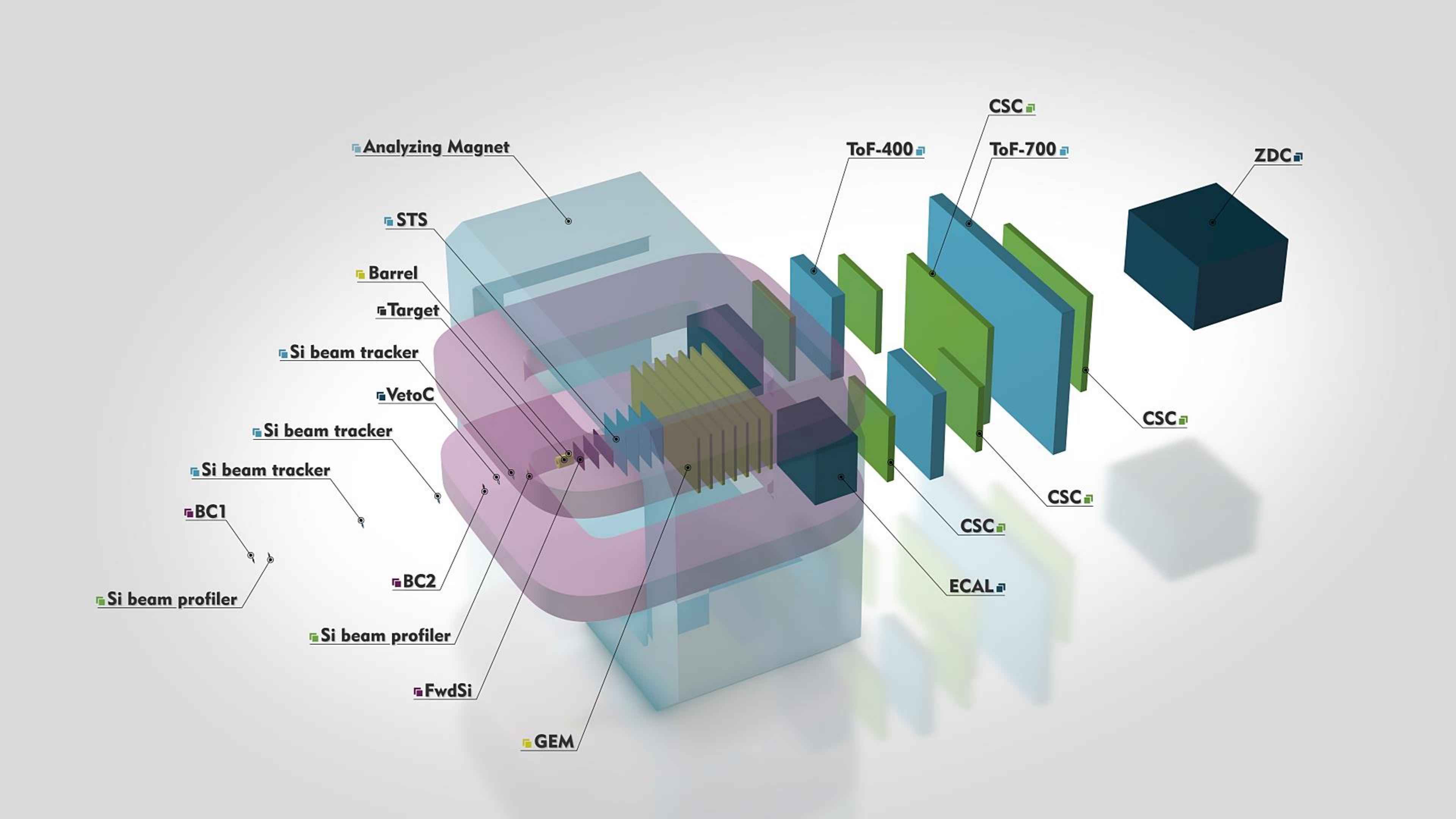
Upgrade of the BM@N detectors

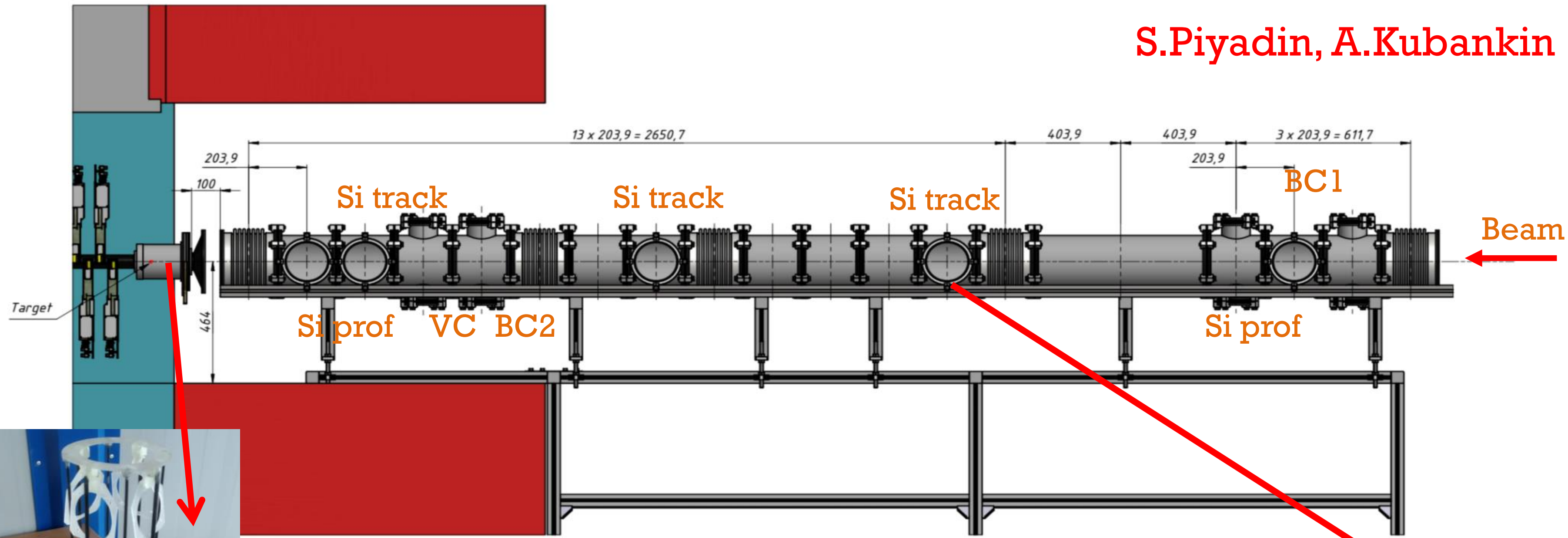
Anna Maksymchuk on behalf of the BM@N Collaboration
19/04/2021

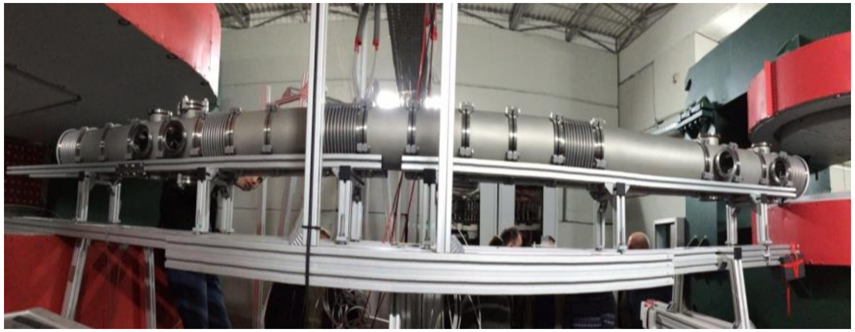
BM@N Experimental Setup

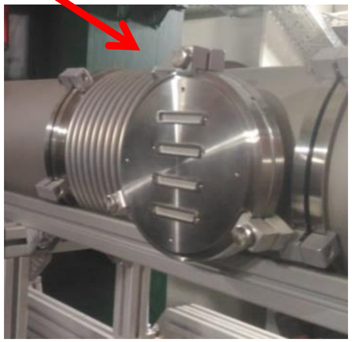


Beam pipe before the target

S.Piyadin, A.Kubankin



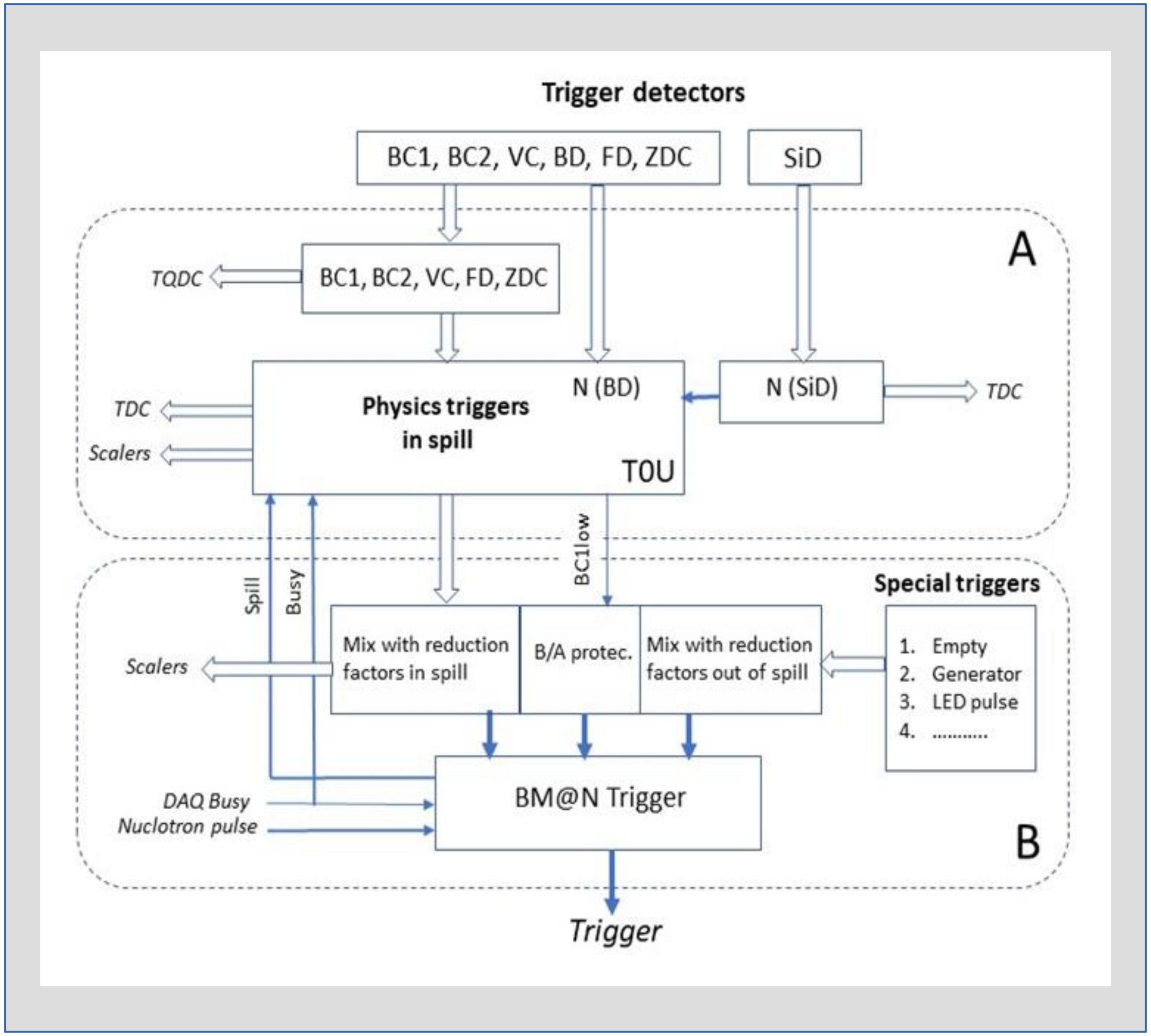




Four stainless steel vacuum boxes downstream the target are replaced by aluminum ones. The design and production of the target station control system and pneumatic actuator mechanics is performed by A.Kubankin group. Works to be finished by June 2021.

Trigger system. Changes in general scheme.

Trigger and DAQ groups



Part A
(managed by the trigger group):

generates physics triggers;

Fragment Detector (FD) and FHCal (ZDC) are added to trigger detectors.

Part B
(managed by the DAQ group):

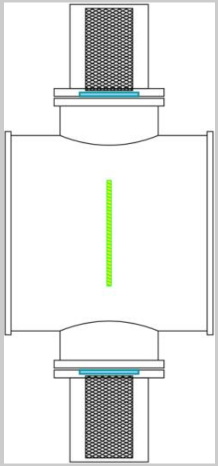
makes downscaling of the physics triggers (up to 16 triggers can be provided);

makes Before/After protection;

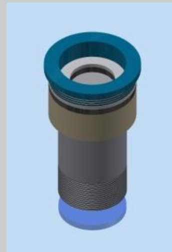
generates special triggers.

