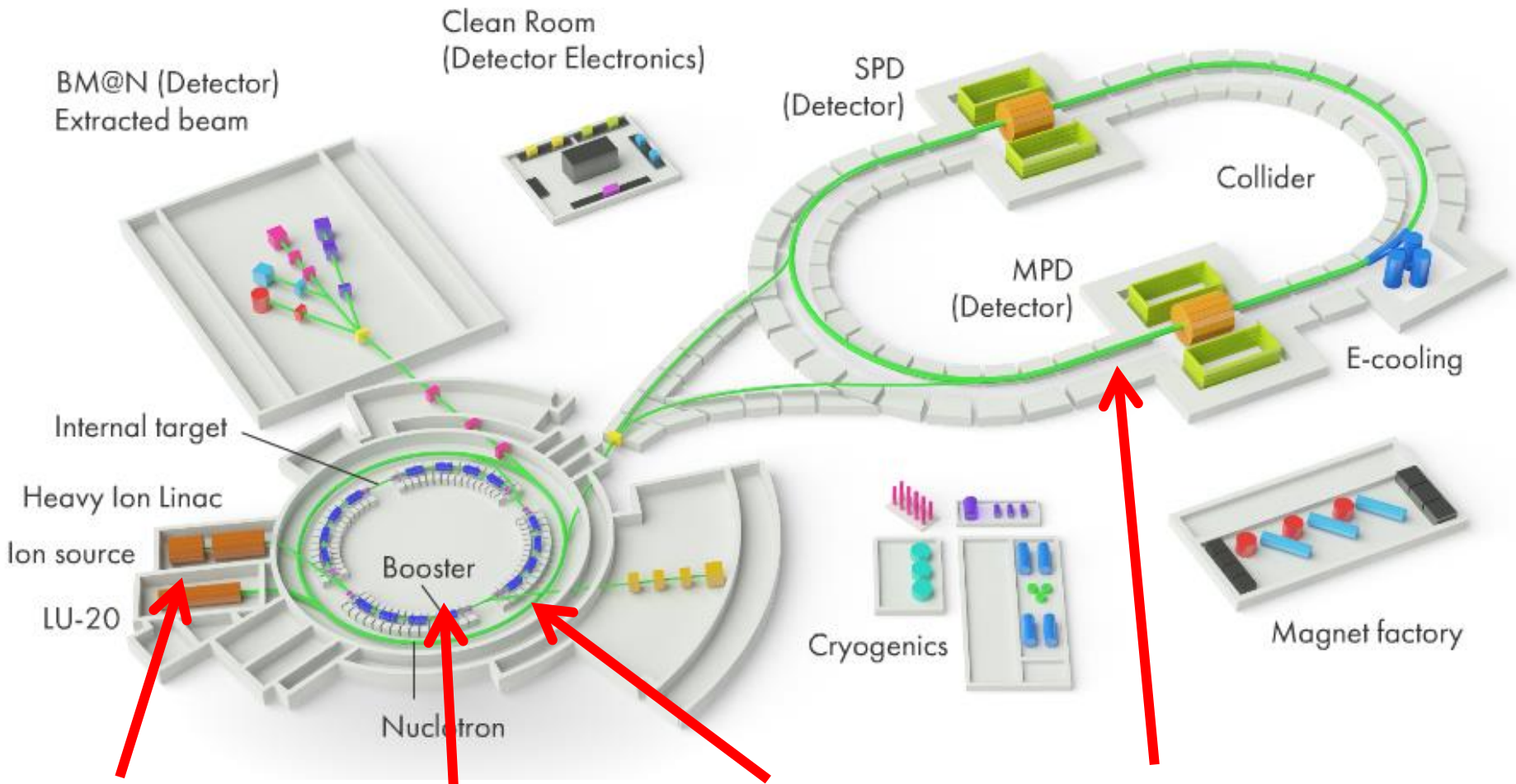
Status of the GEM tracking system at the BM@N experiment

Andrei Galavanov on behalf of the BM@N Collaboration

The XXIV International Scientific Conference of Young Scientists and Specialists (AYSS-2020)

