Prospects for the study of heavy-ion collisions at the NICA collider @ JINR

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(JINR)

On behalf of NICA-MPD

The European Physical Society Conference
on High Energy Physics
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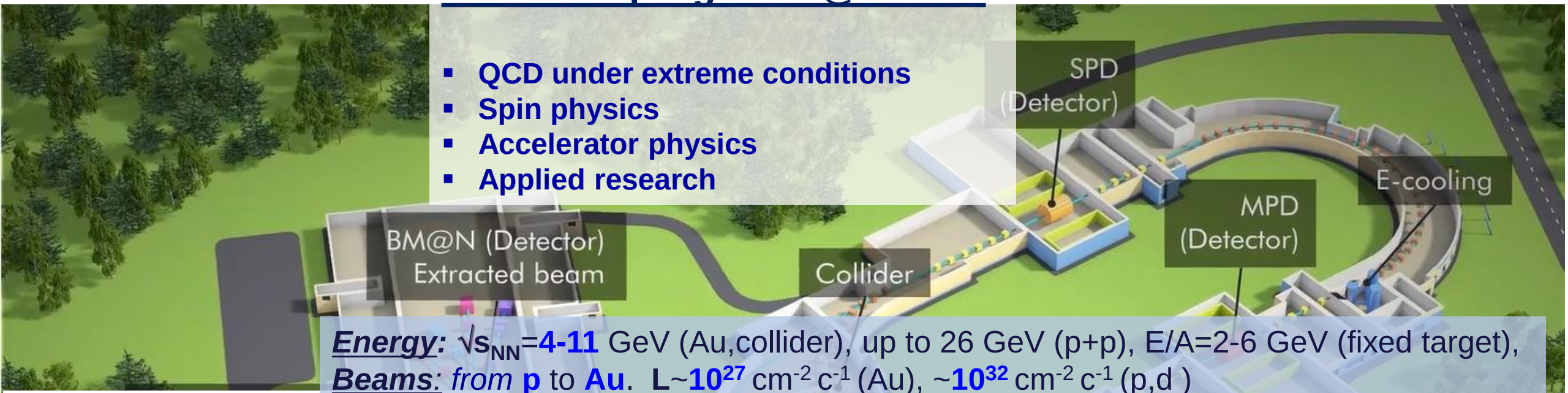
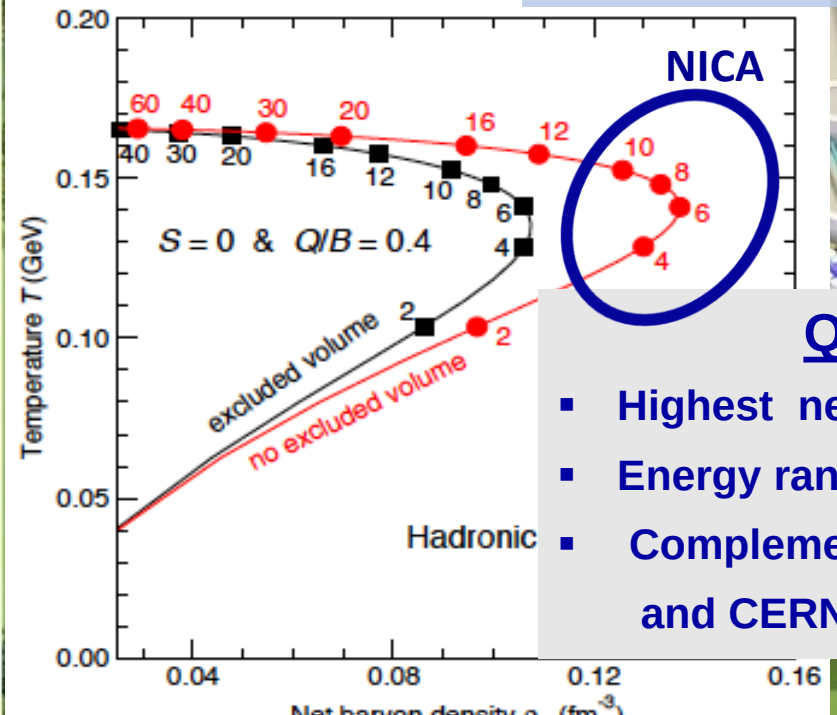
Research programs @ NICA

- QCD under extreme conditions
- Spin physics
- Accelerator physics
- Applied research

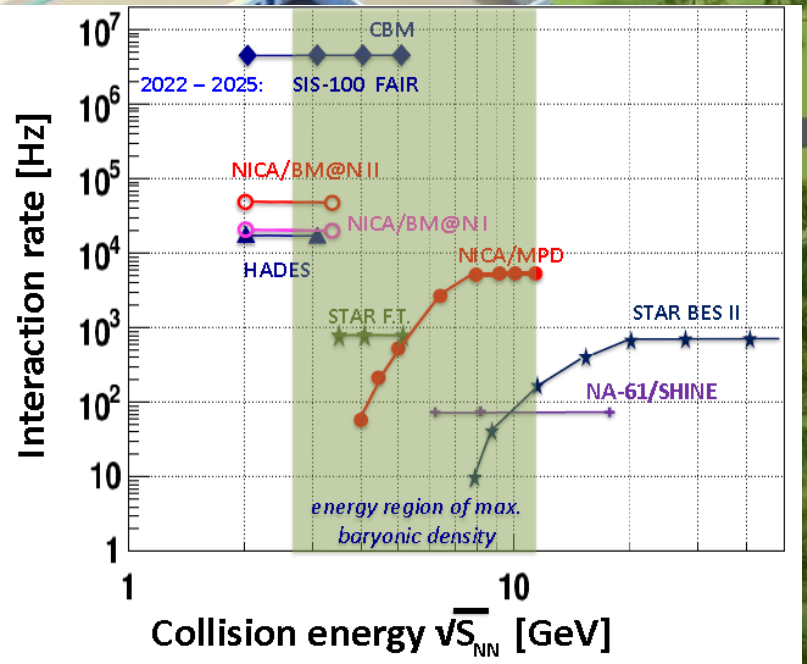


Energy: $\sqrt{s_{NN}}$=**4-11** GeV (Au,collider), up to 26 GeV (p+p), E/A=2-6 GeV (fixed target),
Beams: *from* **p** to **Au**. **L~10^{27}** cm^{-2} c^{-1} (Au), ~**10^{32}** cm^{-2} c^{-1} (p,d)



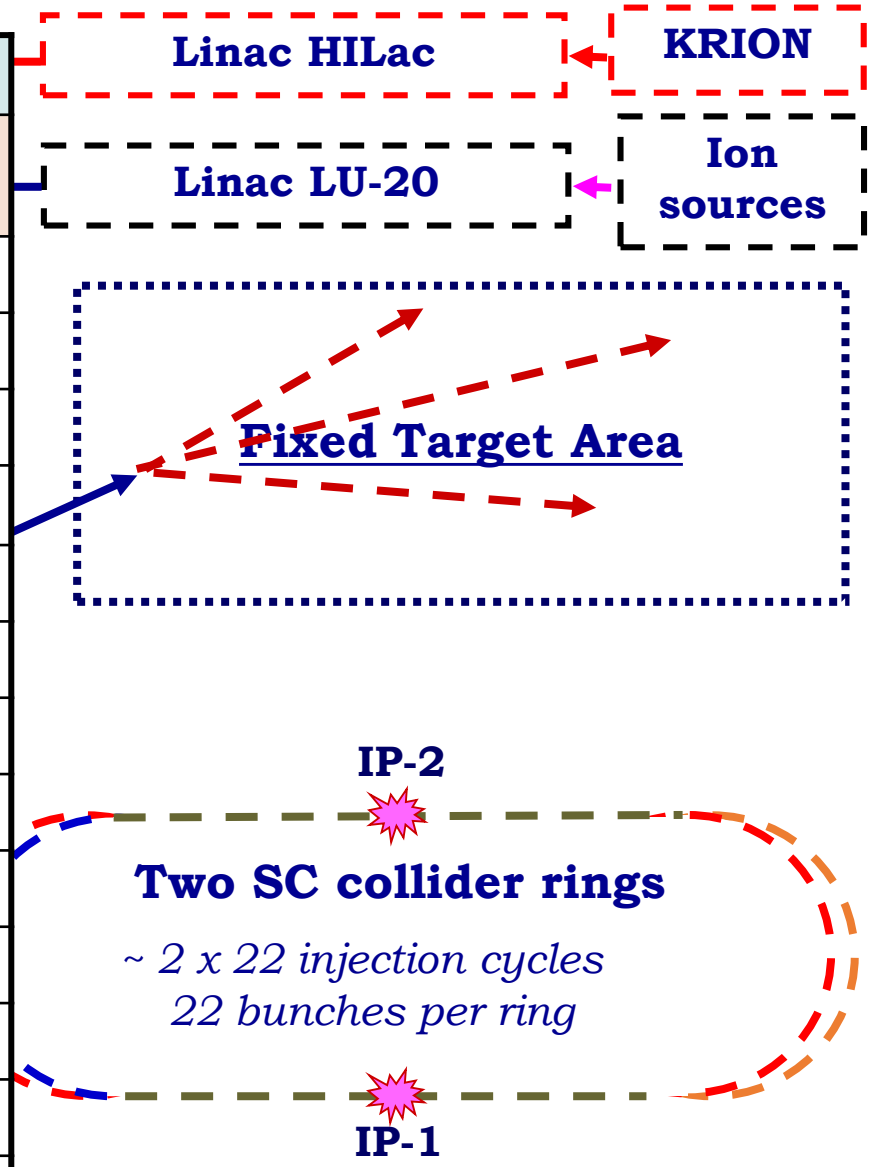
QCD matter at NICA :

