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RESEARCH PROGRAMME AND MAIN RESULTS IN 2007 OF THE VEKSLER AND BALDIN LABORATORY OF HIGH ENERGIES

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The activity of LHE in 2007 was concentrated on the realization of the 1st stage of the NICA/MPD project (Nuclotron-M subproject), as well as on the fulfillment of the existing obligations on IREN, ILC, in particle physics experiments and R&D of particle detectors and acceleration systems.

1. NICA/MPD

The new flagship project of the Joint Institute for Nuclear Research is the NICA/MPD project. The main goal of this project is an experimental study of hot and dense strongly interacting QCD matter at the new JINR facility. This goal is proposed to be reached by:

1. development of the existing accelerator facility (1st stage of the NICA/MPD accelerator program: Nuclotron-M subproject) as a basis for generation of intense beams over atomic mass range from protons to uranium and light polarized ions;
2. design and construction of heavy ion collider with maximum collision energy of $\sqrt{s_{NN}}$ = 9 GeV and averaged luminosity 10^{27} $cm^{-2}\cdot s^{-1}$ (for U^{92+});
3. design and construction of the Multipurpose Detector (MPD).

In order to strengthening work on the development and deep study of NICA physics program and ensure required man-power and financing so-called NICA-Center (lead by Prof. A.Sorin) has been created.

To concentrate an effort on the 1st stage of accelerator program, which is the key point in the NICA/MPD project, namely, upgrade and modernization of the Nuclotron (**Nuclotron-M** subproject) LHE accelerator division was reorganized and reinforced by joining existed LHE and PPL accelerator groups (lead by Dr. G.Trubnikov).

NICA/MPD Goals and Physics Problems

New JINR facility will make it possible to study in-medium properties of hadrons and nuclear matter equation of state, including a search for possible signatures of de-confinement and/or chiral symmetry restoration phase transitions mixed phase and QCD critical endpoint in the region of the collider energy $\sqrt{s_{NN}}$ = 3 – 9 GeV and to shed light on the evolution of the Early Universe and formation of the neuteron stars [1].

The following processes will be studied at the first stage of experiment:

- multiplicity and spectral characteristics of the identified hadrons including strange particles, multi-strange baryons and antibaryons characterizing entropy production and system temperature at a final interaction stage;

- event-by-event fluctuations in multiplicity, charges, transverse momenta and *K/π* ratios as a generic property of critical phenomena;

- collective flows (directed, elliptic and higher ones) for observed hadrons including strange particles driven by the pressure in the system;

- HBT interferometry of identified particles and particle correlations (femtoscopy).

At the second stage of the experiment the electromagnetic probes (photons and dileptons) will be used to study heavy ion interactions.

The beam energy of the NICA is lower than the energy of the RHIC and the LHC but it is located right on the top of the region where the baryon density at the freeze-out is expected to be the highest. In this energy range the system occupies a maximal space-time volume in the mixed quark-hadron phase (the phase of coexistence of hadron and quark-gluon matter similar to the water-vapor coexistence-phase). The energy region of NICA will allow analyzing the highest baryonic density under laboratory conditions. The conditions similar to NICA are expected to be reproduced at FAIR facility in Darmstadt after put the synchrotron SIS300 into operation (in 2015) [2].

By the end of 2007 first draft of the **Letter of Intent** for the Multipurpose Detector (**MPD**) to study Heavy Ion Collisions has been prepared [3].

NICA general layout

Construction of the new facility is based on the existing buildings and infrastructure of the Synchrophasotron/Nuclotron of the Veksler-Baldin Laboratory of High Energies. The accelerator chain includes: **heavy ion source – RFQ injector – linac – booster ring – Nuclotron – Superconducting collider rings**. The designed kinetic energy of U^{92+} ions in the collider is 3.5 AGeV. Beam cooling and bunching systems are foreseen. The collider is fitted to the existing building 205.

Several schemes of the NICA accelerator complex have been considered. The specified average luminosity of 10^{27} $cm^{-2}\cdot s^{-1}$ can be reached at the chosen parameters of the collider presented in the **Table 1**. The project design presumes the use some of fixed target experiments. Polarized deuteron and proton beams will be available also.

