Joint Institute for Nuclear Research
International Intergovernmental Organization

Dedicated to the memory of
Albert Nikiforovich Tavkhelidze and
Alexei Norairovich Sissakian

The NICA Project at JINR

A.S. Sorin (for the NICA/MPD collaboration)

International Workshop “Bogoliubov readings”
BLTP JINR, Dubna, September 25, 2010


To the 100th anniversary
of N.N.Bogolyubov's birth

High Energy Machines at JINR, Dubna
the Laboratory of High Energy Physics

10 GeV **Synchrophasotron**
put in operation in 1957

↓

the first superconducting
accelerator for relativistic ions
NUCLOTRON launched in 1993

Nuclotron-based Ion Collider fAcility (NICA)

Flagship project at JINR/Dubna
Based on the technological development of the existing Nuclotron facility
Optimal usage of the existing infrastructure
Modern machine which incorporates new technological concepts
Operational ~ 2016

NICA advantages:
optimal energy range $\sqrt{s_{NN}}$ = 4-11 GeV (system of max. baryon density)
rich nomenclature of colliding systems (from p+p to Au+Au)
high luminosity (up to 10^{27} $cm^{-2}s^{-1}$ for Au^{79+})

The goal of the project is

<u>construction at JINR of a new accelerator facility,</u> that provides

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 $L_{average}$ = 1E27 $cm^{-2} \cdot s^{-1}$ (at $\sqrt{s_{NN}}$ = 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↑ $\sqrt{s_{pp}}$ = 12 ÷ 27 GeV (5 ÷ 12.6 GeV kinetic energy)

d↑d↑ $\sqrt{s_{NN}}$ = 4 ÷ 13.8 GeV (2 ÷ 5.9 GeV/u ion kinetic energy)

$L_{average} \geq$ 1E30 $cm^{-2} \cdot s^{-1}$ (at $\sqrt{s_{pp}}$ = 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 on ion beams at kinetic energy from 0.5 GeV/u up to 12.6 GeV (p) and 4.5 GeV /u (Au)

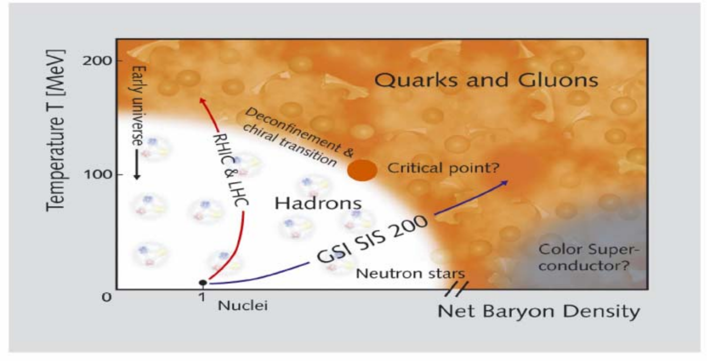
- **the study of BM could provide us with information on**

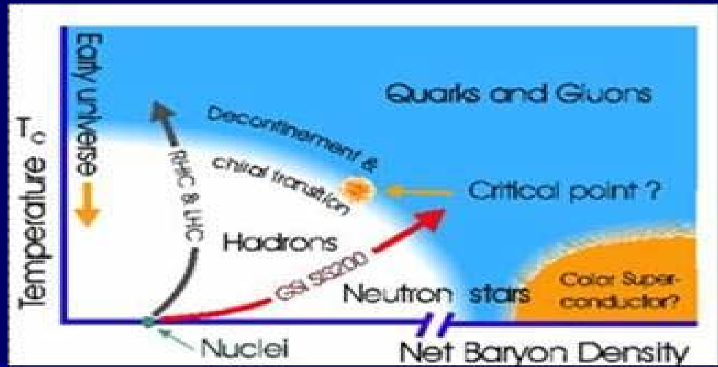
  -in-medium properties of hadrons
  & nuclear matter equation of state (EOS)

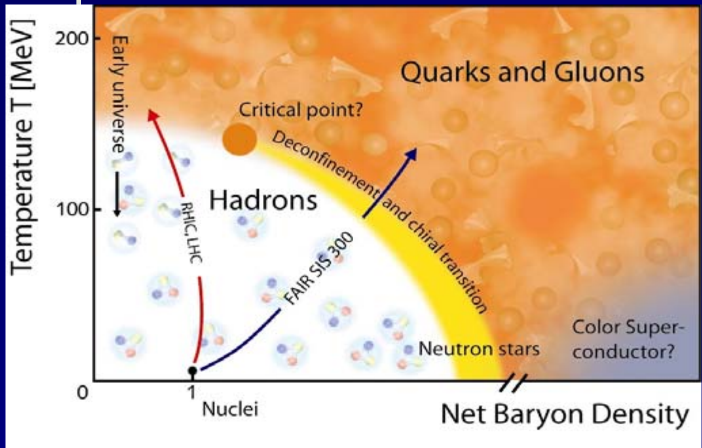
  -onset of deconfinement (OD) & chiral symmetry restoration (CSR),
  -phase transition, mixed phase & critical end-point (CEP)

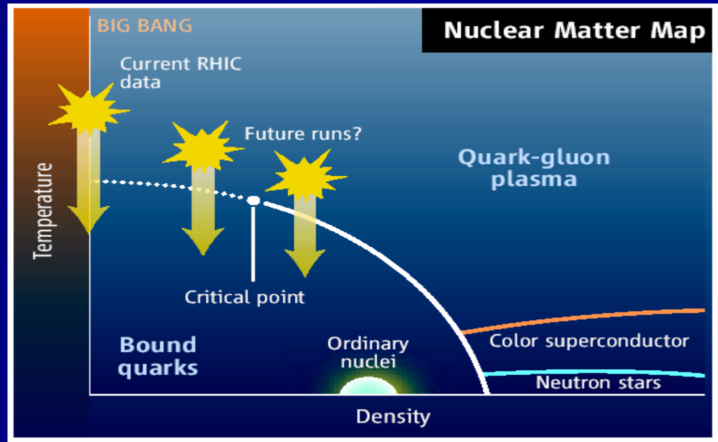
  -possible local parity violation (LPV)

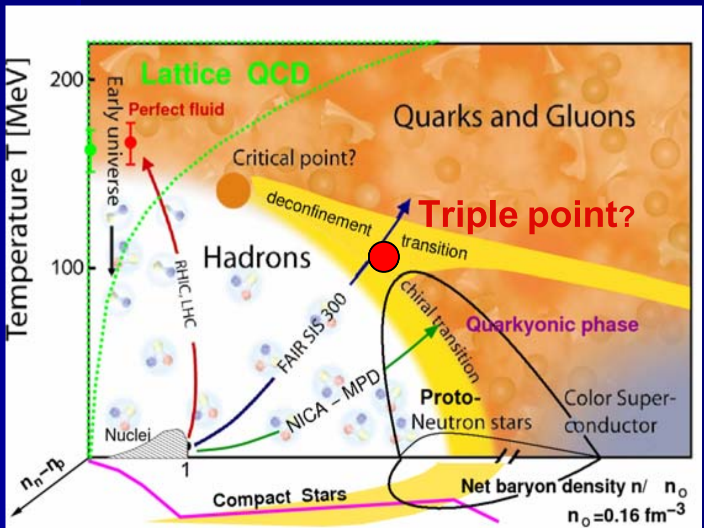
- **the study of spin physics is aimed**
  - ***to shed light on the origin of spin***
  - ***to define the nucleon spin structure***

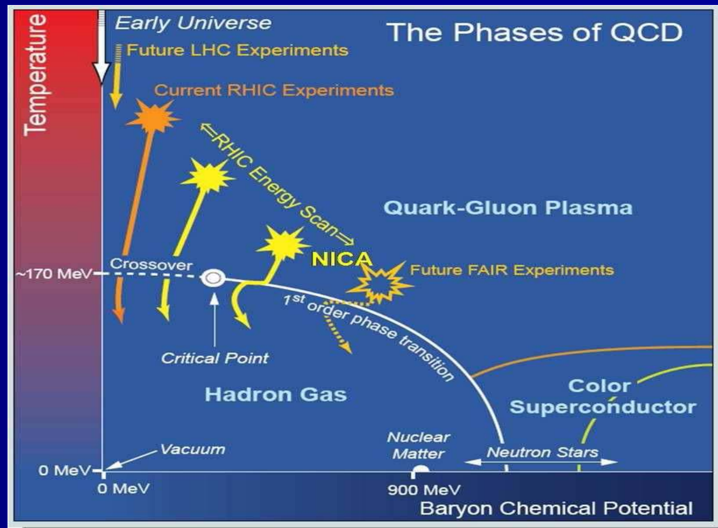

Temperature T [MeV]
200
100
0
Early universe
Quarks and Gluons
Deconfinement & chiral transition
Critical point?
RHIC & LHC
Hadrons
GSI SIS 200
Color Super-conductor?
Neutron stars
1
Nuclei
Net Baryon Density


Early universe
Temperature
Quarks and Gluons
Deconfinement & chiral transition
Critical point ?
RHIC & LHC
Hadrons
GSI SIS200
Neutron stars
Color Super-conductor?
Nuclei
Net Baryon Density

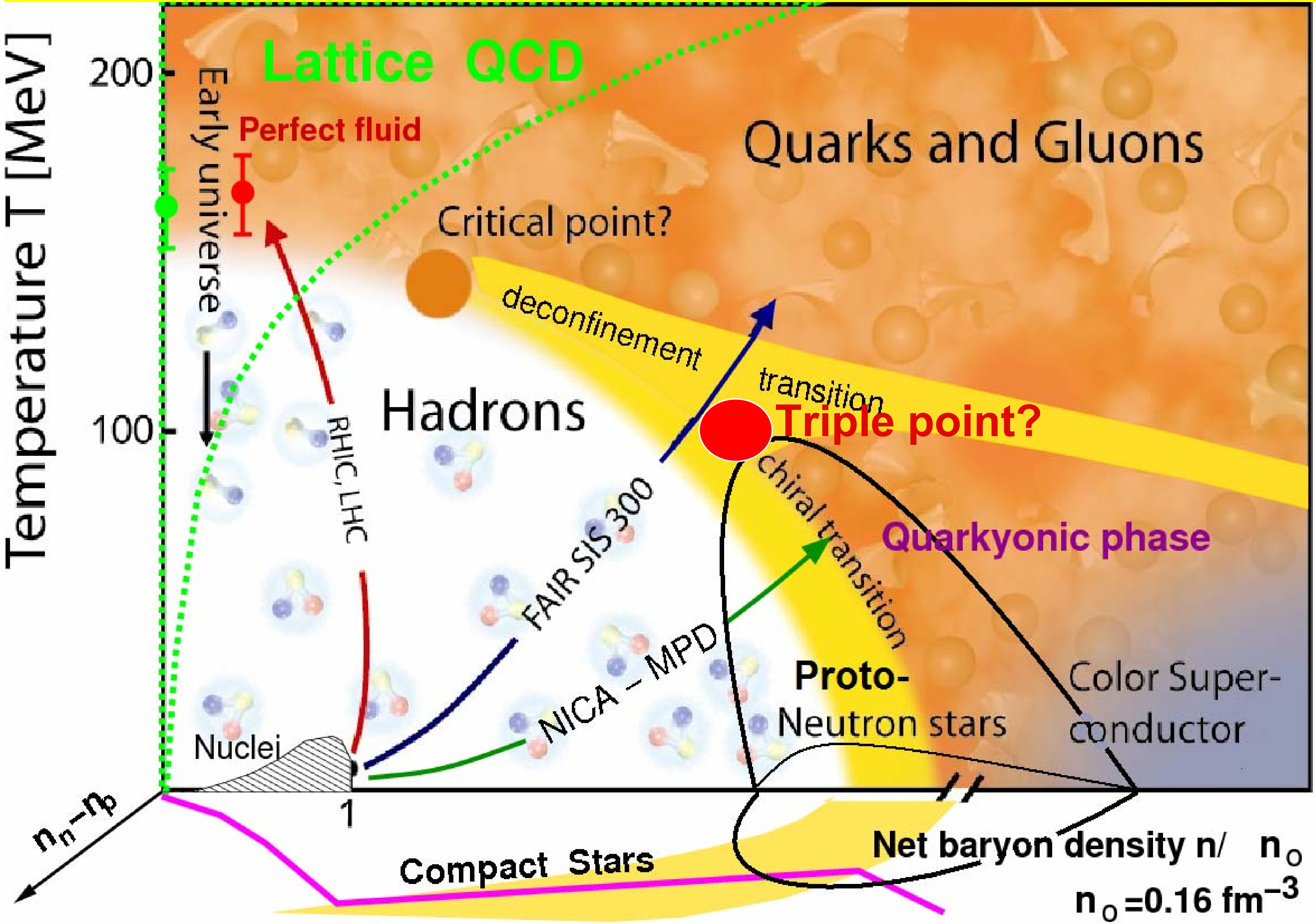

Temperature T [MeV]
200
100
0
Early universe
Quarks and Gluons
Critical point?
Deconfinement and chiral transition
Hadrons
RHIC,LHC
FAIR SIS 300
Neutron stars
Color Super-conductor?
1
Nuclei
Net Baryon Density


BIG BANG
Nuclear Matter Map
Current RHIC data
Future runs?
Quark-gluon plasma
Temperature
Critical point
Bound quarks
Ordinary nuclei
Color superconductor
Neutron stars
Density


Temperature T [MeV]
200
100
Lattice QCD
Early universe
Perfect fluid
Quarks and Gluons
Critical point?
deconfinement
transition
Triple point?
Hadrons
RHIC, LHC
chiral transition
Quarkyonic phase
FAIR SIS 300
NICA – MPD
Proto-Neutron stars
Color Super-conductor
Nuclei
1
n_n-n_p
Compact Stars
Net baryon density n/ n_0
n_0=0.16 fm^-3


Temperature
Early Universe
The Phases of QCD
Future LHC Experiments
Current RHIC Experiments
⇐RHIC Energy Scan⇒
Quark-Gluon Plasma
~170 MeV
Crossover
NICA
Future FAIR Experiments
1st order phase transition
Critical Point
Hadron Gas
Color Superconductor
Nuclear Matter
Vacuum
Neutron Stars
0 MeV
0 MeV
900 MeV
Baryon Chemical Potential

