Track and event reconstruction in BM@N

D.Baranov, M.Kapishin, G.Pokatashkin, I.Rufanov, V.Vasendina, A.Zinchenko

for the BM@N collaboration

VBLHEP, JINR, Dubna, Russia

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Outline

"Everything's gonna be alright".
Jason Voorhees

1. BM@N detector geometry
2. Software & Central tracker optimization
3. MC simulation of Λ, Ξ^-, ${}^{3}_{\Lambda}H$
4. MC simulation of GEM response (Garfield++)
5. Technical run with deuteron beam (December 2016)
6. Technical run with carbon beam (March 2017)
7. Summary & Plans

Detector geometry

BM@N setup:

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

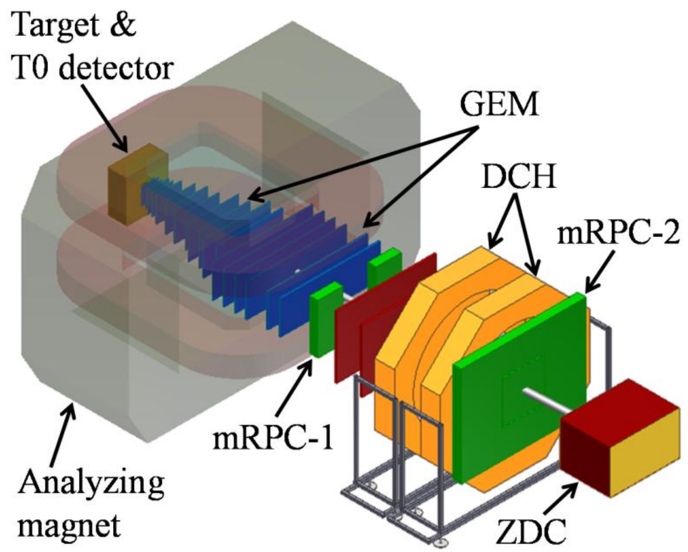
✓ Outer tracker (DCH, CPC) behind magnet to link central tracks to ToF detectors

✓ 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

Software

Framework: BmnRoot – branch of FairRoot

Reconstruction: Several developments ongoing

The most advanced: Cellular Automaton track reconstruction

Method: adaptation of the CBM so-called L1 tracking (following the synergy paradigm) and CBM STS detector digitization and hit finding scheme

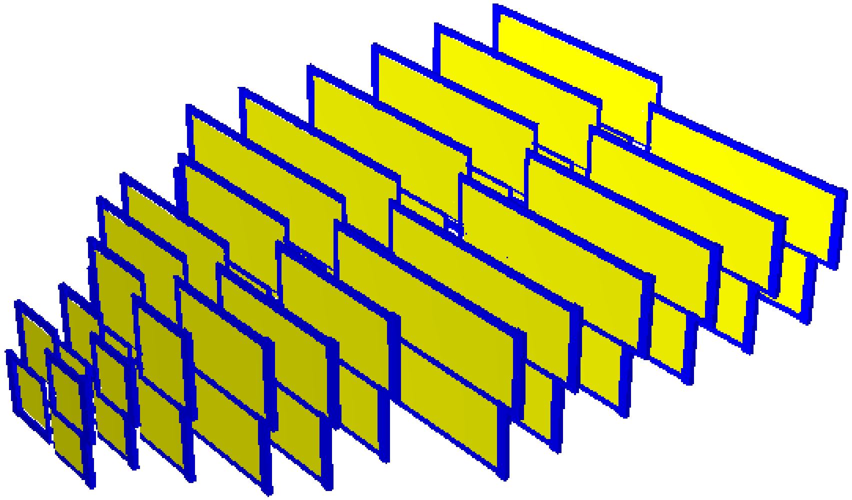
Decay reconstruction: CbmKFParticle formalism

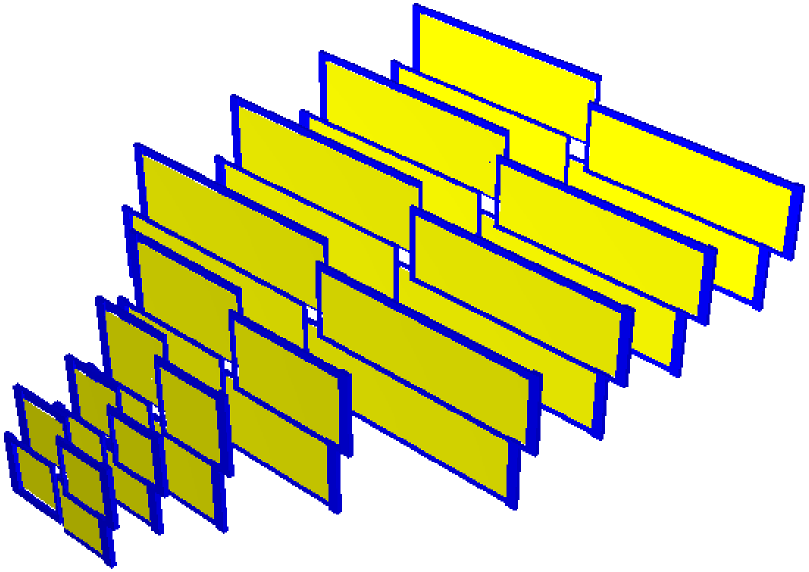
Pros and cons:

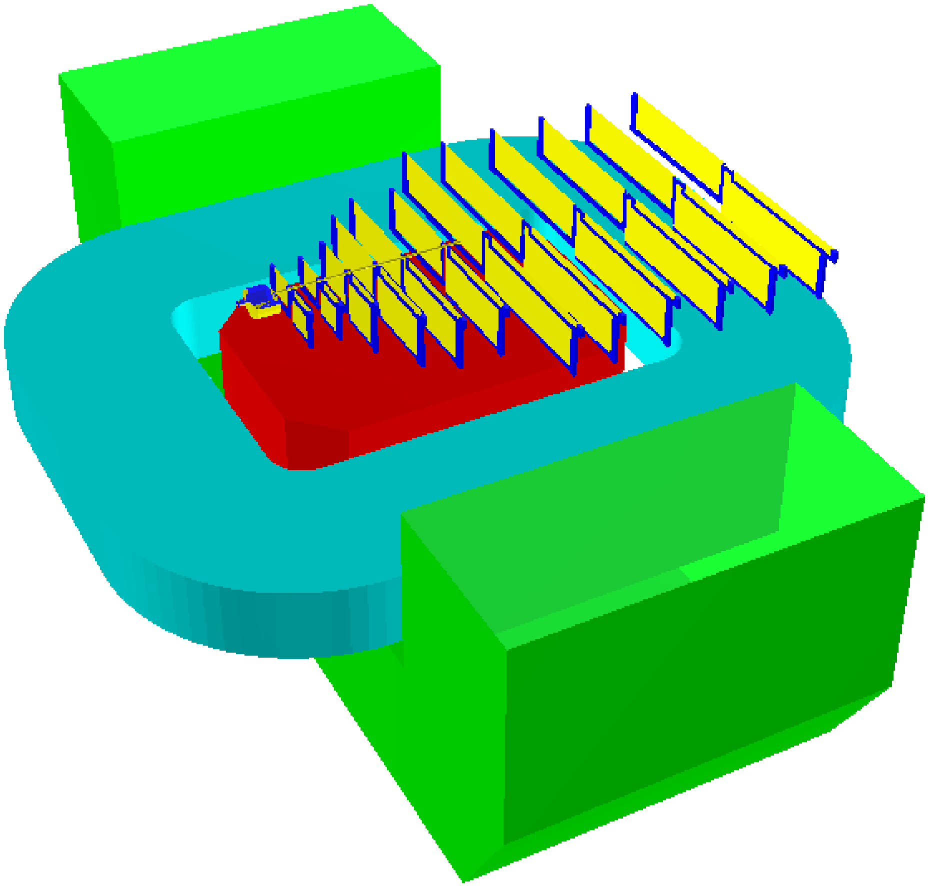
Pro: quite mature and well tested – save manpower and time

Con: external code, optimized for different configuration

GEM tracker (12 vs 8 stations)







Decay reconstruction (Ξ^- & ${}^3_\Lambda H$)

Data set: central Au+Au, E_{kin}=4.5A GeV ($\sqrt{s}$=3.46 GeV)

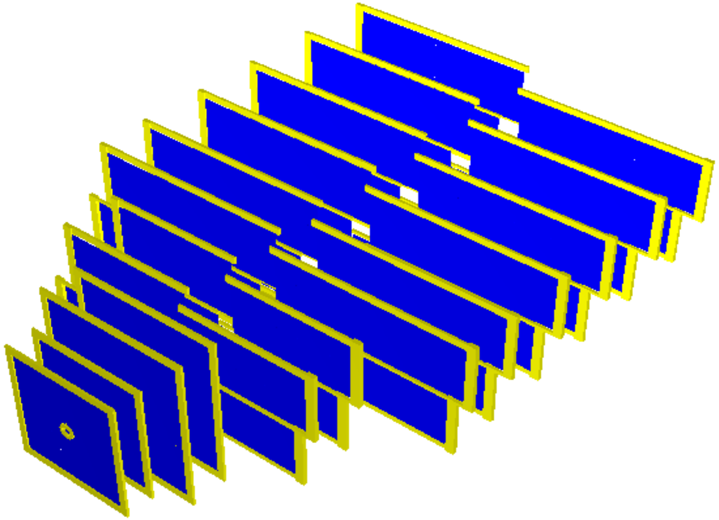
Formalism: CbmKFParticle

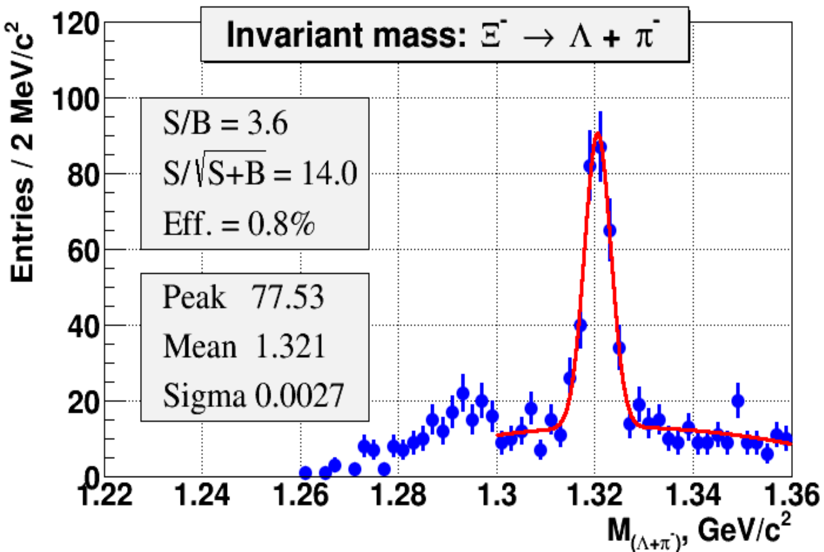
Central tracker:

12 GEM stations, Z (cm): 30-45-60-80-100-130-160-190-230-270-315-360

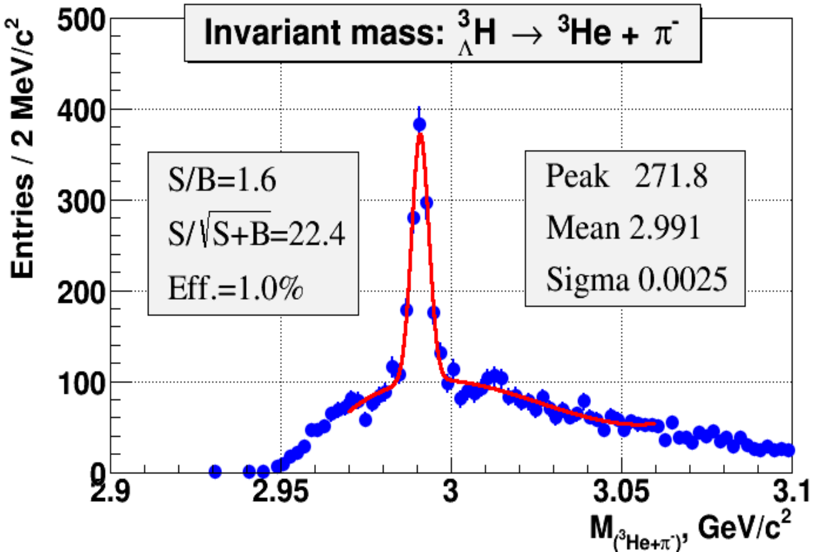
Stereo angles: 0-7.5 deg in stat. 1-4; 0-5 deg in stat. 5-12

Pitch: 400 um in stat. 1-4, 800 um in stat. 5-12



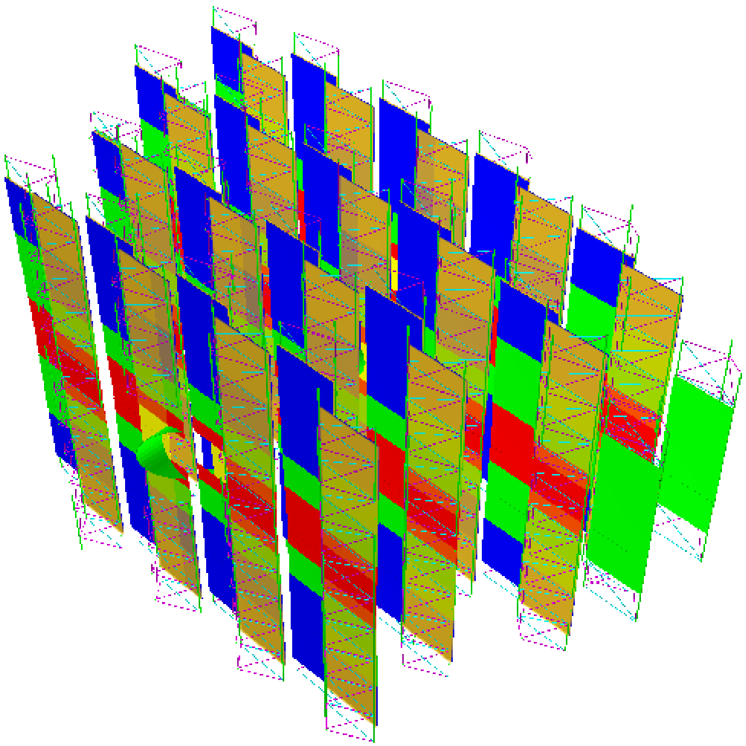


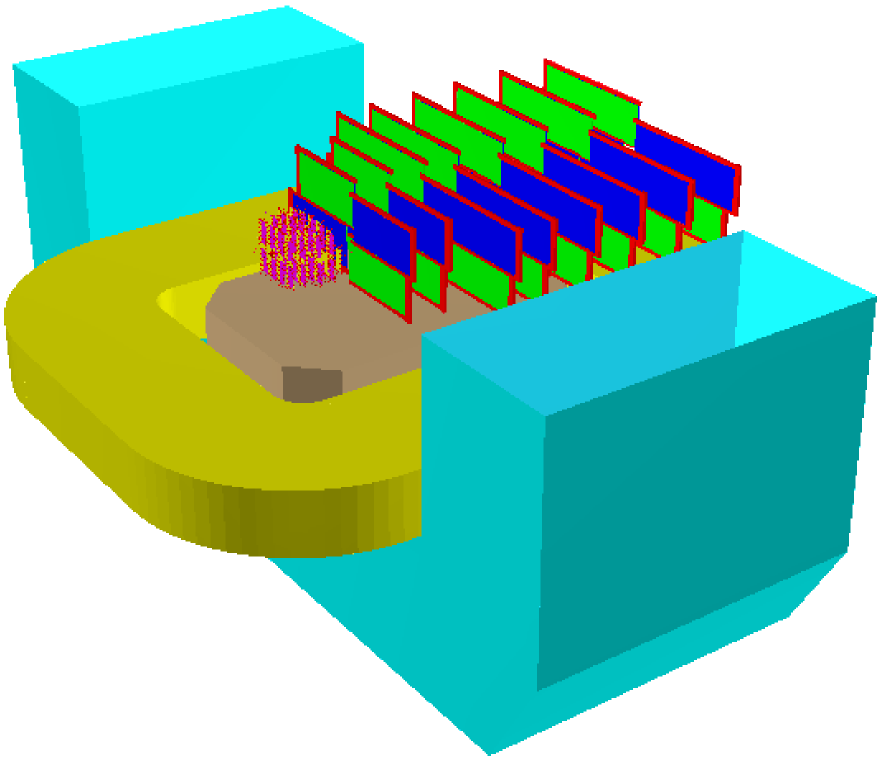
900k events



2.6M events

Central tracker (STS+GEM)





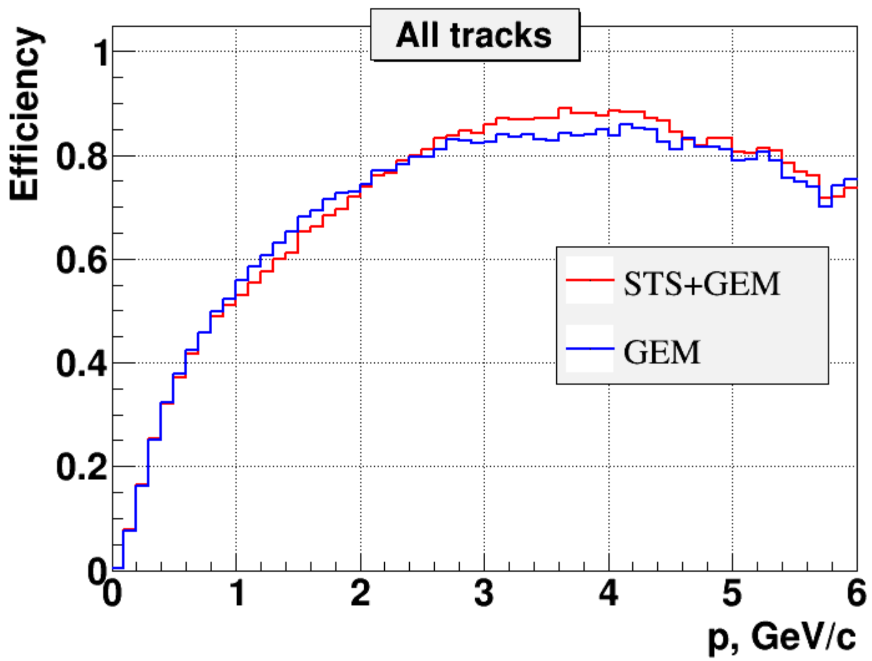
CBM STS stations: 1+1+2+2

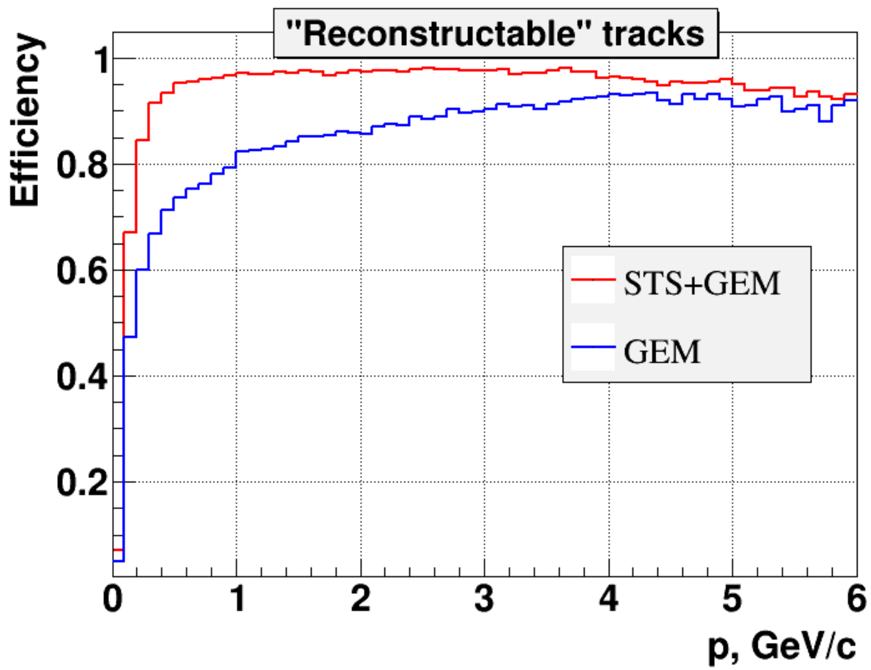
(48x40, 48x40, 72x40, 72x40 cm)

BM@N tracker: STS (4)+ GEM (8)

Track reconstruction efficiency

STS (4)+GEM (8) vs GEM (12)





“Reconstructable” track – having points in at least 3 consecutive stations

Λ reconstruction

Data set

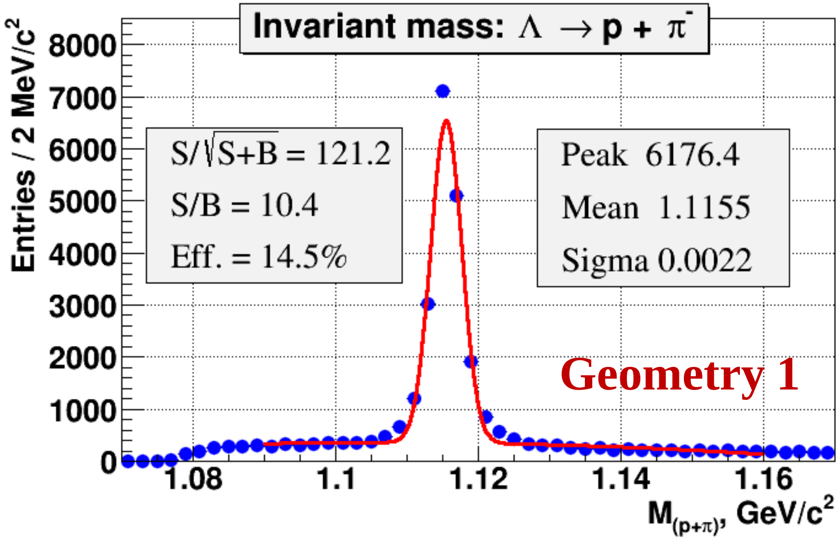
Generator: UrQMD, Au+Au, 10 kevents
E_{kin} = 4.5A GeV, b = 0-3 fm
Formalism: CbmKFParticle

