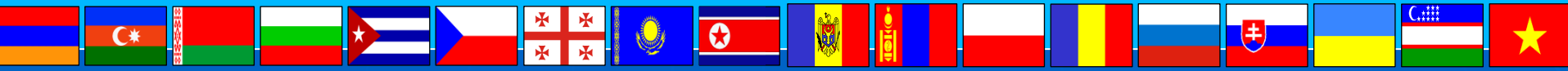
Joint Institute for Nuclear Research
International Intergovernmental Organization



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

JOINT INSTITUTE FOR NUCLEAR RESEARCH

JINR

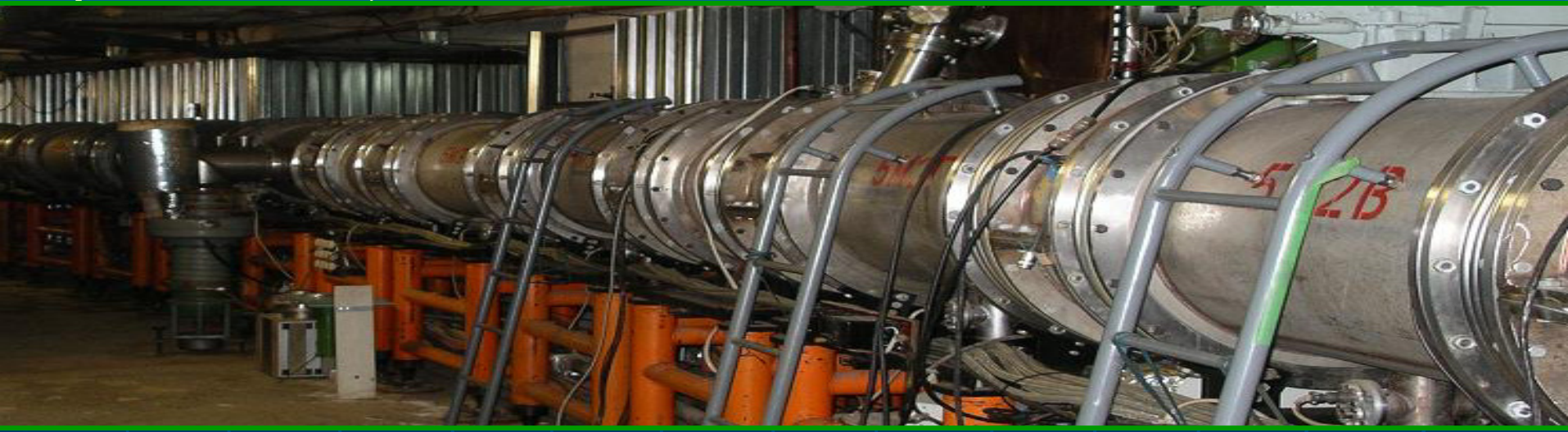
NICA

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 ~ 10^{27} cm^{-2} s^{-1} (for Au^{79+}), and polarized proton beams with energy $\sqrt{s}$ ~ 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**

