Development of detailed ROOT geometry for the inner tracker detectors in the BM@N experiment

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BM@N experiment

BM@N (**B**aryonic **M**atter at **N**uclotron) is the first stage experiment at the accelerator complex of NICA.

It is a fixed target experiment aimed to study nuclear matter in the relativistic heavy ion collisions.

Since 2015 **seven BM@N RUNs** have been carried out:

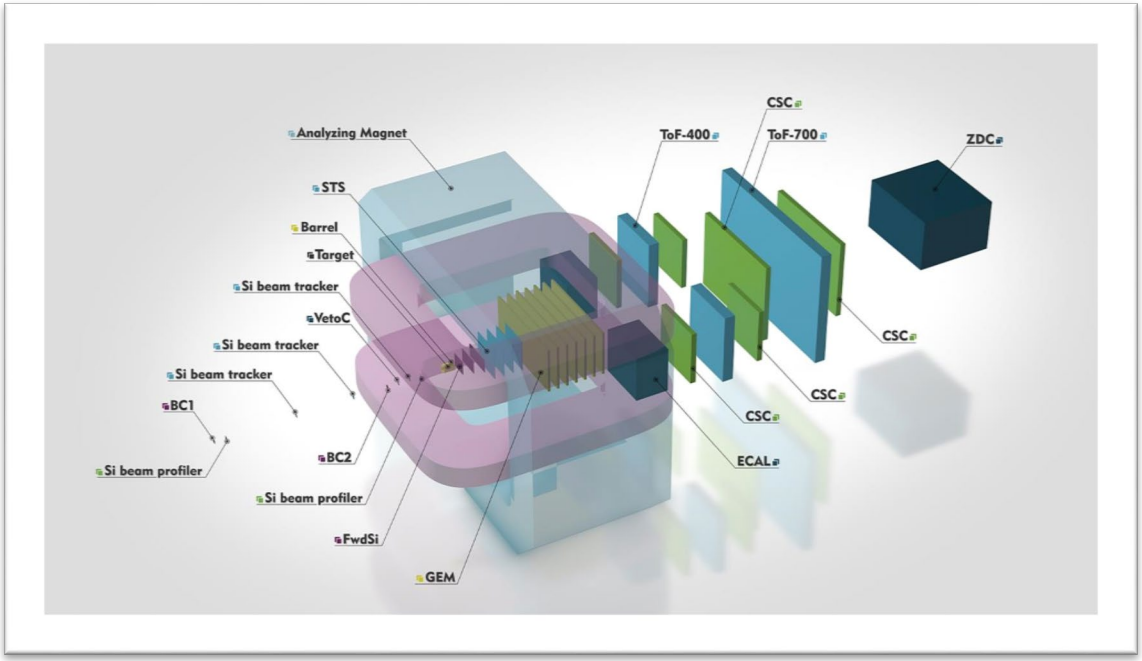
RUN 1-2-3-4 (2015)
beam: deuteron; target: C, Cu

RUN 5
beam: deuteron; target: CH2, C, Cu, Pb

RUN 6 (2017)
beam: deuteron, C; target: CH2, C, Al, Cu, Pb

RUN 7 (2018)
beam: Ar, Kr; target: C, Al, Cu, Pb

future RUNs (2021-2022)
beam: Ar, Xe

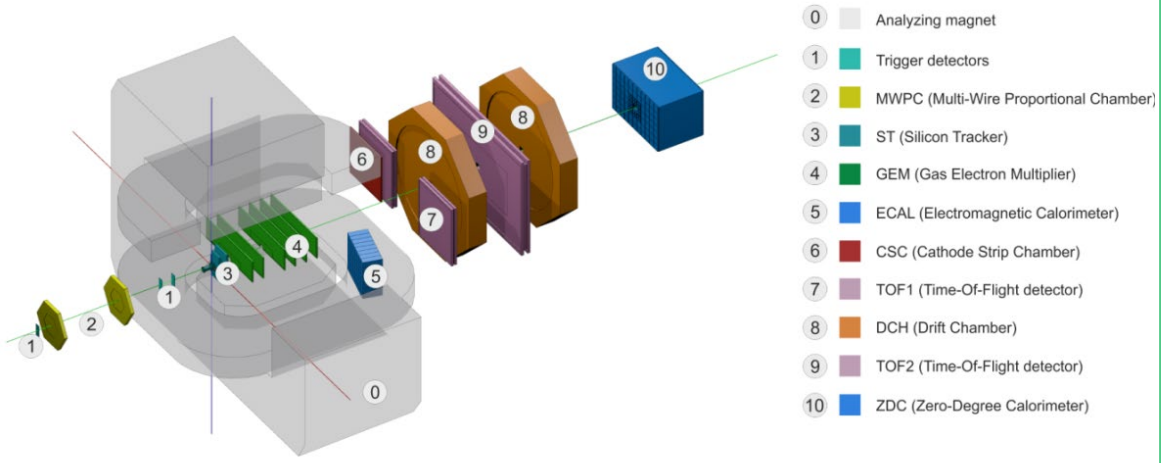


The full configuration of the BM@N setup for the next RUNs

The latest RUN was divided into two parts:

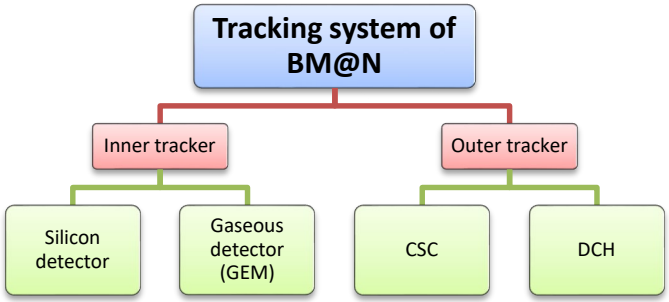
- Basic program of BM@N
- Additional program - SRC (Short Range Correlations)