Trigger system. Status of beam counters

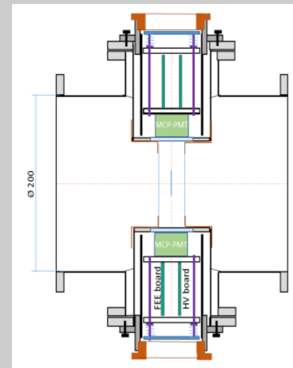
Trigger group



Sketch of vacuum box for BC1 and VC



Design of BC1/VC PMT mount



Sketch of vacuum box for BC2

Design of BC2 PMT base and FEE

BC1 and VC Status and plans:

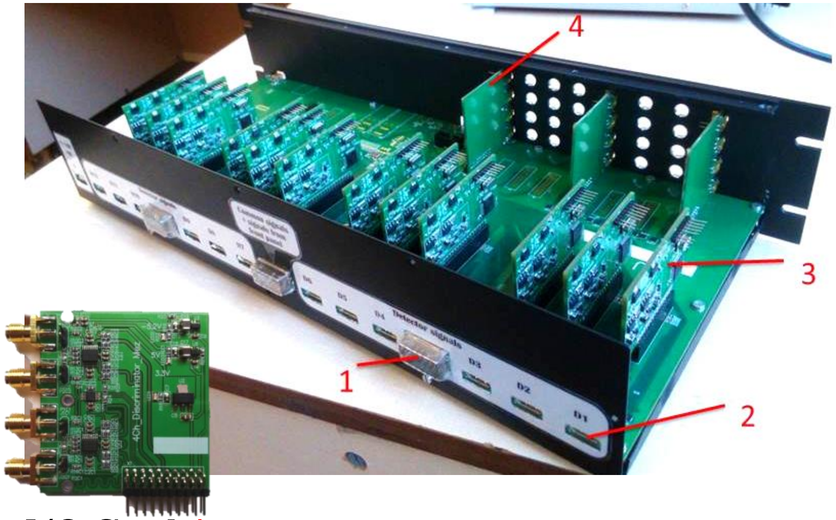
- Vacuum components ready
- PMT Hamamatsu R2490-07 available
- PMT sockets ordered, exp. May 2021
- PMT voltage dividers production, June-July 2021
- Scintillators 100x100x0.25mm^3 (BC1) and Ø100x10mm, hole Ø27mm (VC) available
- Scintillator mount design in progress

BC2 Status and plans:

- Vacuum components ready
- MCP-PMT XPM85112/A1-Q400 (Photonis) available
- PMT base and FEE parts, produced and delivered
- PMT assemby and testing, May-June 2021
- Scintillators BC400B 30x30x0.15mm^3 available
- Scintillator mount design in progress

Trigger system. Upgrade of T0U module

Trigger group



I/O Card 4

T0U Module Functionality:

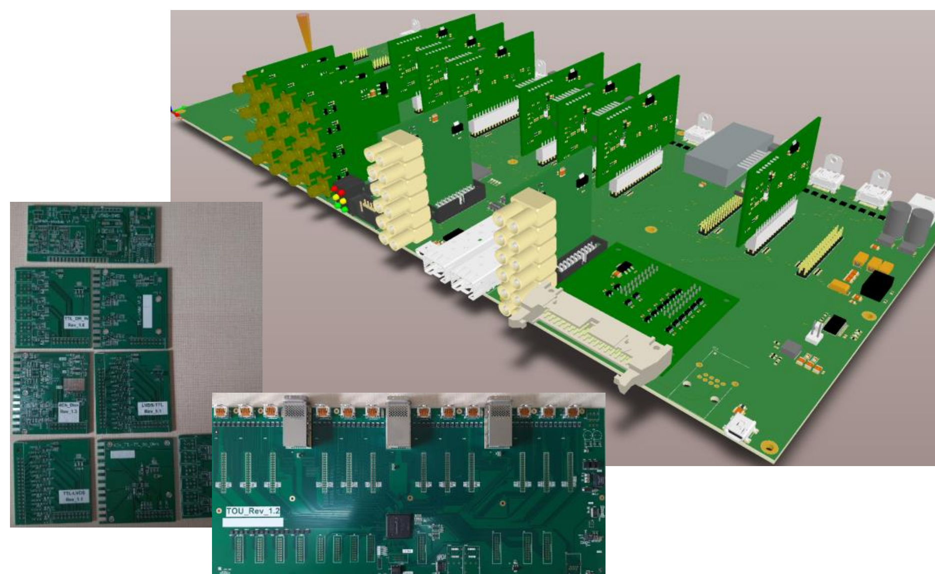
- Implements trigger logic in FPGA
- Accepts or provides I/O analog, NIM, TTL signals via cards 4
- Accepts LVDS signals via HDMI connectors 2
- Provides LV to FEE (cards 3, HDMI connectors 2)
- Forms input signals to TDC (Molex connectors 1)

Points of upgrade:

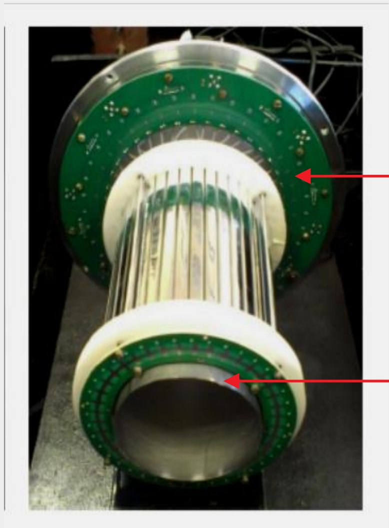
- Improved input boards with discriminators (16 inputs)
- Additional I/O boards TTL (LEMO),
- up to 24 channels (e.g., can be used for output signals to scalers)
- New power converter, capable to drive extended set of I/O cards
- Second USB 2.0 port + 2 optical links

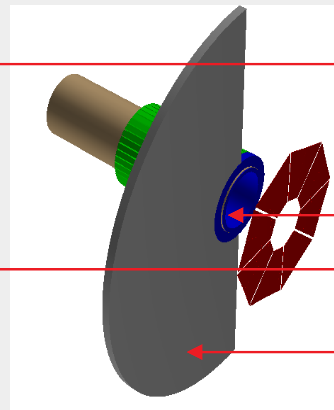
- **Status and plans:**
- All parts are produced and delivered
- Assembly and testing May-July 2021

Design and produced parts of upgraded T0U



Trigger system. Multiplicity detectors





Trigger group

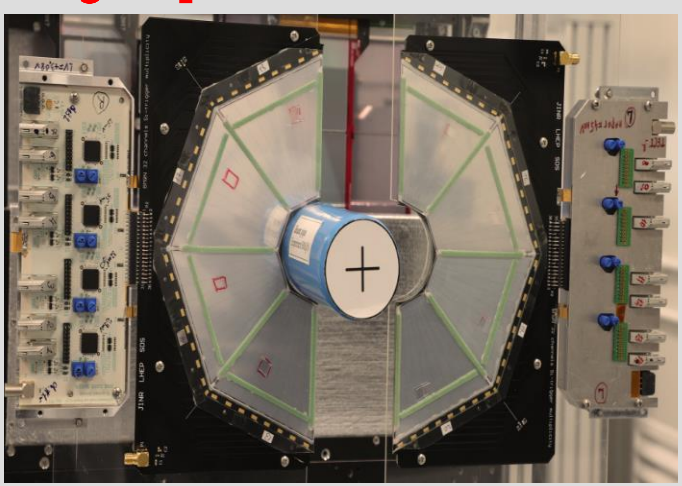
Barrel Detector upgrade:

- New (with lower noise) FEE board;
- the board is produced and delivered,
- the old one will be replaced Jun.-Aug.2021

- Inner cylindrical Pb shield (5 mm thick,
- 10 cm long)

- Outer Pb shield (R=50cm, 1cm thick)

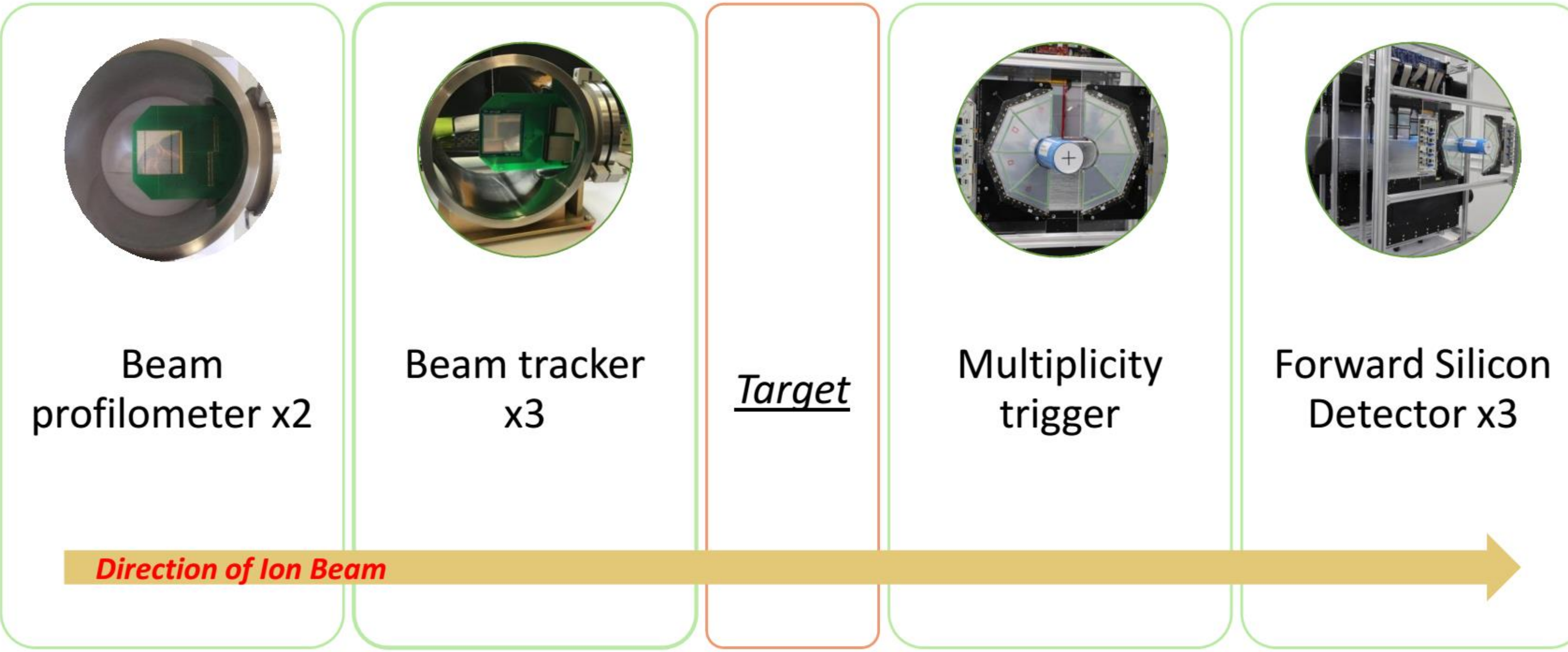
FSD group



Multiplicity detector upgrade

- **detector:** Silicon single-sided Detector, 525 μm thickness, 8 strips located at an angle with an interval of 5.63° and is an isosceles trapezoid in shape (45°) and active area 30.8 cm^2 (5 times bigger than previous Si-multiplicity trigger 2018).
- **mechanical design :** new design is based on 2 symmetric half-planes (inner diameter Ø52 mm), which simplify multiplicity trigger assembling process around installed beam pipe. Multiplicity trigger is located at 62 mm downstream the target.
- **FEE:** based on 32 channel IC-AST-1-1 (Minsk) with adjustable threshold.
- **current status:** two half-planes assembled and tested with previous FEE (2018). New FEE design with new gain parameters is under discussion (due to strip capacitance 5 times increase).

