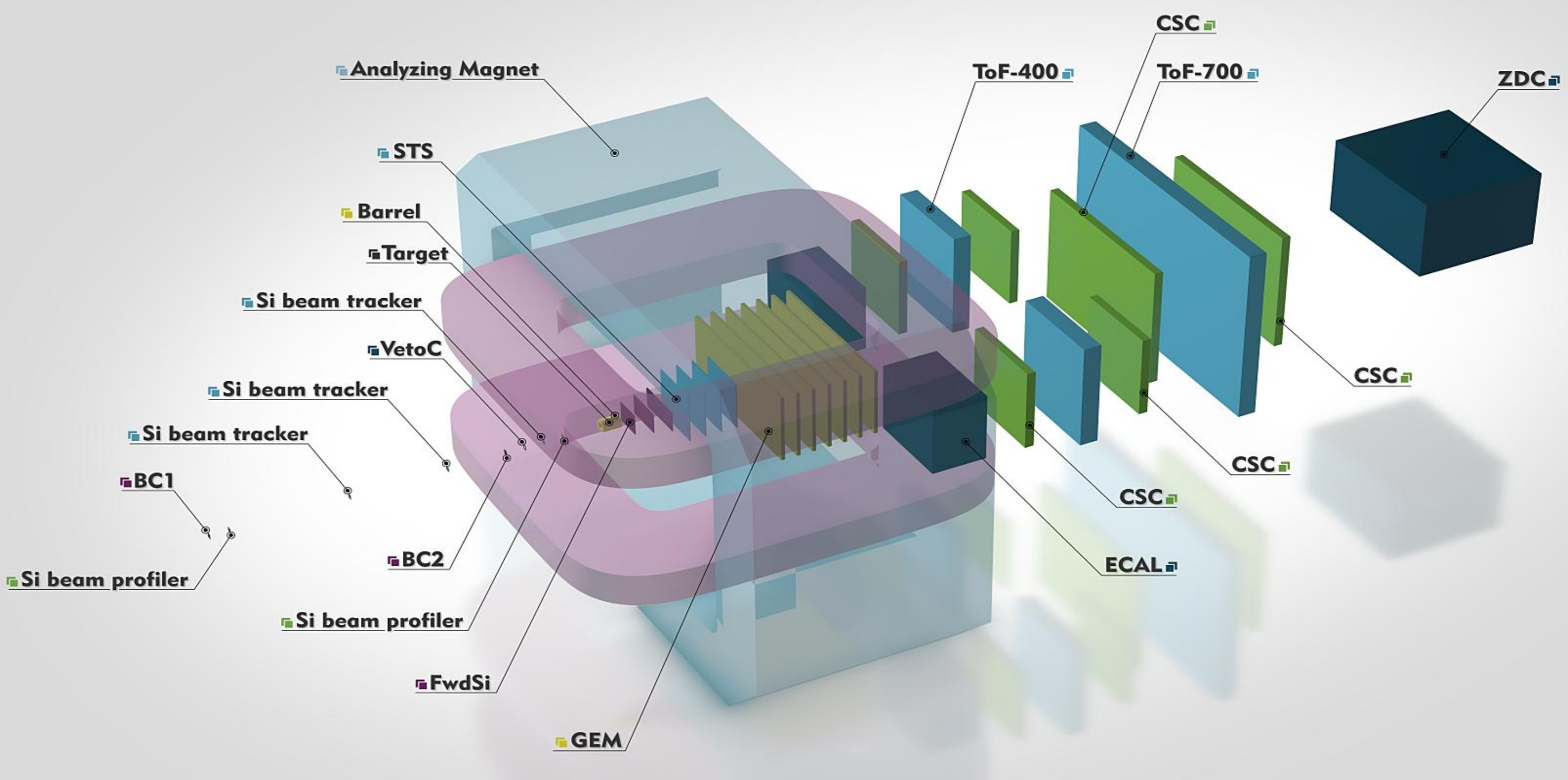
Study of the BM@N GEM/CSC tracking system performance

Andrei Galavanov 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.



Basic requirements for the BM@N tracking system

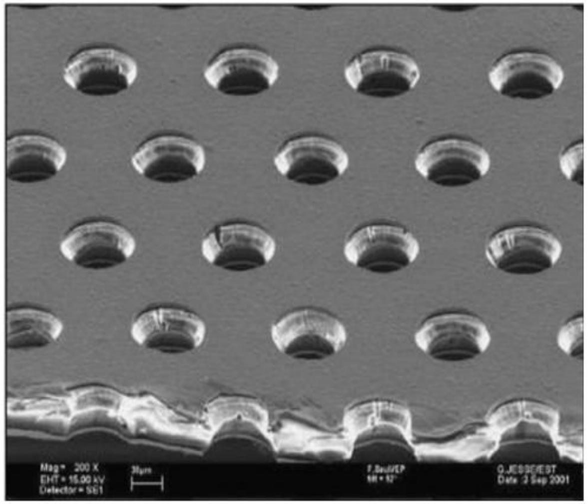
Tracking system of the BM@N experiment will provide precise momentum measurements of the cascade decays products of multi-strange hyperons and hyper-nuclei produced in central Au-Au collisions. All physics measurements will be performed in conditions of high beam intensities in collisions with large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

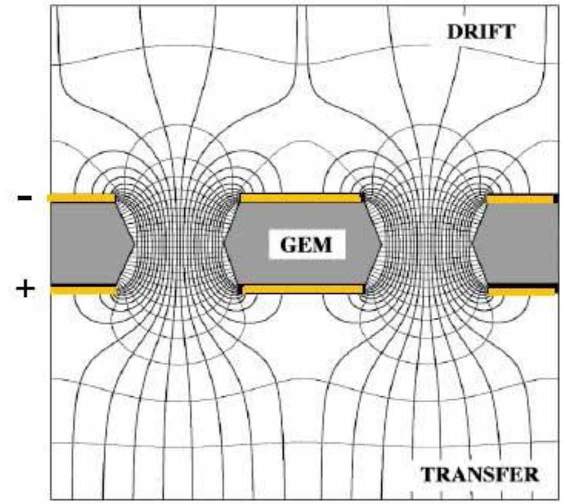
- capability of stable operation in conditions of high loadings up to 10^5 Hz/cm^2;
- high spatial and momentum resolution;
- high geometrical efficiency (better than 95%);
- maximum possible geometrical acceptance within the BM@N experiment dimensions;
- tracking system detectors must function in a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

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 and ToF700).

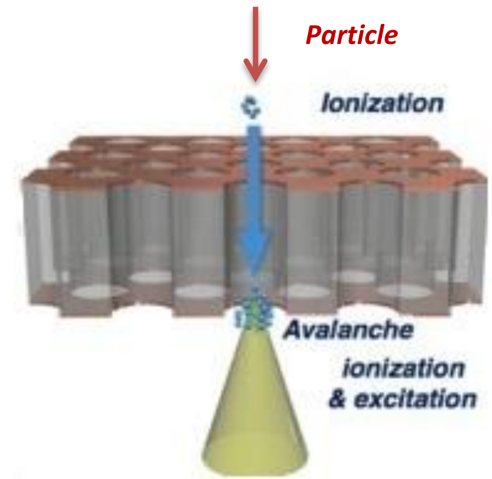
The gas electron multiplier (GEM)



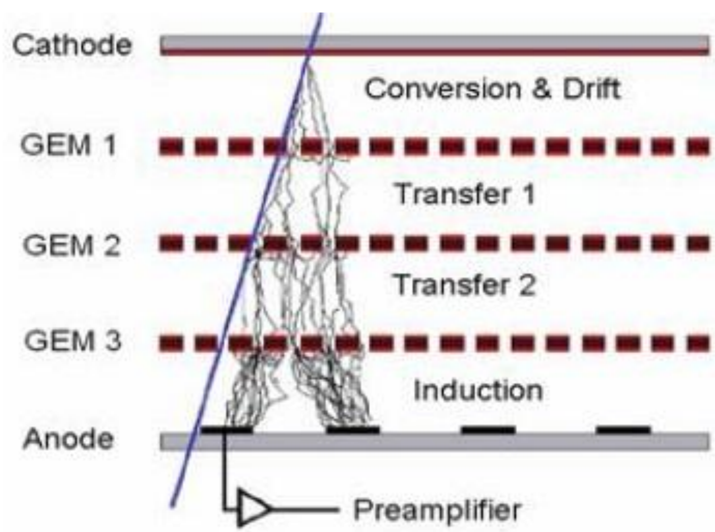
Electron microscope picture of a section of typical GEM foil: 50 μm thick capton foil, metalized on each side by 5 μm thick copper electrodes . The holes pitch and diameter are 140 and 70 μm, respectively.



Electric field in the region of the holes in a GEM foil.

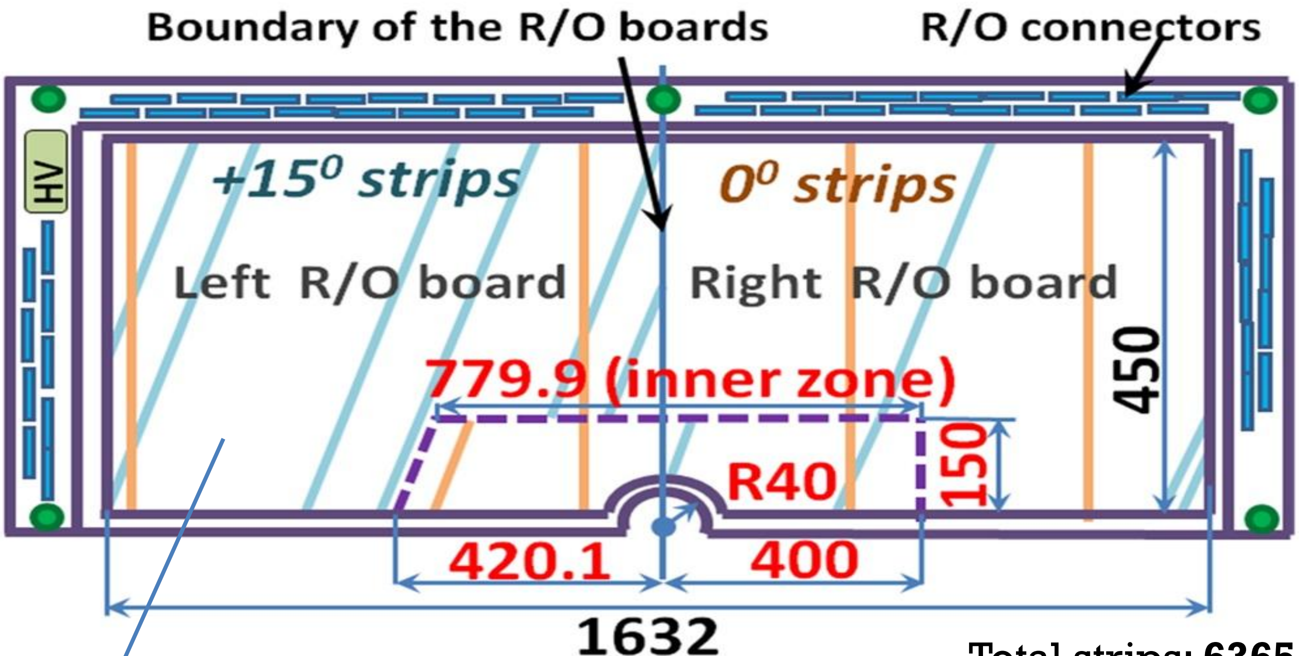


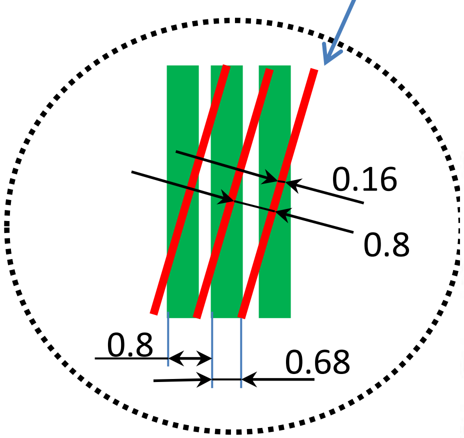
Electron avalanche in a GEM holes.

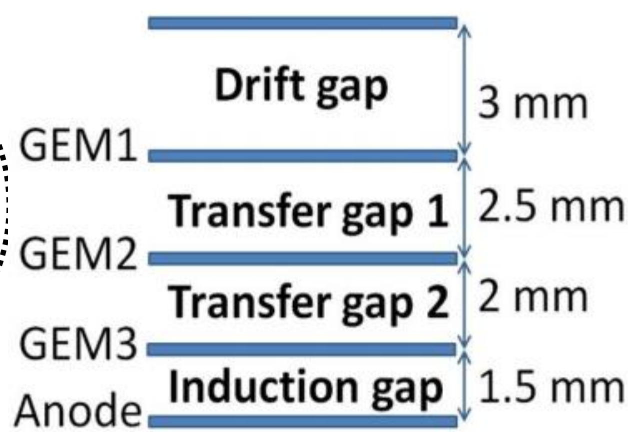


Typical scheme of triple GEM detector.

