizing imaging system performance in practical implementations.

Neutron Displacement Damage Effects in GaN Devices: A Comparative Analysis of PIN Diodes and High Electron Mobility Transistors

Authors: Yuanyuan Xue[1]; Lili Ding[1]; Yangni Zhu[1]; Yufei Liu[2]; Liang Zhang[1]; Wenxu Liu[1]; Wei Chen[1]

[1] *NINT, China*

[2] *XJTU, China*

Gallium nitride (GaN) materials have attracted significant attention for neutron detection and related applications due to their exceptional advantages including high-temperature tolerance, high-voltage resistance, rapid response characteristics, etc. The evaluation of irradiation damage and radiation-hardened design for GaN-based devices remains a critical research focus. GaN detector configurations are primarily categorized into two types: multilayer planar structures and AlGaN/GaN heterojunction architectures. This study investigates GaN PIN diodes and AlGaN/GaN high-electron-mobility transistors (HEMTs) fabricated on silicon substrates. Systematic neutron irradiation experiments were conducted to characterize the degradation patterns of electrical performance parameters in these devices post-irradiation. Through TCAD (Technology Computer-Aided Design) simulations, the physical mechanisms underlying irradiation-induced damage were thoroughly analyzed. Furthermore, a comparative assessment of radiation resistance between GaN-based devices and conventional silicon-based counterparts was performed, providing critical insights into the radiation tolerance disparities between these material systems.

Universal Cryogenic Moderator for Research Neutron Sources of Any Power and Intensity

Author: Maksim Bulavin[1]

[1] *FLNP, JINR*

For the first time, the author proposed the concept of a new direction in the field of cold (cryogenic) neutron moderators for research neutron sources of low, medium and high power and intensity, which is based on the use of a universal cryogenic neutron moderator based on hydrocarbons. It is shown that the successful development of fundamentally new methods, installations, devices and facilities in the field of this direction will make it possible to get high-intensity beams of cold neutrons based on any research neutron source.

Experimental Study on Differential Cross Section of ^{14}N(n, p)^{14}C Reaction

Author: Qiuyue Luo[1]

[1] *CSNS*

The report briefly outlines the significance and background of this experimental study, the experimental setup, and the preliminary results. The ^{14}N(n,p)^{14}C reaction is the most significant poisoning reaction in the s-process nucleosynthesis. The measurement of its differential cross-section is crucial for producing ^{19}F, determining neutron dose in boron neutron capture therapy (BNCT), estimating spin-parity of nuclear energy levels, and testing some nuclear models. Currently, there are discrepancies between existing experimental data and evaluated data, and there is a lack of differential cross-section data across the entire energy range. This experiment was conducted at CSNS Back-n, aiming to provide a scientifically robust supplement to the controversies and gaps in the nuclear data of this reaction. The result obtained in this experiment represent the first differential cross-section result in this energy region. During the experiment, neutron beams irradiated targets such as aluminum-backed $C_3H_3N_6$ and aluminum-backed ^{6}LiF, with signals detected by silicon detectors and data acquired by waveform digitizing electronics. The report provides a detailed description and explanation of the data analysis process and experimental results. After data processing and R-matrix fitting, the differential cross-section measurements were found to be consistent with the JENDL-5.0 evaluation within the error margins. The fitting results were consistent with the measurements and showed a distinct angular distribution in the 2.2~5.5 MeV range. Additionally, resonance parameters for approximately 40 ^{14}N+n resonances in the 0.1~6 MeV range were obtained from the fitting results, including the spin-parity of the ^{15}N compound nucleus excited states and the reaction widths of the ^{14}N+n, ^{14}C+p, ^{15}N+γ, and ^{11}B+α reaction channels.

Neutron Dispersion Law for Matter Moving with Acceleration

Author: Maxim Zakharov[1]

[1] *FLNP, JINR*

The report is devoted to the problem of interaction of slow neutrons with matter moving with acceleration. The possibility of transformation of the neutron dispersion law due to the general effect of acceleration is considered. The Acceleration effect consists of that the result of the interaction of a particle with any object moving with acceleration should be a change in its frequency ω and energy E=ħω. This change in frequency is determined by relation $\Delta\omega \approx ka\tau$, where k is the wave number, a is the object acceleration and τ - interaction time.
The effect was investigated in an experiment [1] in which neutrons were observed passing through a sample moving with acceleration. The experimental results were in a quite well agreement with theoretical estimates, but the estimates were based on an assumption that dispersion theory is valid

in the case of accelerated matter, which is not obvious.
Furthermore, there are theoretical estimates of acceleration at which phenomena associated with neutron wave re-scattering in matter become significant for the theory of dispersion [2]. At the same time the results of [3, 4] allow to suggest that the energy changes should take place by a single scattering on an accelerated nucleus.
In connection with the above, the calculation of corrections to the neutron dispersion law in the case of accelerated matter and the analysis of the possibility of their experimental observation becomes relevant. The report presents possible ways to solve this problem.

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Energy-Sensitive Photon and Neutron Bimodal Imaging System: Design and Performance Validation

Authors: Yuxuan Lai[1]; Yigang Yang[1]

[1] *Tsinghua University, China*

Conventional photon and neutron bimodal imaging systems suffer from inherent limitations such as different imaging beam geometry, leading to challenges in direct fusion of transmission image and system complexity. While the single-source-single-detector configuration based on a compact electron linear accelerator proposed by Tsinghua University addresses imaging beam geometry issue, it remains susceptible to beam-hardening effects that correlate material properties with sample mass-thickness, thereby compromising material identification accuracy. To resolve this problem, this study introduces a quasi-monoenergetic bimodal imaging system utilizing a gamma converter and an event-based detector instead of frame-based detector. The gamma converter ensures monoenergetic photon generation, while Time-of-Flight (TOF) spectrum filtering via the event-based detector achieves quasi-monoenergetic neutron imaging. This paper elaborates on three critical aspects of the system design: energy-sensitive target station optimization, event-based imaging detector configuration, and energy-resolved bimodal reconstruction methods. Experimental results on pure elemental material demonstrate that the proposed system effectively corrects beam-hardening effects, significantly enhancing the reliability of material identification. The performance highlights the system's potential to establish a robust framework for optimizing the accuracy of bimodal material discrimination.

