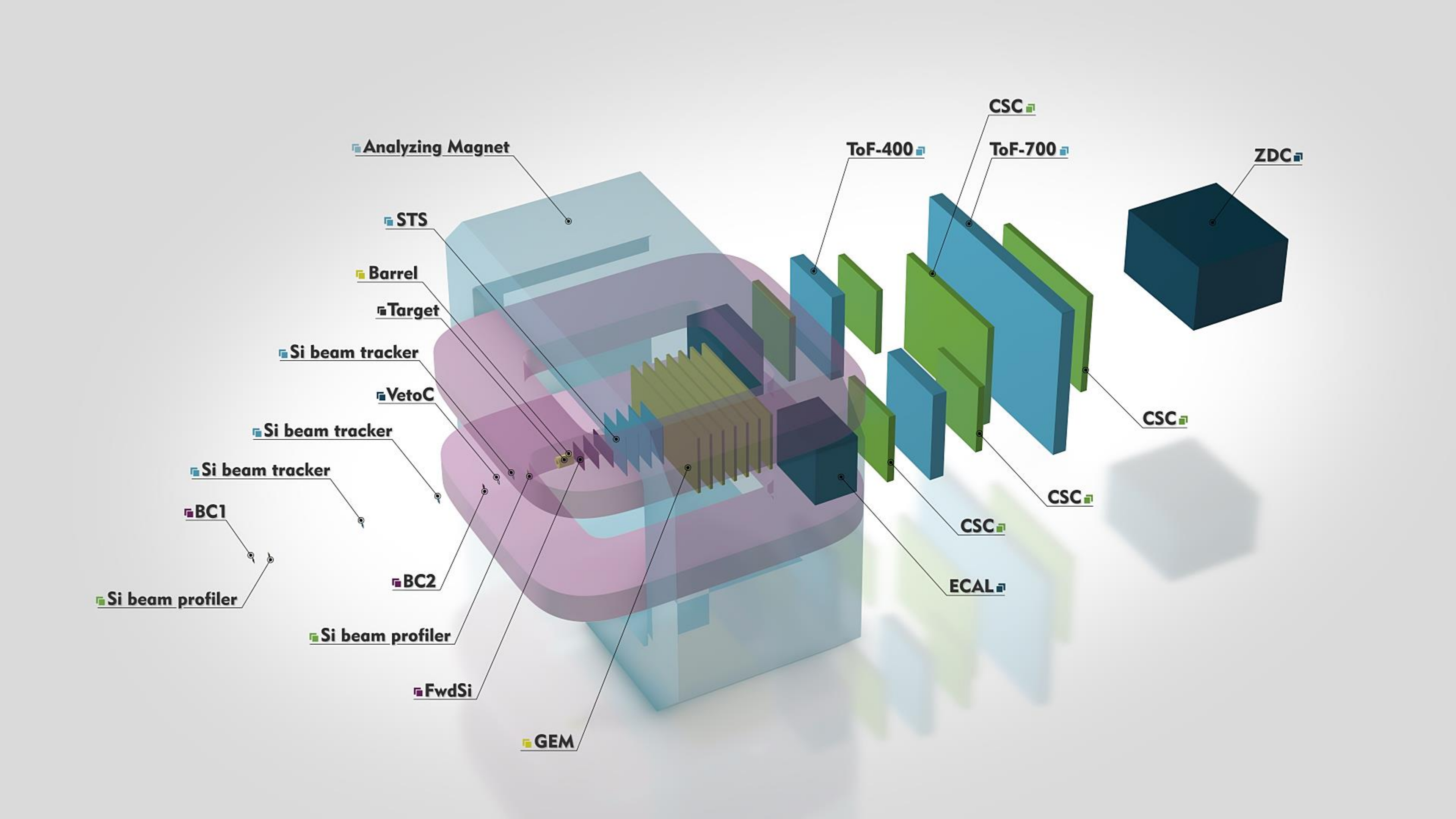
Upgrade of the BM@N detectors

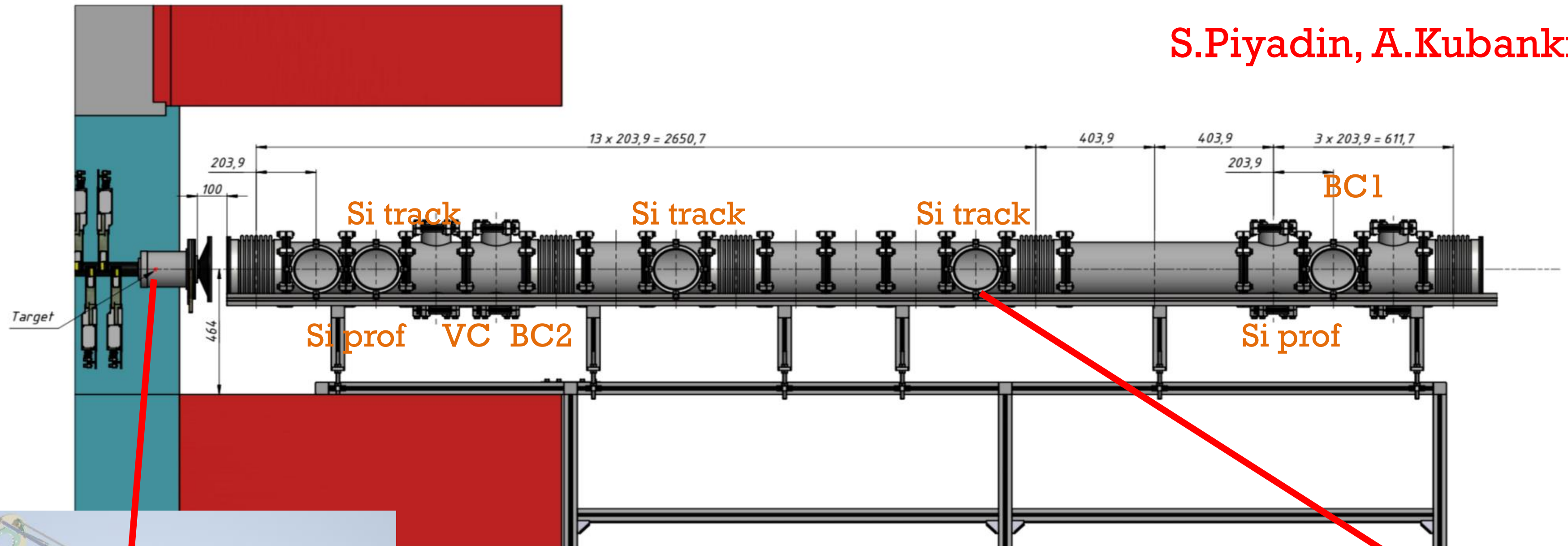
Anna Maksymchuk on behalf of the BM@N Collaboration
26/10/2020

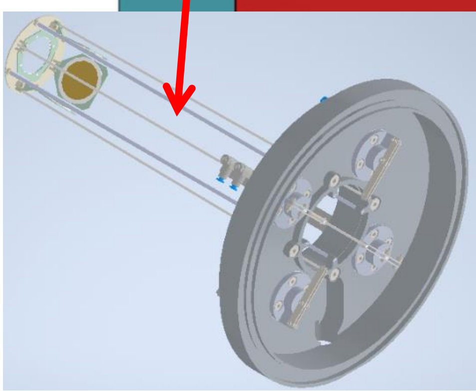
BM@N Experimental Setup

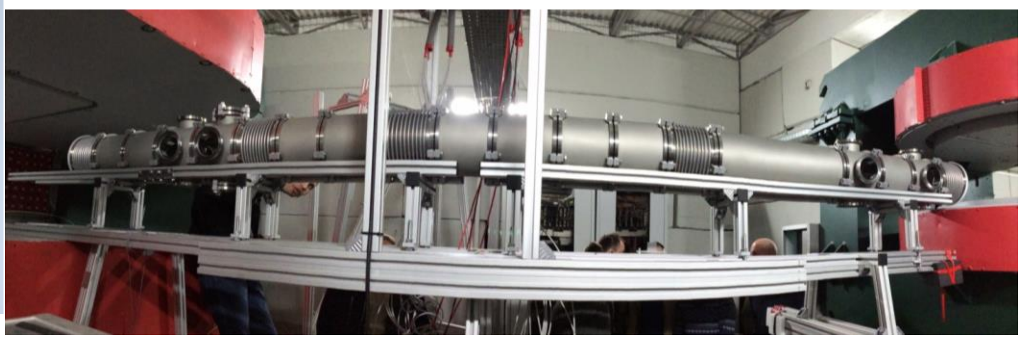


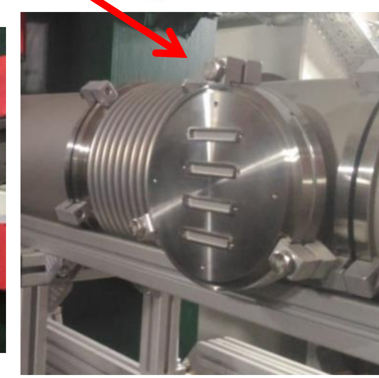
Beam pipe before the target

S.Piyadin, A.Kubankin







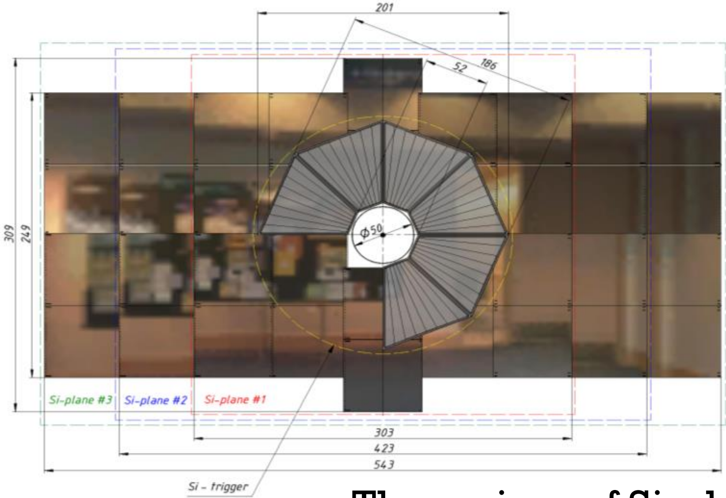


Four stainless steel vacuum boxes downstream the target are replaced by aluminum ones.
The design and production of the target station mechanics is performed by A.Kubankin group

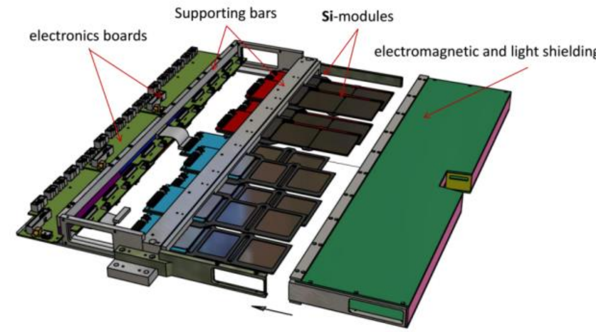
See talk of S.SEDYKH

Production of the beam pipe: Belgorod University

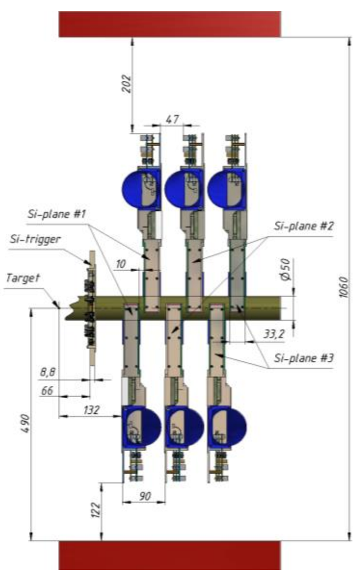
Upgrade of the forward Si tracking detectors

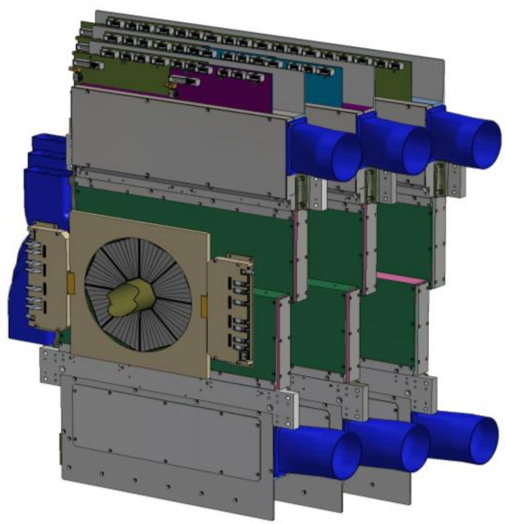


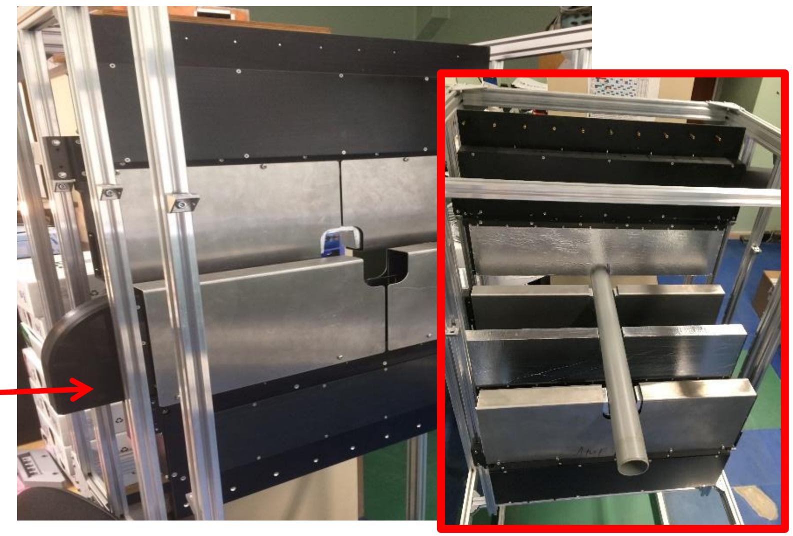
Three sizes of Si-planes



Half-plane design







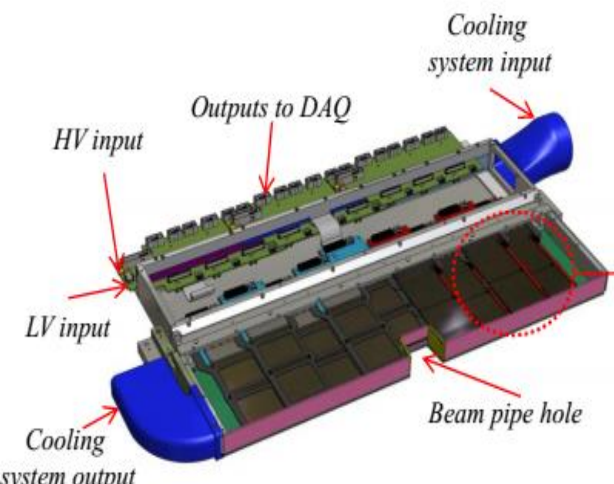
Design of the Si-planes
on the BM@N beam-channel

group of N.Zamiatin

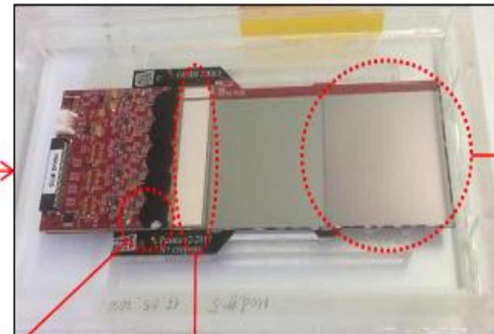
Station#	Number of DSSD modules	DSSD station square	Number of Readout channels
Station1	10	720 cm^2	12800
Station2	14	1008 cm^2	17920
Station3	18	1296 cm^2	23040
Total	***42***	***~0.3 m^2***	***53760***