Tracking system in BM@N



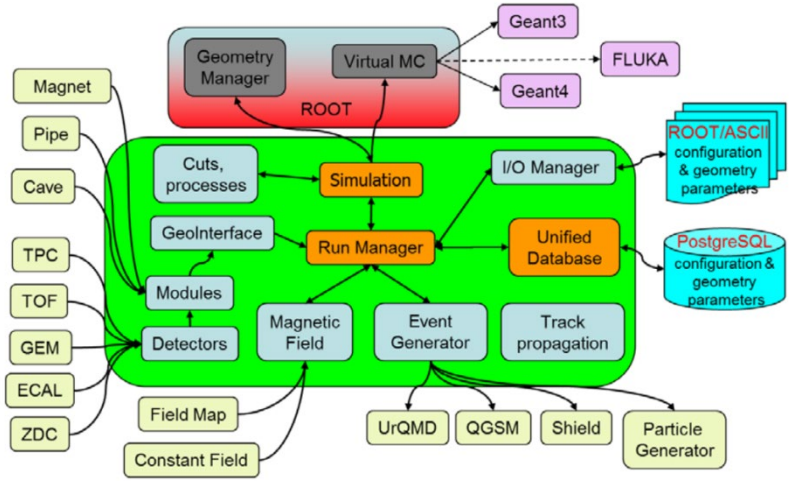
BM@N setup for the RUN-7 configuration

The complete **tracking system** of the BM@N setup is divided into the **inner** and **outer** trackers



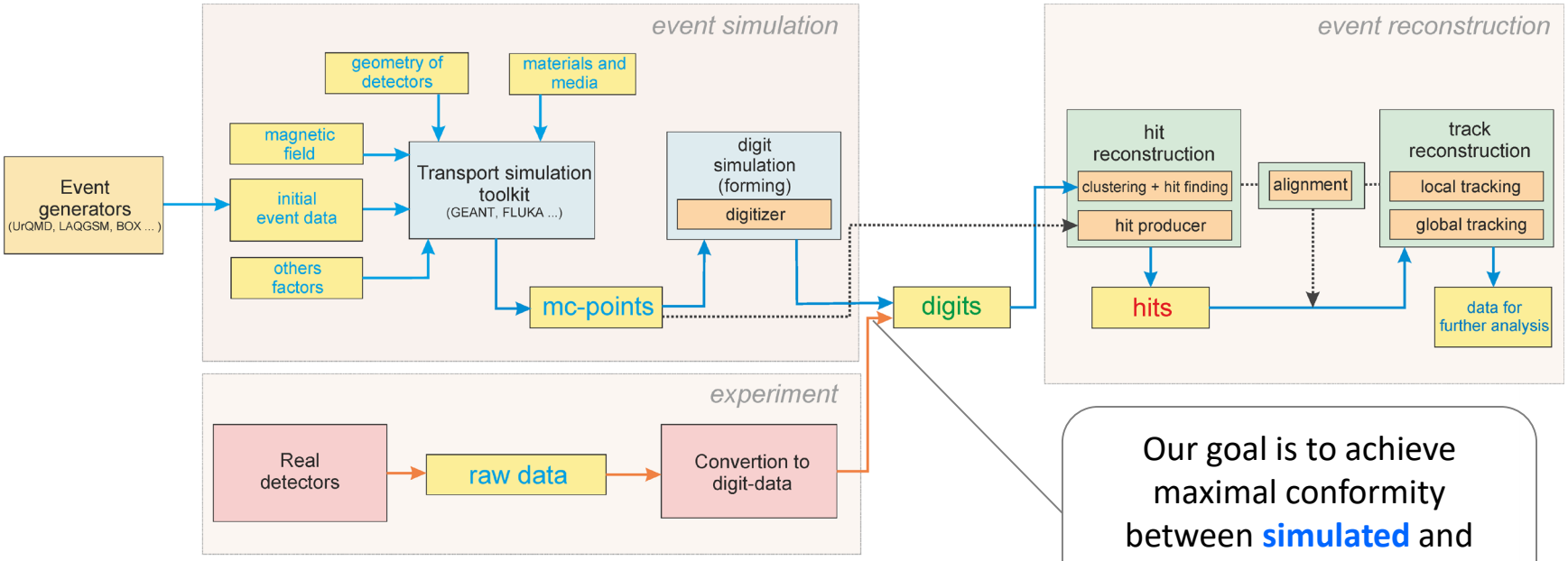
Framework **BMNROOT** was developed to support BM@N experiment.

It provides powerful tools for simulations, reconstruction and data analysis.

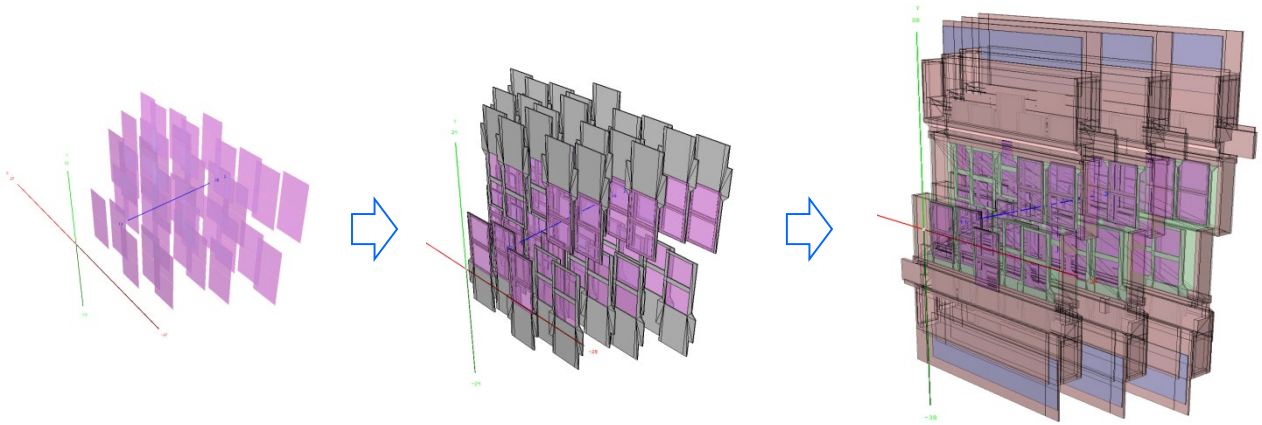


The scheme of the BMNROOT modules in the simulation

Why we need to use detailed ROOT geometry



The scheme of data processing in the BMNROOT framework



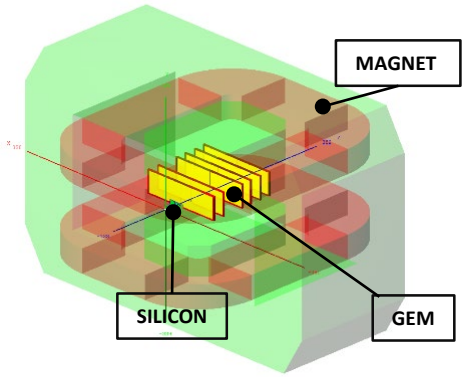
Refinement of the geometric model for the Forward Silicon detector