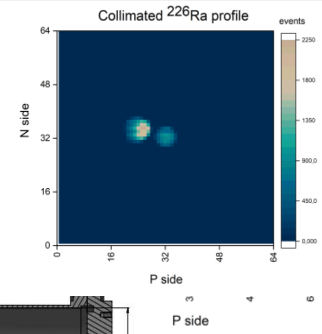
Forward Silicon and beam detectors

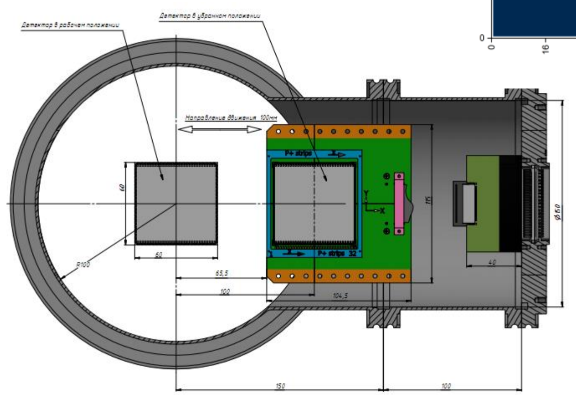


See talk by B.Topko

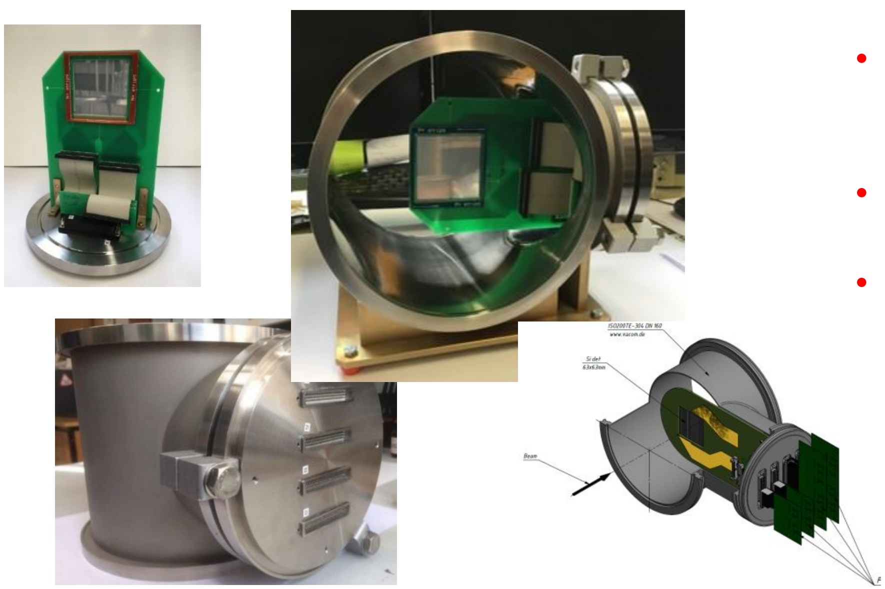
Beam profilometer and beam tracker

FSD group





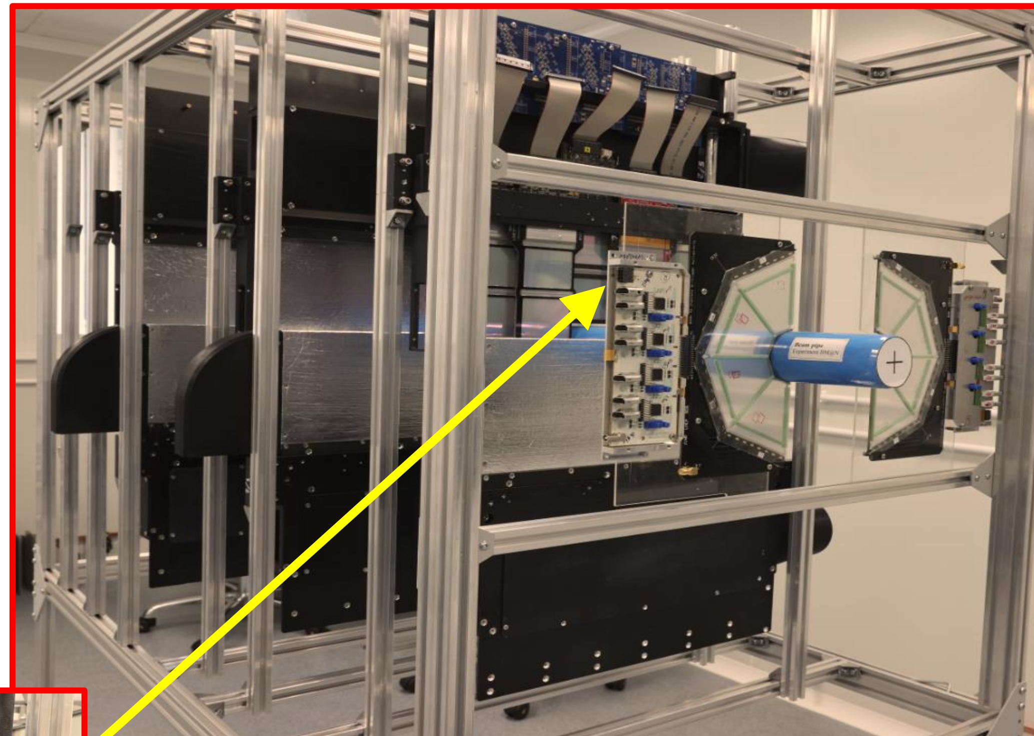
- **detector:** DSSD, 32×32 strips, pitch p+ / n+ strips 1.8 mm, thickness 175 μm, active area 60 × 60 mm^2;
- **mechanical design:** The mechanical construction supports automatic removal of profilometer planes from beam zone to special branch pipe after beam tuning;
- **FEE:** for light ions based on **VA163 + TA32cg2 (32 ch, dynamic range: -750fC ÷ +750fC)**;
- **current status:** two vacuum stations with flanges and cable connectors are ready, Silicon Detectors assembled on PCBs and tested with alpha-source (5.5 MeV), (**FEE+ADC+DAQ**) design in progress within schedule.

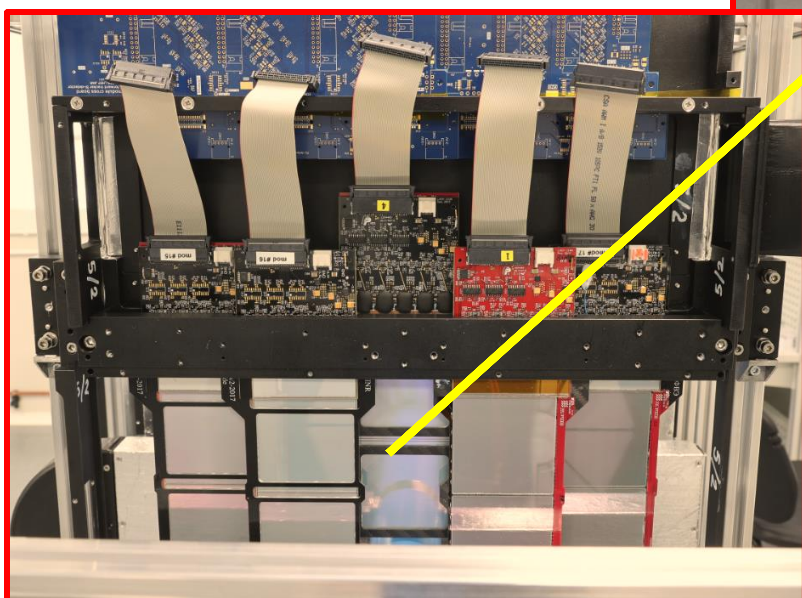


- **detector:** DSSD, 128×128 strips, pitch p+ / n+ strips 0.47 mm, thickness 175 μm, active area 61×61 mm^2;
- **FEE:** based on **VATA64HDR16.2 (64 ch, dynamic range: -20 pC ÷ +50 pC)**;
- **current status:** three vacuum stations with flanges and cable connectors are ready, Silicon Detectors assembled on PCBs and tested with alpha-source (5.5 MeV). Cross-board and FEE PCB are under test. Mechanical support and FEE cooling in progress within schedule.

Forward Silicon detectors

Upper half-plane without EM
+ light shielding (5 modules)



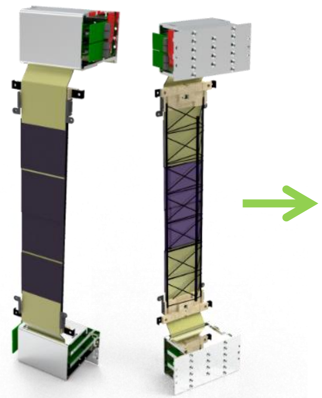


- **Detector:** DSSD, 640×614 strips, pitch p+ / n+ strips 95/103 μm, thickness 300 μm, stereo angle between strips: 2.5^0, active area 63×63 mm^2;
- **FEE:** based on VATAGP7.1 (128 ch., dynamic range: ±30fC). 5 ASIC per PCB.
- **Current status:** all 84 FEE PCB fully assembled (100%), 38 from 84 FEE PCB are tested (45%), 12 from 42 FSD Si modules fully assembled (29%), 10 from 42 FSD Si modules are tested (24 %), FSD half-plane assembly has started.

BM@N STS

STS group

BM@N STS Station



BM@N STS Ladder

BM@N STS Module

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

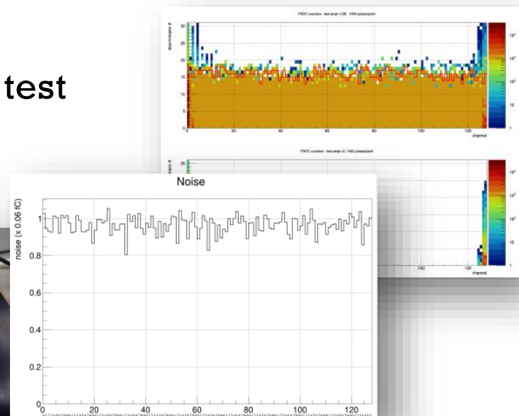
- Pitch 58μ
- Stereo angle 7.5°
- Thickness 300μ
- Sizes: 62x62, 62x42 mm²

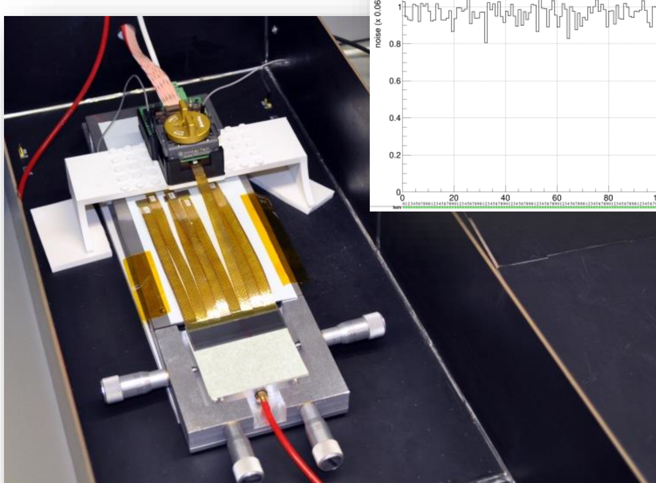
Number of modules: 292

Number of channels: ~600k

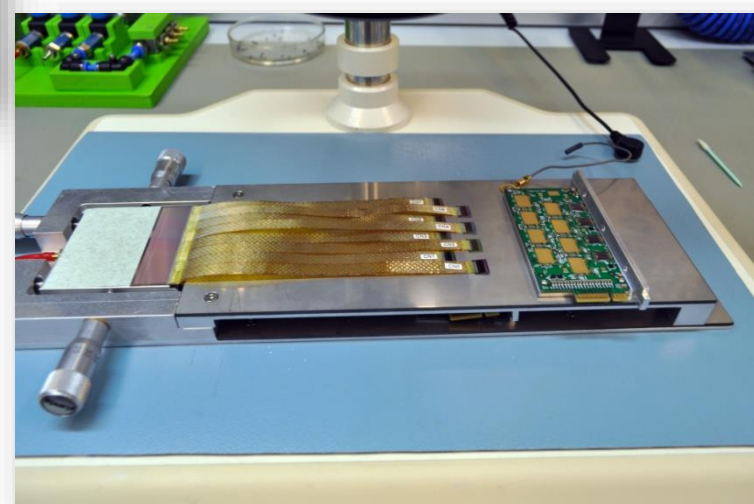
Number of ladders: 34

Customized electrical test setup used through the assembly process

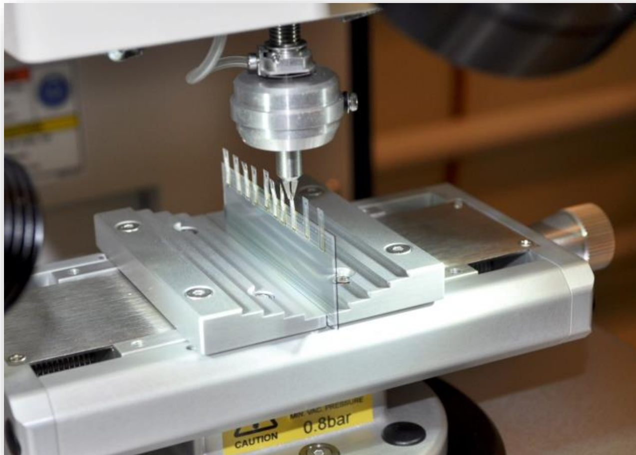




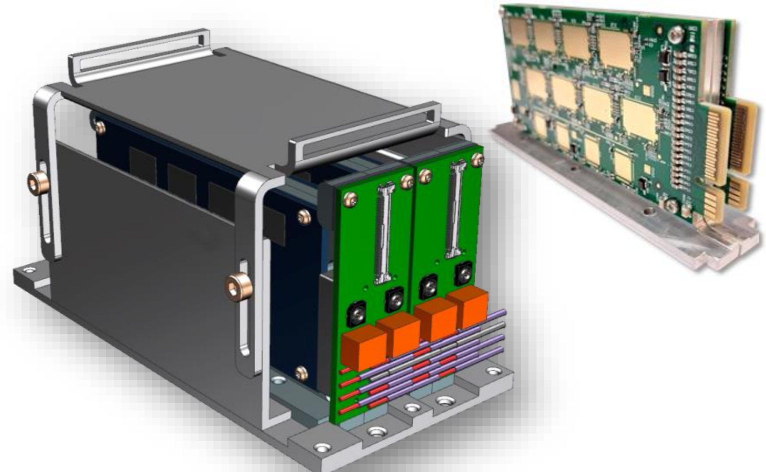
Custom-designed jigs for the assembly of BM@N modules



BM@N STS



Mechanical testing of flexible cables during assembly



Custom-designed mechanical parts for the Front-end board

Key milestones of the BM@N STS project

1. *Technical Design Review (100%)*
2. *R@D of the model and supermodel (the ladder) components EDR(90%)*
3. *Technology for module assembly including step-by- step QA control (90%)*
4. *Technology for ladder assembly (75%) endurance and long time testing*
5. *Mainframe mechanics (25%)*
6. *Liquid cooling - choice between water and freon (10%)*
7. *Gas cooling for temperature stabilization (?)*
8. *DCS with WinCC OA (5%)*
9. *Infrastructure extension (50%)*
10. *Readout electronics (?)*

See talk by Yu.Murin

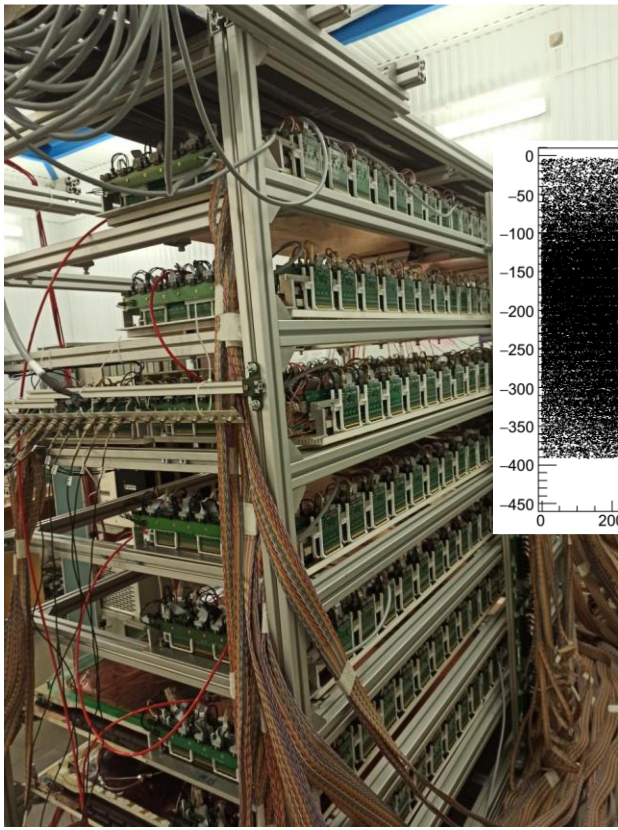
- 2023 – pilot v. of STS based on two stations with 42 modules
- 2023-2024 – expansion of the system to 292 modules *provided priority given to BM@N STS and not CBM STS*

