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Hyperons at BM@N experiment: first results

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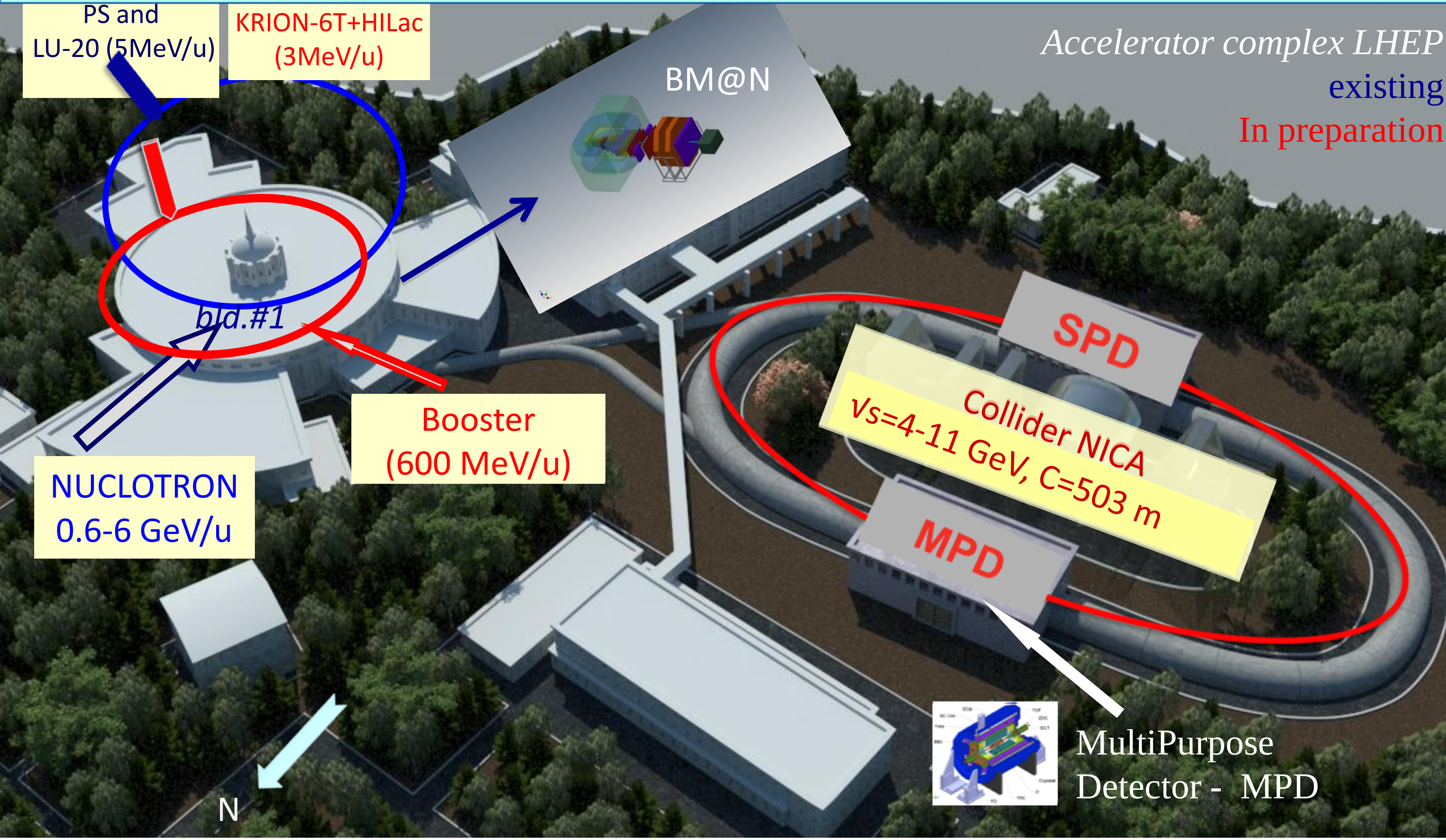
Outline

1. NICA complex & BM@N experiment
2. Technical run with C beam (March 2017)
   - ✓ BM@N detector set-up
   - ✓ Λ & K_s^0 reconstruction
   - ✓ Exp. vs MC
3. Run with Ar & Kr beams (March 2018)
   - ✓ BM@N detector set-up
   - ✓ PV & Λ reconstruction
4. Summary & Plans

Complex NICA

Parameters of Nuclotron for BM@N: E_{beam}=**1-6** GeV/u; *beams:* **p -Au**; Intensity~ **10^{7}** c^{-1} (Au)



Physics possibilities at BM@N

1. In A+A collisions at Nuclotron energies:

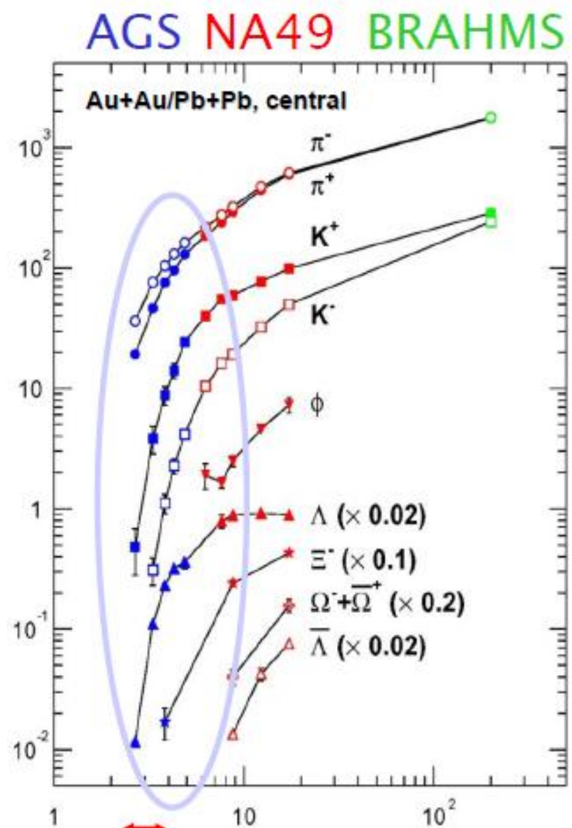
✓ Opening thresholds for strange and multistrange hyperon production ⟶ strangeness at threshold

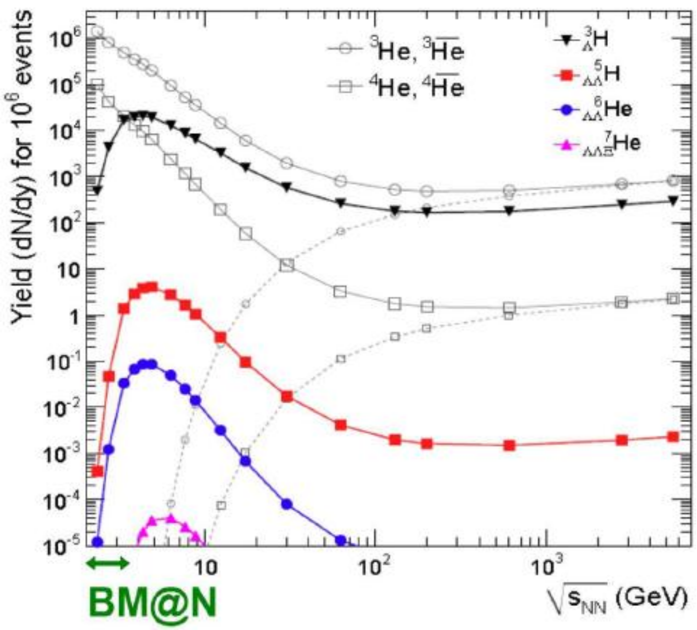
⟶ Need more precise data for strange mesons and hyperons, multy-variable distributions, unexplored energy range

✓ Collective flows v_1, v_2

2. In p+p, p+n, p+A collisions:

⟶ hadron production in elementary reactions and 'cold' nuclear matter as 'reference' to pin down nuclear effects





3. In heavy-ion reactions: production of hypernuclei through coalescence of Λwith light fragments enhanced at high baryon densities

Maximal yield predicted for $\sqrt{s_{NN}}$ = 4-5 GeV (stat.model)

Detector geometry

BM@N setup:

✓ Central tracker (GEM+Si) inside analyzing magnet to reconstruct AA interactions

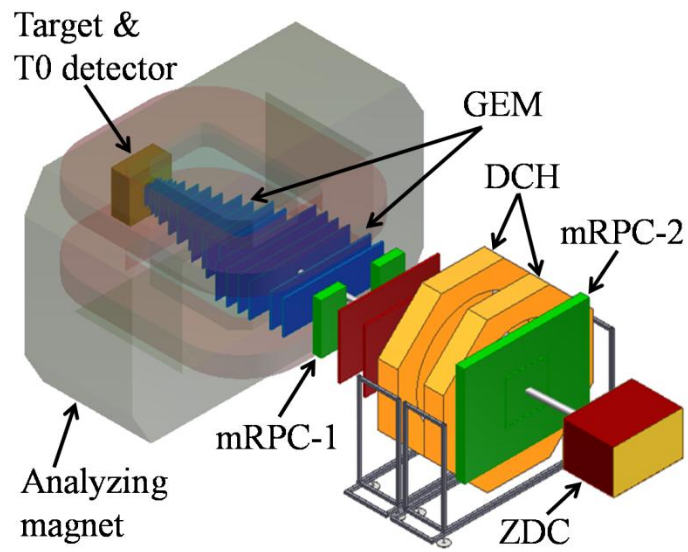
✓ Outer tracker (DCH, CSC) behind magnet to link central tracks to ToF detectors

