ISINN-25

XXV International Seminar on Interaction of Neutrons with Nuclei

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

Dubna, 2017 **Abstracts**

Joint Institute for Nuclear Research

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

XXV International Seminar on Interaction of Neutrons with Nuclei

Dubna, Russia, May 22–26, 2017

Abstracts

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UCN, VCN, neutrons properties

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EPITHERMAL NEUTRON ACTIVATION ANALYSIS AND X-RAY COMPUTED TOMOGRAPHY OF SOME SCLERACTINIAN RED SEA CORALS

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Five corals belonging to very common scleractinian reef-building species collected from Suez Gulf, Egypt were analyzed using neutron activation analysis (NAA). Only the content of 26 elements (Na, Mg, Al, Cl, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Zn, As, Br, Rb, Sr, I, Cs, Ba, La, Ce, Gd, Hf, Th, and U) could be experimentally determined. As it is expected, Ca and Sr to have the highest content (32 to 34 % for Ca and 0.5 to 0.7 % for Sr) while the content of all other elements were within the range reported for worldwide corals. For a better understanding of the coral exoskeleton elemental content, the enrichment factor *EF* calculated for all analyzed elements showed a wide range of values varying from 0.2 in the case of Cl and $2 \cdot 10^6$ for Th and other insoluble elements suggesting, in the last case, a rather physical insertion of the neighboring soil dust. Although all corals were collected in the proximal vicinity of the Port Suez, no traces of anthropogenic pollution could be evidenced.

Key words Red Sea, Scleractinian corals, Enrichment factors, Neutron activation analysis

MICROPIXEL AVALANCHE PHOTODIODES AS ALTERNATIVE TO VACUUM PHOTOMULTIPLIER TUBES

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Recently, many types of Silicon photomultiplier tubes (SiMP) are produced by various manufacturers and available on markets. One of successful types of SiMP is micro pixel avalanche photodiodes (MAPD) which combine the advantages of conventional photomultipliers and solid-state photo detectors. MAPD is manufactured by Zecotek Photonics Inc. (Canada) and possesses advantages such as low operation voltage (~ 90 V), high gain (~ 10^6), high photon detection efficiency (~ 40%) and high pixel density (up to $4 \cdot 10^4$ pixels/mm^2). Typical photosensitive areas of MAPDs are 1.0×1.0, 3.0×3.0 and 3.7×3.7 mm^2. Main MAPD features are discussed and a number of examples of its applications are demonstrated in this work. Performances of MAPDs are discribed with different scintillator samples for various ionization particles and radiation types. In addition to spectroscopic performance, the timing performance of the photodiodes is also reported. These types of photodiodes can be applied in low temperature measurements due to their different design in comparison with products of other manufactures.

SCINTILLATION GAMMA DETECTORS BASED ON MICRO-PIXEL AVALANCHE PHOTO-DIODES

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In this work it is discussed gamma ray scintillation detectors based on micro-pixel avalanche photo-diodes (MAPD) and inorganic scintillators. The energy spectral performances of MAPD are evaluated with different inorganic scintillator samples of type LFS-8 and NaI(Tl). The energy spectra of LFS-8 scintillator sample with MAPD were measured using gamma-ray sources with energies of 23 keV to 1332 keV. Obtained results show that MAPD device has well linearity between the studied energies. Several gamma ray spectra are measured with MAPD + NaI(Tl) scintillation detector, too. Energy resolutions are evaluated from photopeaks and compared. The results show that MAPD are well suited with various scintillation crystals for gamma-ray detections in a broad energy range. These types of silicon photomultipliers have a great promise to use as scintillation light readout in scintillation detectors.

TRENDS AND TENDENCIES OF A TEN-YEAR BIOMONITORING STUDY OF ATMOSPHERIC DEPOSITION OF TRACE ELEMENTS AT THE TERRITORY OF BELARUS

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For the third time Belarus is participating in the moss survey carried out in the framework of the UNECE ICP Vegetation. Samples of moss species of Hylocomium splendens and Pleurozium schreberi were collected at 86 sites over the Gomel, Vitebsk and Minsk Regions in the summer of 2015. Out of 86 sample sites 30 samples were collected in the previously studied areas, other samples covered some new regions. A total of 30 elements were determined by epithermal neutron activation analysis. In general, moss was sampled at 250 sites evenly distributed over nearly the whole territory of the country. At present, there is enough data for sampling network optimization because previously it was too dense in some areas. Optimized network will allow completing moss survey over the whole country during a one-year period. Trends in atmospheric elemental concentrations from 2005 to 2015 were examined. The results showed that, except Cr, other element concentrations reduce or are at the same levels. Although we noticed the increase of metal concentration at some sampling sites, the comparison of the results for Belarus with the analogous data for the other European countries showed relatively low contamination levels for the most of heavy and toxic elements.

Silicon two-dimensional position-sensitive fast neutron detector for beam profile measurement

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Recently, a new experimental setup named TANGRA (TAgged Neutron and Gamma RAys), for studying the neutron-induced nuclear reactions, has been created and successfully tested in the Joint Institute for Nuclear Research (JINR) in Dubna, Russia.

In the present geometry TANGRA-setup in used to investigate the angular and energy distributions of gamma rays from nuclear reactions induced by 14 MeV neutrons.

It consists of: a portable 14 MeVneutron generator ING-27, an array of 22 Amcrys© NaI(Tl) gamma-ray spectrometers anda computerized 14bit, 100MHz, 32 channel JINR-AFI electronics data-acquisition system.

Silicon (Si) two-dimensional position-sensitive fast neutron detector was constructed and used for adjusting the neutron beam and measuring its profile.

In the present article we briefly describe the neutron profile meter and report some results from the characterization of the ING-27 "tagged" neutron beams.

Keywords: Gamma-rays, spectrometry, multichannel analyzer, neutron source.

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Investigation of the $^{171}Yb(n_{th},2\gamma)$ Reaction

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The proposed in Dubna method of measuring the intensities of the two-step cascades at γ-decay of the neutron resonances allows obtaining the most probable values of both the level density ρ of intermediate levels in compound-nucleus and the partial widths Γ of emission of reaction products (or radiative strength functions $k = \Gamma/(A^{2/3} \cdot E_\gamma^3 \cdot D_\lambda)$, where A is a mass of the nucleus, D_λ is average space between its levels, and E_γ is an energy of emitted γ-quantum). As in investigated $(n,2\gamma)$-reaction the energies of tree (initial, intermediate and final) cascade levels along with the probabilities of transitions between them are determined, the method also makes for clarification of a change dynamics in behavior of superfluidity phase of nuclear matter at excitation energy growing.

ENAA of Soil Profile from the Nile Delta, Egypt

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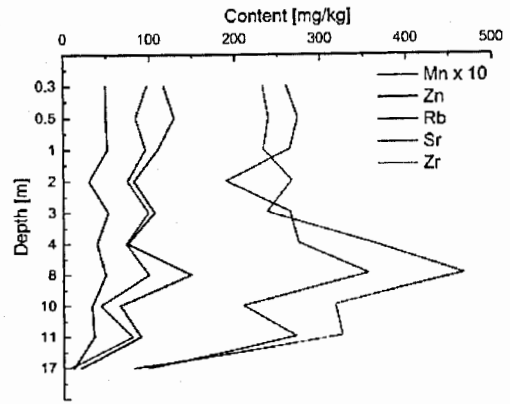
Abstract:
Ten soil samples collected at different depths in the soil profile of 0.25 – 17 m were subjected to epithermal neutron activation analysis at the reactor IBR-2 of FLNP JINR. A total of 38major and trace and elements were determined. Symbathic behavior of geochemically bounded elements was observed: Th and U; Cs and Mo; Cl and Br; and Fe, Ti, Ca, Al and Mg; *etc.* Sharp increase of concentrations at the depth of 8 m followed by no less sharp decrease of concentrations confirms the hypothesis that ~ 2.5 billion years ago the Nile Delta was a bay of the Mediterranean Sea.

Keywords: Nile Delta, INAA, Soil profile, Major and trace elements



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Major and Trace Element Distribution in Soils and Sediments from the Egyptian Central Nile Valley

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ABSTRACT: The distributions of 32 major and trace elements in 72 surface soil and sediment samples collected from Asyut to Cairo Nile river section were determined by epithermal neutron activation analysis and compared with corresponding data for the Upper Continental Crust, North American Shale Composite, Average Soil and Average Sediment as well as suspended sediments from Congo and Upper Niger Rivers, in order to establish to which extent the Nile sedimentary material can be related to similar material all over the world as well as to local geology. Their relative distributions indicate the presence of detrital material of igneous origin, most probably resulting from weathering of the Ethiopian Highlands and transported by the Blue Nile, the Nile main tributary. The distributions of nickel, zinc, and arsenic contents suggest that the lower part of the Nile and its surroundings including the Nile Delta is not seriously polluted with heavy metals, so that, in spite of a human activity, which lasted four millennia, the Nile River continues to be less affected by any anthropogenic contamination.

Keywords: Nile River; soil; sediment; neutron activation analysis, trace elements

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A METHOD TO COMPUTE FRAGMENT ANGULAR DISTRIBUTIONS FROM FISSION OF HIGHLY EXCITED NUCLEI

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In the interaction of high-energy particles with nuclei, high-energy states are excited which then decay with emission of a significant number of particles. In particular, fission may occur at some stage of nuclear decay if the nuclei are sufficiently heavy. The spectra and the multiplicities of the emitted particles, as well as the cross sections for the fission and yield of various daughter isotopes, are of great interest not only from the applied but also from the scientific point of view. Indeed, these observables are determined by the dynamics of the decay and carry an information on contributions of equilibrium and nonequilibrium processes, density of nuclear levels, fission barriers, and matrix elements of transitions.

To describe the decays of excited nuclei, computer programs are widely used, for example, the thoroughly documented and free TALYS program [1]. It uses both experimental data, in particular, for low-lying nuclear levels, as well as a large number of models for calculating nuclear characteristics and nuclear interactions. These models contain many free parameters, which are established in a usual way by comparing the measured cross sections and spectra with the calculated ones. Angular distribution of the emitted particles is also an important observable quantity. However, the TALYS program has limited possibilities for calculating angular distributions. In particular, in TALYS there are no means for calculating the angular distributions of fission fragments.

There are several reasons for these limitations. In particular, a semiclassical nature of the used models for pre-equilibrium processes are among them. This makes impossible the calculation of the change in the alignment of nuclear spins in these processes. Another reason is related to the specific mechanism of the formation of the fission fragment angular anisotropy which differs from the more simple mechanism acting in the case of the emission of light particles. Meanwhile, the well documented and free programs for computing the angular distributions of fragments from fission of nuclei by fast neutrons and protons are of obvious significance, in particular, due to existence of the appropriate experimental data and to the interest in their interpretation (see, i.e., [2,3]).

In this paper, we describe the capabilities of a modified version of the TALYS program which allows to compute the angular distributions of the emitted particles, in particular, the angular distributions of the fission fragments at any decay stage of the highly excited nuclei.

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INVESTIGATION OF DISC CHOPPER FOR TEHRAN RESEARCH REACTOR NEUTRON DIFFRACTOMETRY SYSTEM USING VITES S3.3A CODE

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Abstract

Structure is one of the most fundamental properties of materials in a broad range of disciplines. Our understanding of modern materials and systems such as superconductors, magnetic materials, Liquid crystals, layered materials, materials for renewable energy, polymers, rocks and zeolites depends on a detailed understanding of the structure at the atomic and molecular level [1–3]. Diffraction techniques are the standard tool for structural determination. There are many diffractometer systems rely on time-of-flight (TOF) techniques. The TOF technique is a general method for determining the kinetic energy of a traveling neutron, by measuring the time it takes to fly between two fixed points whose distance is known. Disc choppers are useful tools to chop the neutron beam to limit the neutron wavelength bandwidth. The neutron flux at an instrument positioned at a distance (r) from the neutron source will be dramatically reduced according to the r^2 law for isotropic radiation. This reduction can be significantly decreased by using neutron guides. A neutron guide works via total reflection of neutrons from the guide's glass walls, which are covered with a smooth single layer material such as nickel, or the even more efficient ^{58}Ni. Along such total-reflecting surfaces, neutrons can be guided from the source to the instrument with almost no loss. The angular acceptance of a neutron guide can be further increased by reflection from a so-called supermirror. The supermirror beam deviator, consisting of two flat supermirrors, is used to separate out and shield the fast neutron and γ-ray components of the original beam coming from the reactor, thus minimizing the undesirable radiation background. In this work, we have considered the F channel of Tehran Research Reactor (TRR) for diffractometry based on chopper and guide system. Neutron flux has been obtained after a disc chopper, with an opening window of 45^{o} and in chopper various speeds. The best speed was 25000 rpm and neutron flux at the sample position was $2.5\times10^{7}n/cm^{2}\cdot s$. The results show that, F channel of TRR can be equipped with TOF technique.

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ASSESSING THE ENVIRONMENTAL POLLUTION USING NEUTRON ACTIVATION ANALYSIS – K_0 METHOD ON MOSSES

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The problem of toxic pollutant agents that exists in environment was and still is a main interest subject for nowadays health protection issues. Evaluating the impact of these agents on human health can influence major decisions that are to be taken by the authorities concerning the industrial activities developed in the inhabited areas or from the surrounding areas that directly impact the environment and inferentially the man. Precise measurements of toxic particles in the environment at the level of microelements are essential for exact and correct evaluations of the pollution degree. In order to determine the chemical elements that have negative effects on human health, we used as vegetal indicator, the ground moss. This plant has the ability to retain in the tissue the chemical elements precipitated from the atmosphere, because it is missing the cuticle that would normally prevent the elements from penetrating the cell interior. In order to determine the elements' concentration in the samples, it was employed as analysis method the neutron activation (NAA-k_0) using k_0 standardization. The neutron activation analysis is an analytic technique based on measuring the number and energy of gamma radiation emitted by the radioactive isotopes produced in the sample matrix by irradiation with thermal neutrons in a nuclear reactor. After the irradiation and the specific radioactive decay, the energy spectrum of gamma rays is obtained by measuring the sample with a detection system for high-resolution gamma spectrometry. The sample irradiation was processed in the TRIGA ACPR reactor in the rabbit (D10 location). The study was conducted on a total of four samples of ground moss from the environment (rough samples) and these were processed, irradiated and studied and the results obtained were recorded in a database. The thermal neutron flux supplied by the ACPR reactor in the rabbit location was fare enough for activating elements like manganese, potassium, bromine, europium, lanthanum, arsenic, scandium, antimony, iron. During the entire irradiation period, the presence of the sample in the irradiation location did not disturb the average value of the thermal neutron flux. The differences showed between the elements concentrations in the samples are actually because of the pollution more or less intense in the areas from which they were taken. Hence the quality of the ground moss as a good monitor. From the analysis of the results obtained on these samples and following the comparison with the reference values, it was noticed a slight excess concentration for arsenic and antimony. These overhauls are smaller than 2 ppm. Nevertheless, the alert value is not reached.