- Highest net baryon density
- Energy range brackets onset of deconfinement
- Complementary to the RHIC/BES, FAIR, and CERN experimental programs



NICA : Structure and Operation Regimes

Beam	Nuclotron beam intensity (particle per cycle)		
	Current	Ion source type	at NICA
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")	$5 \cdot 10^{10}$
^{40}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	-	--- ,, ---	$1 \cdot 10^{9}$

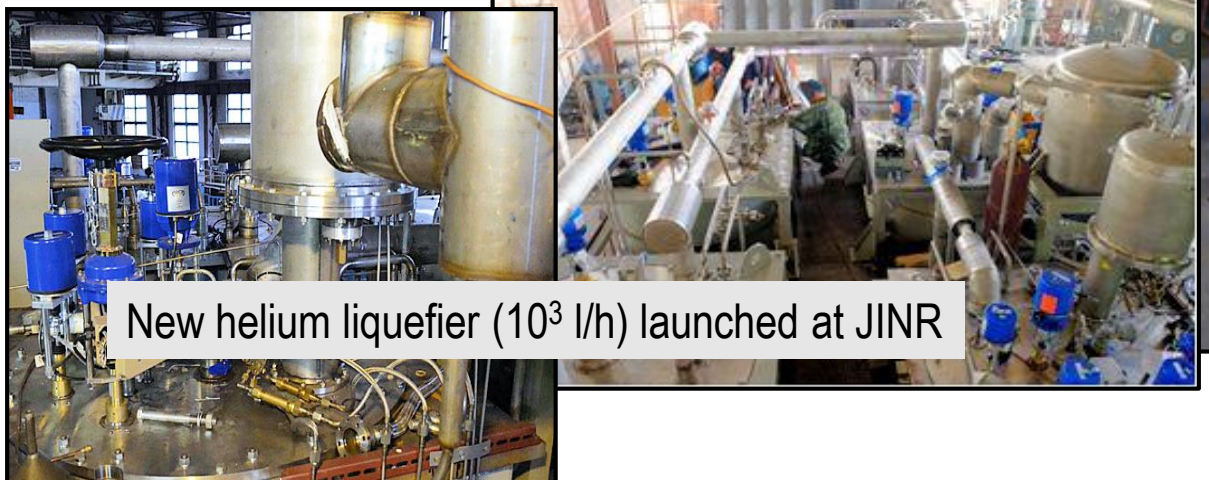


NICA infrastructure development

- ***Civil Construction***
- ***Service systems: water cooling, cryogenics, electric power, etc.***

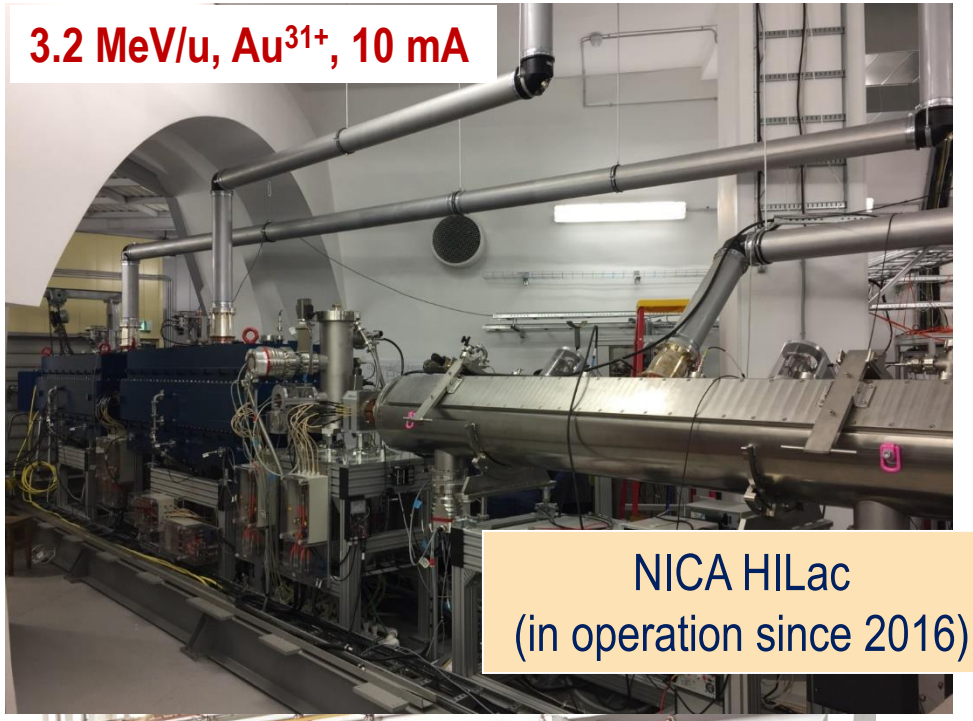
“Strabag" and 7 sub-contractors:
- **total number of engineers and workers – 154**
- **70% of reinforced concrete and piled works done**

15 kA power supply (assembled & tested)



New helium liquefier (10^3 l/h) launched at JINR

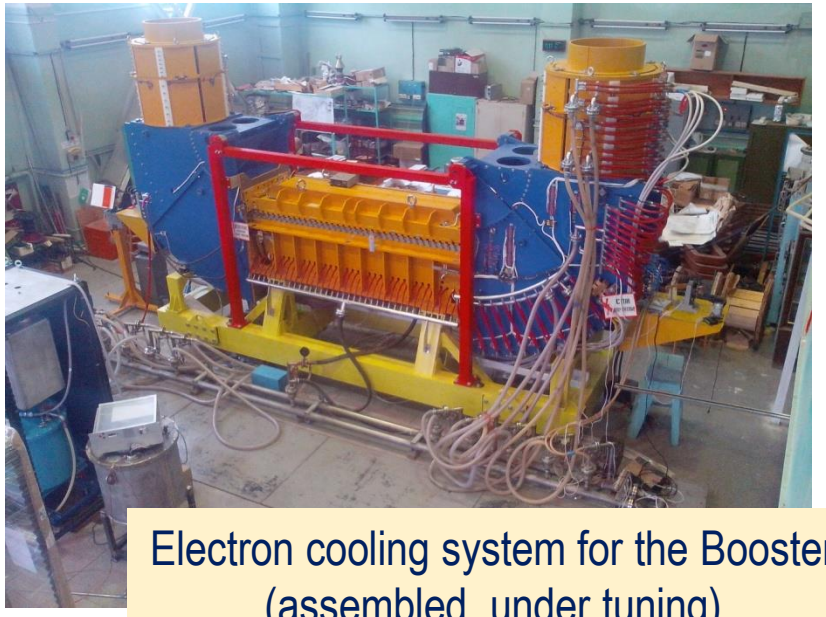
NICA elements. Construction status



NICA HILac
(in operation since 2016)

