Status of the BM@N experiment and possible tasks for the HSE group

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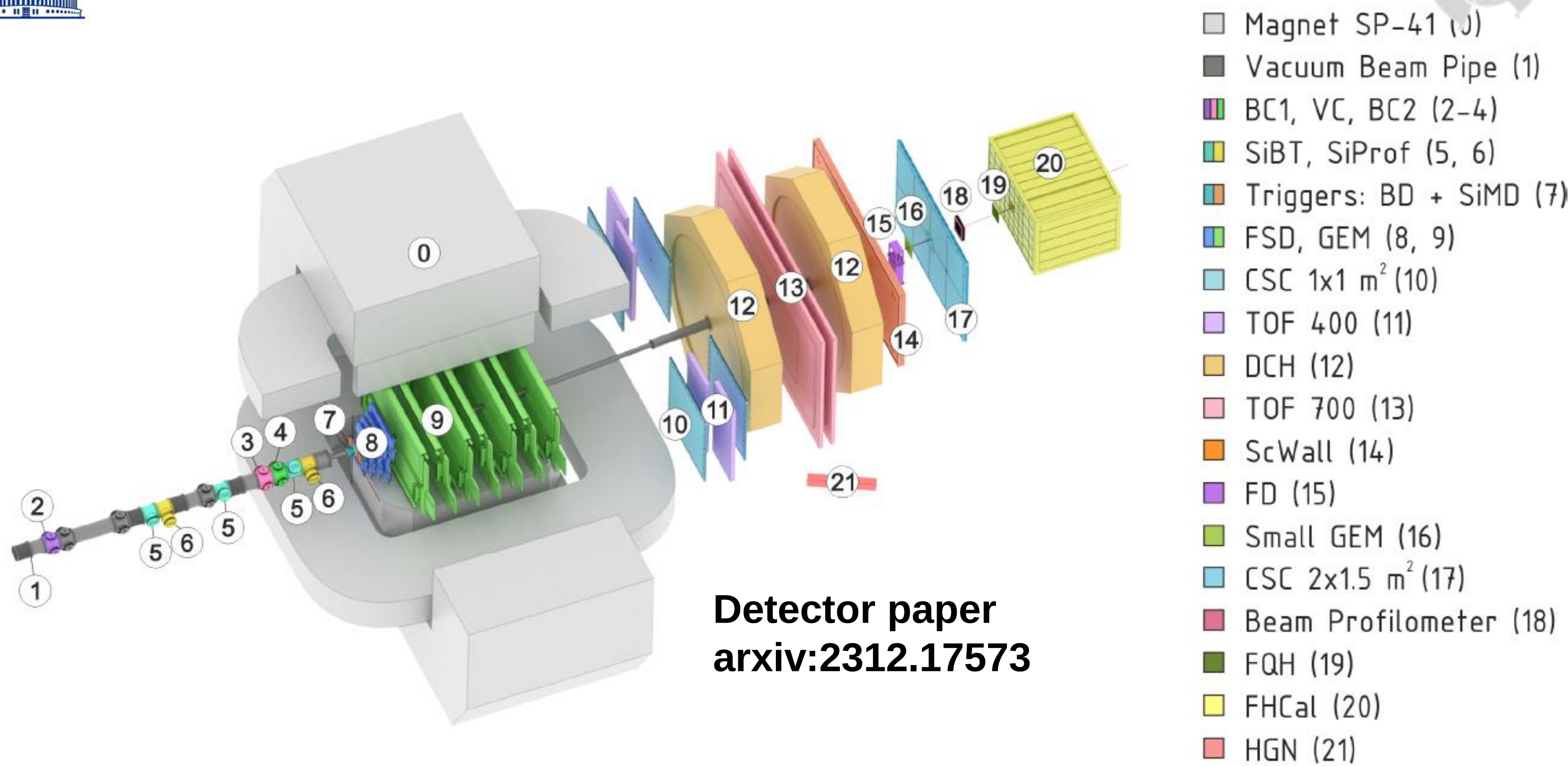
Baryonic Matter at Nuclotron (BM@N) Collaboration:

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

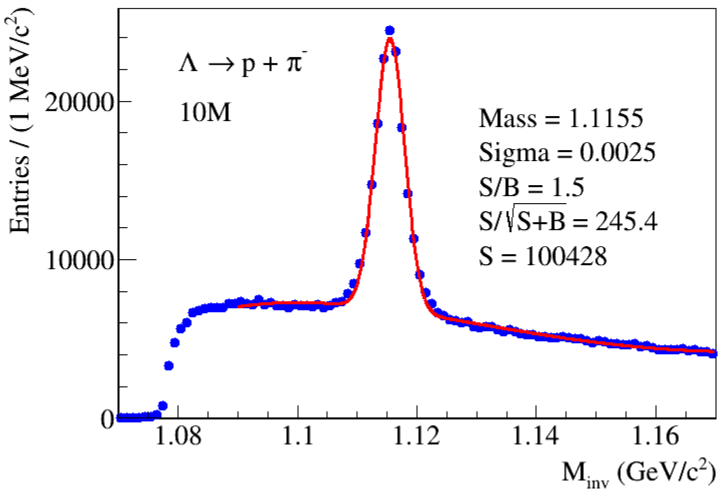
Configuration of BM@N detector in Xe+CsI run

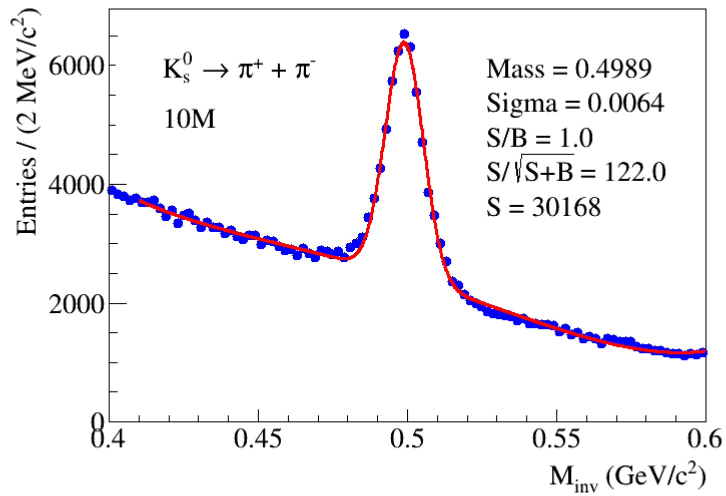


Detector paper
arxiv:2312.17573

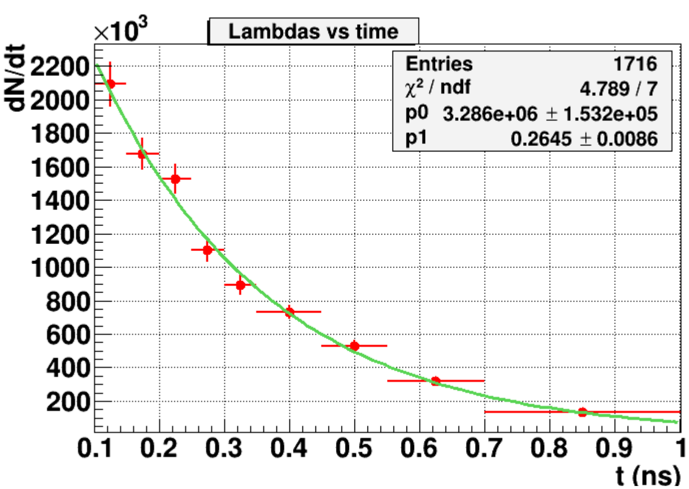
Xe^{124} + CsI interactions at 3.8 and 3.0 AGeV → 550M events
main trigger cover centrality < 70-75% (85% events)
min bias trigger (7% events), beam trigger (3% events)

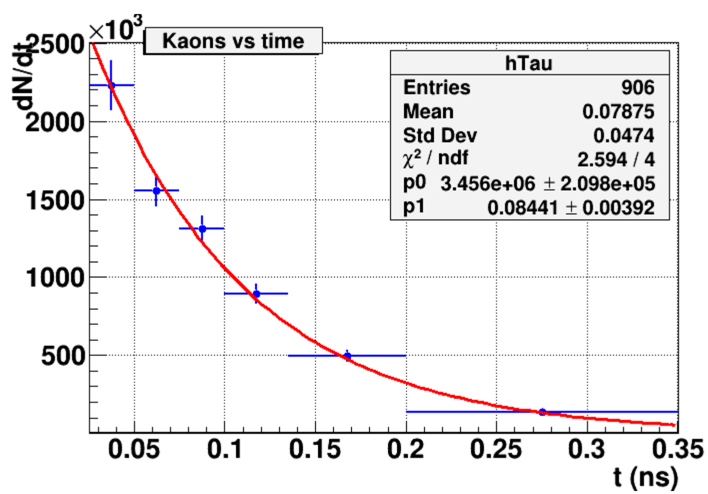
Xe+ CsI data : $\Lambda \to p\pi^-$, $K^0_s \to \pi^+\pi^-$





