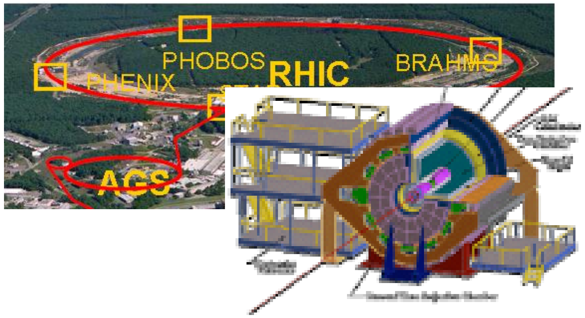
Joint Institute for Nuclear Research
International Intergovernmental Organization

Status of the NICA Project and the White Paper

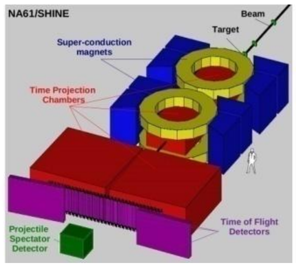
V. Kekelidze, A. Kovalenko, R. Lednicky, I. Meshkov, A. Sorin, G. Trubnikov
(for the NICA/MPD collaboration)

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

2^{nd} generation HI experiments

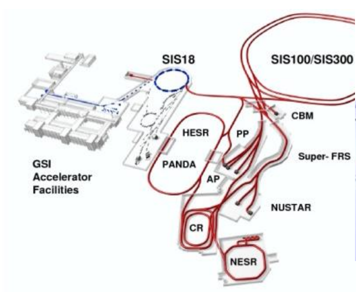


