New Trends in Nuclear Physics Detectors (NTNPD-2021)

Monday 25 October 2021 - Wednesday 27 October 2021

Heavy Ion Laboratory, University of Warsaw, Warsaw, Poland

Book of Abstracts

Contents

Session 1 / 2

FIRST EXPERIMENTS WITH RADIOACTIVE BEAMS AT ACCULINNA-2 SETUP

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Investigations of the 6H and 7H hydrogen isotopes were carried out as a flag ship experiments of the recently commissioned ACCULINNA-2 fragment separator [1]. The 8He secondary beam with intensity 105 1/s and energy 26 AMeV was used for the population of the systems of interest in the 8He+d interaction. The detection of low-energy recoils 4He or 3He allowed us to reconstruct the missing-mass spectra of 6H and 7H populated in the 2H(8He,4He)6H and 2H(8He,3He)7H reactions, respectively. The reference reactions 2H(10Be,4He)8Li and 2H(10Be,3He)9Li with 44 AMeV 10Be radioactive beam were studied as well. The key issues of the measurements were i) clear 3,4He identification at low energies (˜ 8 – 20 MeV), ii) good energy and angular resolution of the experimental setup and iii) high efficiency of coincidences between decay products.
The applied experimental techniques including the cryogenic deuterium gas target and unique detector systems provided the new results on the low-energy spectra of 6H and 7H systems [2-5]. In particular, the obtained data shed light on the spectra of these exotic systems and decay mechanisms of their ground and exited states. Analysis of the other runs on 7He, 9He, 10Li isotopes populated in the (d,p) reaction and 27S with OTPC has been progressing. The next step of experimental program is under discussion.
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Session 7 / 3

The SFiNx Detector System

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A new detector system aimed to study spontaneous fission properties of short-lived nuclei was created. The system consists of DSSSD array surrounded by 116 ^{3}He-counters of neutrons. Focal plane DSSSD has 128×128 strips and 100×100 mm^2 area. Single neutron registration efficiency of counters

assembly was measured as 54.7±0.1% with using ^{248}Cm-source. The setup was tested in June 2021 during an experiment on SHELS separator. The characteristics of spontaneous fission of the ^{252}No isotope were studied. ^{252}No prompt neutrons multiplicity distribution were obtained and then also was restored using Tikhonov statistical regularisation method.

Session 3 / 4

NEDA @ HIL

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The NEutron Detector Array (NEDA) was constructed within the European collaboration, with a primary aim to serve as a neutron multiplicity filter in conjunction with gamma spectrometers, such as AGATA, GALILEO and EAGLE.
In 2022-2023 NEDA will be installed at HIL creating the opportunity for the spectroscopic studies of neutron-deficient nuclei.
The properties of NEDA and the plans for the NEDA@HIL campaign will be discussed during the presentation.

Poster session / 5

Investigation of biological response of human glioma cell lines after exposure to carbon-ion radiation

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Investigation of biological response of human glioma cell lines after exposure to carbon-ion radiation

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Radiotherapy is currently the main method of cancer treatment in addition to surgery and chemotherapy. The choice of the right treatment method depends on the tumor type and location in the patient's body. Therefore, it is principal to compare available alternative methods in order to choose

the most optimal one. To understand better the effects of ionizing radiation on the tumor and surrounding tissue, it is important to explore and quantify the relationship between energy deposition and initial biological events.
Glioblastoma is the most common and the most malignant and difficult to treat among brain tumors [1]. Two human glioma cell lines which differed in their intrinsic sensitivity to ionizing radiation (radiosensitive M059J and radioresistant M059K) [2] were chosen for preliminary research.
Both of the cell lines were irradiated by a carbon ion beam (12C) of energy 45.3 MeV generated by a U200P cyclotron located at the Heavy Ion Laboratory at University of Warsaw according to the irradiation procedure described previously [3]. To investigate the biological response of the irradiated cells, a colony formation assay was performed.
To obtain the desired doses, the radiation field's parameters and the time of irradiation were estimated by Monte Carlo simulations using the MCNP6.2 code.
Results of the cancer cell's survival fraction after irradiation by carbon ion beam will be compared with the data obtained after irradiation by other high LET (Linear Energy Transfer) and low LET radiation that is planned to perform.

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The radiation damage of PIN diode detectors irradiated with heavy ions studied with the positron annihilation spectroscopy

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The radiation damage of PIN diode detectors irradiated with heavy ions studied with the positron annihilation spectroscopy

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The damage of semiconductor detectors caused by the ionizing radiation is a widely known phenomenon. In particular, the radiation resistance of PIN diodes used in various measuring systems have been the subject of research in the past. The response of such detectors to the high flux of gamma quanta [1], neutrons [2], protons and electrons [3] was studied.

The deterioration of the quality of the energy spectrum of the registered particles determines the scope of the detector's applicability. This is especially important when designing detection systems that are to operate with large streams of charged particles.

In the HIL in Warsaw [4] and at the JINR in Dubna the attempt has been made to document the radiation damage process of the 300 μm PIN diode type detectors.

