

Joint Institute for Nuclear Research International Intergovernmental Organization



Status of the NICA Project and the White Paper

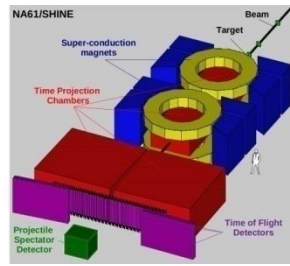
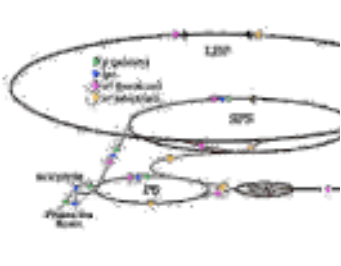
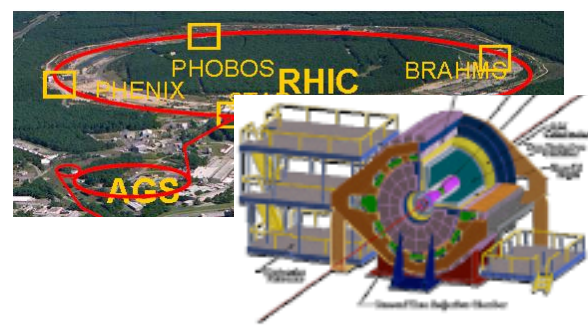
V. Kekelidze, A. Kovalenko, R. Lednicky, I. Meshkov, A. Sorin, G. Trubnikov
(for the NICA/MPD collaboration)



Bilateral FAIR-JINR-NICA Workshop
FIAS, Frankfurt, April 2 - 4, 2012

2nd generation HI experiments

BES STAR/PHENIX@BNL/RHIC

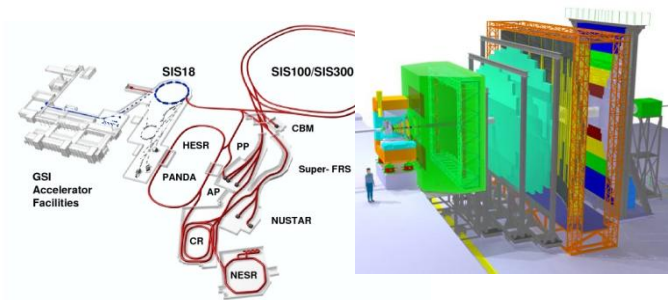


NA61@CERN/SPS

3rd generation HI experiments

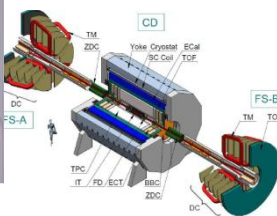
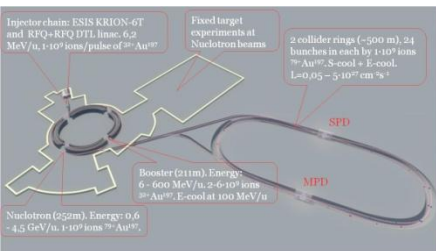
CBM@FAIR/SIS-100/300

