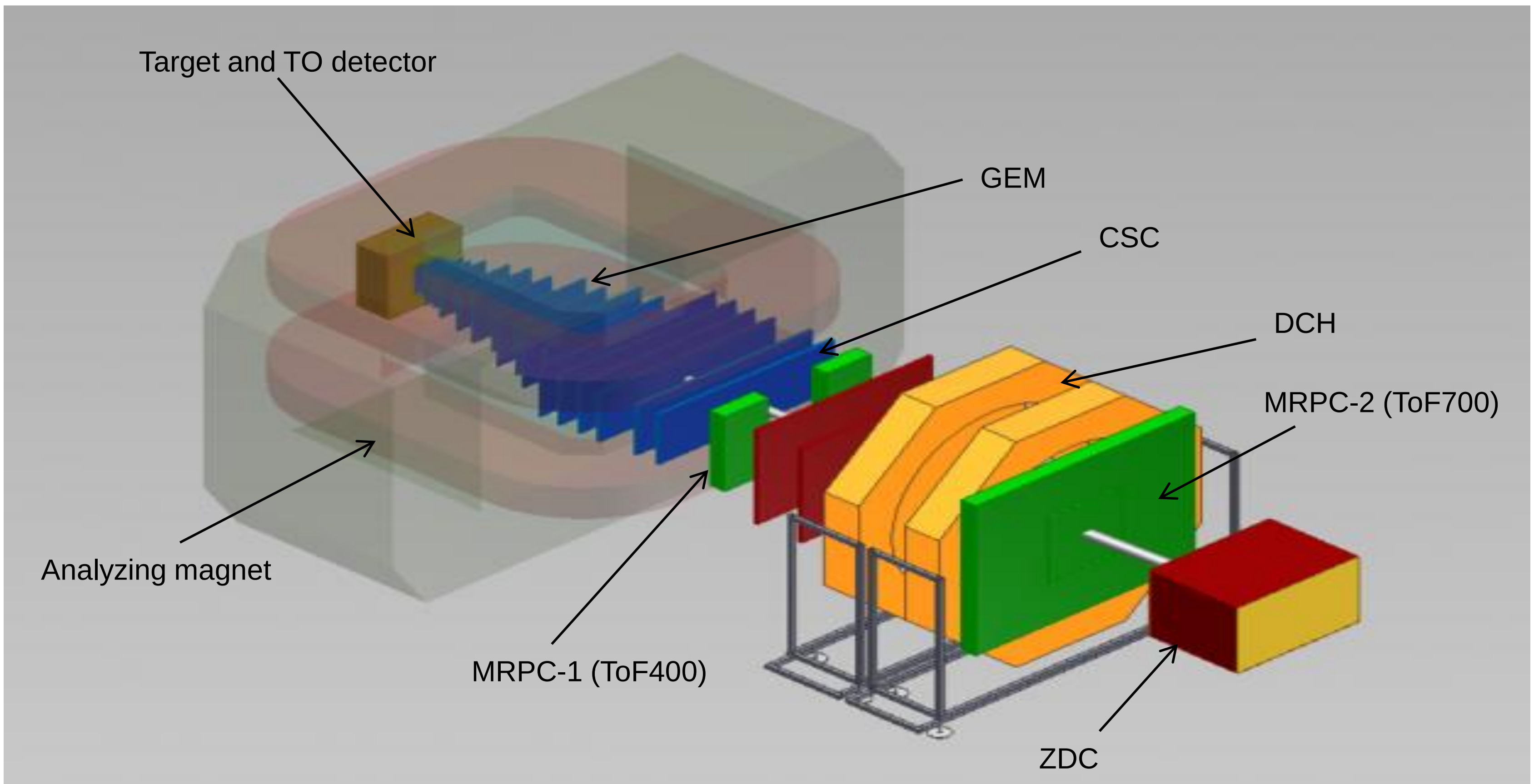
GEM / CSC tracking system of the BM@N experiment at the Nuclotron

Anna Maksymchuk on behalf of BM@N Collaboration

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.



Central tracking system
Gas electron multipliers
(GEM)

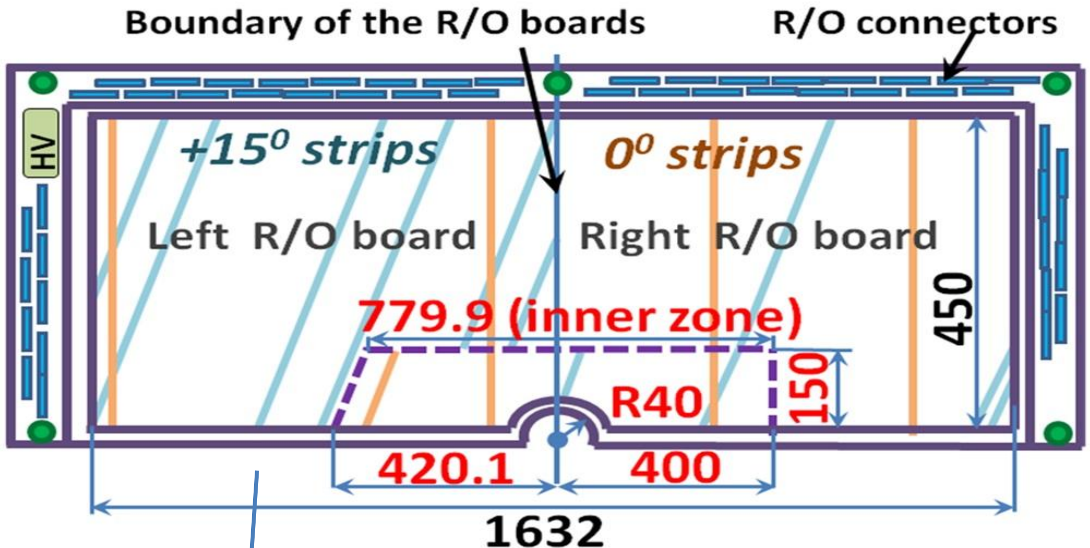
Basic requirements for the BM@N tracking system

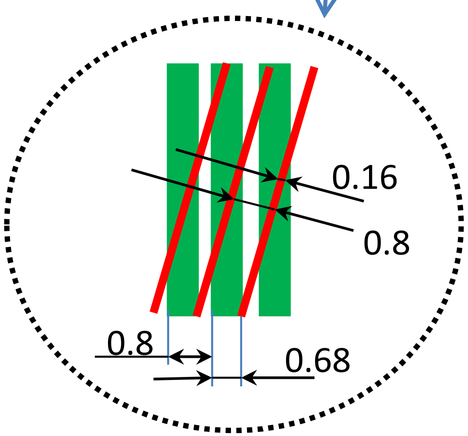
Tracking system of the BM@N experiment will provide precise momentum measurements of the cascade decays products of multi-strange hyperons and hyper-nuclei produced in central Au-Au collisions. All physics measurements will be performed in conditions of high beam intensities in collisions with large 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:

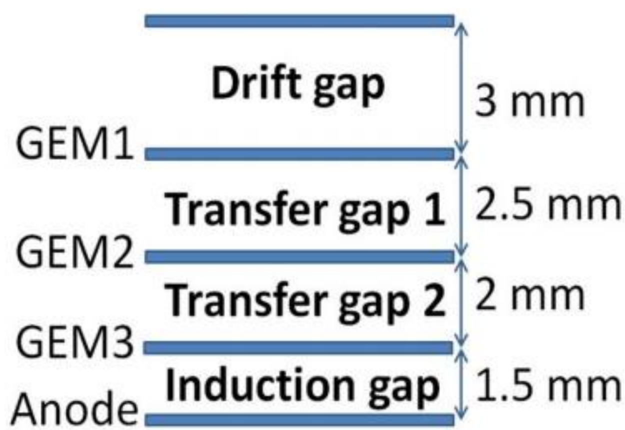
- capability of stable operation in conditions of high loadings up to 10^5 Hz/cm^2;
- high spatial and momentum resolution;
- high geometrical efficiency (better than 95%);
- maximum possible geometrical acceptance within the BM@N experiment dimensions;
- tracking system detectors must function in a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

BM@N GEM 1632x450 mm^2 chambers

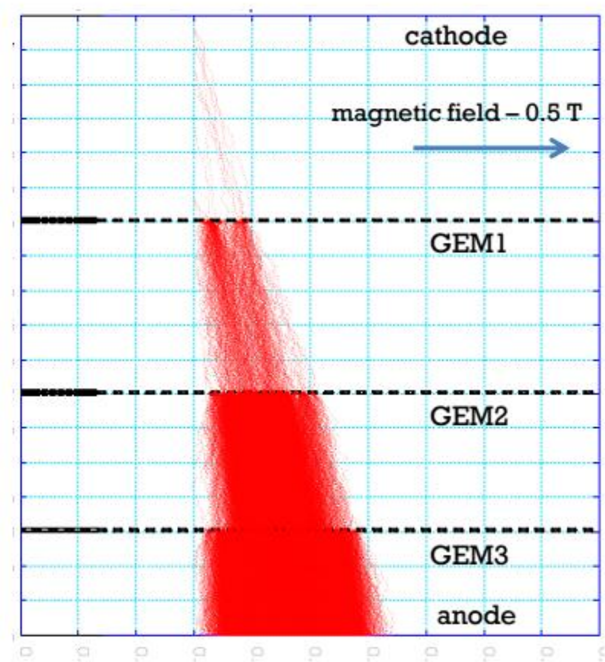




Schematic cross section of BM@N triple GEM detector

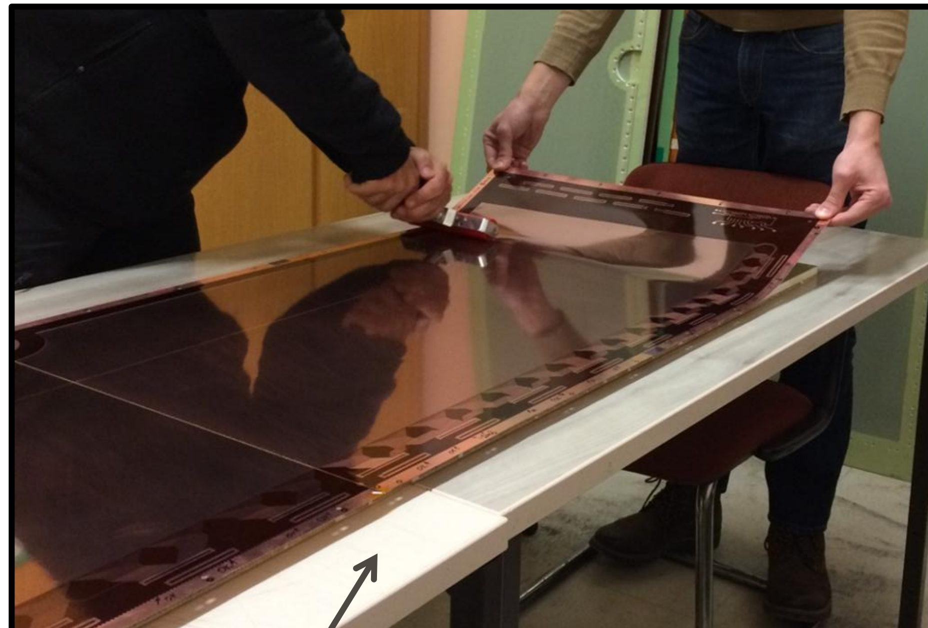


Simulation of electron shift in magnetic field



Ar(70)/CO_2(30) gas mixture

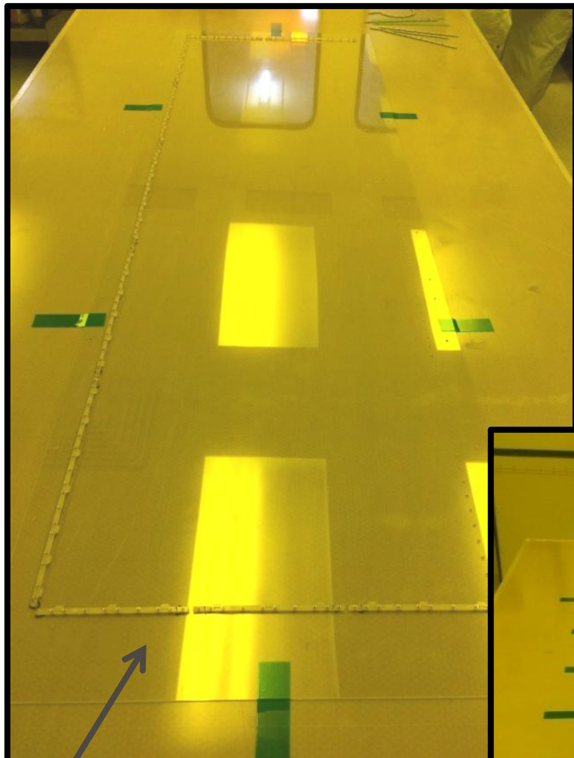
GEM assembly at CERN Workshop
Readout board preparation

