

VEKSLER AND BALDIN LABORATORY OF HIGH ENERGY PHYSICS

The activity of the V.I. Veksler and A.M. Baldin Laboratory of High Energy Physics in 2012 was concentrated on the realization and further development of

the NICA project (Nuclotron-NICA, MPD, and BM@N subprojects) and the participation in current researches in various world-class accelerator centres.

THE MOST IMPORTANT RESULTS IN THE DEVELOPMENT OF THE ACCELERATOR COMPLEX

Basic Facilities Development

In 2012, the main activities connected with the Nuclotron development were aimed at the increase of energy and intensity up to the maximum design values; the improvement of stability and reliability; the reduction of losses during capture and acceleration, as well as the quality improvement of the slowly extracted beam.

Nuclotron-NICA

In the course of Nuclotron modernization and further development the following tasks were fulfilled:

1. Two runs (the 45th and 46th) of Nuclotron operation with a total duration of about 1650 hours were held.

2. All elements of the KRION-6T heavy ion source were fabricated, the assembly of the source was completed and the commissioning of KRION-6T has started.

3. The new source of polarized ions was assembled at the test bench, the commissioning of the source has begun.

4. The further development of the cryogenic complex has continued.

5. Installation and commissioning of the fast current transformer for the Nuclotron injection line have been completed.

6. Commissioning of the new thermometry system was completed.

7. The stable operation of the complex was demonstrated at the beam circulation time of 1000 s; the study of the accelerator's optical and cryogenic systems behavior in a long plateau mode has been carried out.

8. The acceleration and slow extraction of the deuteron beam up to an energy of 4.5 GeV/n was realized; ion beams (carbon at 3.4 GeV/n and deuterons

at 4 GeV/n) were delivered to the BM@N experimental hall.

9. R&D on the accelerator parameters' setting and measurements, tests and the study of the ion beam diagnostic have been continued.

NICA

The following tasks were fulfilled in the course of the NICA project realization:

1. Experimental studies of the booster dipole magnet have been carried out after upgrading the power supply on the test bench.

2. The development of the infrastructure for the mass-production of new models and prototypes of the superconducting magnets for NICA and FAIR has been continued.

3. The technical design of the new heavy ion linear accelerator (HILac) was prepared.

4. The technical design of the collider rings has been approved.

5. Studies of the NICA collider stochastic cooling prototype were carried out at the Nuclotron.

6. Studies of various stochastic cooling methods and of particle loss mechanisms during the long circulation have been undertaken.

ILC

JINR actively participates in the International Linear Collider (ILC) project — one of the most interesting future accelerator projects. The basic results obtained in 2012 contributing to the ILC project are the following:

1. The commissioning of the first acceleration station of the JINR electron linac was performed. The cur-

rent of the e -bunch has achieved a value up to 6 mA at energy of 23–25 MeV.

2. The undulator based on a changeless magnetic structure has been assembled at the test-bench in VBL-HEP and the field quality was measured. The results show that the required values of the field distribution and, in particular, the field magnitude at the poles have been achieved. Tasks contribution to the design and manufacturing of the FEL IR deflection magnet have been performed.

THE MOST IMPORTANT EXPERIMENTAL RESULTS

CMS

The main efforts of the JINR group participating in the CMS physics programme have been focused on research of muon pairs and multiple jet production in order to check the SM predictions and to search for physics beyond the SM [1]. The dimuon mass spectrum was studied in different invariant mass ranges. The kinematic cuts were optimized and a good agreement between experimental data and Monte Carlo predictions was demonstrated.

A search for a new high mass resonance decaying to muon pairs has been performed. It is based upon data taken during the years 2011–2012 and corresponds to an integrated luminosity of 5.0 fb^{-1} for 2011 and 5.3 fb^{-1} for 2012 of CMS data collected at 7 TeV and 8 TeV, respectively.

Upper limits on the inclusive cross section of heavy dilepton resonances had been predicted in theoretical models with extra gauge bosons Z' or as Kaluza–Klein graviton excitations G_{KK} in the Randall-Sundrum model. These limits exclude at 95% confidence level a Z' with standard-model-like couplings (a Z_{SSM}) below 2270 GeV as well as the superstring-inspired Z_ψ below 1940 GeV. The combined analysis using dimuon and dielectron events increases significantly these limits up to 2590 GeV for Z_{SSM} and 2260 GeV for Z_ψ . Thus, CMS has extended the invariant mass region studied so far (covered by LHC and Tevatron at FNAL, USA) and has established new limits for the onset of new physics.

