VEKSLER AND BALDIN LABORATORY OF HIGH ENERGIES

In 2005, the scientific programme of the Veksler and Baldin Laboratory of High Energies (VBLHE), Joint Institute for Nuclear Research (JINR), as in the previous years, was concentrated on investigation of interactions of relativistic nuclei in the energy range between a few hundred MeV and a few TeV per nucleon to search for manifestations of quark and gluon degrees of freedom in nuclei and asymptotic laws of nuclear matter in high-energy collisions, as well as on study of the spin structure of the lightest nuclei [1–4].

Experiments in this field were carried out with the beams of the VBLHE accelerator complex and the accelerators at CERN, BNL, GSI, and others. Today VBLHE is the accelerator centre at which a wide range of research is possible in the energy range in which the transition from the effects of nucleon structure of a nucleus to the asymptotic behavior in nuclear interactions takes place. International scientific cooperation of the Laboratory is diverse: CERN, many physics centres in Russia, scientific centres in the JINR Member States, a number of research centres in the USA, Germany, France, Japan and other countries.

This report presents some new results obtained at VBLHE in 2005.

New results were obtained in testing the superconducting fast-cycling and fast-ramped magnets and cables designed for SIS100 (GSI) and the Nuclotron booster. The obtained data can also be useful for the future LHC booster upgrade. The total run time of the Nuclotron amounts to 2008 hours.

Delta–Sigma Collaboration

Energy dependence of the ratio $R_{dp} = d\sigma/d\Omega(nd)/d\sigma/d\Omega(np)$ was measured at 0 degree in the laboratory frame. The experimental observable R_{dp} is the ratio of the quasi-elastic nd and free np elastic scattering differential cross sections.

The experimental results are shown in Fig. 1. They were reported at the International Workshop [5] being very important results. These measurements showed that no asymptotic behavior is observed at least up to 2 GeV, and the momentum approximation is not valid.

In the framework of the scientific programme of the «Delta–Sigma» project preliminary results on energy dependence of the R_{dp} ratio of differential cross section of the quasi-elastic np charge exchange at 0° in the laboratory frame on a bound proton in a deuteron and the free np elastic charge exchange were first obtained. The data were obtained using the neutron beam produced by the decay of relativistic deuterons of the high-intensity beam extracted from the Nuclotron and the magnetic spectrometer of the «Delta–Sigma» setup.

The R_{dp} observable measured with the unpolarized neutron beam at the Nuclotron using the cryogenic H2 and D2 targets, according to a particular theoretical approach, can be connected with the spin-dependent np amplitudes; in this case the R_{dp} data will give an opportunity to avoid ambiguity in reconstruction of these amplitudes. The simplest dependence of R_{dp} on the np amplitudes is obtained under the momentum approximation. However, it is seen from Fig. 1 that the momentum approximation which was used to express R_{dp} in terms of the np amplitudes, known from the *phase shift analysis* (see the curve and small solid points), is not valid in this case. Presently, the data are being analyzed using another theoretical model. In December 2005, sufficient statistics for calculation of R_{dp} was obtained during the Nuclotron run using the «Delta–Sigma» setup and the *neutron* beam with energies 0.8, 1.4, and 1.7 GeV. The processing and analysis of the obtained data is under way.

The scientific programme of the «Delta–Sigma» project includes measurements in the energy range of 1–4 GeV of polarization np observables (the difference of the total cross sections $\Delta\sigma_{L,T}(np)$ for parallel and antiparallel spin directions of interacting particles for longitudinal (L) and transverse (T) spin orientations and the spin-correlation parameters $A_{00kk}(np)$ and $A_{00nn}(np)$) sufficient for direct reconstruction of the real and imaginary parts of the spin related amplitudes for the np

forward elastic scattering. The set of data on energy dependence of the np polarization observable $\Delta\sigma_L(np)$ was obtained earlier at the Synchrophasotron using the longitudinally polarized neutron beam and large longitudinally polarized proton target. We plan to continue measurements with the polarized target using polarized neutron beams at the Nuclotron after the new high-current source of polarized deuterons is put in operation.

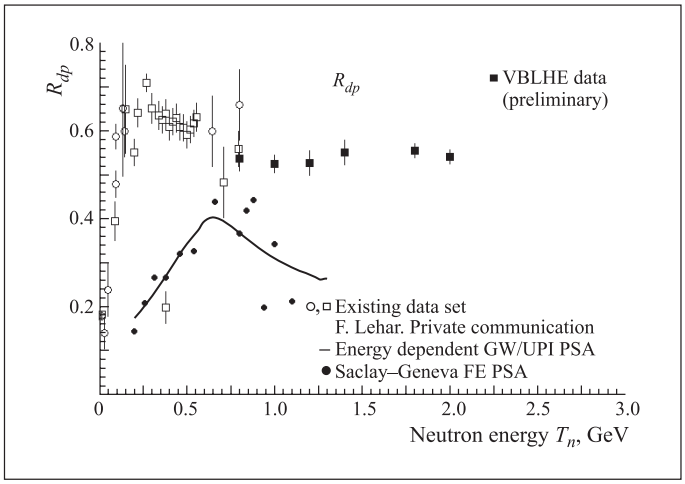

Fig. 1. Energy dependence of the R_{dp} ratio for elastic charge-exchange process $np \to pn$ at 0° in the lab. system

LNS–pHe3 Collaboration

The first phase of the experiment with an energy up to 270 MeV was carried out in Japan at RIKEN under the leadership of Dr. V. P. Ladygin. The results of this experiment on polarization characteristics of the $d + d \to {}^3\mathrm{He} + n$ reaction were published in 2005 [6].

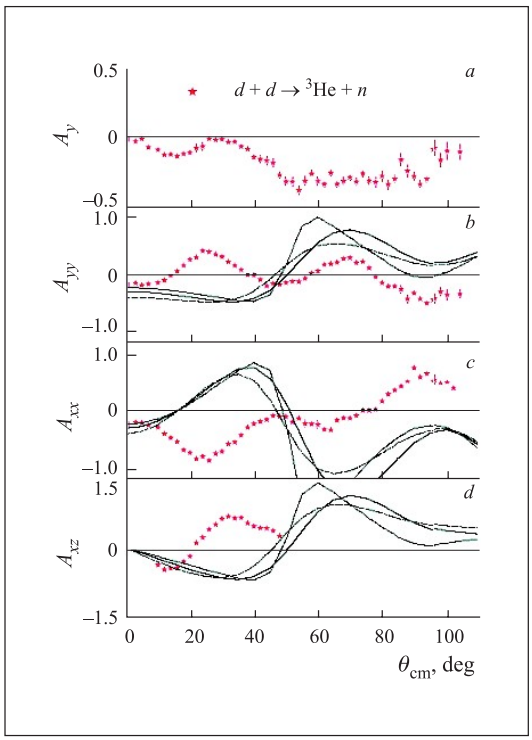

Fig. 2. Angular dependences of the analyzing powers of the deuteron beam in the $(d,{}^3\mathrm{He})n$ reaction at 270 MeV

These measurements were carried out with high accuracy and are very important for construction of the theory of three-nucleon forces (Fig. 2).