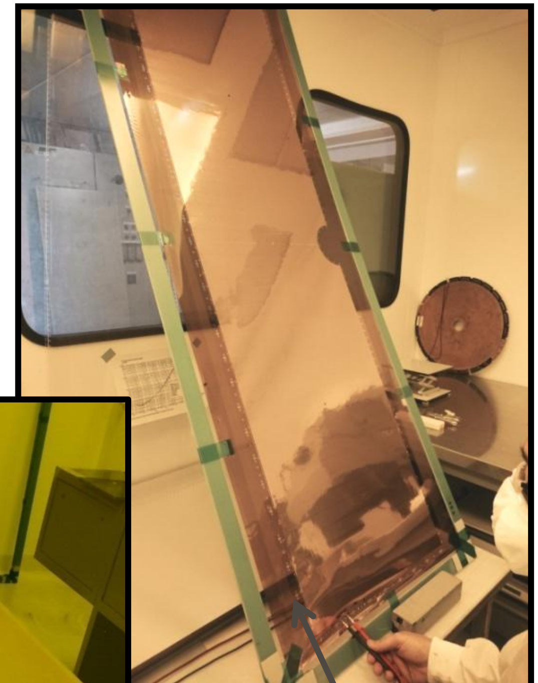


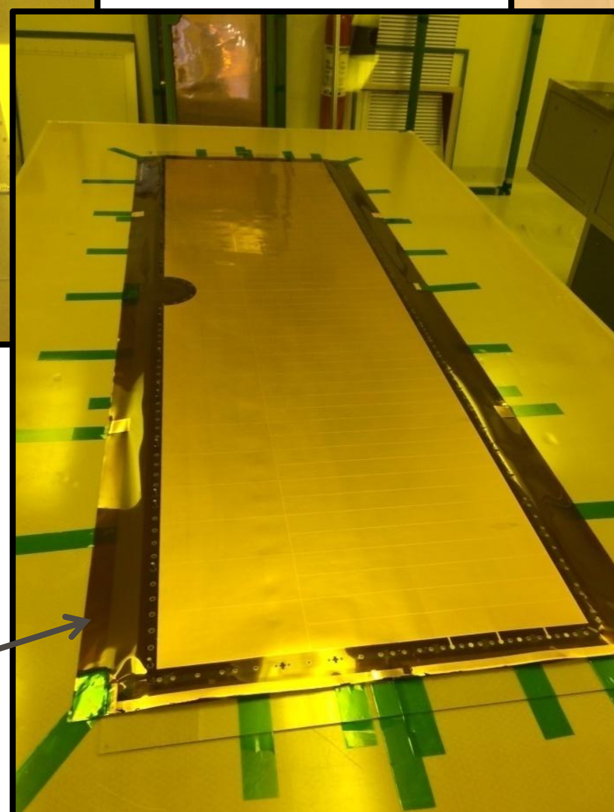
Right readout board

Gluing of the readout boards
on the honeycomb support plane

GEM assembly at CERN Workshop





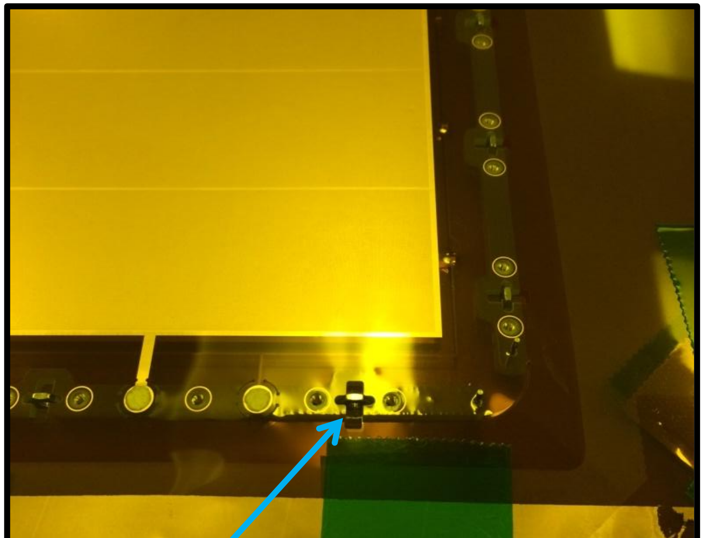


Base plastic frame

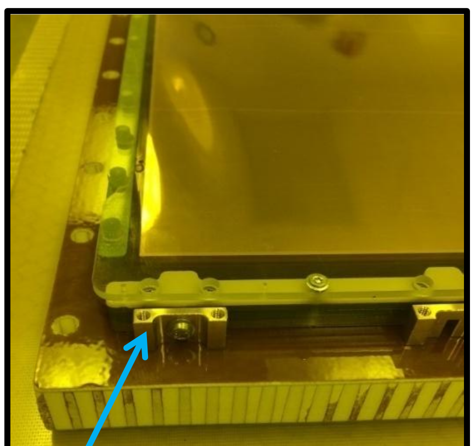
GEM foil tests

GEM foil preliminary stretching

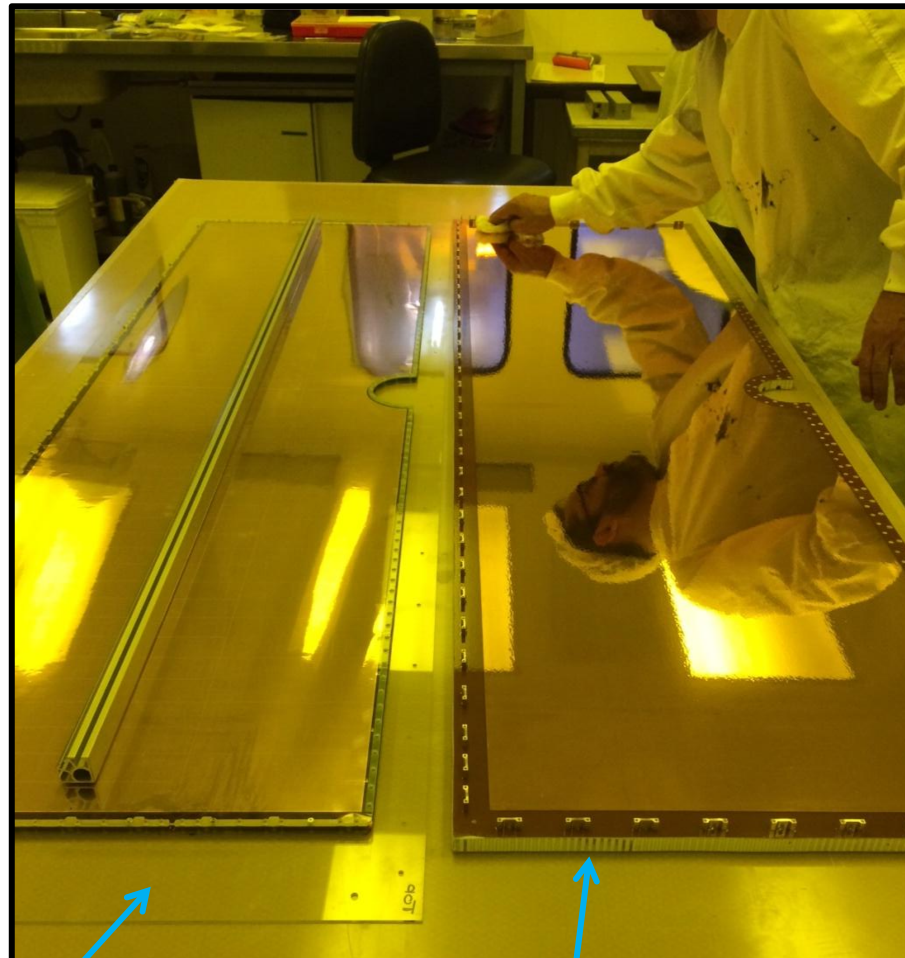
GEM assembly at CERN Workshop



Nuts in plastic frames



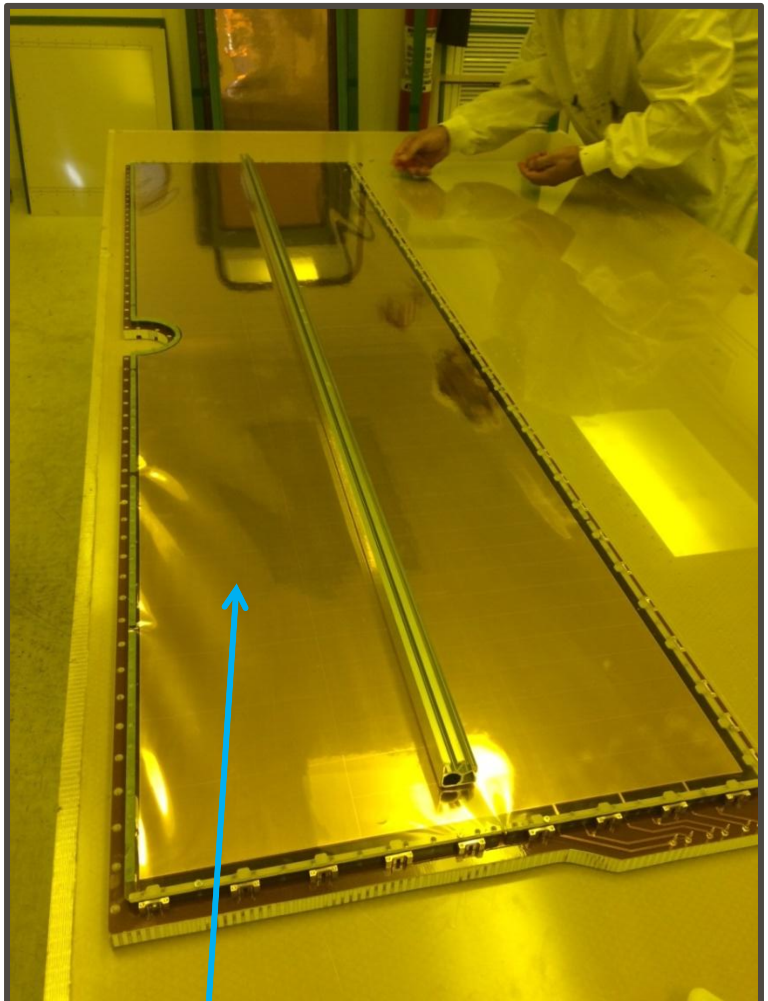
Brass fitting



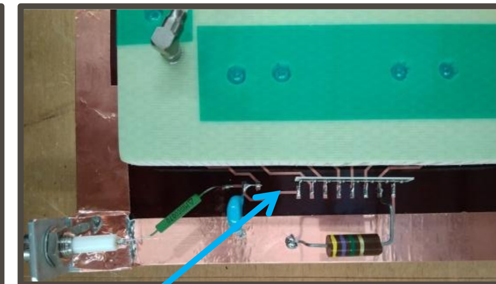
Stack of 3 GEMs

Cathode plane

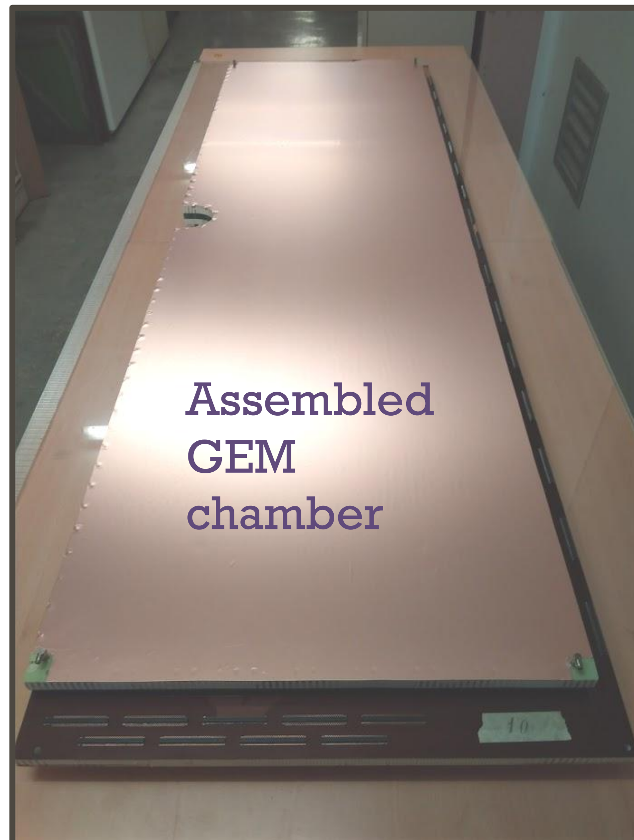
GEM assembly at CERN Workshop



Stretching process

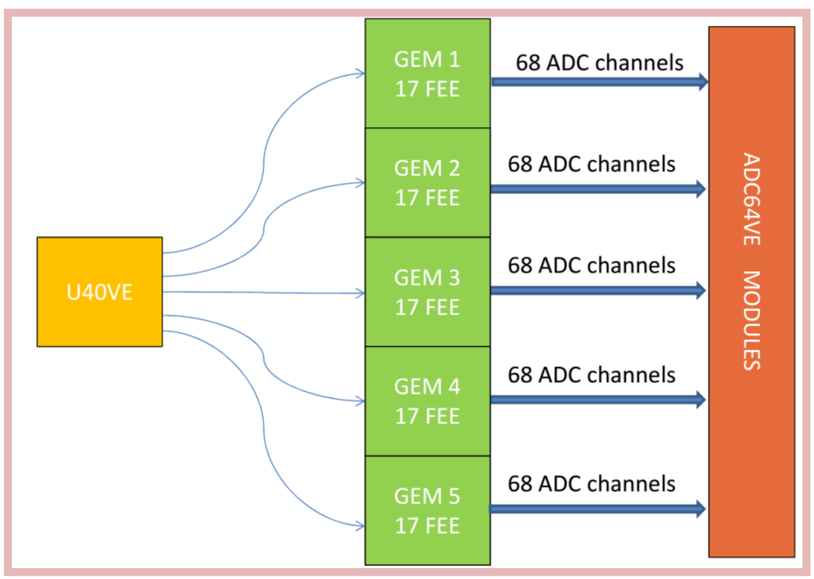


HV divider

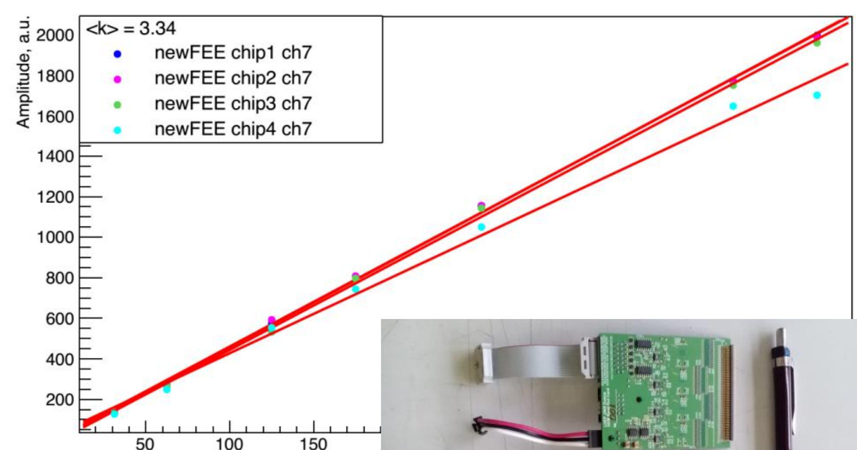


GEM and CSC electronics

	VA162	VA163
Number of channels	32	32
Input charge	-1.5pC ÷ +1.5pC	-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

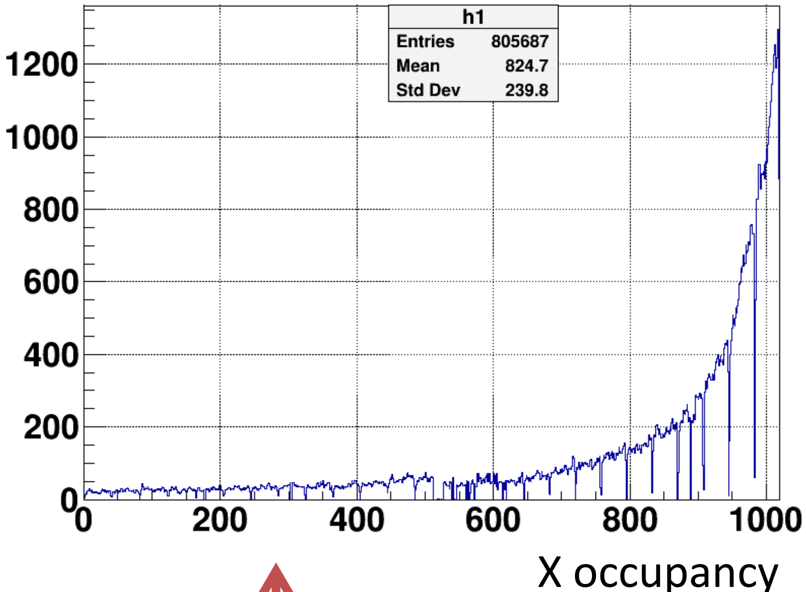


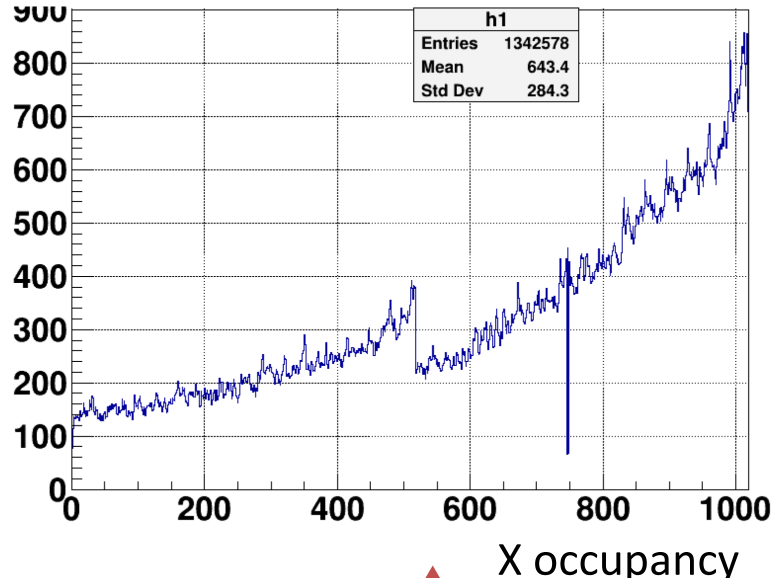
DAQ scheme



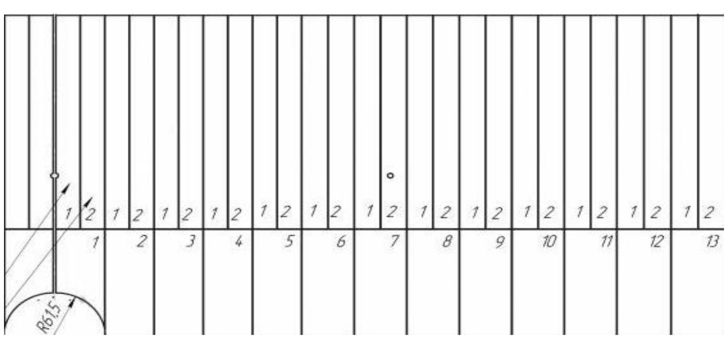
128 channel read-out card. Front and back side view