The JINR group has also contributed to the observation of a new boson with a mass of $125.3 \pm 0.4(\text{stat.}) \pm 0.5(\text{syst.})$ in $2Z \rightarrow 4l$ decays (Fig. 1). This has followed the Higgs boson searches of 2011 in five decay modes: two photons, two tau-leptons, two b -quarks, two W -bosons and two Z -bosons. The combined analysis of the 2011 (5.1 fb^{-1}) and 2012 (5.3 fb^{-1}) data results in the observation of an excess of characteristic events above the expected background with a significance of 3.2σ .

3. The work on the DC photogun test bench aiming to the development of the hollow photocathode conception development is going on.

During 2012, at the total number of 8 articles and 19 reports have been prepared or delivered at international conferences by the members of the LHEP accelerator division. Two Ph.D. theses and one habilitation (Dr. sc.) have been successfully defended.

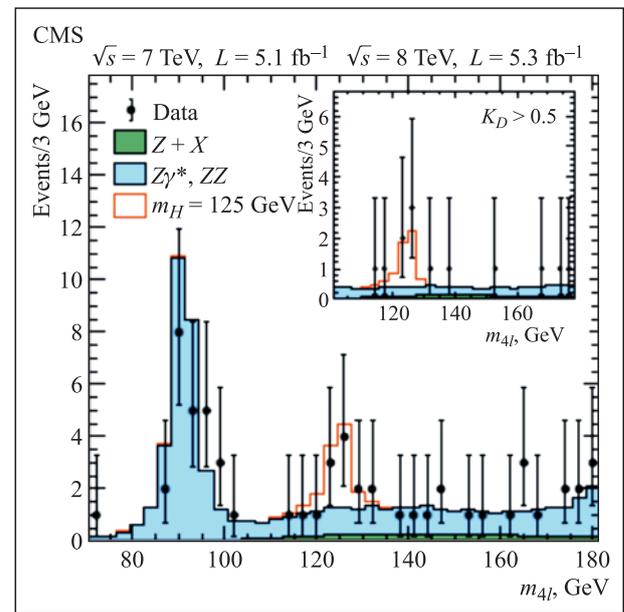


Fig. 1. (Color online) Distribution of the four-lepton invariant mass for the $ZZ \rightarrow 4l$ ($4e$, 4μ , and $2e2\mu$) analysis. The points represent the data, the filled histograms represent the background, and the open histogram shows the signal expectation for a Higgs boson, added to the background expectation

JINR scientists have given 5 presentations at international conferences.

ALICE

ALICE is a general-purpose heavy-ion detector designed to study the properties of strongly interacting matter in the form of quark–gluon plasma created in nucleus–nucleus collisions at the LHC. In 2012, ALICE carried out data taking with proton beams at 8 TeV, with the minimum bias trigger (10^8 events) and other rare triggers (10^9 events). The short pilot p -Pb run at 5.02 TeV also has been successfully carried out. The statistics of nearly $2 \cdot 10^6$ events from this p -Pb run has been analyzed, and two first articles have been published.

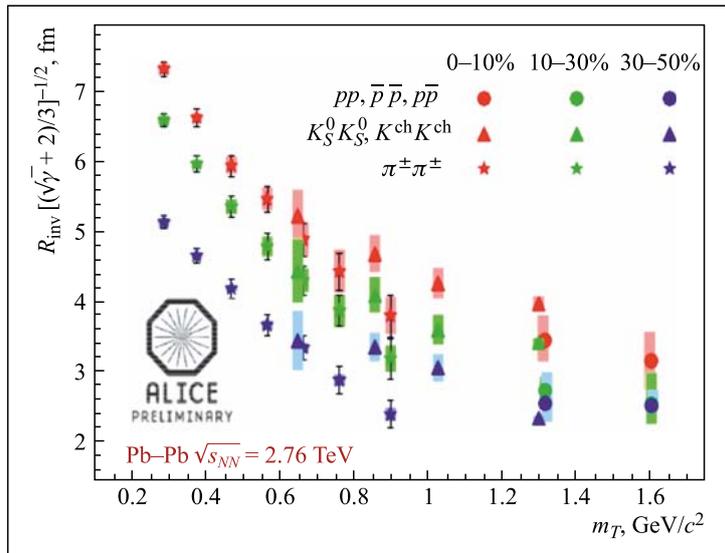


Fig. 2. (Color online) Invariant radii versus transverse mass of different particle pairs extracted from the analysis of femtoscopic correlations for Pb–Pb collisions at 2.76 TeV per nucleon pair. Blue, green and red points are for event centrality 0–10%, 10–30%, and 30–50%, respectively. An approximate m_T scaling is demonstrated

