JOINT INSTITUTE FOR NUCLEAR RESEARCH

2004-194

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SOME RESULTS OF 2004 AND RESEARCH PROGRAMME OF THE VEKSLER AND BALDIN LABORATORY OF HIGH ENERGIES FOR 2005–2007

Report to the 97th Session
of the JINR Scientific Council
January 20–21, 2005

Dubna 2004

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1. Introduction

Today the Veksler and Baldin Laboratory of High Energies (VBLHE) of the Joint Institute for Nuclear Research (JINR) is an accelerator center where research in the transition energy region is carried out. VBLHE co-operates with CERN, many physics centers in Russia, JINR member states, research institutes in the US, Germany, France, Japan, and other countries.

In 2004 the scientific programme of VBLHE, as in the previous years, was focused on Relativistic Nuclear Physics [1, 2].

This report presents the new results obtained at VBLHE in 2004 and the research programme for the next three years.

2. Main results of the Nuclotron development in 2004 and plan for next three years

The annual running time of the VBLHE accelerator complex is presented in fig.1 The Synchrophasotron was stopped in 2003. The Nuclotron annual running time has reached 2500 hours in 2004. It is planned to increase it up to 4000 hours in the coming three years.

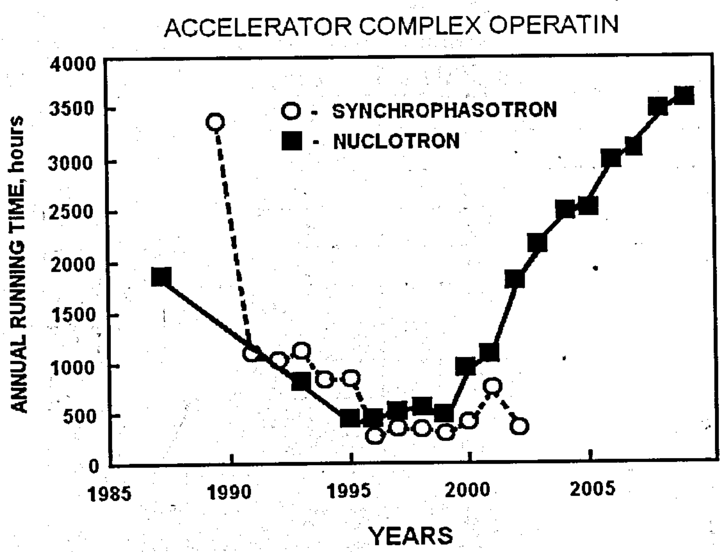

Fig.1. The annual running time of the VBLHE accelerator complex.

The Nuclotron main parameters achieved in 2004 are presented in Table 1.

Table.1. The Nuclotron main parameters

Parameter	Planned	Achieved
Particles	1<Z<92	1<Z<36
Maximum energy, A·GeV	6(A/Z=2)	4.2
Maximum magnetic field, Tl	2.0	1.5
Injection energy, A·MeV	5	5
Slow extraction, s	10	10
Vacuum, Torr	$1\cdot10^{-10}$	$1\cdot10^{-10}$
Pulse repetition rate, Hz	0.5	0.2
Magnetic field ramp, T/s	2	1

The parameters of the Nuclotron beams are shown in Table 2.

Table 2. Extracted beams of Nuclotron

	Intensity (Particles per cycle)		
Beam	Year 2002	Year 2004	Year 2005
p	$3\cdot10^{10}$	$1\cdot10^{11}$	$2\cdot10^{11}$
d	$5\cdot10^{10}$	$5\cdot10^{10}$	$1\cdot10^{11}$
^{4}He	$8\cdot10^{8}$	$3\cdot10^{9}$	$2\cdot10^{10}$
^{7}Li	$8\cdot10^{8}$	$1\cdot10^{9}$	$2\cdot10^{9}$
^{10}B	$2.3\cdot10^{7}$	$2\cdot10^{8}$	$2\cdot10^{9}$
^{12}C	$1\cdot10^{9}$	$2\cdot10^{9}$	$1\cdot10^{10}$
^{14}N	-	$1\cdot10^{7}$	$5\cdot10^{7}$
^{16}O	$5\cdot10^{8}$	$7\cdot10^{8}$	$1\cdot10^{9}$
^{24}Mg	$2\cdot10^{7}$	$1\cdot10^{8}$	$3\cdot10^{8}$
^{40}Ar	$1\cdot10^{6}$	$3\cdot10^{7}$	$2\cdot10^{9}$
^{56}Fe	-	$1.2\cdot10^{6}$	$5\cdot10^{7}$
^{84}Kr	$1\cdot10^{3}$	-	$5\cdot10^{6}$
^{131}Xe	-	-	$1\cdot10^{6}$

The main task of the Nuclotron development in 2004 was to accelerate deuterons to the maximum energy 6 A·GeV. Works dedicated to this goal were provided during the December run of Nuclotron.

The next important task for 2005-2007 is to increase the beam intensity 3 ÷ 5 times. To fulfill this, beam losses during the first 100mksec of acceleration time should be reduced. Adiabatic capture of particles in the acceleration process will be used for this purpose.

During 2004 construction of the new internal target station at Nuclotron was completed [3,4]. The Prague Vacuum plant and Physical Institute of SAS, Bratislava took active part in this work. The layout of the internal target station is presented in fig.2.

Fig.2. The view of the internal target station in the Nuclotron ring.

A very important event in 2004 was signing an agreement between the Indiana University and JINR on handing over the CIPIOS polarized ion source to be mounted at Nuclotron. The source parameters are:

- Pulsed 1 Hz to 4 Hz
- 25 keV beam energy
- Polarized H or d
- Normal polarization > 80%
- 1.5 mA (peak) from source
- > 25 mA (peak) unpolarized.

Using this source at Nuclotron it will be possible to provide intensity of the external beam of polarized deuterons up to $5 \cdot 10^{10}$ per cycle. Reaching such intensity of polarized deuterons is the main task in 2005-2007. INR RAS (Troitsk) will take active part in this work.

At present this source is ready for transportation to Dubna (fig. 3a and fig. 3b).

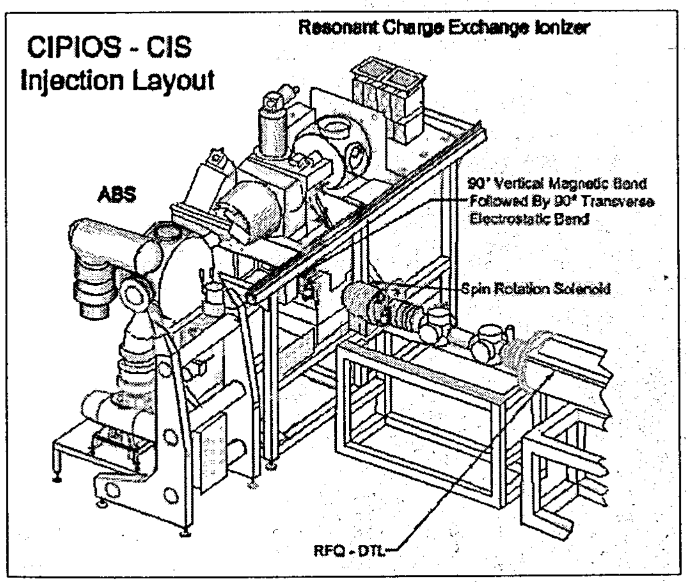

Fig.3a. The CIPIOS polarized source

Fig.3b. The packing process
(S. Shimanski, N. Agapov and V. Fimushkin from left to right).

During 2005-2007 a project of the Nuclotron booster and prototype superconductive magnets and magnetic lenses for the beam lines of the VBLHE accelerator complex will be developed.

The prototypes of the superconductive magnets for the new international accelerator center FAIR at GSI, Germany will also be tested.

Nuclotron operation opens new possibilities for different research programs with ion beams and polarized ion beams. The experience of its maintenance and exploitation is very helpful for design and construction of new accelerators.

3. Physics results in 2004 and plans for 2005-2007

3.1. Results obtained at the VBLHE accelerator center and plans for 2005-2007

Search for resonant structure in pion production reaction using the Nuclotron internal beam

We have searched for an enhancement in the excitation function of the pion yield in the $p+d$ reaction at projectile energies near 350 MeV/nucleon. The measurements were carried out on DELTA-2 setup at the Nuclotron internal beam with Ag, Cu, Al and C targets during two runs in March and June, 2004. The layout of the DELTA-2 setup and preliminary experimental results are presented in fig. 4a and fig. 4b. It is seen that for heavier targets (beginning with Cu) a narrow peak appears in the region of the beam energy 350 MeV/nucleon. It means that this effect has a nuclear nature.