✓ ToF system based on mRPC and T0 detectors to identify hadrons and light nucleus

✓ ZDC calorimeter to measure centrality of AA collisions and form trigger

✓ Detectors to form T0, L1 centrality trigger and beam monitors

✓ Electromagnetic calorimeter for γ,e+e-



BM@N advantage: large aperture magnet (~1 m gap between poles)

→ fill aperture with coordinate detectors which sustain high multiplicities of particles

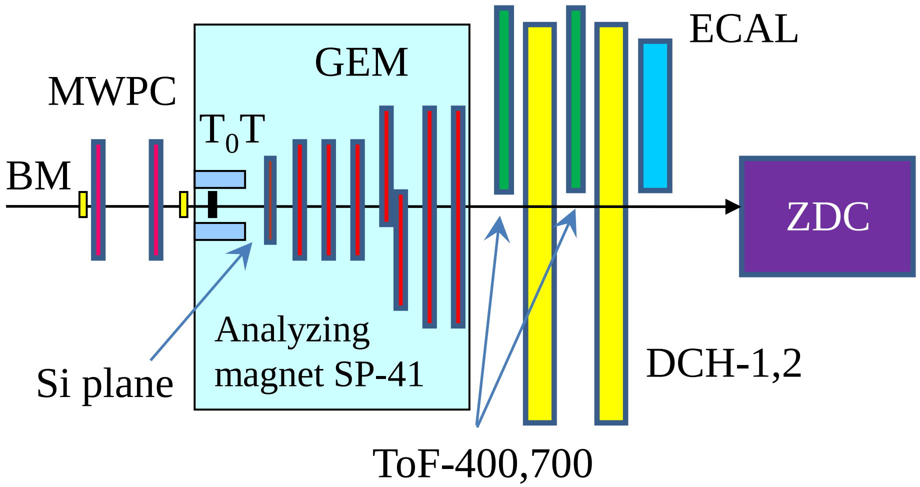
→ divide detectors for particle identification to "near to magnet" and "far from magnet" to measure particles with low as well as high momentum (p > 1-2 GeV/c)

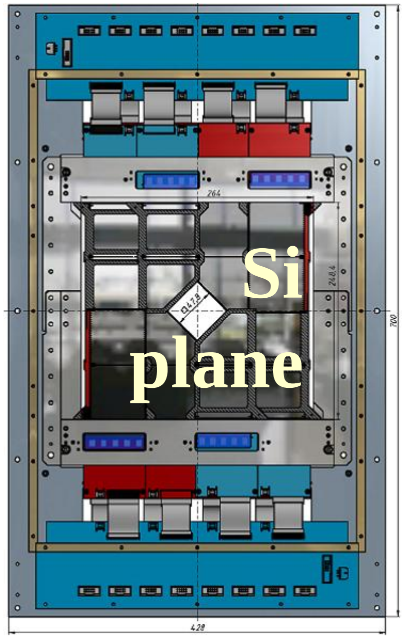
→ fill distance between magnet and "far" detectors with coordinate detectors

BM@N set-up in 2016 / 2017

Deuteron beam: T_0= 3.5, 4.0 GeV/n

Carbon beam: T_0= 3.5, 4.0, 4.5, (5.14) GeV/n





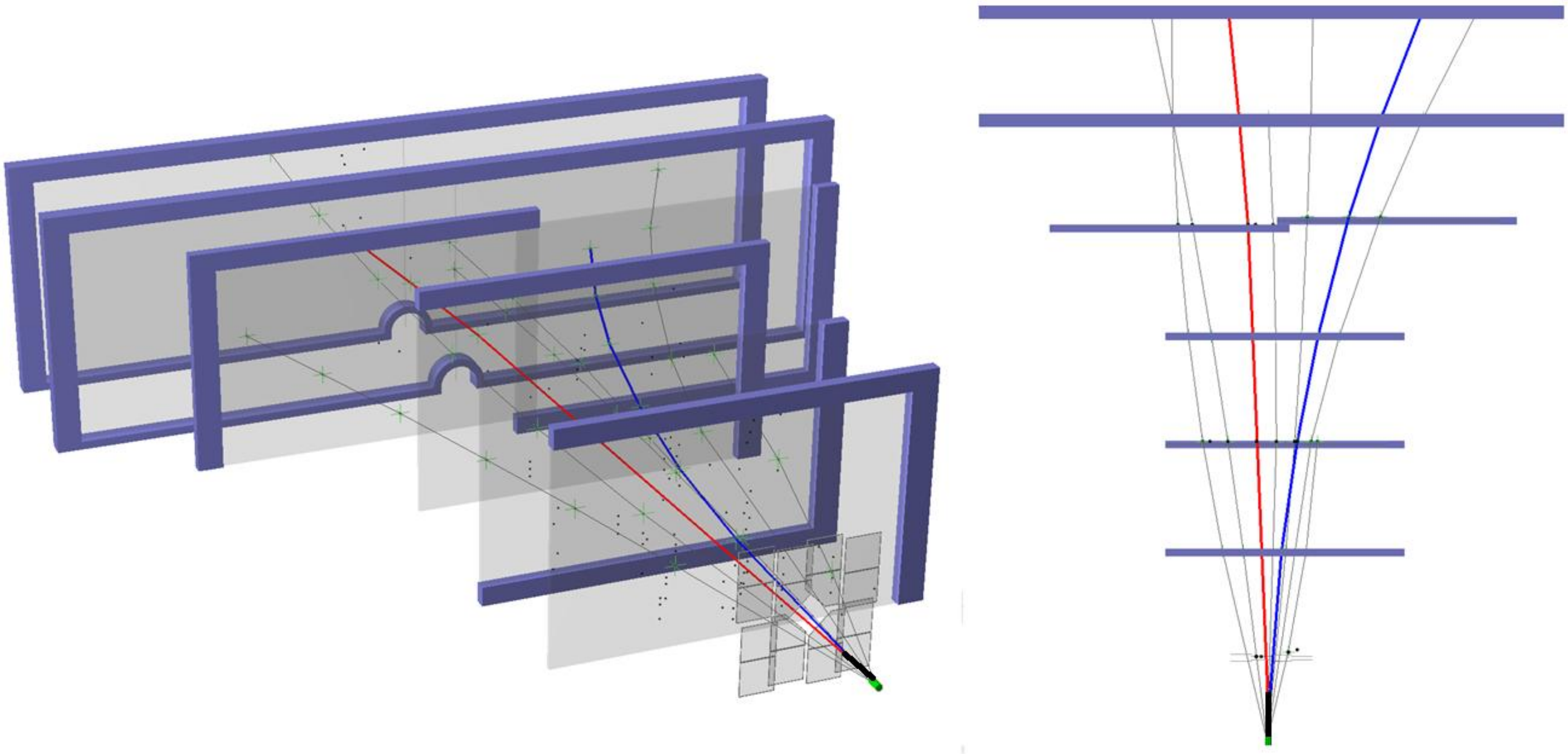
✓ Focus on tests and commissioning of central tracker inside analyzing magnet → 5 GEM detectors 66 x 41cm^2 + 2 GEM detectors 163 x 45 cm^2 and 1 plane of Si detector for tracking (2-coordinate Si detector X-X'(±2.5^o) with strip pitch of 95/103 μm, full size of 25 x 25 cm^2)

Program:

✓ Trace beam through detectors, align detectors, measure beam momentum in mag. field of 0.6 T

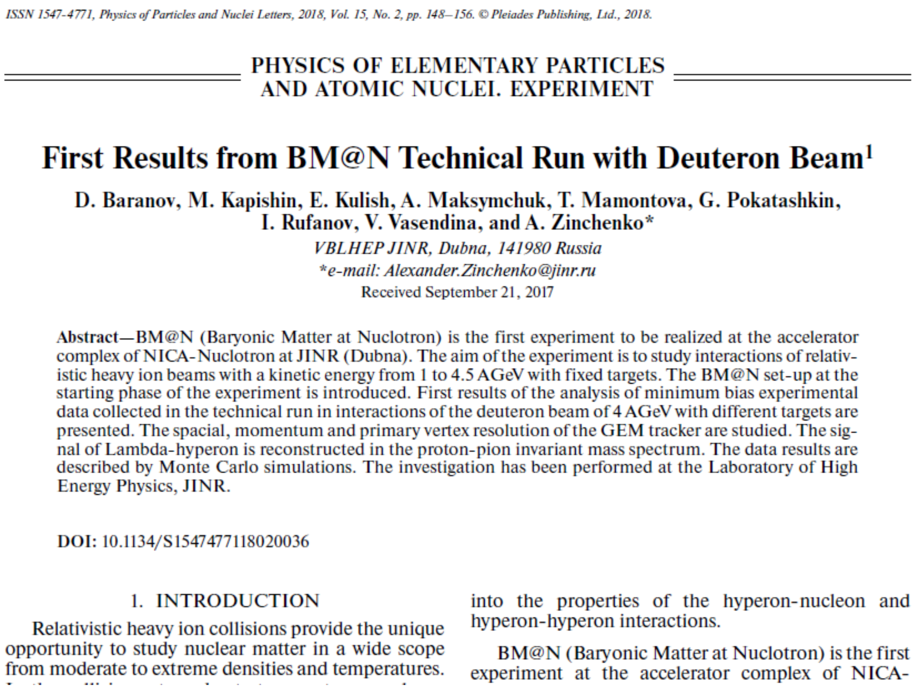
✓ Measure inelastic reactions C + target → X with carbon beam energies of 3.5 - 4.6 GeV/n on targets C, Al, Cu, Pb

Visualization of Λ decay



Event Display: Example of the Λ decay reconstruction in the tracker (GEM + Si) in C+C interaction.