JINR group concentrates on the study of Bose–Einstein correlations between identical mesons. In 2012, an analysis of the dependence of invariant source radii on the transverse mass of charged kaons created in Pb–Pb collisions at $\sqrt{s} = 2.76$ TeV was carried out at different selected values of the event centrality (see Fig. 2) [2]. These results have been presented at four international conferences

ATLAS

In 2012, the activities of the LHEP group participating in the ATLAS experiment could be listed as follows:

- search for the Standard Model (SM) Higgs boson produced in association with a W -boson which decays to a b -quark pair;
- search of manifestations of SUSY;
- investigation of the ATLAS liquid argon calorimeter’s electronic degradation caused by the LHC high luminosity;
- global QCD fit of DIS data.

The LHEP group has actively participated in the search for the SM Higgs boson by studying its production in association with a W -boson. In 2012, $\sim 5 \text{ fb}^{-1}$ of data recorded in 2011 and $\sim 13 \text{ fb}^{-1}$ of data recorded in 2012 have been analyzed. As a result, new limit on the cross-section value for this channel has been obtained (see Fig. 3). An analysis of this channel is also important for the determination of the spin of epy candidate particle to be the SM Higgs-boson finally reported in 2012.

The programme aimed at searching for hints at SUSY has been continued in 2012. An inclusive search for the SUSY with one «hard» lepton and with large jet multiplicity in the final state has been carried out explo-

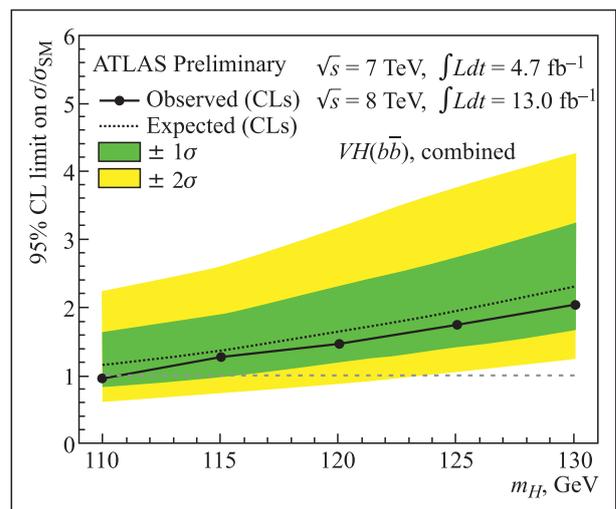


Fig. 3. (Color online) The limit on the cross-section value of the SM Higgs boson production in association with W -boson based on the statistics of 2012 ($\sim 13 \text{ fb}^{-1}$)

iting the 2011 ATLAS data. No indication for a statistically significant excess over the SM prediction was obtained and new limits for predictions of some SUSY have been set.

The obtained results have been reported by LHEP members at two international conferences.

NA62 and NA48/2 Experiments

Main results obtained in 2012 are:

1. The straw mass-production has been continued at LHEP. More than 3000 straws were manufactured; approximately 2000 straws have been delivered to CERN. The straw parameters correspond to the specification. A long-term overpressure test of each straw is in progress.