GEM central tracking system

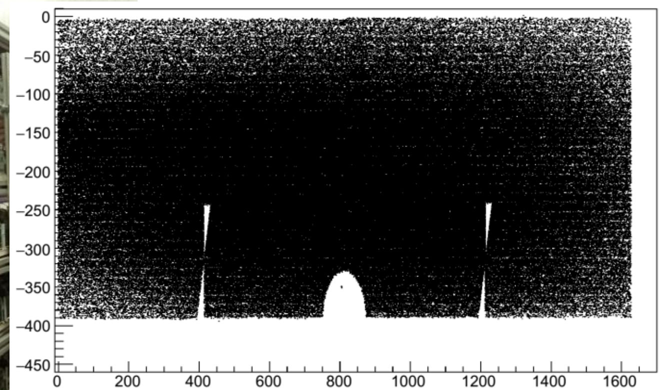
Cosmic stand for long-term GEM tests

GEM group

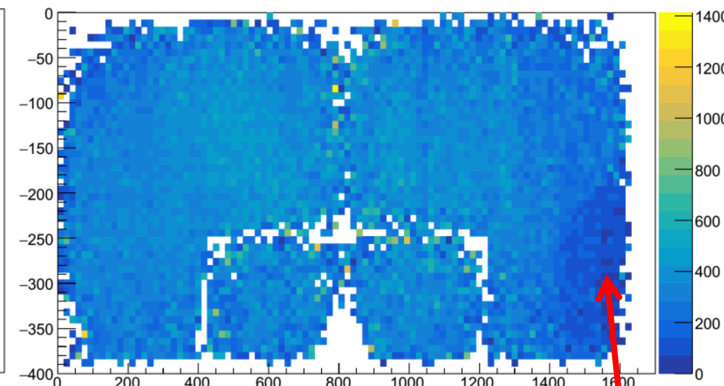
Goal: quality "passport" for every module.
Left r/o, right r/o and hot-zones are treated as independent parts



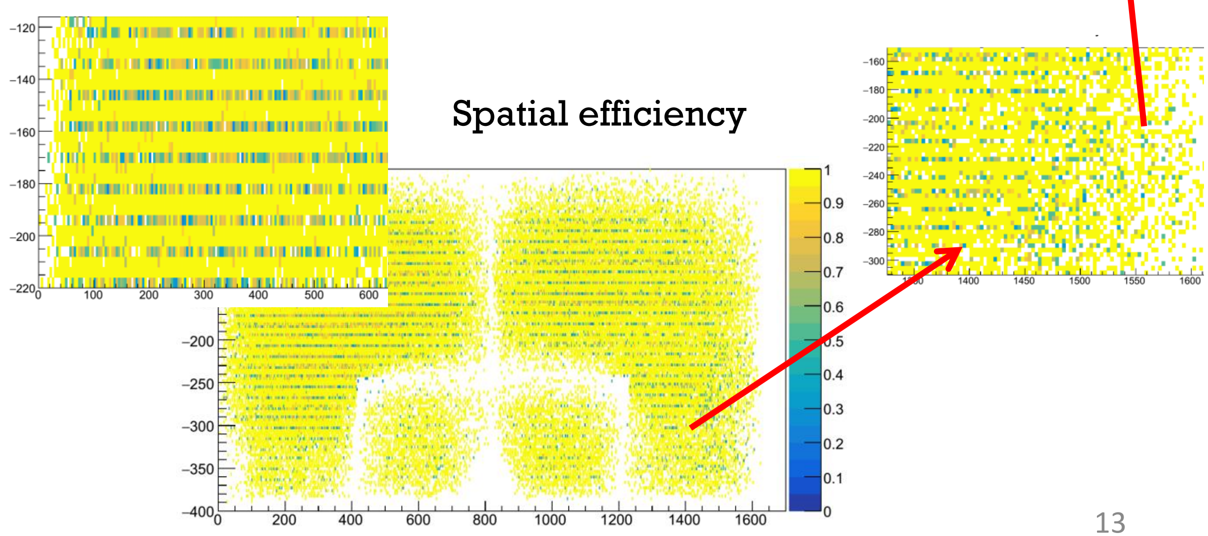
2D occupancy plot



Spatial response uniformity



Spatial efficiency

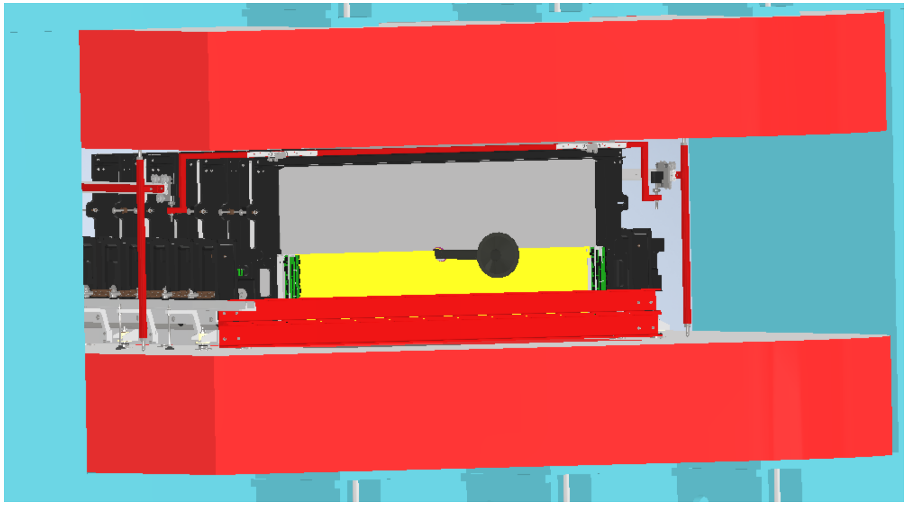


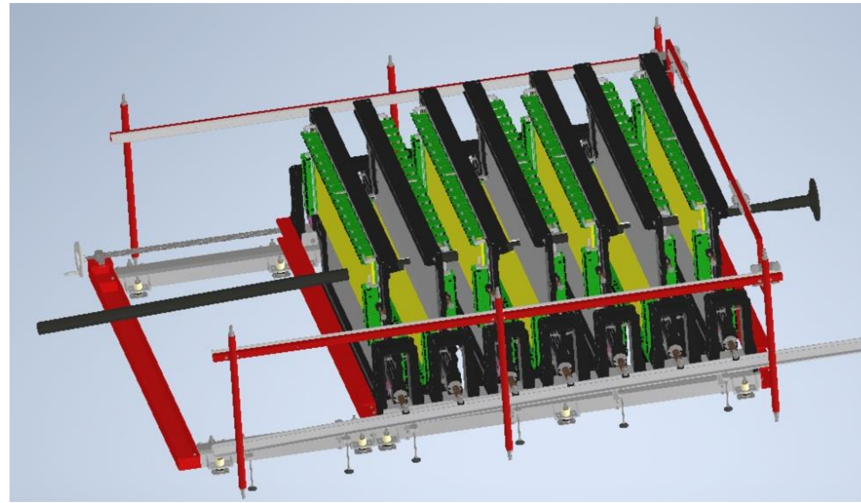
First stage – tests of 1632*390 mm^2 detectors (finished, data is under analysis)

Second stage – tests of 1632*450 mm^2 detectors (05-06/2021)

GEM central tracking system

GEM support mechanics inside the SP-41 magnet





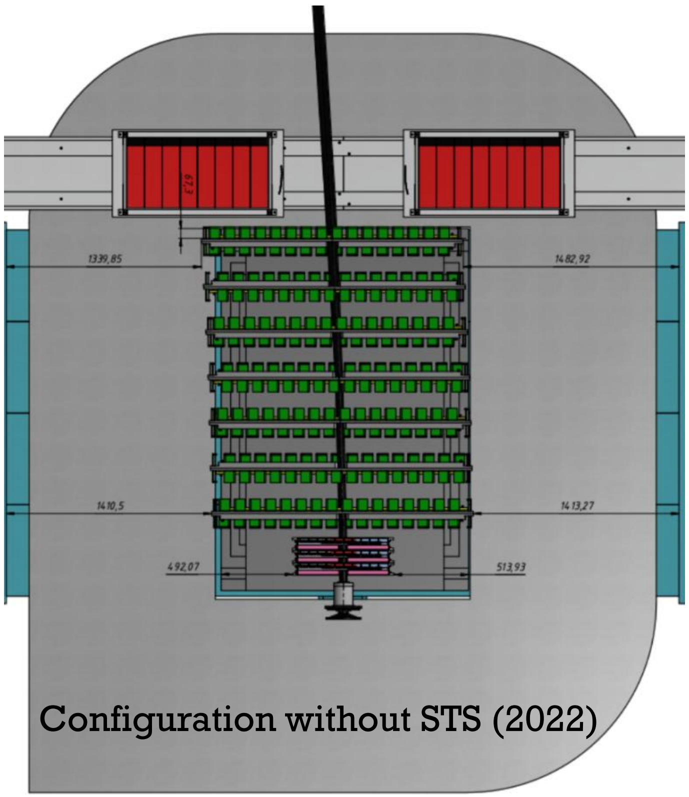
Status and plans:

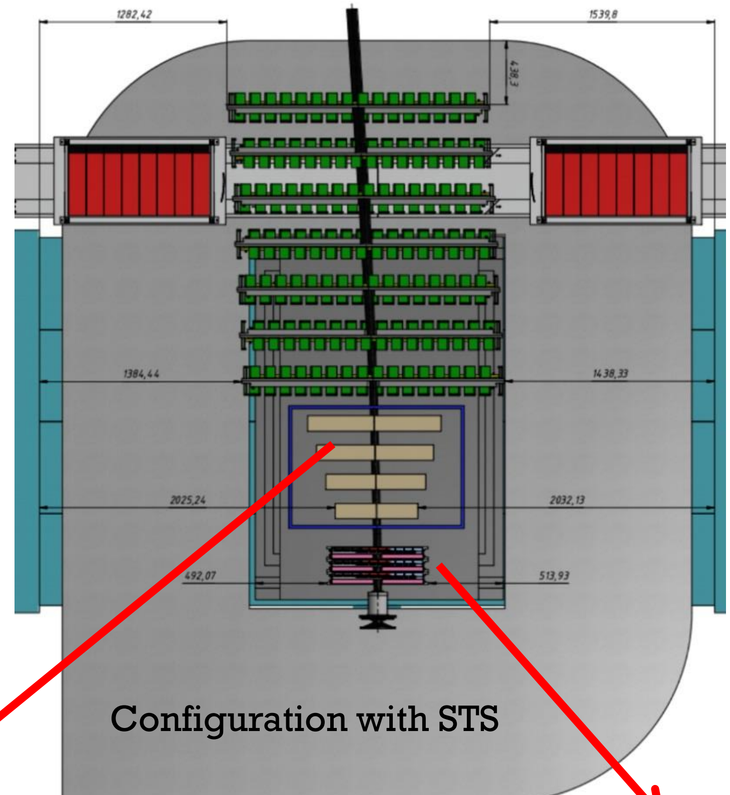
- 13 GEM detectors are assembled and pass long-term quality tests at cosmic test-bench;
- 1 defected GEM detector is shipped to CERN for repair;
- 2 spare detectors are planned to be assembled at CERN at summer 2021 (all parts are ready);
- Data on spatial efficiency, resolution and response uniformity is under analysis;
- Development of the mechanics design for GEM planes precise installation inside the magnet was done by "Pelcom" (Dubna)- finished;
- Production of the mechanics is currently performed by "Pelcom" (Dubna) – deadline 09.2021;
- Material budget of the GEM central tracking system full configuration together with mechanics for heavy ion runs is estimated;
- Gas control system is under construction, all components are ordered;
- New fast electronics is planned to be integrated after 2022. Kintex7 based 128ch GEM evaluation board was designed and produced by DAQ group for VMM3a tests.

