Physics @ NICA, JINR

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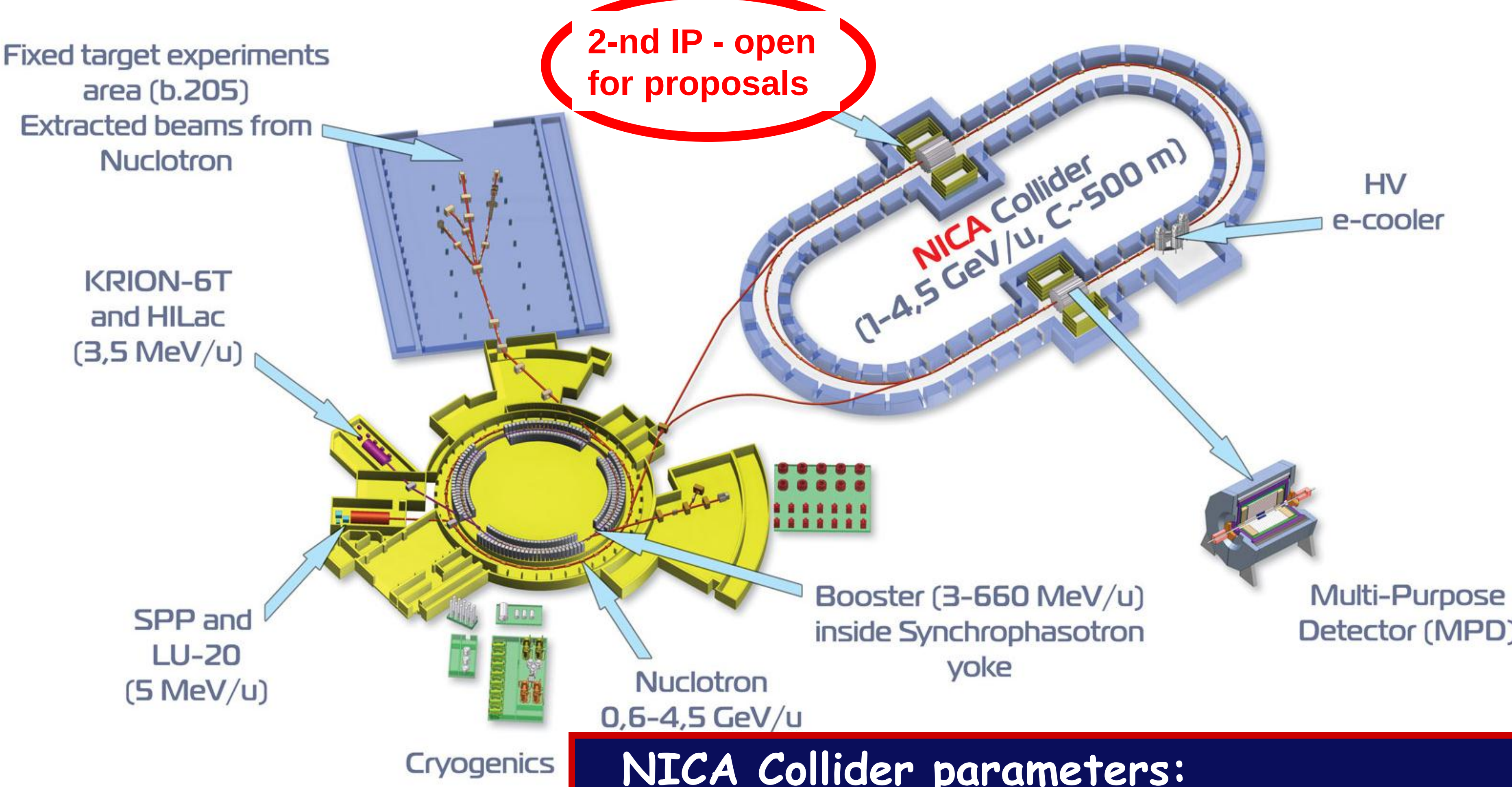
*XXXVI International Conference on High Energy Physics,
4-11 July, Melbourne, Australia*

Superconducting accelerator complex NICA
(Nuclotron based Ion Collider fAcility)

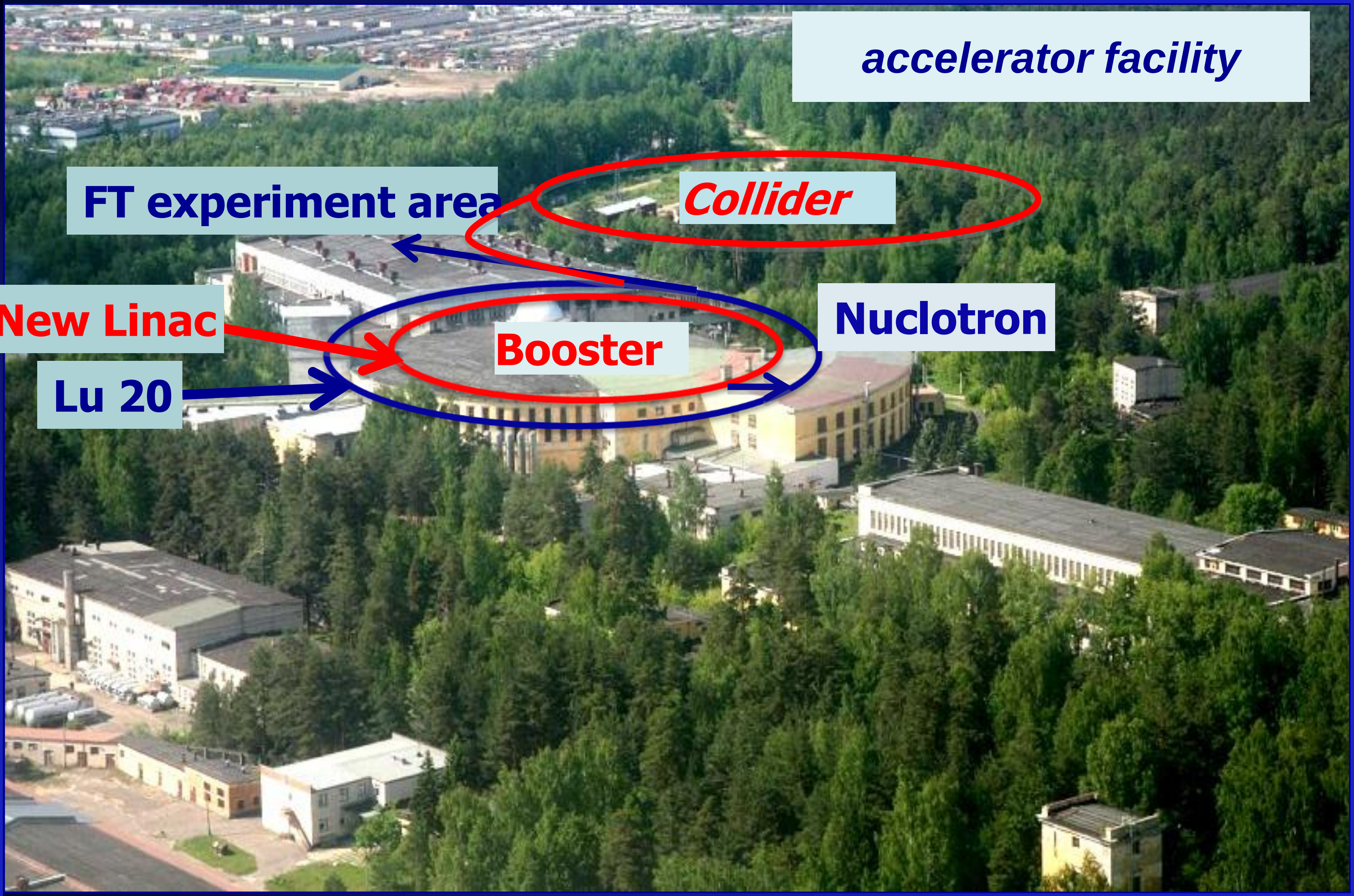


see details in tomorrow report of Prof. G.Trubnikov: NICA @ JINR (r.218, 10:15)

NICA Collider parameters:

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

Veksler & Baldin Laboratory of High Energy Physics, JINR



Main targets of "NICA Complex":

- *study of hot and dense baryonic matter*

& 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)***

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

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

Barionic Matter @ Nuclotron *(2015)*

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

NICA Collider
the 1-st IP
(2017)

