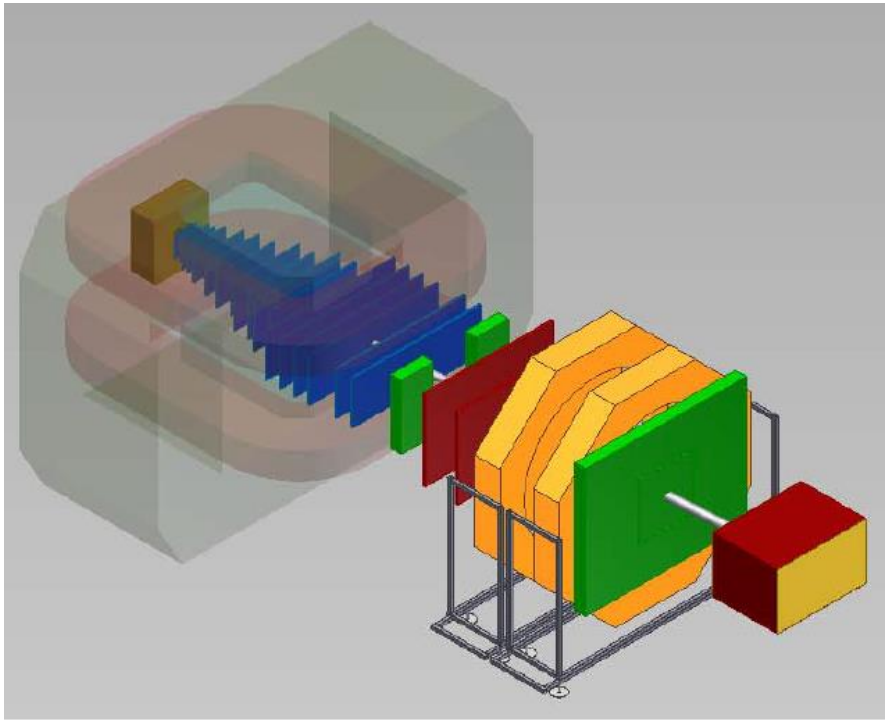
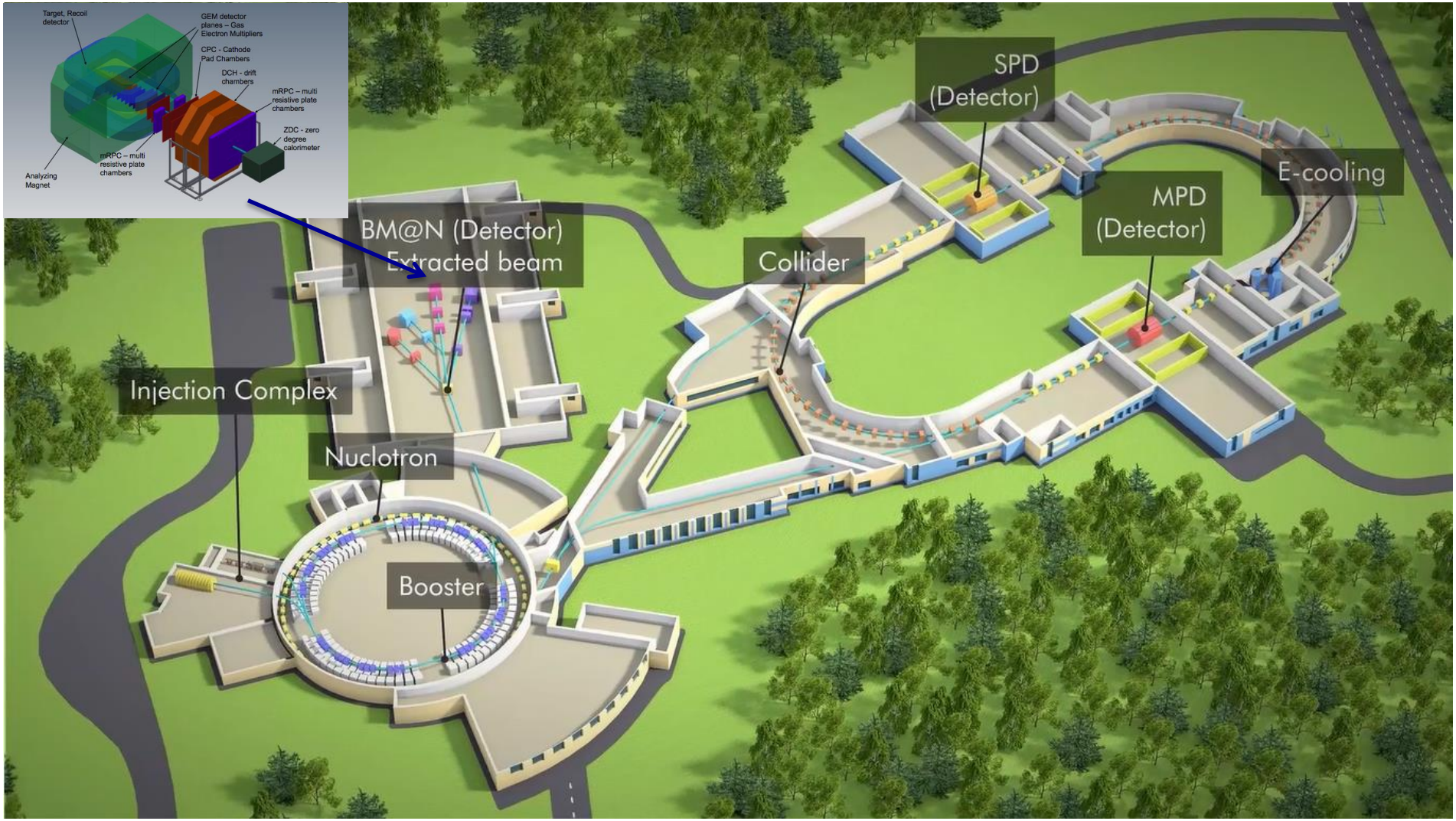
Progress towards realization of the BM@N project

M.Kapishin



NICA Heavy Ion Complex

BM@N: heavy ion energy 1 - 4.5 GeV/n, beams: p to Au, Intensity ~few 10^6 /s (Au)

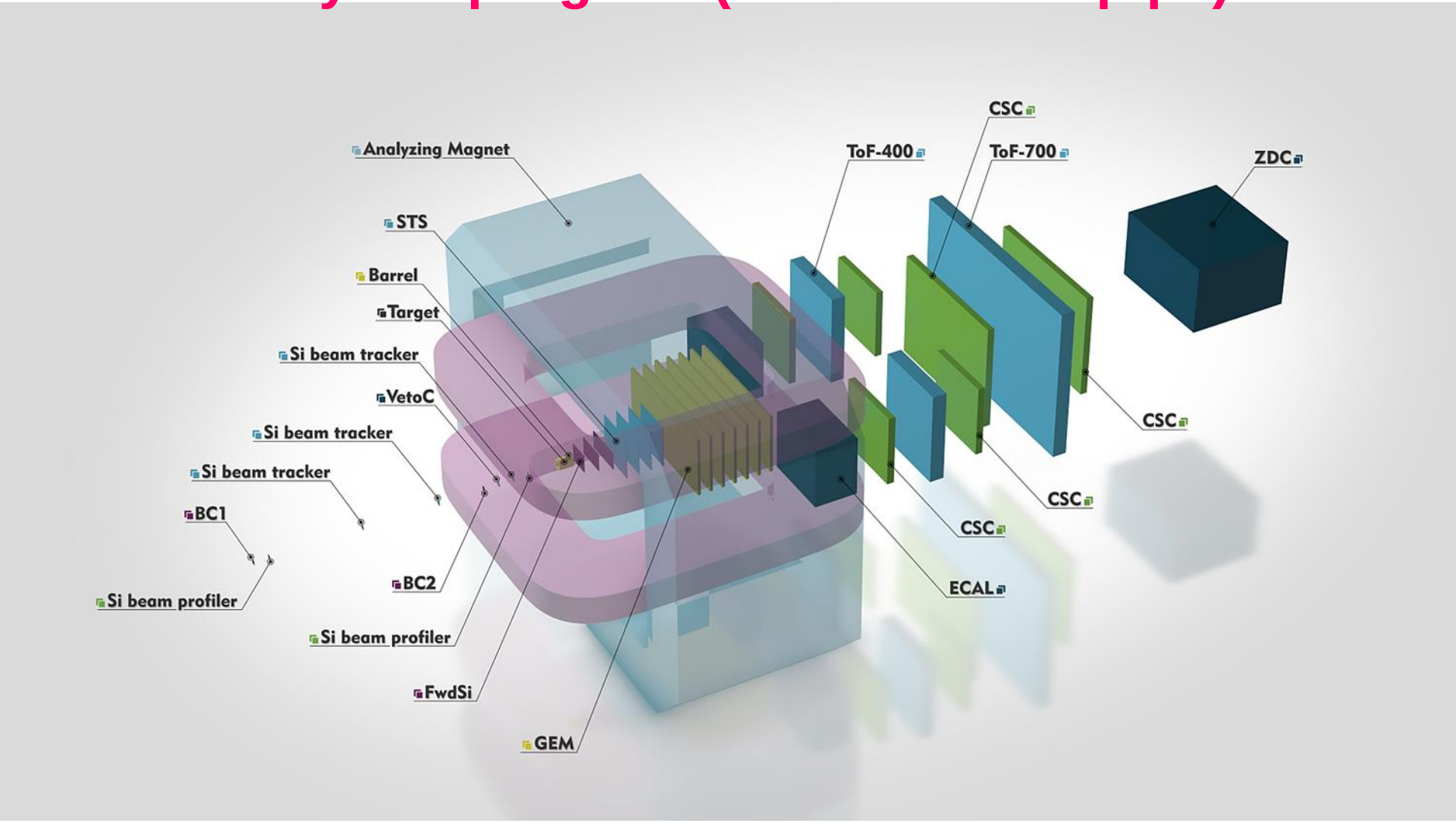


First BM@N paper on physics results in circulation in BM@N Collaboration

Production of Λ hyperons in 4 and 4.5 AGeV carbon-nucleus interactions at the Nuclotron

