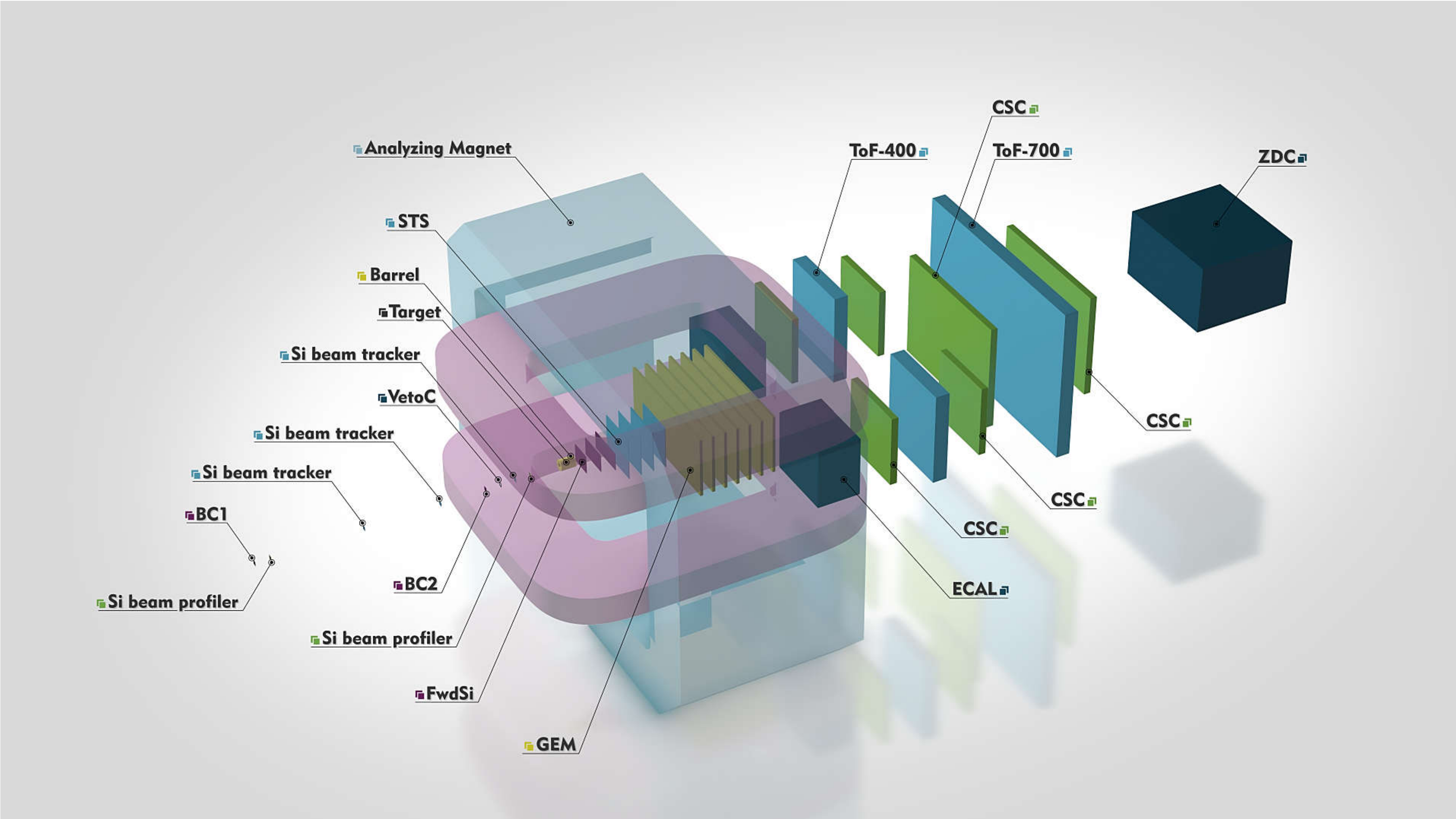
Upgrade of the BM@N detectors