Table 1. The expected parameters of the collider

Ring circumference, m	224
Ion kinetic energy [GeV/u], min/max	1/3.5
Particle number per bunch, $N_{ion/bunch}$	$1.0 \cdot 10^9$
Bunch number, n_{bunch}	10÷20
Horizontal emittance, ε[π mm mrad]	0.7
Momentum spread, Δp/p	0.001
IBS life time [sec]	≥100
β function at interaction points, β*, m	0.5
RF voltage, U_{RF} [kV]	100
Laslett tune shift, ΔQ	0.0044
Beam-beam parameter	0.009
Luminosity, L [$cm^{-2}s^{-1}$], peak/average	$2/(1\div1.5)\cdot10^{27}$

Subproject Nuclotron-M

The Nuclotron, 6 AGeV accelerator, was designed and constructed at JINR (1987-1992) and commissioned in March 1993. The annual running time of 2000 hours is provided during the last years. Ion beams up to iron and polarized deuterons have been available. The ions up to Au were obtained from the prototype of the highly charged state ion source (KRION).

In 2007 the **Conceptual Design Report** (CDR) of the NICA facility [4] has been prepared and the realization of the 1st stage (Nuclotron-M subproject) was started. During 37th acceleration session, the LHE accelerator division carried out set of experiments and tests directed on the investigation of current Nuclotron conditions and started its modernization. In particular:

- $^6Li^{3+}$ has been accelerated (beam with intensity 10^9 particle and 5 MeV, were accelerated up to 25 MeV);

- estimation of beam life time using comparison of deuterons and H_2^+ circulation time was done. Measured value τ >3ms corresponds to $1\div3\cdot10^{-8}$ Torr (for N_2 equivalent) that is one order of magnitude better than it was expected (≤ 10^{-7});

- started and successfully performed 1st experiment on pseudo-adiabatic bunching at constant magnetic field. Shown that the beam intensity can be increased by factor 2;

- methodical shifts aimed on investigation of particle losses on the first turns were done.

Some other technical experiments and methodical studies were done and some new diagnostic equipment were installed and successfully tested.

NICA/MPD scientific and accelerator programs have been broadly presented in 2007 at different Workshops and Conferences. Mention the presentation at the *"XXIII International Symposium on Lepton and Photon Interactions at High Energy"* [5] by Prof. A.Sissakian and the "*International seminar dedicated to the 100th anniversary of V.I.Veksler and 50 years since the Synchrophasotron starts-up*", hold at JINR in Laboratory of High Energy 10-12 October, where the hole day (11th October) has been completely dedicated to reports and discussions on different topics of the NICA/MPD science and accelerator programs.

The strategy of the **NICA/MPD** project has been reported on the 27th and 28th sessions of the Particle Physics PAC and at the JINR Scientific Council session where it was completely approved and supported.

2. Ongoing experiments at Nuclotron

36th accelerator run of the Nuclotron has been successfully carried out from 26th of Febrary until March 21st. 362 hours (>60% of the total run duration) has been used by physicist, 124 hours took cooling, the rest has been taken by accelerator division staff for the tests and tuning of the accelerator systems. The experiments TPD, NIS/GIBS, STRELA, FAZA, Delta-Sigma and "Energy and Transmutation" have been used deuteron beam with intensity up to 10^{10} particles/cycle and the maximal kinetic energy up to 2.2 GeV.

TPD experiment

A high intensity extracted deuteron beam of the Nuclotron allows to carry out a number of experiments with unpolarized deuterons to study spin effects becoming when they passing through the unpolarized targets. In particular, the appearance of the tensor polarization of deuterons when they crossing the lengthly target can be studied. It is also possible to perform the quantitative check of two different mechanisms which can be responsible for the polarization appearance. Namely:

- phenomena of spin rotation and spin dichroism for particles with spin $S \geq 1$ in the unpolarized medium;
- effect correlated with presence of large tensor effects in the inclusive inelastic reaction $A+d \to d'+X$ in the region of 4-momentum transfer near $|t| = 0.3(GeV/c)^2$.

Measurements of deuteron tensor polarization at different target densities will help to distinguish between these two effects.