- Upgrate 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**

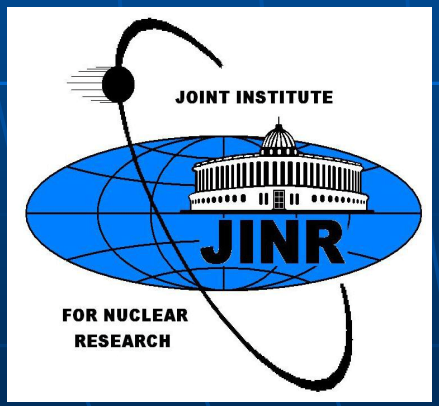
Manufacturing and mounting NICA and MPD

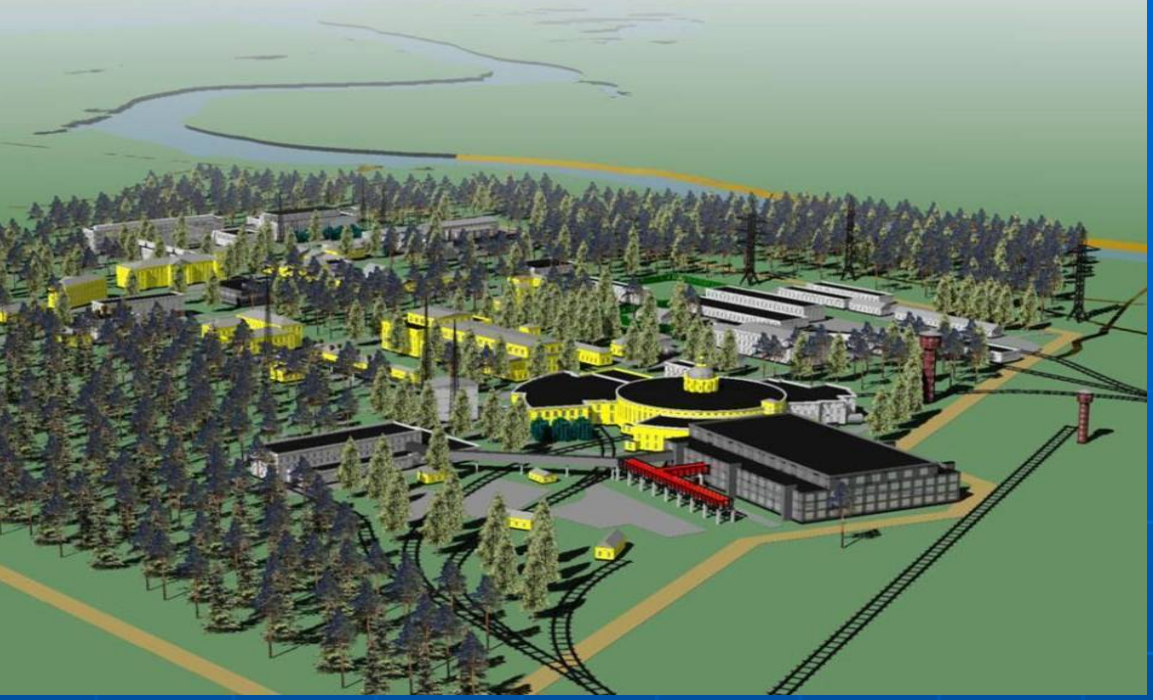
• **Stage 3: year 2014**

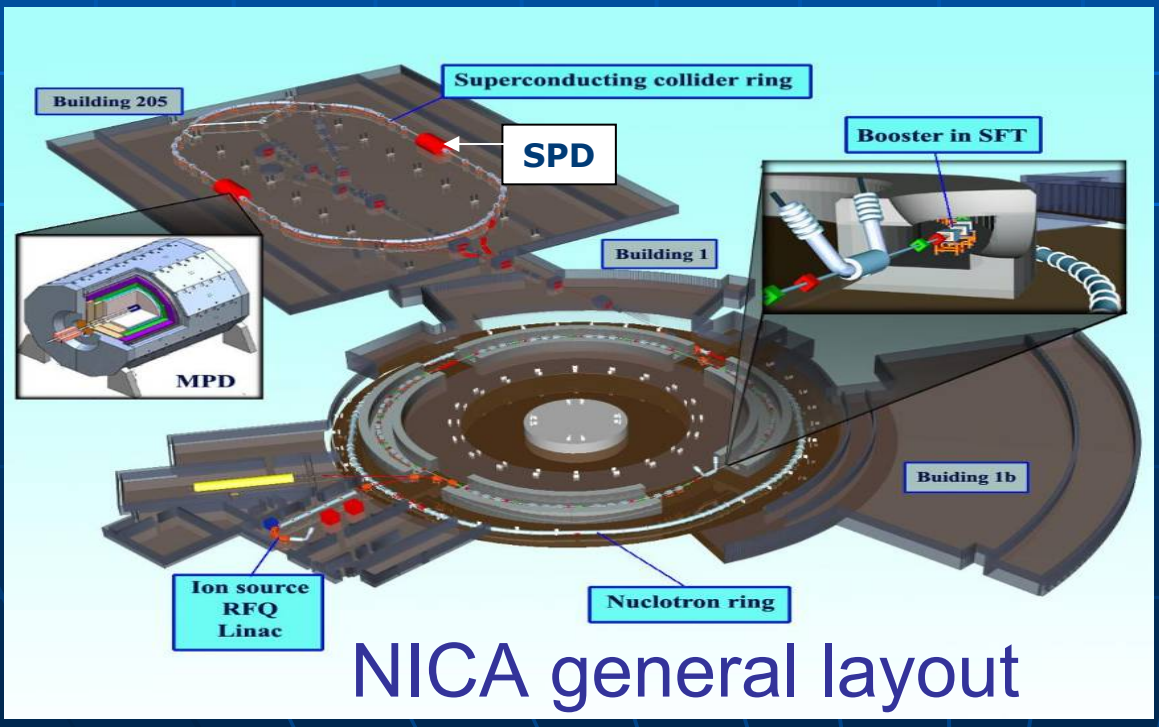
-Commissioning

• **Stage 4: year 2015**

- Operation

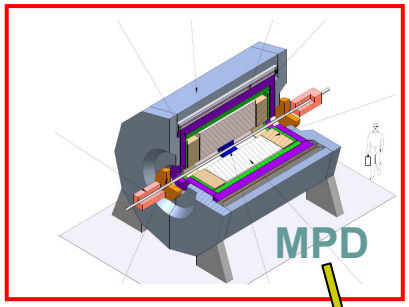


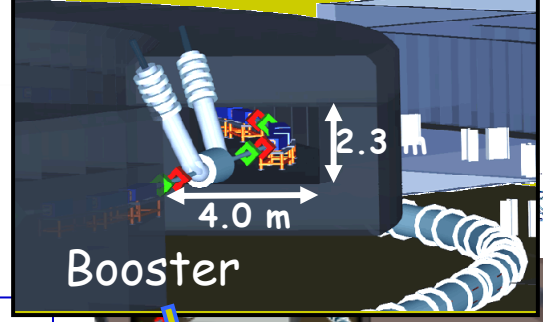




NICA general layout

NICA layout





Synchrophasotron yoke

Bldng 205

Collider
C = 251 m

Nuclotron

Spin Physics Detector (SPD)

Existing beam lines (solid target exp-s)

Krion & Linac

LU-20

Scheme of the NICA compex

Injector: 2×10^9 ions/pulse of $^{179}Au^{32+}$ at energy of 6 MeV/u

Booster (25 Tm)
1(2-3) single-turn injection, storage of 2 (4-6)$\times10^9$, acceleration up to 70 MeV/u, electron cooling, acceleration up to 640 MeV/u

Collider (45 Tm)
Storage of 17 (20) bunches $\times$ $1\cdot10^9$ ions per ring at 1÷4.5 GeV/u, electron and/or stochastic cooling

Stripping (80%) $^{197}Au^{32+} \Rightarrow {}^{197}Au^{79+}$

IP-1

Two superconducting collider rings

IP-2

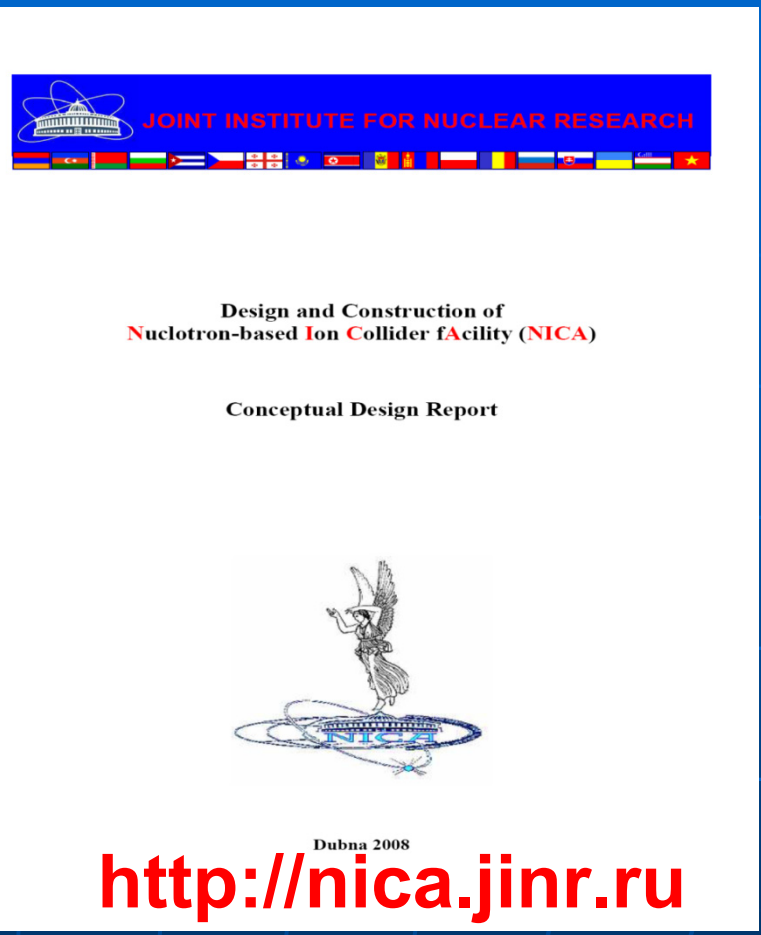
Nuclotron (45 Tm)
injection of one bunch of 1.1×10^9 ions, acceleration up to 1÷4.5 GeV/u max.