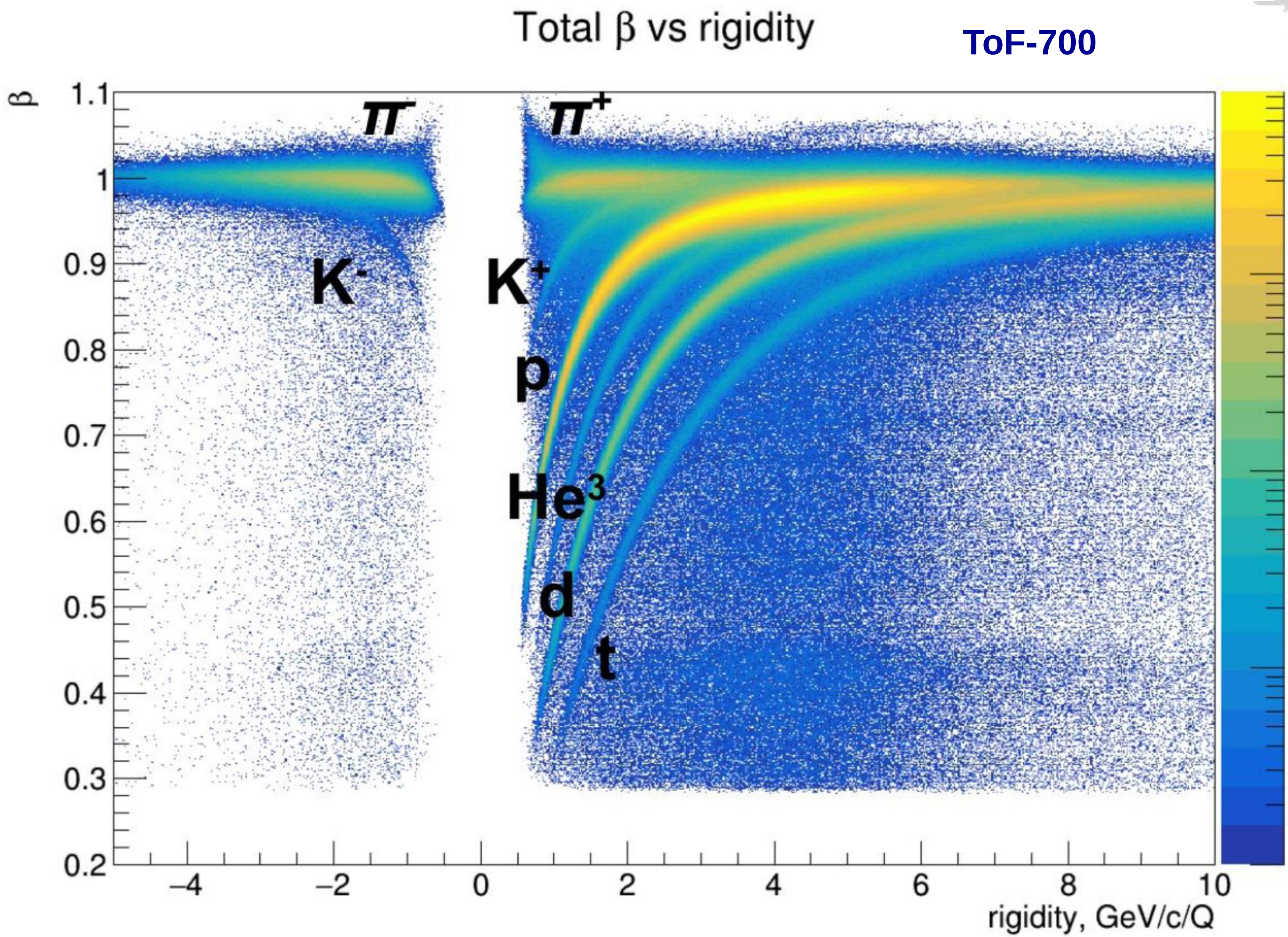
In 500M events expect: 4M Λ, 1.2M K^0_S





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