MultiPurpose Detector *(2017)*

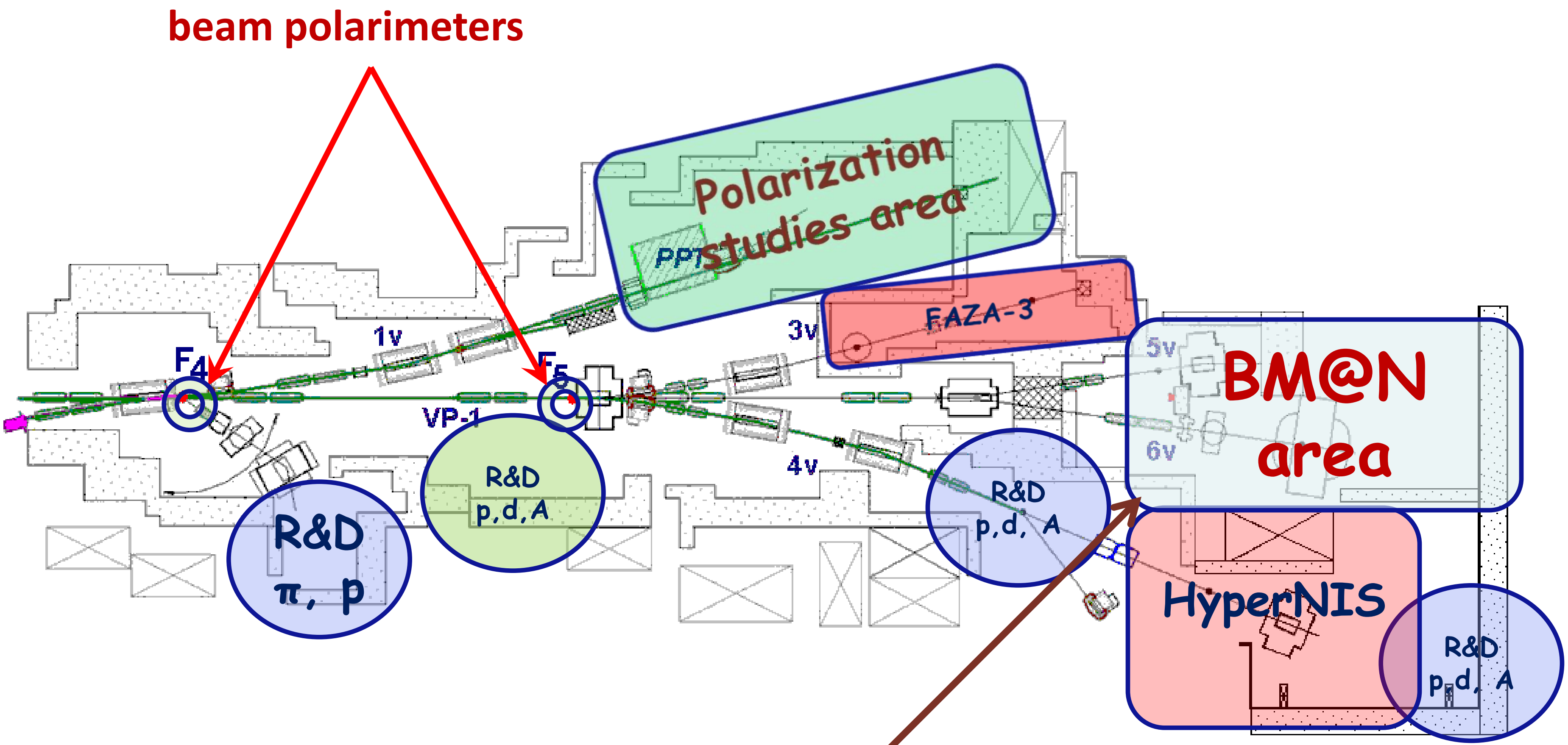
approved, in preparation

running experiments

NICA Collider
the 2-nd IP
(2017)

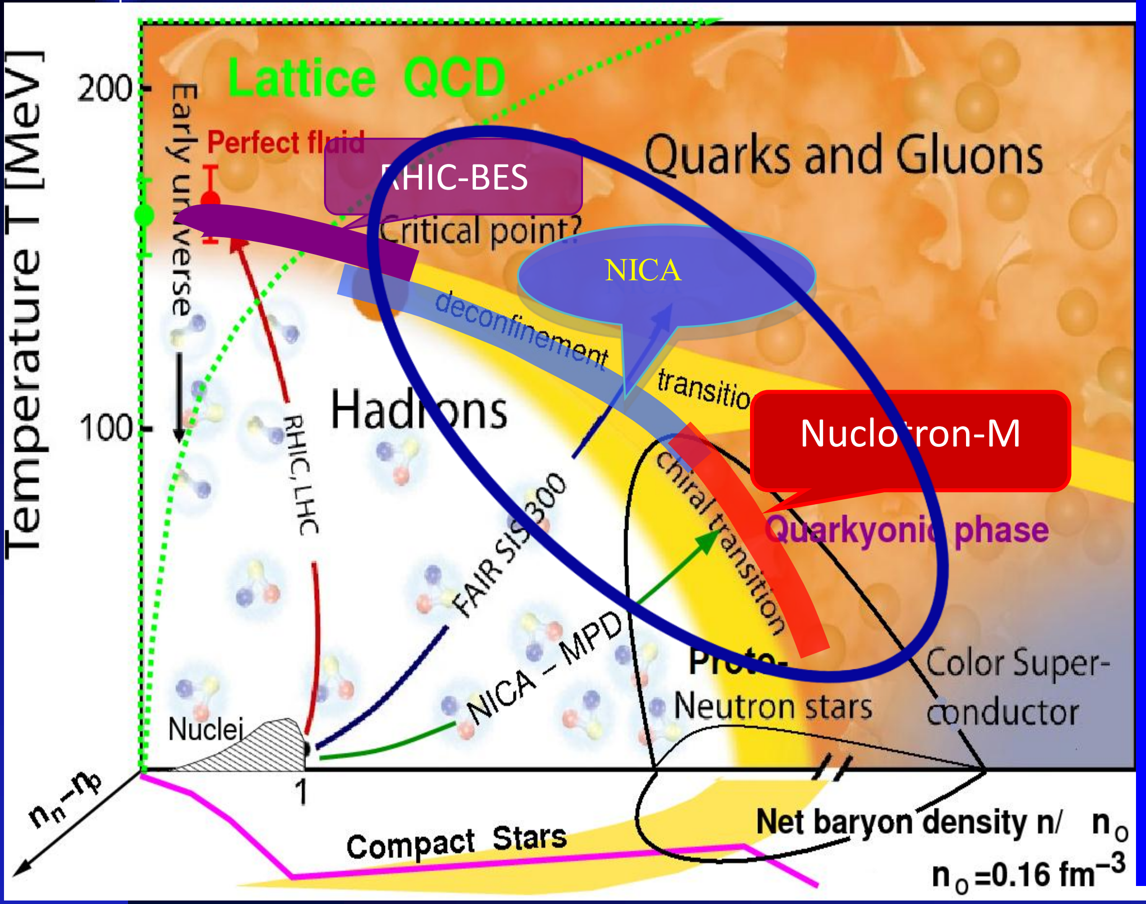
open for proposals

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



Baryonic Matter at Nuclotron (DBM@N)

QCD phase diagram - Prospects for NICA

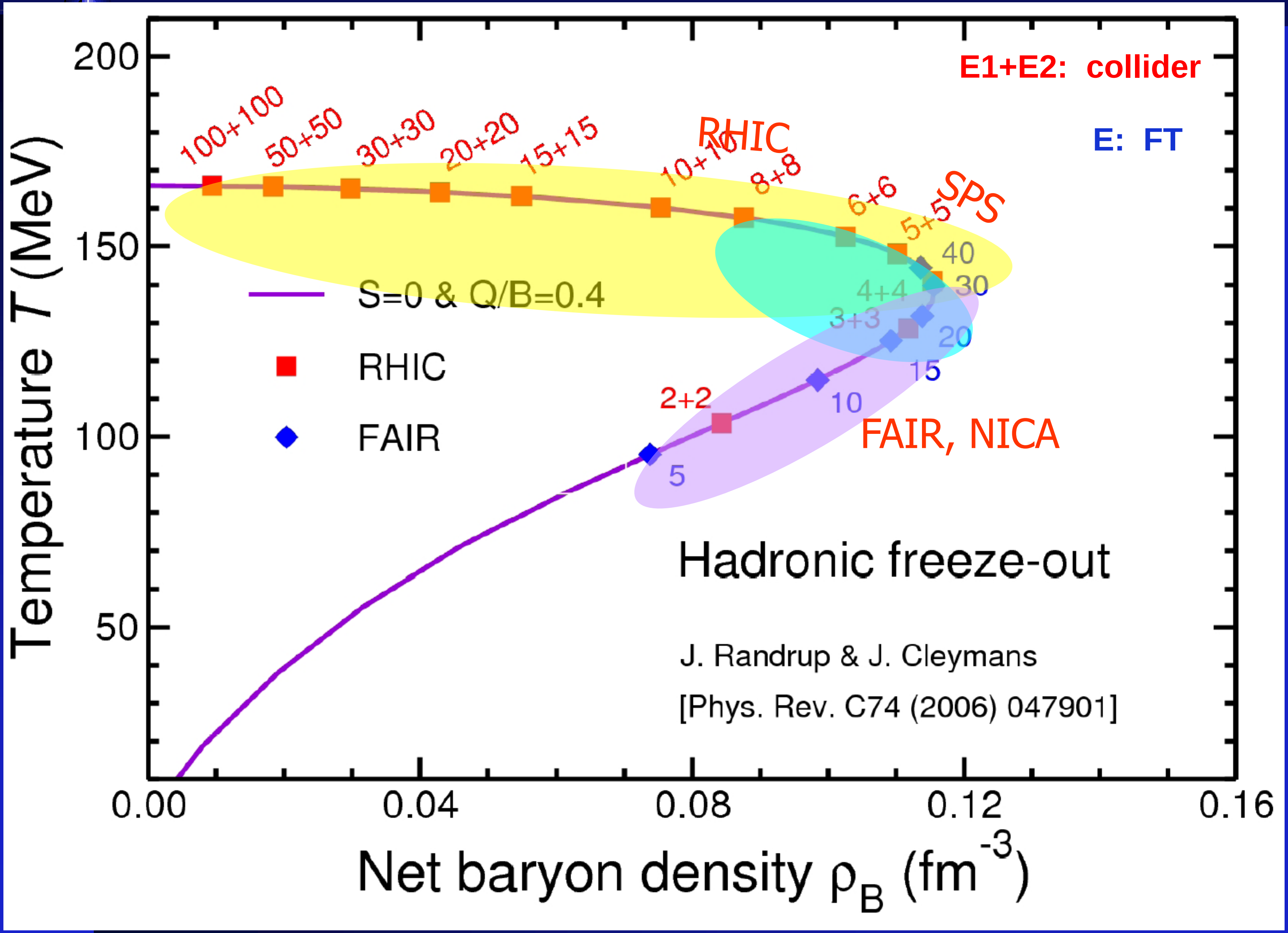


Energy Range of NICA
unexplored region of
the QCD phase diagram:

