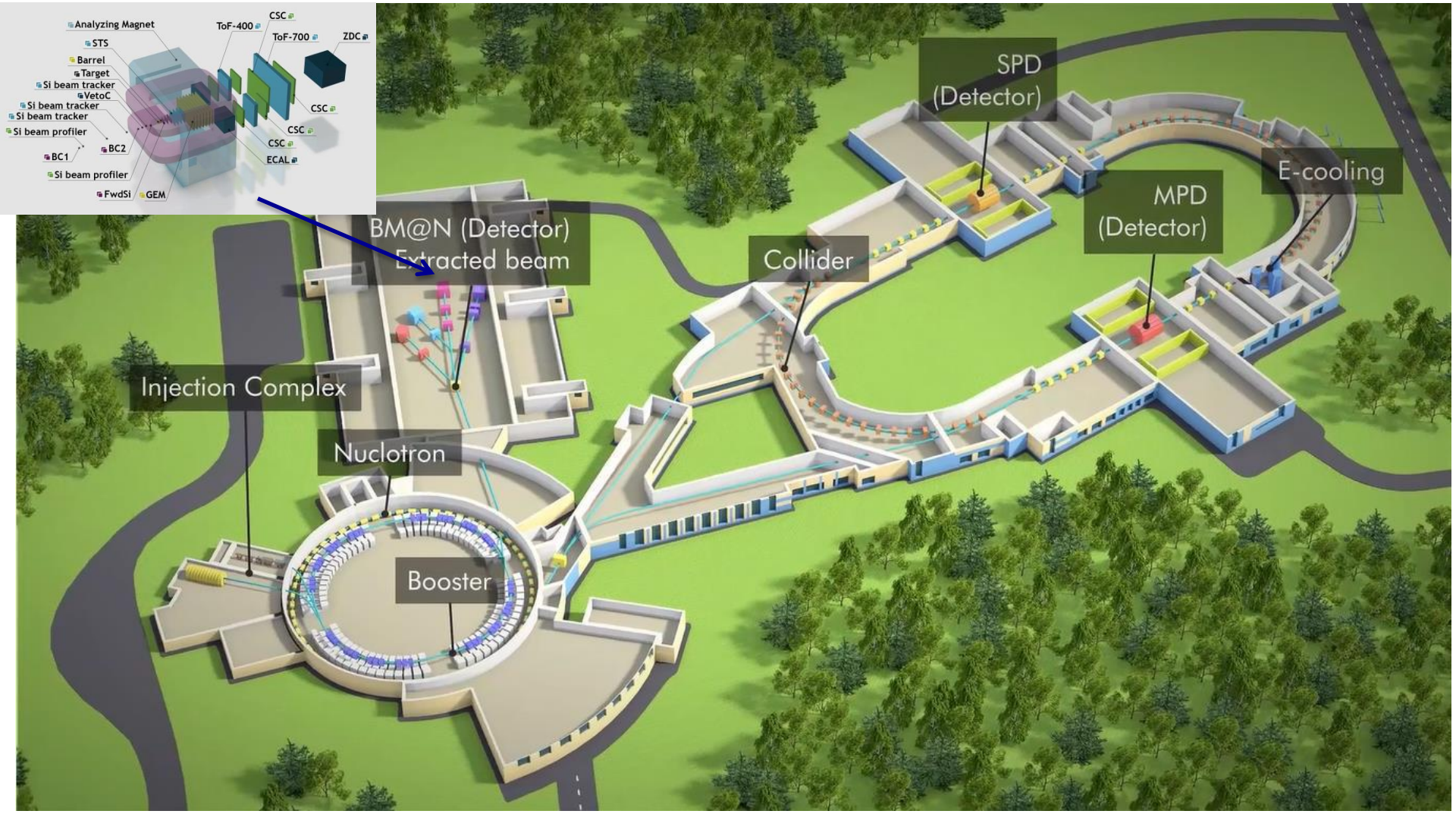
Implementation of the BM@N project

M.Kapishin

NICA Heavy Ion Complex

BM@N: heavy ion energy 1- 3.8 GeV/n, beams: d to Bi, Intensity ~few 10^6 Hz (Bi)



Baryonic Matter at Nuclotron (BM@N) Collaboration:

5 Countries, 13 Institutions, 214 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**

Production of protons, deuterons and tritons in argon-nucleus interactions at 3.2A GeV

BM@N Collaboration

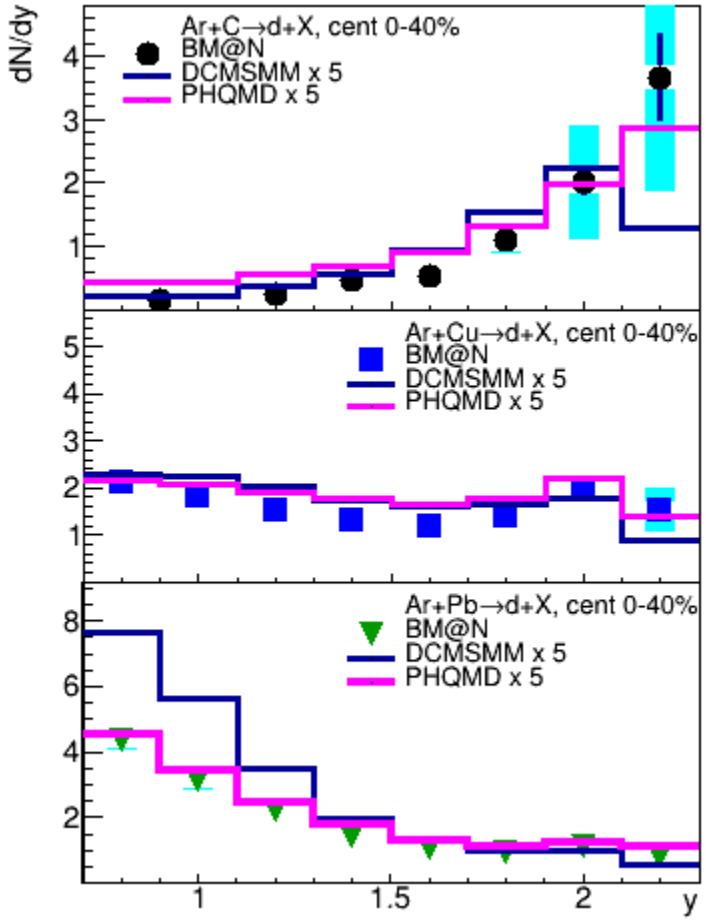
Abstract

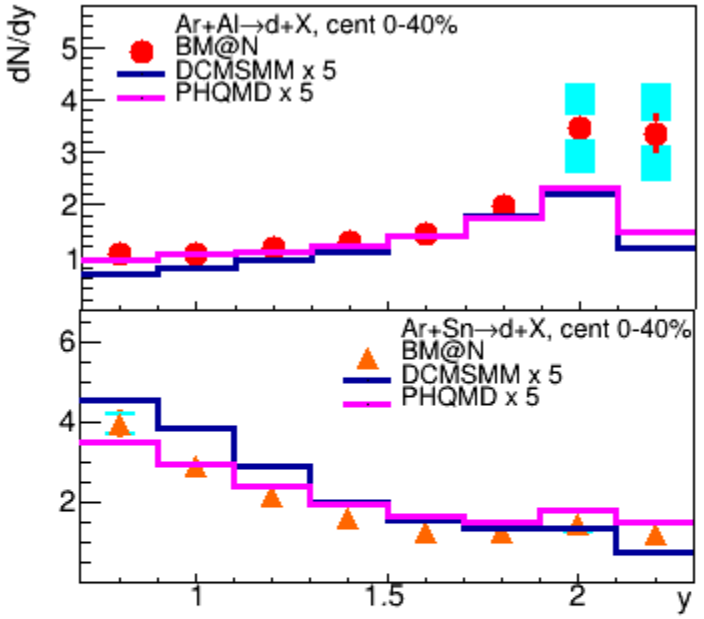
Results of the BM@N experiment at the Nuclotron/NICA complex are presented on proton , deuteron and triton production in interactions of an argon beam of 3.2A GeV with fixed targets of C, Al, Cu, Sn and Pb. Transverse mass spectra, rapidity distributions and multiplicities of protons, deuterons and tritons are measured. The results are treated within a coalescence approach and compared with predictions of theoretical models and with other measurements.

