The upgrade of Baryonic Matter@Nuclotron Experiment at NICA

Dmitrii Dementev for the BM@N collaboration

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CREMLIN PLUS
Connecting Russian and European Measures for Large-scale Research Infrastructures

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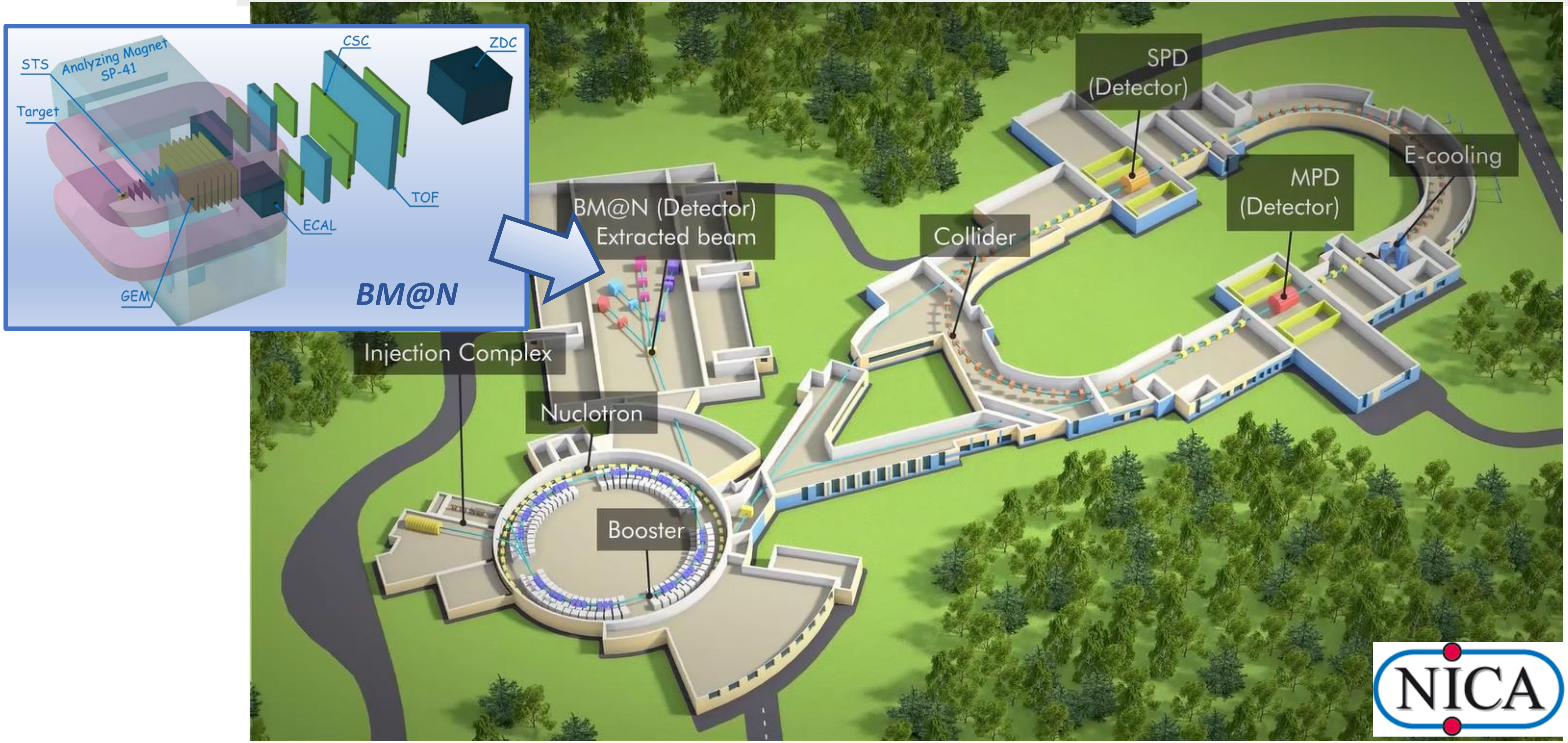
Outline

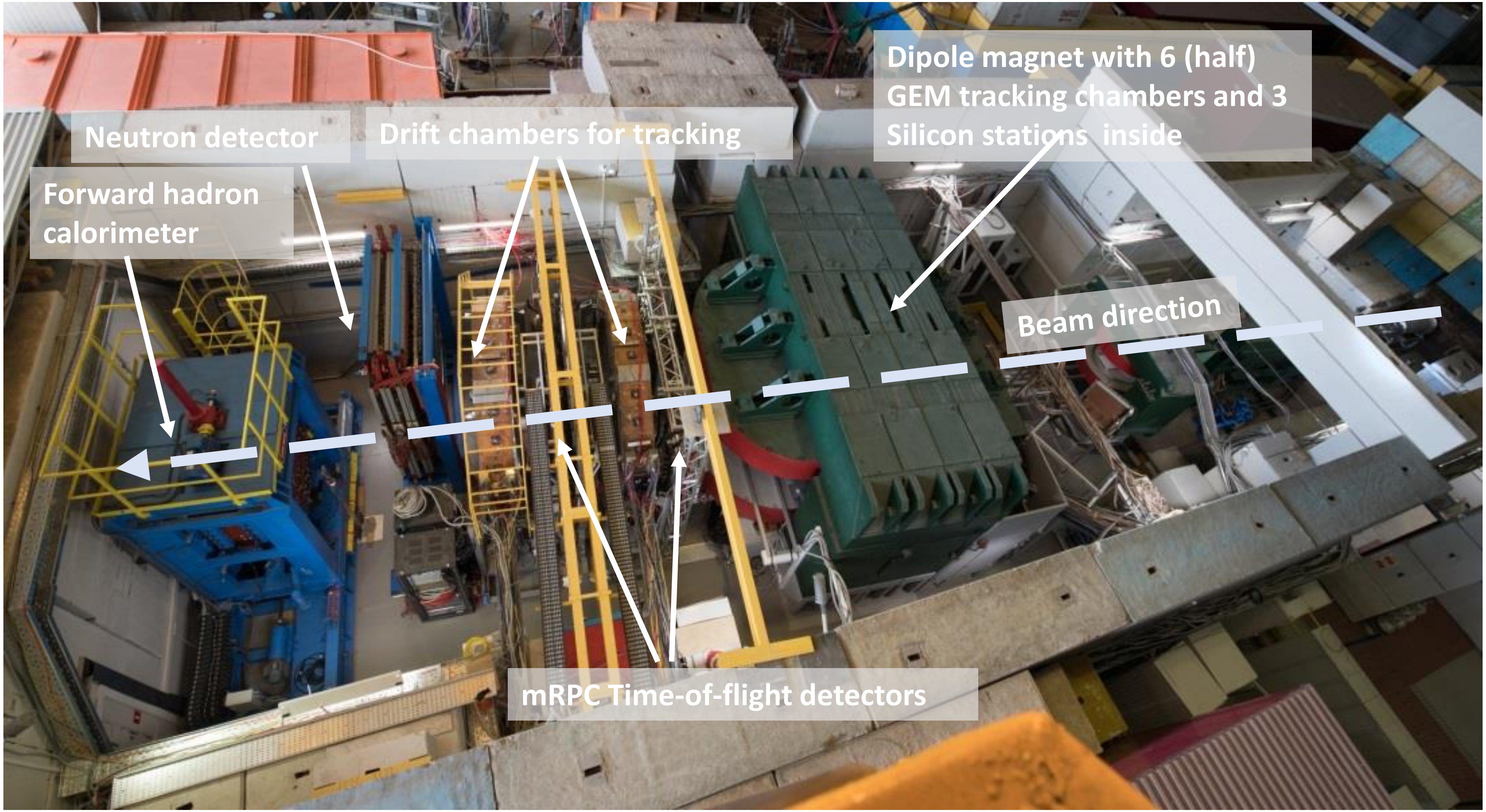
- BM@N experiment at NICA;
- Heavy ion program at BM@N;
- Upgrade of the BM@N experiment;
- Summary

