ISINN-20

XX International Seminar
on Interaction of Neutrons with Nuclei,
dedicated to the memory of
Ilia M. Frank and Fedor L. Shapiro,
the founders of the Laboratory of Neutron Physics

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

Dubna, 2012

Abstracts

Joint Institute for Nuclear Research

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

XX International Seminar on Interaction of Neutrons with Nuclei, dedicated to the memory of Ilia M. Frank and Fedor L. Shapiro, the founders of the Laboratory of Neutron Physics

Alushta, Ukraine, May 21–26, 2012

Abstracts of the Seminar

Dubna 2012

F97

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Фундаментальные взаимодействия и нейтроны, структура ядра, ультрахолодные нейтроны и связанные вопросы: Тезисы докладов XX Международного семинара по взаимодействию нейтронов с ядрами, посвященного памяти И. М. Франка и Ф. Л. Шапиро, основателей Лаборатории нейтронной физики (Алушта, Украина, 21–26 мая 2012 г.). — Дубна: ОИЯИ, 2012. — 105 с.
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19:00 Welcome party

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8:30 – 9:00 Registration

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Fundamental properties of the neutron, UCN& related topics

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2.	09:50 – 10:20	**Daum M.** The new UCN source at PSI.
3.	10:20 – 10:50	**Kawasaki S.** A new spallation ultracold neutron source at RCNP.

10:50 – 11:05 Coffee break

4.	11:05 – 11:45	**Dubbers D.** The beta decay of the neutron.
5.	10:45 – 12:15	**Masuda Ya., Asahi K., Hatanaka K., Sun-Chan Jeong, Kawasaki Sh., Matsumiya R., Matsuta K., Miharaand M., Watanabe Yu.** A new EDM measurement with a new generation UCN source.
6.	12:15 – 12:40	**Ino T.** Neutron lifetime measurement with a pulsed neutron beam at J-PARC.
7.	12:40 – 13:15	**Frank A.** Precise UCN spectroscopy using neutron Fabry Perrot interferometers.

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13:30 – 14:30 Lunch
16:15 – 16:30 Coffee

First parallel session

Fundamental properties of the neutron, UCN& related topics

8.	16:30 – 17:00	**Voronin V.** Crystal-diffraction neutron EDM search experiment.
9.	17:00 – 17:25	**Kuznetsov I., Voronin V.V.** Measurement of neutron electric charge by the spin interferometry technique.
10.	17:25 – 17:55	**Nesvizhevsky V. et al.** Quantum levitation of nanoparticles seen by ultracold neutrons.
11.	17:55 – 18:15	**Lychagin E. et al.** Temperature dependence of UCN "small heating" probability and spectrum of up-scattered UCN at surface of fombline Y-HVAC 18/8 oil.

Second parallel session

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14.	17:20 – 17:40	**Ivanova T.** The tritium production cross section for neutron interaction with ^{10}B nuclei.
15.	17:40 – 18:00	**Kadenko A.** Cross-sections of (n,p), (n, α), (n,2n)-reactions on isotopes of Dy, Er, Yb at E_n= 14.6 MeV.
16.	18:00 – 18:20	**Sedysheva M.** Systematical analysis of (n,α)-reaction cross-sections for (6-20) MeV neutrons.
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Plenary sessions

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19.	09:20 – 09:40	**Novitsky V.** Investigation of the TRI and ROT effects in the emission of prompt fission neutrons.
20.	09:40 – 10:05	**Guseva I., Gagarski A., Petrov G., Val'sky G.** The comparison of binary and ternary fission configurations close to the instant of scission.
21.	10:05 – 10:25	**Barabanov A.** Nuclear spin-orbit interaction in ternary fission.
22.	10:25 – 10:45	**Tchuvil'skyYu.** ROT-effect in (n, α γ)- reactions.
23.	10:45 – 11:10	**Kamanin D., Pyatkov Yu., Alexandrov A. et al.** Summary of experimental results on collinear cluster tri-partition studies.

11:10 – 11:25 Coffee break

"Miscellany"

24.	11:25 – 12:00	**Cser L.** New developments in atomic resolution holography.
25.		**Cser L.** Budapest neutron center: instrumentation and highlights.
26.	12:00 – 12:30	**Jentschel M.** Gamma ray optics.
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13:00 – 14:30 Lunch

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31.	17:40 – 18:00	**Kopatch Yu.** Angular correlations in neutron emission from the spontaneous fission of ^{252}Cf.
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Fundamental properties of the neutron, UCN& related topics

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Nuclear analytical methods in the life sciences, biology and medicine

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70.	16:15 – 16:35	**Shvetsov V.** Measurements of the neutron flux density at IBR-2M extracted beams.
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73.	**Kamanin D., Pyatkov Yu., Alexandrov A. Kuznetsova E., Shvetsov V., Ryabov Yu.** Proposal on guide based experimental channel at the IBR -2 reactor.
74.	**Kamanin D., Pyatkov Yu., Kondratyev N., , Zhuchko V., Alexandrov A., Alexandrova I., Jacobs N., Kuznetsova E., Malaza V., Mulgin S., Strekalovsky A., Strekalovsky O.** COMETA spectrometer for studying of multi-body decays of heavy nuclei.
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94.	**Dmitriev A., Pavlov S., Ostrovnaya T., Gundorina S.** Software for Automation of Neutron Activation Analysis at the IBR-2 Reactor of FLNP JINR.
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TIMETABLE OF ISINN-20

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8-00	A R R I V A L	*Breakfast* **Registration**	*Breakfast*	*Breakfast*	*Breakfast*	*Breakfast*
8-30						
8-30					Fundamental symmetries	
9-00						
9-00		Fundamental properties of the neutron UCN & related topics 1-st session	Fission	Nuclear Analytical Methods in the Life Sciences, Biology and Medicine		D E P A R T U R E
10-00						
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11-55						
12-00					*Lunch*	
13-00			*Lunch*			
13-00					Accelerator driven subcritical systems	*Lunch*
13-15						
13-15		*Lunch*				
13-30						
13-30				*Lunch*		
14-10						
14-10					Methodical aspects, detector development	
14-30						
14-30		Time for discussions	Poster session	Excursion for those who wish		Depar-ture
15-00						
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16-55					Closing of Seminar	
17-00						
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18-00						
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18-40		Free				
18-50		Free				
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20-00						
20-00			***Memorial event***			
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EFFECTS OF FAST NEUTRONS AND GAMMA RADIATION ON SOME BIOPHYSICAL PROPERTIES OF RED BLOOD CELLS MEMBRANE OF ALBINO RATS (IN VIVO STUDY)

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The radiation hazard through measurements of possible changes on some biophysical properties of red blood cell membrane of albino rats in vivo is studied. It has been founded that counting of red blood cells is unsatisfactory to represent the radiation hazards. The biophysical structural functions of blood plays the major role to represent the injury occurred to the system. Sixty male albino rats were equally divided in to three groups namely A, B, C. Animals of group A used as a control group and didn't receive any treatment and housed at normal environmental conditions. Animals of groups B was used for the study of γ-rays effects. The γ-dose rate from the Am^{241} source was $16\,\mu$Sv/h at the irradiation facility. Animals of groups C was used for study of neutrons and gamma effects. The average neutron component of the dose rate was $6\,\mu$Sv/h. Osmofragility of the r.b.cs, blood film were carried for each collected blood samples. The blood viscosity and solubilization of the membrane by non ionic detergent (octylglucoside) were also measured. The results showed decrease in the average osmotic fragility and average membrane solubilization. The effects of radiation on the red blood cell membrane were discussed.

Key words: Red blood cell membrane, radiation, osmotic fragility, blood morphology, blood viscosity, membrane solubilization.

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SILICON MICRO-PIXELS AVALANCHE PHOTODIODES AND SCINTILLATION DETECTORS

Ahmadov F.[1,3], **Ahmadov G.**[1,3], **Kopatch Yu.**[1], **Madatov R.**[3], **Sadygov Z.**[1,2], **Shvetsov V.**[1], **Tiutiunnikov S.**[1], **Zhezher V.**[1]

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In this work the performance of new generation Micro-Pixel Avalanche Photodiode (MAPD) is described. Micro-pixel avalanche photodiode manufactured by Zecotek Photonics Inc. Micro-Pixel Avalanche Photodiode has the following features: gain can reach values of 10^5, photon detection efficiency is 30-35 % in a wide wavelength range and pixels density is 15000 pixels/mm^2.

We report the results of gamma-rays and alpha particle detecting measurements performed using lutetium fine silicate (LFS) crystal by micro-pixel avalanche photodiode. In the experiment was used different size of LFS scintillators (3x3x0.5 mm^3, 2x2x10 mm^3 and 2x2x20 mm^3) which were manufactured by Zecotek Photonics Inc. The following results are obtained energy resolution of 23% for 59.6 keV gamma rays from ^{241}Am, 11% for 662 keV gamma rays from ^{137}Cs, 6.5% for 1.3 MeV gamma rays from ^{60}Co source and 9% for 5.5MeV alpha particle from ^{241}Am source.

SPATIAL DISTRIBUTIONS OF $^{238}U(n,\gamma)$ AND $^{238}U(n,f)$ REACTIONS IN URANIUM TARGET OF "KVINTA" ASSEMBLY IRRADIATED WITH 2, 4 AND 6 GEV DEUTERONS

V.A. Voronko [1], V.V. Sotnikov [1], M.Y. Artiushenko [1], Y.T. Petrusenko [1], M.G. Kadykov [2], S.I. Tyutyunnikov [2], V.V. Chilap [3], A.V. Chinenov [3]

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Experiments described in this paper were conducted within the framework of the research program "Investigation of deep subcritical Accelerator Driven Systems and possibilities of their use for energy production and transmutation of radioactive waste" (project "Energy + Transmutation RAW"). An extended "KVINTA" assembly ($m_U \approx 500$ kg) was irradiated with an extracted beam of 2, 4 and 6 GeV deuterons from the Nuclotron accelerator at the Laboratory of Physics High Energies, JINR, Dubna, Russia. Information on the spatial and energy distribution of neutrons in the volume of the uranium target was obtained with sets of activation detectors (natural uranium). Activation method was used to obtain the spatial distributions of $^{238}U(n,\gamma)$ and $^{238}U(n,f)$ reactions. Based on the spatial distributions of capture and fission reactions of ^{238}U in the uranium target, the total number of ^{239}Pu and total number of fission reactions accumulated for all time of irradiation also was determined and comparison of this values at the energies 2, 4 and 6 GeV was performed. Spatial distributions of spectral indices values $\bar{\sigma}_{capt}^{238U} / \bar{\sigma}_{fission}^{238U}$, representing the integral nuclear data were defined.

PROPOSAL ON GUIDE BASED EXPERIMENTAL CHANNEL AT THE IBR-2 REACTOR

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In our previous works [1–3] different modes of a new type of ternary decay of low excited heavy nuclei called collinear cluster tri-partition (CCT) were reported. In the most populated "Ni"-mode based on the magic isotopes of Ni two CCT partners flight after scission almost collinearly with angular divergence of ~ 0.2^0. This mode was identified in the frame of the missing mass approach, but direct detection of all three partners is of course very desirable for working out of the physical model of the process. Detection of almost collinear fragments is very complicated experimental task keeping in mind the necessity to shadow the edges of PIN diodes. The width of the frame between neighboring diodes put a limit for distinguishing two fragments. For the moment this limit is about 1^0 and hardy can be decreased due to quick lost of registration efficiency.

We are going to use electrostatic guide system for transporting of the fission fragments from the target in the vicinity of the IBR-2 active zone to the detectors placed in some meters from the target (fig. 1). Similar guide system has been already used at the reactor [4]. It was proposed for the first time in [5]. Important difference of our proposal is that two-armed system is planning for realization.

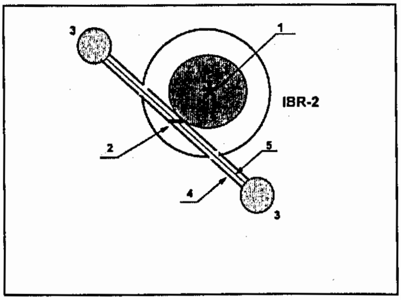

Fig. 1. Schematically view of the setup. Active zone (1), target (2), detectors chambers (3), reactor channel (4), central filament of the guide (5).

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NUCLEAR SPIN–ORBIT INTERACTION IN TERNARY FISSION

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Spin–orbit interaction is a relativistic correction of the second order on v/c to Hamiltonian of particles connected by electromagnetic or nuclear forces. Spin–orbit interaction manifests itself in the specific splitting of levels in atoms and nuclei. This interaction leads also to well-known spin-angular correlations, e.g. to left-right asymmetry, arising on scattering of polarized light nuclear particles on nuclei. Effects caused by the interaction of the orbital momentum of an incident particle and the spin of a target nucleus have been found also.

Earlier it was noted [1] that the nuclear spin–orbit interaction can be responsible for the asymmetries observed in ternary fission of nuclei by slow longitudinally polarized neutrons (see e.g. [2,3]). The emission asymmetries were detected for the third (besides two fragments) particle, usually – α-particle, with respect to two perpendicular planes. Both planes pass through the direction of the neutron spin, and one of them passes also through a fission axis, normal to the neutron spin.

In this work the review of available experimental and theoretical results about the nuclear spin–orbit interaction is presented. Special attention is paid to its possibility to cause the observable asymmetries in ternary fission. Quantitative estimations for observed asymmetries in the frameworks of a three-particle model of ternary fission are given.

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TENTATIVE RESULT OF THE NEUTRON LIFETIME MEASUREMENT BY THE METHOD OF ULTRACOLD NEUTRON STORAGE WITH REGISTRATION OF INELASTIC SCATTERED NEUTRONS

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Result of the calculative and experimental investigations on the detection of the methodical adjustments of the experiment on the neutron lifetime measurement is presented. Taking into account these adjustments, the data of three independent experiments made with different ultracold neutron energy spectra and under different temperatures were handled resulting the averaged neutron lifetime value equal to 880.7(1.0) sec.

NEW EXPERIMENTAL DATA OF $^{19}F(n, alpha)^{16}N$ REACTION EXCITATION FUNCTION

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Molten salt reactor has been recognized as one of the most perspective just recently – that is why cross section data of neutrons with fluorine nuclei interaction is so important. This reactor type has molten salts both as coolant and as nuclear fuel. Huge number of fluorine atoms are exposed by high flux of fast neutrons in the reactor core and so, neutron-nucleus interaction in fluorine atoms can define reactor kinetics. The experimental investigation of $^{19}F(n, alpha)^{16}N$ reaction cross-section in 4-7 MeV energy region is represented in this work. The detector filled up with 95% Kr and 5% CF_4 gas mixture was used for particles registration. Neutron flux was determined by ^{238}U fission fragments calculation. The obtained data differ from existing estimations.

CALCULATIONS OF THE EFFECTIVE RESONANCE INTEGRALS

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Calçulations of the effective resonance integrals which include the real energy dependence for neutron flux density and correction on the neutron capture in the sample is presented. The expression for the effective resonance integral is:

$$I_{eff.res} = I_v(\alpha) + \frac{\pi}{2}\sum \frac{\sigma_{0i} G_i}{E_{ri}^{1-\alpha}} \Gamma_{\gamma i}$$

Where $I_v(\alpha)$ is the part of the resonance integral which includes a low energy capture cross-section. The values $\sigma_{0i} = \frac{4\pi}{k_{ri}^2} g_{Ji} \frac{\Gamma_{ni}}{\Gamma_i}$ are the peak cross-sections for every resonance. Factors G_i depend on a sample thickness and temperature and describe the probability of the neutron capture in the sample. Sum is taken on number of low energy resonances. The parameter α describes the real energy dependence for neutron flux density $\varphi(E_n) = \frac{\Phi_{res1}}{E_n^{1-\alpha}}$, Φ_{res1} is the neutron flux density at 1 eV.

These calculations are needed for the determination of the neutron flux with high accuracy and for neutron activation analysis on the IREN and IBR-2M facilities. The method of the calculations for Bethe-Plachek function is based on Pade approximation. The results of the calculations for different nuclides are shown.

