

# Joint Institute for Nuclear Research International Intergovernmental Organization



The **Nu**clotron-based **I**on **C**ollider **f**Acility at the Joint Institute for Nuclear Research:  
new Prospects for Heavy Ion Collisions and Spin Physics

A.N.Sissakian, A.S. Sorin



*Fourth International Sakharov Conference on Physics  
LPI RAS, Moscow, May 18-23, 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  $\sqrt{s_{NN}} = 9$  GeV and average luminosity  $10^{27} \text{ cm}^{-2} \text{ s}^{-1}$  (for  $\text{U}^{92+}$ ), and polarized proton beams with energy  $\sqrt{s} \sim 25$  GeV and average luminosity  $> 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$
- design and construction of the MultiPurpose Detector (MPD)

# The NICA Project Milestones

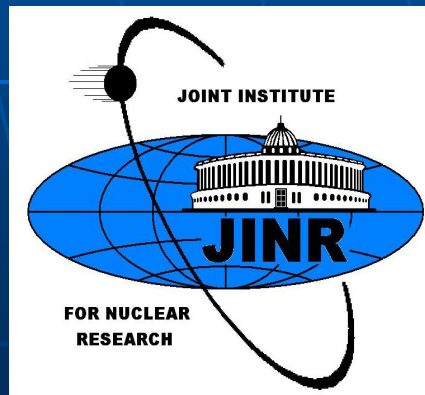
I

- **Stage 1: years 2007 – 2009**

- Upgrade and Development of the Nuclotron
- 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



# **The Basic Conditions for the Project Development**

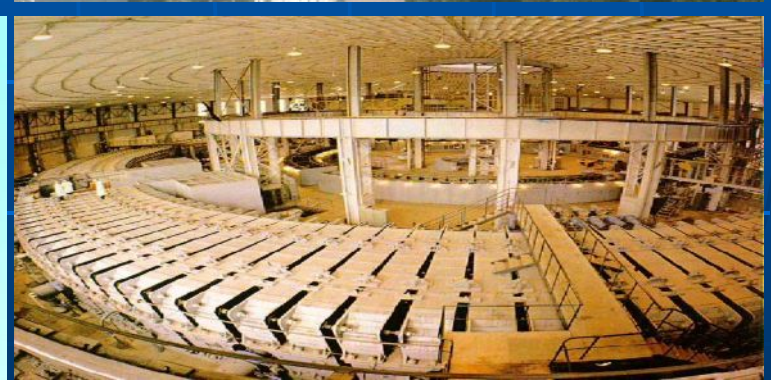
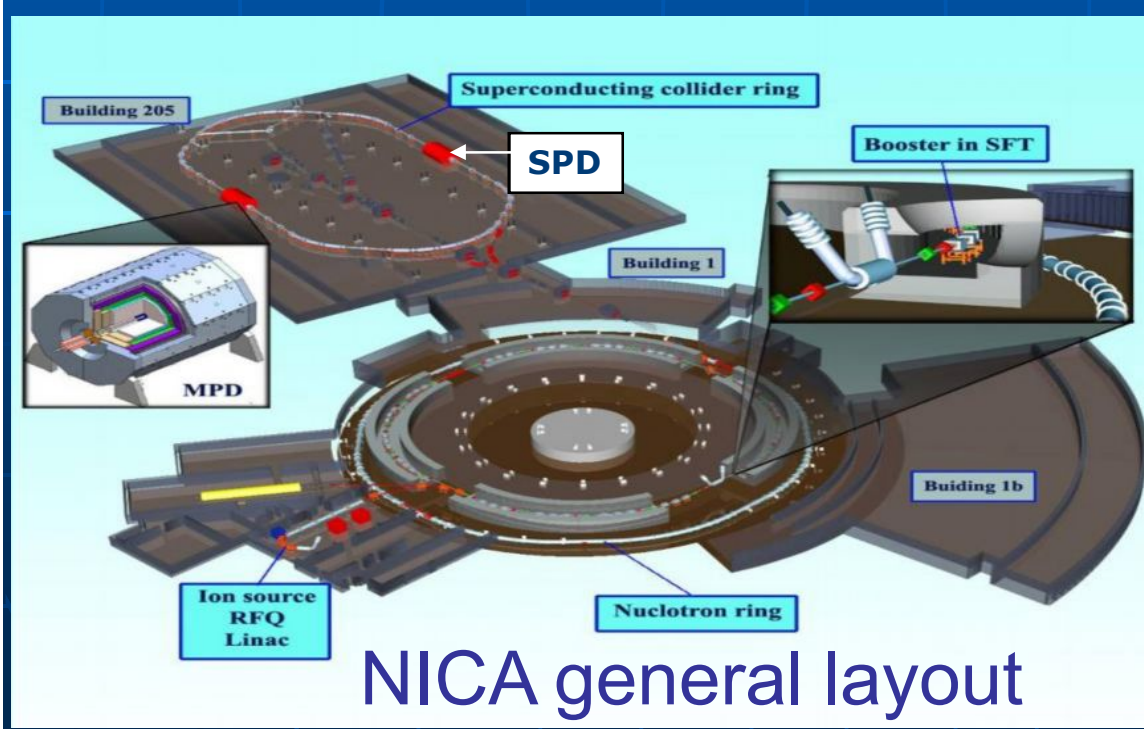
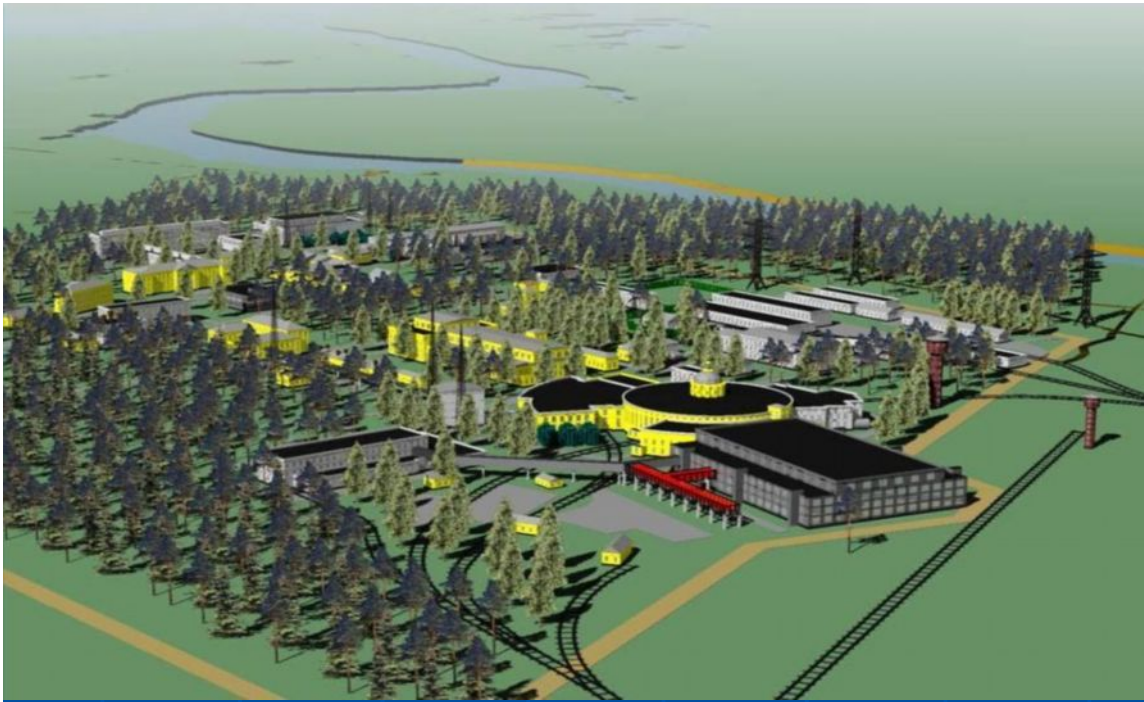
I