Physical Design and Simulation of a Fission Spectrometer Based on the Velocity-Kinetic Energy Method

Authors: Jun Ma[1]; Zheng Wei[1]; Ze En Yao[1]

[1] *Lanzhou University, China*

The investigation of neutron-induced fission independent yields of actinides is critically important for both the efficient utilization of nuclear energy and nuclear physics research. The fission spectrometer based on the velocity-kinetic energy method consists of a Time Of Flight (TOF) detector and a Frisch-Grid Ionization Chamber (FGIC), achieving mass yield distribution with a mass resolution less than 1 amu. This presentation focuses on the physical design and simulation studiy of the fission spectrometer. The Micro Channel Plate (MCP) time detector, which constitutes TOF, maintains secondary electron flight time spread of 50 ps and the flight distance is 70 cm. The FGIC

operates with isobutane as the working gas, operating at an optimal E/P of 6 V/(cm·Torr) and a pressure of 5000 Pa. When the energy resolution is less than 0.8 % for light fragments and 0.6 % for heavy fragments, the mass resolution can be less than 1 amu. Based on the physical design, fission data for 14 MeV neutron-induced ^{238}U was simulated by coupled calculations using Geant4, COMSOL and Garfield++. The mass yield distribution was calculated by the energy loss correction method. A measurement method for charge yield distribution based on K-means clustering algorithm is proposed, and the Root Mean Square Error (RMSE) and Error Ratio (ER) of the charge yield distribution are 6.36E-6 and 29.26%.The simulated independent yield distribution demonstrate agreement with the ENDF/B-VIII data. The physical design and simulation studies provide a foundation for future fission physics experiments.

Calculation for Improving the Efficiency of Ultracold Neutron Transport Using Monte Carlo Method

Author: K.T. Pham[1]

Co-authors: A.Yu. Nezvanov [2]; A.Yu. Muzychka [2]

[1] *Moscow Institute of Physics and Technology, Russia*

[2] *FLNP, JINR*

The development of intense low-energy neutron sources requires extensive calculations to refine the design to meet practical needs. With the appearance of liquid helium-based ultracold neutron sources (UCN), from which all UCN can be released through a small outlet, it became possible to use a new type of mirror neutron guides. They consist of three main parts: a short expanding part, a long parallel part, and a short tapering, focusing part. This research has shown that such neutron guides reduce UCN losses during transportation several times and increase the UCN density at the outlet several times, compared to traditional parallel neutron guides. The research was conducted using the GEANT4 simulation toolkit [1-4]. Such a neutron guide can be used in the design of the ALSUN UCN source at the Institute of Nuclear Physics in the Republic of Kazakhstan [5].

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Monte Carlo Simulation of the Impact of High-Energy and Thermal Neutron Fluxes on InAs Semiconductor Films on Sapphire Substrates

Author: Vladik Yamurzin[1]

[1] *FLNP, JINR*

Numerical modeling of the interaction of fast and thermal neutrons with semiconductor microcrystals (InSb, InAs, GaAs) was conducted using the GEANT4 software environment. The study aimed

to determine the rates of nuclear reactions (elastic and inelastic scattering, radiative capture) and analyze the influence of secondary fission products on the radiation resistance of semiconductor electronics. Additionally, the SRIM software was used to evaluate the linear energy transfer (LET) and ranges of secondary particles within the materials, providing further insight into the mechanisms of radiation damage.
The obtained data are of key importance for understanding the physical processes occurring in semiconductors under neutron irradiation and can be used to develop methods for enhancing the radiation tolerance of materials. The simulation results are planned to be verified experimentally using reactor facilities with a defined neutron spectrum, ensuring more accurate predictions of the electrophysical properties of semiconductors under radiation exposure. The practical significance of this research lies in its applicability in nuclear energy, aerospace, medical technology, and microelectronics, where radiation resistance of materials is a critical parameter.

Research and Development of a Large-Size CsI(Tl) Detector for Neutron Capture γ-ray Measurement at the Back-n White Neutron Source of CSNS

Authors: You Lv[1]; Ruirui Fan[1]

Co-authors: Juan Liu [1]; Anran Huang [1]; Xinyu Yuan [1]

[1] *CSNS*

Neutron capture reactions play a crucial role in nuclear physics research, as their cross-section measurements provide critical data for nuclear structure studies and nuclear databases, while also enabling the examination of symmetries and conservation laws in nuclear reactions. To meet the requirement for neutron capture cross-section measurements at the back-streaming neutron facility (Back-n) of China Spallation Neutron Source (CSNS), we have developed a large-size CsI(Tl) detector with a diameter of 10 cm and a length of 21 cm. The CsI(Tl) crystal is coupled to a photomultiplier tube (PMT) for signal readout. The PMT's performance, including single-photoelectron response and gain curve were characterized in the laboratory using an LED light source. The reflective layer material, energy response, and uniformity of the CsI(Tl) detector system were evaluated using gamma-ray radioactive sources. Preliminary results demonstrate that the detector achieves a uniformity better than 5% and an energy resolution of 2.5% at 662 keV. Beam experiments for neutron capture cross-section measurements were conducted using lead samples at the Back-n beamline to validate the detector's performance. Based on the preliminary results, an improved experimental protocol has been proposed. This work provides a detailed description of the design of the large-size CsI(Tl) detector system, the results of radioactive source tests, and the progress of beamline experiments.

Parallel Session 4: Nuclear and related analytical techniques in environmental and materials science

Air Pollution Studies in Asia and the Pacific Based on Moss Analysis by Nuclear and Related Analytical Techniques

Authors: Marina Frontasyeva[1]; Inga Zinicovscaia[1]

[1] *FLNP, JINR*

Air pollution is the world's most pressing environmental crisis It is responsible for more than 7 million deaths annually, the bulk of which – 70 percent – occurs in Asia-Pacific region. Air pollution in these countries is several times higher than WHO guideline for safe air. Heavy metals (HM) are among the most dangerous environmental pollutants. In most European countries, the need to study the consequences of their impact on the environment and human health has led to

the establishment of national and international programs for biomonitoring of heavy metal atmospheric deposition. Data on atmospheric deposition of HM and other toxic elements obtained on the basis of analysis of moss biomonitors, which serve as an analog of aerosol filters. Under the auspices of the United Nations Commission on UNECE Convention on Long-range Transboundary Air Pollution (UNECE ICP Vegetation), the Atlases (Reports) of Atmospheric Deposition of Heavy Metals are published every five years. Since 1995, the international team of the JINR FLNP Sector of Neutron Activation Analysis and Applied Research has been contributing to these Atlases. Study of atmospheric deposition of heavy metals and other toxic elements in a number of JINR member and non-member states made it possible to identify and assess the areas of these pollutions in the studied territories and compare with the levels of similar pollution in Western Europe.
The possibility of extending our experience to Asia-Pacific countries is currently being discussed with representatives of several countries in this region in January 2025 at an online workshop organized by JINR. Some examples of our previous research on deposition of trace elements in China in 2002 [2] are cited to draw the attention of Chinese scientists to our cooperation in studying air pollution in the Asia-Pacific region.

