



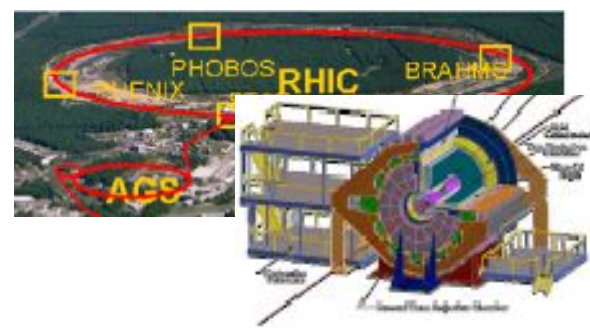
Status of the NICA Project at JINR

V. Kekelidze, A. Kovalenko, R. Lednicky, V. Matveev,
I. Meshkov, A. Sorin, G. Trubnikov
(for the NICA/MPD collaboration)

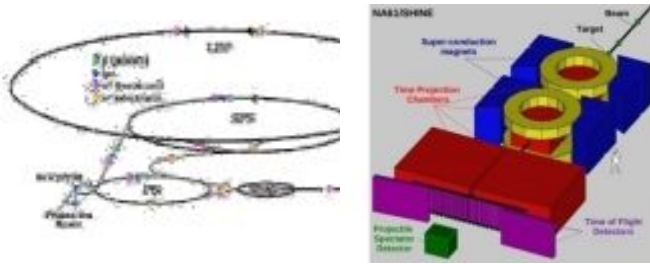


2nd generation HI experiments

BES STAR/PHENIX@BNL/RHIC



NA61@CERN/SPS



3rd generation HI experiments

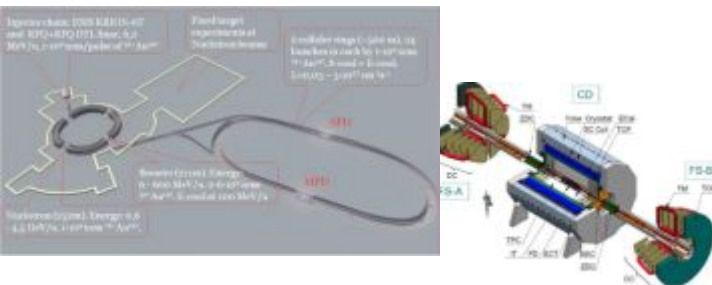
CBM@FAIR/SIS-100/300

Fixed target, $E/A=10-40$ GeV, highest intensity