NICA complex



Linear accelerators, 3 MeV/u

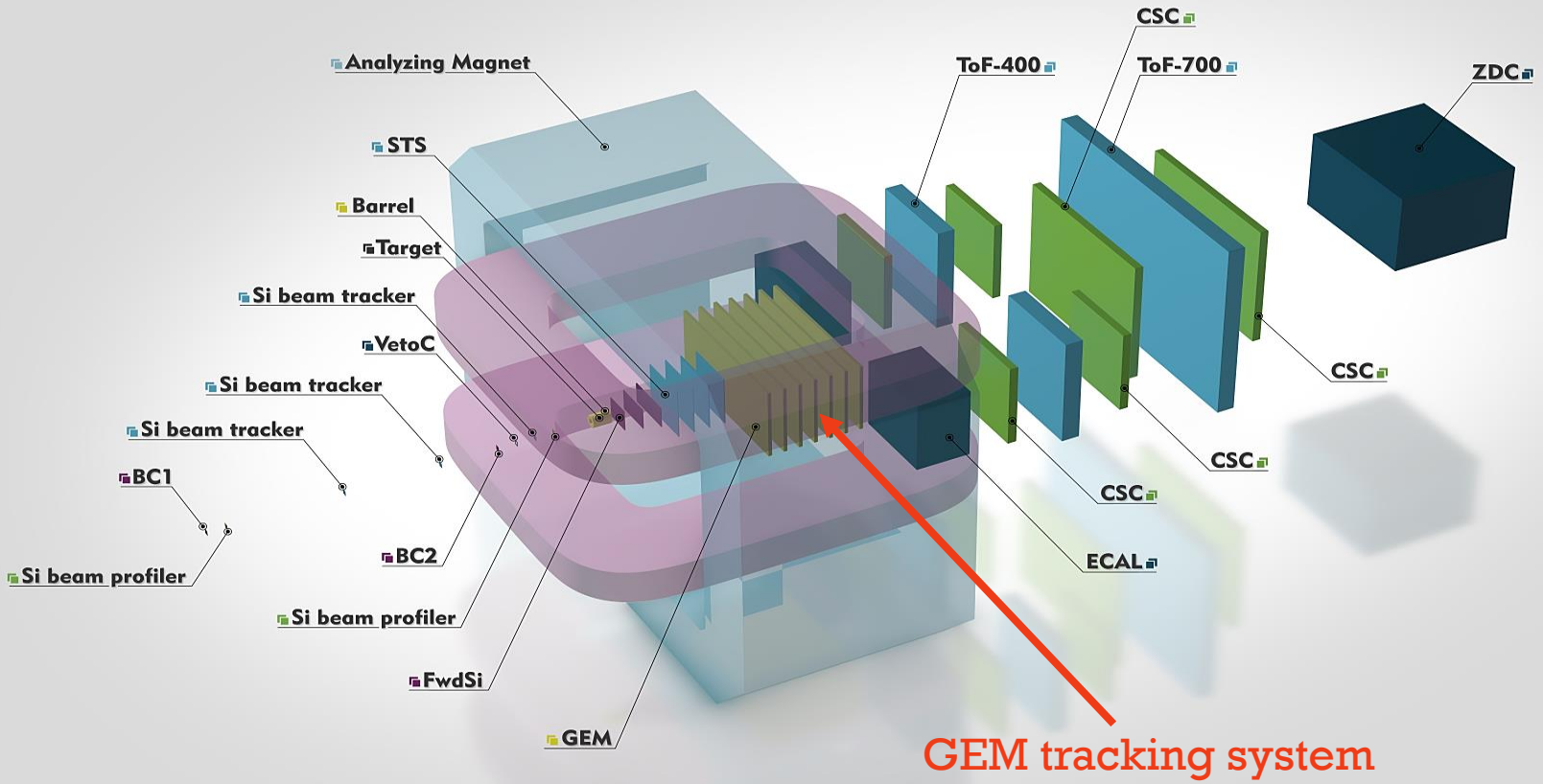
Booster, 3 – 660 MeV/u

Nuclotron, 0.6 – 4.5 GeV/u

Collider, $\sqrt{S}$ = 4 – 11 GeV/u

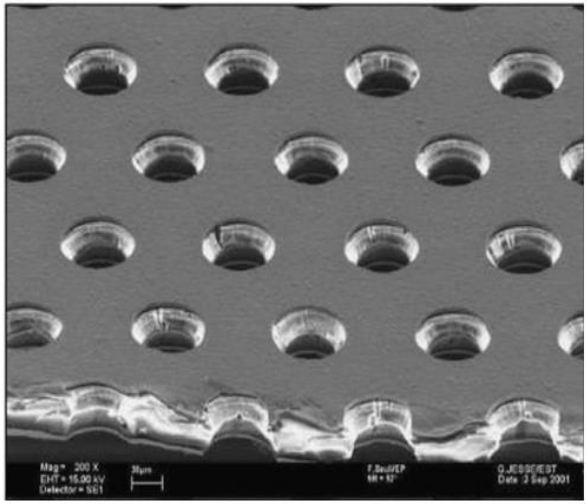
BM@N experiment

BM@N provides a unique opportunity to study strange mesons and multi-strange hyperons close to the kinematic threshold. One of the main goals is to measure yields of light hyper-nuclei, which are expected to be produced in coalescence of Λ-hyperons with nucleons.

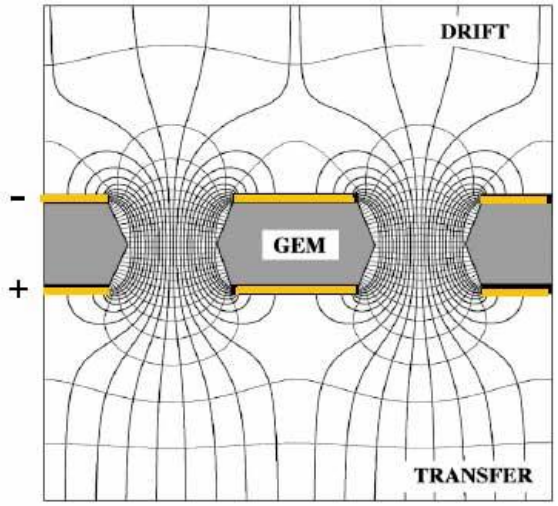


Experimental setup for high intensity heavy ion beams

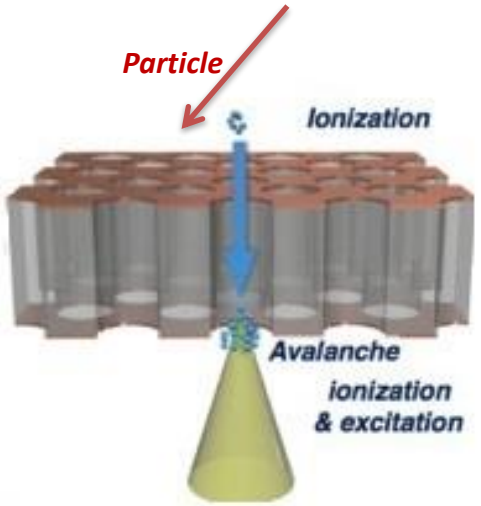
The gas electron multiplier (GEM)



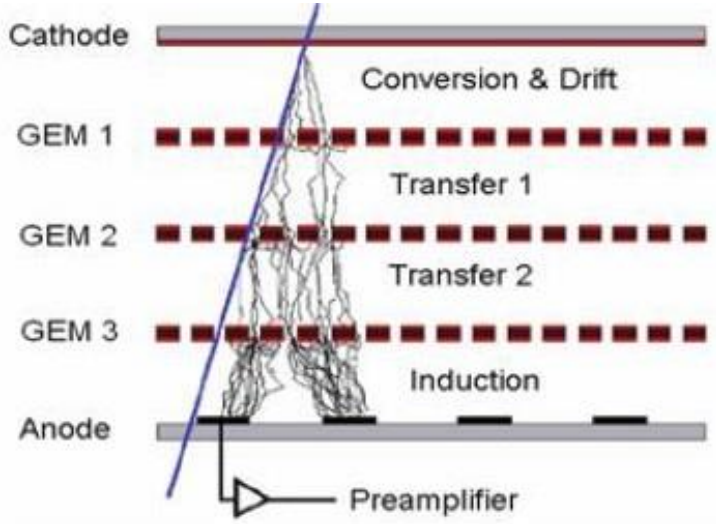
Electron microscope picture of a section of typical GEM foil: 50 μm thick capton foil, metalized on each side by 5 μm thick copper electrodes . The holes pitch and diameter are 140 and 70 μm, respectively.



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

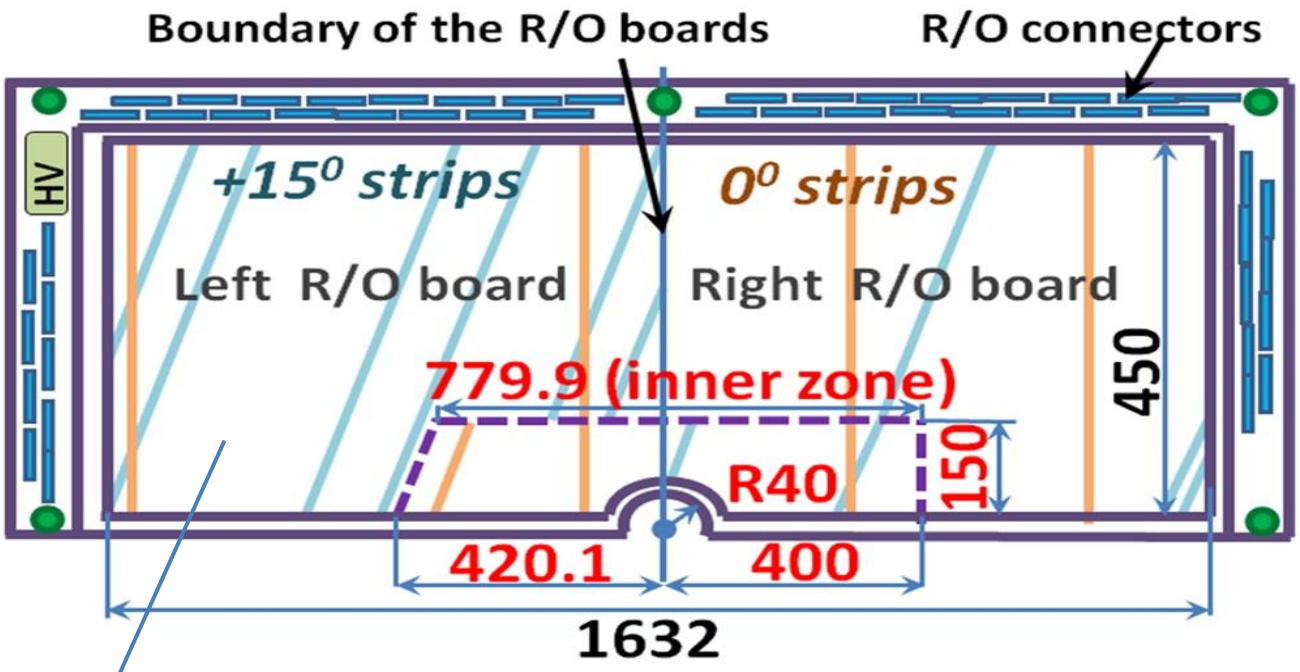


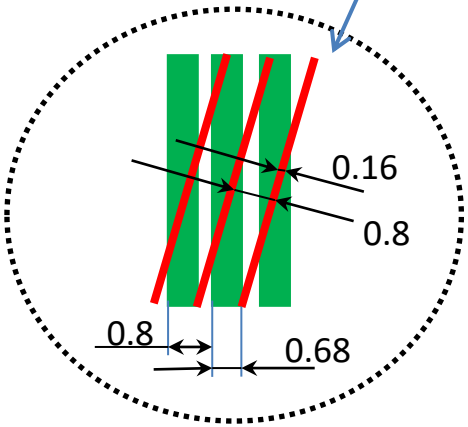
Electron avalanche in GEM holes.