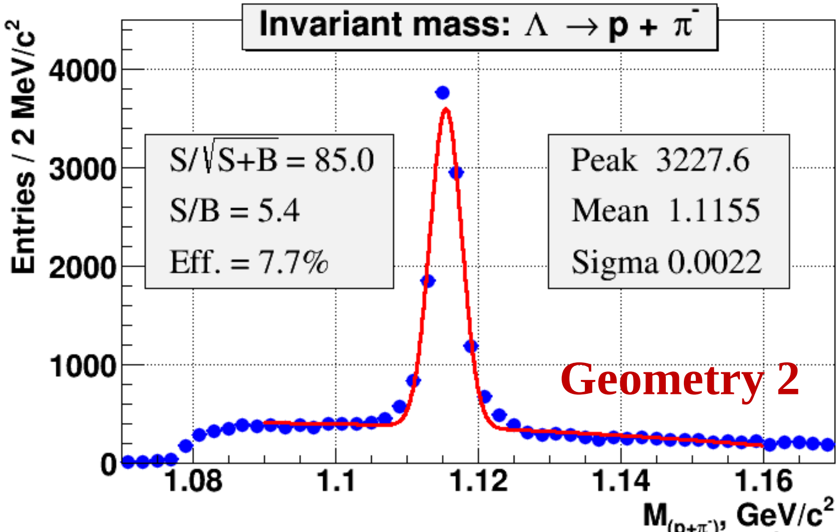
Geometry 1: STS (4 stations) + GEM (8 stations)

Geometry 2: GEM (12 stations)

Magnetic field: B = 0.44 T

No PID



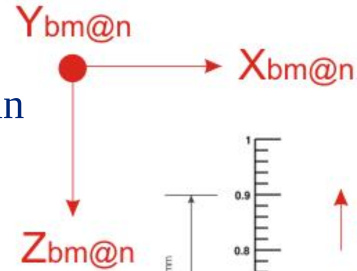


Simulation of GEM response: Garfield++

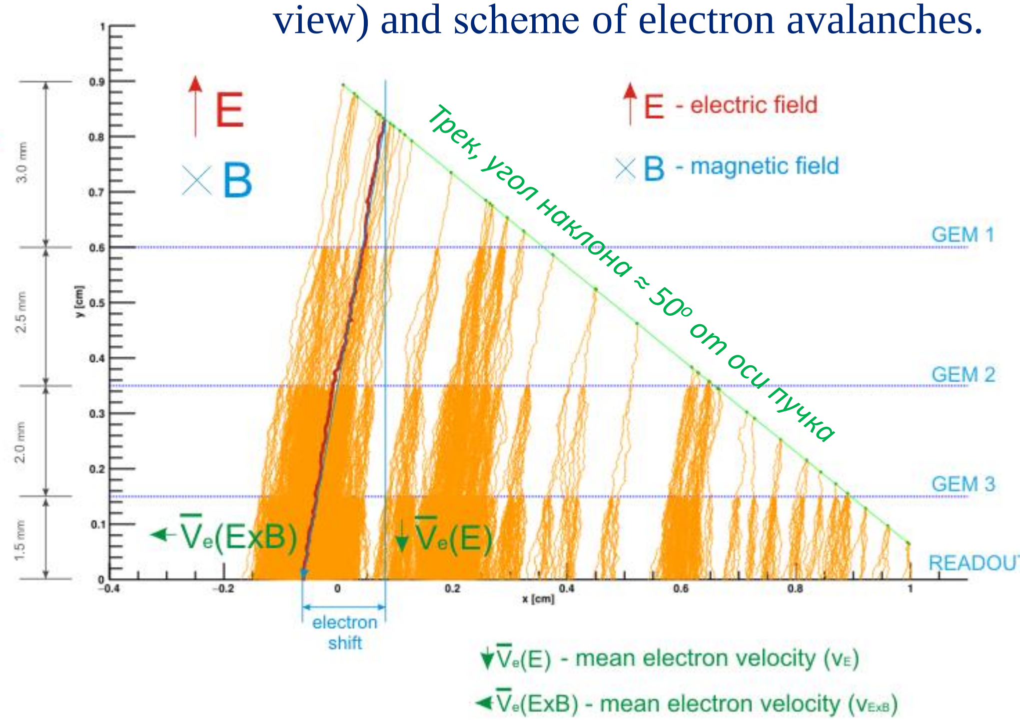
Garfield++ - framework for microsimulation of physical processes in the gas detectors.

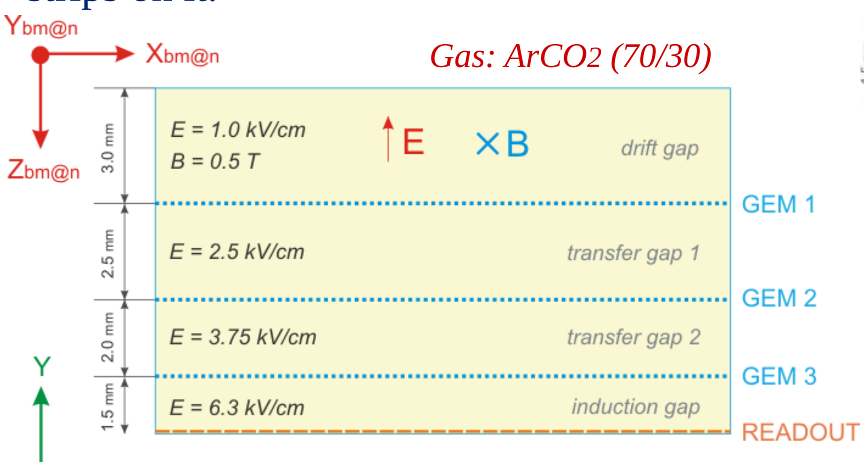
Charged particle passing through the GEM chamber detecting volume ionizes the gas.

The electrons passing through multilayer GEM-cascades form avalanches which drift to the readout-plane and fire the strips on it.

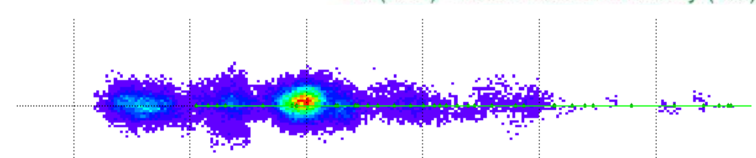


Structure of BM@N GEM chamber (top view) and scheme of electron avalanches.



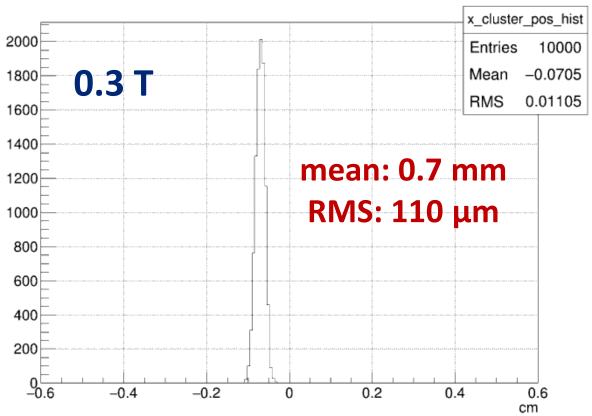


Simulation parameters in Garfield++

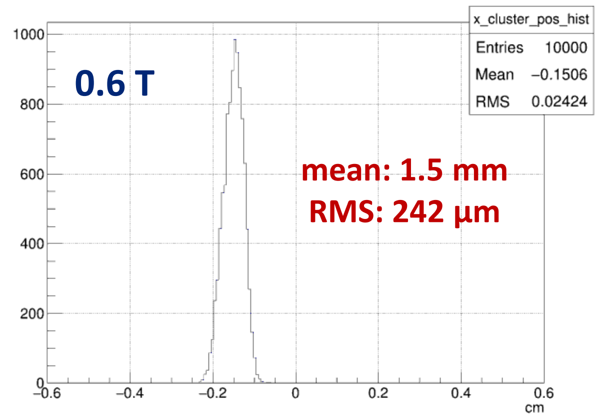


Profile of electron avalanche at the readout-plane (cluster).

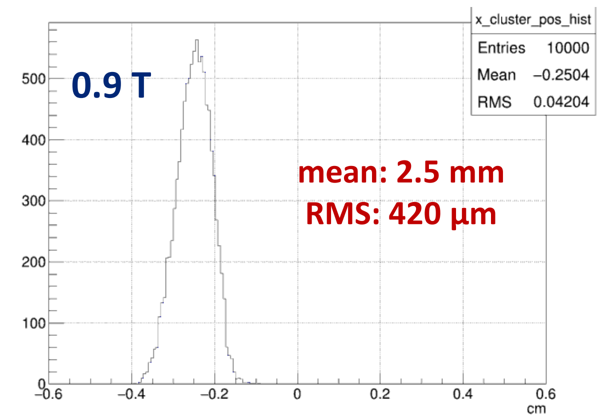
Simulations of GEM response: Garfield++



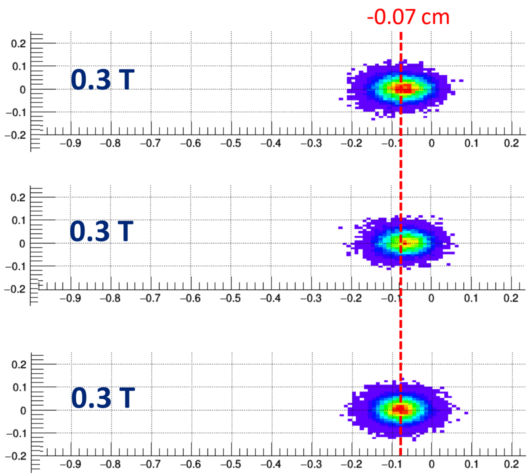
X distribution of the avalanche centers at read-out plane. B = *0.3 T*

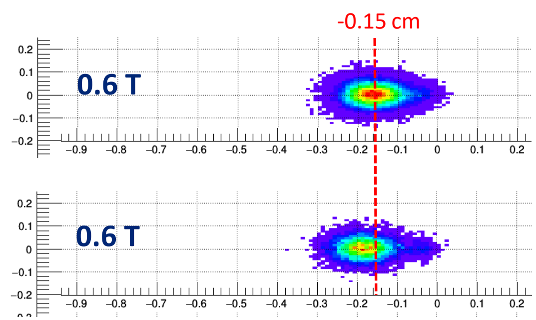


X distribution of the avalanche centers at read-out plane. B = *0.6 T*

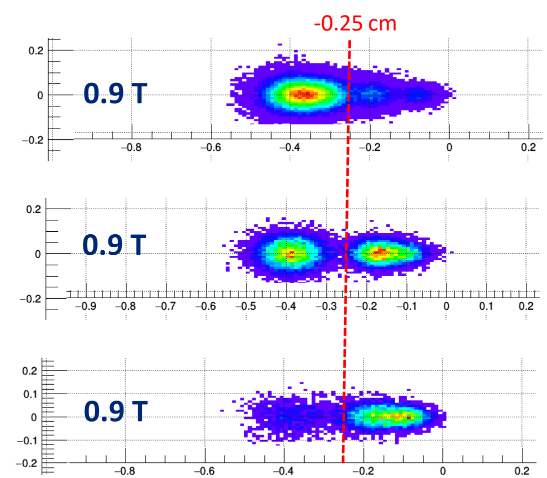


X distribution of the avalanche centers at read-out plane. B = *0.9 T*





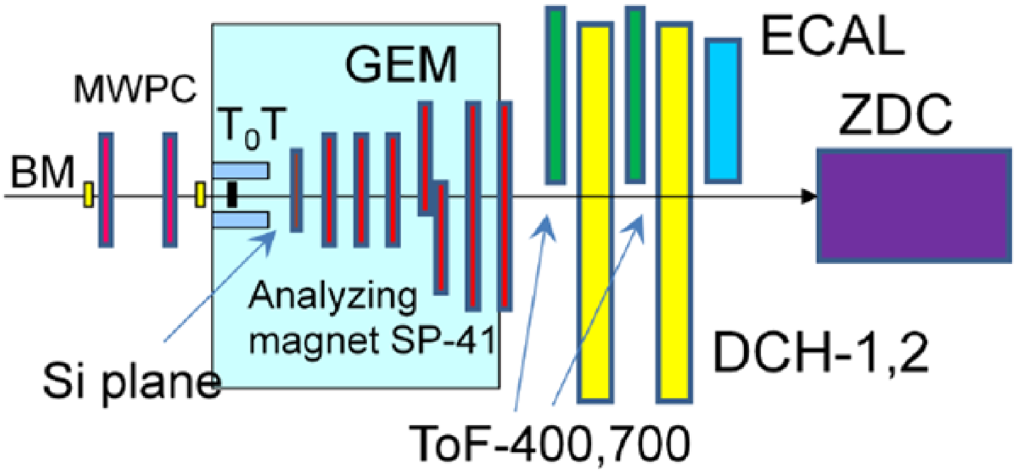
Examples of the avalanche profile of single track at the read-out plane.