Key words: Neutron activation analysis, K_0 method, moss, ACPR

APPLICATION OF FLASH ADC FOR MIXED GAMMA-NEUTRON FIELDS SPECTROMETRY

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Modern spectrometers of ionizing radiations are based on the digital conversion of analog output signals from detectors, their subsequent processing and interpretation in the form of an energy spectrum. In most commercial spectrometers analogue spectrometric processing is implemented. It involves several analog blocks and a spectrometric ADC. The ADC holds the amplitude maximum of the input pulse, which is used to calculate the energy of a registered particle and build amplitude histograms.

The emergence of Flash-ADCs with sampling frequencies up to several GHz with a resolution up to 14 bits, as well as high-speed FPGAs, made it possible to develop a fundamentally new approach to analog-to-digital processing of pulsed signals. Continuous acquisition of the signal occurs at the output of the charge-sensitive preamplifier. After that, a sequence of pulses can be processed with one of the digital pulse processing algorithms (DPP).

CAEN flash ADCs are the most ready and promising among other similar devices on the market, as they have been widely used by a number of big international experiments as well as smaller laboratories. Several digital pulse processing algorithms can be implemented in the ADC's FPGA, of particular interest is the DPP-PSD (pulse shape discrimination). Operation of the algorithm is based on the fact that neutrons and gamma quanta have different ratios of fast and slow decay components of the pulse.

When the on-line analysis is not sufficient, the raw digitized signals can be used for advanced off-line analysis. The choice of the digitizer characteristics, in terms of sampling rate and resolution, depends on the detector signals and the requirements of the specific application.

STUDIES OF TOTAL, BIOACCESSIBLE, PROTEIC, LIPIDIC, AND IONIC SPECIES OF IODINE IN NUTRITIONAL MATERIALS BY VARIOUS FORMS OF NEUTRON ACTIVATION ANALYSIS

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Iodine is considered an essential trace element (micronutrient) for humans. Either the lack or the excess of it can cause health problems. Iodine deficiency disorder (IDD) is quite common in many African and Asian countries while in countries such as Canada the daily iodine intake can be several times higher than the recommended value. The main source of iodine for general population groups is food items such as marine fish, seaweed, egg, and milk. Milk provides 16-30% of the dietary iodine intake, and in many countries in the Northern hemisphere high milk consumption could be a major contributor to the bodily iodine intake. Obviously, total iodine, its chemical species and absorbable fraction are of much interest in both nutritional and toxicological studies. Iodide is the most common form of iodine in foods and is readily bioavailable. Much of the iodine in muscle meats is bound to protein. Iodine in milk, on the other hand, is reported as not bound.

The determination of iodine at trace levels with high precision and accuracy in nutritional materials is a rather difficult task. Neutron activation analysis (NAA) is ideally suited for the measurement of low iodine levels in a variety of complex sample matrices. Over the last 30 years or so we have developed various methods for the detection, identification and measurement of proteic, lipidic and ionic species of iodine in nutritional materials by various forms of NAA. These methods include conventional instrumental NAA (INAA) and epithermal INAA (EINAA), pseudo-cyclic INAA (PC-INAA) as well as EINAA (PC-EINAA), then INAA, EINAA, PC-INAA and PC-EINAA in conjunction with anti-coincidence (AC) gamma-ray spectrometry, preconcentration NAA (PNAA), and radiochemical NAA (RNAA). We have also developed speciation NAA (SNAA) methods by combining methyl esterification, gas and liquid chromatography, capillary electrophoresis, mass spectrometry, and nuclear magnetic resonance spectrometry with NAA to study iodine species in macromolecules to subcellular fractions of fish and milk. These methods and some results will be presented.

STUDIES OF NUTRITIONALLY AND TOXICOLOGICALLY IMPORTANT ELEMENTS IN FOODS AND DIETS BY NEUTRON ACTIVATION

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Food has long been known to play a key role not only in the health status of humans but also in their social lives. Preventive medicine promotes healthy eating and nutritional aspects of food where the interest is mainly focused on the adequacy of the daily intake of all essential elements through diet by the population at large. Toxicologists, on the other hand, are concerned about the levels of various heavy metals in food. The present knowledge about the dietary requirements for elements is rather poor as evident from the facts that in Canada (as a typical example) Recommended Dietary Allowance (RDA) levels have so far been given for only 9 elements (Ca, Cu, Fe, I, Mg, Mo, P, Se, Zn), Adequate Intake (AI) levels for 6 elements (Cl, Cr, F, K, Mn, Na), and only Tolerable Upper Intake Levels (UL) for B, Ni, and V. The situation is worse for most toxic elements where sufficiently reliable data are not available for setting maximum permissible levels (MPL) to minimize health hazards. It is therefore necessary to monitor diets for as many elements as possible, may they be of nutritional or toxicological importance.

We have developed a combination of instrumental (INAA), epithermal (EINAA), preconcentration (PNAA), and radiochemical (RNAA) neutron activation analysis (NAA) methods for the determination of up to 24 elements in duplicate diets and individual food items. We have used both fission and epithermal neutrons for irradiations and conventional or anti-coincidence (AC) gamma-ray spectrometry for counting. We have developed: (i) pseudo-cyclic INAA (PC-INAA) and cyclic INAA (CINAA) methods for rapid determinations of low levels of Se through the 17.4-s nuclide of ^{77m}Se; (ii) EINAA and EINAA-AC methods for measuring even 3-5 μg kg^{-1} levels of I in food; (iii) an EINAA method for measuring As after 16 h irradiation in a Cd-site; (iv) a combination of INAA and EINAA methods for Al in food after making correction for ^{31}P(n,α)^{28}Al reaction; (v) an INAA method for Br, Ca, Cl, K, Mg, Mn, Na and Sn through their medium-lived nuclides; (vi) another INAA method for the longer lived nuclides of Co, Cr, Fe, Rb, Sb, Sc and Zn; (vii) a simple RNAA method using sulfide coprecipitation for measuring low levels of As, Au, Cu, Fe, Hg, Mo, Sb, Se and Zn; and (viii) a PNAA method consisting of coprecipitation of U and Th with calcium phosphate. We have also calculated expanded uncertainties of measurement for several elements by these methods. We have applied these methods to individual food items as well as duplicate diets. The details of the methods will be presented along with results.

Possibility of Fast Neutron Detection with Position Sensitive Pixel Detector Timepix

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This paper presents a position-sensitive detection method for fast neutrons by proton recoil in a plastic scintillator. The detector consists of a plastic scintillator with silicon photomultiplier readout and pixel detector Timepix. As known plastic scintillators are hydrogen-rich materials adopted as neutron to proton convertors by elastic (n,p) scattering. Silicon pixel detector Timepix is used for position-sensitive detection of recoil protons which exit the plastic scintillator. Scintillation light is read out using micropixel avalanche photodiode of type MAPD-3NK from Zecotek Photonics Inc. MAPD-3NK allows to measure the energy loss by protons in the plastic scintillator and to trigger Timepix detector.

Timepix detector is a silicon based hybrid pixel detector which allows obtaining information from each pixel. The detector consists of 256×256 square pixels (55 μm) with pitch size of 55 μm. The active area and thickness of the detector are about 1.96 mm^2 and 300 μm, respectively.

Micropixel avalanche photodiode of type MAPD-3NK is one of silicon based alternatives to common vacuum photomultipliers. MAPD-3NK consists of deeply burned pixels connected in parallel and operating in the Geiger mode. MAPD-3NK has a total photosensitive area of 3.7×3.7 mm^2 and 10000 pixels per mm^2. Operating voltage is about 90 V for this photodiode.

Experiments have been carried out with ^{239}Pu-Be radioisotopic neutron source and monoenergetic neutrons from the reaction D(d,n)^{3}He on the EG-5 Van de Graaff accelerator, FLNP, JINR.

DEVELOPMENT OF THE SOFTWARE COMPLEX FOR HIGH-VOLUME MULTI-ELEMENT NEUTRON ACTIVATION ANALYSIS AT THE IBR-2 REACTOR AND THE IREN FACILITY OF FLNP JINR

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The hardware-software complex for automation of multi-element high-volume neutron activation analysis at the IBR-2 reactor of FLNP at JINR was put into operation in 2014. This hardware-software complex is a reliable basis for numerous surveys of various types of samples at the IBR-2 reactor, as well as at the IREN facility. It should be noted, the first steps to share the experience of FLNP in the field of automation of NAA at the Institute of Nuclear Physics, Almaty, Kazakhstan (research nuclear reactor WWR-K) were made.

Various variants for improvement of programs from the complex was proposed and implemented over several years of active using the complex. Besides, some problems were identified and resolved during long-time round-the-clock work of the complex.

This paper discusses the changes concerning the software for automation of measurement of gamma-spectra of induced activity of samples "Measurements", the software for automation of quantitative determination of element concentrations in samples "Concentration" and the "Standards search" software, which is designed for the selection of standard samples, providing the decision of tasks of neutron activation analysis. In addition, the work describes a new hardware-software tool that solved the problem of incorrect operation of sample changers controllers' driver.

EPITHERMAL NEUTRON ACTIVATION ANALYSIS OF ENVIRONMENTAL AND GEOLOGICAL SAMPLES AT THE FRANK LABORATORY OF NEUTRON PHYSICS

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The epithermal neutron variant of the instrumental neutron activation analysis (INAA) proved to be one of the most sensitive analytical methods able to determine the content of more than 40 elements with mg/kg accuracy and without sample pre-treatment. Therefore, the epithermal neutron activation analysis (ENAA) was successfully used at the FLNP JINR to investigate the elemental content of great diversity of samples beginning with rocks and soil collected from various geological formations and ending with lichens and mosses as environmental bioindicators. The main goal of such projects was first of all to document any connection between the presence of a certain group of elements and some general traits of the investigated medium such as the anthropogenic influence, geology or geochemistry as well as the past climate. To accomplish this task, more statistical data analysis method such as Principal Component, Discriminant or Cluster Analysis, Analysis of Variance as well as differentiating diagrams were intensely used. In this regard, the rootless lichens and mosses showed to be the best indicators of any anthropogenic pollution. It was the case of the former industrial centre Baia-Mare (Romania) where the *Sphagnum girgenshonii* moss proved that the newly operating non-ferrous smelter were the main source of pollution. *Hypnum cupressiforme* (Hedw.) and *Pleurocarpous* sp mosses showed that the Moldavian cities of Chisinau and Balti experience a particular environmental stress. On contrary, the Antarctic *Polytrichastrum alpinum*, *Pohlia cruda, Sanionia georgicouncinata* and *Syntrichia ilaris* mosses as well as *Usnea antarctica* and *Usnea aurantiaco-atra* lichens, in spite of their different capacity to retain the polluting elements, documented no traces of anthropogenic contamination of the Western Antarctica Livingstone Island. A correlated ENAA and Discriminant Anlaysis of the elemental transfer from soil to wine of 18 major and trace in wines from two well-known Moldovian vineyard: Ramanesti and Cricova allowed not only to prove in all sort of wine an increased content of potassium varying from 370 to 700 mg/l, but also to classify all wine samples according to their types: red and white as well as to their origin. ENAA was also used to determine the distributions of 36 major and trace elements in 214 surface soil and sediment samples collected from the Egyptian section of the Nile River. Their relative distributions indicate the presence of detrital material of igneous origin, most probably resulting from weathering on Ethiopian highlands and transported by the Blue Nile, the Nile while the Ni, Zn and As content suggest that the lower part of the Nile including the Nile Delta is not seriously polluted with metals from local human activity. Ten samples of loess and palaeosols collected from the Costinesti - Dobrogea (Romania) loess deposit and covering a time span of about 690 ± 90 ka, were analysed by XRD, ENAA and XRF in order to determine the origin as well as the climatic conditions during loess deposition. The Chemical Index of Alteration, Chemical Index of Weathering as well as the Rb/Sr ratio confirmed rather limited weathering during the formation of the south-eastern Dobrogea loess deposits. The elevated content of Cr and Ni indicated the presence of a certain amount of felsic rock material while the Zr and Hf whose content was more than twice that of the Upper Continental Crust indicate significant sediment sorting.

OPTICAL OBSERVATION OF HYDROGEN AND DEUTERIUM CRYSTAL GROWTH AND IMPLICATIONS FOR ULTRACOLD NEUTRON TRANSMISSION EXPERIMENTS

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Abstract

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

The precise knowledge of UCN cross sections in solid deuterium is pivotal to the design and improvement of new UCN sources, which promise to provide higher UCN densities than the current frontrunner – the "turbine" at Institut Laue-Langevin (ILL) in Grenoble, France.

Total UCN cross sections in hydrogen and deuterium were measured in transmission geometry with a time-of-flight (TOF) setup. For the first time, the crystals and liquids were measured in a highly polished and optically transparent sample container. This allowed for proper online observation of the sample along the beam axis prior to the transmission measurement with UCNs, and revealed thermodynamic effects that are important to take into account.

The experimental data were corrected for neutron absorption and several side effects, in particular for UCN scattering on rough material surfaces, which is significant at small neutron velocities. In my talk, I will present velocity-dependent cross section data (σ^{scatt}) for UCNs in liquid and solid deuterium and hydrogen.

*Forschungsneutronenquelle Heinz Maier-Leibnitz (FRM-II) at Technische Universität München, Germany, and Leonhard-Lorenz-Stiftung Munich, Germany, contributed financially to this project.

Determination of Rare Earth Elements in Phosphate Samples by Instrumental Neutron Activation Analysis and Inductively Coupled Plasma Mass Spectrometry

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The rare earth elements (REE) form the largest chemically coherent group in the periodic table. The versatility and specificity of the REE have given them a level of technological, environmental, and economic importance considerably greater than might be expected. The objective of this work was to determine the concentration of rare earth elements in phosphate samples from Egypt and Saudi Arabia, using both instrumental neutron activation analysis (INAA) and inductively coupled plasma mass spectrometry (ICP-MS). The samples were prepared together with standard reference material and simultaneously irradiated in a neutron flux of 7×10^{12} $n\cdot cm^{-2}\cdot s^{-1}$ at ACTLAB activation laboratories Canada. Irradiated samples were measured using gamma-ray spectrometer based on HPGe detector. The choice of the nuclear reaction, irradiation and decay times and of the proper gamma ray measurement to determine the concentration of La, Ce, Nd, Sm, Eu, Yb, Lu and Tb concentrations are presented and discussed. The rest rare earth elements Pr, Gd, Dy, Ho, Tm and Er were measured by ICP-MS at ALS-chemix Lab, Vancouver- Canada.

Determination of major and trace elements in soils around industrial facilities in Romania using nuclear and related techniques

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Determination of elemental content in soil samples collected in the vicinity of several industrial enterprises in Romania was conducted in order to assess whether the potential high content of certain metals is due to anthropogenic impact on the study area, or their occurrence in soil is due to the geological peculiarities.