THE E-LINAC-BASED YIELD OF THE VITAL RADIO-ISOTOPES

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We treat the bremsstrahlung induced by an initial electron beam in W-converter, and the production of a desirable radio-isotope due to the photo-nuclear reaction caused by this bremsstrahlung in irradiated sample that involves an appropriate original isotope, for instance, ^{100}Mo to obtain ^{99}Mo/^{99m}Tc. The yield of a number of some, the most applicable in practice, radio-isotopes is evaluated, ^{99}Mo/^{99m}Tc , ^{117m}Sn , ^{237}U. Thereto we treat the production of desirable radio isotopes due to the ^{238}U photo-fission, and through the ^{238}U fission by the neutrons that stem in the ^{238}U sample. The *Table 1* depicts the yield of activity of ^{99}Mo, that is the precursor of ^{99m}Tc, the most vital medical radio-isotope. As understood, the photo-neutron production of radio isotopes proves to be more practicable than the production via the uranium photo- and neutron-fission. Dependence of radio-isotope yield on sample thickness R_{Mo} is understood from *Table 2*. The time $T_{max} \sim 25$h of a maximum accumulation of the isotope ^{99m}Tc, the daughter produce of ^{99}Mo, and the respective yield of its activity and amount are determined for various expositions T_e, electron energies, sample thickness. For a pure ^{100}Mo sample with longitudinal size 2cm and area 1cm^2 irradiated during 150h by a reasonable electron beam with the energy E_e = 50MeV and current J_e = 10mA/cm^2, the *6-day curies per week* ^{99}Mo activity attains the value $\mathcal{Y}_{6-day}(150\mathrm{h}, 10\mathrm{mA}) \approx (1.0 - 1.5) \cdot 10^3$Ci. This amount proves to be competitive with the marketable *large-scale* productivity of the *large-scale producers*, who furnished on the market more than 1000 *6-day curies* of ^{99}Mo *per week*, recovered on the routine reactor basis with operating very undesirable *HEU* targets. The all-round advantages of the E-linac-based radio-isotope production over the reactor-based come to light with finding of [1], which are: far more simple irradiated sample processing, much smaller danger of contamination, no deal with treating waste, especially weapon-usable, no long chain from producer to end-user, far more cheaper construction and refurbishing, etc. The modern E-linac-driven vital radio-isotope producing facilities are certain to supersede the obsolescent routine reactor-based plants.

Table 1. *The yield* $\mathcal{Y}[Bq \cdot 10^{10}]$ *of* ^{99}Mo *total activity produced in* ^{100}Mo *and* ^{238}U *samples with* $R_S = 2cm$ *(S = Mo, U) and* $1cm^2$ *area, due to the electron current with* $\bar{E}_e[MeV]$ *and* $J_e = 1mA/(cm^2)$*, during* $1h$ *exposition. The second string presents* $\mathcal{Y}$ *obtained in the reaction* $^{100}Mo(\gamma,n)^{99}Mo$*, and the third describes* ^{99}Mo *production within U sample.*

$\bar{E}_e$	20.0	25.0	50.0	100.0
$\mathcal{Y}_{\gamma Mo}$	2.9	5.86	16.87	28.17
$\mathcal{Y}_{UFMo}$	0.145	0.277	0.805	1.405

Table 2 *The yield of activity* $Y[Bq/(h \cdot \mu A \cdot mg^{100}Mo)]$ *and amount* $\mathcal{M}(mg10^{-5})$ *of the* ^{99}Mo *at various sample thickness* $R_{Mo}(cm)$*, upon irradiating the* ^{nat}Mo *sample during* $1h$ *by electrons with* $\bar{E}_e = 50MeV$, $J_e = 1mA/cm^2$.

R_{Mo}	0.01	0.5	1.0	1.5	2.0	2.5
Y	11.73	10.73	9.86	9.07	8.37	7.78
$\mathcal{M}$	0.58	26.3	48.4	66.8	82.2	94.4

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STUDY OF THE NEUTRON FLUX PRODUCED AT E-LINAC-DRIVEN NEUTRON SOURCES

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We treat generic physical performances of the neutrons production provided by an electron beam irradiating high atomic number materials. The bremsstrahlung of incident electrons is considered. The experimental data on photo-nuclear reactions are utilized to describe neutrons generating caused by the γ-radiation absorption. The generally received theoretical approach is applied to explore the photo-neutrons energy distribution. A main contribution to neutron flux is due to photo-nuclear reactions with the photon energy in the giant resonance area, and a discernible contribution comes from the high energy photons absorption as well. The evaporation neutrons constitute dominant part of a neutron flux, yet at neutron energy $\gtrsim$ 2.5MeV the direct neutrons share is of value. Neutrons generating is analyzed for different, both non-fission-able and fission-able, materials of irradiated samples and for various electron beams. The spectrum of neutron flux, the mean neutron energy and the total neutron yield are calculated in terms of the electron beam energy and current, and the characteristics of irradiated samples. All the analysis is immediately carried out just in framework of the quantum electrodynamics and photo-nuclear physics, without having any recourse to the "numerical Monte-Carlo simulations". Our findings prove mainly to conform satisfactory to the experimental measurements, so far as those are available by now, Table 1. Neutron yield grows substantially non-linearly with electron energy increase, Table 2. Because of yield saturation, sample thickness ought't to be $\gtrsim$ 5cm. An U radiator is preferable to gain an abundant neutron yield.

Table 1. *The total yields Y and mean energies $\bar{\varepsilon}$ of the neutrons generated by an electron beam with the initial energy $E_e[MeV]$ and average current $J_e[10\mu A]$ from irradiated U-, Ta-, Pb-samples, as designated in the first row, with the thickness $R_S[cm]$. $\bar{\varepsilon}_{Scomp}[MeV]$ and $Y_{Scomp}[10^{11}n/s]$ are the computed quantities, whereas $\bar{\varepsilon}_{Sexp}[MeV]$ and $Y_{Sexp}[10^{11}n/s]$ are obtained from the experimental data, when available.*

	U^a	U^b	U	$^{181}Ta^c$	$^{181}Ta^d$	^{181}Ta	$^{nat}Pb^e$	$^{nat}Pb^f$
R_S	$\gtrsim 5$	$\gtrsim 5$	5	≈ 7	3.175	5	1.68	1.12
E_e	105	55	30	65	140	30	45	30
J_e	10	10	10	0.09	1	1	100	100
$\bar{\varepsilon}_{comp}$	1.66	1.63	1.56	1.65	1.76	1.46	1.59	1.47
$\bar{\varepsilon}_{exp}$	1.61	1.69		1.7	~ 1.8		1.7	1.40
Y_{comp}	310	163	78.5	1	17.2	3.5	560	195
Y_{exp}	340	189		1	18.2		540	190

[a]GELINA performances; [b]Arzamas performances; [c]POHANG performances; [d]ORELA performances; [e]Data from IAEA Tech. Rep. Ser. No 188 (1979); [f]ELBE performances.

Table 2. *The yield of neutrons $Y_S[10^{11}n/s]$ in tantalum and uranium samples, with the thickness $R_S = 3\,cm$ and $1\,cm^2$ area, irradiated by the electron current $J_e = 10^{-5}A/cm^2$, with the energy $E_e MeV$.*

E_e	20.0	22.0	25.0	30.0	40.0	50.0	100.0
Y_{Ta}	0.85	1.2	1.74	2.63	4.28	5.73	11.34
Y_U	2.51	3.42	4.80	7.12	11.41	15.07	28.94

Overview on the scientific activity at the Budapest neutron Center

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The Budapest Research Reactor (BRR) upgraded up to 10 MW received the operation license in November 1993. The BRR has been utilized as a neutron source for research and various industrial and health care applications. Irradiations are performed in vertical channels (the reactor has now more than 40 channels, they can be used for isotope production and material testing) whereas physical experiments are carried out at the horizontal neutron beam ports. The reactor has ten beam ports (eight radial and two tangential) and nearly all of them are constantly in use. There are a total of thirteen so called 'larger scale experimental facilities' installed at the BRR's beam ports. The utilization matters are coordinated and managed by the International Scientific Council of the Budapest Neutron Centre.
In the present talk a brief overview of the instrumentation and scientific activity at the BBR is given. The scientific activity at the horizontal channels is mainly concetrated on the study of condensed matter properties aiming both the fundamental and applied physical goals. The results obtained are illustrated by several outstanding achievements, so called „high lights".
Applied nuclear science is dominantly represented by activation analysis including neutron capture promt gamma-ray approach. An in-beam Mössbauer installation is under preparation.
A remarkable feature of the operation principle of BNC facilities – a suit of reactor irradiation equipment, thermal neutron beam instruments and cold neutron spectrometers in the neutron guide hall – that they are open for the international user community. Under amongst as an example I should like to mention BRR have been invited as the "neutron facility" in the CHARISMA projects, which puts together a consortium of large European museums (Louvre, British Museum, Prado...) and scientific facilities to join efforts for the investigation of objects of cultural heritage.

Present Status of Atomic Resolution Neutron Holography

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According to quantum mechanic thermal neutrons behave as matter waves postulated by de-Broglie therefore induced a series of optical properties. In addition, a wave-packet belonging to a single particle displays interference effect with oneself. Relying on these properties it is I principle realistic to put into practice of holographic imaging using thermal neutrons. Thanks to the similar values of the wavelength of the thermal neutrons and the inter-atomic distance in solid states one can expect high resolution holographic imaging. Atomic resolution neutron holography (ARNH) constitutes a novel technique to obtain structural information in three dimensions of the local crystal structure. It is based on the recording of the interference of neutron waves coherently scattered by atoms located on a crystal lattice with a suitable reference wave. In the present talk the ways of carrying out successful observation of ARNH. Amongst others the optimization of the instrumentation and the estimation of the signal-to-noise ratio are considered. At present time the ARNH is demonstrated on more than five systems. The involvement of an absolutely new approach, the so called double reconstruction method, improves significantly the observation of the holographic signal allowing to get rid of side oscillation inherently appearing in the holographic intensity distribution. A practical application of the ARNH is demonstrated. Future prospects and some unresolved problematic observation is presented for discussion.

STATUS OF THE ULTRACOLD NEUTRON SOURCE AT PSI

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Construction of the new ultracold neutron (UCN) source at the Paul Scherrer Institute (PSI), Switzerland, is completed. The key elements are a very intense (I_p > 2.2 mA) pulsed proton beam with a low duty cycle (1%), a lead/Zircaloy spallation target, a 3.6 m^3 heavy water moderator and a 30 liter solid Deuterium (sD_2) converter system. Spallation neutrons are thermalized in the heavy water, further cooled and partially downscattered into the ultracold energy regime (E < 300 neV) in the sD_2 crystal. User operation and a first experiment have started. An overview of the final design of all essential components of the source is reported as well as the current status.

SOFTWARE FOR AUTOMATION OF NEUTRON ACTIVATION ANALYSIS AT THE IBR-2 REACTOR OF FLNP JINR

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To enhance analytical capacity of neutron activation analysis (NAA) at the installation REGATA at the reactor IBR-2 the software package to automate different stages of NAA is designed. It serves to minimize manual data input in the preparation and conduct of the NAA, to automate the process of calculating the concentrations of the elements in question on the basis of data obtained in the processing of spectra of the induced gamma activity by the program Genie 2000.
The software package includes the following stages of the NAA:

- registration of information on samples received and clients;
- samples preparation for irradiation;
- irradiation of the samples and measurement of the spectra of the induced gamma activity;
- calculation of elemental concentrations in the samples based on comparative method taking into account the fluctuations of the neutron flux;
- storage and processing of the full range of information about the process and results by means of NAA data base;
- evaluation of the results of tests on the quality control and quality assurance (QC/QA) of the performed investigations.

STUDY OF THE HEAVY METAL CONTENT IN SOIL, RIVER WATER, SNOW, NEEDLES AND MOSSES IN IVANOVO REGION

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An increase of anthropogenic impact causes a degradation of environmental quality, heavy metals (HM) being one of the most dangerous pollutants. They exist in all natural environments and frequently have a tendency of bioaccumulation. Their expressed toxicity and high level of the influence define the urgency of investigation of heavy metals migration and transformation in natural ecosystems. This paper is concerned with the study of HM contamination level in Ivanovo region carried out in this scale for the first time.

Ivanovo region situated at interfluve of the Volga and Klyaz'ma rivers with an area of 22 000 km^2 was the object of the investigation. There were 45 squares (Fig. 1) separated within the region with average area of 400 km^2. Samples of soil, needle of spruce (*Picea Abies*), mosses and snow were taken from each square. Water samples from the main rivers were also sampled.

The analysis of HM content (Pb, Cd, Cr, Cu, Co, Ni, Mn, Fe and Zn) was carried out with the use of flame atomic absorption spectrometry.

Average HM content in the soil samples was within the range of maximum permissible concentration (MPC). However, the increasing HM content in the soil near large industrial centers evidenced of their anthropogenic origin. The most of samples sites had a HM concentration, which was lower than background.

The factor analysis of the given data also confirmed anthropogenic character of areas with higher HM content.

The analysis of needles showed the absence of Cd, Pb, Cr, Co and particularly Ni. Other elements likely had natural origin. Heavy metals can migrate from soils into rivers. Thereby, it was also necessitate carrying out the analysis of river water. The content of Fe, Zn and Mn was below maximum permissible concentration for water for all rivers.

Data of 25 moss samples (*Hylocomium splendens, Pleurozium schreberi* and *Polytrichum commune*) were processed. All obtained metals were present in samples. Values of HM content in moss were compared with the results of the research in Yaroslavl, Tver', Tula region and Udmurtia republic. All these data will measured by NAA method. In fact level of HM content in Ivanovo region was very close with neighbor regions.

The results of the research will be given in community ecological council for the development of measures of Ivanovo region aimed at the maintenance of favorable quality of environment.

It will be possible to define spatial and temporal trends of HM distribution in natural environments and determine the regularity of their behavior in the environment during next two years.

The Relation between the Isoscalar and Isovector Interaction Potential

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The interaction potentials of (n,n), (p,p) and (p,n) have been calculated using isoscalar and isovector parts of M3Y interaction. The constant of density dependence of the effective interaction are obtained by reproducing the saturation energy per nucleon and saturation density of spin and isospin symmetric cold infinite nuclear matter. The interaction potentials are used to calculate the diffrential scattering cross section of (n,n), (p,p) and (p,n) reactions by some nuclei at low energy region. The relation between the isoscalar and isovector potentials is studied.

Keywords : Interaction potential, DWUCK4, elastic scattering, quasi-elastic scattering.

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COMBINED XRF-NAA NUCLEAR TECHNIQUES FOR THE QUANTIFICATION OF TRACE ELEMENTS IN SOILS

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Two complementary analytical techniques, X-Ray Fluorescence (XRF) and Neutron Activation Analysis (NAA), were used to study the concentration of trace elements in surface soil affected by the Integrated Iron and Steel Works in Galati, Romania. Soil samples were collected at 0–5 cm depth in the open sampling sites along different cardinal directions and distances from the Works, as well as from remote area in Galati County considered as unpolluted zone. XRF analyses were performed by portable XRF energy-dispersive spectrometer Thermo Scientific XLTj NITON from 700 series at "Dunarea de Jos" University of Galati, Romania and the detected elements in the soils samples were the following: Ag, As, Ca, Cd, Cr, Cu, Fe, Hg, K, Mn, Ni, Sb, Sc, Se, Sn, Ti, V, and Zn. The XRF analyzer has as excitation source a miniaturized 30 kV X-ray tube and, by automatically adjusting for matrix effects, is able to determine the content of soil samples typically in seconds, without any requirement for instrument users to input empirical, sample specific calibrations. Each soil sample was analyzed five times for 240 s using two X-ray filters, one for elements from K to Cu and the second for elements from Zn to Sb. The analyzer features a Peltier-cooled Si-PiN X-ray detector. The standard software is programmed to analyze and automatically report 18 elements. All major interferences by overlapping X-ray alpha emission lines (such as those between As and Pb) are known and accounted for by the program algorithm that then separates close peaks based on the element's characteristic X-ray beta lines. NAA at Frank Laboratory of Neutron Physics (FLNP) of Joint Institute of Nuclear Research (JINR) at Dubna, Russia, allowed determination of Na, Mg, Al, Si, S, Cl, K, Ca, Ti, V, Mn, Cu, Zn, Br, Sr, In, Sn, I, Ba, Dy, and U in the same soil samples after 30 s of irradiation in the conventional irradiation channel of the reactor IBR-2 with the neutron flux density ~ 10^{12} . neutron·cm^{-2}·s^{-1}. Software developed in the Sector of NAA and Applied Research FLNP JINR was used to calculate the concentrations of the determined elements using Standard Reference Materials (NIST USA soil and sediment SRMs). The analytical capabilities of the two employed techniques are discussed in terms of number of elements detected, sensitivity and matrix effects. The results obtained are compared with the permitted concentration values for heavy metals and other trace elements in Romania, and with values found in the literature for the European and world median elemental concentrations in the earth crust.