→ **paper is in circulation in the BM@N Collaboration**

Deuterons in 3.2 AGeV argon-nucleus interactions: dN/dy dependence on y

Centrality 0-40%

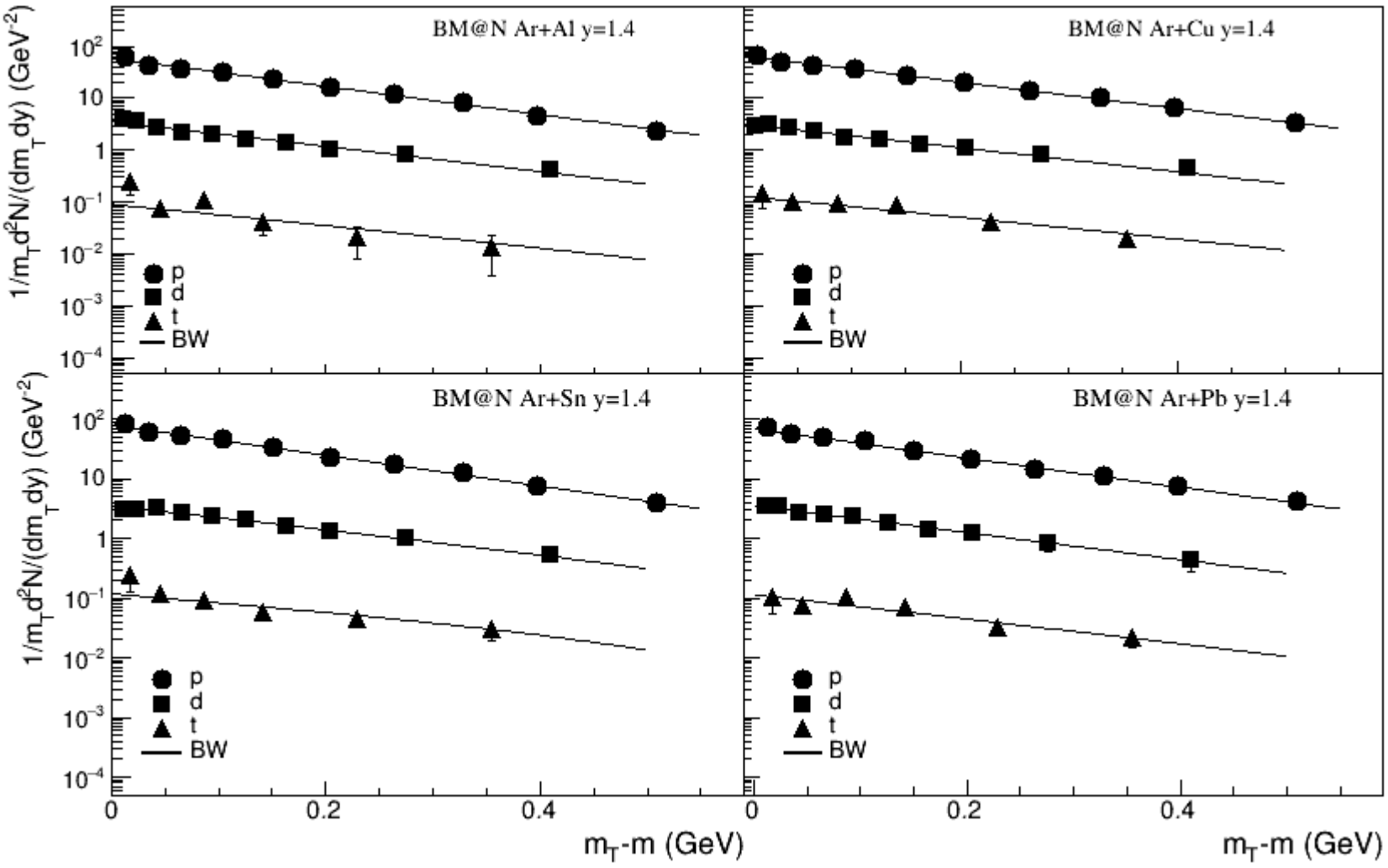




- **dN/dy spectrum softer in interactions with heavier target**
- **DCM-SMM and PHQMD models describe data shape, but are lower in normalization by factor 5**

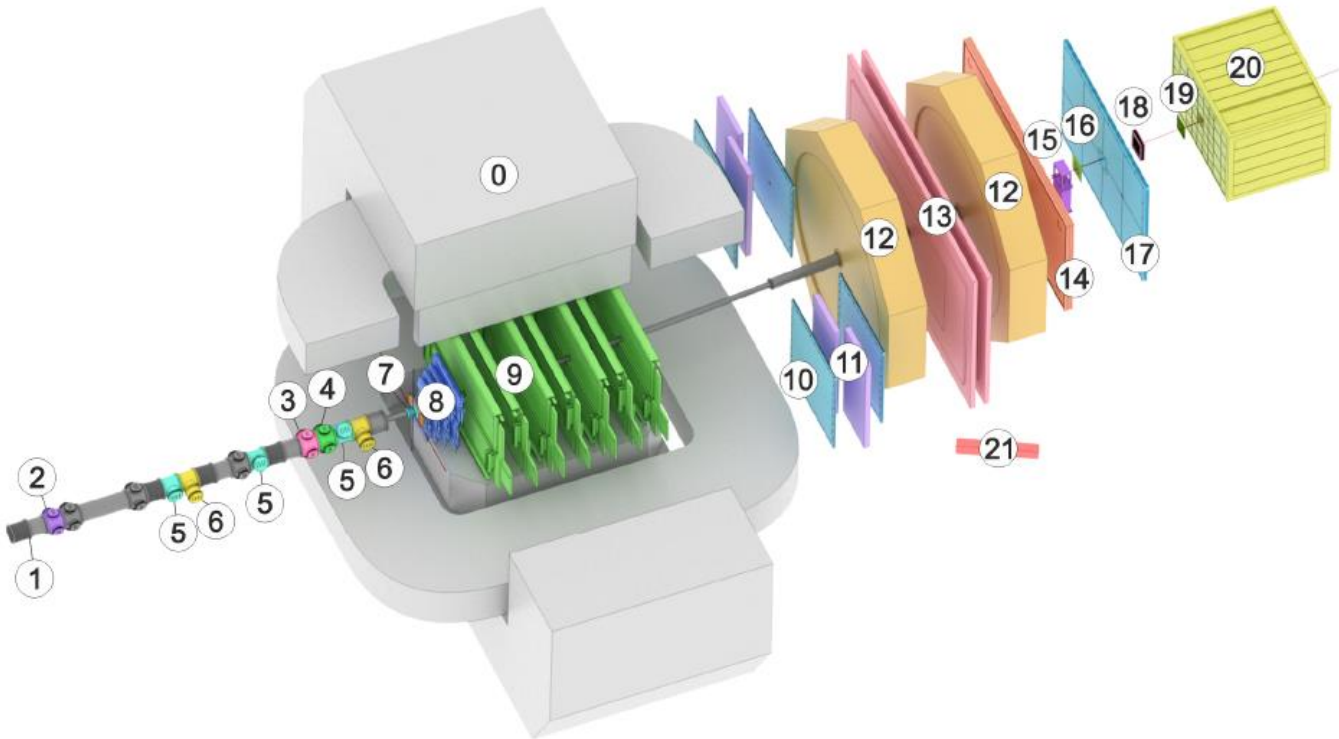
Blast-Wave model fit of p,d,t spectra

Centrality 0-40%



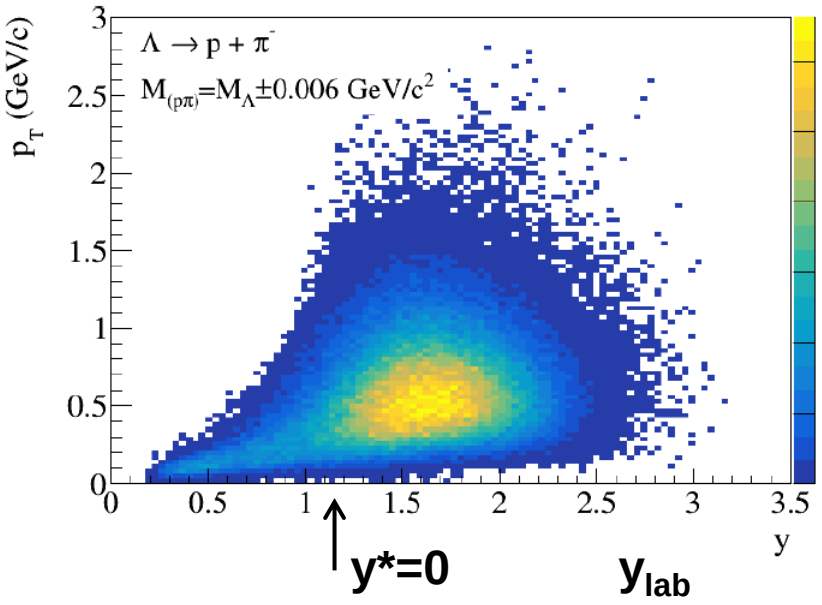
Configuration of BM@N detector in Xe+CsI run published in NIM A: BM@N Spectrometer at the NICA-Nuclotron facility

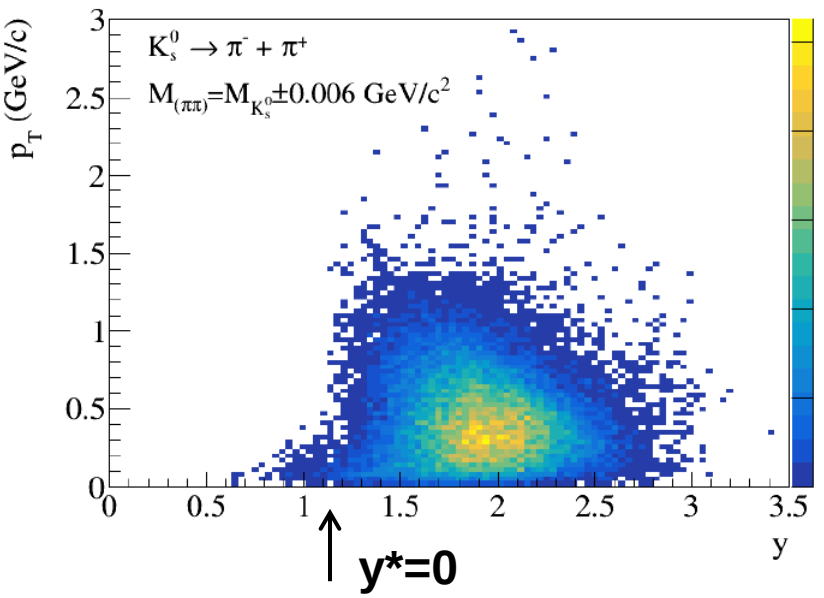
Detector paper
NIMA 1065, 169532 (2024)