The run with polarized deuterons took place at the Nuclotron in the summer of 2005. During this run the upgraded LNS setup operated at the internal beam (Fig. 3).

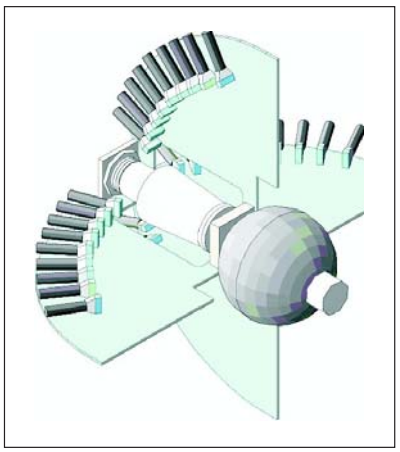

Fig. 3. The upgraded LNS setup at the internal beam of the Nuclotron. The scintillation detectors (36) mounted in four planes are directed towards the internal target area (spherical area)

The experimental data on the angular dependence of dp elastic scattering were obtained for deuteron energies of 270, 880, and 2000 MeV. The data for 270 MeV were collected for comparison with the data obtained at RIKEN for the same energy. This comparison is shown in Fig. 4. A good agreement of the results obtained at RIKEN and JINR is observed.

The preliminary results of data processing were obtained for 880 MeV and those for 2 GeV are being processed. The results for 880 MeV are shown in Fig. 5.

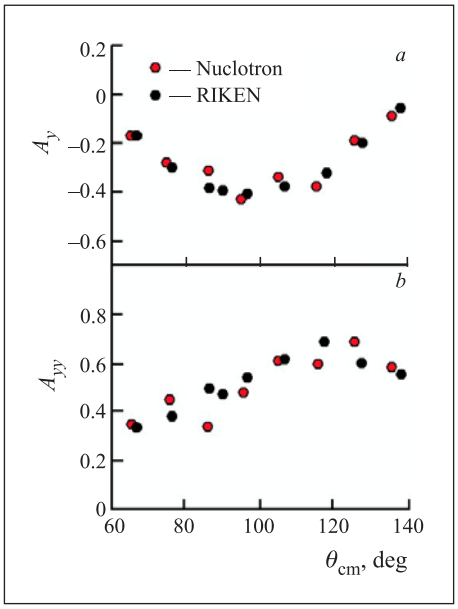

Fig. 4. The *dp* elastic scattering in the region of the Sagara discrepancy effect for a deuteron energy of 270 MeV (preliminary)

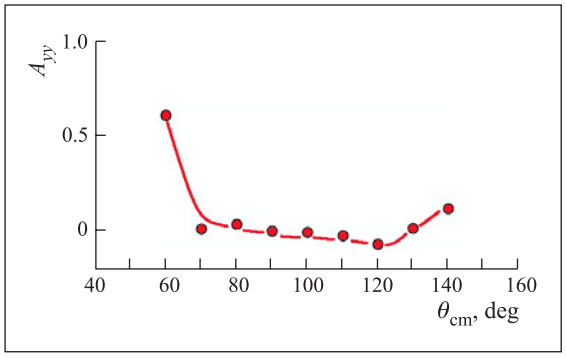

Fig. 5. The *dp* elastic scattering in the region of the Sagara discrepancy effect at a deuteron energy of 880 MeV (preliminary)

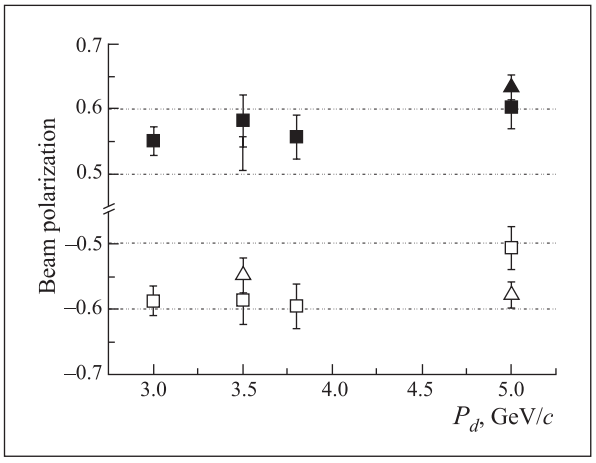

Fig. 6. Deuteron beam polarization measured with the internal (squares) and external (ALPOM) (triangles) polarimeters

The polarization of the internal and extracted beams was measured (Fig. 6). A good agreement of the results from both measurements is observed.

Some other results on polarization experiments are given in [7–10].

BECQUEREL Collaboration

Peripheral collisions of nuclei with an energy above 1 $A \cdot$GeV are collisions of a special type in which the breakup of the primary nuclei is provoked by electromagnetic and diffraction interactions, as well as by nucleon collisions for a minimum overlap of nuclear densities. Nuclear emulsions exposed to beams of relativistic nuclei make it possible to obtain information concerning charged products of such collisions. This information is unique as regards the details of observation of particle tracks and the accuracy of their spatial metrology. The dissociation degree of a nucleus can reach its total destruction into separate nucleons and the lightest nuclei, that is, ^{2,3}H and ^{3,4}H nuclei. Relative intensity of their production permits one to demonstrate the importance of different cluster degrees of freedom.

The metrology of such events is laborious and requires high skills. Nevertheless, such events are of undoubted scientific interest, therefore the BECQUEREL collaboration continues their accumulation. Detailed study of the nuclear fragment ensembles makes it possible to proceed to the search for complicated quasi-stationary states of fragments. In the nuclear scale of distances and excitations they can possess properties which make them similar to dilute quantum gases in atomic physics at ultralow temperatures. The proof of the existence of such systems can be important for nuclear astrophysics problems. In this regard, fragment jets are a microscopic model of stellar media.