Paper with first results (deuteron beam)



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PHYSICS OF ELEMENTARY PARTICLES AND ATOMIC NUCLEI. EXPERIMENT

First Results from BM@N Technical Run with Deuteron Beam[1]

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Abstract—BM@N (Baryonic Matter at Nuclotron) is the first experiment to be realized at the accelerator complex of NICA-Nuclotron at JINR (Dubna). The aim of the experiment is to study interactions of relativistic heavy ion beams with a kinetic energy from 1 to 4.5 AGeV with fixed targets. The BM@N set-up at the starting phase of the experiment is introduced. First results of the analysis of minimum bias experimental data collected in the technical run in interactions of the deuteron beam of 4 AGeV with different targets are presented. The spacial, momentum and primary vertex resolution of the GEM tracker are studied. The signal of Lambda-hyperon is reconstructed in the proton-pion invariant mass spectrum. The data results are described by Monte Carlo simulations. The investigation has been performed at the Laboratory of High Energy Physics, JINR.

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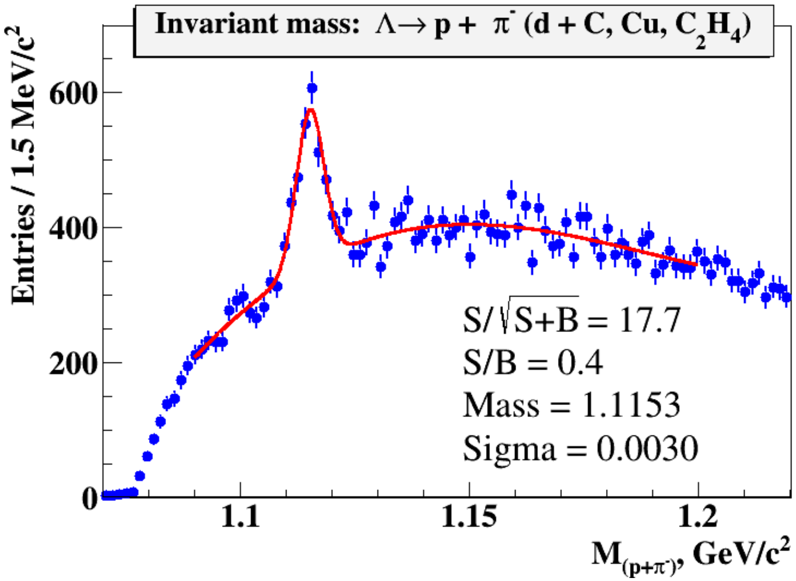
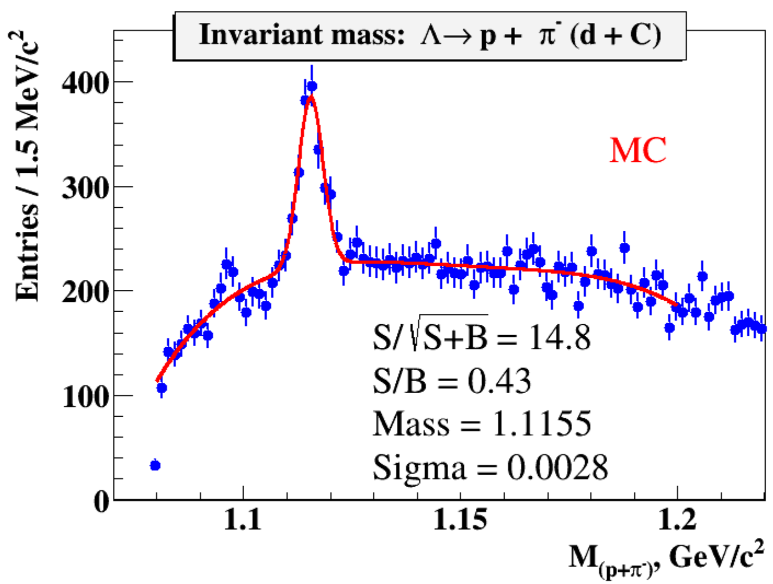
1. INTRODUCTION

Relativistic heavy ion collisions provide the unique opportunity to study nuclear matter in a wide scope from moderate to extreme densities and temperatures. into the properties of the hyperon-nucleon and hyperon-hyperon interactions.

BM@N (Baryonic Matter at Nuclotron) is the first experiment at the accelerator complex of NICA-

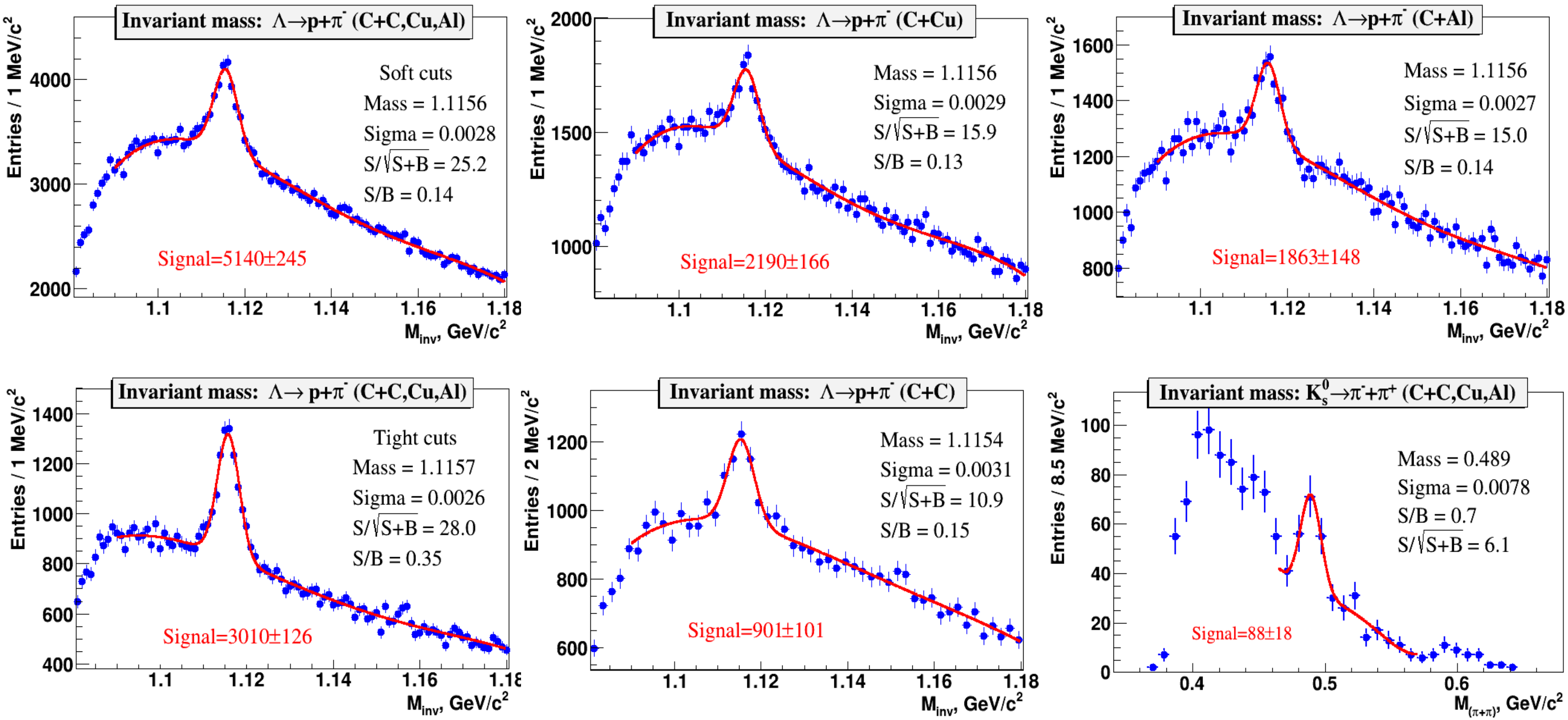




Methodical Paper published in PEPAN Letters, v.15, p.136, 2018(2)