Thesoil samples were collected at sites located in the industrial areas of Galati, Braila and Targoviste, Romania, as well as from protected zones in south and eastern part of Romania (control soils). Soil samples were randomly taken from the surface layer (0–5 cm) in each location in 20 x 20 m plots as 5–8 subsamples, which were mixed to form a composite sample. The samples have been analyzed by combined nuclear and atomic techniques, such as epithermal neutron activation analysis (ENAA) at the reactor IBR-2 of the Frank Laboratory of Neutron Physics, Joint Institute of Nuclear Research in Dubna, Russia, energy-dispersive X-ray fluorescence (ED-XRF) at "Dunarea de Jos" University of Galati, Romania, particle-induced X-ray emission (PIXE) at "Horia Hulubei" National Institute for R & D in Physics and Nuclear Engineering (IFIN-HH), Magurele, Romania and inductively-coupled plasma mass spectrometry (ICP-MS) at "Valahia" University of Targoviste, Romania.

A total of 39 elements were determined: Na, Mg, Al, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Co, Zn, As, Br, Rb, Sr, Zr, Mo, Sb, I, Cs, Ba, La, Ce, Nd, Sm, Eu, Tb, Dy, Tm, Yb, Hf, Ta, W, Au, Hg, Th, and U. The results obtained are discussed in relation with legislated permissible levels, and are compared to values reported in literature for similar studies and elemental concentrations in EU topsoil and Earth's crust average and median values.

Further work will be performed for some trace elements in industrially contaminated soils by employingatomic absorption spectrometry at "Dunarea de Jos" University of Galati, Romania. The study was carried out in relation with air pollution monitoring in south and south-eastern Romania using mosses and tree bark as biological indicators, in the frame of the Romania-JINR project no. 91/2017.

NUCLEAR AND ATOMIC ANALYTICAL TECHNIQUES AND IMAGING MICROSCOPY USED FOR THE INVESTIGATION OF ADVANCED FUNCTIONAL MATERIALS

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In this paper we present some applications of nuclear and related analytical techniques and imaging microscopy in materials science. The employed techniques were: instrumental neutron activation analysis (INAA), Energy-Dispersive X-ray Fluorescence (ED-XRF), and Scanning Electron Microscopy Energy-Dispersive X-ray Analysis (SEM-EDX).

The results of INAA and SEM-EDX techniques obtained in the frame of JINR-Romania bilateral projects between Frank Laboratory of Neutron Physics (FLNP) of Joint Institute of Nuclear Research (JINR) at Dubna, Russia, and Dunarea de Jos University of Galati, Romania (UDJG), for the investigation of micro-composition of high purity materials such as cubic boron nitrides (cBN) and various brands of synthetic diamonds obtained at National Academy of Sciences of Belarus, in combination with their micro-structure characterization using imaging techniques SEM and X-ray Diffraction (XRD) are described. Application of SEM-EDX for the investigation of micro-composition of crystalline samples allowed the determination of impurity content in cBN (Na, Al, Mg, Si, Ca, Fe, Cl, Zn) and diamond samples (Al, O, Si, Ca) in dependence with the synthesis conditions, besides the transformation of boron nitride into carbonate with increasing synthesizing pressure. Also, the techniques were used to determine the influence of the catalyst composition and synthesis conditions on the crystallization processes and characteristics of the diamonds, including the degree of conversion of graphite to diamond, and to study the impurity composition of diamonds and its impact on the physical and technical characteristics. Electron microscopy highlighted the structural differences between the powder diamond samples with various grain sizes, synthesized in different pressure and temperature conditions.

On-going work is carried out in the frame of Romanian-Russian collaboration between UDJG and JINR (project no. 79/2017), by using Atomic Absorption Spectroscopy for the investigation of trace constituents of selected functional materials and Fourier-Transformed Infrared Spectroscopy and Raman Spectroscopy for the analysis of the spectral region of absorption peaks and vibrational spectra of diamonds and cBN.

NEW BORON DIRECT BEAM DETECTOR FOR SMALL ANGLE NEUTRON SCATTERING SPECTROMETER

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One of the important part of YuMO (SANS) spectrometer is a direct beam detector, which is located in the end ofthe pathway of neutron beam [1]. Key goal of this detector is to measurethe beam-line flux and use it for normalization in case of measurements with strong scattering or high absorption samples [2]. Up to the last upgrading of IBR-2 the semiconductor detector with ^{6}Li convertor with special geometry andefficiency 0.1% was used. Here, we present new type of boron detector in Al-alloy body with the thickness of incoming window 5 mm and B_4C convertor with about several cm^2 sensitive part. The spectra of neutrons for samples are given. The efficiency, stability and some experimental results are discussed. The possibility of development of this type of detector is suggested.

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

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An investigation of the angular and energy distributions of gamma rays from the inelastic scattering of 14 MeV neutrons on a number of light nuclei was performed in the frame of the project TANGRA (TAgged Neutron and Gamma RAys) at JINR Frank Laboratory of Neutron Physics [1]. Using the experimental setup, consisting of ING-27 portable generator of 14-MeV "tagged" neutrons and Fe-shielded ring of 22 NaI(Tl) gamma-ray detectors, we have accomplished the measurements with C, O, Al, Si and Mg samples.

The precise measurements of the gamma-ray yields at large ($\theta > 160^\circ$) and small ($\theta < 20^\circ$) angles are very important for making correct assumptions about the *n*-induced nuclear reaction mechanism.

The existing database on the gamma ray angular distributions at these angle ranges contains contradictory and quite scattered values.

On the other hand, the theoretical description of the angular distribution in these areas is very sensitive and dependent on the theoretical model features.

Here, we report the recently obtained experimental data, as well as the model calculations for the angular distributions of gamma-rays from the (n,n'γ)-reaction on ^{12}C and some of the nuclei listed above.

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Concentrations of 50 Elements in the Atmosphere in Bratislava

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Abstract

The instrumental neutron activation analysis (INAA), atomic absorption spectrometry (AAS), inductively coupled plasma–mass spectroscopy (ICP-MS) and PIXE methods were used in order to evaluate the concentrations of 50 chemical elements (heavy metals, rare earths, noble metals and actinides) in the atmospheric aerosols. We used the nitro-cellulose membrane filters PRAGOPOR with the collection efficiency of approximately 100%. The sampling sites Líščieúdolie and Kamennénamestie (square) in Bratislava were examined. The sampling device has been exposed at the height of 2.8 m above the ground. The first site is relatively pristine location with a low density traffic. The second sampling site is characterized by a higher density traffic.

PRESENT STATUS OF THE MOSS SURVEY IN 2015/2016

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A summary of the present situation in the mosssurvey 2015/2016 is given. In agreement with the long-term strategy of the LRTAP Convention to enhance participation and improve air quality in Eastern Europe, the Caucasus, Central Asia and South Eastern Europe, efforts to extend the moss survey to former republics of the USSR were successfully undertaken in countries such as Armenia, Azerbaijan, Georgia, Kazakhstan, Moldova, and Tadjikistan. In the current moss survey the following territories of the Russian Federation were sampled: Moscow, Tver, Tula, Ivanovo, Leningrad (Tikhvin district), Bryansk, and Kaliningrad Regions, Voronezh Reserve, Yamal Penisular, Republic of Udmurtia, and Far East (Kamchatka). Up-to-date results are reported by Austria, Latvia, Norway, Poland, Serbia, and Sweden. Scandinavina countries, in addition to the requested 12 elements (Al, As, Cd, Cr, Cu, Fe, Hg, Ni, Pb, Sb, V, Zn), have reported data on Li, Be, B, Na, Rb, Sr, Y, Nb, Rh, Ag, Tl, Cs, Ba, La, Ce, Pr. Nd, Sm, Eu, Gd, Tb, Dy, Er, Yb, Ir, Pt, Te, Bi, Th, U, Mg, S, Ca, Sc, Ti, Mn, Co, Ga, K, and Se, whereas Serbia extended the request list of elements to include Ba, Ca, Ce, Co, In, Ga, K, Mg, Mn, Mo, Na, Rb, Sr, Sm, Y, and W. Switzerland reported extra data for S,Ag, Bi, Co, Se, and Tl. Sector of NAA and Applied Research of FLNP JINR (Dubna) continues support for the moss survey program in some of its member states: Bulgaria, Czech Republic, Mongolia, Poland, Romania, Slovakia, Vietnam, as well as in some non-member states: Albania, Hungary, Thailand, South Korea, and China. In spite of the growing interest in assessment of the deposition of persistent organic pollutants (PAHs, PCBs, PBDEs, dioxins, PFOS, etc.) using moss, only a limited number of the Western European countries determine POPs. Most countries report results on nitrogen determination in moss samples. Some countries will report results on radionuclides of technogenic origin in Europe. The relevance of these studies to the UN Convention on long-range transboundary air pollution (LRTAP) is emphasized. Some details are given on the newly established database for storage of information about the European and Asian moss survey, conducting and storing analytical results on heavy metals, nitrogen, persistent organic compounds, and radionuclides (^{137}Cs, ^{210}Pb, etc) based on moss analysis. Potentialities of using moss planchettes for search of cosmic dust deposition are illustrated with images obtained using microanalysis (SEM and TEM).

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ANISOTROPY IN THE FRAGMENTS EMISSION FROM FISSION INDUCED BY INTERMEDIATE ENERGY NEUTRONS (1–200 MeV) IN ^{nat}Pb AND ^{239}Pu

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At the previous ISINN Meetings, the experimental data on angular distributions of fission fragments for some actinide nuclei measured at intermediate neutron energies up to 200 MeV using the neutron TOF-spectrometer GNEIS in Gatchina have been presented. Recently, the measurements of the angular distributions of fission fragments have started for ^{239}Pu and have been carried out for ^{nat}Pb at 36 m flight path of the GNEIS utilizing the PNPI 1 GeV proton synchrocyclotron as a pulsed neutron source. The measured angular distributions and anisotropy $W(0^{\circ})/W(90^{\circ})$ calculated from them are presented and compared with results obtained earlier for other nuclei.

ACTIVE BIOMONITORING OF AIR POLLUTION IN BAKU, AZERBAIJAN

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For the first time active biomonitoring (moss bags technique) was applied to air pollution study in Baku, the capital of Azerbaijan. Moss *Sphagnum girgensohnii* Russow was collected in the pristine wetland area of Central Russia and exposed in bags at twenty-one urban sites in Absheron Peninsular. Exposure time was 3 months (November 2016 – January 2017). The samples were subjected to multi-element epithermal neutron activation analysis at the reactor IBR-2 of FLNP, JINR. Major and trace elements were determined, including heavy metals, rare earth elements and U and Th. Atomic absorption spectrometry was used to determine Pb, Cd, and Cu in the same moss samples. Multivariate statistical analysis allowed characterization of potential pollution sources. GIS (geographic information system) technology was used for creations of pollution maps in the study area.

Map of the studies site in Baku urban area.

NEUTRON DIFFRACTOMETRY CHANNEL OPTIMIZATION TO OBTAIN THE HIGHEST NEUTRON FLUX AND THE LEAST FAST NEUTRON NOISE

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Abstract

Neutron powder diffraction (NPD) is complementary to many other materials characterization techniques. Whereas the large capital costs associated with intense neutron sources, neutron diffraction is rarely the first technique used to study a particular material or a highly specialized way to provide critical information or facilitate a critical in situ experiment. However, some material analyses are not possible using the other procedures such as investigation of magnetic properties of materials or distinguishing between the adjacent elements in the periodic table. In overall, neutron diffraction could involve many unique advantages: the neutron scattering strength is not dependent on the atomic number. It is possible to observe the effect of light elements in the presence in heavy ones in the diffraction pattern. Neutrons are deeply penetrating so they can diffract off specimens contained in cryo-refrigerators or furnaces, making it easy to examine materials under special conditions and in special environments. Unlike the case for X-Rays, the scattering of neutrons from materials can be accurately calculated making comparison to theoretical [1]. Mazzochi et al. reported a powder diffractometer has been recently installed on the IEA-R1 reactor at IPEN-CNEN/SP. IEA-R1 is a light-water open-pool research reactor. At present it operates at 4.5 MW thermal with the possible maximum power of 5 MW. At 4.5 MW the in-core flux is ca. 7×10^{13} $cm^{-2}s^{-1}$. In spite of this low flux, installation of both a position-sensitive detector (PSD) and a double-bent silicon monochromator has turned possible to design the new instrument as a high-resolution powder diffractometer [2]. In the present work, NPD system of 5 MW Tehran Research Reactor was modeled using MCNPX2.7.0 and Vitess3.3a codes in details. The system uses a PG reflector to reflect 0.02–0.33 eV neutrons through the second collimator. The neutron spectra achieved by Vitess code at sample position showed good conformity with the experimental measurements. Our simulations showed registration of an adequate thickness of Al_2O_3 inside the NPD facility could decrease fast neutron noise drastically.

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POTENTIAL INVESTIGATION OF ^{99}Mo PRODUCTION VIA UO_2SO_4 LIQUID TARGETS CONTAINING 1.6 GRAM OF ^{NAT}U IN A 5 MW RESEARCH REACTOR

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Abstract

The most routine methods of ^{99}Mo production are either by $^{98}Mo(n,\gamma)^{99}Mo$ reaction or by $^{235}U(n,f)^{99}Mo$ fission process; the highest specific activity of ^{99}Mo among all production methods is achieved by the second process [1, 2]. However, recently some research centers have directed their attention toward liquid target application instead of the previously mentioned solid ones. Obviously, after the irradiation, ^{99}Mo recovery from the liquid targets is easier and faster than routine solid LEU targets. Meanwhile, the effluent can be used for the next irradiation. Therefore, this work investigates the production potential of ^{99}Mo using uranyl sulphate liquid target irradiation in a 5 MW nuclear research reactor. Irradiation of four liquid targets involving natural uranium was theoretically investigated in the TRR irradiation boxes. The most optimize uranyl sulphate concentration was determined to fulfill convection condition of the TRR irradiation box cooling. The burnup calculations using the MCNPX 2.7.0 code showed about 5 Ci of ^{99}Mo is produced after 7-days irradiation at 4 MW power. Application of an enforced cooling inside the irradiation boxes could easily increase the radioisotope production rate to >100 Ci. Low cost of such liquid targets, extraction of gaseous fission products, short-time chemically separation of the proposed products and reusability of the irradiated liquid target are the main attractions of such method for ^{99}Mo production.