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Assessment of the Recreational Zones in Moscow Using Neutron Activation Analysis and Atomic Absorption Spectrometry

Author: Margarita Shvetsova[1]

Co-authors: Inna Kamanina [1]; Inga Zinicovscaia [1]

[1] *FLNP, JINR*

Instrumental neutron activation analysis was used to determine the content of more than 30 chemical elements in moss, soil and leaves samples collected in seven Moscow parks, Russia. To determine Cd, Pb and Cu atomic absorption spectrometry was applied. In general, in moss samples used to assess air pollution the content of elements increased with exposure time, except alkali element (K, Cs and Rb) which content decreased, probably due to pollutants impact. In leaves the highest content of elements was observed at the end vegetation period, that may be associated with processes in plants which promote elimination of toxic elements. In some soil samples was revealed excess of As, Zn and Cd. According to calculated total pollution index, the highest values was observed for soil, that can be associated with their ability to accumulate pollutants emitted by aerotechnogenic way for a longer period.

A Comprehensive Study of Ruined Mural Fragments from the 12th Century Church of Transfiguration of Our Savior on the Nereditsa Hill (Veliky Novgorod, Russia)

Authors: Ekaterina Zhukova[1]; Andrey Dmitriev[1]; Olga Philippova[1]; Svetlana Lennik[2]

[1] *FLNP, JINR*

[2] *INP, Kazakhstan*

The church of Transfiguration of Our Saviour on the Nereditsa Hill is one of the earliest Old Russian buildings, raised in 1198 by order of Knyaz of Novgorod Yaroslav Vladimirovich. The church was included in the UNESCO list of World Heritage sites in 1992. During the World War II, the monument was partially destroyed. As a result, almost the entire painting crumbled, with the exception of a few fragments. The comprehensive architectural restoration of the church was completed in 2004. Currently, the unique ruined wall paintings need to be studied in more detail in order to carry out work on their restoration. A total of 27 mural fragment were examined in the Sector of Interdisciplinary Research of Cultural Heritage (FLNP JINR, Russia). According to restorers, these fragments date back to the 12th century. Neutron activation analysis with further statistical treatment did not reveal the separation of plaster samples into different groups. A complex of analytical techniques was used to study color layers: X-ray fluorescent analysis, Raman spectroscopy, optical and polarized microscopy. Red and yellow ochre, green earth, lapis lazuli, soot, and lime white were used in the painting of the church. This set is typical for Old Russian painting of that time. Thus, results of comprehensive analysis confirmed that all the samples studied date back to the 12th century.

Analysis of ^{234}U/^{238}U Ratio by ICP-MS

Author: Igor Izosimov[1]

[1] *FLNP, JINR*

$ICP-MS$ method has been used for analyses [1] 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. It was also observed that the $^{234}U/^{238}U$ ratio (Table) differ from $^{234}U/^{238}U = 5.4 \times 10^{-5}$ secular equilibrium value. In this report the various mechanisms responsible for this difference are discussed.

Table. Data on uranium isotope ratios, detected by $ICP-MS$ with $1-SD$ errors in prehistoric bones, standard bone, and soils collected around these bones.

Sample	$^{234}U/^{238}U \times 10^{-5}$	$^{235}U/^{238}U \times 10^{-3}$
MB1	**16.0±0.6**	**7.4±0.2**
SMB1	**11±1**	**7.5±0.2**
MB2	**9.5±0.2**	**7.5±0.2**
SMB2	**8.4±0.4**	**7.6±0.2**
BA	**8.1±0.2**	**7.2±0.2**
BB	**7.7±0.3**	**7.4±0.2**
DB	**7.1±0.4**	**7.2±0.2**
SDB	**7.2±0.3**	**7.5±0.2**
STB	**7.2±0.5**	**7.5±0.2**
SSTB	**10.6±0.3**	**7.4±0.2**

MB1& & SMB1 – South mammoth bone found in Angren and soil collected near this bone respectively; MB2& SMB2 - South mammoth bone found in Kashkadari and soil collected near this bone respectively; BA-arhantrope bone; BB – bone of bear from Selungur cave; DB& SDB – Dinosaur bone and soil collected near this bone respectively; STB & SSTB – standard bone and soil collected near the standard bone. The natural abundance ratio of the isotopes $^{235}U/^{238}U$ is 0.007257, secular equilibrium ratio $^{234}U/^{238}U$ is 5.4×10^{-5} .

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A Synergy of ICP–MS/AES and Machine Learning for Elemental Characterization of Soil

Author: Wael Badawy[1]

Co-authors: E.S. Mohamed [1]; F. I. El-Agawany [1]; M. G. Blokhin [1]; T.M. Morsi

[1] *FLNP, JINR*

A comprehensive analysis of soil elemental content in the Nile Delta, Egypt, was conducted using advanced analytical techniques, including Inductively Coupled Plasma Atomic Emission Spectrometry (ICP–AES) and Inductively Coupled Plasma Mass Spectrometry (ICP–MS). A total of 55 elements were analyzed across 53 soil samples. Of these, 10 major elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, and P) were quantified using ICP–AES, while the remaining elements were measured using ICP–MS. The study employed a range of statistical methods, including both descriptive and inferential analyses, to evaluate the data. Additionally, multivariate statistical analysis was applied to gain deeper insights into the shared geochemical characteristics and to identify potential common sources of pollution. Geochemical discriminative ternary diagrams, ratio biplots, and unsupervised machine learning algorithms were utilized to classify the sampling locations based common traits. Various pollution indices were calculated to evaluate the ecological situation in Nile Delta - Egypt. In addition, the background values of the geochemical elements were determined using Bayesian inference, and the influence of outliers was thoroughly analyzed. By integrating the obtained chemical elements through a combination of analytical methods and machine learning algorithms, the background values of elemental content were accurately characterized, providing a precise representation of the soil composition. The collected data can serve as a valuable baseline for monitoring the environmental situation, particularly in terms of elemental abundances, and for assessing future dynamics.