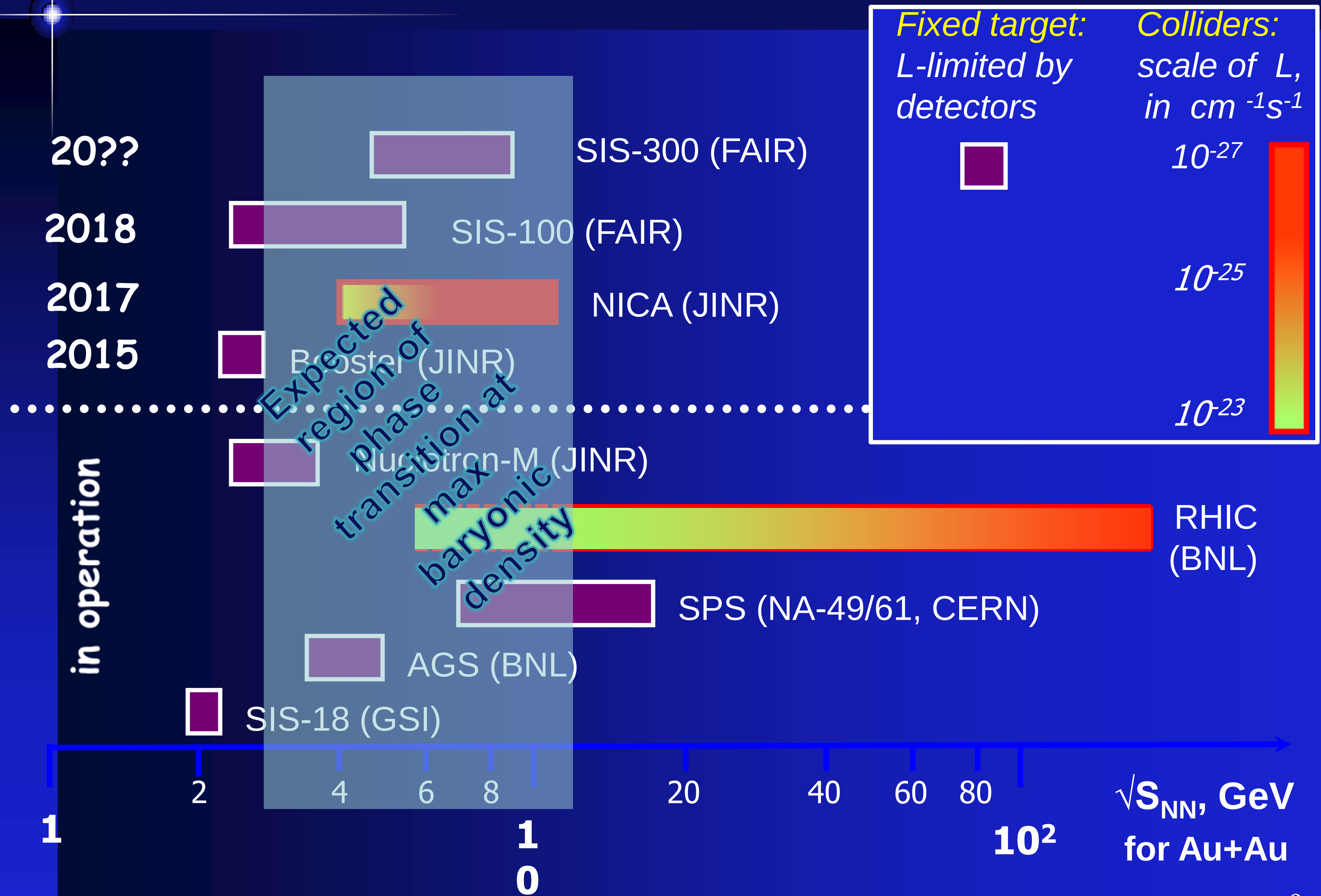
- Highest net baryonic density
- Onset of deconfinement & phase transition
- Discovery potential:
  a) Critical End Point (CEP)
  b) Chiral Symmetry Restoration
- Complementary to the RHIC/BES, FAIR, CERN experimental programs

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



beams extracted from Nuclotron-M-NICA

covers the gap between SIS-18 and AGS *(with some overlaps)*

	Z/A	**max** $\sqrt{s_{NN}}$ *(GeV/n)*	**max.** T_{kin} *(GeV/n)*
p	***1***	$\approx$ ***5.2***	$\approx$ ***12***
d	***1/2***	$\approx$ ***3.8***	$\approx$ ***5.7***
			(including polarized deuterons)
Au	***0.4***	$\approx$ ***3.5***	$\approx$ ***4.5***

These allow:

- *study of dense baryonic matter at temperatures up to **100** MeV,*
- *(multi)-strangeness (open & hidden) production in dense baryonic matter,*
- *modification of particle properties in dense nuclear matter*

The corresponding multi-purpose setup

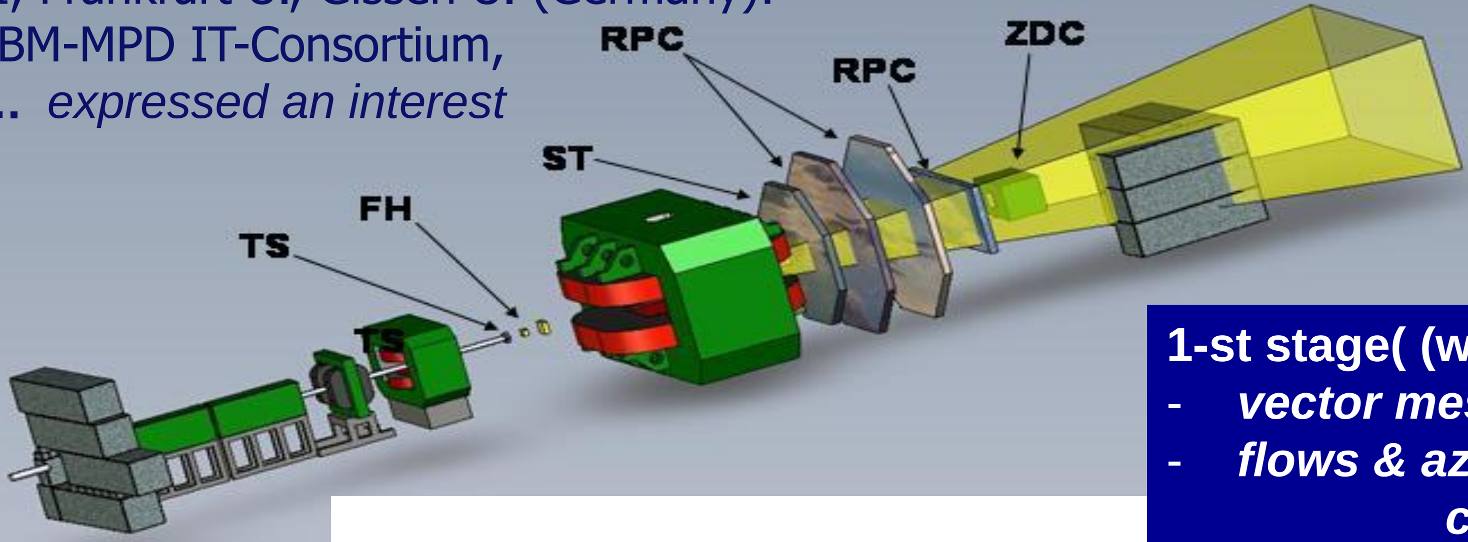
Baryonic Matter at Nuclotron (BM@N)

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	-	--- „ ---	$1 \cdot 10^{9}$