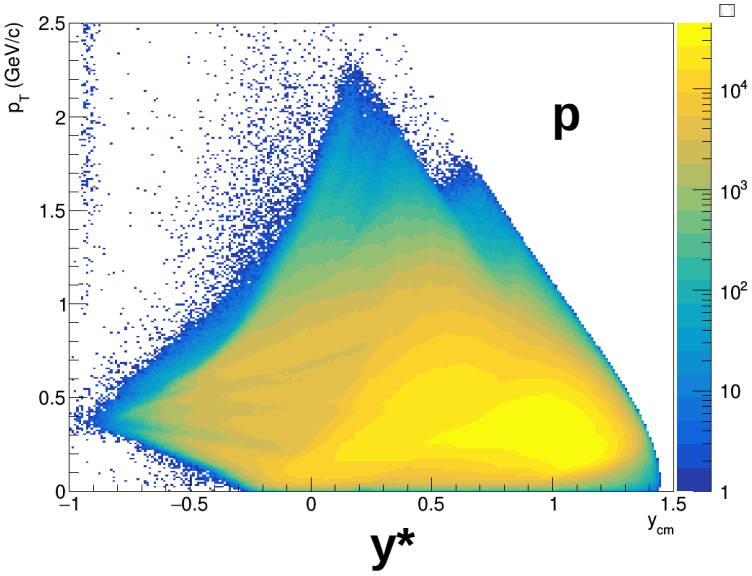


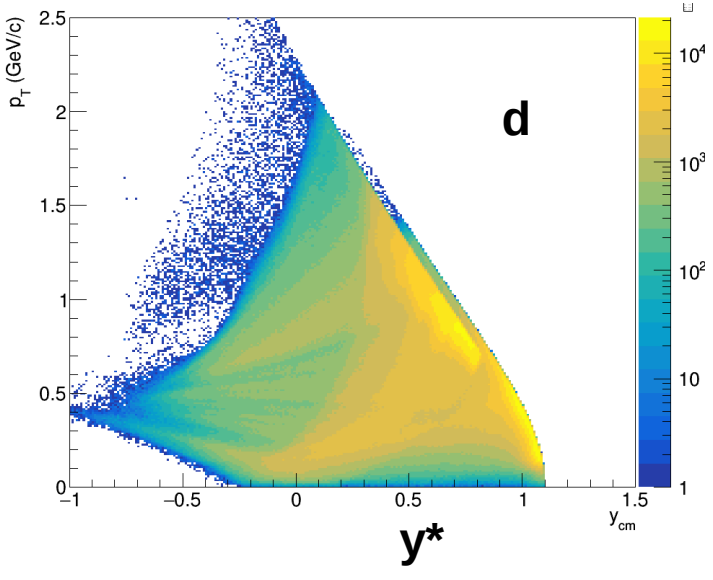
- Magnet SP-41 (0)
- Vacuum Beam Pipe (1)
- BC1, VC, BC2 (2-4)
- SiBT, SiProf (5, 6)
- Triggers: BD + SiMD (7)
- FSD, GEM (8, 9)
- CSC 1x1 m^2 (10)
- TOF 400 (11)
- DCH (12)
- TOF 700 (13)
- ScWall (14)
- FD (15)
- Small GEM (16)
- CSC 2x1.5 m^2 (17)
- Beam Profilometer (18)
- FQH (19)
- FHCal (20)
- HGN (21)

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

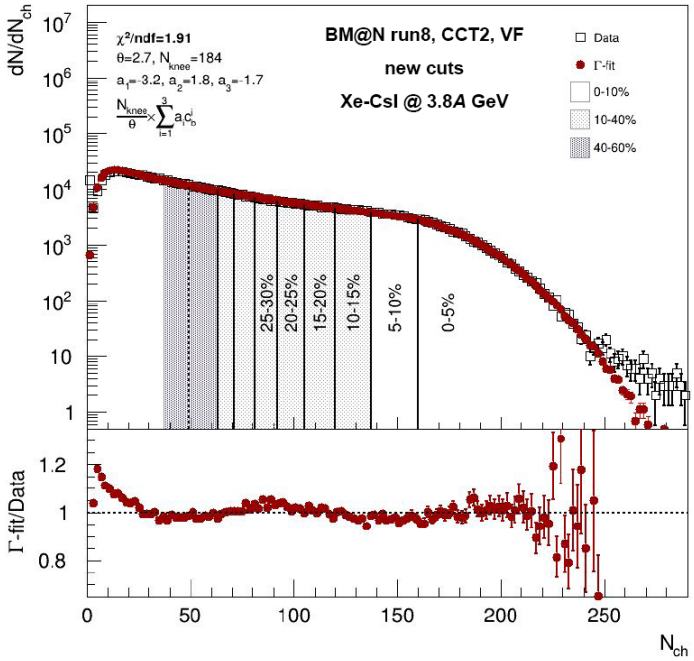


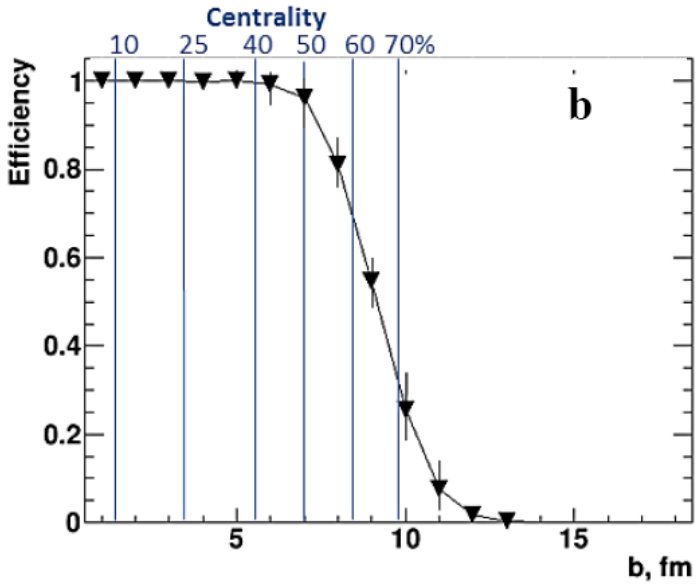






Centrality from track multiplicity and forward detectors

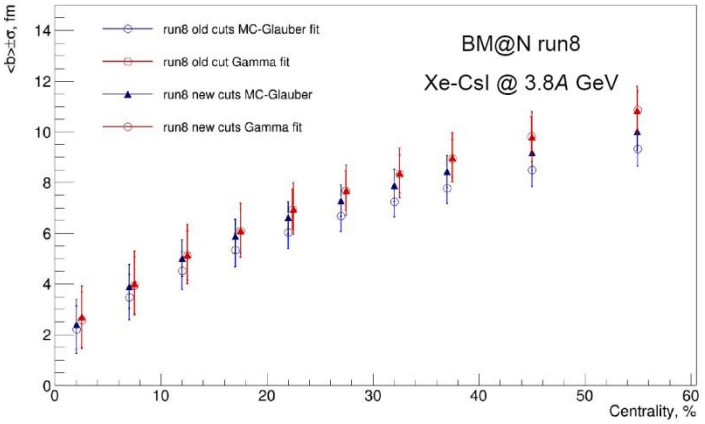


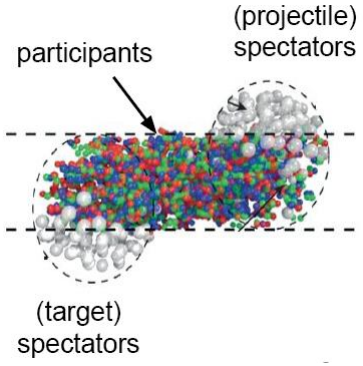


Parametrization of data track multiplicity N_{ch} by MC Glauber model or Negative Binominal Distribution (Γ-fit) with free parameters

→ Extract P(b | N_{ch})

