JINR today and tomorrow

Nikolai Russakovich, JINR

2010 European School of High-Energy Physics
Raseborg, Finland
20 June - 3 July, 2010
Academician Alexey Sissakian
14.10.1944 – 01.05.2010
Established in March 1956
Mission: Promoting international cooperation in Fundamental Science for non-commercial & non-military use
Founders

1. G. Flerov
2. V. Dzeleleopov
3. V. Veksler
4. N. Bogoliubov, D. Blokhintsev
5. B. Pontecorvo
6. L. Infeld
7. H. Niewodniczanski
8. I. Frank
9. M. Meshcheryakov
10. A. Baldin
11. H. Hulubei
12. Wang Ganchang

2010 European School of HEP
JINR’s partners are about 700 institutions located in 60 countries
Collaboration with CERN

The history of cooperation between CERN and JINR spans over about 50 years.

CERN is JINR’s main partner in Particle Physics. Dubna physicists are widely involved in more than 20 CERN projects, including 3 LHC experiments.

1963, JINR, Dubna
CERN Director-General Prof. V. Weisskopf, Prof. V. Dzhelepov and Prof. B. Pontecorvo

2004, CERN Director-General Dr R. Aymar in Dubna

1971, Dubna
CERN Director-General Prof. W. Jentschke and JINR Director Prof. N. Bogoliubov
CO-OPERATION AGREEMENT

between

THE EUROPEAN ORGANIZATION
FOR NUCLEAR RESEARCH (CERN)

and

THE JOINT INSTITUTE FOR NUCLEAR
RESEARCH (JINR)

concerning

Scientific and Technical Co-operation
in High-Energy Physics

2010

Done at Geneva on 28 January 2010, in two copies in the English language.

For the European Organization
for Nuclear Research (CERN)

Prof. Rolf-Dieter Heuer

For the Joint Institute
for Nuclear Research (JINR)

Prof. Alexei N. Salakhian

28 January 2010, CERN
Signing of the Agreement
between CERN and JINR

3.2 Possible projects at the date of this Agreement include:

- the commissioning and operation of the Large Hadron Collider (“LHC”) at CERN, including the ALICE, ATLAS and CMS experiments using the LHC;

- upgrades of the Nuclotron and the construction, commissioning and operation of the NICA collider project at JINR, including the MPD and SPD experiments using NICA;

- upgrades of the LHC injector chain, including the Linac4, SPL and PS2 projects;
Three Pillars of JINR

Great experience and world-wide recognized traditions of scientific schools:
- more than 40 discoveries
- 46 prestigious academic and state awards of Member States and other countries

Large and unique park of basic facilities for fundamental and applied research:
- various types of particle accelerators
- high flux pulsed reactor

Status of an international intergovernmental organization:
- JINR was established through the Convention signed on 26 March 1956 by eleven founding States and registered with the United Nations on 1 Feb. 1957
- broad international cooperation – more than 700 institutions located in 60 countries
JINR Governing Bodies & Structure

Committee of Plenipotentiaries

- Scientific Council
  - PAC for Particle Physics
  - PAC for Nuclear Physics
  - PAC for Condensed Matter Physics

- Directorate
  - Science & Technology Council
  - 7 Laboratories
  - University Centre
  - Office of Administration

- Finance Committee
Some figures

JINR’s staff members ~ 4500
Researchers ~ 1200
including from the Member States (but Russia) ~ 500

Doctors and PhD ~ 1000

More than 50 Conferences/Workshops yearly

Budget forecast
Discoveries

- 46 prestigious academic and state awards, and prizes of Russia, Bulgaria, Georgia, Romania, Czech Republic, Uzbekistan and other countries.

More than 40 discoveries, including:

- 1959 – nonradiative transitions in mesoatoms
- 1960 – antisigma-minus hyperon
- 1963 – element 102
- 1972 – postradiative regeneration of cells
- 1973 – quark counting rule
- 1975 – phenomenon of slow neutron confinement
- 1988 – regularity of resonant formation of muonic molecules in deuterium
- 1999–2005 – elements 114, 116, 118, 115 and 113
- 2006–2009 – chemical identification of superheavy elements
JINR’s ROAD MAP

Basic Scientific Directions

- **High Energy Physics**
- **Nuclear Physics**
- **Condensed Matter Physics**

Main Supporting Activities:

- Theory of PP, NP, CMP
- Networking and computing
- Physics instruments and methods
- Education
Special attention should be given to the interests of the JINR Member States in developing the Road Map.