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 , 2023
- Forward Si + 4 STS stations + 7 GEMs: beam intensity few 10^5 Hz, after 2023
- 4 STS stations + 7 GEMs (fast FEE): high beam intensity few 10^6 Hz, after 2023-

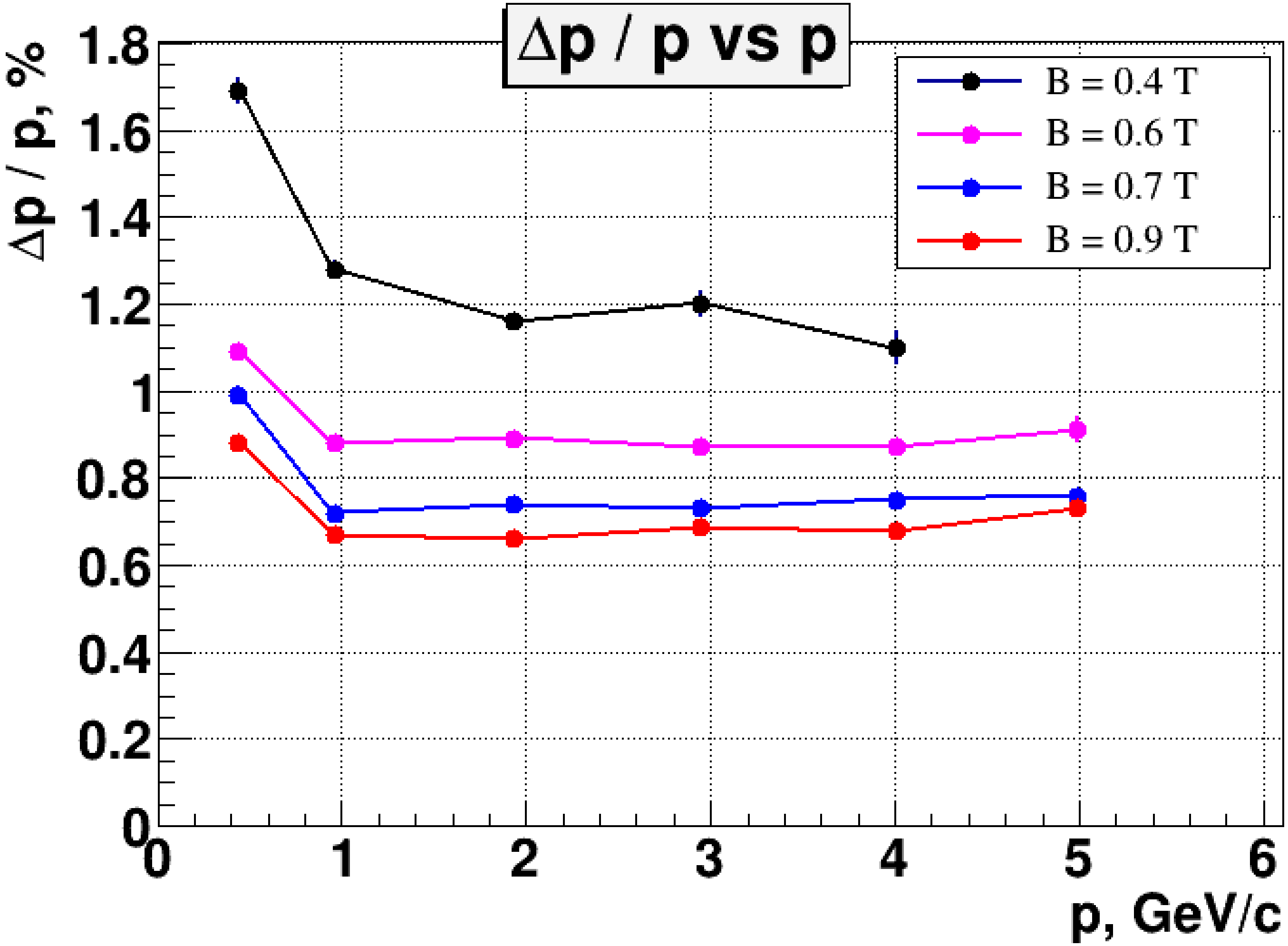




2023 year – "pilot" configuration
After 2023 year – full configuration

Forward Si will be removed after integration of STS full configuration into BM@N setup (after 2023 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

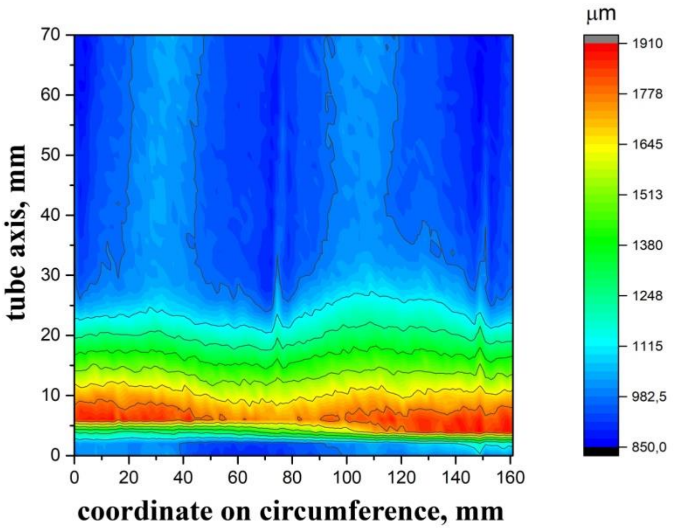
S. Piyadin, V. Spaskov, A.Kubankin

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

Experimental setup for X-ray tests

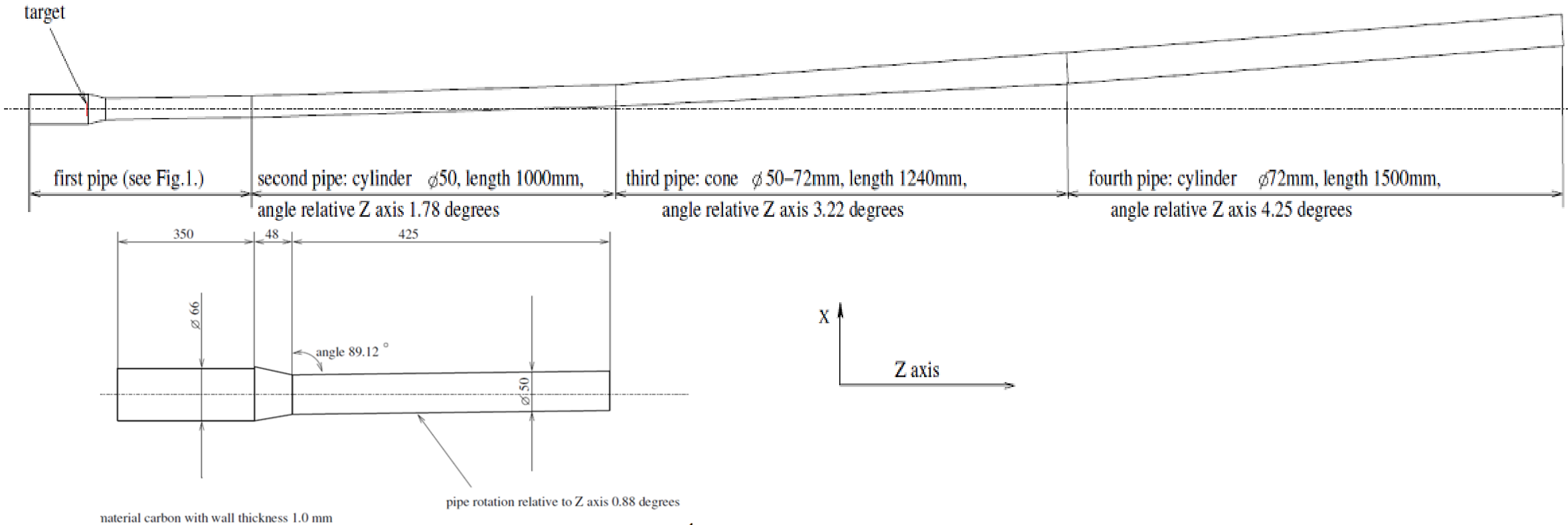
First vacuum tests were done at LHEP JINR (Spring 2020). Tests have shown an insignificant leakage level of side surfaces of the sample, vacuum up to 10^{-5}.

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).

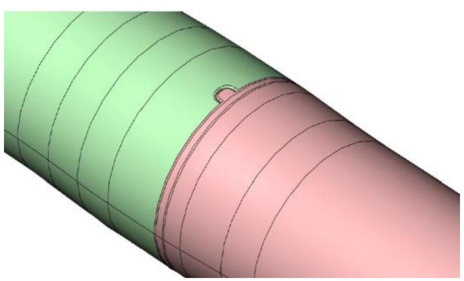


X-ray 3D map of the wall thickness distribution

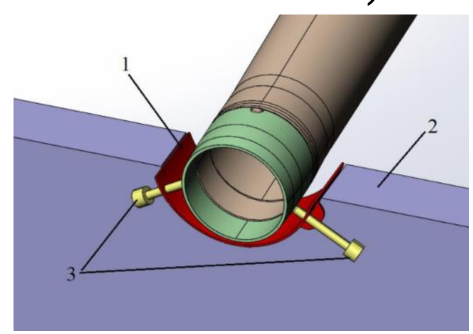
Beam pipe inside the SP-41 magnet



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



Design of the non-flange connections



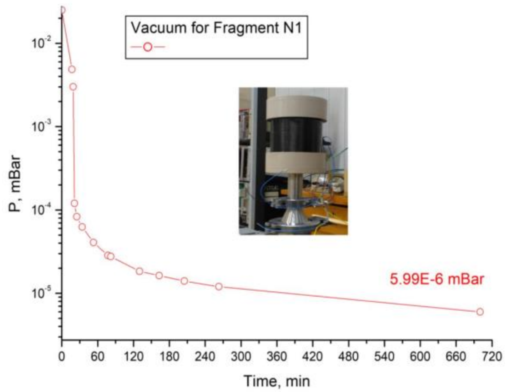
Design of the support system, which uses the surface of GEMs

KB "Arkhipov" (Moscow, Russia) was selected through a tender procedure for the beam pipe manufacture.
<u>First stage of the contract</u>: 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.
<u>Second stage</u>: Production of the beam pipe and non-flange connectors (June 2021).

Design and tests of the carbon vacuum beam pipe

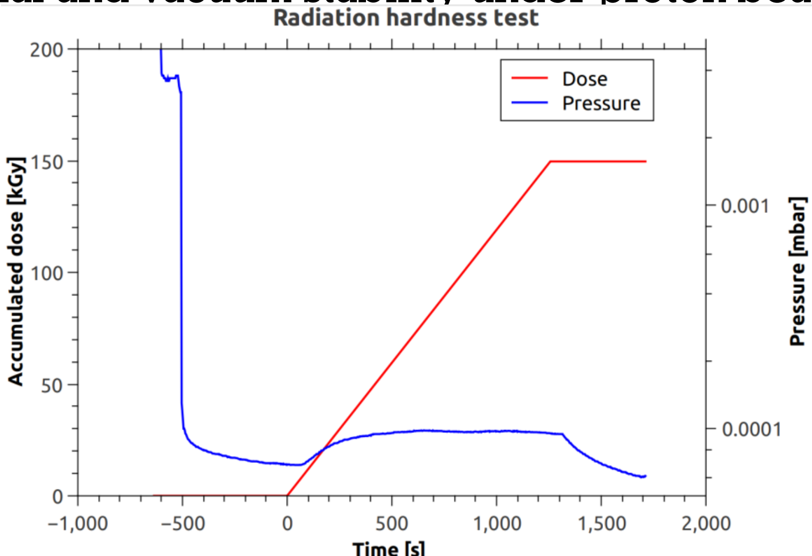
Faculty of Mechanical Engineering of the Czech Technical University
Nuclear physics institute, The Czech Academy of Sciences

Test of vacuum compatibility

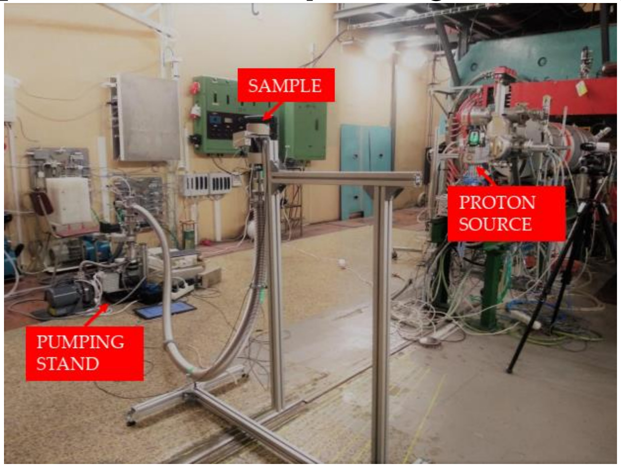


The ultimate pressure 6 x 10^{-6} hPa (scroll pump and turbomolecular pump)

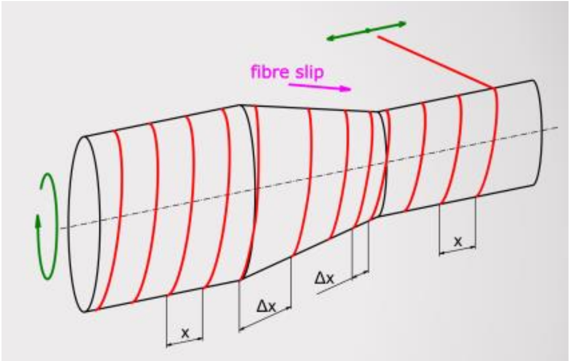
Test of material and vacuum stability under proton beam

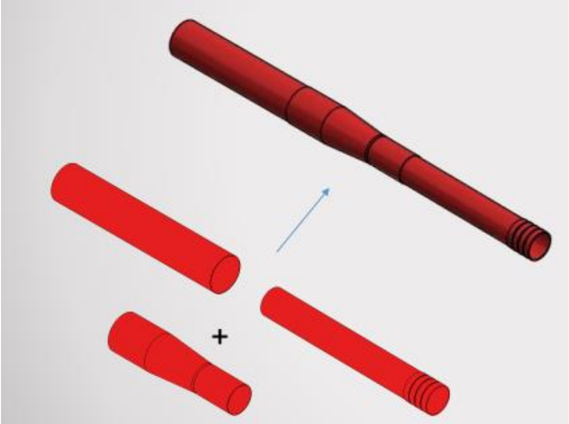


The test was performed September 3, 2020
The sample behaved stably during the testing



Updated design of the pipe connectors





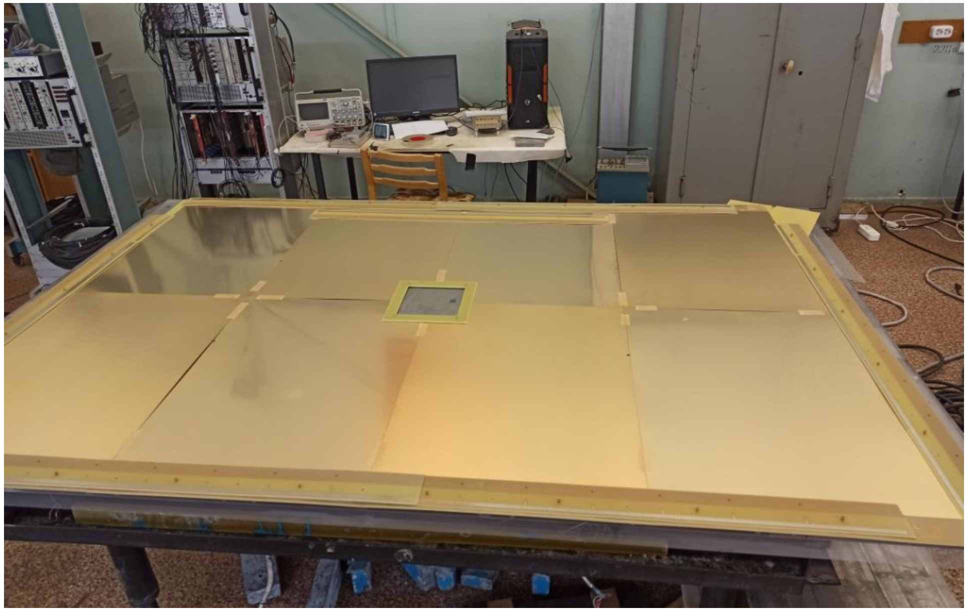
- *The critical apex angle ϑ of the cone was found by testing*
- *To achieve a vacuum-tight cone, the apex angle must be 20° or less*
- $\vartheta \leq 20°$

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

Cosmic stand for the1065x1065 mm^2 CSC

Status and plans:

- One CSC 1065x1065 mm^2 is produced and tested at Nuclotron beam;
- Assembly of the three1065x1065 mm^2 chambers is finished.
- Tests of the assembled chambers with r/a source and cosmic rays are to be performed by the end of summer 2021.



