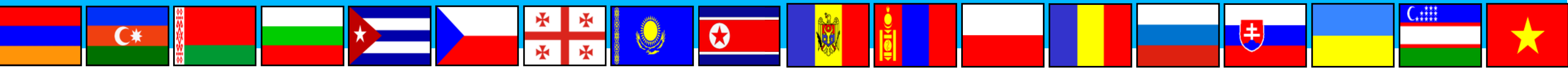
Joint Institute for Nuclear Research
International Intergovernmental Organization



The NICA project at JINR, Dubna

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

NICA

INTERNATIONAL WORKSHOP ON DISCOVERY PHYSICS AT THE LHC
KRUGER 2012
DECEMBER 3 - 7, 2012

The Nuclotron-based Ion Collider fAcility (NICA) at Joint Institute for Nuclear Research (JINR), Dubna

Main targets of "NICA Complex":

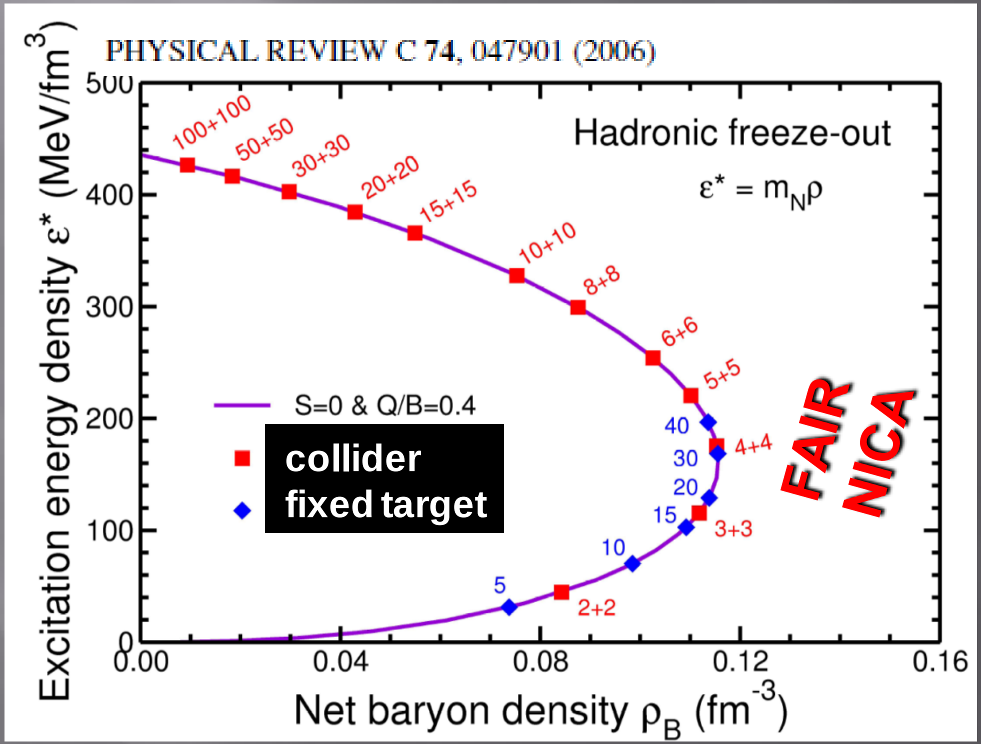
- ***study of hot and dense baryonic matter***
- ***investigation of nucleon spin structure, polarization phenomena***

- ***development of accelerator facility for HEP @ JINR providing intensive beams of relativistic ions from p to Au polarized protons and deuterons with max energy up to***

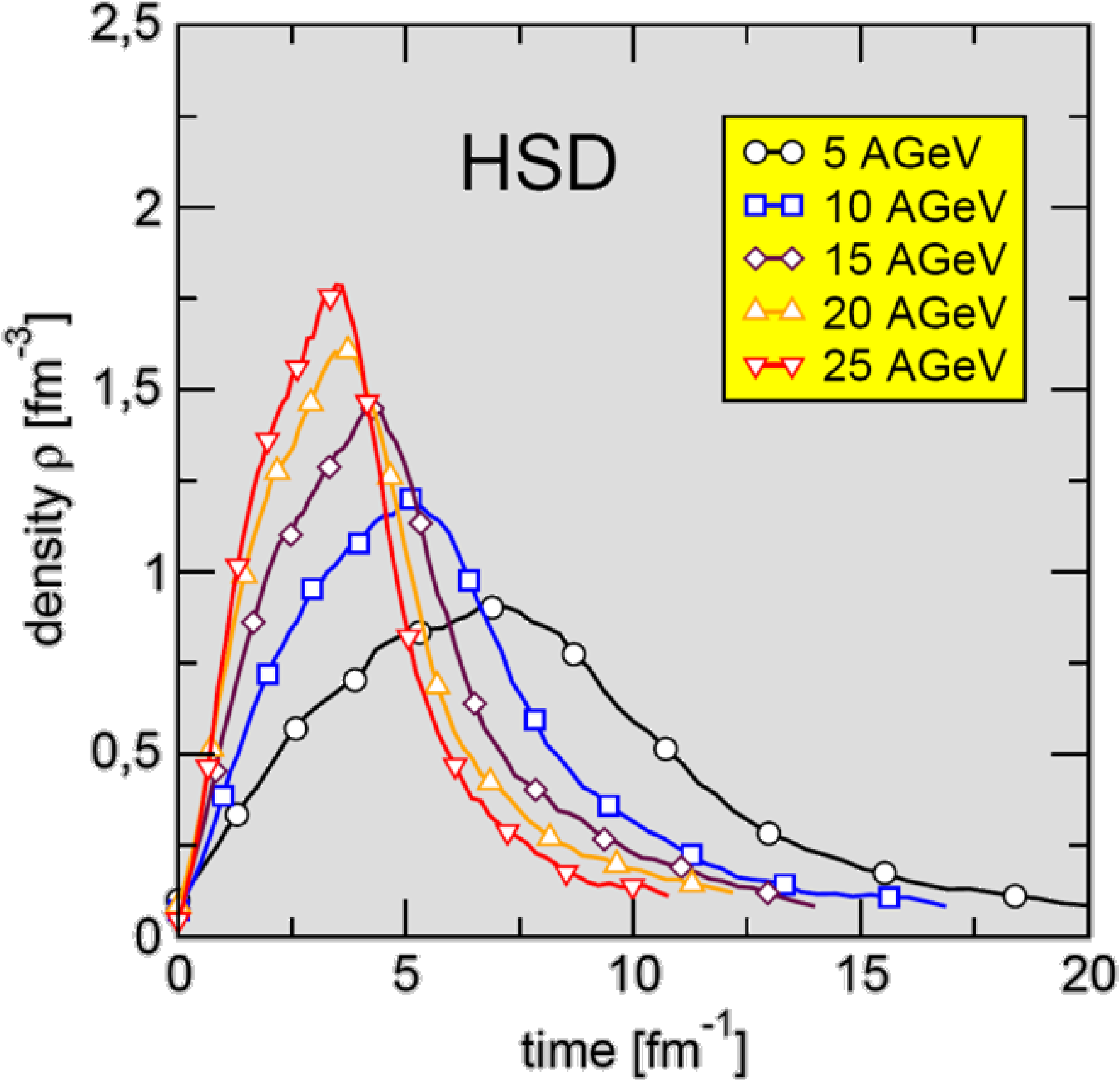
$\sqrt{S_{NN}}$= 11 GeV (Au^{79+}) and =27 GeV (p)

Highest baryon density at Lab

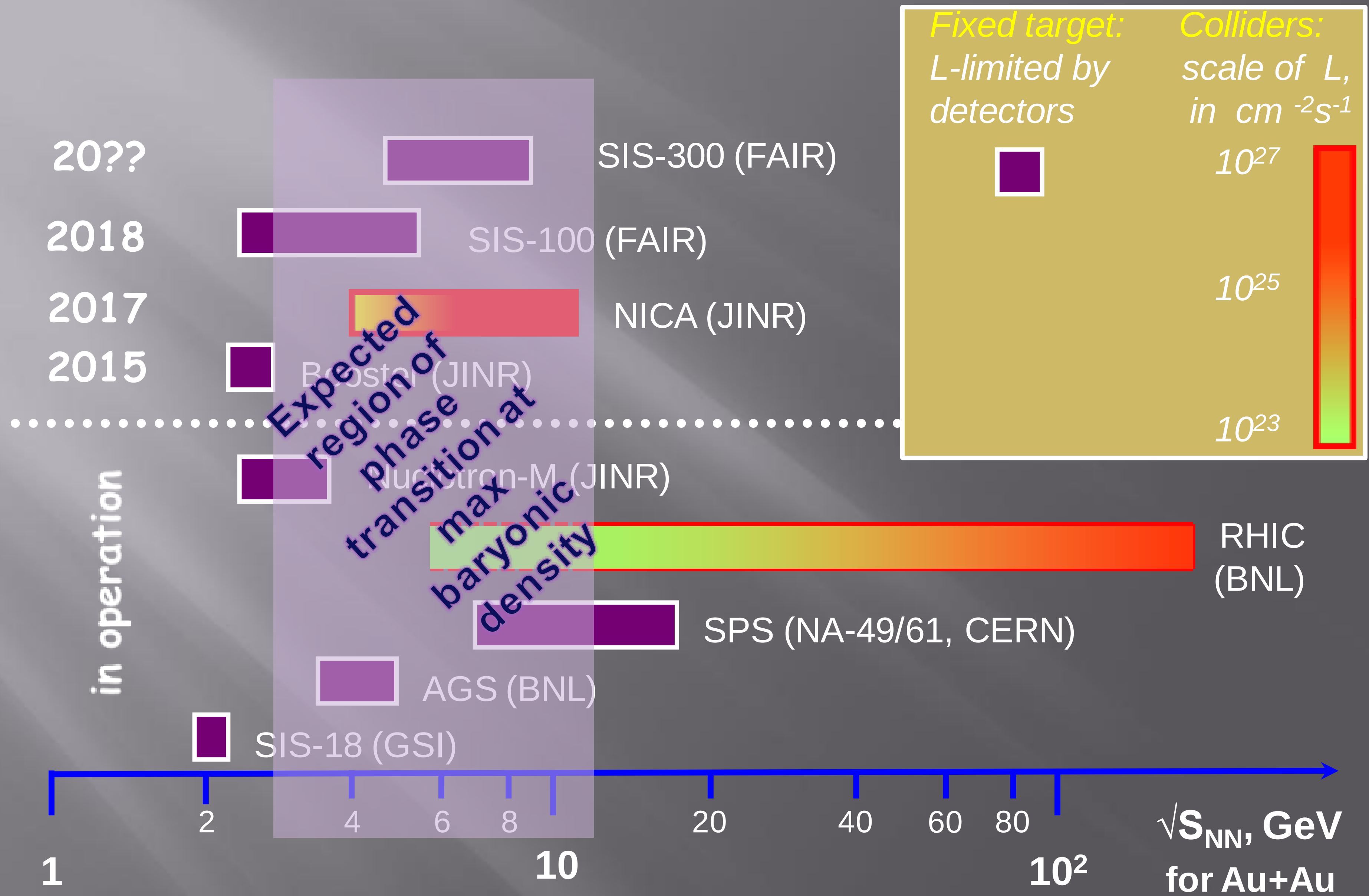
System of maximal net baryon (freeze-out) density is created in A+A collisions at NICA energies → optimum for the compressed baryon matter exploration

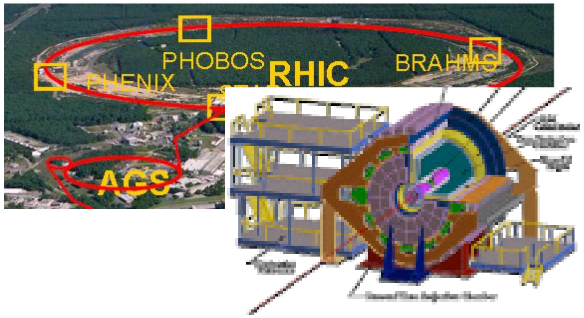


J.Randrup, J.Cleymans, 2006


HSD
5 AGeV
10 AGeV
15 AGeV
20 AGeV
25 AGeV
density ρ [fm^-3]
time [fm^-1]
0
0,5
1
1,5
2
2,5
5
10
15
20

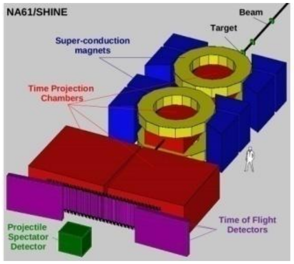
Existing & Future HI Machines





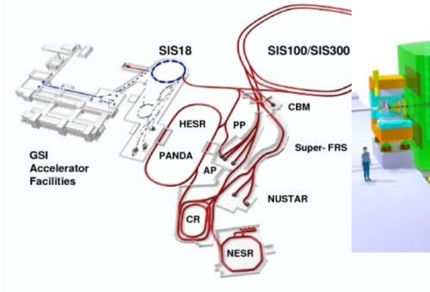
2^{nd} generation HI experiments

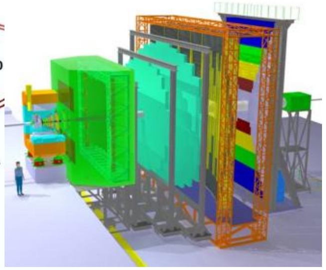
BES STAR/PHENIX@BNL/RHIC



NA61@CERN/SPS

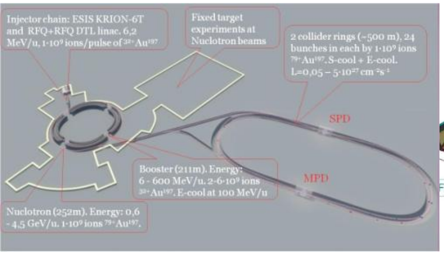
3^{nd} generation HI experiments

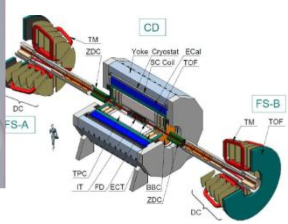




CBM@FAIR/SIS-100/300

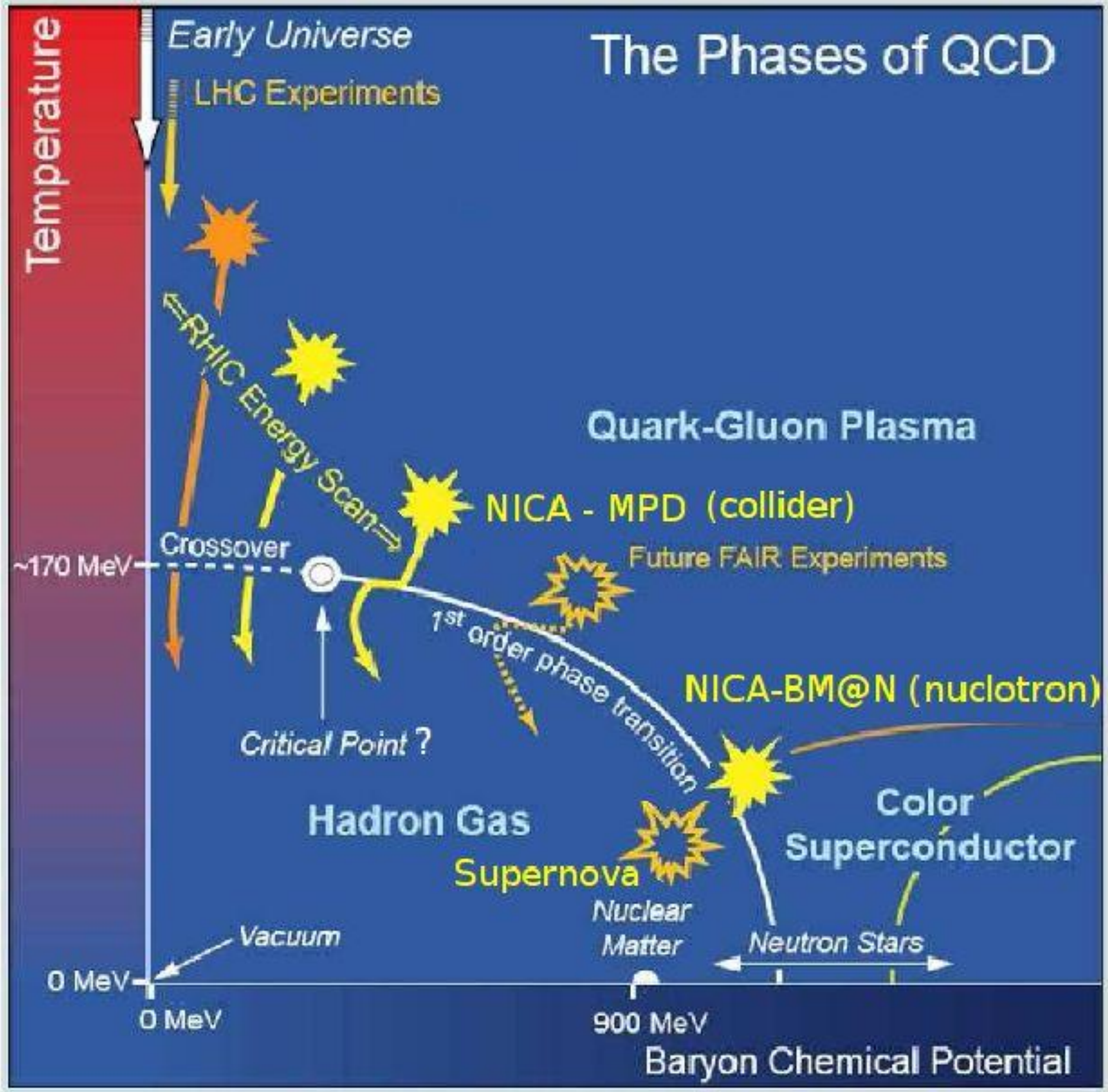
Fixed target, E/A=10-40 GeV, highest intensity





MPD@JINR/NICA

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



The Phases of QCD
Temperature
Early Universe
LHC Experiments
RHIC Energy Scan
Quark-Gluon Plasma
NICA - MPD (collider)
Crossover
~170 MeV
Future FAIR Experiments
1st order phase transition
NICA-BM@N (nuclotron)
Critical Point ?
Hadron Gas
Color Superconductor
Supernova
Nuclear Matter
Vacuum
Neutron Stars
0 MeV
0 MeV
900 MeV
Baryon Chemical Potential

Dense QCD Matter Physics

- **Nuclear equation-of-state, new forms of matter at high densities?**
  What are the properties and the degrees of freedom of QCD matter at neutron star core densities?