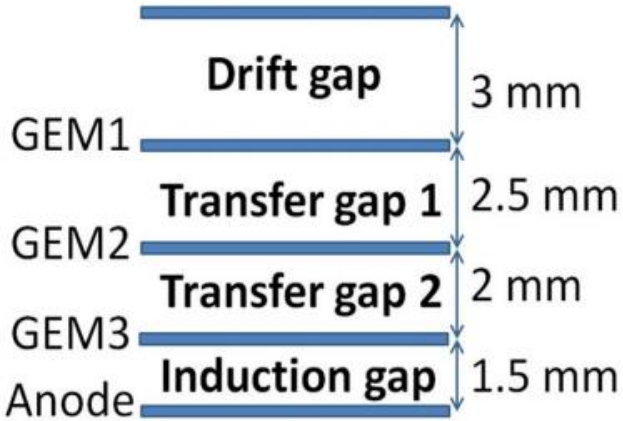


Typical scheme of a triple GEM detector.

BM@N GEM detectors





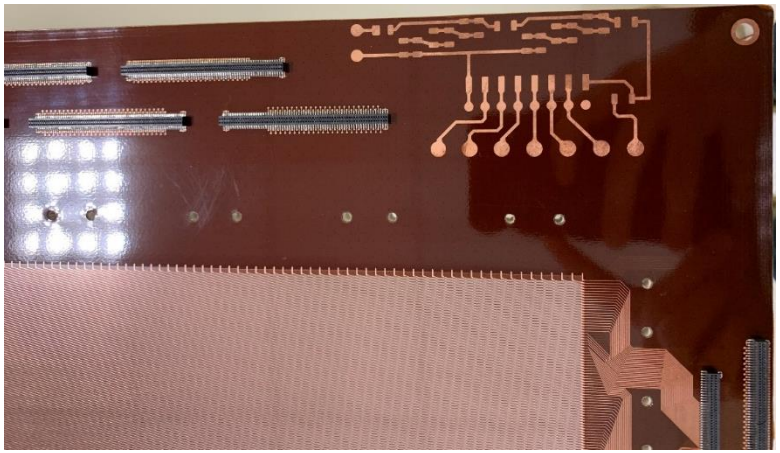


Now we have:
7 detectors 1632 × 450 mm²
7 detectors 1632 × 390 mm²

2 spare detectors will be produced in 2021

Schematic cross section of the BM@N triple GEM detector

BM@N GEM detectors

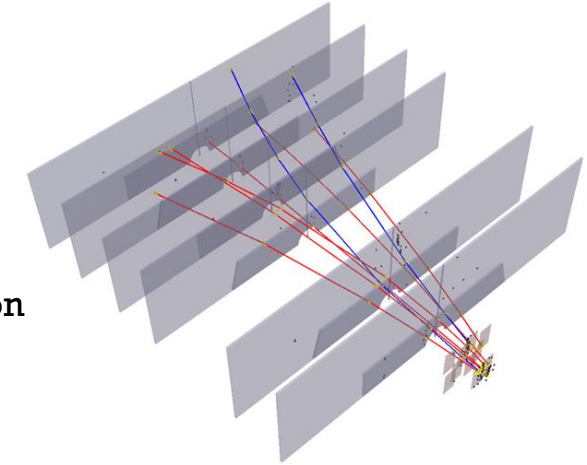


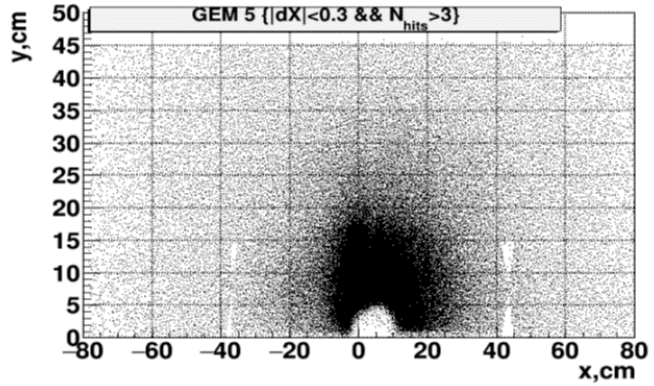
Readout board

Cathode plane

GEM tests on Nuclotron beams

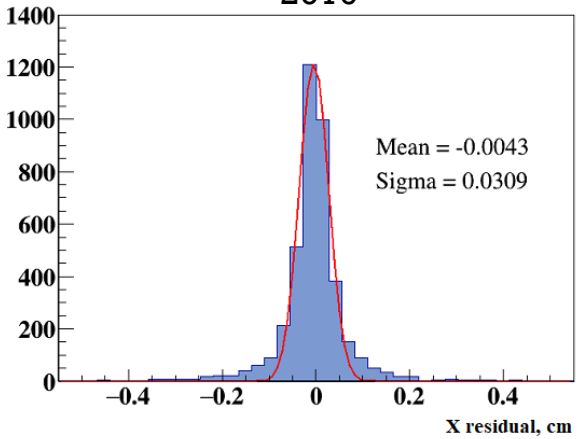
Example of the event reconstruction





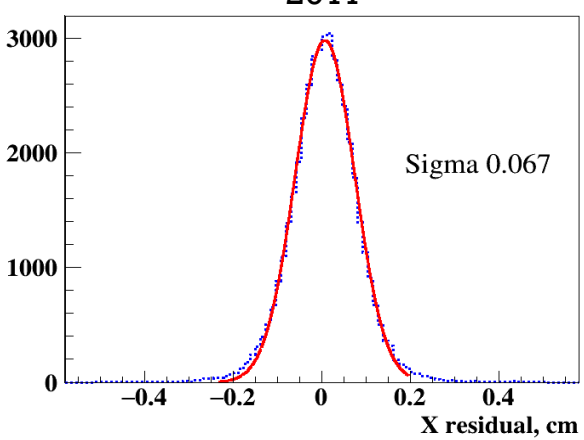
Fragments of Ar beam in detector

2016



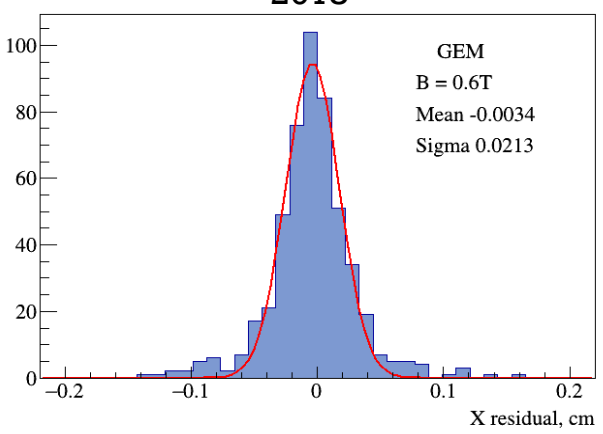
Magnetic field 0.6 T,
Ar(70)/CO2(30),
C beam, E_{drift} = 1.2 kV/cm
σ = 309 μm