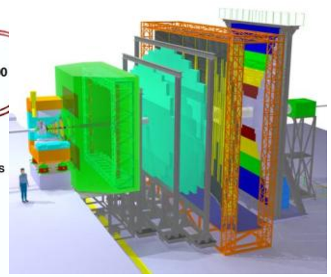
BES STAR/PHENIX@BNL/RHIC



NA61@CERN/SPS

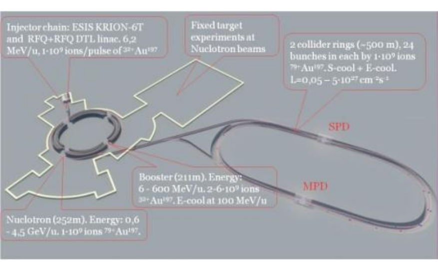
3^{nd} generation HI experiments

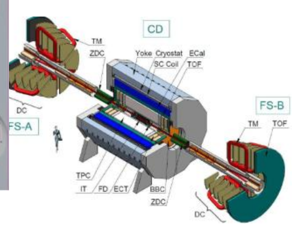




CBM@FAIR/SIS-100/300

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

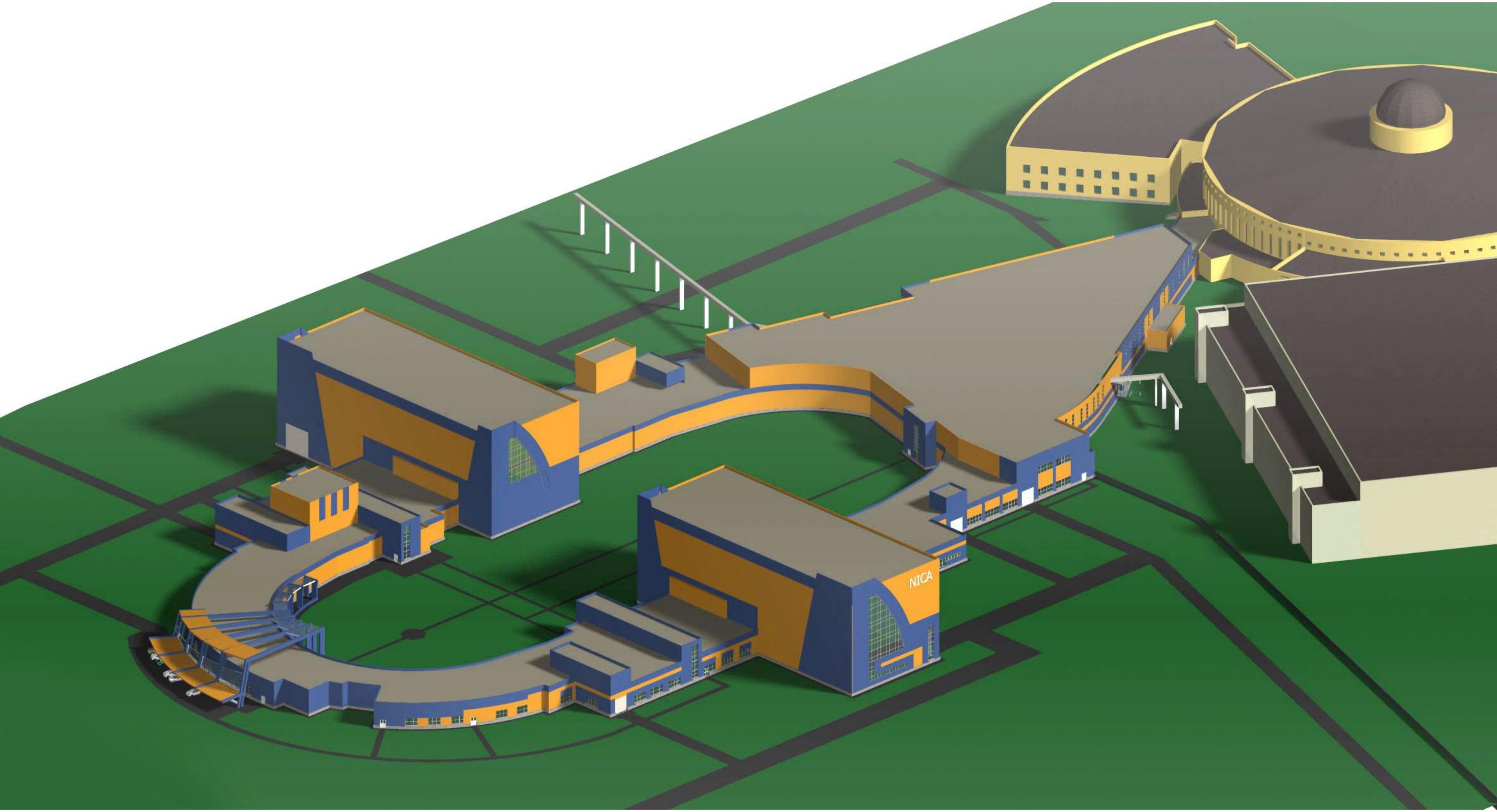




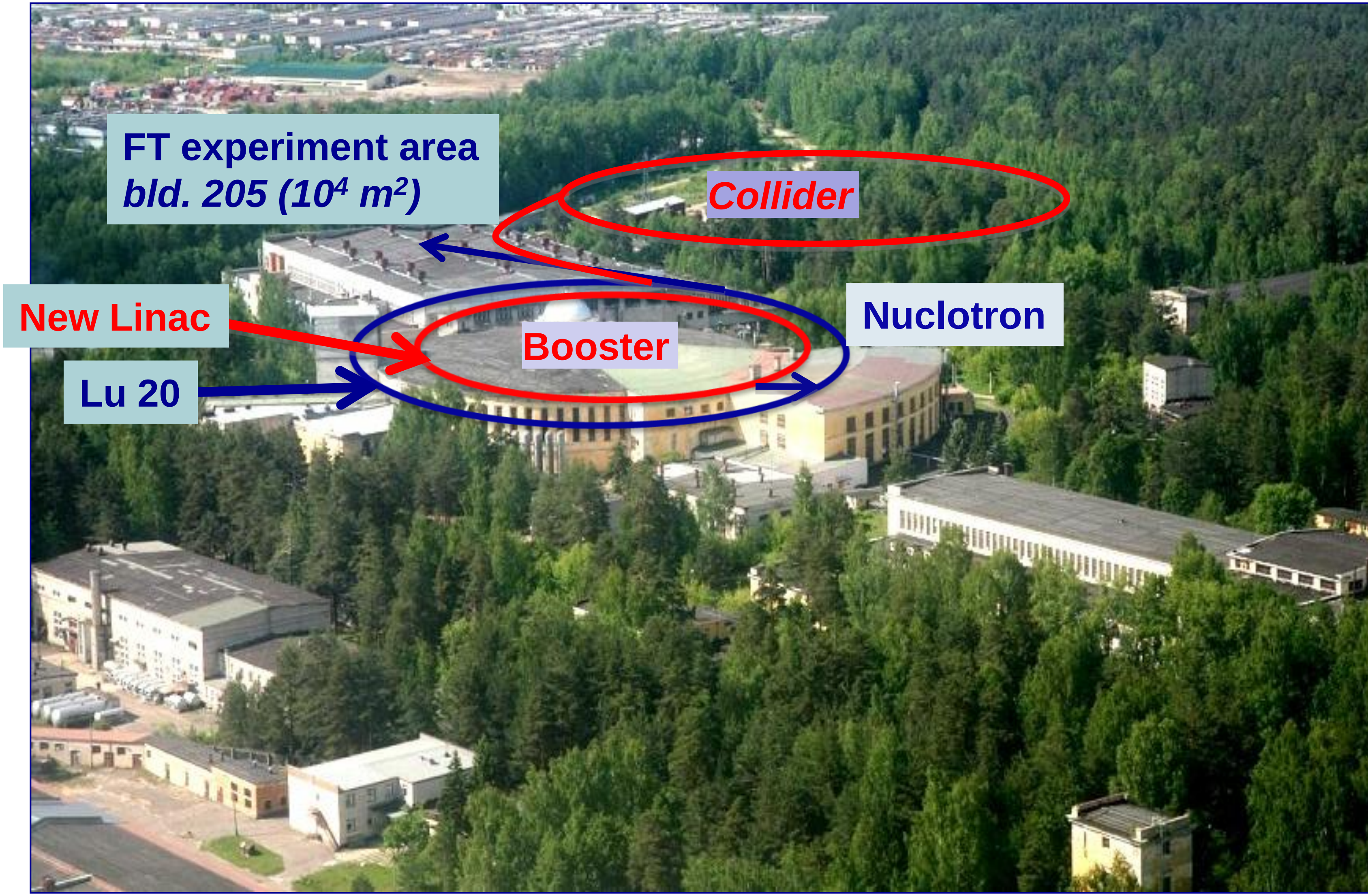
MPD@JINR/NICA

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

Nuclotron-based Ion Collider fAcility (NICA)



NICA


FT experiment area
bld. 205 (10⁴ m²)
Collider
New Linac
Booster
Nuclotron
Lu 20

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

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

at Laverage= 1E27 $cm^{-2}\cdot s^{-1}$ (at √sNN = 9 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↑p↑ √spp = 12 ÷ 27 GeV (5 ÷ 12.6 GeV kinetic energy)

d↑d↑ √sNN = 4 ÷ 13.8 GeV (2 ÷ 5.9 GeV/u ion kinetic energy

Laverage ≥ 1E30 $cm^{-2}\cdot s^{-1}$ (at √s_pp = 27 GeV)