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



Optimal energy region

to reach the highest possible baryon density

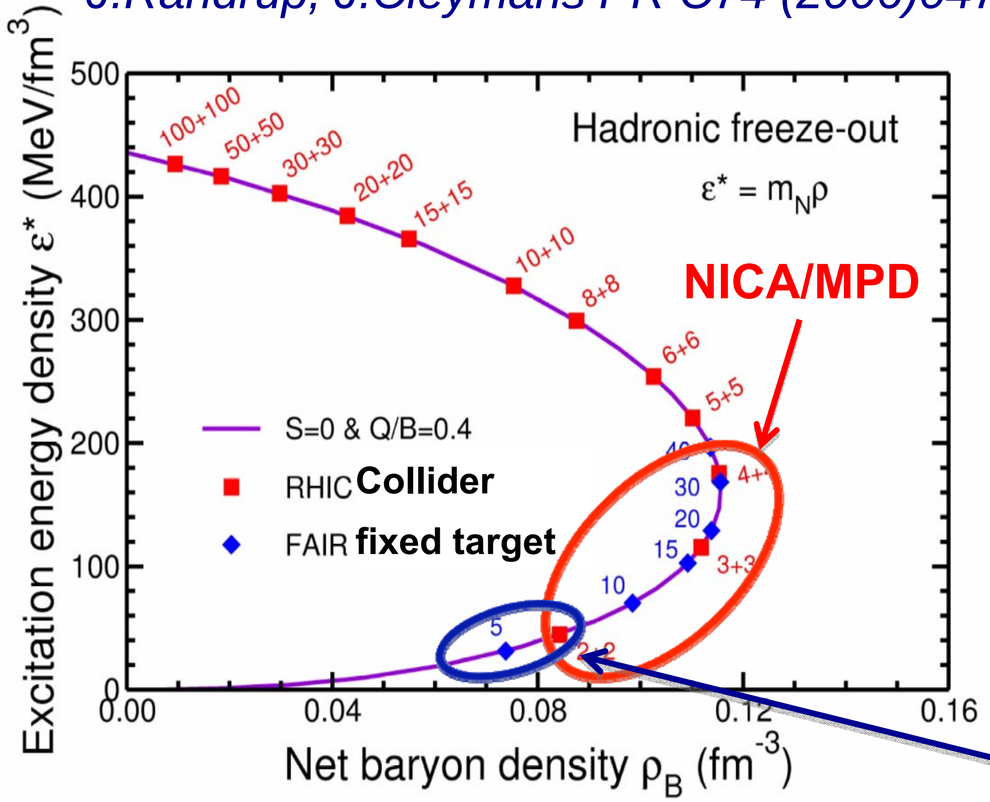
heavy ion collision at $\sqrt{S_{NN}}$ = 4 - 11 GeV/u

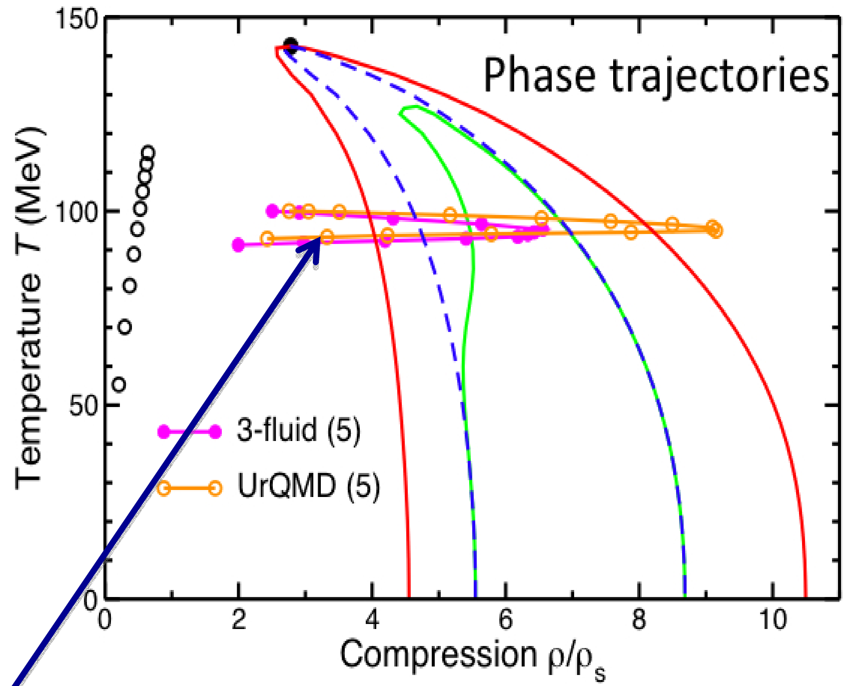
➔

Baryon density in A+A collisions

J.Randrup, J.Cleymans PR C74 (2006)047901.

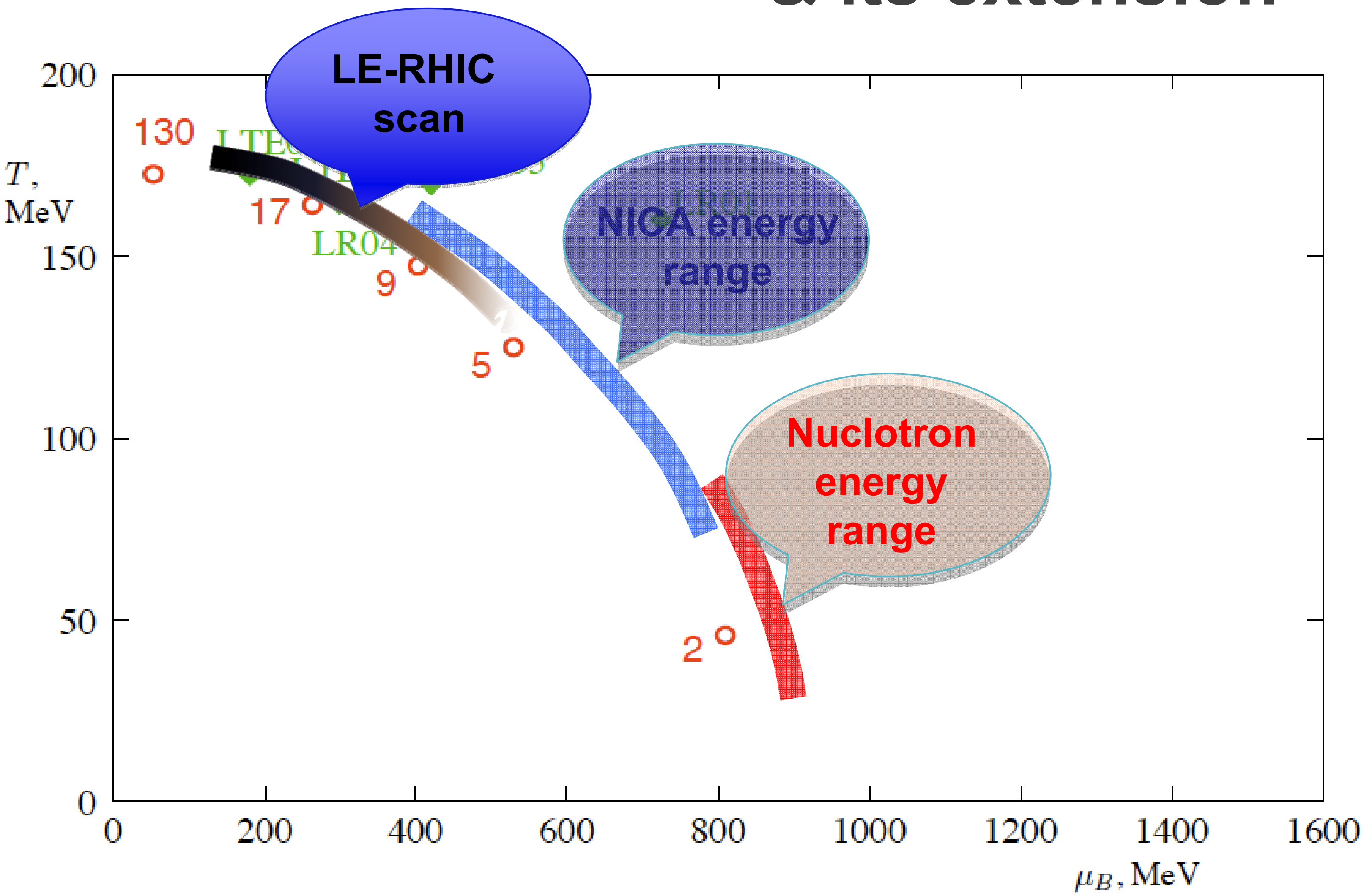
J.Randrup, CPOD2010



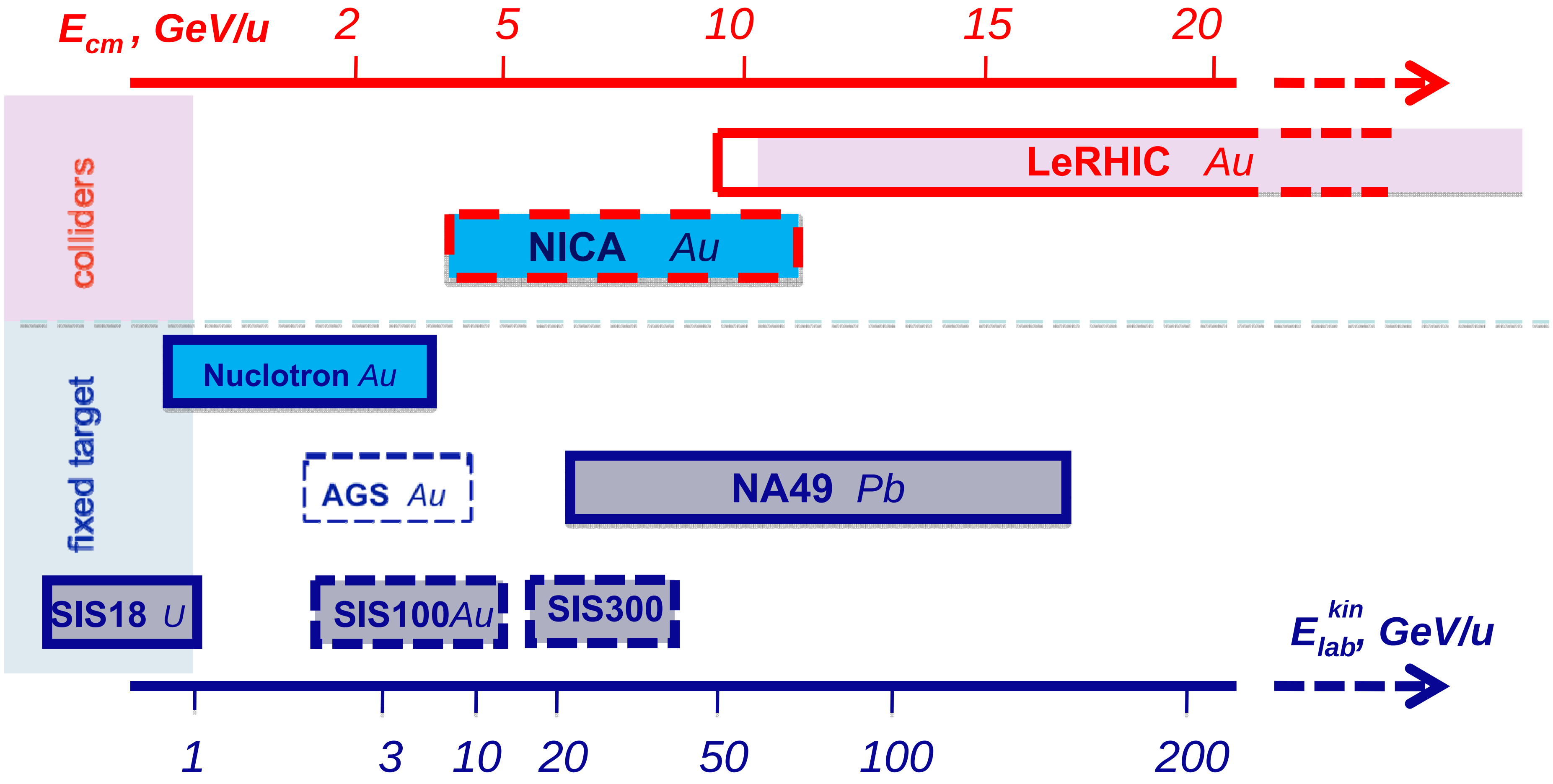


Nuclotron energies

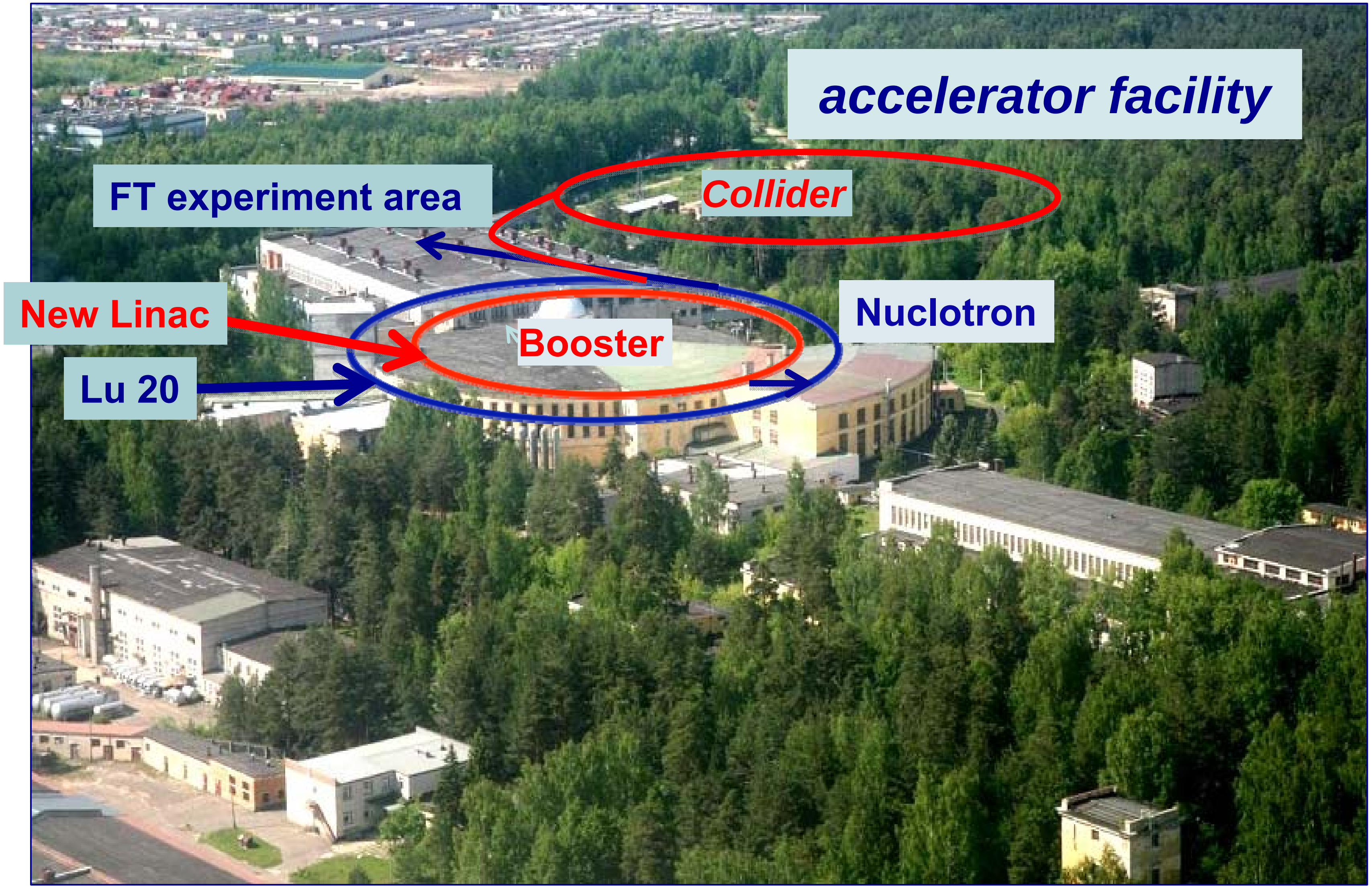
Available energy regions & its extension



