National Academy of Sciences of Ukraine

National Science Center
«Kharkov Institute of Physics and Technology»

Institute of High-Energy Physics and Nuclear Physics

ABSTRACTS OF REPORTS XXII CONFERENCE OF HIGH ENERGY PHYSICS AND NUCLEAR PHYSICS

Kharkiv
2024

Content

Section 1. Nuclear physics and elementary particles

NSC KIPT PARTICIPATION IN THE CMS EXPERIMENT: STATUS AND PROSPECTS

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In May 2023, the Large Hadron Collider (LHC) Run 3 was resumed with the record (for accelerators) proton-proton collision energy of 13.6 TeV. In the CMS experiment, the rate of event selection by the high-level trigger (HLT) for offline processing is ~2.5 kHz, which is ~2.5 times greater than in the LHC Run 2 (2015-18) and ~8 times greater than in Run 1 (2010-13). Processing of the large experimental information array accumulated in the experiment continues. In particular, a number of outstanding results on the Higgs boson properties, as well as a number of important results related to both studies of Standard model (SM) phenomena and searches for signals of "new physics" beyond the SM have been obtained. Over the past year, a wide range of activities within participation in the CMS experiment has been fulfilled at the NSC KIPT. In particular, operation of the only Ukrainian Tier-2 (T2) center of the CMS grid infrastructure, T2_UA_KIPT, was supported. Large-scale work was carried out to restore the facility's power-supply system, and a detailed analysis of the state of its computing and disk nodes was accomplished, with fixing detected hardware malfunctions. In addition, the necessary software configuration changes for the center were prepared to provide the earliest possible resumption of its operation. Owing to the successful completion of these works, the full-scale participation of the T2_UA_KIPT center in the CMS distributed data processing has been restored since the beginning of July 2023. As for the functioning quality determined by the readiness to participate in data processing, the center (for the time since the restoration of its operation) is in the group of the most reliable CMS Tier-2 sites. In addition, a high rate has been provided for transferring to the center of the CMS experimental information, which sometimes reached 10 Gbps (the maximum possible value for the existing outer network channel), and the total amount of the transferred information has reached ~2 PB, which significantly exceeds the T2_UA_KIPT mass disk storage capacity. Thus, CMS data processing has been completely restored at the T2_UA_KIPT center. Since this center is the only Ukrainian site obtaining experimental information from the LHC for processing, this also means the resumption of processing of this information in Ukraine. Also, using the LatinoAnalysis "universal" software package, the physics analysis of the CMS data of the UltraLegacy version was continued with the aim of searching for a SUSY signal – the direct chargino pair production in 13 TeV proton-proton collisions. Processing of the data sets recorded in the first half of 2016, as well as in 2017 and 2018 was carried out. Event distributions over relevant kinematic quantities were built for the "combined" Run 2 CMS data sample, which corresponds to the integral luminosity of 137.6 fb^{-1}. The work on estimation of the systematic

uncertainties has been carried out. The obtained results demonstrate a fair agreement between the CMS data and SM calculations and indicate the absence (at the confidence level of CL=95%) of the signal for a wide range of chargino and neutralino masses. Also, activities continued within the CMS endcap calorimetry upgrade program. The stand for light yield measurements in scintillator samples was moved to a premise that was not damaged by the hostilities of 2022. Repair work was carried out on the stand damaged equipment and electronic units, and installation of the equipment and (partial) upgrade of the communication line with the PC were carried out. As of the beginning of 2024, the stand is in working order and ready for measurements.

The work was supported in part by grants of the NAS of Ukraine (NASU) within the targeted research program “Collaboration in advanced international projects on high-energy and nuclear physics” and the “NASU informatization program”.

ANALYSIS OF CMS EXPERIMENTAL DATA FOCUSED ON SEARCH FOR DIRECT LIGHTEST CHARGINO PAIR PRODUCTION

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Samples of 13 TeV proton-proton collisions obtained in the CMS experiment at the Large Hadron Collider in 2017 and 2018 were analyzed in order to search for the supersymmetry signal – the direct production of lightest chargino pairs with their subsequent decay into charged leptons, neutrinos and neutralinos. (The latter are often considered as candidates for the role of dark matter particles in the Universe). We followed the processing technique that we had earlier used when analyzing the 2016 samples. Visualization of the spectra essential for the analysis (in the form of ROOT histograms) was fulfilled, and (in case of the 2017 samples) data cards for the statistical analysis were generated. As a result, the expected and experimentally observed exclusion regions (at the confidence level of CL=95%) for possible chargino and neutralino masses were found for the signal being searched for. Based on “alternative” samples generated by the Monte Carlo (MC) method, a number of systematic uncertainties in calculating the expected yield of background and signal events were estimated. In this case, the distributions of events in quantity MT2 were exploited. Our calculations have shown that the main sources of the uncertainties are due to the finite energy resolution for the reconstructed hadronic jets and energy scale ambiguities for both the jets themselves and particles with low transverse momenta not clustered into the jets. A significant contribution also results from theoretical uncertainties associated with the choice of the parton momentum distribution density and the corresponding renormalization (μR) and factorization (μF) scales. A substantial uncertainty is generated by the ambiguity of the weights that put the MC spectra in accordance with the experimentally observed distribution of events in the number of primary vertices. In case of the signal, there are additional uncertainty contributions coming from the difference in methodology for the signal and

background simulations. Some other, less significant, sources of systematic uncertainties have been also taken into account. The total systematic uncertainty is represented by the “error band” in the MT2 distributions of events, which allows one to get a more adequate interpretation of the CMS results.

The work was supported in part by grants of the NAS of Ukraine (NASU) within the targeted research program “Collaboration in advanced international projects on high-energy and nuclear physics” and the “NASU informatization program”.

FOUR b-QUARK PRODUCTION IN ELECTRON-POSITRON ANNIHILATION

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Production of two b anti-b quark pairs in annihilation of electrons and positrons is studied at the tree level of the perturbative quantum chromodynamics (pQCD). The considered processes with the heavy quarks and the light jets correspond to the 2nd, 3rd, and 4th orders of pQCD. The final states of parton processes contain four bottom quarks along with one or two gluons or a pair of u,d,s,c quark-antiquarks. The hard-parton events are generated with MadGraph5_aMC@NLO, parton showers are simulated taking advantage of Pythia 8.

Integral cross sections and differential distributions of bottom quarks in transverse momentum pT and rapidity are calculated for longitudinally polarized electrons and positrons with energies of 500 GeV. The region of the quark and jet pT and invariant masses of b quark pairs, where application of the pQCD methods is justified, is considered. For b quarks with the largest transverse momentum "forward-backward" asymmetries of the cross sections are obtained. The helicity asymmetries of b quarks with polarized leptons in the initial state are evaluated in the leading order of pQCD. The polarization observables are shown to take on values that can be measured. Such measurements may be feasible in experiments at ILC and CLIC.

POLARIZATION EFFECTS IN ELASTIC DEUTERON-ELECTRON SCATTERING

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The differential cross section and some polarization observables (PO’s) for the elastic reaction induced by deuteron scattering off electrons at rest are calculated in the one-photon-annihilation (Born) approximation. Special attention is given to the kinematical conditions; that is, to the specific range of incident energy and transferred momentum. The special interest of this reaction is to access very small transferred momenta. Analytical expressions for PO’s are obtained under condition that all the particle polarizations, both vector and tensor, are defined in the rest frame of the target

electron. Numerical results, at the deuteron beam energies from 5 GeV up to 200 GeV and the electron scattering angles up to 20 mrad, plotted are. Two single-spin PO's due to tensor polarization of the initial deuteron (analyzing power or polarization asymmetry) and the scattered one (deuteron polarization) as well all the possible six double-spin PO's caused by vector polarizations of a particle in the reaction are considered.

CHARGED PION PRODUCTION IN THE ANNIHILATION REACTIONS $e^+ + e^- \to p + \bar{n} + \pi^-$ AND $e^+ + e^- \to \bar{p} + n + \pi^+$

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The non-resonant mechanism in the reactions $e^+ + e^- \to p + \bar{n} + \pi^-$ and $e^+ + e^- \to \bar{p} + n + \pi^+$ is investigated in frame of the one-photon annihilation approximation. The description of the hadronic phase space in terms of invariant variables and formalism based on the use of invariant amplitudes, developed were by us earlier for the reactions with the neutral pion. Application of this formalism for the reactions with the charged pions requires some modifications to fulfill the gauge invariance and to account for an additional contribution due to diagram with the pion pole. Two different variants of such modifications, which lead to dipole and monopole asymptotic behavior of the pion electromagnetic form factor, are considered. Analytical expressions for the double- and single differential distributions over invariant variables obtained are and the total cross section derived is by numerical integration. Numerical results are plotted for the squared total beams energy in c.m.s. s = *5, 6, 10, 16 GeV*^{2}.The calculations are performed for the $p\bar{n}\pi^-$ channel and the rules to proceed to the $p\bar{n}\pi^-$ channel are formulated for every distribution.

MANIFESTATION OF HEAVY 3/2-SPIN LEPTON IN LARGE-ANGLE $e^+ + e^- \to \gamma + \gamma$ REACTION AT HIGH ENERGIES

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Manifestation of the heavy 3/2-spin lepton ($h^{\pm}$), as possible virtual intermediate state in Feynmann diagrams, have been searched in the $e^+ + e^- \to \gamma + \gamma$ reaction at

high energies and large photon angles. The spin-vector field Ψ_α of the 3/2-lepton is described by the Rarita-Schwinger one and phenomenological Lagrangian of $h^{\pm}e^{\pm}\gamma$ - interaction is chosen similarly to interaction of Δ isobar with nucleon and γ quant. It contains two independent structures with dimensional constants $[g_1] = [M^{-1}]$ and $[g_2] = [M^{-2}]$. The differential cross section and polarization asymmetries have been calculated for the case when both beams are polarized longitudinally along their directions, as well transversally, in the reaction plane, and normally, perpendicularly to it. Numerical estimations are performed in wide diapason of the collision energy and parameters entering phenomenological Lagrangian.

SPLITTING OF ENERGY GAP IN SUPERFLUID NEUTRON MATTER WITH SPIN-TRIPLET ANISOTROPIC p-WAVE PAIRING AT NUCLEAR AND SUPRANUCLEAR DENSITIES IN SUPERSTRONG MAGNETIC FIELDS

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The nonlinear integral equations for the components of the order parameter of dense superfluid neutron matter (SNM) with spin – triplet anisotropic *p* – wave pairing (similar to pairing in ^{3}He−A_2 in magnetic fields, i.e. with spin S=1 and orbital moment L=1 of anisotropic Cooper pairs of neutrons) in superstrong magnetic fields (exceeding the 10^{17} G) are solved analytically in the limit of zero temperature. These solutions are derived for the family of so-called BSk – type generalized parameterizations of the effective Skyrme forces (with three terms dependent on density n) in neutron matter. The obtained general solutions for splitting of energy gap in SNM in superstrong magnetic fields (see also [1]) are specified for the generalized BSk21 parameterization of the effective Skyrme forces at nuclear density n_0=0,17 fm^{-3} and at two supranuclear densities n=1,25·n_0 and n=1,5·n_0 for magnetic fields 10^{17} G ≤ H ≤ 10^{18} G. The main results are the splitting of energy gap and its asymmetry which increase nonlinearly with growing both superstrong magnetic field H and supranuclear density $n>n_0$. Such effects in SNM might exist in liquid outer core (at densities $n \square n_0$) in strongly magnetized neutron stars known as "magnetars".

1. A.N. Tarasov, About magnetic properties of superfluid neutron matter with spin – triplet anisotropic p – wave pairing in superstrong magnetic fields and at supranuclear densities. Low Temp. Phys. 49, No. 10 (2023) 1111-1121.

ELECTRON-POSITRON ANNIHILATION IN A PAIR OF SHORT-LIVED BARYONS: CONTRIBUTIONS OF MAGNETIC AND ELECTRIC DIPOLE MOMENTS

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The annihilation of an electron-positron pair into a pair of short-lived baryon-antibaryon with subsequent decay of each baryon into another baryon and a meson is studied. For this purpose, the polarized states of intermediate baryons are considered. In addition, the electric dipole moment of intermediate baryons (Λ and Λ_c) is introduced in the consideration. This electric dipole moment is responsible for the CP symmetry breaking in this process. Using a simplified Monte Carlo simulation, "pseudo-data" of 500,000 events were generated for each process. Using these statistics, the parameters of the scattering cross-section were selected and parameter errors and correlation matrices were obtained. The accuracy with which the electric dipole moment of short-lived baryons can be measured for a given number of events was estimated. In addition, the effect of the initial state electron polarization on the error of the scattering cross sections is investigated. It is shown that the presence of the polarization of the initial electron beam can significantly reduce the error of the obtained parameters.

The results can be useful in the analysis of experiments at e^+e^- colliders in Japan (KEKB) on the Belle II detector and in China (BEPC) on the BESIII spectrometer.

DYNAMICS OF DEFORMATION FORCES IN SINGLE-PARTICLE SPECTRA OF ODD 2s1d-SHELL NUCLEI

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To study the properties of collective forces that give rise to a stable deformation of odd 2s1d-shell nuclei in the ground and low-laying single-particle excited states, we have developed a model-independent evolutionary approach /1/ that allowed to extract the information on the form of nuclear potential directly from experimental data on the energies, spins and parities of the ground and low-laying single-particle excited states and the measured probabilities of electromagnetic transitions between them. With the increase of mass number of all studied odd 2s1d-shell nuclei ^{23}Na, ^{27}Al, ^{31}P and ^{35,37}Cl, the dominant deformation of the shape of nuclei in low-laying states changes from quadrupole to hexadecapole and further to hexacontatetrapole. The single states and the continuous sets of states with abnormally weak deformation are found in the single-particle spectra of the nuclei studied. The points of shape phase transitions with

a change in the multipolity of deformation are found in the sin-gle-particle spectrum of ^{37}Cl nucleus.

1. V.Yu. Korda, I.S. Timchenko, L.P. Korda, O.S. Deiev, and V.F. Klepikov // Nucl. Phys. A 1025 (2022) 122480.

SEARCH FOR DARK MATTER CANDIDATE PRODUCED IN ASSOCIATION WITH A HIGGS BOSON AND TAU LEPTONS AT √S=14 TEV

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A search for dark matter produced in association with a Higgs boson in final states with two τ-leptons and missing transverse momentum, pp→A→ahτ+τ-. is presented. The corresponding experimental analysis between 2015-2018 years used 139 fb^{-1} of proton–proton collision data at √s = 13 TeV collected by the ATLAS experiment at the LHC, [1]. The results are interpreted in terms of a 2HDM+a model with physics beyond the Standard Model featuring two scalar Higgs doublets and a pseudoscalar singlet field, [2]. Two sets of parameters, derived from experimental exclusion limits, for calculating the axions and bosons production cross sections were selected using the MADGRAPH5@NLO computer program. The obtained information, together with kinematic constraints on the transverse momentum and angular distribution of axions and bosons, allows us to conclude the existence of CP-odd Higgs bosons with a mass in the region of 400 GeV and a dark matter candidate, the axion, with a mass of up to 200 GeV. The obtained data demonstrate the priority of the second scenario, BP2, which correlates with the latest experimental constraints, [2].

1. The ATLAS Collaboration. Search for dark matter produced in association with a Higgs boson decaying to tau leptons at √s = 13 TeV with the ATLAS detector, CERN-EP-2023-072, arXiv:2305.12938 [hep-ex].
2. ATLAS Collaboration. Combination and summary of ATLAS dark matter searches interpreted in a 2HDM with a pseudo-scalar mediator using 139 fb^{-1} of √s = 13 TeV pp collision data. CERN-EP-2023-088, arXiv:2306.00641 [hep-ex].

ANALYSIS OF THE POLARIZATION CHARACTERISTICS OF PROTON SCATTERING BY NUCLEI IN THE BORN APPROXIMATION

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Analytical expressions for the amplitudes and observables for the elastic scattering of protons by ^{40}Ca, ^{58}Ni, ^{120}Sn, and ^{208}Pb nuclei were obtained on the basis of the second Born approximation. Using of the second Born approximation is due to the fact that the polarization of nucleons, calculated in the first Born approximation with the Hermitian potential, is equal to zero.

It is shown that taking into account the second Born approximation makes it possible to satisfactorily describe the available experimental data at the energies E_p = 150÷320 MeV.

The results of the calculations obtained in the Born approximation are compared with those in the optical model approach.

The performed analysis shows a reasonable agreement between the calculated observables with the existing experimental data when using both of these approaches. The advantage of the Born approximation consists in the use of the analytical expressions for the scattering amplitudes and observables, which cannot be obtained in the non-relativistic optical model.

SPIN-POLARIZATION EFFECTS IN THE PROCESS OF SYNCHROTRON RADIATION IN A SUPERCRITICAL MAGNETIC FIELD

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Within the framework of quantum field theory, a study of the synchrotron radiation process of an electron in an external magnetic field has been conducted. Analytical expressions for the probabilities of the process have been found for arbitrary field values, taking into account particle polarization. It is demonstrated that in the case of a supercritical field, where radiation is emitted perpendicular to it, the probabilities of the ground and spin-flip channels become equalized. The Stokes parameters of radiation are determined, showing that it is fully polarized for both spin projections of the initial electrons. It is shown that when the electron radiates along the magnetic field, right circular polarization occurs while radiating perpendicular to it results in normal polarization for the ground spin state and anomalous polarization for the inverted state. The dependence of the differential radiation intensity on the angle is found, indicating that with an increase in the magnetic field, a synchrotron radiation cone appears perpendicular to the field. In the case of an unpolarized electron beam, when radiation is emitted perpendicular to the field, linear polarization depends on the magnetic field strength. In a subcritical field, radiation will be normally polarized, while in a supercritical field, the degree of polarization approaches zero.

THE FISSION ENERGY OF AMERICIUM ISOTOPES, CONSIDERING THE EMISSION OF NUCLEAR PARTICLES

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Establishing the energy capacity is one of the most critical problems in the physics of fission of atomic nuclei. Its indicator can be fission fragments' average kinetic energy (AKE), which can be measured experimentally. Currently, the theory is able to take into account the influence of the temperature of the initial nucleus on the value of fission energy. Still, solving such a problem when considering the emission of nuclear

particles - from alpha or beta particles, neutrons is a difficult task of the nuclear theory. This paper presents the results of the calculation of the AKE for americium isotopes within the framework of the post-fission approximation, which allows obtaining the mass-charge spectra of fission fragments of these isotopes for different temperatures, without and taking into account the emission of nuclear particles. Within the framework of this approach, the total kinetic energy of fission, or AKE of nuclear fragments, requires knowledge of $F(A_i)/F(Z_i)$ – mass/charge probabilities of fission fragment yields with mass/charge A_i/Z_i, respectively. The fission energy value Wi for the two fragment cluster is found by the formula $W_i=E_0 - U_i$, where E_0 is the binding energy of the original isotope N_p, and U_i is the sum of the binding energies of the fission fragments of the ith cluster. Then, for the jth A_m isotope, the AKE is found as:

$$\overline{W}(j) = \sum_{\{A_i\}} W_i \cdot F_j(A_i) = \sum_{\{Z_i\}} W_i \cdot F_j(Z_i)$$

We discuss the role of nuclear particle emission, temperature, and shells 50 and 82 in shaping the features and topology of differential energy spectra.

Section 2. Fundamental research at intermediate and high energies

FINE STRUCTURE OF MAGNETIC DIPOLE RESONANCE IN SD CORE AND 1F2P SHELLS

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An overview and analysis of experimental research related to the development of magnetic dipole resonance (MDR) in the nuclei of sd and 1f2p shells, conducted at the NSC KhPTI, was carried out. Analysis of the position of the center of gravity (CG), fine structure and overall strength of the MDR in paired nuclei, allowing the transfer of the position of the fine structure of the MDR in unpaired nuclei ^{34}Cl, ^{38}K. It was revealed that the position of the CT MDR in unpaired nuclei with an unaligned $d_{5/2}$-subcolumn is in the region of excitation energy 5–6 MeV, which is due to the energy of spin-orbital splitting. For unpaired nuclei with a filled $d_{5/2}$-subcolumn, the CT MDR has an excitation energy of 8–10 MeV, and the fragments of the molded MDR take part in the nn- and pp- pairing with the $d_{5/2}$-subcolumn.

