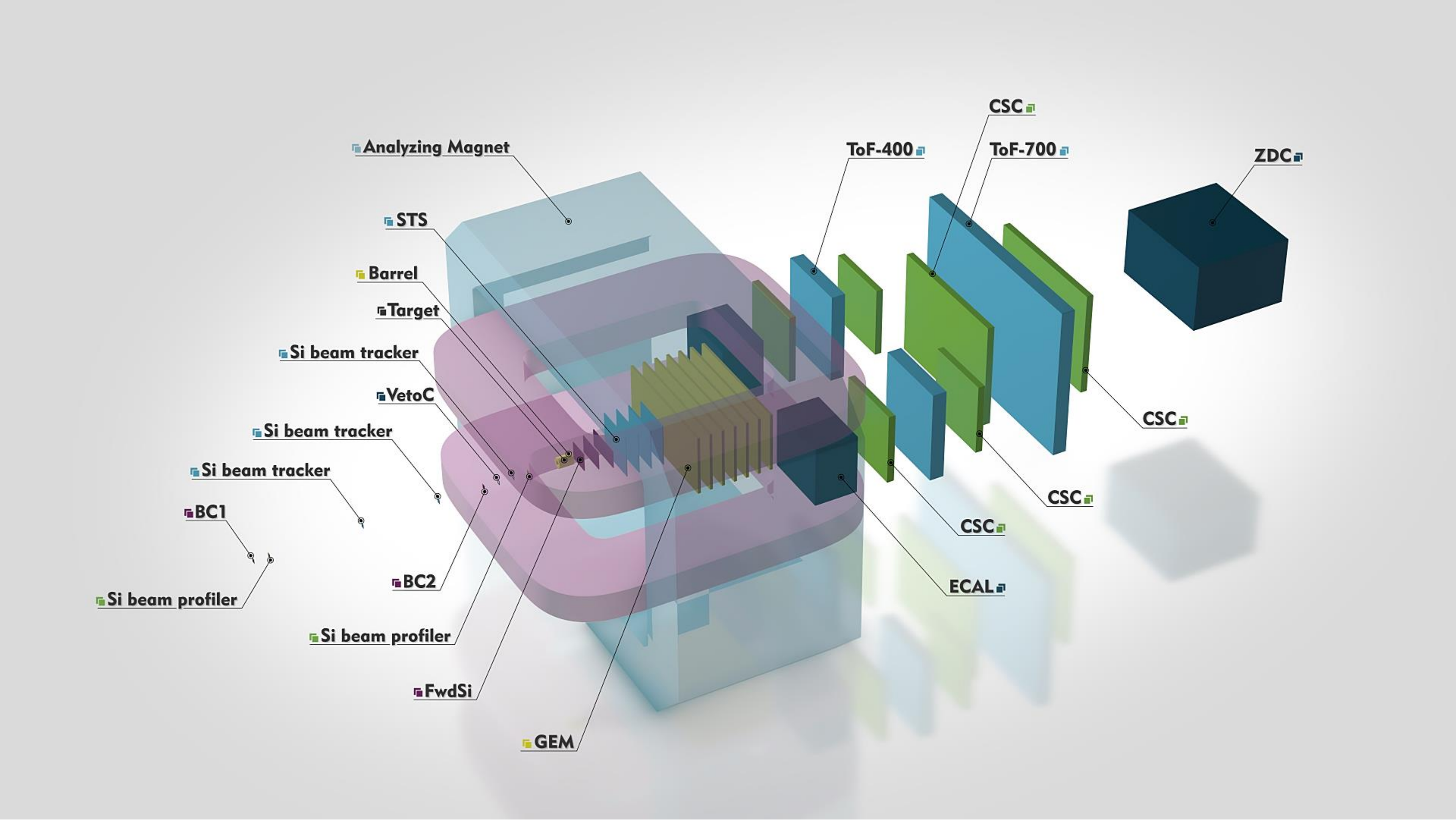
Status of the BM@N detectors upgrade

Anna Maksymchuk on behalf of the BM@N Collaboration

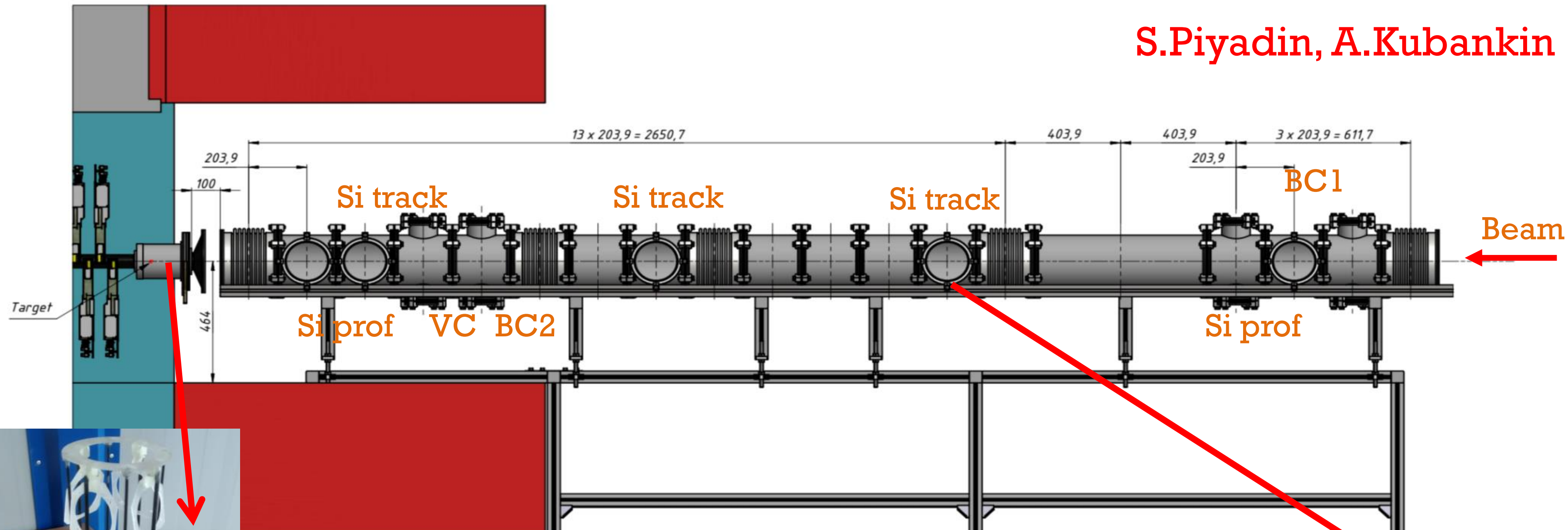
19/01/2021

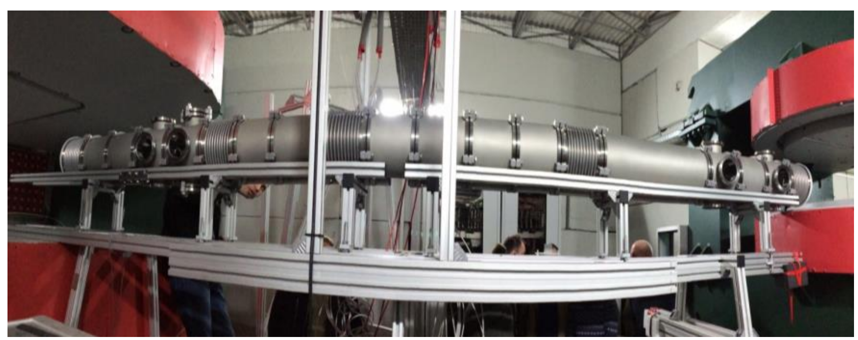
BM@N Experimental Setup

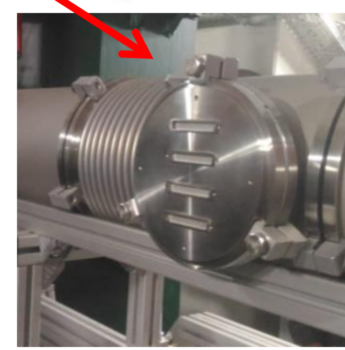


Beam pipe before the target

S.Piyadin, A.Kubankin





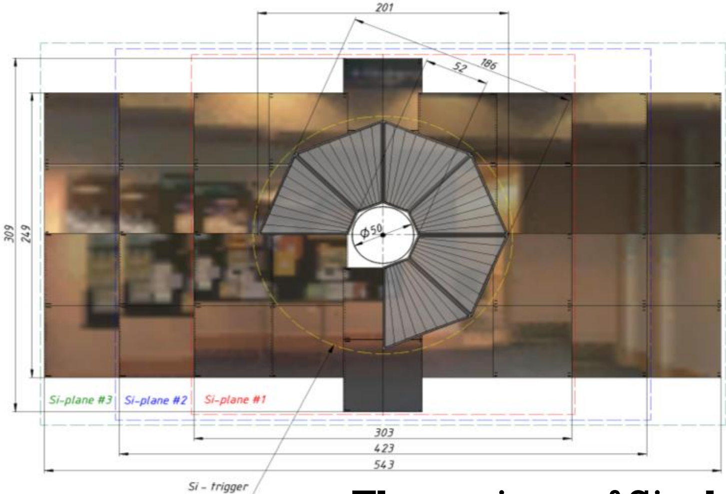


Four stainless steel vacuum boxes downstream the target are replaced by aluminum ones.
The design and production of the target station pneumatic actuator mechanics is performed by A.Kubankin group.

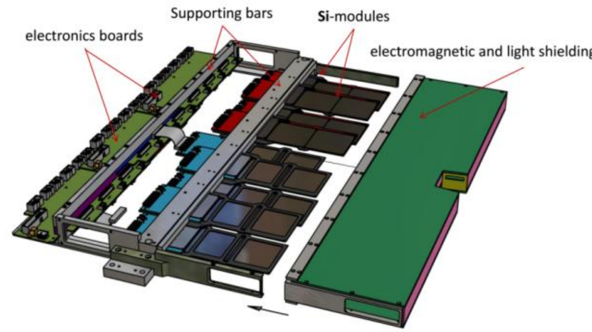
Production of the beam pipe: Belgorod University

See talk of S.Sedykh

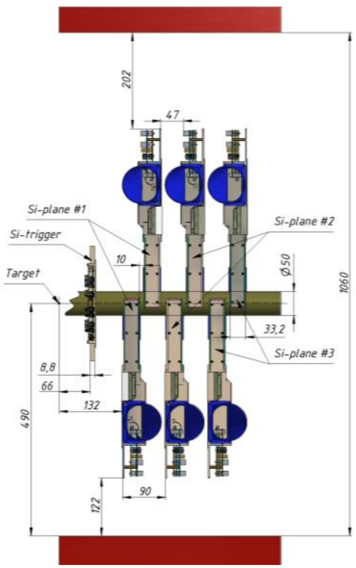
Upgrade of the forward Si tracking detectors

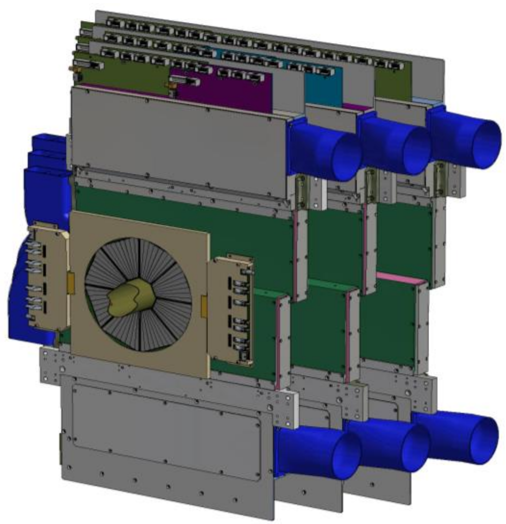


Three sizes of Si-planes



Half-plane design





Design of the Si-planes
on the BM@N beam-channel

group of N.Zamiatin

Station#	Number of DSSD modules	DSSD station square	Number of Readout channels
Station1	10	720 cm^2	12800
Station2	14	1008 cm^2	17920
Station3	18	1296 cm^2	23040
Total	***42***	***~0.3 m^2***	***53760***

Upgrade of the forward Si tracking detectors

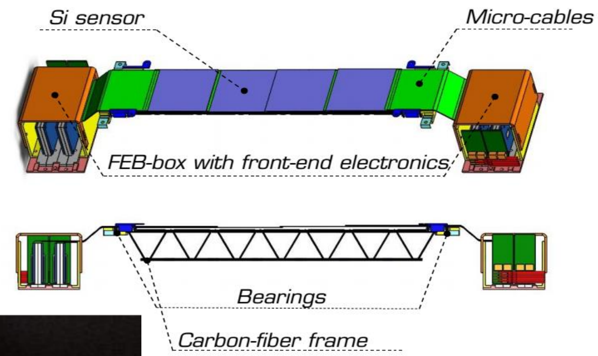


group of N.Zamiatin

Plans and status:

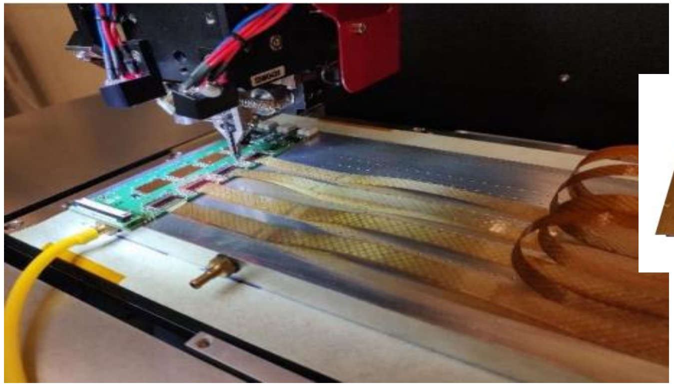
- Test bench for module tests with cosmic rays and r/s ^{106}Ru is under development
- Clean room for the module assembly is ready
- Assembly and tests of the FEE-640 ch. – 02.2021
- Assembly and tests of the detector modules with r/a source - 03.2021
- Assembly of the Si-planes, measurements of the positions and tests with r/a source and cosmic rays – 09.2021
- Installation of the planes into the SP-41 magnet together with cooling, LV, HV, Slow control systems – 07.2021-10.2021

BM@N STS



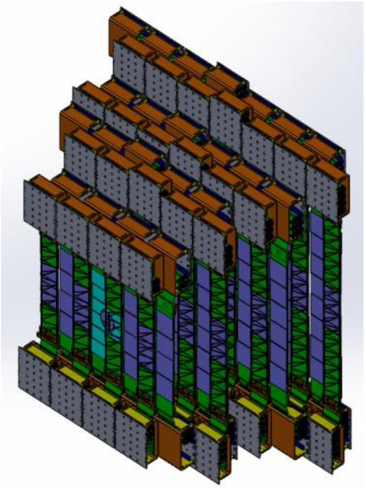
Four stations are based on CBM-type modules with double-sided microstrip silicon sensors:

- Pitch 58μ
- Stereo angle 7.5°
- Thickness 300μ
- Sizes: 62x62, 62x42 mm²



Module assembly

Assembled module covered with shielding



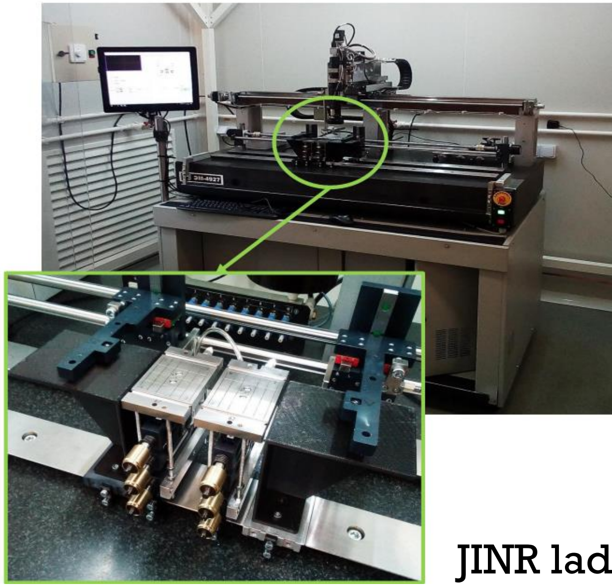
Number of modules: 292
Number of channels: ~600k
Number of ladders: 34
Power consumption: ~15 kW

Current status:
• Set of jigs was developed and produced;
• Assembly workflow developed and tested on the mockups and first operational modules;
• QA tests were developed and implemented in Elog;
• **JINR assembly team is ready to start serial production of STS modules in Feb. 2021 if supplying components from GSI on the regular base is established and financed.**

• 2022 – pilot v. of STS based on two stations with 42 modules
• 2023-2024 – expansion of the system to 292 modules *provided priority given to BM@N STS and not CBM STS*
Delays of the project caused by pandemic control measures in Russia – ½ year

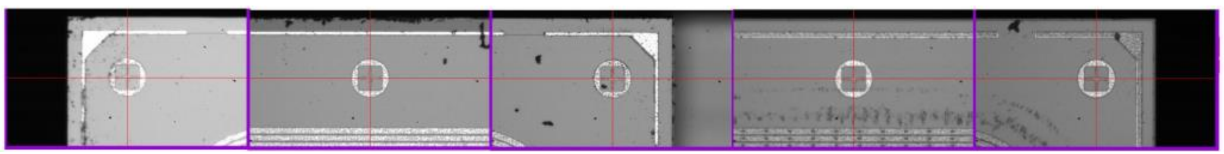
STS group

Status of BM@N STS

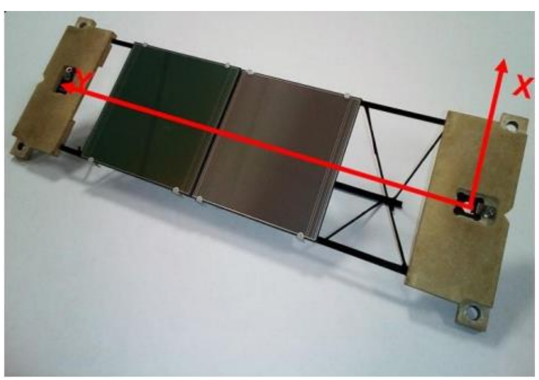


LAD consists of:
• optical system, which is used for the monitoring of the sensor position in a horizontal plane and has an accuracy of 2μm.
• different sets of sensor positioning tables with microscrews
• lift unit for the vertical displacement of the ladder sensor supporting CF truss.
• Device is installed on the heavy diabase table to avoid vibrations of the LAD during operation.
LAD should provide the following accuracy of the sensor positioning:
X coordinate: ±15 μm on 1200 mm along the truss;
Y, Z coordinates: ± 50 μm across the truss;

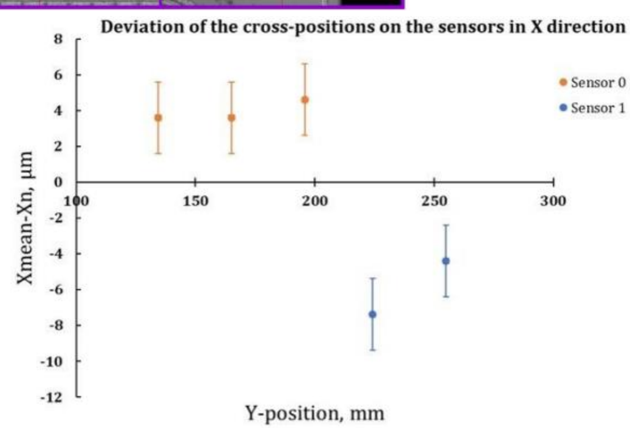
JINR ladder assembly device



Fiducial marks on the sensor



Mockup of the ladder



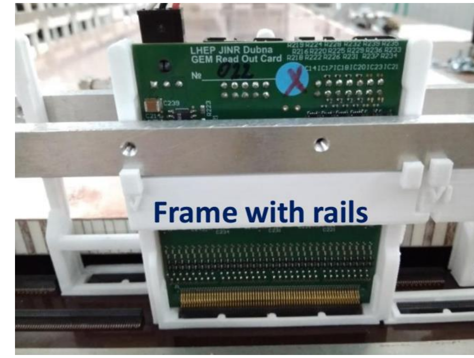
Measured deviations of X coordinates of the fiducial marks on the sensors from the mean value

GEM central tracking system status

Stand for long-term GEM tests

First stage – tests of 1632*390 mm^2 detectors
Second stage – tests of 1632*450 mm^2 detectors

Trigger system – ten 10*200 cm^2 scintillation detectors



Frames for FEE electronics

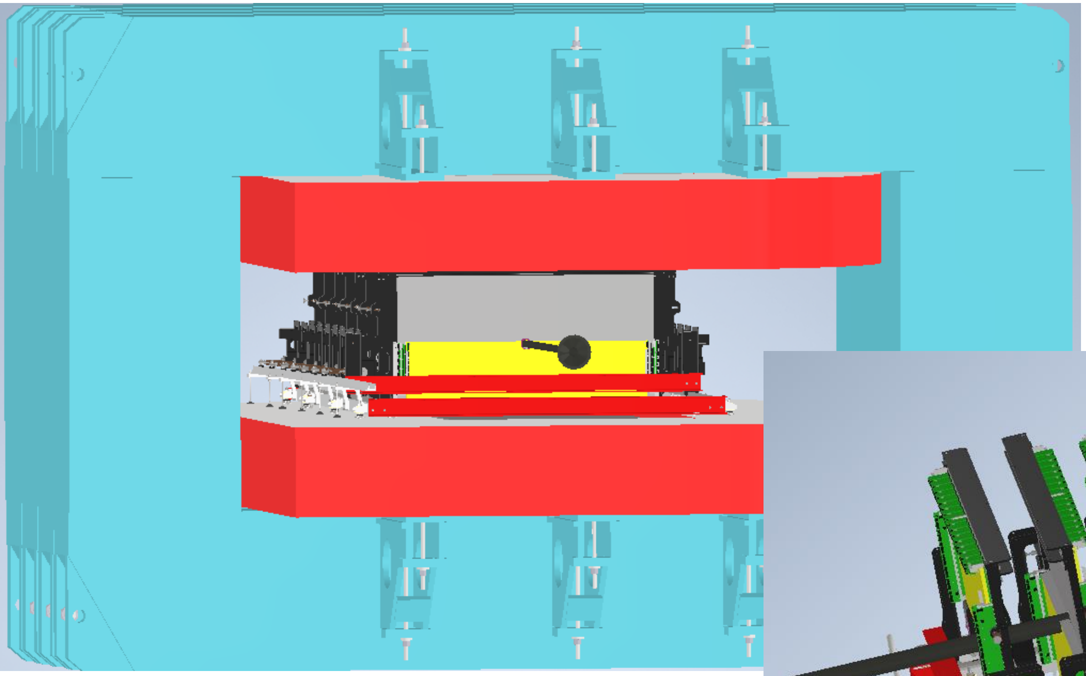
Status and plans:

- 14 GEM detectors are assembled and pass long-term quality tests cosmic test-bench
- 2 spare detectors are to be assembled at CERN at summer 2021 (all parts are ready)
- Data on spatial efficiency, resolution and response uniformity is under analysis

GEM group

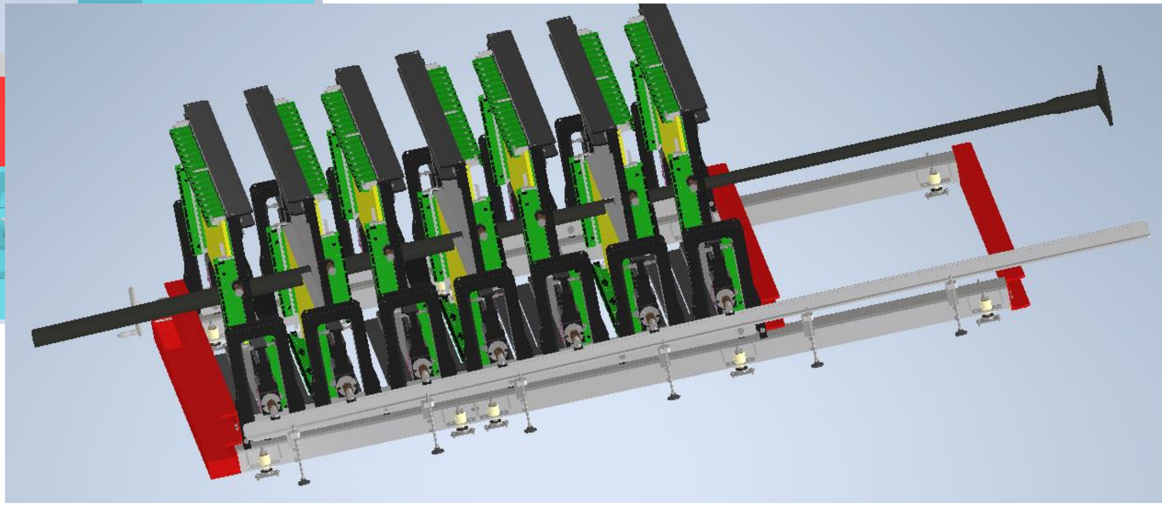
Status of the GEM support mechanics inside the SP-41 magnet

S. Piyadin, E. Kulish



Active area of the GEM tracking system ~ 9.5 m^2

Space for installation and alignment is limited by the magnet aperture

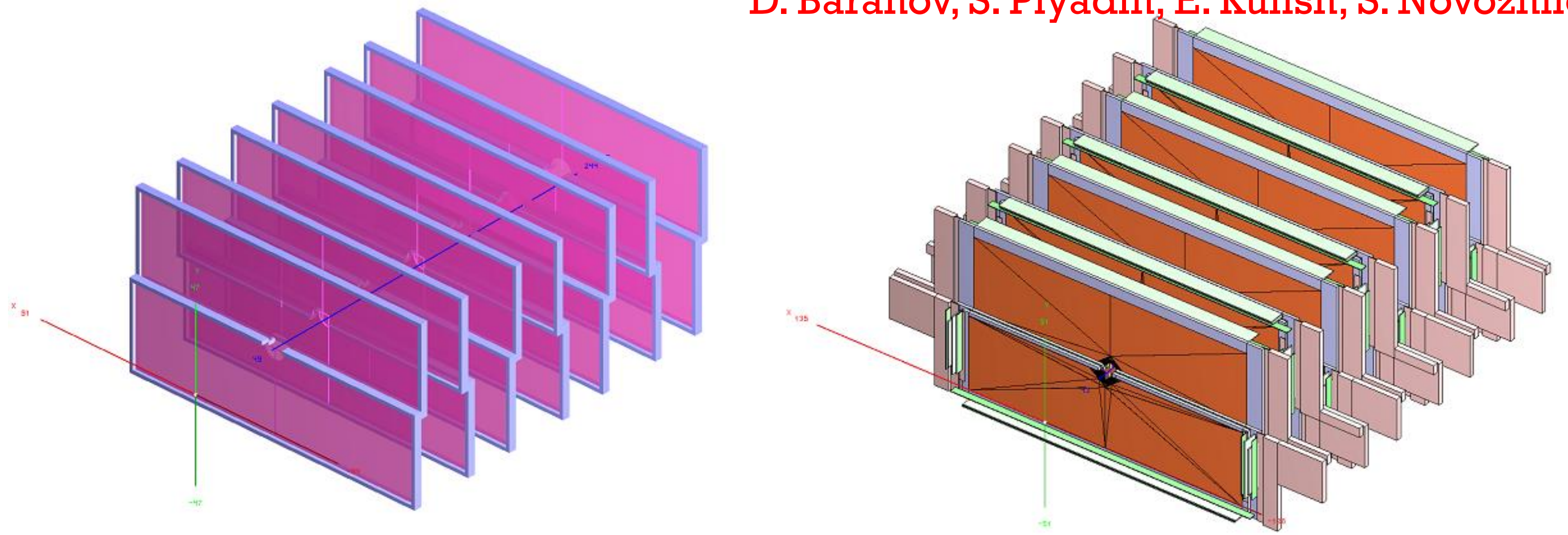


Development of the mechanics design for GEM planes precise installation inside the magnet was done by "Pelcom" (Dubna). Final cross-checks of the design are performed by BM@N chief engineer and GEM group. Technical documentation on the mechanics is at JINR.

