GEM tracking system of the BM@N experiment

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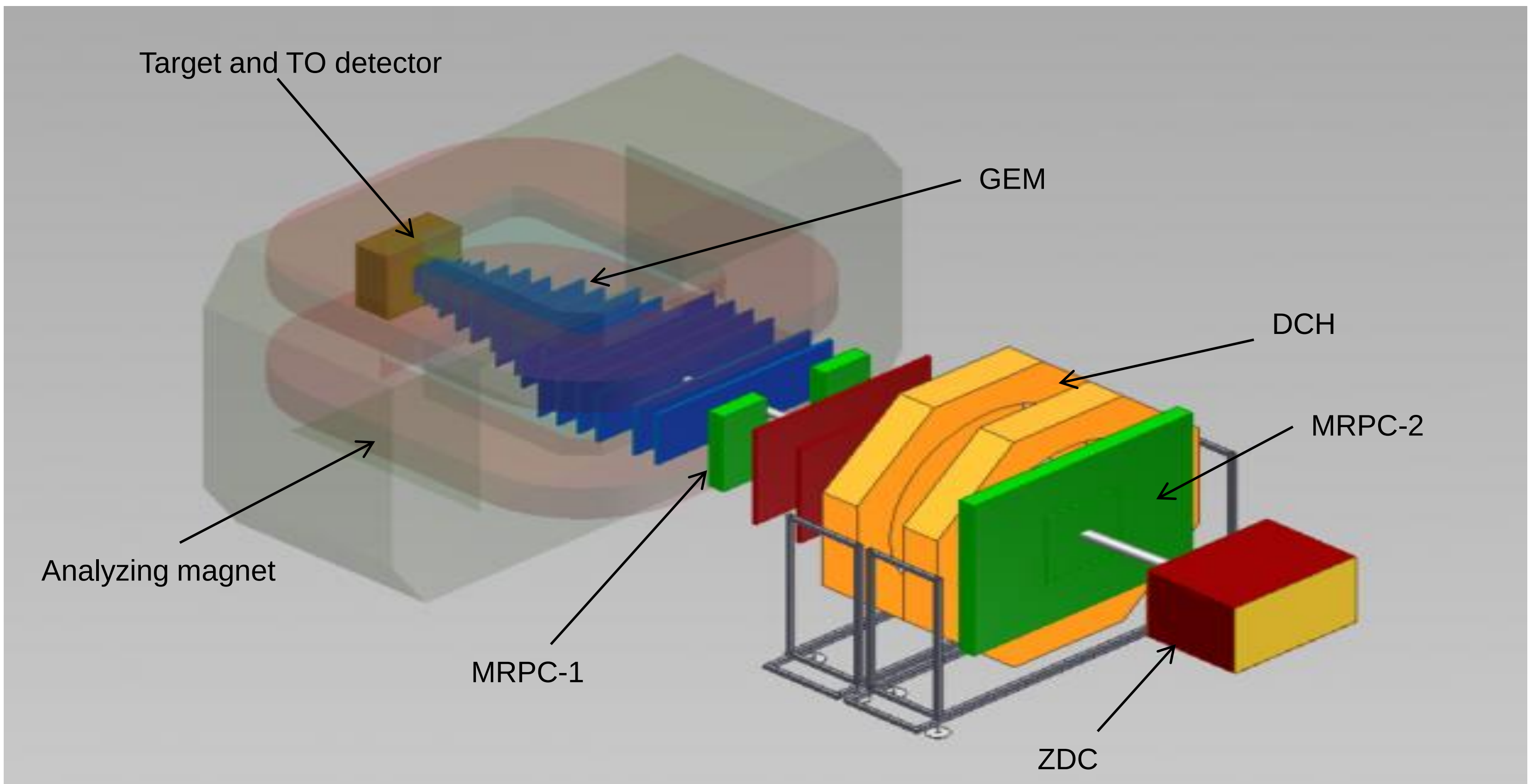
BM@N experiment

Collisions of Nuclotron heavy ion beams with fixed targets provide a unique opportunity to study strange mesons and multi-strange hyperons close to the kinematic threshold. One of the main goals of the experiment is to measure yields of light hyper-nuclei, which are expected to be produced in coalescence of Λ-hyperons with nucleons.



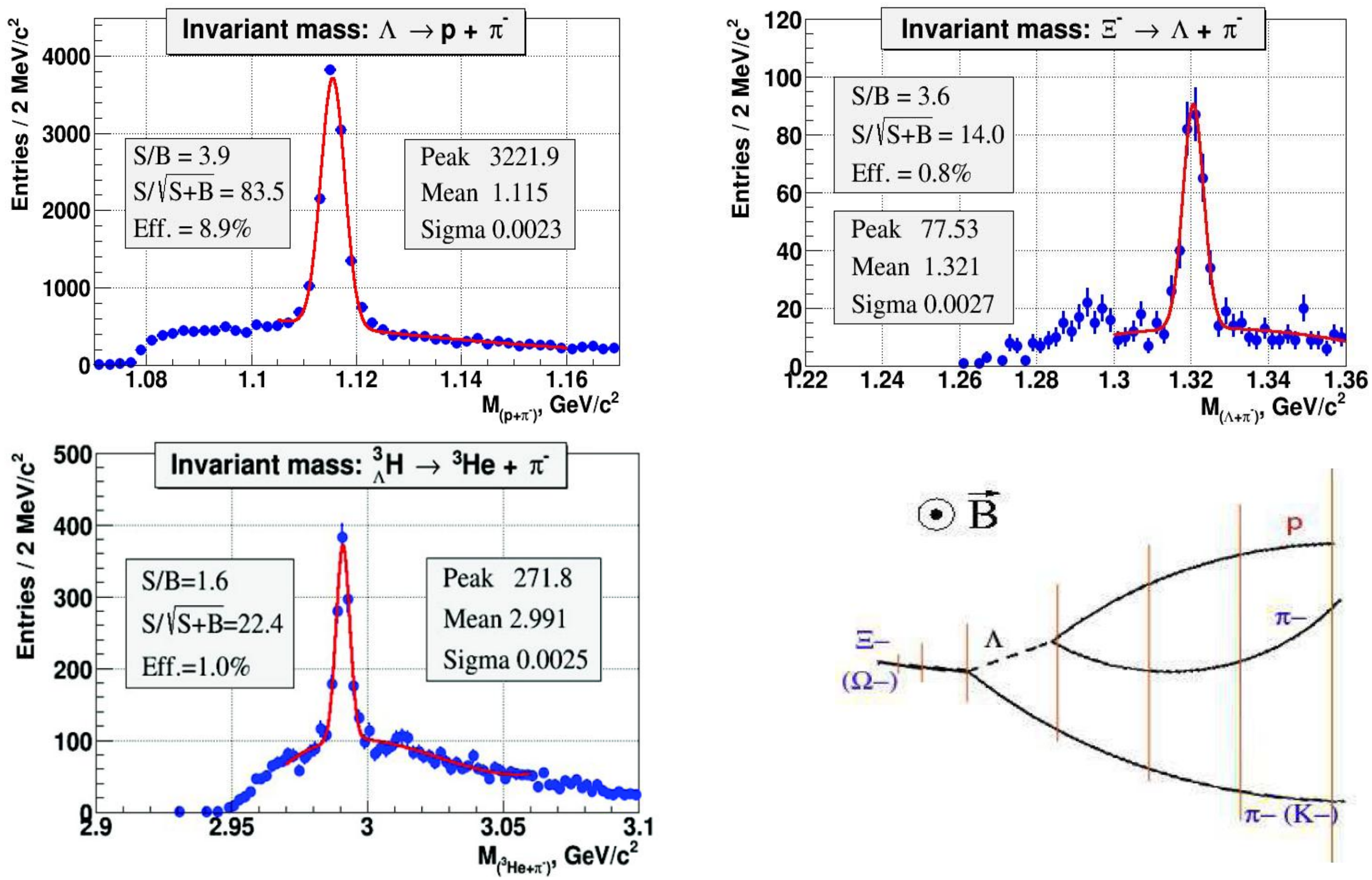
Basic requirements for the BM@N tracking system

Tracking system of the BM@N experiment will provide precise momentum measurements of the cascade decays products of multi-strange hyperons and hyper-nuclei produced in central Au-Au collisions. All physics measurements will be performed in conditions of high beam intensities in collisions with large multiplicity of charged particles. This requires the use of detectors with the capacity to resolve multi tracks produced at very high rate.