The home experimental base, its upgrade programme should become a priority task for the Institute’s further development.

Available at http://www.jinr.ru/
Upgrade of JINR Basic Facilities


**Telecommunication channels:**
- 20 Gbps – 2009
- 800 Gbps – 2016

**JINR networks:**
- GRID technology
- improvement of computer links with Member States (2010-2016)

**Participating in LHC, RHIC, TEVATRON...**
In future: FAIR, ILC ...

**New reactor IBR-2M – 2010**
Complex of modern neutron spectrometers (2011-2016)
Heavy-Ion Physics at “high” energies: Nuclotron-M (up to 4.5 GeV/n), NICA/MPD facility: $\sqrt{s_{NN}} = (4 – 11) \text{ GeV}$ corresponding to $E_{\text{lab.}} \sim (8 – 60) \text{ GeV/n}$

Nuclear Physics (Heavy-Ion Physics at low and Intermediate energies (5 – 100 MeV/n), U400MR, U400R, DRIBs

Condensed Matter Physics using nuclear physics methods, (neutron sources: IBR-2M, IREN-I)
Nuclotron is a superconducting synchrotron for heavy ions (has been operating since 1993).

The main home facility today: Nuclotron complex of VBLHEP (under upgrade till the end 2010)

Future plan: NICA/MPD – Nuclotron-Based Ion Collider Facility and Multipurpose Detector (2014)
Nuclotron-M: 1st stage of the NICA

The main goal: development of the existing accelerator facility (Nuclotron-M project) as a basis to generate intense beams over atomic mass range from protons to gold and light polarized ions:

- accelerated heavy ions $A \sim 200$
- beam intensity $\sim 10^9$ A/cycle (0.2-0.4 Hz) at kinetic energy $\sim (1,0-4,5)$ GeV/u for Au$^{79+}$

BASIC ACTIVITIES in 2008-2010:

- Development of new injection complex
- Modernization of RF system
- Upgrade of diagnostics and beam control systems
- Modernization of the vacuum system
- Modernization of the electric- and cryo- systems
- Development of the infrastructure
The main goal of the NICA project is an experimental study of hot and dense strongly interacting QCD matter and spin physics at the new JINR facility.

**Fields of research:**

- High Energy Relativistic Ion Physics
- Spin Physics
- SM checks & search for new physics at LHC
- Flavour physics (new physics)
- Neutrino physics and rare phenomena
- International Partnership programs on unique accelerator facilities
- Applied research (medicine, nanotechnology,...)
Hadron gas
Mixed Phase
QGM
Pre-equilibrium
Initial nuclei
Time
Freezout
Space
Lattice QCD

Early universe

Perfect fluid

Quarks and Gluons

Critical point?

Hadrons

deconfinement

Triple point?

Quarkyonic phase

Net baryon density $n/n_0 = 0.16 \text{ fm}^{-3}$

Color Superconductor

Hadrons

Transition

Chiral transition

Translational

Compact Stars

RHIC, LHC

NICA, MPD

FAIR SIS 300

Proto-Neutron stars

Nuclei

Net baryon density

Temperature $T$ [MeV]

http://theor.jinr.ru/twiki-cgi/view/NICA/WebHome
Introduction: NICA Layout & Main Elements

December 3, 2009
Coordination Committee Meeting

Collider 2T
C = 336 m

KRION-6T & HILac

Synchrophasotron yoke

“Old” linac

Nuclotron

Existing beam lines
(Fixed target exp-s)

Beam transfer line

MPD

Booster

Spin Physics Detector (SPD)