- **Hadrons in dense matter:**
  What are the in-medium properties of hadrons?
  Is chiral symmetry restored at very high baryon densities?

- **Production of single and double hypernuclei**
  How far can we extend the third (strange) dimension of the nuclear chart?

- **Strange matter:**
  Does strange matter exist in the form of heavy multi-strange objects?

Physics Topics and Observables

The equation-of-state at high ρ_B

- collective flow of hadrons
- particle production at threshold energies (multistrange hyperons)

Deconfinement phase transition at high ρ_B

- excitation function and flow of strangeness (K, Λ, Σ, Ξ, Ω)
- excitation function of low-mass lepton pairs

QCD critical endpoint

- excitation function of dynamical event-by-event fluctuations

Onset of chiral symmetry restoration at high ρ_B

- in-medium modifications of hadrons ($\rho,\omega,\phi \rightarrow e^+e^-(\mu^+\mu^-)$)

Strange matter

- (double-) lambda hypernuclei
- strange meta-stable objects (e.g. strange dibaryons)

Experiments on superdense nuclear matter

Experiments	Energy range (Au/Pb beams)	Reaction rates Hz
STAR@RHIC BNL	$\sqrt{s_{NN}}$ = 7 – 200 GeV	1 – 800 (limitation by luminosity)
NA61@SPS CERN	E_{kin}= 20 – 160 A GeV $\sqrt{s_{NN}}$= 6.4 – 17.4 GeV	80 (limitation by detector)
MPD@NICA Dubna	$\sqrt{s_{NN}}$= 4.0 – 11.0 GeV	~7000 (design luminosity of 10^{27} $cm^{-2}s^{-1}$ for heavy ions)
CBM@FAIR Darmstadt	E_{kin}= 2.0 – 35 A GeV $\sqrt{s_{NN}}$= 2.7 – 8.3 GeV	10^5 – 10^7 (limitation by detector)

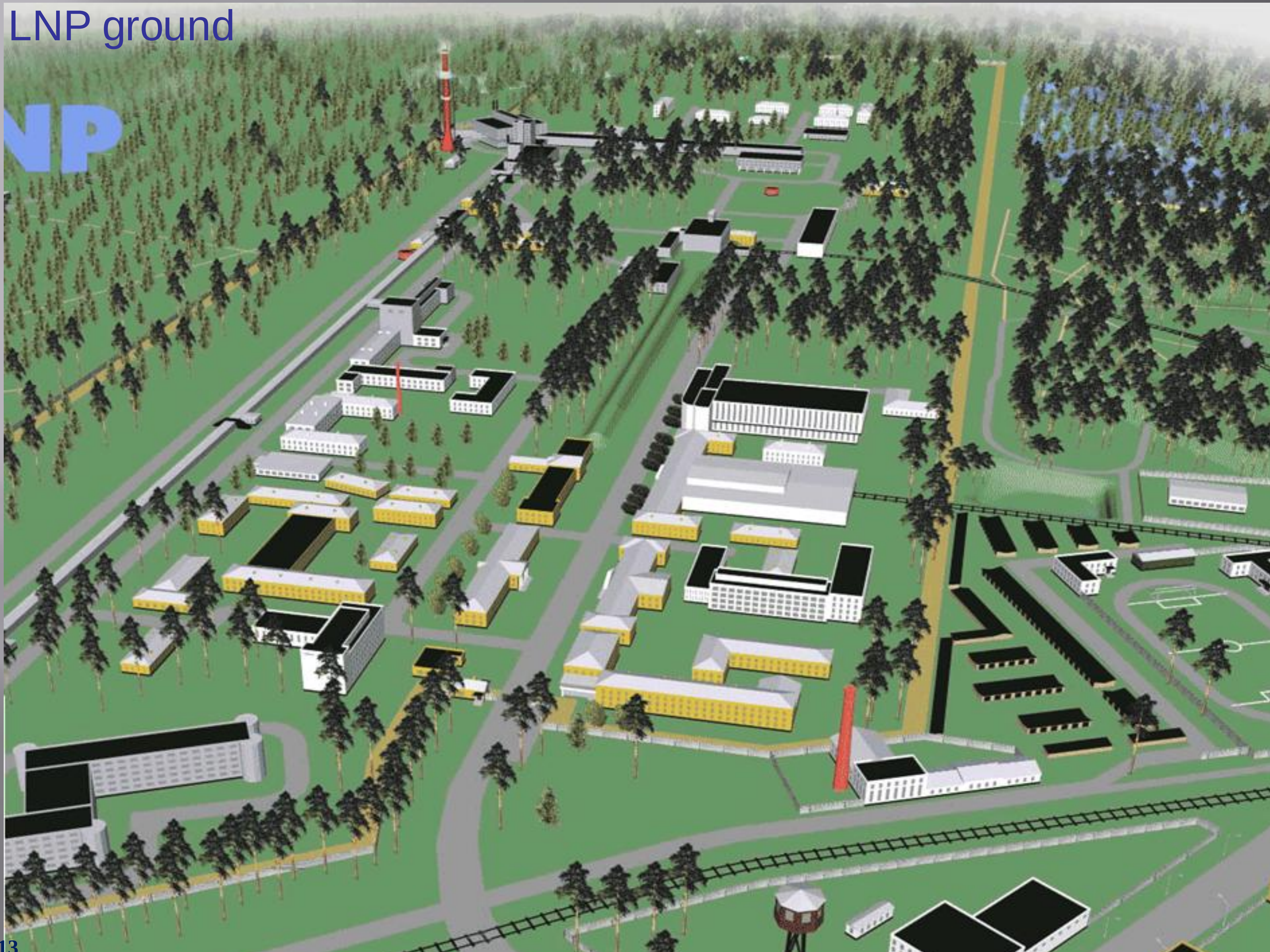
Experiments on superdense nuclear matter

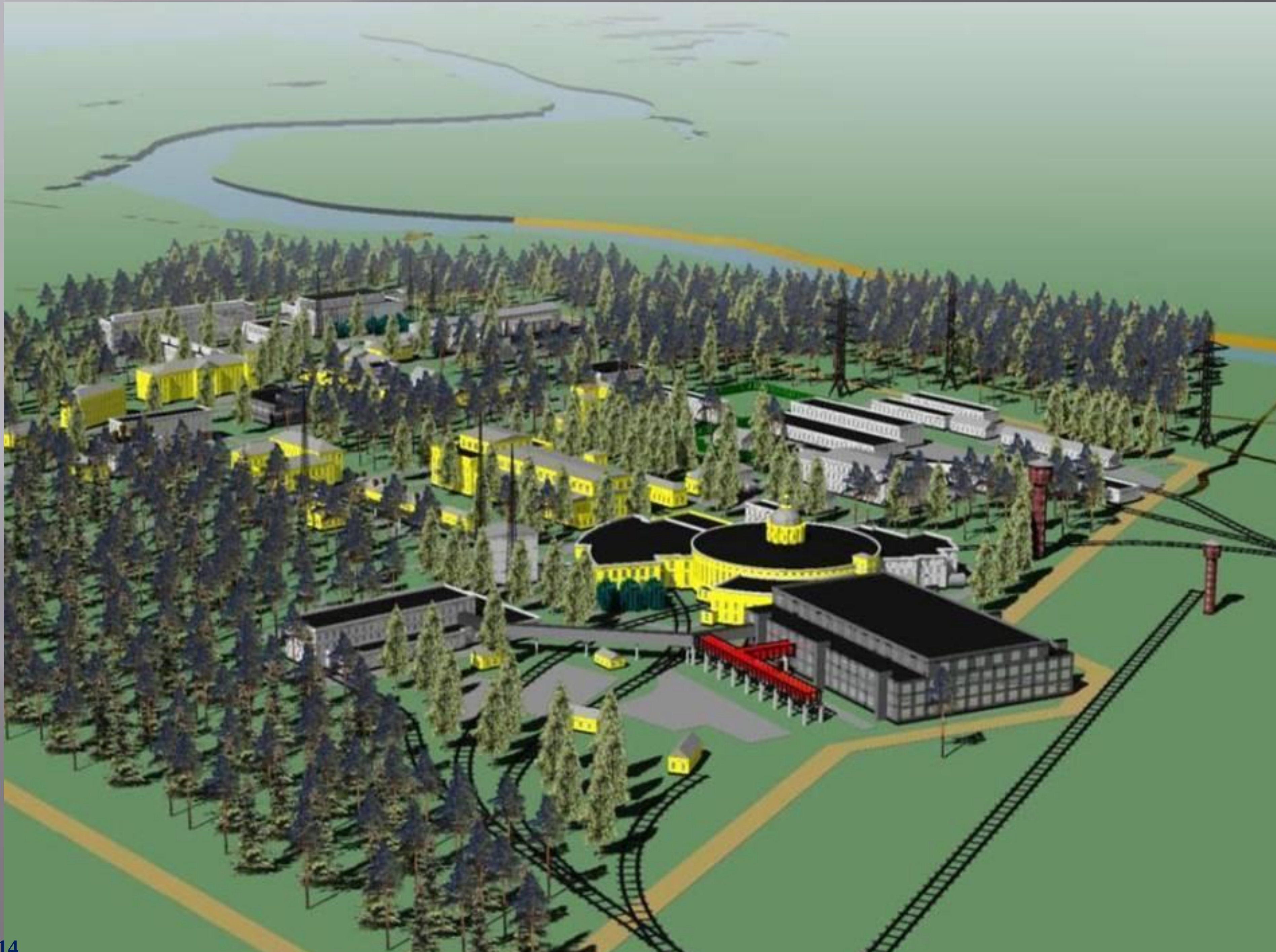
Experiments	Observables for high baryon density region			
	hadrons	correlations, fluctuations with high statistics	dileptons	charm
STAR@RHIC BNL	yes	no	no	no
NA61@SPS CERN	yes	no	no	no
MPD@NICA Dubna	yes	yes	yes	no
CBM@FAIR Darmstadt	yes	yes	yes	yes

Advantage of collider experiments:
Uniform phase-space coverage when measuring excitation functions.

NICA site

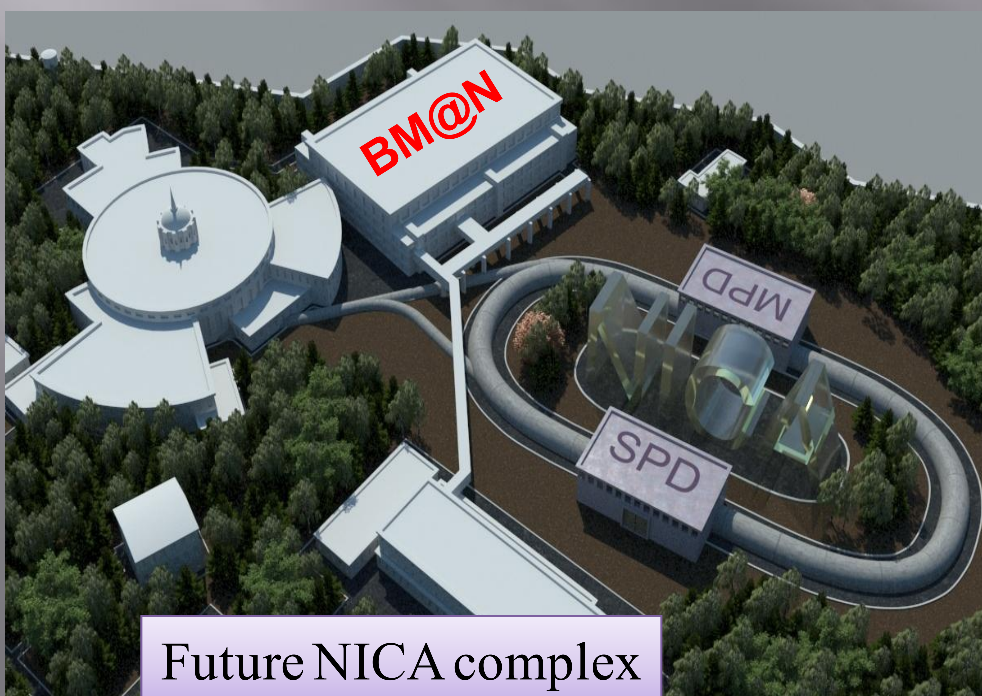
LNP ground





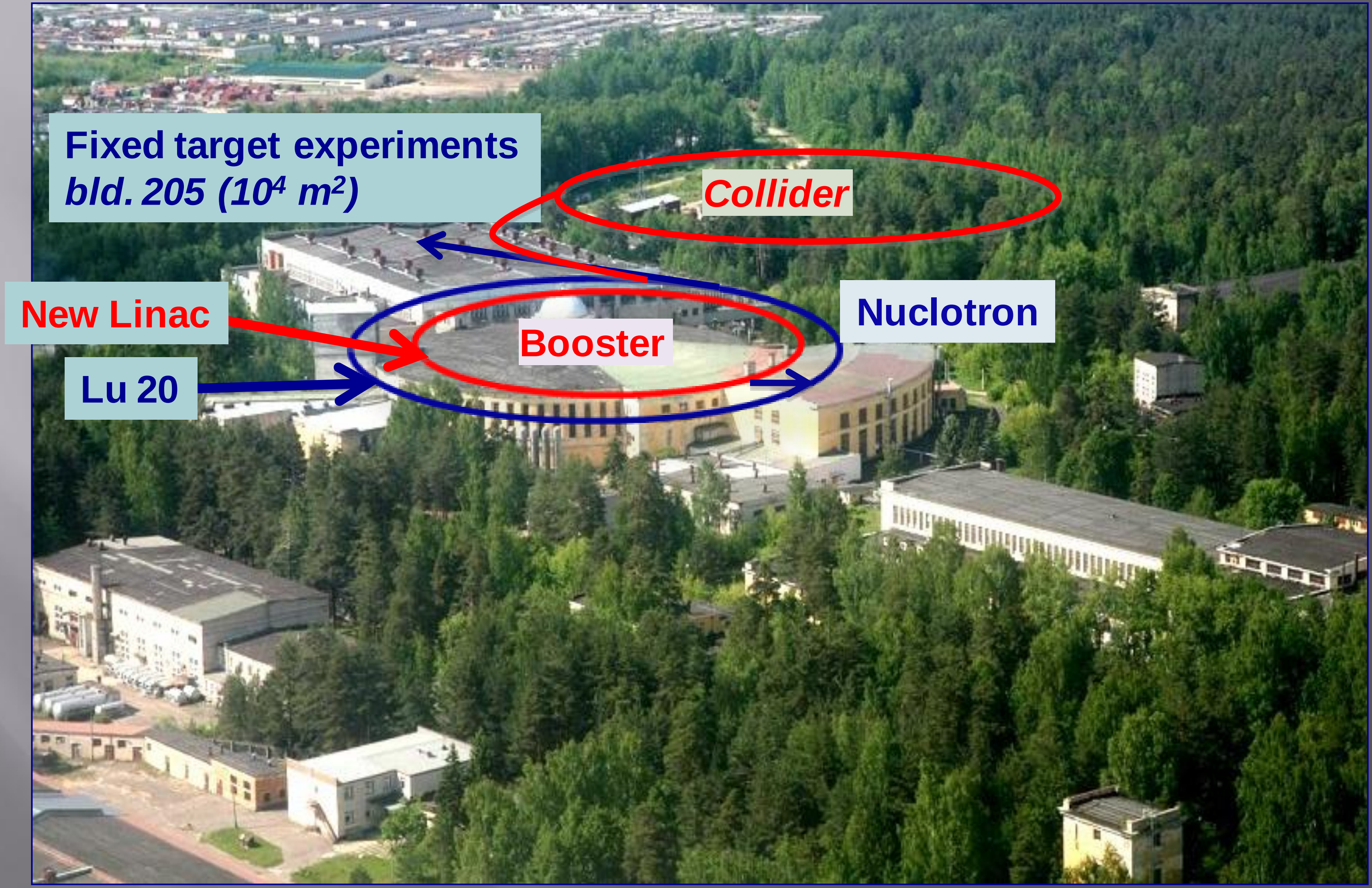

Nuclotron


LHEP JINR


BM@N
MPD
SPD
Future NICA complex


Synchrophasotron

Nuclotron-based Ion Collider fAcility (NICA)