2017



Magnetic field 0.6 T,
Ar(90)/Isobutane(10),
d beam, E_{drift} = 0.8 kV/cm
σ = 670 μm

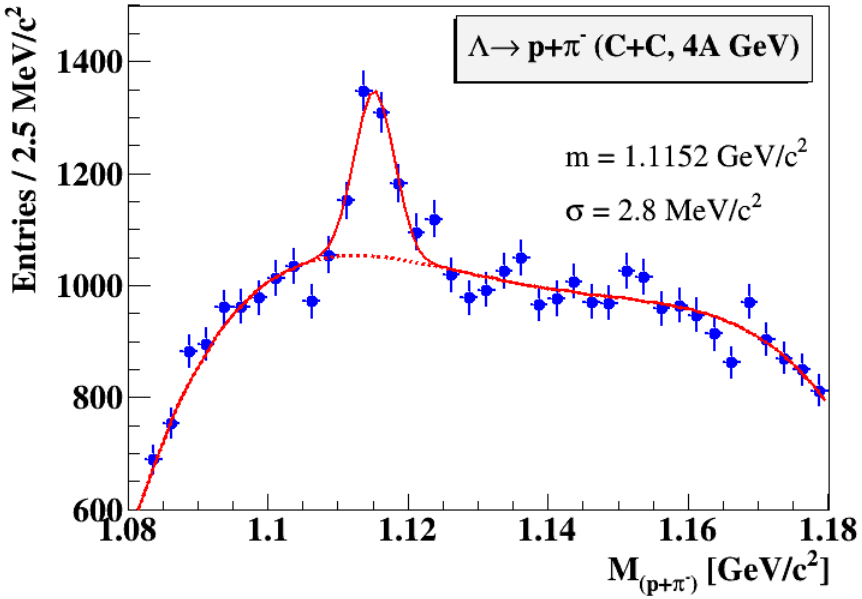
2018

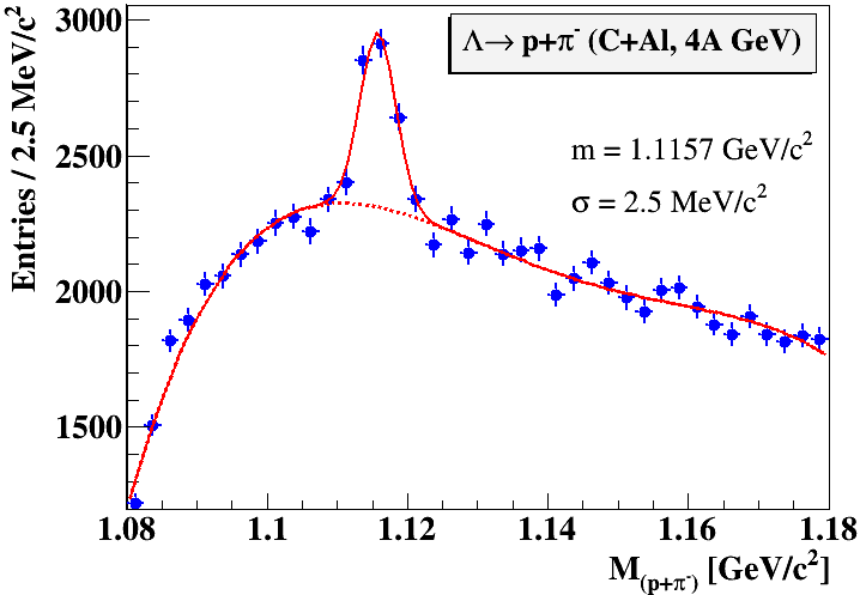


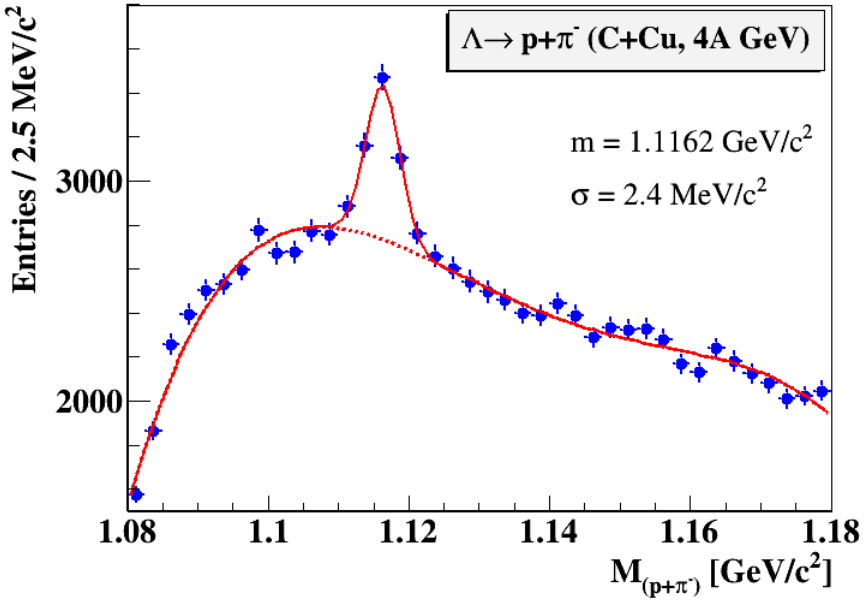
Magnetic field 0.6 T,
Ar(80)/Isobutane(20),
Ar beam, E_{drift} = 1.5 kV/cm
σ = 213 μm