Detailed ROOT geometry: configurations

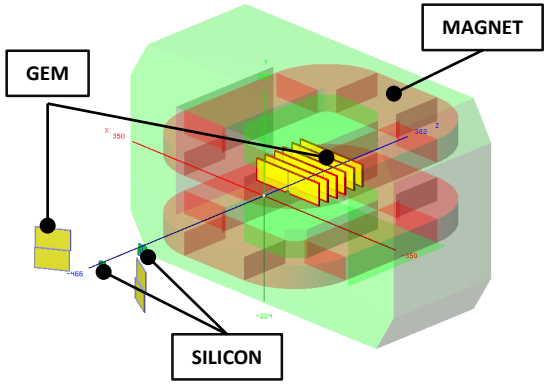
- The detailed ROOT geometry was created for the following configurations:
  - **GEM RUN-7** (spring, 2018)
  - **GEM RUN SRC** (spring, 2018)
  - **GEM Future Configuration** (2021-2022)
  - **Forward SILICON Future Configuration** (2021-2022)

- The design of these detector has a lot of supporting elements, such as frames, electronics and others. It influences the detector efficiency.

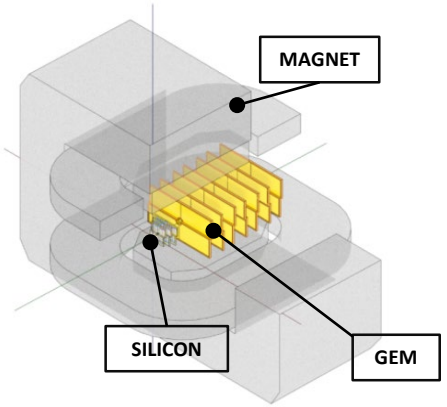
- There are two versions of the ROOT geometry (simplified and detailed) for each configuration.



SILICON and GEM detectors (RUN-7)



SILICON and GEM detectors (SRC)

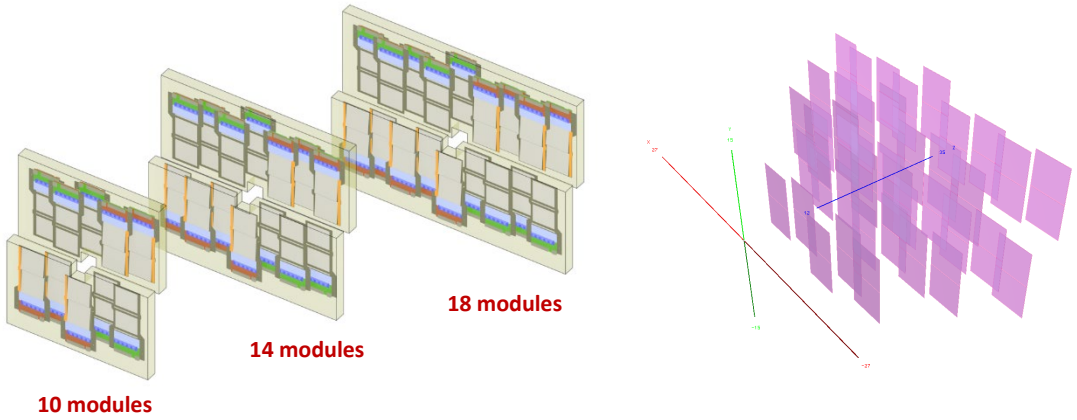


SILICON and GEM detectors (Future RUN)

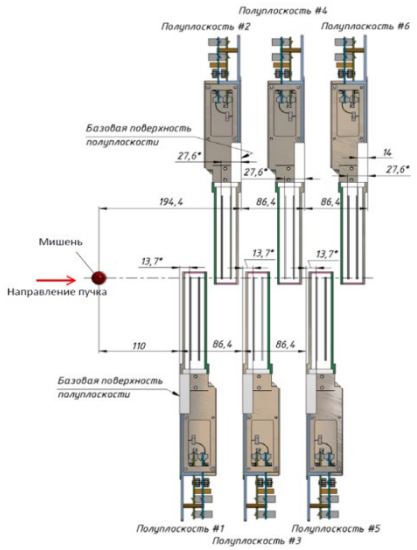
Forward Silicon detector

Forward Si in our BM@N configuration is a silicon based semi-conductor detector consisting of separate si-modules which are combined into stations of 10, 14 and 18 modules (42 modules in total).

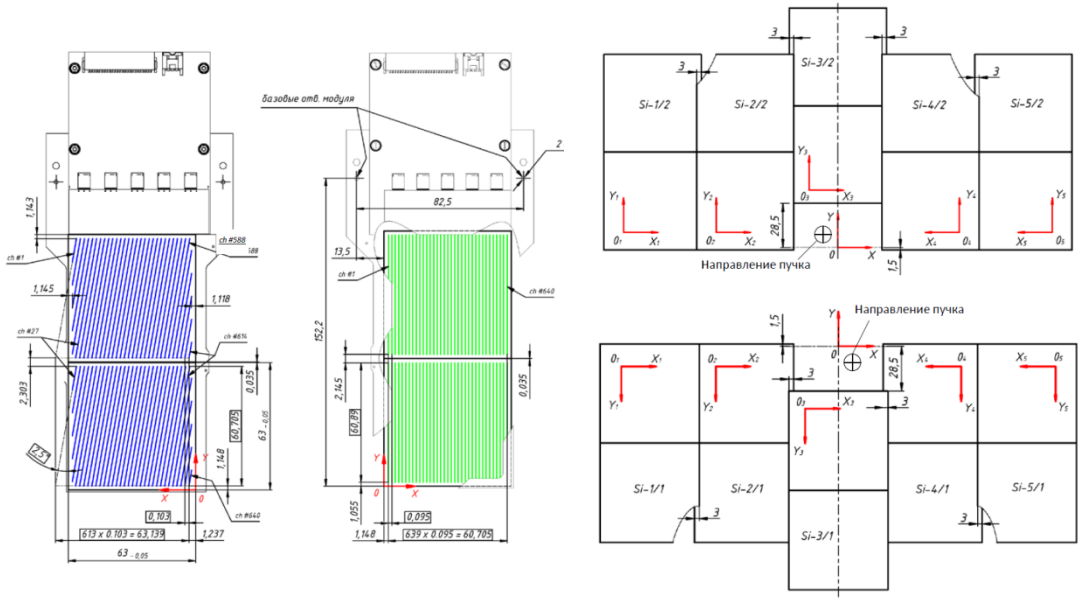
At the moment we have complete ROOT geometry for this detector in the BMNROOT repository for using it in simulation and reconstruction procedures.