2x17 (20) injection cycles

Bunch compression (RF phase jump)

NICA Collaboration

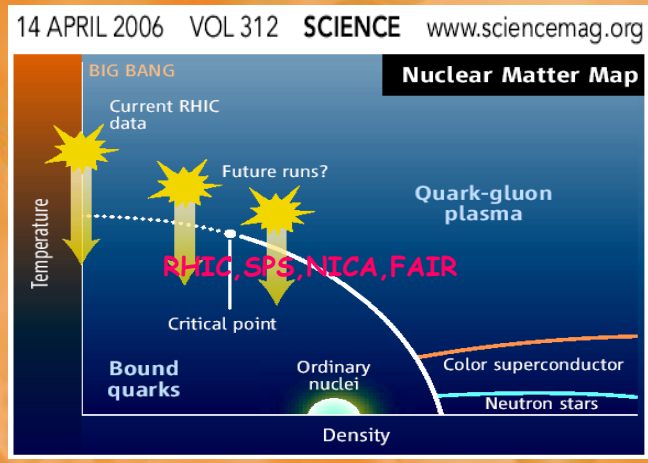
- **Joint Institute for Nuclear Research**
- **Institute for Nuclear Research Russian Academy of Science**
- **Institute for High Energy Physics, Protvino**
- **Budker Institute of Nuclear Physics, Novosibirsk**
- ***ITEP***
- All-Russian Institute for Electrotechnique
- Corporation “Powder Metallurgy”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



http://nica.jinr.ru

May 2009:
NICA TDR
is completed

II. Heavy ion physics at NICA



Early universe

Quarks and Gluons

Critical point?

Deconfinement and chiral transition

Mixed phase

Hadrons

RHIC, LHC

FAIR SIS 300

NICA

Neutron stars

Color Super-conductor?

N_B

Round Table Discussions I, II, III

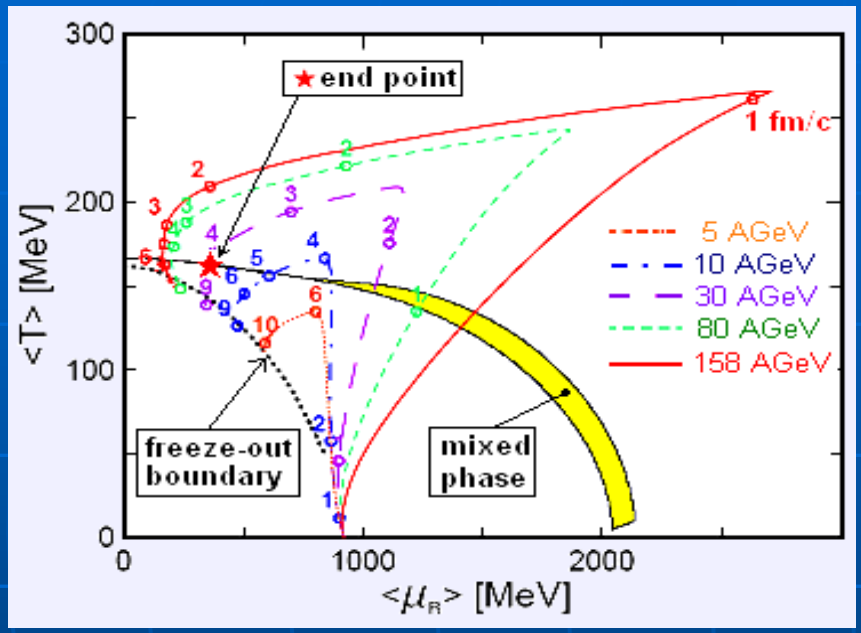
JINR, Dubna, 2005, 2006, 2008

http://theor.jinr.ru/meetings/2008/roundtable/

Phase Diagram

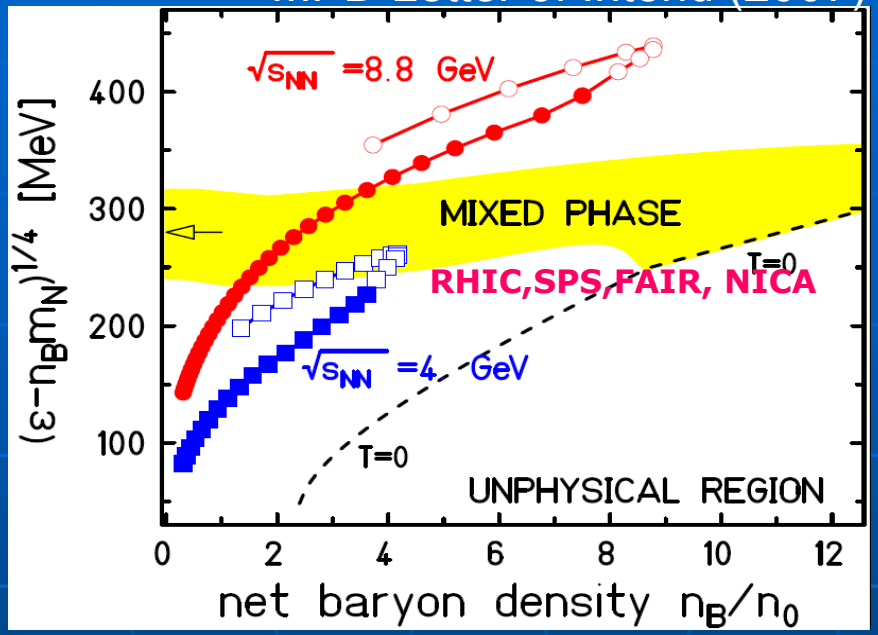
II

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



1

MPD Letter of Intend (2007)