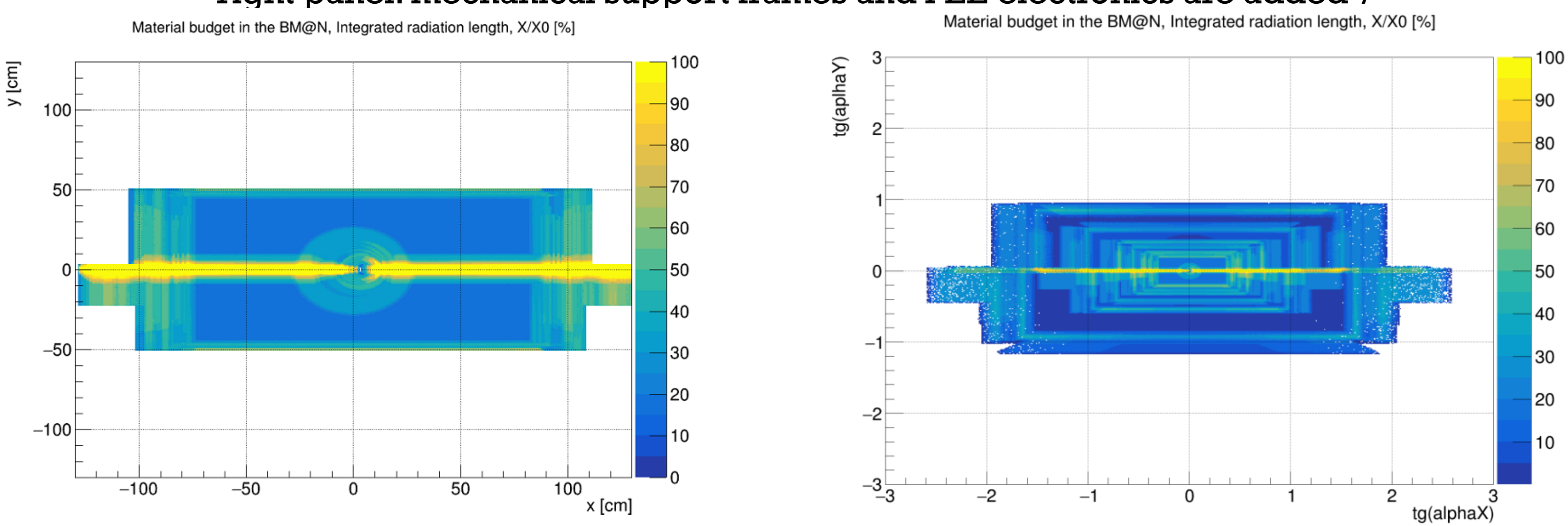
A tender procedure is initiated to select a manufacturer of support mechanics.

Full configuration of the GEM central tracking system

D. Baranov, S. Piyadin, E. Kulish, S. Novozhilov



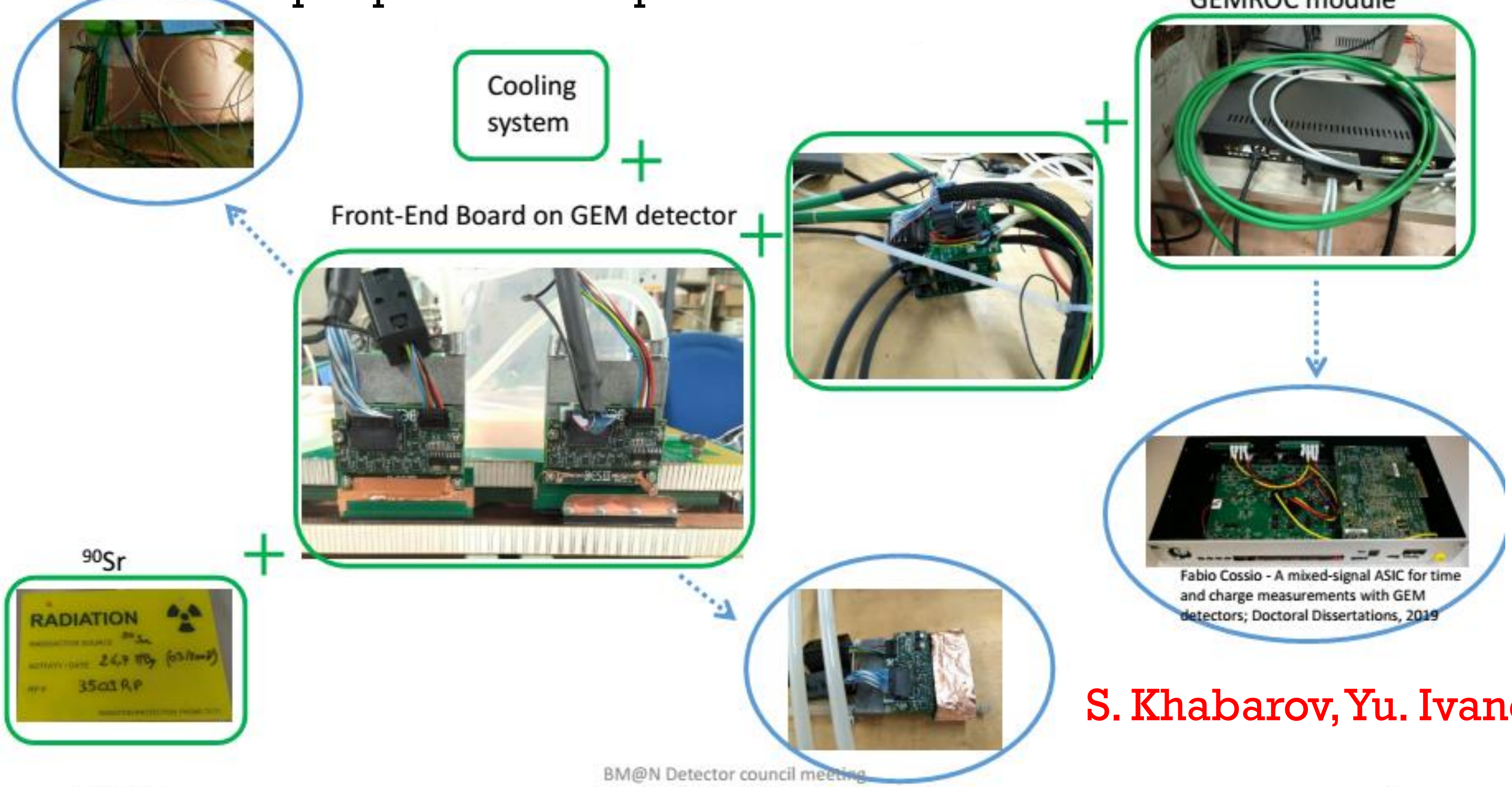
Detailed geometry of GEM planes for heavy ion beam runs (Left panel: GEM active areas, right panel: mechanical support frames and FEE electronics are added)



Material budget of the GEM central tracking system full configuration

Development of new FEE based on TIGER/VMM3a

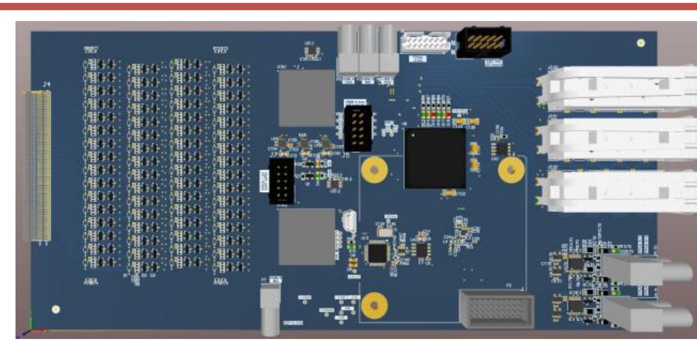
TIGER (**T**urin **I**ntegrated **G**em **E**lectronics for **R**eadout) tests at CERN. First run of TIGER FEE on GEM detector was performed. Next tests were planned on March 2020 at JINR, but postponed due to pandemic control measures.



S. Khabarov, Yu. Ivanova

Kintex7 based 128ch GEM evaluation board was designed and produced for **VMM3a** tests.

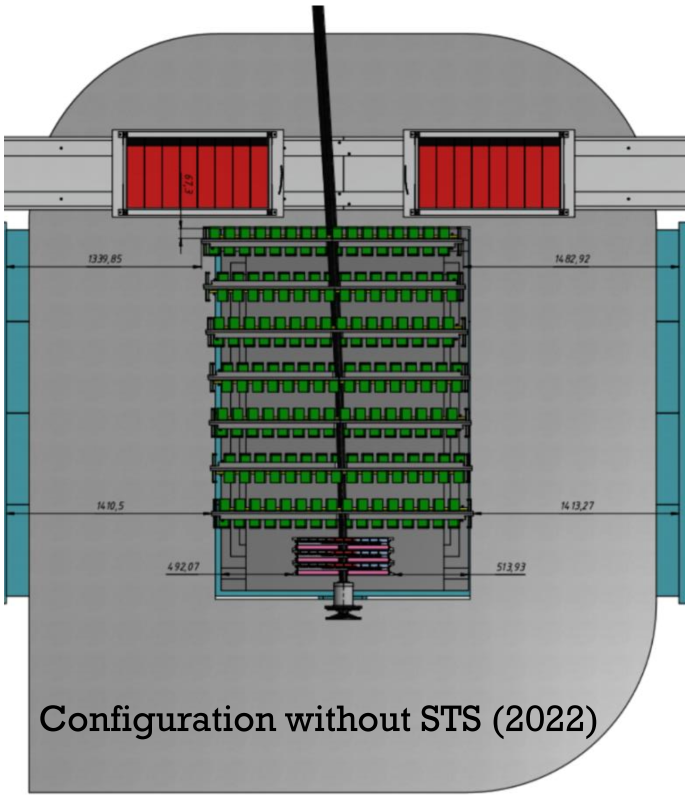
DAQ Group (V. Burcev)



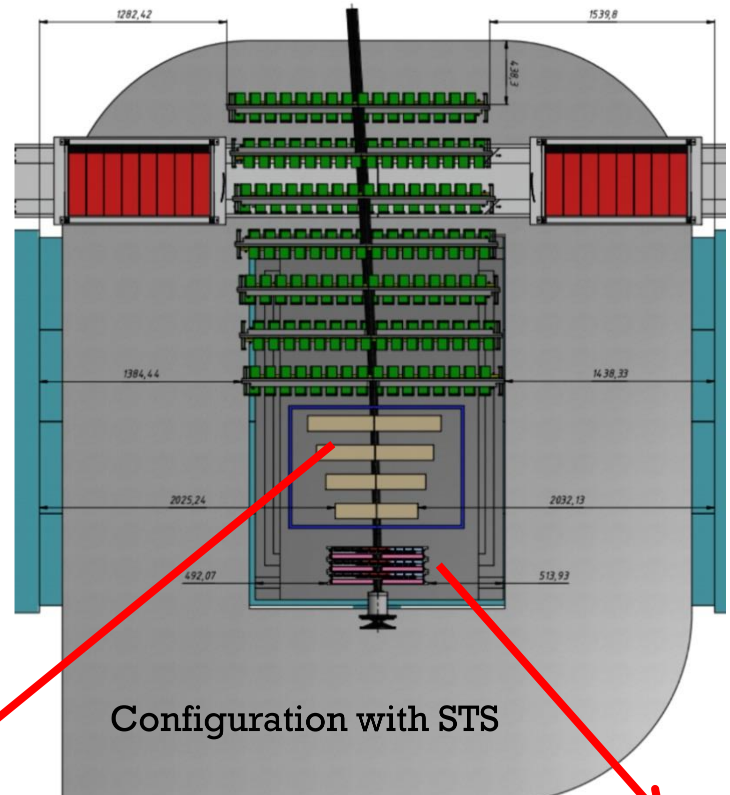
Forward Si+ STS +Gem configuration

Four configurations of the tracking detectors are foreseen:

- Forward Si + 7 GEMs: beam intensity few 10^5 Hz , 2022
- Forward Si + "pilot" STS station + 7 GEMs: beam intensity few 10^5 Hz , 2022
- Forward Si + 4 STS stations + 7 GEMs: beam intensity few 10^5 Hz, after 2022
- 4 STS stations + 7 GEMs (fast FEE): high beam intensity few 10^6 Hz, after 2022-



Configuration without STS (2022)

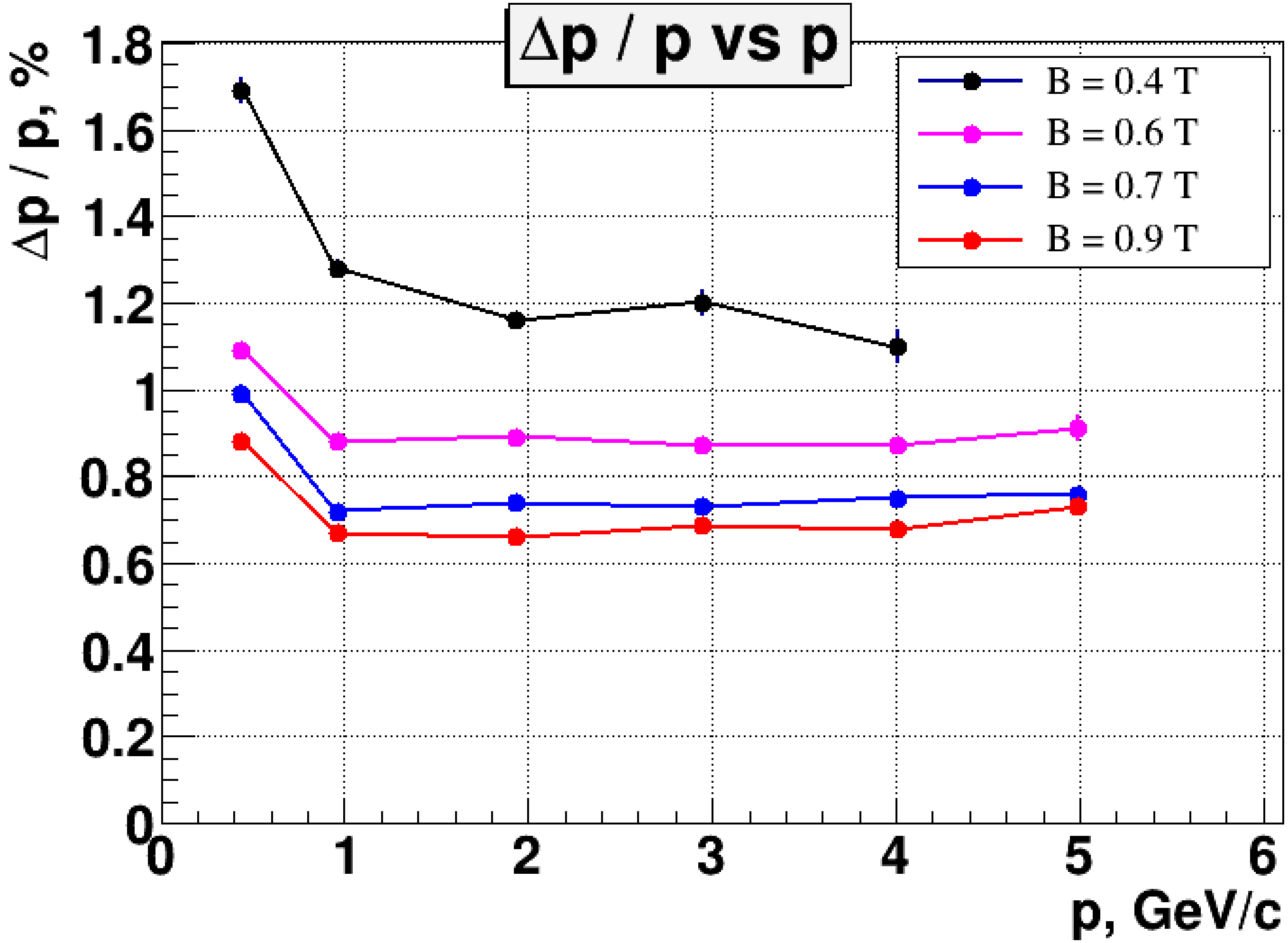


Configuration with STS

2022 year – "pilot" configuration
After 2022 year – full configuration

Forward Si will be removed after integration of STS full configuration into BM@N setup (after 2022 year, high beam intensity - few 10^6 Hz)

Hybrid central tracker STS+GEM momentum resolution for different magnetic field values



A.Zinchenko

Beam pipe inside the SP-41 magnet

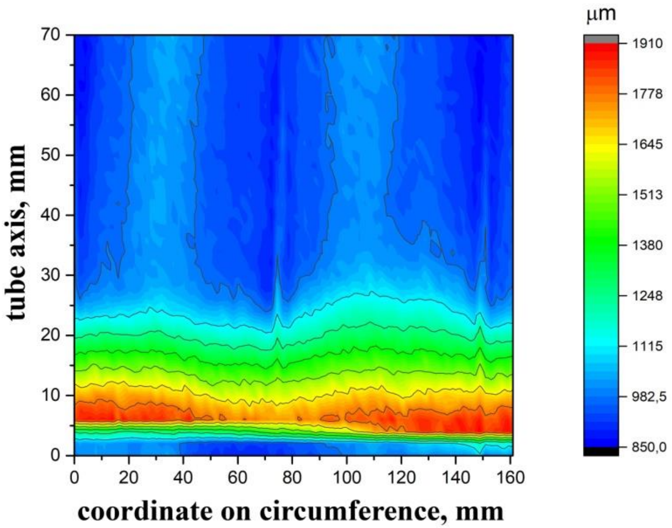
S. Piyadin, V. Spaskov, A.Kubankin

1 meter prototype of the BM@N carbon beam pipe (DD "Arkhipov")

Experimental setup for X-ray tests

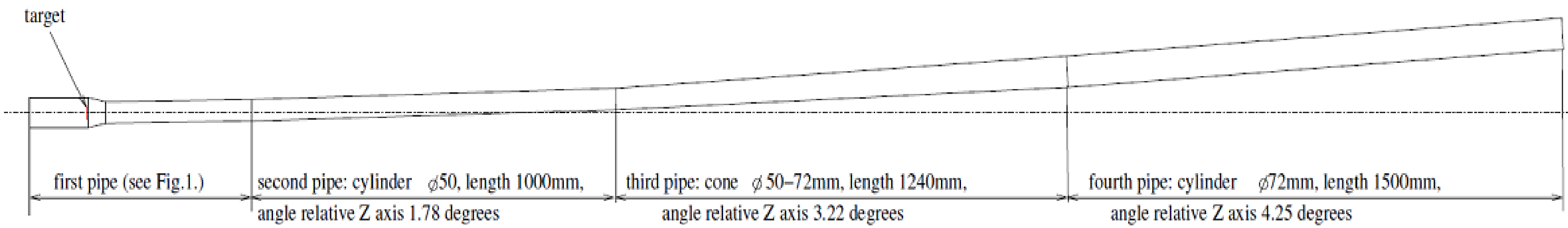
First vacuum tests were done at LHEP JINR (Spring 2020). Tests have shown an insignificant leakage level of side surfaces of the sample, vacuum up to 10^{-5}.

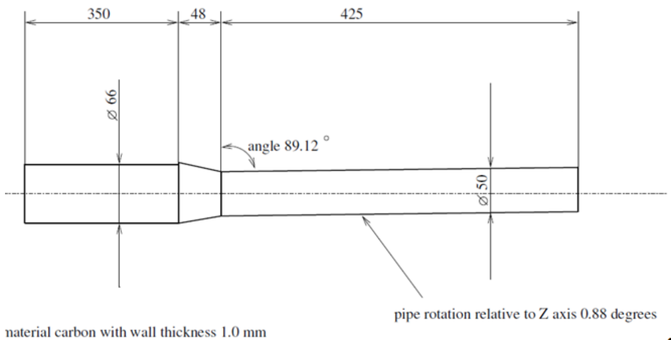
Tests of the sample with X-ray radiation are performed by A. Kubankin group (Belgorod University) to check the carbon layer thickness. The achieved accuracy of the wall thickness measurement: better than 10 um for the time of measurement 10 seconds (one point).

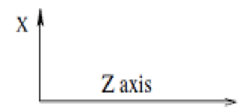


X-ray 3D map of the wall thickness distribution

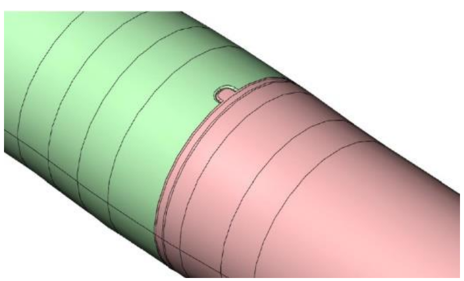
Beam pipe inside the SP-41 magnet



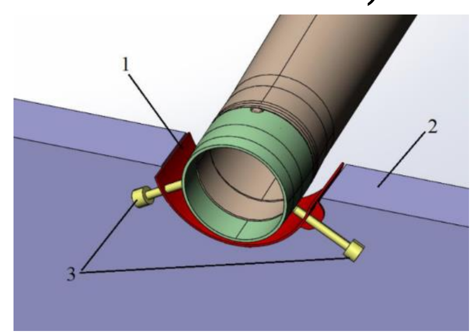




BM@N carbon beam pipe configuration (Au 3.8 AGeV 1800 A ~ 0.9 Tl)



Design of the non-flange connections



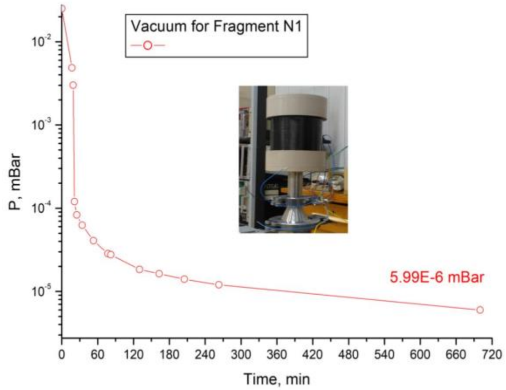
Design of the support system, which uses the surface of GEMs

DD "Arkhipov" (Moscow, Russia) was selected through a tender procedure for the beam pipe manufacture.
First stage of the contract: Development of the 3D models of the beam pipe, non-flange connectors, production and assembly equipment, calculation of the strength characteristics of 3D model nodes.
Second stage: Production of the beam pipe and non-flange connectors (April 2020).

Design and tests of the carbon vacuum beam pipe

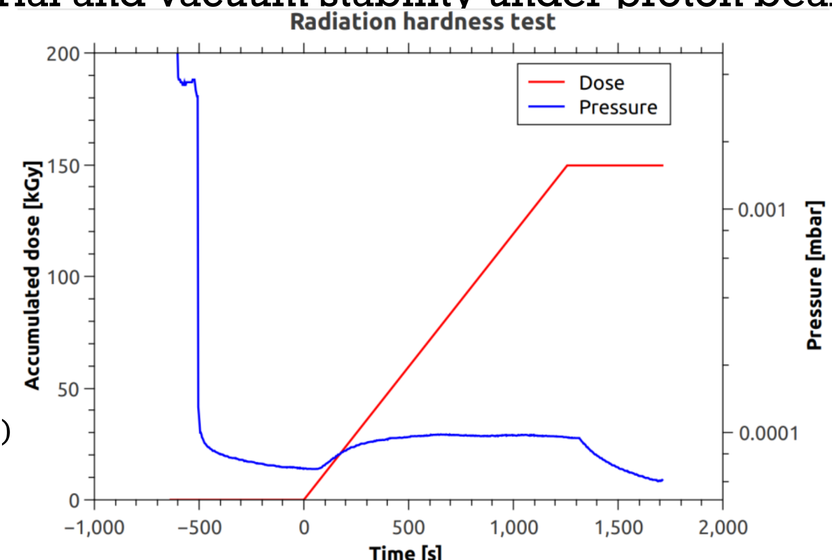
Faculty of Mechanical Engineering of the Czech Technical University
Nuclear physics institute, The Czech Academy of Sciences

Test of vacuum compatibility

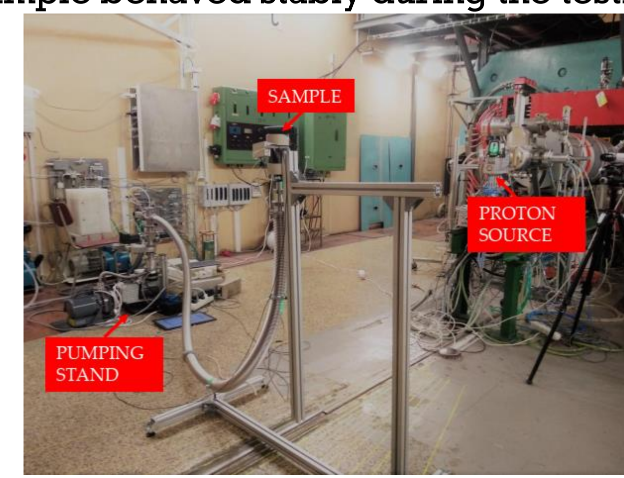


The ultimate pressure 6 x 10^{-6} hPa (scroll pump and turbomolecular pump)