Upgrade of the forward Si tracking detectors

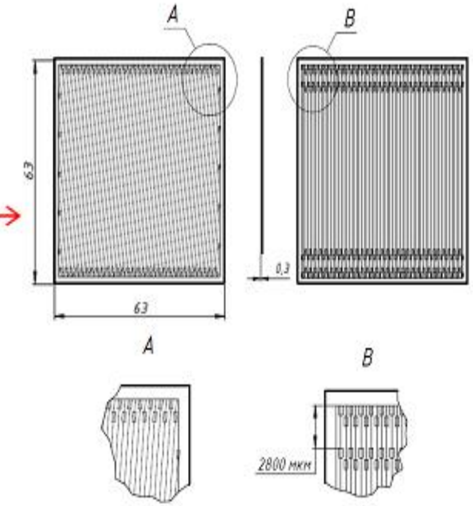
See talk of B.Topko

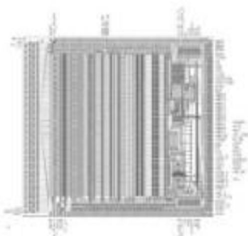


Silicon half-plane with FEE

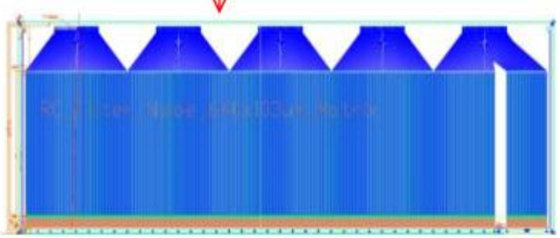


Silicon Detector Module





ASIC VATAGP7.1 (5 chips on each side of module)
Number of CSA: 128 channels
Dynamic range: $\pm$30 fC
Peaking time (slow/fast shaper): 500 ns/ 50ns
Noise (ENC): 70e +12e/pF (typ.)
Voltage supply: +1.5 V, -2.0 V
Gain from input to output buffer: 16.5 µA/fC
Output Serial analog multiplexer clock speed: 3.9 MHz
Power dissipation per channel: 2.2 mW



Pitch Adapter (n+) side
sapphire plates with an epitaxial layer of silicon (SOI)
Number of channels: 640
Value of poly-Si resistors: ≈ 1 MΩ
Value of integrated capacitors: ≈ 120 pF
Capacitor working voltage: 100 V
Capacitor breakdown voltage: >150 V

Size: 63x63x0,3 mm^3 (on 4" – FZ-Si wafers)
Topology: double sided microstrip (DSSD) (DC coupling)
Pitch p^+ strips: 95 µm;
Pitch n^+ strips 103 µm;
Stereo angle between p^+/n^+ strips: 2.5^0
Number of strips: 640 (p^+)× 640(n^+)

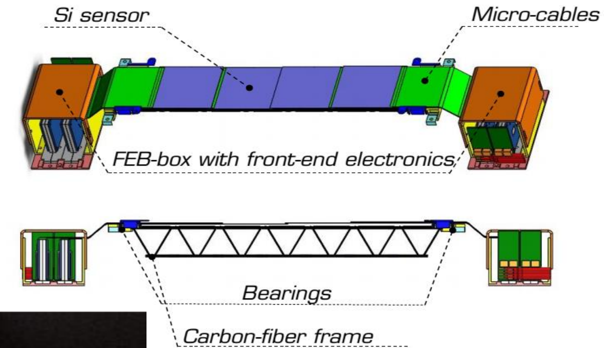
Upgrade of the forward Si tracking detectors


See talk of B.Topko

Plans and status:
- DSSD, Pitch adapters, ASICs VATAGP7.1, FEE PCBs are delivered, tested and ready for assembly
- Cross boards and mechanical support for FwdSi detectors installation inside the magnet are being designed at the moment
- FFE is currently in the process of assembly and tests
- First module is to be assembled and tested this month, after the assembly process is finished it would be possible to estimate time required for the assembly of 42 modules
- Test bench for module tests with cosmic rays and r/s ^{106}Ru is under development
- Clean room for the module assembly is ready

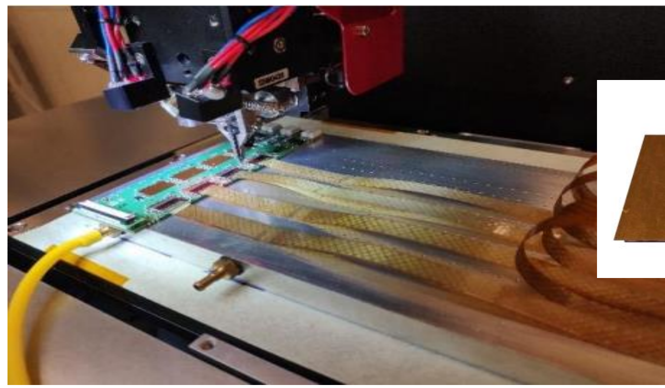
See talks of STS group

BM@N STS



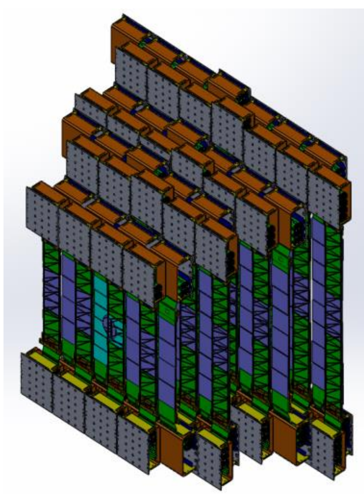
Four stations are based on CBM-type modules with double-sided microstrip silicon sensors:

- Pitch 58μ
- Stereo angle 7.5°
- Thickness 300μ
- Sizes: 62x62, 62x42, 62x22 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:

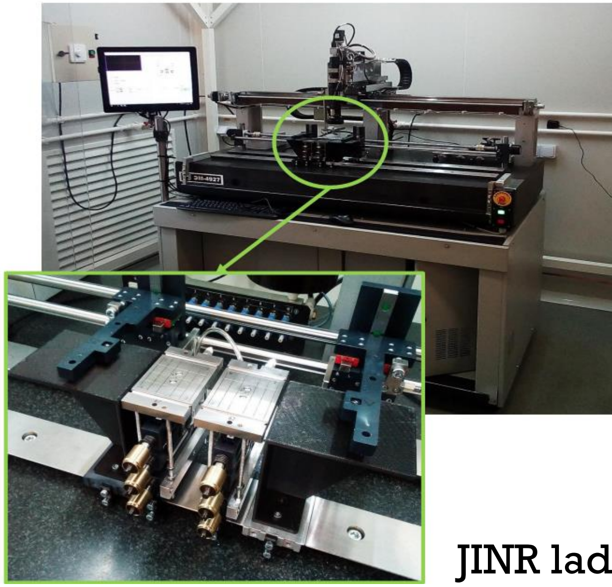
- Set of jigs was developed and produced;
- Assembly workflow developed and tested on the mockups and first operational modules;
- QA tests were developed and implemented in Elog;
- Yields still to be estimated

- 2022 – pilot v. of STS based on two stations with 42 modules
- 2023 – readout chain for 292 modules

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.

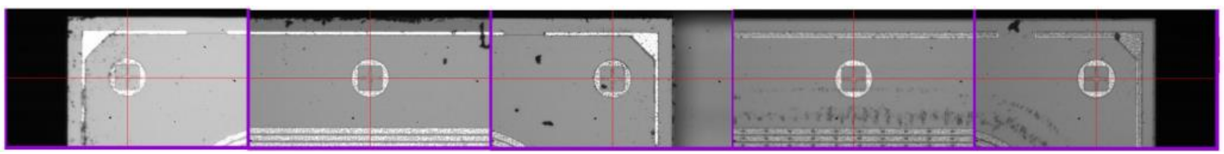
• Device is installed on the heavy diabase table to avoid vibrations of the LAD during operation.

LAD should provide the following accuracy of the sensor positioning:

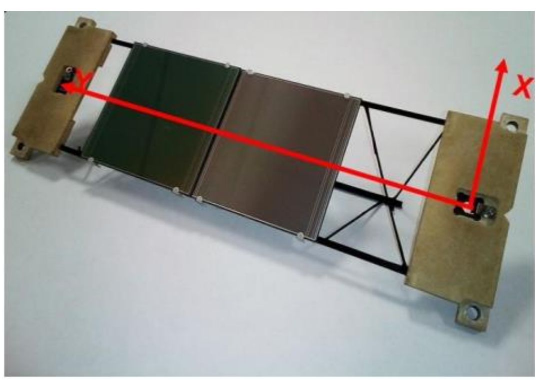
X coordinate: ±15 μm on 1200 mm along the truss;

Y, Z coordinates: ± 50 μm across the truss;

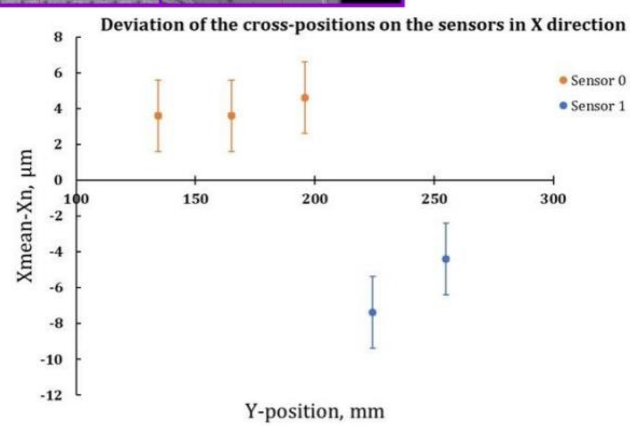
JINR ladder assembly device



Fiducial marks on the sensor



Mockup of the ladder

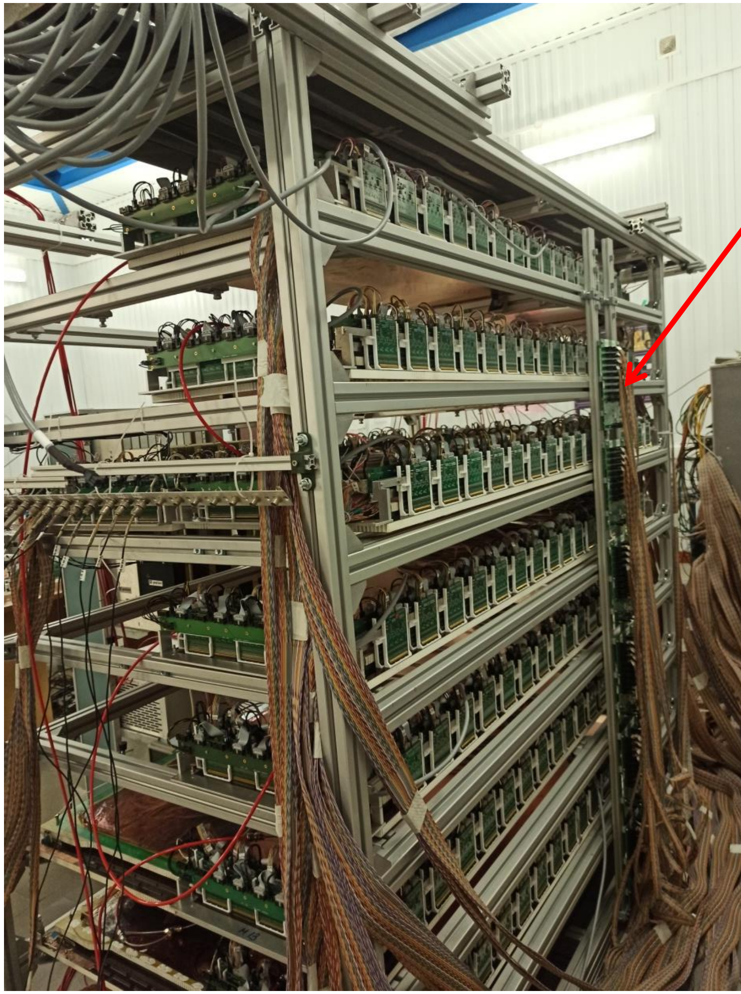


Measured deviations of X coordinates of the fiducial marks on the sensors from the mean value

GEM central tracking system status

Assembly of the stand for long-term GEM tests

S. Khabarov

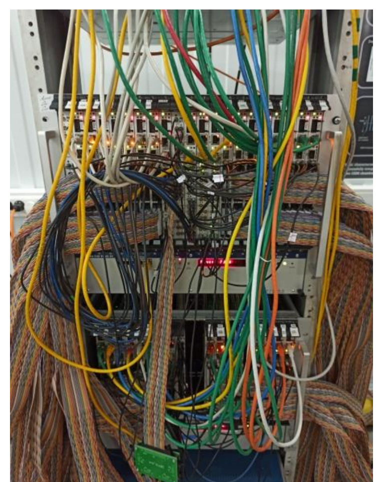


First stage – tests of 1632*390 mm^2 detectors
Second stage – tests of 1632*450 mm^2 detectors