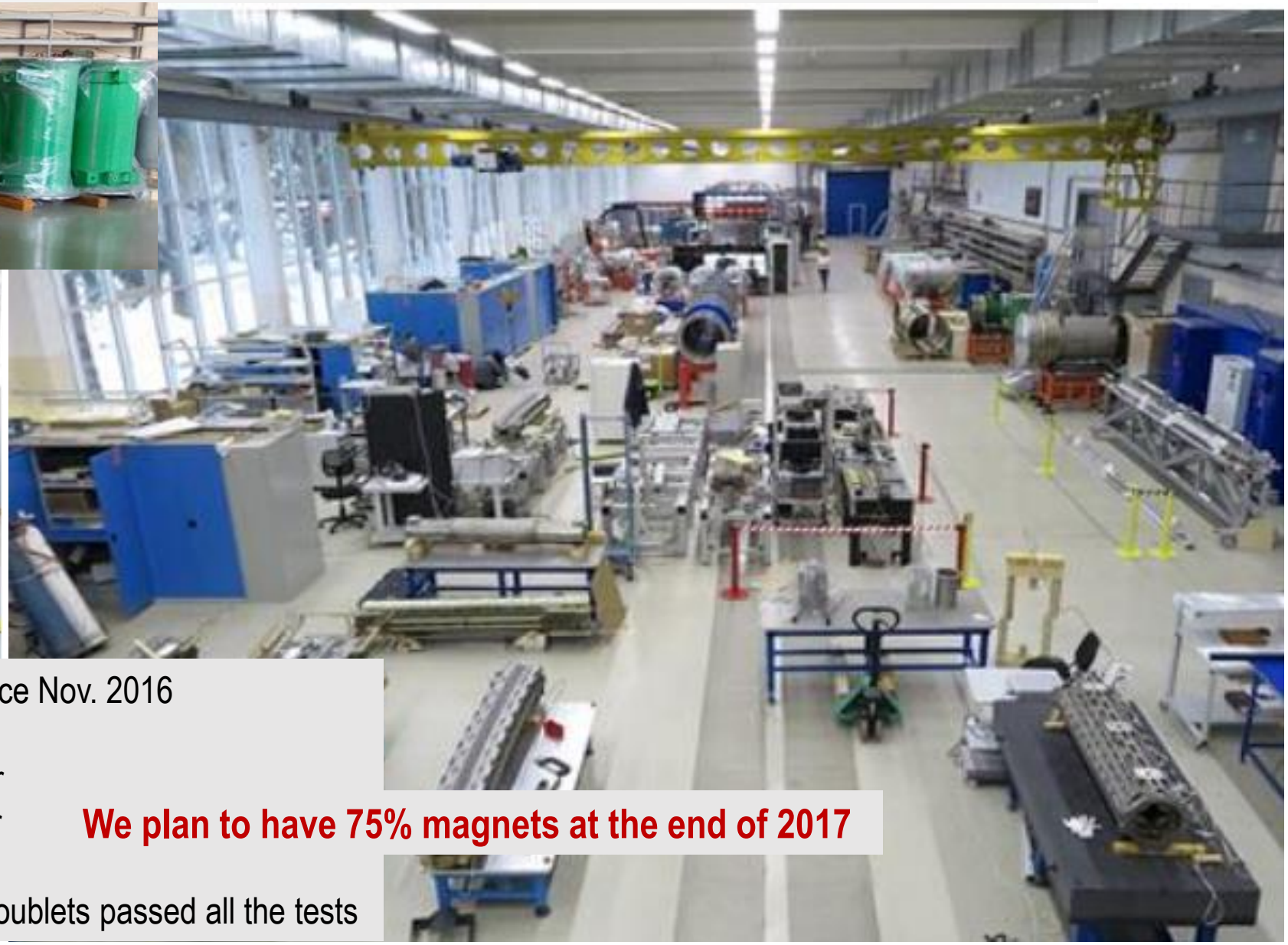
Heavy ion source: Krion-6T ESIS
(in operation since 2015)

The booster power supply
(up to 600 A, since 2016)



Electron cooling system for the Booster
(assembled, under tuning)

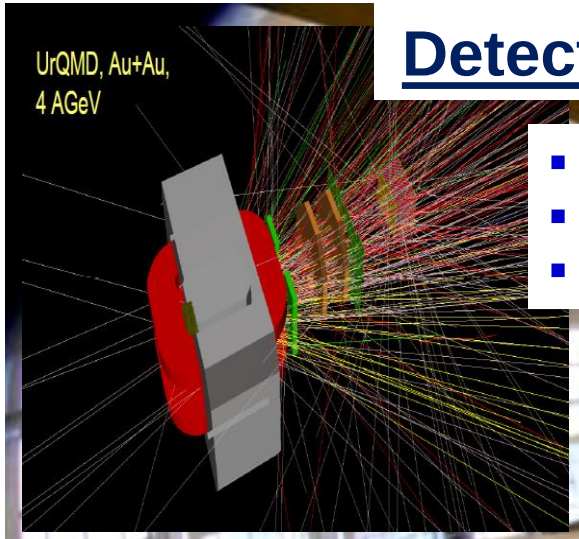
SC Magnets for the NICA Booster, Collider & SIS-100/FAIR (workshop at VBLHEP JINR)



- The facility for SC-magnets: in operation since Nov. 2016
- Working plans:
  40 dipoles + **48** quadrupoles for the Booster
  80 dipoles + **86** quadrupoles for the Collider
  175 quadrupoles for SIS100 (FAIR)
- NICA booster: 33% of dipoles and 10% of doublets passed all the tests

We plan to have 75% magnets at the end of 2017

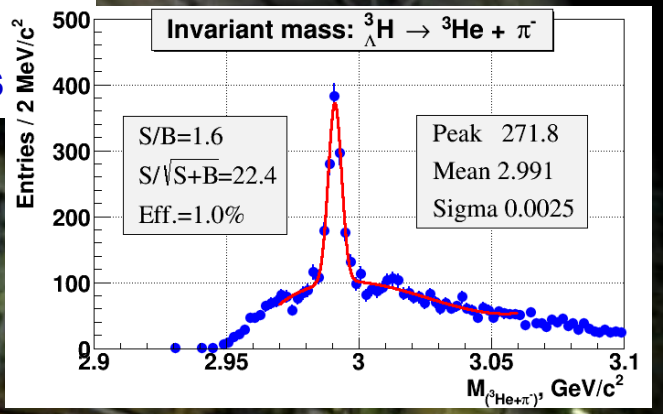
Detectors at NICA: Baryonic Matter at Nuclotron (BM@N)

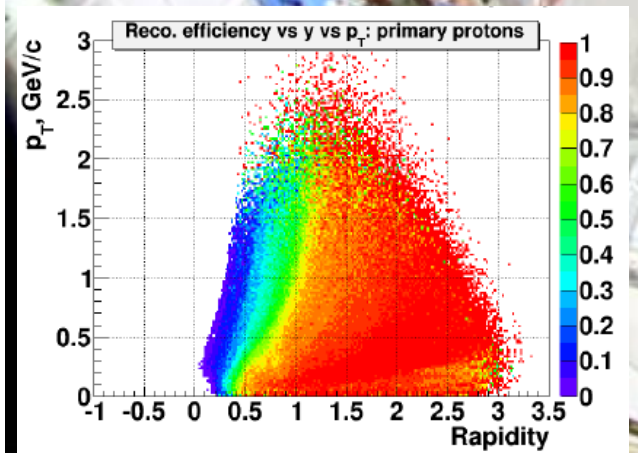


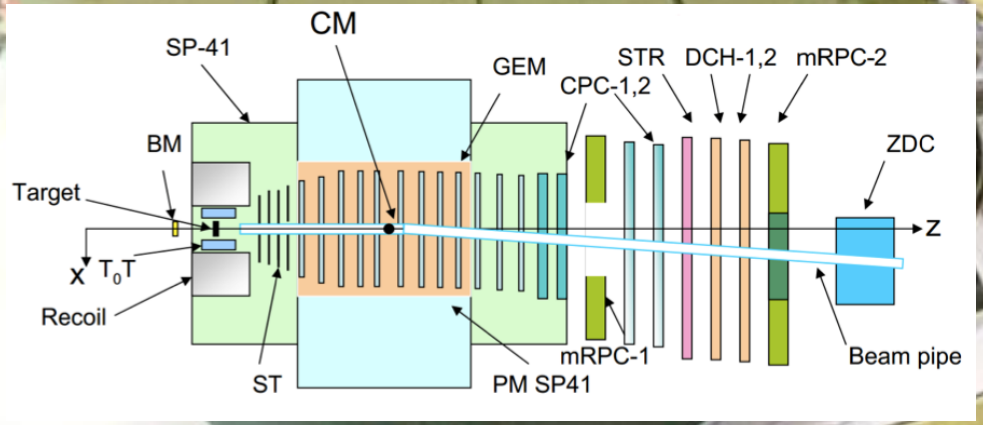
- Ideally suited for exploration of reaction mechanism & in-medium properties
- Energy range of limited experimental information
- Expectation of rich structure of the QCD phase diagram @ high densities

