VEKSLER AND BALDIN LABORATORY OF HIGH ENERGIES

In 2003 the scientific programme of the Veksler and Baldin Laboratory of High Energies (VBLHE), as in the previous years, was concentrated on investigations of interactions of relativistic nuclei in the energy region between a few hundred MeV and a few TeV per nucleon to search for manifestations of quark and gluon degrees of freedom in nuclei, asymptotic laws of nuclear matter in high-energy collisions, as well as on the study of the spin structure of the lightest nuclei [1, 2]. Experiments along these lines were carried out with the beams of the VBLHE accelerator complex as well as accelerators at CERN, BNL, GSI, and others. Today VBLHE is an accelerator centre at which a wide range of research is feasible in the energy region where the transition from the effects of nucleon structure of a nucleus to the asymptotic behaviour in nuclear interactions takes place. The international scientific cooperation of the Laboratory is diverse: CERN, scientific centres in the JINR Member States, a number of research centres in the USA, Germany, Japan, India, Egypt and other countries.

Termination of the Synchrophasotron in 2003 was approved by the 93rd session of the JINR Scientific Council. Research is currently continued at the new accelerator, the Nuclotron.

THE MAIN RESULTS OF THE DEVELOPMENT OF THE NUCLOTRON IN 2003

The Nuclotron accelerator complex at VBLHE is the basic facility of JINR. It produces proton, polarized deuteron (as well as neutron/proton) and multicharged ion beams in the energy range up to 6 $A\cdot$GeV. In 2003, the total running time of the Nuclotron was limited by 2113 h.

Parameters of the Nuclotron extracted beams

	Intensity, particles per cycle			Intensity, particles per cycle	
Particle	Year 2003	Year 2006	Particle	Year 2003	Year 2006
p	$1\cdot10^{11}$	$2\cdot10^{11}$	^{16}O	$7\cdot10^{8}$	$1\cdot10^{9}$
d	$5\cdot10^{10}$	$1\cdot10^{11}$	^{24}Mg	$1\cdot10^{8}$	$3\cdot10^{8}$
^{4}He	$3\cdot10^{9}$	$2\cdot10^{10}$	^{40}Ar	$3\cdot10^{7}$	$2\cdot10^{8}$
^{7}Li	$1\cdot10^{9}$	$2\cdot10^{9}$	^{56}Fe	$1.2\cdot10^{6}$	$5\cdot10^{7}$
^{10}B	$2.3\cdot10^{7}$	$5\cdot10^{7}$	^{84}Kr	—	$5\cdot10^{6}$
^{12}C	$2\cdot10^{9}$	$1\cdot10^{10}$	^{131}Xe	—	$1\cdot10^{6}$
^{14}N	$1\cdot10^{7}$	$5\cdot10^{7}$	$d\uparrow$	$3\cdot10^{8}$	$3\cdot10^{9}$

Particle beams available now and projected for a period up to 2006 at the Nuclotron are shown in table [3, 4].

Recent progress in production of intermediate ion beams, such as Ar^{16+} and Fe^{24+}, at the Nuclotron results mainly from the success in the design and application of a new EBIS-type ion source «Krion-2» in «a string mode of operation» [5]. Such an ion source, called Electron String Ion Source (ESIS), is based on multiple longitudinal reflections of electrons in the drift space of the source. The investigation of a reflection mode of EBIS operation based on a specially designed electron gun and electron reflector resulted in the discovery and study of an electron string phenomenon and finally allowed one to reconstruct the existing EBIS «Krion-2» into ESIS suitable for application at the accelerator facility.

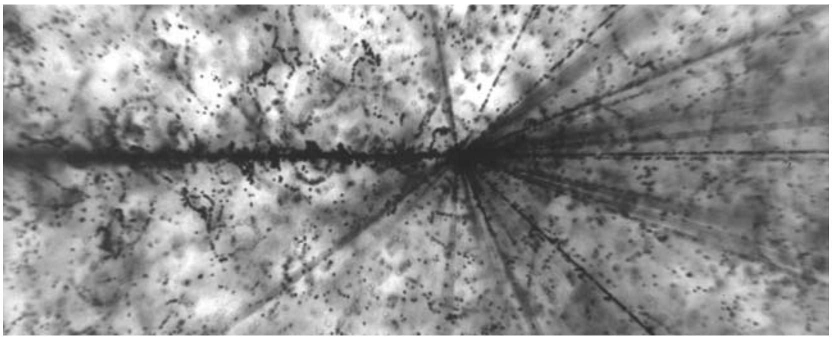

Fig. 1. Interaction of ^{56}Fe ion with $E_{\rm kin} = 1\ A \cdot$GeV from the Nuclotron with an emulsion nucleus