Three stations of the Forward Si detector (left) and ROOT geometry of them for MC-simulation (right)

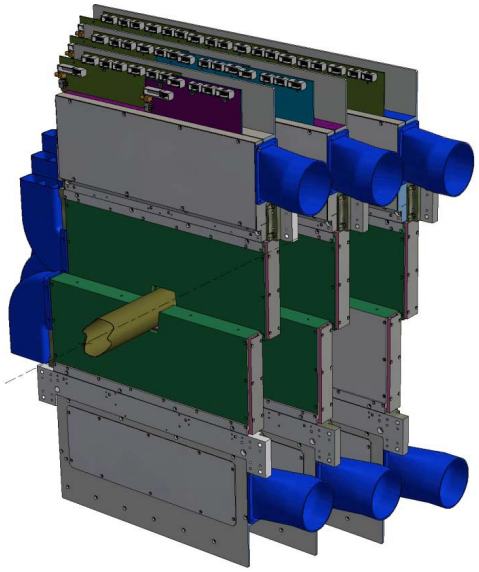


Scheme of the Forward Si detector

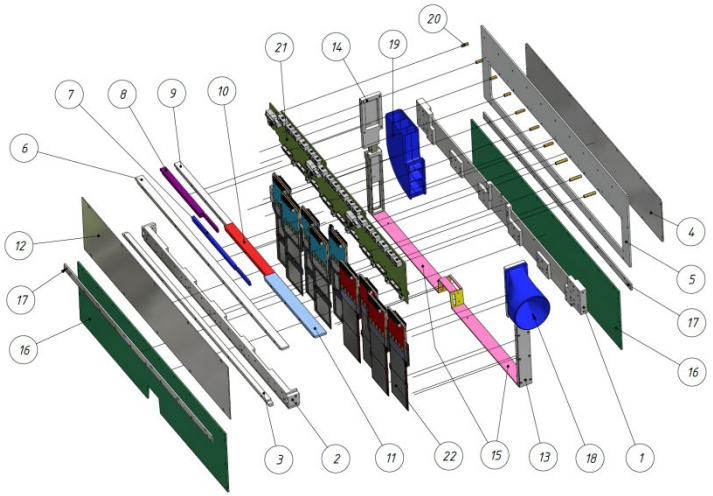


Schemes of a single Si-module (left) and their composition in the first station (right)

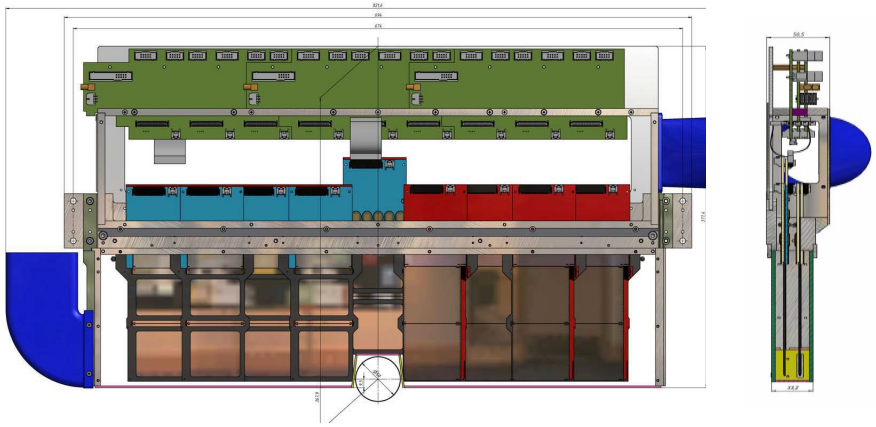
Forward Silicon detector



Full assembly of Forward Silicon detector



Parts of one half-plane of Forward Silicon Detector

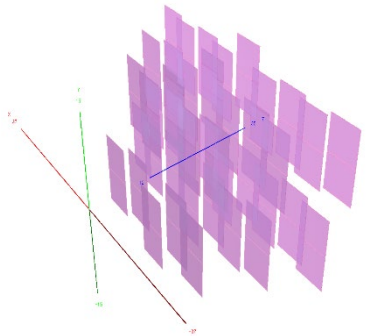


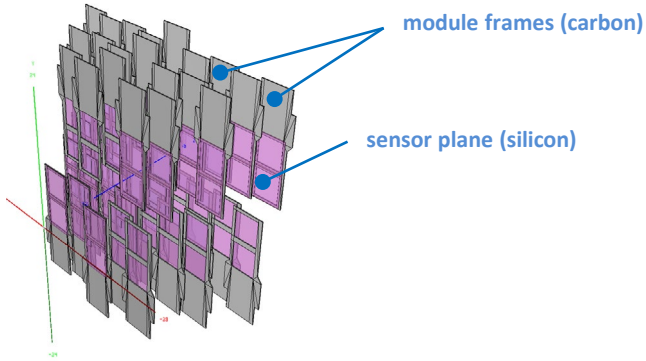
Scheme of one half-plane: front and side views

	Описание	Материал	Размер вдоль пучка	
1	Базовая планка	Алюминиевый сплав	8…14 мм	Вне чувствительной зоны Si-сенсоров
2	Планка	Алюминиевый сплав	6…12 мм	Вне чувствительной зоны Si-сенсоров
3	Планка	Алюминиевый сплав	10 мм	Вне чувствительной зоны Si-сенсоров
4	Пластина	Алюминиевый сплав	1.5 мм	Вне чувствительной зоны Si-сенсоров
5	Пластина	Алюминиевый сплав	3 мм	Вне чувствительной зоны Si-сенсоров
6…11	Рейки	Алюминиевый сплав	Суммарная толщина	Вне чувствительной зоны Si-сенсоров
12	Пластина	Алюминиевый сплав	1.5 мм	Вне чувствительной зоны Si-сенсоров
13	Боковая стенка экрана	Алюминиевый сплав	27 мм	Вне чувствительной зоны Si-сенсоров
14	Боковая стенка экрана	Алюминиевый сплав	27 мм	Вне чувствительной зоны Si-сенсоров
15	Горизонтальная стенка экрана	Пенопласт	27 мм	В чувствительной зоне Si-сенсоров
16	Лицевая стенка экрана	Пенопласт	3 мм	В чувствительной зоне Si-сенсоров
17	Планка экрана	Алюминиевый сплав	3 мм	Вне чувствительной зоны Si-сенсоров
18…19	Тонкостенный патрубок	Пластик АБС	Стенка - 2 мм	Вне чувствительной зоны Si-сенсоров
20	Втулки крепления плат электроники	Латунь	25 мм	Вне чувствительной зоны Si-сенсоров
21	Платы электроники	Стеклотекстолит	2 мм + компоненты	Вне чувствительной зоны Si-сенсоров
22	Модули Si-сенсоров и электроники			