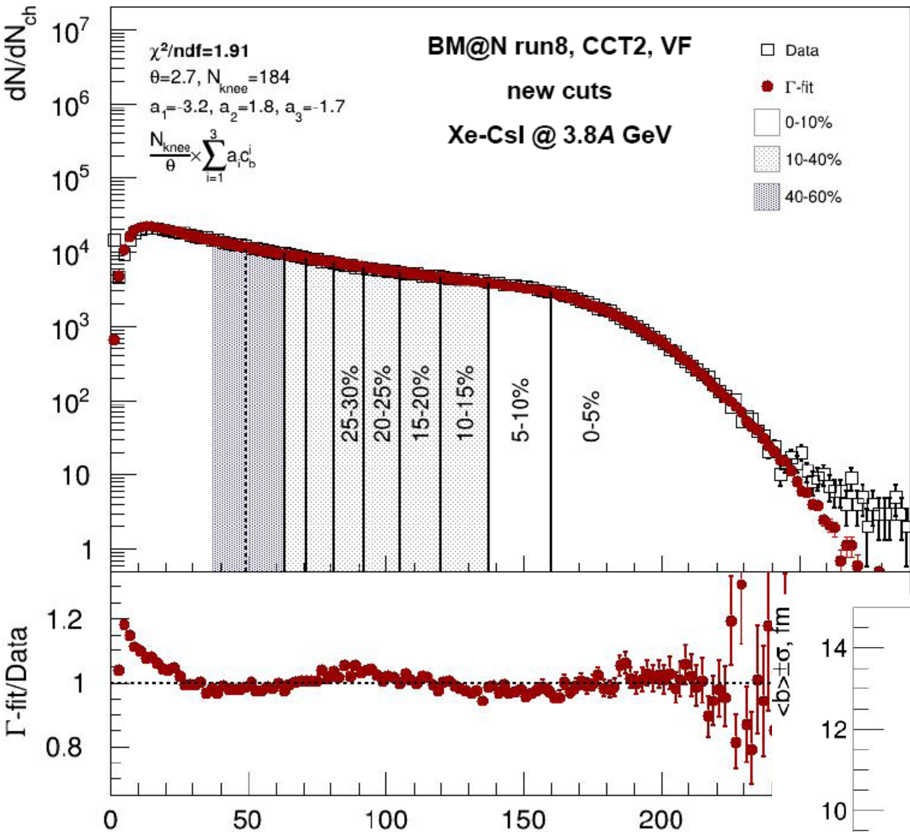


Centrality selection from fits of the track multiplicity

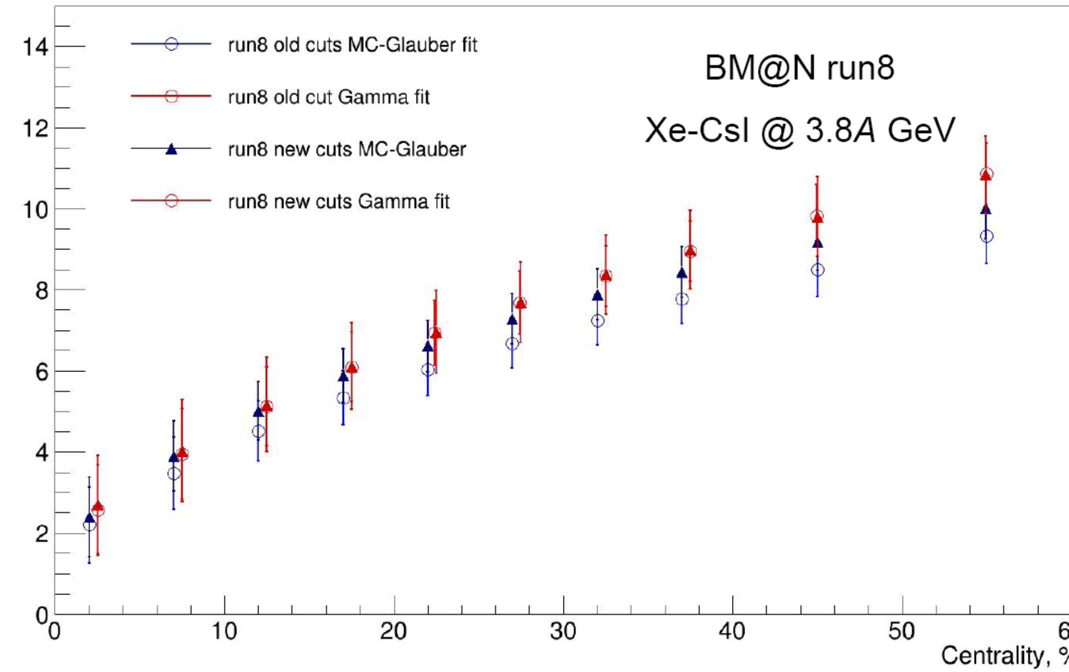
MEPhI group

