Status of the BM@N experiment

Dubna, May 13, 2025

BM@N experiment

Baryonic Matter at Nuclotron (BM@N) Collaboration:

207 participants from 5 Countries **Bulgaria, China, Kazakhstan, Russia & Uzbekistan**
13 Institutions & 7 towns **Alma-Aty, Dubna, Moscow, Plovdiv, Shanghai, St. Petersburg & Tashkent**

- ***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**

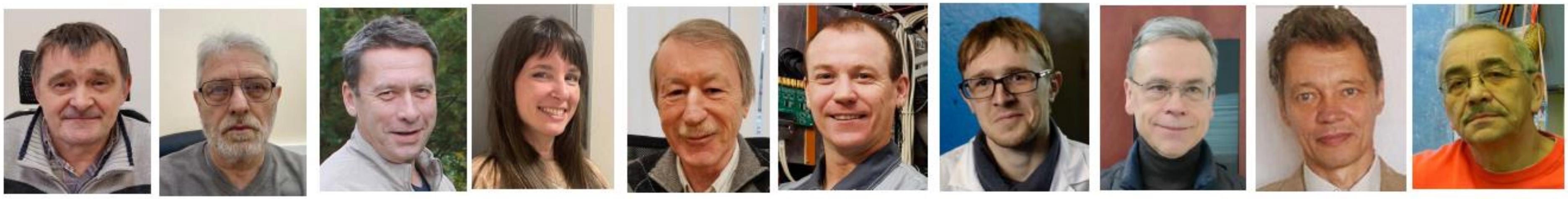
BM@N experiment

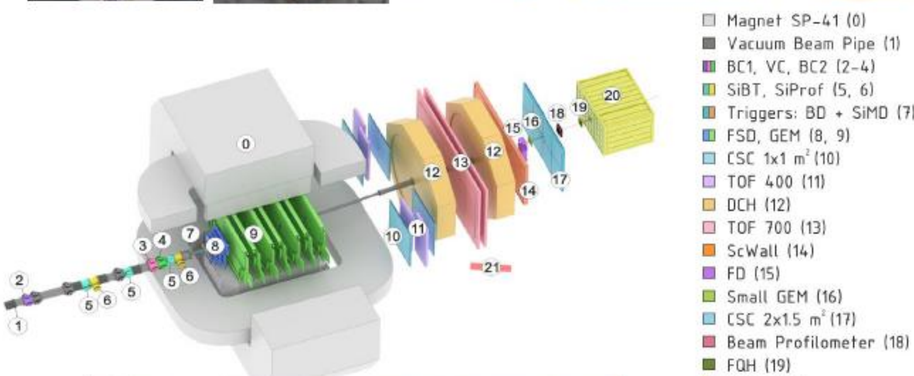
JINR prizes 2024

For physics instruments and methods

First prize *“Development of the BM@N spectrometer at the NICA accelerator complex”*

M.N.Kapishin, S.N.Bazylev, S.V.Khabarov, E.M.Kulish, A.M.Makankin, S.M.Piyadin, M.M.Rumyantsev, S.A.Sedykh, V.I.Yurevich, N.I.Zamyatin





Abstract

The BM@N spectrometer is designed to conduct fixed-target experiments with extracted beams of the Booster-Nuclotron accelerator complex and is the first large experimental setup created within the NICA project. The main goal of the BM@N physics program is to study dense nuclear matter formed in nucleus-nucleus collisions at beam energies of 1.5 – 5 AGeV. The program includes a series of measurements in beams of light (C), medium (Ar, Kr) and heavy (Xe, Bi) relativistic nuclei. To implement this program, over the past few years, the experimental setup has been equipped with modern detector systems. A range of works was carried out to prepare the spectrometer for experiments with heavy ion beams. **In December 2022 – January 2023, the first physics run was performed at the set-up with the Xe + CsI reaction at Xe beam energies of 3.0 AGeV and 3.8 AGeV. During the run, experimental data with statistics of more than 500 million events were collected, and all detector subsystems demonstrated performance compliant with the design parameters.** A detailed technical description of the spectrometer and its major subsystems is presented in a paper published in 2024 in the journal Nuclear Instruments and Methods.

Second prize:

“Development of the software complex for the implementation of a unified architecture for distributed data processing and storage at the BM@N/NICA experiment”.

Authors: E. Alexandrov, I. Alexandrov, N. Balashov, A. Chebotov, I. Filozova, K. Gertsenberger, P. Klimai, A. Moshkin, I. Pelevanyuk, G. Shestakova.