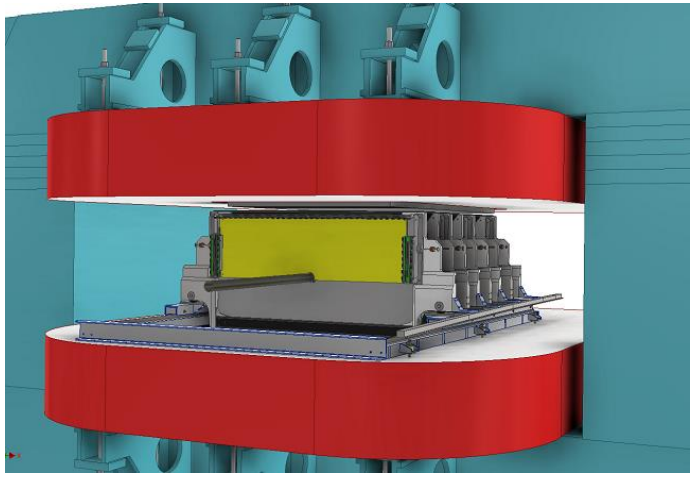
The BM@N (Baryonic Matter at Nuclotron) is the first experiment undertaken at the accelerator complex of NICA-Nuclotron. The BM@N scientific program comprises studies of dense nuclear matter in heavy ion beams of the intermediate energy range between the SIS-18 and NICA/FAIR facilities. The first experimental run was performed in the carbon beam of the 4 and 4.5 AGeV kinetic energy with fixed targets. First physics results are presented on Λ hyperon production in carbon-nucleus interactions. Transverse momentum, rapidity spectra and yields of Λ hyperons are measured. The results are compared with predictions of theoretical models and with the experimental data on carbon-carbon interactions measured at lower energies.

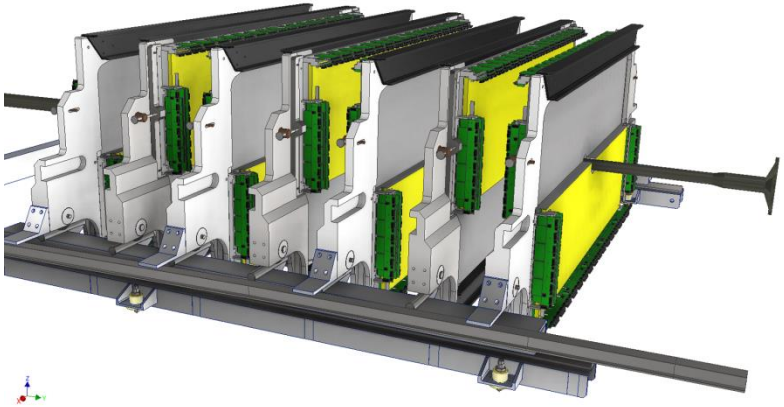
Configuration of BM@N detector for heavy ion program (without beampipe)



GEM central tracker for heavy ion runs

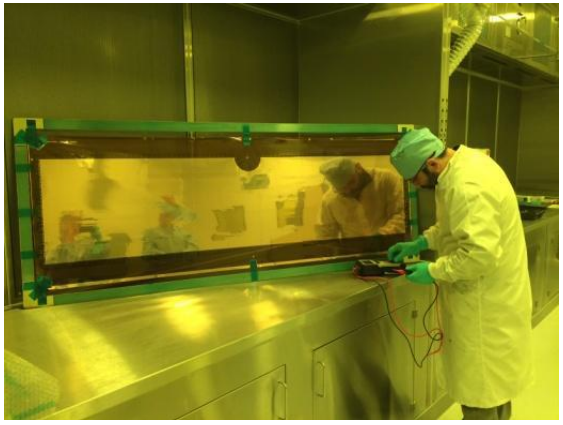
GEM group





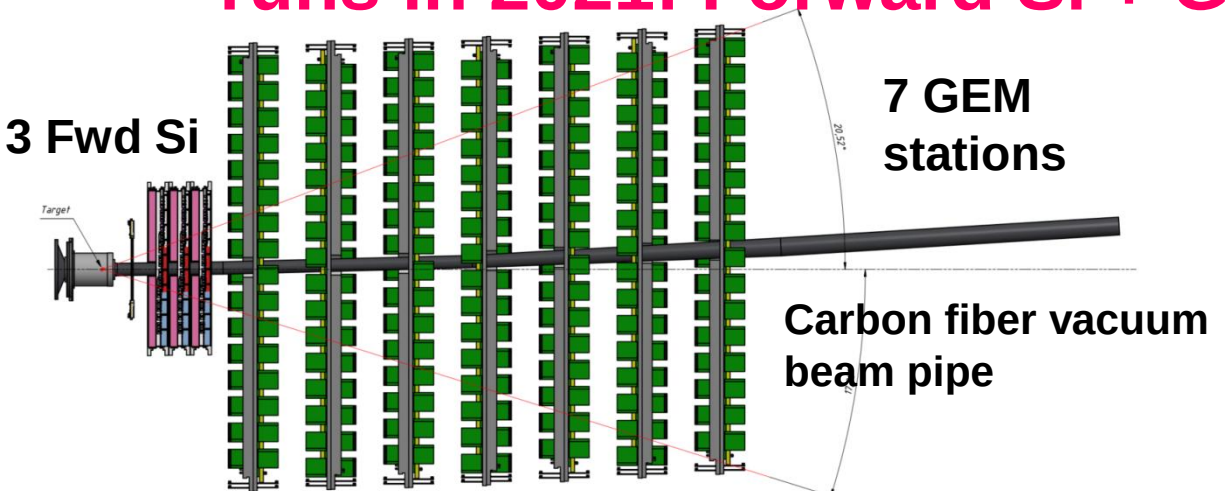
Setup of GEM detectors for cosmic tests

GEM 163x39 cm^2 chamber assembly process at CERN



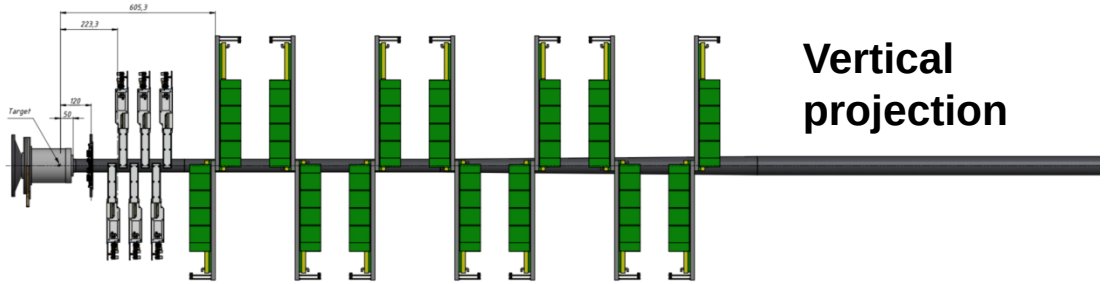
- 7 upper GEM 163x45 cm^2 chambers produced at CERN workshop were integrated into BM@N experimental setup
- 7 lower GEM 163x39 cm^2 chambers were assembled, delivered to BM@N and tested

