Track reconstruction and GEM detector performance in BM@N experiment

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JINR LHEP

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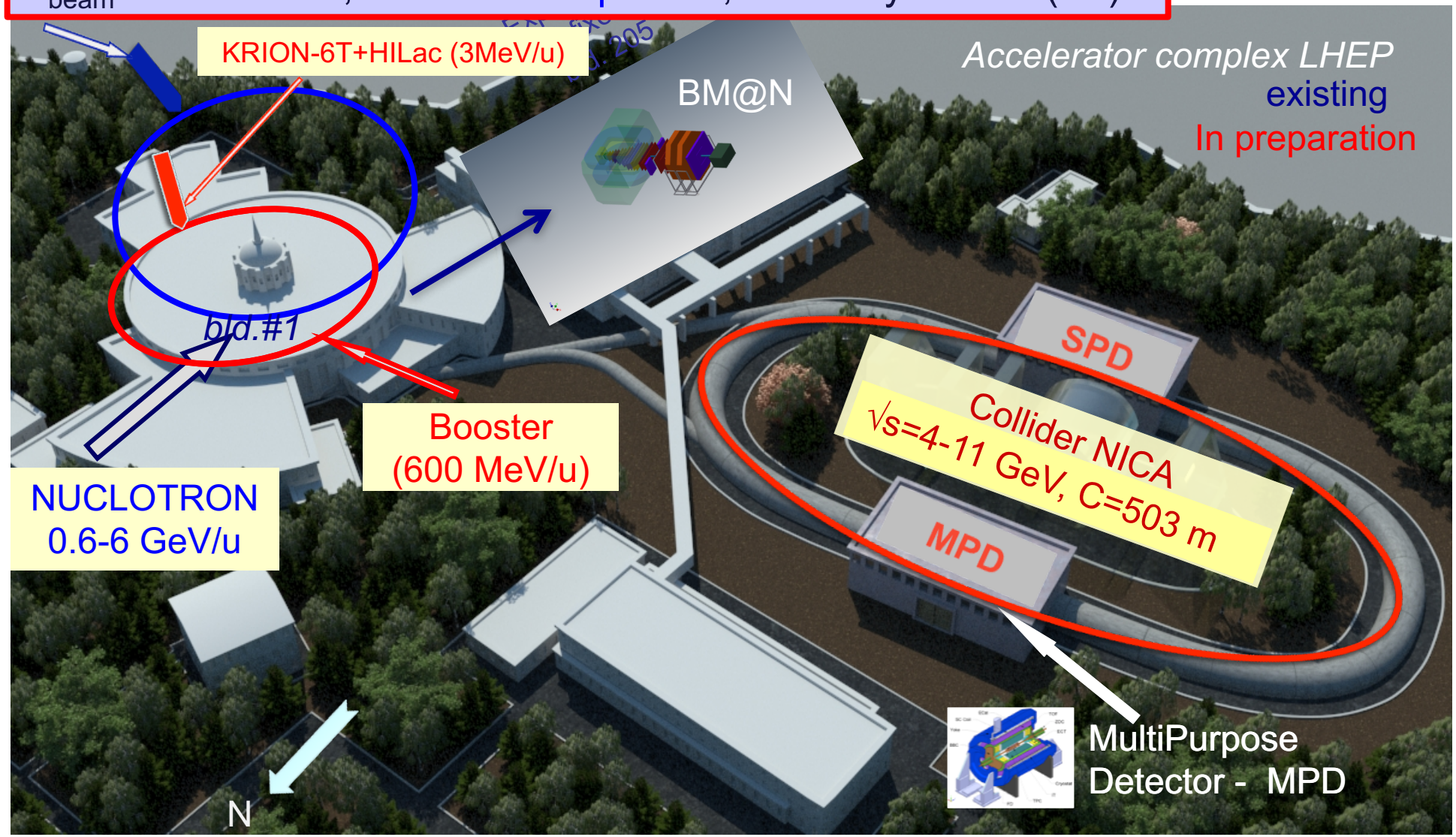
Outline

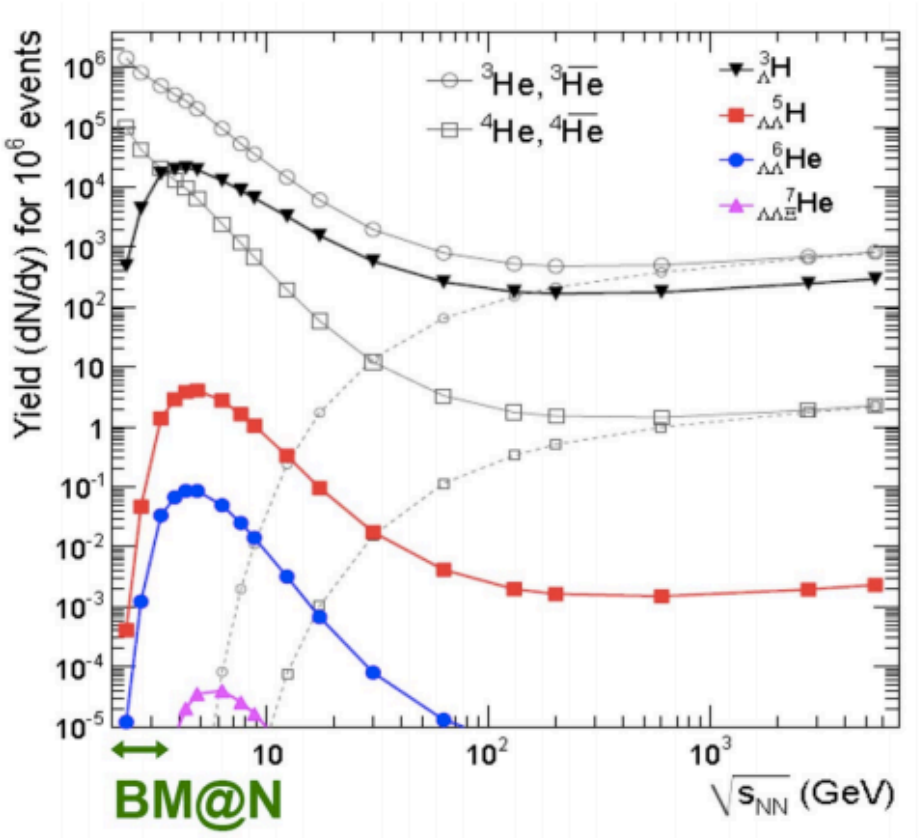
- BM@N experimental set-up
- Multi-Wire Proportional Chamber(MWPC)
- Drift Chamber (DCH)
- Beam momentum reconstruction
- The Gas Electron Multiplier (GEM) tracking
- GEM hit efficiency with Nuclotron data
- Resolution for GEM

Complex NICA

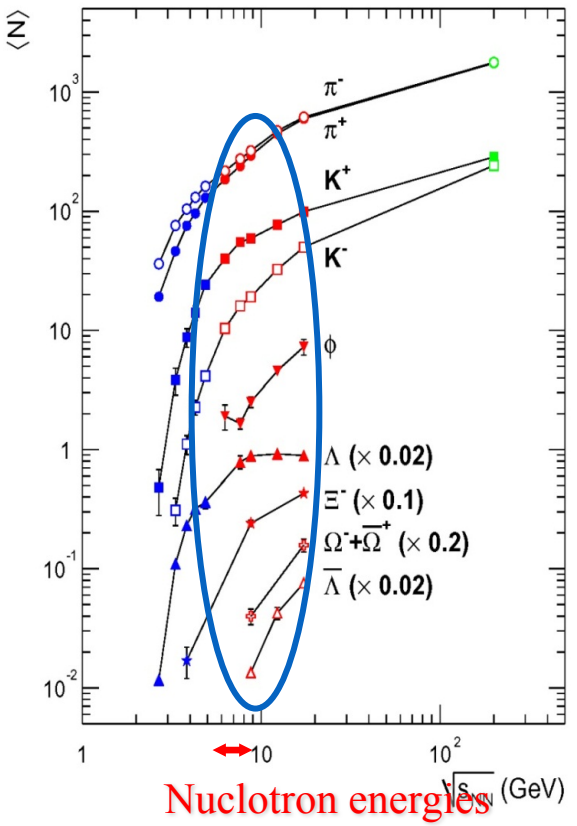
Parameters of Nuclotron for BM@N experiment:
E_{beam} = 1-6 GeV/u; *beams: from* p to Au; Intensity~10^7 c^{-1} (Au)