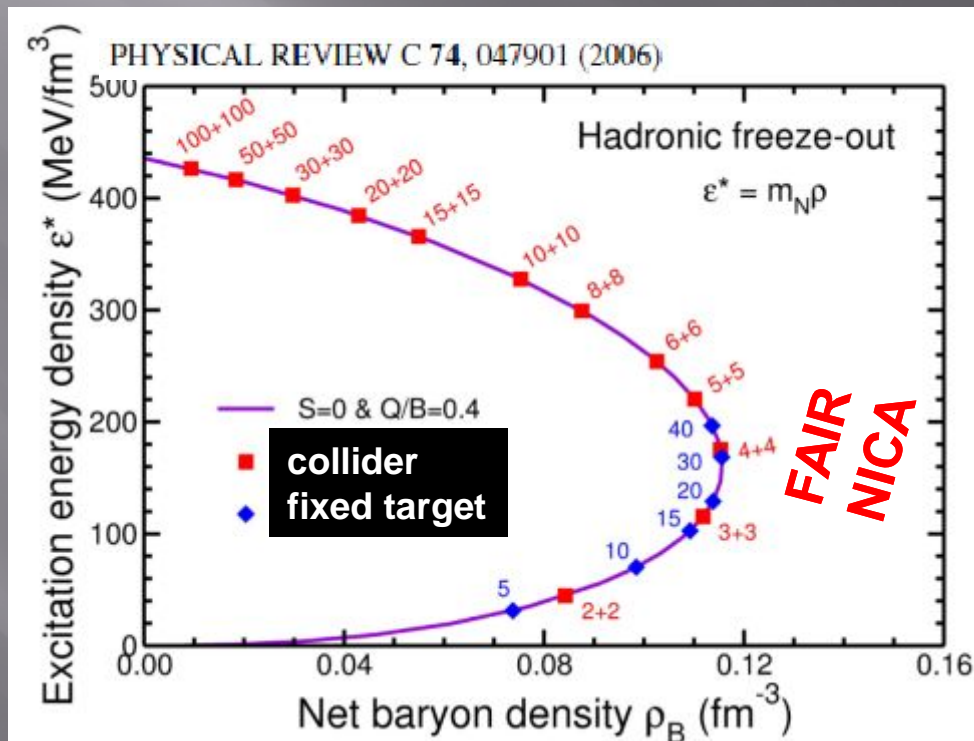
MPD@JINR/NICA

Collider, $\sqrt{s_{NN}} = 4-11$ GeV, $L \sim 10^{27}$ cm⁻²s⁻¹ for Au⁷⁹⁺



Highest baryon density at Lab

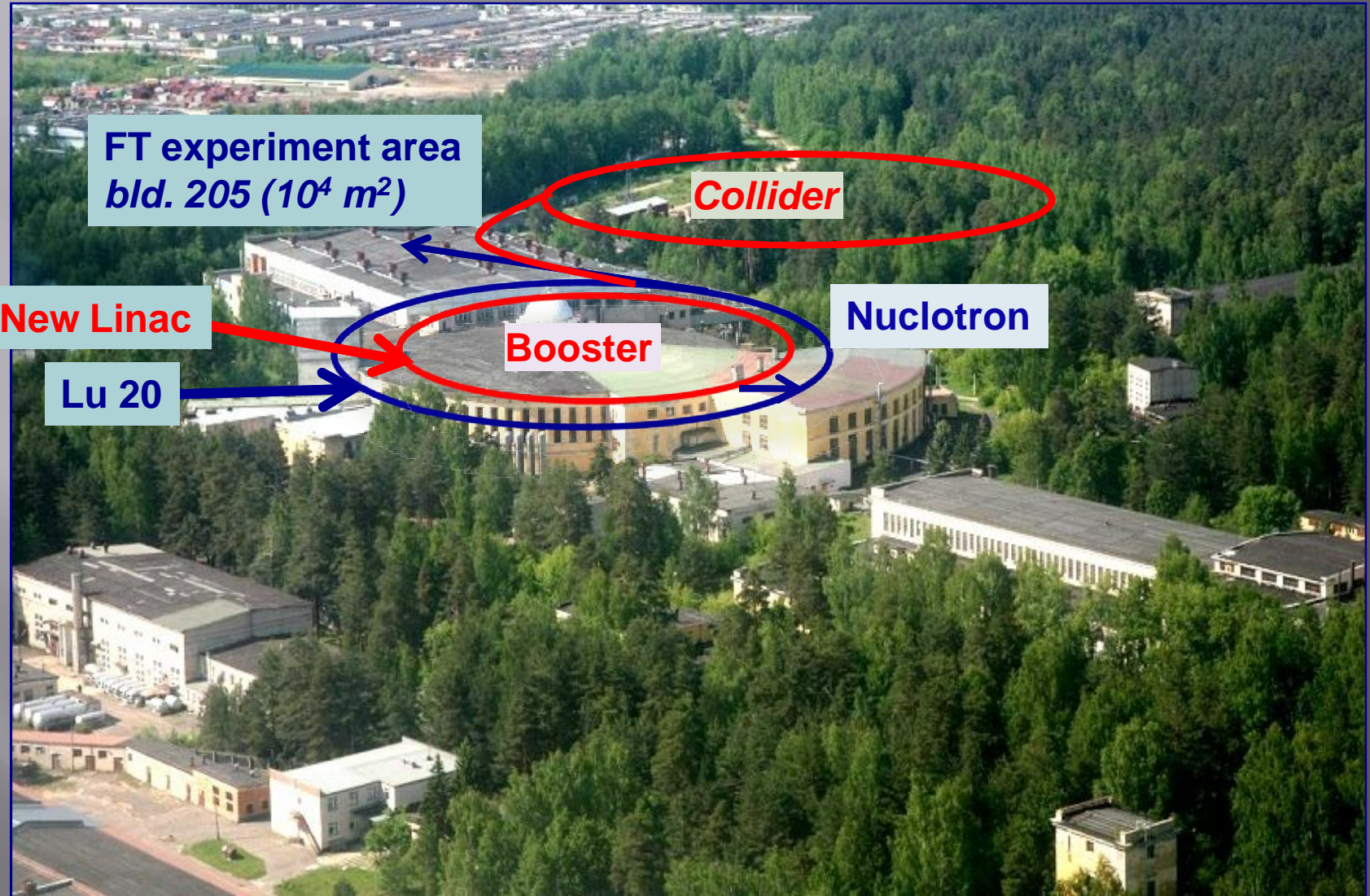
System of maximal net baryon (freeze-out) density is created in A+A collisions at NICA energies → optimum for the compressed nuclear matter exploration



NICA site

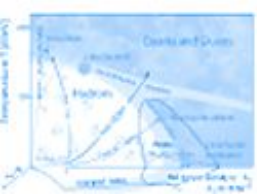


NICA



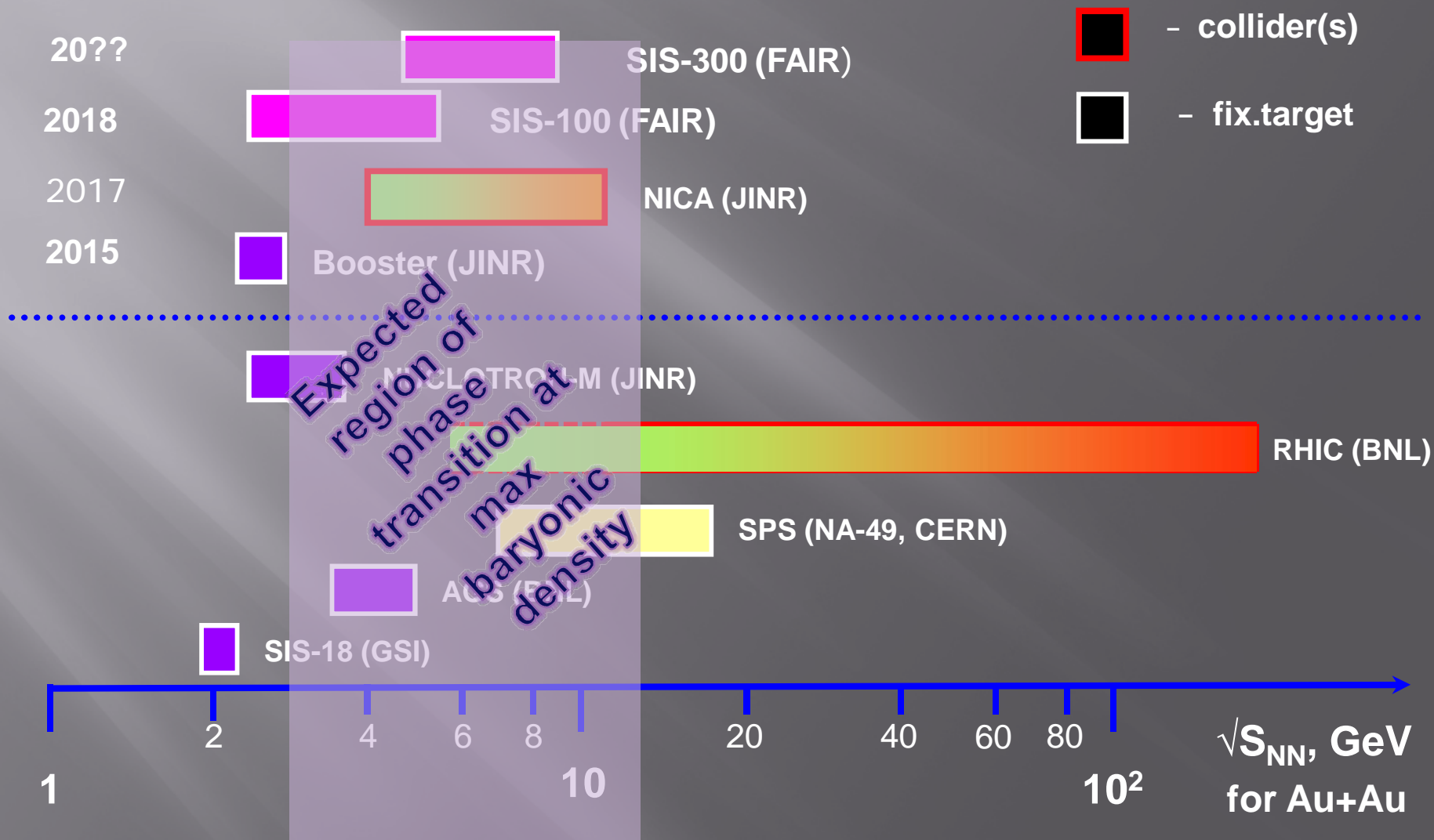
Nuclotron-based Ion Collider fAcility (NICA)