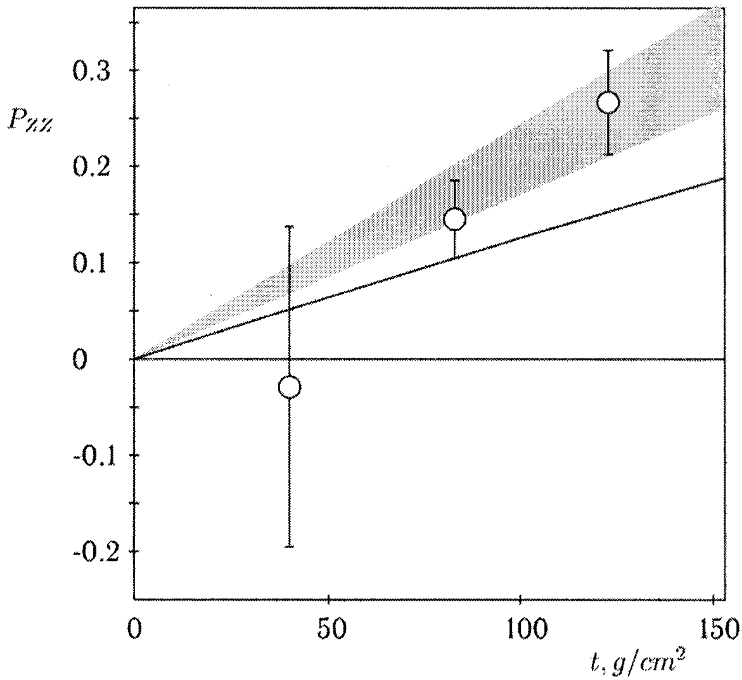

Figure 1. The value of the tensor polarization as a function of carbon target thikness. Curve corresponds to calculations performed developed in framework of the Glauber multiple scattering theory. Shadow region shows experimental uncertainty.

In March 2007, during the set of experiments carried out at the Nuclotron,has been discovered that:

- initially unpolarized deuteron beam has passed through the carbon target becomed to be polarized. The value of polarization increases with the target thikness (Figure 1);
- the phenomenon of spin dichroism (defined as a production of spin polarization in the unpolarized beam) predicted by V.Baryshevsky was observed with unpolarized deuteron beam 5.5 GeV/c;
- to describe observed effect formalism developed in framework of the Glauber multiple scattering theory was elaborated. Results of calculations are in qualitative agreement with the experimental data;

- Observed effect can be used to produce tensor polarized deuteron beam of small intensity at high energy.

Obtained results have been reported at the Conference DSPIN-2007 (3-7 September, JINR, Dubna).

LNS-PHe3

LNS and PHe_3 projects are studing spin effects in few-nucleon systems in polarized nuclei interactions at RARF (RIKEN,Japan) and at the Nuclotron. In 2007 work in the collaboration was concentrated on the analysis of the experimental data on the analyzing power in $dd \to {}^3\mathrm{He}n({}^3\mathrm{H}p)$ reactions and *dp* elastic scattering obtained at RARF and at the Nuclotron, respectively.

The aim of the experiment at RARF is the measuring of the vector, A_y, and tensor, A_{yy}, A_{xx} and A_{xz}, analyzing powers in the $dd \to {}^3\mathrm{He}n({}^3\mathrm{H}p)$ reaction at moderate energies in order to study the short-range spin structure of ^{3}He(^{3}H) and to search for the charge symmetry breaking (CSB) in polarization observables for two mirror channels: ^{3}He-*n* and ^{3}H-*p*.

The final results on the angular dependences of the analyzing powers A_y, A_{yy}, A_{xx} and A_{xz}, in the $dd \to {}^3\mathrm{He}n({}^3\mathrm{H}p)$ reactions at 270 MeV at the forward angles are presented in [6-8]. The difference between ^{3}H-*p* and ^{3}He-*n* channels is small and within achieved experimental accuracy for all analyzing powers. Therefore, no evidence of CSB is observed. The evaluation of the systematic errors for the analyzing powers diferences is in progress.

In 2007 preliminary results on the A_y, A_{yy}, A_{xx} and A_{xz} analyzing powers in the $dd \to {}^3\mathrm{H}p$ reaction at 200 MeV have been obtained [9,10]. The peculiarities of data for ^{3}H-*p* channel at 200 MeV are the same as those obtained at 270 MeV: small value of the vector analyzing power A_y; reasonable agreement of the tensor analyzing powers with the non-relativistic calculations at small angles and strong deviation at large angles in cms. The analysis of data at 200 MeV is in progress.

