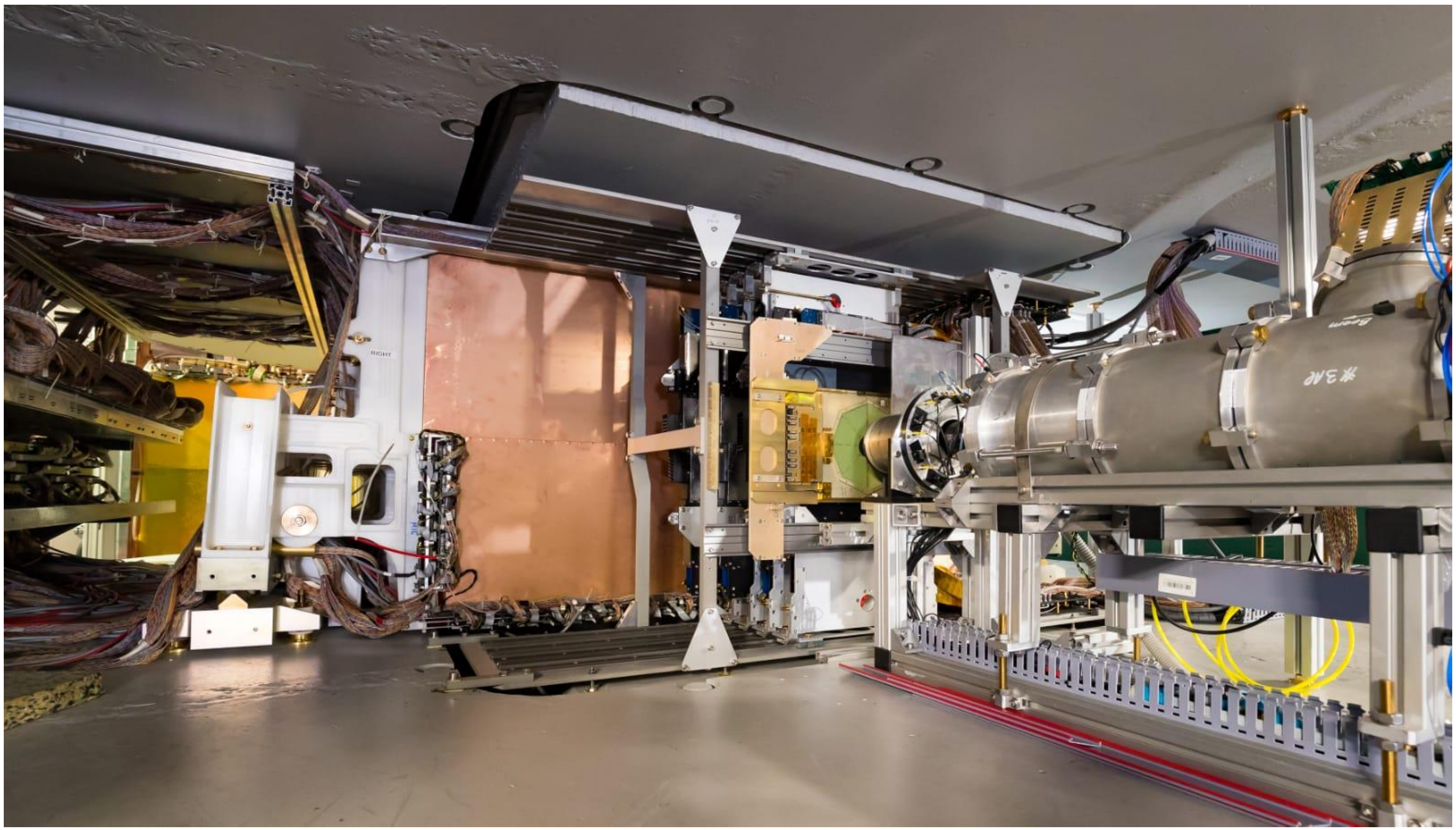
Implementation of the BM@N project

M.Kapishin

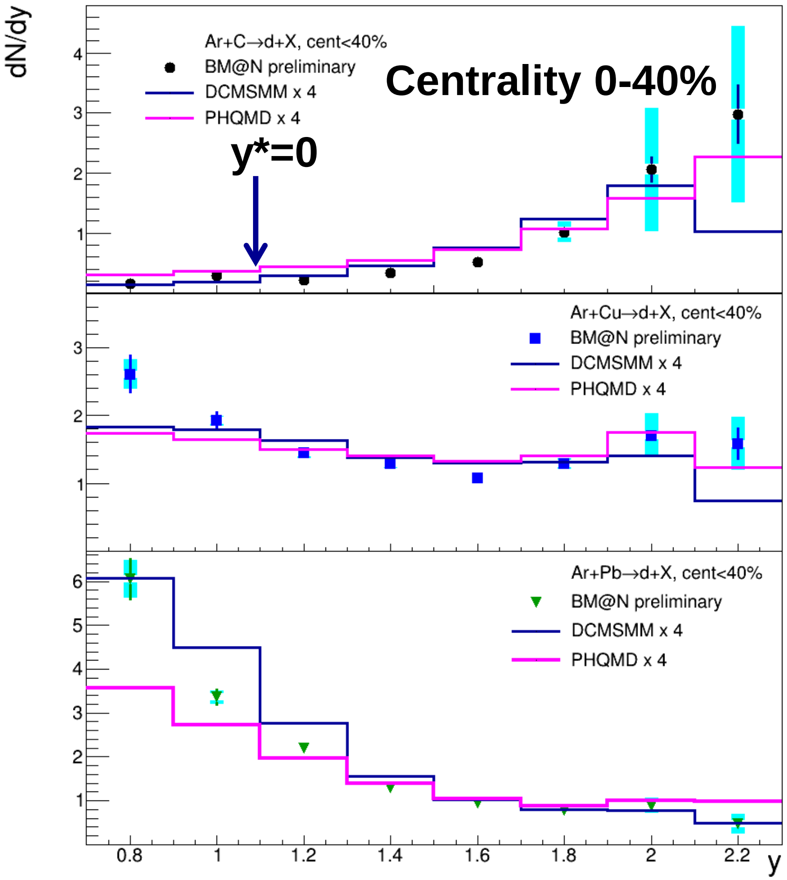


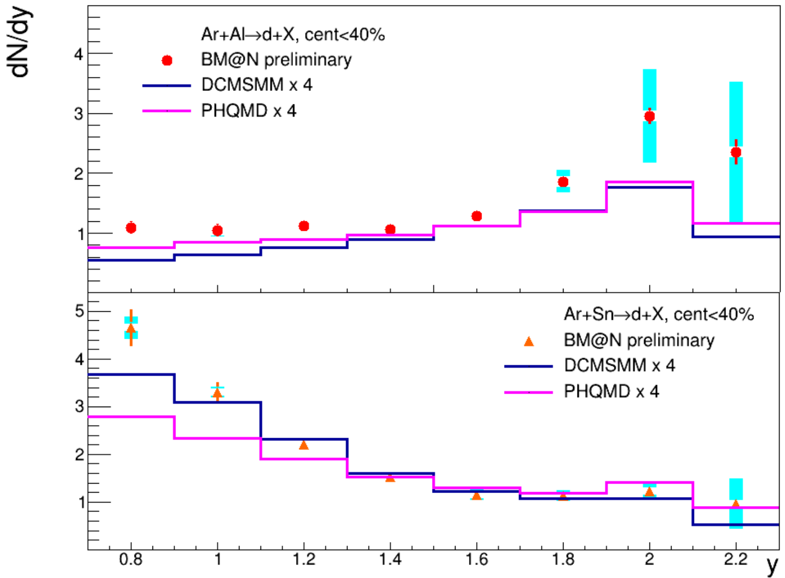
Baryonic Matter at Nuclotron (BM@N) Collaboration:

5 Countries, 13 Institutions, 217 participants

- *University of Plovdiv, Bulgaria*
- *St.Petersburg University*
- *Shanghai Institute of Nuclear and Applied Physics, CFS, China;*
- *Joint Institute for Nuclear Research;*
- *Institute of Nuclear Research RAS, Moscow*
- *NRC Kurchatov Institute, Moscow combined with Institute of Theoretical & Experimental Physics, NRC KI, Moscow*
- *Moscow Engineer and Physics Institute*
- *Skobeltsyn Institute of Nuclear Physics, MSU, Russia*
- *Moscow Institute of Physics and Technics*
- *Lebedev Physics Institute of RAS, Moscow*
- *Institute of Physics and Technology, Almaty*
- Physical-Technical Institute Uzbekistan Academy of Sciences, Tashkent
- High School of Economics, National Research University, Moscow

BM@N paper draft: Production of *p, d, t* in 3.2 AGeV argon-nucleus interactions at the Nuclotron





$y^* = y_{lab} - y_{CM}$, $y_{CM} \approx \langle y(\pi) \rangle$

Ar+C: $\langle y(\pi) \rangle = 1.27$

Ar+Pb: $\langle y(\pi) \rangle = 0.82$

- **dN/dy spectrum softer in interactions with heavier target**
- **DCM-SMM and PHQMD models describe data shape, but are lower in normalization by factor 4**

BM@N preliminary results, papers, conferences

Production of *p, d, t* in 3.2 AGeV argon-nucleus interactions at the Nuclotron

BM@N preliminary, extension of the paper draft

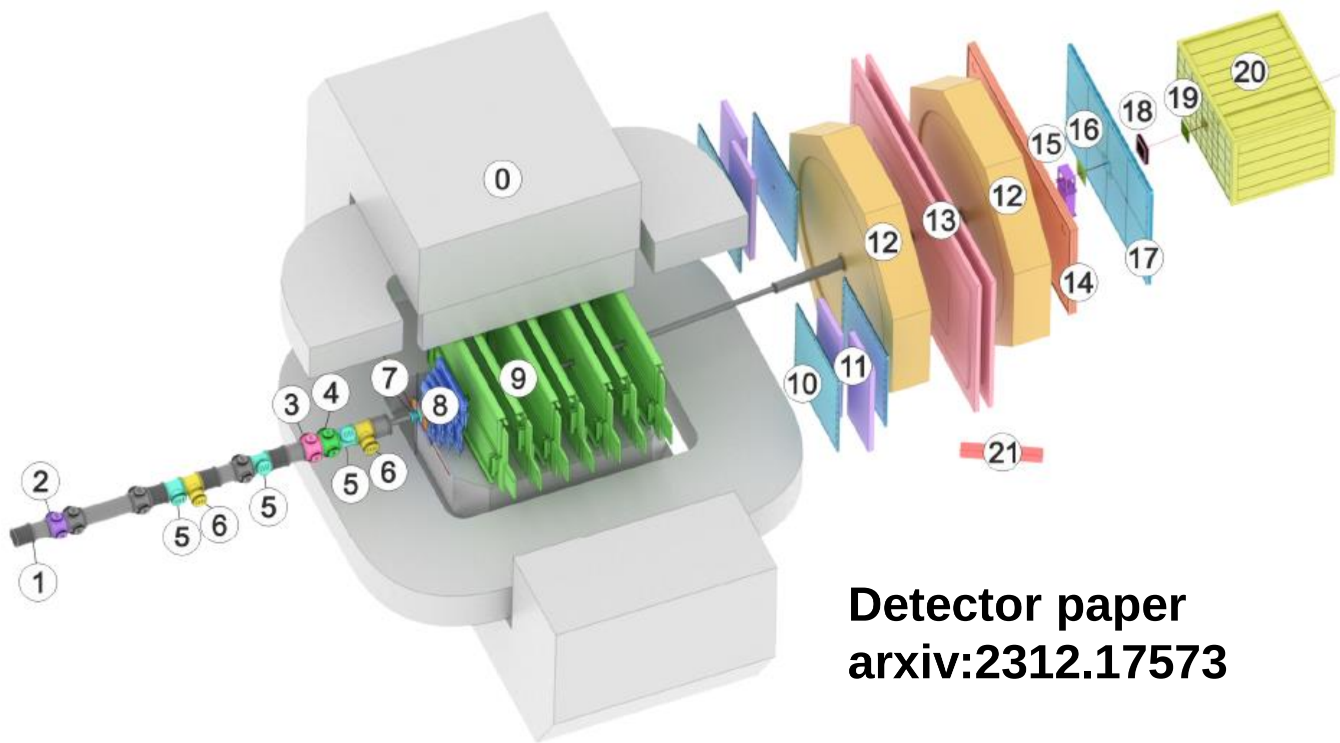
The BM@N spectrometer at the NICA-Nuclotron facility