Physics possibilities at the Nuclotron



AGS NA49 BRAHMS

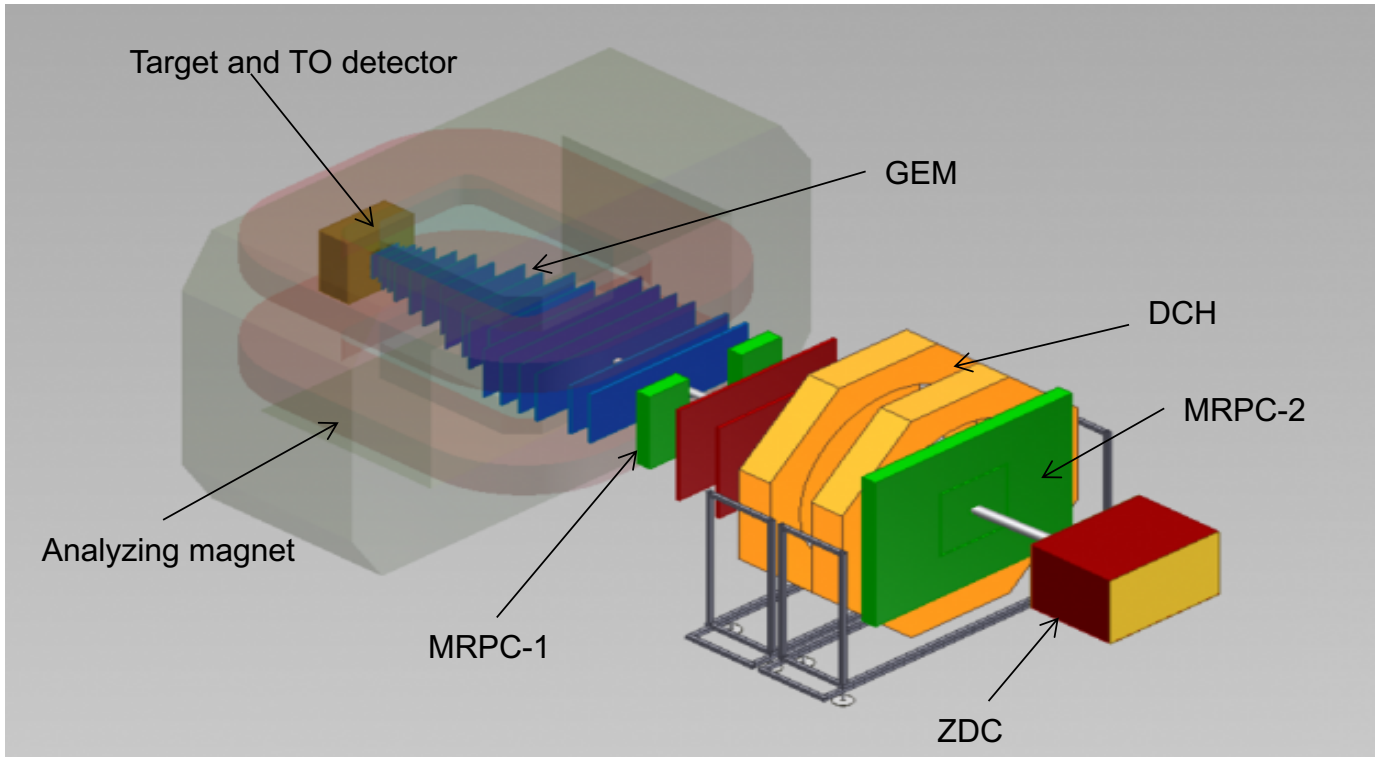


The aim of the experiment is to study interactions of relativistic heavy ion beams.

- **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

BM@N setup

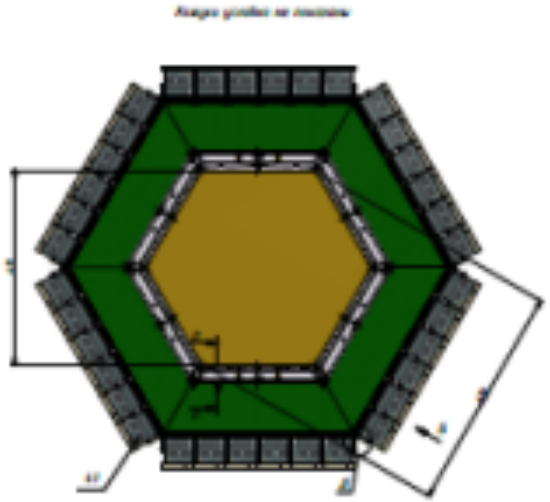


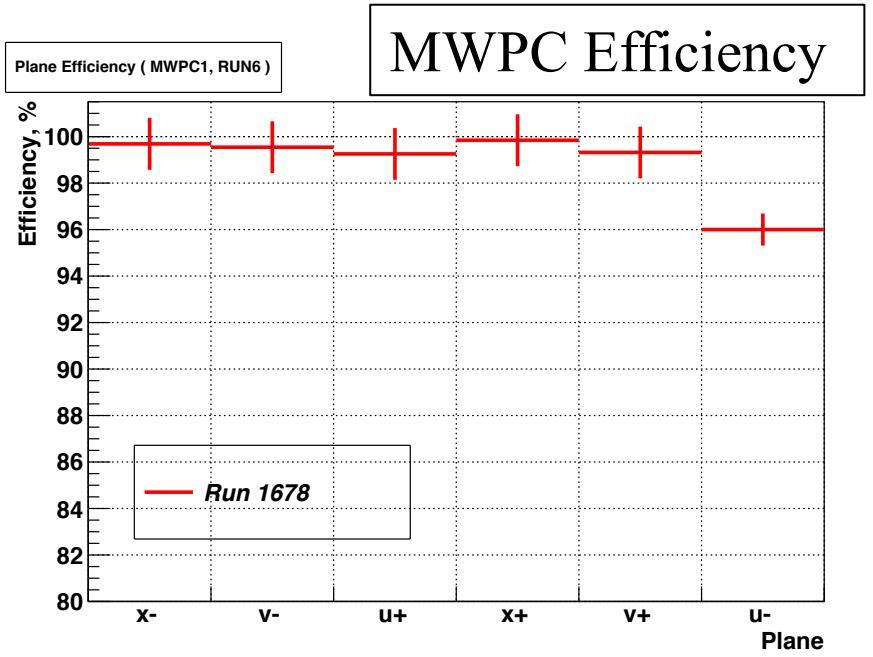
- Central tracker (GEM) inside analyzing magnet to reconstruct AA interactions
- Outer tracker (DCH, CPC) behind magnet to link central tracks to ToF detectors
- ToF system based on mRPC chambers and T0 detectors to identify hadrons and light nucleus
- ZDC calorimeter to measure centrality of AA collisions and form trigger
- Detectors to form T0, L1 centrality trigger and beam monitors
- Electromagnetic calorimeter for γ,e+e-
- MWPC chambers were used as beam trajectory detectors

Multi-Wire Proportional Chamber(MWPC)

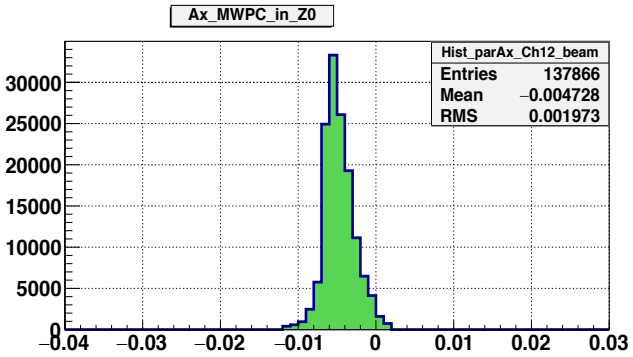
In the last experiment (RUN5, RUN6), two chambers were placed on the beam

- 6 planes in each chamber : two X, two U and two V-planes.
- 3 double coordinate planes
- wire angles 0°,±60°
- wire pitch d = 2.5 mm
- Resolution $^{d}/_{\sqrt{12}}$ = 0.72 mm
- 576 wires per chamber

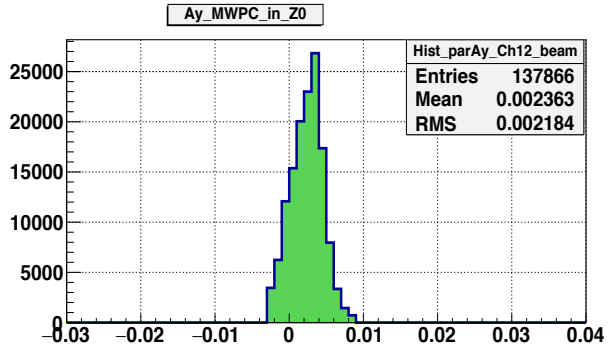




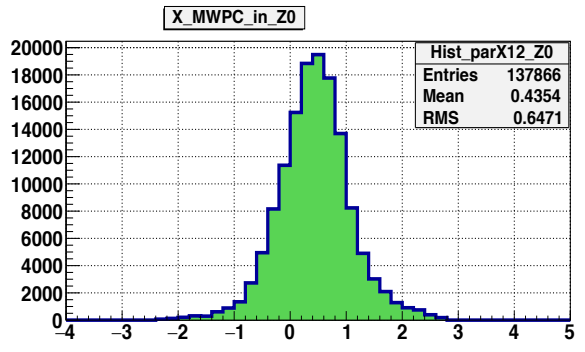
α_{in}



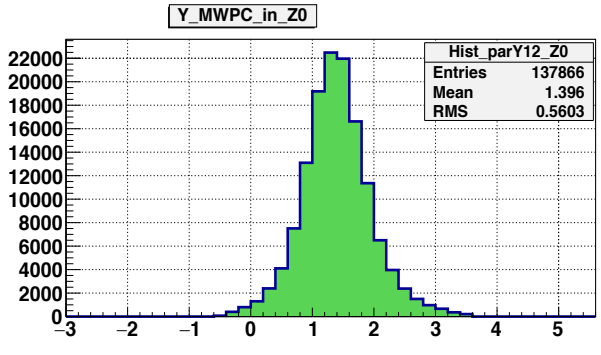
α_x



α_y



X

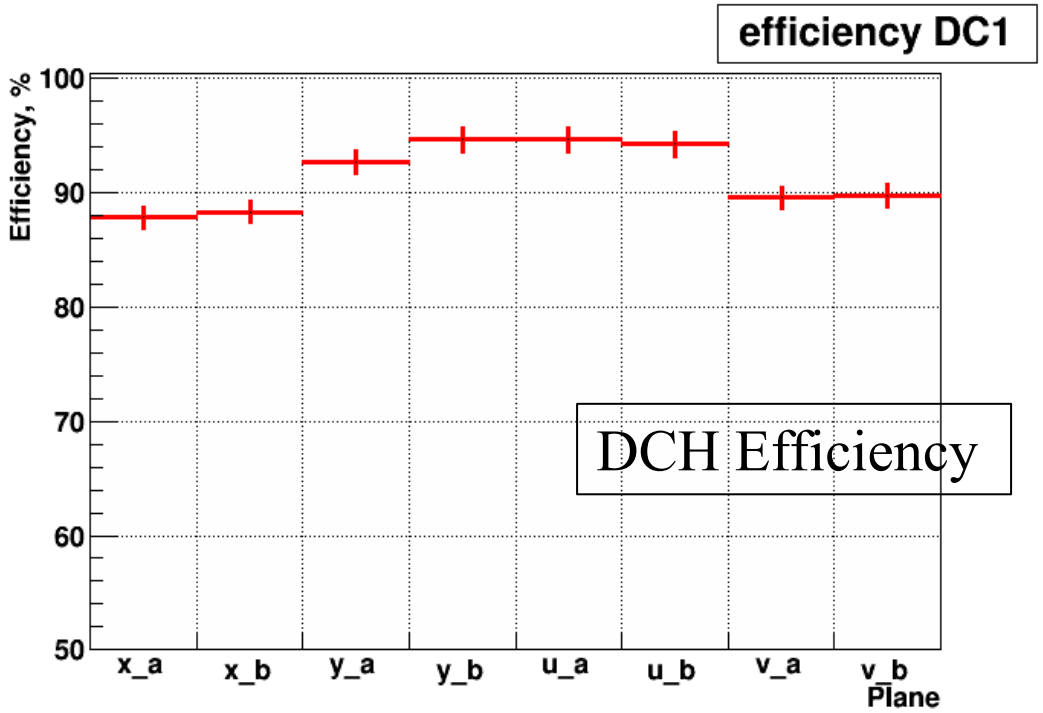


Y

Drift Chamber (DCH)