Energy regions covered by present & future experiments



Veksler & Baldin Laboratory of High Energy Physics



Nuclotron

- JINR HEP basic facility, *in operation since* **'93**
- based on the unique technology of **super-conducting fast cycling magnets** *developed in JINR*
- provides proton, **polarized** deuteron & **multi charged** ion beams

Nuclotron development plans:

- **Nuclotron-M** *(vac., PS, orbit corr.)* **2010**
- **Nuclotron-N** *(Krion-6, LU-20, RF)* **2012**
- **Nuclotron-N*** *(New Linac, Booster)* **2013**

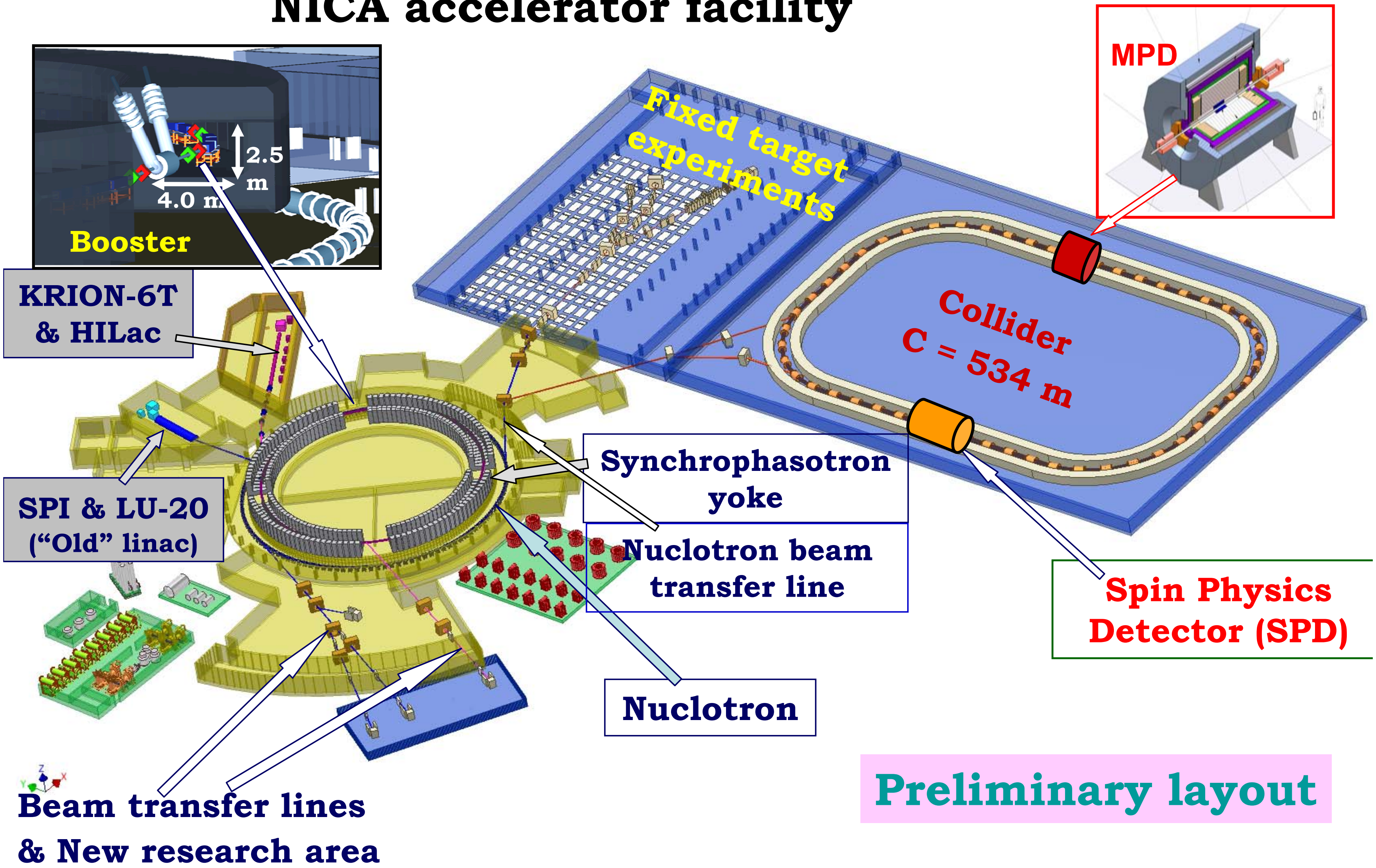
Parameter	design	obtained
Accelerated ions	1<Z<92	1<Z<42
Energy, GeV/amu	6, A/Z=2	5.2
Magnetic field, T	2.0	1.8
Inj. Ener.	5	5
Vacuum pressure, Torr cold chamber	$1 \cdot 10^{-7}$ $1 \cdot 10^{-10}$	$2 \cdot 10^{-9}$ $1 \cdot 10^{-10}$
Repetition rate,	0,5	0,2
Field ramp rate, (T/s)		
stand testing	4	2
in the ring	4,1	1,0

Beam	Nuclotron beam intensity (particle per cycle)		
	Current	Ion source type	New ion source + booster (2013)
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↑	$2{\cdot}10^{8}$	ABS ("Polaris")	$1{\cdot}10^{10}$ *(SPI)*
^{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-2")	$5{\cdot}10^{10}$
^{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	-	--- ,, ---	$1{\cdot}10^{9}$

Comparison, particles per cycle

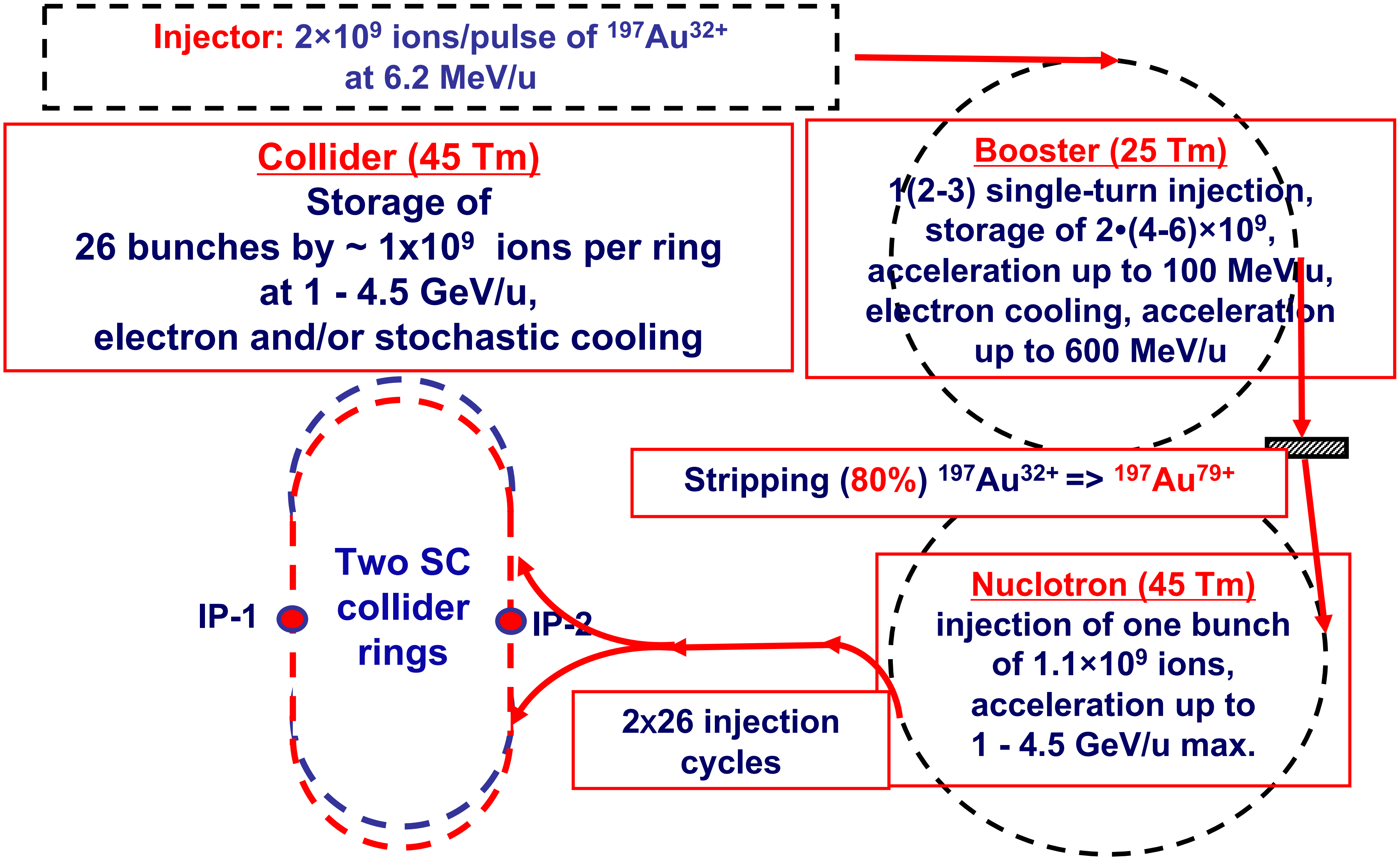
Beam		Nuclotron-M (2010)	Nuclotron-N (2012)	New ion source + booster (2014)
p		$8 \cdot 10^{10}$	$5 \cdot 10^{11}$	$5 \cdot 10^{12}$
d		$8 \cdot 10^{10}$	$5 \cdot 10^{11}$	$5 \cdot 10^{12}$
^{4}He		$2 \cdot 10^{9}$	$3 \cdot 10^{10}$	$1 \cdot 10^{12}$
d↑		$2 \cdot 10^{8}$	$7 \cdot 10^{10}$ *(SPI)*	$7 \cdot 10^{10}$ *(SPI)*
$^{7}Li^{6+}$		$7 \cdot 10^{9}$	$3 \cdot 10^{10}$	$5 \cdot 10^{11}$
$^{12}C^{6+}$		$6 \cdot 10^{9}$	$3 \cdot 10^{10}$	$3 \cdot 10^{11}$
$^{14}N^{7+}$		$3 \cdot 10^{7}$	$3 \cdot 10^{8}$	$5 \cdot 10^{10}$
$^{24}Mg^{12+}$		$7 \cdot 10^{8}$	$4 \cdot 10^{9}$	$5 \cdot 10^{10}$
$^{40}Ar^{18+}$		$8 \cdot 10^{6}$	$2 \cdot 10^{9}$	$2 \cdot 10^{10}$
$^{56}Fe^{28+}$		$4 \cdot 10^{6}$	$2 \cdot 10^{9}$	$5 \cdot 10^{10}$
$^{58}Ni^{26+}$				
$^{84}Kr^{34+}$		$2 \cdot 10^{5}$	$1 \cdot 10^{8}$	$1 \cdot 10^{9}$
$^{124}Xe^{48/42+}$		$1 \cdot 10^{5}$	$7 \cdot 10^{7}$	$1 \cdot 10^{9}$
$^{181}Ta^{61+}$				
$^{197}Au^{65/79+}$			$1 \cdot 10^{8}$	$1 \cdot 10^{9}$
$^{238}U^{28+}$				

NICA accelerator facility



Preliminary layout

Heavy Ion Mode: Operation Regime & Parameters *(preliminary)*

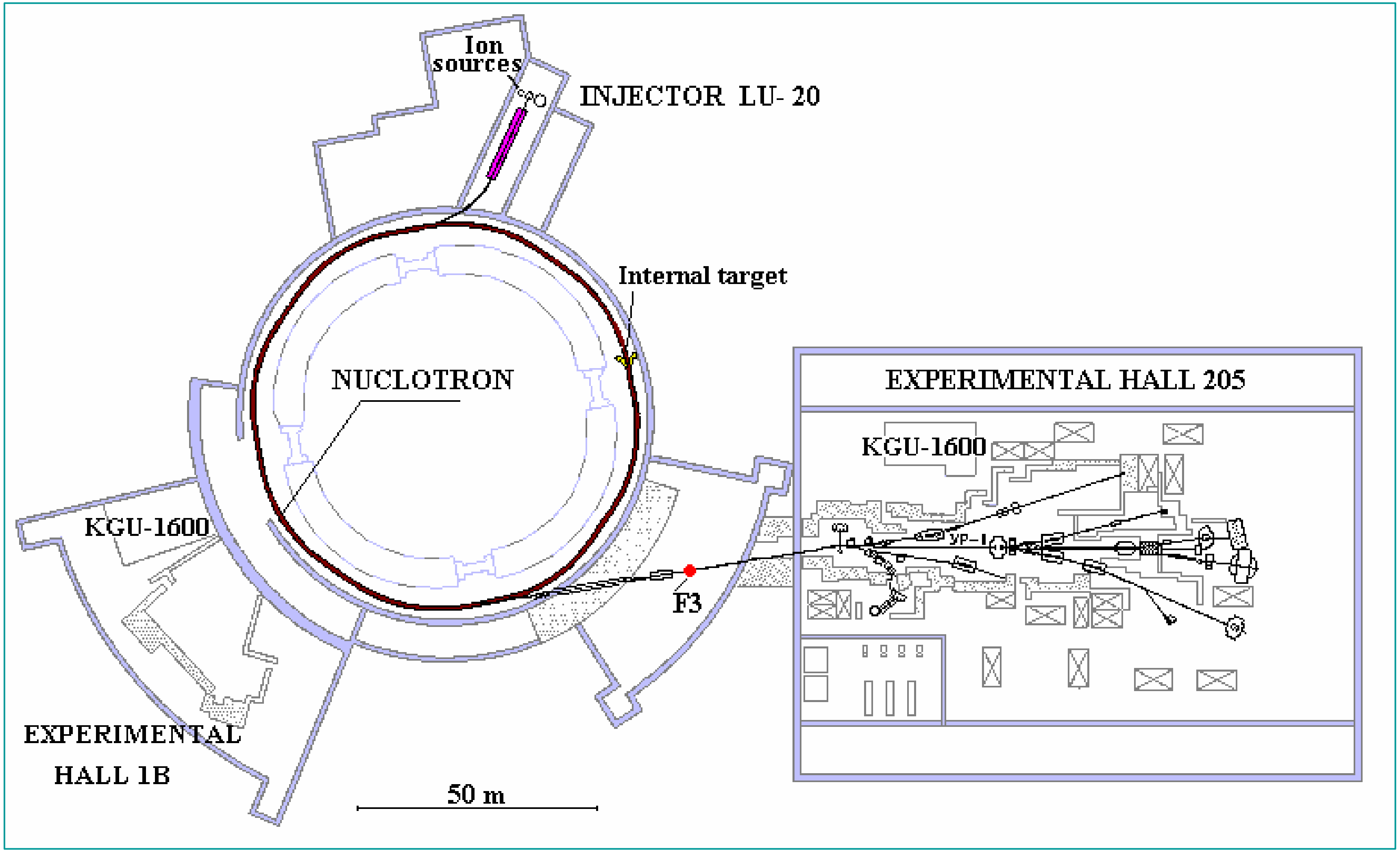


Collider–general parameters *(preliminary)*

Bρ max [T·m]	45.0
Ion kinetic energy (Au79+), [GeV/u]	1.0 ÷ 4.56
Dipole field (max), [T]	2.0
Free space at IP (for detector)	9 m
Beam crossing angle at IP	0
Vacuum, [Torr]	10^{-11}
Luminosity per one IP, $cm^{-2} \cdot s^{-1}$	0.02÷5.0 ·10^27