The BM@N detector paper for the Xe+CsI run configuration, accepted for publication in NIM A, arxiv:2312.17573

BM@N presented / submitted physics and detector talks at conferences:

Workshop NICA-2023, December 2023
Scientific session of the Russian Academy of Sciences, Dubna, April 2024
Conference Nucleus-2024, Dubna, July 2024
Conference "Hadron Structure and Fundamental Interactions” - HSFI'2024, Gatchina, July 2024

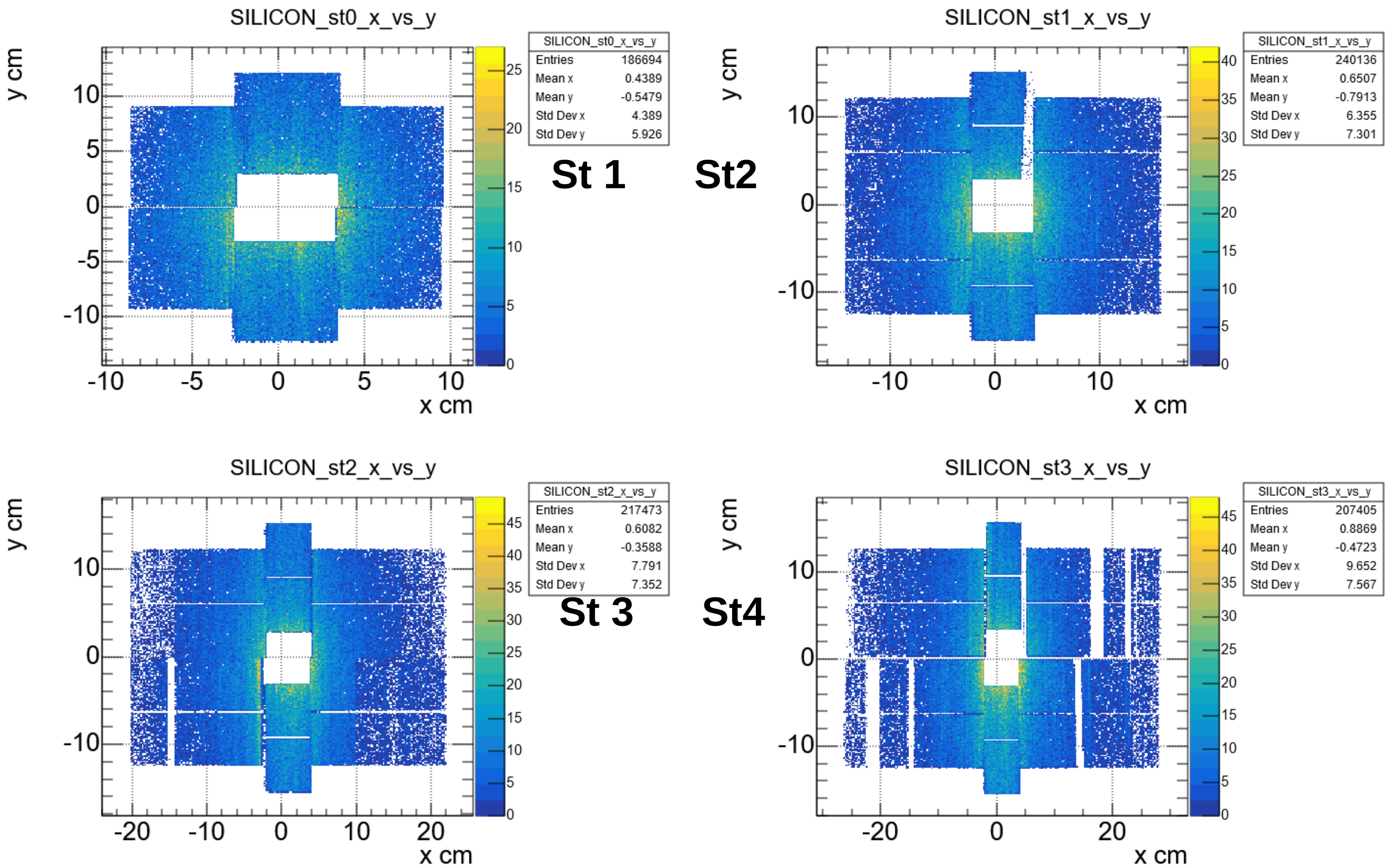
Configuration of BM@N detector in Xe+CsI run



Detector paper arxiv:2312.17573

Xe^{124} + CsI interactions:
main trigger cover centrality < 70-75% (85% events)
min bias trigger (7% events), beam trigger (3% events)

FSD hit reconstruction in Xe run: 4 Si stations



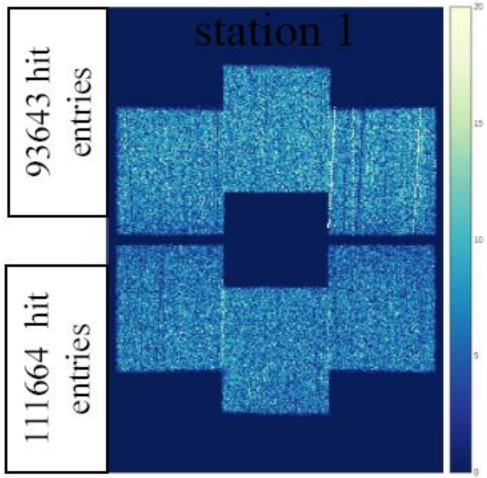
→Readout cards with defected chips in stations 2, 3 and 4 are replaced

Repair FSD detectors:

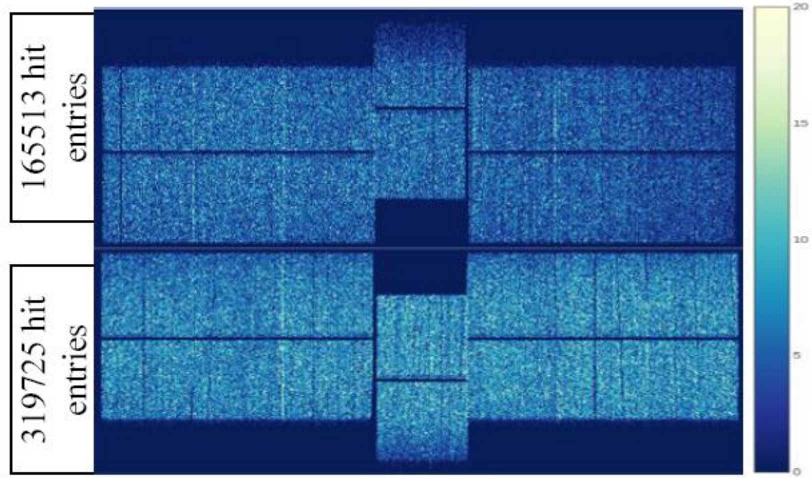
FSD: after replacing

FSD group

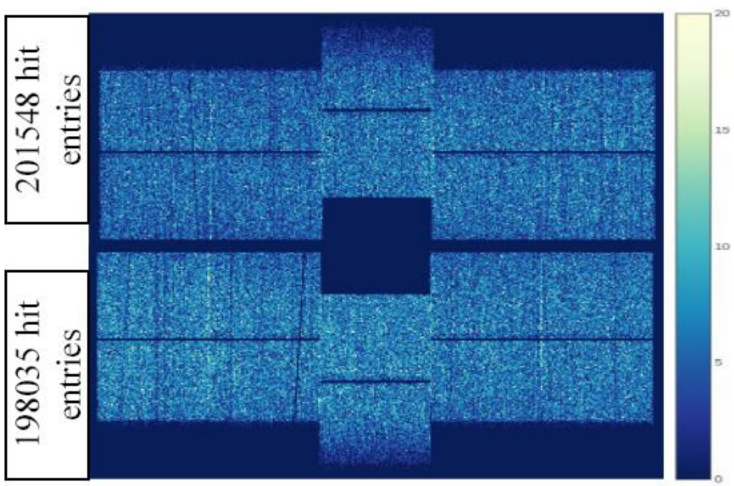
Cosmic tests station 1



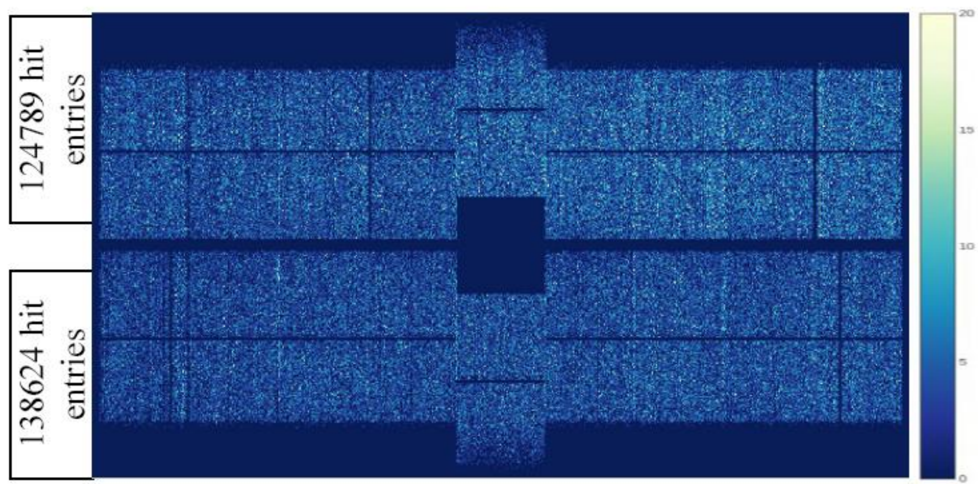
Cosmic tests station 3



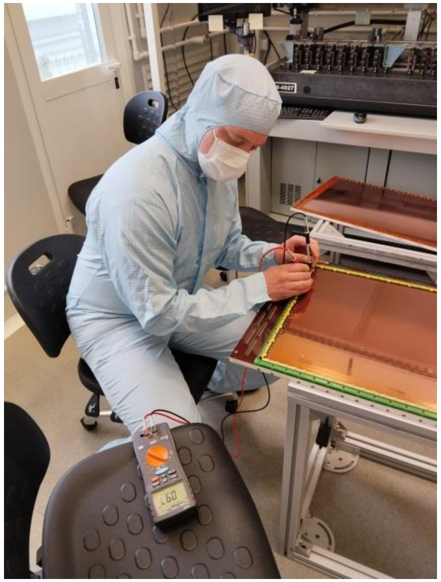
Cosmic tests station 2

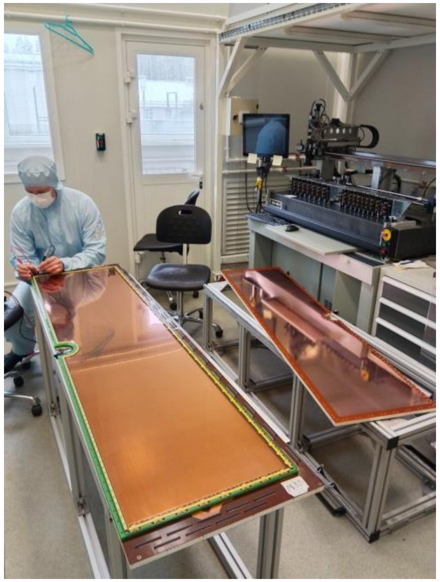


Cosmic tests station 4

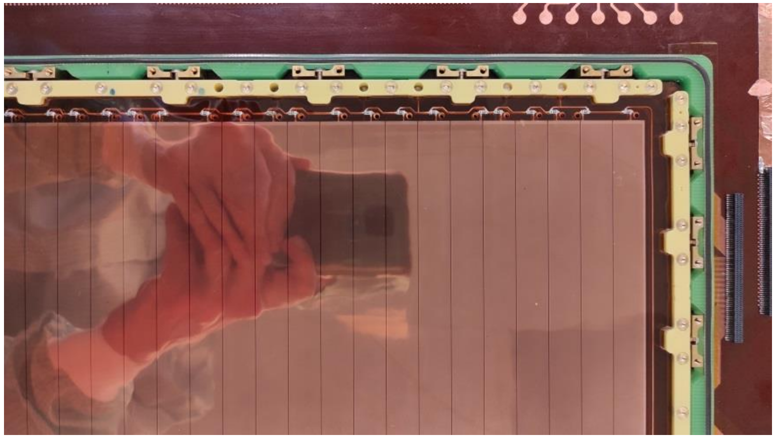


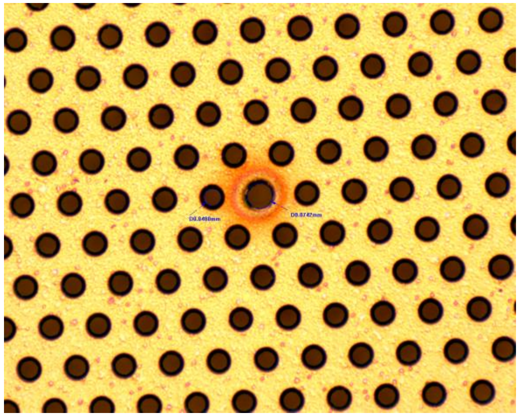
Repair and tests of GEM detectors

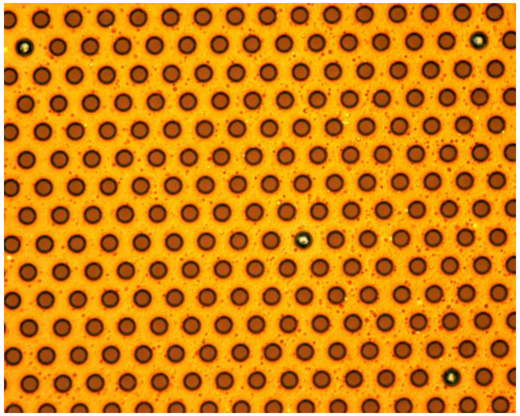




S.Piyadin
E.Kulish
S.Khabarov
A.Makankin
and support team

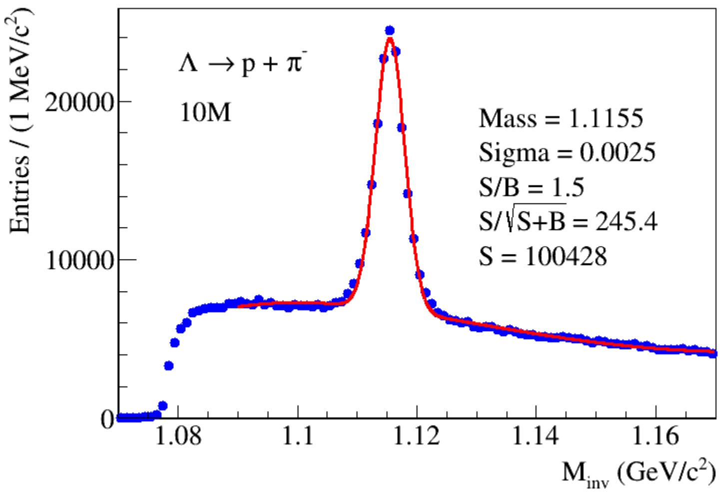


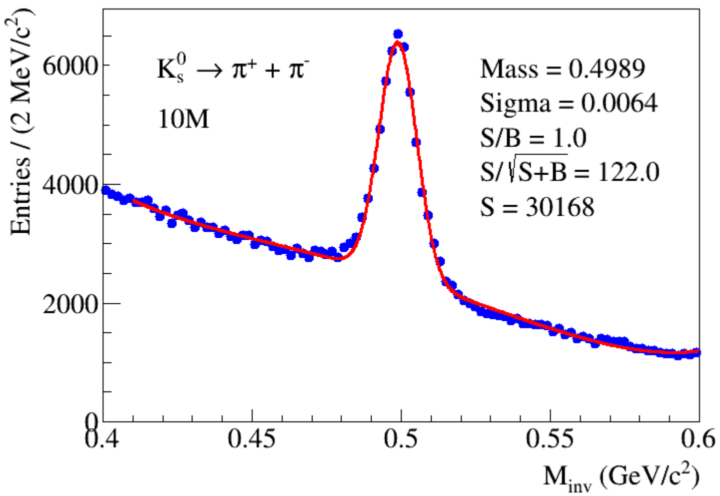




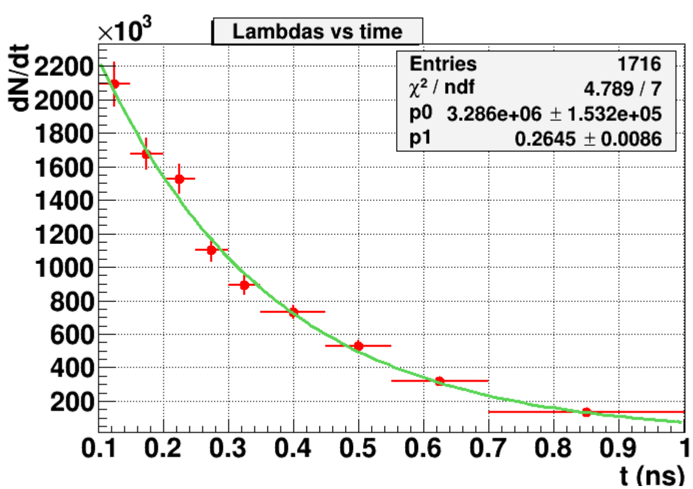
Xe+ CsI data : $\Lambda \rightarrow p\pi^-$, $K^0_s \rightarrow \pi^+\pi^-$

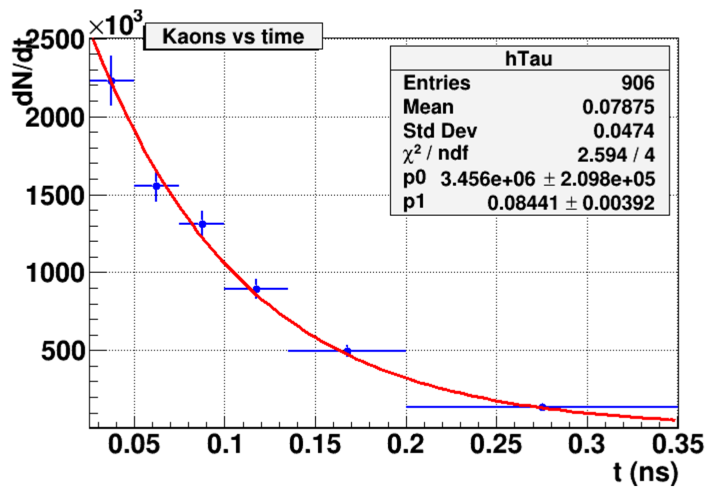
A.Zinchenko, V.Vasendina, J.Drnoyan





In 500M events expect: 4M Λ, 1.2M K^0_S



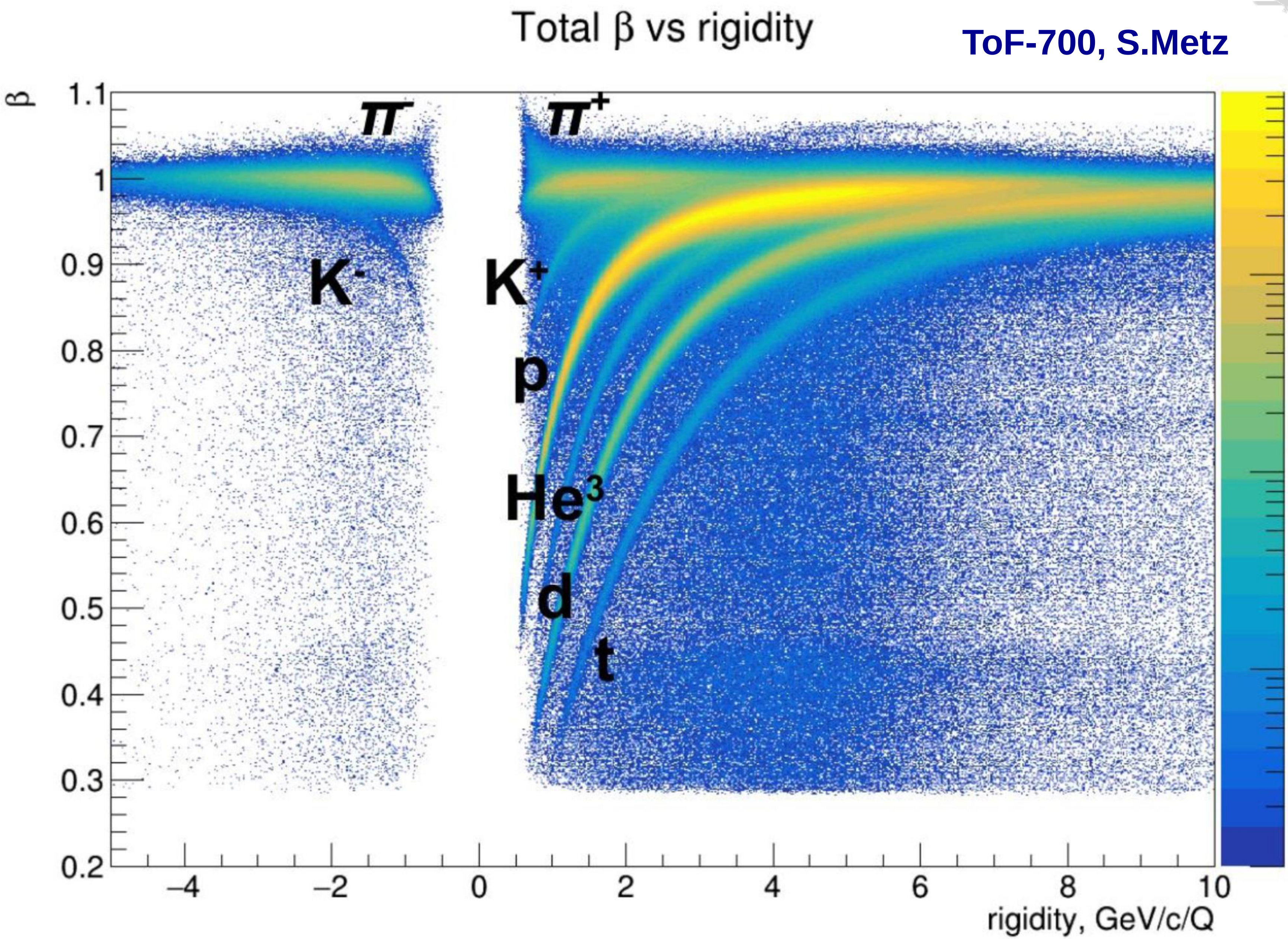


Life time is in agreement with PDG values: 0.2632 ns for Λ, 0.0895 ns for K^0_s

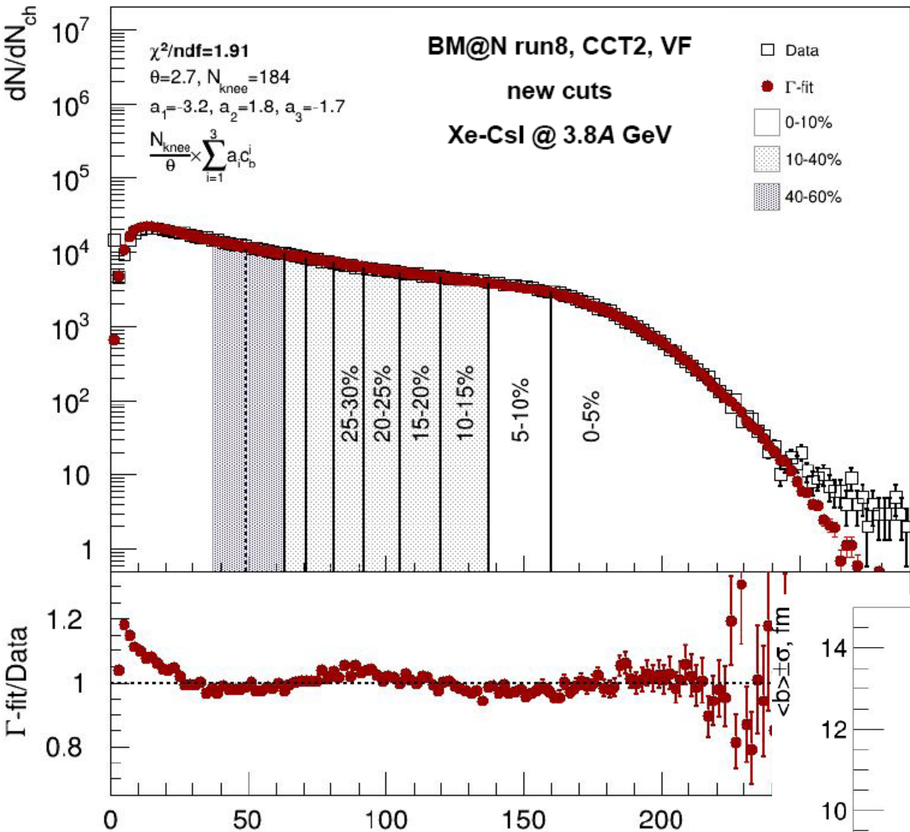
Xe+CsI data: π±, K±, p, He3, d, t identification