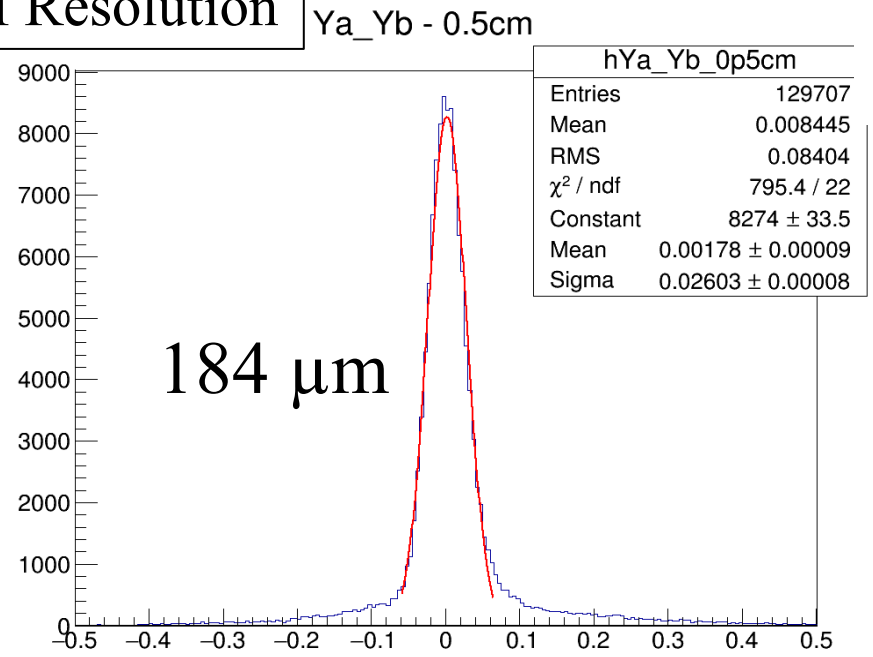
The detectors were brought from NA48 experiment:

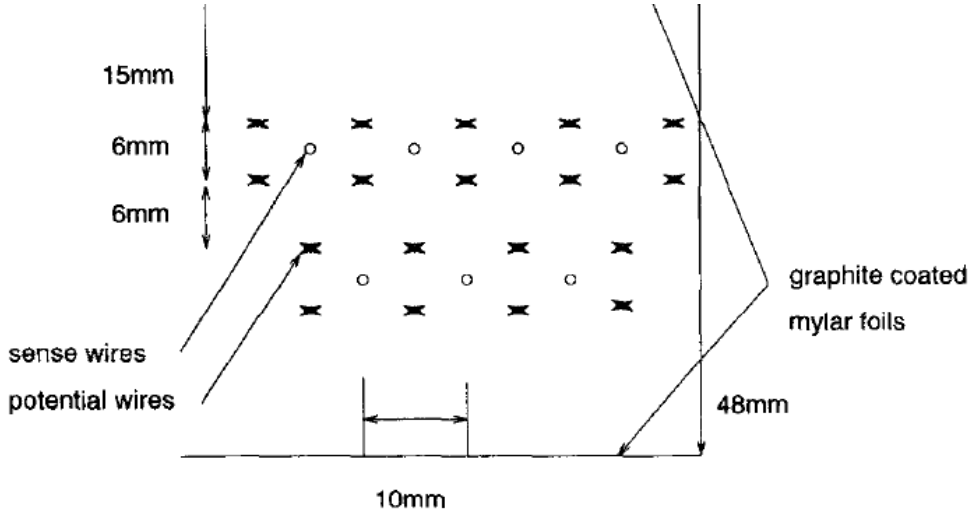
- 4 double coordinate planes
- wire angles 0°,90°,±45°
- wire pitch 10 mm
- Yout ± 1.35 m, Xout ± 1.35 m
- R_hole = 10 cm
- 2048 wires per chamber



DCH Efficiency

DCH Resolution



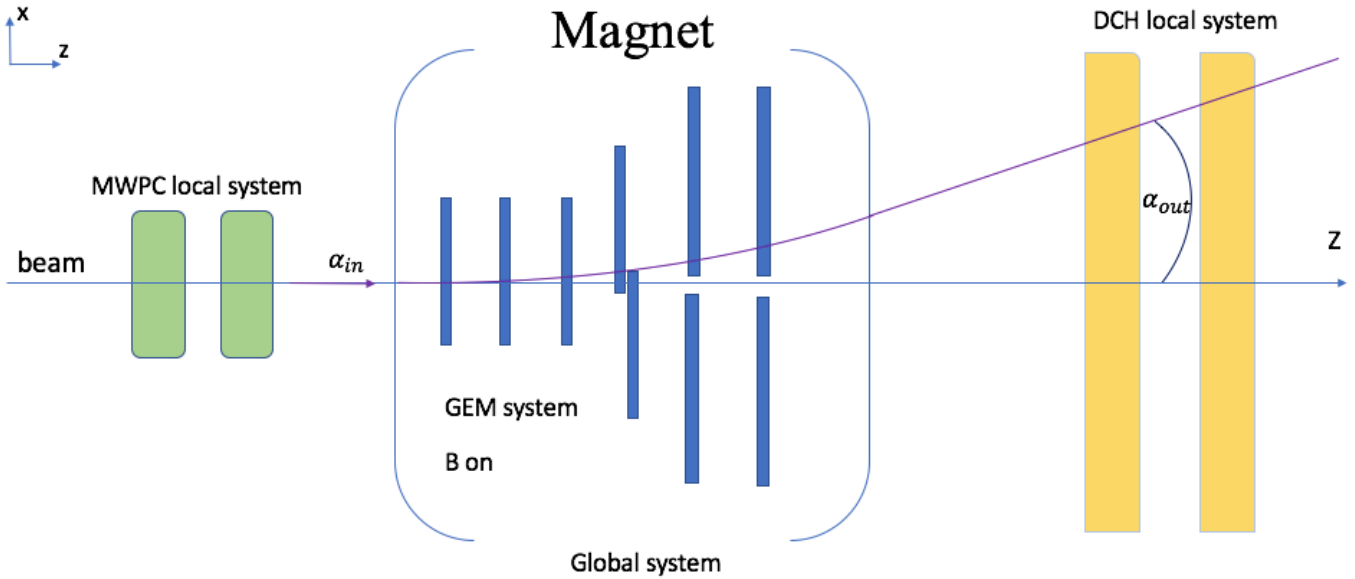


Schematic representation of one DC plane

Beam momentum estimation

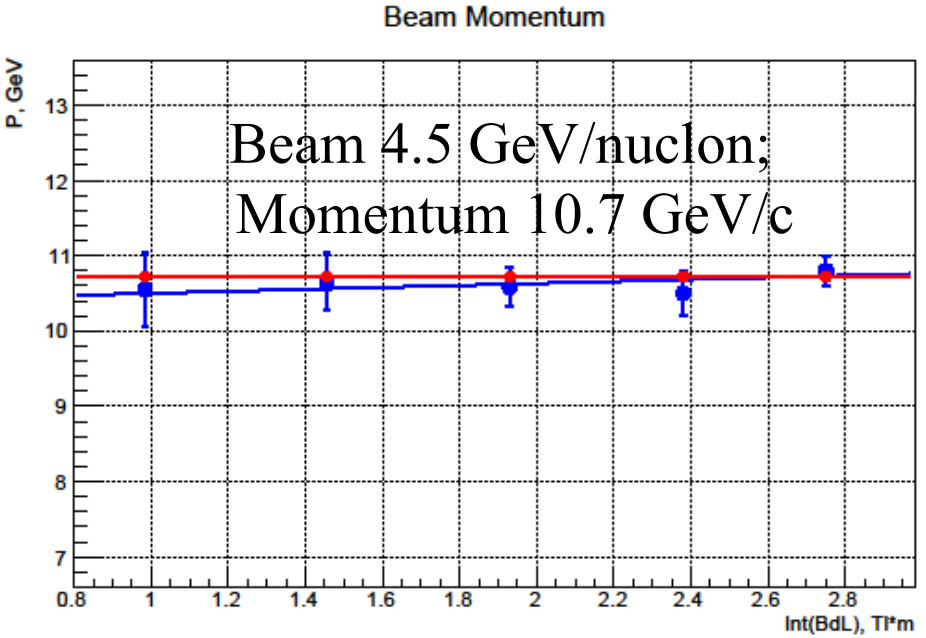
α_{in} - angle of beam before magnet;
α_{out} - angles of beam after magnet;
$\int Bdl$ - magnet field integral [T*m].