INAA and XRD Investigation of the Serbian Sector of the Danube River and Its Tributary

Authors: Otilia Ana Culicov[1]; Tatjana Trtic-Petrovic[2]; Octavian G. Duliu[3]; Pavel S. Nekhoroshkov[4]; Inga Zinicovscaia[5]

[1] *Joint Institute for Nuclear Physics and National Institute for R&D in Electrical Engineering ICPE-CA*

[2] *Vinča Institute of Nuclear Sciences, National Institute of the Republic of Serbia, University of Belgrade*

[3] *University of Bucharest, Faculty of Physics, Department of Structure of Matter, Earth and Atmospheric Physics, Astrophysics & Geological Institute of Romania*

[4] *Joint Institute for Nuclear Physics*

[5] *Joint Institute for Nuclear Physics & Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering,*

To get more data concerning the geochemistry and mineralogy of the Danube River tributaries mainly from the Eastern Serbian sector and to elucidate the status quo of sedimentary material, Instrumental Neutron Activation Analysis (INAA) and X-Ray Diffraction (XRD) were used in tandem to investigate 10 samples of unconsolidated bottom sediments, two samples collected at 1.5 and 7.5 m below the river bed, respectively.
The high sensitivity of INAA coupled with a high accuracy achieved at the IBR-2 reactor, Joint Institute for Nuclear Research (JINR) allowed the determination of the mass fractions with accuracy up to 0.5 mg/kg and lower. In this regard, the mass fraction distribution of 22 elements from Sc (Z= 21) to U (Z=92), including 10 Lanthanides permitted to characterize not only the nature of sedimentary

material but also the degree of anthropogenic contamination with seven Presumably Contamination Elements (PCE) V, Cr, Co, Ni, Zn, As, and Sb. The Upper Continental Crust (UCC) was considered as a reference environment for both sediment origin and the contamination degree. The XRD performed at the Geological Institute of Romania (GIR) enabled the determination of the main mineralogical component of the sediments.
Among the investigated trace elements, the incompatible and litophilic elements Sc, Zr, the lanthanides, as well as Hf, Th, and U were used to determine the global nature of sedimentary material. On this matter, more descriptors such as La/Th, Th/U ratios or the Sc-La-Th discriminant ternary diagram pointed towards a remarkable similarity between the depositional material and the UCC, also expressed by the felsic origin as proved by the La/Sc ratio vs. Hf biplot. At their turn, the Th/Sc. vs. Zr/Sc suggested a relatively new, less recirculated material. The similarity to UCC was also documented by the distribution of the lanthanides mass fraction normalized to chondrite, showing the characteristic Eu negative anomaly.
As mentioned before, the mass fractions of the investigated PCE normalized to the corresponding UCC mass fraction, which was considered a pristine, uncontaminated environment, presented increased values of the Contamination Factors (CF) of which values monotonously increased from V of which CF was of 0.91 ± 0.28 to 7.71 ± 4.2 in the case of Sb. As a consequence of this fact, the global Pollution Loading Index (PLI) varied between reached values from 1.24 to 4.04 with an average value of 2.32 ± 0.95, pointing towards a moderate to locally high contamination level.
The XRD results were in good agreement with the INAA ones as the main mineralogical component of sedimentary material consisted mainly of quartz, clay minerals (smectite, illite, and more or less montmorillonite), calcium carbonate, plagioclase feldspars with traces of iron minerals such as magnetite, hematite, and goethite.

Study of the Wall Painting from the Vladychaya Palata of the Novgorod Kremlin (Velikiy Novgorod, Russia) Using Complementary Physico-Chemical Methods

Authors: Valerii Lobachev[1]; Andrey Dmitriev[1]; Olga Philippova[1]; Svetlana Lennik[2]

[1] *FLNP, JINR*

[2] *INP, Kazakhstan*

This work presents the results of a comprehensive study that applied complementary physico-chemical methods to 29 mural fragments from the Vladychnaya Palata in the Novgorod Kremlin. Plaster samples were subjected to neutron activation analysis (NAA) at the WWR-K research reactor (Institute of Nuclear Physics, Kazakhstan) to determine elemental composition. The pigment composition of the paintings was studied using a combination of methods: X-ray fluorescence analysis, micro-Raman spectroscopy, as well as optical and polarized microscopy.
NAA results were statistically treated. K-means clustering revealed two groups of plaster samples. Comparing the statistical treatment results with the pigment composition revealed a richer palette of pigments for one of the sample groups. Visualization of the k-means clustering results with color coding of samples clearly demonstrates the differences between the groups.
Combining results of complementary physico-chemical methods enabled a detailed characterization of the materials used in the wall painting of the Vladychnaya Palata. This data can serve as a basis for further studies in the fields of art history, restoration, and preservation of cultural heritage of Novgorod.

Radiosensitivity of Rice to Fast Neutrons

Author: Yulia Aleksiayenak[1]

Co-author: Anastasiya Kruglyak [1]

[1] *FLNP, JINR*

Determination of radiosensitivity for plant species is important in order obtain desirable plant characteristics. As a rule, median lethal dose(LD50) is considered as appropriate dose to obtain the highest mutation frequency [1].
Such a task for fast neutrons (FN) is a complex challenge due to the unique properties of neutron radiation, the biological variability of the plant, the difficulty in accurate dosimetry, and the intricate nature of radiation-induced damage. Even for gamma radiation, the LD50 for rice vary widely. For some rice varieties, the LD50 is in the range of 350-390 Gy [2, 3], for different Basmati varieties, the values are lower, about 230 Gy [4], for the Mira-1 variety, 520 Gy [5]. Although many authors consider neutron irradiation as a perspective mutagen for further plant breeding there is still no clear information on the dose-response relationship. Researchers use different fast neutron sources and rice varieties. There is no clear information for the neutrons, while some studies use 10 Gy to produce a new variety, other sources consider 20, 33 Gy as LD30 for FN [6, 7, 8].
As the specific results may vary depending on the experimental conditions, the variety of rice, and the radiation source the aim of our research was to study radiosensitivity of Kazakhstan rice variety "Syr Suluy" on two parameters seedling growth reduction (GR) and median lethal dose (LD50). The seeds were irradiated by fast neutrons at the EG-5 electrostatic generator in the Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research (Dubna, Russian Federation). The neutron energy (En) was 4.1 MeV; neutron flux intensity was 3×10^7 particles/cm^2, studied doses were 10, 25, 40, 50, and 75 Gy.
It was found out that the GR50 dose is 40 Gy, while the LD50 is 50 Gy. These data will be used for the further plant mutagenesis studies conducted at the EG-5 and could be extended to other cereals.