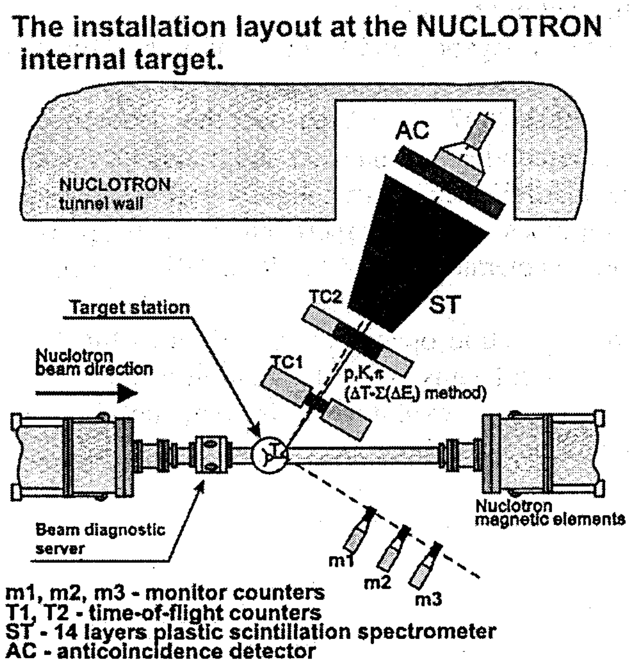

Fig.4a. Layout of the DELTA-2 setup

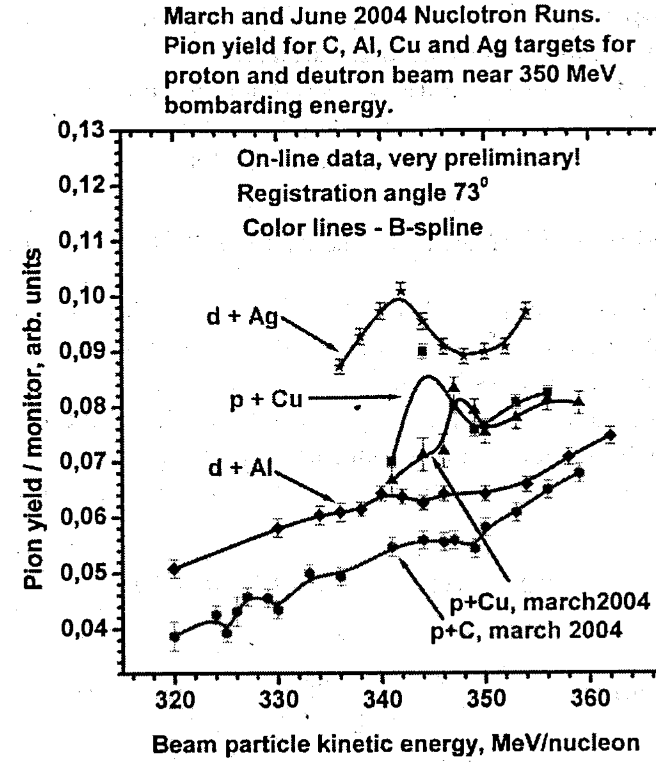

Fig.4b. Preliminary normalized pion yields in $d + A$ and $p + A$ reactions as functions of beam energy

The possible physical explanations of the observed effect are the following:

- Excitation of a narrow dibarion state
- Increased transparency of nuclei for low energy pions
- Large binding energy of nuclear matter leading to a narrow 2Δ state
- Localized Δ isobar in nuclear matter: “Snow ball”, “Δ ball” (a meta-stable localized Δ isobar, effect of the medium)

- Two-pion Cooper pair in nuclei (two pion states when two pions scatter within nuclear matter).

For final interpretation more experimental data are required. It is planed to study the effect in more detail for various targets, projectiles and pion emission angles in 2005-2006.

Observation of the narrow exotic barions (pentaquarks)

Three VBLHE groups participated in search for the narrow exotic barions (pentaquarks). Two groups used the existing data from the VBLHE bubble chambers for analysis.
The group headed by Yu.A. Troyan used the data obtained at the VBLHE 1m hydrogen bubble chamber and the group of R. Togoo (Mongolia) used the data from the VBLHE 2m propane bubble chamber.

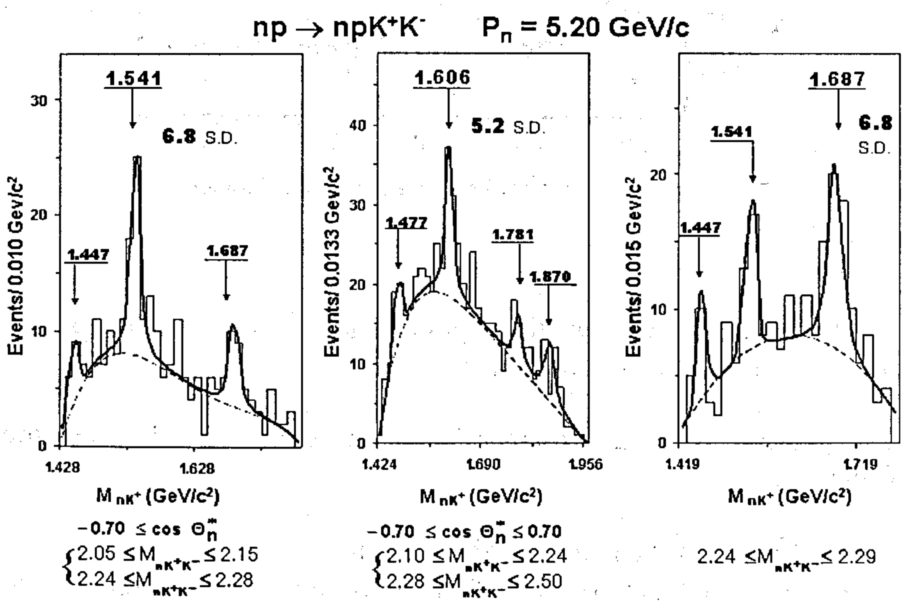

Fig.5. Three peaks with significance exceeding 5σ are observed in the K^+n system. The data were obtained using the VBLHE hydrogen bubble chamber.

The group of G.L. Melkumov actively participated in obtaining the data on pentaquarks at NA49 setup (SPS CERN).

A special project NIS (in collaboration with LPP) exists aimed at the search for such objects at Nuclotron. The leaders of the project NIS are: A.G. Litvinenko (VBLHE) and E.A. Strokovsky (LPP).

The group of Yu.A. Troyan analyzed the reaction $np \rightarrow npK^+K^-$ at neutron momentum P_n=5.20 ± 0.12 GeV/c. Narrow exotic barions were studied in the K^+n system. The results were published in [5]. Some plots are shown in fig.5. Three peaks with significance exceeding 5σ can be seen. These peaks are produced by the resonances with the masses M = 1.541, 1.606 and 1.687 GeV/c^2.

One of the possible mechanisms of Θ^+ production is presented in fig.6.

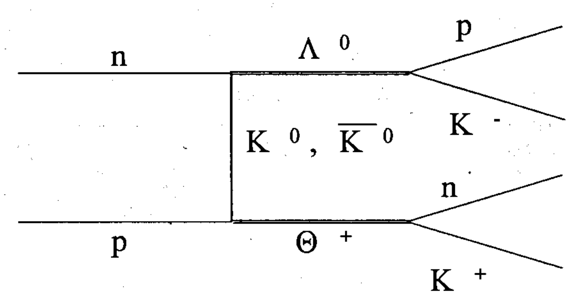

Fig.6. One of the possible mechanisms of $\Theta^+(uudd\bar{s})$ production.

The results on observation of pentaquarks were obtained by the group of P. Togoo (Mongolia) using the data from the VBLHE 2m propane bubble chamber. This group studied the reaction $C + C_3H_8 \rightarrow K_s^0 p + x$ at carbon beam momenta P_C = 4.2 A·GeV/c. A narrow peak with M = 1532 ± 6 MeV/c^2 and width Γ ≈ 26 ± 4 MeV/c^2 was observed in the $K_s^0 p$ effective mass spectrum (fig.7) [6].

The observation of pentaquarks in the Ξπ system was discussed in the previous report of VBLHE. The work has been published [7].