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

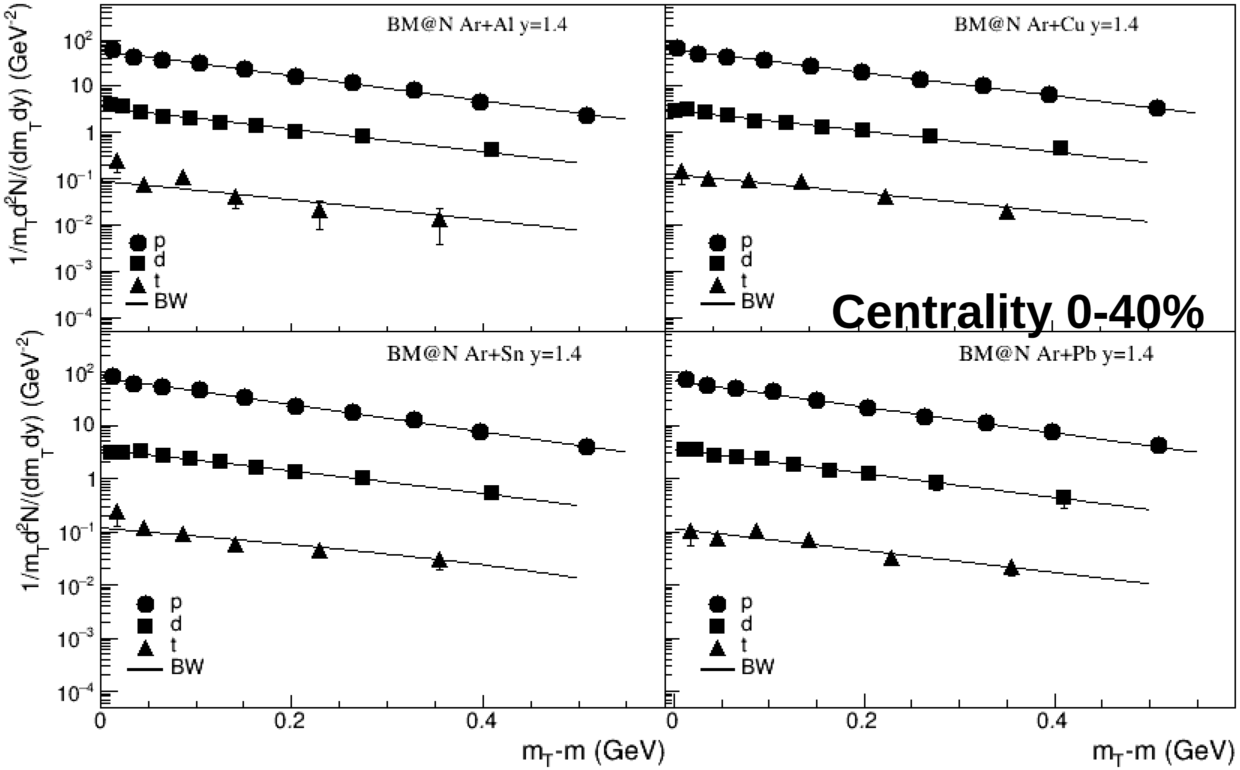
BM@N Collaboration

Abstract

Results of the BM@N experiment at the Nuclotron/NICA complex on the production of protons, deuterons and tritons in interactions of an argon beam of 3.2 A GeV with fixed targets of C, Al, Cu, Sn and Pb are presented. 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.

arXiv:2504.02759 → paper submitted to JHEP

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



	Ar+C	Ar+Al	Ar+Cu	Ar+Sn	Ar+Pb
T , MeV	140 ± 18	129 ± 10	132 ± 11	113 ± 10	126 ± 12
$\langle\beta\rangle$	$0.0\pm^{0.12}_{0.0}$	0.19 ± 0.05	0.21 ± 0.04	0.27 ± 0.03	0.23 ± 0.05
χ^2/ndf	44/49	127/55	113/55	86/55	172/55

BM@N experiment

The fitted temperature of ~130 MeV and transverse expansion velocity of ~0.2 c are practically the same for all the targets,

except for a smaller flow indicated for the Carbon target

Coalescence parameters B_2 (d) and B_3 (t)

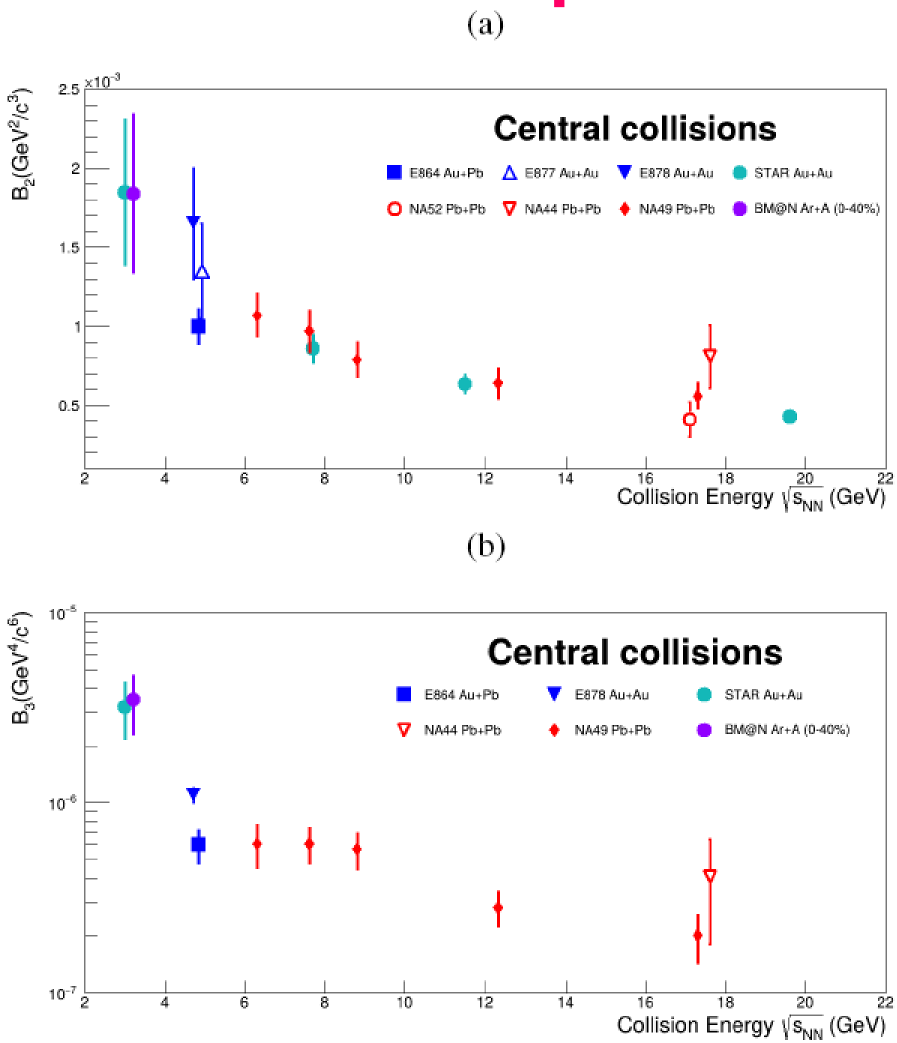


Figure 15. Coalescence parameters $B_2(p_T = 0)$ (a) and $B_3(p_T = 0)$ (b) for deuterons and tritons as functions of the nucleon-nucleon center-of-mass energy. The BM@N result is the weighted average value calculated in the rapidity range $-0.18 < y^* < 0.22$ for Ar+Al, Cu, Sn and Pb interactions with centrality 0–40%.

The Coalescence parameters measured by BM@N follow the increasing trend with the decreasing collision energy.

Since these parameters are inversly proportional to the femtoscopic (coalescence) volume for deuterons or volume squared for tritons, this volume shows the opposite trend – increases with the collision energy.

The estimated BM@N coalescence radius of ~2.5 fm at zero pT appears to be practically independent of the target mass.

