NICA Project at Dubna

(Physics case, status of the NICA project and distributed computing model)

G. Trubnikov

for the Project Group

JINR, Dubna
NICA: Nuclotron based Ion Collider Facility

Veksler & Baldin Laboratory of High Energy Physics
NICA Physics case. QCD phase diagram

Deconfinement matter (high $\varepsilon, T, n_B$):
$\varepsilon > 1 \text{ GeV/fm}^3$, $T > 150 \text{ MeV}$, $n_B > (3-5)n_0$

The most intriguing and little studied region of the QCD phase diagram:

- Characterized by the highest net baryon density
- Allows to study in great detail properties of the phase transition region
- Has strong discovery potential in searching for the Critical End Point and manifestation of Chiral Symmetry Restoration

Recently became very attractive for heavy-ion community: RHIC/BNL, SPS/CERN, FAIR/GSI, NICA/JINR

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

Challenge: comprehensive experimental program requires scan over the QCD phase diagram by varying collision parameters: system size, beam energy and collision centrality
NICA project at JINR

NICA includes two main parts:

1. Accelerator complex **NICA** (Nuclotron-based Ion Collider Facility)

2. **MPD** (Mixed Phase Detector)

**NICA/MPD physics problems:**

Study of in-medium properties of hadrons and nuclear matter **equation of state** including a search for possible signs of deconfinement and/or chiral symmetry restoration **phase transitions** and QCD critical endpoint
Simulation with UrQMD model for U+U при $\sqrt{s_{NN}} = 7$ Gev/amu
The evolution of the fireball

- Au+Au collision at 10.7 A GeV in UrQMD

- $\bar{p}, \bar{\Lambda}$

- $\rho \rightarrow e^+e^- , \mu^+\mu^-$

- $\pi, K, \Lambda, \ldots$

- Resonance decays
What to measure

♣ Multistrange hyperons. The yields, spectra and collective flows of (multi) strange hyperons are expected to provide information on the early and dense phase of the collision. Therefore, these particles are promising probes of the nuclear matter equation-of-state at high baryon density.

♣ Event-by-event fluctuations. The hadron yields and their momenta should be analyzed event-wise in order to search for nonstatistical fluctuations which are predicted to occur in the vicinity of the critical endpoint and when penetrating the coexistence phase of the first order deconfinement phase transition.

♣ HBT correlations. Measurement of short range correlations between hadrons π, K, p, Λ allows one to estimate the space-time size of a system formed in nucleus-nucleus interactions. Along with the increase of fluctuations, the spatial size of the system is expected to be getting smaller near the deconfinement phase transition due to softening of the equation of state (the “softest point” effect).

♣ Penetrating probes. Measurements of dilepton pairs permit to investigate the in-medium spectral functions of low-mass vector mesons which are expected to be modified due to effects of chiral symmetry restoration in dense and hot matter. Specific properties of the ς meson, the order parameter of chiral symmetry restoration may be in principle detected near the phase boundary via particular channel of ς-decay into dileptons or correlated γγ-pairs.
MPD detector

1-st stage
barrel part (TPC, Ecal, TOF) + ZDC, FFD, BBC, magnet, ...

2-nd stage
IT, EC-subdetectors

3-d stage
F-spectrometers (optional ?)
Physics tasks for Spin Physics Detector

- MMT-DY processes with L&T polarized p & D beams:
  - extraction of unknown (poor known) PDF
  - PDFs from J/y production processes
- Spin effects in baryon, meson & photon productions

- Spin effects in various exclusive reactions & diffractive processes

- Cross sections, helicity amplitudes & double spin asymmetries (Krisch effect) in elastic reactions

- Spectroscopy of quarkoniums

- Polarimetry
NICA/MPD – competitive & complimentary to

- running experiments:
  - STAR, Phenix at RHIC
  - NA49/NA61 at CERN
  - HADES at GSI

- in preparation:
  - ALICE at CERN
  - CBM at GSI

NICA / MPD advantages
- optimal energy range for max baryonic density close to 4 geometry
- homogeneous acceptance & resolution functions versus measured & scanned parameters (kinematics, $b$, energy etc.)
Relativistic Nuclear Physics

Colliders & Synchrotrons: Luminosity vs Energy ($\sqrt{s}$)

- Synchrotrons: SIS300, SIS100, Nuclotron, U-70, SPS, LHC (Pb$^{82+}$), RHIC (Au$^{79+}$)