INVESTIGATION OF NATIVE AND MODEL LIPID MEMBRANES BY NEUTRON SCATTERING

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Functional properties of biological membrane are determined by its nanostructure in many respects. Self-assembly of lipid molecules in liquid crystal has made possible to apply the neutron and X-ray scattering techniques for the characterization of their nanostructure.

Results of structural investigations of membranes based on synthesized lipids DMPC/lysoMPC with different molar ration and extracted lipids from living bacteria *Streptomyces hygroscopicus* are presented.

Analysis of neutron diffraction spectra demonstrates that phospholipids fraction of bacteria *Streptomyces hygroscopicus* at T=20°C и relative humidity 97% consists of multilamellar membranes with repeat distance d=85.8±0.5 Å and micelles with size of 54.2±0.2 Å.

Parameters of the internal nanostructure of mixed DMPC/lysoMPC membranes are determined. It is shown that lysoMPC molecules create lipid bilayer on the quartz substrate at specified conditions. Thus, lysoDMPC has membrane-generating properties. From the other hand, molecule of lysoMPC has micelle-generating properties in water excess.

SOME RESULTS ON COOPERATION BETWEEN SLOVAKIA AND FLNP JINR IN THE ENVIRONMENTAL RESEARCH (2000–2012)

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In during last twelve years cooperation between Slovakia and FLNP JINR focused on the environmental studies. The moss (from 86 sampling sites located in Slovakia) and airborne particulate matter were the objects of investigations. INAA at the IBR-2 reactor and flame AAS were applied in order to determine 44 elements in moss collected in 2000, 2005, and 2009. The concentrations of trace metals, rare earths, and actinides were evaluated in the atmospheric aerosols. To the best of our knowledge, such a large association of elements has never been studied before in the environmental samples from Slovakia. Factor analysis was applied to determine possible sources of trace element deposition in the Slovakian moss. The trans-boundary contamination by Hg through dry and wet deposition from Czech Republic and Polish is evident in the bordering territory in the north-west part of Slovakia (The Second Black Triangle), known for metallurgical works, coal processing and chemical industries. In comparison to the average Austrian and Czech values of heavy metal contents in moss, the Slovak atmospheric deposition loads of the elements were found to be 2–3 times higher on average. Knowledge of the current contents of individual elements in the moss-biomonitors allowed us to estimate their absolute atmospheric deposition levels ($mg{\cdot}m^{-2}year^{-1}$). Our date (only trace metals) were incorporate to the European programme "*Atmospheric heavy metal deposition in Europe – estimation based on moss analysis*". The moss samples collected in Slovakia and Belarus were assayed with respect to gamma-emitting radionuclides (^{137}Cs and ^{210}Pb) using the low-level background facilities of in the laboratory of the Comenius University in Bratislava. Moss was employed for the first time in Belarus as a biological indicator of radioactive environmental pollution in consequence of the Chernobyl accident in 1986. The results of measurements of ^{137}Cs in moss samples collected in 2000, 2006, and 2009 at the same localities of Slovakia were compared with the results of air monitoring of ^{137}Cs carried out in Slovakia since 1977 till 2010. Measurements of the ^{210}Pb concentration in moss samples collected over the territory of Slovakia showed that the median value exceed 2.3 times median value of ^{210}Pb obtained for Belarus moss. For that reason, the inhalation dose for man (from ^{210}Pb and ^{137}Cs) in Slovakia was shown to be more than twice as higher as in Belarus in spite of the initially very high ^{137}Cs exposure in the latter country.

PRECISE UCN SPECTROMETRY WITH FABRY-PERROT INTERFEROMETERS

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In the review report the results obtained by the methods of the precise UCN spectroscopy with neutron Fabry-Perrot interferometers will be presented.

Namely:

1. Development of the method (Gravity + Fabry-Perot intrferometry) 1996-98. The sensitivity to the small energy variation at the level of 10^{-11} eV.
2. Observation of the energy quantization at neutron diffraction by a moving matter (1999-2000).
3. Test of the neutron optics of highly absorbed matter. Transmission of the UCN through Gd samples with the cross-section up to 20 Mb (2000-2003).
4. First demonstration of neutron time focusing. (2002).
5. Test of the equivalence principle with UCN (2007).
6. Discovering of the accelerating medium effect (2005-2011).

The status of the new experiment for the test of the equivalence principle with UCN will be reported in separate reports

MEASUREMENT OF THE ^{241}Am(n,γ) CROSS SECTION AT THE n_TOF FACILITY AT CERN WITH C_6D_6 DETECTORS

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The interest for nuclear data in the actinide region is constantly renewed by the reactor physics community, both for generation IV reactor designs or transmutation studies. Indeed the NEA has placed several minor actinides, including ^{241}Am, on its High Priority Request List for cross section measurements. In this context, and as a part of the FP7-ANDES project, the (n,γ) reaction yield on ^{241}Am has been measured in 2010 at the n_TOF facility at CERN. The method used was time-of-flight (TOF) spectrometry, and two C_6D_6 scintillators were used for gamma-ray detection. This presentation will first detail the experimental setup at n_TOF, the TOF method and the C_6D_6 cascade efficiency, especially the use of pulse height weighting. The discussion will then focus on the background estimation as part of the calculation of the experimental capture yield. After having explained the issue of normalization, the R-matrix resonance analysis in the resolved resonance region (RRR) will be detailed, and will be compared with current evaluations. Significant improvement, mostly through the extension of the RRR from 150 eV to 300 eV is possible. Results of a statistical analysis of the newly obtained set of nuclear levels will also be given, notably for the average level spacing of s-waves resonances, D_0. Finally, the analysis will go up to the unresolved resonance region (URR), where the widths of the resonances are too large to be distinguished. An ensemble average of the R-matrix expressions based on the Gaussian Orthogonal Ensemble allows for a calculation of the average cross section in the URR, and will be presented.

PERSPECTIVES OF MOSS BIOMONITORING OF TRACE ELEMENTS AND RADIONUCLIDES IN RUSSIA

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The use of mosses as biomonitors of atmosphertic deposition of heavy metals and radionuclides in Russia started more than 30 years ago in connection with the development and problems of the nuclear and military-industrial complexes in Siberia and the Urals. In the 1990s, within the framework of UNECE ICP Vegetation programme, systematic studies using moss were carried out in north-western Russia (Karelia, Kola Peninsula, Kaliningrad, Pskov, and Leningrad regions), and the results were presented in the European Atlas *Atmospheric Heavy Metal Deposition in Europe – Estimations Based on Moss Analysis*. In 1998–2002, JINR participated in the IAEA-coordinated research project "Biomonitoring of air pollution in the Chelyabinsk region (South Ural Mountains, Russia) through trace elements and radionuclides" in one of the most contaminated areas of the world experiencing strong ecological stress from heavy metals and radionuclides. JINR took part in the 2000/2001 European moss survey reporting data on some areas of Central Russia (Tula, Yaroslavl, and Tver regions) and in the 2005/2006 moss survey in the north-east of the Moscow region and the Republic of Udmurtia. The active moss biomonitoring (moss bags technique) was used to study air pollution in street canyons of the intensely growing megapolice of Moscow. A combination of instrumental ENAA at the IBR-2 reactor at JINR, Dubna, and AAS at counterpart laboratories provides data on concentrations of about 40 chemical elements (**Al**, **As**, Au, Ba, Br, Ca, **Cd**, Ce, Cl, Co, **Cr**, Cs, **Cu**, Dy, Eu, **Fe**, Hf, **Hg**, I, In, La, Lu, Mg, Mn, Na, Nd, **Ni**, **Pb**, Rb, **Sb**, **S**, Sc, Se, Sm, Ta, Tb, Ti, Th, **V**, W, Yb, **Zn**), which substantially exceeds the requested by the European Atlas number of elements (given in bold) [1]. Distribution of the determined elements over the sampled areas is illustrated by the contour maps produced by the Russian software package GIS-INTEGRO with raster and vector graphics. The 2010/2011 moss survey extended study areas in Russia as PhD students, teachers and pupils of secondary schools in the Smolensk, Ivanovo, Kostroma, and Yekaterinburg regions, Stavropol area, and some districts of the Moscow and Leningrad regions were involved in terrestrial moss sampling. The moss technique is supposed to be used for assessing sequences of the Fukushima disaster in the Far East of Russia (mapping of radionuclide distribution around the city of Vladivostok). It is also planned to use moss as natural planchette for tracing deposition of cosmic dust in peat bog cores in Western Siberia and some mountainous areas of Russia.

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DETERMINATION OF A SCISSION NEUTRON YIELD IN ^{252}Cf SPONTANEOUS FISSION FROM THE EXPERIMENT ON MEASURING THE ANGULAR DEPENDENCE OF COINCIDENCES BETWEEN FISSION NEUTRONS

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Apart from the neutrons evaporated from accelerated and excited fission fragments (FFs), neutrons can also be emitted during descent to the scission point or at the moment of the nuclear neck rupture. Such Scission Neutrons (SNs) are an object of interest since many years, because their characteristics (yield, energy and angular distributions) are closely related with fission dynamics and their studying can give new information about the scission dynamics. In the work [1] the SN yields were estimated as ~5% for ^{252}Cf(sf) and ~20% for ^{235}U(n_{th},f) by extrapolating of the ternary particle yields systematic based on statistical approach. In the work [2] it was shown quantum-mechanically, that due to nonadiabatic change of the nuclear potential at scission up to 30% of the total number of neutrons can be emitted in ^{235}U(n_{th},f).

Generally speaking, the way to separate experimentally the SNs from "usual" neutrons, emitted by FFs, is the precise measurements of angular and energy correlations in the prompt neutron yields. The SNs manifest themselves as a deviation of the measured distributions from ones calculated in assumption that all neutrons are emitted from accelerated fragments. One can study the neutron angular distributions relative to the FF (the most of such experiments are analyzed in [3]), or can measure the angles between neutron directions in *n-n* coincidences [4, 5, 6]. Unfortunately, the experimental information is rather poor and inconsistent. The reported SNs yield values lie from 0 to 30% of the total neutron yield in ^{252}Cf(sf) and ^{235}U(n_{th},f). A review of experimental data on the SNs characteristics was given in [7].

In this work we performed precise measurements of the angular dependence of *n-n* coincidences rate in ^{252}Cf(sf). Evidently, that for to get the SNs parameters it is crucially important to obtain the experimental angular distributions free of systematical errors. The special attention in our work was paid to studying of the possible experimental effects which can distort the experimental distributions (neutron scattering in the construction of fission source and other surrounding materials, "cross-talks" between neutron detectors, etc.). It had been shown that possible corrections may be up to ~10%! The series of different control experiments together with their cross-check by Monte-Carlo simulations have allowed us to estimate the final uncertainty of our experimental *n-n* angular distribution as ~1%. Obtained experimental distributions turned to be definitely not consistent with ones calculated for hypothesis where all 100% of neutrons are emitted from accelerated fission fragments, but the distributions can be perfectly fitted if about 10% of the total amount of fission neutrons are supposed to be emitted isotropically in the laboratory system having Weisskopf energy spectra (T~1.0 MeV). These neutrons can be attributed as scission neutrons.

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COLLECTIVE STATES IN NUCLEAR LEVEL DENSITY WITHIN CLOSED-FORM METHODS

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The nuclear level densities in spherical and deformed atomic nuclei are studied using different semi-phenomenological approaches with allowance for quasiparticle and collective excitations [1-4]. Intrinsic quasiparticle component of nuclear level density is calculated within different variants of the generalized superfluid model and enhanced generalized superfluid model [1,2] An effect of collective states on the temperature of the intrinsic states is taken into account [3,4].

The ready-to-use table of the asymptotic values of level density parameter (a) and addition shift to excitation energy are prepared by fit of the experimental values of neutron resonance spacing and cumulative number of low-energy levels to theoretical quantities. The best expressions for enhancement factor of nuclear level density due to collective states are recommended.

An effect of collective state enhancement on gamma-ray spectra and cross sections of nuclear reactions induced by neutrons is investigated with the use of EMPIRE code [5] with modified level density subroutines.

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CONCENTRATION FACTOR (CF) OF THE ESSENTIAL ELEMENTS IN WOODY PLANTS

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Modern nuclear and relate analytical techniques allow determination of a wide range of elements in biological objects. This has an important implication for environmental studies, in particular, for biomonitoring of environmental contamination by heavy metals. Interpretation of the data is only possible when using standards (in the absence of MPC - «Reference plant»), or comparing with the background or using variables that determine the degree of accumulation of elements from the environment.

An objective criterion, which characterizes the efficiency of accumulation of chemical elements, is the factor of concentration factor (CF) or transfer factor (TF) (ratio of element content in the plant to it concentration in the soil).

As was shown in our previous studies, the biological accumulation CF (TF) of macronutrients by woody plants leaves from the soil is in the range 2–20 (Ca ≥K>Na). In conifers (*Larix sibirica*) it is lower than in the desiduous ones in 1.5-2 times (for monovalent ions) and in 2–5 times less in case of Ca. For trace elements CF (TF) is in the range of 0.01-0.8 and decreases as Zn>Cu>Mn>Fe. The analysis showed that for a number of elements which role in the plant is not established or poorly studied (Rb), as well as for heavy metals toxic for plants, the CF (TF) corresponds to transfer factor of trace elements: Cu ≥Rb; Cd, Ni, Sb, Pb ≈ Fe. This fact is important to further examine the role of these elements in living organisms and the mechanisms of their accumulation from the soil. For the elements Cr and Co CF is lower than for other elements and it is in the range of 0.002–0.02.

The calculation of this value at different elemental content in the environment allows revealing the toxic to plants concentrations, among them for the elements for which the MPC are not established. For a number of elements such as Mn, Co, Zn, As, La, Ce a sharp decrease in CF (TF) with increasing concentration of elements in the soil is observed. According to our calculations, one can conclude that the recommended concentration of Mn in the soil has to be below 1500 mg/kg, Zn<125, As<5, Cd<1, Co<28, La<40, and Ce <100 mg/kg.

In biomonitoring it is important to identify species-accumulators of elements that can be used for bioremediation of the environment. The value of CF (TF) greater than 1 indicates a high degree of accumulation of the element from the environment and determines the species-accumulators.

For example, for *Populus* leaves known as accumulator of heavy metals, the TF for Cd > 1 (1.6–2.6) and it is 5–15 times higher than for other species. However, under the increase of Cd content in the soil we observed decrease of TF in five time. The content of Zn in the *Populus*, was higher than its total content in the soil (CF (TF)=1-2).

The value of TF most fully reflects the specific absorption and transfer of elements from the soil and gives an indication of the presence in plants of barrier mechanisms in the absorption and transport of elements (reduction in TF with increasing concentration of the element in soil). The values of CF (TF) also may be a criterion for grading elements by category: essential, trace, or toxic.

CHOPPER-MODULATOR FOR UCN GRAVITATIONAL SPECTROMETER

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UCN gravitational spectrometer was constructed for new experimental test of the weak equivalence principal for the free neutron. The main idea of future experiment consists in using peculiar time-of-flight method. For this purpose the neutron flux will be modulated by the chopper-modulator and the detector will measure the corresponding count rate oscillation.

Spectrometer with chopper-modulator was tested at the PF2 UCN source in ILL(France). In this report some results of this test are presented. One of the main characteristics of a chopper-modulator is stability of modulation frequency, which was found at the level of 10^{-4}.

THE COMPARISON OF BINARY AND TERNARY FISSION CONFIGURATIONS CLOSE TO THE INSTANT OF SCISSION

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The shift of angular distribution for light charge particles was discovered in 2005 during a detailed investigation of ternary fission induced by slow polarized neutrons [1]. This phenomenon was connected with a rotation of dividing system before rupture and named as ROT-effect. Its quantitative estimation was done by modified trajectory calculations [2]. During this calculation was shown that the shift, which was observed through the neutron spin-flip, is the lag angle of alpha particle in comparison with the angle of fission axis deflection. Due to neutrons obtained spin polarization of compound nuclei determines direction of dividing system rotation and influences on its average velocity. The absolute value of effect depends also on inertia moment of fissioning system at the rupture point, it means on compound system deformation.

