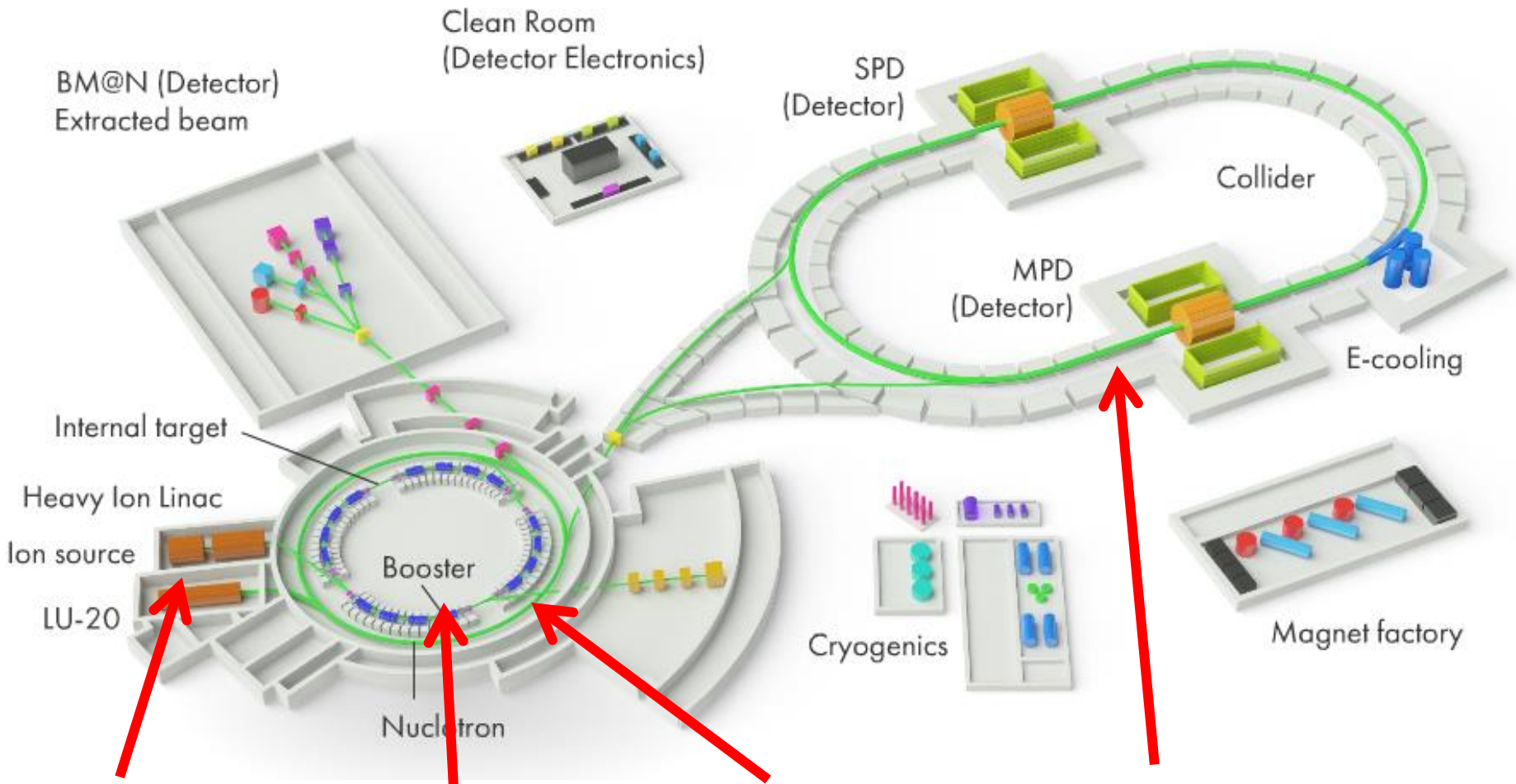
The Central Tracking System of the BM@N Experiment Based on GEM Detectors

Andrei Galavanov on behalf of the BM@N Collaboration

The XXVI International Scientific Conference of Young Scientists and Specialists (AYSS-2022)

NICA complex



Linear accelerators, 3 MeV/u

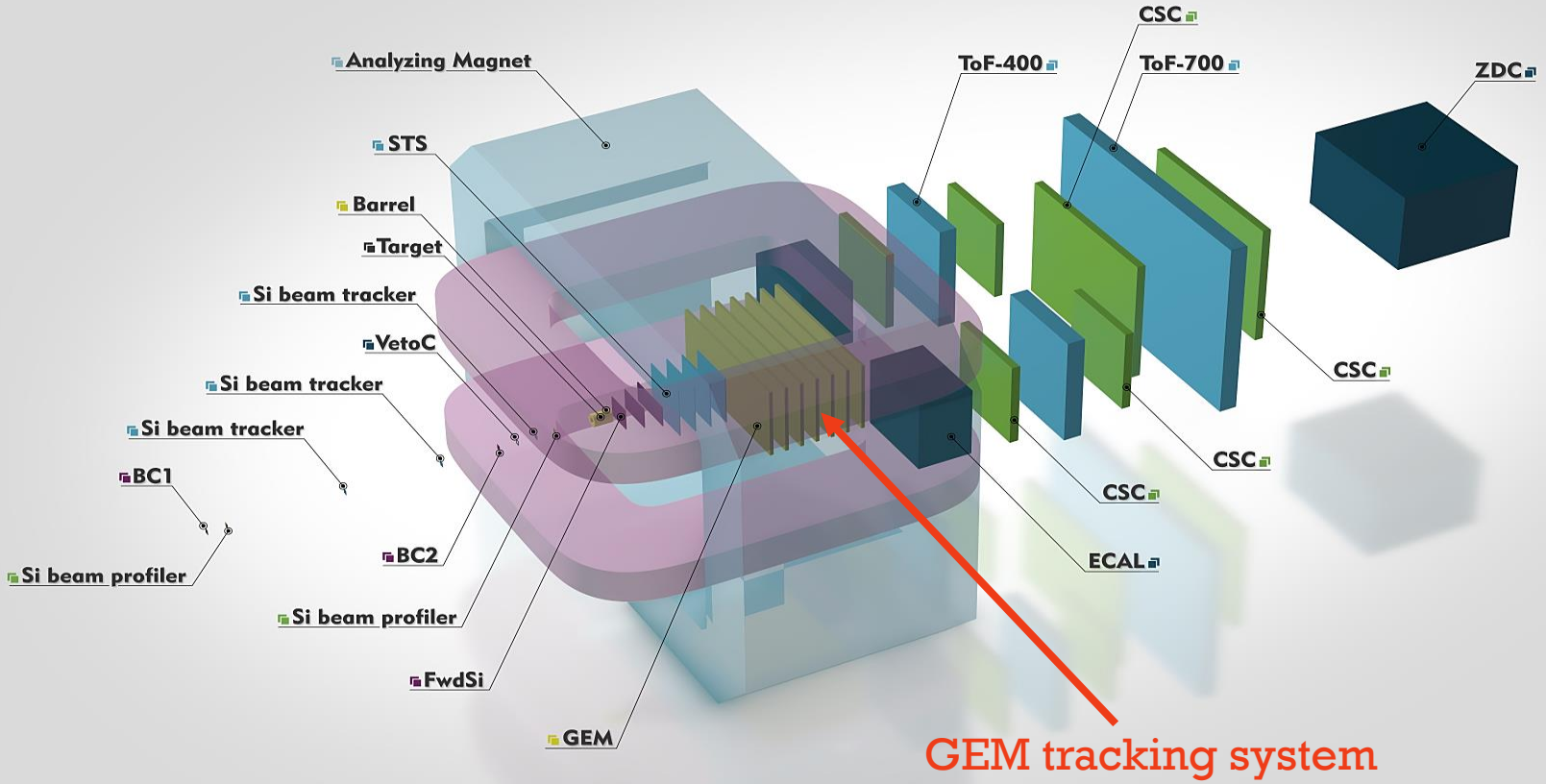
Booster, 3 – 660 MeV/u

Nuclotron, 0.6 – 4.5 GeV/u

Collider, $\sqrt{S}$ = 4 – 11 GeV/u

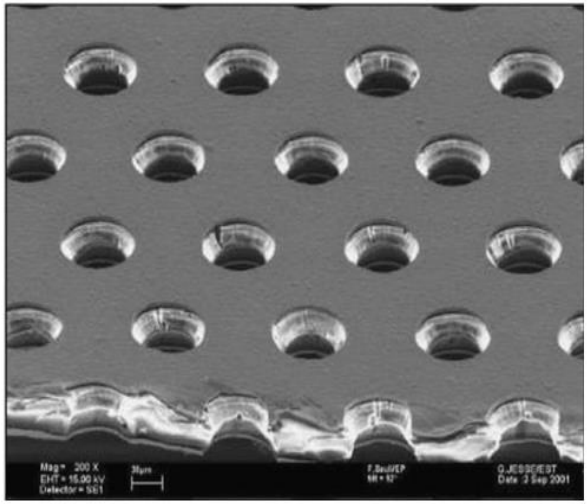
BM@N experiment

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.