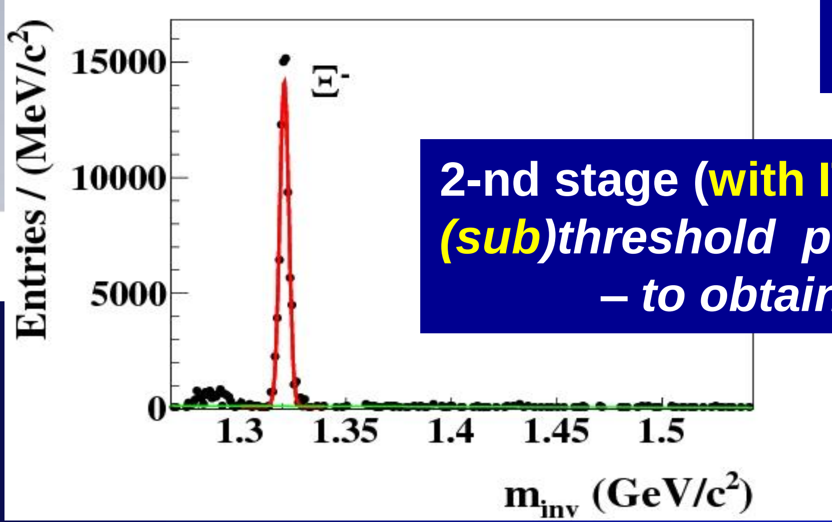
BM@N Collaboration

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*

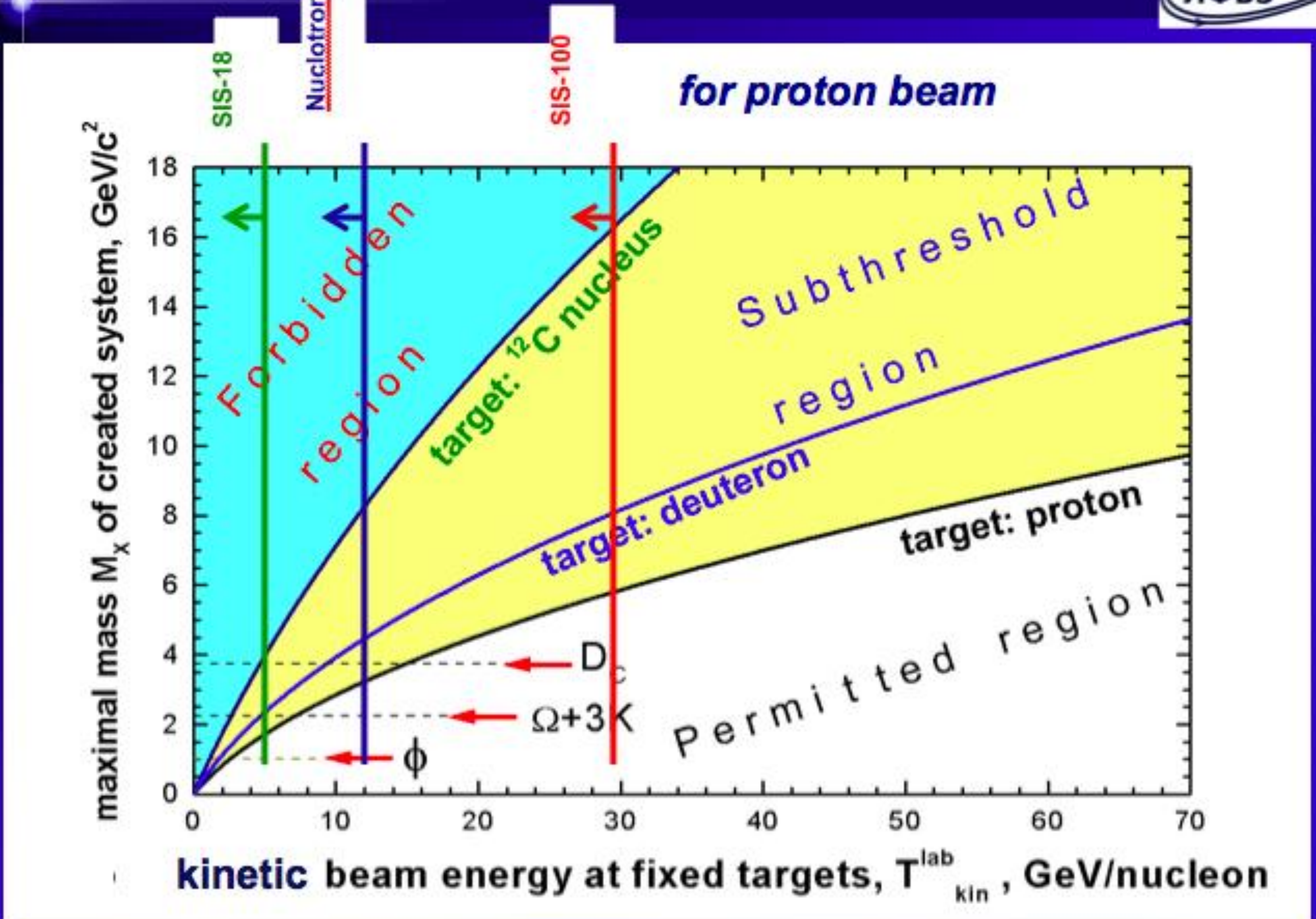


1-st stage((w/o IT):
- *vector mesons*
- *flows & azhimuthal correlations*
- *femtoscopy*

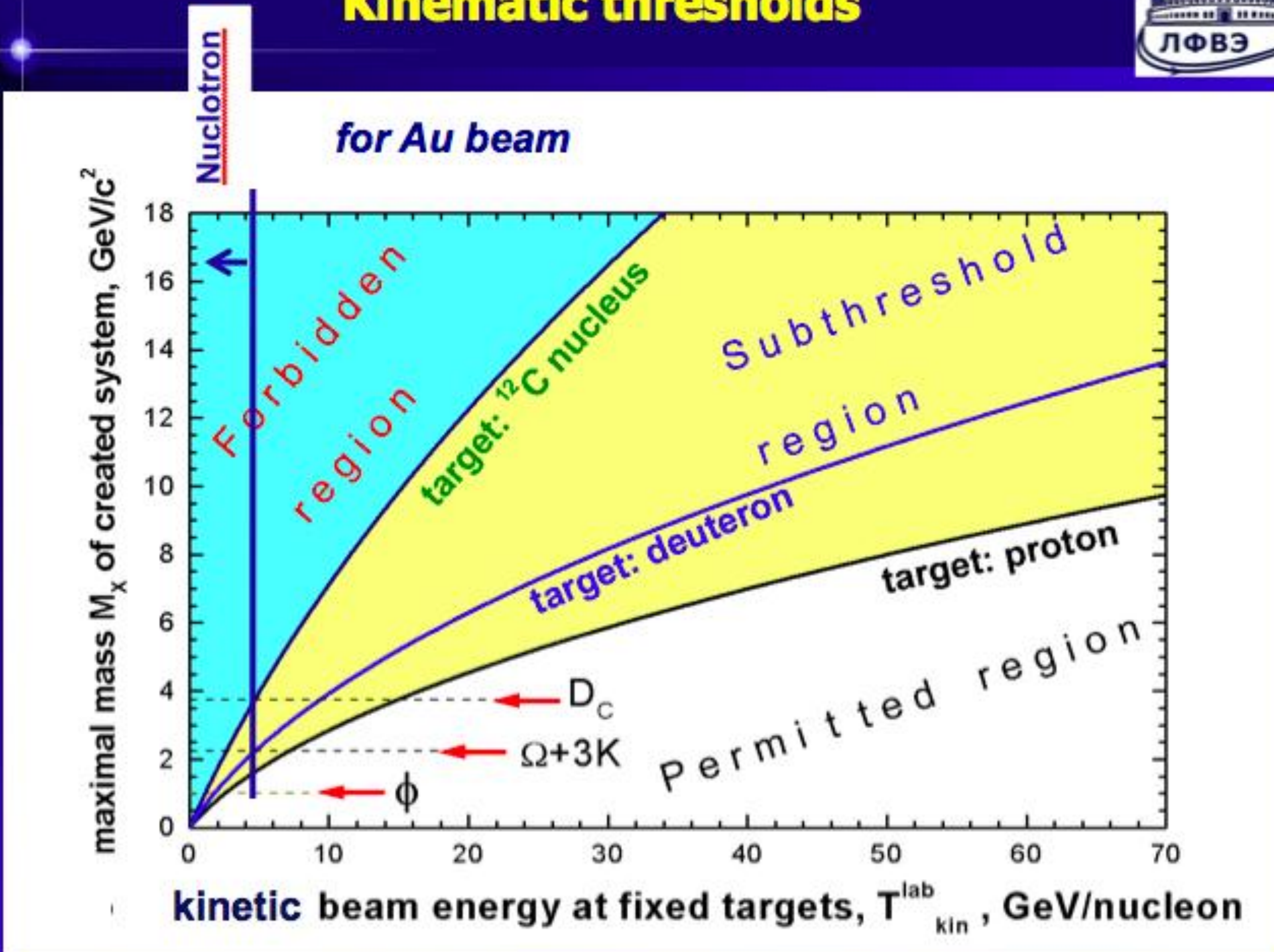


2-nd stage (with IT):
(sub)threshold production of cascades – to obtain the information on EOS

Kinematic thresholds



Kinematic thresholds



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.