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

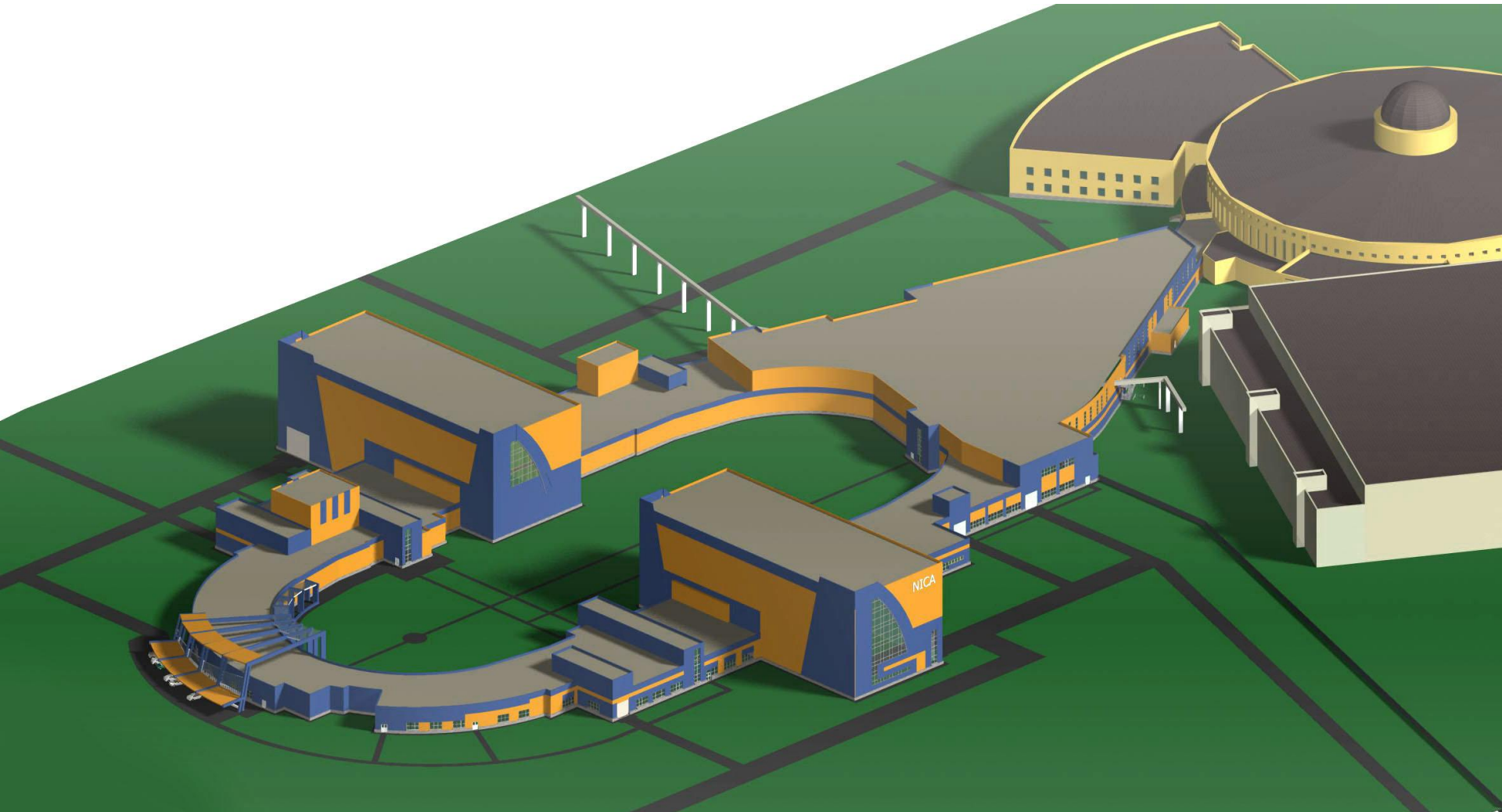


MPD@JINR/NICA

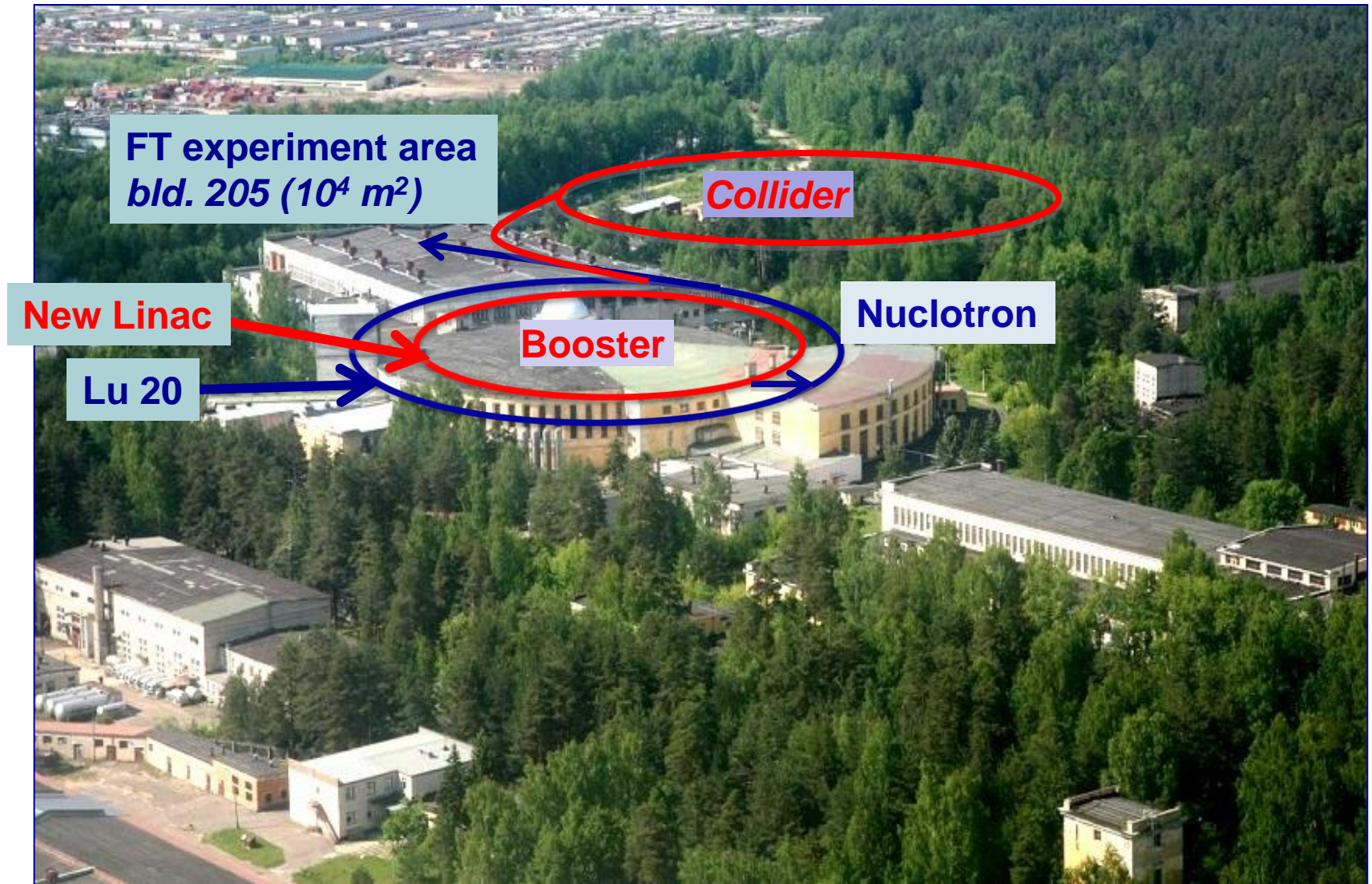
Collider, $\sqrt{s_{NN}} = 4-11$ GeV, $L \sim 10^{27} \text{ cm}^{-2}\text{s}^{-1}$ for Au^{79+}

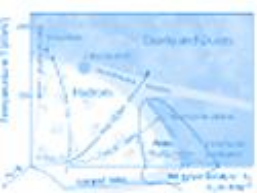


Nuclotron-based Ion Collider fAcility (NICA)



NICA





1a) Heavy ion colliding beams $^{197}\text{Au}^{79+} \times ^{197}\text{Au}^{79+}$ at

$\sqrt{s_{\text{NN}}} = 4 \div 11 \text{ GeV}$ (1 \div 4.5 GeV/u ion kinetic energy)

at **Lverage** = $1\text{E}27 \text{ cm}^{-2}\cdot\text{s}^{-1}$ (at $\sqrt{s_{\text{NN}}} = 9 \text{ GeV}$)

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

2) Polarized beams of protons and deuterons in collider mode:

$p\uparrow p\uparrow \sqrt{s_{\text{pp}}} = 12 \div 27 \text{ GeV}$ (5 \div 12.6 GeV kinetic energy)

$d\uparrow d\uparrow \sqrt{s_{\text{NN}}} = 4 \div 13.8 \text{ GeV}$ (2 \div 5.9 GeV/u ion kinetic energy

Lverage $\geq 1\text{E}30 \text{ cm}^{-2}\cdot\text{s}^{-1}$ (at $\sqrt{s_{\text{pp}}} = 27 \text{ GeV}$)