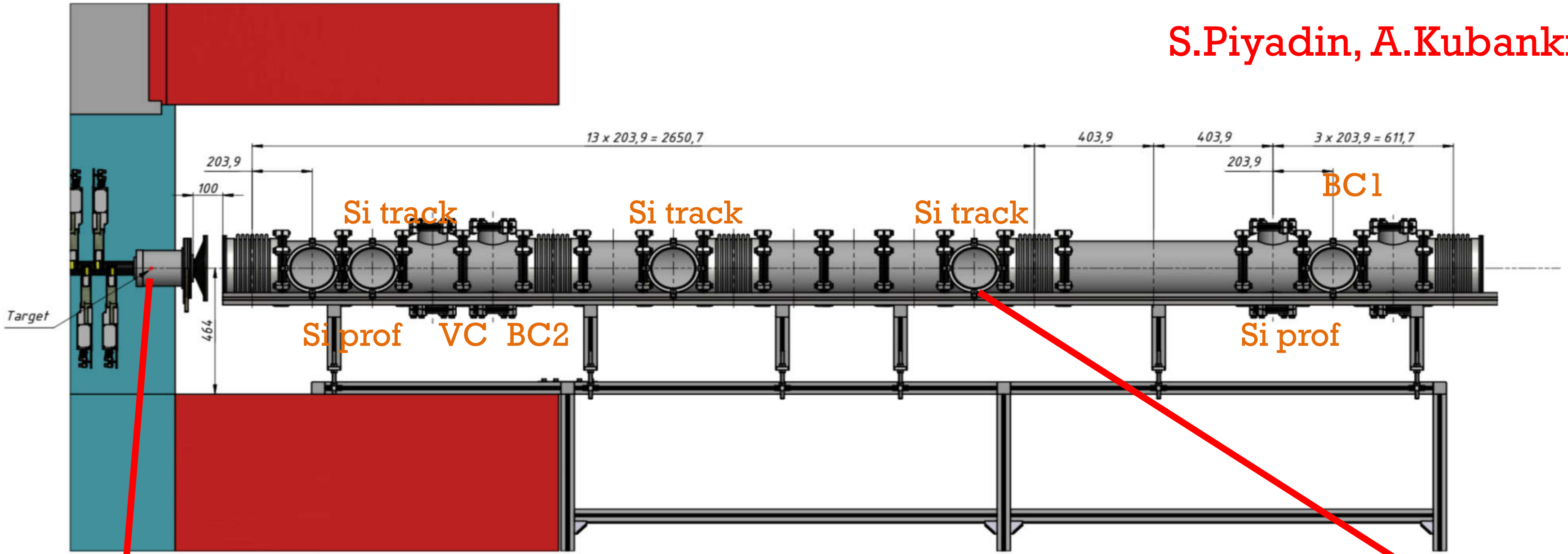
Anna Maksymchuk on behalf of the BM@N Collaboration
05/02/2020