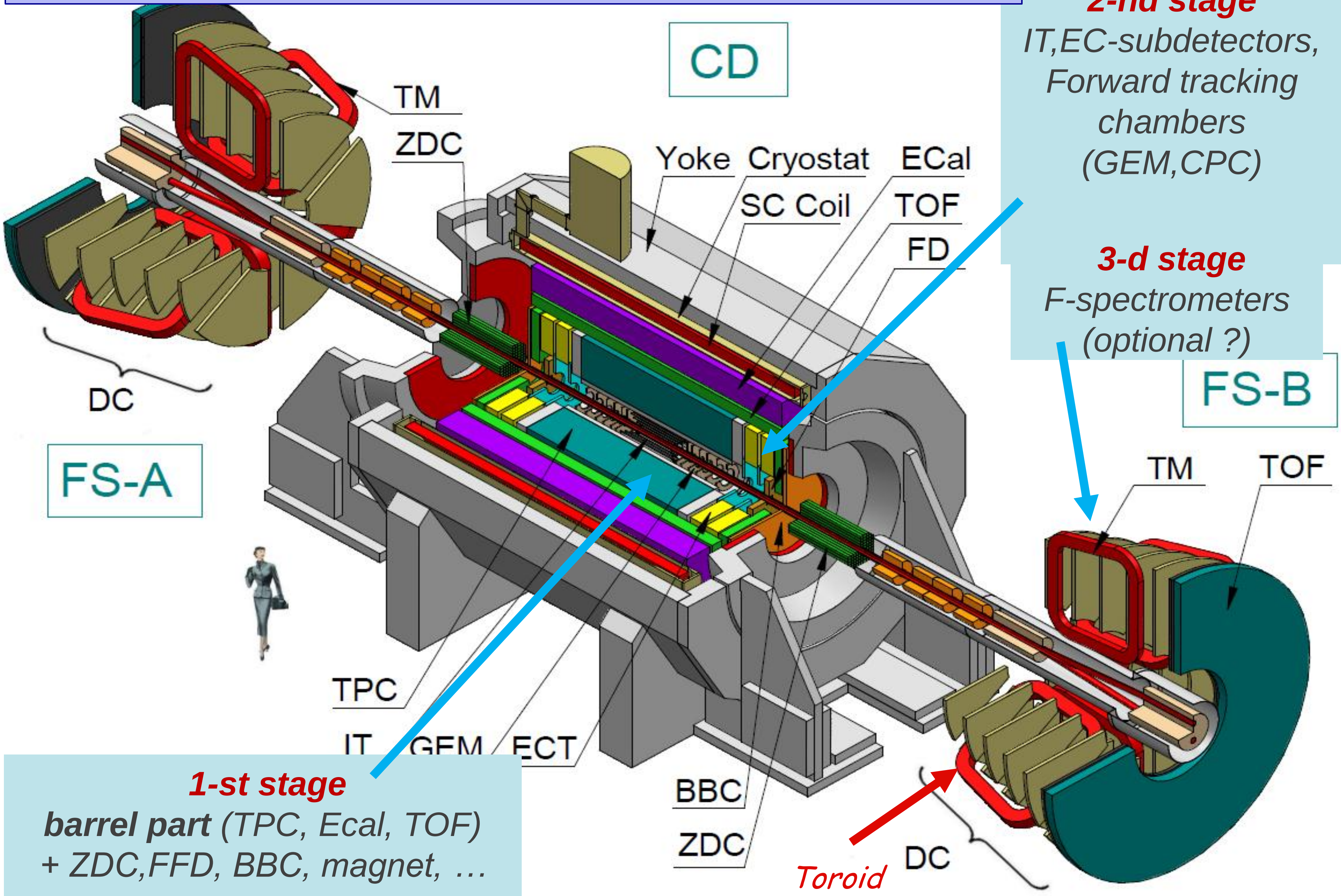
- **pA, nA, dA interactions in direct & inverse (Ap, Ad) kinematics:**
  - to get a "reference" data set for comparison with AA interactions,
  - to look for polarization effects in particle production off nuclear targets by polarized d, p, n.

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 is Scan of the QCD phase diagram

Strategy:

detailed energy & system size scan

*with a step ~ **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,

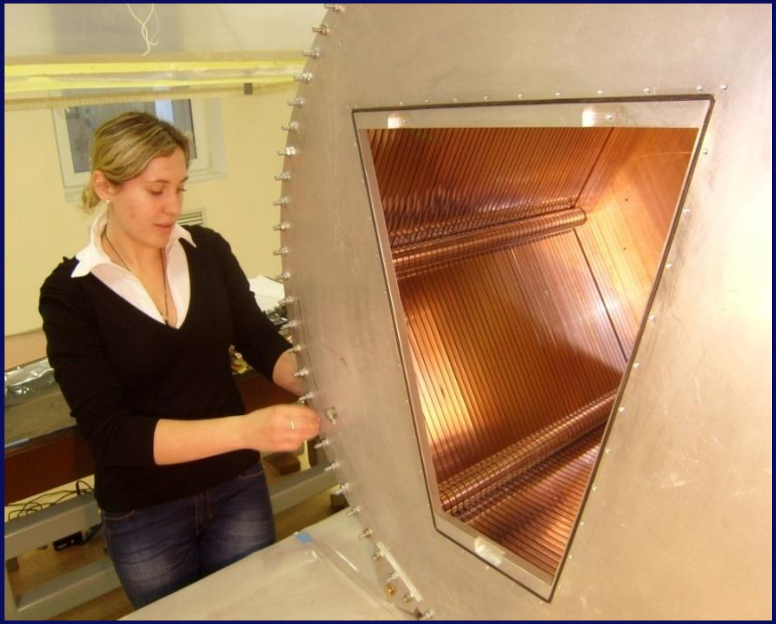
- study of the properties of the mixed phase of strongly interacting matter.

MPD

progress in R&D

Straw full scale prototype for EC tracking

Technological TPC prototype

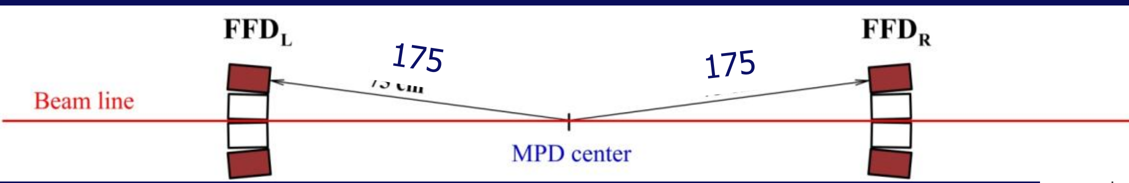


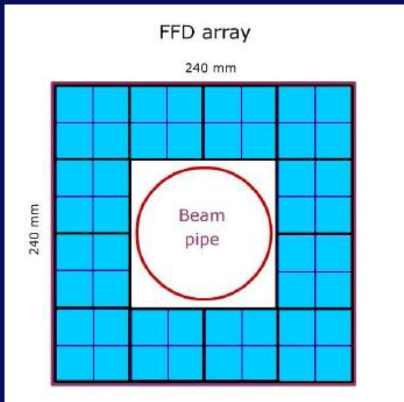
Material:
Kevlar laminated by Tedlar film

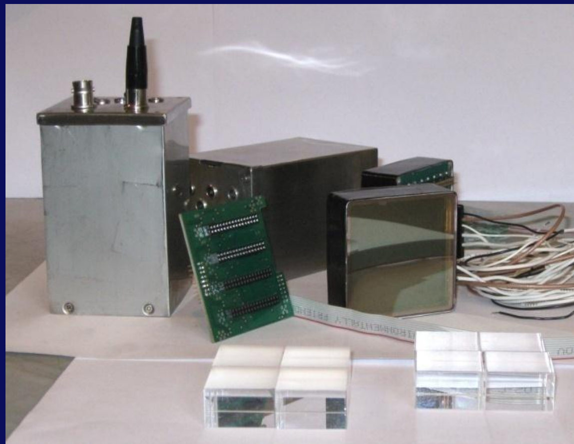
Diameter - 950 mm
Length - 900 mm
Wall thickness - 2 mm
Weight ~ **10 kg**

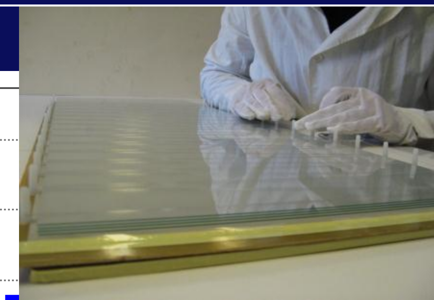
Fast Forward Detector (FFD)