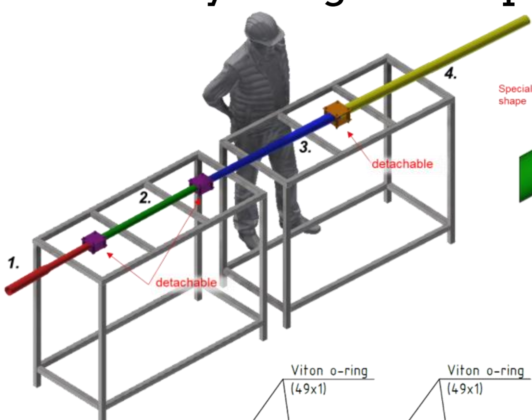
Test of material and vacuum stability under proton beam

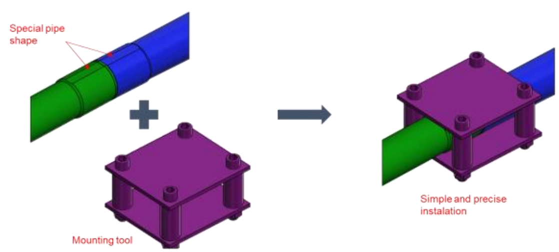


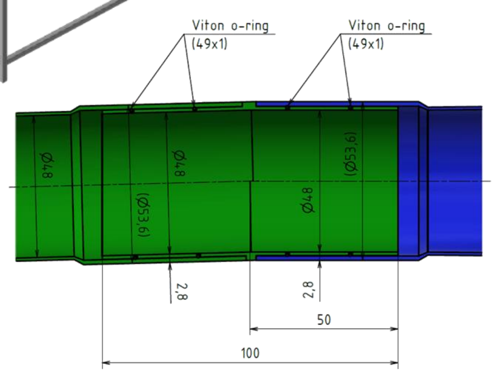
The test was performed September 3, 2020
The sample behaved stably during the testing

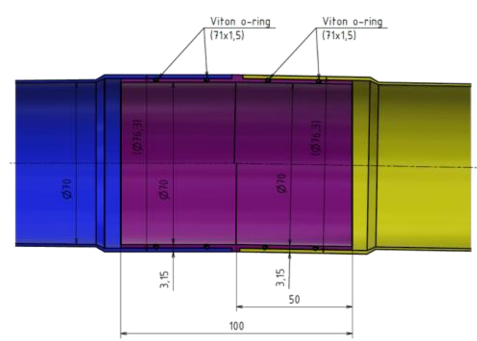


Preliminary design of the pipe connectors

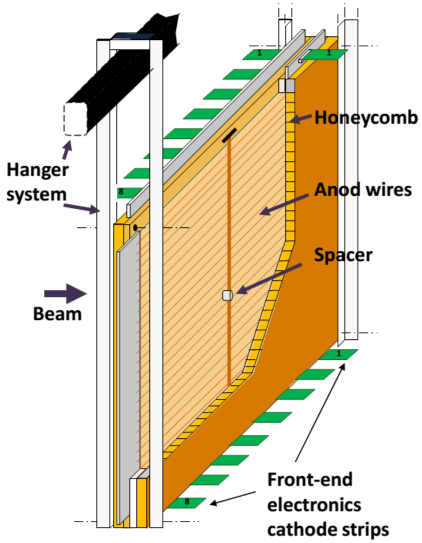


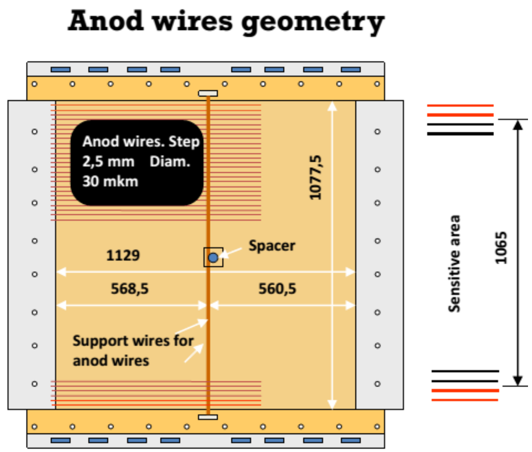


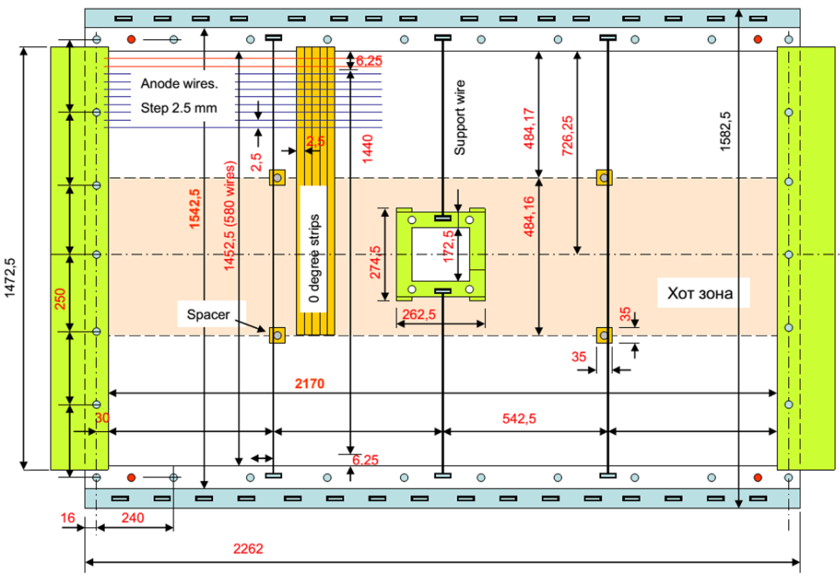




1065x1065 mm^2 and 2190x1453 mm^2 CSC chambers







Design of the1065x1065 mm^2 CSC chamber

Design of the 2190x1453 mm^2 CSC chamber

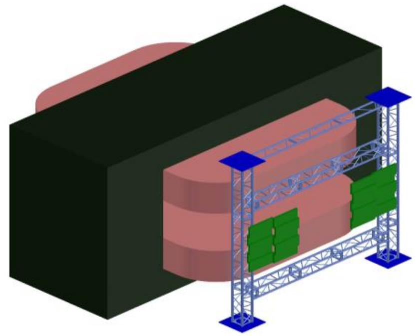
Status and plans:
- One CSC 1065x1065 mm^2 is produced and tested at Nuclotron beam;
- Assembly of the three1065x1065 mm^2 chambers is at the final stage. 95% of work is done;
- Tests of the assembled chambers with r/a source and cosmic rays are to be performed by the end of 02.2021.

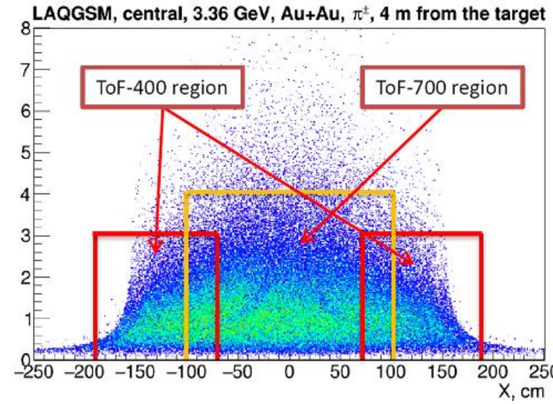
Status and plans:
- Design of the cathode planes is finished;
- Production and delivery of the cathode planes to JINR – end of 02.2021;
- Assembly of two 2190x1453 mm^2 CSC chambers – 02.2022;
- Tests of the assembled chambers with r/a source and cosmic rays are to be performed by the middle of 2022.

CSC group

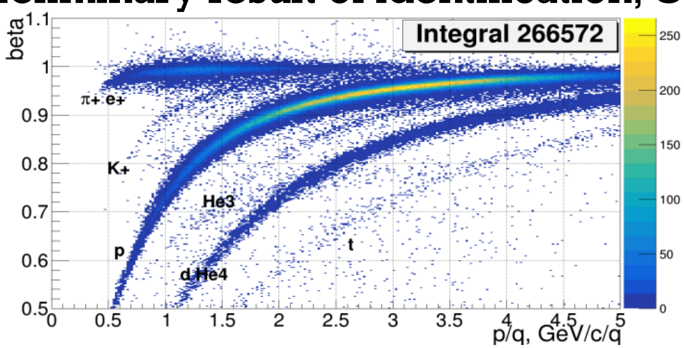
Status of ToF-400 & ToF-700

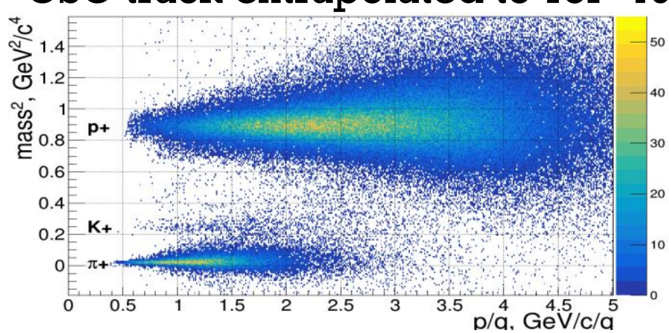
Both time-of-flight systems are ready for the heavy ion beam program



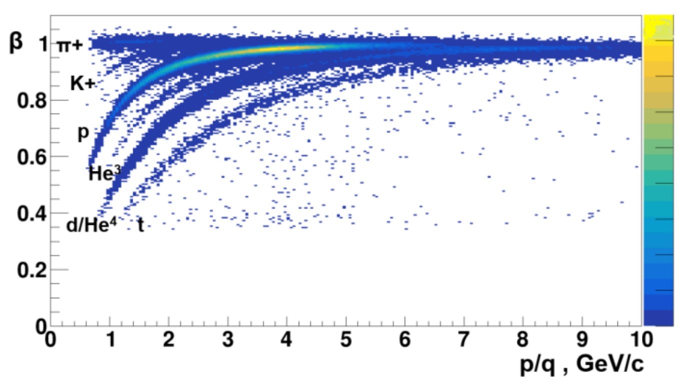


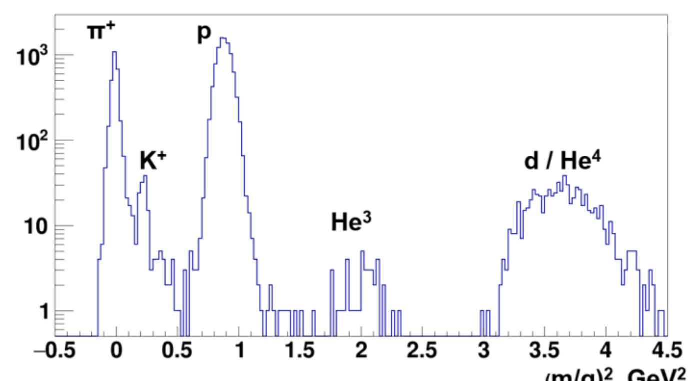
Preliminary result of identification, GEM+CSC track extrapolated to ToF-400





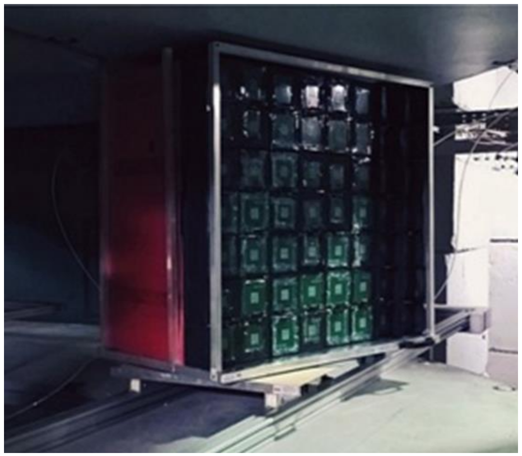
Preliminary result of identification, GEM+DCH track extrapolated to ToF-700





ECAL status

- two racks for ECAL in the magnet are assembled
- tests of array of modules for second arm of the ECAL are performed