A. Kuznecov

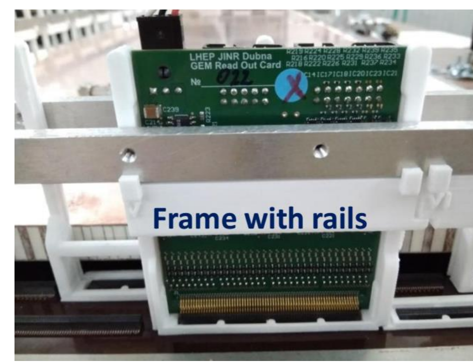
Trigger system – ten 10*200 cm^2 scintillation detectors

DAQ group



DAQ

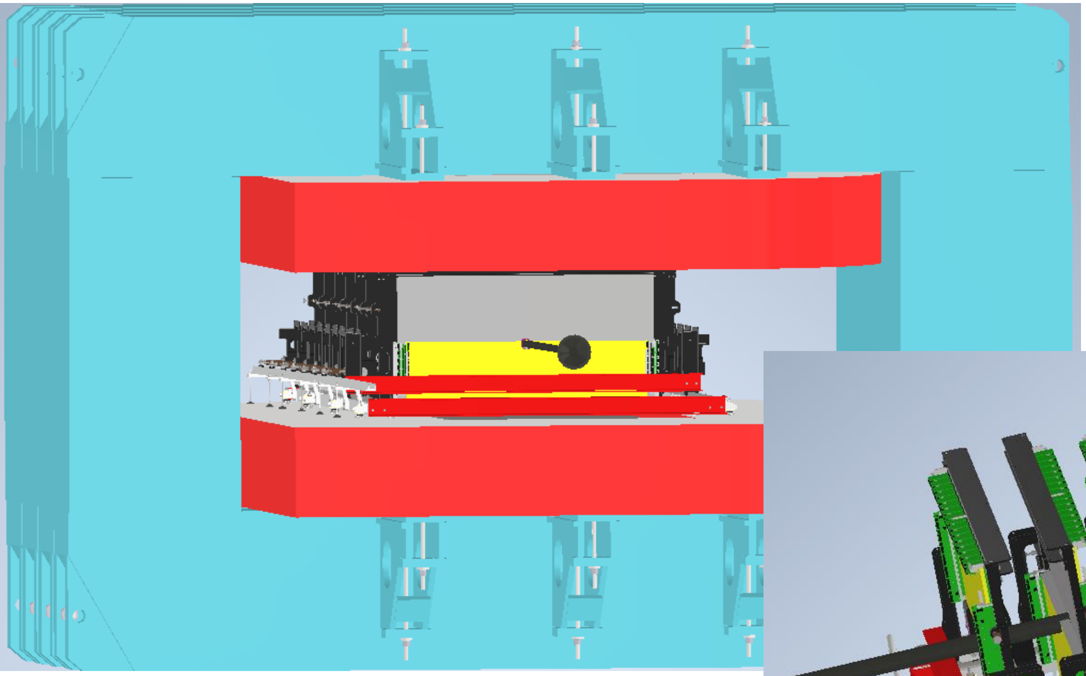
S. Novozhilov



Frames for FEE electronics

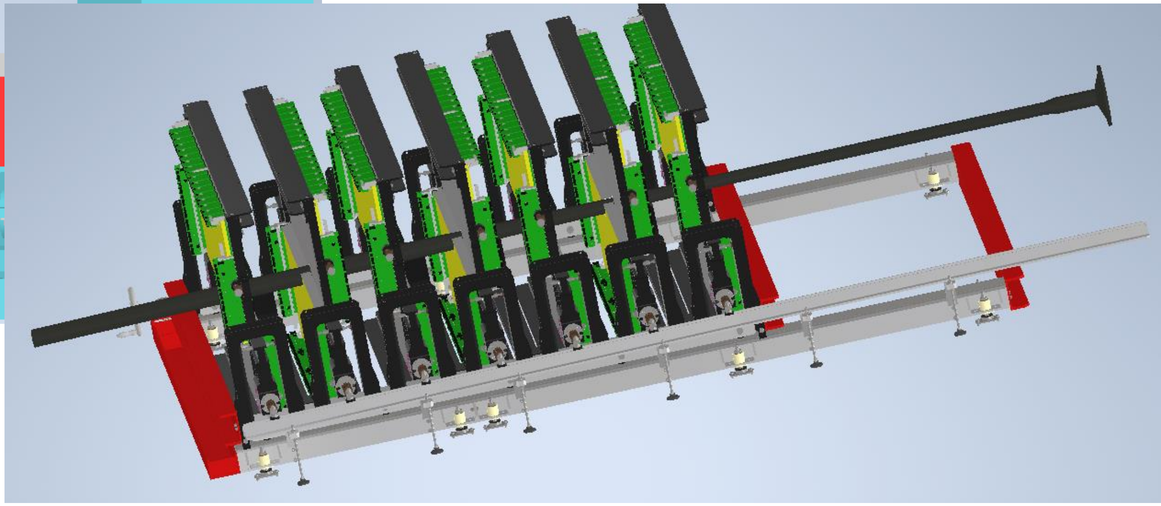
Status of the GEM support mechanics inside the SP-41 magnet

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

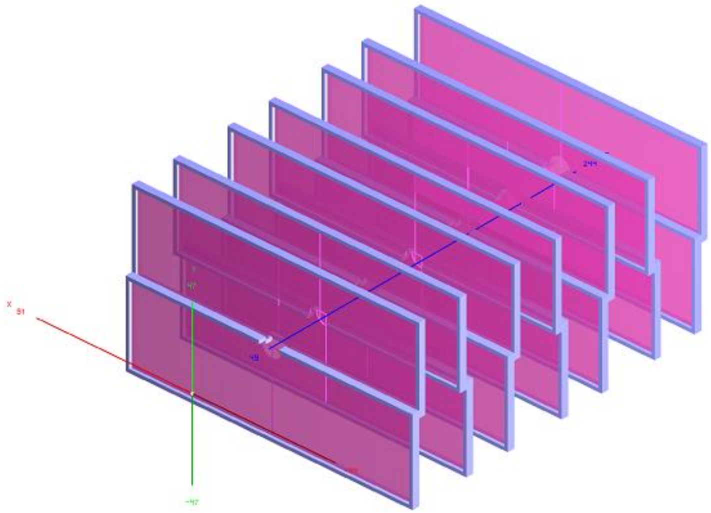


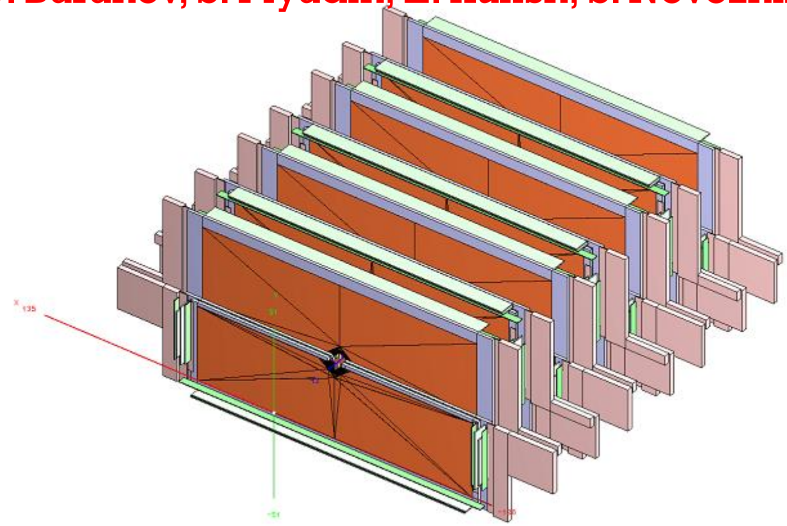
Development of the mechanics design for GEM planes precise installation inside the magnet was done by "Pelcom" (Dubna). Final cross-checks of the design were performed by BM@N chief engineer and GEM group. Technical documentation on the mechanics will be at JINR by the end of the week.

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

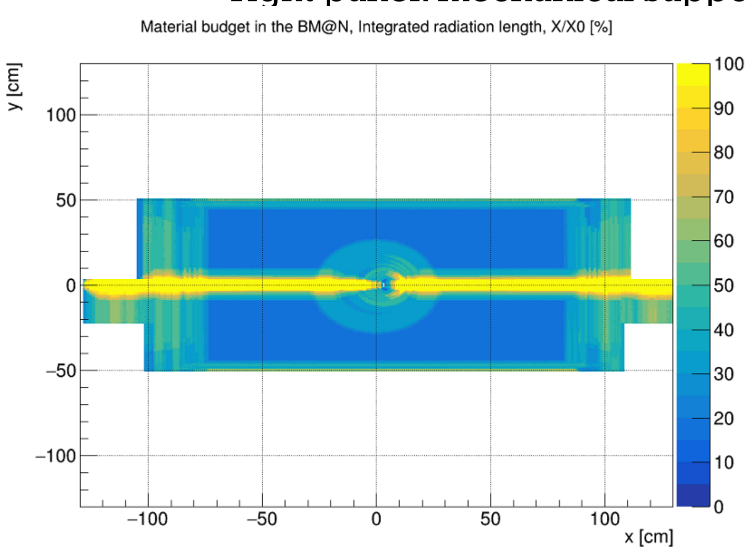
Full configuration of the GEM central tracking system

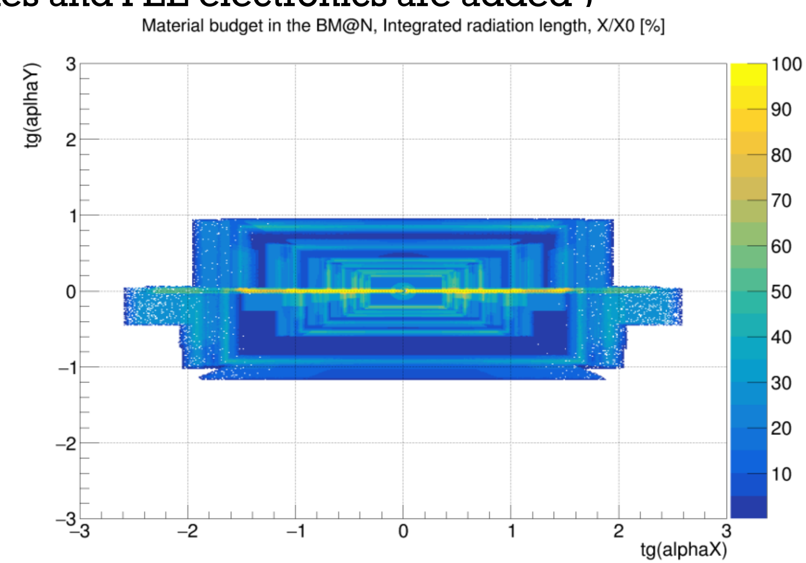
D. Baranov, S. Piyadin, E. Kulish, S. Novozhilov





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)

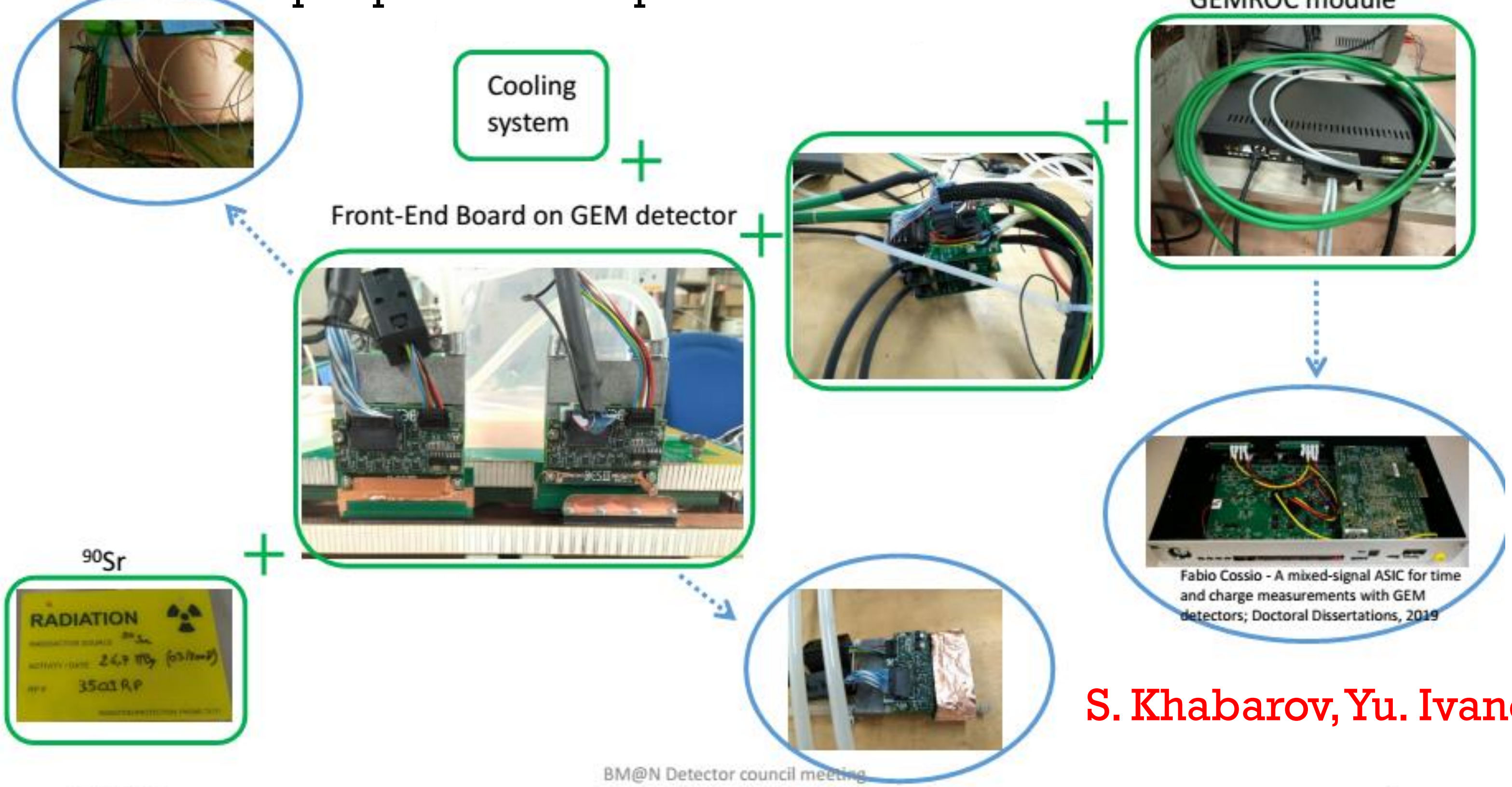




Material budget of the GEM central tracking system full configuration

Development of new FEE based on TIGER/VMM3a

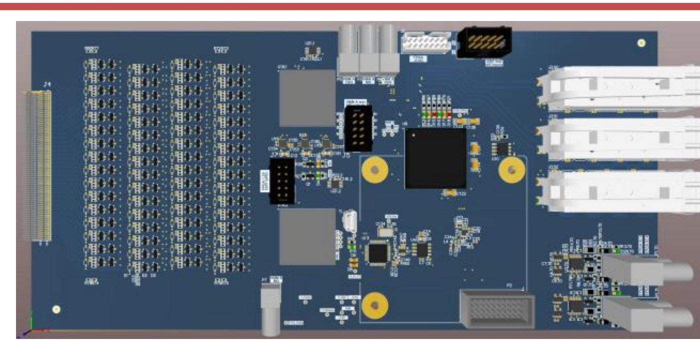
TIGER (**T**urin **I**ntegrated **G**em **E**lectronics for **R**eadout) tests at CERN. First run of TIGER FEE on GEM detector was performed. Next tests were planned on March 2020 at JINR, but postponed due to pandemic control measures.



