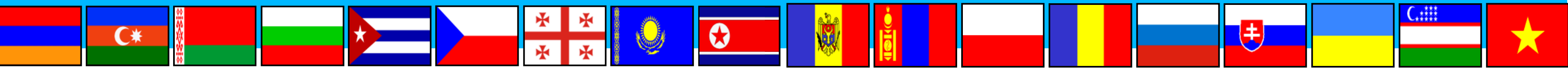
Joint Institute for Nuclear Research
International Intergovernmental Organization



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

EMMI Workshop
Prospects and Challenges for Future Experiments in Heavy Ion Collisions
February 15 - 16, 2013

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

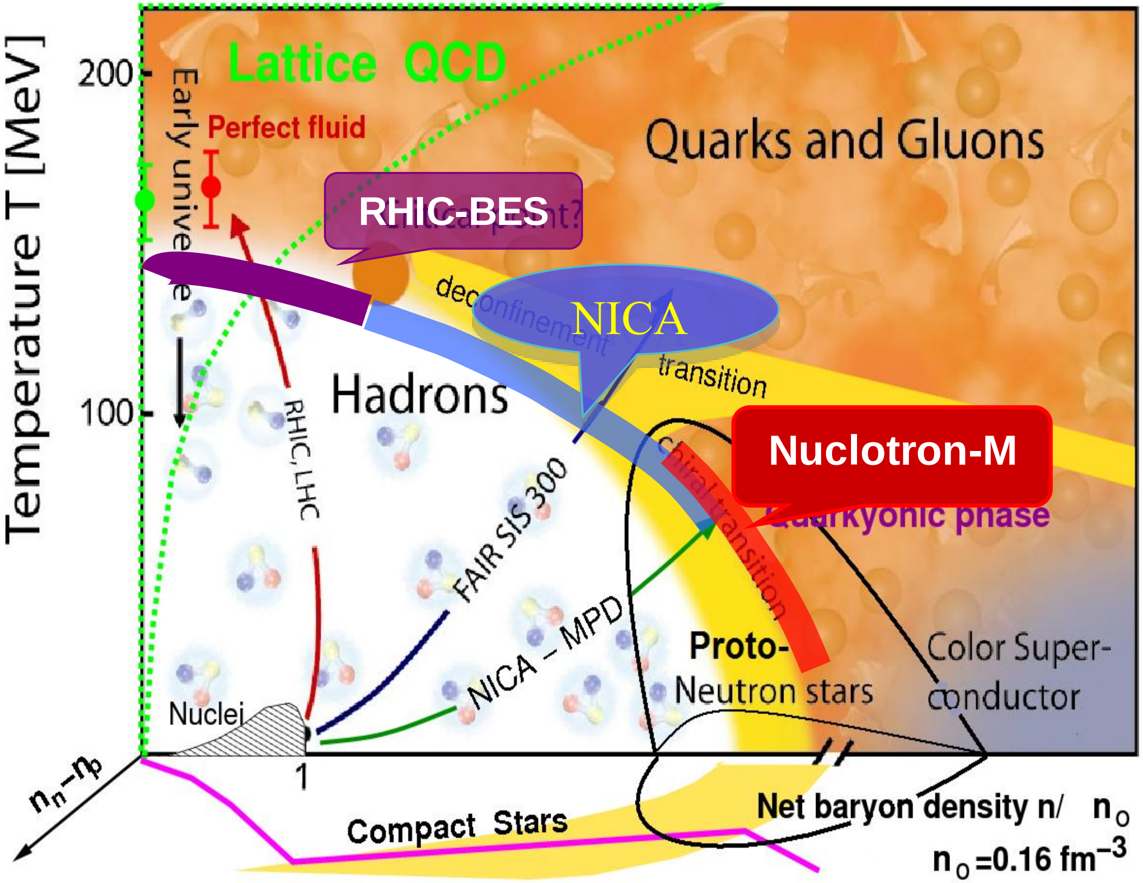
Main targets of NICA:

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

NICA will provide intensive beams of ions from p to Au and polarized protons and deuterons with maximal energy up to

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

QCD phase diagram: prospects for NICA



Energy Range of NICA

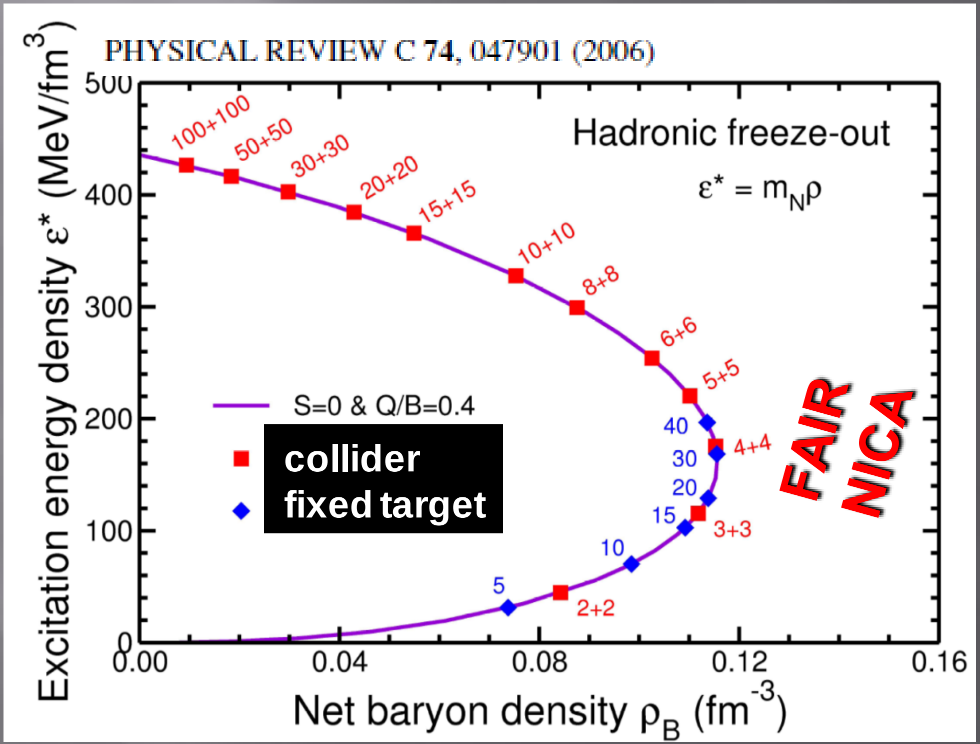
unexplored region of the QCD phase diagram:

- **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.

Highest baryon density at Lab

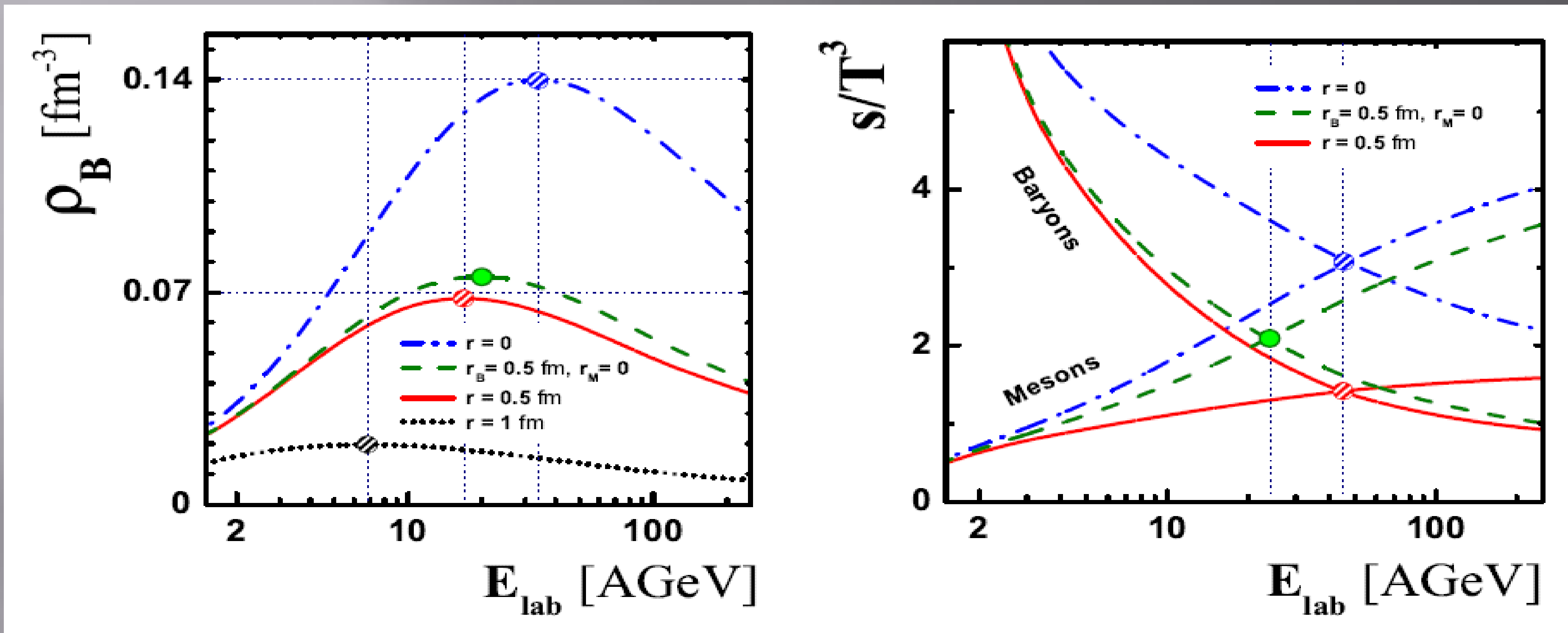
System of maximal net baryon (freeze-out) density is created in A+A collisions at NICA energies → optimum for the compressed baryon matter exploration



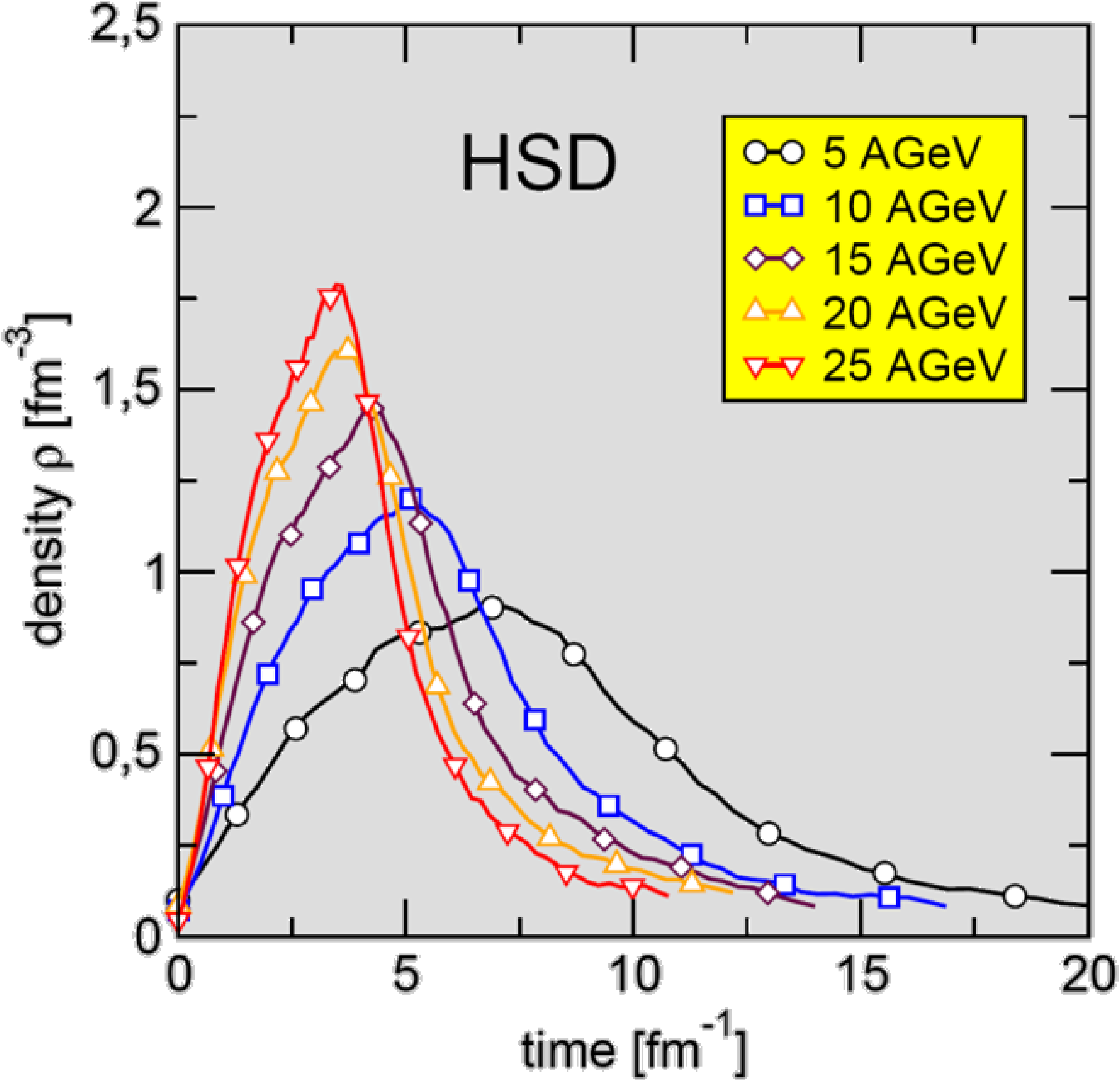
J.Randrup, J.Cleymans, 2006

Excluded volume effects on baryon density and transition from baryon to meson dominated matter

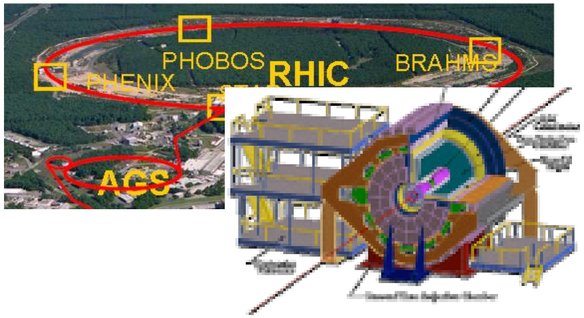
V. V. Begun, M. Gaździcki, M. I. Gorenstein (2013)



By varying the hadron radii in the range r = (0-1.0) fm the collision energy at which the baryon density is maximal changes between 7A and 34A GeV. This range is fully covered by the NICA collider. Thus experiments at NICA will allow to study in detail freeze-out conditions in heavy ion collisions in the domain of their rapid changes and the relation to the onset of deconfinement.