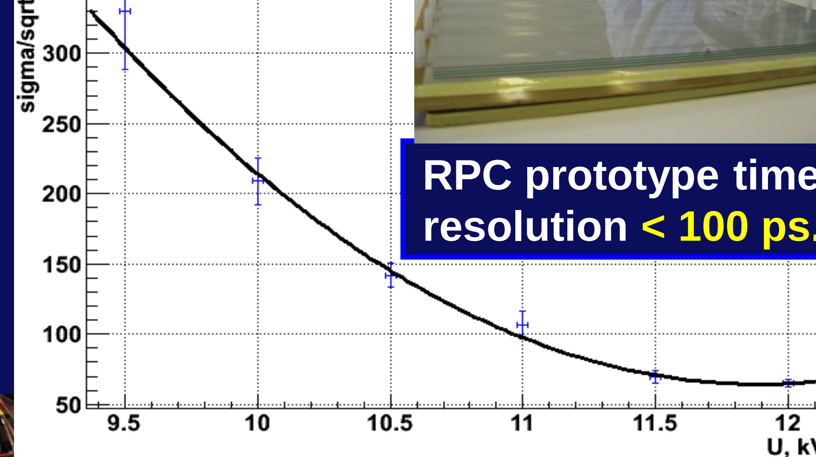
tests of full scale RPC prototype



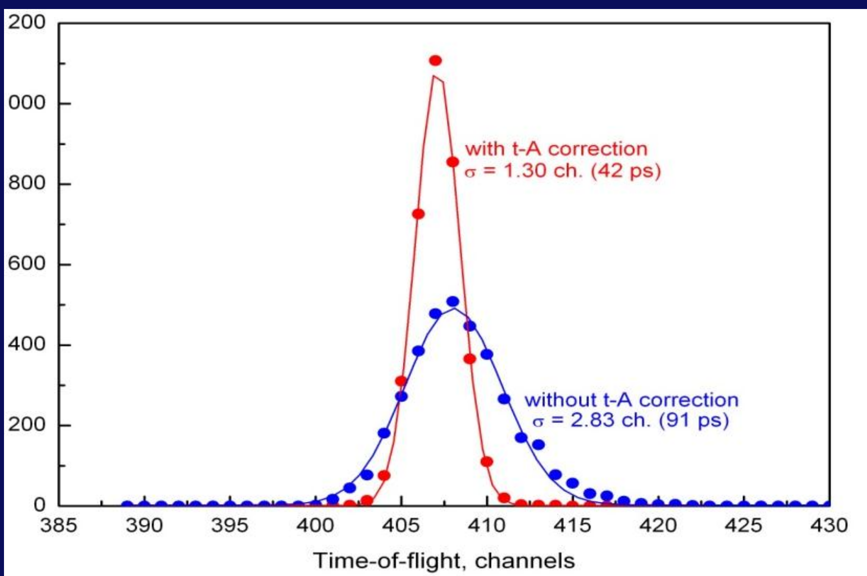


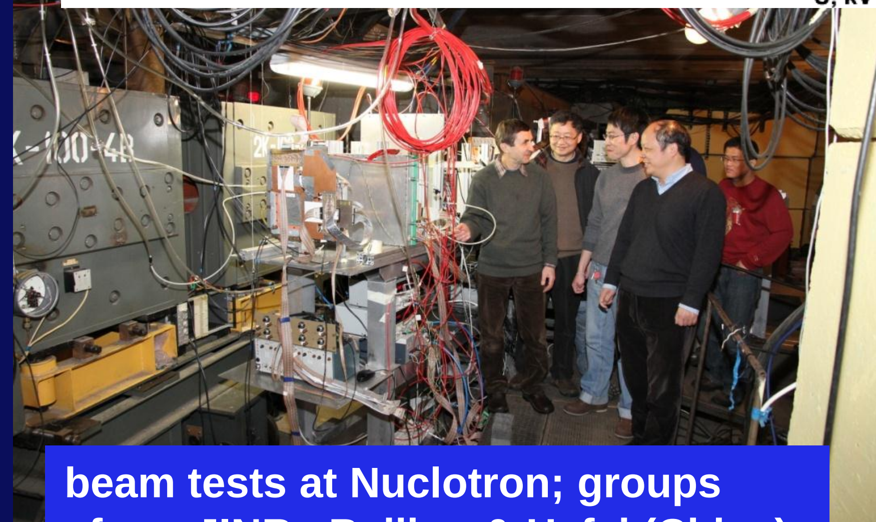






RPC prototype time resolution < 100 ps.





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

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

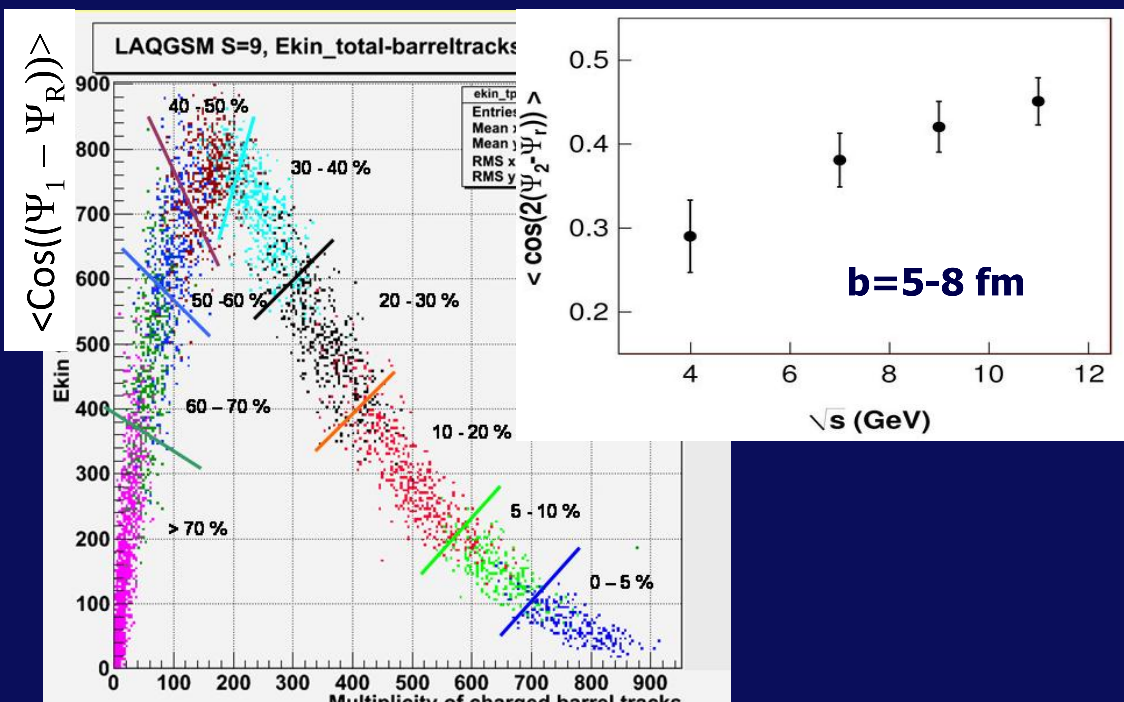
Reaction plane determination & flow study

- ✓ 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

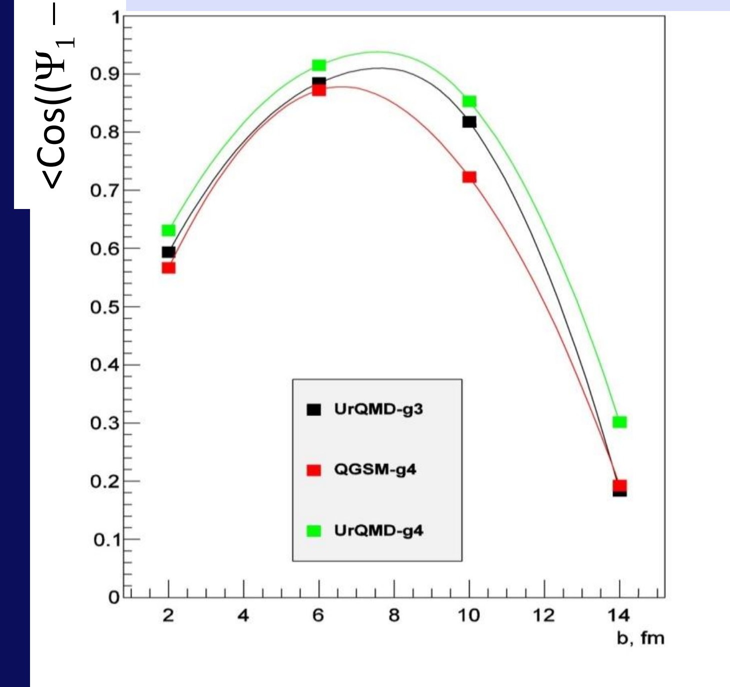
Extended ZDC detector ($2<\eta<5$)
improves RP resolution
at low & medium b

- L = 120 (60) cm
- 5 < R < 71 cm, $1<\theta<14^o$ ($2<\eta<5$)

Event plane resolution for "central events"