The spectroscopic properties of the irradiated PIN diode detector were monitored by measuring the spectrum collected off-beam with the 241Am α source. Structural defects caused by the heavy ions in the irradiated PIN diodes were tested using the positron annihilation spectroscopy. This is a sensitive tool for the investigation of the open-volume defects as vacancies and their clusters [5,6,7].

The results of measurements will be presented.

[1] B. Abi, F. Rizatdinova, Proceedings of the Topical Workshop on Electronics for Particle Physics, 390-393 (2009).
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[7] P. Horodek, Vacuum 164, 421 (2019).

Session 2 / 7

Optical TPC track reconstruction - behind the scenes

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The Optical Time Projection Chamber detector (OTPC) constructed at the University of Warsaw has been successfully used in recent years to study rare radioactive decays, like two proton radioactivity or beta-delayed multi-particle emission. One of the main advantages of the OTPC detector is a full 3D reconstruction of events - one can not only determine energies of individual particles, but also get directions and angles of particle tracks. Angular distribution of 2p decays proved to be an important probe for developing theoretical models of nuclear structure and for the understanding the mechanism of the decay itself.

At the core of the OTPC data analysis lies the track reconstruction algorithm - a procedure for finding energy and direction of a particle track. While the reconstruction is relatively straightforward for single-particle events, decays involving two or more particles pose more of a challenge.

In context of the recent OTPC experiment involving 2p radioactivity, the reconstruction algorithm has been revised. The author will present the reconstruction procedure step by step, discuss its advantages and drawbacks as well as show results for some simulated and real life events.

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Study of the 7He spectrum and decay products correlations in the (d,p)-reaction with 6He (29 AMeV) at ACCULINNA-2

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The helium-7 system has been experimentally studied many times, however, there are still uncertainties in the description of ^{7}He structure.
According to the systematics for the single-particle state widths, the excited states of this nucleus have a large (comparable to the decay energy) decay width. So, it is impossible to obtain convincing indications of the existence of excited states ^{7}He only from the analysis of the inclusive spectrum (and therefore, from the analysis of the inclusive spectrum, it is impossible to obtain information about the properties of the ^{7}He excited states). Therefore, more complex analysis are required for ^{7}He spectrum studies.
An example of such kind of analysis is going to be presented in the talk. The experimental design and preliminary results for the recent experiment conducted at FLNR JINR are going to be discussed. Possibilities of using the discussed experimental approach for studies of other nuclei beyond neutron drip-line are also going to be discussed in the talk.

Poster session / 9

Performance and applications of standard and non-standard GEM foils

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Gas Electron Multiplier (GEM) technology is widely used in many applications in nuclear and particle physics. It offers the potential to develop new gaseous detectors with unprecedented spatial resolution, high rate capability, sizable sensitive area, operational stability and radiation hardness.

The aim of research was to study the performance of GEM in two thickness: 50 μm (standard) and 125 μm (non-standard) in a broad range of gas mixture pressures. It was observed that non-standard, thicker, GEMs are particularly suitable for applications in experiments employing low-pressure gas mixtures due to effective gas gain capabilities and efficient suppression of secondary effects (like ion back-flow).

In this contribution, basic concepts, operational mechanisms and performance of the gas amplifier structures based on standard and non-standard GEM foils will be presented.

Session 1 / 10

The prospective scientific program of the ACCULINNA-2 fragment-separator

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The first experimental campaign of the ACCULINNA-2 fragment separator in 2018-2020 was very successfull, providing novel results for the exotic nuclides 7H, 6H, 7He, and 10Li.
Now the U-400M cyclotron is under renovation which will be completed in 2022.
The beam-off time is used to upgrade the scientific instruments at ACCULINNA-2 facility and prepare the "post renovation" experimental campaign. We dicuss the new experimental oppotunities at ACCULINNA-2 and possible prospective scientific program of the facility.

Session 2 / 11

Studies of gamma-ray and neutron induced reactions with an active-target Time Projection Chamber

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An active-target Time Projection Chamber (TPC) has been developed at the University of Warsaw to investigate the photo-disintegration reactions relevant for nuclear astrophysics and for studies of nuclear structure phenomena, e.g. alpha-clustering effects in light nuclei.
Recently, the performance of the detector was tested in experiments conducted at the Van de Graaf accelerator at the IFJ PAN in Cracow, Poland. There, a 13 MeV gamma beam produced in the ^{15}N(p, γ)^{16}O reaction was interacting with the CO_2 gas in the TPC. Events corresponding to the ^{16}O(γ, α)^{12}C reaction were clearly observed.
At the IGN-14 MeV neutron source at the IFJ PAN, the ^{12}C(n,n') reaction was investigated with the goal to observe population and 3-alpha decay of the Hoyle state in ^{12}C.
In this contribution first results of these measurements will be presented and an outlook for future studies will be discussed.

This work was supported by the Polish Ministry of Science and Higher Education fromthe funds for years 2019-2021 dedicated to implement the international co-funded project no. 4087/ELI-NP/2018/0, by University of Connecticut under the Collaborative Research Contract no. UConn-LNS UW/7/2018 and by the National Science Centre, Poland, under Contract no. UMO-2019/33/B/ST2/02176.