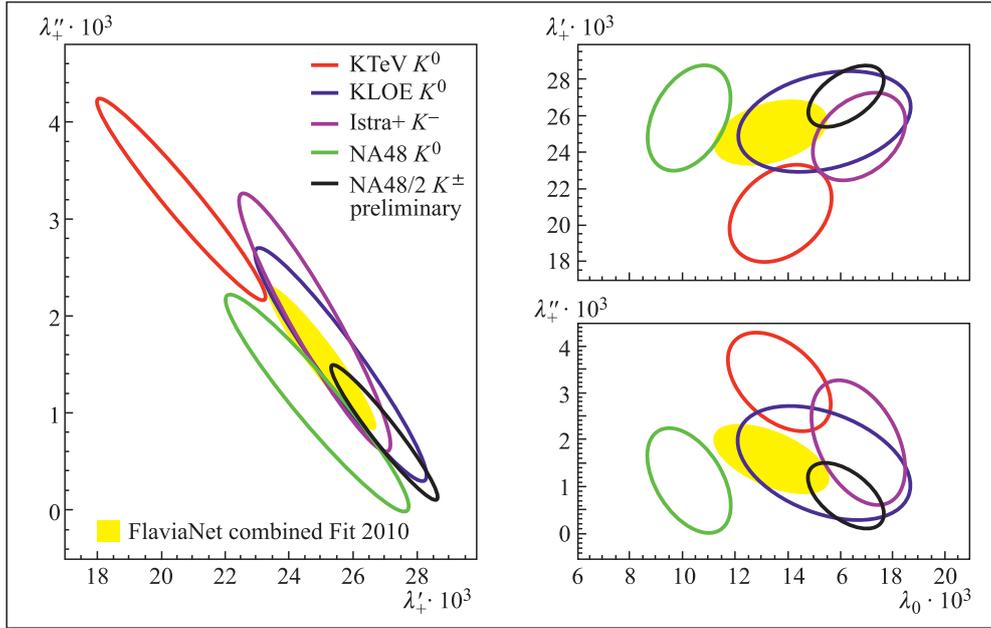


Fig. 4. (Color online) NA48/2 combined measurement of $K^\pm \rightarrow \pi^0 l^\pm \nu$ (K_{l3}) quadratic parameterization form factors, based both on K_{e3} and $K_{\mu3}$ data, in comparison with other experiment results. 68% confidence level contours are shown

2. The assembling of Module-0 (1) and Module-2 was finished at CERN. Assembling of Module-5 was started. A frame for Module-3 was delivered to JINR, its hermiticity has been tested and its assembling has started in the new LHEP assembling area.

3. The main straw assembly tool was tested and is now in use. A straw layer quality measurement system was manufactured. The system was equipped by a laser rangefinder and by an INFN mounting beam.

In the course of NA48/2-experiment data analysis, the following results have been obtained:

1. A new measurement of the form factors of the semileptonic decays of charged kaons has been performed, based on 4.0 million K_{e3}^\pm and 2.5 million $K_{\mu3}^\pm$ decays, collected during the years 2003 and 2004 (Fig. 4). The results are matching the precision of the current world average on the vector and scalar form factors and allow one to significantly reduce the form factor uncertainty contribution to $|V_{US}|$.

2. More than one million $K^\pm \rightarrow \pi^+ \pi^+ e^\pm \nu$ decays have been analyzed. As a result the accuracy of the determination of the branching fraction has been improved by a factor of 3 [3]. Concurrently, about 45000 $K^\pm \rightarrow \pi^0 \pi^0 e^\pm \nu$ decays have been analyzed. A background contamination below the percent level and a very good π^0 reconstruction allow the first accurate measurement of the branching fraction and of the decay form factor at the percent level.

3. The branching fraction of the $\Xi^0 \rightarrow \Sigma^+ \mu^- \nu_\mu$ rare decay has been measured with the best precision to be $(2.17 \pm 0.32_{\text{stat.}} \pm 0.17_{\text{syst.}})10^{-6}$.

4. A precise measurement of the ratio R_K of the rates of kaon leptonic decays $K^\pm \rightarrow e^\pm \nu$ and $K^\pm \rightarrow \mu^\pm \nu$ within the full data sample collected by

the NA48 experiment at CERN in the years 2007–2008 has been performed. The result, obtained in the analysis of ~ 150000 reconstructed $K^\pm \rightarrow e^\pm \nu$ candidates with 11% background contamination, is $R_K = (2.488 \pm 0.010)10^{-5}$, in agreement with the Standard Model expectation.

Four articles have been prepared and six reports presented at international conferences by the JINR team members.

COMPASS Experiment

In 2012, COMPASS was taking data with pion and muon beams to measure Primakoff reactions, and Deeply Virtual Compton scattering. The data analysis is in progress.

The main results obtained in 2012 are given below.

COMPASS has presented the results of a determination of the gluon polarization $\Delta g/g$ in the polarized nucleon, based on the longitudinal asymmetry of DIS events with a pair of large transverse momentum hadrons in the final state. The data was obtained using a 160 GeV/c polarized muon beam scattering off a polarized ${}^6\text{LiD}$ target. The values obtained at leading order in QCD do not show any significant dependence on x_g . The average is $\Delta g/g = 0.125 \pm 0.060(\text{stat.}) \pm 0.063(\text{syst.})$ at $x_g = 0.09$ at a scale of $\mu^2 = 3$ (GeV/c) 2 .

