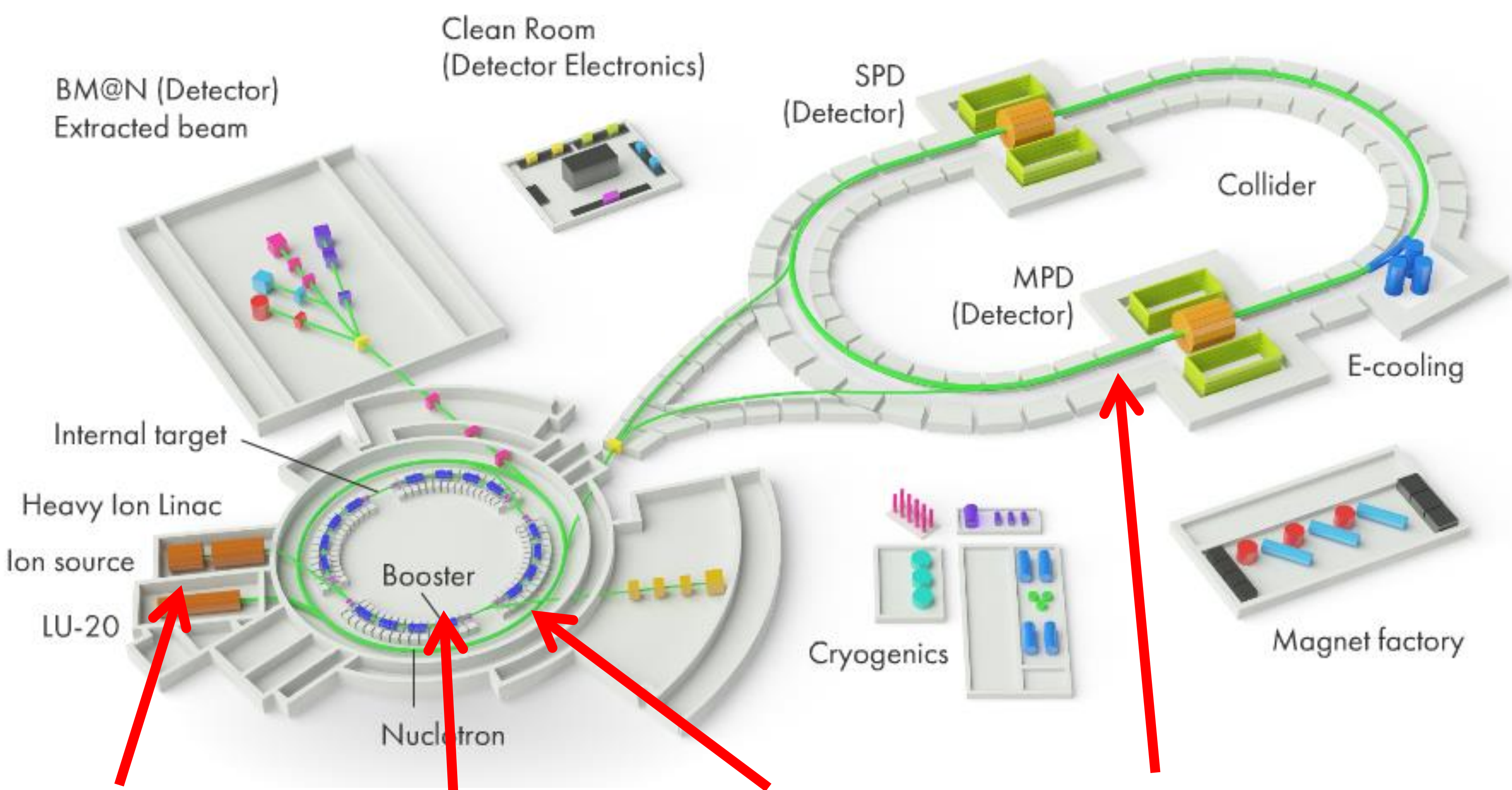
GEM Central Tracking System at the BM@N Experiment

Andrei Galavanov on behalf of the BM@N Collaboration

The 6th International Conference on Particle Physics and Astrophysics (ICPPA-2022), 02.12.2022

NICA complex



Linear accelerators, 3 MeV/u

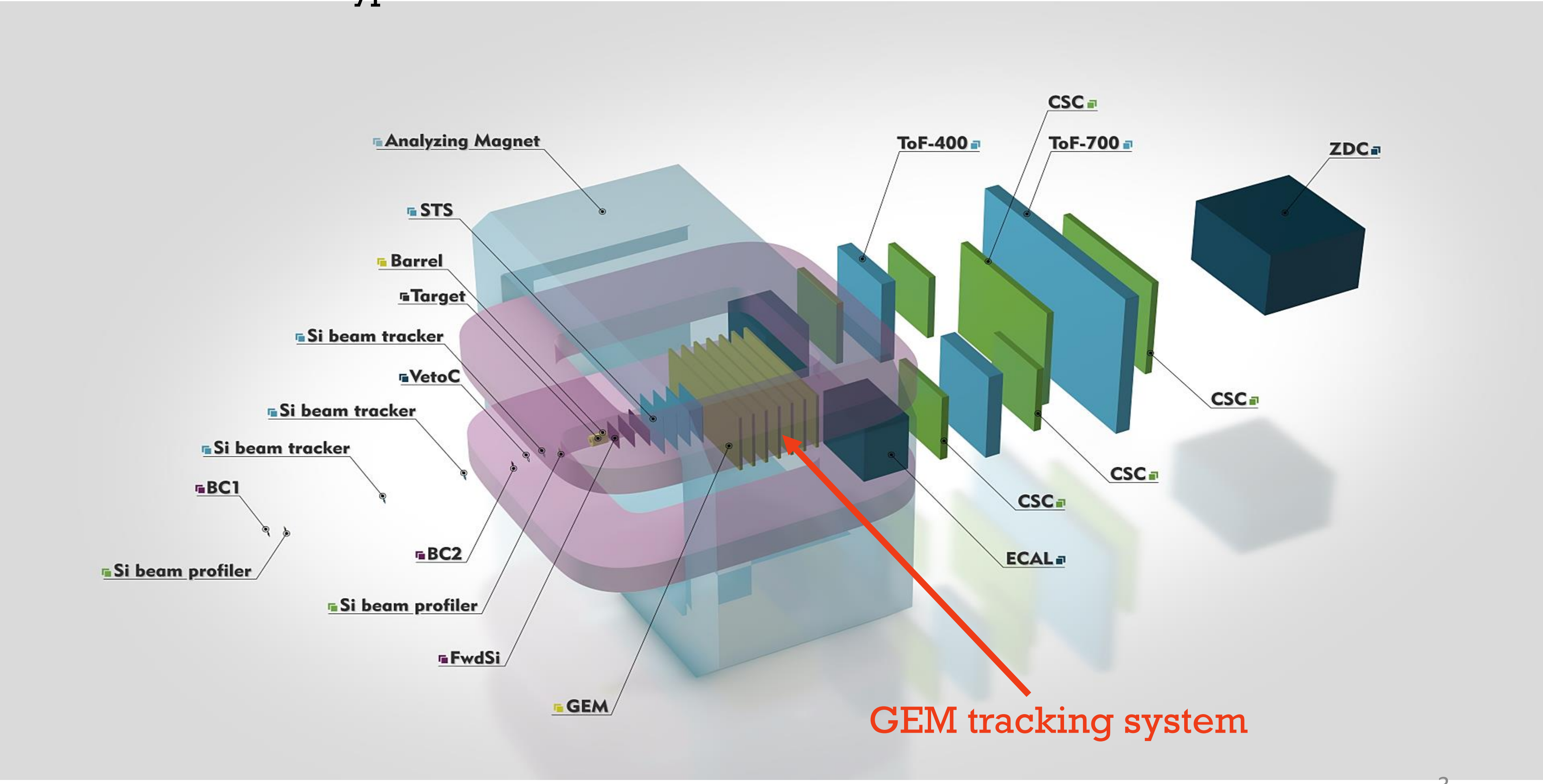
Booster, 3 – 660 MeV/u

Nuclotron, 0.6 – 4.5 GeV/u

Collider, $\sqrt{S}$ = 4 – 11 GeV/u

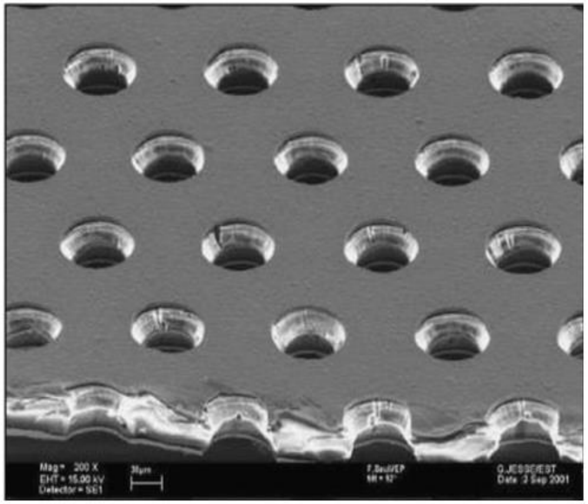
BM@N experiment

Baryonic Matter at Nuclotron (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.