Also identification (MDR) on awakening stages in unpaired nuclei. The full strength of the MDR in awakening countries does not indicate that the Kurata sum has been abolished from the rules. This is due to the increased role of the collective movement in the structure of the awakening camps. The fine structure of resonance-like structures (RLS) in the nuclei of sd and 1f2p shells has been aligned. A complex structure of the RPS for the cores of the 1f2p shell is indicated, which may also be associated with the greater role of the collective movement in the structure of awakening camps.

CROSS SECTIONS OF THE ^{113}In(γ,n)^{112m,g}In REACTION FOR THE γ-SCENARIO OF THE STELLAR NUCLEOSYNTHESIS

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The vast majority of naturally abundant isotopes of trans-iron chemical elements were synthesized in the stellar scenarios of slow (s) and rapid (r) neutron capture of nuclear reactions. However on the proton-enriched side of the valley of stability there is a group of about 35 so-called p-nuclei which could not be made in these processes because of the relation of their masses with the masses of nuclei of neighboring isotopes and isobars. The indium-113 (^{113}In) isotope is included in this group although additionally could be formed in the r-process in small amounts. To understand the stellar nucleosynthesis of the p-nuclei there is need to know a large set of certain nuclear data among which the very important ones are proton and photon induced nuclear reaction cross sections.

In this work using the electron linear accelerator (LINAC-30) of the NSC KIPT (Kharkiv) and off-line high resolution gamma-ray spectrometry the integral yields of the ^{113}In(γ,n)^{112m,g}In photonuclear reaction producing the isomeric and ground levels of the residual $\left(T_{1/2}^{m} = 20.56\ m,\ J_{m}^{\pi} = 4^{+},\ T_{1/2}^{g} = 14.97 m,\quad J_{g}^{\pi} = 1^{+}\right)$ were measured in the bremsstrahlung end-point energy range from the threshold (9.44 MeV) to 14 MeV - the relevant one for the γ-scenario modelling. The individual yields for each member of the ^{112m,g}In isomeric pair production were defined from the intensities of the following γ-rays. The method [1] of approximation of the experimental yield of a photonuclear reaction by a parametric function connecting it with the cross section was used to determine the latter. Analyzing the decay curve of the genetically coupled ^{112m,g}In isomeric pair we were able both to determine new values of the branching coefficients of the γ-rays following the ^{112g}In nuclide decay which turned out to be different from the currently accepted ones [3] and to derive the correct values of the experimental reaction yields.

The experimental data are compared with the predictions of the Hauser-Feshbach statistical theory of nuclear reactions implemented by the NON-SMOKER [4] and TALYS [5] computer codes varying the models of nuclear level density and radiation strength function.

1. O. Itoh et al. Journal of Nuclear Science and Technology, 48, 834 (2011).
2. I. Semisalov, A. Chekhovska, Ye. Skakun, S. Karpus, V. Kasilov. Appl. Rad. and Isotopes, 176, 10984, (2021).
3. https://www.nndc.bnl.gov/nudat2/.
4. J.Koning, S. Hilaire and M.C. Duijvestijn, “TALYS-1.0”, Proceedings of the International Conference on Nuclear Data for Science and Technology, April 22-27, 2007, Nice, France, editors O.Bersillon, F.Gunsing, E.Bauge, R.Jacqmin, and S.Leray, EDP Sciences, 211 (2008).

DIFFERENTIAL CROSS SECTIONS OF GAMMA RADIATION GENERATION FROM THE (p,γ) REACTION ON AVERAGE ATOMIC WEIGHT NUCLEI IN THE PROTON ENERGY INTERVAL 1 – 2.5 MeV

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The paper presents the results of measuring the differential cross sections of the generation of gamma radiation from the reaction (p,γ) on the nuclei of titanium, vanadium, chromium and nickel isotopes. Experimental studies were carried out at the ESU-5 accelerators of the NSC KIPT and ‘Sokol’ in the energy range of accelerated protons from 1 to 2.5 MeV on isotope targets. Gamma quanta with energies in the range from 90 keV to 1400 keV were measured by HPGe and Ge(Li) detectors.

The data obtained can be used in the PIGE technique for analyzing impurities in various materials and alloys.

The numerical data of the obtained cross sections are posted in the international nuclear database IBANDL.

This work was carried out with partial support from the IAEA (project CRP No. 16698).

INVESTIGATION OF THE PARTIAL CHANNEL FORMATION OF THE GROUND STATE OF THE ^{8}Be NUCLEUS IN ^{14}N(γ,αα^{6}Li) REACTION

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The analysis of multiparticle photoreactions is of particular interest for studying the properties of virtual cluster structures in nuclei, their influence on the mechanism of nuclear reactions and on the dynamics of nucleosynthesis in the Universe. The ^{14}N nucleus can be considered as an intermediate one between the ^{12}C and ^{16}O nuclei, which are considered as 3- and 4-α cluster structures in the cluster model.

The ^{14}N(γ,2α^{6}Li) reaction was studied, the events of which had been reconstructed from digital stereo frames of photon reactions obtained by photographing the track 4π detector (diffusion chamber in a magnetic field on a beam of bremsstrahlung γ quanta with the endpoint energy $E_{\gamma\max}$ = 150 MeV). Using a digital technique, the tracks were measured and the kinematic parameters of the particles were obtained [1].

A resonance was revealed in the excitation dependence of the 2α-particle system, which was identified as the ground state of ^{8}Be nucleus. The partial channel ^{14}N(γ,^{6}Li)^{8}Be$_0$ with the subsequent two-particle decay ^{8}Be→α+α was resolved and the cross section of this channel was measured. The analysis of energy and angular distributions of particles at each stage of decay is performed.

1. Afanasiev S.N., Afanasieva I.O. Digital study of the ^{14}N(γ,2α)^{6}Li reaction // Problems of Atomic Science and Technology. 2023. №3(145), p. 33 37.

ANALYSIS OF NMR SYSTEM FOR NUCLEI POLARIZATION MEASUREMENT IN NEUTRON SPIN FILTER

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In a neutron spin filter, ^{3}He nuclear polarization is achieved using the optical pumping technique. The necessity for remote (up to 100 m away) monitoring of the ^{3}He polarization requires the use of additional synchronizing elements when transmitting signal via coaxial lines. Computer simulation of the power supply regime for the radiofrequency (RF) coils was performed to provide appropriate magnetic field generation in the target cell with polarized ^{3}He gas. Computation of magnetic flux induced by ^{3}He and hydrogen nuclear spin precessions was carried out. The signal amplitudes sensed by pickup coils from the helium cell and a cell filled with pure

water were derived. The signal-to-noise ratio was calculated for the NMR signal from protons in water. Options were considered for reducing the reactive component of the cable impedance with inductance when powering the RF coils remotely. Technical specifications of the pick-up and RF systems have been developed to provide the ^{3}He nuclear polarization measurement with a relative accuracy to about 5% in the dynamic range of NMR absorption signals of no less than 120 dB and depolarization during the measurement of no more than 1%. Also, parameters of the confining magnetic field sweep, as well as requirements for the ADC to record spectra to a computer have been calculated. The LTspice and SciLab software packages were used to calculate the amplitude and phase characteristics of currents and voltages on the circuit elements of the RF coils and the characteristics of the NMR signals and resonance parameters.

ANALYSIS OF EXPERIMENTAL DATA ON THE DISINTEGRATION OF ^{12}C, ^{14}N AND ^{16}O NUCLEI BY HIGH-ENERGY PROTONS

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Experimental studies based on the application of streamer and diffusion chambers, as well as photo emulsion techniques, allow observing rare multiparticle events with the recording of track information on nuclear reaction products. The data obtained are widely used in nuclear astrophysics to study stellar nucleosynthesis processes. The collected data set [1] on experimental results of the cross sections of high-energy protons interaction with ^{12}C, ^{14}N, and ^{16}O require more detailed study and analysis. Since these experimental techniques do not provide complete information on all possible nuclear reaction channels, using Talys allows for a more detailed study of the contribution of intermediate reactions. Particular attention is paid to forming intermediate ^{9}B ($t_{1/2}$= 800 zs) and ^{8}Be ($t_{1/2}$= 81.9 as) and their contribution. The calculated spectra of the accompanying neutron background are obtained, and its influence on the production of additional track events is estimated.

1. www-nds.iaea.org/exfor

CPT/PT INVARIANT ISOSPECTRAL HAMILTONIANS OF SUPERSYMMETRIC QUANTUM MECHANICS WITHIN THE INVERSE SCATTERING FORMALISM

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One of the unusual properties of the method of the Inverse Scattering Problem (ISP) is the ambiguity in the restored, by scattering phases and the spectrum of the bound states, potential. The same ambiguity arises upon the construction of isospectral Hamiltonians in the formalism of Supersymmetric Quantum Mechanics (SQM). Although the correspondence between the ISP and the SQM was established almost

since the appearance of the latter, it works either in the case of stationary isospectral Hamiltonians, or exclusively for non-stationary ones. We propose a new approach to the construction of isospectral Hamiltonians, that makes it possible, in frameworks of the ISP formalism, to pair stationary and non-stationary Hamiltonians with an (almost) equivalent spectrum of state energy values. The potential of the new nonstationary isospectral Hamiltonian, constructed out in this way, contains a non-trivial imaginary part that reflects possible dissipation in the system. The conditions under which the non-stationary Hamiltonian with complex potential has a real-valued spectrum, corresponding to the PT-symmetric Hamiltonians of C. Bender, have been found. Thus, we implemented the CPT/PT correspondence of stationary and non-stationary isospectral Hamiltonians for the first time. This work is performed within the Cambridge-NRFU 2022 initiative "Individual research grants for researchers in Ukraine (supported by the University of Cambridge, UK)", project №2022.02/0052 (A.J. Nurmagambetov).

STUDY OF OCTUPOLE DEFORMATION OF NUCLEI IN CHAINS OF ISOTONS AND ISOTOPES IN THE REGION OF ACTINIDES IN THE MEAN FIELD APPROXIMATION

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Calculations of the properties of even-even isotones N=134 of nuclei with Z=86-96, as well as isotopes of Rn with A=218-226 and Pu with A=222-230 were carried out in the Hartree-Fock-Bogolyubov approximation, taking into account the axial symmetry of nuclei with forces Skyrme (SkM*, SLy4). This work is a continuation of our previous study of the properties of Ra [1], Th and U [2] isotopes. As in [1, 2], in the calculations we used the computer code HFBTHO v2.00d [3]. Pairing of nucleons in nuclei is described by zero-range pairing forces of mixed type with different sets of pairing force constants. In the calculations we used constrained conditions on the parameters of the quadrupole β_2 and octupole β_3 deformations of the nuclei. To define more precisely the minimum value of the total energy of the nucleus E in the vicinity of the minimum of the dependence $E(\beta_2, \beta_3)$, the calculations were carried out without constrained conditions on β_2 and β_3. It is shown that for the considered chains of isotones and isotopes, as well as for the chains of isotopes of Ra [1], Th and U [2], the deformation of β_3 nuclei strongly depends on the choice of parameters of the nucleon pairing force and weakly depends on the type of parameterization of the Skyrme forces used in this study. Overestimated values of the pairing force constants lead to a decrease or complete disappearance of deformation in the considered chains of isotones and isotopes.

1. V.I. Kuprikov, V.N. Tarasov // Phys. At. Nucl., 2021, 84, №6, pp. 796–803.
2. V.N. Tarasov et al. // Probl. Atom. Scien. Techn., 2023, 3(145), pp. 8-11.
3. M.V. Stoitsov et al. // Comput. Phys. Commun. 2013, 184, pp. 1592-1604.

CROSS-SECTIONS OF MULTIPARTICLE PHOTONUCLON REACTIONSON ^{92}Mo AND ^{94}Mo NUCLEI

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The development of modern theoretical models for describing the mechanisms of nuclear reactions and program codes based on these concepts requires verification with data on cross-sections for multiparticle photonuclear reactions (γ,*x*n) and (γ,*x*n*y*p). To date, there is no comprehensive information on multiparticle reactions in international databases. Differences between experimental cross-sections measured in different laboratories are observed. This led to the emergence of works on analyzing the reliability of previously measured cross-sections and, as a consequence, stimulated new experiments.

The results of studies of the ^{92}Mo and ^{94}Mo nuclei photodesintegration at bremsstrahlung end-point energy $E_{\gamma max}$ = 35–95 MeV are presented. Experiments were performed on electron beam of the linac LUE-40 RDC "Accelerator" NSC KIPT using an activation method and off-line γ-ray spectrometric technique. Experimental flux-averaged cross-sections $\langle\sigma(E_{\gamma max})\rangle$ were determined for the formation of ^{90}Nb, ^{90}Mo, ^{93m}Mo and ^{92m}Nb nuclei in reactions on natMo targets. A comparison was made of the experimental values of $\langle\sigma(E_{\gamma max})\rangle$ with data from the literature.

The comparison with the theoretical calculations of the cross-sections $\langle\sigma(E_{\gamma max})\rangle$ was performed, using cross-sections $\sigma(E)$ from the TALYS1.95 code. The contributions of the ^{94}Mo isotope in yields of the reactions ^{nat}Mo(γ,xn)^{93m}Mo and ^{nat}Mo(γ,p*x*n)^{92m}Nb were calculated. It has also been shown that the main contribution to the total yield of nuclei ^{90}Nb and ^{90}Mo on natural molybdenum comes from the isotope ^{92}Mo.

INVESTIGATION OF MULTIPARTICLE PHOTONUCLEAR REACTIONS CROSS-SECTIONS AT THE RDC "ACCELERATOR" NSC KIPT

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Investigation of the mechanism of nuclear reactions (direct, compound, pre-equilibrium, etc.) is performed using experimental data on photonuclear reactions. To test and update modern computational codes, such as TALYS, EMPIRE, CCONE, COH3, used to simulate photoinduced reaction cross-sections, experimental values of the cross-sections $\sigma(E)$ and $\langle\sigma(E_{\gamma max})\rangle$ are needed at a wide range of atomic masses and energies. However, at present, the available experimental data in the GDR region, obtained in different laboratories, are not always consistent. There is also a lack of data on photoproton and multiparticle photonuclear reactions (including emission of small clusters).

This work presents the results of a study of multiparticle photonuclear reactions performed at the RDC "Accelerator" NSC KIPT on the linear electron accelerator

LUE-40 over the last five years. Experimental flux-averaged cross-section $\langle\sigma(E_{\gamma max})\rangle$ were obtained for reactions on nuclei with atomic mass 27 < A < 181 at bremsstrahlung end-point energy in the range $E_{\gamma max}$= 30–100 MeV.

To obtain experimental values of cross-sections, the activation γ-spectrometric method was used. In the experiments, two methods were used to clean the bremsstrahlung γ-flux from the electron component: using an aluminum absorber or a deflecting magnet. The bremsstrahlung flux incident on a target was simulated using the GEANT4.9.2 code and monitored by the yield of the ^{100}Mo(γ,n)^{99}Mo reaction.

The results of these experiments were compared with data available in the literature and estimated values, calculated using cross-sections σ(*E*) from the TALYS code. The obtained $\langle\sigma(E_{\gamma max})\rangle$ are presented in the international EXFOR database.

ISOMERIC RATIOS IN HIGH THRESHOLD PHOTONUCLEAR REACTIONS ON NUCLEI Zr, Ni AND Mn

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Isomeric ratios IR of nuclei-products of photonuclear reactions make it possible to determine the population of the metastable (*m*) state of the nucleus under study relative to its ground (*g*) state. Such information is useful in studying issues related to nuclear reactions and nuclear structure, such as the spin dependence of nuclear level density, angular momentum transfer, nucleon pairing, and shell effects. These experimental data are used to refine the theory of gamma transitions and test theoretical models of the nucleus.

In experiments with the use of bremsstrahlung flux, the isomeric ratio $IR(E_{\gamma max})$ is measured as the ratio of yields $Y(E_{\gamma max})$ or the flux-averaged cross-sections $\langle\sigma(E_{\gamma max})\rangle$ formation of nuclei-product in an isomer and the ground states. The study of $IR(E_{\gamma max})$ using photonuclear reactions has the advantage that the γ-quantum introduces small angular momentum and does not change the nucleus nucleonic composition.

The work investigates isomeric pairs of nuclei that are products of photonuclear reactions on Zr, Ni and Mn. Isomeric ratios $IR(E_{\gamma max})$ were estimated in the energy range $E_{\gamma max}$ up to 100 MeV using cross-sections $\sigma(E)$ from the TALYS1.95 code and the bremsstrahlung flux obtained by simulation in the GEANT4.9.2 code. Calculation of the $IR(E_{\gamma max})$ values was performed for real conditions of the linear electron accelerator LUE-40 RDC "Accelerator" NSC KIPT.

PHOTOPRODUCTION OF ^{95}Nb ON NATURAL MOLYBDENUM AT BREMSSTRAHLUNG END-POINT ENERGIES UP TO 95 MeV

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Photodisintegration of molybdenum stable isotopes was performed in many works. However, in the case of the ^{95}Nb nucleus production, experiments were carried out to define the isomeric ratio in the region of the giant dipole resonance and at intermediate energies. There are little data in the literature for reactions of the formation of the ^{95m}Nb nucleus in a metastable state on ^{nat}Mo. In [1] such results were obtained in the energy range 30–68 MeV and presented as the average cross-section per equivalent photon $\langle\sigma(E_{\gamma max})\rangle_Q$.

The work presents the results of the study of photoproduction of ^{95m}Nb nucleus on natural molybdenum. Measurements were carried out using an activation method and off-line γ-ray spectrometric technique, at the electron beam of the linac LUE-40 RDC "Accelerator" NSC KIPT. The experimental flux-averaged cross-sections $\langle\sigma(E_{\gamma max})\rangle_m$ for the ^{nat}Mo(γ,xnp)^{95m}Nb reaction at the bremsstrahlung end-point energy range $E_{\gamma max}$ = 38–93 MeV have been obtained and compared with the data [1]. Based on the known values of the isomeric ratio $IR(E_{\gamma max})$ for the ^{95g,m}Nb pair, the estimated values $\langle\sigma(E_{\gamma max})\rangle_g$ for the formation of ^{95}Nb in the ground state and total cross-sections $\langle\sigma(E_{\gamma max})\rangle_{tot}$ for the studied reaction were determined. The contribution of the ^{96}Mo(γ,p) reaction in the photoproduction of the ^{95g,m}Nb nucleus on ^{nat}Mo was defined.

The theoretical values of the yields $^{Ym,g}(E_{\gamma max})$ and flux-averaged cross-sections $\langle\sigma(E_{\gamma max})\rangle_{m,g}$ for the ^{nat}Mo(γ,xnp)^{95m,g}Nb reactions were calculated using the cross-sections $\sigma(E)$ from the TALYS1.95 code for six different level density models. The comparison showed a significant excess of the experimental results over the theoretical estimated $\langle\sigma(E_{\gamma max})\rangle_{m,g}$.

1. K. Masumoto, T. Kato, N. Suzuki, Activation Yield Curves Of Photonuclear Reactions For Multielement Photon Activation Analysis // Nucl. Instrum. Meth. 157 (1978) 567.

PRODUCTION OF THE ^{55,56,57}Co ISOTOPES IN PHOTONUCLEAR REACTIONS ON ^{nat}Ni AT ENERGY UP TO 95 MeV

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At present, experimental studies of photo-disintegration of nuclei in the photon energy range above the GDR and up to the threshold of pion production (E_{th} = 145 MeV) are in high demand. This is due to the change in the mechanism of interaction of photons with nuclei: photodisintegration of nuclei through excitation of

GDR and quasi-deuteron photo-absorption. However, the lack of experimental data in this energy range severely restricts both the general insight into the processes of γ-quantum interaction with nuclei and the model-approach testing capabilities. There is a particular lack of data for photonuclear reactions with the escape of charged particles.