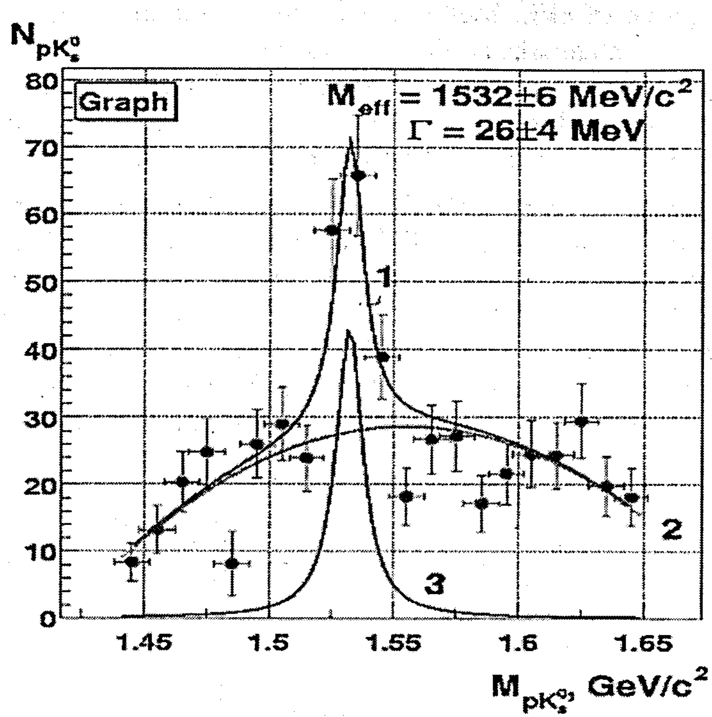

Fig.7. The spectrum of K_s^0p effective masses in $C+C_3H_8 \rightarrow K_s^0p + x$ reaction at carbon beam momenta $P_C = 4.2$ A·GeV/c.

The physical programme of the NIS experiment at Nuclotron includes:

(A) Search for effects of nucleon polarized strangeness in production of φ and ω mesons in *pp* and *np* scattering close to thresholds (at $\varepsilon \approx 30 \div 100$ MeV above the thresholds).

(B) Search for production of the Θ^+ baryons in pp interactions close to threshold in reactions:

$$pp \rightarrow \Theta^+ + K^- + p + \pi^+,\ \Theta \rightarrow nK^+$$
$$pp \rightarrow \Theta^+ + K^- + p + \pi+,\ \Theta \rightarrow pK^0,$$
$$K^0{}_S \rightarrow \pi^+\pi^-.$$

Study of thermal multifragmentation induced by light relativistic ions and nuclear phase transitions

It has been shown in the previous studies at the FAZA setup (leader V.A. Karnaukhov, DLNP) that nuclear disintegration takes place after an expansion of the exited nucleus. The break up density is $\rho_t = (0.3 \div 0.4)\ \rho_0$ and the temperature is $T_b = 5 \div 7$ MeV. Thermal multifragmentation can be interpreted as the first order nuclear *liquid-fog* phase transition at this temperature.

An important model parameter of the scenario of spinodal decomposition is the critical temperature for the nuclear *liquid-gas* phase transition $T_c = 17 \pm 2$ MeV which was measured by FAZA collaboration. That is a very important result as it gives direct evidence, that multifragmentation takes place deep inside the spinodal region.

A very significant observation was made recently [8, 9]. It was proved experimentally that the multifragmentation process has two characteristic densities. The first one, ρ_t, determined from the intermediate mass fragments (IMF, 2<Z<20) charge distribution, corresponds to the moment of fragment formation, when the properly extended hot target spectator transforms into a configuration consisting specified prefragments. They are not yet fully developed, there are still links (nuclear interaction) between them. The final channel of disintegration is completed during the evolution of the system up to the moment when receding and interacting prefragments become completely separated at the mean density ρ_f (freeze-out density). This is just as in ordinary fission. The saddle point (which has a rather compact shape) resembles the final channel of fission by way of having a fairly well-defined mass asymmetry. Nuclear interaction between fission prefragments ceases after descent of the system from the top of the barrier to the scission point.

Figure 8 presents the proposed spinodal region in the T−ρ plane with the experimental data obtained by FASA. The points for the partition and freeze-out configurations are located at ρ_t and ρ_f. These points are deep inside the spinodal region, the top of which is specified by the critical temperature, T_c, for the liquid-gas phase transition.

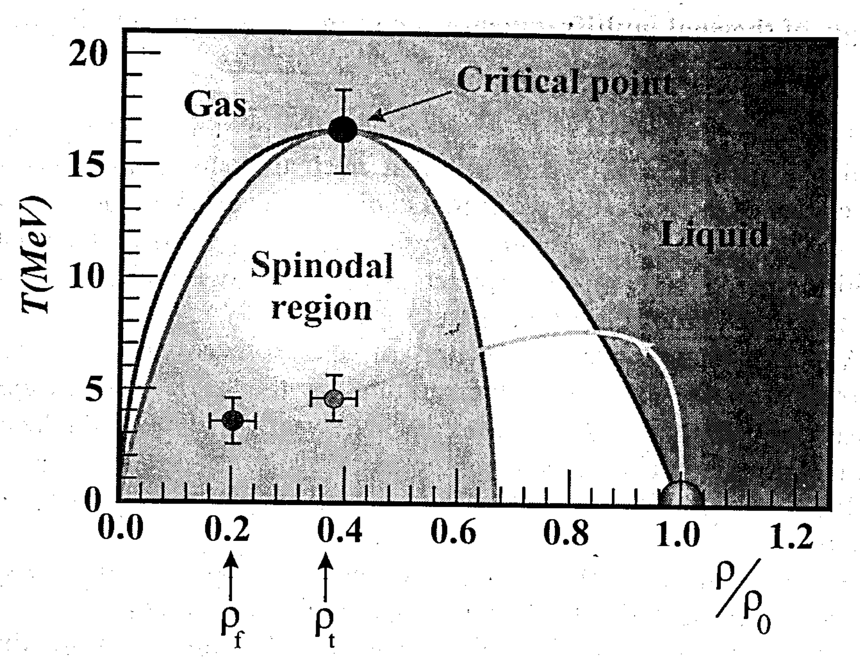

Fig.8. The proposed spinodal region for a nuclear system. The experimental points were obtained by the FASA collaboration. The arrow line shows the way of the system from the starting point at $T = 0$ and ρ_0 to the multi-scission point at ρ_f.

These studies will be continued. The first priority tasks (for the next 3 years) are the following:

1. Further investigation of the evolution of the thermal multifragmentation mechanism with increasing the projectile mass from the relativistic protons to neon. As a result, the nature of the collective flow observed for the beams heavier than helium will be found out.

2. Obtaining and analysis of the experimental data on IMF multiplicity, their charge and energy distributions, as well as the angular and velocities correlations, to get new information on the nuclear liquid-fog phase transition.

3. Study of the dependence of the IMF-IMF correlation function (with respect to the relative angle and velocity) on the entrance channel conditions to obtain new information about spatial configuration of the system at the break-up.

4. Investigation of the expansion dynamics of hot nuclei driven by thermal pressure, measuring the mean time of expansion. Experimental method for that is now under development.

Anomalous behavior of the dp elastic cross-section (Sagara discrepancy)

Anomalous behavior of the *dp* elastic cross-section is called Sagara discrepancy. This effect reflects the experimental fact that modern nucleon-nucleon potentials can not reproduce the behavior of the cross section in deuteron-proton elastic scattering in the vicinity of 120^0 in the c.m.s. (fig. 9). Only taking into account strong contribution of the 3 nucleon forces allows to reach an agreement with the data. The influence of the 3 nucleon forces on this effect is studied at the LNS setup (leader V.P. Ladygin). The LNS detectors are now at stage of construction and calibration and the first measurements are beginning (fig.10a and fig10b).

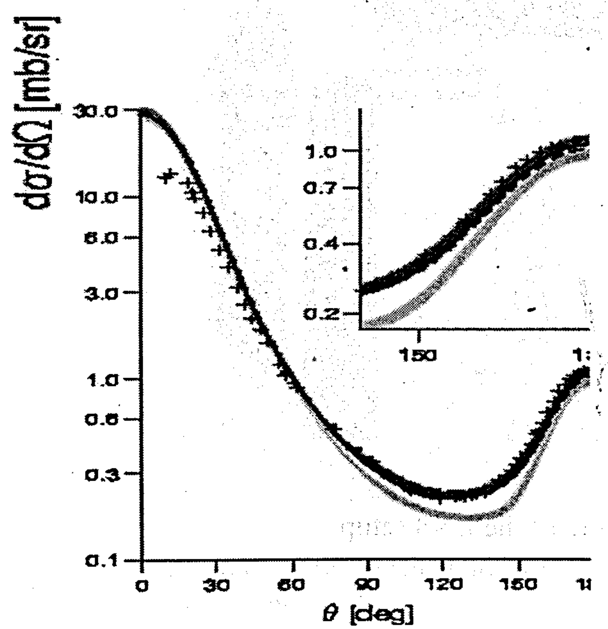

Fig.9. Sagara discrepancy effect: modern nucleon-nucleonpotentials can not reproduce the behaviour of the cross section in *dp* elastic scattering in the vicinity of 120^0 in c.m.s..