Crystallographic Texture Changes during Martensitic Transformations: X-Ray and Neutron Diffraction Studies and Modeling

Author: Roman Vasin[1]

[1] *FLNP, JINR*

Crystallographic texture (or crystallographic preferred orientation) is an inherent property of polycrystalline materials, which defines the anisotropy of their bulk physical properties. Textures are formed during inelastic deformation processes, crystallization, recrystallization, etc. They are also influenced by structural phase transformations, which may be studied in situ. Such experiments are usually performed using diffraction of high-energy synchrotron X-rays, or thermal neutrons.
For diffusionless martensitic transformations, orientation relationships between parent and product phases are often known. It is shown that in this case, bulk crystallographic textures of product phases may be easily modeled from bulk crystallographic textures of parent phases, and variant selection rules may be inferred by comparing model and experimental preferred orientations. When the orientation relationship is not defined, it might be possible to determine it using measured crystallographic textures.
Examples of transformation texture studies will be presented and discussed in detail.

Radiation Effects of White Neutron Source on COTS Devices

Author: Yingqi Ma[1]

[1] *NSSC, CAS, China*

The reliability of commercial off-the-shelf (COTS) devices such as solid-state drives (SSDs) under radiation has become a critical concern in space applications and high-altitude environments. Radiation testing has proved to be an effective method for investigating failure mechanisms and evaluating reliability. An overview of the common reliability of SSDs, focusing primarily on failure

mechanisms and design mitigation techniques in relation to factors such as NAND program/erase cycles and temperature dependence, is provided in this study.
Commercial solid-state drives (SSDs) were subjected to broad-spectrum neutron exposure at the China Spallation Neutron Source (CSNS) to analyze radiation-induced errors in components and functional interruptions in nonvolatile memory express (nVMe) and serial advanced technology attachment (SATA) SSDs. The experiments revealed apparent sensitivity differences, with NVMe SSDs demonstrating better resistance at the module level due to advanced controller technology and enhanced error correction capabilities than SATA SSDs. For NVMe SSDs, functional interruptions were primarily identified as NAND Flash faults, such as timeouts, and dynamic random access memory (DRAM) errors, such as stuck bits, while controller vulnerabilities contributed minimally. Moreover, this study examines the dominance of read errors as the primary failure mode in NAND Flash and explores how the cumulative characteristic of these errors correlates with functional interruptions.

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Calculation Model and Static Parameters of the IBR-2M Reactor

Author: Yakov Vdovin[1]

[1] *FLNP, JINR*

In this work the results of modeling and simulating the burnup of the IBR-2M pulsed fast reactor in the Monte Carlo software package. A three-dimensional geometric model of the reactor has been developed, including an active zone with 64 fuel assemblies, a PO-3 reactivity modulator, a control and protection system, and a liquid metal sodium coolant. Critical calculations and simulation of the fuel campaign up to an energy production of 2040 MW·d have been performed, taking into account two fuel refueling.
It was found that the effect of the first replacement of the simulator with a fresh fuel assembly at an energy production of 6 MW·d/kg was ~1.55%, and at the next replacement at 18 MW·d/kg it was ~1.43% keff. Analysis of the dynamics of the coefficients of non-uniformity of energy release showed an increase in the radial coefficient with a stable axial one, which is associated with the redistribution of the fuel mass after refueling. The critical parameters of the reactor obtained by the Monte Carlo method include keff = 1.0023, the initial reactivity margin of ~2.5 βeff and the neutron generation lifetime of 58 ns.
The results confirm the adequacy of the Monte Carlo model for predicting the behavior of the IBR-2M reactor under fuel burnout conditions and demonstrate the impact of overloads on operational stability and power distribution.

Investigations of the Gamma and Neutron Radiation Produced by High Energy Electrons at Interaction with the Model of the Head of Siemens Primus LINAC Medical Accelerator

Authors: Peter Rudnev[1]; Valerii SHVETSOV[2]; Artem Zontikov[2]; Valerii Kobets[2]

[1] *Center ADC, Moscow 125040, Russia*

[2] *FLNP, JINR*

The use of high-energy particles in the treatment of cancer patients is growing rapidly every year. The result of burning pathogenic cells can be used to judge the effectiveness of tumor destruction, i.e. the effectiveness of the therapeutic beam. At the same time, patients experience a decrease in comfort after the procedures and relapses occur.

There may be different reasons for this, but we must be sure that there is no non-targeted irradiation of the patient "from head to toe" among the reasons. There are no published experimental data anywhere on the produced side flows of gamma quanta and especially on fast neutrons at medical accelerators such as LINACs. As is known, gamma quanta and neutrons are neutral particles, and therefore have high penetrating ability. In addition, the sources of neutrons and gamma quanta are isotropic, i.e. they fly out in different directions with the same probability.
As a result, the patient is exposed to whole-body irradiation in addition to the therapeutic beam. The treatment mode uses high radiation intensity, which leads to a correspondingly high density of secondary isotropic radiation. This is especially noticeable at the point of interaction of electrons with the heavy target and the primary collimator. It is not possible to measure this radiation at the places of application and production of LINAC due to the poor geometry and pulsed nature of the radiation.
We performed full-scale experiments to determine the yield of neutrons and gamma quanta from a heavy target with acceptable loads for the measuring device. The LINAC-200 electron accelerator was selected as the electron-producing facility (simulating the LINAC medical accelerator), and a certified spectrometer-dosimeter of the SDMF-1206SN type (registration number in the Russian State Register of Measuring Instruments # 90065023) was used as the measuring device. The main sources of gamma quanta and fast neutrons are the equalizing filter, the heavy target with a holder, the secondary collimator/jaws (if present), and the primary collimator. The sources are arranged in ascending order of the yield of secondary particles. The 15MV Siemens Primus model described earlier [1] was taken as the sample LINAC head.

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Multi-Beam Accelerator-Driven Systems: A Safer and Scalable Approach to Nuclear Waste Transmutation

Authors: Xunchao Sun[1]; Xiaochong Zhu[1]; Guopeng Sun[1]

[1] *IMP, CAS, China*

This study analyzes the differences in the operation and heat distribution of single-beam and multi-beam Accelerator-Driven Systems (ADS) through burn-up simulation calculations. Compared to conventional single-beam configurations, the multi-beam ADS achieves a flat neutron flux and heat distribution, effectively suppressing radial power peaking. The distributed spallation target design in multi-beam ADS enhances minor actinide (MA) incineration efficiency under subcritical conditions while requiring substantially lower proton beam currents to sustain stable operation. These results demonstrate the feasibility of multi-beam architectures as a viable approach to sustainable nuclear waste transmutation, supporting further exploration of next-generation ADS technologies for industrial applications.