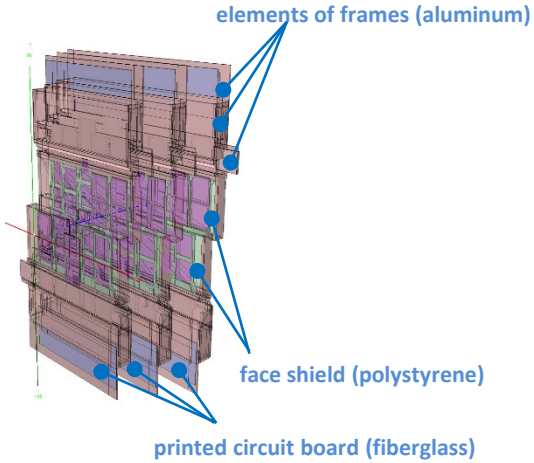
Description of the parts

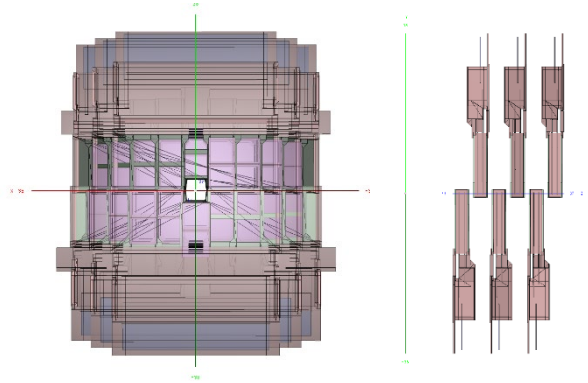
Forward Silicon detector: ROOT geometry





***Simplified ROOT geometry**: only sensitive planes (left) and sensitive planes with carbon frames (right)*

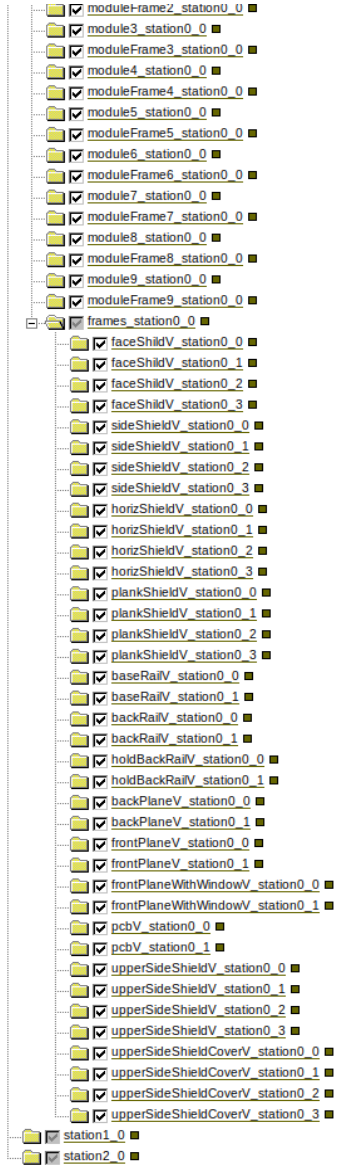




front view *side view*

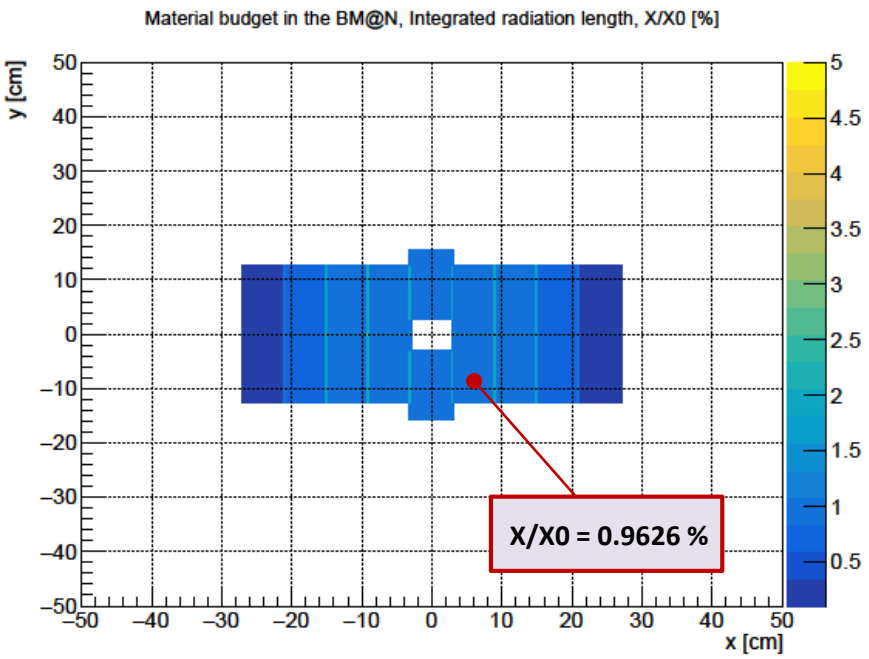
***Detailed ROOT geometry**: sensitive planes and supporting elements (passive volumes)*