→ Γ-fit and MC-Glauber fit are in agreement



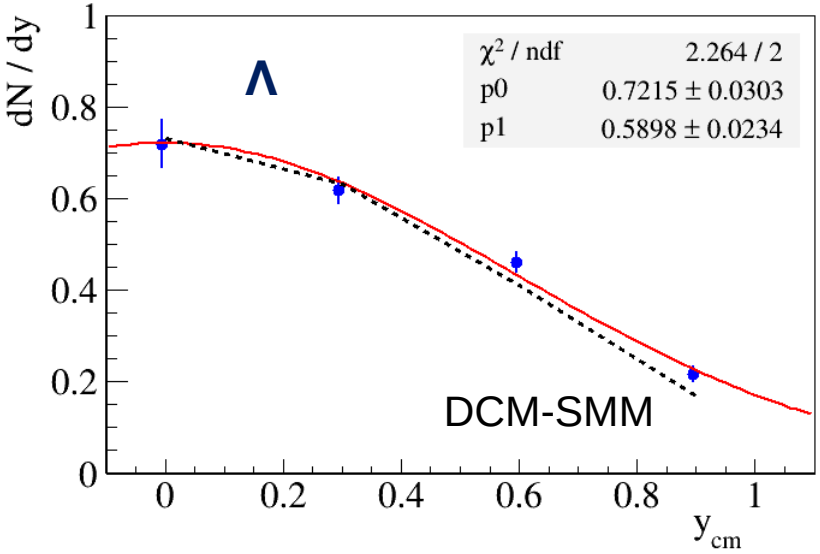


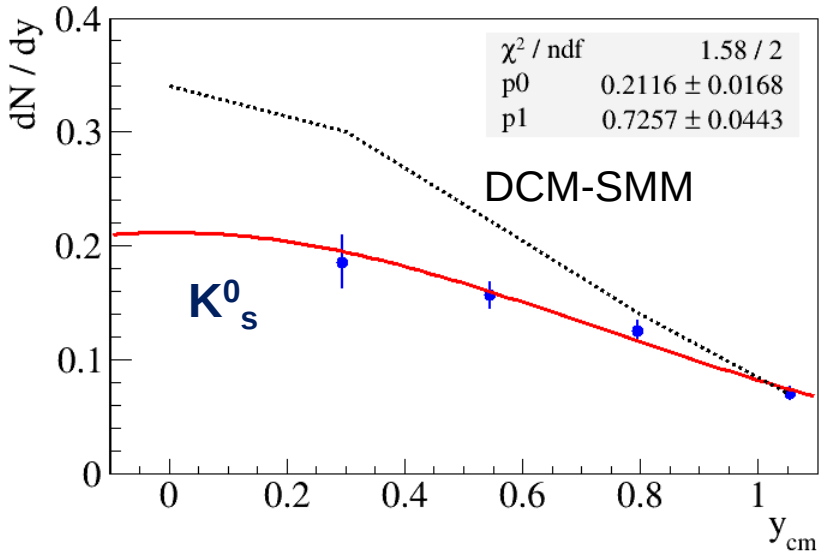
Trigger efficiency vs centrality

Towards Λ and K^0_s yields in Xe+CsI interactions

A.Zinchenko and team

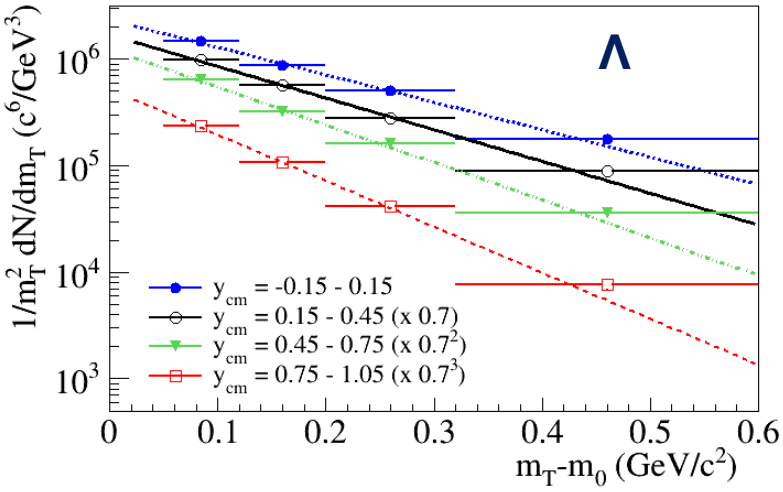
Rapidity spectra of Λ and K^0_s compared with DCM-SMM model

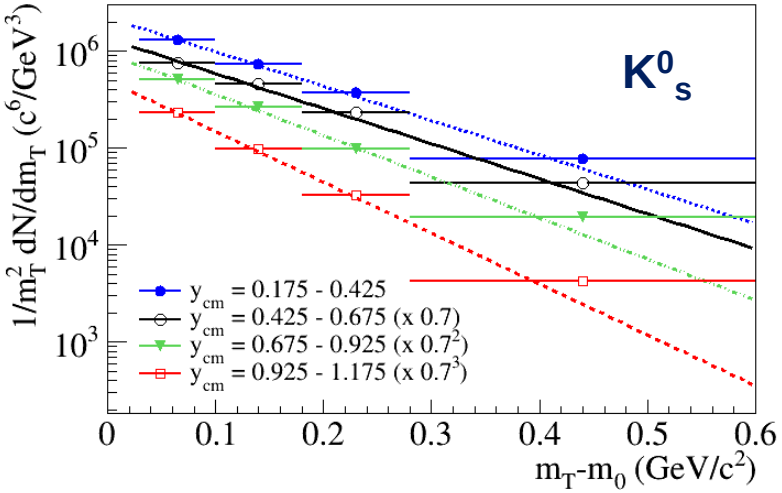




$$\frac{1}{m_T^2}\frac{dN}{dm_T} = C(y)\cdot\exp\left(-\frac{m_T - m_0}{T_{eff}}\right)$$

Transverse mass spectra of Λ and K^0_s





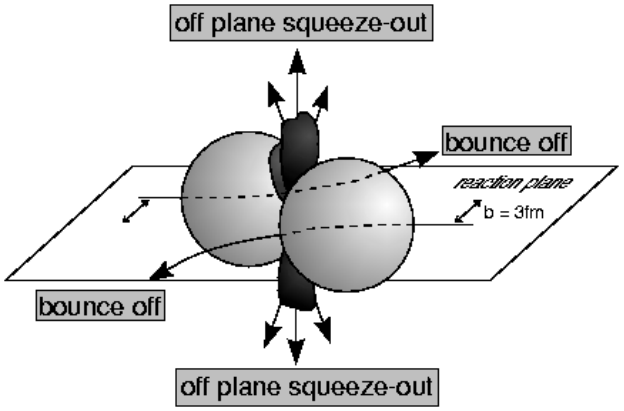
Collective flow of protons in Xe+CsI interactions

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

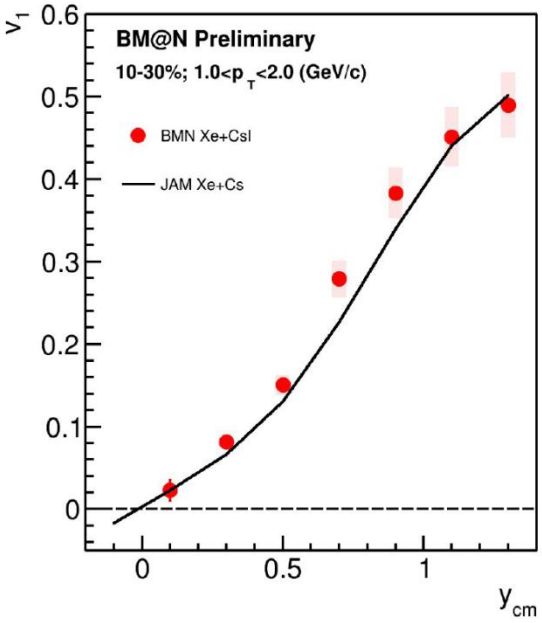
MEPhI group

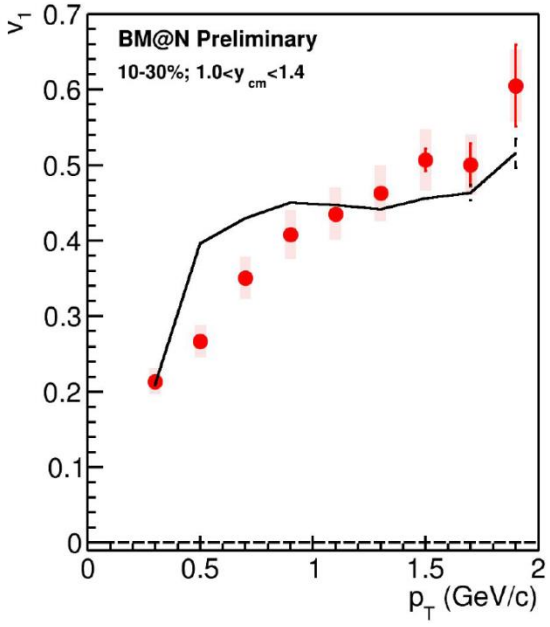
→ Direct flow $v1$ of protons as a function of rapidity, transverse momentum; compared with the JAM model

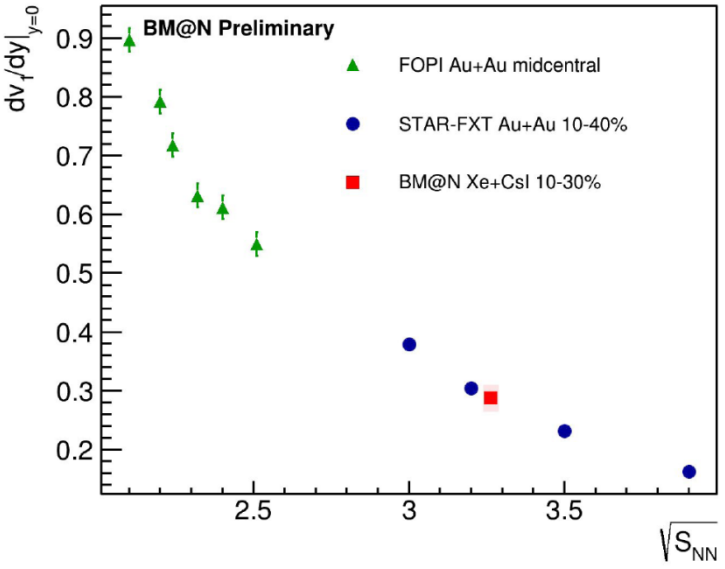
→ BM@@N result is in line with the energy dependence of the world data