1. Minimum of R & D
2. Application of existing experience
3. Co-operation with experienced research centers
4. Cost: as low as possible
5. Realization time: 6 – 7 years

## **Consequences**

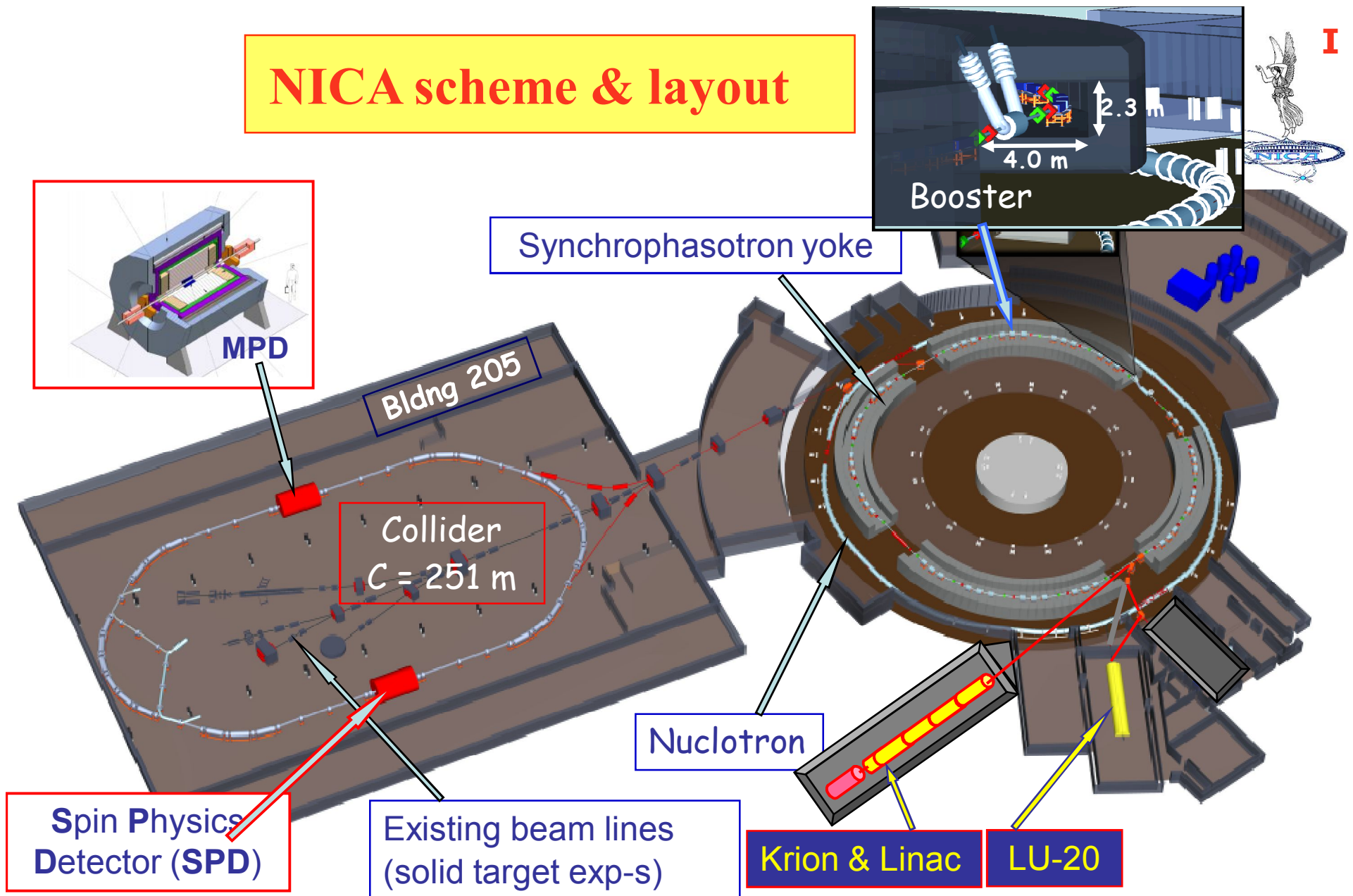
1. Choice of an existing building for dislocation of the collider
2. Collider circumference is limited by  $\sim 250$  m