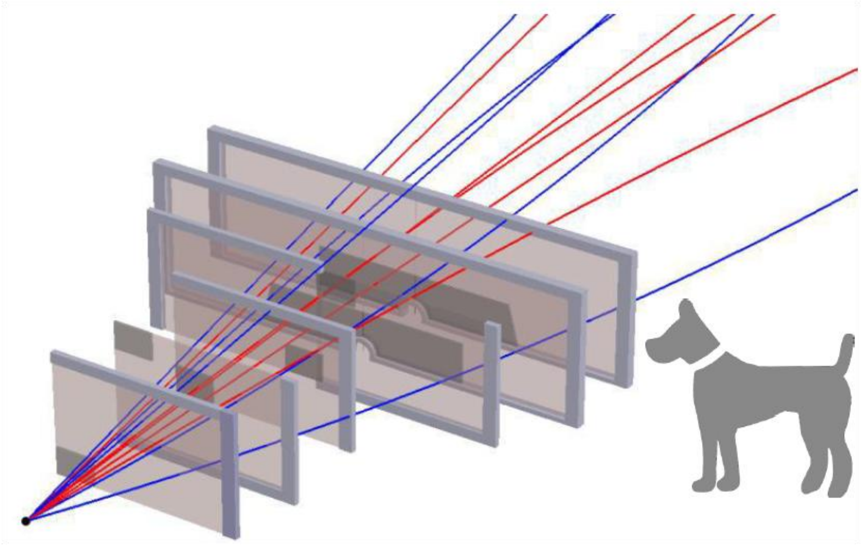


The results are presented for configuration: Ar+Isobuthane = 90:10.

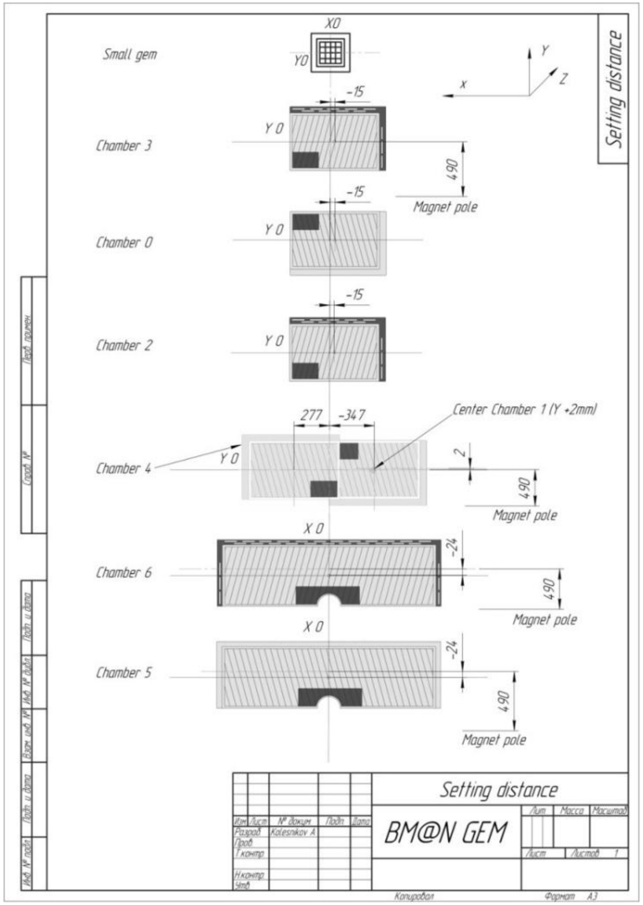
Technical runs in 2016-2017

BM@N set-up used in the deuteron run



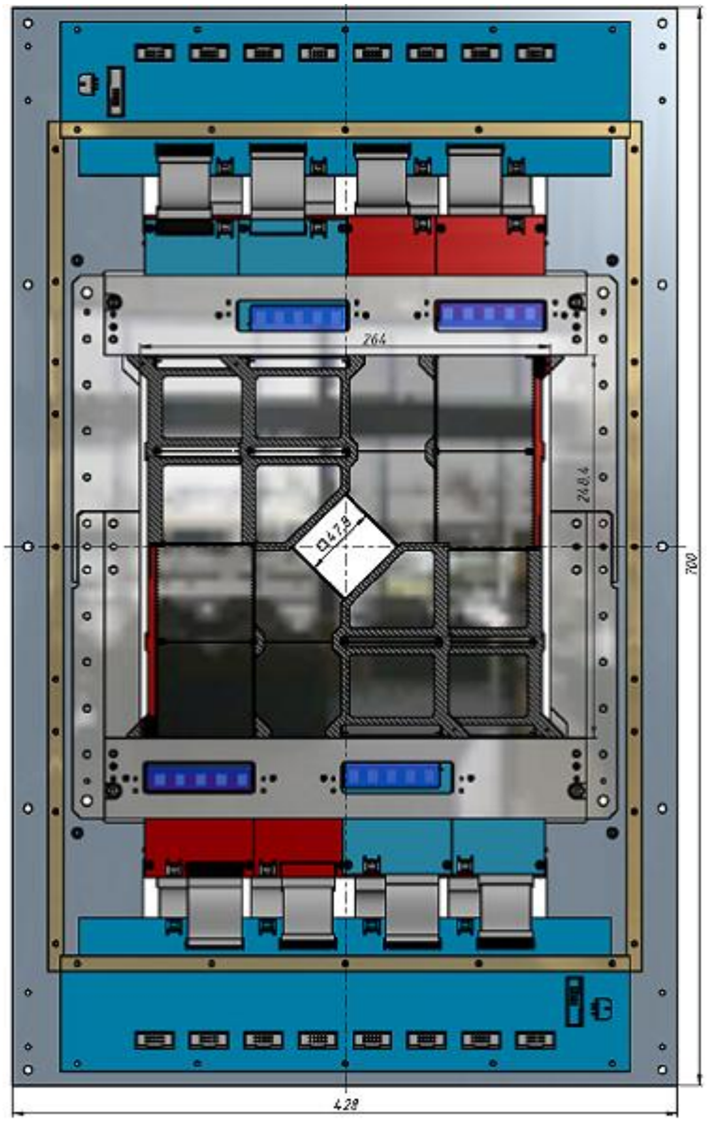


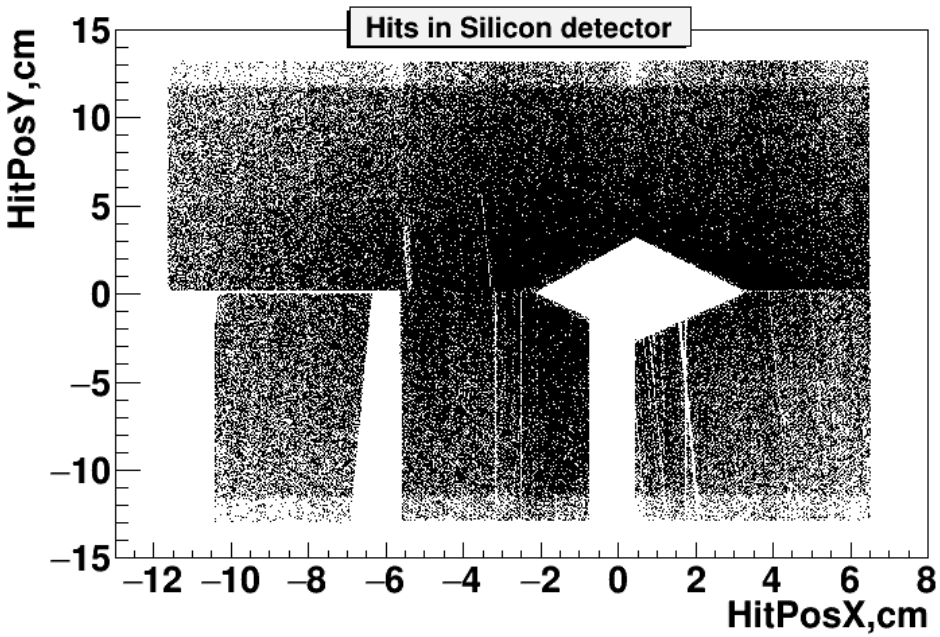
GEM tracker



Example of an event reconstruction in the central tracker.