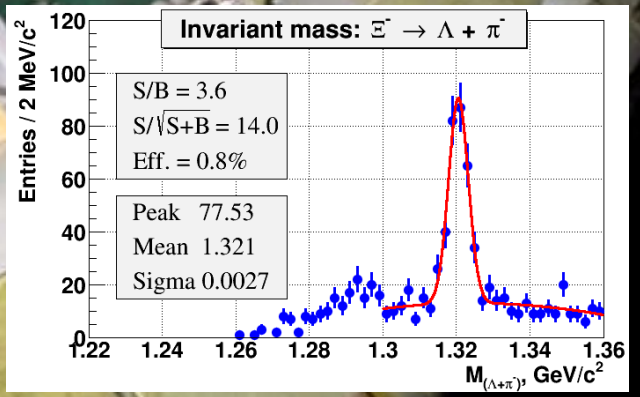
Physics cases:

- Bulk properties, EOS
- In-medium meson-nucleon potential at high ρ_B
- Sub-threshold production of strange hadrons in A+A
- Measurement of elementary reactions

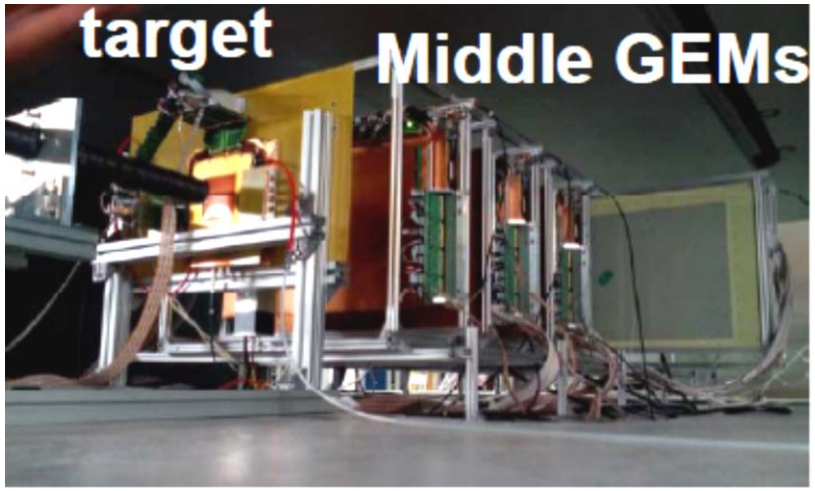


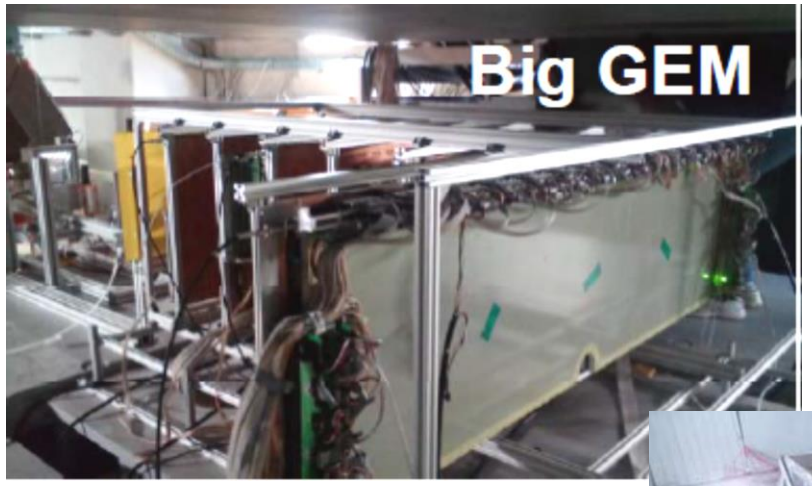






BM@N status and data taking plans

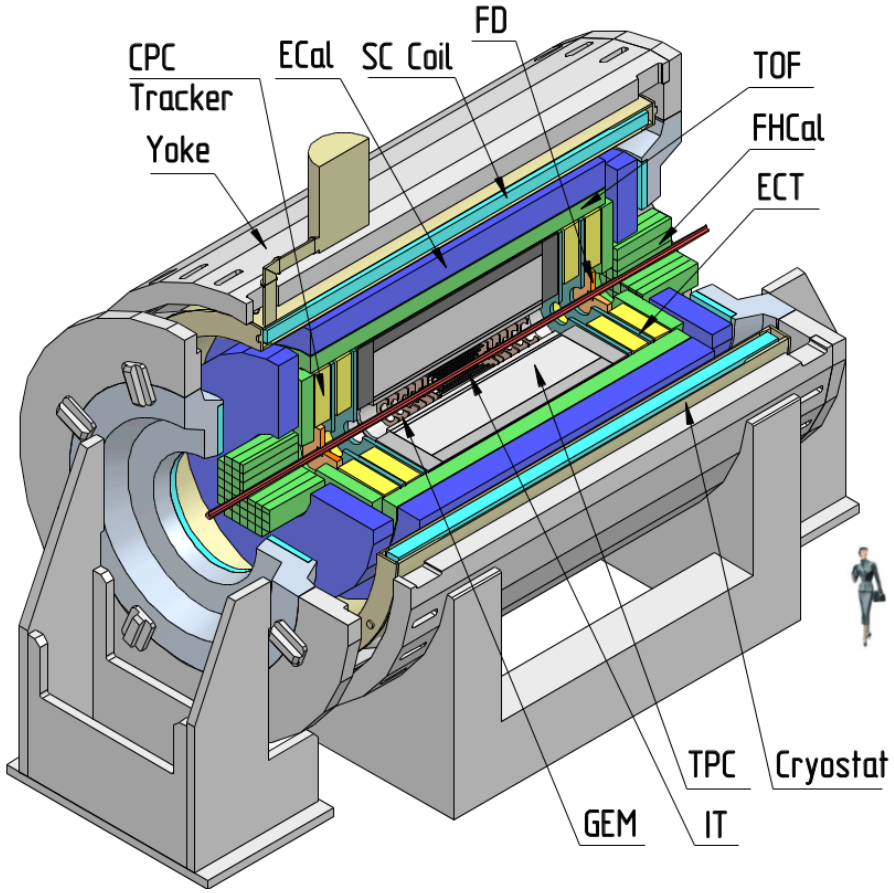




year	2016	2017 Feb.-Mar.	2017 Nov.-Dec.	2019	2020 + ..
beam	d ( )	C, Ar	Kr	Au	Au, p
maximum intensity, Hz	1M	1M	1M	1M	10M
trig. rate, Hz	10k	10k	20k	20k	50k
central tracker	6 GEM half pl.	8 GEM half pl.	10 GEM half pl.	8 GEM full pl.	12 GEM or 8+2Si
expiment status	techn. run	techn. run	commis.& physics run	physics stage 1	physics stage 2