The charge topology of relativistic fragmentation of N, O, Ne, Mg, and Si nuclei in peripheral interactions in emulsion is described in [11]. A specific feature of the excitation growth in this group of nuclei consists in the growth of the multiplicity of He and H nuclei with decreasing charge of the single fragment with $Z > 3$. In light nuclei, the pairing splitting channel is practically suppressed. The decay of the excited states in Be, B, and C isotopes has the pronounced cluster character. In overcoming the mass threshold of the reaction their dissociation proceeds through the production of the unstable ^{8}Be nucleus in the ground and excited states. Among the reaction channels, three-particle decays into He and H nuclei are dominant. Fragments with $Z > 3$ do not play a crucial role. It should be noted that this effect can be of importance in problems of cosmic-ray physics related to the element abundance in the region of the Li–Be «gap». The fundamental problem of considerable prevalence of Li, Be, and B elements in cosmic rays of the galactic origin, as compared to their prevalence in the matter of the Solar system, has not been solved yet. This pattern points out that the main

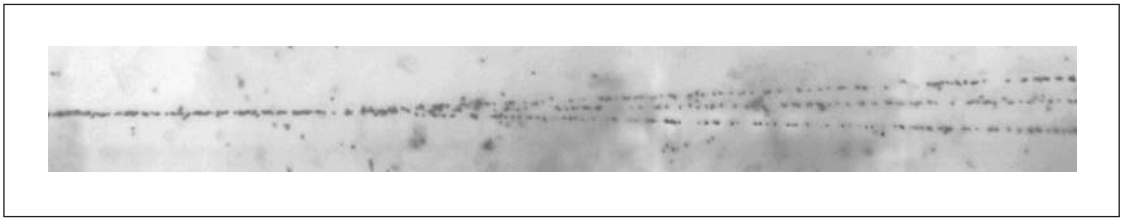

Fig. 7. Reconstructed image of dissociation of the 11 $A \cdot$GeV ^{10}B nucleus in emulsion into three He nuclei without production of target nuclear fragments and mesons («white» star)

chain of subsequent splitting of nuclei, when they are spread in interstellar H and He gases, passes over the production of the Li, Be, and B nuclei. This fact stimulates greatly the interest in the search for the sources of origin of the mentioned group of nuclei, especially the ^{6,7}Li isotopes.

The microphotograph (Fig. 7) shows the event of the three-particle decay of the ^{10}B nucleus in the charge-exchange reaction without production of a charged meson. Its charge topology can unambiguously be interpreted as $^{10}\mathrm{B} \rightarrow 2^{3}\mathrm{He} + {}^{4}\mathrm{He}$. Because of the deep rearrangement of nucleons which resulted in the production of the ^{3}He cluster, an essentially higher (18 MeV) threshold was probably overcome in this event. Thus, the population of the strongly excited state in the totally symmetric ^{10}C nucleus increased. This event points to the fact that in stellar media consisting of the mixture of ^{3,4}He isotopes the inverse process $2^{3}\mathrm{He} + {}^{4}\mathrm{He} \rightarrow {}^{10}\mathrm{C}$ can occur which is similar to the 3α process $3^{4}\mathrm{He} \rightarrow {}^{12}\mathrm{C}$. The fusion process results in larger energy yield which is followed in the world of stable nuclei by the production of the ^{10}B nucleus as the final product.

The study of the ^{9}Be nucleus dissociation into two alpha particles allows one to reconstruct their resonance states without combinatorial background. Owing to a low-energy threshold this process dominates the channel $^{3}\mathrm{He} + {}^{4}\mathrm{He} + 2n$ which is similar to the latter in the shape of the tracks. The emission of the neutron from the ^{9}Be nucleus can lead to the production of the unstable ^{8}Be nucleus with the decay via the ground state 0^{+}, as well as via the 1st $2^{+}$and the 2nd 4^{+} excited states. On the basis of reliable observation of these states in the excitation spectrum Q, i.e., of the invariant masses of pairs of relativistic alpha particles minus their masses, it is possible to verify the validity of the excitation energy estimate using only the angular measurements.

Emulsions are exposed to the secondary beam of ^{9}Be nuclei with an energy of 1.2 $A \cdot$GeV formed on the basis of fragmentation of the ^{10}B nuclei. Up to now, a total of 160 stars with a pair of relativistic He nuclei have been found in the exposed material. The directions of their tracks are within the forward cone with an opening angle of about 3°. The emission angles were measured for 70 events which allows one to present the spectrum Q of their excitation energies (Fig. 8). The first peak of the distribution relates to the ^{8}Be nucleus decay from the ground state 0^{+}. The scale of this part of the spectrum, given in the inset in Fig. 4, is increased by a factor of 10. In this figure one can see a good agreement of the distribution centre with the decay energy of the ground state of the ^{8}Be nucleus. The width of the peak makes it possible to determine also the resolution of the method in this spectral region. It is about 30 keV. Thus, in the system of two relativistic alpha particles there are manifestations of two known resonances.

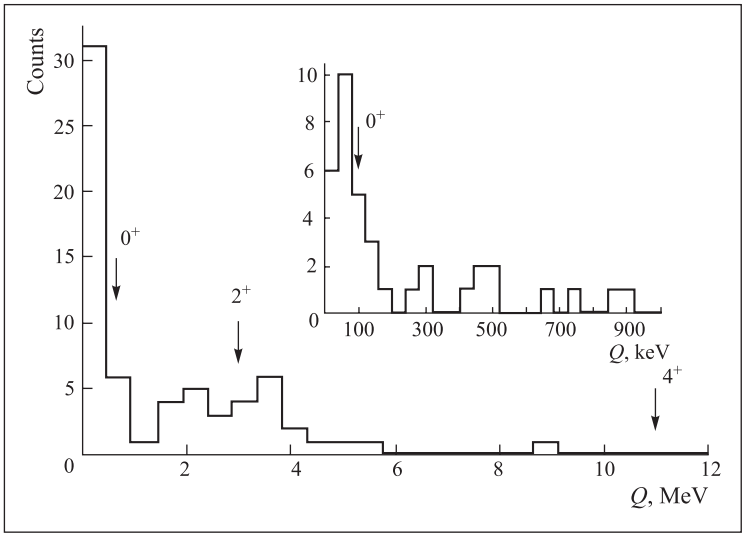

Fig. 8. Distribution of α particle pairs vs. $Q_{2\alpha}$ for the fragmentation mode $^{9}\mathrm{Be} \rightarrow 2\alpha$. Inset: the distribution part zoomed between 0–1000 keV

These excitations can be compared with those of more complicated alpha particle systems. The comparison will be made for the events of the type of «white» stars, that is, the events which contain neither target-nucleus fragments, no produced mesons. In such events, a more «delicate» excitation of the fragmenting nucleus occurs. The excitation of the system is determined by the mean values of the transverse momenta of α particles. The mean values obtained for the alpha particle transverse momenta are as follows: for $^{9}\mathrm{Be} \to 2\alpha\langle P_t^* \rangle \approx 103$ MeV/c, for $^{16}\mathrm{O} \to 4\alpha\langle P_t^* \rangle \approx 121$ MeV/c, and for $^{22}\mathrm{Ne} \to 5\alpha\langle P_t^* \rangle = 200$ MeV/c. These values clearly demonstrate a tendency to the increase in the average momentum of the alpha particles with increasing their multiplicity and consequently the increase in the total Coulomb interaction of α clusters.