The basic requirements for the tracking system are:

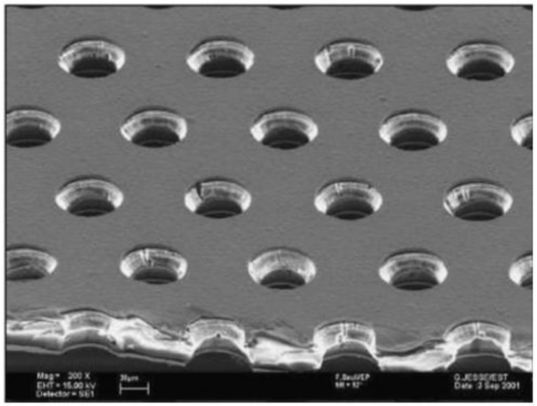
- capability of stable operation in conditions of high radiation loadings up to 10^5 Hz/cm^2;
- high spatial and momentum resolution;
- high geometrical efficiency (better than 95%);
- good timing resolution (5-10ns);
- maximum possible geometrical acceptance within the BM@N experiment dimensions;
- tracking system detectors must function in a 0.8 T magnetic field.

GEM tracking system performance in central Au-Au collisions (simulation studies)

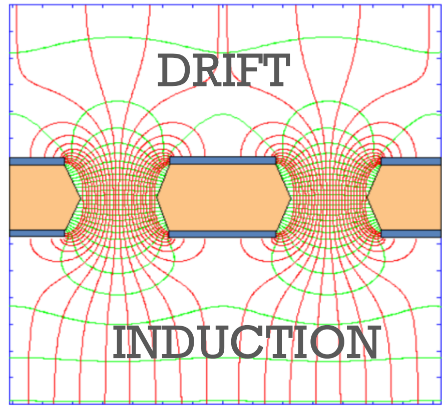


Distributions of the invariant mass of decay products of Λ hyperon, Ξ^- hyperon and hyper-triton $^3{}_\Lambda H$ reconstructed with the GEM tracker in central Au+Au collisions at the beam kinetic energy of 4.5 AGeV. Right bottom: topology of the cascade hyperon decays.

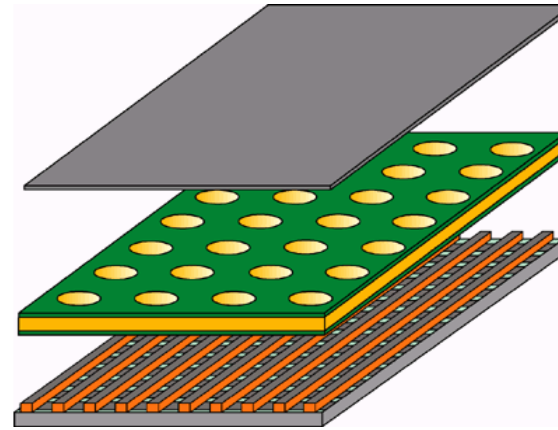
The gas electron multiplier (GEM)



Electron microscope picture of a section of typical GEM electrode, 50 mkm thick. The holes pitch and diameter are 140 and 70 mkm, respectively.



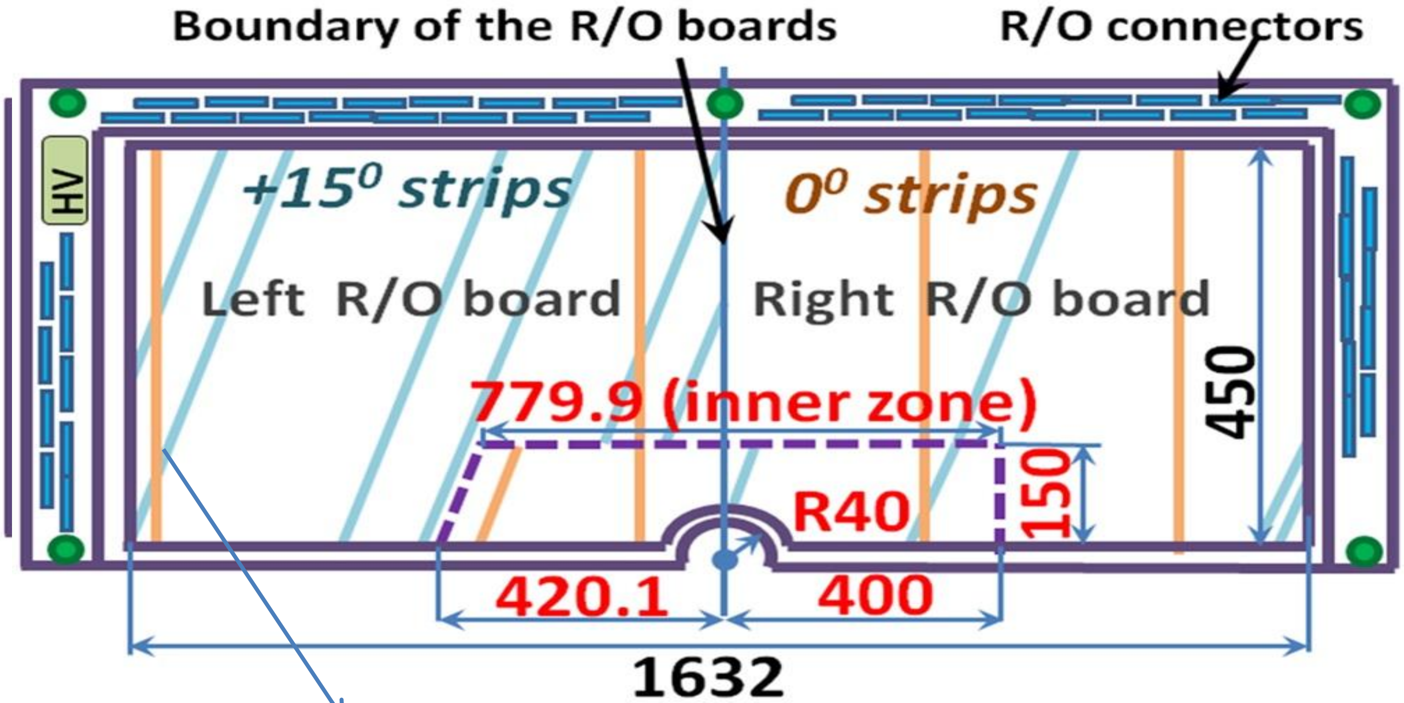
Electric field in the region of the holes of a GEM electrode

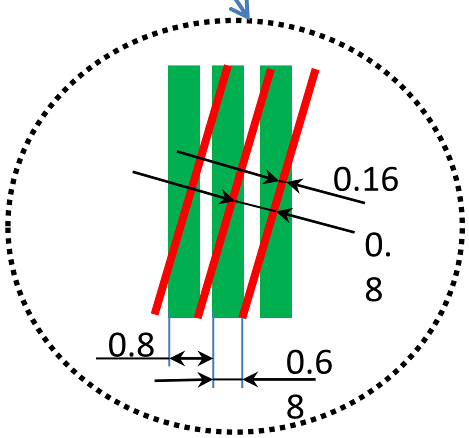


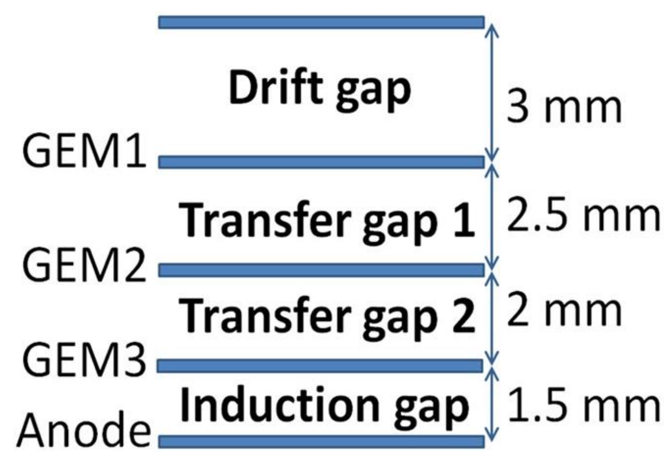
Schematics of single GEM detector with Cartesian two-dimensional strip readout.