- Luminosity vs Energy ($L(E)$) vs Energy ($\sqrt{s}$)

- Particles: $\eta$, $\rho$, $\omega$, $\phi$, $J/\Psi$, $Y$, $W^{\pm}$, $Z^{0}$, $t$
### Particle yields in Au+Au collisions

\[ \sqrt{s_{\text{NN}}} = 7.1 \text{ GeV (10\% central)} \]

<table>
<thead>
<tr>
<th>Particle (mass)</th>
<th>Multiplicity</th>
<th>decay mode</th>
<th>BR</th>
<th>( \epsilon ) (%)</th>
<th>yield ((s^{-1}))</th>
<th>yield (10^w)</th>
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<tbody>
<tr>
<td>K(^+) (494)</td>
<td>55</td>
<td>--</td>
<td>--</td>
<td>20</td>
<td>(7.7 \cdot 10^3)</td>
<td>(4.6 \cdot 10^{10})</td>
</tr>
<tr>
<td>K(^-) (494)</td>
<td>16</td>
<td>--</td>
<td>--</td>
<td>20</td>
<td>(2.2 \cdot 10^3)</td>
<td>(1.3 \cdot 10^{10})</td>
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<tr>
<td>(\rho) (770)</td>
<td>23.6</td>
<td>e(^+)e(^-)</td>
<td>(4.7 \cdot 10^{-5})</td>
<td>2</td>
<td>(1.6 \cdot 10^{-2})</td>
<td>(9.4 \cdot 10^4)</td>
</tr>
<tr>
<td>(\omega) (782)</td>
<td>14.2</td>
<td>e(^+)e(^-)</td>
<td>(7.1 \cdot 10^{-5})</td>
<td>2</td>
<td>(1.4 \cdot 10^{-2})</td>
<td>(8.6 \cdot 10^4)</td>
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<tr>
<td>(\Phi) (1020)</td>
<td>2.7</td>
<td>e(^+)e(^-)</td>
<td>(3 \cdot 10^{-4})</td>
<td>2</td>
<td>(1.1 \cdot 10^{-2})</td>
<td>(6.8 \cdot 10^4)</td>
</tr>
<tr>
<td>(\Xi^-) (1321)</td>
<td>2.4</td>
<td>(\Lambda\pi)</td>
<td>1</td>
<td>4</td>
<td>67</td>
<td>(4.0 \cdot 10^8)</td>
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<tr>
<td>(\Omega^-) (1672)</td>
<td>0.16</td>
<td>(\Lambda\kappa)</td>
<td>0.68</td>
<td>2</td>
<td>1.5</td>
<td>(9.2 \cdot 10^6)</td>
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<tr>
<td>(D^0) (1864)</td>
<td>(7.5 \cdot 10^{-4})</td>
<td>K(^+)(\pi^-)</td>
<td>0.038</td>
<td>1</td>
<td>(2.0 \cdot 10^{-4})</td>
<td>1200</td>
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<tr>
<td>J/(\psi) (3097)</td>
<td>(3.8 \cdot 10^{-5})</td>
<td>e(^+)e(^-)</td>
<td>0.06</td>
<td>5</td>
<td>(8.0 \cdot 10^{-5})</td>
<td>480</td>
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</table>

Luminosity \(L = 10^{27} \text{cm}^{-2}\text{s}^{-1}\)

Event rate (central) 700 Hz
<table>
<thead>
<tr>
<th>Facility:</th>
<th>CERN</th>
<th>BNL</th>
<th>JINR</th>
<th>FAIR</th>
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<tbody>
<tr>
<td></td>
<td>SPS</td>
<td>RHIC</td>
<td>NICA</td>
<td>SIS-300</td>
</tr>
<tr>
<td>Exp.:</td>
<td>NA61</td>
<td>STAR</td>
<td>MPD</td>
<td>CBM</td>
</tr>
<tr>
<td>Start:</td>
<td>2010</td>
<td>2010</td>
<td>2017</td>
<td>2018</td>
</tr>
<tr>
<td>Pb Energy:</td>
<td>4.9-17.3</td>
<td>4.9-50</td>
<td>≤ 11</td>
<td>≤8.5</td>
</tr>
<tr>
<td>(GeV/(N+N))</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event rate:</td>
<td>100 Hz</td>
<td>1 Hz(?)</td>
<td>≤10 kHz</td>
<td>≤10 MHz</td>
</tr>
<tr>
<td>(at 8 GeV)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Physics:</td>
<td>CP&amp;OD</td>
<td>CP&amp;OD</td>
<td>OD&amp;HDM</td>
<td>OD&amp;HDM</td>
</tr>
</tbody>
</table>

\[ CP \quad \text{– critical point} \]
\[ OD \quad \text{– onset of deconfinement, mixed phase, 1^{st} order PT} \]
\[ HDM \quad \text{– hadrons in dense matter} \]
Searching for nuclear matter at extreme states

