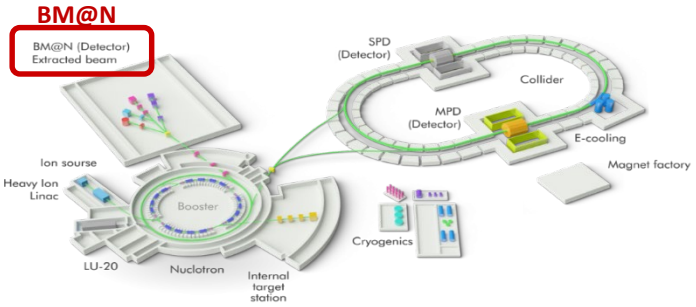
Status: Configuration of the tracking detectors for RUN 8

Baranov Dmitry

BM@N experiment

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

This is a fixed target experiment aimed to study interactions of relativistic heavy ion beams with a fixed target



NICA (Nuclotron-based Ion Collider fAcility) accelerator complex located at Joint Institute for Nuclear Research in Dubna

At this moment, **seven BM@N RUNs** have already been carried out since 2015:

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

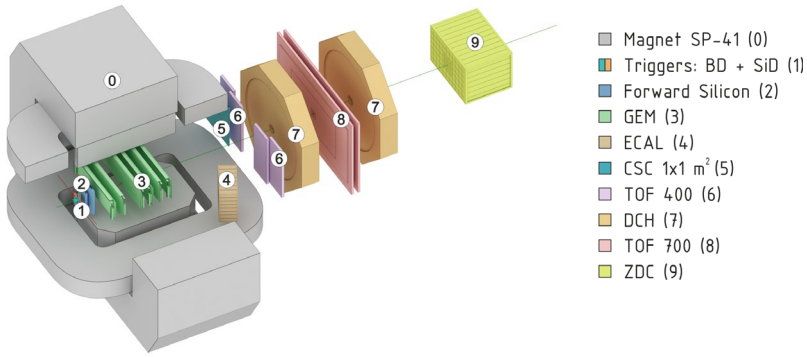
RUN 8 (2023)
beam: Ar, Xe; target: CsI

The detector setup of BM@N

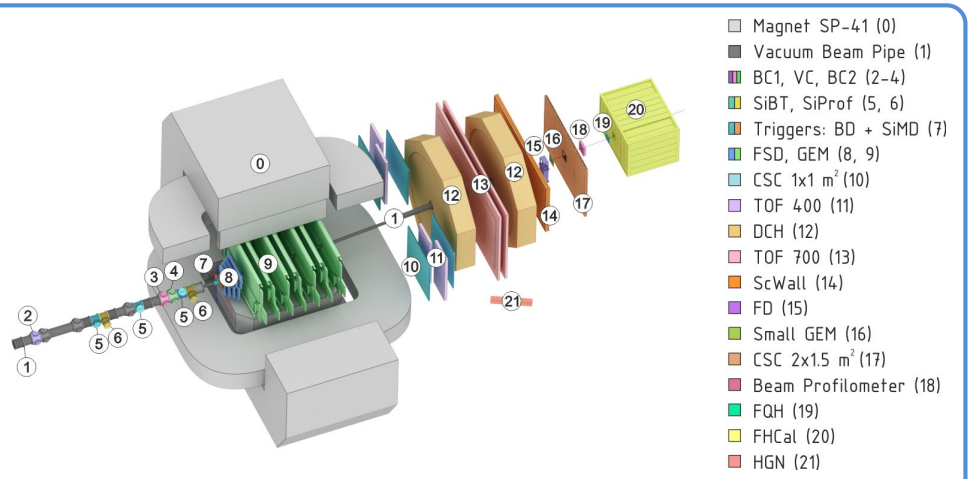
Tracking system
- **SiBT** (*Silicon Beam Tracker*)
- **FSD** (*Forward Silicon Detector*)
- **GEM** (*Gas Electron Multipliers*)
- **CSC** (*Cathode Strip Chambers*)
- **DCH** (*Drift Chambers*)

Particle identification system
- **TOF400** (*1st Time-of-Flight detector*)
- **TOF700** (*2nd Time-of-Flight detector*)

Other detector systems
- **Triggers system**
- **FQH** (*Forward Quartz Hodoscope*)
- **ScWall** (*Scintillator Wall*)
- **FHCall** (*Fwd. Hadron Calorimeter*)
- **HGN** (*High Granularity Neutron*)