Unlike other gaseous counters, the (negative) signal on the anode is generated only by the collection of electrons, without a contribution from the slow positive ions, making the device potentially very fast and minimizing space charge problems.

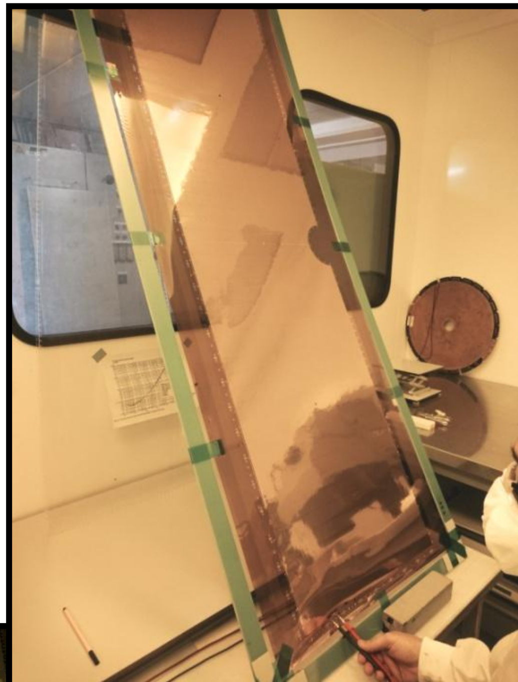
BM@N GEM 1632x450 cm^2 chambers

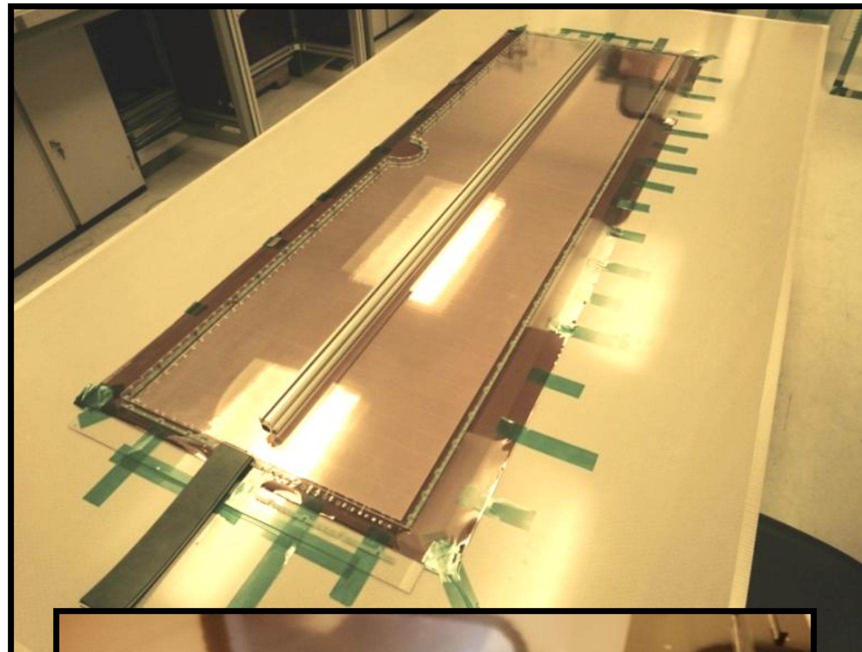






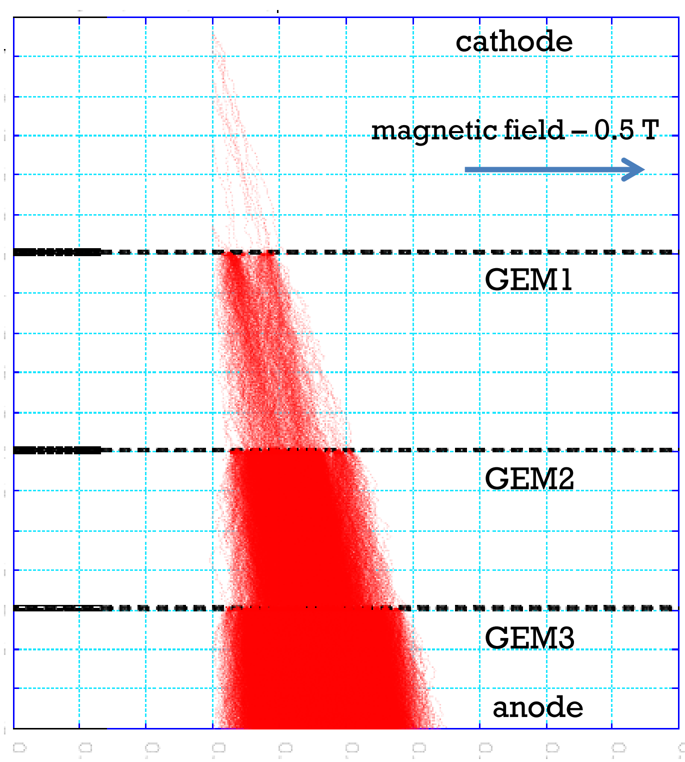
GEM assembly at CERN Workshop





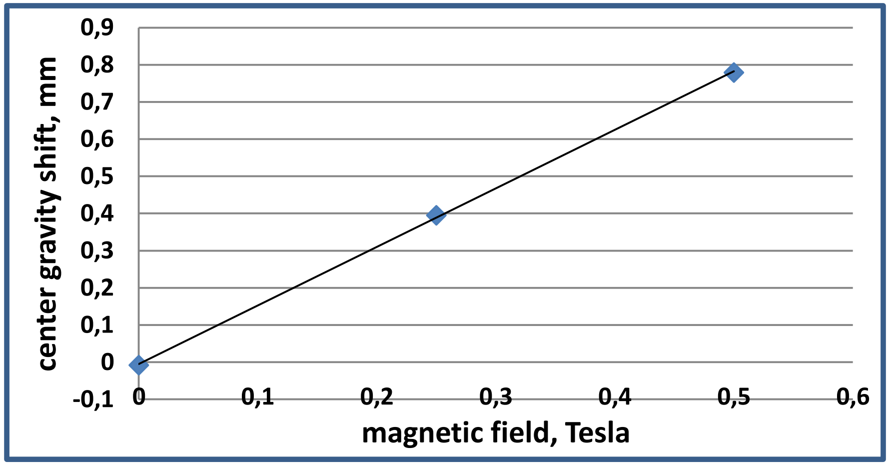
Electrons drift due to magnetic field (Garfield & Maxwell simulations)