Compound yield ratio $N_p\ N_t\ /\ N_d^2$

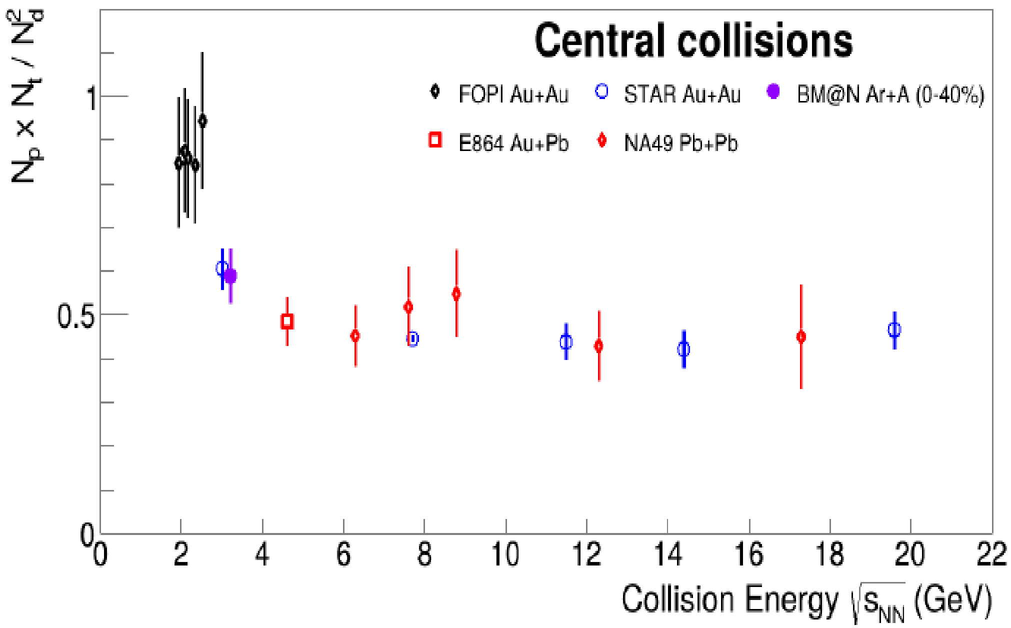


Figure 23. Compound yield ratio $N_p \cdot N_t/N_d^2$ of protons (N_p) and tritons (N_t) to deuterons (N_d^2) as a function of the center-of-mass energy of nucleus-nucleus interactions. The BM@N result represents the weighted average value in the rapidity range $-0.18 < y^* < 0.22$ calculated for Ar+Al, Cu, Sn and Pb interactions with centrality 0–40%.

In the Coalescence model, the ratio

$N_p\ N_t\ /\ N_d^2\ \approx 0.3\ (1 + \Delta n)$

is a measure of the neutron density fluctuation Δn and an irregular increase is expected near the critical point of the phase transition between the quark-gluon and hadron matter.

The measured BM@N ratio agrees with that of STAR and confirms the increase with the decreasing collision energy, expected in the coalescence model.

The search for the critical point however requires a more detailed scan of the BM@N energy region.

Production of Λ hyperons in 4.0 AGeV and 4.5 AGeV carbon-nucleus interactions at the Nuclotron