Forward silicon strip detector





Hits in silicon detector

✓ 2-coordinate Si detector X-X'(±2.5°) with strip pitch of 95/103 μm, full size of 25 x 25 cm^2 , 10240 strips
✓ Detector combined from 4 sub-detectors arranged around beam, each sub-detector consists of 4 Si modules of 6.3 x 6.3 cm^2

Data set (deuteron beam)

Magnetic field: 0.79 T

Events: 1.2M with Λ candidates

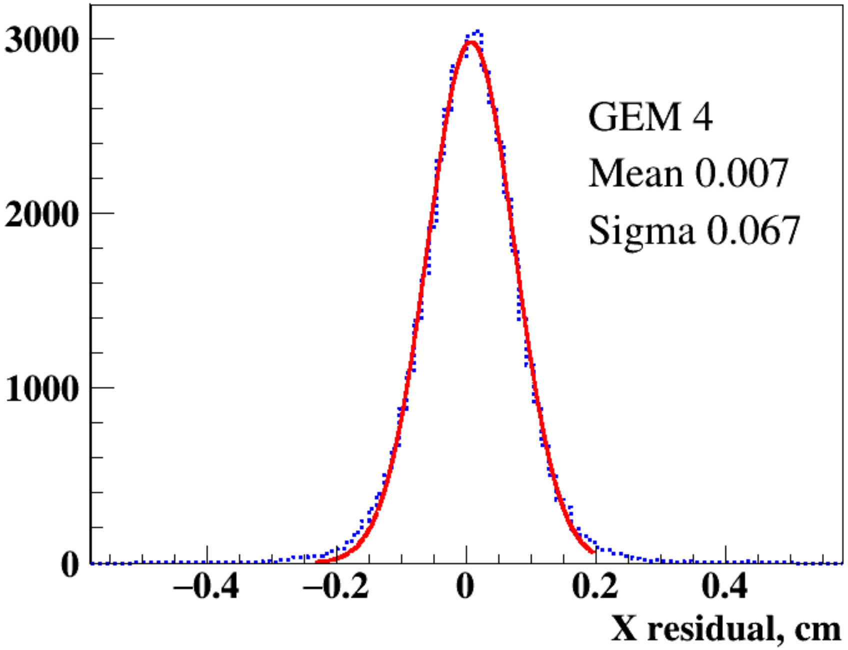
Beam / Target: d / C_2H_4 , C, Cu, E_{kin} = 4A GeV

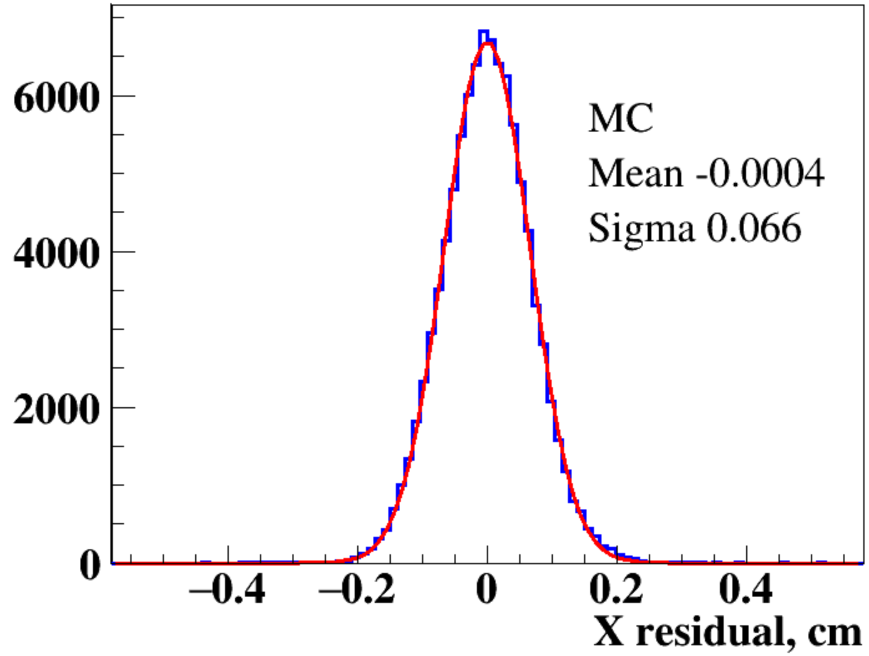
Gas in GEM: Ar + Isobuthane (90:10)

GEM position from target: 51-86-116-151-181-216 cm

No Si-detector

GEM Hit residuals: Exp. vs MC





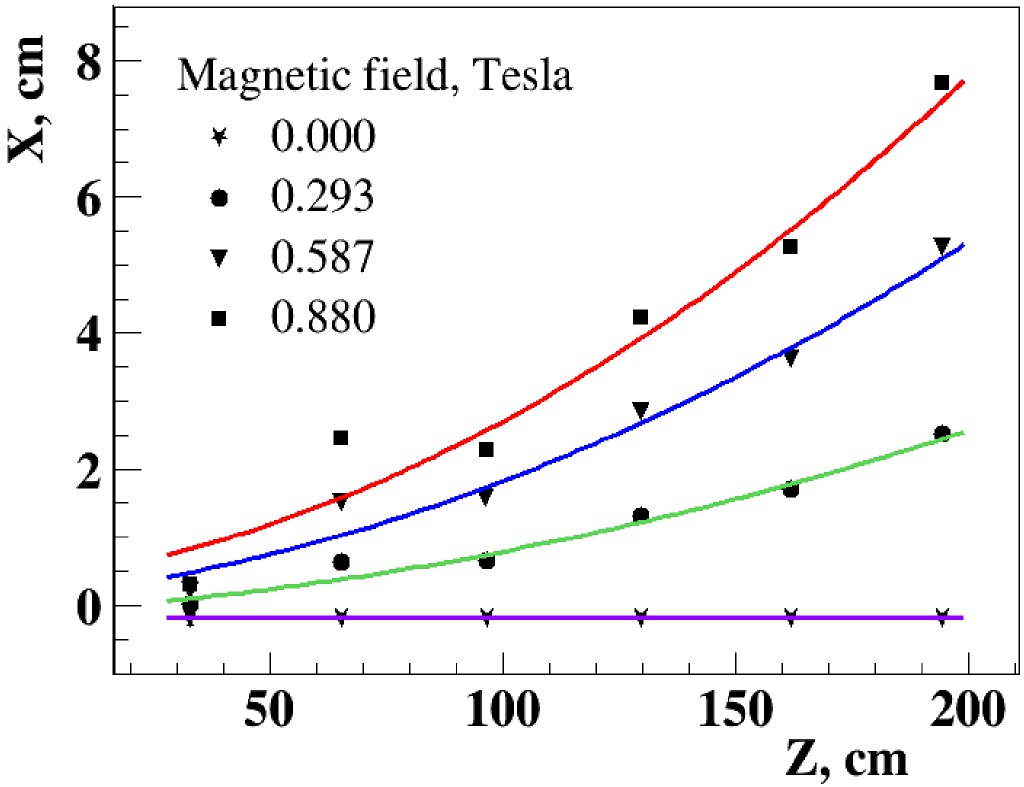
GEM hit residuals vs reconstructed tracks in horizontal plane after Lorentz shift corrections σ~0.67 mm.

Mag. field 0.79 T

Gas mixture Ar + Isobuthane

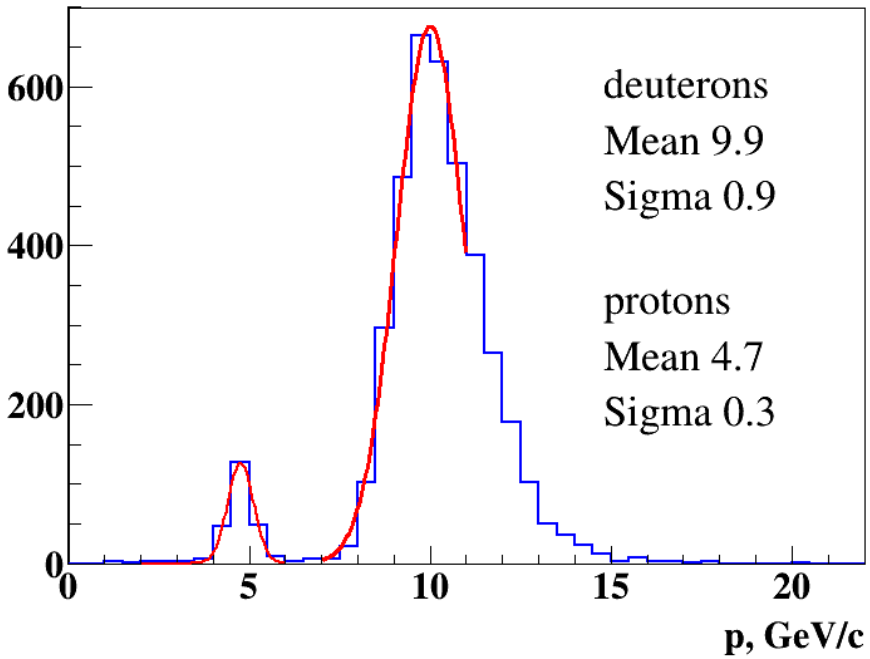
MC simulation with Garfield ++ parameterization reproduces exp. data.

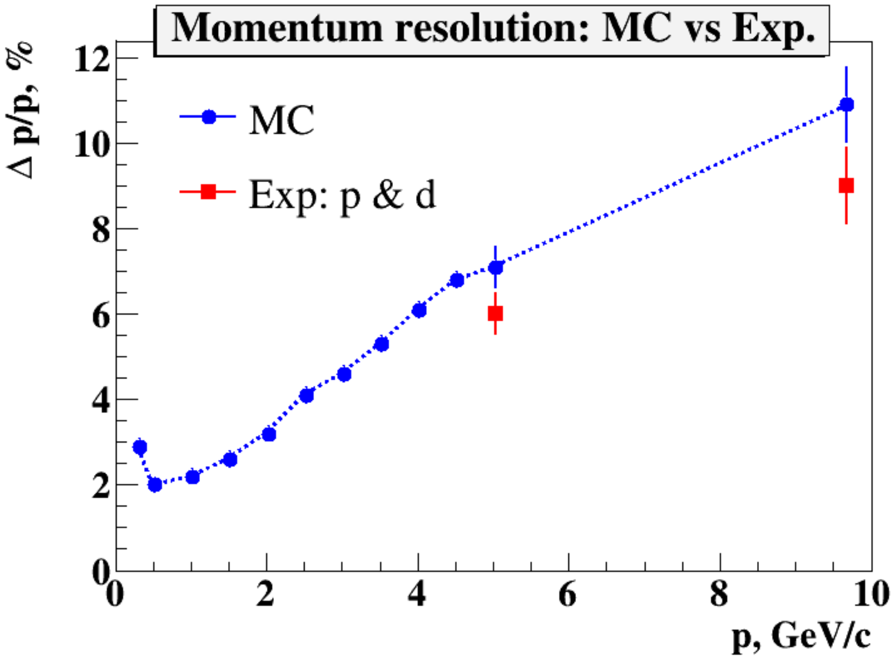
Beam in GEM detectors



Averaged positions of deuteron beam with E_{kin} = 4A GeV
reconstructed in 6 GEM planes at different values of magnetic field

Momentum resolution: Exp. vs MC





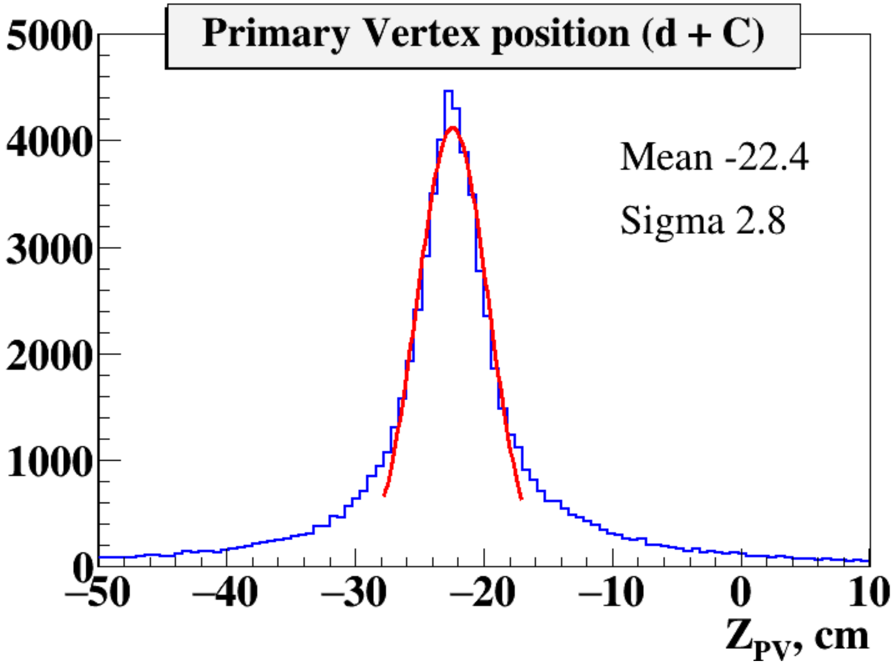
✓ Momentum resolution for deuteron beam of 9.7 GeV/c ~9%.