BM@N GEM chambers







Schematic cross section of BM@N triple GEM detector

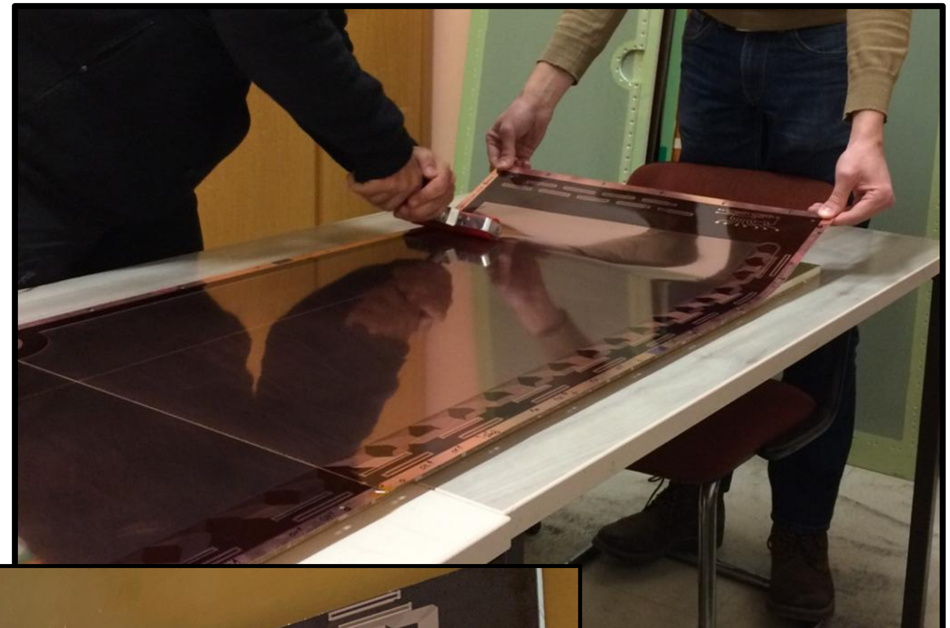
Total strips: **6365**
R/O connectors (128 pins): **50**

