First results from BM@N technical run with deuteron beam

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Outline

1. Motivation
2. Detector geometry
3. MC: actual acceptance vs optimized acceptance
4. Simulation of GEM response (Garfield++)
5. Technical run (Run 5, Dec. 2016):
   - ✓ Alignment & Lorentz shift correction
   - ✓ Momentum resolution: MC vs Exp.
   - ✓ PV reconstruction: MC vs Exp.
   - ✓ Λ reconstruction: MC vs Exp.
   - ✓ Pile-up effect
6. Summary & Plans

Motivation

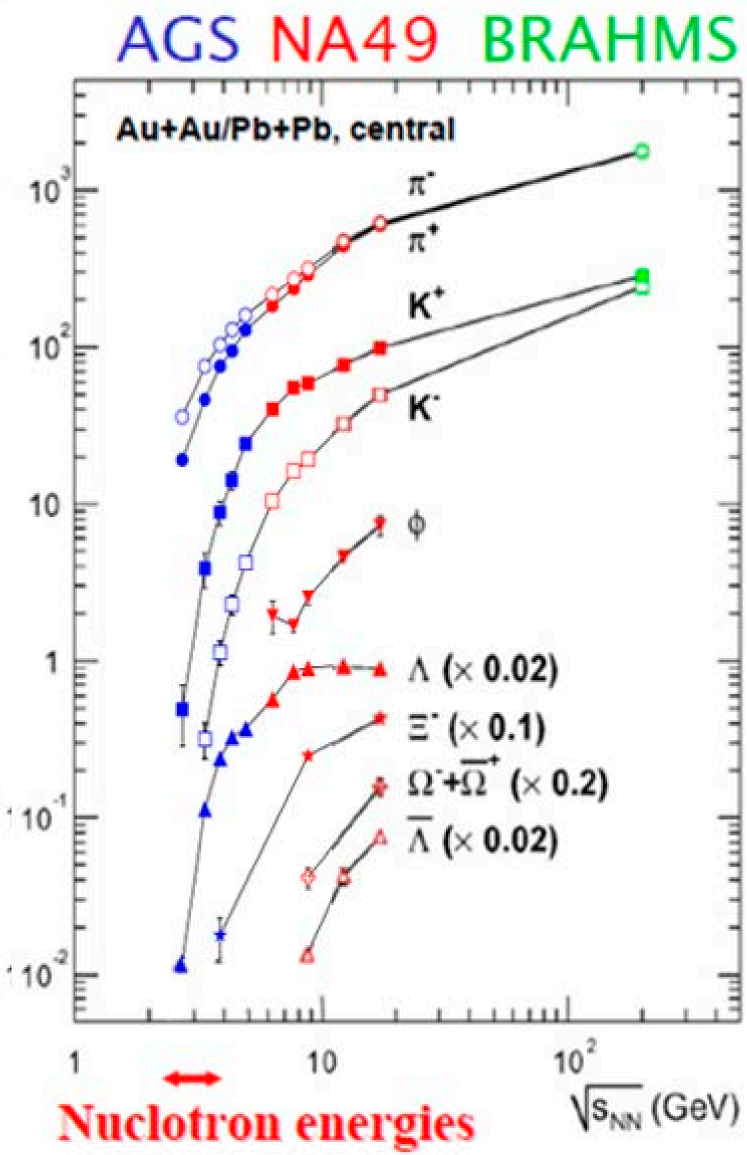
✓**In A+A collisions** at Nuclotron energies:

Opening thresholds for strange and multi-strange hyperon production

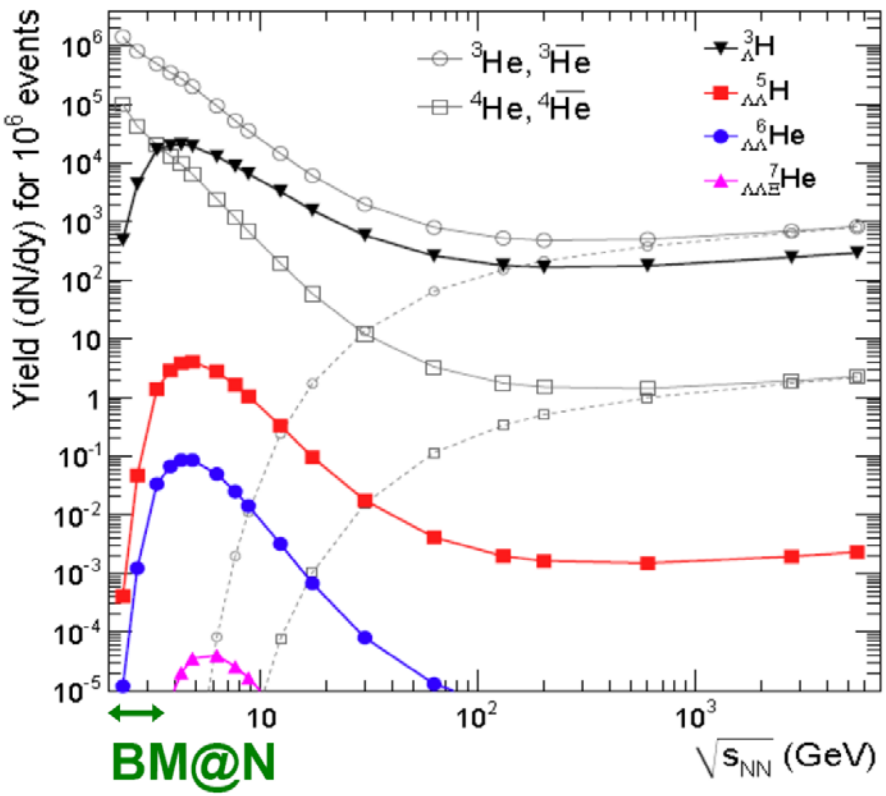
→ strangeness at threshold

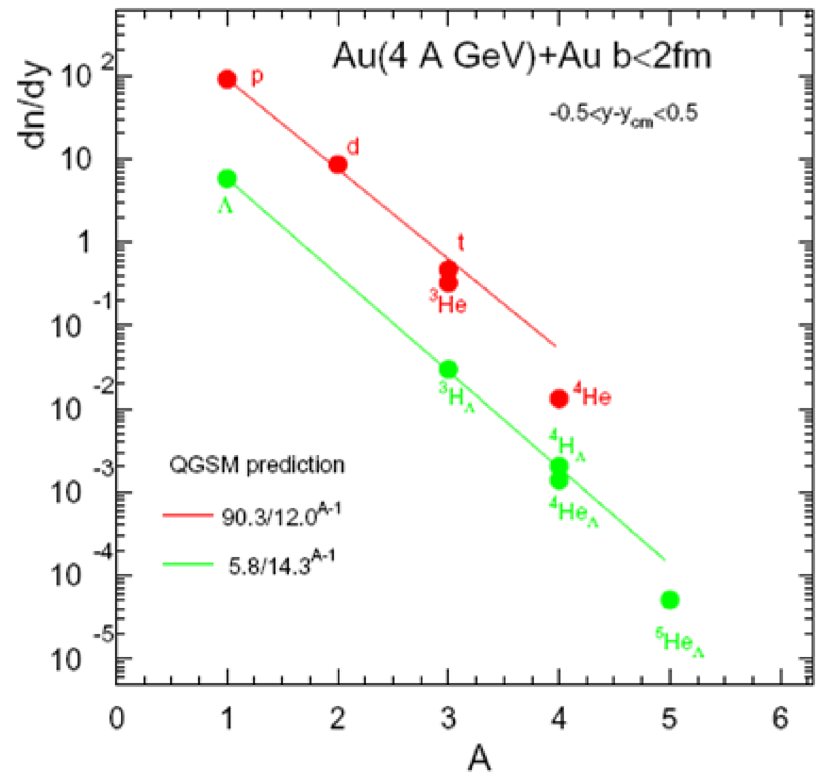
✓**In *p+p, p+n, p+A* collisions:**

hadron production in elementary reactions and ‚cold‘ nuclear matter as ‚reference‘ to pin down nuclear effects



Motivation



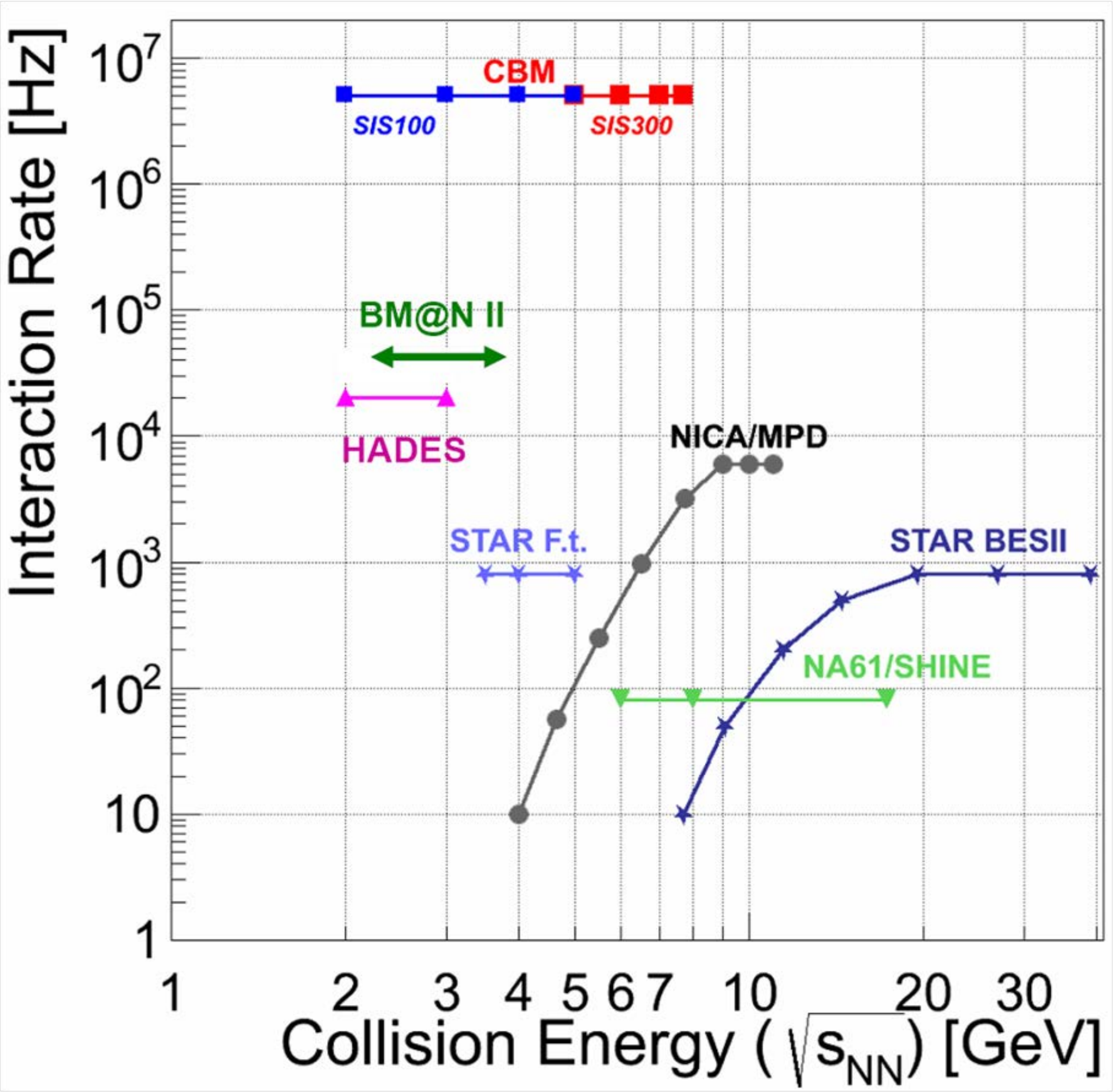


✓ In heavy-ion reactions: production of hypernuclei through coalescence of Λ with light fragments enhanced at high baryon densities.

✓ Maximal yield predicted for √s=4-5A GeV (stat. model) (interplay of Λ and light nuclei excitation function).

→ BM@N energy range is suited for the search of hypernuclei.