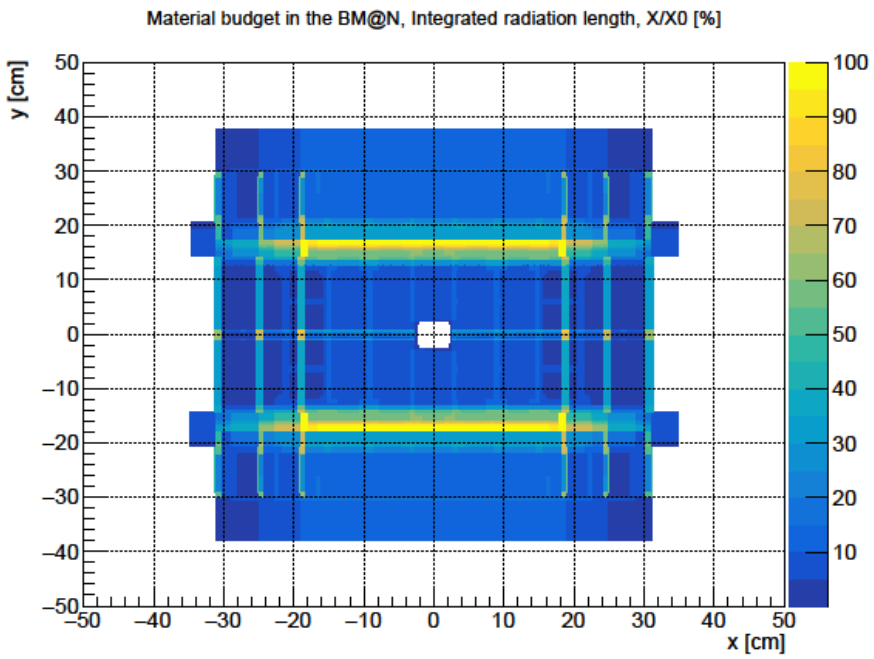
passive elements in each SI-station



Hierarchical structure of ROOT geometry

Forward Silicon detector: material budget





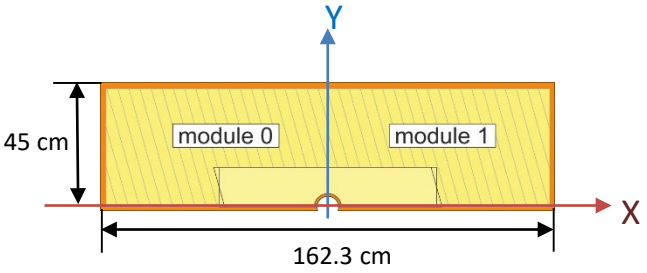
Material budget for the Forward Silicon Detector:
Left – simplified geometry (only sensitive planes), right – detailed geometry

GEM: configuration for RUN-7 (RunSpring2018)

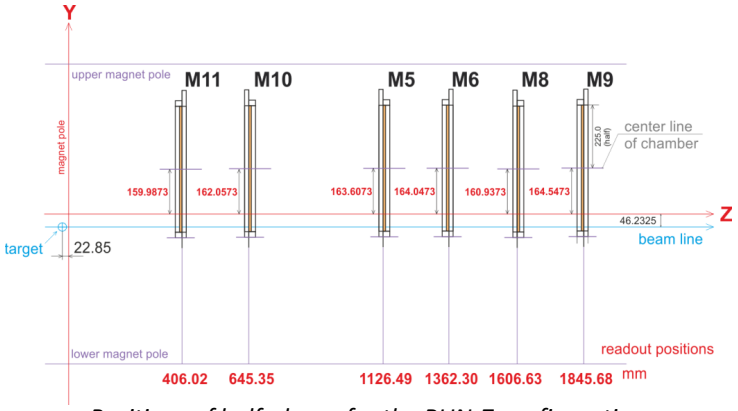
GEM (**G**as **E**lectron **M**ultiplier) is a gaseous detector with micro-strip readout.

The **configuration for RUN-7** consists of six GEM stations located inside the magnet along the beam axis (axis Z).

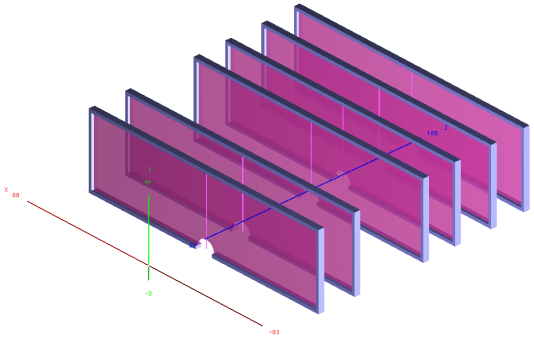
One station is represented by a GEM half-plane with the sizes of 163x45 cm



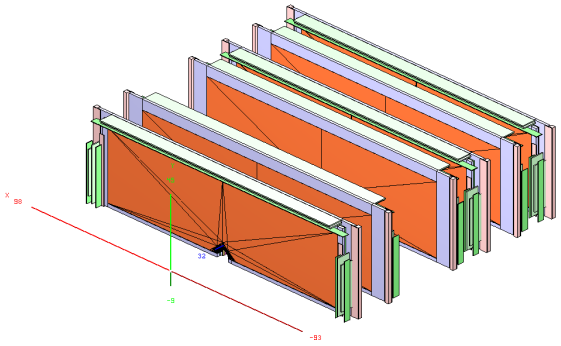
GEM half-plane with sizes of 163x45 cm



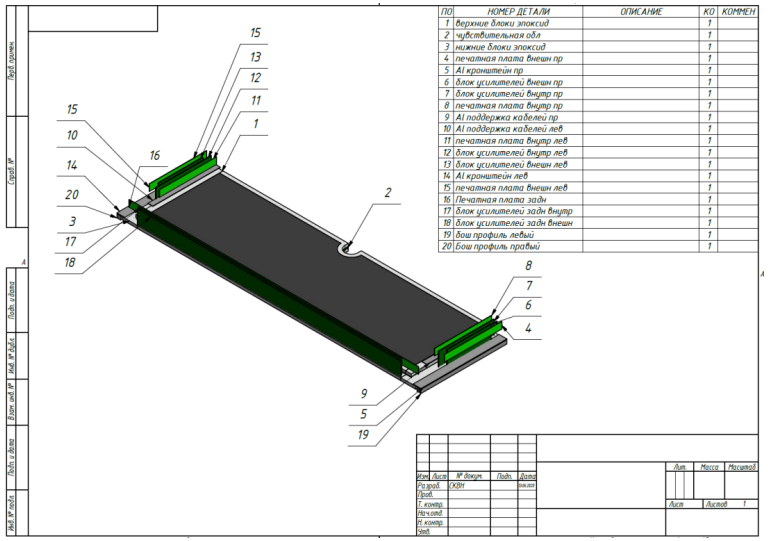
Positions of half-planes for the RUN-7 configuration



Simplified ROOT geometry of GEMs for RUN-7: only sensitive planes (as volumes filled with a gas mixture) and ordinary frames.



Detailed ROOT geometry of GEMs for RUN-7: passive elements (such as frames, electronics and material layers in sensitive areas) were added .