Now we have:
7 chambers 1632 × 450 mm^2
1 chamber 1632 × 390 mm^2

6 chambers 1632 × 390 mm^2 have been prepared to assembly in March 2019

GEM assembly at CERN Workshop

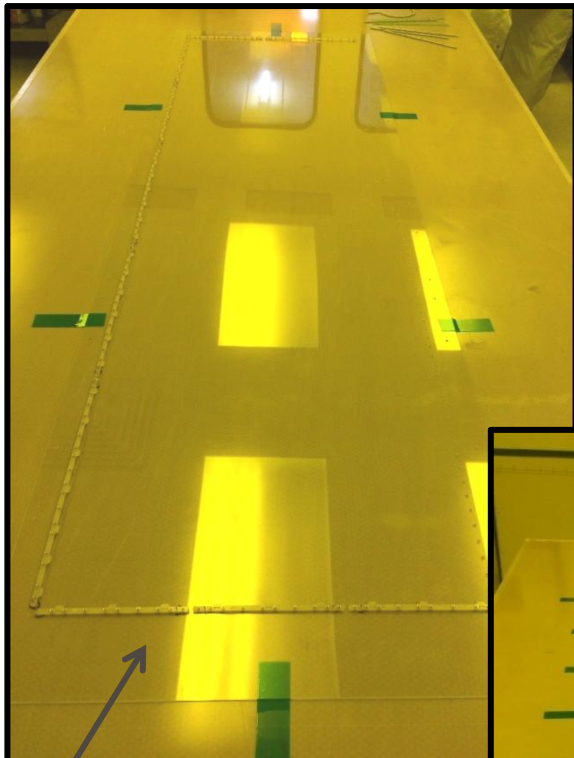
Right readout board

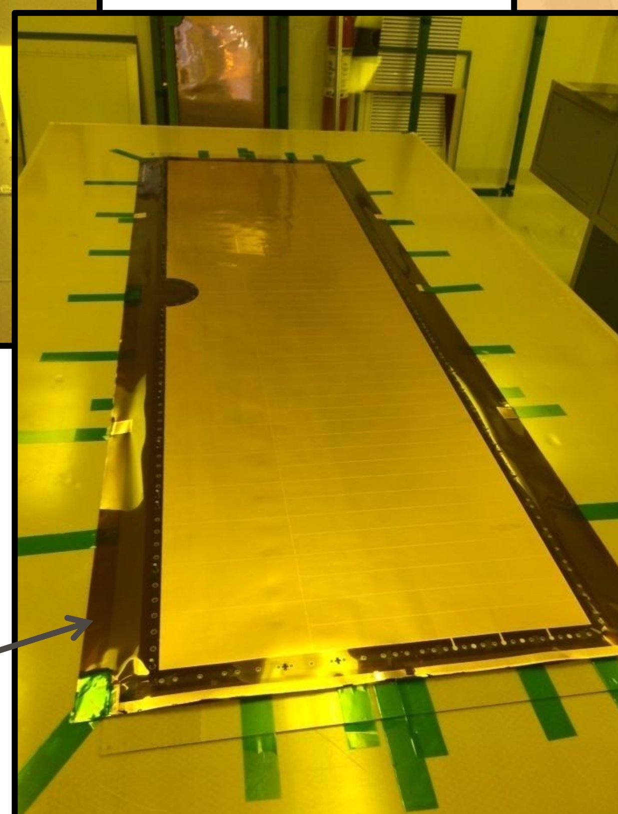


Gluing of the readout boards on the honeycomb support plate

Glued readout board

GEM assembly at CERN Workshop



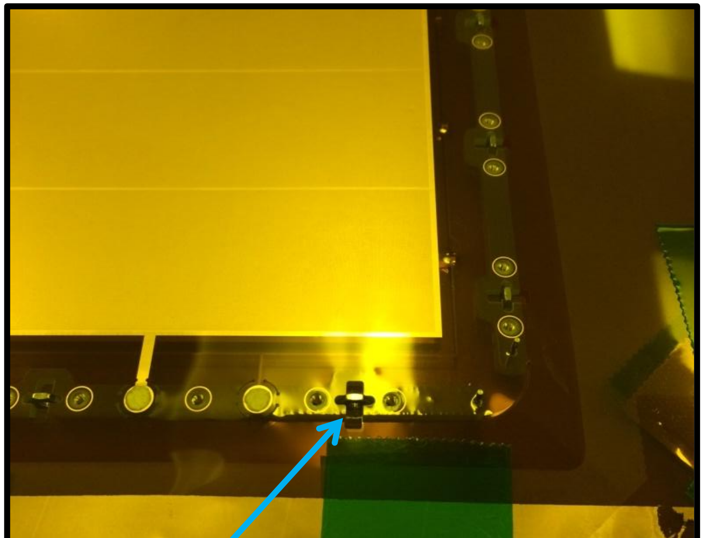


Base plastic frame

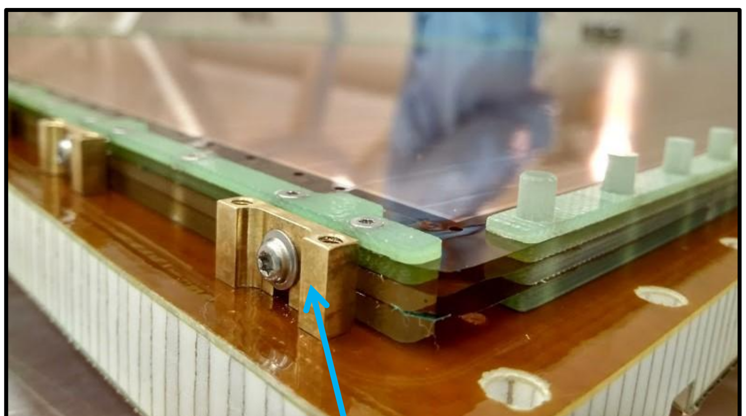
GEM foil tests

GEM foil preliminary stretching

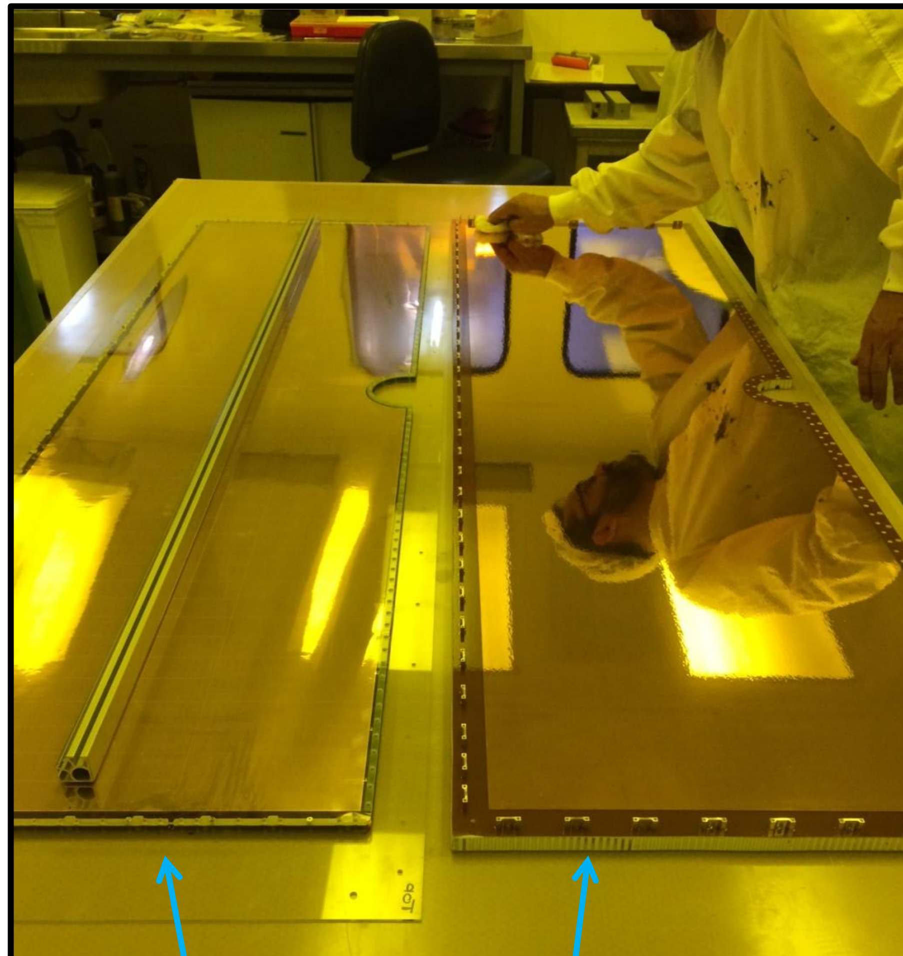
GEM assembly at CERN Workshop



Nuts in plastic frames



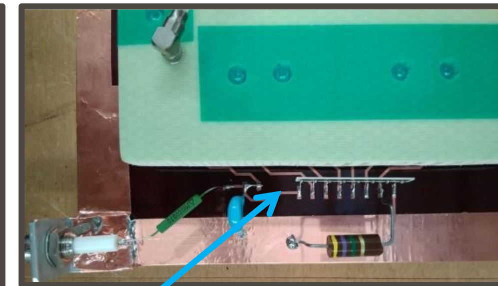
Brass fitting



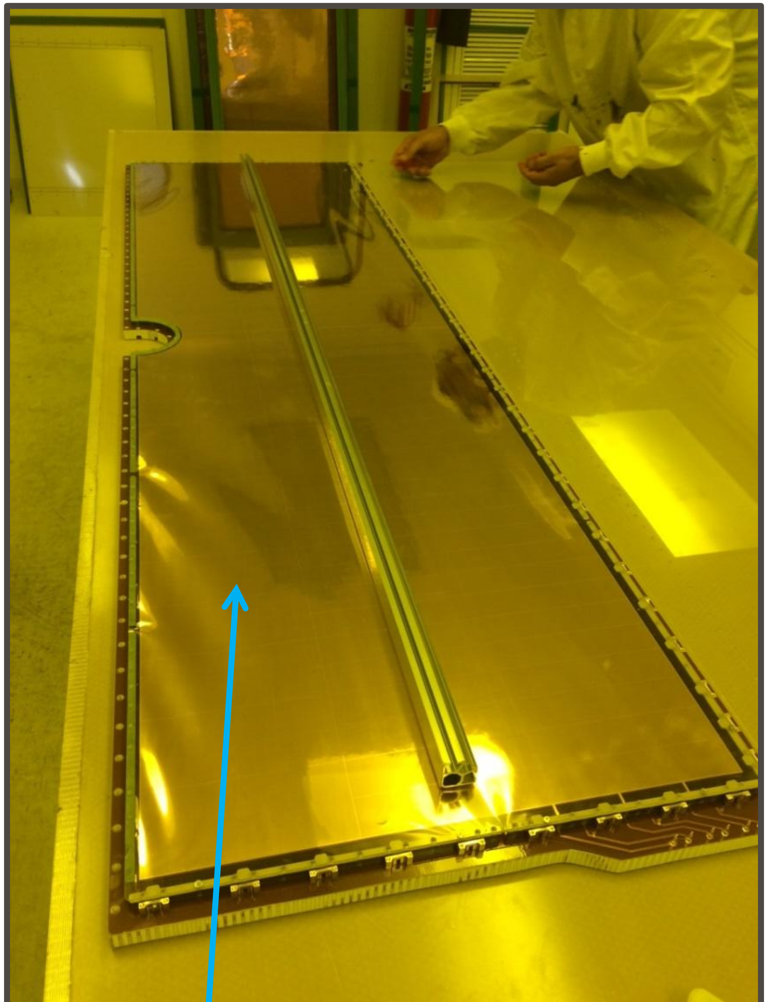
Stack of 3 GEMs

Cathode plane

GEM assembly at CERN Workshop

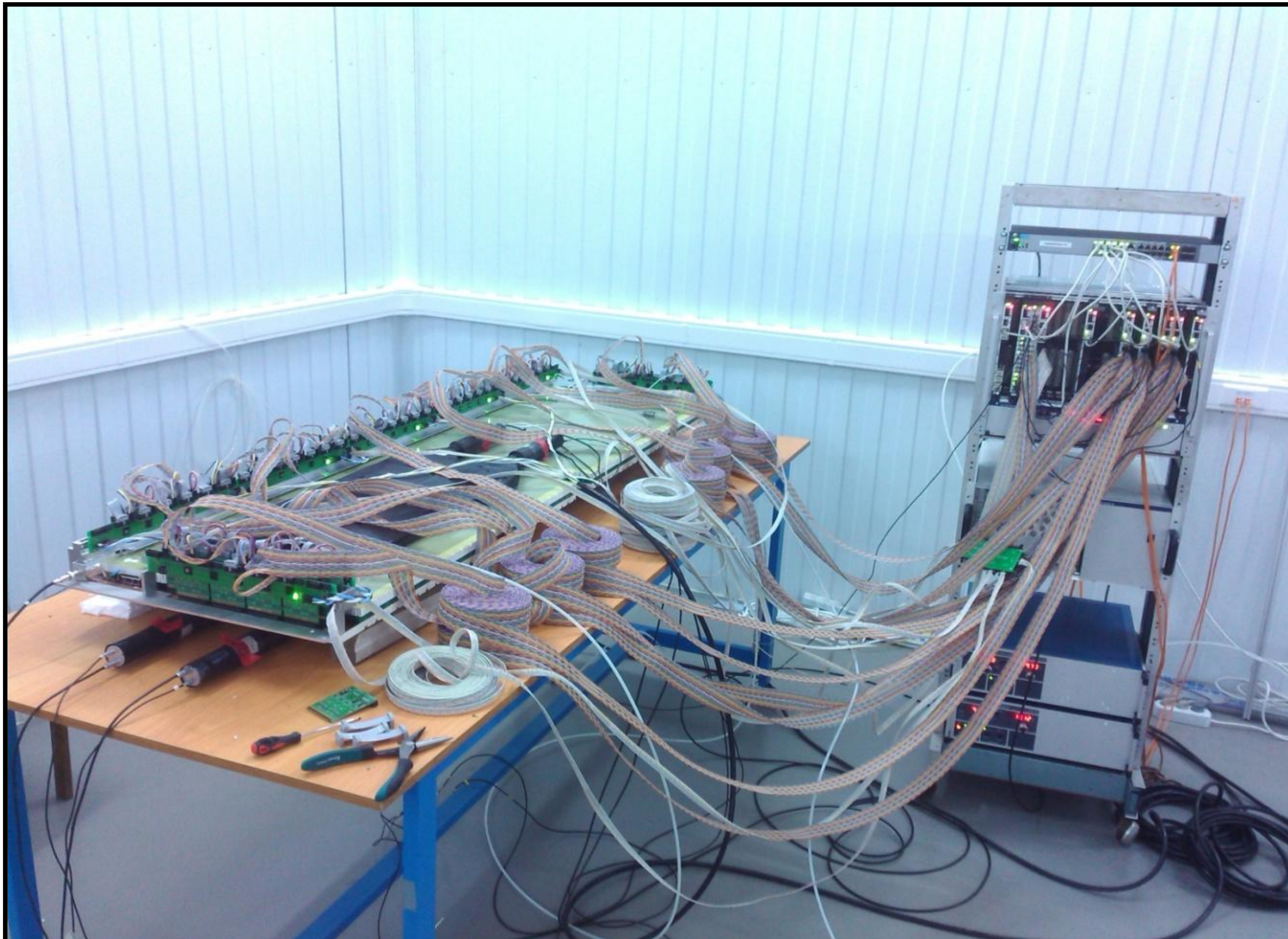


HV divider



Assembled GEM chamber

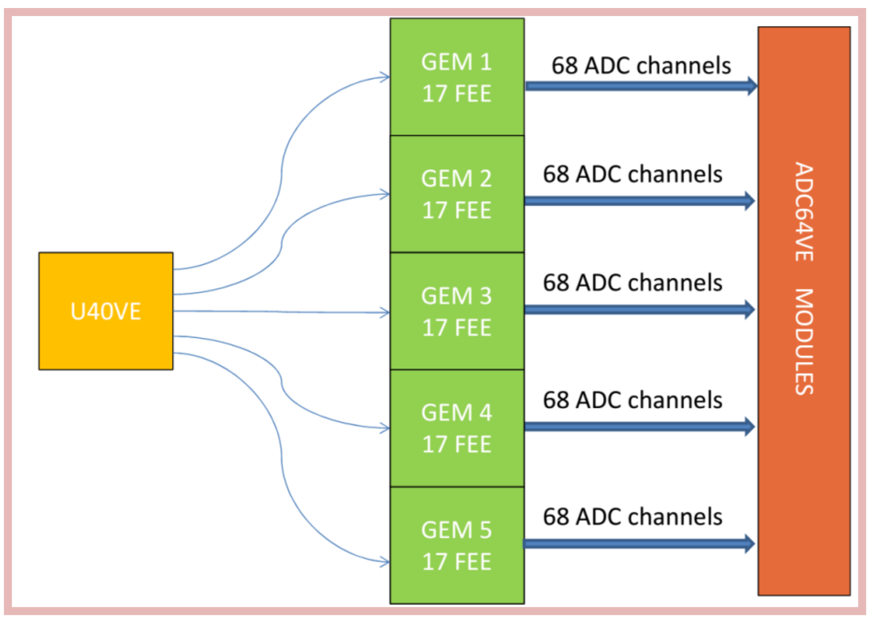
Stretching process



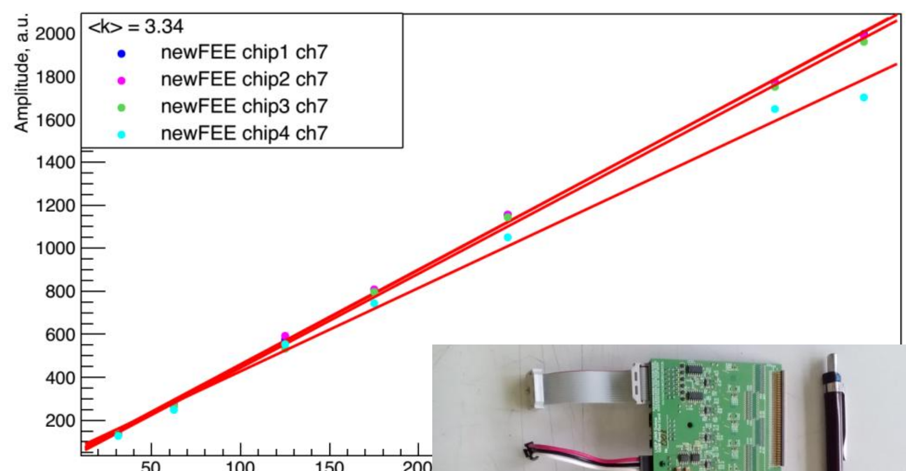
GEM and CSC electronics

	VA163
Number of channels	32
Input charge	-750fC ÷ +750fC
Shaping time	500ns
Noise	1797e ENC at 120pf load
Linearity positive charge	0.5%
Linearity negative charge	1.4%
Gain	0.88μA/fC
Total power max.	77mW

We plan to change the FE electronics based on VA163 ASIC to more fast ASIC (VMM3, n-XYTER or another)

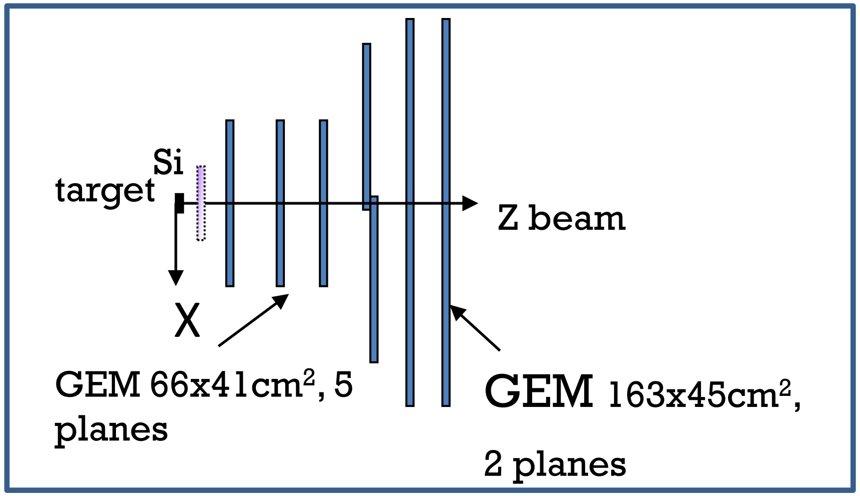


DAQ scheme

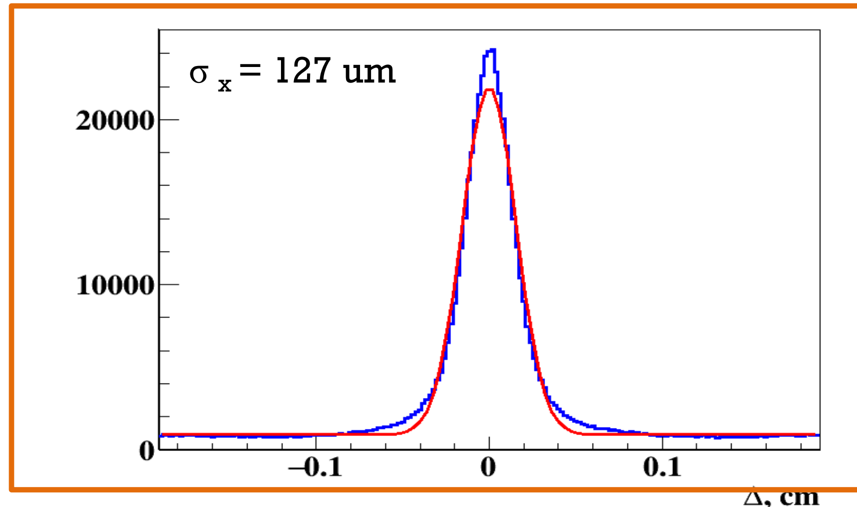


128 channel read-out card. Front and back side view

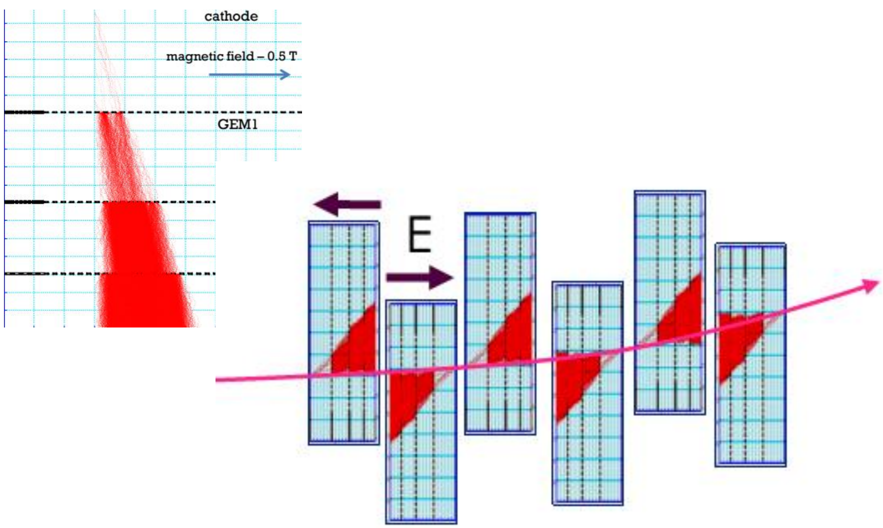
GEM tests at Nuclotron deuteron beam

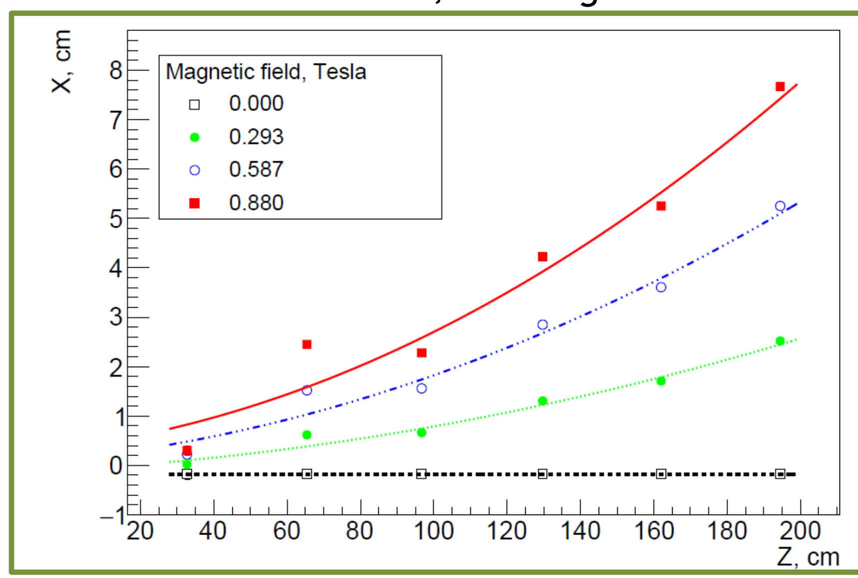


GEM configuration



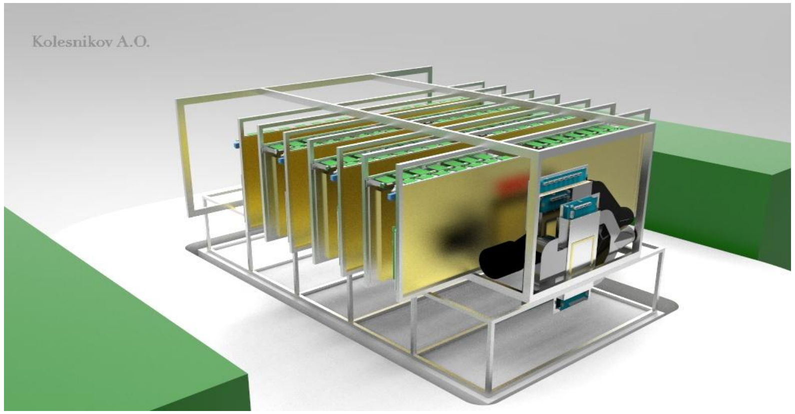
GEM resolution, w/o magnetic field

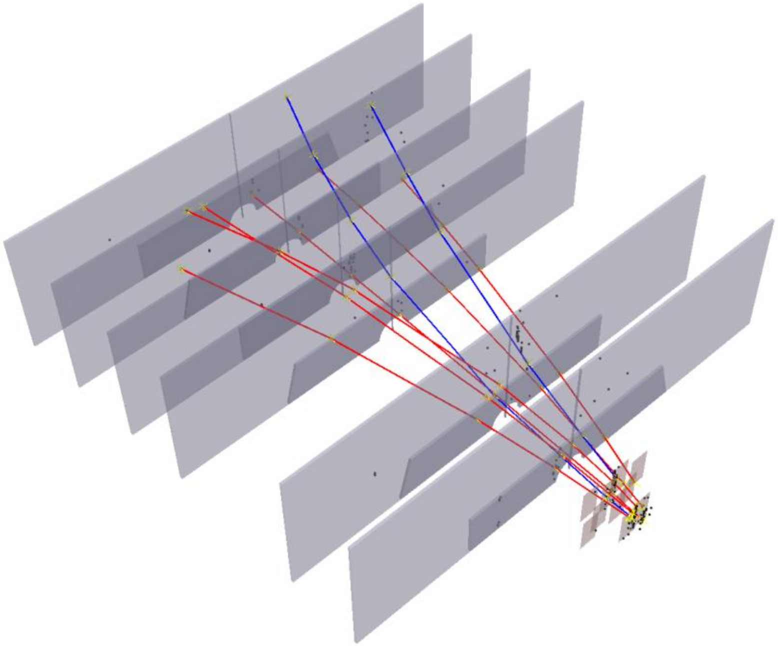


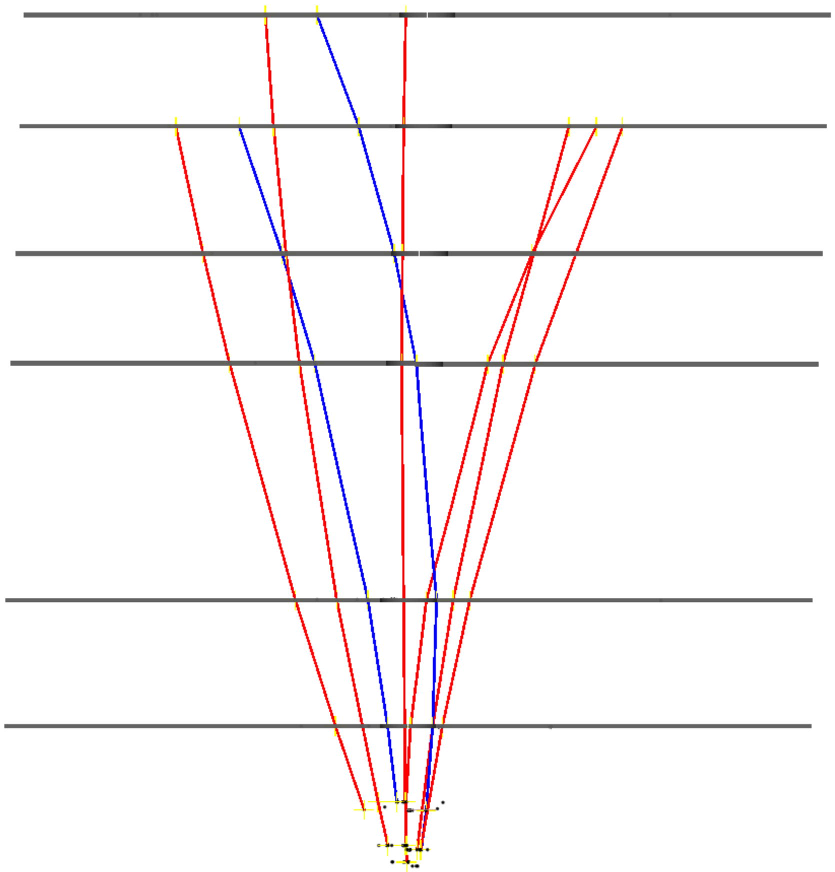


The average trajectories of the deuteron beam and the average Lorentz shifts of an electron avalanche in 6 GEM planes measured for four values of the magnetic field.