Structure & details of the storage rings
- subject of consideration by the forthcoming ***MAC***

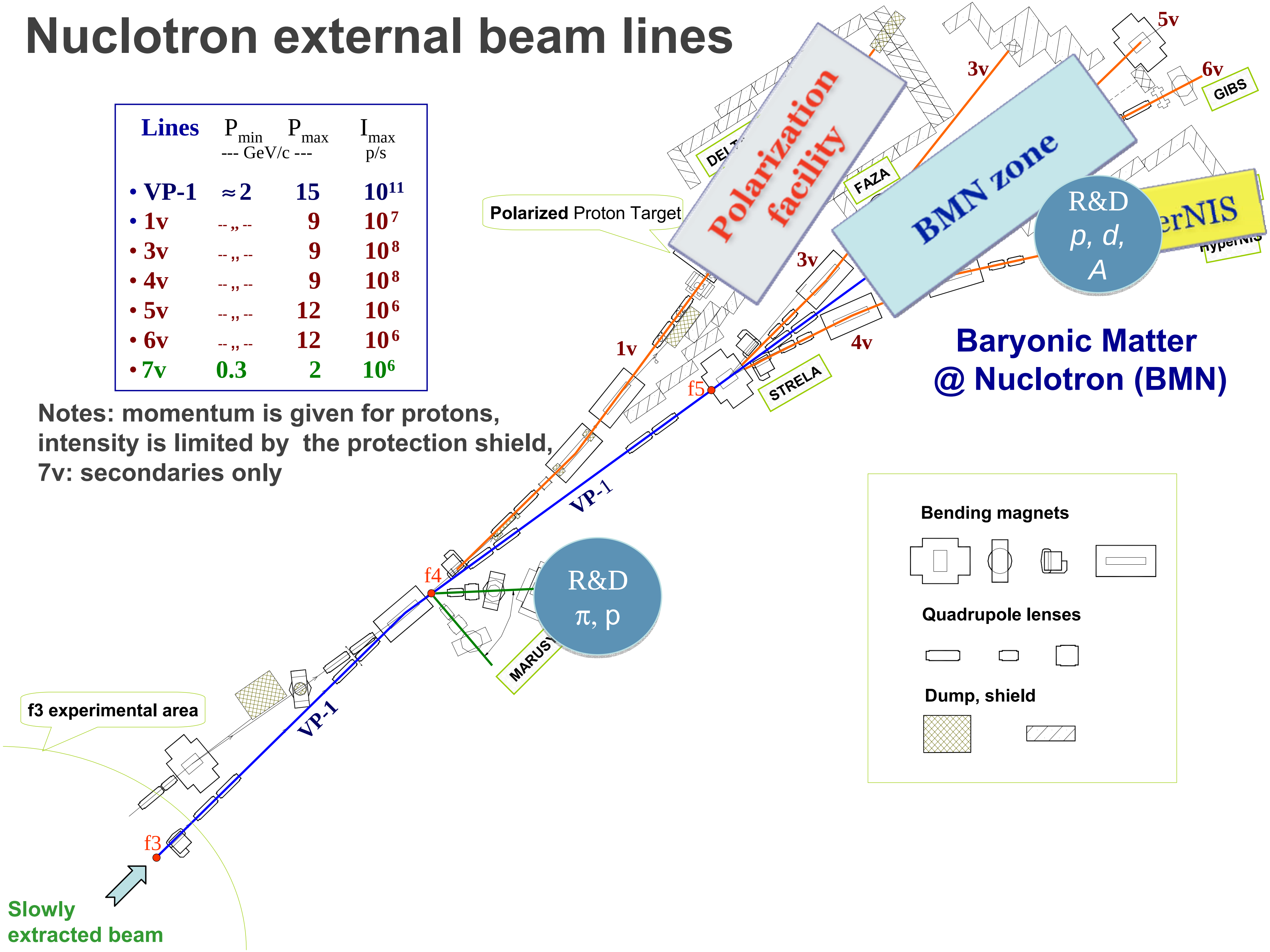
The plan of Nuclotron and experimental zones



Nuclotron external beam lines

Lines	P_{min}	P_{max}	I_{max}
	--- GeV/c ---		p/s
• VP-1	≈ 2	15	10^{11}
• 1v	-- „ --	9	10^{7}
• 3v	-- „ --	9	10^{8}
• 4v	-- „ --	9	10^{8}
• 5v	-- „ --	12	10^{6}
• 6v	-- „ --	12	10^{6}
• 7v	0.3	2	10^{6}

Notes: momentum is given for protons,
intensity is limited by the protection shield,
7v: secondaries only



Baryonic Matter @ Nuclotron (BMN)

***Schedule** (preliminary)*

- **Start of project preparation** **2010**
- **presentation for the consideration at PAC** **2011**
- **Experimental area preparation** **2012**
  major subdetector for the starting kit are prototyped & mounted
- **BMN starting kit commissioning** **2013**
- **Start of physics runs** **2014**

Fixed target experimental area

Should be properly developed in parallel with
Nuclotron upgrade & NICA collider construction

This is the high priority task, because it provides:

- **relevant experimental *program* in BM**, *(could be started in 2014)*

- **proper *monitoring* of Nuclotron performance & beam parameters**

- **highly required beams - *to test MPD various subsystems***

- **development of modern experimental *infrastructure,* organization necessary services, & training of corresponding *personal***

- **better *integration* of the JINR HEP facility into the common European research infrastructure**

Next MAC will be held on October 4-5 at Dubna.

The Committee is asked to review and offer comment/recommendations relative the Nuclotron-M/NICA and the accompanying R&D plan on sub-projects.
In particular we request specific comments/recommendations in the following areas:

-Does NICA TDR (and namely approved NICA collider concept) describe a configuration that is likely to meet the proposed mission objectives (NICA physics case)?

- Does it meet physics demands on beams: possibility of energy scan (optics flexibility) at maximal required luminosity?

-Does the execution strategy of Nuclotron-M/NICA mesh with the requirements of NICA project? What recommendations and modifications to the R&D program would be effective?

NICA construction schedule

The main tasks for the NICA project

In 2010:

- ✓ Conceptual / working design of the collider,
- ✓ Preparation of the project for the state expertise in accordance with regulations of Russian Federation (under preparation at *State Specialized Project Institute*, Moscow),
- ✓ Construction of SC magnets prototypes (booster and collider dipoles).

In 2011:

- ✓ Passing through the state expertise,
- ✓ Beginning of construction of the HILAC, KRION (working version), Booster, Collider elements,
- ✓ Stochastic cooling experiment at Nuclotron.

The NICA Collaboration

Budker INP

- ✓ Booster RF system
- ✓ Booster electron cooler
- ✓ Collider RF system
- ✓ Collider SC magnets

  (expertise)
- ✓ HV e-cooler for collider
- ✓ Electronics
- ✓ Injector linac (under discussion)

IHEP (Protvino): Injector Linac

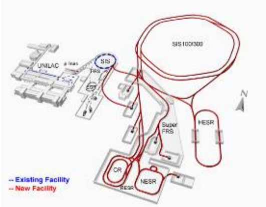
FZ Jűlich (IKP): HV E-cooler
& Stoch. cooling

Fermilab: HV E-cooler,
Beam dynamics, Stoch. cooling

CERN: Beam dynamics, E-cooling, Acceler. technique

All-Russian Institute for Electrotechnique
HV Electron cooler

BNL (RHIC)
Electron &
Stoch. Cooling

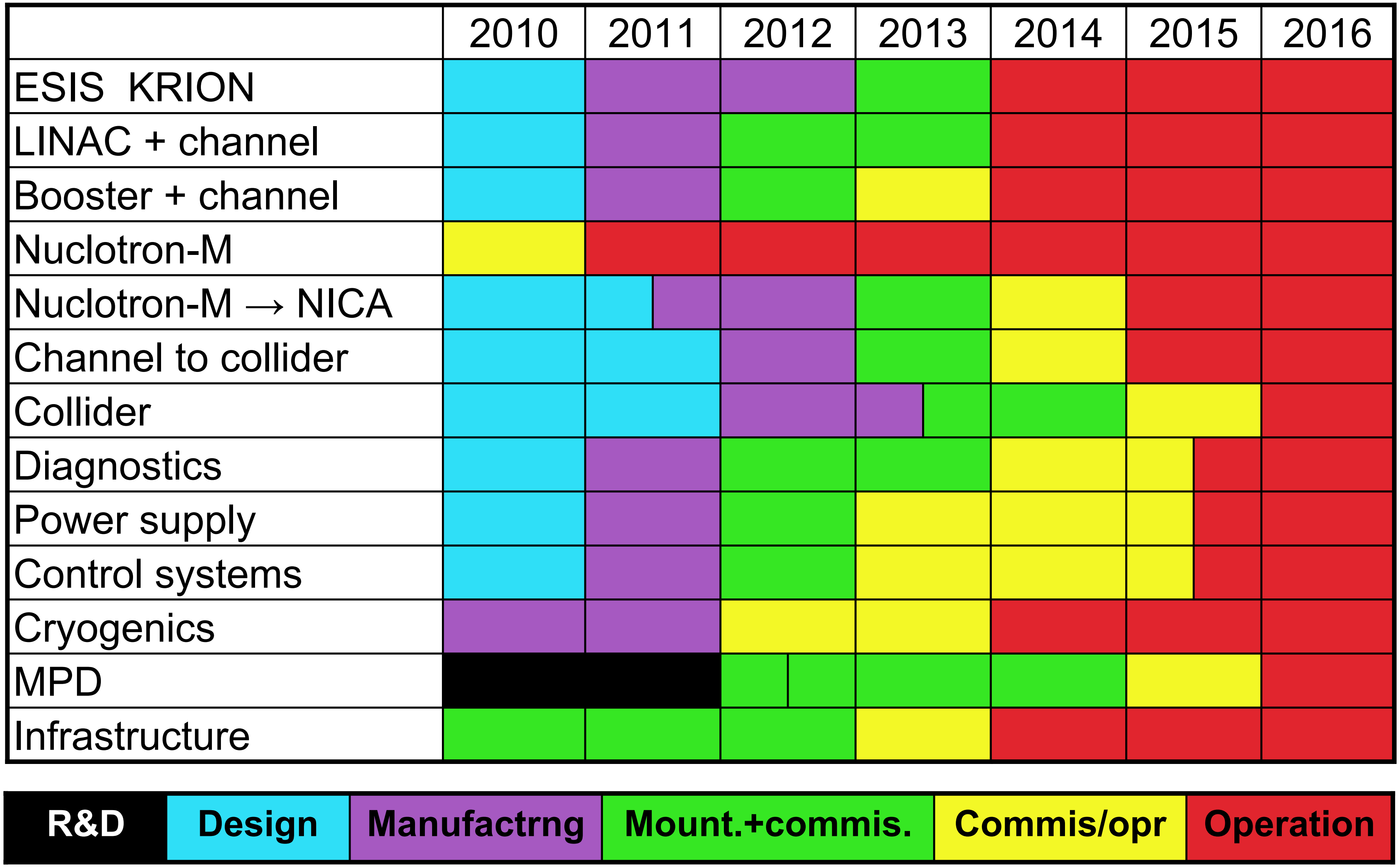


GSI/FAIR
lipoles for Booster/SIS-100
lipoles for Collider

ITEP: Beam dynamics in the collider

Corporation "Powder Metallurgy" (Minsk, Belorussia): Technology of TiN coating of vacuum chamber walls for reduction of secondary emission