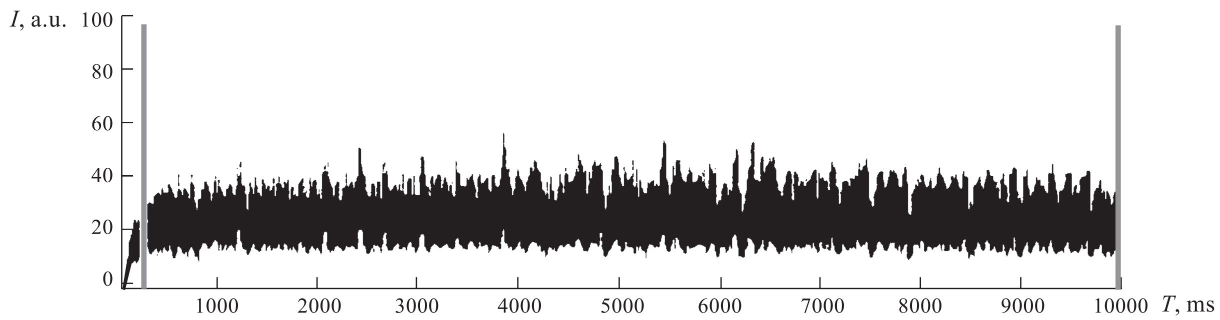

Fig. 2. A pulse duration of an extracted beam

The new source made it possible to obtain beams of N^{6+}, N^{7+}, Ar^{16+} and Fe^{24+} ions during the runs of the Nuclotron in 2002 and 2003. The output ion currents of ESIS «Krion-2» were 300, 350, 200, and 150 μA, respectively. Typical times of ion confinement in electron string were: 40 ms for N^{6+}, 120 ms for N^{7+}, 300 ms for Ar^{16+}, and 1100 ms for Fe^{24+}. The estimated effective density of electron current in a string is about 150–200 A/cm^2. The ion pulse duration from the source is about 8 μs (which corresponds to a single-turn injection in the Nuclotron ring). The EBIS-type ion sources used ionization of gases for ion production. Thus, the possible set of ion species was limited. A new technology for injection of molecules evaporated from solid materials into the source was developed at the Laboratory. Solid material ferrocene ($FeC_{10}H_{10}$) was used to obtain Fe ions. The efficiency of ferrocene vapour ionization was close to 100%, providing a long-term utilization of a small amount of the material, stored in a special container. All the important parameters of ESIS are monitored. Stabilization circuits allow keeping the source in automatic mode of operation during the run time. Stability of the ion beam intensity of the source output was about 95%. A more detailed description of the current status of ESIS «Krion-2» is presented in [6]. An event of interaction of ^{56}Fe ion with the kinetic energy $E_{\rm kin} = 1\ A \cdot$GeV with an emulsion nucleus is shown in Fig. 1.

Substantial progress was also made in improvement of the slow beam extraction system in 2003. Feedback systems for stabilization of both the extracted beam intensity and the extracted beam time structure were put into operation. The result is exemplified in Fig. 2. A pulse duration of an extracted beam of up to 10 s was obtained. Intensity oscillations are suppressed by the feedback system [3].

The PIKASO Experiment

Strong transverse momentum dependence of A_{yy} in the fragmentation of 9-GeV tensor polarized deuterons into cumulative pions was obtained as a result of data analysis of the PIKASO experiment (Fig. 3). The data were obtained during the last run of the Synchrophasotron. As the pion transverse momentum increases from $P_t = 0.4$ to 0.8 GeV/c, the tensor analyzing power A_{yy} drops from near zero to -0.4. The starting point of $A_{yy}(P_t)$-drop corresponds to the cumulative variable $x_c = 1$ — the beginning of the cumulative regime. $A_{yy}(P_t)$-drop is linear at the two angles of pion emission, 135 and 180 mrad.

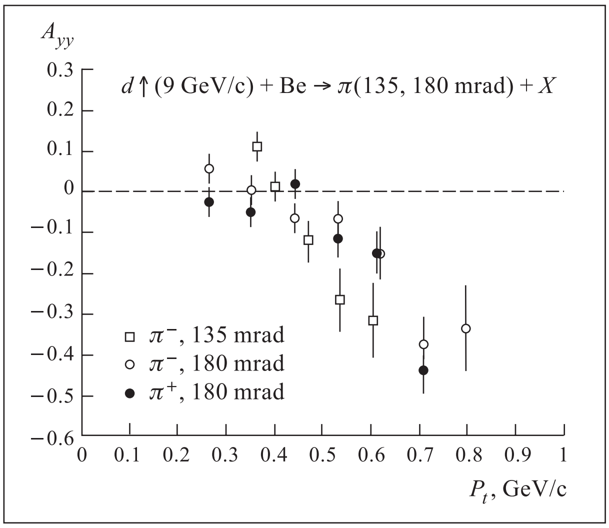

Fig. 3. Tensor analyzing power A_{yy} as a function of P_t for 9-GeV tensor polarized deuterons

The STRELA Experiment

The aim of the STRELA experiment is the study of the spin-dependent component of nucleon scattering amplitude in the charge-exchange process $np \to pn$ using an extracted deuteron beam at the Nuclotron. At zero momentum transfer the differential cross section of the reaction $dp \to (pp)n$ is determined by the spin-flip section of the charge-exchange $np \to pn$ amplitude.

During the June run of the Nuclotron the experiment using 3.5 and 4.0 GeV/c deuteron beams was carried out at the STRELA set-up (Fig. 4, *a*). The extracted deuteron beam hit a liquid hydrogen target T, and primary deuterons were separated from secondary particles by the analyzing magnet M. The flux of the deuteron beam was measured using the ionization chamber IC. The scintillation counters S_1 and S_2 were used to determine the angular (~ 0.2 deg) and momentum ($\sim 10\%$) acceptance and to form the trigger of event. The drift tubes DT_1–DT_4 and the multiwire proportional chambers PC_1–PC_2 were used to detect one- or two-proton events. The Cherenkov counter $\check{C}_1$ with a quartz radiator served for pion suppression. Registration of events with two protons is illustrated schematically in Fig. 4, *b*.