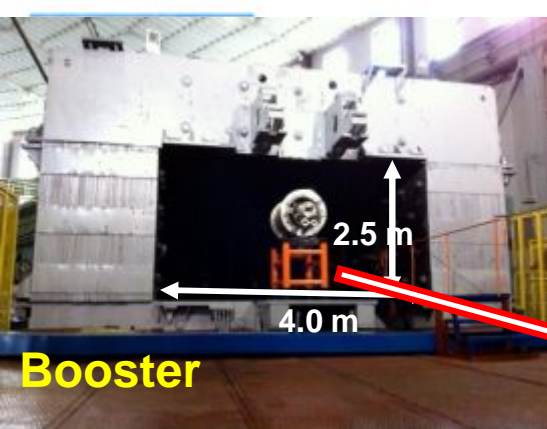




- 1a) Heavy ion colliding beams $^{197}\text{Au}^{79+} \times ^{197}\text{Au}^{79+}$ at
 - $\sqrt{s_{NN}} = 4 \div 11 \text{ GeV}$ (1 \div 4.5 GeV/u ion kinetic energy)
 - at **Lverage**= $1\text{E}27 \text{ cm}^{-2}\cdot\text{s}^{-1}$ (at $\sqrt{s_{NN}} = 9 \text{ GeV}$)
- 1b) Light-Heavy ion colliding beams of the same energy range and luminosity
- 2) Polarized beams of protons and deuterons in collider mode:
 - $p\uparrow p\uparrow \sqrt{s_{pp}} = 12 \div 27 \text{ GeV}$ (5 \div 12.6 GeV kinetic energy)
 - $d\uparrow d\uparrow \sqrt{s_{NN}} = 4 \div 13.8 \text{ GeV}$ (2 \div 5.9 GeV/u ion kinetic energy
 - Lverage** $\geq 1\text{E}30 \text{ cm}^{-2}\cdot\text{s}^{-1}$ (at $\sqrt{s_{pp}} = 27 \text{ GeV}$)
- 3) The beams of light ions and polarized protons and deuterons for fixed target experiments:
 - Li \div Au** = 1 \div 4.5 GeV /u ion kinetic energy
 - p, p \uparrow** = 5 \div 12.6 GeV kinetic energy
 - d, d \uparrow** = 2 \div 5.9 GeV/u ion kinetic energy
- 4) Applied research with ion beams at kinetic energy
 - from 0.5 GeV/u up to 12.6 GeV (**p**) and 4.5 GeV /u (**Au**)

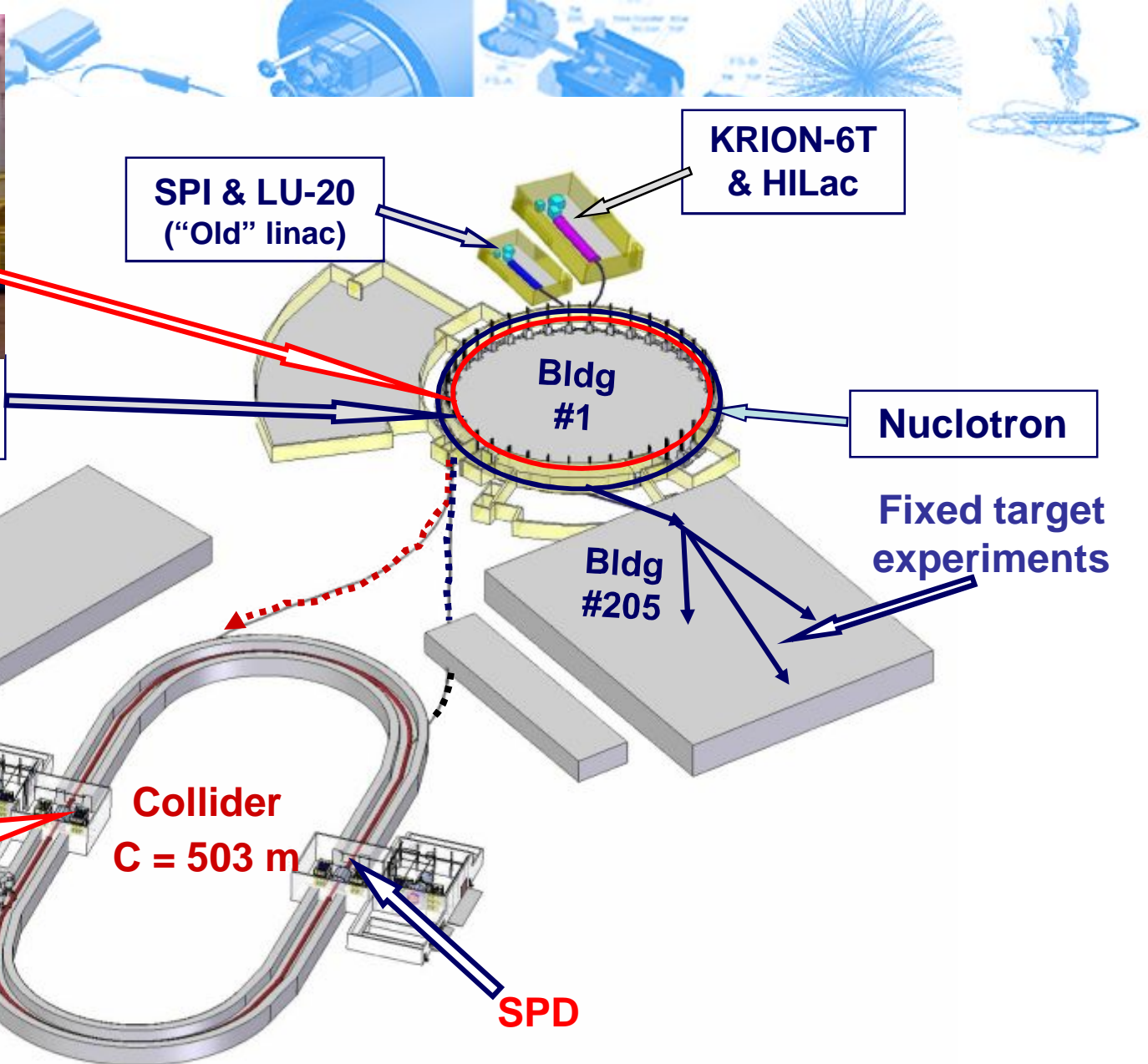
Luminosity 1/(s cm ²)	10 ²⁴ -10 ²⁵	10 ²⁵ -10 ²⁶	10 ²⁶ -10 ²⁷	10 ²⁷ -10 ²⁸	10 ²⁸ -10 ²⁹	10 ²⁹ -10 ³⁰	10 ³⁰ -10 ³¹	10 ³¹ -10 ³²
color								