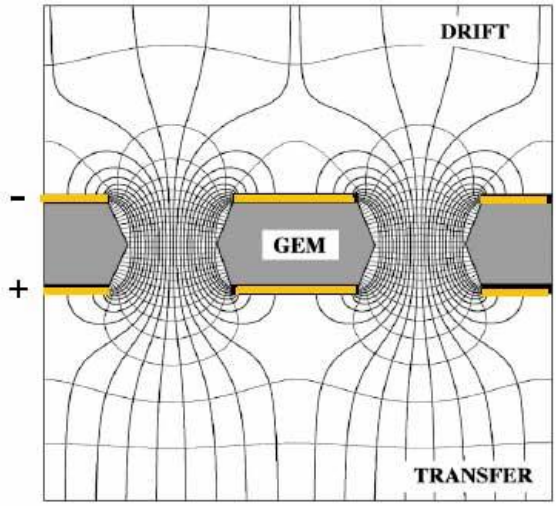


Experimental setup for high intensity heavy ion beams

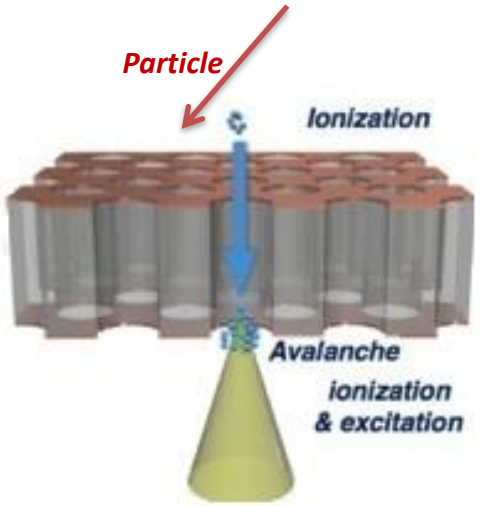
The gas electron multiplier (GEM)



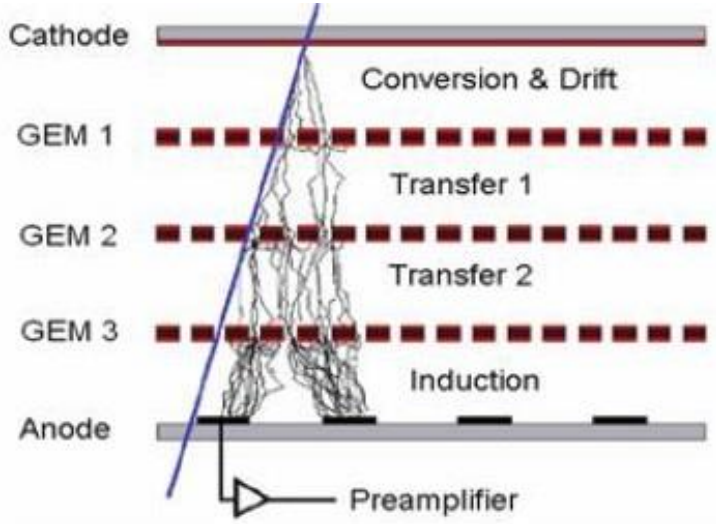
Electron microscope picture of a section of typical GEM foil: 50 μm thick capton foil, metalized on each side by 5 μm thick copper electrodes. Holes pitch and diameter are 140 and 70 μm, respectively.



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

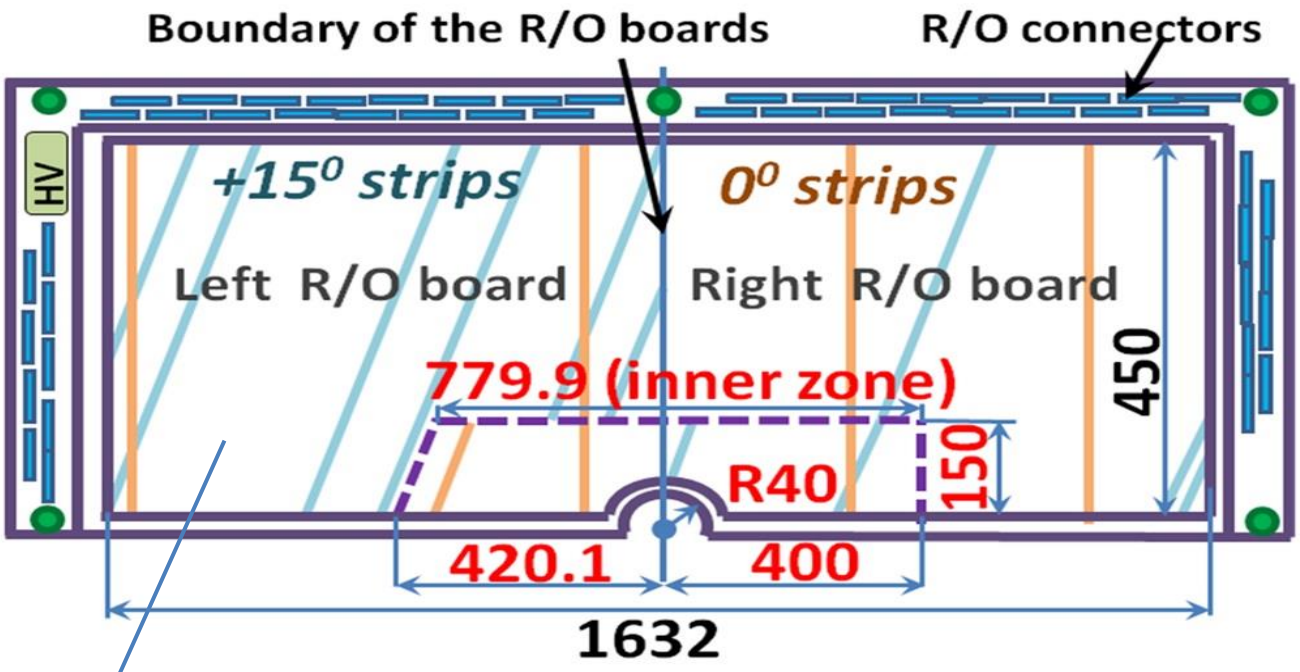


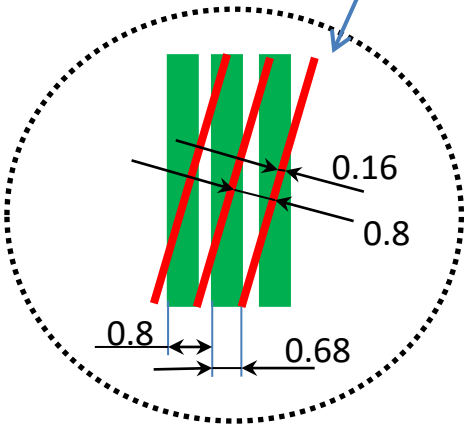
Electron avalanche in GEM holes.

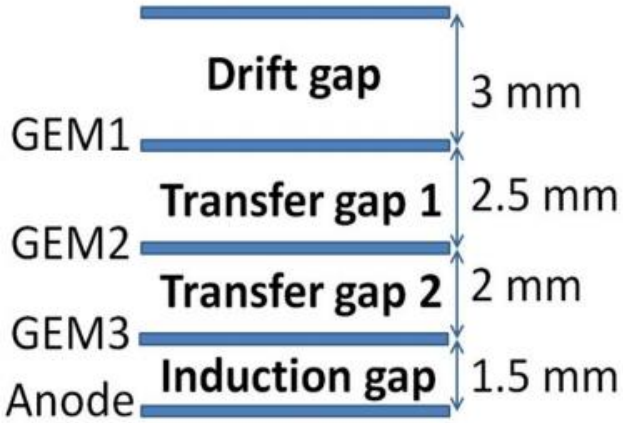


Typical scheme of a triple GEM detector.