Session 2 / 12

R&D programme on active-target TPCs at the University of Warsaw

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An R&D program on gaseous active-target time-projection chambers (TPCs) with strip readout for studying nuclear reactions of astrophysical interest is carried out by the University of Warsaw in collaboration with University of Connecticut and ELI-NP/IFIN-HH since 2013. The long-term goal of this project is to measure cross-sections of time-reverse processes using TPC detection technique by measuring energies and angular distributions of the charged products of photo-disintegration reactions induced by intense monochromatic gamma-ray beams. In particular several (p, γ) and (α, γ) reactions can be studied by tuning composition and density of the gaseous target for particular energy of the gamma beam.
The full scale ELITPC prototype with a low-pressure gaseous target volume of about $33\times20\times20$ cm^3 has been recently build and tested. The three-dimensional kinematics of the reaction events is reconstructed from about 1000 signal strips read out by the Generic Electronics for TPCs (GET).
The ELITPC detector can utilize gamma-ray beams available at the High Intensity Gamma-Ray

Source facility at Duke University, Durham, NC, USA and at the new Extreme Light Infrastructure – Nuclear Physics facility in Magurele, Romania. In addition, the same TPC detector and data reconstruction algorithms can be used to study astrophysically-relevant neutron-induced reactions or decays of radioactive-ion beams.
The talk will cover several aspects of the TPC design, readout structure, DAQ electronics and gas system, as well as demonstration of the capabilities of the proposed detection technique using scaled down and full-size prototypes.

This scientific work is supported by the Polish Ministry of Science and Higher Education from the funds for years 2019-2021 dedicated to implement the international co-funded project no. 4087/ELI-NP/2018/0, by University of Connecticut under the Collaborative Research Contract no. UConn-LNS_UW/7/2018 and by the National Science Centre, Poland, under Contract no. UMO-2019/33/B/ST2/02176.

Session 2 / 13

Toward event reconstruction in an active-target TPC with strip readout

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An active-target Time Projection Chamber with electronic readout has been developed at the University of Warsaw. The ability to accurately reconstruct events is critical for the success of the experiments using this detector. For this purpose a novel set of data analysis tools is being built. Several methods and algorithms have been considered and investigated.
In my talk, I will present the current state the event reconstruction procedures and show its capabilities. I will discuss the challenges faced by our data analysis and which solutions we have adopted.

This scientific work is supported by the Polish Ministry of Science and Higher Education from the funds for years 2019-2021 dedicated to implement the international co-funded project no. 4087/ELI-NP/2018/0, by University of Connecticut under the Collaborative Research Contract no. UConn-LNS_UW/7/2018 and by the National Science Centre, Poland, under Contract no. UMO-2019/33/B/ST2/02176.

Poster session / 14

Implementation of PPAC type detectors on ACCULINNA-2 separator – gas system topology and working principles

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The PPAC detectors are used for particle tracking systems in experiments with rare isotope beams in which particle identification is made in an event-by-event mode. The delay-line readout method allows measuring positions of beams. The serial placement of two detectors provides a possibility of determining a beam trajectory and a focus point. The critical factor for the proper operation of the detectors is to ensure the very high purity of the gas mixture and its stable flow at a given pressure. Tests of detectors showed that even remains of contamination in the system can lead to incorrect functioning of the PPAC detector. To meet the strict requirements, it is necessary to assemble the individual components with utmost care and to prepare optimal gas system topology and control system.

Session 5 / 15

MPD TPC status

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In the frame of the JINR scientific program on study of hot and dense baryonic matter a new accelerator complex Ion Collider fAcility (NICA) based on the Nuclotron-M is under realization. It will operate at a luminosity up to 1027 cm-2 s-1 for ions up to Au79+. Two interaction points are foreseen at NICA for two detectors which will operate simultaneously. One of these detectors, the Multi-Purpose Detector (MPD), is optimized for investigations of heavy-ion collisions.
The Time-Projection Chamber (TPC) is the main tracking detector of the MPD central barrel. It is a well-known detector for 3-dimensional tracking and particle identification for high multiplicity events.
The conceptual layout of MPD, TPC design and it's parameters, the current status of the readout based on multiwire proportional chamber (MWPC) and readout electronics based on SAMPA chip as well as the status of TPC subsystems are presented.

Poster session / 18

Multi-Wire gas-filled Electron Multiplier (MWEM). COMSOL results for Crossing wires (CWEM) and Parallel wires (PWEM) options with single and double multiplication gaps

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Idea of the Multi-Wire gas-filled Electron Multiplier (MWEM) was proposed 20 years ago. Such type of detector was not widely implemented due to technological problems of it realization. At this moment new technology widely used for manufacture of MPGDs (GEM, THGEM, RETGEM, WELL, RPWELL, SRWELL, μ-RWELL, FTM). COMSOL simulation results are presented for 2 options of MWEM with single and double multiplication gaps. Proposed options will be tested at JINR and PNPI.