It was established tree years after by the group of Danilyan [3] and then in PNPI [4] that oriented rotation of fissioning system causes an analogical effect in gamma-quanta emission, too. This effect explanation in PNPI group was based on the idea of a conservation of primary fission fragment spin orientation and on gamma radiation anisotropy generated by this spin in the reference frame of fragment centre-of-mass. As a result of this experiment we have got the angle, which characterizes rotation of fission axis in binary fission and corresponding angular shift for gamma distribution. This angle has the same sign as the angle of axis deflection in ternary fission. Although its absolute value is not differ very much from analogical axis deflection in ternary fission, too, nevertheless it is necessary to point out that in such a way obtained angle for binary fission process is 1.7 times larger than for ternary fission. It can serve as a proof that close to the instant of scission compound system has more elongated configuration in binary fission than in ternary case. This result agrees with the conclusion in article [5] that the fragment deformation in ternary fission is considerably less than in binary fission.

So the exact correlation between two angles of fission axis rotation (in binary and ternary fission) can help to specificate these fission configurations.

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LOSSES AND PRODUCTION OF UCN IN CRYOGENIC CONVERTERS

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At time strong sources of ultra-cold neutrons (UCN), based on super - thermal conversion in cryogenic converters like solid deuterium or solid oxygen, are in the design phase, ore are even under construction. These UCN are very important for low energy particle physics experiments like the lifetime of the neutron or the possible determination of a finite electric dipole moment of the neutron.

Precise data for UCN production and loss cross sections of cryogenic converters are highly eligible. The talk will present new data for such cross-sections, deduced from neutrons scattering experiments with thermal and cold neutrons.

GAMMA-RAY OPTICS

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The PN3 facility at the neutron high-flux reactor of the Institut Laue-Langevin consist of an tangential through going beam tube equipped with an in-pile sample changer allowing to irradiate samples at a thermal neutron flux of 5×10^{14} neutrons per second and cm^2. At the two exits of the beam tube the facility is equipped with crystal spectrometers aiming to carry out ultra high resolution gamma ray spectroscopy. In a first part of the talk an overview on the functioning and specific properties of the instruments will be given.

The second and main part of the talk focuses on studies to develop gamma ray optics. These concepts, basing on refractive or diffractive scattering should allow to shape gamma ray beams in terms of beam divergence, spot size and monochromaticity. This might be particular important in combination with future highly brilliant gamma ray sources and might push the sensibility of planned experiments by several orders of magnitude.

Using diffraction we will demonstrate the experimental feasibility of gamma ray monochromatisation on a ppm level and the creation of a gamma ray beam with nanoradian divergence. Since the refractive index is believed to vanish to zero with $1/E^2$ the concept of refractive optics has never been considered for gamma rays. The combination of refractive optics with monochromator crystals is proposed to be a promising design. Using our crystal spectrometers we have measured for the first time the refractive index at energies in the energy range of 180 – 2000 keV. The results indicate a deviation from simple $1/E^2$ extrapolation of X-ray results towards higher energies. A first interpretation of these new results will be presented. We will discuss the consequences of these results on the construction of refractive optics such as lenses or refracting prisms for gamma rays and their combination with single crystal monochromators.

THE MOST PROBABLE MEAN VALUES OF LEVEL DENSITY AND RADIATIVE STRENGTH FUNCTIONS OF ^{28}Al COMPOUND-STATE CASCADE GAMMA-DECAY

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In this work the spectrum of random functions of level density and radiative strength functions of dipole E1- and M1-transitions was determined. Obtained functions reproduce with high precision the intensity of two-step cascades following radiative capture of thermal neutrons in ^{27}Al for given energy of primary transitions. The mean value of these functions for level density correctly enough reproduces density of intermediate levels corresponding to the observed energetically resolved cascades (including those firstly established in reaction $(n_{th},2\gamma)$). This fact gives the grounds to consider that the hypothesis on dependence of radiative strength functions of gamma-transitions in heated nucleus on density of excited levels (with the use practically realized up to now method of determination of cascade gamma-decay parameters) allows one to get their realistic estimation in any (including light) nuclei.

Neutron lifetime measurement with a pulsed neutron beam at J-PARC

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Precise neutron lifetime measurement is underway at J-PARC in Japan. A time projection chamber (TPC) was developed and installed in BL05, the NOP beamline at the pulsed spallation neutron source of J-PARC to detect electrons from the neutron decay in flight. The instantaneous peak neutron intensity from the J-PARC neutron source is more than 10 times higher than the ILL cold source. Taking this advantage of the peak intensity, the neutron beam is chopped into short bunches by the spin flip chopper to minimize gamma-ray background produced at the windows of the TPC vessel as well as to define the time and position of each neutron bunch. Small portion of ^{3}He is mixed in the TPC gas to monitor the neutron beam intensity by tagging the neutron capture events of ^{3}He nuclei. It also unambiguously defines the neutron decay volume or the fiducial area of the TPC. Our apparatus is essentially a reproduction of the neutron lifetime measurement by Kossakowski *et. al.* [1] with recent advanced technologies – a high intensity neutron source, high-tech data acquisition electronics, precise computer simulation, etc.

After the disasterous earthquake hit northeastern Japan in March, last year, J-PARC had been shut down for almost one year. However, we had enough time to study basic performances of the TPC as well as to develop sophisticated analysis methods to minimize systematic uncertainties in the measurement.

After hard and difficult recovering works, J-PARC recovered its normal operation in January, this year, and our experiment also restarted at the same time. The commissioning of the TPC system is on going as of early March, and we hope to present a preliminary result at the ISINN-20 seminar.

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THE TRITIUM PRODUCTION CROSS SECTION FOR NEUTRON INTERACTION WITH ^{10}B NUCLEI

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Tritium production reactions are important for the safe service of nuclear power plant. The ^{10}B isotope is widely used in practice both for power management of nuclear reactor and for building of shielding for thermal neutrons. $^{10}B(n,\alpha t)^{4}He$ reaction is the main reaction in tritium production. This kind of reactions in which formed more than two reaction products are very difficult for experimental researching with classical methods where solid target is used. The method developed in the IPPE uses gaseous target and allows to absorb energy of all charged reaction products and to select useful events from background. Ionization chamber was filled by the gas mixture of 95%Kr+5%BF3. Boron atoms in working gas was a target for investigating reaction. $^{10}B(n,\alpha t)^{4}He$ reaction was measured in 4 to 7 MeV neutron energy region. The received data are lower than ENDF B VII and JENDL 4 estimation. Some structure in the excitation function of the reaction is similar to the structure in Bonner's work, and it is not described by existing estimations.

CROSS SECTIONS OF (n,p), (n,α), (n,2n) REACTIONS ON ISOTOPES OF Dy, Er, Yb AT E_n= 14.6 MEV

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The cross sections of the neutron reactions at E_n= 14.6 MeV on the isotopes of Dy, Er, Yb with emission of neutrons, proton and alpha-particle were studied by the use of new experimental data and different theoretical approaches.

New and improved experimental data were obtained by the neutron-activation technique [1,2]. The samples of natural composition of corresponding elements were irradiated by d-t neutrons from neutron generator NG-300. Gamma-ray spectra of the induced activities in samples were measured with HPGe detectors. The uncertainties of the experimental cross sections were estimated.

Present experimental results and evaluated nuclear data from EXFOR, TENDL, ENDF data libraries were compared with different systematics and calculations within codes of EMPIRE 3.0 and TALYS 1.2 [3,4]. Contribution of pre-equilibrium decay was studied. It was demonstrated, that the calculations within EMPIRE code are most closely agree with experimental data.

The recommendations on validity of different systematics for estimations of cross-sections of considered reactions are given.

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SUMMARY OF EXPERIMENTAL RESULTS ON COLLINEAR CLUSTER TRI-PARTITION STUDIES

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In series of experiments at different time-of-flight spectrometers we have observed multiple manifestations of a new type of multibody decay of low excited heavy nuclei called by us collinear cluster tri-partition (CCT) [1, 2].

The background produced by the scattered fragments of binary fission is the main factor giving rise to an imitation of ternary events. In order to distinguish ternary events from the background ones we use different selections sensitive to the CCT events.

In our works [2, 3] the CCT events were selected with a help of the experimental observables sensitive to the fission fragment nuclear charge.

Selection of the events showing increased experimental neutron multiplicity proved to be very effective way to reveal the CCT events. A special design of the mosaic neutron detector used delivers preferential registration of the neutrons emitted from the isotropic source. Regular nonrandom structures observed in the mass-mass correlation plots for the neutron gated data in the region of a meaningful missing mass are treated as the manifestations of at least ternary decays. The structures are bounded by magic nuclei. Such feature is hardly to be supposed for the events linked with scattering.

Detailed comparison of different manifestations of the CCT process obtained so far will be presented.

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A New Spallation Ultracold Neutron Source at RCNP

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Ultracold neutrons (UCN) are used for many experiments like as a neutron electric dipole moment search, a neutron lifetime measurement, a gravity experiment and so on. A high density UCN source is required by such experiments.

A new spallation UCN source has been developing at RCNP, Osaka University. Superfluid helium is used for a UCN converter in our source. Superfluid helium and solid deuterium are usually used for production of UCN. An advantage of solid deuterium is large production rate. On the other hand, the superfluid helium has long neutron's storage time. Since ^{4}He do not absorb neutrons, storage life time depends on phonon upscattering rate. It depends on superfluid helium temperature. The storage time in superfluid helium is 36s at 1.2K and 600s at 0.8K. It is important to keep helium temperature below 1K. If helium temperature keeps below 1K, the large UCN production volume can be achieved.

In our source, the superfluid helium is surrounded by liquid and solid D_2O moderators. These are located just above a spallation target. Spallation neutrons are firstly moderated in D_2O, and then transfer their energy to phonon of superfluid helium. Since distance between the spallation target and the superfluid helium is close, UCN are produced effectively in this layout.

First UCN were produced at RCNP at 2002. At that time, UCN density was 0.7UCN/cm^3. Improving superfluid helium temperature, cleaning of inner wall of helium container, ^{3}He contamination and so on, 26 UCN/cm^3 were available in 2011. Since UCN were extracted vertically from superfluid helium, maximum energy of the UCN was about 90neV in this source.

A new source has been developed at RCNP. A main improvement is horizontal extraction of UCN. All UCN can be extracted from superfluid helium in spite of their energy. Layout of the D_2O moderator and the spallation target is also optimized. In addition, the volume of the superfluid helium is increased. With these improvements, the UCN density will be five times as much as the former UCN source.

The installation of the new UCN source has almost finished. UCN will be produced soon.

Time Spectra in Radiative Neutron Decay

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The main methodology for experimental detection of the key characteristic of radiative neutron decay, namely its relative intensity (branching ratio - B.R.) is the measurement of time spectra. To obtain the number of ordinary neutron decay events for electron, recoil proton and antineutrino, it is necessary to study the spectrum of electron and recoil proton double coincidences, and to obtain the number of triple coincidences, it is necessary to research the spectrum of triple coincidences of electron, proton, and radiative gamma quantum. The report covers time spectra of double and triple coincidences obtained in our research, where we succeeded in discovering events of radiative neutron decay and measure its relative intensity B.R.=$(3.2\pm1.6)10^{-3}$ (with C.L.=99.7% and gamma quantum energy in excess of 35 kev) [1]. The spectrum of double coincidences measured by our team corresponds in all of its characteristics to an analogous spectrum obtained by the emiT group, studying the ordinary beta decay of neutron [2]. Unfortunately, the same cannot be said for the results of the measurements conducted at NIST [3-4]. Their spectra are in sharp contradiction to both the emiT group and our measurements. Analysis of the spectra demonstrates that the cause of this radical difference lies in the NIST experiment's reliance on strong magnetic fields of several tesla. The report proves that the use of strong magnetic fields not only disallows the detection of the radiative peak on the spectra of triple coincidences, but also makes it impossible to identify events of ordinary neutron decay in the spectrum of double coincidences. Moreover, the report demonstrates that to accurately identify the number of radiative events in the spectrum of triple coincidences one must use the method of non-local response function [1].

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RECENT INVESTIGATION OF (n, alpha) REACTION CROSS SECTION FOR CHROMIUM ISOTOPES

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The (n,α) reaction cross section of chromium isotopes has significant role in radiation resistance of stainless steel, which is wildly used in nuclear reactor industry. In EXFOR there is only limited number of experimental data for this reaction and mainly they take place at 14 MeV. The experimental data for (n,α) reaction probability in fission neutron energy range are almost absent. In this work results for ^{50}Cr(n,α) and ^{52}Cr(n,α) reaction excitation function investigations are presented. It was shown that ENDF B VII library for ^{50}Cr(n,α) reaction has estimation, which is more then 20 times higher then result of our measurement. Furthermore, we observe irregularity in energy dependence of ^{50}Cr(n,α) cross section which not predicted by any library. The experimental data for ^{52}Cr(n,α) reaction in reactor neutron energy region was obtained for first time.

SYSTEMATICAL ANALYSIS OF (n,α) REACTION CROSS SECTIONS FOR 6-20 MeV NEUTRONS

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Neutron-nuclear data evaluation analysis is an important subject of the contemporary neutron physics study. Specifically, it is often necessary in practice to evaluate the neutron cross sections of the nuclides for which no experimental data are available. On the other hand, systematical analysis of fast neutron induced (n,α) reaction cross sections is useful to evaluate helium production, nuclear heating and transmutations in the structural materials of fusion and fission reactors. In addition, the nuclear reaction model analysis of the fast neutron induced reaction cross sections is of interest for understanding of nuclear reaction mechanisms.

Because of this, in last years systematic analysis of the fast neutron induced (n,α) reaction cross sections in the wide energy interval of neutrons and for the broad mass range of target nuclei was carried out at the Nuclear Research Center, National University of Mongolia. As results of these studies we observed so-called isotopic effect in the energy range of 8 to 16 MeV [1]. To explain the systematic regularity of known experimental (n,α) cross sections we deduced some formulae using the compound mechanism [2]. In the framework of the statistical model, the evaporation model and the constant nuclear temperature approximation were used.

In this work a systematical analysis of the (n,α) cross sections at the energy range of 6 to 20 MeV was performed using the statistical model formulae. The alpha-particle clusterization factor was obtained from the comparison of experimental and theoretical (n,α) cross sections. It was shown that the clusterization factor depends on neutron energy.

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POSSIBILITIES OF THE NEUTRON AND SYNCHROTRON RADIATION FOR THE CHARACTERIZATION OF THE LIPID NANOSYSTEMS

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Lipids are important components of biological membranes and essential components of vesicular and liposome drug carriers. Different methods of lipid structural investigations are presented for the solving of modern problems of cryobiology, membrane biophysics, dermapharmacology, and nanodiagnostic of drugs and drug carriers:

- Method of lamellar and lateral synchrotron X-ray diffraction in real time for the cryoprotector characterization
- Method of neutron diffraction for study of model stratum corneum membranes
- Method of separated form factors for characterization of vesicular nanodrugs
- Method of contrast variation of X-ray scattering by disaccharides.

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COMETA SPECTROMETER FOR STUDYING OF MULTI-BODY DECAYS OF HEAVY NUCLEI

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In our previous experiments [1, 2] we have observed multiple manifestations of new ternary decay of low and middle excited heavy nuclei called "collinear cluster tri-partition" (CCT) due to the features of the process observed. From the methodical point of view the most important peculiarity of the process is that at least two CCT partners fly in the same direction with angular divergence of about 1^0. Direct detection of all the resultant fragments needs a high granularity setup capable to measure all masses independently what means using of so called TOF-E (time-of-flight vs. energy) method. In order to increase reliability of selecting of the CCT events additional identification parameter based on their experimental neutron multiplicity was introduced as well in COMETA (Correlation Mosaic E-T Array) setup (fig. 1) put into operation at the Flerov Laboratory of the JINR.

COMETA is double arm time-of-flight spectrometer which includes micro-channel plate (MCP) based "start" detector with the ^{252}Cf source inside, two mosaics of eight PIN diodes each and a "neutron belt" comprises 28 ^{3}He filled neutron counters. The geometry of the belt provides preferential detection of the neutrons emitted isotropically. According to modeling and previous experiments, the detection efficiency is estimated to be ~5% and ~12% for the neutrons emitted in binary fission and from an isotropic source, respectively.