NICA Heavy Ion Complex

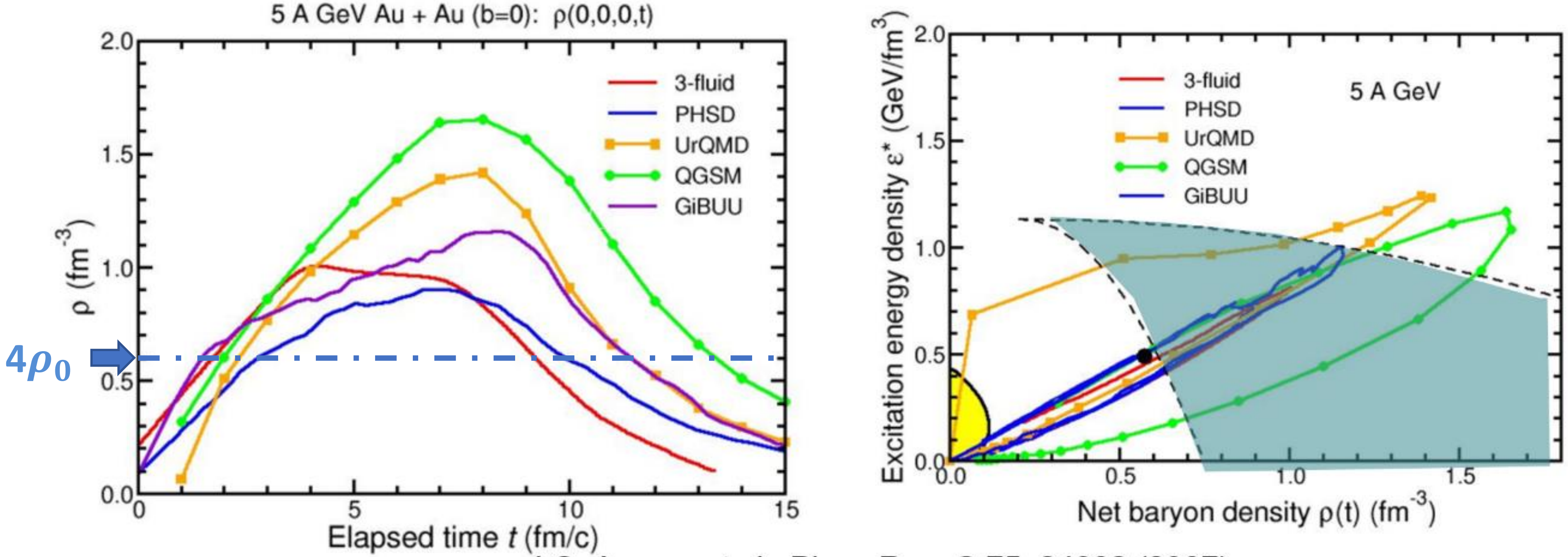
BM@N: *beams from p to Au, heavy ion energy 1-3.8 AGeV, Au intensity up to 2 MHz*



Baryonic Matter at Nuclotron Experiment



Heavy Ion program at BM@N

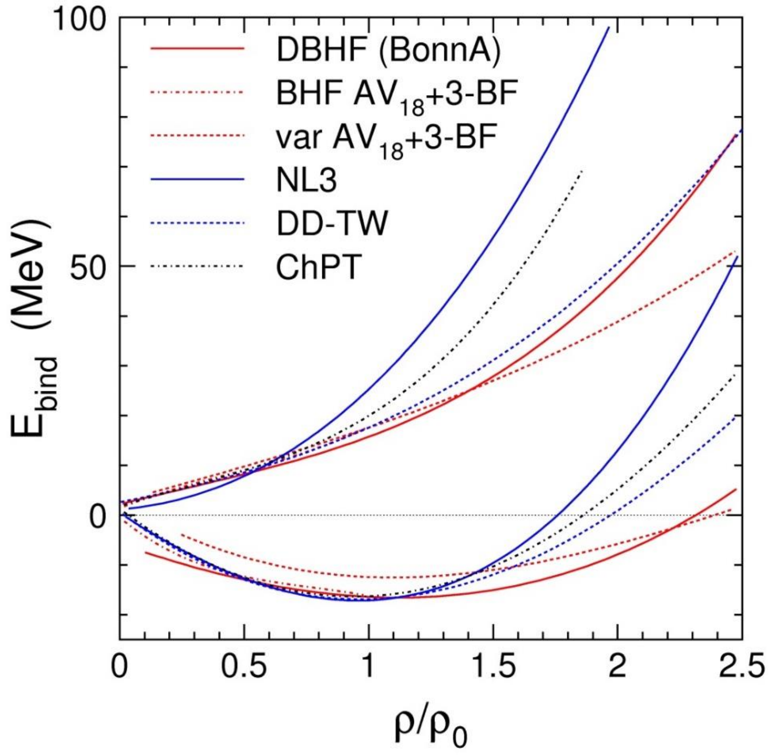


I.C. Arsene et al., Phys. Rev. C 75, 24902 (2007)

The research program of BM@N includes:

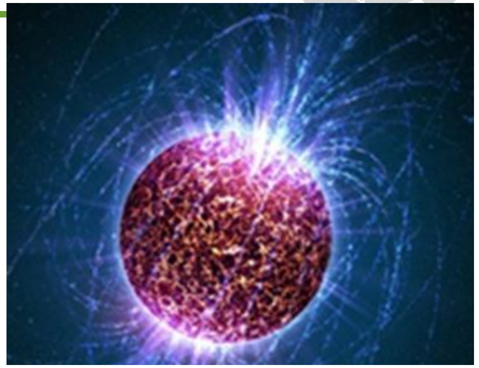
- Scouting the location of transition between hadronic and partonic dominated matter;
- Onset of deconfinement and chiral symmetry restoration;
- Searching the critical endpoint of a possible 1st order phase transition at Nuclotron energies;
- Exploring the high net-baryon density EoS for symmetric nuclear matter ;
- Study of the ΛN, ΛNN, and ΛΛN interactions