BM@N

ToF-700, S.Metz



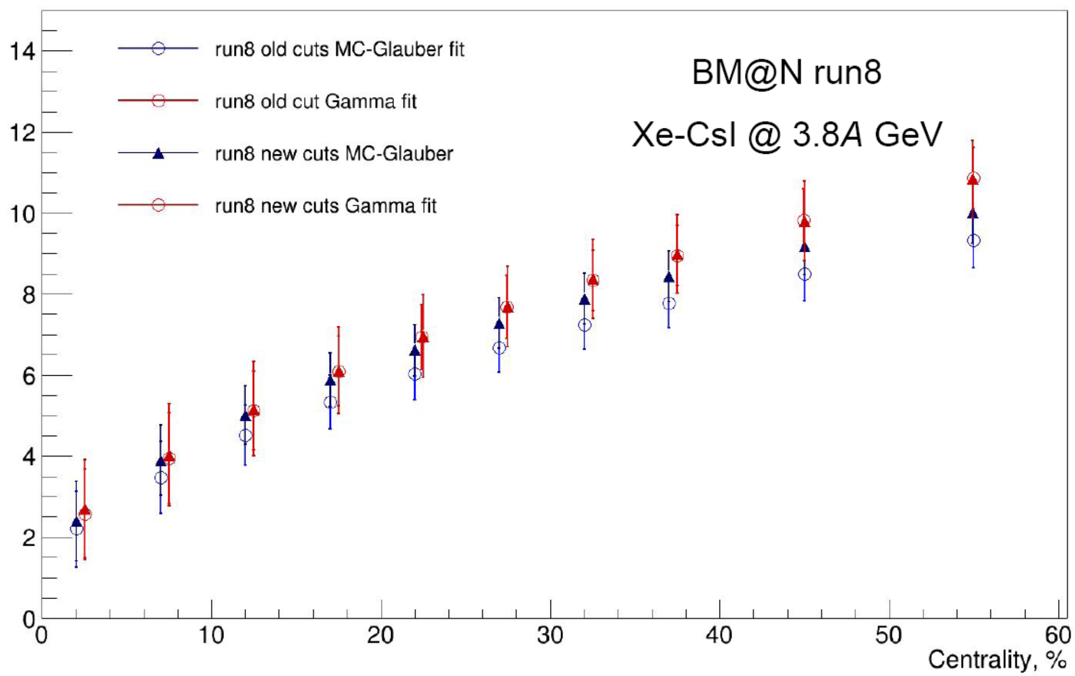
Centrality selection from fits of the track multiplicity



MEPhI group

- Parametrization of data track multiplicity N_{ch} by MC Glauber model or Negative Binominal Distribution (Γ-fit) with free parameters
- Extract $P(b \mid N_{ch})$

- Still need to correct for trigger efficiency, changes in central tracker (FST, GEM) efficiency

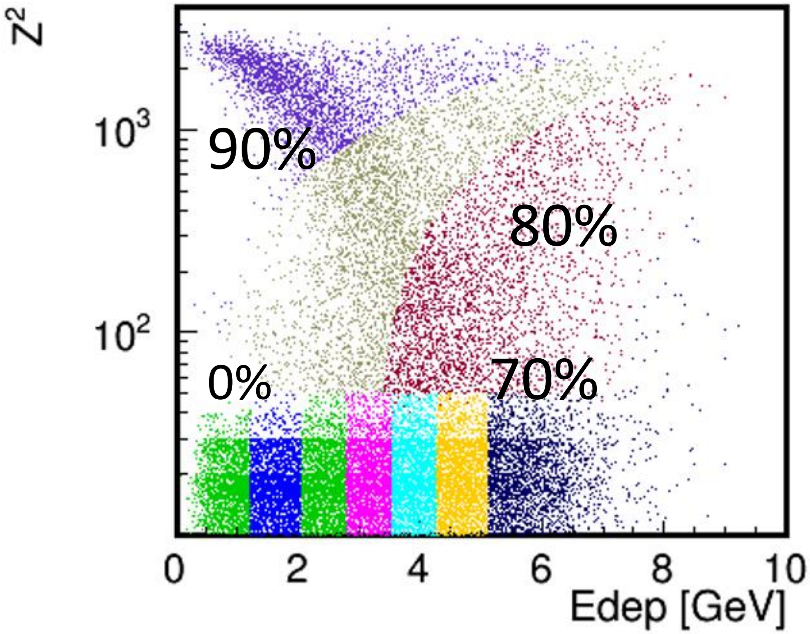


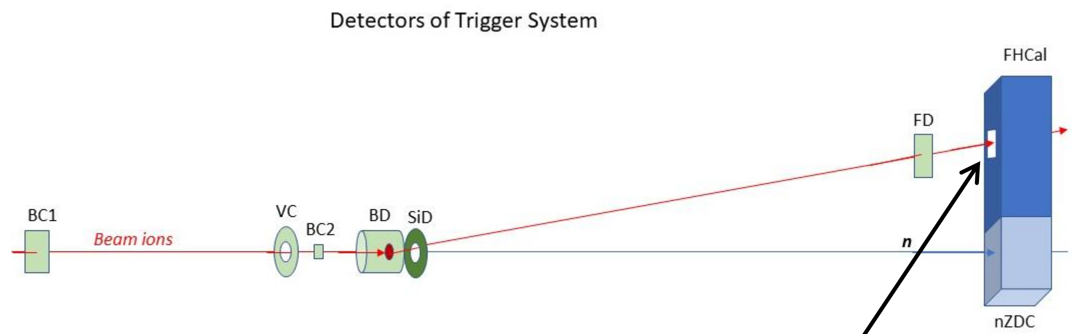
Γ-fit and MC-Glauber fit are in agreement

Centrality selection in forward detectors: hodoscope and FHCal

Color bins – 10% of number of events in each bin

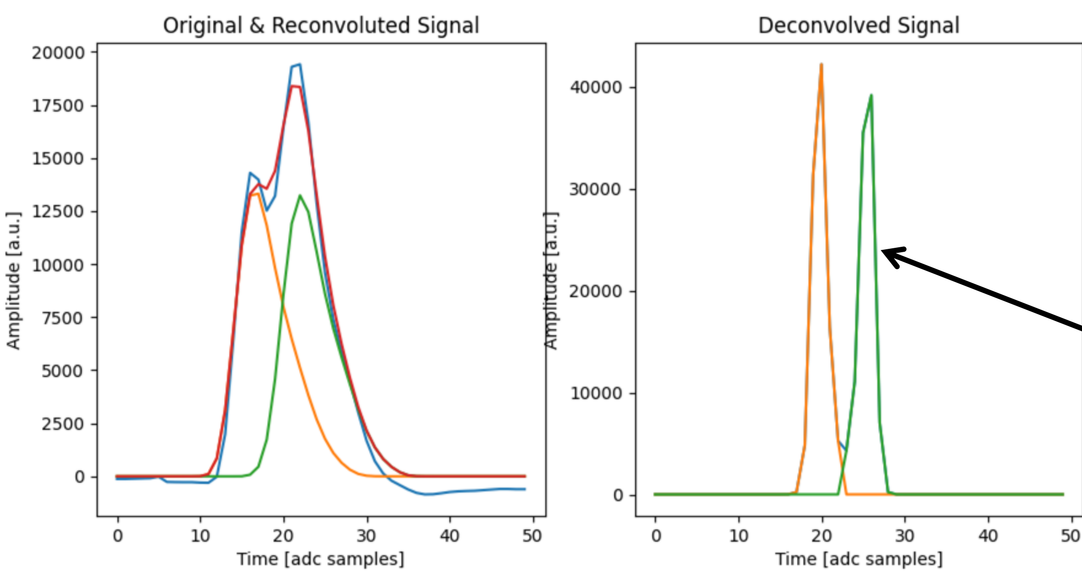
INR RAS group





Fragment hodoscope

~30% events with Z^2 signal pile-up in the beam hodoscope



Need to subtract pile-up to determine centrality unbiased

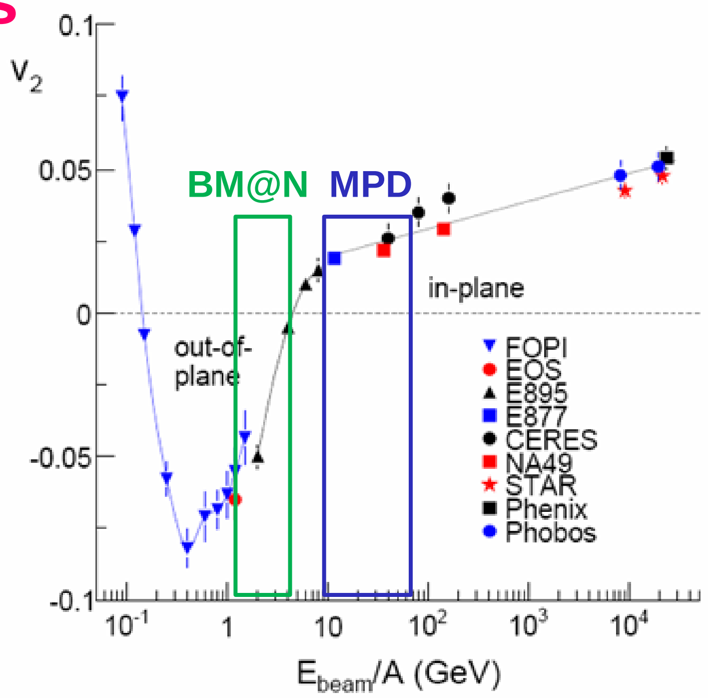
Pile-up correction in fragment hodoscope by signal unfolding