3) The beams of light ions and polarized protons and deuterons for fixed

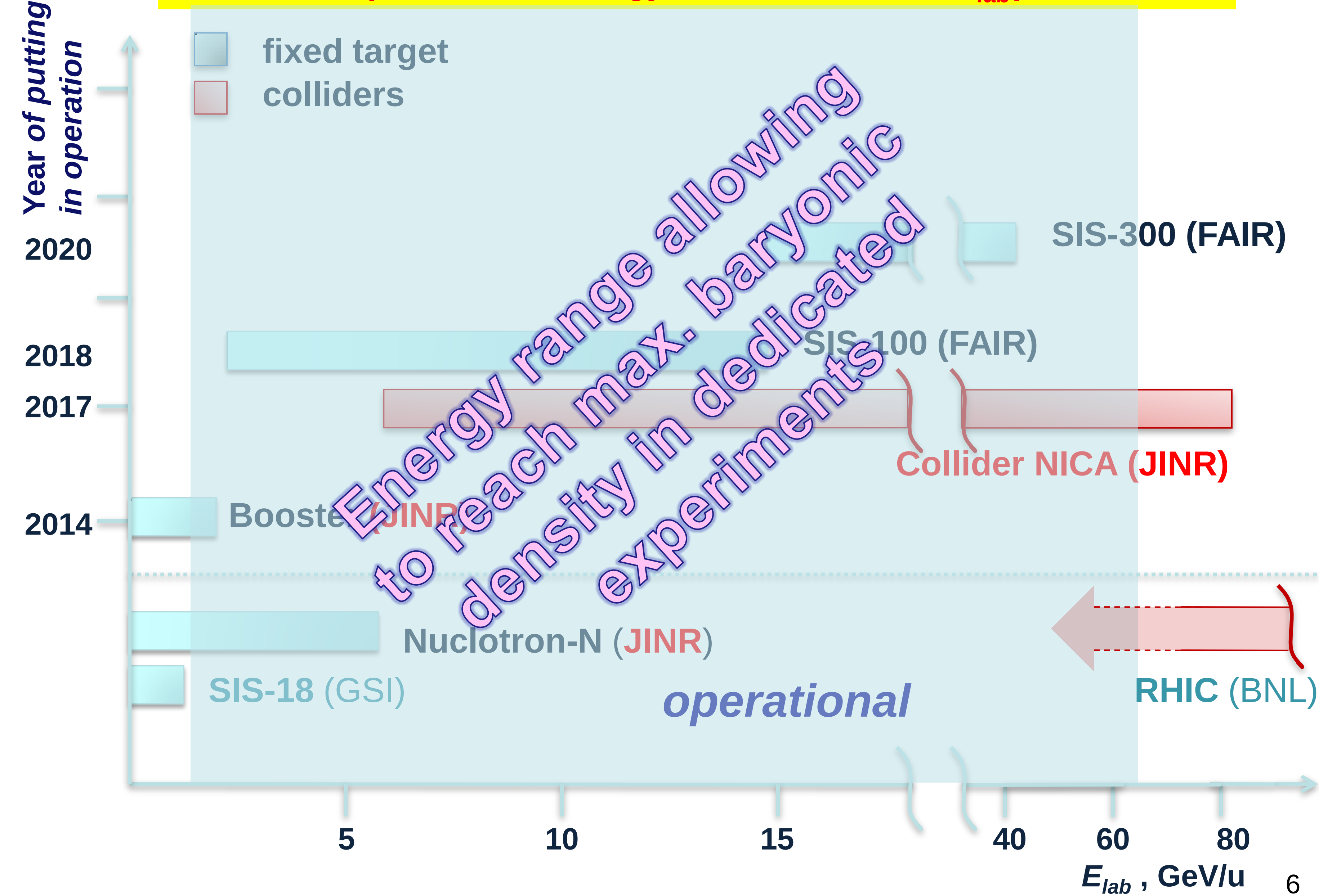
target experiments:

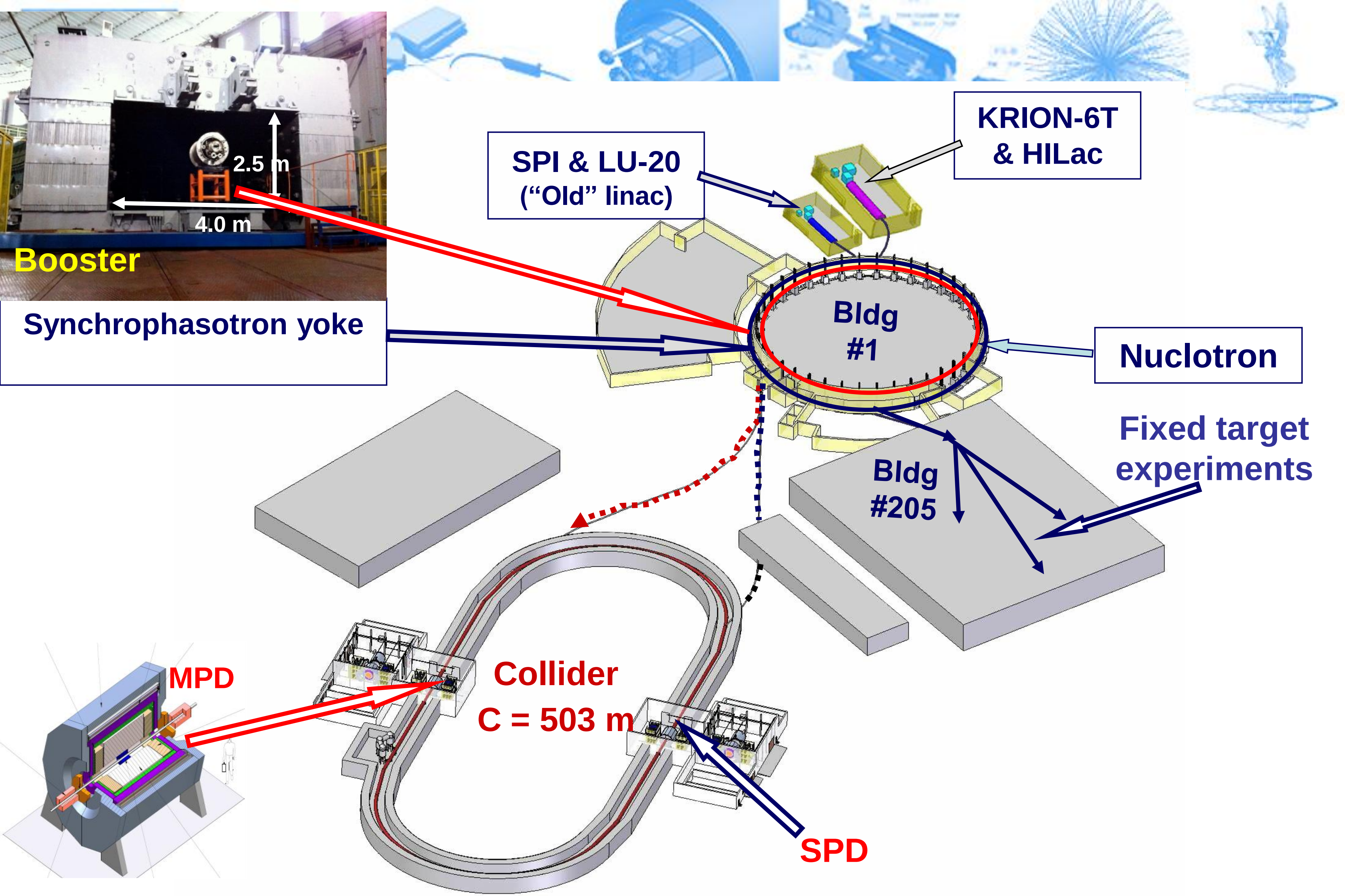
Li ÷ Au = 1 ÷ 4.5 GeV /u ion kinetic energy
p, p↑ = 5 ÷ 12.6 GeV kinetic energy
d, d↑ = 2 ÷ 5.9 GeV/u ion kinetic energy

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 deutron energy, recalculated for E_{lab})





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 C^{6+} 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