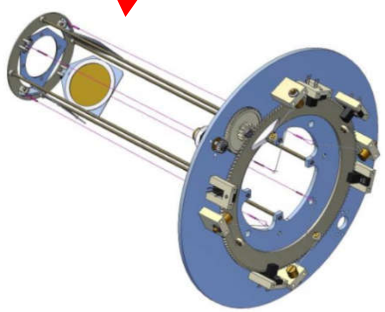
BM@N Experimental Setup

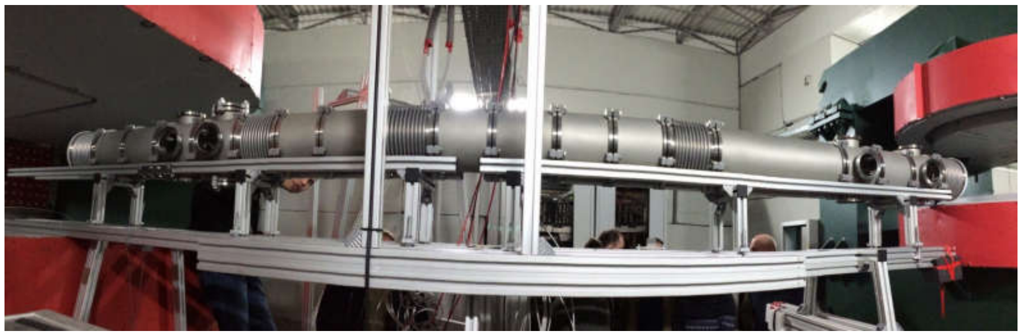


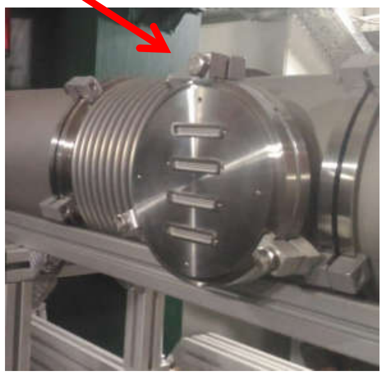
Beam pipe before the target

S.Piyadin, A.Kubankin







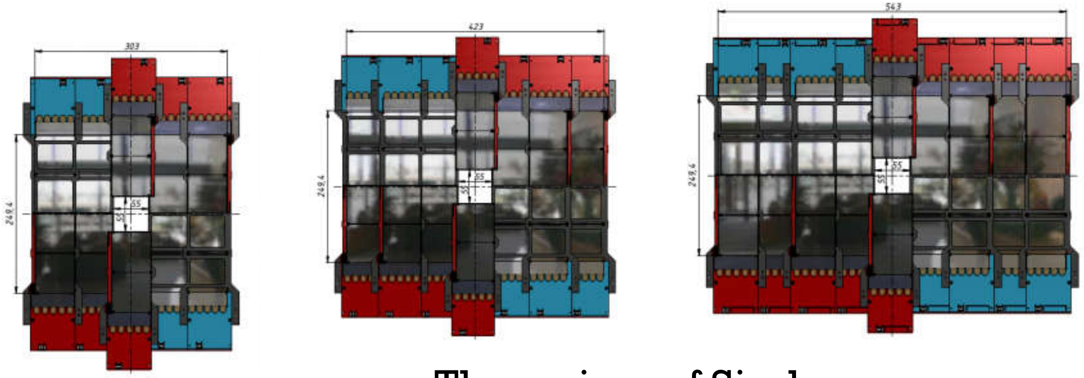


Four stainless steel vacuum boxes downstream the target will be replaced by aluminum ones.
The design and production of the target station mechanics will be performed by A.Kubankin group

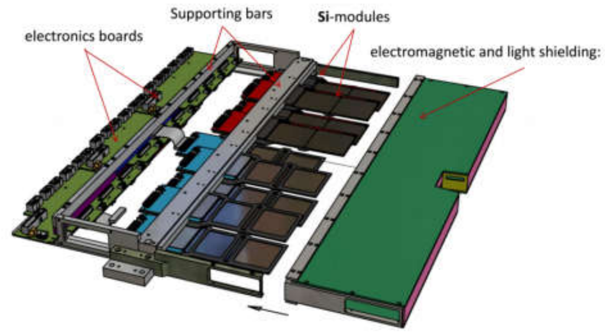
See talk of S.SEDYKH

Production of the beam pipe: Belgorod University

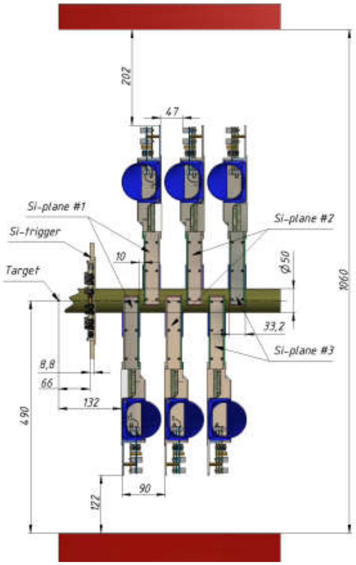
Upgrade of the forward Si tracking detectors