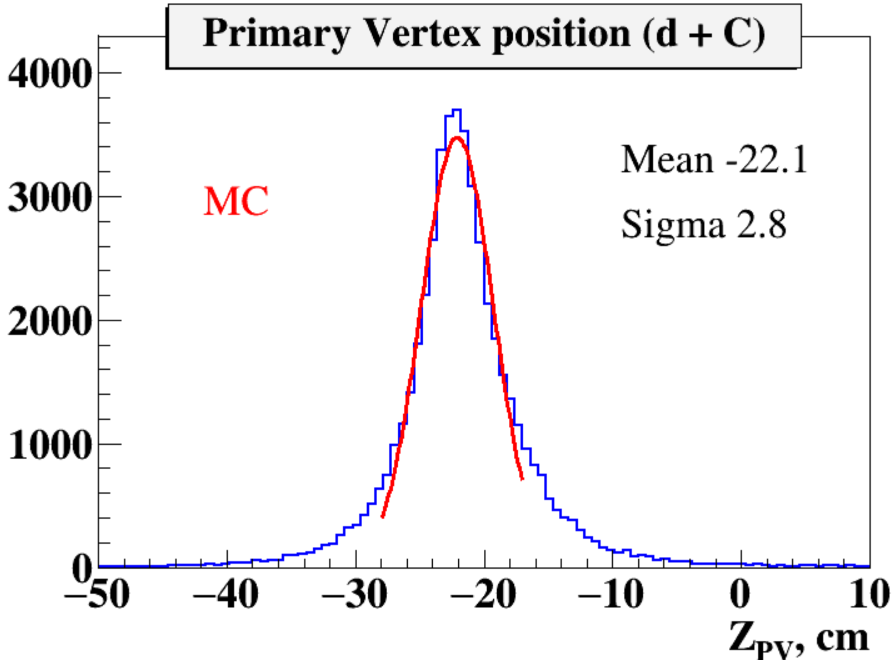
✓ Momentum resolution for proton spectators with momentum of 4.85 GeV ~6%.

✓ Momentum resolution from MC as function of particle momentum.

✓ MC results reproduce exp. data for spectator protons and deuteron beam.

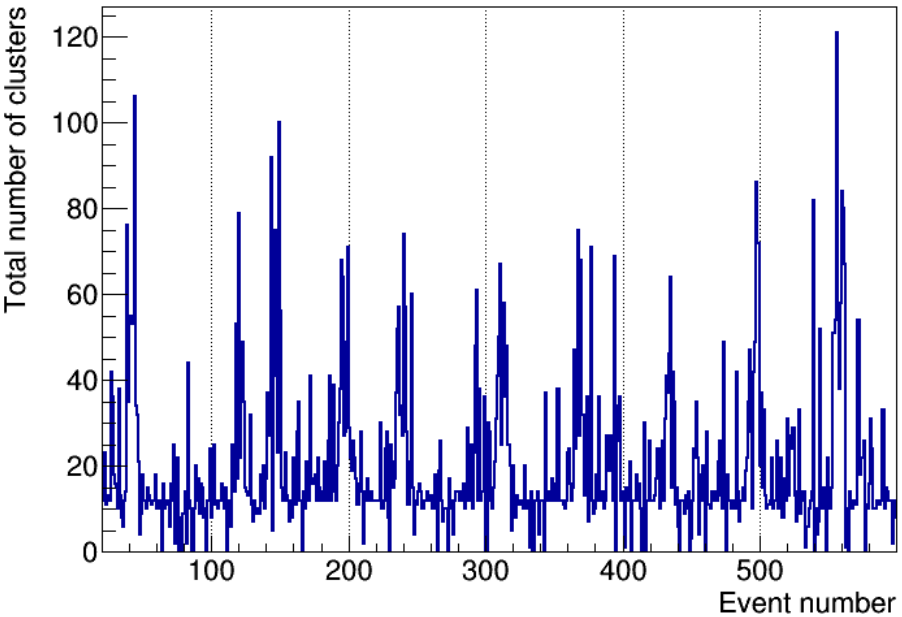
PV reconstruction: Exp. vs MC

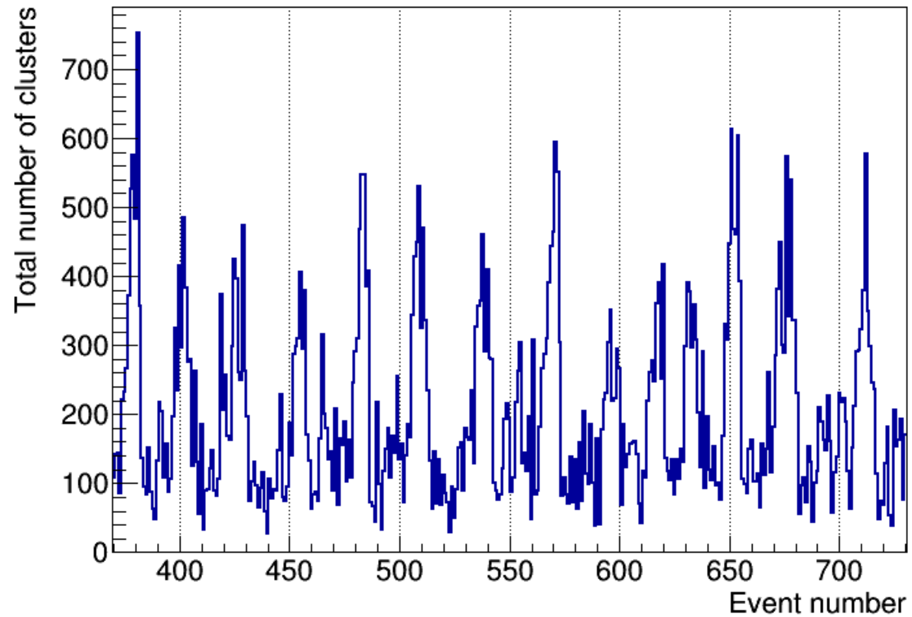




- ✓ Width of reconstructed vertex distribution along beam direction in data is reproduced in MC simulation.
- ✓ Longer tails in data distribution are due to pile-up events.

Beam structure (pile-up effect)

