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# RESEARCH PROGRAMME AND MAIN RESULTS IN 2008 OF THE VEKSLER AND BALDIN LABORATORY OF HIGH ENERGY PHYSICS

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The V.I.Veksler and A.M.Baldin Laboratory of High Energy Physics was founded on the 4th of May 2008 by the JINR Order №112 of the 19th of February 2008 according to the Resolution of the Committee of Plenipotentiaries of JINR to perform high priority research in high energy heavy ion and particle physics. The main task of LHEP is to create an adequate accelerating, experimental and research basis which enables JINR to occupy a leading position among the world scientific centres in the above directions and strengthen the attractiveness of the Institute for the JINR Member-States.

# I. The most important results in the development of the accelerating complex

### The Nuclotron-M

In 2008 the work to upgrade the accelerating complex of the Laboratory was carried out according to the schedule of the project Nuclotron-M. The Laboratory directorate made up a decision to perform runs only at rather good guarantees for the accelerator stable operation. The priorities for the runs were determined on the basis of the following principal tasks:

- the total revision of the main accelerator systems to meet the requirements of the project;
- repair, improvement, substitution of the elements having expired their resources, for the more advanced ones to provide the required quality of the beams, long-lasting, reliable and stable operation of the accelerator.

Main results concerning the subsystems of the accelerating complex:

1. Modernization of the Nuclotron vacuum system.
   In the result of the complex of the performed work the average vacuum value has been improved in 100 times. In the 38th run (June 2008) the average vacuum value was measured $\sim 5 \cdot 10^{-9}$ Torr. Thus, the 1st stage of the Nuclotron vacuum system modernization was completed and the work of the 2nd stage began: further improvement of the vacuum and construction of the automatic vacuum control system for the Nuclotron ring.
2. Modernization of the RF system.
   In 2008 new apparatus for adiabatic capture over all the RF-amplitude range, beam injection to the descending and rising magnetic field and other was manufactured and installed for testing.
3. Slow beam extraction system. Control systems.

The supply system EC of the septum was modernized to increase the operating voltage from 110-120 kV until 160-180 kV, that will provide to carry out extraction of the ion beam with the energy close to the design (4 GeV/n), now - it is 2.3 GeV/n.

4. Modernization of the power supply systems for the accelerationg complex.

   A principally important stage of work was completed to increase the fields in magnets and lenses from 0,9T till 1.4-1.5T during the 39$^{th}$ run by using a specially developed and installed prototype SEE. The next step – to increase the magnetic field until the designed value - 1,8-1,9T, is supposed to perform at the end of 2009 (by using the operating variant of SEE).

5. Modernization of the cryogenic supply system.

   The apparatus of the cryogenic complex used at the Nuclotron had fully expired its resources and required total modernization and repair. Performance of runs under these conditions did not guarantee the fulfilment of the given tasks and could result in loosing the expensive devices. In June 2008 when the 38$^{th}$ run was over, the total modernization of the Nuclotron cryogenic complex was begun.

   - Jointly with KRIOGENMASH the repair of the oil-cleaning block MO-800 was carried out. At the moment the work on its installation, mounting, testing and commissioning is completed.
   - At the beginning of 2009 the work to refurbish the systems of helium liquidizer KGY-1600 has been completed (6 pairs of oil-separators and adsorbers, purification and de-oiling of the low-temperature blocks, substitution of the adsorbents, cleaning and blowing- through, block-pressing, substitution of the CASCADE compressor filtering elements), repair of turbo-detenders is performed by HELIUMASH.

6. Linear pre-accelerator Linac.

   In collaboration with Protvino was prepared the Technical Design Report for a new heavy ion linear accelerator.

7. Heavy Ion Source KRION.

   In 2008 the electron-jet ionizer Krion-2 with a solenoid magnetic field of 3T had 4 runs, 1 month long each on the average. Many subsystems and devices have been developed, manufactured and tested.

   A series of experiments has been performed to obtain high-voltage ions of xenon with «the electron string» technics. Ions of $Xe^{36+}$ have been obtained at the energy of injected electrons 3.7 keV. It has been shown that this method leads to «poisoning» of the electron gun cathode of the ionizer. Investigation is in progress.

The developing a new ion source Krion-6Tc was fulfilled according to the schedule.

**NICA**

In January 2008 the Conceptual Design Report of the accelerating complex NICA was prepared and issued. The following concept of the collider was considered as the basic one:

- 17 bunches with the intensity of $10^9$ ions of $^{197}Au^{79+}$ circulate in 2 rings;
- electron cooling is used to suppress IBS;
- $\beta$= 0.5 m; L= $1 \cdot 10^{27}$ $cm^{-2} \cdot c^{-1}$;
- the colliding angle of the beams is 0 mrad.