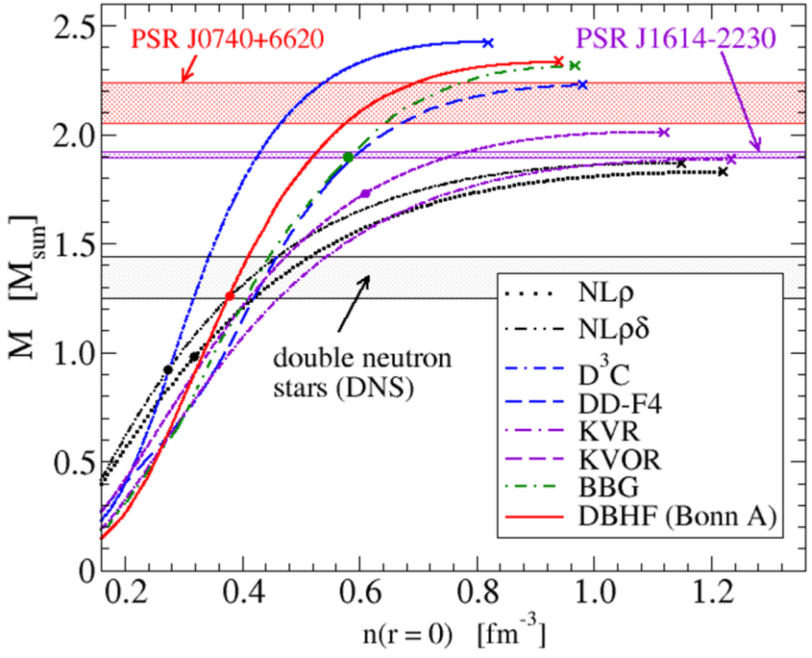
Study of the EOS of nuclear matter



Ch. Fuchs and H.H. Wolter, EPJA 30 (2006) 5

Study of the EOS at densities above 2 ρ_0 may provide insight for the mass/density relation of neutron stars





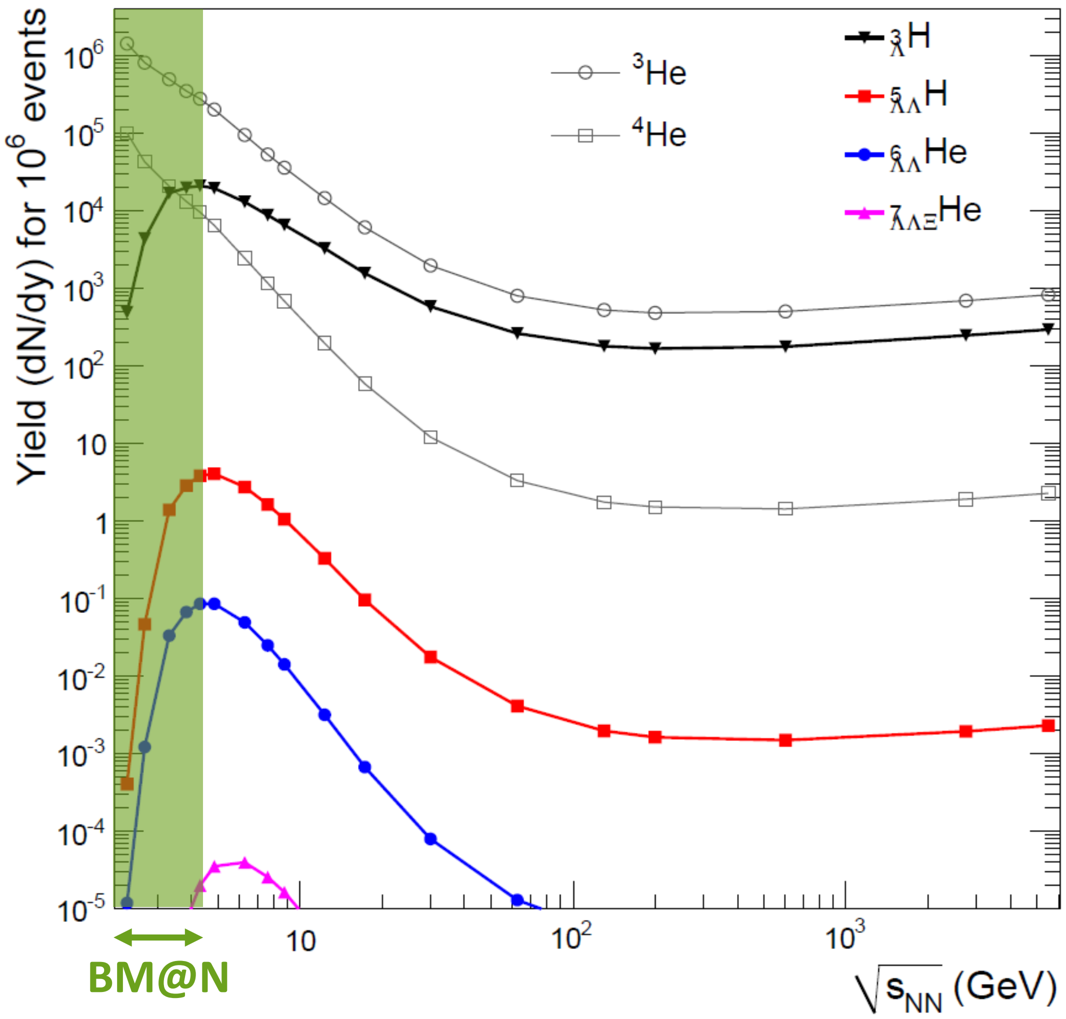
Mass-density relation of neutron stars for different EOS

T. Klaehn et al., Phys. Rev. C74: 035802, 2006.
Update by D. Blaschke, priv. comm.

Observables sensitive to EoS:

- Collective flow ($v_1, v_2, \ldots$)
- Subthreshold particle production (Ξ^- ,Ω^-)