BM@N GEM detectors







Central tracking system:
7 detectors 1632 × 450 mm^2
7 detectors 1632 × 390 mm^2

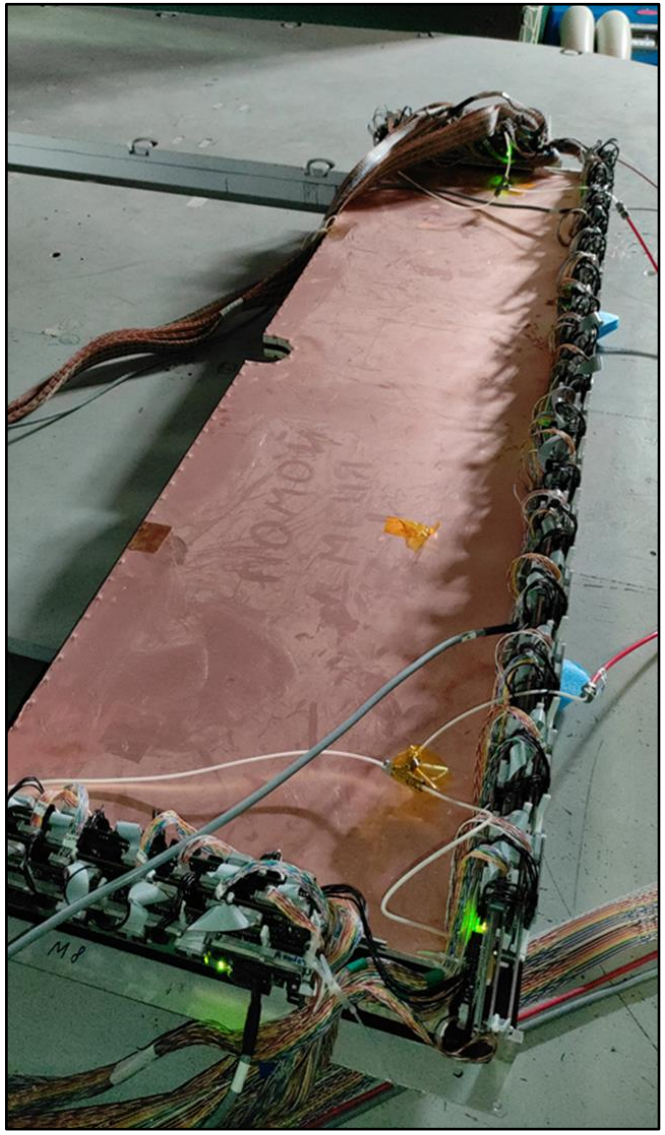
1 detector: 50 FEE cards with 128 channels = 6400 channels
All system = 89600 channels