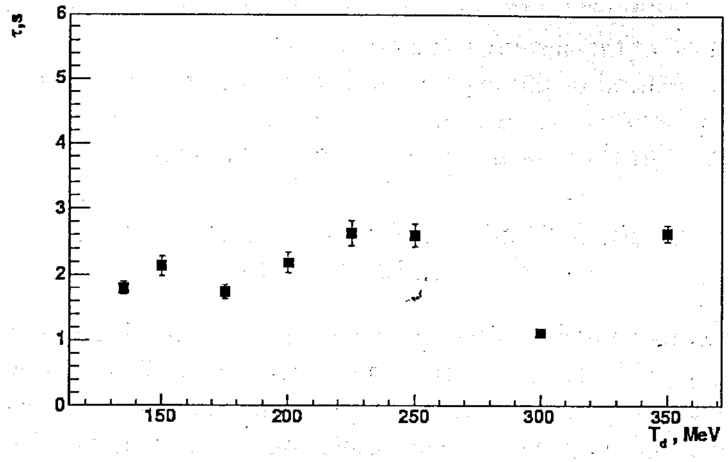

Fig.10a. Deuteron beam lifetime at the internal Nuclotron target station vs deuteron kinetic energy T_d.

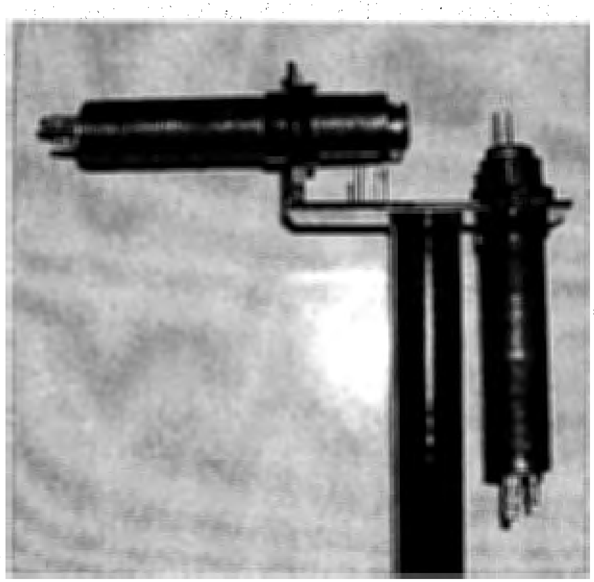

Fig.10b. Typical detectors of the LNS setup

The study of spin structure of three nucleon systems

The main objective of the joint VBLHE-RIKEN experiment (**pHe3** project, leaders V.P. Ladygin and T. Uesaka, Japan) is to study the ^3He (^3H) structure at distances, beyond the reach of electromagnetic probes at present, by measuring the angular dependences of the tensor analyzing powers A_{yy}, A_{xx} and A_{xz} in the $d+d\rightarrow {}^3He+n$ and $d+d\rightarrow {}^3H+p$ reactions [10]. These polarization observables are sensitive to the neutron (proton) spin distributions in ^3He (^3H) at small distances in the framework of one-nucleon data exchange. On the other hand, both ^3He and ^3H are mirror nuclei with respect to the number of protons and neutrons, and the difference in their observed values can be interpreted in terms of charge symmetry violation.

An interesting fact is that interactions of polarized deuterons with polarized ^{3}He nucleus are allowed only in D state (D wave). This fact is demonstrated in fig.11. So, since interaction of polarized deuterons with polarized ^{3}He nucleus is possible only in D state, a pure D wave in a deuteron can be studied in this process.

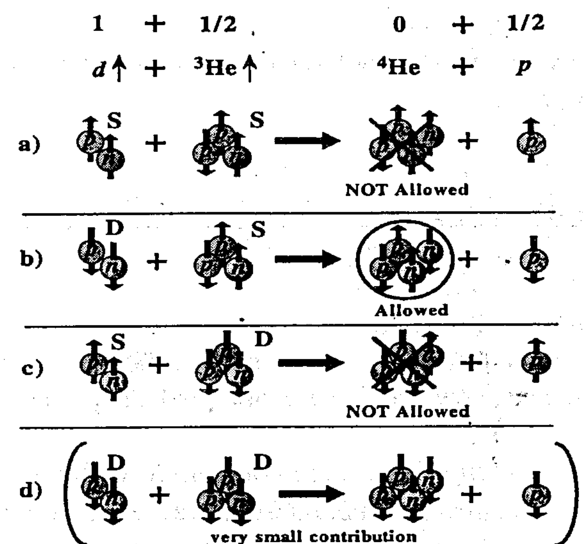

Fig.11. Possible interaction mechanisms between polarized deuterons and polarized ^3He nuclei.

The view of the He3 polarized target manufactured at CNS, Japan, is presented in fig.12.

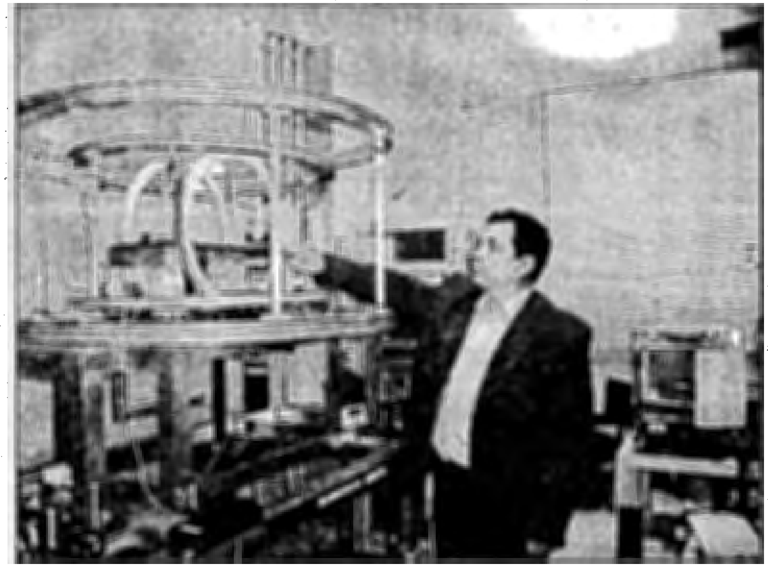

Fig.12. The view of the He3 polarized target manufactured at CNS, Japan for **pHe3** project.

<u>New results on measurement of np total cross section difference $\Delta\sigma_L(np)$</u>

New accurate results of the neutron-proton spin-dependent total cross section difference $\Delta\sigma_L(np)$ at the neutron beam kinetic energies 1.39, 1.69, 1,89 and 1.99 GeV were obtained [11]. The results are shown in fig.13.

The measured $\Delta\sigma_L(np)$ values are compatible with the existing np results, using free neutrons. The rapid decrease of $\Delta\sigma_L(np)$ values above 1.1 GeV is confirmed and a minimum or a "shoulder" around 1.8 GeV is observed.

The $\Delta\sigma_L$(I=0) values obtained from the measured $\Delta\sigma_L(np)$ values and the existing $\Delta\sigma_L(np)$ data are also presented. They show a plateau

or a weak maximum around 1.4 GeV, followed by a rapid drop with energy growth and by a minimum around 1.8 GeV.

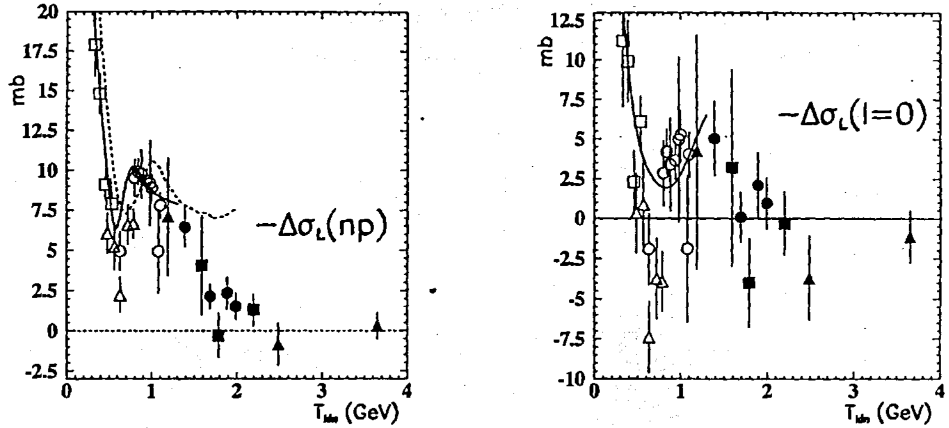

Fig.13. Energy dependence of - $\Delta\sigma_L(np)$ (left) and - $\Delta\sigma_L$(I=0) (right). The symbols denote: black dots – our experimental data, black triangles and black squares - our earlier data, open squares - PSI data, open triangles – LAMPF data, open circles – Saturn II data.

The obtained results were compared with the dynamic model predictions and with the recent ED GW/VPI PSA fit. The necessity of further accurate $\Delta\sigma_L(np)$ measurements around 1.8 GeV and new $\Delta\sigma_L(np)$ data in the kinetic energy region above 1.1 GeV is emphasized.

The spin-dependent results were supplemented by the measurement of unpolarized total cross sections $\sigma_{0tot}(np)$ and $\sigma_{0tot}(nC)$.

<u>Clustering pattern of light nuclei in peripheral dissociation above 1 A·GeV</u>

In 2004, emulsion stacks were exposed to 2.0 A· GeV/c ^{9}Be, ^{8}B, and ^{9}C nuclei (The BECQUEREL project, leader P.I. Zarubin).