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GEOMETRY OPTIMIZATION OF URANYL NITRATE LIQUID TARGET SYSTEM FOR ^{99}Mo PRODUCTION USING 30 MeV PROTON CYCLOTRON

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Abstract

^{99}Mo radioisotope is widely demanded by world community for both therapy and imaging purposes. Accelerator and reactor-based routine procedures are applied to produce this radioisotope. Newly proton-fission production method has been taken in attention by some research centers. In the present work, computationally investigation of the ^{99}Mo production yield in uranyl nitrate liquid targets irradiated by 30 MeV proton particles was aimed. In the present work, height and radius of the chamber of the liquid target are optimized considering minimum required solution for production of an adequate amount of ^{99}Mo. The obtained results showed uranyl nitrate liquid targets could be efficiently used to produce 15.67 Ci yield of ^{99}Mo using 30 MeV proton irradiation of the optimized-dimension target after 150 μA current application for 24 hours irradiation. Also this accelerator-based procedure using proton-fission induction in the natural uranium dissolved in nitrate solution presents a potentially competitive alternative in comparison with the reactor-based or other accelerator-based methods to produce ^{99}Mo and some other fission products simultaneously.

Measurements of P-odd Asymmetry of α-Particle Emission in the ^{10}B(n,α)^{7}Li Nuclear Reaction

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Abstract

We present measurements of P-odd asymmetry of emission of α-particles in the ^{10}B(n,α)^{7}Li nuclear reaction, which are carried out using beams of polarized cold neutrons at Petersburg Nuclear Physics Institute (PNPI, Gatchina, Russia) and Institut Max von Laue - Paul Langevin (ILL, Grenoble, France) nuclear reactors. The α-particle detector is an ionization chamber. We employed an ionisation chamber with insensitive gaseous layer in a configuration allowing us to suppress the left-right asymmetry well below 10^{-8}. As final result of this experiment we obtained $\alpha_{P-odd}^{^{10}B,\alpha} = -(11.2 \pm 3.4) \cdot 10^{-8}$.

INVESTIGATION ON THE USE OF TEHRAN RESEARCH REACTOR MEDICAL ROOM FOR THERMAL NEUTRON THERAPY

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Abstract

BNCT is under development at Tehran Research Reactor, TRR [1–4]. Recent researches show that the thermal column of TRR is an appropriate facility which can be modified for epithermal BNCT [2]. The main needed modification is to remove all graphite blocks from it but at present it is impossible. The most important challenge is the high gamma dose rate in the thermal column. The other alternative facility for BNCT is the TRR medical room. The medical room is located in the eastern part of the reactor pool structure. In order to use this facility for BNCT, it needs operation of the reactor core in the open pool position, and an in-pool BSA to guide neutrons to the medical room. In this work an experimental and theoretical investigation of the use of this room for BNCT has been presented. The experimental investigation consists of (1) the possibility of operation of the reactor core in the open pool position, and (2) measurement of neutron energy spectrum near the eastern side of the reactor core. The theoretical investigation consists of MCNP Monte Carlo simulation to estimate the epithermal neutron flux at the patient position. Multi-foil activation method and SANDII unfolding code were used to measure the neutron energy spectrum. The MCNP simulation was consisted of the reactor core, medical room, reactor pool and a beam tube (between the core and patient position). The results show that in view of the technical aspects, the reactor core can operate in the open pool position. In an experiment the reactor core operate in this position for 20 min at 30 kW power. MCNP result shows that by considering a special in-pool BSA an appropriate epithermal neutron beam (~5×10^9 n·cm^2/s) could be achieved.

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PROMPT NEUTRON EMISSION IN THE REACTION ^{235}U(n,f)

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Investigations of prompt fission neutron (PFN) emission are of importance in understanding the fission process in general and the sharing of excitation energy among the fission fragments in particular. Experimental activities at JRC-Geel on PFN emission in response to OECD/NEA nuclear data requests are presented in this contribution. The focus is on on-going investigations of PFN emission from the reaction ^{235}U(n,f) in the region of the resolved resonances, taking place at the GELINA facility. For this reaction strong fluctuations of fission fragment mass distributions and mean total kinetic energy as a function of incident resonance-neutron energy have been observed [1]. In addition, small fluctuations of prompt neutron multiplicities have also been reported in the literature [2]. The goal of the present study is to verify the current knowledge of PFN multiplicity fluctuations and to study correlations with fission fragment properties. The experiment employs the scintillation detector array SCINTIA for neutron detection, while fission fragment properties are determined via the double kinetic energy technique employing a recently developed position-sensitive twin ionization chamber.

Results on PFN multiplicity correlations with fission fragment properties will be presented, as well as results on PFN angular distributions with respect to the fission axis. PFN multiplicity correlations in the present study show significant differences compared to earlier studies of this reaction with thermal neutrons [3–6].

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TWO METHODS OF THE DETERMINATION OF THE PARITIES OF LOW-LYING STATES IN ^{159}Gd FROM ANALYSIS OF THE γ-RAY INTENSITIES FROM REACTION ^{158}Gd$(n_{res},\gamma)^{159}$Gd

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Abstract: The ^{158}Gd$(n_{res},\gamma)^{159}$Gd reaction was measured at FLNP laboratory of JINR Dubna. Measurements were held on the pulse reactor IBR-30 as booster with the 40 MeV electron linac LUE-40. Absolute intensities of 80 γ-ray transitions in the range 3500-6000 keV on the low-lying states of ^{159}Gd from 12 neutron resonances of ^{158}Gd were obtained. Two methods of statistical analysis of the intensities were used to determine parities of low-lying states using the fact that E1 transitions on levels with negative parities in this region of γ-ray energies have intensities which are greater in 5-7 times than intensities of M1 transitions on levels with positive parities. The first method used analysis of the intensities on each level which were averaged in 12 resonances while in the second method intensities from all 12 resonances were used. Results of two methods were compared and the second analysis gave more number of determined parities. This says that the second method is more powerful criterion than the first though at some cases this method gave certain results which were not obtained from the second method.

MEASUREMENTS OF GAMMA RAYS FROM THE INELASTIC SCATTERING OF 14 MeV NEUTRONS USING TARGET NEUTRON METHOD

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

We used an array of 22 hexagonal NaI(Tl) crystals for spectrometry of the coincided with α-particles characteristic γ-rays following the INS-reaction.

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

In this cycle of measurements, we succeed to measure the angular distributions of gamma rays from the INS of 14 MeV neutrons on a number of light elements. Here we report and discuss the preliminary results from some of the investigated samples.

Keywords: Gamma-rays, spectrometry, multichannel analyzer, neutron source.

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ROT-Effect Dependence on Light Charged Particle Energy in Neutron Induced Ternary Fission of ^{235}U

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In experiments where ternary fission was studied with polarized neutrons two effects were observed: asymmetry in ternary particle registration relative to the plane perpendicular to the neutron polarization axis (TRI-effect) and a small shift of their angular distribution (ROT-effect) [1]. For the ROT-effect supporting evidence was given by modified trajectory calculations [2, 3]. These calculations were performed with alphas as the light charged particles, since they dominate in ternary fission. The evaluated angular shift averaged over the energy of alpha particles was in good agreement with the experimental result. But the detailed distribution of the calculated ROT-effect values depending on the energy of alpha particles deviated from the experimental results. The experimental result for the angular shift was larger than the calculated one in the energy range (8÷12) MeV of the third particle. This discrepancy was explained by the fact that not only alpha particles were detected in the experiment. The experimental results were obtained without identification of the light charged particles. It was therefore assumed [1], that taking into account the presence of tritium, which contributes about 7% to the ternary particles yield, it may be possible to bring closer together calculated and experimental data. The present work shows the results of a new calculation of trajectories for ternary particles from fission, where the influence of tritium was considered. It is demonstrated that alphas and tritons taken together improve the agreement between calculation and experiment of the ROT-effect depending on light charged particle energy.

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DETERMINATION OF THE COSMIC DUST FROM THE ISON COMET IN THE MOSCOW REGION

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The attention of astronomers around the world in 2012–2013 years was chained to the comet C/2012 S1 (ISON). Comet passed at a distance of 1.17 million kilometers from the Sun's surface 28.11.13 (at 22:30 on Moscow time). With the passage of the perihelion, the comet disintegrated into pieces.

According to the calculations of most astronomers, the dust cloud resulting from the comet collapse has covered the Earth in the period from 12.01.2014 to 17.01.2014 (Yu. Gorbunov, Astronomical Observatory of I.I. Mechnikov ONU). According to calculations, most of the cosmic dust particles were smaller than 10 μm.

The study of the substance of the comet has of great scientific interest. Some scientists believe that comets may be carriers of life in the Universe (the hypothesis space of panspermia). The comet first flew in the inner region of the Solar system from the Oort cloud, so the volatile substances her ice cores have not been disturbed and has not been seriously affected by heat and gravity). The age of the comet was estimated at 4.5 billion years and the study of dust particles from the ISON comet may answer on questions about the substance at the time of formation of our planetary system.

To conduct the study, we selected samples of snow in the vicinity of the Dubna city in the period of Earth passage through the dust cloud of the comet. The snow samples collected before 01.01.2014 and after 25.01.2014 were taken as background. Samples of melt water were filtered through nuclear filter with a diameter of 1 μ. Samples of sediments and water leachate was analyzed using nuclear-physical methods of analysis (XRF, GAA). We also assessed the possible anthropogenic contamination of snow samples, in particularly cesium-137.

In snow samples collected during the fall of the particles of the comet to Earth, found elevated compared to background levels of elements such as Ag, Os, Ir, Pt, Au, U.

THE ELEMENT CONTENTS AND RADIOACTIVE NUCLIDES IN MUSHROOMS

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The mushrooms accumulate of microelements in significant quantities from supply substratum and the sensitivity to changes of conditions of environment allow to consider this component of forest biogeocenosis like the bio-indicator. The purpose of work was determination of radionuclides of the ^{137}Cs, ^{90}Sr, U and minor elements in mushrooms.

The edible mushrooms growing on the different substrates in various forest-vegetable conditions on territory with various level of man-caused load was chased for the analysis.

Multielemental analysis of samples carried out using nuclear-physical methods of analysis (XRF, GAA, γ-spectroscopy). Standard ring-shaped radioisotope sources ^{109}Cd (E = 22.16 keV, $T_{1/2}$ = 453 days) and ^{241}Am (E = 59.6 keV, $T_{1/2}$ = 458 years) with an activity of 20 mCi for excitation of X-ray radiation were used. Characteristic X-ray radiation registered semi-conductor Si(Li) detector with full width at half maximum (FWHM) resolution 145 eV for a line of Fe (6.4 keV).

For gamma-activation analysis the samples irradiated 2–4 h bremsstrahlung of electrons with E_e = 25 MeV by microtron MT-25. The electron current – 15 mA.
Isotopes in irradiated samples were determined using HPGe detector (Ir, Au, Pt, Os, U) and a detector of the XRFA instrument is developed (Th). Measuring time – 600–3600 s

Natural and technogenic influence radioactivity of samples and gamma-ray spectra of the irradiated samples after gamma-activation by the MT-25 microtron were measured using HPGe detector with FWHM resolution 1.5 keV for the 1332.5 keV photons of ^{60}Co.

The registration of spontaneously fissioning nuclides in the samples were produced by solid-state detectors (TTD) with an area of 15 cm^2, made from a lavsan with a thickness of 175 μm.

In *Boletus edulis* assembled in various regions the contents of elements potassium (K), iron (Fe) nickel (Ni), copper (Cu), zinc (Zn), led (Pb), selenium (Se), bromine (Br), rubidium (Rb), indium (In) practically is at the same level but for all that the contents Fe, Cu, Zn, Se, Br, Rb and strontium(Sr) corresponds maximum permissible concentration

Armillaria mellea concern to macromycetes: living on the vegetative rests of wood, which concentrate Sn, Sb, Ba.
The high levels of toxic trace elements found in mushrooms grown in both geochemically and environmentally contaminated areas may be of food safety concern the countries where wild growing mushrooms form non-negligible part of diet.

High selectivity in the uptake of individual elements and small lifespan of the fruiting bodies (about 10 days) allows the use of mushrooms as bio-indicators for radioactive, industrial and space elements of pollution.

LIFE IN THE UNIVERSE

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Almost a century ago Alexander Oparin first advanced his hypothesis that life originated by a long, slow chemical evolutionary process in which energy from volcanoes or lightning delivered to a primitive reducing atmosphere could yield nitrogen and carbon based organic molecules. The resultant amino acids and other biomolecules then undergo a long slow chemical evolutionary process in Earth's primordial oceans to ultimately yield coacervates, protocells and simple cells. The 1953 Miller report demonstrated that amino acids can form by electric spark discharges in a reducing atmosphere of methane, ammonia, water and hydrogen and validated a primary feature of the Oparin hypothesis. It became widely accepted that understanding the origin of life was almost at hand. However, although a vast amount of knowledge has been obtained in the last 6 decades, the question of *where, how* and *when* life originated still remains one of the greatest unsolved problem of Science.

Advances in biochemistry, molecular biology, genomics and microbiology have revealed the phenomenal complexity of all known viruses and cells of eukaryotic and prokaryotic organisms. Protocells and "simple cells" do not appear to exist in modern terrestrial ecosystems and evidence for them has never been detected in the fossil record. Stromatolites formed by filamentous cyanobacteria are present in the 3.7 Gya rocks of the Isua supracrustal belt of Greenland and putative filamentous microfossils were reported in the 3.77 to 4.28 Gya ferruginous sedimentary rocks of Canada. These discoveries suggest life appeared soon after the Earth cooled enough (~4.2 Gya) for oceans to exist. The 2008 Antarctica Astrobiology Expedition discovered large conical stromatolites on the floor of the perennially ice-covered Lake Untersee. The orange, red and purple colors of the stromatolites are form carotenoid pigments in filamentous cyanobacteria (*Phormidium* spp. and *Leptolyngbya* spp.) growing in low light conditions under the thick ice cover and mimic the colors observed on cometary nuclei and in surface cracks of Pluto and the Jovian ice moon, Europa.

This Lecture presents observational evidence obtained by Space Probes, microbial life on the exterior of the International Space Station and laboratory studies of microfossils in ancient rocks and meteorites which tend to invalidate the long held paradigm that microbial life originates by slow evolutionary processes on the Primordial Earth. It is now generally accepted that comets, asteroids and meteorites delivered water and organics to the early Earth. This presentation will provide evidence from ancient terrestrial rocks and carbonaceous meteorites that life may be widely dispersed in the Universe and that the Origin of Life on Earth may have been the delivery of viable cells, filaments and spores encased within protective ice, frozen mud, and rocks to early oceans by comets, asteroids and meteorites.

Keywords: Oparin, Miller-Urey experiment, origin of life, astrobiology, physical properties of water, dynamic albedo of neutrons, comets, icy moons, Pluto, carbonaceous meteorites, extremophiles, microfossils, diatoms, cyanobacteria.