Schematic cross section of the BM@N triple GEM detector

BM@N GEM detectors

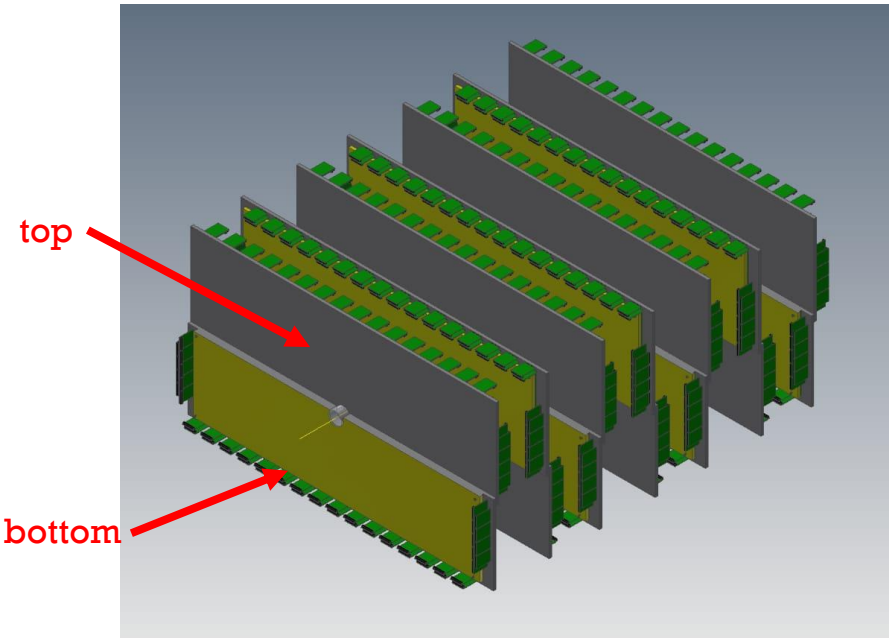
Readout board

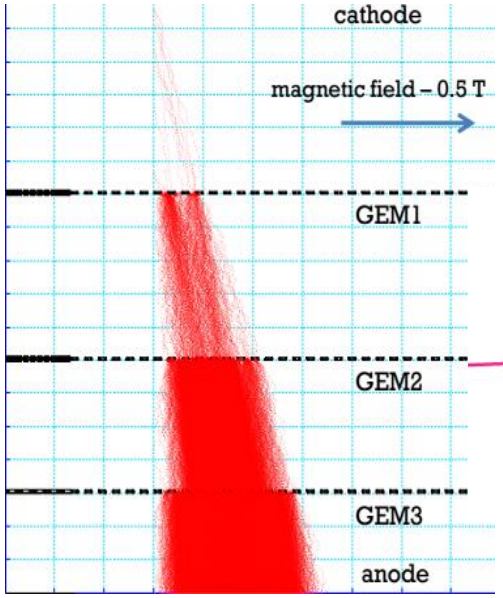
Cathode plane

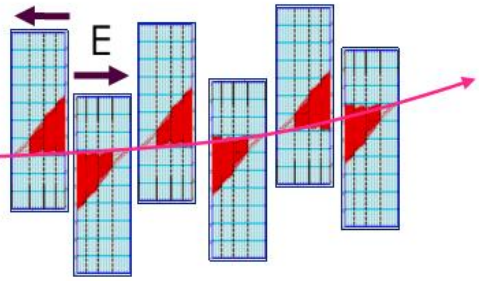


Full equipped detector

Scheme of the GEM full planes configuration

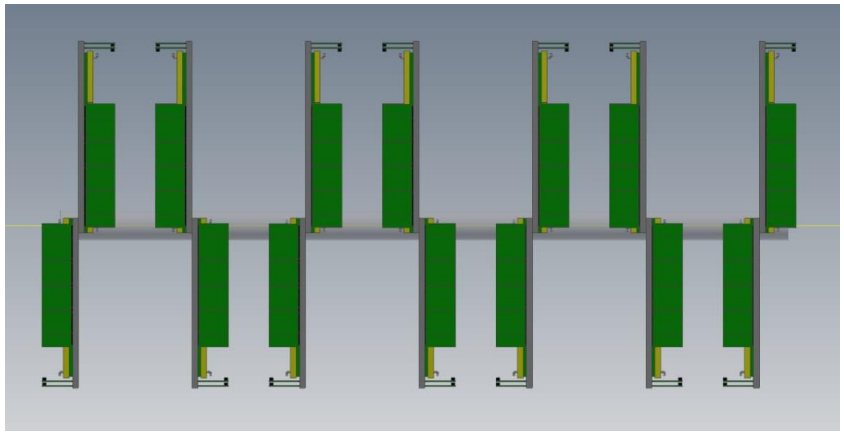


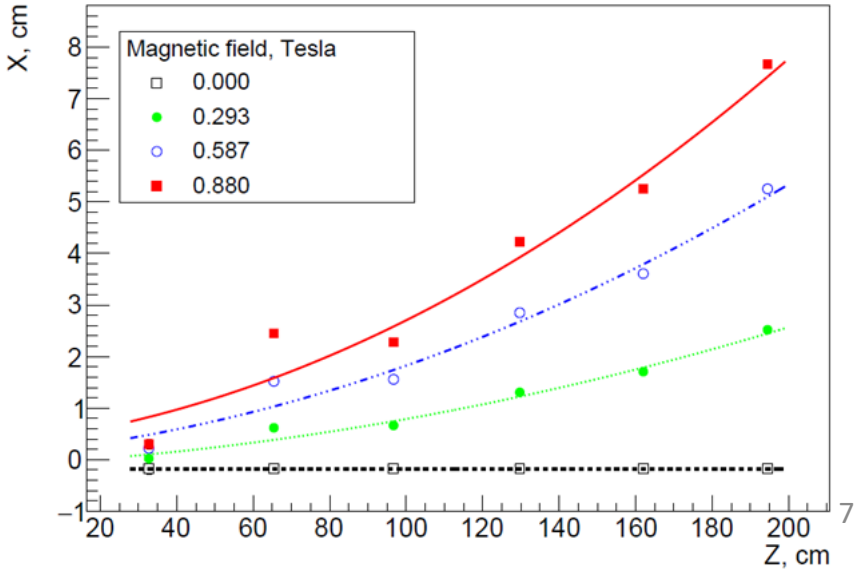




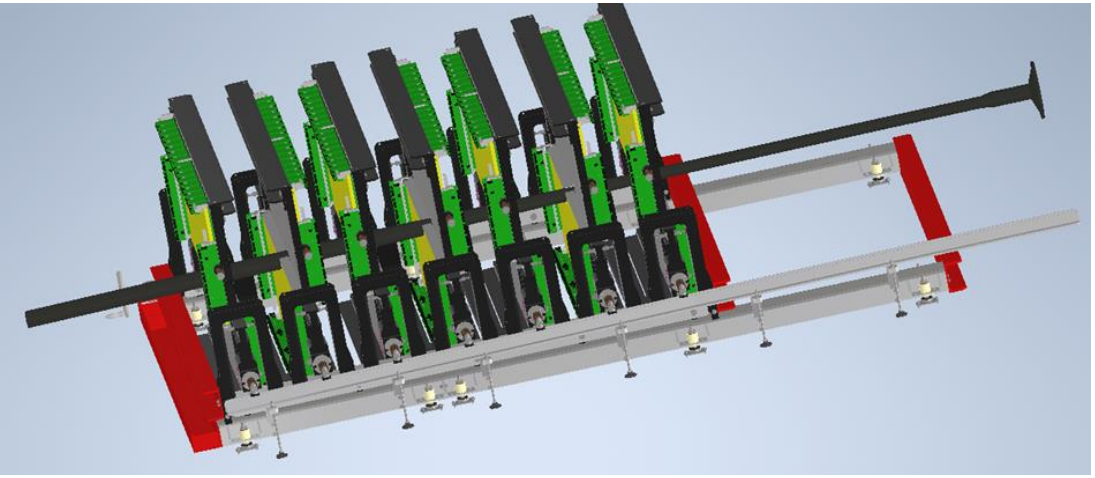
Lorentz shifts of an electron avalanche in GEM planes

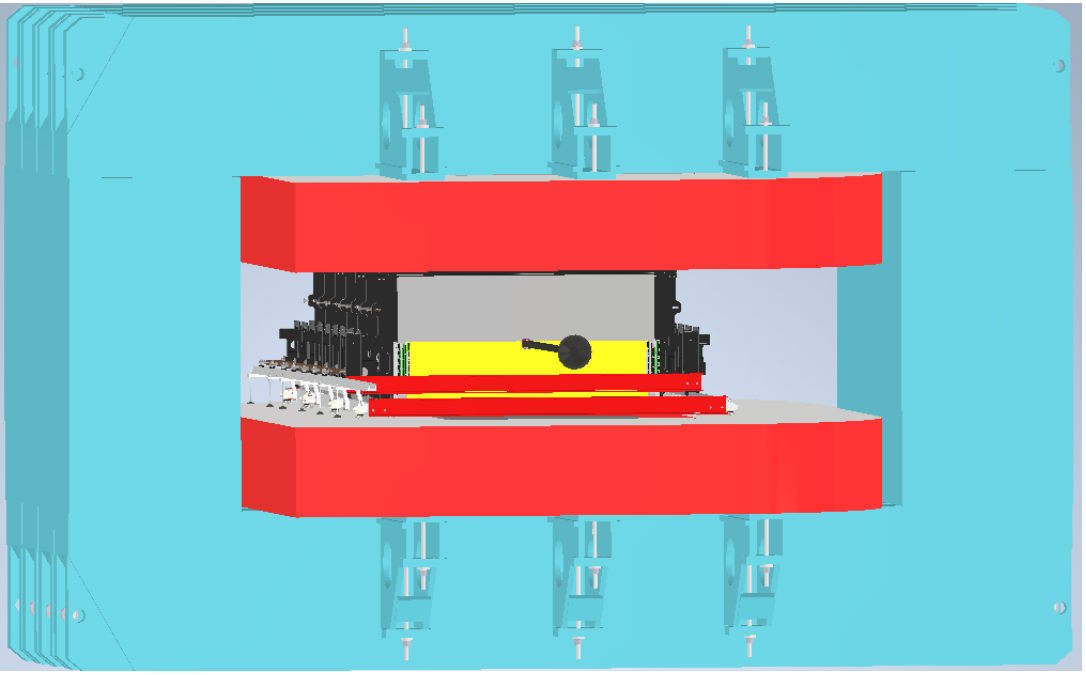
On the top - 7 detectors with active area of 1632×450 mm^2
At the bottom - 7 detectors with active area of 1632×390 mm^2