- 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



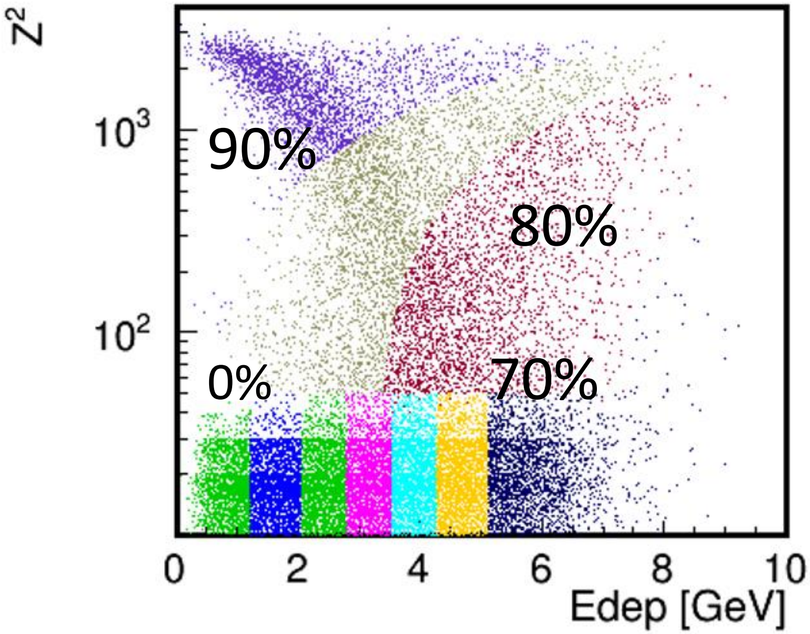
Γ-fit and MC-Glauber fit are in agreement