First measurements of azimuthal asymmetries in hadron pair production in deep-inelastic scattering of muons on transversely polarized ${}^6\text{LiD}$ (deuteron) and NH_3 (proton) targets have been presented [4] on the basis of data which had been taken in the years 2002–2004 and 2007. The asymmetries provide access to

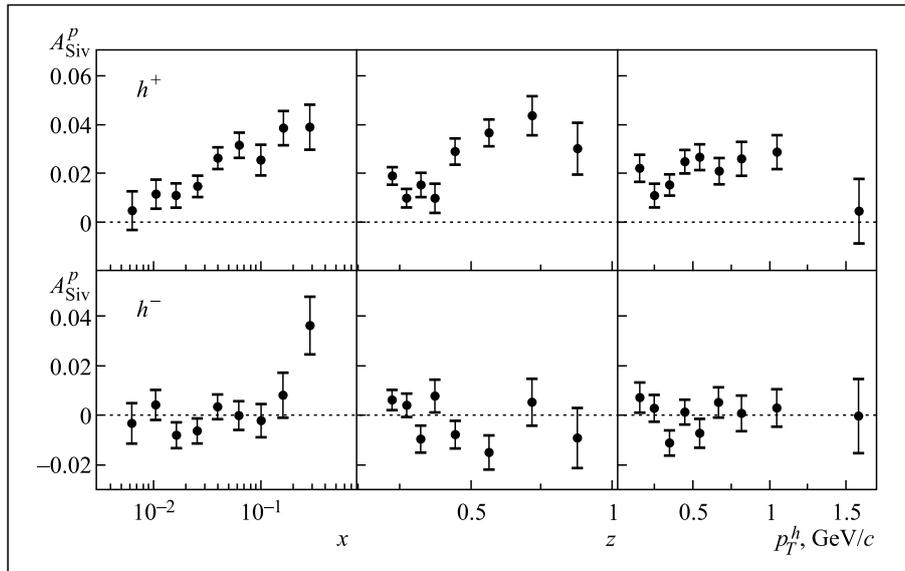


Fig. 5. Sivers asymmetry as a function of x , z , and p_T^h for positive (top) and negative (bottom) hadrons

the transversity distribution functions, without involving the Collins effect as in a single hadron production. The sizeable asymmetries measured on the NH_3 target indicate a nonvanishing u quark transversity. The small asymmetries measured on the ${}^6\text{LiD}$ target can be interpreted as indication for a cancellation of u and d quark transversities.

COMPASS has presented the transverse spin azimuthal asymmetry of charged hadrons produced in semi-inclusive deep inelastic scattering of 160 GeV μ^+ off a transversely polarized NH_3 target. The Sivers and Collins asymmetries of the proton have been extracted in the Bjorken- x range $0.003 < x < 0.7$.

The Sivers asymmetry was found to be compatible with zero for negative hadrons and positive for positive hadrons. This is a clear indication of spin orbit coupling of quarks in a transversely polarized proton (Fig. 5).

To perform measurements of Generalized Parton Distributions (GPD) at COMPASS, the present setup has to be upgraded by adding two new detectors: Recoil Particle Detector (RPD) and electromagnetic calorimeter. This calorimeter with already existing ECAL1 and ECAL2 calorimeters will provide hermiticity of the setup. The ECAL0 was suggested and designed at JINR.

The pilot run of DVCS has been performed in November last year. For this run, about one quarter of the calorimeter was successfully assembled and installed in the setup. For the first time, the calorimeter with read-out, based on avalanche Multi-Pixel Photo-Detectors (MAPD) instead of PMT, was built for use in a large-scale experimental setup. Also a new technique of calorimeter calibration was used, which is based on photon data from π^0 decays.

Five reports were presented by JIBR team members at international conferences. The JINR group ac-

tively participated in the preparation and smooth running at JINR of the International Spin Physics Symposium SPIN 2012.

STAR

In 2012, the research activity of the LHEP group participating in the STAR experiment was focused on solving two tasks:

1. The following results were obtained during participation in the energy scan (ES) programme at RHIC studying Au-Au collisions at a series of energies, $\sqrt{s_{NN}} = 7.7, 11.5, 19.6, 27,$ and 39 GeV:

- first preliminary results on the charged hadron spectra with high p_T and multiplicity distributions;
- preliminary results on the distribution of charged hadrons vs. momenta for different collision centralities;
- dependence of the hadron net charge yield on p_T at different centralities;
- in the z -scaling approach, a preliminary analysis of charged hadron spectra was performed.

2. Measurements of double spin asymmetries in the jet production and single spin transverse (π) and longitudinal (W) asymmetries were done in a frame of the programme with polarized proton beams.

Six reports were presented by JINR members at international conferences.