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

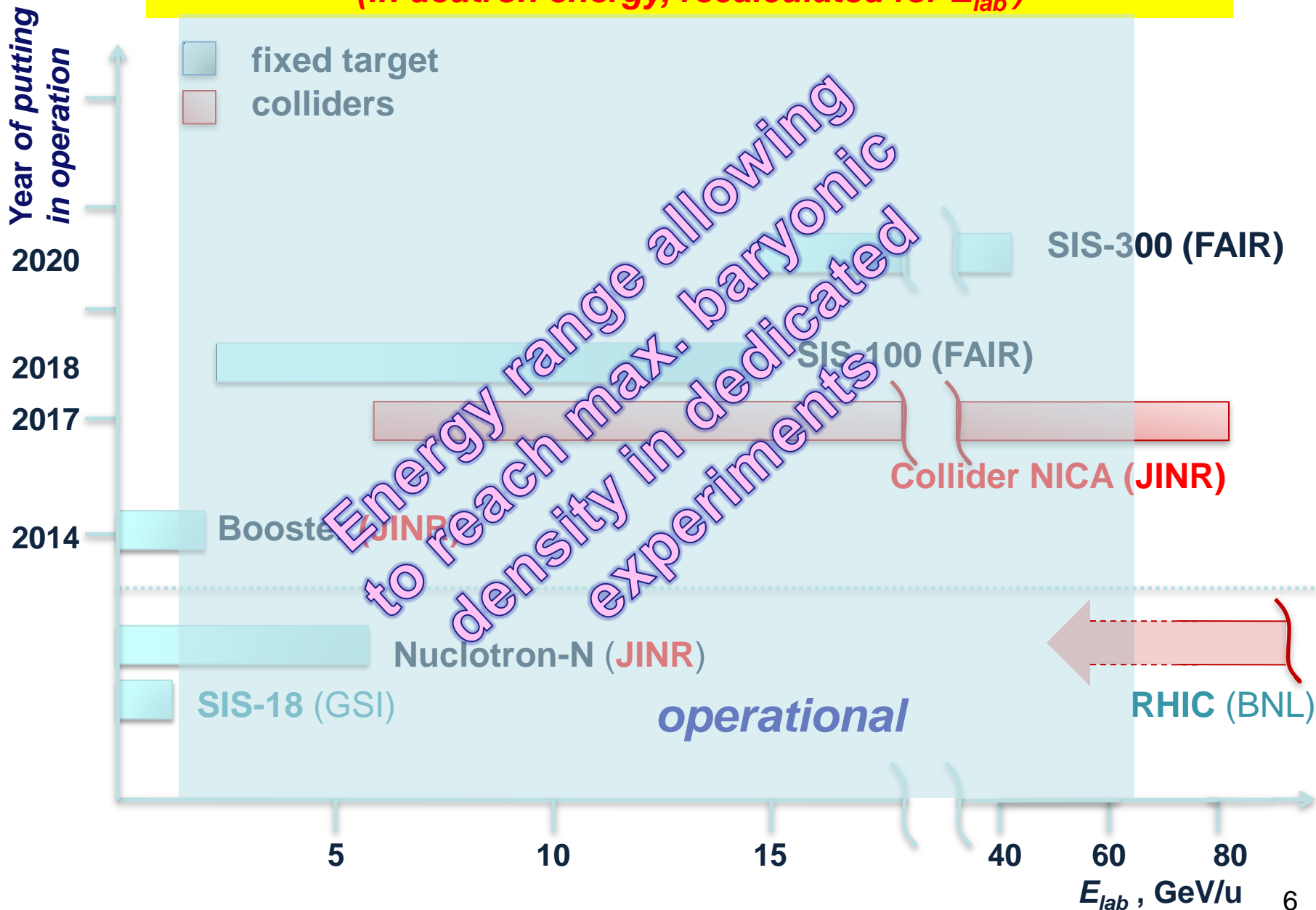
p, p \uparrow = 5 \div 12.6 GeV kinetic energy

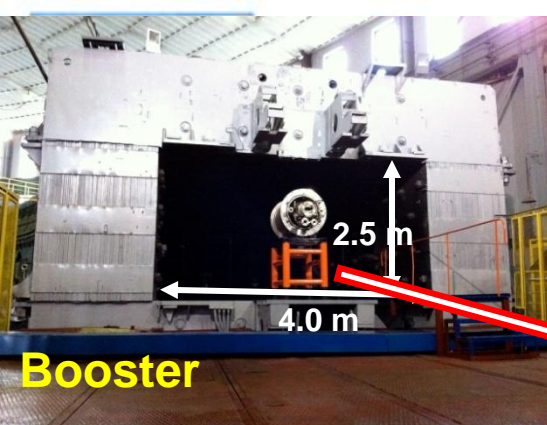
d, d \uparrow = 2 \div 5.9 GeV/u ion kinetic energy

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**)