GEM occupancy

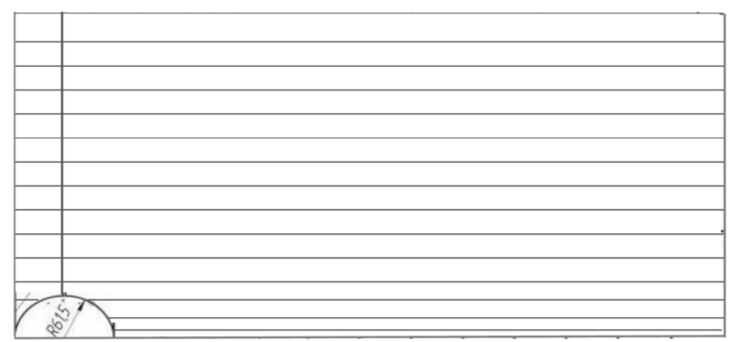




GEM foil sector design

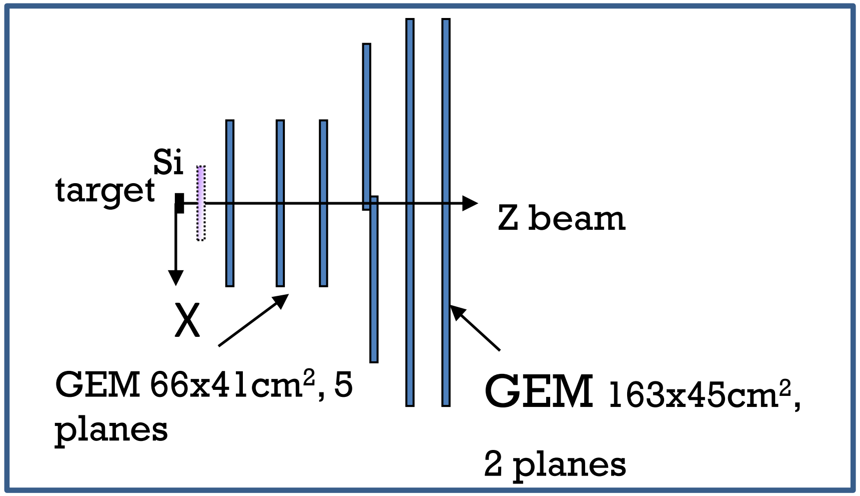


Vertical sectors

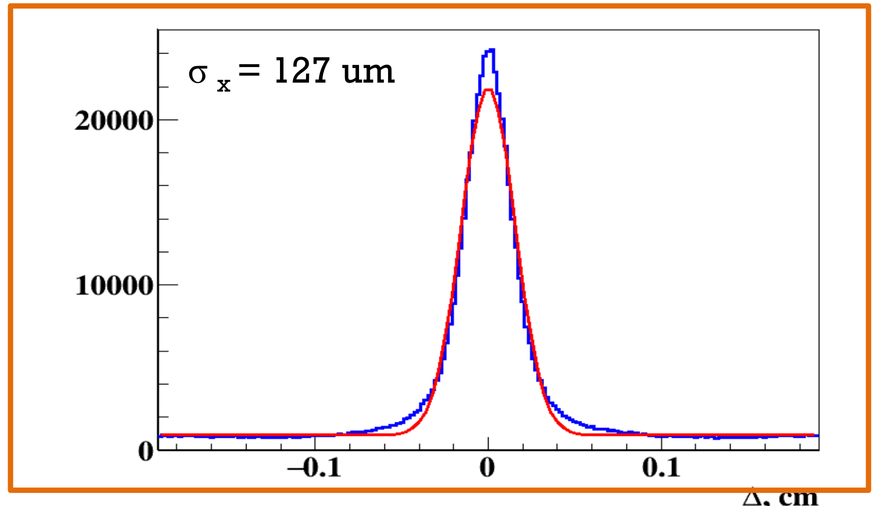


Horizontal sectors

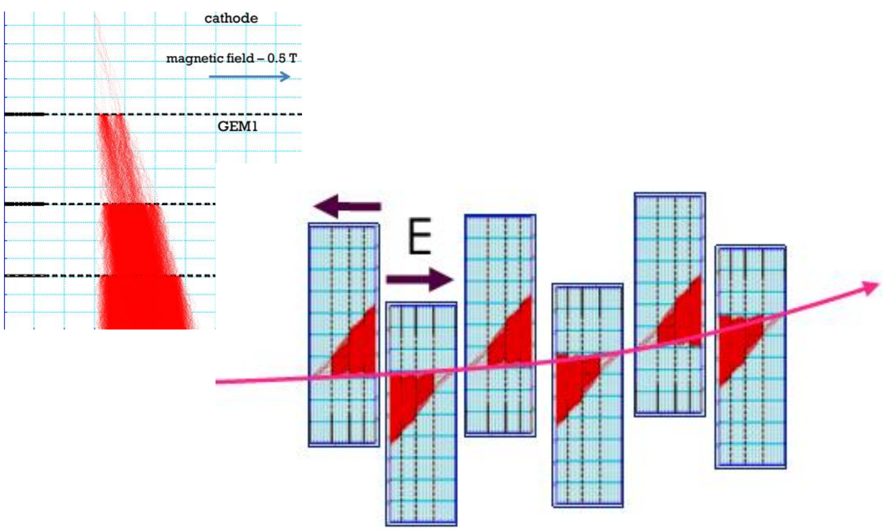
GEM tests at Nuclotron deuteron beam

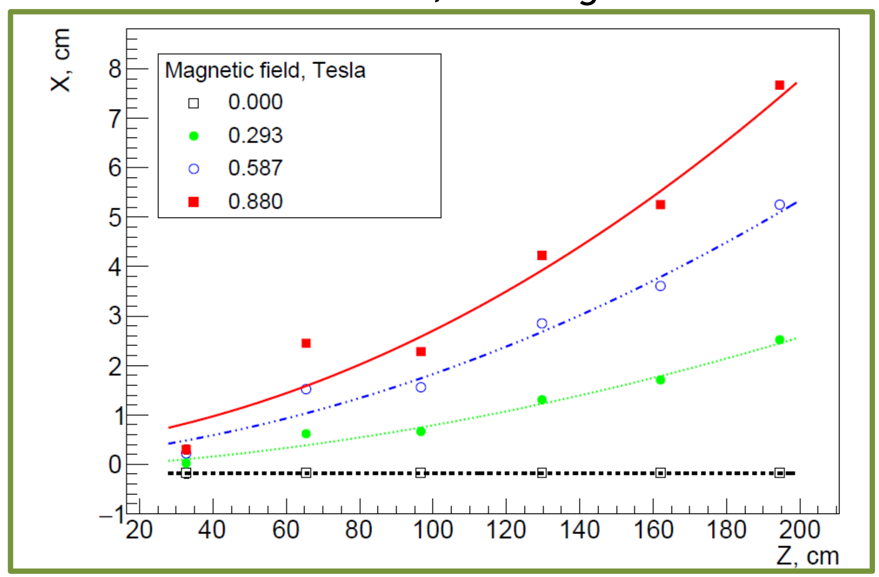


GEM configuration



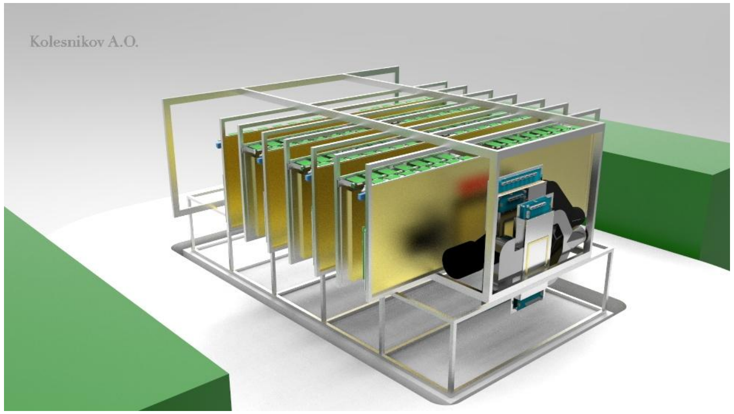
GEM resolution, w/o magnetic field

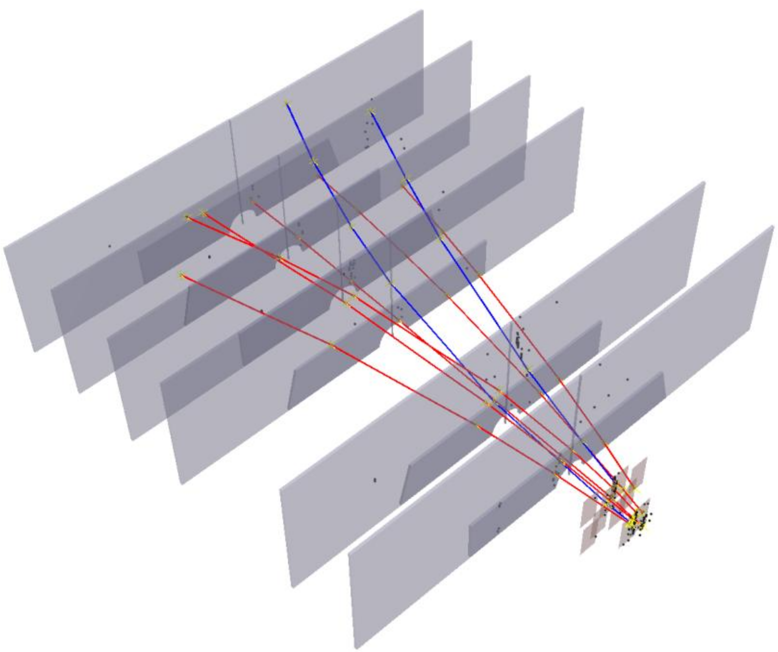


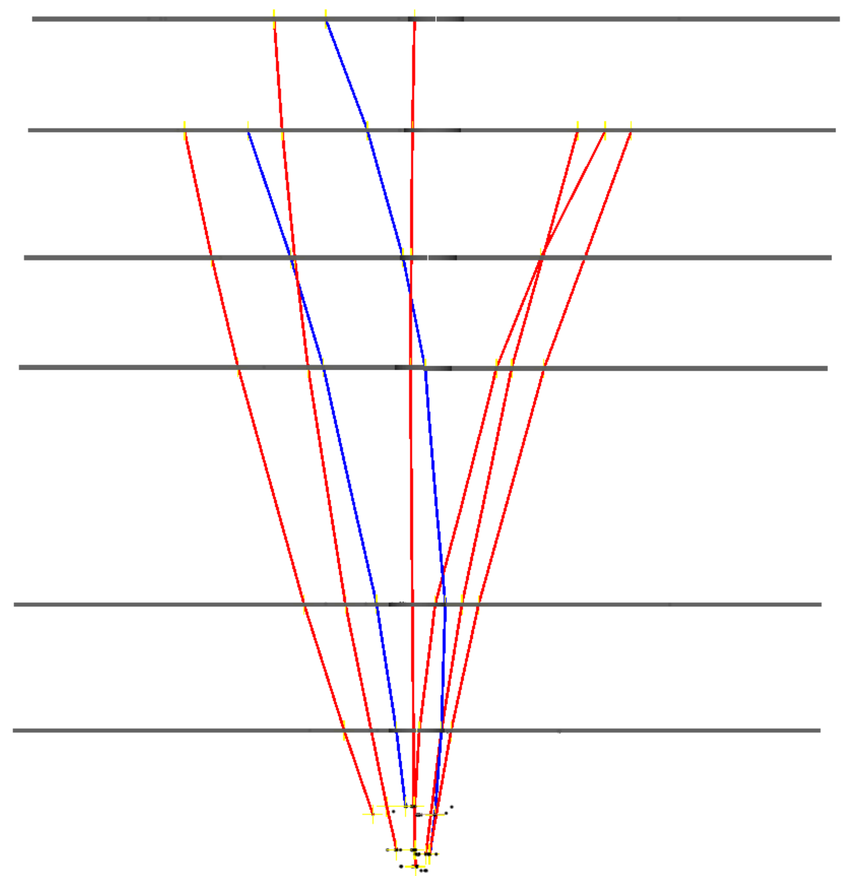


The average trajectories of the deuteron beam and the average Lorentz shifts of an electron avalanche in 6 GEM planes measured for four values of the magnetic field.