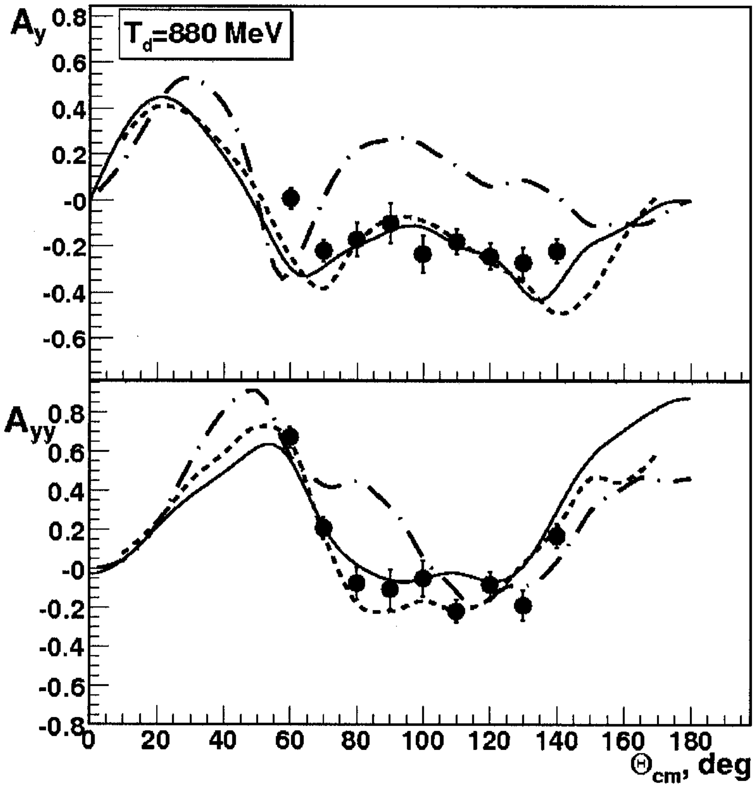

Figure 2. Preliminary results on the vector A_y and tensor A_{yy} analyzing powers in *dp*-elastic scattering at 880 MeV. The curves are the results of different calculations.

The aim of the experiment at Nuclotron is the investigation of the energy dependence of the analyzing powers in *dp* elastic scattering in the region of large scattering angles where the spin structure of three-nucleon forces is relevant. In 2007 collaboration concentrated on the experimental and theoretical analysis of the A_y, A_{yy} and A_{xx} measured in *dp* elastic scattering at 880 MeV using polarized deuteron beam and ITS at Nuclotron.

Preliminary results on the analyzing powers A_y and A_{yy} in *dp*- elastic scattering obtained at 880 MeV [11-14] were compared with different theoretical predictions (Figure 2), good agreement with the calculations [15] has been observed. The description of the experimental data can be improved by the inclusion of the three-nucleon forces. At the moment the analysis and calculations are in progress.

DELTA-SIGMA

The aim of the project is to extend investigations of properties of nucleon-nucleon (*NN*) interaction over 1.2 – 3.7 GeV energy region with polarized neutron beam, accessible at present only at the LHE Nuclotron. The main task of the study is the determination of the imaginary and real parts for all spin dependent forward scattering NN amplitudes over the specified energy region.

During the 36th accelerator run:

- methodical studies and calibrations of different subsystems were done with low intencity deuteron beam ($1 \div 2 \cdot 10^5$ with energy 1.1 GeV) in 1B channel;
- set-up were tested with secondary neutrons generated in 1B channel by the deutron beam with intencity $5 \cdot 10^9$ d/cycle and energy 1.1 GeV;
- ~50k triggers have been stored with the neuteron beam E=0.55 GeV scattered on the solid CH_2, CD_2 and C targets to study $np \rightarrow pn$ and $nd \rightarrow pnn$ processes of elastic charge-exchange under 0^0;

Results were presented at Conference SPIN-2007 [16].

Hypernuclear

The spectrometer dedicated to hypernuclear research was created in 2006 in collaboration with NIS experiment group. In March of 2007 the test run with deuteron beam (energy 2 GeV per nucleon) was carried out and all systems except hypernuclear trigger were successfully tested.

BECQUEREL

The technique of nuclear track emulsions is used to explore the fragmentation of light relativistic nuclei down to the most peripheral interactions - nuclear "white" stars.

In an emulsion exposed to relativistic ^{9}Be nuclei 371 events of fragmentation to a narrow pair of relativistic He nuclei were analyzed under the assumption of their correspondence two α particles [17,18]. The clear appearance of two peaks in the distribution over the invariant mass above the α particle pair mass threshold $Q_{2\alpha}$ was observed (Figure 3). It was concluded that the 0^+ and 2^+ states of ^{8}Be are revealed in the spectra over $Q_{2\alpha}$.