NA61 Experiment

In 2012, the NA61 Collaboration carried out a number of runs aimed on:

- study of the interaction of 120 GeV/c protons with a carbon target;
- measurement of the ratio of yields of various hadrons to that of kaons at 158 GeV/c;

- study of $p(158 \text{ GeV}/c) + \text{Pb}$ interactions in the heavy ion physics programme.

The possible indication of the QCD critical point signatures was investigated in the event-by-event fluctuations of various observables such as the mean transverse momentum, particle multiplicity and azimuthal angle distributions as well as in the particle ratio [5]. The energy dependence of these observables was measured in central PbPb collisions in the full SPS energy range while for analysis of the system size dependence data from pp , CC, SiSi, and PbPb collisions at the top SPS energy were used.

HADES Experiment

In 2012, the analysis of data on dp elastic scattering has been successfully finished. Data on double production of charged pions in np collisions are under analysis. Possibility of a HADES setup at the future FAIR was under investigation.

Experiments at the Nuclotron Carried out During the 2012 Year Runs

During the 45th and 46th Nuclotron runs more than 50% of the beam time was used for the operation of the current experimental setups and beam detector tests.

In particular, there have been benefitted:

FAZA-3 Experiment. Following the FAZA-3 experiment, the transition from particle evaporation to multibody decay with growth of excitation of a nucleus has been observed. For the first time, the FAZA Collaboration was able to measure the total time duration of the process including not just emission time, but also an expansion stage of the hot nucleus up to the moment of breakup ($\sim 100 \text{ fm}/c$). For the first time, an important thermodynamic parameter — the critical temperature of the nuclear «liquid-gas» phase transition — was measured [6].

The appearance of a collective flow of nucleons inside a hot nucleus has been experimentally confirmed

BM@N Project. The BM@N project is a fix target experiment which was proposed for realization as the first stadium of the NICA project. In that framework, to advance the BM@N project preparation, the following activities have started in 2012:

- Preparation of the beam line. Two test runs with a 3.42 A GeV carbon beam and a 4 A GeV deuteron beam have been performed in December 2011 and March 2012. The goal was to check the conditions of the 6 V beamline and to formulate the technical requirements.

- R&D works on the warm resistive plane chambers for the BM@N experiment have been started.

- The WA98 hadron calorimeter was delivered to JINR from CERN. This calorimeter will be reassem-

bled for the use as Zero Degree Calorimeter as a part of the BM@N setup.

- The work on the tracking system has started. Almost all equipment which is needed in order to perform the tests of the large drift chambers (originally part of the NA48 experiment) was delivered from CERN to JINR.

- The first scintillation fiber hodoscope equipped with multi-anode H6568 phototubes has been prepared.

«Energy and Transmutation» Project. The QUINTA setup was assembled with a new, more extended and massive (500 kg, $\varnothing 30 \times 65 \text{ cm}$) uranium target and irradiated by the Nuclotron deuteron beam with energy in the range from 1 to 8 GeV. Simultaneously during this experiment, the time spectra of delayed neutrons (DN) have been measured (with the help of the IZOMER-M detector) as well as the spatial distributions of the ^{238}U fission rates. Besides that, the first direct measurements of the energy spectra of prompt leakage neutrons produced within the target assembly have been carried out by the liquid scintillation detector DEMON. These measurements have revealed a large background of high energy neutrons. Special calculations have been performed aiming at the optimization of the existed detector shielding. The required modifications were done.

In contrast to previous calculations it was experimentally proven that in the accelerator-driven subcritical (ADS) system with a deep subcritical natural uranium target the total number of fissions increases linearly within the incident energy range under study. The group analysis of DN time spectra indicates that their energy is growing with the increase of the incident deuterons' energy

DSS Project.

- Two runs have been carried out using the Nuclotron internal target. The energy scan for dp -elastic scattering was performed at 400, 500, 600, 700, and 800 MeV to measure the differential cross section. Also the reaction of deuteron break-up $dp \rightarrow ppn$ was measured at energies 150, 200, and 250 MeV. The data analysis is in progress.

- The final results on the vector A_y and tensor A_{yy} and A_{xx} analyzing powers for dp elastic scattering at 880 MeV have been obtained and published [7].

- Final results on the cross sections for dp elastic scattering at energies 500, 700, and 880 MeV have been obtained. An article has been submitted to Part. Nucl., Lett.

- Within the multiple-scattering model, results concerning the cross sections and the analyzing powers for the reaction $dd \rightarrow \text{He}^3 n$ have been obtained at moderate and high energies.