Simulation of electron shift in magnetic field

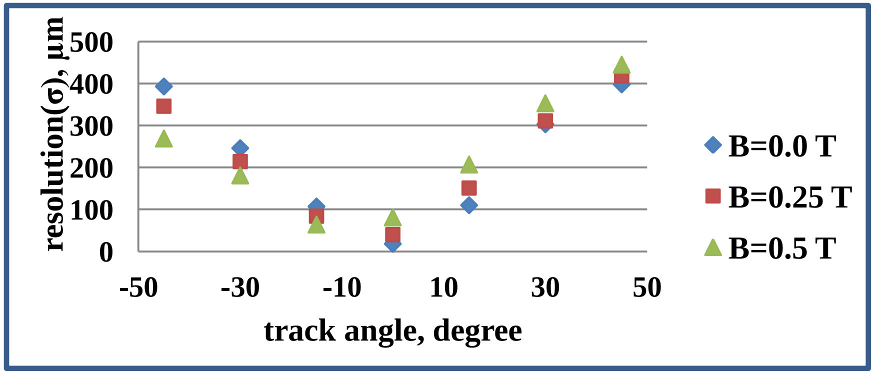


Ar(70)/CO_2(30) gas mixture

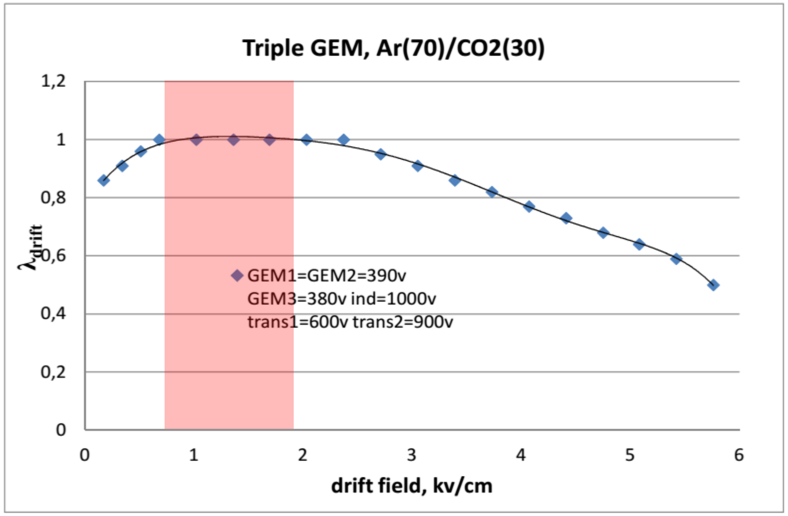
Center gravity shift vs magnetic field

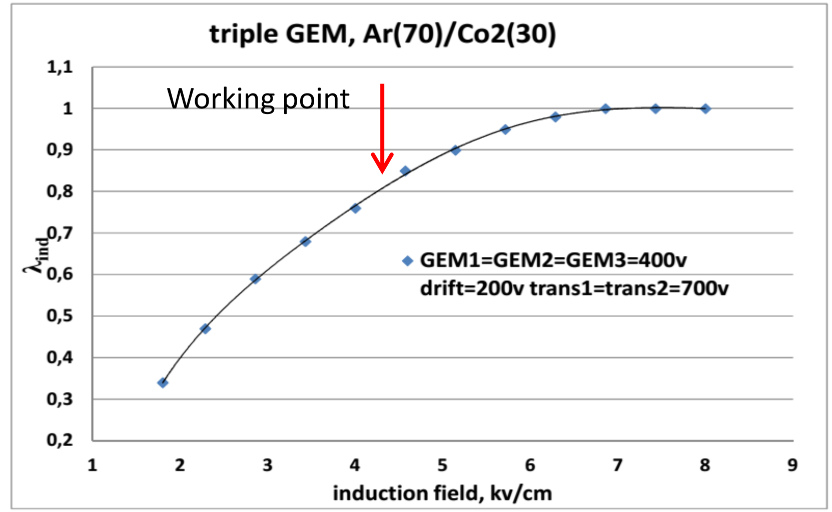


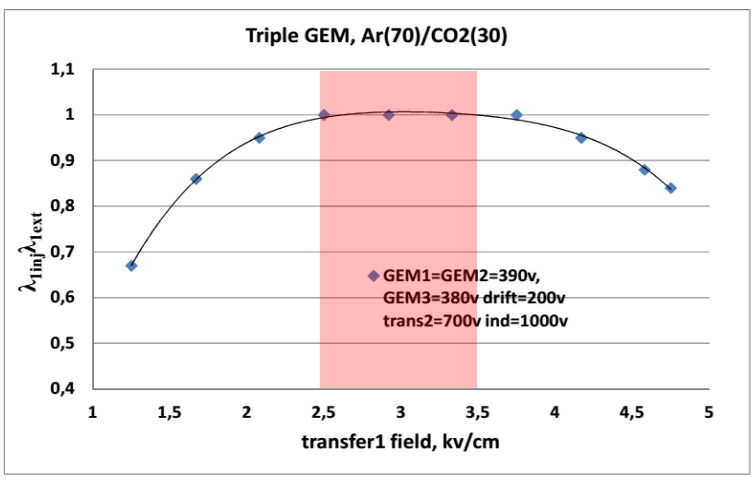
Space resolution vs magnetic field and track angle