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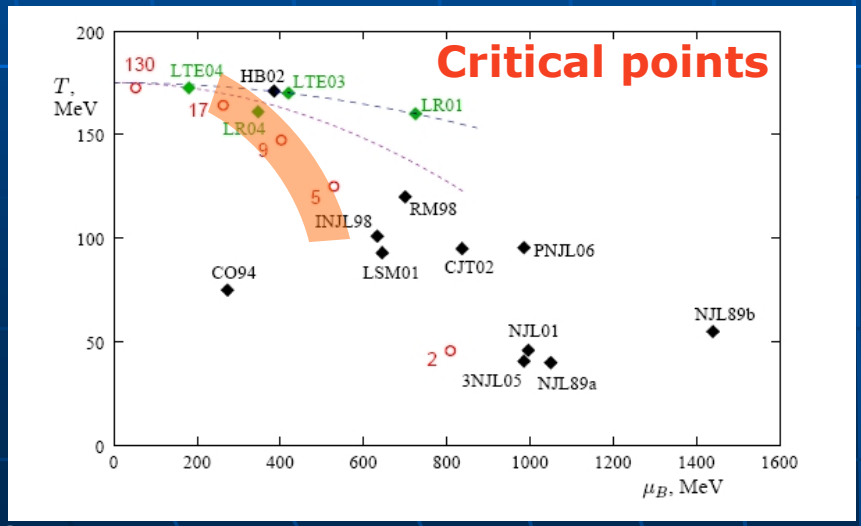
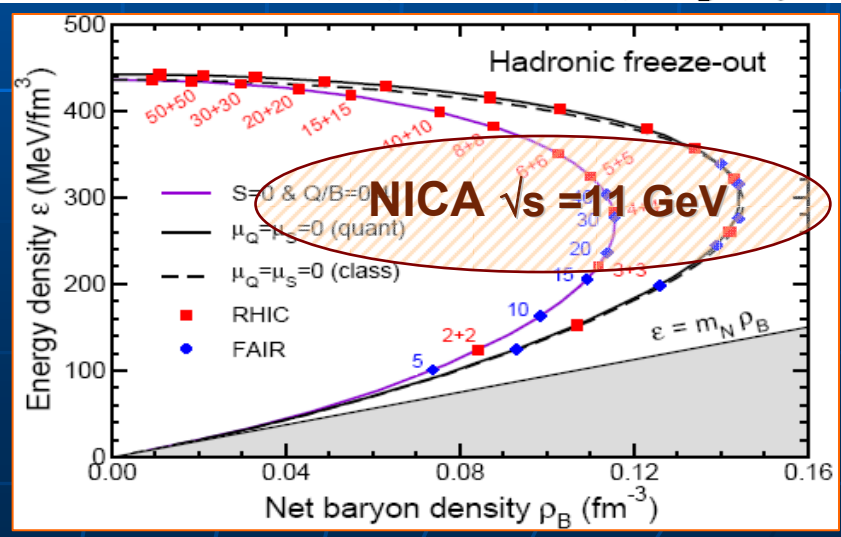


3

M.Stephanov, 2006



4

J.Randrup, J.Cleymans, 2006

The NICA Physics Program

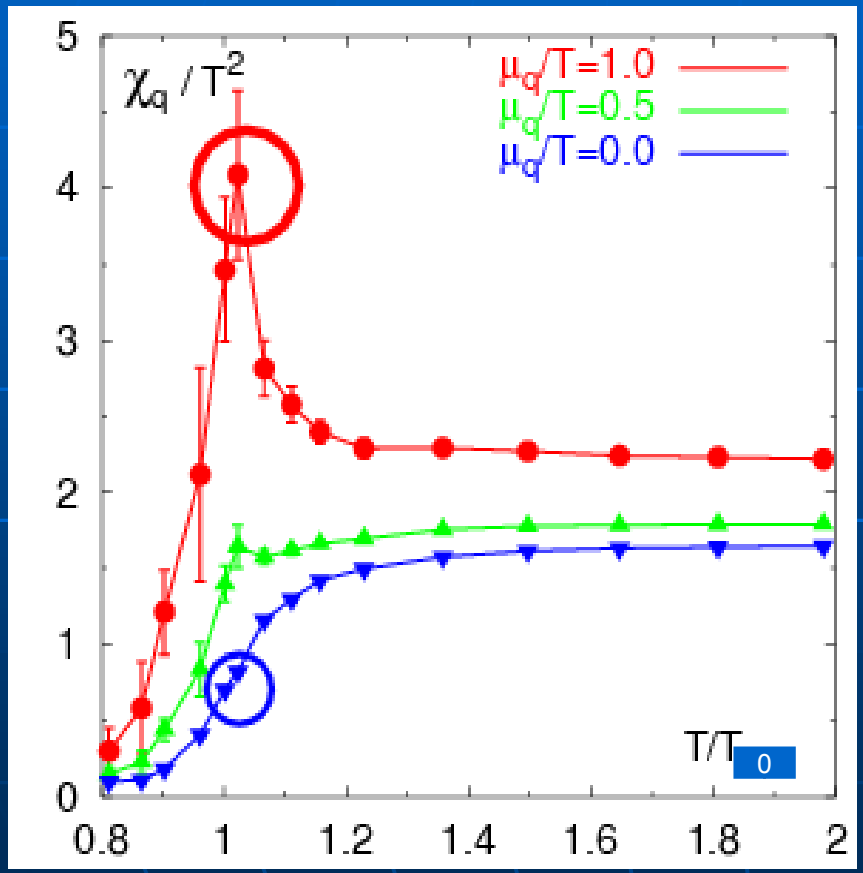
Study of in-medium properties of hadrons and nuclear matter equation of state including a search for possible signs of deconfinement and chiral symmetry restoration phase transitions and QCD critical endpoint

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 indentified hadrons
- particle correlations
- Dileptons and photons

Fluctuations

Lattice QCD predictions: Fluctuations of the quark number density (susceptibility) at μ_B >0 (C.Allton et al., 2003)



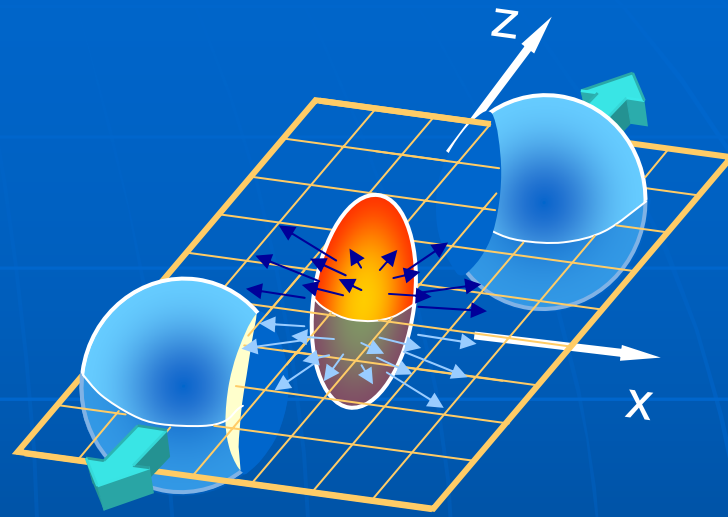
$$\frac{\chi_q}{T^2} = \left[\frac{\partial^2}{\partial (\mu_q / T)^2} \frac{P}{T^4} \right]_{T\ fixed}$$