NICA/MPD

\textit{Nuclotron-based Ion Collider \textit{fa}cility}

GSI: FAIR/CBM

Average luminosity $10^{27}\text{sm}^2\text{s}^{-1}$

(!!!) Au x Au

$E_{\text{lab}} < 60 \text{ GeV/n}$

$s_{\text{NN}} = 4 \div 11.0 \text{ GeV/n}$

$E_{\text{lab}} \sim 34 \text{ GeV/n}$

$s_{\text{NN}} = 8.5 \text{ GeV}$

$\sqrt{s_{\text{NN}}} = 11 \text{ AGeV}$

J. Randrup, J. Cleymans, 2006
The FAIR Accelerator Complex

Total project: 1300 M€
Start Version = Phase A: 940 M€
Phase B: SIS 300, HESR ecooler, Electron linac & ring

Primary beams:
protons to $^{238}$U

Upgraded existing facility: provides ion-beam source and injector for FAIR

Accelerator Components & Key Characteristics

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<tr>
<th>Ring/Device</th>
<th>Beam</th>
<th>Energy</th>
<th>Intensity</th>
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<tr>
<td>SIS 100 (100Tm)</td>
<td>protons</td>
<td>30 GeV</td>
<td>$2 \times 10^{13}$</td>
</tr>
<tr>
<td></td>
<td>$^{238}$U</td>
<td>2.7 GeV/u</td>
<td>$5 \times 10^{11}$</td>
</tr>
<tr>
<td></td>
<td>(intensity factor 100 over present)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIS 300 (300Tm)</td>
<td>$^{40}$Ar</td>
<td>45 GeV/u</td>
<td>$2 \times 10^{9}$</td>
</tr>
<tr>
<td></td>
<td>$^{238}$U</td>
<td>34 GeV/u</td>
<td>$2 \times 10^{10}$</td>
</tr>
<tr>
<td>CR/RESR/NESR</td>
<td>ion and antiproton storage and experiment rings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HESR</td>
<td>antiprotons</td>
<td>14 GeV</td>
<td>$10^{11}$</td>
</tr>
<tr>
<td>Super-FRS</td>
<td>rare isotope beams</td>
<td>1 GeV/u</td>
<td>$&lt;10^9$</td>
</tr>
</tbody>
</table>

Secondary beams: RIBs, pbars

New future facility: provides ion and anti-matter beams of highest intensities and up to high energies
The strategy is staged development of the project: module-by-module from 0 to 5th. Nearest 3 modules – will be fulfilled during nearest 7 years. Modules 4 and 5 – will be realized in case of additional funding.
RHIC
Phase transitions in the strongly interacting matter
(mixed phase, critical points, …)

Mixed Phase Detector MPD - NICA
Compressed Baryonic Matter – CBM - FAIR
In the beginning of XX\textsuperscript{th} century it was considered, that solar energy is generated by chemical reactions.

1938 – H.Bethe theoretically predicted the mechanism of energy generation driven by thermonuclear reaction (fusion)

1943 – Carl Seyfert (astronomer) discovered galactics with active core:

Active core – object with size $< 1$ parsec (3.26 light year), it’s energy-release overbalances all stars of our galactic

Possible source – phase transitions in the dense and hot strongly interacting matter
Booster-synchrotron application to nanostructures creations:

Design and parameters of booster, including wide accessible energy range, possibility of the electron cooling, allow to form dense and sharp ion beams. System of slow extraction provides slow, prolonged in time ion extraction to the target with space scanning of ions on the target surface and guaranty high controllability of experimental conditions.

Ion-track technologies:

Production of nanowires, filters, nanotransistors, ...