Experimental Demonstration of Fast Neutron Absorption Spectroscopy Driven by Repetitive Laser Neutron Source

Author: Hao Xu[1]; Jie Feng[1]; Mingyang Zhu[1]; Bingzhan Shi[1]; Guoqiang Zhang[3]; Jinguang Wang[4]; Yifei Li[4]; Xin Lu[4]; Wenchao Yan[1]; Liming Chen[1]

[1] *State Key Laboratory of Dark Matter Physics, Key Laboratory for Laser Plasmas (MoE), School of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 200240, China*

[2] *Collaborative Innovation Center of IFSA, Shanghai Jiao Tong University, Shanghai 200240, China*

[3] *Shanghai Advanced Research Institute, Chinese Academy of Sciences, Shanghai 201210, China*

[4] *Beijing National Laboratory of Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China*

[5] *School of Physical Sciences, University of Chinese Academy of Sciences, Beijing 100049, China*

[6] *Songshan Lake Materials Laboratory, Dongguan 523808, China*

Fast neutron absorption spectroscopy enables isotope-specific material analysis with deep penetration and high nuclear sensitivity. However, achieving high-resolution, table-top fast neutron absorption spectroscopy remains challenging, primarily due to constraints in neutron time duration and diagnostic capability. Here, we report the first experimental demonstration of fast neutron absorption spectroscopy using a repetitive laser driven neutron source. With single-neutron counting and pulse shape discrimination techniques, we achieved high-precision, high-resolution (0.02 MeV at 0.5 MeV) neutron spectrum measurements. Magnesium resonance absorption features at 0.268 MeV and 0.432 MeV were clearly resolved. Local Pearson correlation analysis confirmed good agreement of experimental result and theoretical model. This work combines the ultrashort, table-top laser driven neutron source with advanced detection technique, opening a new avenue for non-destructive testing application and fundamental nuclear science.

Risks Assessment of Gold Nanoparticles Exposure for the Soil-Plant-Consumer System

Authors: Alexandra Peshkova[1]; Inga Zinicovscaia[1]; Liliana Cepoi [2]

[1] *FLNP, JINR*

[2] *Institute of Microbiology and Biotechnology, Technical University of Moldova, Republic of Moldova*

Extensive production and application of gold nanoparticles leads to contamination of aquatic and terrestrial ecosystems, creating risks for consumers of plant products. The effects of gold nanoparticles in concentration range of 1-100 mg/L applied in two routes on *Mentha spicata* L. plants, soil and human health was investigated. k0-neutron activation analysis was used to determine gold content in soil and plant segments and atomic absorption spectroscopy to determine its concentration in herbal remedy. Plants watering with 100 mg/L of gold nanoparticles contributed to accumulation of gold in soil (up to 1769 mg/kg) and root system (up to 454 mg/kg) and reduced the activity of soil microbiota by 28% compared to the control. Foliar application resulted in maximum gold uptake by leaves (552 mg/kg) and stems (18.4 mg/kg). Nanoparticles affected the content of chlorophyll and carotenoids in *Mentha spicata* L. leaves and led to an increase in antioxidant activity. High gold extraction from leaves into infusion indicates a risk of trophic transfer, and decreased soil microbiota activity points at the potential harmful effect of nanoparticles.

Activation by Neutrons and Related Analytical Methods as a Tool of Medical Elementology

Authors: Vladimir Zaichick[1]; Marina Frontasyeva[2]; Inga Zinicovscaia[2]

[1] *Medical Radiological Research Center, Obninsk*

[2] *FLNP, JINR*

The new direction in medicine that emerged in the second half of the XX century –medical elementology – opens fundamental basis for the development and use of new methods of diagnosis and treatment of various diseases, including oncological ones, as well as for solving many other problems facing modern medicine. The subject of research in this new direction consists of four points:
- study of patterns of content and distribution of chemical elements (ChE) in various systems of the

human body, organs, tissues, liquids, cells, subcellular structures and biological molecules, under conditions of constant contact and exchange with the environment, considering gender, age, physiological cycles, nationality, race, profession, social status, everyday traditions, lifestyle and bad habits of the individual;
- determination of the role and degree of participation of ChE in the construction and normal functioning of vital systems of the body at all levels of its organization during the periods of origin, formation, maturity and involution, under conditions of constant contact and exchange with the environment;
- study of adaptive shifts in the content of ChE in the body at all levels of its organization with changing conditions in the environment, extreme loads and external influences;
- identification of the role of ChE in the etiology and pathogenesis of various diseases, as well as the effectiveness of using chemical elements in corrective and therapeutic measures.
The outlined subject of the new direction implies a wide range of tasks and their scale. The selected tool - neutron activation analysis (NAA) and related analytical methods, having unique advantages over other methods of determining ChE, allows successfully solving the set tasks.
These unique advantages include the ability to simultaneously determine the content of about 45 ChE in the studied medical and biological samples without their destruction and preliminary preparation for analysis, as well as the ability to in vivo determine some ChE in organs and tissues of the human body. The non-destructibility and multi-element nature of the tool determine its productivity, and in vivo analysis capability is of exceptional interest for the development of non-invasive diagnostic methods.
This report presents specific examples of the use of NAA and related analytical methods in oncology, environmental medicine and pharmaceuticals.

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

Author: Almas Yskakov[1]

[1] *FLNP, JINR*

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 $2 \cdot 10^{14}$ cm^{-2} ÷ $5\cdot 10^{17}$ cm^{-2}. The low-temperature photoluminescence spectra, electron concentration and mobility, and high-resolution X-ray diffraction curves were measured after the deactivation and during the neutron irradiation. The work 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 and InAs/Al_2O_3 heterostructures in electronic applications.