The clear production of "white" stars with α particle pairs is initiated in the ^9Be fragmentation with removal of a loosely bound neutron (fig.14). An analysis of the data will allow one to conclude about clustering in the ^9Be nucleus and extent experience of ^8Be identification in n-^8Be, n-$^8Be^*$, and $\alpha n \alpha$ excitations [12-15].

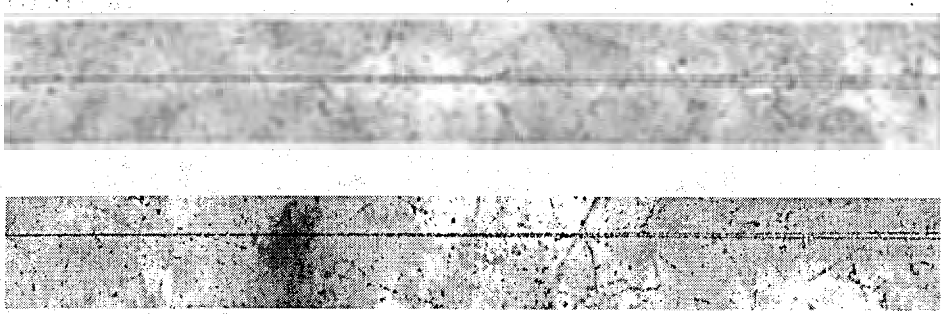

Fig. 14. Examples of the events of the peripheral ^9Be in emulsion at 1.3 A· GeV: a splitting to two *He* fragments (upper photo) without target nucleus excitation or visible recoil and to two *He* fragments with a recoil proton (lower photo).

It is planned to determine the relative probabilities of $^8B^* \to p\,^7Be$, $p\,^3He\,\alpha$, $pp\,^6Li$, and $ppd\alpha$. There arises a possibility of studying the decays $^7B \to ppp\alpha$ and $p\,^3He\,^3He$ since a nuclear stability border gets crossed in the $^8B \to {}^7B$ fragmentation. In the relativistic case such decays would be appearing as narrow jets convenient for analysis.

Using carbon-12 beam for cancer therapy

The JINR Program advisory committee approved in 2004 a new MED-NUCLOTRON project. During the first stage of this project it is planned to prepare the Nuclotron carbon beam with the parameters required for irradiation of patients. The first measurements of the Bragg peak at the ^{12}C Nuclotron beam are presented in fig.15. The energy of the carbon beam was 500 A·MeV.

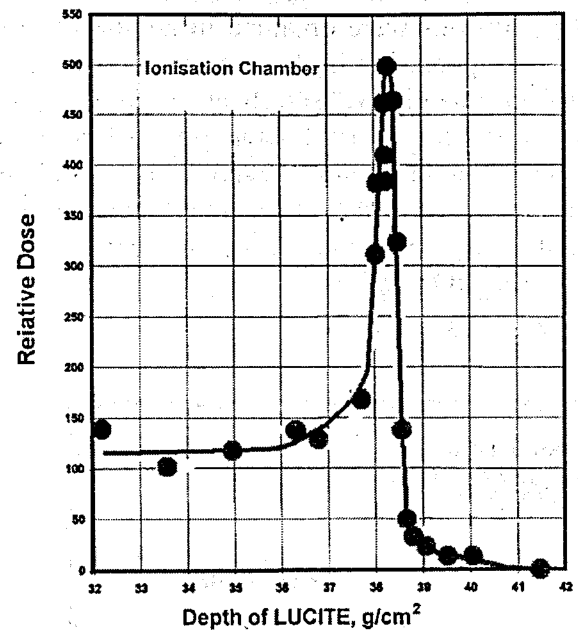

Fig.15. The Bragg peak of 500 A·MeV ^{12}C ions from Nuclotron.

During the next three years the required carbon beam and a special place for irradiation of biological samples will be prepared.

3.2. Results obtained at other accelerator centers and plans for 2005-2007

Suppression of high p_t hadrons

The VBLHE group (leader A.G.Litvinenko) participated in design and manufacturing of the aerogel detector for the PHENIX setup. The detector system consisting of 80 aerogel counters was assembled, tested and installed at the PHENIX setup and used for obtaining new physical information at RHIC in 2004.

At the PHENIX setup the new data on suppression of high p_t hadrons in $d + Au$ collisions were obtained in addition to the earlier obtained data on such suppression in $Au + Au$ collisions (fig. 16a and fig. 16b). As seen from this picture, significant suppression of high p_t hadrons is observed in $Au + Au$ interactions, while in $d + Au$ interactions such suppression is not observed [16]. High p_t hadron suppression in the $Au + Au$ collisions is interpreted as a result of strong energy losses in quark-gluon plasma in central collisions at RHIC energies (Jet Quenching Effect).

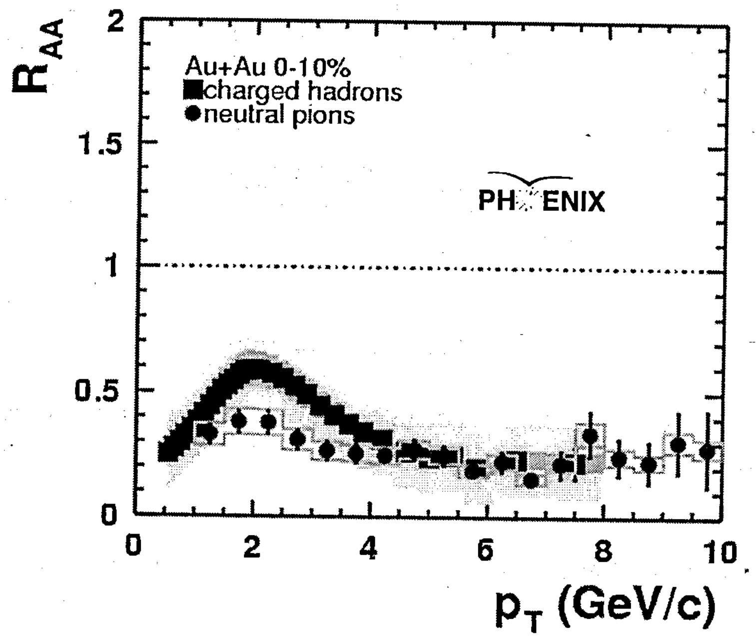

Fig.16a. High p_t hadron suppression in $Au + Au$ collisions obtained in PHENIX experiment at RHIC.

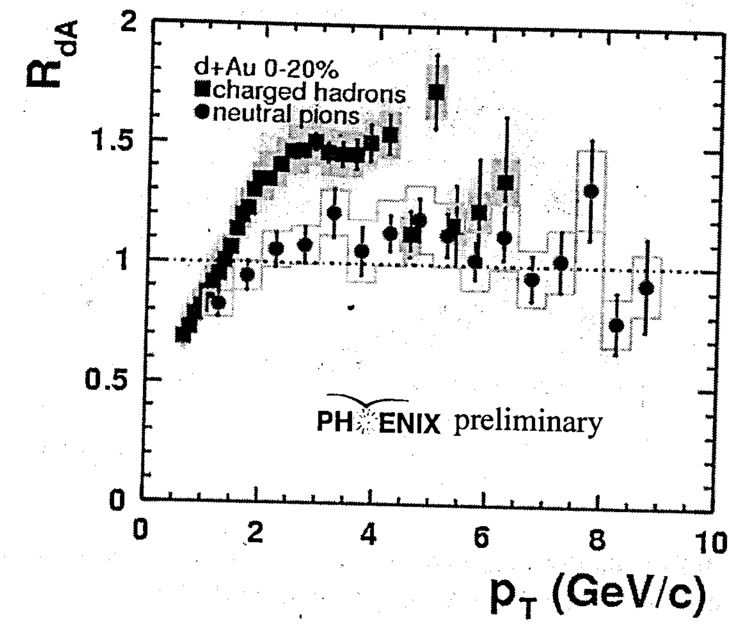

Fig.16b. High p_t hadron suppression in $d + Au$ collisions obtained in PHENIX experiment at RHIC.

The similar result was obtained in the STAR experiment at RHIC. The VBLHE group headed by Yu.A. Panebratsev took active part in this work (fig.17).

High p_t hadron suppression in central $Au + Au$, but not in $d + Au$, clearly proves Jet Quenching Effect to be a final-state phenomenon, indicating very strong interactions of hard scattered partons or their fragments with dense, dissipative medium.

Participation in PHENIX and STAR experiments at RHIC will be continued in 2005-2007.