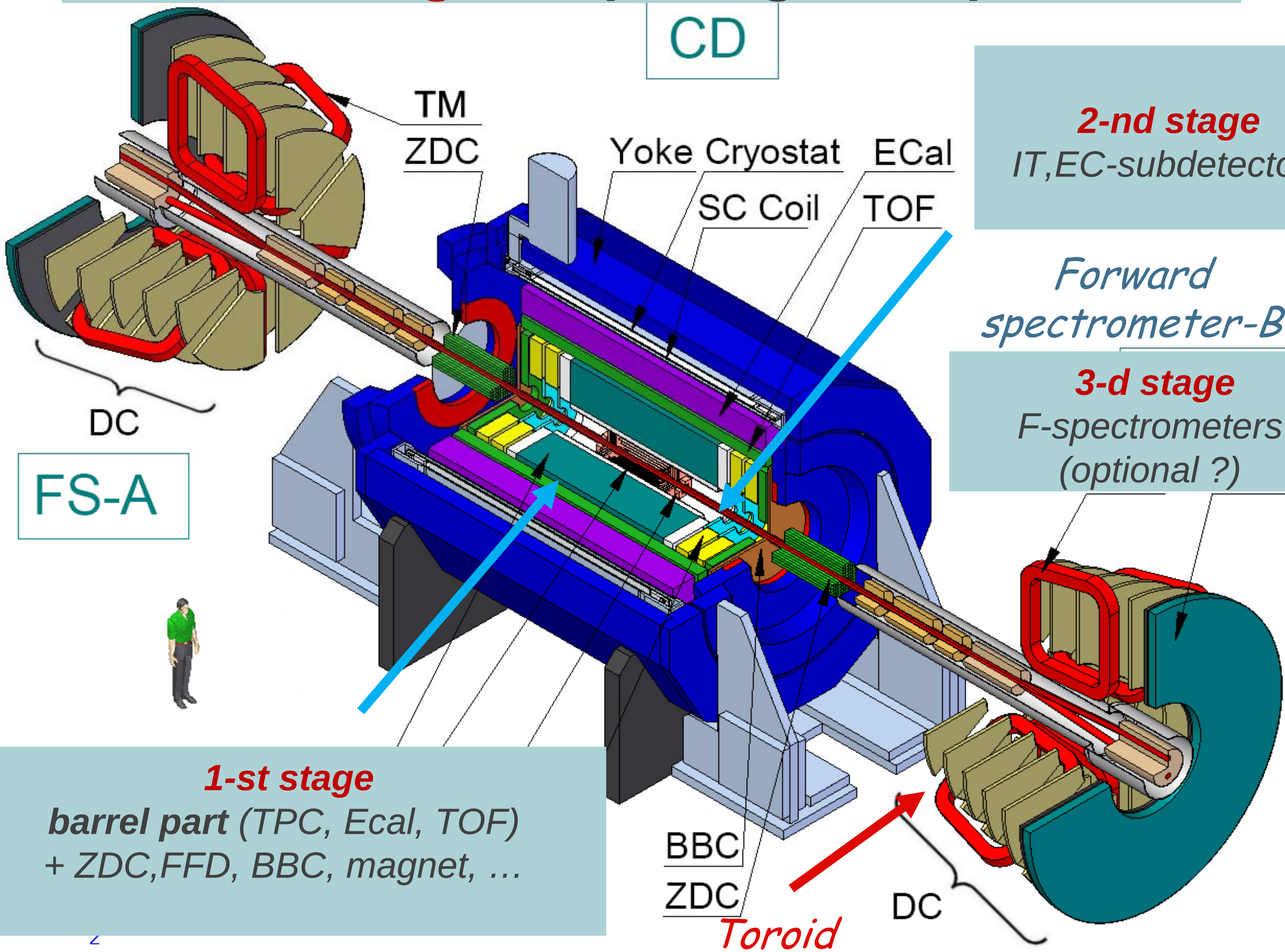
NICA construction schedule



MPD

- ❑ *Concept of* universal detector for collider experiments; a central part inserted into 0.5T superconducting solenoid *(D=5m, L=8m)*
- ❑ Could be used for both studies: BM & SP
- ❑ Three stages of putting in operation

MPD: 3 stages of putting into operation



2-nd stage
IT,EC-subdetectors

3-d stage
F-spectrometers
(optional ?)

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

List of Tasks for MPD

.. To measure a large variety of signals at systematically changing collision parameters (energy, centrality, system size).
Reference data (i.e. p+p) will be taken at the same experimental conditions.

- **bulk observables (hadrons): 4π particle yields (OD, EOS)**
- **multi-strange hyperon production : yields & spectra (OD, EOS)**
- **electromagnetic probes (CSR, OD)**
- **azimuthal charged-particle correlations (LPV)**
- **event-by-event fluctuation in hadron productions (CEP)**
- **correlations involving π, K, p, Λ (OD)**
- **directed & elliptic flows for identified hadron species (EOS,OD)**
- **…….**

NICA White Paper (http://nica.jinr.ru)
Round Table materials (http://jinr.ru/theor/)

Timetable MPD

	Stage/Year	2009	2010	2011	2012	2013	2014	2015	2016
1	MPD Conceptual Design Report								
2	MPD TDR								
3	**R&D program**								
	TPC								
	TOF								
	ZDC								
	Si inner tracker								
	EMC								
	Straw Tracker								
	DAQ								
4	**Production and tests (the 1st stage detectors)**								
	Superconducting Magnet of MPD								
	TPC								
	EMC								
	ZDC								
	TOF barrel								
	Slow Control								
	DAQ								
	Installation& Commissioning								
	Si inner tracker								
5	**Production and tests (the 2nd stage detectors)**								
	TOF(EndCap)								
	Straw Tracker								
	DAQ								
	Slow Control								
	Installation								
6	**Production and tests (the 3rd stage, Forward Spectrometer)**								
	Toroidal Magnet construction								
	Coordinate detectors production								
	Coordinate detector testing								
	Installation& Commissioning								

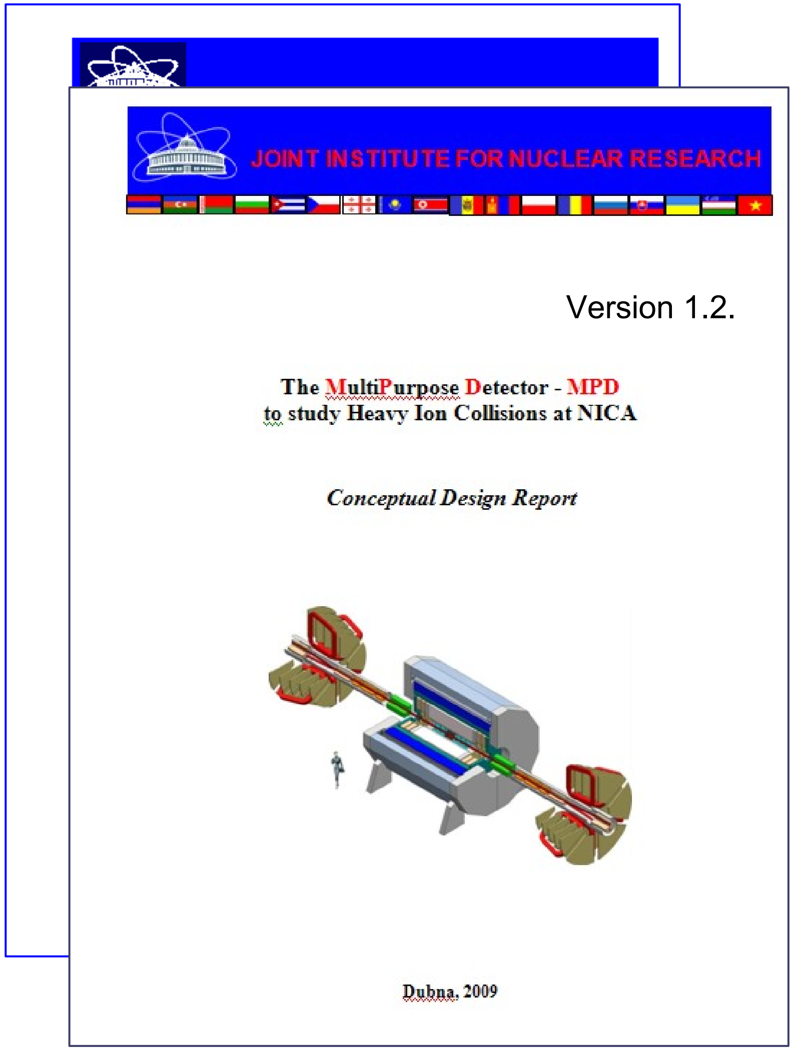
Status of MPD project & physics

◆ *MPD project (1st stage) was recommended for approval by PAC of PP in January 2010*

◆ *White Book*
- *the last version in August 2010 (>100 authors from>40 centers)*

◆ *MPD CDR*
- *the first version -June 2009*
- *the last v.1.2 - August 2010*

◆ *MPD LoI - the first version in February 2008*


JOINT INSTITUTE FOR NUCLEAR RESEARCH

Version 1.2.

The MultiPurpose Detector - MPD
to study Heavy Ion Collisions at NICA

Conceptual Design Report

Dubna, 2009

Angle coverage of MPD

TPC $(|\eta| <2)$

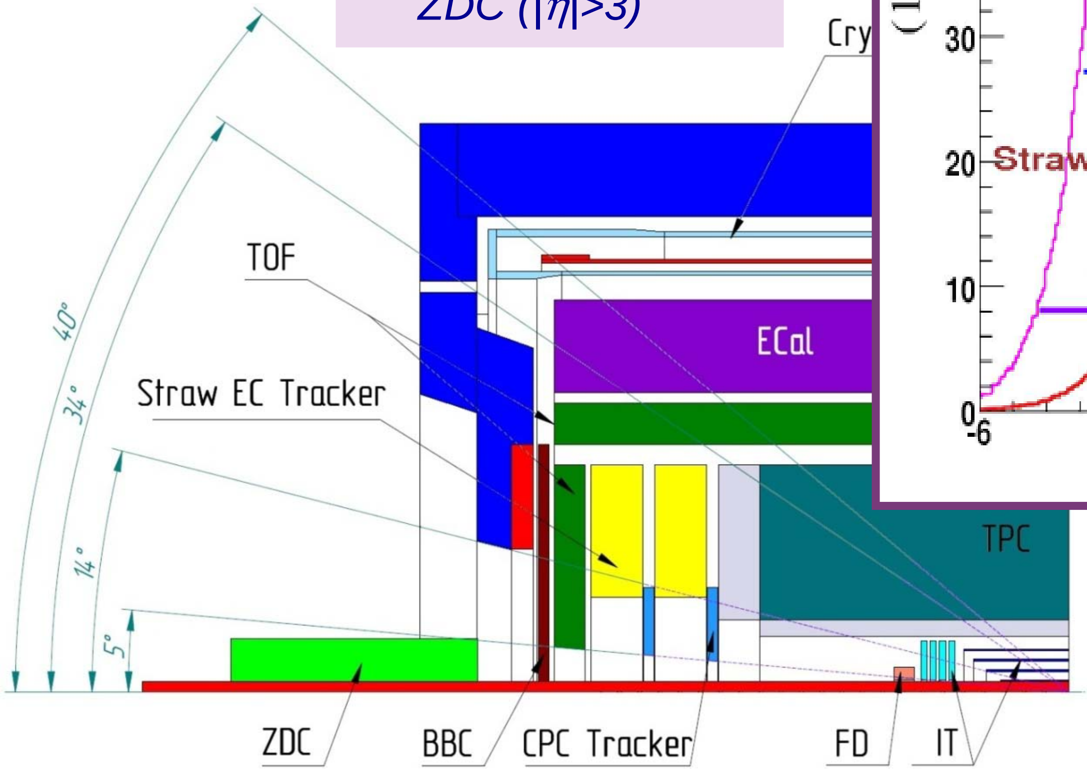
ECAL $(|\eta|<1.2)$

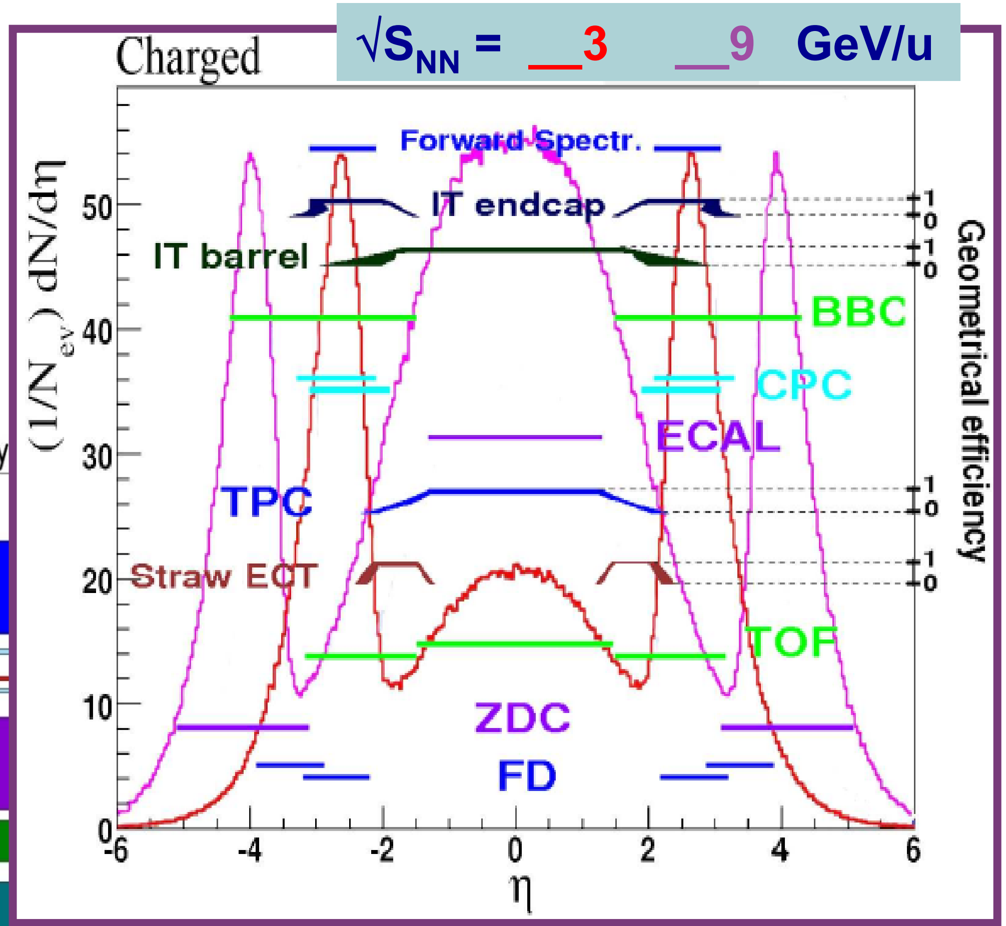
FD $(2<|\eta|<4)$

TOF $(|\eta|<3)$

IT $(|\eta|<2.5)$

ZDC $(|\eta|>3)$





B = 0.5 T

Particle yields in Au+Au collisions $\sqrt{s_{NN}}$ = 7.1 GeV (10% central)

Luminosity L = $10^{27} cm^{-2}s^{-1}$
Event rate (central) 7 kHz

Particle (mass)	Multi-plicity	decay mode	yield (s^{-1})	yield 10w
K^+ (494)	55	--	$7.7 \cdot 10^3$	$4.6 \cdot 10^{10}$
K^- (494)	16	--	$2.2 \cdot 10^3$	$1.3 \cdot 10^{10}$
ρ (770)	23.6	e^+e^-	$1.6 \cdot 10^{-2}$	$9.4 \cdot 10^4$
ω (782)	14.2	e^+e^-	$1.4 \cdot 10^{-2}$	$8.6 \cdot 10^4$
φ (1020)	2.7	e^+e^-	$1.1 \cdot 10^{-2}$	$6.8 \cdot 10^4$
Ξ^- (1321)	2.4	$\Lambda\pi^-$	67	$4.0 \cdot 10^8$
Ω^- (1672)	0.16	ΛK^-	1.5	$9.2 \cdot 10^6$
D^0 (1864)	$7.5 \cdot 10^{-4}$	$K^+\pi^-$	$2.0 \cdot 10^{-4}$	1200
J/ψ (3097)	$3.8 \cdot 10^{-5}$	e^+e^-	$8.0 \cdot 10^{-5}$	480

Spin Physics

NICA design allows to reach effectively polarized
- protons up to $\sqrt{s}$ ~ 26 GeV with average L = 2 10^{30} cm^2/s
- deuterons up to $\sqrt{s}$ ~ 12 GeV with the average L= 10^{29} cm^2/s.