Session 1 / 19

New Detectors at GANIL - status and perspectives

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New facilities and detector systems of the GANIL-SPIRAL2 facility will be presented with an emphasis on recent developments of innovative and multi-detector systems. The NFS and S3 experimental areas of SPIRAL2 required a development of dedicated experimental approaches for physics with fast neutrons and heavy-ions respectively. Combination of gamma-ray multi-detectors like AGATA, EXOGAM and PARIS were recently used or will be used soon in combination with magnetic spectrometers VAMOS and LISE and charged-particle or neutron detectors to study properties of nuclei far from stability and nuclear Giant Resonances. Active target ACTAR has been recently very successfully employed in experiments studying decays of or reactions with nuclei at the drip-lines. Powerful new charged-particle arrays INDRA-FAZIA and MUGAST which are under development by international collaborations at GANIL will be shortly described.

Session 6 / 20

Short overview of the ELI-NP detector arrays

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The instrumentation, which is under construction at ELI-NP, will be presented with an emphasis of the parameters of the detectors. These include the ELIADE HPGe Clover array, the ELIGANTs - ELIGANT-GN, an array of large-volume scintillators and neutron detectors, and ELIGANT-TN, an array of 3He proportional counters, the ELISSA array of Si DSSDs and the fission detectors, ELI-BIC and ELITHGEM.

Poster session / 21

The radiation damage of PIN diode detectors irradiated with heavy ions studied with the positron annihilation spectroscopy

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The radiation damage of PIN diode detectors irradiated with heavy ions studied with the positron annihilation spectroscopy

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The damage of semiconductor detectors caused by the ionizing radiation is a widely known phenomenon. In particular, the radiation resistance of PIN diodes used in various measuring systems have been the subject of research in the past. The response of such detectors to the high flux of gamma quanta [1], neutrons [2], protons and electrons [3] was studied.

The deterioration of the quality of the registered particles' energy spectrum determines the scope of the detector's applicability. This is especially important when designing detection systems that are to operate with large fluxes of charged particles.

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The spectroscopic properties of the PIN diode detector irradiated using the heavy-ion beam were monitored by measuring the spectrum collected off-beam with the 241Am α source. Structural defects caused by the heavy ions in the irradiated PIN diodes were tested using the positron annihilation spectroscopy. This is a sensitive tool for the investigation of the open-volume defects as vacancies and their clusters [5,6,7].

The results of the performed measurements will be presented.

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Session 5 / 22

The cosmic ray detekctor (MCORD) for new NICA-MPD collider.

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The MPD (Multi-Purpose Detector) complex is the main component of the NICA (New Ion Collider fAcility) being built at the Joint Institute for Nuclear Research (JINR) in Dubna, Russia. The experiments conducted at MPD are to complement the research carried out in CERN laboratories. To increase the functionality of MPD, it was proposed to supplement it with an additional muon trigger system. This trigger will be used to calibrate and test other MPD sub-detectors with cosmic ray particles while the accelerator is not producing the experimental beam. Additionally, the trigger can be used as a Veto detector to reject cosmic rays background during experiments. A group of Polish scientists from the NICA-PL Consortium was invited to design and construct it. It was proposed to surround the MPD detector with an additional cylinder-shaped cosmic ray detector called MCORD (MPD COsmic Ray Detector). The MCORD will be based on long (1.6 m) plastic scintillators with silicon photomultiplier (SiPM) for light reading and an FPGA electronics for the analysis of the obtained signals. The MCORD detector was designed also to be used for astrophysical observations of extended air showers (EAS), especially for central part of it. It will enable the registration of multi-muon events. Due to its design, it enables the analysis of signals from any direction in relation to the zenith and horizon. This feature makes it a unique tool of this type in the world. The potential goals of these observations may be to try to explain the GZK-cutoff problem by trying to identify the sources of extremely high energy primary particles.

Session 5 / 23

Status of the MPD experiment

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The status of the preparation of the MPD experiment in the JINR NICA Complex will be presented. Construction and commissioning of the apparatus will be discussed, including progress of works in the MPD Hall. Physics performance studies will also be given.

Session 6 / 24

ELIADE gamma ray spectrometer for NRF Experiments at ELI-NP

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The laser based facility, Extreme Light Infrastructure - Nuclear Physics (ELI-NP), will benefit gamma beams produced via the Inverse Compton Scattering. Thus, the gamma beam delivered to users at high intensity and very narrow bandwidths. It opens unique opportunity to study the nuclear electromagnetic response below and above the particle separation energy. The ELIADE gamma-ray spectrometer will advance the nuclear structure studies using the Nuclear Resonance Fluorescence (NRF) method to derive new information on various effects manifested below such as the collective magnetic dipole Scissors Mode in deformed nuclei, quadrupole excitations with mixed proton-neutron symmetry, the electric Pygmy Dipole Resonance, octupole coupled excitation etc. A sound range of industrial, homeland security and healthcare applications based on NRF nuclear excitation will

be also hosted at ELIADE. The ELIADE array, as it will be discussed in the talk, consists of 8 segmented Clover detectors arranged in two rings (90 and 135 degree in respect to the beam direction) around the target position. The possible day-one (day-two, etc) experiments at ELIADE using mono energetic gamma beams are presented in the second part of the talk.