At present the following variant has been preferred in the result of studies and calculations carried out during the last year:

- 25 bunches, each - $10^9$ ions of $^{197}Au^{79+}$ circulate in 2 rings;
- stochastic cooling is used to suppress IBS;
- $\beta$< 0.5 m; L= $2 \cdot 10^{27}$ $cm^{-2} \cdot c^{-1}$;
- the colliding angle of the beams = 10 mrad.

The preparation of the «Technical Design Report» is close to be completed.

Machine Advisory Committee (MAC) made a review on the progress in "Nuclotron-M" project realization and conclude:

1. the project Nuclotron-M is on the whole aiming at resolving the key technological problems that restrict the operating parameters of the Nuclotron accelerator essential both for the NICA project and for the efficiency of the physics experiments currently being conducted and planned at the accelerator;

2. to the moment essential results were obtained in the realization of the main part of sub-projects;

3. the nearest milestone of the Nuclotron-M project summarizing subprojects results has to be passed in the fall of 2009 during the Nuclotron run with $Xe^{44}$+ ions (A=129, Z/A=0,341).

MAC recommends to JINR directorate to provide regularly required funding of the activities in accordance with the time schedule for successful completion of the "Nuclotron-M" project.

The preparation of the first concept of the polarized proton and deuteron beams has begun.

**IREN, LUE-200**

The employees of the LHEP acceleration division actively take part in the project IREN, their obligation is the key element – Linear Accelerator of Electrons LUE-200.

In December 2008 IREN 1-st stage assembling was accomplished, the technical startup was fulfilled, electrons were accelerated and first neutrons were registered (Fig.1).

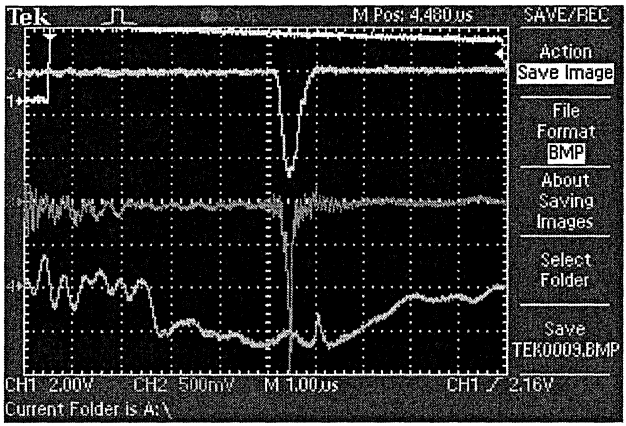



**Fig.1.** The dependence of beam shifting on the corrector field corresponds to the energy of electrons of 20MeV. The current on the exit of the accelerator is1.2 A (top curve). The signal of «Rogovsky belt» at the entrance to the target hall is 0.4 A (middle curve). The amplitude line of RF field - (bottom curve).

**LHC**

The transverse oscillation damping system for LHC which is an important part of accelerator operation was successfully started up. The project parameters were achieved in 2008 with the LHEP's group certain contribution.

## II. The Most Important Results in Physics

**NA48/NA62**

Very large statistics of high performance data of charged kaon decays have been accumulated by this experiment at CERN SPS. The

following results were obtained in 2008 with significant contribution of the JINR team:

- Analysis of ~60·10$^6$ decays of $K_{3\pi}$ ($K^{\pm} \to \pi^0\pi^0\pi^{\pm}$) and ~10$^6$ decays of $Ke_4$ ($K^{\pm} \to \pi^+e^+e^-\gamma$) was performed [1]. Values $a_0$ and $a_2$ were extracted for the length of S-wave of $\pi\pi$ scattering with isotopic spin of 0 and 2 within the experimental error of several percent that exceeds by 3 times the accuracy of the previous measurements and gives an opportunity to carry out a precision checking of the Chiral Perturbative Theory predictions taking into account the isotopic symmetry breaking (Fig.2).

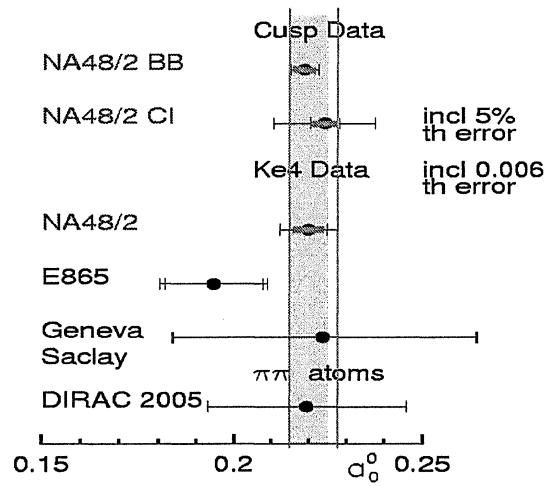



**Fig.2** New $a_0$ measurements from NA48 and other experimental results using ChPT constrains. The coloured band corresponds to the most precise theoretical prediction.