S. Khabarov, Yu. Ivanova

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

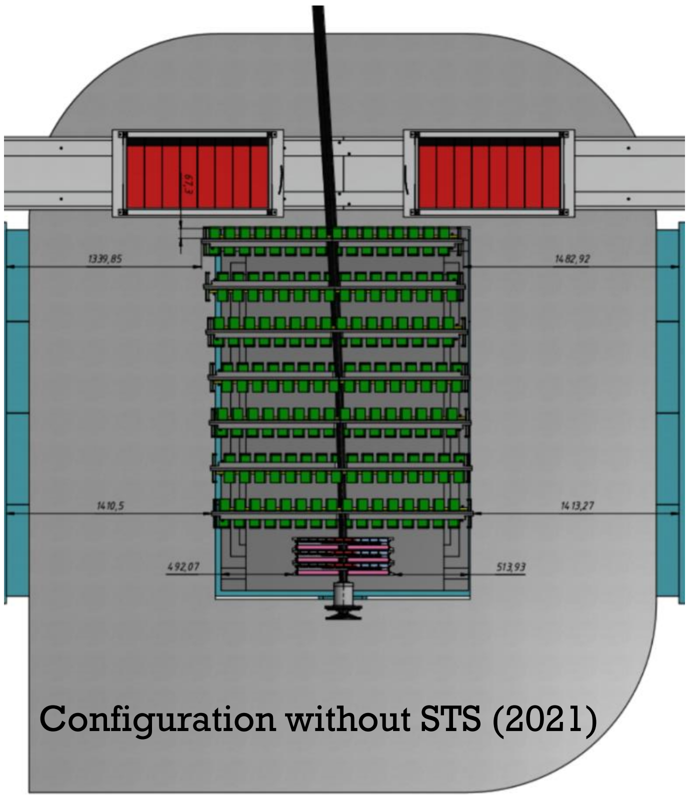
DAQ Group (V. Burcev)



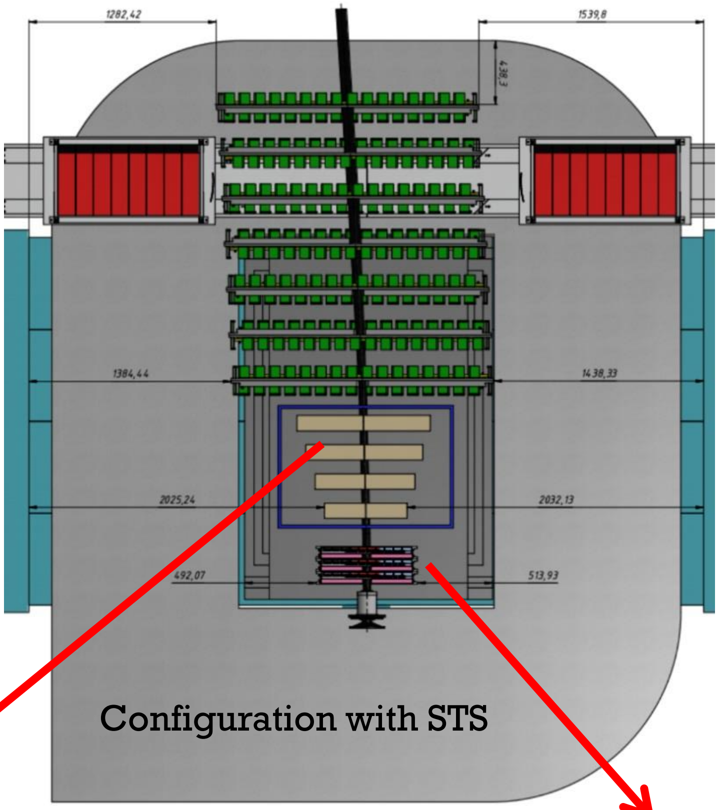
Forward Si+ STS +Gem configuration

Four configurations of the tracking detectors are foreseen:

- Forward Si + 7 GEMs: beam intensity few 10^5 Hz , 2021-22
- 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 (2021)



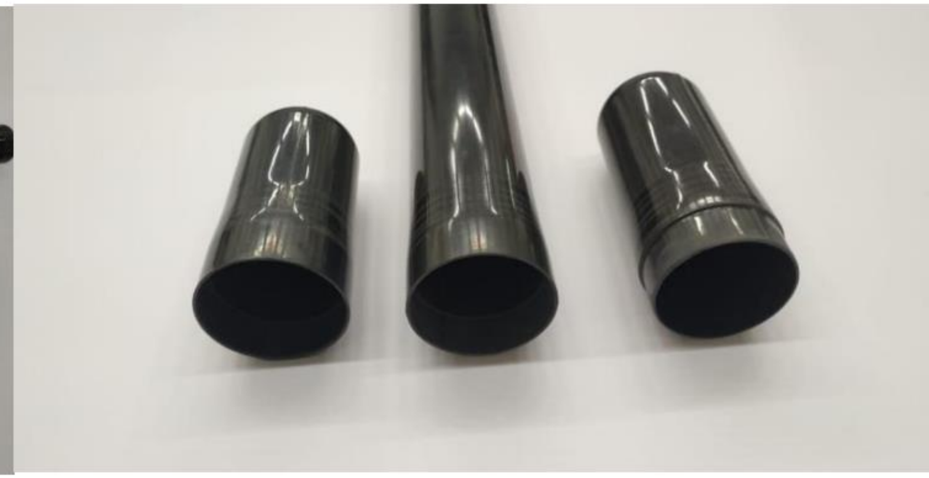
Configuration with STS

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)

Beam pipe inside the SP-41 magnet

S. Piyadin, V. Spaskov



Prototype of the BM@N carbon beam pipe

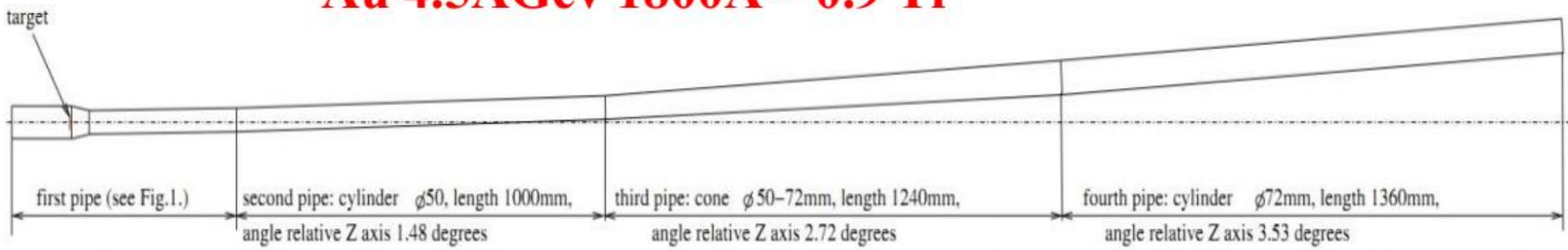
One meter test sample of the BM@N carbon beam pipe was produced by DD "Arkhipov" (Moscow, Russia).

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}.

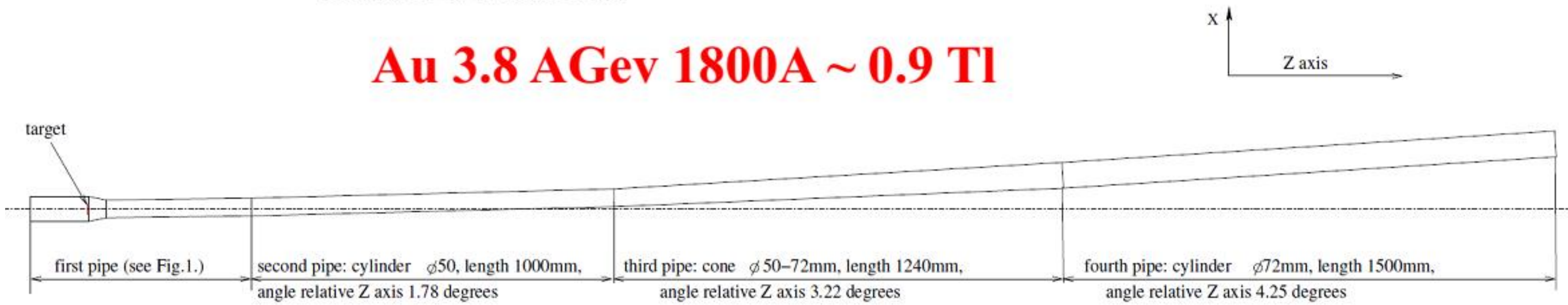
Tests of the sample with X-ray radiation are performed by A. Kubankin group (Belgorod University) to check the carbon layer thickness.

Beam pipe inside the SP-41 magnet

Au 4.5AGev 1800A ~ 0.9 Tl



Au 3.8 AGev 1800A ~ 0.9 Tl



BM@N carbon beam pipe configuration

DD "Arkhipov" (Moscow, Russia) was selected through a tender procedure for the beam pipe manufacture.

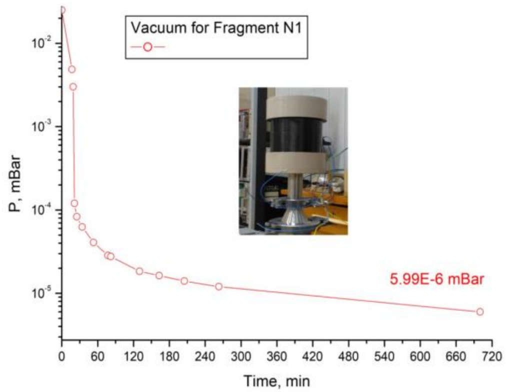
First stage of the contract: Development of the 3D models of the beam pipe, non-flange connectors, production and assembly equipment, calculation of the strength characteristics of 3D model nodes . Technical documentation is at JINR.

Second stage: Production of the beam pipe and non-flange connectors (April 2020).

Design and tests of the carbon vacuum beam pipe

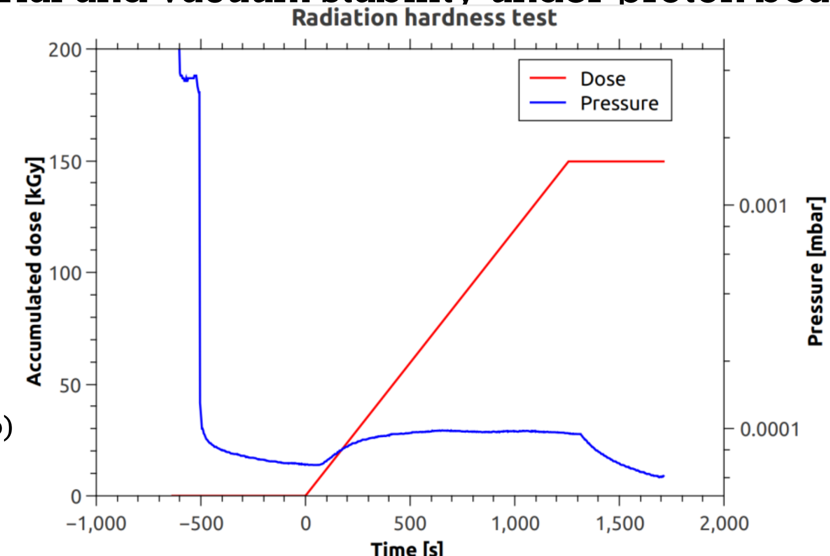
Faculty of Mechanical Engineering of the Czech Technical University
Nuclear physics institute, The Czech Academy of Sciences

Test of vacuum compatibility



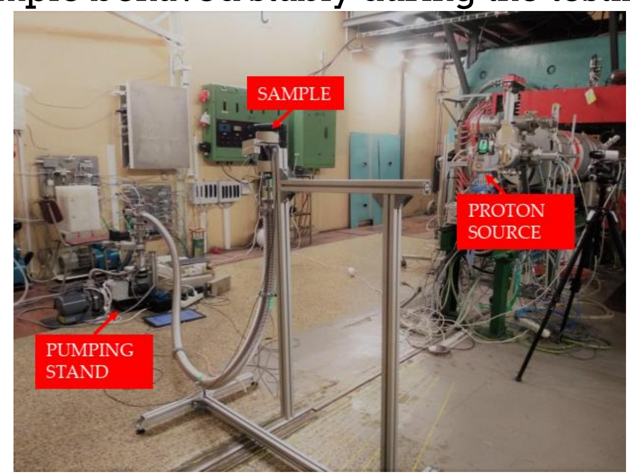
The ultimate pressure 6 x 10^{-6} hPa (scroll pump and turbomolecular pump)