Session 3 / 25

Neutron detectors for spectroscopy and cross-section measurements at ELI-NP

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The Extreme Light Infrastructure – Nuclear Physics (ELI-NP) facility under implementation is projected to provide the European community with the highest brilliance gamma beam to date for physics experiments utilizing photonuclear reactions. One vital family of instruments implemented and ready for the operational phase with the Variable Energy Gamma-ray (VEGA) system is ELI Gamma Above Neutron Threshold (ELIGANT). ELIGANT consists of two complementary setups: ELIGANT Thermal Neutron (ELIGANT-TN) is an array of ^{3}He counters embedded in a polyethylene matrix, and ELIGANT Gamma Neutron (ELIGANT-GN) comprises EJ-301 liquid scintillator detectors and GS20 ^{6}Li glass detectors for spectroscopy of both fast and slow neutrons, and a mixed array of $CeBr_3$ scintillators and $LaBr_3$:Ce scintillators for γ rays. Dedicated digital data acquisition systems read out these detector systems. In addition to the VEGA system, ELI-NP also houses three high-power laser-system (HPLS) beamlines with 100 TW, 1 PW, and 10 PW of power, respectively. The extremely harsh environment, both in terms of electromagnetic intensity and the intensity of the radiation field, the HPLS environment induces, puts additional strong constraints on candidate neutron-detection systems. Recent developments for neutron detection systems with these constraints will also be discussed.

Poster session / 26

Automatization systems for NICA MPD Magnet tests

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At JINR (Joint Institute for Nuclear Research) in Dubna, a project called NICA (Nuclotron-based Ion Collider fAcility), (NICA is the JINR flagship project for the next decade), is being implemented to create an ionic collider based on the Nuclotron as part of a program to study nuclear matter in a hot and dense state. The main objectives of the program: the creation of an accelerator complex of ions with high luminosity in the energy range up to 11 GeV/nucleon and a modern multi-functional detector for the study of heavy-ion collisions.
The collider has two meeting points for the beams, which makes it possible to install two detectors and simultaneously carry out two experiments.
One of the detectors, the MPD (Multi-Purpose Detector), is planned to study the properties of hot and dense nuclear matter formed during collisions of high-energy heavy ions, in particular, to search for effects associated with deconfiguration and/or restoration of chiral symmetry, to study the properties of phase transitions and mixed hadron and quark-gluon phases.
The planned accelerator-accumulative complex will open new great opportunities for carrying out

applied programs at JINR in the fields of radiation technology, biology, and medicine.
An important goal of the NICA project is to provide users with a research machine that will allow them to acquire new scientific knowledge, research, and understand the physical properties of a substance at an early stage of its occurrence.
The multi-functional MPD detector is an advanced technical device. Some of its sub-detectors require a homogenous magnetic field for proper operation.
To ensure a homogeneous magnetic field, a great size superconducting solenoid was produced. To exhibit superconducting properties, it will be cooled with the use of gaseous and liquid nitrogen (thermal shield) and gaseous and liquid helium (cold mass). Four tests are required to ascertain that the magnet will perform correctly during experiments: vacuum test, leak test, electrical test, and magnetic field test.
The poster describes automation systems prepared for two of four required tests - vacuum test and leak test. For vacuum pumping, a vacuum system has been designed, consisting of three different pumps that must work in a strictly defined sequence. A leak test will be performed using the MFS (Magnet Flushing Station), which allows regulating gaseous nitrogen temperature on the outlet of the station. Using it, the magnet will be slowly cooled down to the close to liquid nitrogen temperature.

Session 6 / 27

Time Projection Chambers

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Time projection chambers (TPCs) are based on ionization chambers from the earliest days of nuclear physics. In the last several decades, gaseous electronic TPCs have come of age, with applications worldwide in nuclear and particle physics. TPCs are able to measure three dimensional trajectories of ionizing radiation tracks as well as their energy loss, with high efficiency and essentially full solid angle coverage. The talk will describe aspects of the history of TPCs, a successful example case of injecting a radioactive 30S beam into a TPC, and prospects of the future TPC project at ELI-NP with both stable ion beams delivered from tandem accelerators and the gamma-ray beam.

Poster session / 28

Gaseous detector with boron-coated blades in multi-grid configuration for fast neutron detection in homeland security and waste monitoring applications

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In this presentation we report on the construction and performance of a gaseous detector with boron-coated blades in multi-grid configuration for fast neutron detection. The aim of this project is to adapt a solution originally designed for neutron scattering experiments[1] and use it for detection of fast neutrons by adding appropriate polyethylene (PE) shielding. Multi-grid configuration of thin

layers covered with ^{10}B enriched material was proposed as an alternative to ^{3}He neutron counters due to rise of ^{3}He price and limited accessibility. In the course of this study we characterize the performance of a small size evaluation kit detector equipped with sets of aluminum blades covered with ^{10}B nanoparticles manufactured by Lubrina company (Lodz, Poland)[2]. In addition, a ^{3}He neutron counter was used in the same experimental conditions for comparison. The results of the laboratory tests were used to evaluate the size and to design a full scale detection system that will fulfill requirements for neutron detection system in homeland security and waste monitoring applications.