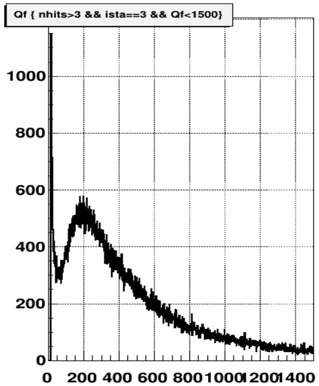
Example of the event reconstruction in the central tracker (GEM + Si) in Ar+Al interaction

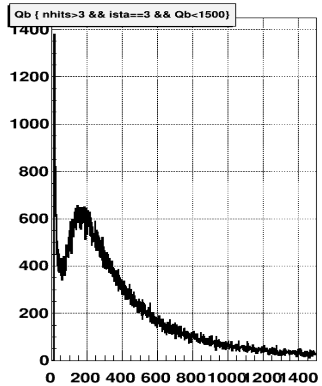






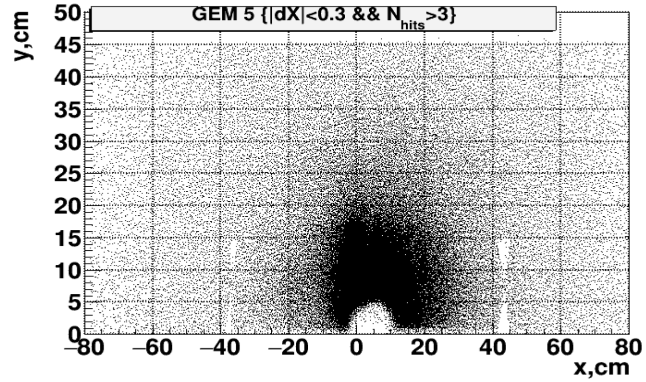
GEM tests at Ar and Kr beams





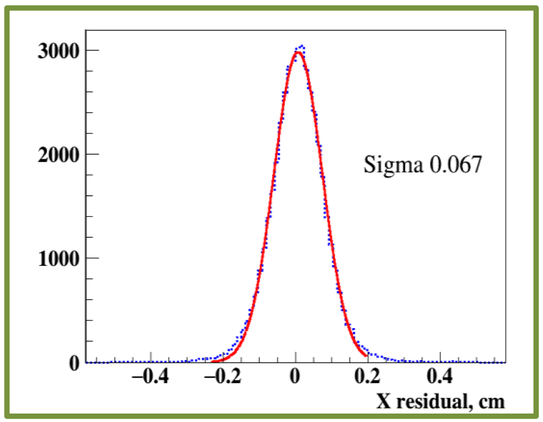
Amplitude, ADC counts Amplitude, ADC counts

GEM X&Y amplitude distributions

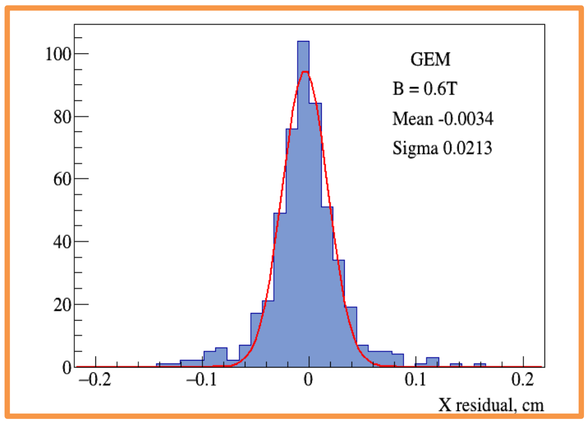


Fragments of Ar beam in one of the GEM chambers

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



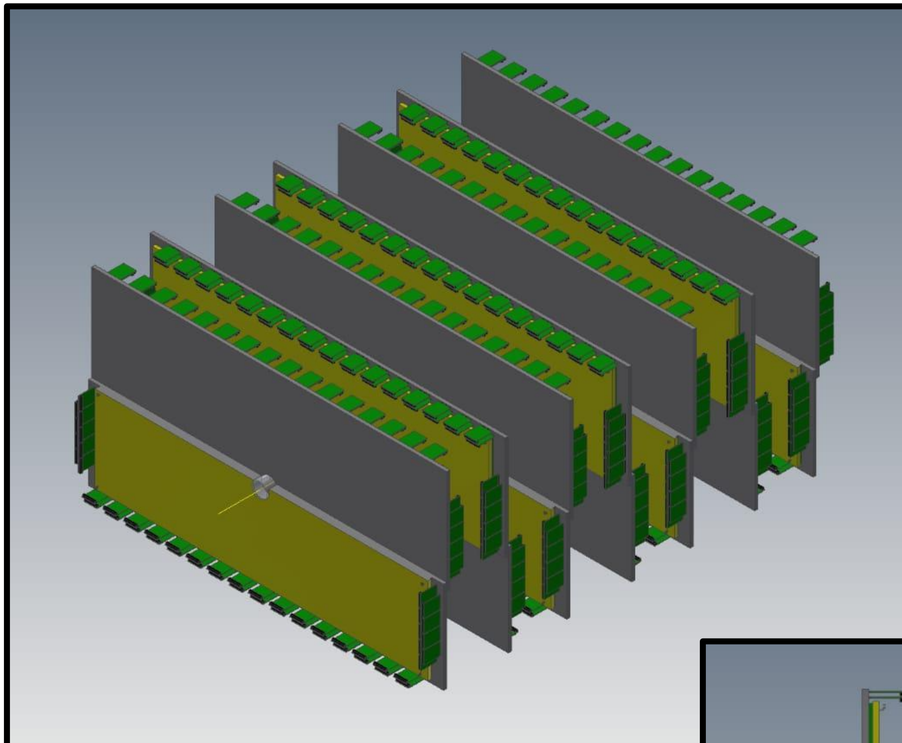
Magnetic field 0.6 T,
Ar(90)/Isobutane(10),
d beam, Edrift = 0.8kV/cm



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

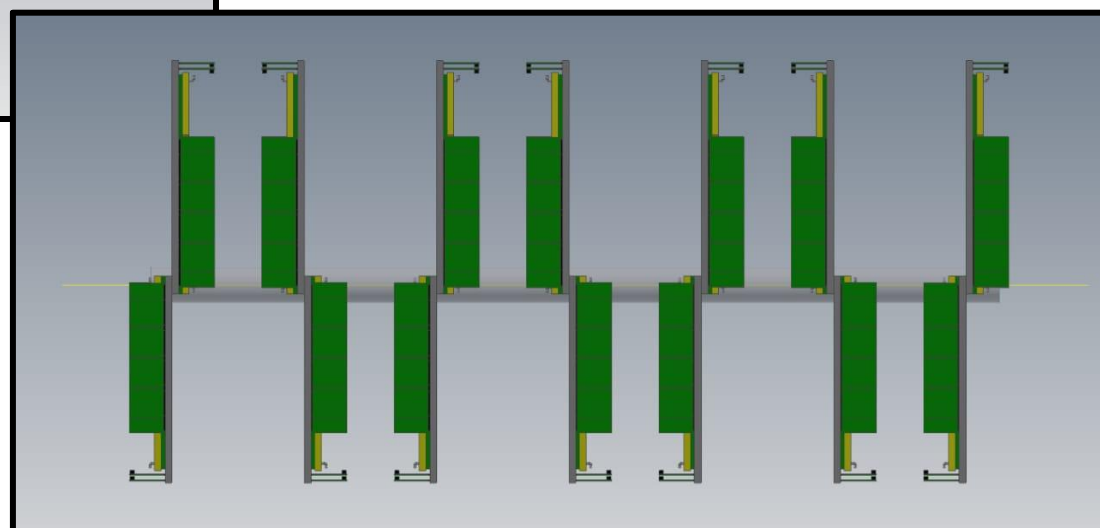
In Ar and Kr runs the value of electric field in drift gaps of GEM chambers was increased. The gas mixture was changed to Ar(80)/Isobutane(20). The Lorentz shift of electrons avalanche was decreased.

Scheme of the GEM full planes configuration inside the magnet

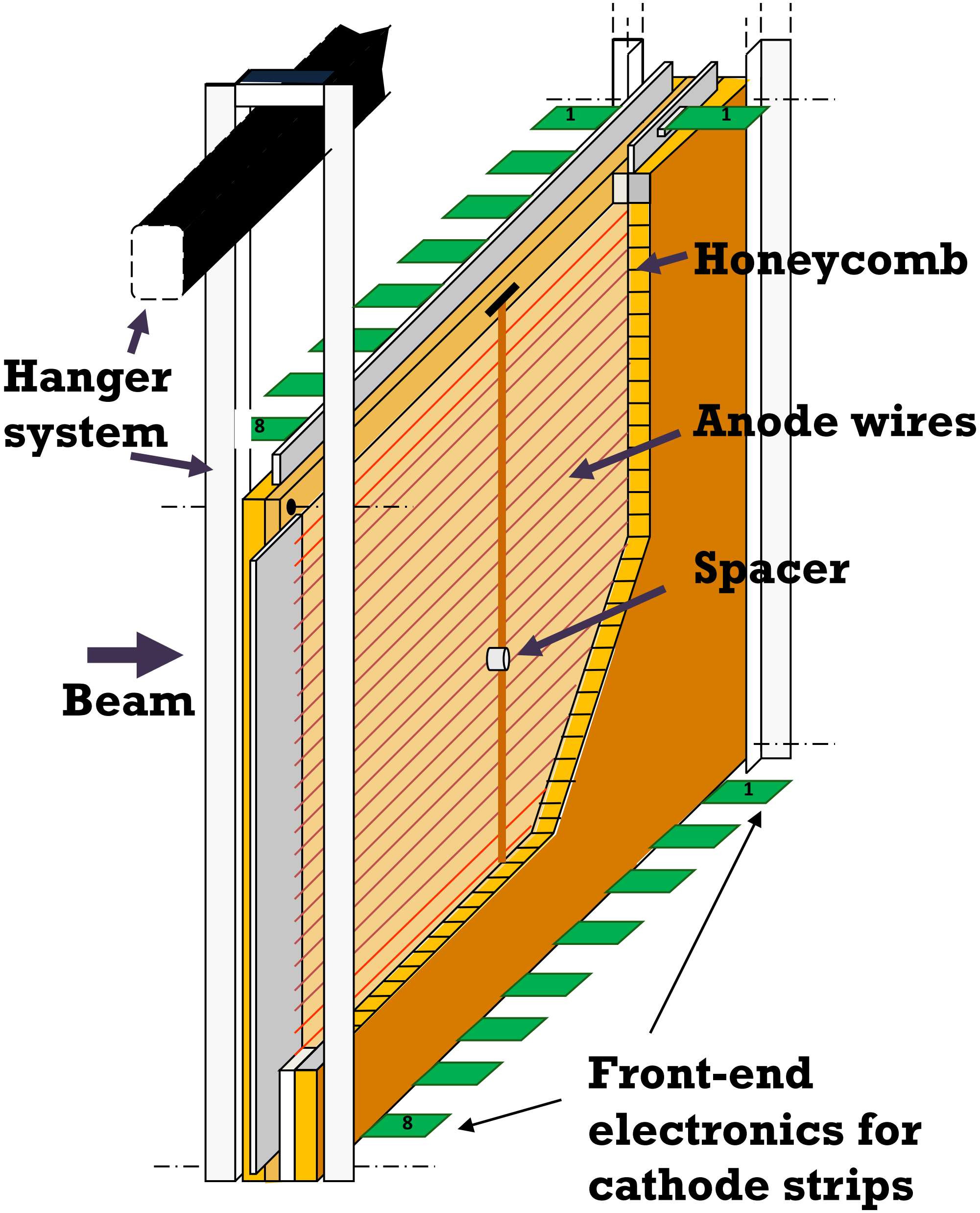


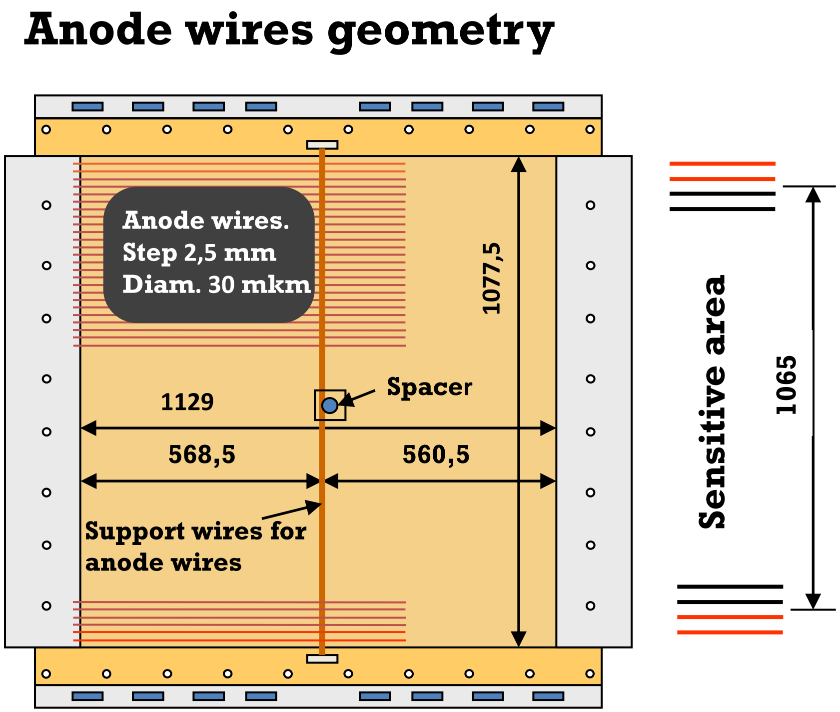
First half of the 2019 – development of the mechanics for GEM planes precise installation inside the magnet.