Nuclotron

2.3 m

4.0 m
### NICA parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumference</td>
<td>m</td>
<td>336</td>
</tr>
<tr>
<td>Number of collision points</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Beta function in the collision point</td>
<td>m</td>
<td>0.5</td>
</tr>
<tr>
<td>Rms momentum spread</td>
<td></td>
<td>0.001</td>
</tr>
<tr>
<td>Rms bunch length</td>
<td>m</td>
<td>0.3</td>
</tr>
<tr>
<td>Number of ions in the bunch</td>
<td></td>
<td>10⁹</td>
</tr>
<tr>
<td>Number of bunches</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Incoherent tune shift</td>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>Rms beam emittance at 1 GeV/u / at 3.5 GeV/u</td>
<td>π mm mrad</td>
<td>3.8 / 0.26</td>
</tr>
<tr>
<td>Luminosity per one interaction point at 1 GeV/u at 3.5 GeV/u</td>
<td>cm⁻²s⁻¹</td>
<td>6.6·10²⁵ / 1.1·10²⁷</td>
</tr>
</tbody>
</table>
The NICA Project Milestones

- **Stage 1: years 2007 – 2009**
  - Upgrade and Development of the Nuclotron facility
  - Preparation of Technical Design Report of the NICA and MPD
  - Start prototyping of the MPD and NICA elements

- **Stage 2: years 2008 – 2012**
  - Design and Construction of NICA and MPD

- **Stage 3: years 2010 – 2013**
  - Assembling

- **Stage 4: year 2013 - 2014**
  - Commissioning
NICA/MPD TENTATIVE LIST OF OBSERVABLES

- Anti-proton to proton ratio
- Baryon to meson ratios
- Charged particle directed flow
- Charged particle elliptic flow
- DCC searches
- Elliptic flow for identified charged hadrons & photons
- Femtoscopy of identical particles
- Femtoscopy of $K\pi$, $\Xi\pi$, $\Omega\pi$, etc
- Fluctuations of particle ratios, esp. $K/\pi$, $p/\pi$
- Fluctuations of $<p_T>$, $<v_2>$, photon multiplicity, etc
- Hyperons and light hypernuclei
- Invariant mass and $p_T$ distributions of leptons
- Longe-range forward-backward correlations
- Net-proton and net charge kurtosis
- Nuclear modification factor
- Production of light nuclei and antinuclei
- Standard femtoscopy source parameters
- Strong parity violation
- Triggered azimuthal correlations
- Untriggered pair correlation in $\Delta\phi$ and $\Delta\eta$
- Yields of strange particles

...
Progress towards a White Paper on the NICA/MPD

Welcome to the collaboration!

http://theor.jinr.ru/twiki-cgi/view/NICA/WebHome

Editorial board:
D. Blaschke
D. Kharzeev
A. Sissakian
A. Sorin
O. Teryaev
V. Toneev
I. Tserruya

31 research centres in 15 countries (including 8 JINR Member States).
Progress towards NICA/MPD: International Expertise and the White Paper

Round Table Discussion IV
Searching for the mixed phase of strongly interacting QCD matter at the NICA: Physics at NICA (White Paper)
JINR (Dubna), 9-12 September 2009

First R–ECFA meeting in Russia
8 – 10 October 2009
Moscow, Dubna
“Concerning the NICA project, its already existing infrastructure and modern standards that are higher than in the present accelerators should be definitely considered as its advantages. The collider’s physics programme is very interesting”.

ECFA Chairman Prof. Tatsuya Nakada

Round Table Italy-Russia in Dubna
JINR, 18-19 December 2009

Nuclotron-M/NICA
Machine Advisory Committee (MAC)
JINR, 14-15 January 2010
Programme Advisory Committee for PP
Particle Physics on external facilities - examples
## Participation in the LHC projects

### ATLAS
- **Tile & Liq. Ar Calorimeters**
- **Monitored Drift Tubes (Muon system)**
- **TRT (34 straw wheels 3072 ch.each)**

### CMS
- **End-cap Hadron Calorimeter**
- **Part of muon system (ME1)**
- **Preshower (participation)**

### ALICE
- **TRD (125 modules)**
- **Dipole magnet (forward μ spectrometer)**
- **800 PWO crystals for PHOS**
JINR has started ATLAS data taking and data analysis

- Top-quark
- QCD @ Standard Model Physics
- Higgs Physics
- SUSY Physics
- Exotics Physics
- b-quarks
- Heavy Ions Physics

The real time ATLAS remote monitoring system is operational at JINR

MOTIVATION

- Monitoring of the detector and data flows at any time
- Participation of the subsystem experts from Dubna in the shifts and data quality checks remotely
- Training the shifters before they come to CERN
Study phenomena in the frame of the Standard Model and beyond.