Cathode planes of the 2190x1453 mm^2 CSC

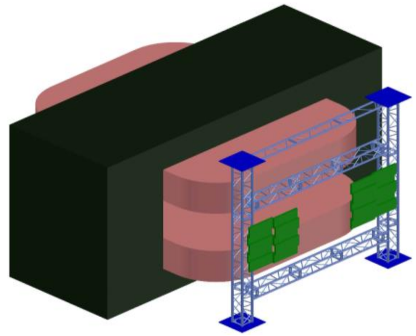
Status and plans:

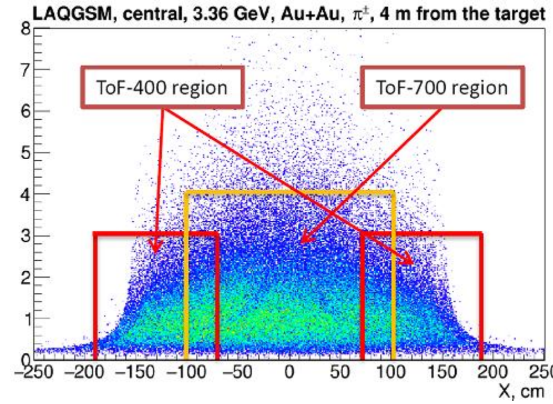
- Cathode planes and honeycomb panels are delivered to JINR;
- Assembly and tests of the first 2190x1453 mm^2 CSC chamber – 03.2022;
- Assembly and tests of the second 2190x1453 mm^2 CSC chamber – middle 2022;

CSC group

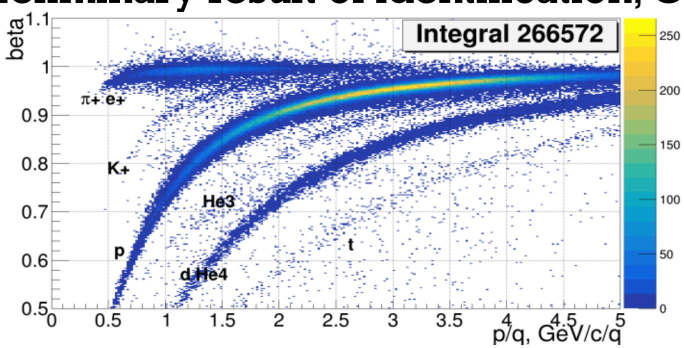
Status of ToF-400 & ToF-700

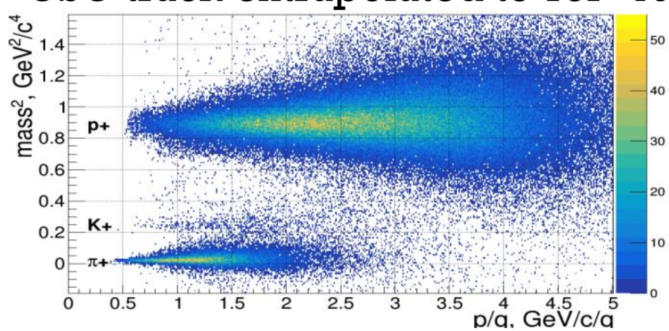
Both time-of-flight systems are ready for the heavy ion beam program



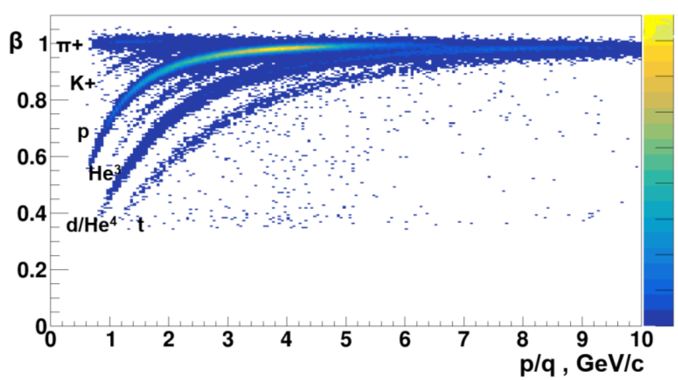


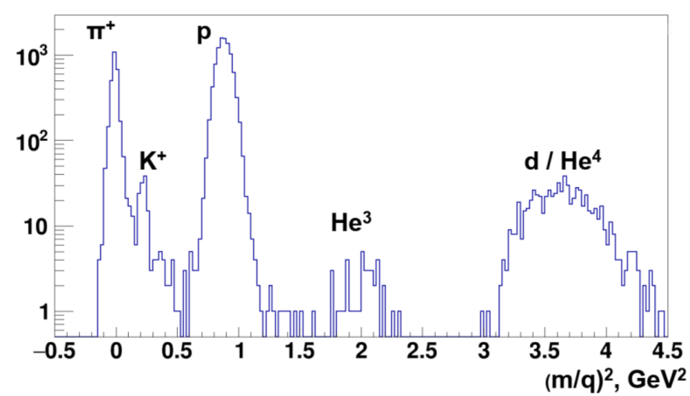
Preliminary result of identification, GEM+CSC track extrapolated to ToF-400





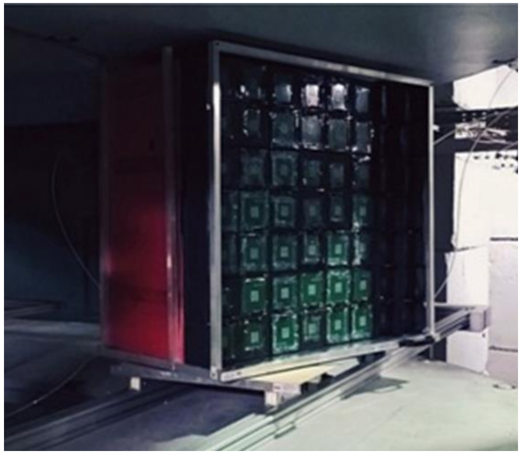
Preliminary result of identification, GEM+DCH track extrapolated to ToF-700





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

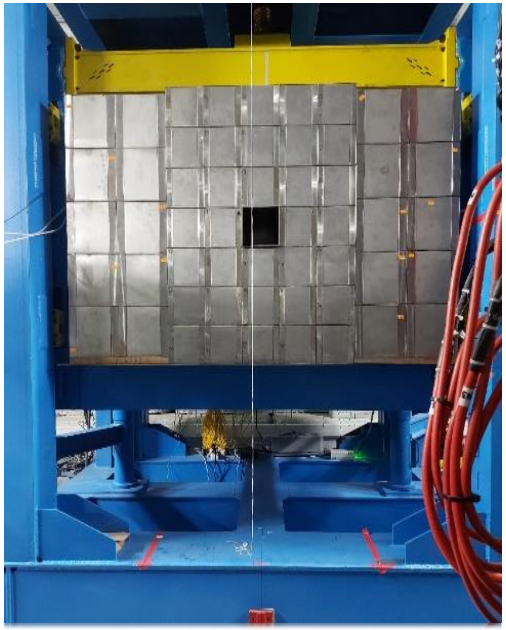
New racks for ECAL

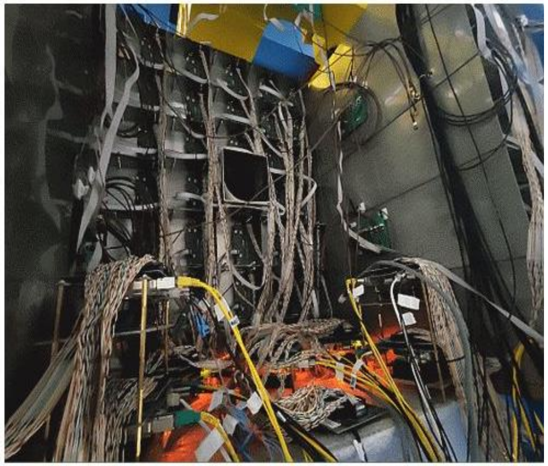
Cosmic tests of the modules

New mechanics for the two-arm calorimeter is ready

The ADC and modules for the two arms ECAL have been prepared.

Status of new FHCal





20 PSD CBM nodules - transverse size 20x20 cm^2, 5.6 nuclear interaction lengths.

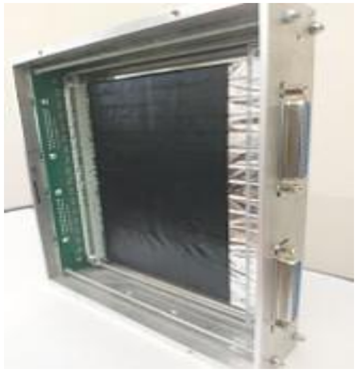
34 MPD/NICA like modules - transverse size 15x15cm^2, 4 nuclear interaction lengths.

Light collection:
– 6 WLS fibers from 6 sequentially scint. tiles
combined into one optical connector at the end of module.

Light readout:
10 MPPC (3x3 mm^2)/PSD module
(7 MPPC/MPD module)

Signal readout – 8 sampling ADC64

FHCal is completely assembled and installed at the BM@N



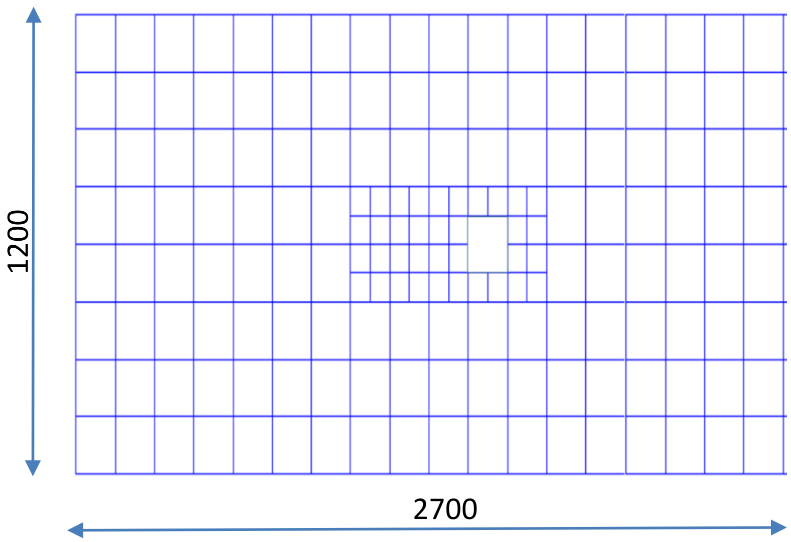
Forward Quartz Hodoscope (FQH)
FQH covers the beam hole 15x15 cm^2 in the FHCal

- **16 quartz strips with sizes 10x160x4 mm^3;**
- **Light readout of each strip with 2 SiPMs from each strip ends;**
- **64 readout channels – 4 TQDC.**

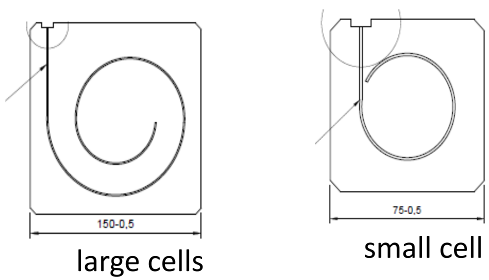
FQH is ready for installation on the FHCal

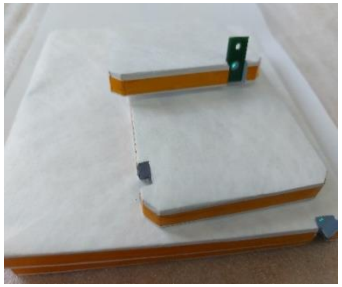
group of INR RAS Troitsk

Status of the ScWall development and construction



Large cells (150x150x10mm^3) - 134 pcs
Small cells (75x75x10mm^3) - 36 pcs
Light collection – with WLS fiber glued in the grove.