ATMOSPHERIC DEPOSITION STUDY IN SOUTHERN BULGARIA BASED ON MOSS BIOMONITORS, NEUTRON ACTIVATION ANALYSIS AND INDUCTIVELY COUPLED PLASMA ATOMIC EMISSION SPECTROSCOPY

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For the fifth time Bulgaria participates in the moss survey carried out in the framework of the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (the UNECE ICP Vegetation). In the summer of 2015, 115 moss samples (*Hypnum cupressiforme, Pleurozium schreberi* and *Pseudoscleropodiumpurum*) were collected in accordance with the sampling strategy. Concentrations of a total of 37 elements were determined in moss biomonitoring species using instrumental epithermal neutron activation analysis (Na, Mg, Al, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Ni, Co, Zn, As, Se, Br, Rb, Sr, Sb, I, Ba, Cs, La, Ce, Nd, Eu, Tb, Tm, Yb, Lu, Hf, Ta, W, Th, U). Three additional environmentally important elements were analysed using inductively coupled plasma atomic emission spectroscopy (Cd, Cu, Pb).The determined concentrations were compared with data from previous moss surveys conducted in Bulgaria, as well as with data from other European countries participating in the ICP Vegetation programme.

Prompt Gamma Emission Measurements Following Neutron Captures on ^{93}Nb, ^{107}Ag and ^{109}Ag

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Measurements of prompt-gamma emission following neutron capture are one of the most important techniques in experimental nuclear physics for obtaining useful information about nuclear structures. The data are necessary for determination of nuclear structure parameters such as level density and radiative strength functions. One of those methods for obtaining the level density and radiative strength functions was developed at FLNF, JINR, Dubna, Russia [1–5]. In additional, reliable spectroscopic data (energy and intensity of gamma transitions after neutron capture) are very important for applications in the investigation of astrophysical reactions, the production of medical isotopes, reactor technology, the production of rare isotope beams, etc. Hence, the measurement of coincident gamma rays emitted after neutron capture on the ^{107}Ag and ^{109}Ag are performed at PGAA facility at MLZ, Munich [6], Germany, and on the ^{93}Nb at PGAA facility at MTA EK, Budapest, Hungary [7]. The preliminary results are presented here.

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FUNDAMENTAL ACTIVITIES IN SETTING UP OF TEHRAN RESEARCH REACTOR BNCT FACILITY

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Abstract

Boron Neutron Capture Therapy (BNCT) is a promising method to treat malignant brain tumors. The basic principle of this technique is to irradiate the boron-containing tumor with an appropriate neutron beam. Lethal dose deposited by $^{10}B(n,a)^{6}Li$ reaction products causes destruction of the tumor cells. Two different neutron beams are commonly used in BNCT: Thermal beams which are employed for treatment of superficial tumors such as melanoma, and epithermal beams which are used for treatment of deep-seated tumors like Glioblastoma Multiform. Nuclear research reactors and accelerators are the major neutron sources for BNCT. Tehran Research Reactor (TRR) is the only active neutron source which can be used for BNCT in Iran. The first attempt to construct a neutron beam for BNCT at TRR has been done in 1990s. The result has been shown no sufficient neutron flux. Since then, no attempt was made to design a neutron beam for BNCT at TRR. After about 20 years, attempts for producing an appropriate neutron beam for BNCT studies in TRR have been started again based on the use of the thermal column. The thermal and epithermal neutron beams have been designed for BNCT by modification of the thermal column of TRR. The thermal column is filled with graphite blocks. In practice, due to the high gamma dose, it was impossible to remove all graphite blocks from the thermal column in order to produce an epithermal neutron beam, however the thermal column of TRR has been modified to provide an appropriate thermal neutron beam for BNCT. The measured in-air beam parameters are close to other BNCT facilities and satisfy the IAEA criteria with a good approximation. To perform the necessary dosimetric studies at this facility, an appropriate head phantom has been constructed and different beam parameters including the beam uniformity, the distribution of the thermal neutron dose, boron dose, gamma dose in a phantom and also the Therapeutic Gain (TG) have been obtained. The results of measurements show that, the thermal column is usable for biological studies and animal trials. In addition to thermal column, there is a medical room in reactor which is located behind the east wall of the open pool. Simulations show that, the medical room is the best choice which could provide an appropriate practical epithermal beam for clinical BNCT for brain tumors treatment. But there are some challenges to use this facility. It is necessary to operate the reactor core in the open pool position and it is also need to construct a beam shaping assembly inside of the pool. These problems are under consideration with details in future research activities. The results of BNCT activities in TRR confirm its potential as a pilot facility for BNCT research in the Middle East.

The Ion and Gamma Backgrounds in the Experiment on Radiative Neutron Decay

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The aim of the new experiment on radiative neutron decay is the measurement of its main characteristic, the branching ratio – BR. The methodology is focused on measuring the spectra of triple coincidences of radiative gamma-quantum, beta electron, and recoil proton and double coincidences of beta electron and recoil proton. The peak on the spectrum of triple coincidences shows the number of radiative neutron decays, while the peak on the spectrum of double coincidences shows the number of regular neutron beta-decays. This methodology enabled us to become the first team to measure the branching ratio of radiative neutron decay B.R.= $(3.2\pm1.6)10^{-3}$ (where C.L.= 99.7% and gamma quanta energy exceeds 35 KeV) [1] in 2005 on our old experimental equipment.

The precision of branching ratio measurement is determined using the value of the ion and gamma backgrounds. The spectrum of double coincidences obtained in our experiment shows a fairly significant ion background, the fluctuations of which indicate the precision of measurement for the number of recoil protons [1, 2]. The spectrum of triple coincidences shows a significant gamma background, the fluctuations of which determine the precision of measurement for the number of triple coincidences. Because the ion background specifically is quite significant, it appears even under super deep vacuum as beta electrons ionize the highly rarified air inside the chamber. Besides, we discovered an additional wide peak on the spectrum of triple coincidences. This peak consists of delayed gamma quanta created during the ionization of rare gas by beta-electrons.

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

From this it follows that the research of the ion and gamma backgrounds is a critically important task for this experiment. This report is dedicated to a discussion of the computer experiment we conducted using the well-known GEANT4 software package. One of the main goals of these Monte-Carlo calculations is to obtain the ion and gamma background conditions for conducting the experiment. The report presents the results of these calculations along with a comparison of our measurements of double coincidences [2] and triple coincidences [3, 4], with two other experimental groups. One of the main results of our computer experiment is the evaluation of background conditions, which shows that the geometry and materials we selected allow us to measure the branching ratio with precision of several percentage points.

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Monte Carlo Simulations and Experimental Results on Neutron Production in the Spallation Target QUINTA Irradiated with 660 MeV Protons

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Abstract

The activation experiment was performed using the accelerated beam of Phasotron accelerator at the Joint Institute for Nuclear Research (JINR). The natural uranium spallation target QUINTA was irradiated with protons with energy 660 MeV. Monte Carlo simulations were performed using FLUKA and Geant4 codes. The number of leakage neutrons from the sections of the uranium target surrounded by the lead shielding and the number of leakage neutrons from the lead shield were determined. The total number of fissions in the setup QUINTA was determined. Experimental values of reaction rates for the produced nuclei in the ^{127}I sample were obtained and several values of reaction rates were compared with the results of simulations by FLUKA and Geant4 code. Experimentally determined fluence of neutrons in energy interval 10–200 MeV using the (n,xn) reactions in the ^{127}I(NaI) sample was compared with the results of simulations. Possibility of transmutation of the long-lived radionuclide ^{129}I in the QUINTA setup was estimated.

EVALUATION OF ALPHA-CLUSTERING IN FAST AND SLOW NEUTRON-INDUCED (n,α) REACTIONS

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Alpha-particle clustering in nuclei is a one of important subjects for understanding of α-decay, α-particle emission reactions and nuclear structure. The α-clustering problem was considered for long time by many authors who used different theoretical approaches. However, up to now there is no common opinion to explain the α-clustering effect.

In this work we suggest an unified view-point of the α-clustering problem for fast and slow neutron induced (n,α) reactions, namely, the statistical model is utilized. Using the statistical model we analyzed experimental (n,α) and (n,p) cross sections for fast neutrons and obtained the α-clustering factor from the relative interaction rates of incident neutrons with protons and alphas. In the case of slow neutrons the α-clustering factor was found from the analysis of experimental averaged over the 30 keV neutrons (n,α) cross sections by the statistical model of nuclear reactions.

Our results are compared with other values of α-clustering factor obtained from different approaches to this problem.

Study of *n-n* Interaction in *nd*- and *dd*-Breakup Reactions

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It is known that in absence of a neutron target, data on *nn*- interaction are obtained primarily from reactions with two neutrons in the final state. According to the authors of the Dibaryon Model of NN-interaction [1], the strong discrepancies of experiment and theory observed in *nd*- and *pd*-breakup reactions can be explained by a significant strengthening of *nn*- and *pp*-correlations of attractive character in the third nucleon field in ^{3}H (*pnn*) and ^{3}He (*ppn*) systems. One can propose that such mechanism also may be induced by σ-exchange between two dibaryons ($^1S_0$) in $d+d\rightarrow(pp)^S+(nn)^S\rightarrow p+p+n+n$ reaction.

We investigated $d+^2\mathrm{H}\rightarrow(pp)^S+(nn)^S\rightarrow p+p+n+n$ reaction going through a formation and breakup of singlet diproton and dineutron in the intermediate state. In the kinematically complete experiment performed at E_d =15 MeV two protons and neutron were detected at angles close to those of emission of $(pp)^S$ and $(nn)^S$ systems. Simulation of the reaction showed that the shape of neutron energy (timing) spectrum depends on E_{nn} – the energy of virtual $^1S_0$ state of *nn*-system. The most likely value E_{nn} = 0.076 ± 0.006 MeV was obtained by fitting procedure using the experimental data and simulations. The E_{nn} energy is related to the scattering length a_{nn} and the effective range r_{nn} by the equation:

$$\frac{1}{a_{nn}} = -\left(\frac{m_n E_{nn}}{\hbar^2}\right)^{1/2} - \frac{1}{2} r_{nn} \frac{m_n E_{nn}}{\hbar^2} + \ldots \qquad (1)$$

According to Eq. (1), the obtained value of the virtual energy E_{nn} = 0.076 ± 0.006 MeV corresponds to the value of the singlet *nn*-scattering length a_{nn} = −22.2 ± 0.6 fm. This value of *nn*-scattering length was compared with experimental values of $^1S_0$ nn-scattering length obtained in *nd*-breakup reaction. It is shown that the difference in the scattering lengths obtained under different kinematic conditions can be explained by the influence of 3N-forces depending on the relative velocity between the *nn*-pair and the charged fragment.

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MEASUREMENT OF T-ODD EFFECTS IN THE NEUTRON-INDUCED FISSION OF ^{235}U AT A HOT SOURCE OF POLARIZED RESONANCE NEUTRONS

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The T-odd effects in fission of heavy nuclei have been known since more than a decade. The first effect of this type, so called TRI-effect was discovered at the ILL reactor (Grenoble) by a collaboration of Russian and European institutes [1]. It was found that the probability of emission of an alpha-particle in ternary fission in the direction perpendicular to the plane formed by the neutron spin and the fragment momentum shows a pronounced anisotropy. Furthermore, it was noticed that when reversing the direction of polarization of the neutron beam, angular distribution of α-particles is shifted by a small angle relative to the axis of fragment emission, the offset direction being determined by the direction of polarization of the neutron beam. The authors called this effect the ROT-effect [2].

Similar effect has been observed in the emission of prompt gamma rays and neutrons in fission of ^{235}U and ^{233}U, although its value was an order of magnitude smaller than in the α-particle emission from ternary fission [3].

At present, there are several theoretical models which can describe both effects. According to the theory of A. Bohr, both effects depend on the quantum numbers J and K, which characterize the fission channel. For the thermal (or cold) neutron induced fission (where all previous data are obtained), there is a mixture of several spin states, and the weights of these states are not known [4]. The only way to get "clean" data is to perform measurements on isolated resonances. Such an experiment was performed at the POLI instrument of the FRM2 reactor in Garching, which provides necessary polarized neutron beam with the energy of 0.3 eV, corresponding to the lowest resonance of ^{235}U. First results of this experiment will be reported.

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The Stand for Irradiation of Printed Circuit Boards at the INR RAS Linac: Particle Fluxes, Activation and Dose Rate

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Abstract

Using the SHIELD transport code and the program DCHAIN-SP for calculating the activation and cooling of target, we simulated the planned stand for irradiating of printed circuit boards (PCB) at the INR RAS proton linac. The maximal parameters of the proton beam are taken as follows: energy 209 MeV, current 1 μA. Total and differential in energy neutron fluxes from the beam trap into the experimental hall are calculated. Secondary nucleon fluxes (albedo from the beam trap), which achieve PCB irradiated by the proton beam, are estimated. Activation and cooling of PCB and of elements of the beam trap after irradiation during one shift (8 hours) are calculated. For the electronic board the dose rate as well as the heating rate by the proton beam are calculated. It is shown that the dose rate after one day of cooling does not exceed the maximum acceptable level, for staff category A. The heating rate of the board is significant and requires scanning of the beam. Neutron fluxes into experimental hall have to be reduced by additional biological shielding. Neutron fluxes into the surrounding space behind the soil moundover the accelerator tunnel are two orders of magnitude or more below the acceptablevalues.

THE PROBLEM OF THE REACTOR ANTINEUTRINO SPECTRUM ERRORS AND PROPOSED SOLUTION IN THE SCHEME WITH REGULATED SPECTRUM

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The investigation devoted to development and research of performance for novel type of $\bar{\nu}_e$-source which ensures: 1) hard antineutrino flux significantly larger then reactor hard $\bar{\nu}_e$-flux; 2) rate of antineutrino detector counts about ~ 10^3 per day; 3) drop of $\bar{\nu}_e$-count flux errors (due to decrease of summary $\bar{\nu}_e$-spectrum errors) in several times at $E_{\bar{\nu}} \geq 3$ MeV.

Up today the nuclear reactors are the most intensive artificial neutrino sources with the exception of nuclear explosions. Antineutrino reactor spectra are formed by ^{235}U, ^{238}U, ^{239}Pu and ^{241}Pu are characterized by large uncertainties in the summary $\bar{\nu}_e$-spectrum causing serious problem in interpretation of oscillation experiments. So, for energy $E_{\bar{\nu}} \leq 6$ MeV the reactor $\bar{\nu}_e$-spectra are known with ~ (4 – 5)% -precision which dramatically increases to tens percents at higher energies. The all four spectra are dropping rapidly as energy increases (that is especially negatively for registration of threshold reactions): at increase of $E_{\bar{\nu}}$ from 2 MeV to 4, 6 and 8 MeV the ^{235}U-spectrum drops in 5, 35 and 956 times, respectively [1 – 3].