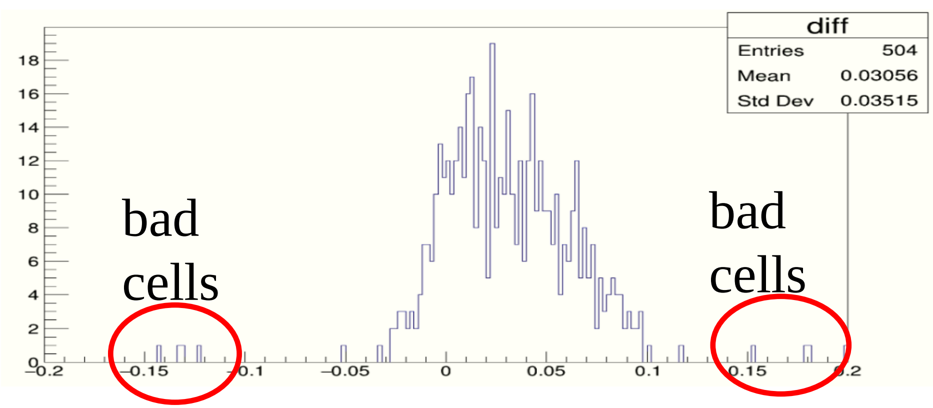


Location of ECal in the magnet SP-41

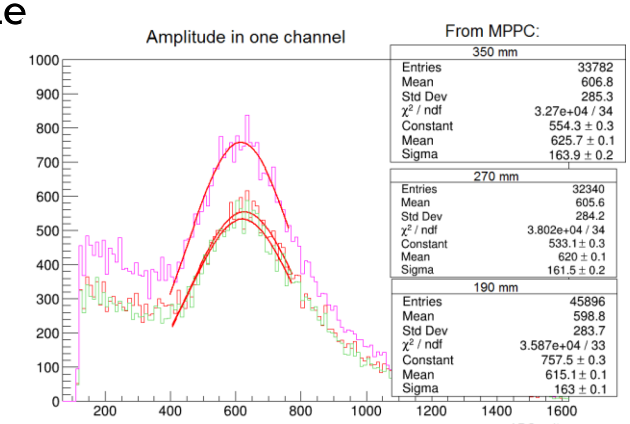
New racks for ECAL

Cosmic tests of the modules

The modules were tested using monitors in three position. Each positions gives attenuated amplitude and allows to calculate quality of the module



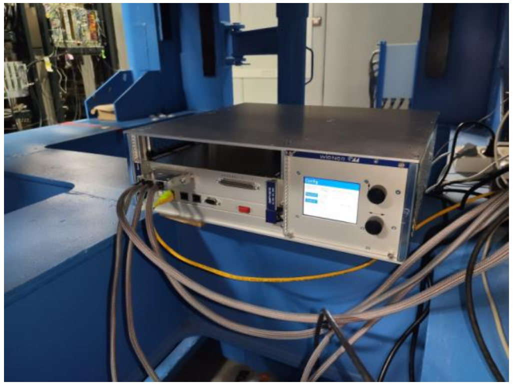
The decay coefficients for tested modules



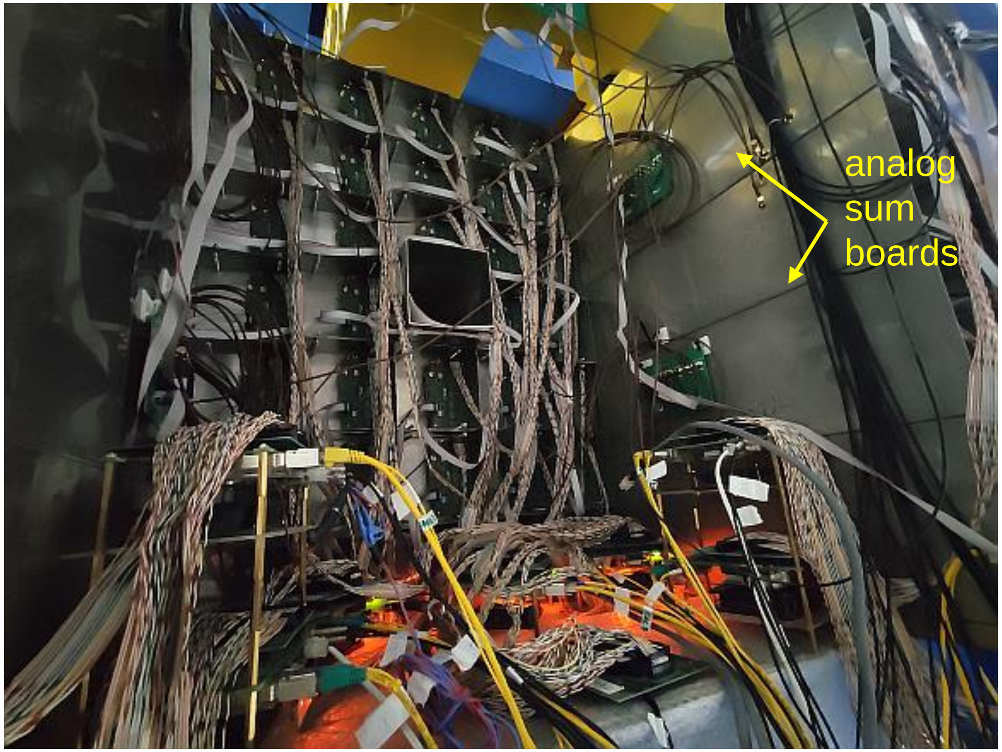
Status of new FHCal

group of INR RAS Troitsk

FHCal has been assembled and installed in the BM@N area

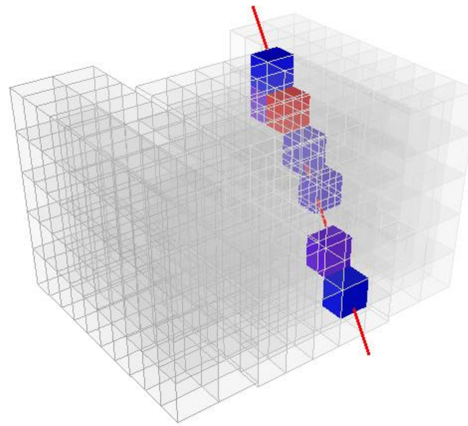


New WIENER MPOD power supply unit has been installed

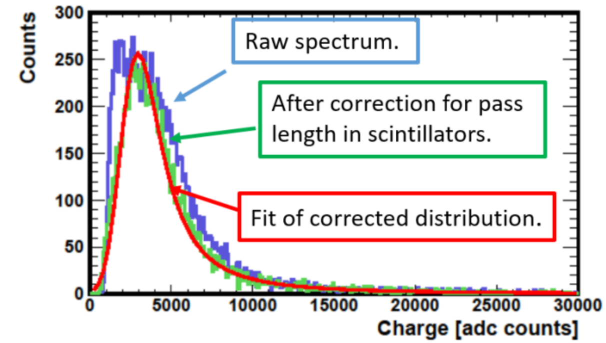


- 54 FEE boards have been connected and tested
- 8 ADC64s2 board are in places, tested, connected with new cables (yellow on photo) to Rack 6 + WR optical fibers
- 6 analog sum boards are connected to FEEs
- new power supply (WIENER MPOD) is being tested now

Status of new FHCal

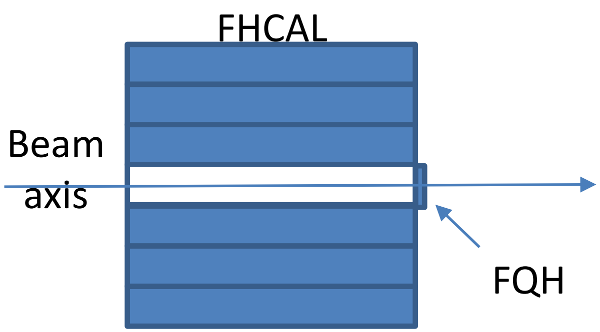


group of INR RAS Troitsk



- new cosmic muon calibration procedure based on 3D tracking with transverse and longitudinal granulation of FHCal has been developed and is under testing on cosmics with FHCal (remotely from INR). The final goal: prepare "the quality passport" for each module of FHCal.

Forward Quartz Hodoscope (FQH)



- Forward Quartz Hodoscope (FQH) is ready - two options – quartz or scintillator plates(16 strips with sizes 10x160x4 mm^3). 2 SiPMs from each strip end are used for light readout.

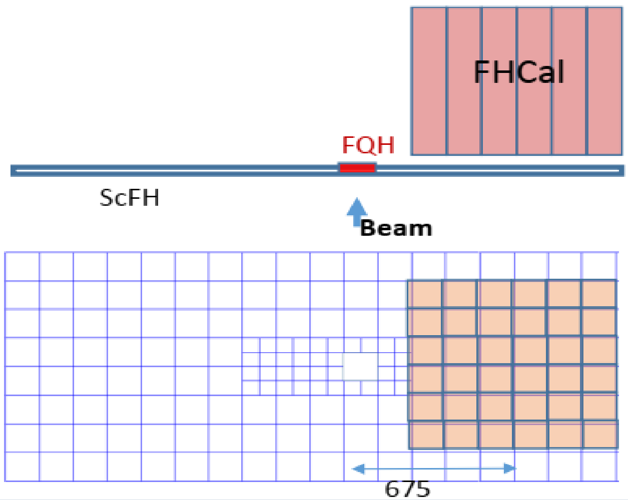
- TQDC board planned to use for read-out is under testing now with new FEE (at INR)

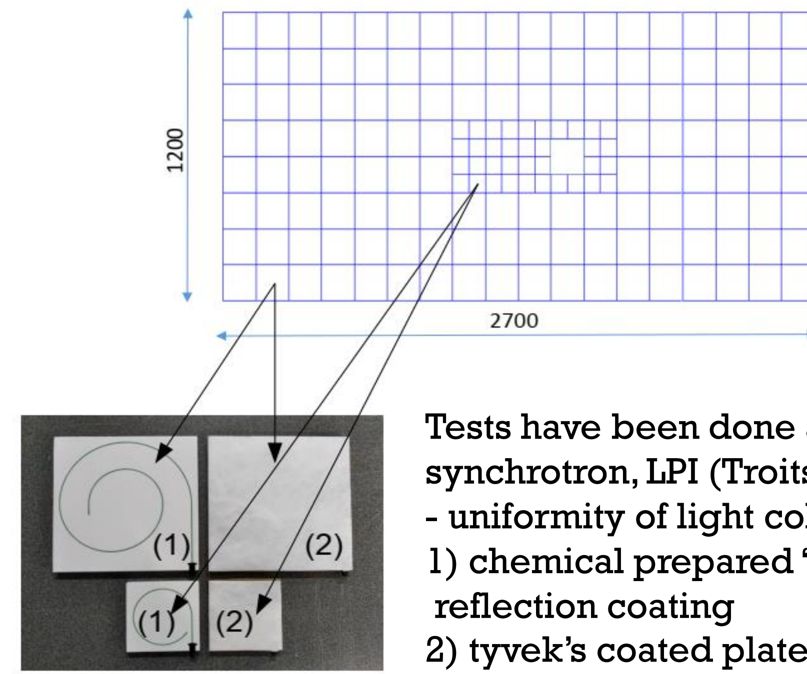
- fragments charge measurements in the FHCal beam hole.
- alignment of the FHCal
- MB and centrality triggers

Status of new FHCal

Additional segmented scintillation wall is planned:
- FHCal (36 MPD modules 15 x 15cm2) to measure neutron spectators
- Scint. Wall: 36 cells (75 x 75 x 10 mm3)+ 134 cells (150 x 150 x 10 mm3)
- FQH (16 quartz strips 160 x 10 x 4 mm3) to measure heavy fragments

Separate measurements of the neutron, proton and fragments could be possible with such detector system.





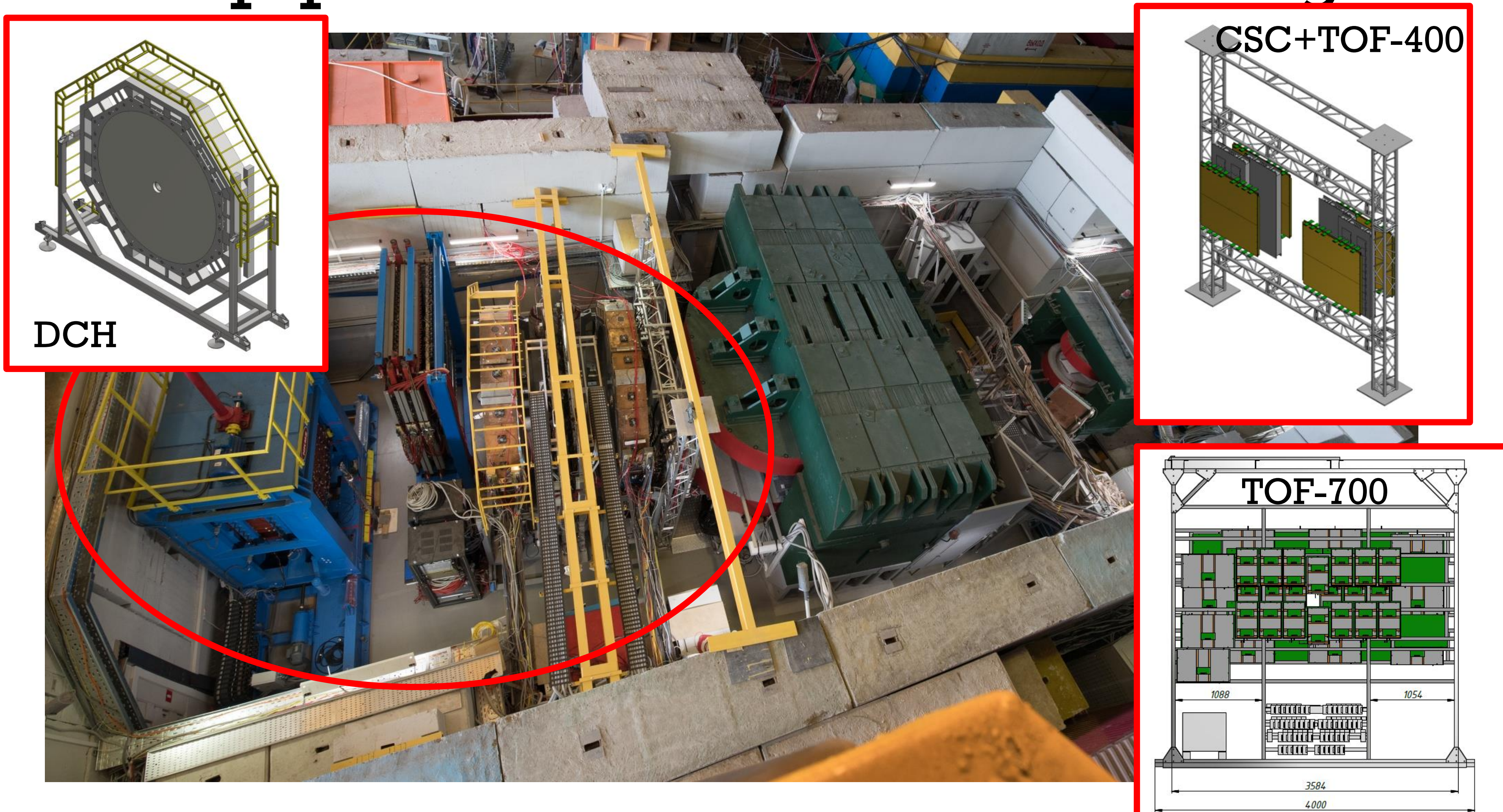
Tests have been done at "PAKHRA" synchrotron, LPI (Troitsk)
- uniformity of light collection
1) chemical prepared "foam" type reflection coating
2) tyvek's coated plates