Initial Hybrid Central Tracker for heavy ion runs in 2021: Forward Si + GEM

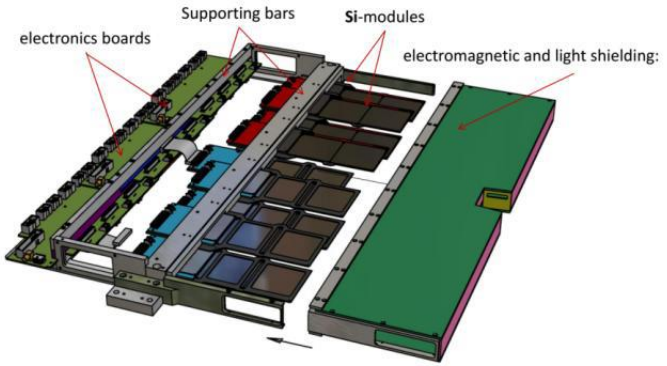


GEM group
Group of N.Zamiatin

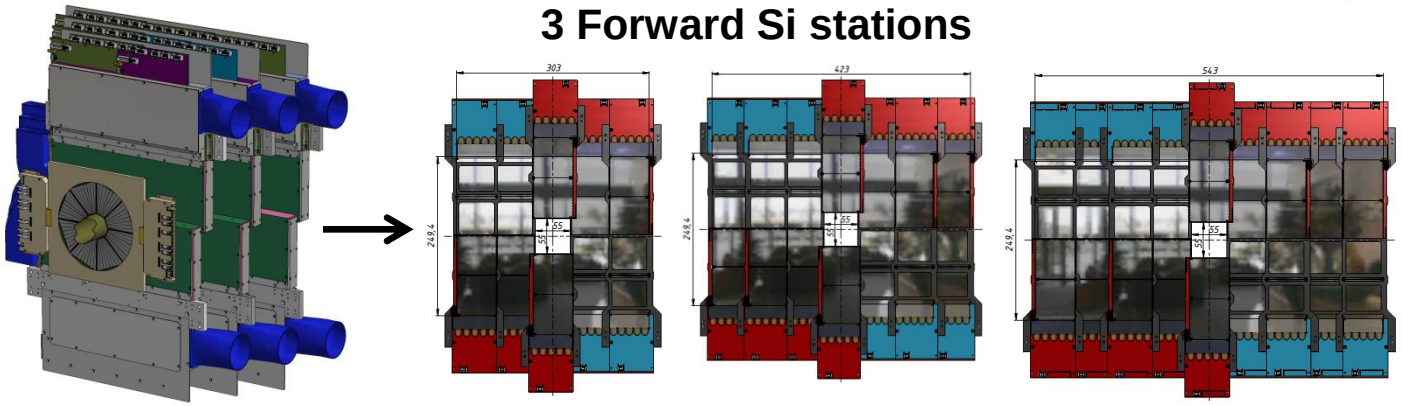
Heavy ion beam intensity ~few 10^5 Hz



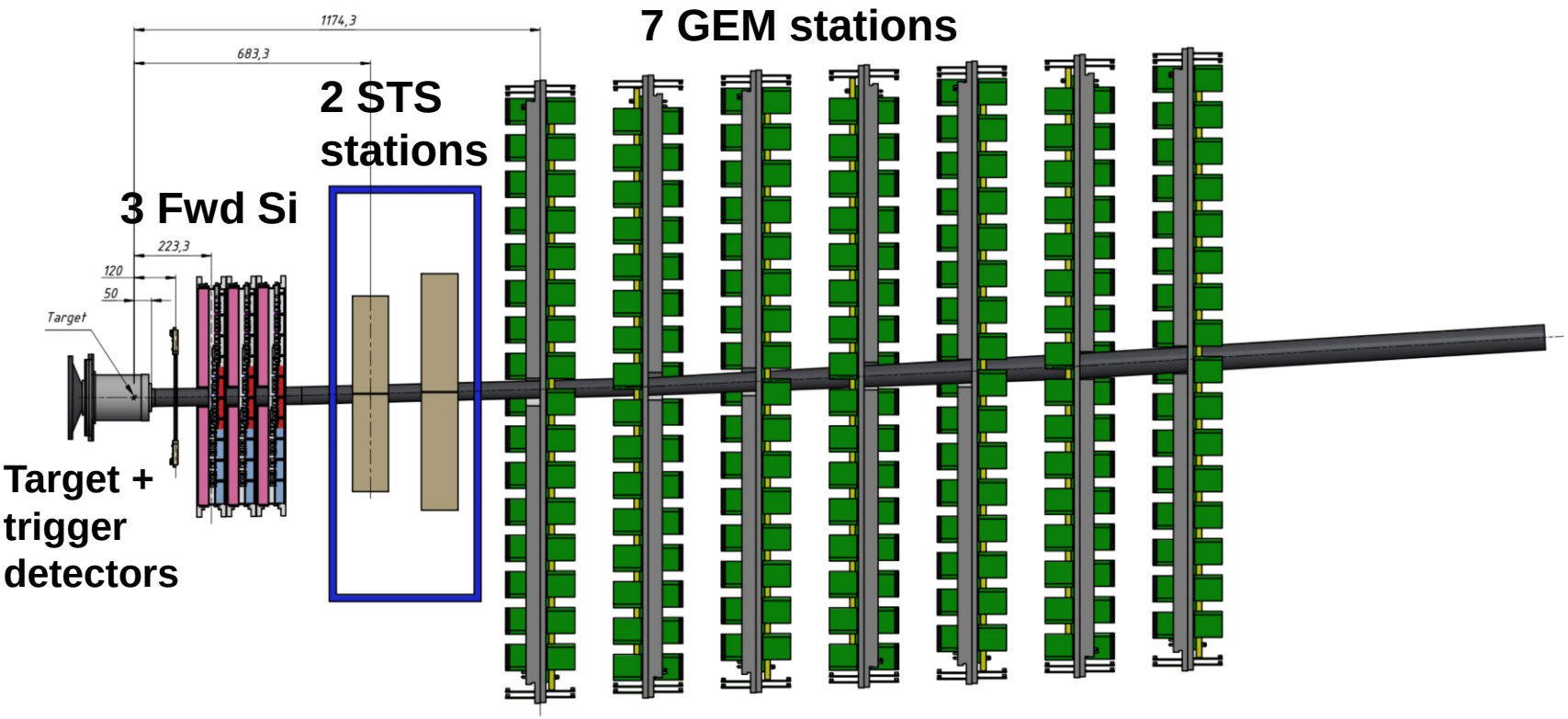
Fwd Si half plane



3 Forward Si stations



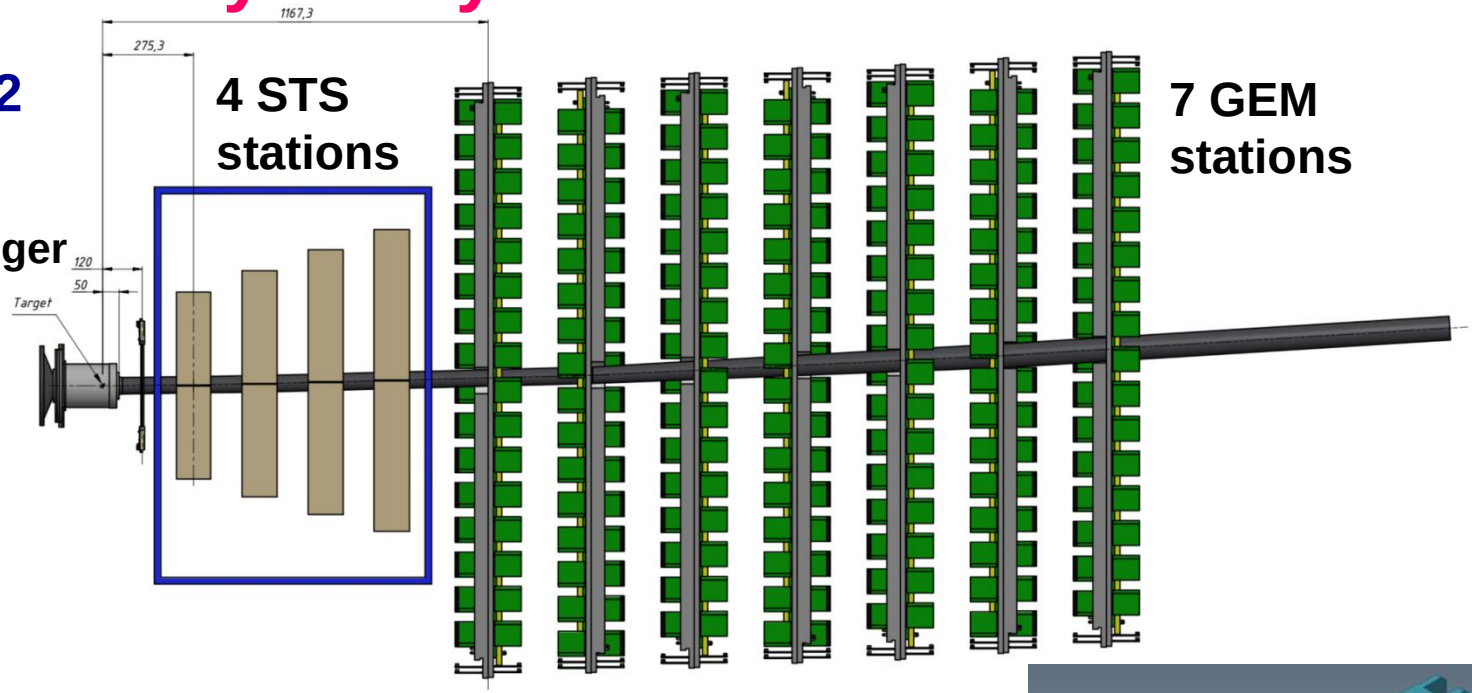
Transitional Hybrid Central Tracker for heavy ion runs: Forward Si +“Pilot” STS + GEM



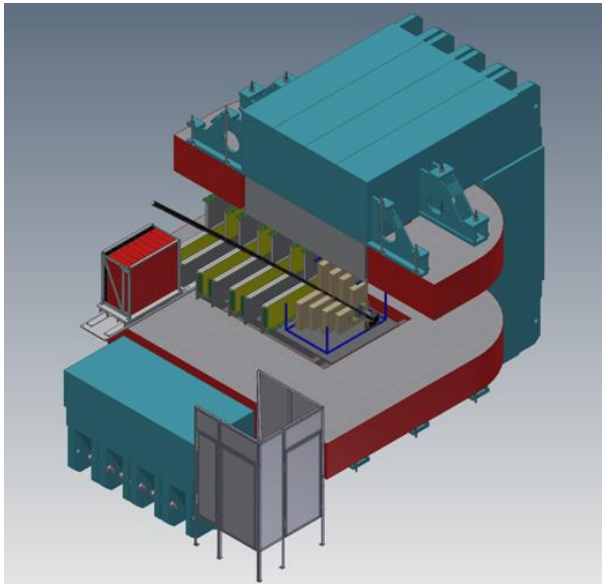
Heavy ion beam intensity ~few 10^5 Hz

Final Hybrid Central Tracker for high intensity heavy ion runs: STS +GEM

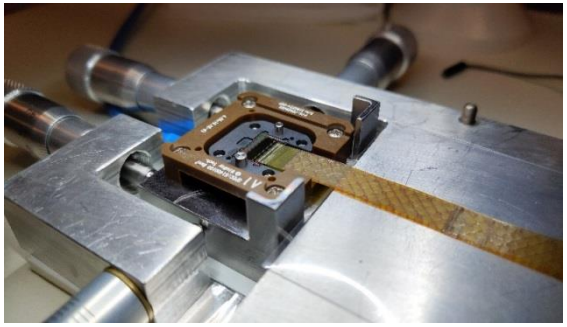
after 2022



For heavy ion beam intensities of few 10^6 Hz
→ keep 4 STS + 7 GEM
→ fast FEE and readout electronics