*BM@N setup for the previous **RUN-7** configuration (spring 2018)*

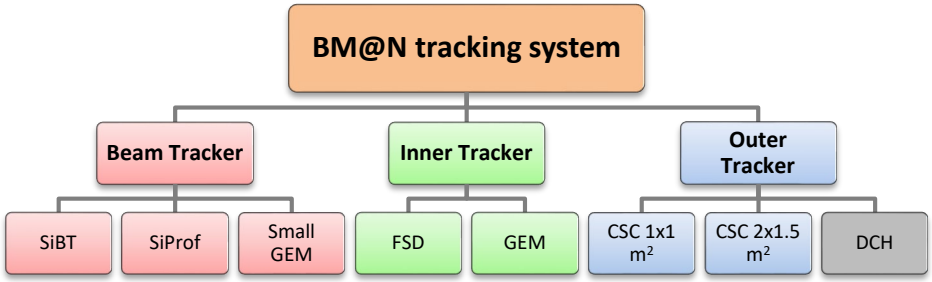


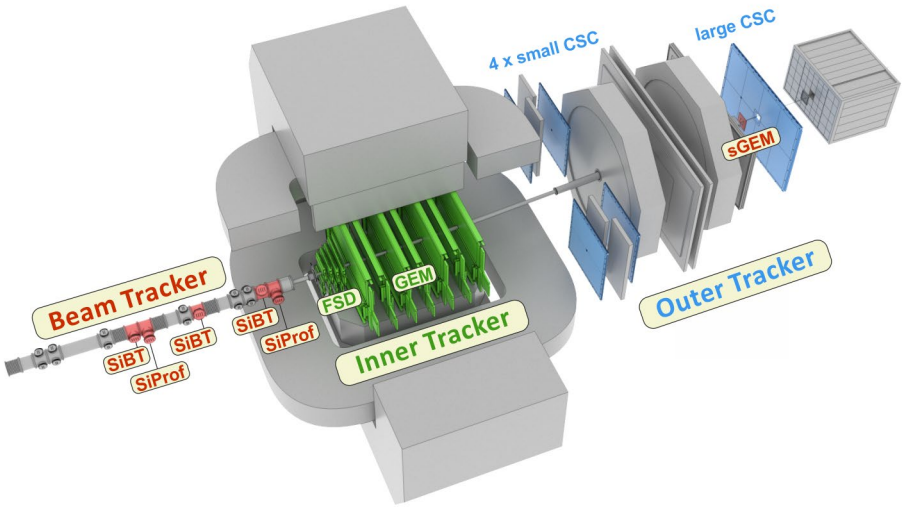
*BM@N setup for the latest **RUN-8** configuration (winter 2023)*

BM@N tracking system

BM@N tracking system consists of high-precision coordinate detectors for charged particle track registration.

The tracking system is subdivided into three parts: **beam tracker**, **inner tracker** and **outer tracker**. The beam tracker includes detectors located inside the vacuum pipe to monitor the beam. The inner tracker comprises detectors located inside the magnet, the outer – outside





BM@N tracking system for RUN-8 consisting of microstrip detectors (highlighted with different colors)

BM@N tracking detectors for RUN-8:

Inner tracker:

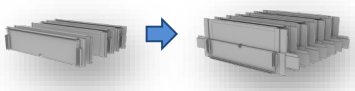
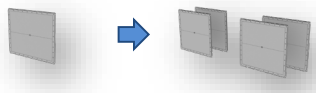
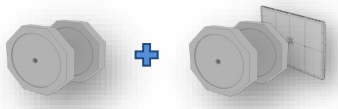
- **SiBT (Silicon Beam Tracker)** : 3 planes of 63x63 mm^2
- **SiProf (Silicon Profilometers)** : 2 planes of 63x63 mm^2
- **sGEM (small GEM *as beam profilometer*)** : 1 plane of 10x10 cm^2

Inner tracker:

- **FSD (Forward Silicon Detector)** : 8 half-planes
- **GEM (Gas Electron Multipliers)** : 14 half-planes

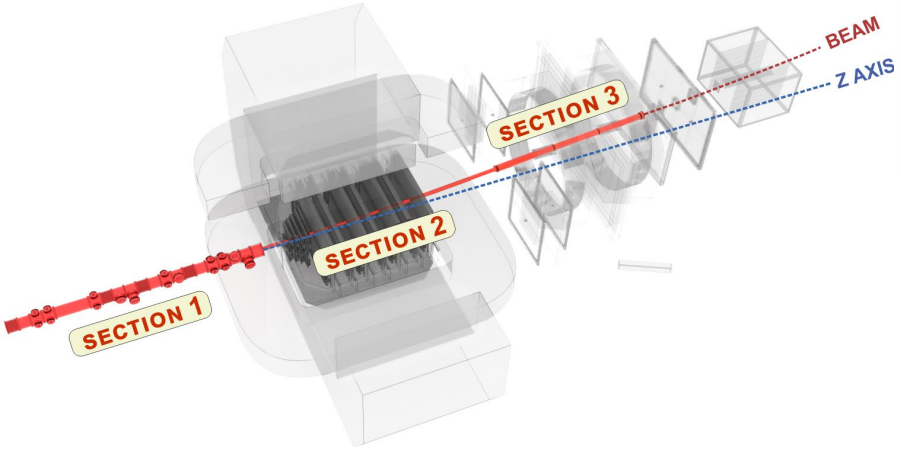
Outer tracker:

- **small CSC (Cathode Strip Chamber)** : 4 planes of 1x1 m^2
- **large CSC (Cathode Strip Chamber)** : 1 plane of 2x1.5 m^2
- **DCH (Drift Chambers)** : 2 large multi-wire chambers