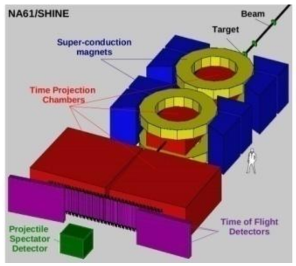


HSD
5 AGeV
10 AGeV
15 AGeV
20 AGeV
25 AGeV
density ρ [fm^-3]
time [fm^-1]
0
0,5
1
1,5
2
2,5
5
10
15
20



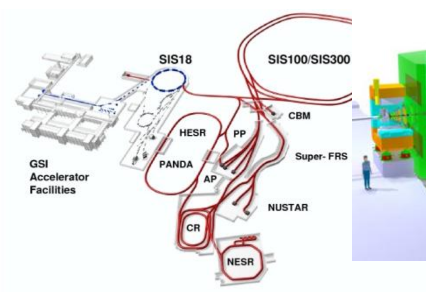
2^{nd} generation HI experiments

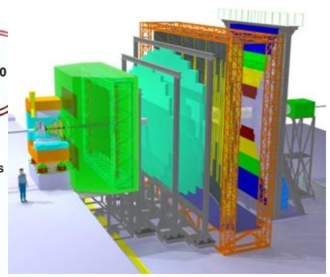
BES STAR/PHENIX@BNL/RHIC



NA61@CERN/SPS

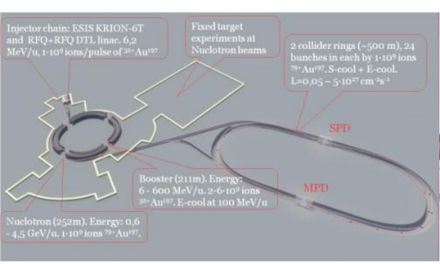
3^{nd} generation HI experiments

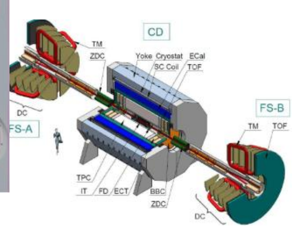




CBM@FAIR/SIS-100/300

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

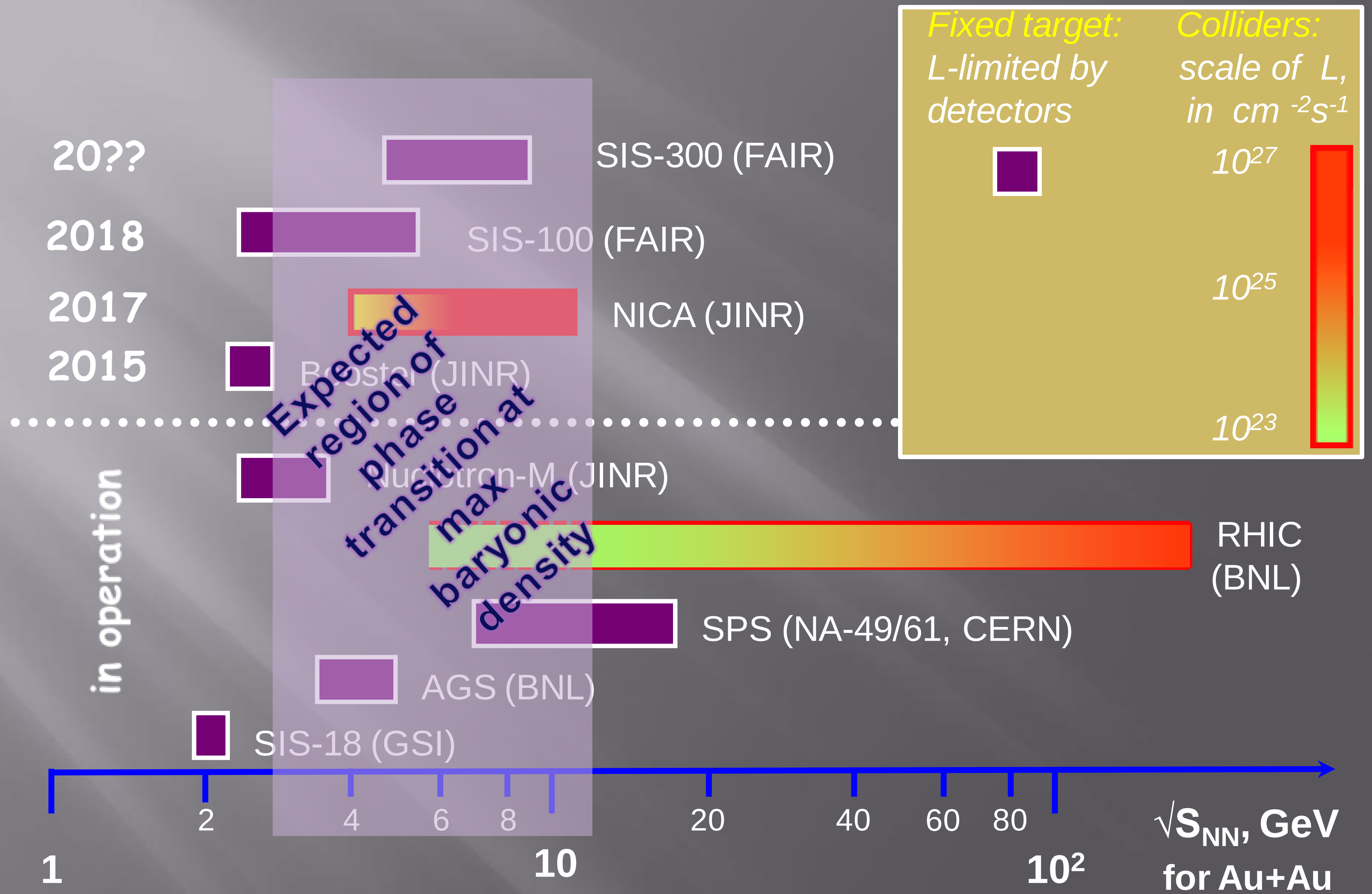




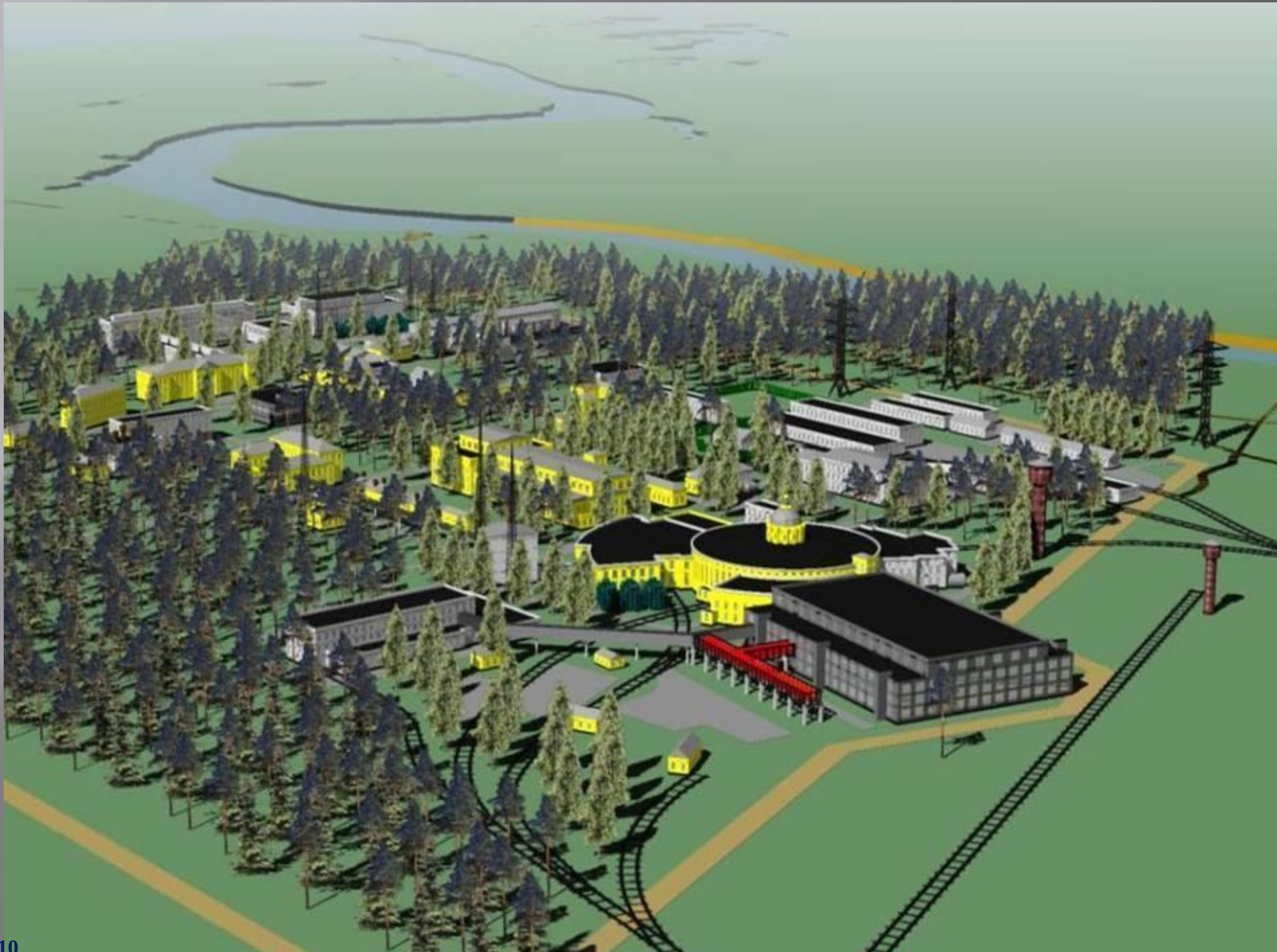
MPD@JINR/NICA

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

Existing & Future HI Machines

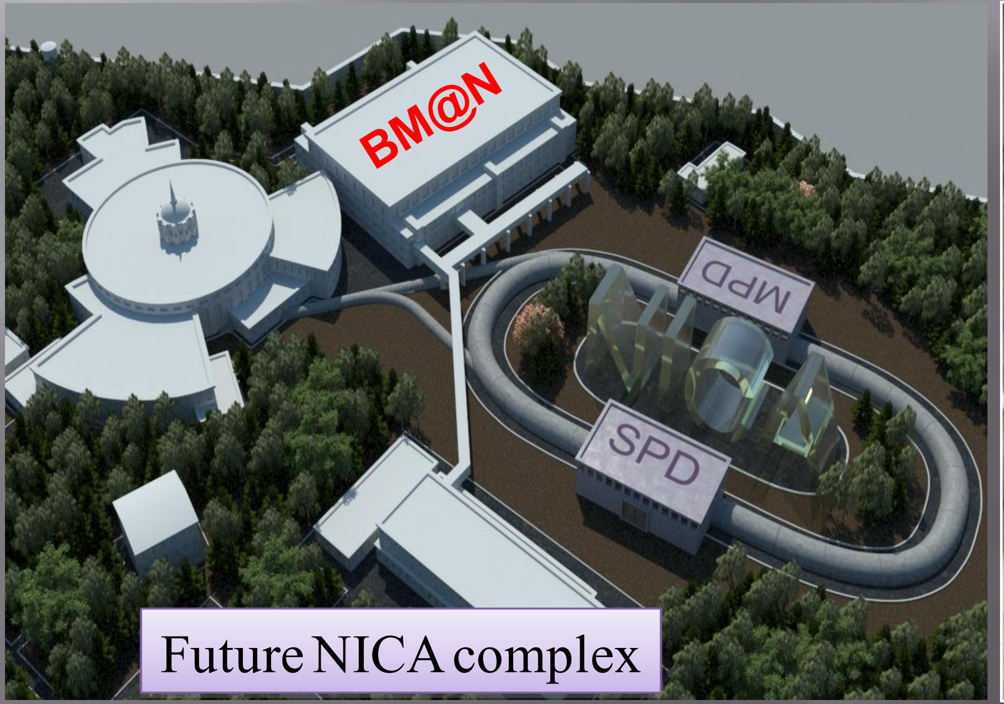


NICA site



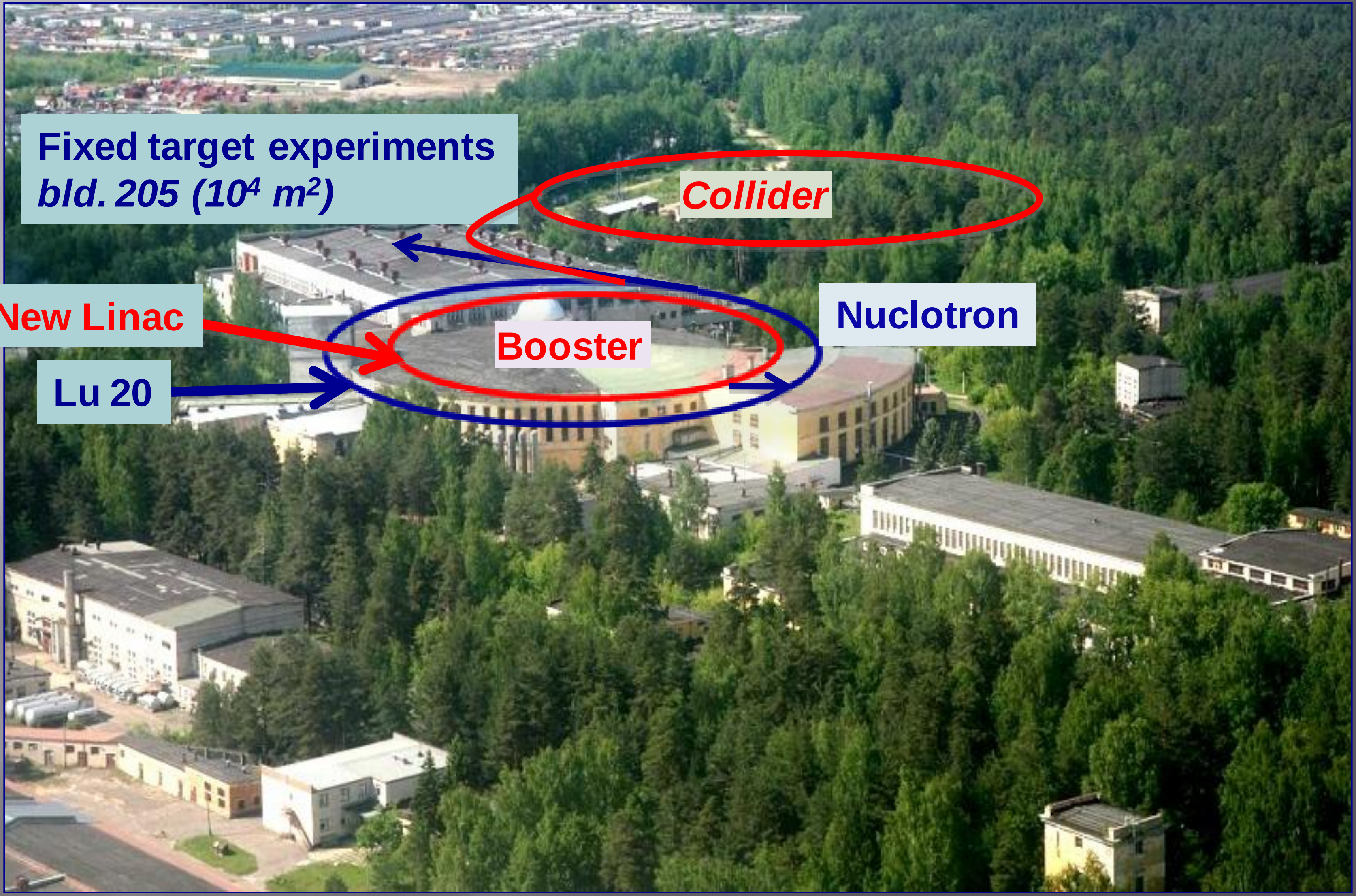

Nuclotron


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 > 1E31 $cm^{-2}\cdot s^{-1}$ (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

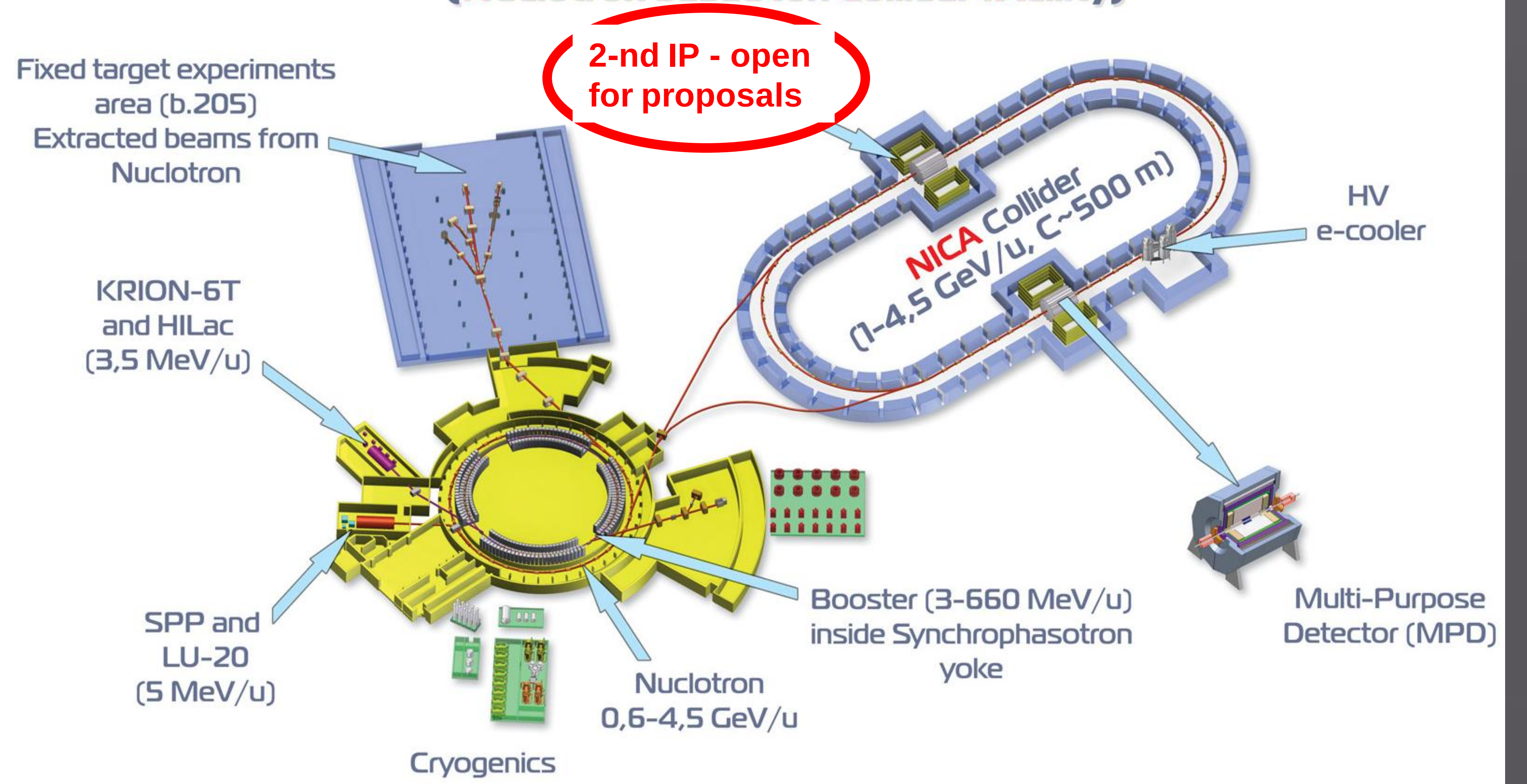
4) Applied research with ion beams at kinetic energy