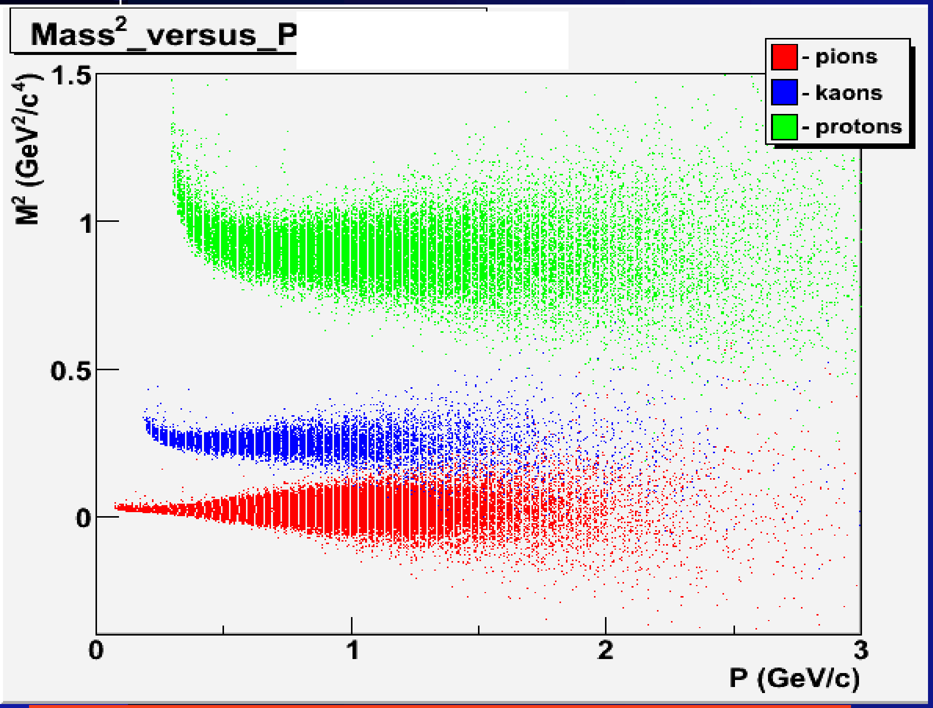


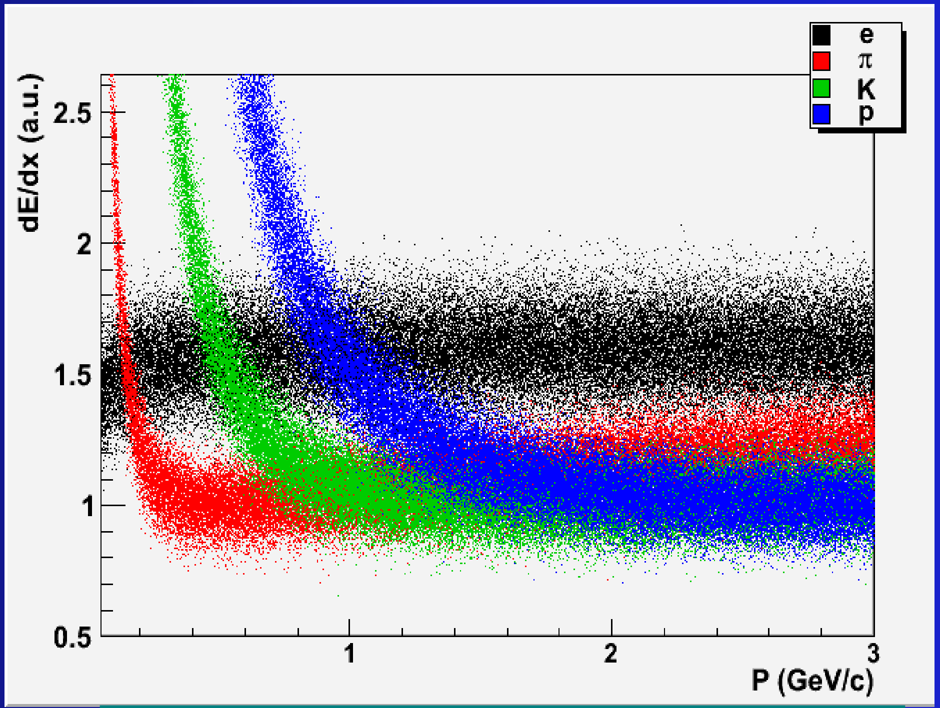
Event plane resolution with extended ZDC)



Particle IDentification in MPD

(realistic detector simulation)





PID: *Time Of Flight*

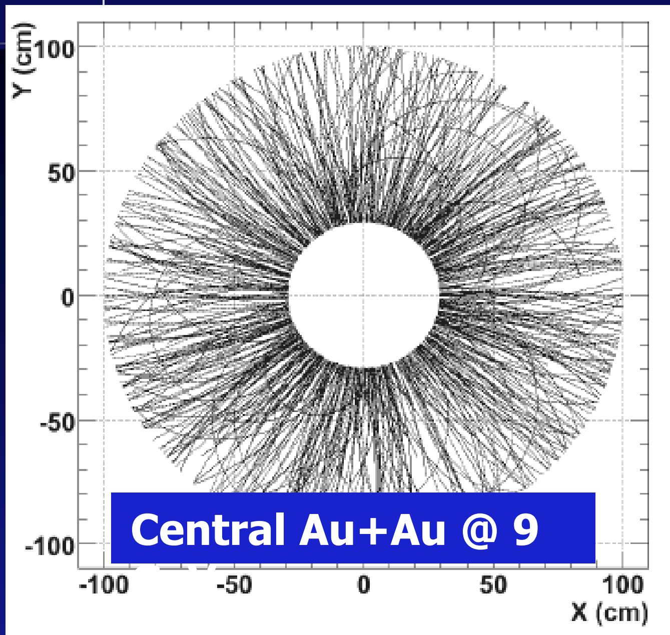
Separation: e/h – 0.1..0.35 GeV/c
π/K – 0.1..1.5 GeV/c
K/p – 0.1..2.5 GeV/c

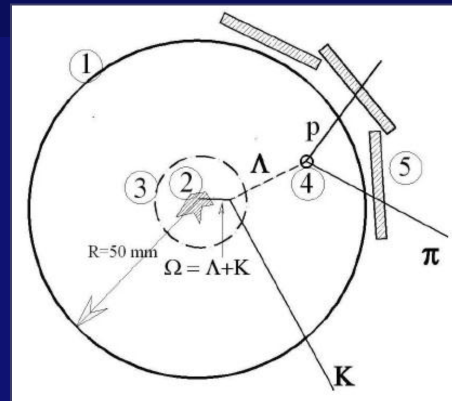
PID: *Ionization loss (dE/dx)*

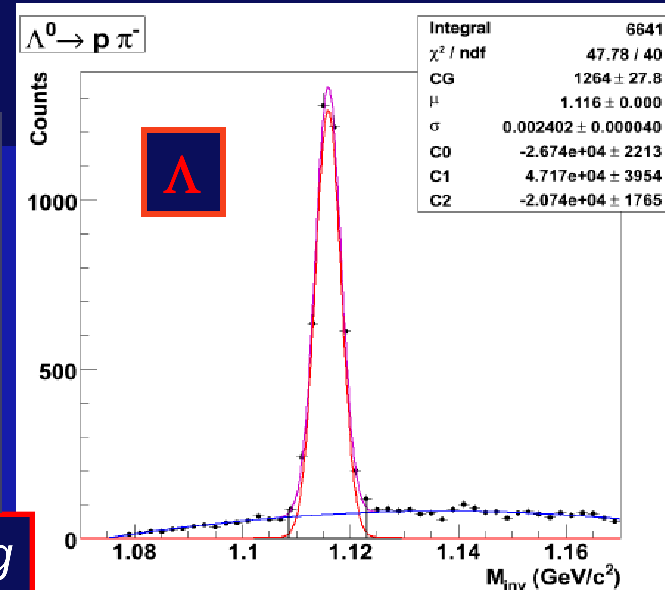
Separation: e/h – 1.3..3 GeV/c
π/K – 0.1..0.6 GeV/c
K/p – 0.1..1.2 GeV/c

- **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)

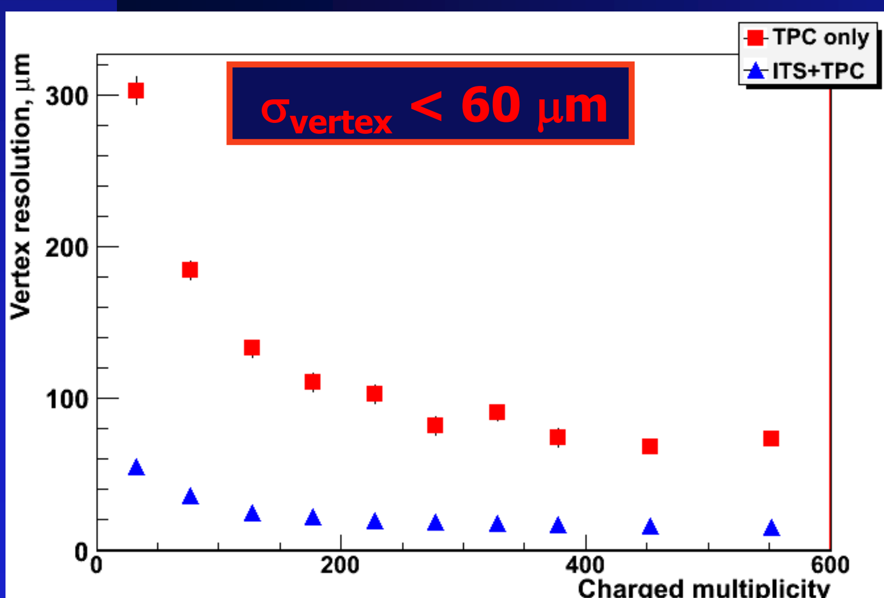


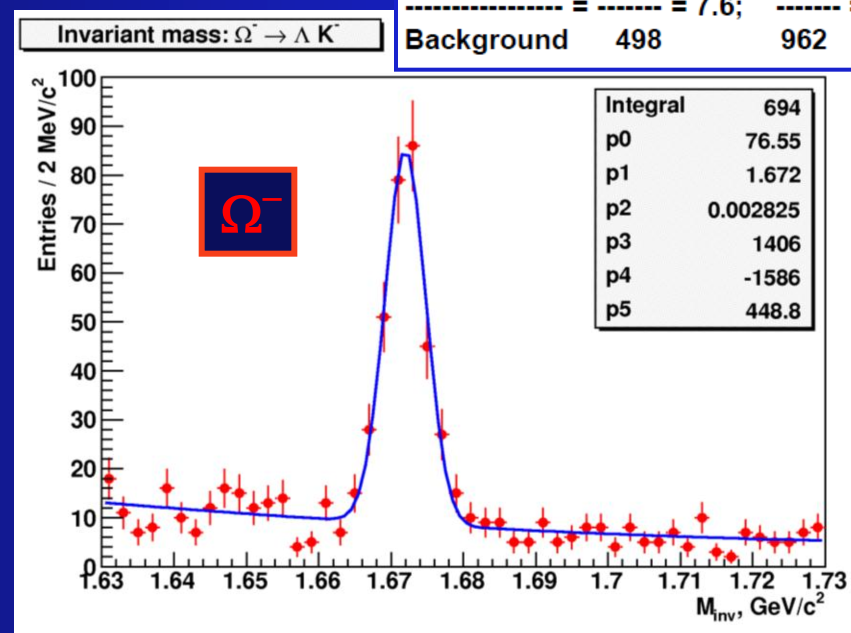




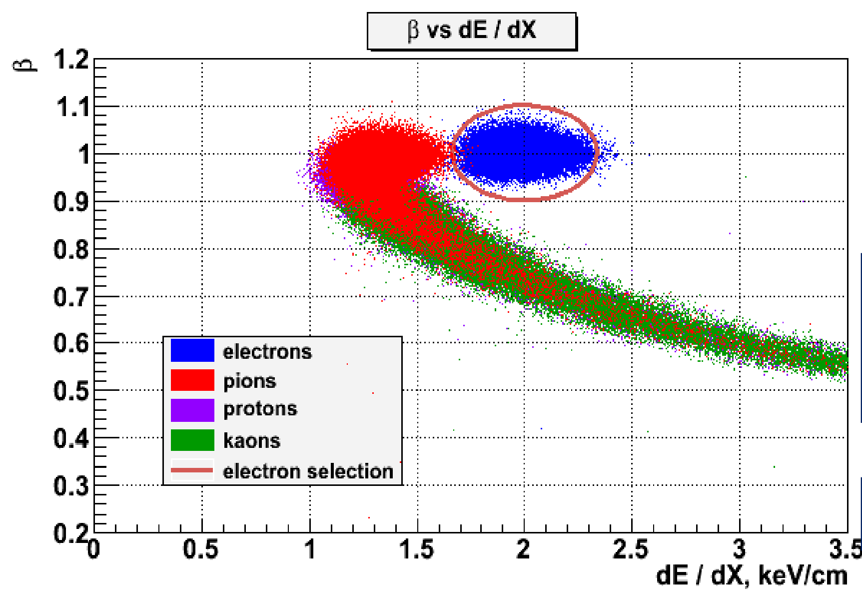
- *Improved Sg-to-Bg ratio (S/B) with the vertex IT detector*