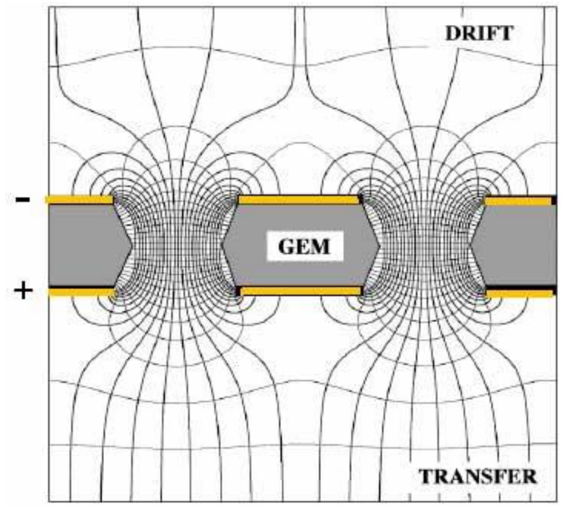


Experimental setup for high intensity heavy ion beams

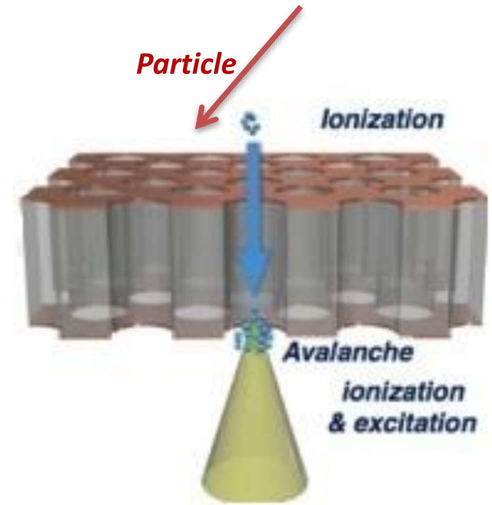
The gas electron multiplier (GEM)



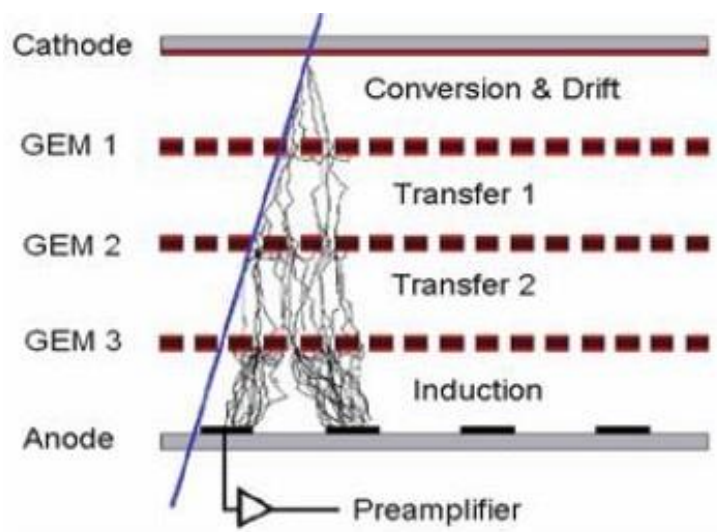
Electron microscope picture of a section of typical GEM foil: 50 μm thick capton foil, metalized on each side by 5 μm thick copper electrodes. Holes pitch and diameter are 140 and 70 μm, respectively.



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

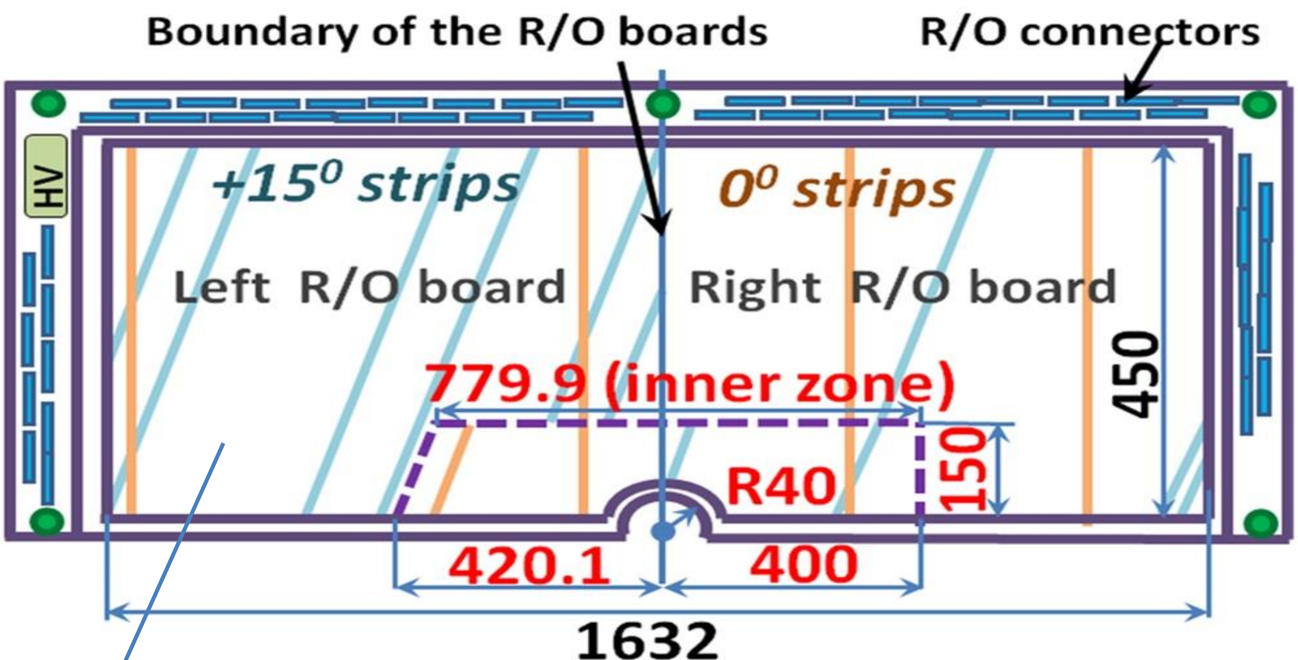


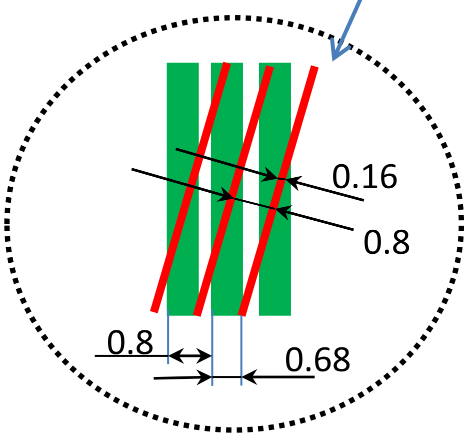
Electron avalanche in GEM holes.

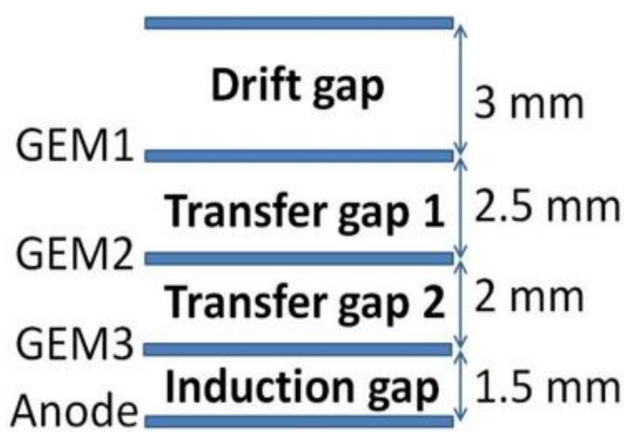


Typical scheme of a triple GEM detector.

BM@N GEM detectors





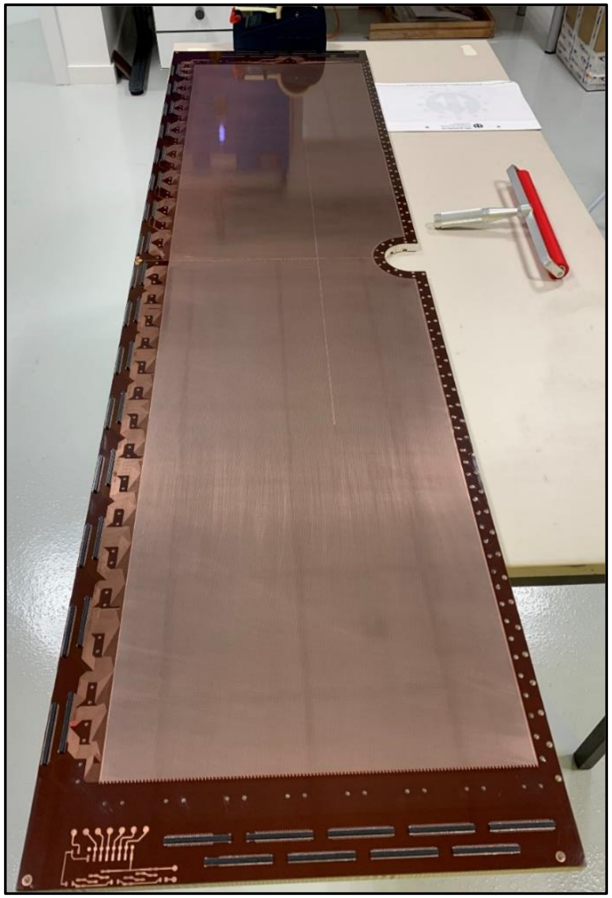


Schematic cross section of the BM@N triple GEM detector

Central tracking system:
7 detectors 1632 × 450 mm²
7 detectors 1632 × 390 mm²

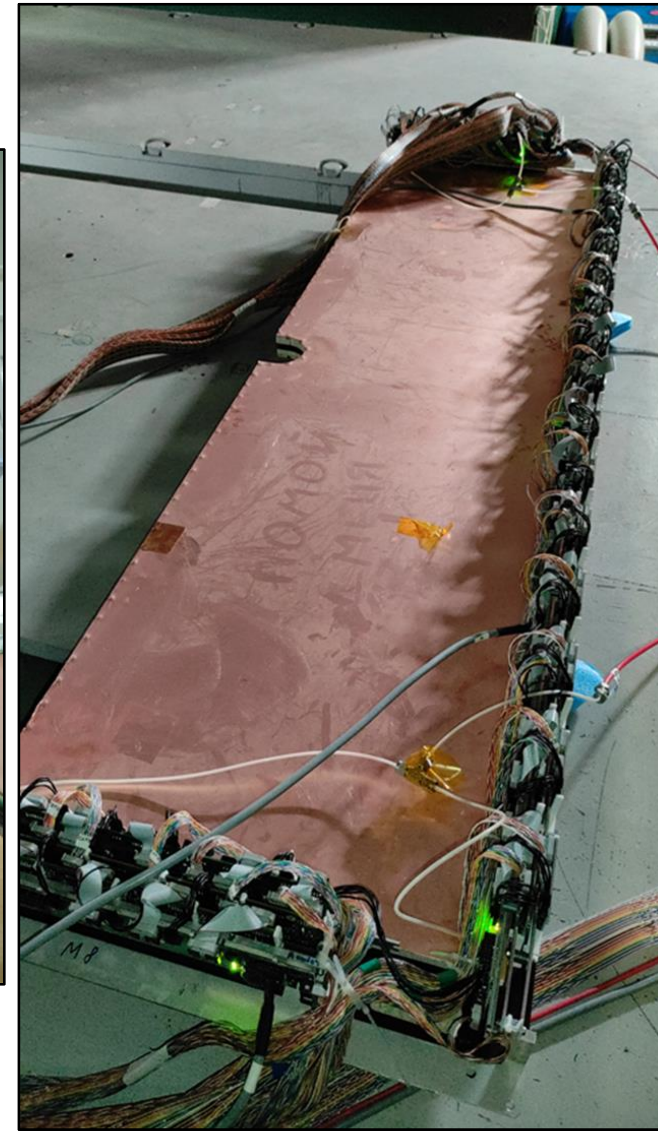
1 detector: 50 FEE cards with 128 channels = 6400 channels
All system = 89600 channels