χ_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



Non-central collisions

$$\frac{dN}{dy p_T dp_T d\varphi} = \frac{dN}{dy p_T dp_T}\frac{1}{2\pi}\left(1 + 2v_1\cos(\varphi) + 2v_2\cos(2\varphi) + \ldots\right)$$

directed flow

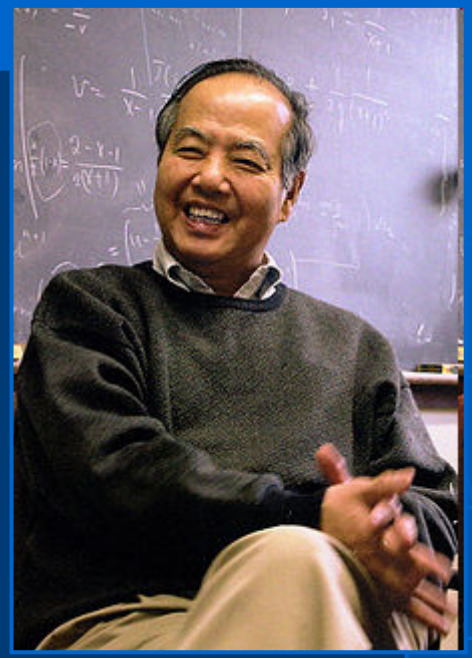
elliptic flow

Correlation femtoscopy of identical particles

$q = p_1 - p_2$, $\Delta x = x_1 - x_2$

$$C_2 = 1 + (-1)^S < Cos\ q\Delta x > \rightarrow 1 + \lambda \exp(-R^2_{long} q^2_{long} - R^2_{side} q^2_{side} - R^2_{out} q^2_{out} - 2R^2_{out} q_{out} q_{long})$$

Round Table Discussions I, *JINR, Dubna, 2005*
http://theor.jinr.ru/meetings/2005/roundtable/



From: "T.D. Lee" <tdl@phys.columbia.edu>
To: "Sisakian A.N." <sisakian@jinr.ru>
Sent: Wednesday, January 14, 2009 7:01 PM
Subject: Comment on the goals of the NICA heavy ion collider

Dear Prof. Sissakian:

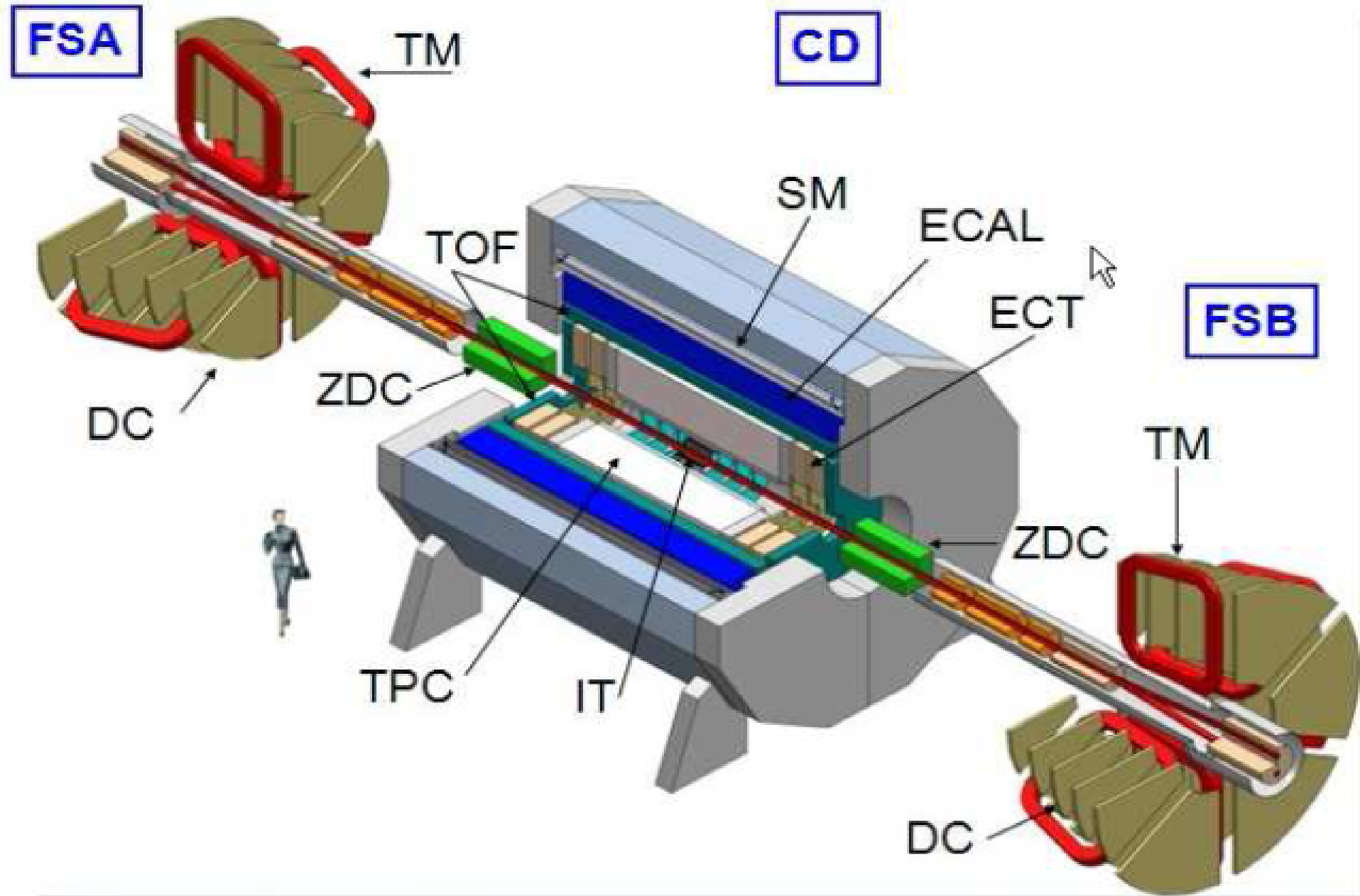
The NICA heavy ion collider will be a very major step towards the formation of a new phase of quark-gluon matter.