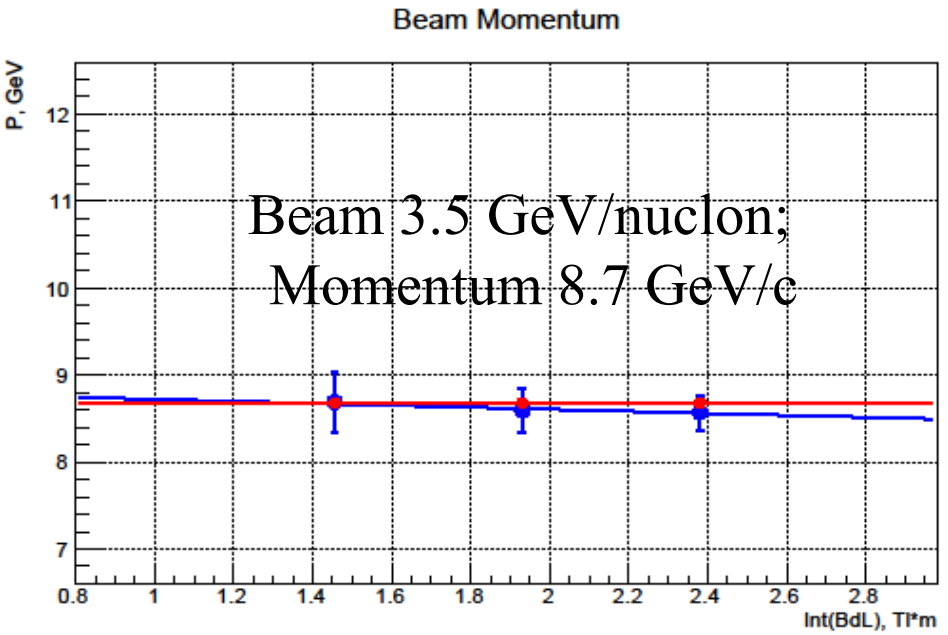
$$P_{beam} = \frac{0.3 * \int Bdl}{\sin(\alpha_{out} - \alpha_{in})}$$



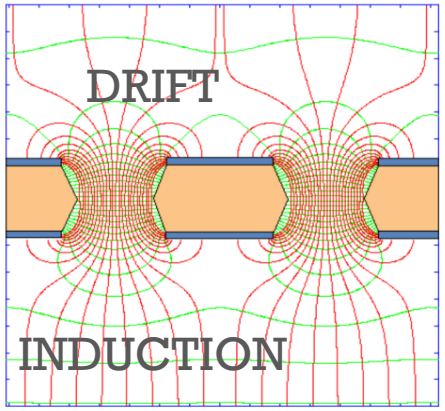
$$P_{beam} = \frac{A}{Z} * \sqrt{\left(E/n + M_p\right)^2 - M_p^2}$$

A - mass number; Z - number of protons;
E/n- beam energy per nucleon; M_p - proton mass.

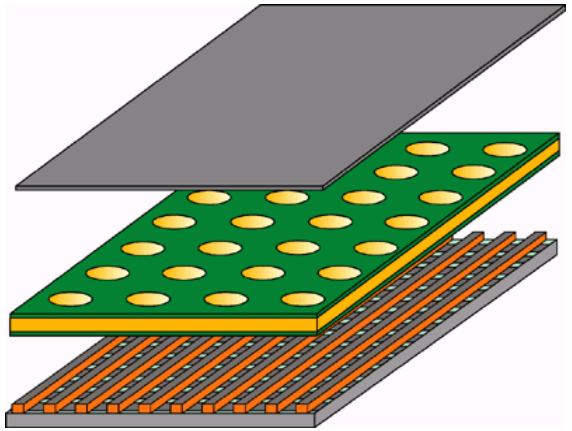




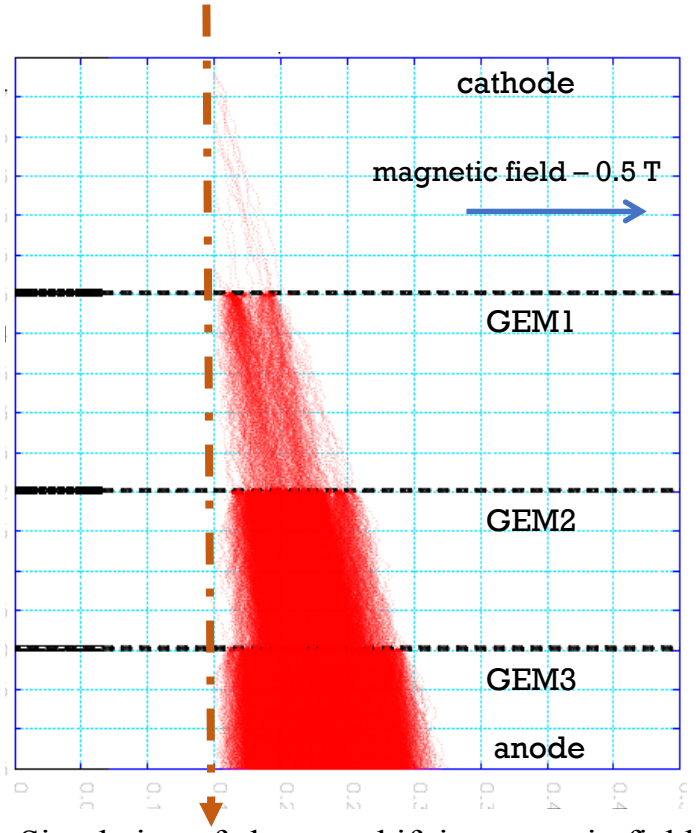
The Gas Electron Multiplier (GEM)



Electric field in the region of the holes of a GEM electrode



Schematics of single GEM detector with Cartesian two-dimensional strip readout.

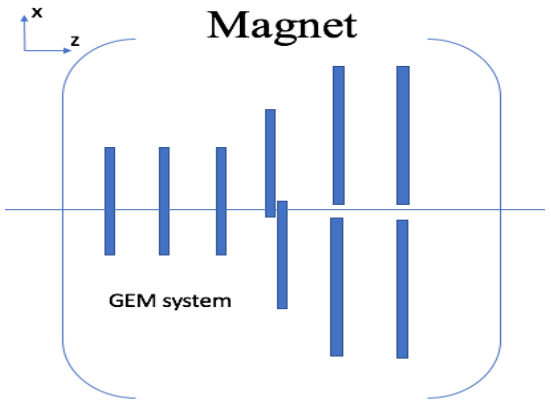


Simulation of electron shift in magnetic field

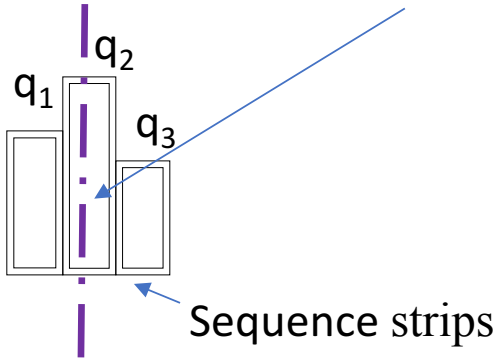
The basic requirements for the tracking system are:

- capability of stable operation in conditions of high radiation loadings up to 10^5 Hz/cm^2;
- maximum possible geometrical acceptance within the BM@N experiment dimensions;
- good timing (5-10ns) and spatial resolution (100 -150 microns).

Track-segment building algorithm (Mag.field off)

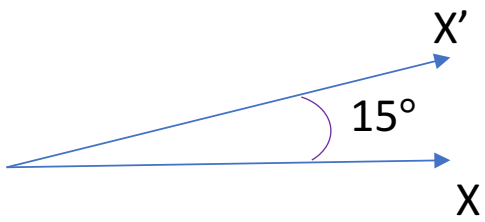


In each fired strip charge from electron avalanche is collected.

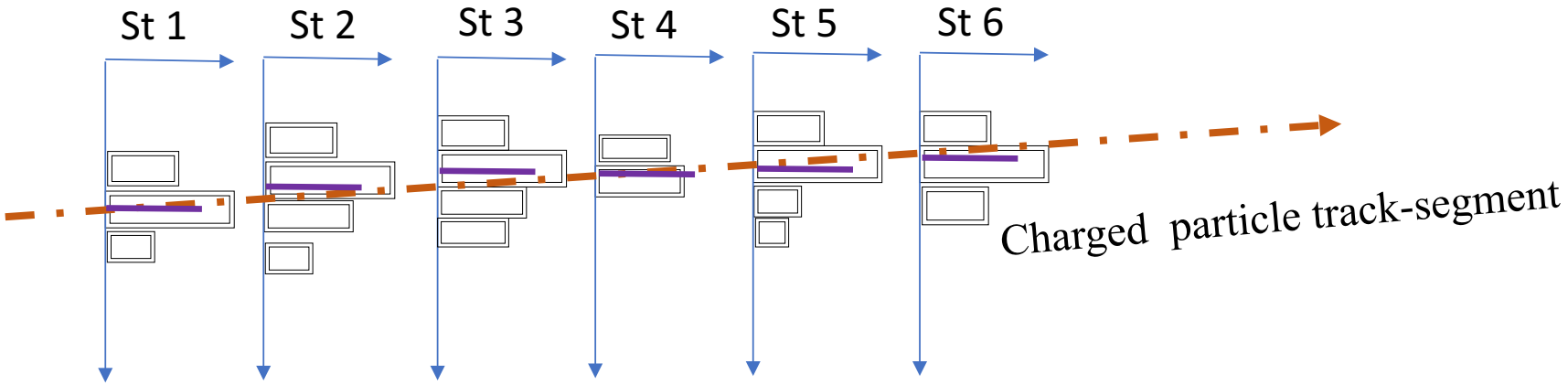


Reconstructed hit coordinate (measurement) :