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

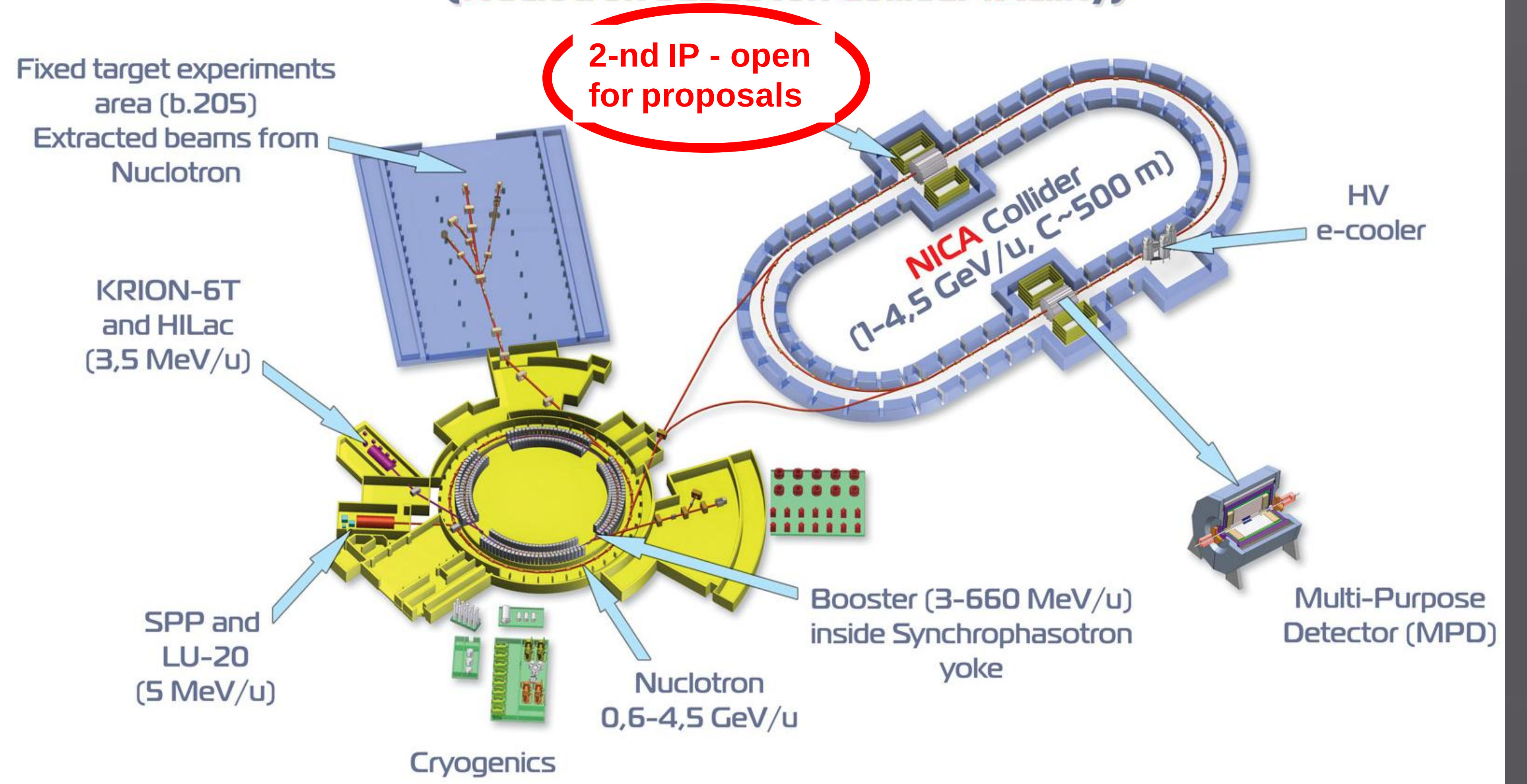
p, p↑ = 5 ÷ 12.6 GeV kinetic energy

d, d↑ = 2 ÷ 5.9 GeV/u ion kinetic energy

4) Applied research with ion beams at kinetic energy

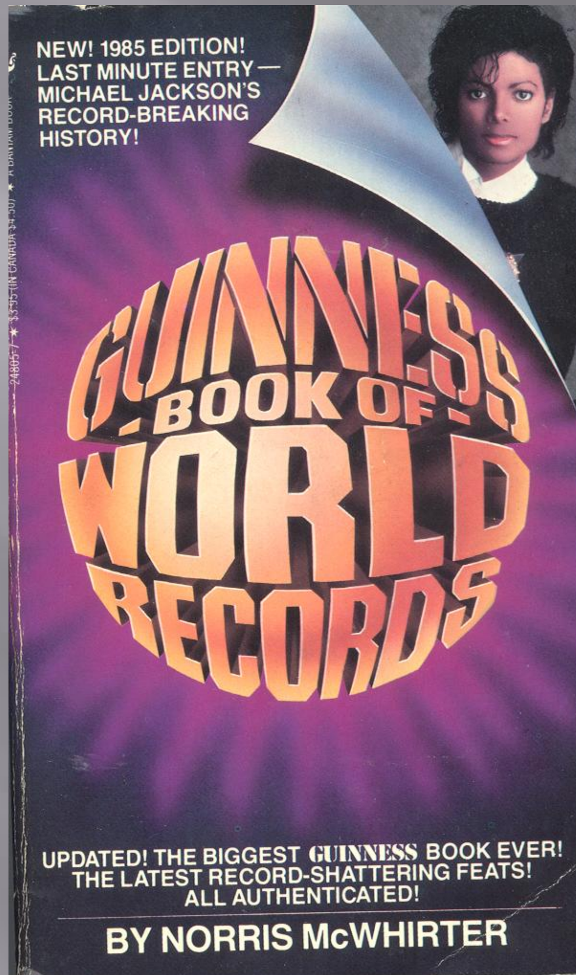
from 0.5 GeV/u up to 12.6 GeV (p) and 4.5 GeV /u (Au)

Superconducting accelerator complex NICA
(Nuclotron based Ion Collider fAcility)



NICA Collider parameters:

- **Energy range: $\sqrt{s_{NN}}$ = 4-11 GeV**
- **Beams: from p to Au**
- **Luminosity: L~10^{27} (Au), 10^{32} (p)**
- **Detectors: MPD; Waiting for Proposals**



GUINNESS

1985 BOOK OF

WORLD RECORDS

Editors and Compilers
NORRIS McWHIRTER
(ROSS McWHIRTER 1955–1975)

1985 EDITION:

DAVID A. BOEHM, American Editor

MARIS CAKARS, Sports Editor

CYD SMITH, Assistant Editor

JIM BENAGH, Sports Contributor

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Heaviest Magnet

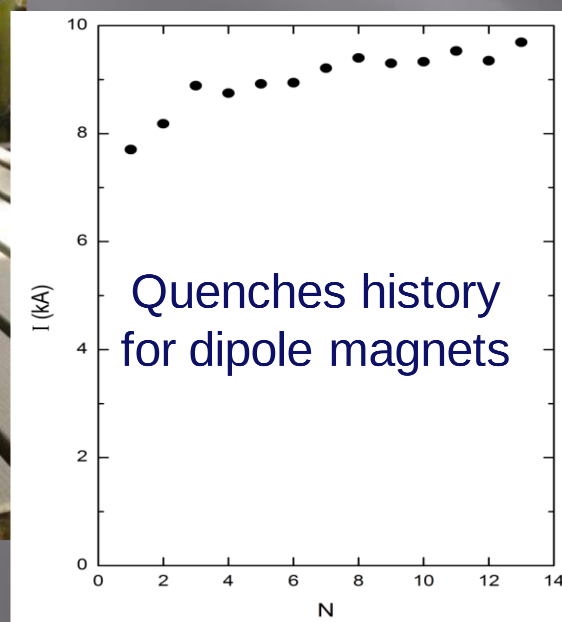
The heaviest magnet is one measuring 196 ft in diameter, with a weight of 40,000 tons, for the 10 GeV synchrophasotron in the Joint Institute for Nuclear Research at Dubna, near Moscow.

SC magnet production for NICA *(booster, collider)* & FAIR

Dipole magnet in cryostat

yoke of quadrupole lens after final treatment

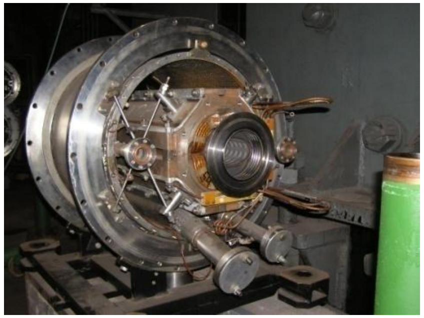
Prototype of curved dipole



Dipole magnet for collider

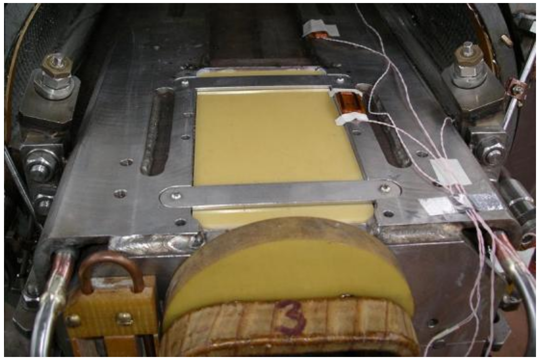
The building is ready for the equipment installation

Constructing and Testing JINR Experience

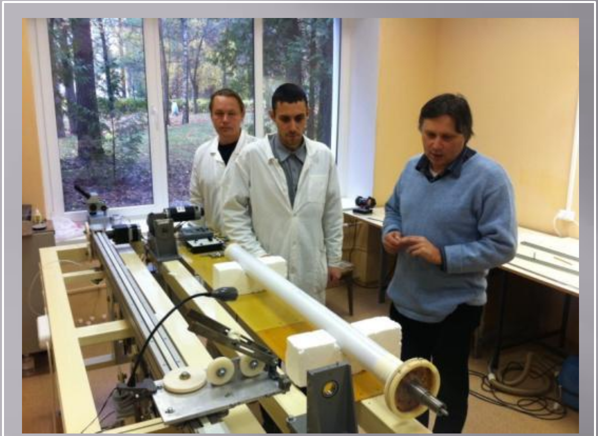

160 SC dipole and quadrupole magnets for the Nuclotron: construction, test and operation since1993.

26 model magnets for SIS100



SIS100 prototype dipole and prototype quadrupole magnets


Modern SC technologies + unique accelerator physics at JINR



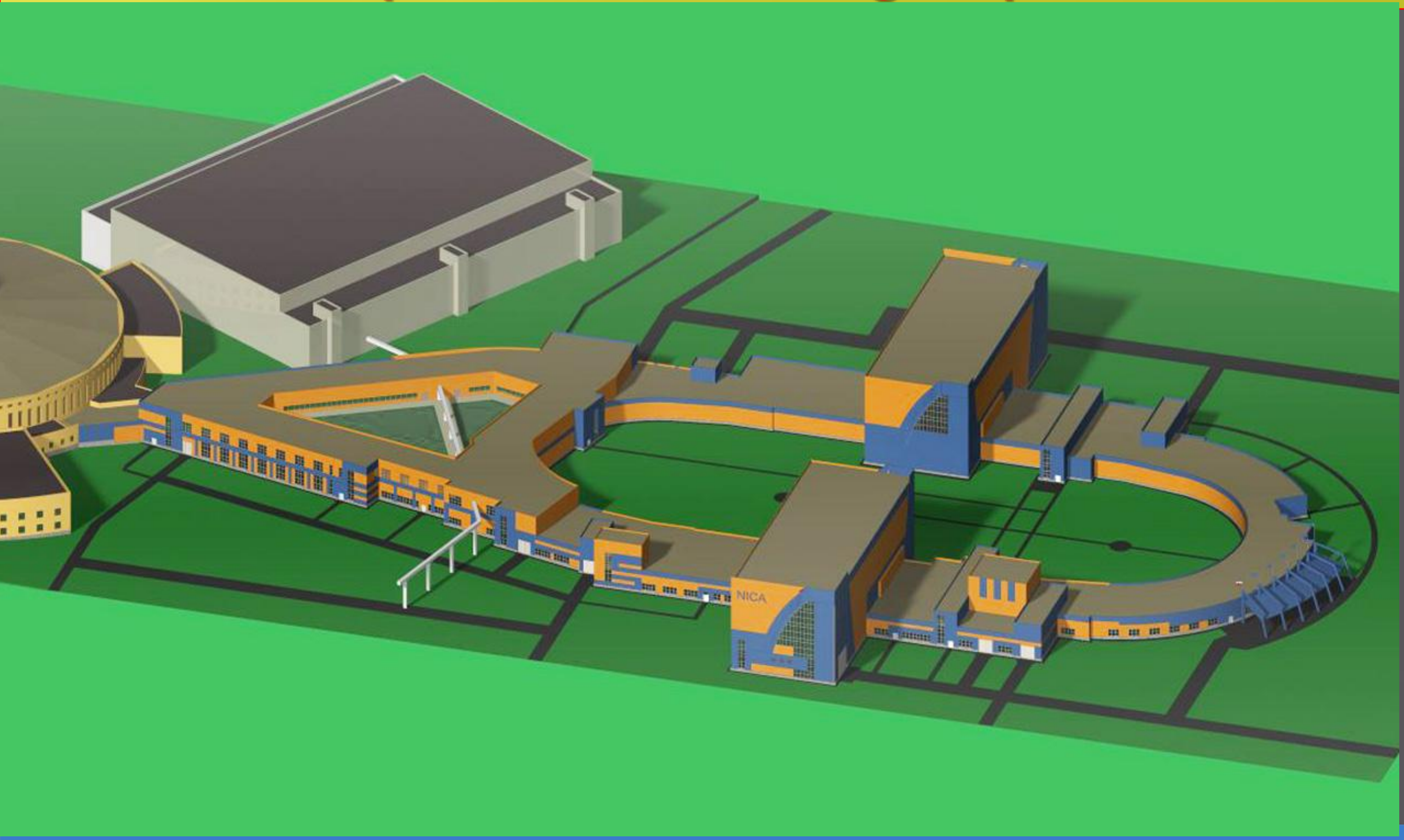
Highly charged ion state for heavy ions with high intensity, e.g., Kr 28+, Xe 44+, Au 65+..32+

Quadrupole and curved Dipole magnet for booster

Dipole magnet for NICA collider

New Source of Polarized Ions (≤10 mA *for* ↑D+ (↑ H+)) assembled and first test has been started.

NICA complex technical design report status



Geological, geodetical, topography measurements and drillings had been fulfilled and analyzed. Technological part of the TDR (main equipment, engineering systems, etc), radiation and environmental safety, architecture had been fulfilled. Now – the final stage: capital spending sights. Plan – to submit all documents to the State Expertise – end of 2012

NICA TDR

MultiPurpose Detector (MPD): Observables

I stage: *mid rapidity region (good performance)*

- *Particle yields and spectra (π, K, p, clusters, Λ, Ξ, Ω)*
- *Event-by-event fluctuations*
- *Femtoscopy involving π, K, p, Λ*
- *Collective flows for identified hadron species*
- *Electromagnetic probes (electrons, gammas)*

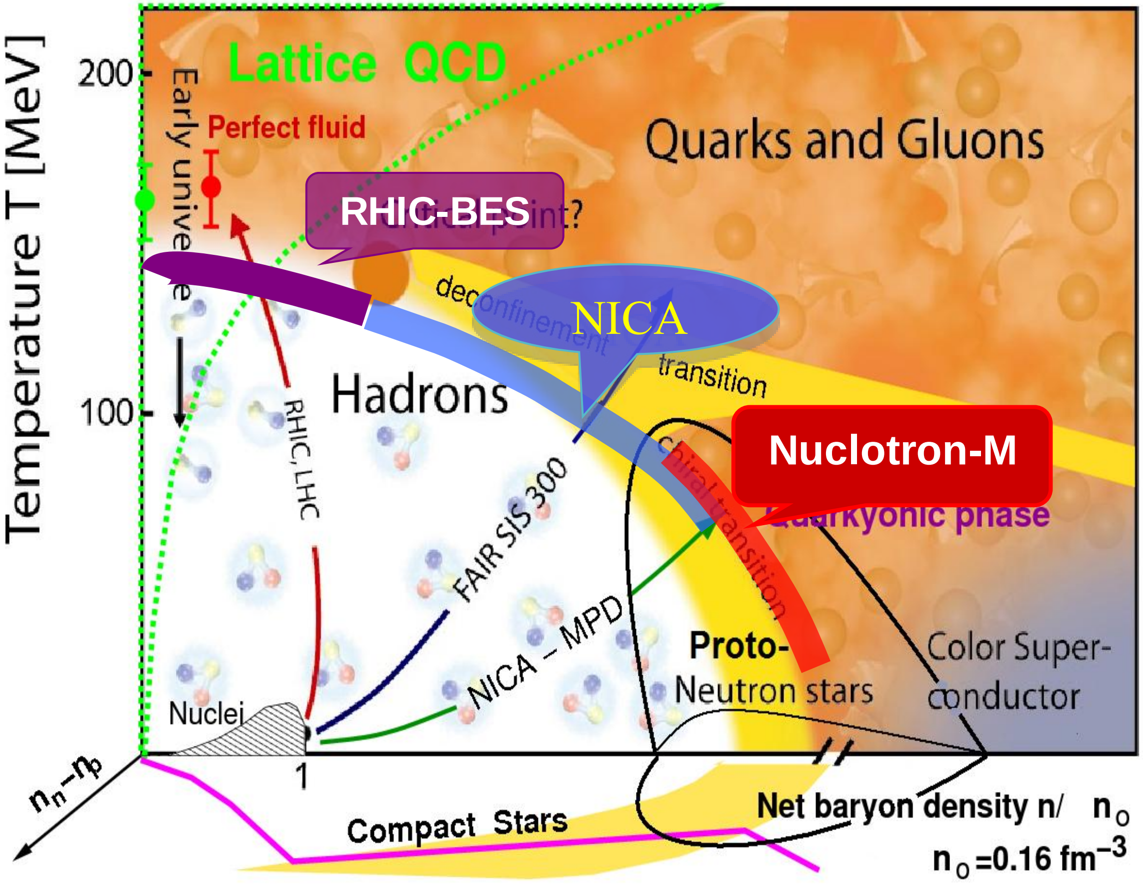
II stage: *extended rapidity + IT*

…..

- *Total particle multiplicities*
- *Asymmetries study (**better reaction plane determination**)*
- *Di-Lepton **precise** study (**ECal expansion**)*
- *Exotics (soft photons, hypernuclei)*

Measurements regarded as complementary to RHIC/BES, CERN/NA61 & FAIR

QCD phase diagram: prospects for NICA



Energy Range of NICA

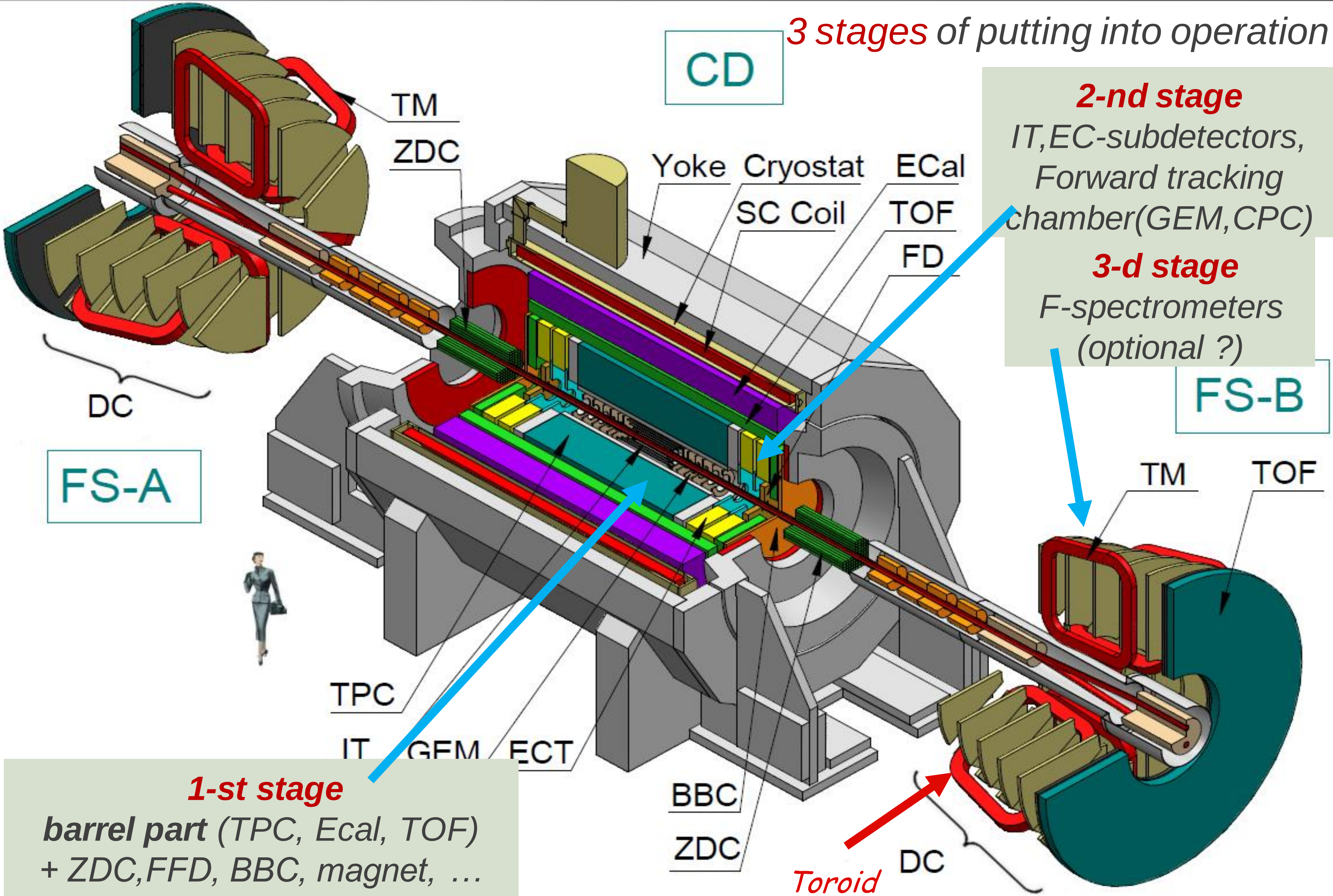
unexplored region of the QCD phase diagram:

- **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. NICA provides capabilities for studying a variety of phenomena in a large region of the phase diagram.