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

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	-	--- „ ---	$1 \cdot 10^{9}$

Superconducting accelerator complex NICA

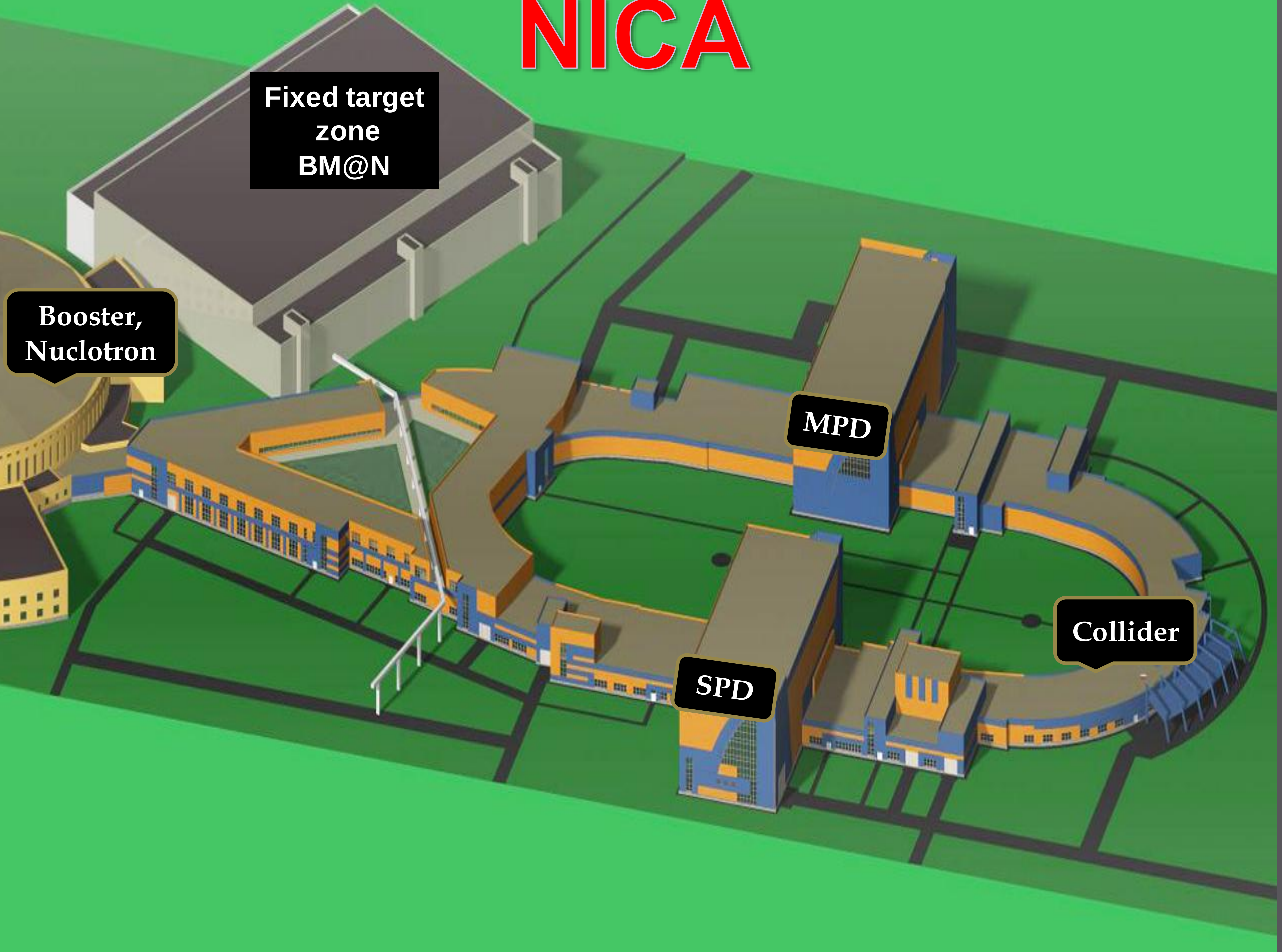
(Nuclotron based Ion Collider fAcility)



NICA Collider parameters:

- Energy range: $\sqrt{s_{NN}}$ = 4-11 GeV
- Beams: from p to Au
- Luminosity: $L \sim 10^{27}$ (Au), 10^{32} (p)
- Detectors: MPD; 2-nd is waiting for Proposals

NICA



MultiPurpose Detector (MPD): Observables

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

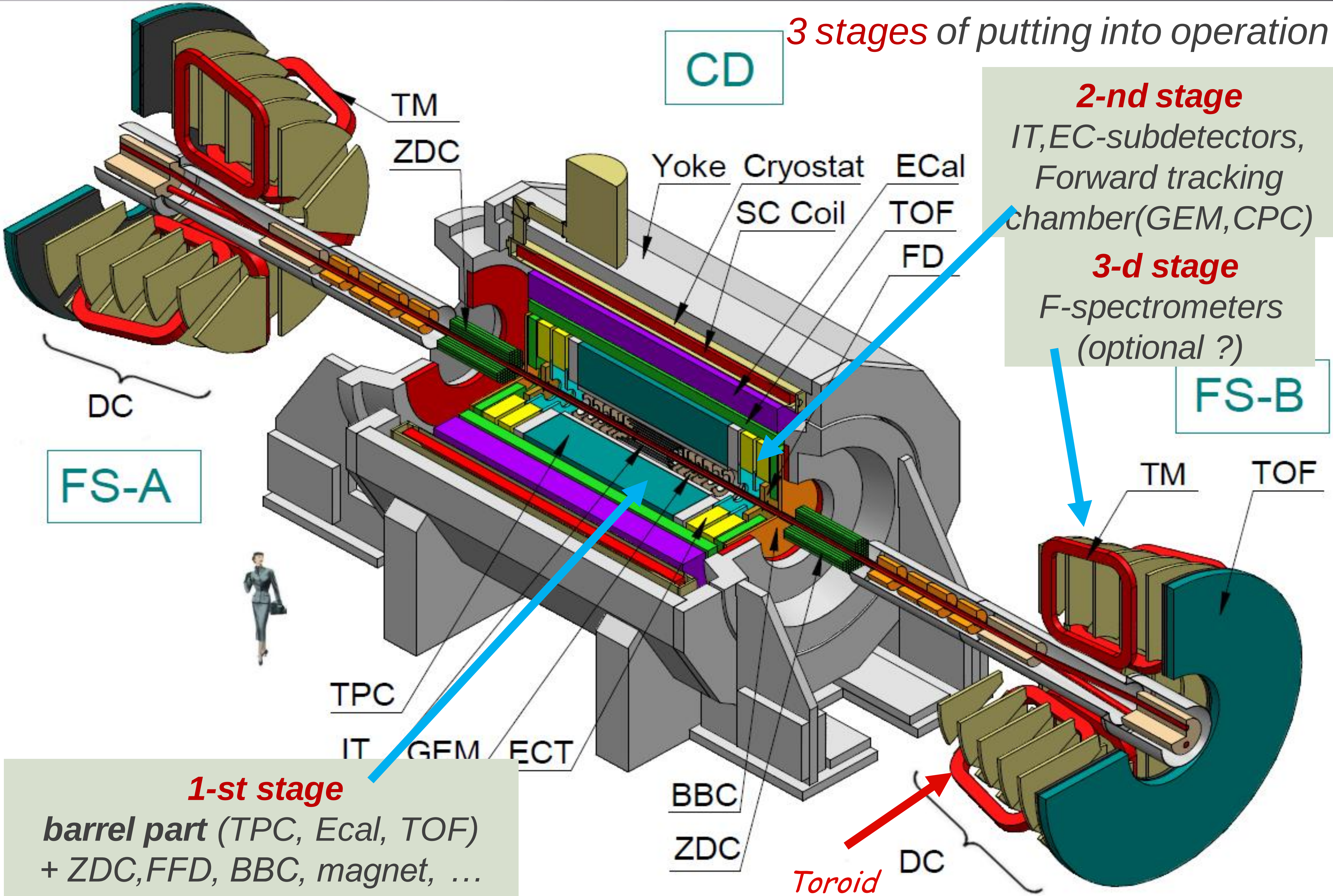
- *Particle yields and spectra*
- *Event-by-event fluctuations*
- *Femtoscopy involving π, K, p, Λ*
- *Collective flows for identified hadron species*
- *Electromagnetic probes (electrons, gammas)*

II stage: *extended rapidity + IT*

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

MultiPurpose Detector (MPD)

3 stages of putting into operation

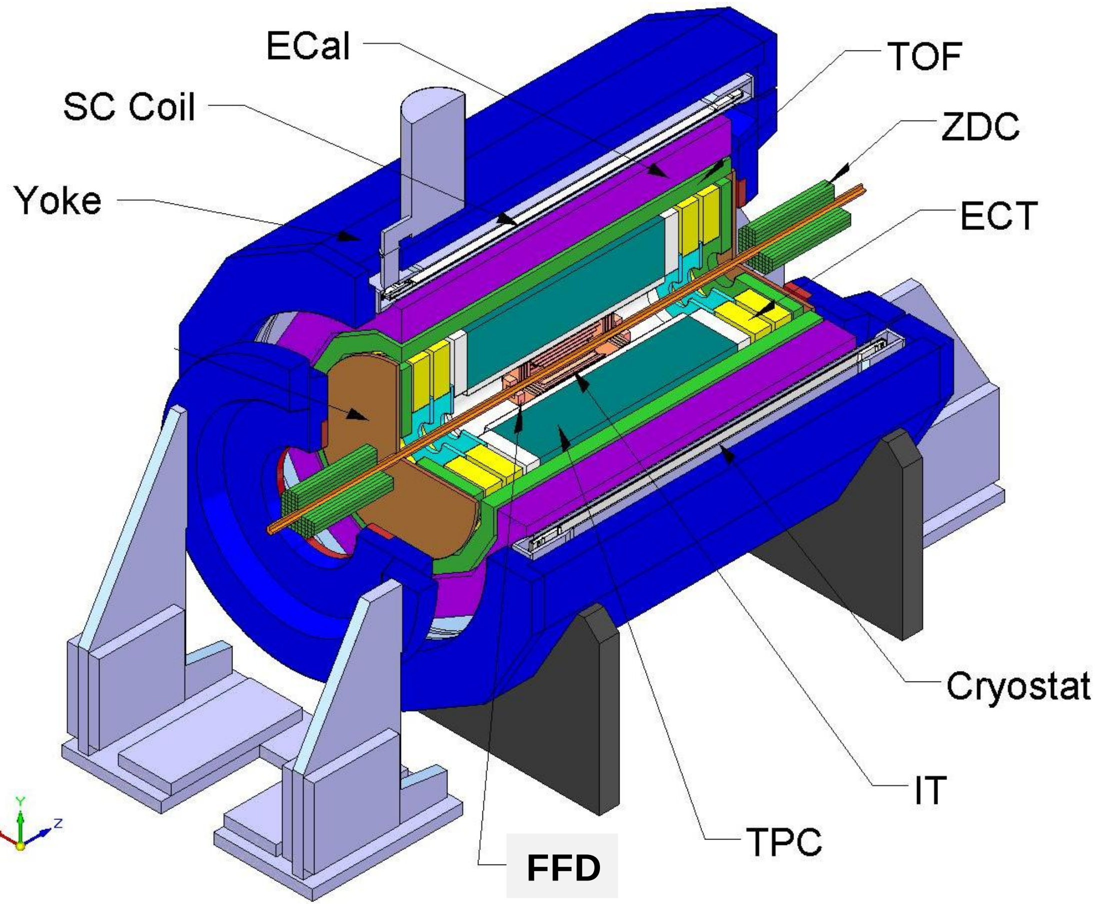


2-nd stage
IT,EC-subdetectors, Forward tracking chamber(GEM,CPC)

3-d stage
F-spectrometers (optional ?)

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

The MPD Apparatus



Magnet : 0.5 T superconductor

Tracking : TPC

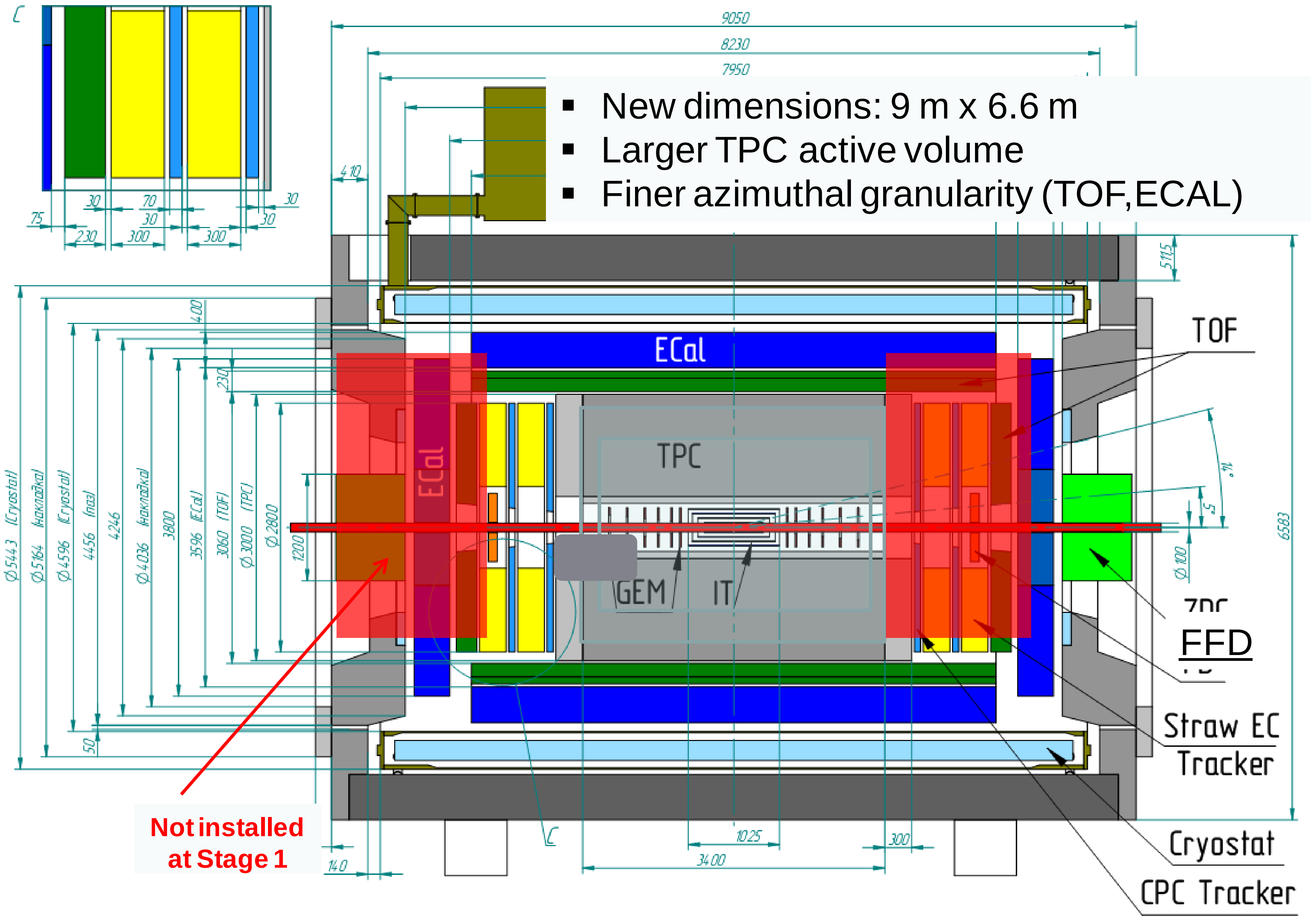
ParticleID : TOF, ECAL, TPC

T0, Triggering : FFD

Centrality, Event plane : ZDC

MPD advantages:

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



New dimensions: 9 m x 6.6 m
Larger TPC active volume
Finer azimuthal granularity (TOF,ECAL)
ECal
TPC
GEM
IT
TOF
ZDC
FFD
Straw EC Tracker
Cryostat
CPC Tracker
Not installed at Stage 1
9050
8230
7950
6583
3400
1025
300
140
410
Ø 5443 (Cryostat)
Ø 5164
Ø 4596 (Cryostat)
4456
4246
Ø 4036
3800
3596 (ECal)
3060 (TOF)
Ø 3000 (TPC)
Ø 2800
1200
Ø 100
30
70
75
230
300
400
50

NICA Physics plan for 2017-19 (Stage 1)

In the beginning energy-system size scan will be performed at NICA-MPD with the listed beam species varying the collisions energy from 4 to 11 GeV in steps of 1-2 GeV.