The JINR group has the following plans for 2010-2016:

data taking, monitoring of the detection systems, maintenance of operation, data processing

Participation in the physics investigations where JINR physicists reached the advantages at the preparation stage of the CMS Physics Program:
- Study of Higgs bosons
- Testing of the SM in the MMT-DY processes
- Study of inclusive jet production and gamma+jet
- etc.
The goal is to study strongly interacting matter at extremely high energy densities, a new form of matter - quark-gluon plasma.

The JINR team is planning to participate in:

- the studies of light vector meson production;
- the investigation of heavy quarkonium production;
- the study femtoscopic correlations;
- the measurements of direct photon and dilepton yields;
Two major parameters - $a_0$ and $a_2$ of pi-pi scattering lengths have been extracted with an unprecedented experimental precision of few percents. This result is highlighted at CERN as experimental achievement in 2008.

**Measurement of pi-pi sc. length in two processes**

- **Cusp**: $a_0 = 0.224 \pm 0.004 \pm 0.011_{\text{theor}}$
- **Ke4 (FF phases)**: $a_0 = 0.220 \pm 0.008$

**measurements of $a_0$ & $a_2$**

**measurement of $a_0$ using $a_0=f(a_2)$ from ChPT**

![Graph showing dispersion relations and data points for $a_0$ and $a_2$](image)

![Graph showing Cusp and Ke4 data](image)
The D0 collaboration identified 18 events that have the distinctive signature of the expected decay products of the Omega-sub-b.

The mass of the particle is $6.165 \pm 0.016$ GeV/c$^2$.
Direct search for $\nu$ oscillations by looking at the appearance of $\nu_\tau$ in a pure $\nu_\mu$ beam to explain atmospheric neutrinos anomaly and results of K2K and MINOS.

Experiment is taking data now.

Expected produced interactions ($22.5 \times 10^{19}$):
- $\sim 25400 \, \nu_\mu$ CC + NC
- $\sim 170 \, \nu_\tau$ CC + NC
- $\sim 125 \, \nu_\tau$ CC ($\Delta m^2 = 2.5 \times 10^{-3} \text{ eV}^2$)

<table>
<thead>
<tr>
<th>Year</th>
<th>Pot</th>
<th>Int.</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>$0.076 \times 10^{19}$</td>
<td>0</td>
<td>Commissioning</td>
</tr>
<tr>
<td>2007</td>
<td>$0.082 \times 10^{19}$</td>
<td>38</td>
<td>Commissioning</td>
</tr>
<tr>
<td>2008</td>
<td>$1.78 \times 10^{19}$</td>
<td>1663</td>
<td>First physics run</td>
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<tr>
<td>2009</td>
<td>$1.93 \times 10^{19}$</td>
<td>$2036$</td>
<td>Extrapolation is $3.5 \times 10^{19}$ pot at end of the run. $\sim 2 \nu_\tau$ expected in total</td>
</tr>
<tr>
<td>Nominal</td>
<td>$4.5 \times 10^{19}$</td>
<td>$\sim 10$ tau decays are expected to be observed</td>
<td>Less than 1 background after 5 years running</td>
</tr>
</tbody>
</table>
The activities at JINR on Physics and Detector for ILC are underway and will be continued in order to provide JINR’s visible participation in this ambitious project.

Challenging tasks

- Factory of the Higgs boson
- Supersymmetry
- Dark matter, dark energy
- …
NUCLEAR PHYSICS
Home Research programme in Nuclear Physics:

- Heavy ion physics at low energies
- Nuclear physics with neutrons
- Low and intermediate energy nuclear physics

The main home facilities (today):
Cyclotrons U400MR and U400, accelerator complex DRIBs-I, IREN-I, Phasotron.