Heavy Ion Collision experiments



BM@N: $\sqrt{s_{NN}}$=2.3 - 3.5 GeV

Nuclotron and BM@N beam line

26 elements of magnetic optics:

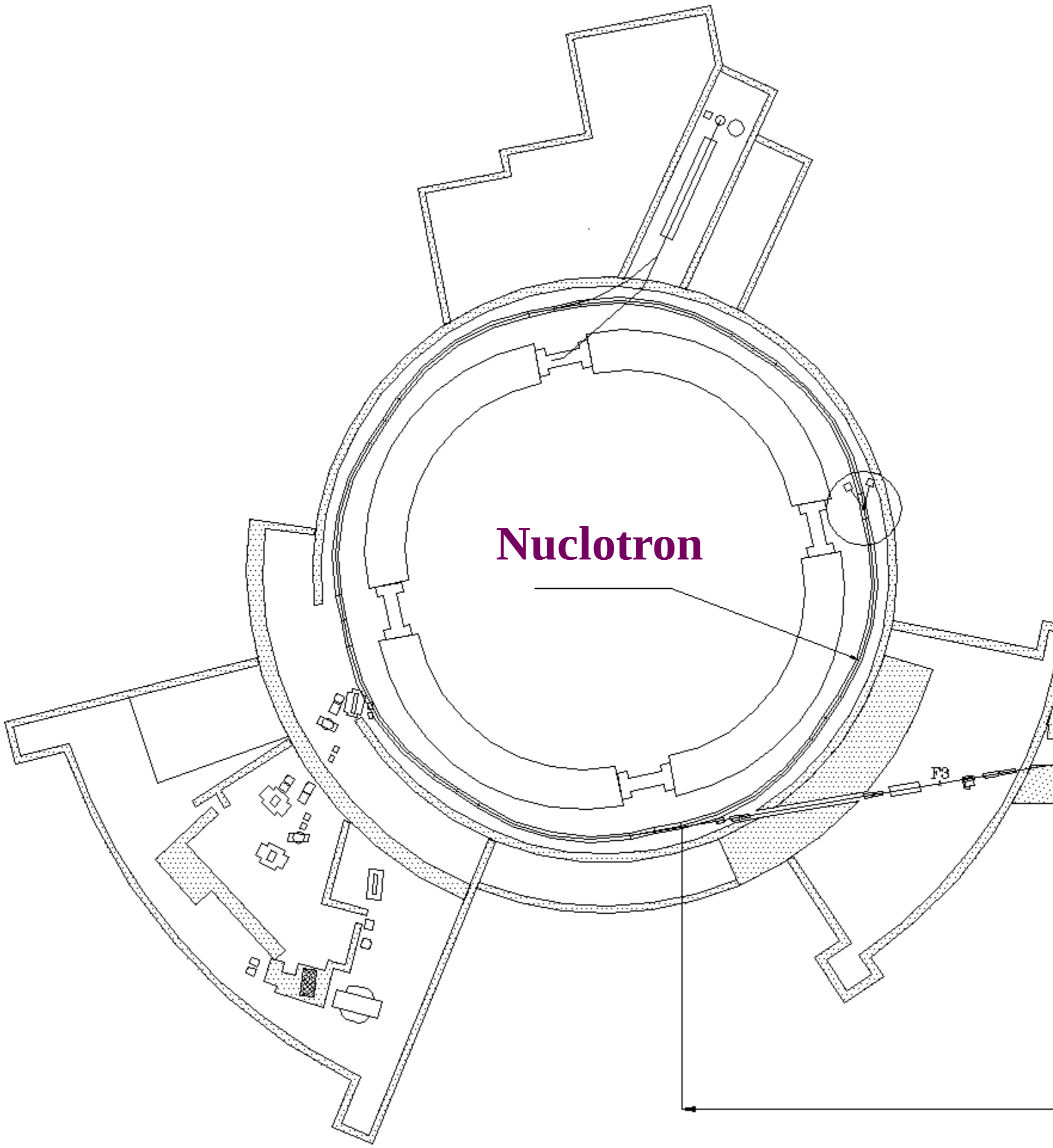
→ 8 dipole magnets

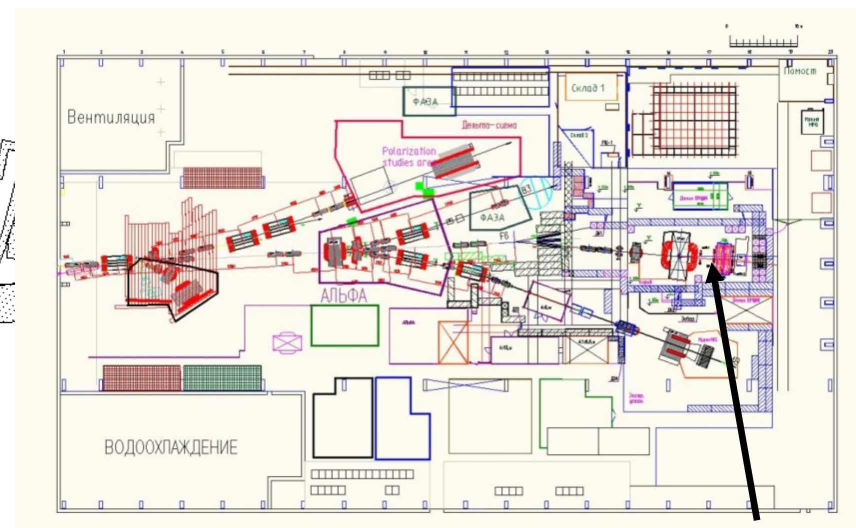
→ 18 quadruple lenses

Requirements for Au beam:

✓ Minimum dead material

→ need to replace 40 m air intervals/foils with vacuum





~160 m

Building 205

BM@N

Detector geometry

BM@N setup:

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

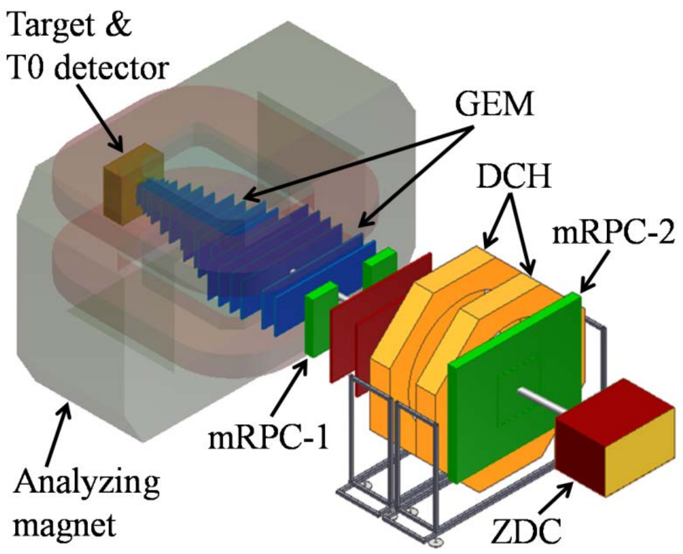
✓Outer tracker (DCH, CPC) behind magnet to link central tracks to ToF detectors

✓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-



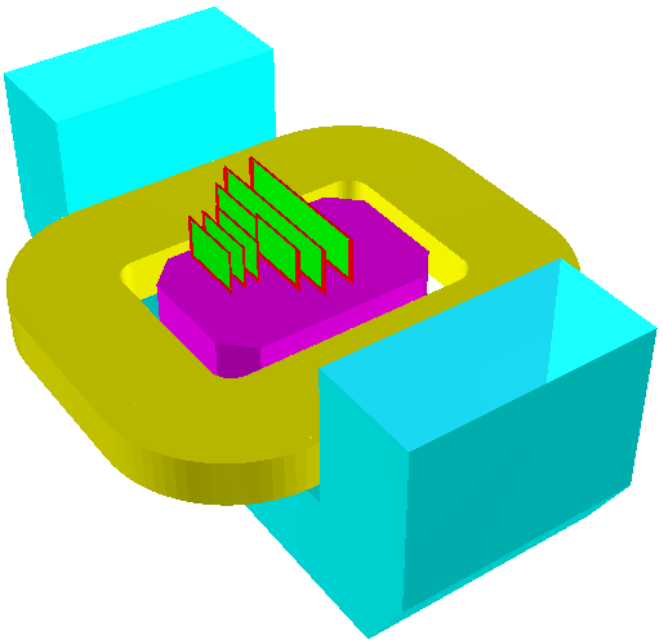
BM@N advantage: large aperture magnet (~1 m gap between poles)

→ 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)

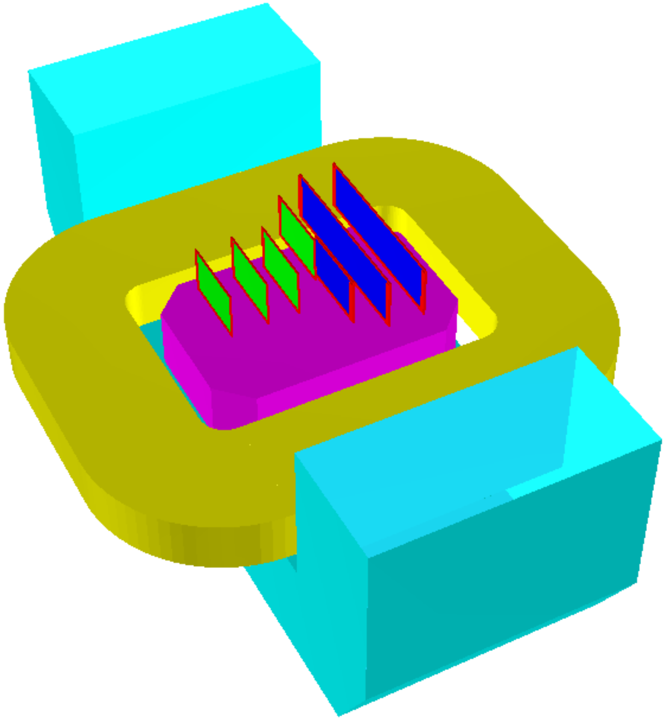
→ fill distance between magnet and "far" detectors with coordinate detectors

GEM tracker set-up in MC



Optimized positions of 6 GEM planes (MC-2015)

GEM position from target:
30-45-60-80-100-130 cm



Actual positions of 6 GEM planes in last technical runs (MC-2017)

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

K_s^0 simulation: MC-2015 vs MC-2017

MC-2015	**MC-2017**
DCM model (minbias events)	DCM model (minbias events)
C+C interactions	d+C interactions
E_{kin} = 4 AGeV	E_{kin} = 4 AGeV
0.5 M events	1 M events
GEM position from target: 30-45-60-80-100-130 cm	GEM position from target: 51-86-116-151-181-216 cm
K_s^0: 28229 (gen) / 2500 (rec)	K_s^0: 19020 (gen) / 167 (rec)
Eff. Rec. = **8.9%**	Eff. Rec. = **0.8%**
Magnetic field B = **0.44** T	Magnetic field B = **0.7** T

Λ simulation: MC-2015 vs MC-2017

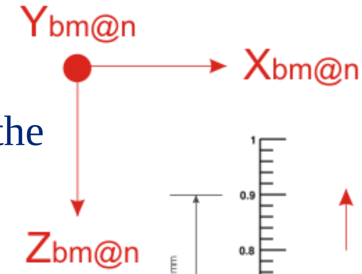
MC-2015	**MC-2017**
DCM model (minbias events)	DCM model (minbias events)
C+C interactions	d+C interactions
E_{kin} = 4 AGeV	E_{kin} = 4 AGeV
0.1 M events	1 M events
GEM position from target: 30-45-60-80-100-130 cm	GEM position from target: 51-86-116-151-181-216 cm
Λ: 11933 (gen) / 2359 (rec)	Λ: 43432 (gen) / 1832 (rec)
Eff. Rec.= **19.8%**	Eff. Rec.= **4.2%**
Magnetic field B = **0.44** T	Magnetic field B = **0.7** T

Simulation of GEM response: Garfield++

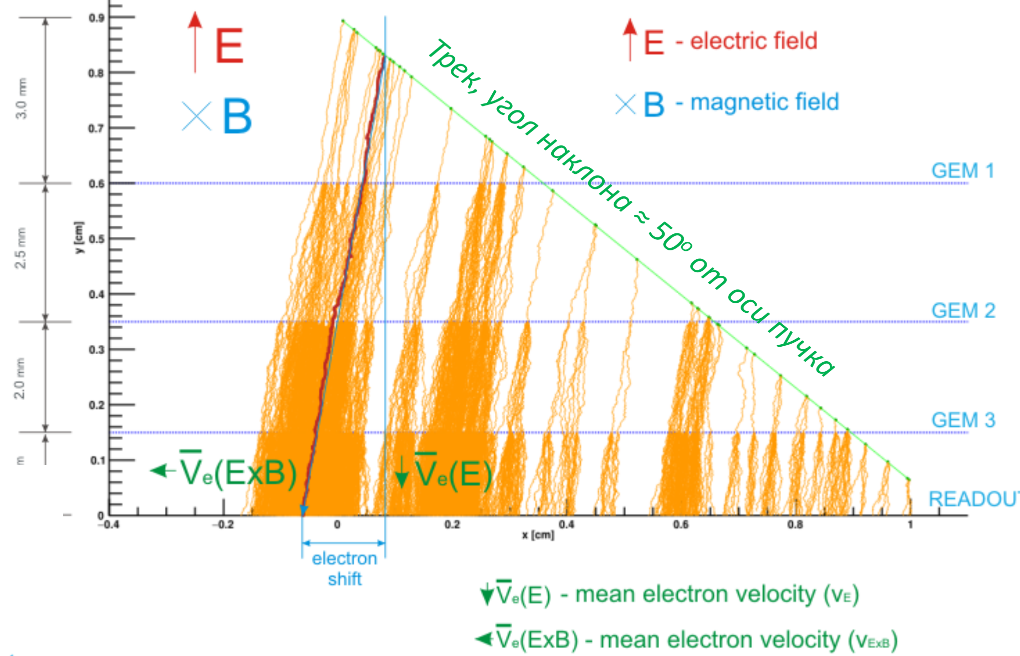
Garfield++ - framework for microsimulation physical processes in the gas detectors.

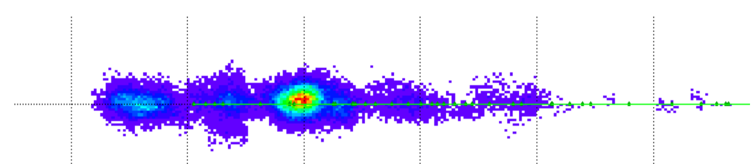
A charge particle passing through GEM chamber detecting volume ionizes the gas.

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

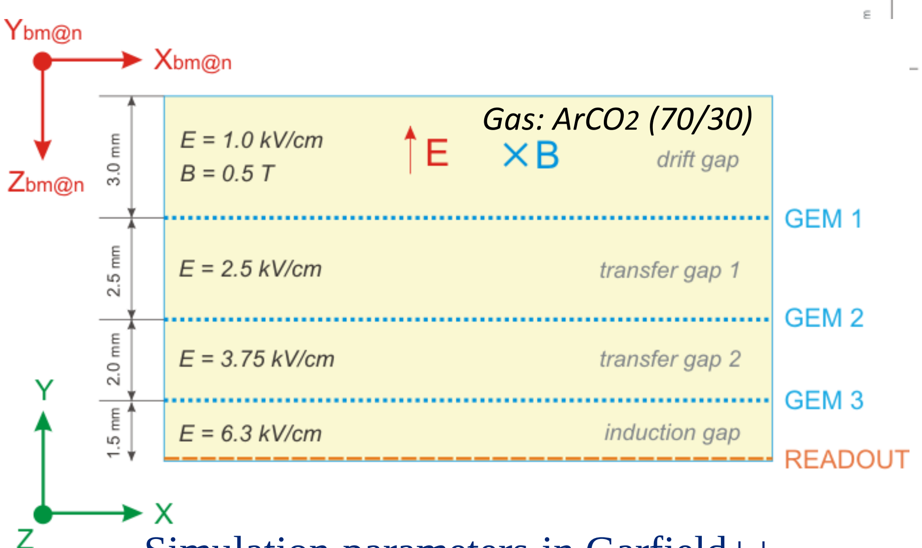


Structure of BM@N GEM chamber (top view) and scheme of electron avalanches.