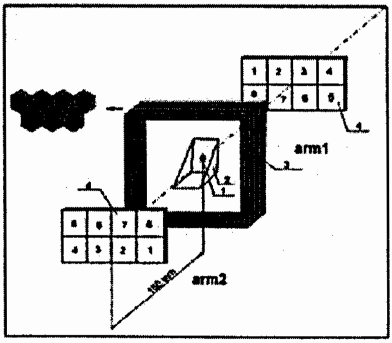

Fig. 1. Scheme of the COMETA setup which consists of two mosaics of eight PIN diodes each (4), MCP based start detector (2) with the ^{252}Cf source inside (1) and a "neutron belt" (3) consisting of 28 ^{3}He-filled neutron counters in moderator. The section of the belt is marked by the arrow.

The TOF-E calibration and the calculation of the M_{TE} masses presented in [3] were used. In brief, the mass spectrum of binary decays, which depends on the measured variables and parameters for describing of pulse height defect, was forced to fit the known mass spectrum of ^{252}Cf fission.

Other parameters of the spectrometer as well as the examples of the results obtained are discussed in the report.

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Neutron Data Activity in INRNE, Sofia

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The activity on Neutron Data in INRNE, Sofia is related to investigations of neutron induced cross-sections in the resonance region (resolved and unresolved resonances). This includes both experimental measurements (neutron cross sections, transmission and self-indication functions) with subsequent evaluations of resonance parameters for the nucleus in investigation.

The experiments have been performed at the Frank Neutron Physics Laboratory of Joint Institute for Nuclear Research (JINR), in Dubna, Russia [1,2] and at the Institute for Reference Materials and Measurements (IRMM , Geel, Belgium) [3] of the European Commission Joint Research Centre. Formerly neutron measurements with Hafnium (Hf) enriched isotopes have been performed in thermal energy region with the scintillation spectrometer "ROMASHKA", that was situated on the research reactor IRT-2000 (2 MW) in Sofia [4]. "ROMASHKA" is now placing on a channel of the new neutron source of resonance neutrons IREN in JINR, Dubna .

Efforts were aimed on improvement of the theoretical methods for evaluation of modern high accuracy neutron resonance data and also in their practical application. In the Resolved Resonance Region this concerns the correct identification of level positions and cross sections in the resonance minima, that improves the accuracy of the resonance parameters and gives a useful information about the phases of s-wave potential scattering at corresponding energies and contribution of p-wave in the cross section as well [5].

A physical accurate algorithm for calculation of resonance average cross sections and their functional is of practical interest in the URR. Recently, a new statistical model based on Wigner's *R*-matrix theory has been developed and applied for analysis of experimental data in the URR [6]. The resonance cross section structure is modulated as a periodical structure through a ladder of 'mock-up' *R*-matrix resonances, which are periodically reiterated on the energy scale. For non-fissile nuclei and under the threshold of inelastic scattering, this method exploits the characteristic function of the *R*-matrix elements' distribution. The main advantage of the model, in relation to the existing schemes in the URR, is the capability for *accounting of the resonance effects in a real reactor medium that differ from the common standard procedures used in the URR.* A scheme for accounting of the self-shielding and multiple scattering corrections in measured neutron absorption yield was proposed in the region of unresolved resonances.

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A highly sensitive ^{3}He-Magnetometer for the future n2EDM-Experiment

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The measurement of the electric dipole moment of the free neutron is directly linked to the question on the accurate determination of the magnetic field conditions inside the EDM spectrometer. Using in-situ the spin-precession of polarized ^{3}He monitored by optically pumped Cs-magnetometers a sensitivity on the ft Tesla - scale can be obtained.

At the institute of physics of the Mainz university a ^{3}He/Cs-test facility was built to investigate the readout of ^{3}He-spin-precession with a lamp-pumped Cs-magnetometer.

Additionally, an ultra-compact and transportable polarizer unit was developed and installed in Mainz, which polarizes ^{3}He gas up to 55% of polarization before the compressed gas is delivered to two sandwich magnetometer cells inside the EDM chamber.

This talk will present some results of the first successful test of the polarizer unit in January 2012. ^{3}He was polarized in the ultra compact polarizer unit and transferred via guiding fields into a 4 layer mu-metal shield, where the free spin precession was detected with a lamp pumped Cs magnetometer.

AQUATIC ORGANISMS USED TO STUDY MARINE POLLUTION. ROLE OF NUCLEAR AND RELATED ANALYTICAL TECHNIQUES

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It is commonly known, that aquatic ecosystems are the most exposed to contamination including heavy metals (HM) pollution within the other biosphere components. Therefore, the assessment of their contamination is an important scientific and applied task. Biomonitoring based on the ability of organisms to accumulate a substance defined makes it possible to obtain an integrated assessment of the level of pollution. Many aquatic species, their tissues and organs, especially those ones of the fish, are used as indicators of HM pollution, but still the common methodological principles of their choice are absent and the mechanisms of accumulation and the species adaptation to high concentrations of metals are not studied enough. Although it is more accepted to use mollusks as biomonitors, it is believed that macroalgae are more preferable ones, because reflect the environmental pollution with HM in a most adequate way, as well as adapt to a wide range of their concentrations. In recent years at many regions of the World Ocean, including the Black Sea, macroalgae and such methods as atomic absorption spectroscopy, X-ray fluorescence and neutron activation analysis (NAA) are used for HM pollution assessment. At the same time the advantages of a highly sensitive multi-element NAA were shown (Joron et al., 1997; Roelandts, 2000; Frontasyeva, 2011) when the analysis of a large number of samples is needed. Application of NAA for the monitoring purposes (up to 40–45 elements) using macroalgae as biomonitors will allow assessing the level of pollution of the Black Sea coastal waters, including those with high protectoral and recreational value, to develop recommendations on the level of anthropogenic load. Such problems will be considered in the framework of the joint project of the Institute of Biology of the Southern Seas in Sevastopol and the Sector of Neutron Activation Analysis and Applied Research of the Division of Nuclear Physics of the Frank Laboratory of Neutron Physics of the Joint Institute for Nuclear Research *"Use of macroalgae and nuclear-physical analytical techniques to assess the pollution of coastal waters with heavy metals on the example of Russian and Ukrainian Black Sea shelf"*.

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New UCN Experiment for Test of the Equivalence Principle for Free Neutron

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The main idea of the experiment is to compensate the change in the energy of the ultracold neutrons falling in the Earth's gravitational field (mgH) by the energy ($h\Omega$) transferred to the neutron due to nonstationary interaction with a moving phase grating. The controlled variation of the neutron energy in this experiment will be measured by a peculiar time-of-flight method. For this purpose the neutron flux will be modulated by a chopper and the detector will measure the corresponding oscillation of the count rate. The count rate oscillation phase $\Phi = 2\pi F\tau$, where F is the frequency of the chopper, is proportional to the time of flight τ. For this experiment a new spectrometer with neutron interference filters (NIF) has been built.

In 2011 main phases of the planned experiment were tested. Details of these tests are reported.

The main results of these test experiments are the following. New UCN spectrometer was built and successfully tested in both modes which would be used in gravity experiment for test the validity of the equivalence principle. With the present installation the intensity of the PF2 UCN sources is not enough to perform experiment with planned accuracy. To rich necessary sensitivity it is necessary to slightly modify spectrometer and use new Farbry-Perrot monochromator and diffraction grating.

MEASUREMENT OF NEUTRON ELECTRIC CHARGE BY THE SPIN INTERFEROMETRY TECHNIQUE

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New experiment for checking neutron electroneutrality is proposed. The main idea of this experiment is to use the spin interferometry technique. Such technique is used in SESANS (Spin Echo Small Angle Neutron Scattering) installations for condense matter investigations.

There is a spatial splitting of neutron on two eigenstates with different projection of spin on magnetic field. After passing through the working area these two eigenstates are reduced back. So, the phase of the interference pattern, i.e. azimuthal spin direction, is defined by phase difference of two neutron eigenstates, accumulated in working area. If such system is placed into uniform electric field **E**, then two neutron eigenstates, due to their spatial splitting, will be under different electric potentials. With presence of electric charge of neutron $\mathbf{q_n}$ it will give the energy splitting $\mathbf{\Delta E_e = q_n E \Delta z}$ and, respectively, will give additional phase shift $\mathbf{\Delta\varphi_e = \Delta E_e \tau/\hbar}$, where $\mathbf{\Delta z}$ – value of spatial splitting, $\boldsymbol{\tau}$ – time of staying of the neutron in electric field. So, one can see that such system is sensitive to neutron electric charge.

Preliminary estimations show the using of technique mentioned above can improve the recent restriction on neutron electric charge on two order of magnitude as minimum and it can reach the value better than $\mathbf{\sigma(q_n) \sim 10^{-23} e}$.

Study of the effects of parity violation in neutron diffraction in perfect single crystal

V.L. Kuznetsov, E.V. Kuznetsova

The investigation of the effects of parity violation in neutron diffraction in perfect single crystal of KBr is perfomed. The possibility of enhancing the effects of spatial parity violation in neutron diffraction, as in the reflected and transmitted neutron beam diffraction is shown. The calculation results agree well with the theoretical estimate [1-3], despite the weaker demand for neutron beam divergence. The obtained results allow us to perform a correct planning of the experiment and to create a fundamentally new method (diffraction-compensating) to search for the effects of spatial parity violation in neutron diffraction. Sensitivity of the set up according to the results of calculations increases by 5.6 times. The influence of the angular divergence of the neutron beam on the magnitude of the parity violation in neutron diffraction is investigated. On the basis of the research presented to the setup project to search for spatial parity violation in neutron diffraction by diffraction-compensation method. It is shown that in this case the parasitic effects connected with the parity violation dichroism in the total cross section is suppressed, at about 800 times.

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Investigation of the Possibilities for Measurement of the Parity Violation in Neutron Diffraction at IBR-2M

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As it was shown in works [1-4] the effects of parity violation can increase significantly in case of dynamical Laue diffraction of neutrons.

During a power cycle of two days the testing a prototype of installation for the search of parity violation in neutron diffraction (PVND) was carried out. The experiment was performed at a 30-meter time of flight path of the channel N1 of IBR-2 reactor. The neutron beam parameters were determined by fission chamber. In the region of p-resonance of ^{81}Br a neutron flux was $\sim 4 \cdot 10^4$ n/(cm$^2 \cdot$sec$\cdot$eV). As a neutron detector four neutron counters SNM-17 were used. The detection efficiency of neutrons with energy 0,8 eV was ~ 0,3. A KBr perfect single crystal with a thickness of 1 cm was used as a sample. We changed the thickness of the crystal rotating it around an axis which was a perpendicular to the (200) lattice plane of reflection. The integral intensity of reflection was measured for three thicknesses of crystal. An indication to the pendellosung effect was observed, that is evidence of a good quality of the potassium bromide single crystal as well as the low divergence of neutron beam [5,6]. Using these results we have estimated the time for detecting the effect of parity violation in the neutron diffraction with the statistical accuracy of 10^{-4}. This time is about 30 days.

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THE TEMPERATURE DEPENDENCE OF THE UCN "SMALL HEATING" PROBABILITY AND THE SPECTRUM OF UCN UP-SCATTERED ON A SURFACE OF FOMBLINE Y-HVAC 18/8 OIL

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We investigated quasi-elastic scattering of UCN ("small heating" of UCN) in the specialized Big Gravitational Spectrometer (BGS) [1] at ILL. This study had been motivated by the recent observation that the hypothesis on levitating nanoparticles [2] agrees well with existing experimental results for solid surfaces and nanoparticles. To explore validity of this hypothesis for UCN small heating on liquid surfaces we performed dedicated measurements using hydrogen-free oil "Fomblin Y-HVAC 18/8". The probability of UCN small heating, its temperature dependence and spectra of up-scattered neutrons are measured with high accuracy.

The spectra obtained for Fomblin look exactly like the spectra measured for solid surfaces and for nanoparticles, also like the theoretical predictions within the hypothesis on levitating nanoparticles. The probability temperature dependence is analogous to the results of work [3] in spite of the fact that another part of the up-scattered neutron spectrum was measured. This similarity indicates that the spectra shape depends weakly on temperature.

We know only one sufficiently developed reasonable alternative to explain the small heating of UCN at liquid surfaces: scattering of UCN on the surface capillary waves [4]. Our measured temperature dependence is opposite to the dependence calculated in [4]. This result indicates that the hypothesis [4] does not explain the experimental data for UCN small heating on Fomblin surfaces. The last statement contradicts to the conclusion in ref. [3].

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CONCENTRATION OF ELEMENTS IN TEETH OF ROE DEER (Capreolus capreolus L.) AND MOSSES IN SLOVAK INDUSTRIAL POLLUTED SITES

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Abstract
Element analysis in roe deer teeth from the 3 polluted sites and control locality Podlavice-NAPANT are discussed in a context of their values. We found the highest concentration in the roe deer teeth: As, Ba, Br, Cl and Na in Žiar nad Hronom (aluminium plant); Cd, Cu, Hg and Zn in area Spiš (iron ore and mercury plant); Al, Ca, Co, Fe, Mg, Mn, Pb, Rb, Sb and Sr in Orava (smelter complex from Czech republic). There is statistically significant difference between the concentration of of As, Cd, Co, Cu, Hg, Na, Pb, Rb, Sr and Zn in roe deer teeth from the sites Orava, Žiar, Spiš and control locality NAPANT. Results are compared with European bryophyte analyses. The obtained data can be useful as a reference level for comparison with the future measurements of air pollution in the examined area, whenever a hazard due to accumulation of heavy metals along the food chain is assessed.

Keywords: Roe deer teeth; Heavy metals; Bioindication

MOSS BIOMONITORING IN SLOVAKIA: PAST, PRESENT AND FUTURE

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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 dyinig in Slovakia.1990s, within the framework of UNECE ICP Vegetation programme, systematic studies using moss were carried on in Slovakia (net 16x16 km), and the results were presented in the European Atlas *Atmospheric Heavy Metal Deposition in Europe – Estimations Based on Moss Analysis*. It is assumed that in the 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 recognise the distribution of element deposition in the SK, the moss monitoring technique, also known as bryomonitoring, was applied to the whole territory in 1990, 1995, 1996, 1997, 2000,and 2005 (Maňkovská et al, 2008, Schröder, et al.,2008).

The moss samples of *Hylocomium splendens, Pleurozium schreberi* and *Dicranum* sp. were collected in the Slovakia. Separate we are evaluated in National parks, in Landscape protection area and industrial area. In comparison to the median northern Norway values of heavy metal contents in moss the Slovak atmospheric deposition loads of the elements were found to be the survey has been repeated and in this paper we report on the temporal trends in the concentration of Cd, Cr, Cu, Fe, Hg, Ni, Pb, V and Zn between 1990 and 2005. Metal- and sites -specific temporal trends were observed. In general, the concentration of Cd, Cr, Cu, Fe, Hg, Ni, Pb, V and Zn in mosses decreased between 1990 and 2005; the decline was higher for Pb than Cd. The observed temporal trends for the concentrations in mosses were similar to the trends reported for the modelled total deposition of cadmium, lead and mercury in Europe. The level of elements determined in bryophytes reflects the relative atmospheric deposition loads of the elements at the investigated sites. Factor analysis was applied to determine possible sources of trace element deposition in the Slovakian moss. In the industrial area of Central Spiš we found in comparison with Norwegian limit values (Central Norway- as relatively the cleanest region) exceeded levels for Al, As, Ca, Cd, Cl, Co, Fe, K, Mn, Sb, Sm, Sr, W and Zn.

Keywords: air pollution, bryomonitoring, Heavy metals;

Maňkovská, B., Oszlányi, J., Barančok, P. 2008: Measurement of the atmosphere loading of the Slovak Carpathians using bryophyte technique. Ekology (Bratislava), 7 (4): 339-350.
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FINE STRUCTURES OF THE NEUTRON EMISSION FUNCTION: POST-SCISSION THEORY

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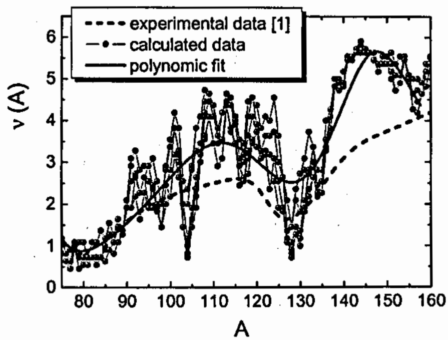
The results of the neutron fission characteristics investigation within the new statistical approach (color statistics) are presented. The subject of the studies is not the pre- or scission, but the post-scission state of the final nuclear fragments ensemble and fission neutrons. This method allows to use statistical thermodynamic methods to investigate the ordering of the nuclear fission fragments. Since the theory takes into account the presence of neutron fission in the two-fragment fission scheme, it is possible to calculate the number of equilibrium neutron as a function of the initial fragment mass $\nu(A)$ and the total neutron multiplicity $\bar{n}$.
The method of the $\nu(A)$ calculation is based on determining the probability of realization (yield) of the fission preneutron fragment, A_i, $F(A_i)$, and the equilibrium number of neutrons n. The total number of neutrons emitted in the act of nucleus fission $\bar{n}$ is calculated in a following way (normalization to 200% is used), $\bar{n} = 1/200 \sum_{A_i=1}^{A_i=A_0} \nu(A_i)F(A_i)$. In Figure, the calculated and experimental [1] neutron emission functions for fission fragments of ^{236}U are shown.