Beam	Luminosity ($cm^{-2}\ c^{-1}$)		Data sample per 1 week at $\sqrt{s}$ = 4 GeV
	$\sqrt{s}$=4 GeV	$\sqrt{s}$=11 GeV	
p	10^{32}	10^{32}	$1.5 \cdot 10^{10}$
^{12}C	$4 \cdot 10^{28}$	$2 \cdot 10^{29}$	$1.5 \cdot 10^{10}$
^{64}Cu	$6 \cdot 10^{27}$	$3.5 \cdot 10^{28}$	$5 \cdot 10^{9}$
^{124}Xe	$8 \cdot 10^{26}$	$6 \cdot 10^{27}$	$1 \cdot 10^{9}$
^{197}Au	$1.5 \cdot 10^{26}$	10^{27}	$3 \cdot 10^{8}$

Disk storage for data ≈ 10 PB/year

Measurements of hadrons (π, K, (anti)p, (anti)hyperons, light (anti)nuclei and dilepton spectra as a function of energy, system size, centrality, pT, rapidity and azimuthal angle.

The strategy

- **Localize the QCD CEP, then investigate in detail the critical region (in finer steps)**
- **Detailed study of the LMR dilepton enhancement in the unexplored region of the highest baryon density. If an indication for dropping mass found → detailed look in this region**
- **Study of the QCD mixed phase - hadroproduction and rare probes**

NICA-MPD physics cases

Observable	Set-up	Coverage	New insights
Hadron yields & ratios	TPC, TOF ZDC	$\|\eta\| < 1.5$ $pT < 3$ GeV/c	Data for $5<\sqrt{s}<7$ GeV, critical assessment of y-spectra and K/π-ratio
Hyperons: yields, flow, Polarization	TPC, TOF ZDC	$\|\eta\| < 1.5$ $pT < 3$ GeV/c	High statistics data on yields, flow and polarization $\sqrt{s} < 7$ GeV
Dileptons	TPC, TOF ECAL, ZDC	$\|\eta\| < 1.1$ $pT < 3$ GeV/c	New data at $\sqrt{s} > 5$ GeV
Fluctuations & Correlations	TPC, TOF ECAL, ZDC	$\|\eta\|<1.5$ $pT < 3$ GeV/c	New data on Ev-by-Ev fluct. for $\sqrt{s} > 4$ GeV
Anti-protons Anti-nuclei	TPC, TOF ZDC	$\|\eta\| < 1.1$ $pT < 2$ GeV/c	New data on antinuclei, Flow of Pbar and antiL
Flow (v1,2,3) Hadrons & nuclei	TPC, TOF ZDC	$\|\eta\| < 1.5$ $pT< 3$ GeV/c	New measurements @ $\sqrt{s}<7$GeV Precise v_n data for ϕ,Ω
Chiral Magnetic & vortical effects	TPC, TOF ZDC	$\|\eta\| < 1.5$ $pT < 3$ GeV/c	Data @ $\sqrt{s} < 7$GeV (CME) Vortical @ $4 < \sqrt{s} < 11$ GeV
(Hyper)Nuclei	TPC, TOF ZDC	$\|\eta\| < 1.5$ $pT< 5$ GeV/c	New data at $5 < \sqrt{s} < 11$

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)*

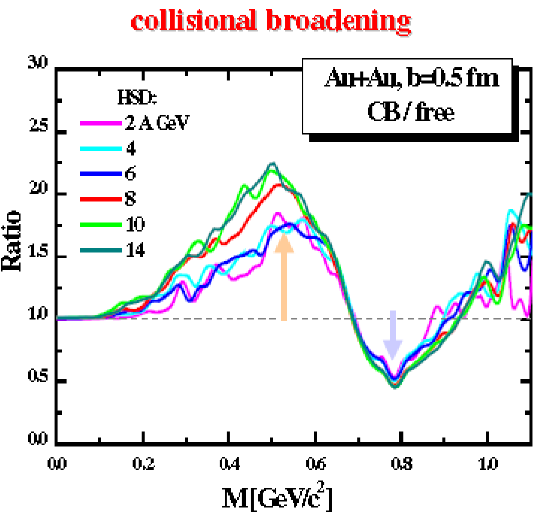
Particle	Yields		Decay mode	BR	*Effic. %	Yield/10 w
	4π	y=0				
π^+	293	97	----	---	61	$2.6 \cdot 10^{11}$
K^+	59	20	---	----	50	$4.3 \cdot 10^{10}$
p	140	41	---	----	60	$1.2 \cdot 10^{11}$
ρ	31	17	e+e-	$4.7 \cdot 10^{-5}$	35	$7.3 \cdot 10^{5}$
ω	20	11	e+e-	$7.1 \cdot 10^{-5}$	35	$7.2 \cdot 10^{5}$
φ	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}

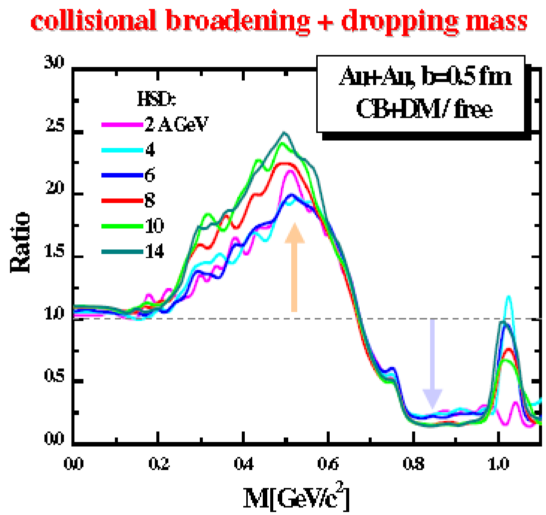
*Efficiency includes the MPD acceptance, realistic tracking and particle ID.
Particle yields are from experimental data (NA49), statistical and HSD models.
Efficiency from MPD simulations. Typical efficiency from published data (STAR)

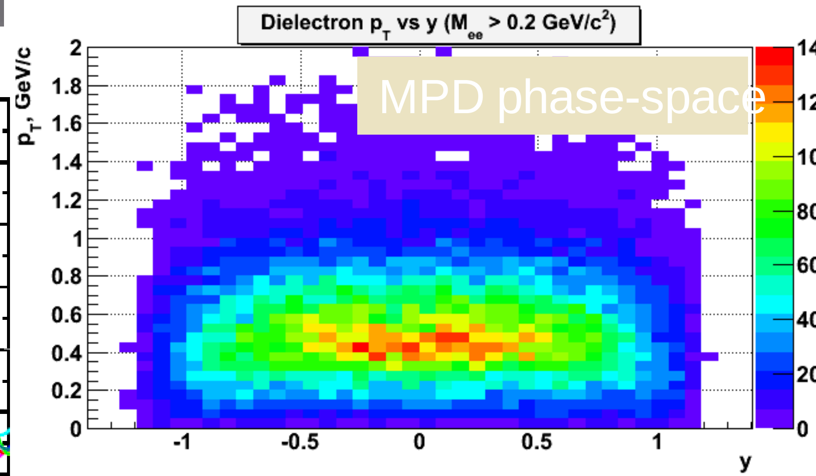
Dileptons. Prospects for NICA

NICA's energy range very well suited to fill an important niche ($5<\sqrt{s}<11$ GeV):
- **Unveil the onset of the low-mass region (LMR) pair enhancement**
- **Study LMR signal under highest baryon density conditions**

E.Bratkovskaya et al.







❖ enhancement of dilepton yield for 0.2<M<0.7 GeV and reduction at $M \sim m_{\rho/\omega}$ for all energies from 2 to 14 A GeV!

Yields (central Au+Au, $\sqrt{s}$ = 8.8 GeV)

Particle	Yields		Decay mode	BR	Effic. %	Yield/1 w
	4π	y=0				
ρ	31	17	e+e-	$4.7 \cdot 10^{-5}$	35	$7.3 \cdot 10^{4}$
ω	20	11	e+e-	$7.1 \cdot 10^{-5}$	35	$7.2 \cdot 10^{4}$
φ	2.6	1.2	e+e-	$3 \cdot 10^{-4}$	35	$1.7 \cdot 10^{4}$

Version 1.4

The MultiPurpose Detector – MPD

to study Heavy Ion Collisions at NICA
(Conceptual Design Report)

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Editorial board:
V.Golovatyuk, V.Kekelidze, V.Kolesni
O.Rogachevsky

Internal referee board:
N.Gorbunov, V.Kolesnikov, I.Meshkov
I.Tyapkin, Yu.Zanevsky, A.Kurepin

The MPD Collaboration:[1]

The MPD Collaboration consists of 195 scientists from JINR (110) and other Institutions (85)

Participating Institutions : JINR + 18 Institutes from 9 countries

- The experienced persons from heavy-ion experiments at GSI, SPS, BNL (HADES, WA98, NA45, NA49, STAR, PHENIX, ALICE)
- Young scientists account for about 40% of th Collaboration

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[1]The list of participating Institutes is currently a subject of update.

MPD Collaboration

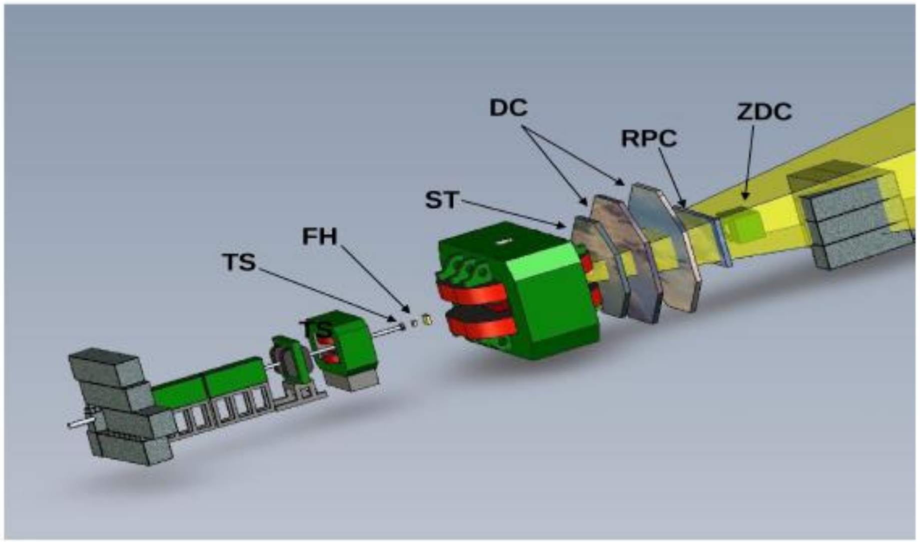
http://nica.jinr.ru/MPD_CDR

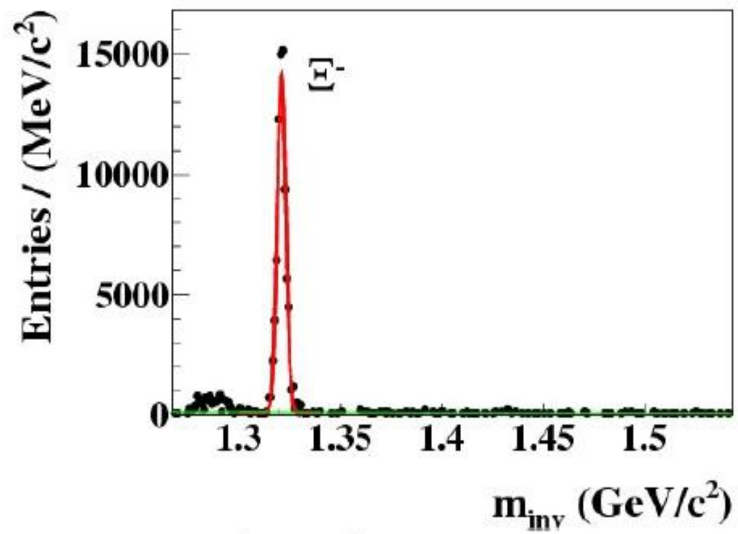
1) Joint Institute for Nuclear Research (Dubna, Russia)
2) Institute for Nuclear Research (Troitsk, Russia)
3) Institute of Nuclear Physics (Moscow, Russia)
4) Institute for Theoretical Experimental Physics (Moscow, Russia)
5) St.Petersburg State University (St.Petersburg, Russia)
6) Radium Institute (St.Petersburg, Russia)
7) “Neva-Magnet” S&E, Ltd. (St. Petersburg, Russia)
8) Department of Engineering Physics, Tsinghua University (Beijing, China)
9) Center of Particle Physics and Technology of the University of Science and Technology of China (Hefei, China)
10) Warsaw University of Technology (Warsaw, Poland)
11) Institute of Physics &Technology Mongolian Academy of Sciences (Ulan Bator, Mongolia)
12) Institute for Nuclear Research & Nuclear Energy (Sofia, Bulgaria)
13) Plovdiv University (Plovdiv, Bulgaria)
14) National Institute of Physics and Nuclear Engineering (Bucharest, Romania)
15) Bogolyubov Institute for Theoretical Physics (Kiev, Ukraine)
16) Institute for Scintillation Materials (Kharkiv, Ukraine)
17) State Enterprise Scientific & Technology Research Institute(Kharkiv, Ukraine)
18) Particle Physics Center of Belarusian State University (Minsk, Belorussia)
19) Physics Institute Az. AS (Baku, Azerbaijan)

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)

Physics at BM@N





Physics for the first stage of the BM@N spectrometer (2015):

-In-medium effects for strangeness and vector mesons decaying in hadron modes

-Flows, polarizations, vorticity and azhimuthal correlations of hadrons

-Femtoscopy for different hadrons (and photons)

-NN and NA interactions as the reference for AA collisions

-Electromagnetic probes (optionally)

Physics for the BM@N spectrometer with inner tracker(2017):

-The measurements of the (sub)threshold cascade hyperons production in order to obtain the information on the nuclear matter EOS.

Participants

Countries: **Belarus, Bulgaria, Chezh, Moldova, Romania, Russia, Slovakia, Ukraine + Germany + France+ China PR**

Russia: INR, SINP MSU, IHEP + 2 Universities
Germany: GSI, Frankfurt U., Giessen U., FIAS

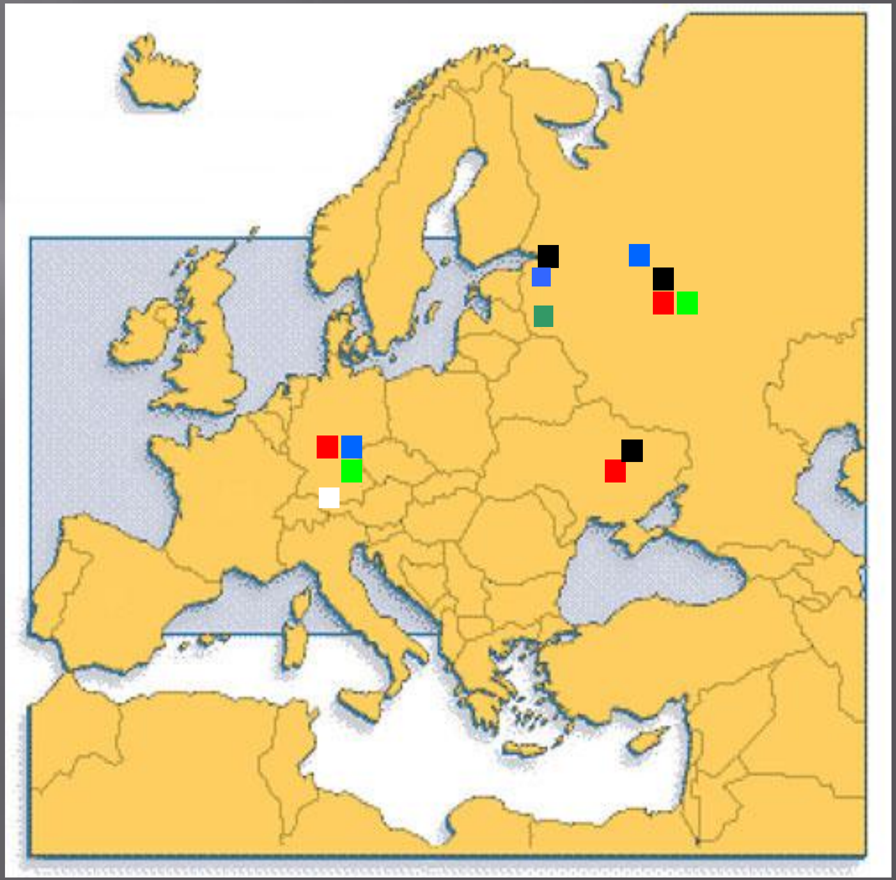
About 200 peoples.
List for authors is open !