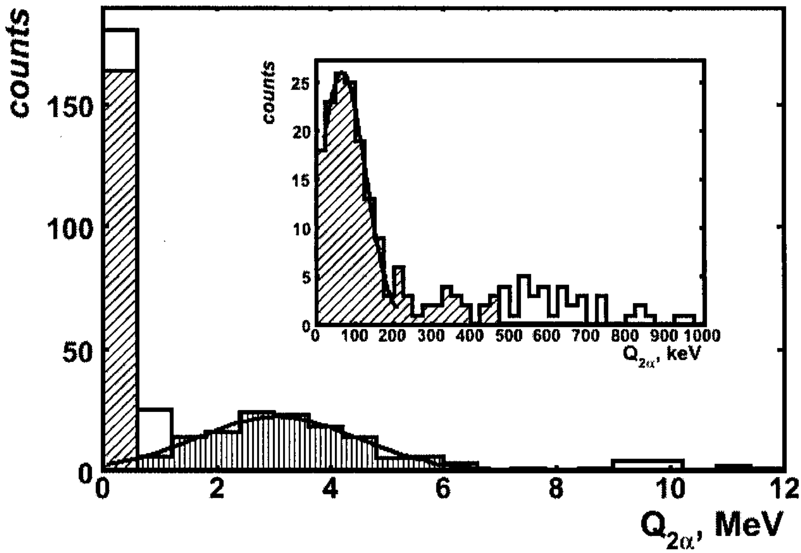

Figure 3. The invariant energy $Q_{2\alpha}$ distribution of α particle pairs in the ^{9}Be → 2α fragmentation reaction at 1.2A GeV energy. On the intersection: $Q_{2\alpha}$ range from 0 to 1 MeV.

3. Ongoing experiments at CERN, GSI and BNL

ALICE

Scientific program of the ALICE experiment aimed on the study of Quark-Gluon Plasma and phase transition in the relativistic heavy-ion experiment at the LHC by measuring particle ratios and p_t spectra (strangeness production, collective flow, jet quenching), particle interferometry, multiplicity fluctuations and event structures, direct photons (thermal radiation), and lighter, heavier meson and heavy quarkonia decays into lepton pairs (resonance line-shape parameters and partial chiral symmetry restoration at low masses, color screening and deconfinement at high masses). Study of parton (gluon) function in the nuclear media at the Bjorken variable 10^{-5}-10^{-6}.

Main results obtained with JINR group participation in 2007:

1. **Electromagnetic calorimeter PHOS**:
   - o lead tungsten crystals were tested at JINR setup and certified (optical properties) to use;
   - o one fully assembled module of PHOS has been tested on cosmic muons at CERN.

2. **Transition radiation detector TRD**:
   - o new detector laboratory with climate facility and clean rooms (~120m²) was build up at Bldg. 40 of LHE JINR for the chambers construction and test;
   - o Drift chambers were constructed and tested at LHE;
   - o The TRD module has been tested at CERN.

3. **Physics simulation:**
   - o Investigation of vector meson production in p+p at 14 TeV and in Pb+Pb at 5.5 ATeV:
     - Simulation study of $\phi \rightarrow K^+K^-$ decays using p+p ALICE-GRID production data of 2006. Installation of analysis packages in the frame of GRID-AliEn-CAF analysis system on PC servers of Dubna and CERN. Study of particle identification possibility for K^+/K^- using ITS, TPC and TOF detectors. Work on the increasing of the signal-background ratio. The results were reported in two ALICE Meetings at CERN.

     - Simulation of $\phi \rightarrow K^+K^-$, $\phi \rightarrow e^+e^-$, $\omega \rightarrow e^+e^-$, $J/\psi \rightarrow e^+e^-$ decays in Pb+Pb collisions at 5.5 ATeV. The first step of resonance peak analysis was finished using TPC and TRD detectors for e+/e- identification and taking into account e^+e^- background from gamma conversions. The final results were reported in ALICE Meeting at CERN. The publication is under preparation.