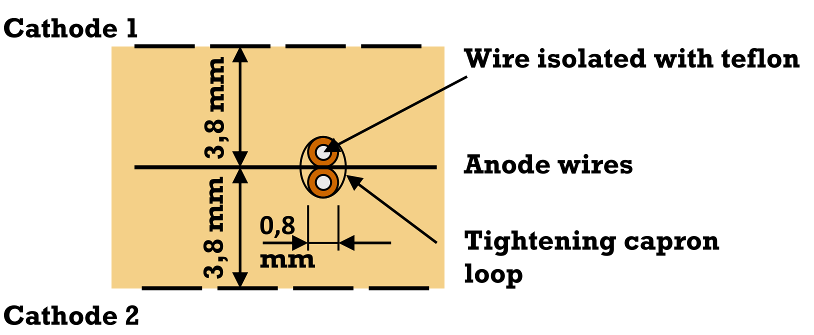
End of the 2019 – mechanics production, installation of the GEM planes.



Schematic view of CSC

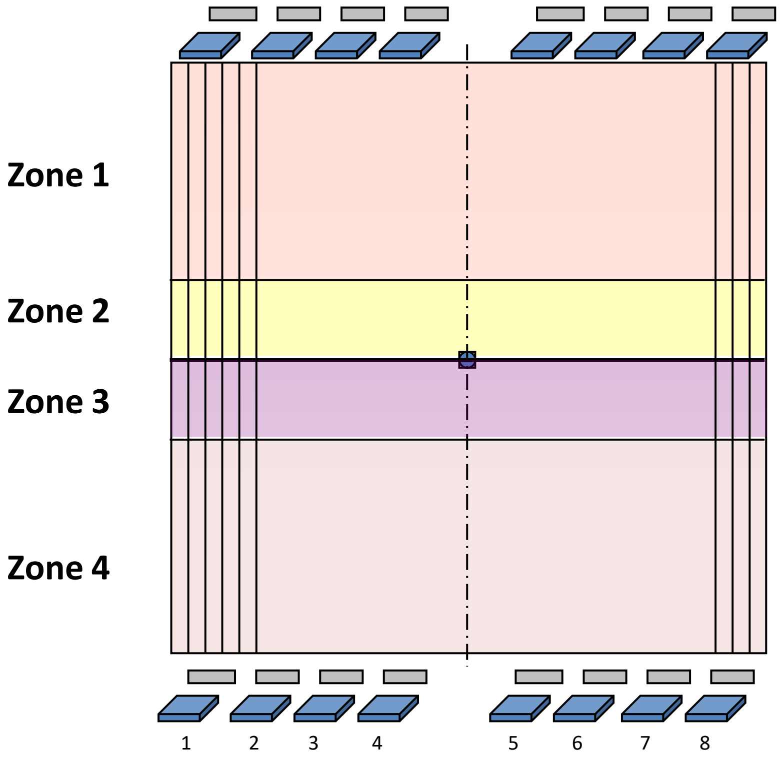




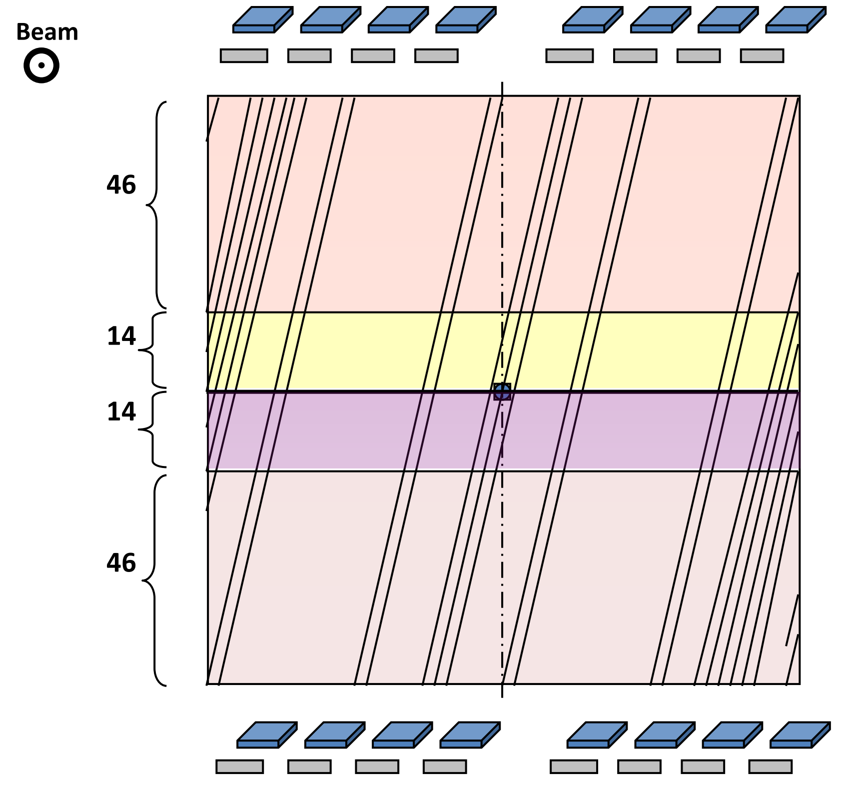


Readout cathode planes

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

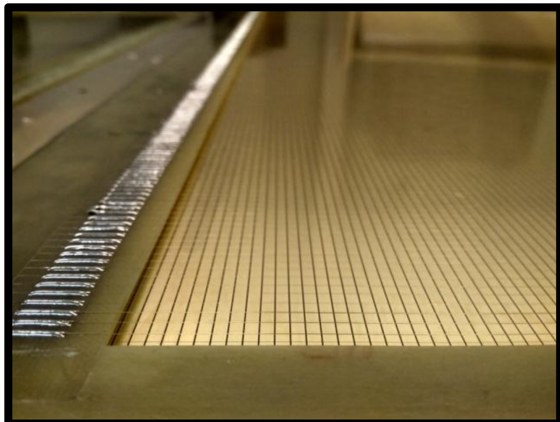


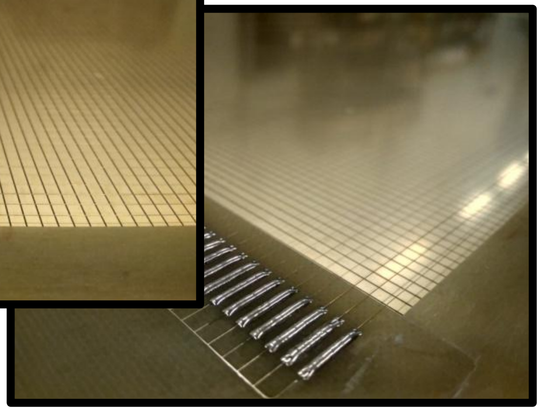
Vertical (X) strips

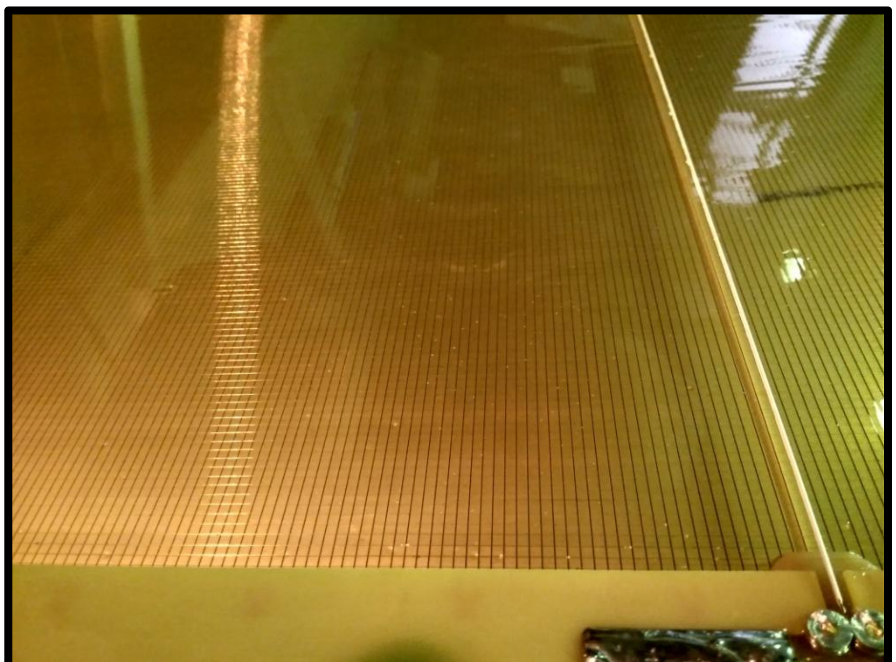


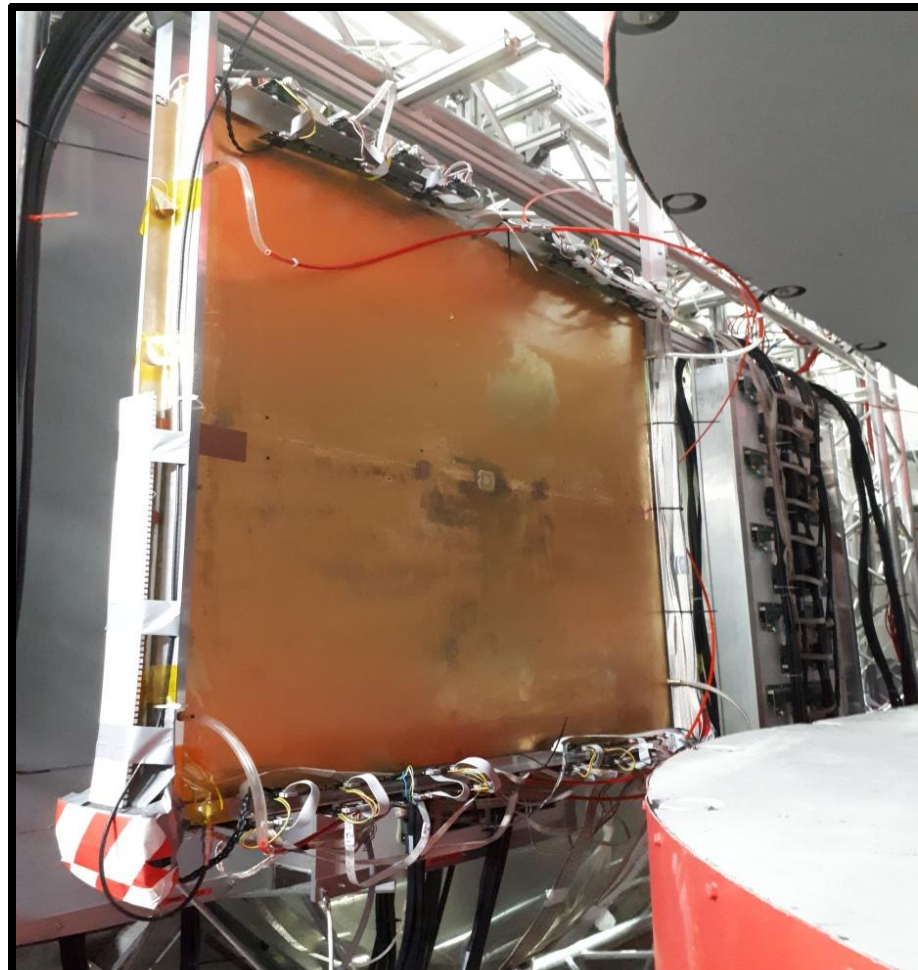
Inclined (Y) strips

CSC prototype 1129 × 1065 mm^2



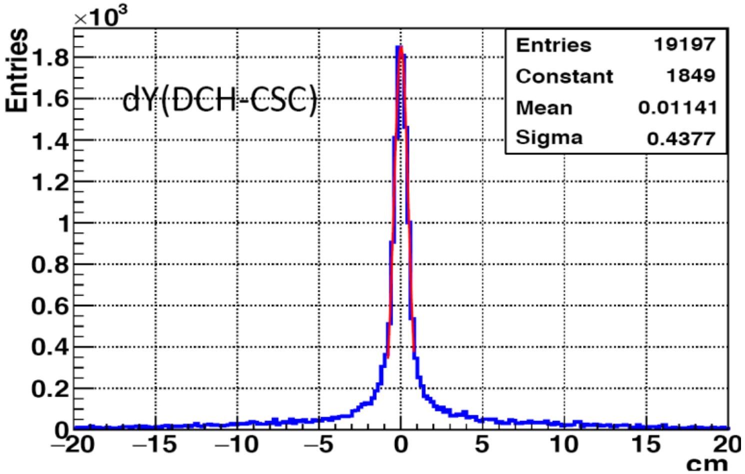




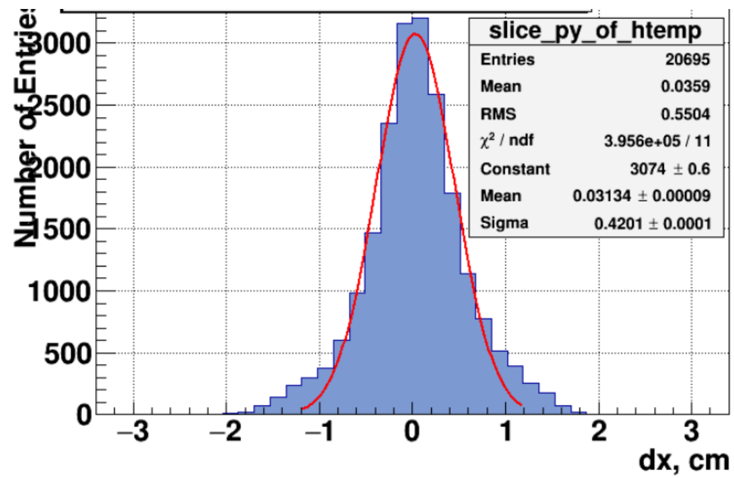


First beam test of CSC

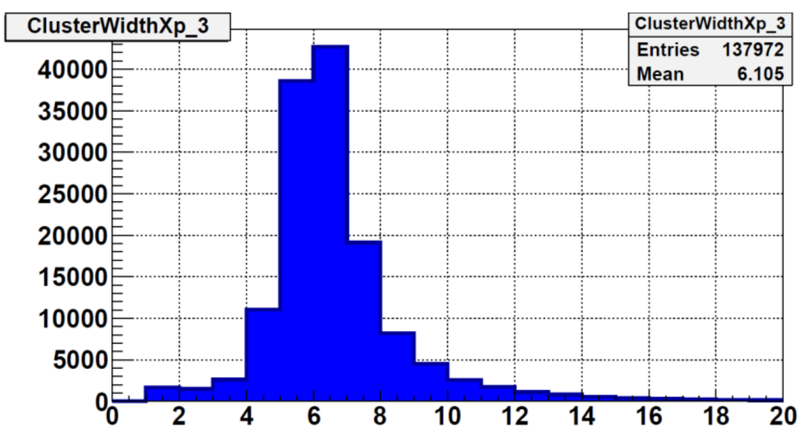
C, Ar and Kr runs in March 2018: CSC chamber is installed in front of ToF-400 to check its performance as outer tracker for heavy ions