MultiPurpose Detector (MPD)

3 stages of putting into operation

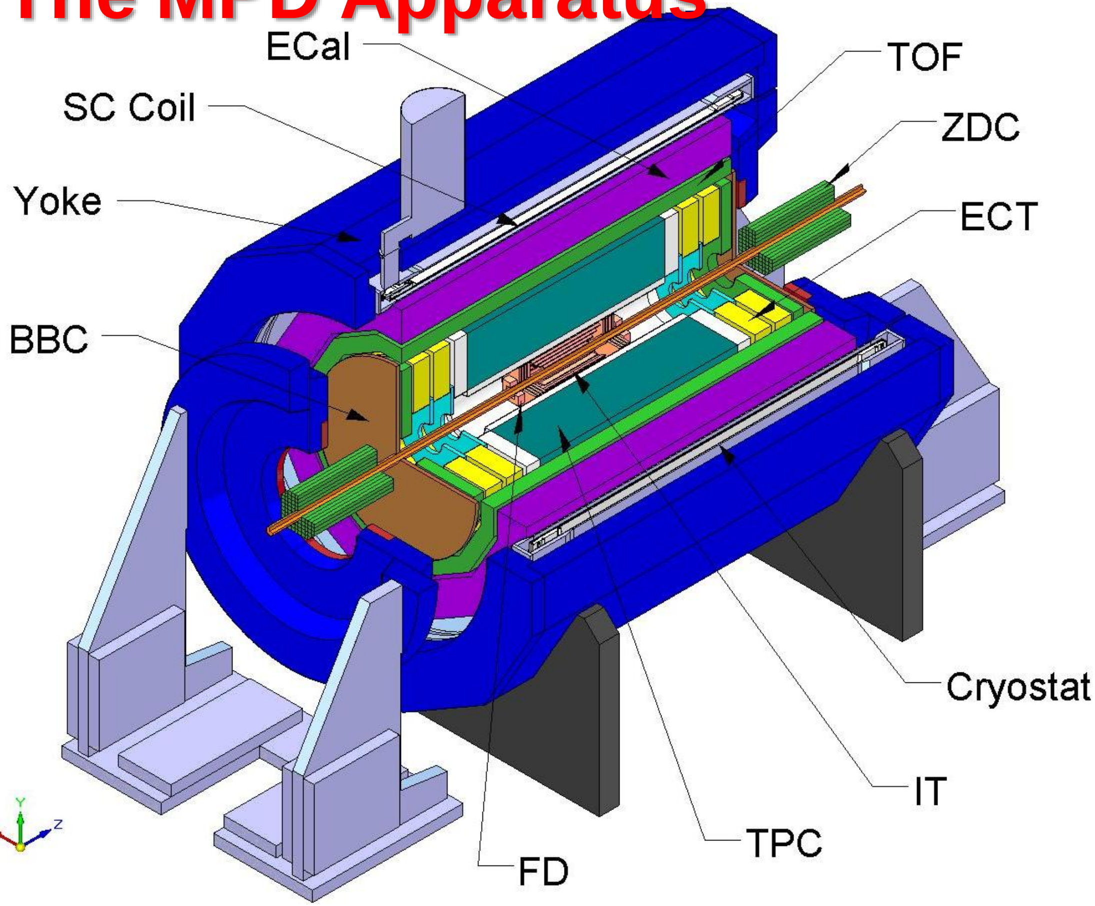


2-nd stage
IT,EC-subdetectors, Forward tracking chamber(GEM,CPC)

3-d stage
F-spectrometers (optional ?)

1-st stage
barrel part *(TPC, Ecal, TOF)*
+ ZDC,FFD, BBC, magnet, …

The MPD Apparatus

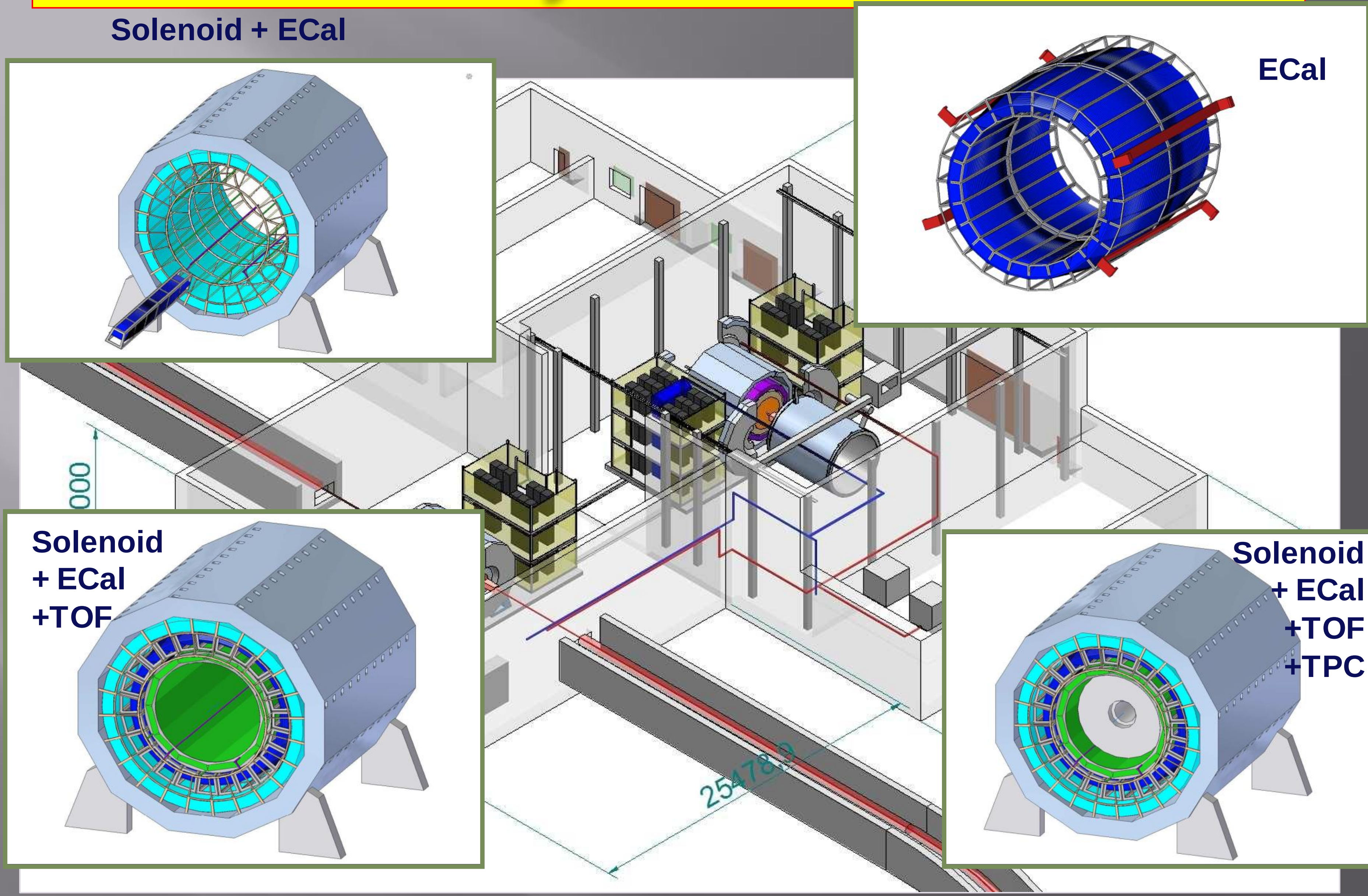


- **Active volume**
  5 m (length) x 4 m (diameter)
- **Magnet**
  0.5 T superconductor
- **Tracking**
  TPC & straw EndCapTracker & silicon pixels (IT) for vertexing
- **Particle ID**
  hadrons(TPC+TOF), π^0,γ (ECAL), e^+e^-(TPC+TOF+ECAL)
- **Centrality & T0 timing**
  ZDC FD

MPD Advantages:

- **Hermeticity, homogenous acceptance (2π in azimuth), low material budget**
- **Excellent tracking performance and powerful PID**
- **High event rate capability and careful event characterization**

Assembly & maintenance



Particle yields, Au+Au @ $\sqrt{s_{NN}}$ = 8 GeV *(central collisions)*

Expectations for 10 weeks of running at $L = 10^{27} cm^{-2}s^{-1}$ *(duty factor = 0.5)*

Particle	Yields 4π	Yields y=0	Decay mode	BR	*Effic. %	Yield/10 w
π^+	293	97	----	---	61	$2.6 \cdot 10^{11}$
K^+	59	20	---	----	50	$4.3 \cdot 10^{10}$
p	140	41	---	----	60	$1.2 \cdot 10^{11}$
ρ	31	17	e+e-	$4.7 \cdot 10^{-5}$	35	$7.3 \cdot 10^{5}$
ω	20	11	e+e-	$7.1 \cdot 10^{-5}$	35	$7.2 \cdot 10^{5}$
φ	2.6	1.2	e+e-	$3 \cdot 10^{-4}$	35	$1.7 \cdot 10^{5}$
Ω	0.14	0.1	ΛK	0.68	2	$2.7 \cdot 10^{6}$
D^0	$2 \cdot 10^{-3}$	$1.6 \cdot 10^{-3}$	$K^+\pi^-$	0.038	20	$2.2 \cdot 10^{4}$
J/ψ	$8 \cdot 10^{-5}$	$6 \cdot 10^{-5}$	e+e-	0.06	15	10^{3}

*Efficiency includes the MPD acceptance, realistic tracking and particle ID.
Particle yields are from experimental data (NA49), statistical and HSD models.
Efficiency from MPD simulations. Typical efficiency from published data (STAR)

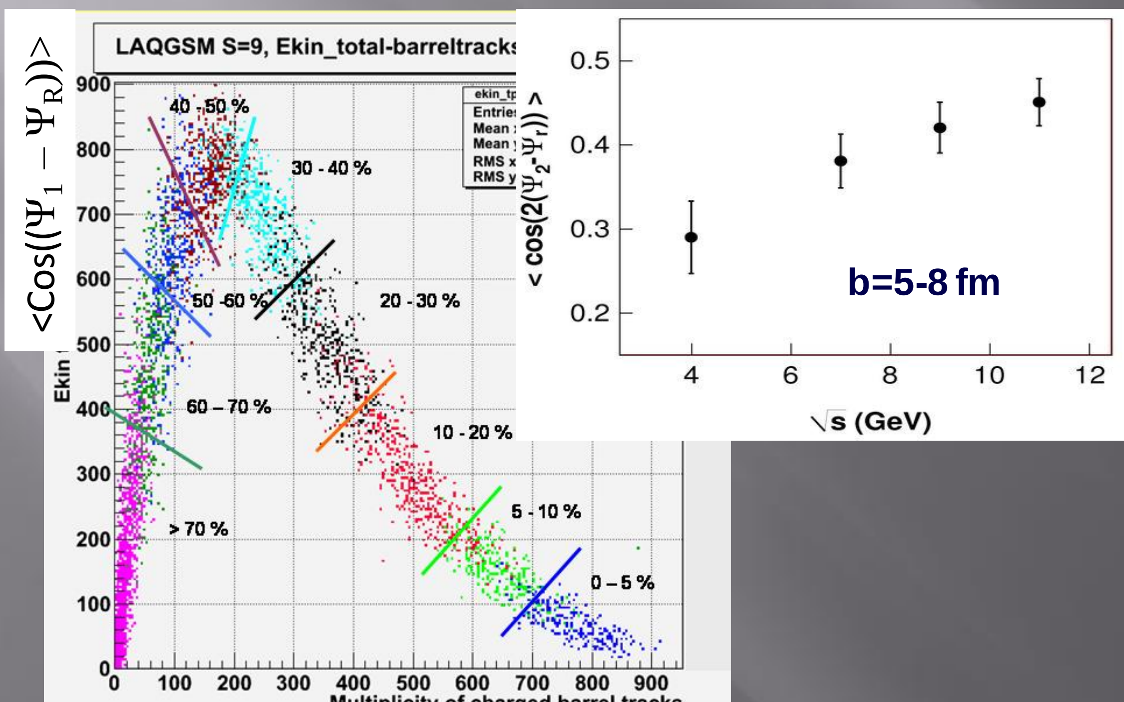
Reaction plane determination & flow study

- ✓ v2 in TPC & v1 at high rapidities
  (a possibility for improvement)
- ✓ v2 in TPC by a 'two sub-events '
  to avoid autocorrelations
- ✓ Measurement of spectators of both colliding nuclei;
  centrality determination by track multiplicity
  & spectator energy deposit

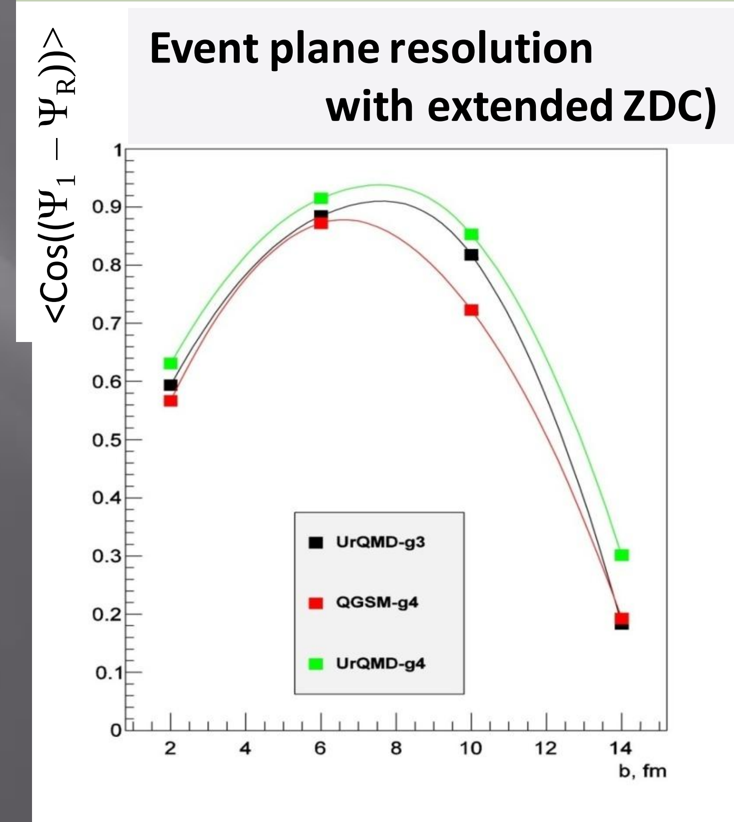
Extended ZDC detector (2<η<5)
improves RP resolution
at low & medium b

- L = 120 (60) cm
- 5 < R < 71 cm, 1<θ<14° (2<η<5)

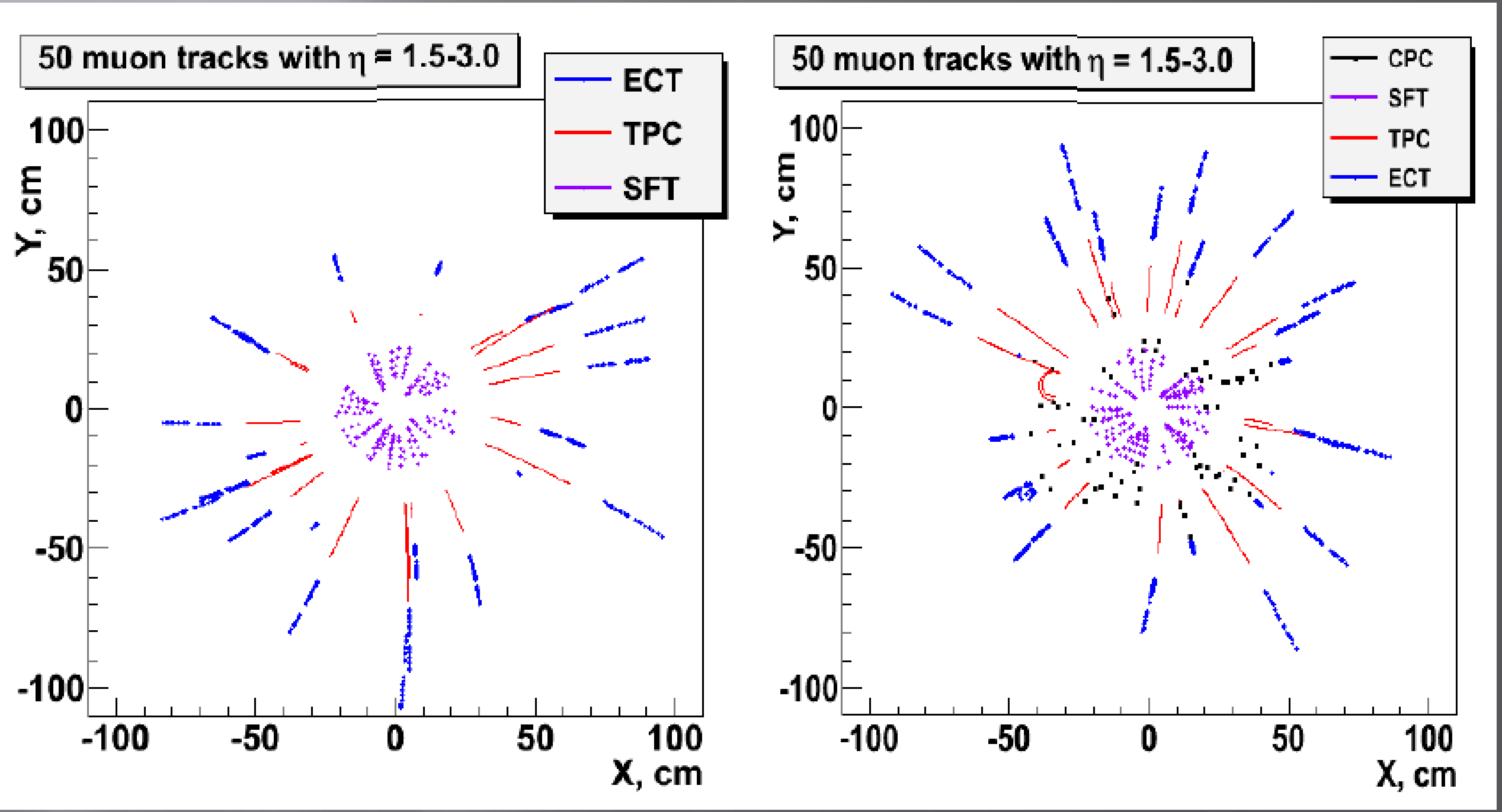
Event plane resolution for "central events"