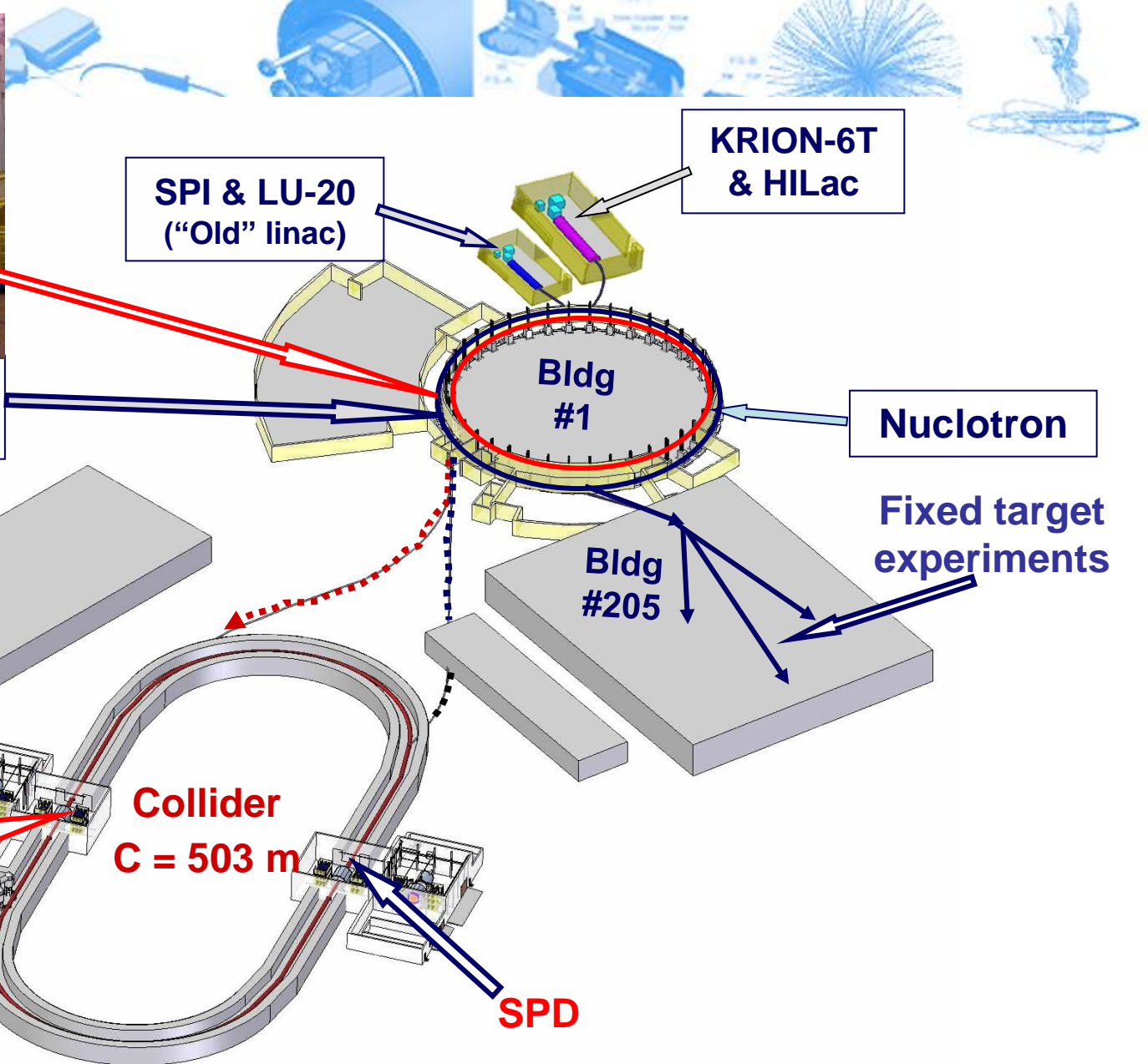
**Energy region covered by the JINR and GSI facilities
(in deuteron energy, recalculated for E_{lab})**





Booster

Synchrotron yoke



NICA structure and operation regimes



The Cosmonaut Yi So-Yeon (South Korea) flies inside the yoke of Synhrophasotron JINR

The latest Nuclotron Runs

44 (8 November - 30 December 2011)

45 (20 February – 25 March 2012)

Achievements:

- Run # 44 was the longest run for Nuclotron since 1993: **1230 hours**;
- *For the first time at the Nuclotron **deutrons and C⁶⁺ were accelerated and slow beam extracted at 4 GeV/u for physicists**;*
- Unique mode of operation for SC magnets (**magnetic flattop@1Tesla** field with length **500s**) had been performed – NICA collider operation modeling;
- All elements of the beam **stochastic cooling system** for Nuclotron had been commissioned and tested. Stochastic cooling of the beam is studied.