for BM@N Collaboration

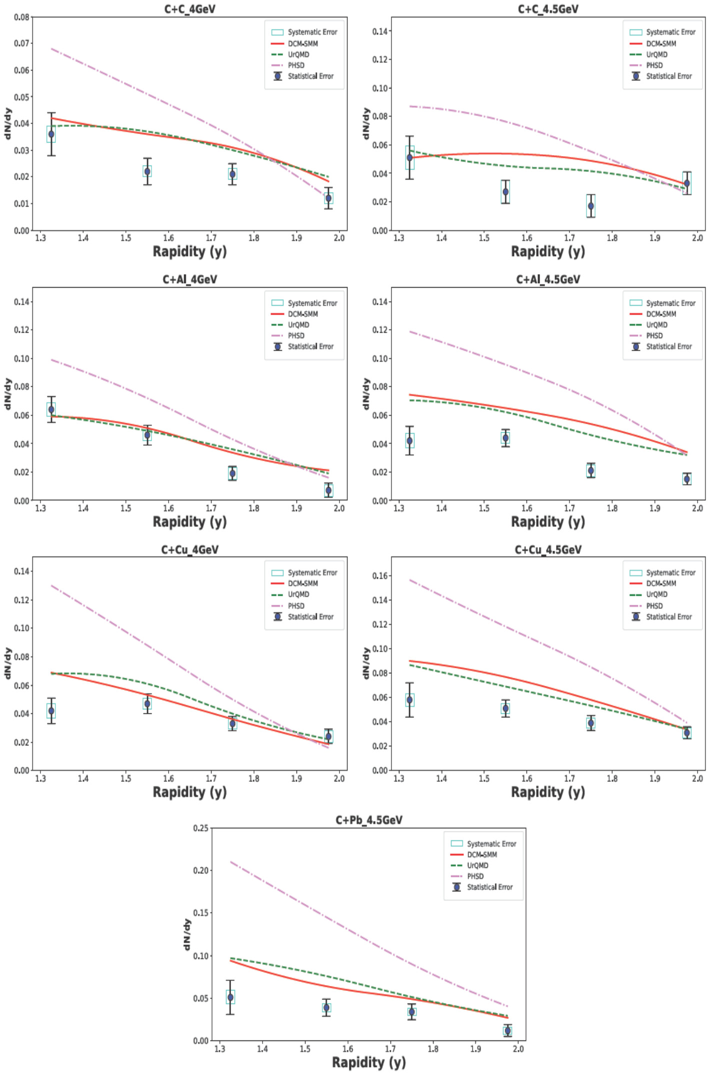
April, 2025

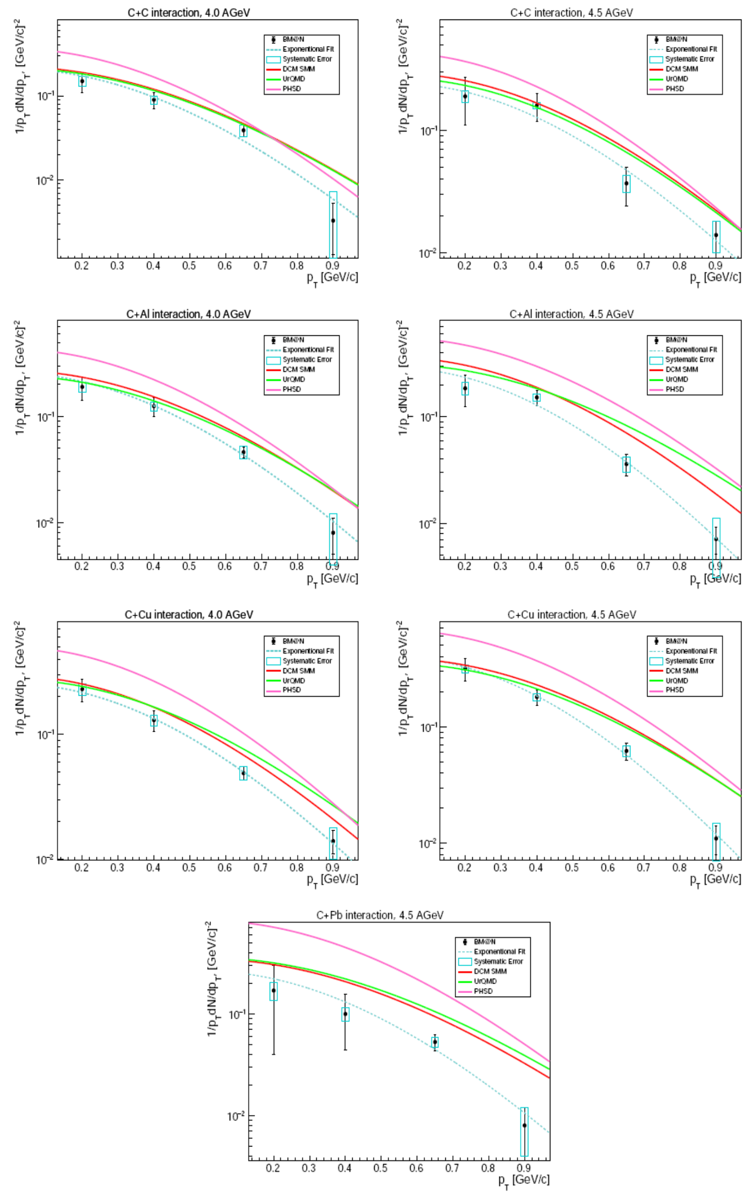
Abstract

The BM@N experiment (Baryonic Matter at the Nuclotron) is the first experiment undertaken at the JINR NICA-Nuclotron accelerator complex. The BM@N scientific program comprises studies of dense nuclear matter in heavy ion beams of the intermediate energy range between the SIS-18 and NICA/FAIR facilities. In this paper the results of the analysis of data are collected with the carbon beam at the 4.0 and 4.5 AGeV kinetic energy interacting with the different solid targets (C, Al, Cu, Pb). Transverse momentum, rapidity spectra and yields of Λ hyperons are measured. The results are compared with the theoretical models predictions and with the experimental data on carbon-carbon interactions measured at lower energies.

→draft in circulation in the BM@N Collaboration

Λ rapidity and p_T spectra in C+C, Al, Cu, Pb interactions





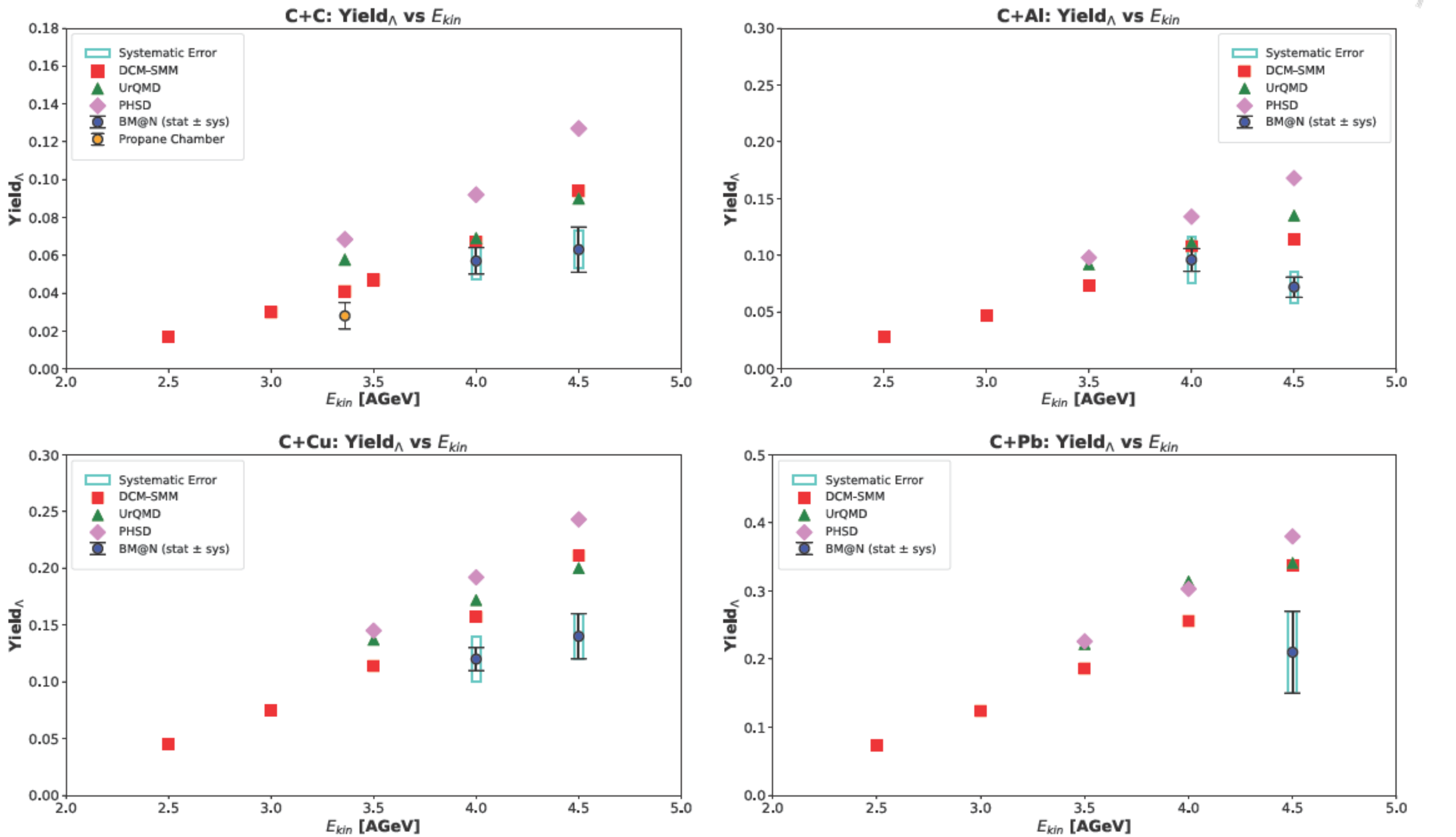
The DCM-SMM, UrQMD and PHSD models overestimate the Lambda yields

The measured inverse pT slope (effective temperature) is ~100 MeV

It is practically independent of the target mass

BM@N experiment

Energy dependence of Λ yields in C+C, Al, Cu, Pb interactions



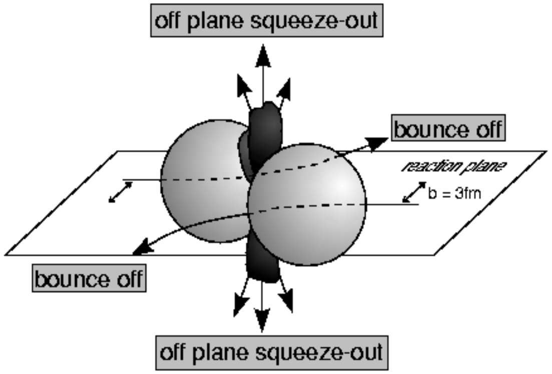
The BM@N Lambda yields are consistent with the expected increase with the collision energy, except for ~2 s.d. drop on the Aluminium target