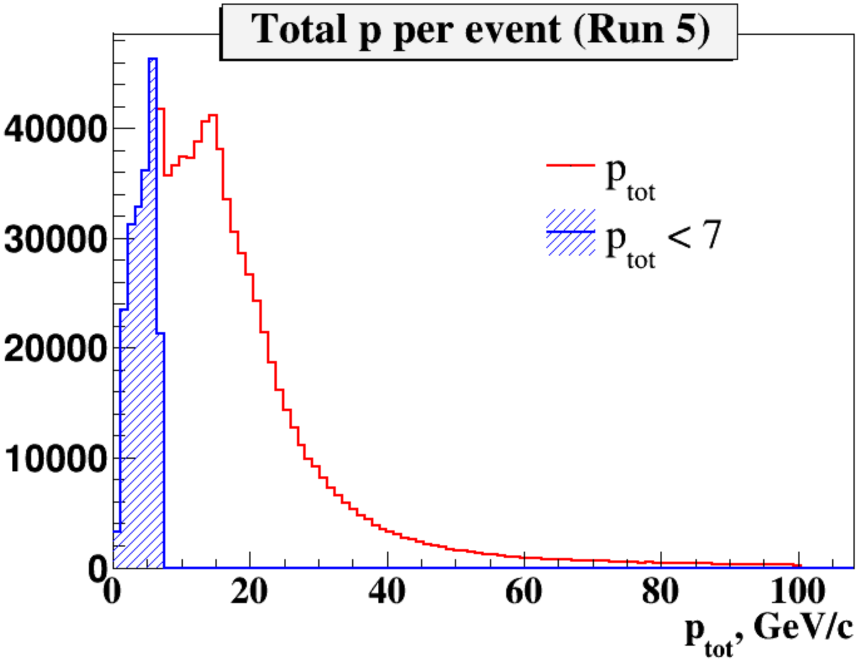


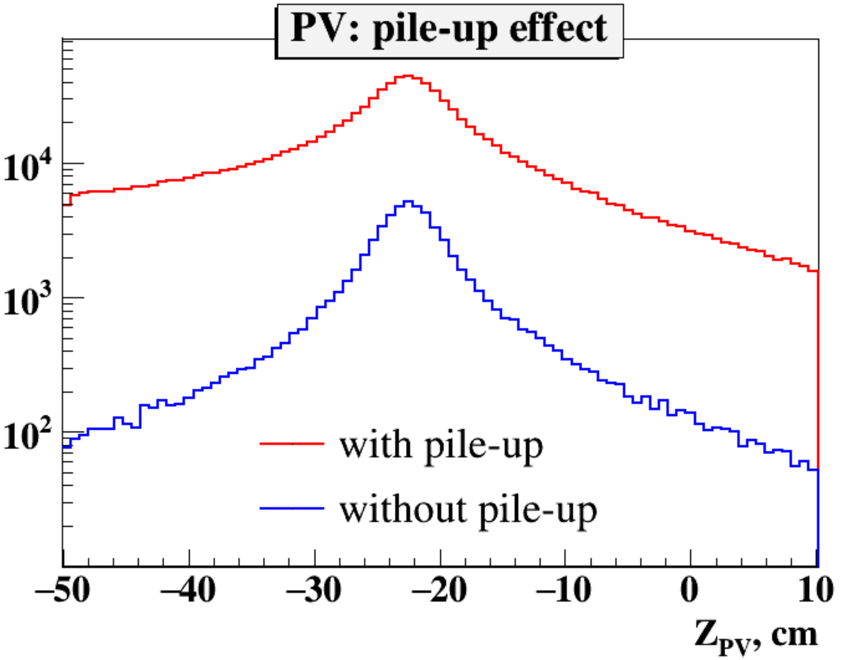


Run 5 (Dec-2016)
Deuteron beam trigger

Run 6 (Mar-2017)
CA collisions. N barrel >= 3

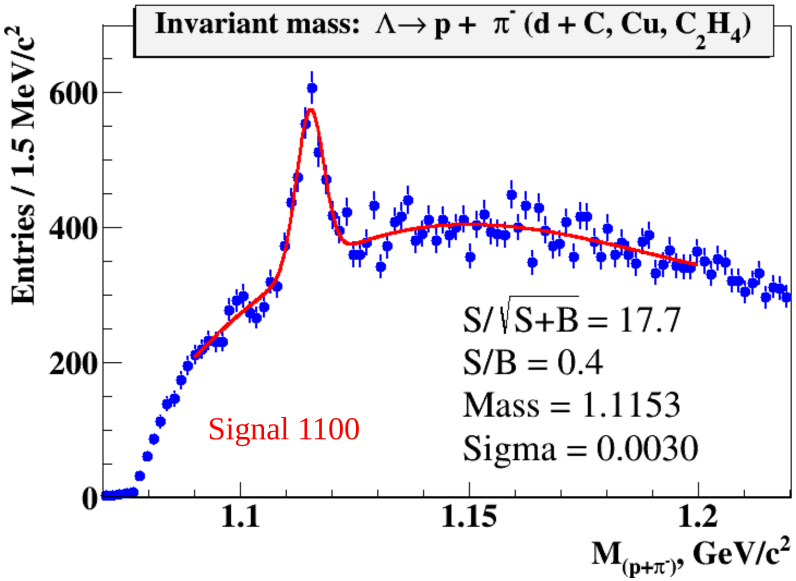
Pile-up effect with deuteron beam

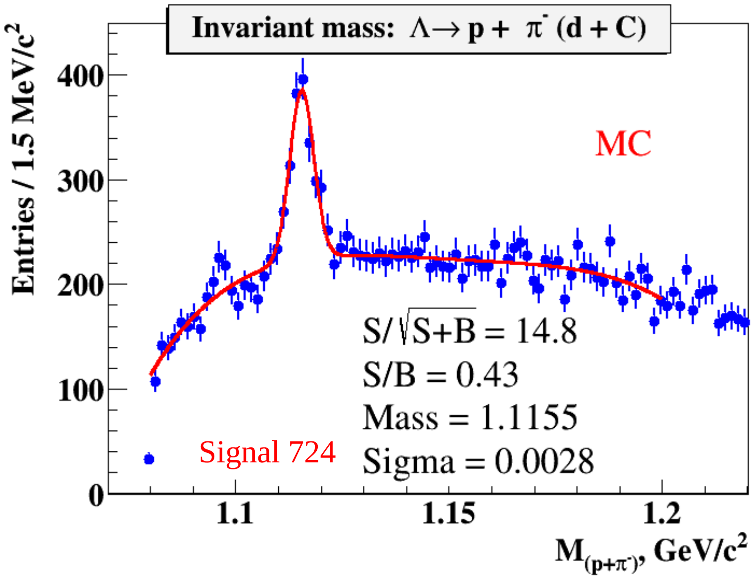




- ✓ Event pile-up due to non-uniform time structure of deuteron beam
- ✓ Cut on total momentum of particles in event < 7 GeV/c reduces pile-up significantly

Λ reconstruction: Exp. vs MC

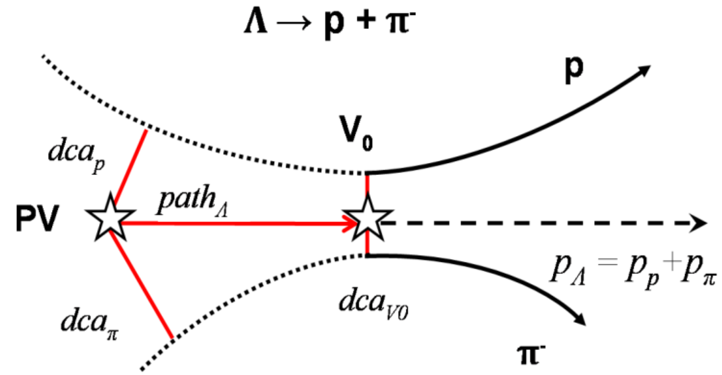




Signal event topology defined selection criteria:

- ✓ relatively large distance of closest approach (DCA) to primary vertex of decay products
- ✓ small track-to-track separation in decay vertex
- ✓ relatively large decay length of mother particle

Λ signal width of 3 MeV and background level is reproduced by MC simulation.



Event topology:

- ✓ PV – primary vertex
- ✓ V_0 – vertex of hyperon decay
- ✓ dca – distance of the closest approach
- ✓ path – decay length

Data set (carbon beam)

Magnetic field: 0.59 T

Gas in GEM: $Ar+CO_2$ (70:30)

Beam / Target: C / C,Al,Cu E_{kin} = 4.5A GeV

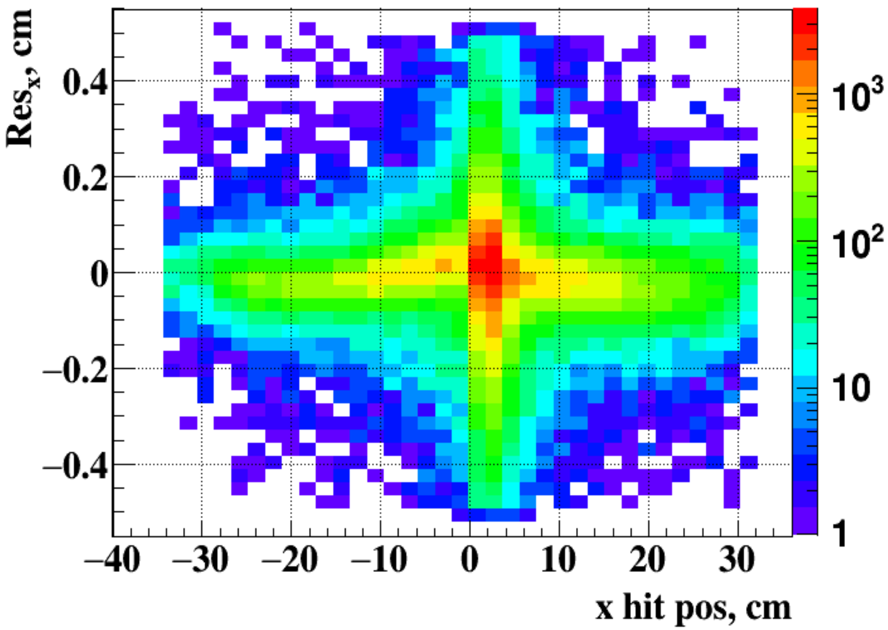
Beam / Target: C / C,Al,Cu E_{kin} = 4.0A GeV

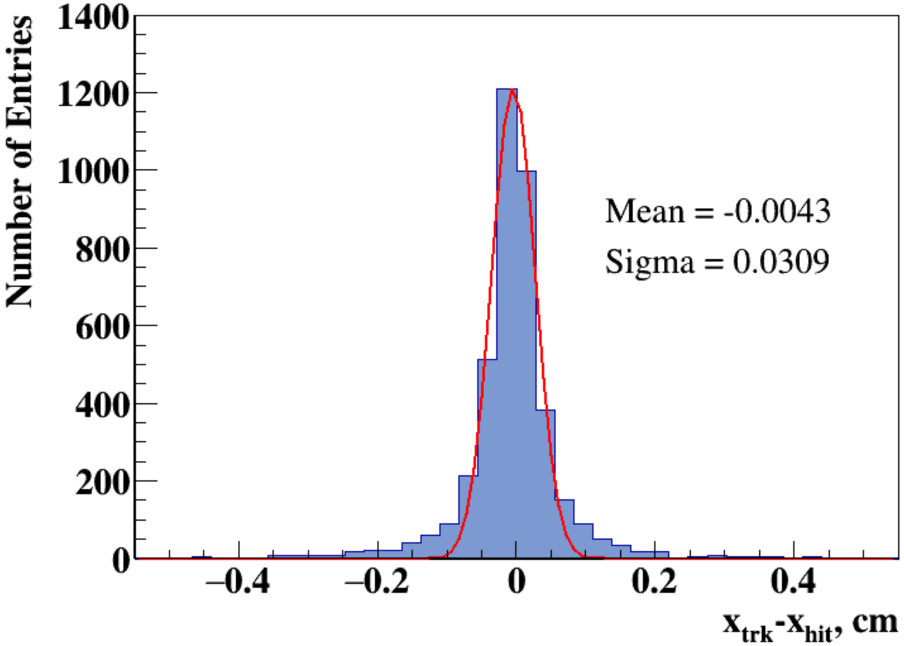
Beam / Target: C / C E_{kin} = 3.5A GeV

GEM position from target: 51-86-116-151-181-216 cm

Si detector position from target: 30 cm

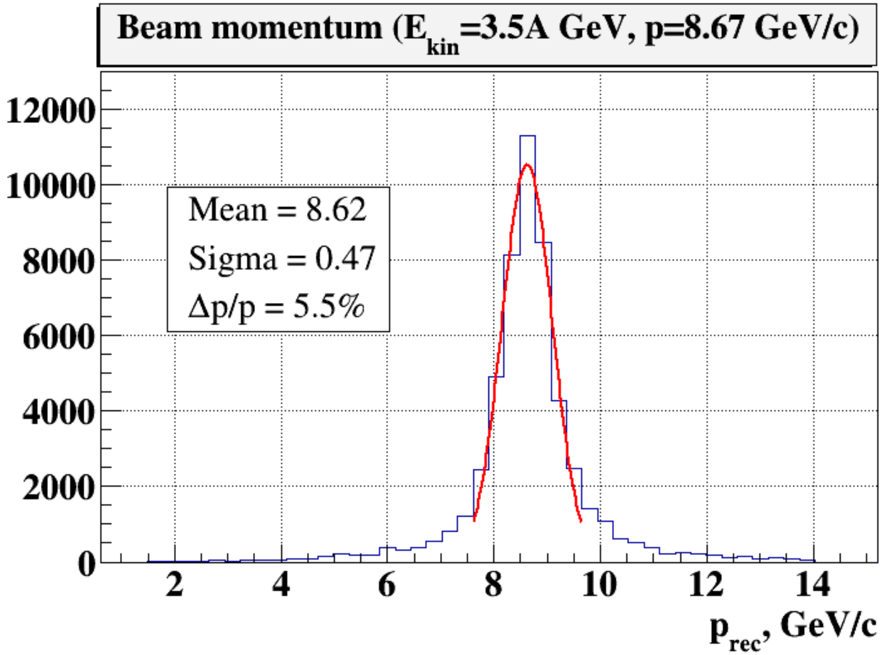
GEM alignment for X,Y, Z position





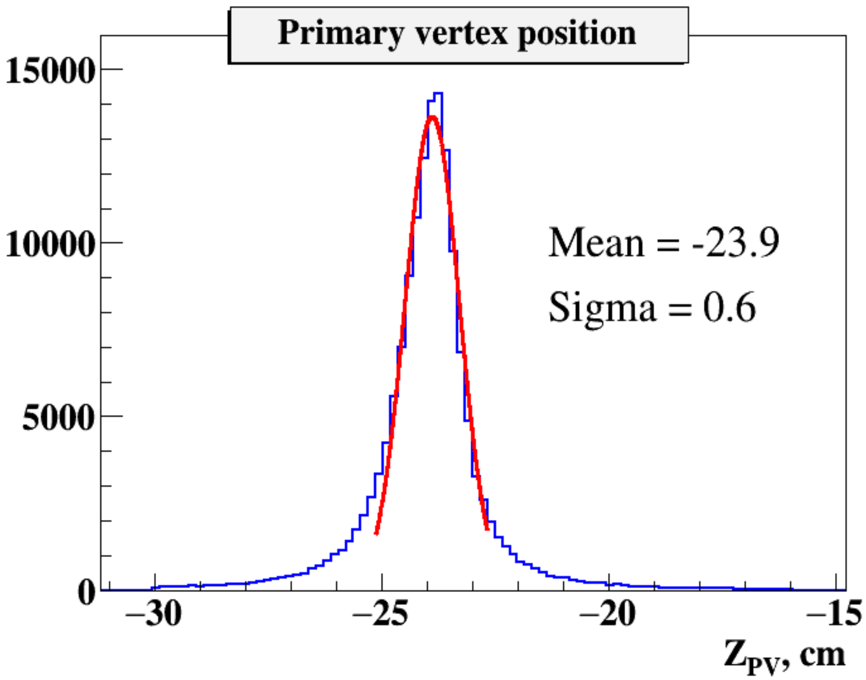
Residuals for GEM 3 after alignment & Lorentz shift correction
gas in GEM: Ar+CO_2