- A new measurement of the properties of decay $K^{\pm} \to \pi^+\pi^-e^{\pm}\nu$, was fulfilled, which was based on the part of the existing statistics including more than 67 thousand of decays for the both kaon charges registered in the run of 2003 [2]. In ten intervals independent of $\pi\pi$ masses the hadron current formfactors were measured (F,G,H) as well as the phase difference of $\pi\pi$-scattering ($\delta=\delta_s-\delta_p$) to study their variations. Significant acceptance for big masses of the pair $\pi\pi$, low background level and a very good resolution affected the improvement of the experimental precision of measuring the scattering length of pions $a_0^0$ and $a_0^2$ that was improved by twice in comparison with the previous experiment. Supposing the isospin symmetry and using a numerical solution of the Roy equation, the following values in the plane ($a_0^0$,$a_0^2$) were

obtained: $a_0^0 = 0.233 \pm 0.016_{stat} \pm 0.007_{syst}$, $a_0^2 = -0.0471 \pm 0.011_{stat} \pm 0.004_{syst}$.

- The «cusp» effect analysis was completed in Dalitz distribution of $K^{\pm} \to \pi^0\pi^0\pi^{\pm}$, the concluding paper is in progress.

The collaboration has started the preparation of **NA62** experiment dedicated to the study of extremely rare decays of charged kaons into a charged pion and two neutrinos. A methodical run on the beam at CERN tested different read-out electronics and carried out optimization of the gas mixture for the straw detector developed and constructed at JINR.

## COMPASS

In 2008 the collaboration took data on the hadron beam of CERN SPS. The programme included the search for glueballs in the region of masses more than 2 GeV/c in the inclusive diffraction *pp* scattering, the study of lepton and semi-lepton decays of charmed hadrons, the diffraction and Primakov scattering.

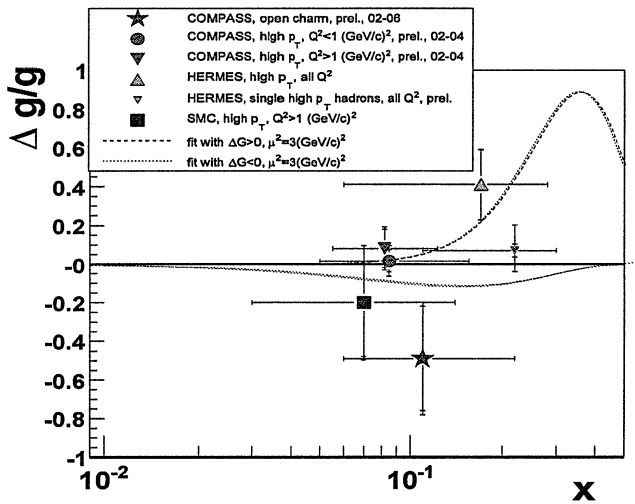



**Fig. 3.** Compilation of the $\langle \Delta g/g \rangle_x$ measurements from the open charm and high $p_T$ hadron pair production by COMPASS, SMC and HERMES as a function of Bjorken x. The curves display parameterizations from the NLO QCD analysis in the MS-bar scheme at 3 (GeV/c)$^2$: fits with $\Delta G > 0$ - (the broken line) and with $\Delta G < 0$ - (the dotted line).

The data analysis was completed on measurements of Collins and Sivers asymmetries [3]. The both asymmetries was found to be comparable with zero what is in agreement with the expected compensation between u- and d- quarks.

The gluon polarization from $D^0$ meson decays [4] in the leading order (LO) of QCD was found $\langle \Delta g/g \rangle_x = - 0.49 \pm 0.27(\text{stat.}) \pm 0.11(\text{syst.})$ for $\langle x_g \rangle \approx 0.11$ (Fig. 3)

Preliminary data on polarized parton distributions in LO QCD were obtained from 2002-2006 data [5]. It was found that the value $(\Delta u_v + \Delta d_v)$ is positive and weakly sensitive to the type of the fragmentation function used in the analysis; antiquarks and $x\Delta s$ – are comparable with zero.

During the methodical run the JINR group carried out testing of the prototypes for the electromagnetic calorimeter with new avalanche multi-pixel photo-diodes produced at JINR. This calorimeter is planned to use for measuring the generalized parton distributions in the future physical programme of COMPASS.