BM@N GEM detectors



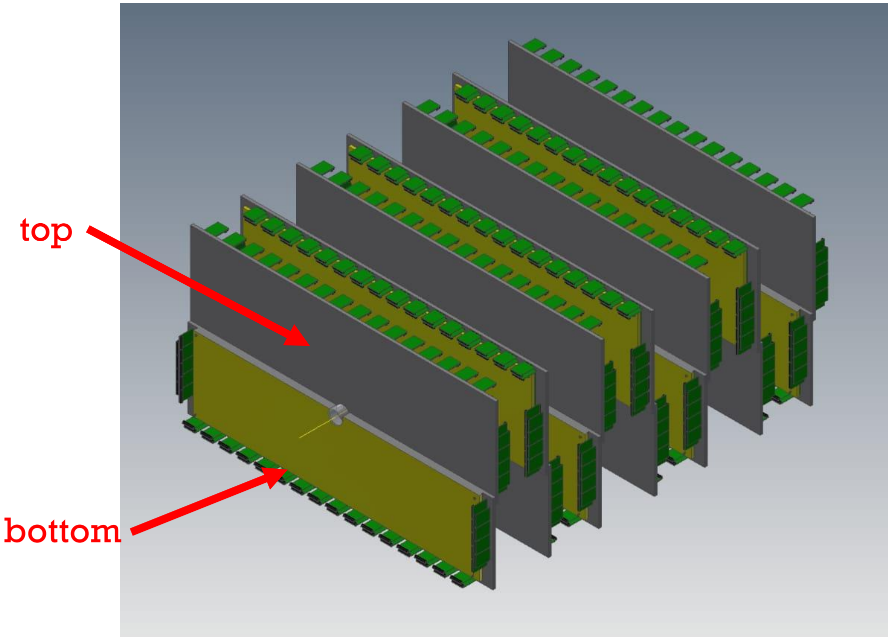
Readout board

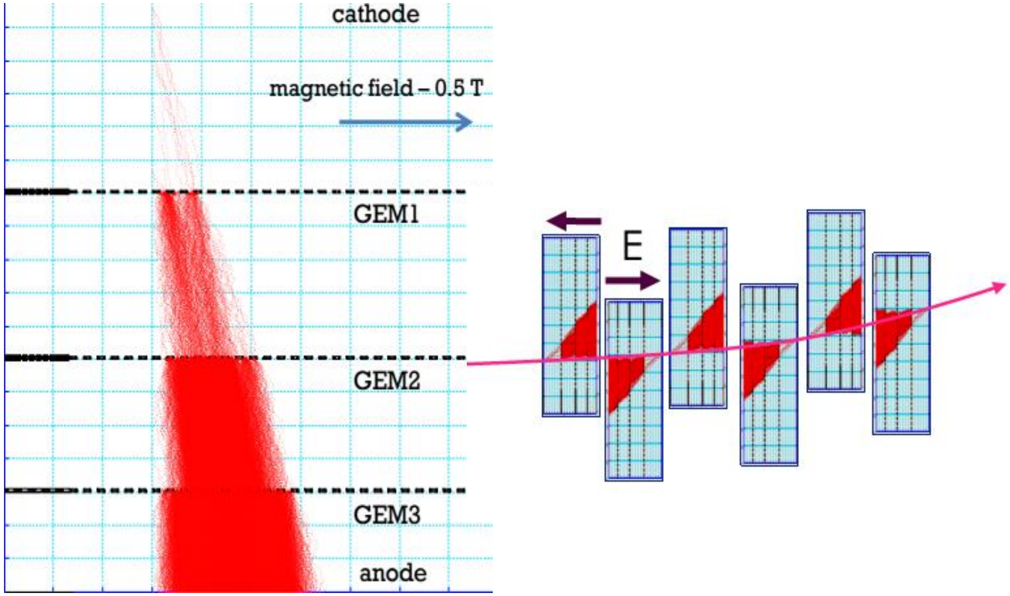
Cathode plane



Full equipped detector

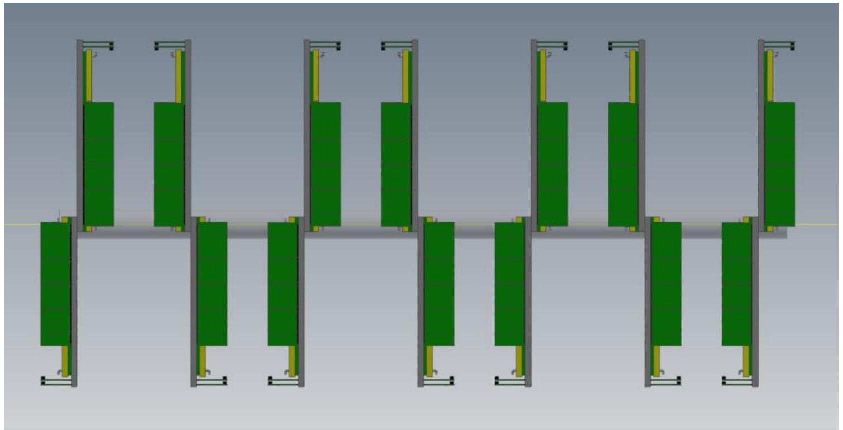
Scheme of the GEM full planes configuration

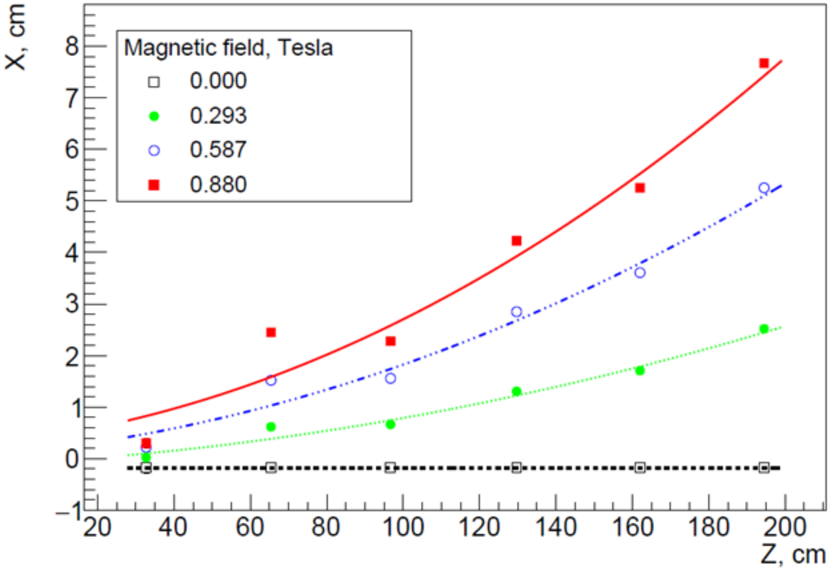




Lorentz shifts of an electron avalanche in GEM planes

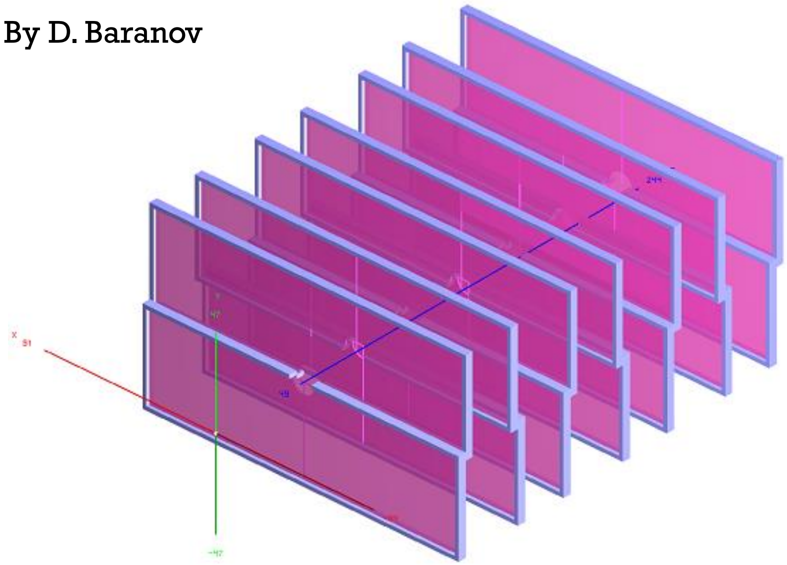
On the top - 7 detectors with active area of 1632×450 mm²
At the bottom - 7 detectors with active area of 1632×390 mm²

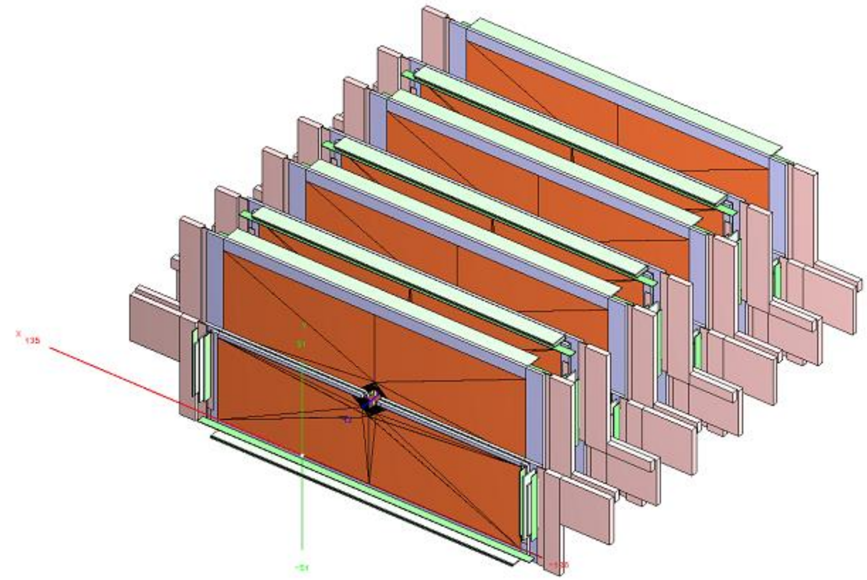




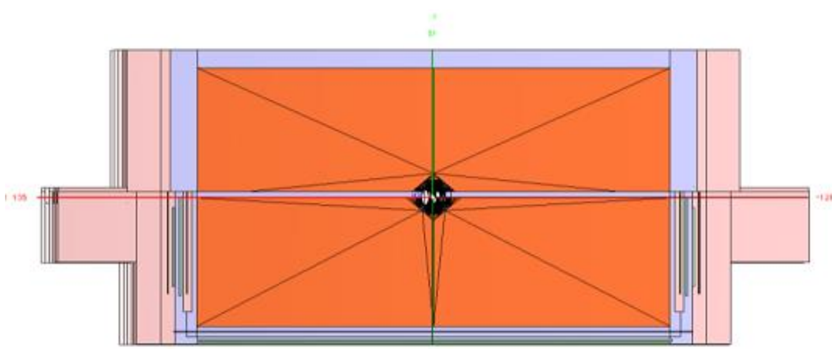
Full planes configuration inside the SP-41 magnet