The SPD (Spin Physics Detector) program includes:
- **Drell-Yan / MMT processes,**
- **J/Ψ production processes,**
- **Spin effects in elastic *p↑p↑*, *p↑d* & *d↑d↑* scattering,**
- **Spin effects in inclusive high-pT reactions,**
- **Polarization effects in heavy ions collisions**

All these give unique possibilities to investigate "spin puzzle"
- one of the main tasks of the modern hadron physics

The 1-st stage could be started already at ***MPD***

essential extension of COMPASS (CERN SPS) program

MPD Collaboration

+ Nuclotron-M/NICA/MPD/SPD cooperation

Members of the Collaboration

- JINR ~100
- Other Institutes ~54

Institutions

- JINR
- 12 institutes from 7 countries

- **Joint Institute for Nuclear Research**
- Institute for Nuclear Research, RAS, **RF**
- Bogolyubov Institute for Theoretical Physics, NAS, **Ukraine**
- Nuclear Physics Institute of MSU, **RF**
- Institute Theoretical & Experimental Physics, **RF**
- St.Petersburg State University, **RF**
- Institute of Applied Physics, AS, **Moldova**
- Institute for Nuclear Research & Nuclear Energy BAS, Sofia, **Bulgaria**
- Institute for Scintillation Materials, Kharkov, **Ukraine**
- State Enterprise Scientific & Technolog Research Institute for Apparatus construction, Kharkov, **Ukraine**
- Particle Physics Center of Belarusian State University, **Belarus**
- Department of Engineering Physics, Tsinghua University, Beijing, **China**
- Physics Institute Az.AS, **Azerbaidjan**

The Collaboration is permanently growing

New participants – are welcome !

Major milestones for 2011

- **launch the magnet production line**
  (final assembly, test, QC & certification)

  *required for **booster, collider, FAIR +….***

- **to complete Nuclotron-M & start Nuclotron-N**ica **project**
  *with beams required for both **NICA** & **BMN***

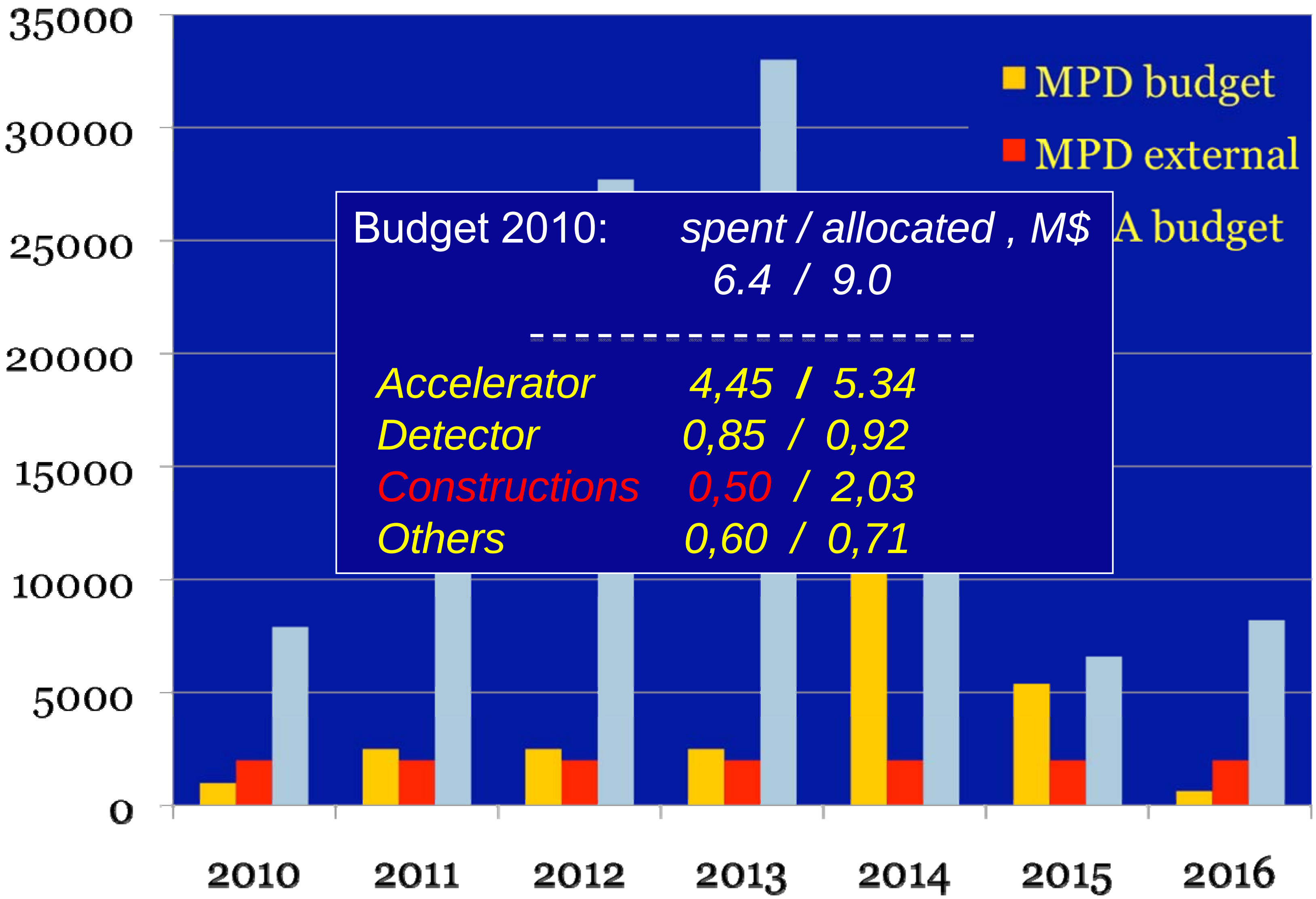
- **to approve project for collider civil engineering & start works on**
  Collider layout design, & construction + infrastructure

- **to complete design works on MPD solenoid,**
  & launch a tender for the production

- **development of fixed target area, & infrastructure upgrade** *(bld.205)*

- **to start the BMN project**

Resources for NICA & MPD, in k$



Round Table Discussions on NICA@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 IV: ***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

Critical point and onset of deconfinement - CPOD-2010

22-29 August, 2010, Dubna

- *very fruitful discussions on the* ***NICA/MPD*** *program have indicated a great interest of the community to* ***this project***
- *an importance of experiments at* ***Nuclotron*** *was emphasized*

- *essential contribution to the* ***NICA White Book*** *(****114*** *authors,****19*** *countr.)*

IHEP-JINR seminar at Protvino, 14.02.08

MEMORANDUM

МЕМОРАНДУМ
Совместного семинара ИТЭФ-ОИЯИ
Институт теоретической и экспериментальной физики
27 мая 2009 года, г. Москва

Участники семинара заслушали доклады:
А.Н. Сисакян "Ускорительный комплекс NICA: статус и перспективы".
Б.Ю. Шарков "Новые возможности ускорителей для исследования вещества экстремальных условиях".
И.Н. Мешков "Коллайдеры тяжёлых ионов RHIC и NICA: статус и перспективы".
В.Д. Тонеев "Физика тяжёлых ионов на ускорительном комплексе NICA".

Отмечены:
1) актуальность и возрастающая привлекательность исследований тяжелоионных столкновений в диапазоне энергий $\sqrt{s_{NN}} \sim 4 - 11$ ГэВ для фундаментальных проблем поиска новых состояний ядерной материи и изучения процессов экстремально высоких плотностей;
2) прогресс в развитии проекта NICA, получившего широкую международную известность и высокую оценку авторитетных экспертов мирового уровня;
3) заинтересованность специалистов ИТЭФ в активном участии в совместных с ОИЯИ работах по проекту NICA;
4) необходимость более тесной кооперации в решении проблем, представляющих взаимный интерес, включая организацию ассоциации (консорциума, сообщества) по исследованию экстремальных состояний вещества и фазовых превращений в ионных столкновениях.

Соруководители семинара:

А.Н.Сисакян академик РАН	**В.И.Захаров** профессор

Участники семинара:

Б.Ю.Шарков член-корреспондент РАН	**И.Н.Мешков** член-корреспондент РАН	**А.Б.Кайдалов** член-корреспондент РАН

А.С.Сорин профессор	**В.Д.Тонеев** профессор	**А.Д.Коваленко** профессор	**Г.В.Трубников** кфмн

ITEP-JINR seminar at ITEP, 27.05.09

Round Table Discussions I, II, III, IV,V…
JINR, Dubna, 2005, 2006, 2008, 2009…

Решение
Общемосковского семинара по релятивистской ядерной физике

27 марта 2008 года
Институт Ядерных Исследований РАН

Участники семинара "Проект NICA (тяжелоионный коллайдер: концепции, планы реализации и перспективы совместных работ)" заслушав доклады, представленные разработчиками Проекта NICA/MPD (ОИЯИ):

1. А.Н. Сисакян "Статус проекта NICA/MPD".
2. А.Н. Сисакян, А.С. Сорин "Программа физических исследований на ускорительном комплексе NICA".
3. И.Н. Мешков "Концептуальный проект ускорительного комплекса NICA".
4. В.Д. Кекелидзе "Концептуальный проект многоцелевого детектора MPD".

и обсудив цели и содержание проекта, а также перспективы его осуществления, пришли к следующему заключению.

1. Физическая проблема, инициировавшая разработку Проекта, является одной из наиболее важных среди фундаментальных проблем физики микромира и начальных этапов эволюции Вселенной.

2. Представленные на семинаре концептуальные проекты NICA и MPD выполнены на современном уровне с привлечением передовых технологий и использованием оригинальных идей, предложенных и развитых в России.

3. Осуществление Проекта на базе лабораторий ОИЯИ представляется вполне реальным, а представленные планы работ - выполнимыми.

4. Для успешного и быстрого выполнения Проекта целесообразно создание широкой Всероссийской и международной коллаборации.

5. Институты России располагают необходимым научным и инженерно-техническим потенциалом.

6. Успешная реализация Проекта позволит всем участникам Проекта занять лидирующие позиции в физике высоких энергий и войти в число самых передовых исследовательских центров мира.

В.А.Матвеев Директор ИЯИ РАН академик РАН	А.Н.Тавхелидзе академик РАН	Б.Ю.Шарков Директор ИТЭФ чл.-корр. РАН
А.Н.Лебедев чл.-корр. РАН	В.А.Рубаков академик РАН	

All Moscow-JINR seminar at INR, 27.03.08

Round Table Discussion V

Searching for the mixed phase of strongly interacting QCD matter at the NICA: Physics at NICA

JINR (Dubna), August 28, 2010

http://theor.jinr.ru/~cpod/program.html

TOPICS:

I: Fixed target experiments at Nuclotron-N

II: Status and progress of the NICA White Paper

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

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

Editorial board:

- **D. Blaschke**
- **D. Kharzeev**
- **A. Sissakian**
- **A. Sorin**
- **O. Teryaev**
- **V. Toneev**
- **I. Tserruya**

NICA

Draft v 3.01
June 17, 2010

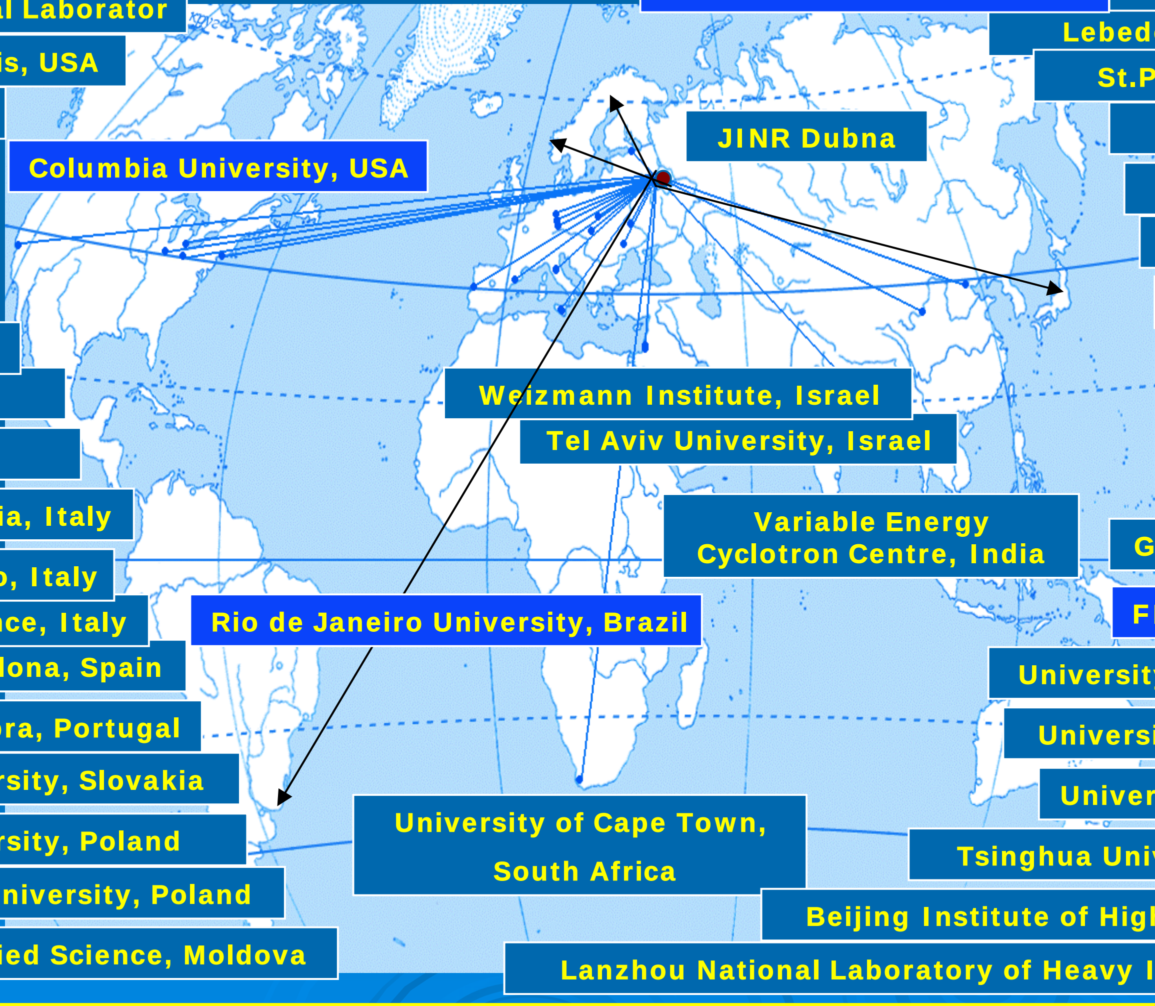
SEARCHING for a QCD MIXED PHASE at the NUCLOTRON-BASED ION COLLIDER FACILITY (NICA White Paper)