The emulsion collaboration is presently engaged in accumulating statistics on the interactions of ^{14}N nuclei with an energy of 2.1 $A \cdot$GeV in emulsion for the study of «white» stars $^{14}\mathrm{N}^* \to d(p)\alpha\alpha\alpha$ in the forward cone to about 1°. The major task is a fast search for «white» stars whose cross section is a few percent of the inelastic cross section. An example of such star is given in Fig. 9. There is an indication of the leading role of the charge configuration $2 + 2 + 2 + 1$.

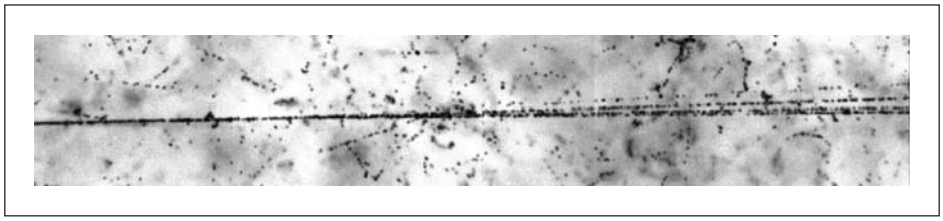

Fig. 9. Reconstructed image of dissociation of the 2.1 $A \cdot$GeV ^{14}N nucleus in emulsion into one H and three He nuclei without production of target nuclear fragments and mesons («white» star)

First Observation of the Parametric X-Ray Radiation from Moderately Relativistic Nuclei in Crystals

The observed parametric X-ray radiation emitted by carbon nuclei is tens times higher than that emitted by protons. Observation of the parametric X-ray radiation from nuclei opens possibilities for parametric X-ray radiation applications in nuclear beam diagnostics.

Parametric X-ray radiation from moderately relativistic nuclei interacting with crystals has beed observed for the first time in the experiments at the Nuclotron (LHE, JINR) beams carried out by the collaboration of scientists from JINR, Institute for Physical and Technical Problems (Dubna), Nuclear Physics Institute at Tomsk Polytechnic University and Moscow State Institute of Electronic Technology [12]. The measurements were performed with silicon and graphite crystals at the extracted beams of 5 GeV protons and 2.2 GeV/n carbon nuclei. The silicon semiconductor detector with high energy resolution was used for registration of X-rays photons. In the registered spectra the radiation maxima were detected, their positions depending on the crystal angle are in agreement with the theoretical values. Thus, it was the first experimental confirmation of the existence of parametric X-ray radiation in crystals from heavy particles — relativistic nuclei.

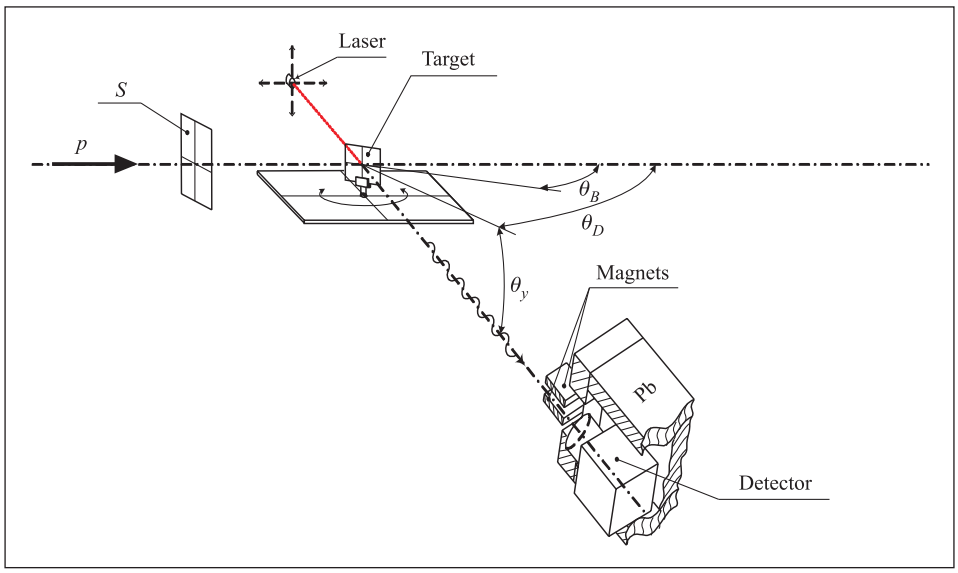

Fig. 10. Schematic diagram of the experimental setup: S is the ionization monitor of the beam, θ_B is the crystal orientation angle, and θ_D and θ_y are the detection angles

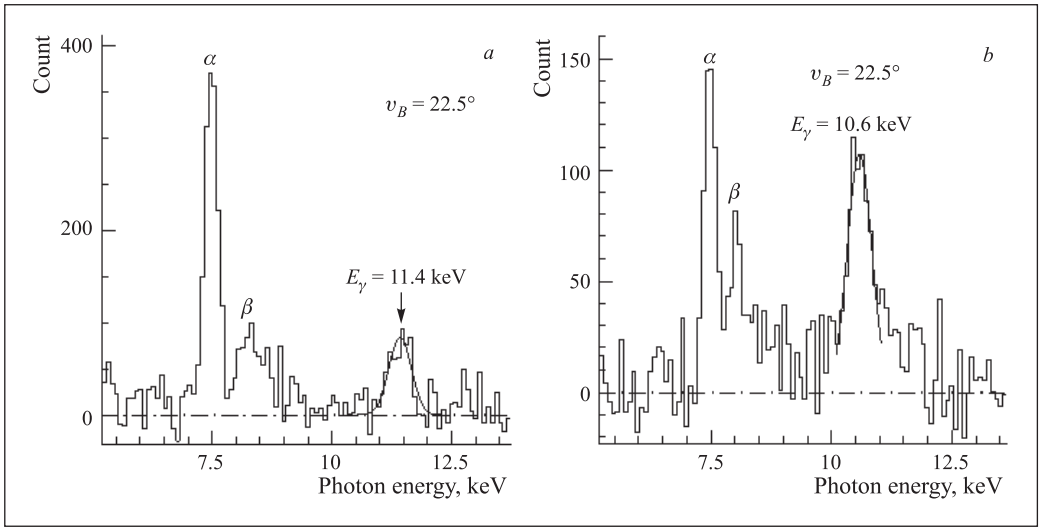

Fig. 11. Radiation spectra registered with the semiconductor detector at irradiation of the (001) silicon crystal by the 5 GeV proton beam (*a*) and 2.2 GeV/n carbon nuclei beam (*b*)

Parametric X-ray radiation (PXR) is emitted by fast charged particles in crystals due to the diffraction of the virtual-photon field of particles on crystallographic planes. The PXR occurs at uniform straight-line motion of a particle in a crystal and the radiation yield depends weakly on the value of the relativistic factor γ of the particle. Therefore, it was natural to assume practical feasibility of observation of PXR from heavy charged particles — relativistic nuclei. Besides, PXR from nuclei with the charge $Z > 1$ should be more intensive than PXR from electrons because the parametric radiation yield is proportional to the particle charge Z squared.