Booster

Synchrotron yoke



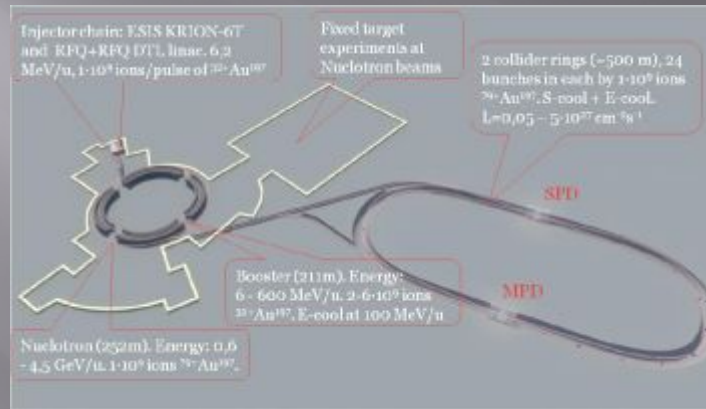
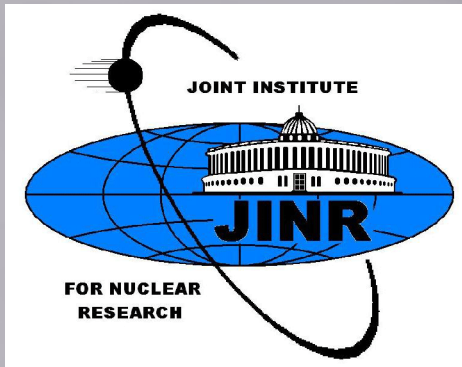
NICA structure and operation regimes



NICA construction schedule

	2011	2012	2013	2014	2015	2016	2017
ESIS KRION	Green	Green	Green	Green	Red	Red	Red
LINAC + channel	Cyan	Purple	Green	Green	Red	Red	Red
Booster + channel	Cyan	Purple	Green	Yellow	Red	Red	Red
Nuclotron-M	Yellow	Red	Red	Red	Red	Red	Red
Nuclotron-M → NICA	Cyan	Cyan Purple	Purple	Green	Yellow	Red	Red
Channel to collider	Cyan	Cyan	Purple	Green	Yellow	Red	Red
Collider	Cyan	Cyan	Purple	Purple Green	Green	Yellow	Red
Diagnostics	Cyan	Purple	Green	Green	Yellow	Yellow Red	Red
Power supply	Cyan	Purple	Green	Yellow	Yellow	Yellow Red	Red
Control systems	Cyan	Purple	Green	Yellow	Yellow	Yellow Red	Red
Cryogenics	Purple	Purple	Yellow	Yellow	Red	Red	Red
MPD	Black	Cyan	Cyan	Purple	Purple	Green	Yellow
Infrastructure	Green	Green	Green	Yellow	Red	Red	Red
R&D	Black	Cyan	Purple	Green	Yellow	Red	Red
Design	Cyan	Purple	Green	Yellow	Red	Red	Red
Manufactrng	Purple	Green	Yellow	Red	Red	Red	Red
Mount.+commis.	Green	Yellow	Red	Red	Red	Red	Red
Commis/opr	Yellow	Red	Red	Red	Red	Red	Red
Operation	Red	Red	Red	Red	Red	Red	Red

NICA Physics tasks and challenges



□ Exploration of the QCD phase diagram

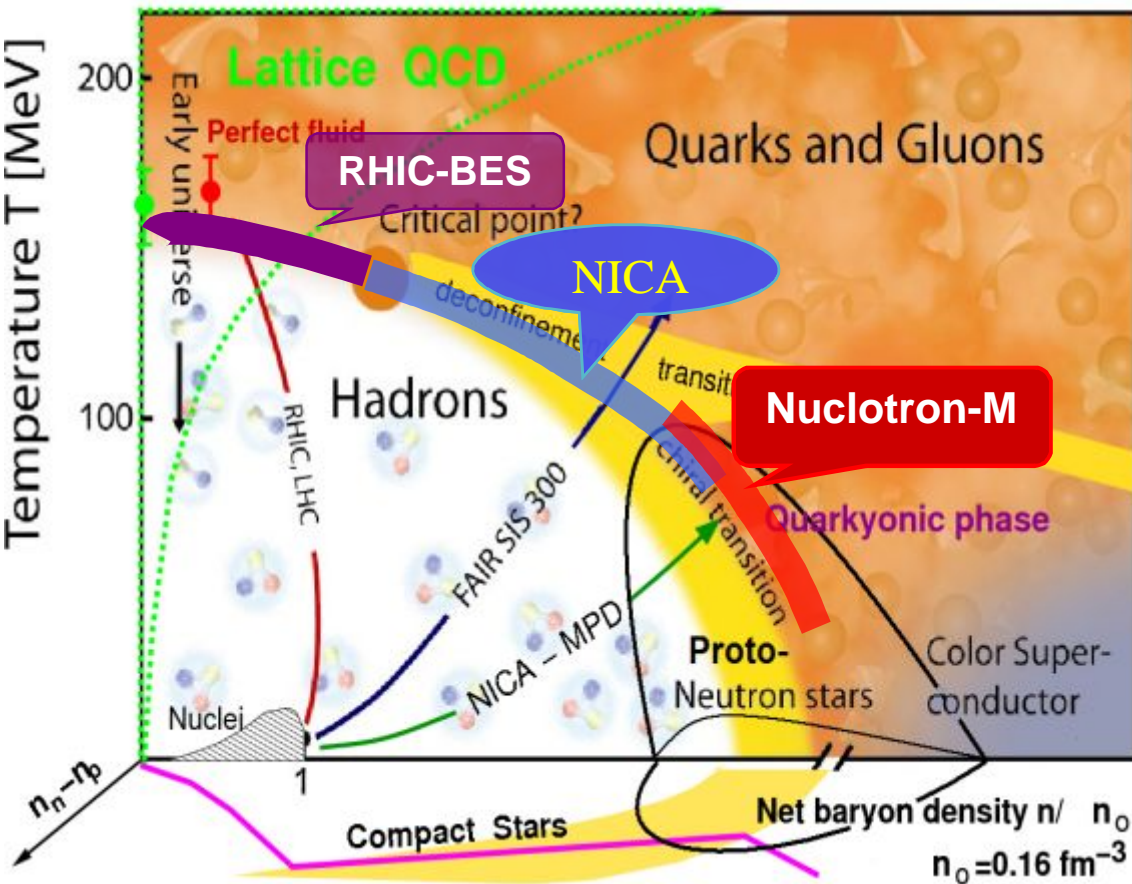
- *in-medium properties of hadrons & nuclear matter equation of state*
- *onset of deconfinement & chiral symmetry restoration*
- *phase transitions, mixed phase & critical phenomena*
- *local parity violation (P-odd effects)*