PROGRESS WITH THE MPD SUBSYSTEMS

In 2012, the MPD Collaboration worked for the further development of the detector subsystems as part of the preparation of the Technical Design Report (TDR). In particular, the following results were achieved:

TOF

- During the test of the multigap resistive chamber prototype a time resolution of 80 ps has been achieved. During the optimization of the prototype with the strip readout a time resolution of 70 ps has been obtained.

- The test bench for the study of different detectors on cosmic rays has been prepared. It is used now for the test of TOF and FFD prototypes. It allows one to study in detail the on-camera features and fast readout electronics.

- New prototypes with various readout structures (strips and pads with different step and active area sizes) were developed in parallel with the testing of already existed prototypes of the TOF detector. This study is needed for the TOF detectors' optimization for both MPD and BM@N.

TPC

- The TPC technological prototype has been built out of composite materials. The body thickness is 2 mm. The full size prototype of the ROC chamber is used for the readout. The chamber has been tested using radioactive sources and trying out working gas mixes Ar/CH₄(90/10) and Ar/CO₂(80/20).

- An investigation of the ROC body deformation caused by the wires' tension has been performed.

- First data were obtained with cosmic rays and a UV-laser source ($\lambda = 266$ nm).

- The internal cylinder of TPC has been manufactured.

- Six first prototypes of the 64-channel readout electronic plates for ROC based on specialized ALTRO and PASA chips have been manufactured. The main advantage of these plates is simultaneously low power consumption, low noise, and high data compression (~ 10 times).

Straw

The prototype (with a sector $\sim 70^\circ$) of the detector was manufactured to investigate the methodology of the straw linearity control. The test bench including the gas system, high and low voltage sources, readout electronics and DAQ as well as a gamma ray source Fe-55 has been built (Fig. 6).

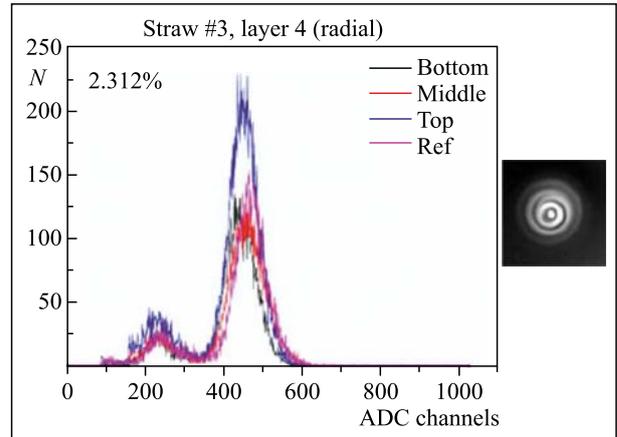


Fig. 6. (Color online) Spectra of signal obtained with gamma-rays source at 3 positions: blue curve — top position (5 cm), red curve — center of the straw (30 cm), black — bottom position (55 cm), lilac — the spectrum from monitoring counter. The difference in the amplitudes is 2.3%, it corresponds to the curvature less than $200 \mu\text{m}$

Calorimetry

The tests at electromagnetic calorimeter ECAL module are carried out with the use of cosmic rays and light sources. The pilot versions of the DAQ, slow control and calibration system have been created. The assembly of four modules is prepared and ready for the beam tests to be carried out.

As zero degree calorimeter (ZDC) of the MPD setup it is expected to use an assembly of modules made as 60 sandwiches of Pb and plastic scintillator with cross section 20×20 cm. The thickness of each Pb plate is 16 mm, of the plastic scintillator — 4 mm. The prototype was manufactured in 2012. The material budget in the ZDC module corresponds to 5.7 nuclear lengths. The semiconductive micropixel photodiodes MAPD (from Zecotek Photonics Inc, Singapore) were chosen as a photodetector. Good linearity of the signal was observed up to 10^4 photoelectrons, what is sufficient for the intended energy range. The ZDC calorimeter response was tested on the T10 PS beam line at CERN with pion and proton beams at 2–6 GeV/c.

The study of the energy resolution and of the linearity of the test module has demonstrated the validity of the choice (Fig. 7). The obtained energy resolution is described by the formula

$$\frac{\sigma_E}{E} < \frac{60\%}{\sqrt{E(\text{GeV})}}$$

in the NICA energy range.