Note that the intensity of radiation due to the change of the particle velocity such as bremsstrahlung and synchrotron radiation has a strong dependence on the value of γ. Therefore, both bremsstrahlung and synchrotron radiation are practically absent for protons and nuclei with the Nuclotron energies in contrast to electrons with the same energies.

The schematic diagram of the experiment is shown in Fig. 10. The beam of particles accelerated and extracted from the Nuclotron hit a thin silicon crystal target. The crystal was inclined to the beam axis at the angle θ_B. The large crystal face was cut parallel to the (001) crystal planes. The Bragg scheme was used: the detector was placed at the angle θ_D close to the angle of diffraction from the (001) planes $2\theta_B$.

X-ray radiation spectra registered at the interaction of 5 GeV proton beam and 2.2 GeV/n carbon nuclei beam with the silicon crystal are shown in Fig. 11. The peaks α and β correspond to the parasitic characteristic radiation of nickel atoms which were excited in the detector case by secondary particles. The maxima γ were formed by photons of parametric radiation.

The angular density of parametric radiation was equal to $2.25 \cdot 10^{-6}$ and $9.76 \cdot 10^{-5}$ photon/(particle $\cdot$ sr) from protons and carbon nuclei, respectively, for the crystal inclination angle $\theta_B = 22.5°$. The density of radiation from carbon nuclei is considerably higher. This confirms qualitatively the dependence of parametric radiation yield on the particle charge.

The observation of parametric X-ray radiation from relativistic nuclei in the experiments at the Nuclotron beams opens possibilities for application of this effect in nuclear beam diagnostics at other high-energy accelerators. The significant advantage of this approach is the large angle of PXR photons with respect to the beam direction. The crystal target for such diagnostics can be made very thin, less than 100 μm, to decrease its influence on the beam.

It is interesting and important to investigate the dependence of the parametric radiation yield and its characteristics on the charge and energy of nuclei and on the crystal parameters. For this purpose the experiments at the Nuclotron will be continued.

DELTA-2 Collaboration

In 2005, a series of measurements at the internal target was carried out at the DELTA-2 setup.

The purpose of measurements was to verify the results obtained in 2004 concerning resonant structure in the reaction of π-meson production for the beam energies between 340 and 350 MeV/n. In March 2005, the π-meson production in the interaction of the internal deuteron beam with the silver target was measured at 73 degrees. The preliminary data obtained in these measurements confirm the results obtained in 2004. These results testify the existence of the resonant structure of the reaction excitation function (Fig. 12).

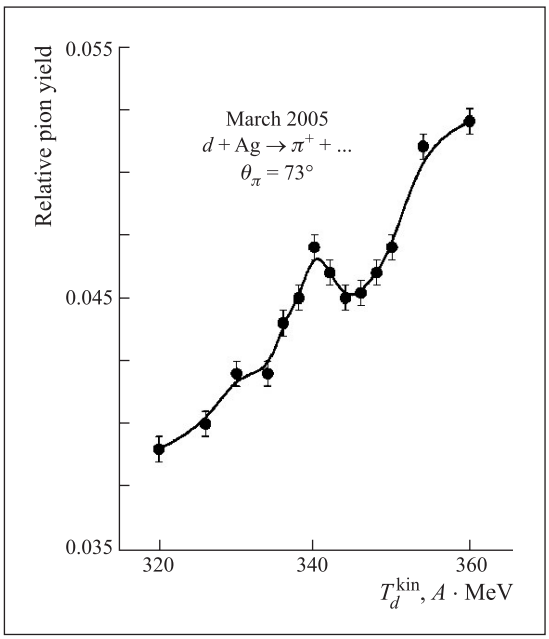

Fig. 12. Relative pion production in the $d+$ Ag reaction as a function of the beam kinetic energy

MARUSYA Collaboration

Measurements were performed on the carbon beams with an energy of 2.2 GeV/nucleon using small-size Cu targets (4×4 mm). Particles produced in interactions (π, K, p) with momenta 500, 1500 MeV/c were registered at an angle of 30° with the angular spread $1-2°$. The main methodical purpose of measurements was the adjustment and study of the operation modes of the magnetooptical spectrometer on the basis of the focal factor method using the new hodoscope detector placed in close vicinity of the target.

During measurements, experimental estimates were made of the possibility of registration and identification of two particles in one event with close momenta and traveling at the same angle (within the angle of registration $2-3°$ of the magnetooptical spectrometer). Measurements demonstrated the possibility of registration of such events with sufficient statistical confidence (up to 100 events per hour) for investigation of the effective mass spectrum for states produced via the channels $(\pi K, \pi p, Kp, pp, \pi\pi)$. Special attention was paid to the reaction $A+A \to K^+p$ in the region of effective masses 1500 MeV in regard with the interest to investigation of possible states called pentaquarks.

Brightness Award

In 2005, the group under the leadership of Prof. E. D. Donets (LHE) was awarded the prestigious international premium «Brightness Award» for the series of works «The Source of Highly Charged Ions on the Basis of the Electron String». This award was founded by the international community of researchers in the field of physics and technology of ions and ion sources and is awarded once in two years.

The achievements of the group under the leadership of Prof. E. D. Donets were characterized as a breach in physics of ions; and it was emphasized that the authors had not only discovered the phenomenon of electron strings, but had also developed the theory in agreement with experiment and implemented it into practice at the Nuclotron.

«Mixed Phase». Proposal for New Research

The round-table discussion on the search for the mixed phase of strongly interacting matter at the Nuclotron was held on July 7–9, 2005.

The idea of the search for the mixed phase of nuclear matter at the Nuclotron was put forward by Prof. A. N. Sissakian.

Calculations at an energy of 5 $A \cdot$GeV carried out by Prof. V. D. Toneev et al. showed the feasibility of observation of the mixed phase at the Nuclotron (Fig. 13).