The photonuclear production of the $^{55\text{-}57}$Co isotopes on natural nickel targets was investigated. The experimental data were collected in the experiments carried out at the linac LUE-40 RDC "Accelerator" NSC KIPT at bremsstrahlung end-point energy in the range $E_{\gamma max}$ = 35–95 MeV. For this purpose, an activation method and off-line γ-ray spectrometric technique were used. Experimental flux-average cross-sections $\langle\sigma(E_{\gamma\max})\rangle$ were obtained for the studied reactions, which are the cumulative result of two processes: ^{nat}Ni(γ,p*x*n) and ^{nat}Ni(γ,*x*n)^{55,56,57}Ni (EC/β^+) → ^{55,56,57}Co. Comparison of the experimental data discussed in this contribution with literature data, measured using the method of induced activity, are in a good agreement.

Calculation of flux-average cross-sections $\langle\sigma(E_{\gamma\max})\rangle$ of reactions ^{nat}Ni(γ,p*x*n)^{55,56,57}Co and ^{nat}Ni(γ,*x*n)^{55,56,57}Ni was performed for all stable Ni isotopes using the cross-sections $\sigma(E)$ from the TALYS1.95 code. We see the experiment and theory agree in the case of the ^{56,57}Co formation. However, a significant discrepancy is observed when the formation of ^{55}Co is considered. The dominant reaction channels for the cumulative yields of ^{55,56,57}Co nuclei on natNi were determined.

This work was supported by the Slovak Research and Development Agency under No. APVV-20-0532 and APVV-22-0304, and the Slovak grant agency VEGA (Contract No. 2/0175/24). Funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I03-03-V01-00069.

DETERMINATION OF ISOMERIC YIELD RATIOS IN THE REACTION (γ,n) FOR ^{165}Ho

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It is known that for the isotope ^{164}Ho the isomeric state is characterized by spin parity $J_p=6^-$, energy 140 keV, and half-life $T_{1/2}$=37.0 min.

The report presents the results of determining the isomeric ratios of the yields obtained in the reaction ^{165}Ho(γ,n)^{164m,g}Ho on the M-30 microtron of the Institute of Electron Physics of the NAS of Ukraine at the maximum energies of the braking spectrum $E_{\gamma max}$=10.0-18.0 MeV by measuring instrumental gamma lines from of decay ^{164m}Ho. The population intensity of the isomeric state was determined by the gamma line E_m = 37.5 keV and that of the ground state by the average intensity of the two lines E_γ = 73.5 keV and E_γ = 91.5 keV.

The isomeric ratios were calculated according to the well-known formula [1], which takes into account the number of registered pulses in the photopeaks responsible for the decay of the isomeric and ground states during irradiation in a beam of bremsstrahlung gamma quanta, as well as coefficients that take into account

miscalculations and superimposition of pulses, the intensity of gamma transitions, that populate the isomeric and ground states, which accounts for the act of decay of the activated nucleus, the efficiency of registration of the corresponding gamma lines, the self-absorption of gamma quanta in the target and the time function that takes into account the times of irradiation, cooling and measurement.

As a result of the measurements and calculations, the following experimental isomeric ratios of total yields were obtained: $h = Y_m/(Y_m+Y_g) = 1/(1+1/d)$ depending on the maximum energy of gamma quanta: $E_{\gamma max}$ =10.0 MeV $\eta = 0.15$; $E_{\gamma max}$ = 11.0 MeV $\eta = 0.19$; $E_{\gamma max}$ =12.0 MeV $\eta = 0.23$; at $E_{\gamma max}$=13.0 MeV $\eta = 0.26$; $E_{\gamma max}$ =14.0 MeV $\eta = 0.28$; $E_{\gamma max}$ =15.0 MeV $\eta = 0.29$; $E_{\gamma max}$ =16.0 MeV $\eta = 0.297$; at $E_{\gamma max}$=17.0 MeV $\eta = 0.30$; $E_{\gamma max}$ =18.0 MeV $\eta = 0.305$. It can be seen from the given data that the isomeric ratio of yields η above the reaction threshold of ^{165}Ho(γ,n) ^{164m,g}Ho increases, and in the region > 18 MeV, it reaches saturation and is ~ 0.3.

1. Vanska R., Rieppo R. The experimental isomeric cross-section ratio in the nuclear activation technique // Nucl. Instrum. and Meth. –1981. –V.179. –P.525.

USING THE REGGE-DUAL MODEL OF THE F2 PROTON STRUCTURE FUNCTION AT ALL AVAILABLE ENERGIES

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Two decade ago the precise CLAS data on the proton structure function F2 was successfully described within the framework of Regge-dual model which is based on the nonlinear complex Regge trajectories in form of N and Δ isobar resonances dual to the effective bosonic f trajectory in the cross-channel and smooth background based on exotic trajectories dual to the Pomeron. On the other hand he CKMT model for the F2 provided a good description of the HERA data. Here we will try to combine these two approaches, first of all, to adequately take into account the background when describing the already mentioned exact CLAS experiment. This required modification of the non-singlet part of F2, which makes the main contribution to the desired background. In the region of low and moderate Q_2 ($\leq$ 5 GeV^2), which interests us, there is no need to consider QCD evolution, which greatly simplifies the problem.

TWO-EXPONENTIAL T-DEPENDENT DIPOLE POMERON AND ODDERON AMPLITUDE FOR CALCULATING THE CROSS SECTIONS AND PHASE OF ELASTIC PP AND ANTI PP SCATTERING AT HIGH ENERGY

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The article [1] describes the differential cross sections of elastic pp-scattering at high energies using a simple dipole Pomeron amplitude with two t-dependent exponents. This amplitude contains three free parameters and a scaling factor. A

number of inequalities were also obtained for the parameters, which are fulfilled at the obtained values of the parameters.

For calculations of total and differential cross sections and phase, not only for the scattering mentioned above but also for anti-pp-scattering, an amplitude is proposed, which, in addition to the pomeron, contains an odderon and two secondary regions, that is, f- and ω-mesons. The trajectories of the pomeron and odderon have an intersection of 1. In this amplitude, the number of free parameters is equal to 14. They will be determined from experimental data according to the equations of the least squares method by numerical calculations.

1. Norbert Bence, Alexander Lengyel, Zoltán Tarics. A Simple Model for Describing the Minimum Differential Cross-Section of Elastic Proton Scattering on Protons at High Energies. Scientific Herald of Uzhhorod University. Series Physics. Iss. 51. P. 30-38. 2022.

Section 3. Fundamental research of ultra-relativistic particle interaction with single crystals and matter

LOW-ENERGY SPECTRA OF SECONDARY ELECTRON EMISSION FROM DIFFERENT THICKNESSES OF ALUMINUM TARGETS

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Measurements of the outputs of low-energy (E < 50 eV) secondary electron emission from aluminum targets with a thickness of 8 and 50 μm at an initial energy of the primary electron beam of 15 MeV were carried out on the LPE-300 accelerator.

The following data were obtained for the 8-μm target: the low-energy spectrum has a maximum in the region of 0.66 eV; the full width at half height is 1.62 eV, and the value of the total emission is 2.86%.

The following data were obtained for a 50 μm target: the low-energy spectrum has a maximum in the region of 1.29 eV; the full width at half height is 3.16 eV, and the value of the total emission is 2.85%.

A comparison of the spectra of low-energy secondary electron emission for two thicknesses allowed us to conclude that with increasing target thickness:

a) to the spectrum coming from the surface layer, a contribution from electrons coming from the thickness of the target is added;

b) the maximum of the spectrum shifts towards higher energies, and its width increases due to a small addition of electrons that are formed in the thickness of the target.

MODELING THE PASSAGE OF HIGH-ENERGY ELECTRONS THROUGH THIN ALUMINUM FOILS

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The results of using the Geant4 11.2 toolkit to simulate the interaction of high-energy electrons with thin aluminum foil are presented. A computer program was implemented to conduct two series of computational experiments. The energy of primary electrons was 15 MeV in both computational experiments. Simulations were carried out for 8 μm and 50 μm aluminum foils. The dynamics of secondary electron formation along the main beam's axis (perpendicular to the foil surface) were studied depending on the foil's thickness. The threshold for delta electron registration was 4.2 eV. The energy spectra of delta electrons yield in the forward and backward directions were obtained and analyzed. The processes of electron generation in aluminum (secondary, tertiary, etc. electrons) are studied in detail. The simulation results determined the discussed high- and low-energy secondary electron yields.

The calculations presented above were performed using computer resources [1] within the Aalto University School of Science "Science-IT" project.

1. https://scicomp.aalto.fi/triton/

FEATURES OF THERMAL-STIMULATED EMISSION OF SECONDARY ELECTRONS FROM A Cu-Al-Mg ALLOY

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An analysis of the energy spectra of secondary electrons emitted from the Cu-Al-Mg alloy at sample temperatures of 293 K, 523 K, 623 K, and 673 K is presented. Experimental data were obtained in [1] using the spherical capacitor method (scanning potential range from -50 up to +50 V) when samples are irradiated with a beam of primary electrons with an energy of up to 500 eV. The peculiarities of the energy spectra of secondary electrons in the region of retarding potentials and the effect of temperature on their distribution function have been established. It is shown that in the range of the specified temperatures, the distribution of secondary electrons by energy changes, namely: the position of the maximum, the relative yield, and the contribution of low-energy electrons in the region of positive potentials of the spherical capacitor.

1. V. L. Borisov, V. N. Lepeshinska "Secondary emission properties of magnesium and beryllium alloy emitters after short-term activation": Science. manual: M.: "Izvestia Academy of Sciences of the USSR", 1958, vol. XXII, No. 5, p. 534-545

GENERALIZED EXPERIMENTAL DATA OF THE DELTA ELECTRON YEILD

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Generalized experimental results of delta electron yield obtained at NSC KIPT electron accelerator facilities in the energy range from 0.5 to 1.6 GeV are presented. As the targets: Be, Al, Si, Ni, and Nb were used. It was established that the yield of delta electrons is proportional to the $\sqrt{T \cdot Z/A}$, where T is the target thickness in g/cm^2 and has a linear dependence. It is shown that the main factor in the increase in the delta electron yield is not the energy of the primary beam, but the density of electrons in the target.

ON THE POSSIBILITY OF DEFLECTING HIGH-ENERGY ELECTRONS AND POSITRONS USING BENT CRYSTALS

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The problem of deflecting high-energy electrons and positrons is an important task in accelerator physics. Typically, such deflection is achieved using multi-meter electromagnets. However, bent crystals with a length of several millimeters in some cases provide the opportunity to deflect charged particles at the same angles as electromagnets. In [1], the possibility of using planar channeling in a bent crystal to extract part of the electron beam with an energy of 6 GeV from the DESY II Booster Synchrotron accelerator was recently demonstrated. The report is dedicated to the results of investigating the efficiency of deflecting electrons and positrons using bent crystals in various ranges of particle energy.

The work was carried out with the support of the National Research Foundation of Ukraine, Grant No. 0123U105211 (222/0004).

1. Sytov A. et al. Eur. Phys. J. C. 2022. Vol. 82. P. 197.

ON FAST CHARGED PARTICLES SCATTERING ON A FLAT RELATIVISTIC BEAM OF CHARGED PARTICLES IN THE EIKONAL APPROXIMATION

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The problem of fast charged particles scattering on a flat relativistic beam of charged particles in the eikonal approximation is considered. The selected beam shape is close to the shapes found in modern experiments, for example, at the KEKB accelerator (Japan). To find the differential scattering cross section, we used the approach [1,2], which allows considering the problem of scattering on various targets from a single point of view, both in the eikonal and in the Born approximation of

quantum electrodynamics. The eikonal approximation was chosen since it has a wider application region in comperison with the frequently used Born approximation.

Using numerical methods, we obtained the differential scattering cross sections for certain parameters of the problem. The considered problem is relevant for explanation of modern experiments on the study of radiation during beam collisions, since the radiation cross section is proportional to the scattering cross section.

1. N.F. Shul'ga, V.D. Koriukina. On coherent and incoherent scattering of fast charged particles in ultrathin crystals. Problems of Atomic Science and Technology. V. 127. pp. 120-125. 2020. https://doi.org/10.46813/2020-127-120.
2. Shul'ga N.F., Koriukina V.D. The Eikonal Approximation of the Scattering Theory for Fast Charged Particles in a Thin Layer of Crystalline and Amorphous Media. Nucl. Instr. Meth B. 2021. Vol. 487. P. 25-29. https://doi.org/10.1016/j.nimb.2020.09.014

ORIENTATIONAL DEPENDENCE OF DISTRIBUTION OF PROTON IONIZATION ENERGY LOSS IN A CRYSTAL

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With the help of computer simulation, the distributions of ionization energy loss of protons with 15 GeV/c momentum, which move in a thin oriented silicon crystal, were obtained at different values of the angle θ between the particle momentum and atomic planes and the angle ψ between the particle momentum and atomic strings. The evolution of probability distribution of the particle ionization energy loss and position of the distribution maximum E_m with the change of the mentioned angles has been investigated. For the planar orientation of the crystal, it is shown that at angles θ close to the critical angle of planar channeling, E_m can noticeably exceed the corresponding value typical for the amorphous target (while at smaller θ, the magnitude of E_m is smaller than this value). Under the condition of axial orientation of the crystal, there has been considered the case when, with the increase of angle ψ, the particles proceed from the axial channeling mode to the planar channeling one. It is shown that in this case the distribution of ionization loss acquires a two-humped structure. One of its peaks gradually turns into a distribution typical for planar channeling, while the other peak, at angles of the order of the critical angle of axial channeling ψ_c, resides in the region of higher values of ionization loss than the corresponding peak typical for the amorphous target. At the same time, the dependence of the most probable value E_m of ionization loss on ψ undergoes a leap at ψ close to ψ_c.

The work was supported by the DFG project No. 531314364.

X-RAY TRANSITION RADIATION AT GRAZING INCIDENCE OF ELECTRON ON ARTIFICIAL PERIODIC STRUCTURE

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X-ray transition radiation, which is generated when an ultrarelativistic electron impinges on an optical diffraction grating at a small angle to its plane, is considered. The main attention is paid to the radiation in the 'backward' direction, which propagates on the same side of the grating from which the particle arrives. Expressions for the radiation spectral-angular distribution are obtained. It is shown that due to interference of contributions from different strips of the grating, the radiation is monochromatized and a discrete spectrum of frequencies is emitted in each observation direction. This opens up possibilities for using such radiation as a monochromatic source of x-ray photons. The possibility of using this radiation to measure parameters of charged particle beams is investigated. It is shown that the width of the radiation spectral peak is sensitive to the transverse size of the beam and could be applied for its measurement. Such sensitivity is noticeably stronger than for transition radiation diffracted in a crystal, for which such a method was first proposed [1]. In addition, the spectral peak shape depends on the shape of particle transverse distribution in the beam and could be applied to obtain information about this shape.

1. Shchagin A. V. et al. XVIII Conference on high-energy physics and nuclear physics: Book of abstracts. Kharkiv, 2020, p. 69.

STUDY OF ANGULAR DISTRIBUTIONS OF VOLUME REFLECTED POSITIVELY CHARGED HIGH ENERGY PARTICLES IN BENT CRYSTALS

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The process of positively charged high energy particles scattering in a thin bent crystal at volume reflection on the bent crystal planes of atoms is considered. The consideration was carried out on the basis of numerical simulation of the particle scattering process taking into account incoherent scattering effects on the thermal oscillations of atoms in the crystal lattice.

A comparative analysis of the influence of incoherent effects in the scattering of such particles in thin bent crystals at positron energies in the range from 1 to 200 GeV was carried out. It is shown that at positron energies in the range from 20 to 200 GeV the influence of incoherent effects in the particle scattering practically does not change the angular distribution in the particle deflection on large angles. When the positron energy is reduced to 1-2 GeV, taking into account incoherent effects at particle scattering changes the angular distribution when particles are deflected on large angles, and the intensity of particle scattering on large angles decreases by 20-30%.

In order to exclude the influence of effects related to the channeling phenomenon on the particles scattering in the crystal, the passage of particles in small-sized crystals was considered, when the thickness of the crystals was chosen to be close to the value of the average value of the half-period of oscillations of channeled particles.

The analysis shows that the use of volume reflection of positively charged particles in a curved crystal to deflect particles is most expedient for particles with energy greater than several tens of GeV.

POLARIZATION EFFECTS IN TOP-QUARK DECAYS IN ELECTRON-POSITRON ANNIHILATION AT HIGH ENERGY

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The purpose of the work is to study polarization effects in the presence of CP violation in the process of e^+e^- annihilation with a focus on the future electron-positron collider CLIC with energy $s^{1/2}$ = 380 GeV. The study is primarily focused on the annihilation of electron-positron pairs into top quark pairs, which, upon decay, produce bottom quarks and W bosons. The Lagrangian describing the interaction of quarks with carrier particles such as photons and Z bosons was modified to account for CP-violation effects by including terms proportional to the electric and weak dipole moments.

As a result, the cross-section of the process was obtained as a function of several important variables, such as the energies of bottom quarks and electrons, the polarizations of the initial electron beams, scalar and pseudo-scalar interaction constants of the Higgs boson with top quarks, which determine the appearance of CP disturbance effects. The asymmetry in the number of events in which the energies of bottom quarks are measured in experiments compared to the energies of anti-bottom quarks was analyzed. The physical meaning is to detect differences between the number of events in which the energy of the bottom quark is greater than the energy of the antiquark, and the number of events in the opposite case. The observed corresponding to the difference in the average energies of bottom quarks and antiquarks in the presence of different degrees of polarization of the initial electron beam was also considered. These observables are sensitive to the CP-violation.

MULTI-PHOTON INTERACTIONS OF PERIODIC COHERENT FIELD WITH ULTRA RELATIVISTIC ELECTRONS

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Interactions of coherent photons with ultra-relativistic electrons are expansively studied nowadays both experimentally and theoretically. We construct a multiphoton

model of interaction electrons with periodic fields. The model is based on kinematics of the interactions - the laws of momentum-energy preservation. We consider the periodic field as aggregation of number states consisting of real (laser field) or virtual (undulators, crystals) photons. Number states are assumed distributed according to the Poisson law. The electrons in such a field acquire an additional mass and may interact with the individual number state. The mass shift (a classical parameter equal to averaged squared transverse momentum acquired in the field) assumed equal to the Poisson parameter. This interaction results in scattering off the state - nonlinear Compton radiation or produce the electron-positron pair - nonlinear trident process. We show that interactions of electrons with the coherent field are governed by two parameters: (i) photon's energy in the electron rest frame, and (ii) average number of the photons per the wavelength. Statistical parameters of the recoils exerted due to the interaction are estimated as well.

RESONANCE APPROACH FOR THE PROCESS OF THE PHOTO-TRIDENT IN THE FIELD OF A LINEARLY POLARIZED ELECTROMAGNETIC WAVE

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In the framework of the resonance approximation the process of the creation of an electron-positron pair at the scattering of a polarized high-energy photon (photo-trident) in the field of a monochromatic linearly polarized electromagnetic wave was investigated. This approximation allows to neglect the interference of amplitudes, i.e. amplitude resonance occurs in different kinematic regions. In addition the choice of linear polarization of the wave field allows to significantly reduce the number of terms in the probability of process. Despite these simplifications the expression for the probability for the investigated process, which has a second order in the fine structure constant, is sufficiently cumbersome. That is a consequence of the polarization properties of the intermediate state.

PHOTOIONIZATION OF HEAVY IONS BY A SHORT LASER PULSE OF ELLIPTIC POLARIZATION

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The photoionization of the inner electron of a heavy ion by a short laser pulse with elliptical polarization is considered within the framework of the relativistic theory. The motion of the electron is described using exact solutions of the Dirac equation in the Coulomb potential. The radiation pulse is taken into account as a perturbation in the form of a classical field in the dipole approximation. The electric field strength of the laser pulse should be less than the typical value of the Coulomb field, a condition met in the case of heavy ions and practically feasible radiation intensities.