The proposed scheme is based on ^{7}Li (n,γ)^{8}Li activation near the reactor active zone (AZ) and transport of the fast β$^-$-decaying ^{8}Li ($T_{1/2}(^8\text{Li}) = 0.84$ s) toward a remote neutrino detector and back in the closed loop to AZ for the next activation in the continuous cycle. Well known $\bar{\nu}_e$-spectrum of ^{8}Li is hard: mean energy – ~ 6.5 MeV; its maximum – up to 13 MeV. For the neutrino investigations the source of such combined hard $\bar{\nu}_e$-spectrum (from ^{8}Li and β$^-$-decays of fission products in AZ) has the serious advantages compare to nuclear reactors $\bar{\nu}_e$-spectrum because the neutrino interaction cross section depends on the energy as $\sigma \sim E_\nu^2$. For increasing of a hard lithium antineutrino's part in the total spectrum a being pumped reservoir is installed near the $\bar{\nu}_e$-detector. Such an installation will ensure not only harder $\bar{\nu}_e$-spectrum in the detector volume but also an opportunity to register $\bar{\nu}_e$-interaction at different summary spectrum hardness varying smoothly (without stop of the experiment) a rate of ^{8}Li (or its chemical compound) pumping in the closed loop [4, 5].

The proposed installation with combined $\bar{\nu}_e$-spectrum can ensure hard antineutrino flux (in the detector position) significantly higher compare to reactor one. The rate of neutrino detector counts in such hard flux can be increased strongly (from times to order and more) compare to reactor flux part. High count rate allows to use compact detectors with volume about ~ m^3. The calculation confirmed that count errors in such combined $\bar{\nu}_e$ spectrum can be decreased in two times and more [6].

The high $\bar{\nu}_e$-flux, large counts in the detector, its small volume (low cost detector), small count errors (from summary spectrum) of the proposed $\bar{\nu}_e$-source scheme allows to consider the scheme as perspective for oscillation experiments (especially for sterile neutrinos search).

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TEMPORAL AND SPATIAL TRENDS (1990–2015) OF TRACE ELEMENT ATMOSPHERIC DEPOSITION IN SLOVAKIA: ASSESSMENT BASED ON MOSS ANALYSIS

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The use of mosses as biomonitor of atmospheric deposition of heavy metals in Slovakia started more than 30 years ago in connection with the problems of the forest dying in Slovakia. In the 1990s, in the framework of UNECE ICP Vegetation programme, systematic studies using moss were carried out in Slovakia (net 16×16 km), and the results were presented in the European Atlas of Atmospheric Heavy Metal Deposition in Europe – Estimations Based on Moss Analysis. It is assumed that in Slovakia (SK) a large gradient of the atmospheric deposition load of elements exists because part of the SK territory belongs to the most polluted areas in central Europe known as the 'Black Triangle II'. In order to recognize the distribution of element deposition in the SK, the moss monitoring technique, also known as biomonitoring, was applied to the whole territory in 1990, 1995, 1996, 1997, 2000, 2005, 2010, and 2015. The application of mosses as biomonitors of trace elements in selected Slovak industrial areas, mining country, and National parks affected by anthropogenic activity is reviewed. Moss was successfully used also to study temporal and spatial deposition of N and S. A combination of analytical data (NAA, and AAS in our case) with principle component analysis and correlation analysis allowed pollution source characterization and apportioning in the sampled areas: Central Spiš (effect of heavy metals); Aluminium plant Žiarnad Hronom; Thermal power plant Horná Nitra; Central Slovakia (mining area of Staré Hory, Ľubietová, Španiadolina); Beskydy (north part of Slovakia-influence of Poland and Czech pollutants); High Tatra National Park (TANAP), and Low Tatra National Park (NAPANT).

Keywords: Air pollution, biomonitoring, heavy metals

SCINTILLATION NEUTRON DETECTORS BASED ON MICRO-PIXEL AVALANCHE PHOTO-DIODE

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Micro-pixel avalanche photo-diode is one of existing silicon photomultiplier types which offer gains and efficiencies similar to those of common vacuum photo-multipliers. These types of photo-diodes characterized with their low mass and volume, high ruggedness, no high-voltage requirements, insensitivity to magnetic field etc. This paper is focused on neutron detectors comprising silicon based MAPD coupled to stilbene and plastic scintillator. MAPDs of type MAPD-3NK and MAPD-3N-1P with a sensitive area of 3.7 × 3.7 mm^2 and 3 × 3 mm^2 are used in the experiment. Fast neutron detection performance of these diodes have been investigated with stilbene scintillators in cylindrical shape with dimensions of 30 mm × 20 mm and in cubic shape with dimensions of 5 × 5 × 5 mm^3. Plastic scintillator coupled to used MAPDs have been also studied for fast neutron detection.

Parity Violation Effects in the Neutron Capture Process on Lead Nucleus

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Abstract. In the capture process of slow neutrons on lead nucleus the PV effects are evaluated in the framework of resonance – resonance approach. The neutron capture and scattering results are related to the existing experimental data in order to extract the weak matrix element. The present obtained results are of interest in order to prepare PV effect measurements at the neutron sources of FLNP and abroad.

Isomers Production of Sn Nucleus in Nuclear Reactions Induced by Photons and Fast Neutrons

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Abstract. The isotopes of Sn can be obtained in the nuclear reactions of type (p,n) on indium nucleus and in photoneutron processes on Sn nucleus. The cross sections of (p,n) and (gamma, xn) processes were evaluated and compared with experimental data. For each reaction the contributions of compound, direct and pre-equilibrium processes were evaluated and the parameters of nuclear potentials and other nuclear data were also extracted. A quite good agreement was obtained between existing experimental data and the present evaluations, and therefore we have calculated the isomer ratios using different models of incident gamma and protons sources. We have also analyzed the possibility to effectuate experiments on the cross sections and isomer ratios measurements at FLNP (JINR, Dubna) basic facilities.

Nuclear Reactions with 14 MeV Neutrons on Molybdenum Isotopes

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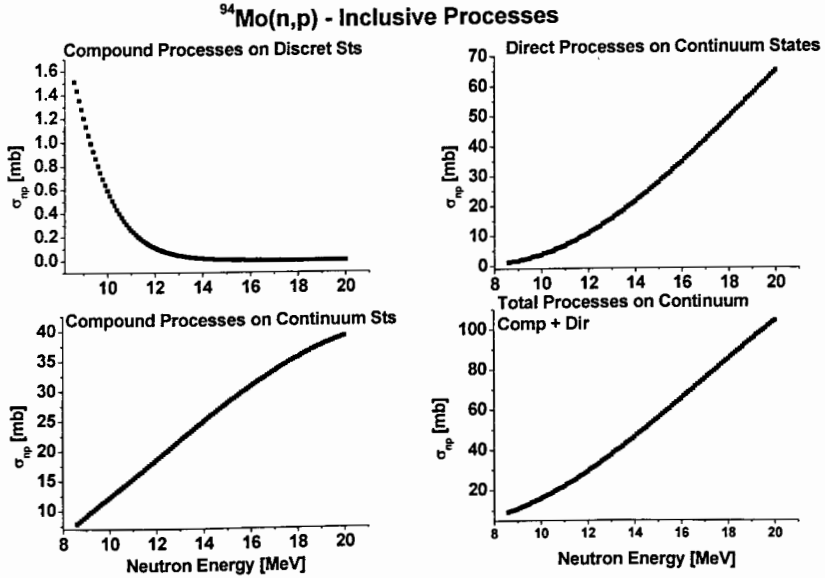
Molybdenum is a structural metal suitable for harsh neutronic environments with more than 30 isotopes which provide an extensive basis for neutron data production. The 14 MeV neutron induced cross sections are necessary for practical applications such as ADS and fusion reactor technology and for testing nuclear models. Unfortunately there are still discrepancies between the theoretical and experimental values and even between recent measured values, and further studies are necessary.
The cross sections of fast neutron induced reactions with emission of charged particles have been evaluated. For each process the contribution of compound, direct and pre-equilibrium nuclear reaction mechanism and the corresponding nuclear data (parameters of nuclear potential, density states and the others) were extracted.



The present evaluations were performed in order to realize new fast neutron cross section measurements at IREN neutron source of FLNP, JINR, Dubna.

Remarks on the IREN resolution function

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Abstract

During the analysis of experimental data obtained by the time-of-flight method and depending on resonance structure of neutron sections, it is necessary to use the so-called resolution function of a spectrometer. Possible resolution functions of installation IREN and their dependences on the channel width of a time encoder are considered.

ENAA OF IRIDIUM AND CHROMIUM IN THE CRETACEOUS-PALEOGENE BOUNDARY FISH CLAY AT THE KIRKEVIG SITES (STEVNS KLINT, DENMARK): PRELIMINARY CONSIDERATIONS

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The Fish Clay at Stevns Klint is a classic Cretaceous-Paleogene (KPB) section [1–3]. The famous Fish Clay at the site of the Højerup Old Church (near village of Højerup) is characterized by an anomalous Ir, probably of chondritic origin. Apart from Ir, this clay is enriched in other trace metals such as meteoritic or partly meteoritic Cr. Cr is one of the trace metals that are invariably enriched in a numerous impact-related KPB strata together with Ir and it also well-correlates with Ir. For this reason, Cr is considered to be one of most important indicators of cosmogenic material in the KPB sections worldwide. The other KPB site nearby village of Højerup is Kirkevig for which no geochemical data were previously published. Chemical and semiquantitive X-ray diffraction analyses showed that the ejecta and boundary layers contain about 30 % of smectite (montmorillonite). The smectite-rich fraction of each layers (SRF) were prepared by the chemical treatment of their whole-rock samples by 6 M molar hydrochloric acid at room temperatures for 48 h. This treatment removes all carbonates (mainly calcite, $CaCO_3$), >90 % of predominant iron (Fe) oxides, mainly hematite (Fe_2O_3) and goethite α-FeO(OH), and sulfides. The high smectite contents of SRF (> 90 %) were confirmed by the fourier transfer infrared (FTIR) spectrometry, the X-ray diffraction, the scanning electron microscopy (SEM) and the energy-dispersive X-ray spectroscopy (EDS). The Ir and Cr content in SRF was determined by epithermal neutron activation analysis at the reactor IBR-2 of FLNP, JINR. Relative error in the precision of these analyses ranges from 5% to 10%. Total uncertainties (including accuracy errors) were up to 20%. The carbonate-free underlying Maastrichtian and overlying Danian rocks of the Fish Clay contain <5% of Ir and < 85 ppm of Cr [2].

Table. The concentrations of Ir and Cr (ppm) in the SRF and their average in CI chondrites

Geological material / Element	Ejecta layer	Boundary layer	CI Chondrite [3]
Ir	18	24	472
Cr	174	214	2796

To assess the extraterrestrial (asteroid) components in the SRF's, we normalize the Cr data to Ir using the data of Table.The Cr/Ir ratios of the ejecta (about 9800) and boundary (about 8900) layers are relatively close to the chondritic ratio (about 5900). It seems that Cr is also largely chondritic. On the other hand, employing the Ir data of Table, we estimate that SRF of the ejecta and boundary layers contain, respectfully, about 3% and 6% of chondritic material.

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How to check the hypothesis of the neutroneum existence?

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Many puzzles of the low-energy nuclear physics one can solve in the framework of the "orthodox" approach on the base of hypothesis of the exotic electroweak resonance "neutroneum" existence [1] – [5].

The evidence of the "neutroneum" existence is a result of the experiment on the underthreshold carbon photoproduction in dense helium [2], [3]. But we have to confirm this conclusion in the independent "experimentum crucis".

In [1], [4] – [5] was predicted the possibility of the neutroneum generation as in continuous spectrum state as in the bound state in a usual atomic nucleus.

We propose the unexpected way to check the fact of neutroneum existence.

Let's carry out the experiment on the glow discharge in argon with nickel anode and magnesium cathode. Prediction: the nuclear reactions of the exoargon ${}^{40}_{18}\mathrm{Ar}_\nu$ (argon's nucleus in which one proton replaced by neutroneum) with argon and magnesium leads to hydrogen, carbon and copper production.

We predict the follows reactions

$$e^- + {}^{40}_{18}\mathrm{Ar} \rightarrow {}^{40}_{18}\mathrm{Ar}_\nu + \mathrm{X}\cdot e^- \quad (1)$$

$${}^{40}_{18}\mathrm{Ar}_\nu + {}^{24}_{12}\mathrm{Mg} \rightarrow n_\nu + {}^{63}_{29}\mathrm{Cu} + 9.328\,\mathrm{MeV} \quad (2)$$

$$n_\nu \rightarrow p + e^- \quad (3)$$

$${}^{40}_{18}\mathrm{Ar}_\nu + {}^{24}_{12}\mathrm{Mg} \rightarrow {}^{12}_{6}C_\nu + {}^{52}_{24}\mathrm{Cr} + 6.445\,\mathrm{MeV} \quad (4)$$

Recommended pressure in a discharge chamber is $p = 0.1\ Torr$, voltage is $U = 650\ V$, current is $I = 0.11\ A$.

The alternative explanation of this elements production in glow discharge is impossible.

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NEUTRON-INDUCED FISSION OF NP-237 – NEW NEEDS, CHALLENGES AND OPPORTUNITIES

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Nowadays there is an increased interest in a complete study of the neutron induced fission of ^{237}Np. This is due to the need from accurate and reliable nuclear data for nuclear science and technology.^{237}Np is generated and accumulated in the nuclear reactor core in the process of its operation.

As one of the abundant long-lived isotopes in the nuclear reactor spent fuel (waste), the incineration of ^{237}Np becomes an important issue. It can be done in future fast neutron reactors, which aim is to reduce the radiotoxicity of the nuclear "waste" via transmutation and partitioning technology. For testing the fission models, which are the base of the new generation of nuclear reactors development, highly accurate and detailed neutron data are needed.

The EXFOR nuclear data library on the neutron induced fission cross section of ^{237}Np and the characteristics of the fission products (fragments, neutrons and gamma rays) was not updated for decades.

The most recent ^{237}Np(n,f) measurements al LANL, GELINA and n_TOF are briefly discussed. Possible experiments on investigation of the resonance and 14 MeV neutron induced fission of ^{237}Np at FLNP experimental facilities are proposed.