→ remain 4% events with unresolved peaks in multi-ion pile-up

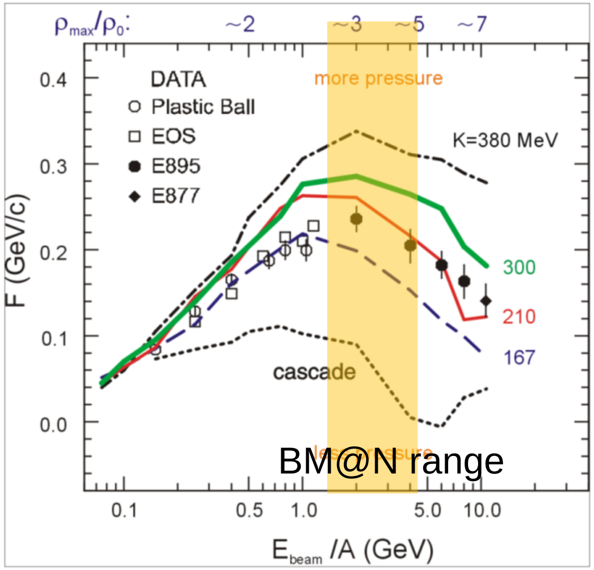
Collective flow of identified particles

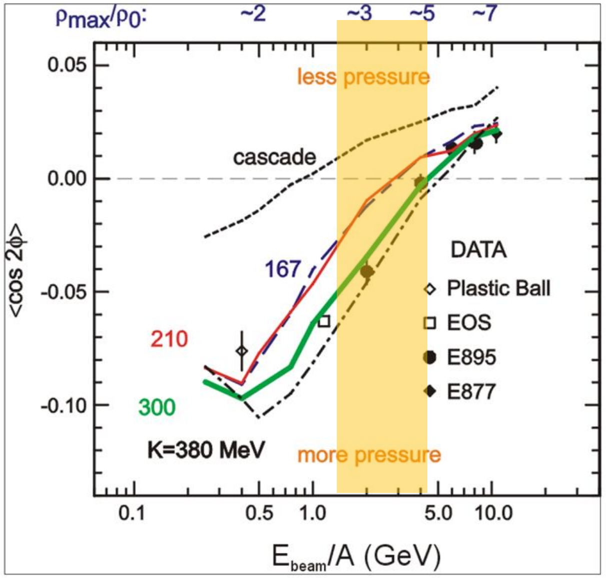
➢ collective flow of identified particles (π,K,p,Λ,Ξ,Ω,...) driven by the pressure gradient in the early fireball

Azimuthal angle distribution:
$dN/d\varphi \propto (1 + 2v_1 \cos\varphi + 2v_2 \cos 2\varphi)$

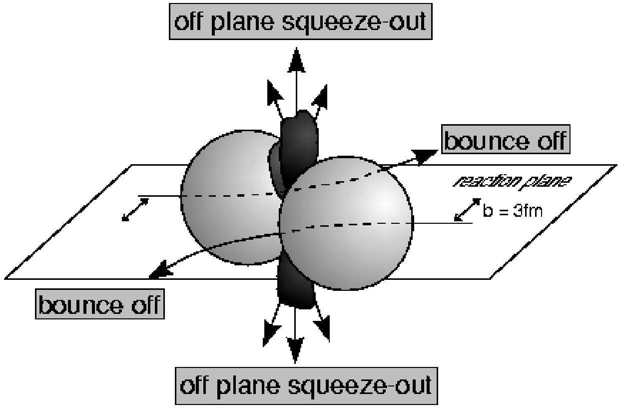


Proton flow in Au+Au collisions
in-plane flow ~ v_1 out-of-plane flow v_2



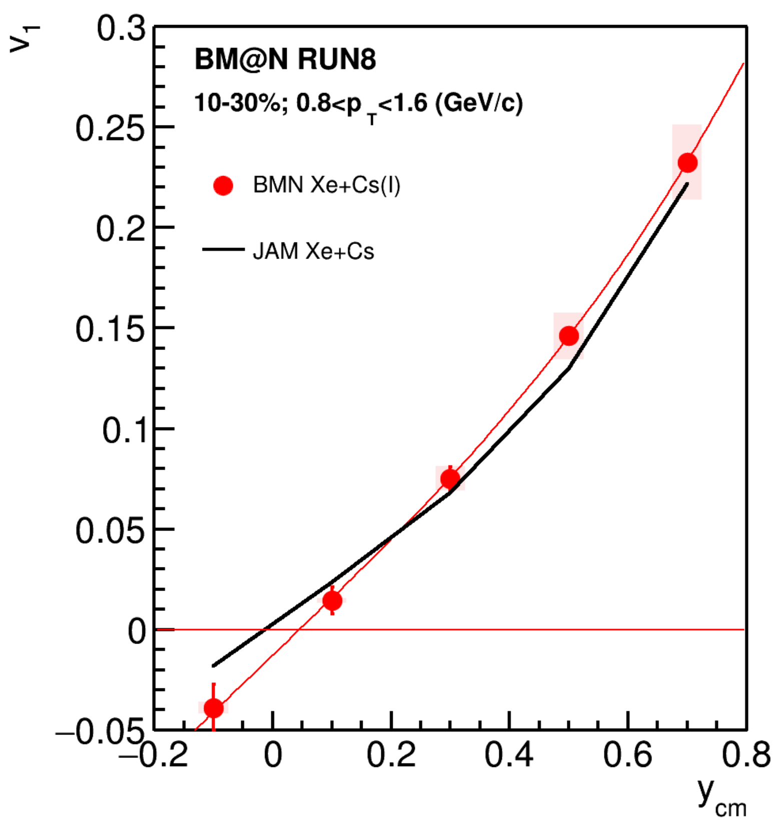


P. Danielewicz, R. Lacey, W.G. Lynch, Science 298 (2002) 1592

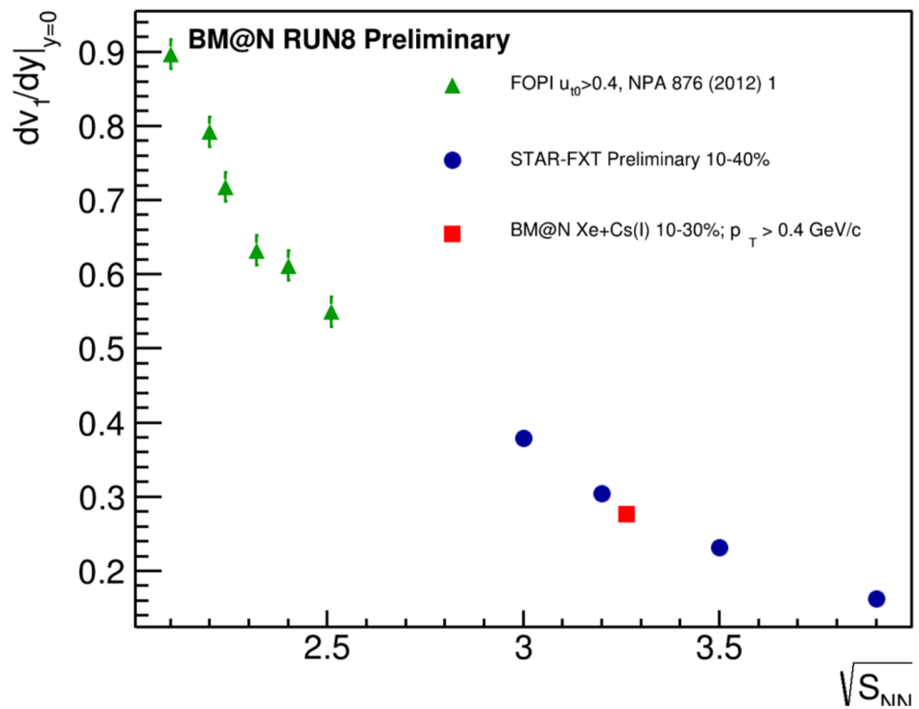


Progress in proton v_1 flow measurement: v_1 vs y_{cm} and $dv_1/dy|_{y=0}$ vs $\sqrt{s_{NN}}$

MEPhI group



JAM model describes $v_1(y)$ well



$dv_1/dy|_{y=0}$ is in a good agreement with the world data

Current tasks for the Xe data analysis

Activities since the last Collaboration meeting in November 2023:

- 2 times processing of event reconstruction using DIRAC at Tier MLIT

→ Reasonable signals of Λ and K^0_S, life time within 1 sigma from PDG (A.Zinchenko, V.Vasendina, J.Drnoyan, R.Barak)

→ Good agreement between data and reconstructed Λ and K^0_S simulation

→ Progress in identification of charged particles in ToF-400 and ToF-700 (M.Rumyantsev, I.Zhavoronkova, S.Merts, N.Huhaeva, V.Plotnikov)

→ newly processed data could be used for physics analyses of charged mesons and light nuclear fragments

→ Analysis of v1 and v2 flows for protons (MEPhI)

→ Beam pile-up corrections in fragment hodoscope are done, they are needed for the centrality measurement in fragment hodoscope and hadron calorimeter (INR RAS)

Tasks to be completed for physics analyses:

- Centrality measurement with forward detectors (INR RAS) and track multiplicity (MEPhI), need to compare the results of two methods for Λ and K^0_S
- Evaluate trigger efficiency for different centrality classes

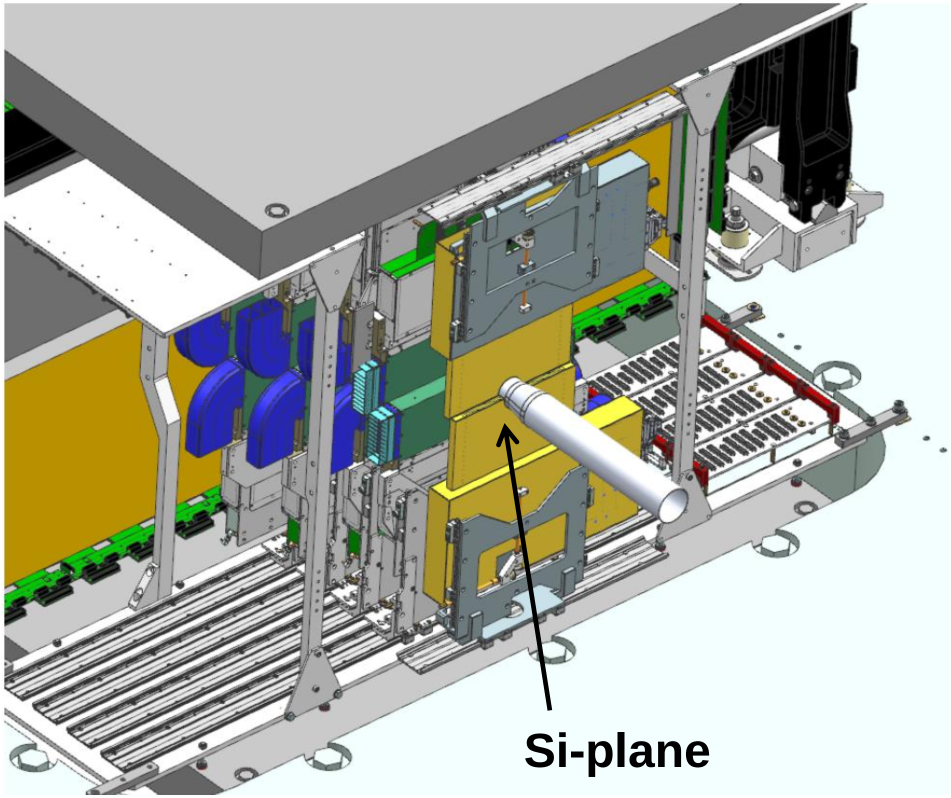
- **Topics of physics analyses:**
- analysis of production of Λ, Ξ- hyperons, K^0_S , K±, π± mesons, light nuclear fragments and neutrons in Xe+CsI interactions;
- analysis of collective flow of protons, π±, light nuclear fragments
- search for light hyper-nuclei $_{\Lambda}H^3$, $_{\Lambda}H^4$