Poster session / 29

Radiation damages experiments

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The purpose of the current study was to investigate the effects of radiation on scintillators with SiPM senors and electronics elements. These components will be in the MPD detector which is one of the main parts of the NICA project and it's very important to know the sensivity level on radiation of these items. Therefor, three experiments were prepared in which the proton, neutron and heavy ion beams were used to irradiate the elements. Changes in the samples were checked during irradiation. The obtained results turned out to be surprising and the sensivity of the SiPM sensors is much higher than expected.

Poster session / 30

Exploring high-energy cosmic ray scenarios with global CREDO network of detectors

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Among theoretical approaches in unveiling the physics of ultra-high-energy cosmic rays (UHECR) one can distinguish the models assuming interactions of exotic super-heavy matter (including extra dimensions, Lorentz invariance violation, cosmic strings, dark matter particles or particles beyond the standard model etc.) and acceleration scenarios describing processes, in which the particles are accelerated by a particular astrophysical object (shocks in relativistic plasma jets, unipolar induction mechanisms, second-order Fermi acceleration, energy transfer from black holes or compact stars etc.). Special interest is also paid to understanding of the cosmic ray ensembles (CRE) – the phenomena composed of at least two cosmic ray particles, including photons, with a common primary interaction vertex or the same parent particle with correlated arrival directions and arrival times. In this contribution, we review various theoretical UHECR models and CRE scenarios potentially observable by the global network of detectors within the CREDO (Cosmic Ray Extremely Distributed Observatory) Collaboration.

Poster session / **31**

Detectors for measurements at heavy charged particles beams for radiation therapy

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Radiotherapy by beams of heavy charged particles has significant advantages in comparison with gamma therapy and electron beams. The main advantage of the use of proton and ion beams in radiotherapy is the possibility of the formation of spatial dose distributions, the region of maximum dose which most closely coincides with the shape of the irradiated target and falls sharply beyond its boundaries. The implementation of these advantages imposes high demands on the quality of beam formation and high accuracy of dosimetry. In addition, under the influence of radiation on biological objects, the most important characteristic is the magnitude of the linear energy transfer (LET), on which the mechanism of the action of radiation on living cells depends. Realization of these advantages requires higher precision of the proton beam dosimetry, treatment planning and patient location in the beam.
A large number of different types of detectors must be used for dosimetric and microdosimetric measurements of beams of heavy charged particles. These are ionization chambers for dosimetric calibration of beams, track detectors, various types of semiconductor detectors for microdosimetric measurements. This work presents the results of measurements of the dosimetric characteristics of heavy charged particles beams intended for radiotherapy.

Online session / **32**

Trigger system of the NA61/SHINE experiment

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NA61/SHINE is a fixed target experiment operating at the CERN Super-Proton-Synchrotron (SPS). The NA61/SHINE Collaboration aims to study the properties of strongly interacting matter on the onset of deconfinement. The SPS beam energy range allows creating nuclear matter around the critical point. Beam momentum in the range 13A-150A GeV/c and a wide selection of the system size (p+p, Be+Be, Ar+Sc, Xe+La; Pb+Pb was measured previously by NA49) create a two-dimensional scan enabling systematically significant studies.

In this contribution I will provide brief description of the NA61/SHINE facility. The main part of my talk will be devoted to the new trigger system of the NA61/SHINE, which was recently developed. The system allows for flexible choice of trigger conditions derived from signals provided by the beam detectors. Construction of the new trigger system is part of the major hardware upgrade of the NA61/SHINE detectors performed during CERN Long Shutdown 2 (2018-2021).

Session 7 / **33**

Experimental complex ACCULINNA-2: status and development

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The ACCULINNA-2 fragment separator was newly built at FLNR JINR [http://aculina.jinr.ru/] for providing RIB with Z≤20 and 20-40 AMeV. The driver U-400M cyclotron is under reconstruction until end of 2022.
The experimental complex ACCULINNA-2 includes a wide range of tools and detector systems:
• Beam equipment: production target unit, beam dump, wedge and slits.
• Additional RIB cleaning device - RF-kicker for proton-rich isotopes.
• T-o-F and tracking ion-by-ion secondary beam diagnostic.
• Cryogenic isotope thin foil physical targets:
o H2, D2 gas/solid
o Unique T2 gas/liquid
o Low temperature He3, He4 gas/liquid
• 20-1500 mkm thickness SSD with scintillator arrays allows one to combine dE-E telescopes for the wide range of tasks.
• Neutron wall based on monocrystalline stilbene (neutron/gamma pulse-shape identification) and plastic segmented array.
• Zero-angle spectrometer for beam like charged particle detection.
Thus, the directions developed by our team cover the whole spectrum of experimental tasks at ACCULINNA-2 and can be applied at other facilities.

Poster session / 34

Experimental study of fast neutron detectors with a pulse shape discrimination

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The performance of a single fast neutron detector was studied. Two different scintillators were evaluated, namely stilbene crystal and liquid EJ-301 (NEDA) scintillators. The efficiency and the calibration of each detector were done. Gamma rays and neutrons are well separated with both pulse shape discrimination (in single mode) and Time of Flight measurement of neutron-gamma particles (coincidence mode). Number of detected neutrons obtained in NEDA were ˜3 times higher than stilbene due to the bigger active volume of ˜3.15 liters liquid scintillator with 20 cm height compared to 8 cm in diameter and 5 cm long of stilbene at the same distance from the source.