The CBM/FAIR-MPD/NICA Consortium

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

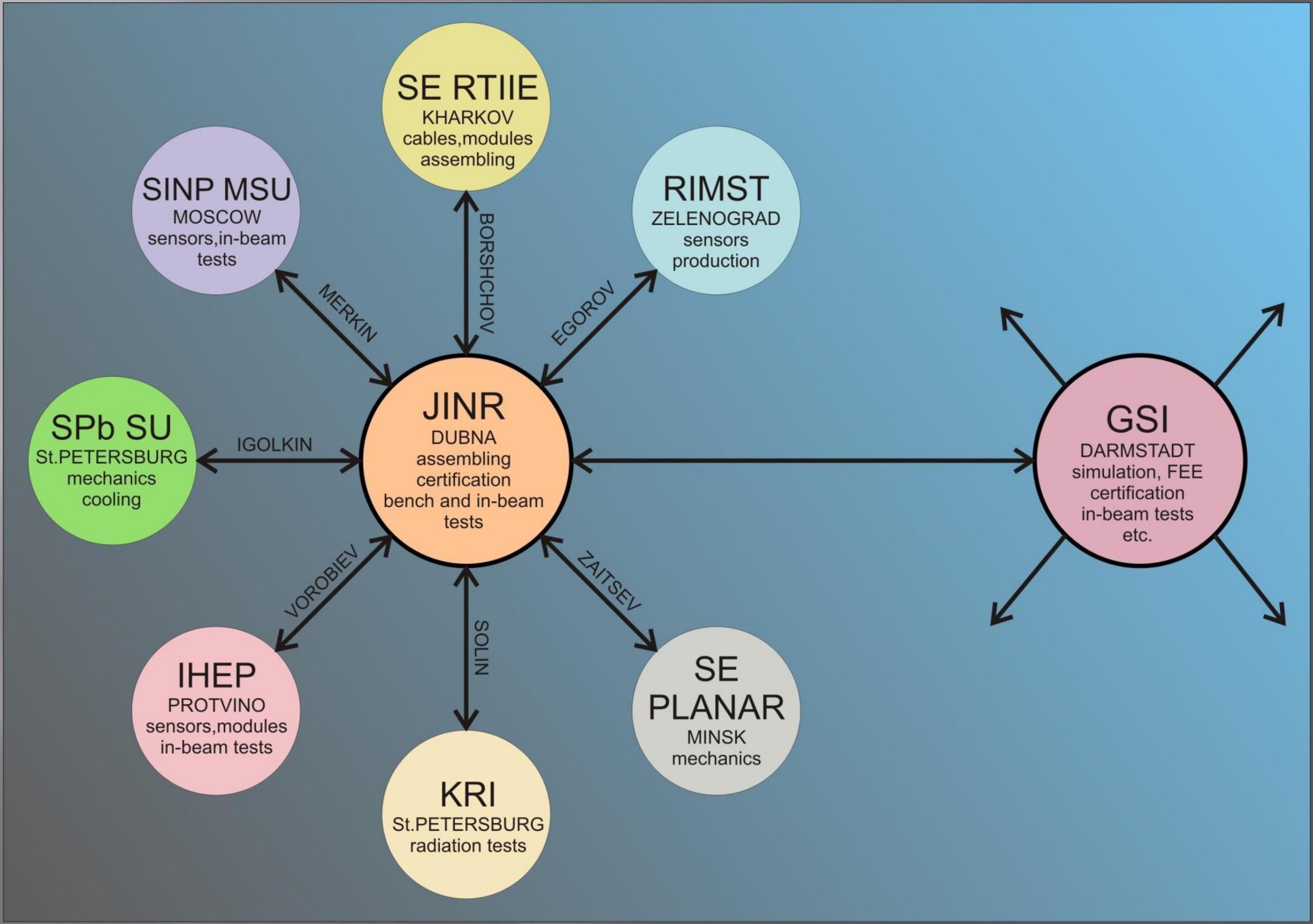
CBM @ FAIR (Darmstadt)	MPD @ NICA (Dubna)	BM@N (Dubna)

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

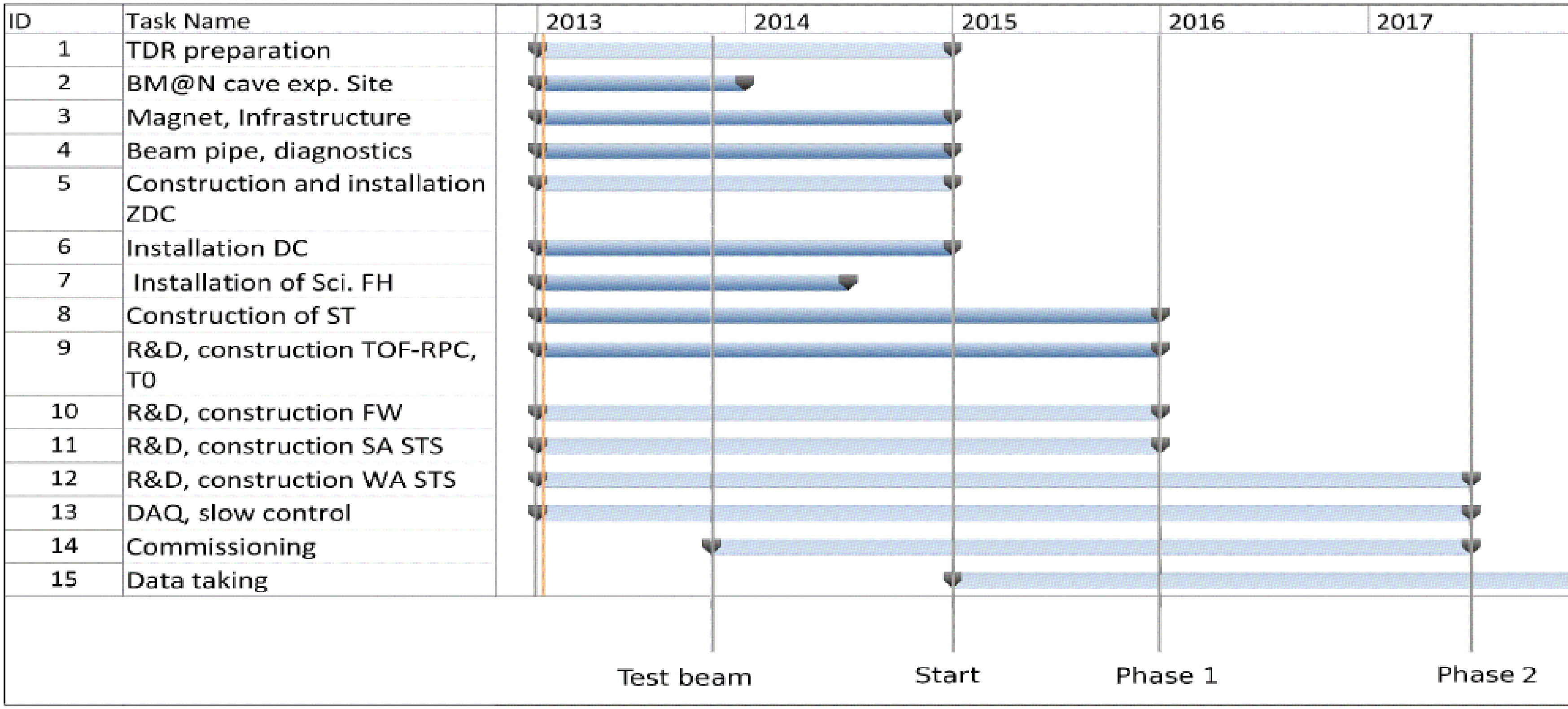


- Modules assembly
- Components
- Ladder assembly
- Radiation tests
- In-beam tests

The CBM-MPD Consortium Structure



Time table of the experiment



Testbeam (2013...)
Start version (2014-...) – Part of RPC, DC, SciFH, ZDC
Phase1 (2015-...) - Full RPC, DC, ZDC, ST, FW, SA STS
Phase2 (2017-...) - The data taking at Au+Au with WA STS.

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 > ~ 10^{32} cm^{-2} s^{-1}**
- **both proton and deuteron beams can be effectively polarized.**

The main topics are:

1. Studies of 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.

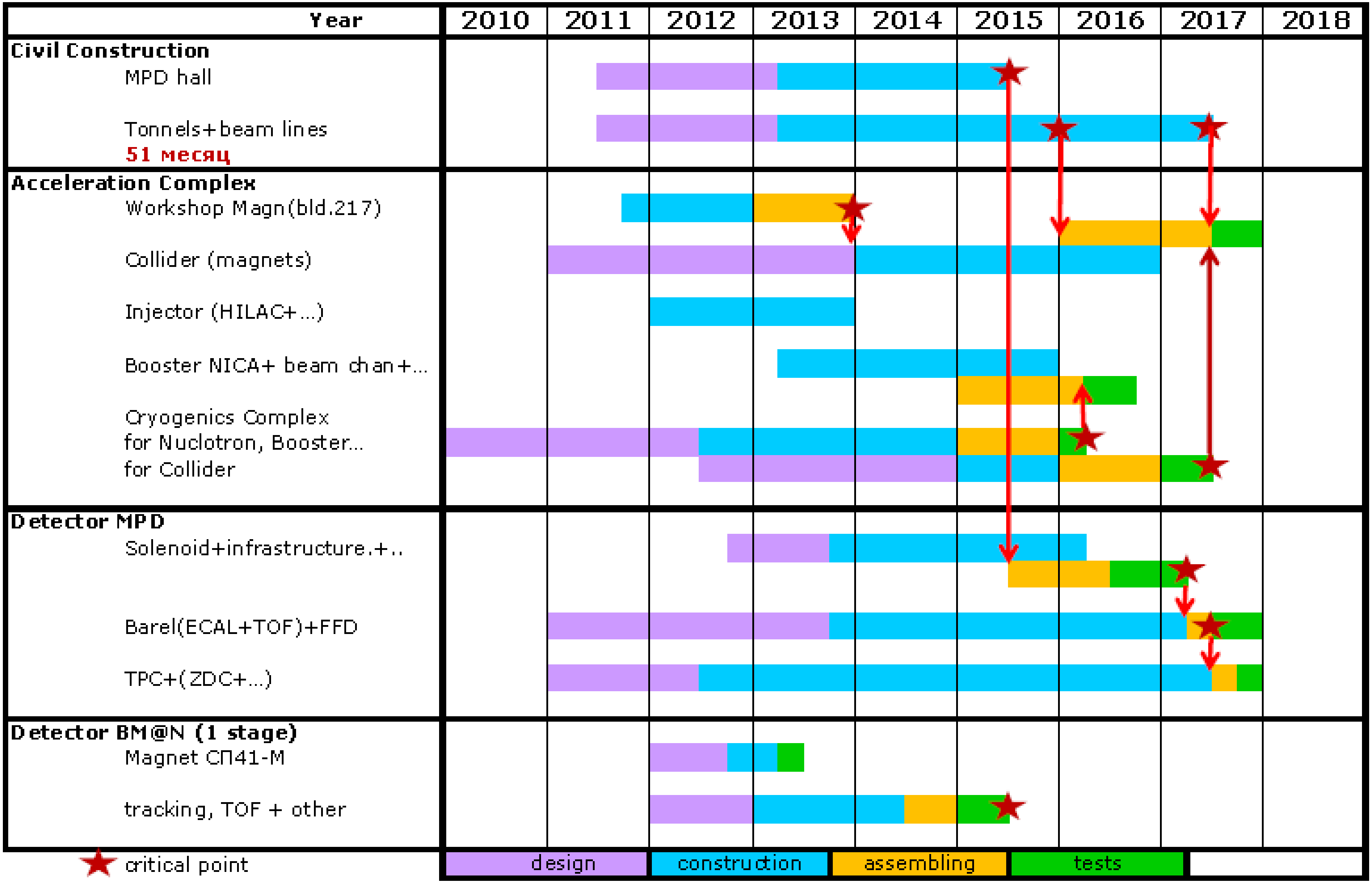
7. Spectroscopy of quarkoniums.

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

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

Call for the Proposals

NICA project timetable



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

NICA

Draft v 8.03
January 24, 2013

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

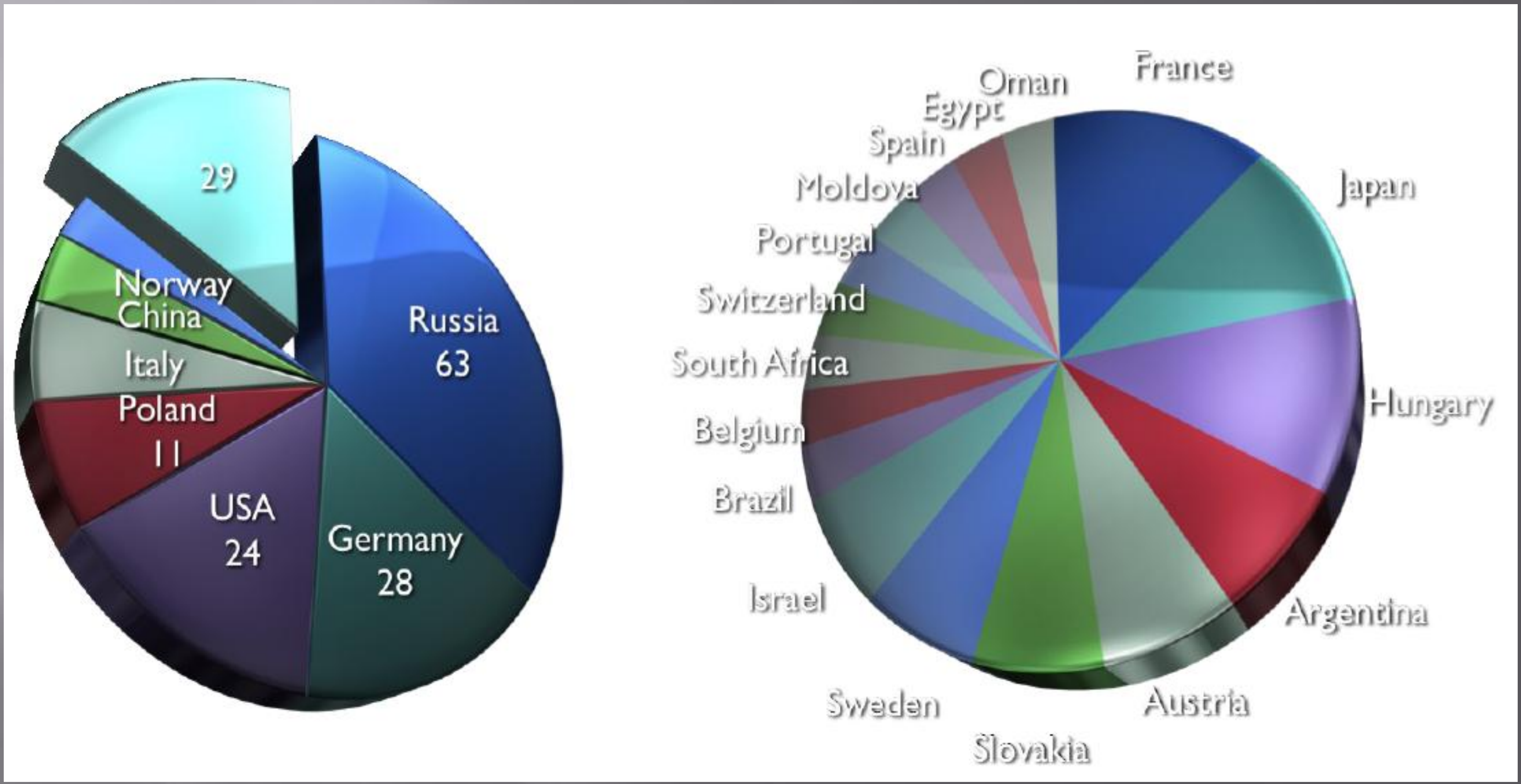
The NICA White Paper addresses the following key topics:

- 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

NICA White Paper - Contents

(98 contributions)

NICA White Paper – International Effort



1.1 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**)

Section 1: Editorial

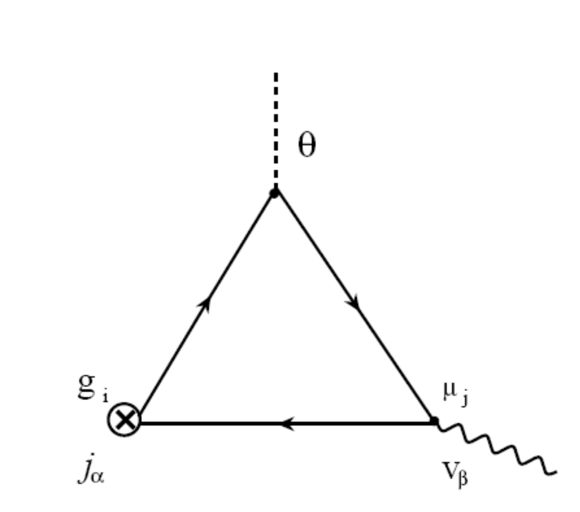
Observables	Physical Phenomena							Detectors	Reference in the White Paper
	MMH	EoS	OD	CSR	PT	CEP	LPV		
yields of hadrons, normal and exotic light nuclei	x	x	x					tracking, TOF	3.6, 3.9, 3.11, 3.12, 4.3, 4.12, 4.18, 4.19, 6.7, 6.8, 9.3, 12.7, 12.8, 12.9
yields and spectra of multistrange hyperons	x	x	x					precision tracking (seconday vertices)	2.6, 5.3, 6.4, 12.3, 12.5, 12.6, 12.7
electromagnetic probes			x	x				tracking, electron identifiers (e.g. RICH)	7.1, 7.2, 7.3, 7.7, 7.8, 7.9
azimuthal charged particle correlations					x		x	tracking	2.9, 8.1 - 8.7, 8.8, 10.4
event-by-event (EBE) fluctuations						x		tracking, TOF	2.1, 2.6, 3.10, 5.4, 5.9
Radial, elliptic and triangular flow of hadrons		x	x		x			tracking, TOF	4.4, 4.8, 4.14, 5.8, 11.5
higher moments of hadron distributions			x		x	x		tracking, TOF	3.10, 4.1, 4.5, 4.6, 4.10, 4.12-4.15, 4.17, 4.19, 4.20
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 using DCM (M. Baznat, K. Gudima, A. Sorin, O. Teryaev)

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.