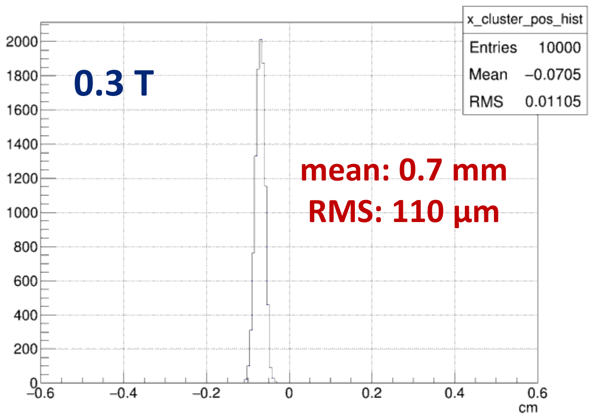


Profile of electron avalanche at the readout-plane (cluster).

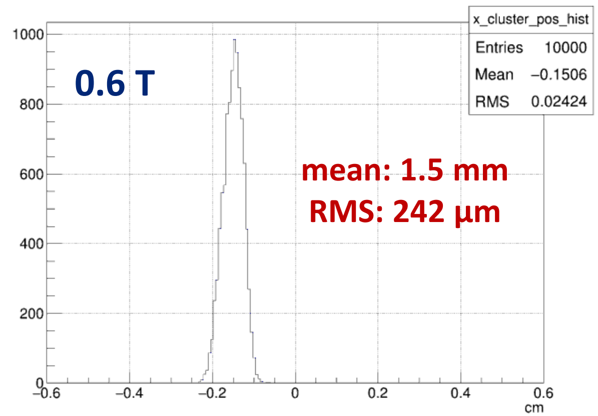


Simulation parameters in Garfield++

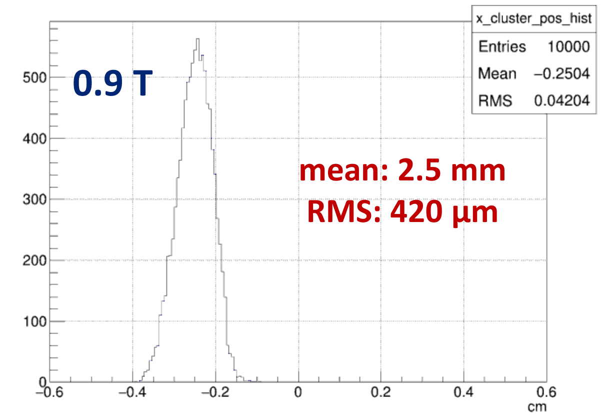
Simulations of GEM response: Garfield++



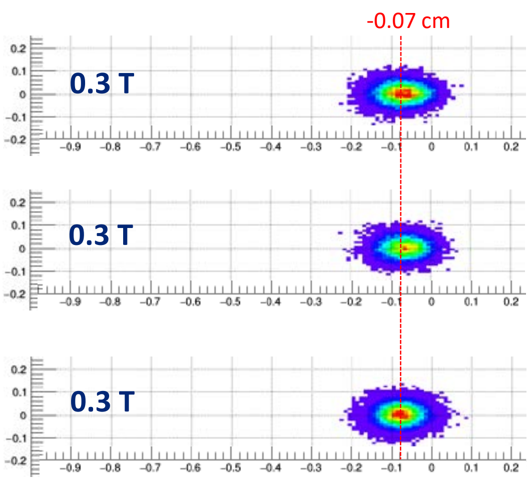
X distribution of the avalanche centers at read-out plane. B = *0.3 T*

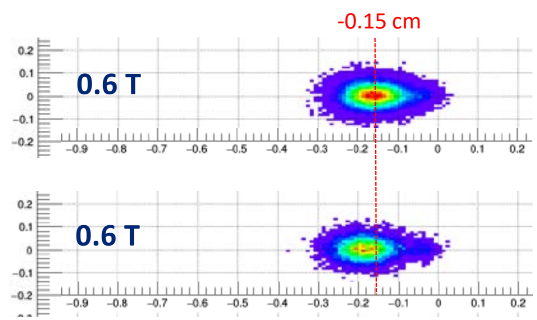


X distribution of the avalanche centers at read-out plane. B = *0.6 T*

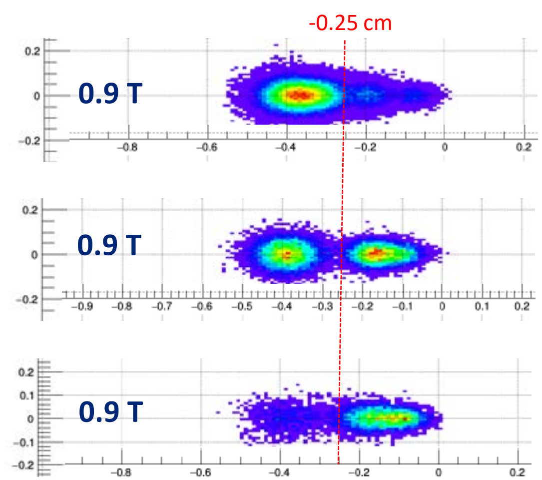


X distribution of the avalanche centers at read-out plane. B = *0.9 T*





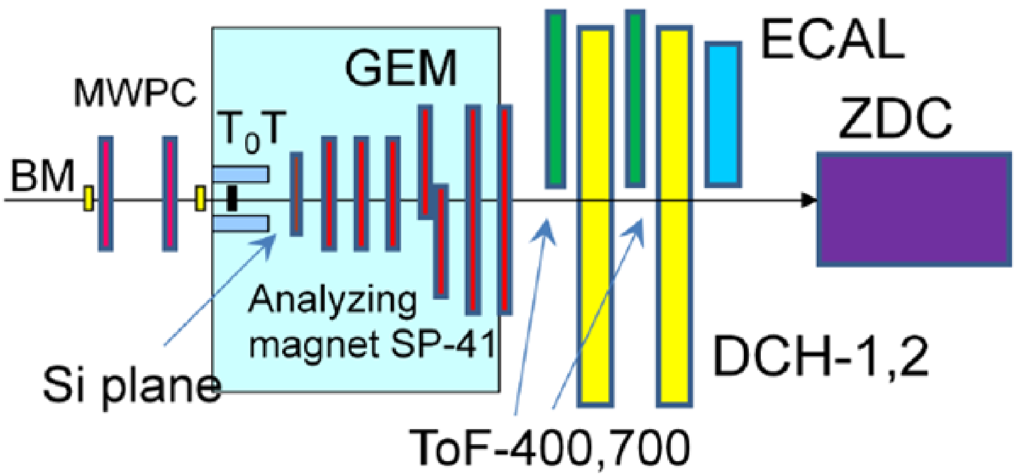
Examples of the avalanche profile of single track at the read-out plane.

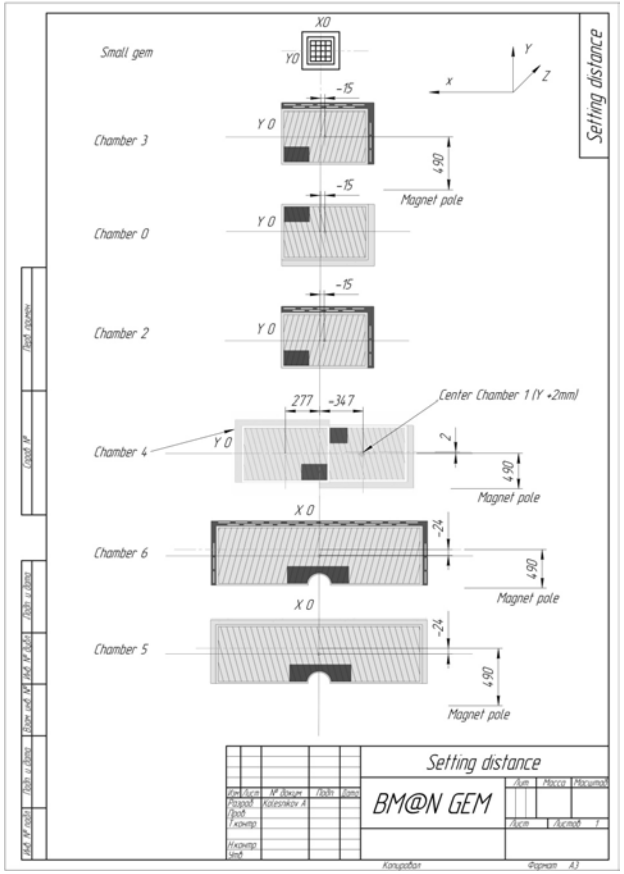


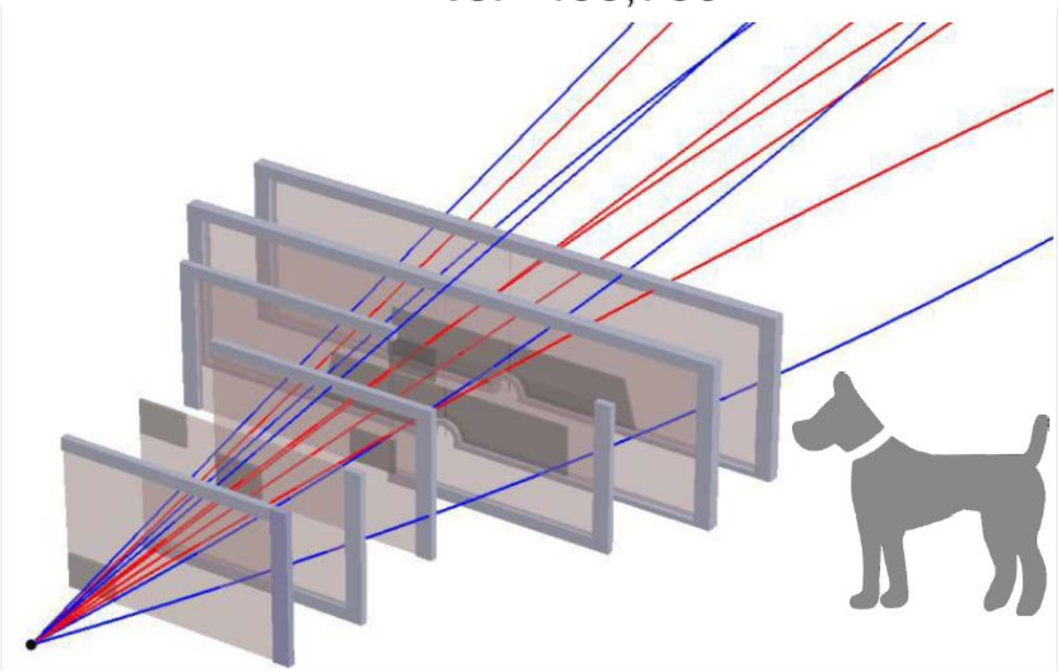
The results are presented for configuration: Ar+Isobuthan = 90:10.

Technical run in December 2016

BM@N set-up used in the deuteron run.