$$CoG_x = \frac{\sum q_i * x_i}{\sum q_i}$$



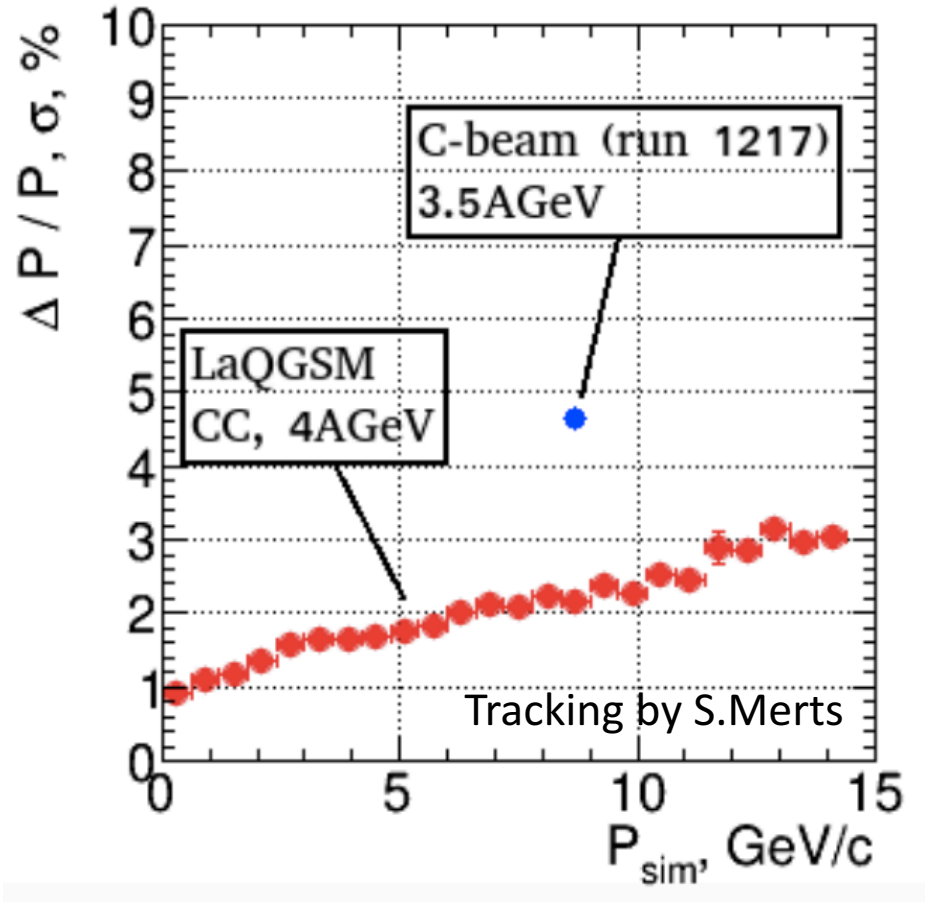
X & X' layers in each station

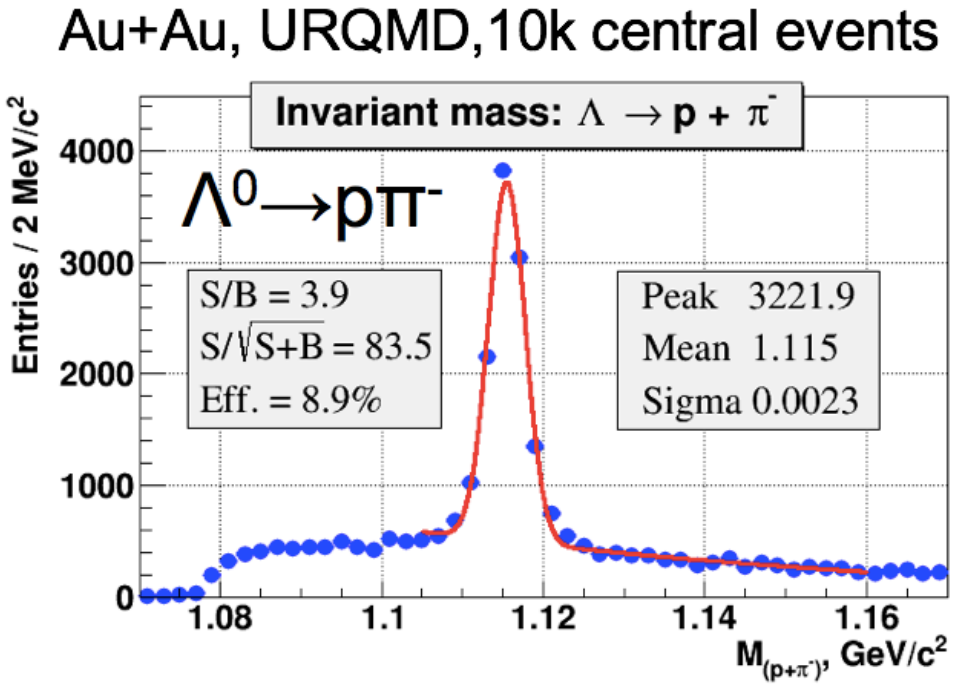


Collecting X & X' hits located around straight line we build spatial track-segments.

Track-segment building (Mag.field on)