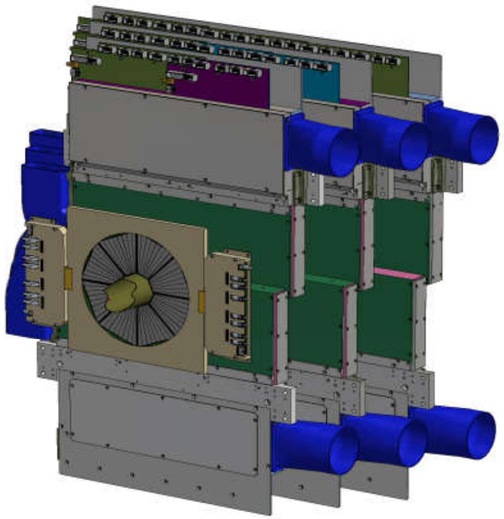


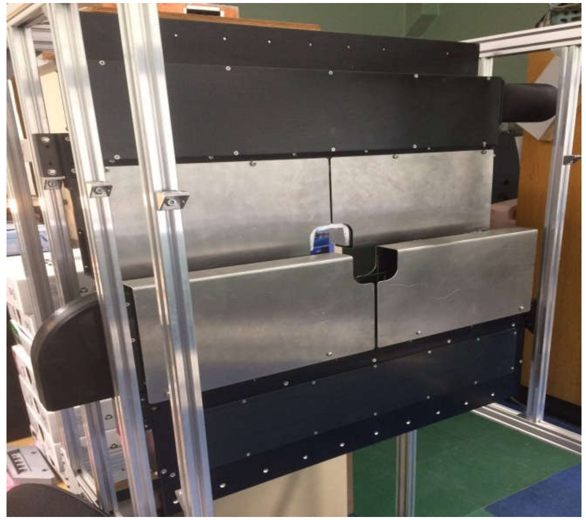
Three sizes of Si-planes



Half-plane design





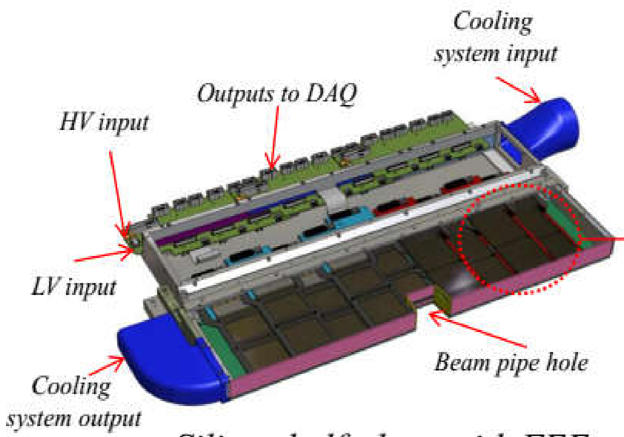


Design of the Si-planes
on the BM@N beam-channel

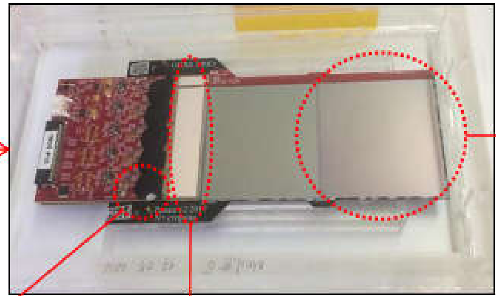
Station#	Number of DSSD modules	DSSD station square	Number of Readout channels
Station1	10	720 cm^2	12800
Station2	14	1008 cm^2	17920
Station3	18	1296 cm^2	23040
Total	***42***	***~0.3 m^2***	***53760***

group of N.Zamiatin

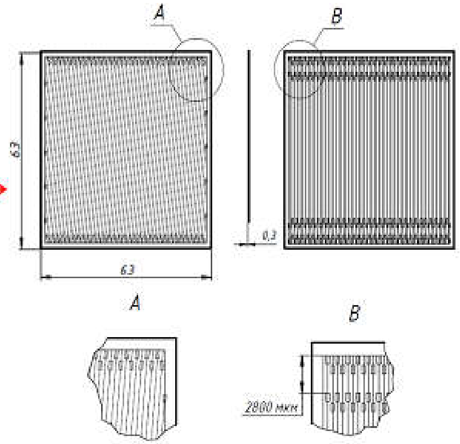
Upgrade of the forward Si tracking detectors