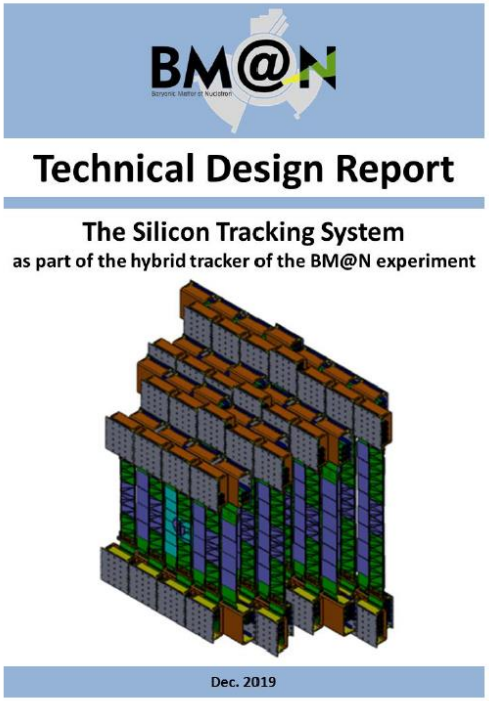


Status of BM@N STS



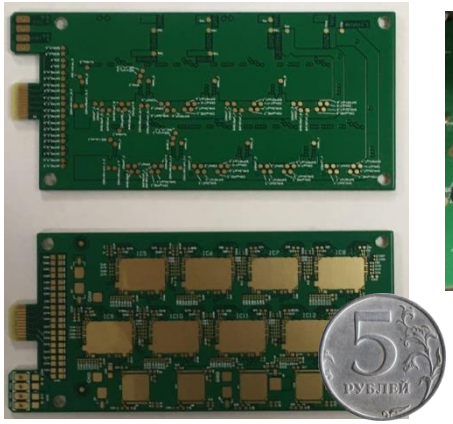
Quality Assurance tests of the modules were developed and tested on the first assembled modules. Module assembly procedure was improved with the aim to minimize the number of not-operable channels (less than 3%)

Ladder Assembly Device and corresponding fixtures were developed and produced for the assembly of the BM@N and CBM ladders. Accuracy of the sensor positioning is tested.



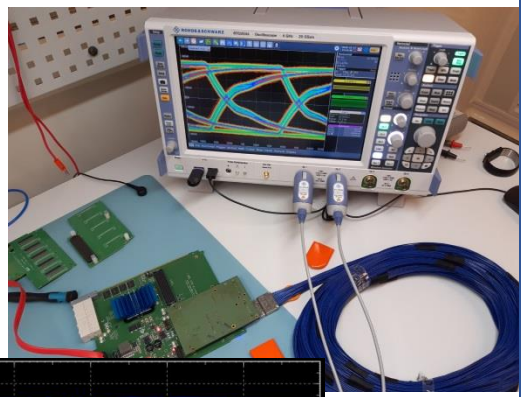
Dec 2019: TDR - to be approved by DAC
Joint effort by the groups from JINR, NRNU MEPhI, SINP MSU, GSI, WUT

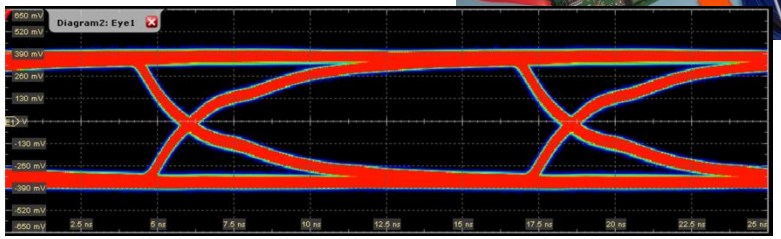
Status of BM@N STS Readout Electronics



New version of BM@N FEB with 8 STSXYTER ASICs

GBTxEMU board





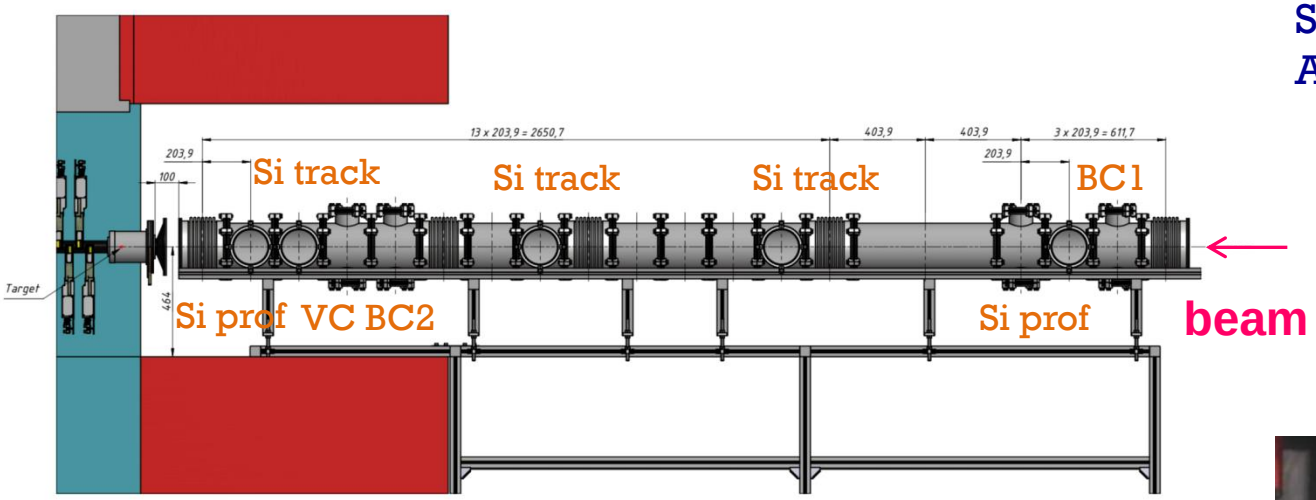
SI test of the e-link connection between FEB and GBTxEMU board

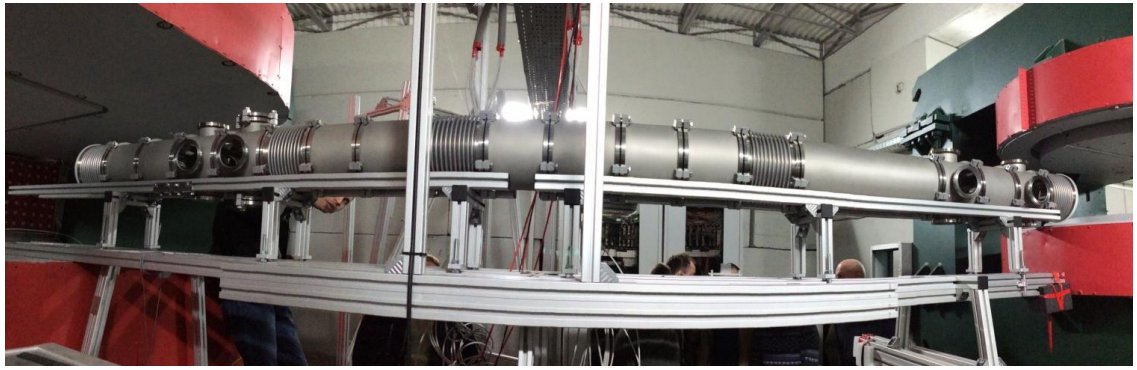
Adaptation of the CBM-type readout chain for the BM@N STS system:

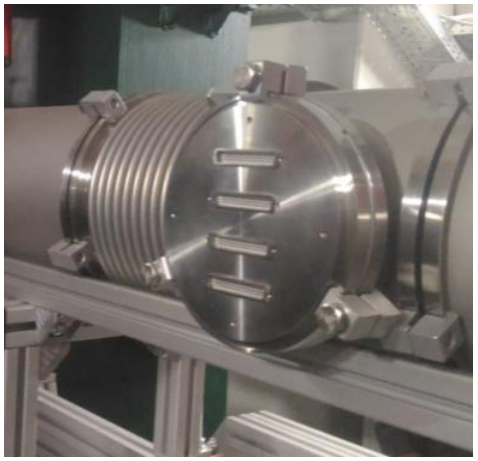
- A new version of the Front-End Board (FEB) was developed and produced. It is adopted to the integrational and cooling requirements of BM@N STS. *(MSU group)*
- Different types of data cables were tested to provide 10m LVDS connection between the front-end electronics and GBTxEMu board. *(JINR group)*
- A GBTxEMU board based on the Xilinx Artix 7 FPGA module was developed, produced and tested *(GSI group)*

Beam pipe in front of the target

S.Piyadin
A.Kubankin (Belgorod Uni)