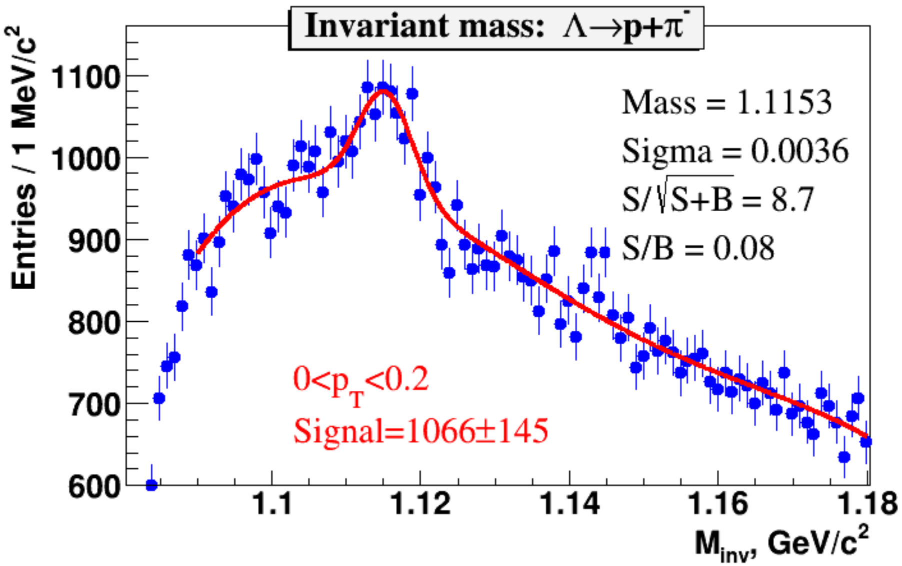
Λ & K^0_s reconstruction in carbon run

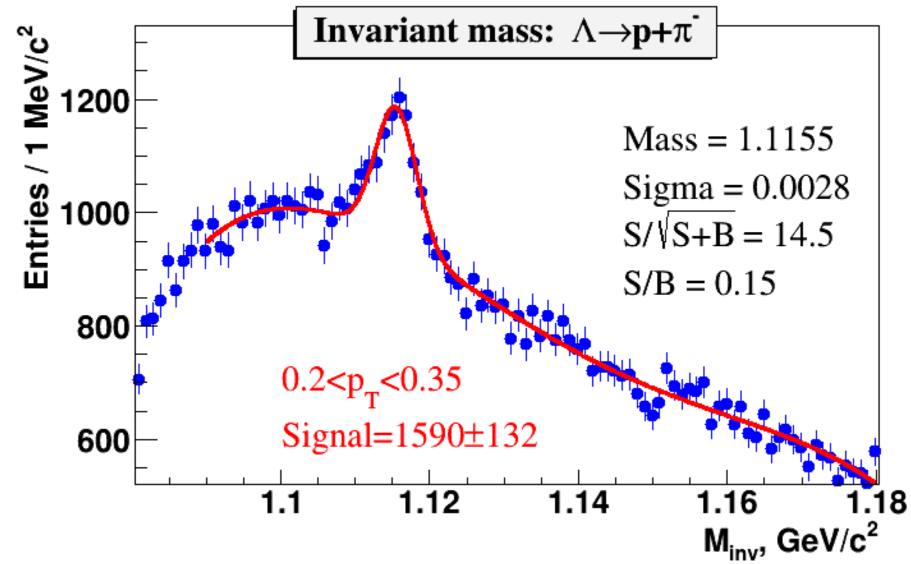
Beam /Target: C/C,Al,Cu; E_{kin} = 4.0A GeV, No PID, only GEM+Si

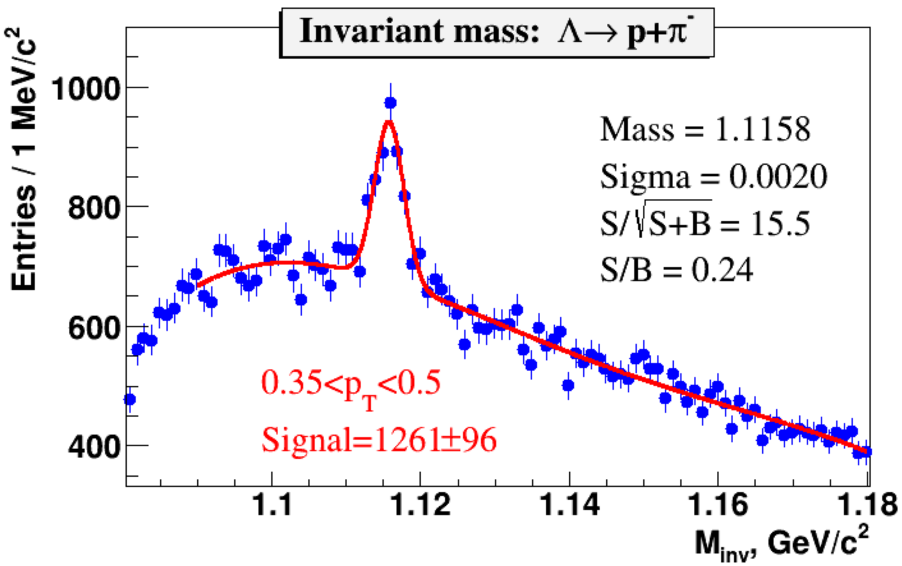


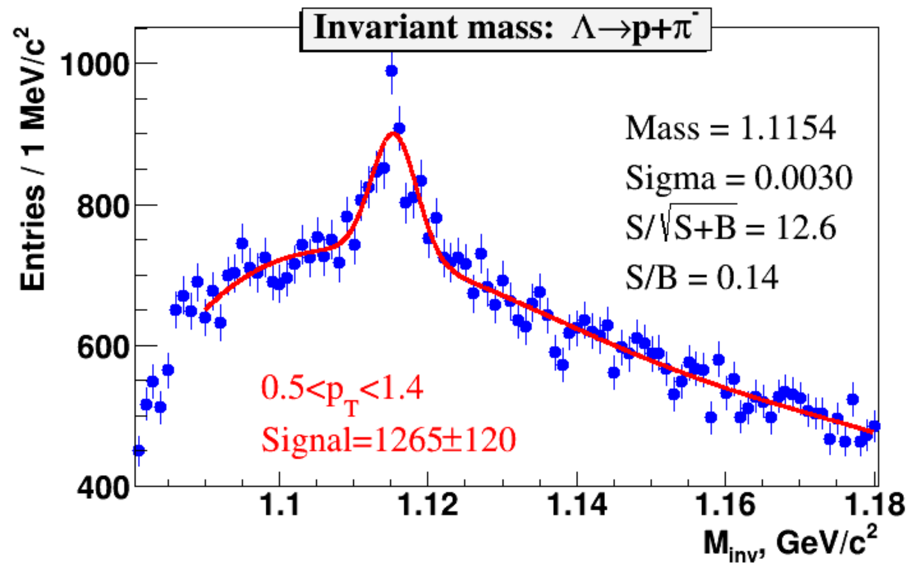
Since the GEM tracker configuration was tuned to measure relatively high-momentum beam particles, the geometric acceptance for relatively soft decay products of strange V0 particles was rather low. The Monte Carlo simulation showed that only **~4%** of Λ and **~0.8%** of K_s^0 could be reconstructed.