Hypernuclei production in heavy-ion collisions

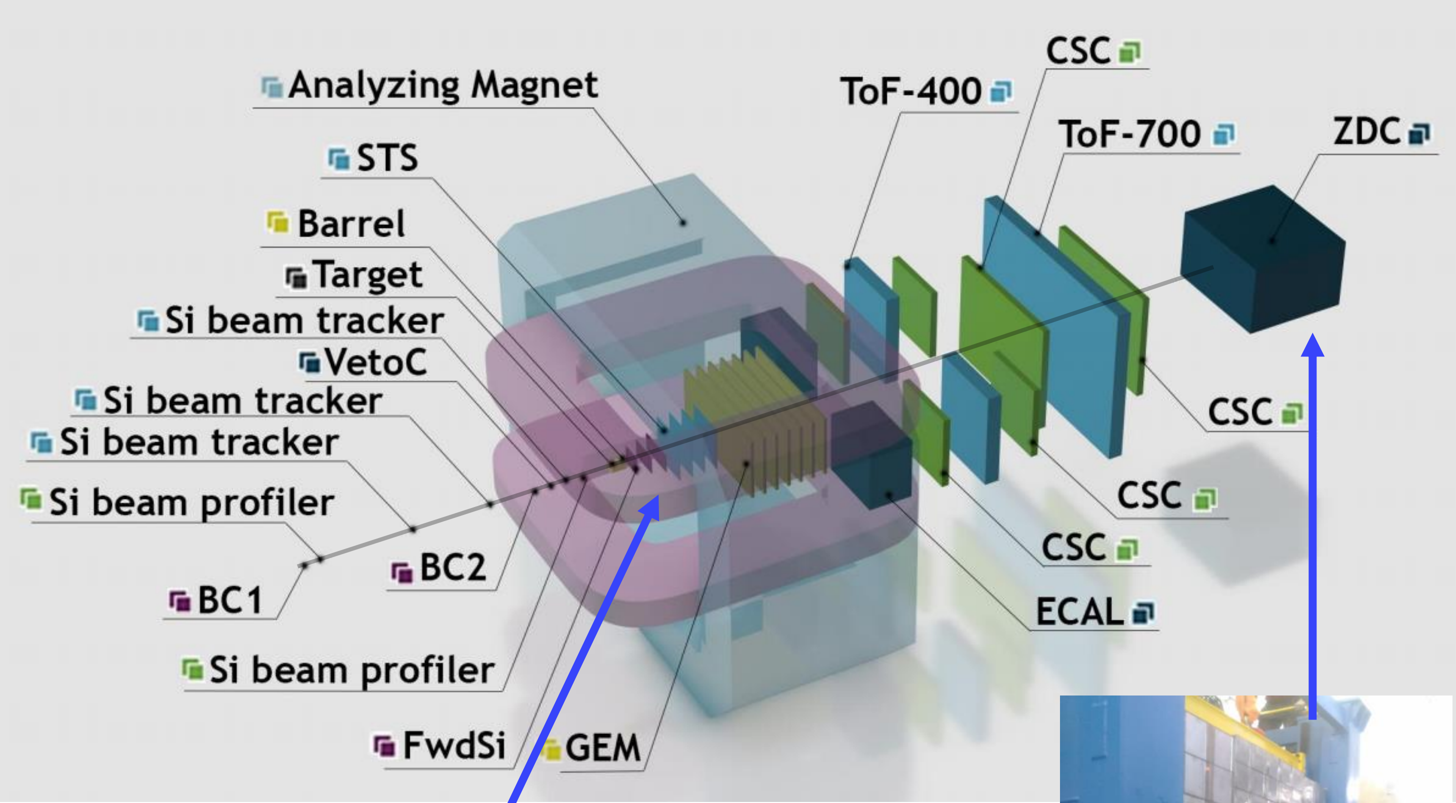


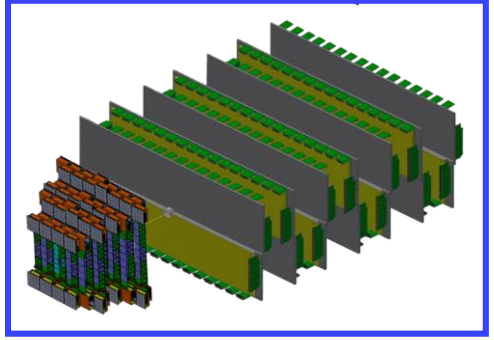
A. Andronic et al., Phys. Lett. B697 (2011) 203

- Maximum yield predicted for √s=3-5 GeV

Precision measurements of lifetime and mass of hypernuclei will shed light on the ΛN, ΛNN, and ΛΛN interactions

BM@N upgrade for heavy ion collisions





New hybrid tracker (STS +GEM)

FHCal

- New hybrid tracking system:
  - 4x stations of Silicon Tracking System (STS) with double-sided silicon microstrip sensors;
  - 7x planes of Gas-Electron-Multiplier chambers (GEM)
- Vacuum beam pipe
- Upgrade of the outer tracking system based on Cathode Strip Chambers
- New Forward Hardron Calorimeter (FHCal) instead of ZDC

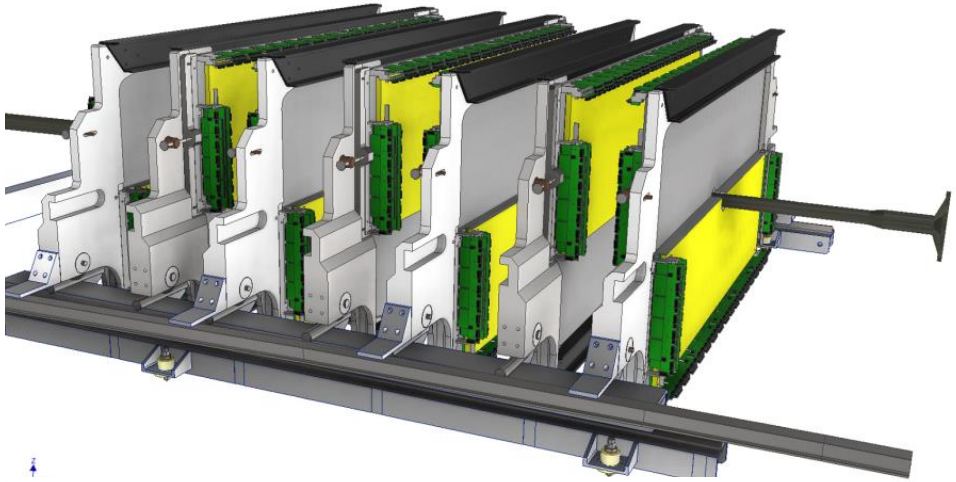
Fall 2021 - start new experiments with Kr beams

2022+ -start experiments with heavy ion beams up to Au, Bi, Pb

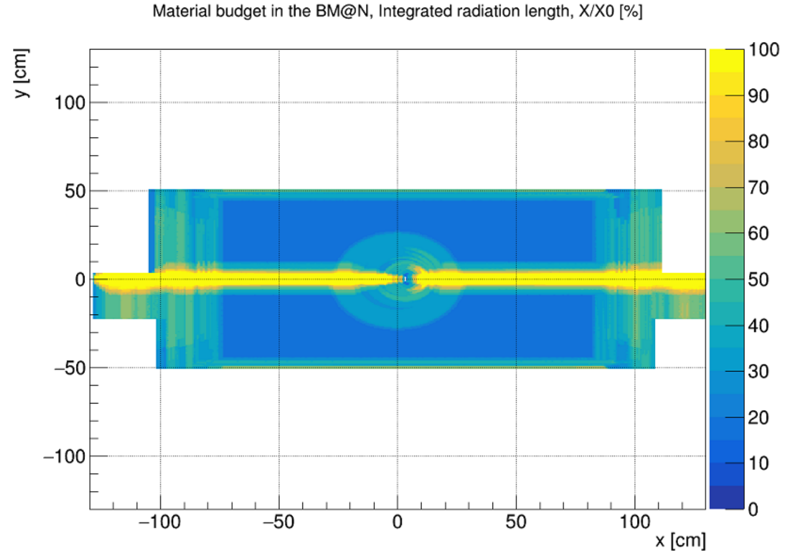
GEM central tracker

GEM team

- 7 upper GEM 163x45 cm^2 chambers produced at CERN were integrated into BM@N
- 7 lower GEM 163x39 cm^2 chambers were assembled, delivered to BM@N and tested

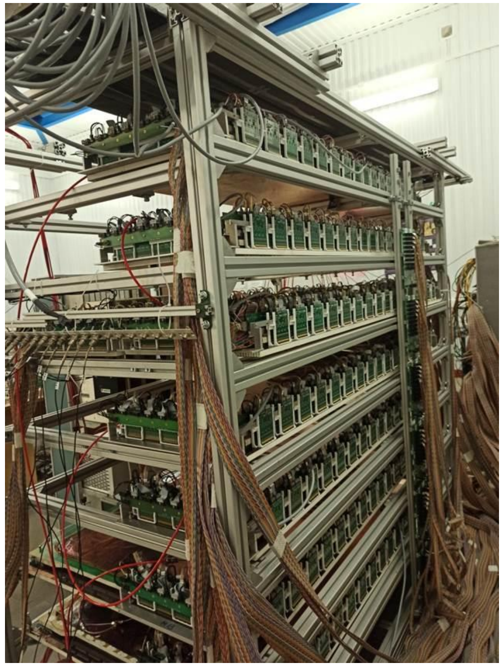


- *Two-coordinate GEM planes;*
- *Stereo angle between strips: 15°;*
- *Pitch: 0.8 mm*