In Situ Neutron-Diffraction Studies of Structural Phase Transitions in Fe-xGa Alloys

Authors: Anatoly Balagurov[1]; Alexandr Shcherbakov[2]; Sergei Sumnikov[1]; Tatiana Vershinina[1]; Igor S. Golovin[2]; Valeria Palacheva[2]; Roman Vasin[1]; Jiazheng Hao[3]; LU Huaile[3]; Lunhua He[4]; Bekarys Yerzhanov[1]

[1] *FLNP, JINR*

[2] *National University of Science and Technology "MISIS"*

[3] *CSNS*

[4] *Institute of Physics, CAS, China*

It is already well known that Fe-Ga alloys possess increased values of the magnetostriction constant. This characteristic has been studied in a wide range of gallium concentration (up to 35 at.%) [1, 2] and the presence of two peak of magnetostriction at 19 and 27 at.% of gallium has been established. At present, work is underway to analyze the influence of certain structural phases on the magnetostrictive properties of Fe-Ga alloys, including the influence of metastable pseudocubic phases, which can form already at gallium concentration of 27 at.% [3]. Therefore, the identification of general regularities of metastable phases and their transition to equilibrium phases is an important step in the development of the scientific basis for the formation of the optimal structural-phase state of Fe-Ga alloys in terms of their functional characteristics.

The use of neutron diffraction eliminates the influence of surface effects and local inhomogeneities of the structure on the experimental data. Also, the possibility of studying samples of large sizes minimizes the influence of coarse-grained structure on the diffraction patterns. Therefore, neutron diffraction is a very effective method for studying phase transitions in Fe-Ga alloys. In addition, the High-Resolution Fourier Diffractometer (IBR-2 pulsed reactor in JINR, Dubna, Russia) and General Purpose Powder Diffractometer (China Spallation Neutron Source, Dongguan, China) used by us made it possible to carry out in situ experiments with the data acquisition rate at the level of several minutes. This allowed us to analyze in detail the structural changes during continuous heating and isothermal exposures.

In situ comparative studies of the phase composition evolution during continuous heating of the $Fe_{68}Ga_{34}$ alloy, characterized by different initial states, were carried out. In addition, the kinetics of phase transformations in this alloy was studied under conditions of long-term isothermal exposure at temperatures of 360-600 ℃. Details of the experiments and obtained results will be presented in the report.

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Research on Time-Resolved Prompt Gamma Neutron Activation Analysis Based on Back-n Facility

Authors: Gaole Yang[1]; Wei Jiang[2]

[1] *SYSU, China*

[2] *CSNS*

Time-Resolved Prompt Gamma Neutron Activation Analysis (T-PGAA) is an innovative nuclear analytical technique that combines the advantages of Neutron Resonance Capture Analysis (nRCA) and Prompt Gamma Activation Analysis (PGAA). It exhibits high sensitivity and exceptional isotopic resolution capabilities. T-PGAA holds significant potential in diverse fields such as lunar soil analysis, nuclear leakage tracking, and cultural heritage archaeology. However, the technology remains in its developmental stage, with challenges persisting in data analysis methodologies and system optimization. The Back-n beamline at the China Spallation Neutron Source (CSNS) provides a neutron beam characterized by a broad energy spectrum, high flux intensity, and superior energy resolution, making it an ideal platform for T-PGAA research. In December 2023, an experiment was conducted using a natural lutetium (Lu) target irradiated by neutrons from the Back-n beamline. High-purity germanium detector (HPGe) were employed to measure prompt gamma rays emitted from neutron-induced interactions. By correlating neutron energy derived from time-of-flight (TOF) measurements with characteristic gamma rays and neutron resonance signatures, the isotopic composition and quantitative analysis of the target were achieved. The experimental data underwent systematic processing, including detector calibration, identification of characteristic nuclides, and content analysis. The results confirmed the relative abundance of two isotopes in the Lu target, thereby validating the feasibility of T-PGAA methodology on the Back-n beamline. Additionally,

the performance of the detector and data acquisition systems was rigorously tested. This study establishes a foundational framework for analyzing T-PGAA experimental data and paves the way for refining analytical methods.

Analysis of Physical Parameters of the New High-Flux Pulse Reactor

Author: Dimitar Chereshko[1]

[1] *FLNP, JINR*

The development of a design for a new, high-class reactor, NEPTUNE, is required to effectively continue the neutron research program once the IBR-2M's service life ends and to satisfy new needs. This reactor, like the IBR-2M, will be unique, more powerful, and competitive among other facilities in the world. It will be a tool for physicists, biologists, and creators of new substances and nanomaterials.
To achieve this goal, we plan to increase the flux density of the NEPTUNE by an order of magnitude compared to the IBR-2M. This will allow us to explore completely new objects and conduct a more extensive analysis of research results in real-time. The main goal of our Laboratory is to provide a solid scientific basis for the importance of this new source for scientific research.
In this paper, we will analyze the optimal design of a high-flux, pulsed neutron source and further elaborate on the concept of a pulsed fast reactor. The reactor development involves research on the kinetics and dynamics of power pulses, development of nitride fuel based on ^{237}Np, optimization of main elements' design, and optimization of moderator complex configuration.
One way to optimize physical characteristics is by changing the isotopic composition of fuel to reduce irregularities in fuel rods' energy release, achieving desired average lifetime for neutron generation, and creating conditions for stable reactor operation. To obtain the required neutron spectrum and flux, thermal and cold moderators were optimized. At the same time, it is important to justify the design features of the reactor from the perspective of its safe operation.
This paper outlines the basic design and estimated parameters of a pulsed reactor using ^{237}Np as a nuclear fuel. The main characteristic of the ^{237}Np isotope, compared to traditional nuclear compositions based on ^{235}U and ^{239}PU, is its threshold nature for fission cross-section (it effectively splits at a neutron energy above 0.4 MeV). This results in the following benefits for the reactor: the lifetime of fast neutron generation in the neptunium zone is approximately 10 nanoseconds, leading to a shorter neutron pulse; the low fraction of delayed neutrons reduces background power between pulses compared to the IBR-2M reactor; there is a little effect on reactivity during fuel burning due to the long half-life of ^{238}Pu; and the efficiency of reactivity modulation can be increased by using materials with good neutron-moderating properties.