Ion tracks in a polymer matrix (GSI, Darmstadt)

Topography and current of a diamond-like carbon (DLC) film. The 50 nm thick DLC film was irradiated with 1 GeV Uranium ions.
Creation of economical and efficient proton-carbon (400 MeV) synchrotrons for medicine

Gantry for carbon medical centers and SC channels for ion beams

Proton-nuclear accelerators for relativistic nuclear energetics

Construction of the heavy ion SIS100 synchrotron at FAIR GSI

R&D at development stage of future LHC upgrade at CERN

Creation of the magnetic systems for NICA collider and booster

SC magnets

CONSTRUCTION OF THE HEAVY ION SIS100 SYNCHROTRON at FAIR GSI

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Proton-nuclear accelerators for relativistic nuclear energetics
The goal of the project is

construction at JINR of a new accelerator facility, that provides

1a) Heavy ion colliding beams $^{197}\text{Au}^{79+}$ x $^{197}\text{Au}^{79+}$ at
\[
\sqrt{s_{NN}} = 4 \text{ 11 GeV (1 4.5 GeV/u ion kinetic energy )}
\]
at $L_{\text{average}} = 1\text{E}27 \text{ cm}^{-2}.\text{s}^{-1}$ (at $\sqrt{s_{NN}} = 11 \text{ GeV}$)

1b) Light-Heavy ion colliding beams of the same energy range and luminosity

2) Polarized beams of protons and deuterons in collider mode:
\[
\text{p} \uparrow \text{p} \uparrow \sqrt{s_{pp}} = 12 \text{ 27 GeV (5 12.6 GeV kinetic energy )}
\]
\[
\text{d} \uparrow \text{d} \uparrow \sqrt{s_{NN}} = 4 \text{ 13.8 GeV (2 5.9 GeV/u ion kinetic energy )}
\]
\[
L_{\text{average}} \geq 1\text{E}30 \text{ cm}^{-2}.\text{s}^{-1} \text{ (at } \sqrt{s_{pp}} = 27 \text{ GeV)}
\]

3) The beams of light ions and polarized protons and deuterons for fixed target experiments:
\[
\text{Li} \div \text{Au} = 1 \div 4.5 \text{ GeV /u ion kinetic energy}
\]
\[
\text{p, p} \uparrow = 5 \div 12.6 \text{ GeV kinetic energy}
\]
\[
\text{d, d} \uparrow = 2 \div 5.9 \text{ GeV/u ion kinetic energy}
\]

4) Applied research on ion beams at kinetic energy from 0.5 GeV/u
up to 12.6 GeV (p) and 4.5 GeV /u (Au)
Nuclotron provides now performance of experiments on accelerated proton and ion beams (up to $\text{Fe}^{24+}$, $A=56$, now $\text{Xe}^{42+}$, $A=124$) with energies up to 6 AGeV ($Z/A = 1/2$)
Optic structure of the Nuclotron: 8 super-periods, each contains 3 regular periods and 1 period, which does not contain dipole magnet. Regular period includes focusing and defocusing quadrupole lenses, 4 dipoles and 2 small straight sections for multipole correctors and diagnostics.

Chromaticity $\Delta Q_x/(\Delta p/p)$ and $\Delta Q_z/(\Delta p/p)$

<table>
<thead>
<tr>
<th></th>
<th>7.8</th>
<th>-10.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compaction factor</td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td>Corrected orbit amplitude</td>
<td>4 mm</td>
<td></td>
</tr>
<tr>
<td>Acceptance horiz/vert [π mm mrad]</td>
<td>40 / 45</td>
<td></td>
</tr>
<tr>
<td>Emittance inj/acc [π mm mrad]</td>
<td>30 / 1.7$_x$ and 2.0$_z$</td>
<td></td>
</tr>
<tr>
<td>DP/P inj/max/accel</td>
<td>±10$^{-3}$ / 4·10$^{-4}$ / 8·10$^{-3}$</td>
<td></td>
</tr>
</tbody>
</table>
10 stages-subprojects of the Nuclotron-M project

- Modernization of ion source KRION to KRION 6T;
- Improvement of the vacuum in the Nuclotron ring;
- Development of the power supply system, quench detection and energy evacuation system;
- Modernization of the RF system (including trapping & bunching systems, controls and diagnostics);
- Modernization of the slow extraction system for accelerated heavy ions at maximal energies;
- Modernization of automatic control system, diagnostics and beam control system;
- Transportation channel of the extracted beams and radiation safety;
- Improvement of the safety, stability and economical efficiency of the cryogenics;
- Modernization of the injector complex (fore-injector and linac) for acceleration of heavy ions;
- Development and creation of high intensity polarized deutron source