Helicity separation in Heavy-Ion Collisions

M. Baznat, K. Gudima, A. Sorin, O. Teryaev arXiv:1301.7003

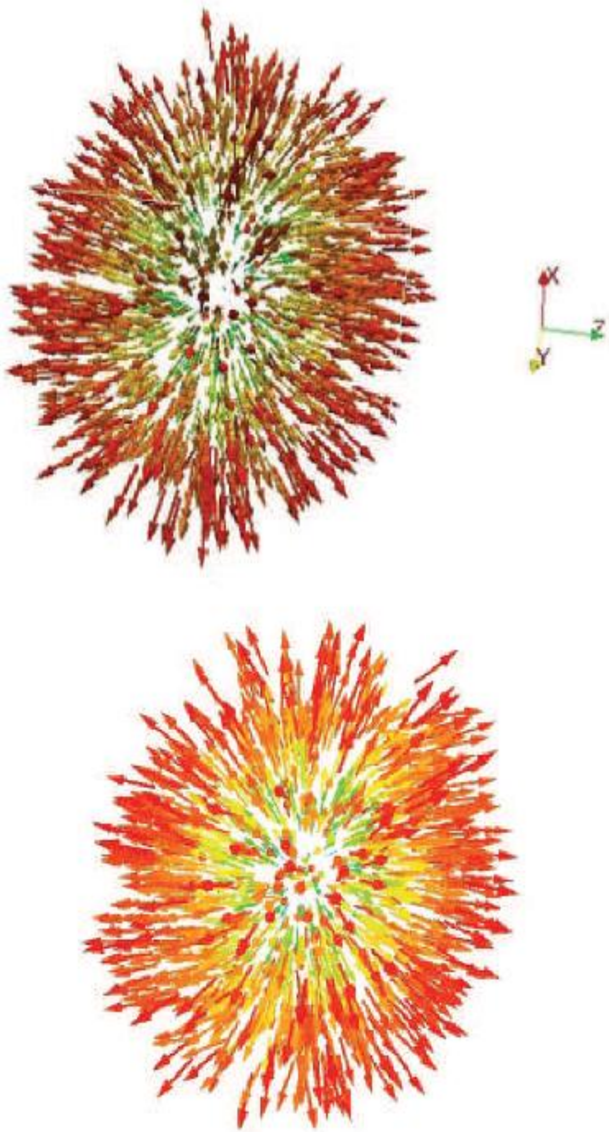


Figure 1: (color online) Three dimension image (top) and projection on plane XY (bottom) of velocity field in Au+Au at $\sqrt{s_{NN}} = 5\ GeV$, $b = 8\ fm$ and $t = 10\ fm/c$

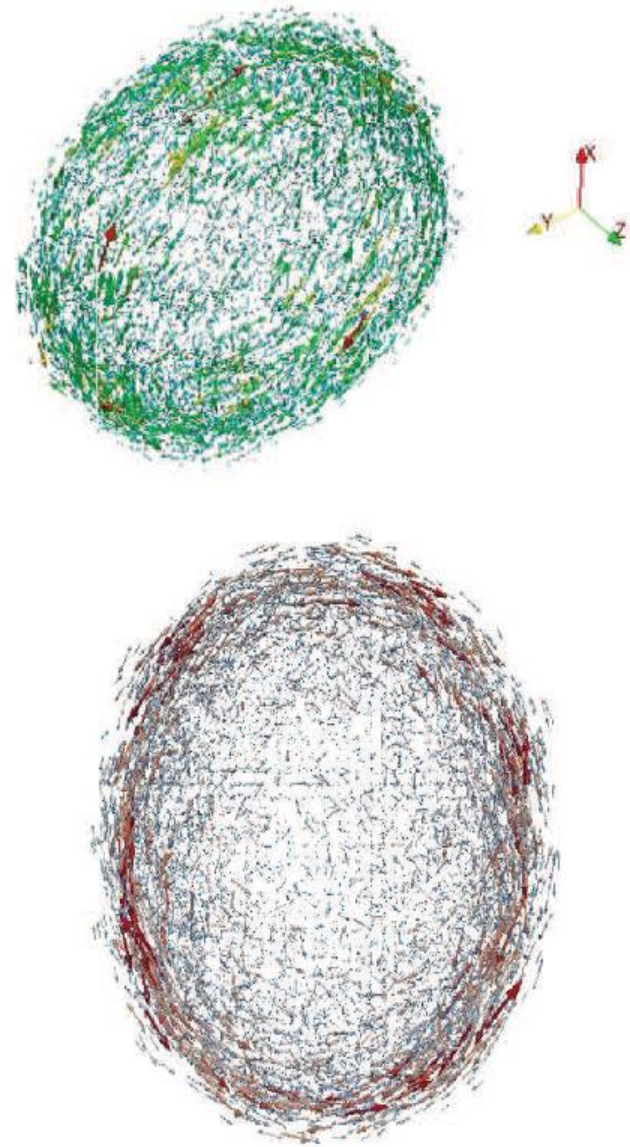
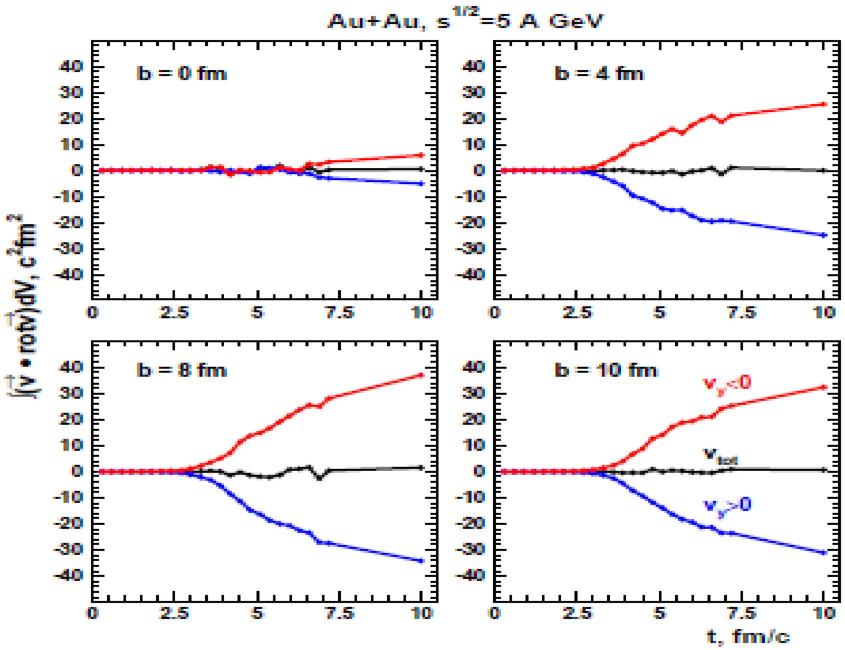


Figure 2: (color online) Three dimension image (top) and projection on plane XY (bottom) of vorticity field in Au+Au at $\sqrt{s_{NN}} = 5\ GeV$, $b = 8\ fm$ and $t = 10\ fm/c$

arXiv:1301.7003



e 3: (color online) Time dependence of helicity at different impact parameters

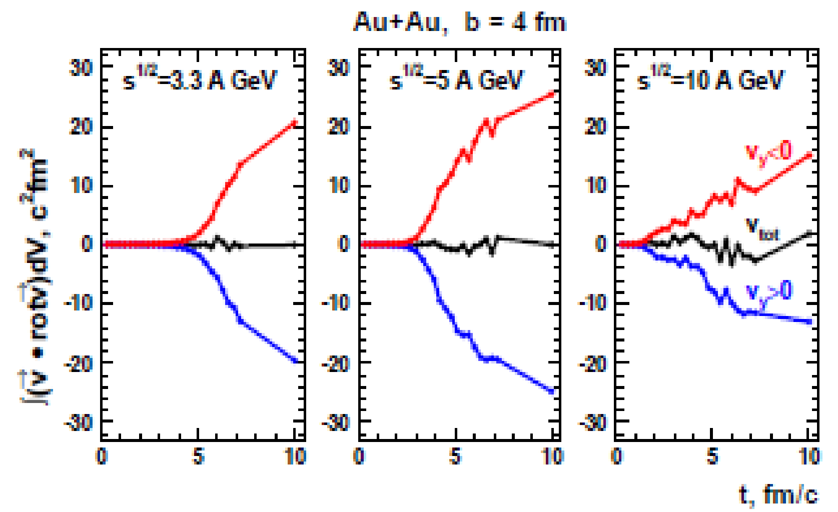
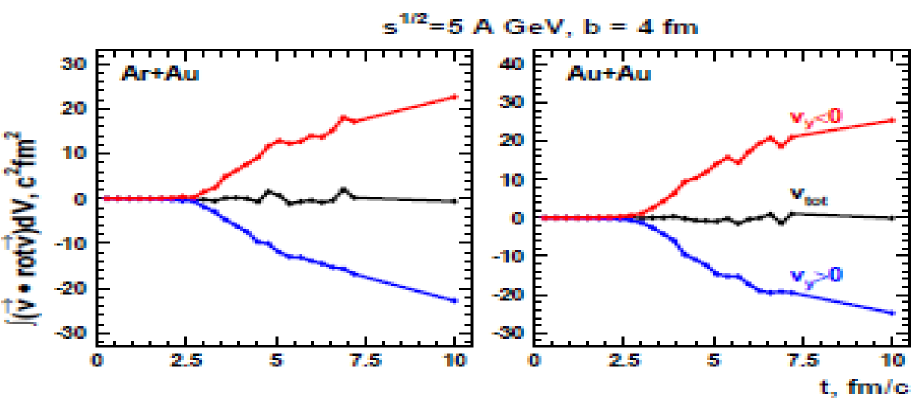


Figure 4: (color online) Time dependence of helicity at different energies



ure 5: (color online) Time dependence of helicity in asymmetric collisions

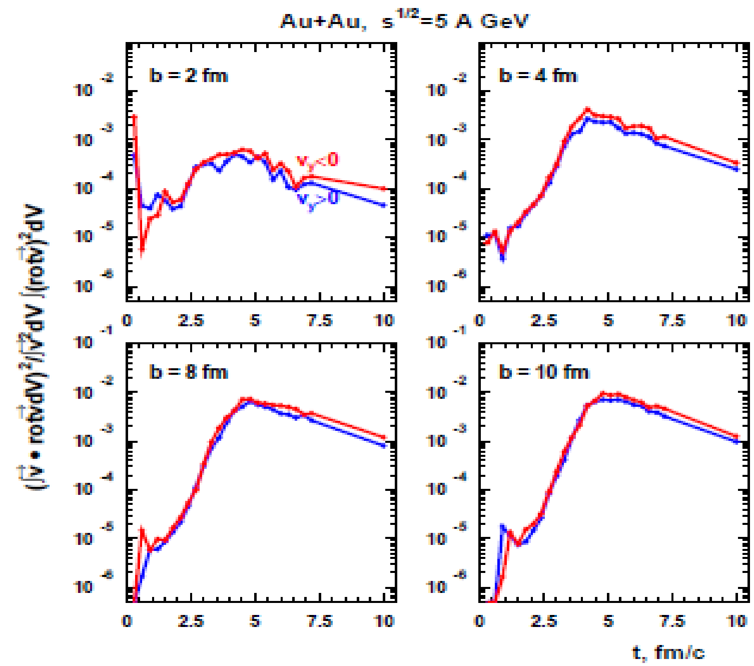


Figure 6: (color online) Time dependence of Cauchy-Schwarz bound for helicity

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

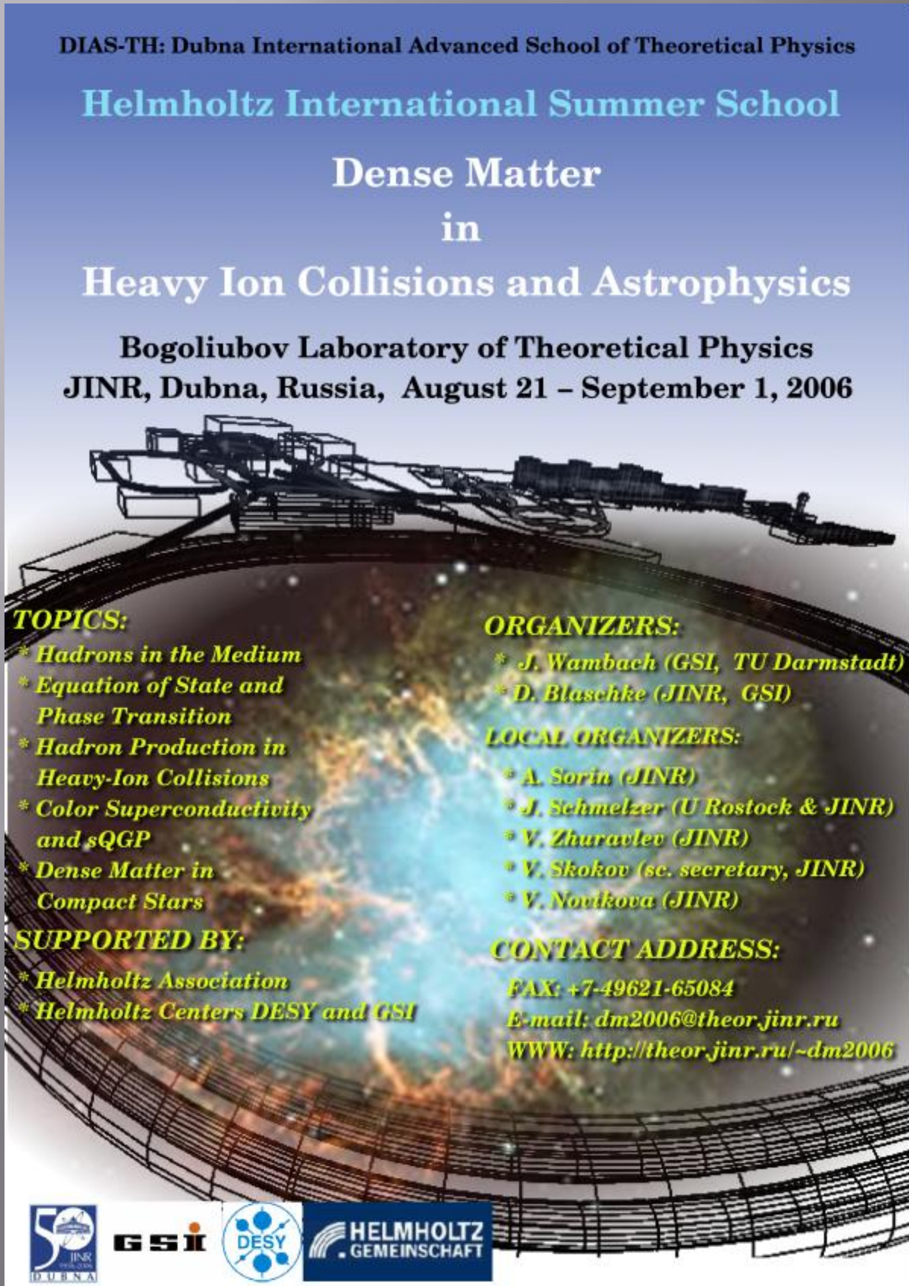
XX International Symposium on Spin Physics (SPIN2012)
Dubna, September 17 – 22, 2012