□ Spin physics

- *origin of spin*
- *nucleon spin structure*



QCD phase diagram: prospects for NICA



- Energy Range of NICA**
 The most intriguing and unexplored region of the QCD phase diagram:
- Highest net baryon density
 - Onset of deconfinement phase transition
 - Discovery potential:
 - a) Critical End Point (CEP)
 - b) Chiral Symmetry Restoration
 - c) Hypothetic Quarkyonic phase
 - Complementary to the RHIC/BES, NA61/CERN, CBM/FAIR and Nuclotron-M experimental programs

Comprehensive experimental program requires scan over the QCD phase diagram by varying collision parameters: system size, beam energy and collision centrality



MPD: tasks and challenges

- ❑ ***bulk observables (hadrons): 4p particle yields (OD, EOS)***
- ❑ ***event-by-event fluctuation in hadron productions (CEP)***
- ❑ ***femtoscopic correlations involving π , K, p, Λ (OD)***
- ❑ ***flows (directed, elliptic,...) for identified hadron species (EOS,OD)***
- ❑ ***multistrange hyperon production: yields & spectra (OD, EOS)***
- ❑ ***electromagnetic probes (CSR, OD)***
- ❑ ***hypernuclei (DM)***
- ❑ ***local parity violation (P-odd effects)***

OD – Onset of Deconfinement

CEP – Critical End Point

DM – Dense Matter

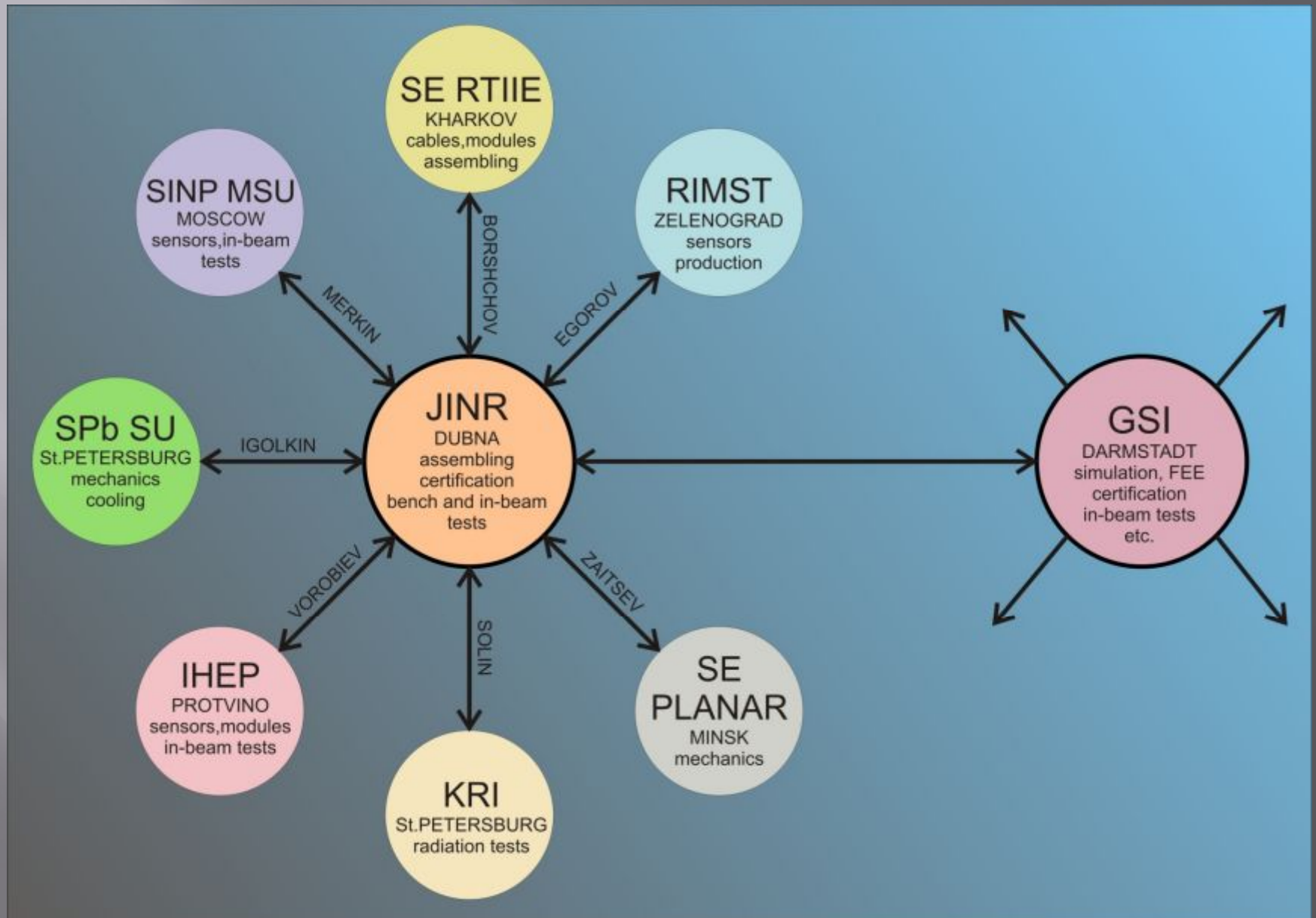
CSR – Chiral Symmetry Restoration

EOS – Equation Of State

Challenges:

- ☀ **Vast nomenclature of colliding systems – from p+p to Au+Au**
- ☀ **Simultaneous observation of a variety of phenomena**
- ☀ **Small effects over large kinematical range, sensitivity to acceptance constrains ('correlations & fluctuations' studies)**
- ☀ **Pattern recognition in high track multiplicity environment**

The CBM-MPD Consortium Structure



Beam	Nuclotron beam intensity (particle per cycle)		
	Current	Ion source type	New ion source + booster
p	$3 \cdot 10^{10}$	Duoplasmatron	$5 \cdot 10^{12}$
d	$3 \cdot 10^{10}$	--- ,, ---	$5 \cdot 10^{12}$
^4He	$8 \cdot 10^8$	--- ,, ---	$1 \cdot 10^{12}$
d↑	$2 \cdot 10^8$	SPI	$1 \cdot 10^{10}$
^7Li	$8 \cdot 10^8$	Laser	$5 \cdot 10^{11}$
$^{11,10}\text{B}$	$1 \cdot 10^{9,8}$	--- ,, ---	
^{12}C	$1 \cdot 10^9$	--- ,, ---	$2 \cdot 10^{11}$
^{24}Mg	$2 \cdot 10^7$	--- ,, ---	
^{14}N	$1 \cdot 10^7$	ESIS ("Krion-6T")	$5 \cdot 10^{10}$
^{24}Ar	$1 \cdot 10^9$	--- ,, ---	$2 \cdot 10^{11}$
^{56}Fe	$2 \cdot 10^6$	--- ,, ---	$5 \cdot 10^{10}$
^{84}Kr	$1 \cdot 10^4$	--- ,, ---	$1 \cdot 10^9$
^{124}Xe	$1 \cdot 10^4$	--- ,, ---	$1 \cdot 10^9$
^{197}Au	-	--- ,, ---	$1 \cdot 10^9$

Energy of beams extracted from Nuclotron

covers the gap between **SIS-18** and **AGS** (*with some overlaps*)

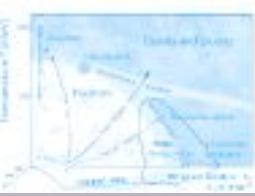
	Z/A	$\max \sqrt{s_{NN}}$ (GeV/n)	$\max. T_{kin}$ (GeV/n)
p	1	\approx 5.2	\approx 12
d	1/2	\approx 3.8	\approx 5.7
			(including polarized deuterons)
Au	0.4	\approx 3.5	\approx 4.5
			(at 2T in dipoles)

It allows:

- *study of dense baryonic matter at temperatures up to 100 MeV,*
- *(multi)strangeness (open & hidden) production*
in dense baryonic matter,
- *modification of particle properties in dense nuclear matter*

The corresponding multi-purpose setup

Baryonic Matter at Nuclotron (BM@N)



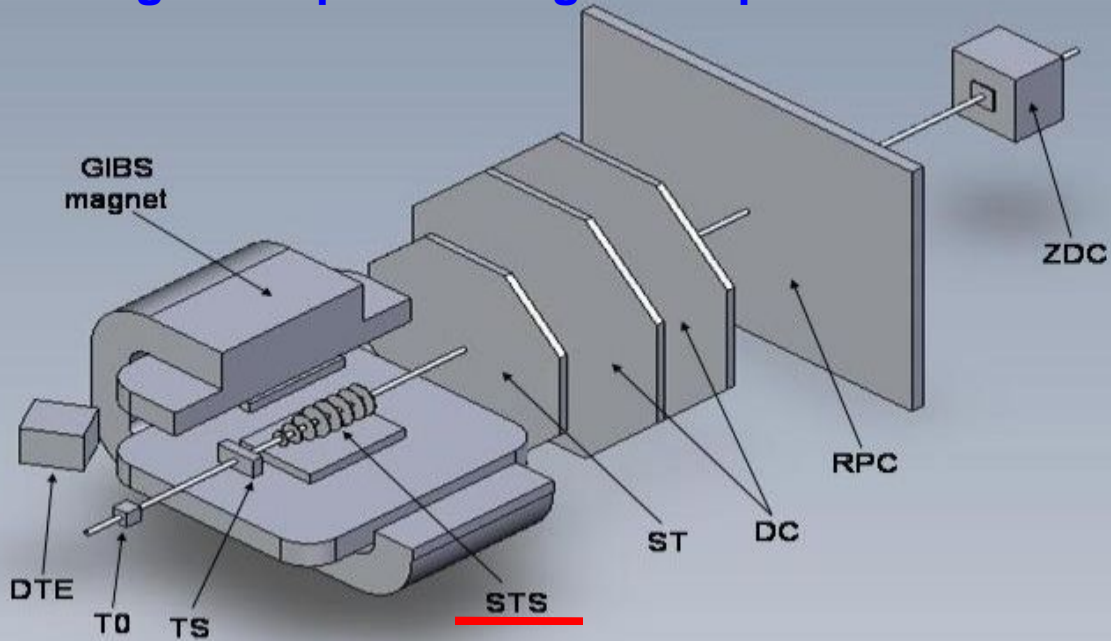
Strange matter production in heavy ion collisions at the Nuclotron extracted beam: Baryonic Matter at Nuclotron (BM@N)

- ▣ Collaboration **GSI-JINR** (preparation of the joint experiment has started)
- ▣ The goal of the experiment is the systematic measurements of the observables for multistrange objects (Ξ^- , Ω^- , *exotics*) in Au-Au collisions in the energy domain of the Nuclotron extracted beam (up to 5 A GeV)

Baryonic Matter at Nuclotron (BM@N)

- measurements of the multi-strange (Ξ , Ω , exotics) & hypernuclei in HI collisions
- close to the threshold production in the region of high sensitivity to the models prediction

Large Acceptance Magnetic Spectrometer



GIBS magnet (SP-41)

*TS-target station,
T0- start diamond detector,
STS - silicon tracker,
ST- straw tracker,
DC- drift chambers,
RPC- resistive plate
chambers,
ZDC- zero degree calorimeter,
DTE – detector of tr. energy.*