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

MPD conceptual design



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 Apllied Physics, Academy of Science Moldova
- …
- *Open for extension …*

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

Signed MoU with GSI in July

The MultiPurpose Detector – MPD

II

to study Heavy Ion Collisions at NICA
(Conceptual Design Report)

Project leaders: A.N. Sissakian, A.S. Sorin, V.D. Kekelidze

The MPD Collaboration:[1]

Kh.U.Abraamyan, S.V.Afanasiev, N.Anfimov, D.Arkhipkin, P.Zh.Aslanyan, V.A.Babkin, S.N.Basylev, D.Blaschke, D.N.Bogoslovsky, I.V.Boguslavski, V.V.Borisov, A.V.Butenko, V.V.Chalyshev, S.P.Chernenko, V.F.Chepurnov, V.F.Chepurnov, G.A.Cheremukhina, I.E.Chirikov-Zorin, D.E.Donetz, K.Davkov, V.Davkov, D.K.Dryablov, D.Dmitrojan, V.B.Dunin, L.G.Efimov, E.Egorov, D.D.Emeljanov, O.V.Fateev, Yu.I.Fedotov, V.M.Golovatyuk, N.V.Gorbunov, Yu.A.Gornushkin, A.V.Guskov, A.Yu.Isupov, V.N.Jejer, G.D.Kekelidze, V.D.Kekelidze, Yu.T.Kiryushin, V.Kizka, V.I.Kolesnikov, A.D.Kovalenko, R.Lednitsky, A.G.Litvinenko, E.I.Litvinenko, S.P.Lobastov, V.M.Lysan, J.Lukstins, V.M.Lutcenko, N.Krahotin, Z.V.Krumshtein, D.T.Madigozhin, A.I.Malakhov, I.N.Meshkov, V.V.Mialkovski, I.I.Migulina, N.A.Molokanova, S.A.Movchan, Yu.A.Murin, G.J.Musalmanbekov, V.A.Nikitin, A.G.Olchevski, V.F.Peresedov, D.V.Peshekhonov, V.D.Peshekhonov, I.A.Polenkevich, Yu.K.Potrebenikov, V.S.Pronskikh, S.V.Razin, O.V.Rogachevsky, A.B.Sadovsky, Z.Sadygov, A.A.Savenkov, S.V.Sergeev, B.G.Shchinov, A.V.Shabunov, A.O.Sidorin, A.N.Sissakian, I.V.Slepnev, V.M.Slepnev, T.M.Solovjeva, A.S.Sorin, O.V.Teryaev, V.V.Tichomirov, V.D.Tonsev, G.V.Trubnikov, I.A.Tyapkin, N.M.Vladimirova, S.V.Volgin, V.I.Yurevich, Yu.V.Zanevsky, A.I.Zinchenko, V.N.Zrjuev, R.Ya.Zulkarneev, Yu.R.Zulkarneeva
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K.K.Gudima, M.I.Baznat
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B.V.Grinyov
Institute for Scintillation Materials, Kharkov, Ukraine

V.N.Borshchov, O.M.Listratenko, M.A.Protsenko, I.T.Tymchuk
State Enterprise Scientific & Technology Research Institute for Apparatus construction, Kharkov, Ukraine

N.M.Shumeiko, F.Zazulia
Particle Physics Center of Belarusian State University

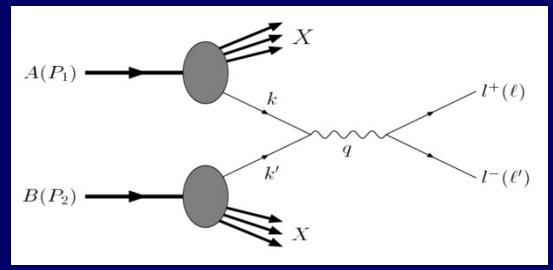
III. Spin Physics at NICA

EMC, 1987 $\Delta\Sigma = 0.12 \pm 0.17$

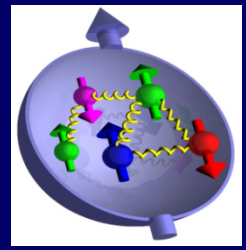
Polarization data has often been the graveyard for fashionable theories. If theorists had their way they might well ban such measurements altogether out of self-protection.

J.D. Bjorken, 1987

Preliminary topics:

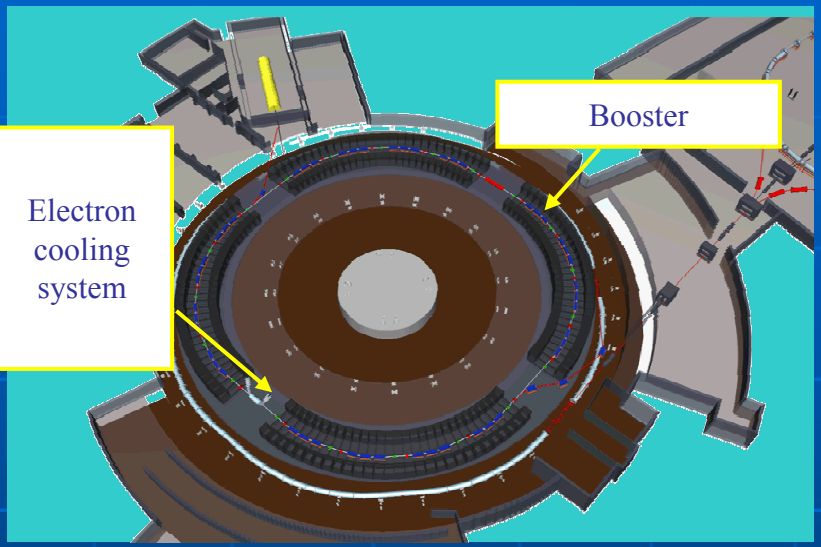


- *MMT-DY processes with L&T polarized p & D beams*: *extraction of unknown (poor known) PDF*
- *PDFs from J/y production processes*
- *Spin effects in baryon, meson and photon productions*
- *Spin effects in various exclusive reactions*
- *Diffractive processes*
- *Cross sections, helicity amplitudes & double spin asymmetries (Krisch effect) in elastic reactions*
- *Spectroscopy of quarkoniums with any available decay modes*
- *Polarimetry*



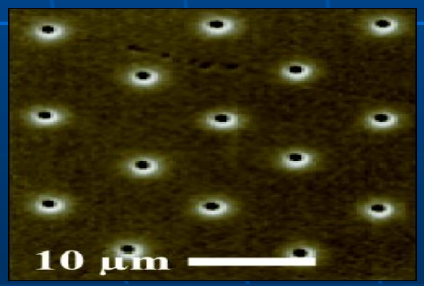
IV. Applied research at NICA

Booster-sinhrotron appliction to nanostructures creations:

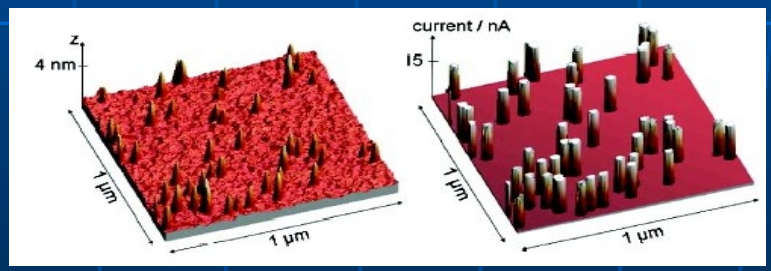


Design and parameters of booster, including wide accessible energy range, possibility of the electron cooling, allow to form dense and sharp ion beams. System of slow extraction provides slow, prolongated in time ion extraction to the target with space scanning of ions on the target surface and guaranty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

Ion-track technologies:



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.