Beam dynamics: minimization of the beam losses at all stages from injection to acceleration and to extraction of the beams (not more then 15-20%, we have about 50-80%).
Part I. NICA Project Concept & Status

NICA Layout

- Synchrophasotron yoke
- Booster
- Collider
  - $C = 503 \text{ m}$
- Spin Physics Detector (SPD)
- MPD
- KRION-6T & HILac
- SPI & LU-20 (“Old” linac)
- Nuclotron
- Fixed target experiments

Bldg #1
Bldg #205
Part I. NICA Project Concept & Status

Facility operation scenario

Nuclotron (45 Tm)
- Injection of one bunch of 1.1 $10^9$ ions
- Acceleration up to 1 - 4.5 GeV/u max.

Booster (25 Tm)
- 1(2-3) single-turn injection, storage of 2(4-6) $10^9$
- Acceleration up to 100 MeV/u, electron cooling, acceleration up to 600 MeV/u

Stripping (80%) $^{197}\text{Au}^{31+}$ => $^{197}\text{Au}^{79+}$

Fixed Target Area
- $\approx 2 \times 24$ injection cycles
- 24 bunches per ring

Linac HILac

Linac LU-20

KRION

Ion sources

Two SC collider rings

IP-1

IP-2
Magnetic field (T) versus current (A) for SC solenoids; experimental and expected data.  
1) **26 layers** (green line, 21 Jan.'11) – 7.41T at \( I_{\text{crit}} = 131 \) A (experimental data);  
2) **32 layers** (top green line, 25 Apr.'11) – 7.81T at \( I_{\text{crit}} = 114 \) A (experimental data);  
3) **red line**: critical current for SC wire according to its manufacturer data;  
4) **blue line**: expected for Krion-6T ESIS – 22 layers, L=120 cm, B=6 T at \( I_{\text{working}} = 118 \) A.  
Should be ready in September 2011.
We plan to assemble and TEST SPP at Nuclotron with $^3$d in the end of 2012
Recent: Maximum HILAC energy is reduced from 6.2 MeV/u to ~ 3 MeV/u
Heavy Ion Linac (HILAc)

HILAC – 1 section of RFQ + 4 sections of Drift Tube Linac (DTL), 2H cavities of "Ural" RFQ (prototype)

Status: Design at IHEP (Protvino) and JINR, Construction at VNIIEF (Sarov) – recent agreement.
Booster

Prototype of the Booster dipole

Vladimir I. Veksler
Booster synchrotron
## NICA Project Concept & Status
### SC Synchrotron Nuclotron

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Project</th>
<th>Status (April 2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. magn. field, T</td>
<td>2.05</td>
<td>2.05</td>
</tr>
<tr>
<td>Magn. rigidity, T·m</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Cycle duration, s</td>
<td>2.0</td>
<td>5.0</td>
</tr>
<tr>
<td>B-field ramp, T/s</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Accelerated particles</td>
<td>p–U, p↑, d↑</td>
<td>p–Xe, d↑</td>
</tr>
<tr>
<td>Max. energy, GeV/u</td>
<td>12.6(p), 5.87(d)</td>
<td>3.5 (d), 1.5 (124Xe42+)</td>
</tr>
<tr>
<td></td>
<td>4.5( 197Au79+)</td>
<td></td>
</tr>
<tr>
<td>Intensity, ions/cycle</td>
<td>1E11(p,d), 1E9 (A &gt; 100)</td>
<td>5E10(p,d), 1E10(d↑), 1E5 (124Xe24+)</td>
</tr>
</tbody>
</table>
First test results for booster dipole

Installation of the cryostat with the magnet on the bench for the cryogenic test.