NEUTRON MATTER AS THE «BEGINNING» AND THE «END» OF THE PERIODIC SYSTEM OF D.I. MENDELEEV

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The neutron matter in our time is quite concrete physical reality, which strongly demands its rightful place in the Periodic System of elements (PS) and to be studied from point of view of not only its physical but also chemical, and possibly in the near future, technical properties. It is postulated, that the PS of elements begins (zero period) with the neutron matter, or rather with the Element it corresponds to, and finishes (supercritical atoms) by it. The paper deals with the formation of neutron matter and, in addition to the gravitational neutronization, considers other mechanisms, such as condensation of ultracold neutrons (UCN) and neutronization by critical increasing of atomic number of elements in the PS. I.E. Tamm's "original" theory of exchangeable β-nuclear forces (e - exchange of nucleons), but not only its modification made by Hideki Yukawa (π-exchange of nucleons), is still awaiting its acceptance (since except as meson cloud around a nucleon, there are certainly other particles) and "dominates" in the neutron matter of the Universe, providing its stability and a wide cosmic spreading.Another factor of additional stability of the neutron matter during the significant increase of its mass (up to a macro scale) will be the ever-increasing contribution to the gravitational interaction. The neutron matter is conferred the sustainability already at the micro-level by means of Tamm interaction, not just at the macro-level due to the gravitational interaction, as it is now considered to be in astrophysics. The possibility of neutronization is not only due to the gravitational interaction, but also due to other mechanisms (supercritical increase the atomic number of elements and UCNs condensation), so there is a principal possibility of the neutron matter obtaining in the Earth conditions. Also, the possibility of chemical interaction of UCN with molecules of substances with an odd number of electrons is considered. The possible plan of the experiment on "chemistry" of UCN is discussed. The neutron matter is necessary link connecting (inducing a bridge) the micro-, the macro- and mega-World, from the free neutron to the neutron stars and the black holes. The neutron matter consistently fits into the original concept of the Periodic Law and the System proposed by Dmitry Ivanovich Mendeleev.

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NEUTRONS IN LIGHT NUCLEI AND NEUTRON TRANSFER IN REACTIONS WITH LIGHT NUCLEI

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The energies and the wave functions of the ground states of ^{3,6}He nuclei have been calculated by Feynman's continual integrals method in Euclidean time [1, 2]. The few-body nucleus ^{3}He was considered as consisting of two protons and a neutron, whereas the cluster nucleus ^{6}He was considered as an α-cluster and two neutrons. The obtained results demonstrate overall satisfactory agreement with the experimental data on charge radii, charge distribution and binding energies.

It is well known that neutron rearrangement may play an important role in nuclear reactions. The processes of neutron transfer are extensively studied both experimentally and theoretically.

Experimental cross sections for formation of isotopes ^{44,46}Sc in reaction ^{3}He + ^{45}Sc, ^{46}Sc in reaction ^{6}He + ^{45}Sc, ^{65}Zn in reaction ^{6}He + ^{64}Zn, ^{196,198}Au in reactions ^{3,6}He + ^{197}Au have been analyzed within the time-dependent Schrödinger equation approach for the external neutrons of ^{3,6}He, ^{45}Sc and ^{197}Au nuclei [3, 4].

The initial conditions for the wave functions were obtained from the shell model calculations with the parameters providing neutron separation energies close to the experimental values. Within the shell model, new parametrization of mean field for neutrons inside ^{3,6}He nuclei is used based on the obtained results of calculations by Feynman's continual integrals method.

Fusion-evaporation was taken into account using the NRV [5] evaporation code. Results of calculation demonstrate overall satisfactory agreement with the experimental data.

It is found that in the reactions ^{3,6}He + ^{197}Au, ^{3,6}He + ^{45}Sc, ^{6}He + ^{64}Zn neutron transfer is one of the most important channels.

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THE ABSOLUTE NEUTRON FLUX MEASURMENT AT THE VAN DE GRAAFF ACCELERATOR OF THE FRANK LABORATORY OF NEUTRON PHYSICS

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We have measured the flux of fast neutrons at 4.6 MeV. A twin gridded ionization chamber and back to back ^{238}U two samples were employed. Experiments were performed at the Van de Graaff accelerator of the Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna, Russia. Fast neutrons were produced through the D(d,n)^{3}He reaction by using a deuterium gas. Cross section at E_n = 4.6 MeV of the ^{238}U(n,f) reaction was used as the standard for absolute neutron flux determination. The abundance of the ^{238}U isotope in the sample is 99.999%. The working gas of the ionization chamber was Ar + 3%CO_2.

INVESTIGATIONS OF THE NATURE OF WEAK NEUTRON CAPTURE RESONANCES OF U-238

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Anomalously small capture widths of a few weak neutron resonances of U-238 with the energies near 720 eV and 1210 eV, 3–5 times smaller than average value of 23.5 meV, have been observed for the first time nearly 40 years ago. Since then several attempts have been undertaken to clarify experimentally a nature of this phenomenon by measuring shape of the capture gamma-ray spectra and capture widths. In spite of making use of the modern sophisticated techniques and detectors, the data obtained very recently did not give new information about these resonances leaving a space for new experiments to be done.

From the theoretical point of view, the most plausible explanation of the observed effects is based on the double-humped fission barrier model by V. Strutinsky which postulated an existence of so-called class-II excited states in a second well of two-humped fission barrier. The properties of these states acting as door-way states in exit channel ultimately determine capture and fission widths of neutron resonances. In spite of an obvious success of the Strutinsky's model, some alternative hypotheses have been proposed and discussed 3–4 decades ago. Among the others, a model of "extraordinary" excited nuclear states by G. Muradyan should be mentioned.

In any case, only new measurements of the characteristics of the neutron resonances belonging to sub-burrier fission clusters of U-238 could provide information necessary to stimulate a progress in our understanding of capture and fission mechanisms in this nucleus. The same conclusion is true for other even-even isotopes of U, and Pu as well.

Proposal of the ADS Research Stand of the Institute for Nuclear Research RAS

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Abstract

This report summarizes the results of discussions of a Research ADS Stand at the Institute for Nuclear Research (INR), to couple for the first time a proton beam to a subcritical core at a thermal power exceeding 1 MW (1 to 3 MW) for investigations in areas of nuclear transmutation and thorium fuel cycle.

The existing infrastructure provided by the INR linear accelerator and experimental area is a great asset, however, it imposes restrictions on the level of power and various technical aspects of the project, which will be discussed. The basic approaches to the design process are stated. Possible physical and design features of the Research ADS Stand, from the point of view of physical and technical safety at all stages of work, are considered.

Among other aspects, the horizontal insertion of the beam, additional barriers for safety to exclude loss of coolant, features of the tungsten and uranium targets providing the maximal neutron yield and rather long lifetimes, owing to the distributed thermal load on the beam window, will also be discussed. Results of the initial design studies will be given.

Further directions of research for the development of the neutron facility at INR will also be presented.

NEUTRON MONITORING THE ENVIRONMENT NEAR THE PROTON LINAC USING SCINTILLATION DETECTORS ZnS(Ag)/LiF AND SiPM SENSORS

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The radiative effect of the high-current proton linear accelerator on the environment by means of detecting neutrons is studied. The technogenic neutron background from a high-current proton accelerator can be dangerous in the adjacent territory. Monitoring online the neutron background is carried out in the zone of the accelerator influence using scintillation detectors ZnS(Ag)/LiF and SiPM sensors. The thermal neutron detection efficiency is about 70%. This high sensitivity of the detector makes it possible to record the natural background of thermal neutrons with a count rate of about 5 pulses per minute. Based on the scintillation detector, a network system of neutron monitors has been created, which makes it possible to measure the density of thermal and fast neutron fluxes near the earth's surface in a controlled area. Data on the neutron background are transmitted via the Raspberry Pi 2 electronic modules to the local computer network to the server. The central server processes the data and presents them on the page in the Internet. The accuracy of measuring technogenic background neutron irradiation in the environment is about 10 nSv / h.

RADIATION RESEARCH OF A PHOTONEUTRON REACTION TO DEUTERIUM IN THE PROCEDURAL OF MEDICAL ACCELERATOR SL75

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The gamma and neutron radiations from the photoneutron reaction to deuterium were investigated. The photons from the medical electron accelerator SL75 with energy up to 6 MeV and a frequency of about 300 Hz irradiated the D2O target. About 10% of the bremsstrahlung photons have energies above the deuteron breakup threshold. The photonuclear reaction produced fast neutrons that slowed down in the target. The neutron and gamma fluxes have been measured using neutron and radiation detectors of a system monitoring radiation. The density of the flow of slow neutrons in a 10-volume target was about 10^6 neutrons/cm^2/s. Measurements of the radiation background without a photoneutron reaction were performed with the H2O target. Gamma monitors showed a 20% excess of the gamma radiation level in the medical accelerator procedural when the D2O target was irradiated compared to the gamma radiation level without the photoneutron reaction in the H2O target. Perhaps this additional gamma radiation is created by the absorption of slow neutrons in the materials of the target and the procedural of the medical accelerator.

MODELING OF THE IMPACT OF NEUTRONS IRRADIATION ON CURRENT TRANSPORT THROUGH HTc MULTILAYERED SUPERCONDUCTORS

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Keywords: neutrons irradiation, HTc superconductors, pinning forces, nano-sized defects

In the paper is presented new model treating the influence of fast neutrons irradiation, as creating nano-metric defects in the structure of multilayered HTc superconductors, on the current carrying properties of these materials, especially current-voltage characteristics, critical current and pinning forces. This subject has both basic scientific meaning since it deals to the description of the vortex dynamics, as well as technical one connected with more frequent work of superconducting accelerators. It has been regarded static and also dynamical case. Various initial states of the magnetic pancake shape vortices captured on the nano-sized defects were considered as well as their influence on the pinning potential barrier. It has been investigated the influence of the fast neutrons irradiation dose on the transport current phenomena, especially critical current density in the function of physical parameters: magnetic field, temperature and elasticity constant of the vortex lattice. The influence of the interlayers interaction on the current-voltage characteristics has been also taken into account. Results of the calculations in this model of the critical current dependence on the fast neutrons irradiation dose are shown in the Fig. 1 for initially half captured vortices, versus temperature, magnetic induction and coefficient of the spring constant of magnetic vortex lattice α.

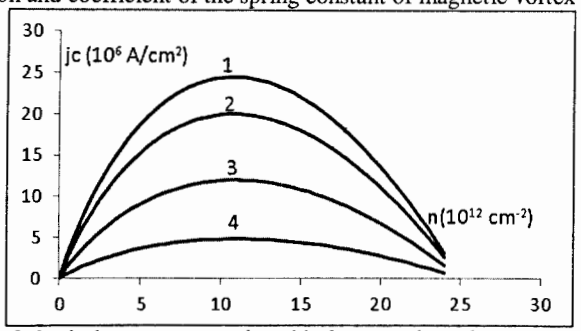

Fig. 1. Influence of physical parameters on the critical current dependence versus the nano-defects concentration, induced by fast neutrons irradiation: (1) B=2T, T=77K, $\alpha=10^{-9}$J/m^2, (2) B=2T, T=77K, $\alpha=10^{-4}$J/m^2, (3) B=2T, T=85K, $\alpha=10^{-9}$J/m^2, (4) B=2,5T, T=77K, $\alpha=10^{-9}$J/m^2.

It will be presented in the paper the influence of irradiation on volume pinning force, taking into account the statistics of occupation finite number of nano-sized defects by varying with magnetic field concentration of the vortices. Especially interesting will be analysis of the case of dynamically varying magnetic field, in which appear dynamic anomalies of current-voltage characteristics. Influence of fast neutrons irradiation on them will be considered.

In the paper it will be described too briefly the present state of art, concerning the influence of fast neutrons irradiation on the characteristics of the superconducting materials.

Studies of Air Pollution with Toxic Elements in Industrial Areas from South and South-Eastern Parts of Romania

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Studies of air pollution with toxic elements in industrial areas from south and south-eastern part of Romania were performed using terrestrial moss. The moss samples were collected at sites located in the industrial areas of Galati, Braila and Targoviste, Romania. The moss samples have been analyzed by combined nuclear and atomic techniques, such as epithermal neutron activation analysis (ENAA) at the reactor IBR-2 of the Frank Laboratory of Neutron Physics, Joint Institute of Nuclear Research in Dubna, Russia, energy-dispersive X-ray fluorescence (ED-XRF) at "Dunarea de Jos" University of Galati, Romania, particle-induced X-ray emission (PIXE) at "Horia Hulubei" National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Magurele, Romania and inductively-coupled plasma mass spectrometry (ICP-MS) at "Valahia" University of Targoviste, Romania.

A total of 29 elements were determined: Na, Mg, Al, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Cd, Sb, Cs, Ba, Pb, Ce, Sm, Eu, Tb, Th, and U.

The obtained results were compared with the concentrations of the same elements obtained in terrestrial moss at European level obtained in the European surveys of heavy metal accumulation in mosses. The site specific temporal trends for most of the elements were observed. The study was carried out in the frame of the Romania-JINR project no. 91/2017 entitled: Applied Research on air and soil pollution with toxic elements using nuclear and related analytical techniques.

COMBINED ANALYSIS OF NUCLEAR AND PARTICLE MASS DATA

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In the first part of this work we considered the presence of stable intervals in spacing distribution between all particle masses from recent compilation Particle Data Group-2016. We turned attention on the appearance of stable intervals between particle masses with values ΔM=445-460 MeV close to M_q=441 MeV=$m_\Xi/3$ - one of the standard parameters of NRCQM (Nonrelativistic Constituent Quark Model) - the initial constituent quark mass originated from the QCD-based effect of the gluon quark-dressing. Estimates of baryon quark mass M_q=441 MeV and the similar standard estimate of meson constituent quark mass M''_q=$m_\rho/2$=389 MeV were shown together with these $3M_q$=m_{Ξ^-} and $2M''_q$=m_ρ and interval between low-lying particle masses noticed in empirical correlations by G. Wick, R. Sternheimer, P. Kropotkin and others.

These NRCQM parameters 441-389 keV are presented (with n=3·18 and n=3·16) together with three pions parameters f_π=130 MeV (n=16), m_π (n=17) and ΔM_Δ=147 MeV (n=18), as a part of the common structure with the period δ=8.176 MeV observed directly in CODATA relations.

Two prominent maxima of this structure ΔM=104-142 MeV (n=13,17) observed in mass-spacing distribution contained masses of the muon and the pion. Distinguished character of the pion masses was discussed earlier and application of the correlation program AIM (Adjacent Interval Method) to all these intervals clearly shows a maximum at ΔM^{AIM}=493 MeV=$K^\pm$ (in upwards AIM direction), which corresponds to the appearance of the second member of well-known low-lying multiplet (π-K-η).

Masses of kaon and the singlet meson are given as m_μ+M''_q and m_μ+M_q in empirical Wick-Sternheimer representation.

We come to conclusion about the existence of a common structure in particle masses and in nuclear data, observed in CODATA relation. The shift of the neutron mass dm_n=161 keV (relative to the integer numbers of m_e) is exactly 1/8 part the nucleon mass splitting δm_N. This fine structure exists in nuclear data as long range correlations with the parameter m_e in nuclear binding energies E_B and stable intervals/periods 161-170 keV in nuclear excitations E^*. The origin of the similarity of fine-structure parameters is connected with the universal character of the QCD which is responsible for particle masses and for nucleon interaction. In new data for excitations in near-magic ^{57}Ni spacing distributions contain maxima at 342 keV (splitting of low-lying levels), 510 keV (all negative parity levels), 481-510 keV (the same with small J<(9/2) and 680 keV (all positive parity levels). These preliminary results are in accordance with the systems of n(m_e/3) or n(δm_N). The period of the common fine structure δ=9.5 keV (n=1, δ'=8ε') is observed directly in neutron resonance positions and spacing of near-magic nuclei with N=20,28,82 and many unstable nuclei with N,Z=51 etc.