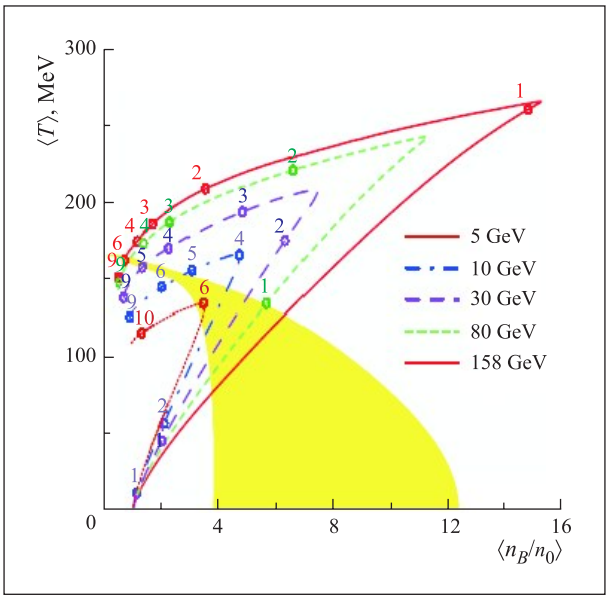

Fig. 13. Numerical results (Prof. Toneev V. D. et al.)

Now the new project for observation of the mixed phase at the Nuclotron is being prepared at the Bogoliubov Laboratory of Theoretical Physics and Veksler and Baldin Laboratory of High Energies.

PHENIX Collaboration

The group of Dr. A. G. Litvinenko actively participated in the physical runs at RHIC at the PHENIX installation. The system of aerogel Cherenkov counters produced together with the colleagues from Japan was used to obtain experimental data. Very interesting data on the anisotropy parameter v_2 (Fig. 14), jet quenching (Fig. 15), J/Ψ suppression (Fig. 16) and direct photons (Fig. 17) were obtained [13–22].

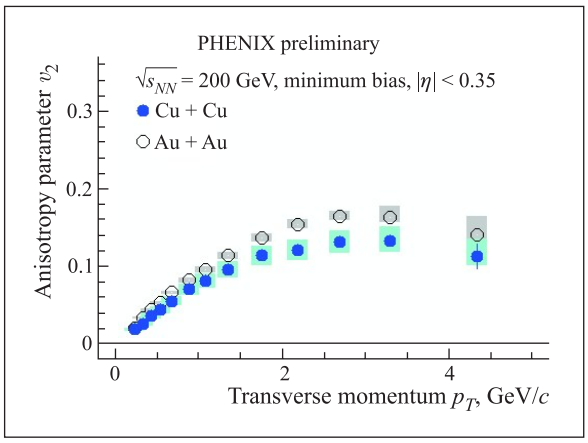

Fig. 14. Elliptic flow v_2 as a function of transverse momentum p_T. The thermalization parameter $\tau_{\rm therm} \sim 0.6-1.0$ fm at the density $\varepsilon \sim 15-25$ GeV/fm^3 ($\varepsilon_{\rm norm} \sim 0.16$ GeV/fm^3) was evaluated using the above data

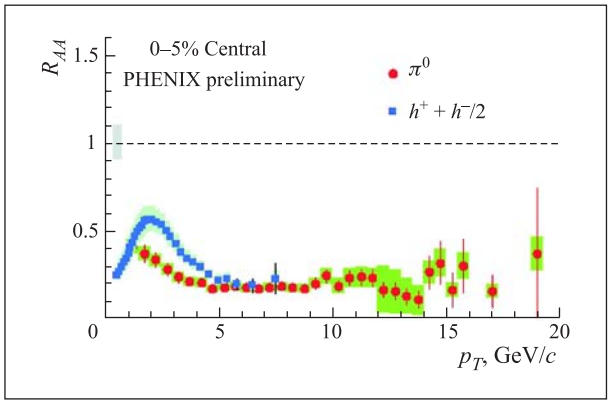

Fig. 15. Jet quenching. Suppression of high p_T neutral pions' and charged hadrons' yield in central Au + Au collisions persists all the way till 20 GeV/c. R_{AA} — nuclear modification factor (the ratio of the measured AA invariant yields to the NN-collision invariant yields)

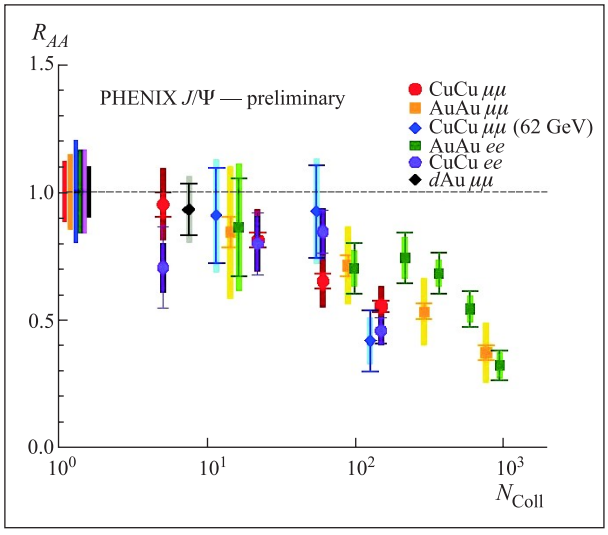

Fig. 16. J/Ψ suppression in collisions of various nuclei. The suppression factor is about 3 in the central region

Figure 14 implies the following:

- The suppression is strong ($R_{AA} = 0.2$!) and flat up to 20 GeV/c
- The matter is extremely opaque
- The data should provide a *lower bound* of the initial gluon density.

J/Ψ suppression in collisions of various nuclei at 62 and 200 $A \cdot$GeV in central nucleus–nucleus collisions was observed (Fig. 16). For these collisions the suppression factor is about 3.

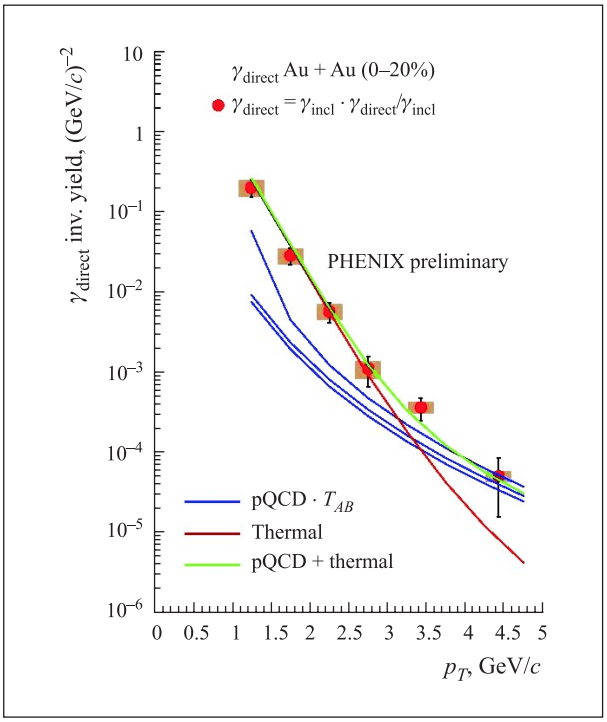

Fig. 17. The p_T dependence of direct photon invariant yield. The best fit is given by the perturbative QCD taking into account thermalization

The next step of the VBLHE participation in PHENIX is related to the construction of the Nose Cone Calorimeter (NCC) (Fig. 18). This calorimeter is necessary for studying the proton spin structure and the Color Glass Condensate (CGC).