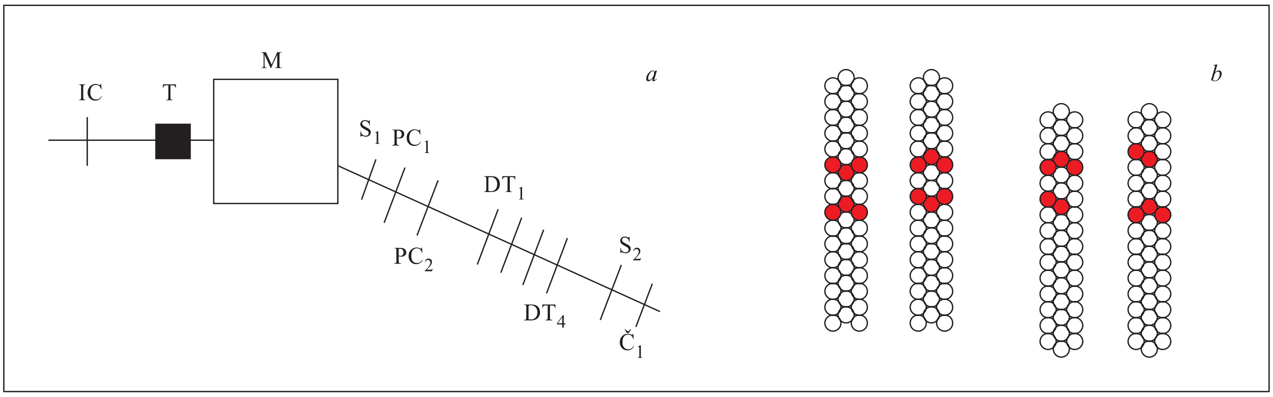

Fig. 4. *a*) The scheme of the STRELA set-up. *b*) Samples of events with two protons in the drift tubes

The BECQUEREL Project

The BECQUEREL Project (BEryllium (Boron) Clustering QUEst in RELativistic Multifragmentation) is oriented toward emulsion irradiation with light stable and radioactive nuclei with an energy of the order of a few GeV per nucleon in the Nuclotron beams [7, 8]. Observations of the fragmentation of light relativistic nuclei open up new opportunities to explore highly excited nuclear states near multiparticle decay thresholds. The interest in such states is motivated by their predicted properties as loosely bound systems with spatial spread significantly exceeding the fragment sizes. The natural components of such states are the lightest nuclei having no excited states below particle decay thresholds, i.e., deuterons, tritons, ^{3}He and ^{4}He nuclei. ^{3}He clustering manifests itself in decays of light neutron-deficient nuclei. The aim of the investigation is to clarify a role of ^{3}He clustering in the forthcoming exposures with ^{7}Be (^{4,3}He–^{3}He), ^8B (^{1,2}H–^{4,3}He–^{3}He), ^{9}Be (^{4}He–^{4}He), ^{9}C (^{3}He–^{3}He–^{3}He), ^{10}C (^{3}He–^{3}He–^{4}He), and ^{11}C (^{3}He–^{4}He–^{4}He).

A secondary beam containing a significant fraction of 1.23 $A \cdot$GeV ^{7}Be nuclei was formed during the run of Nuclotron in 2003 by selecting the products of charge exchange of primary ^{7}Li nuclei with the aid of a beam transport channel. Emulsion stacks were irradiated. ^{7}Be nucleus is convenient for magnet optics selection due to the maximum charge-to-weight ratio. Besides, it gives the most complete observation of final fragments. By visual scanning along tracks, 22 decays of incoming nuclei to helium fragments without other accompanying tracks were found. The examples of events are shown in Fig. 5. Helium isotopes were identified via their total momentum derived from multiple scattering measurements. This makes it possible to conclude that a dominant fraction is due to a coherent dissociation $^3\text{He} + {}^4\text{He}$ and only 3–4 decays to $^3\text{He} + {}^3\text{He} + n$. Thus, it may be inferred that ^{3}He clustering manifests itself in decays of excited relativistic ^{7}Be nuclei.