Light readout: MPPC Hamamatsu S14160-1310(1.3x1.3 mm^2)
Signal readout – 3 ADC64

Study of cells light output on LPI RAS synchrotron (March 2021)

Large cells

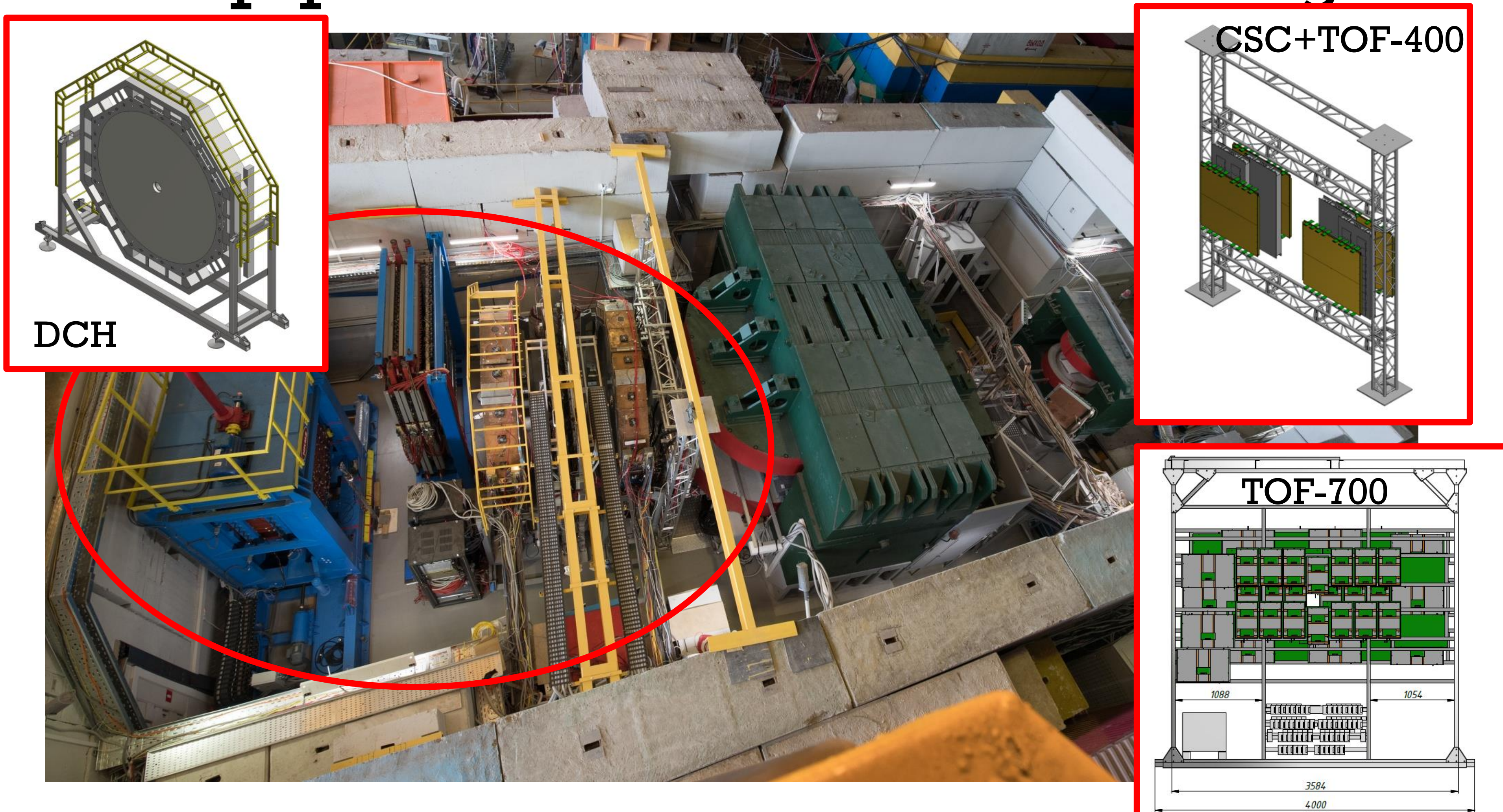
- Mean light output: 35 ph. el./MIP
- inhomogeneity of the light output: $\sigma \sim 7\%$

Small cells

- Mean light output: 55 ph. el./MIP
- inhomogeneity of the light output: $\sigma \sim 2\%$

group of INR RAS Troitsk

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).

S. Piyadin

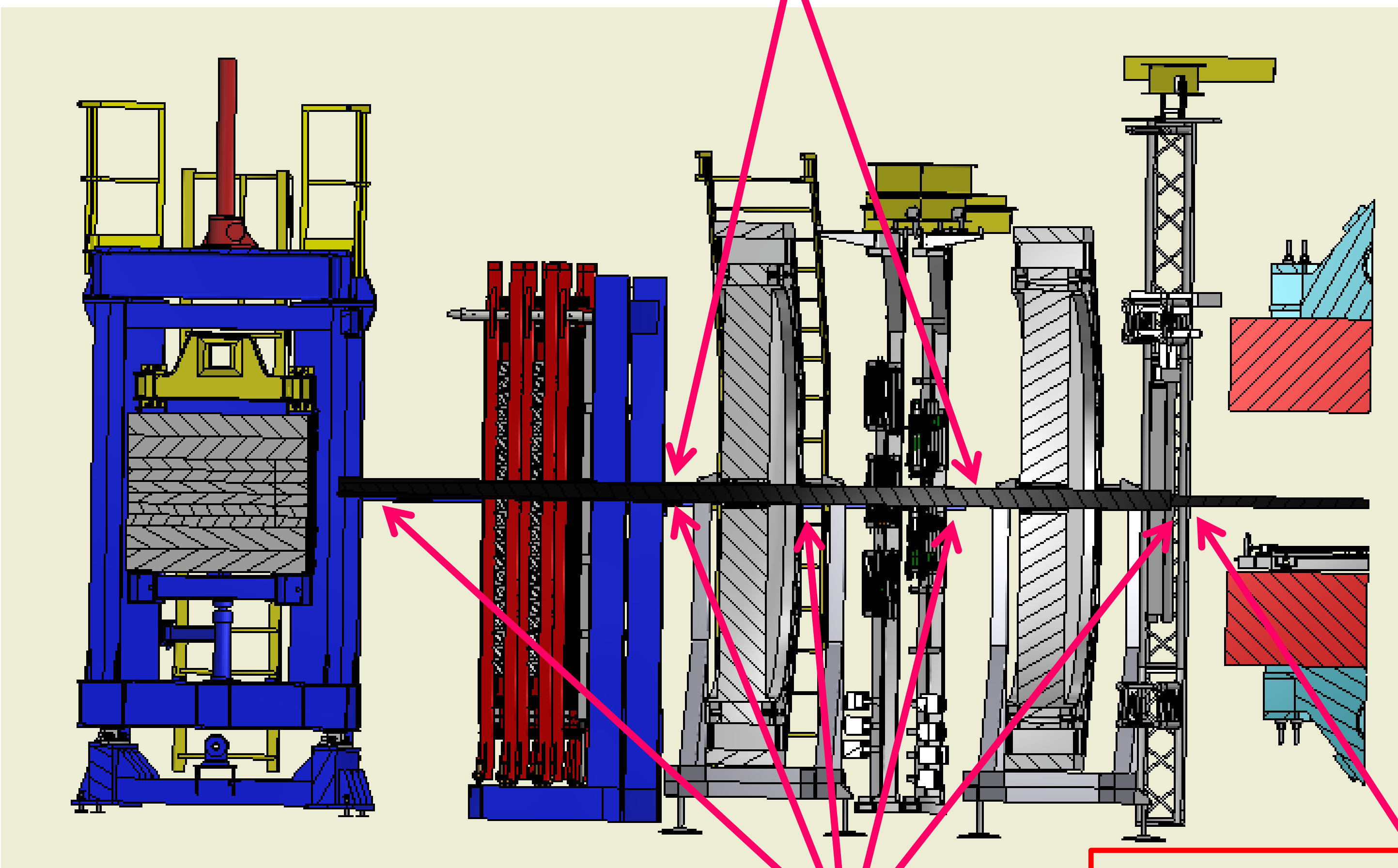
Technical task is currently under discussion.

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

Beam pipe downstream the SP-41 magnet

S. Piyadin

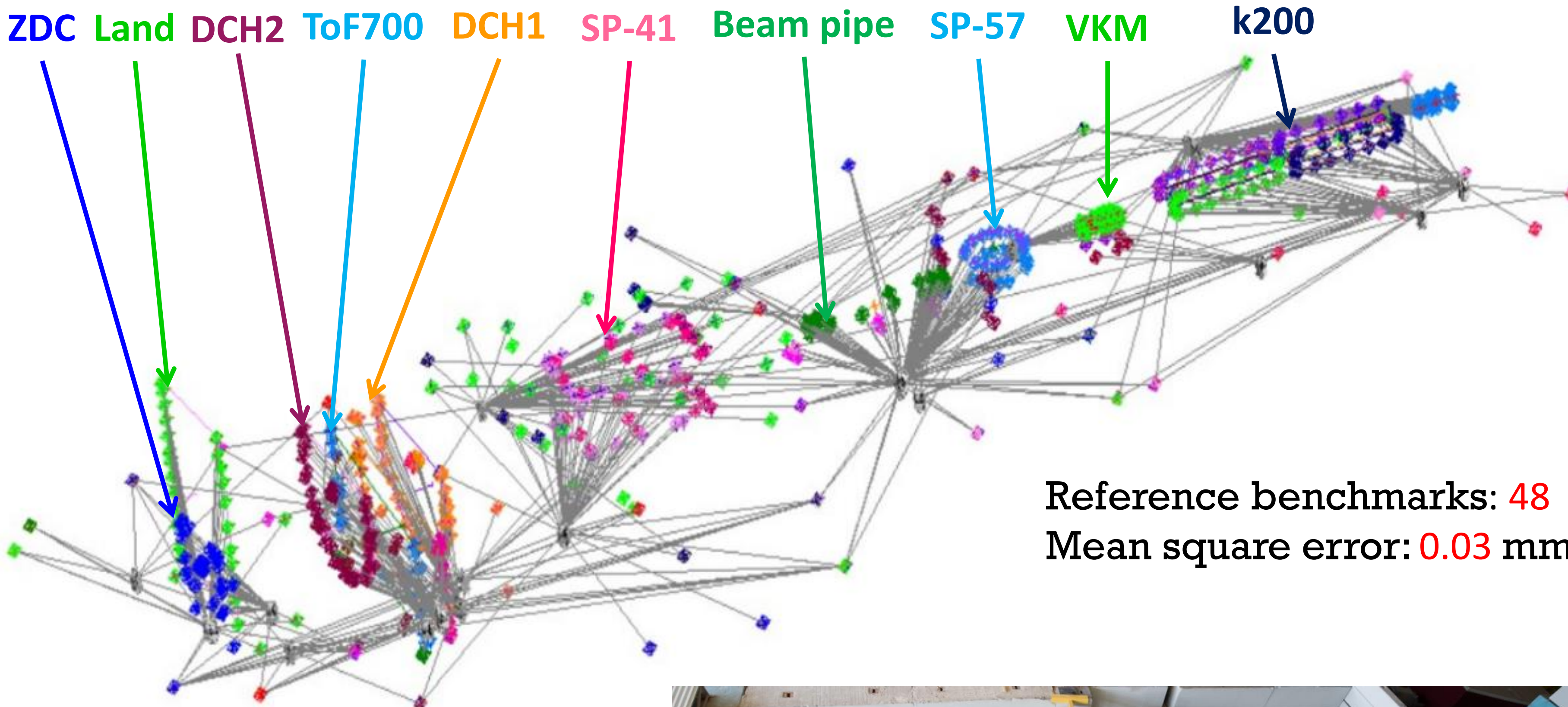
Non-flange connection



5 points for support

Connection: flange
Material: aluminum
Conversion: 72mm to 125mm

Development of a BM@N reference metrological grid



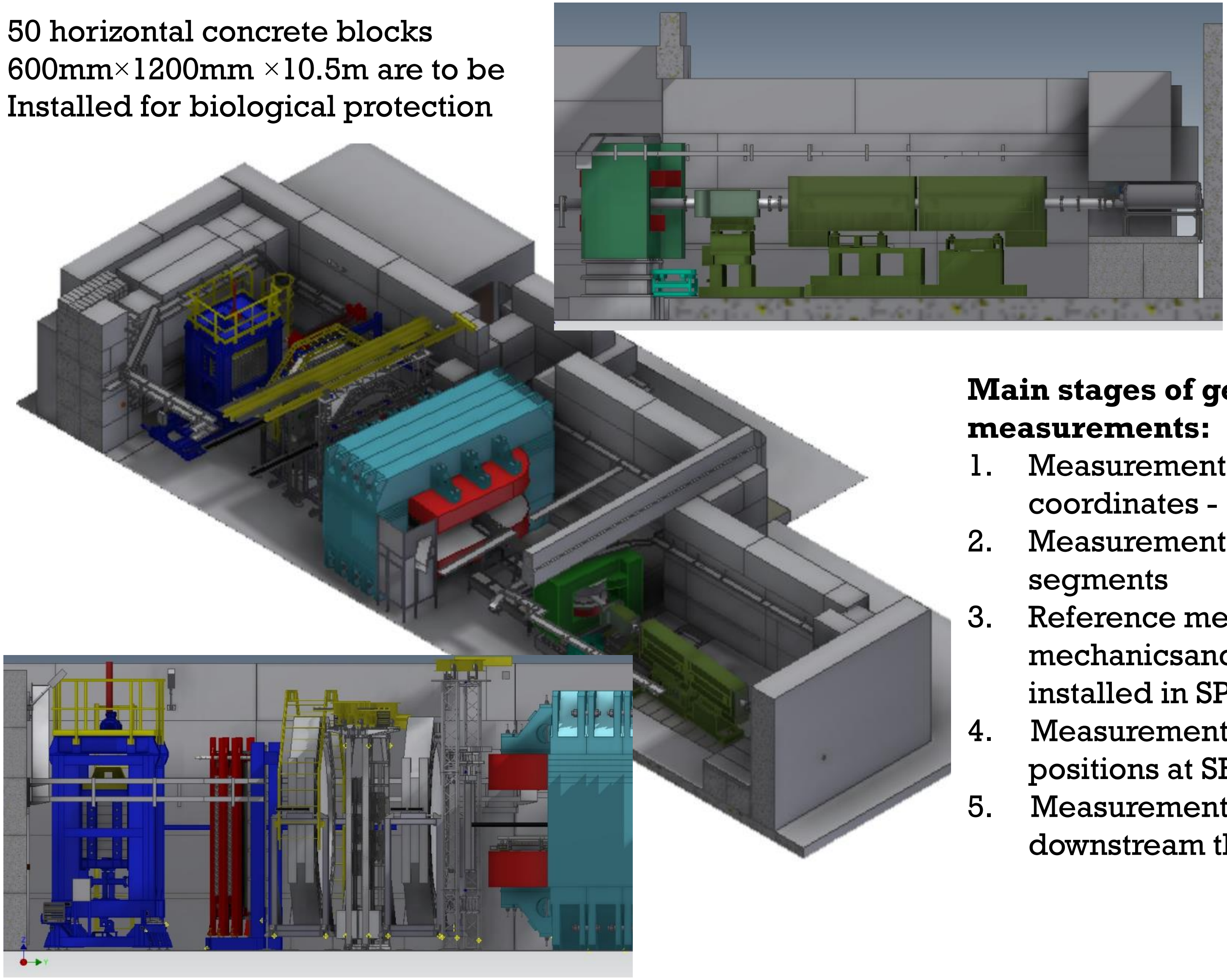
Reference benchmarks: 48
Mean square error: 0.03 mm