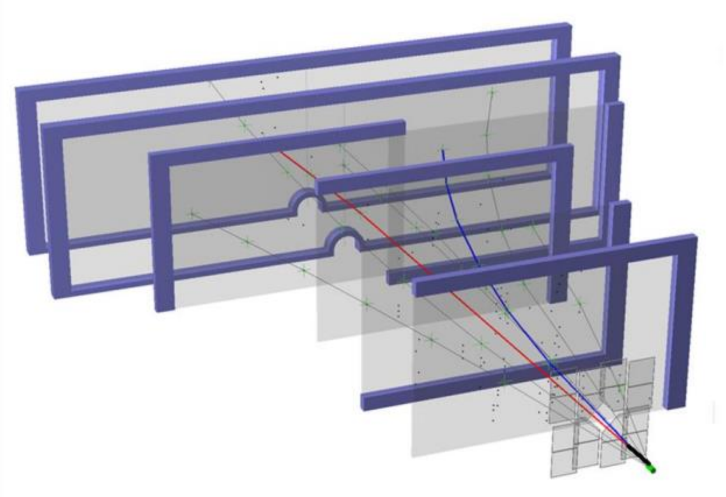
Material budget of GEM tracker

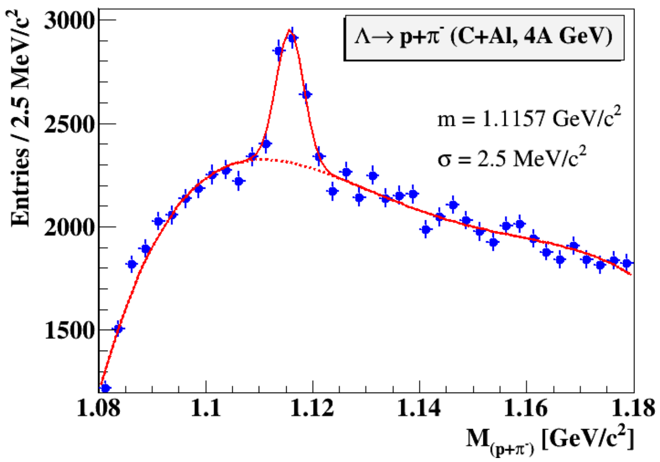
Photo of assembled GEM chamber

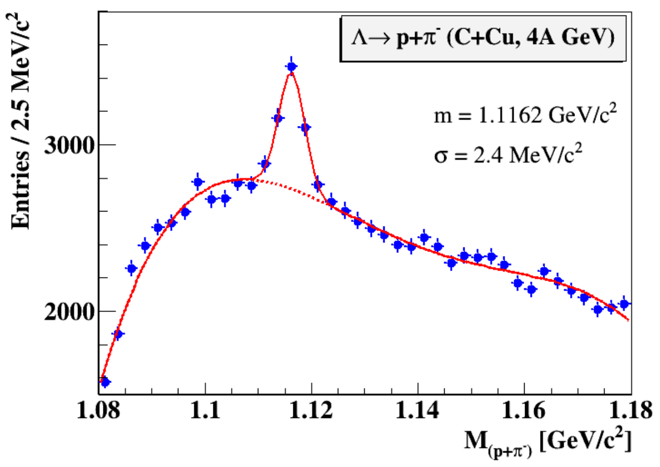


Setup of GEM detectors for cosmic tests

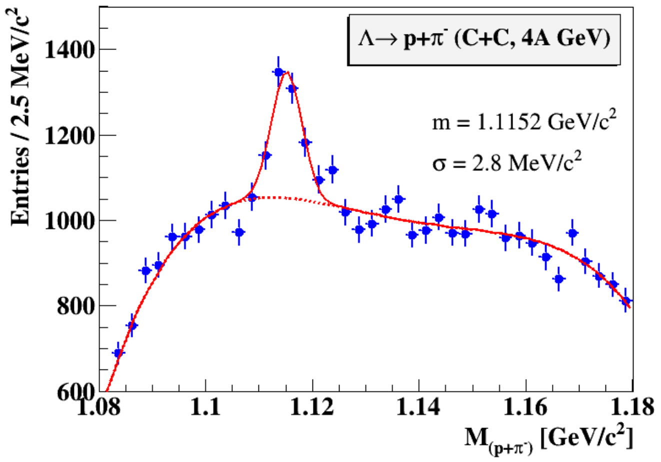
Λ decay reconstruction in carbon beams with GEM tracker







Λ→pπ⁻ decay reconstruction in GEM + Si tracker in C+C interaction, **March 2017**

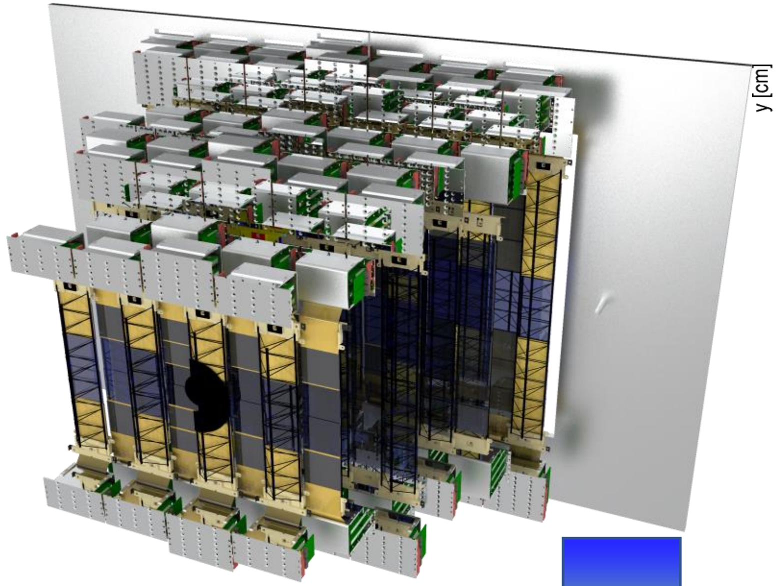


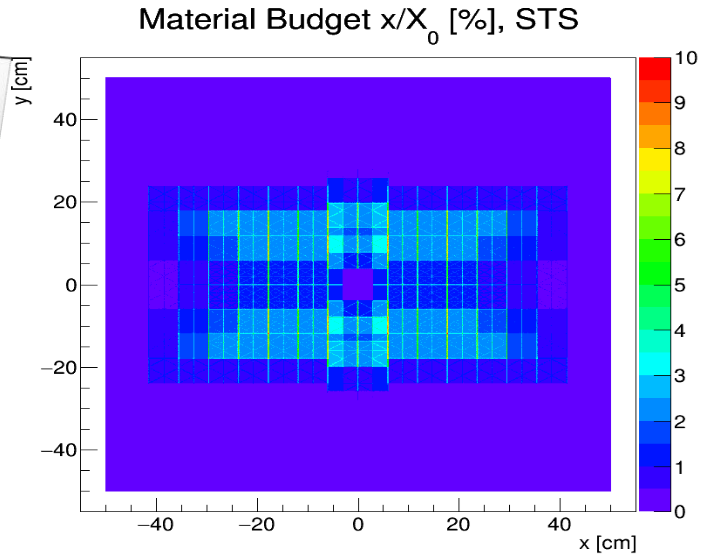
experimental limitations of the first setup:

- low granularity of tracking systems (small S/B ratio);
- no vacuum beam pipe in BM@N (large background)

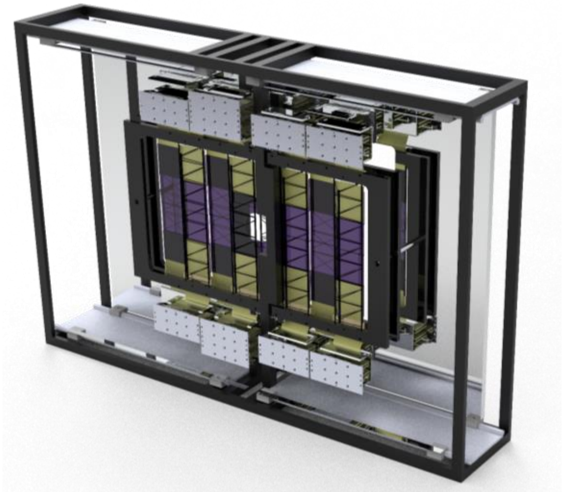
Silicon Tracking System

STS team





STS Material budget



4 x STS stations

34 x Ladders

292 x Modules

Technical solutions:

- *double-sided silicon microstrip sensors*
  - *hit spatial resolution ≈25 μm*
  - *material budget per tracking station: ≈0.3% – 2% X_0*
  - *radiation tolerance up to 1×10^{14} n/cm^2 (1 MeV equivalent)*
- self-triggering front-end electronics, time-stamp resolution ≈ 12,5 ns
- low-mass detector modules/ladders

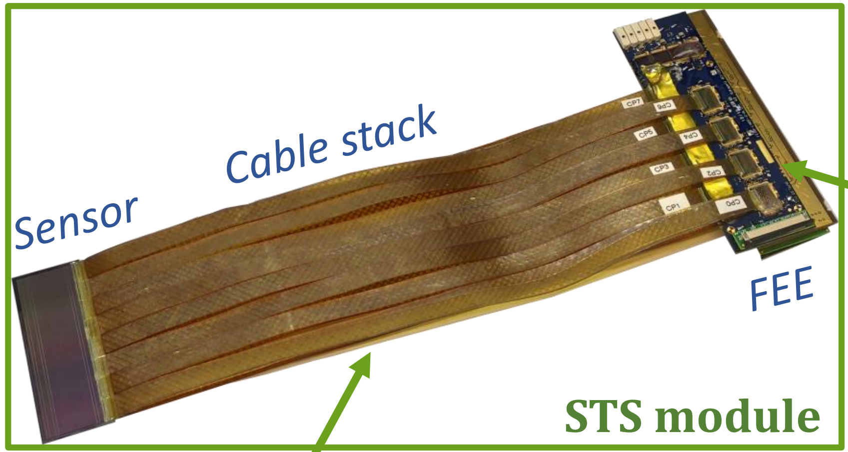
The project is being implemented as a joint effort of CBM and BM@N STS teams under the GSI-JINR Roadmap Agreement

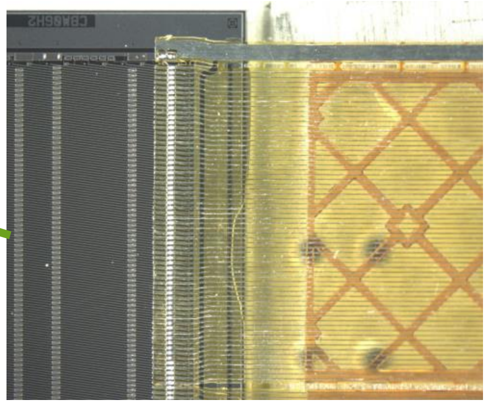
2022 – installation of the first two stations

2024 - commissioning of the full STS

STS modules

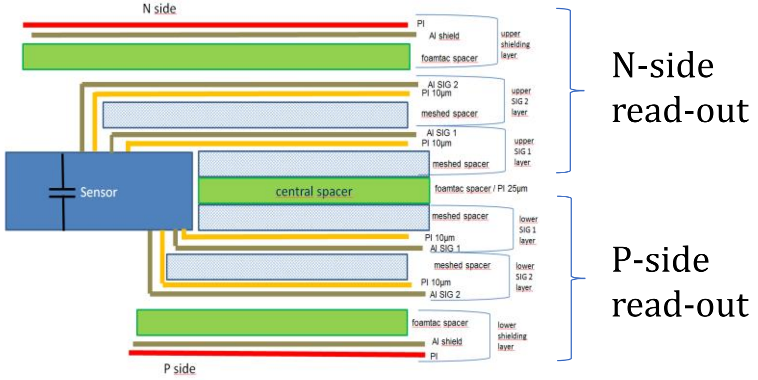
BM@N
Baryonic Matter at Nuclotron
STS team





STS XYTER ASIC Tab-bonded with micro-cables

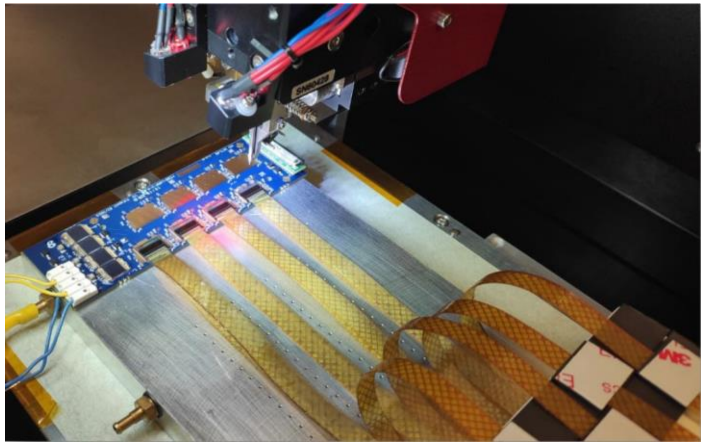
Module assembly at JINR



cable stack: *thickness ~ 800 µm / 0.23%* X_0

Performance:

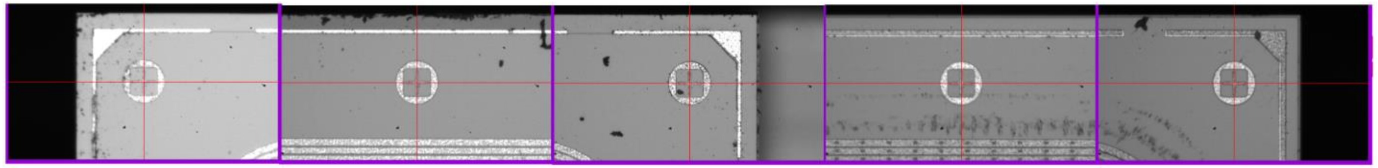
- noise: 1090 ±150 e (N-side);
  1350 ±200 e (P-side);
- r/o threshold: 7000 e;
- signal-to-noise: 15±3 ;
- hit detection eff.: > 95%;