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

Λ-hyperon signals







Carbon beam, 4 GeV/n

C + C, Al, Cu → Λ + X minimum bias

Λ signal width 2.4 – 3 MeV

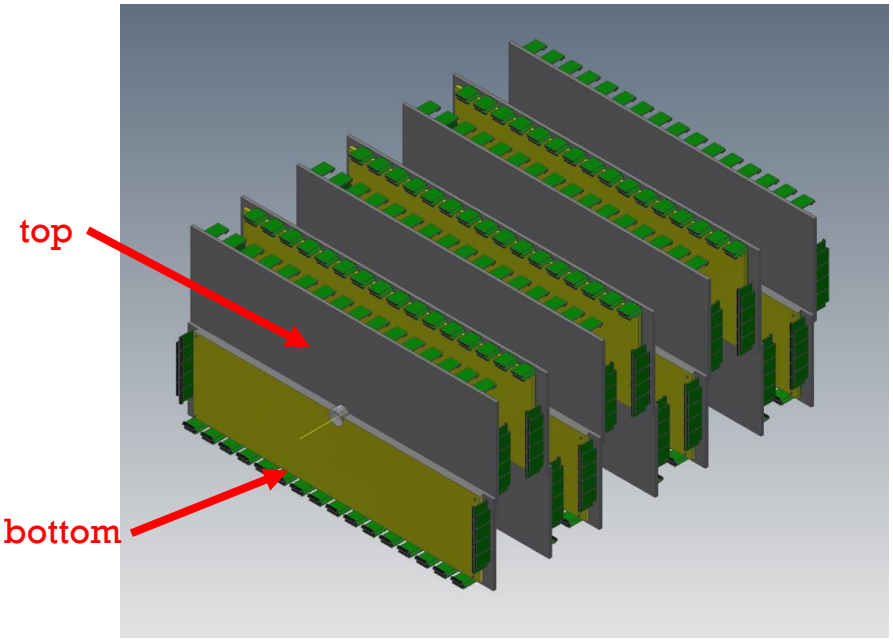
C+C: 4.6M triggers

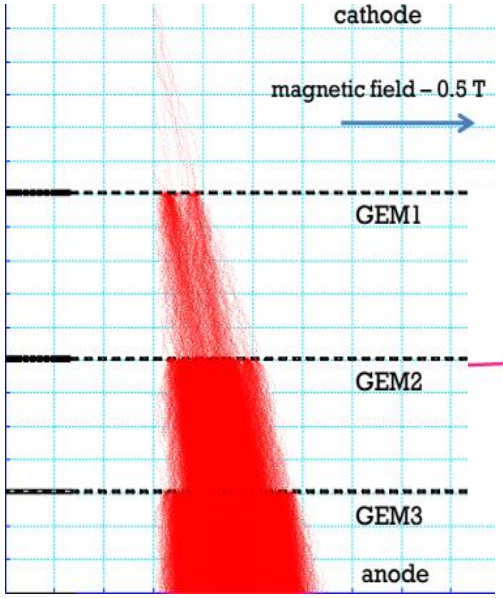
C+Al: 5.3M triggers

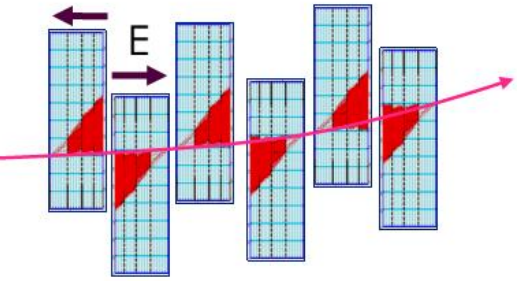
C+Cu: 5.3M triggers

2.5 days of data taking

Scheme of the GEM full planes configuration

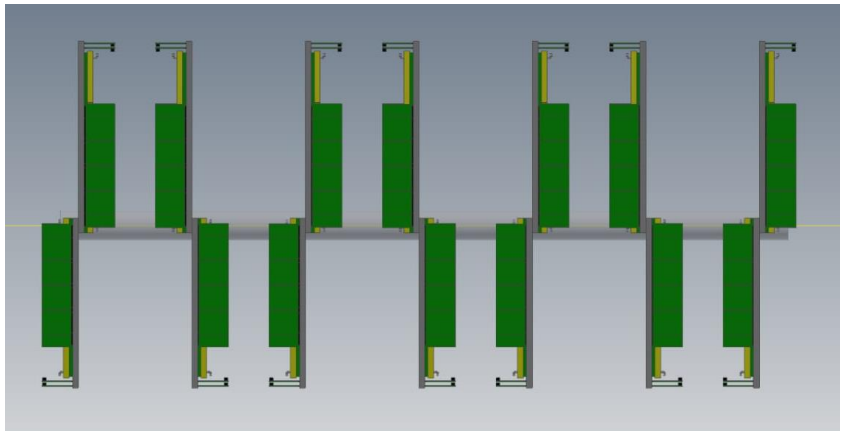


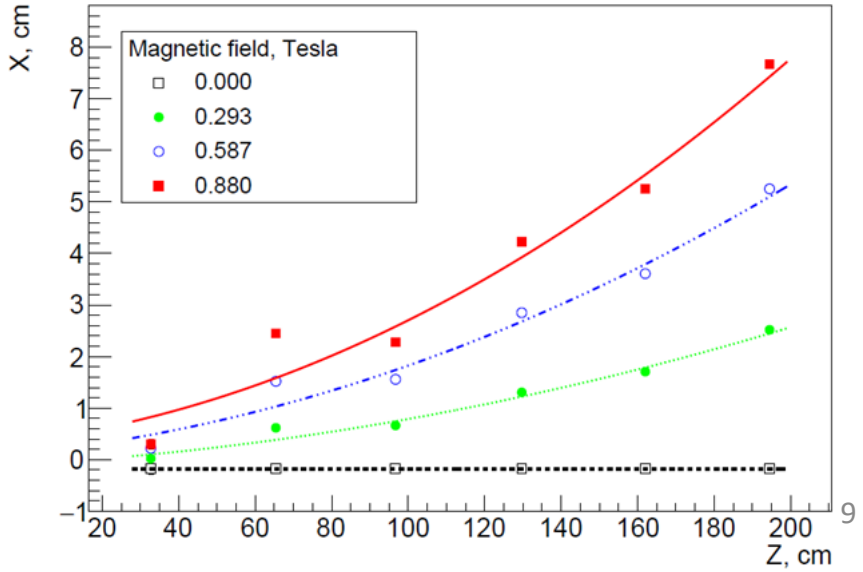




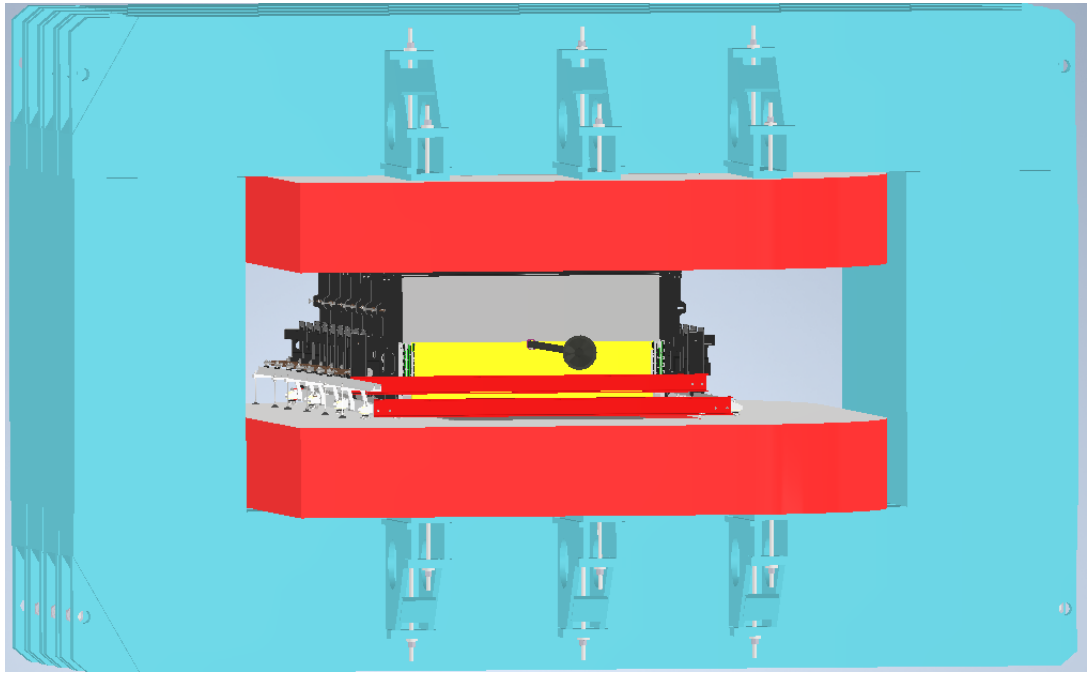
Lorentz shifts of an electron avalanche in GEM planes

On top - 7 detectors with active area 1632×450 mm^2
On bottom - 7 detectors with active area 1632×390 mm^2