BM@N Preliminary



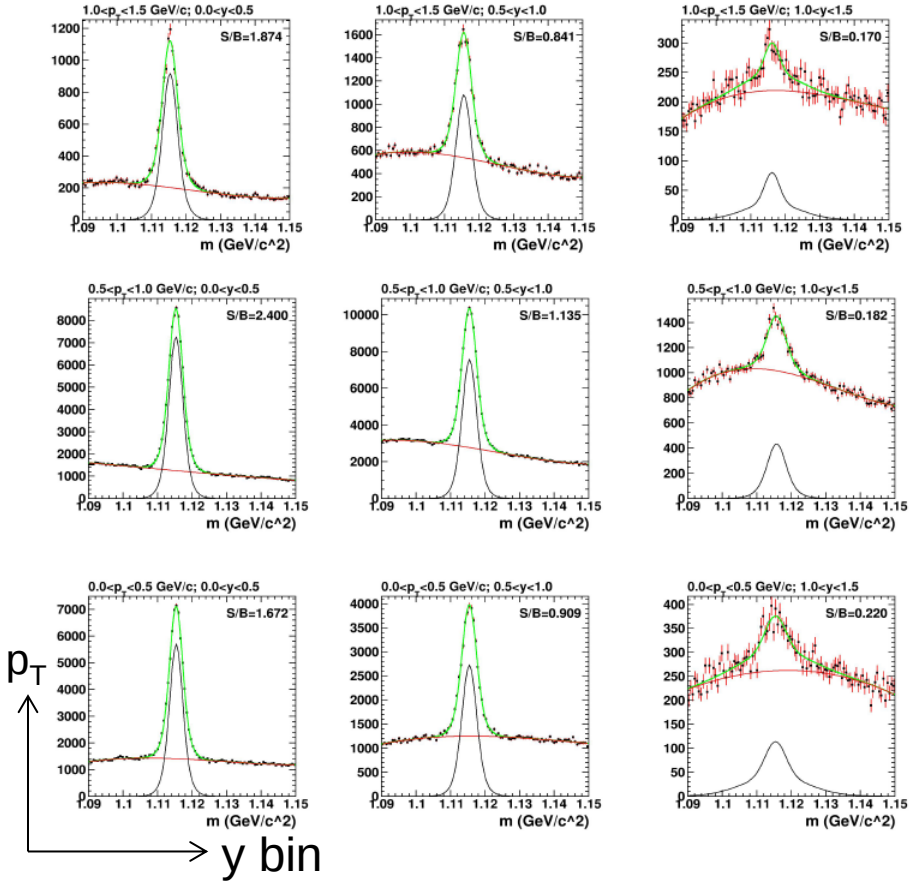




Towards Λ hyperon direct flow $v1$ in Xe+CsI interactions

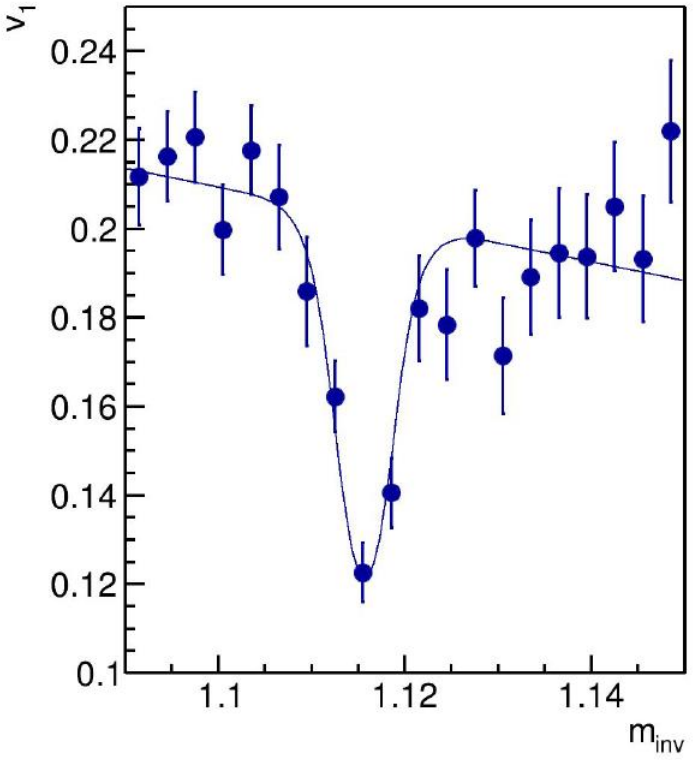
MEPhI group

Fitting the m_{inv} distributions in p_T-y bins



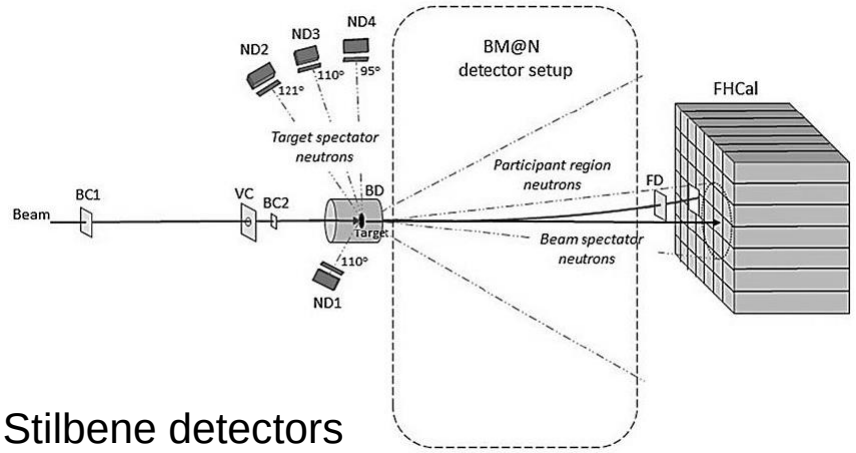
Fitting the m_{inv} distributions of v_1

$$v_1^{SB}(m_{inv}, p_T) = v_1^S(p_T)\frac{N^S(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)} + v_1^B(m_{inv}, p_T)\frac{N^B(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)}$$



Study of neutron emission from target spectators in ^{124}Xe + CsI collisions at 3.8 A GeV

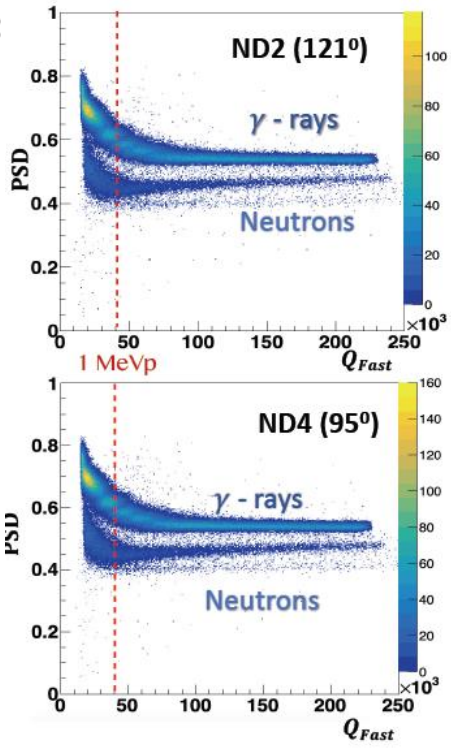
N.Lashmanov,
V.Yurevich



Stilbene detectors

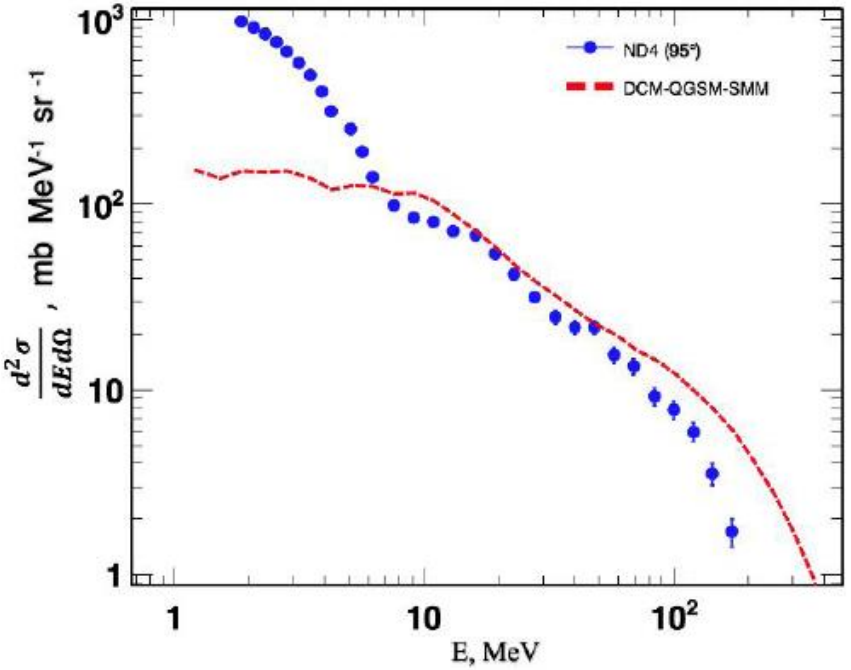
Quality of pulse shape discrimination:

$$PSD = \frac{Q_{fast}}{Q_{total}}$$

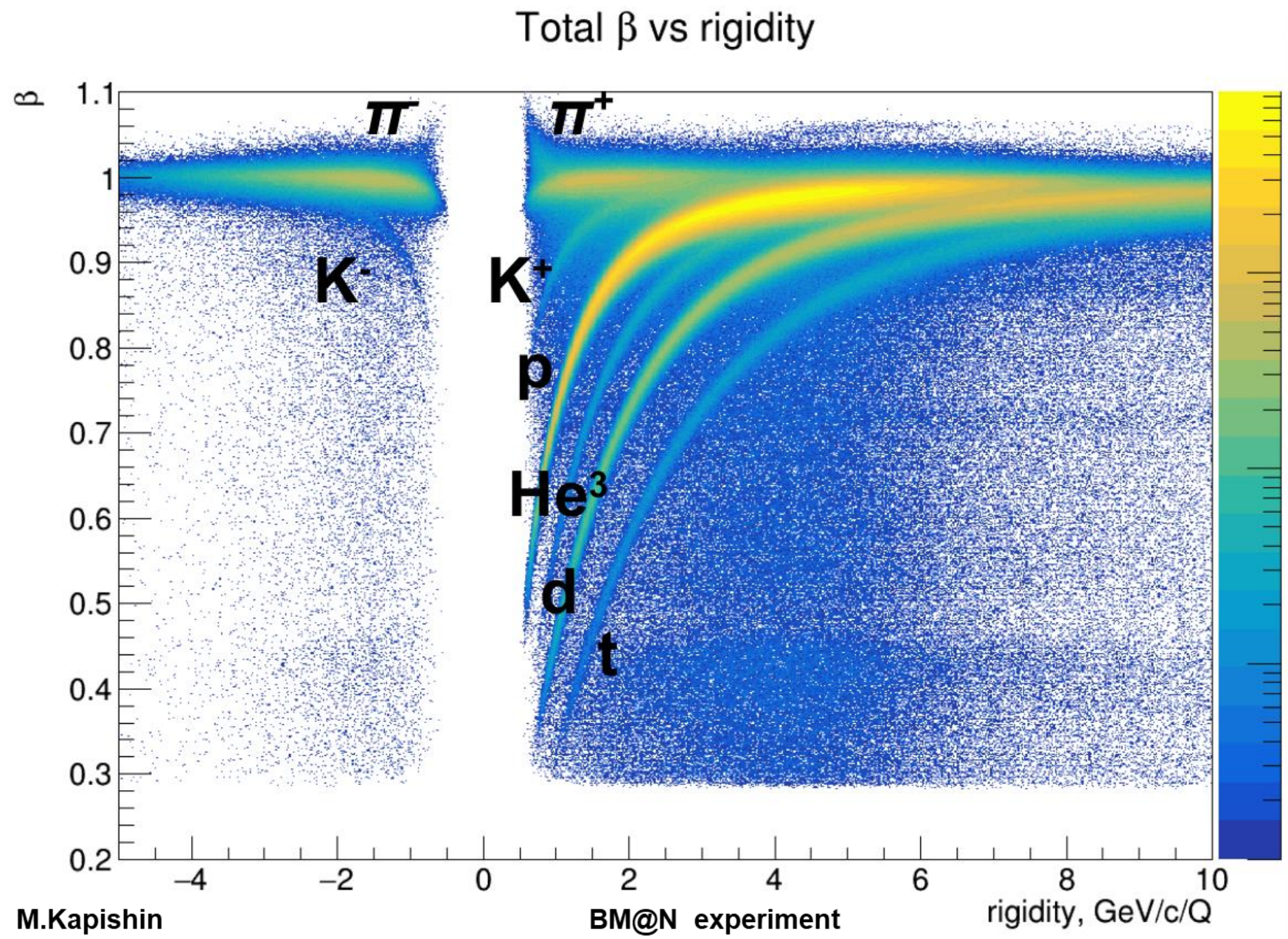


Compare spectra with DCM-SMM model

BM@N Preliminary



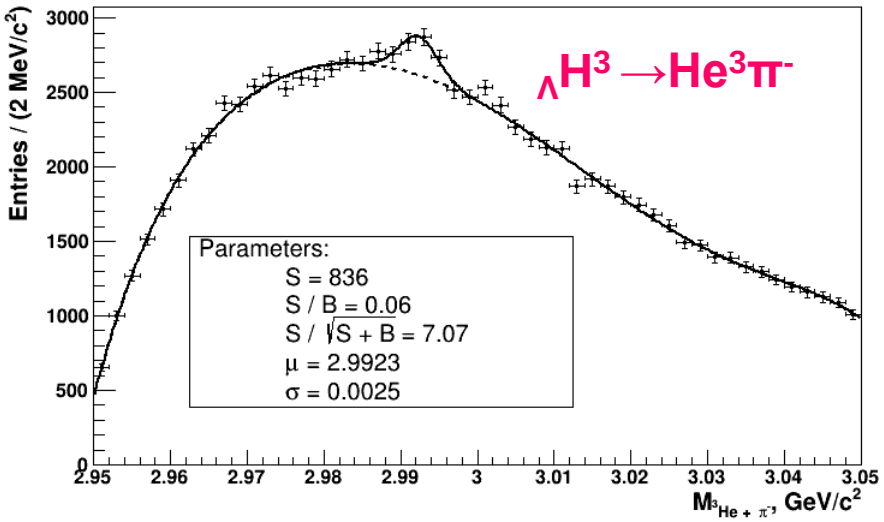
Xe+CsI data: π+-, K+-, p, He3, d/He4, t identification

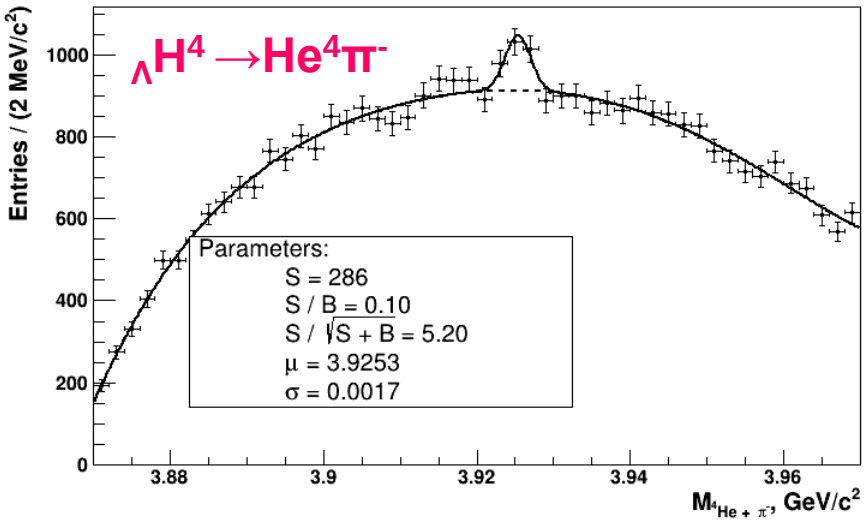


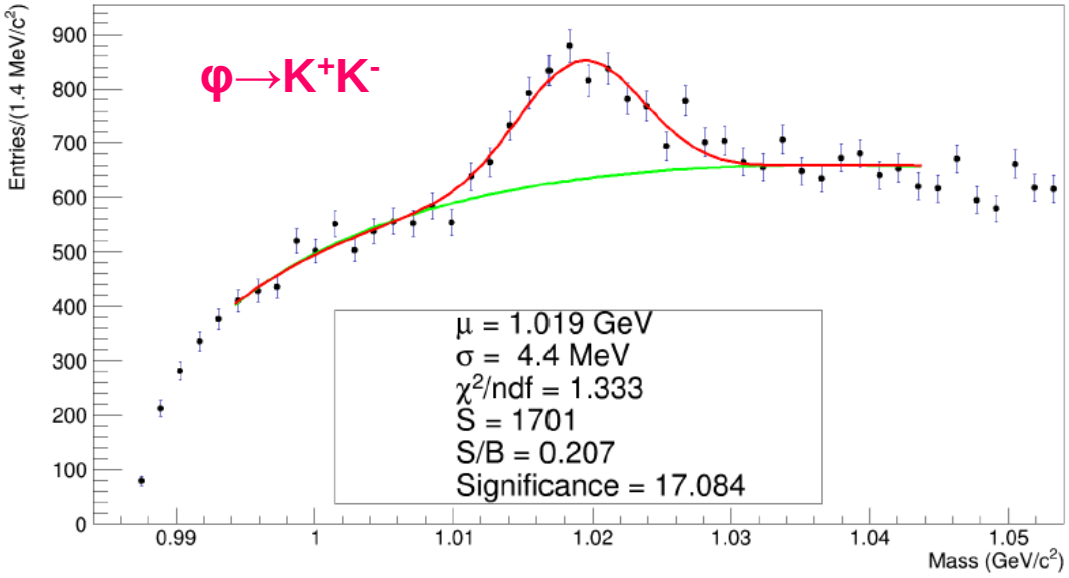
Search for $_{\Lambda}H^3$, $_{\Lambda}H^4$, φ decays in Xe+CsI interactions

First signals of $_{\Lambda}H^3$, $_{\Lambda}H^4$

S.Merts, R.Barak







Ongoing improvements:

- **Increase ToF-700 hit finding efficiency**
- **Improve dE/dx in GEMs for He^3, He^4 selection**

Status of data analysis and plans for next physics runs

Topics of physics analyses:

- analysis of production of Λ, Ξ- hyperons, K^0_S , K±, π±, φ mesons, light nuclear fragments in Xe+CsI interactions;
- collective flow of protons, π±, Λ, deuterons
- femtoscopy of protons, π±, deuterons
- light hyper-nuclei $_{\Lambda}H^3$, $_{\Lambda}H^4$

Physics run in the Xe beam in 2025

→ beam energy scan in the range of 2-3 AGeV
→ same central tracker configuration based on silicon micro-strip and GEM detectors,
→ additional 1st vertex plane of silicon micro-strip detectors
→ ToF-400 acceptance extended by 1.5