MPD at NICA: design and tasks

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



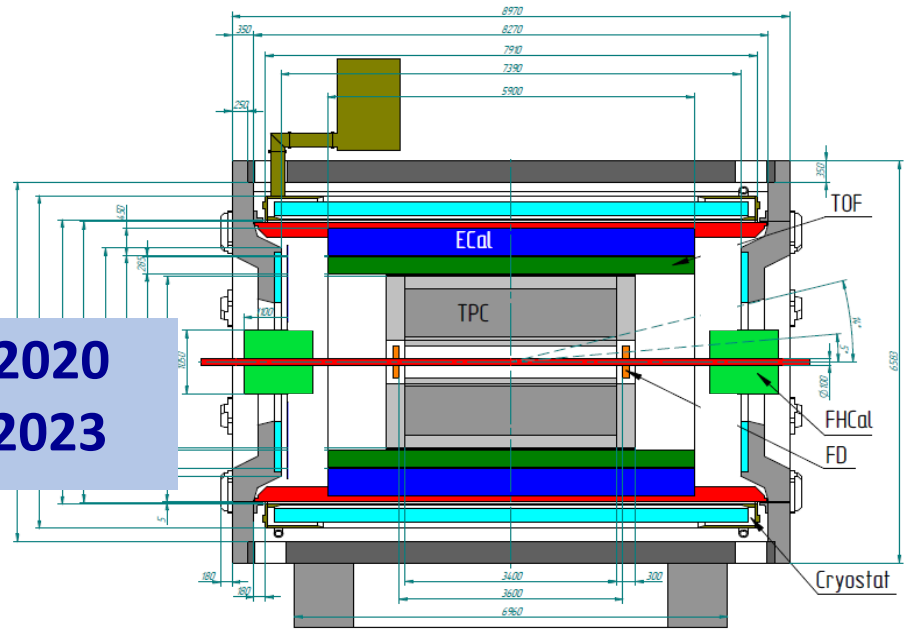
Bulk properties, EOS
particle yields & spectra, ratios, femtoscopy, flow
measure: γ, π, K, p, Λ, Ω, (anti)particles, light nuclei

In-Medium modification of hadron properties
onset of low-mass dilepton enhancement
measure: ρ, ω, $\phi \rightarrow e^+e^-$

Deconfinement (chiral) phase transition at high ρ_B
enhanced strangeness production
Chiral Magnetic (Votical) effect, Λ polarization

QCD Critical Point
event-by-event fluctuations and

Strangeness in nuclear matter
hypernuclei, exotica



Magnet : 0.5 T superconductor
Tracking : TPC, ECT, IT
ParticleID : TOF, ECAL, TPC
T0, Triggering : FFD
Centrality, Event plane : FHCAL

I stage (barrel) – **2020**
upgraded (IT + endcaps) – **2023**

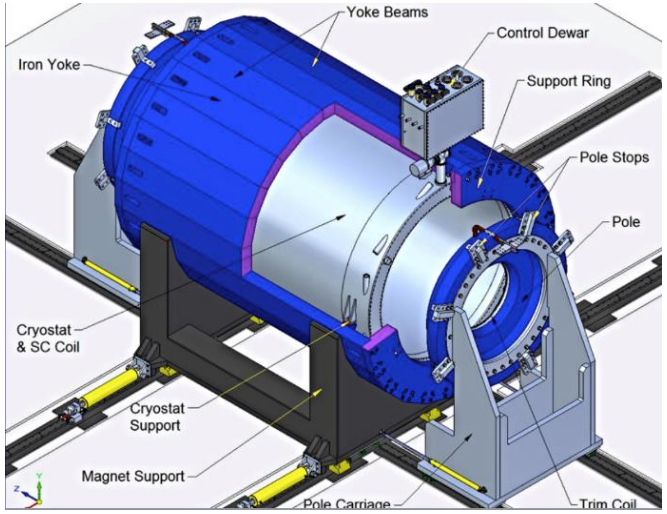
Particle yields in Au+Au collisions @ $\sqrt{s_{NN}}$ = 8 GeV
(central collisions)

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

Particle	Multiplicity	Decay mode	BR	*Efficiency %	Yield/10 w
π^+	293	----	---	61	$2.6 \cdot 10^{11}$
K^+	59	---	----	50	$4.3 \cdot 10^{10}$
p	140	---	----	60	$1.2 \cdot 10^{11}$
ρ	31	e+e-	$4.7 \cdot 10^{-5}$	35	$7.3 \cdot 10^{5}$
ω	20	e+e-	$7.1 \cdot 10^{-5}$	35	$7.2 \cdot 10^{5}$
φ	2.6	e+e-	$3 \cdot 10^{-4}$	15	$1.7 \cdot 10^{5}$
Ω	0.14	ΛK	0.68	2	$2.7 \cdot 10^{6}$
D^0	$2 \cdot 10^{-3}$	$K^+\pi^-$	0.038	20	$2.2 \cdot 10^{4}$
J/ψ	$8 \cdot 10^{-5}$	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 estimates based on MPD simulations

MPD magnet: construction status



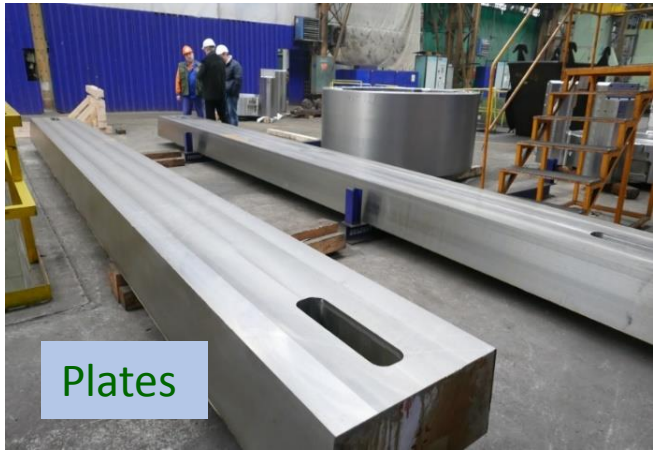
MPD Solenoid production stages (AGS superconductors, Genova, Italy)

Manufacturing	Jan. 2016-Aug. 2018
Final Solenoid tests by AGS	Jun. 2018
Packaging and Transportation	Apr. 2018-Oct. 2018
Assembly at JINR, tests	Oct. 2018-Apr. 2019

Magnet yoke (VHM, Vitkovice, Cech Rep.) – 80% ready, control assembling in Oct. 2017