Directed flow of deuterons and protons in Xe+CsI interactions

BM@N Preliminary: MEPhI group

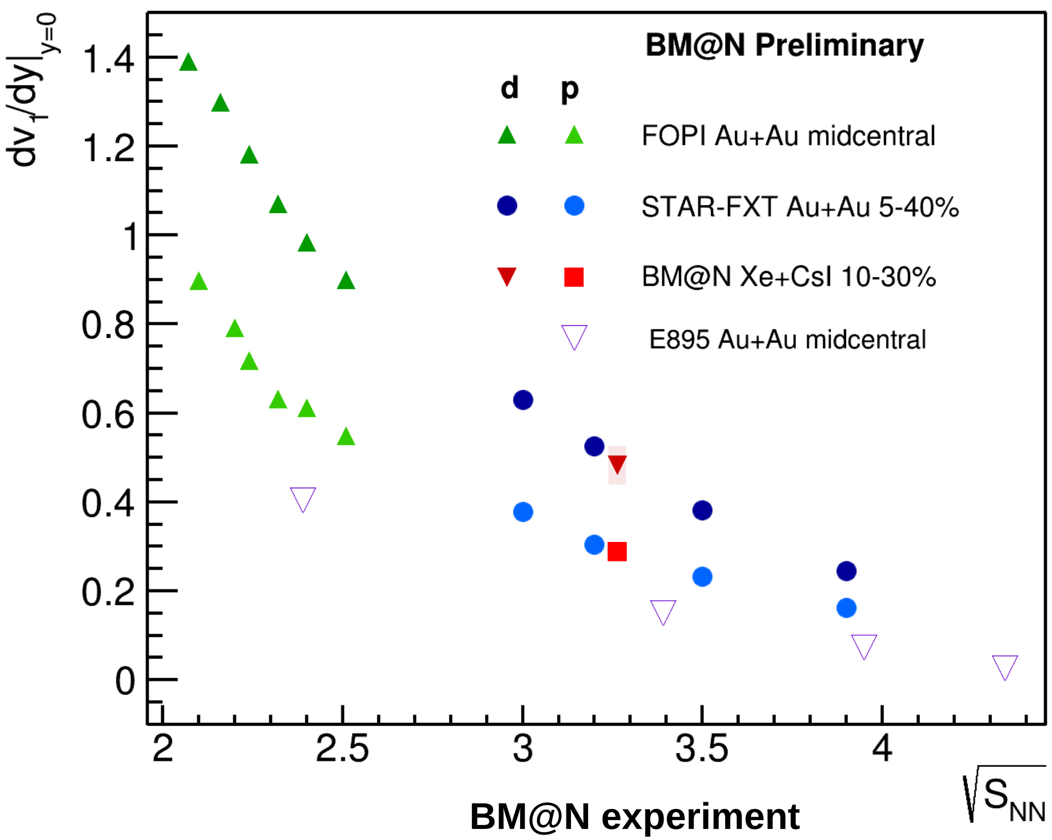
Azimuthal angle distribution:

$dN/d\varphi \propto (1 + 2v_1 \cos\varphi + 2v_2 \cos 2\varphi)$



→ **Directed flow *v*1 of protons and deuterons scales with A (1:2), as expected in the Coalescence model**

