Physics @ NICA, JINR

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XXI International Baldin Seminar
On High Energy Physics
10-15 September, 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* ***deutrones*** *with max energy up to* $\sqrt{S_{NN}}$ = ***11 GeV (Au^{79+})*** *and* = ***26 GeV (p)***

Historical background of Veksler & Baldin Laboratory

Remarkable dates in 2012:

- the 105-th Jubilee of acad. V. I. Veksler
  - **the first Director of the Lab**
  - *in 1944 conceived the principle of phase stability*
  - *the leader of the Synchrophasotron*
  - *discovery of anti sigma minus hyperon*

- the Synchrophasotron's 55-th anniversary

  1957 -> the record in energy (> x 10 m_p)

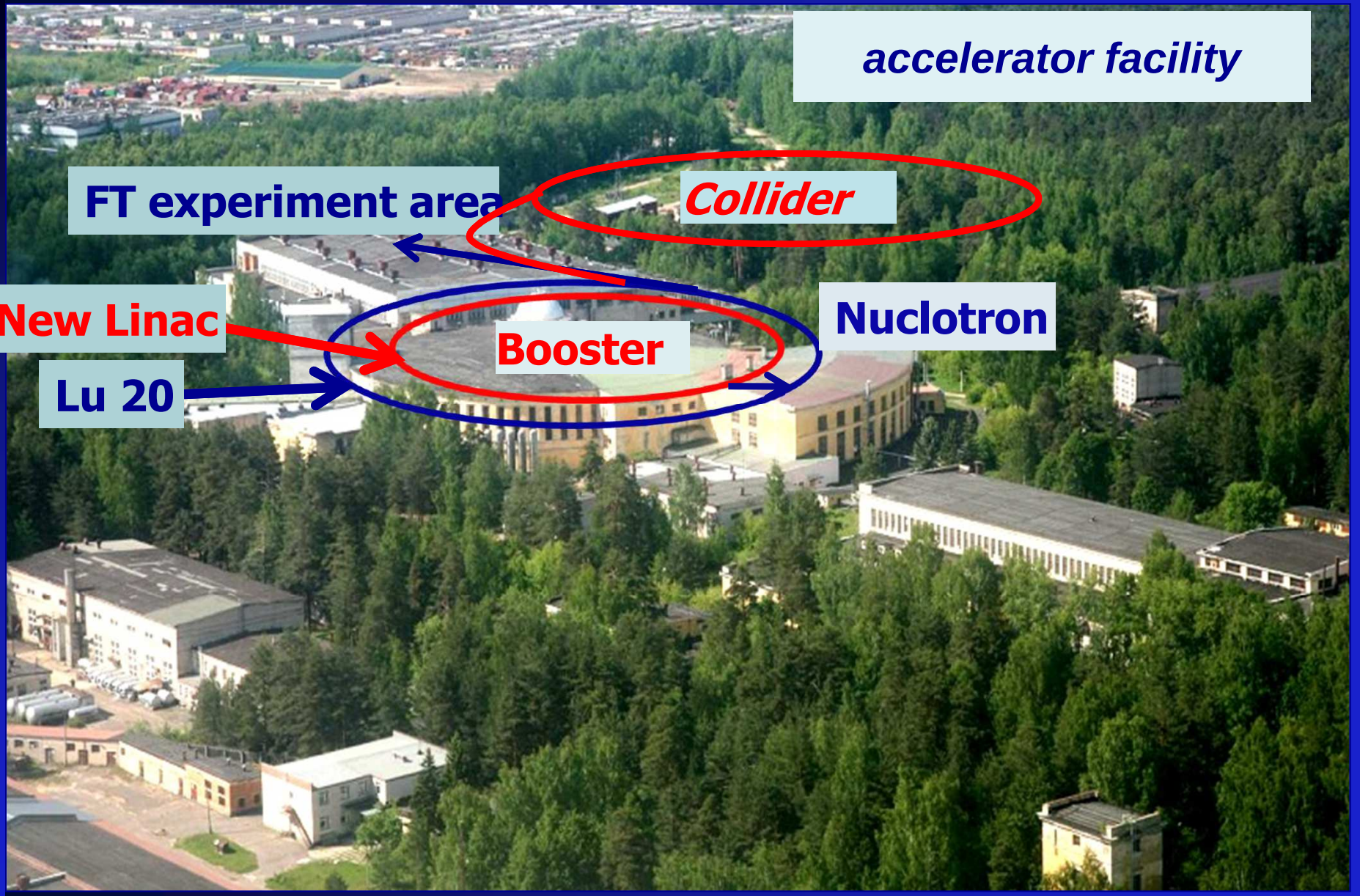
Historical background of Veksler & Baldin Laboratory

NUCLOTRON

- the pioneer in superconducting accelerator for relativistic ions

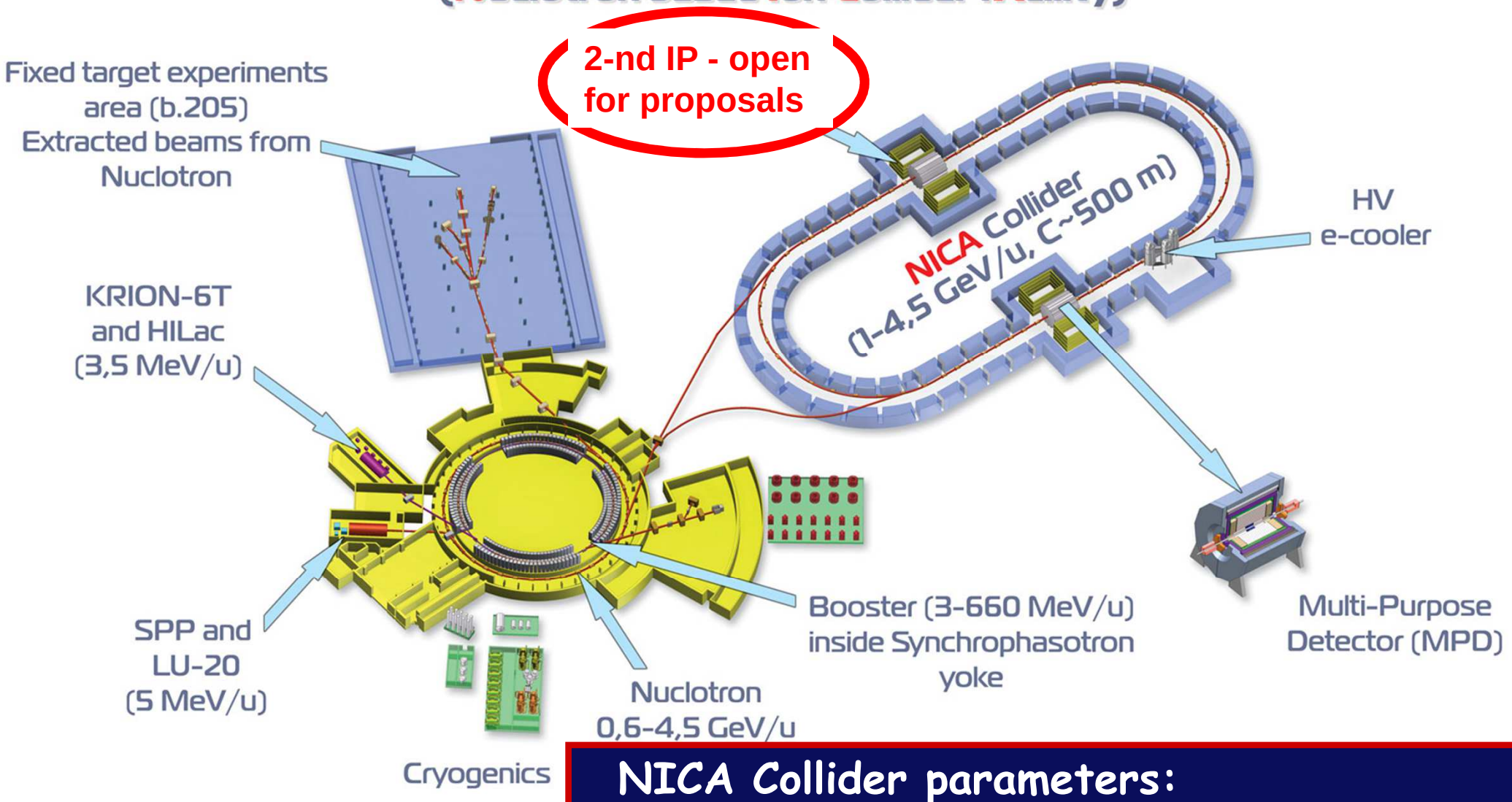
- initiated by acad. A.M. Baldin
  - built within five years
  - & commissioned in 1993

Veksler & Baldin Laboratory of High Energy Physics, JINR



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; SPD-> Waiting for Proposals

NICA beams

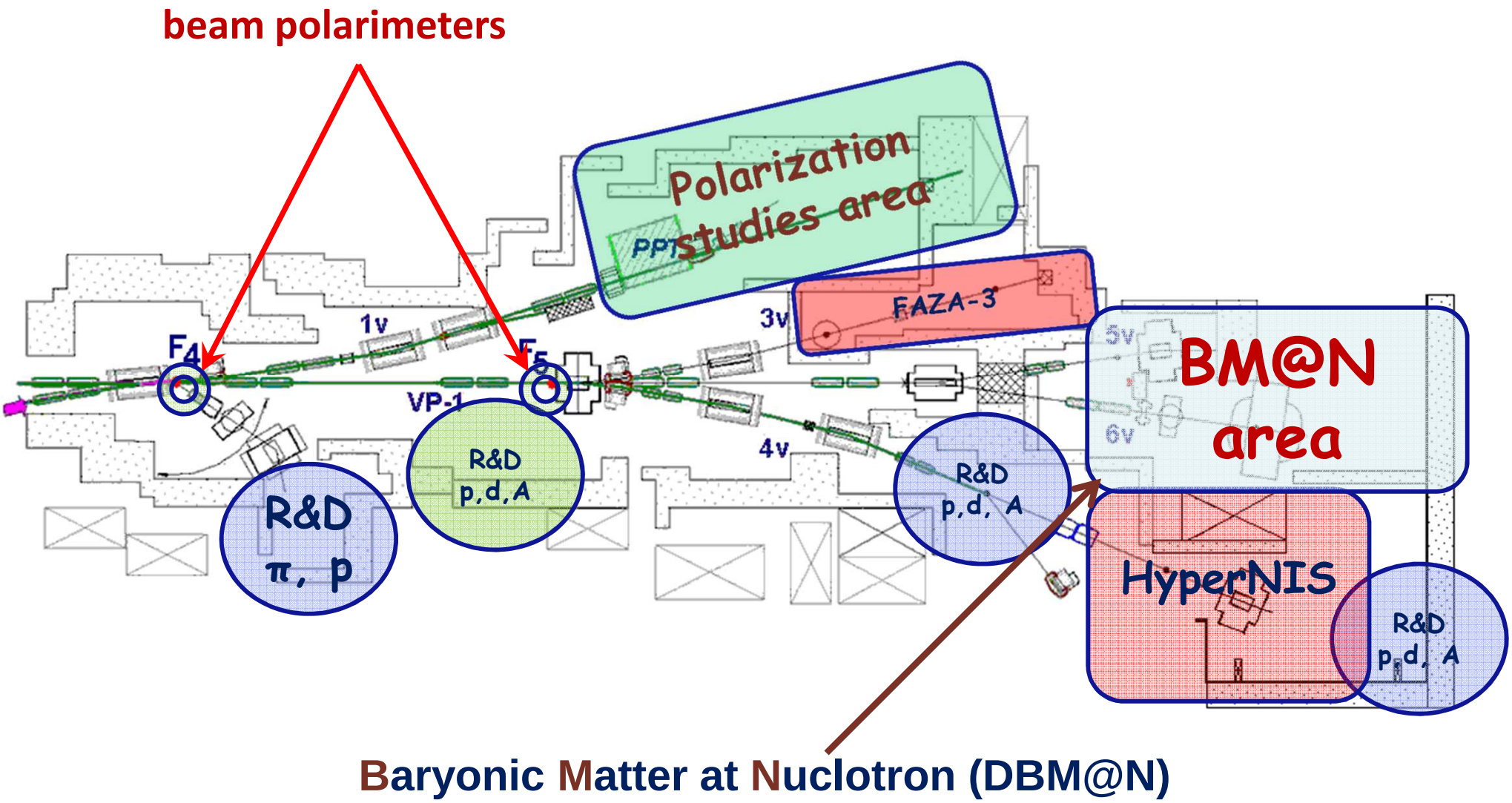
- *Heavy ion colliding beams up to $^{197}Au^{79+}$ x $^{197}Au^{79+}$*
  at $\sqrt{s_{NN}} = 4 \div 11$ GeV , $L_{average} = 1x10^{27}\ cm^{-2} \cdot s^{-1}$
  Light-Heavy ion colliding beams of the same energy range and L
- *Polarized beams of protons and deuterons in collider mode:*
  $p\uparrow p\uparrow$ $\sqrt{s_{pp}} = 12 \div 27$ $L_{average} \geq 1x10^{30}\ cm^{-2} \cdot s^{-1}$
  $d\uparrow d\uparrow$ $\sqrt{s_{NN}} = 4 \div 13.8$ GeV
- *Extracted beams of light ions and polarized protons and deuterons for fixed target experiments:*