Momentum resolution Exp. vs. MC

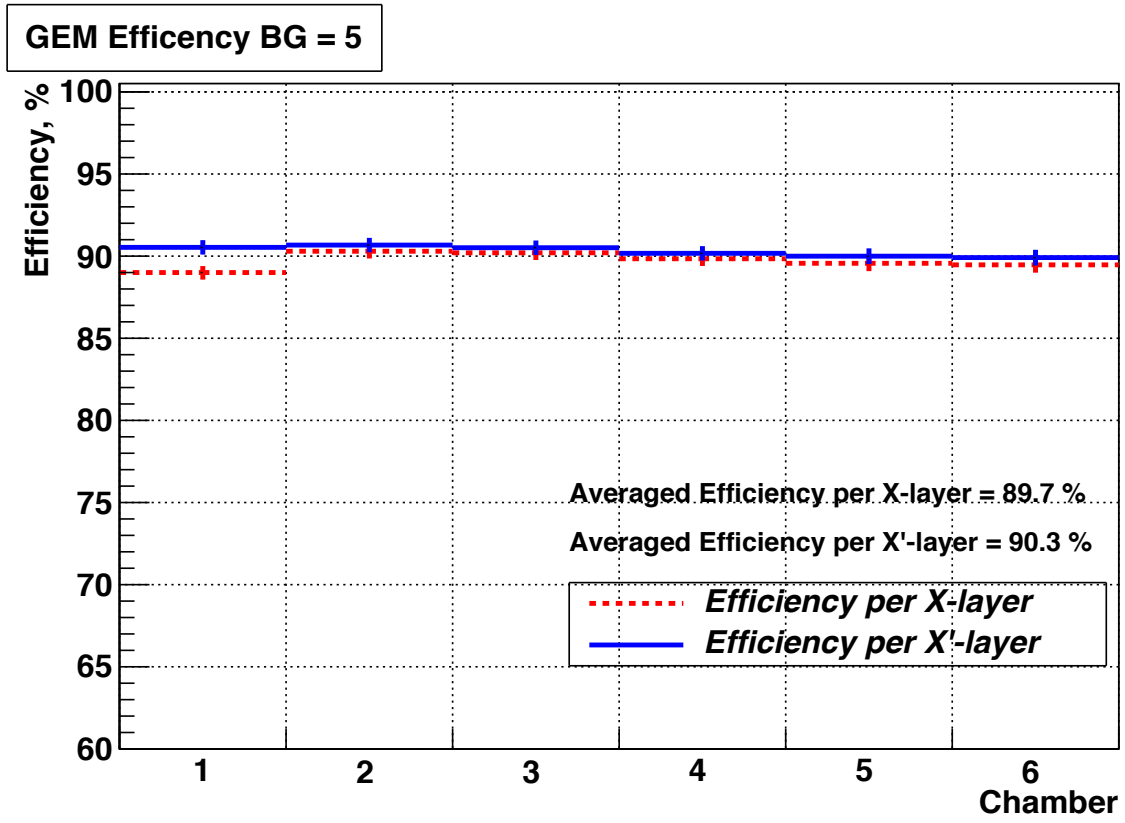


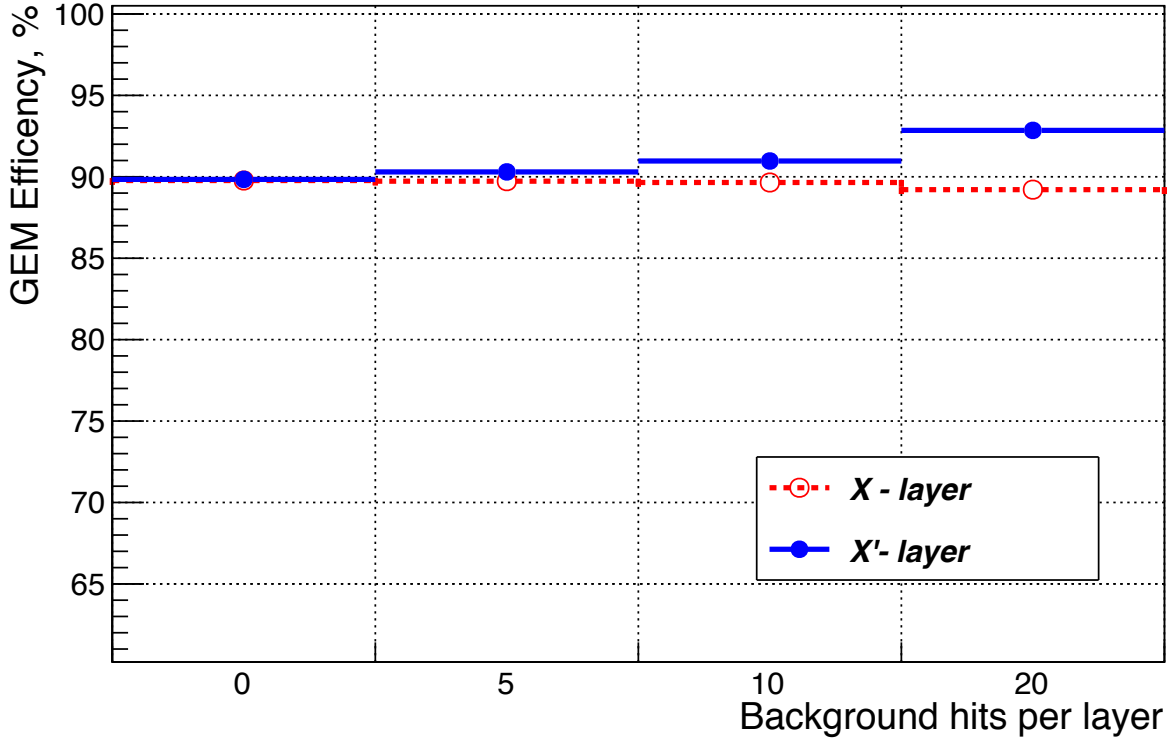


work is in progress

Testing of efficiency calculation algorithm with MC

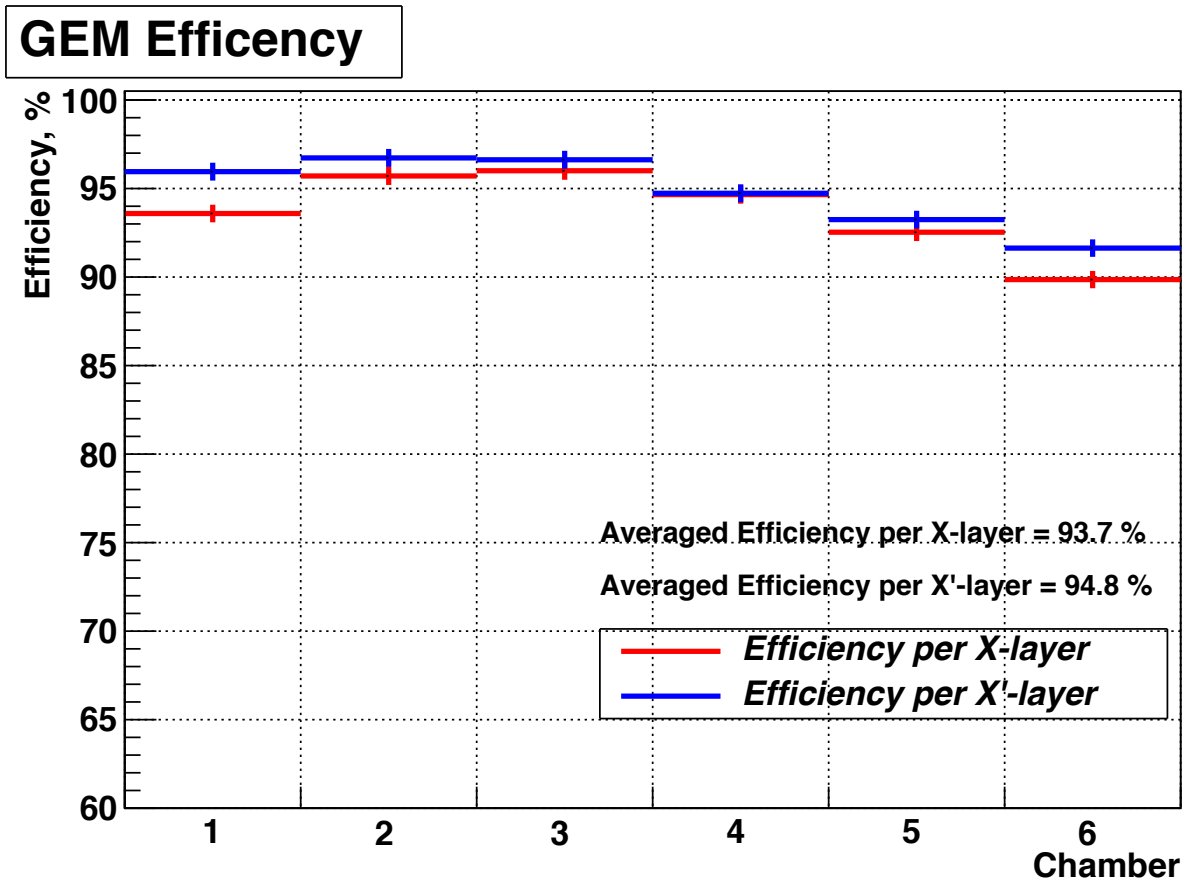
Established Efficiency per layer is 90%



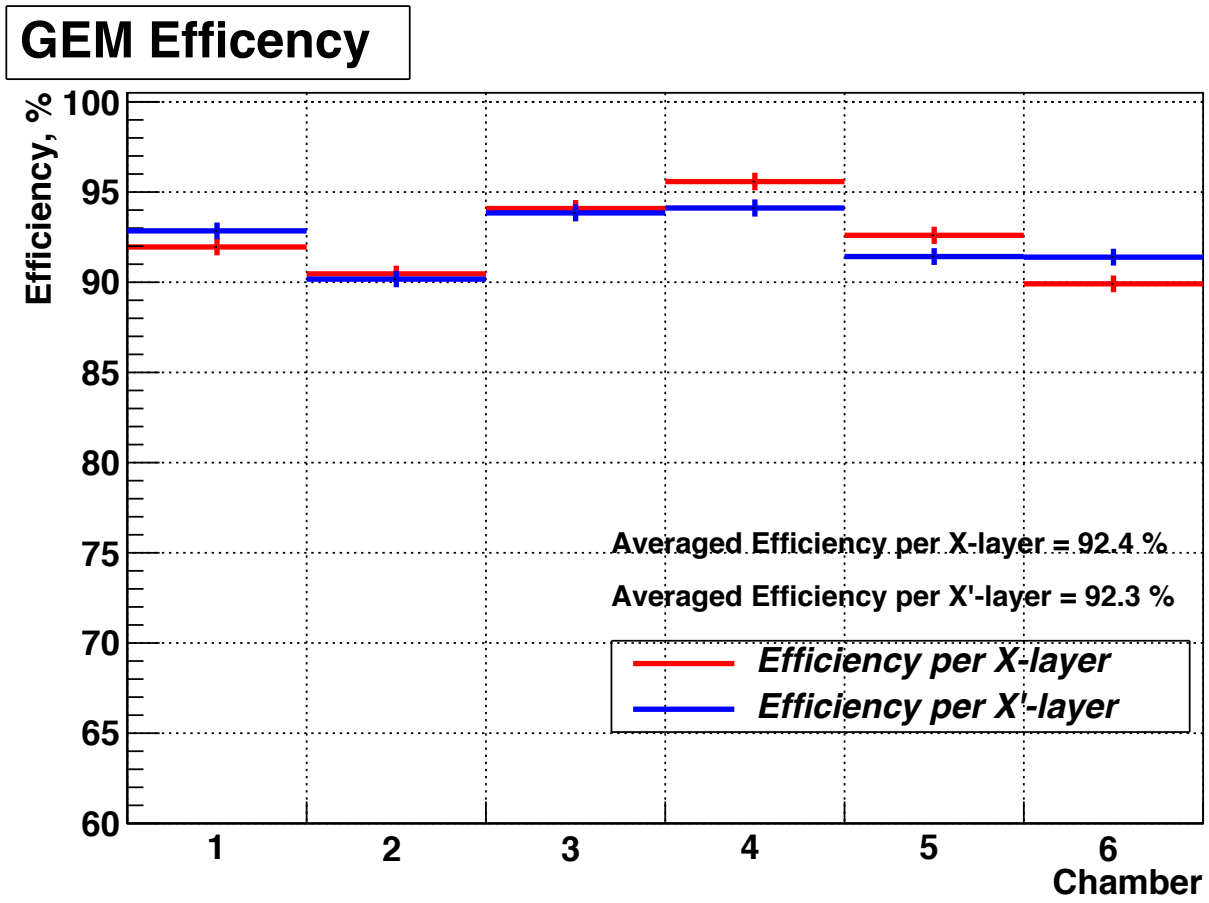


GEM hit efficiency per layer with Nuclotron data

Ar + CO_2



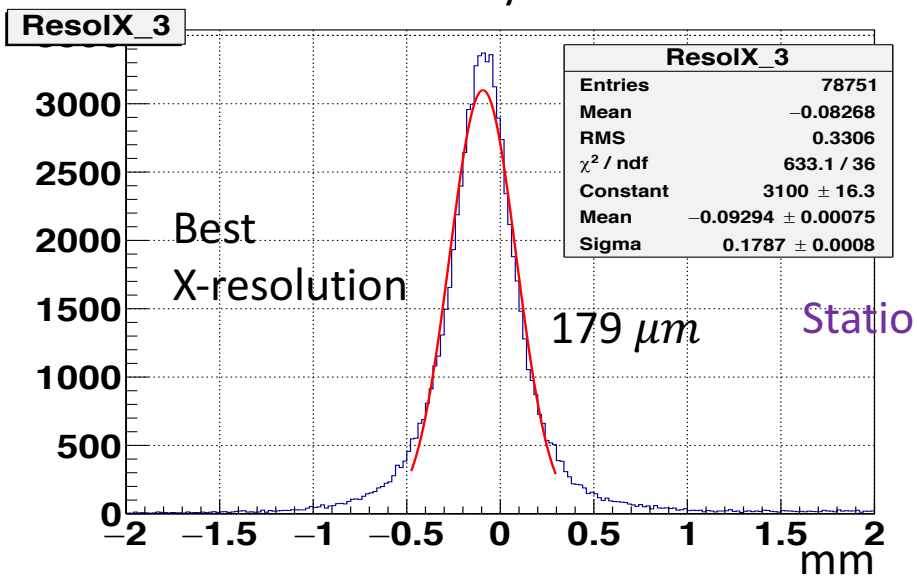
Ar + Isobutane



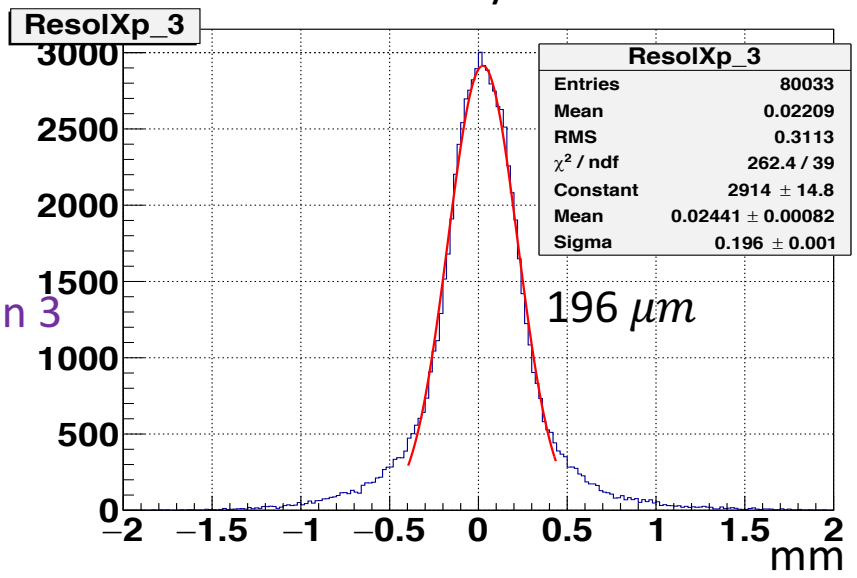
Difference between gas mixtures is not so essential 1-2 %

Resolution for GEM with Ar + CO_2 (Run6)