**Progress on the MPD project**

During 2008 big progress has been achieved in R&D for different MPD subsystems:

1. **TPC**

   - the main parameters of TPC have been determined.
   - simulation of the working characteristics for the read-out chamber (ROC) was carried out (loading, drift time, signals from pads and etc.).
   - the study of the proposal to use electronics TPC/ALICE is about to be completed.

2. Time-of-Flight Detector (**TOF**)

   - the prototype of a multi-gap plane-parallel chamber (mRPC) was assembled;
   - the gaseous system was assembled and calibrated to provide the prototype mRPC with the working mixture.
   - simulation of the particle identification system based on the TOF , TPC and straw tubes information were carried out.

3. **End-Cap Tracker** of the setup

Different versions of the End-Cap tracker geometry was described in the MPD-Root. The energy losses by light charged hadrons (p,K,π) were calculated while their passing through the substance of the End-Cap tracker.

4. **Calorimetry**

- The work with a calorimeter of the «shashlyk» type was carried out. The calorimeter module with the sizes 12x12 cm, length - $20X_0$ type «KOPIO», was prepared for the run. The new $16^{th}$ block of fast digitizing ADC16 was used as read-out electronics.
The data taking run was successfully performed on the accelerator in Hamburg. The processing of the obtained data will allow to make a conclusion on the opportunities of using the calorimeter of the given construction for MPD and develop a technical task for manufacturing of the calorimeter module adapted to the requirements of MPD.

- During the $38^{th}$ run of the Nuclotron 9 modules 15x15 $cm^2$ with the structure of 40·(2 cm iron+ 0.5 cm scincillator) have been tested. The work was carried out in a close co-operation with the group headed by A.B. Kurepin (INR RAS).

5. **Software development**

During 2008 the framework FairRoot was adapted to the computer farm and system platforms used at LHEP. Upgrading of the external libraries (ROOT, GEANT, CLHEP and others) used in the framework was also carried out. Description of the main track detectors of the set-up MPD (TPC and TOF) was implemented into the framework mpdroot as well as of the detectors ZDC, StrawECT tracker and electromagnetic calorimeter.

The Conceptual Design Report (**CDR**) is in preparation.

**Start up of the LHC experiments**

LHEP scientists participate in ALICE, CMS and ATLAS experiments at LHC.

The main effort in the CMS project were concentrated on the design and construction of the end-cap detectors, where JINR bears

full responsibility in the frame of the Russia and Dubna Member States (RDMS) CMS Collaboration. All our obligations have been fulfilled.

JINR obligations on the construction of the ALICE detector (dipole magnet, drift chambers, lead tungstate crystals) also have been fulfilled.

LHEP group participating in ATLAS was involved in the construction of the part of hadron calorimeter. All obligations have been successfully fulfilled.

All detectors of JINR responsibility are ready for data-taking.

## III. The research programme of the Laboratory

The Laboratory of High Energy Physics will continue to develop in 2009 and in the next 7 years the following key lines of research in compliance with the JINR "Road Map":

- heavy ion physics at high energies (up to 4,5 GeV/n);
- spin physics;
- hot problems in particle physics related to testing of the Standard Model (SM), search for new physics beyond its realm and CP-violation.

Investigations will be carried out both at the Laboratory accelerator base, which includes the existing **Nuclotron-M** accelerator and the **NICA** collider planned to be started up in 2015, and at the world's largest accelerator centres in experiments with significant or dominant contribution made by the Institute's staff.

### 1. High Energy Heavy Ions physics research in JINR

#### LHEP's Accelerator complex

For the purpose of creating an accelerator base and infrastructure required for realization of the key physics task facing the Laboratory – experimental studies of hadron (strongly interacting) matter in its most fascinating forms of manifestation – phase transitions, the **NICA** project has been prepared and is currently being realized.

The main goal of the project is to construct, based on the accelerator complex of the Laboratory of High Energy Physics, the "Nuclotron-M" collider that allows one to carry out investigations on:

- colliding beams of high-intensity ions (up to $Au^{+79}$) at an average luminosity of $L=10^{27}cm^{-2}sec^{-1}(Au^{+79})$ within the energy region $\sqrt{s}$=2-9 GeV/n;

- polarized proton and deuteron beams (with longitudinal and cross polarization);

- extracted ion beams as well as polarized proton and deuteron beams.

This requires:

1. creating highly charged heavy ion source (at present much attention is focused on the development of a source working according to the electron string principle);
2. constructing a linear injector accelerator;
3. designing and building a booster synchrotron;
4. developing and constructing two superconducting storage rings;
5. integrating the developed systems and existing "Nuclotron-M" accelerator into a single complex providing an intersection point for two (or more) beams in the collider.

Table 1 shows the schedule of activities for the NICA project.

The physical start-up of the NICA accelerator complex is planned for 2015.