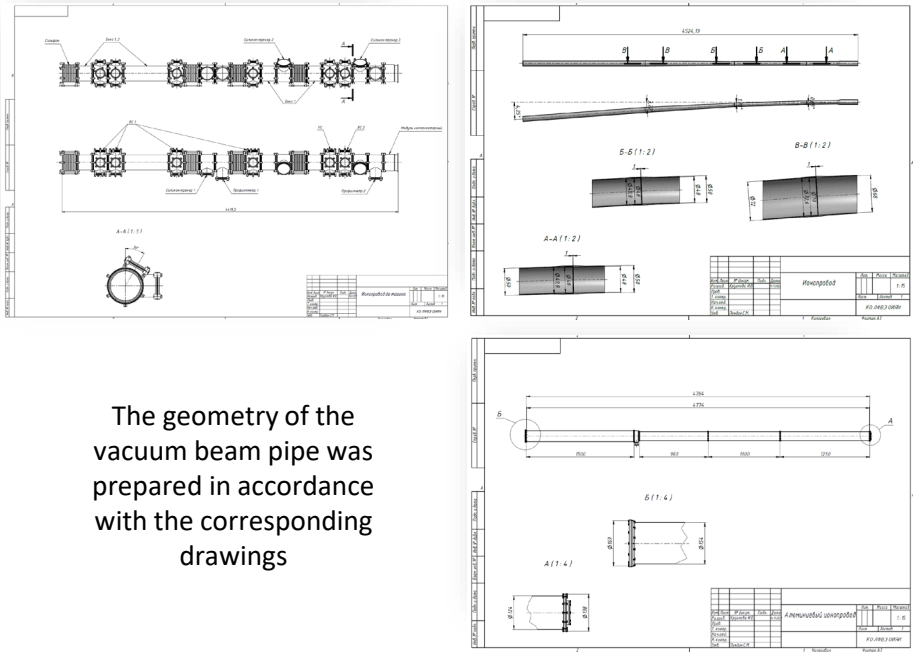
Detector	RUN-7	RUN-8	Features
FSD			**RUN-7**: 2 stations (14 Si-modules) **RUN-8**: 4 stations (48 Si-modules)
GEM			**RUN-7**: 6 stations (6 half-planes) **RUN-8**: 7 stations (14 half-planes)
CSC			**RUN-7**: 1 chamber (1x1 m^2) **RUN-8**: 4 chambers (1x1 m^2)
DCH + CSC			**RUN-7**: only 2 DCH **RUN-8**: 2 DCH + 1 large CSC (2x1.5 m^2)

Vacuum Beam Pipe

Vacuum Beam Pipe is designed to minimize the amount scattering material on the way of heavy ions.

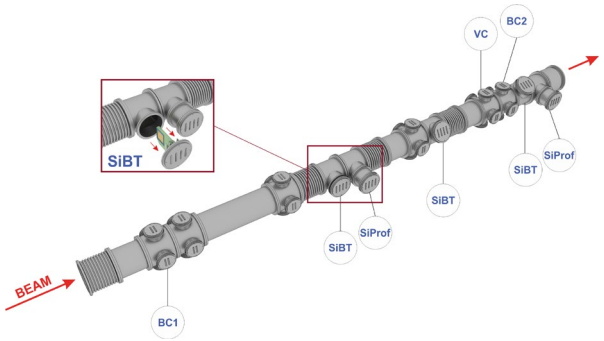


Vacuum beam pipe (in red color) consists of three sections and has angle bends of its parts in accordance with the the ion beam deflection in the magnetic field



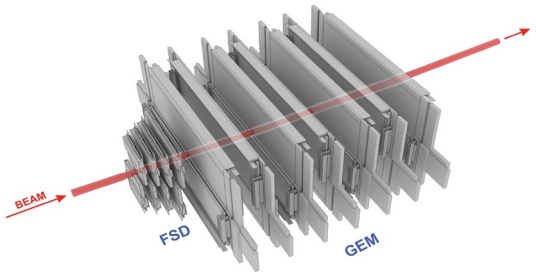
The geometry of the vacuum beam pipe was prepared in accordance with the corresponding drawings

SECTION 1



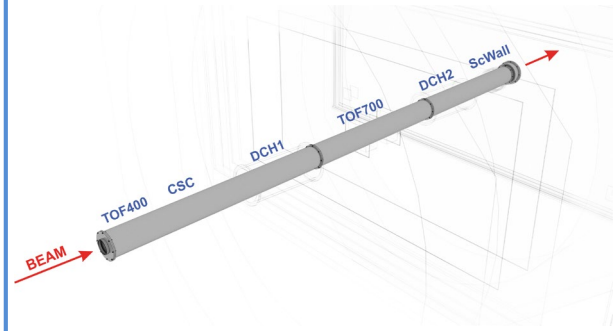
The first part is located before the magnet and its parts are made of aluminum and steel. This pipe includes special vacuum boxes containing different detectors.

SECTION 2



The second part is located inside the magnet and made of carbon materials. As you can see, the detectors, placed in this section, have openings for passing the pipe.

SECTION 3



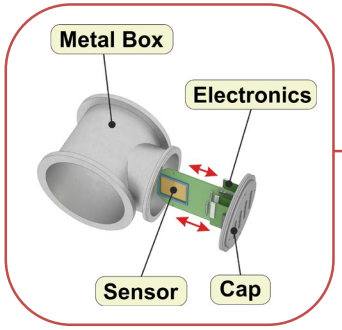
The third part is located after the magnet and comprises of aluminum parts. The beam pipe ends at the scintillation wall detector.

Beam tracking detectors and profilometers

SiBT (*Silicon Beam Tracker*) and SiProf (*Silicon Beam Profilometer*) detectors are designed to monitor and track the ion beam.