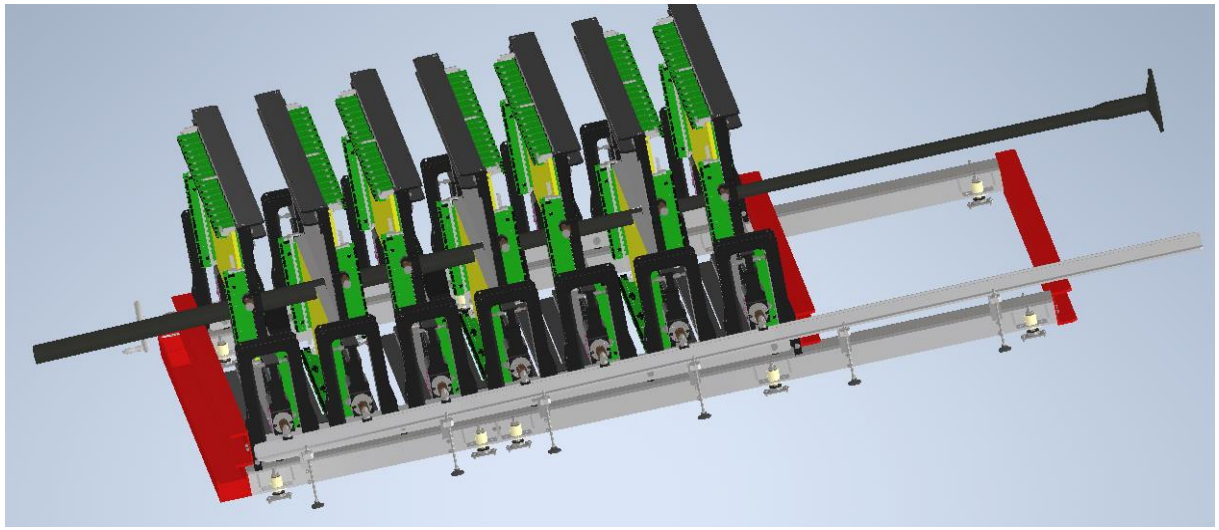
Full planes configuration inside the SP-41 magnet



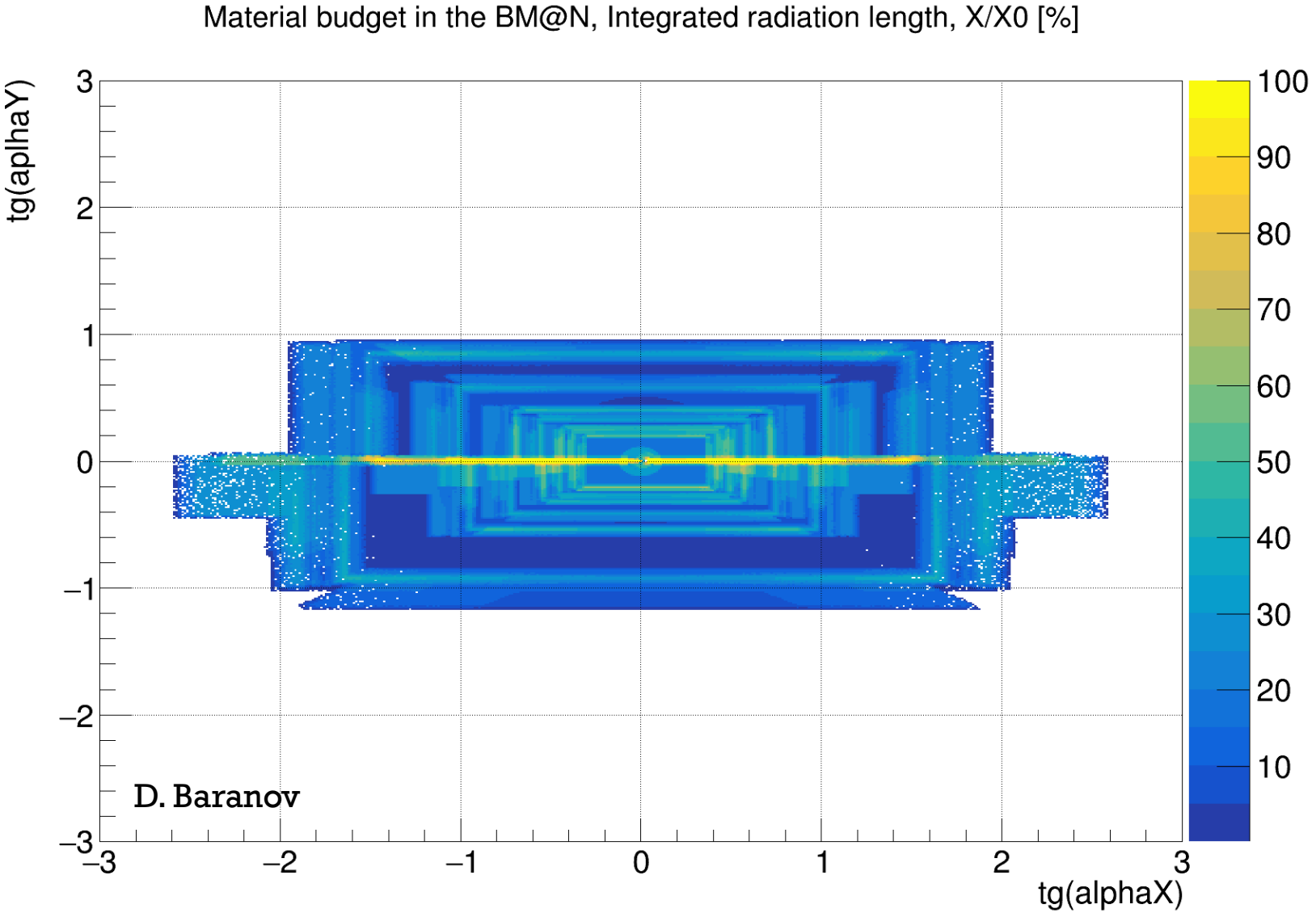
Active area of the GEM tracking system is around 9.5 m^2

Space for the installation and alignment is limited by the aperture of our magnet

10.2020 – development
of the mechanics design for GEM planes inside the magnet.
2021 – mechanics production, installation of the GEM planes.



Material budget of the GEM central tracking system full configuration



Assembly of the stand for long-term GEM tests

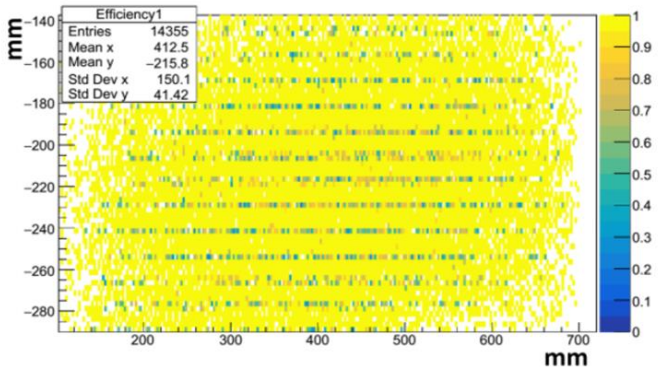
First stage – tests of 1632*390 mm^2 detectors, in progress

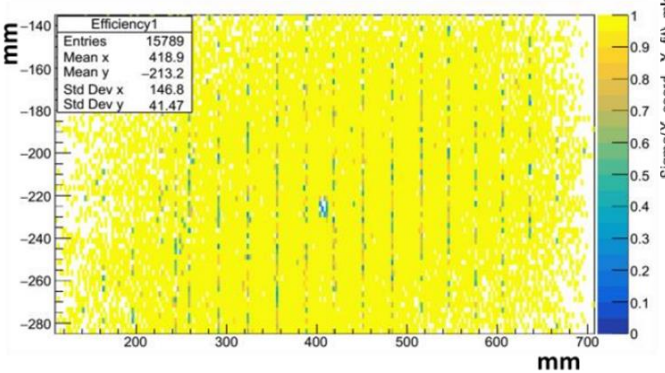
Second stage – tests of 1632*450 mm^2 detectors