By D. Baranov

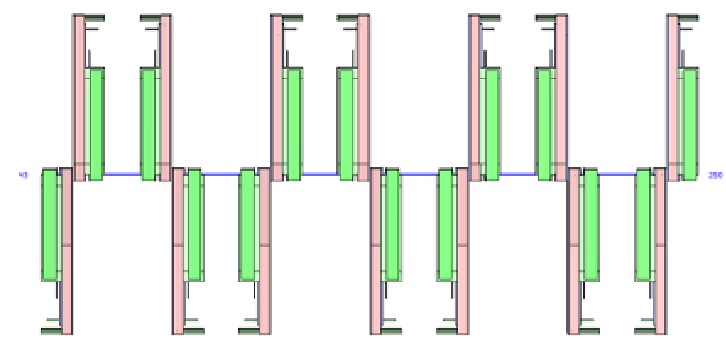




Detailed geometry of GEM planes for heavy ion beam runs (Left panel: GEM active areas, right panel: GEM planes with mechanical support frames and FEE electronics)



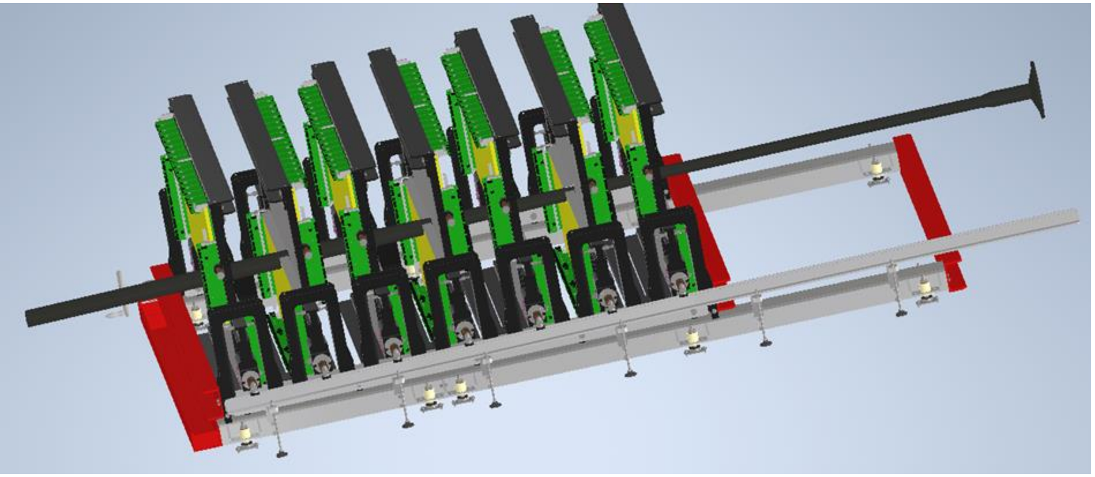
XY projection

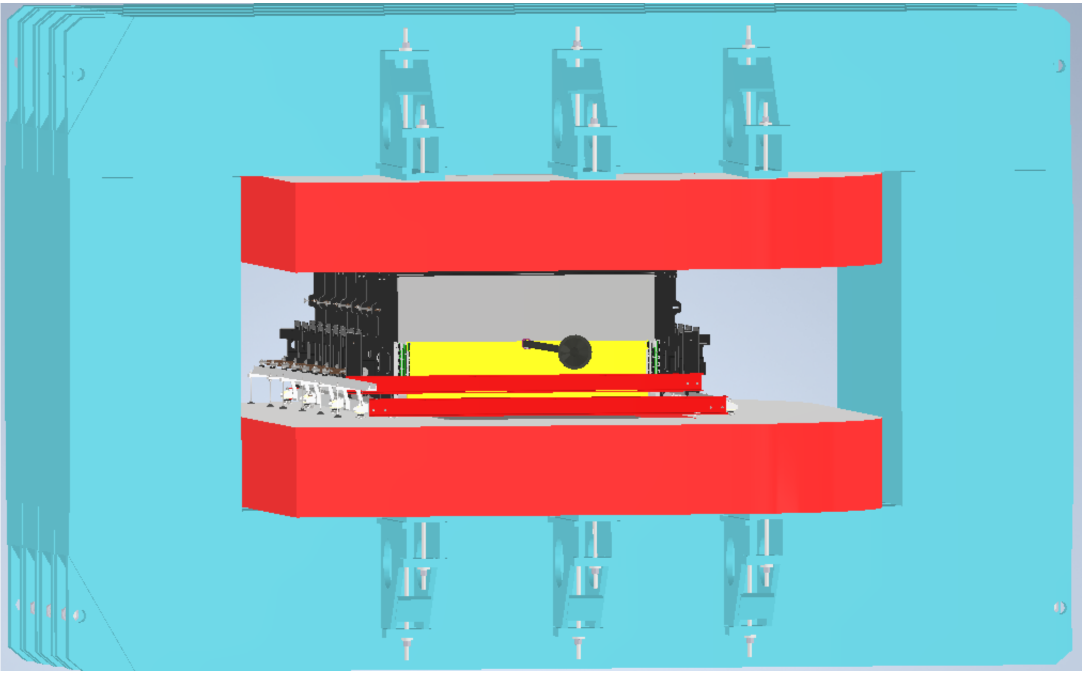


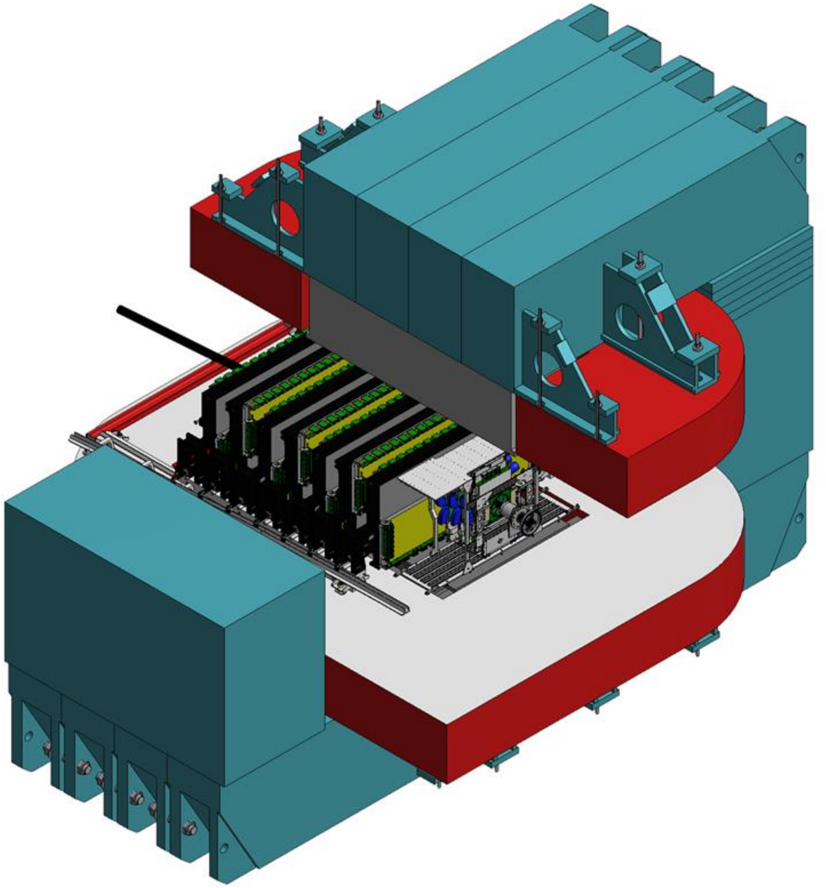
ZY projection

Integrated into BM@Nroot

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

SP-41 magnet

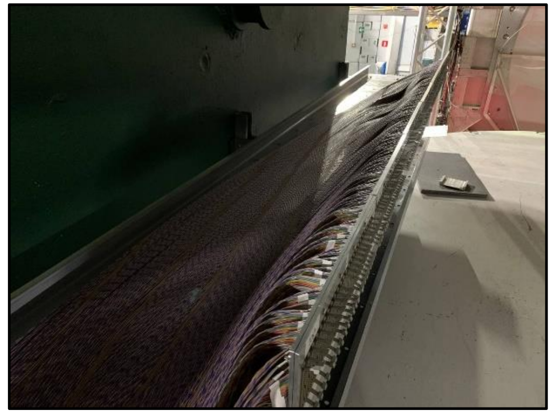
SP-41 it's a dipole warm magnet with magnetic field up to 1 Tesla.

Our comfortable workspace

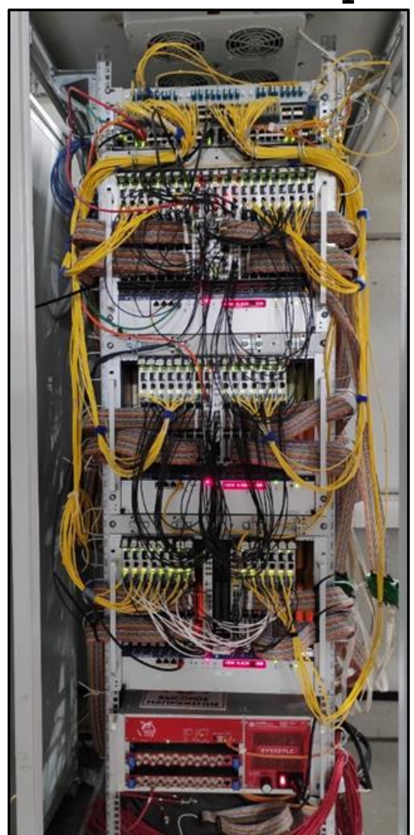
Preliminary works

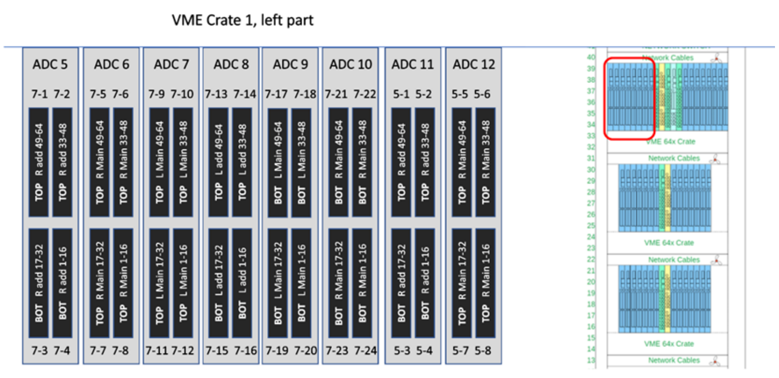
Before the central tracking system assembly was done:

- ADC cables management (175 cables 15m long);
- Patch panels installation;
- Scheme of ADC and patch panels connection;
- Daily plan of detectors installation;



ADC cables: to patch panels↑; to DAQ rack↓





Scheme of ADC cables connection to ADC modules on DAQ rack

Installation of detectors

Daily plan.