Explicit expressions for the probability of ionization from the ground state have been obtained. The allowed values of the spin-orbital quantum number of an ionized electron are $\varkappa = -2$ (total angular momentum $j = 3/2$) and $\varkappa = 1$ ($j = 1/2$). Suppression of ionization into states with $j = 1/2$ is observed for the radiation frequency $\omega \approx mc^2/\hbar$ regardless of the value of the projection of the total moment. This effect is relativistic and has been confirmed by nonperturbative numerical calculations.

POLARISATION EFFECTS IN THE PROCESS OF INVERSE COMPTON SCATTERING IN THE LASER WAVE FIELD

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The effect of laser polarisation on the process of photon emission by an electron in a strong laser wave field is investigated theoretically. It is shown that the emission occurs in a narrow cone of electron emission with a solution angle of the order of milliradians. The probability of the process in the field of a circularly polarised laser is higher than in the case of linear polarisation. The dependences of the degree of polarisation of the emitted photon on the laser ellipticity parameter are obtained. It is shown that for circular polarisation of the laser, the radiation of the final photon is purely polarised and it is also circularly polarised. If the laser is linearly polarised, then the radiation is linearly polarised, but not purely polarised. It should be noted that as the laser intensity increases, the degree of photon polarisation increases, and as the number of external wave photons increases, it decreases. The analysis was carried out for the cases of laser intensities and electron beam characteristics planned for the LUXE experiment (DESY, Hamburg, Germany) [1].

1. H. Abramowicz et.al. Conceptual design report for the LUXE experiment, , Eur. Phys. J. Special Topics 230, 2445 (2021).

Section 4. Physics and technology of radiation detectors

DEVELOPMENT OF A RADIOMETER FOR MEASURING RADON CONCENTRATION IN AIR

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Preliminary results on developing an experimental prototype of a radiometer for the determination of radon concentration in the air are presented. A "warm" silicon detector with an area of ~ 6 cm^2 was manufactured by NSC KIPT and was used as a sensor. The software of the measuring complex based on the radiometer provides the determination of radon concentration over a set time. During the measuring session, the experimental data is collected and saved in the device's internal memory for further processing and analysis. The USB interface is used to transfer the stored information. The further ways of expanding the analytical capabilities of the measuring complex by increasing the efficiency of radon decay registration and improving the technique of measuring its activity are discussed.

MEASUREMENT OF TECHNICAL LIGHT OUTPUT IN SCINCILLATOR SAMPLES BEFORE AND AFTER IRRADIATION

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Studies of the influence of high radiation doses on scintillation and optical properties of plastic and composite scintillators focuses on measurement of the technical light output in scintillator samples before and after irradiation. Earlier, a stand for such measurements was developed and constructed. The measurement is based on an analysis of the amplitude scintillation α-spectra for the samples using photomultipliers 'ФЕП-85' or '9954B05–THORN EMI Electron Tubes Ltd.' and multi-channel charge-to-digital (QDC) and analog-to-digital (ADC) analyzers. To obtain the amplitude distribution of scintillation pulses, the QDC '43ЦП393' (an analogue of the QD808/CAMAC from ORTEC) and ADC 712 (POLON) were used. The obtained amplitude α-spectra were subsequently subjected to mathematical processing – in particular, to the Gaussian fitting with determination of the α-peak position, which corresponds to the value of the technical light output. The study of the technical light output for the scintillator samples was performed using the α-radioactive source (RS) ^{239}Pu. It should be noted that the penetration ability for α-particles from the ^{239}Pu RS is no more than 100 microns for plastic scintillators, and it is much smaller for composite scintillators which have much greater density. Since the sample thickness is 3 to 6 mm, the scintillation from α-particles occurs only in the surface layer of the sample. In order for scintillation to occur throughout the thickness, it is proposed to use electrons, which have the much greater penetration. As a proper

source, one can choose the $^{90}Sr+^{90}Y$ RS which provides the electron penetration of up to 10 mm in the case of plastic scintillators based on polystyrene. The amplitude spectrum for electrons does not have clearly manifesting lines, so a comparison between the spectra measured before and after irradiation and their mathematical processing causes certain difficulties. This can be prevented by carrying out "absolute" measurements of the technical light output in terms of the number of photoelectrons. To provide the use of the $^{90}Sr+^{90}Y$ RS and the "absolute" measurements of the technical light output in scintillators, the stand is being upgraded, and manufacturing of its units is underway.

SOME APPROACHES TO OBTAINING COMPOSITE SCINTILLATORS WITH A SHORT DECAY TIME

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Scintillation materials are widely used in many fields of science and technology. The development of modern scintillation technology leads to the need to find new scintillators or to improve the characteristics of existing ones. The scintillation properties of inorganic crystals can be improved by creating mixed crystals with the replacement of some ions by others.

In this work, composite scintillators based on the grown LuYAG:Ce inorganic crystals were produced. For the obtained samples, studies of optical transmission, luminescence, light output, and decay time were carried out. The optimal conditions and sizes of crystalline grains for the creation of composite scintillators have been determined.

Studies of the radiation resistance of these scintillators under electron irradiation have shown that its radiation resistance more than 100 Mrad.

NEW METHOD OF OBTAINING ORGANIC POLYCRYSTALLINE SCINTILLATORS

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Last time we have developed organic polycrystalline scintillators, which are the effective detectors of short-range radiations. In contrast to fragile single crystals, they have more possibilities for mechanical processing. This allows us to create complex shape detectors. One of the disadvantages of polycrystalline scintillators is a significant degradation of their scintillation and optical characteristics with an increase in thickness of a scintillator [1]. All known methods of producing organic polycrystals are limited to pressing either grains, which are obtained by cryogenic crushing of a

single crystal ingot, or plates, which are obtained by recrystallization from an organic solvent.

This work proposes a new approach to obtaining the initial material for polycrystals based on p-terphenyl, in which zone melting and an additional stage of reverse movement allows producing material for pressing in the form of an ingot. This method of producing polycrystals provides a significant improvement in their scintillation and optical characteristics in relation to existing analogues, namely, an increase of the light output when detecting alpha and beta radiations up to 185%, an increase in optical transmittance by 170% at a wavelength corresponding to the maximum of the photoluminescence (360 nm).

1. M. Angelone, at al. Properties of para-Terphenyl as a Detector for α, β, and γ Radiation. IEEE Transactions on Nuclear Science (2014). – Vol. 61, No.3. – pp.1483–1487.

INFLUENCE OF THE MECHANISM OF TRIPLET EXCITON REFLECTION AT GRAIN BOUNDARIES ON SCINTILLATION AND OPTICAL CHARACTERISTICS OF ORGANIC COMPOSITE SCINTILLATORS

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A separate detection of the ionizing radiations with different values of the specific energy losses is of great practical importance. This can be the detection, for example, of neutron fluxes in the presence of a gamma background, as well as the actual the spectroscopy of fast neutrons. Organic scintillators are used for these tasks.

The paper examines the effect of a grain size on the characteristics of composite scintillators of p-terphenyl and stilbene. The triplet exciton reflection effect from the crystal boundary [1] was previously not taken into account, as its influence was negligibly small for the studied single crystal samples. However, the use of the grains in which the diffusion displacement of the triplet exciton is close in value to the size of individual grains significantly increases this effect. The results of modeling the diffusion of triplet excitons in a single spherical grain confirmed the results of the previous studies, in which the optimal grain size was experimentally shown to be 60 μm.

This work was supported by the National Research Foundation of Ukraine, project № 2021.01/0042 “Development of effective detection systems for the most harmful ionizing radiation for humans, for radioecology tasks”.

1. Agranovich, V.M. & Galanin, M.D. Electronic Excitation Energy Transfer in Condensed Matter. Amsterdam: North-Holland, 1983.

AUTOMATED COMPLEX OF TECHNOLOGICAL CONTROL OF NEWEST MONOLITHIC ACTIVE PIXEL SENSORS

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For technological control of newest silicon monolithic active pixel sensors (MAPS) ALPIDE type (developed by ALICE collaboration at CERN) with assembled ultralight microcables (made of adhesiveless aluminum-polyimide dielectrics) at assembling high-tech multisensor detector modules for international ALICE ITS3 and FoCal experiments and pCT project, together with experts from University of Bergen (Norway), a specialized automated control complex was created. The complex includes hardware (contacting and readout unit based on Yamaichi IC51-4364-1221-1 socket and readout board based on FPGA Xilinx Zynq UltraScale type) and software (specialized software developed in Python for Lynux OS).

The automated complex allows to control power supply circuits, registers and high-speed data links of the sensor and to perform a FIFO test. Based on obtained test results quality of the sensor according to the ALPIDE sensor classification is determining ("GOLD", "SILVER", "BRONZE" or "Not OK/BAD").

Functionality of the automated control complex of MAPS sensors has been tested and verified on ALPIDE sensors, and, at implementing in technological process will allow to guarantee to exclude using defective sensors in detector modules.

THERMALLY CONDUCTIVE ALUMINUM-POLYIMIDE DIELECTRICS

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Continuously growing requirements to polyimide (PI) materials lead to needs to enlarging assortment and creating new composite PI systems, in particular with high electrical insulation and, at the same time, thermal conductivity characteristics.

Main purpose of this work was to perform structural modeling and calculating effective thermal conductivity of new thermally conductive PI composites. Also, development and researches of single-sided aluminum-polyimide lacquer foil dielectrics based on thermally conductive PI composites with thermal conductivity of 0,8 – 2,0 W/(m·K).

In the work development and study of thermally conductive PI composite materials based on binders from Pyre ML RC 5069 polyamide acid solutions and dispersed fillers of powders of micron and nano sizes AlN particles were carried out. Structural modeling and calculating effective thermal conductivity of PI composites were performed. Single-sided micro- and nanostructured composite aluminum-polyimide PI lacquer foil dielectrics with thermal conductivity of 0,8 – 2,0 W/(m·K) were developed and their basic chemical, mechanical, electrical and thermal properties were investigated.

New thermally conductive lacquer foil aluminium-polyimide composite dielectrics are designed for high-power electronic modules, including detector modules for research in elementary particle physics.

EMPIRICAL FORMULAS FOR THE DEPENDENCE OF HPGe- DETECTOR EFFICIENCY ON ENERGY FOR GAMMA RADIATION SOURCES IN STAINLESS STEEL CONTAINERS

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To analyze the isotopic and quantitative composition of nuclear materials, which are in hermetic containers made of stainless steel, the method of gamma spectrometric measurements of their characteristic or stimulated radiation is used. The accuracy of the analysis depends on the accuracy of calibration of HPGe- detectors by energy efficiency, which depends on the technical characteristics of the detectors, the geometry of the measurements and the characteristics of the absorbing screens (containers).

The paper presents the results of experimental research on the dependence of the efficiency of the HPGe- detector on the energy of gamma quanta, the distance between the detector and the point source of gamma radiation, and the thickness of the screen made of stainless steel. On the basis of the conducted experimental studies, parametric formulas describing the dependences of the efficiency of the detector on energy, distance, and screen thickness were obtained. Their successful experimental verification was carried out on another HPGe- detector with other technical characteristics.

Section 5. Research and development of charged particle accelerators

LONG-TERM FIELD STABILITY OF A PERMANENT MAGNET FROM SmCo ALLOY

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When developing a magnet for operational determination of electron energy at a 10 MeV technological accelerator [1], the main attention was paid to the selection of a rare earth alloy, the magnetic characteristics of which changed the least under the influence of radiation at the accelerator. The best data were obtained for samples from the Sm2Co17 alloy, which were exposed to a direct impact of an electron beam with an energy of 10 MeV [2]. The characteristics of a magnet made using this alloy were comprehensively investigated in 2018.

Since for the long-term use of the magnet in energy measurements on the accelerator it is important to be sure of the stability of the magnet parameters over time, in 2023 the measurements were repeated with the maximum reproduction of the geometry of the experimental conditions.

The obtained data indicate that the metrological characteristics of the magnet remained within the limits that were determined in the studies conducted in 2018.

1. V.A. Bovda, A.M. Bovda, I.S. Guk, S.G. Kononenko, V.N. Lyashchenko, A.O. Mytsykov, L.V. Onischenko, Sm-Co Based Magnetic System for 10 MeV Technological Electron Accelerator Lu-10M. // EastEur.J.Phys.,Vol.5, No.3,(2018), 68-74. DOI:10.26565/2312-4334-2018-3-08.

2. A.M. Bovda et al. Magnetic properties of Sm2Co17 magnets under 10 MeV electron beam // Problems of Atomic Science and Technology. Series "Nuclear Physics Investigations". 2017, № 6, p. 162-166.

RESEARCH OF PHYSICAL PROCESSES IN PERMANENT MAGNETS UNDER THE ACTION OF ELECTRONS, NEUTRONS AND GAMMA QUANTUM

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Energy conservation is one of the main ideas that are taken as a basis for the development and implementation of modern projects of both multi-kilometer colliders and technological accelerators for applied research in industry [1].

One of the technologies that makes it possible to significantly reduce energy consumption during the operation of accelerators is the use in projects of magnetic elements: dipole magnets, quadrupole lenses, undulators made of permanent magnets

based on rare earth alloys. One of the important problems that arises in this case is the stability of the magnetic characteristics of these materials under the influence of various types of radiation that occur during the operation of accelerators.

In recent years, quite a lot of research has been conducted on this issue. They are made in a wide range of energies of particles falling on materials: electrons, neutrons, gamma quanta of different intensities. However, the review of these works does not make it possible to draw unambiguous conclusions regarding the mechanisms of changing the magnetic characteristics of these materials under the influence of irradiation. This is caused by the fact that all these works were carried out in different conditions, with different materials, and the goals of the works were also different.

In order to establish the mechanisms of such influence, it is necessary to carry out detailed targeted studies of changes in the structure of materials after irradiation.

1. C. Benabderrahmane. Review of Permanent Magnet Technology for Accelerators. // 8th International Particle Accelerator Conference, Copenhagen, Denmark, 2017 MAY, p.14 – 19.

OPTIMIZATION OF THE MAGNETO-OPTICAL STRUCTURE OF THE MULTIFUNCTIONAL ACCELERATOR COMPLEX NSC KIPT

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In order to implement the development program in Ukraine in the field of fundamental and applied research in nuclear and high-energy physics, as well as the physics of the interaction of radiation with matter, it is necessary to create an accelerator built on the basis of the latest world trends in the development of accelerator technologies.

In work [2], an analysis of the work of the existing global accelerator complexes and tasks performed in the mentioned fields of research on the beams of these accelerators was carried out. On the basis of the analysis, a conceptual design of a multifunctional accelerator complex (MAC) with a continuous beam for energy up to 600 MeV was proposed. Further development of the proposed complex involves the creation of a neutron source based on an electron beam with an energy of 200 MeV, positron beams for fundamental and applied research, the use of beams to create radiation sources based on free electron lasers and a source of synchrotron radiation.

The work presents the results of the search for the optimal magneto-optical structure of the recirculator, the focusing functions and beam parameters are given.

1. M.F. Shul'ga, G.D. Kovalenko, V.B. Ganenko, L.G. Levchuk, S.H. Karpus, I.L. Semisalov. Concept of the state targeted NSC KIPT program of experimental base development for basic and applied research in nuclear and high-energy physics and physics of radiation interaction with matter. // PAST, "Nuclear Physics Investigations". № 3,139, 2022, p. 3-6. https://doi.org/10.46813/2022-139-003.

2. М.Ф. Шульга, Г.Д. Коваленко, І.С. Гук, П.І. Гладких, Ф.А. Пєєв. Багатофункціональний прискорювальний комплекс ННЦ ХФТІ «MAC NSC KIPT» PROJECT. ННЦ ХФТІ, Харків, 2023, 92 с.

NSC KIPT MULTI-BEAM ION IRRATIOATION FACILITY REVIEW

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The development of radiation technologies in Ukraine is inextricably linked to the operation and modernization of irradiation facilities based on charged particle accelerators at KIPT. A special place among irradiation facilities is occupied by multi-beam ion irradiation systems. They allow to carry out a whole range of studies to predict the behaviour of microstructural changes in materials under the influence of simultaneous or separate irradiation with ion beams with the required specified parameters (energy, current, cross-sectional area, presence of impurities, etc.). The presented review of the development of ion irradiation systems for materials developed by KIPT was prepared as part of the elective course "Accelerators in Radiation Physics" for PhD students at KIPT.

ON WAKEFIELD ACCELERATION IN INHOMOGENEOUS PLASMA

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In laser-plasma wakefield acceleration, an actual and widely studied issue is the obtaining small self-injected bunches and enhancement of their energy and acceleration rate by variation the parameters of laser pulses and plasma. In particular, using the special plasma profiles has a significant effect. Earlier [1] it has been shown that with a longitudinal linearly increasing plasma density profile, due to compression of the wakefield bubble, synchronism of the maximum accelerating field at the rear wall of the wakefield bubble and the self-injected bunch is achieved.

In this work, by numerical simulation using the OSIRIS code [2], the wakefield acceleration in an inhomogeneous plasma with alternating regions in which the plasma density increases or decreases in order to extend the time of movement of a self-injected bunch in the wakefield acceleration phase and enhancement the bunch energy was investigated.

1. Bondar D.S., Maslov V.I., Onishchenko I.N. Improving Stability of the Self-Injected Bunch by Variation of a Sequence of Two Laser Pulses Parameters at Wakefield Excitation in a Metal Density Plasma // Problems of Atomic Science and Technology. 2023. № 6(148). DOI: 10.46813/2023-148-069.
2. Fonseca R.A. et al. OSIRIS: A Three-Dimensional, Fully Relativistic Particle in Cell Code for Modeling Plasma Based Accelerators // Computational Science — ICCS 2002. 2002. LNCS 2331. P. 342–351. DOI: 10.1007/3-540-47789-6_36.

COLLECTIVE PARTICLE DYNAMICS AT CYCLOTRON RESONANCES: PHASE SYNCHRONIZATION

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Cyclotron resonances are widely used both to accelerate charged particles and to excite electromagnetic oscillations. The efficiency of field interaction with particles increases significantly if the interaction occurs with particle clumps bunches, which can arise as a result of phase synchronization of particles. In particular, in the MCR and in gyrotrons, the phase grouping bunching of particles occurs due to the effects of relativism. We show that there are other mechanisms for phase grouping bunching of particles. One of them is due to a fairly strong field of an electromagnetic wave. It is shown that this field can lead to phase grouping bunching of particles. The characteristic time of formation of the corresponding phase bunches is estimated. It was found that this synchronization mechanism can be more effective than the mechanism caused by the effects of relativism. In addition, we show that cyclotron radiation emitted by charged particles, which is usually ignored due to its small size value, leads to self-synchronization of electrons. In this case, the natural eigen oscillations of such a complete complex of particles (plasma) can acquire a wide range of natural eigen low-frequency oscillations. Moreover, when a certain threshold particle density is exceeded, the external magnetic field may no longer retain these particles. Instability develops, which leads to the ejection of particles from the confinement region. We estimate the level of random fluctuations required to disrupt the synchronization process and stabilize plasma dynamics.

ON THE EFFICIENCY OF WAVE-PARTICLE INTERACTION

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The efficiency of acceleration and heating of charged particles during cyclotron resonances and during acceleration of particles in a vacuum without an external magnetic field are considered. Some features of new cyclotron resonances are considered, under the conditions of which the role of the external wave field is taken into account. The conditions for particle acceleration and mechanisms that limit the energy level of accelerated particles are determined. The conditions for the acceleration of charged particles in a vacuum without an external constant magnetic field are considered too. The conditions of the Lawson-Woodward theorem are discussed. It is shown that the statement formulated in this theorem that relativistic particles do not exchange energy with an external electromagnetic wave in a vacuum is strictly untrue. It is shown that such an exchange almost always takes place. In

addition, it is shown that there are regions of parameters (initial energy of particles, intensity of an external electromagnetic wave, components of the wave vector of an electromagnetic wave) in which effective energy exchange occurs between the wave and particles. However, it has also been shown that with increasing initial particle energy, in most cases the efficiency of energy exchange decreases. This result is quite obvious (relativism effect) and is in qualitative agreement with the Lawson-Woodward theorem.