They are located before the target inside metal boxes integrated into the first section of the vacuum pipe.

Software for simulation and reconstruction, including detailed geometric models of these detectors, was implemented in the BMNROOT framework.



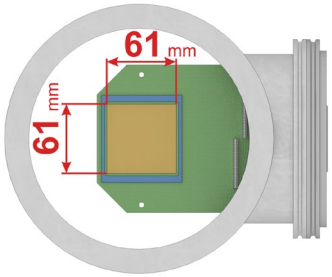
SiBT detector

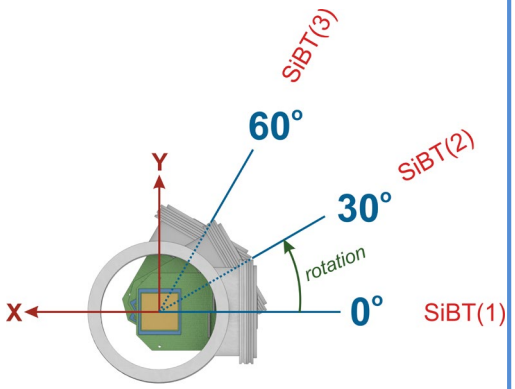
Metal box, as a part of the vacuum tube, contains one detector inside

The first section of the vacuum pipe containing different detectors

Silicon Beam Tracker

128x128 strips



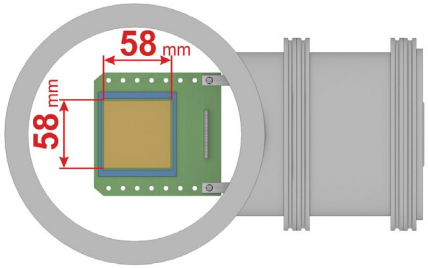


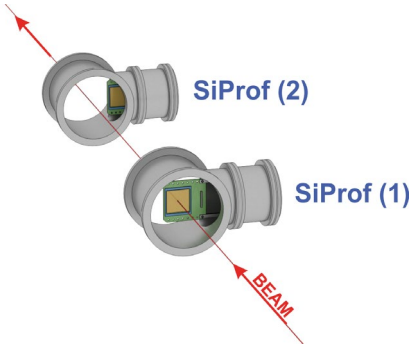
sensor: **61x61 mm²**
sensor thickness: **175 µm**
strip pitch: **0.475 mm**
stereo angle between strips: **90°**

Three SiBT detectors are arranged along the beam axis and each one is rotated by a certain angle around this axis

Silicon Beam Profilometers

32x32 strips



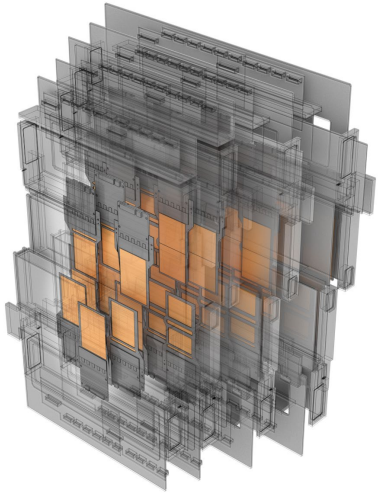


sensor: **61x61 mm²**
sensor thickness: **175 µm**
strip pitch: **0.475 mm**
stereo angle between strips: **90°**

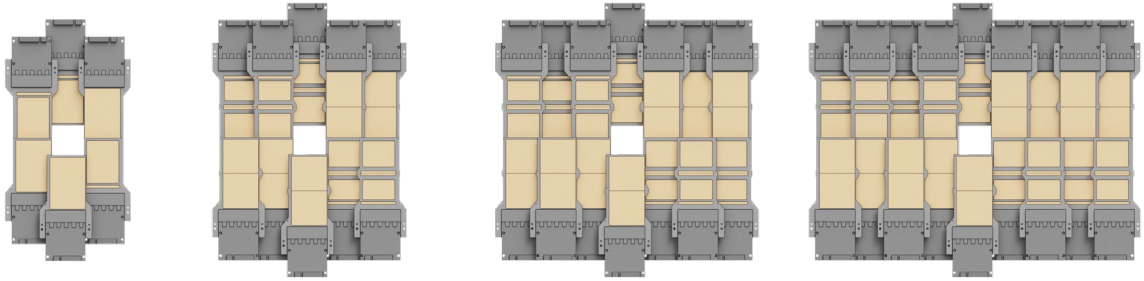
Each silicon profilometer can have two positions: "sensor on the beam" (1) and "sensor removed" (2)

Forward Silicon Detector

Forward Silicon Detector (FSD) is a high-precision coordinate detector of the inner tracking system of the BM@N setup. It consists of a set of silicon modules which are assembled into 4 stations.