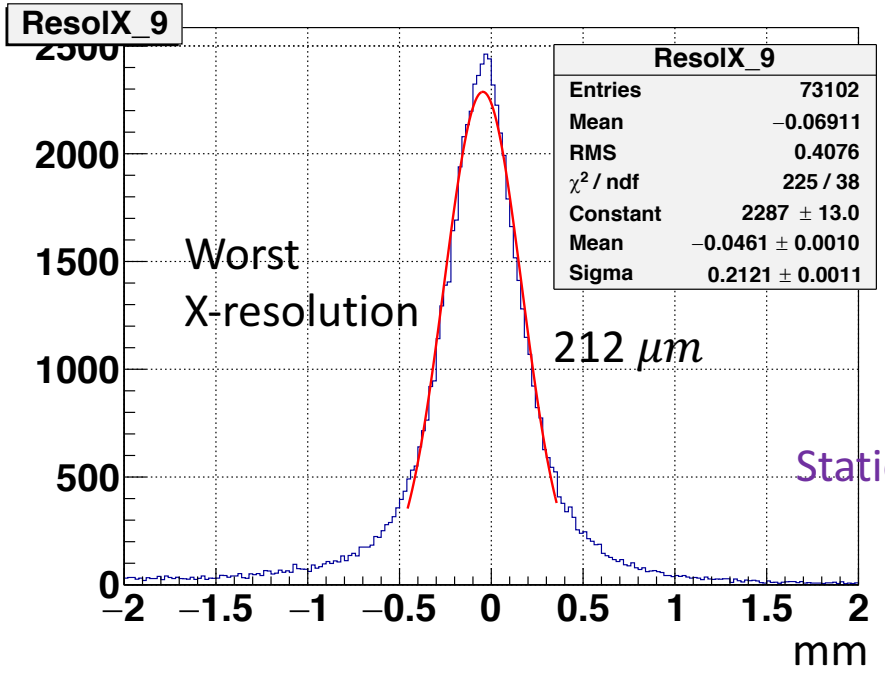
X layers

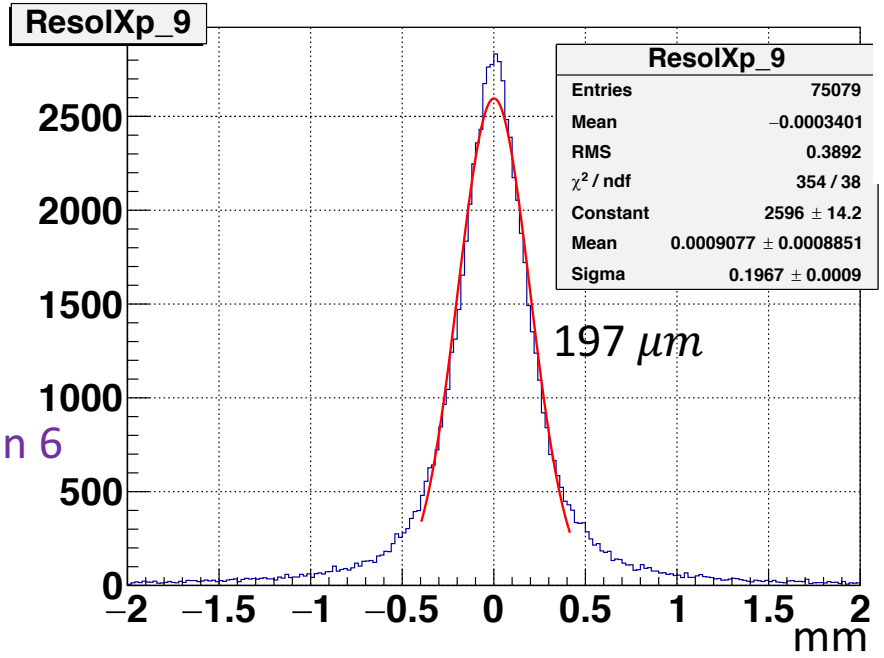


X' layers

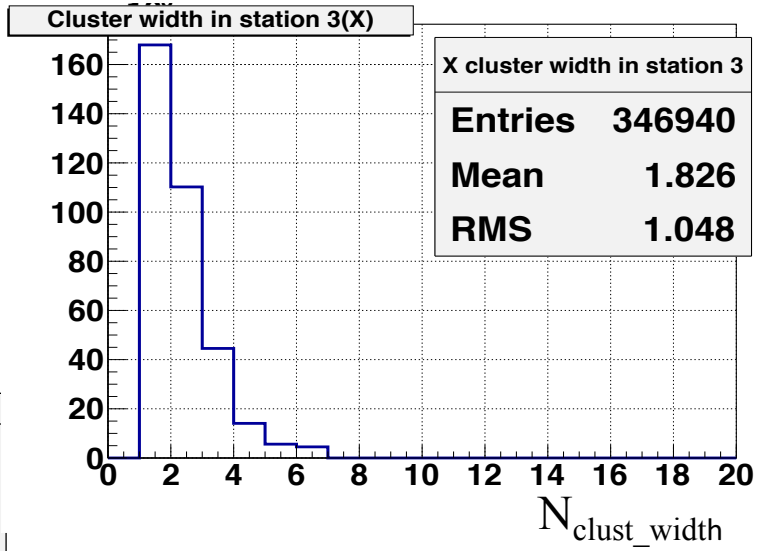


Station 3





Station 6

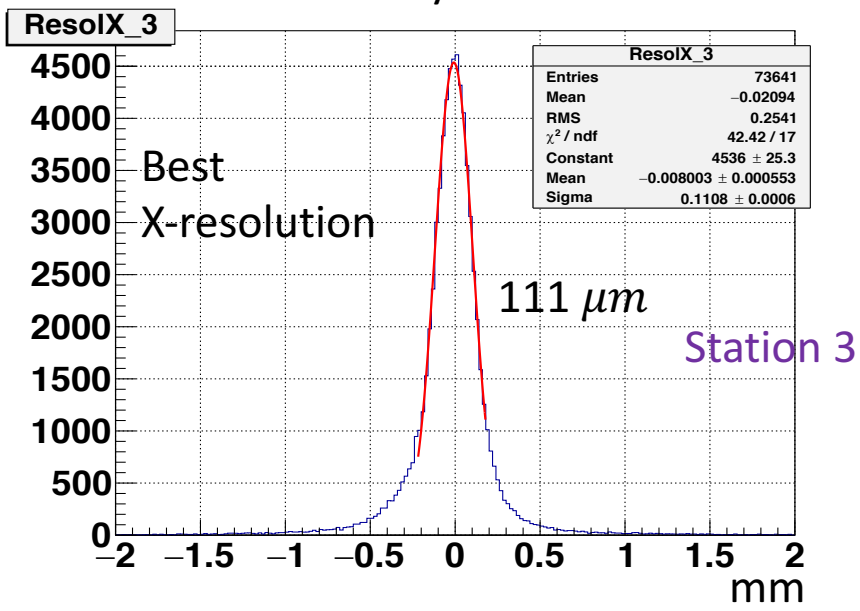


$$\frac{\Delta}{\sqrt{12}} = \frac{800\mu m}{\sqrt{12}} = 231\ \mu m$$

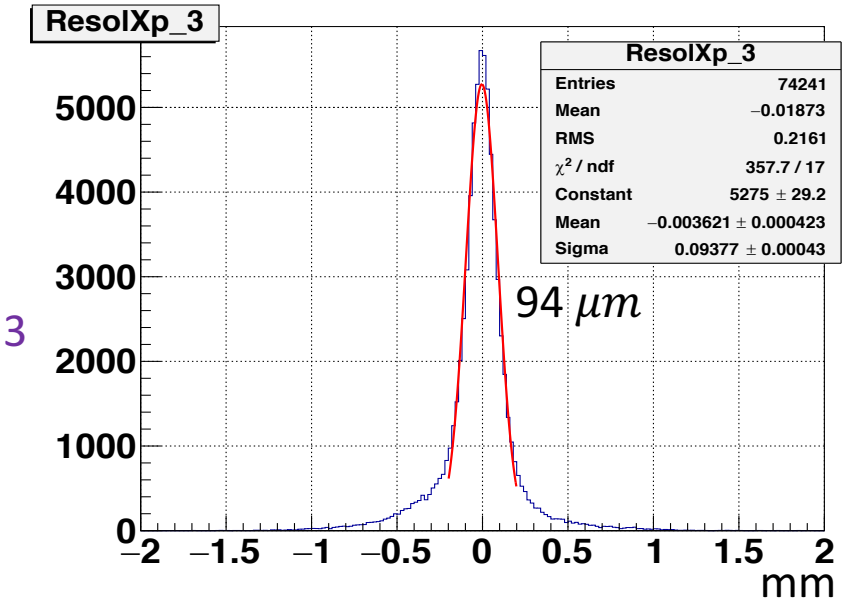
Δ - GEM strip width

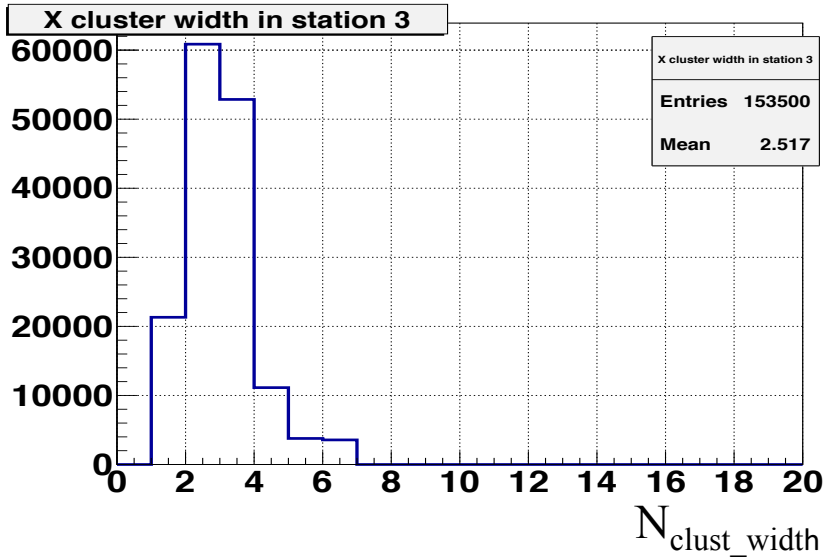
Resolution for GEM with Ar + Isobutane (Run5)