MEASUREMENT OF THE PEAK POWER OF HF AND MICROWAVE SIGNALS ON PULSE ACCELERATORS WITH A VIRTUAL CATHODE

V.V. Katrechko, D.V. Vinnikov, O.M. Ozerov, V.I. Tkachev, O.V. Manuylenko, I.M. Onishchenko, V.B. Yuferov, S.V. Marchenko, V.T. Fomin

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A generator based on a virtual cathode (vircator), due to its high power (from tens of MW to several GW), wide possibilities of frequency adjustment (from hundreds of MHz to tens of GHz), and conceptual simplicity, stands out among other microwave sources [1]. Measuring its main parameters (power and frequency spectrum) is a problem due to short pulse durations (usually from hundreds of ps to hundreds of ns) and the inertia of diagnostic equipment - detectors [2,3].

The work considers the principles of measuring the power of electromagnetic radiation in the frequency ranges from 1 to 18 GHz using detector assemblies. The results of preliminary peak power measurements and signal spectra (up to 6 GHz) on an accelerator with a DIN-2K plasma current switch, with electron beam parameters: ~ 30 kA and ~ 200 kV, are presented. Graphs of the dependence of the amplitude of the power of the microwave signal on the amplitude of the interruption current in the primary circuit of the accelerator are presented.

1. D.J. Sullivan et al., "Virtual cathode oscillator (vircator) theory", Artech House Microwave Library, p. 441 (1987).
2. Rishi Verma et al "Characterization of High Power Microwave Radiation by an Axially Extracted Vircator", IEEE Transactions on Electron Devices, p. 141 – 146. (2014).
3. Tsukasa Nakamura, et al. "Output Evaluation of Microwave Pulse Emitted from Axially-Extracted Vircator with Resonance Cavity", Hasegawa, p. 55-60 (2018).

ISOLATION OF ELECTRONS BY MAGNETIC FIELD OF CUSP FOR HIGH-CURRENT ION BEAM ACCELERATION

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Previous research [1] on the magnetic isolation of electrons by a 0.05T cusp magnetic field to accelerate a beam of Ar+ ions at plasma injection with a density of up to 10^{14} cm^{-3} and a speed of 10^{7} cm/s, equivalent to an ion beam, compensated in

charge and current, showed that an ion beam with a density exceeding 10^8 cm^{-3} under the influence of the polarization field moves together with the electron beam along magnetic lines, that makes impossible its passing into the region with an accelerating electric field.

In this work, in order to increase the density of the ion beam passing to the accelerating gap, it is proposed the following scheme of magnetic isolation of electrons by the cusp magnetic field, which provides their removal to a metal chamber to prevent the occurrence of a polarization field: In this scheme the distance from the compensated ion beam to the chamber is reduced to 0.3 cm and the accelerating gap is shifted closer to the injection plane on distance 2.7 cm. It is shown that in such a configuration the isolation of electrons and the passage of an ion beam with a density of up to 10^{10} cm^{-3} to the acceleration region is realized.

1. I.N. Onishchenko, V.I. Maslov, O.V. Fedorovskaya. Acceleration of compensated high-current ion beam with cusp magnetic electron insulation in the accelerating gap and subsequent compensation with an electron beam // Problems of Atomic Science and Technology. Series “Nuclear Physics Investigations (79). 2023, №3 (145), p. 116-119.

MODERNIZATION OF THE SMALL-SIZED ACCELERATOR DIN-2K WITH A PLASMA OPENING SWITCH FOR INCREASE OF THE ELECTRON BEAM CURRENT

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Modernization of the small-sized DIN-2K electron accelerator with inductive energy storage and plasma opening switch was carried out in order to increase the beam current. With the use of modern diagnostic equipment, the sequence of physical processes during the entire cycle of the accelerator was determined, which made it possible to more accurately regulate the dependence of the output parameters of the beam on the parameters of the primary circuit. The output parameters of the discharge circuit have been improved by increasing the charging voltage on the pulse current generator to 45 kV, and on plasma guns to 18 kV. A number of technical solutions regarding the vacuum diode are provided. The selected geometry and material of the cathode provided the maximum beam current. Dielectric focusing lenses were made, which increased the beam current on the collector to 30 kA. The estimated energy of the beam was about 200 keV. The power of the beam is about 6 GW. The dependences of the induced voltage and beam current from the cathode-anode gap, the charging voltage on the pulse current generator and plasma guns in the vacuum diode were obtained. Based on the obtained dependencies, recommendations are given for increasing the efficiency of the DIN-2K accelerator.

ANALYSIS OF CHANGES IN COOLANT PARAMETERS IN THE PRIMARY CIRCUITS OF COOLING SYSTEMS OF LINEAR ELECTRON ACCELERATORS

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Cooled elements of linear accelerators are acceleration sections, solenoids, gun bodies, collimators, vacuum pumps, high-frequency loading, etc. From the experience of accelerator operation, it is known that deposits primarily accumulate on the surface of heaters and in the coil of the pulse transformer block. To predict the rate of growth of the thickness of the sediment layer, water was analyzed weekly for some parameters – pH, conductivity, and sometimes the content of metal ions. Irradiation affects the oxidizing capacity of water and, as a result, increases the corrosion of equipment, as evidenced by the presence of a noticeable concentration of chromium in the return water. In turn, corrosion products together with carbonates and sulfates of alkaline earth metals pass into sediments. As water circulates, the conductivity decreases, and the pH increases, indicating that the number of ions in the water has decreased, the bicarbonates have decomposed, the carbon dioxide that acidified, the water has been released into the atmosphere, and the layer of sediments has grown. Based on the data obtained, the time of acid flushing of the equipment was predicted.

ANALYSIS OF THE INNER SURFACE OF A SUPERCRITICAL WATER CONVECTION LOOP AFTER AN ELECTRON IRRADIATION SESSION

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To conduct experiments on the study of corrosion in supercritical water, a device was manufactured in the form of a rectangular loop 1.5x1.2 m with rounded corners and a welded irradiation chamber and a total volume of approximately 3.9 liters. The supercritical water convection loop was made of a steel pipe (12X18H10T) with a thickness of 4 mm and an inner diameter of 32 mm. The electron beam at the output of the LPE-10 accelerator during each irradiation session had an average energy of 10 MeV and an average electron beam current of 0.71 mA. The maximum fluence on the surface of the irradiation chamber in each session reached $2 \cdot 10^{20}$ el/cm^2. At the initial stage of work, a fairly high concentration of metals in water was observed, in particular chromium up to 0.7 mg/l, this can be explained by corrosion of the loop body and samples for corrosion tests, then the concentration of metal ions decreased due to their release on the inner surface of the loop in the form of insoluble compounds. As later observed, the inner surface of the loop was covered with a very thin whitish-blue sediment with reddish specks. Probably, a film of corrosion products forms on the loop, which are minerals that protect the metal from corrosion.

RADIATION TESTS AT THE LUE-40 ELECTRON LINAC OF OPTICAL MATERIALS AND COMPONENTS FOR HEP DETECTORS

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One of the critical challenges in designing new or upgrading existing facilities for high-energy physics research is the creation of detectors that experience significant absorbed doses and associated radiation damage. This requires the development of new radiation-resistant equipment based on their pilot and radiation tests. At present, there is a need for neutron and gamma radiation sources that can create radiation conditions adequate to the operating conditions of materials and devices in detector systems. The main goal of the work is to create a facility on the basis of the LUE-40 electron accelerator for conducting relevant experiments at absorbed dose levels up to 10^6 Gy and neutron fluence up to 10^{14} n/см^2.

The report describes the current state of the LUE-40 electron accelerator and presents the main beam parameters in the particle energy range of 35-95 MeV. The design of various types electron-neutron converters [1] and a system for obtaining a uniform distribution of electron density used for radiation tests are presented. The technique for irradiating of optical elements for HEP detectors (quartz tablets for Cherenkov light generation, plastics scintillators of various types, quartz fibers for light transmission, etc.) are described.

This work was partially supported by a grant from the NAS Ukraine under the Programme "Participation in the Latest International Projects in High Energy Physics and Nuclear Physics" (contract Ц-3/35-2021-2023).

1. V.V. Mytrochenko, et al. LUE-40 linac based neutron source for irradiation tests of HEP detector materials and components. Problems of Atomic Science and Technology, 2023, N. 6 (148), P. 150. doi.org/I0.46813/2023-148-150

STUDY OF THE ACOUSTIC PICTURE OF KLYSTRONS AND MODULATORS OF THE LU10 ACCELERATOR DURING RADIATION EXPOSURE OF A SUPERCRITICAL WATER LOOP

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Currently, there is an urgent problem of diagnosing the operation of klystrons and accelerator modulators for prompt response to possible emergency situations. According to the obtained data, the normal and emergency mode of operation of the equipment differ quite significantly in terms of the acoustic picture. Since there is a certain volume of acoustic information on the operation of the LU10 accelerator, a decision was made to investigate the cases of emergency and regular versions of the equipment operation. On the basis of time-dispersed cases of phase transition of the coolant and the list of cases of disconnection of HV and PAK from the logs, datasets approximated in time were formed, intended for research.

According to the recording conditions, the sound-recording sensor was partially isolated from external influences, therefore, in order to find the necessary information, it is necessary to conduct a study of the datasets, additional processing using filtering methods is necessary, since the received recordings have a high level of white noise pollution, and the useful signal (from modulators and klystrons) does not have sufficient amplitude to distinguish with the bare eye.

HOSE INSTABILITY SUPPRESSION BY ELECTRON ANHARMONIC OSCILLATIONS CAUSED BY WEAKLY NONLINEAR REGIME

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Acceleration by the wakefield in the plasma can provide compact sources of relativistic electron bunches of high brightness. Free electron lasers and particle colliders, using plasma wakefield accelerators, require high efficiency and bunches with low energy spread. In a strongly nonlinear blowout regime the radial wake force is homogeneous along the bubble, Fr=const, radial electron bunch oscillations is harmonic and a hose instability appears. Investigations [1-3] show that the instability is essentially suppressed due to anharmonic oscillations of bunch electrons if the focusing force Fr(z) is inhomogeneous along the bubble and radial inhomogeneity can be additional effect. The problem of the instability can be solved in weakly nonlinear regime, when not all plasma electrons left the bubble. In weakly nonlinear regime throughout the area of the driver-bunch Fr is inhomogeneous. Radial inhomogeneity of residual plasma electron distribution also leads to anharmonic oscillations of bunch electrons and to bunch stabilization. We evaluated period of oscillations and showed that the optimal form of electron bunch is a hollow cone with finite wall thickness. In the case of hollow cone, a longer bunch can be stable providing higher efficiency.

1. Mehrling T J, Fonseca R A, Martinez de la Ossa A, Vieira J 2017 Mitigation of the hose instability in plasma-wakefield accelerators Phys. Rev. Lett. 118 174801.
2. Diederichs S, Benedetti C, Esarey E et al 2022 Stable electron beam propagation in a plasma column Phys. Plasmas 29 043101.
3. Martinez de la Ossa A, Mehrling T J, Osterhoff J. Intrinsic Stabilization of the Drive Beam in Plasma-Wakefield Accelerators. Phes. Rev. Let. 121 (2018) 064803.

PASSIVE PLASMA LENS, REDUCING ENERGY SPREAD OF GAUSSIAN-KIND BUNCHES

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Acceleration by the wakefield in the plasma can provide compact sources of relativistic electron beams of high brightness. Free electron lasers and particle colliders, using plasma wakefield accelerators, require high efficiency and beams with low energy spread. In this paper, we investigated by numerical simulation the focusing of Gaussian-kind bunches by a passive plasma lens depending on their length. We have shown that for a homogeneous focusing field and to prevent loss of energy from bunches, the presence of an electron bunch-precursor is necessary. This plasma lens decreases the energy spread of bunches, since the first front of the bunch, which is of more energy, is in decelerating field, and its back front, which is of smaller energy, is in accelerating field. In addition, we investigated the evolution of the bunches with time to visually demonstrate the effect of the plasma lens in the wakefield accelerator.

ON THE DEVELOPMENT OF SUPER-RADIATION IN NOISE CONDITION

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The influence of noise on field generation in the superradiant regime, when all oscillators interact with each other, is discussed. The process of phase synchronization of excited oscillators is considered and it is noted that its efficiency is affected by the spread of their amplitudes. External noise leads to phase mismatch and can suppress generation. The behavior of a system of oscillators near the generation threshold is considered. It has been shown that even below the threshold, a small external field can provoke generation up to amplitudes characteristic of processes in the absence of noise.

STUDY OF VACUUM BREAKDOWNS ON COPPER SAMPLES WITH HIGH ENTROPY COATINGS

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The problem of resistance of accelerating structures to high-voltage breakdowns is relevant in the development of modern charged particle accelerators, in particular linear electron accelerators.

At the Institute of Applied Physics of the National Academy of Sciences of Ukraine, the technology of synthesis of high-entropy TiMoW and TiMoWCu coatings, as well as their sputtering on copper samples, has been developed by the method of

high-frequency magnetron sputtering. The first experiments were conducted on three- and four-element samples to investigate the effect of these coatings on resistance to high-gradient high-vacuum breakdowns. It is shown that for high-entropy coatings, better results are observed on samples with a more disordered crystal structure, while the voltage at which breakdown currents occur increases by 79%, breakdown voltage by 35%, and final breakdown voltage by 27%.

The conducted experiments indicate the prospects of using high-entropy materials and copper coatings with them in the accelerating structures of electron/ion accelerators.

SPUTTERING SOURCE OF NEGATIVE CARBON IONS

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Carbon therapy is known to be more effective than proton therapy. Since modern ion accelerators use sources of negative ions, the issues of developing efficient sources of C^- ions are relevant.

An attempt to obtain negative carbon ions from a multi-casp source is known from the literature. Acetylene was used as the working gas. Spectrometric analysis of the beam showed that it consists mainly of $C_2H_2^-$, C_2H^-, C_2^- but no atomic carbon ions were recorded in the spectrum.

We have developed the design of the sputtering source of C^- ions. The work of the source is based on the formation of a plasma emitter containing carbon ions using a glow discharge with an empty graphite cathode. To increase the reliability of the source, all kinds of heaters were fundamentally excluded from the design, and the required temperature regime of the electrodes of the discharge chamber is achieved due to the distribution of the discharge power. Ion-plasma spraying of the graphite cathode and graphite insert, which is sprayed, is used to obtain the working medium from the solid-phase material. This will avoid the generation of impurity negative ions. Sputtered carbon atoms thermalized on the hot surface of the thermalizer, and then fall to the surface with low work output (LaB_6), where their conversion into C^- occurs. After their desorption from the surface of the converter, they are formed into an ion beam.

ELECTRICAL BREAKDOWN OF GAS ISOLATION AT AN ELECTROSTATIC ACCELERATOR

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Breakdown voltage of high-voltage structures is generally calculated with a statistic method based on numerical modeling of a breakdown probability in a gas-insulated electrode system. The method was adjusted by the author to the direct voltage accelerators and has been improved for more than twenty years.

The article considers a method for calculating the operating voltage of high-voltage gas isolation for a 2 MeV proton accelerator. The method was verified for gas isolation with a binary nitrogen (N_2) and sulfur hexafluoride (SF_6) mixture, through analysis of calculated and experimental data for the 2 MV electrostatic accelerator.

INFLUENCE ON THE FIELD EMISSION OF DIELECTRIC FORMATIONS IN THE NEAR-SURFACE LAYER OF STRUCTURAL MATERIALS OF ACCELERATORS

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One of the main directions of development of accelerator technology is to increase the acceleration rate to 100 MV/m, as, for example, in the Compact LInear Collider (CLIC) project, which will reduce the linear dimensions of modern electron accelerators, make them more compact and achieve record acceleration energies of charged particle beams (on the order of several TeV). A technical limitation for achieving the required high accelerating gradients is the occurrence of an electrical breakdown, which leads to a drop in the accelerating voltage and damage to the structural elements of the accelerator itself.

The onset of such a phenomenon is associated with the field emission of electrons from the surface of the accelerator structure, followed by heating, melting of the surface, and formation of plasma.

The study theoretically considers the influence of dielectric formations in the near-surface metal layer on the nature and magnitude of the field emission current. The magnitude of the field emission current is determined in the presence of gas-filled nanopores in the near-surface layer.

POLARISATION EFFECTS IN THE PROCESS OF INVERSE COMPTON SCATTERING IN THE LASER WAVE FIELD

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The effect of laser polarisation on the process of photon emission by an electron in a strong laser wave field is investigated theoretically. It is shown that the emission occurs in a narrow cone of electron emission with a solution angle of the order of milliradians. The probability of the process in the field of a circularly polarised laser is higher than in the case of linear polarisation. The dependences of the degree of polarisation of the emitted photon on the laser ellipticity parameter are obtained. It is shown that for circular polarisation of the laser, the radiation of the final photon is purely polarised and it is also circularly polarised. If the laser is linearly polarised, then the radiation is linearly polarised, but not purely polarised. It should be noted that as the laser intensity increases, the degree of photon polarisation increases, and as the number of external wave photons increases, it decreases. The analysis was carried out

for the cases of laser intensities and electron beam characteristics planned for the LUXE experiment (DESY, Hamburg, Germany) [1].

1. H. Abramowicz et.al. Conceptual design report for the LUXE experiment, , Eur. Phys. J. Special Topics 230, 2445 (2021).

MODERNIZATION AND ADJUSTMENT OF THE MICROWAVE POWER CONTROL SYSTEM OF THE “ALMAZ-2M” ACCELERATOR

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The microwave power source of the “Almaz-2M” accelerator is controlled by supplying pulses modulated at a frequency of 2805 MHz from the “Rubin” master microwave generator to the KIU-12a amplification klystron. The operation of the “Rubin” modulator and the klystron modulator is launched and synchronized from the accelerator systems launcher.

The “Rubin” frequency must be tuned to the resonant frequency of the accelerator, which can change under the influence of external conditions and aging of the materials of the accelerator elements. Therefore, when preparing the accelerator for operation, it is necessary to adjust the frequency of the master generator. This frequency is measured by the built-in “Rubin” wave meter, which also needs calibration. This paper proposes a method for calibrating a wave meter with an accuracy of up to 1 MHz.

In addition to the modulation frequency of the klystron control pulse, important parameters are the time characteristics of the control pulses for the launch of the master microwave generator "Rubin" and the synchronization of the remaining accelerator systems (their relative position relative to the reference signal of the timing, their duration, the duration of the edges and their stability). For experiments on wakefield acceleration of an electron beam, they are especially important in obtaining a charge-profiled pulse sequence. For this purpose, the standard accelerator launch system was modernized. This made it possible to obtain trigger pulses with a rise time of about 200 ns and with the same accuracy of setting the beginning of the pulses. Based on modern microcircuits and radio components, a new scheme for launching accelerator systems with a rise time of less than 100 ns has been developed.

Section 6. Computer technologies for physical research

ANALYSIS OF SEARCH SPECTRA AND METHODS OF PEAKS LOCATION DETERMINATION IN GAMMA SPECTRA

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The program of γ- spectra processing "GAMMAPEAKS" is developed for determination of reactions cross sections, RFF and other important physical parameters of nuclear reactions. The algorithm of peaks search and the algorithm of search spectra creation by means of which one is possible to find borders and centers of peaks in the initial γ- spectrum were modified and improved in the latest version of this program. Search spectra were constructed with the convolution of the initial

γ- spectrum with the negative smoothed second derivative of Gaussian which has the form of a step. The convolution of the initial spectrum with ideal Gaussian having relatively small amplitude was performed before constructing of a search spectrum. This convolution smoothed the initial spectrum well especially its sections with "weak" statistics. After modification of the algorithms the program was tested on real γ- spectra. The comparison of peaks marking with results of other programs for such spectra was performed. As a result, analysis of spectra processing revealed that edges and centers of peaks were marked more reliably than when used previous algorithms.