Silicon stations



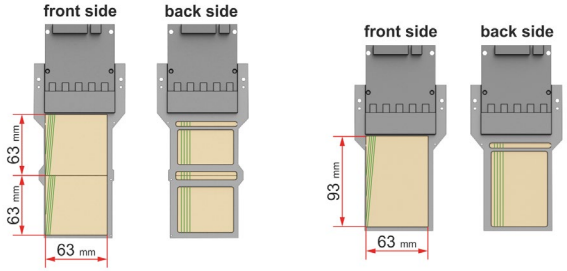
Station 1:
6 modules of 63x93 mm²

Station 2:
10 modules of 63x126 mm²

Station 3:
14 modules of 63x126 mm²

Station 4:
14 modules of 63x126 mm²

Silicon module types

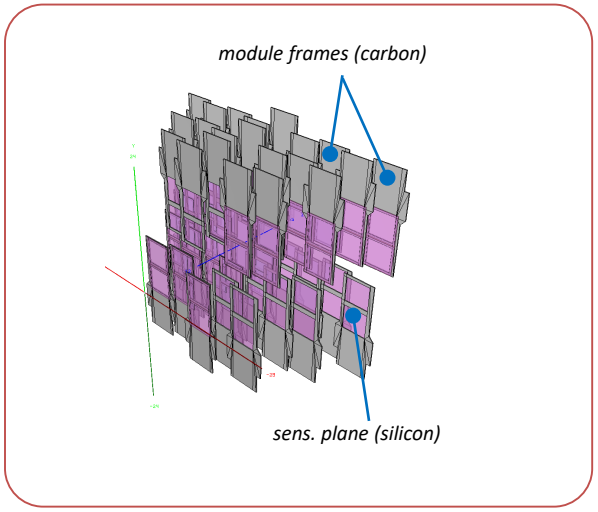


*Si-module with two double-sided strip sensors of **63x63** mm² each*

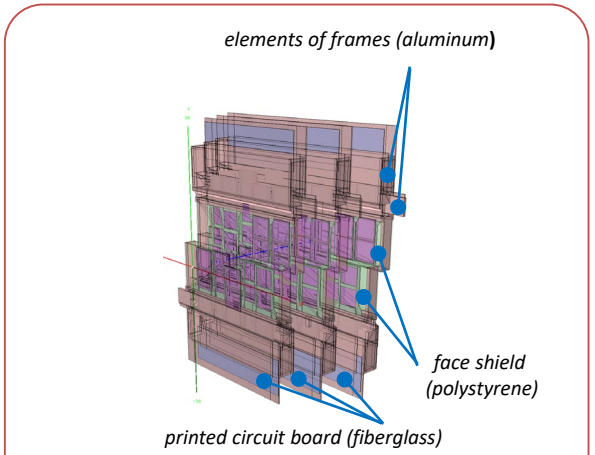
*Si-module with one double-sided strip sensor of **63x93** mm²*

sensor thickness: **300 µm**
strip pitch: **≈ 100 µm**
stereo angle between strips: **2.5°**

ROOT geometry



Basic ROOT geometry of the FSD detector



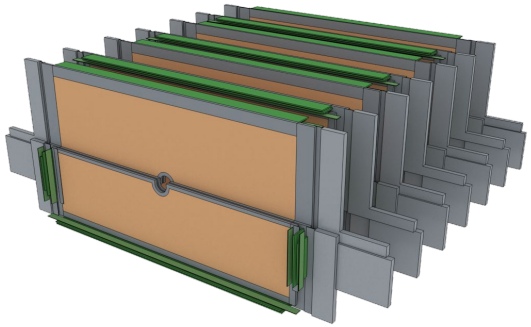
Detailed ROOT geometry of the FSD detector

Adding passive elements to the geometry allows us to take into account detector materials which affect the passage of particles trough matter. This, in turn, improves the accuracy of the Monte-Carlo simulation.

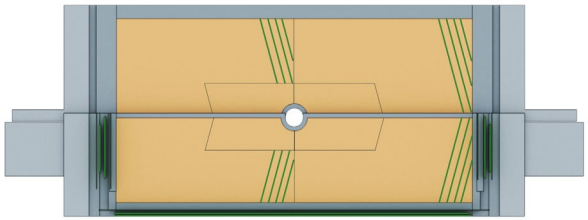
GEM detector

GEM (Gas Electron Multipliers) is a microstrip coordinate detector of the central tracker in the BM@N setup. It consists of gaseous chambers with electron multiplier system inside.

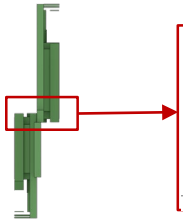
The configuration of this detectors for RUN-8 comprises **seven stations** located inside the magnet along the beam axis.



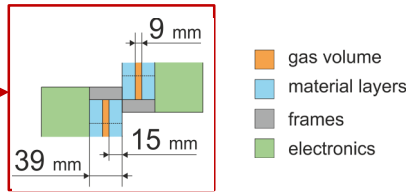
GEM station assembly



1st GEM station (front view)

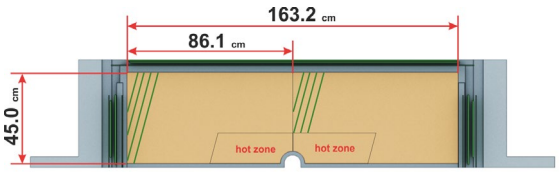


1st GEM station (side view)

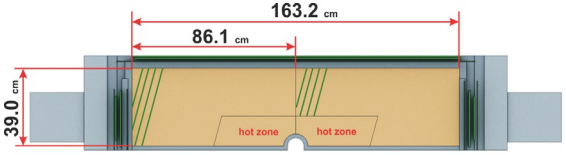


Scheme of joining two half-planes together into a station (side view)