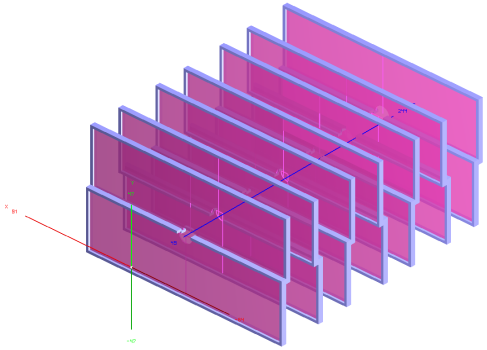


One drawing of the GEM half-plane

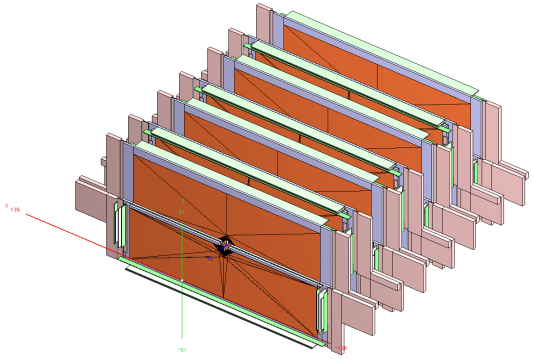
GEM: configuration for the next RUN (2021-2022)

The **configuration for the next RUN** consists of seven GEM stations located inside the magnet along the beam axis (axis Z).

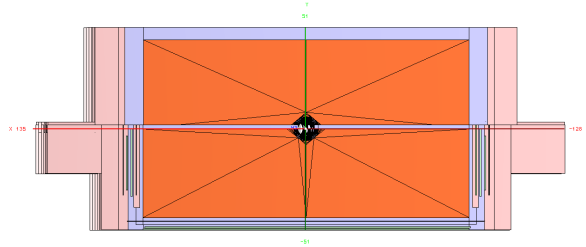
One station in this configuration is represented by two GEM half-planes – upper and lower, with the sizes of 163x45 cm for each.



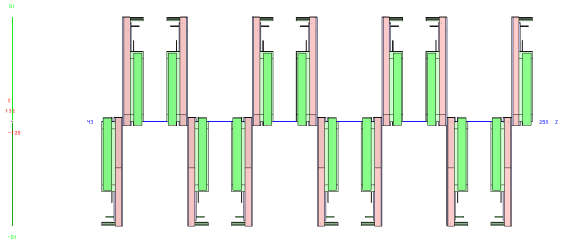
Simplified ROOT geometry of GEMs for the next run: only sensitive planes and ordinary frames.



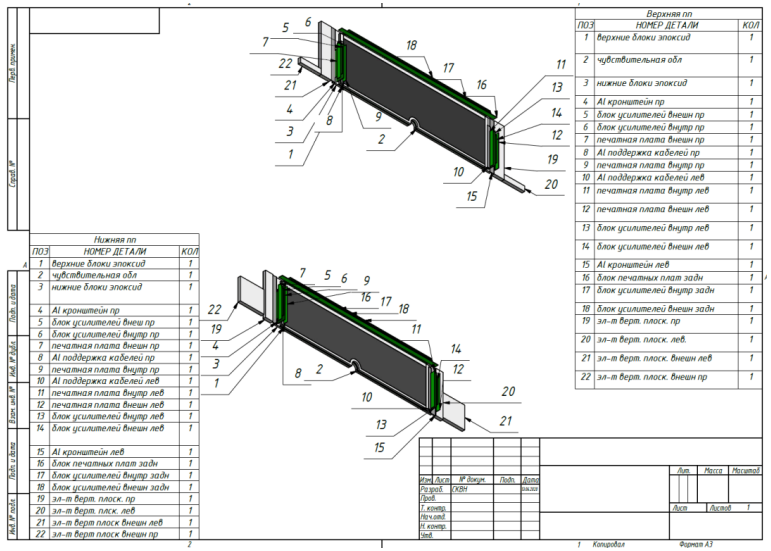
Detailed ROOT geometry of GEMs for the next run: passive elements (such as frames, electronics and material layers in sensitive areas) were added .



Detailed geometry of GEMs for the next run: front view (XY)



Detailed geometry of GEMs for the next run: side view (ZY)

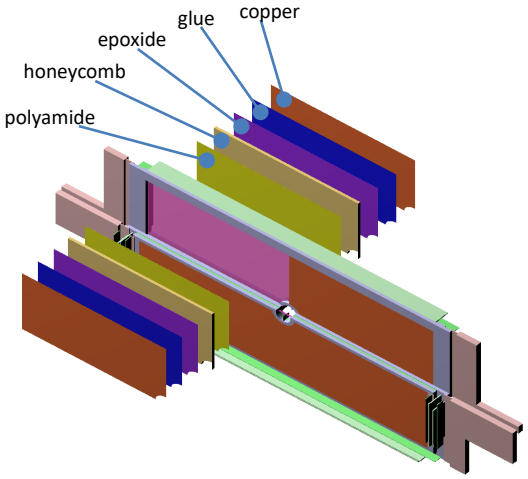


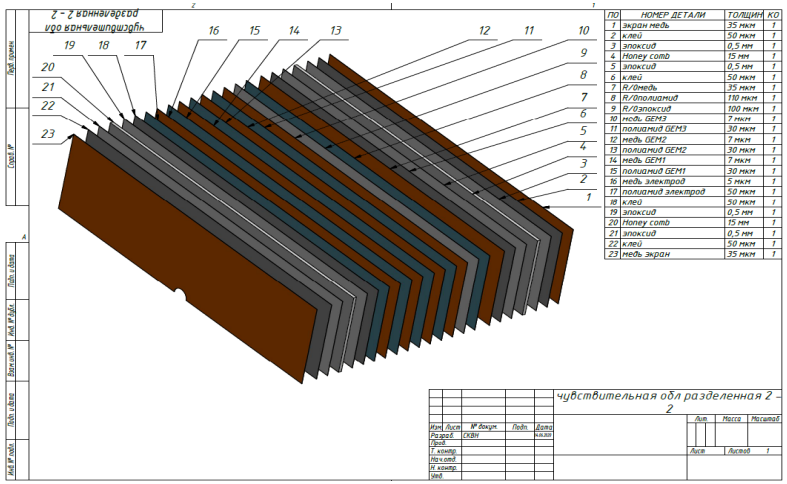
Drawing of two GEM half-planes (upper and lower) for the future runs

GEM: sensitive area structure

Besides frames and electronic elements, layers of materials in sensitive areas have been added to the detailed geometry.