RESUMING OF OPERATION OF NSC KIPT SPECIALIZED COMPUTING FACILITY FOR PROCESSING OF CMS EXPERIMENTAL DATA

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The NSC KIPT specialized computing facility for processing of the Large Hadron Collider (LHC) data operates at Tier-2 of the CMS grid infrastructure, being registered under the name of T2_UA_KIPT. With the start of hostilities in Ukraine (that is, from February 24, 2022), the T2_UA_KIPT operation was suspended. Over the past year, large-scale work was carried out to restore the facility's power supply system. In total, 136 faulty batteries were replaced by new ones in the uninterruptible power supplies (UPS), with fulfilling a calibration procedure that determines how long the UPS would run on batteries during a power outage. Necessary changes in the configuration of the center were also prepared, which should be implemented after the facility's operation is stopped. In particular, the new grid certificates with the SAN extension were obtained (and later installed on the servers). The site configuration has been changed following the need to replace the SRM protocol, which is used to store job results, with the WebDav one. A detailed analysis of the facility's computing and disk nodes condition was performed. Replacement of 10 Gbps network cards, which were no longer detected by the operating system or worked with short-term interruptions, was accomplished on two disk servers of the distributed data storage. On several

computing nodes, as well as on one of the disk servers, non-working memory cards were removed. To comply with the requirements of the CMS grid infrastructure concerning the transition of user authentication and authorization from proxy certificates to the SciTokens system, appropriate updates were installed on the facility's head node. Finally, the master server of the facility's distributed data storage was turned on along with the disk servers. Upon some extra tuning, all the fourteen WLCG/CMS SAM test probing system capabilities to receive and process grid jobs, as well as all the monitoring tests of the OPS virtual organization, were successfully fulfilled. Data transfer restoration resulted in congestion of the outer network channel being then limited to the 1 Gbps bandwidth. Since further operation under such conditions turned out to be impossible, the channel enabling access to the LHCONE network was extended to 10 Gbps, which led to reduction of data transfer errors. In view of attainment, in general, of successful fulfilment at the T2_UA_KIPT center of all the "critical" SAM tests, the decision was taken to end the system forced shutdown in the beginning of July 2023. After resolving some additional problems together with CMS computing infrastructure experts, processing of CMS experimental information was restarted at the facility in full scale after the 16-month break. This also means resuming of LHC data processing in Ukraine.

The work was supported in part by grants of the NAS of Ukraine (NASU) within the targeted research program "Collaboration in advanced international projects on high-energy and nuclear physics" and the "NASU informatization program".

MATHEMATICAL MODELING OF MAGNETIC WINDING SURFACES OF PLASMA INSTALLATIONS

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The most important property of the magnetic configuration of the system designed to contain high-temperature plasma is the presence of magnetic surfaces, which are formed by the trajectories of the lines of force of the magnetic field at multiple rotations around the main axis of the torus. Obtaining three-dimensional geometric models of magnetic surfaces, among which the helical winding (HE) is the most complex, is the most important time-consuming design task. The GO installation is presented in the form of current-carrying conductors formed into poles. The poles are stacked on the torus surface. When a current is passed through them, a magnetic configuration is formed that holds the plasma.

Input data: the law of winding (winding line) of the pole on the torus surface; frame of forming curves; boundary conditions; the law of surface interpolation between forming curves.

The paper presents mathematical models, methods, and algorithms that allow obtaining three-dimensional solid-state and surface geometric models of the GO plasma installation. The methods of kinematic modeling, Bezier splines and the

Overhauser equation are used to determine the coordinates of the points of the modeled surface.

On the basis of the developed mathematical models, it is possible to carry out a number of engineering calculations of the system - calculations of the stress-strain state of the system and heat exchange processes.

STUDY OF EXTERNAL NEUTRON RADIATION OF THE HI-STAR 190 TRANSPORT CONTAINER DEPENDING ON THE PLACEMENT AND BURNUP LEVEL OF SPENT NUCLEAR FUEL

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In Ukraine, there is currently no experience in transporting more than 12 spent fuel assemblies, as was done in TK-13 containers. Consequently, the radiation and operational safety of the HI-STAR containers, as well as the operating personnel, requires immediate study. Such a study should substantiate the radiation and operational safety of HI-STAR containers and operating personnel, which is a necessary condition for the safe operation of the Centralized Spent Fuel Storage Facility (CSFSF), which in turn is a strategically important task for the energy independence of Ukraine.

For a detailed analysis of the distribution of the dose rates level outside the TC, the authors built a three-dimensional model for calculating neutron dose rates levels. This model is as close as possible to the real geometry. No simplifications were applied in this model, with the exception of the spent fuel assemblies zone, which was partially homogenized. At the same time, the model of the internal structure of the MPC (Multi-Purpose Canister) is fully consistent with its design features, including plates made of Metamic-HT nanomaterial (Al - B_4C), which are located inside the MPC.

A simulation of the passage of neutron radiation through the HI-STAR 190 TC was carried out when different numbers of spent fuel assemblies were placed in the MPC. It has been established that the neutron radiation dose at the middle of the side surface of the TC is not maximum, which means that there are areas where the dose level exceeds the maximum level established according to calculations by the HOLTEK company. To ensure radiation safety, research was carried out to optimize the placement of assemblies in fuel cells with different levels of burnup and exposure time, and the feasibility of installing additional shields was analyzed.

POSSIBILITIES OF USING THE ROOT PACKAGE FOR PHYSICAL RESULTS PROCESSING

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ROOT is an object-oriented software currently being actively developed at CERN, which enable event generation, detector modeling, event reconstruction, data

collection and analysis. At the moment, the software is focusing on data analysis and processing, but thanks to the use of object-oriented programming, ROOT can be used in other areas in the future, including together with such a well-known set of libraries as GEANT4. ROOT can be used to analyze large data sets, which is very relevant for LHC experiments.

This work shows the possibilities of using ROOT for effective analysis of data from mathematical modeling and physical experiments, as well as visualization of radiographic images obtained using MCNPX.

DEVELOPMENT OF ALICE-ITS DETECTOR MONITORING SOFTWARE

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This work is dedicated to creation of specific software for monitoring ITS detector quality parameters. The main purpose of this work is the quick and timely problem detection related to sensors with main parameters approaching critical values. It allows us to solve problems before it starts to corrupt experimental data. The ITS detector is one of the highest priority detectors in ALICE experiment, and its uninterrupted and high-quality operation is very important and ensures the high-quality operation of other detectors. The resulting software was successfully applied to real experimental data from LHC throughout the so-called Pb+Pb RUN at the end of 2023. The observed effects are discussed.

STUDYING STRUCTURAL CHANGES IN THE SURFACE OF TUNGSTEN THAT OCCUR AS A RESULT OF IRRADIATION BY A BEAM OF IONS OF HELIUM WITH ENERGY OF 4 MeV

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The work studied the characteristics of tungsten with a purity of 99.7%, which can be used as a material for the first wall of a thermonuclear reactor. The samples of tungsten were irradiated with a ions of helium beam with an energy of 4 MeV (acceleration mode). Irradiation was carried out in "cold mode" at a temperature of 380 °K. Thin filaments of tungsten ("fluff") were found on the surface of samples of tungsten. This "fluff" was formed as a result of the diffusion of ions of helium to the surface and the extrusion of tungsten into thin filaments. The height of filaments of tungsten filaments was three times greater than the thickness. It was found that the

height of filaments of tungsten depends on energy of ions of helium and their flux density. The flux density of ions of helium had a value of $(0.15…0.44)\cdot10^{13}$ part./cm^2.

1. O.V. Manuilenko, E.M. Prokhorenko, K.V. Pavlii, B.V. Zajtsev, S.N. Dubniuk, V.V. Lytvynenko, T.G. Prokhorenko. Features of structural damages of surface of tungsten as a result of irradiation with helium ion beams with energy 4 MeV. // Problems of atomic science and technology. 2023, № 6, v. 148, p. 33-38.

NUMERICAL SIMULATION OF PHYSICAL PROCESSES THAT OCCUR IN TUNGSTEN WHEN IT IS IRRADIATED BY ION BEAMS WITH ENERGY OF 4 MeV

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Numerical modeling of the processes that occur in the surface layer of tungsten when it is irradiated with ions of helium with energy of 4 MeV has been performed. These processes occur when tungsten is used as the material of the first wall of a thermonuclear reactor. Helium ion beams were produced in a real accelerator. All processes were numerically simulated using the SRIM program code. It has been shown that impurities change the results by no more than 0.1% (for samples with a purity of 99.7%). It was found that the maxima of the processes of ionization, phonon formation, and segregation are located at a depth of 6.1 μm. The half-widths of the profile peaks of these values were in the depth range of 5.8 – 6.3 μm. Ions penetrate tungsten to depths of 7 μm. All these calculated parameters are in good agreement with experimental data [1].

1. O.V. Manuilenko, E.M. Prokhorenko, K.V. Pavlii, B.V. Zajtsev, S.N. Dubniuk, V.V. Lytvynenko, T.G. Prokhorenko. Features of structural damages of surface of tungsten as a result of irradiation with helium ion beams with energy 4 MeV. // Problems of atomic science and technology. 2023, № 6, v. 148, p. 33-38.

CHANGES IN RADIATION SHIELDING PROPERTIES OF COMPOSITE MATERIALS WITH POLYSTYRENE BASE

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The radiation shielding characteristics of composite materials with a polystyrene base were studied. The radiation shielding additive was powdered tungsten. To

increase the strength characteristics, the composite material is reinforced with powdered aluminum. The radiation shielding characteristics of samples in which the mass of component of tungsten was 45%, 75%, 90% of the total mass of the composite were studied. Such composites have high strength and hardness characteristics. Weakening of dose of ionizing radiation was calculated using the Geant4 v 4.9.6p03 code. We considered samples of composites that had a continuous structure with a layer thickness of 10 mm. It was found that all samples effectively absorb gamma radiation with energies up to 100 KeV. Also, using numerical methods, the values of half attenuation of ionizing radiation were obtained. For composite materials of this class, the half-attenuation value was in the energy range from 250 KeV to 600 KeV. The results obtained are in good agreement with experimental researches [1].

1. E.M. Prohorenko, V.V. Lytvynenko, A.A. Zakharchenko, M.A. Khazhmura -dov, S.A. Sokolov, T.G. Prokhorenko. Analysis of radiation protective properties of polystyrene based composite materials. // Problems of atomic science and technology. 2021, № 3, v. 133, p. 111-118.

COMPUTER MODELING OF PLASMA-CHEMICAL PROCESSES IN A REACTOR WITH HIGH-VOLTAGE DISCHARGES IN WATER

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A mathematical model of a reactor used for water treatment and wastewater treatment by means of nanosecond high-voltage discharges has been created. The physical model is based on the flow of air bubbles into the discharge zone and consideration of reactions involving oxygen atoms and molecules, water vapor in excited and ground states, their respective rate constants and initial concentrations, which describe the processes in electric discharges and make the greatest contribution to the synthesis of active particles such as -OH radicals. The value of the concentration of active particles in time in the gas bubble between the high-voltage electrode and the wall of the gas bubble-water interface was obtained. It is shown that the calculated temperature of electrons in energy units is sufficient for the formation of -OH radicals by electron impact from water molecules. It is shown that the calculated temperature of electrons in energy units is sufficient for the formation of -OH radicals by electron impact from water molecules. It is also shown that the average electric field strength in the treated water reaches 30 kV/cm, which, together with the radiation from the discharge, is sufficient for the irreversible inactivation of large concentrations of bacteria and the destruction of certain harmful chemical compounds.

METHODOLOGY OF DIGITAL PROCESSING OF OPTICAL SPECTRA OF MAGNETRON DISCHARGE PLASMA

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This work describes the functionality of the application for digital processing of the optical spectra of magnetron discharge plasma glow created in the Python programming language, which allows obtaining qualitative and quantitative plasma characteristics.

The plasma radiation spectrum was recorded remotely using a professional digital camera Canon EOS 80D with a resolution of 7000*5000 pixels. The application allows you to upload a digital image and automatically determine the spectrum location and set the wavelengths of the spectrum lines. The application also provides the ability to interpret spectral lines using a database of spectral lines for various elements [1].

The use of a digital camera for recordsng the spectrum makes it possible to obtain information on the distribution of line intensities along the discharge axis (spatial distribution of the intensity of the spectral line luminescence), which reflects the change in the number of excited particles along the discharge axis. It is established that the distribution of excited atoms in the discharge is a complex function of the distance along the discharge axis, which varies depending on the mode of operation of the magnetron discharge.

1. https://physics.nist.gov/PhysRefData/ASD/lines_form.html.

RELATIVISTIC ELECTRON BUNCH FOCUSING IN PLASMA IN BLOWOUT REGIME

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Focusing of relativistic electron bunches by a wakefield excited in a plasma is important for multi-cells acceleration. In [1], the mechanism of focusing by a plasma wakefield, in which the bunches are focused identically and uniformly, was proposed and studied by numerical simulation. In this contribution, this wake plasma lens is investigated by numerical simulations in the nonlinear regime for relativistic electron bunches. To prevent the bunch from exchanging energy with the wakefield, it is necessary to use a precursor bunch. The precursor bunch excites a nonlinear wakefield and prepares a uniform focusing field. The radial wake force Fr in the region where the focused bunch is located is approximately constant along the bunch. It is shown that by selecting the shape of the bunch, it is possible to reduce the energy spread of the focused bunch. In particular, a small decelerating field acts on the head of a

Gaussian-like bunch, with greater energy. The tail of the bunch, with less energy, is subjected to a small accelerating field.

1. V.I.Maslov, I.N.Onishchenko, I.P.Yarovaya. Plasma Wakefield Excitation, Possessing of Homogeneous Focusing of Electron Bunches. Problems of Atomic Science & Technology. 2013. N1. p. 134-136.

SIMULATION AND OPTIMIZATION OF WATERLOAD AT 2.45 GHz FREQUENCY

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Using the CST microwave studio program, simulation and optimization of waterload parameters for power levels up to 3 kW were performed. The load includes a short (120 mm) section of a copper rectangular waveguide with a cross section of 90x45 mm^2, into which an absorbing device is inserted through a hole in the wide wall. It is a metal cylinder with a diameter of about 50 mm and a length of 150 mm, coupled with a hollow dielectric cone 70 mm long. Water circulates inside the absorption device and then enters the heat exchanger. Absorption of microwave power occurs directly in the water without intermediate absorbers

The purpose of simulation was to calculate the main characteristics of the load, determine the optimal geometry (shape and dimensions of the cone, the depth of its immersion in the waveguide, etc.), as well as the selection of additional matching elements. Simulation results show that very high performance can be achieved with this device in an acceptable frequency range. Based on the computer simulation, a real structure of a matched waterload was developed and manufactured. Preparations are underway for its full-scale testing.

SIMULATION THE YIELDS OF PHOTONS AND PHOTONEUTRONS FROM TANTALUM CONVERTER UNDER ELECTRON IRRADIATION AT THE M-30 MICROTRON

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Bremsstrahlung radiation obtained at electronic accelerators is widely used to solve a wide range of applied tasks (for example: alternative production of medical radioisotopes). Simultaneously with the bremsstrahlung beams formed during the interaction of electrons with the converters, photoneutrons are generated, which can significantly affect the final characteristics of the irradiated samples. Therefore, information on the characteristics of photoneutrons is necessary to optimize irradiation schemes.

The paper presents the results of modeling of the dependence of the yields of bremsstrahlung photons, photoneutrons and their ratios, on the thickness of the Ta-converter (0.04 - 10 mm) for fixed values of the energies 10 - 20 MeV.

Calculations were performed fora real electrons beam of the M-30 microtron using the GEANT4 toolkit.

The present work was carried out within the framework of the project of research works of young scientists of the National Academy of Sciences of Ukraine. State registration number – 0123U102958.

KINETIC MODEL OF PHOSPHORESCENCE OF DOSEMETRIC MATERIALS IRRADIATED AT THE M-30 MICROTRON

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It is known that the phenomenon of phosphorescence belongs to the accompanying tasks of solid-state dosimetry of high-energy nuclear radiation, which can be used to improve control of radiation field parameters.

The phenomenon of post-radiation illumination can be observed for a long time after irradiation; its optical characteristics depend on the energy spectrum of alloying or structural objects in optical materials.

In the course of the work, the results of using a single-level model for the interpretation of the curves of the luminescence characteristics of materials based on LiF, $Li_2B_4O_7$, and others, which were irradiated in different modes on the M-30 microtron with an energy of 12.5 MeV, were obtained.

The proposed scheme for fitting theoretical and experimental data (the method of clips) is considered, and the dependence of the parameters of the illumination curve on the conditions of irradiation of the energy level and kinetic coefficients of the model is established. The possibility of researching the ordering of phosphorescent characteristics using the Monte Carlo method is discussed.

Section 7. Nuclear-physical methods applications (Nuclear energy, industry and medicine. Physical and environmental problems of nuclear-physical facilities exploitation and modernization).

CONTENT OF ELEMENTS AND STRUCTURAL CHANGES IN NATURAL PYROPHYLLITE BY THE INFLUENCE OF GAMMA RADIATION

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Natural pyrophyllite $Al_2Si_4O_{10}(OH)_2$, a mineral of the aluminosilicate class, has many valuable technological properties (high melting point, chemical resistance, low thermal expansion, good dielectric properties) and is used in nuclear energy as a refractory material. Pyrophyllite is also considered as a promising matrix and protective barrier for the immobilization of radioactive waste. Therefore, the study of the influence of radiation on the structure and physicochemical properties of this mineral is relevant.

Using the methods of gamma activation analysis, IR- spectroscopy and crystal optics, the elemental composition, structural and phase features of pyrophyllite in the initial state and after irradiation with gamma rays were studied.

Irradiation was carried out with bremsstrahlung gamma radiation at the LEA, the electron energy was 12 MeV. Using gamma activation analysis, impurities are detected in the samples: Ca, Ti, Fe, Mn. As a result of long-term irradiation with gamma rays, the IR- spectra show a consistent increase in the intensity of the bands characteristic of vibrations of the Al-O-H and Si-O-Si bonds due to ordering of the structure. In addition, the appearance of many small peaks associated with adsorbed moisture in the region of 3400-3450 cm^{-1} is observed, which does not lead to degradation of the pyrophyllite structure and makes it more resistant to radiation exposure.

STUDY OF MASS TRANSFER OF RAW ANALOGUES IN GRANITE

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The use of natural minerals from Ukrainian crystal shiel granites is considered as one of the most reliable disposal of large amounts of radioactive waste. The similar mineralogical composition of the immobilizing matrix and the burial medium can provide significant stability during geological immobilization barrier-rock.

The study of the diffusion of actinides into granite samples (Korosten pluton) was carried out using a Yb_2O_3 sample activated by bremsstrahlung radiation at a LEA. During the irradiation of ytterbium oxide, radionuclides were produced, the most notable of which $^{175,169,167}Yb$ have half-lives of 4.19, 32.03 and 2.36 days, respectively. Using the developed methodology, layers were removed by precision grinding from

samples of native and irradiated (up to a dose of 3 10^7 Gy) granite. The thickness of the removed layers ranged from 2 to 100 μm, which made it possible to more accurately judge the diffusion profile. Gamma radiation from active ytterbium isotopes in native and irradiated granite samples was recorded by a germanium detector with an energy resolution of 3.2 keV along the 1333 keV line.

Note that the values of the diffusion coefficients of ytterbium isotopes into irradiated granite samples were higher both for crystals and for the grain boundary zone due to the release of elements such as Na, Ca, K, Si into the intercrystalline space.

COMBINATION OF CHEMICAL AND NUCLEAR-PHYSICAL METHODS IN DETERMINING RARE EARTH ELEMENTS CONTENT IN ORES

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The growing need to use rare earth elements for the production of anti-corrosion, heat-resistant alloys requires the development of more sensitive methods for their determination in ores and waste. Using traditional analytical chemistry methods to determine each REE is difficult and expensive task.