The prototype of NCC is ready for test runs with the beam. This prototype was produced by the group of the Moscow State University and the PHENIX group in Dubna (Fig. 19).

STAR Collaboration

The group of Prof. Yu. A. Panebratsev actively participates in the STAR collaboration.

The following results of the STAR collaboration are of the most interest: the evidence for early thermalization, the thermodynamic and chemical equilibrations, the parton energy loss, the evidence of degrees of freedom relevant to hadronization, the saturation at high gluon density [23–26].

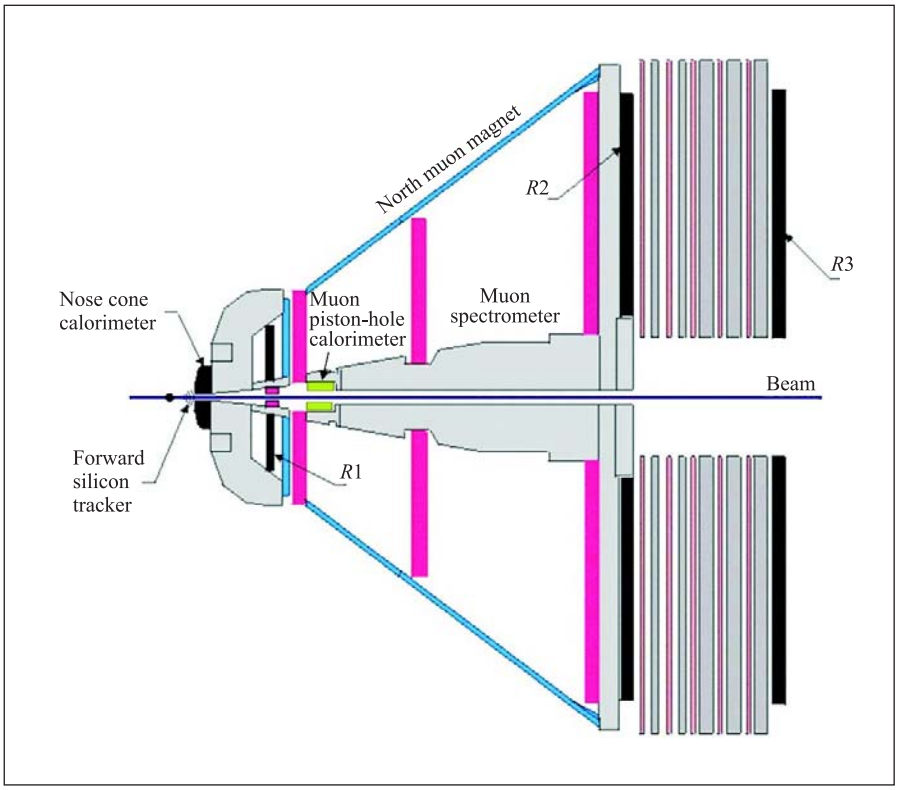

Fig. 18. Layout of the nose cone calorimeter for PHENIX. The calorimeter consists of tungsten plates and semiconductor detectors

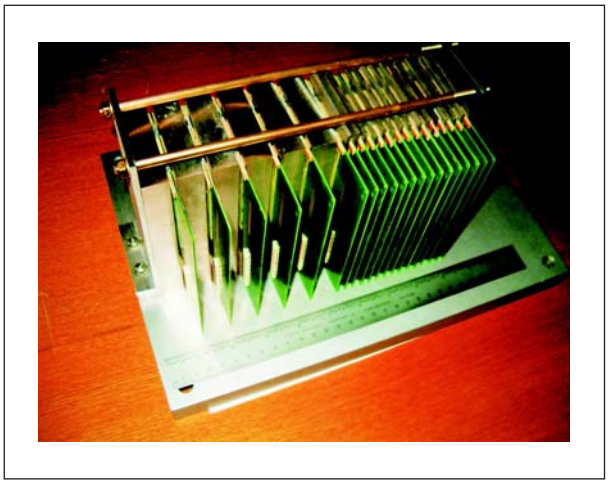

Fig. 19. Prototype of the nose cone Calorimeter for PHENIX

ALICE Collaboration

The dipole magnet was disassembled and then successfully assembled in the operational position. It was tested and mapped at full current.

- About 700 crystals for the photon spectrometer out of 1000 were available by the end of 2005
- The spectrophotometer to test the crystals was delivered to JINR
- 60 drift chambers were constructed by the end of 2005
- Extensive physics simulations were performed for the Physics Performance Report
- GRID computing for the Russia–ALICE team was developed.

CMS Collaboration

The group of Prof. V. A. Smirnov carried out a large series of studies:

1. Test of the readout system before the detector installation.

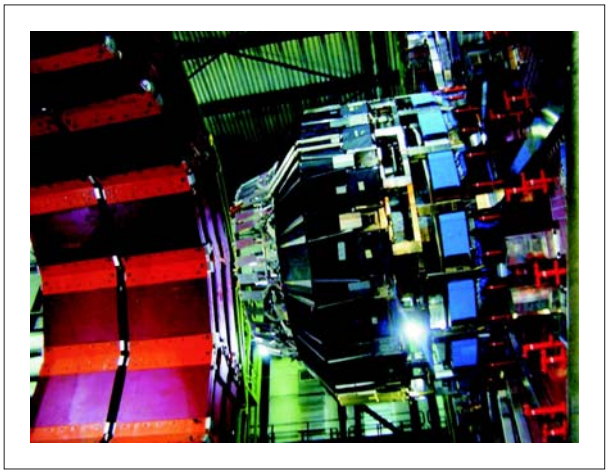

Fig. 20. The view of the hadron endcup calorimeter with the installed readout system for CMS

2. Installation of the readout systems in the detector. 36 readout boxes were installed on both absorbers. After completion of installation of the cables on both detectors, the modules were mounted inside the readout boxes and all connections between them were made (Fig. 20).

3. The test of installed readout system. The set of tests after installation of the readout boxes were performed.

Applied Research

During 2005, analysis of γ spectra of the ^{239}Pu target exposed to the secondary neutron beam generated at the GAMMA-2 setup (the extended lead target 50 cm long, 8 cm in diameter with the paraffin moderator) irradiated by 1 GeV protons from the Nuclotron, was carried out. More than 30 fission products were identified, their activities were determined (see Fig. 21). This work is continued with the aim of determination of the specific reaction rates.