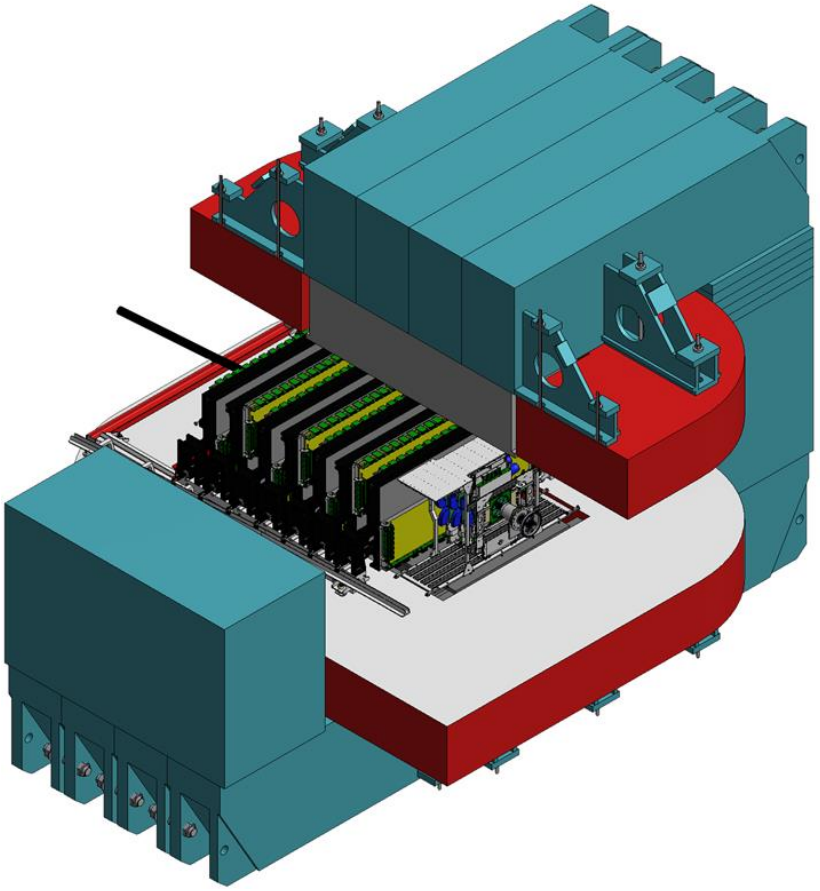




Full planes configuration inside the SP-41 magnet



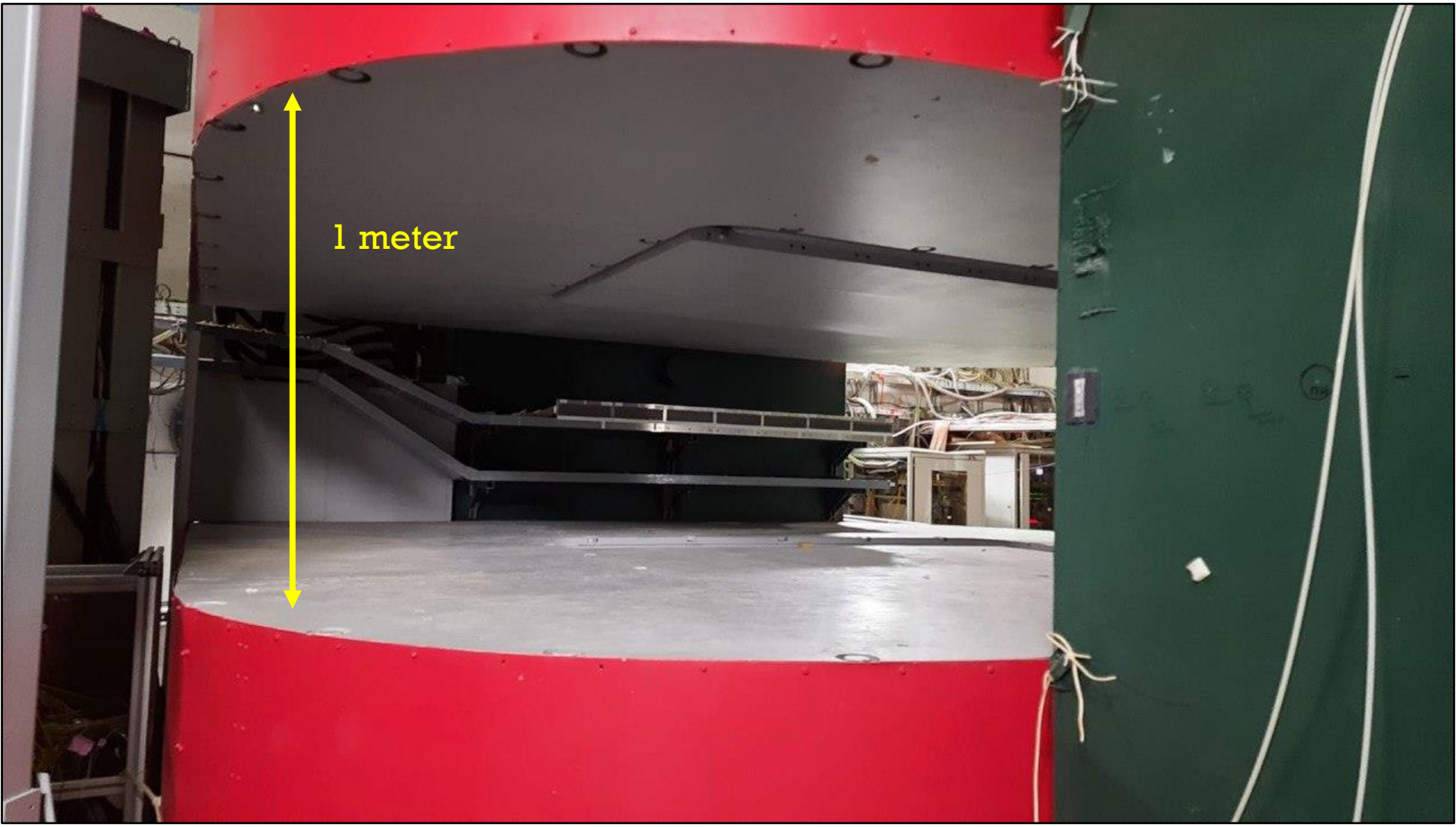




Active area of the GEM tracking system is around 9.5 m^2

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

SP-41 magnet

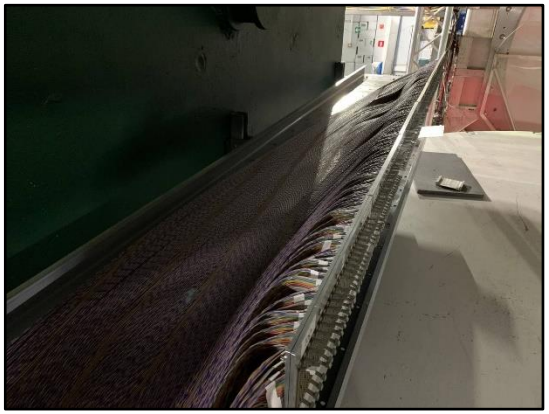


Our comfortable workspace

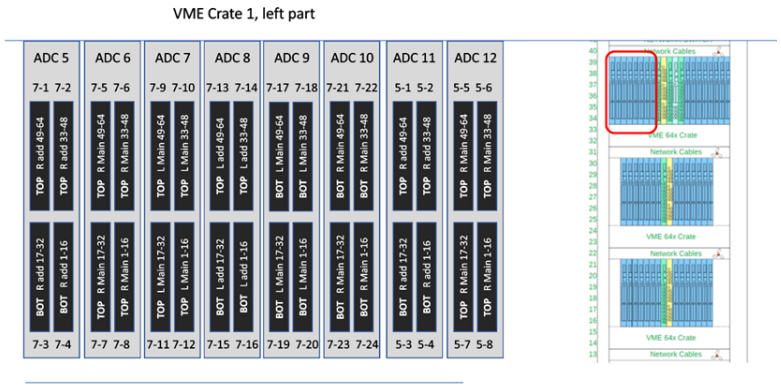
Preliminary works

Before the central tracking system assembly was done:

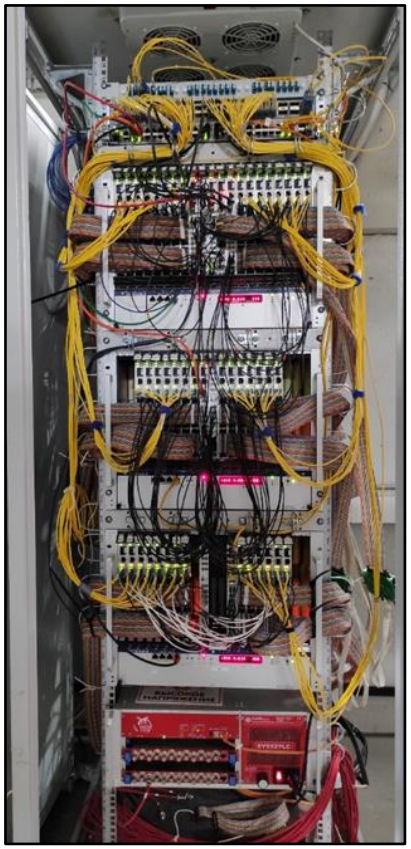
- ADC cables management (175 cables 15m long);
- Patch panels installation;
- Scheme of ADC and patch panels connection;
- Daily plan of detectors installation;

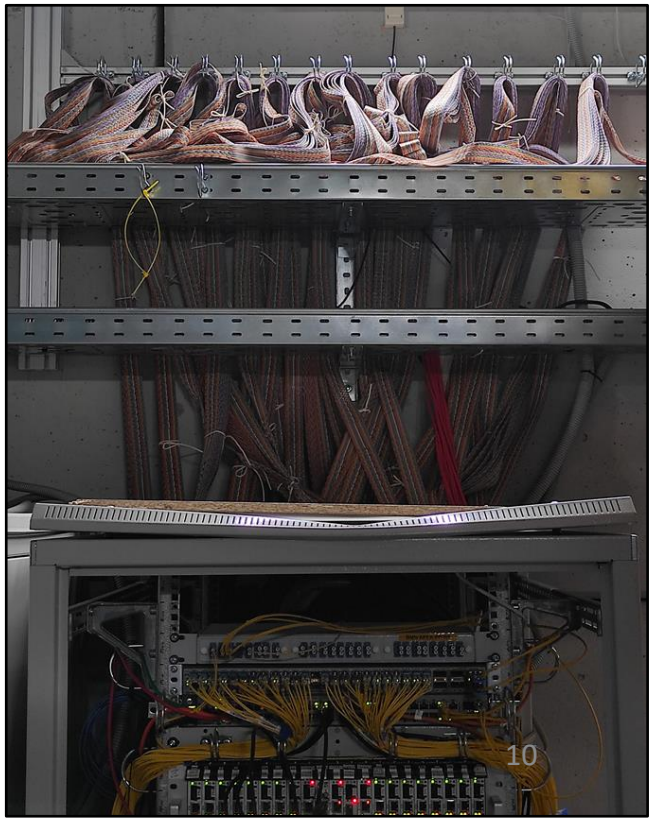


ADC cables: to patch panels↑; to DAQ rack↓



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:

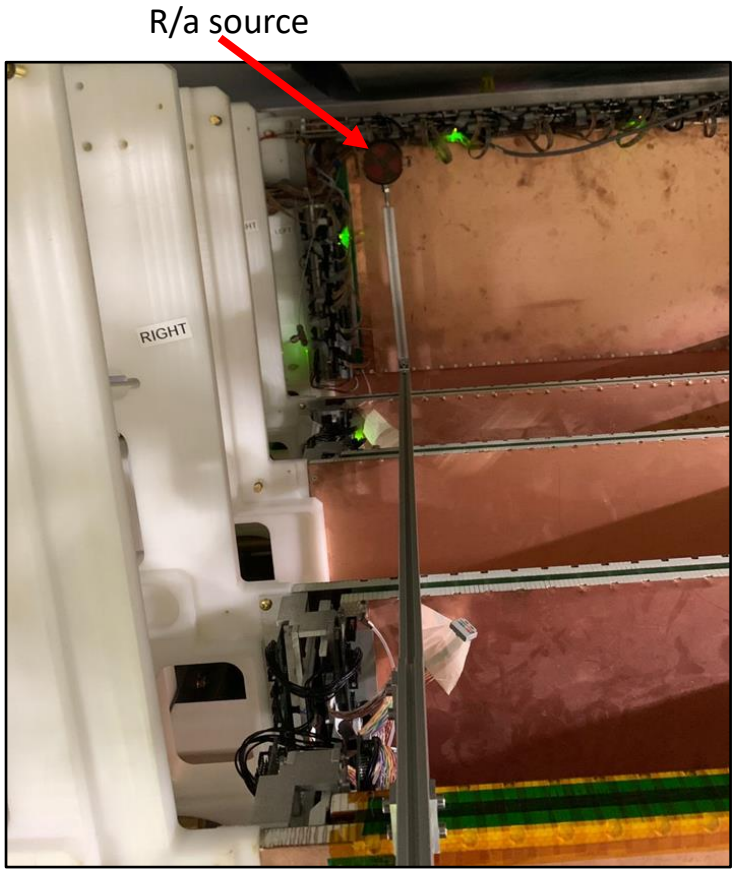
- Disconnect the GEM from gas line and HV;
- Move it at the experimental zone and install to mechanical support inside the magnet;
- Connect the detector to gas line, and connect all cables (ADC, LV, HV) to patch panels/supply blocks;
- Test all FEE cards for stable work;
- At the end of the day rise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

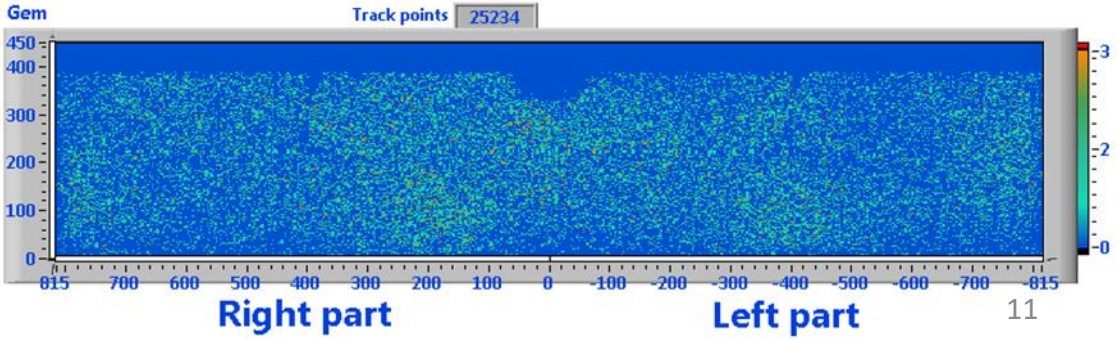
Day 2:

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

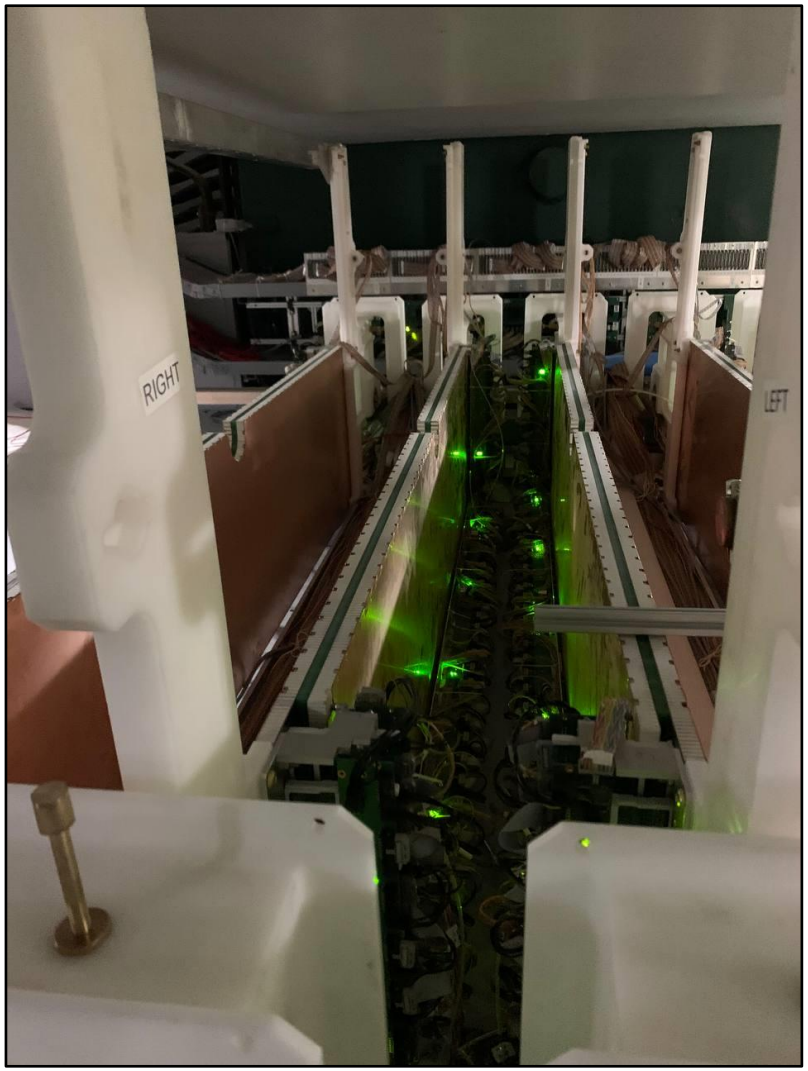
Repeat it 13 times

In theory: 14 days for bottom GEMs installation; 5 days for vacuum beampipe; 14 days for top GEMs.
In real life: 49 days from start to finish.