   - o Investigation of particle momentum correlation (femtoscopy physics);

   - o Integration of Universal-Hydro-Kinetic-Model (UHKM) code created in Dubna to the ALICE simulation package (AliRoot). Installation of new official version of AliRoot with special package for the femtoscopy physics. Integration of the UHKM code to the new femtoscopy package. Tuning the UHKM model parameter for Pb-Pb collisions at the LHC energy and carry out an analysis of $\pi\pi$ pairs correlation. Carry out of 3D-analysis to study correlation radii dependence from transverse momentum. Comparison with the RHIC results.

4. **Software and computing:**
   - The revision of the combined reconstruction code of the MUON spectrometer software and some reconstruction performance algorithms development was performed (publication is under preparation).

   - The permanent control and support of the ALICE Data Challenge 2007 at 8 Russian sites (RDIG) including JINR has been done.

NA49/NA61 experiments

Large Acceptance Hadron Detector for Investigation of Pb induced Reactions at CERN SPS (NA49) and *Study of Hadron production in Hadron-Nucleus and Nucleus-Nucleus Collisions at CERN SPS* (NA61) experiments study of hadron production in hadron and nucleus induced reactions at CERN SPS for relativistic heavy ion, neutrino and cosmic ray physics.

In 2007:

- CERN SPSC approved the continuation of the analysis program and the request to support by CERN NA49 experiment;

- NA61 experiment has been approved by the Research Board as a new experiment at the CERN SPS;

- JINR group participated in the preparation and maintenance of 1800 channels of TOF to data taking. During the accelerator session the reaction $p+^{12}C$ at 31 GeV/c with different target thickness were studied.

JINR group are involved in the analysis devoted to (anti)nucleus and (anti) hyperon production in nucleus-nucleus collisions at CERN SPS. Obtained results have been presented by LHE scientists at the International conferences HEP2007 (Manchester, UK) and CPOD2007 (Darmstadt, GSI, Germany). The talk *"The results and perspectives of the NA49/NA61 experiment"* has been presented at the Laboratory seminar. NA49/NA61 results were released in [19].

HADES

The HADES project aims to the systematic investigation on the accelerator facility SIS, GSI (Darmstadt) of the properties and behaviour of hadrons in the nuclear medium by studying collisions ranging from pions and protons as projectiles to heavy nuclei. Observables include masses, decay widths, and special functions of vector mesons, such as **ρ** and **ω** mesons. Dileptons are an ideal probe for vector meson spectroscopy in the nuclear medium, since they do not interact with the surrounding nuclear matter and leave the reaction zone nearly unhindered.

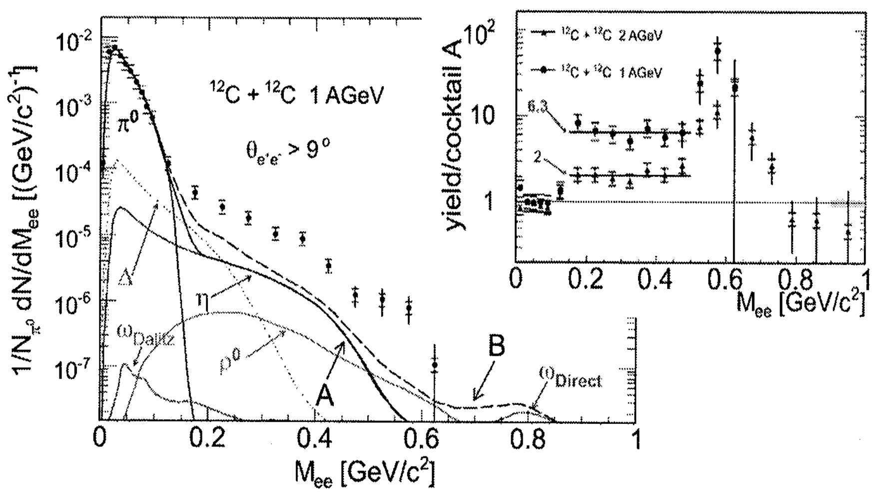

Figure 4. *HADES confirmed the DLS puzzle in C+C (1 AGeV) experiments. There was shown ~ 6 times excess overproduction of di-electron pairs in the mass region 0.15 GeV <M <0.55 GeV [7]. It also has been shown that for C+C (2 AGeV) this excess value is two times less [21,22].*

Previous experimental study conducted by the DLS Collaboration at Berkeley (Ca+Ca, at 1AGeV) has shown an overproduction of e^+e^- pairs in the low pair mass region (M < 0.6 GeV/c²) compare to theoretical calculations based on the known sources of dielectrons. The in-medium modifications of hadrons is thought to be a signature of the partial restoration of chiral symmetry, predicted by QCD. However the DLS data suffered from the detector's poor pair mass resolution (10%) and very limited acceptance.