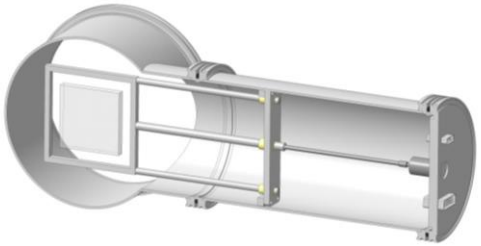




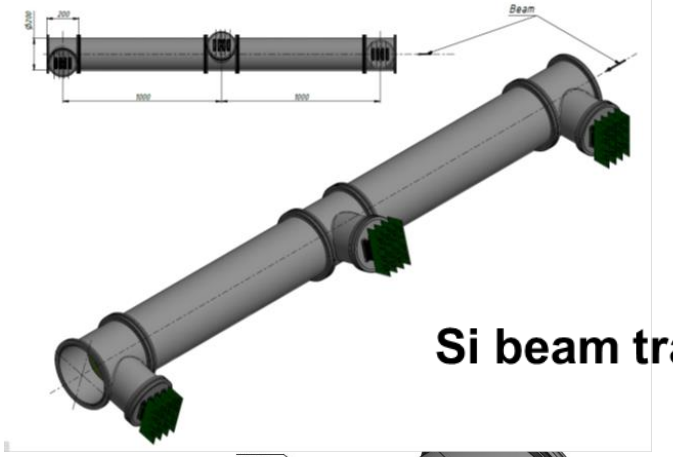
- **Beam pipe elements and detector boxes are produced and delivered to Dubna**

Beam, Si tracking detectors and target station

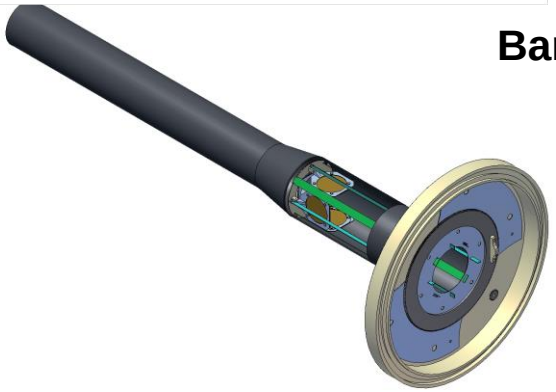
S.Piyadin, Yu.Gusakov
A.Kubankin group (Belgorod)
Group of N.Zamiatin



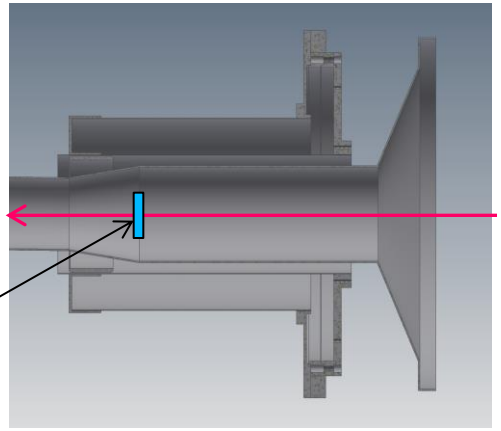
Movable beam profile detector



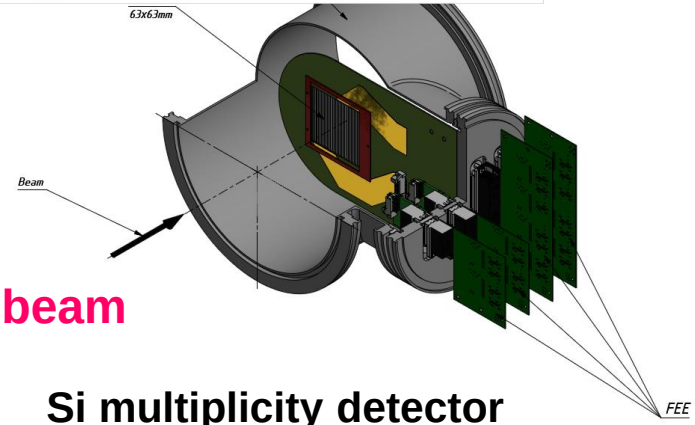
Si beam tracker



Barrel detector around target

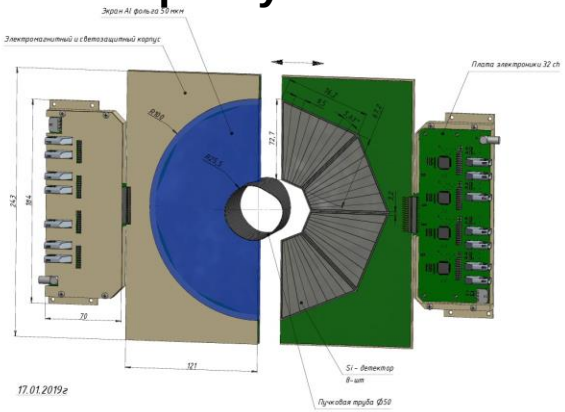


Target station with 3 targets in vacuum box



beam

Si multiplicity detector

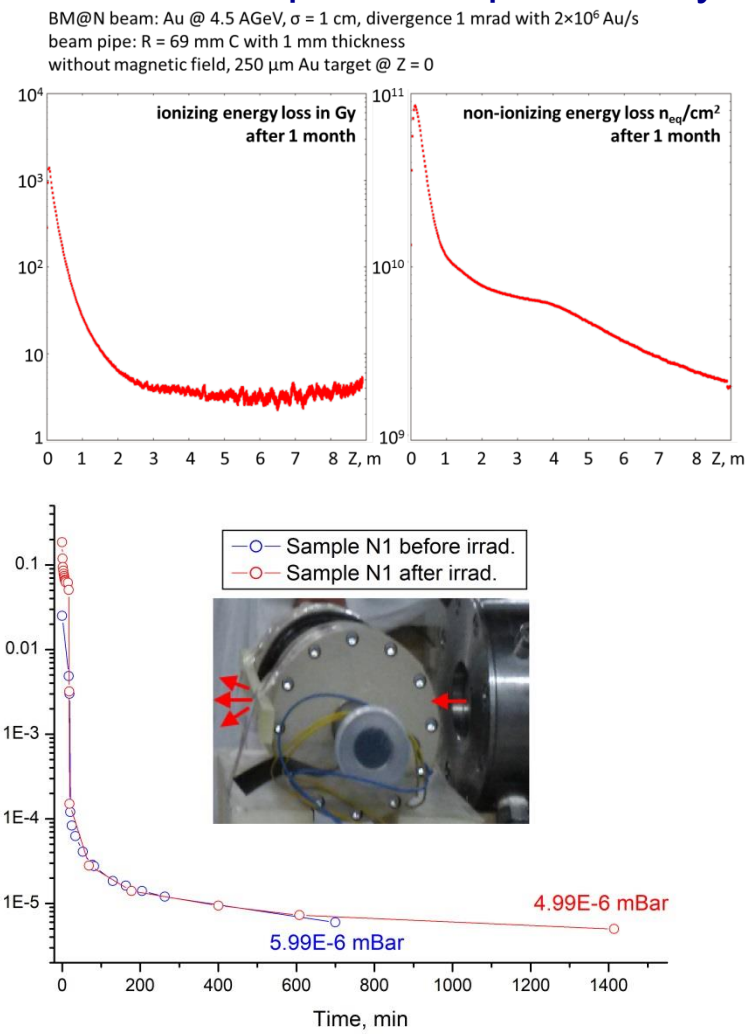


►All detectors and target station to be ready by spring 2021

Carbon fibre beam pipe for heavy ion runs

- DD "Arkhipov" (Moscow, Russia) – 1m test sample of carbon beam pipe is ready
- Vacuum tests of the sample are to be performed this week in LHEP JINR

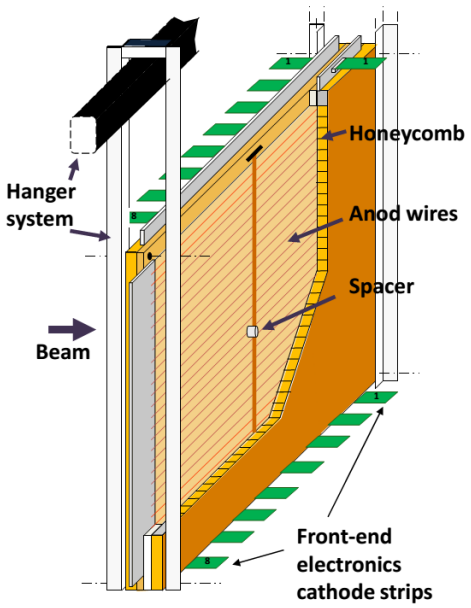
NPI CAS Rez group: irradiation tests done with $7 \cdot 10^{12}$ n/cm^2 neutrons
→ next test with protons up to 1 kGy



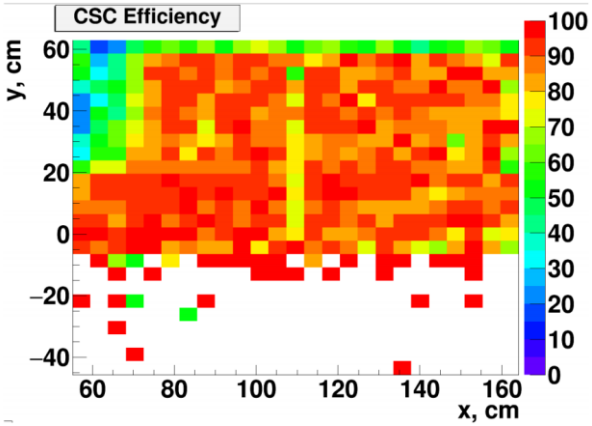
CSC chambers for Outer tracker in heavy ion runs