As one can see, the proposed method allows one to obtain the fine structure of $\nu(A)$, like local minima at 93, 101, 107, 119, 121, 125, 133, 155 and local maxima at 92, 104, 116, 118, 128, 136, 156. The reasons for such fine structure as the presence of light and heavy fragments with the magic and near-magic numbers in the post-fission cluster, the optimal proton/neutron ratio in the fragments or by the influence of the odd/even effects, etc are discussed.

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A new EDM measurement with a new generation UCN source

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The neutron electric dipole moment (EDM) is a clue to understand baryogenesis in the universe. The standard model of particle physics predicts far smaller baryon asymmetries than observed. We need new physics, such as supersymmetric theory (SUSY). SUSY as well as multi Higgs model and left-right-symmetric model predicts a neutron EDM of 10^{-26} to 10^{-27} $e\cdot$cm, although the standard model predicts an extremely small neutron EDM. The last EDM measurement at Grenoble, which is presently the most precise measurement, provides the upper limit of 3×10^{-26} $e\cdot$cm. The precision is limited by ultracold neutron (UCN) density. The systematic error is dominated by a geometric phase effect (GPE) of the order of 10^{-26} $e\cdot$cm for a magnetometer, which is a key element for compensating magnetic field drift. Here, we discuss a new neutron EDM measurement of 10^{-28} $e\cdot$cm [Phys. Lett. A (2012) in press]. For the improvement of the UCN density, we apply a new spallation UCN source of superfluid helium [Phys. Rev. Lett. (2012) in press]. For magnetometry, ^{129}Xe nuclear spins are injected into a cylindrical cell, where a cylindrically symmetric magnetic field and an electric field are applied for the EDM measurement. The GPE arises from particle motion in a magnetic field gradient. The motion of the ^{129}Xe atom is largely suppressed because of a short mean free path for interatomic collisions. The field gradient is precisely controlled by means of a neutron to ^{129}Xe NMR frequency ratio without the Earth's rotation effect. We also discuss the development of the Ramsey resonance for the EDM measurement by using the present UCN source.

SPECTROMETRY AND MONITORING OF FAST NEUTRON FLUXES: THE FACILITIES AND TECHNIQUES OF THE INR RAS

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The unique spectrometers and monitors of fast neutrons ($E_n > 1$ MeV) developed at the INR and providing one with an ability to make measurements in a wide range of fluxes are rewieved. First, the low-background spectrometer of fast neutrons based on combination of organic liquid scintillator and ^{3}He counters is able to measure a flux down to 10^{-7} s^{-1} cm^{-2} with pulse height resolution of ~60% at 14 MeV. Second, the sectioned fast neutron spectrometer based again on organic scintillator provides one with ~30% of PHR at 14 MeV in the flux range of 10^{1}—10^{4} s^{-1} cm^{-2}. Next, the device detecting ^{37}Ar online in flow from the $^{40}Ca(n,p)^{37}Ar$ reaction is able to monitor neutrons with the energy above 2.5 MeV in the flux range of 10^{8}—10^{16} s^{-1} cm^{-2}. Another one, the threshold integral detector based on $^{40}Ca(n,p)^{37}Ar$ reaction has a high resistance in the fluence range of 10^{6}—10^{14} neutron cm^{-2}. In addition, the low-background fast neutron detector (again based on $^{40}Ca(n,p)^{37}Ar$, 200 kg of CaC_2O_4) is sensitive to flux of 10^{-6} s^{-1} cm^{-2} above 2.5 MэB.

Computing Investigations of the Neutron Producing Target for Electron Accelerator

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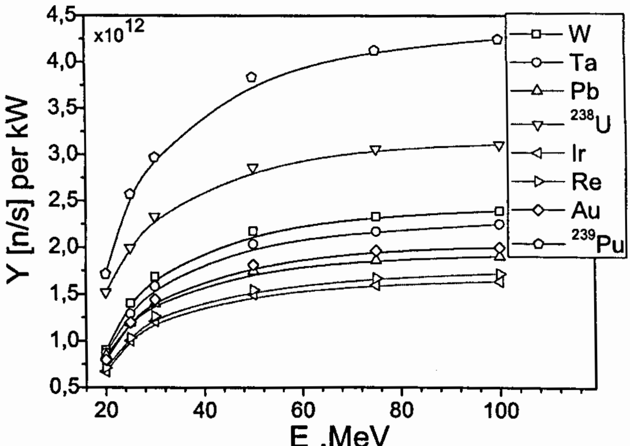
Using FLUKA code investigations of neutron yields under irradiation of tungsten target by the accelerated electrons were carried out. An influence of beryllium around the target on integral neutron intensity was also considered. The obtained results show that the neutron yield augmentation stops at 30 – 50 MeV electron energy if a thickness of W target is more than 4 cm. The beryllium block located around the target can give an increase of neutron yield from 5% up to 40% when electron energy is reduced from 50 MeV to 20 MeV. The results for W-target are compared with EKON-experiment data obtained earlier on IBR-30 booster. Neutron yields comparison for different target materials was also presented. Usage of U-238 or combined W-Pu targets is proposed for consideration as an alternative to application of the second section of linac at IREN-neutron source.



Calculations of the neutron yields (per 1 kW of beam power per second) depending on electron energy for different heavy targets.

FLEXIBLE POLYVINYL CHLORIDE TUBES TO TRANSPORT LOW ENERGY NEUTRONS AND SOME POSSIBILITIES OF ITS EMPLOYMENT

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The experimental results on transportation of ultracold (UCN) and cold neutrons by flexible polyvinyl chloride tubes are presented. Dependence of its transmission coefficient on a tube length and curvature of tube turns were investigated. It was discussed the application possibilities of these tubes for construction of portable and tiny sources of UCN and gamma rays.

QUANTUM LEVITATION OF NANOPARTICLES SEEN WITH ULTRACOLD NEUTRONS

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Physical adsorption of atoms, molecules and clusters on surfaces plays a key role in various phenomena in physics, chemistry, biology, in applications [1-4]. Here we show that physical adsorption of larger objects: nanoparticles/ nano-droplets, levitating in highly excited states in a deep and broad potential well formed by van der Waals/ Casimir-Polder (vdW/CP) forces [5-6] results in new effects on a cross-road of fundamental interactions, neutron, surface and nanoparticle physics. Experiments with ultracold neutrons (UCN) provide us an access to this rich multi-disciplinary field. Accounting for the interaction of UCNs with such nanoparticles explains long-standing puzzles in UCN physics and provides a key for further fascinating developments in this and other domains. In particular, it explains a recently discovered intriguing small heating of UCNs in traps [7-12]. It might be relevant to the striking conflict of the neutron lifetime experiments with smallest reported uncertainties by adding false effects there; thus it affects fundamental conclusions on precision checks of unitarity of the Cabibbo-Kobayashi-Maskawa matrix, as well as those in cosmology and astrophysics. The present results show a close relation with other phenomena of quantum levitation of massive particles above surface.

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On Cross Sections and Durations of Elastic Neutron-Nucleus Scattering near an Isolated Resonance Distorted by a Non-Resonant Background in the Laboratory System and in the Center-of-Mass System

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Here we analyze the cross section and duration of elastic neutron-nucleus scattering near an isolated resonance, distorted by a non-resonant background, in the laboratory system and in the center-of-mass system. Then it was shown that the standard cinematic formulas of transition from the laboratory system into the center-of-mass-system and vice versa are not enough namely because that near resonances of a compound nucleus the transitions from one system to another are essentially different for prompt (direct or potential processes) and for delayed processes, which are going on with the formation of a compound nucleus. That is why in the first case there are the usual cinematic formulas of transitions, and in the second case it is necessary to consider also the motion of a compound nucleus (which velocity coincides with the velocity of the center of mass), which is slowly decays emitting a neutron. The general formula, connecting the cross section of elastic neutron-nucleus scattering in the laboratory system near a resonance, distorted by a non-resonant background, with the parameters of the cross section in the center-of-mass system, is derived. Some calculations for the cross sections of neutron-nucleus scattering near the isolated resonances of small energies are fulfilled for both systems.

AVERAGE DESCRIPTION OF DIPOLE GAMMA-TRANSITIONS IN HOT ATOMIC NUCLEI

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Average description of the E1 gamma-transitions in atomic nuclei using the gamma-ray (phonon, radiative) strength functions (RSF) [1,2] are discussed.

Main features of the RSF descriptions in dependence on energy range of gamma-transitions are considered. The effect of folding procedure for calculations of average RSF within microscopic methods without allowance of the 2p2h states is discussed.

The practical semi-phenomenological methods of the RSF calculations based on excitation of the isovector giant dipole resonance (GDR) [1-3] are overviewed. The different mechanisms of GDR splitting are considered. An origin of dependences of RSF shape parameter ("width") on gamma-ray energy and the nuclear temperature is discussed. The RSF shapes in dependence on energy averaging at different excitation energies are studied.

New systematic expressions for the GDR parameters are proposed on the base of the renewed values and uncertainties of the GDR parameters [2,4]. The volume and surface coefficients of the symmetry energy are extracted from GDR energy systematic and compared with used values. Dependence of the excitation functions and gamma-ray spectrum from (n,xγ) reactions on middle-weight and heavy atomic nuclei on the GDR parameter uncertainties are demonstrated.

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POTENTIAL OF THE NEUTRON LLOYD'S MIRROR INTERFEROMETER FOR THE SEARCH OF NEW INTERACTIONS

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The consideration is presented of possible use of the neutron Lloyd's mirror interferometer to search for new short-range interactions. The chameleon scalar field proposed to solve the enigma of accelerating expansion of the Universe may produce short-range interaction between particles and matter. The axion-like spin-dependent nucleon-nucleon interaction between neutron and nuclei may produce P- and T-non-invariant potential between nucleons and bulk matter. These interactions cause phase shift of neutron waves in the interferometer. Estimates of sensitivity of these experiments are performed.

POSSIBLE POLARIZED NEUTRON-NUCLEUS SCATTERING SEARCH FOR A NEW SPIN-DEPENDENT NUCLEON-NUCLEON COUPLING

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An experimental opportunity is presented for the future to measure possible P- and T-non-invariant axion-like interaction between nucleons in a Fermi range. It may be searched for in the measurement spin-dependent asymmetry of scattering of polarized neutrons in a keV-MeV energy range by heavy nuclei.

FIRST STEPS IN PHYSICAL TREATING OF THE COLLINEAR CLUSTER TRI-PARTITION MECHANISM

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In our recent publications [1, 2] we have summarized experimental evidences of existing of a new type of ternary decay of heavy low excited nuclei called by us collinear cluster tri-partition (CCT). The results obtained inspired the series of theoretical woks dedicated to the CCT process [3–6]. Theoretical predictions put forward are based on the comparison of the energy prices of different pre-scission nuclear configurations leading to the ternary decay. Possible kinetic energies of all decay partners are estimated as well in [3].

Bearing in mind all the predictions to be strongly model dependent we have compared them with our experimental results for choosing the most realistic ones. We discuss as well our own scenarios of some CCT modes.

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FLUCTUATION OF THE PROMPT GAMMA-RAY EMISSION YIELD IN RESONANCE NEUTRON INDUCED FISSION OF ^{239}Pu

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The scientific interest in resonance neutron induced capture and fission reactions on ^{239}Pu is continuously rising during the last decade. From a practical point of view, this is because more precise data on capture and fission cross-sections, fission fragment mass and kinetic energy distributions, variation of prompt fission neutron and gamma yields in resonance neutron region, are needed for modelling of new generation nuclear power plants and for nuclear spent fuel and waste transmutation. From heuristic and fundamental point of view, such a research improves our knowledge and understanding of the atomic nucleus fission phenomena itself. To achieve these goals more powerful neutron sources and more precise fission product detectors have to be used. At the Joint Institute for Nuclear Research (JINR) Frank Laboratory of Neutron Physics (FLNP), where already half a century the thermal and resonance neutron induced nuclear reactions are studied, a new electron accelerator driven white-spectrum pulse neutron source IREN has been built and successfully tested. The improved characteristics of this facility, in comparison with those of the former pulse neutron fast reactor IBR-30, will allow measuring some of the neutron-nuclear reaction data with better precision and accuracy. A new experimental set-up for detecting gamma rays (and neutrons) has been designed and construction. It consists of 2 rings (arrays) of 12 NaI(Tl) detectors each with variable ring diameter and distance between both rings. Such set-up makes possible not only to measure the multiplicity, energy and angular anisotropy of prompt fission gammas, but also to separate the contribution of prompt fission neutrons by their longer time-of-flight from the fissile target to the detectors. The signals from all the 24 detectors are recorded simultaneously in digitized form and stored on the computer hard disks for a further off-line analysis. Measurement of the prompt gamma-ray emission from ^{239}Pu resonance neutron induced fission is one of the most probable candidates for the first experiments to be performed at IREN facility, using the newly build gamma-rays detector system.

Characterization of large area, thick, and segmented silicon detector for electron and proton detection from neutron β-decay experiments in the cold and ultracold energies

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Abstract

The "Nab" and "UCNB" collaborations have proposed to measure the correlation parameters in neutron β-decay at Oak Ridge and Los Alamos National Laboratory, using a novel detector design and electromagnetic spectrometers. Two large area, thick, hexagonal-segmented Silicon detectors containing 128 pixels per detector are going to be used to detect the electron and proton from neutron decay. Both Silicon detectors are connected by magnetic field lines of few Tesla field strength, and set on an electrostatic potential, such that protons can be accelerated up to 30 keV in order to be detected. We report the characterization, operation, proton detection from 15 to 30 keV, dead layer measurements, and pulse-height-defect analysis of these large area and thick Silicon detectors.

New cold neutron moderator for the IBR-2M reactor

E. Shabalin

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The world first pelletized cold neutron moderator for the IBR-2M reactor based on solid mesithylene beads is created in LNPh. Nowdays the start-up of the moderator at the nominal reactor power is going on. Concept of its operation, technology parameters and neutron characteristics known to date are reported.

Oklo Phenomenon and Nuclear Data

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Oklo natural reactor phenomenon provides unique information on possible change of the fine structure constant α and on how the buried nuclear waste behave in geological formations. Nuclear data are indispensable in the Oklo analysises but not all of them are known or have required precision. We draw attention to neutron capture cross sections needed in the application of the ^{176}Lu/^{175}Lu thermometry /1/ for solving the existing uncertainty in operating temperatures of Oklo reactor zones. In particular we propose to improve measurements of the branching ratio $B_g = \sigma_g/(\sigma_g + \sigma_m)$ in ^{175}Lu thermal neutron capture leading to the ^{176m}Lu isomer and ^{176g}Lu ground states. For Oklo reactor zone RZ10 /2/ we calculate, besides neutron fluxes, also the gamma-ray fluxes to clarify a role of the photo excitation of the isomeric state ^{176m}Lu by the ^{176}Lu(γ,γ) fluorescence. Our values of the constant $\lambda_{\gamma,\gamma}$ for Oklo phenomenon do not support burning of ^{176}Lu through the (γ,γ) channel.

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MEASUREMENTS OF THE SPECTRAL NEUTRON FLUX DENSITY AT IBR2-M EXTRACTED BEAMS

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Replacement of spent fuel elements and reconditioning of IBR-2M reactor of Frank Laboratory of Neutron Physics of the Joint Institute for Nuclear Research (FLNP JINR) was successfully finished. As the part of startup works the energy dependent neutron flux densities were experimentally investigated on the IBR-2M pulsed reactor flight paths.