▣ the detector based on the sub-detectors developed for **CBM**, **MPD** & **SPD**

Preparation of the joint **GSI - JINR** experiment Baryonic Matter at Nuclotron (**BM@N**) has started. **The planned data taking - 2015**

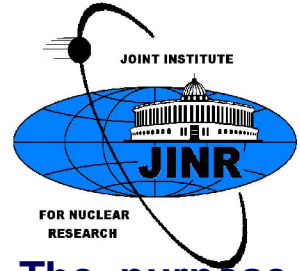
Time table of the BM@N experiment

ID	Task Name	2011	2012	2013	2014	2015	2016	2017
1	Simulations	█						
2	Preparation of experimental site	█						
3	Installation beam line 6V		█					
4	Installation BM@N cave		█					
5	Installation beam tube, beam monitors			█				
6	Installation drift chambers		█					
7	Construction TOF-RPC, T0		█					
8	Tracker TDR		█					
9	Construction STS			█				
10	Design of SC magnet			█				
11	Construction GD tracker		█					
12	Construction DAQ, slow-control		█					
13	Installation detectors, commissioning			█				
14	Data taking			█		█		

Phase0 (2011) – The site preparation and simulation

Phase1 (2012-2014)–The detector construction and commissioning

Phase2 (2015-.....) - The data taking at 3.5, 4 and 4.65 A GeV



SPD EXPERIMENT AT NICA



The purpose is study of the nucleon spin structure with high intensity polarized light nuclear beams:

- high collision proton (deuteron) energy up to $\sqrt{s} \sim 26(12)$ GeV
- the average luminosity up to 10^{30} - 10^{31} cm²/s
- both proton and deuteron beams can be effectively polarized.

The main topics are:

1. Studies of MMT-DY processes with longitudinally and transversely polarized p and D beams. Extraction of unknown (poorly known) parton distribution functions (PDFs).
2. PDFs from J/Ψ production processes.
3. Spin effects in baryon, meson and photon productions.
4. Studies of spin effects in various exclusive reactions.
5. Diffractive processes studies.
6. Cross sections, helicity amplitudes and double spin asymmetries (Krisch effect) in elastic reactions.
7. Spectroscopy of quarkoniums.

NICA Spin program plans:

2012-2014 – CDR and TRD preparation, SPD collaboration, R&D

2015-2018 – R&D, Detectors production



Draft v 6.02
January 20, 2012

**SEARCHING for a QCD MIXED PHASE at the
NUCLOTRON-BASED ION COLLIDER FACILITY
(NICA White Paper)**

Editorial board:

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D. Kharzeev
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N. Xu**

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



NICA

NICA White Paper

SEARCHING for a QCD MIXED PHASE at the NUCLOTRON-BASED ION COLLIDER FACILITY

The final goal of the NICA White Paper is to address the following key topics:

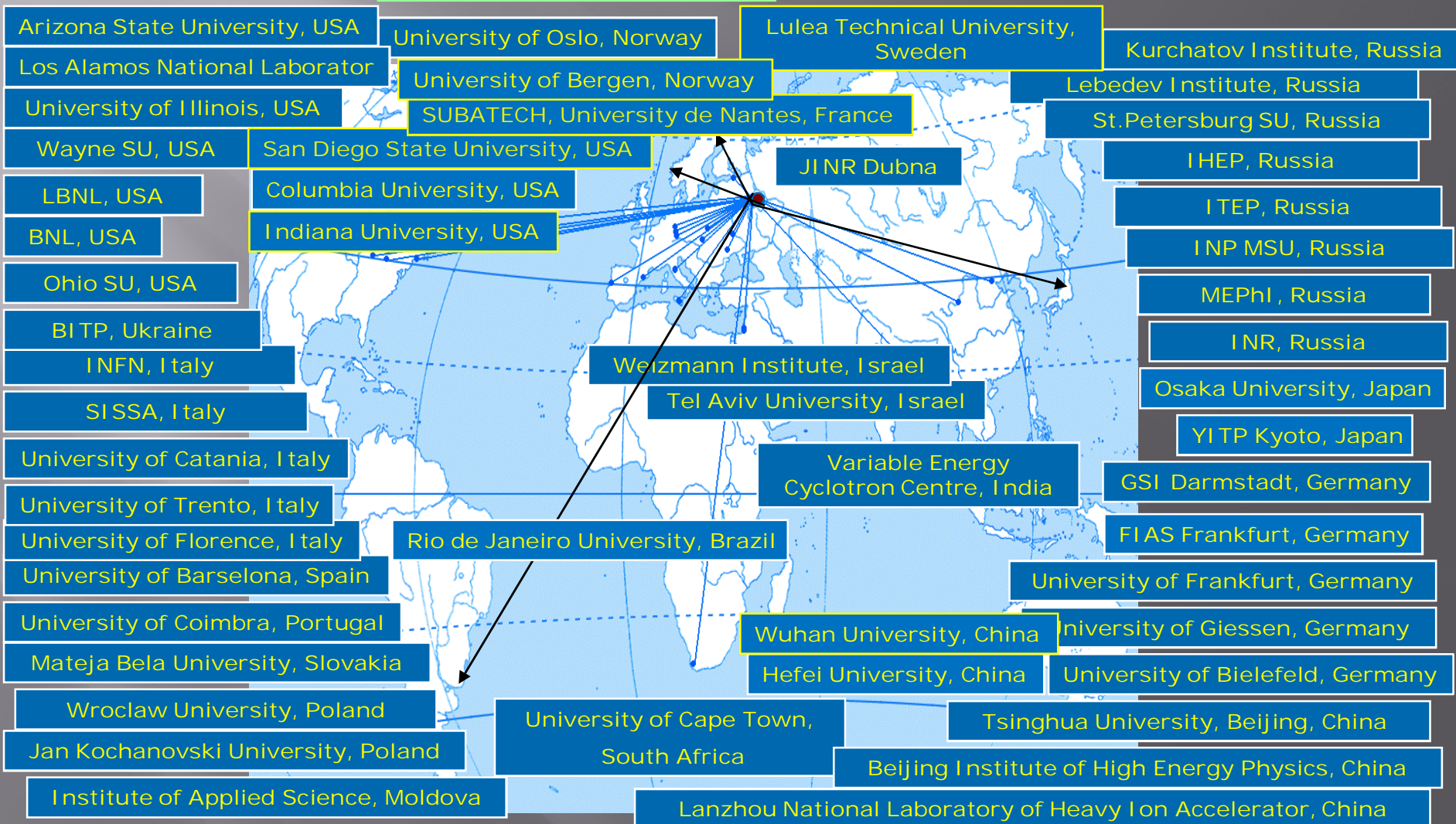
- Phases of dense QCD matter and conditions for their possible realization
- Characteristic processes as indicators of phase transformations
- Estimates of various observables for events
- Comparison to other experiments