→ **BM@@N result is in line with the STAR FXT Au+Au data**



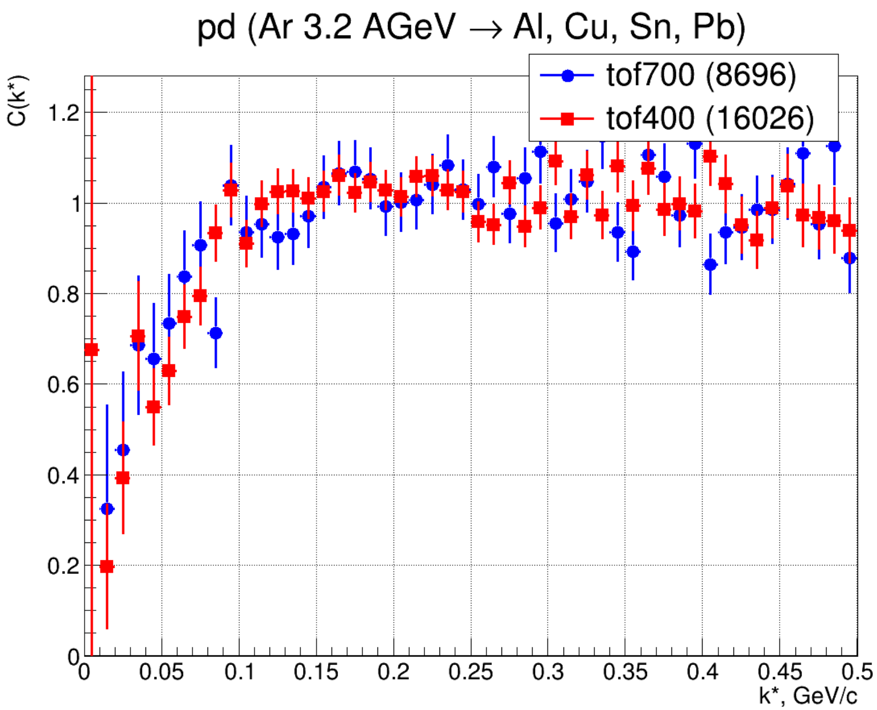
See talk of Mikhail Mamaev

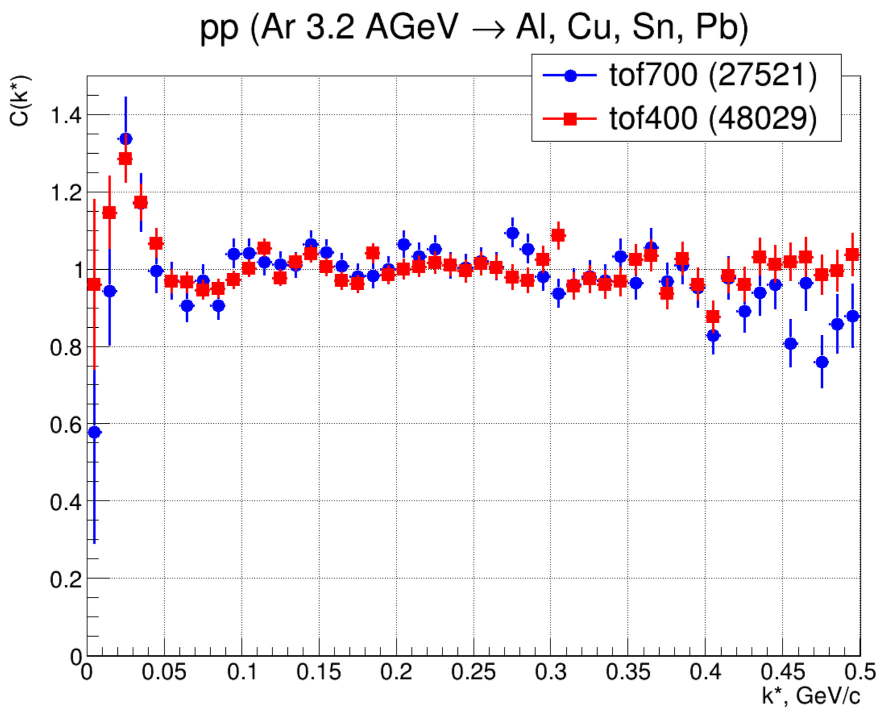
pp & pd femtoscopy in Ar+A collisions

→ **Measured CFs agree with theoretical expectations:**
pp CF peaked at k* = 20 MeV/c
pd dominated by Coulomb suppression at small k*

→ **estimated reasonable source radii R ~ 3 fm**

→ **coalescence model predicts R(pA) = $\sqrt{\frac{A+1}{2A}}$ R(pp):**
a few % accuracy required to check R(pd)/R(pp) = 0.87





See talk of Petr Alekseev

BM@N Note
REC-2025-01, ANA-2025-01

Reconstruction of decays of strange particles produced in Xe+CsI interactions with the BM@N detector

Roman Zinchenko[1], Julieta Drnoyan[1], Mikhail Kapishin[1], Igor Roufanov[1], Veronika Vasendina[1], Alexander Zinchenko[*,1], and Dmitry Zinchenko[1]

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February 18, 2025

Abstract

In December, 2022 - January, 2023 the BM@N experiment conducted its first physics run with full detector configuration. Over 500 million events of Xe beam interactions with CsI target with the beam kinetic energy of 3.8A GeV were collected.

Since then, strong efforts have been put to reconstruct the collected data and make preparations for physics analyses. The current status of such an activity related to reconstruction of strange particles weakly decayed to charged hadrons is presented in this paper. Main steps of the analysis procedure for a study of the strangeness production in nuclear collisions are outlined as well.

See talk of Alexander Zinchenko

BM@N Note
DET-2025-02

Performance study of the Highly Granular Neutron Detector prototype in the BM@N experiment

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Abstract: The time-of-flight Highly Granular Neutron Detector (HGND) with a multilayer longitudinal structure of interleaved absorber and scintillator plates, high transverse granularity and a time resolution of about 150 ps is currently under development. The detector is designed to identify neutrons produced in nucleus-nucleus collisions and measure neutron kinetic energies of 0.3–4 GeV by the time-of-flight method in the BM@N experiment at the NICA accelerator complex at JINR. In order to validate the concept of the full-scale HGND, a compact HGND prototype was first designed and built, and its performance was studied in the BM@N experiment. The acceptance of the HGND prototype and the detection efficiency of forward neutrons emitted in hadronic fragmentation and electromagnetic dissociation (EMD) of 3.8A GeV ^{124}Xe projectiles interacting with a CsI target were calculated by means of the DCM-QGSM-SMM and RELDIS models, respectively. The energy distributions of forward spectator neutrons and neutrons from the EMD were measured and compared with the simulations. The developed methods will be used to calibrate the full-scale HGND and to study its efficiency.

Keywords: neutron detectors; high energy neutrons; particle identification methods

[1] 2
[2] E-mail: zubankov@inr.ru

See talk of Alexander Zubankov

BM@N Note
DET-2025-02

Performance of the Scintillation Wall in the BM@N experiment

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[b] *Joint Institute for Nuclear Research (JINR), Joliot-Curie 6, Dubna, Moscow region 141980, Russia*

Abstract

The performance of the scintillation wall (ScWall) has been studied in the first physics run at the Baryonic Matter at Nuclotron (BM@N) in Xe+CsI reaction at a xenon beam energies of 3.8 and 3.0 AGeV. The design and functionality of the ScWall emphasizing its ability to detect charged spectator fragments produced in nucleus-nucleus interactions are shown. The simulation results regarding ScWall's capability to determine collision geometry and the simulated charged spectators fragments spectra are discussed.

Keywords: heavy ion, fixed target, scintillation wall, centrality, reaction plane

See talk of Vadim Volkov

Status of data analysis and plans for next physics runs

Topics of current physics analyses:

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

Physics run with the Xe beam in 2025

→ beam energy scan: 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 a factor of 1.5

Preparations for a physics run with the Bi beam

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

BM@N conferences , PhD activities

BM@N presented / submitted talks at conferences in 2025:

Conference of the Nuclear Physics Section of the Russian Academy of Sciences, Moscow, February 2025

Conference Nucleus-2025, St Petersburg, July 2025

26th International Baldin Seminar on High Energy Physics Problems "Relativistic nuclear physics and quantum chromodynamics", Dubna, September 2025

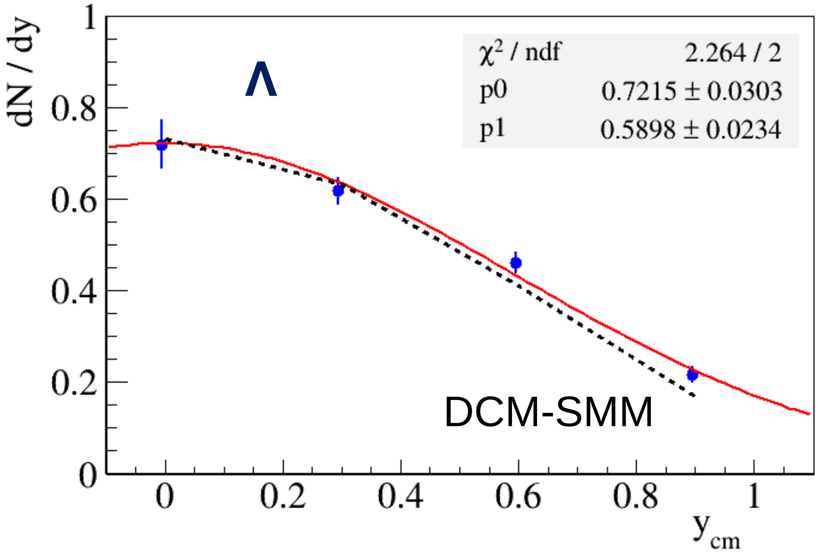
- 1 candidate dissertation on the 1st BM@N physical result defended in 2024
- 10 young scientists and PhD students (LHEP, MEPhI, INR RAS) are doing physics analyses at BM@N for future dissertations