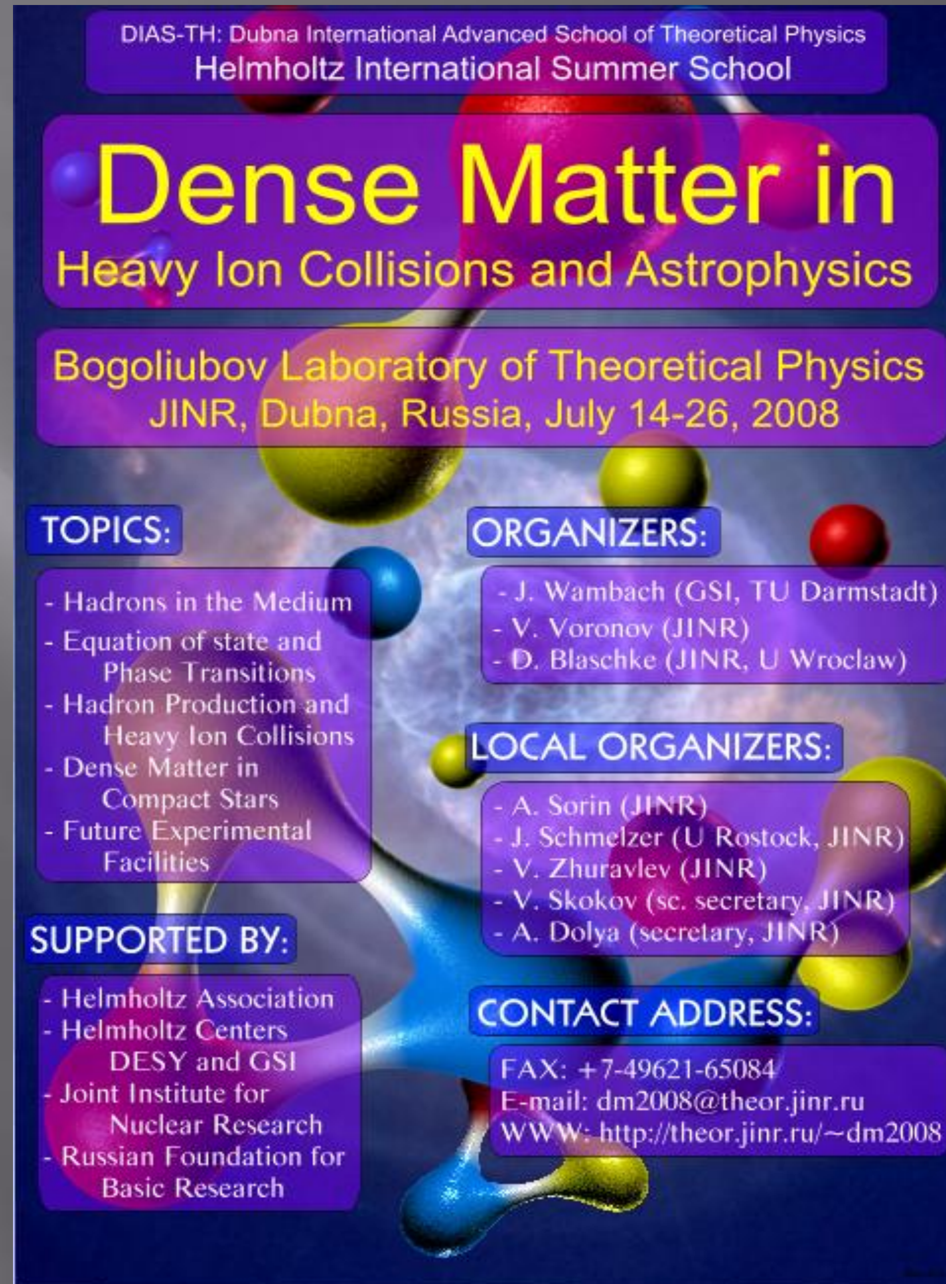
The conferences in Dubna

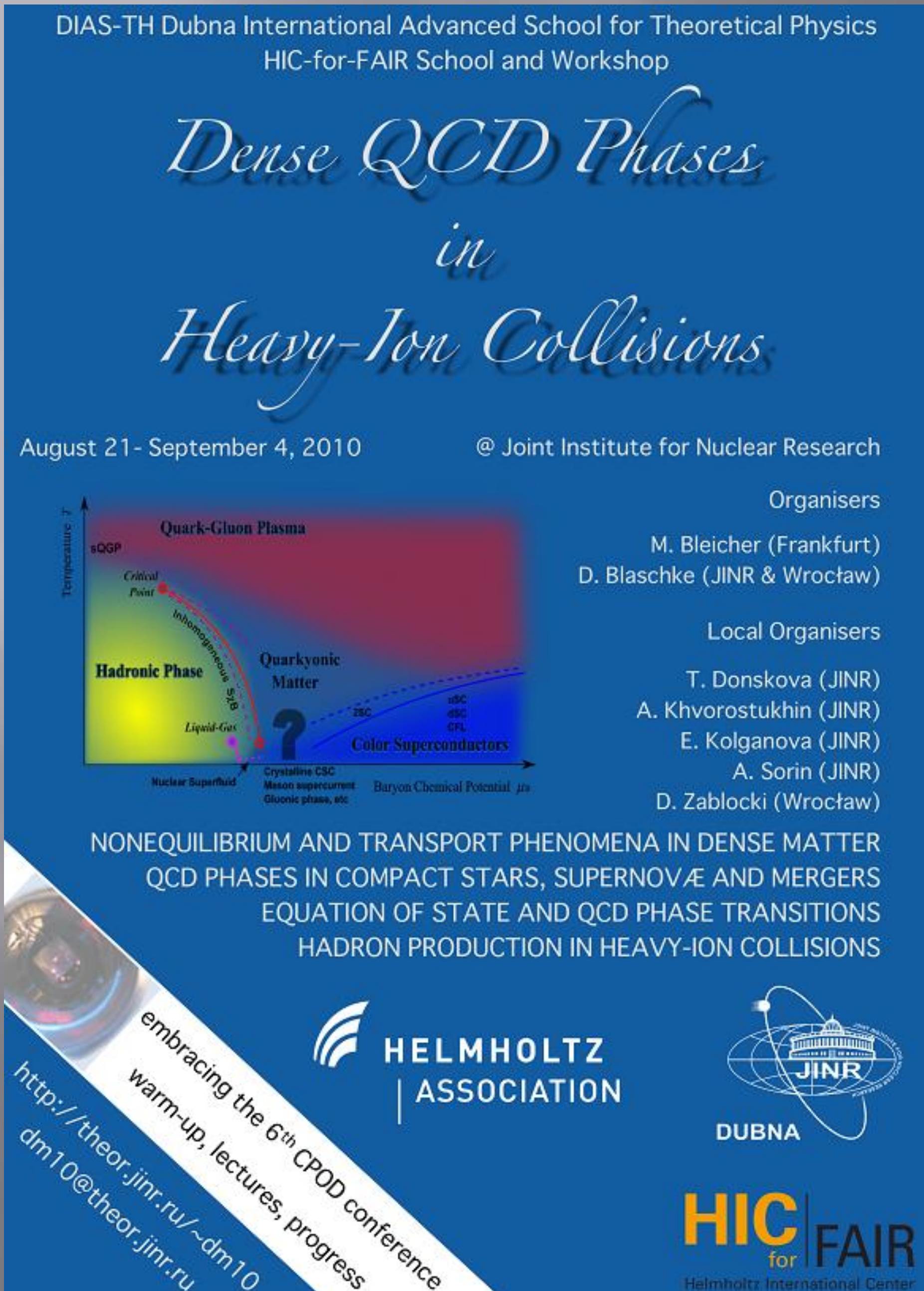
CPOD 2010

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)
Quark-Gluon Plasma
sQGP
Critical Point
Hadronic Phase
Quarkyonic Matter
Liquid-Gas
Color Superconductors
Nuclear Superfluid
Crystalline CSC
Meson supercurrent
Gluonic phase, etc
Baryon Chemical Potential
Temperature
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


ДУБНА
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:
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DESY
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CONTACTS:
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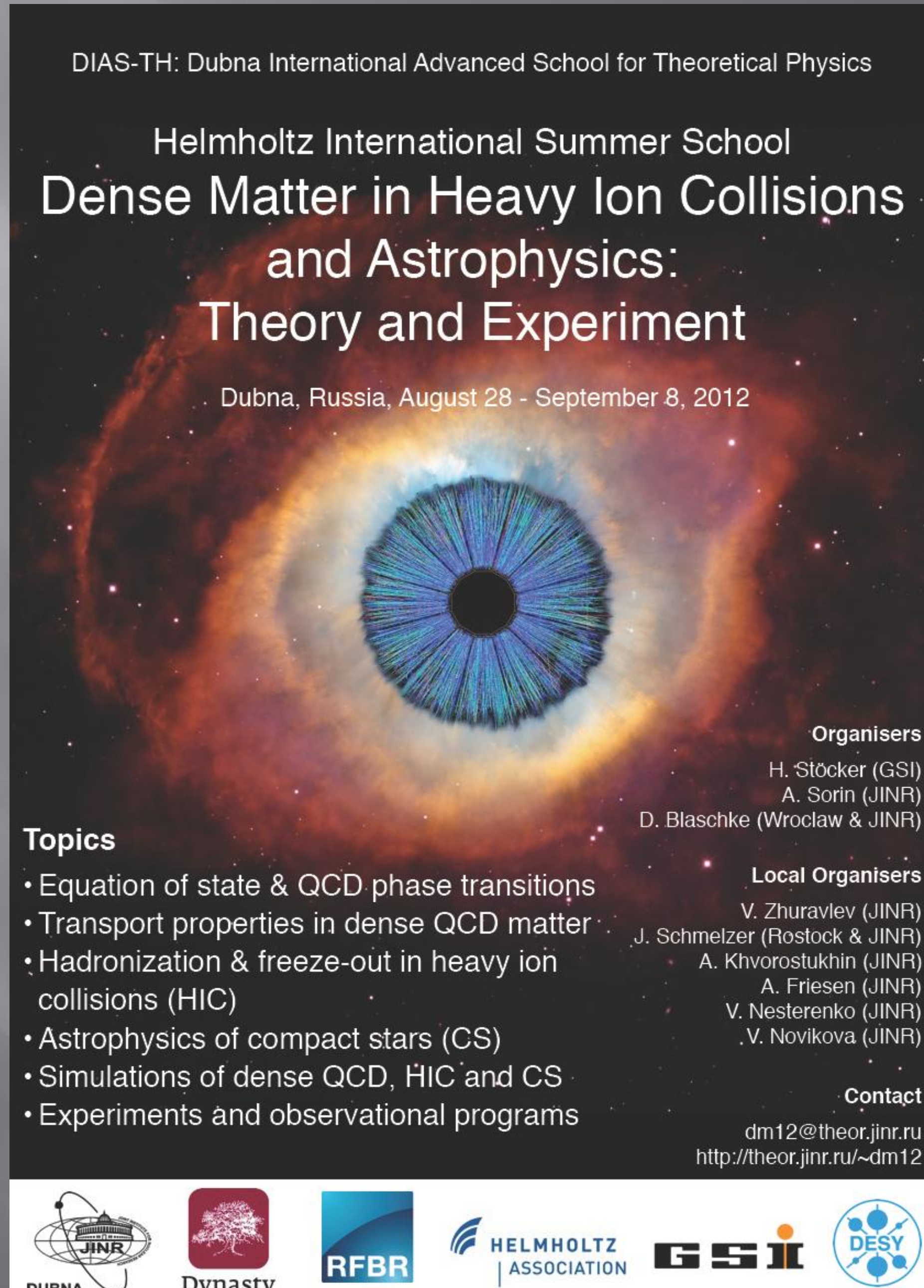
141980 Dubna, Russia; Phone: (+749621) 65084; e-mail: diastp@theor.jinr.ru
http://theor.jinr.ru/~diastp/summer11


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)
A. Khvorostukhin (JINR)
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JINR
DUBNA
Dynasty
RFBR
HELMHOLTZ
ASSOCIATION
GSI
DESY

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

NICA is in the approved Russian mega-science program

ПРАВИТЕЛЬСТВО РОССИЙСКОЙ ФЕДЕРАЦИИ

РАСПОРЯЖЕНИЕ

от 20 декабря 2012 г. № 2433-р

МОСКВА

1. Утвердить государственную программу Российской Федерации "Развитие науки и технологий".

2. Минобрнауки России разместить государственную программу Российской Федерации "Развитие науки и технологий" на своем официальном сайте, а также на портале государственных программ Российской Федерации в информационно-телекоммуникационной сети "Интернет" в 2-недельный срок со дня официального опубликования настоящего распоряжения.

Председатель Правительства
Российской Федерации — Д.Медведев

№1

**Государственная программа
Российской Федерации
"Развитие науки и технологий" на 2013 – 2020 годы**

Предусматривается создание комплекса сверхпроводящих колец на встречных пучках тяжелых ионов NICA. В результате реализации проекта будет создан уникальный ускорительный комплекс, который позволит развернуть программу фундаментальных научных исследований в области физики элементарных частиц с недоступными на сегодняшний день энергиями и массами взаимодействующих частиц. Будут получены новые знания о фундаментальной структуре и свойствах материи.

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!

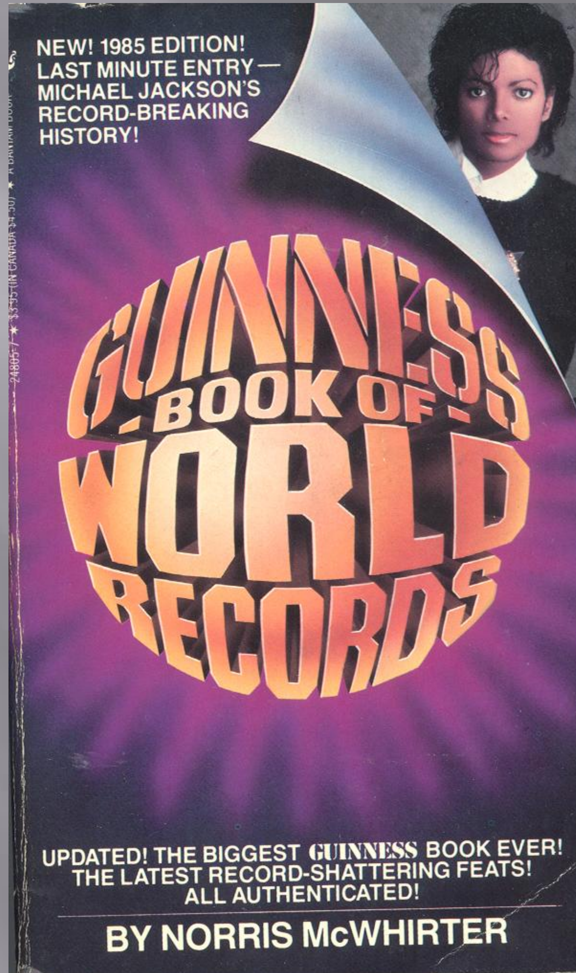
JOINT INSTITUTE

JINR

FOR NUCLEAR RESEARCH

NICA

Thank you for attention!