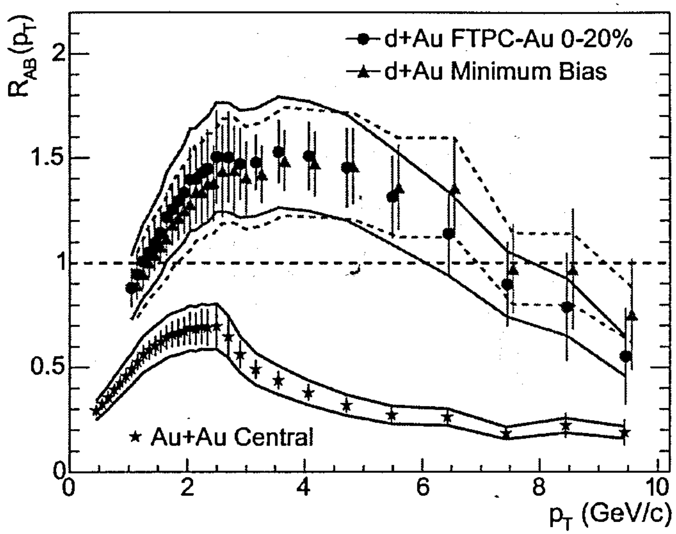

Fig.17. High p_t hadron suppression in *Au* + *Au* collisions and in *d* + *Au* collisions obtained in STAR experiment at RHIC.

Heavy ions interaction at CERN SPS

The e^+e^- invariant-mass spectrum obtained at the NA45 setup (SPS, CERN) is presented in fig.18. The enhancement of the experimental data compared to the hadron cocktail in the mass range m_{e+e-} > 200 MeV/c^2 is 3.1 ±0.3 (stat.) The VBLHE group (leader Yu.A. Panebratsev) conducted comparison of the experimental data with various models in 2004. The NA45 spectrometer offers a unique possibility to study *φ*-meson production in the K^+K^- decay channel also. The group obtained the new data on *φ*-meson production in nuclear matter in *Pb* + *Au* collisions (invariant mass and transverse momentum spectra).

The group of Yu.A. Panebratsev also participated in the preparation for study of e^+e^- production in heavy ion collisions at LHC CERN.

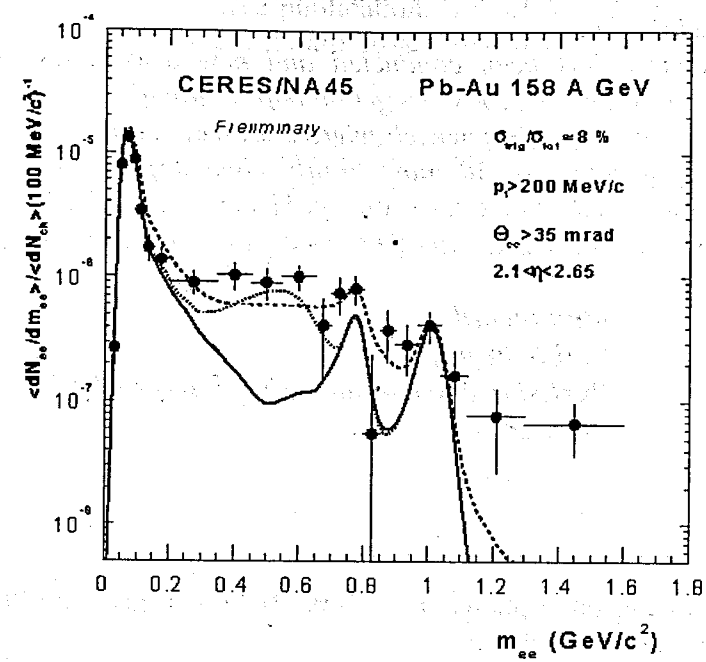

Fig.18. The e^+e^- invariant-mass spectrum obtained in the NA45 experiment at SPS, CERN.

The group of G.L. Melkumov actively participate in the NA49 experiment. During 2004 the following results were obtained [17-19]:

1. The results on the pentaquark barion with S = - 2 and strangeness production from 20 to 158 A·GeV, and energy and centrality dependence of deuteron and proton production in *Pb+Pb* collisions at the CERN-SPS were published.
2. Presentations at the conference Quark Matter 2004 and Strange Matter 2004 were made.
3. A new proposal from NA49 was prepared and presented at the SPSC workshop in Villars in September 2004.

In connection with the NA49 results the following letter was received:

Dear Dr Malakhov,
*Great research has been conducted and new discoveries made during the 50 years of CERN. To get an impression of this research, please visit our website **www.elsevier.com/locate/cern** where you will find a selection of **50 most highly cited papers** written by scientists affiliated with CERN and published with Elsevier. We wish everybody at CERN another successful 50 years of great research.*

Kind regards,
Carl Schwarz
Publisher Nuclear and High Energy Physics
Elsevier

The following three publications in the field of Heavy Ion Physics can be found on that website:

ANAMALOUS J/PSI SUPPRESSION IN PB + PB COLLISIONS AT 158 AGEV/C. NA50 Collaboration (M. Gonin et al.); published in: Nuclear Physics A .

HADRON PRODUCTION IN NUCLEAR COLLISIONS FROM THE NA49 EXPERIMENT AT 158 GEV/C/A. NA49 Collaboration (Authors from LHE JINR: V.I.Kolesnikov, A.I.Malakhov, G.L.Melkumov, A.Yu.Semenov); published in: Nuclear Physics A661 (1999) 45c-54c.

HADRON YIELDS AND HADRON SPECTRA FROM THE NA49 EXPERIMENT. NA49 Collaboration (Authors from LHE JINR: S.V.Afanasiev, V.I.Kolesnikov, A.I.Malakhov, G.L.Melkumov, A.Yu.Semenov); published in: Nuclear Physics A610 (1996) 188c-199c.

The two of these publications are related to the NA49 results and the VBLHE scientists are co-authors of these ***most highly cited papers***.

It is planned participate in the NA49 experiment in future. The nearest plans of participation in the NA49 experiment are the following:

1. Calibration of the TOF data. Processing and analysis of the antiproton and antideuteron data and submission of the results for publication.
2. Upgrade of the NA49 detector for the experiments after 2005. Inspection and repairment of the Dubna TOF detector.
3. Further analysis of the data obtained at the NA49 on the energy, centrality and size dependence of particles produced in *pp*, *pA*, *CC*, *SiSi* and *PbPb* collision.

Participation in preparation of the experiments for LHC in CERN

The group of A.S. Vodopianov continued to participate in ALICE project for LHC in CERN.
The main results obtained in 2004 are the following:

1. The yoke of the dipole magnet was successfully assembled in the ALICE underground area by the JINR team.
2. 230 lead tungstate crystals were delivered for the photon spectrometer (PHOS) from Kharkov (Ukraine) to JINR.
3. The data analysis program for the PHOS beam test data was performed.
4. During the summer of 2004 JINR physicists took part in the beam test of PHOS calorimeter prototype of 256 crystals at the CERN beams.
5. The construction of drift chambers for TRD detector started at JINR (leader Yu.V. Zanevsky). Further development of the Kalman filter method for the dimuon spectrometer tracking is going on in collaboration with SUBATECH (Nantes, France).
6. Simulation of *p-Pb* and *Pb-p* interactions for the production of Upsilon family was performed.

Some expected results in 2005-2007:

1. Production of the crystals for the photon spectrometer.
2. Construction of the spectrophotometer to test crystals.
3. Participation in the assembly of the 1st PHOS module at CERN.
4. Preparation of the test setup to test PHOS module at RHIC (BNL).
7. Continuation of the construction of the drift chambers for TRD detector.
8. Continuation of the study of the quarkonia production at pA and Ap interaction for the dimuon spectrometer for the various level of collision centrality.
9. Organization of the ALICE-Russia and ALICE-JINR participation in the Data Challenge in the framework of GRID.

Another VBLHE group (leader A.I. Malakhov) participated in CMS project. This group participated in development of Heavy Ion Program for CMS and in the test beam run of the hadronic calorimeter and electronics at CERN in 2004. It is planned to enhance participation in the CBM project in future. V.P.Ladygin and T.A.Vasiliev took part in the test beam run on calibration of the Hadron Endcap Calorimeter at CERN. The express online analysis of some data was performed. In particular, the VBLHE group obtained the ratios of the calibration coefficients for different types of particles. With these coefficients the resolution of Hadron Endcap Calorimeter $\sigma_E/E \approx 12.5\%$ for 150 GeV pion beam was obtained (see Fig.19).

The VBLHE group also continued the analysis of the wire-source calibration data for Hadron Endcap Calorimeter. The semi-authomatic procedure to obtain the calibration constants was developed. The effect of geometry due to the various sizes of the scintillators obtained as a ratio of the signal from the wire source to the collimated source was studied. This effect was found to be several per cents, which is essential for correct calibration of the Hadron Endcap Calorimeter.

It is planned to intensify participation in the CBM project in future.