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

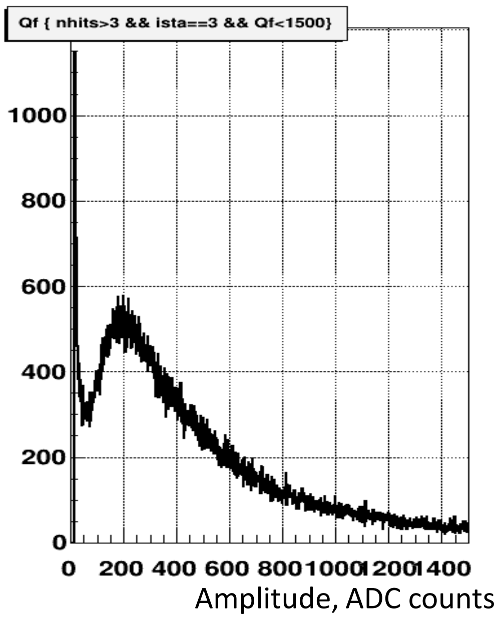


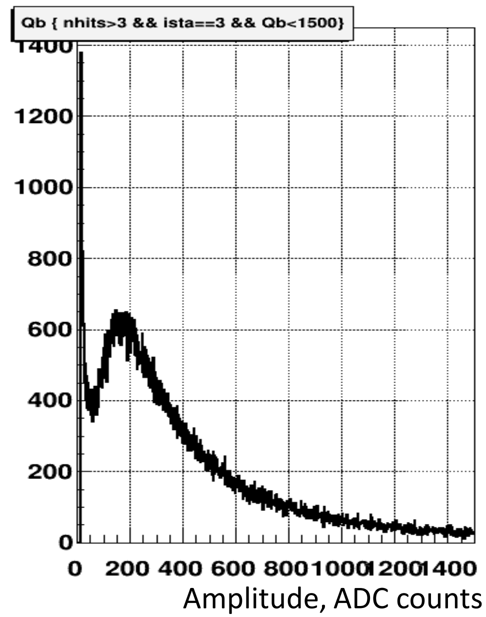




Gleb Pokatashkin

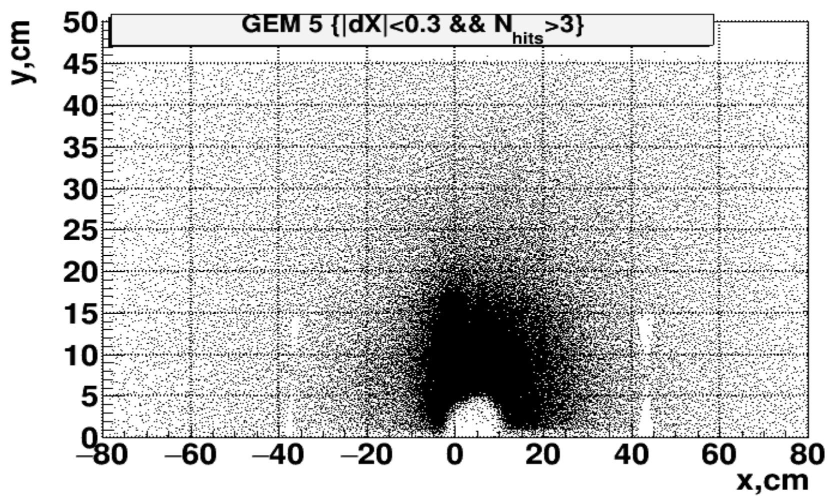
GEM tests at Ar beam





GEM X&Y amplitude distributions

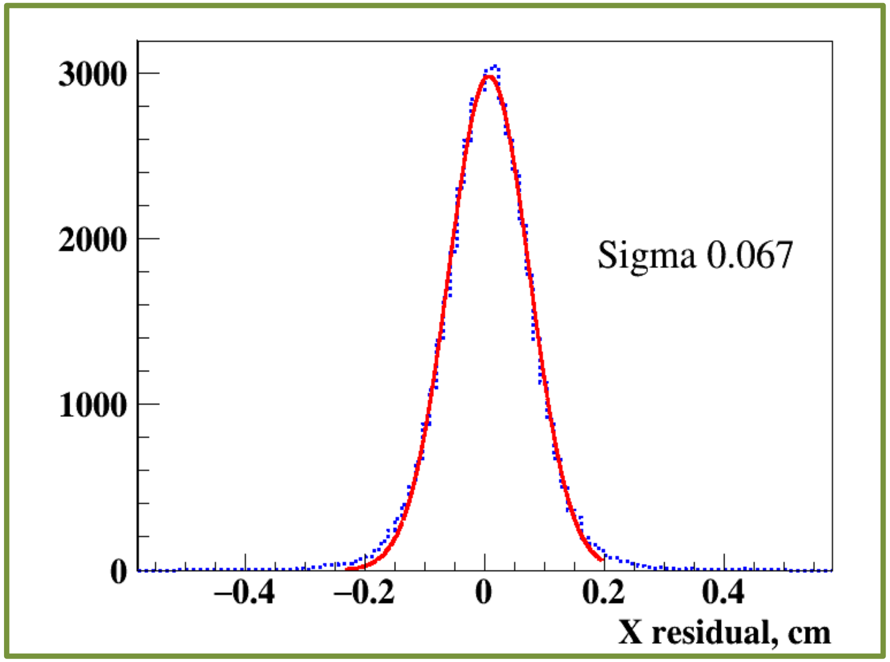
Fragments of Ar beam in one of the GEM chambers

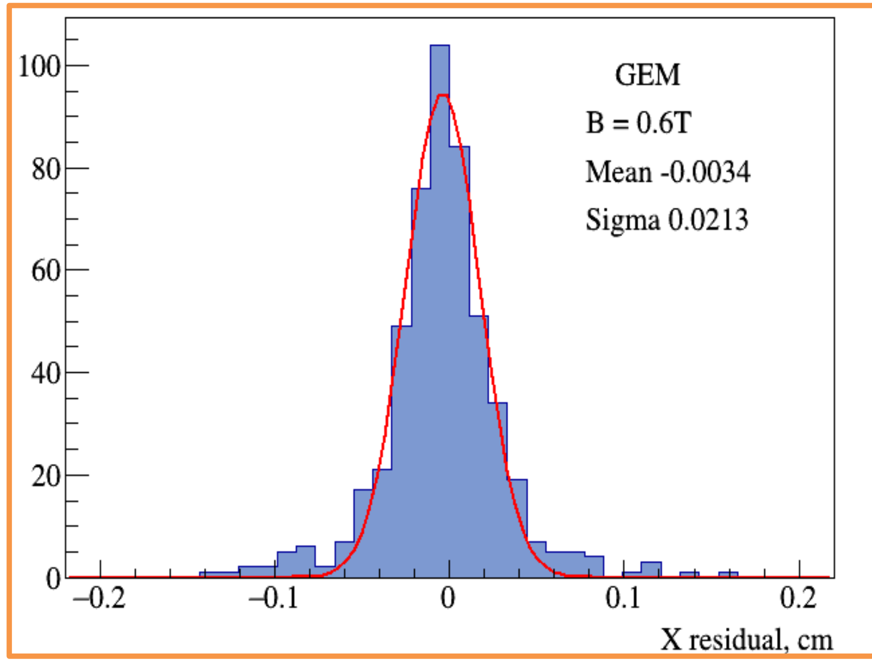


Pile-up suppression in Ar, Kr runs: 3 μs before and 0.5 μs after trigger signal

Gleb Pokatashkin

GEM hit residuals in magnetic field





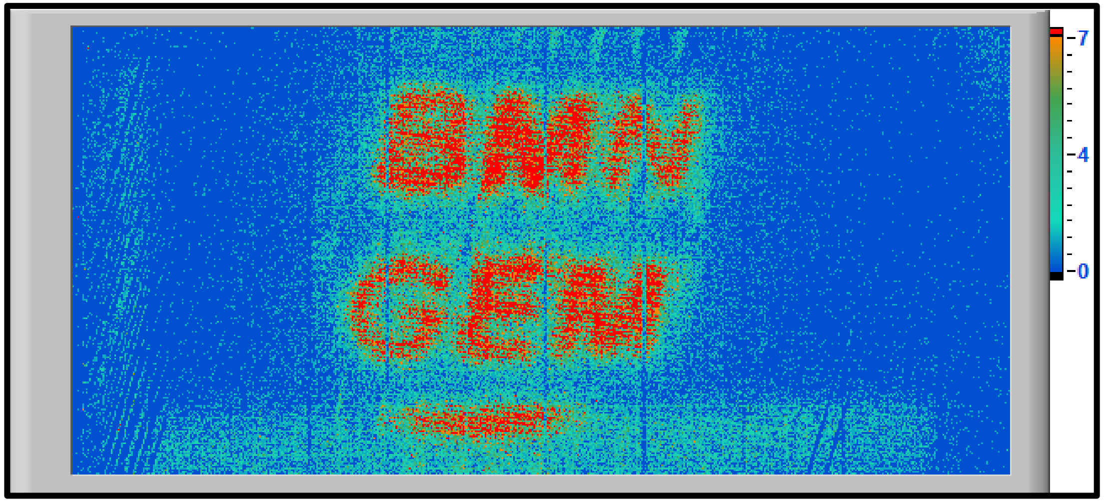
Magnetic field 0.6 T,
Ar(90)/Isobutane(10),
d beam, Edrift = 0.8kV/cm

Magnetic field 0.6 T,
Ar(80)/Isobutane(20),
Ar beam, Edrift = 1.5kV/cm

In Ar and Kr runs the value of electric field in drift gaps of GEM chambers was increased. The gas mixture was changed to Ar(80)/Isobutane(20).
The Lorentz shift of electrons avalanche was decreased.

Plans:

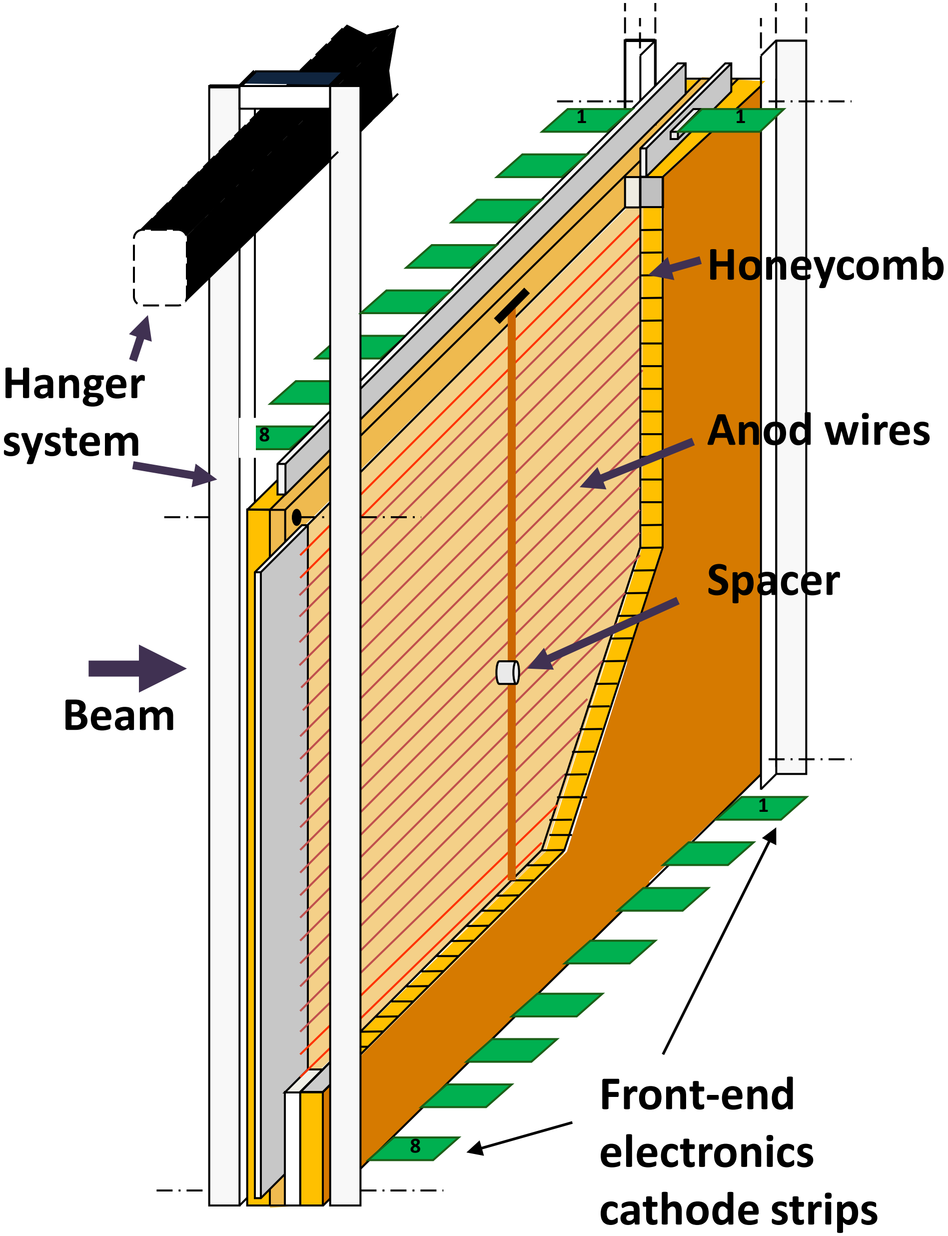
- 2019 year - production of 7 GEM chambers of size 1632 mm × 390 mm to cover vertical acceptance of analyzing magnet



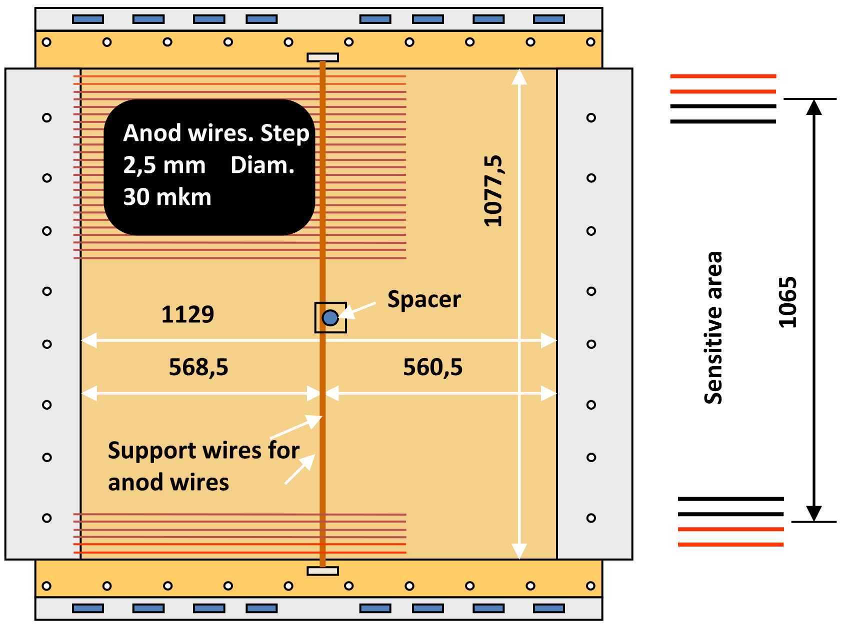
Cathode strip chambers

Cathode Strip Chamber (CSC) is intended to precise parameters of tracks, obtained in GEM detectors inside the analyzing magnet. Beside improvement of particles momentum identification, refined track in CSC is used to find corresponding hit in time-of-flight system (ToF400).

Schematic view of CSC



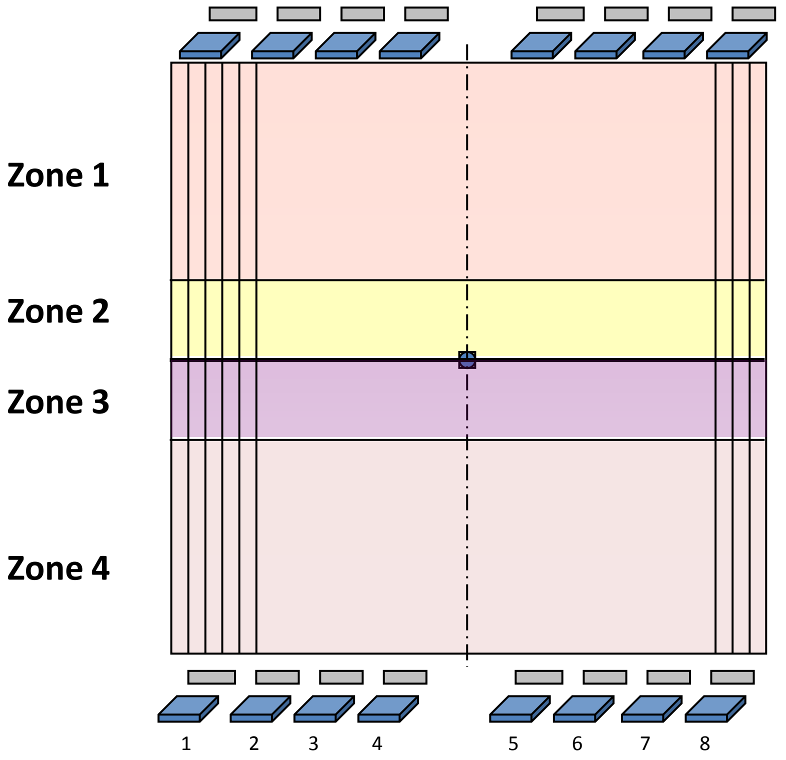
Anod wires geometry



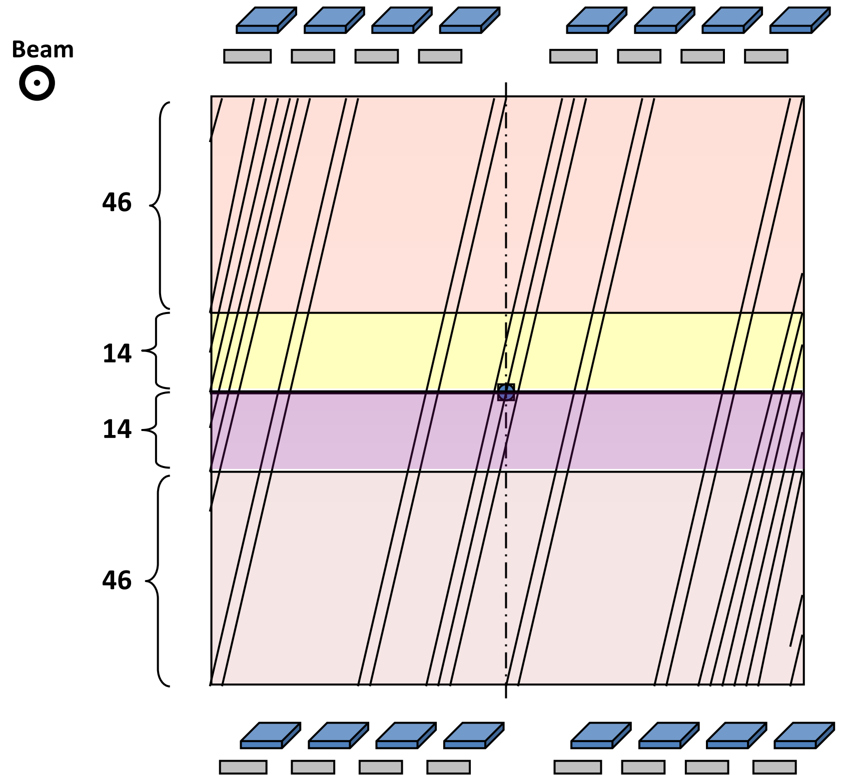
Design and assembly – JINR LHEP

Readout cathode planes

Each cathode plane consists of two printed circuit boards. Each pcb is divided on hot and cold zones.