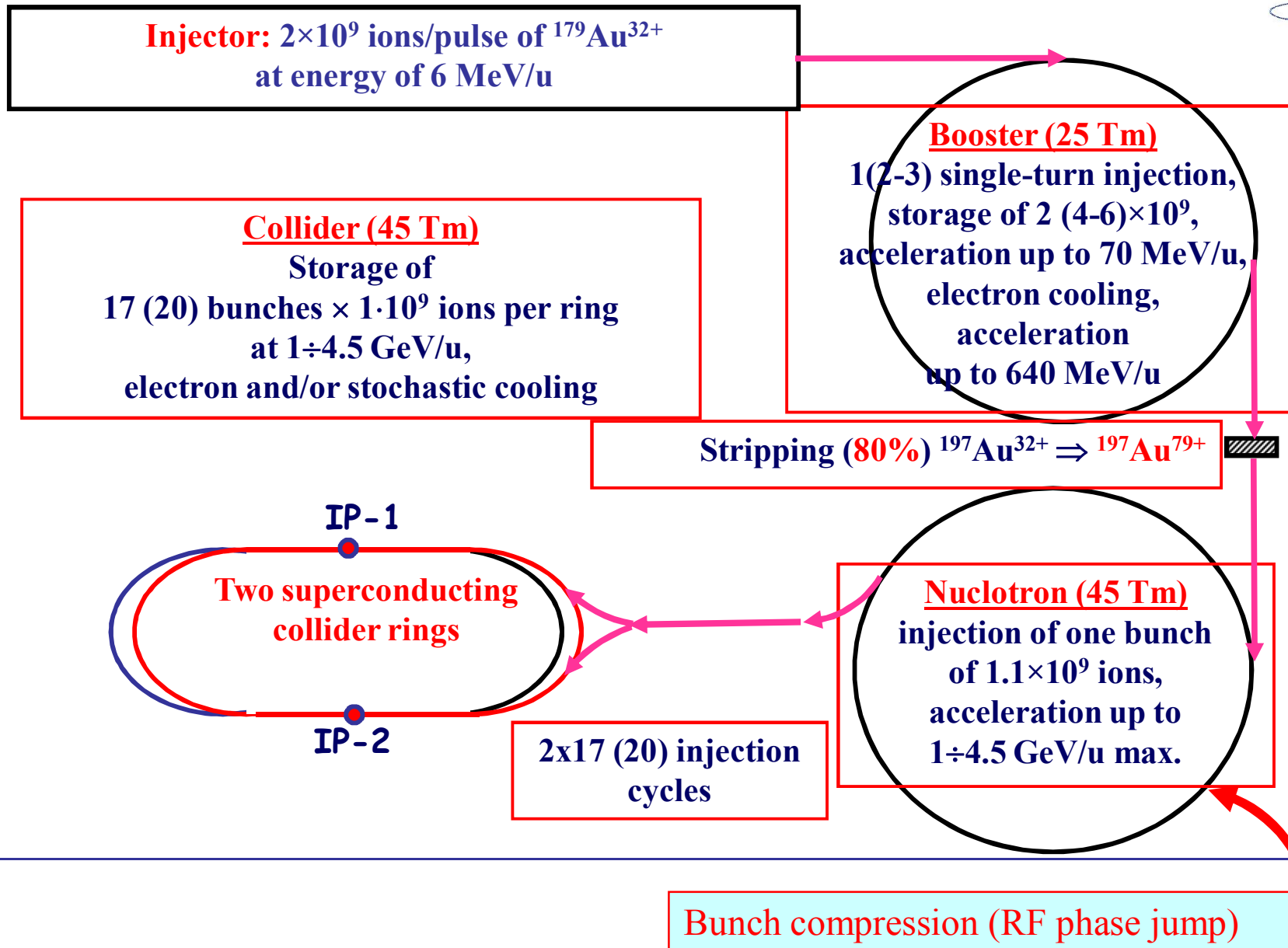


# NICA scheme & layout



# Scheme of the NICA complex

I





# NICA Collaboration

I

- 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
- MoU with GSI
- *Open for extension ...*



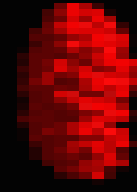
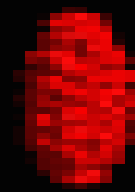
Design and Construction of  
Nuclotron-based Ion Collider fAcility (NICA)