Preparations for a physics run with the Bi beam

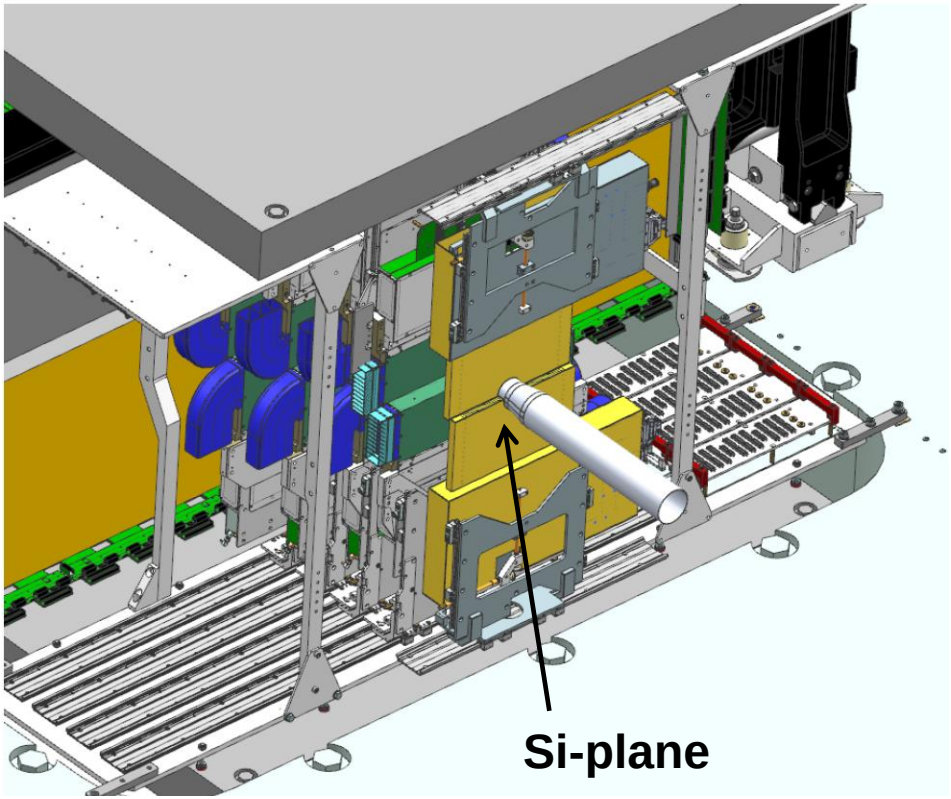
- Further development of the central tracker is foreseen: installation of additional station of silicon micro-strip detectors
- It is planned to put into operation a 2-coordinate (X/Y) neutron detector of high granularity to measure neutron yield and collective flow

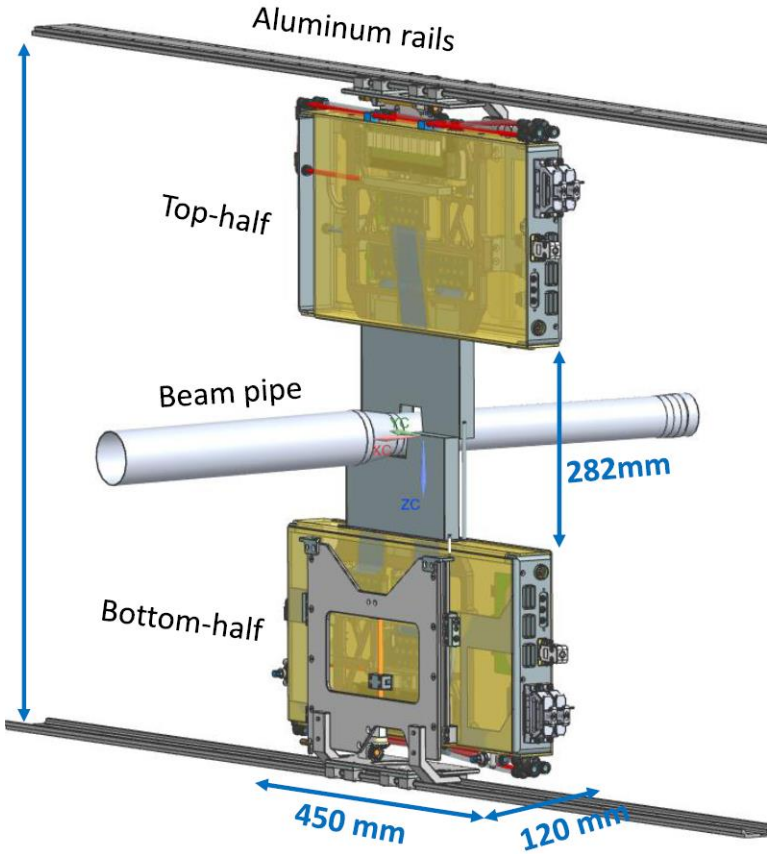
2-coordinate Si-plane based on STS modules

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



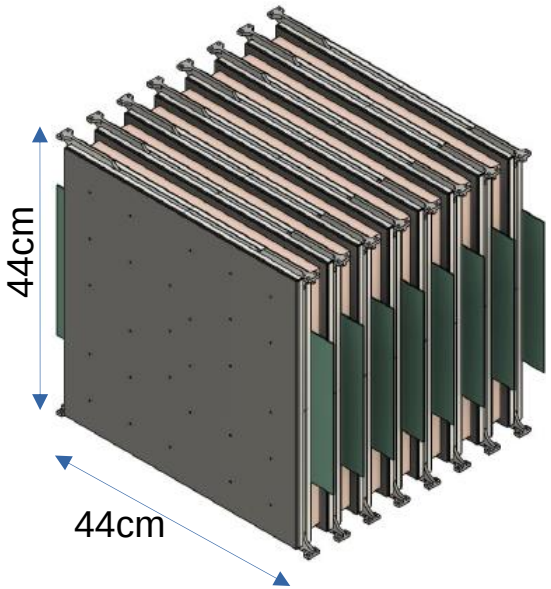


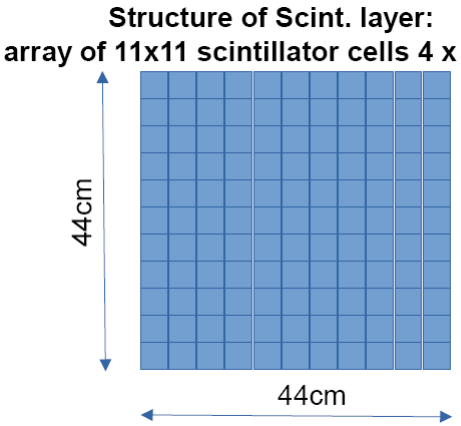
Plan to install and commission the new Si plane for the next experimental run

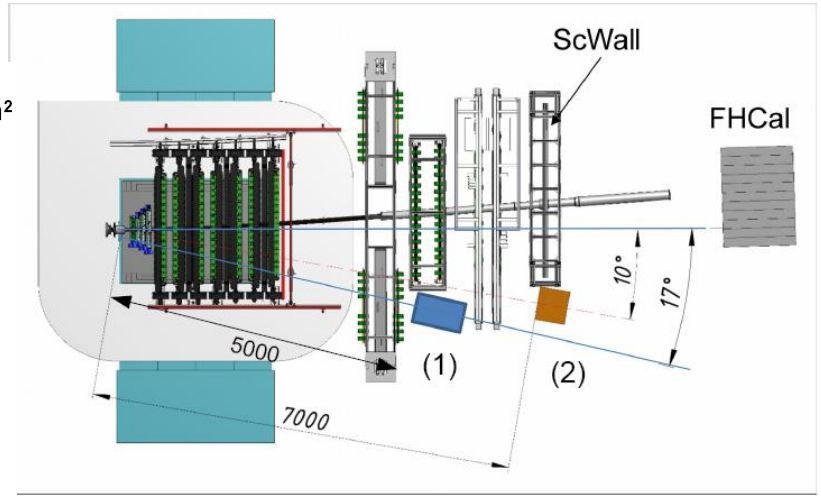
New neutron detector of high granularity

→ **plan to install in 2026**

INR RAS, LHEP, Kurchatov NRS





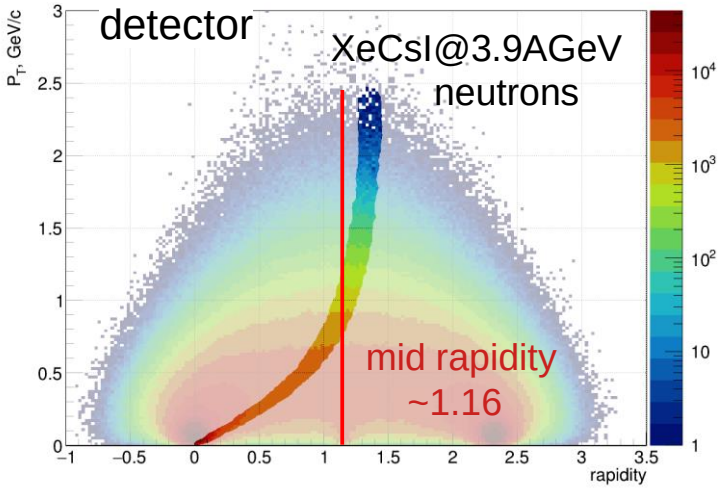


2 positions of HGN detector at BM@N: at 10° and 17°

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



BM@N papers, preliminary results, conferences

The BM@N spectrometer at the NICA-Nuclotron facility

The BM@N detector paper for the Xe+CsI run configuration, published in NIMA 1065 (2024) 169532

Preliminary results presented at conferences:

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

Directed flow $v1$ of protons in Xe+CsI collisions at 3.8 AGeV

Study of neutron emission at large angles in Xe+CsI interactions at an energy of 3.8 AGeV

BM@N presented about 20 physics and detector talks in 2024:

Scientific session of the Russian Academy of Sciences, Dubna, April 2024

Conference Nucleus-2024, Dubna, July 2024

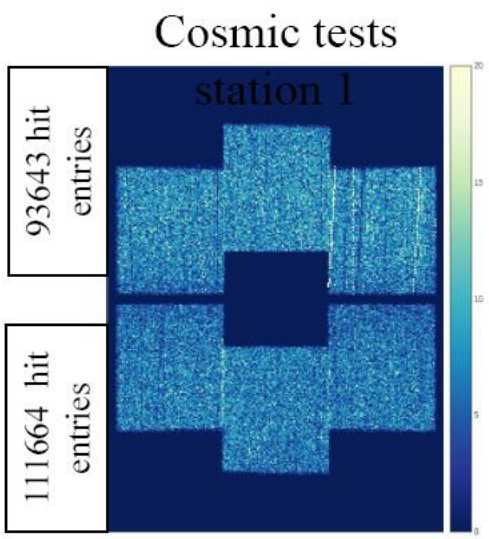
Conference "Hadron Structure and Fundamental Interactions" - HSFI'2024, Gatchina, July 2024