HADES experiment was designed to improve these disadvantages, most notably with a full system design goal of ~1% mass resolution (in **ρ** and **ω** region) and 50% pair acceptance.

The JINR group has performed the very challenging task to design and build up of the HADES low mass Drift Chambers and front-end electronics. After the detector was completed, the JINR group concentrated on development of the tracking software which is the central part of dielectron reconstruction.

The physics results obtained by HADES in C+C collisions (**Figure 4**) [20-22] agree with DLS results. There was shown by theorist that this effect can be explained by bremsstrahlung as the dominant contribution for 0.15 GeV < M < 0.55 GeV at 1 AGeV.

Presently HADES has collected $\sim 7 \cdot 10^9$. Analysis of the recent (2007) experiments with proton and deuteron beams is expected to provide better understanding of elementary process and to shed more light on the anomalous pair yield. HADES is the first priority experiment for the future programme at FAIR (SIS-100) in range of nuclei energy of 2-8 AGeV.

STAR

The first discovery phase at RHIC has yielded unambiguous scientific evidence for the creation of a new state of matter the strongly interacting quark-gluon plasma (sQGP) in central collisions of ^{197}Au + ^{197}Au. Above ~6 GeV/c in transverse momentum, particles containing light quarks are suppressed by a factor of five compared to p+p collisions when scaled by the number of binary scatterings in the Au nucleus clear evidence of the quenching of jets in the dense matter which has been produced. Particles containing up, down, and strange quarks exhibit strong elliptic flow resulting from the pressure gradient in the asymmetrically shaped strongly interacting matter mutually initially swept out by the two gold nuclei when they collide. Such measurements provide indisputable proof that at RHIC, what has been discovered is the hottest, densest matter every studied in the laboratory, which flows as a nearly perfect liquid, with systematic patterns suggesting quark degrees of freedom and a viscosity to entropy density ratio lower than any known fluid.

The next step in RHIC's exploration of this new frontier is to characterize the properties of the sQGP to determine its critical parameters such as its shear viscosity, speed of sound, transport coefficients, and ultimately equation of state. This will require the development of new approaches to the analysis of RHIC heavy ion data, and upgrades of the detector capability and machine luminosity.

The Laboratory of High Energy is actively participating in pioneering the next phase of RHIC exploration. Specifically, it is developing new techniques for precise detection of short-lived hadrons, improving the signal to noise dramatically through constrained fitting techniques. This work is essential for detection of strange and multi-strange hadrons, and charm hadrons in the future, heavy flavor being a sensitive probe of the early conditions and possible thermalization at the partonic stage in the sQGP. It is researching the scaling behavior of high p_T particle production over a wide range of beam systems and energies to develop tools to detect novel behavior indicating new physics at RHIC. Similarly, it is studying correlations and fluctuation (the K3 correlator in particular) to see if different populations of RHIC events can be isolated based on the observed correlations. The study of correlations at RHIC is extremely useful. As one example, the study of 3-particle correlations suggests that conical emission from a mach cone set up by traversal of the sQGP by an energetic particle may have been observed. Confirmation of this phenomena would provide direct access to the speed of sound in the sQGP, and correspondingly, to its equation of state. The study of back-to-back charm correlations and tagging of the quark parent of leading particles in jets will provide a unique window on the production processes which form heavy quarks and the conditions in the earliest moments of the collision. The techniques being developed by LHE will be essential to tease out the necessary information from such observables in this exceptionally complex final state. Finally, the JINR group is exploring the possibility of a technical contribution to the STAR Heavy Flavor Tracker (HFT).

Presently, transverse stochastic cooling of heavy ion beams appears to be a promising approach to reduce inter-bunch and intra-bunch beam scattering to achieve the necessary luminosity for the exploration of heavy flavor and rare probes in the next phase of RHIC discoveries. The STAR detector is upgrading its data acquisition system to handle higher luminosity with (almost) zero dead time. Additionally it is constructing a TOF barrel to provide additional particle identification capability, and a new "charm class" micro-vertex detector called the Heavy Flavor Tracker. A Forward Meson Spectrometer, constructed of lead glass cells, will allow study of the parton distribution in the initial state Au nucleus to document the initial conditions which lead to such dramatic final state effects.