Conceptual Design Report

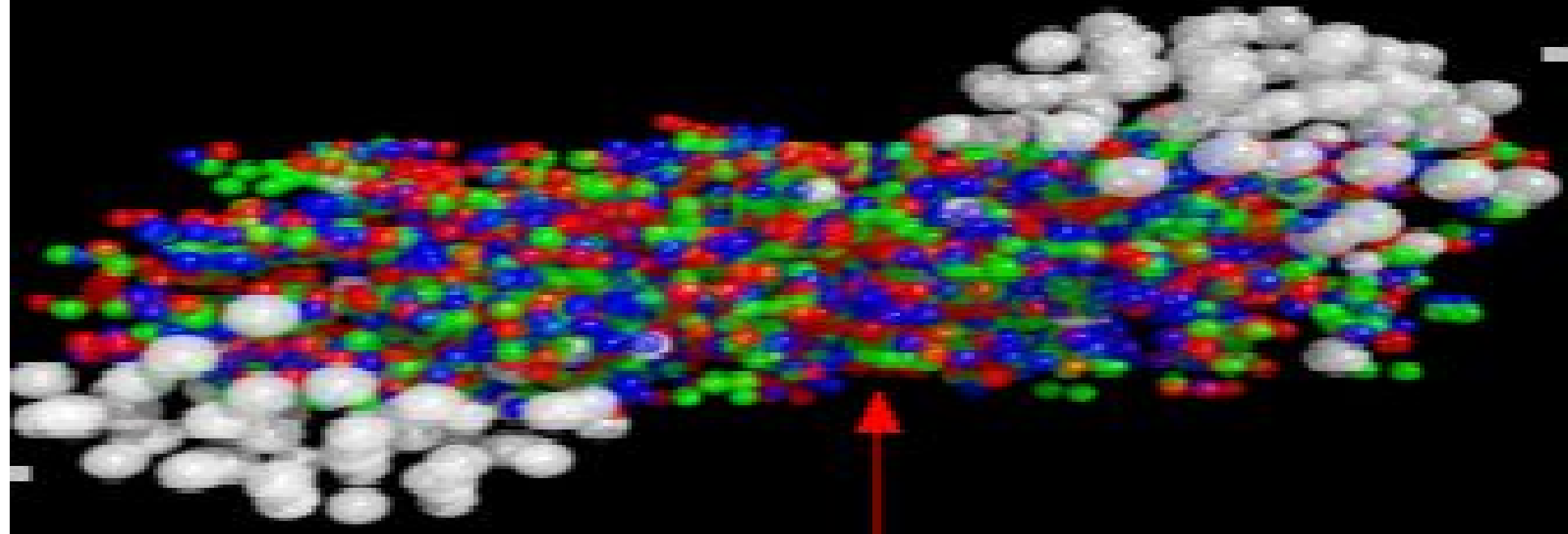


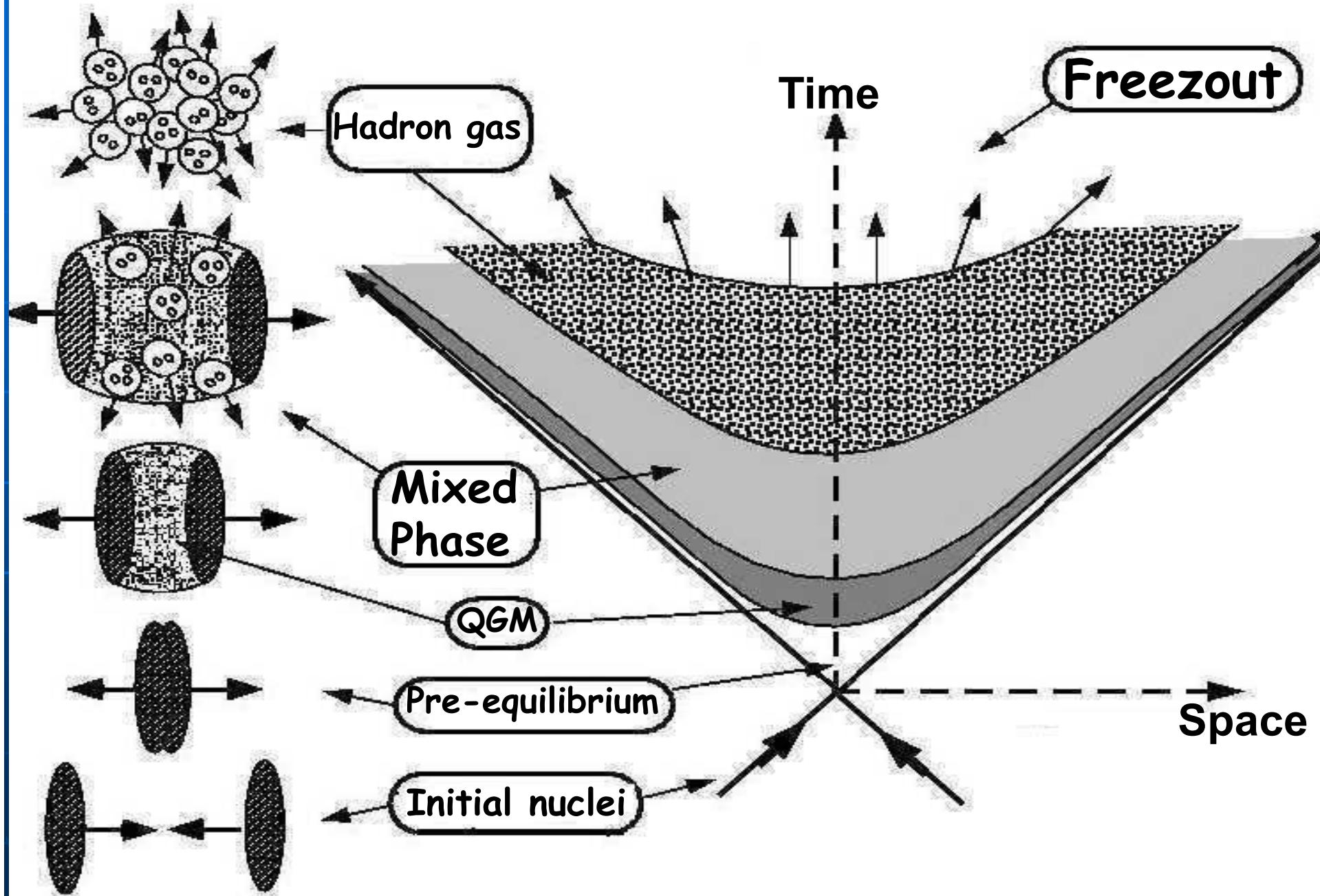
Dubna 2008

<http://nica.jinr.ru>

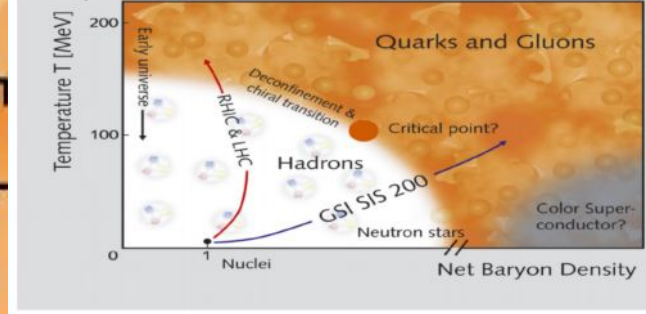


2019/07/06/2019



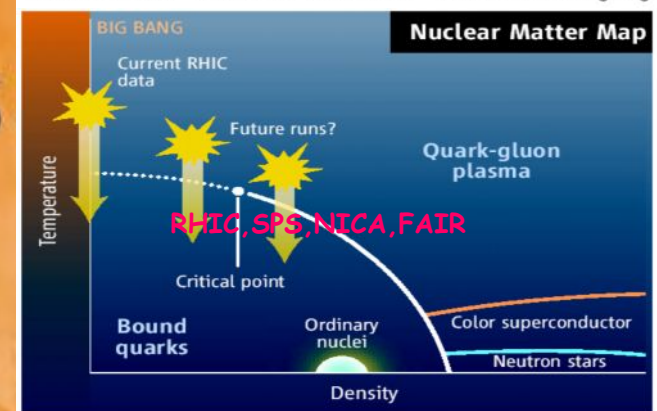






## II. Heavy ion physics at NICA

14 APRIL 2006 VOL 312 SCIENCE www.sciencemag.org



Quarks  
and Gluons

Critical point?

Hadrons

Deconfinement and chiral transition

Mixed phase

Round Table Discussions I, II, III

JINR, Dubna, 2005, 2006, 2008

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

Neutron stars

Color Super-conductor?

$N_B$



## MPD Letter of Intend (2007)



*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

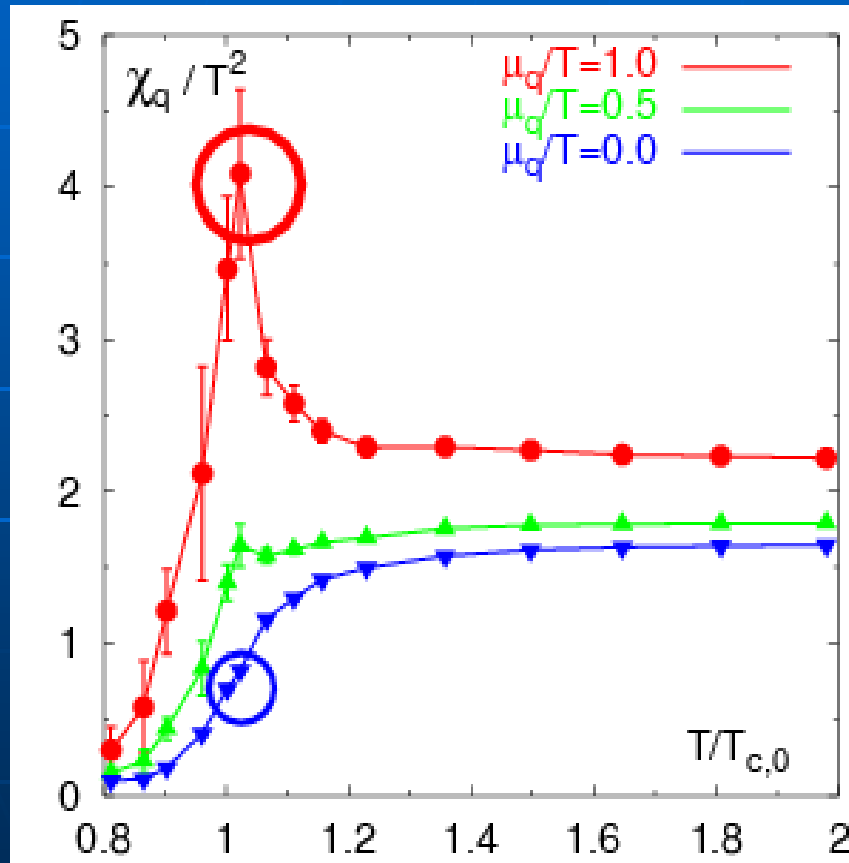
- ♣ Multiplicity and global characteristics of identified hadrons including **(multi)strange** particles
  - ♣ Fluctuations in multiplicity and transverse momenta
  - ♣ Directed and elliptic flows for various identified hadrons
    - ♣ particle correlations
    - ♣ Dileptons and photons



# Fluctuations



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



$$\frac{\chi_q}{T^2} = \frac{1}{T^2} \frac{\partial^2 P}{\partial \mu_q^2} \bigg|_{T_{fixed}}$$

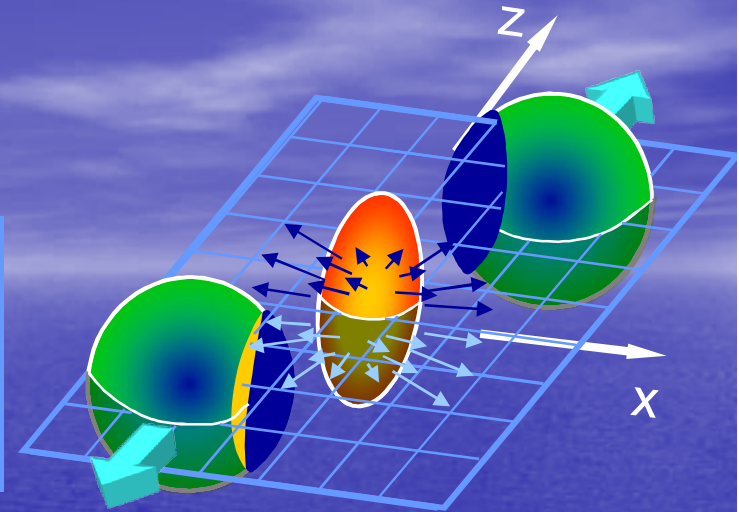
←  $\chi_q$  (quark number density fluctuations) will diverge at the critical end point