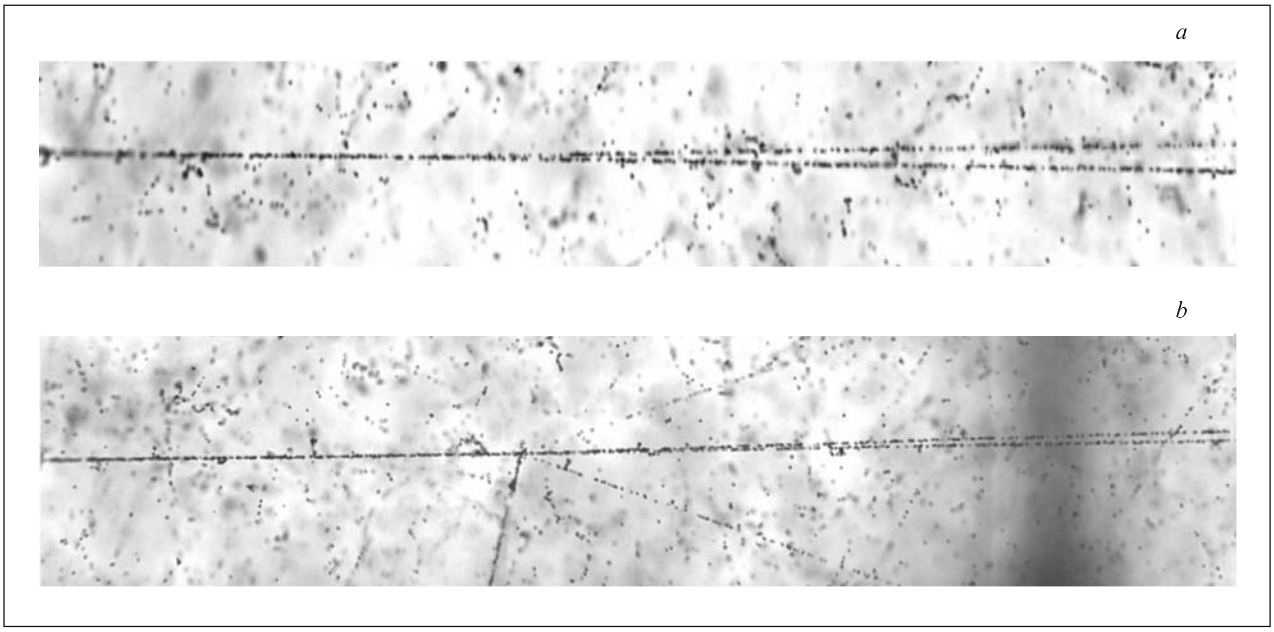

Fig. 5. Examples of peripheral dissociation of 1.23 $A \cdot$GeV ^{7}Be nuclei into pairs of He nuclei. *a*) Dissociation without target nucleus excitation and without charged meson production. *b*) Dissociation accompanied by production of a target fragment and a meson-like pair

The MARUSYA Project

The novelty of the proposed research is in the study of rare subthreshold, cumulative processes and antimatter production taking into account the polarization of colliding objects, the extraction of events by the degree of centrality and reaction plane on the basis of the additional measurement of multiplicity and identification of nuclear fragments not participating in an interaction. Investigation of such processes is possible only with magnetooptical spectrometers of high acceptance and high selectivity of secondaries. The MARUSYA magnetooptical spectrometer was put into operation in 2002.

The new experimental data on one-spin analyzing powers in production of π^+, p, d at interactions of 3.3-GeV/c polarized protons and of 5-GeV/c tensor polarized deuterons with carbon target obtained with the Synchrophasotron beams were analyzed and reported at international conferences. Below are the main results of these investigations (Fig. 6).

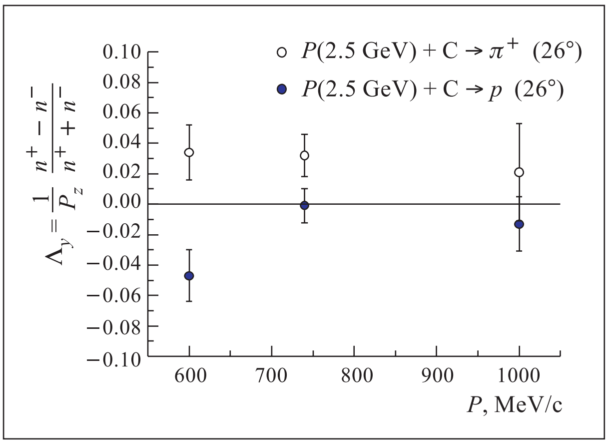

Fig. 6. Analyzing power for the vector polarized beam

Analyzing powers in inclusive spectra of p and d at interaction of polarized proton (3.3 GeV/c) and deuteron (5 GeV/c) beams with carbon nuclei were measured in the momentum range of registered particles $0.6 \div 1.2$ GeV/c at the angle 26°. It is shown that the existing intensities of polarized beams of the Nuclotron are sufficient for the planned future investigations at the MARUSYA set-up.

In December, 2003, the experimental investigation of antimatter production at the Nuclotron began. The first experimental data on production of antiprotons and K^- in the reactions $p+$Pb, $p+$Al were obtained.

Secondary beams produced at the MARUSYA magnetooptical spectrometer provide the experimental conditions for development and testing of new types of detectors.

THE RESULTS OBTAINED AT OTHER ACCELERATOR CENTRES

The PHENIX Experiment

The JINR group participates in this project at all stages of its realization (from LOI and R&D to installation and maintenance). Two tests using Nuclotron beams were performed in 2003. The boxes for this detector system were designed and manufactured at the JINR Experimental Workshop and delivered to the Brookhaven National Laboratory. The detector system consisting of 80 aerogel counters was assembled, tested and installed at the West Arm of PHENIX in 2003 (Fig. 7). The whole aerogel detector of area 4 m^2 will consist of 160 individual Cherenkov counters with aerogel radiators.