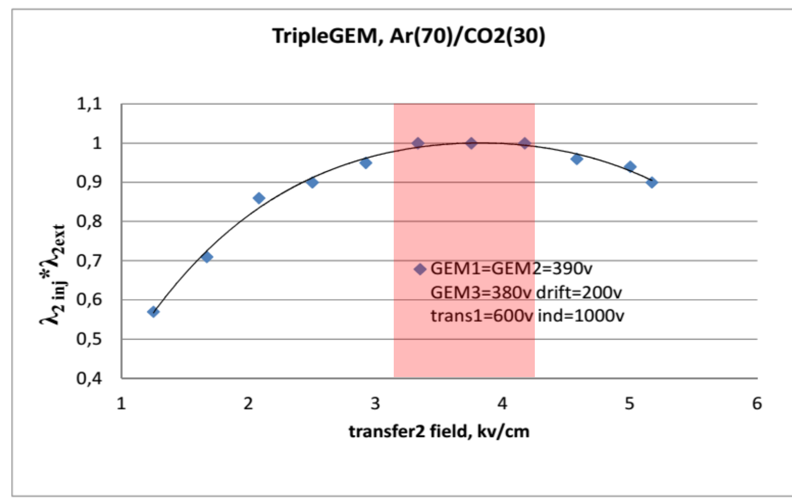


GEM Optimization



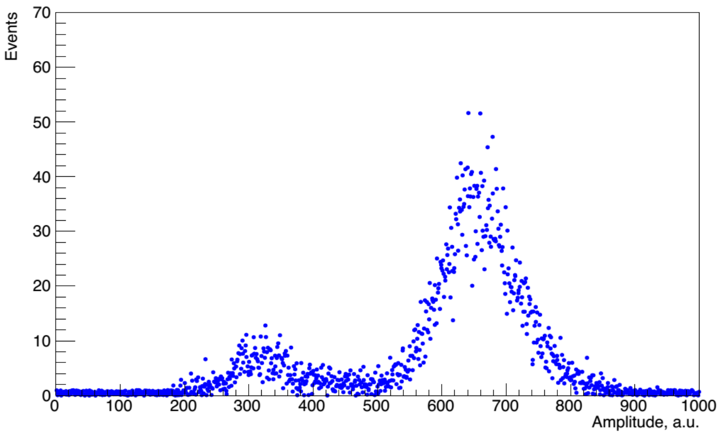




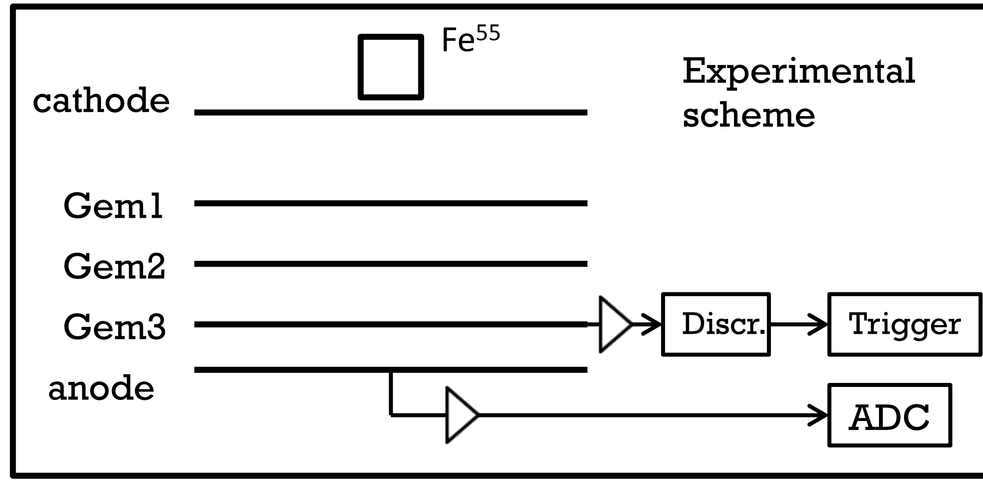


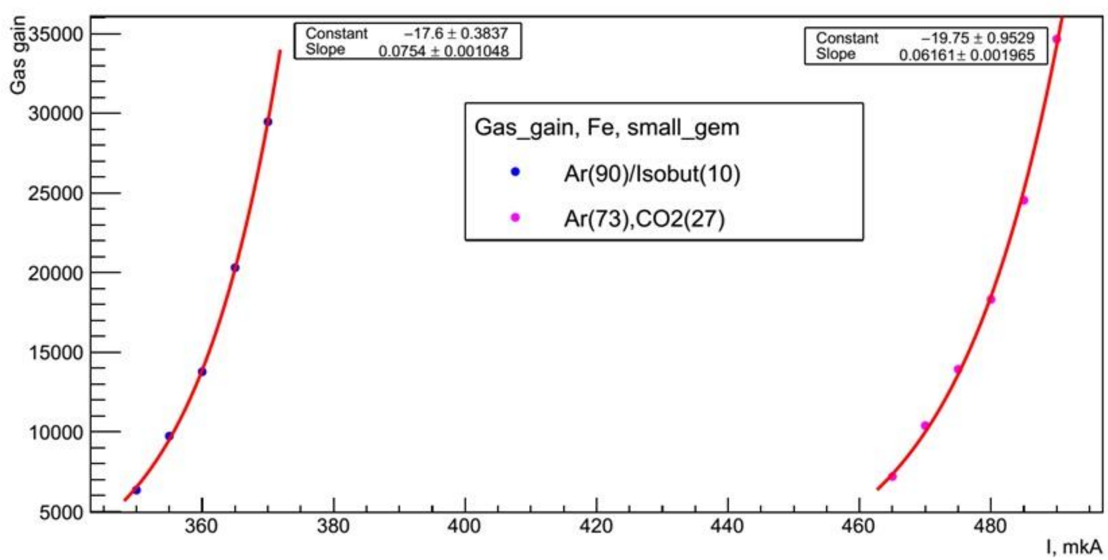
- Working range of field, kV/cm (Ar(70)/CO_2(30)gas mixture)

GEM gas gain measurements



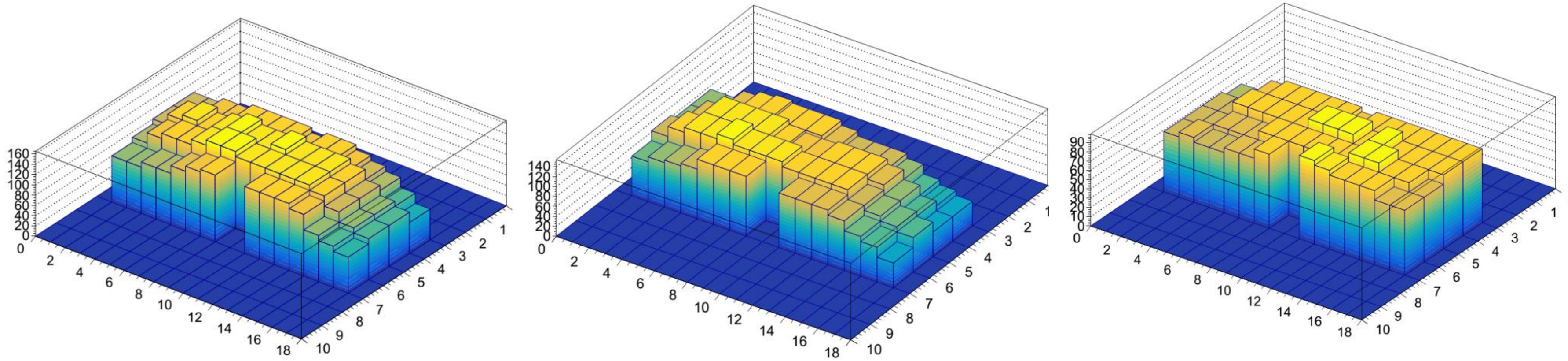
Amplitude distribution, Ar(70)/CO2(30), Fe^{55}



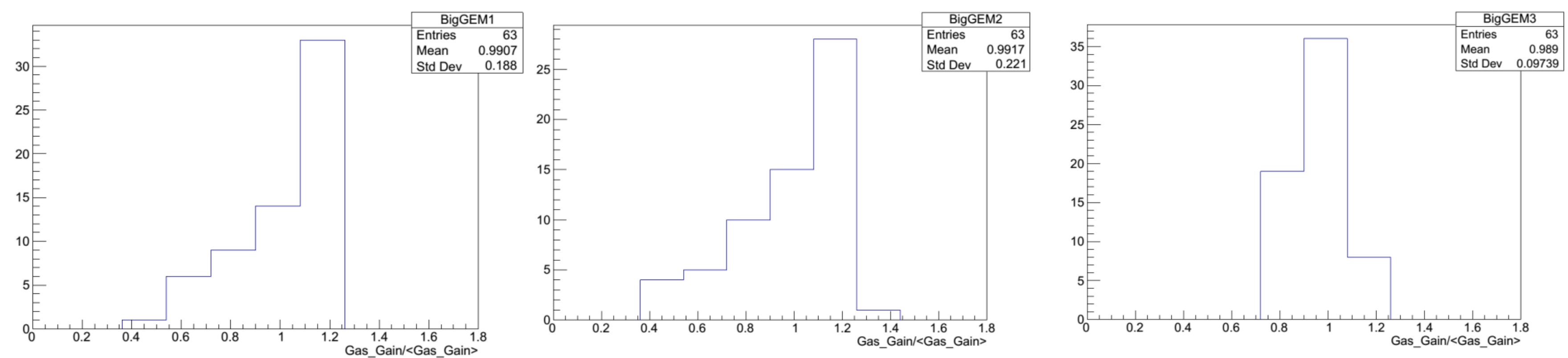


GEM gas gain for Ar(70)/CO2(30) and Ar(90)/Isobutane(10) gas mixtures

GEM 1632x450 mm^2 response uniformity

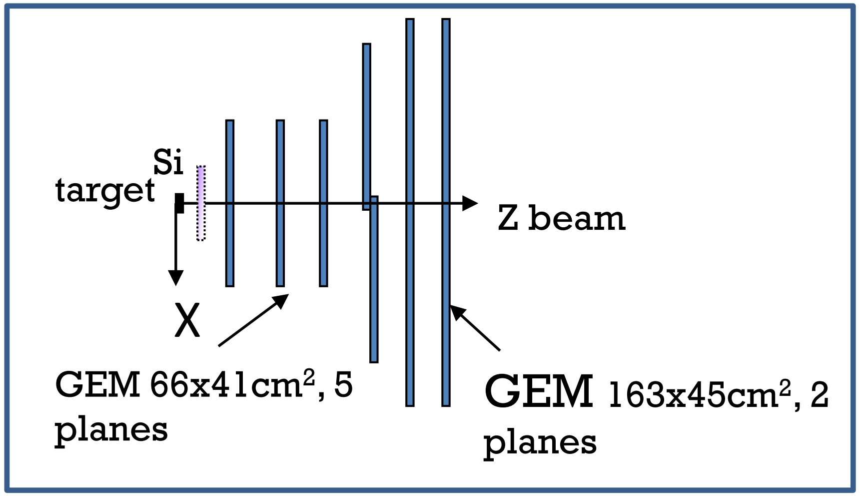


Response uniformity 3D plot of three 1632x450 mm^2 chambers, Ar(90)/Isobutane(10) gas mixture