  Li ÷ Au = 1 ÷ 4.5 GeV /u ion kinetic energy
  p, $p\uparrow$ = 5 ÷ 12.6 GeV kinetic energy
  d, $d\uparrow$ = 2 ÷ 5.9 GeV/u ion kinetic energy
- *Applied research in ion beams at kinetic energy*

  starting from from 0.3 GeV/u

Beam	Nuclotron beam intensity (particle per cycle)		
	Current	Ion source type	New Injection facility + 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	-	--- „ ---	$1 \cdot 10^{9}$

Bld. 205 (*10 000 m²*): structure of research zones with extracted beams



Experiments & activities at Nuclotron

- ALPOM → ALPOM-2
- STRELA (finished)
- LNS, pHe3 → DSS
- DELTA-2 (finished)
- DELTA-SIGMA (→2011, finished)
- NIS, GIBS → HyperNIS
- TPD (to be completed)
- MARUSYA (test beams of secondaries)
- η- nuclei (work in parasitic mode)
- PHASA → PHASA-3
- BECQUEREL (work in parasitic mode)
- Thermalisation (IHEP) (to be completed)
- Energy & transmutation → new encouraging results

- Mednuclotron
- Compact electron & ion accelerators
- Straw detectors

existing & future HEP experimental facility of Joint Institute for Nuclear Research

Nuclotron-M –> NICA
(SC synchrotron)
extracted beams

NICA Collider
the 1-st IP
(2017)

NICA Collider
the 2-nd IP
(2017)

Barionic Matter
@ Nuclotron *(2015)*

MultiPurpose Detector
(2017)

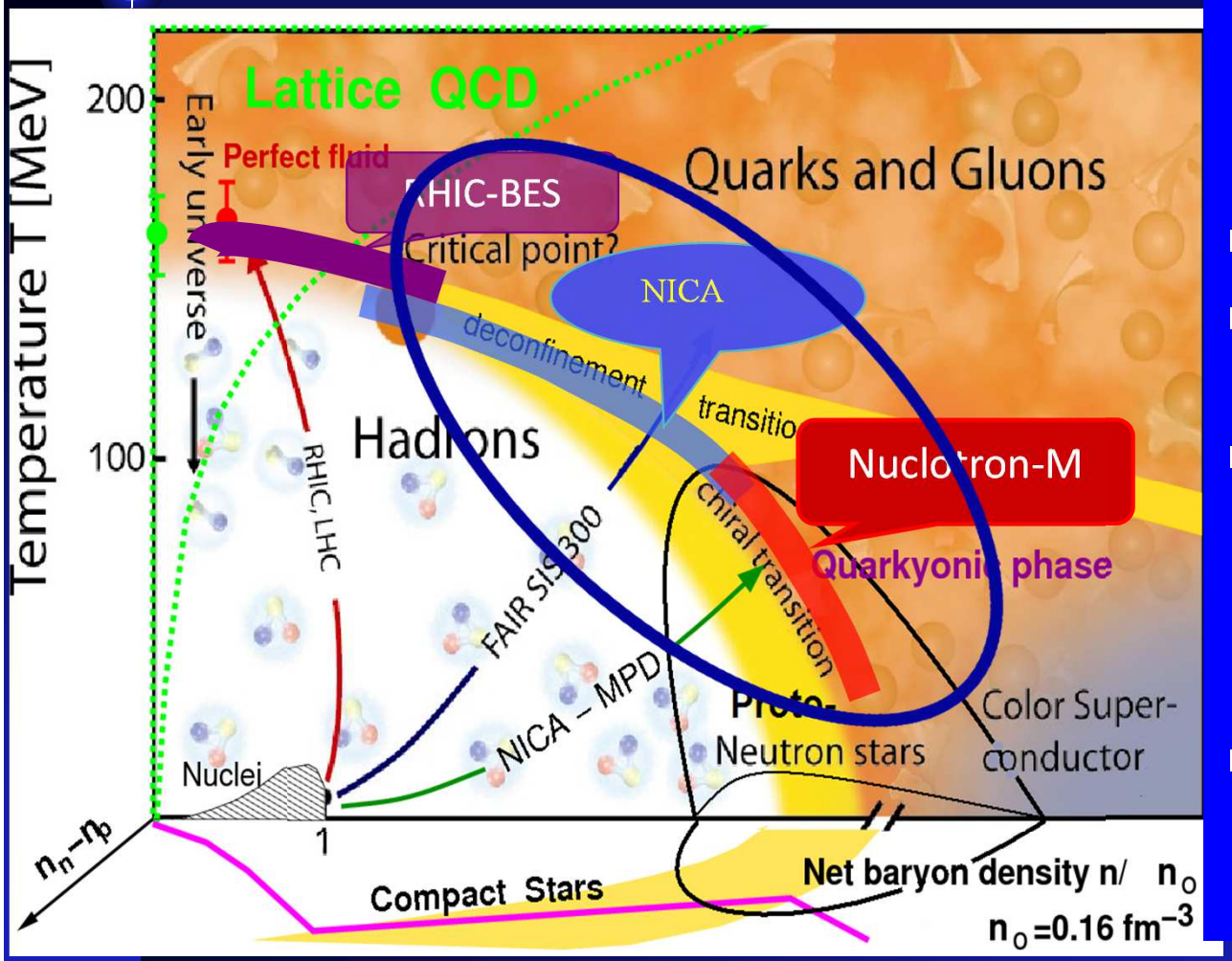
open for proposals

- Gibs–NIS (FS)
- Faza-3
- polarized beams & target
- **test beams**
- **beams for applied researches**

approved, in preparation

running experiments

QCD phase diagram - Prospects for NICA

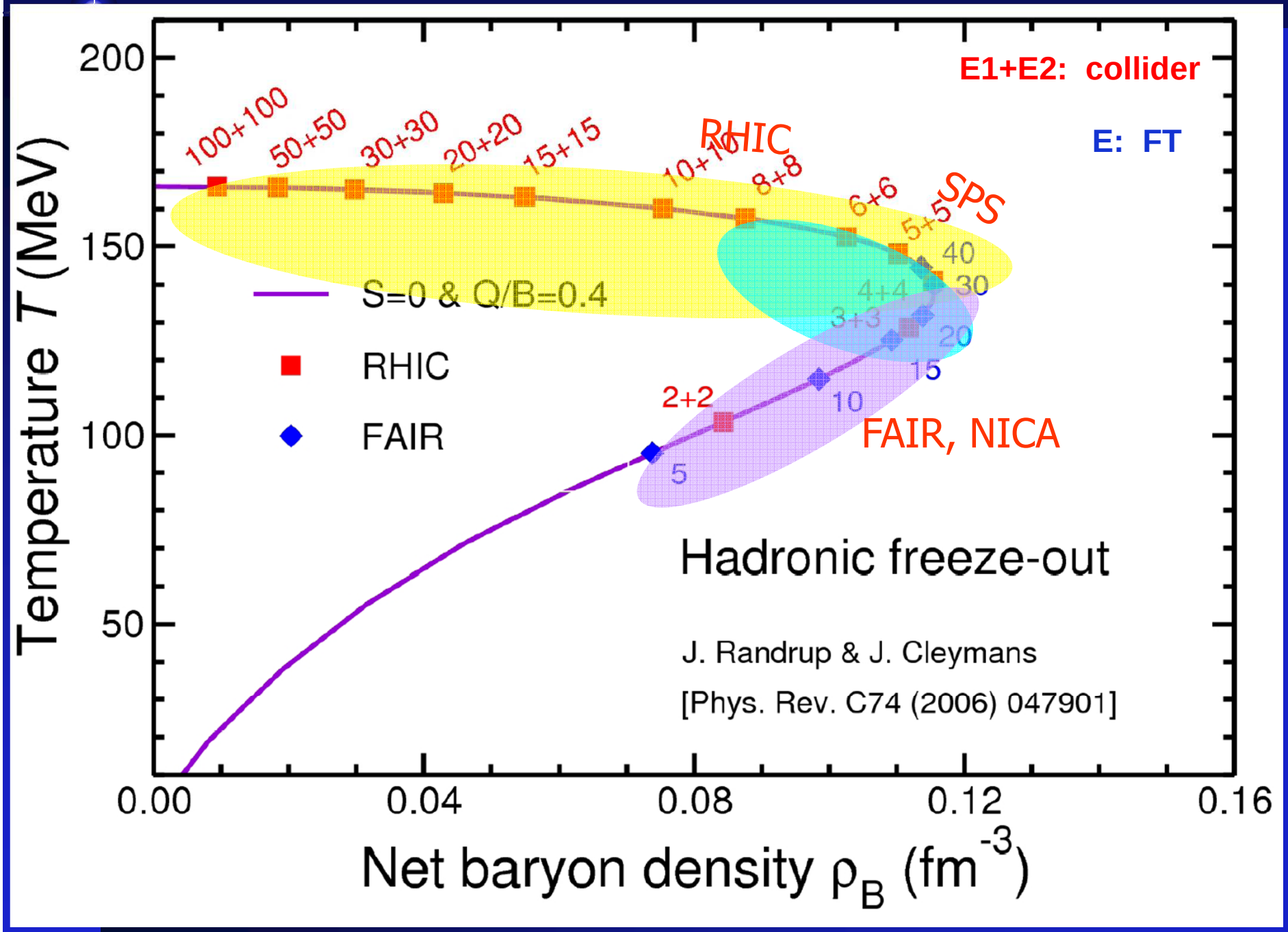


Energy Range of NICA
unexplored region of
the QCD phase diagram:

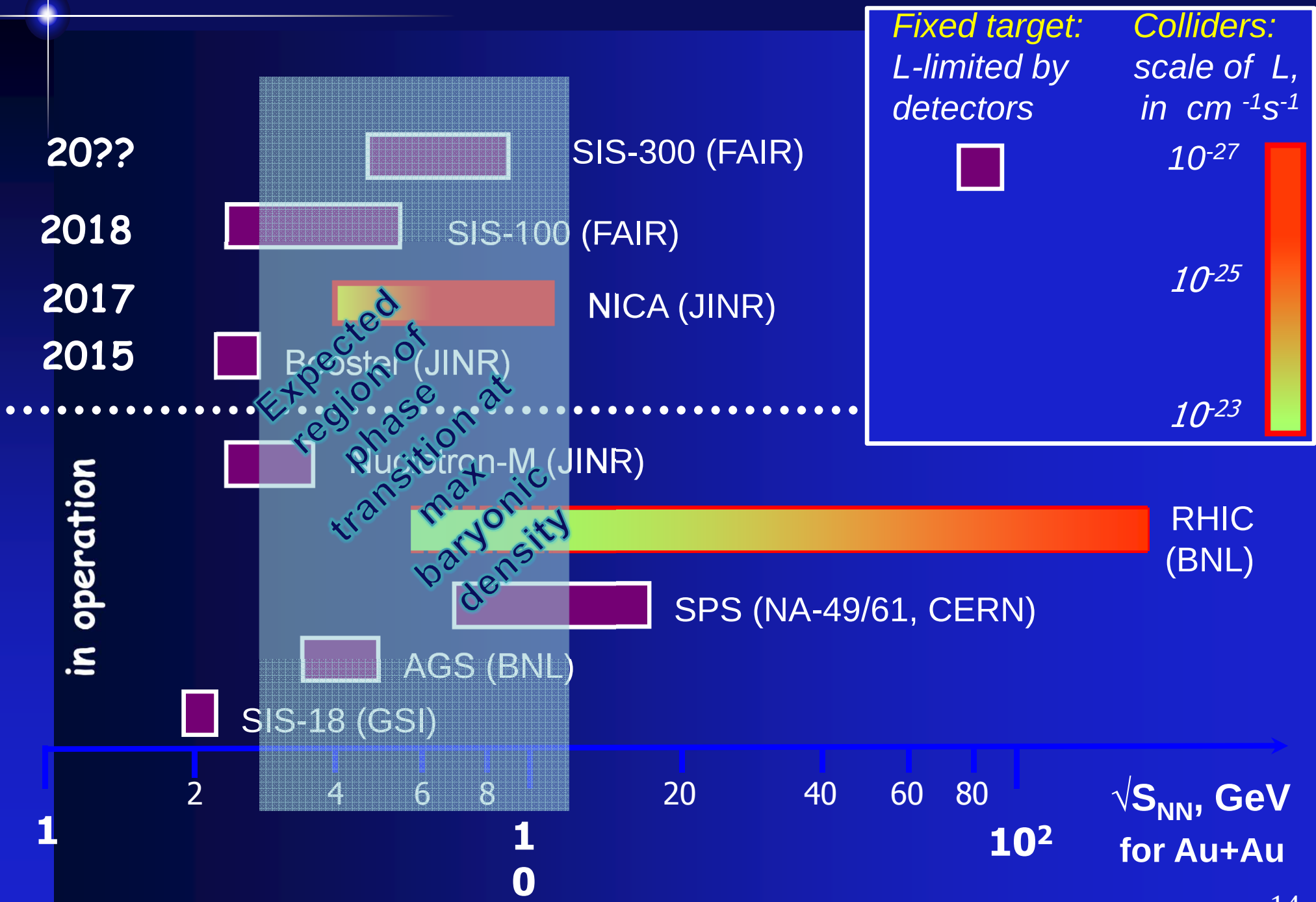
- Highest net baryonic density
- Onset of deconfinement & phase transition
- Discovery potential:
  a) Critical End Point (CEP)
  b) Chiral Symmetry Restoration
- Complementary to the RHIC/BES, FAIR, CERN experimental programs

NICA facilities provide unique capabilities for studying
a variety of phenomena in a large region of the phase diagram

Freeze-out conditions



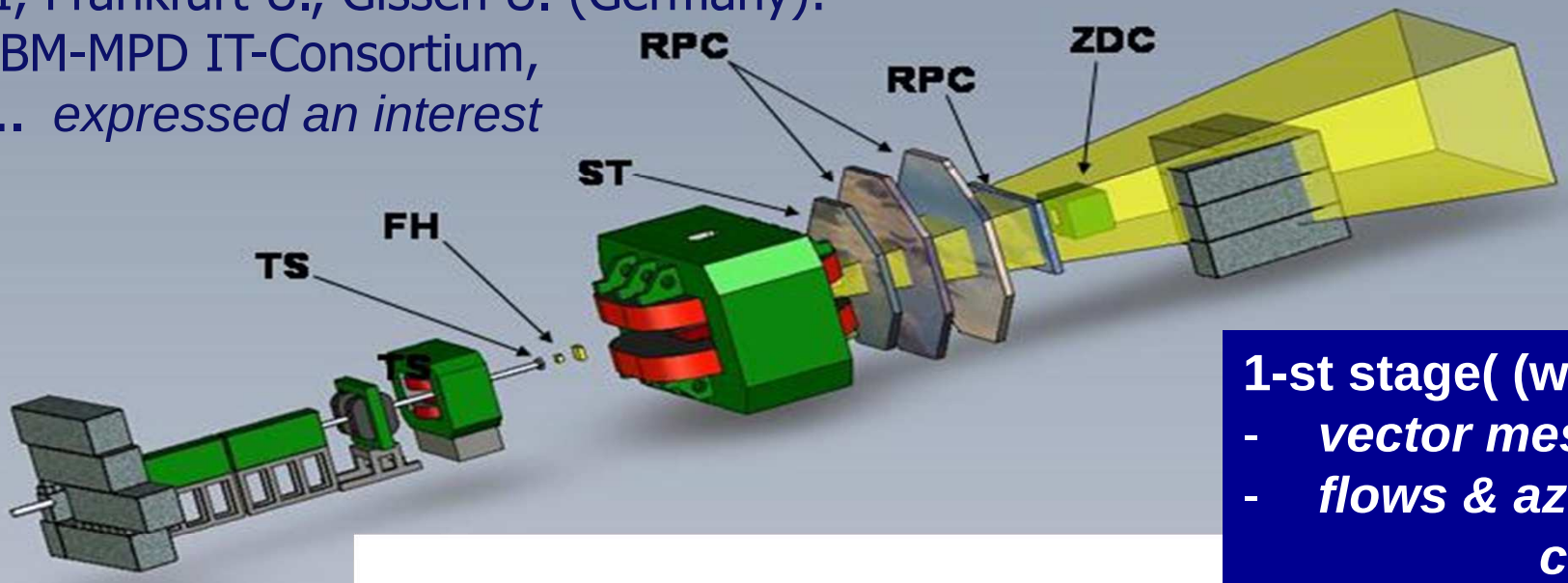
Existing & Future HI Machines



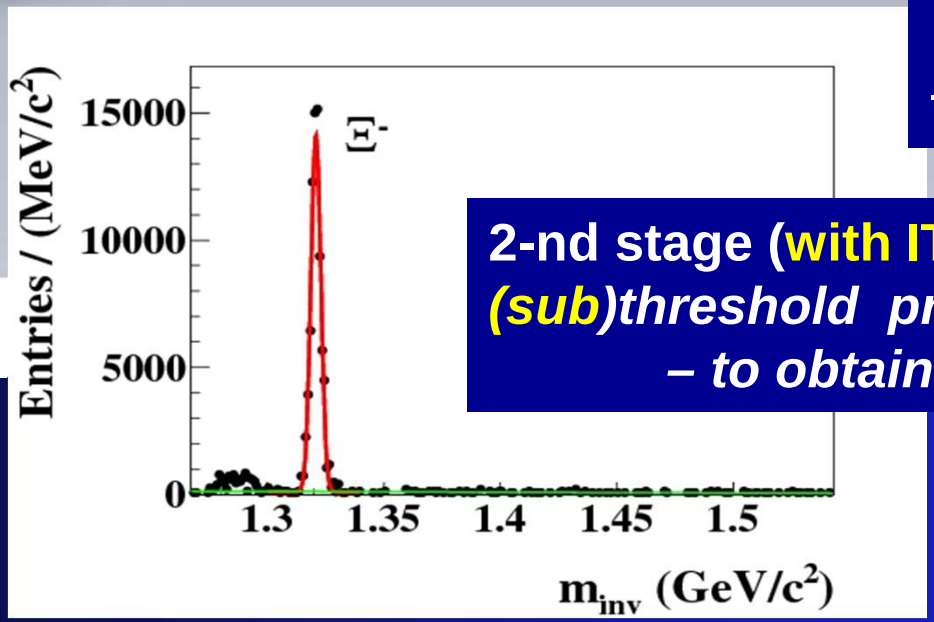
BM@N Collaboration

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*



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

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.