Beam momentum reconstruction

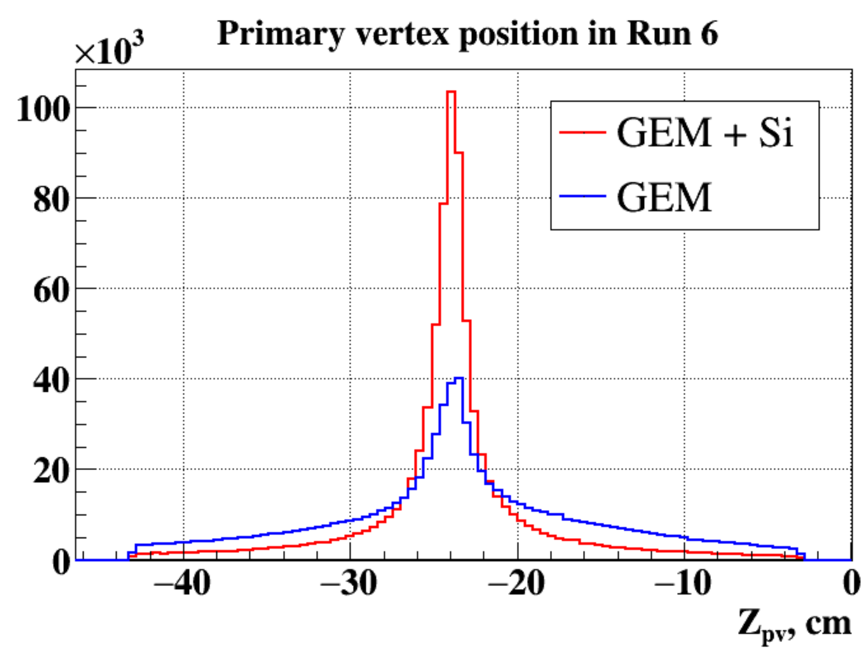


Carbon beam, gas in GEM: $Ar+CO_2$

PV reconstruction

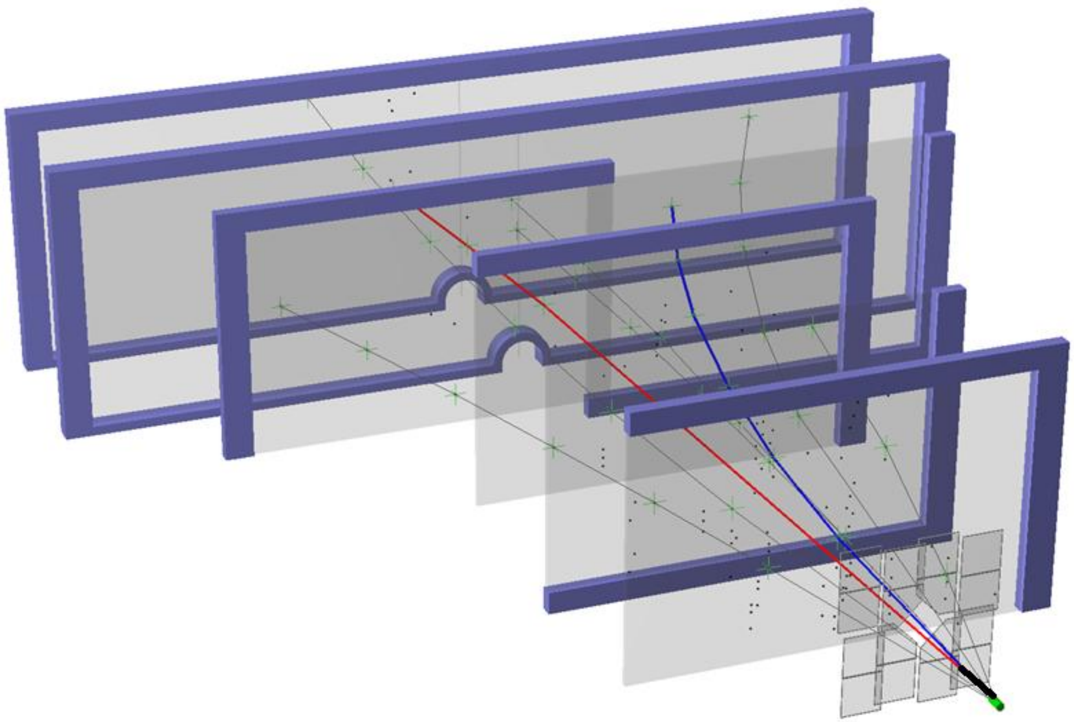


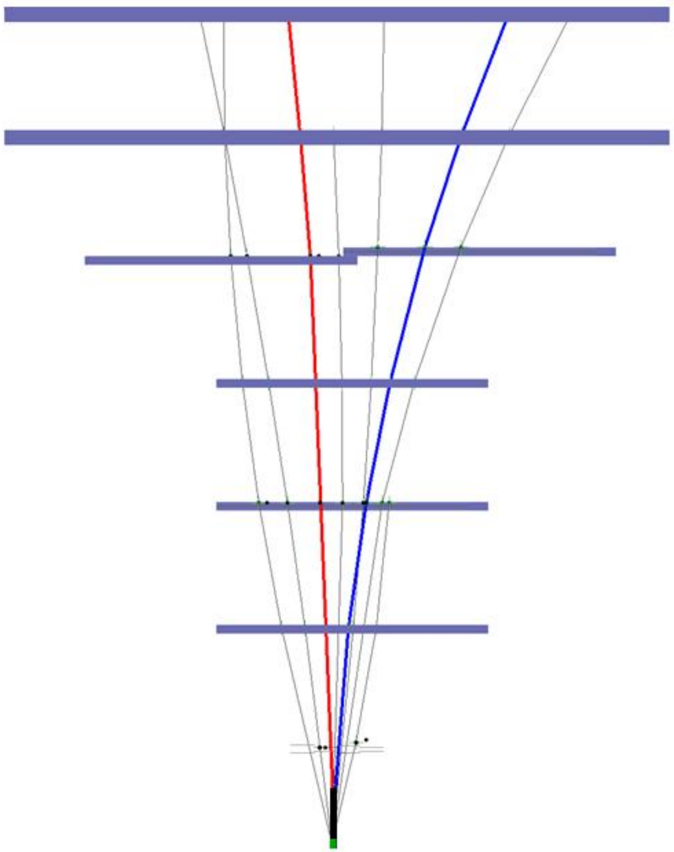
Primary Vertex with Si detector & Pile-up suppression.



Primary Vertex with Si detector vs without Si detector.

Visualization of Λ decay





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

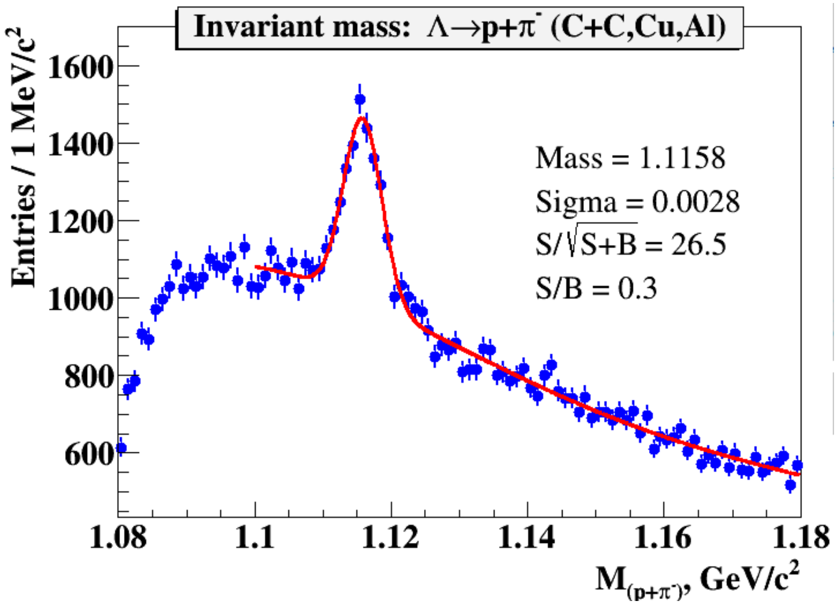
Λ & K_s^0 reconstruction

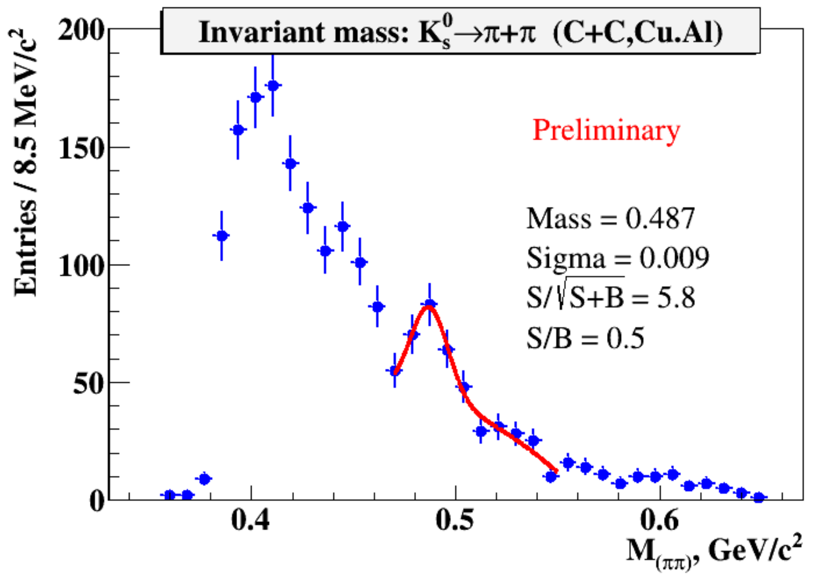
C+(C, Al, Cu), E_{kin} = 4A GeV

Signal of Λ - 3173

Signal of K_s^0 - 98

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 hyperons and ~0.8% of K_s^0 could be reconstructed.





Summary & Plans

✓ Following the cynergy paradigm, the CBM CA and CbmParticle formalisms have been adapted to the BM@N software framework for track and event reconstruction.

✓ They have been extensively used for Monte Carlo studies of different configurations.

✓ BM@N experiment has recorded experimental data with different 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.

✓ Signal of Λ-hyperon is reconstructed in proton-pion invariant mass spectrum.

✓Spatial, momentum, primary vertex and invariant mass resolution of GEM tracker are reproduced by Monte Carlo simulation for deuteron beam.

Summary & Plans (cont'd)

✓ Work is ongoing to tune MC simulation for heavier beams to describe the data and extract detector efficiencies in order to obtain Λ yields.

✓ The adopted approach to the reconstruction problem allowed us to save development time and efforts.

✓ However, track reconstruction in real events raised some issues which need to be clarified. The chief reconstructor (Gleb Pokatashkin) is working on this. A good advice from CBM people would be quite useful.

Everything's going to be OK!

Thank you for attention!