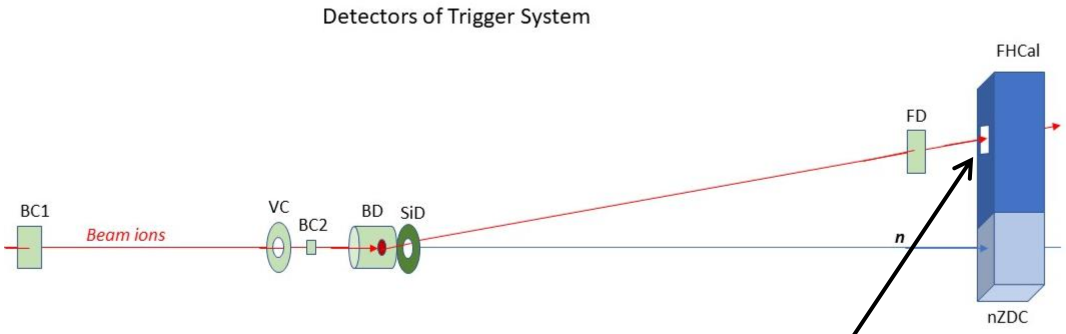


Centrality selection in forward detectors: hodoscope and FHCal

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

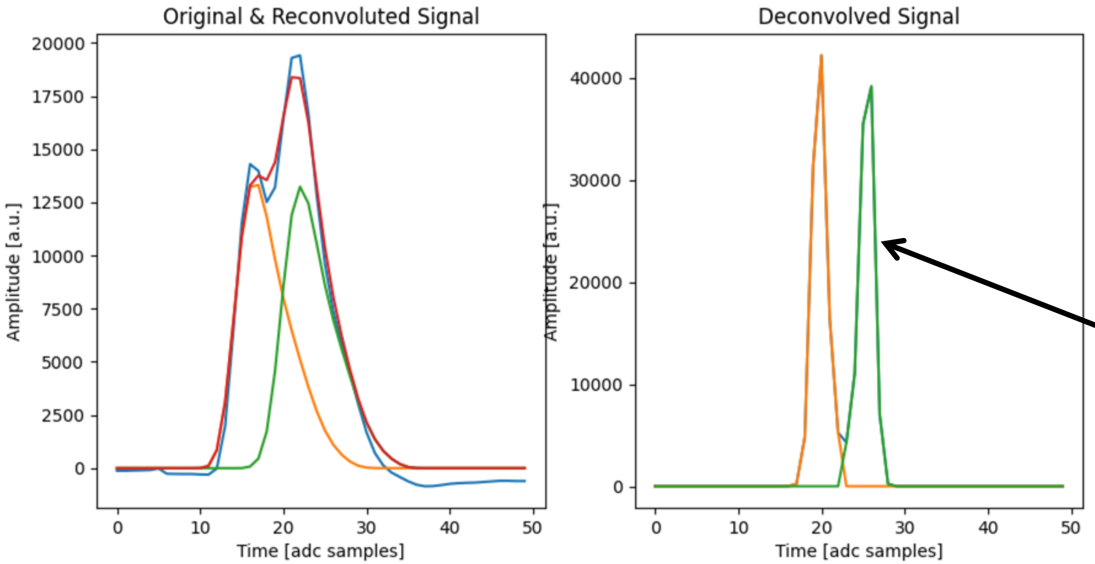
INR RAS group





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

Current tasks for the Xe data analysis

Activities in the data analysis:

- 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

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

→ Progress in identification of charged particles in ToF-400 and ToF-700

→ 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 $_{\Lambda}H^3$, $_{\Lambda}H^4$

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
→ additional ToF-400 modules to extend acceptance by factor 1.5

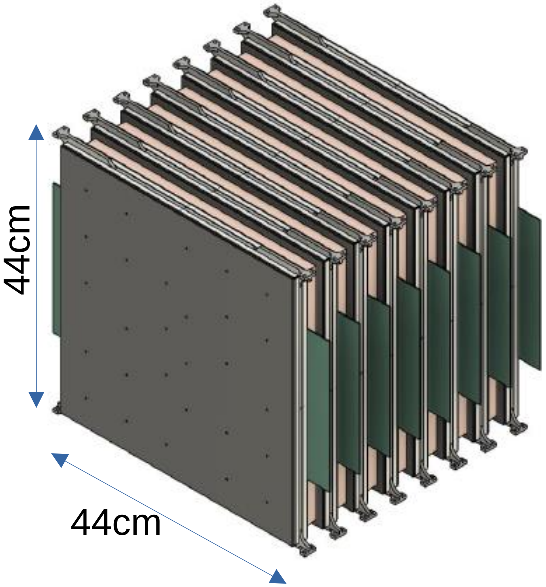
Preparations for the physics run with the Bi beam

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

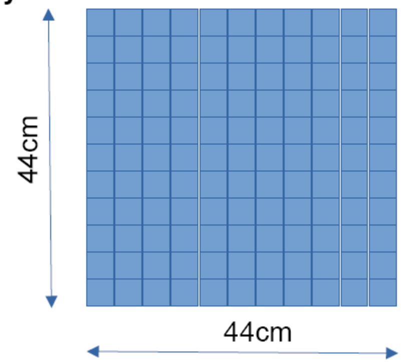
- It is planned to put into operation a 2-coordinate (X/Y) neutron detector of high granularity to measure neutron yields and collective flow