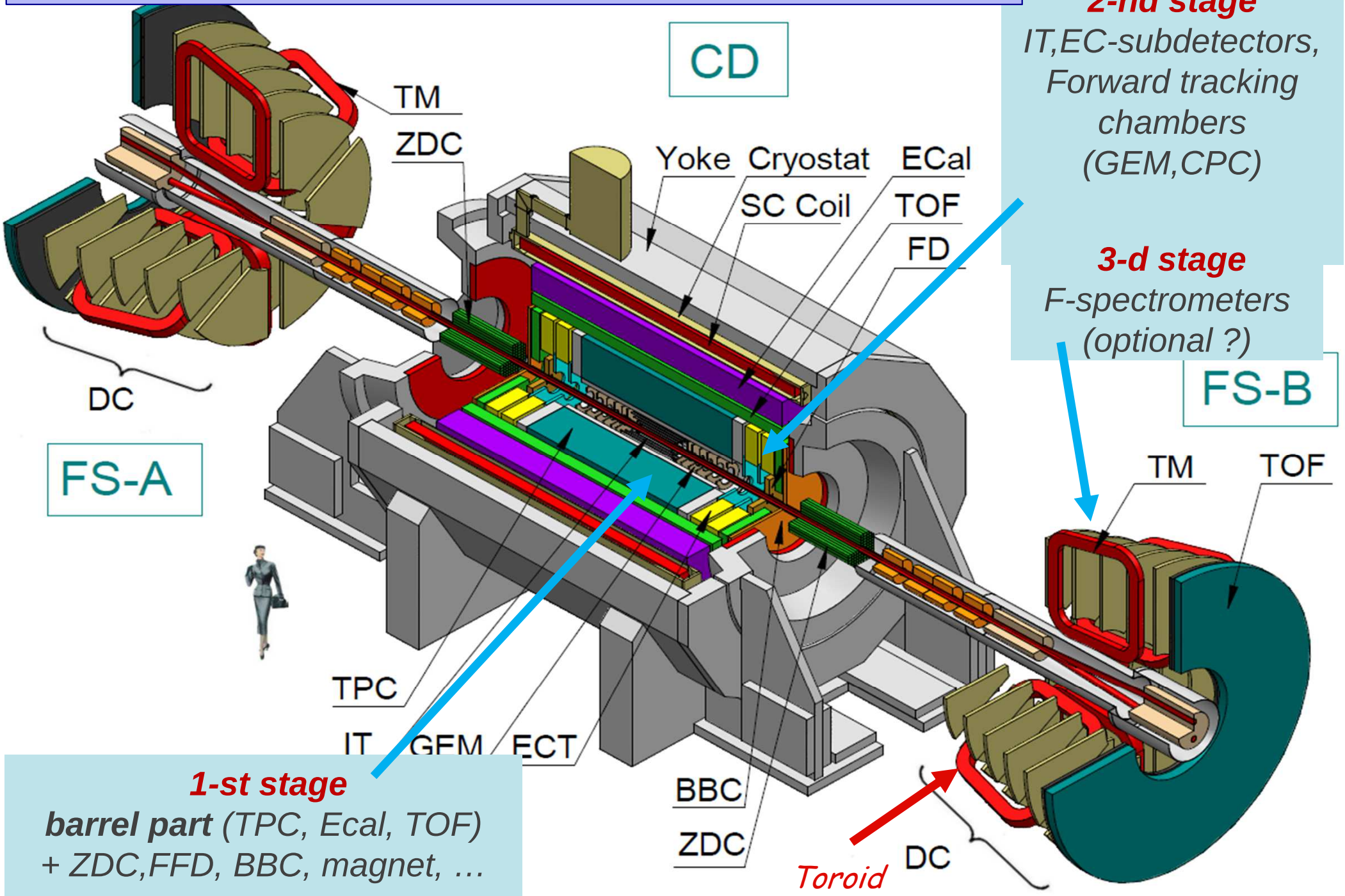
- **pA, nA, dA interactions in direct & inverse (Ap, Ad) kinematics:**
  - to get a "reference" data set for comparison with *AA* interactions,
  - to look for polarization effects in particle production off nuclear targets by polarized d, p, n.

MultyPurpose Detector (MPD)

1-st IP @ NICA Collider

4 GeV $< \sqrt{s_{NN}} <$ ***11 GeV*** ***(for*** Au^{79+}***)***

MultiPurpose Detector (MPD) @ 1st IP



2-nd stage

IT,EC-subdetectors, Forward tracking chambers (GEM,CPC)

3-d stage

F-spectrometers (optional ?)

1-st stage

barrel part *(TPC, Ecal, TOF)*
+ ZDC,FFD, BBC, magnet, …

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 flow 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

MPD/NICA - advantage in Scan of the QCD phase diagram

Strategy:

detailed energy & system size scan

*with a step of ~ **10 MeV/u** in selected regions*

with a high **L** aimed in a search for anomalies:

- in particle production in the vicinity of the critical point,

- signatures of in-medium modification of the vector-spectral functions,

- study of the properties of the mixed phase of strongly interacting matter.

Spin Physics at NICA

Working Group started preparation the spin physics program to operate with polarized pp, pD & DD beams.

Preliminary topics:

- Matveev-Muradyan-Tavkhelidze-Drell-Yan (MMTDY) processes with L&T polarized p & D beams
- extraction of unknown (poor known) PDF
- PDFs from J/ψ production processes
- Spin effects in baryon, meson and photon productions
- Spin effects in various exclusive reactions
- Diffractive processes
- Cross sections, helicity amplitudes & double spin asymmetries (Krisch effect) in elastic reactions
- Spectroscopy of quarkoniums with any available decay modes
- Polarimetry

Accelerator complex

progress in R&D & construction

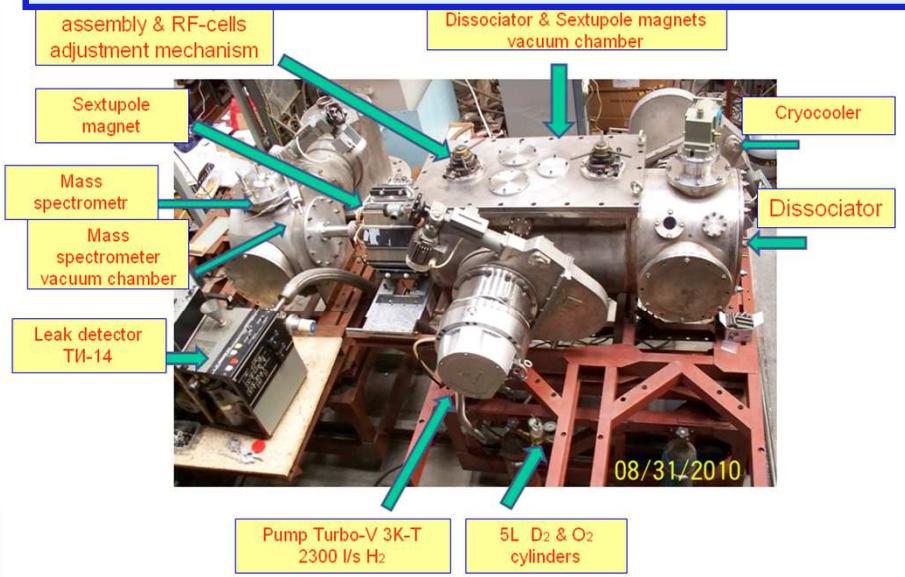
Unique SC Heavy Ion Source KRION with 3T and 6T SC solenoid

Highly charge ion state for heavy ions with high intensity:
Kr 28+, Xe 44+, Au 52+

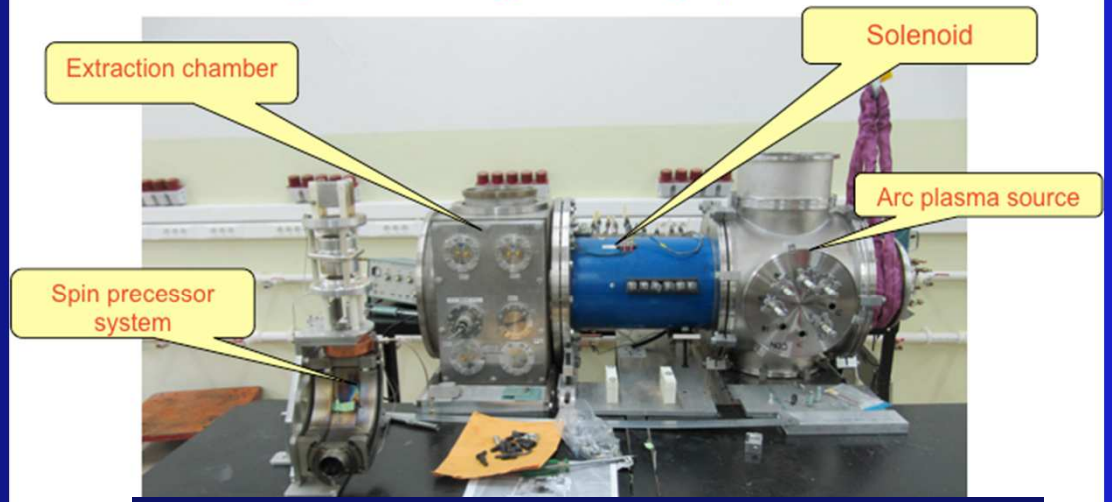
Thermometry & cryo-magnetic tests done in June-July 2012;

1st e-beam/e-string tests are planned for October 2012.

Collaboration with INR RAS: high intensity polarized particle source: up to 10^{11} particles/pulse



Atomic Beam Source setup general view



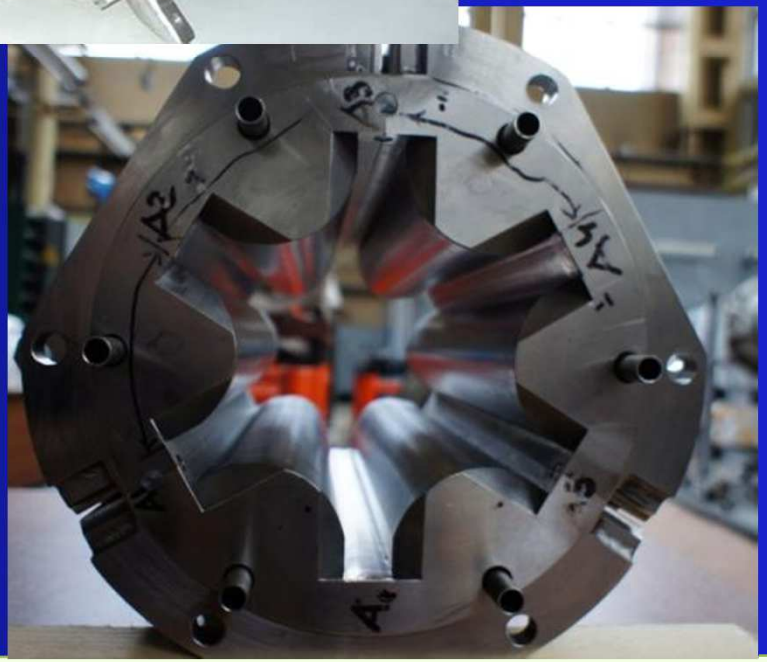
Assembly of the charge-exchange plasma ionizer (JINR responsibility)