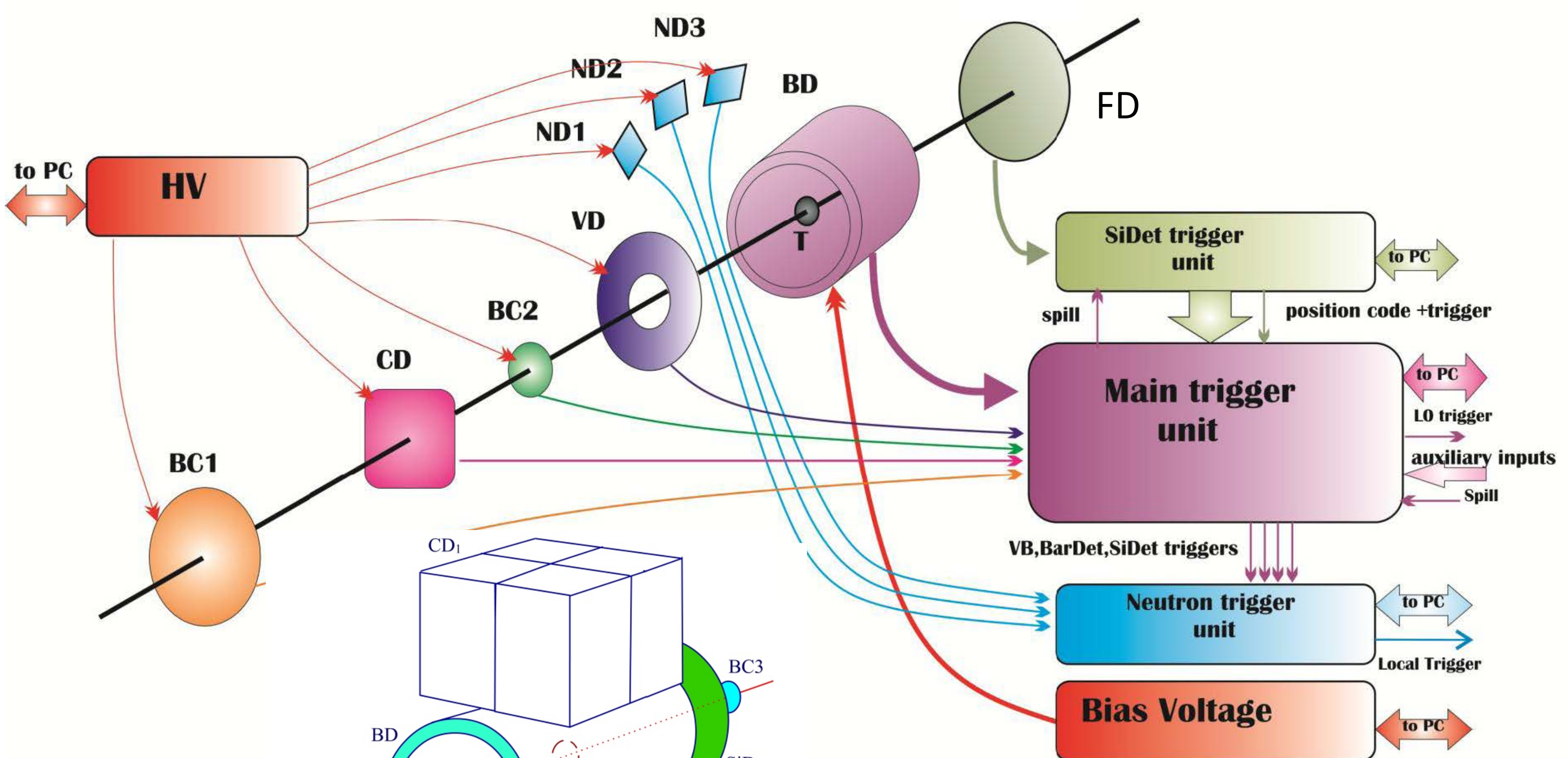


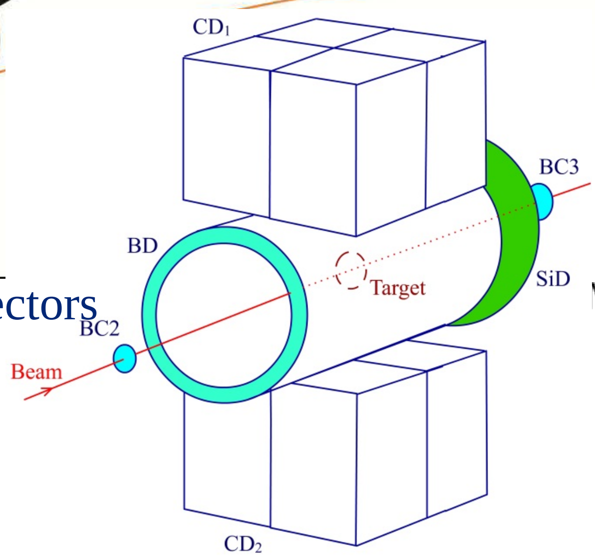




Example of an event reconstruction in the central tracker.

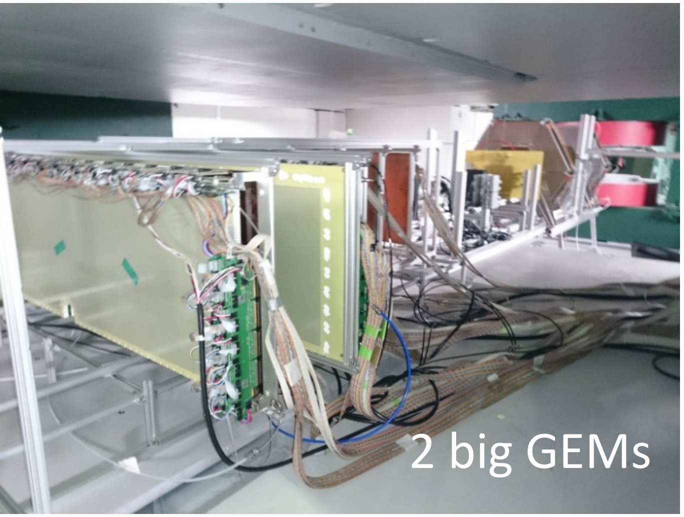
Trigger detectors

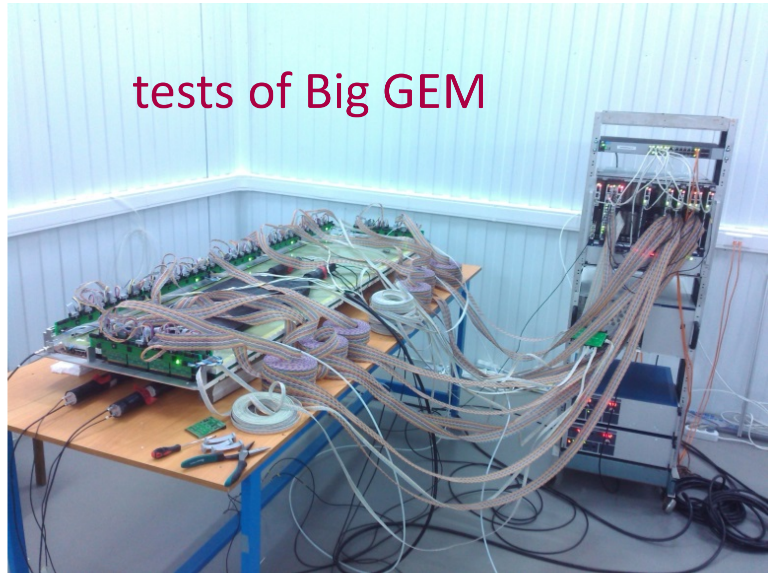


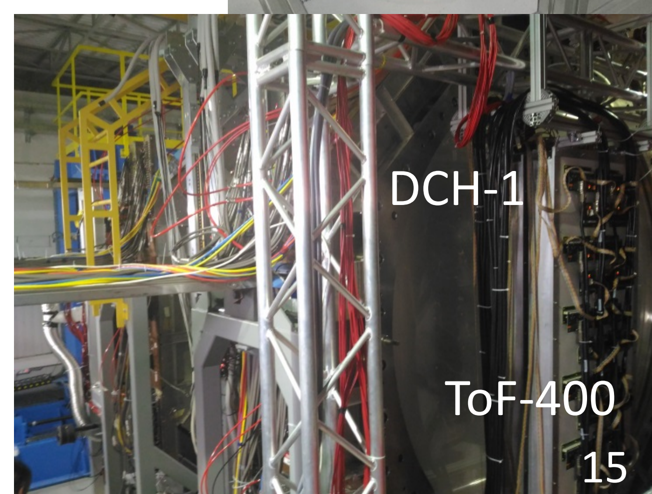


Trigger and T0 detectors for heavy ions

Technical run in December 2016







Data set

Magnetic field: 1600 A (0.79 T)

Events: 7M (0.76M with Λ candidates)

Beam / Target: d / Cu, E_{kin} = 4 AGeV

Beam / Target: d / CH_2, E_{kin} = 4 AGeV

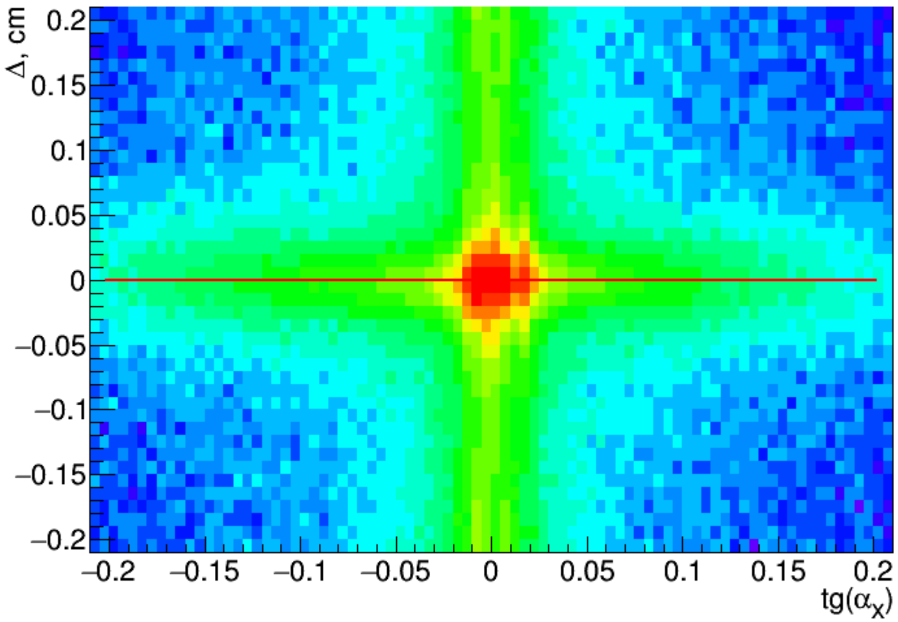
Beam / Target: d / C, E_{kin} = 4 AGeV

Gas in GEM: Ar + Isobuthan

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

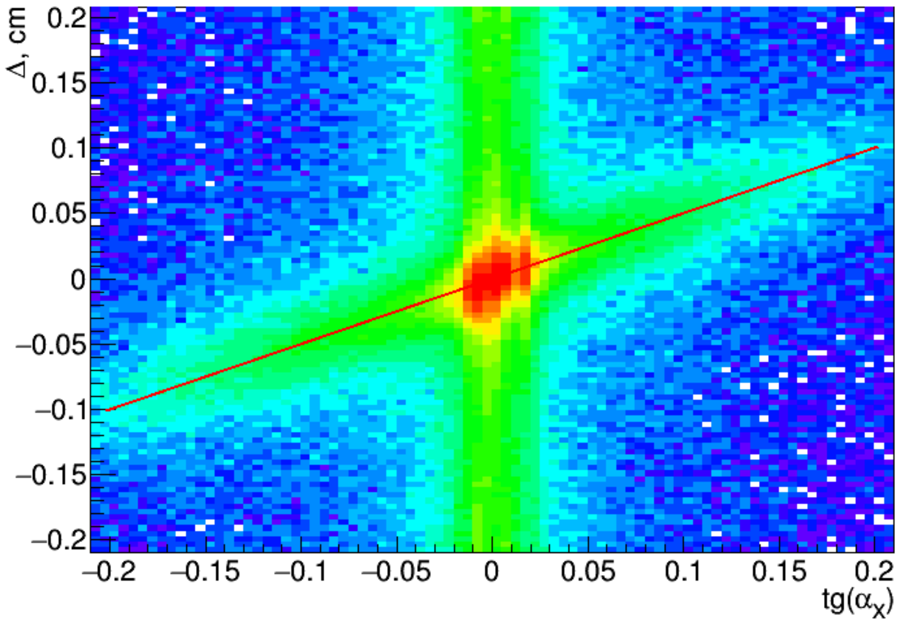
Alignment of GEM Z position

Proper Z position.



Residual distribution is horizontal along X for adjusted Z position along beam.

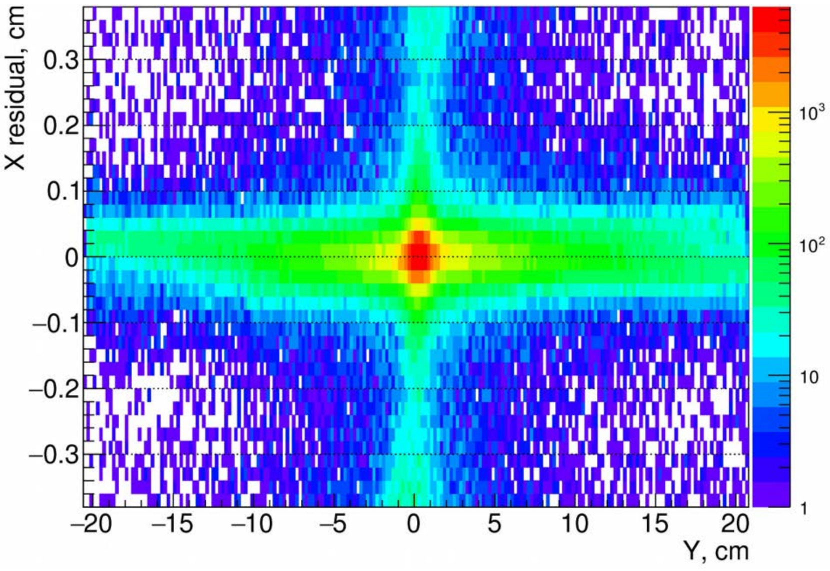
5 mm Z displacement.



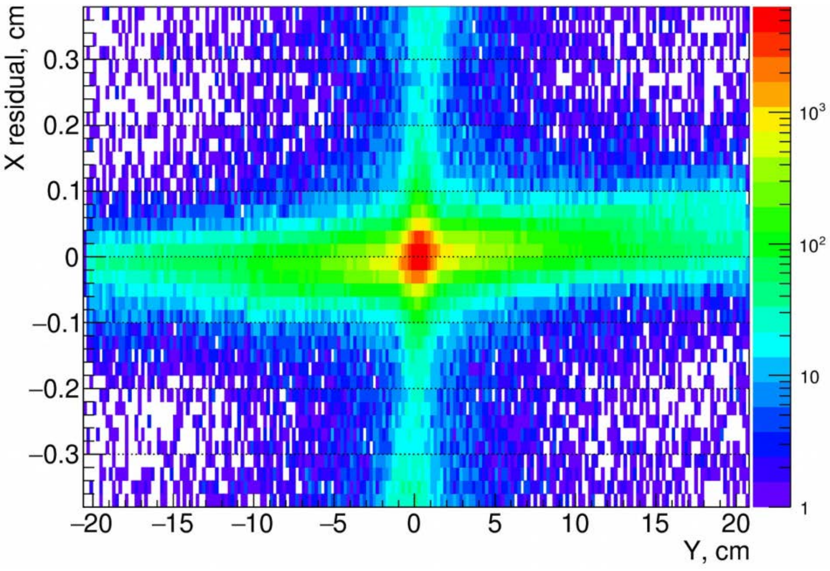
Residual distribution is inclined along X for shifted Z position.