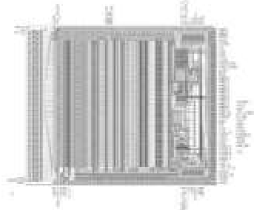


Silicon half-plane with FEE

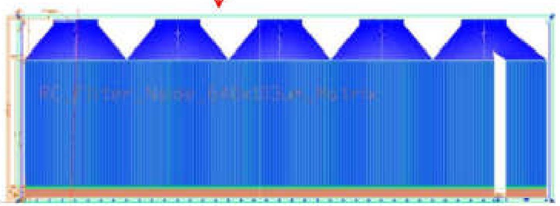


Silicon Detector Module





ASIC VATAGP7.1 (5 chips on each side of module)
Number of CSA: 128 channels
Dynamic range: ±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

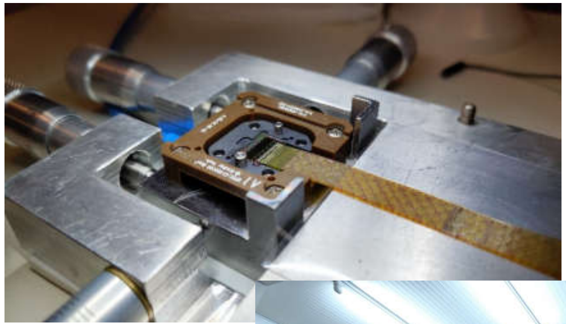
Size: 63x63x0,3 mm^3 (on 4" – FZ-Si wafers)
Topology: double sided microstrip (DSSD)
(DC coupling)
Pitch p^+ strips: 95 µm;
Pitch n^+ strips 103 µm;
Stereo angle between p^+/n^+ strips: 2.5^0
Number of strips: 640 (p^+)× 640(n^+)

Plans:
- DSSD, Pitch adapters, ASICs VATAGP7.1, FEE PCBs are delivered and ready for assembly
- Cross boards and mechanical support for FwdSi detectors installation inside the magnet are being designed at the moment

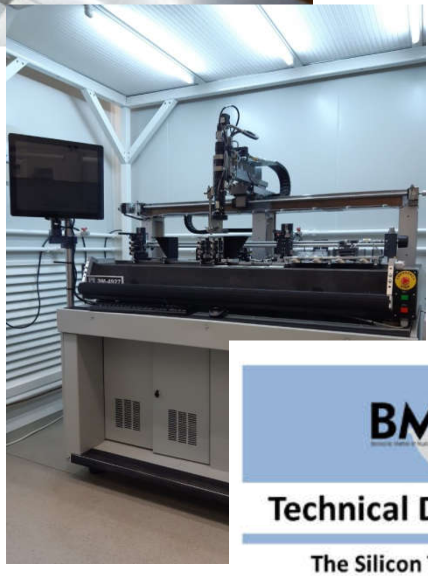
Status of BM@N STS

STS group

See talk of D.Dementev



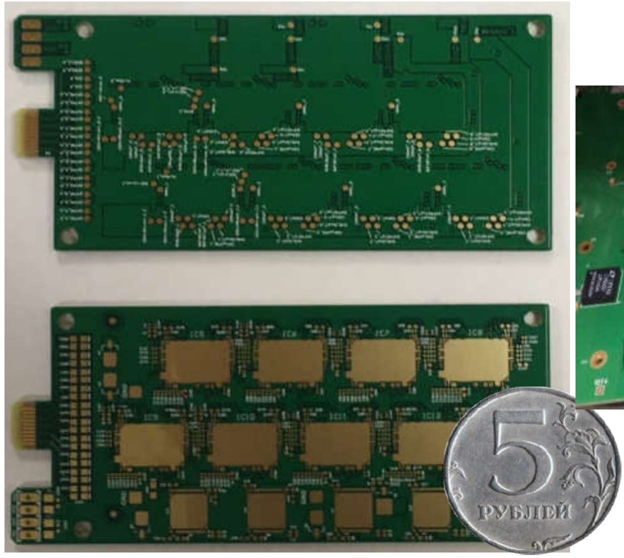
Quality Assurance tests of the modules were developed and tested on the first assembled modules. Module assembly procedure was improved with the aim to minimize the number of not-operable channels (less than 3%)