Λ reconstruction: p_T dependence

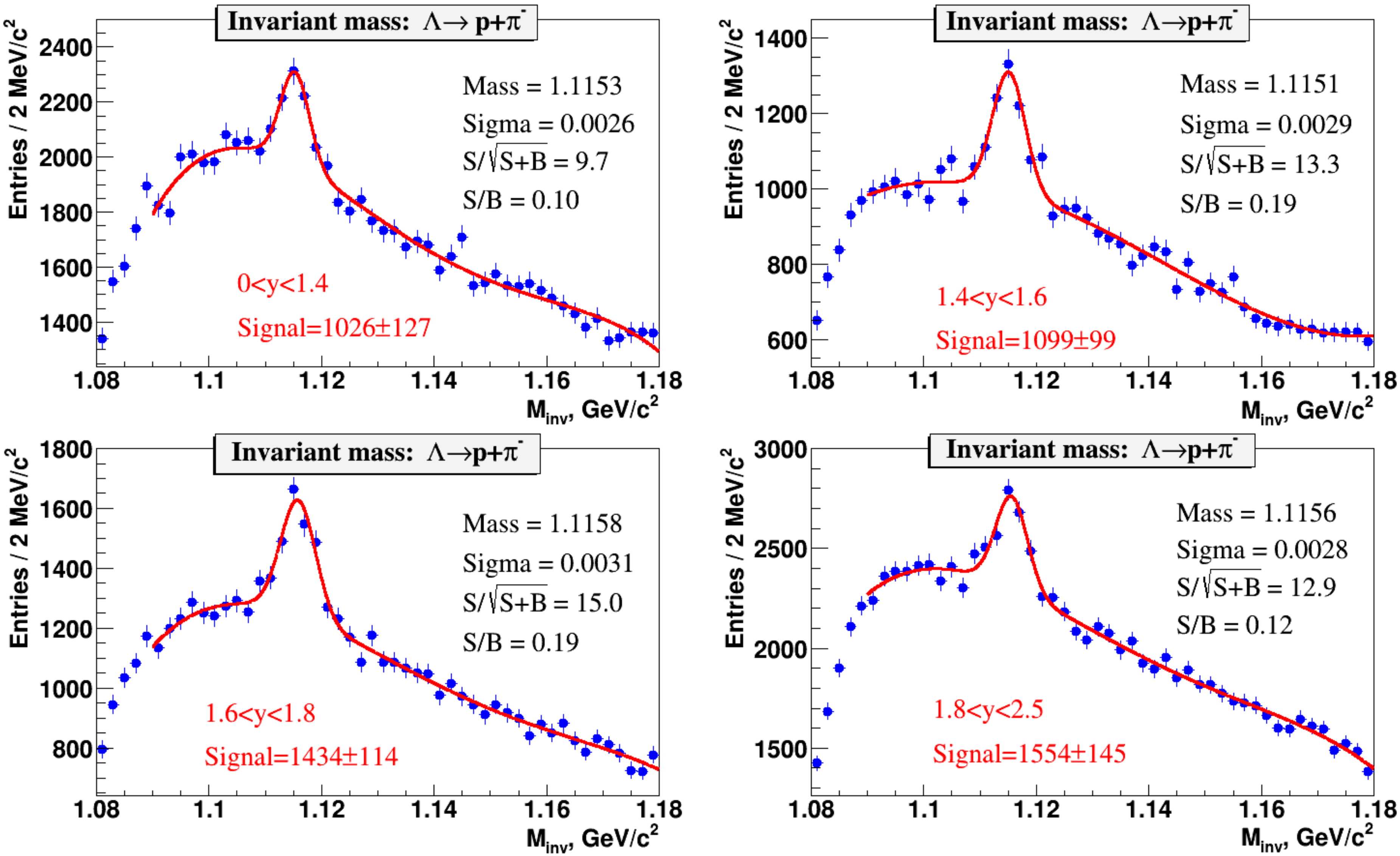




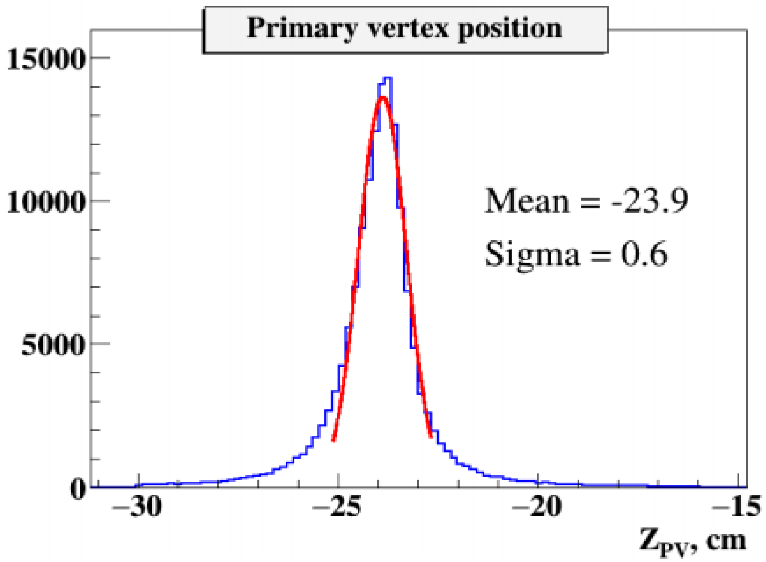


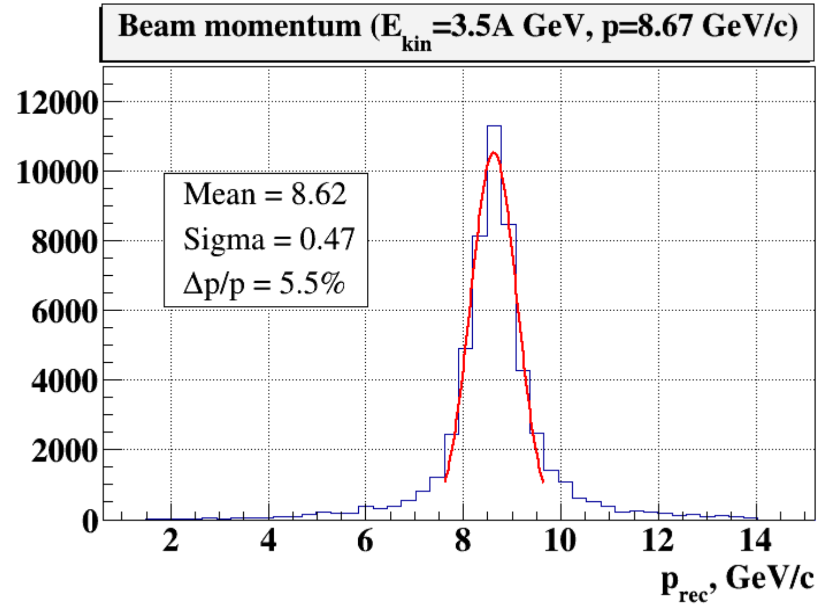


Λ reconstruction: y_{lab} dependence



Primary Vertex & Beam momentum





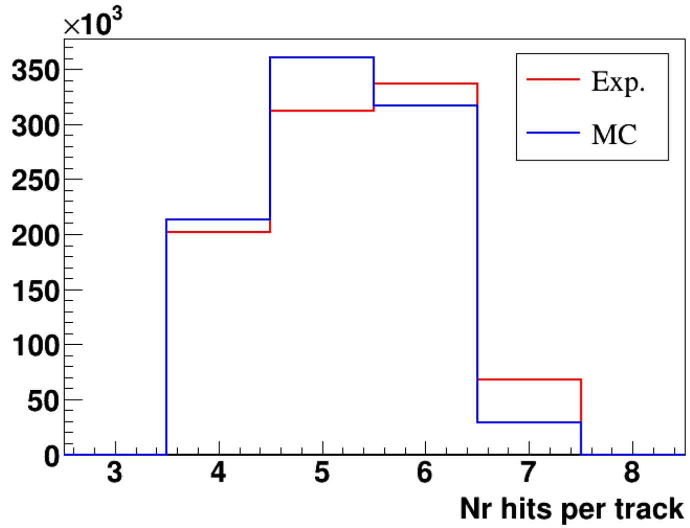
Primary Vertex (along the beam) with Si detector & Pile-up suppression

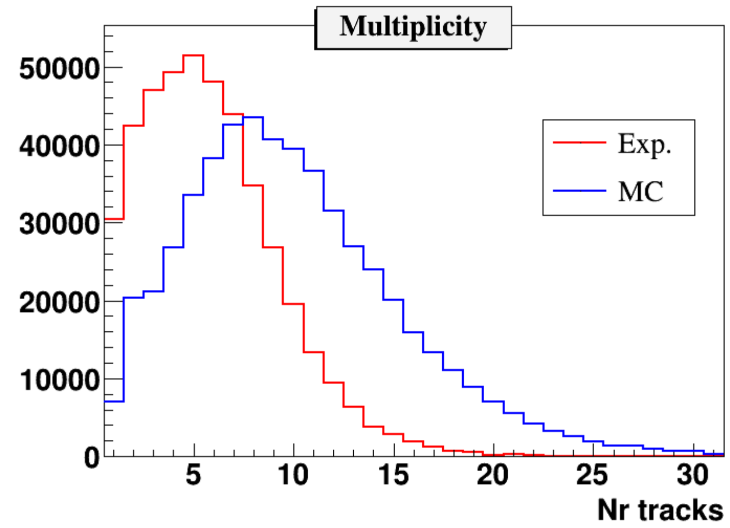
Beam momentum reconstruction

To improve vertex and momentum resolution and reduce background under Λ:

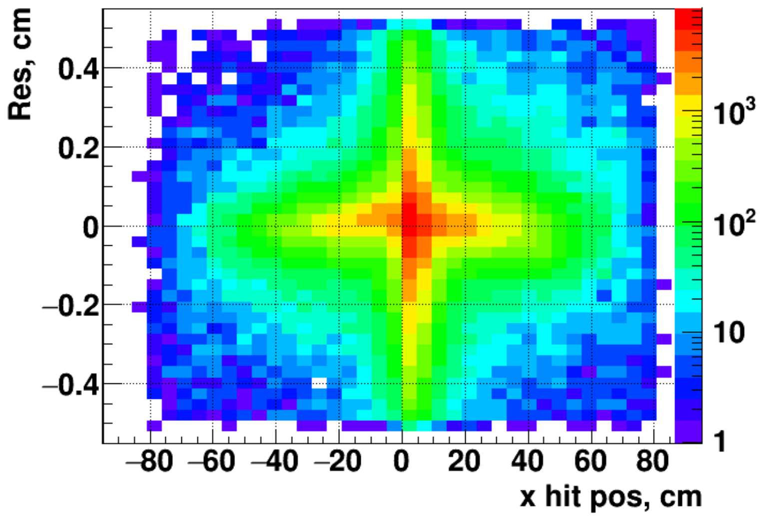
- ✓ Need few planes of forward Silicon detectors
- ✓ Need more GEM planes to improve track momentum reconstruction