Future plans:
- U400R, accelerator complex DRIBs-II (2009), DRIBs-III (2015)
Low Energy Heavy Ion Physics

The main home facilities (today):
Cyclotrons U400 and U400MR,
accelerator complex DRIBs-I

Future plans:
U400R, accelerator complex DRIBs-II

PRIORITIES:
● Physics and chemistry investigations of the superheavy nuclei with \( Z \geq 112 \);
  structure and properties of the neutron-rich light exotic nuclei

● Heavy ion interaction with matter; accelerator technology, applied research.

(in operation since 1979) U400

(in operation since 1993) DRIBs – Dubna Radioactive Ion Beams

U400M
<table>
<thead>
<tr>
<th>Период</th>
<th>Группа элементов</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
<th>VIII</th>
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</tr>
</tbody>
</table>

### Discovered at JINR
- **113**: Discovered in 2003
- **114**: Discovered in 1999
- **115**: Discovered in 2003
- **116**: Discovered in 2000
- **117**: Discovered in 2009
- **118**: Discovered in 2001

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*Source: 2010 European School of HEP*
New elements in the reactions $\text{Ac} + ^{48}\text{Ca}$

Number of observed decay chains
- Element 118: 3
- Element 116: 26
- Element 115: 4
- Element 114: 43
- Element 113: 2
- Element 112: 8
Synthesis of element 117

$^{249}\text{Bk} + ^{48}\text{Ca}: E_{\text{beam}} = 252 \text{ MeV}$

$^{249}\text{Bk} + ^{48}\text{Ca}: E_{\text{beam}} = 248 \text{ MeV}$
"MULTI" multi-detector setup was designed to study properties of light nuclei, such as \(^6\text{He}, \ ^6\text{Li}\) and exotic nuclei reaction mechanism.

U400 and the transport line with U400MR
Some results in study of light exotic nuclei

Discovery of di-neutron inside $^6$He

Observation of sub-barrier fusion enhancement of $^6$He

$\sigma( ^6\text{He} + ^{206}\text{Pb} \rightarrow ^{212}\text{Po}) \over \sigma( ^4\text{He} + ^{208}\text{Pb} \rightarrow ^{212}\text{Po}) = 1000$ !

$E_{c.m.} = 15 \text{ MeV}$
FASA:
Reliable measurement of Critical Temperature parameter for liquid-gas phase transition of nuclear matter solved the long standing contradiction that existed previously.

GEMMA:
Best limit on neutrino magnetic moment was obtained in GEMMA experiment at Kalinin Power Plant.

NEMO:
World class results were obtained on double beta decay from NEMO experiment.

MUNU (Bugey, 2003): $\mu_N < 0.9 \times 10^{-10} \mu_B$
TEXONO (Taiwan, 2003): $\mu_N < 7.4 \times 10^{-11} \mu_B$
GEMMA-1 (2006): $\mu_N < 5.8 \times 10^{-11} \mu_B$
BOREXINO (2008): $\mu_N < 5.4 \times 10^{-11} \mu_B$
GEMMA-1 (2008): $\mu_N < 5.2 \times 10^{-11} \mu_B$
Medico-technical complex for hadron (proton) therapy
CONDENSED MATTER PHYSICS
IBR idea

Idea (1955) – D.I. Blokhintsev


IBR theory was further developed by Shabalin, Govorkov, Asaoka, Larrimore, Blaeser, Schwalm, Kozik.

\[ \varepsilon(t) = \varepsilon_m - \alpha t \cdot t^2 \]

\[ \theta_{1/2} \approx 1.35 \cdot (\tau / \alpha)^{1/3} \]
The IBR-2 reactor is included in the 20-year European strategic programme of neutron scattering research.