- ✓ $\Delta = \Delta_z * tg(\alpha_x)$, α_x - track angle in XoZ
- ✓ Precision of Z position alignment ~1 mm

Alignment of rotation angles in XoY



α_Z displacement 0

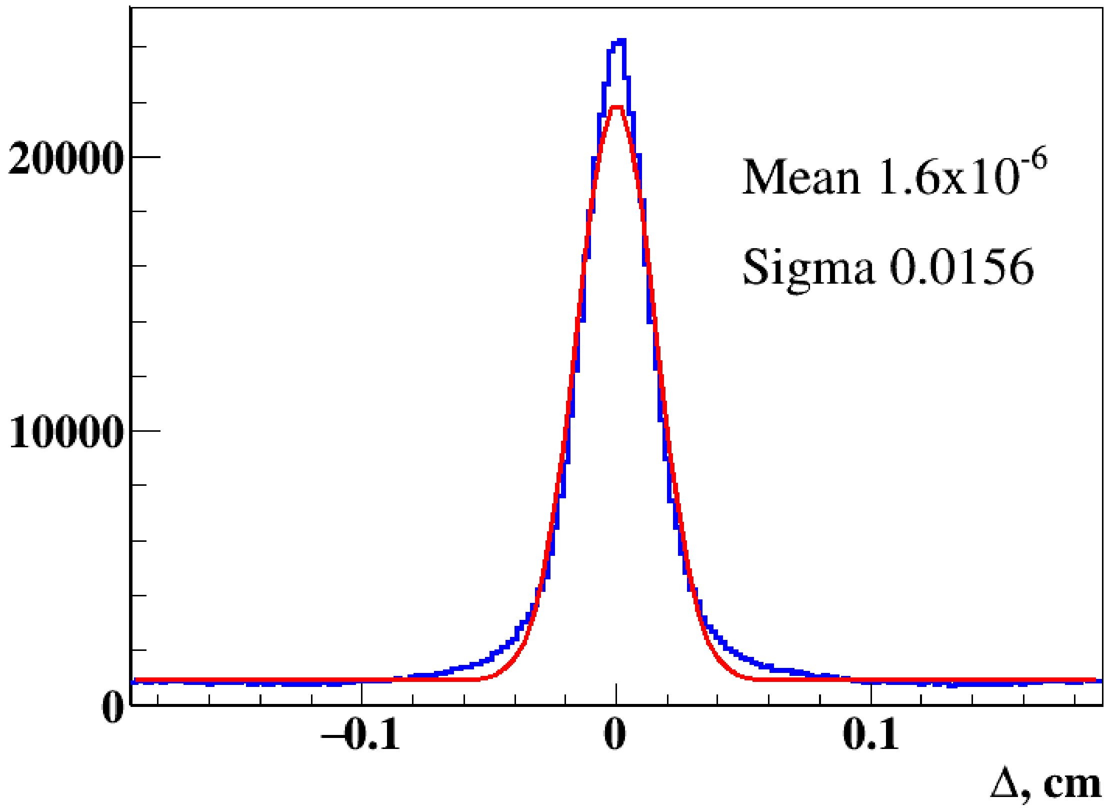


α_Z displacement 0.1°

Effect of detector rotation in XoY:

✓X residual distribution inclined along Y coordinate
✓0.1 degree rotation is clearly detectable

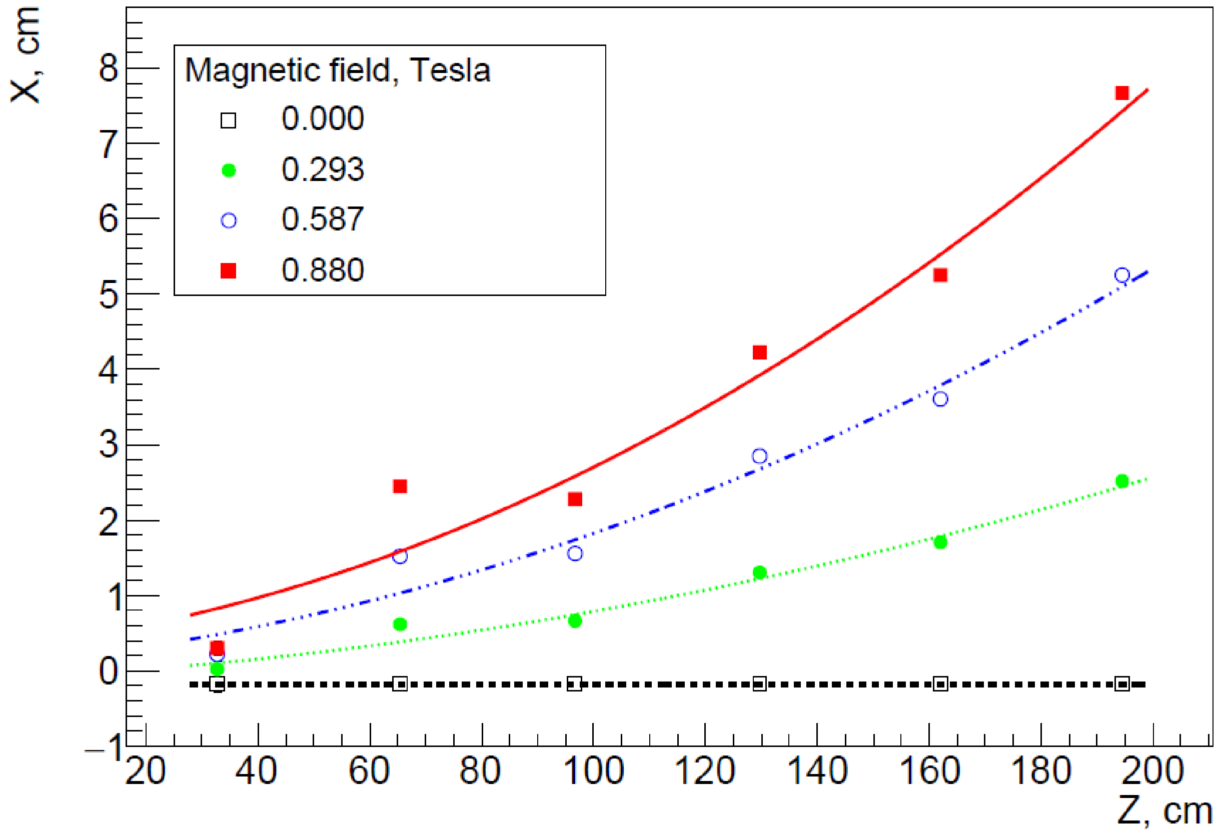
GEM hit residuals without mag. field



✓ X residual of 2-nd station for straight lines (tracks) defined by hit combinations on stations 1 and 3.

✓ An assumption of the same resolution of all three stations leads from the 156 um residual to σ = 127 um resolution. ($\sigma_x = \sigma_\Delta / \sqrt{1.5} = 156 / \sqrt{1.5} = 127$ um)

Beam trajectory in GEM detectors

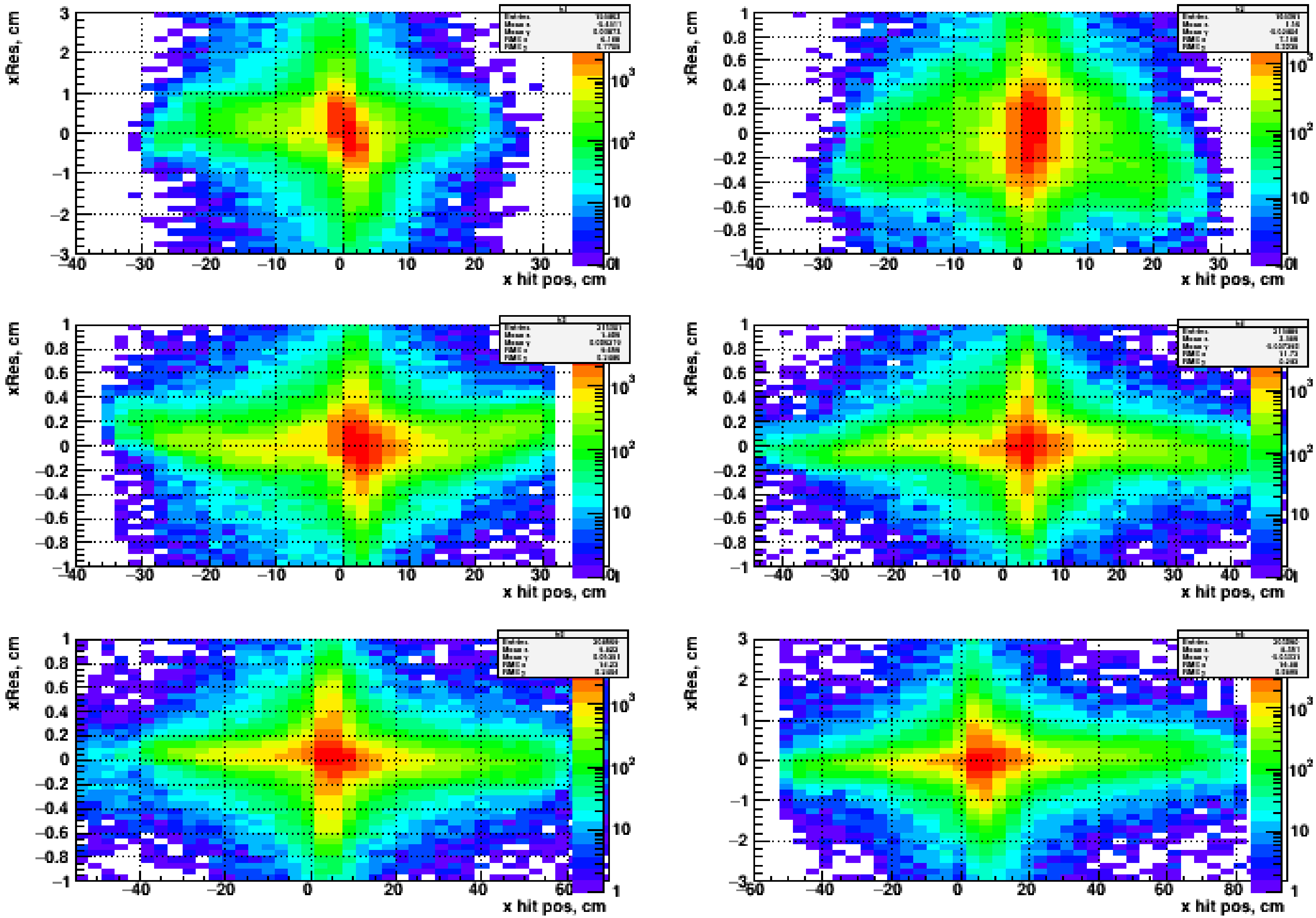


✓ Averaged positions of deuteron beam with E_{kin} = 4 AGeV reconstructed in 6 GEM planes at different values of magnetic field.

✓ Opposite electric field direction in consecutive GEM planes.

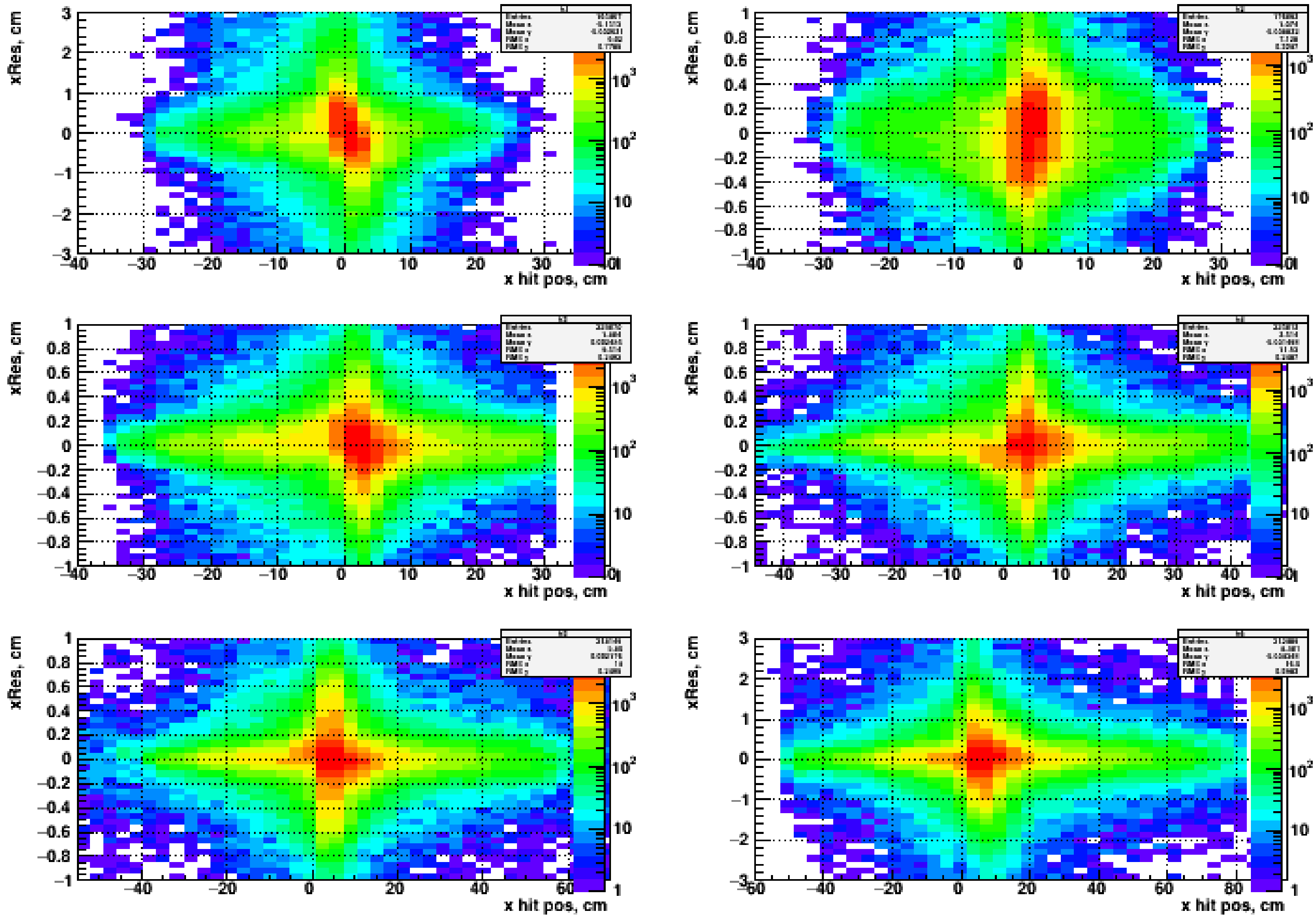
X residuals before Lorentz shift correction