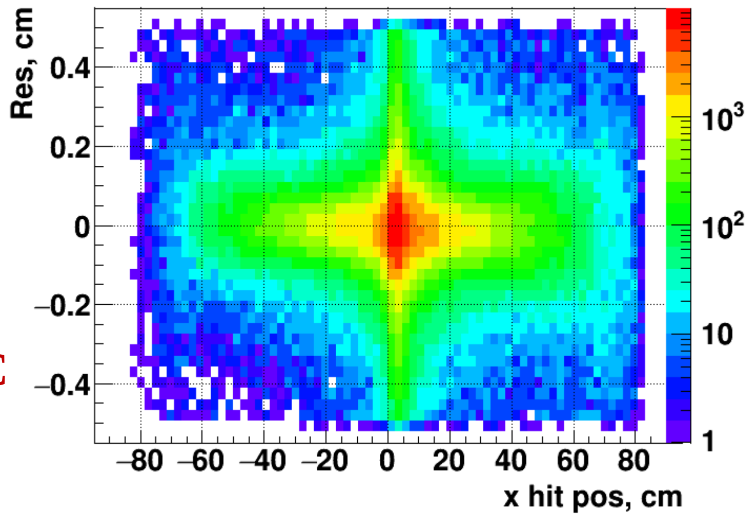
Comparison of data and QGSM MC



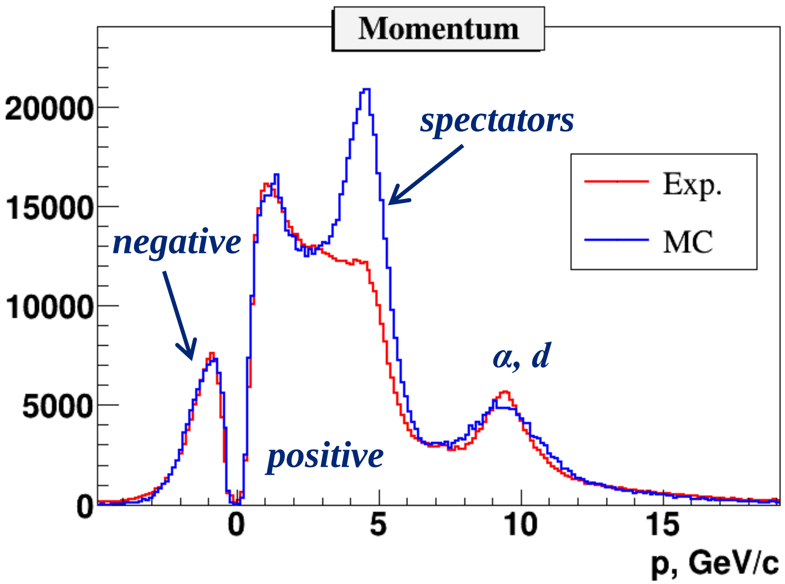


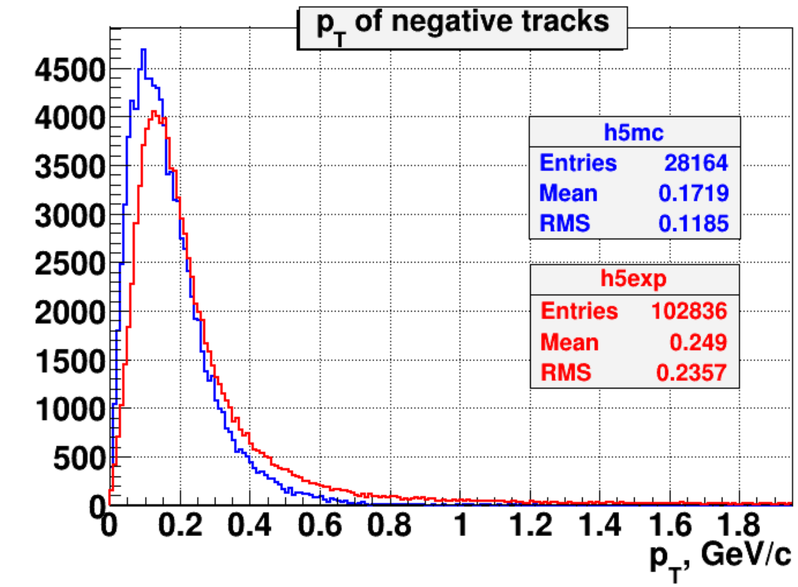
Residuals in GEM detectors:

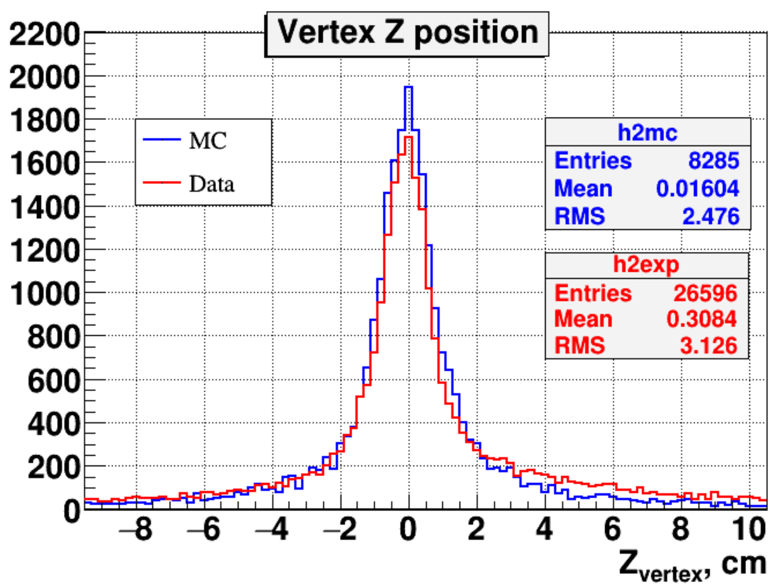


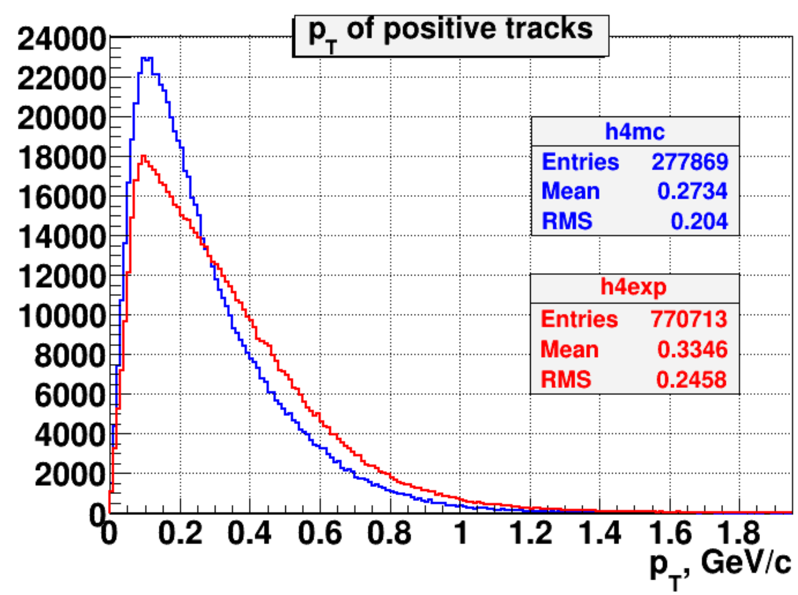


Momentum & PV (Exp. vs QGSM MC)





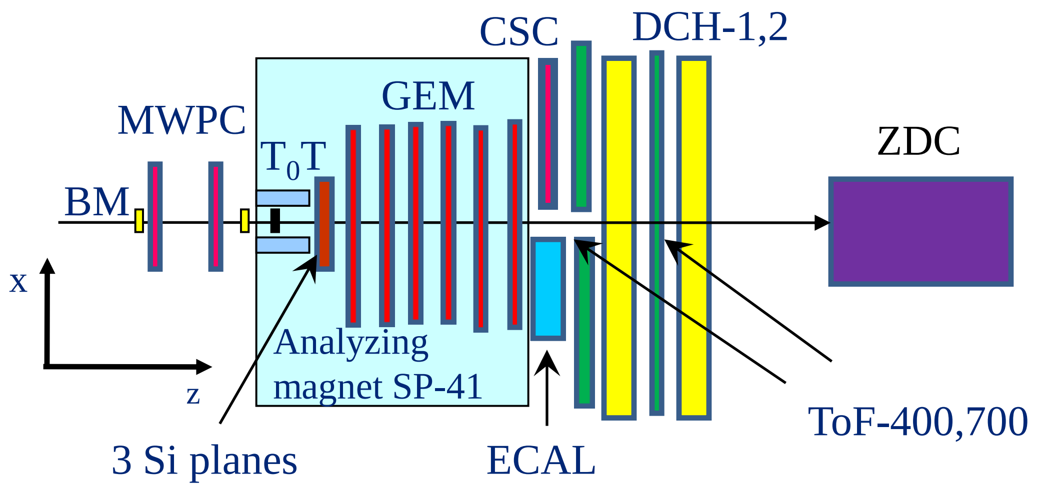




BM@N set-up in March 2018

BM@N run with Ar and Kr beams:

Ar beam, T_0= 3.2 GeV/n
Kr beam, T_0= 2.4 (3.0) GeV/n



✓ Central tracker inside analyzing magnet → 6 GEM detectors 163 x 45 cm^2 and forward Si strip detectors for tracking

✓ ToF system, trigger detectors, hadron and EM calorimeters, outer tracker

Program:

✓ Measure inelastic reactions Ar (Kr) + target → X on targets Al, Cu, Sn, Pb

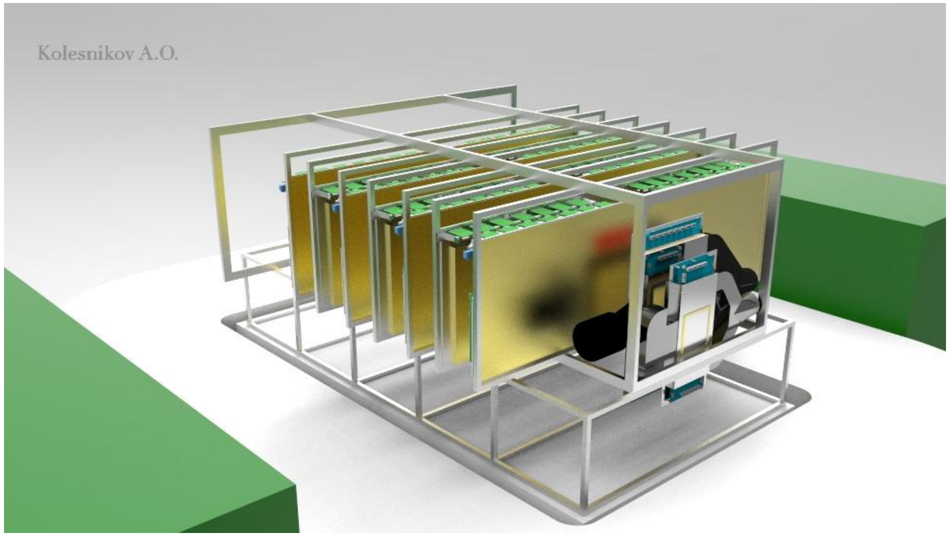
→ Hyperon production measured in central tracker (Si + GEM)

→ Charged particles and nuclear fragments identified with ToF

→ Gamma and multi-gamma states identified in ECAL

→ SRC program in Carbon beam with Liq H_2 target

Central Tracker



6 planes of big GEM detectors
3 planes of Si detector in front of GEMs

Beam crosses Si detectors in center,
big GEMs – in beam hole
→ configuration is based on results of Λ and K^0_S simulation

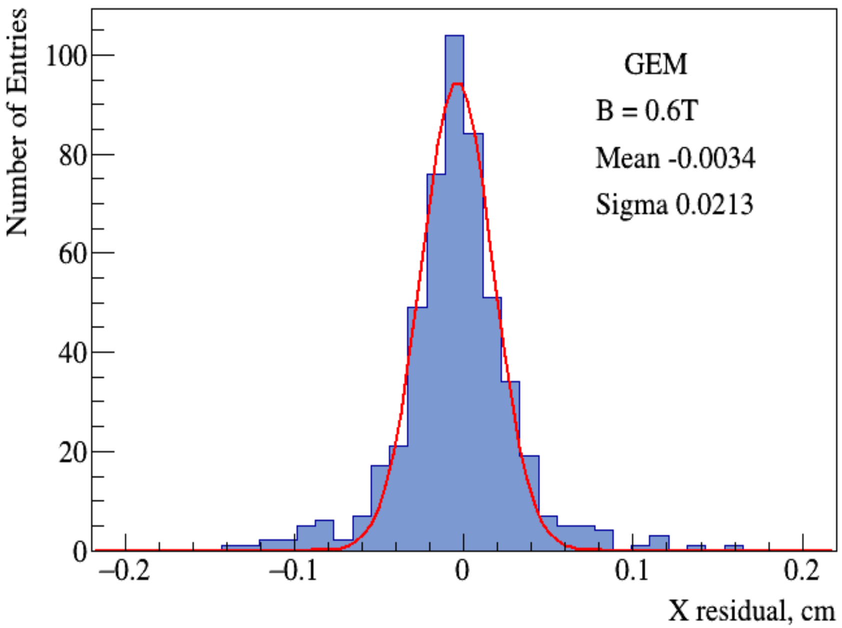
✓ 2-coordinate Si detector with strip pitch of 95/103 μm, full size of 25 x 25 cm^2

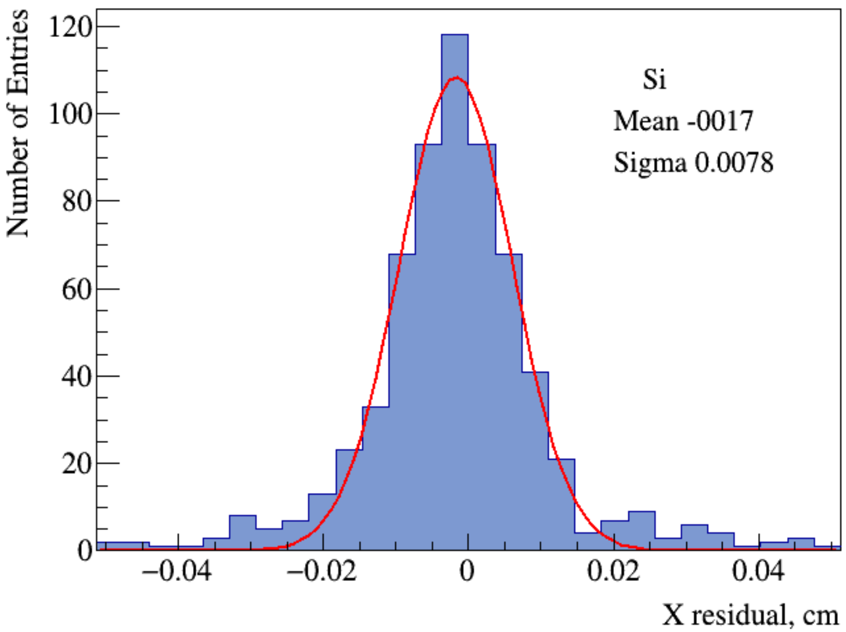
✓ Detector combined from 4 sub-detectors arranged around beam

+ 2 smaller vertex detectors

Residuals in Central Tracker

Residuals in GEM & Si by horizontal plane

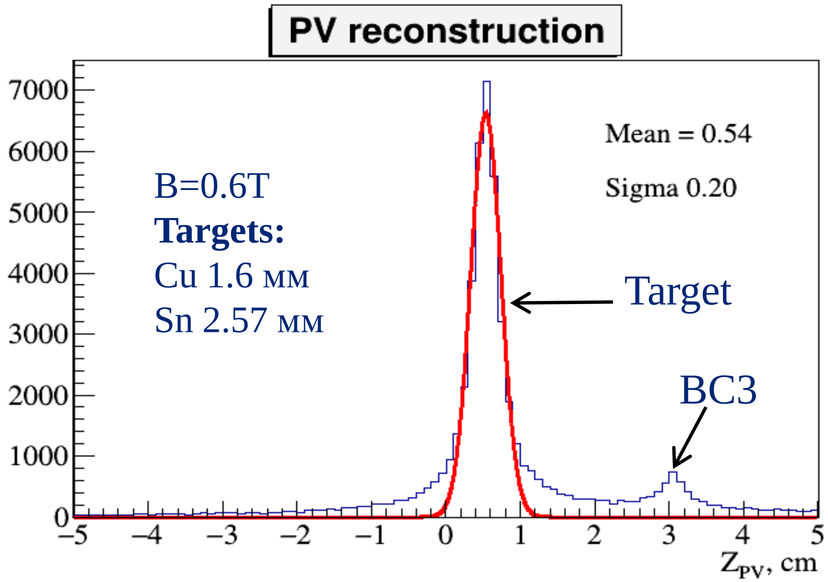


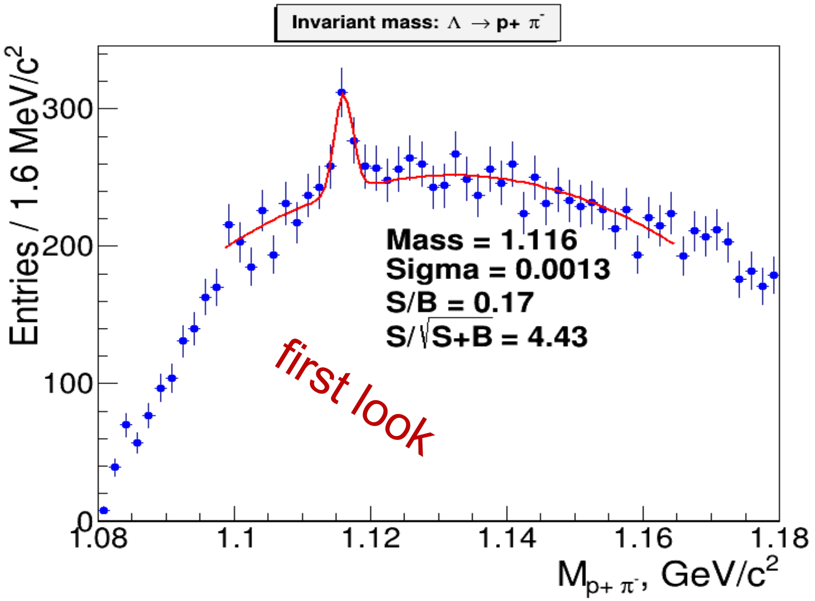


GEM detectors (pitch 800μm)