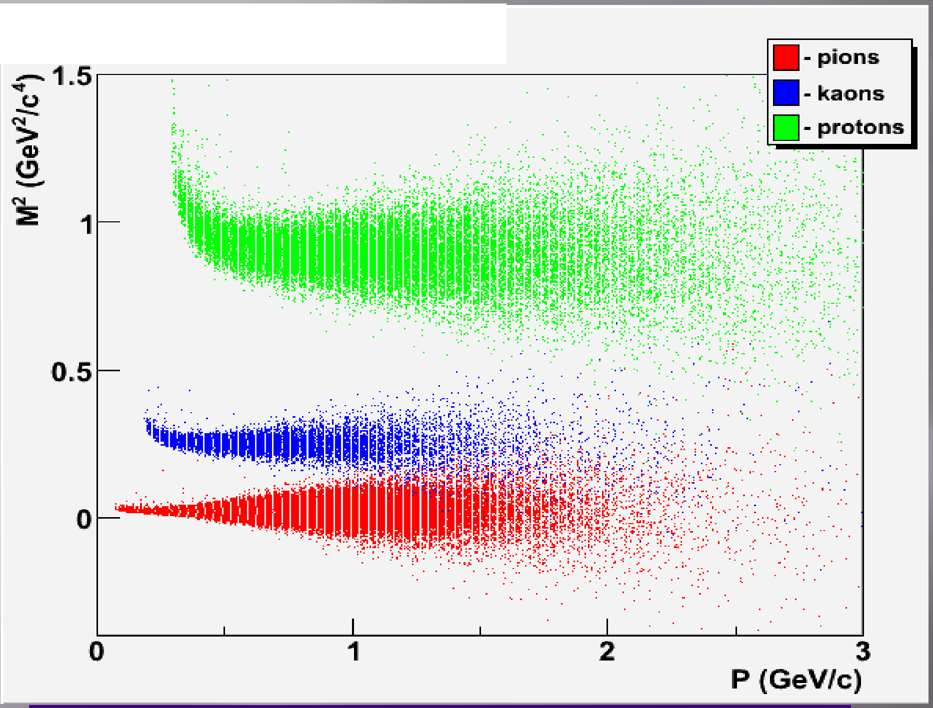
**Event plane resolution
with extended ZDC)**

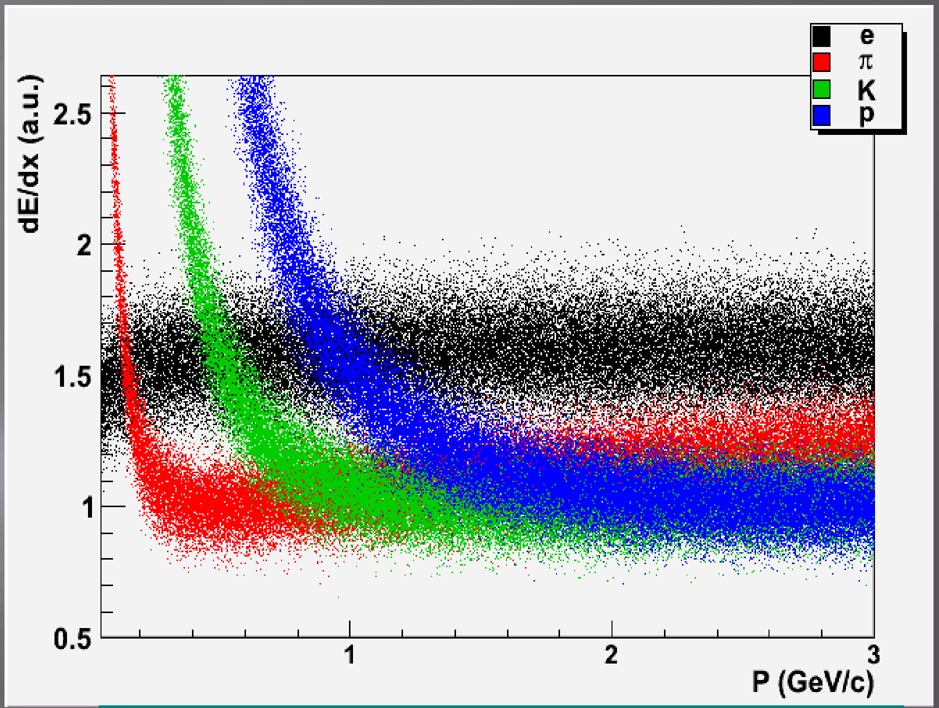


Global tracking



Particle IDentification at MPD
(realistic detector simulation)



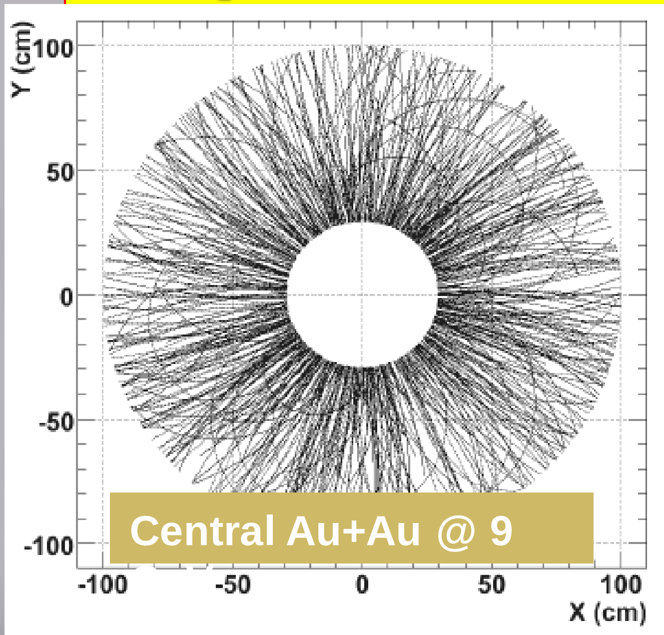


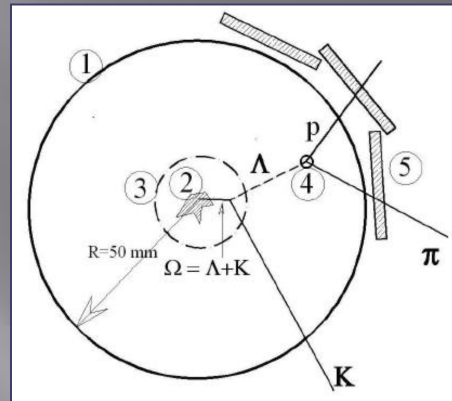
PID: *Time Of Flight*
Separation: **e/h – 0.1..0.35 GeV/c**
π/K – 0.1..1.5 GeV/c
K/p – 0.1..2.5 GeV/c

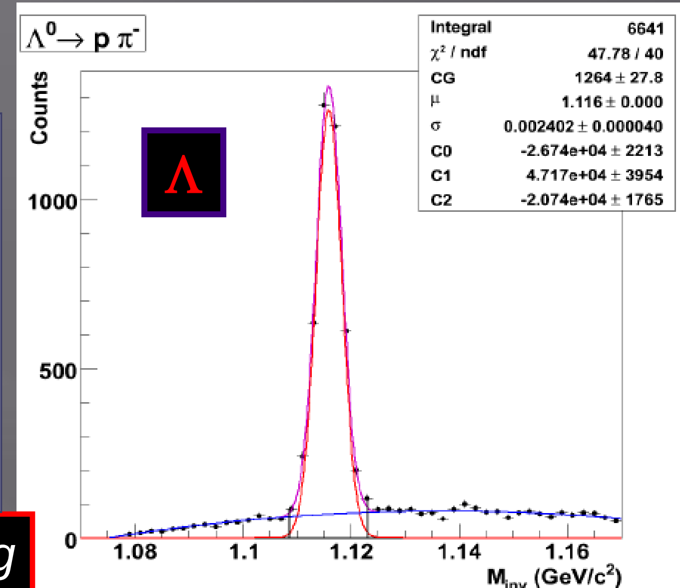
PID: *Ionization loss (dE/dx)*
Separation: **e/h – 1.3..3 GeV/c**
π/K – 0.1..0.6 GeV/c
K/p – 0.1..1.2 GeV/c

- **Coverage:** *$|\eta| < 1.4$, p_t=0.1-2 GeVc barrel / : $|\eta| < 2.6$, pt=0.1-2 GeVc barrel+EC*
- **Matching eff.:** *> 85% at $p_t > 0.5$ GeV/c*
- **PID:** *2σ π/K ~ 1.7 GeV/c, (π,K)/p ~ 2,5 GeV/c*

V0 performance (TPC+IT)

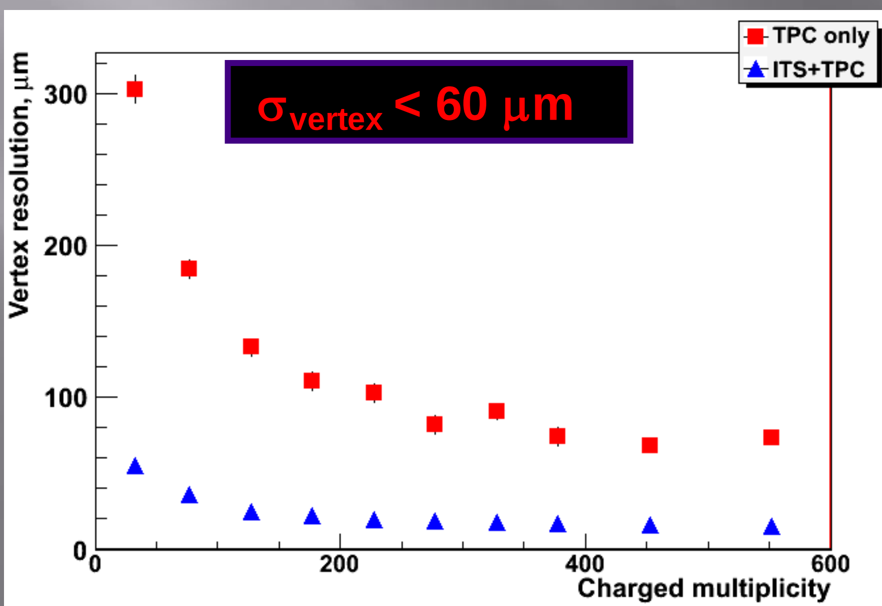


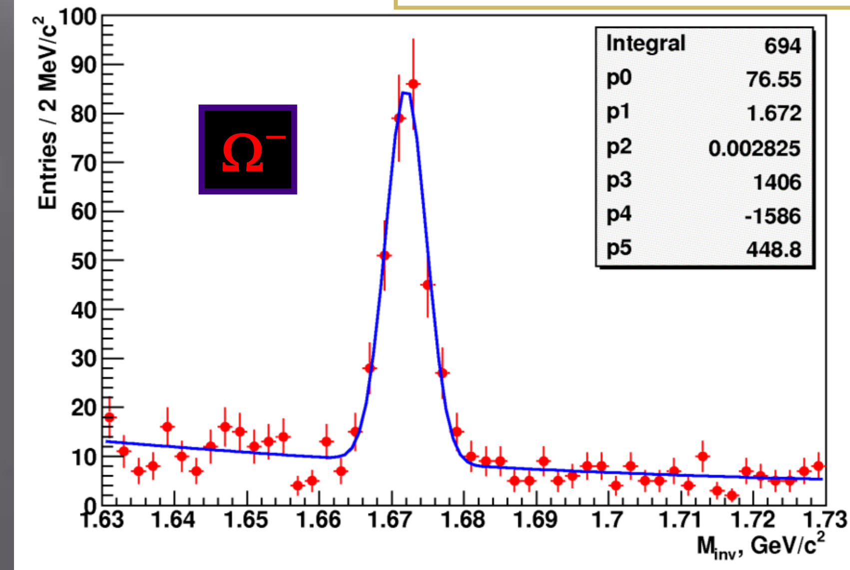




- *Improved Sg-to-Bg ratio (S/B) with the vertex IT detector*

	Λ^0		K_s^0	
Signal	3796		4845	
---------------- =	-------	= 7.6;	-------	= 5
Background	498		962	



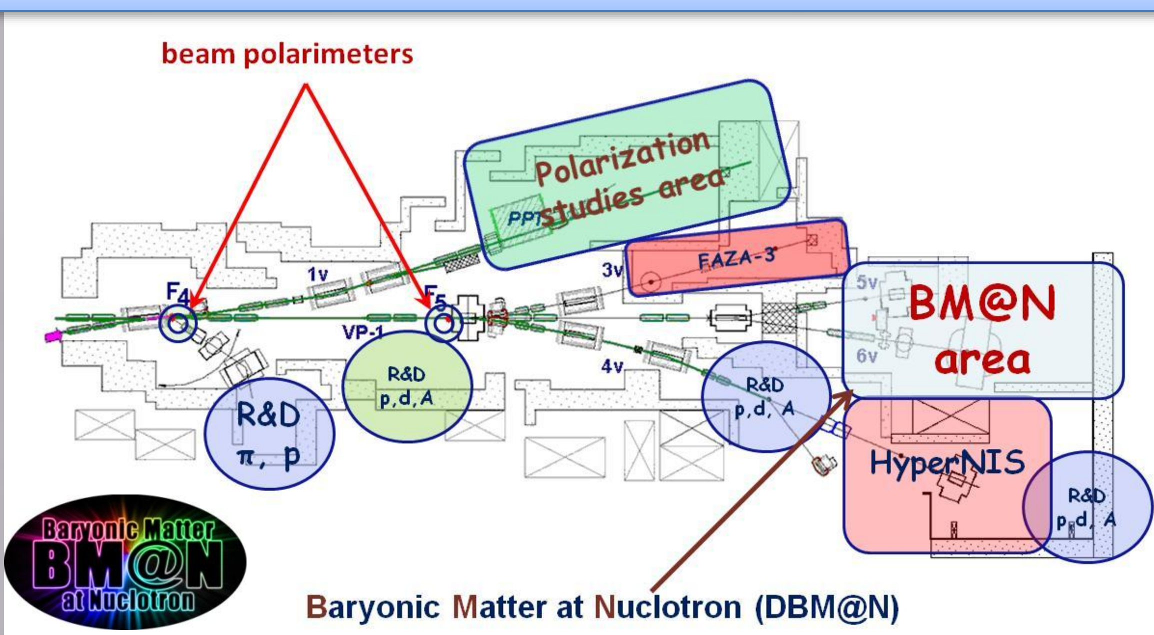


Beam	Nuclotron beam intensity (particle per cycle)		
	Current	Ion source type	New ion source + booster
p	$3 \cdot 10^{10}$	Duoplasmotron	$5 \cdot 10^{12}$
d	$3 \cdot 10^{10}$	--- „ ---	$5 \cdot 10^{12}$
^{4}He	$8 \cdot 10^{8}$	--- „ ---	$1 \cdot 10^{12}$
d↑	$2 \cdot 10^{8}$	SPI	$1 \cdot 10^{10}$
^{7}Li	$8 \cdot 10^{8}$	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	-	--- „ ---	$1 \cdot 10^{9}$

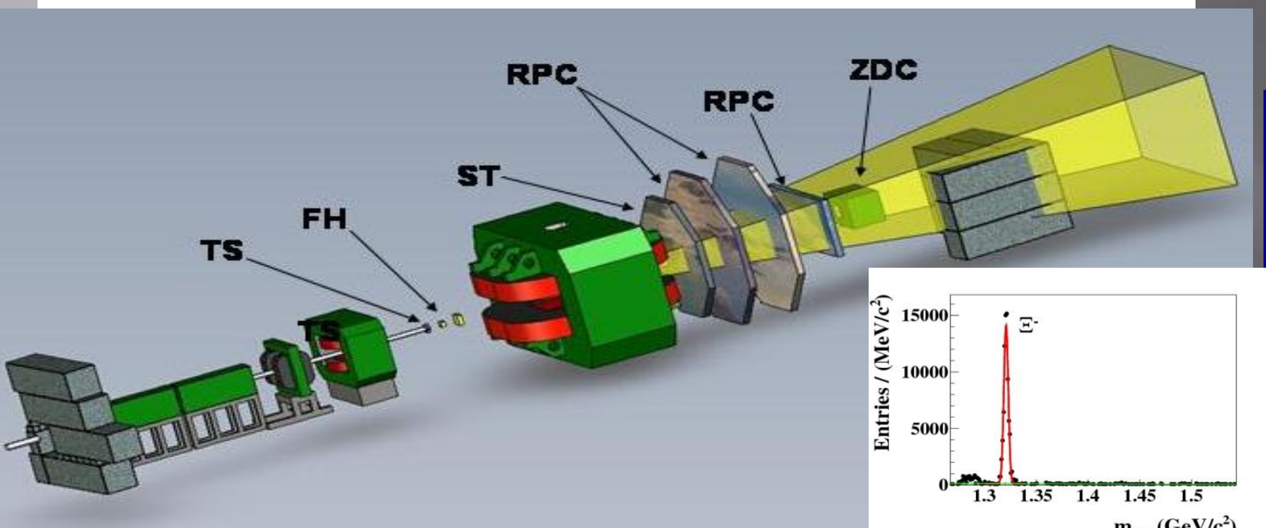
Strange matter production in heavy ion collisions at the Nuclotron extracted beam: Baryonic Matter at Nuclotron(BM@N)

- 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 beams (up to 5 A GeV)