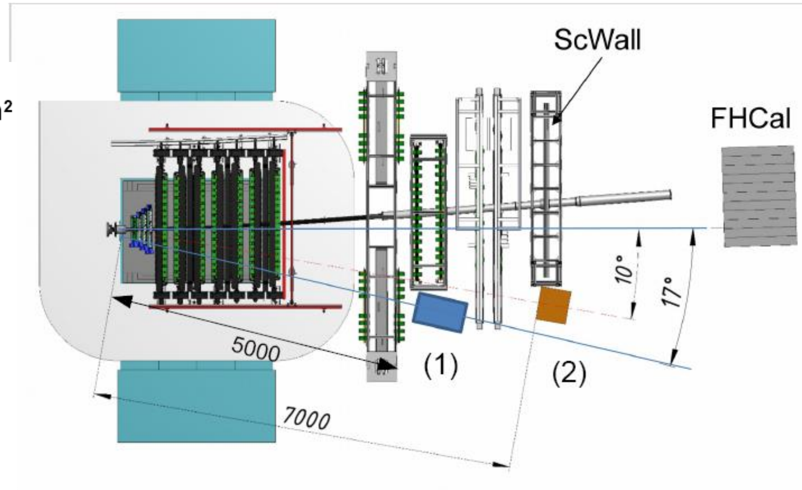
High Granularity Neutron detector

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



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

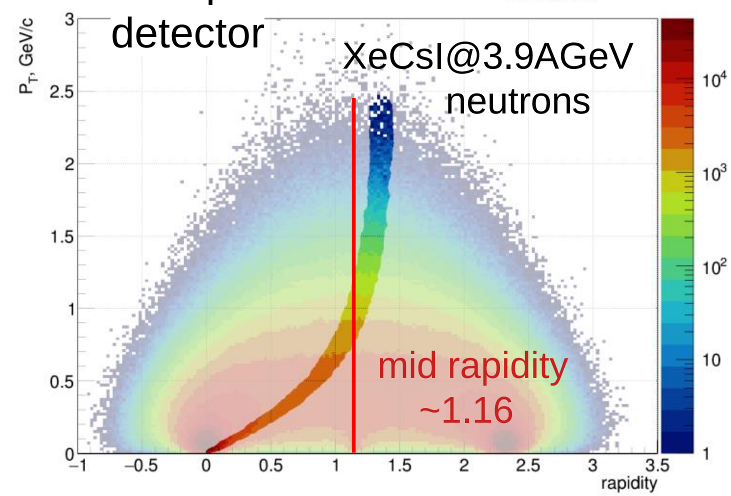




2 positions of HGN detector at BM@N: at 10º and 17º

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



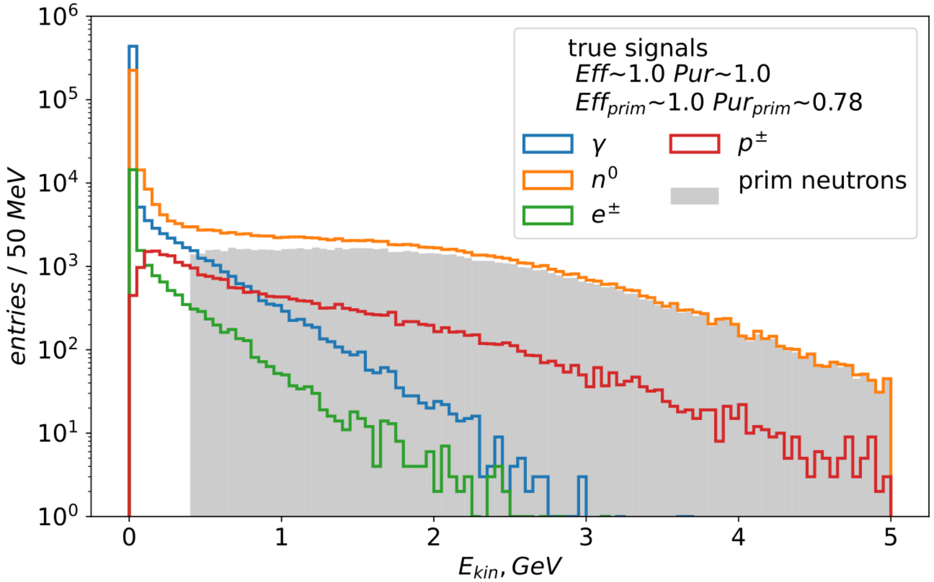
ML-based neutron reconstruction

HSE group contribution

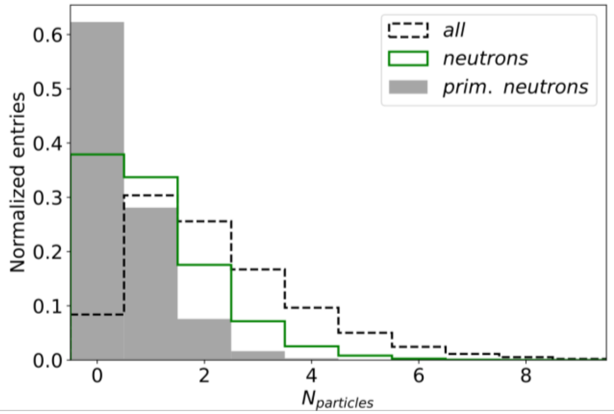
Neutron reconstruction in a Highly Granular Neutron Detector (HGND):