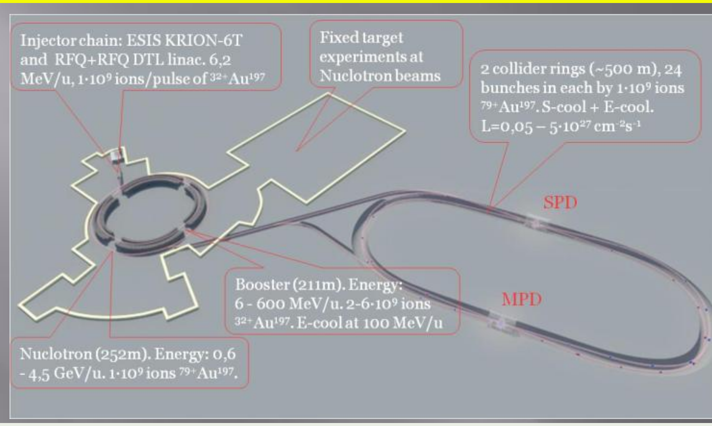
Production, assembly, cryo- and vacuum tests for superconducting magnets serial production for NICA and FAIR

NICA construction schedule

	2011	2012	2013	2014	2015	2016	2017
ESIS KRION							
LINAC + channel							
Booster + channel							
Nuclotron-M							
Nuclotron-M → NICA							
Channel to collider							
Collider							
Diagnostics							
Power supply							
Control systems							
Cryogenics							
MPD							
Infrastructure							

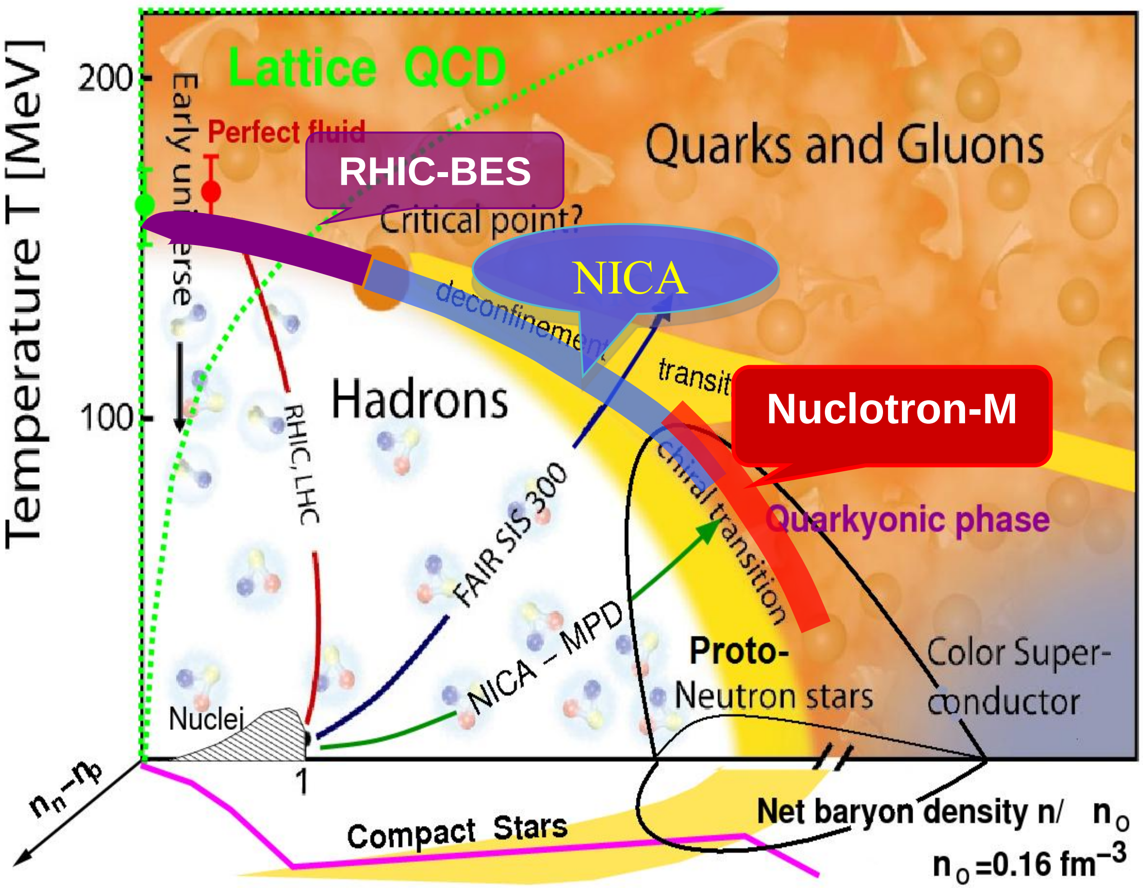
R&D	Design	Manufactrng	Mount.+commis.	Commis/opr	Operation