Test of material and vacuum stability under proton beam

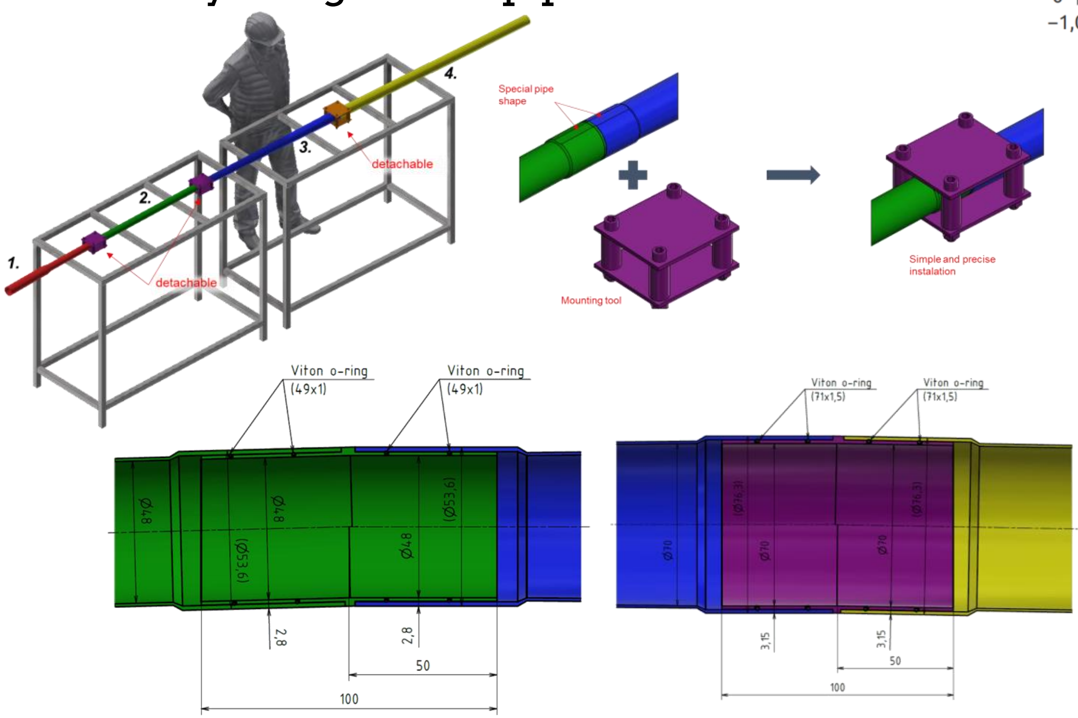


The test was performed September 3, 2020

The sample behaved stably during the testing



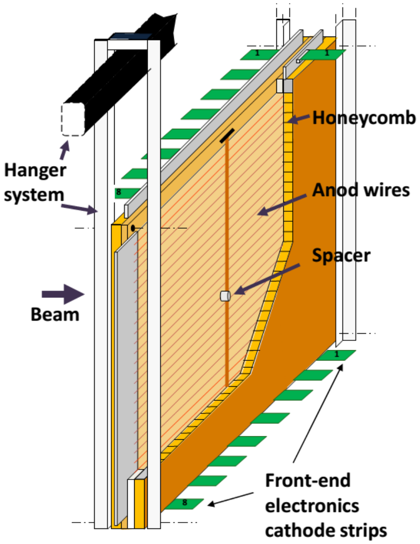
Preliminary design of the pipe connectors

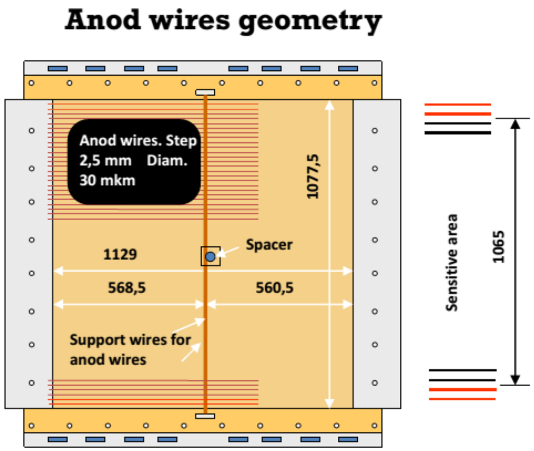


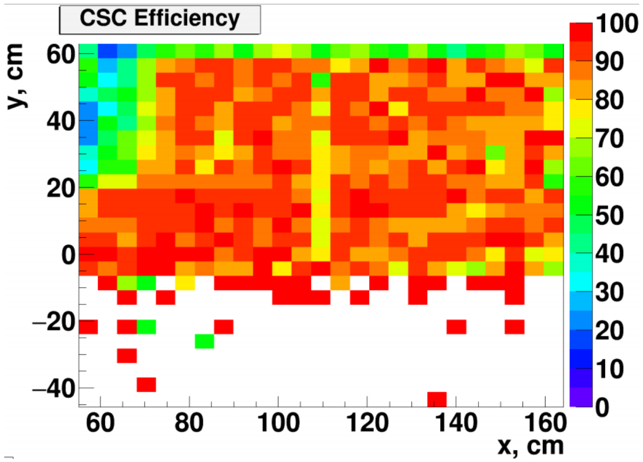
1065x1065 mm^2 CSC chamber

CSC group

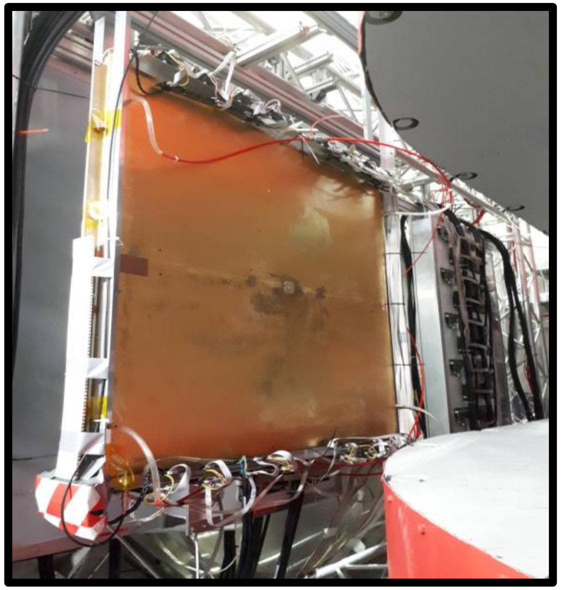
C, Ar and Kr runs in March 2018: CSC chamber is installed in front of ToF-400 to check its performance as outer tracker for heavy ions







CSC efficiency in Ar run
Track extrapolated from GEM
Residual (CSC_hit – GEM) < 2cm



One CSC 1065x1065 mm^2 is produced and tested at Nuclotron beam.

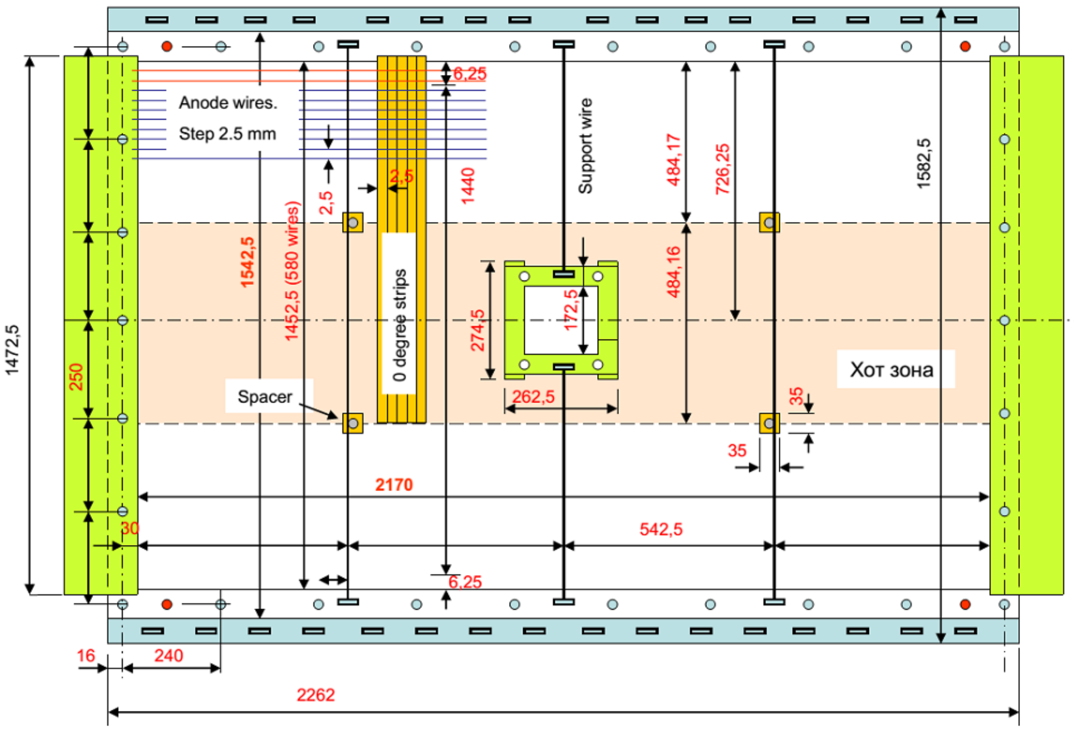
Plans:

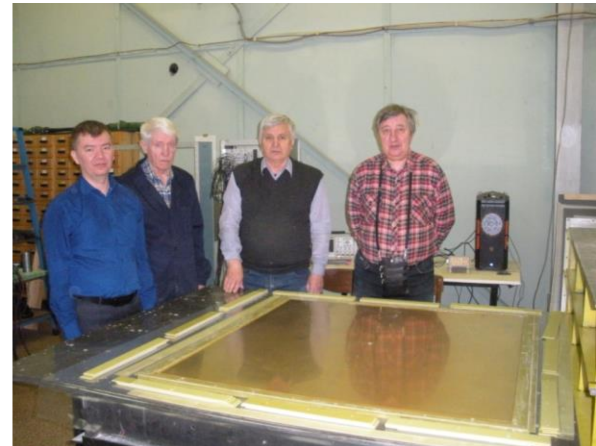
- assembly of the three1065x1065 mm^2 chambers is at the final stage. 95% of work is done.

- by the end of 2020 will start tests of the assembled chambers with r/a source and at cosmic stand

2190x1453 mm^2 CSC chamber

CSC group





Two cathode planes with strips inclined at 0° and 15°

Each cathode plane consists of 8 printed circuit boards.

Each pcb is divided on hot and cold zones.

Design of the PCB is finished.

Design and assembly – JINR LHEP

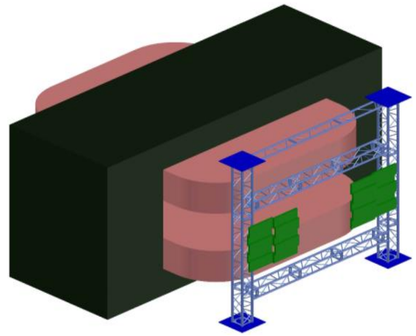
Production plans:

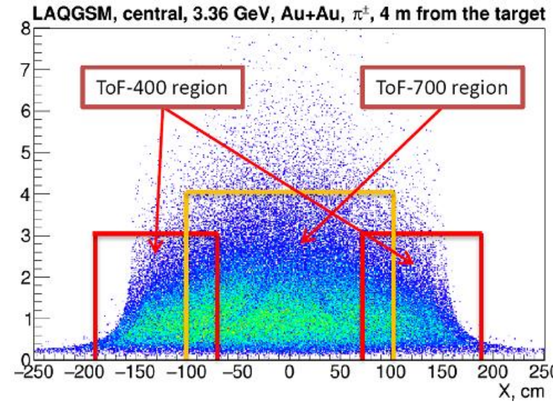
- 11.2020 – production of the cathode planes for 2190x1453 mm^2 CSC chambers. Cathode planes are to be delivered to JINR

- End of 2021 – end of the assembly of two 2190x1453 mm^2 CSC chambers

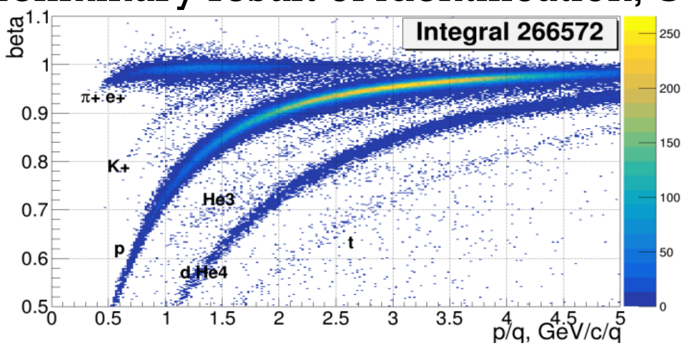
Status of ToF-400 & ToF-700

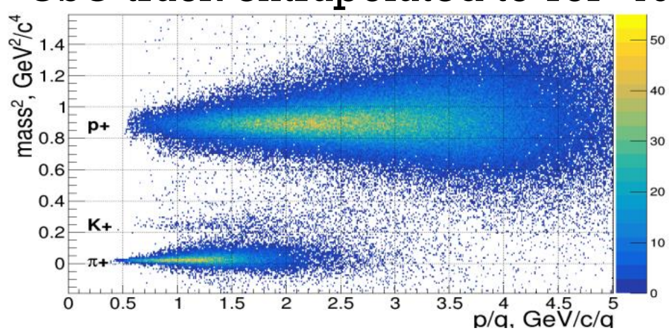
Both time-of-flight systems are ready for the heavy ion beam program



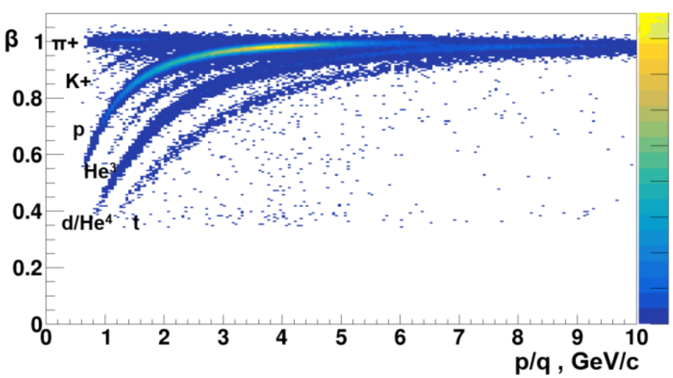


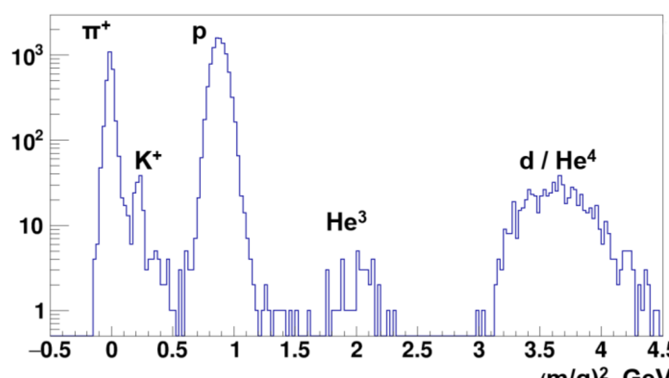
Preliminary result of identification, GEM+CSC track extrapolated to ToF-400