GEM chamber types

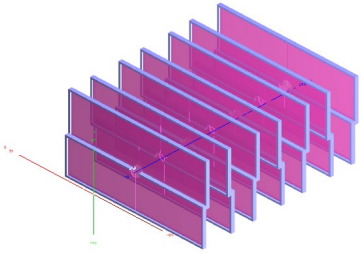


Upper half-plane

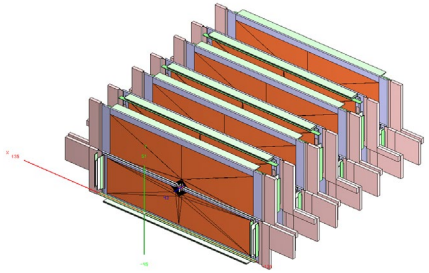


Lower half-plane

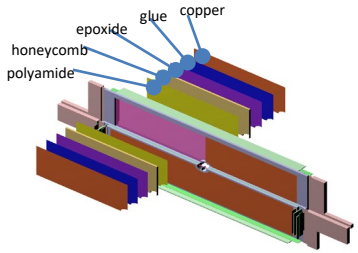
ROOT geometry



Basic ROOT geometry of the GEM detector



Detailed ROOT geometry of the GEM detector



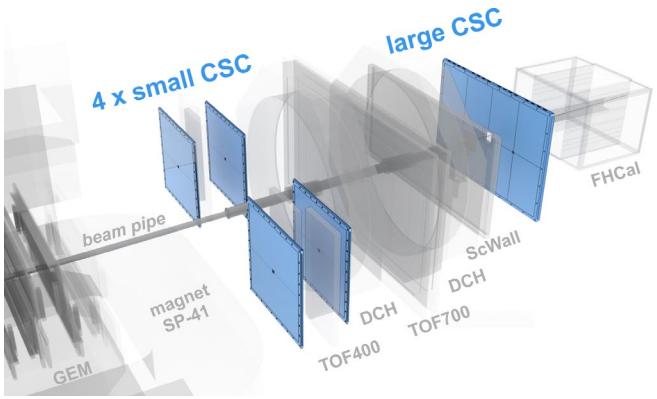
Sensitive area of a GEM chamber

Each active zone in a GEM chamber has a multi-layer structure. A layer has the following properties: thickness, material type and other characteristics which are taken into account in the Monte-Carlo simulation.

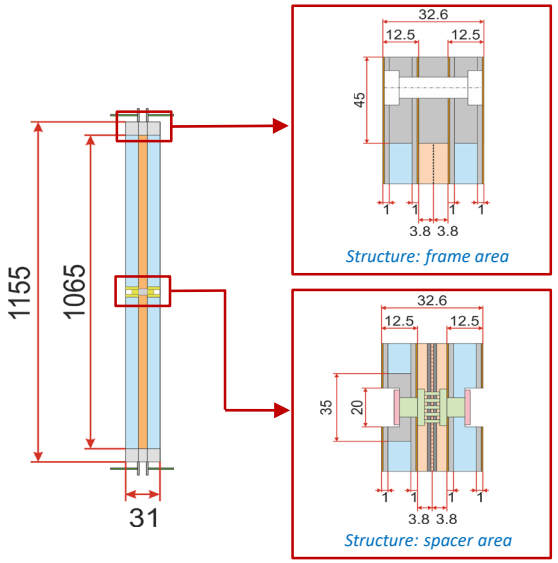
CSC detector

CSC (Cathode Strip Chamber) is a gaseous detector with microstrip readout. It belongs to the **outer tracking system** in the BM@N setup.

The configuration of this detector for RUN-8 consists of four small and one big stations located behind the magnet.

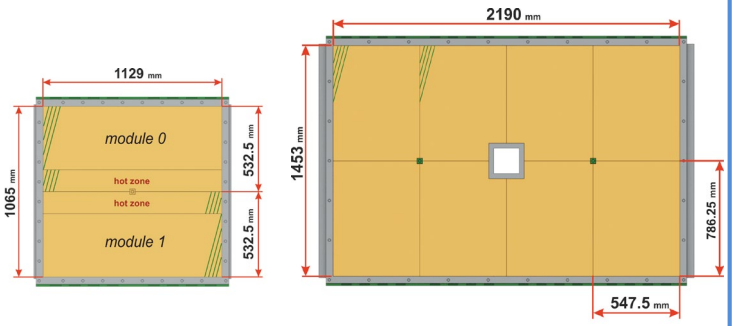


SCS chamber structure



Structure of small CSC chamber

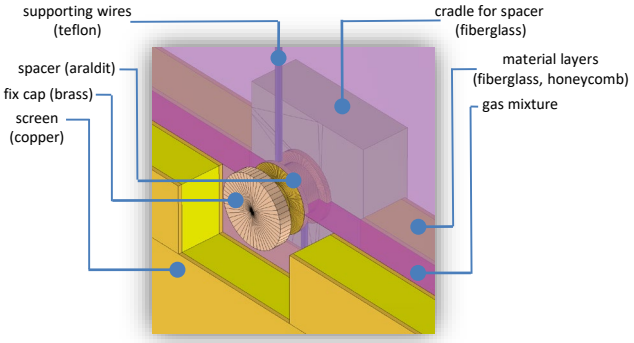
CSC chamber types



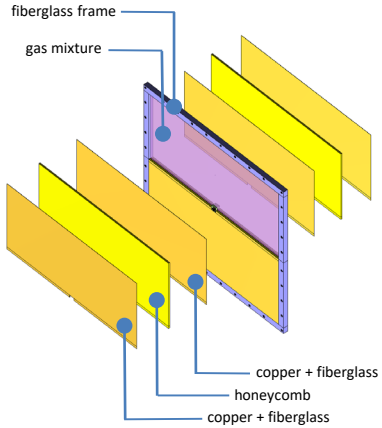
Small CSC *Large CSC*

gas volume thickness: **7.2 mm (small CSC) and 6 mm (large CSC)**
strip pitch: **≈ 2.5 mm**
stereo angle between strips: **15°**