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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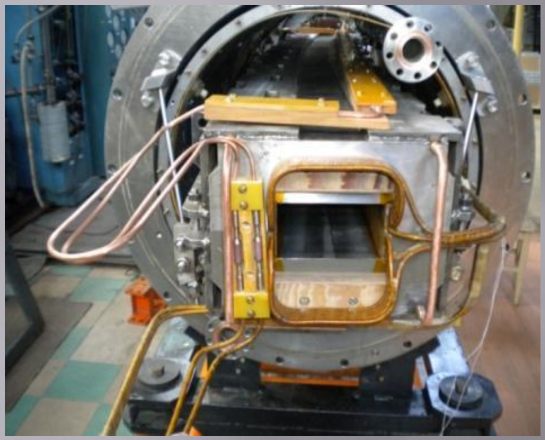
Heaviest Magnet

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

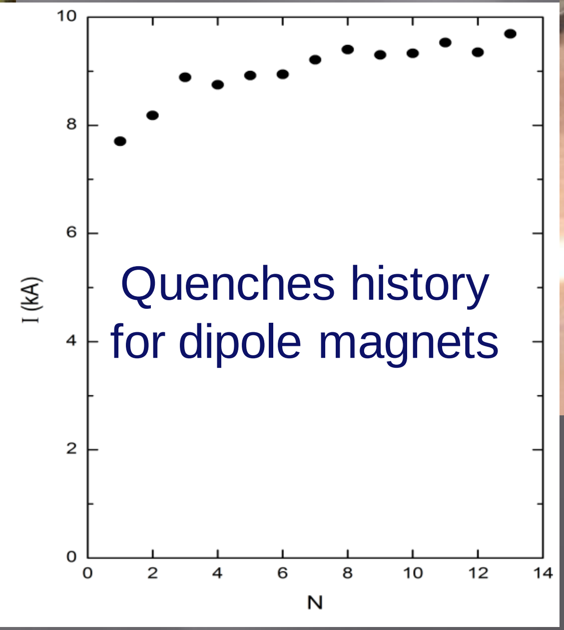


Dipole magnet in cryostat

yoke of quadrupole lens after final treatment

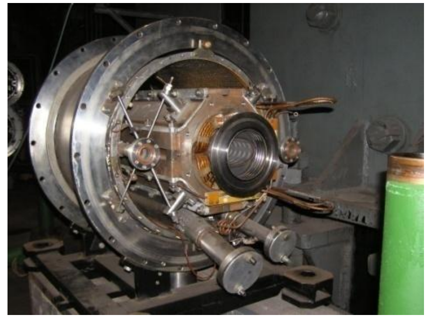
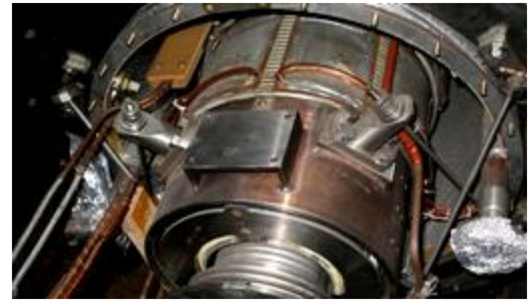
Dipole magnet for collider

Prototype of curved dipole



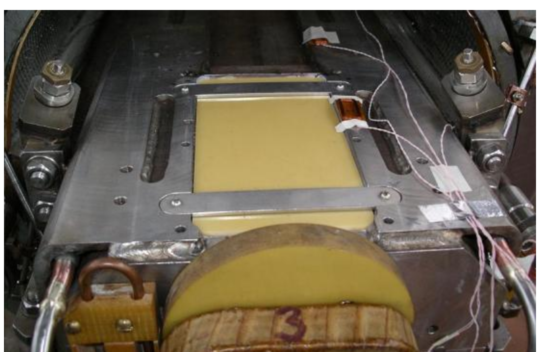
The building is ready for the equipment installation

Constructing and Testing JINR Experience

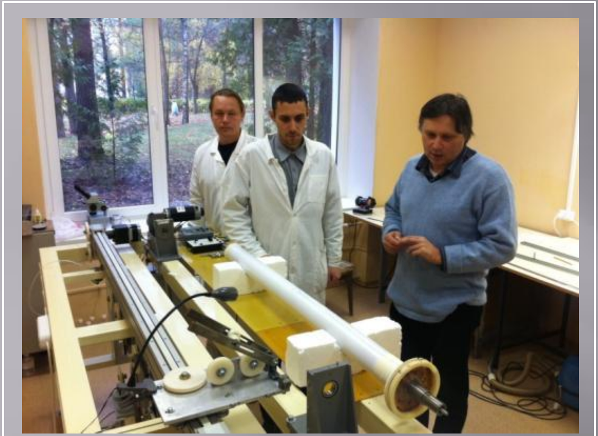
160 SC dipole and quadrupole magnets for the Nuclotron: construction, test and operation since1993.

26 model magnets for SIS100



SIS100 prototype dipole and prototype quadrupole magnets


Modern SC technologies + unique accelerator physics at JINR



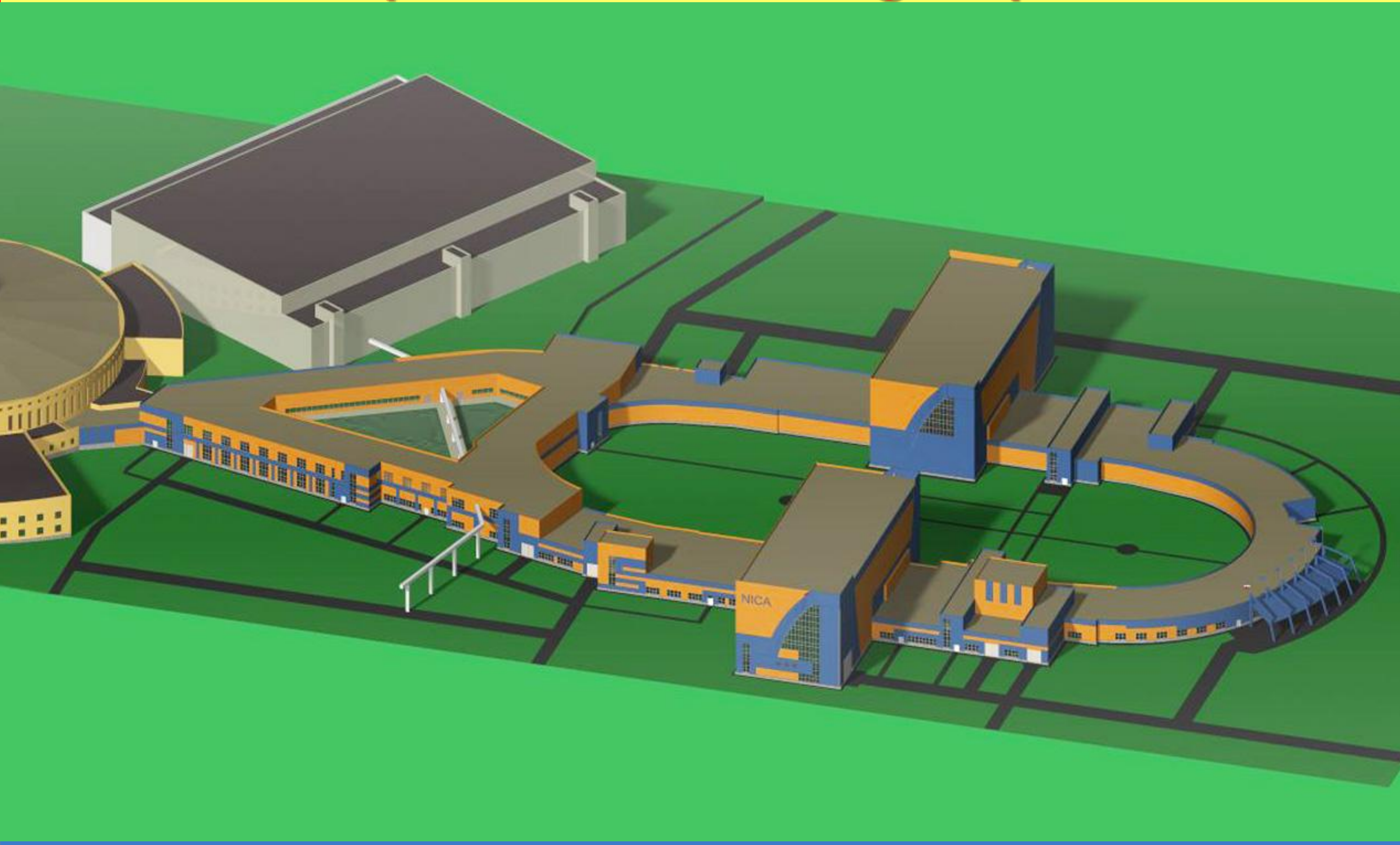
Highly charged ion state for heavy ions with high intensity, e.g., Kr 28+, Xe 44+, Au 65+..32+

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

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

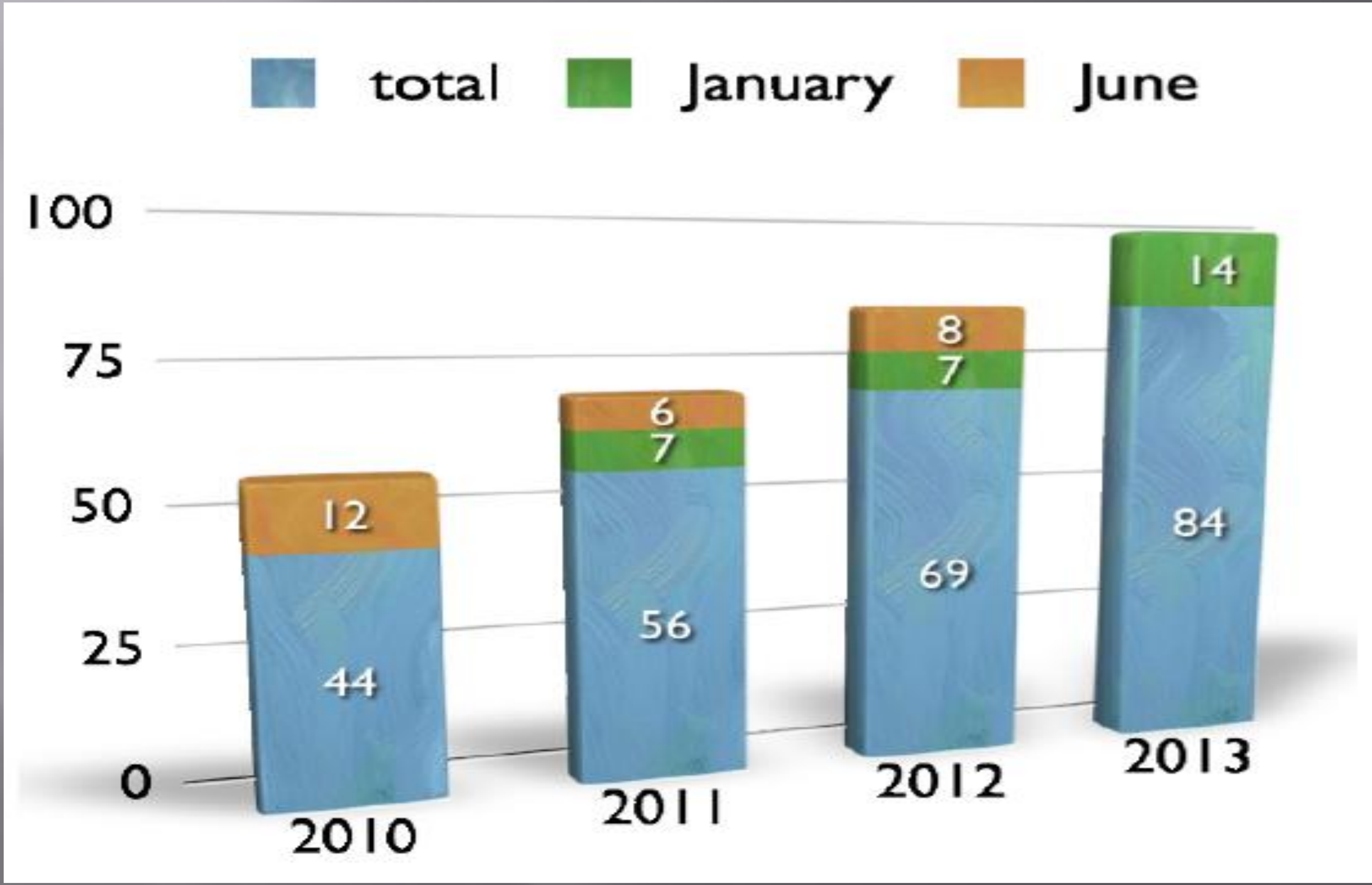
Accelerator facility	*Experiments on Collider*	*Experiments with extracted beams*
▪ Nuclotron-M		
▪ Nuclotron-NICA	▪ MPD	▪ BM@N
		▪ test beams
▪ Collider	▪ SPD	▪ innovations
infrastructure	*infrastructure*	*infrastructure*

projects

completed

approved, in progress

Statistics of White Paper Contributions



Experiments on superdense nuclear matter

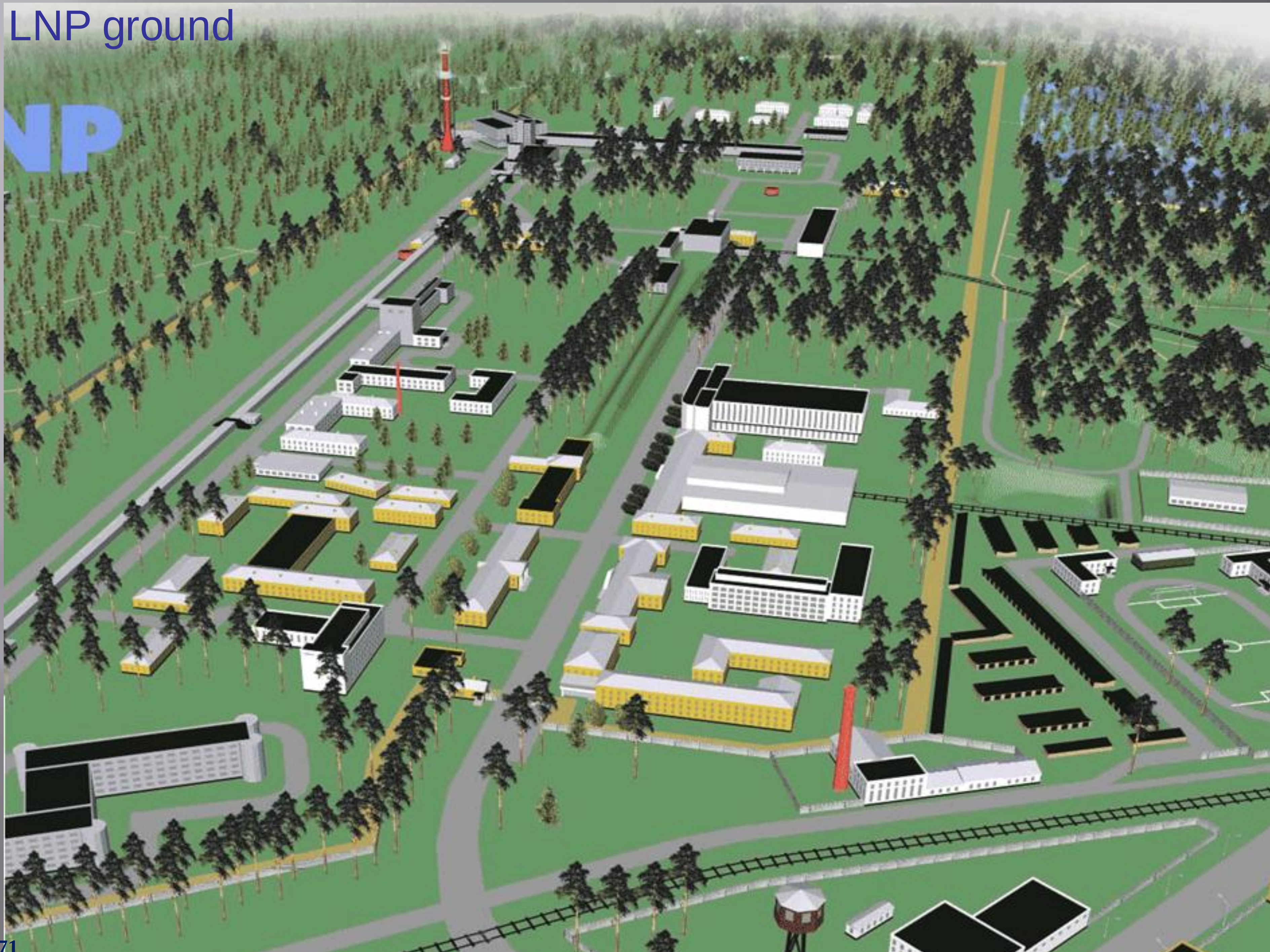
Experiments	Energy range (Au/Pb beams)	Reaction rates Hz
STAR@RHIC BNL	$\sqrt{s_{NN}}$ = 7 – 200 GeV	1 – 800 (limitation by luminosity)
NA61@SPS CERN	E_{kin}= 20 – 160 A GeV $\sqrt{s_{NN}}$= 6.4 – 17.4 GeV	80 (limitation by detector)
MPD@NICA Dubna	$\sqrt{s_{NN}}$= 4.0 – 11.0 GeV	~7000 (design luminosity 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.

LNP ground



The goal of the BM@N experiment

I. Heavy-ion collisions *A+A* - study of the properties of dense nuclear (dominantly baryonic) matter with strangeness :

- production mechanisms and modifications of hadron properties in dense nuclear matter – ‚in-medium effects‘

  Probes: strange mesons, strange and multi-strange baryons;
  vector mesons via hadronic mode (dilepton/photon mode – perspectives)

- study of the EoS with strangeness

- hypermatter production:
  search for light hypernuclei and multi-strange meta-stable objects

II. Study of elementary reactions: *p+p, p+n(d)*

III. Study of ‚cold‘ nuclear matter: physics with *p+A*

Observables

Way to study:

Experimental energy scan of differential observables in comparison with theory

Observables:

- **Excitation function of particle yields and ratios**
- **Transverse mass m_T- and momentum p_T- spectra**
- **Rapidity distributions**
- **Collective flow - anisotropy coefficients (v_1, v_2, v_3, v_4)**
- **Fluctuations**
- **Correlations**