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The NICA White Paper

140 authors from **59 scientific centers** in **21 Countries (8 JINR members)**



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Physical phenomena and relevant observables:

- in-medium modification of hadron properties (MMH)
- the nuclear matter equation of state (EoS)
- the onset of deconfinement (OD) and/or
- chiral symmetry restoration (CSR)
- signals of a phase transition (PT)
- the mixed phase and the critical end-point (CEP)
- possible local parity violation in strong interactions (LPV)

The correlations between observables and physical phenomena:

Observables	Physical Phenomena							Detectors	Reference in the White Paper
	MMH	EoS	OD	CSR	PT	CEP	LPV		
yields of hadrons, normal and exotic light nuclei	x	x	x					tracking, TOF	3.6, 3.9, 4.3, 3.11, 4.12, 6.7
yields and spectra of multistrange hyperons	x	x	x					precision tracking (secondary vertices)	2.6, 5.3, 6.4, 12.3, 12.5, 12.6
electromagnetic probes			x	x				tracking, electron identifiers (e.g. RICH)	7.1, 7.2, 7.3, 7.7
azimuthal charged particle correlations					x		x	tracking	8.1 - 8.7, 10.4
event-by-event (EBE) fluctuations						x		tracking, TOF	2.1, 2.6, 3.10, 5.4
Radial, elliptic and triangular flow of hadrons		x	x		x			tracking, TOF	4.4, 4.8, 4.14, 5.8
higher moments of hadron distributions			x		x	x		tracking, TOF	3.10, 4.1, 4.5, 4.6, 4.10, 4.12-4.15
interferometric parameters		x			x			tracking	3.5, 5.1, 5.2, 5.5

Round Table Discussions on NICA/MPD@JINR

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 9 - 12, 2009
<http://theor.jinr.ru/meetings/2009/roundtable/>

Round Table Discussion V: *Searching for the mixed phase of strongly interacting QCD matter at the NICA: Physics at NICA (White Paper)* JINR (Dubna), August 28, 2010
http://theor.jinr.ru/~cpod/Dubna_2010_program2.htm

NICA/JINR-FAIR Bilateral Workshop

Matter at Highest Baryon Densities in the Laboratory and in Space

Frankfurt Institute for Advanced Studies, April 2 - 4, 2012

http://theor.jinr.ru/~nica_fair/

Topics:

- Phases of QCD at high baryon densities
- Effects signalling phase transitions
- Observables in heavy-ion collisions and in astrophysics
- Simulations of ion collisions and supernovae

Aims:

- identify discovery potential of Nuclotron-NICA and FAIR in the canon of current and future HIC experiments
- chiral symmetry restoration
- onset of deconfinement
- in-medium modification of hadron properties
- color superconductivity, multiquark states, etc.

Results:

- Most promising and feasible suggestions for experiments at Nuclotron-NICA and CBM/FAIR
- Priorities for detectors and formation of international collaborations

* German-Russian Year of Science 2011/2012



Conclusion

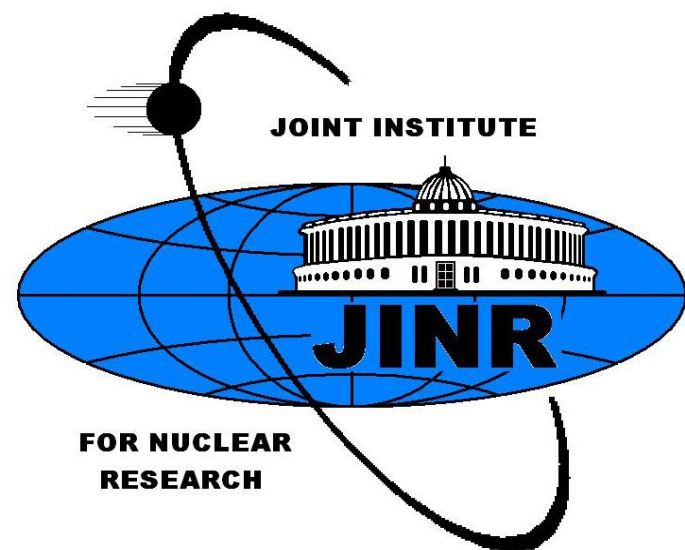
The combination of NICA collider and Nuclotron-NICA fixed target energy ranges is perfectly suited for the investigation of:

Observables	Physical Phenomena							Detectors	Reference in the White Paper
	MMH	EoS	OD	CSR	PT	CEP	LPV		
yields of hadrons, normal and exotic light nuclei	x	x	x					tracking, TOF	3.6, 3.9, 4.3, 3.11, 4.12, 6.7
yields and spectra of multistrange hyperons	x	x	x					precision tracking (secondary vertices)	2.6, 5.3, 6.4, 12.3, 12.5, 12.6
electromagnetic probes			x	x				tracking, electron identifiers (e.g. RICH)	7.1, 7.2, 7.3, 7.7
azimuthal charged particle correlations					x		x	tracking	8.1 - 8.7, 10.4
event-by-event (EBE) fluctuations						x		tracking, TOF	2.1, 2.6, 3.10, 5.4
Radial, elliptic and triangular flow of hadrons		x	x		x			tracking, TOF	4.4, 4.8, 4.14, 5.8
higher moments of hadron distributions			x		x	x		tracking, TOF	3.10, 4.1, 4.5, 4.6, 4.10, 4.12-4.15
interferometric parameters		x			x			tracking	3.5, 5.1, 5.2, 5.5

The White Paper demonstrates the unique physics potential of the NICA/MPD Complex. Broad international resonance to the NICA White Paper is an important step towards an international collaboration for the creation of the NICA/MPD and BM@N experiments.

Physics in the NICA energy range is rich and attractive!

Welcome to the collaboration!



Thank you for attention!