Magnets for the Booster

Booster dipole at cryo-test (9690A) and magnetic measurements

Quadrupole lense

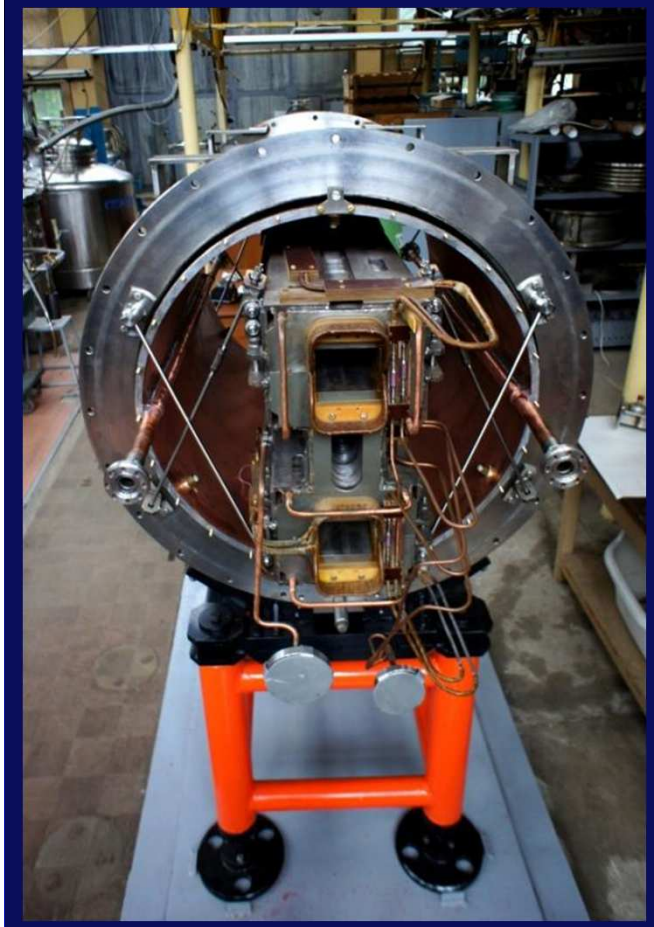
Cryogenic test-bench @ LHEP



Sextupole corrector prototype (for SIS100 & NICA booster) at assembly

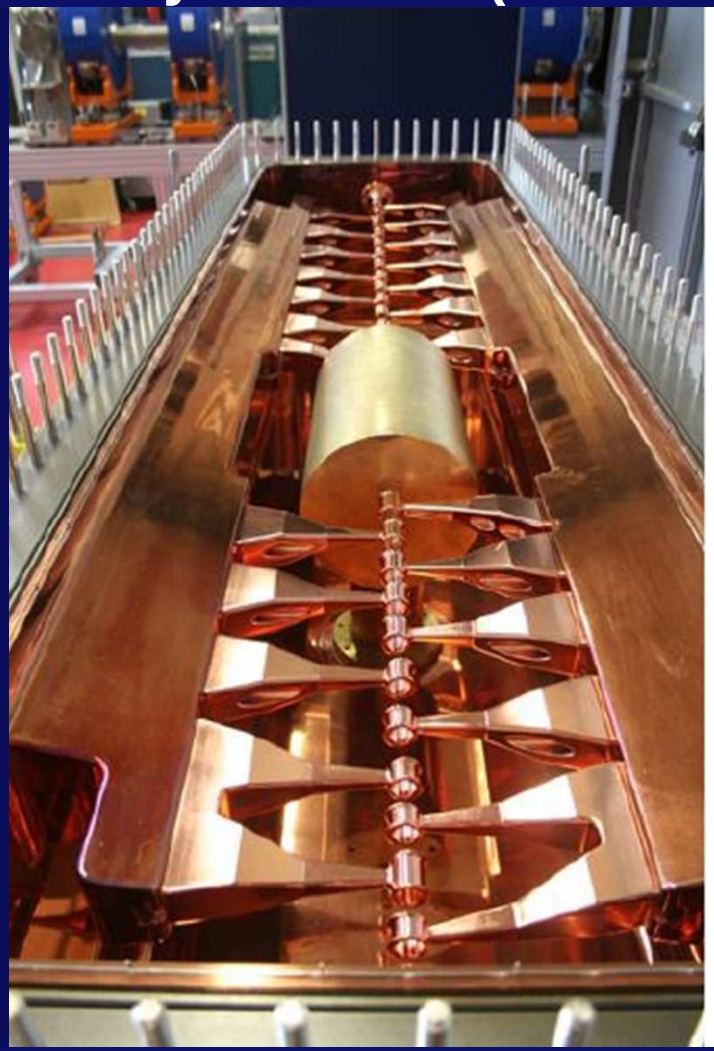
Progress with the accelerator complex

Collider magnets



Cryo-tests (Nov 2012)
New cryo-plant (2600 m^2)
at Bldg.217
– 1st stage will be commissioned in 2013.

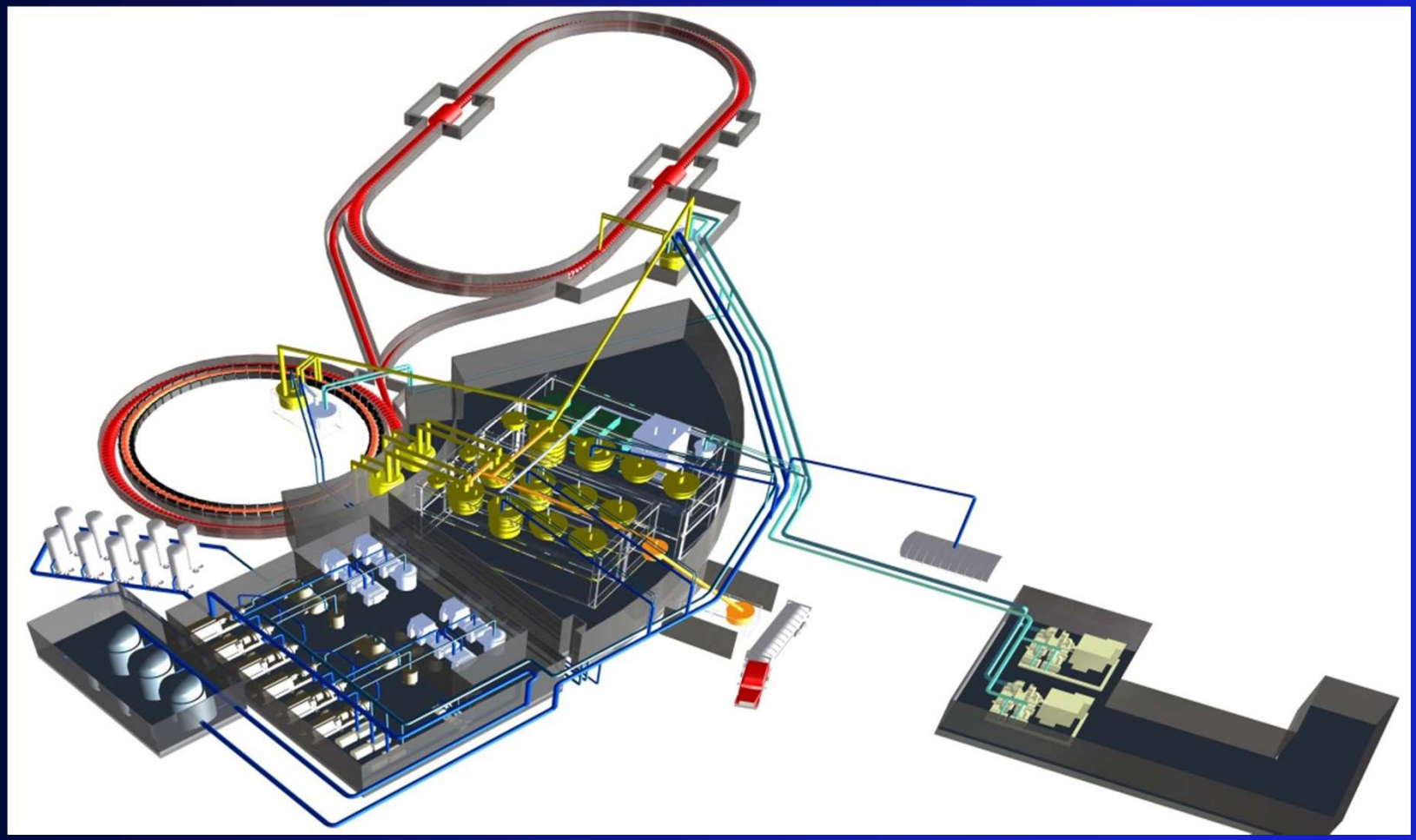
Heavy Ion Linac (HILac.



Design and fabrication
Under contract with "BEVATECH OHG"
Germany, Offenbach/Main,
to be delivered at JINR September 2013.

Progress with NICA project

cryogenic complex



Technical design project is in final stage: new helium liquefier-plant.
Now it has 4 kW@4.5K,
with new plant the cooling power will be doubled up to 8kW@4.5K;

New 2 screw compressors are under design

The Synchrophasotron

Progress with NICA project

NICA complex technical design report status

the State Expertise foreseen in 2012.

ALL geological, geodesical, topography measurements and drillings had been fulfilled, as well as technological part of the TDR, radiation and environmental safety, and architecture

MPD

progress in R&D

Straw full scale prototype for EC tracking

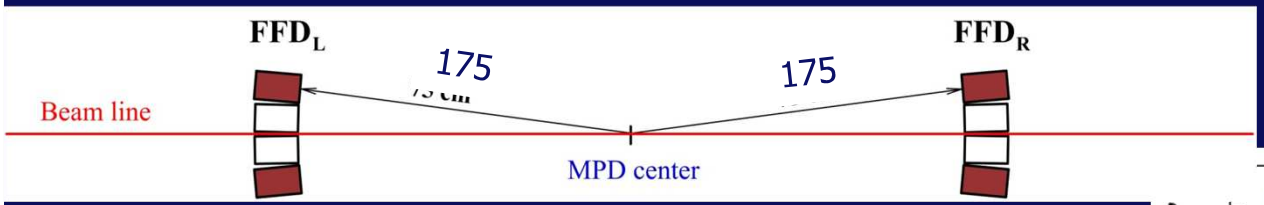
Technological TPC prototype

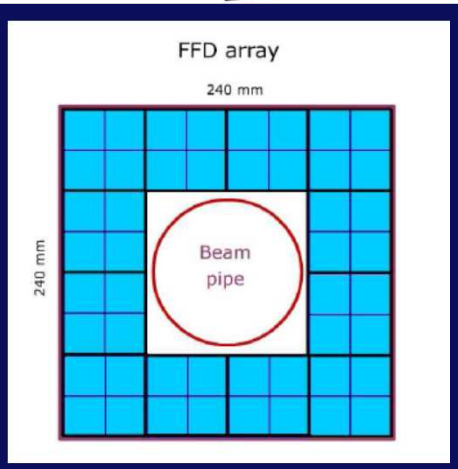
Material:
Kevlar laminated
by Tedlar film

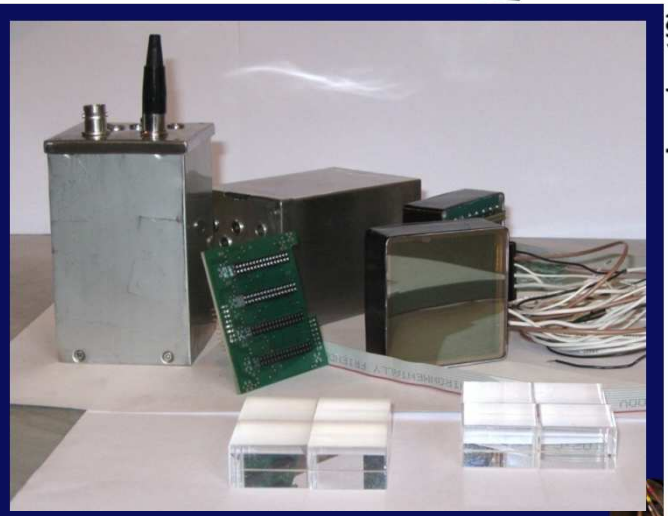
Diameter - 950 mm
Length - 900 mm
Wall thickness - 2 mm
Weight ~ **10 kg**