Before the start of installation, all GEM detectors are connected to the gas line and "training" high voltage (2000 V) in the test room.

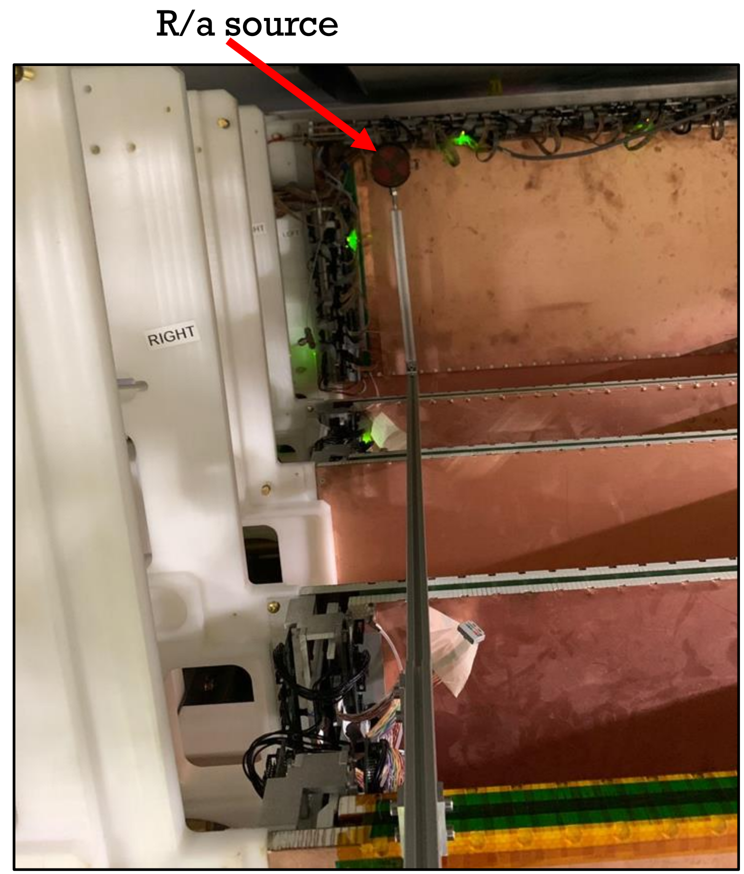
Day 1:

- Disconnect the GEM from gas line and HV;
- Move it at the experimental zone and install to mechanical support inside the magnet;
- Connect the detector to gas line, and connect all cables (ADC, LV, HV) to patch panels/supply blocks;
- Test all FEE cards for stable work;
- At the end of the day rise the HV up to 1000V.

Day 2:

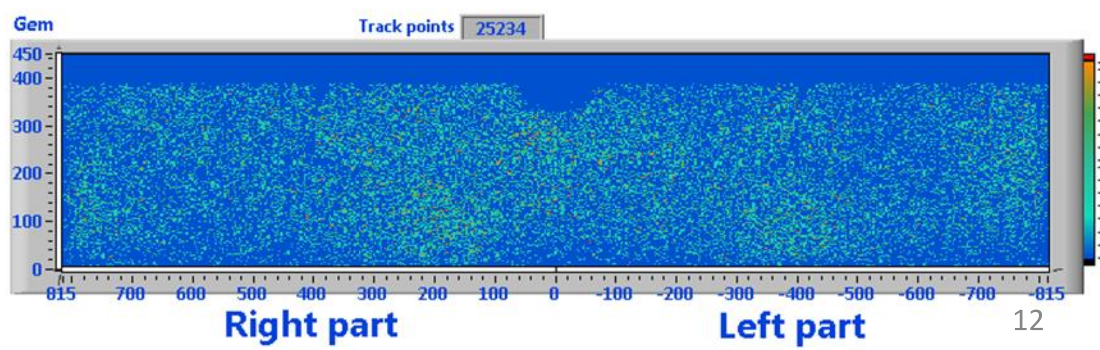
- Increase the HV to the working point (3200 V) during the day;
- Test the GEM response on all active area with radioactive source.

<u>Repeat it 13 times</u>

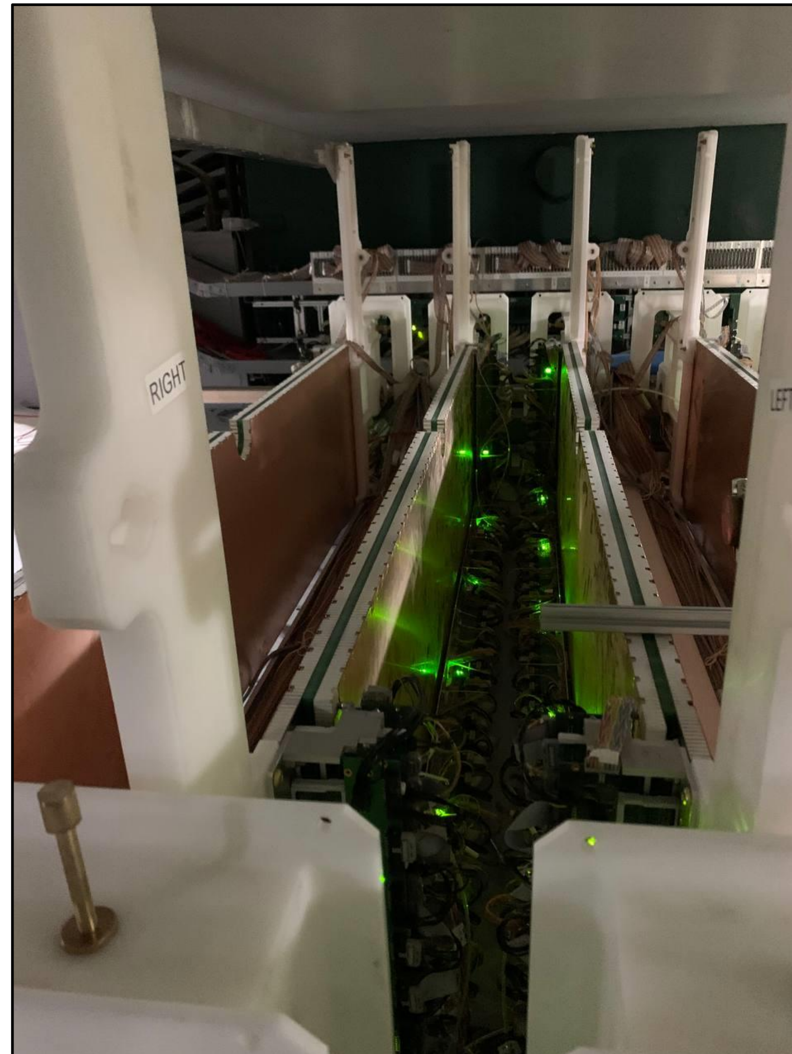


<u>In theory</u>: 14 days for bottom GEMs installation; 5 days for vacuum beampipe; 14 days for top GEMs.

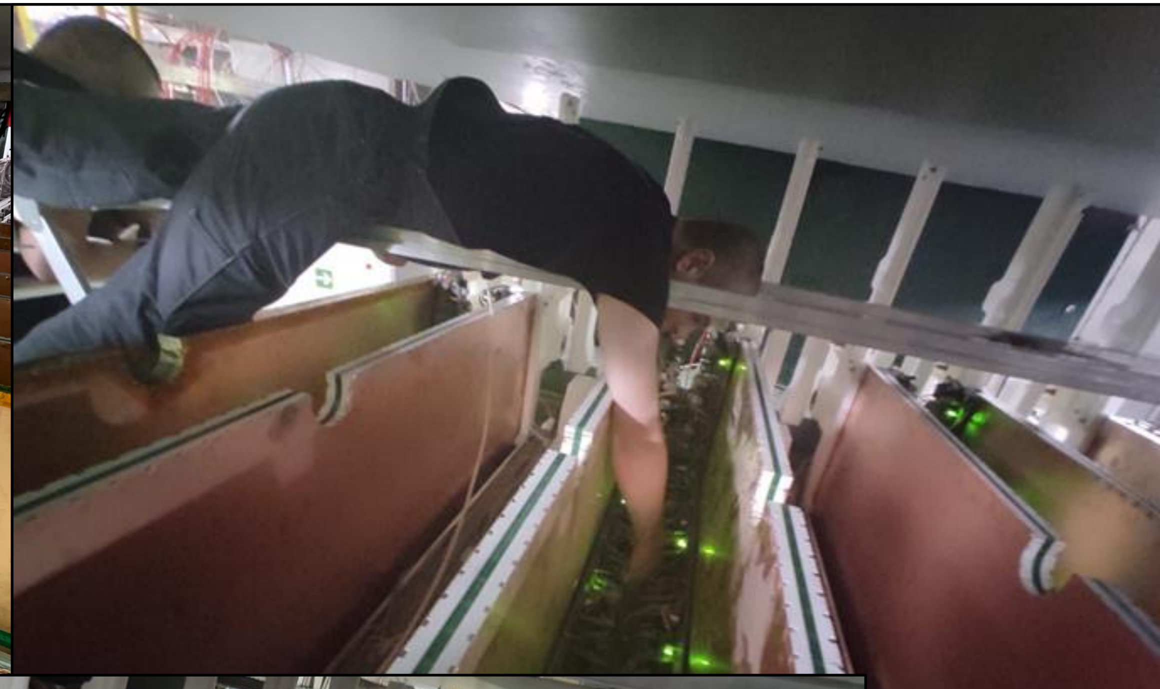
<u>In real life</u>: 49 days from start to finish.