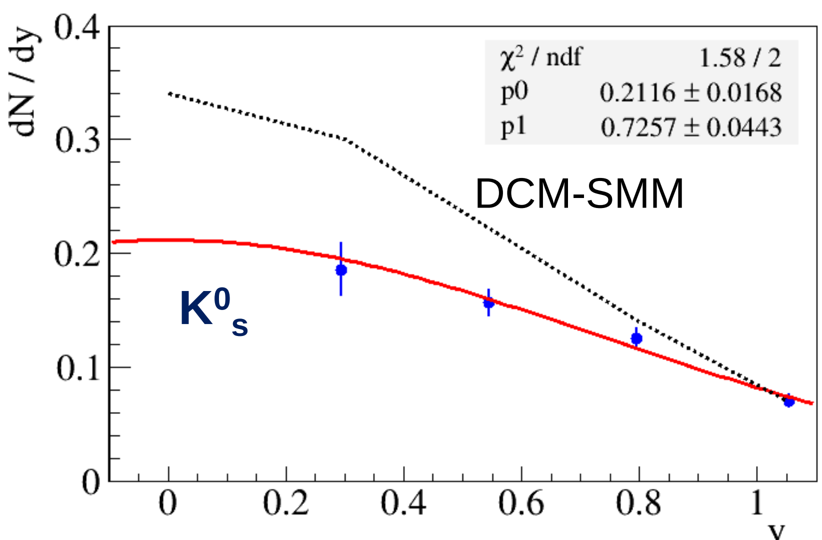
Thank you
for the attention!

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

A.Zinchenko and team

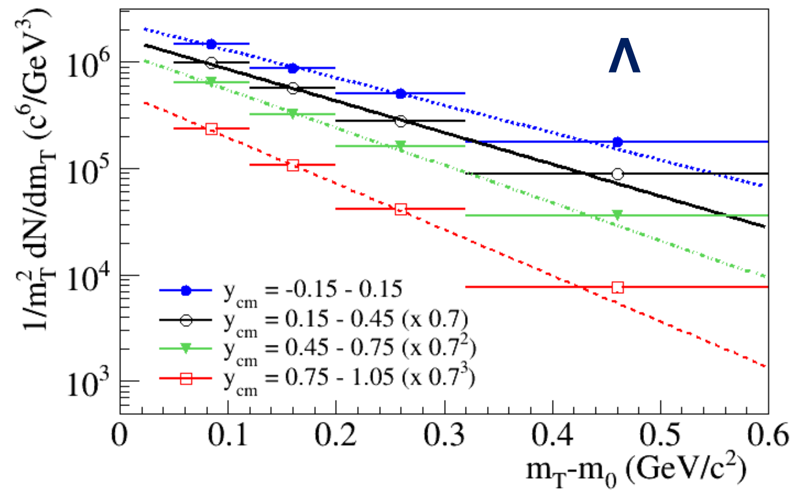
Rapidity spectra of Λ and K^0_s compared with DCM-SMM model

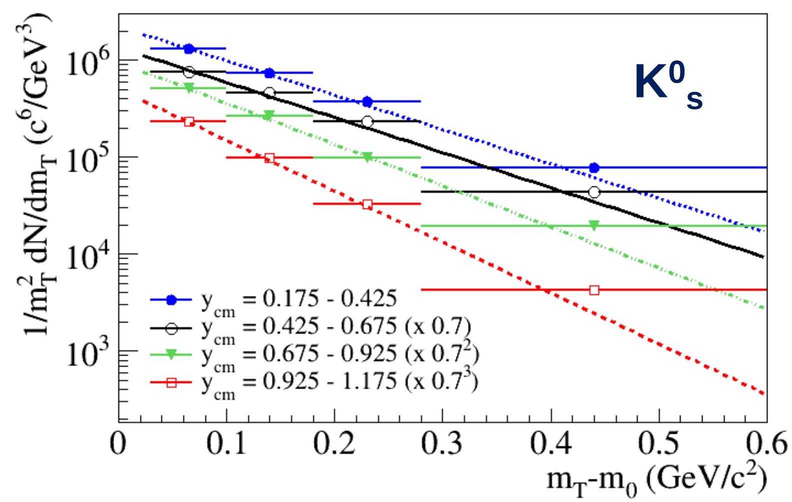




$$\frac{1}{m_T^2}\frac{dN}{dm_T} = C(y)\cdot\exp\left(-\frac{m_T - m_0}{T_{eff}}\right)$$