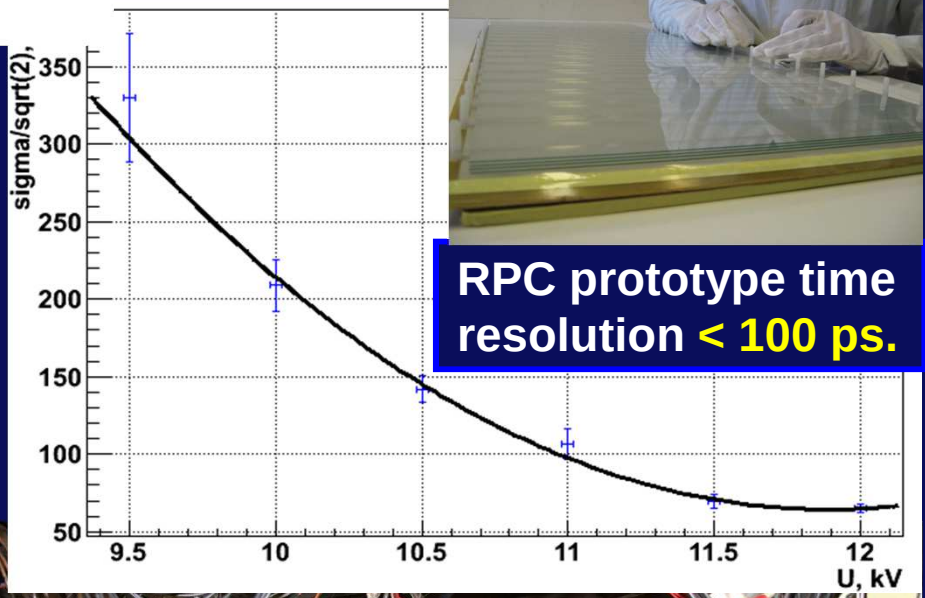
Fast Forward Detector (FFD)

tests of full scale RPC prototype

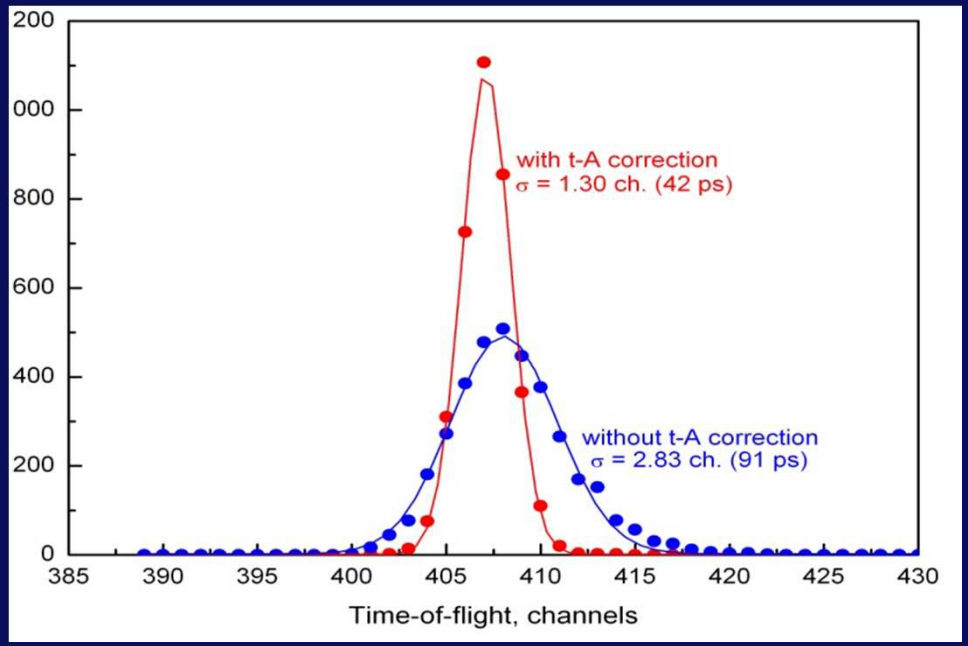


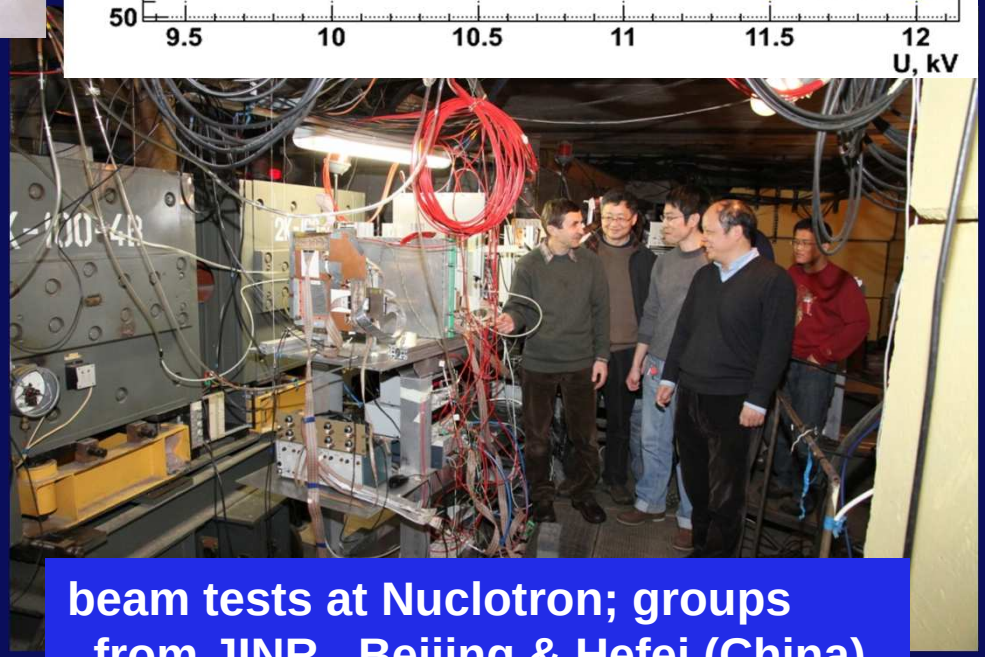






RPC prototype time resolution < 100 ps.





beam tests at Nuclotron; groups from JINR , Beijing & Hefei (China)

MPD
feasibility study
simulation with MPDROOT

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 from experimental data (NA49), statistical and HSD models.
Efficiency from MPD simulations. Typical efficiency from published data (STAR)

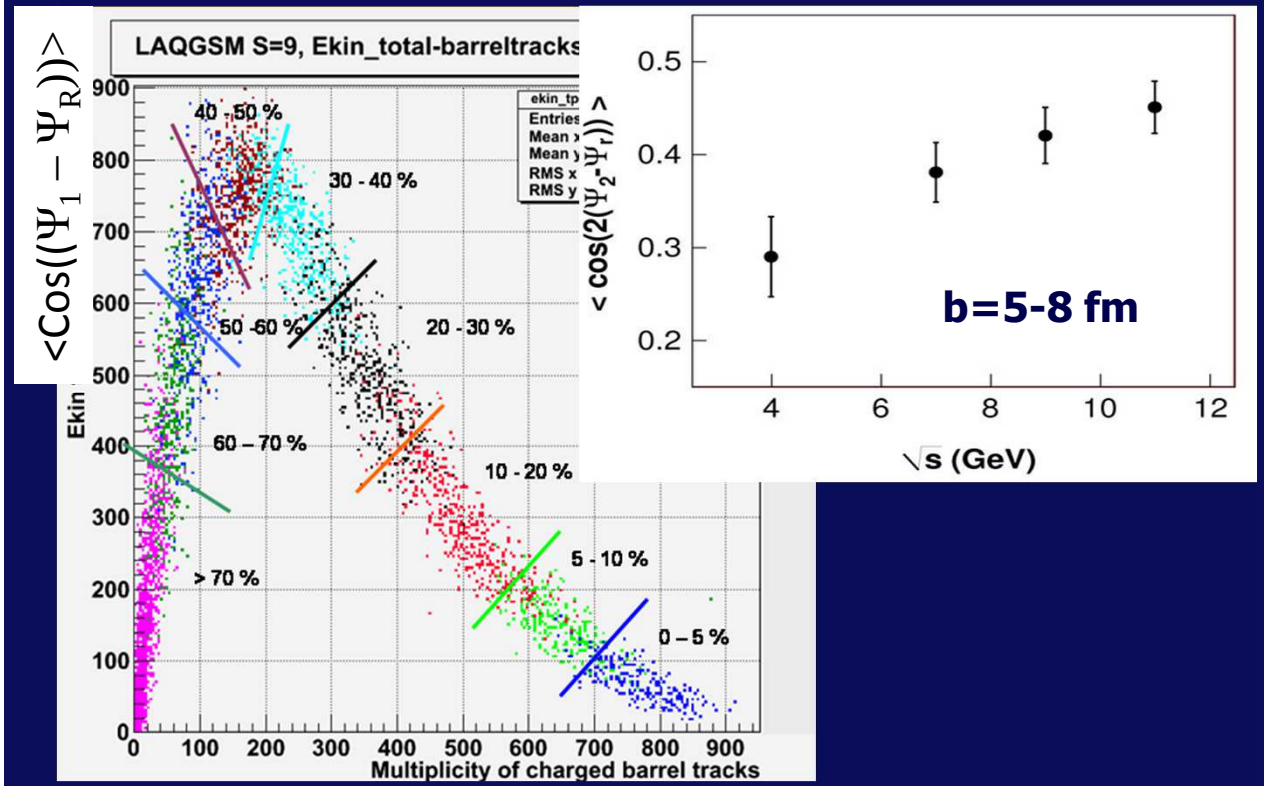
Reaction plane determination & flow study

- ✓ v2 in TPC & v1 at high vapidities
  (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

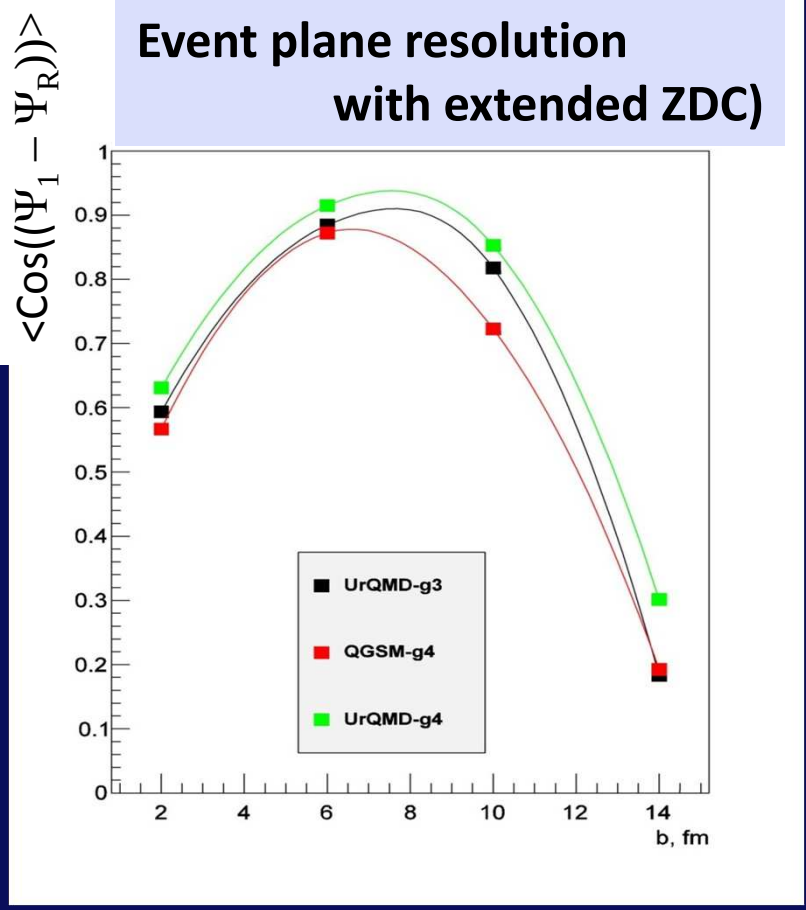
Extended ZDC detector (2<η<5)
improves RP resolution
at low & medium b