A.Vishnevsky and team, LHEP JINR

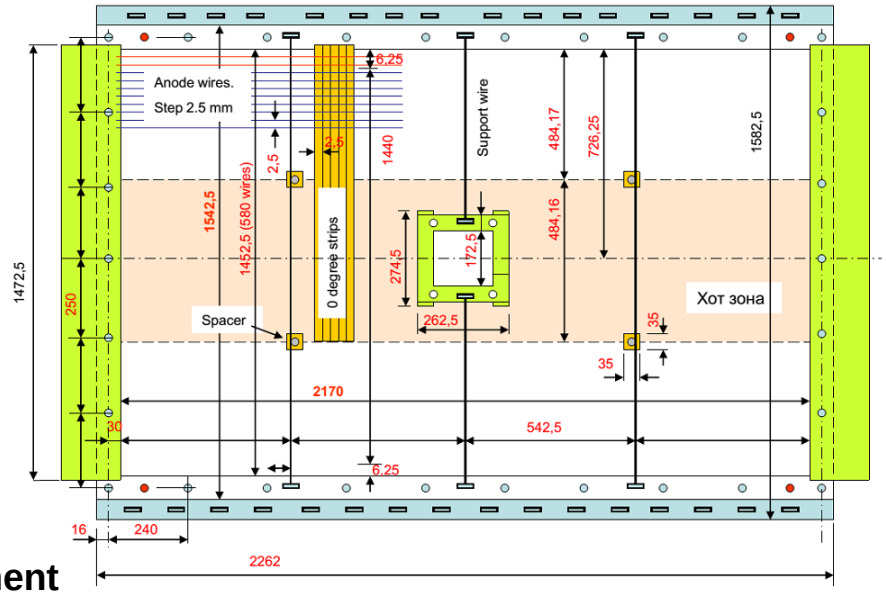
- Four 1065x1065 mm^2 CSC chambers to be installed in front and behind ToF-400 should be ready by end of 2020
- Two 2190x1453 mm^2 CSC chambers to be installed in front and behind ToF-700 should be produced in 2021



First 1065x1065 mm^2 CSC chamber in BM@N Ar run



CSC efficiency in Ar run

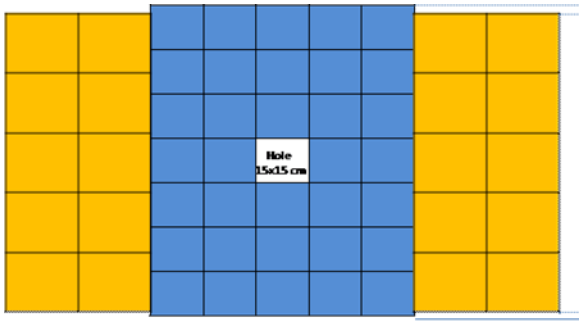


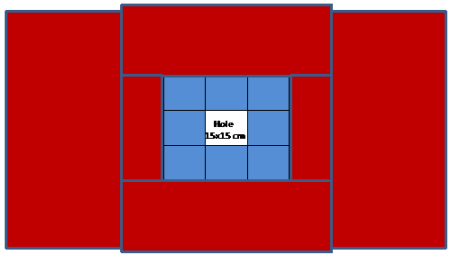
New FHCAL hadron calorimeter

Team of INR RAS, Troitsk

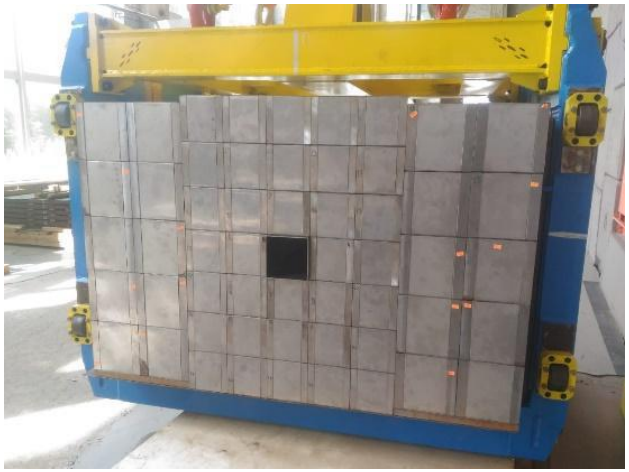
- **FHCAL assembled and installed into BM@N setup**
- **Cosmic tests are under way**

CBM modules MPD modules





$$A_E = \frac{E_{dep}\ (blue) - E_{dep}\ (red)}{E_{dep}\ (blue) + E_{dep}\ (red)}$$



Measure E_{dep} v Asymmetry of E_{dep} and ΣZ^2 with quartz hodoscope in the beam hole to resolve central and peripheral interactions

Beam parameters and setup at different stages of BM@N experiment

Year	2016	2017 spring	2018 spring	fall 2021	2022 and later
Beam	d(↑)	C	Ar,Kr, C(SRC)	Kr,Xe	up to Au
Max.intensity, Hz	0.5M	0.5M	0.5M	0.5M	2M
Trigger rate, Hz	5k	5k	10k	10k	20k→50k
Central tracker status	6 GEM half planes	6 GEM half planes	6 GEM half planes + 3 forward Si planes	7 GEM full planes + forward Si planes	7 GEM full planes + forward Si + large STS planes
Experimental status	technical run	technical run	technical run+physics	stage1 physics	stage2 physics

BM@N present status and next plans

- First BM@N paper with physics results on Λ hyperon production in C + C, Al, Cu, Pb interactions is in circulation in the BM@N Collaboration
- TDR report on the large aperture Silicon Tracking System of the BM@N experiment is released
- Progress in hardware development and production for heavy ion program:

►Full set of GEM detectors for the central tracker is produced and delivered to BM@N

►Development of forward silicon detectors, silicon beam detectors is according to time plan

►Development of STS detectors, FEE and readout electronics

►Development and production of cathode strip chambers for the outer tracker

►Beam pipe in front of the target produced and delivered to BM@N

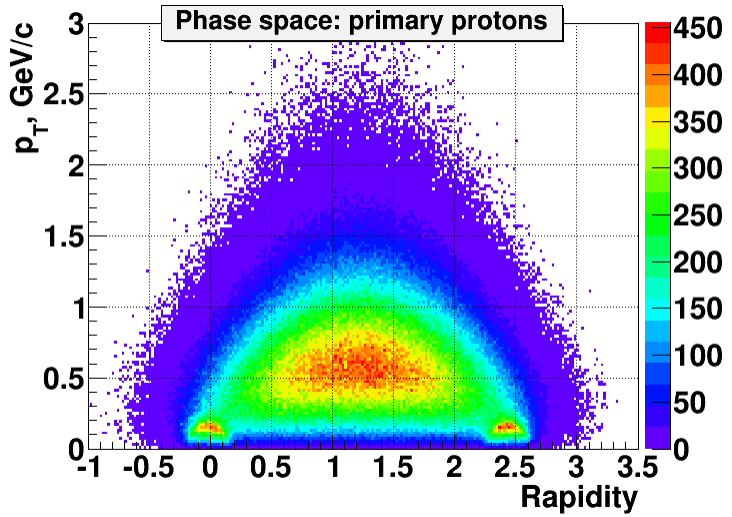
►Prototypes of carbon fiber beam pipe are under tests for vacuum and radiation resistance

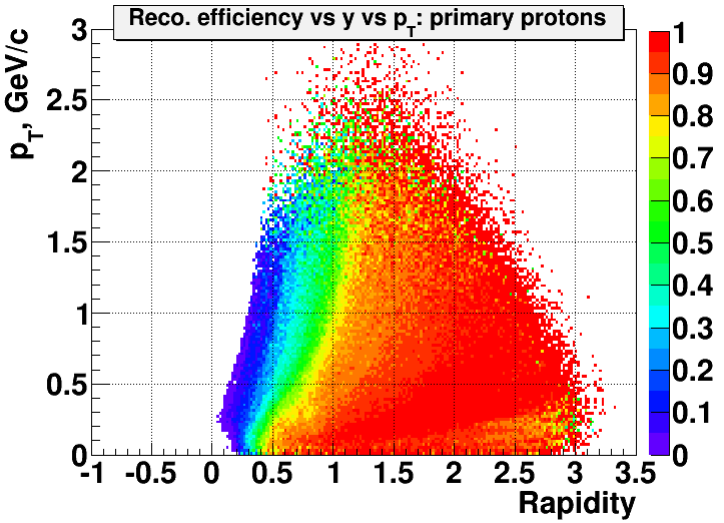
►MPD / CBM type of hadron FHCAL calorimeter installed into BM@N setup

Thank you
for attention!