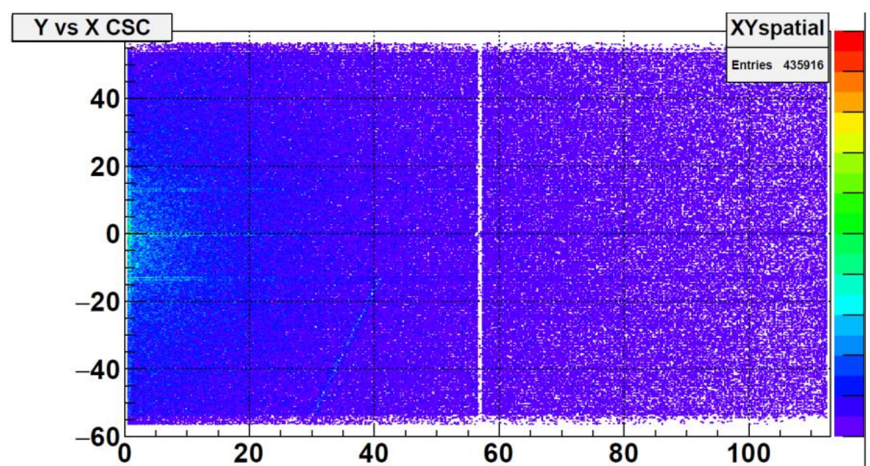
Residuals (DCH track - CSC)



Residuals (GEM track - CSC)



Cluster width

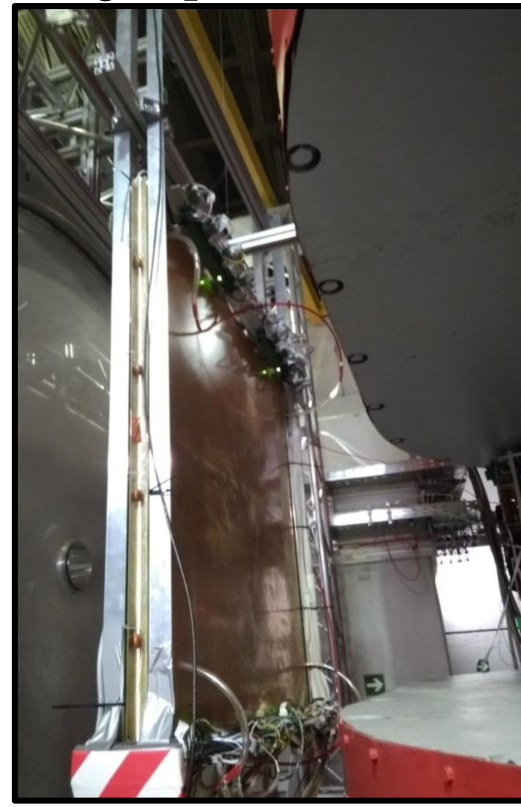


Events distribution on the chamber surface

Conclusions

Triple GEM detectors of the BM@N tracking 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.

GEM chambers integrated into BM@N experimental setup



CSC prototype integrated into BM@N

For today BM@N GEM tracking system is:

- 7 detectors 1632x450 mm^2 and 1 detector 1632x390 mm^2;
- > 50000 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.

Conclusions

Plans:

Production of **6** GEM chambers of size **1632 × 390 mm^2** to full cover vertical acceptance of analyzing magnet;

Production of **3** CSC **1129 × 1065 mm^2** and **2** CSC **2190 × 1453 mm^2** (A. Vishnevskiy and CSC team) which will be installed in front of and behind **ToF 400** and **ToF 700** system on minimal distance to improve measurements of time of flight;

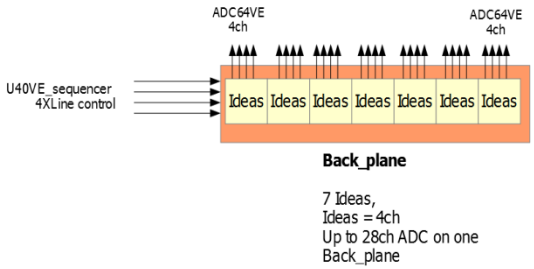
Tests of the VMM3 and n-XYTER ASICs.

Thank you for your attention!

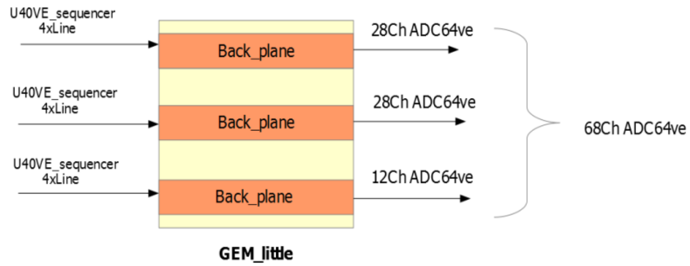
Back-up slides

GEM DAQ Scheme

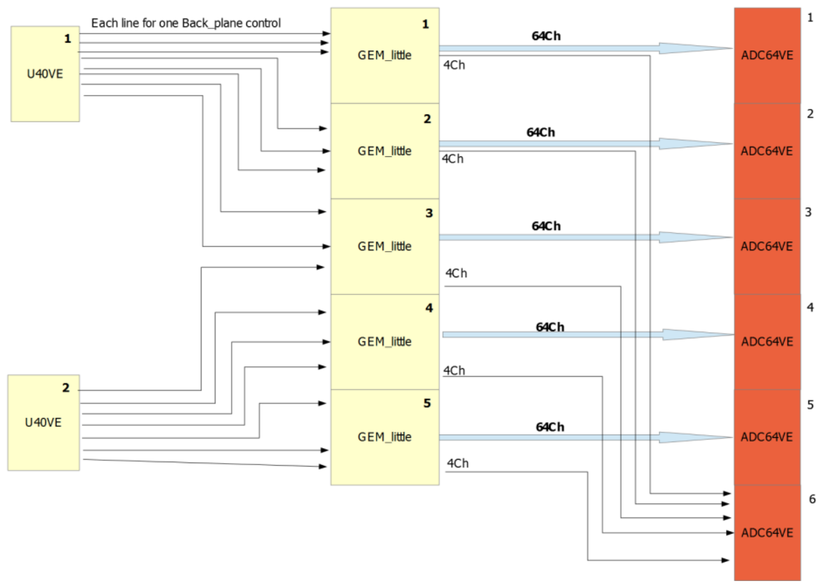
BACK PLANE SCHEM



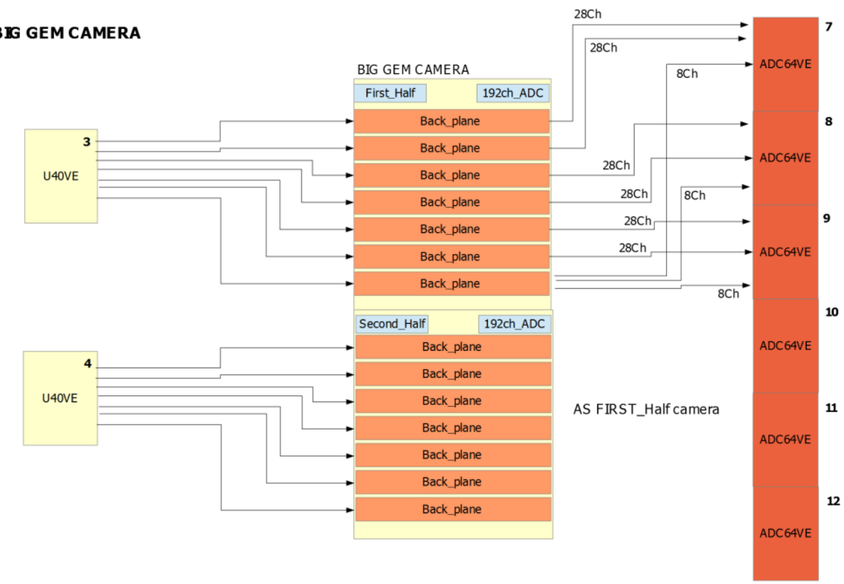
ONE LITTLE GEM CAMERA SCHEM



LITTLE GEM CAMERA

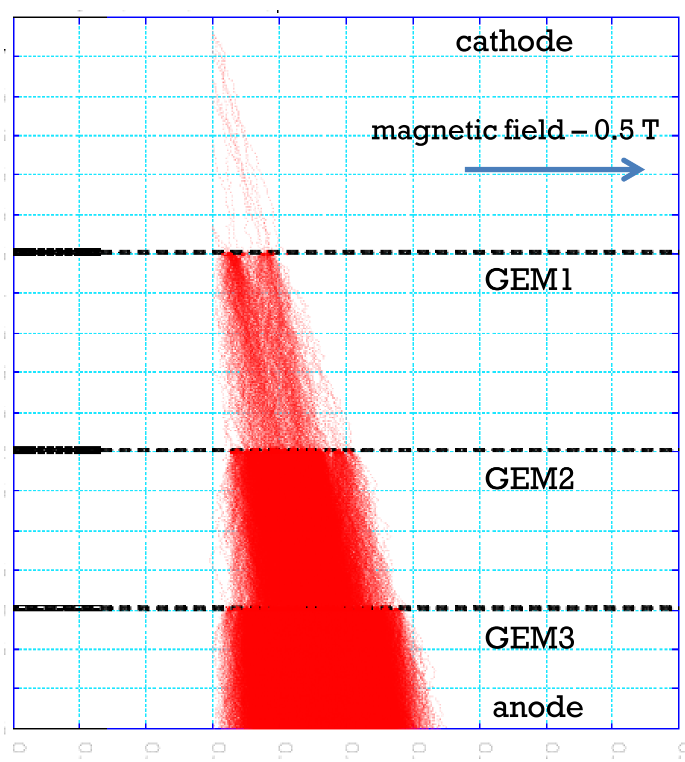


BIG GEM CAMERA

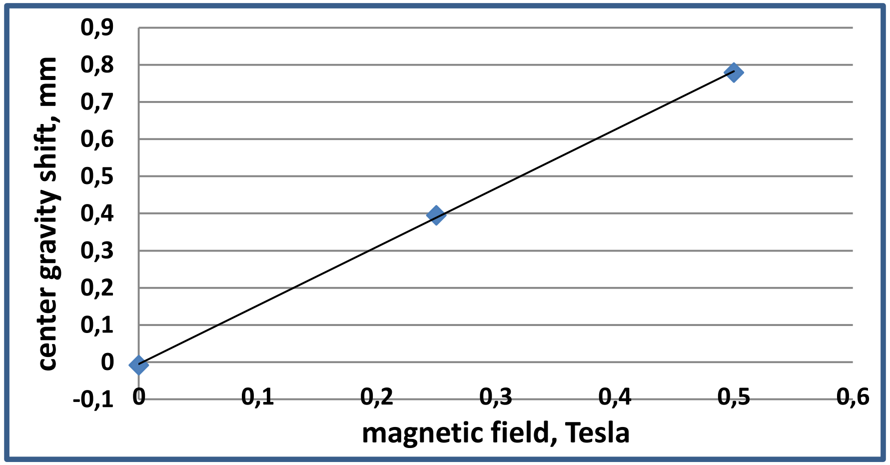


Electrons drift due to magnetic field (Garfield & Maxwell simulations)

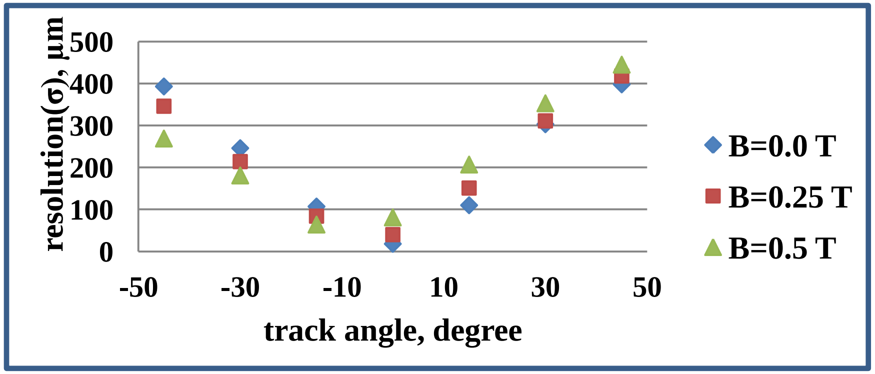
Simulation of electron shift in magnetic field



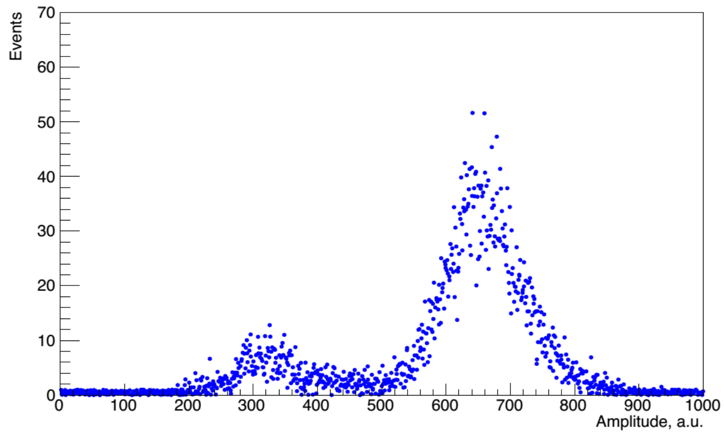
Center gravity shift vs magnetic field



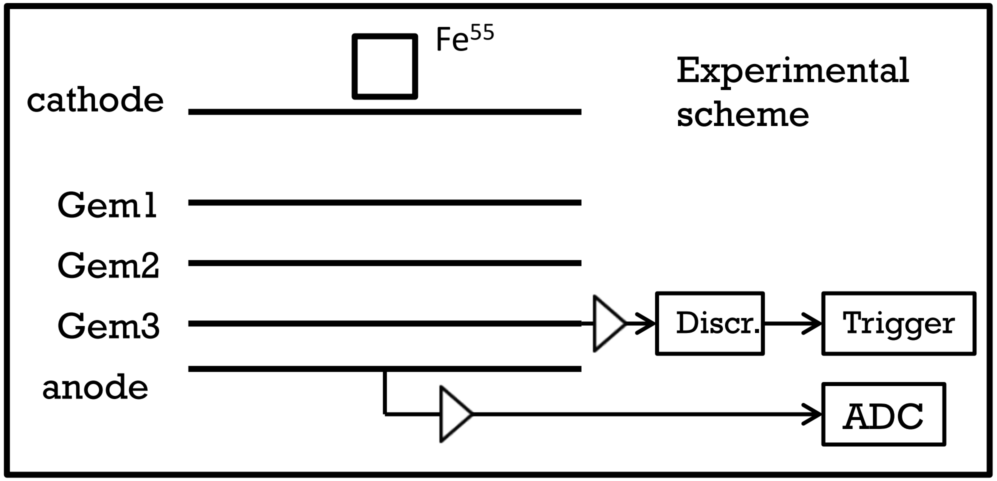
Space resolution vs magnetic field and track angle