The neutron energy spectrum at the different beams was measured using the time of flight (TOF). A twin parallel plate fission chamber (PPFC) with ^{235}U target, mounted on the common cathode was used as the thermal neutron detector. Target was prepared by depositing of thin layer (50 μg/cm^2) of UF_4 on the gold plated (~20 μg/cm^2) organic foil (~70 μg/cm^2). Total number of ^{235}U nuclei in the circular spot of 10 mm in diameter was $9.97 \cdot 10^{16}$. The neutron induced fission of the target nucleus caused powerful pulse on the common cathode of the PPFC, which TOF value was measured after the pulse height analysis.

To investigate the counting losses during measurements of the brightest beams the specially designed current preamplifier was used in addition to traditional charge sense preamplifier. The cause of the counting losses was detected and explained by the saturation of the charge sense preamplifier during gamma-flash of the IBR-2M.

We present here the preliminary results, obtained at the end of 2011 during first two cycles of IBR-2M routine operation. More detailed measurements are foreseen for 2012.

Polarized ^{3}He for the Neutron Research

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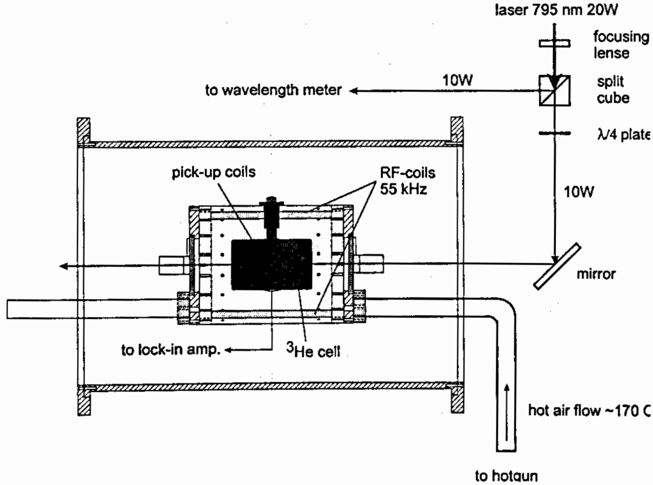
The polarized 3He nuclei are widely used in many fields of applied and fundamental researches. Basically there are two methods of 3He polarization: low pressure optical pumping through the metastable stage (MEOP), and spin exchange optical pumping (SEOP). The last technique assumes the optical pumping of alkali metal vapor with production of atomic shell polarization, and then this polarization is transformed to the 3He nuclei via hyperfine interaction during collisions. We report the first results of development of SEOP based ^{3}He device for research purposes at HANARO nuclear reactor in KAERI. Schematic view of the experiment for pumping of ^{3}He inside a solenoid is shown on figure.



During experiment we have checked the procedure of transporting of polarized cell from a pumping site in optical laboratory to a test cold neutron beam line of HANARO reactor. For the test purposes we have pumped a cell about 8 hours. The progress of ^{3}He polarization was observed with NMR method. After the pumping we have cooled down a cell, turned off a laser and switched a solenoid supply from power supply to a commercial motorcycle battery. Then we take a solenoid with polarized cell and a supply battery to a car and bring it to a HANARO beam line. The beam provides monoenergetic neutron beam with a wavelength 5 A. We have performed two measurements: neutron transmission of polarized cell, then we have depolarized a ^{3}He with a permanent magnet and measured transmission. This two transmissions allowed us to obtain a neutron polarization 0.38±0.02 which corresponds to polarization of ^{3}He: 0.18±0.01. The pumping during 30 - 40 hours allows to get ^{3}He polarization at the level 0.6 - 0.7. These methods will be used for experiments with polarized neutrons at HANARO.

MIXED METAL POLLUTION FROM SMELTER INDUSTRIES STUDIED BY MOSS BIOMONITORING, INAA AND ICPMS: MO I RANA (NORWAY) CASE STUDY

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The moss biomonitoring technique has been employed for many years in Norway to study the deposition of metals from various industries. In Mo i Rana, a town with 30000 inhabitants, three industries are located close together within the urban area: a ferro-manganese smelter, a silicon production plant, and a factory recovering metals from scrap iron and other metallic wastes. Investigations in 2000 and 2005 showed that Mo i Rana is polluted with a great number of metals from these industries. By comparing results for samples from different locations surrounding the industries (Steinnes et al. 2004) it was possible to some extent to identify relative contributions from each of the factories. In 2010 a new moss survey was performed, and samples from Mo i Rana were analyzed by ENAA at JINR and ICPMS at NILU for a large number of elements. In this presentation temporal and spatial trends are shown for some of the most important pollutants, and relative contributions from each of the three smelters are discussed based on the distributions of data among different sampling sites.

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GENERAL TREND AND LOCAL VARIATIONS OF NEUTRON RESONANCE CASCADE GAMMA-DECAY RADIATIVE STRENGTH FUNCTIONS

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The suggested hypothesis on dependence form of the radiative strength functions of electric and magnetic dipole gamma-transitions in heated nucleus on the excited level density was tested experimentally. For this purpose, the region of possible values of random values of the level density and radiative strength functions which precisely reproduced experimental intensity of two-step cascades for 41 nuclei from ^{40}K to ^{200}Hg was determined. It was obtained that suggested here hypothesis can provide the maximal increase of radiative strength functions values by order of magnitude and even more in comparison with existed notations. This result points out necessity to take into account this possibility in existing and future models of radiative strength functions.

THE ROLE OF NEUTRON RESONANCE DATA IN FUNDAMENTAL PHYSICS

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A search in neutron resonance spectra for systematic deviations from statistical-model predictions was started in 70-ties. Academician I. M. Frank proposed the name "superfine structure" for the empirically observed by K.Ideno, M.Ohkubo, W.Havens and other authors regularities in spacing distributions. For such analysis great number of resonance parameters are needed. We are collecting now NRF-4 – the fourth compilation of neutron resonance parameters to be published by LB Springer (Editor H.Schopper).

Recent progress in understanding of nuclear dynamics is connected with the fact that nuclear tensor forces are result of pion-exchange mechanism manifested at long distances. T. Otsuka showed that a strong attraction exists between nucleon moving in the opposite directions. This conclusion was supported by observation of a stable character of the resulting shifts in nucleon energies. Several examples of tensor force effects were considered in the literature. T. Otsuka introduced simbols < and > for marking interacting nucleons (located in different subshells). As a result many regions of nuclear chart can be considered in a search for systematic effects connected with the action of tensor forces, In Table linear trend in excitations of Sb-isotopes considered by T. Otsuka is presented. The stability of linear trend permitted to determine the parameter 161 keV of the tensor force (boxed values n×161 keV) and to study similar effects in many other nuclei and nonstatistical effects in highly excited states of the same nuclei as well.

Table. Comparison of E^* in $Z = 51$ nuclei with n×(161 keV=1293 keV/8).

^{A}Z	^{133}Sb	^{131}Sb	^{129}Sb	^{127}Sb	^{125}Sb	^{123}Sb	^{125}Sb	^{119}Sb	^{101}Sn	^{103}Sn
$2J^\pi$,J^π	5^+	5^+	5^+	5^+	5^+	5^+	3^+,5^+	1^+		
E^*, keV	$\boxed{962.0}$	$\boxed{798.4}$	$\boxed{645.2}$	$\boxed{491.2}$	$\boxed{332.1}$	$\boxed{160.3}$	644	644.0	171	168
$n\frac{D_0}{8}$	969	808	646	484	323	161	646	646		
n	6	5	4	3	2	1	4	4		
N	82	80	78	76	74	72				
Sb,Pd, eV			$\boxed{750}$		375					

The stable character of valence neutron excitations (170 keV) presented in the right part of Table together with the above mentioned parameters 161 keV were found in many other nuclear regions. For existing two stable antimony isotopes many neutron resonances are known. They correspond to the highly excited states. The grouping effect at D=375 and 570 eV was noticed in the D-distribution of ^{124}Sb by several authors. These superfine-structure effects were found also in many nuclei (^{104}Rh, ^{105}Pd, ^{odd}Nd, ^{179,181}Hf, ^{80}Br). Unification of nucleon interaction at long distances permits to select nonstatistical effects from the fundamental point of view.

ROT-EFFECT IN (n,$\alpha\gamma$)-REACTIONS

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The five-vector P-even T-odd (pseudo-T-noninvariant) correlation of fission products – so called ROT-effect – is now the subject of active investigations and discussions. In the fission process however this effect manifests itself in an extremely complicated process due to the huge number of exit microchannels which differ by the masses of fragments, their spins, relative angular momentum etc. and what is more the emission of some number of various light particles attends any fission act. The (n,$\alpha\gamma$)-process looks essentially simpler and nevertheless offers some analogous properties. In particular it may displays the same correlation appearing as a consequence of the final state interaction (FSI) of the alpha-particle with the residual nucleus.

In the presented talk the correlation $(k_\alpha[s\times k_\gamma])(k_\alpha\cdot k_\gamma)$, where s is the vector of the neutron polarization and symbols k denote the respective linear momenta, in the sequential alpha-gamma cascade is discussed. FSI manifests itself in the interference of the alpha-decay amplitudes with different angular momentum L. Naturally the values of spins of the compound and the residual states must be not less than 1. Unfortunately this requirement does not give a chance to use the most convenient for this reaction ^{10}B target. Because of that the problem of more or less suitable target isotope turns out to be the basic one. The nuclide ^{67}Zn seems to be optimal among the stable targets but even in that case the flux of the gamma-quanta producing by (n,γ)-reaction going on this isotope and the admixtures of the other Zn isotopes is about 10^5 times more intensive than the gamma-signal searched for. Thus the very fast gamma-detector such as BaF_2 is required. Probably the radioactive target ^{41}Ca is more promising being free of this disadvantage. However such an experiment requires: extremely powerful reactor-producer to create a sample with significant resulting percentage of the isotope, a high-flux beam of polarized neutrons to achieve a satisfactory value of the counting rate on the small sample, and a well-developed technology of the work with the targets which are soft radioactive sources of high intensity. In the discussed case the major origin of such a radioactivity is unremovable admixture of ^{45}Ca nuclide produced by (n,γ)-reaction on the ^{44}Ca isotope containing in the Ca sample.

TRI-effect is not a feature of the (n,$\alpha\gamma$)-reaction because of the sequential mechanism of the process.

It is important to note that the discussed correlation in (n,$\alpha\gamma$)-process is computable from the results of some independent experiments with unpolarized neutrons. Therefore a discrepancy between the experimental and calculated results if it took place would be an evidence of some effect. In particular it is possible in principle to estimate an upper limit of the actual T-noninvariant phase shift after the discussed measurements and calculations.

VERIFICATION OF THE WEAK EQUIVALENCE PRINCIPLE WITH LAUE DIFFRACTING NEUTRONS. TEST EXPERIMENT

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Recently experiment to test the weak equivalence principle (WEP) for the Laue diffracting neutron was proposed [1,2]. WEP postulates the inertial to gravitational masses ratio to be equal to unity, what is going to be checked in our experiment. Direct test of WEP is straightforwardly connected with investigations of gravitational properties of the neutron as an elementary particle, the field of modern physics where not so much is still clear.

Our experiment is based on an essential magnification of an external affect on neutron diffracting by Laue for the Bragg angles close to the right one in couple with additional enhancement factor which exists due to the delay of the Laue diffracting neutron at such Bragg angles [2]. The total diffraction enhancement factor may be as large as $\mathbf{10^9}$. This enhancement phenomena is proposed to be utilized for measuring the force which deviates from zero if WEP is violated [3].

Our estimations showed that sensitivity to the external force of the two-crystal experimental setup can reach the magnitude $10^{-18}\ eV/cm$ for the close to $\pi/2$ Bragg angles of diffraction and ~200 mm silicon crystal. The accuracy of measuring inertial to gravitational neutron masses ratio for the introduced setup can reach $\sim\mathbf{10^{-6}}$, that is two orders higher than the best modern result [4].

At the first stage we analyzed external impacts on the experimental setup: vibration, deformation of a working crystal under its own weight, temperature gradients etc. In the work [5] we showed that available technical equipment allows us to fight against all of mentioned impacts on acceptable level.

Also setup for the test experiment was built. We made a series of experiments to observe specific dynamical diffraction effects that showed us the possibility of working with extremely (>200 mm) thick crystals and with Bragg angles up to $\mathbf{88^0}$ [6].

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CORRELATION BETWEEN E_{CM}/u AND UNEXPLAINED EXPERIMENTAL OBSERVABLES

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A new concept is introduced for the classification of unresolved problems in the understanding of interactions in thick targets irradiated with relativistic (E_{kin} ≥1 GeV/u) ions: The centre-of-mass energy per nucleon of a hypothetical compound nucleus from a primary interaction, E_{CM}/u, is calculated and correlated with several experimental observations in thick target irradiations.

One observes in various reactions of relativistic primary ions with thick targets [1, 2] that there appears to be a threshold for reactions leading to unresolved problems which lies around **E_{CM} /u ~ 150 MeV** where E is the kinetic energy of the beam. When reaction products from the first nuclear interaction in a target induce secondary nuclear interactions then the target is described as being a thick target. Whereas results measured in thin target experiments are in good agreement with model calculations, even at very high projectile energies, there are significant discrepancies encountered for thick target results from high-energy reactions between experimental cross sections and theoretical model calculations:

- the neutron production significantly exceeds calculations
- the cross section of distant fragmentation products is enhanced
- the limited fragmentation principle is violated

We consider these discrepancies as "unresolved problems" and note that all unresolved problems are exclusively observed above around E_{CM}/u~150 MeV, whereas below this threshold no unresolved problems are found and experiments agree well with calculations.

The classification of reactions below or above a limit value of E_{CM}/u~150 MeV cannot be an explanation of the physics of the interactions; however, it may be a useful tool to select specific reaction systems for further investigation. Some considerations will be presented and experimental studies in this field will be suggested.

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Twin Ionization Chamber for Prompt Fission Neutron Investigation

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The aim of the present work was modification of setup (similar to described in ref. [1]) for prompt fission neutron (PFN) emission investigation in resonance neutron induced fission of ^{235}U and ^{239}Pu nuclei. Recently we reported our results [2] of application of digital pulse processing (DPP) to investigation of ^{252}Cf(sf) reaction. Thanks to DPP a significant qualitative transition was made in the research paradigm by replacement of conventional electronic apparatus by the virtual apparatus, described by DPP software. Experimentalist now can benefit from reproducing the same experiment with different pulse processing algorithms, highlighting selected features of the investigation. Finally the best combination of DPP and data analysis can be developed for final data analysis. This approach was implemented in investigation of PFN emission on the total kinetic (TKE) energy and mass split of the fission fragments (FF) in ^{252}Cf(sf) reaction. Spectroscopic measurement of FF mass and kinetic energy was done using a modified twin Frisch-grid ionization chamber (TGIC) with split anodes. Modification of TGIC allowed measurement of FF motion direction in respect to the normal of TGIC cathode (polar and azimuth angles). A fast neutron detector (ND) with NE213 (or analog) scintillation liquid was used for PFN time-of-flight measurement. Reasonable agreement between experimental results and theoretical calculations of TKE and mass split dependence of average PFN number was achieved thanks to application of digital pulse processing to the recorded signals. In the first time the linear dependence of the average number of PFN on TKE in the range of (140 – 220) MeV was demonstrated. The long time existing contradiction between experiment and theory was resolved. Further development and improvement of modified TGIC was discussed.

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BIOTECHNOLOGY OF GOLD NANOPARTICLES BY SOME STRAINS OF ARTHROBACTER GENERA

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The synthesis of gold nanoparticles by two novel strains of Arthrobacter sp. 61B and Arthrobacter globiformis 151B isolated from basalt rocks in Georgia was studied. To characterize formed gold nanoparticles UV-vis spectrometry, Scanning electron microscopy (SEM) and Energy-dispersive analysis of X-rays (EDAX) were used. It was shown that after 1.5–2 days the extracellular formation of nanoparticles of spherical form with size in the range of 8–40 nm (on average of 20 nm) took place. To determine total gold concentrations in the bacterial biomass neutron activation analysis (NAA) was applied. The results obtained evidence that the concentration of gold accumulated by bacterial biomass is rapidly growing in the beginning followed by an insignificant increase during the next few days. Beside gold, concentrations of essential (Mg, Mn, Cl, Ca, P) and trace (V, U) elements were determined. Preliminary data interpretation is given.