SYMMETRY-MOTIVATED ANALYSIS OF PARTICLE MASS DATA

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In this work a continuation of an analysis of fine structure effects in nuclear data is combined with the analysis of particle mass data. The material used in the work is based on nuclear data compilations collected in PNPI (Neutron Resonance Parameters File NRF-5, File of nuclear excitations CRF and Mass Difference File MDF) and data from the Compilations PDG-16 and the evaluation CODATA. These data provide a base for the combined analysis of all existing information for suggested by Y. Nambu further development of the Standard Model (SM). Involvement of nucleon masses into correlations with masses of other particles, including such fundamental particles as leptons, the pion and masses of vector and scalar fields allowed a combined consideration of data in all these data files (NRF, CRF, MDF, PDG, CODATA) due to the commonly accepted basic role of the QCD (one of SM components) in the mass generation and in the nucleon interaction.

We start with CODATA relations for the electron and nucleon masses:

$$m_n = 115 \cdot 16m_e - m_e - \delta m_N/8 \qquad m_p = 115 \cdot 16m_e - m_e - 9\delta m_N/8. \quad (1)$$

Here the shift in the neutron mass (relative to the integer number of m_e) δm_n=161.65 keV is exactly rational 8(1.000(1)) to the nucleon mass splitting δm_N=1293.3 keV. It was found that the fine structure period 161 keV from this ratio is very close (but not coincident) with the value m_e/3=170.3 keV which can be considered as an additional shift (assigned to each of three quarks of the nucleon, see -m_e in (1)). The same stable intervals 161 keV=δm_N/8 and 170 keV=m_e/3 were observed as the fine structure in nuclear data. The relation in mass shifts confirmed with analysis of nuclear data was an indication on the presence of very general dynamics connected with charge discreteness in the Standard Model, with symmetry properties of the fermion system and the nature of the physical condensate. The QCD-based common nature of both fine structures (in CODATA relation and in nuclear data) was considered as empirical observation on the distinguished character of the period $\delta = 16m_e$ and the lepton ratio L=13·16-1 which was found to be close to ratios between vector boson masses (M_Z, M_W) and standard constituent quark estimations in NRCQM (Nonrelativistic Constituent Quark Model), namely $M_q = m_{\xi^-}/3$=441 MeV and $M''_q = m_\rho/2$=387.7 MeV. Recently, the interconnection between masses of d- and b-quarks (m_d = 4.8MeV≈ $9m_e$ and m_b = 4.2GeV≈ $9M_q$, ratio 114·10^{-5}) was added to earlier noticed coincidences of some ratios between particle masses with the QED radiative correction $\alpha/2\pi$=115.9·10^{-5}, for example, between muon and Z-boson masses (a ratio 115.9·10^{-5}) and between m_e and M_q (a ratio 1/(32·27)=115.7·10^{-5} ≈ $\alpha/2\pi$). Three-fold value $m_e = 3 \times m_e/3$ (the SM-parameter) was found to be in the ratio close to $(\alpha/2\pi)^2$ with scalar boson mass (M_H=125.1(3) GeV). It was logical to perform an additional analysis of data in PDG-16. Here the selection of the material and obtained distributions are given. In the second work that follows a part of preliminary results is presented.

Determination of the Breaking Threshold of Cooper Pair at the Cascade Gamma-Decay of the Compound State

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Experimental measurement of the intensities of cascades of two products, which evaporate sequentially as a result of a nuclear reaction, is the only possibility for a study of interaction of Fermi- and Bose-systems in an excited nucleus. In the experiment the values of the level density and reduced emission probabilities of $(n_{th},2\gamma)$-reaction products are obtained for 43 investigated nuclei. The resulted data show a dependence of breaking thresholds for Cooper pairs in the particular investigated nucleus. For obtaining the reliable information it is necessary to investigate in detail the decay process, revealing sources of its distortion and reduce it.

ANGULAR AND ENERGY DISTRIBUTIONS OF THE PROMPT FISSION NEUTRONS FROM THERMAL NEUTRON-INDUCED FISSION OF PU-239

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The measurements of angular and energy distributions of the prompt fission neutrons from thermal neutron-induced fission of ^{239}Pu were carried out at the WWR-M research reactor in Gatchina, Russia. Some peculiarities were found in the angular distribution of the prompt fission neutrons. It is possible to explain them by assuming that in the centre of mass system of fission fragment the neutrons are more likely emitted along fission direction than in the perpendicular to one. The value of anisotropy of neutrons emission in the center of mass system of fission fragment was obtained and was equal to ~7%. Also the yield of "scission" neutrons and their spectrum have been estimated.

Compact Accelerator-Driven Neutron Imaging System Development for Non-Destructive Inspection

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The neutron is weakly interacting neutral particle, which has strong penetration power and can provide good contrast between light atoms and heavy atoms. The unique attribute of neutron makes neutron imaging become an excellent non-destructive testing technique. Compact accelerator-driven neutron imaging system is demonstrated to be simple, effective, reliable, low cost and feasible for non-destructive inspection. In this study, several non-destructive inspections of actual materials used in industries and infrastructures are successfully performed on compact accelerator-driven neutron source, such as the visualization of water in corroded region of painted steels by employing neutron radiography and the microscopic plastic deformation behavior of metal by utilizing neutron diffraction. Furthermore, the development of a transportable neutron imaging system for detection of concrete structures, aircrafts and other large objects on-site will also be discussed in this paper.

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

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

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

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

It was not found the statistically significant changes of chemical element mass fraction ratios in the intact roots of male teeth with age.

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

INAA AND ICP-MS IN THE INVESTIGATION OF CADMIUM/TRACE ELEMENT CONTENT RATIOS IN MALIGNANT PROSTATE GLAND

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Prostate cancer (PCa) is the most common non-cutaneous male cancer in most populations. Although the etiology of PCa is unknown, several risk factors including age, diet, and environment (Cd and some other trace element) have been welldetermined. It is also reported that the risk of having PCa drastically increase with age, being three orders of magnitude higher for the age group 40 – 79 years than for those younger than 39 years. Trace elements are involved in regulation of cellmembrane and cell function, gene regulation, activation or inhibition of enzymatic reactions. Essential or toxic (mutagenic, carcinogenic) properties of trace elements depend on tissue-specific need or tolerance, respectively. Excessive accumulation or an imbalance of the trace elements may disturb the cell functions and may result in cellular degeneration, death or, on the contrary, intensive uncontrolled proliferation, and malignancy.

Questions on the role of trace elements in etiology and pathogenesis of PCa are far from being answered. First of all, it is necessary to establish the normal level and changes of trace element contents in PCa tissue, and relationships of trace elements in norm and disease. To that end, we determined the ratio to Cd of 42 trace element (Ag, Al, Au, B, Be, Bi, Br, Ce, Co, Cr, Cs, Dy, Er, Fe, Gd, Hg, Ho, La, Li, Mn, Mo, Nb, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Sm, Sn, Tb, Th, Ti, Tl, Tm, U, Y, Yb, Zn, and Zr) in normal and cancerous prostate gland. Measurements of trace element contents were performed using a combination of instrumental neutron activation analysis and inductively coupled plasma mass spectrometry. Then the levels of ratios Cd/trace element contents in every sample were calculated. Intact prostates (control group) were removed at necropsy from 37 men (mean age 55 ± 11 years, range 41 – 87) who had died suddenly. The age of 60 patients with PC arranged from 40 to 79 years, the mean being 65 ±10 years (M±SD). In all cases the diagnosis has been confirmed by clinical and morphological results obtained during studies of biopsy and resected materials. All tissue samples were divided into two parts. One part was morphologically examined while trace element contents of another one were estimated.

It was observed that in the malignantly transformed prostate the ratios to Cd of Ag, Al, Au, B, Be, Bi, Br, Ce, Co, Cs, Dy, Er, Fe, Gd, Hg, Ho, La, Li, Mn, Mo, Nd, Ni, Pb, Pr, Rb, Sb, Se, Sm, Sn, Tb, Th, Ti, Tl, Tm, U, Yb, and Zr mass fraction were significantly lower than those in normal tissues. It was supposed that the ratios toCd of some trace elements may be used as tumor's markers.

APPLICATION OF NEUTRON ACTIVATION ANALYSIS FOR THE MEASUREMENT OF Br, Ca, Cl, K, Mg, Mn, AND CONTENTS IN THE INTACT THYROID OF FEMALE

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A large proportion of the world and European populations has some evidence of thyroid dysfunction. For example, the prevalence of goiter in areas of severe iodine deficiency can be as high as 80%. In Germany, an area of relative iodine deficiency, thyroid nodules or goiterwere found in 33% of working adults aged 18 – 65 years. Another problem is thyroid cancer. In the last decades, thyroid cancer incidence has continuously and sharply increased all over the world. Moreover, thyroid cancer mortality, in spite of earlier diagnosis and better treatment, has not decreased but is rather increasing. The reasons for this increase are not well understood, but some environmental carcinogens in the industrialized lifestyle may have specifically affected the thyroid. Among potential carcinogens, the increased iodine and some other chemical elementintakeisone of the most likely risk factors. Excessive accumulation or an imbalance of the chemical elements may disturb the cell functions and may result in cellular degeneration, death or, on the contrary, intensive uncontrolled proliferation, and malignancy. Questions on the role of chemical elements in etiology and pathogenesis of thyroid cancer are far from being answered. First of all, it is necessary to establish the normal level and changes of chemical element contents in thyroid tissue, and their relationships in intact gland.

This study aimed to perform a nondestructive method to evaluate the Br, Ca, Cl, K, Mg, Mn, and Na mass fraction in thyroid parenchyma and present data on relationships of these element contents in intact thyroid of females. To that end, we determined Br, Ca, Cl, K, Mg, Mn, and Na mass fraction in intact thyroid glands using aninstrumental neutron activation analysiswith high resolution spectrometry of short-lived radionuclides. Intact thyroids were removed at necropsy from 30 females who had died suddenly. The mean age (mean ± standard error of mean) of females was 55 ± 4 years, range 3.5 – 87. Mean values (M ± SEM) for mass fraction (mg/kg, dry mass basis) of chemical elements in intact female thyroid were: Br – 22.4 ± 3.2, Ca – 1663 ± 198, Cl – 3317 ± 290, K – 5395 ± 723, Mg – 212 ± 24, Mn – 1.50 ± 0.22, and Na – 6421 ± 320.

The positive inter-correlations between mass fractions Br–K, Br–Mn, Cl–Mg, Cl–Na, K–Mg, and Mn–Na as well as negativeinter-correlations between mass fractions of Ca–Cl were found in intact female thyroid. If some correlations between the elements were predictable (e.g., Na–Cl), the interpretation of other observed relationships requires further study for a more complete understanding.

A Proton Imaging System for Magnetic Proton Recoil Neutron Spectrometer

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ABSTRACT

Magnetic proton recoil (MPR) neutron spectrometer is considered as a high-performance instrument to measure deuterium-tritium (DT) neutron energy spectrum in magnetic confinement fusion and inertial confinement fusion experiments. A compact proton imaging system (PIS) has been developed for MPR neutron spectrometer. The PIS was used as focal plane detector (FPD) to detect and image the fluence distribution of recoil protons. The PIS consists of a thin plastic scintillator, fiber optic taper and image guide, electron-multiplying charge-coupled device (EMCCD) and data acquisition system. The key imaging properties, including resolution, response to proton and capability as a FPD for the MPR neutron spectrometer, were evaluated using proton beams at accelerators. The imaging properties of the PIS shown in this paper have demonstrated that the PIS is suitable for the MPR spectrometer in DT neutron measurement.

Keywords: MPR neutron spectrometer, proton imaging system, thin plastic scintillator, light yield, spatial resolution

GEOGRAPHICAL ORIGIN IDENTIFICATION OF MOLDAVIAN WINES BY NEUTRON ACTIVATION ANALYSIS

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To get more data regarding the elemental transfer from soil to wine, the neutron activation analysis was used to determine 35 elements in vineyard chernozem soil and 18 elements in wines from Romanesti and Cricova, Republic of Moldova. Soil elemental content allowed evidencing more similarities between considered soils and the Upper Continental Crust and the World Average Soil as well as to calculate the soil-to-wine transfer factor for 18 of investigated elements. From all 28 trace elements evidenced in soil, only 13, the soluble ones, were found in all wines samples, which finally allowed determination the corresponding transfer factors whose values varied between 0.02 mg/l (U) and 38 mg/l (K). In this regard, all sorts of wines showed a significant concentration of potassium, varying from 370 to 700 mg/l. A subsequent Discriminant Analysis allowed discriminating all wine samples according to their types: red and white as well as to their origin.

AIR POLLUTION IN TULA REGION: PRELIMINARY RESULTS OF MOSS SURVEY IN 2015–2016

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The method of passive moss biomonitoring was used in Tula regionfor the second time to study atmospheric deposition of trace elements. Sampling of mosses was carried out at 82 sampling sites in the forest, forest-steppe, steppe and marsh phytocoenosis of the Tula region. A total of 42 elements were determined using epithermal neutron activation analysis. Retrospective comparative analysis of the atmospheric deposition of trace elements in 2000–2015 showed an increase since 2000 of Fe, Cr, Co, As, Cd, Sr, and Sm concentrations in atmospheric deposition in the region. In comparison with the other regions of Russia, the air of Tula region is polluted by such elements as V, Fe, Co, As, Sr, La, Ce, Tb, Hf, Ta, Th, U, and Sm. These elements are of technogenic origin associated with the activity of the enterprises of metallurgical, metalworking, defense, and coal mining in Tula region.

Compared with data of passive moss biomonitoring for the Republic of Belarus and the EU and the UK, the atmospheric deposition in Tula region contains 1.5–7 times more V, Cr, Fe, Zn, As, Cd, that may be a cause cancer, chronic cardiovascular and respiratory system diseases in adults and children, as well as the cause of weakening the immune system of the population of the study area.

Multivariate statistical analysis revealed 4 factors:

Factor 1 is associates with soils. Industrial pollution of soil and weathering processes;

Factor 2 can be attributed to technogenic air pollution;

Factor 3 is associated with physiological activity of mosses;

Factor 4 is associated with the extraction and processing of ores.

A comparison of different moss species with those recommended by the Moss Manual 2015/2016 was also undertaken. Such species as *Oxyrrhynchium hians, Eurhynchium angustirete, Orthotrichum speciosum, Brachythecium rutabulum, Atrichum undulatum, Brachythecium salebrosum, Abietinella abietina, Rhytidiadelphus triquetrus* showed similar accumulative characteristics as the recommended ones or even surpass them.

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