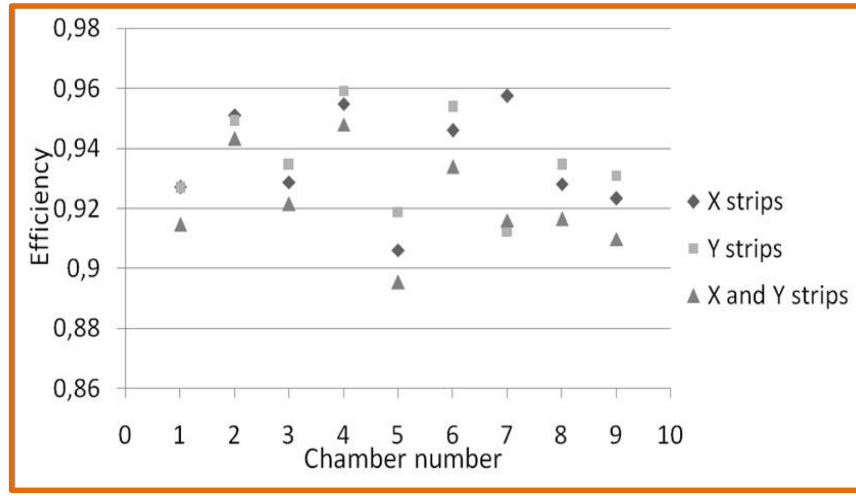


Gas gain distribution normalized on average gas gain for three 1632x450 mm^2 chambers, Ar(90)/Isobutane(10) gas mixture

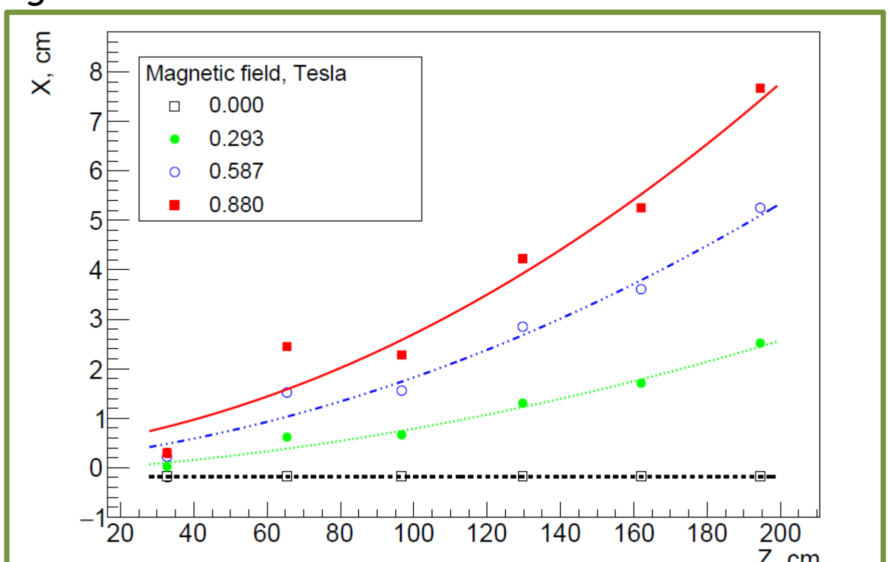
GEM tests at Nuclotron deuteron beam



GEM configuration

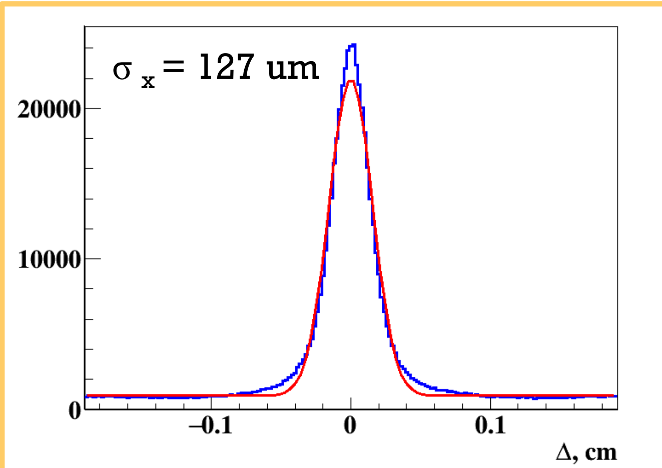


GEM efficiencies

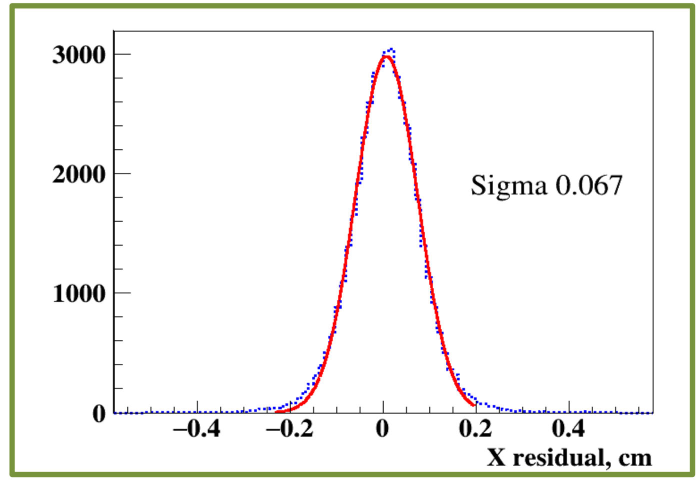


The average trajectories of the deuteron beam and the average Lorentz shifts of an electron avalanche in 6 GEM planes measured for four values of the magnetic field.

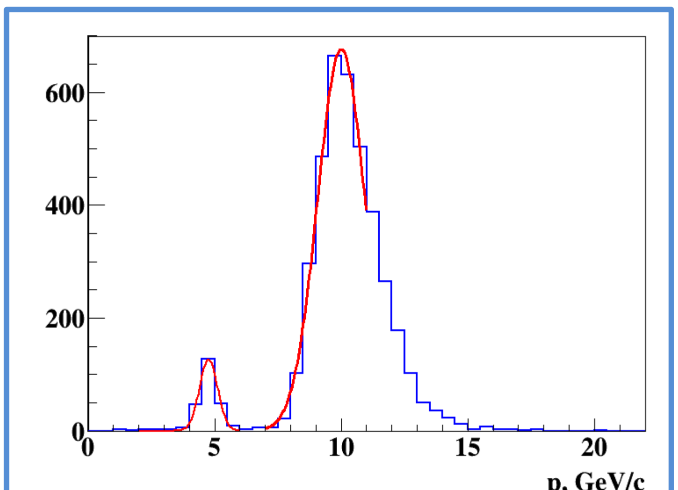
GEM tests at Nuclotron deuteron beam



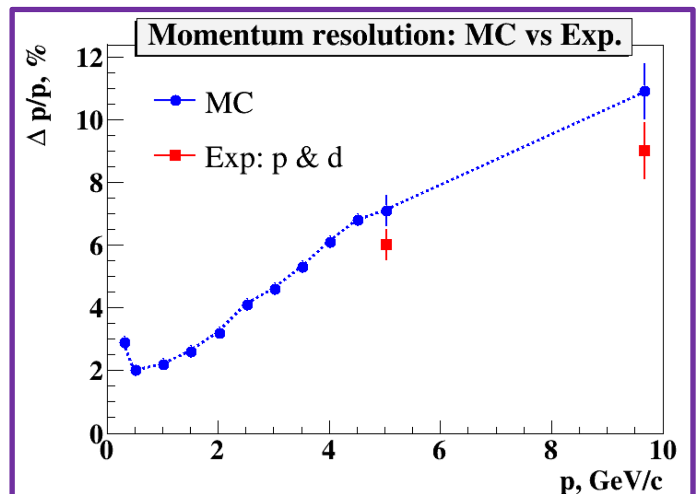
GEM resolution, w/o magnetic field, Ar(90)/IsoButane(10)