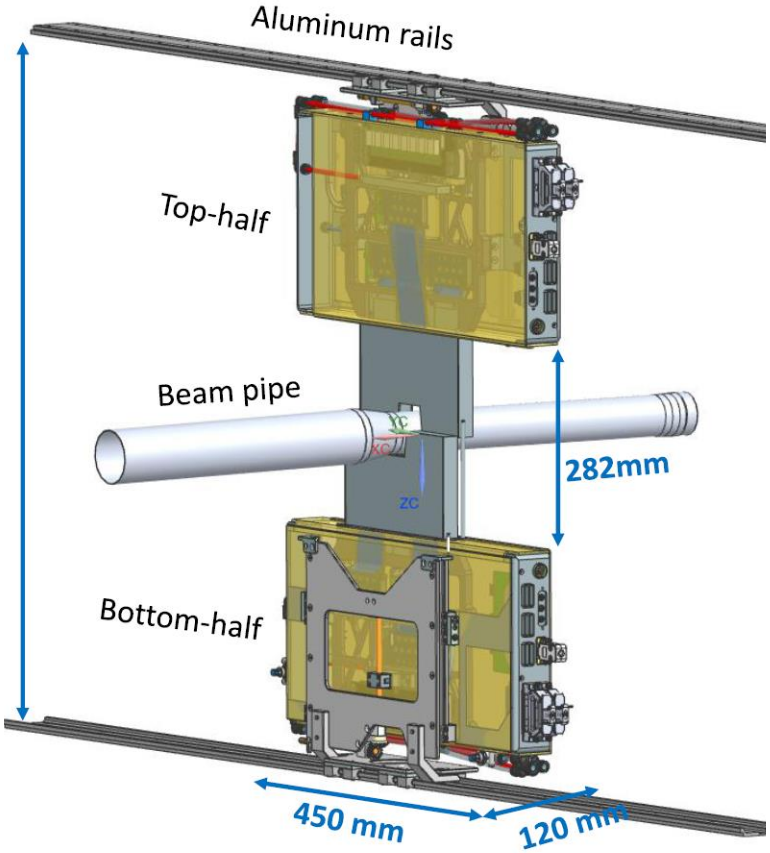
2-coordinate Si-plane based on STS modules

STS group

A new Si-plane based on STS modules to be installed between the **Target** and **Forward Si-Tracker**

Motivation: to improve track and momentum resolution for the low-momentum particles

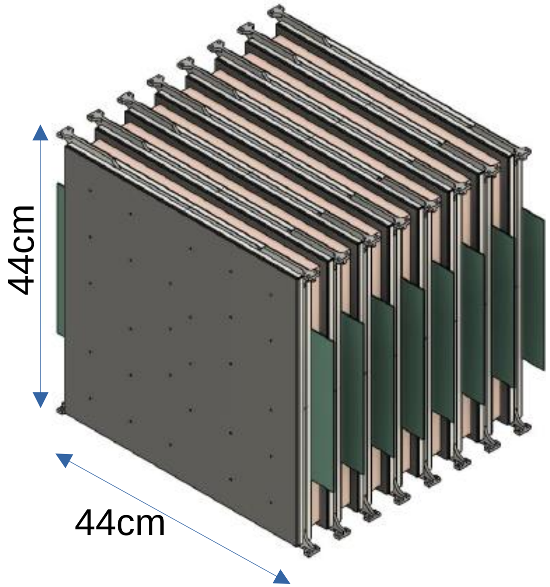




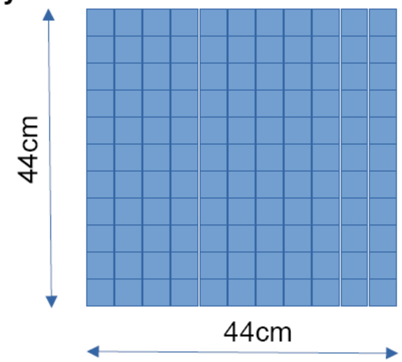
Plan to install and commission the new Si plane in fall 2024

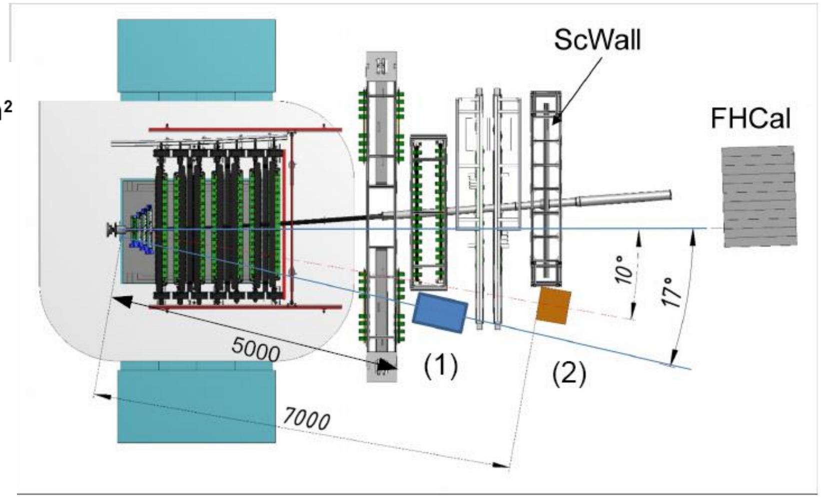
High Granularity Neutron detector

INR RAS, JINR, NRC Kurchatov → **plan to construct in 2024-25**



Structure of Scint. layer:
array of 11x11 scintillator cells 4 x 4 cm²

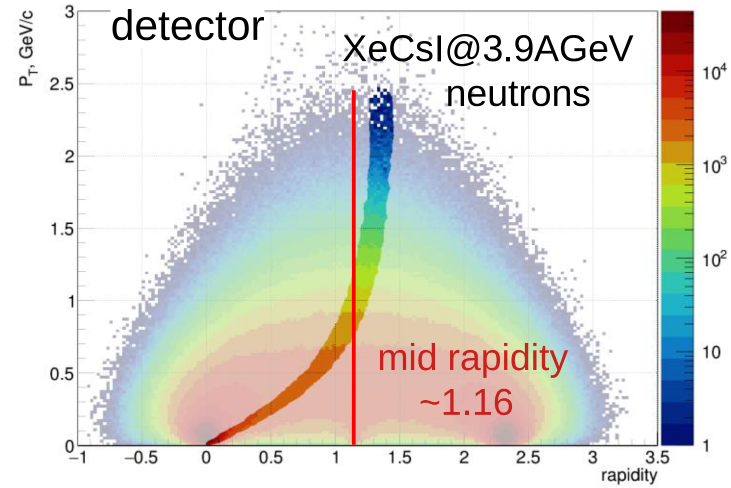




2 positions of HGN detector at BM@N: at 10º and 17º

HGN detector parameters: 2 sub-detectors with 8 layers each (~1.5 λ_{int})
- 11 x 11 cells in one layer with SiPM read-out
- first layer works as VETO
- next 7 layers: 3cm Cu + 2.5cm scintillator
- FPGA based fast TDC read-out with additional ToT amplitude measurement
  - time resolution of one scint. cell ~ 120ps
  - neutron detection efficiency: > 60% @ 1GeV

Acceptance of HGN detector



Plans for BM@N upgrade and physics runs

Physics run with the Xe beam in 2024-2025

→ beam energy scan in the range of 2-3 AGeV
→ same central tracker configuration based on silicon FSD and GEM detectors,
→ additional 1st vertex plane of silicon STS detectors
→ complete replacement of outer drift chambers with cathode strip chambers
→ additional ToF-400 modules to extend acceptance by factor 1.5

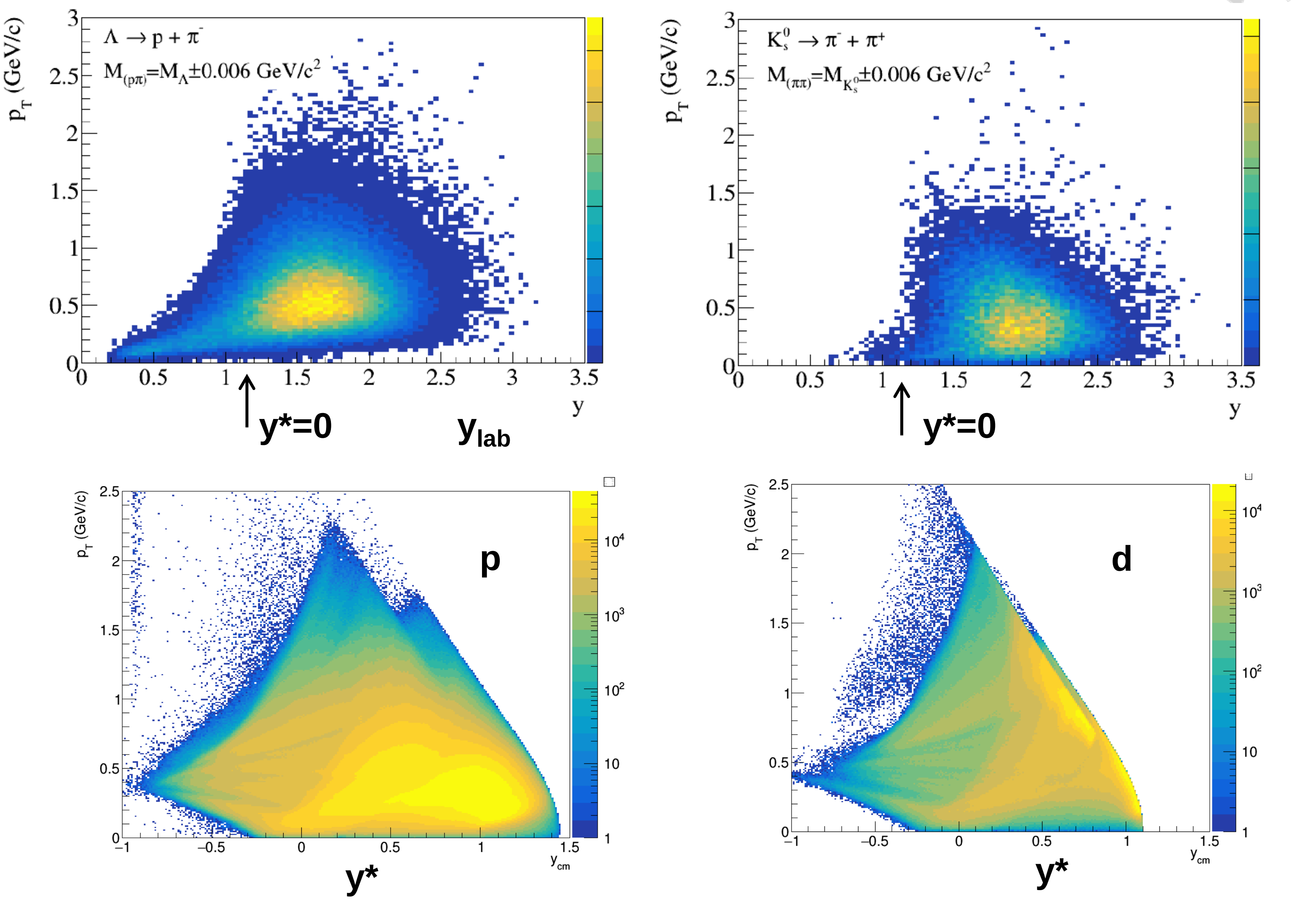
Preparations for the physics run with the Bi beam

- further development of the central tracker is foreseen: installation of additional stations of silicon FSD detectors

- It is planned to put into operation a 2-coordinate (X/Y) neutron detector of high granularity to measure neutron yields and collective flow

Thank you
for attention!