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





Dileptons: e+e-



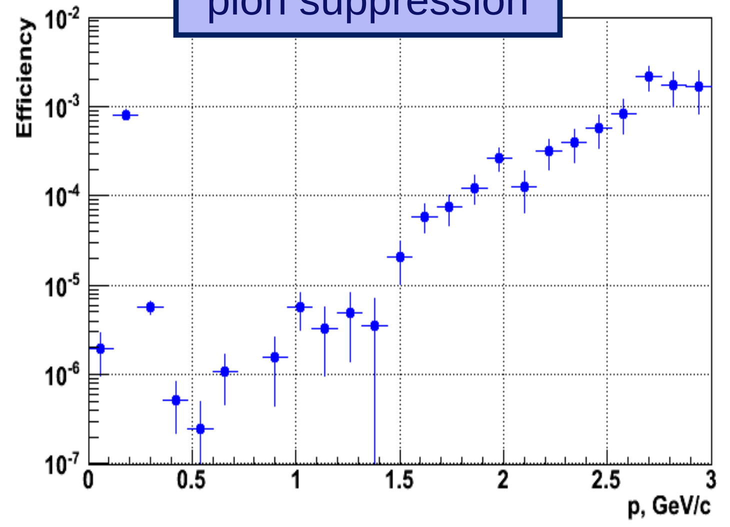
Input : central Au+Au at 7 GeV, Pluto + RQMD

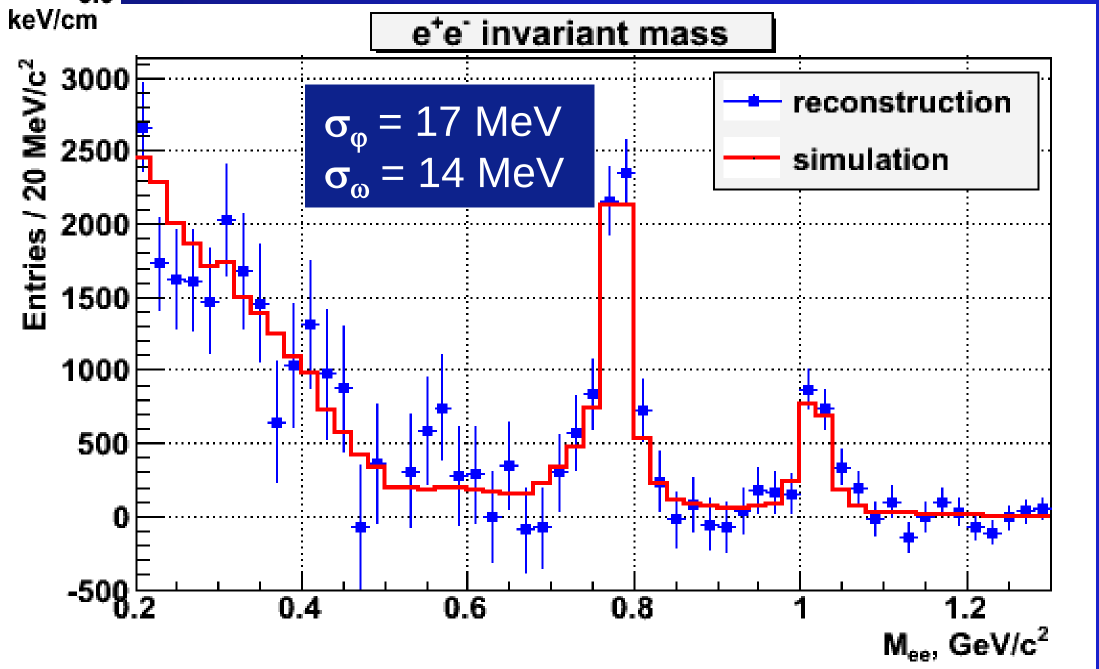
- track selection and e-conversion suppression
- PID by dE/dx & TOF, hadron suppression ~ 10^{-5}
- Extra suppression by ECAL

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

Selection: |η| < 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**

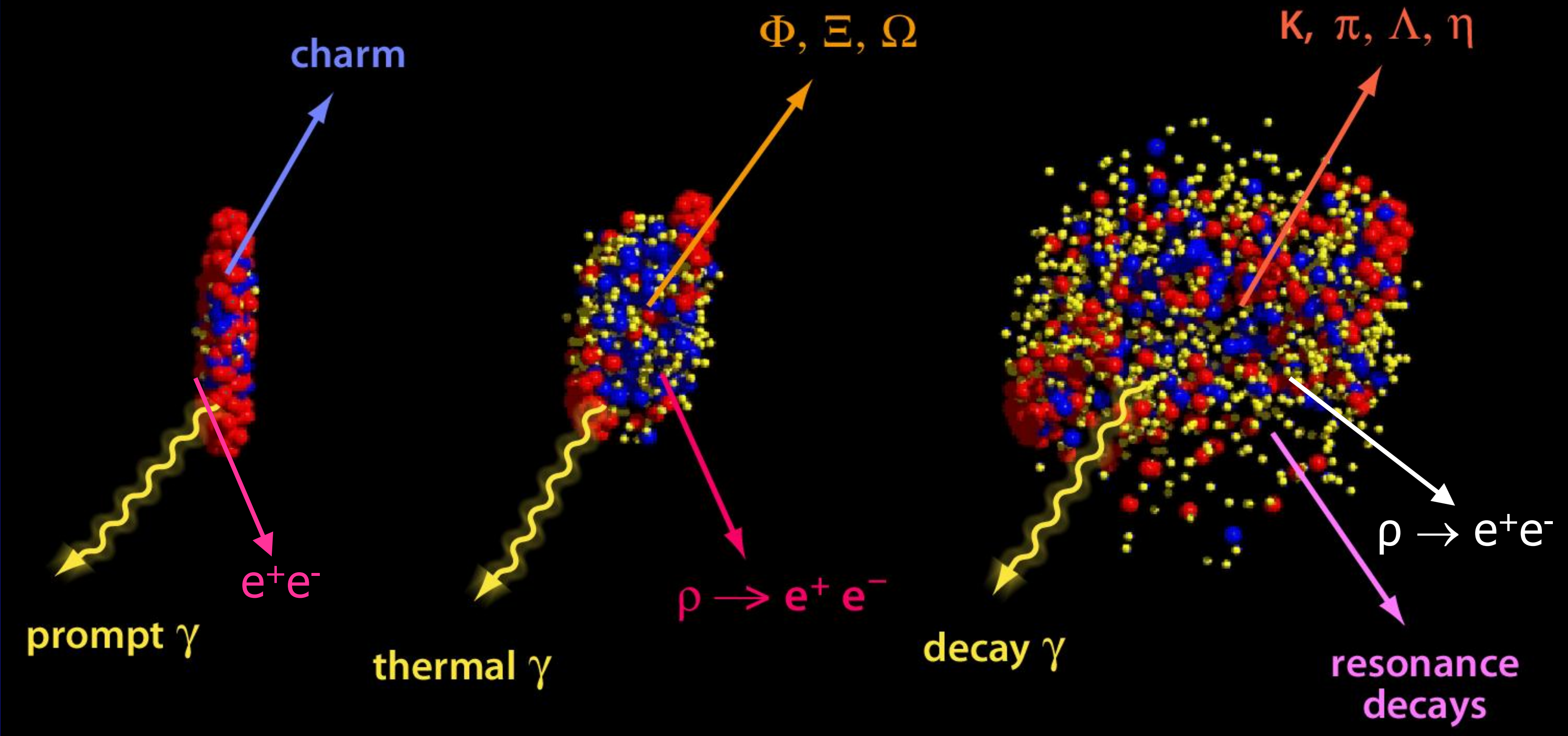
Concluding Remarks

- The BM@N TDR preparation
  & Collaboration formation
  - are going on
- The MPD R&D's are well progressing;
- The MPD final design - close to completion
  - under the permanent supervision
  by the external referee's
- New participants are welcomed to join
  to BM@N &/or MPD projects
- The second Interaction Point is waiting for

Your PROPOSALS !

Thank you

spare



charm
Φ, Ξ, Ω
K, π, Λ, η
e^+e^-
prompt γ
thermal γ
ρ → $e^+ e^-$
decay γ
ρ → e^+e^-
resonance decays