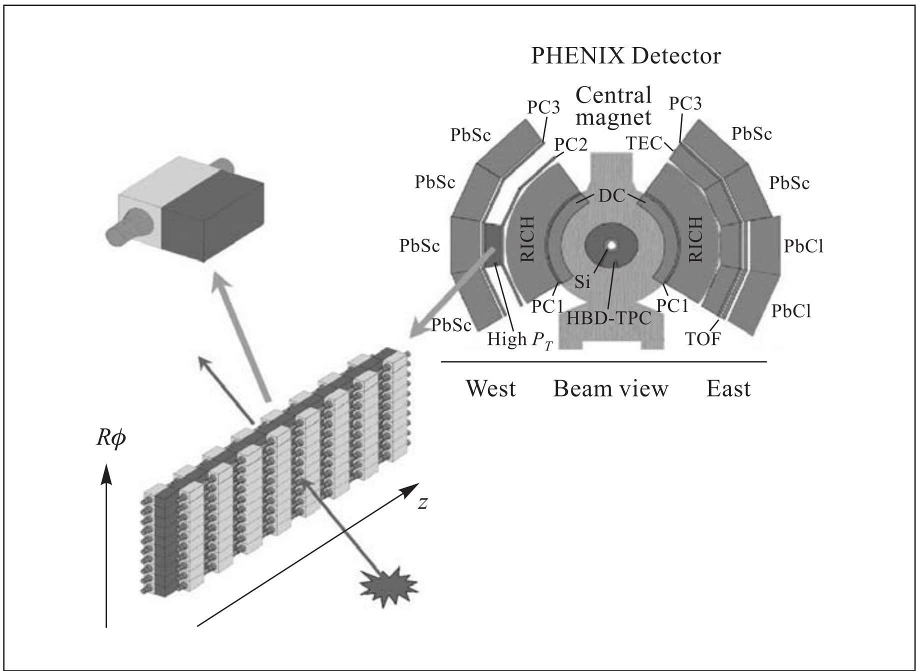

Fig. 7. The layout of the aerogel subsystem installed at PHENIX

This aerogel detector is needed to study events with high P_t with a view to investigating the so-called Jet Quenching Effect. It manifests itself as a strong suppression of high-momentum tail in momentum transfer spectrum for central Au + Au collisions. This suppression is interpreted as a result of strong energy losses in quark–gluon plasma in central collisions at RHIC energies [11]. This effect has essentially different values for different kinds of particles. Installation of the aerogel detector can give additional information for clarification of the nature of this effect as well as properties of quark–gluon plasma created in collisions, if it exists. The latest results obtained by the PHENIX collaboration with the participation of VBLHE's physicists are published in [9–11].

The NA49 Experiment

Observation of New Exotic Baryonic Resonances. The results of resonance search in the $\Xi^-\pi^-$, $\Xi^-\pi^+$, anti-$\Xi^+\pi^-$, anti-$\Xi^+\pi^+$ invariant mass spectra in proton–proton collisions at $\sqrt{s} = 17.2$ GeV are presented in [12]. Evidence is shown for the existence of a narrow $\Xi^-\pi^-$ baryonic resonance with the mass (1.862 ± 0.002) GeV/c^2 and the width below the detector resolution of about 0.018 GeV/c^2 (Fig. 8). The significance is estimated to be 4.0σ. This state is a candidate for the hypothetical exotic $\Xi^{--}(3/2)$ baryon with $S = -2$, $I = 3/2$ and quark content $(dsds\bar{u})$. At the same mass a peak is observed in the $\Xi\pi^+$ spectrum, which is a candidate for the $\Xi^\circ(3/2)$ member of this isospin quartet with quark content $(dsus\bar{d})$. The corresponding antibaryon spectra also show enhancement at the same invariant mass.

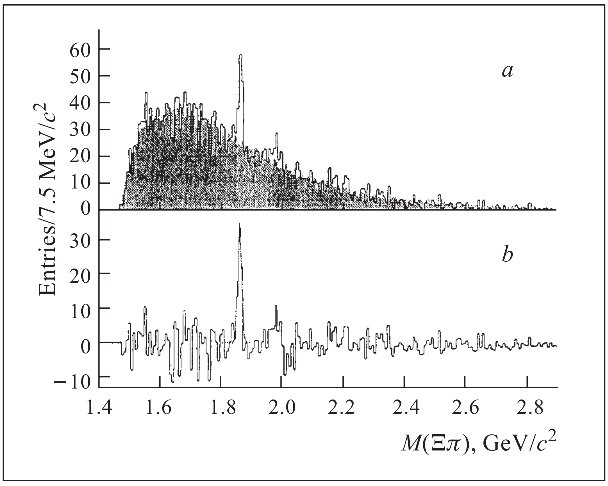

Fig. 8. *a*) The sum of $\Xi^-\pi^-$, $\Xi^-\pi^+$, anti-$\Xi^+\pi^-$, anti-$\Xi^+\pi^+$ invariant mass spectra. The shaded histogram shows the normalized mixed-event background. *b*) Background subtracted spectrum with the Gaussian fit to the peak

Observation of the deconfinement phase transition. The VBLHE group was responsible for measurement and analysis of charged kaon spectra, and spectra of protons and deuterons in Pb + Pb collisions at 20 and 30 $A \cdot$GeV, as well as for completion of the energy scan program (20, 30, 40, 80 and 158 $A \cdot$GeV beam energies).

The results of this analysis are the following:

• The number of pions produced per nucleon participating in the collision increases with energy in both pp and NN reactions. However, the rate of increase in NN becomes larger within the SPS energy range and then remains constant up to the RHIC energy range (Fig. 9, *a*).

• The most dramatic effect is seen in the energy dependence of the ratio $\langle K^+\rangle/\langle\pi^+\rangle$ of the average multiplicities of K^+ and π^+ produced in central Pb + Pb collisions (Fig. 9, *b*).

• The temperature of K^+ mesons in central Pb + Pb collisions at SPS energies is constant (Fig. 9, *c*).

These results suggest that deconfinement phase transition exists and that in Pb + Pb collisions it begins to manifest itself in the SPS energy range.