Constructed samples of scintillator cells for tests

Results have shown tyvek coated plates to be better

Plans for the future:
- check all problems with FEE boards and fix them – January 2021
- module calibration and "module passport" – February 2021
- mounting the beam quatrz/scint hodoscope (FQH) on the FHCal back side – March 2021
- design and construction of new scintillation hodoscope wall – September 2021 (optimistic)

Beam pipe downstream the SP-41 magnet



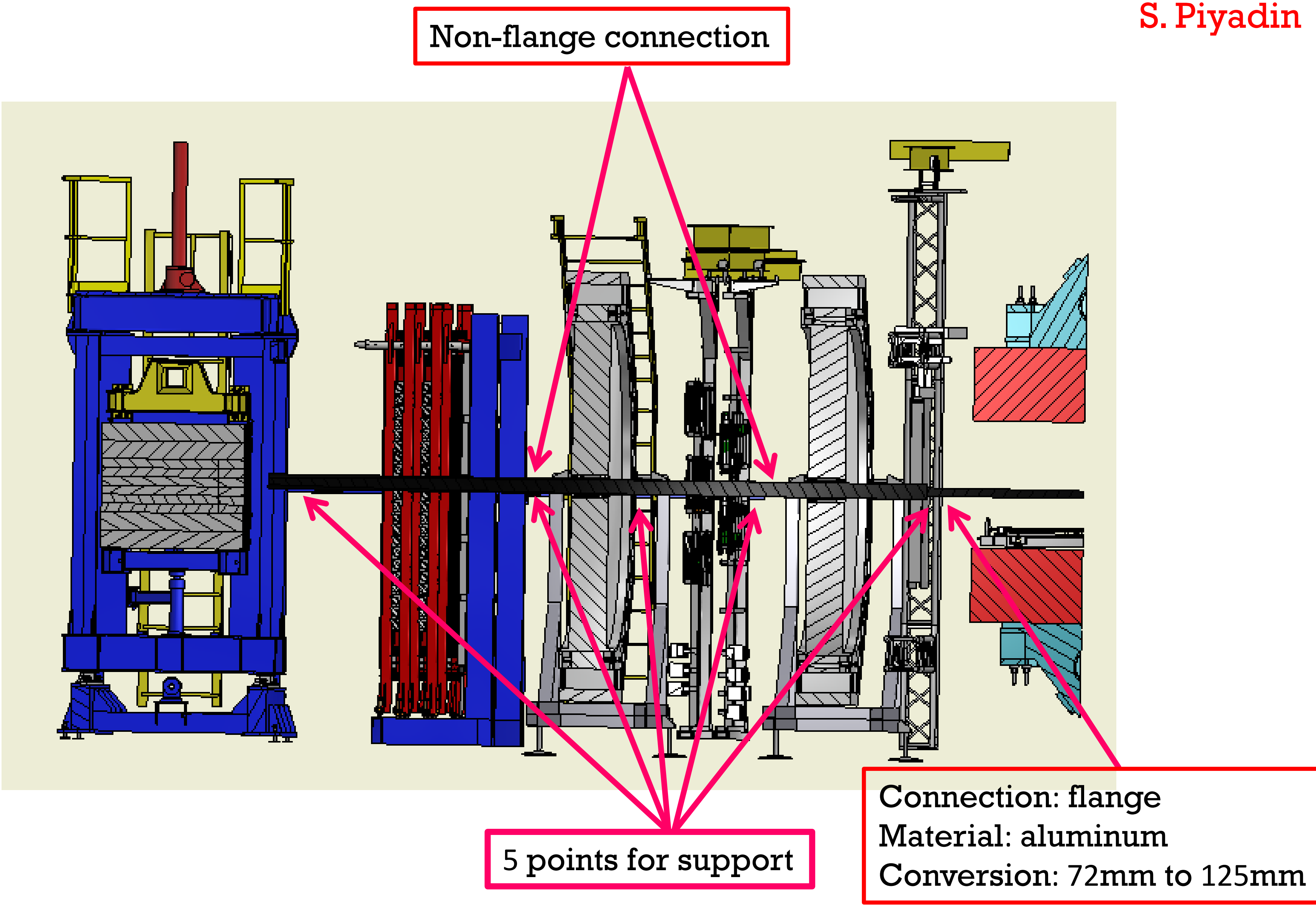
Development and production of the aluminum beam pipe downstream the SP-41 magnet will be performed by A. Kubankin group (Belgorod University). Technical task is currently under discussion.

3D model development of the detectors after the SP-41 magnet is finished.

S. Piyadin

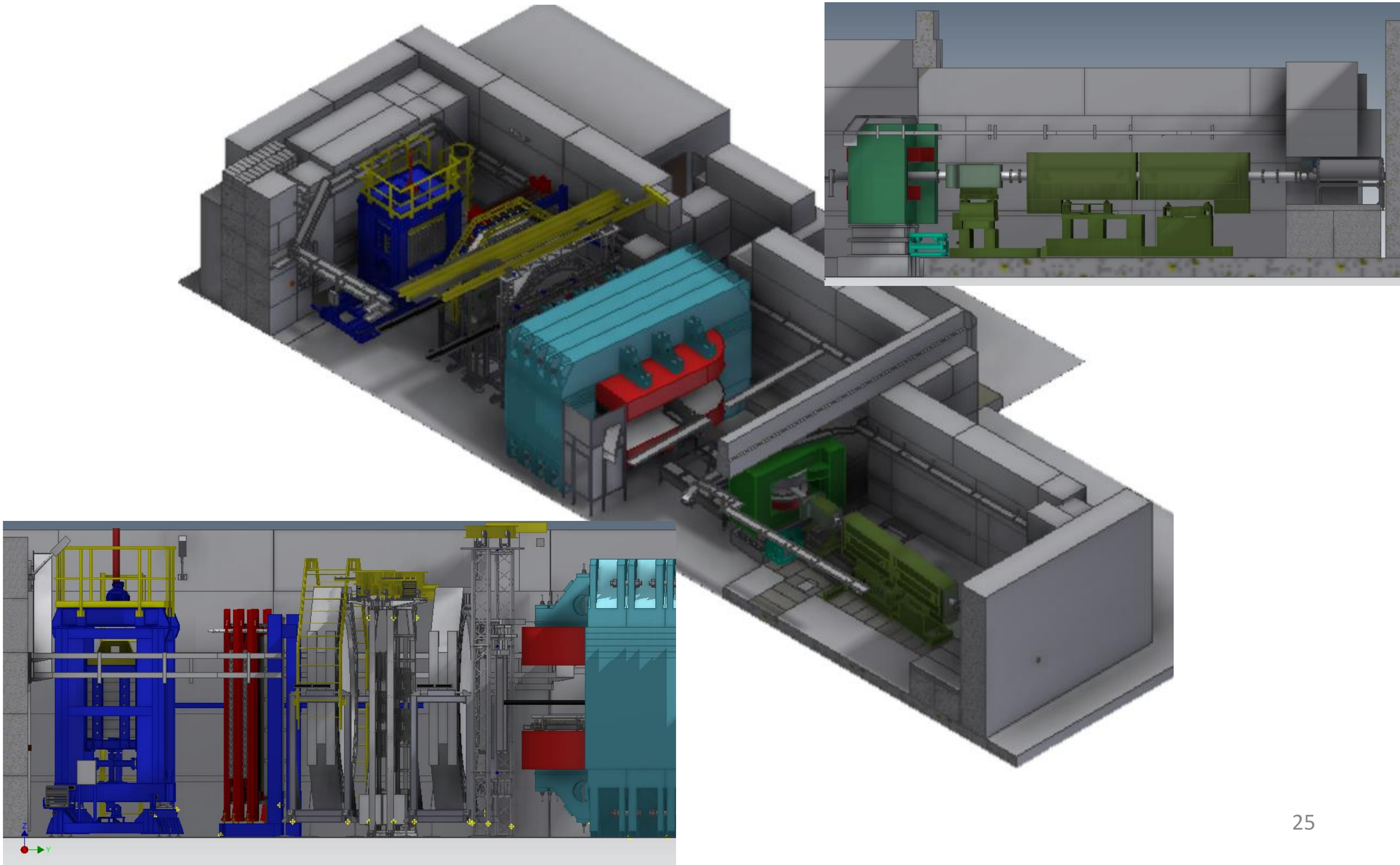
Beam pipe downstream the SP-41 magnet

S. Piyadin

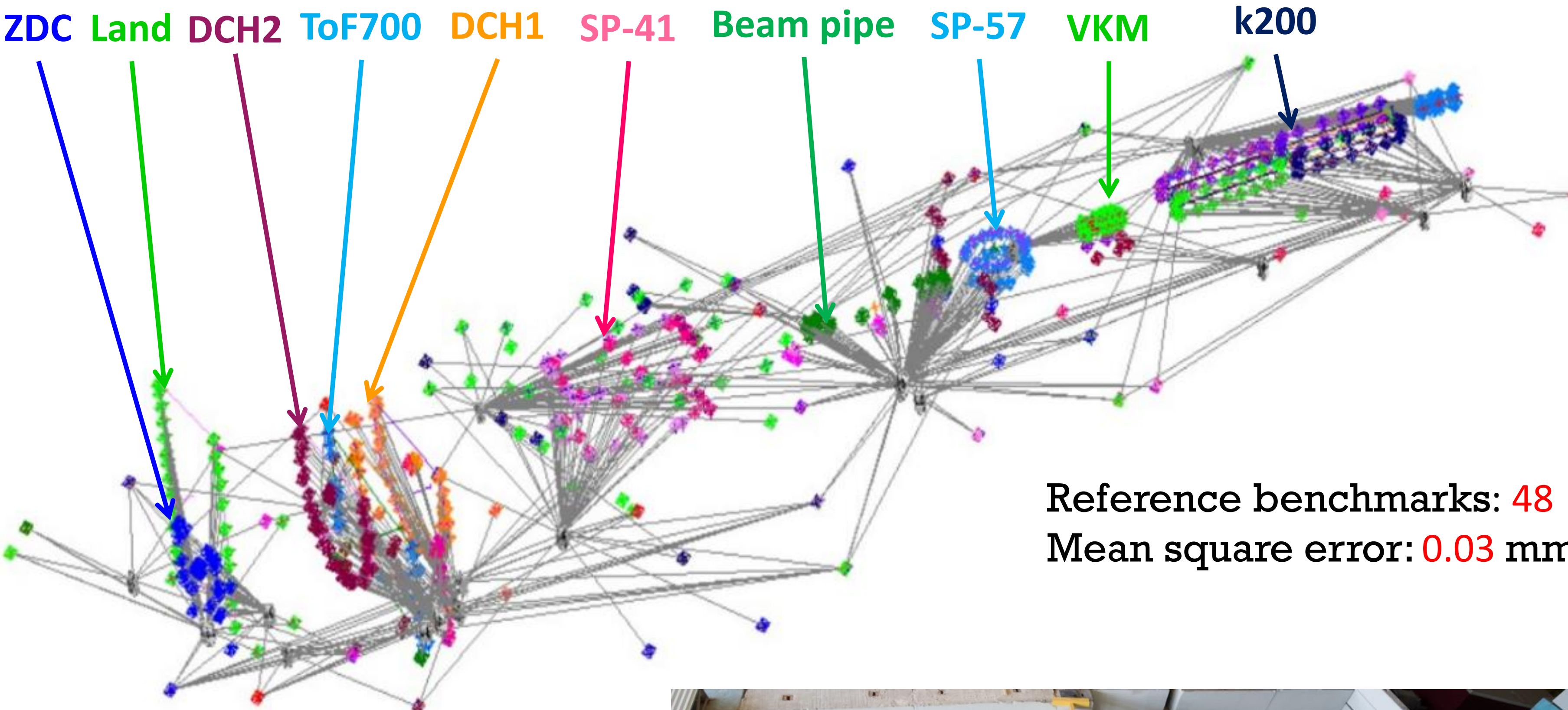


3D model of the BN@N experimental hall

S. Piyadin, S. Novozhilov, I. Kruglova



Development of a BM@N reference metrological grid



Reference benchmarks: 48
Mean square error: 0.03 mm

- The BM@N coordinate system is fixed
- Measurements of the coordinates of reference marks and basic elements are performed
- BM@N reference metrological grid is developed
- Measurements of the relative position of BM@N elements are done