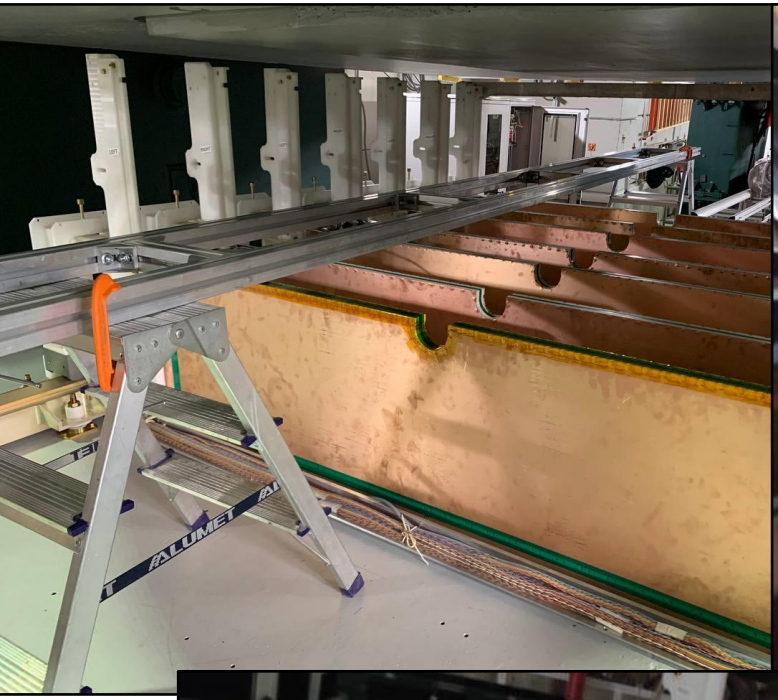


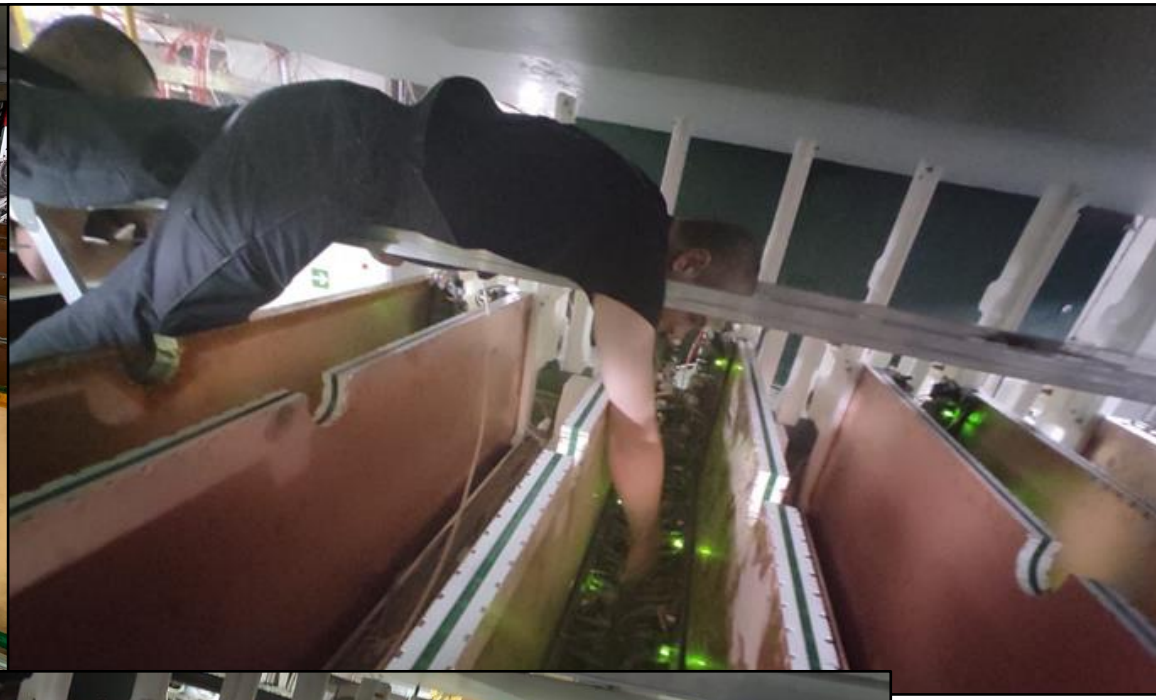


Installation of detectors

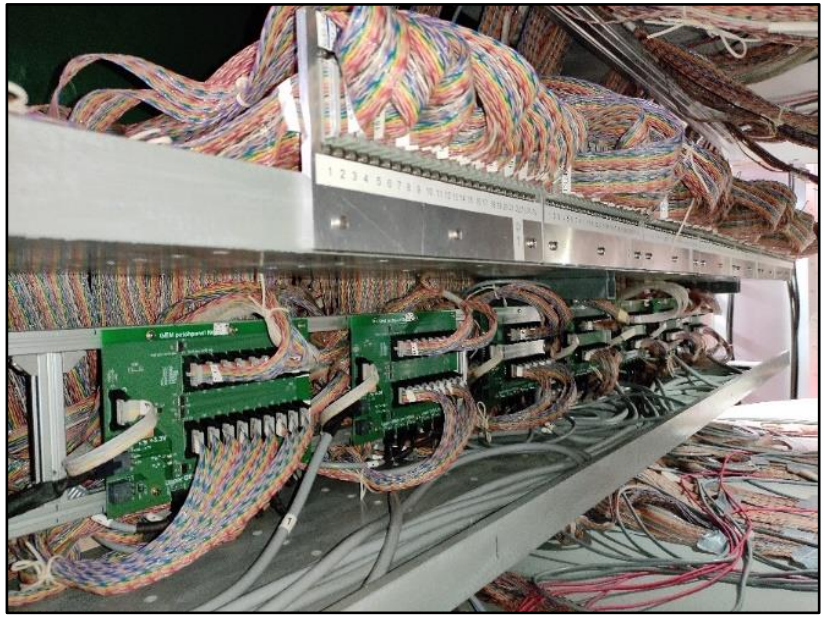


Installation of detectors

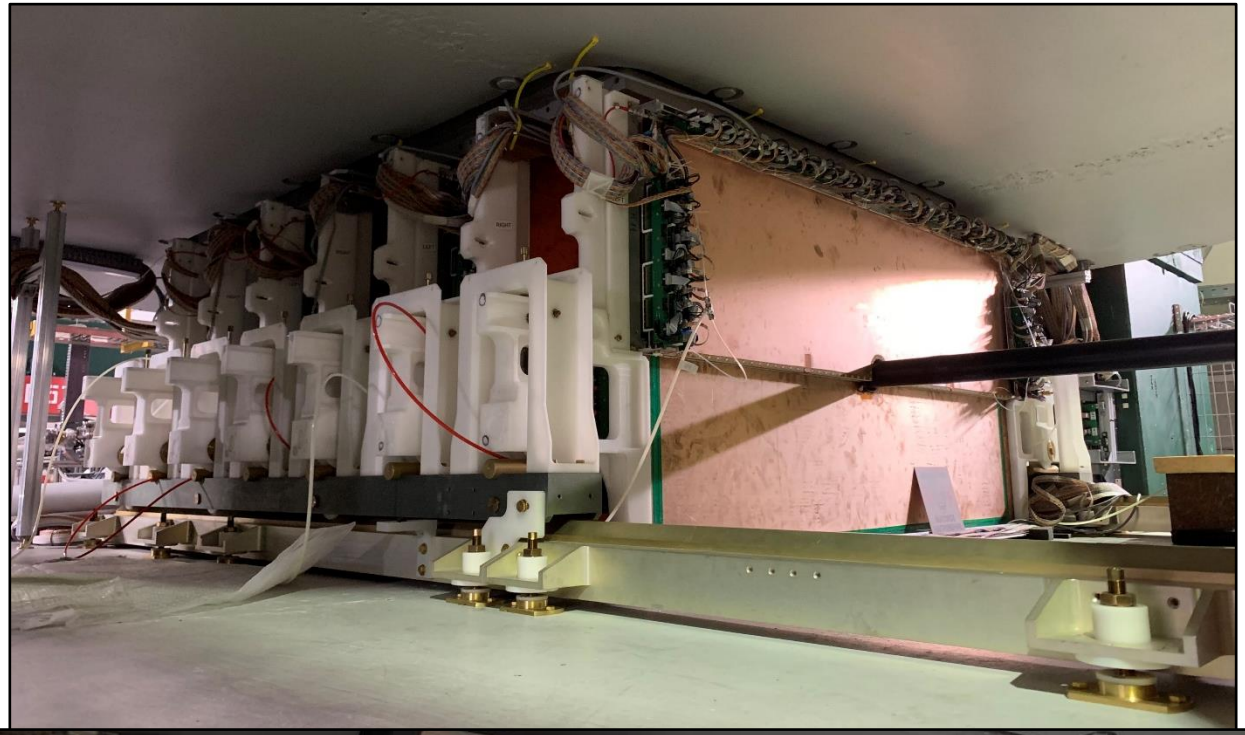


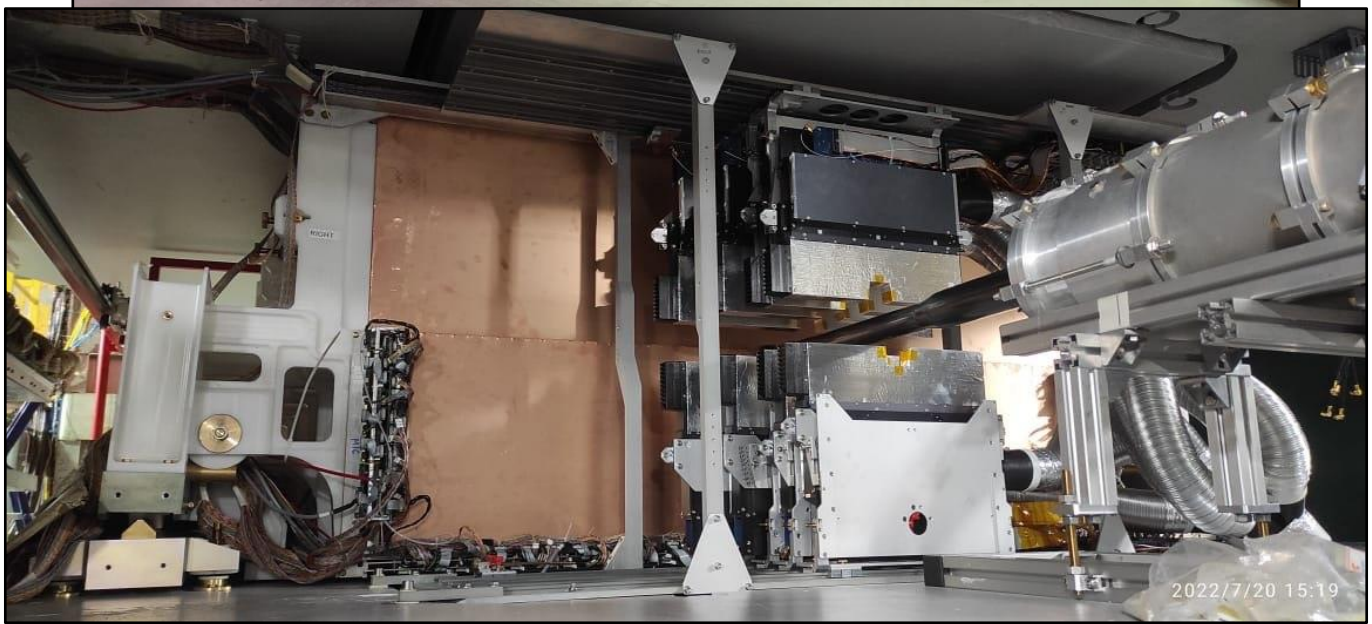


Installation of detectors



Installation of detectors





Physics run

BM@N Experimental physics run in October-December 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

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. These are still the biggest GEM detectors in the world.

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.

In total, the assembly of central tracking system took 49 days.

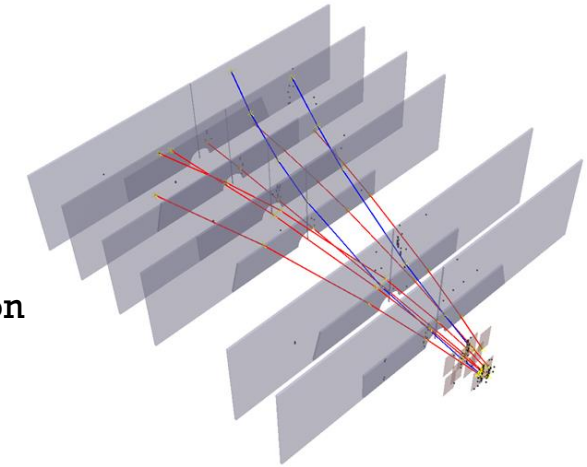