X residuals vs X coordinate, $\delta \sim B_y$

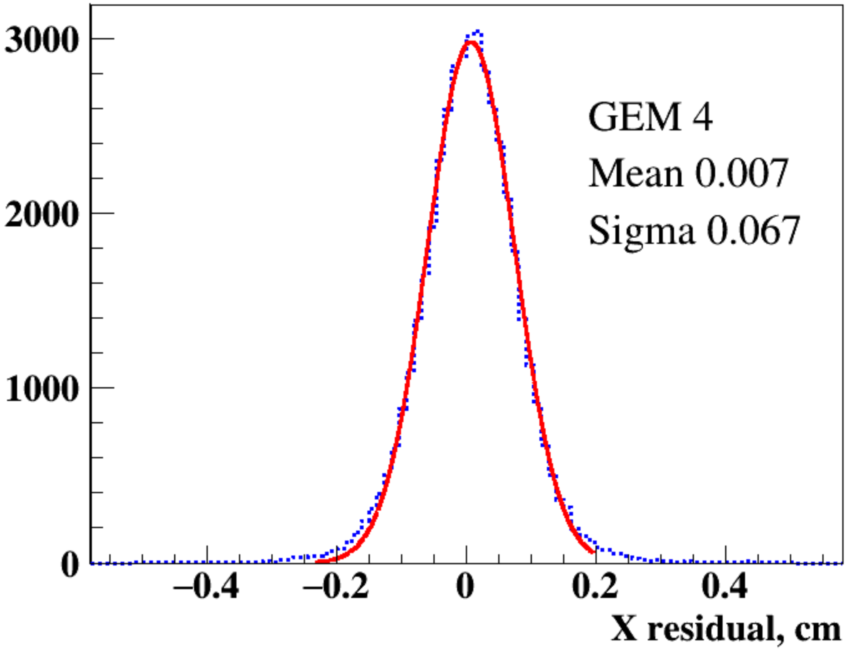


X residuals after Lorentz shift correction

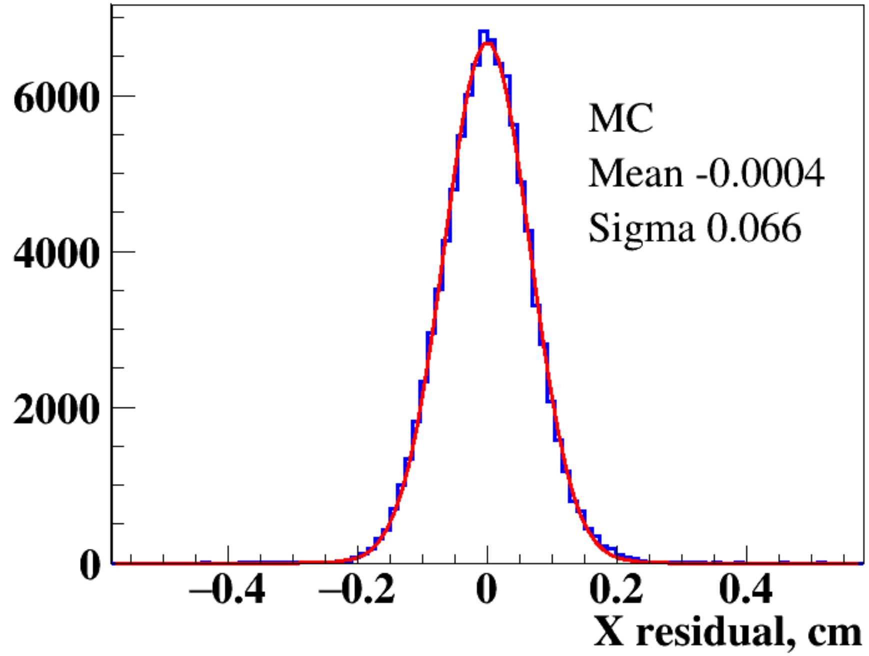
X residuals vs X coordinate, $\delta \sim B_y$



GEM hit residuals in mag. Field 0.79 T



GEM hit residuals for exp. data.

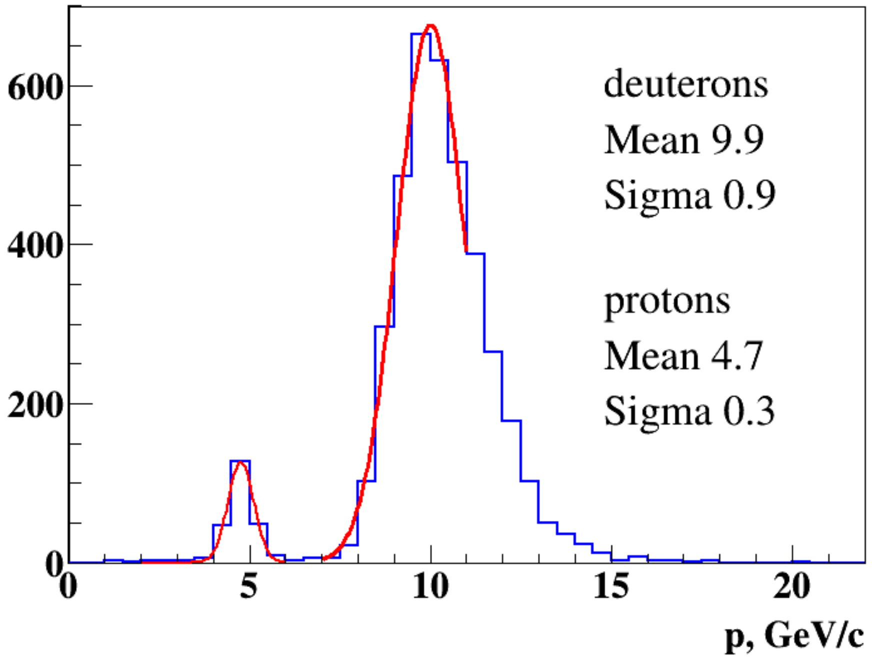


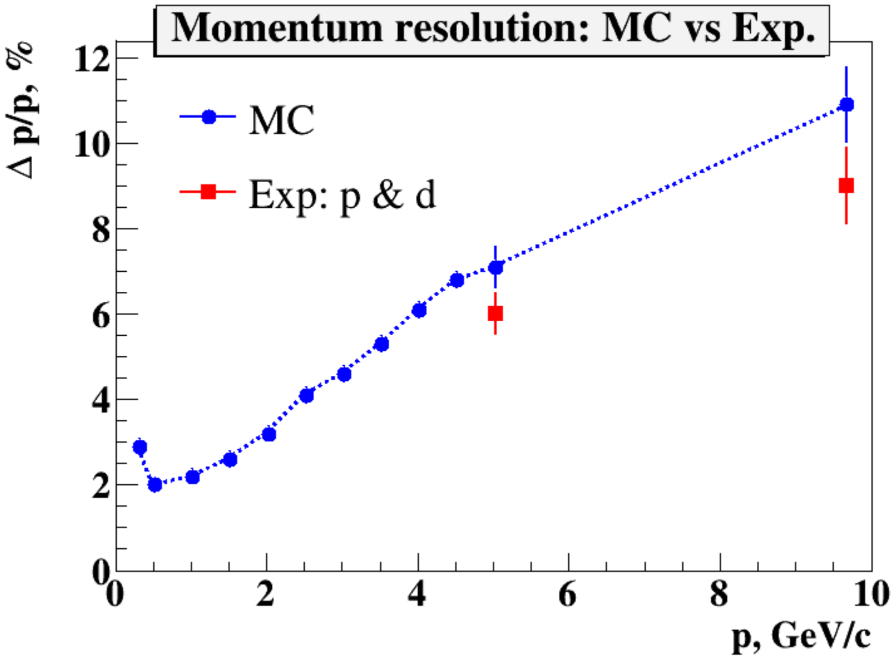
GEM hit residuals for MC simulation with Garfield parametrization.

Mag. field 0.79 T

Gas mixture Ar+ Isobuthan

Momentum resolution: Exp. vs MC





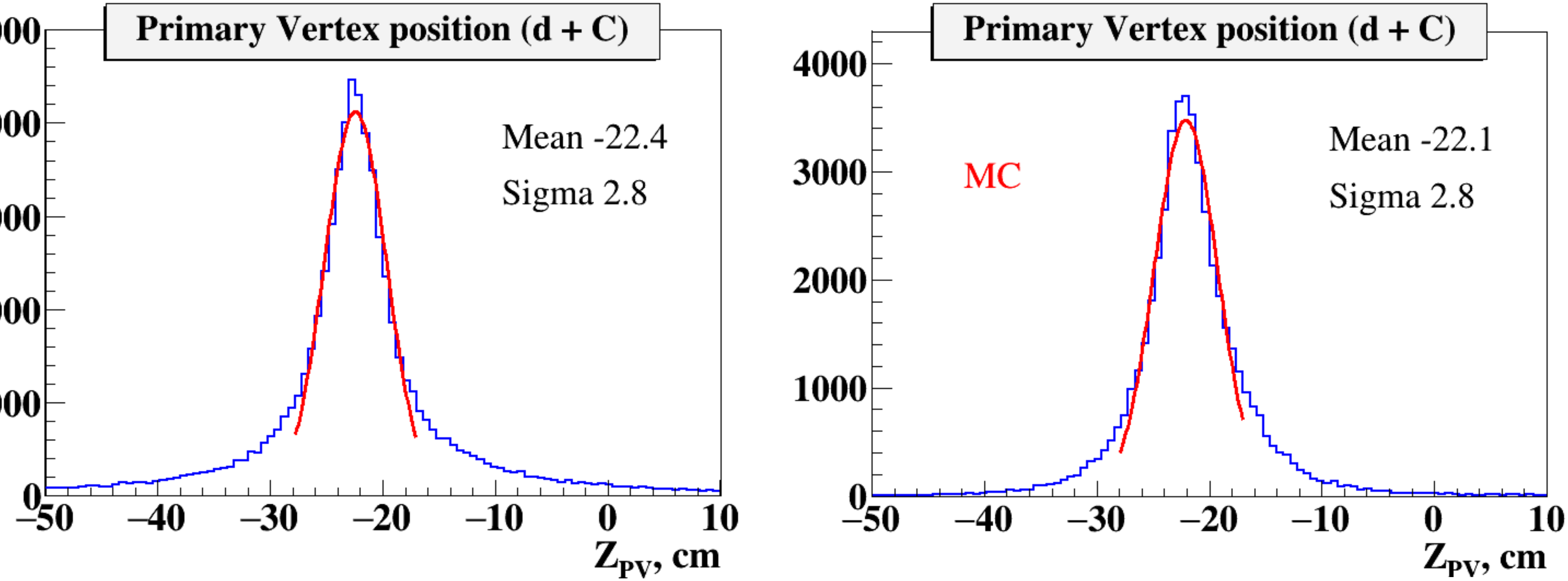
✓ Momentum resolution for deuteron beam of 9.7 GeV/c ~9%.

✓ 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.

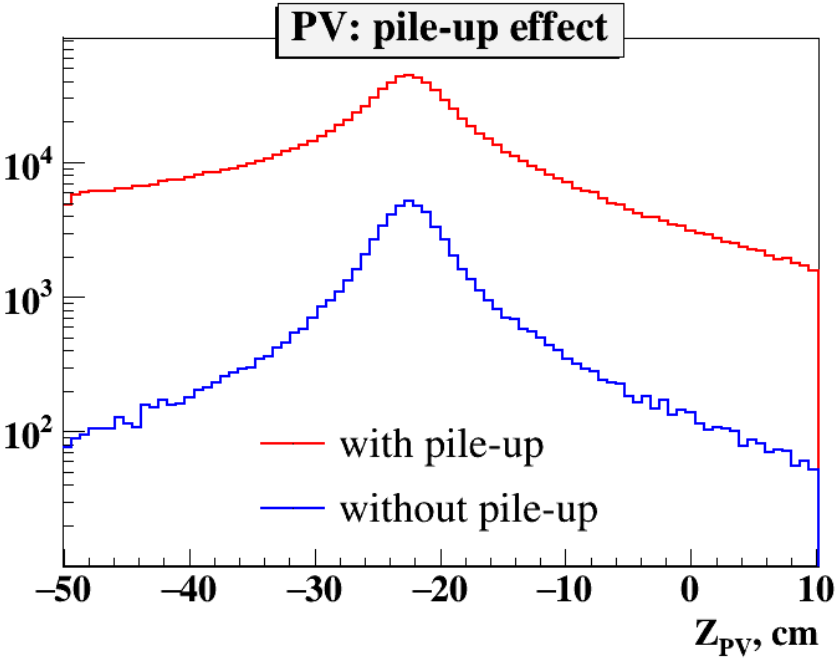
Primary vertex reconstruction

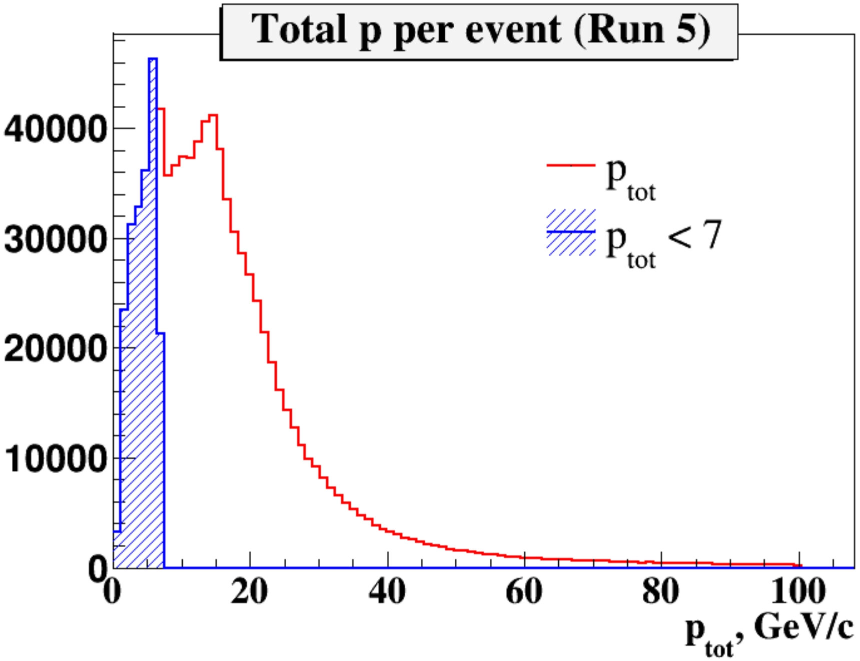


✓ Width of reconstructed vertex distribution along beam direction in data is reproduced in MC simulation.