GEM hit residuals, magnetic field 0.79 T, Ar(90)/IsoButane(10)



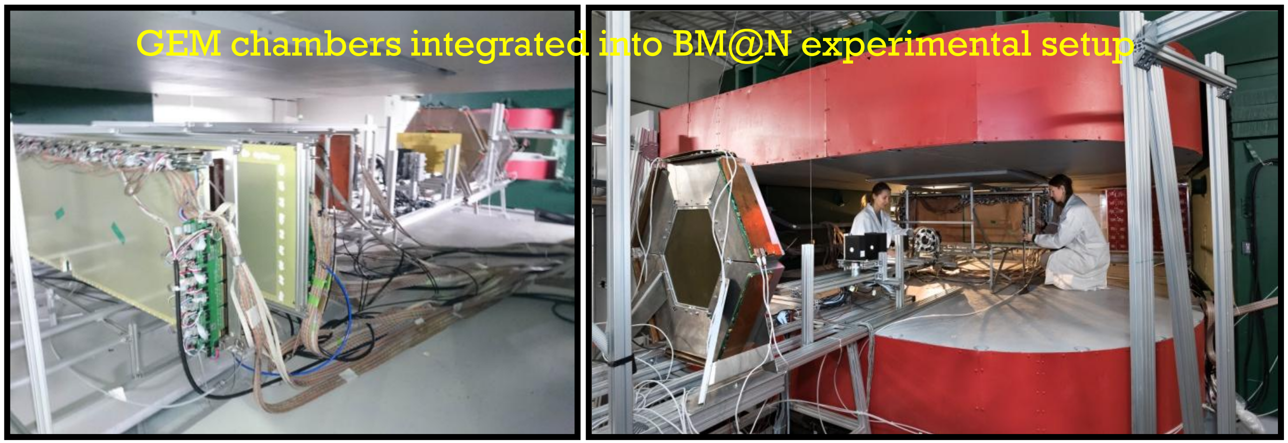
Momentum resolution for deuteron beam of 9.7 GeV/c ~9%, for proton spectators with momentum of 4.85 GeV ~6%.

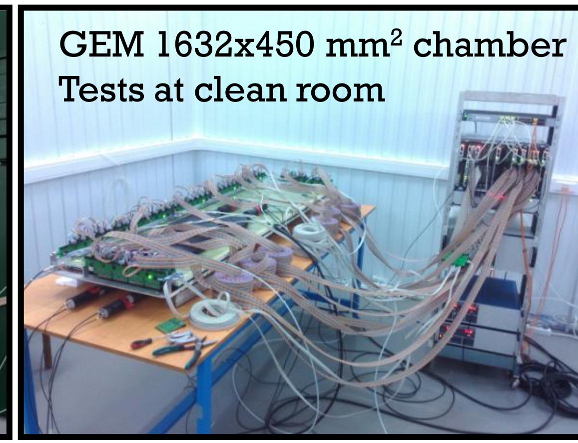


Momentum resolution as function of particle momentum

Conclusions

Triple GEM detectors of the BM@N tracker system have been assembled and studied in the deuteron beam of the Nuclotron accelerator. The measured parameters of the GEM detectors are consistent with the design specifications. Three GEM chambers with the size of 1632 mm × 450 mm are the biggest GEM detectors produced in the world for today.





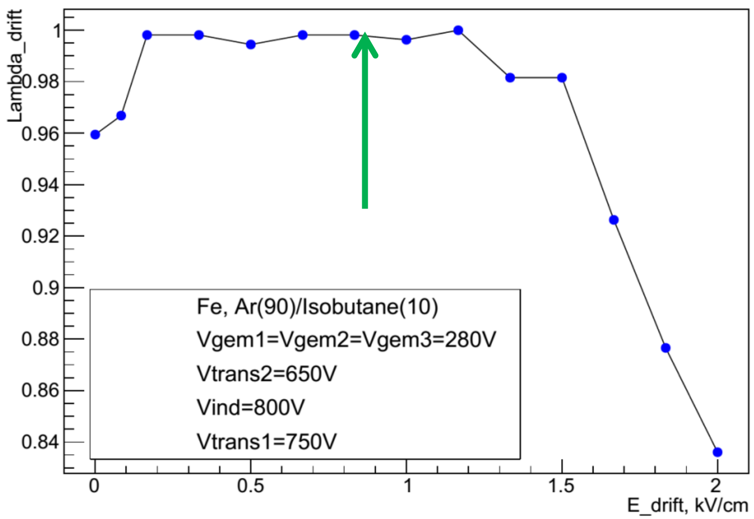
For today GEM tracking system is:

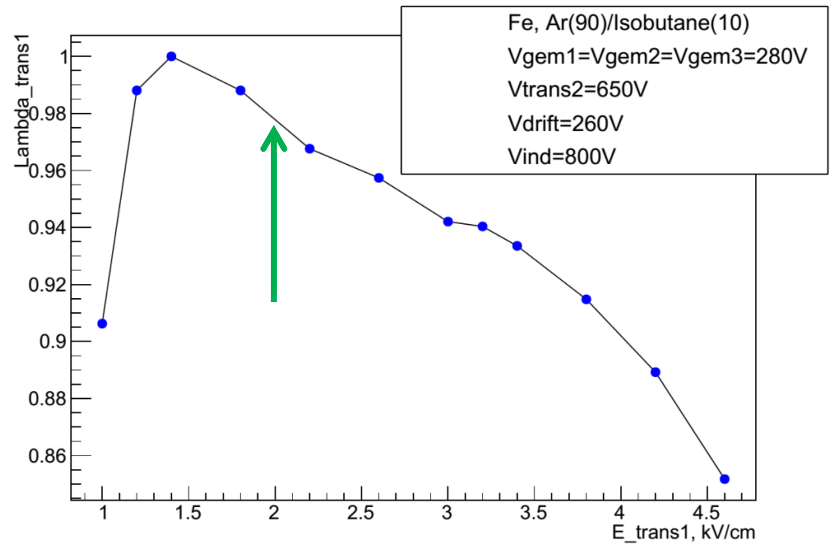
- 8 chambers 660x412 mm^2 (5) and 1632x450 mm^2 (3),
- ~ 3.6 m^2 active area,
- ~ 540 millions of independent amplification channels,
- ~ 30000 strips/electronics channels,
- > 1.5 km of control and readout cables.