Cryogenic test facility for superconducting magnets

The quench history of the magnet

AC losses as a function of the field ramp rate at magnet operation in triangular cycle
Booster quadrupole magnet manufacturing

Finished yoke of the quadrupole magnet
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>p</td>
<td>8.10^{10}</td>
<td>5.10^{11}</td>
<td>5.10^{12}</td>
</tr>
<tr>
<td>d</td>
<td>8.10^{10}</td>
<td>5.10^{11}</td>
<td>5.10^{12}</td>
</tr>
<tr>
<td>^4He</td>
<td>2.10^{9}</td>
<td>3.10^{10}</td>
<td>1.10^{12}</td>
</tr>
<tr>
<td>d↑</td>
<td>2.10^{8}</td>
<td>7.10^{10} (SPI)</td>
<td>7.10^{10} (SPI)</td>
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<tr>
<td>^7Li^{6+}</td>
<td>7.10^{9}</td>
<td>3.10^{10}</td>
<td>5.10^{11}</td>
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<tr>
<td>^12C^{6+}</td>
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<tr>
<td>^14N^{7+}</td>
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<td>3.10^{8}</td>
<td>5.10^{10}</td>
</tr>
<tr>
<td>^24Mg^{12+}</td>
<td>7.10^{8}</td>
<td>4.10^{9}</td>
<td>5.10^{10}</td>
</tr>
<tr>
<td>^40Ar^{18+}</td>
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<td>^56Fe^{28+}</td>
<td>4.10^{6}</td>
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<tr>
<td>^58Ni^{26+}</td>
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<tr>
<td>^84Kr^{34+}</td>
<td>2.10^{5}</td>
<td>1.10^{8}</td>
<td>1.10^{9}</td>
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<tr>
<td>^124Xe^{48/42+}</td>
<td>1.10^{5}</td>
<td>7.10^{7}</td>
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<td>^181Ta^{61+}</td>
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<tr>
<td>^197Au^{65/79+}</td>
<td></td>
<td>1.10^{8}</td>
<td>1.10^{9}</td>
</tr>
<tr>
<td>^238U^{28+}</td>
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Nuclotron external beam lines

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<tr>
<th>Lines</th>
<th>$P_{\text{min}}$</th>
<th>$P_{\text{max}}$</th>
<th>$I_{\text{max}}$</th>
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<tbody>
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<td>VP-1</td>
<td>$\approx 2$</td>
<td>15</td>
<td>$10^{11}$</td>
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Notes: momentum is given for protons, intensity is limited by the protection shield, 7v: secondaries only

Energy range, GeV/amu: 0.2 - 6.0
Duration, s, from up to: 0.01 - 10
Extraction efficiency, %: 95
Cycle: 1 Hz

Slowly extracted beam spill
### NICA collider

**Ring circumference, m** | 503.04
---|---
**Number of bunches** | 23
**Rms bunch length, m** | 0.6
**Beta-function in the IP, m** | 0.35
**Ring acceptance (FF lenses)** | 40 π mm mrad
**Long. acceptance, Δp/p** | ±0.010
**Gamma-transition, γ_tr** | 7.091
**Ion energy, GeV/u** | 1.0 3.0 4.5
**Ion number per bunch** | 2.75·10^8 2.4·10^9 2.2·10^9
**Rms momentum spread, 10^{-3}** | 0.62 1.25 1.65
**Rms beam emittance, h/v, (unnormalized), π-mm-mrad** | 1.1/1.01 1.1/0.89 1.1/0.76
**Luminosity, s^{-1}** | 1.1·10^25 1·10^27 1·10^27
**IBS growth time, sec** | 186 702 2540
Luminosity scaling with energy

When $\Delta Q$ is fixed the peak luminosity is scaled with energy as the following (two outmost cases):

1. $L_1(E) = \text{Const} \cdot \beta^5 \cdot \gamma^6$ if unnormalized ("geometrical") emittance is constant;
2. $L_2(E) = \text{Const} \cdot \beta^4 \cdot \gamma^5$ if normalized emittance is constant.

Here $\beta(E)$ and $\gamma(E)$ are Lorenz factors.

Luminosity scaling for collider 2T-534

$L(4.5 \text{ GeV/u}) = 6\times10^27 \text{ cm}^{-2}\cdot\text{s}^{-1}$
$L(3.5 \text{ GeV/u}) = (1.7 \div 2.1)\times10^27$
$L(1 \text{ GeV/u}) = (0.7 \div 2.1)\times10^25$
Luminosity life-time

Without beam cooling - beam emittance grows due to intra-beam scattering
Characteristic time (growth rate) of the luminosity decrease
~ several minutes (at RHIC operating with 100 GeV/u ~ 4 hours)

RHIC:
Construction of the Electron cooling system at low energy ions (< 5 GeV/u),
Stochastic cooling is used at maximal energy.