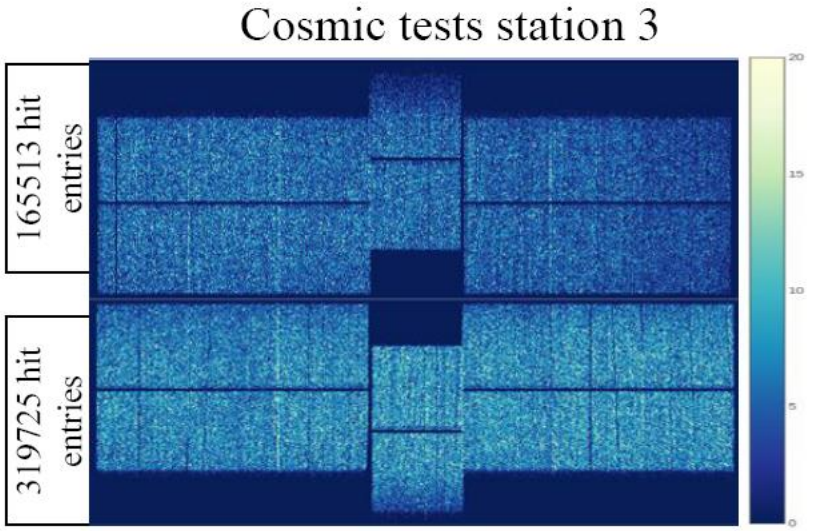
Conference ICPPA-2024, Moscow, October 22-25

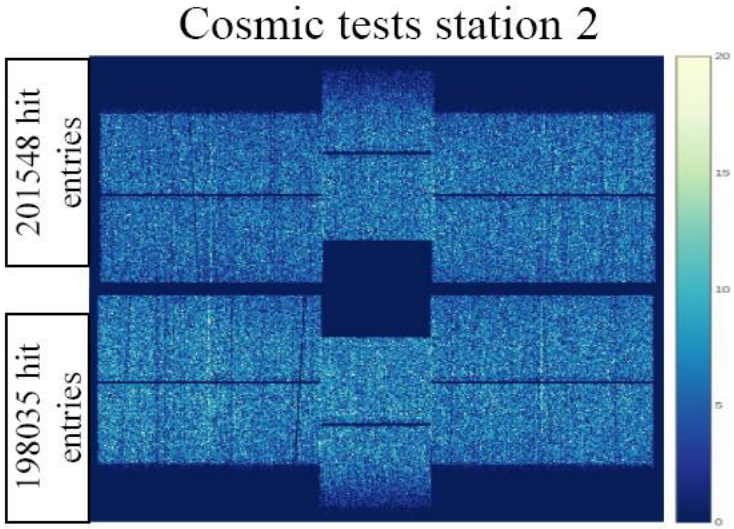
- 1 candidate dissertation on the 1st BM@N physical result defended in 2024
- ~10-12 young scientists (LHEP, MEPhI, INR RAS, Kurchatov NRC) are doing physics analyses at BM@N for future dissertations

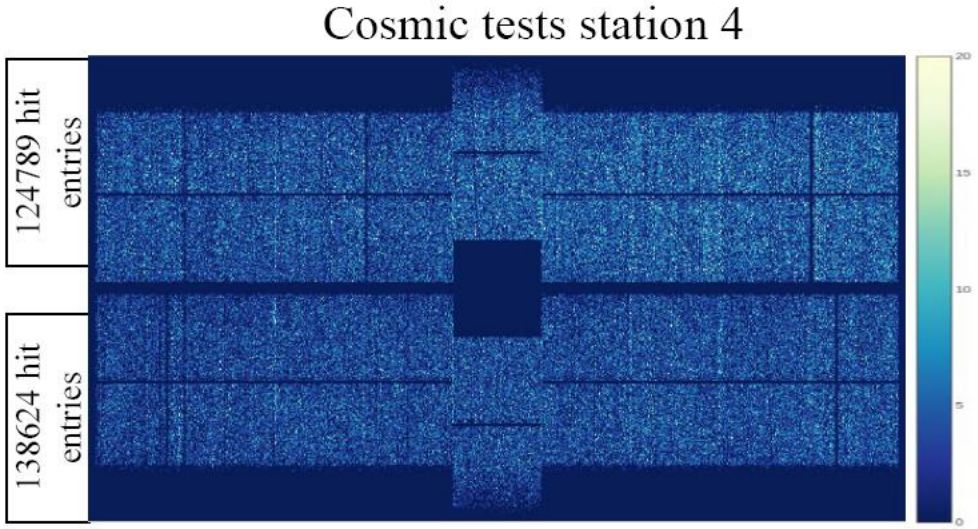
Thank you
for attention!

Forward Silicon Detectors

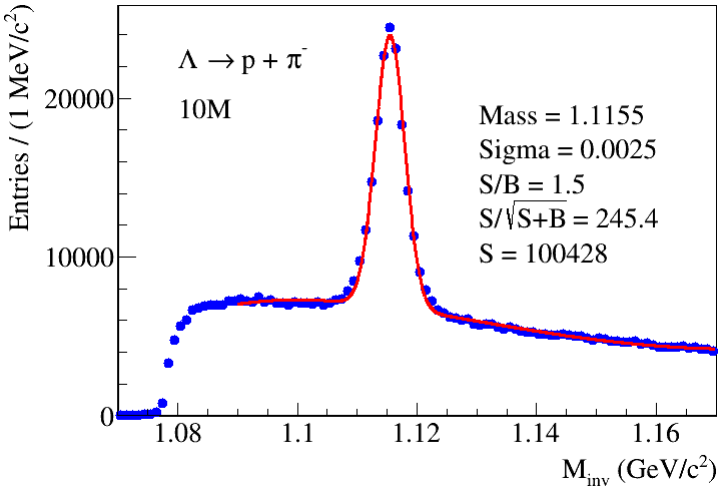


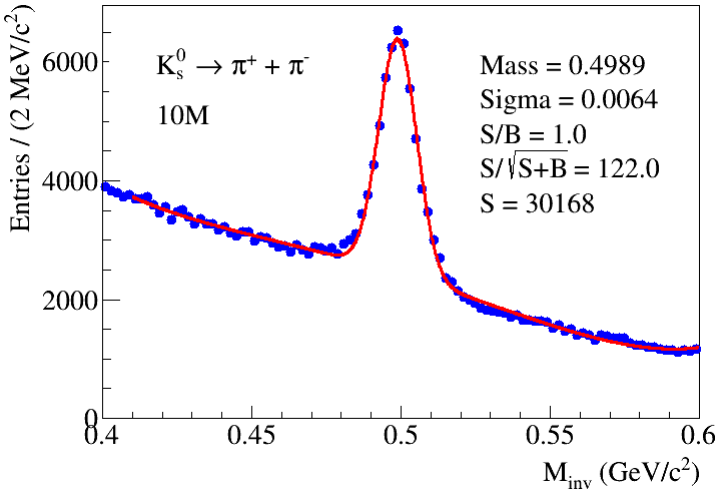




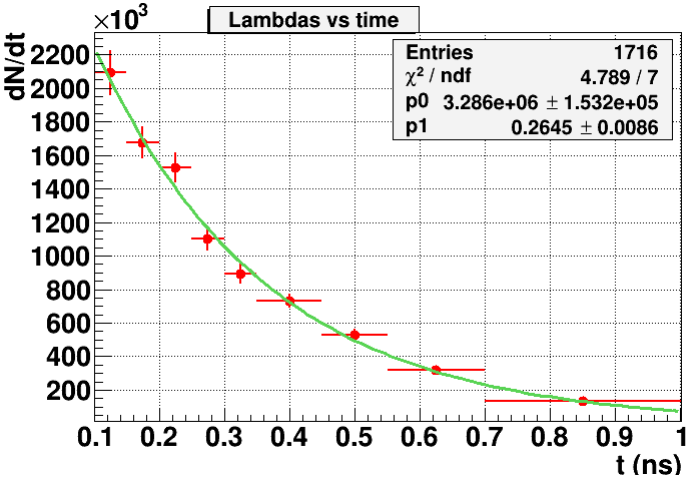


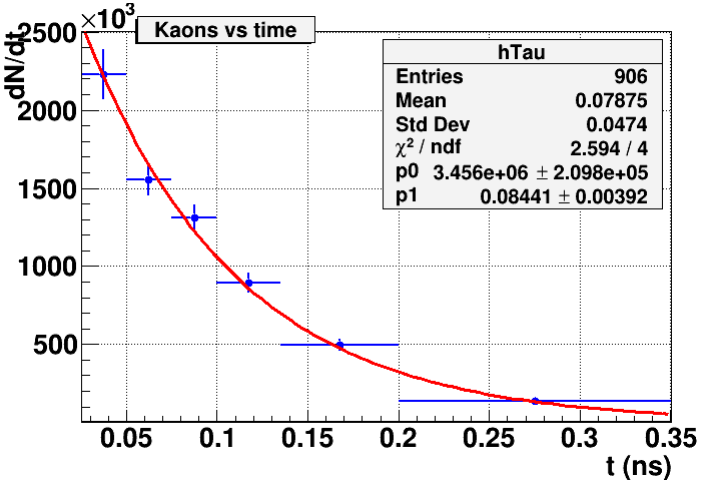
Λ and K^0_s production in Xe+CsI interactions





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