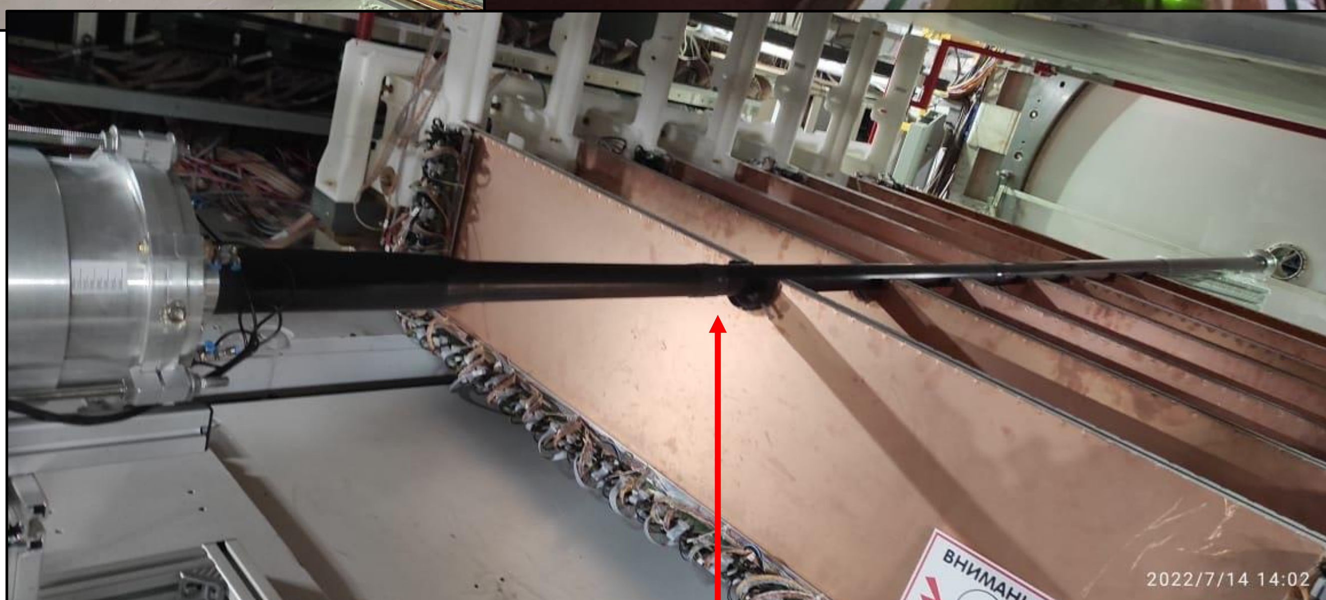


Installation of detectors



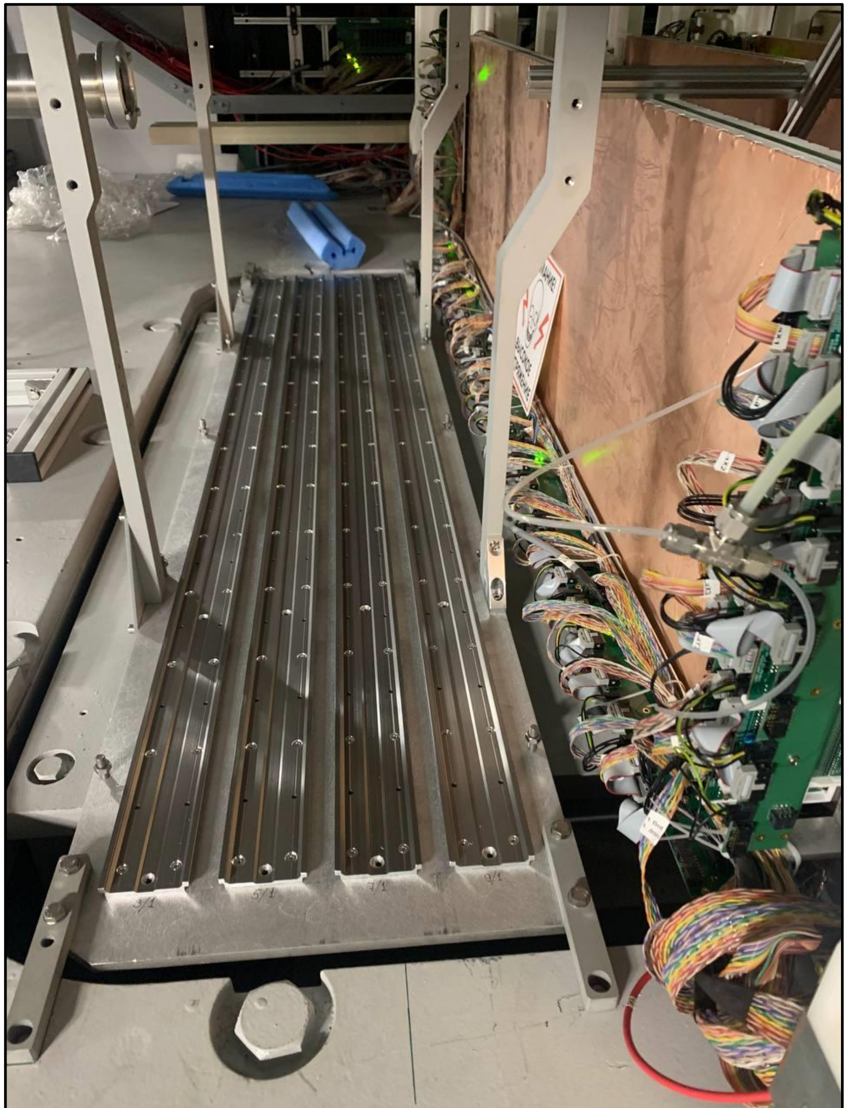
Installation of detectors

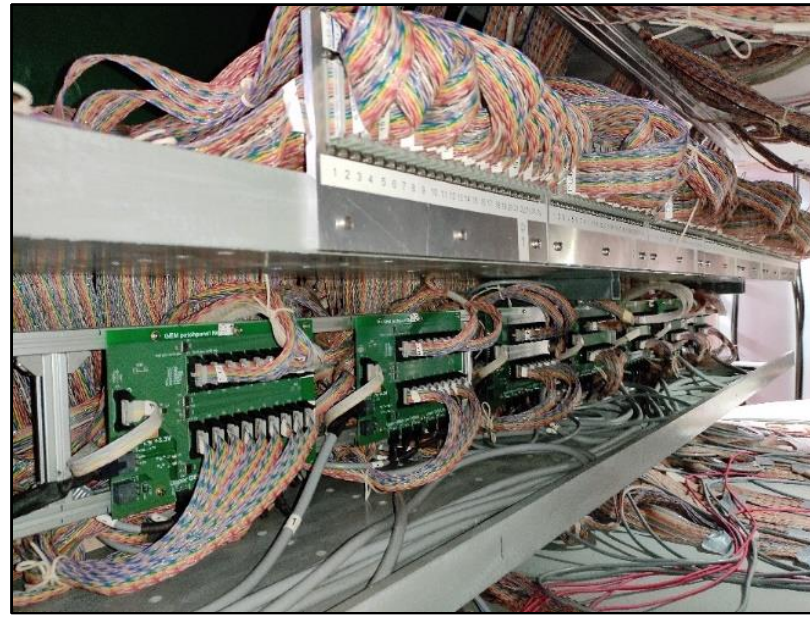




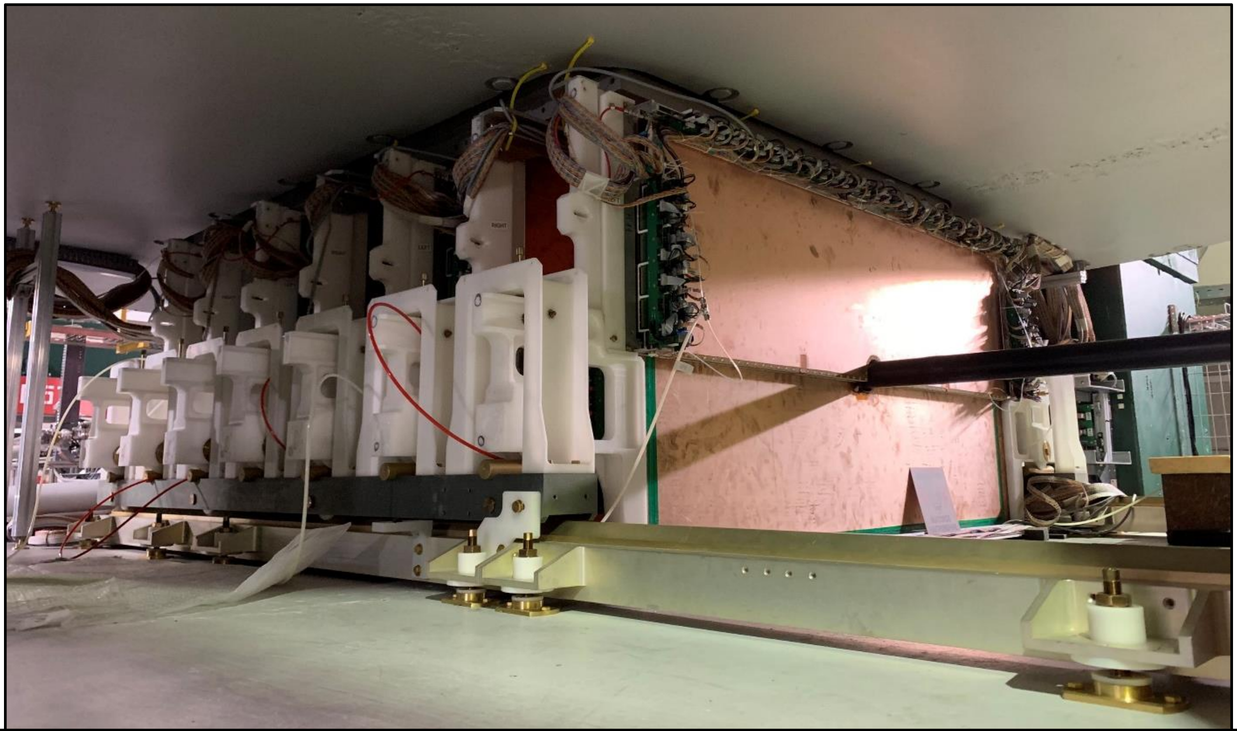
Carbon vacuum beampipe lie on the bottom halfplanes