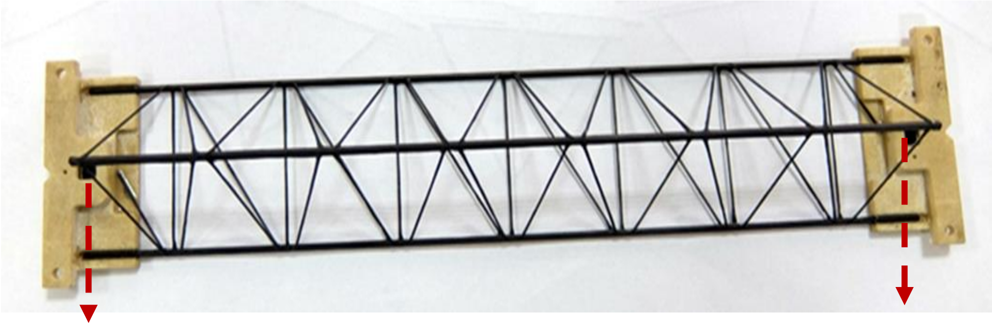
STS ladders

STS team

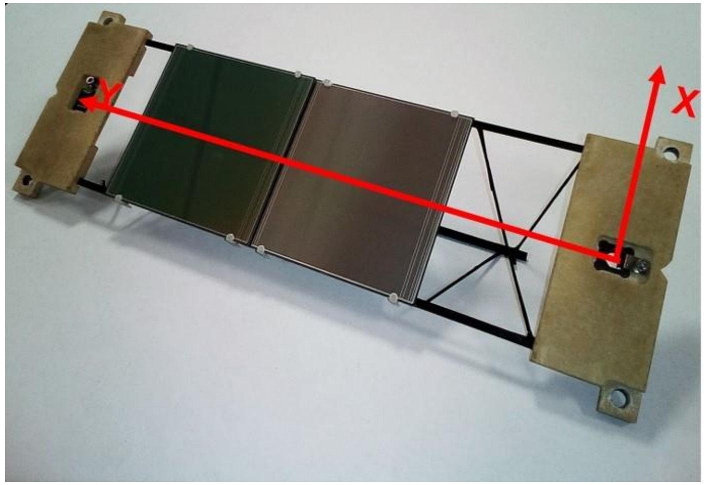
Ladder assembly device



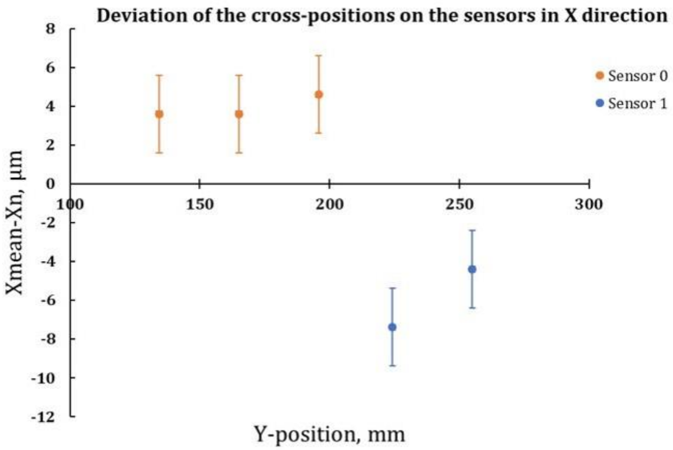
Fiducial marks on sensors



CF-truss with bearings



Mockup of the ladder



Measured deviations of X coordinates of the fiducial marks on the sensors from the mean value.

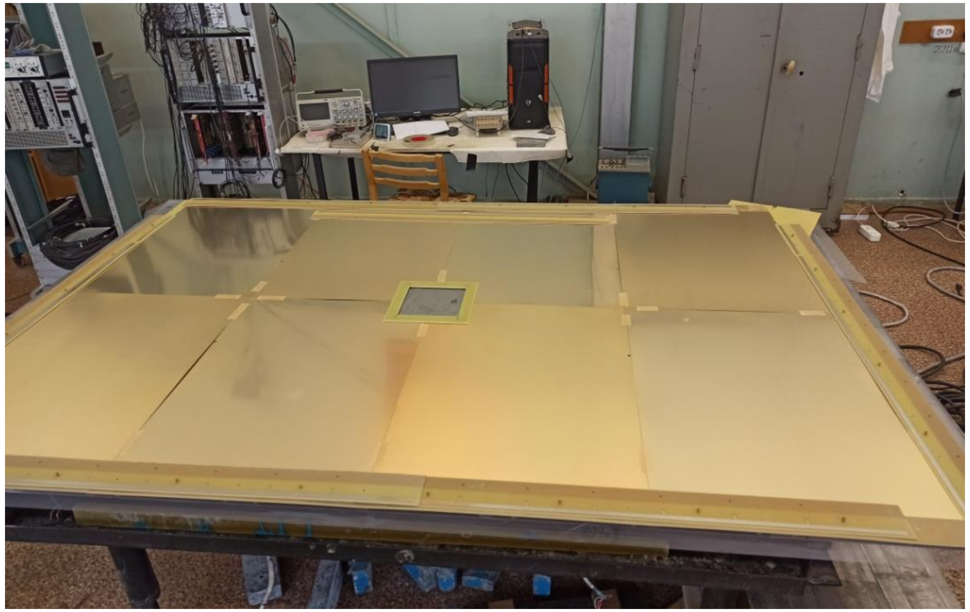
Cathode Strip Chambers

6 CSC chambers for the track measurements outside the magnet:

- 4 chambers with a size of 1065x1065 mm^2 (already assembled)
- 2 chambers with a size of 2190x1453 mm^2 (will be installed in 2022)

- *Two-coordinate CSC chambers;*
- *Stereo angle between strips: 15°;*
- *Pitch: 2.5 mm*

Cosmic stand for the1065x1065 mm^2 CSC



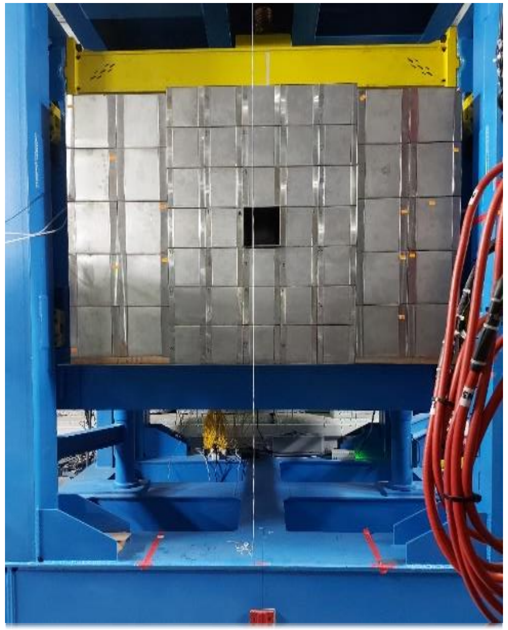
Cathode planes of the 2190x1453 mm^2 CSC