Bld. 205 (*10 000 m²*): research zone with set-up on extracted beams



Data taking : **QUINTA**, project Energy+Transmutation: study of neutron generation in uranuim-238 target with lead blanket, energy dependence: spatial/time/energy distributions of the neutron spectra;
DELTA-LNS: search for a resonance in secondary pion spectra;
DSS: elastic d-p scattering, differential cross sections $d\sigma / d\Omega$;
FAZA-3: effects of phase transition in thermal multifragmentation
HyperNIS – search for exotic hypernuclei



1-st stage((w/o IT):
- ***vector mesons***
- ***flows & azhimuthal***
- ***correlations***
  femtoscopy

2-nd stage (with IT):
(sub)threshold production of cascades – to obtain the information on EOS

Technical project – in preparation. 19 scientific centers:
INR, SINP MSU, IHEP + 2 Universities (Russia);
GSI, Frankfurt U., Gissen U. (Germany), + CBM-MPD IT-Consortium
+ …. *expressed an interest*

Dipole and area for BM@N equipment installation

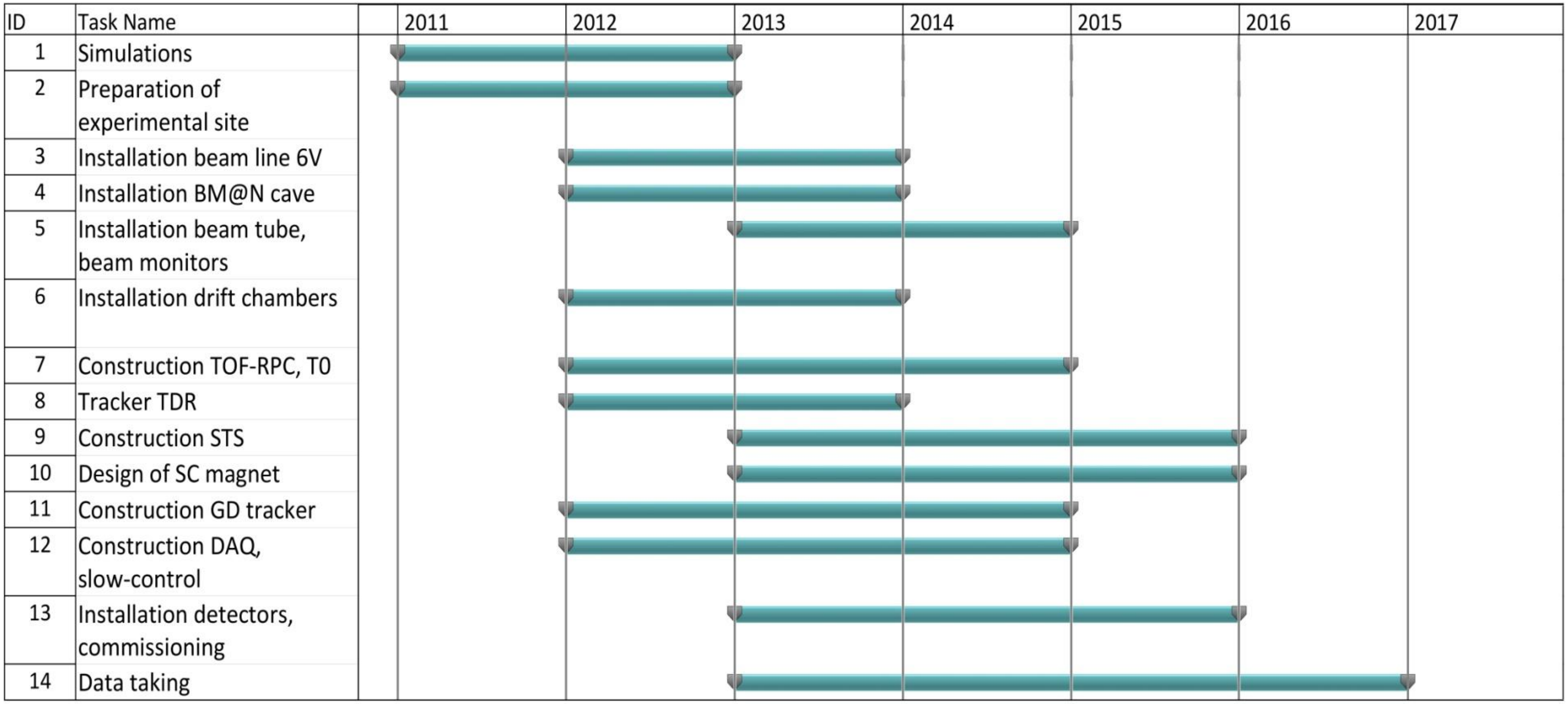
Study of dense baryonic matter at < 6 GeV/n

Physics is complementary to the MPD program & will be actual even after start of the MPD runs:

- **AA interactions:**
  - particle production, incl. sub-threshold processes;
  - particle (collective) flows, event-by-event fluctuations, correlations;
  - multiplicities, phase space distributions of p, n, π, K, hyperons, light nuclear fragments, vector mesons, hadronic resonances, direct light **hypernuclei** production in central AA collisions.

- **pA, nA, dA interactions in direct & inverse (Ap, Ad) kinematics:**
  - to get a "reference" data set for comparison with AA interactions,
  - to look for polarization effects in particle production off nuclear targets by polarized d, p, n.

Time table of the BM@N experiment



Phase0 (2011-2012) – Site preparation and simulation
Phase1 (2013-2014) – Detector element construction & commissioning
Phase2 (2015-.....) – Data taking at 3.5, 4 and 4.65 A GeV

Cooperation@Nuclotron-M/NICA experiments

- **Joint Institute for Nuclear Research**
- The University of Sidney, **Australia**
- Physics Institute Az.AS, **Azerbaijan**
- Particle Physics Center of Belarusian State University, **Belarus**
- Institute for Nuclear Research & Nuclear Energy BAS, Sofia, **Bulgaria**
- Hilendarski University of Plovdiv, **Bulgaria**
- Blagoevgrad University, Blagoevgrad**, Bulgaria**
- University of Science and Technology of China, Hefei, **China**
- Department of Engineering Physics, Tsinghua University, Beijing, **China**
- Osaka University, **Japan**
- RIKEN, **Japan**
- GSI, Darmstadt, **Germany**
- Aristotel University of Thessaloniki, **Greece**
- Institute of Applied Physics, AS, **Moldova**
- Institute of Physics & Technology of MAS, University of **Mongolia**
- Warsaw Technological University, Warsaw**, Poland**
- Institute for Nuclear Research, RAS, **RF**
- Nuclear Physics Institute of MSU, **RF**
- St.Petersburg State University, **RF**
- Institute Theoretical & Experimental Physics, **RF**
- University of Cape Town, **RSA**
- Bogolyubov Institute for Theoretical Physics, NAS, **Ukraine**
- Institute for Scintillation Materials, Kharkov, **Ukraine**
- State Enterprise Science & Tech. Research Design Institute, Kharkov, **Ukraine**
- TJNAF (Jefferson Laboratory), **USA**

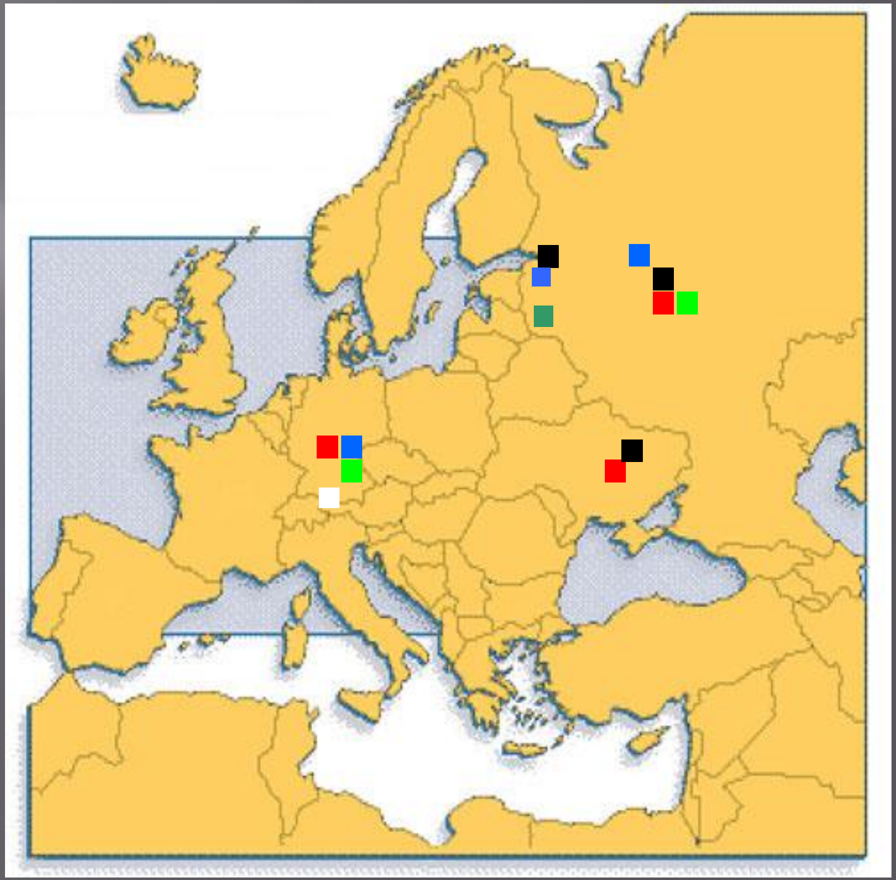
The CBM/FAIR-MPD/NICA Consortium

- **7 institutes**
- **3 countries**

CBM @ FAIR (Darmstadt)

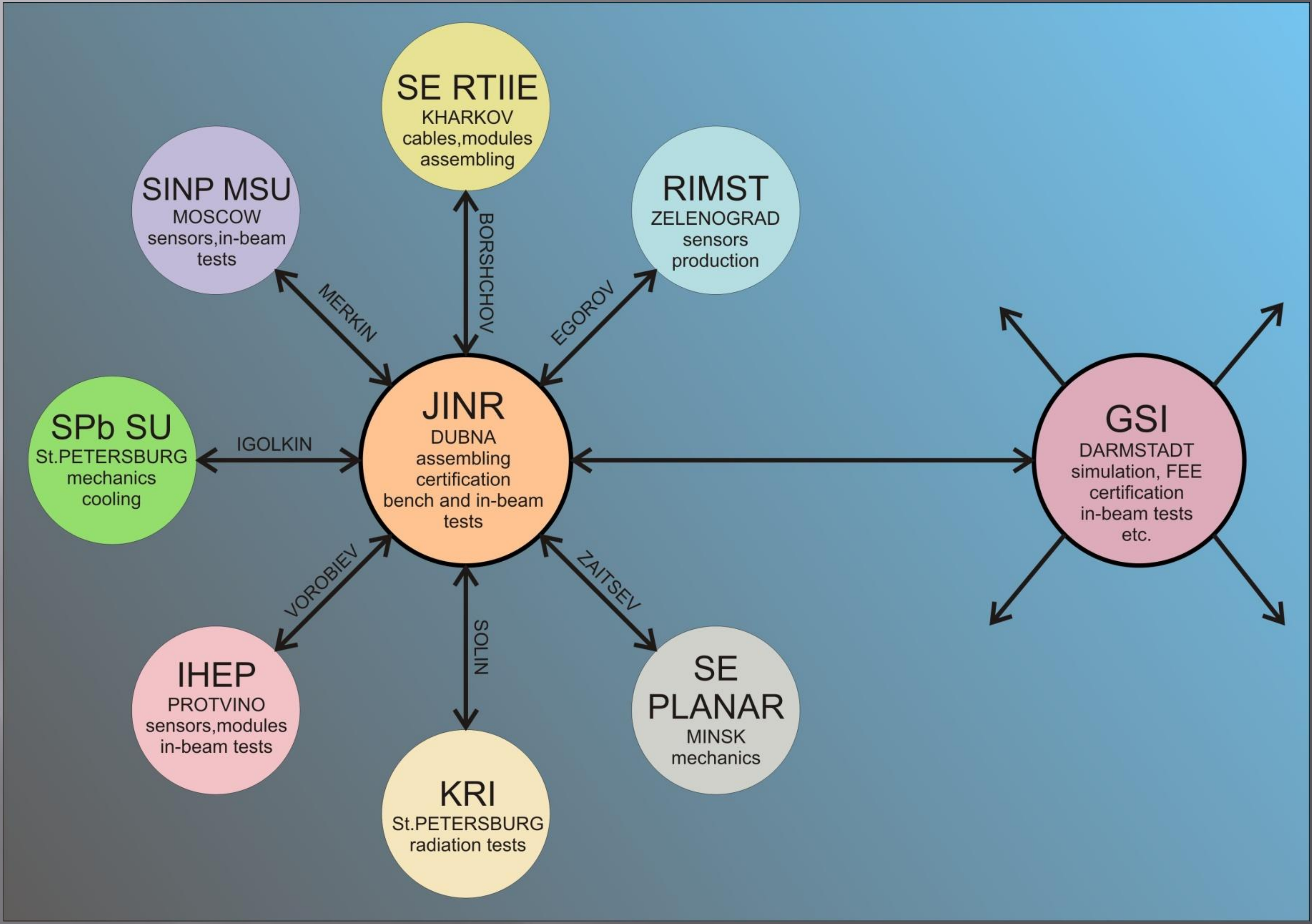
MPD @ NICA (Dubna)

- **GSI**, Darmstadt, Germany
- **JINR**, Dubna, Russia
- IHEP, Protvino, Russia
- MSU, Moscow, Russia
- KRI, St.Petersburg, Russia
- University, St.Petersburg
- SE SRTIIE, Kharkov, Ukraine



- Modules assembly
- Components
- Ladder assembly
- Radiation tests
- In-beam tests

The CBM-MPD Consortium Structure



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 $\sqrt{s} \sim 26$ (13) GeV**
- **the average luminosity up to 10^{30}-10^{31} cm^{-2} s^{-1}**
- **both proton and deuteron beams can be effectively polarized.**

The main topics are:

1. **Studies of MMT-DY processes with longitudinaly 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 amplidudes and double spin asymmetries (Krisch effect). in elastic reactions.**
7. **Spectroscopy of quarkoniums.**

<u>NICA Spin program plans:</u>

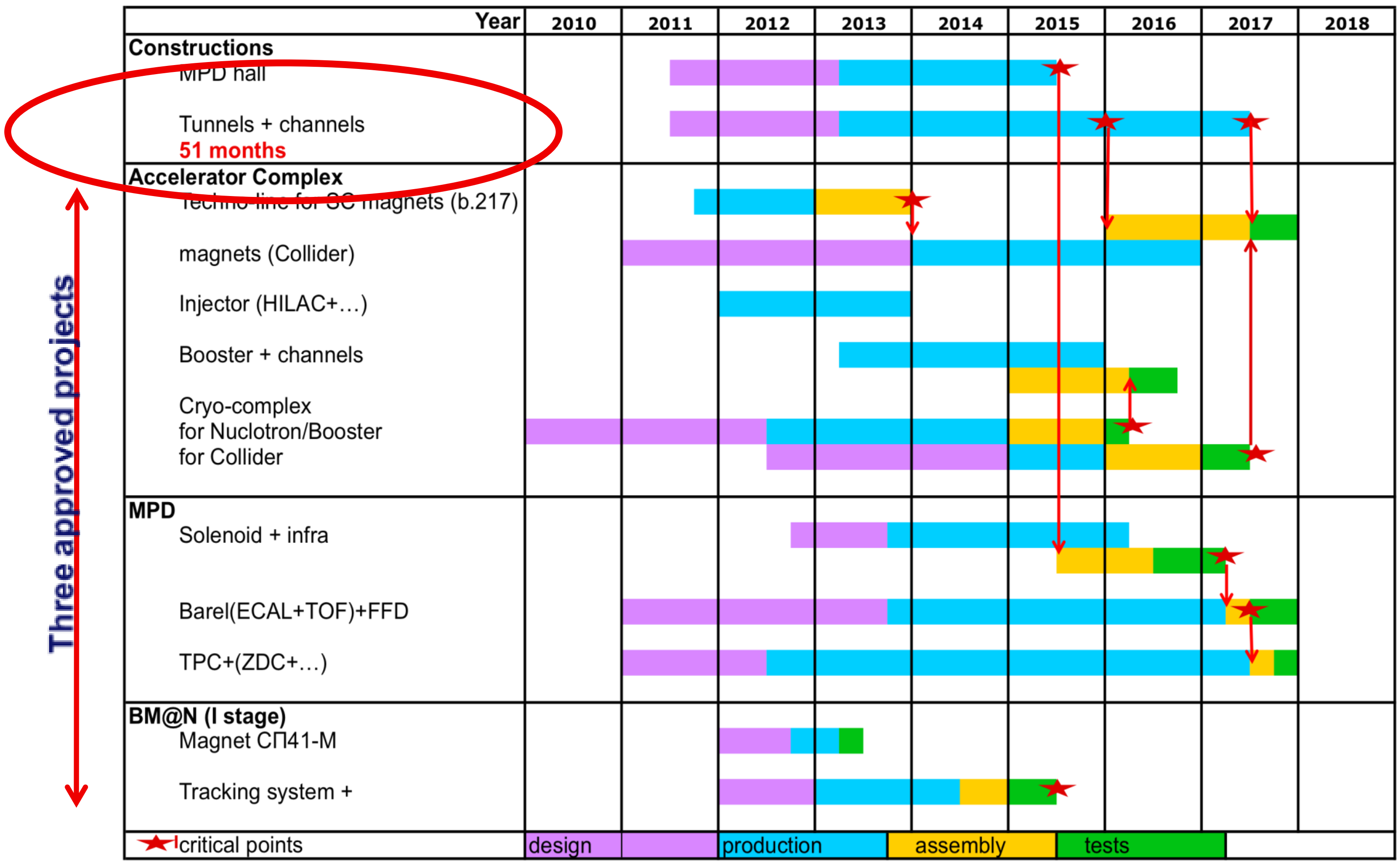
2012-2014 – CDR and TRD preparation, SPD collaboration, R&D

2015-2018 – R&D, Detectors production

First version of SPD CDR (June 2010) at http://nica.jinr.ru/files/Spin_program/spd_cdr.htm

XX International Symposium on Spin Physics (SPIN2012)
Dubna, September 17 – 22, 2012

Time table of key part constructions



NICA/MPD construction schedule

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

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

Time scales & Major milestones

Infrastructure

- Work project
- Tender for Subcontractor

Collider

- Lattice
- Magnet production
- Cryogenics

MPD

- Sc. magnet
- Barrel TDR
- DAQ TDR
- EndCap TDR

NICA Complex

Accelerator facility

- **Nuclotron-M**
- **Nuclotron-NICA**
- **Collider**

infrastructure

Experiments on Collider

- **MPD**
- **SPD**

infrastructure

Experiments with extracted beams

- **BM@N**
- test beams
- innovations

infrastructure

projects

completed

approved, in progress

Editorial board:
- D. Blaschke
- E. Bratkovskaya
- D. Kharzeev
- V. Matveev
- A. Sorin
- H. Stoecker
- O. Teryaev
- I. Tserruya
- N. Xu