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	$3{\cdot}10^{10}$	Duoplasmotron	$5{\cdot}10^{12}$
d	$3{\cdot}10^{10}$	--- ,, ---	$5{\cdot}10^{12}$
^{4}He	$8{\cdot}10^{8}$	--- ,, ---	$1{\cdot}10^{12}$
d↑	$2{\cdot}10^{8}$	SPI	$1{\cdot}10^{10}$
^{7}Li	$8{\cdot}10^{8}$	Laser	$5{\cdot}10^{11}$
^{11,10}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***	**≈ *5.2***	**≈ *12***
d	***1/2***	**≈ *3.8***	**≈ *5.7***
			(including polarized deuterons)
Au	***0.4***	**≈ *3.5***	**≈ *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)

Editorial board:
D. Blaschke
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I. Tserruya
N. Xu

NICA

Draft v 6.02
January 20, 2012

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

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

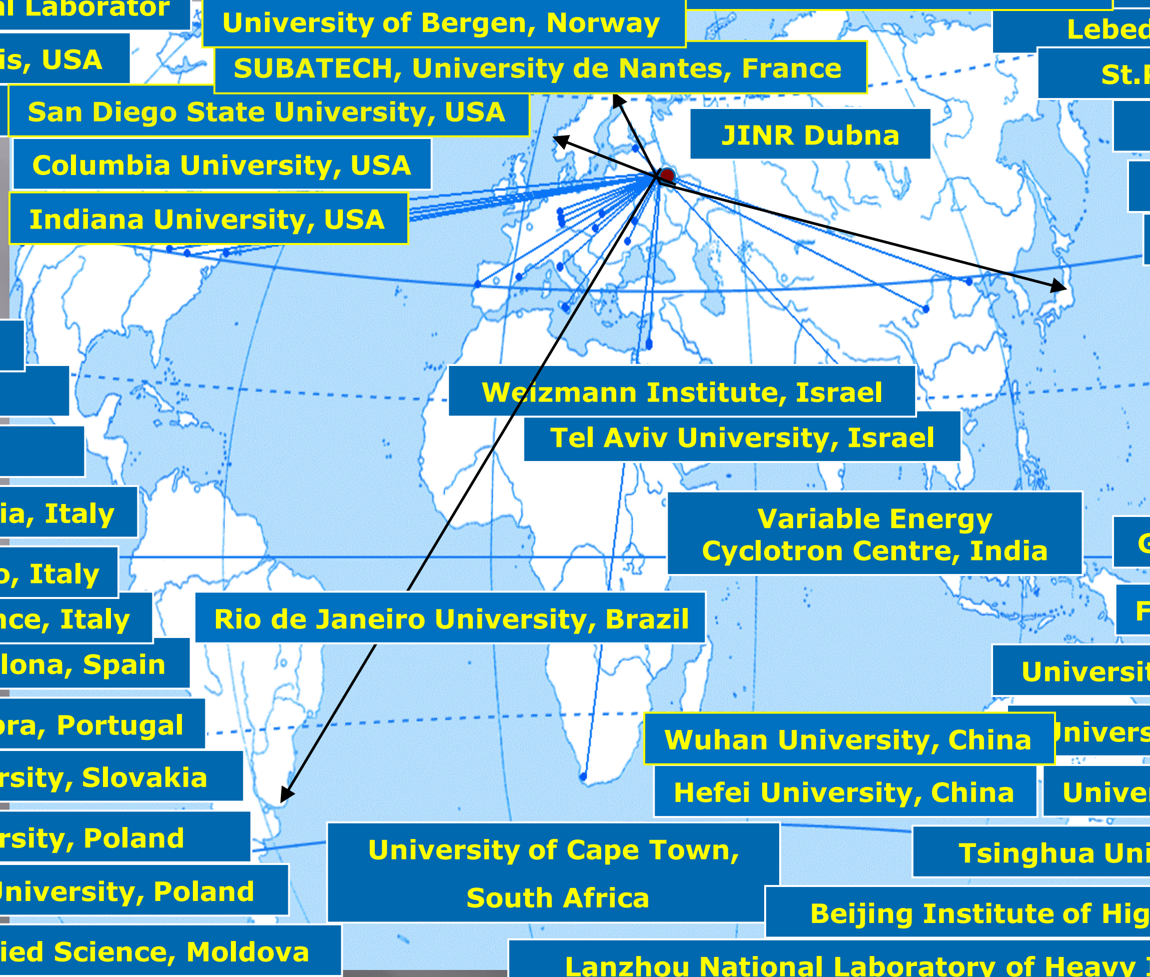
The final goal of the NICA White Paper is to address the following key topics:

- 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

Contents

The NICA White Paper

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



- Arizona State University, USA
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- Wayne SU, USA
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- Indiana University, USA
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- Lanzhou National Laboratory of Heavy Ion Accelerator, China

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

List of authors (140)

Kh.Abraamyan, J.Aichelin, A.Andrianov, V.Andrianov, A.Andronic, M.Asakawa, V.Avdeichikov, F.Becattini, R.Bellwied, D.Blaschke, M.Bleicher, H.Blume, E.Bratkovskaya, L.Bravina, P.Braun-Munzinger, A.Bzdak, K.Bugaev, P.Buividovich, X.Cai, W.Cassing, Y.Cheng, L.Csernai, M.Chernodub, J.Cleymans, M.Colonna, P.Costa, O.Denisovskaya, D.E.Donets, E.D.Donets, E.E.Donets, M. DiToro, I.Dremin, A.Efremov, D.Espriu, S.Fantoni, V.Friese, A.Friesen, K.Fukushima, S.Gandolfi, M.Gazdzicki, M.Gorenstein, V.Greco, K.Gudima, C.Hartnack, P.Huovinen, A.Illarionov, Yu.Ivanov, A.Jerusalimov A.Kaidalov, Yu.Kalinovsky, F. Karsch, D.Kharzeev, T. Klähn, T.Kodama, V.Koch, E.Kolomeitsev, E.Kokoulina,V.Korotkikh, A.Kovalenko, A.Kurepin, A.Kutov,V.Ladygin, N.Ladygina, R.Lednicky, A.Leonidov, E.Levin, J.Liao, M.Lisa, B.Liu, Y. Liu , I. Lokhtin, X.Luo, G.Lykasov, V.L.Lyuboshitz, V.V.Lyuboshitz, E.Luschevskaya, L.Malinina, C.Markert, L.McLerran, K.Mikhailov, B.Mohanty, S.Mrowczynski, A.Nagaytsev, V.Nikitin,V.Okorokov, F.Pederiva, S. Petrushanko, S.Plumari, M.Polikarpov, P.Polozov, M.Prokudin, J.Randrup, P.Rau, K.Redlich, H.G.Ritter, O.Rogachevsky, I.Rufanov, V.Salnikov, F.Sandin, L.Sarycheva, H.Satz, I.Savin, P.Senger, G. Shao, G.Sharkov, O.Shevchenko, V.Shutov, K.Schmidt, Yu.Sinyukov, A.Sissakian, V.Skokov, A.Snigirev, A.Sorin, A.Stavinskiy, J.Steinheimer, M.Stephanov, H.Stoecker,V.Stolin, O.Teryaev, R.Tolochek, S.Tolstoukhov, B.Tomasik, V.Toneev, N.Topilskaya, G.Torrieri, S.Troshin, I.Tserruya, L. Turko, S.Typel, Yu. Usikov, S.Voloshin, D.Voskresensky, S. Weber, D.Wang, N.Xu, Yu.Zaitsev, E.Zabrodin, P.Zhuang, D.Zhou, …

NICA White Paper - Contents

75 contributions

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 (seconday 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 (seconday 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!