**Table 1.** The schedule of activities on bringing the elements of the NICA accelerator complex into operation.

| Year / Stage | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|
| *1. Project "Nuclotron-M"* | | | | | | |
| *2. NICA TDR completion* | | | | | | |
| *3. R&D programs* | | | | | | |
| KRION ion source | | prototypes | | | | |
| Linac | | | | | | |
| SC magnets for Booster | | prototypes | | | | |
| SC magnets for Collider | | | prototypes | | | |
| El. cooling system for Boosterer | | prototypes | | | | |
| El. cooling system for Collider | | prototypes | | | | |
| Any other elements | | | | | | |
| *4. Designing & manufacturing* | | | | | | |
| KRION ion source | | | | | | |
| Linac | | | | | | |
| Booster | | | | | | |
| Collider | | | | | | |
| Transfer channels | | | | | | |
| Power supplies | | | | | | |
| Diagnostics and control systems | | | | | | |
| Infrastructure and rad. Shielding | | | | | | |
| *5. Mounting* | | | | | | |
| KRION ion source | | | | | | |
| Linac | | | | | | |
| Booster | | | | | | |
| Collider | | | | | | |
| Transfer channels | | | | | | |
| Power supplies | | | | | | |
| Diagnostics and control systems | | | | | | |
| Infrastructure and rad. Shielding | | | | | | |
| *6. Commissioning* | | | | | | |
| KRION ion source | | | | | | |
| Linac | | | | | | |
| Booster | | | | | | |
| Collider | | | | | | |
| Transfer channels | | | | | | |
| Power supplies | | | | | | |
| Diagnostics and control systems | | | | | | |
| Infrastructure and rad. Shielding | | | | | | |
| Year | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |

Table 2 provides a draft schedule of sessions at Nuclotron-M.

**Table 2.** Draft schedule of sessions at the extracted beam of Nuclotron-M for 2009-2016.

| | Feb-Apr | | | Oct-Dec | |
|---|---|---|---|---|---|
| | Light nuclei | | | Protons, nuclei | |
| 2009 | 700 h. | d, tests | | 800 h. | d, A (Xe) |
| 2010 | 700 h. | d, Li | | 800 h. | A>20 |
| 2011 | 900 h. | d, d↑, Li | | 1000 h. | p,A>20 |
| 2012 | 1000 h. | d, d↑, Li | | 1000 h. | p,C,A>20 |
| 2013 | 1000 h. | d, d↑, Li | | 1000 h. | p,C,A>20 |
| 2014 | 1000 h. | d, d↑, Li | | 1000 h. | p,C,A>20 |
| 2015 | 1000 h. | d, d↑ | | 1000 h. | A>20 |
| 2016 | 1000 h. | d, d↑ | | 1000 h. | A>20 |

Creation of the source of polarized deuterons and upgrade of the moveable polarized target allow to provide on the Nuclotron-M an unique researches with beams of polarized deuterons, as well as protons and neutrons.

The Krion Source can be used to obtain extracted ion beams up to superheavy elements in the Nuclotron-M.

The extracted beams and possibility to work on the internal target of the Nuclotron-M will be provided to collaborations, which take the hole responsibility on necessaried for the experiment funding, with the approval of their proposed research program by the PAC and with a minimal attraction of the Laboratory resources.

Part of the Nuclotron-M beam time will be used for R&D in frame of MPD and SPD development.

**MPD and SPD experimental set-ups**

The goal of the **MPD**-project is to create a complex of facilities for experimental study of strong interaction in hot and dense hadron matter as well as to search for a possibility to form the so-called "mixed phase" of such matter – a mixture of quark-gluon and hadron states, and a possibility to carry out investigations on the search for P- CP-violation in a strong interaction. The energy region for the colliding particles is 1÷4,5 GeV per nucleon.

The requirements to the **MPD** detector are as follows:

- intensity up to 10 kHz at a multiplicity up to 1500 charged particles in an event;
- effective particle reconstruction in a maximally possible pseudorapidity region (up to $|\eta| \sim 3$) providing a sufficient pulse and angular resolution for particles in the energy range from 100 MeV to 2 GeV;
- identification of charged particles and a possibility to detect electrons, photons and $\pi^0$;
- a possibility to build a trigger taking into account data about the "centrality of events";
- a possibility for precise measurement of charged asymmetries in studied reactions.

The design concept of the MPD set-up envisages placing the central complex of detecting equipment in the solenoid magnetic field and the forward detectors beyond its realm.

Construction of the set-up is planned to perform in three stages:

1. the start-up minimum (the barrel part includes TPC and ECAL or(and) RPC; ZDC and BBC are put into service);

2. IT is added to the barrel and the end-cap is brought into action;

3. the forward-detectors are placed into operation.