The thickness of some layer is a summarized thickness of all layers with the same material.





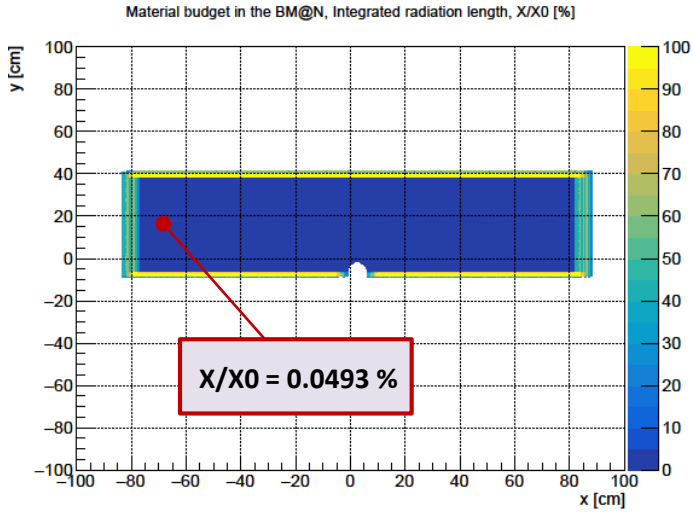
Layer structure of a sensitive area for one half-plane of GEM (prepared by the GEM group)

copper: 35µm + 35µm + 7µm + 7µm + 7µm + 5µm + 35µm = **131µm**
glue: 50µm + 50µm +50µm + 50µm = **200µm**
epoxide: 0.5mm + 0.5mm + 100µm + 0.5mm + 0.5mm = **2.1mm**
honeycomb: 15mm + 15mm = **30mm**
polyamide: 110µm + 30µm + 30µm + 30µm + 50µm = **250µm**

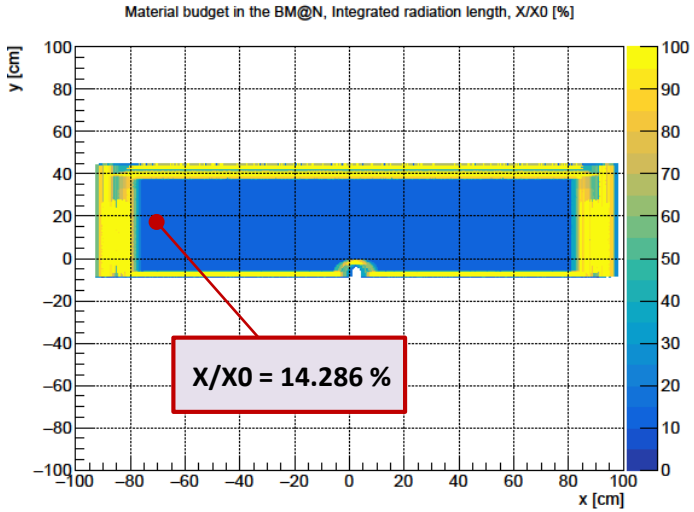
layer	material	density [g/cm-3]	thickness (X) [cm]	X0 [cm]	X/X0 [%]
gas	*ArCO2 (70/30)*	0.0019	0.9	10960.2	0.0082
copper	*copper*	8.96	0.0131	1.435	0.9129
glue	*acrylic glue*	1.25	0.02	32.1603	0.0622
epoxide	*polyurethane (high dens.)*	1.8	0.21	22.5351	0.9319
	polyurethane (medium dens.)	0.59	0.21	68.7512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

Table: properties of material layers in the sensitive area of GEM chambers

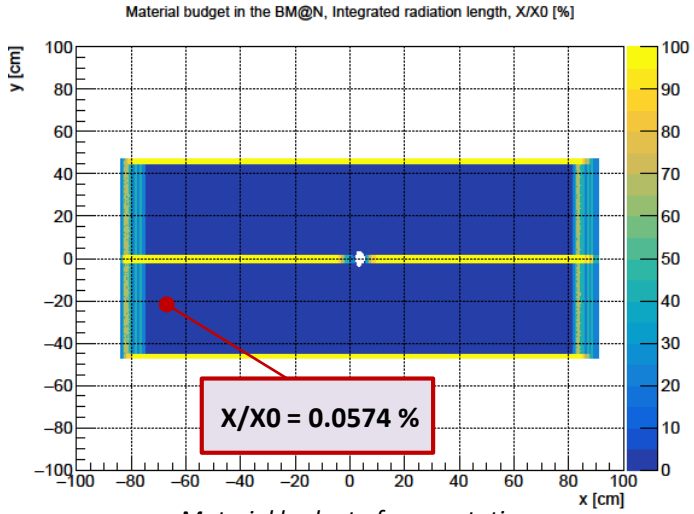
GEM: material budget



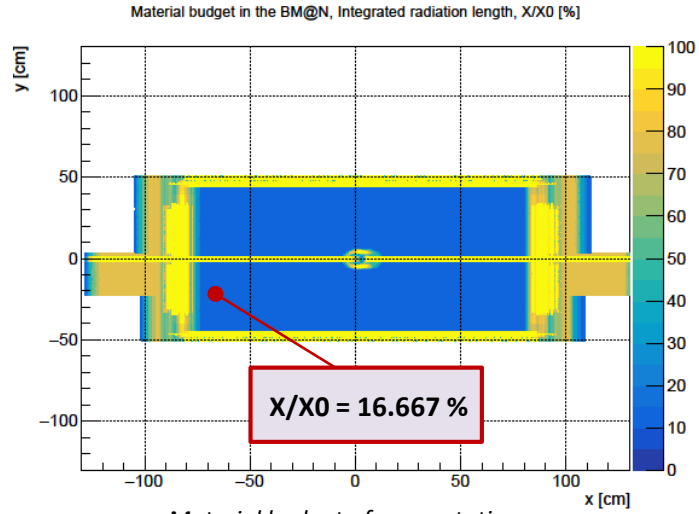
Material budget of six stations for tracks parallel to Z axis (simplified geometry)



Material budget of six stations for tracks parallel to Z axis (detailed geometry)



Material budget of seven stations for tracks parallel to Z axis (simplified geometry)



Material budget of seven stations for tracks parallel to Z axis (detailed geometry)

Summary

- ✓ The detailed geometry for the inner tracker detectors (GEM and SILICON) of the BM@N setup was prepared for the following runs:
  - RUN-7 (2018)
  - the next run (2021-2022)
- ✓ The material budget distribution for each configuration was calculated

Thank you for your attention…