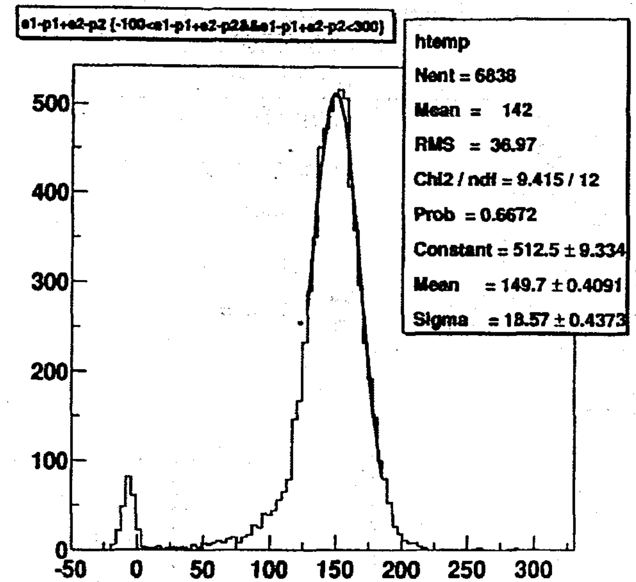

Fig.19. Signal from 150 GeV pions in Hadron Endcap Calorimeter.

Collaboration with GSI

The group of Yu.V. Zanevsky continued participation in HADES experiment. The following was carried out for HADES:

- six low mass multilayer inner drift chambers were constructed, tested and integrated into the HADES spectrometer.
- Front End Electronics for Drift Chambers system was developed and tested.
- track reconstruction software was developed and successfully applied for data analysis.

The preliminary effective mass spectrum of e^+e^- pairs obtained at HADES for *Ca* + *Ca* interactions at 2.2 A·GeV is presented in fig.20. It is in a good agreement with the simulation.

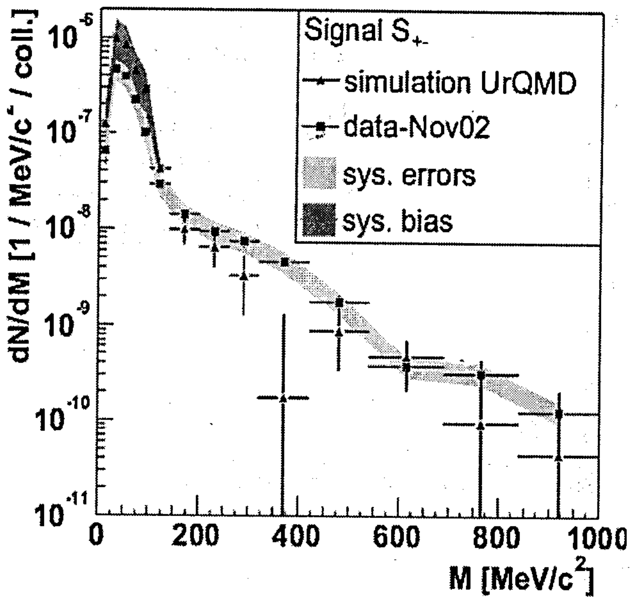

Fig.20. The preliminary effective mass spectrum of e^+e^- pairs obtained at HADES.

The following studies are planned in 2005-2007:

- dielectrons from *pp/pd* interactions
- threshold η production in $d + p$ collisions
- ω production in *pp* collisions
- dielectrons from *Ca* + *Ca* interactions.

The VBLHE participates in R&D for the New Facility at GSI (FAIR – Facility for Antiproton and Ion Research) (accelerators, detectors, and physics):

- fast–ramped magnets (Nuclotron-type)
- SIS100/SIS300 lattice optimization

- cryogenic magnetic system, superconductive beam lines
- TRD detector for the CBM project
- superconductive magnets for the CBM and PANDA projects
- simulation (track fitter and track finder)
- physical program (production of vector mesons and lambda particles in nuclear collisions).

Miscellaneous

The some other results obtained at VBLHE in 2004 are published in [20-30].

The main topics of the VBLHE research programme in 2005-2007 is presented in table 3.

Table 3. Main topics of the VBLHE research programme in 2005-2007

Polarization Phenomena at Relativistic Energies
▪ Spin effects in the interactions of polarized nucleons and the lightest nuclei at energies above 1 *GeV*: ***ALPOM, KAPPA, SMS MSU, DISK, SPIN, BES, SINGLET*** ▪ Spin structure of the *np* forward scattering amplitude: ***DELTA-SIGMA*** ▪ Spin-dependent part of the nucleon scattering amplitude: ***STRELA*** ▪ Search for the role of three nucleon forces: ***pHe3, LNS*** ▪ Investigation of the spin structure of the lightest nuclei at short distances: ***PIKASO*** ▪ Investigation of meson production and resonances in collisions of polarized nucleons and the lightest nuclei: ***DELTA-2, NIS and WASA (CELSIUS, Uppsala)***

Table 3. Main topics of the VBLHE research programme in 2005-2007 (continued)

Nuclear Beams at Relativistic Energies
Study of multiple production processes in collisions of relativistic nuclei from the lightest to the heaviest ones at energies from hundreds of *MeV* to *TeV*
▪ Investigation of multiple particle production at the Nuclotron energies in inclusive and semi-inclusive measurements and measurements in 4π- geometry: o External Beams: ***BECQUEREL, MARUSYA, SMS MSU, DISK*** o Internal Beams: ***MARUSYA, DELTA-2, LNS*** ▪ Study of asymptotic multiple particle production at ultrarelativistic energies: ***STAR, PHENIX (BNL), ALICE, NA49 and Heavy_Ions@CMS (CERN)*** • Participation in the new International Project at GSI.
Manifestation of the structure and excited states of nuclei at relativistic energies
▪ Research of clusterization in light stable and radioactive nuclei: ***BECQUEREL*** ▪ Investigation of multifragmentation of the medium and heavy target nuclei: ***FAZA*** ▪ Investigation of light hypernuclei: ***GIBS*** ▪ Observation of eta-mesonic nuclei: ***ETA-NUCLEI*** ▪ Search for pentaquarks: ***NIS (Together with LPP), GIBS, NA49*** ▪ Investigation of lepton pairs: ***NA45 (CERN), HADES (GSI)***

Table 3. Main topics of the VBLHE research programme in 2005-2007 (continued)

Applied Research using the Nuclotron Relativistic Nuclear Beams
▪ Provision of space apparatus elements with ground tests ▪ Radiobiology and space biomedicine (in cooperation with DRRR). Transmutation of radioactive wastes, problems of the electronuclear energy generation method: ***GAMMA-2, Energy+Transmutation*** ▪ Use of the carbon beam for medical purposes (in cooperation with DLNP): ***MED-NUCLOTRON***

References

1. A.I.Malakhov. Research program for the Nuclotron. Nuclear Physics, A734C, (2004) pp. 82-90.
2. A.I.Malakhov. Relativistic Nuclear Physics at the Veksler and Baldin Laboratory of High Energies. Physics of Particles and Nuclei. Vol.1, No.6 (2004) pp.314-324.
3. Ю.С.Анисимов, А.С.Артемов, В.В.Архипов, С.В.Афанасьев, В.К.Бондарев, Д.К.Дряблов, В.И.Иванов, А.Ю.Исупов, Я.Климан, А.Г.Литвиненко, А.И.Малахов, В.Матоушек, М.Морхач, И.Турзо. Поляриметр для внутреннего пучка нуклотрона. Письма в ЭЧАЯ, 2004, №1[118], с.68-79.
4. A.Yu.Isupov. DAQ Systems for the High Energy and Nuclotron Internal Target Polarimeters with Network Access to Polarization Calculation Results and Raw Data. JINR Preprint, E10-2004-13, Dubna (2004).
5. Yu. A.Troyan et al., D1-2004-39, Dubna, 2004; hep-ex/0404003.
6. P. Togoo et al., Proc.of the Mongolian Academy of Sciences, vol.170, No.4, p.3, 2003.