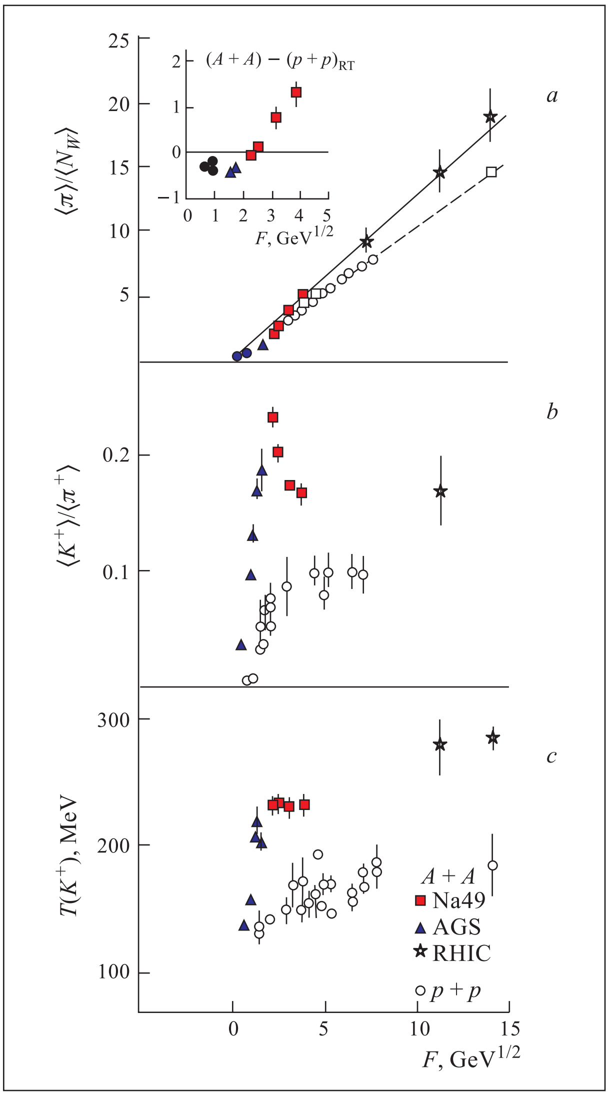

Fig. 9. Collision energy dependence of the various hadron production rates measured in central Pb + Pb and Au + Au collisions (solid symbols) compared with the results from p+p reactions (open circles). The changes within the SPS energy range (solid squares) suggest the onset of the deconfinement phase transition. $F = (\sqrt{S_{NN}} - 2m_0)^{3/4}/((\sqrt{S_{NN}})^{1/4} \approx \sqrt{S_{NN}})$, where m_0 is the nucleon mass

The latest results obtained by the NA49 collaboration with the participation of the physicists from VBLHE are published in [12–15].

The NA45 Experiment

Mass data processing of 31 million Pb + Au events at 158 $A \cdot$GeV was completed.

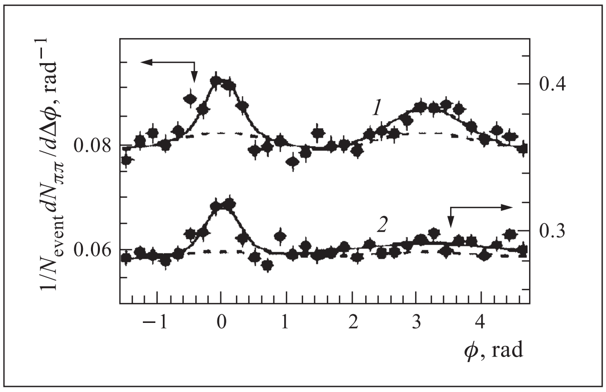

Fig. 10. Two-pion opening angle distributions for $P_t > 1.2$ GeV/c for the first centrality bin, (24–30%) (*1*) and for the fourth centrality bin, (11–15%) (*2*). A cut $\Delta\phi \geqslant 20$ mrad and corrections for close-pair efficiency losses were applied. Solid line shows Gaussian fits to semihard components above the flow-modulated background (dashed line)

The recent back-to-back correlation analysis of the charged hadrons and high P_t pions with account of flow ($v2$) and HBT corrections shows the significant contribution of nonflow component possibly originating from the semihard processes (Fig. 10).

The centrality-dependent HBT analysis at different energies shows that thermal pion freeze-out occurs at constant mean free path $\lambda_f \sim 1.0$ fm, which implies a significant opaqueness of the pion source. These studies are exceptionally interesting now as RHIC has claimed the discovery of jet-quenching phenomenon in the region of pQCD applicability.

The LNS Project

The final data on the energy dependence of the tensor analyzing power T_{20} in the $dd \to {}^3\mathrm{He}n$ and $dd \to {}^3\mathrm{H}p$ reactions in collinear geometry are presented. The data demonstrate the sensitivity to the spin structure of the deuteron and three-nucleon bound states, however, disagree with the one-nucleon exchange calculations using standard light-nuclei wave functions [18].

The high-momentum structure of the ^{3}He, ^{3}H and deuteron in the experiment with polarized deuteron beam performed at $E_d = 270$ MeV at RIKEN (Japan) in December, 2000, was investigated. For this purpose the tensor and vector analyzing powers were measured for the reactions $dd \to {}^3\mathrm{H}p$ and $dd \to {}^3\mathrm{He}n$ over the full angular range [19].

INTERPRETATION OF THE EXPERIMENTAL DATA

The spectra of pions from semicentral CC and CTa collisions at a momentum of 4.2 GeV/c per nucleon are studied in terms of light front variables. At high energies different dynamical mechanisms contribute to the spectra of secondary particles. Among them, «pionization» and fragmentation mechanisms have been widely discussed. «Pionization» means the existence of secondary pions with relatively low momenta and almost isotropic angular distribution in the c.m.s. of colliding nuclei. The fragmentation component has a sharply anisotropic angular distribution in the c.m.s. A problem in this direction is the separation of these two components. The presentation of inclusive spectra in terms of light front variables provides a unique possibility of separating these two components.

The angular distribution of pions in the region $|\zeta^\pm| < |\tilde\zeta^\pm|$ is sharply anisotropic in contrast to an almost flat distribution in the region $|\zeta^\pm| > |\tilde\zeta^\pm|$. A flat behaviour of the angular distribution allows one to think that a partial thermal equilibrium is observed in the region $|\zeta^\pm| > |\tilde\zeta^\pm|$ of phase space.