✓ Longer tails in data distribution are due to pile-up events.

Pile-up effect in Run 5

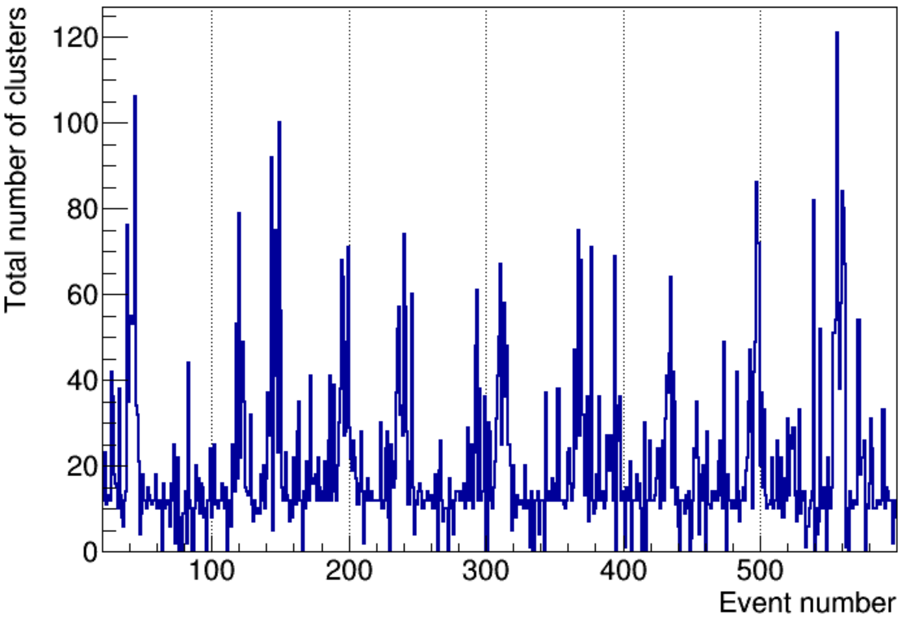


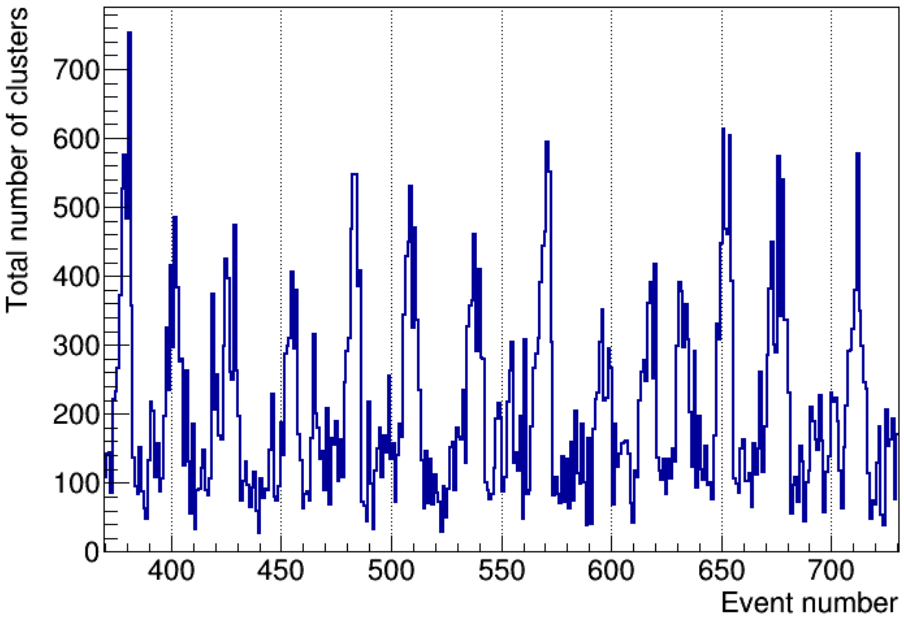


✓ Event pile-up due to non-uniform time structure of deutron beam.

✓ Cut on total momentum of particles in event < 7 GeV/c reduces pile-up significantly.

Deuteron & carbon beam structure

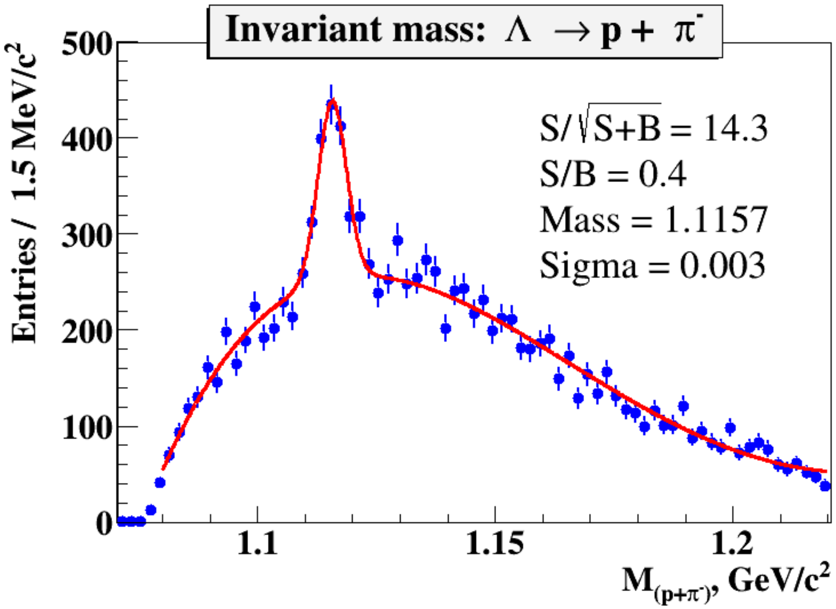


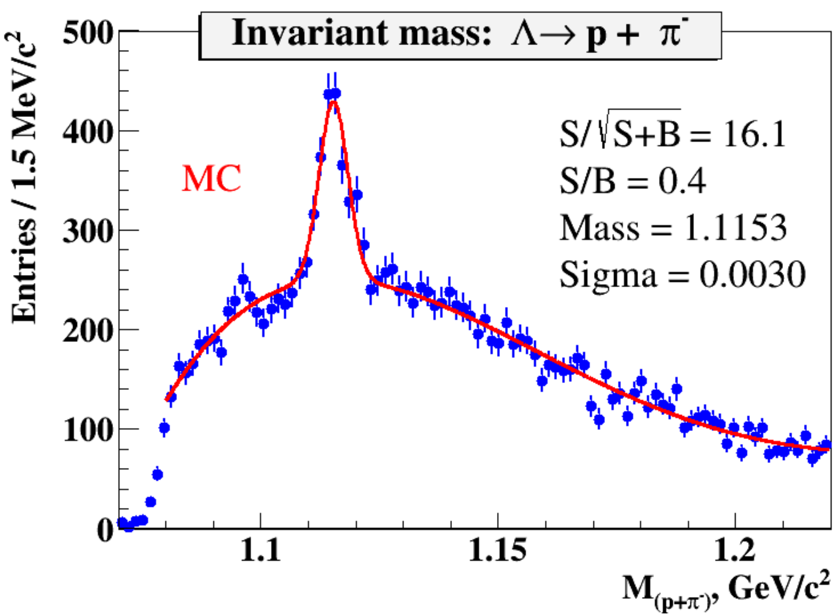


Run 5 (Dec-2016).
Deuteron beam trigger.

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

Λ reconstruction (d + Cu, C, CH_2)

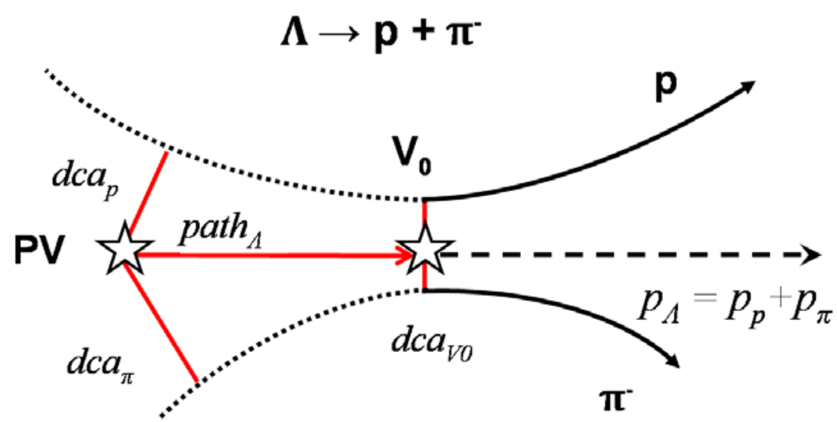




Signal event topology defined selection criteria:

✓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

Summary and next plans

✓ BM@N experiment is in starting phase of its operation and has recorded first experimental data with deuteron beam of 4 AGeV.

✓ Minimum bias interactions of deuteron beam with different targets were analyzed with aim to reconstruct tracks, primary and secondary vertexes using central GEM tracking detectors.

✓ Spatial, momentum and primary vertex resolution of GEM tracker are reproduced by Monte Carlo simulation.

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

✓ To improve vertex and momentum resolution and reduce background under Λ-hyperon signal, additional planes of GEM detectors and a set of silicon detectors in front of GEM tracking detectors will be implemented.

✓ BM@N set-up will extend continuously to adapt its performance for measurements of interactions of heavier ion beams with targets.

Thank you

for attention!

Backup slides

Data set (Run 6)

Magnetic field: 1200 A (0.59 T)

Gas in GEM: Ar+CO_2

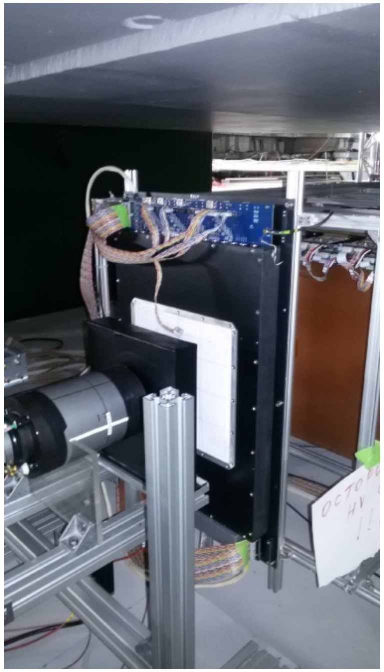
- **Beam / Target:** C / Cu (2205k events), E_{kin} = 4.5 AGeV
- **Beam / Target:** C / C (2050k events), E_{kin} = 4.5 AGeV
- **Beam / Target:** C / Al (1730k events), E_{kin} = 4.5 AGeV

Gas in GEM: Ar+Isobuthan

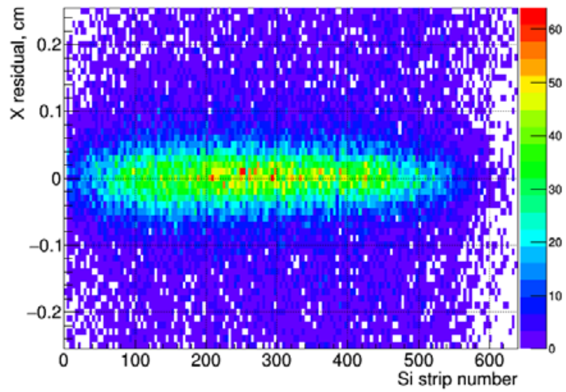
- **Beam / Target:** C / C (2028 k events), E_{kin} = 4.5 AGeV
- **Beam / Target:** C / Al (2163k events), E_{kin} = 4.5 AGeV

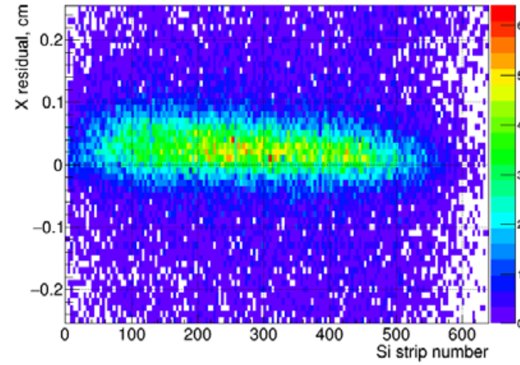
GEM position from target: 51-86-116-151-181-216 cm