LEVEL DENSITIES FOR NUCLEI WITH 47≤A≤59

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The basic statistical function of excited nuclei is the nuclear level density. Knowledge of the level density values and their functional peculiarities is very important for the creation of consistent theoretical description of excited nucleus statistical properties and in making nuclear reaction cross-section calculations in the framework of statistical model. The general features of nuclear level density are known, but there are considerable uncertainties of its functional forms conditioned by the unhomogeneity of a single-particle state spectrum, residual interaction, effects of collective nature et al. The required accuracy of level density knowledge for nuclear cross-section calculation problems is ~ 10 % in a wide range of excitation energy from 0.1 MeV to 20 MeV, and the existing data are often differed in 1.5 times. The experimental data on the nuclear level densities for many nuclei are derived, in the main, from the analysis of neutron resonance data and low- lying states. But this information is limited to rather narrow ranges of excitation energy and spin, and its extrapolation can lead to essential errors both in absolute value of nuclear level density and its energy dependence, especially, in transition field from well-identified discrete states to continuum part of excitation spectrum. In eddition for light nuclei the problems caused by the small number of levels of appropriate spin and parity, possible missing levels, and the need to know the parity ratio and the spin cut-off parameter create big difficulties with such data. Obviously, it is necessary to attract other experimental methods of nuclear level density determination with scope of more wide ranges of excitation energy and spin. One of the information sources on nuclear level density in a range between the discrete states and the neutron binding energy with accuracy comparable with neutron resonance data are the spectra of particles emitted in nuclear reactions. In this case the type of reaction and the energy of incident particles should be chosen so that the contribution of non-equilibrium processes was reduced to a minimum. These conditions are satisfied with the (p,n) reaction at proton energy up to 11 MeV. In the present work neutron spectra from (p,n) reaction on nuclei of ^{47}Ti, ^{48}Ti. ^{49}Ti, ^{53}Cr, ^{54}Cr, ^{57}Fe, ^{59}Co have been measured at proton energies between 7 and 11 MeV. The measurements of neutron spectra were performed by time-of-flight fast neutron spectrometer on the pulsed tandem accelerator EGP-15 of IPPE. Analyses of the measured data have been carried out in the framework of statistical equilibrium and pre-equilibrium models of nuclear reactions. The calculations are done with use of the exact formalism of the statistical theory as given by Hauser-Feshbach with the generalized superfluid model of nucleus, the back-shifted Fermi-gas model and the composite formula of Gilbert-Cameron for nuclear level density. The nuclear level densities of ^{47}V, ^{48}V, ^{49}V, ^{53}Mn, ^{54}Mn, ^{57}Co, ^{59}Ni and their energy dependences have been determined. The obtained results have been discussed in totality with existing experimental and model systematic data.

Proposal for experiments on evaluation of the neutron capture cross section of light nuclei

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The presence in medium and heavy nuclei of resonance states in case of interaction with slow neutrons makes possible the determination of their concentration with a good precision by neutrons activation methods. For light nuclei the situation is changing because the first resonant states occur from tens or hundred keV and therefore to obtain the concentration using activation methods become very difficult because the capture cross section is very small.

The ^{6}Li nucleus is important in various field of activity like medicine, biology, electronics, and nuclear weapons and therefore it is of interest to measure the concentration of this nucleus in different industrial, biological and environmental samples. It has the capture cross section of thermal neutron $\sigma_{n\gamma} = (0.0385 \pm 0.003)$ b and this value is much lower than the (n,α) cross section at the same energy $\sigma_{n\alpha} = (940 \pm 4)$ b.

For the quantitative determination of the presence of a light nucleus like ^{6}Li in some samples we can proceed in the following way. First, by activation methods we evaluate the concentration of medium and heavy nuclei. After, it is necessary to evaluate the concentration of the main elements in the matrix sample. For example, for biological samples the matrix of main elements contains C, O, N, but these elements also can not be determined by neutron activation methods due to the small values of the thermal neutron capture cross section. The nest step is to obtain the neutron spectra in a transmission experiment using the analyzed sample. From the transmission spectra the contribution of main elements from sample matrix and of medium and heavy nuclei is subtracted. Then from the new obtained spectra it is possible to extract the concentration of the light nucleus ^{6}Li.

In this work was realized a simple evaluation for ^{6}Li nucleus in a sample with the possibility to extend this method to other light nuclei. The experimentally measurements will be realized at IREN, the new neutron source of FLNP – JINR Dubna.

Cross sections analysis in (n,α) reaction with fast neutrons on ^{64}Zn nucleus

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Abstract. The differential cross section was evaluated for ^{64}Zn nucleus using the Talys computer codes. From calculations result that in the range of a few MeV-s, the main contribution to the cross section are given by compound processes on discrete and continuum states of residual nucleus. By comparing the theoretical evaluation with existent experimental data we obtain the parameters of optical potential.

The experimental data in this work are obtained mainly at the Electrostatic Generators of FLNP JINR Dubna and Pekin University – Heavy Ions Physics.

This work is a part of a scientific program on fast neutrons reactions which is running at FLNP JINR Dubna and in future will be analyzed also, others nuclei.

On the heavy elements content of sediments and rocks from two semiclosed ecosystems: proglacial lake Bâlea (Fagaras Mountains) and crater lake St. Ana (Harghita Mountains)

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In order to establish to which extent two semiclosed lakes, proglacial Bâlea (Fagaras Mountains) and volcanic St. Ana (Harghita Mountains) could be considered affected by anthropogenic pollution, the content of seven heavy elements (Sc, Cr, Co, AS, Sb, Br and Se), was determined by Instrumental Neutron Activation Analyze in 29 samples of sediments and surrounding rocks. A Principal Component Analysis performed in R-mode showed that Sc, Cr, and Co, on one hand, and As, Sb, Br, and Sb, on the other one, form two distinct clusters, regardless the lake while Q-mode analysis pointed towards a significant difference between two lakes regarding both sediments and rocks. The final results showed that the average content of considered elements in sediments was close to the surrounding geological formations, and, at the same time, comparable with the normal environmental content as defined by the Romanian Regulations. In this way, although different regarding geological location, all elements could be considered as normal, nonpolluting components of the investigated environments.

SEARCH FOR P-ODD EFFECTS IN THE INTERACTION OF POLARIZED NEUTRONS WITH NATURAL LEAD

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The lead isotopes have no any suitable pair of s- and p-resonances that may be responsible for P-odd effects in reactions with neutrons. Nevertheless, in two independent experiments a large effect of the neutron spin rotation in natural lead sample was observed. Another measurement of $\Delta\phi$ was done with a sample enriched in the ^{204}Pb isotope. The obtained result is somewhat smaller than it is necessary to reproduce the effect in natural lead, but ^{204}Pb could be considered as a source of the P-odd effects. To explain this effect in the framework of the two levels mixing mechanism the existence of a negative p- wave resonance in ^{204}Pb was suggested. However this it is not confirmed experimentally.

Additional information can be obtained from other P-odd effects. The P-odd effects in interaction of polarized neutrons by using the two levels approximation for the ^{204}Pb isotope were evaluated: a neutron spin rotation; an asymmetry in the total cross section; an asymmetry in the radiative capture cross section; an asymmetry of the emitted neutrons with respect to the spin of the incident neutrons. The calculations were performed for two sets of resonance parameters: (1) for the known resonances of ^{204}Pb with E_S = -2980 eV and E_P = 480 eV and (2) for the above suggested negative p-wave resonance with E_P = -16 eV. The energy dependence of the above effects has been obtained and discussed. Results have been rescaled to the natural composition of lead isotopes. The calculations accomplished during this study were compared with existing experimental values. Based of this research two experiments are proposed: the measurement of the asymmetry in the total cross section and that in the radiative capture cross section. Although these effects are much weaker than that in the $\Delta\phi$ measurement, however the realization of these experiments is much easier methodologically. The experiments are planned to be performed at the PF1B instrument of the ILL reactor. It is shown that by using the technique and equipment developed by us we can reach an accuracy of $\sim 1.5\cdot10^{-8}$ for the first effect and $\sim 7\cdot10^{-8}$ for the second one for 50 days of measurements.

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NUCLEAR AND IMAGING TECHNIQUES USED IN MATERIAL SCIENCES

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Nuclear analytical technique Neutron Activation Analysis (NAA) was used to determine the concentration of minor and trace elements in some metallurgical materials (steels, slags) involved in the steelmaking process at the Integrated Iron and Steel Works in Galati, Romania.

The NAA results for steels obtained at Horia Hulubei Institute of Physics and Nuclear Engineering IFIN-HH, Bucharest-Magurele, Romania, are compared with those obtained by Ion Beam Analysis techniques Particle-induced X-ray (PIXE) and Gamma-ray (PIGE) Emission, in terms of number of elements detected, sensitivity and matrix effects.

Supplementary, analysis of metallurgical samples employing the imaging technique SEM-EDX analyses was performed at "Dunarea de Jos" University of Galati, Romania, using a scanning electron microscope (SEM) of Quanta 200 FEI type, with energy-dispersive X-ray microanalysis (EDX) integrated system, having 5 detectors of secondary and backscattered electrons, 1 detector for transmitted electrons and software for: processing of data, quantification of chemical composition using a correction algorithm of ZAF (*Z*-atomic number, *A*-absorption, *F*-fluorescence) type, multi-point chemical analysis with matrix effects corrections and analysis of concentration profile along a defined line.

Using the data obtained for metallurgical slag samples by low background gamma-ray spectroscopy, corroborated with their physical and mechanical properties, a discussion is made on the possibility of using these by-products as building materials.

Further work involving nuclear and imaging techniques will be carried out as a collaboration between "Dunarea de Jos" University of Galati, Romania, and Joint Institute of Nuclear Research, Frank Laboratory of Neutron Physics, Dubna, Russia, for the investigation of new synthesized materials for different uses.

INAA OF LEAVES AND STEAMS OF GREEN VEGETABLES

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The paper presents an application of Instrumental Neutron Activation Analysis (INAA) to determine major, minor and trace elements in green vegetables collected from selected sites in Romania (industrial and control zones). Leaves and stems of parcel (*Petroselinum hortense*), dill (*Anethum graveolens*), lovage (*Levisticum officinale*), celery (*Apium graveolens*), and kale (*Brassica oleracea*) were studied.

INAA was applied at the Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH) in Bucharest-Magurele, Romania for long-lived radionuclides and at Joint Institute for Nuclear Research (JINR) in Dubna, Russia for short-lived ones. Neutron irradiation was carried out at the TRIGA nuclear reactor of the Institute of Nuclear Researches (RAAN-SCN) Pitesti in Romania and IBR-2 reactor of JINR Dubna in Russia. The elements determined were Al, Cl, K, Ca, and Mn (short-term neutron irradiation) and K, Ca, Cr, Fe, Co, Ni, Zn, As, Se, Br, Rb, and Sr (long-term neutron irradiation).

Comparing the leaves and stems morphological parts of the green vegetables studied, higher concentrations of Na, Cl, and Br were observed in stems, while higher contents of most elements (e.g. Mg, Ca, Sc, Cr, Mn, Fe, Co, Ni, Zn, Se, Mo, Sb, Au, Hg, and Th) were determined in leaves. Industrial contamination of green vegetables could be observed in some of the cases.

This work was supported in part by the PNCDI II Project No. 72-172/2008 in Romania and Joint Research Project No. 3871-4-08/10 between JINR Dubna and IFIN-HH.

INDUSTRIAL IMPACT ON SOME ROOT VEGETABLES STUDIED BY INAA

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This paper presents the levels of elemental concentrations determined by Instrumental Neutron Activation Analysis (INAA) in some root vegetable species collected from industrial and control zones in Romania. The following industries were considered: phosphorous fertilizer production, non-ferrous (Pb-Zn) metallurgy, as well as iron and steel metallurgy. The vegetables examined were: carrot (*Daucus carota*), potato (*Solanum tuberosum*), garlic (*Allium sativum*), onion (*Allium cepa*), celery (*Apium graveolens*), and parsnip (*Pastinaca sativa*).

INAA was applied at IFIN-HH in Romania for long-lived radionuclides and JINR Dubna in Russia for short-lived radionuclides. Neutron irradiation was carried out at TRIGA reactor in Pitesti and IBR-2 reactor in Dubna. The elements determined were: Al, Ag, As, Au, Ba, Br, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Eu, Fe, Hf, K, La, Mn, Mo, Na, Ni, Rb, Sb, Sc, Se, Sm, Sr, Ta, Tb, Zr, and Zn.

Higher than control elemental concentrations were observed in some of the samples collected from industrial zones: e.g. Zn, Sb, Cd, As, and Ag (non-ferrous metallurgy); As and Sb (fertilizer industry); Mn, Fe, Co, Ni, Se, and Mo (iron and steel industry). Similar concentrations with normal levels in Romania were obtained for Cl, K, and Ca in all vegetables investigated.

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GRAVITATIONAL AND CENTRIFUGAL QUANTUM STATES OF ANTIHYDROGEN

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We predict the existence of long-living quasistationary gravitational and centrifugal quantum states of antihydrogen atoms [1-2] in close analogy to recently measured gravitational and centrifugal quantum states of slow neutrons [3-4]. The quasistationary character of such states is due to the quantum reflection of ultracold (anti)atoms from the Casimir-Polder (anti)-atom-surface potential. The typical lifetime of such states in vicinity of an ideally conducting surface is 0.1 s; and could be even further improved by proper choice of the mirror structure/material. The relatively long lifetime is due to smallness of the ratio of the characteristic spatial antiatom-surface interaction scale and the spatial gravitational scale.

We point out principal methods of measuring differences in energy of these quantum states. These methods include those analogous to the methods used in experiments with slow neutrons, but also methods specific for experiments with antihydrogen atoms. In particular annihilation of antihydrogen atoms in a surface provides a clear signal, which could be localized in space and time thus providing a convenient method for detection and study of these quantum states.

We analyze the general feasibility of performing experiments of this kind and conclude that they are feasible at certain conditions, which could be met in practical terms. The key parameter is the phase-space density of antihydrogen atoms, which could be achieved.

Measurements of gravitational quantum states of ultracold antihydrogen atoms would provide the most precise known method to study gravitational properties of antimatter, in particular for testing the equivalence between the gravitational and inertial masses of antimatter, also for exploring extra fundamental short-range forces between matter and antimatter.

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RECENT RESULTS OF EXPERIMENTS WITH MASSIVE URANIUM TARGET SETUP QUINTA AT NUCLOTRON

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Recently new ADS scheme was proposed [1] aimed at energy production and transmutation of radioactive wastes. Main physical idea of this approach is to use deep subcritical and quasi infinite (with negligible neutron leakage) multiplying target of natural (depleted) uranium or thorium combined with ~ 10 GeV proton or deuteron incident beam. In accordance with semi-phenomenological estimations such ADS provides large enough beam energy gain and extremely hard neutron spectrum inside of subcritical core that can ensure effective burning of core material as well as spent reactor fuel added to the initial core. To preserve hard neutron spectrum it is necessary to use helium gas cooling of the fist circuit and core material as target for incident beam.

During December 2011 and March 2012 the experiments with massive natural uranium target assembly QUINTA have been carried out at JINR NUCLOTRON with energy of deuteron beam from 1 up to 8 GeV. Preliminary results of these measurements confirm a validity of basic ideas of proposed ADS scheme and provide solid grounds for planning of future experiments with quasi-infinite (22 tons) target of depleted uranium available for the "Energy and Transmutation RAW" collaboration at JINR.

RESEARCH FOR THE TRI AND ROT EFFECTS WITH PROMPT NEUTRONS

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Study of the TRI and ROT effects in the emission of prompt fission neutrons and gamma rays has been continued at the facility MEPHISTO of the FRM II reactor (Technical University of Munich). No signs of the TRI-effect have been found up to now in neutron or gamma-ray emission. The upper limits for the relevant asymmetry coefficients in ^{235}U fission have been set to $|D_n| < 6\times10^{-5}$ and $|D_\gamma| < 5\times10^{-5}$ at 99% confidence level, whereas for ternary fission the present correlation coefficient $D_\alpha = (170 \pm 20)\times10^{-5}$. ROT-effect has been found in prompt fission neutron emission as well as in gamma ray emission in ^{235}U fission. Unlike ROT-effect in gamma ray emission, magnitude of the ROT-effect in neutron emission shows great difference at the adjacent angles θ and π-θ to the direction of light fragment's momentum. The ROT-effect is higher at $\theta = 157.5°$ than at $\theta = 22.5°$. This and other features of ROT-effect in neutron emission are in qualitative agreement with theoretical prediction by Guseva [1] based on the assumption that the angular distribution of fission neutrons in the rest frame of the fragment is anisotropic, although quantitative agreement is poor. Preliminary results of measurement of T-odd effects in ^{233}U fission are presented as well.

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