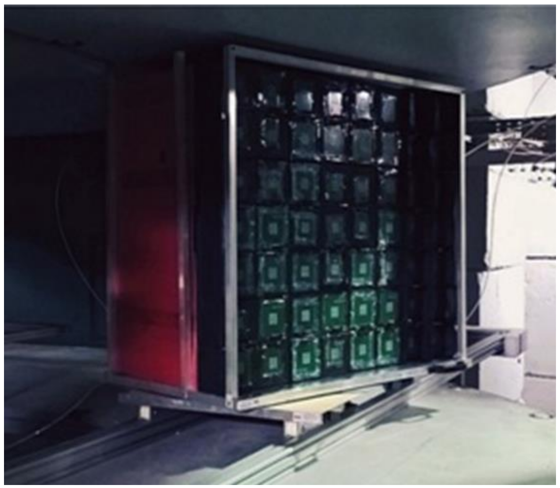
Preliminary result of identification, GEM+DCH track extrapolated to ToF-700





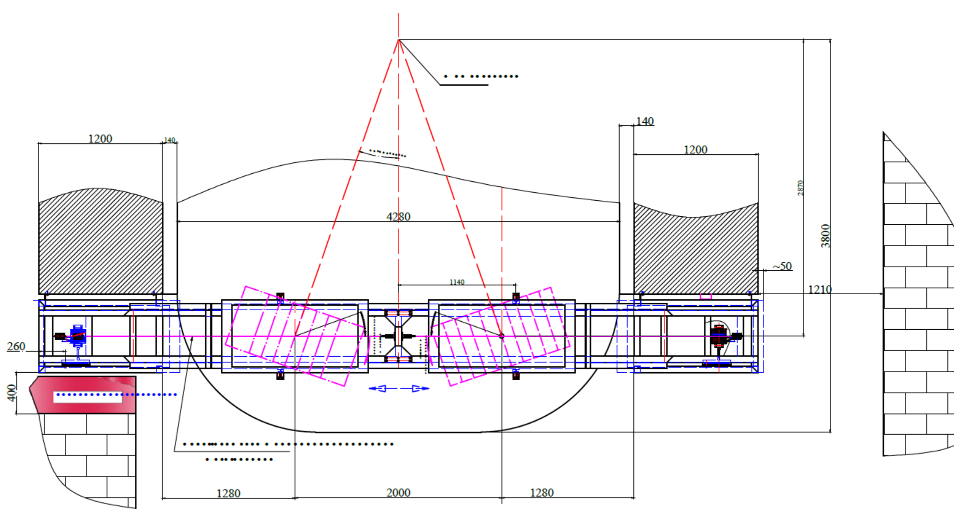
ECAL two arms installation (status 2020)

- main effort was to add ECAL data analysis considering signal time parameters
- assembly of two racks for ECAL in the magnet
- performed tests of array of modules for second arm of the ECAL

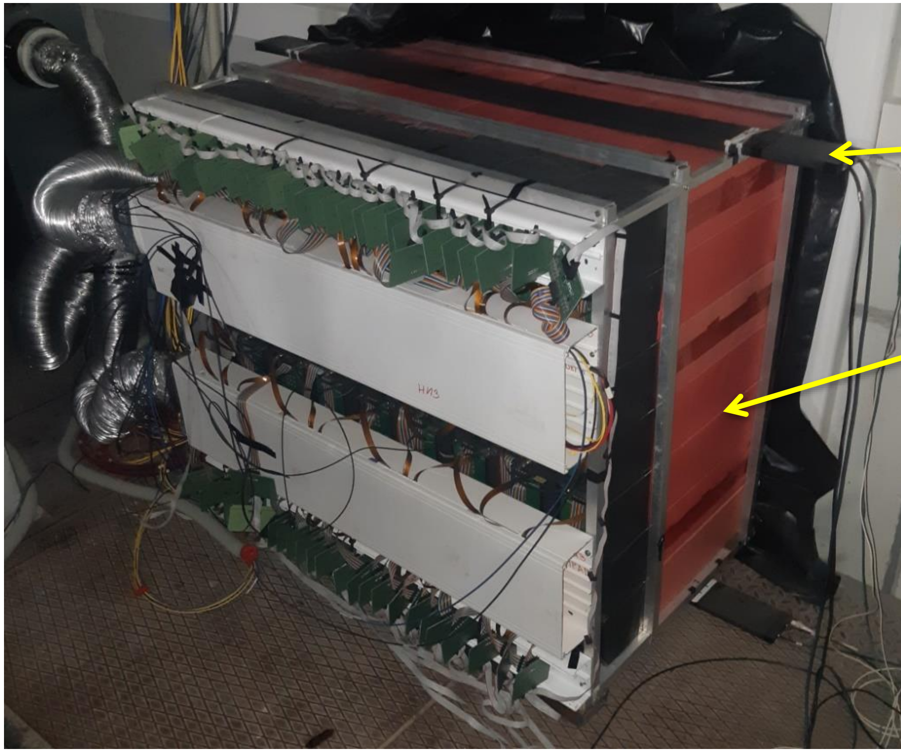


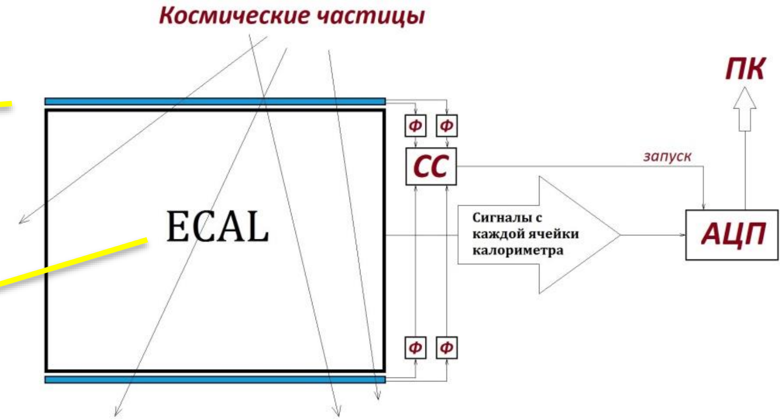
Location of ECal in the magnet SP-41

New racks for ECAL



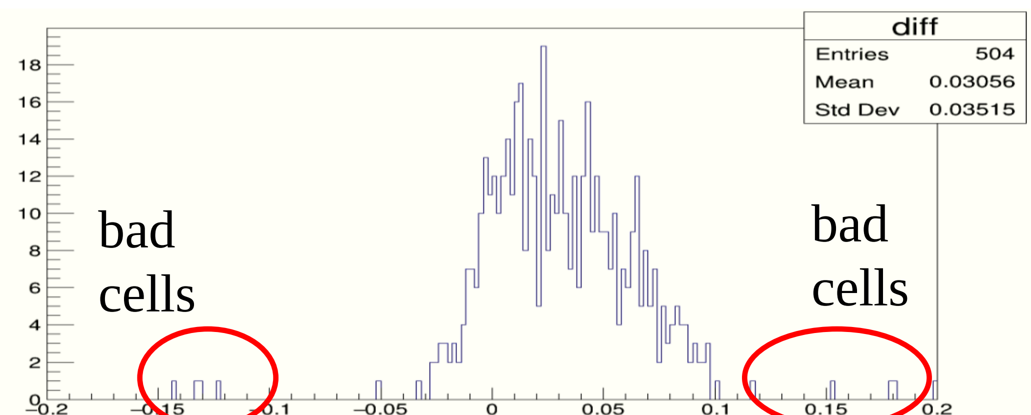
The test of the modules for the second arm of ECAL

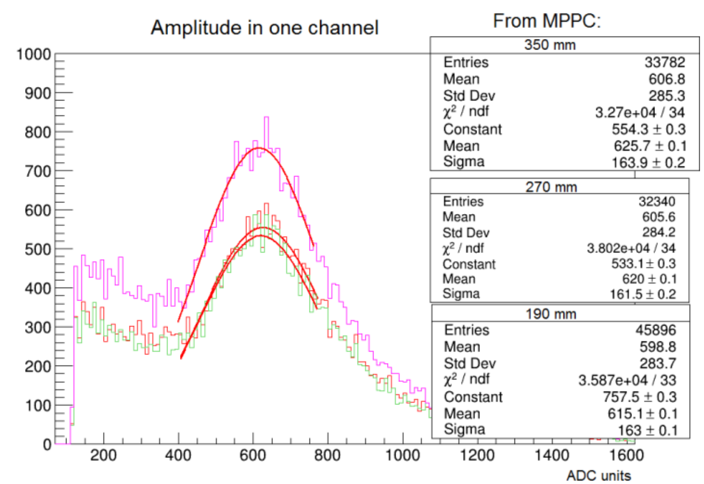




The modules were tested using monitors in three position. Each positions gives attenuated amplitude and allowes to calculate quality of the module.

The decay coefficients for tested modules

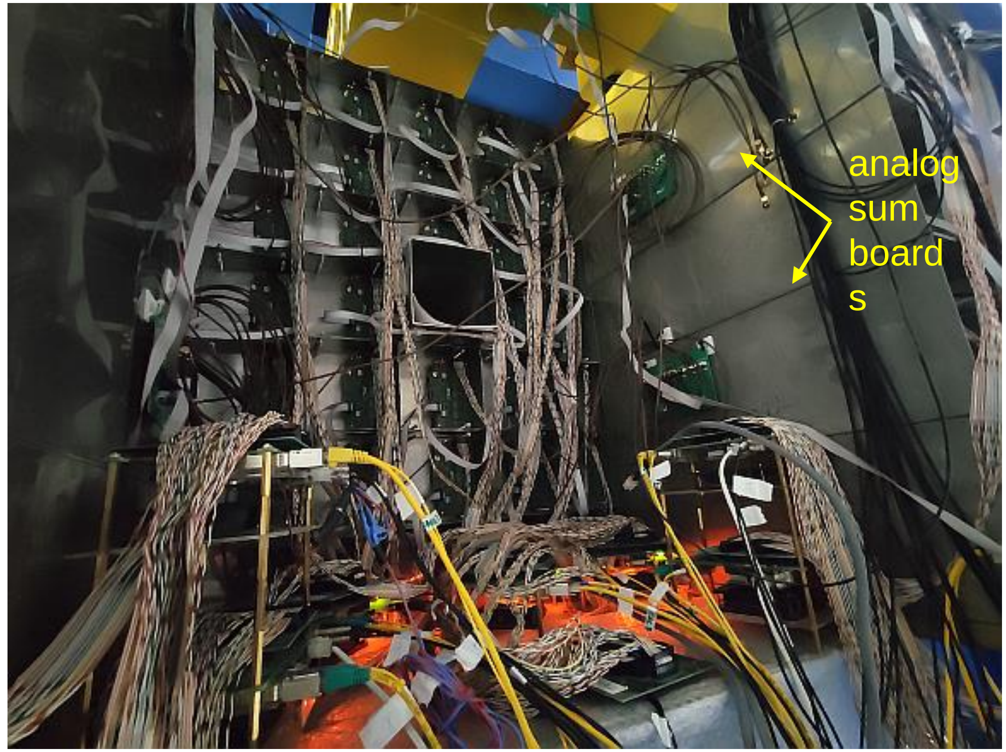




Status of new FHCal

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

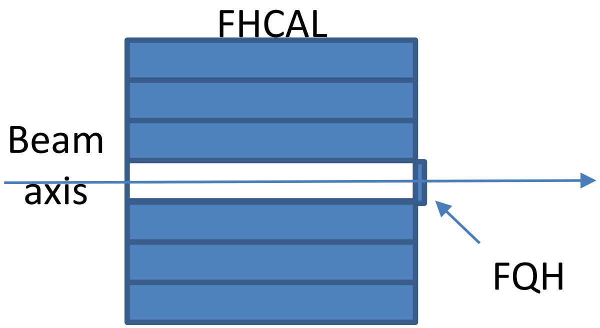
- 54 FEE boards have been connected and tested

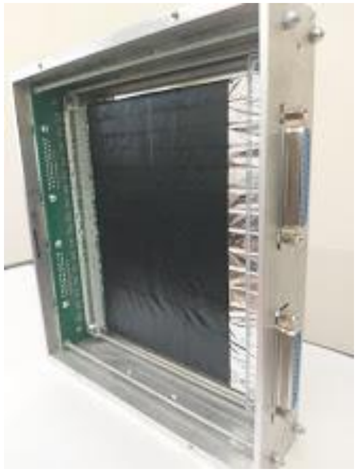
- 8 ADC64s2 board are in places, tested, connected with new cables (yellow on photo) to Rack 6 + WR optical fibers

- 6 analog sum boards are connected to FEEs

- new power supply (WIENER MPOD) is in testing now

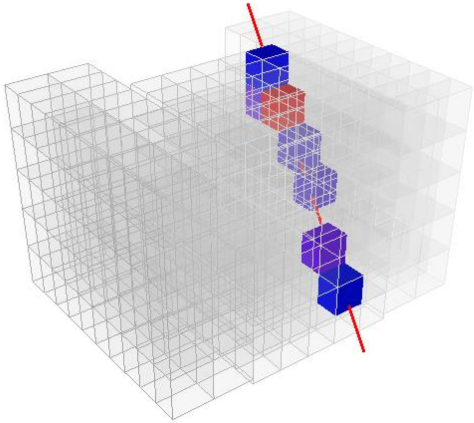
Status of new FHCal

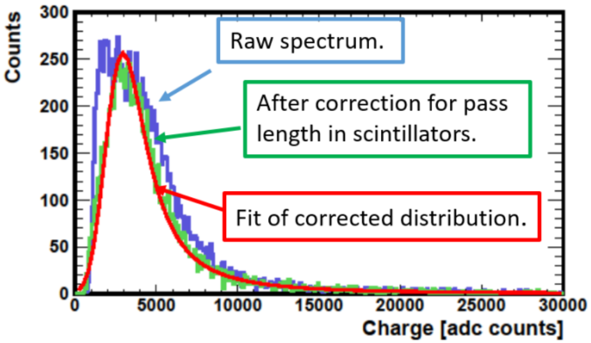




- Forward Quartz Hodoscope (FQH) is ready (16 quartz strips with sizes 10x160x4 mm^3. 2 SiPMs from each strip end are used to light readout.