Unique modes of the machine operation were tested:

- half ring @ room temperature + half ring @ liquid He temperature;
- temporary warming-up of the ring to the 70K and cooling down back to 4.5K during 24 hours (for cryogenics filters exchange)

Building 217 at LHEP - new cryo-factory

Production, assembly, cryo- and vacuum tests for superconducting magnets serial production for NICA and FAIR

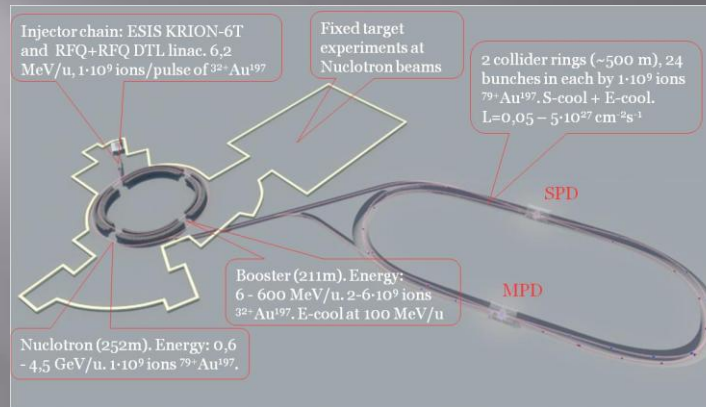
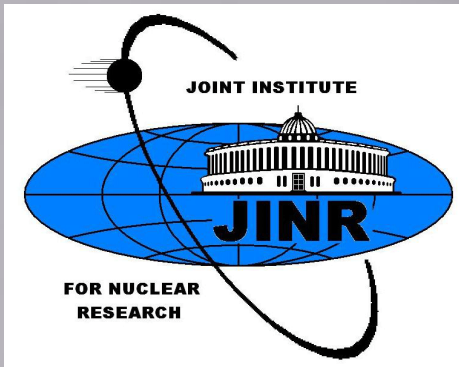


NICA construction schedule

	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	Design	Manufactrng	Mount.+commis.	Commis/opr	Operation
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NICA Physics tasks and challenges