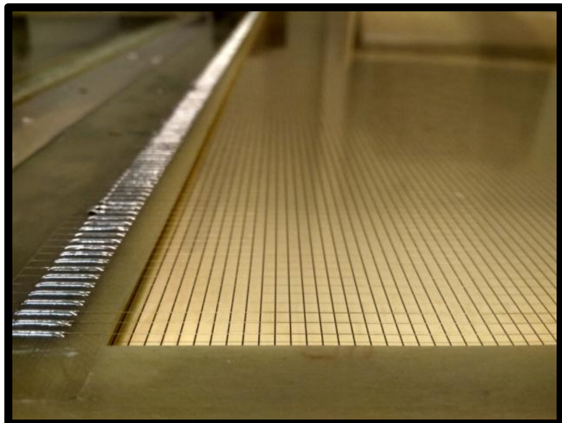


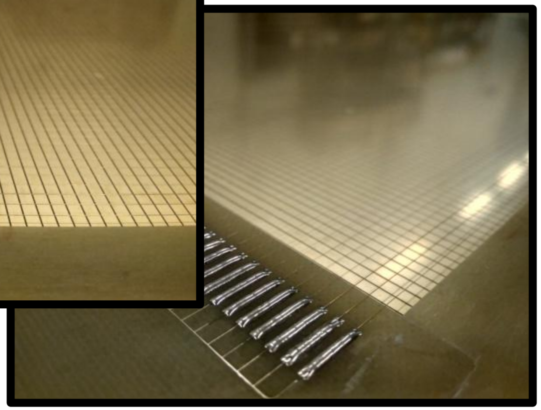
Vertical (X) strips

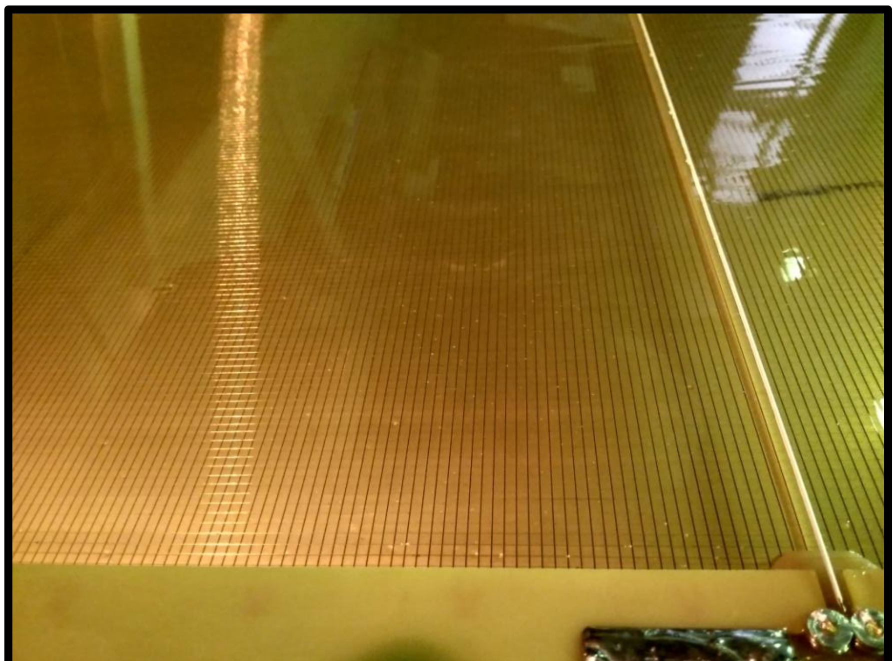


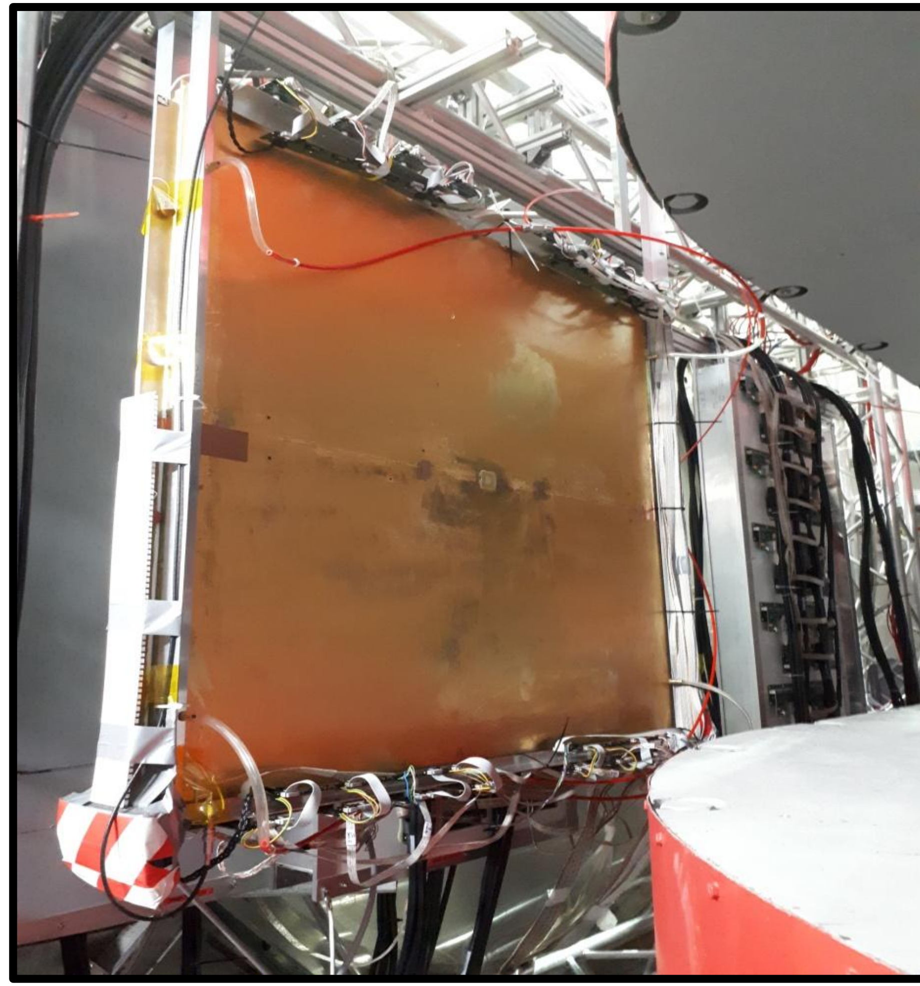
Inclined (Y) strips

CSC prototype 1065x1065 mm^2

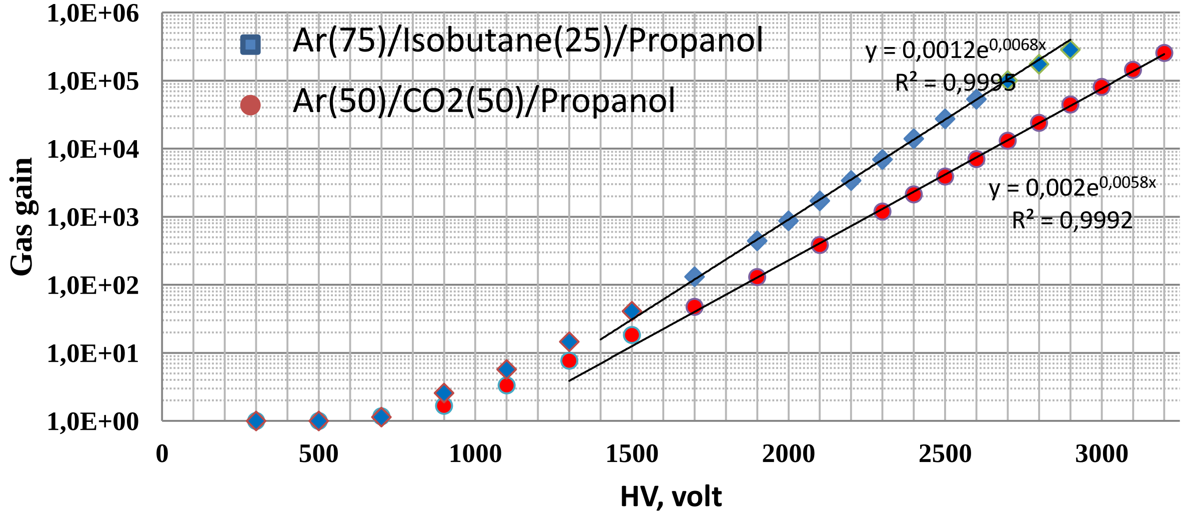




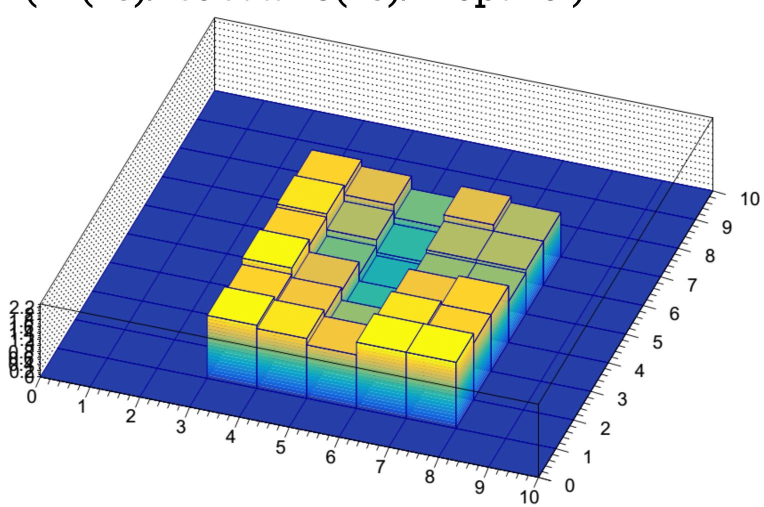




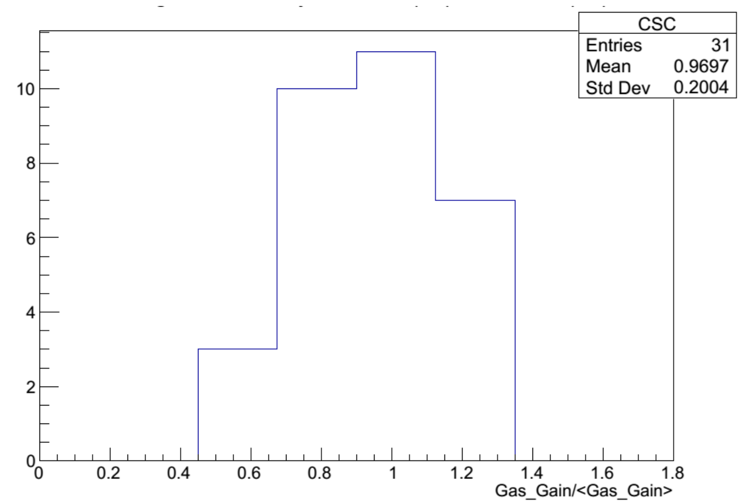
CSC gas gain and response uniformity measurements



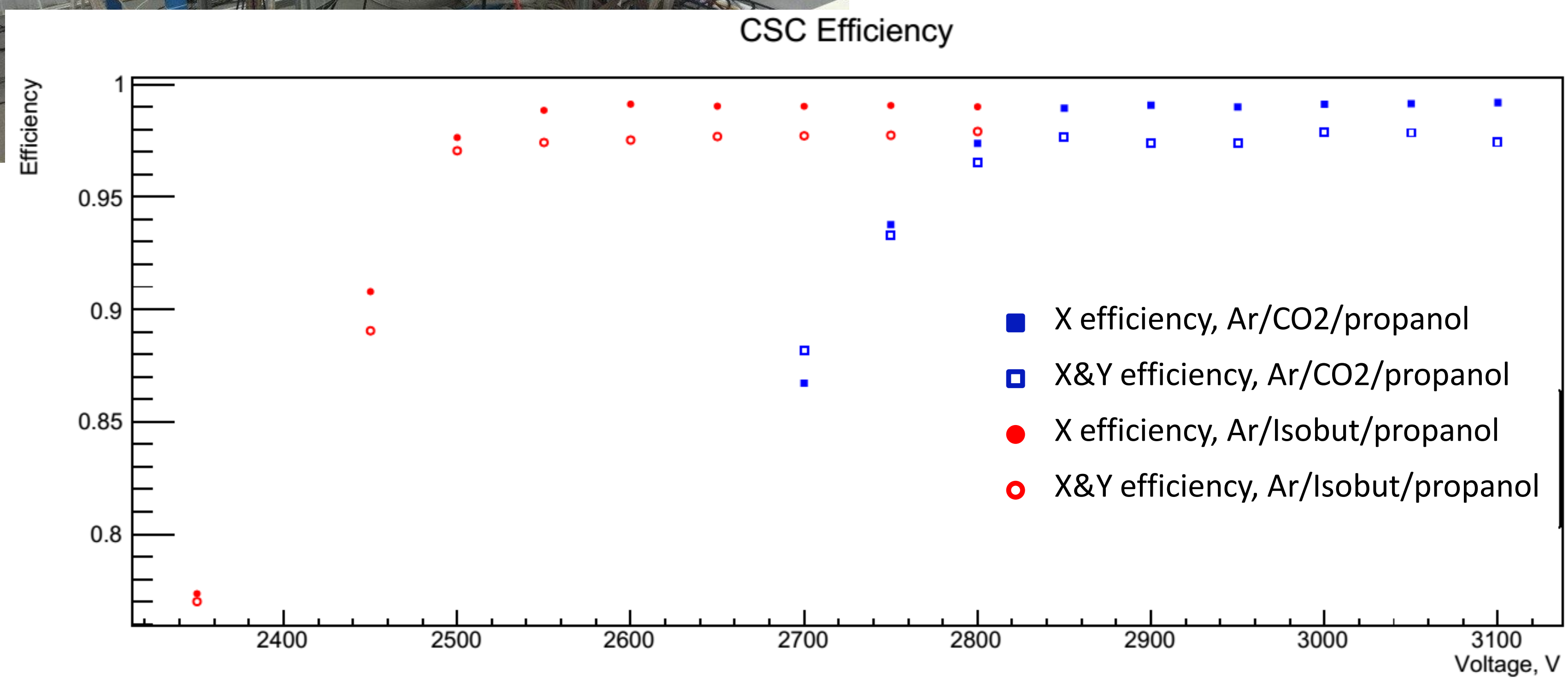
CSC response uniformity (Ar(75)/Isobutane(25)/Propanol)