Over 7 years the first and second stages are have be finished, the start-up of the set-up has to be performed and the experimental data taking will be started. The schedule of activities on building and bringing the MPD set-up into action is given in Table 3.

**Table 3**. Draft schedule of activities on building and bringing the MPD (arrows indicate dates of completion of stages).

| Stage/Year | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|
| MPD Conceptual Design Report | | | | | | | | |
| MPD TDR | | | | | | | | |
| **R&D program** | | | | | | | | |
| TPC | | | | | | | | |
| TOF | | | | | | | | |
| ZDC | | | | | | | | |
| Si inner tracker | | | | | | | | |
| EMC | | | | | | | | |
| Straw Tracker | | | | | | | | |
| DAQ | | | | | | | | |
| **Production (the 1 stage detectors)** | | | | | | | | |
| TPC | | | | | | | | |
| EMC | | | | | | | | |
| ZDC | | | | | | | | |
| TOF (20%) | | | | | | | | |
| Slow Control | | | | | | | | |
| DAQ | | | | | | | | |
| Installation | | | | | | | | |
| **Superconducting Magnet of MPD** | | | | | | | | |
| **Production (the 2 stage detectors)** | | | | | | | | |
| TOF | | | | | | | | |
| Straw Tracker | | | | | | | | |
| Si inner tracker | | | | | | | | |
| DAQ | | | | | | | | |
| Slow Control | | | | | | | | |
| Gas system | | | | | | | | |
| Installation | | | | | | | | |
| **Production (the 3 stage, Forward Spectrometers)** | | | | | | | | |
| Torroidal Magnet construction | | | | | | | | |
| Coordinate detectors production | | | | | | | | |
| Coordinate detectors testing | | | | | | | | |
| Installation | | | | | | | | |
| Commissioning | | | | | | | | |
| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |

## 2 Research in high energy heavy ion physics at the world's accelerator centres

The degree of participation in collaborative research presented in this section will be regularly updated depending on available resources and priorities, which are determined first of all by the progress of the project **NICA/MPD**, and by opportunities to work on the **Nuclotron-M** and **NICA** accelerator complex.

**BNL (RHIC)**

Joint research in heavy ion physics will be continued at the **RHIC** collider energies in the **STAR** experiment within the range of problems similar to the goals of the **MPD** project:

- study the properties of nuclear matter with extremely high density and temperature states;
- search for the manifestations of quark deconfinement and possible phase transitions.

**CERN (SPS)**

A proposal to conduct researches at the CERN **SPS** accelerator is currently being prepared within the **NA61** project, which continues a series of experiments at the **NA49** experiment aimed at obtaining data on the interactions of nuclei at the energies 20-158 GeV/n in order to find manifestations of the phase transition from hadron matter to quark-gluon plasma and mixed phase. In case this proposal receives approval, a LHEP team will participate in this program for the period preceding the start-up of the **NICA** accelerator complex.

**CERN (LHC)**

The **ALICE** facility is intended for experimental investigations of proton-proton, nucleus-nucleus collisions at LHC energies. The JINR team is planning to study:

1. light vector meson production ($\omega$, $\rho$, $\psi$);
2. heavy quarkonia production (J/$\psi$- and Y-families);
3. particle corellations (femtoscopy).

**GSI (SIS-18, SIS-100, SIS-300)**

The goal of the experiment at the **HADES** wide-aperture spectrometer at the **SIS-18** accelerator at GSI is to study the processes occurring in collisions of heavy nuclei at the energies up to 2 GeV/n by way of lepton pair detection. After the start-up of the **SIS-100** accelerator, work at the HADES experimental facility will be continued at the energies of this accelerator (~10 GeV/n).

The **CBM** set-up is being constructed at GSI to study high energy heavy ion interactions at the new **FAIR** accelerator centre in Germany. The CBM experimental complex is intended for investigations associated with the program on the search for and study

of the mixed phase in the "fixed target" experiment scenario. In this respect, the **CBM** and **MPD** set-ups are similar in a number of detector systems that are being created for these facilities. The JINR team is involved in designing and building part of the track detectors for the CBM facility and actively participates in simulating the elements of this set-up and working out a physics program.

**Protvino (У-70)**

The goal of the **THERMALIZATION** project conducted at the modernized SVD facility is to study the collective behavior of secondary particles produced in *pp*-interactions at the proton beam energy 70 GeV. The project is planned to complete in 2011.

## 3. Spin physics at the LHEP accelerator complex

**Nuclotron-M**

A series of experiments are planned to conduct on the extracted polarized beams of Nuclotron-M, particularly, using a moveable polarized target. The key goals of these investigations are associated with preparations for implementing the spin program of the **NICA** project and consist in creating effective polarimetry, as well as elaborating techniques for polarized targets and polarized particle sources.