NICA:
Stochastic cooling during beam stacking,
Electron + stochastic cooling during the experiment (collision mode)
Nuclotron-NICA

Stochastic cooling system prototype at Nuclotron

We plan to assemble and TEST stochastic cooling system prototype at Nuclotron in the end of 2011
HV Electron cooler: working design

Electron energy $0.5 \div 2.5$ MeV
Electron beam current $0.5 \div 1$ A
Collider dipole magnet manufacturing

Test on vacuum tightness of the tubes for cooling the yoke

Manufacturing of the winding (0,9 mm wires)
Infrastructure Development

Building 217 (former workshops)
New cryo-magnetic factory
Production, assembly, cryo- and vacuum tests for superconducting magnets serial production for NICA and FAIR (SIS-100)

30 x 75 m²
3 stages of putting into operation detector MPD

1-st stage **barrel part** (TPC, Ecal, TOF) + ZDC, FFD, BBC, magnet, …

2-nd stage
IT, EC-subdetectors

3-d stage
F-spectrometers (optional ?)

Toroid
GSI facility & FAIR plans

- Compressed Baryonic Matter (CBM) - experiment in preparation for the first stage of FAIR
- JINR cooperation in both experiments are supported by the BMBF
Angle coverage of MPD

Acceptance (B=0.5 T):
- Full azimuthal
- TPC ($|\eta|<2$)
- ECAL ($|\eta|<1.2$)
- FD (2<$|\eta|$<4)
- TOF ($|\eta|$<3)
- IT ($|\eta|$<2.5)
- ZDC ($|\eta|$>3)

Detector dimensions: length 8140, diameter 5344 cm
**Time Projection Chamber (TPC)**

**Challenges**
- low material budget, max. transparency for forward tracking
- high event rates (up to ~ 7 kHz)
- small distortions, stable conditions, $B_r/B_z < 5 \times 10^{-4}$

**TPC parameters**
- Size: 3.4 m (length) x 2.2 m (diameter)
- Drift Length: 150 cm
- # of samples: 50
- Electric field: 140 V/cm
- Magnetic field: 0.5 T (max.)
- Gas: 90% Argon + 10% Methane atm+2mbar)
- Readout: 2x12 sectors (MWPC+pads or GEM)
- Pad size – 4x10 mm in inner sector area
  6x12 mm in outer sector area

**Performance required (MWPC option)**
- Spatial resolution: $\delta_{r\phi} \sim 300$ mm $s_z \sim 2$ mm
- Two track resolution < 1 cm
- Momentum resolution $\Delta p/p < 3\%$ (0.2<p<1 GeV/c)
  $dE/dx$ resolution < 8%

**TPC prototype №1** (Electric field – 140 V/cm, Drift distance – 40 cm)
Basic requirements
- Coverage: barrel > 30 m²
- Endcap covers down to |z| < 3
- s ~ 80 ps (100 ps overall)

Dimensions
- Barrel: 5 m (length), 2.5 m (diameter)
- Endcap: 2 x 2.5 m (diameter) disks
- Gas: 90% C₂H₂F₄ + 5% iC₄H₁₀ + 5% SF₆

Segmentation (barrel)
- 12 sectors
- Module: 10-gap RPC, 48 pads 2.5x3.5 cm²
  or 30-50 cm long and 1-2 cm wide strips

Endcaps
- 24 mRPC 53,37,21x80-100 cm²
- Pad size: 4x4 cm²
- Geom. efficiency ~ 95%
ECAL – “shashlyk” type modules with APD readout
(Lead plates (0.275 mm) and plastic scintillator (1.5 mm), the
radiation length of tower 18X₀ (40 cm))
The active area of APD- 3x3 mm; density of pixels in APD – 10⁴/mm²

Energy resolution 2.5%/√E
Time resolution 80 psec/√E
• The TRD is the part of the electron-positron ID system

• Large experience at LHEP JINR for ALICE@CERN

Visits of Prof. H. Stoeker (GSI), and Prof. R. Hoyer (CERN)
Tracking, particle ID & centrality measurements

NA48 drift chambers
(NA48 – CERN/JINR)

Straw tracker
(CBM/MPD)

RPC TOF

ZDC (CBM/MPD -INR,JINR)
### NICA Time Table

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### R&D

- **Design**
- **Manufacturing**
- **Mount.+commis.**
- **Commis/opr**
- **Operation**
## Timetable of the MPD works

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**CRYOGENICS: He plant:** works schedule & resources, k$.