ROOT geometry

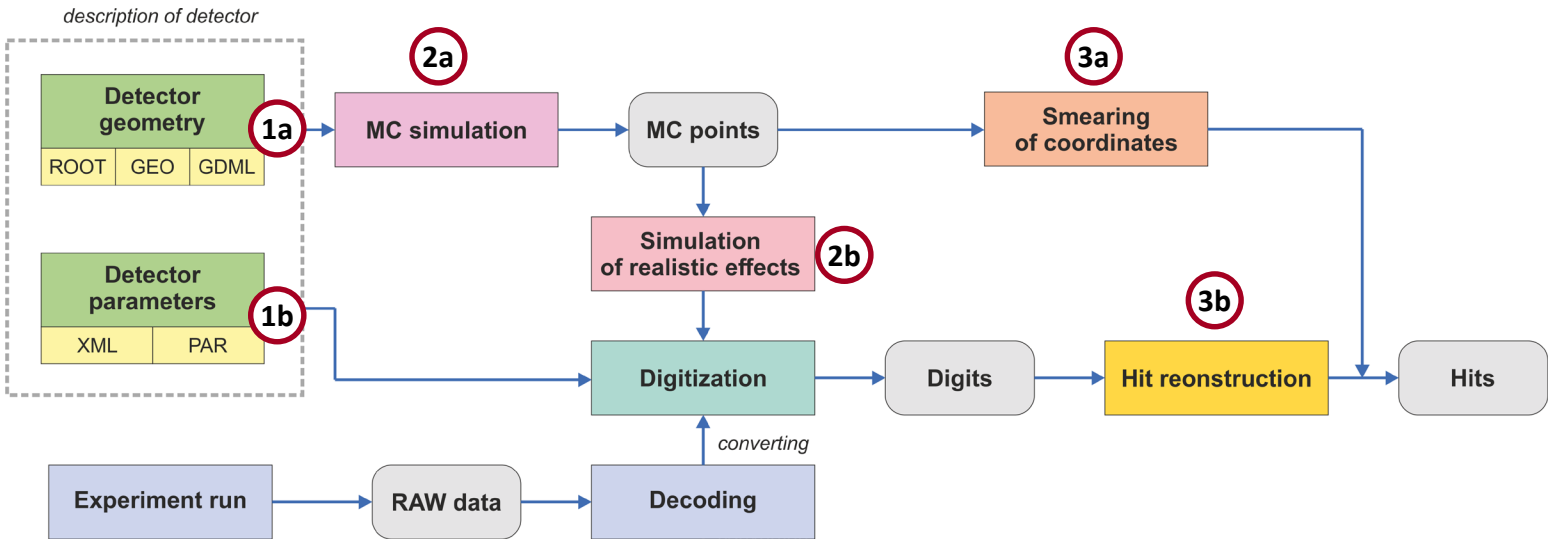


Spacer, as an example of a passive element, was implemented in the ROOT geometry of the CSC chamber



Multi-layer structure of CSC chamber was implemented in the ROOT geometry

Tracking detectors: software for data processing

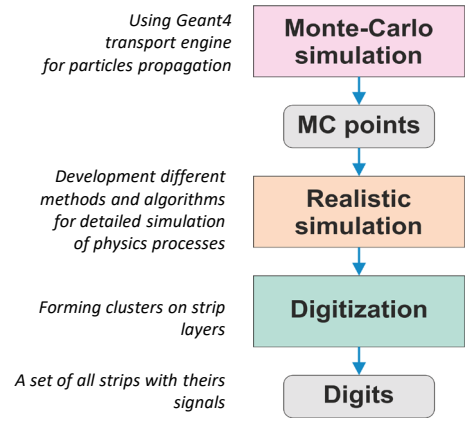


Basic stages of data processing for tracking detectors in BmnRoot

Stages of data processing

1. **Complete description of a detector**:
   a) Description of detector geometry (ROOT files)
   b) Description of detector parameters (XML files)
2. **Simulation**:
   a) Monte-Carlo simulation
   b) Simulation of realistic effects
3. **Procedures of getting "hits" (Hit-reconstruction)**:
   a) Smearing Monte-Carlo points (hit producing)
   b) Hit reconstruction from "digits":
      - Realistic simulation + digitization
      - RAW experimental data + digitization

Realistic simulation steps



Complete simulation for detectors comprises the following stages:

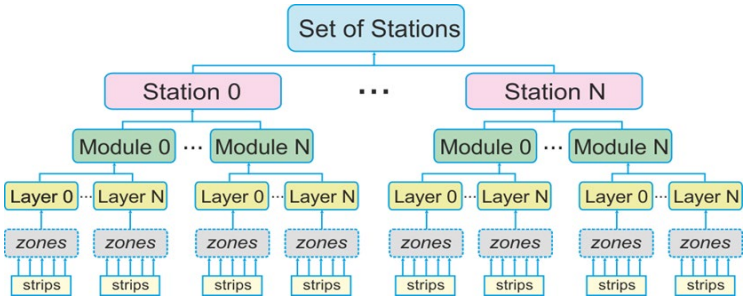
1. Monte-Carlo simulation (getting MC-points by using Geant4)
2. Realistic simulation (taking into account the signal formation features)
3. "Digitization" (forming 'digits' as signal on the strips)

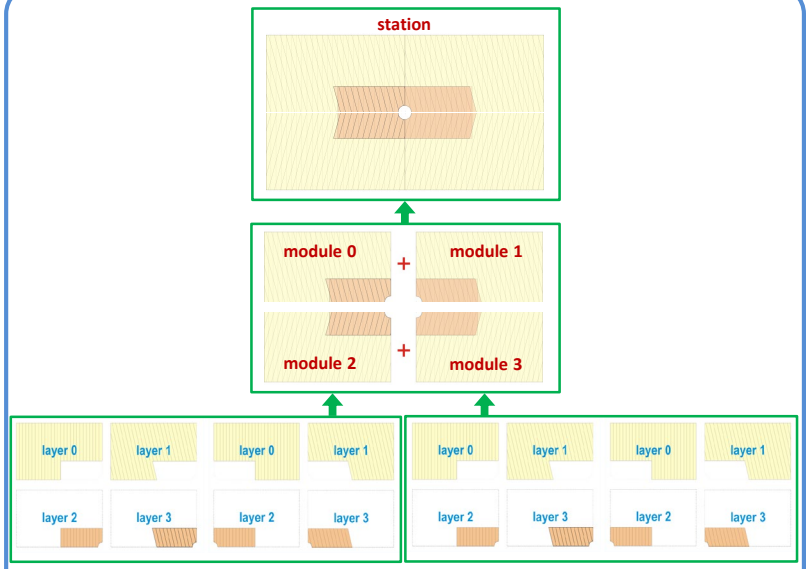
Tracking detectors: software structure

Structure of tracking detectors

All the tracking detectors have the same hierarchical structure, where:

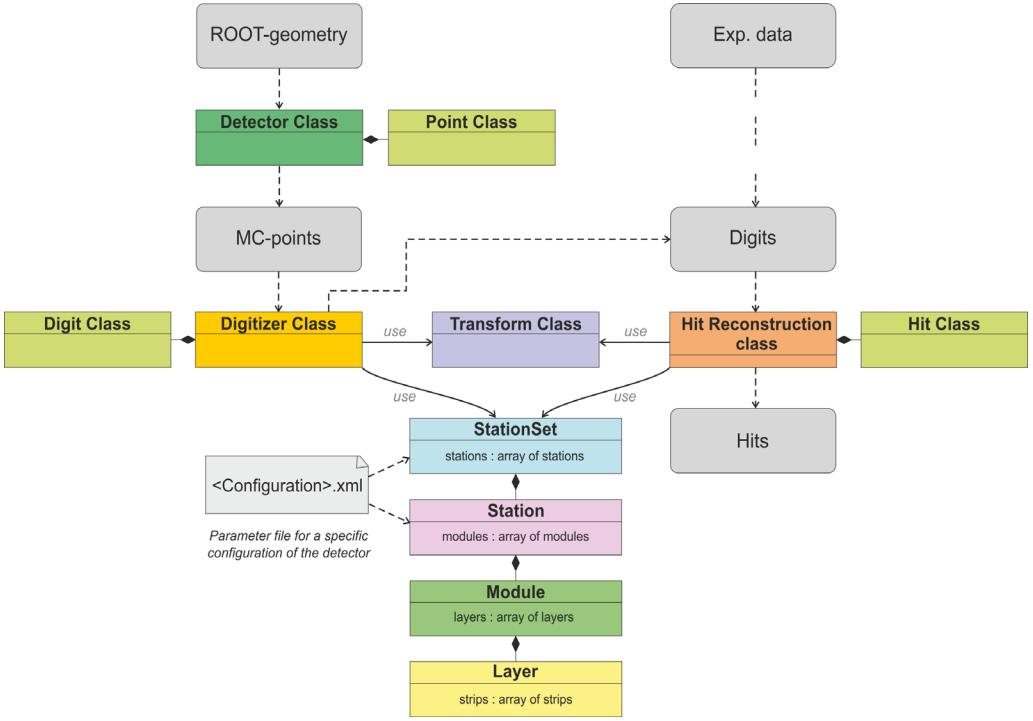
Strips are integrated into a layer,
Layers – into a module,
Modules – into a stations,
Stations – into a set of stations





Visual example of the structure of one GEM chamber

Software implementation



Software structure for the tracking detectors (as a class diagram)

Summary

What has been done:

- Detailed geometry of vacuum beam pipe
- Detailed geometry of microstrip tracking detectors for RUN-8 configuration:
  - Silicon Beam Tracker and Beam Profilometers
  - Forward Silicon and GEM detectors
  - Small and large CSC detectors
- Software for simulation, hit-reconstruction and data processing of these detectors

Thank you for your attention…