A combination of chemical methods (sorption with a selective sorbent, acid decomposition, group precipitation, electrolytic deposition on a mercury cathode or after centrifugation, etc.) and nuclear physical methods (gamma activation analysis on linear electron accelerator with an electron energy of 22 MeV, method of characteristic X-ray radiation excited by protons with an energy of 2.3 MeV at electrostatic accelerator) allows us to effectively solve this problem. The spectra were recorded by germanium- detectors with an energy resolution of 3.2 keV along the 1333 keV line ^{60}Co and with an energy resolution of 0.2 keV along the 5.9 keV line ^{55}Fe for thin.

Experiments carried out using a combination of chemical and nuclear physical methods showed that when analyzing, for example, manganese ores, the detection limit of REE was ~ 0.1 μg/g, which fully satisfies the requirements of searching for and processing industrial ores.

PECULIARITIES OF RADIATION-INDUCED EFFECTS IN ZnO NANOPARTICLES

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Zinc oxide nanoparticles are widely used in many applied areas (solar batteries, resistors, lasers, diodes, acoustic devices, etc.).

A comparative analysis of the features of the original and gamma-activated nano-ZnO (~40 нм, SIGMA, USA) was carried out. The spectrum of the activated ZnO sample was recorded with germanium-detector. The elemental and phase composition,

crystallinity, and emission properties of ZnO samples were studied using gamma spectrometry, X- ray diffractometry, IR- spectroscopy, and photoluminescence.

Confirmation was obtained of the synergism between radiation-induced active centers on the ZnO surface and highly reactive compounds formed in the sample ($OH^{\bullet}$, H_2O_2 peroxides and due to chemical reactions of $HO_2^{\bullet}$). The crystal structure features of activated nano-ZnO with many oxygen vacancies are capable of activating additional oxygen without introducing additives. The presence of such highly reactive centers ensures the targeted use of activated nano-ZnO for catalytic processes and in medical and biological fields.

ASSESSMENT OF RADIOACTIVE AND CHEMICAL IMPURITIES IN PERTECHNETATE PRODUCED BY PHOTONUCLEAR TECHNOLOGY

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The quality of the radiopharmaceutical (RP) $^{99}TcO_4$ pertechnetate, which was obtained by the electrolytic method using photonuclear technology, was controlled by various methods. The content of radioactive impurities in pertechnetate was recorded by measuring germanium emission spectra with an energy separation of 3.2 keV along the 1333 keV ^{60}Co line. The only impurity in technicic acid was the ^{99}Mo isotope. The intensity of impurity radiation did not exceed 0.19%.

Control of chemical purity (decomposition of peroxide in a solution of technicic acid) was carried out by permanganatometry with 0.1 N $KMnO_4$ and by the quantum metric method with PMP-140 with an interference filter in the region of 630 nm. The presence of hydrogen ions (H^+) was determined by pH- metry method.

One of the important advantages in obtaining medical isotopes, including pertechnetate, when using photonuclear technologies relative to reactor and cyclotron technologies is that there is no need to immobilize radioactive waste.

Pertechnetate obtained by photonuclear technology using various carriers was repeatedly tested on animals at S.P. Grigoriev Institute for Medical Radiology.

ON THE COMPLIANCE OF THE REGULATION ACT WITH DE-FACTO DEFECT FORMATION IN THE TUBES OF PGV-1000M OF NPP IN UKRAINE

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Regular annual monitoring of defect formation in the heat exchange tubes (HET) of the steam generators PGV-1000M of NPPs in Ukraine and coordinated data accumulation between NNEGC "ENERGOATOM" and KIPT based on a representative ($>2\cdot10^6$ measurements) database (DB) enhances the factual accuracy and efficiency of future HET control during its partial implementation. The

development of the control plans is strictly regulated by normative documentation and carried out by NPP personnel through multifactor procedures, for which corresponding algorithmic schemes were primarily developed at the design stage. The creation and application of such automated procedures demonstrated a certain variability in planning, and importantly, that over the years, the volumes of measurements and their localization established by the Regulation no longer provide sufficient coverage of areas with defect development.

The results of statistical processing of accumulated defect measurements allow for the modernization of existing HET control procedures, requiring certain changes to the steam generator control Regulation. These adjustments may involve either expanding the volumes of partial control or a less costly redistribution of control localization in favor of statistically significant and critical areas of defect concentration.

At the same time, it is necessary to significantly expand the existing DB by adding results of non-destructive HET control on other NPPs to consider differences in the operation modes of steam generators at different nuclear power stations for the most comprehensive justification of the proposed changes.

CHARGED AND NEUTRAL PARTICLE ACTIVATION YIELDS FOR MEDICAL ISOTOPE ACCUMULATION

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The absolute values of their activation yields are necessary to compare when analyzing experimental data about medical radioisotope production by different accumulation routes. The problem consists of the differences between the physical processes of irradiation interaction with matter (for example proton, neutron, or gamma-rays). Also, it takes into account the characteristics of the available beams (energy spectrum distribution or particle flux density) and the difference in the thin and thick target yield. The mathematical formalism of nuclear reaction activation yields induced by charged and neutral particles was presented and discussed.

THE COMPUTER MODEL OF THE THERMAL DELAYED NEUTRON FLUXES FORMING SYSTEM FOR NUCLEAR MEDICINE

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In the work the computer model of a cell of a system for generating fluxes of therapeutic beams of delayed neutrons, based on the use of delayed fission neutrons, was developed in the Geant 4 software. The principle of such a neutron source is that when a powerful electron beam interacts with a combined tungsten target and a target containing fissile material, a fission reaction occurs; as a result of which neutrons are

emitted. If we move a target activated in this way into a neutron flux generation system, we will obtain a compact neutron source.

In the Geant 4 software, the geometry of this cell was developed and a series of experiments were carried out with 10^7 neutrons. The QGSP_BERT_HP physical sheet was used. A study of neutron energy spectra showed that more than half of the neutrons whose fluxes are formed using such a cell of the formation system have an energy <20 keV, which is suitable for use for therapeutic purposes. Analysis of the data obtained in a computer experiment made it possible to develop a modified cell of the system for generating streams of therapeutic beams of delayed neutrons, which differs from the basic one by the presence of a solid polyethylene moderator with holes for activated targets and a graphite reflector. Analysis of the data obtained showed that in this case the number of thermal neutrons hitting the detector increases 10 times compared to the base cell, and the energy of 80% of the particles does not exceed 5 keV, which is much better suited for therapeutic purposes.

DEVELOPMENT IN THE GEANT4 SOFTWARE OF THE NEUTRON SOURCE COMPUTER MODEL AT THE OUTPUT OF THE ELECTRON ACCELERATOR

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The neutron source computer model at the output of the linear electron accelerator LUE-30 in the GEANT4 software using PhysList QGSP_BERT_HP, was developed in this work. The number of computer experiments were carried out, which showed that the neutron yield at an electron energy of 25 MeV is $5 \cdot 10^{-3}$ N_n/N_e, the most probable energy is 0.6 MeV. The efficiency of using a graphite reflector depends on the radius of curvature of its hemispherical dome: the smaller the radius, the greater the efficiency. It was also found that the graphite reflector not only increases the number of neutrons hitting the detector by 20%, but also moderated the energy spectrum.

When a 5 cm thick polyethylene moderator is added to the neutron generation system, the neutron spectrum is completely moderated. In this case, the energy of 80% of all neutrons falling on the detector does not exceed 100 keV. Also, as a result of the calculations, it was established that when using a graphite reflector, the neutron background near it decreases several times and the neutron spectrum is significantly moderated. This will allow, during experiments, to increase the limiting current of the electron beam while maintaining the same radiation load, and will save the technical equipment of the accelerator.

THE STUDY OF GAMMA RADIATION PARAMETERS ON THE COMPUTER MODEL OF THE NEUTRON SOURCE ON THE LINEAR ELECTRON ACCELERATOR

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In the Geant 4 software, with the help of the computer model of the neutron source at the output of the linear electron accelerator, the main characteristics of gamma radiation were determined at the location of the irradiated samples and outside on top of the lead shielding on a large detector. We conducted several computer experiments on 10^7 primary electrons with an energy of 25 MeV. The following system configurations were considered: 1. Tungsten plates without graphite reflector and lead protection; 2. With reflector, without lead protection; 3. With graphite reflector and lead protection. The samples were both with and without lead protection. For all the considered configurations, energy spectra of gamma quanta were obtained that fall on a small detector at the location of the samples and a large detector (accelerator bunker, environment).

The analysis of the obtained data showed that the graphite neutron reflector is also an effective reflector of low-energy gamma quanta (E<1 MeV), its presence increased the flow of gamma quanta of these energies at the small detector by 30%. In general, the configuration with a graphite reflector and lead shielding around it increases the flux of gamma quanta to the irradiated samples by more than 40%. At the same time, lead protection reduced the gamma background on the samples and in the bunker by more than 20 times. The performed calculations proved that lead shielding with a thickness of 5 cm is sufficiently effective for conducting experiments on neutron programs at primary electron energies of 25 MeV.

CLINICAL NEUTRON SOURCE FOR APPLICATION IN NUCLEAR MEDICINE AND NEUTRON-CAPTURE THERAPY

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The methodology of creation of a medical high-intensity neutron source of clinical basing is proposed. The functional scheme of the source with necessary parameters and minimized accompanying background of fast neutrons and gamma radiation is presented. It is proposed to use delayed fission neutrons to produce therapeutic neutrons. The source consists of a 35 MeV high-current electron accelerator with a stored power in the beam equal to 35 kW, a core, a transport system and beam shapers of therapeutic delayed neutrons. It is assumed that neutron flux concentration will be performed with the help of a set of collimators directed from the spherical surface of the shaper structure to the center of the sphere. The possibility of transportation of

activated targets from the active zone to two shapers of different types for their simultaneous use in the generation of neutron fluxes for NCT and stereotactic surgery is considered.

According to preliminary estimates, the neutron flux densities can significantly exceed the best world standards. It is also proposed to use the accelerator core for the production of radioactive medical isotopes.

INVESTIGATION OF THE CONTRIBUTION OF BACKGROUND SPECTRA AND GAMMA-RAY DETECTION LIMIT USING THE ^{214}Bi/^{234}U CHRONOMETER FOR URANIUM AGE DATING

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One of the methods used to determine the time from the moment of enrichment of uranium is a non-destructive gamma-spectrometric uranium age-dating method based on the measuring the activity ratio ^{214}Bi/^{234}U. It should be noted that the γ-lines for ^{214}Bi and ^{234}U are located in different energy intervals and their activity significantly depends on the enrichment.

This work presents results of the analysis of gamma spectra obtained at the laboratories of NSC KIPT (Kharkiv) and INR (Kyiv) to select the optimal geometry for measuring low-intensity radiation and determining minimum detected activity of ^{214}Bi and ^{234}U. To record gamma spectra we used HPGe detectors placed at KIPT and INR. Natural, low-enriched and highly-enriched certified uranium standards (CRM 969, CRM 146) with enrichment range from 0.3% to 93% were selected as test samples.

We used absolute and also relative ("intrinsic") detection efficiency. The main goal of the research was to evaluate the contribution of background spectra and detection limits of γ-lines to the uncertainty in the uranium age-dating measurement at different measurement geometries.

THE BURN-UP PROFILE OF THE NEUTRON DETECTOR HF EMITTER IN THE WWER-1000 REACTOR CONDITIONS

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Rh-based β-emission detectors are widely used in WWER-1000 reactors to monitor the neutron field. Along with the advantages, they also have a significant drawback - signal delay due to the presence of a half-life in the (n, β)-reaction. To ensure the safety of reactor operation in transient or emergency modes, other means are used, for example, external ionization chambers. At the same time, inertialess detectors (they are also called Compton detectors) could improve safety and economy. One of the

promising candidates for such a role is a detector based on metallic Hf, where the basic processes through which the signal is formed are (n, γ)- and (γ, e)-reactions.

The main idea of this work was to find out how the burn-up affects the neutron absorption capacity of the metallic Hf emitter. This was realized by estimating the number of neutrons that disappear in the emitter as a result of the (n, γ)-reaction. A radial burnout profile was also obtained. The work was performed using the MCNPX program in the WWER-1000 reactor fuel assembly model.

DEVELOPMENT AND OPTIMIZATION OF URANIUM-MOLYBDENUM ALLOY MELTING TECHNOLOGY FOR CREATION OF NEUTRON-GENERATING TARGETS OF THE NEUTRON SOURCE

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Targets made of uranium and its alloys are a promising material for neutron-generating targets in terms of nuclear-physical properties. At the same time, essential requirements for this kind of materials are their high physical and mechanical properties, which ensure structural and geometric stability when working in a thermally stressed state, resistance to radiation growth and swelling under the influence of irradiation during work, corrosion resistance in the heat carrier environment.

During the creation of the uranium target for the neutron source of the NSC KIPT, a vacuum induction smelting of the uranium-molybdenum alloy with bottom casting is envisaged, as well as hot deformation of the ingot with subsequent heat treatment. When developing the smelting technology, it is necessary to take into account the high chemical activity of the uranium melt, which aggressively interacts with the structural materials of the installation. To increase the reliability of the alloy vacuum melting process, its vacuum system was modernized, which made it possible to significantly increase the pumping speed of active gases in the melting process and reduce the residual pressure in the melting zone. In order to safely test the new smelting technology, experimental smelting was carried out on model materials with a melting temperature significantly higher than that of the uranium-molybdenum alloy. They proved the possibility of smelting using a new technology with a uniform distribution of molybdenum across the cross section of the ingot.

HYDROGENATION OF MATERIALS IN A NEUTRON-PRODUCING TARGET

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The neutron-producing target of a subcritical assembly (SCA) consists of twelve uranium plates coated on both sides with Al layers, and the gap between the plates is filled with water. The target is irradiated with a beam of electrons with an energy of

100 MeV, which creates an electron-photon shower in the target, which causes the appearance of photo-neutrons, photo-protons and recoil protons. Using the MCNPX program, the distribution of the proton flux along the depth of the Al layer covering the front side of the second uranium plate (in the region of maximum neutron flux) was calculated. It turned out that the magnitude of the flux of recoil protons falling from water sharply decreases at distances of the order of 20 μm from the surface of the Al layer, and then from a depth of 100 μm the proton flux begins to increase due to the contribution of photo-protons knocked out from Al nuclei according to the $Al^{27}(\gamma,p)Mg^{26}$. As a result, the proton flux increases almost to its original value.

The concentration of hydrogen deposited in the Al layer was calculated. The total amount of hydrogen deposited by the (γ - p) mechanism is four times greater than the amount of hydrogen deposited by driving protons from water. At the same time, part of the photo-protons formed in the aluminum is deposited in uranium. This is an illustration of a ***new effect*** - cross hydrogenation of uranium by photo-protons from aluminum. Thus, photo-protons are the main source of hydrogenation of aluminum and the border region of uranium. The rate of hydrogen accumulation is 26 ppm/year, this should be taken into account when assessing the service life of the target.

PROPERETIES OF MATERIALS IN W-Ta NEUTRON-PRODUCING TARGETS OF SUBCRITICAL ASSEMBLY OF NSC KhFTI

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A review of works in the field of radiation materials science of neutron source target materials based on subcritical assemblies controlled by linear accelerators of electrons or protons (so-called ADS systems) is presented. Electro-nuclear ADS systems are today the prototype of safe 5th generation nuclear reactors.

In connection with the physical launch of the neutron source of the NSC KIPT, the target of which is tungsten powder coated with tantalum using high-temperature vacuum rolling, issues of preparation technology, design, and physical and mechanical properties of W-Ta target materials are considered.

The unique properties of tungsten as a metal are noted in terms of mechanical behavior in a non-irradiated state. The nuclear physical processes of the radiation damageability of a target are analyzed when it is jointly irradiated with neutrons from a subcritical assembly and high-energy (e, γ) beams. Estimates of the service life of ADS-system targets are given.

STABILITY OF THE THERMAL BALANCE OF THE EARTH

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It is known that in the system of Sun, Earth and Space during its existence the Earth's thermal balance (ETB) is maintained. This means that in the long term, the amount of heat emitted by the Earth and heat received from the Sun should be equal to the heat emitted by the Earth into Space. In such a balanced system, any change in the level of incoming or emitted heat can lead to catastrophic consequences: warming or freezing the Earth. However, the heat input from the Sun or the interior of the Earth remains at an unchanged level. Therefore, the main source of a possible violation of the ETB is the processes that occur in the Earth's atmosphere. The main participants in such processes are greenhouse gases (water vapor (WV), CO_2, CH_4, N_2O, O_3, etc.), which reduce heat outflow from the Earth.

The paper considers the effect of WV on ETB, because it is on the first place in the list of gases that have a strong greenhouse effect. WV is directly related to the cloudiness of the Earth.

In the paper proposed a system of Lotka-Volterra equations that describes the mutual influence of cloud cover on heat fluxes coming from the Sun and radiating from the Earth's surface and interior.

DESCRIPTION OF THE SUPERFLUIDITY OF He-IV ON BASE OF THE ROTON´S CONVECTIVE MODEL

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In [1], the convective model (CM) of the roton is proposed, according to which the roton is a convective cell that has the shape of a hexagonal straight pyramid. On the basis of the proposed model, the characteristic geometric dimensions of the roton were estimated, and the spatial distribution of the velocity of 7 helium atoms and the perturbed temperature inside it were described. It is assumed that the spatial distribution of rotons has a horizontal multilayered periodic structure, from which the explanation of the quantization of the energy spectrum of rotons follows.

The CM of the roton allows us to propose a physical basis for the phenomenon of superfluidity. The normal He-IV component behaves like a normal liquid, that is, as a result of wetting, it forms a meniscus near the vessel wall. Inside the meniscus interacting with the vessel wall of downward motion of the roton's helium atoms will cause the roton to move upward and thus drive of superfluid He-IV up the vessel wall.

1. Tkachenko V.I. Konvektivnaya model rotona. EEJP, 2017, V. 4, N. 1, S. 28-46.

CLEAR SKY TURBULENCE FORMATION MECHANISMS

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Clear-sky turbulence (CST) is one of the main types of atmospheric turbulence in aviation, which is not accompanied by significant cloud cover, but is observed when the sky is clear or with a small number of upper-level clouds. CST occurs because of the uneven distribution of temperature, pressure, humidity and wind in the atmosphere, which leads to the emergence of vertical and horizontal gradients of air density and speed [1].

According to the mechanisms of formation, two main types can be distinguished [2]: layered turbulence, which arises as a result of Kelvin-Helmholtz instability, when two layers of air with different speeds and densities are in close contact with each other and form wave-like disturbances of the interface; convective turbulence that results from the Rayleigh-Taylor instability, when warm, light air rises over cold, heavy air, creating thermals and vertical flows.

1. Andreeva O.L., Tkachenko V.I. EEJP, 2015, Vol. 2, № 4, P. 52–57.
2. Bozbiei L.S., Borts B.V., Tkachenko V.I. Navchalno-metodychnyi posibnyk. – Kh.: KhNU imeni V. N. Karazina, 2015. – 41.

SYMMETRY BREAKING OF TRAPPED MODES IN INHOMOGENEOUS METAMATERIALS

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Interest in metamaterials operating on trapped modes is caused by their high Q-factor, which can be used in applications for spaser and nanolaser technologies. For metasurfaces consisting of an array of nanoresonators with periodic boundary conditions, the trapped modes have an infinite Q-factor, which makes it impossible to excite them by an external normally incident field. To perturb these modes, it is traditional to introduce asymmetry into the geometry of the system. In this work, we present the mechanism of perturbation of trapped modes by introducing inhomogeneities into the structure of the metasurface. The eigenmodes, as well as resonant states under the influence of an external normally incident field were investigated. The introduction of inhomogeneities breaks the symmetry of the ground state of the system, which opens a radiation channel for the excitation of high-Q resonances. The experimentally measured values of the effective dielectric constant and the transmission coefficient, which describe the resonance properties of the heterogeneous metastructure, were calculated.