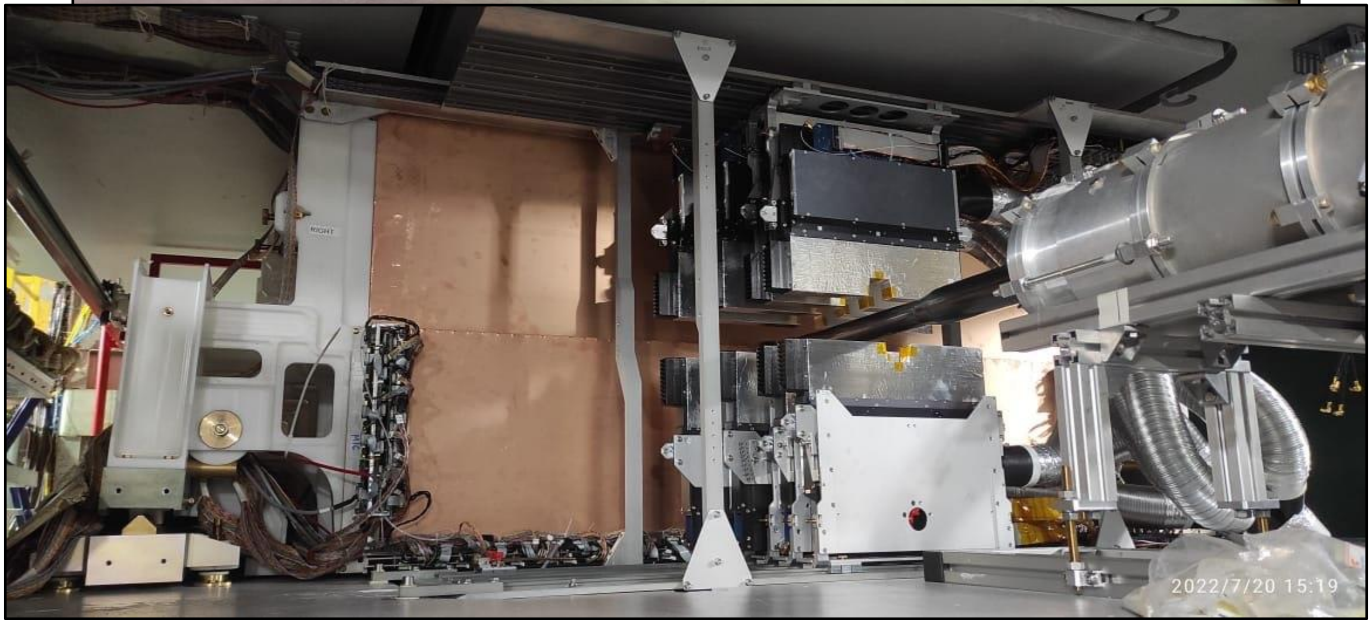
Installation of detectors





Installation of detectors





Accelerator run

BM@N Experimental physics run at the end of the 2022.

Xe beam with CsI target, 800 hours (33 days) of data taking.

Plan: Estimated hyperon yields in Xe + Cs collisions

4 A GeV Xe+Cs collisions, multiplicities from PHSD model,
Beam intensity $2.5 \cdot 10^5$/s, DAQ rate $2.5 \cdot 10^3$/s, accelerator duty factor 0.25

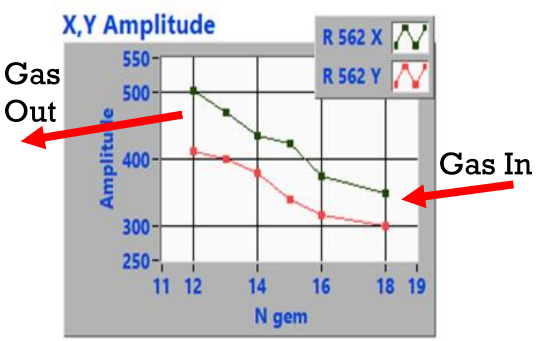
$1.8 \cdot 10^9$ interactions
$1.8 \cdot 10^{11}$ beam ions

Particle	E_{thr}NN GeV	M b<10 fm	ε %	Yield/s b<10fm	Yield / 800 hours b<10 fm
Λ	1.6	1.5	2	150	$5 \cdot 10^7$
Ξ^-	3.7	$2.3 \cdot 10^{-2}$	0.5	0.55	$2 \cdot 10^5$
Ω^-	6.9	$2.6 \cdot 10^{-5}$	0.25	$3.2 \cdot 10^{-4}$	110
Anti-Λ	7.1	$1.5 \cdot 10^{-5}$	0.5	$3.7 \cdot 10^{-4}$	130

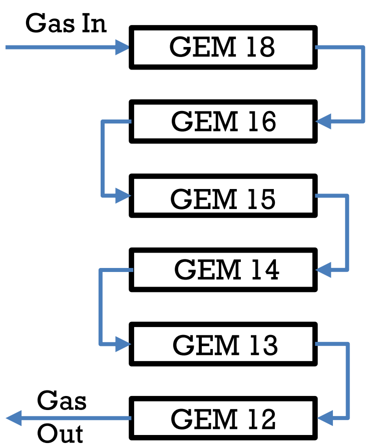
DCM-SMM
x 0.75
x 0.5

Future works

Internal and external influences



Gas mixture go through all 6 detectors in series.



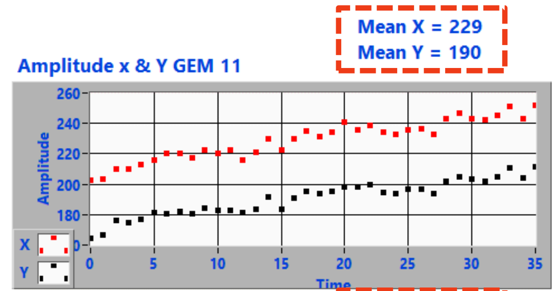
Volume of 1 detector ~ 8 liters.

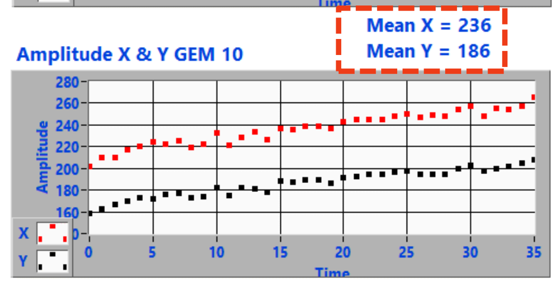
Flow rate = 3 l/h

Amplitude's difference from In(GEM 18) to Out(GEM 12) is about 1.4 times.

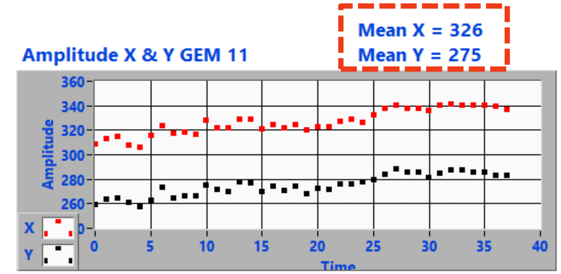
Gas mixture have time to heat up.
<u>Need the split of gas flows.</u>

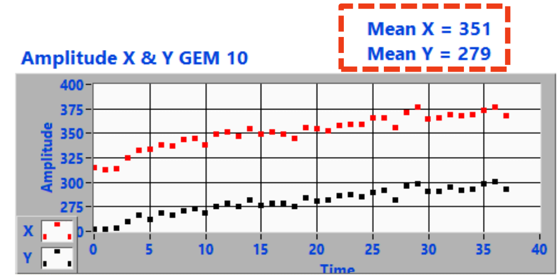
T_{cyl} = 19°C, T_{room} = 20°C

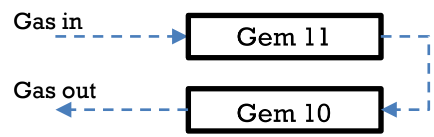




T_{cyl} = 19°C, T_{room} = 25°C







T_{room} grows on 5 °C – amplitudes is increase on 1.4 ÷ 1.5 times.

Oxygen impurities measurements in gas mixture
Analyzer 1 – before GEM 18; Analyzer 2 – after GEM 12

	Analyzer 1, ppm	Analyzer 2, ppm
3 l/h	217	4045
6 l/h	117	1610

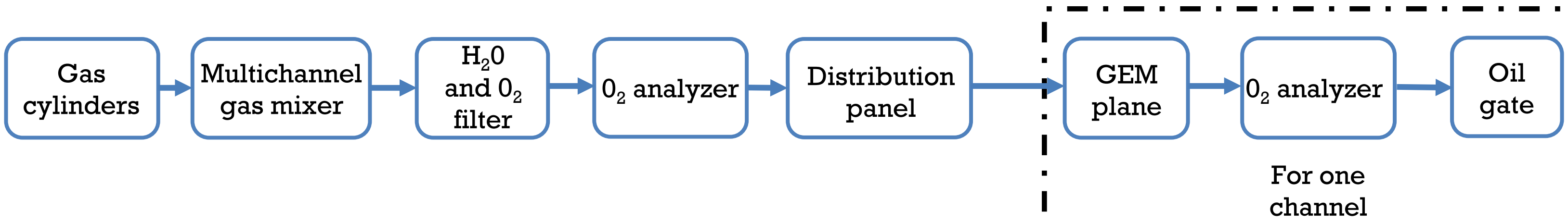
Flow = 3 l/h: each GEM-detector adds around 550 ppm O_2
Flow = 6 l/h: each GEM-detector adds around 220 ppm O_2

Future works

Gas system upgrade

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

Gas mixture: Argon (80)/Isobutane (20),
Flow rate = 3 l/h



Distribution panel:
- 10 channels gas collector;
- On 8 channels – special rotameters for gas mixture flow control (7 GEM planes + 1 channel to test room);
- One channel for pressure control;
- One spare channel.

Gas mixer:

Flow rate is 3 l/h on each channel – 21 l/h for seven GEM-planes.

Conclusions

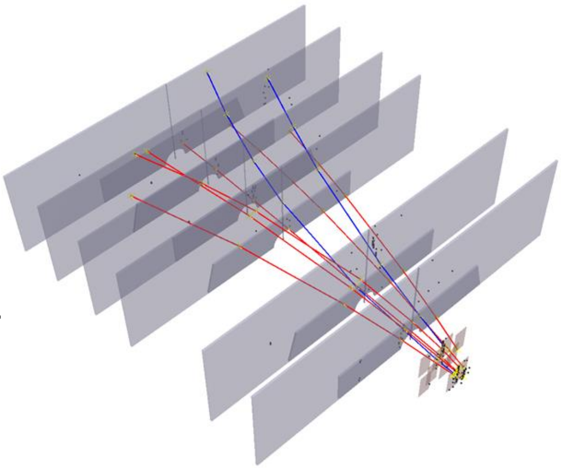
- The central tracking system of the BM@N experiment consists of 7 GEM detectors 1632×450 mm^2 and 7 GEM detector 1632×390 mm^2. <u>These are still the biggest GEM detectors in the world.</u>
- The central tracking system was integrated into the BM@N experimental setup – all detectors were installed inside the BM@N analyze magnet.
- After the installation performance of all detectors was checked with the radioactive source.
- Now we are waiting for the start of the accelerator run.
- We need to split the gas flows. Gas system will be upgrade at the next year.
- We will continue to study the influence of different factors to our GEMs.

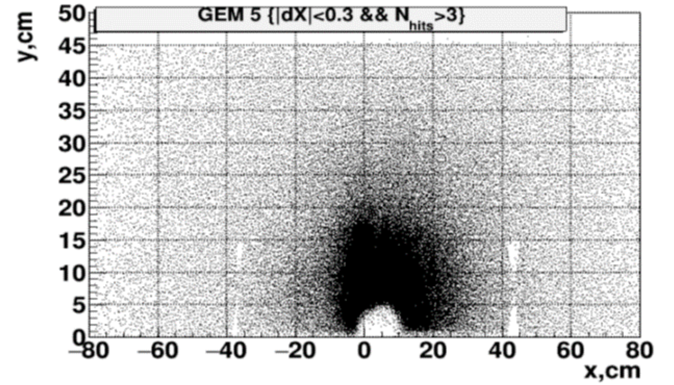
Thank you for your attention!