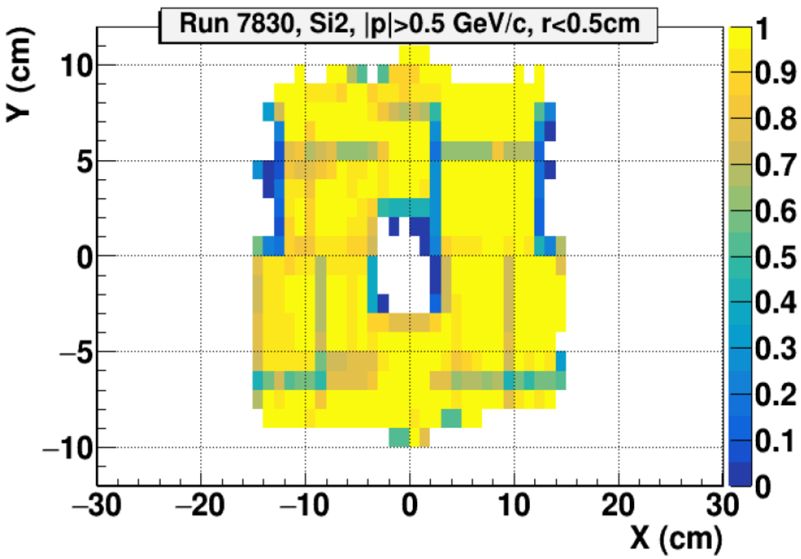
BM@N acceptance for Λ, K^0_s , identified p, d



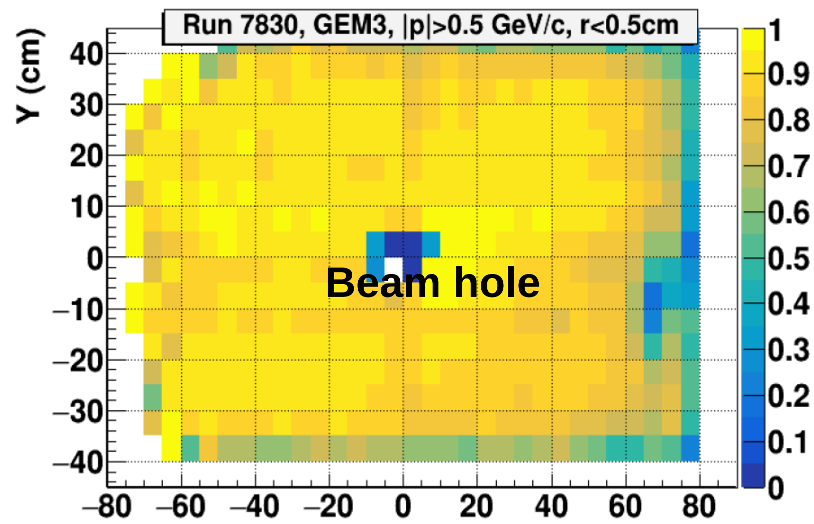
Efficiency of Si and GEM detectors in Si run

A.Zinchenko

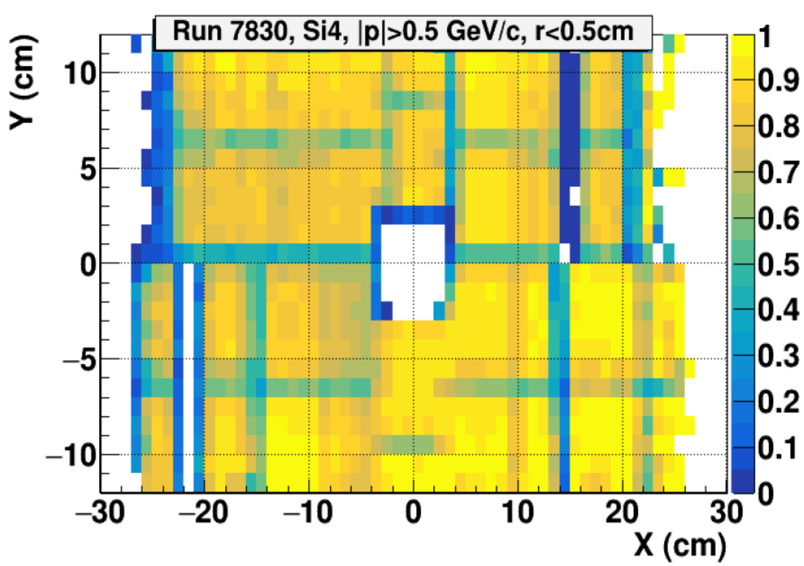
Si-2 station: X/Y map of efficiency



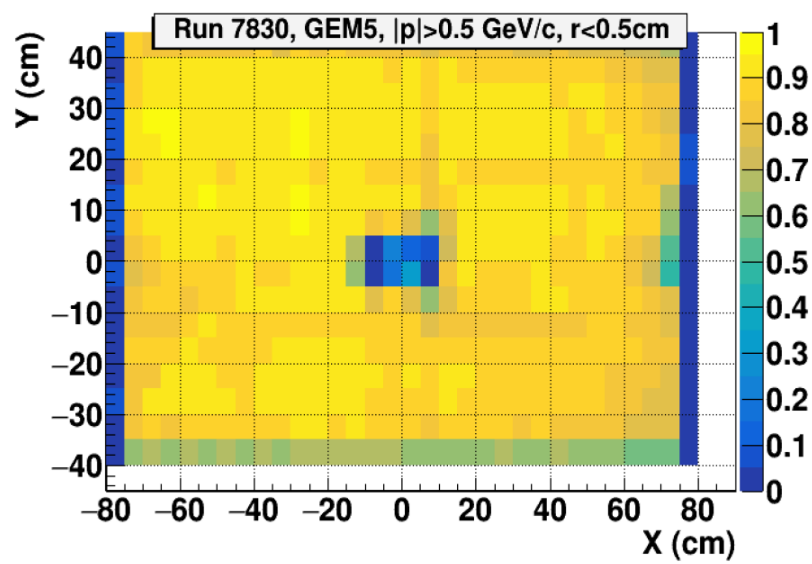
GEM-3: X/Y map of efficiency



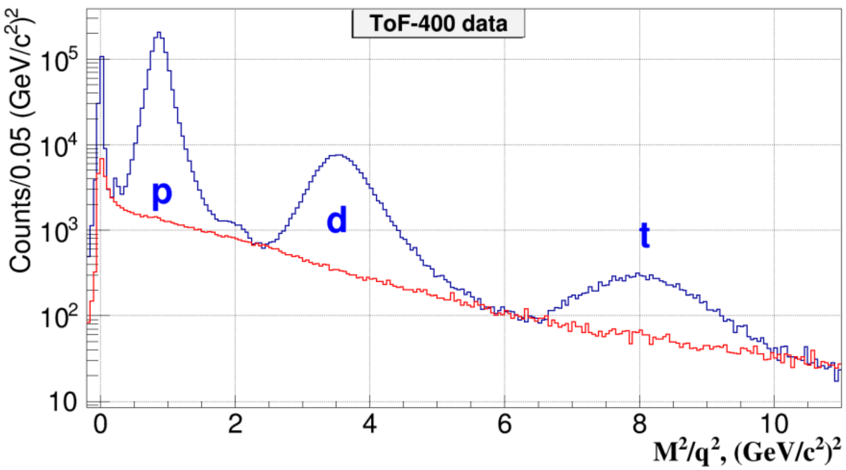
Si-4 station: X/Y map of efficiency

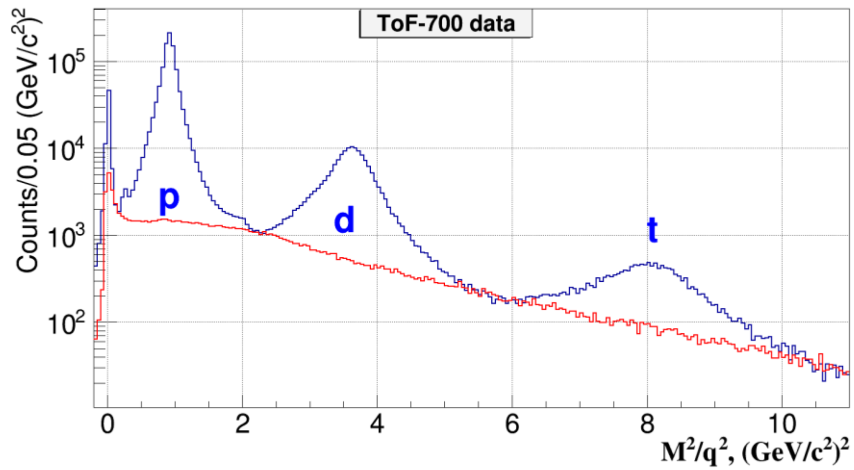


GEM-5: X/Y map of efficiency



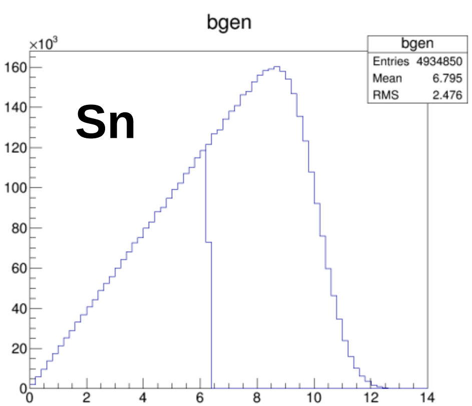
Production of *p, d, t* in 3.2 AGeV argon-nucleus interactions



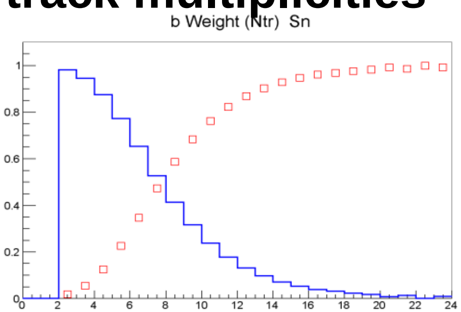


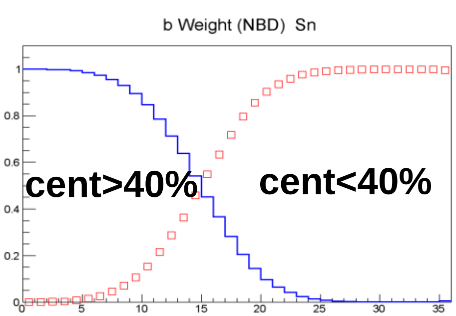
Two classes of centrality <40% and >40% based on barrel detector and track multiplicities