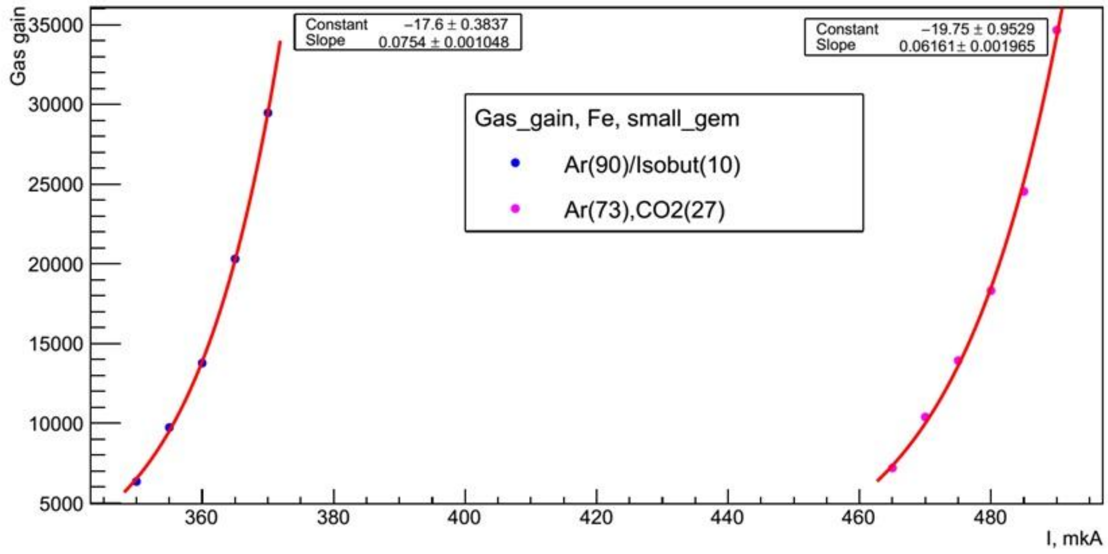


GEM gas gain measurements



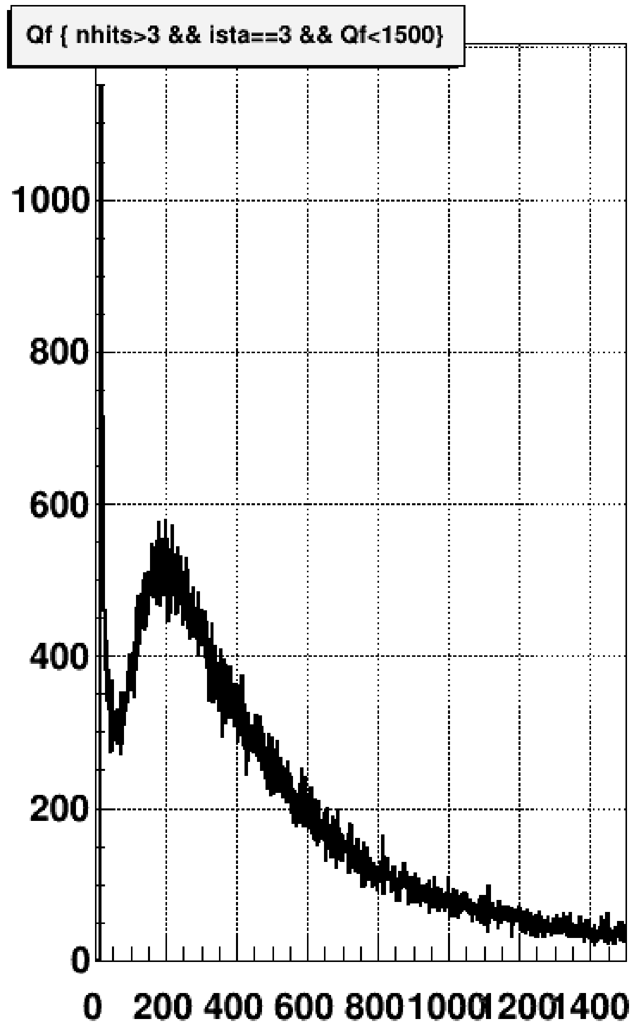
Amplitude distribution, Ar(70)/CO2(30), Fe^{55}

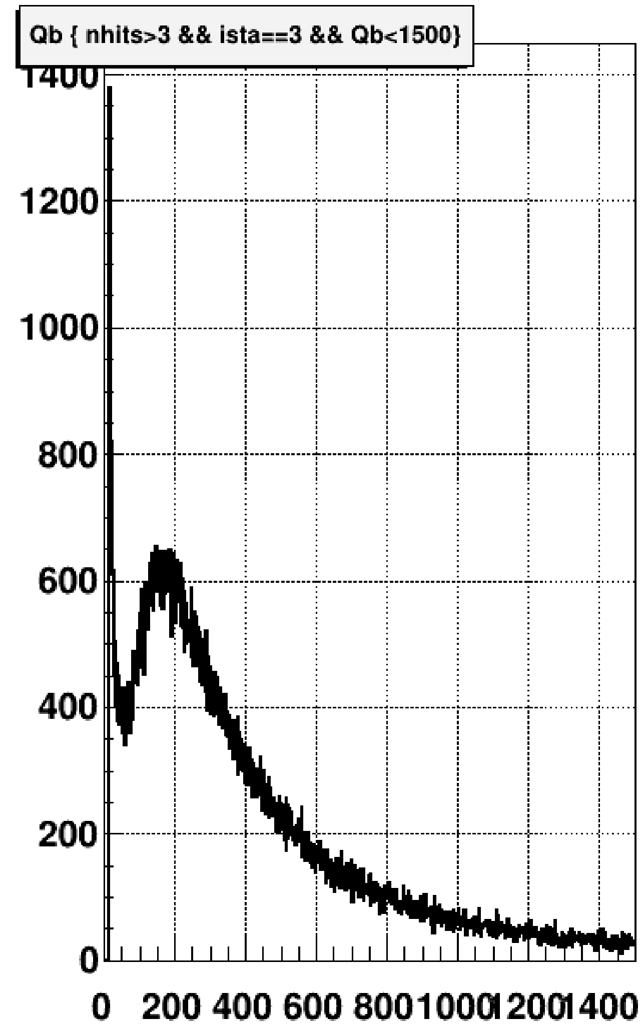




GEM gas gain for Ar(70)/CO2(30) and Ar(90)/Isobutane(10) gas mixtures

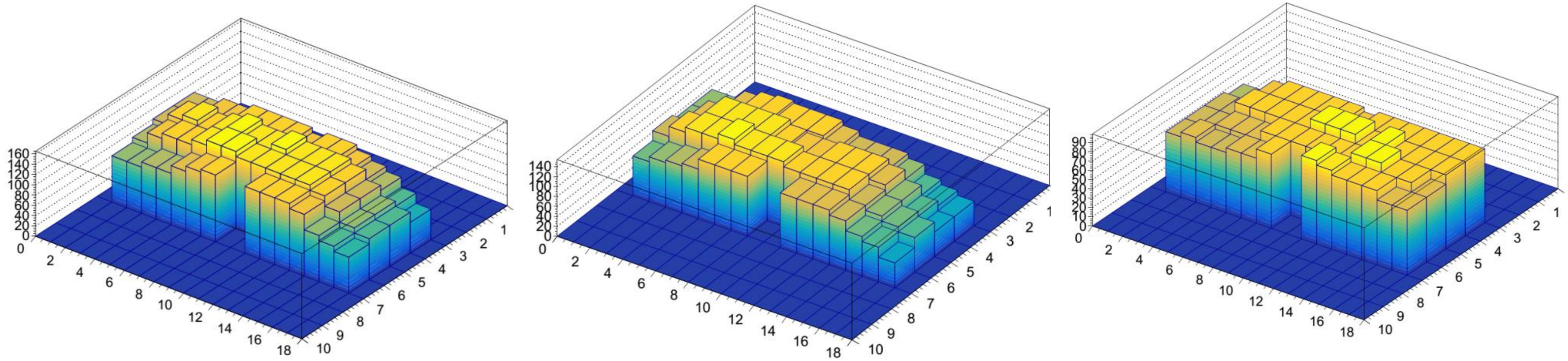
GEM tests at Nuclotron Ar beam



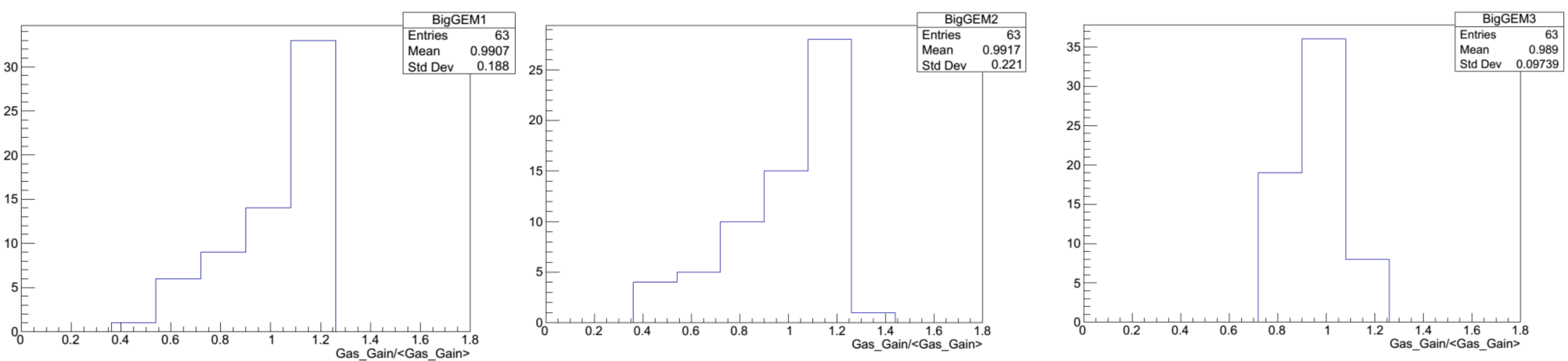


Gleb Pokatashkin

GEM 1632x450 mm^2 response uniformity



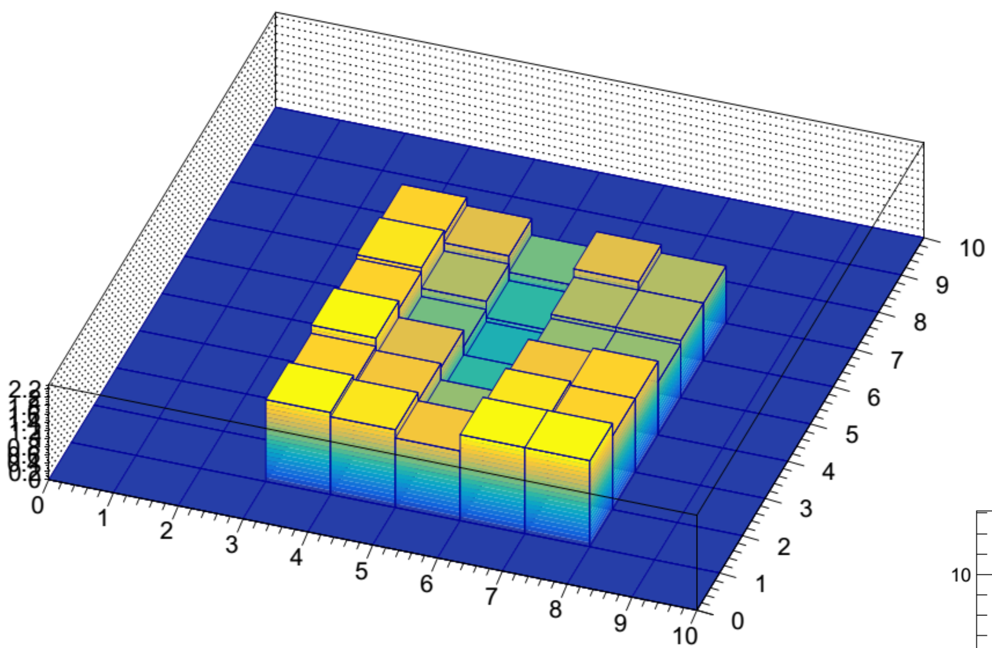
Response uniformity 3D plot of three 1632x450 mm^2 chambers, Ar(90)/Isobutane(10) gas mixture



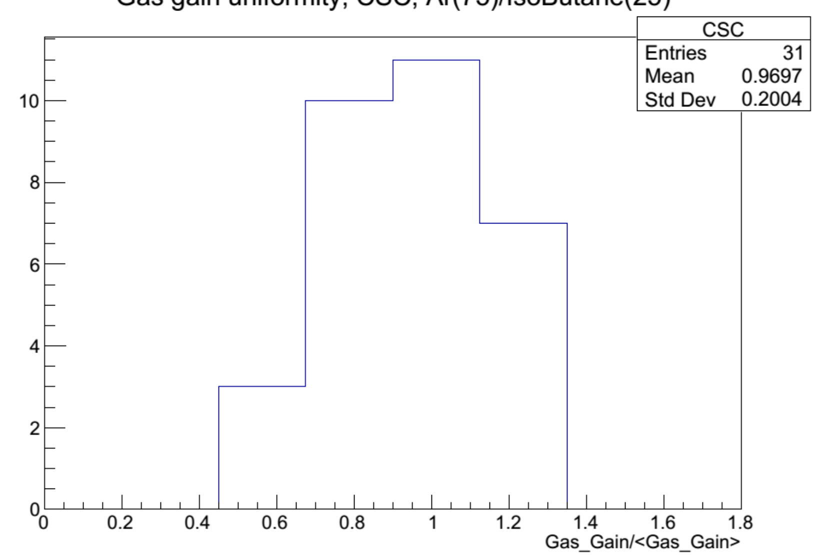
Gas gain distribution normalized on average gas gain for three 1632x450 mm^2 chambers, Ar(90)/Isobutane(10) gas mixture