The scientific priority for the STAR LHE group was to obtain a deeper understanding of the spin structure and dynamics of the proton by studying how the intrinsic spin of the proton is distributed among its underlying constituents (quark, antiquarks and gluons). The obtained data on single and double spin asymmetries of hadron and jet production allows us to determine the spin dependent gluon distribution.

PHENIX

In 2007 activity of the LHE group in the PHENIX experiment was devoted to:

- participation in data taking as shifters and experts responsible on the Aerogel Cherekov Counters (ACC). During this period the highest luminosity has been achieved what allowed to obtain information on the dependence of the cross section for J/Ψ production from the collision centrality;

- participating in the:

  1. development and preparation of "Technical Design Report" of the forward calorimeter (NCC);

  2. designing and manufacturing samples of stripiksel detectors (with the BNL staff);

  3. front-end electronics manufacturing .

- participation in the test run aimed to study samples of stripiksel detectors and electronics. Data obtained during this run are analyzing now.

- participation in the simulation and preparation of the algorithm for neutral pions and jet reconstruction in NCC detector.

Experimental studies with crystals in 2007 (theme 1065)

Investigations with crystals have been fulfilled in 2007 at the SPS proton beam according to the program of the H8RD22 experiment where LHE group participates in collaboration with IHEP, PNPI and Italy universities. The goal of the experiment is the study the possibility of using bent crystals at the LHC and other accelerators in the experiments on the diffractive physics; for the beam extraction and for the halo collimation systems [23,24].

The experiment performed with 400 GeV proton beam proved the possibility to create the sequence of short bent crystals, working in the regime of volume reflection. The efficiency of the beam deflection for the sequence of five silicon crystals was greater than 90%.

The beam deflection due to realization of particle states not connected with the same axial channel during all way through the crystal was observed in the experiment at the axial orientation of a bent silicon crystal. A dynamical keeping of particles near the bent atomic string direction of the crystal occurs due to the uniform distribution of particle transverse momentums established in multiple scattering of particles with the atomic strings.

It was found that the dynamical keeping of particles near the bent atomic string direction of the crystal occurs due to the uniform distribution of particle transverse momentums established in multiple scattering of particles with the atomic strings.

4. Innovation activity

Med-Nuclotron project

In the time period 2005-2006 there were three experiments performed with profilometer, parallel plate ionization chambers, diamond dosimeter and other was tested. The first try of carbon beam visualization when it stops in the plastic was performed. In year 2007 we have worked with data analysis and simulation of the Bragg peak.

The main results:

1. These experiments gave the first experience for construction medico-technical ion beam line with the monitoring system. This experience will be used on the stage of construction of specialized medical accelerator of protons and ions.
2. The results of the first experiment with the carbon beam of energy of 500MeV/n have demonstrated the possibility to carry out irradiation of deeply located (up to 35 cm in the tissue) targets. But 500MeV/n is too high energy for patient treatment, the optimal energy is 350-400 MeV/n
3. The beam intensity of the carbon beam - 10^9 per spill is already enough to provide medico-biological research for the cancer hadron therapy. The Bragg curve was measured with ionization chambers and diamond detector.

4. The controlled dose field with high linear energy transfer (LIT) was formed. The first biological samples of living cells and small animals were irradiated in the absolute dose field.

"Energy and transmutation"

In frame of this activity Nuclotron proton and deuteron beams are used to study of neutron generation and multiplication in heavy targets (Pb, W, etc.), exploration of cross sections of transmutation of radioactive wastes, irradiation of heavy element samples by direct photon and deuteron beams and determination of cross sections of transmutation of long-lived radioactive wastes of nuclear power reactors.

Anniversary

The **4th of March 2007** was celebrate the centurial jubilee since Academician Vladimir Josephovich Veksler was born. He was an outstanding scientist in the field of accelerator physics and the phase stability principle discovered by him is used in all modern cyclic accelerators of the the charged particles and nuclei. The first European electon synchrotron was made at the Physics Institute of the Academy of Sciences under the leadership of V. Veksler in 1947 as well as the proton accelerator - Synchrophasotron, the biggest machine of this type in the world, commissioned in Dubna 50 years ago in April 1957.

V.Veksler was the founder of the Laboratory of High Energy at the Joint Institute for Nuclear Research named after him together with Academician A.M.Baldin.

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