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

Contents

The NICA White Paper

114 authors *from* **46 scientific centers** *in* **19 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
- Columbia 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
- University of Cape Town, South Africa
- 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
- Tsinghua University, Beijing, China
- Beijing Institute of High Energy Physics, China
- Lanzhou National Laboratory of Heavy Ion Accelerator, China

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

List of authors (114)

Kh.Abraamyan, A.Andrianov, V.Andrianov, M.Asakawa, F.Becattini, M.Bleicher, E.Bratkovskaya, L.Bravina, K.Bugaev, P.Buividovich,W.Cassing, M.Chernodub, J.Cleymans, P.Costa, O.Denisovskaya, D.E.Donets, E.D.Donets, E.E.Donets, M. DiToro, I.Dremin, A.Efremov, D.Espriu, S.Fantoni, A.Friesen, K.Fukushima, S.Gandolfi, M.Gazdzicki, M.Gorenstein, V.Greco, K.Gudima, A. Illarionov, Yu.Ivanov, A.Jerusalimov A.Kaidalov, Yu.Kalinovsky, D.Kharzeev, T.Kodama, E.Kolomeitsev, V. Korotkikh, A.Kovalenko, A.B.Kurepin, V.Ladygin, N.Ladygina, R.Lednicky, A.Leonidov, E.Levin, M.Lisa, I. Lokhtin, B.Liu, G.Lykasov, E.Luschevskaya, L.Malinina, K.Mikhailov, B.Mohanty, A.Nagaytsev, V.Okorokov, F.Pederiva, S. Petrushanko, S.Plumari, M.Polikarpov, P.Polozov, M.Prokudin, J.Randrup, O.Rogachevsky, V.Salnikov, L.Sarycheva, H.Satz, I.Savin, P.Senger, G.Sharkov, O.Shevchenko, V.Shutov, K.Schmidt, Yu.Sinyukov, A.Sissakian, V.Skokov, A.Snigirev, A.Sorin, A.Stavinskiy, J.Steinheimer, M.Stephanov, V.Stolin, O.Teryaev, R.Tolochek, S.Tolstoukhov, B.Tomasik, V.Toneev, N.Topilskaya, G.Torrieri, S.Troshin, I.Tserruya, S.Typel, S.Voloshin, D.Voskresensky, N.Xu, Yu.Zaitsev, E.Zabrodin, P.Zhuang, …

Almost all experts in the field of heavy ion collisions have contributed to the NICA White Paper

Contents
(55 contributions = 44 + 11, additional 25%)

New Contributions to the NICA White Paper Draft v 3.03 (last update: June 20, 2010)

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

1) Peter Senger (GSI): Nuclear matter physics at NICA
2) S.M. Troshin (Protvino): Directed flow as signal of liquid state of transient matter
3) Kenji Fukushima (YITP Kyoto): Transitional change to baryon-rich QCD matter at NICA energy
4) Masayuki Asakawa (U Osaka): Importance of third moments of conserved charges
5) Yuri Ivanov (Kurchatov I Moscow and GSI): Baryon stopping in Heavy-Ion Collisions at E=2...160 GeV/nucleon
6) Giorgio Torrieri (FIAS & Columbia U): Statistical hadronization phenomenology in a low-energy collider
7) Giorgio Torrieri (FIAS & Columbia U): Flow scaling in a low-energy collider: when does the perfect fluid turn on?
8) Takeshi Kodama (U Rio de Janeiro): Fluctuations and non-equilibrium processes in collective flow
9) Marcus Bleicher & Jan Steinheimer (FIAS): MEMO production at high baryon densities
10) Oleg Rogachevsky, A.S. & Oleg Teryaev (JINR): Chiral vortaic effect and neutron asymmetries at NICA
11) D.E. Donets et al. (JINR): Development of highly charged ion sources for NICA injector and its possible application for nanofabrication and in medicine

New contributions in preparation:

1. L. McLerran (BNL), K. Redlich (U Wroclaw), et al.
"Triple point and quarkyonic phase in the QCD phase diagram"

2. L.Turko (Wroclaw University, Poland), "TBA"

3. F.Karsch and Ch.Schmidt (BNL, Uni. Bielefeld, GSI Darmstadt)
"Lattice results on QCD at finite temperature and baryon density"

4. Joerg Aichelin (Universit´e de Nantes), "TBA"

5. Hans Georg Ritter (BNL), "TBA"

Nuclear matter physics at NICA

Peter Senger

Helmholtzzentrum Heavy Ion Research, GSI Darmstadt, Germany

Physics case	Observables	Detectors
nuclear EOS at high densities	proton flow, Λ, Ξ, Ω	Silicon tracker, TPC, TOF
deconfinement phase transition, phase coexistence	excit. funct. of yield and flow of K, Λ, Ξ, Ω. e-by-e fluctuations	Silicon tracker, TPC, TOF
strange matter	multi-strange short-lived objects (decay into Λ, Ξ, Ω)	Silicon tracker, TPC, TOF
chiral phase transition, hadrons in dense matter	dileptons (e+e-)	HBD, RICH, TPC, TOF, ECAL, (TRD ?)

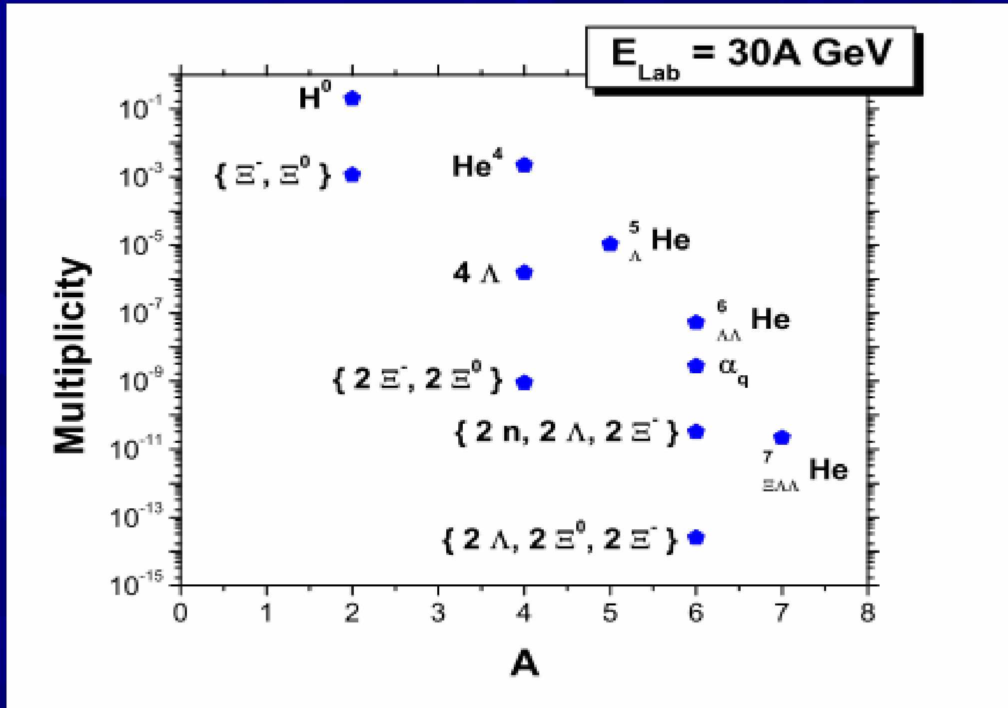
- Most interesting scientific questions with a basic version of the MPD: magnet, TPC, Silicon tracker and TOF detector; upgrade: electron detectors
- NICA/MPD part of worldwide program exploring the QCD phase diagram at high densities: AGS, SPS, NA61/SHINE, GSI/SIS18 --> RHIC, FAIR, NICA
- Problem for STAR @ RHIC: low luminosity, limited beamtime
- Virtues of NICA:
    - high luminosity at high baryon density-->multidifferential observables
    - collider exp. with uniform acceptance, almost independent of energy
- MPD @ NICA and CBM @ FAIR: complementary measurements, joint R&D

MEMO production at high baryon densities

Marcus Bleicher & Jan Steinheimer

FIAS & J.W.Goethe University Frankfurt (Main), Germany

Cluster	Mass [GeV]	Quark content
He^4	3.750	$12q$
H^0	2.020	$4q + 2s$
α_q	6.060	$12q + 6s$
$\{\Xi^-, \Xi^0\}$	2.634	$2q + 4s$
$\{4\Lambda\}$	4.464	$8q + 4s$
$\{2\Xi^-, 2\Xi^0\}$	5.268	$4q + 8s$
$^5_{\Lambda}He$	4.866	$14q + 1s$
$^6_{\Lambda\Lambda}He$	5.982	$16q + 2s$
$^7_{\Xi^0\Lambda\Lambda}He$	7.297	$16q + 2s$
$\{2n, 2\Lambda, 2\Xi^-\}$	6.742	$12q + 6s$
$\{2\Lambda, 2\Xi^0, 2\Xi^-\}$	7.500	$8q + 10s$
$\{d, \Xi^-, \Xi^0\}$	4.508	$8q + 4s$
$\{2\Lambda, 2\Xi^-\}$	4.866	$6q + 6s$
$\{2\Lambda, 2\Sigma^-\}$	4.610	$8q + 4s$



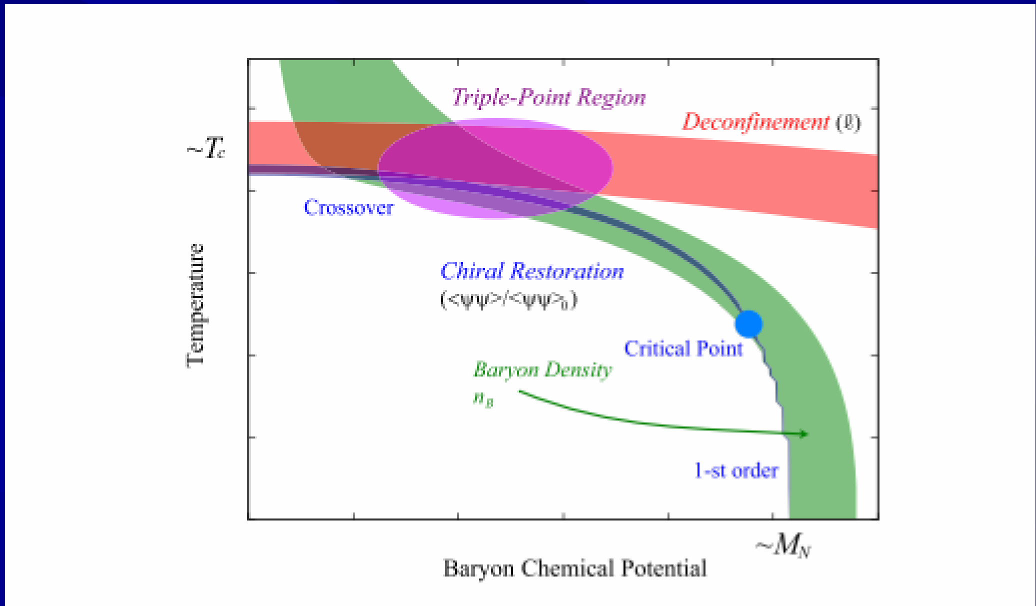
- Production of multi-strange metastable objects (MEMOs) explored in Pb+Pb reactions at 30 AGeV within coupled transport-hydrodynamics model
- Predictions for yields & particle-dependent rapidity and momentum distributions
- Excitation functions show clear maximum in the energy range of NICA and FAIR which are therefore the ideal place to study the production of these MEMOs

Transitional change to baryon-rich QCD matter at NICA energy

Kenji Fukushima

Yukawa Institute for Theoretical Physics,

Kyoto University, Japan



See also arxiv:1006.2596

„Phase diagram of hot and dense QCD constrained by the statistical model“

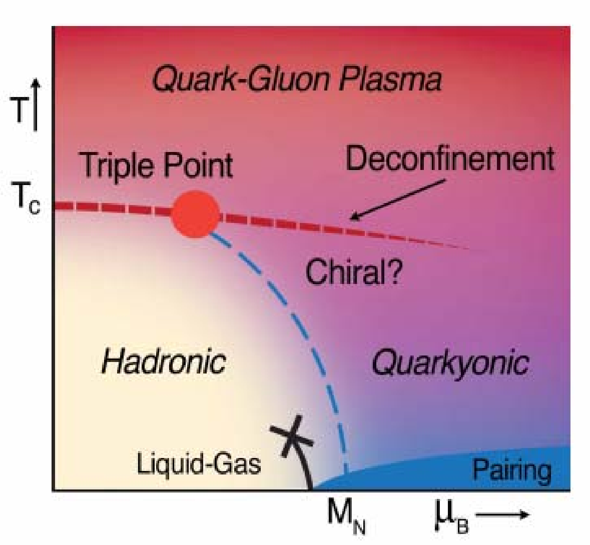
(Polyakov-loop NJL model)

“… the collision energy √s_NN ≈ 8 GeV is a threshold below which abundant baryons can emerge. Such baryon dominant matter yet below deconfinement could be identified with so-called **Quarkyonic Matter**. NICA would be an ideal facility to probe such an onset to enter the baryon-rich regime of QCD matter.“

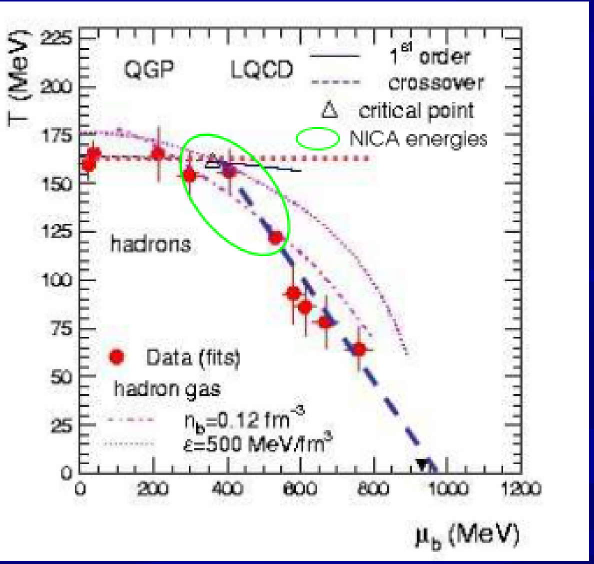
Triple point and quarkyonic matter in the QCD phase diagram

Larry McLerran, Krzysztof Redlich and David Blaschke,
BNL Upton, USA; U Wroclaw, Poland; JINR Dubna, Russia

In preparation



Based on A. Andronic et al.
Nucl. Phys. A 837. 65 (2010)
[arxiv:0911.4806]



The NICA (and CBM) energy range (green ellipse) covers chemical freeze-out parameters in the QCD phase diagram from the fit of hadron production with the statistical model which lie in the transition from meson-dominated to baryon-dominated freeze-out.