Session 4 / 35

Status of the EXPERT project

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The experiment EXPERT (EXotic Particle Emission and Radioactivity by Tracking) is a part of the physics program of the Super-FRS Experiment Collaboration [1,2] which will be the backbone facility of the NUSTAR Collaboration of the FAIR project for research with exotic nuclei. The Super-FRS will be used for the production and transmission of separated isotopes to three experimental areas, and it can be also used as a stand-alone experimental device together with experiment-dedicated detectors.

The EXPERT experiments are aimed at studies of unknown exotic nuclear systems in the most-outer part of the nuclear landscape. The unbound nuclei will be studied by their decays in-flight by the use of tracking trajectories of the decay fragments and reconstructing their decay vertices. Two-, four- and six- proton radioactivity precursors are expected in the extremely proton-rich nuclei, whereas candidates for neutron (n) radioactivity, which has not been observed yet, will be searched in neutron-rich nuclei area in the vicinity of the dripline.

The EXPERT experiments will use the first half of the Super-FRS as a radioactive beam separator and its second half as a high-resolution spectrometer. The exotic nuclei of interest are expected to decay in flight, and outgoing fragments (i.e., precursor-like decay products) will be tracked and then identified by the spectrometer part. For this purpose, the EXPERT working group will equip the Super-FRS focal planes with dedicated particle (charged particles and neutrons) and gamma-ray detectors. Complementarily, 2p-radioactivity will be studied by using the Optical Time-Projection Chamber (OTPC) placed at the final focus of the Super-FRS. These two detection schemes of EXPERT will utilize the same radioactive beam simultaneously, and they can together cover a wide range of half-life.

The current status of detector developments, as well as physical cases, will be presented.

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Session 7 / 36

Fast neutron detection based on delayed neutron measurement and innovative threshold samples

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Fast and high-energy neutrons could be produced by accelerators and high-power lasers. Standard detection and neutron spectrometry techniques start to have challenging problems with neutrons with energies of 20 MeV and higher. There are several groups trying to apply approach of scintillation detectors for this energy area; special layered Bonner spheres method also could be applied with some limited success. Moreover, there are two other methods, which have already been under development by our group for last several years. Quite standard multifoil activation and threshold methodology has been modified to be able to determine very short-lived activation products, which have to be detected specifically when high-power laser with low repetition rate is used for neutron generation. We use thick samples composed of several different materials (isotopes, elements,

compounds) and correction coefficients for HPGe photopeak efficiency determination, as well as for gamma-attenuation and for neutron self-shielding. Neutron spectra are the generated via unfolding method based on several different mathematical approaches combined together. Method is capable to work up to several hundred MeV, if needed threshold and activation cross-section data are available (high-energy libraries could be used, TALYS based TENDL library or EXFOR database). We combine this more standard method with another more innovative one, method based on delayed neutron yields determination. Fission products yield function depends on mass number according to the well-known double maximum "camel" function. However, this function is different for different incident neutron energies and different actinide isotopes (or combination of isotopes like "enrichment" in case of uranium or Pu vector in case of plutonium). Delayed neutrons are usually divided into six groups depending on mother nuclei decay constants (sometimes are divided into two or eight groups). Delayed neutron groups have different fractions (relative ratio of number of neutrons in one group to number of all delayed neutrons produced per one fission reaction), which is determined by its mother nuclei fission yields. So, if these yields change, then fraction of delayed neutron in groups changes too. When we measure ratios of different groups depending on incident neutron energy we could find a monotonous function describing it. When we are able experimentally determine ratios of delayed neutron division into groups, then we could determine effective neutron energy initiating fission. Measurement of delayed neutrons ratios could be done either directly via neutron detection or indirectly through gamma spectrometry measurement of mother nuclei yields. Combining all the measurements together we are able to say a quite interesting information about fast or high-energy neutron field generated by accelerators or high-power lasers.

Online session / 37

Nuclear Astrophysics Experiments using Active Target Detectors at CENS

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Observations of astrophysical phenomena, such as the luminosity of X-ray bursts and the abundance pattern of stars, can be explained by nuclear reactions occurring in the stars. It is well known that the nuclear reaction rates of nuclei involved in nucleosynthesis have a direct impact on stellar evolution, such as energy generation, the nucleosynthesis path, and nal abundance pattern of the elements. However, due to large uncertainties in theoretical models and a lack of measurements with rare isotope beams for proton- and alpha-induced reactions, our knowledge of astronomical observables is still far behind.
One recent sensitivity study showed the light curve of X-ray bursts is extremely sensitive to (,p) reactions on proton-rich radioactive nuclei, including the 14O(,p)17F reaction. In order to constrain the astrophysical reaction rate, the cross section measurement along the large range of Ecm has been proposed using the TexAT active target time projection chamber. With this measurement, we expect to reduce the statistical uncertainty of the cross sections down by 5 to 13%, resulting in the signi cant enhancement of the astrophysical uncertainty. Furthermore, we are developing a new detector system
to provide a high detection e ciency as well as a high energy and position resolution of particles, namely AToM-X, at CENS.
Details of the experiment and new detector system will be presented. We will also discuss plans to utilize this system for experiments of nuclear reactions using radioactive ion beams.