*filled to be done*
- Protocol (addendum) to General MoU CERN-JINR – April 2010
- Accelerator physics and technique (beam cooling, lattice optimization, beam injection/extraction, beam dynamics)
- EVM system
Do we know how our project is doing?

- Are we ahead or behind schedule?
- Are you getting value for money?
- Did you spend money on the right things?

We hope to start with EVM 2012 @ NICA
PPT/EVM for LHC: Summaries

Performance Chart for CERN

Cost Impact:
- Budget code: 964411; cost reduction: 1,390 CHF

Schedule Impact:
- No impact
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<td>2.2.4 Alarm system, slow control system</td>
<td>ANDREEV B.A.</td>
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<td>2.2.5 Beam screen monitors</td>
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<td>2.2.6 BPMs (Pickups)</td>
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<td>2.2.7 Closed orbit DAQ &amp; Correction system</td>
<td>SLEDNEV V.M.</td>
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<td>2.2.9 Residual gas beam monitor</td>
<td>BALDIN A.A.</td>
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<td>2.2.11 Q-meter (kicker)</td>
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<td>2.3 Stochastic cooling system</td>
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<td>2.3.1 Pick-up station (structure + cryo-vacuum assembly)</td>
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<td>2.3.2 Kicker station (structure + vacuum assembly + electronics)</td>
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<td>2.3.3 Optical line + filter + electronics</td>
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<td>2.4 Electron cooling system</td>
<td>MASHIN N.N.</td>
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<td>2.4.1 Electron beam optics (gun, collector)</td>
<td>YAKOVLEV S.S.</td>
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<td>2.4.2 Diagnostic and control system</td>
<td>KOBETS A.G.</td>
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**Project:** Model of a shared distributed system for acquisition, transfer and processing of very large-scale data volumes, based on Grid technologies, for the NICA accelerator complex

**Terms:** 2011-2012

**Cost:** federal budget - 10 million rubles, extrabudgetary sources - 25% of the total cost

**Leading executor:** LIT JINR

**Co-executor:** VBLHEP JINR

MPD data processing model

(from “The MultiPurpose Detector – MPD Conceptual Design Report v. 1.4”)

Nuclotron-M/NICA/MPD/SPD cooperation

- Joint Institute for Nuclear Research
- Institute for Nuclear Research, RAS, RF
- Bogolyubov Institute for Theoretical Physics, NAS, Ukraine
- Nuclear Physics Institute of MSU, RF
- Institute Theoretical & Experimental Physics, RF
- St.Petersburg State University, RF
- Institute of Applied Physics, AS, Moldova
- Institute for Nuclear Research & Nuclear Energy BAS, Sofia, Bulgaria
- Institute for Scintillation Materials, Kharkov, Ukraine
- State Enterprise Scientific & Technolog Research Institute for Apparatus construction, Kharkov, Ukraine
- Particle Physics Center of Belarusian State University, Belarus
- Department of Engineering Physics, Tsinghua University, Beijing, China
- Physics Institute Az:AS, Azerbaidjan

Members of the Collaboration

- JINR ~ 100
- Other institutes 70

Institutions

- JINR
- 24 institutes from 7 countries

The Collaboration is permanently growing

New participants – are welcome!
the state commission on mega-science projects chaired by V.Putin hold in Dubna on 5 July 2011

the commission proposed to prepare the appropriate application with the corresponding Road Map following the suggestion of this commission. The RM was prepared & submitted today for support of cooperation with RF Institutions.

RF Prime Minister V.V. Putin at NICA, 5 July 2011
Conclusion

The NICA design passed the phase of concept formulation and is presently under

✓ detailed simulation of accelerator elements parameters,
✓ development of working project,
✓ manufacturing and construction of prototypes,
✓ preparation of the project for state expertise in accordance with regulations of Russian Federation.

The project realization plan foresees a staged construction and commissioning of accelerators forming the facility. **The main goal is the facility commissioning in 2017.**

*Project requires (!!!) well developed strategy for source and man-power wise management*
Nikola Camille Flammarion (1888)
Thank you for your attention!

Thank you for your attention!