Support rings

Aluminum support cylinder blanks for SC coil during transportation

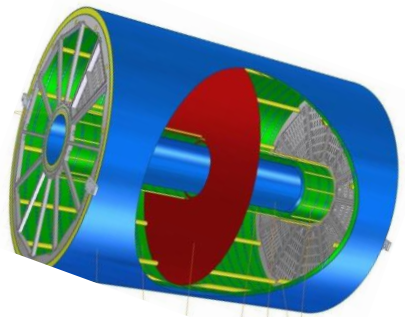


Plates

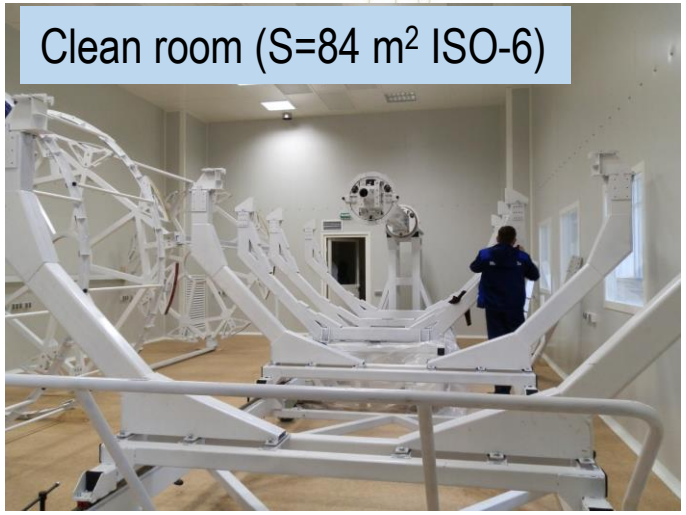
Winding machine for SC solenoid

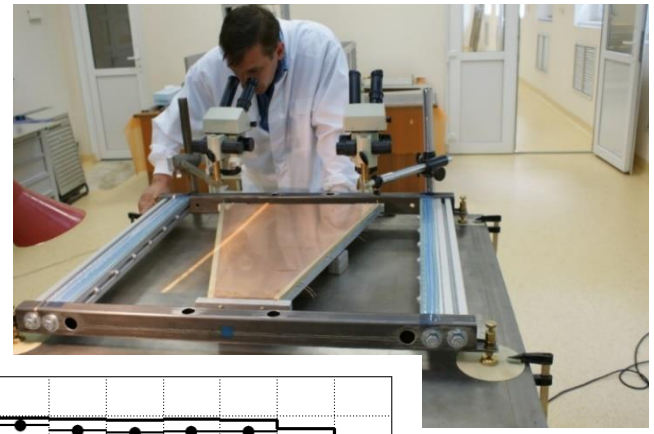
Poles

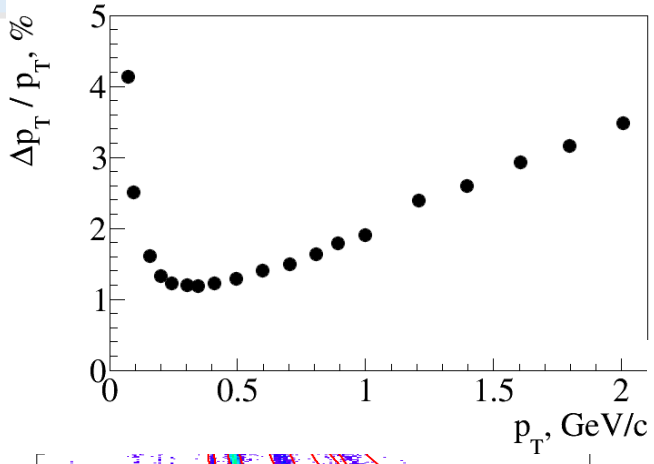
MPD tracker - TPC

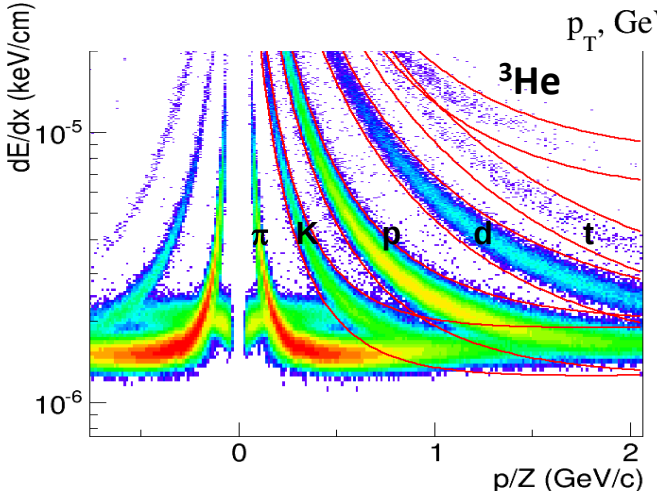


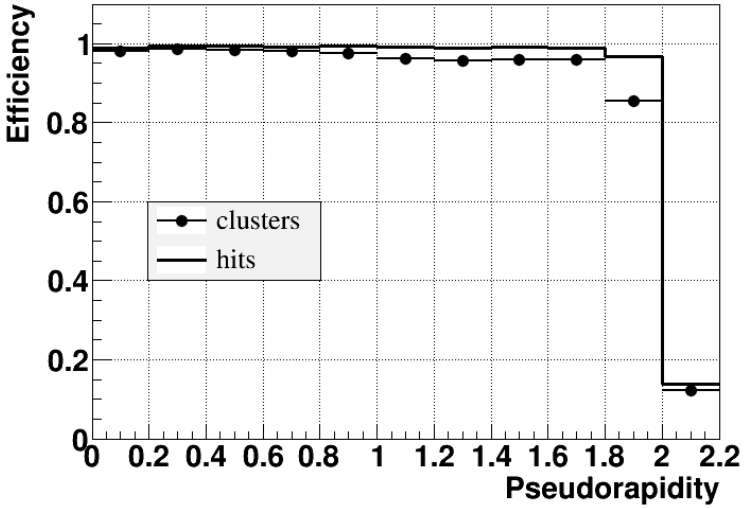
Dimentions: 4 m x 3m
Drift Length: 170cm
Gas: 90% Argon + 10% Methane
Readout: 2x12 sectors (MWPC or GEM)
Rate capability up to 7 kHz
Spatial resolution: $\sigma_{r\phi}$~300 μm, σ_z~ 2 mm
Momentum resolution: $\Delta p/p < 3\%$
dE/dx resolution: < 8%





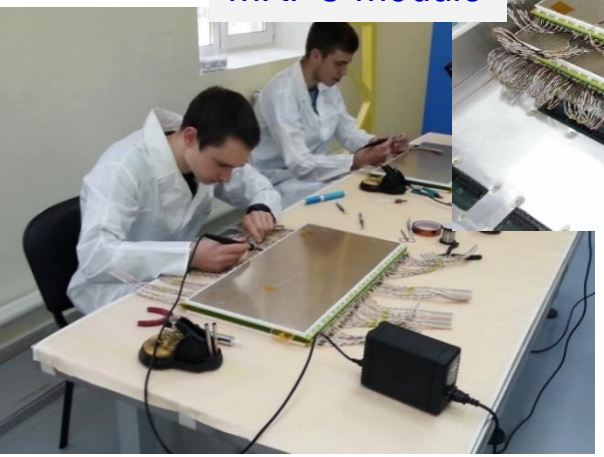


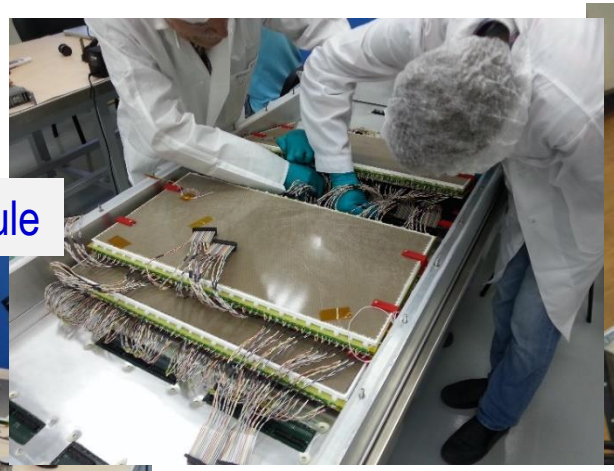




MPD mRPC TOF: preparation to mass-production

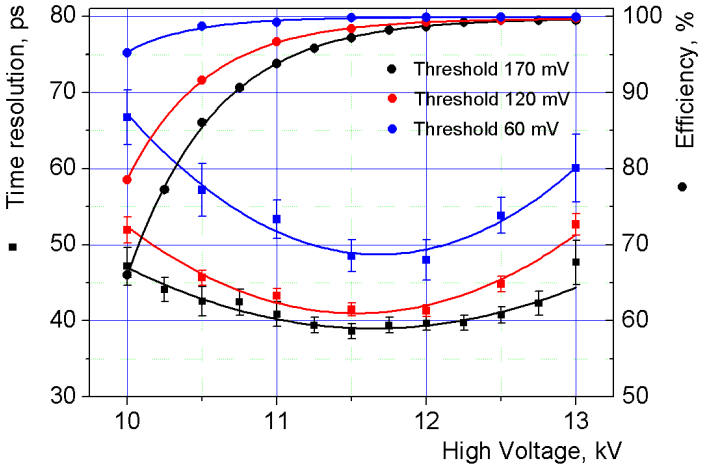
mRPC module

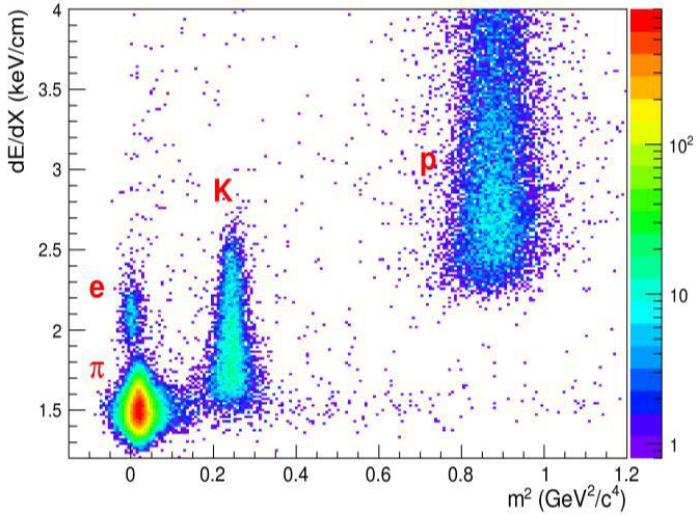




Glass quality control

- **Material ordering**
- **Equipment installation**
- **Personnel training**





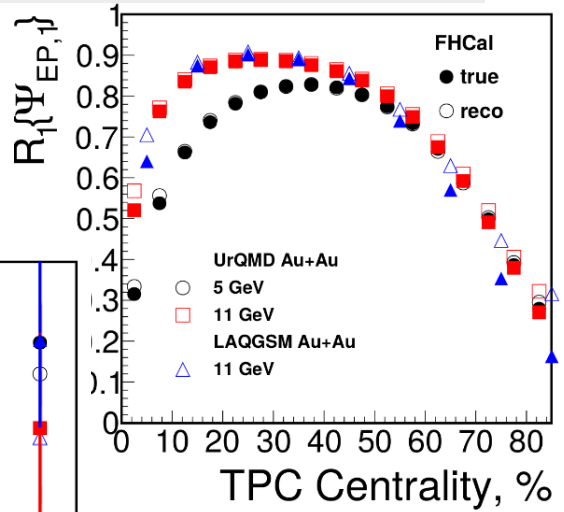
basic elements - NINO & HPTDC chips have been purchased sufficient to produce read-out electronics for the TOF + reserve (~24000 channels).