Pions from the region $|\zeta^+| > |\tilde\zeta^+|$ have a small momentum, up to 0.5 GeV/c.

The pions from the $|\zeta^+| < |\tilde\zeta^+|$ region have a momentum from ~ 0.5 to 3 GeV/c.

Thus, the values $\tilde\zeta^\pm$ are the boundaries of two regions with significantly different characteristics of pions.

In one of the kinematics regions $|\zeta^\pm| > |\tilde\zeta^\pm|$, the angular and P_t^2 distributions of pions are fitted by statistical model predictions. Thermal equilibrium seems to be reached and corresponding temperatures were obtained: $T = (80 \pm 10)$ MeV for π^- mesons from CC and $T = (62 \pm 3)$ MeV for π^- mesons from CTa interactions [17].

APPLIED RESEARCH

Diring the year 2003 the data analysis of the three runs at the VBLHE Nuclotron proton beams using the GAMMA-2 set-up was performed. The set-up target consisted of a lead target 8 cm in diameter and 20 cm long, surrounded with the paraffin moderator of the neutrons. These two runs were the final ones for that geometry. As a result, rather reliable data on transmutation of such highly toxic components of spent nuclear fuel as ^{129}I and ^{237}Np were achieved; estimation of neutron flux using the radioactive indicator ^{139}La in the energy range $0.5 \leqslant E_p \leqslant 4.15$ GeV was made. Some results are shown in Fig. 11.

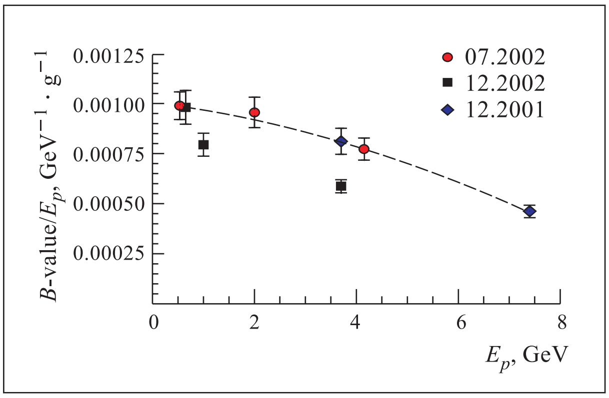

Fig. 11. Transmutation effectiveness (B/E_p) in the reaction ^{237}Np(n, γ)^{238}Np at different proton beam energies. Here the widely used B-parameter is defined as the number of nuclei transmuted per gram of the target matter per incident proton

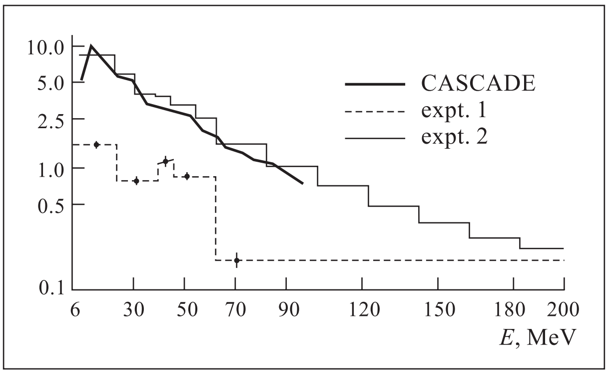

Fig. 12. Experimental and theoretical neutron spectra on the moderator surface of the GAMMA-2 set-up. Here «expt. 1» stands for our measurement and method, «expt. 2» for other method applied to our data, CASCADE — calculations made by Prof. V. S. Barashenkov

As a new technique, the threshold activation detector method was employed for neutron spectrum unfolding. A number of activation detectors like ^{209}Bi were placed onto the outer surface of the moderator and exposed to the secondary neutron beam. Using gamma spectroscopy, the gamma rays accompanying the decay of the reaction (for instance, (n, xn)) products were measured, and some corresponding reaction rates (R-values) calculated. On the basis of those reaction rates a high-energy (up to 200 MeV) part of the neutron spectra was unfolded. It appears to be not in a good agreement with theory prediction as well as unfolding using other methods, for example, those employing calculated neutron spectra at the initial stage of calculations (see Fig. 12).

In December, 2003, the run was carried out using the modified GAMMA-2 set-up, with the length (target and moderator) increased up to 50 cm. The set-up was irradiated at three proton energies of 1, 1.5, and 2 GeV.

As a separate task, a sample of ^{232}Th was irradiated at an energy of 1 GeV, which was consequently measured in continual series during four months at a high-resolution HPGe gamma spectrometer. This kind of data is of high interest for studies of nuclear fragmentation, and for improvement of nuclear reaction models and codes. The choice of ^{232}Th was also motivated by its possible use as a target component in accelerator-driven systems of future.

As a kind of activity within the framework of the theme, the activation method using high-resolution gamma spectrometry has been adopted. High-purity germanium detector of the vendor CANBERRA has been employed with a resolution of about 2 keV at ^{60}Co and efficiency 15%, and the crystal 60.5 mm in diameter and 33 mm long. The spectra are analyzed using the commercially available computer codes Aptec, GAMMAW, and DEIMOS. It is noteworthy to mention that this method was adopted for the first time at VBLHE.

A method of solid state nuclear track detectors was developed. The tracks are scanned automatically.

All the physical and methodical results are regularly reported and published. The theme is realized in the framework of a very wide international cooperation.