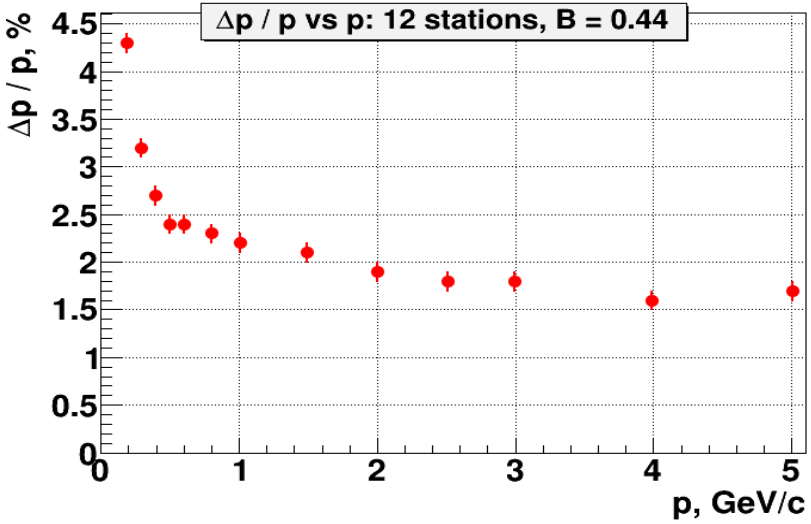
GEM tracker: acceptance / momentum resolution / detection efficiency

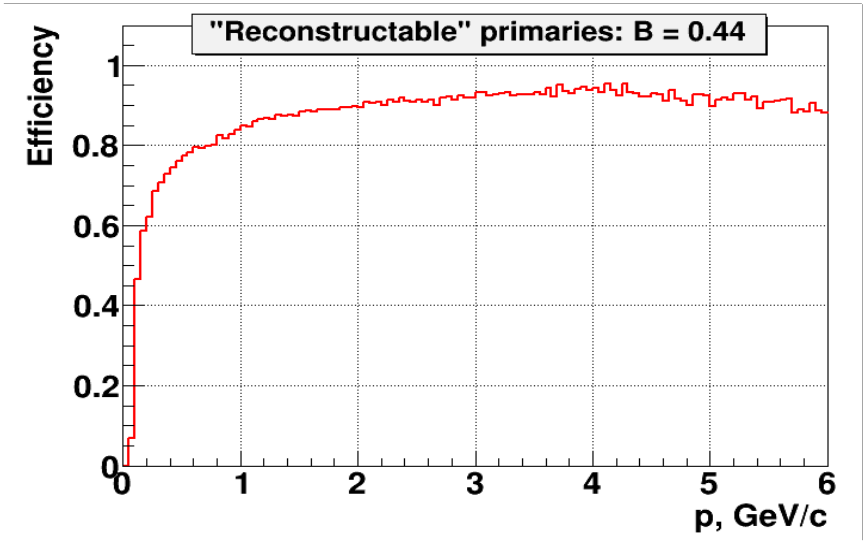
Phase space / acceptance to primary protons: Au+Au, 4.5 AGeV





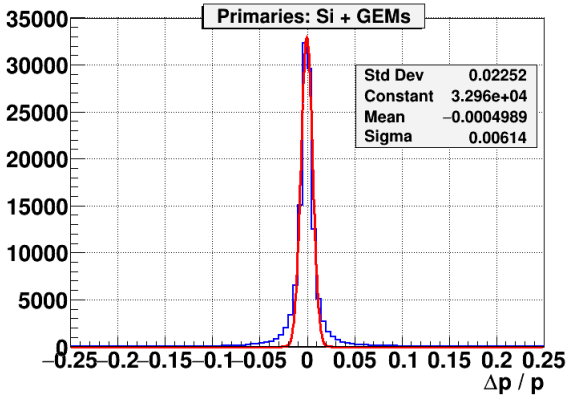
Momentum resolution / detection efficiency

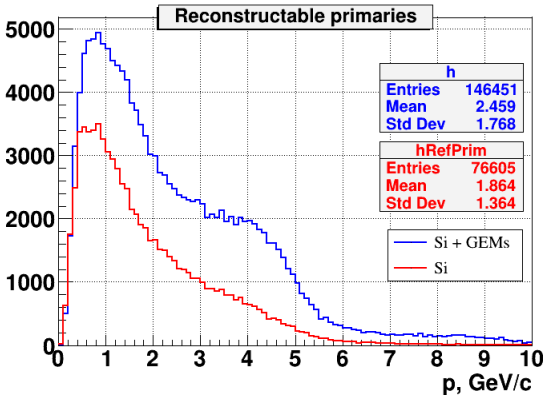


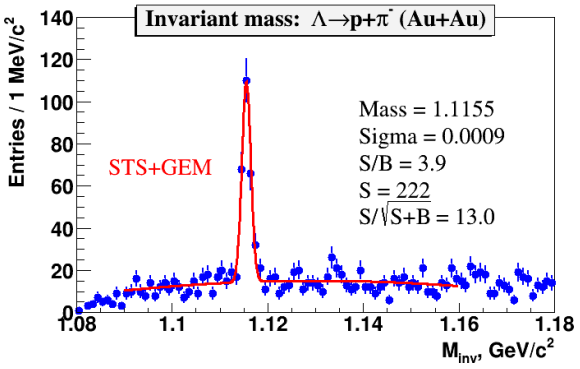


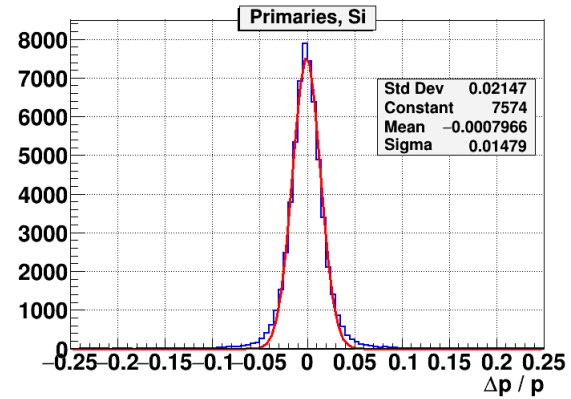
Hybrid central tracker for heavy ion runs: STS vs STS +GEM

A.Zinchenko, P.Senger

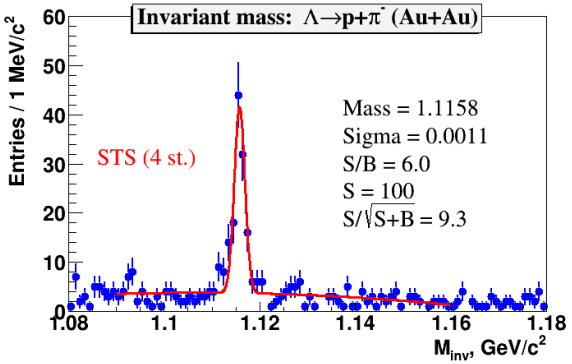






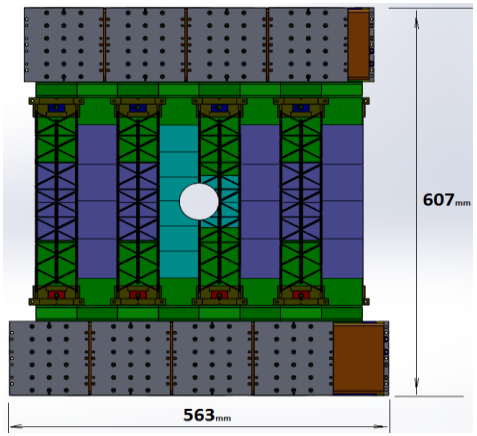


Hybrid STS + GEM tracker:
► 2 times increase in number of reconstructed tracks and Λ hyperons
►2 times better momentum resolution