Experimental Extraction of Neutron Resonance Parameters at 20-300 eV for ^{147,149}Sm

Author: Xinxiang Li[1]

[1] *University of South China*

^{147,149}Sm are slow neutron capture (s-process) nuclides in nuclear astrophysics, whose (n,γ) cross-section are the important input parameters in nucleosynthesis net calculation in the Samarium (Sm) region. Additionally, ^{149}Sm is a fission product of ^{235}U with 1% yield, and its neutron resonance parameters play a critical role in reactor neutronics. According to the available nuclear evaluation databases, significant disagreement have been observed in the resonance peaks of ^{147,149}Sm (n,γ) cross section data within the energy range of 20-300 eV. In this study, the neutron capture cross section of the natural Samarium target was measured at the back-streaming white neutron beamline of China Spallation Neutron Source. The neutron capture yield was obtained and the neutron resonance parameters for ^{147}Sm at 107.0, 139.4, 241.7, and 257.3 eV and ^{149}Sm at 23.2, 24.6, 26.1, 28.0, 51.5, 75.2, 90.9, 125.3, and 248.4 eV were extracted using the SAMMY code based on R-matrix theory. For the parameters Γ_n and Γ_γ in these energies of ^{147,149}Sm, the percentages consistent with the results of the CENDL-3.2, ENDF/B-VIII.0, JEFF-3.3, JENDL-4.0, and BROND-3.1 database are 27%, 65%, 65%, 42%, and 58%, respectively. Meanwhile, 27% of the results were inconsistent with them included in any of the major libraries. This work enrichis the experimental data of ^{147,149}Sm neutron capture resonance and helps to clarify the differences between different evaluation databases at the above energies.

Copper and Nickel Accumulation and Translocation in Leafy Vegetables Irrigated with Metal-Containing Effluents

Author: Aleksandra Kravtsova[1]

Co-authors: Inga Zinicovscaia [1]; Alexandra Peshkova [1]

[1] *FLNP, JINR*

The treated and untreated wastewaters are widely used for irrigation in many developing countries. They often contain not only organic compounds, but also various metals that are both essential (zinc, copper) and potentially hazardous (chromium, nickel) for human health. Since plants, including leafy vegetables, can accumulate metals both in their roots and edible parts, this can be dangerous when consumed by humans.
The laboratory experiment was performed to assess the accumulation and translocation of copper and nickel in the green and underground parts of lettuce (Lactuca sativa), green onion (Allium fistulosum L.), arugula (Eruca vesicaria) and chard (Beta vulgaris var. cicla) irrigated with metal-containing effluents. The concentration of metals in effluents, soil and vegetables was determined by inductively coupled plasma optical emission spectrometry.
The highest average content of copper in the edible parts of vegetables were determined in lettuce (8.34±2.35 mg/kg) and chard (9.79±1.85 mg/kg). The highest content of nickel was determined in arugula (16.8±3.53 mg/kg) and lettuce (24.1±6.13 mg/kg). The content of copper and nickel in the edible parts of plants irrigated with metal-containing wastewater was 5–15 and 25–91 times, respectively, higher than in the control plants irrigated with filtered water.
The bioaccumulation and translocation factors of copper and nickel for leafy vegetables were calculated to assess their capacity to accumulate metals from the soil and transfer them to the above-ground parts of plants. The values of bioaccumulation factors of copper and nickel varied from 0.6 (onion) to 1.0 (chard) and from 0.3 (arugula) to 1.5 (lettuce), respectively. The leafy vegetables showed a low capacity to transfer copper and nickel from underground to above-ground plant parts. Arugula and lettuce were the exceptions with the values of the translocation factors of 0.7 ($n$ickel) and 0.8 (copper), respectively.
The estimated daily intake (EDI) of nickel and copper was determined based on their content in the edible part of leafy vegetables and their daily consumption. The obtained values were one or two order of magnitude lower than the established reference dose for nickel (0.02 mg/kg bw/day) and the nutritional requirements for copper (2-3 mg/day for adults; 0.5-0.7 mg/day for infants).

Development and Application of k_0-standardized Neutron Activation Analysis Utilizing Short-Lived Radionuclides at the Dalat Research Reactor

Author: Ho Manh Dung [1]

[1] *Center for Nuclear Technologies, Vietnam Atomic Energy Institute*

An optimized k_0-neutron activation analysis (k_0-NAA) method, incorporating cyclic irradiations of short-lived radionuclides (SLRNs), was developed at the Dalat Research Reactor (DRR). This study presents the precise characterization of reactor parameters using a fast irradiation facility, rigorous sample preparation, and advanced calibration of HPGe detector-based gamma-ray spectrometry for accurate element quantification. Utilizing SLRNs (^{77m}Se, ^{110}Ag, ^{20}F, ^{179m}Hf, ^{51}V, ^{46m}Sc), with half-lives ranging seconds to minutes, we targeted elements crucial for biological and environmental studies. The "k_0-Dalat" software, a home-made with highly automated capability, facilitated rapid analysis within a single workday. The method's accuracy was validated using certified reference materials (SMELS-I, NIST-SRM-1566b, NIST-SRM-2711a), demonstrated accuracy within 5-8% of certified values, with detection limits of 0.2–1.9 mg/kg for elements of interest in biological samples, confirming the method's high sensitivity and applicability for similar matrix analyses.

Neutron Nucleus Parity Violation Experiment on the Back-n Beamline of CSNS

Author: Mofan Zhang[1]

[1] *Indiana University, USA*

Parity Violation (PV) effects in p-wave resonances of compound nucleus has always been the interest of the NOPTREX ($n$eutron Optical Parity and Time-Reversal EXperiment) collaboration since it may shine lights on the search of Time-Reversal Invariant Violation (TRIV) in the same resonances that exhibit a large PV effect.
NOPTREX collaboration started performing experiments on the Back-n beamline since April of 2023 tested the performance of an in-situ ^{3}He SEOP polarizer to prepare for a future PV experiment on the beamline. (n, γ) angular distribution measurements on ^{139}La and NaI were performed on the GTAF BaF_2 array in 2024. The asymmetry in angular distribution of γ-ray from (n, γ) reaction of p-wave resonance relates to the k(J) factor that theoretically correlates the effect of PV and TRIV and could be a method for searching for new p-wave resonances. From the last day of 2024 to early 2025, a measurement on the PV effect of p-wave resonance in ^{139}La was performed. This measurement was the first attempt on PV measurements in China. We did not see the ~10% PV effect of La at 0.74eV p-wave resonance in an un-normalized crude analysis. Further analysis of this first PV experiment data is still ongoing. A second PV experiment with improved setup is preparing and the planned beamtime is late July of 2025.

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

Author: Ivan Kushnir[1]

[1] *FLNP, JINR*

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 ~10^{14} cm^{-2}·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 power pulse (therefore the stability and safety of the reactor) is sensitive to such parameters as the reactivity and the rate of reactivity change. 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. 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 with forced helium cooling. The results were obtained during thermal calculations in the CFX module of the ANSYS software.