Plans for 2021 – 22 experimental runs

Uncertainties for launching of heavy ion physics program:

- Vacuum transport channel from Nuclotron to BM@N is critical for operation with middle and heavy ion beams
- Accelerator team need time to put Booster – Nuclotron system into routine operation

► plan to start with a new SRC run in November-December 2021 with carbon beam provided by Booster-Nuclotron or Nuclotron alone
► risks: performance of new detectors, travel restrictions, logistics
► critical is a new detector to separate protons from pions in the proton arms to improve data quality

► if the SRC setup is not ready → perform BM@N carbon (Ar) beam run
►need two months to install and align vacuum carbon beam pipe and target, beam track Si, Forward Si, GEM, CSC, FHCAL, trigger detectors
► it is desirable to re-measure magnetic field map in an extended (X,Z) range but need power in building 205 to supply magnet

We consider BM@N experimental run with a middle weight ion beam (Kr, Xe) in Spring 2022
► operate 1st stage of hybrid tracker (3 Fwd Si + 7 GEM)

SRC setup vs BM@N heavy ion setup

► SRC configuration is not consistent with the BMN setup for heavy ions:

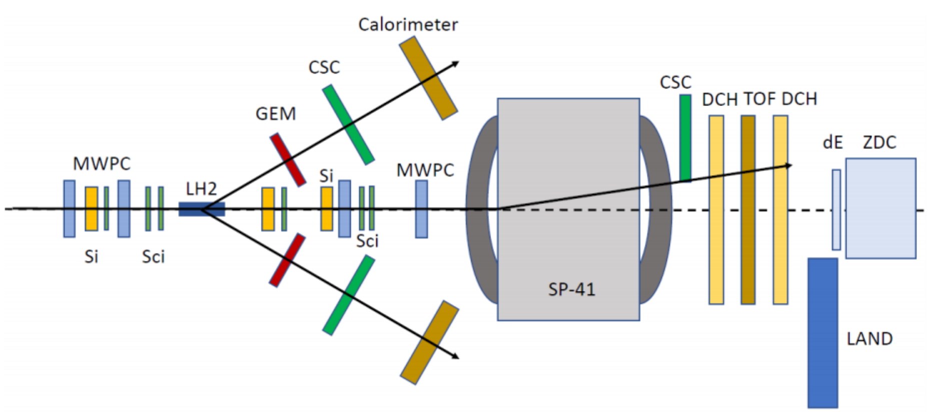
• delicate beam pipe within BM@N magnet, Si, GEM central tracker are obstacles for SRC nuclear fragments,

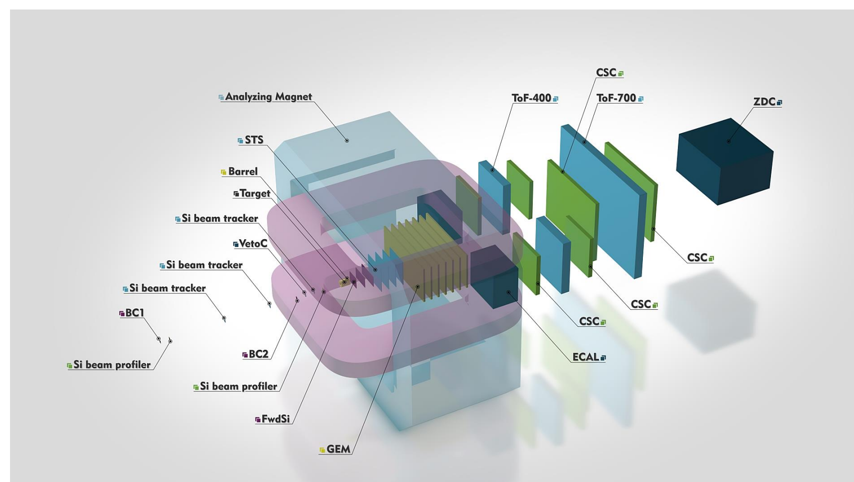
→ detectors will be removed / re-installed only in case major repair / upgrade

• vacuum beam pipe from quadruple should be dismounted to install SRC H2 target, beam and fragment detectors

→ need a couple of months between SRC and heavy ion run to reconfigure and align BM@N detectors

• DCH chambers are used for SRC, but are not suitable for heavy ions





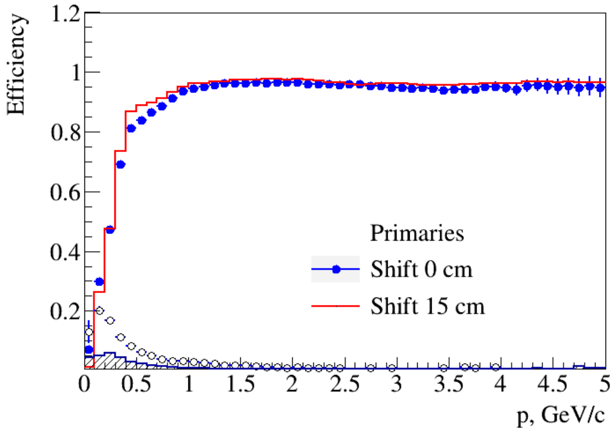
Summary:

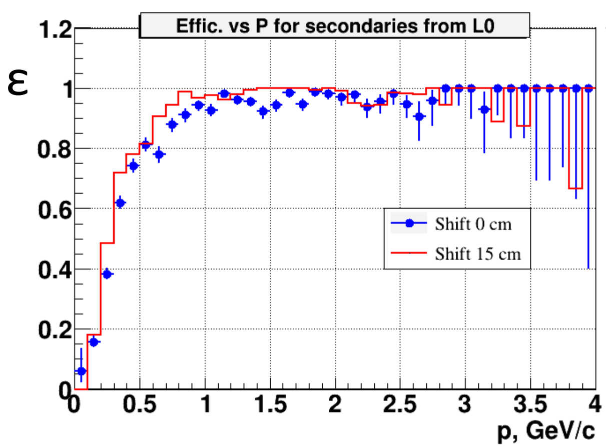
Detector Subsystem	Upgrade Status
Beam pipe before the target	installed
Beam pipe downstream the target, in SP-41 magnet	middle 2021
Beam pipe downstream the SP-41 magnet	2021
Trigger and T0 detectors	2021
Si beam tracking detectors, profilometers	2021
Forward Si detectors	3 full-size planes (2021)
STS BM@N	42 modules (2022) 292 modules (2023-24)
GEM	7 top half-planes + 7 bottom half-planes(assembled)
CSC	4 chambers 1065x1065 mm^2(2021) 2 chambers 2190x1453 mm^2(2022)
ECAL	two arms (2022)
ToF-400 and ToF-700	full configuration
ZDC(MPD/CBM type)	installed

Backup

Simulation of 1st stage of hybrid central tracker: 3 Forward Si + GEM

A.Zinchenko, V.Vasendina





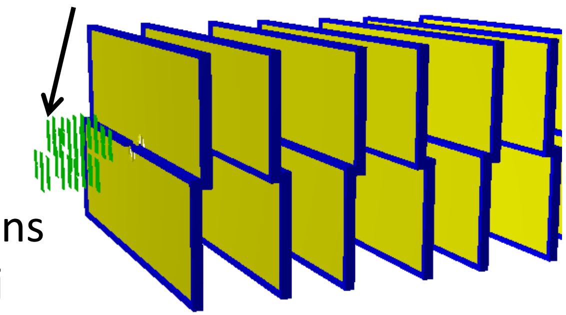
DCM-QGSM model

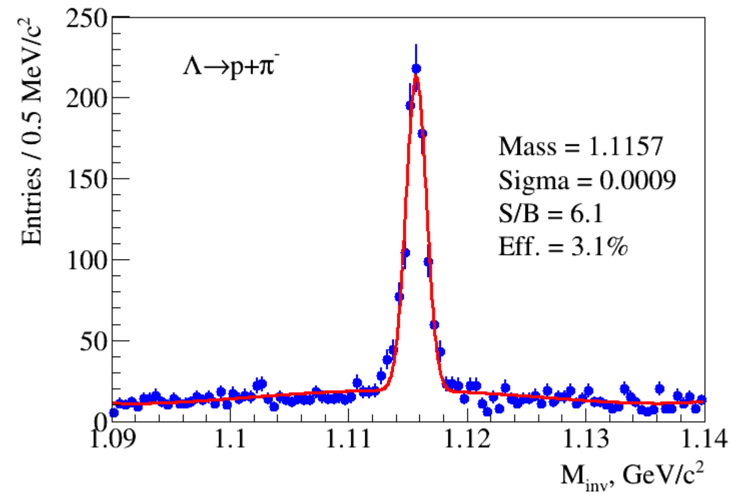
Kr + Pb , T_0= 2.4 AGeV

Aim:

- Optimization of detector positions and rotation angle of Forward Si stations
- Estimation of track reconstruction efficiency and momentum resolution

3 Forward Si + 7 GEM

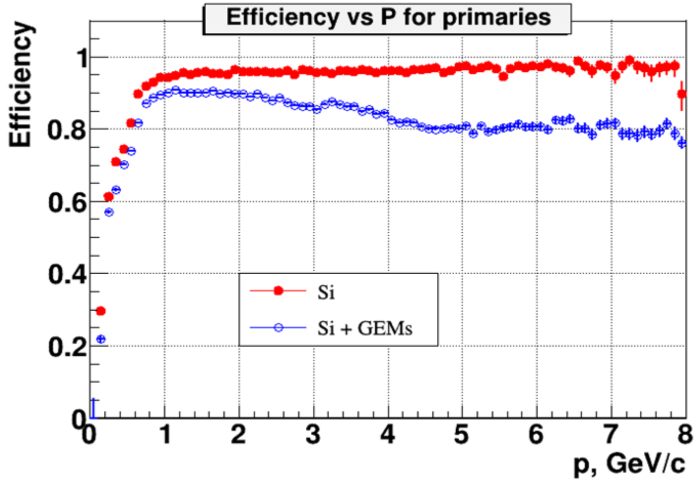


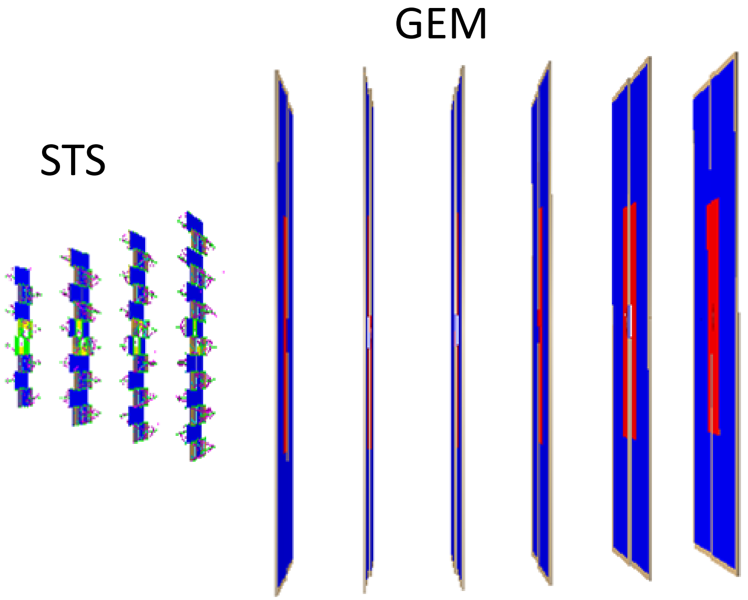


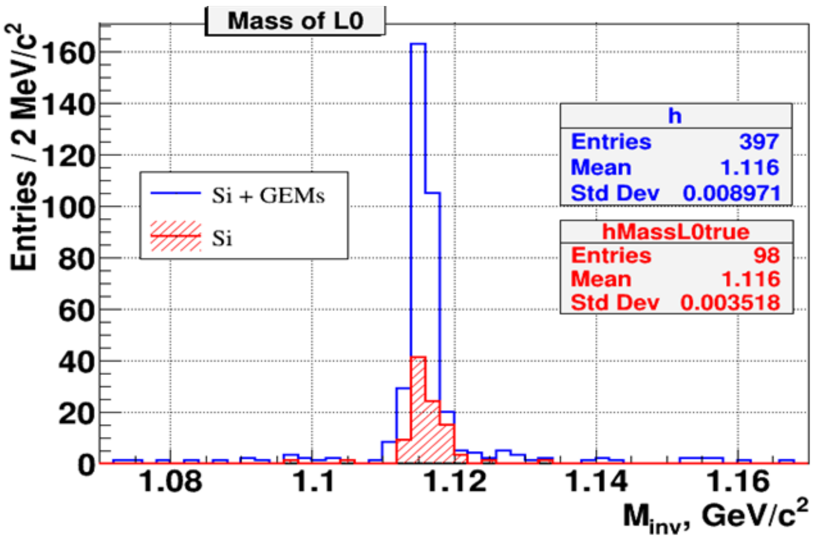
Simulation of hybrid central tracker for heavy ion runs: STS +GEM

A.Zinchenko, V.Vasendina

QGSM model, Au+Au, T_0 = 4 AGeV







Hybrid STS + GEM tracker:
► 4 times increase in number of reconstructed tracks and Λ hyperons