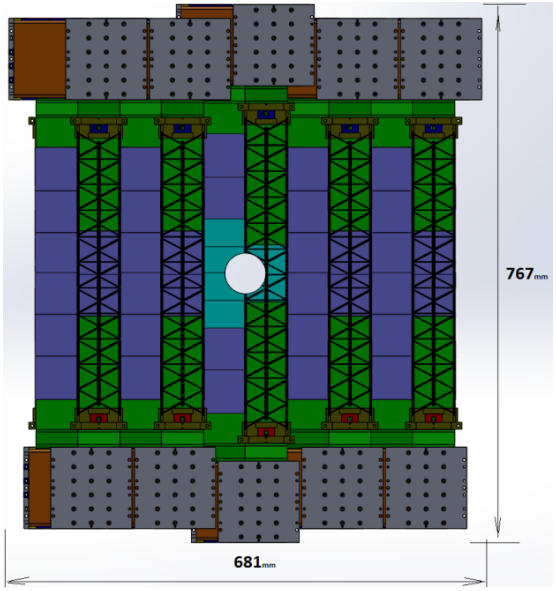
Upgrade of central tracker with STS

STS-1

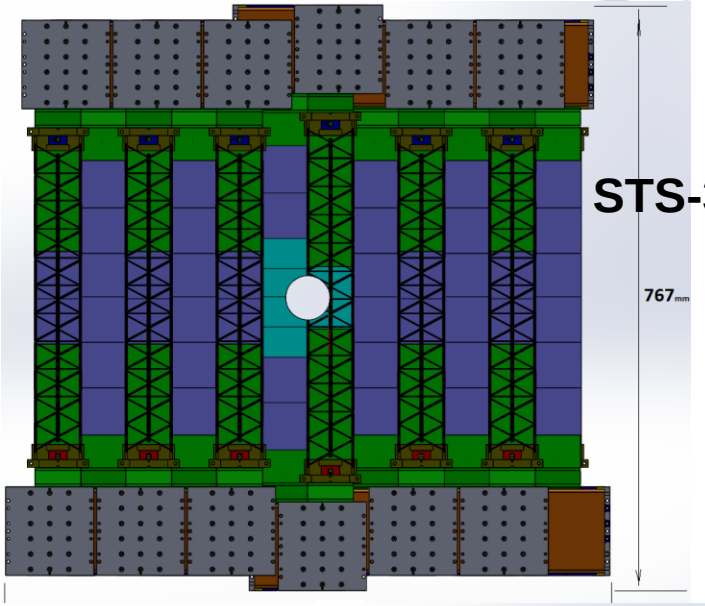


Team: LHEP JINR, MSU, GSI, Tübingen University

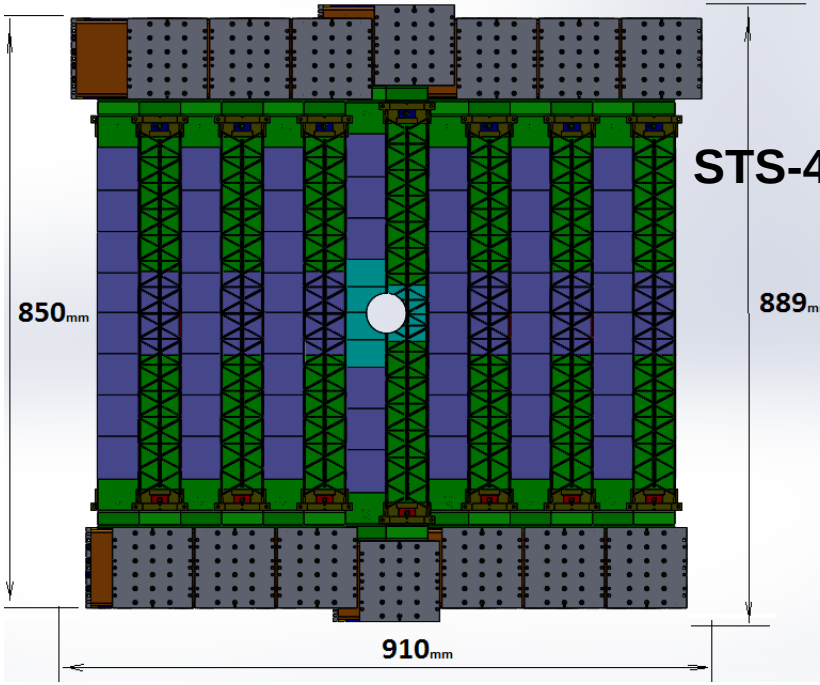
STS-2



STS-3



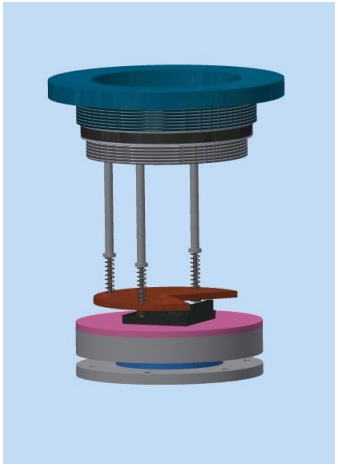
STS-4



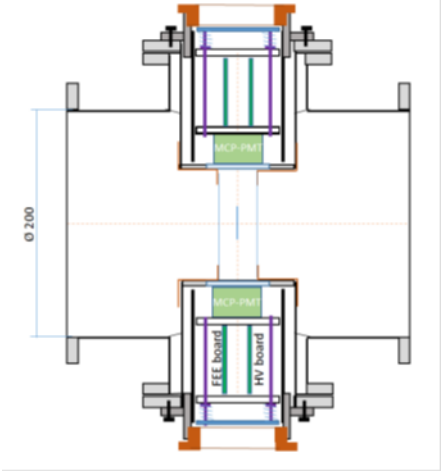
Total: 292 modules, ~600k channels

Trigger and T0 detectors for heavy ions

Trigger group

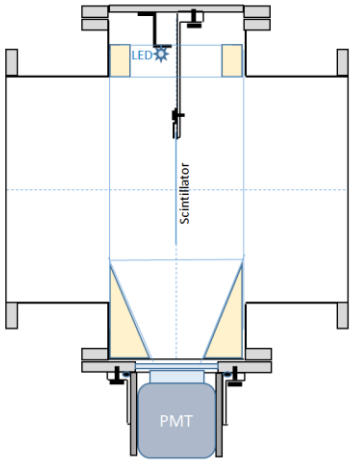


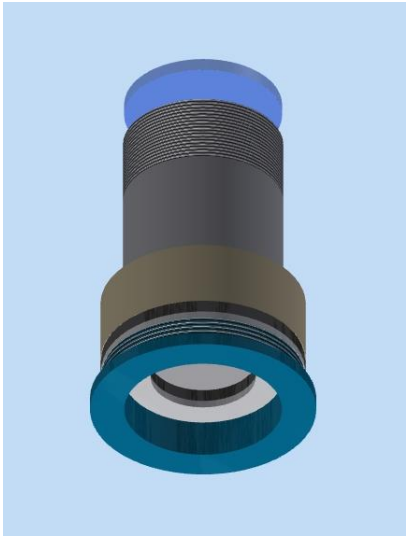
Box for BC2 counter

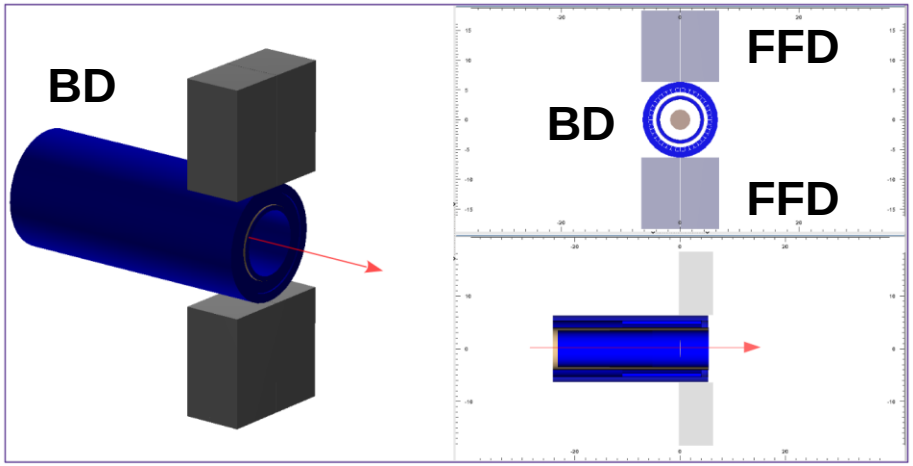


beam

Box for BC1, Veto



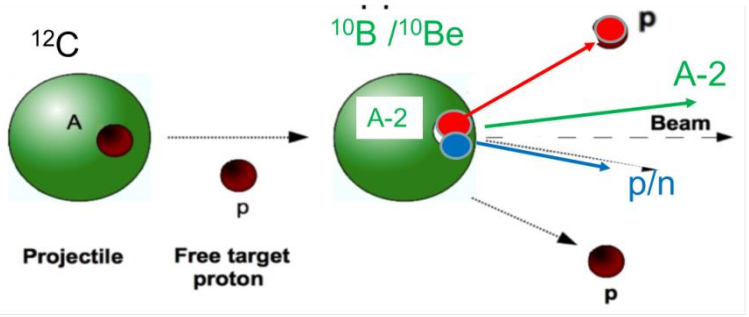




Fast quartz FFD detectors for high intensity heavy ions

BMN & SRC program

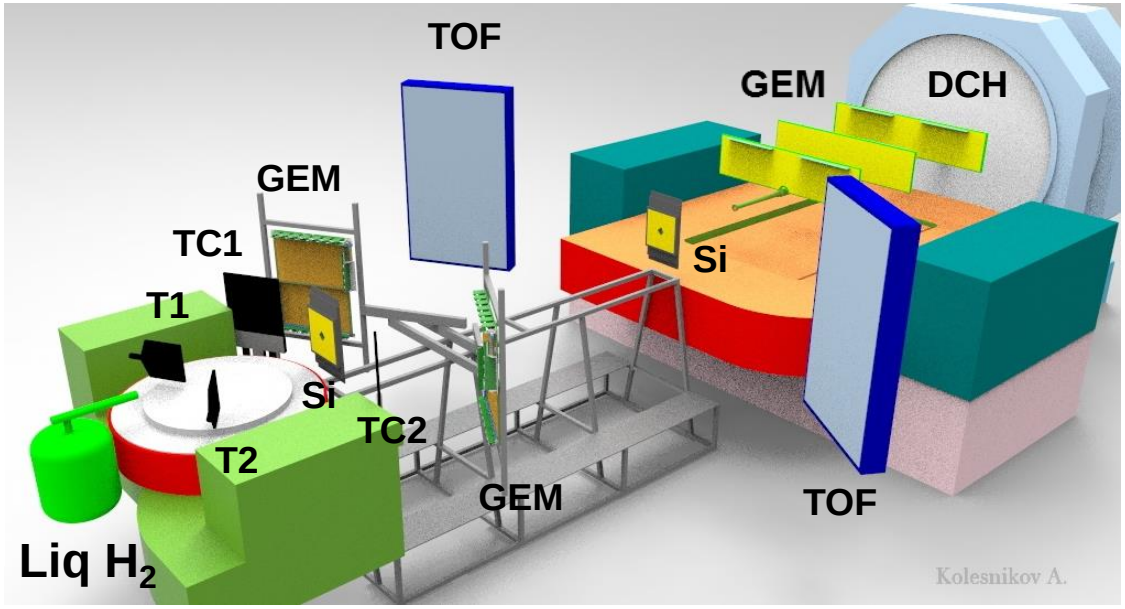
to study SRC with exclusive inverse kinematic reactions



$$^{12}C + p \rightarrow 2p + {}^{10}_{5}B + n \qquad \text{np SRC}$$

$$^{12}C + p \rightarrow 2p + {}^{10}_{4}Be + p \qquad \text{pp SRC}$$

First SRC @ BMN run in March 2018



Objectives:

- identify 2N-SRC events with inverse kinem
- study isospin decomposition of 2N-SRC
- study A-2 spectator nuclear system

First expected result:

- Study A-2 residual system after SRC knockout

Combined PID of outgoing fragments + SRC trigger