Some other results obtained at VBLHE in 2003 are published in [20–25].

REFERENCES

1. *Malakhov A. I.* Selected Problems of Relativistic Nuclear Physics and Multiple Particle Production // Proc. of the XXXII Intern. Symp. on Multiparticle Dynamics. Alushta, Ukraine, Sept. 7–13, 2002. Singapore, 2003. P. 348–352.
2. *Malakhov A. I.* Selected Problems of Relativistic Nuclear Physics // Proc. of Intern. Conf. «Hadron Structure–2002», Herlany, Slovak Republic, Sept. 23–27, 2002. University Kosice, 2003. P. 188–203.
3. *Kovalenko A. D., Butenko A. V.* The Nuclotron — New Superconducting Ion Synchrotron at JINR // Proc. of the Second Intern. COSPAR Colloquium «Radiation Safety for Manned Mission to Mars», Dubna, Russia, Sept. 28 – Oct. 2, 2003.
4. *Agapov N. N., Kovalenko A. D., Malakhov A. I.* // Atom. Energia. 2002. V. 93, No. 6. P. 479–485.
5. *Donets E. D. et al.* // Rev. Sci. Instr. 2002. V. 71. P. 679.
6. *Donets E. D. et al.* // 18th Intern. Conf. on Ion Sources, Dubna, Russia, Sept., 2003 (in press).

7. *Bradnova V. et al.* Nuclear Clustering Quest in Relativistic Multifragmentation // Few-Body Syst. Suppl. 2003. V. 14. P. 241–244.
8. *Adamovich M. I. et al.* Investigation of Light Nucleus Clustering in Relativistic Multifragmentation Processes // Part. Nucl., Lett. 2003. No. 2[117]. P. 29–33.
9. *Adler S. S. et al.* Absence of Suppression in Particle Production at Large Transverse Momentum in $\sqrt{S_{NN}} =$ 200 GeV $d+$Au Collisions // Phys. Rev. Lett. 2003. V. 91. P. 072303.
10. *Adler S. S. et al.* Scaling Properties of Proton and Anti-Proton Production in $\sqrt{S_{NN}} = 200$ GeV Au + Au Collisions // Ibid. P. 172301.
11. *Adler S. S. et al.* Suppressed π^0 Production at Large Transverse Momentum in Central Au + Au Collisions at $\sqrt{S_{NN}} = 200$ GeV // Ibid. P. 072301.
12. *Alt C. et al. (NA49 Collab.).* Observation of an Exotic $S = -2$ and $Q = -2$ Baryon Resonance in Proton–Proton Collisions at the CERN-SPS. hep-ex/0310014; Phys. Rev. Lett. (submitted).
13. *Afanasiev S. V. et al. (NA49 Collab.).* Bose–Einstein Correlations of Charged Kaons in Central Pb + Pb Collisions at $E_{\rm beam} = 158$ GeV per Nucleon // Phys. Lett. B. 2003. V. 557. P. 157–166.
14. *van Leeuwen M. et al. (NA49 Collab.).* Recent Results on Spectra and Yields from NA49 // Nucl. Phys. A. 2003. V. 715. P. 161c–170c.
15. *Hohe C. et al. (NA49 Collab.).* System Size Dependence of Strangeness Production at 158 A·GeV // Ibid. P. 474c–477c.
16. The Programme of the Scientific Research and Development of the Joint Institute for Nuclear Research for the Years 2003–2009. Dubna, 2003.
17. *Djobava T. D. et al.* JINR Preprint E1-2003-67. Dubna, 2003.
18. *Ladygin V. P. et al.* Energy Dependence of the Tensor Analyzing Power T_{20} in the $dd \to {}^3{\rm He}n$ and $dd \to {}^3{\rm H}p$ Reactions // Proc. of SPIN'03 Intern. Workshop, Dubna, Sept. 16–20, 2003 (in press).
19. *Janek M. et al.* Tensor A_{yy} and Vector A_y Analyzing Powers for $dd \to {}^3{\rm H}p$ and $dd \to {}^3{\rm He}n$ Reactions at 270 MeV // Ibid.
20. *Kosmachev O. S.* Covariant Formulation of the Wave Equation for a Doublet of Massive Neutral Leptons. JINR Preprint P4-2003-127. Dubna, 2003; J. Phys. A (submitted).
21. *Golokhvastov A. I.* Independent π^--Meson Production in pp Interactions. JINR Preprint P2-2003-52. Dubna, 2003.
22. *Azhgirey L. S. et al.* Intermediate-Energy Polarimeter for the Measurement of the Deuteron and Proton Beam Polarization at the JINR Synchrophasotron // Nucl. Instr. Meth. A. 2003. V. 497. P. 340–349.
23. *Afanasiev S. et al.* // Nucl. Phys. A. 2003. V. 721. P. 645–648.
24. *Azhgirey L. S. et al.* Measurement of the Differential Cross-Section, Vector and Tensor Analyzing Powers of the 4.5-GeV/c Deuteron Breakup on ^{9}Be with the Proton Emission at 80 mrad // Phys. Atom. Nucl. 2003. V. 66. P. 690; Yad. Fiz. 2003. V. 66. P. 719.
25. *Afanasiev S. et al.* Fragmentation of Polarized Deuteron into High Momentum Mesons as Source of Spin Information of Deuteron Core Structure // Proc. of the 16th Intern. Conf. on Particles and Nuclei (PANIC'02), Osaka, Japan, Sept. 30 – Oct. 4, 2002; Nucl. Phys. A. 2003. V. 721. P. 645.