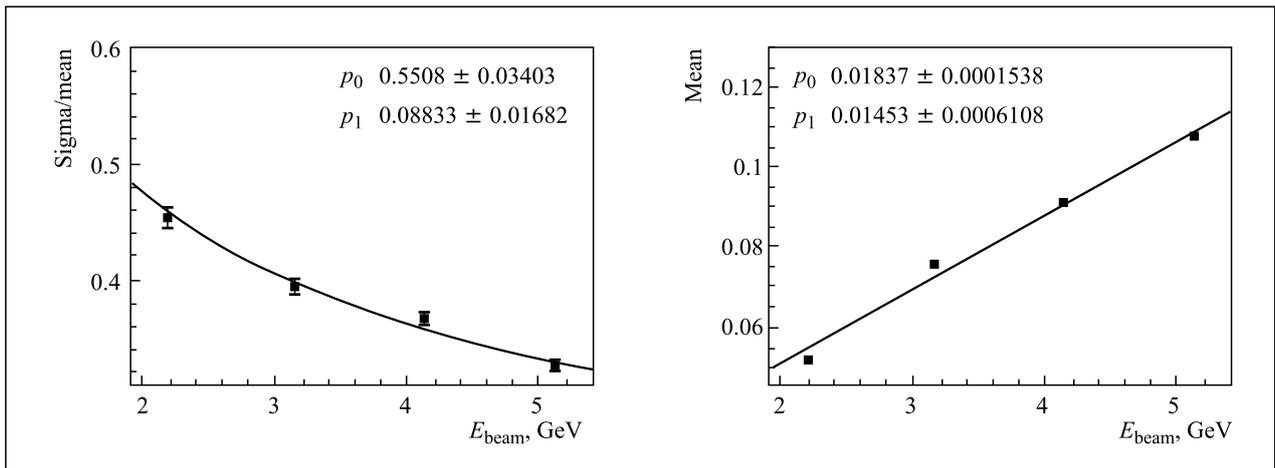


Fig. 7. Energy resolution (left) and linearity of the response (right). Measurements were done with proton beam energy range 3–6 GeV/c

INNOVATIONS

Straw

1. A prototype based on the 4 mm diameter granulated straw was prepared and tested on the bench in various operating modes with ArCO₂ gas mixture at pressure 1–4 bar. Special attention on the radiation hardness was paid to the operation at 3 bar pressure since a spatial resolution better than 50 microns was obtained earlier in this mode. An X-ray tube with Cu-anode has been irradiating the straw with 8 keV photons. Any effect of aging is not detected for the integrated charge about 3C/cm of the straw.

2. A one-layer prototype module based on 2 m long straws with sensitive area $2 \cdot 0.5 \text{ m}^2$ was prepared and tested. The prototype contains 48 straws with an inner diameter of 9.56 mm and a wall thickness of $\sim 60 \mu\text{m}$. The prototype has a rigid planar structure containing N (multiple of 8) straws covered with epoxy resin. The structure thickness is only 0.2 mm larger than the straw diameter due to the increase of 0.1 mm on each surface. The production technique makes it possible to preserve both the straightness and the straw diameter as well as a constant gap between adjacent straws. The technique developed for the prototype makes it possible to construct relatively low-cost planar modules by using straws of arbitrary length as well as to assemble them in a common coordinate detector with a user-specified acceptance. If necessary, the straws of diameter 4 mm and larger can be granulated. A good radiation hardness, low radiation thickness and the possibility of operation with the gas filling from normal pressure up to 4 bar by keeping the geometrical dimensions unchanged offer additional opportunities for optimizing the detec-

tor operation in the proportional or limited proportional modes, for example, as the detector operation mode. In particular, it is of interest to improve the spatial resolution by employing coordinate detectors of the MIP in the high current operating mode based on high pressure straws.

Education

1. Dubna University and JSC InterGrafika have founded an «Enlightment Center Named after Academician A. N. Sissakian» in order to popularize achievements of modern science and technology and to increase the education quality in general in Russia and in the JINR Member States, with the aim to involve talented youth in scientific work. LHEP has played the key role in the creation of the center.

2. The exhibition «Online Science Classroom» was organized and took place in Brookhaven National Laboratory in July and August 2012. It was part of the programme of «Summer Open Days» in BNL. More than 10000 people visited it. The exhibition was a great success. The director of BNL, Sam Aronson, the founder of RHIC, Satoshi Ozaki, and the Associate Director for Nuclear Physics of DOE, Tim Hallman have visited the exhibition. In this connection the words of Tim Hallman concerning the role of the JINR-BNL education programme are worth mentioning: «A new horizon in modern science education has been established which promises to be very important in training the next generation of scientists in the United States and Russia. The success of this effort is very important to advance the technological, economic, and security interests of both nations».

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