7. C.Alt, T.Anticic, B.Baatar, D.Barna, ..., V.I.Kolesnikov, ..., A.I.Malakhov, G.L.Melkumov et al. (NA49 Collaboration). Evidence for an Exotic S= -2 and Q = -2 Barion Resonance in Proton-Proton Collisions at the CERN SPS. Phys.Rev.Lett., V.92, No.4, (2004) pp. 042003-1 – 042003-5.
8. V.A.Karnaukhov, et al., Nucl.Phys.**A 734** (2004) 520.
9. V.A.Karnaukhov, et al., Phys. Rev.C **70** (2004) 1 (R)
10. V.P.Ladygin, T.Uesaka, T.Saito, M.Hatana, A.Yu.Isupov, H.Kato, N.B.Ladygina, Y.Maeda, A.I.Malakhov, J.Nishikawa, T.Ohnishi, H.Okamura, S.G.Reznikov, H.Sakai, N.Sakamoto, S.Sakoda, Y.Satou, K.Sekiguchi, K.Suda, A.Tamii, N.Uchigashima, K.Yako. Measurements of tensor analyzing power T_{20} in $dd \rightarrow {}^3He\ n$ and $dd \rightarrow {}^3He\ p$ at intermediate energies and at zero degree. Phys.Lett. B598, (2004) pp. 47-54.
11. V.I.Sharov, N.G.Anischenko, V.G.Antonenko, S.A.Averichev, L.S.Azhgirey et al. Measurement of the np total cross section difference $\Delta\sigma_L(np)$ at 1.39, 1.69, 1.89 and 1.99 GeV. Eur.Phys.J. C37, (2004) 79-90.
12. V.Bradnova, M.M.Chernyavsky, A.Sh.Gaitinov, L.A.Goncharova, L.Just, S.I.Kharlamov, A.D.Kovalenko, M.Haiduc, V.G.Larionova, F.G.Lepekhin, A.I.Malakhov, G.I.Orlova, N.G.Peresadko, N.G.Polukhina, P.A.Rukoyatkin, V.V.Rusakova, N.A.Salmanova, B.B.Simonov, S.Vokal, P.I.Zarubin, I.G.Zarubina. Studies of Light Nucleus Clustering in Relativistic Multifragmentation Processes. Acta Physica Slovaca, Vol.54, No.4, (2004) pp.1-15.
13. M.I.Adamovich, V.Bradnova, S.Vokal, S.G.Gerasimov, V.A.Dronov, P.I.Zarubin, A.D.Kovalenko, K.A.Kotelnikov, V.A.Krasnov, V.G.Larionova, F.G.Lepekhin, A.I.Malakhov, G.I.Orlova, N.G.Peresadko, N.G.Polukhina, P.A.Rukoyatkin, V.V.Rusakova, N.A.Salmanova, B.B.Simonov, M.M.Chernyavsky, M.Haiduc, S.P.Kharlamov, and L.Just. Phys. of Atomic Nuclei, Vol.67, No.3 (2004), pp.514-517.
14. V.Bradnova, M.M.Chernavsky, L.Just, M.Haiduc, S.P.Kharlamov, A.D.Kovalenko, V.A.Krasnov, V.G.Larionova, A.I.Malakhov, G.I.Orlova, N.G.Peresadko, N.G.Polu-

khina, P.A.Rukoyatkin, V.V.Rusakova, N.A.Salmanova, S.Vokal, P.I.Zarubin. Nuclear Clustering Quest in Relativistic Multifragmentation. Proceedings of the XVI International Baldin Seminar on High Energy Physics Problems. Relativistic Nuclear Physics and Quantum Chromodynamics. Edditors: A.N.Sissakian et al, Vol.II, (2004) pp.131-134.

15. Н.П.Андреева, В.Браднова, С.Вокал, А.Вокалова, А.Ш.Гайтинов, С.Г.Герасимов, Л.А.Гончарова, В.А.Дронов, П.И.Зарубин, И.Г.Зарубина, А.Д.Коваленко, А.Кравчакова, В.Г.Ларионова, О.В.Левицкая, Ф.Г.Лепехин, А.И.Малахов, А.А.Моисеенко, Г.И.Орлова, Н.Г.Пересадько, Н.Г.Полухина, П.А.Рукояткин, В.В.Русакова, Н.А.Салманова, В.Р.Саркисян, Б.Б.Симонов, Е.Стан, Р.Станоева, М.М.Чернявский, М.Хайдук, С.П.Харламов, И.Цаков, Т.В.Щедрина. Топология «Белых звезд» в релятивистской фрагментации легких ядер. Препринт ОИЯИ, Р1-2004-91, Дубна (2004). Направлено в ЯФ.

16. S.S.Adler, S.Afanasiev,…,A.Isupov, V.Ladygin, A.Litvinenko, A.Malakhov, V.Peresedov, L.Zolin et al. High-p_T charged hadron suppression in Au+Au collisions at $\sqrt{S_{NN}}$ = 200 GeV. Physical Review C **69**, 034910 (2004).

17. T.Anticic, B.Baatar, D.Barna, …, V.I.Kolesnikov, …, A.I.Malakhov, G.L.Melkumov et al. Λ and anti-Λ in Central Pb-Pb Collisions at 40, 80 and 158 A GeV. Phys.Rev.Lett, V. 93, No.2, (2004) pp. 022302-1 – 022302-5.

18. T.Anticic, B.Baatar, D.Barna, …, V.I.Kolesnikov, …, A.I.Malakhov, G.L.Melkumov et al. Transverse momentum fluctuations in nuclear collisions at 158 A GeV. Physical Review C **70** (2004) pp.034902-1 – 034902-14.

19. T.Anticic, B.Baatar, J.Bartke,…, V.I.Kolesnikov, …, A.I.Malakhov, …, G.L.Melkumov et al. Energy and centrality dependence of deuteron and proton production in *Pb+Pb* collisions at relativistic energies. Physical Review C 69, 024902 (2004).

20. S.Stoulos, M.Fragopoulou, M.Manolopoulou, A.Sosnon, M.Krivopustov, W.Westmeier, R.Brandt, M.Debeauvais, M.Zamani. Neutron measurements by passive methods in the

Dubna transmutation assemblies. NIM in Phys.Research A 519 (2004) 651-658.

21. S.V.Afanasiev, V.D.Aksinenko, M.Kh.Anikina, S.A.Avramenko, Yu.A.Batusov, A.I.Golokhvastov, A.I.Isupov, S.A.Khorozov. J.Lukstins, A.I.Malakhov, V.T.Matyushin, I.S.Saitov, V.V.Tereshchenko, V.P.Kondratiev, L.V.Krasnov, I.Stepanov. Upgrade of the SPHERE spectrometer for Hypernuclear Experiments. Proceedings of the XVI International Baldin Seminar on High Energy Physics Problems. Relativistic Nuclear Physics and Quantum Chromodynamics. Edditors: A.N.Sissakian et al, Vol.II, (2004) pp.109-113.

22. Yu.S.Anisimov, V.A.Baskov, V.A.Krasnov, A.I.L'vov, A.I.Malakhov, L.N.Pavlyuchenko, G.A.Sokol. Perspectives of Eta-nuclei Investigations at the LHE JINR Nuclotron. Proceedings of the XVI International Baldin Seminar on High Energy Physics Problems. Relativistic Nuclear Physics and Quantum Chromodynamics. Edditors: A.N.Sissakian et al, Vol.II, (2004) pp.200-205.

23. О.С.Космачев. Физическая интерпретация некоторых групповых алгебр. Письма в ЭЧАЯ. Т.1, №5 (122) (2004) сс. 50-57.

24. О.С.Космачев. Волновое уравнение для квартета нейтрино.. Письма в ЭЧАЯ. Т.1, №5 (122) (2004) сс. 58-65.

25. N.B.Ladygina and A.V.Shebeko. Study of deuteron-proton charge exchange reaction at small transfer momentum. Eur.Phys.J. A, v.22 (2004) pp.29-35.

26. M.I.Krivopustov, J.Adam, A.R.Balabekyan et al. Investigation of neutron spectra and transmutation of ^{129}I, ^{237}Np and other nuclides with 1.5 GeV protons from the Dubna Nuclotron using the electronuclear setup "Energy plus transmutation". JINR Preprint, E1-2004-79, Dubna, (2004). Submitted to NIM A.

27. A.S.Artemov, Yu.S.Anisimov, S.V.Afanasiev, S.N.Bazilev, L.S.Zolin, I.B.Issinsky, J.Kliman, A.I.Malakhov, V.Matoushek, M.Morhac, V.A.Nikitin, A.S.Nikiforov, P.V.Nomokonov, A.V.Pilyar, I.Turzo. Control of the beam-internal target

interaction at the Nuclotron by means of light radiation. JINE Preprint, D13-2004-101, Dubna (2004). Submitted to NIM A.

28. A.A.Baldin, E.G.Baldina, E.N.Kladnitskaya, O.V.Rogachevsky. Analysis of experimental data on relativistic nuclear collisions in the Lobachevsky space. Письма в ЭЧАЯ, Т.1, №4 (121) (2004) сс.7-16.
29. И.Адам, А.Балабекян, В.С.Барашенков, В.П.Джелепов, С.А.Густов, В.П.Филинова, В.Г.Калинников, М.И.Кривопустов, И.В.Мирохин, В.С.Пронских, А.А.Солнышкин, В.И.Стегайлов, В.М.Цупко-Ситников, Я.Мразек, Р.Брандт, В.Вестмайер, Р.Одой, С.Г.Машник, Р.И.Праел, К.К.Гудима, М.И.Базнат. Исследование образования продуктов протон-ядерных реакций в мишени ^{129}I при энергии протонов 660 МэВ. Письма в ЭЧАЯ, Т.1, №4 (121) (2004) сс.53-64.
30. Н.Н.Агапов, В.И.Батин, Ю.А.Васенева. Применение струйных аппаратов в криогенной системе нуклотрона-сверхпроводящего ускорителя релятивистских ядер. Письма в ЭЧАЯ, Т.1, №4 (121) (2004) сс.65-71.