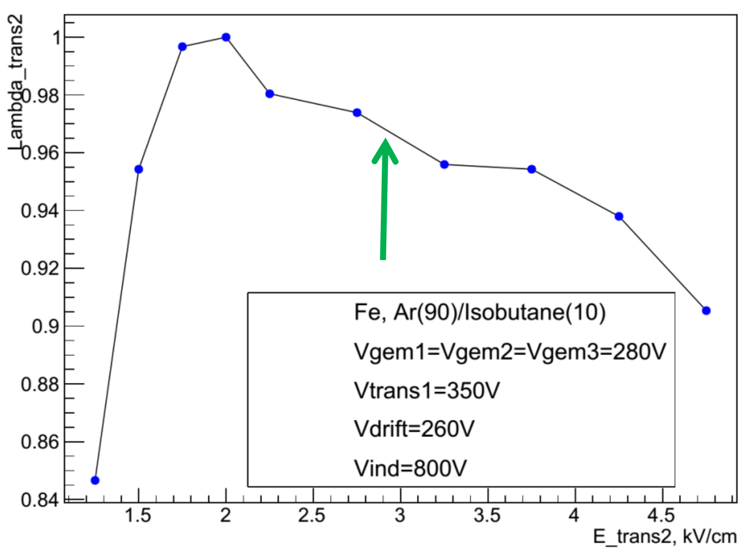
Thank you for your attention!

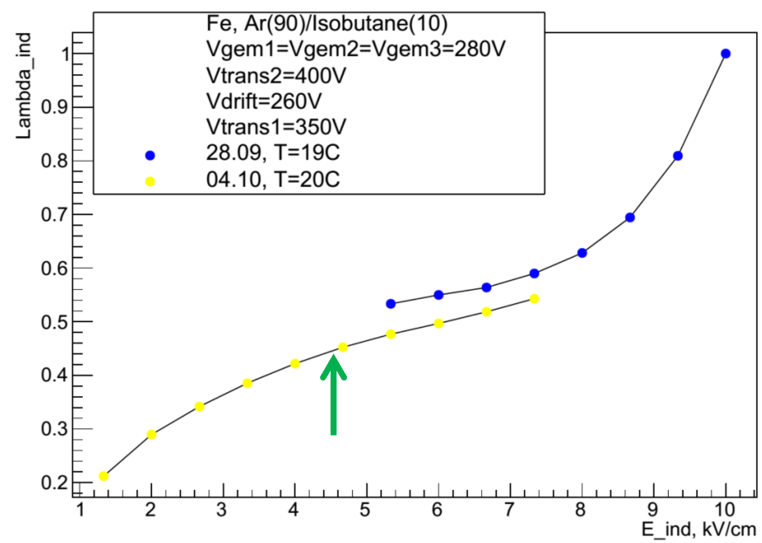
Back-up slides

GEM Optimization (Ar(90)/IsoButane(10) gas mixture)





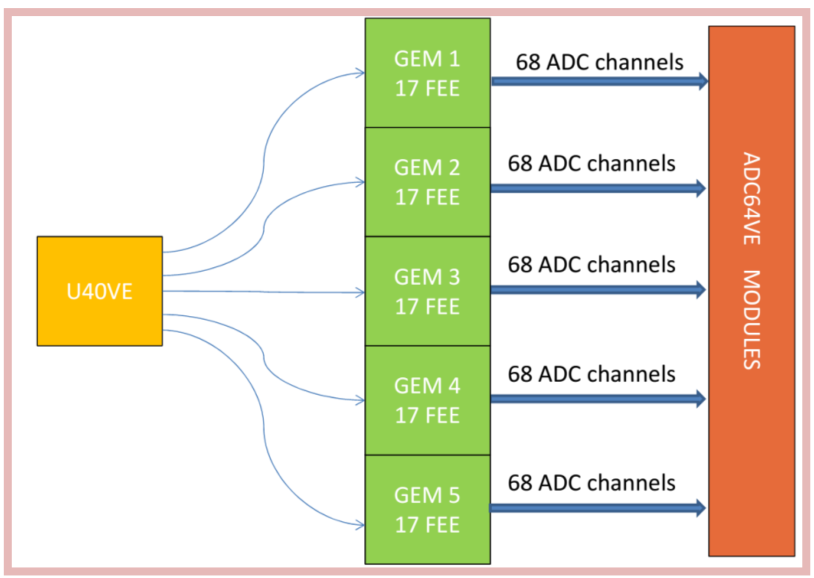


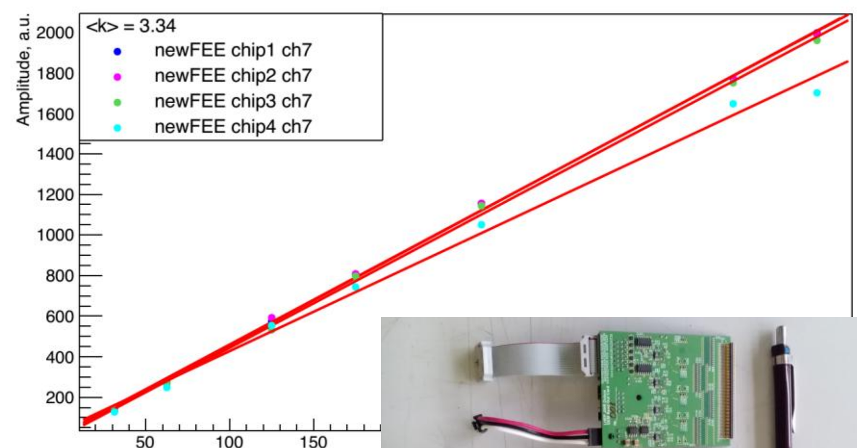


Lambda summary = 0.86

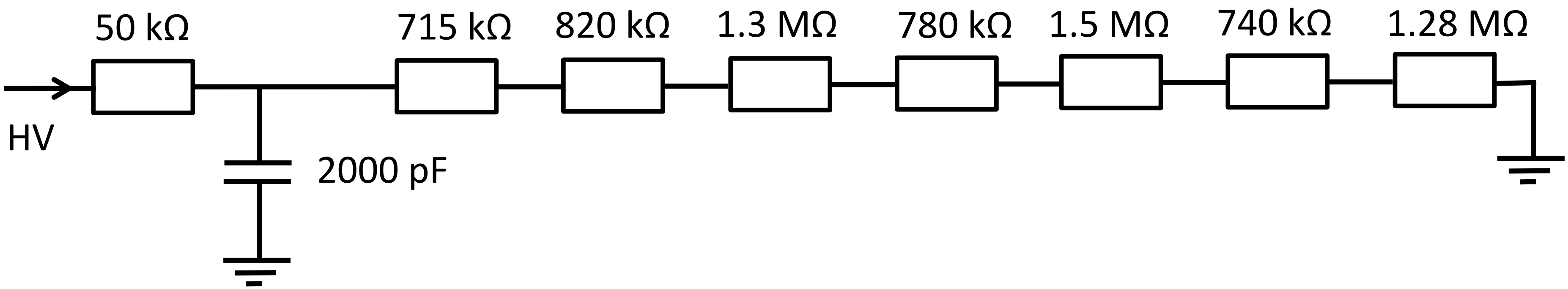
GEM Electronics

	VA162	VA163
Number of channels	32	32
Input charge	-1.5pC ÷ +1.5fC	-750fC ÷ +750fC
Shaping time	2÷2.5μs	500ns
Noise	2000e ENC at 50pF load	1797e ENC at 120pf load
Linearity positive charge	1%	0.5%
Linearity negative charge	3%	1.4%
Gain	0.5 μA/fC	0.88μA/fC
Total power max.	66mW	77mW





GEM HV divider scheme



I, mkA	DR, kv/cm	G1, v	TR1, kv/cm	G2, v	TR2, kv/cm	G3, v	IND, kv/cm
370	0.88	303.4	1.92	288.6	2.78	273.8	3.16
490	1.17	402	2.58	382	3.68	363	4.18

370 mkA – working point for Ar(90)/Isobutane(10) gas mixture
490 mkA – working point for Ar(70)/CO_2(30) gas mixture