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



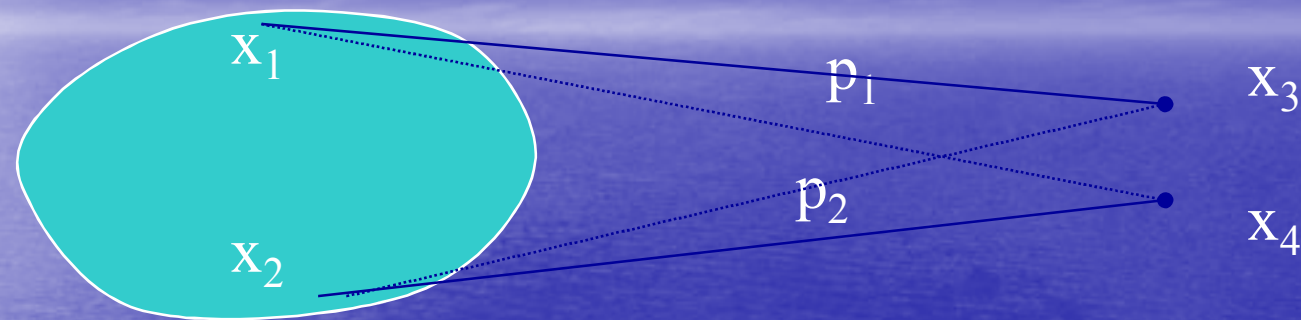
Non-central collisions

$$\frac{dN}{dy_T dp_T d} = \frac{dN}{dy_T dp_T} \frac{1}{2p} \left[ 1 + 2v_1 \cos(\phi) + 2v_2 \cos(2\phi) + \dots \right]$$

directed  
flow

elliptic  
flow

# Correlation femtoscopy of identical particles

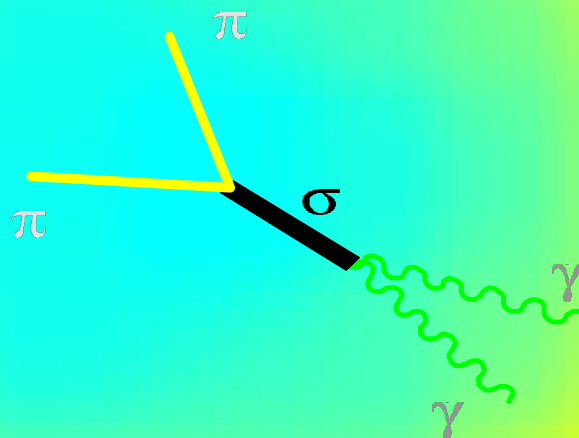


$$q = p_1 - p_2, \quad x = x_1 - x_2$$

$$C_2 = 1 + (-1)^S \langle \cos q \Delta x \rangle \rightarrow 1 + \lambda \exp(-R_{long}^2 q_{long}^2 - R_{side}^2 q_{side}^2 - R_{out}^2 q_{out}^2 - 2R_{out}^2 q_{out} q_{long})$$



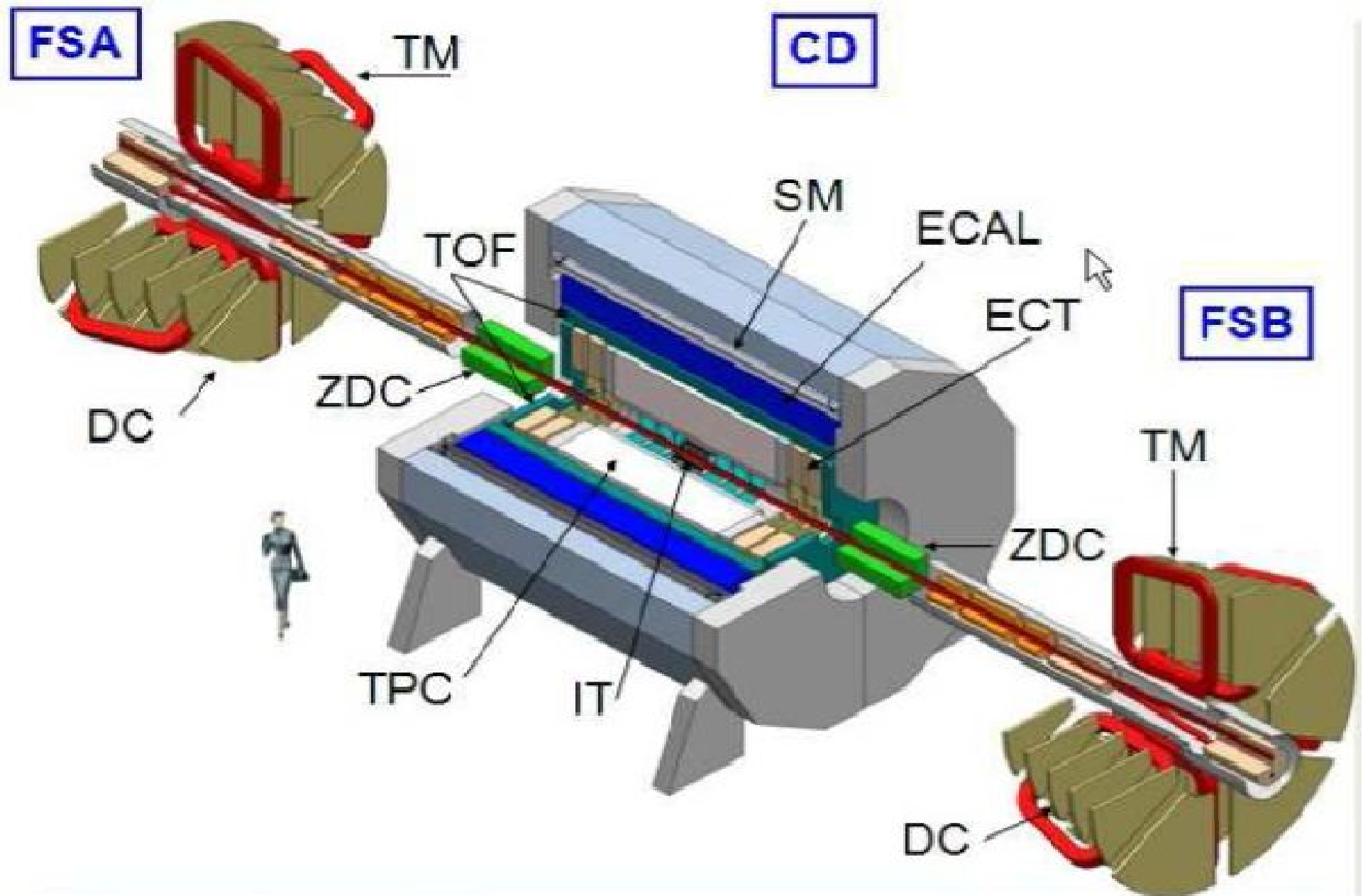
# Signals of chiral symmetry restoration