During the period up to 2010-2012, under this program it is also expected to carry out investigations on the measurement of polarized observables at the **pHe3-2** and **ALPOM-2** facilities.

The **pHe3-2** project**:** the experiment conducted in collaboration with RIKEN is aimed at measuring polarized observables in the $^3He(d,p)^4He$ reaction at the energies $T_d$=1.0-1.75 GeV, which corresponds to the core area in the deuteron, using the polarized deuteron beam at the Nuclotron and polarized $^3$He-target fabricated at the CNS (Japan).

The **ALPOM-2** project goal is to measure the analyzing power in the $p+CH_2$ reaction at the impulse of polarized beams from 3 up to 6 GeV/c. These data are necessary for the experiment at JLAB on the measurement by the polarization method of the ratio between the electric and magnetic form factors of the nucleon at a large four-momentum transfer as this method requires measurement of the components of the polarization vector of the recoil proton with an impulse up to 6 GeV/c from the elastic electron-proton scattering.

**NICA**

The **SPD** (Spin Purpose Detector ) facility is being constructed for the purpose of implementing the second part of the scientific program at the NICA collider which is aimed at providing beams and an experimental set-up for investigations in the interactions of colliding light-ion beams and polarized proton and deuteron beams. This will allow setting up spin physics experiments that continue the JINR research program in this area at a brand new level. A possibility is envisaged to conduct investigations with longitudinally and transversely polarized beams of energy up to 12 GeV (for protons).

For the time being this program is in developmental stage.

**4 Spin physics at other accelerator centers**

**COMPASS(SPS)**

The **COMPASS** project**:** the experiment targets investigation of the hadron structure and hadron spectroscopy using high-intensity muon and hadron beams. The main goals of the 2010-2016 experiment are:

1. measurement of exclusive processes with the aim of obtaining data on generalized parton distributions (GPD);
2. measurement of the Matveev - Muradyan - Tavkhelidze - Drell - Young (MMTDY) processes;
3. study of the transverse structure of the nucleon;
4. continued study of the longitudinal spin structure of the nucleon ($\Delta G/G$, parton distribution functions etc.);
5. study of the doubly charmed baryons.

The JINR team participates in the preparations for measurements of the GPD, MMTDY process and continuation researches of the longitudinal and transverse spin structure of the nucleon.

Proposed scientific program of the **COMPASS** experiment will be continued at the **NICA** accelerator complex in the frames of the **SPD** project. Its start-up is expected to take place in 2016-2017.

**BNL (RHIC)**

The **STAR** project: the spin program of the project targets measurements of spin-dependent structure functions of nucleons and nuclei using polarized beams of the RHIC accelerator, BNL. The JINR

team is planning to continue participating in this program of the STAR experiment until the **SPD** facility has been brought into operation at **NICA**.

## 5 Test of the Standard Model and new physics

### CMS (LHC)

The LHEP group has the following plans of participating in the program of physics investigations at the CMS set-up in respect to the following problems:

- testing of the Standard Model in the MMTDY processes, search for signals from extended gauge models, complementary measurements and other phenomena beyond the SM (imposing new limitations on the existence of these phenomena);
- QCD investigations, study of jet events, measurement of their cross sections for the purpose of verifying the structure functions of gluons in a wide kinematic region by the square of the transferred four-impulse and Bjorken variable;
- study of production of massive states (gauge bosons, Higgs bosons) in the region of pseudorapidity in the processes of single and double pomeron exchange;
- obtaining experimental data in order to measure the constant of self-action of gauge bosons.

### NA62 (SPS)

The **NA-62** project at the CERN **SPS** beam continues a series of **NA48, NA48/1, NA48/2** experiments aimed to investigate the phenomenon of direct CP-violation in the kaon decay and a wide range of other properties of these decays with unprecedented accuracy. The NA62 set-up is being developed to enable study of ultra-rare decay of the charged kaon into a charged pion and two neutrinos – measurement of its probability will allow one to significantly improve the parameters of the Cabibbo-Kobayashi-Maskawa matrix and, probably, determine processes beyond the scope of the Standard Model.

The tasks of the JINR team include:

1. building (in collaboration with CERN) a track detector of new type that would operate in vacuum with a high spatial resolution;

2. developing software for simulation and reconstruction of tracks in the detector and for the entire NA62 experiment;
3. participating in experimental data taking, processing and analysis.

**ATLAS (LHC)**

The objective is the analysis of proton-proton interactions making full use of the LHC collider to analyze a variety of physical processes within the Standard Model predictions and detecting events beyond it. LHEP team participates in the ATLAS project solving a number of physical problems and is responsible for the operation and the possible upgrade of the subsystems of the experimental facility.