NICA

Draft v 7.01
June 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

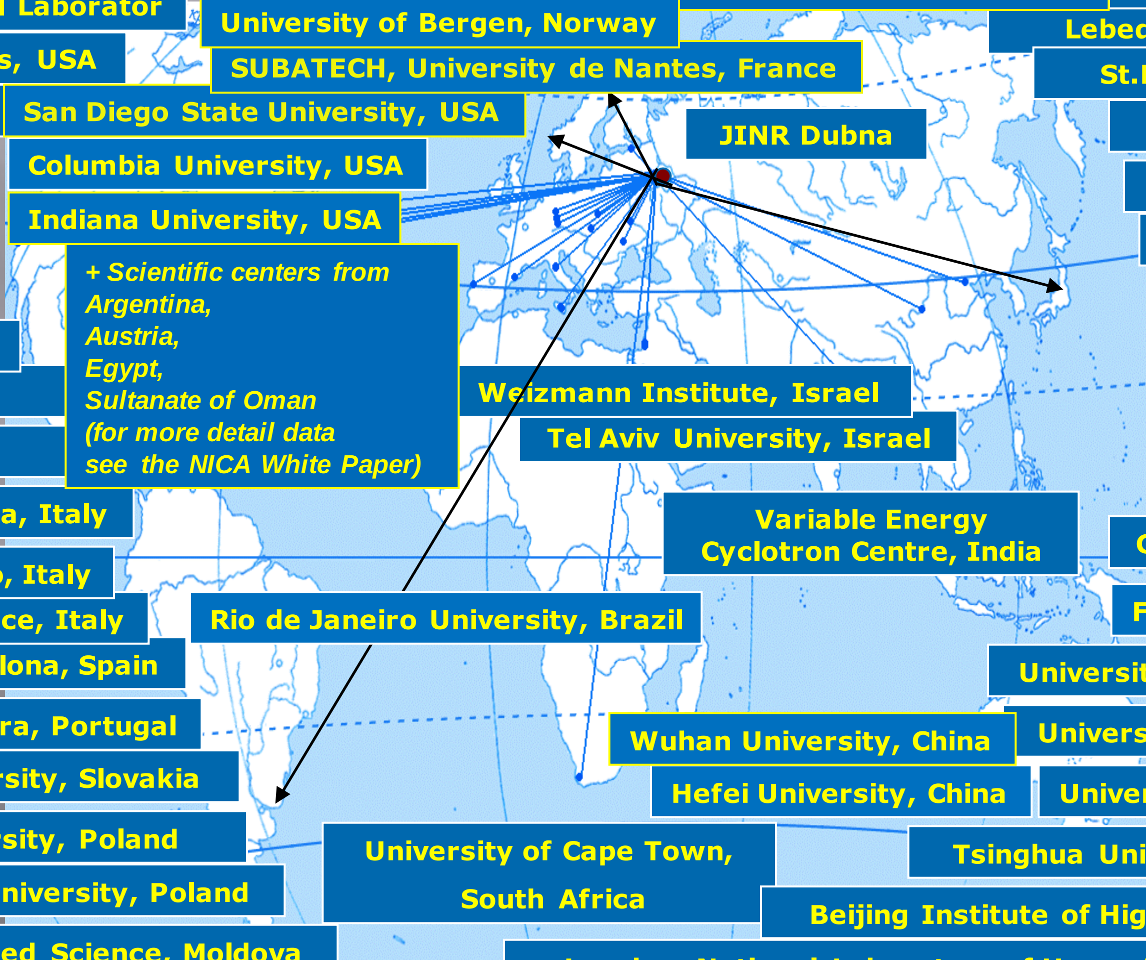
Contents

NICA White Paper - Contents

(83 contributions)

The NICA White Paper
83 contributions

148 authors *from* **69 scientific centers** *in* **25 Countries (8 JINR members)**



- Arizona State University, USA
- Los Alamos National Laborator
- University of Illinois, USA
- Wayne SU, USA
- LBNL, USA
- BNL, USA
- Ohio SU, USA
- BITP, Ukraine
- INFN, Italy
- SISSA, Italy
- University of Catania, Italy
- University of Trento, Italy
- University of Florence, Italy
- University of Barselona, Spain
- University of Coimbra, Portugal
- Mateja Bela University, Slovakia
- Wroclaw University, Poland
- Jan Kochanovski University, Poland
- Institute of Applied Science, Moldova
- University of Oslo, Norway
- University of Bergen, Norway
- SUBATECH, University de Nantes, France
- San Diego State University, USA
- Columbia University, USA
- Indiana University, USA
- Lulea Technical University, Sweden
- JINR Dubna
- Weizmann Institute, Israel
- Tel Aviv University, Israel
- Variable Energy Cyclotron Centre, India
- Rio de Janeiro University, Brazil
- Wuhan University, China
- Hefei University, China
- University of Cape Town, South Africa
- Tsinghua University, Beijing, China
- Beijing Institute of High Energy Physics, China
- Lanzhou National Laboratory of Heavy Ion Accelerator, China
- Kurchatov Institute, Russia
- Lebedev Institute, Russia
- St.Petersburg SU, Russia
- IHEP, Russia
- ITEP, Russia
- INP MSU, Russia
- MEPhI, Russia
- INR, Russia
- Osaka University, Japan
- YITP Kyoto, Japan
- GSI Darmstadt, Germany
- FIAS Frankfurt, Germany
- University of Frankfurt, Germany
- University of Giessen, Germany
- University of Bielefeld, Germany

+ Scientific centers from
Argentina,
Austria,
Egypt,
Sultanate of Oman
(for more detail data see the NICA White Paper)

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

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:

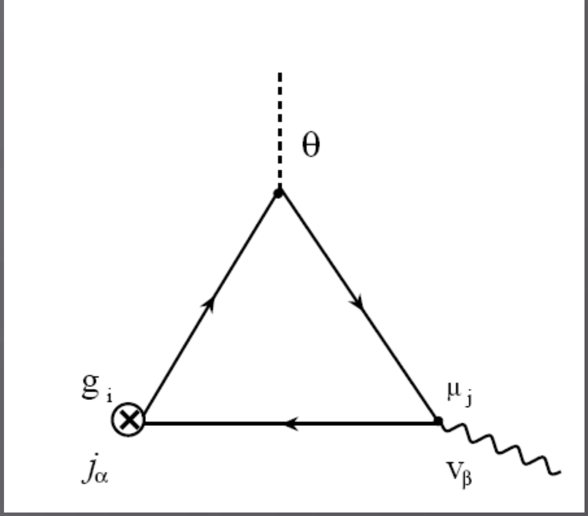
Observables	Physical Phenomena							Detectors	Reference in the White Paper
	MMH	EoS	OD	CSR	PT	CEP	LPV		
yields of hadrons, normal and exotic light nuclei	x	x	x					tracking, TOF	3.6, 3.9, 4.3, 3.11, 4.12, 6.7
yields and spectra of multistrange hyperons	x	x	x					precision tracking (seconday vertices)	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

Studying vorticity

- Vorticity for uniform rotation – proportional to Orbital Angular Momentum
- Rotation – another pseudovector – angular velocity
- Tests are required
- Natural object – hydrodynamical helicity (= *v rot v*)-related to chaos
- Model calculations: JINR (DCM: M. Baznat, K. Gudima, A. Sorin, O. Teryaev) + FIAS (UrQMD: M. Bleicher, J. Steinheimer, H. Stoecker)

Anomaly in medium – new external lines in VVA graph

- Gauge field -> velocity
- CME -> CVE
- Kharzeev, Zhitnitsky (07) – EM current
- Generalization: any (e.g. baryonic) current – neutron asymmeries@NICA O. Rogachevsky, A. Sorin, O. Teryaev PRC82:054910,2010



Coupling: $e_j A_\alpha J^\alpha \Rightarrow \mu_j V_\alpha J^\alpha$

Current: $J_e^\gamma = \frac{N_c}{4\pi^2 N_f}\varepsilon^{\gamma\beta\alpha\rho}\partial_\alpha V_\rho \partial_\beta(\theta \sum_j e_j \mu_j)$

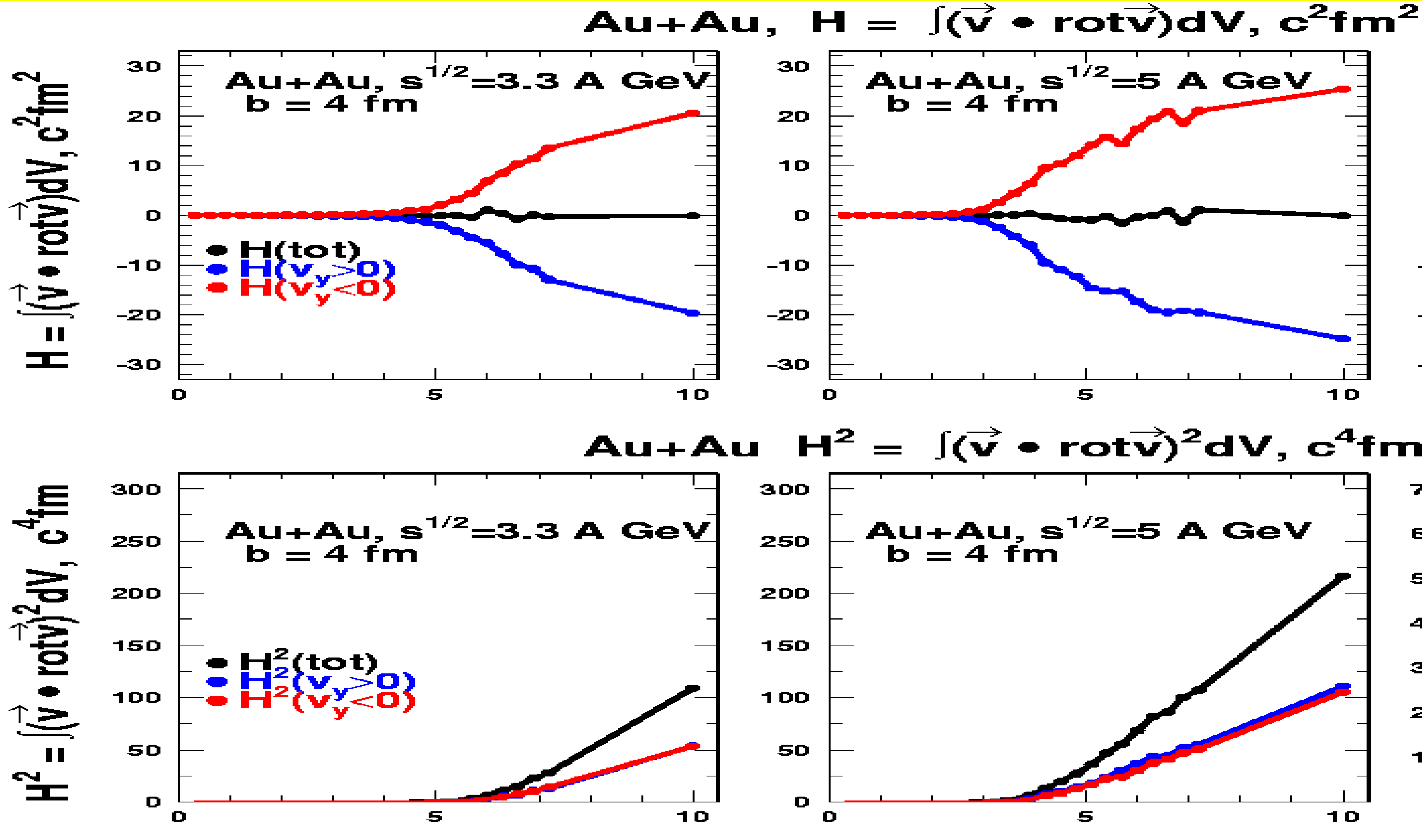
Observable: three-particle correlator: $\langle cos(\phi_\alpha + \phi_\beta - 2\phi_c)\rangle$

CME@RHIC: 15 M events to establish the effect.
CVE@NICA:1000 M events, which can be collected within a few months of the NICA run.

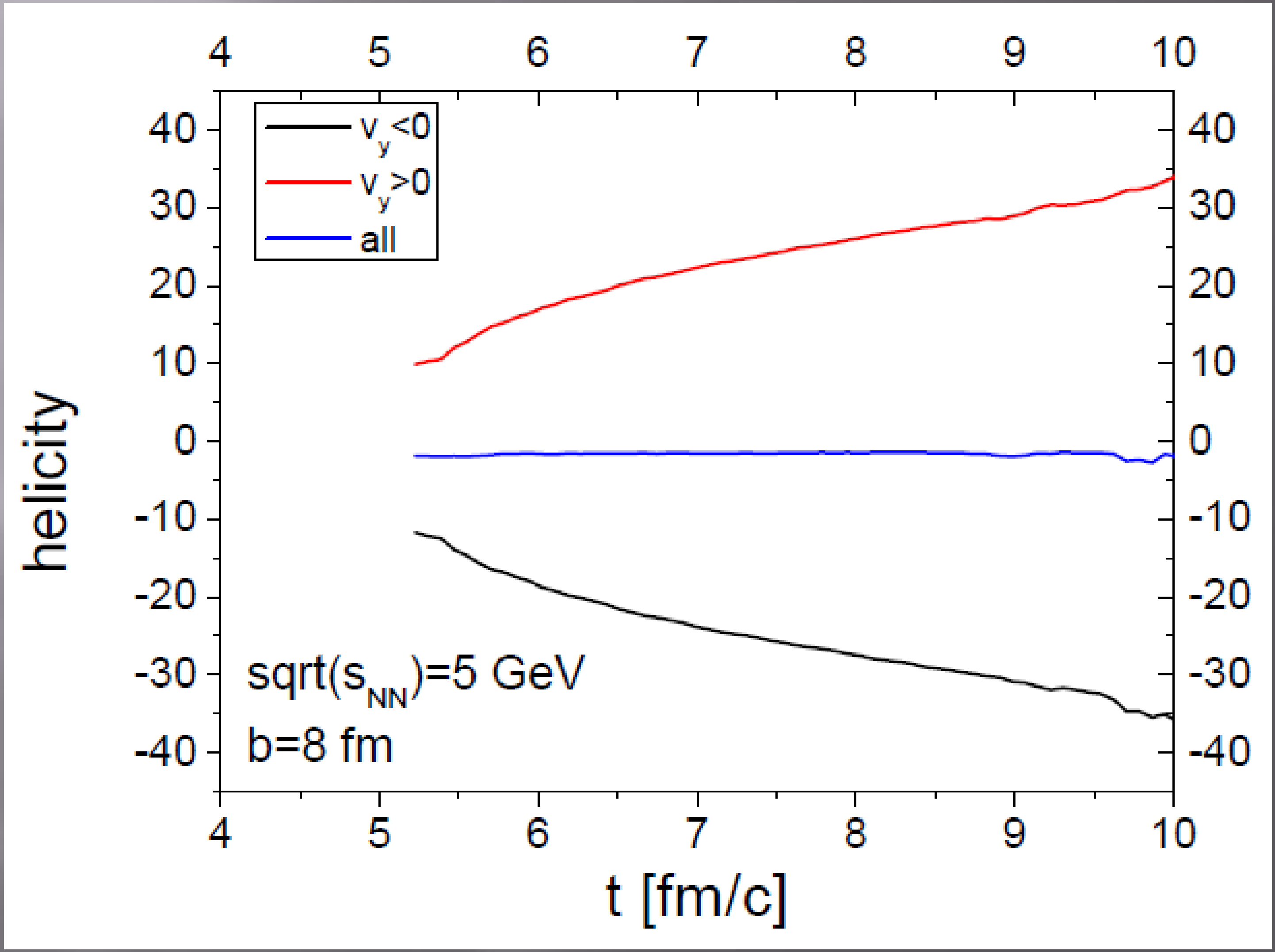
Vorticity simulations in HIC

JINR (DCM: M. Baznat, K. Gudima, A. Sorin,O. Teryaev)
+FIAS(UrQMD: M. Bleicher, J. Steinheimer, H. Stoecker)

Hydrodynamical Helicity separation (DCM)



Hydrodynamical Helicity Separation (UrQMD)



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

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*		

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

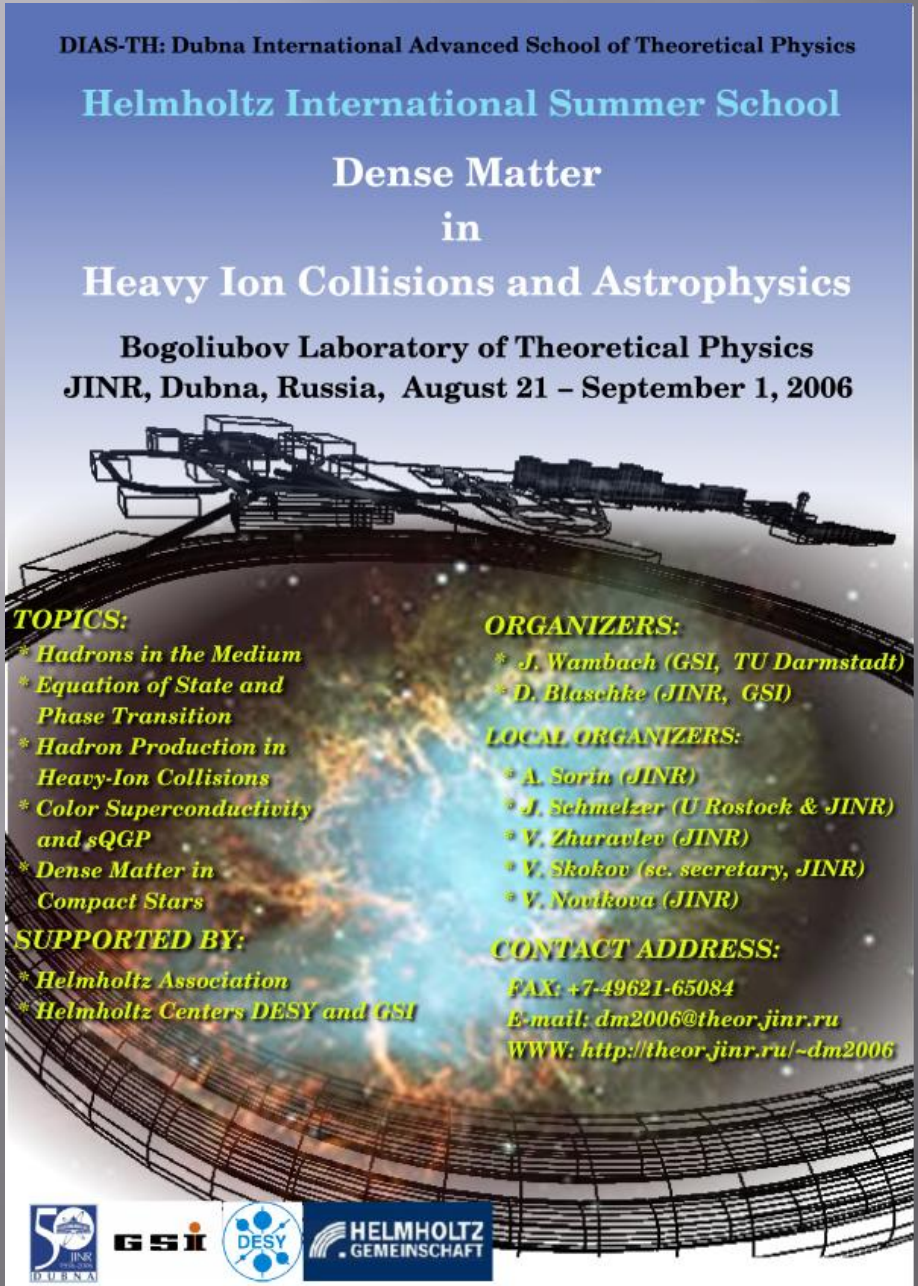
* German-Russian Year of Science 2011/2012