Forward silicon strip detector

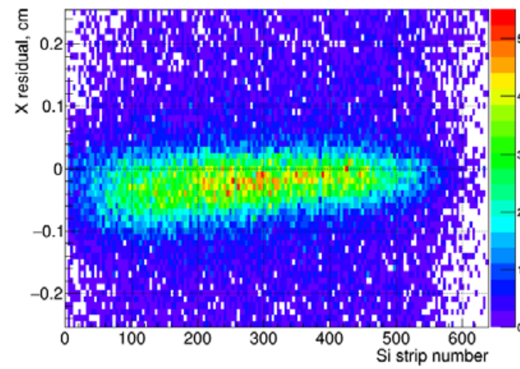


Si-GEM residuals (cm) vs strip number



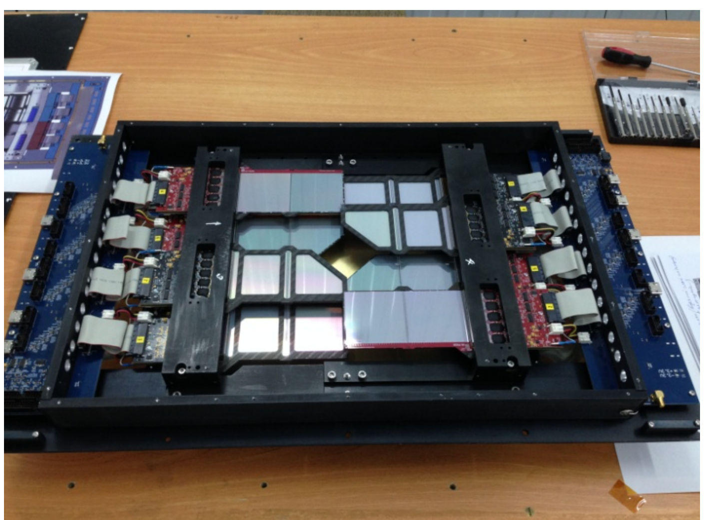


Z + 2mm misalignment



Z - 2mm misalignment

Silicon detector group, N.Zamiatin

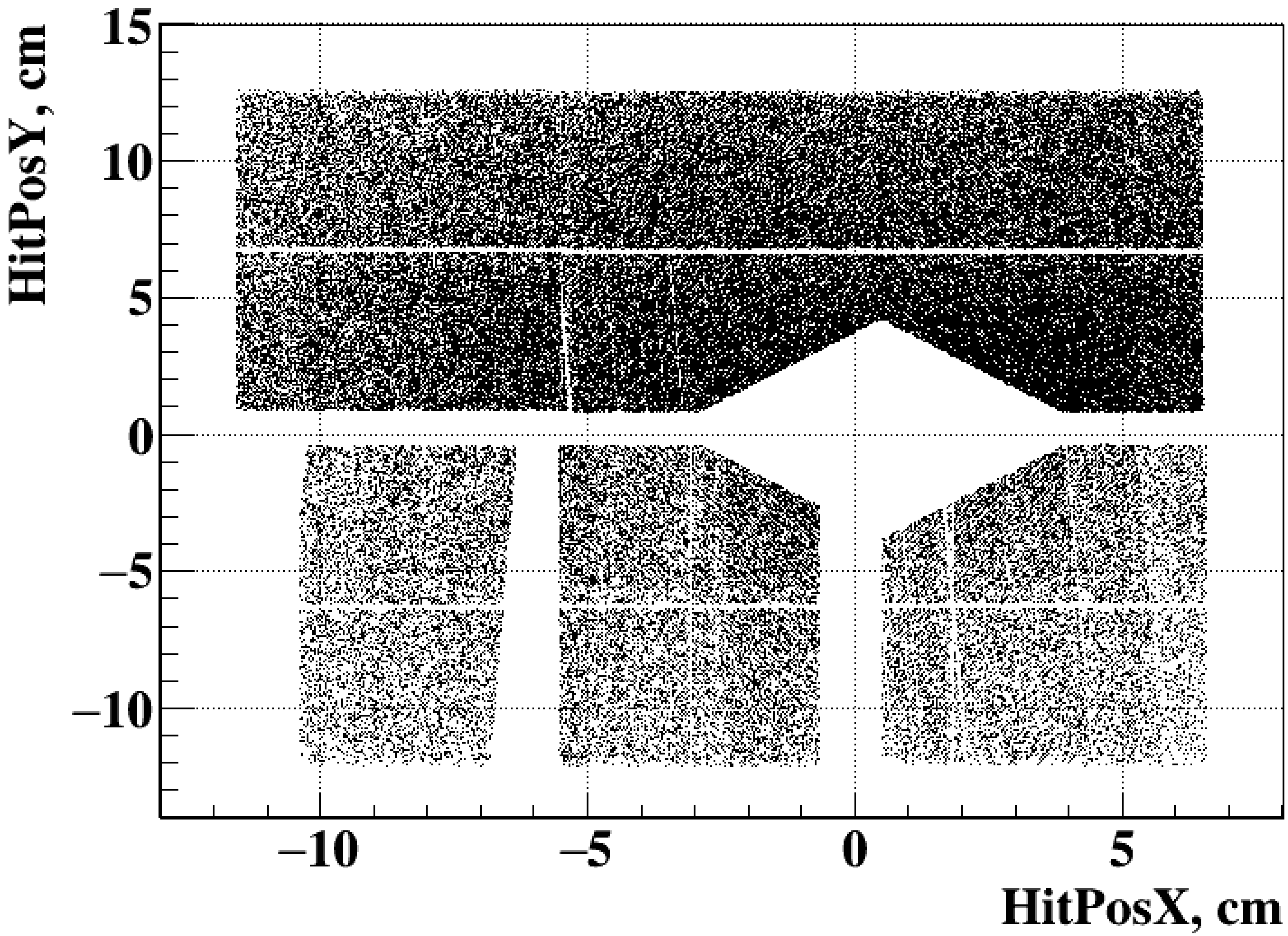


✓2-coordinate Si detector X-X'(±2.5°) with strip pitch of 95/103 μm, full size of 25 x 25 cm^2 , 10240 strips

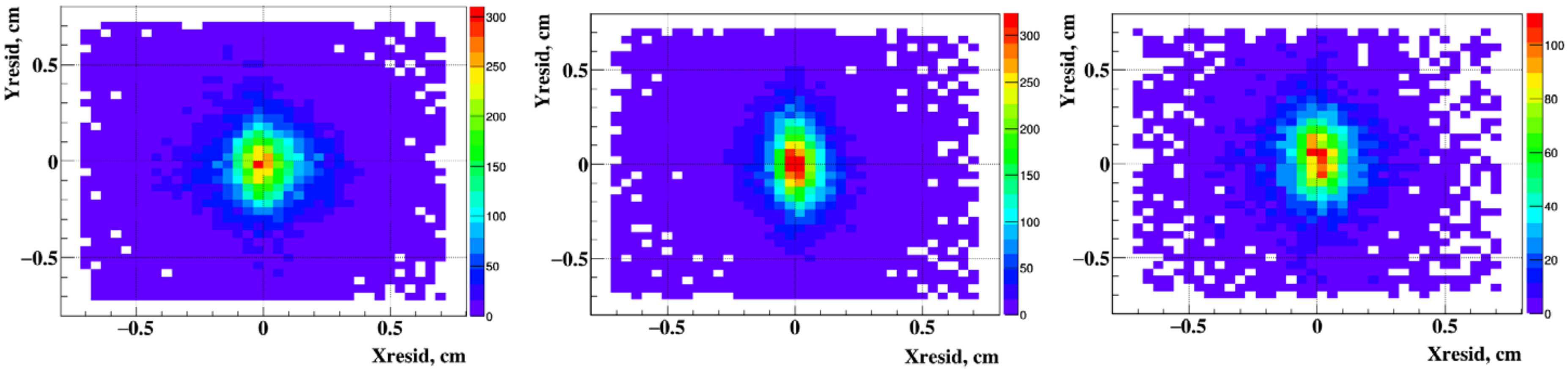
✓Detector combined from 4 sub-detectors arranged around beam, each sub-detector consists of 4 Si modules of 6.3 x 6.3 cm^2

✓One plane installed in front of GEM tracker and operated in March 2017

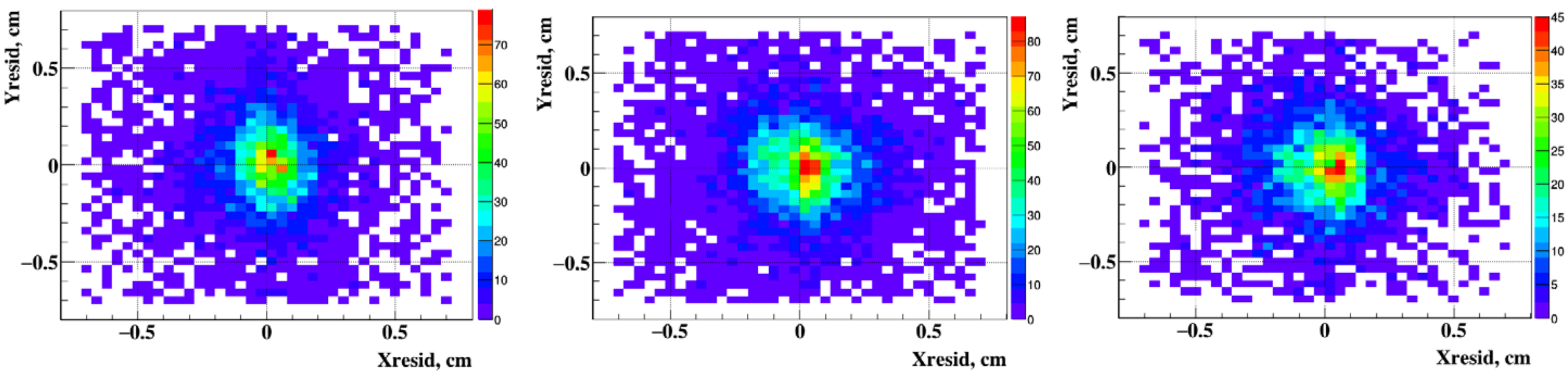
Hits in silicon detector



Residuals in silicon detector

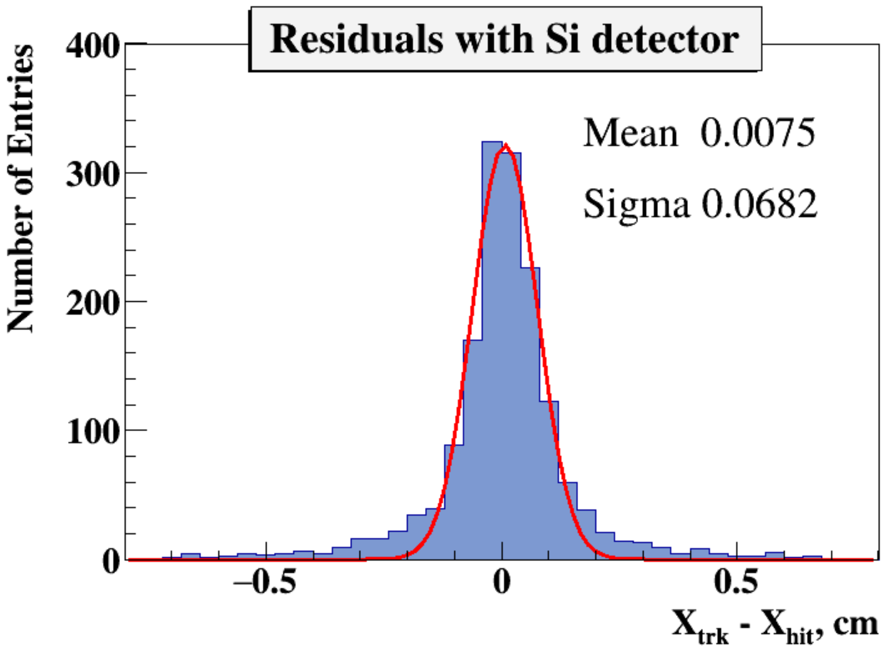


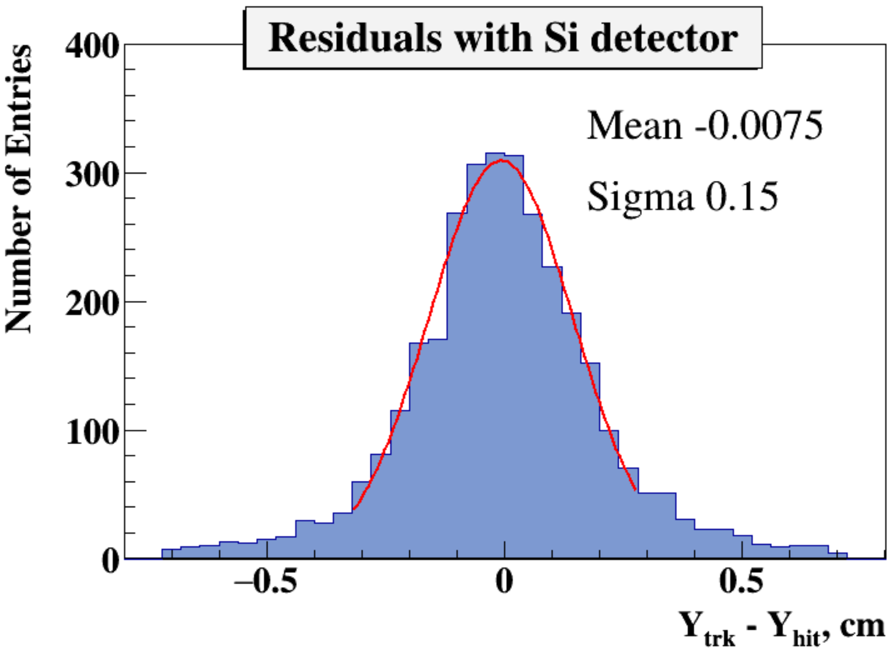
Modules 2,3,4



Modules 6,7,8

Residuals in silicon detector





Primary Vertex reconstruction