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

Event plane resolution for "central events"

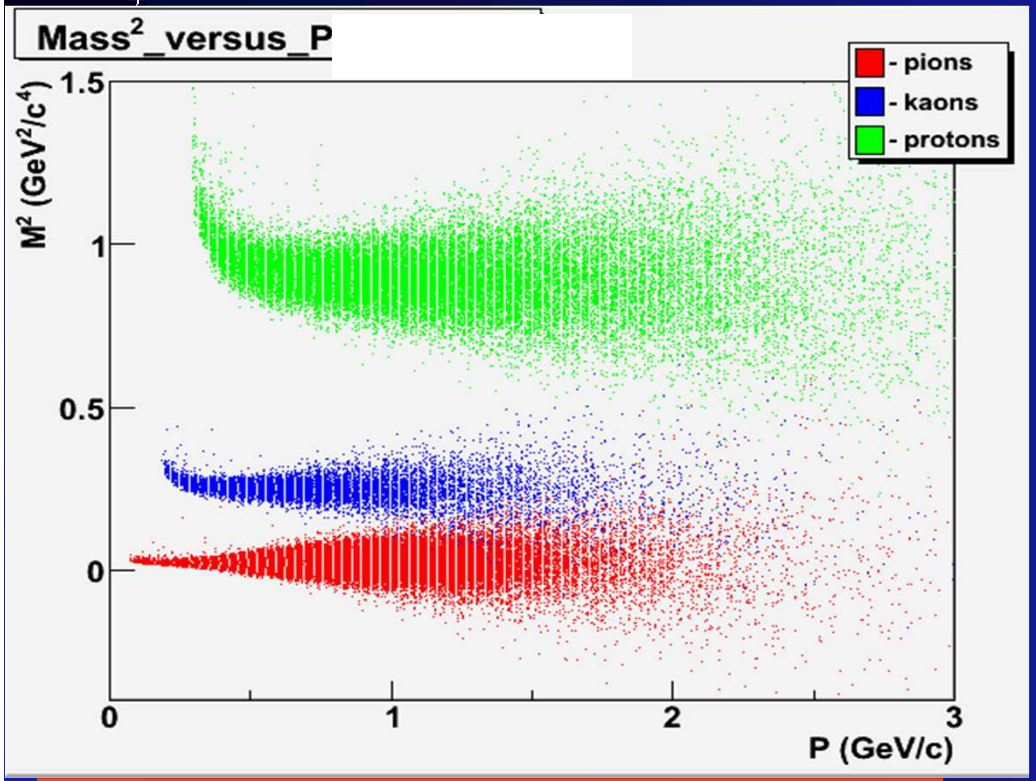


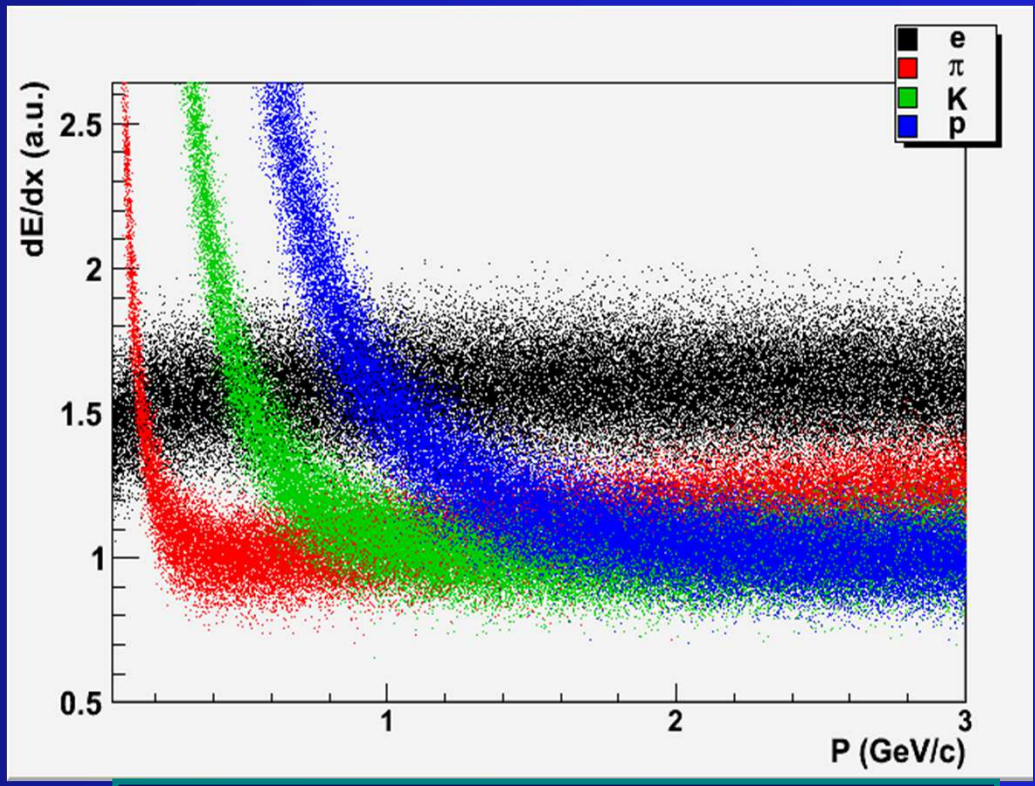
Event plane resolution with extended ZDC)



Particle IDentification in MPD

(realistic detector simulation)



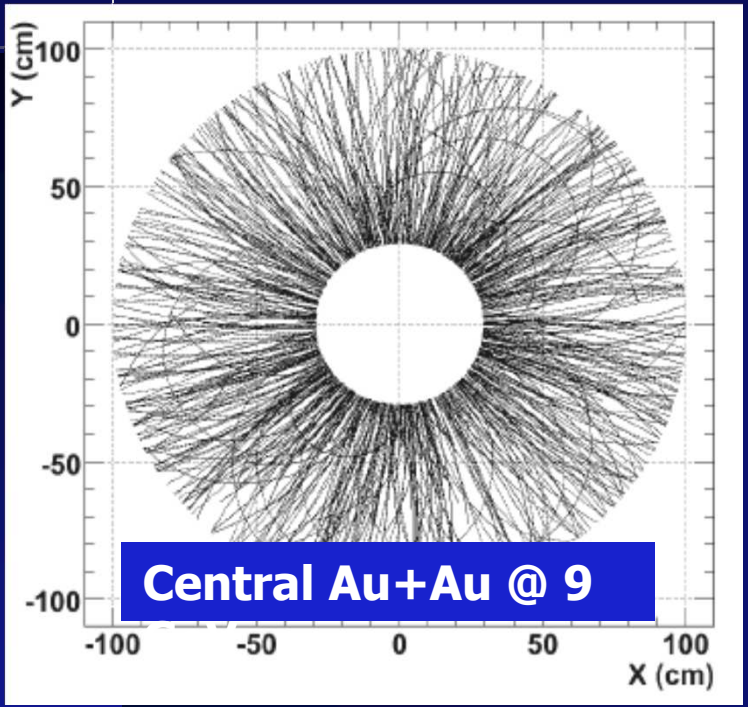


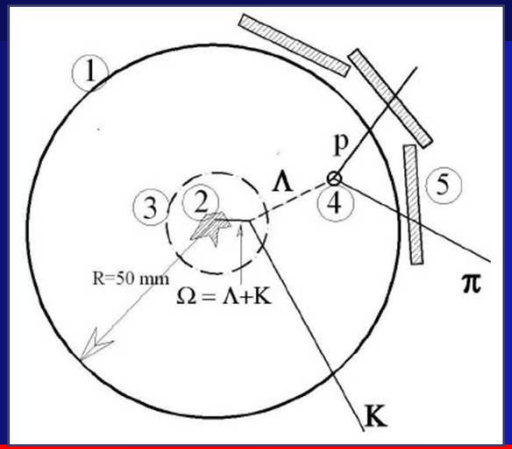
PID: *Time Of Flight*
Separation: **e/h – 0.1..0.35 GeV/c**
π/K – 0.1..1.5 GeV/c
K/p – 0.1..2.5 GeV/c

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

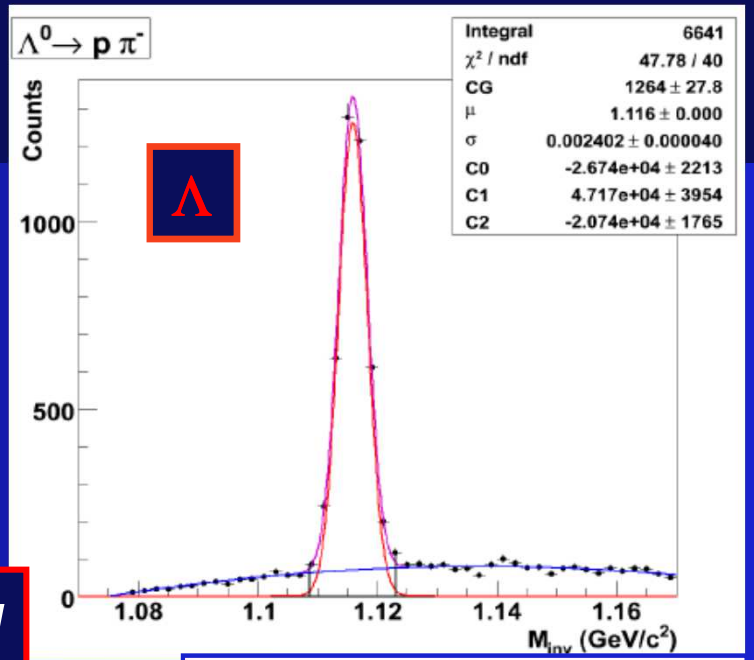
- **Coverage**: *$|\eta| < 1.4$, p_t=0.1-2 GeVc barrel $|\eta| < 2.6$, pt=0.1-2 GeVc barrel+EC*
- **Matching eff.**: *> 85% at $p_t > 0.5$ GeV/c*
- **PID:** *2σ π/K ~ 1.7 GeV/c, (π,K)/p ~ 2,5 GeV/c*

V0 performance (TPC+IT)