- 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

3D model of the BN@N experimental hall

S. Piyadin, S. Novozhilov, I. Kruglova

50 horizontal concrete blocks 600mm×1200mm ×10.5m are to be Installed for biological protection



Main stages of geodetic measurements:

1. Measurements of GEM planes coordinates - done
2. Measurements of ion beam pipe segments
3. Reference measurements of GEM mechanicsand ion beam pipe installed in SP-41 magnet
4. Measurements of the detector positions at SRC configuration
5. Measurements of the beam pipe downstream the SP-41 magnet

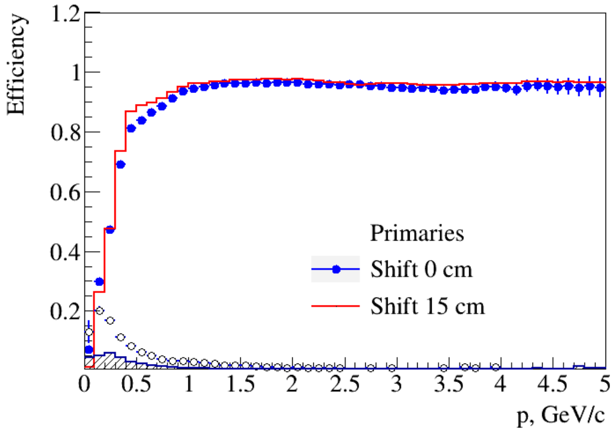
Summary:

Detector Subsystem	Upgrade Status
Beam pipe before the target	installed
Beam pipe downstream the target, in SP-41 magnet	June 2021
Beam pipe downstream the SP-41 magnet	December 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 (2023) 292 modules (2024)
GEM	7 top half-planes + 7 bottom half-planes(assembled)
CSC	4 chambers 1065x1065 mm^2(assembled) 2 chambers 2190x1453 mm^2(03.2022, 06.2022)
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



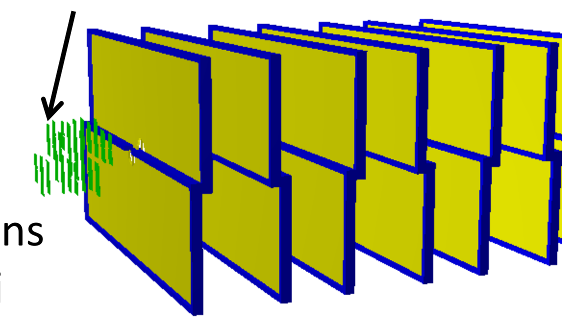
DCM-QGSM model

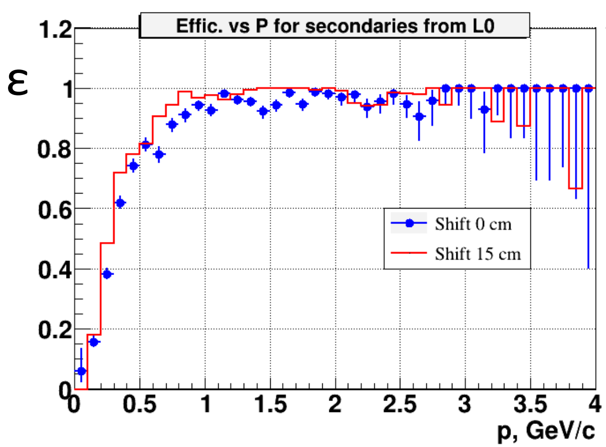
Kr + Pb , T_0= 2.4 AGeV

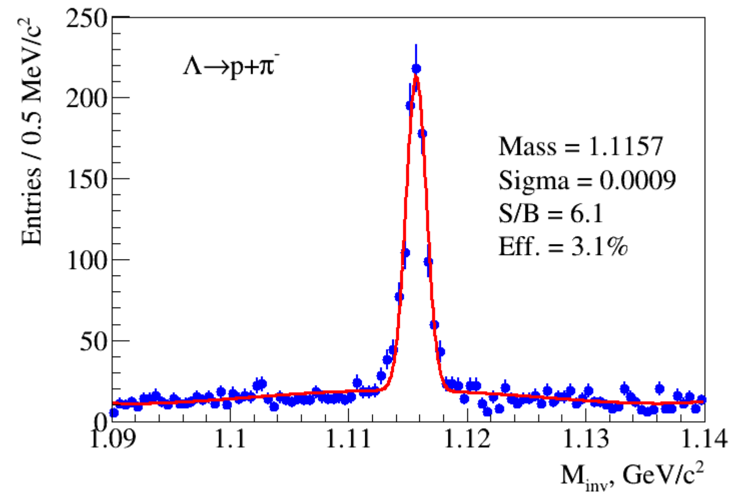
Aim:

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

3 Forward Si + 7 GEM



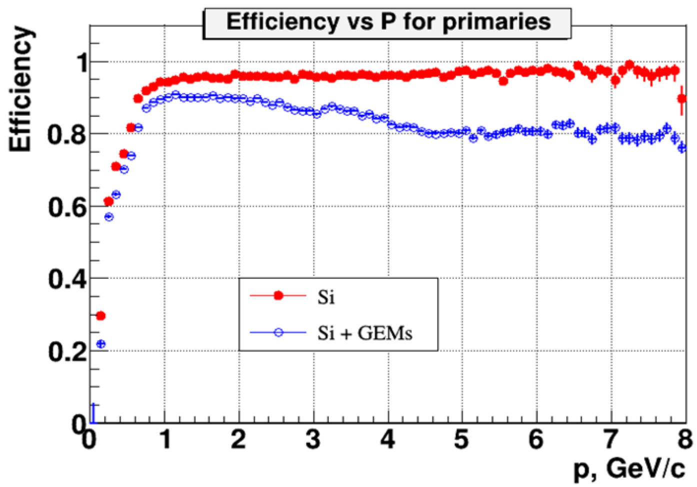


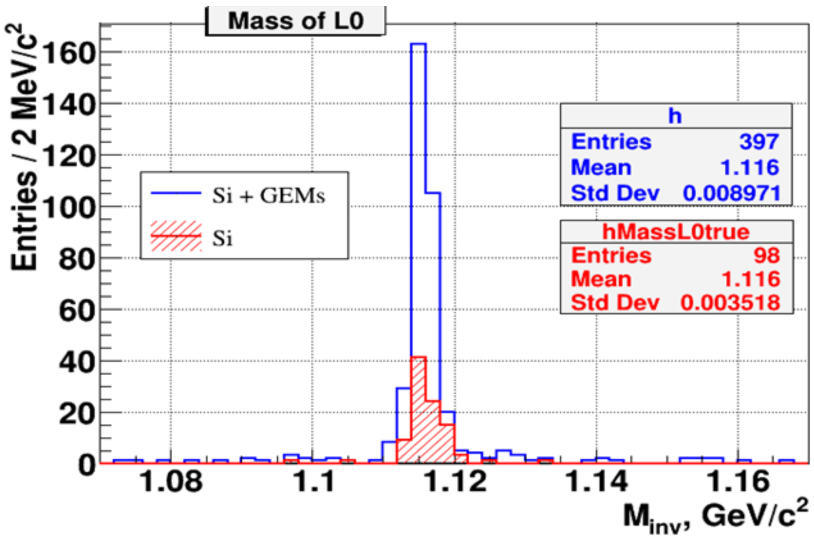


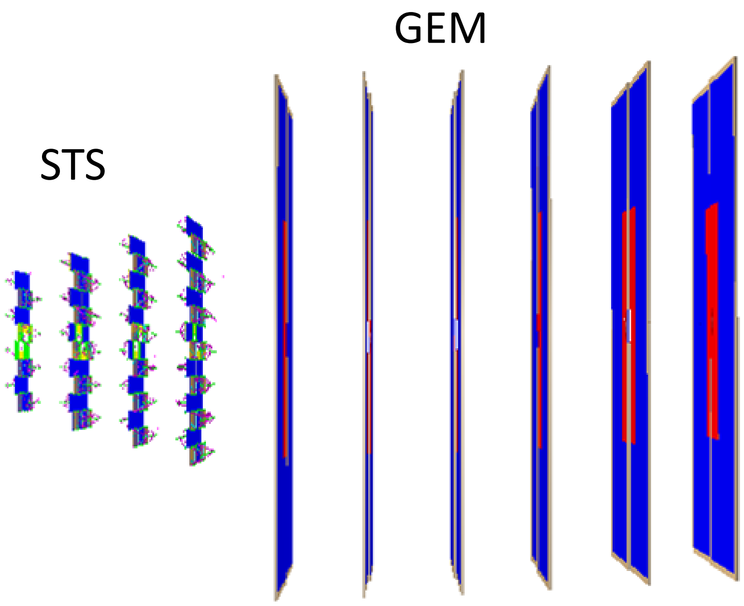
Simulation of hybrid central tracker for heavy ion runs: STS +GEM

A.Zinchenko, V.Vasendina

QGSM model, Au+Au, T_0 = 4 AGeV

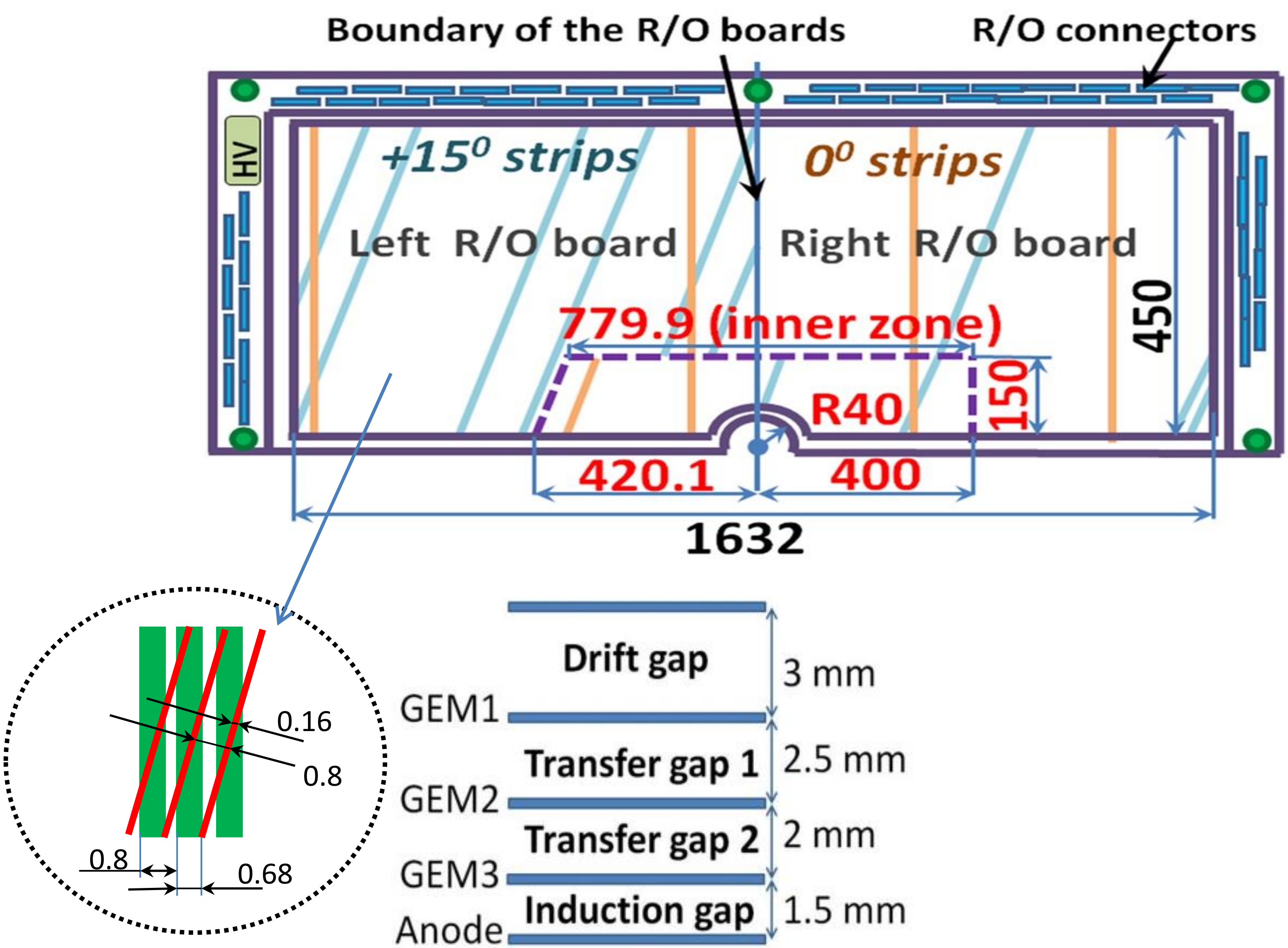






Hybrid STS + GEM tracker:
► 4 times increase in number of reconstructed tracks and Λ hyperons

BM@N GEM detectors



Schematic cross section of the BM@N triple GEM detector