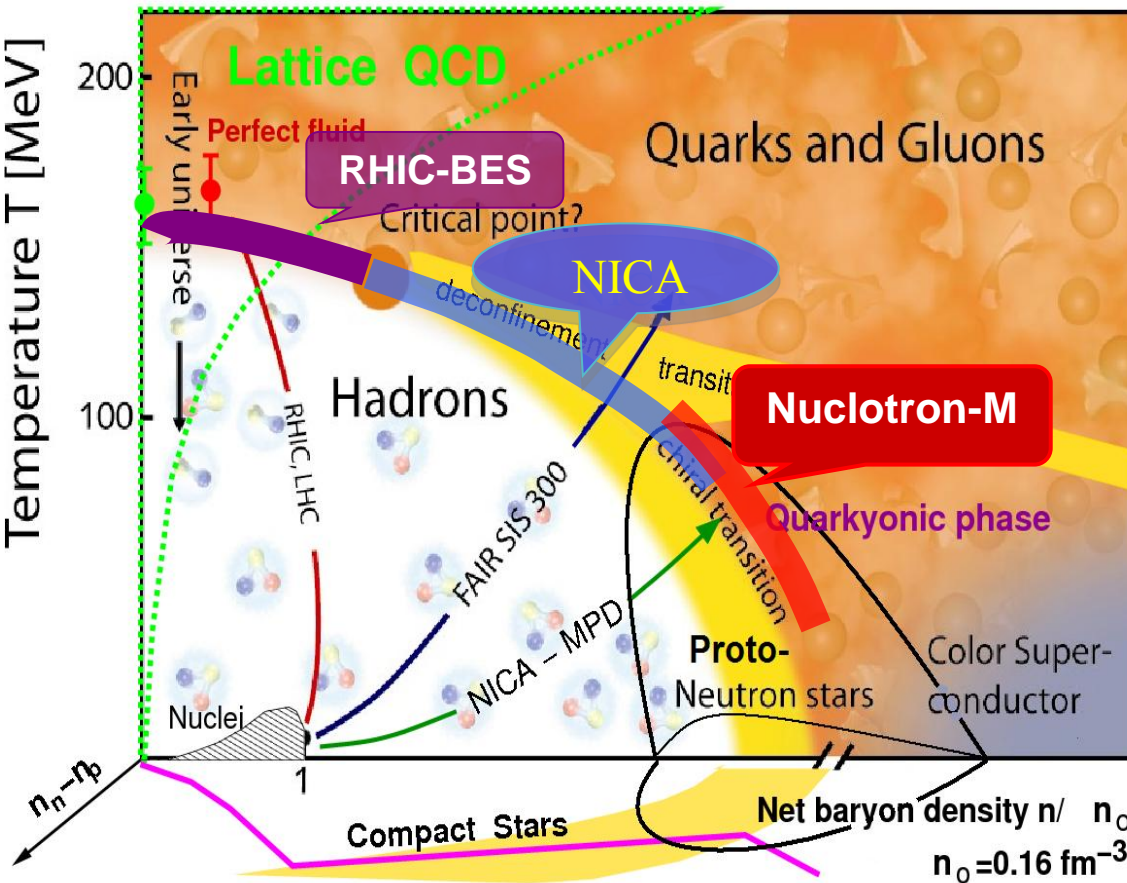
□ Exploration of the QCD phase diagram

- *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**

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)

Workshop
Fixed Target@Nuclotron-N and SIS100@FAIR
Detector R&D, Synergies and Physics Opportunities
GSI Helmholtz Centre, 2010 November 3rd
Wednesday, November 3rd
GSI WD-Zimmer

09:30 – 09:45 **Welcome and Goals of the Meeting** H. Stöcker

Chair: A. Sorin

09:45 – 11:00 **Technical Status of the Facilities**

Nuclotron-M: Status of the Facility and the New Fixed Target Program V. Kekelidze
Towards Nuclotron-N@JINR & SIS100@FAIR Physics Program H. Stöcker / A. Sorin
Coffee Break

Chair: G.Trubnikov

11:15 – 12:15 **Nuclear Structure Physics**

Nuclear Structure and Nuclear Astrophysics opportunities with RIBs G. Martinez-Pinedo
Status of R3B T. Aumann / H.Simon
Lunch Break (small Lunch incl. coffee / WD-Zimmer)

Chair: V. Kekelidze

13:00 – 15:00 **Nuclear Matter Physics**

Status of the HADES Upgrade, recent results R. Holzmann / J. Pietraszko
Status of FOPI, recent results N. Herrmann
Nuclear Matter Physics at Nuclotron and SIS100 energies P. Senger
Status of R&D CBM W. Müller
The STS Consortium J. Heuser
Coffee Break

15:15 – 17:00 **Final Panel Discussion:**
Synergies and Joint R&D Projects

Chair: H. Stöcker

17:30 *Dinner at the GSI Guesthouse*



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)



Draft v 6.02
January 20, 2012

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

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



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:

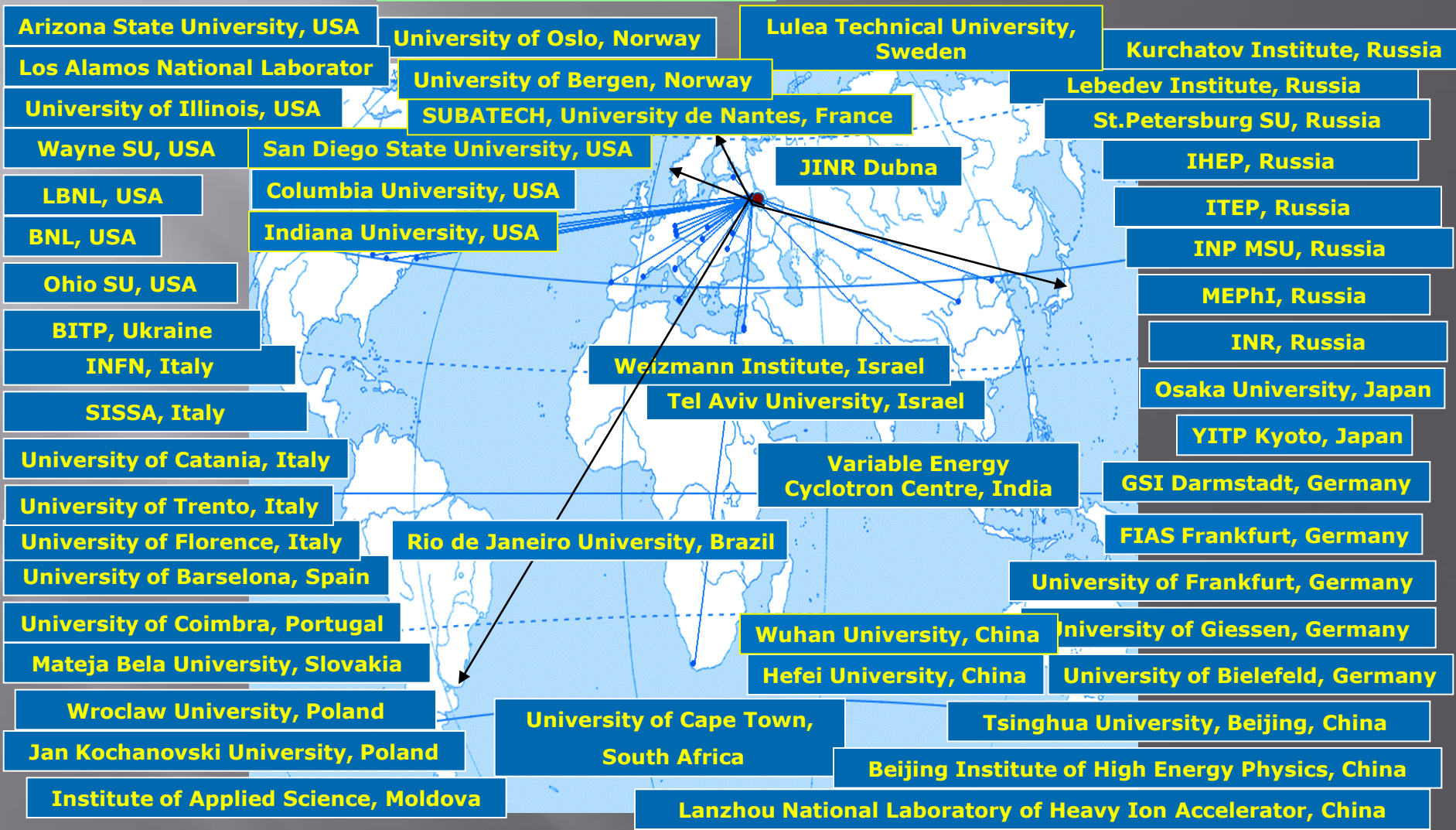
- Phases of dense QCD matter and conditions for their possible realization
- Characteristic processes as indicators of phase transformations
- Estimates of various observables for events
- Comparison to other experiments

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The NICA White Paper

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

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NICA White Paper - Contents

75 contributions

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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

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!



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

Session of the Government Commission on High Technology and Innovation (Dubna, July 5, 2011)

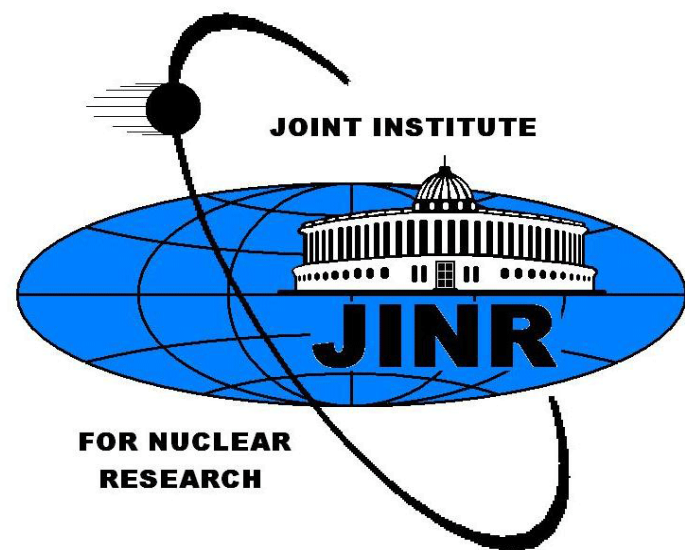


Prior to the session, the Ministry of Education and Science of the Russian Federation, jointly with the interagency working group, selected 6 out of 28 submitted applications which meet the highest requirements imposed to specify the class of “mega-science” facilities. Among them is the NICA project.

The meeting of the Working Group of the Russian Ministry of Education and Science (Moscow, January 17, 2012)

The NICA project has passed the international expertise that is a precondition for funding, along with two other megaprojects – the PIK reactor and the IGNITOR tokamak.

Welcome to the collaboration!



Thank you for attention!