cent<40% cent>40%

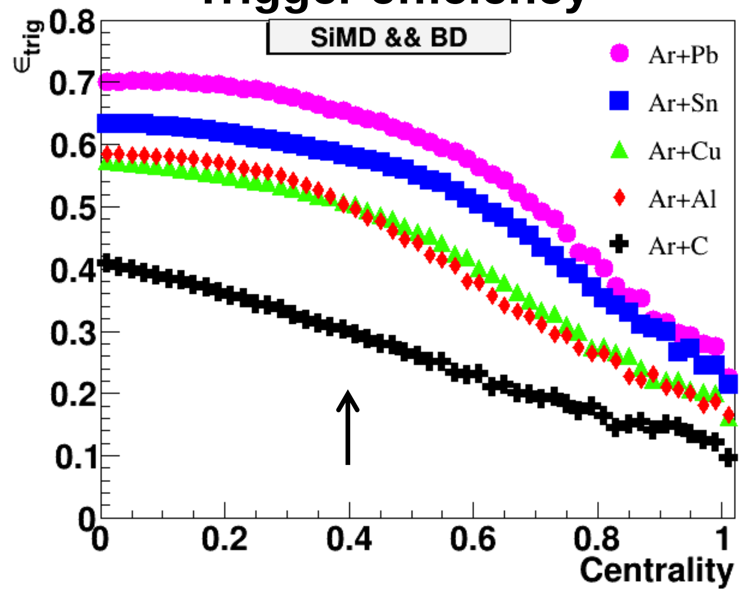


b, fm

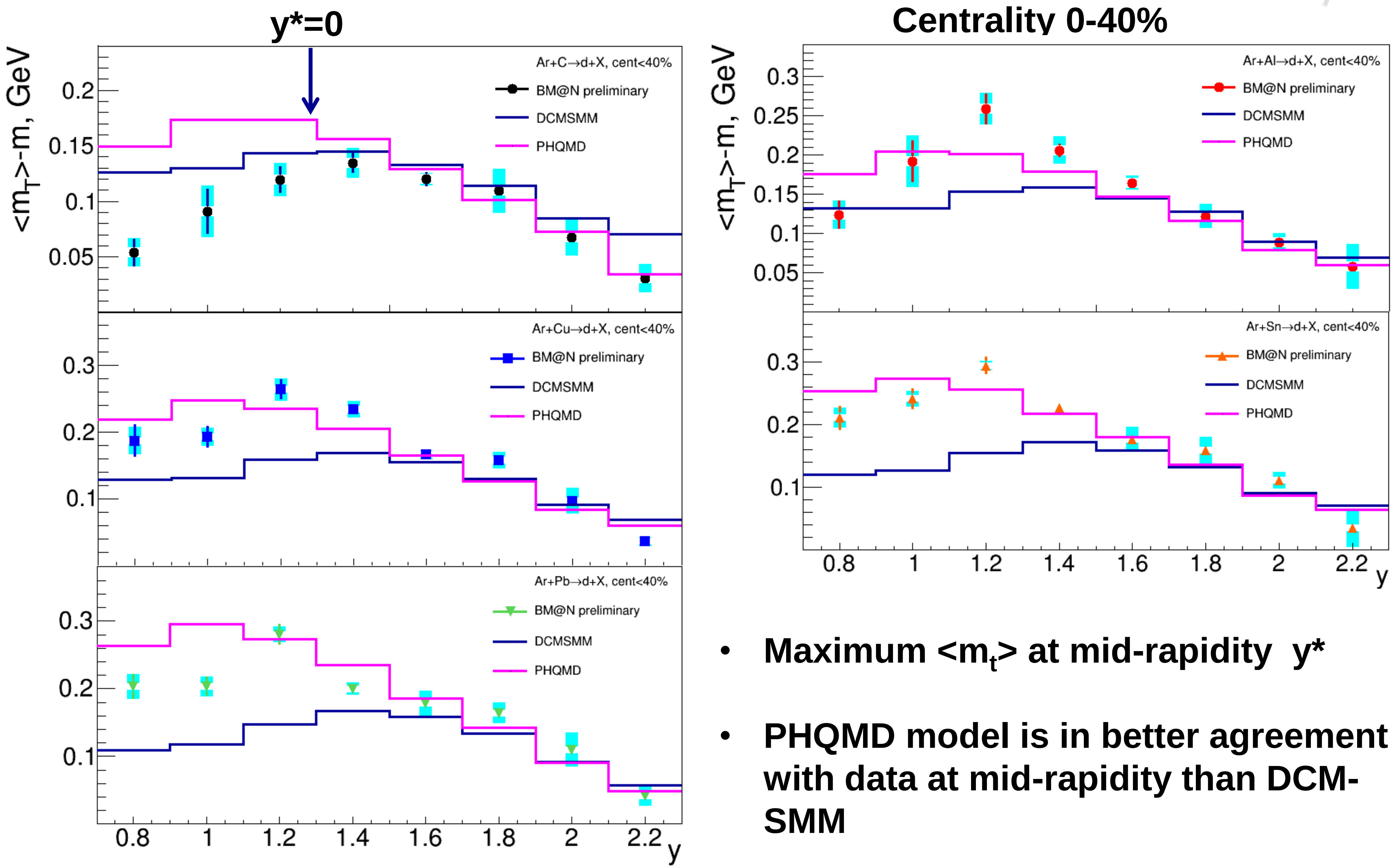




Trigger efficiency

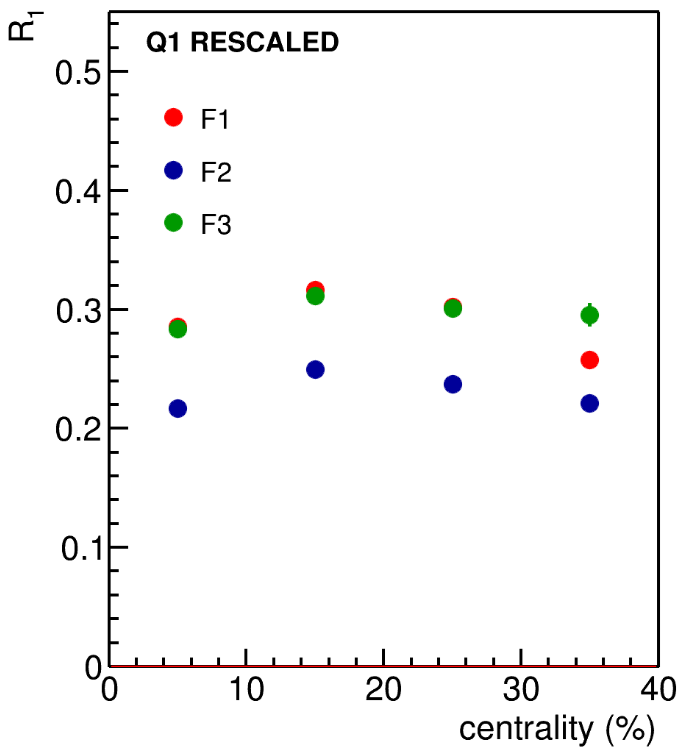


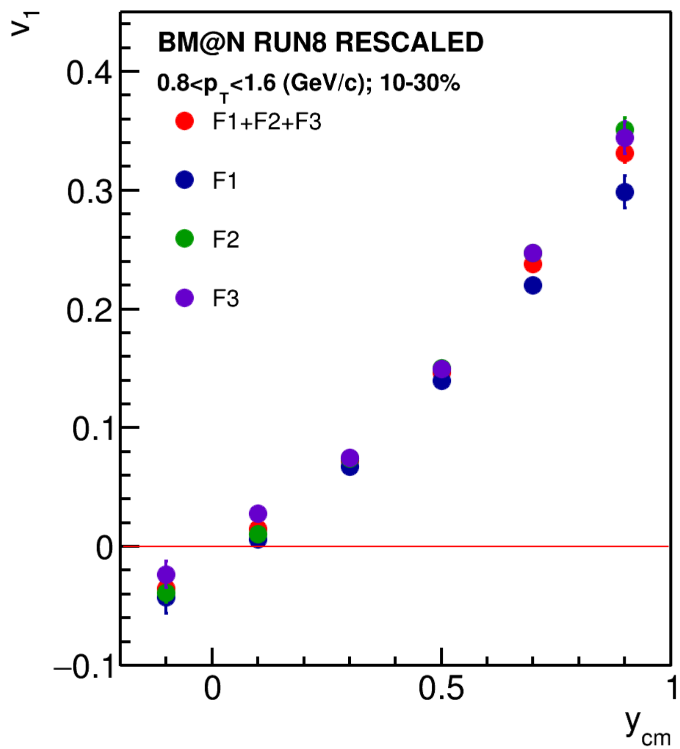
Deuterons: <m_t> dependence on y

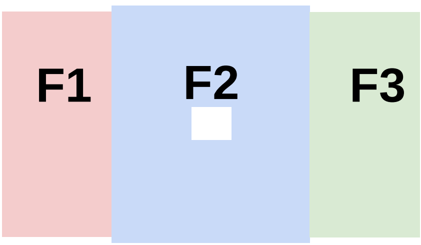


- Maximum <m_t> at mid-rapidity y*
- PHQMD model is in better agreement with data at mid-rapidity than DCM-SMM

Systematics due to non-flow

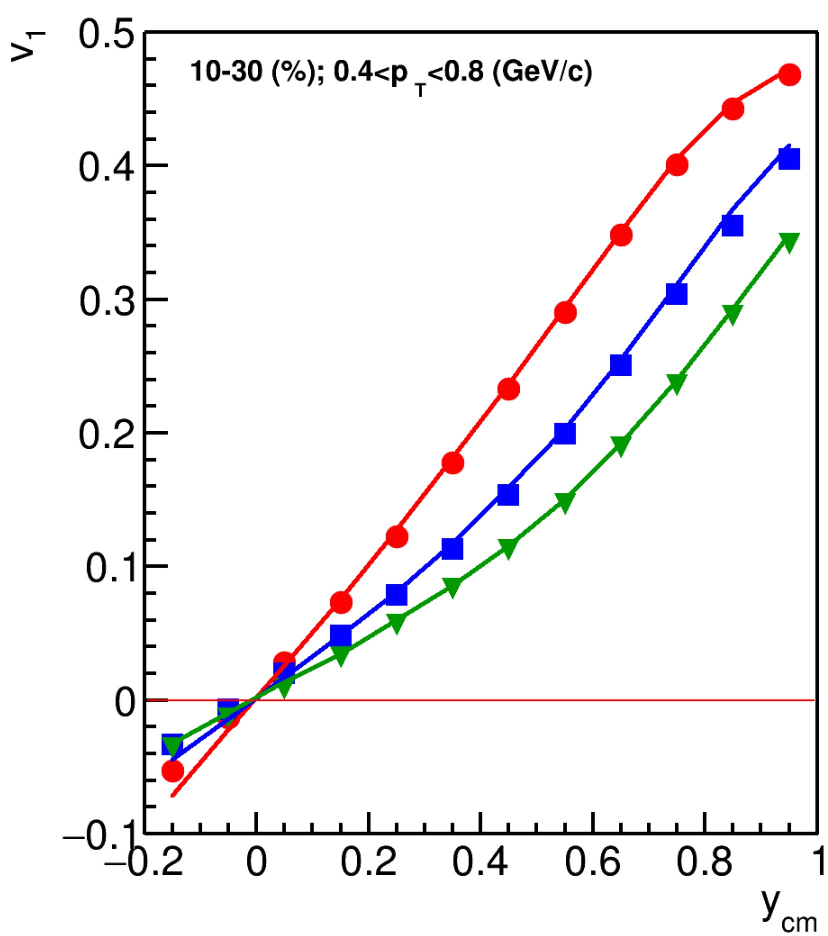


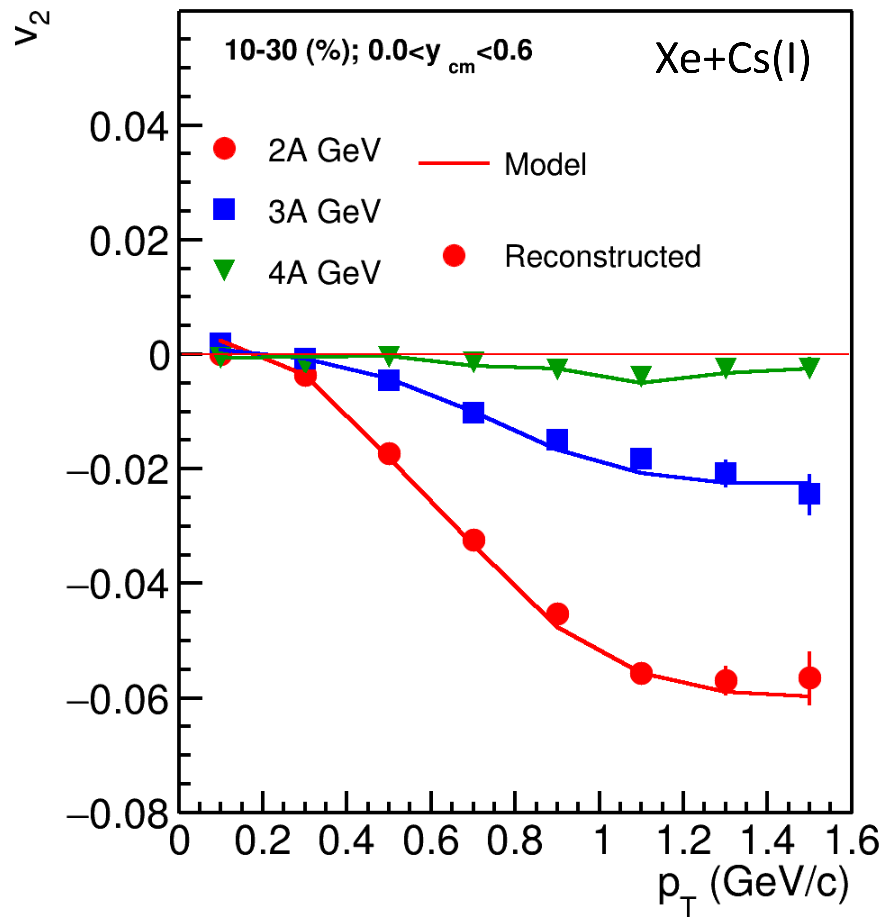




v_1 relative to different event planes is a good agreement ⇒ robust estimation for v_1

Directed and elliptic flow at BM@N





- Good agreement between reconstructed and model data
- Approximately 250-300M events are required to perform multi-differential measurements of v_n