Gas gain distribution normalized on average gas gain

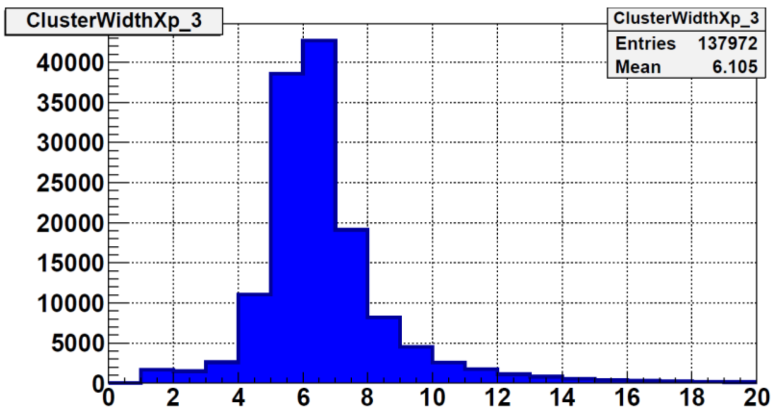


CSC cosmic tests

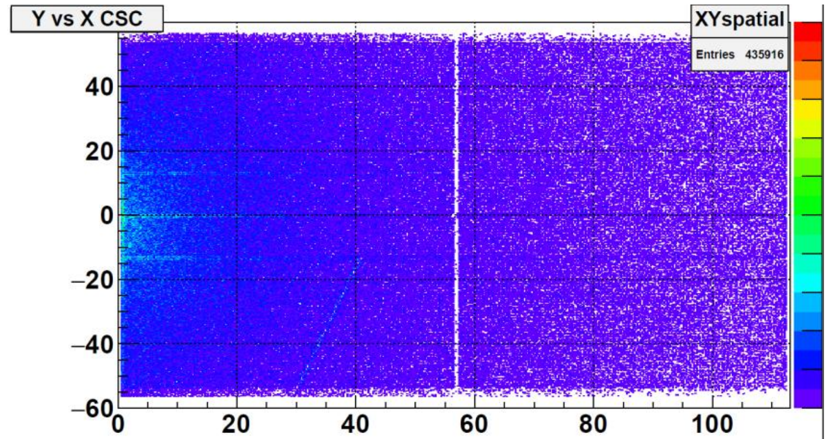


First beam test of CSC

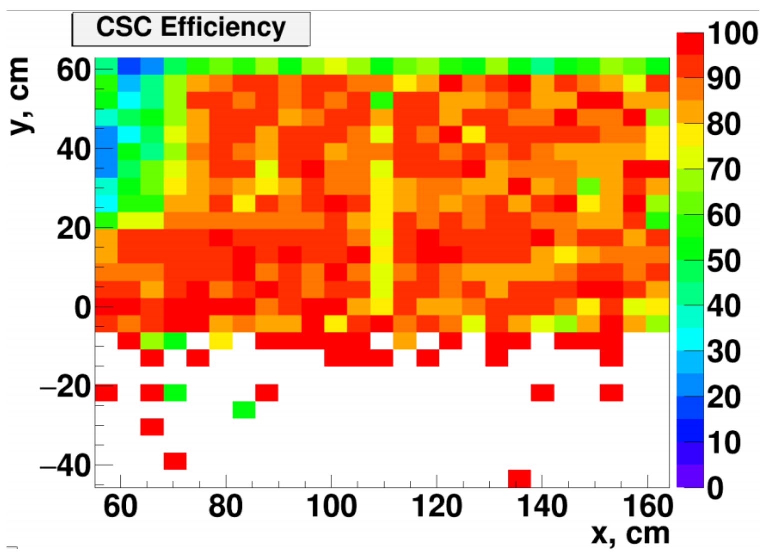
C, Ar and Kr runs in March 2018: CSC chamber is installed in front of ToF-400 to check its performance as outer tracker for heavy ions



Cluster width



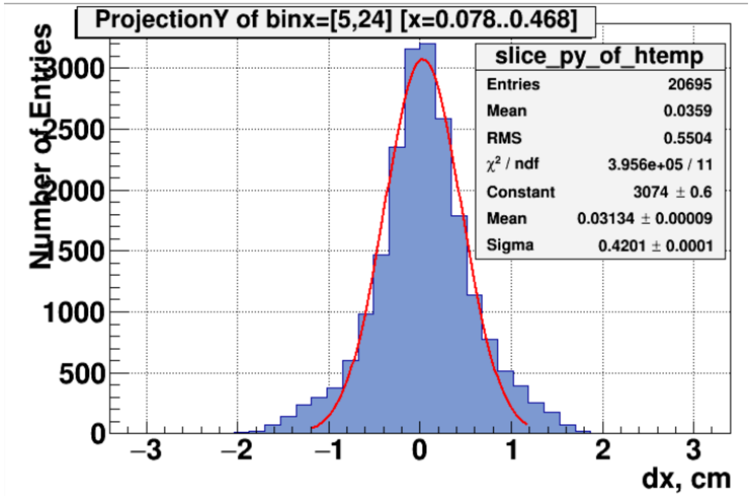
Events distribution on the chamber surface

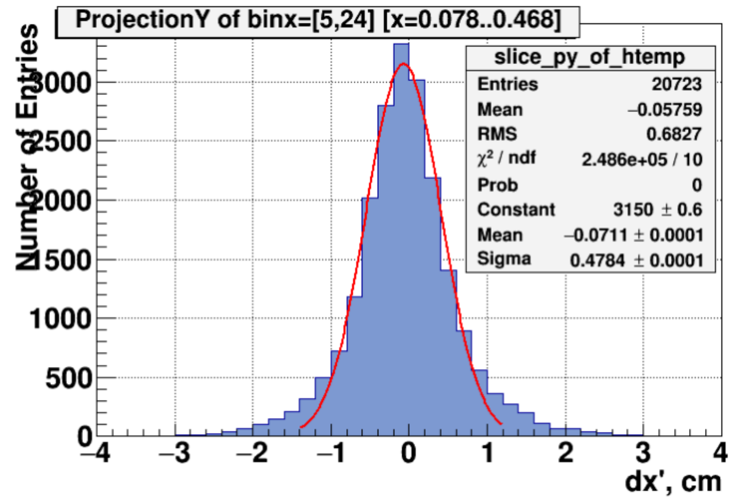


CSC efficiency
Track extrapolated from GEM
Residual (CSC_hit – GEM) < 2cm

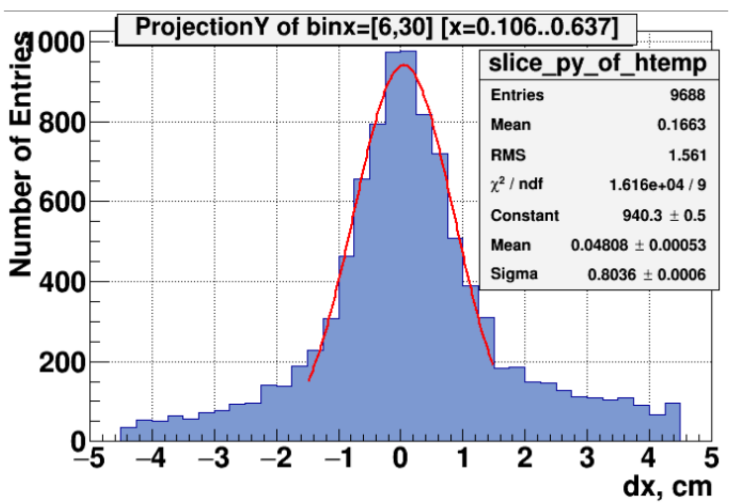
CSC residuals (Ar beam)

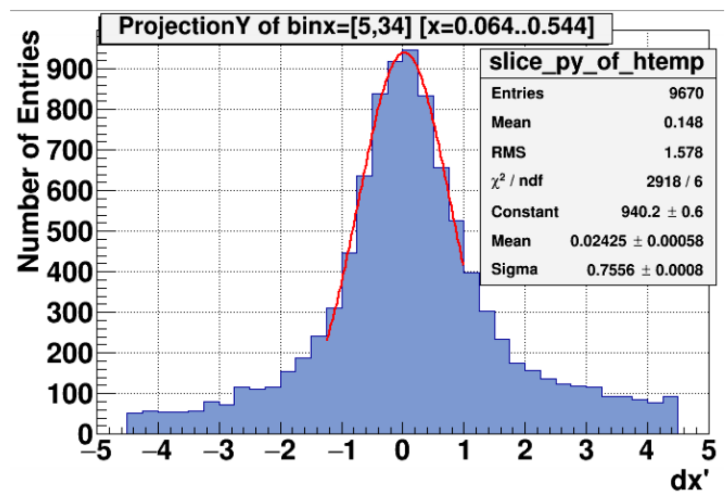
X and Y residuals without magnetic field





X and Y residuals, magnetic field 0.6 T



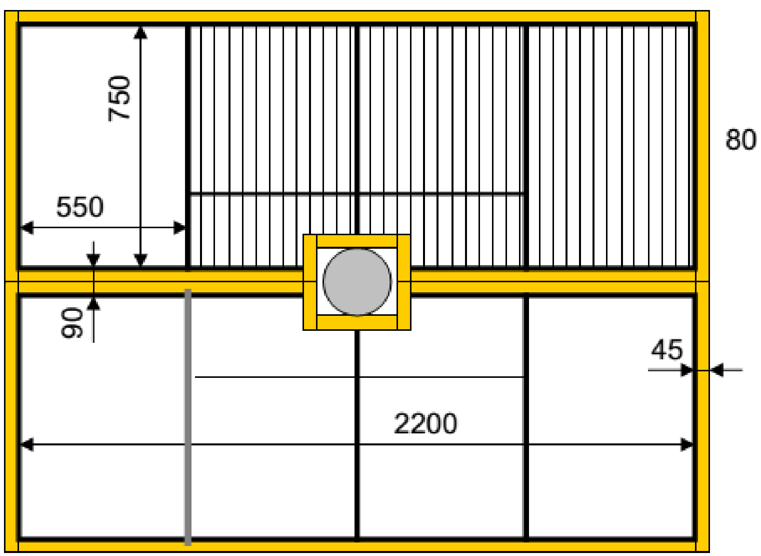


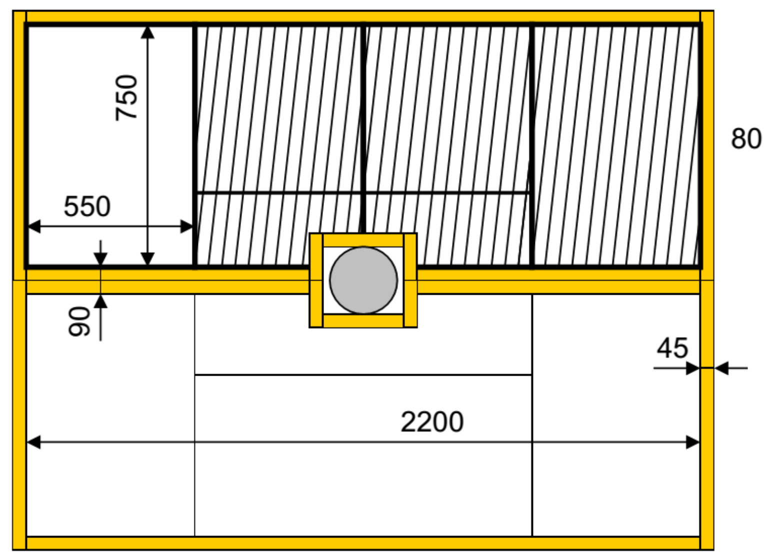
V. Plotnikov

Plans:

-production of 3 CSC chambers 1065x1065 mm^2 (to be installed in front of and
behind ToF400 system)

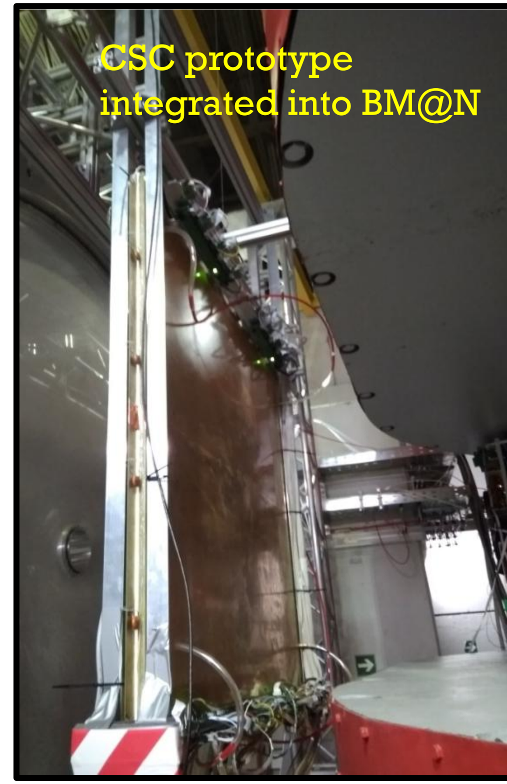
-production of 2 CSC chambers 2x1.5 m^2 (to be installed in front of and behind ToF700 system)





Conclusions

Triple GEM detectors of the BM@N tracker system have been assembled and studied in the d, C, Ar, Kr beams of the Nuclotron accelerator. The measured parameters of the GEM detectors are consistent with the design specifications. Seven 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:

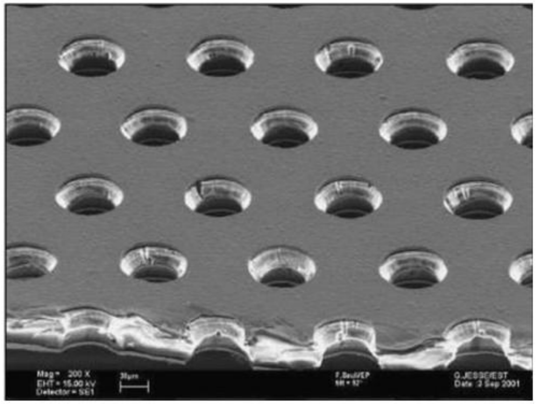
- 12 chambers 660x412 mm^2 (5) and 1632x450 mm^2 (7),
- ~ 6.5 m^2 active area,
- ~ 1 billion of independent amplification channels,
- ~ 45000 strips/electronics channels,
- > 3 km of control and readout cables.

The first prototype of CSC was tested in technical run of BM@N in February-March 2018.

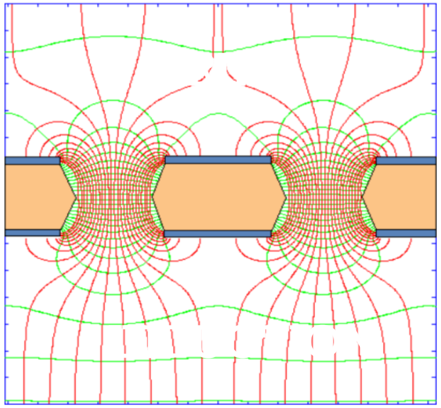
Thank you for your attention!