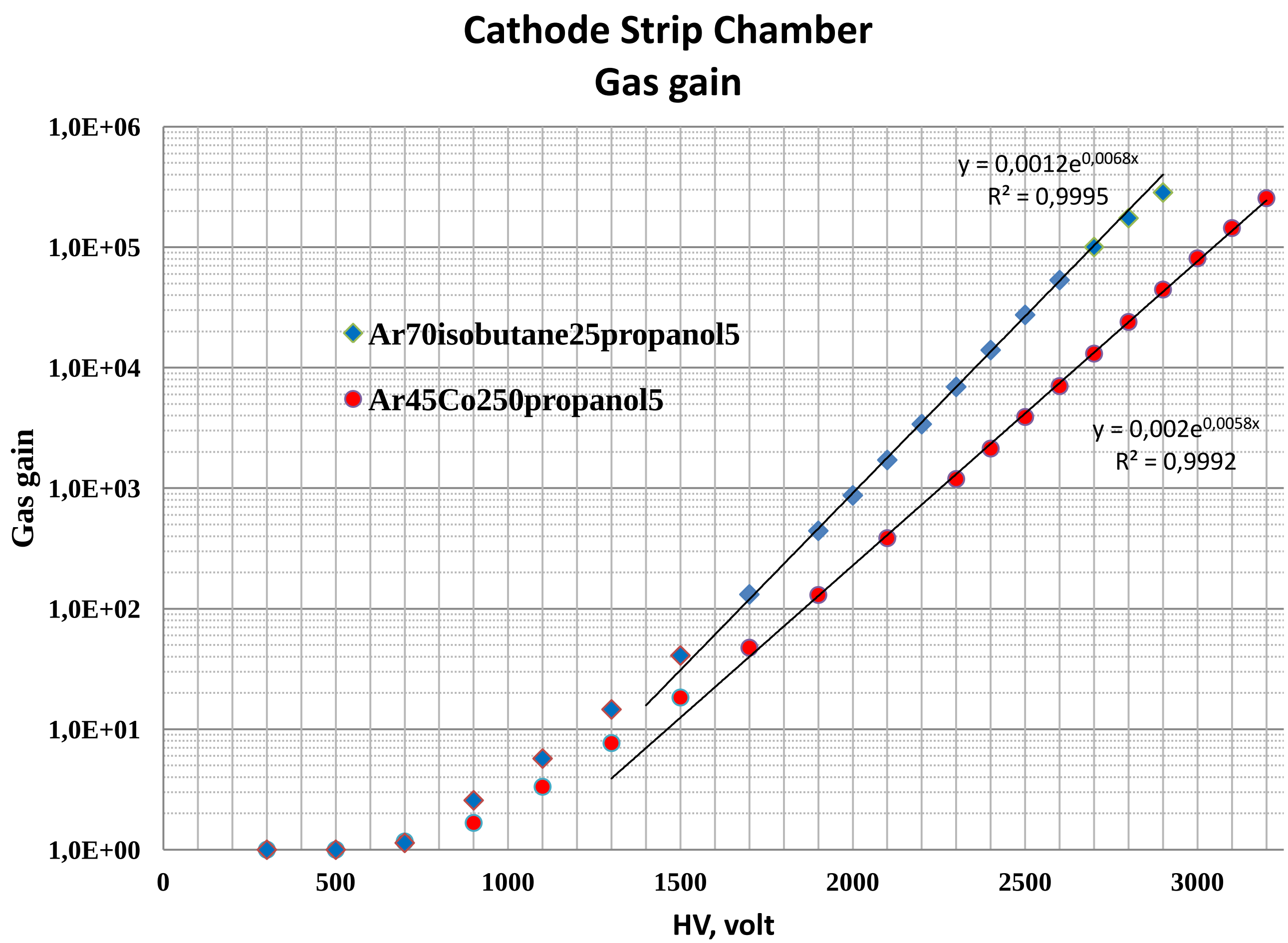
CSC response uniformity

Gas gain uniformity, CSC, Ar(75)/IsoButane(25)



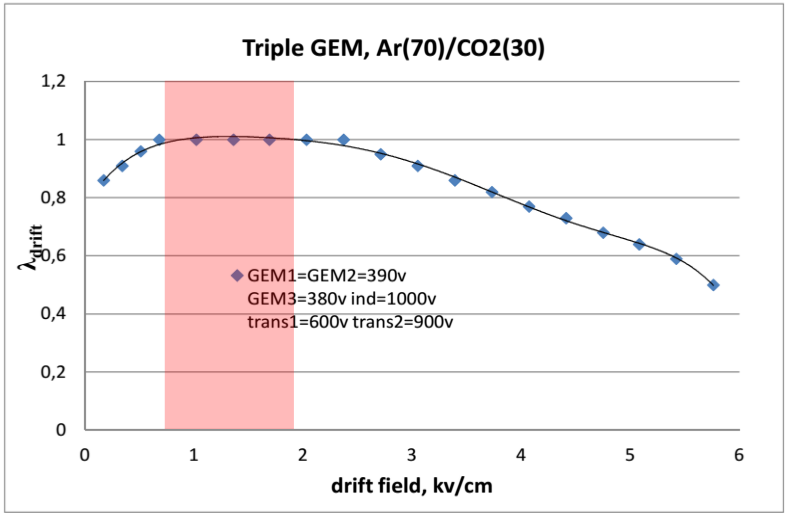
Gas gain uniformity, CSC, Ar(75)/IsoButane(25)

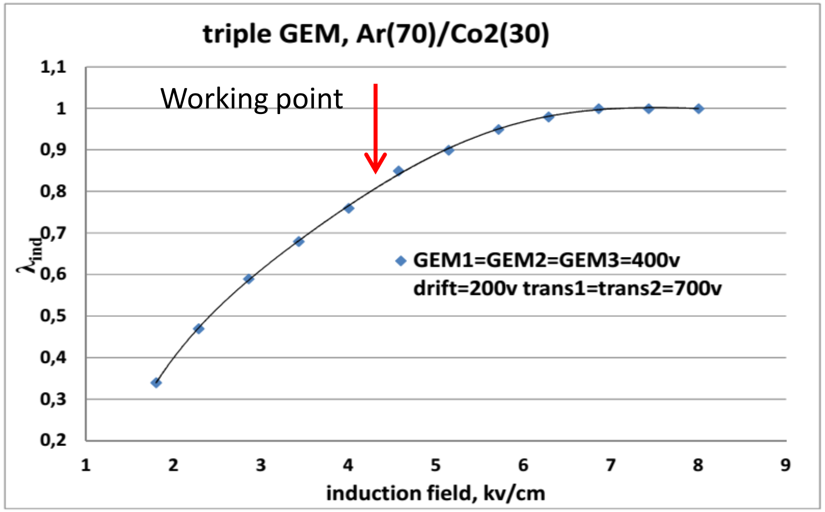


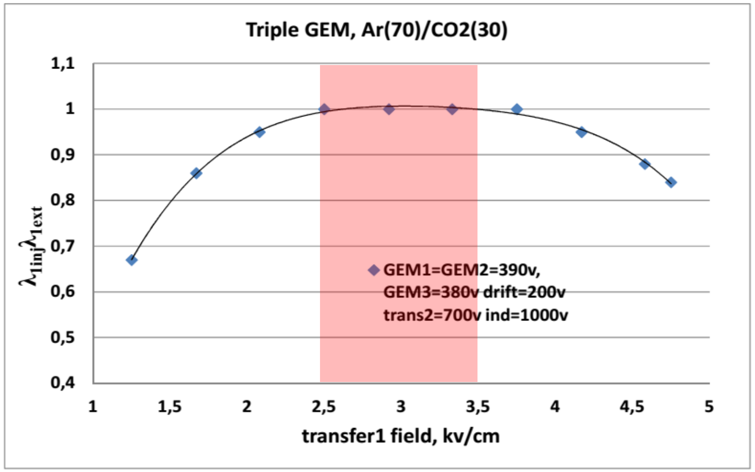


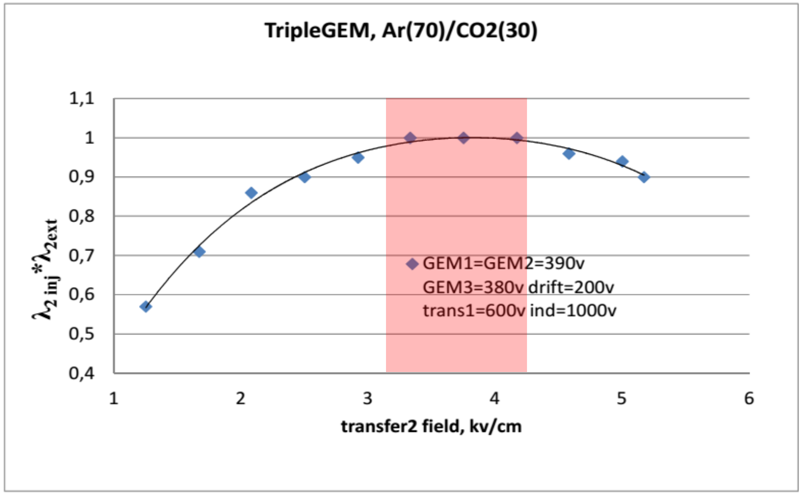
Cathode Strip Chamber
Gas gain
Gas gain
HV, volt
Ar70isobutane25propanol5
Ar45Co250propanol5
y = 0,0012e^0,0068x
R² = 0,9995
y = 0,002e^0,0058x
R² = 0,9992
1,0E+00
1,0E+01
1,0E+02
1,0E+03
1,0E+04
1,0E+05
1,0E+06
0
500
1000
1500
2000
2500
3000

GEM Optimization



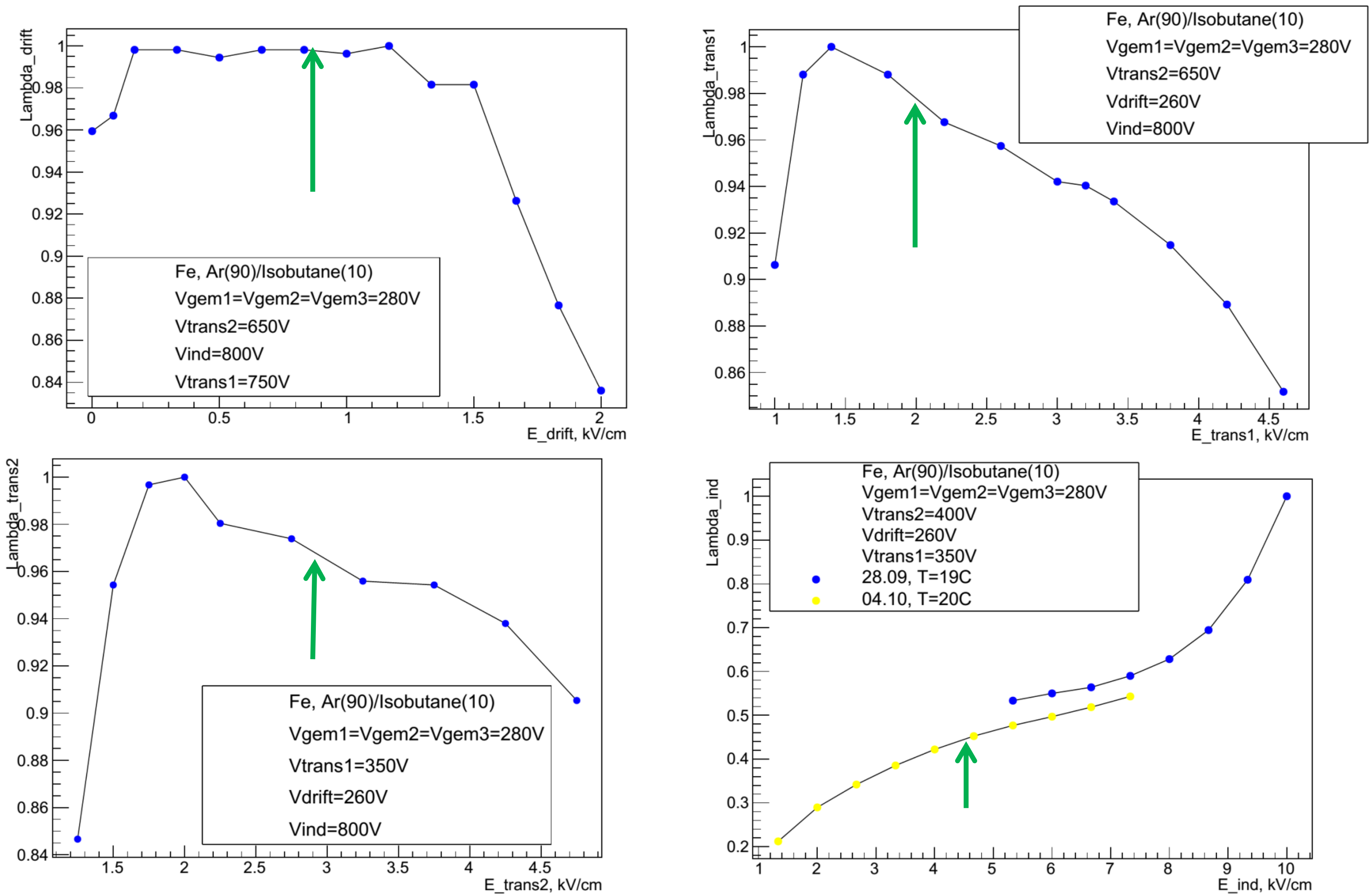






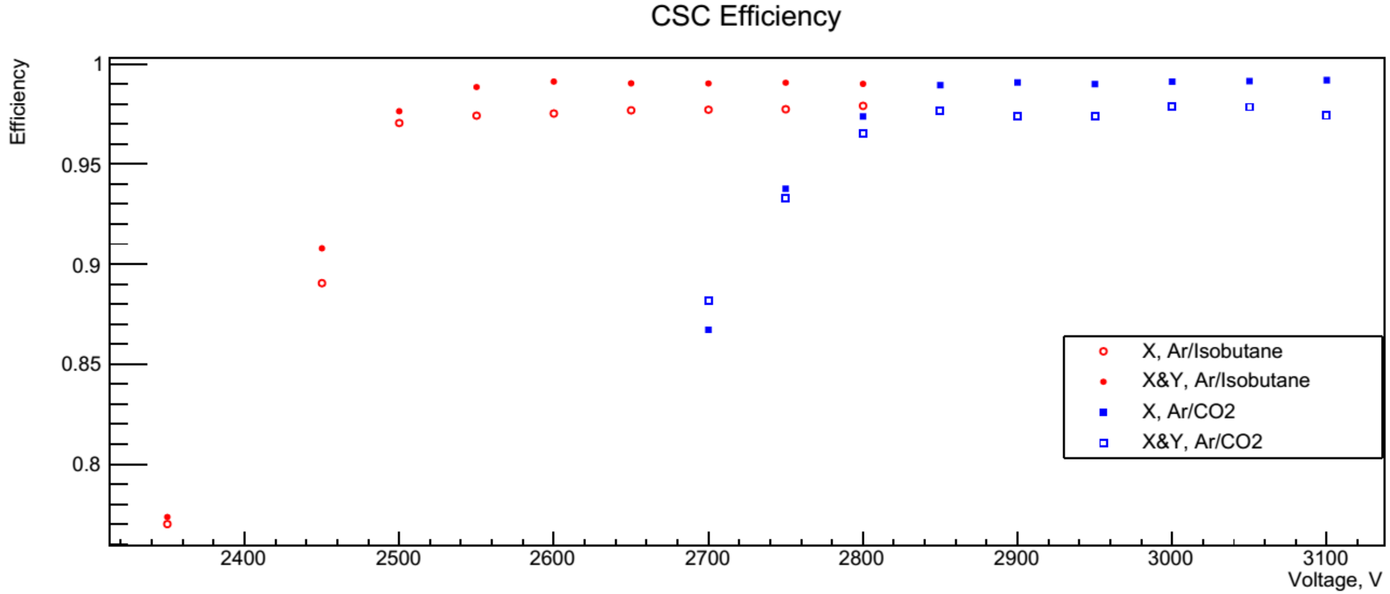
- Working range of field, kV/cm (Ar(70)/CO_2(30)gas mixture)

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



Lambda summary = 0.86

GEM and CSC efficiency (cosmic tests)



GEM Efficiency