Transverse mass spectra of Λ and K^0_s





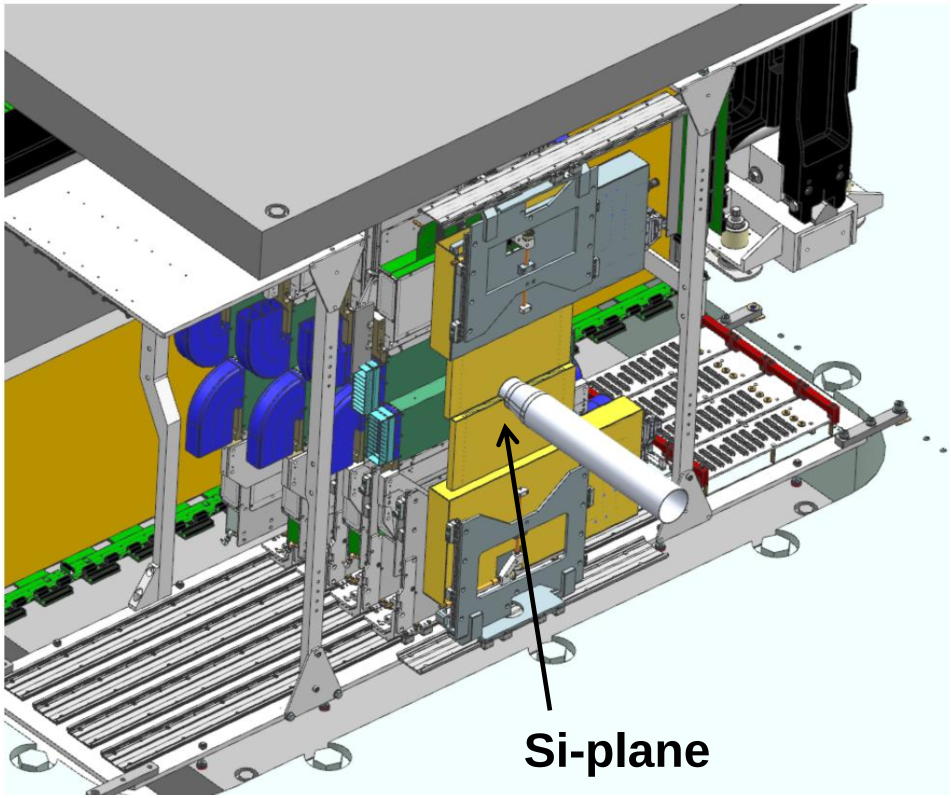
BM@N experiment

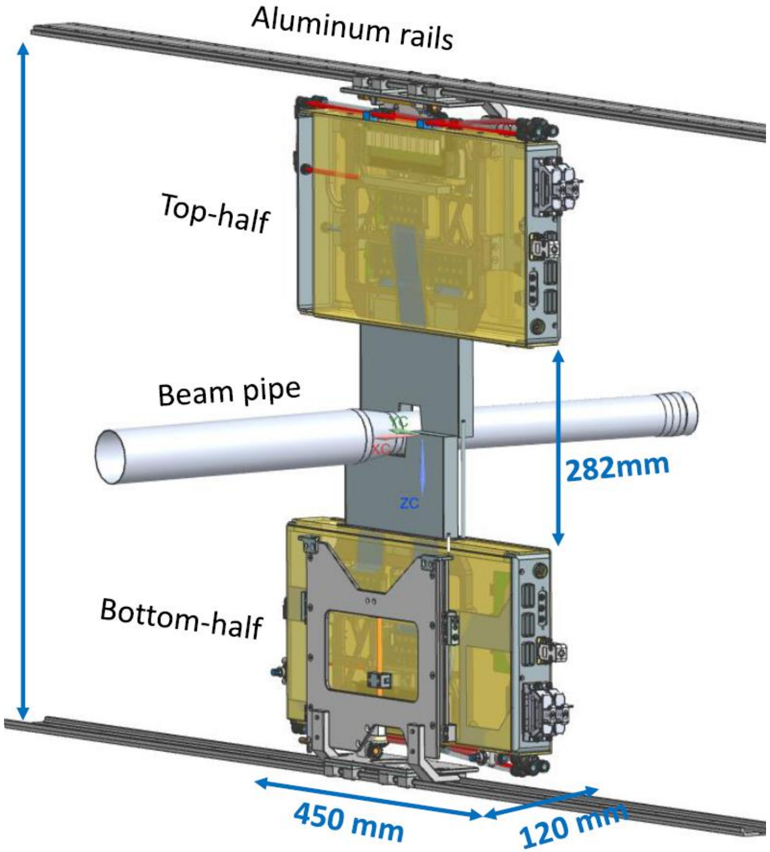
2-coordinate Si-plane based on STS modules

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



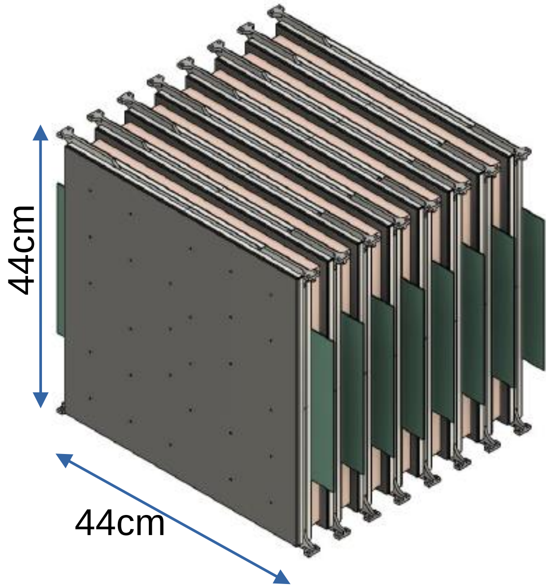


Plan to install and commission the new Si plane for the next experimental run

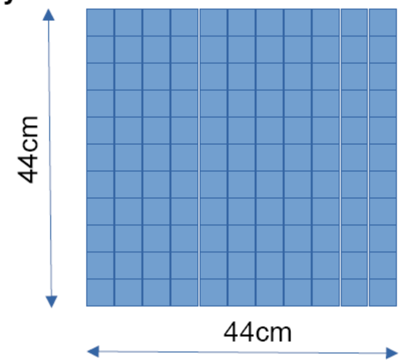
New neutron detector of high granularity

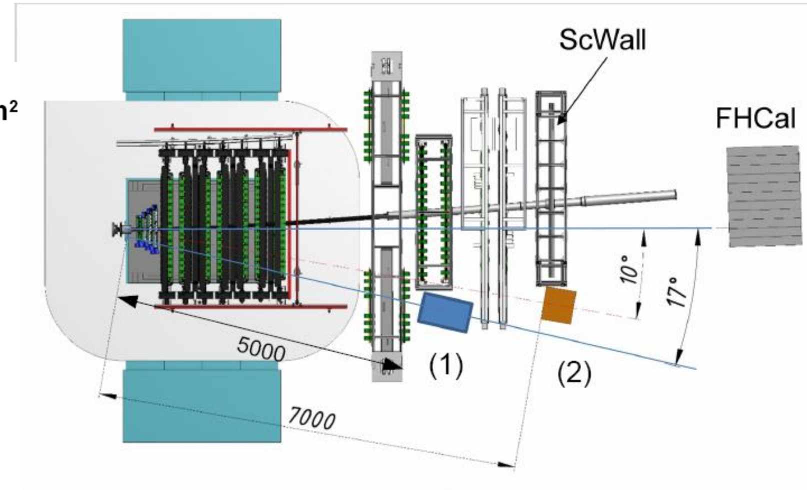
→ **plan to install in 2026**

INR RAS, LHEP, Kurchatov NRS



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



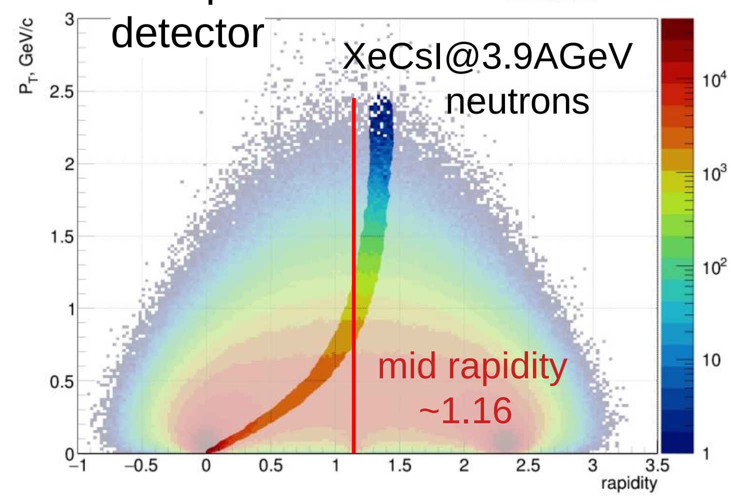


2 positions of HGN detector at BM@N: at 10º and 17º

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



BM@N experiment