Nuclotron-based Ion Collider fAcility (NICA) at JINR: New Prospect for Heavy Ion Collisions and Spin Physics

A.N. Sissakian

14th Lomonosov Conference on Elementary Particle Physics
Moscow State University, August 19 - 25, 2009
The talk plan

I. Status of the NICA project at JINR

II. Heavy ion physics at NICA

III. Spin physics at NICA

IV. Applied research at NICA

V. Concluding remarks
I. Status of the NICA project at JINR

The main goal of the NICA project is an experimental study of hot and dense nuclear matter and spin physics

These goals are proposed to be reached by:

• development of the Nuclotron as a basis for generation of intense beams over atomic mass range from protons to uranium and light polarized ions;

• design and construction of heavy ion collider with maximum collision energy of $\sqrt{s_{NN}} = 11$ GeV and average luminosity $\sim 10^{27}$ cm$^{-2}$ s$^{-1}$ (for Au$^{79+}$), and polarized proton beams with energy $\sqrt{s} \sim 26$ GeV and average luminosity $> 10^{30}$ cm$^{-2}$ s$^{-1}$

• design and construction of the MultiPurpose Detector (MPD)
The NICA Project Milestones

• **Stage 1:** years 2007 – 2011
  - Upgrade and Development of the Nuclotron
  - Preparation of Technical Design Report of the NICA and MPD
  - Designing MPD and NICA elements

• **Stage 2:** years 2010 – 2013
  Manufacturing and mounting NICA and MPD

• **Stage 3:** year 2014
  - Commissioning

• **Stage 4:** year 2015
  - Operation
Nuclotron Collider $C = 251$ m

MPD

Existing beam lines (solid target exp-s)

Bldng 205

Synchrophasotron yoke

Collider $C = 251$ m

Spin Physics Detector (SPD)

Nuclotron

Krion & Linac

LU-20

Booster

2.3 m

4.0 m

NICA layout
Scheme of the NICA complex

**Injector:** 2×10⁹ ions/pulse of ¹⁷⁹Au³²⁺
   at energy of 6 MeV/u

**Booster (25 Tm)**
   1(2-3) single-turn injection,
   storage of 2 (4-6)×10⁹,
   acceleration up to 70 MeV/u,
   electron cooling,
   acceleration up to 640 MeV/u

**Collider (45 Tm)**
   Storage of
   17 (20) bunches × 1·10⁹ ions per ring
   at 1÷4.5 GeV/u,
   electron and/or stochastic cooling

**Nuclotron (45 Tm)**
   Injection of one bunch
   of 1.1×10⁹ ions,
   acceleration up to 1÷4.5 GeV/u max.

**Stripping (80%)** ¹⁹⁷Au³²⁺ ⇒ ¹⁹⁷Au⁷⁹⁺

**IP-1**
   Two superconducting collider rings

**IP-2**
   2x17 (20) injection cycles

Bunch compression (RF phase jump)
Joint Institute for Nuclear Research
Institute for Nuclear Research, Russian Academy of Science
Institute for High Energy Physics, Protvino
Budker Institute of Nuclear Physics, Novosibirsk
ITEP
All-Russian Institute for Electrotechnique
Corporation “Powder Metallurgy” (Minsk, Belorussia):
MoU with GSI
FZ Jülich (IKP)
BNL (RHIC)
Fermilab
Open for extension ...

http://nica.jinr.ru

May 2009: NICA TDR is completed
II. Heavy ion physics at NICA

Round Table Discussions I, II, III
http://theor.jinr.ru/meetings/2008/roundtable/
Phase Diagram

Yu.Ivanov, V.Russkikh, V.Toneev, 2005

MPD Letter of Intend (2007)

\[ \sqrt{s_{NN}} = 8.8 \text{ GeV} \]

\[ \sqrt{s_{NN}} = 4 \text{ GeV} \]

Critical points

M.Stephanov, 2006

J.Randrup, J.Cleymans, 2006

Hadronic freeze-out

NICA \( \sqrt{s} = 11 \text{ GeV} \)
The NICA Physics Program

Study of in-medium properties of hadrons and nuclear matter equation of state including a search for possible signs of deconfinement and chiral symmetry restoration phase transitions and QCD critical endpoint

Experimental observables:

- Scanning in beam energy and centrality of excitation functions for
  - Multiplicity and global characteristics of identified hadrons including (multi)strange particles
  - Fluctuations in multiplicity and transverse momenta
  - Directed and elliptic flows for various identified hadrons
  - particle correlations
  - Dileptons and photons
Lattice QCD predictions: Fluctuations of the quark number density (susceptibility) at $\mu_B > 0$ (C.Allton et al., 2003)

$$\chi_q = \left[ \frac{\partial^2}{\partial (\mu_q/T)^2} \frac{P}{T^4} \right]_{T_{fluid}}$$

$\chi_q$ (quark number density fluctuations) will diverge at the critical end point

Experimental observation:
- Baryon number fluctuations
- Charge number fluctuations
Collective flows