Here we expect the suggested transition from a hadronization out of the Quark-Gluon Plasma to a hadronization out of the „Quarkyonic Phase“, i.e., where three phases meet in a „Triple Point“: QGP, Hadronic and Quarkyonic Phase!

Importance of third moments of conserved charges in HICs

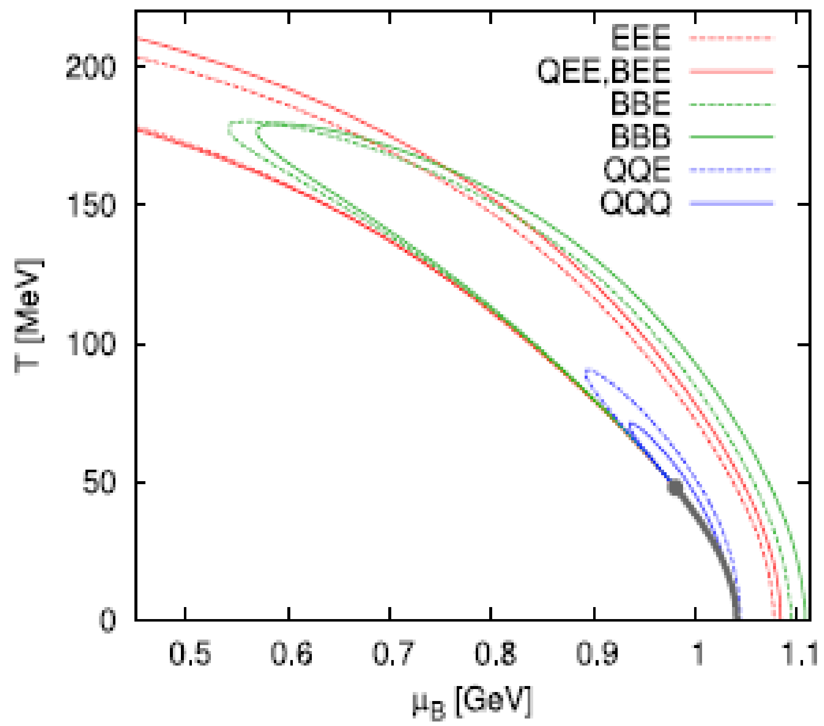
Masayuki Asakawa

Osaka University, Japan

Third moments of conserved charges
(derivatives of susceptibilities)

$$m_3(ccc) \equiv \frac{\langle(\delta N_c)^3\rangle}{VT^2}, \quad m_3(\mathrm{EEE}) \equiv \frac{\langle(\delta E)^3\rangle}{VT^5}$$

where Nc with c=B,Q are net baryon and electric charge numbers in a volume V.
E denotes the total energy, dNc=Nc- <Nc>, dE=E - <E>. Mixed moments accordingly.



Regions where third moments take negative values in the T- mu_B plane are strongly correlated with the suspected phase transition

Establishing negativeness of third moments in experiment is evidence for:
(1) existence of peak structure of susceptibilities in the QCD phase diagram
(2) realization of hot matter beyond the peak, i.e. the QGP, in heavy-ion collisions

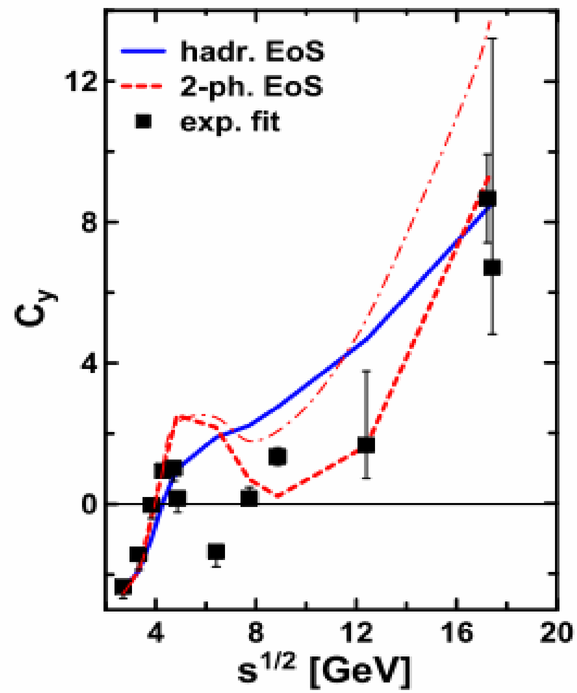
Baryon stopping in heavy-ion collisions at E=2-160 GeV/nucl.

Yuri B. Ivanov

Kurchatov Institute Moscow, Russia & GSI Darmstadt, Germany

Irregularity in the energy dependence of the curvature Cy of the proton spectrum as a function of the (dimensionless) rapidity (y-y_cm)/y_cm

$$C_y \equiv \left(y_{cm}^3 \frac{d^3N}{dy^3} \right)_{y=y_{cm}} \Big/ \left(y_{cm} \frac{dN}{dy} \right)_{y=y_{cm}} = (y_{cm}/w_s)^2 \left(\sinh^2 y_s - w_s \cosh y_s\right).$$



The „wiggle“ in Cy(s) is the characteristics of a first order phase transition in the EoS

- The „wiggle“ in energy dependence of the curvature Cy of the proton spectrum occurs between AGS and low SPS energies
- It is characetristic for a 1st order phase transition („mixed phase“) behaviour !
- NICA @ JINR and CBM @ FAIR will cover the relevant energies to confirm or reject this observed trend in the experimental data

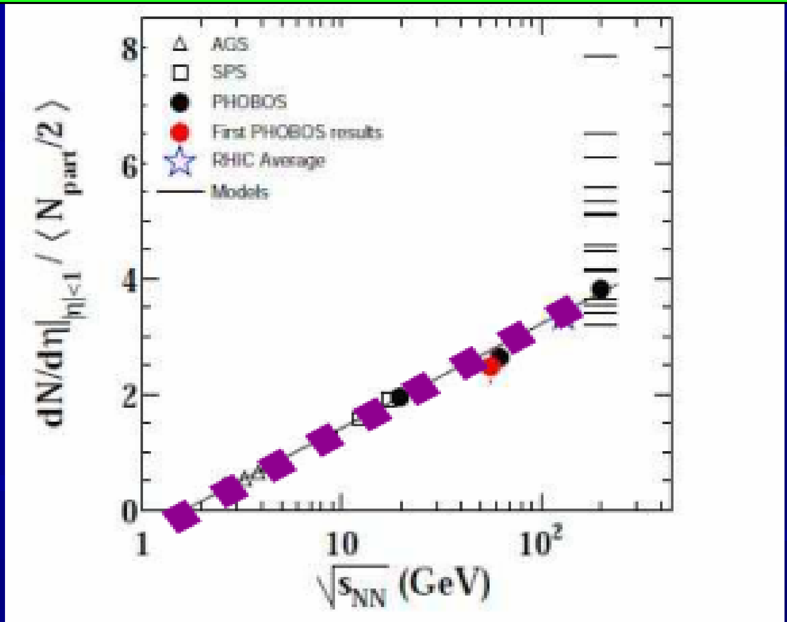
Flow scaling in a low-energy collider: When does the perfect fluid turn on?

Giorgio Torreri

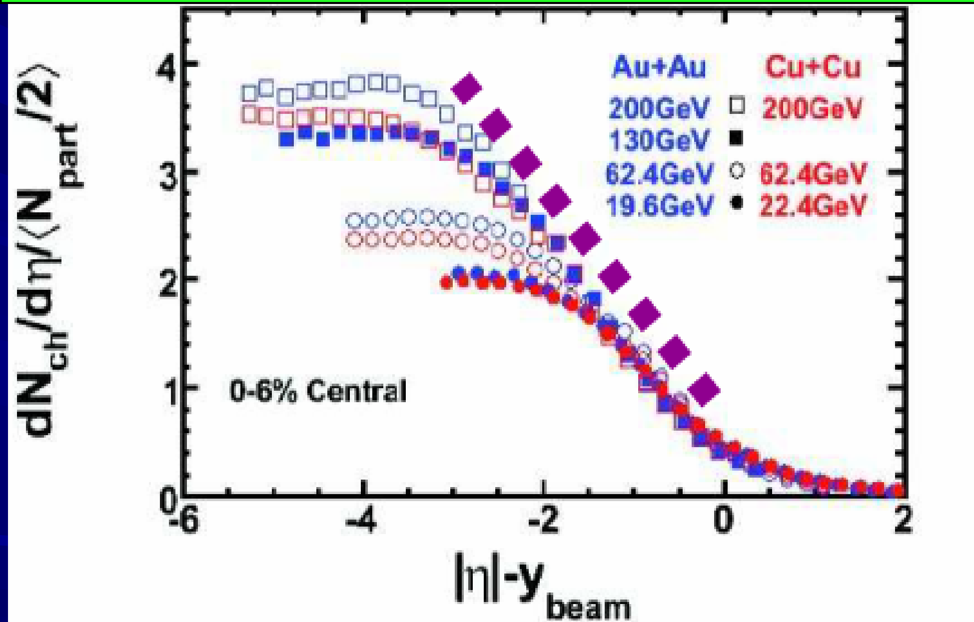
FIAS and University Frankfurt, Germany; Columbia Univ., USA

RHIC found remarkable scaling laws indicating „perfect fluid“ - minimal viscosity!

mid-rapidity dN/dy vs. energy



dN/dy away from y_beam - limiting fragmentation



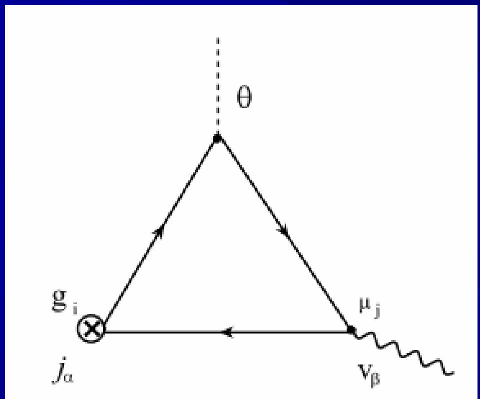
- Establish a lower limit for the onset of the hydro scaling in HIC experiments!
- Collider for scanning energy and rapidity below RHIC energies: NICA optimal!

Chiral vortaic effect and neutron asymmetries at NICA

Oleg Rogachevsky, Alexander Sorin and Oleg Teryaev

JINR Dubna, Russia

Both, chiral magnetic effect (CME) and chiral vortaic effect (CVE) belong to the class of effects based on the triangle anomaly in QFT. CVE is a generalization to conserved charges other than the electric one. In case of baryon charge and chemical potential, it should manifest itself by neutron asymmetries, observable at NICA/MPD!



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

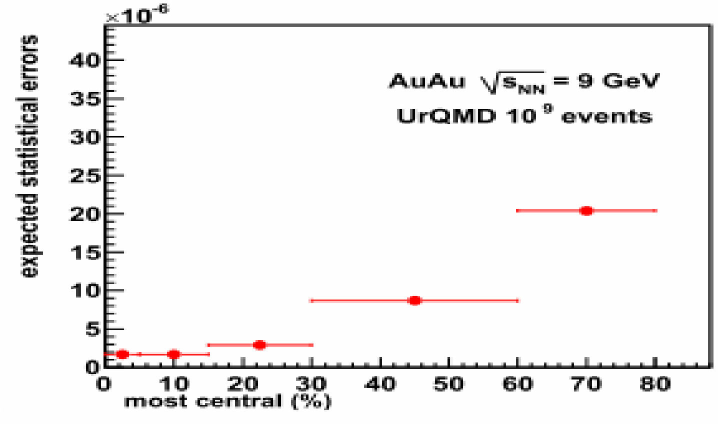
$$e_j \vec{H} \rightarrow \mu_j \vec{\nabla} \times \vec{V}$$

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

$$J_i^\nu = \frac{\sum_j g_{i(j)} \mu_j}{\sum_j e_j \mu_j} J_e^\nu \qquad J_i^0 = \frac{|\vec{\nabla} \sum_j g_{i(j)} \mu_j|}{|\vec{\nabla} \sum_j e_j \mu_j|} J_e^0$$

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

In CME case at RHIC: 15 M events were sufficient to establish the effect
For demonstrating the CVE, we need 1000 M events, which can be collected at NICA/MPD within a few months of running time!



Development of highly charged ion sources for NICA injector & possible applications for nanofabrication and in medicine

D.E. Donets, E.D. Donets, E.E. Donets, V. Salnikov, V. Shutov

Kurchatov Institute Moscow, Russia & GSI Darmstadt, Germany

Novel type of highly charged ions sources – Electron String Ion Sources (ESIS) is under development in JINR in framework of NICA project. This ion sources produce intense beams of highly charged ions of heavy elements, up to gold. Two major applications of this ion sources: for nanofabrication and for cancer therapy are briefly discussed.

1 Production of nanostructures by slow highly charged ions for information storage and processing at nanometer range

2 Resonant combination cancer therapy – newly proposed method with use of highly charged ion source of highest intensity

Basic and applied researches with highly charged intense ion beams of heavy elements, produced with ESIS-type ion sources have a very wide area for applications in nano-sceiences and medicine. Ion source development program in framework of the NICA project has a great potential for various nonaccelerator applications as well.

Summary

The NICA design passed the phase of concept formulation and is presently under

- ✓ **detailed simulation of accelerator elements parameters,**
- ✓ **development of working project,**
- ✓ **manufacturing and construction of prototypes,**
- ✓ **preparation of the project for state expertise**

in accordance with regulations of Russian Federation.

The project realization plan foresees a staged construction and commissioning of accelerators forming the facility. The main goal is the facility commissioning in 2016.

Summary

- **NICA/MPD** project to study hot & dense baryonic matter is *progressing well*
- The accelerator part is properly *supervised*
- The 1st stage **of MPD** conception *is completed,* & the project is *recommended for realization*
- The scientific program in BM will be extended for low energy region – ***BMN***
- External collaborations *are invited* to present proposals
- Project schedule & financing *are fulfilling*
- The **Collaboration around NICA/MPD** is growing

New members are welcome !

Thank you for attention!