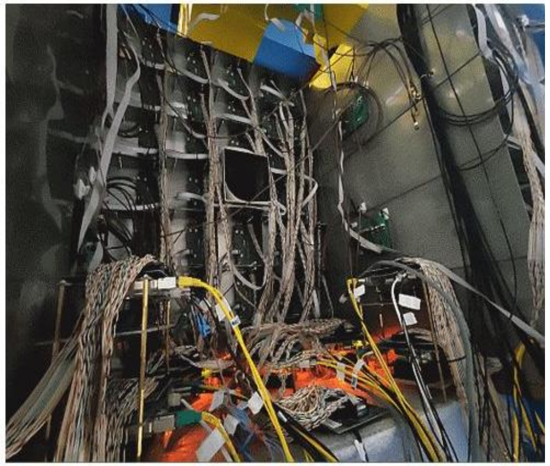
Forward Hardon Calorimetr

Team of INR RAS, Troitsk

Determination of:

- Orientation of the reaction plane
- Collision centrality

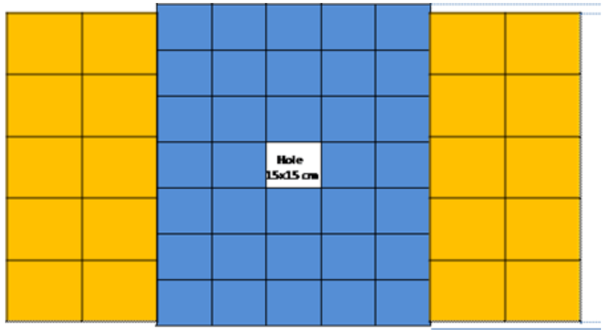


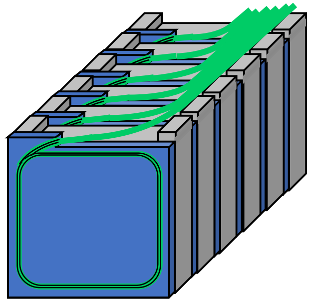


20 PSD CBM modules - transverse size 20x20 cm^2, length 5.6 λ_{int}.

34 MPD/NICA like modules - transverse size 15x15cm^2, length 4 λ_{int}.

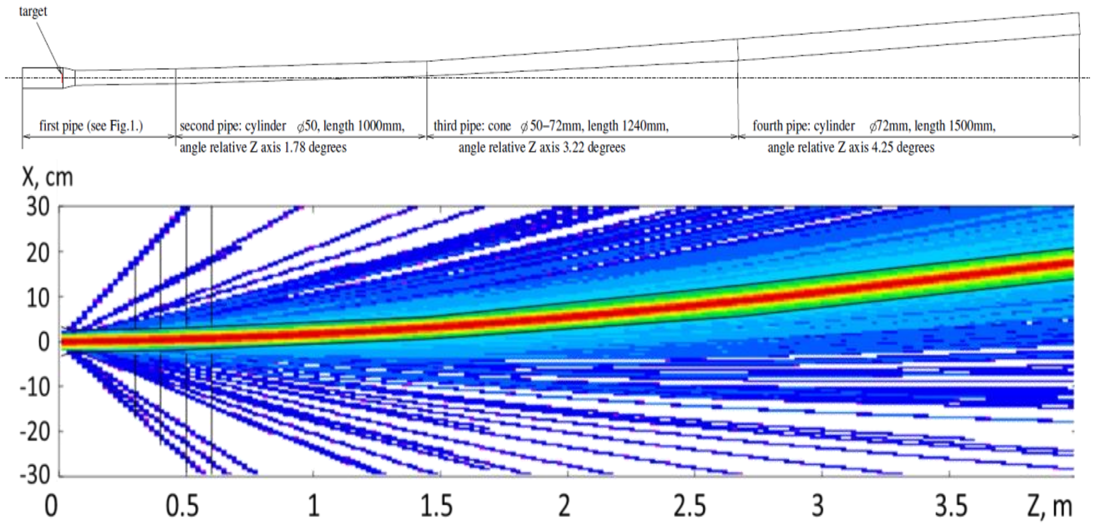
FHCal is completely assembled and installed at the BM@N





CBM modules MPD modules

Beam pipe downstream the target



1 meter prototype of the BM@N carbon beam pipe (DD "Arkhipov")

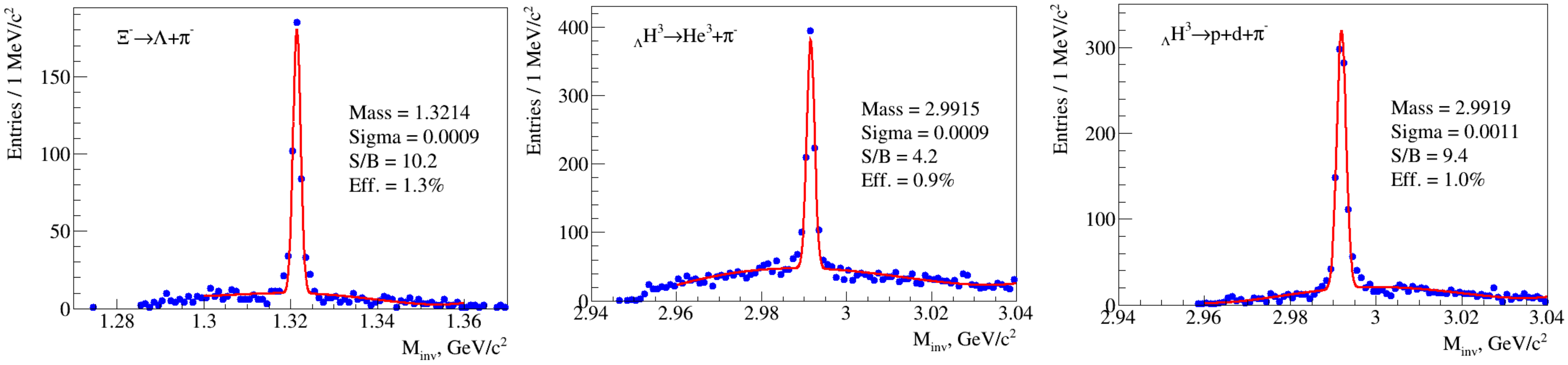
- Beam pipe is made of 1 mm thick carbon fiber;
- Consists of four parts with a non-flange connectors;
- FLUKA simulations have shown that the proposed beam pipe is well suited to guide the high intensity beam;
- First vacuum tests have shown an insignificant leakage level of side surfaces of the sample, vacuum up to 10^{-5} Torr.

A. Senger, P. Senger, S. Piyadin,V. Spaskov, A.Kubankin

Physics performance simulations of the tracking system

Ξ^- and ${}_{\Lambda}H^3$ reconstruction in central Au+Au at 4A GeV

- Generator: PHQMD (V. Kireyeu), 500k events, Au+Au at 4A GeV, b = 0-5 fm
- Statistics: $\approx 2 \cdot 10^6\ \Lambda$, $\approx 2 \cdot 10^4\ \Xi^-$, $\approx 8.4 \cdot 10^4\ {}_{\Lambda}H^3$
- Detectors: STS + GEMs + TOF



A.Zinchenko, M.Kapishin, I.Rufanov, V.Vasendina

Summary

- Nuclotron energy range is well suited for the study of high density baryonic matter
- BM@N is being upgraded in order to start experiments with heavy ion beams up to Au in 2022

Stages of BM@N experiment:

2021: beams of Kr and Xe;

2022: Au beams with max. intensity 0.5 MHz and trigger rate 10 kHz, *installation of 2 stations of STS*;

2023: Au beams with max. intensity 2 MHz and trigger rate 50 kHz;

2024: *Installation of the full STS*.

Thank you for your attention!