- **Identify neutrons** produced in reaction in presence of background
  - ➡ pattern recognition using high granularity
- Reconstruct neutron energy using **time-of-flight** (ToF) method
  - ➡ aggregate information from multiple sensors
- Multi-parameter task ⇒ may benefit from **ML-based methods**

Energy spectrum: all particles in HGN detector DCM-QGSM-SMM, Bi+Bi @ 3 AGeV



Particle multiplicity



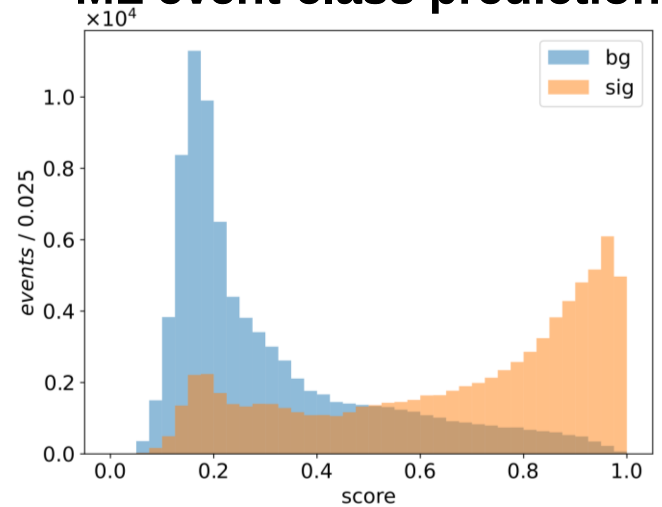
ML-based neutron reconstruction

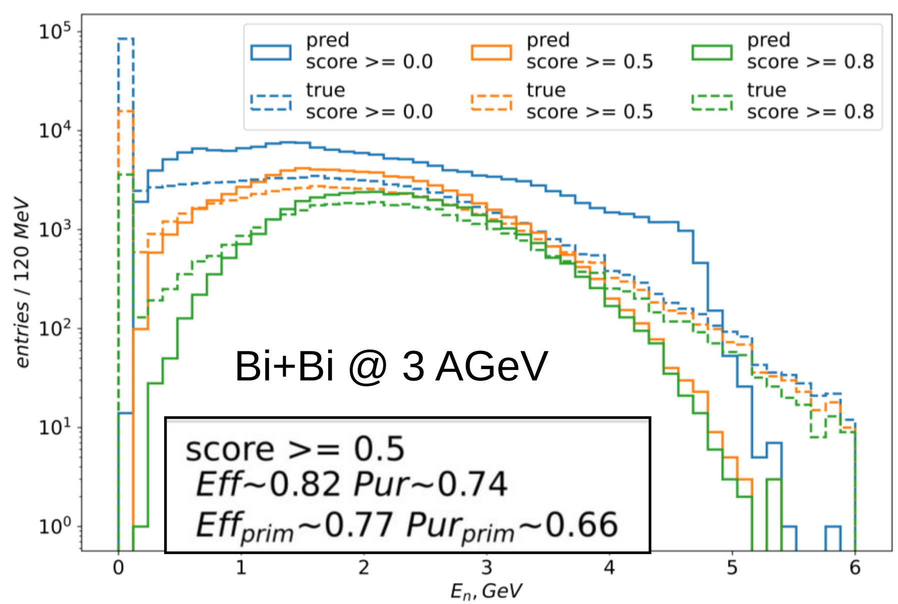
HSE group contribution

Preliminary results for test dataset after applying reconstruction procedure:

▪ Spectra become closer by increasing classification score threshold
▪ Reasonable agreement in the most probable region of the neutron energy spectrum

ML event class prediction





Other possible tasks for ML:

▪ Selection criteria for search for light hyper-nuclei in effective mass spectra
▪ Fast simulation of GEM and FHCAL response
▪ Particle identification algorithm in ToF and dE/dx in GEM
▪ Fake track filtration algorithm in track finder

Thank you
for attention!