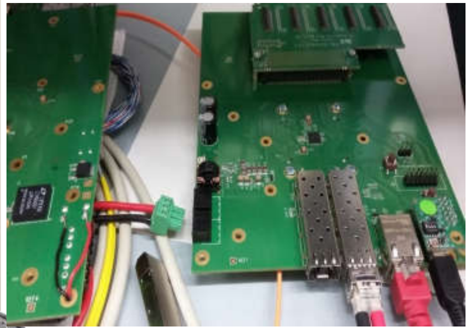
Ladder Assembly Device and corresponding fixtures were developed and produced for the assembly of the BM@N and CBM ladders.
Accuracy of the sensor positioning is tested.

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

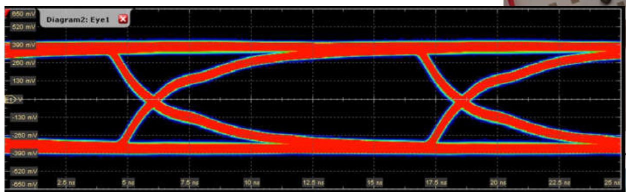
Status of the Readout Electronics of BM@N STS

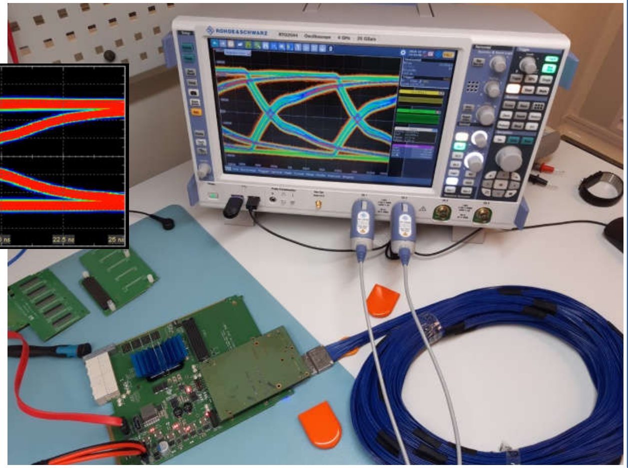


New version of BM@N FEB with 8 STSXYTER ASICs



GBTxEMU board





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

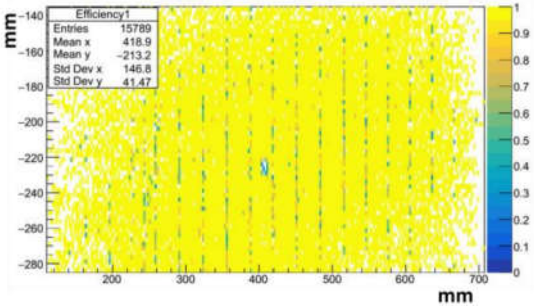
Adaptation of the CBM-type readout chain for the BM@N STS system:

- 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. Twinax cable produced by Samtec was opted. *(JINR group)*
- A GBTxEMU board based on the Xilinx Artix 7 FPGA module was developed, produced and tested *(GSI group)*