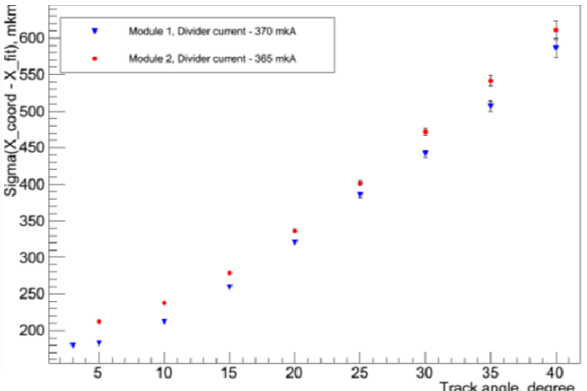
Trigger and HV system

GEM detectors

Main goals: to study geometrical efficiency and spatial resolution



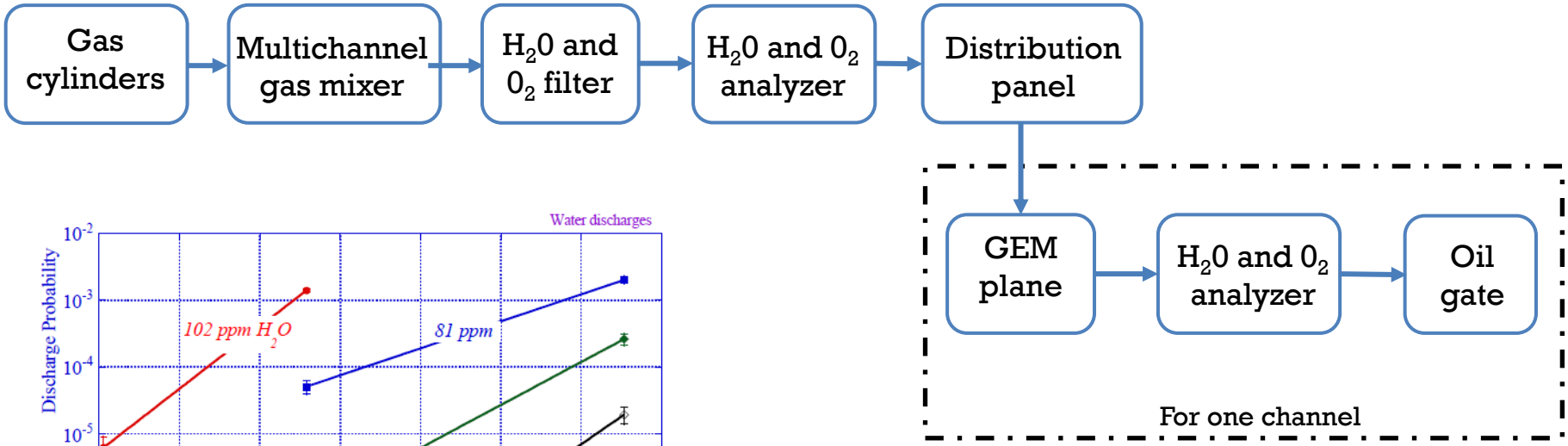


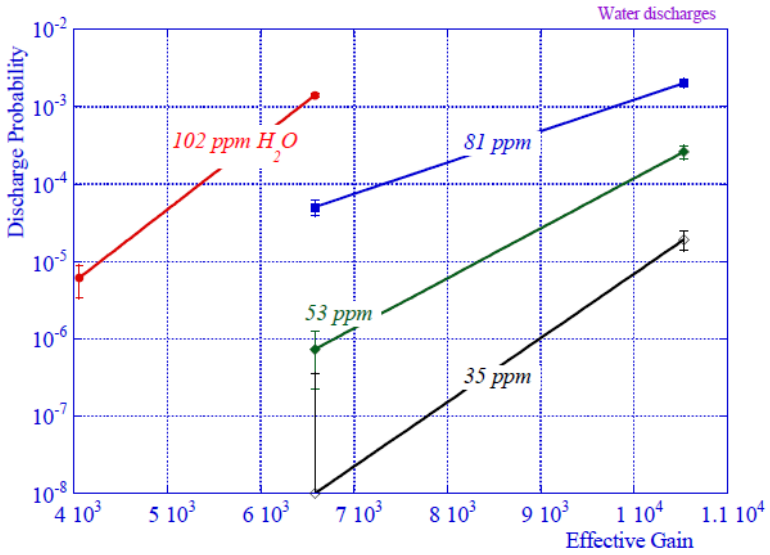


Gas system

Gas system requirements :

- stable flow and mixture parameters;
- 7 independent channels to each GEM-plane;
- reducing and control oxygen and moisture impurities in gas mixture;





Discharge probability on alphas as a function of moisture level in the gas. COMPASS

Oxygen analyze - GE oxy.IQ
Moisture analyze - GE dew.IQ+ GE IQ.probe

Conclusions

- 7 detectors 1632×450 mm^2 and 7 detector 1632×390 mm^2 are produced;
- 7 detectors 1632×450 mm^2 was tested at d, C, Ar, Kr ion beams;
- 2 spare detectors are waiting for the assembly at CERN;
- High Voltage and Low Voltage systems are ready;
- Mechanics for GEM-planes inside the magnet has been developed;
- Assembling the stand for testing the GEM-detectors with cosmic rays has been finished;
- Tests of 1632*390 mm^2 detectors with cosmic rays are in progress;
- Gas system is under upgrade.

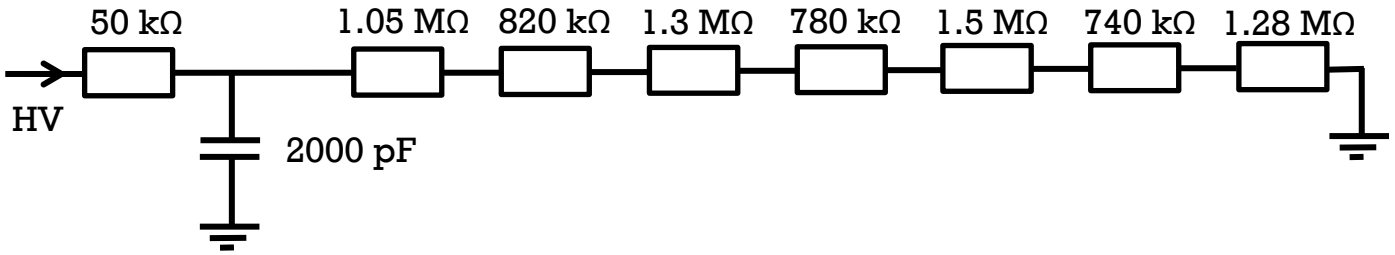
Deadline – autumn 2021

Back up slides

Material budget of one Gem detector

layer	material	density [g/cm-3]	thickness (X) [cm]	X0 [cm]	X/X0 [%]
gas	ArCO2 (70/30)	0.0019	0.9	10960.2	0.0082
copper	copper	8.96	0.0131	1.435	0.9129
glue	acrylic glue	1.25	0.02	32.1603	0.0622
epoxide	polyurethane (high dens.)	1.8	0.21	22.5351	0.9319
	Polyurethane (medium dens.)	0.59	0.21	68.7512	0.3055
	Polyurethane (low dens.)	0.25	0.1	162.253	0.1295
honeycomb	nomex aramid honeycomb (kevlal chemical structure)	0.048	3.0	755.397	0.3971
polyamide	polyamide	1.14	0.025	36.4052	0.0687