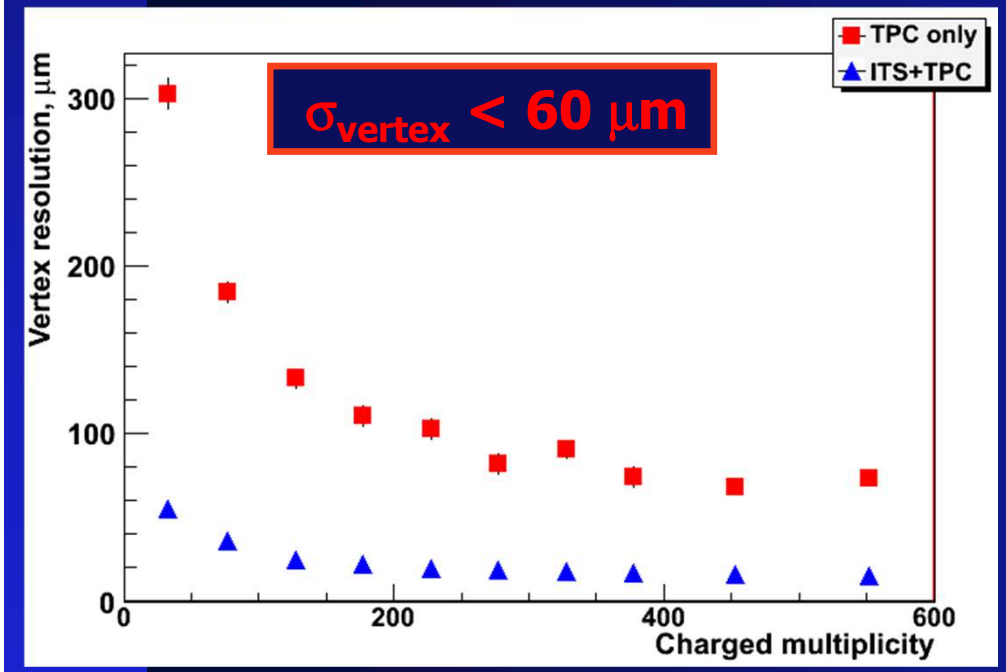


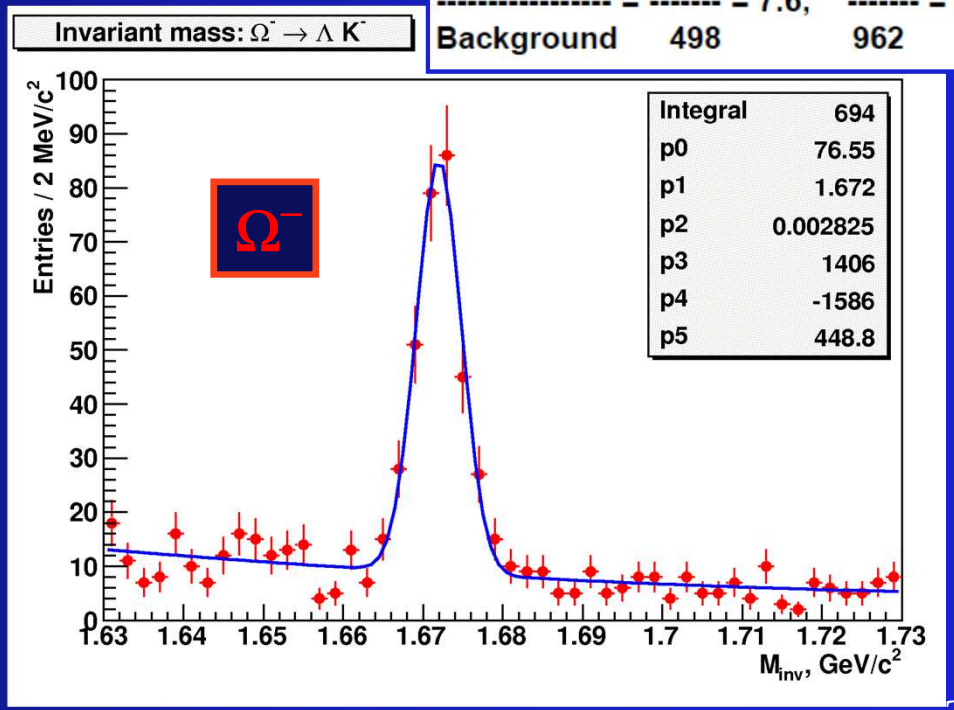


- *Improved Sg-to-Bg ratio (S/B) with the vertex IT detector*

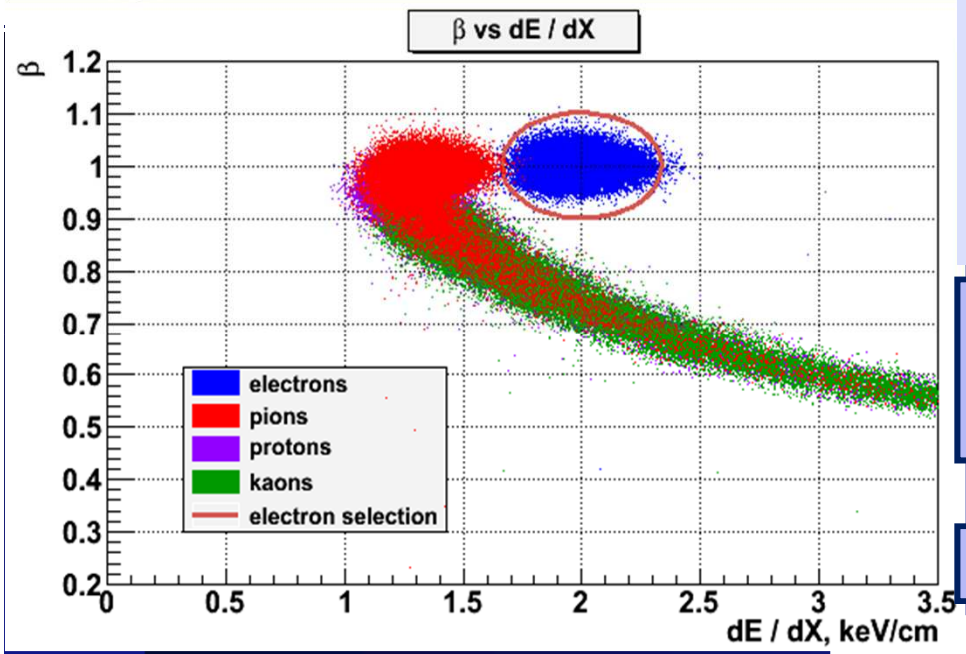


	Λ^0	K_s^0
Signal	3796	4845
---------- = ------- = 7.6;		------- = 5
Background	498	962





Dileptons: e+e-



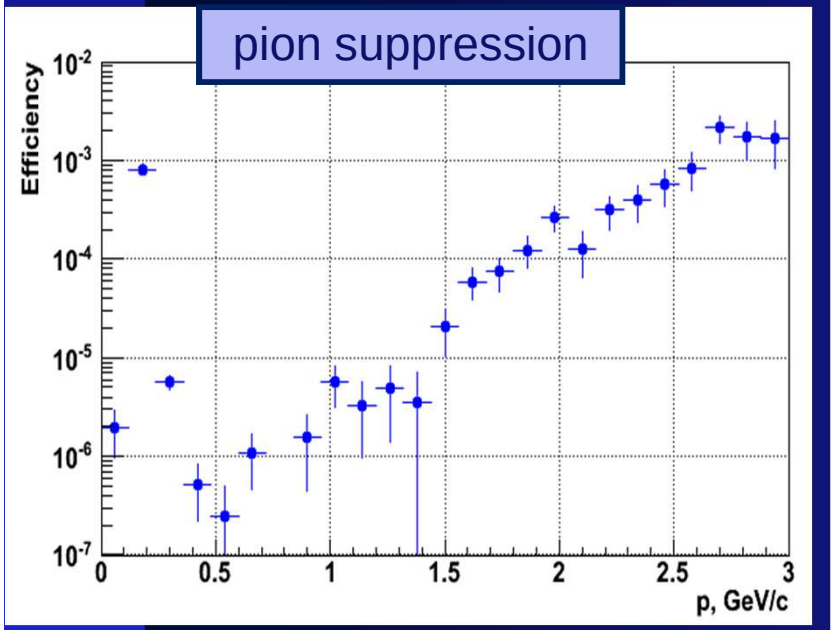
Input : central Au+Au at 7 GeV, Pluto + RQMD

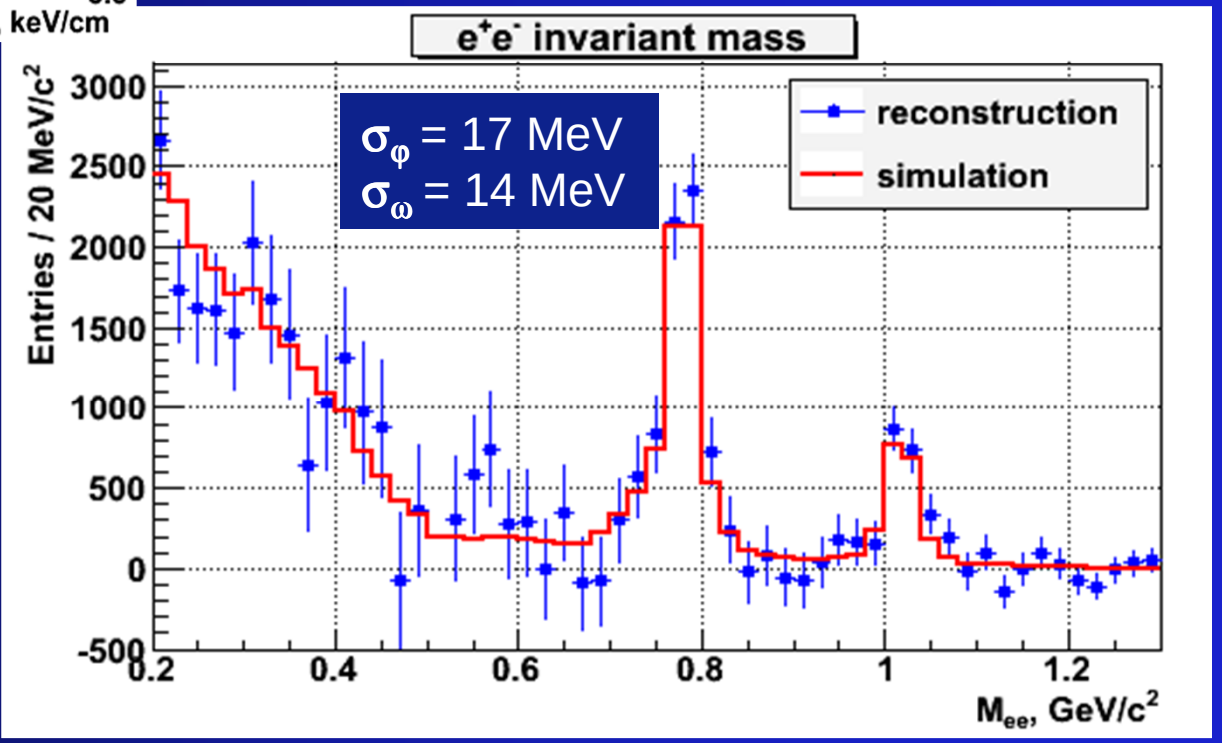
- track selection and e-conversion suppression
- PID by dE/dx & TOF, hadron suppression ~ 10^{-5}
- Extra suppression by ECAL

efficiency: **35%**
misID contamin.: -**19.0**% *(w/o cut on **ECAL** signal)*
- **1.4**% *(w cut on **ECAL** signal)*

Selection: $|\eta| < 1.2$; $0.2 < P < 2.0$ GeV/c

pion suppression





Cooperation @ Nuclotron-M / NICA experiments

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

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

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 an important part of HI program

Concluding Remarks

- The Nuclotron program is going through structural reorganization
- The NICA accelerator complex is well developing & is approaching to the phase of state expertise
- The two physics projects BM@N & MPD are targeting to the HI physics frontiers
- The corresponding collaborations are growing & NICA is getting an international recognition
- New members are welcome & the second Interaction Point is waiting for Your PROPOSALS !

Thank you