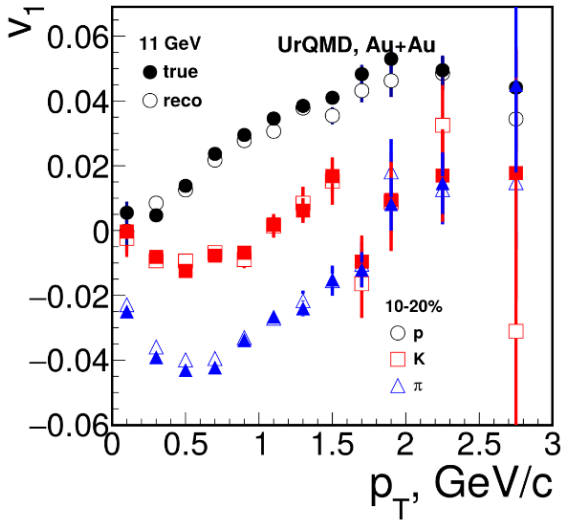
MPD Calorimetry: ECAL and FHCAL

2<|η|<5

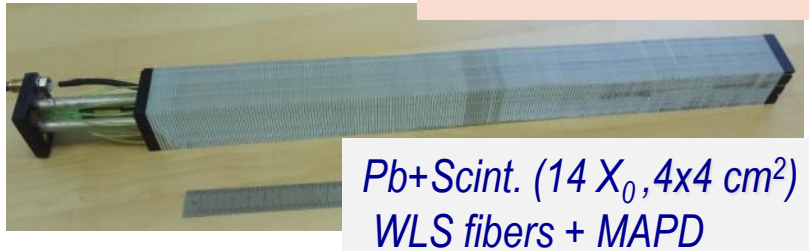
FHCAL calorimeter for centrality & event plane determination

Transverse granularity allowing:
- *the reaction plane with the accuracy ~ 30⁰*



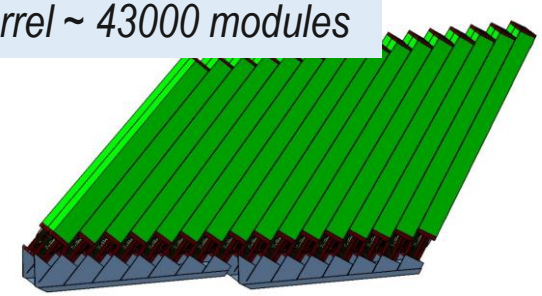


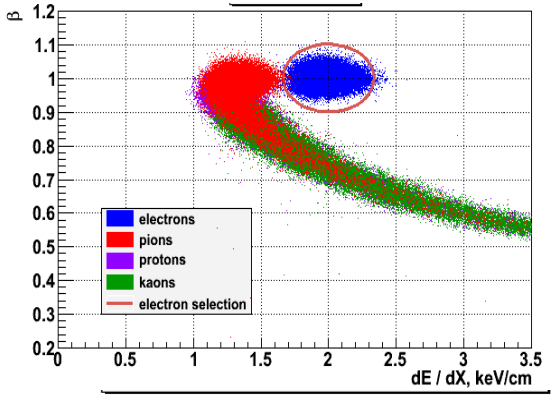
ECAL - high acceptance & purity e/γ identification:
- *in-medium modifications in dilepton spectra*
- *thermal radiation from QGP*

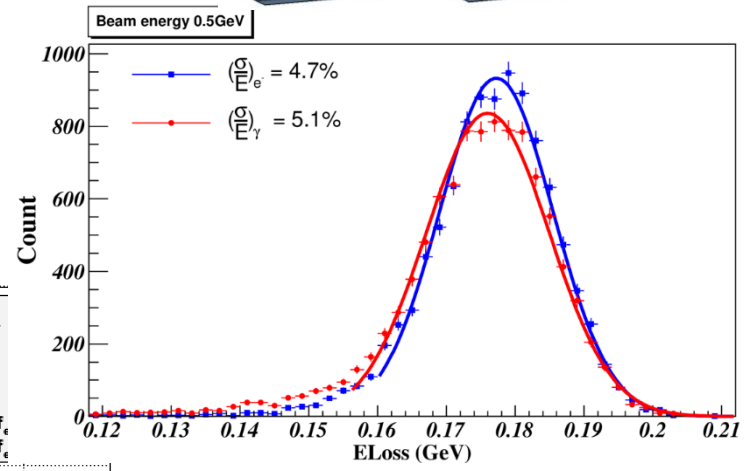


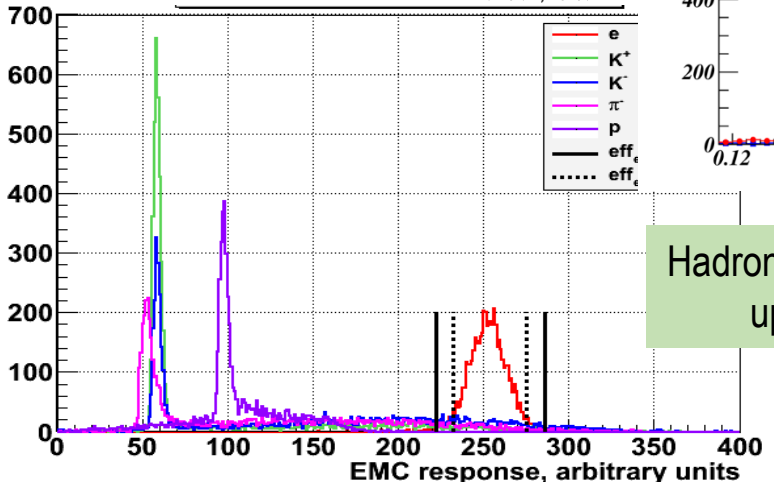
Pb+Scint. (14 X_0, 4x4 cm²)
WLS fibers + MAPD