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

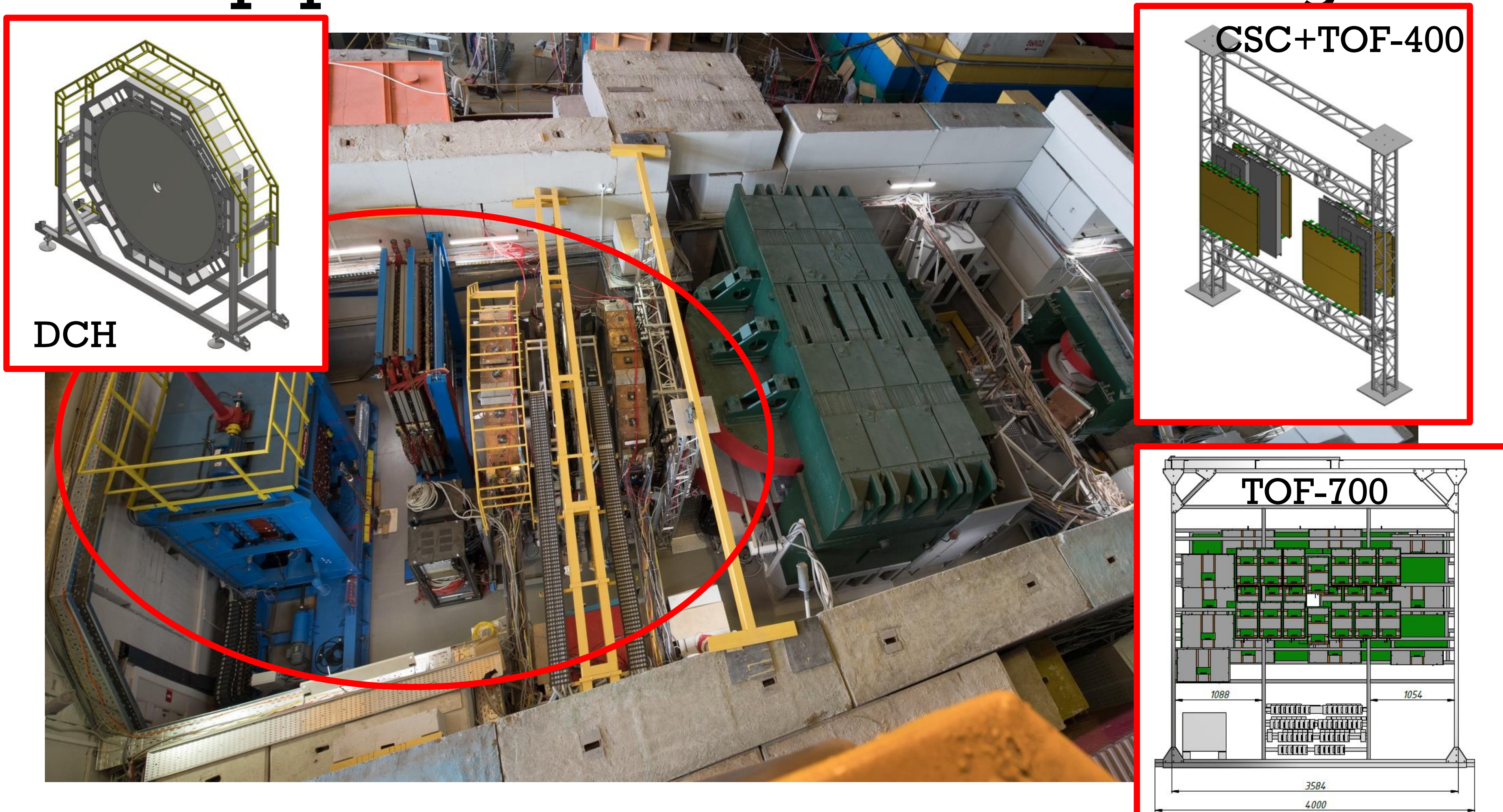




- new cosmic muon calibration procedure based on 3D tracking with transverse and longitudinal granulation of FHCal has been developed and is under testing on cosmics with FHCal (remotely from INR)

group of INR RAS Troitsk

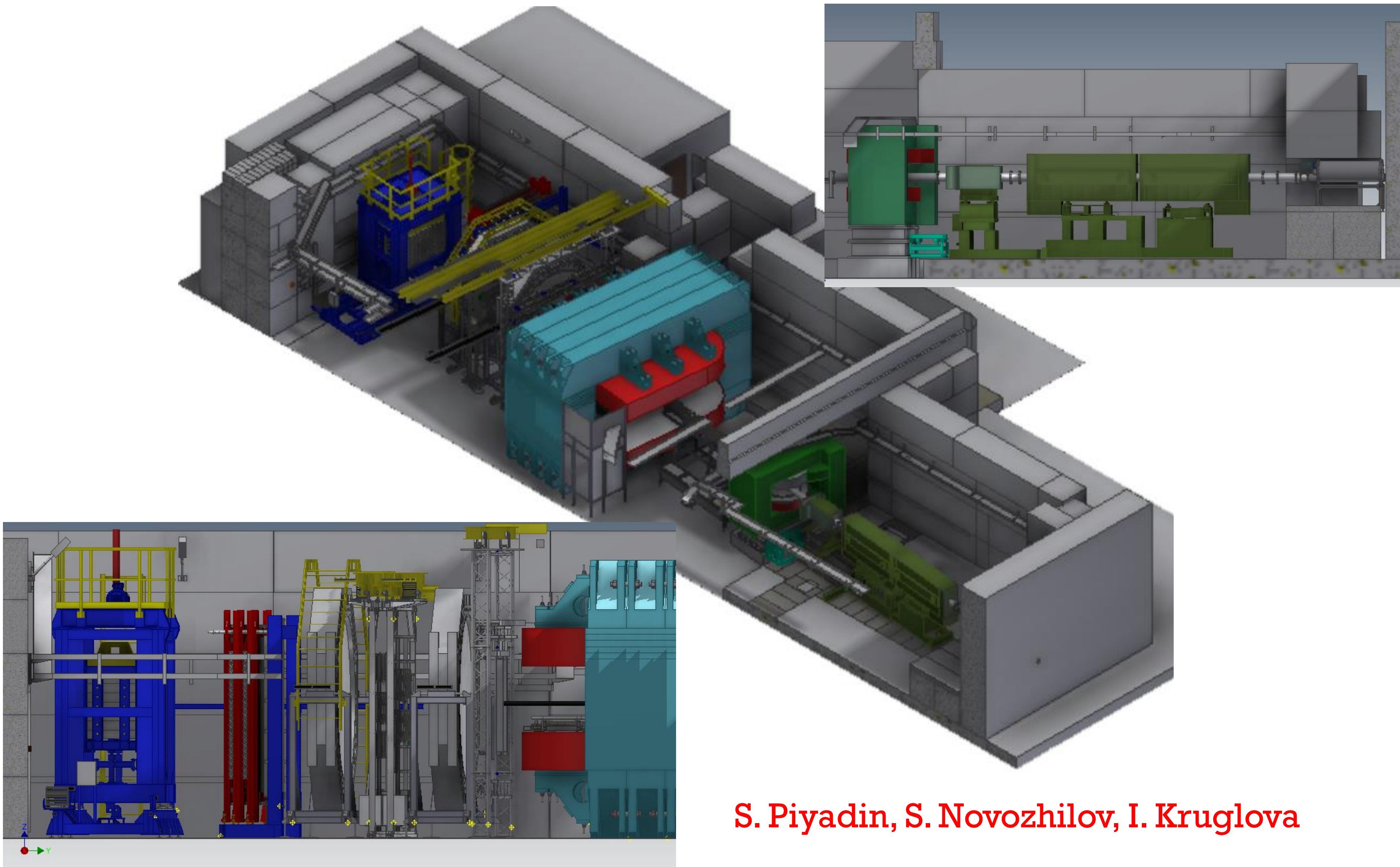
Beam pipe downstream the SP-41 magnet



Development and production of the aluminum beam pipe downstream the SP-41 magnet will be performed by A. Kubankin group (Belgorod University).
3D model development of the detectors after the SP-41 magnet is finished.

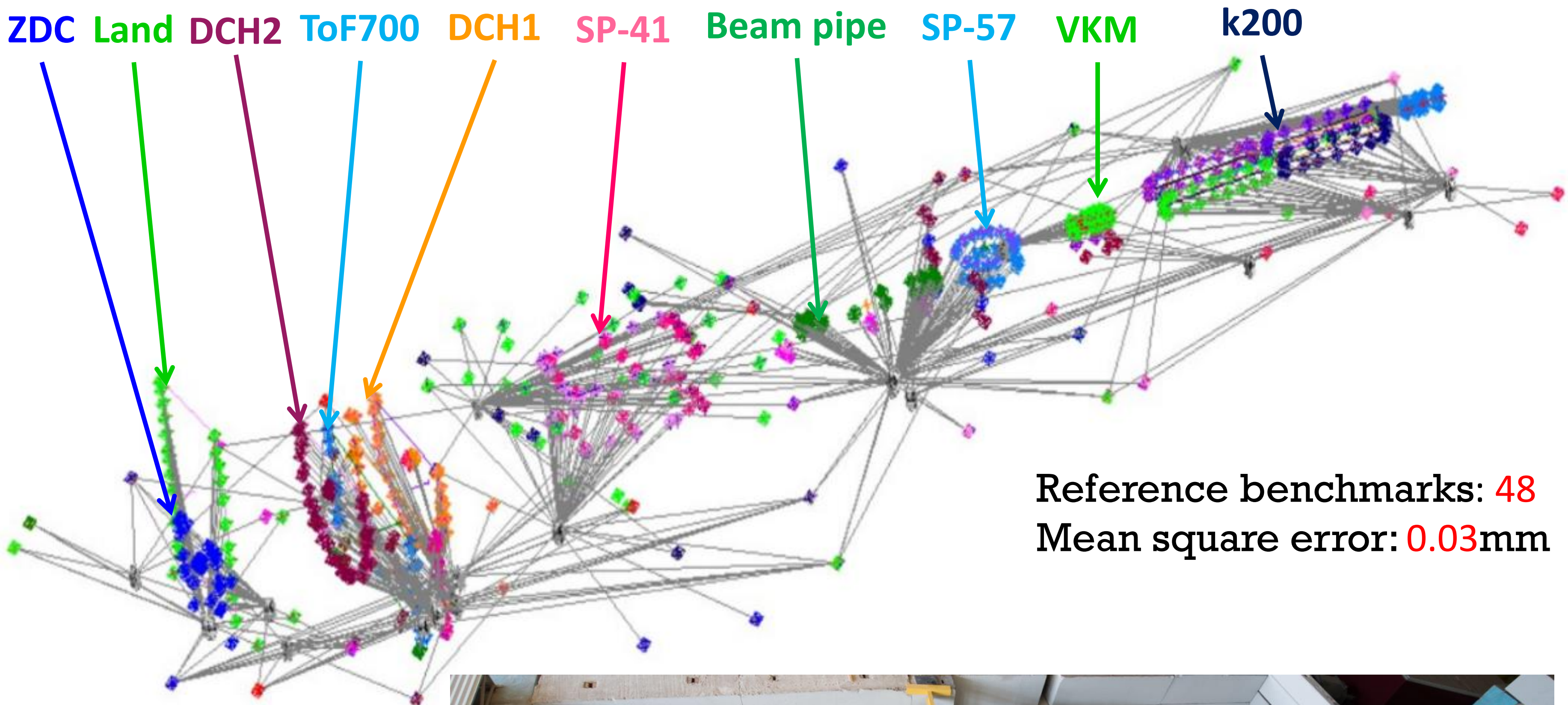
S. Piyadin

3D model of the BN@N experimental hall

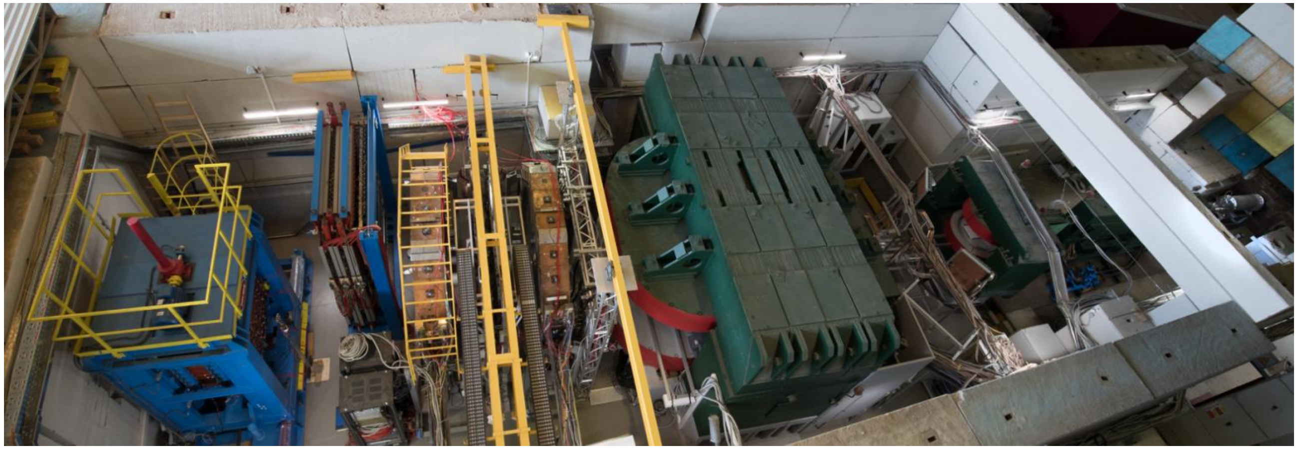


S. Piyadin, S. Novozhilov, I. Kruglova

Development of a reference metrological grid BM@N



Reference benchmarks: 48
Mean square error: 0.03mm



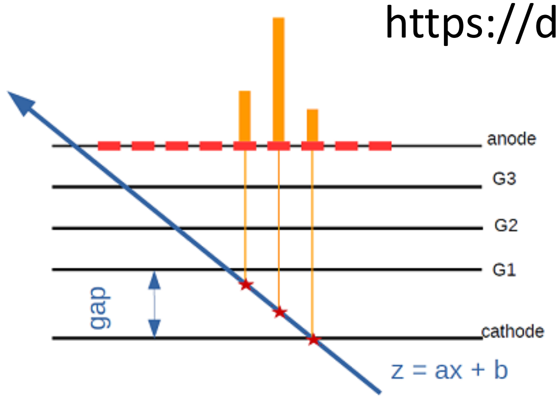
Summary:

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)
GEM	7 top half-planes + 7 bottom half-planes(assembled)
CSC	4 chambers 1065x1065 mm^2(11.2020) 2 chambers 2190x1453 mm^2(2021)
ECAL	two arms (2022)
ToF-400 and ToF-700	full configuration
ZDC(MPD/CBM type)	installed

Backup

TIGER (**T**urin **I**ntegrated **G**em **E**lectronics for **R**eadout)