Now we are waiting for the start of the accelerator run.

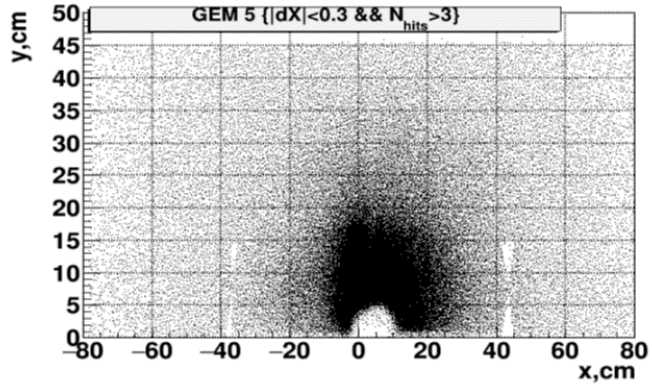
Thank you for your attention!

Back up slides

GEM tests on Nuclotron beams

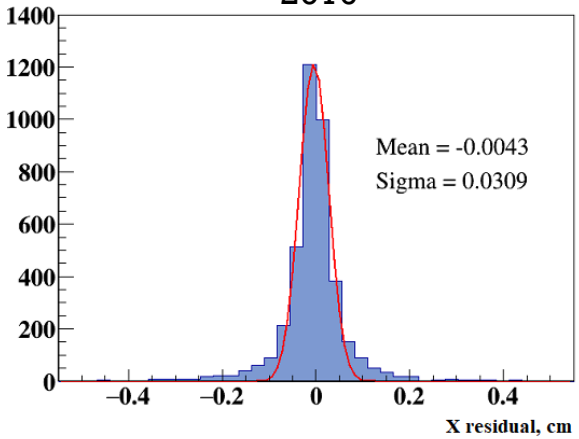
Example of the event reconstruction





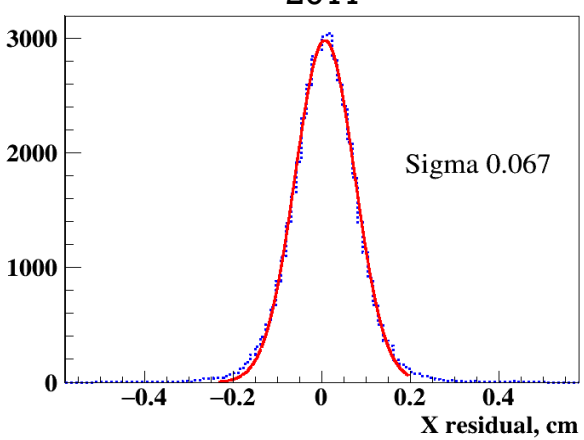
Fragments of Ar beam in detector

2016



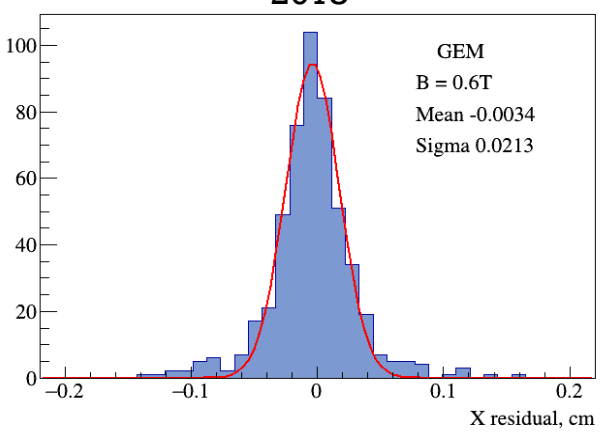
Magnetic field 0.6 T,
Ar(70)/CO2(30),
C beam, E_{drift} = 1.2 kV/cm
σ = 309 μm

2017



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

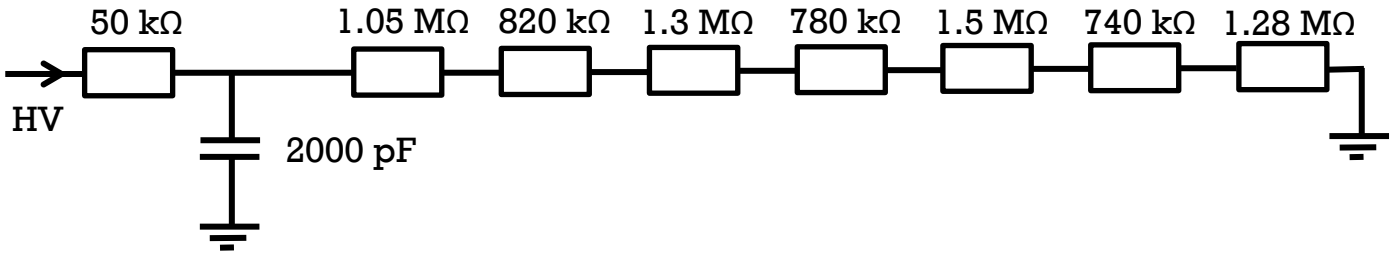
2018



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

Material budget for 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