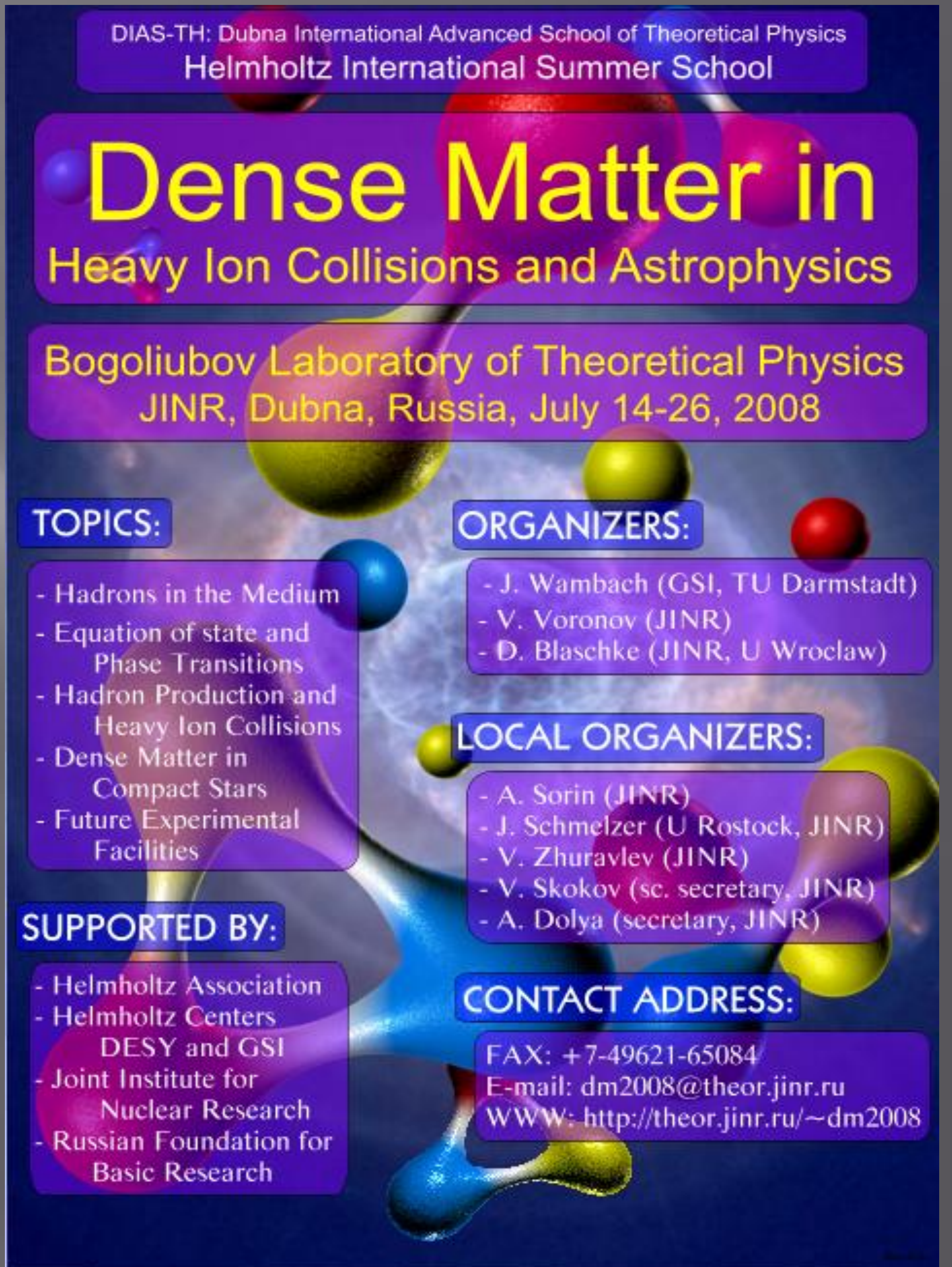
The conferences in Dubna

CPOD 2010

SQM 2015

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

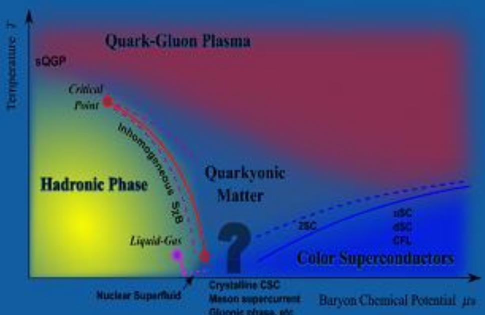




DIAS-TH Dubna International Advanced School for Theoretical Physics
HIC-for-FAIR School and Workshop

Dense QCD Phases in Heavy-Ion Collisions

August 21- September 4, 2010 @ Joint Institute for Nuclear Research



Organisers

M. Bleicher (Frankfurt)
D. Blaschke (JINR & Wrocław)

Local Organisers

T. Donskova (JINR)
A. Khvorostukhin (JINR)
E. Kolganova (JINR)
A. Sorin (JINR)
D. Zablocki (Wrocław)

NONEQUILIBRIUM AND TRANSPORT PHENOMENA IN DENSE MATTER
QCD PHASES IN COMPACT STARS, SUPERNOVÆ AND MERGERS
EQUATION OF STATE AND QCD PHASE TRANSITIONS
HADRON PRODUCTION IN HEAVY-ION COLLISIONS

embracing the 6th CPOD conference
warm-up, lectures, progress

http://theor.jinr.ru/~dm10
dm10@theor.jinr.ru

HELMHOLTZ | ASSOCIATION

JINR DUBNA

HIC for FAIR
Helmholtz International Center

Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research
Dubna International Advanced School of Theoretical Physics
Helmholtz International Summer School

Lattice QCD, Hadron Structure and Hadronic Matter

Dubna, Russia, September 5 - 17, 2011

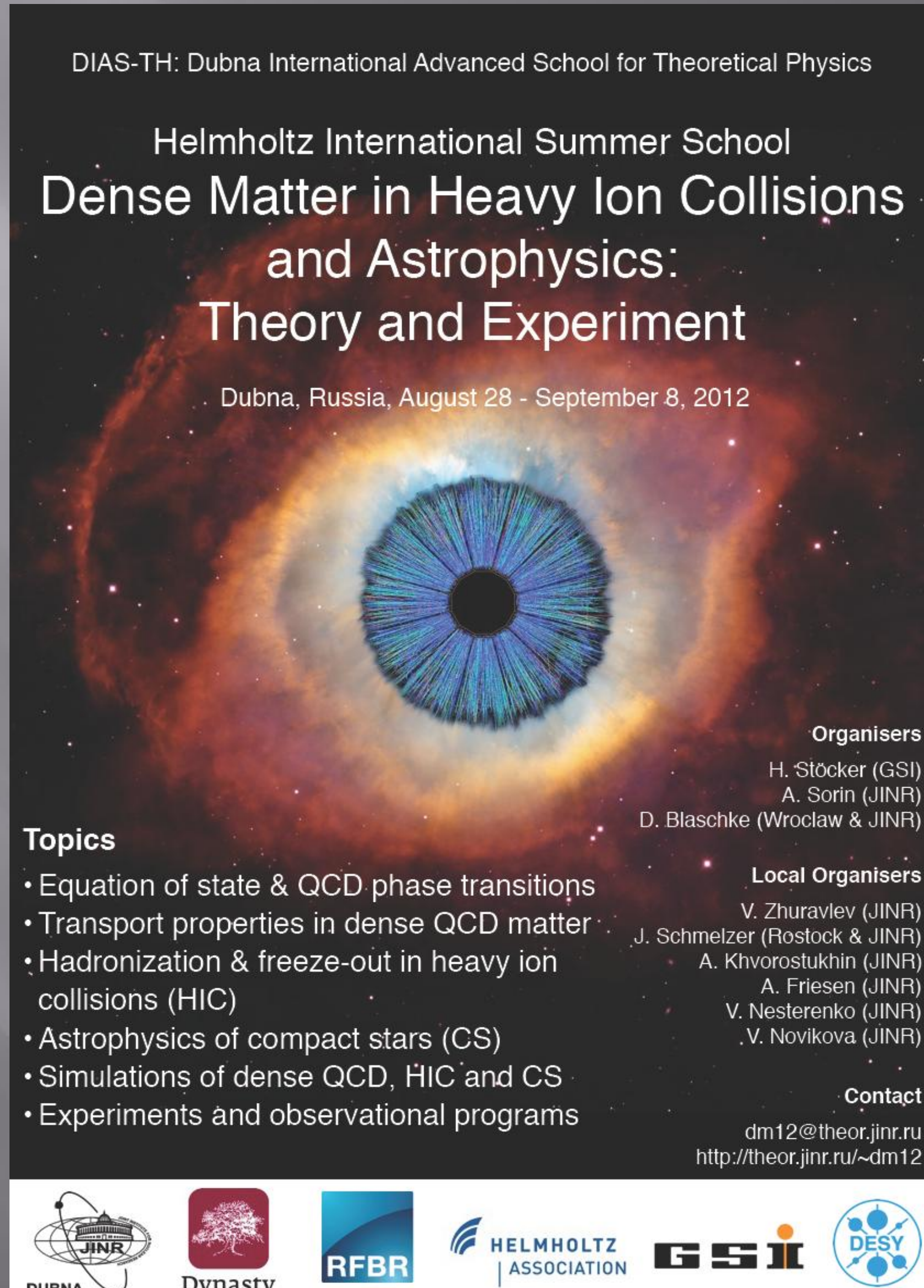
Introduction to Lattice Gauge Theories
Hadron structure and spectroscopy
Nonzero temperature and baryon number density
Heavy quark physics
Beyond the Standard Model
Strong magnetic fields
Simulation algorithms and analysis techniques

LECTURERS:
D. Blaschke (*ITP, Uni. of Wroclaw & BLTP, JINR*)
S. Catterall (*Syracuse U.*)
M. Goeckeler (*ITP, Regensburg U*)
M. Mueller-Preussker (*Humboldt U., Berlin*)
K. Jansen (*NIC, DESY, Zeuthen*)
F. Karsch (*Bielefeld U. & BNL*)
D. I. Kazakov (*BLTP, JINR*)
M. Peardon (*Trinity College, Dublin*)
P. Petreczky (*BNL*)
M. Polikarpov (*ITEP, Moscow*)
M. Polyakov (*S.-Pb. Nucl. Phys. Inst., Gatchina & Bochum U.*)
A.V.Radyushkin (*JLAB, USA & JINR, Dubna, Russia*)
C. Schmidt (*Frankfurt U. & GSI, Darmschtadt*)
R. Sommer (*NIC, DESY, Zeuthen*)
A. S. Sorin (*BLTP, JINR*)
O. V. Teryaev (*BLTP, JINR*)
C. Urbach (*Bonn U.*)
V. I. Zakharov (*ITEP, Moscow*)

ORGANIZERS:
R. Sommer (*NIC, DESY, Zeuthen*)
A. Sorin (*JINR, Dubna*)

HELMHOLTZ GEMEINSCHAFT
JINR
GSI
DESY
Династия
РФФИ

CONTACTS: Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research
141980 Dubna, Russia; Phone: (+749621) 65084; e-mail: diastp@theor.jinr.ru
http://theor.jinr.ru/~diastp/summer11


DIAS-TH: Dubna International Advanced School for Theoretical Physics
Helmholtz International Summer School
Dense Matter in Heavy Ion Collisions and Astrophysics: Theory and Experiment
Dubna, Russia, August 28 - September 8, 2012
Topics
• Equation of state & QCD phase transitions
• Transport properties in dense QCD matter
• Hadronization & freeze-out in heavy ion collisions (HIC)
• Astrophysics of compact stars (CS)
• Simulations of dense QCD, HIC and CS
• Experiments and observational programs
Organisers
H. Stöcker (GSI)
A. Sorin (JINR)
D. Blaschke (Wroclaw & JINR)
Local Organisers
V. Zhuravlev (JINR)
J. Schmelzer (Rostock & JINR)
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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.

BMBF-JINR meeting *(Dubna, August 30 – 31, 2012)*

V.A.Matveev – *the JINR Director*
and **Dr. Beatrix Vierkorn-Rudolph** *- the BMBF Directorate 71 Director*
signed the document
recognizing the NICA complex as the large-scale project on the Russian territory
and appreciating the selection of NICA as one of the "Mega science" projects

Parties agreed to join their efforts in the construction of both FAIR & NICA in:

- *construction of cryogenic facility at LHEP JINR to provide the assembly and the cold testing of the superconducting magnets for the NICA synchrotrons and 175 quadrupole modules for FAIR SIS100*
- *preparation of clean area at LHEP JINR to provide the assembly and test of modern silicon tracking detectors for BM@N, MPD and CBM*
- *stimulation of joint research and educational programs for young scientists*

Signing ceremony of the JINR-BMBF meeting minutes

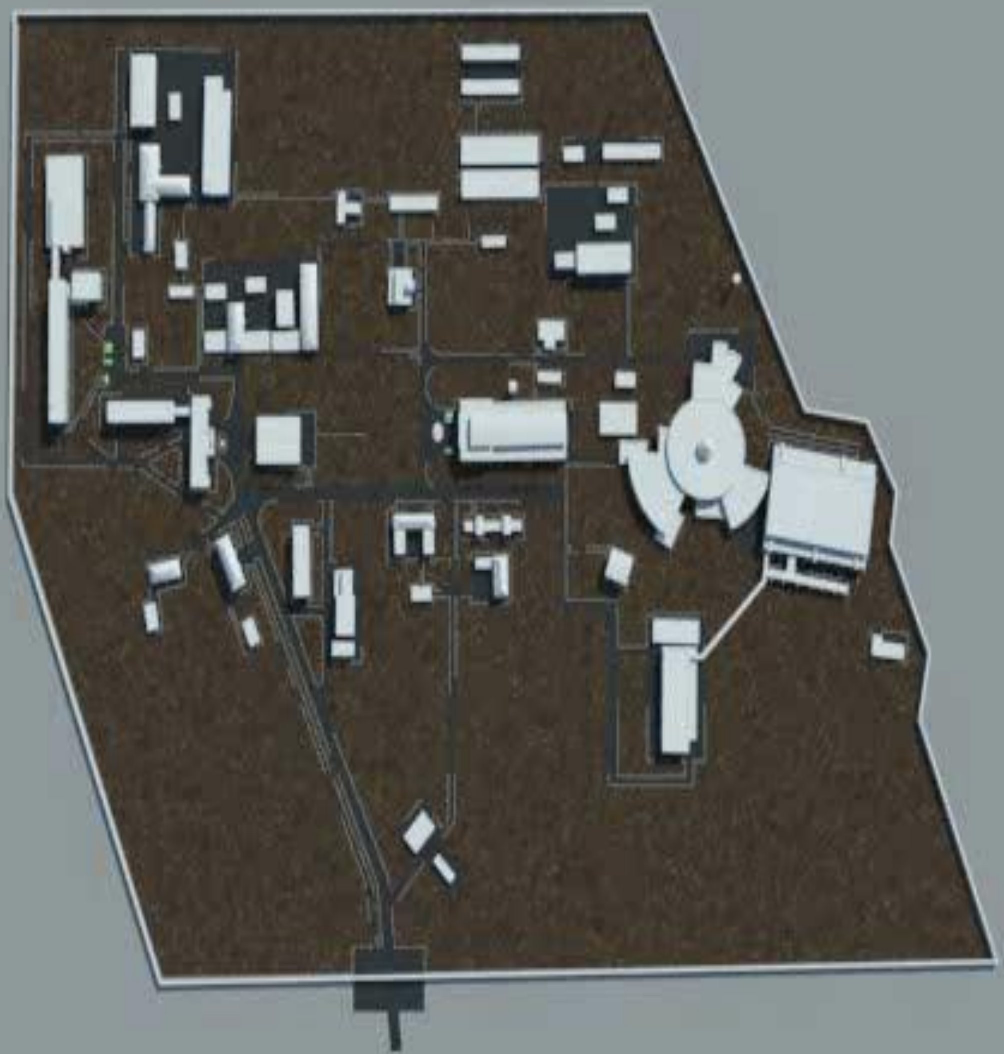
Conclusions of the Town Meeting at CERN, 29 June 2012

On a time scale of less than a decade, using the existing heavy ion beams at the Nuclotron accelerator, the NICA project at JINR in Dubna will provide a similar energy range in a collider geometry at the average luminosity of 10^{27} / cm2 s, as well as, the fixed target experiments with ELab = 2 – 4.5 GeV/nucleon.

This offers important complementarities to the beam energy scan program at RHIC and the programs at FAIR.

The Open Symposium on European Strategy in Particle Physics *(11-12 Sept., Krakow, PL)*

indicated the NICA facility as a part of HI European program



Concluding Remarks

- The NICA complex is well developing
- The two physics projects BM@N & MPD are targeting to the HI physics frontiers
- The NICA program is well integrated into world experimental HI facilities
- The SP program is developing, but could started already at MPD
- The collaborations are growing around NICA & are getting an international recognition
- You are welcome to enlarge the participation in the NICA program

Welcome to the collaboration!

Thank you for attention!