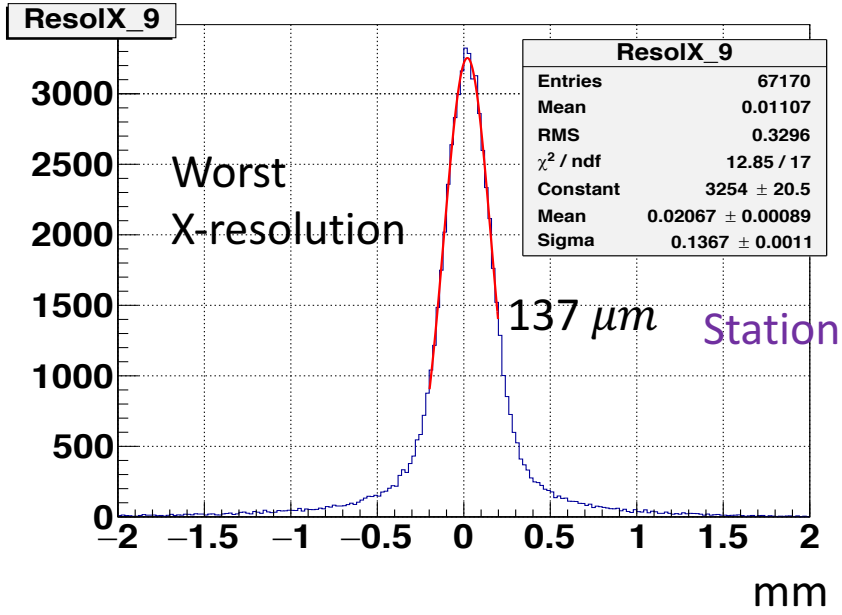
X layers

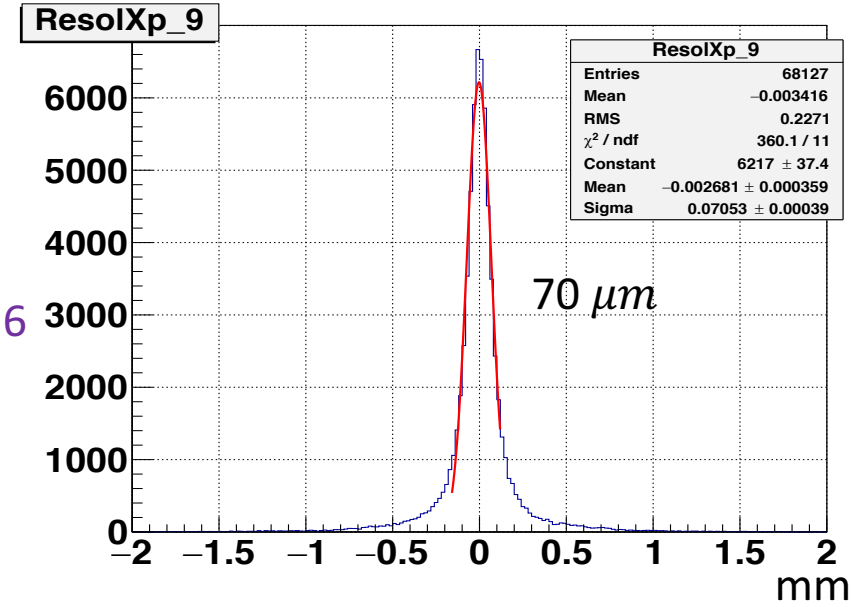


X' layers









Conclusions

1. General tracking includes external and internal detectors:
   - by external(MWPC & DCH) detectors $\frac{dP}{P}$ with maximum the magnetic field $\approx 2\%$
   - by internal(GEM) detectors $\frac{dP}{P}$ with the magnetic field $\approx 5\ \%$ ⟹ work is in progress
2. GEM detector performance in BM@N experiment with Nuclotron data was received:
   - Satisfied hit efficiency per layer 92-95%;
   - Spatial resolution 180-200 microns with gas mixture Ar + CO_2;
   - Good spatial resolution 70-140 microns with gas mixture Ar + Isobutane.

Thank you for your attention!

Backup

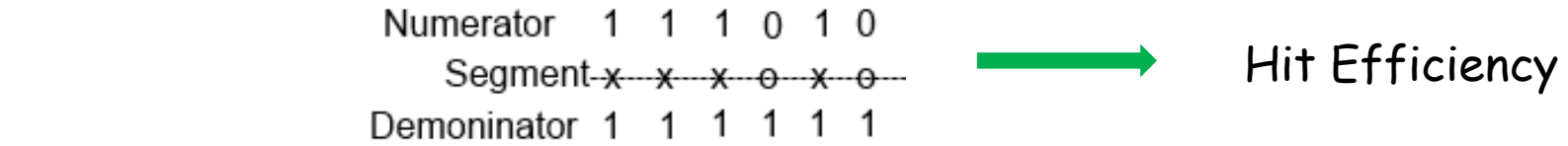
GEM Spatial Resolution & Hit Efficiency

Hit Efficiency per layer (from segments):

GEM hit efficiency per Layer is calculated for events where track-segments were reconstructed and defined as ratio:

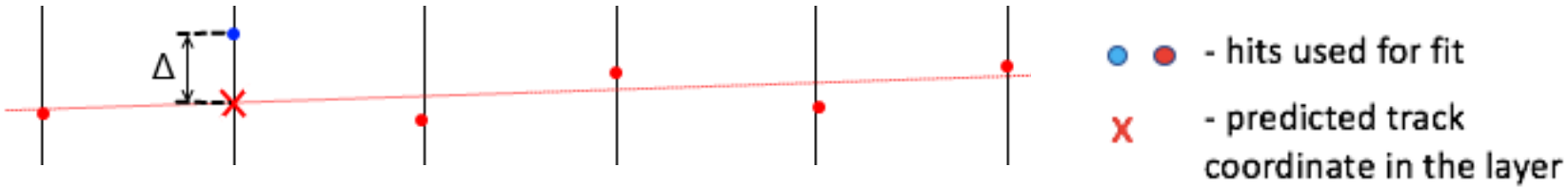
(Number of the reconstructed hits in a Layer) /

(Number of track-segments).

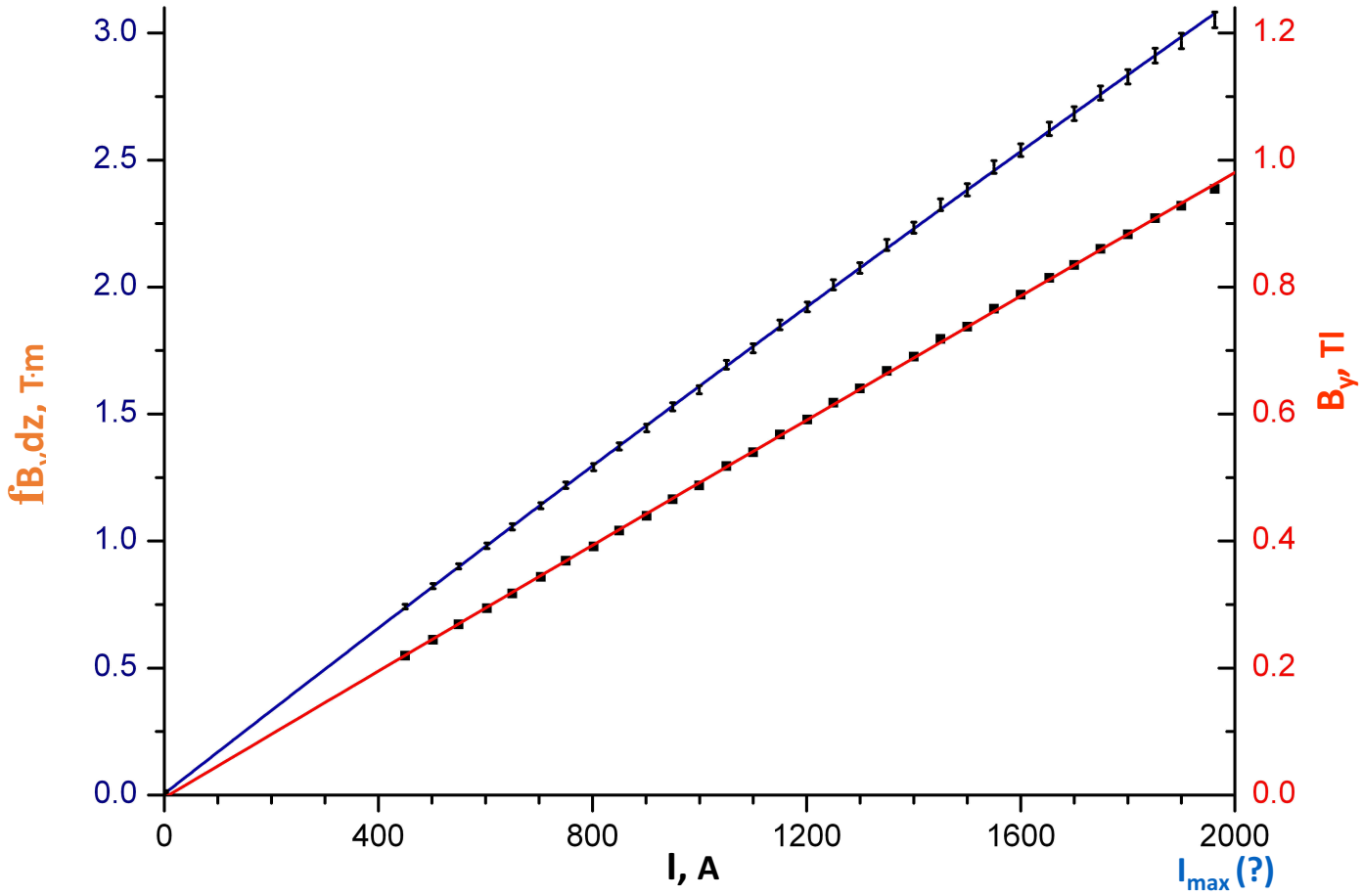


Spatial resolution calculation:

Resolution in the current layer calculated from the residual (Δ) between the measured coordinate (hit) and the predicted track coordinate from straight line fit .



Dependence of the integral of the magnetic field of the magnet SP-41 on the current



- $\int B_y(z, I_{max})dz$ = 2.97 T·m $\Rightarrow$ $\varphi \cong$ 70 мр при p/z = 13 ГэВ/с
- $B_y(0, I_{max})$ = 0.93 T