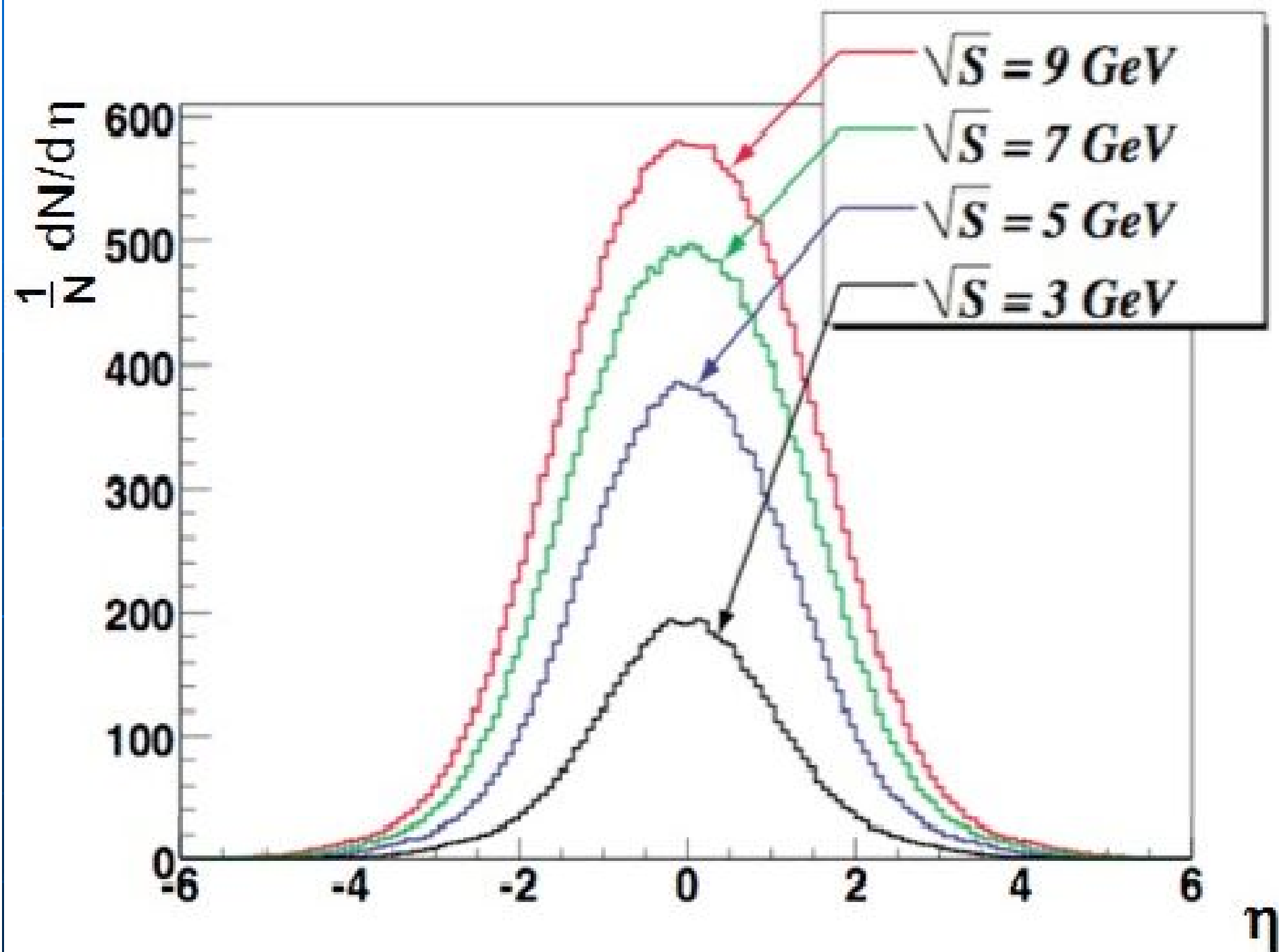


Round Table Discussions I, *JINR, Dubna, 2005*  
<http://theor.jinr.ru/meetings/2005/roundtable/>

# MPD conceptual design

II







# MPD Collaboration



- 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.*

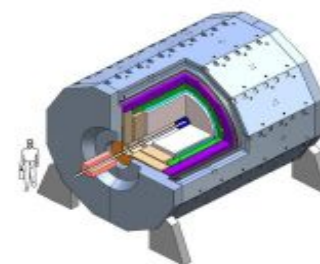
**Signed MoU with GSI in July 2008**



Version 1

The **MultiPurpose Detector (MPD)**  
to study Heavy Ion Collisions at NICA

*Letter of Intent*



Dubna, 2008

<http://nica.jinr.ru>

# III. Spin Physics at NICA

EMC, 1987

0.12 0.17

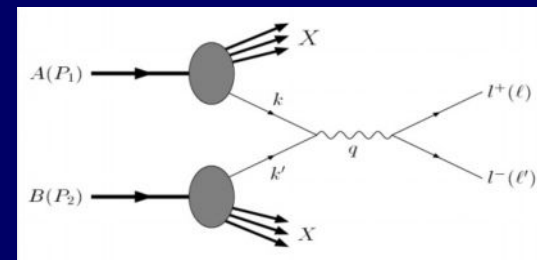


Polarization data has often been the graveyard for fashionable theories. If theorists had their way they might well ban such measurements altogether out of self-protection.

*J.D. Bjorken, 1987*

## Preliminary topics:

- Drell-Yan processes with L&T polarized  $p$  &  $D$  beams: extraction of unknown (poor known) PDF
- PDFs from  $J/\psi$  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



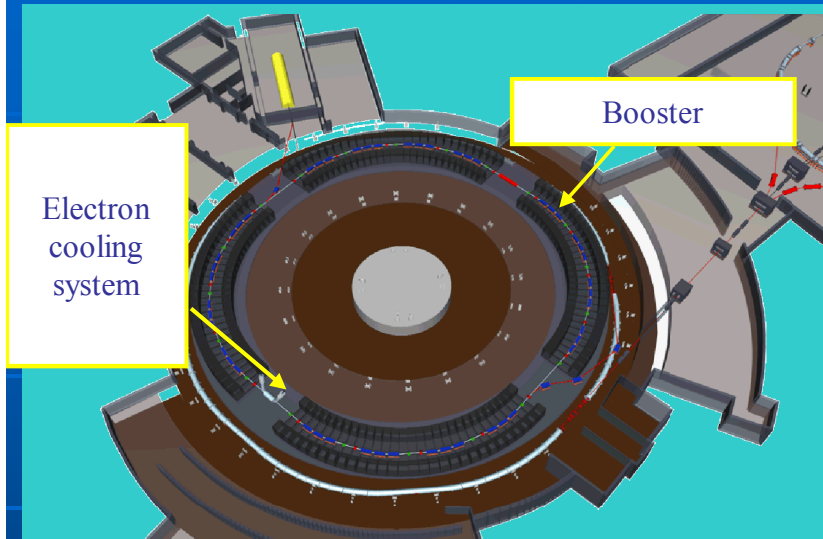
# Experiments on Drell-Yan measurements



Experiment	Status	Remarks
E615	Finished	Only unpolarized DY
NA10	Finished	Only unpolarized DY
E886	Running	Only unpolarized DY
RHIC	Running	Detector upgrade for DY measurements (collider)
PAX	Plan > 2016	Problem with $\bar{p}$ polarization (collider)
COMPASS	Plan > 2010	Only valence PDFs
J-PARC	Plan > 2011	low $s$ (60-100 GeV <sup>2</sup> ), only unpolarized proton beam
SPASCHARM	Plan?	$s \sim 140$ GeV <sup>2</sup> for unpolarized proton beam
NICA	Plan 2014	$s \sim 670$ GeV <sup>2</sup> for polarized proton beams, high luminosity (collider)