### Parameters

- **Fuel**: PuO₂
- **Active core volume**: 22 dm³
- **Cooling**: liquid Na
- **Average power**: 2 MW
- **Pulsed power**: 1500 MW
- **Repetition rate**: 5 s⁻¹
- **Average flux**: 8·10^{12} n/cm²/s
- **Pulsed flux**: 5·10^{15} n/cm²/s
- **Pulse width**: 215 / 320 µs
- **Number of channels**: 14
Milestones in Condensed Matter Physics

- IBR-2M: operation at design parameters of the reactor
- Realization of the full-scale cryogenic complex
- Complex of modern neutron spectrometers
- Wide international user policy

Condensed Matter Physics at IBR-2M
(priority directions)

Nanosystems and Nanotechnologies

Biomedical Research

Novel Materials

Engineering Diagnostics. Earth Sciences
Neutron scattering investigations of condensed matter in 2007 - 2010

Collaboration with other neutron centers in Russia, Europe, USA, Japan, and South Africa

- RAL
- LLB
- ILL
- PSI
- NPI
- HMI
- PNPI
- IMP
- ANL
- NIST
- NECSA
- PNPI
- RSC KI
- KEK
- JAERI
- LANL
- BNC
Main fields of research for 2010-2016:

- Research into the mechanisms of the *genetic action* of accelerated heavy ions and neutrons with different energies.
- Study of the action of heavy particles and neutrons on the *eye's lens and retina*.
- Research into the regularities of the biological action of accelerated heavy ions on the *central nervous system*.
- *Mathematical modelling* of biophysical systems.
- *Radiation protection*. 
2009 - two important projects completed

1. JINR - Moscow 20Gbps telecommunication channel was put into operation.
2. Increase of the JINR Central Information and Computing Complex performance up to 2400 kSI2K and the disk storage capacity up to 500 TB.

At present, JINR segment is one of the 10 best segments of the worldwide Grid infrastructure (WLCG).
First LHC data were transferred and stored in Dubna. *Plots* show: JINR LHS teams uses these data and works at Dubna (via GRID)

GRID computing works very well at JINR
A vitally important task is attracting young people from all the Member States to science.

EDUCATIONAL PROGRAMME

JINR UNIVERSITY CENTRE

More than 300 students and postgraduates from Member States are trained at the UC.

Chairs: MSU, MIPT, MEPI, MIREA, others

JINR is a school of excellence for the Member States!

“Dubna” International University

The UC offers graduate programmes in the fields of:
- Elementary Particle Physics
- Nuclear Physics
- Theoretical Physics
- Condensed Matter Physics
- Technical Physics
- Radiobiology

Dubna International Advanced School on Theoretical Physics

DIAS - TH
Main directions of University Centre activity

- Students, JINR-based departments
- JINR postgraduate programmes
- International education actions
- Student laboratory infrastructure
- Secondary-school oriented activity
- Technical staff retraining
Students at UC in 2003-2009

424 students from the JINR-based departments of MPhTI, MSU, MIREA, Dubna International University (DIU) studied in 2009/2010 at the University Center.

There were also 146 students from the different universities of JINR member-states.
## International Student Practice in 2010

<table>
<thead>
<tr>
<th>Period</th>
<th>Countries/Regions</th>
</tr>
</thead>
</table>
| May 17 – June 6 | Students from Arab students, Republic of Egypt (15 participants)  
|                 | Czech Republic, Poland, Bulgaria (expecting 20 participants)  
|                 | South African                               |
| September 6 - 25| Students from Arab students, Republic of Egypt (15 participants)  
|                 | Slovak Republic, Romania, Belorussia (expecting 70 participants)  
|                 | Czech Republic, Poland, Bulgaria (expecting 20 participants)  
|                 | South African                               |
Innovations and the Special Economic Zone in Dubna
JINR contribution to SEZ activities - examples

Nanotechnologies
- Copper microtubes
- Metallic needles

Hadron therapy

Radiation medicine

IT and Telecommunication

Safety systems
"Science will overcome everything, and the financial crisis as well".

Academician B.E. Paton
December 8, 2008, Moscow

“At such a difficult moment, there are those who say we cannot afford to invest in science, that support for research is somehow a luxury at moments defined by necessities. I fundamentally disagree. Science is more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been before”.

Barack Obama
President of the USA
April 27, 2009
Welcome to JINR (Dubna)