Production of nanowires, filters, nanotransistors, ...

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
http://theor.jinr.ru/meetings/2009/roundtable/

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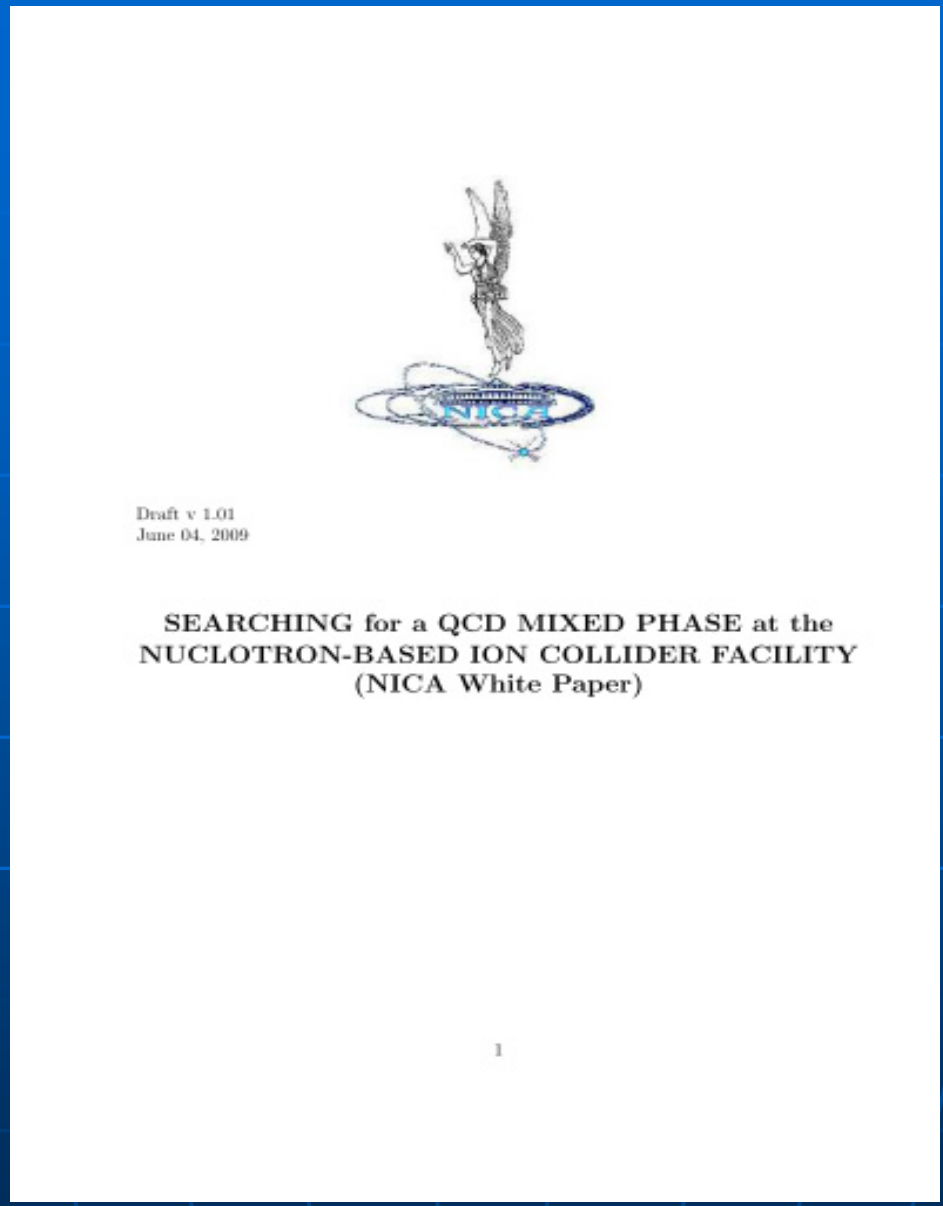
D. Kharzeev
A. Sissakian
A. Sorin
O. Teryaev
V. Toneev
I. Tserruya



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

List of authors (72)