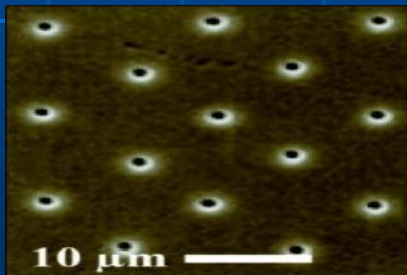
# IV. Applied research at NICA

## Booster-synchrotron application to nanostructures creations:

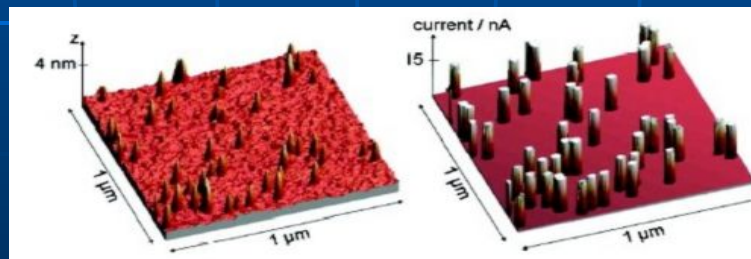


Design and parameters of booster, including wide accessible energy range, possibility of the electron cooling, allow to form dense and sharp ion beams. System of slow extraction provides slow, prolonged in time ion extraction to the target with space scanning of ions on the target surface and guaranty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

## Ion-track technologies:



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, ...



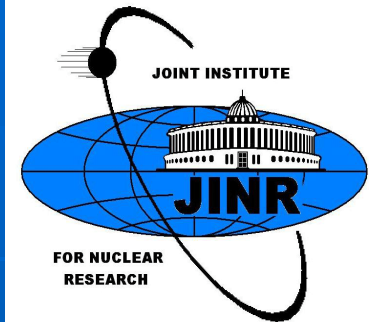
# V. Concluding remarks

## 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/>

## **Draft Contributions to the NICA White Paper (last update: May 14, 2009)**

Jorgen Randrup, "Searching for evidence of spinodal decomposition"

Igor Dremin and Andrey Leonidov, "Some issues in NICA-related research at LPI"

Michael Lisa, "Brief arguments for studying Azimuthally Sensitive HBT (asHBT)"

Mark Gorenstein, "Event-by-event fluctuations in nucleon-nucleus collisions"

Alexei Stavinskiy, "The study of dense cold nuclear matter with cumulative trigger"

Marek Gazdzicki, "MPD at the JINR NICA in the landscape of heavy ion projects"

Vitaly Okorokov, "Physics at NICA MPD: Particle Correlations"

Dmitry Voskresensky, "Search for manifestation of medium effects in dense excited hadron/quark matter"

Kyrill Bugaev, "Rigorous Investigation of Surface Tension and Finite Width of the QGP Bags at NICA Energies"

Yuri Ivanov, "Supercooled Quark-Gluon Phase?"

Alexander Andrianov, Vladimir Andrianov and Domenec Espriu, "Spontaneous P-violation in dense matter accessible with NICA"

A.B. Kaidalov, "New forms of QCD matter and cumulative processes"

Bedanga Mohanty, "Experimental advantages of collider over fixed target"

Francesco Becattini, "Chemical freeze-out and strangeness production study at NICA"

M. Di Toro, V. Greco, B. Liu, S. Plumari, "Isospin Effects on Phase Transitions of Hadronic to Quark Matter: a Proposal for the NICA Project"

Jean Cleymans and Jorgen Randrup, "Optimal conditions for exploring high-density baryonic matter"

Richard Lednicky, "Femtoscopic search for the 1-st order phase transition"

Boris Tomasik, "Hadronic signals of non-equilibrium phase transition"

E.L. Bratkovskaya and W. Cassing, "Observables and open problems for NICA"

Spin physics at NICA

Nu Xu, "Comments Mixed Phase Physics"

G.I. Lykasov, A.N. Sissakian, A.S. Sorin, O.V. Teryaev, "Complementarity and duality in heavy-ion collisions"

E. Levin, "My several thoughts on NICA"

A.V. Efremov, O.V. Teryaev, V.D. Toneev, "Polarization effects in heavy ions collisions at NICA"