**NIS-GIBS (Nuclotron-M)**

The goal of the **NIS-GIBS** project is:

1. to search for manifestations of polarized hidden strangeness of nucleons in the production of φ and ω mesons in proton-proton and neutron-proton interactions;
2. to search for production of exotic five-quark baryons, including baryons with positive strangeness, in nucleon-nucleon interactions at intermediate energies;
3. to search for exotic hyper-nuclei; characteristics of the Nuclotron-M beams provide unique possibilities for the search of hypernuclei and study of their properties. The key task for the near future is to search for neutron-rich ${}^{6}_{\Lambda}\mathrm{H}$ hypernuclei on the ${}^{7}\mathrm{Li}$ beam.

The program of studies is planned to complete in 2015.

**6 Accelerator physics and accelerator facilities**

The staff of the LHEP accelerator department are leading specialists in a variety of directions in accelerator technology and are planning to continue participating in international collaboration on developing elements and systems of high energy accelerators.

**ILC**

Activities under the program of constructing the international ILC linear collider are planned to continue.

### FAIR

Joint activities on constructing the FAIR accelerator complex are planned to continue in the frames of the Russia-FAIR and JINR-FAIR program.

## 7 Applied and methodological research

### Radiocarbon therapy based on the booster of the NICA complex

The following activities will be carried out in this direction:

- working out and creating the required scientific and production infrastructure for the centre of radiocarbon therapy based on the booster of the NICA complex;
- investigations in the field of radiobiology on the relativistic ion beams of the NICA accelerator complex (in collaboration with the LRB). The goal is to study the mechanisms of radiation damage in biological objects;
- developing and start-up of the spectral-analysis complex for the study of nanostructural objects, including biological ones. LRB, LNP, LHEP;
- elaboration and implementation of x-ray spectroscopy methods on the synchrotron-radiation beams at the RSC "Kurchatov Institute" (in cooperation with the LNP and LRB).

## IV. PERSONNEL

In order to fulfill the tasks that faces the Laboratory, it is necessary to involve specialists in such fields as accelerator physics, high energy physics, physics of atomic nucleus, physics experiment techniques, as well as engineering and technical specialists in the field of electronics, cryogenics and low temperatures, designers.

In compliance with the general policies of the Institute, it is planned to reduce the Laboratory staff by approximately 10% by 2016 at the expense of increasing efficiency of the staff's work. Along with this, it is planned to carry out considerable staff rejuvenation.

It is supposed to engage additional short contract staff when the intensity of work and financing will be the largest.

The salary part takes 44% of Laboratory's total budget as for 2010-2016. In 2016 this part would come to 60%.

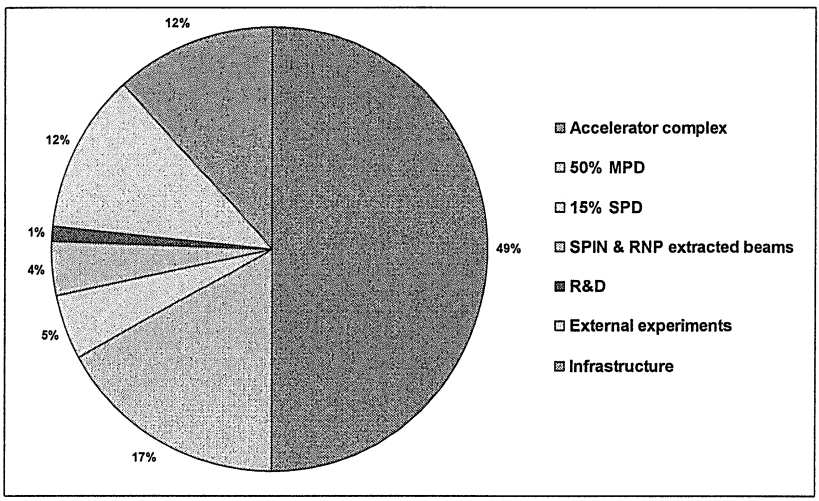
## V. FUNDING

The realization of this research program, especially of the **NICA/MPD** project, requires concentration of essential resources and optimization/minimization of financing for another projects carried out in the Laboratory in frame of the JINR obligations.

Step-by-step schedule of funding necessaried for the **NICA** and **MPD** projects realization (which includes labor and direct costs and coordinated with the requirement of attracting different staff categories: research worker, engineer, technician) as well as for all scientific directions and projects developed in the Laboratory have been prepared.

Diagrams 1 shows the sharing of the all necessary materials and resources required to accomplish the LHEP scientific program in 2009-2016 (assuming the achievement of NICA/MPD project on time).

**Diagram 1.** Estimation of all LHEP necessary materials and resources for 2009-2016 assuming the achievement of NICA/MPD project on time

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