CONTROLLED HEATING OF CYLINDRICAL PLASMA USING A HIGH-ORDER EXCEPTIONAL POINT OF A COUPLED WAVEGUIDE SYSTEM

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In our previous work, we proposed a method of controlled heating of a cylindrical plasma using the features of exceptional point. A system of plasma and dielectric waveguides was investigated, the connection between which allows controlling the heating in the plasma. In this work, we propose a generalized approach using a system of coupled waveguides. The study was carried out in the multimode approximation, taking into account the dissipation in the system. We have proposed a structure consisting of a system of dielectric waveguides located along the ring. The parameters of such a system were found in which the electromagnetic field is localized in the middle of the ring formed by dielectric waveguides. This approach is expected to significantly increase the potential of the previously proposed system for plasma heating. The plasma waveguide is proposed to be placed in the middle of the ring formed by the dielectric waveguides. The heating of the plasma can be controlled by choosing different numbers of dielectric waveguides forming the outer ring. The obtained results can be used to overcome the existing problems of controlled thermonuclear fusion.

NON-STATIONARY ANALYSIS OF GYROTRON CAVITIES WITH SELF-CONSISTENT CONSIDERATION OF OHMIC LOSSES AND MODE CONVERSION

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The existing approaches to the analysis of gyrotron cavities allow to consider their longitudinal profiles of any complexity only in the beamless approximation and with non-self-consistent consideration of ohmic losses. The well-known and widely used stationary [1] and non-stationary [2] approaches can calculate the parameters of only traditional cavities with weak inhomogeneity and take into account ohmic losses by the perturbation method. There are no methods that take into account the losses and mode conversion in a self-consistent manner. Due to the increase in the operating frequency of modern gyrotrons and the need to suppress competing modes, cavities requiring such methods are increasingly considered.

In this work, a generalized non-stationary approach is proposed, that correctly and self-consistently takes into account ohmic losses and mode conversion. The power and efficiency are obtained for a gyrotron with a large inhomogeneity of the longitudinal profile. A comparison with existing approaches is made.

1. V.L. Bratman, M.A. Moiseev, M.I. Petelin, and R.E. Erm, “Theory of gyrotrons with a nonfixed structure of the high-frequency field”, Radiophysics and Quantum Electronics, vol. 16, no. 4, pp. 474-480, 1973.
2. N. S. Ginzburg, G. S. Nusinovich, N. A. Zavolsky, “Theory of non-stationary processes in gyrotrons with low Q resonators,” International Journal of Electronics Theoretical and Experimental, vol. 61, no. 6, pp. 881–894, 1986.

SUPERCRITICAL FLUID EXTRACTION OF ACTINIUM – 225 FROM MONAZITE “BLACK SANDS” OF THE AZOV SEA

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With the development of technologies in nuclear medicine, the alpha emitter actinium-225 (Ac-225) is becoming in demand. It has a half-life of about 10 days. Ac-225 is effectively used to treat prostate cancer and is also an effective drug in the treatment of other forms of cancer.

The Ac-225 isotope can be produced from ThO_2 nuclides of monazite “black sands” under natural irradiation with neutron fluxes. In Ukraine, monazite is mined from titanium-zirconium placers (deposits in the south of the Donetsk region).

To obtain the Ac-225 isotope, it is proposed to use the technique developed for Th complexes for extracting the monazite of “black sands” of the Azov Sea. In [1], a sample preparation method was developed and the sequence of stages for the extraction of Th complexes was determined. In addition, for some metal complexes (U, Mo), a method for separating their isotopes has been developed.

1. Skoromnaya S.F., Kazarinov Yu.G., Tkachenko V.I. Visnik NTU "KHPI", Seriya: Novi rishennya v suchasnikh tekhnologiyakh. 2018, №16(1292), C. 70 - 75.

MODELING OF CHANGES IN THE COMPOSITION OF NUCLEAR FUEL FISSION PRODUCTS AT HIGH VALUES OF BURNUP

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To speed up calculations, when modeling complex reactor systems, instead of modeling all possible fission products of nuclear fuel, one lumped fission product is used, the cross sections of which correspond to the average cross-sections of the distribution of nuclear fission products. However, at high levels of burnout (~ 50%) and significant changes in the magnitude of the scalar flux over time (e.g., in a reactor with a Nuclear Burning Wave [1]), such cross-sections may have a noticeable dependence on the level of burnout.

Simulations of changes in the composition of nuclear fuel fission products depending on the level of its burn-up and calculation of averaged microscopic sections

of nuclear fission products corresponding to these changes were carried out. As a result of the simulation, changes in the dependence of the distributions of nuclear fuel fission products and the averaged microscopic cross-section on the burn-up level were obtained. The nuclei that have the greatest influence on the change in the averaged microscopic cross-section of neutron radiation capture are highlighted. Formulas were obtained for more accurate modeling of the dependence of the averaged microscopic cross-section of nuclear fuel fission products at high levels of fuel burn-up (~ 50%).

1. Fomin S.P., Kirdin A.I., Malovytsia M.S., Pilipenko V.V., Shul'ga N.F. Influence of the radial neutron reflector efficiency on the power of fast nuclear burning wave reactor // Annals of Nuclear Energy. 2020. Vol. 148, Art.: 107699. DOI: https://doi.org/10.1016/j.anucene.2020.107699

LUMINESCENT ON-LINE DOSIMETRY AT AN INDUSTRIAL ELECTRON ACCELERATOR

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Quality control in industrial product processing at an electron accelerator requires continuous monitoring of critical parameters of the irradiation regime, first of all, of absorbed dose. The method of contact-free on-line measuring the surface distribution of absorbed dose in a processed object is described. The novel technique is based on the use of optical radiation induced in the object with an electron beam (cathodoluminescence, CL).

The mechanism of CL in amorphous dielectrics, to which the technical materials commonly used in radiation technologies belong to (packaging carton, polymers, etc.), is studied. The optical scheme and the equipment for CL registration at an industrial electron linac (10 MeV, 10 kW) are described. It is shown, that the intensity of CL is proportional to the absorbed dose rate. An automated system for on-line recording the CL signal and determination of the scanning beam parameters (the profile, width, offset) has been developed. The calibration data of the absorbed dose against the CL yield in the industrial range of the former are presented.

ISOTOPE DILUTION MASS SPECTROMETRY METHOD FOR DETERMINING THE MASS FRACTION OF BORON IN STAINLESS STEEL

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The procedure for measuring the mass fractions of elements in dissolved samples by inductively coupled plasma mass spectrometry is quite complex and time-consuming, even at the stage of sample preparation. The procedures for measuring and processing the results are no less complicated.

This paper proposes to use the isotopic dilution method to determine the concentration of boron in stainless steel. The method does not require the preparation of calibration solutions. The concept of this method involves adding known amounts of an isotopically enriched substance (I) to the sample to be analyzed (II). Determination of the isotopic composition of the resulting mixture (III) together with the isotopic compositions of (I) and (II) allows to determine a quantitative value - the concentration of boron in the sample. Stainless steel with a high boron content (1.6-2.0%) with a natural ratio of boron isotopes was used as the material under analysis: ^{10}B:^{11}B ~ 20:80. Elemental amorphous boron powder with the ratio of boron isotopes was used as an enriched substance: ^{10}B:^{11}B ~ 98:2. The dissolution of stainless steel samples was performed in concentrated sulfuric acid (H_2SO_4) with the addition of a 50 % solution of hydrogen peroxide (H_2O_2) under constant heating and stirring.

Two methods of measuring boron mass fractions (calibration standards and isotopic dilution) were compared and a qualitative coincidence of boron concentration values for the analyzed sample was obtained.

CHARACTERISTICS OF STRENGTH OF RADIATION SHIELDING COMPOSITE MATERIALS WITH A POLYSTYRENE BASE

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Work has been carried out to improve the technological process for the production of radiation shielding composite materials. This made it possible to obtain high homogeneity of the composition of the composites. A composite material with a polystyrene base was made. Powdered tungsten is added to the composite as a radiation shielding additive. The size of grains of tungsten is 20–30 μm. To increase the strength characteristics, the composite is reinforced with highly dispersed powdered aluminum with a grain size of 10-20 μm.

Prototypes of radiation shielding composite materials were manufactured. In these composite materials, the volume of the metal component is half the volume of the polystyrene component. Composite materials with high strength were obtained. Tensile strength tests have been carried out [1]. It was found that with such sizes of grains of metal, the maximum tensile strength was 36 MPa [1]. From a composite material with such strength, it is possible to create radiation shielding structures with a height of more than 3 meters, without destroying the composite itself.

1. E.M. Prohorenko, V.V. Lytvynenko, A.A. Zakharchenko, M.A. Khazhmuradov, S.A. Sokolov, T.G. Prokhorenko. Study of strength characteristics and radiation protective properties of polystyrene tungsten composite materials. // Problems of atomic science and technology. 2023, № 2, v. 144, p. 29-36.

RADIATION TECHNOLOGIES FOR DIAGNOSTIC CONDITION OF SORBENTS OF RADIOACTIVE INERT GASES USING POLARIZATION BREMSSTRAHLUNG

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The increase in nuclear energy capacity puts forward increasingly stringent requirements for minimizing the radioactive impact on the environment. One of the components of this problem is the assessment of the condition of sorbents of inert radioactive gases. It is known that krypton and xenon are present among the fission products of nuclear fuel. The ability of these gases to accumulate in the form of clathrates opens up the prospect of identification using polarization bremsstrahlung. The ability to polarize atoms of inert gases united in clusters is known and was described in [1]. Based on the similarity of shape between the spectra of resonance photoabsorption of atoms of inert gases and polarization bremsstrahlung radiation, the expediency of experimentally checking the polarization of atoms in clusters is substantiated. The effects of the interaction of low-energy electrons with atoms and clusters of inert gases are studied, in particular, the peculiarity of the generation of the ultralow X-ray spectrum of Kr during energy transitions is considered [1].

1. E.T.Verkhovtseva, H.S.Pogrebniak / Ultrasoft X-ray emission spectrum of Kr in the region of the M4,5 – H2,3 transitions // Optics and spectroscopy.-1978.v.45. iss. 5.-p.866-868.

PARTICULARITIES OF THE INFLUENCE OF HIGH CURRENT RELATIVISTIC ELECTRON BEAMS ON GRANITE ROCKS

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The need to develop new hydrocarbon deposits poses the task of finding new physical tools for drilling. Concentrated energy flows are one of the innovative means of rock destruction. We studied the features of the influence of tubular high-current relativistic electron beams (pulse duration 5 μs, beam current 2 kA, particle energy 350 keV) on granites. A model of spatial distribution of the absorbed dose and its conversion into thermal energy was developed using the example of patterns of removal of material from an irradiated gray granite target. An analysis of the elemental composition in the area of action of the electron beam was carried out. It is assumed that the mechanism of target destruction consists in the action of both thermal and electrophysical factors. Experimental and calculated results are compared.

FEATURES OF THE SPECTRAL COMPOSITION OF EXCITED PARTICLE RADIATION DURING ION BOMBARDMENT OF SPINEL

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A study of the main parameters of ion-photon emission at bombarding spinel ($MgO \cdot nAl_2O_3$) with ions of medium energies (Ar^+, 20 keV) carried out. It established that only the emission of excited metals atoms and ions included in the spinel observed. Quantum yield of emission from excited atoms depend significantly on the position of the level of the excited state energy relative to the band structure of the spinel.

The analysis of the radiation spatial distribution and the dependence of various states excitation efficiency on the excitation energy were showed that the two group excited particles with significantly different velocities are knocked out. This is due the action of two mechanisms for knocking them out: i) multiple collisions of the primary ion with target particles, resulting the particle that fly off receives significant kinetic energy (several keV); ii) the development of a cascade of collisions in the solid, leading to the fly off particles with kinetic energy up to several hundred eV. The excitation of these particles occurs due to the electron exchange processes between the oxide and the flying off particle.

Observed significant change of the sputtered particles yield in some excited states on the time of ion irradiation (dose) of spinel are associated with the knocking out excited complex (atom metal – atom oxygen) in unstable state, the decay of which leads to the formation of metal atoms or ions at certain excited states and the oxygen.

ON THE CREATION OF A NETWORK OF CONTROL POSTS FOR THE AUTOMATED RADIATION MONITORING SYSTEM OF THE ENVIRONMENT ON THE TERRITORY OF UKRAINE

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The report is devoted to the analysis of general approaches to the construction of a network of automated control posts of the future **Integrated Automated Radiation Monitoring System (IARMS**) of the environment on the territory of Ukraine, which is planned to be created with the support of the European Commission.

It is shown that the network of object systems of **automated radiation monitoring (ARMS)** existing in Ukraine is unable to quickly reflect changes in the radiation situation in the event of an emergency both inside the country and outside of it.

It is possible to solve this task by taking as a basis the network of existing posts of the object ARMS, a relatively uniform network of atmospheric air radiation monitoring posts belonging to the State Emergency Service of Ukraine, as well as the network of weather stations of the Ukrainian Hydrometeorological Center, which are

located near the same places as the posts monitoring, and, as a result, to form an integrated network of control posts.

Optimization of the number of checkpoints related to the economic side can be carried out using one of the well-known optimization methods.

To ensure a representative and accurate assessment of measurements during radiation control, in particular automated, both around NPPs and other radiation-hazardous objects, as well as on the territory of the country and on its border, the network of posts must be formed taking into account the ecological and hygienic principle on the basis of monitoring meteorological data, landscape and demographic zoning of the studied territory, as well as prognostic calculations using the RODOS system.

APPLICATION METHODS OF ARTIFICIAL INTELLIGENCE TO NUCLEAR REACTOR DESIGN OPTIMIZATION, OPERATION AND MAINTENANCE

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Being one of the lowest carbon-emitting sources of power, the nuclear power industry has unique advantages compared to other energy sources. However, for nuclear energy to be more competitive in modern energy systems, nuclear power plants (NPPs) must be not only economical but also safe, sustainable, and reliable.

Recent years have witnessed a trend of deep integration of information technology such as artificial intelligence (AI) and industry. The talk discusses the application of AI techniques for nuclear reactor design optimization, operation and maintenance.

The most critical part among the various complex systems of an NPP is inherently the nuclear reactor core. A nuclear reactor is a complex nonlinear system involving multiple disciplines such as nuclear physics, materials science, heat transfer, chemistry, fluid mechanics, and radiation shielding. The report examines latest progress in the research on machine learning and AI for designing accident-tolerant fuel for the light water reactors.

Another promising area of AI techniques is thermal-hydraulic simulation analysis that mainly focuses on the flow and heat transfer process of the coolant in the nuclear reactor. Essentially, the reactor is a heat source with a compact structure and a high heat release rate per unit volume. Such studies are especially relevant for accurately estimating supercritical water heat transfer coefficients in the case of supercritical water-cooled reactor.

SPATIAL RESOLUTION IMPROVEMENT OF THE NUCLEAR SCANNING MICROPROBE CHANNEL OF THE ANALYTICAL ACCELERATOR COMPLEX OF THE API NAS OF UKRAINE

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The probe-forming system of a nuclear scanning microprobe based on a quadruplet of magnetic quadrupole lenses with three independent quadrupole power supplies was studied. In the stigmatic focusing mode, the third power supply is a free parameter that affects the ion-optical characteristics of the microprobe. The optimal system was selected as a result of solving an optimization problem in which the figure of merit was the reduced collimated acceptance. The resulting probe-forming system has demagnifications $D_x \times D_y = 109 \times 59$, which is a significant improvement of ion-optical characteristics compared to the existing system based on an orthomorphic quadruplet with demagnifications $D_x \times D_y = 23 \times 23$. It is worth noting that the new system has moderate aberrations. Numerical simulation of the process of proton beam focusing with an energy of 1 MeV, taking into account the experimentally measured distribution of protons in the trajectory phase space, showed that the dimensions of the beam spot on the target can be reduced several times compared to the working system. At the same time, the current density in the focused spot increases by about one order.

EVOLUTION OF INTENSITY IN THE PROPAGATION-BASED X-RAY PHASE CONTRAST

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Visualization of low-absorbing objects and the study of fast-flowing processes are of great importance. In this direction, coherent light sources and experimental methods of recording changes in the wavefront play an increasingly leading role. Recently, one such method has been implemented in the form of next-generation phase tomography[1] and clinical Talbot-Lau radiography[2].

Our work considers the principles of the propagation-based x-ray phase contrast method based on the horizontal-type electrostatic accelerator “Sokil”[3]. Analytical calculations of the propagation of intense X-ray radiation were carried out with the aim of obtaining high-contrast projections of the studied objects, based on the data of the results of the synchrotron experiment (Siemens stars and insect wings)[4]. Expressions for the projection thickness of a homogeneous sample with a given initial inhomogeneous distributions of the intensity and the phase were obtained. To process experimental data, we used Python and Matlab (demo version) computer codes, ANKAphase and SYRMEP Tomo Project packages.

1. M. Viermetz et al., PNAS, Vol. 119, No. 8 (2022).
2. A. Momose, Physica Medica, 79 (2020).

3. O.M. Buhay et al., Phys. Procedia 66, 166 (2015).
4. K.Medjoubi et al., Microsc. Microanal., 24 (Suppl. 2), (2018).

EFFECT OF TEMPERATURE ON PHOSPHORESCENCE OF LiF:Mg, Ti SAMPLES IRRADIATED WITH 18 MeV ELECTRONS

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The dependence of the kinetics of phosphorescence decay caused by the irradiation of LiF: Mg, Ti samples with electrons with an energy of 18 MeV on the temperature is investigated.

Irradiation of all studied samples was carried out with the same fluence of $5 \cdot 10^{11}$ el$\cdot$cm^{-2} and the same intensity of $9 \cdot 10^{9}$ el$\cdot$cm$^{-2} \cdot$s^{-1} on the M-30 microtron of the Department of Photonuclear Processes of the IEF of the NAS of Ukraine at a temperature of 18°C, in the radiation field of scattered electrons with an energy of 18 MeV accompanied by integral bremsstrahlung.

The phosphorescence decay was measured on a setup in which software kept the specified temperature of the sample under study stable.

It was established that the significant influence of temperature on the kinetics of phosphorescence decay is observed at the initial stage (up to ~300 sec), which is in good agreement with the exponential law. At the same time, the final part of the curve is described by the Becquerel curve, while the effect of temperature on the kinetics of phosphorescence decay is not observed.

RADIATION MAPPING OF THE TISA RIVER BASIN (BORZHAVA DISTRICT): CHARACTERISTICS OF THE SPREAD OF RADIONUCLIDE AND ORGANIZATIONAL AND MANAGEMENT SUPPORT OF MOUNTAIN TERRITORIES

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Radioecological monitoring is becoming a vital tool in assessing the state of the environment in the mountainous regions of Transcarpathia. Namely, the Carpathian mountain massif has an essential legal normative status with various zonal differences in the territory according to geological, geochemical, and climatic conditions. First, it concerns the development of regulatory documents, the assessment of the state of

water resources of the Tisza River basin, the draft regulations for conducting an environmental examination, and radiation mapping of the studied territories. Radiation analysis of the Borzhava River is extremely important, as this river is strategically important for determining its impact on the ecological state of the Tisza and for developing effective water resources management strategies in this regional ecosystem.

The work presents the results of radiation mapping of seasonal fluctuations and migration of the content of gamma-active nuclides into the depths of adjacent territories. Their detailed analysis is carried out, which will create a basis for decision-making in the environmental management system to create a database of ecological and regulatory information and radiation mapping of territories.

STUDY OF THE TEMPORAL EVOLUTION OF THE CHARACTERISTICS OF ALCOHOLS AND SACCHARIDES IRRADIATED AT THE M-30 MICROTRON

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It is known that radiation treatment of bioorganic materials allows for the targeted modification of their structure while changing their physical and chemical characteristics and biological activity. Such capabilities are essential for practical applications in creating new products in the food and pharmaceutical industries.

The same studies for a number of bioorganic compounds are carried out on the M-30 microtron with the possibility of studying the effect of irradiation conditions on the nature of changes in their structural characteristics. This paper presents the results of studies of the properties of aqueous solutions of alcohol, glucose, and sucrose irradiated by M-30 with an electron beam energy of 12.5 MeV. Features of their temporal changes in electrophysical and optical parameters are shown. The selectivity of biological activity of irradiated aqueous solutions for selected strains of pathogenic and lactobacilli was established.