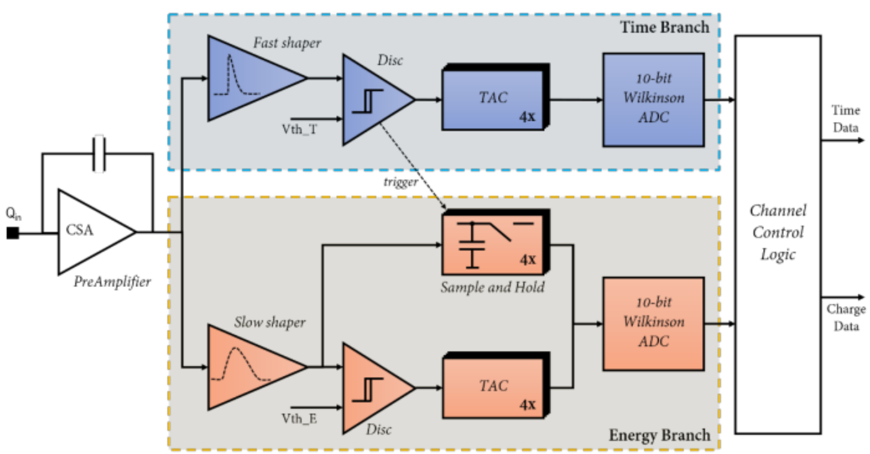
https://doi.org/10.1016/j.nima.2018.09.010



- If known the drift velocity, time information can be used to assign to each fired strip a 2D point
- Particle track is reconstructed from these coordinates
- The spatial resolution can be improved in magnetic field, especially for angled tracks

TIGER v1 - 64-channel readout ASIC was tested at BESIII Experiment (New Inner Tracker based on **Cylindrical Gas Electron Multiplier**)

TIGER channel architecture

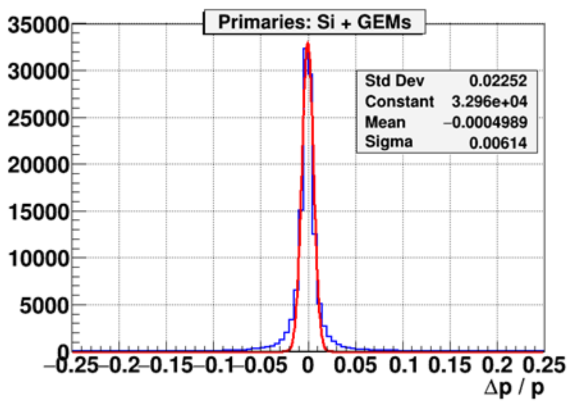


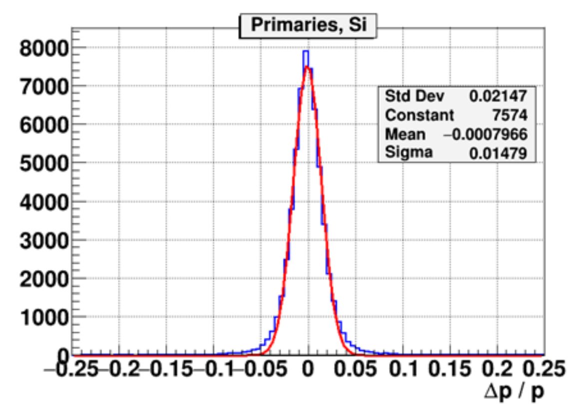
TIGER V2. Programmable gain: range 50-300 fC Input
Sustained event rate > 100 kHz/ch

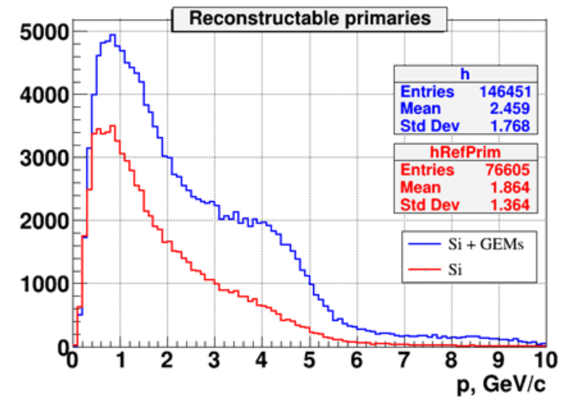
Measured performance of the TIGER ASIC:
Input charge 5-55 fC
TDC resolution 30 ps RMS
Time-walk (5-55 fC range) 12 ns
Average gain 10.75 mV/fC
Nonlinearity (5-55 fC range) 0.5%
RMS gain dispersion 3.5%
Noise floor (ENC) 1500 e^-
Noise slope 10 e^-/pF
Maximum power consumption 12 mW/ch

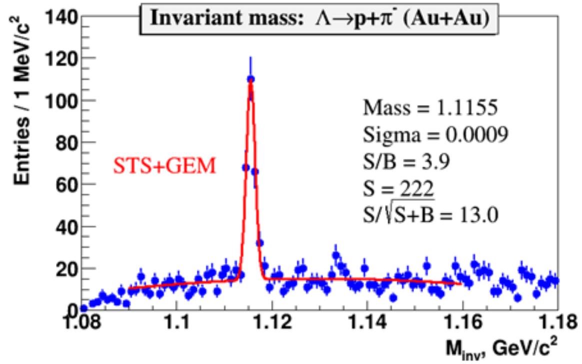
First tests with BM@N GEMs are planed in November 2019 at CERN

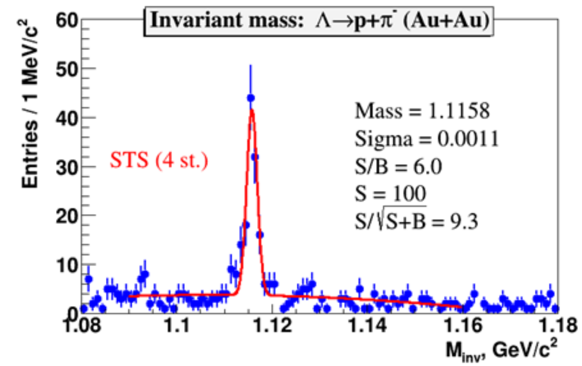
Hybrid central tracker for heavy ion runs: STS vs STS+GEM











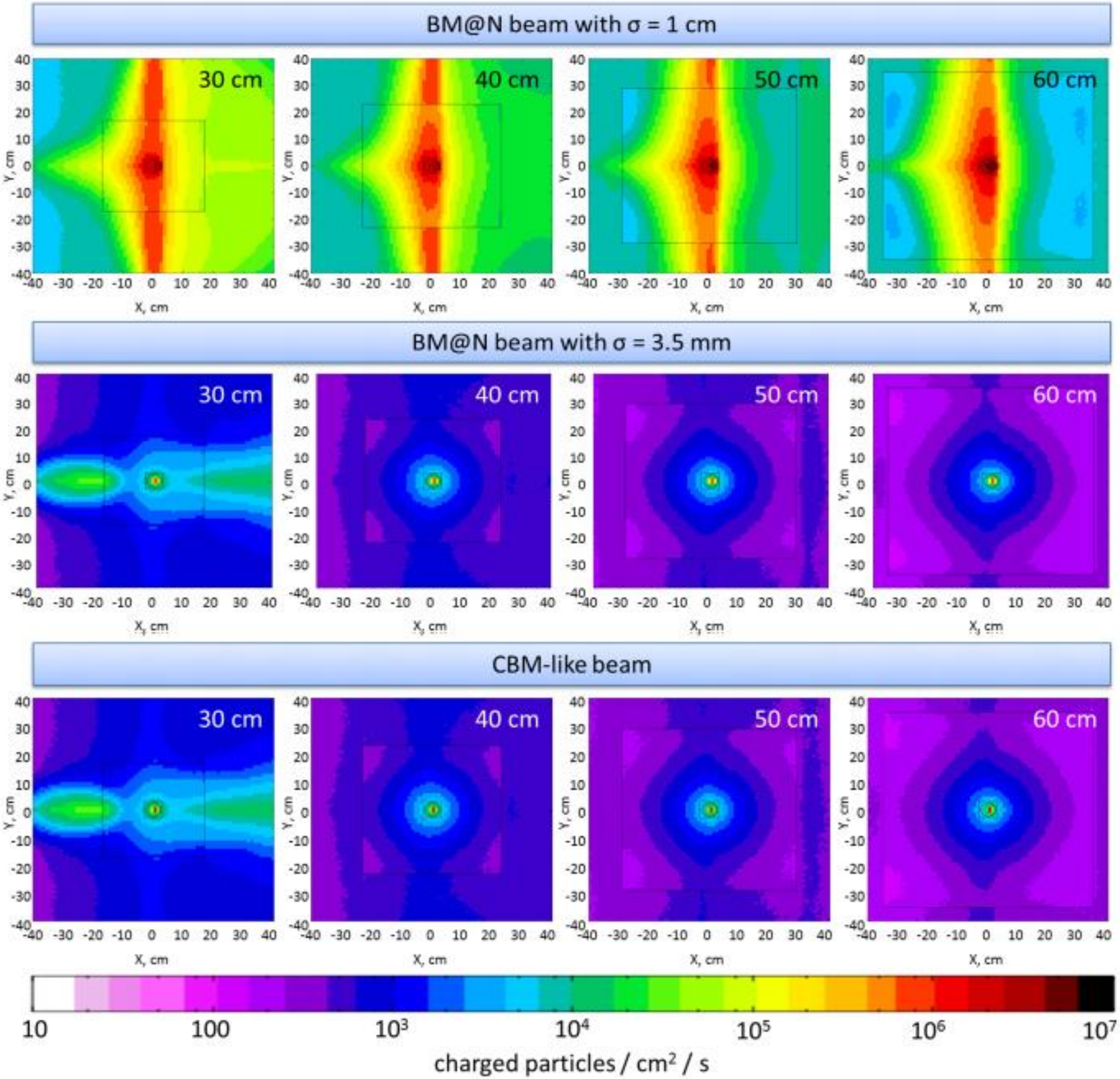
Hybrid STS + GEM tracker:

► 2 times increase in number of reconstructed tracks and Λ hyperons

►2 times better momentum resolution

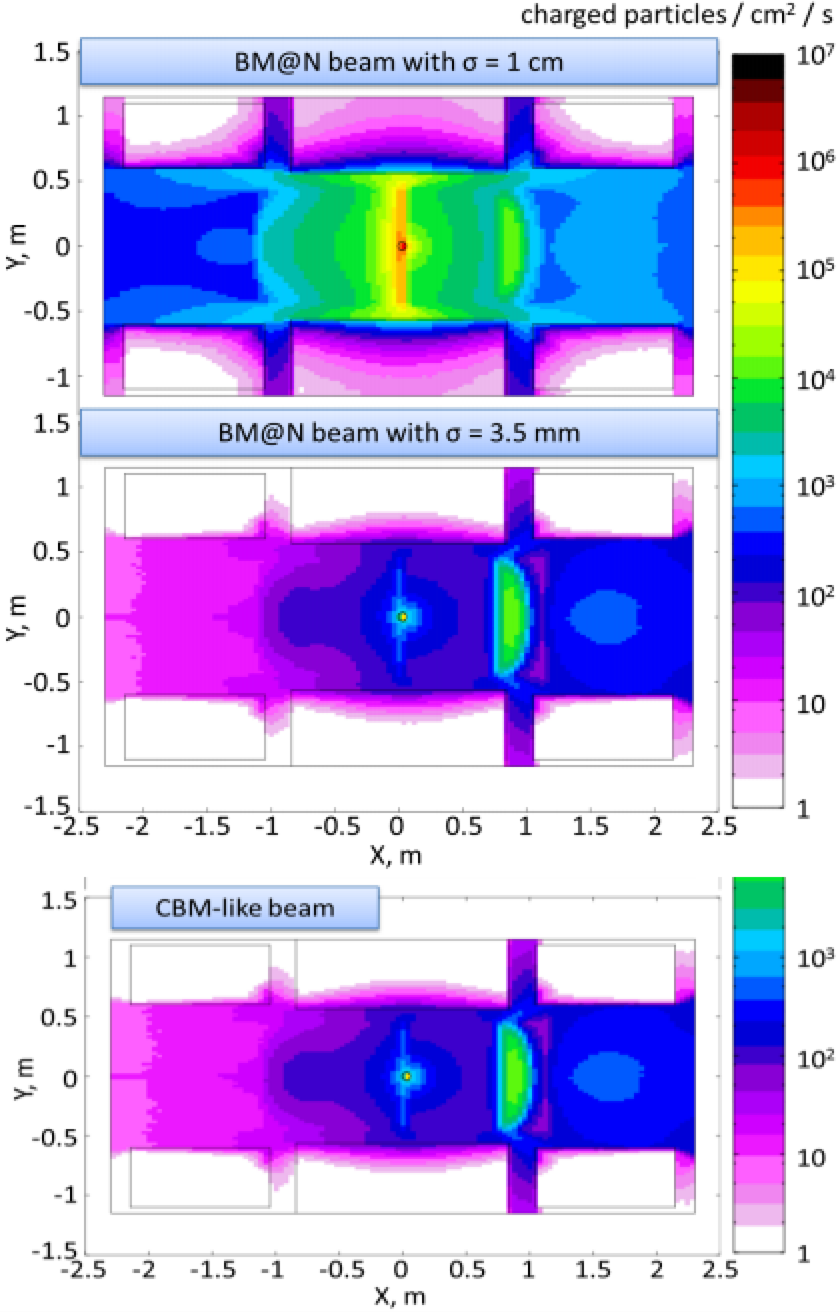
A. Zinchenko, P. Senger

Charged particle densities in the four STS stations



Anna Senger (GSI)

Charged particles in GEM stations at z = 2 m



Anna Senger (GSI)

<u>BM@N beam with σ = 1 cm (2x10^6 Au ions/s):</u>
Delta electron rate: 200 kHz/cm^2

Electron rate on one strip (inner zone):
200 kHz/cm^2·1.2 cm^2 = 240 kHz
Channels busy: 240 kHz·2 μs = **48 %**

Electron rate on one strip (outer zone):
200 kHz/cm^2·2.4 cm^2 = 480 kHz
Channels busy: 480 kHz·2 μs = **96 %**

<u>BM@N beam with σ = 0.35 cm (2x10^6 Au ions/s):</u>
Delta electron rate: 2 kHz/cm^2

Electron rate on one strip (inner zone):
2 kHz/cm^2·1.2 cm^2 = 2.4 kHz
Channels busy: 2.4 kHz·2 μs = **0.48 %**

Electron rate on one strip (inner zone):
2 kHz/cm^2·2.4 cm^2 = 4.8 kHz
Channels busy: 4.8 kHz·2 μs = **0.96 %**