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

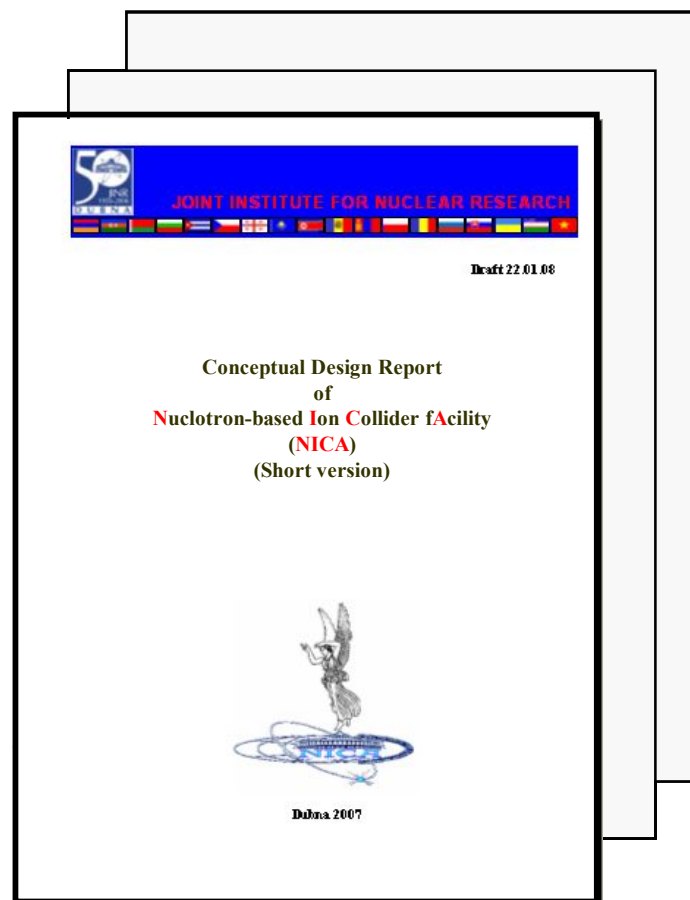


# Development of the NICA Concept and TDR

January 2008



January 2009



**May 2009:  
NICA TDR  
&  
MPD CDR  
to be completed**

# International Coordinating Committee meeting on the NICA Project V



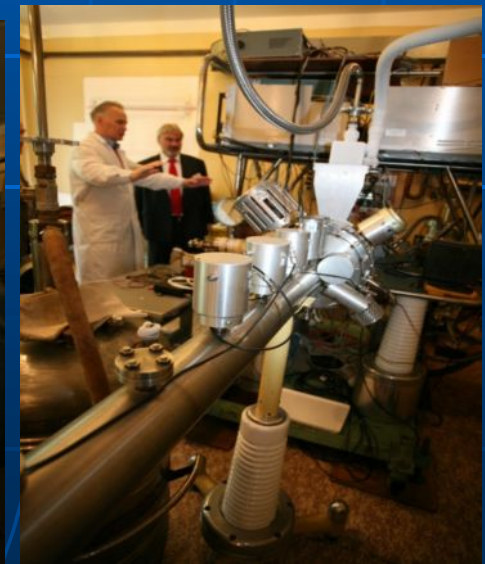


## Nuclotron-M Machine Advisory Committee and Honorary guests



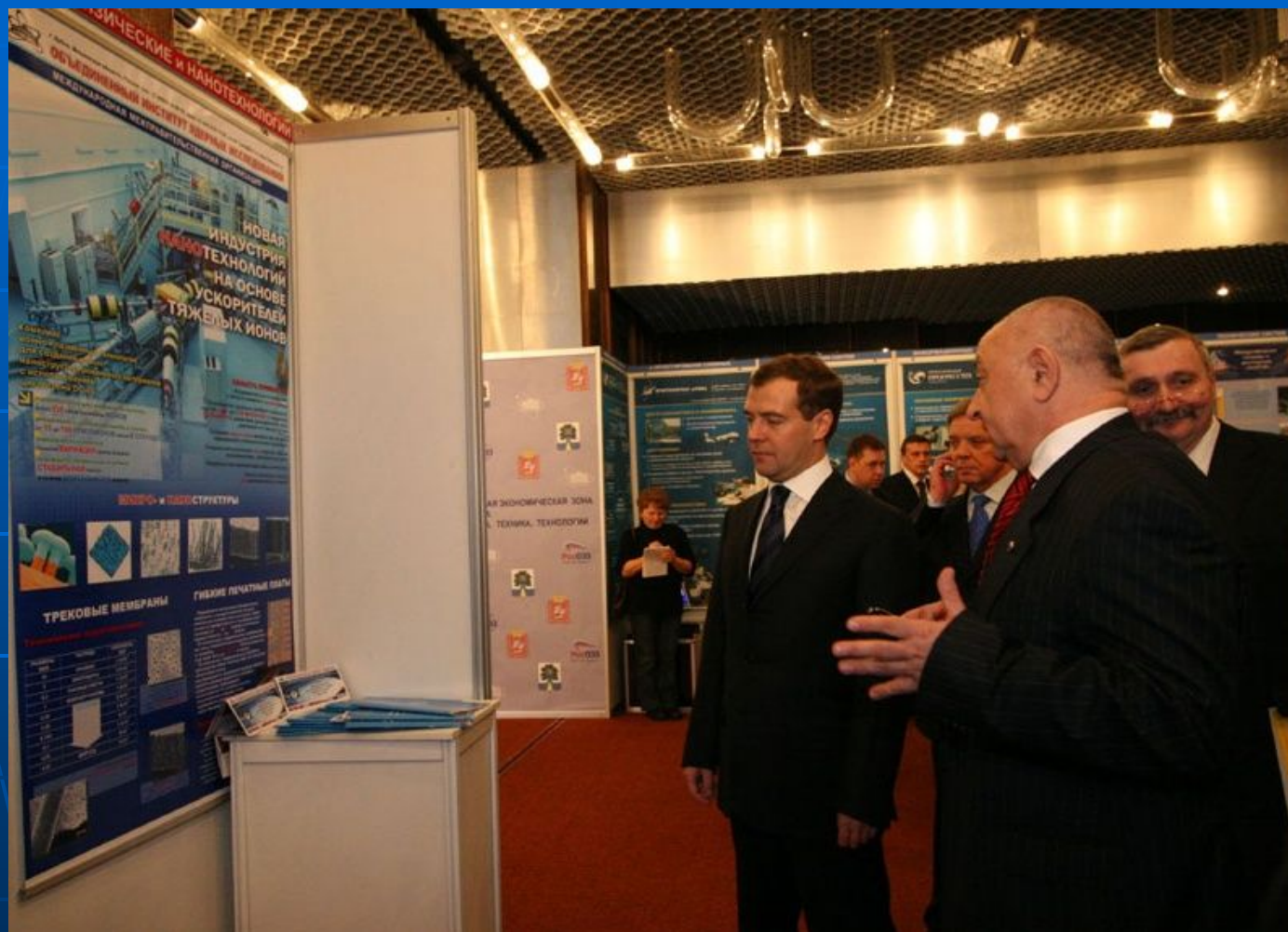
# Visit of the GSI director Prof. Stoecker to JINR

V

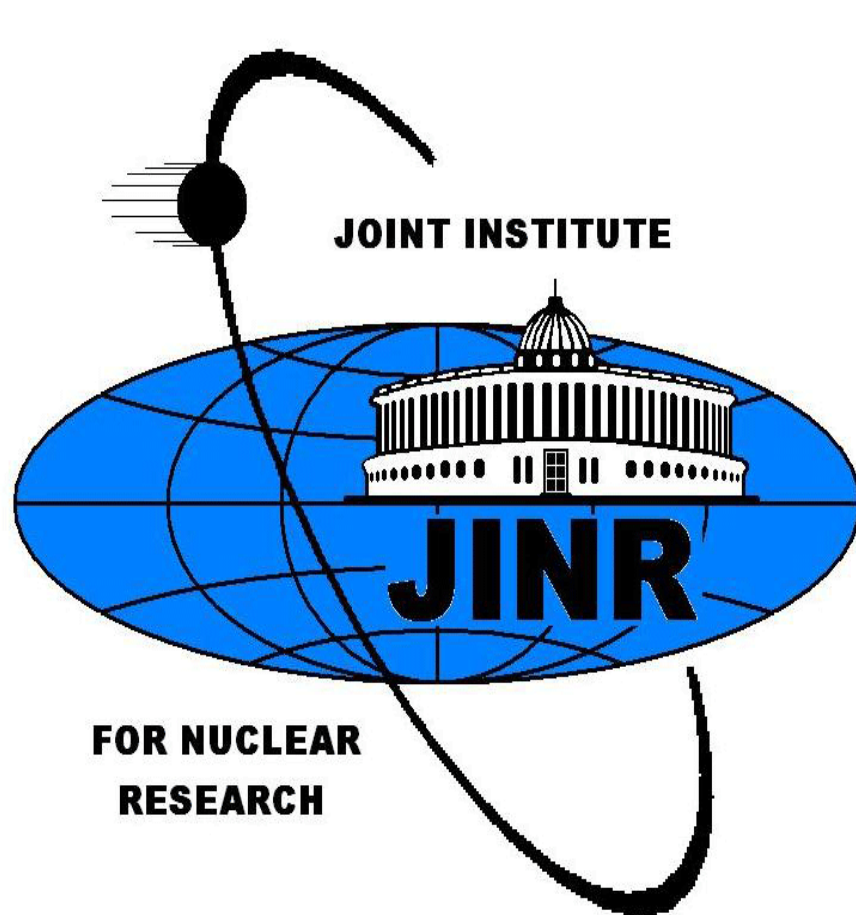




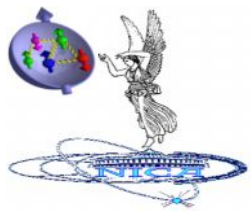
# Visit of D.A.Medvedev to JINR 18.04.08



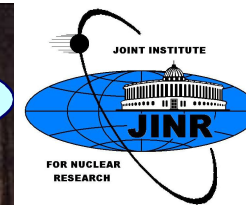
# Welcome to the collaboration!







**Thank you for attention!**



**N  
I  
C  
A  
M  
P  
D**