Projective geometry
Barrel ~ 43000 modules



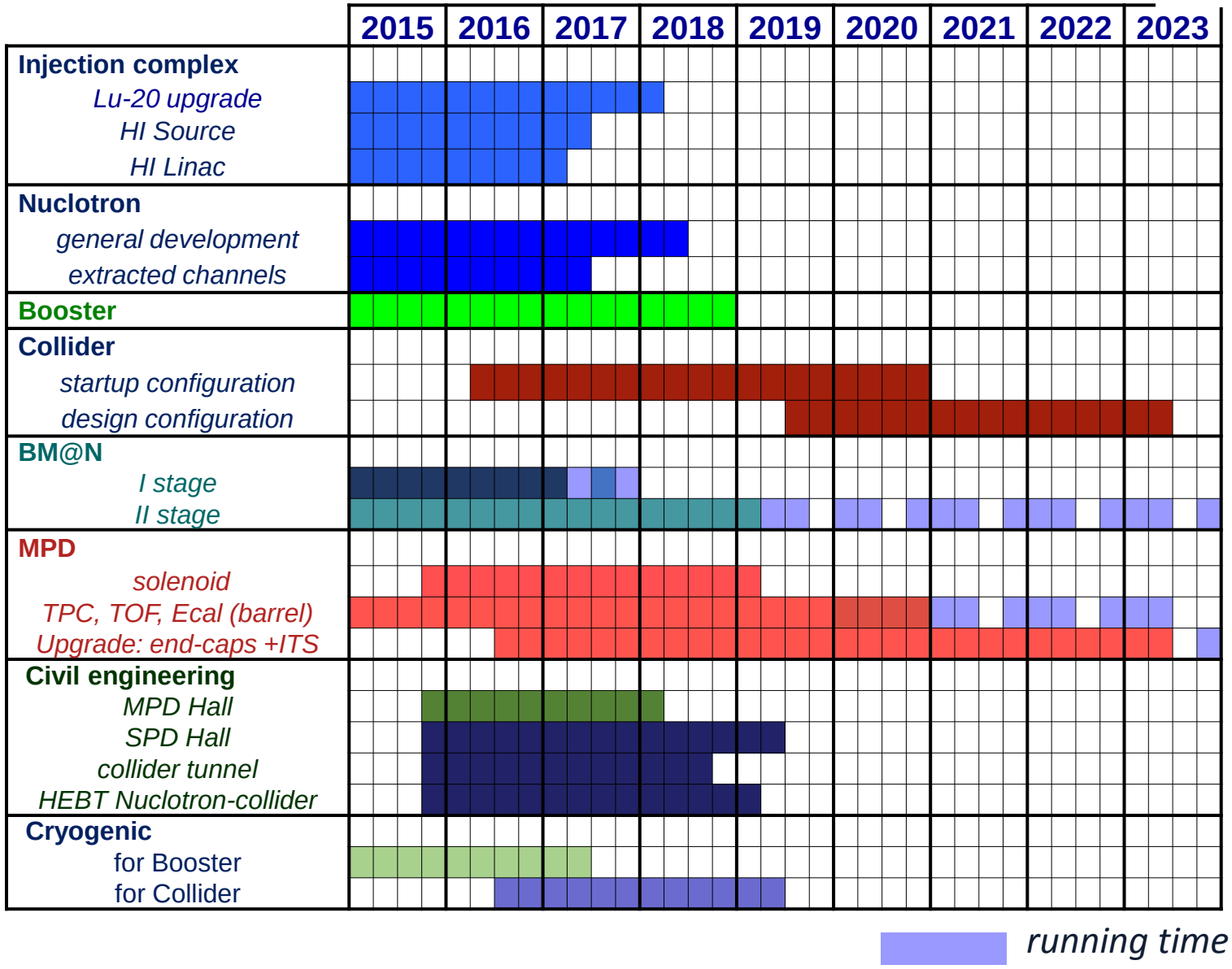






Hadron suppression up to 10^{-5}

NICA schedule



Summary

- **Construction of the NICA complex is well in progress**

  (civil construction, accelerator components, service systems)

- **Substantial progress in the construction of the detectors:**

  - BM&N experiment – commissioning runs started

  - MPD design has optimized for Day'1 physics,

  preparation for mass-production ongoing

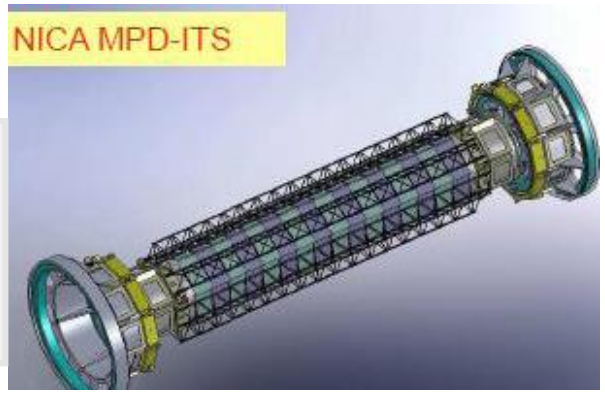
Thank you for your attention!

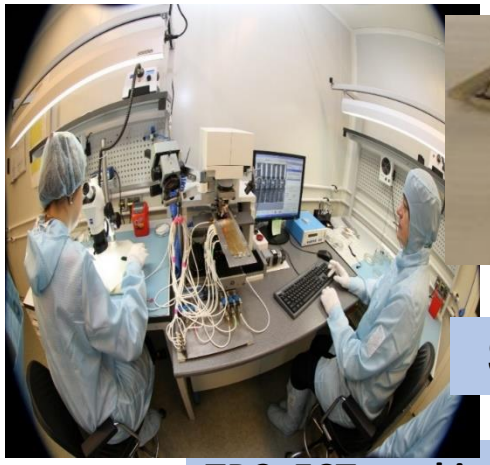
SPARES

MPD after 2023: EndCap and InnerTrackers

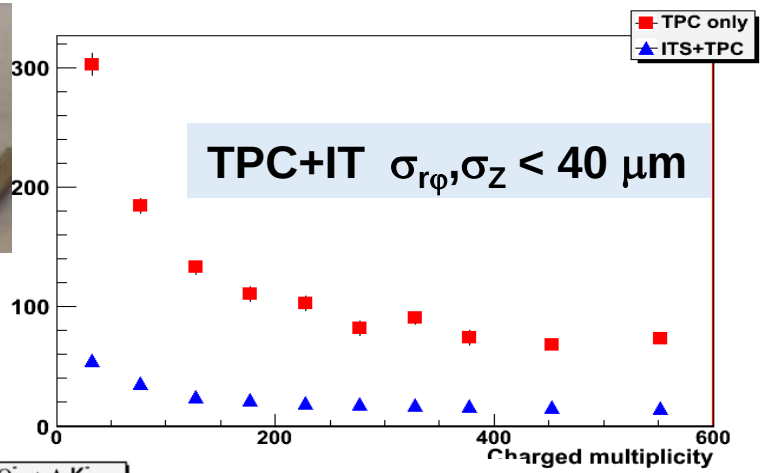
- A new technology developed to build straw detectors as multi-wheel structures
- ECT full size prototype: max. deviation $\Delta R < 300$ mm for a R=1.1 m wheel

- 4 cylindrical layers $|\eta|<2.5$
- 300 μm double-sided microstrip 100 μm pitch
- Thickness/layer ~ 0.8% X_0
- Resolution: σ_z = 120 μm, σ_{rf} = 23 μm

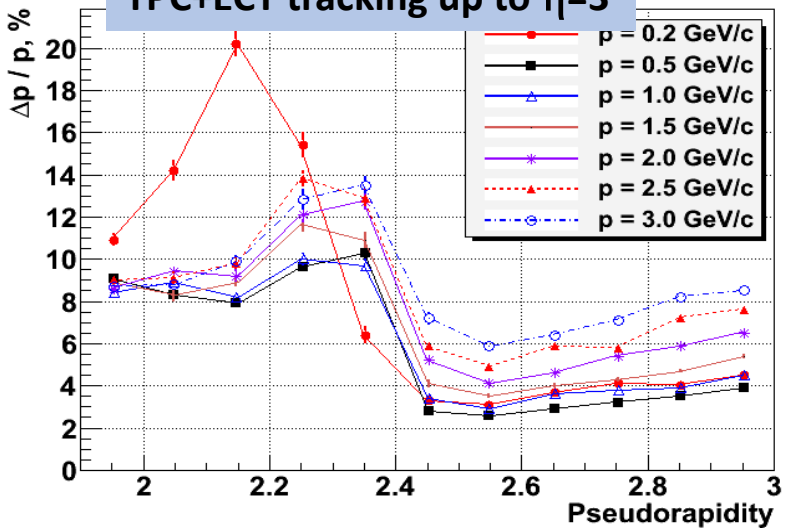


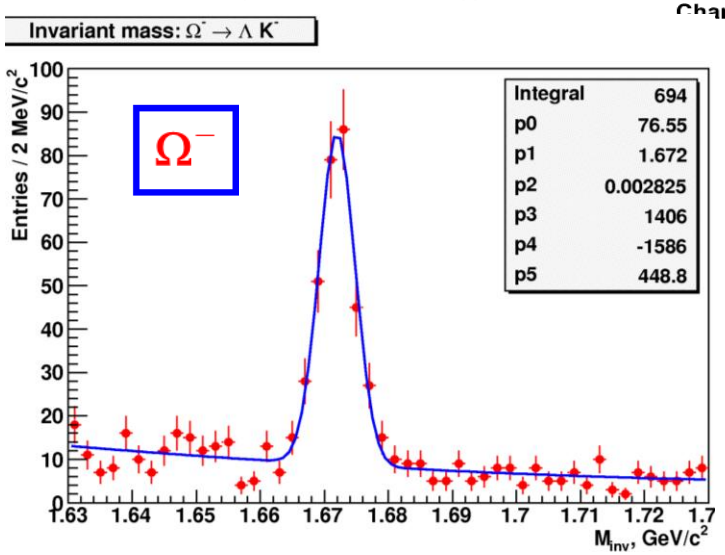


Site for module assembly



TPC+ECT tracking up to η=3





2x60 straw layers1.3<|η|<2.2
72000 straw tubes 4 mm x 60 cm