Online session / 38

Innovative Detector Developments for Nuclear Science

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Electric monopole (E0) studies at iThemba LABS have been recently performed using in-beam reactions with an electron spectrometer (made of a solenoid magnetic lens coupled to a Si(Li), etc. detector). The spectrometer coupled with an array of fast-timing detectors and low energy photon spectrometers (LEPS) has been successfully commissioned and measurements of conversion coefficients and monopole strength parameter in ^{72}Ge and ^{72}Se determined from electron-gamma coincident measurement by ^{70}Ge(α,α') reaction. Here traditional thick (several mm) Si(Li) detectors were used to detect the electrons.
For the study of higher-lying 0^{+} states, where positron-electron pair emission becomes dominant, the adaptation of the spectrometer to use a thick (11 mm) segmented Ge detector for detection of these internal-pairs was successfully carried out. GEANT4 simulations of the performance of the spectrometer have also been undertaken.
The re-encapsulated detector with think window has been employed in source measurements for conversion-electrons. Subsequently spectroscopy of the ^{50}Ti(α,α')reaction has been completed at iThemba LABS.
A research programme has been launched to further improve on this detection method through semiconductor advances and instrumentation. The production and use of these detectors will be invaluable to the scientific programme both at the Joint Institute for Nuclear Research (JINR) and iThemba LABS (Laboratory for Accelerator Based Sciences) to further fundamental science and to catalyse innovative techniques and methodologies between the two institutes and countries.
Results of measurements will be presented together with future plans to develop at the forthcoming Technology Innovation Platform (TIP) at iThemba LABS.

Poster session / 39

FLASH ALGORITHMS FOR TRACKING AND VERTEXING

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Flash-algorithm track and vertex reconstruction routines can increase speed by 3-4 orders of magnitude over iterative routines. Concomitantly the resolution, in the context of stiff magnetic fields and particle energies in the ranges of nuclear and particle physics experiments, is rather good. This is of particular interest for trigger algorithms,or applications in which a seed solution is sought in a very short amount of CPU time. The solutions presented start with straight tracks, for which an analytical solution exists, extended to a helix with an O-III correction. An example from ATLAS MC vertexing is presented as show case.

Online session / 40

Scintillation detectors for fast neutron/gamma discrimination using PSD technique on charge integration ratio

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Charge integration ratio (Q_{ratio}) method in the Pulse Shape Discrimination (PSD) technique has been widely used to discriminate between fast neutron and gamma by using scintillation detectors. Analog pulses from the detectors are digitized by a high-speed sampling digitizer and recorded for digital pulse processing. In this work, we introduce an EJ-276 plastic scintillator and a Stilbene scintillator detector to analyze fast neutrons from a radioisotope Cf-252 and from a proton therapy, respectively. Here, the EJ-276 scintillator detector is set up for measuring neutrons from the Cf-252 source, and the Stilbene detector is used measure neutrons produced from a water phantom irradiated by the proton therapy. Experiment set-up, PSD technique on Q_{ratio} and data analysis for fast neutron and gamma background discrimination will be presented in detail at the workshop.

Session 4 / 43

Experiments at the frontiers of nuclear physics: pilot experiments of the Super-FRS Experiments Collaboration

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The future FAIR facility will comprise the superconducting fragment separator (Super-FRS) as one of its main scientific instruments. This magnetic high-resolution spectrometer, coupled to the heavy-ion synchrotron complex SIS-18/SIS-100, will be the central device of the NuSTAR collaboration for research with exotic nuclei. Together with new detector systems for particle tracking, particle identification, beam profile and intensity monitoring, it will be used for transmitting the produced and separated isotopes to downstream end stations at the exits of its three branches; besides, it can also be used as a stand-alone experimental device with ancillary detectors as a versatile high-resolution spectrometer system for exotic nuclei over a large energy range up to 1,500 MeV/u. The various magnetic sections of the Super-FRS can be operated as dispersive, achromatic or dispersion-matched spectrometer units which are ideally suited to measure the momentum distributions of secondary reaction products with high resolution and precision. In this energy range and with this flexibility, the Super-FRS is a worldwide unique instrument and allows for a variety of novel experiments. Taking advantage of new stages and ion-optical modes, it also allows for a continuation and extension of preceding experiments at the existing FRS. Already today, pilot experiments are carried out by the (Super-)FRS Experiment Collaboration at FRS as preparatory stage in FAIR Phase-0 in order to develop and test new instrumentation. This contribution will present an overview of recent experiments such as the search for new isotopes, basic atomic collision studies, precision mass measurements, studies of hypernuclei, the spectroscopy of mesons bound to nuclei and rare decay modes like multiple-proton emission. Opportunities for new co-operations will be shown, and interested scientists will be invited to join these activities.