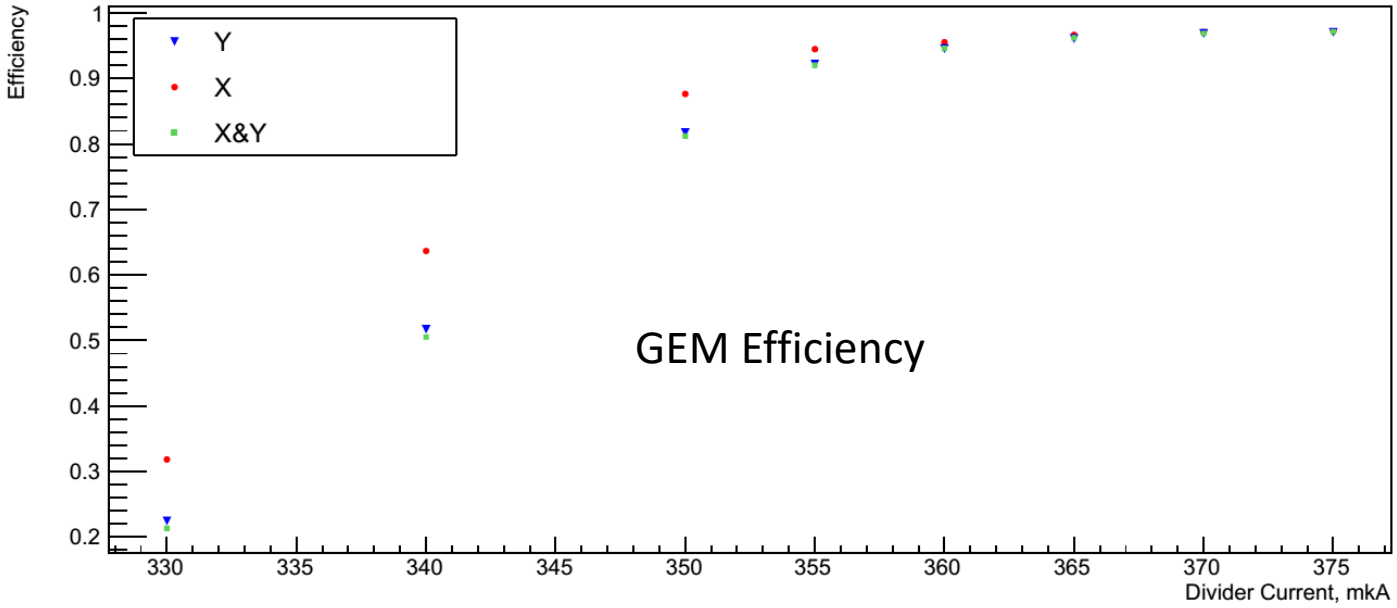
GEM HV divider scheme



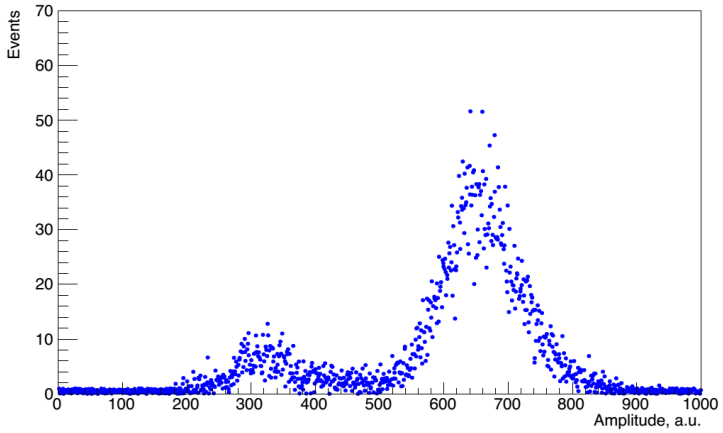
490 mkA – working point for Ar (70) + CO_2 (30) gas mixture
370 mkA – working point for Ar (90) + Isobutane (10) gas mixture
430 mkA – working point for Ar (80) + Isobutane (20) gas mixture

Mixture	I, mkA	DR, kV/cm	Gem 1, V	TR1, kV/cm	Gem 2, V	TR2, kV/cm	Gem 3, V	IND, kV/cm
Ar (70) + CO_2 (30)	490	1.17	402	2.58	382	3.68	363	4.18
Ar (90) + C_4H_{10} (10)	370	0.88	303.4	1.92	288.6	2.78	273.8	3.16
Ar (80) + C_4H_{10} (20)	430	1.5	352.6	2.24	335.4	3.23	318.2	3.67

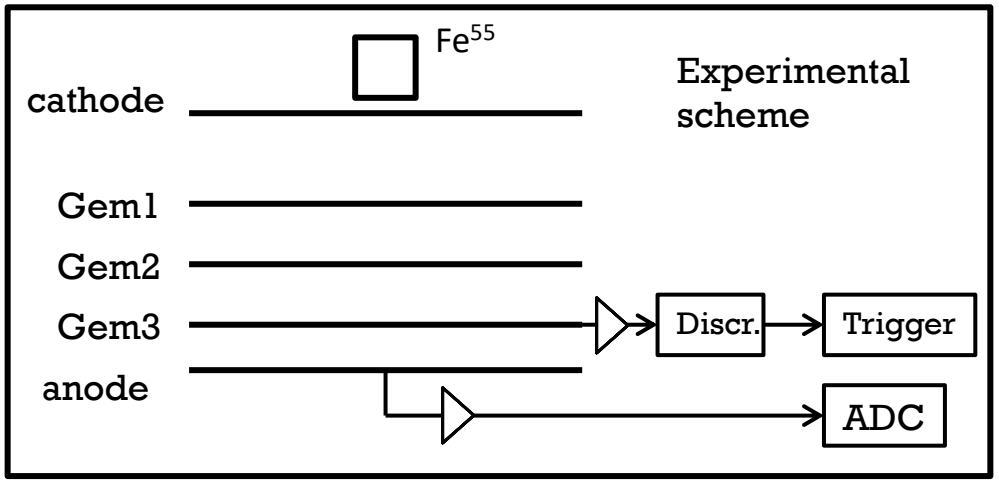
GEM efficiency (cosmic tests)

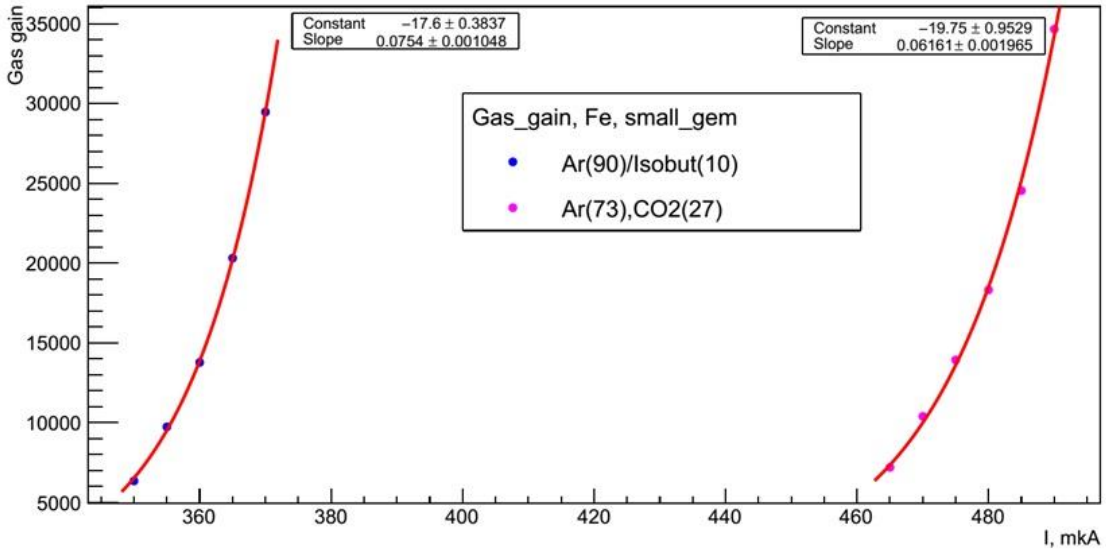


GEM gas gain measurements



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





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