Interactions between constituents lead to a pressure gradients => spatial asymmetry is converted in asymmetry in momentum space => collective flows

\[
\frac{dN}{dyp_T dp_T d\phi} = \frac{dN}{dyp_T dp_T} \frac{1}{2\pi} \left( 1 + 2v_1 \cos(\phi) + 2v_2 \cos(2\phi) + \ldots \right)
\]

directed flow

elliptic flow

Non-central collisions
Correlation femtoscopy of identical particles

\[ q = p_1 - p_2, \quad \Delta x = x_1 - x_2 \]

\[
C_2 = 1 + (-1)^S \langle \cos q\Delta x \rangle \rightarrow 1 + \lambda \exp\left(-R_{\text{long}}^2 q_{\text{long}}^2 \right. \\
- \left. R_{\text{side}}^2 q_{\text{side}}^2 - R_{\text{out}}^2 q_{\text{out}}^2 \right. \\
- \left. 2 R_{\text{out}}^2 q_{\text{out}} q_{\text{long}} \right) 
\]
Dear Prof. Sissakian:

The NICA heavy ion collider will be a very major step towards the formation of a new phase of quark-gluon matter.

The goal of relativistic heavy ion physics is to modify the properties of the physical vacuum. Of particular interest is a possibility to create a phase of quark-gluon matter where some of the fundamental symmetries may be altered. Recent RHIC results indicate that there may be an evidence of parity violation (on an event-by-event basis) in heavy ion collisions at high energies. It would be of great importance to search for this phenomenon in the energy range covered by the NICA collider where a high baryon density is reached.

I am very much looking forward to the completion and future success of the NICA heavy ion collider. Warm regards and very best wishes,

T. D. Lee

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T. D. Lee
University Professor
Dept. of Physics - MC 5208
Columbia University
New York, NY 10027
MPD Collaboration

**http://nica.jinr.ru**

- Joint Institute for Nuclear Research
- Institute for Nuclear Research
- Russian Academy of Science
- Bogolyubov Institute of Theoretical Physics, NASUk
- Skobeltsyn Institute of Nuclear Physics of Lomonosov MSU, RF
- Institute of Applied Physics, Academy of Science Moldova

- Open for extension ...

A consortium involving GSI, JINR & other centers for IT module development & production is created.

Signed MoU with GSI in July 2008
III. Spin Physics at NICA

Preliminary topics:

- 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 and photon productions
- Spin effects in various exclusive reactions
- Diffractive processes
- Cross sections, helicity amplitudes & double spin asymmetries (Krisch effect) in elastic reactions
- Spectroscopy of quarkoniams with any available decay modes
- Polarimetry

\[ \Delta \Sigma = 0.12 \pm 0.17 \]

Polarization data has often been the graveyard for fashionable theories. If theorists had their way they might well ban such measurements altogether out of self-protection.

*J.D. Bjorken, 1987*
IV. Applied research at NICA

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.
V. Concluding remarks

Round Table Discussion I
Searching for the mixed phase of strongly interacting matter at the JINR Nuclotron
July 7 - 9, 2005
http://theor.jinr.ru/meetings/2005/roundtable/

Round Table Discussion II
Searching for the mixed phase of strongly interacting matter at the JINR Nuclotron: Nuclotron facility development
JINR, Dubna, October 6 - 7, 2006
http://theor.jinr.ru/meetings/2006/roundtable/

Round Table Discussion III
Searching for the mixed phase of strongly interacting QCD matter at the NICA: Physics at NICA
JINR (Dubna), November 5 - 6, 2008
http://theor.jinr.ru/meetings/2008/roundtable/

Round Table Discussion IV
Searching for the mixed phase of strongly interacting QCD matter at the NICA: Physics at NICA (White Paper)
JINR (Dubna), September 7 - 11, 2009
SEARCHING for a QCD MIXED PHASE at the NUCLOTRON-BASED ION COLLIDER FACILITY (NICA White Paper)
Almost all Russian speaking experts in the field of heavy ion collisions have contributed to the NICA White Paper
International Coordinating Committee meeting on the NICA Project
Visit of the GSI director Prof. Stoecker to JINR
Президенту Российской Федерации
Д.А. Медведеву

Дорогой Дмитрий Андреевич!

Направлено в г. Джиньйол, Республика Корея, в рамках визита в Республику Корея (дата визита 12.04.08) по приглашению Президента Республики Корея по вопросам развития научно-технической и международной деятельности института и его взаимодействия с ведущими научными организациями мира.

1. Вопросы развития научно-технической и международной деятельности института и его взаимодействия с ведущими научными организациями мира.

2. Вопросы финансирования научных исследований и разработок в области фундаментальных исследований.

3. Вопросы сотрудничества с ведущими научными организациями мира.

В заключение, хочу отметить, что сотрудничество с ведущими научными организациями мира является важным направлением деятельности института. Пользуясь случаем, хочу выразить благодарность за оказанную помощь в реализации национальных проектов.

Приложение:
- Список научных сотрудников института.
- Список международных научных проектов.
- Список патентных заявок.

Губернатор, Московской области
Б.В. Громов

Директор ОИЯИ, член-корреспондент РАН
А.Н. Синякин

Подпись
2 апреля 2008

Подписи:
- Президент Российской Федерации
- Первый вице-президент Российской Федерации

Visit of D.A.Medvedev to JINR 18.04.08
Welcome to the collaboration!