Back-up slides

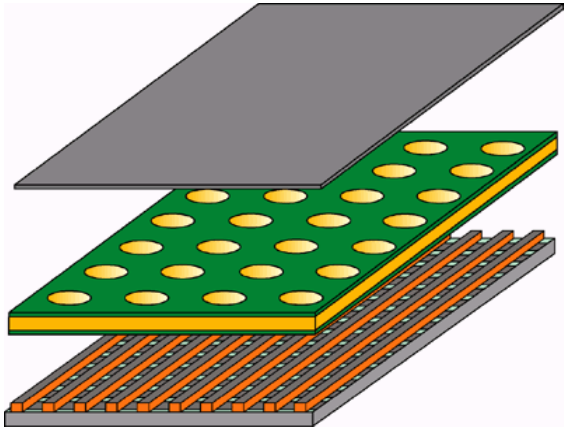
The gas electron multiplier (GEM)



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



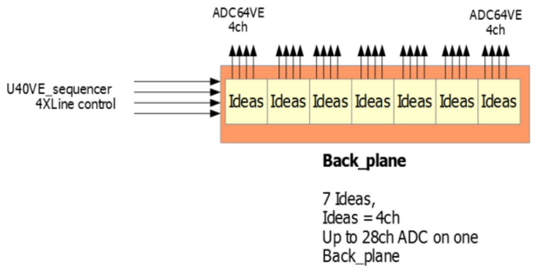
Electric field in the region of the holes of a GEM electrode



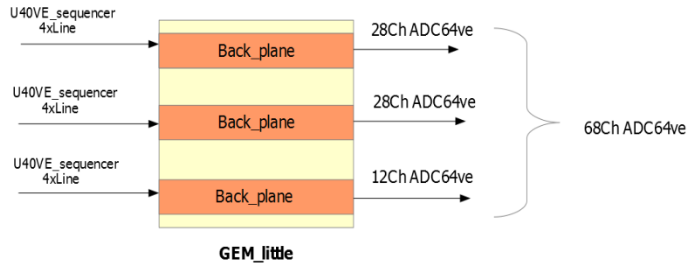
Schematics of single GEM detector with Cartesian two-dimensional strip readout.

GEM DAQ Scheme

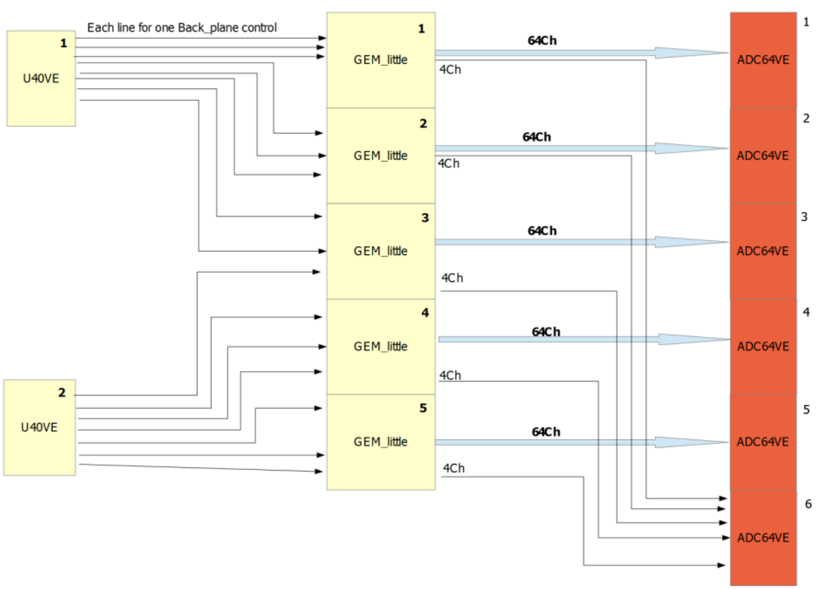
BACK PLANE SCHEM



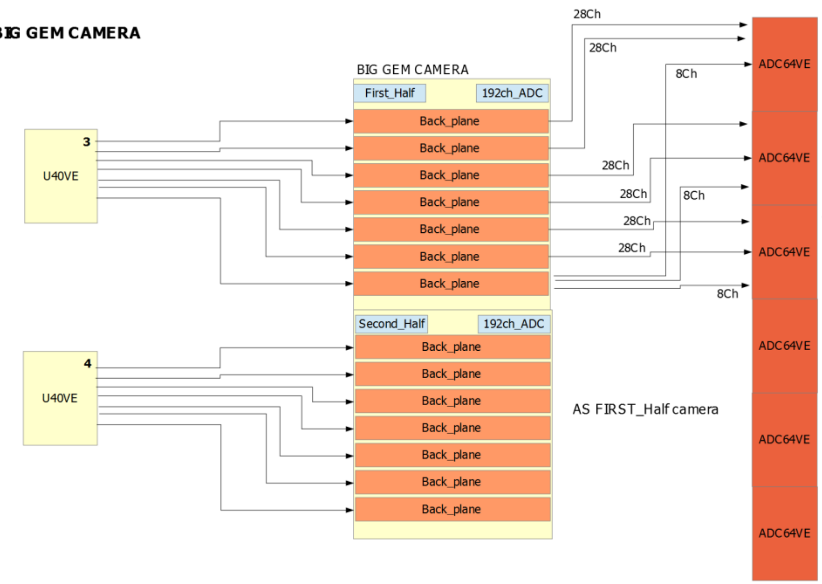
ONE LITTLE GEM CAMERA SCHEM



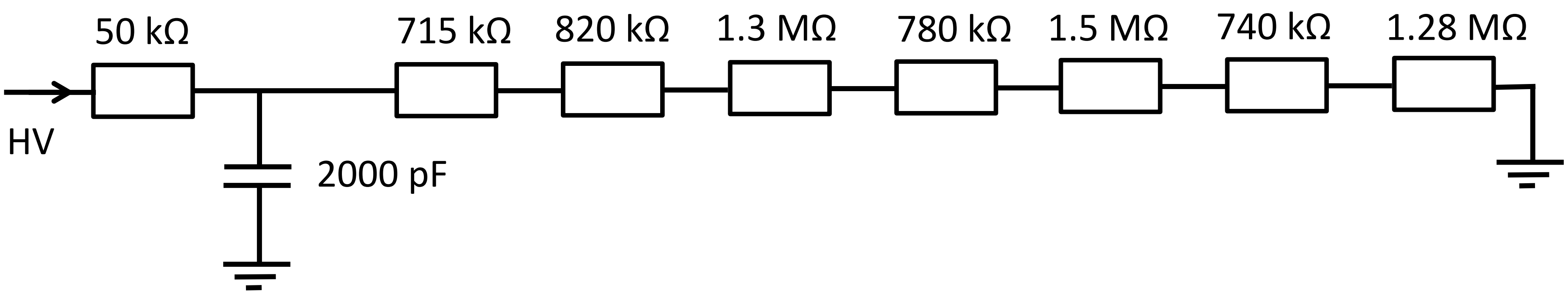
LITTLE GEM CAMERA



BIG GEM CAMERA



GEM HV divider scheme

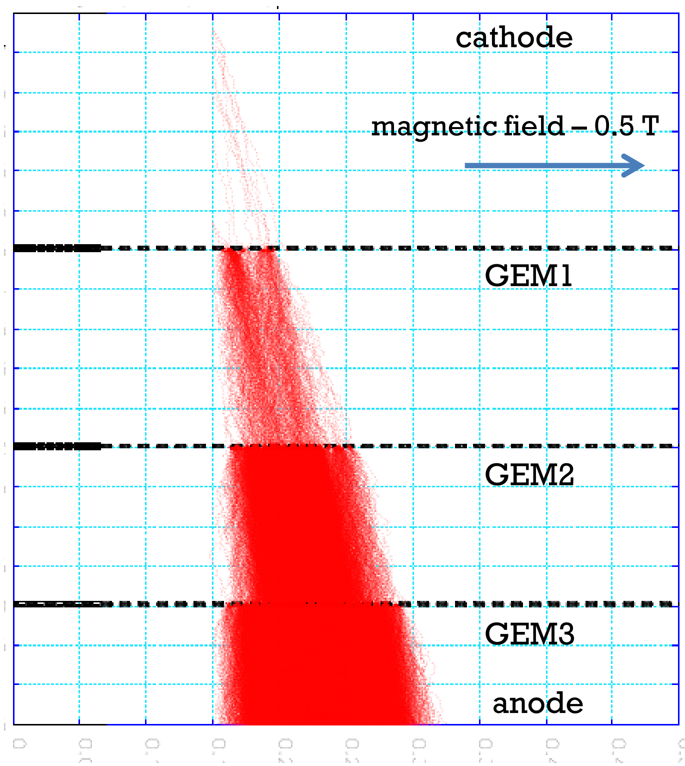


I, mkA	DR, kv/cm	G1, v	TR1, kv/cm	G2, v	TR2, kv/cm	G3, v	IND, kv/cm
370	0.88	303.4	1.92	288.6	2.78	273.8	3.16
490	1.17	402	2.58	382	3.68	363	4.18

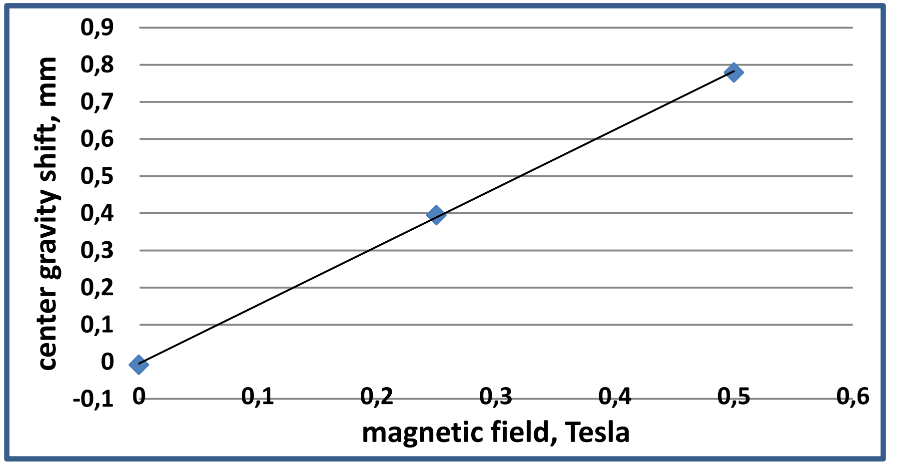
370 mkA – working point for Ar(90)/Isobutane(10) gas mixture
490 mkA – working point for Ar(70)/CO2(30) gas mixture

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

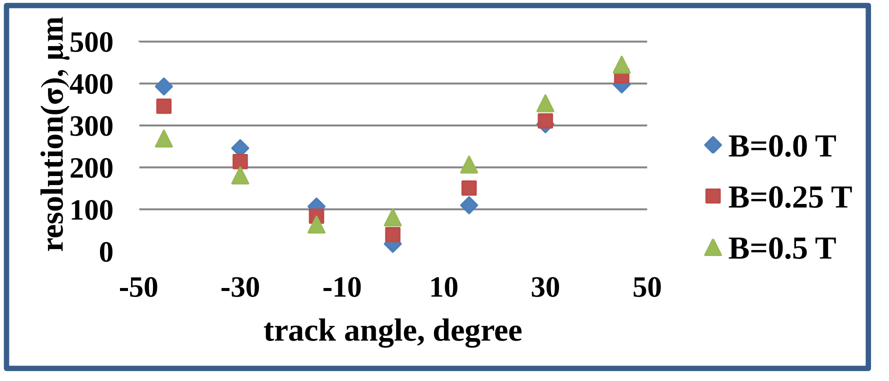
Simulation of electron shift in magnetic field



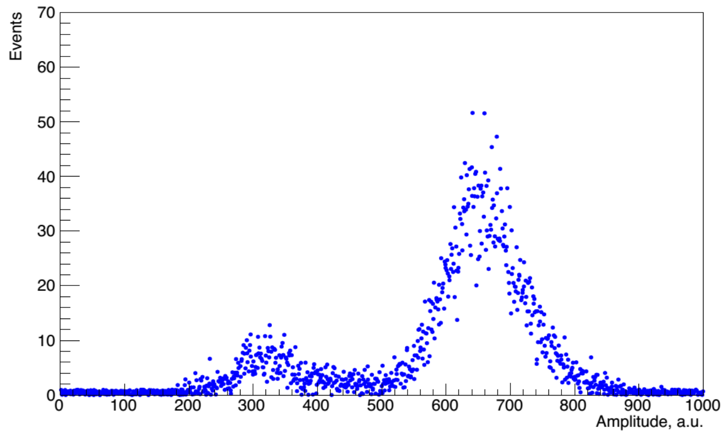
Center gravity shift vs magnetic field



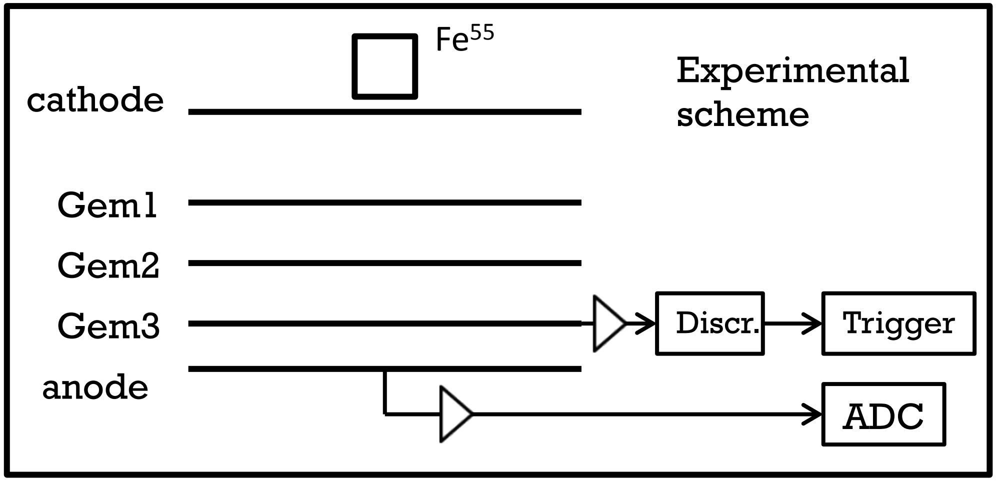
Space resolution vs magnetic field and track angle