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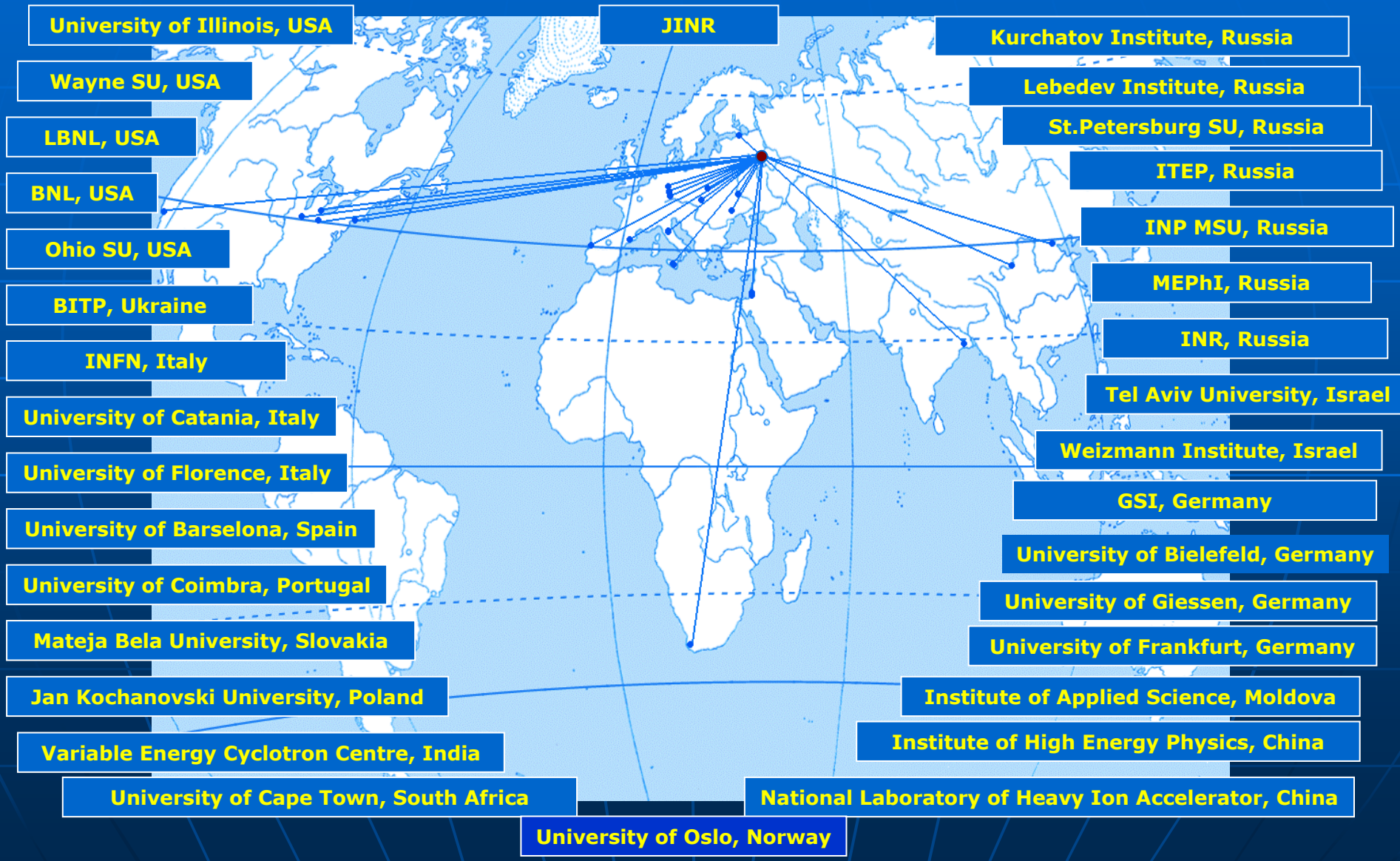
Almost all Russian speaking experts in the field of heavy ion collisions have contributed to the NICA White Paper

Institutes

33 scientific centers *in* **15 Countries (8 JINR members)**



International Coordinating Committee meeting on the NICA Project

Nuclotron-M Machine Advisory Committee and Honorary guests

Visit of the GSI director Prof. Stoecker to JINR

V

Visit of D.A.Medvedev to JINR 18.04.08

Президенту Российской Федерации
Д.А. Медведеву

Уважаемый Дмитрий Анатольевич!

Более 50 лет в г. Дубне Московской области работает Международная межправительственная научная организация - Объединенный институт ядерных исследований (ОИЯИ). В настоящее время государствами-членами ОИЯИ являются 18 стран. На основе отдельных соглашений в деятельности института принимают участие также ФРГ, Венгрия, Италия, Сербия и Южно-Африканская Республика.

Пр-697

Наличие в ОИЯИ развитой инфраструктуры, богатый опыт сотрудничества с ведущими российскими и зарубежными научными центрами обеспечили этой международной организации мировое лидерство в области физики тяжелых ионов низких энергий. В институте разработана и поддержана всеми государствами-членами концепция развития имеющейся ускорительной и реакторной базы до 2015 года. Она предусматривает ежегодное увеличение взносов стран-участниц в бюджет ОИЯИ.

Ключевым звеном этой концепции является создание новой крупной установки для исследований в области физики тяжелых ионов высоких энергий - комплекса NICA стоимостью около 5,5 млрд. рублей. Осуществление этого проекта позволит развернуть широкую программу фундаментальных физических исследований в области недоступных на сегодняшний день энергий и масс взаимодействующих частиц, что позволит России стать лидером в этой области.

Обращаемся к Вам, уважаемый Дмитрий Анатольевич, с просьбой:

- поддержать со стороны Российской Федерации намеченные ежегодные взносы в бюджет ОИЯИ на период до 2015 года;
- рассмотреть возможность целевого финансирования проекта NICA в рамках Федеральной программы фундаментальных научных исследований на 2008-2012 годы.

Губернатор
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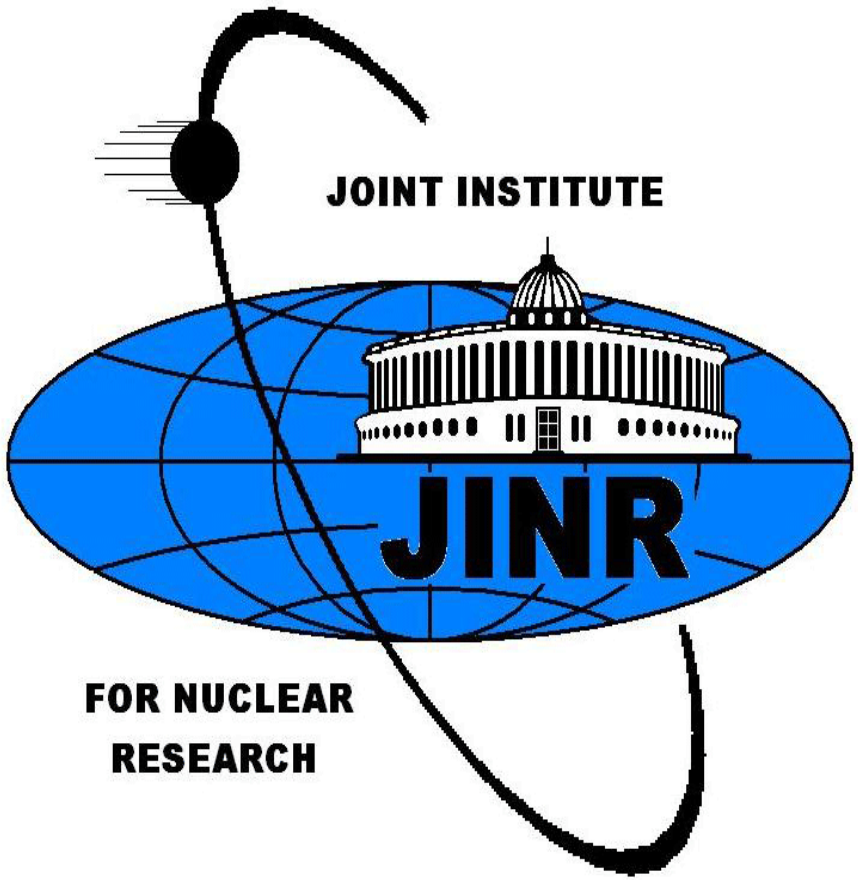
Welcome to the collaboration!



Thank you for attention!