Back up slides

GEM tests on Nuclotron beams

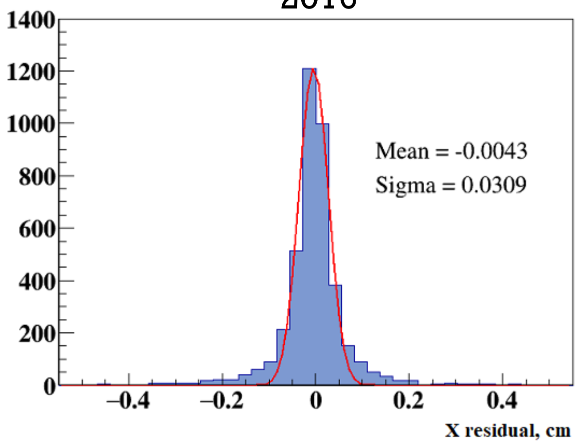
Example of the event reconstruction





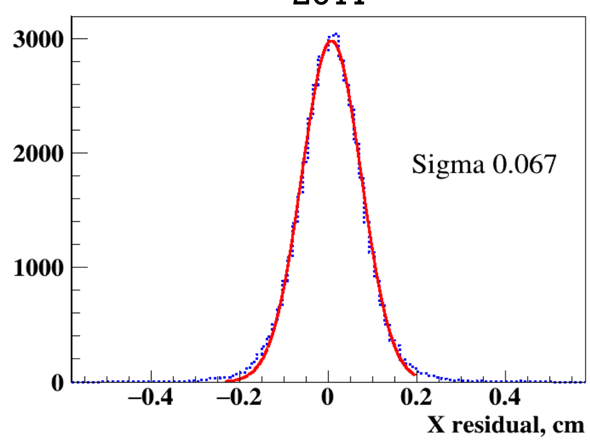
Fragments of Ar beam in detector

2016



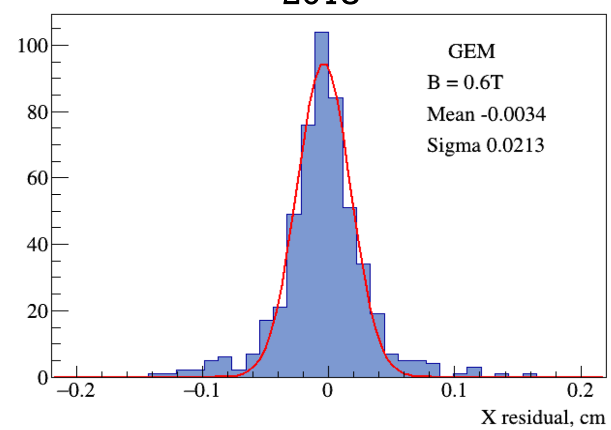
Magnetic field 0.6 T,
Ar(70)/CO2(30),
C beam, E_{drift} = 1.2 kV/cm
σ = 309 μm

2017



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

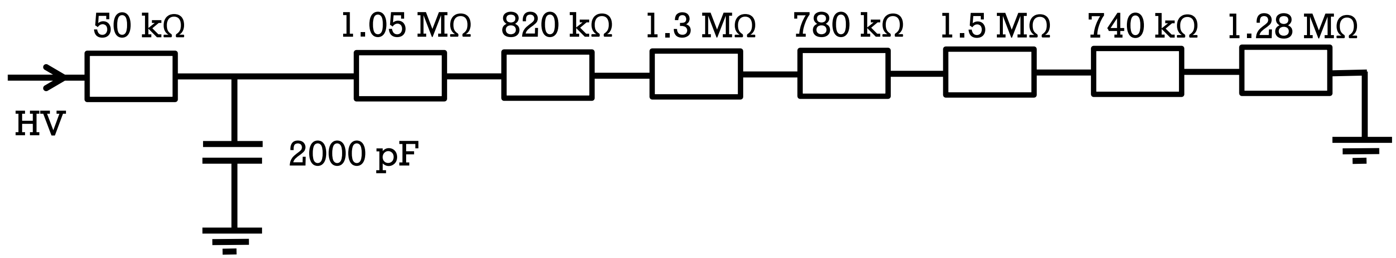
2018



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 decreased.

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

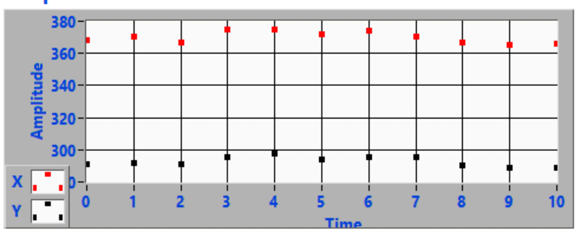
Temperature influence

Temperature of Gas Cylinder = 19 ℃, temperature in GEM test room = 24 ℃

Flow = 3 l/h

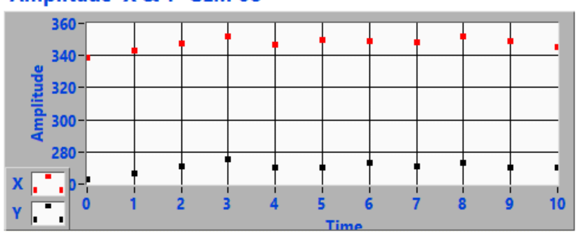
Mean X = 369
Mean Y = 292

Amplitude X & Y GEM 09



Mean X = 347
Mean Y = 270

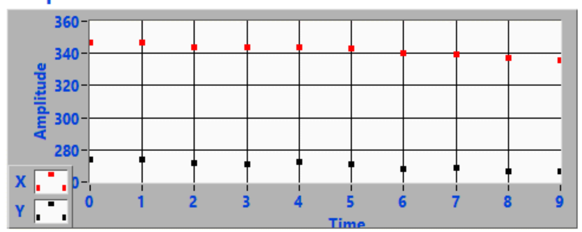
Amplitude X & Y GEM 08



Flow = 4,5 l/h

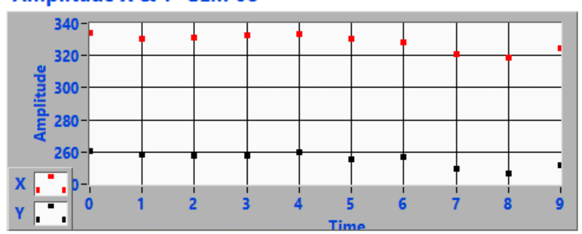
Mean X = 342
Mean Y = 270

Amplitude X & Y GEM 09



Mean X = 328
Mean Y = 255

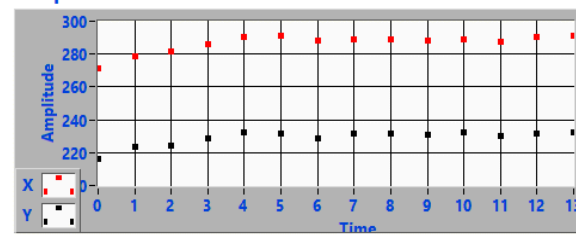
Amplitude X & Y GEM 08



Flow = 6 l/h

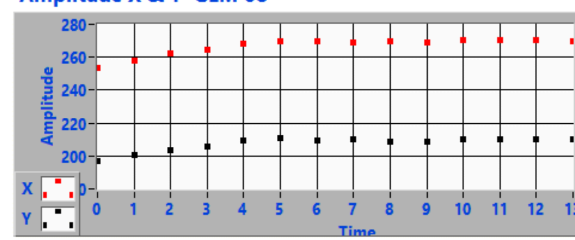
Mean X = 286
Mean Y = 228

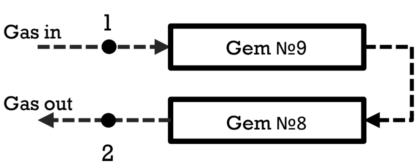
Amplitude X & Y GEM 09



Mean X = 266
Mean Y = 207

Amplitude X & Y GEM 08



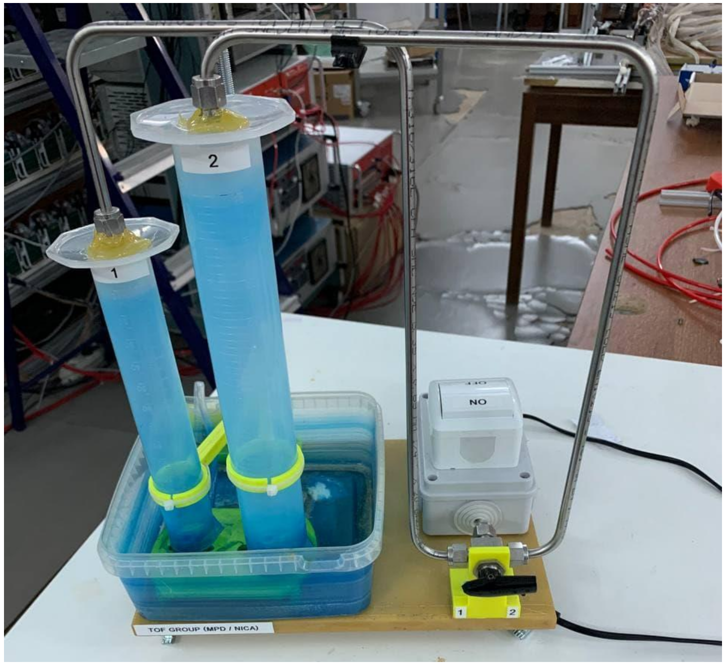


Analyzer	O_2 ppm (3 l/h)	O_2 ppm (4,5 l/h)	O_2 ppm (6 l/h)
1	245	151	105
2	670	429	308

Amplitude is decrease when we increase the flow

Gas system. Gas mixer check

Choose the value of flow → connect the gas pipe with cylinder → fill the cylinder by water → measure the time it takes to displace the certain volume of water by gas mixture.



Argon

Mixer, cc/min	20	30	40	60	80
Measure, cc/min	23,6	34,4	45,3	66,8	90,5
% difference	18	14	13	11	13

Isobutane

Mixer, cc/min	5	10	15	20	30	40
Measure, cc/min	5,5	10,8	16,1	21,1	30,6	41,4
% difference	10	8	7	6	2	4

Mixture

Mixer, cc/min	40/10	60/15	80/20
Measure, cc/min	55,9	77,9	114,1
% difference	12	4	14

The gas mixer produce the gas mixture in slightly larger values, but the composition of gas mixture is about the same – Argon 80% + Isobutane 20%