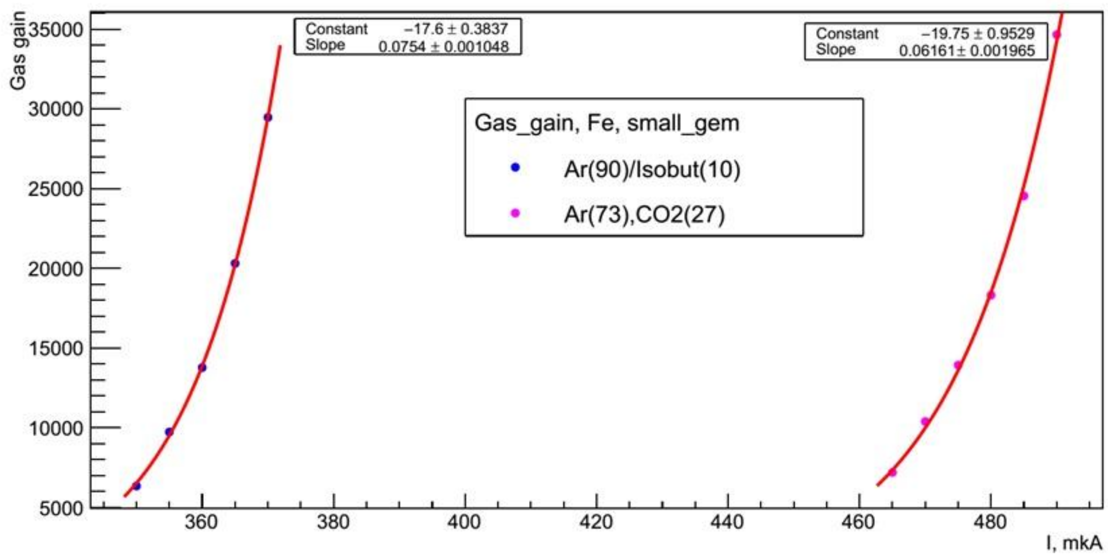


GEM gas gain measurements



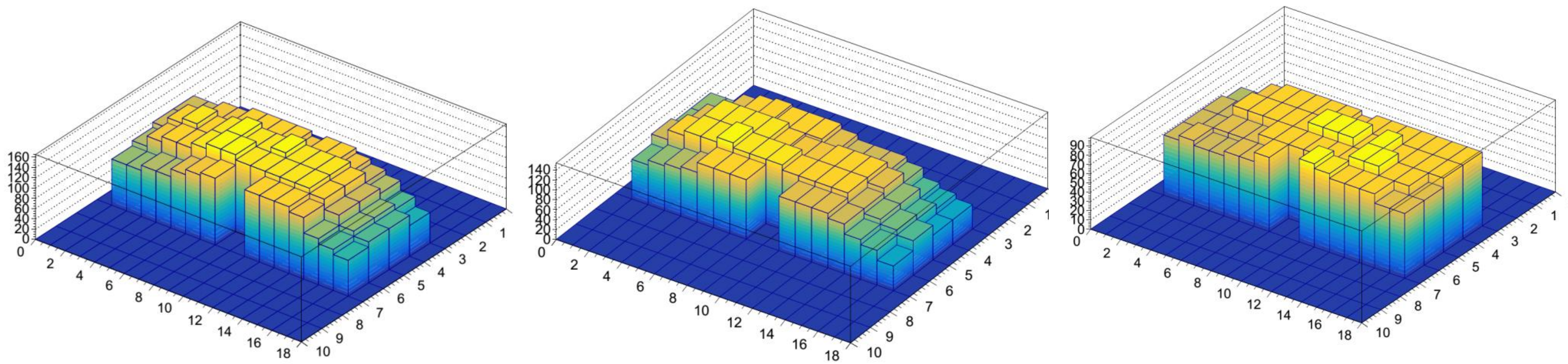
Amplitude distribution, Ar(70)/CO2(30), Fe^{55}



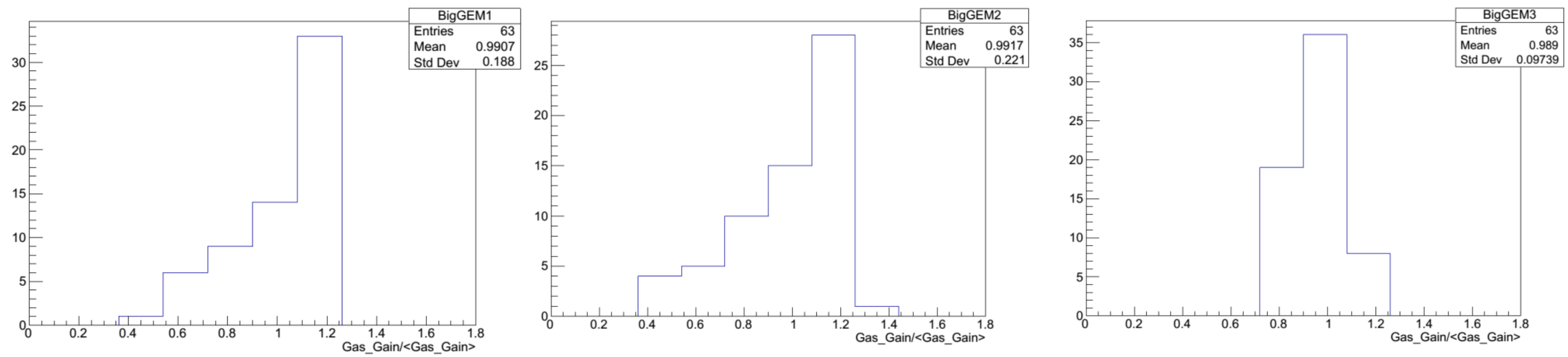


GEM gas gain for Ar(70)/CO2(30) and Ar(90)/Isobutane(10) gas mixtures

GEM 1632x450 mm^2 response uniformity

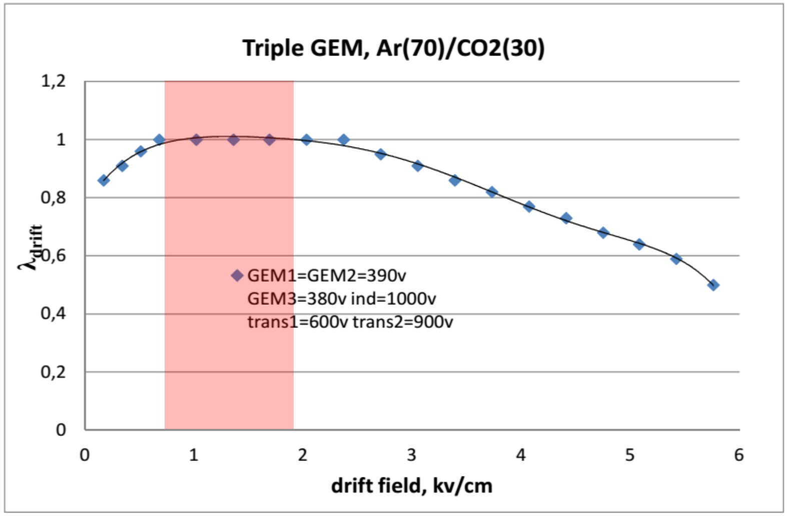


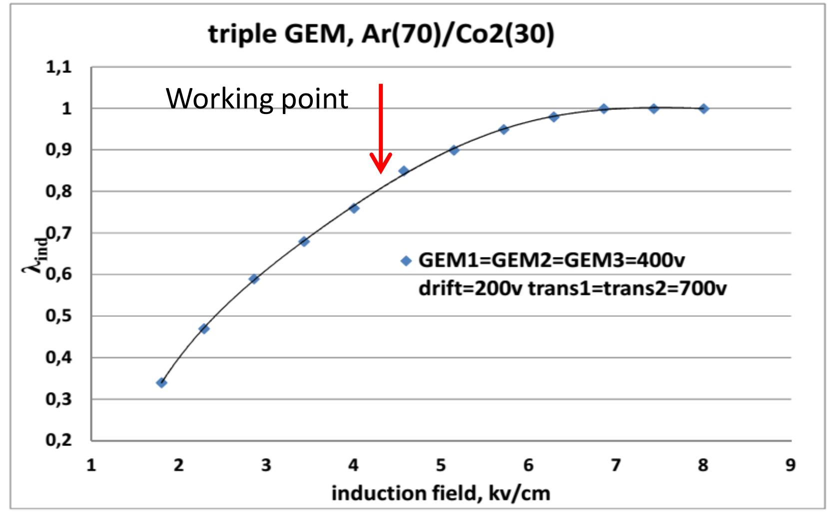
Response uniformity 3D plot of three 1632x450 mm^2 chambers, Ar(90)/Isobutane(10) gas mixture

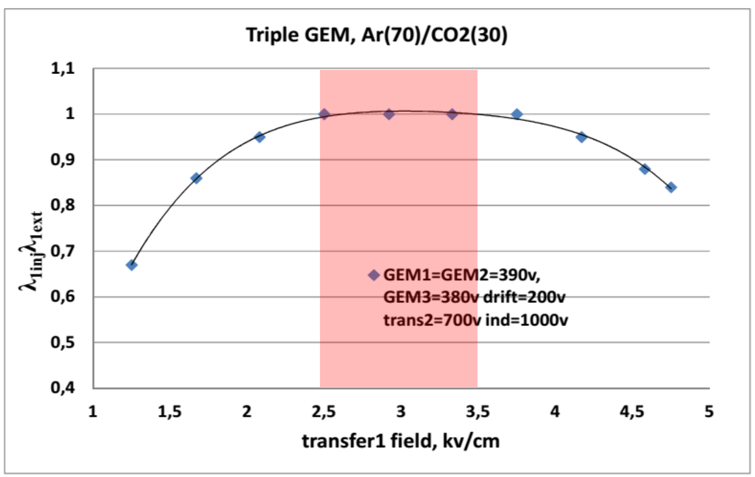


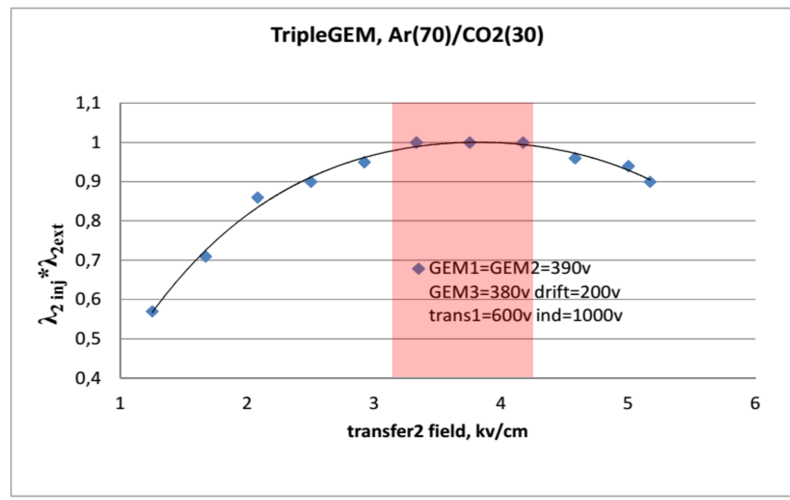
Gas gain distribution normalized on average gas gain for three 1632x450 mm^2 chambers, Ar(90)/Isobutane(10) gas mixture

GEM Optimization



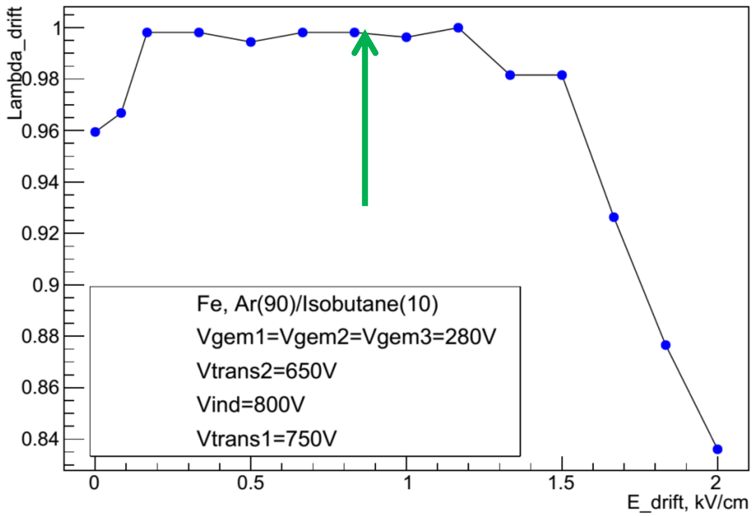


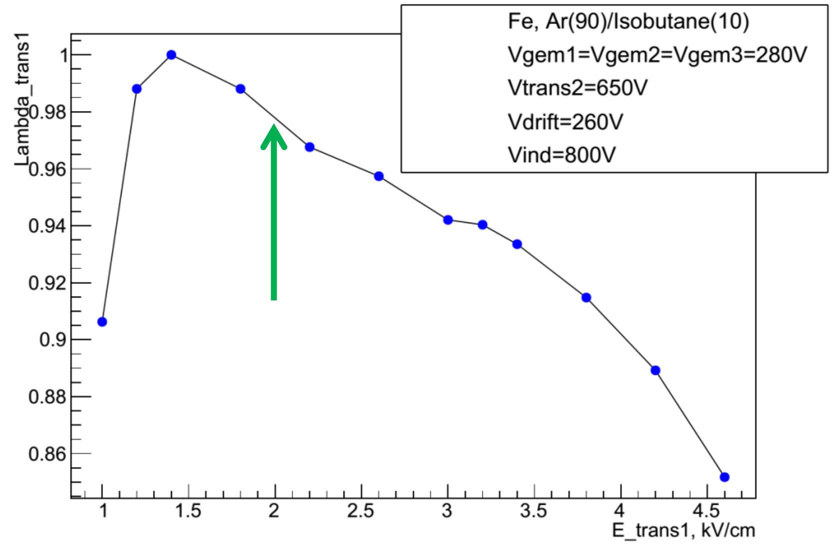


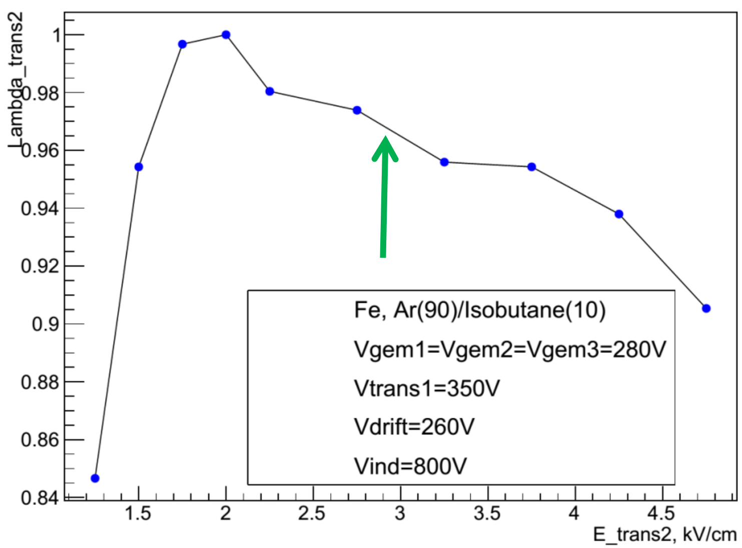


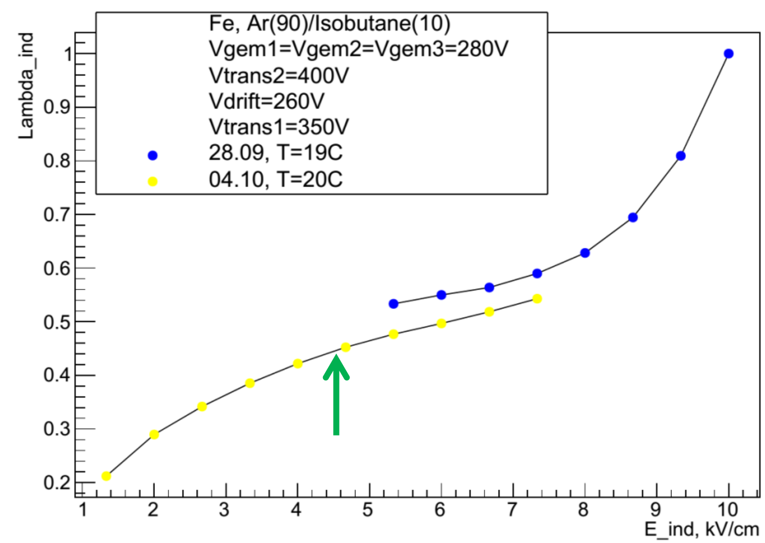
- Working range of field, kV/cm (Ar(70)/CO_2(30)gas mixture)

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









Lambda summary = 0.86

GEM and CSC efficiency (cosmic tests)