Identification of 1 GeV proton-induced reaction products in the thin ^{232}Th target is continued and the corresponding cross sections are calculated.

As a new experimental effort, the new electronuclear setup GAMMA-2 MD, consisting of the lead target 8 cm in diameter and 60 cm long surrounded by the reactor quality graphite moderator, was delivered from the Joint Institute of Nuclear and Power Research «Sosny», Minsk for joint experiments. Special transportation facilities for the new setup were developed at the Laboratory of High Energies, and the GAMMA-2 MD was placed at the F3 focus of the Nuclotron experimental hall (see Fig. 22).

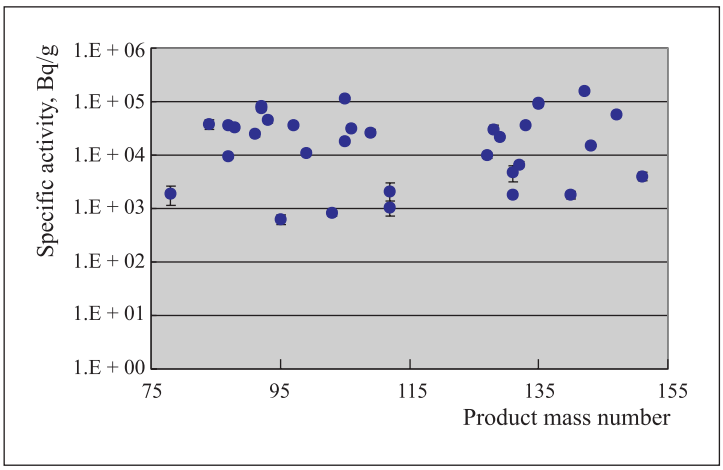

Fig. 21. Specific activity of fission products in the ^{239}Pu target irradiated by 1 GeV protons

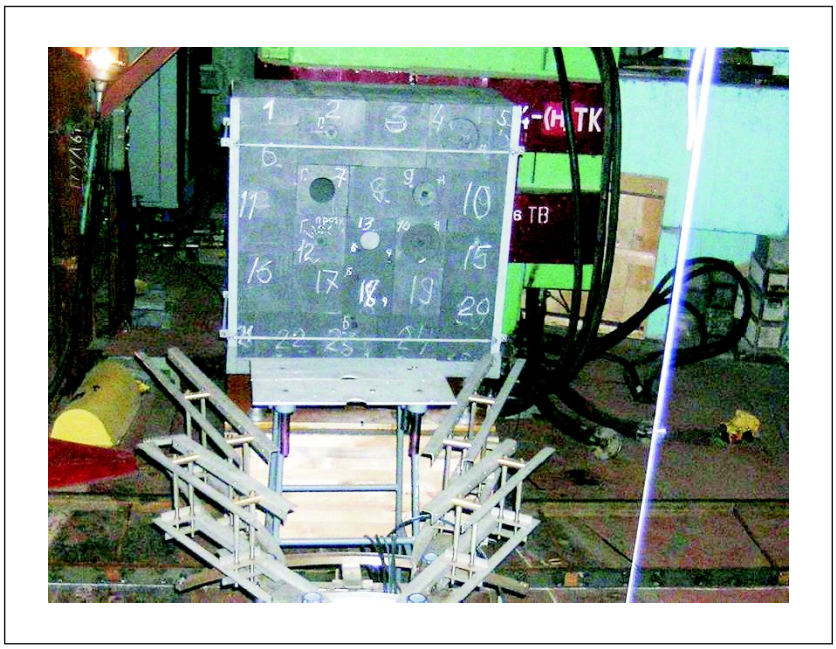

Fig. 22. GAMMA2-MD setup at the F3 focus of the Nuclotron experimental hall

The resolution enhanced NaI(TI)-scintillator micro-SPECT device using the pinhole collimator geometry was built and tested with small animals. This device was constructed on the basis of the depth-of-interaction measurement using the thick scintillation crystal and the position sensitive PMT to measure depth-dependent scintillation light profiles. Such a measurement eliminates the parallax error that degrades the high spatial resolution required for small animal imaging. This novel technique for 3D gamma-ray detection was incorporated into the micro-SPECT device and tested with the ^{57}Co source and ^{98m}Tc-MDP injected in the body of mice [41].

Interpretation of Experimental Data

The experimental data obtained with the JINR 2 m propane bubble chamber are used for the study of the influence of collision centrality on spectra of Λ hyperons and K_s^0 mesons produced in CC interactions at 4.2 $A \cdot$ GeV/c. The multiplicity of participant protons with the momenta larger than 300 MeV/c is taken as the measure of collision centrality. The characteristics of π mesons and protons accompanying the strange particle production are also presented. The experimental data are compared with the prediction of the modified version of the FRITIOF model. It is shown that strange particles are mainly produced in central and semicentral collisions. The average values of the kinematic characteristics of K_s^0 mesons do not depend on the collision centrality. At the same time the average transverse momentum and emission angle of Λ hyperons increase slowly with collision centrality. The angular anisotropy of the Λ hyperons and K_s^0 mesons (calculated with respect to the NN c.m. system) decreases with increasing collision centrality. The average transverse momentum of K_s^0 mesons is 1.6 times larger than the momentum of π mesons [42].

Generalized z Scaling for Charged Hadrons and Jets. Generalization of z scaling observed in the inclusive high-p_T charged hadron and jet production is proposed. The scaling function $\psi(z)$ describing both charged hadrons and jets produced in proton–(anti)proton collisions for various multiplicity densities and collision energies is constructed. Anomalous fractal dimensions and parameters characterizing the corresponding medium for both classes of events are established. The basic features of the scaling established in minimum bias events are shown to conserve up to the highest multiplicity densities measured in experiments UA1, E735, CDF, and STAR. The obtained results are of interest for using z scaling as a tool for the search for new physics phenomena of particle production at high transverse momenta and in high-multiplicity region at U70, Tevatron, RHIC, and LHC [49].

In the [55] report we have presented new physical programme which realization should help to resolve fundamental problems as nature of the cumulative effect and huge disagreement of polarization phenomena with the predictions of naive quark models in high-p_T region.

More complete investigations are needed in the range of maximal p_T in semi-exclusive (and exclusive) experiments for comprehension of the nature of cumulative processes and other phenomena (nuclear color transparency and polarization riddles). These investigations will give us new important information to define real mechanisms which respond the processes with $x > 1$. We could receive proof about SRC or fluctons structures inside nuclei (moreover, we would investigate the structure features of fluctons and nucleons inside nuclei, too).

It is shown that in the region of the Nuclotron energies so many fundamental problems would be accumulated that even a small number of an additional data can radically help for their solution.

Miscellaneous. Other results obtained at VBLHE in 2005 are published in [27–40, 43–48, 50–54].

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