Si detectors (pitch 103μm)

Λ & PV reconstruction in argon run

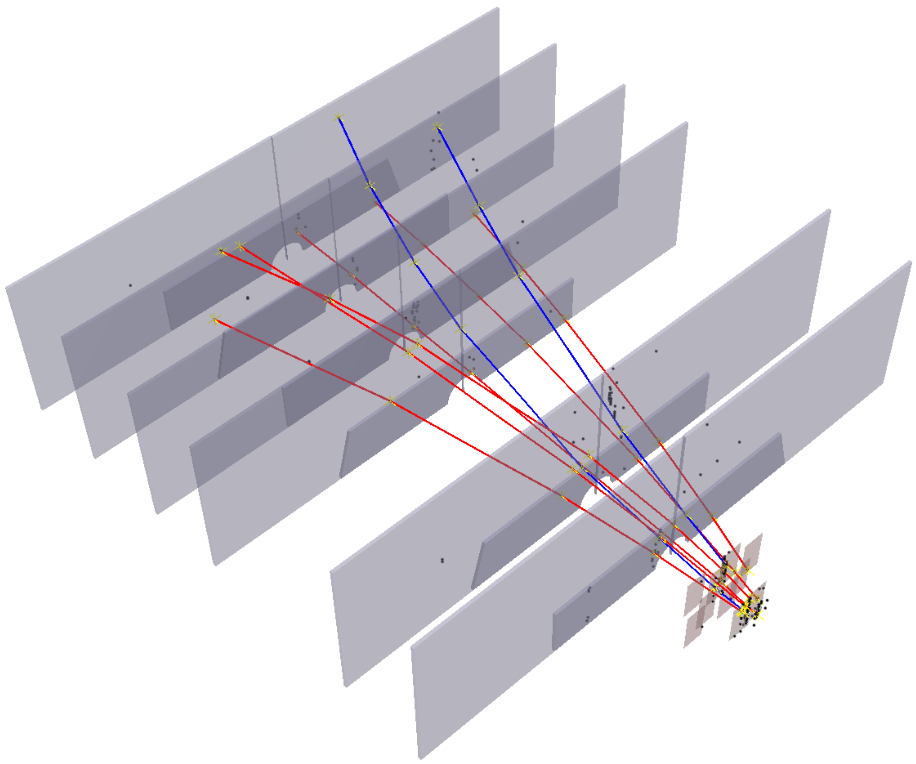


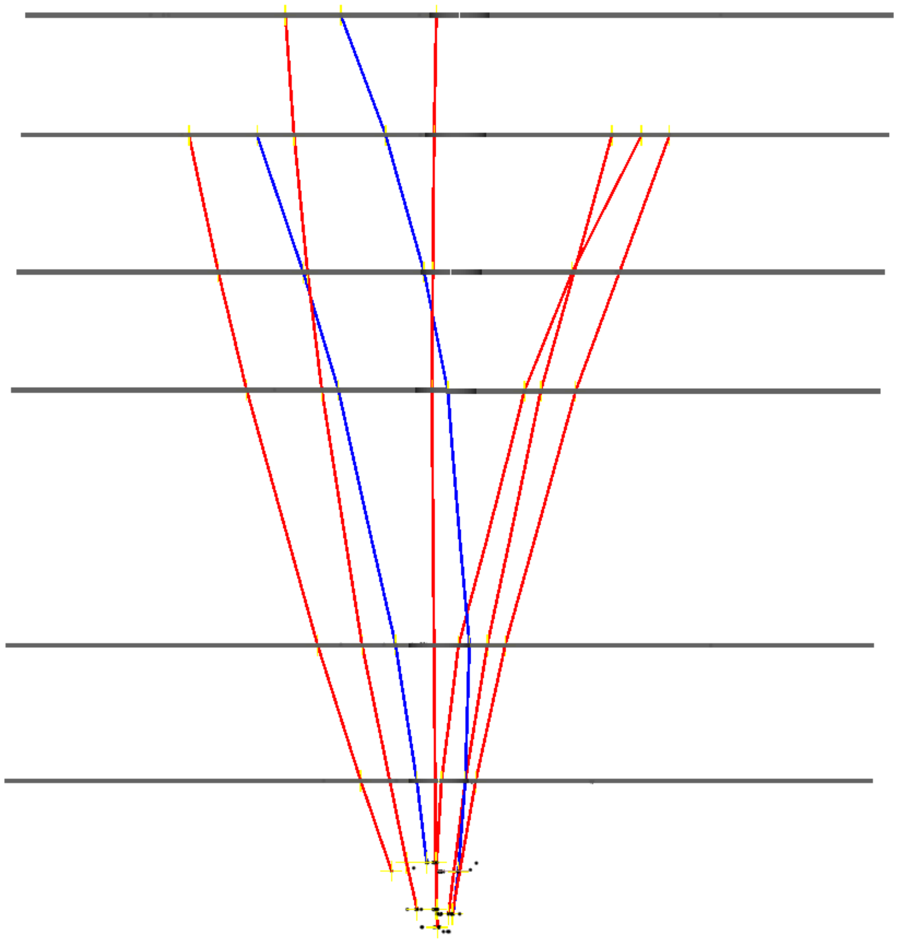


Reconstructed Primary Vertex along the beam

Reconstructed pπ –invariant mass spectrum

Event reconstruction





Event Display: Example of event reconstruction in the central tracker (GEM + Si) in Ar+Al interaction.

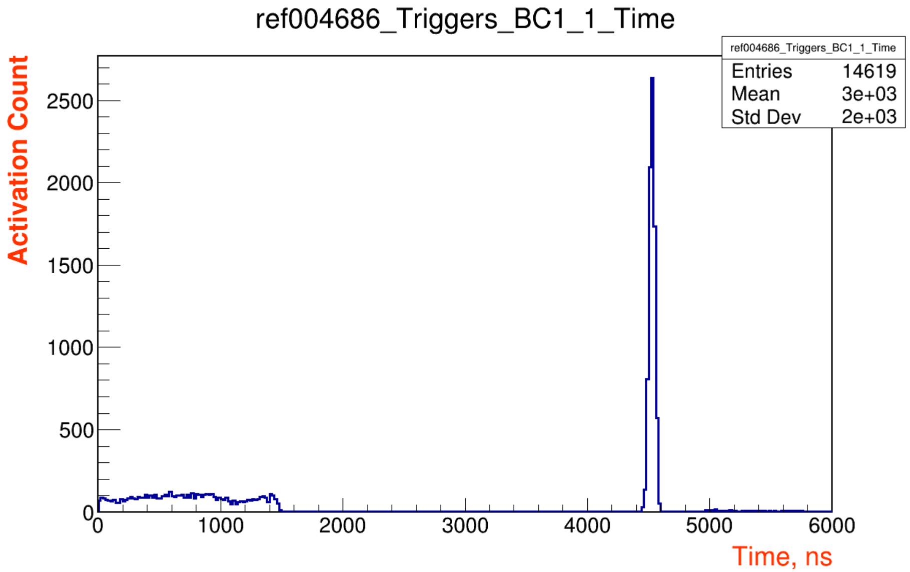
Summary & Plans

- ✓ BM@N experiment has recorded experimental data with carbon, argon and krypton beams at several energies and on several targets.
- ✓ Minimum bias interactions were analyzed with the aim to reconstruct tracks, primary and secondary vertices using central GEM and Si tracking detectors.
- ✓ Reconstructed signals of Λ-hyperon and K_s^0 are visible in proton-pion and pion-pion invariant mass spectra.
- ✓ Work is ongoing to tune MC simulation for carbon beam to describe the data and extract detector efficiencies in order to obtain Λ-hyperon yields.
- ✓ For better results in Ar (Kr) run we have to improve track finding algorithm.

Thank you for attention!

Beam structure & pile-up suppression

Pile-up suppression in Ar, Kr runs:
3 μs before and 0.5 μs after trigger signal



Beam profile:	C^{12} 2017	Ar 2018	Kr 2018
σ_X:	6 mm	5 mm	5.3 mm
σ_Y:	4.9 mm	5 mm	3.2 mm