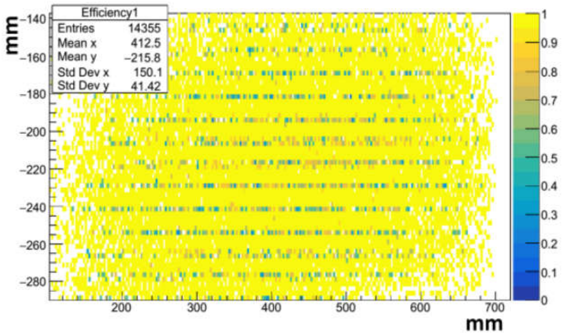
STS group

GEM central tracking system

Stand for cosmic tests



Spatial efficiency for
Different sector design

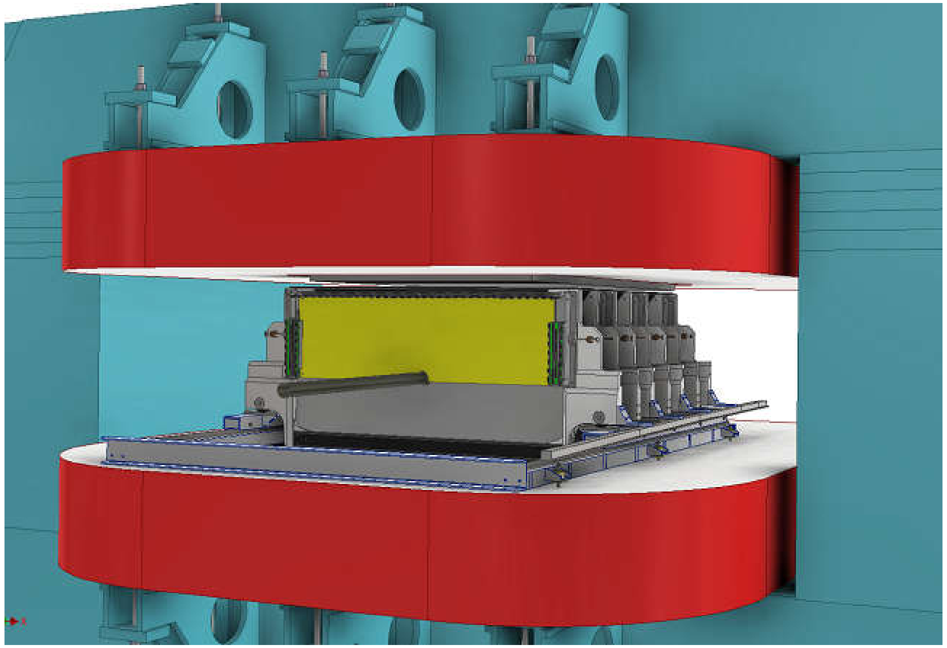


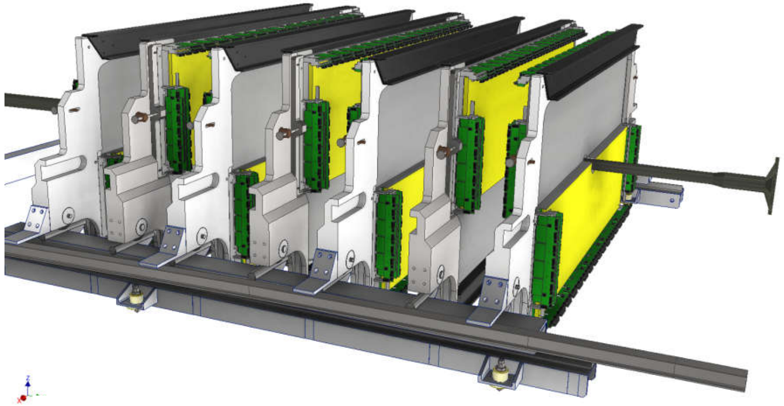
Four last1632x390 mm^2 GEM chambers were assembled at CERN

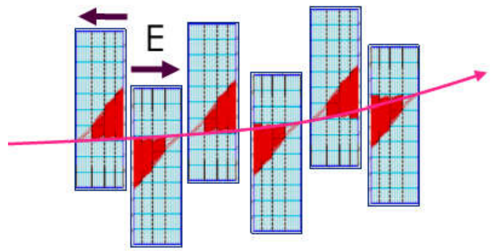
New bracing system for FEE was designed and produced

- Seven GEM 1632x450 mm^2 chambers produced at CERN workshop were integrated into BM@N experimental setup. One was defected and repaired at CERN.
- Seven GEM 1632x390 mm^2 chambers were assembled and delivered to JINR.
- Two spare chambers are to be produced at 06.2020

Mechanics design for GEM planes precise installation inside the magnet







Upgrade plans:

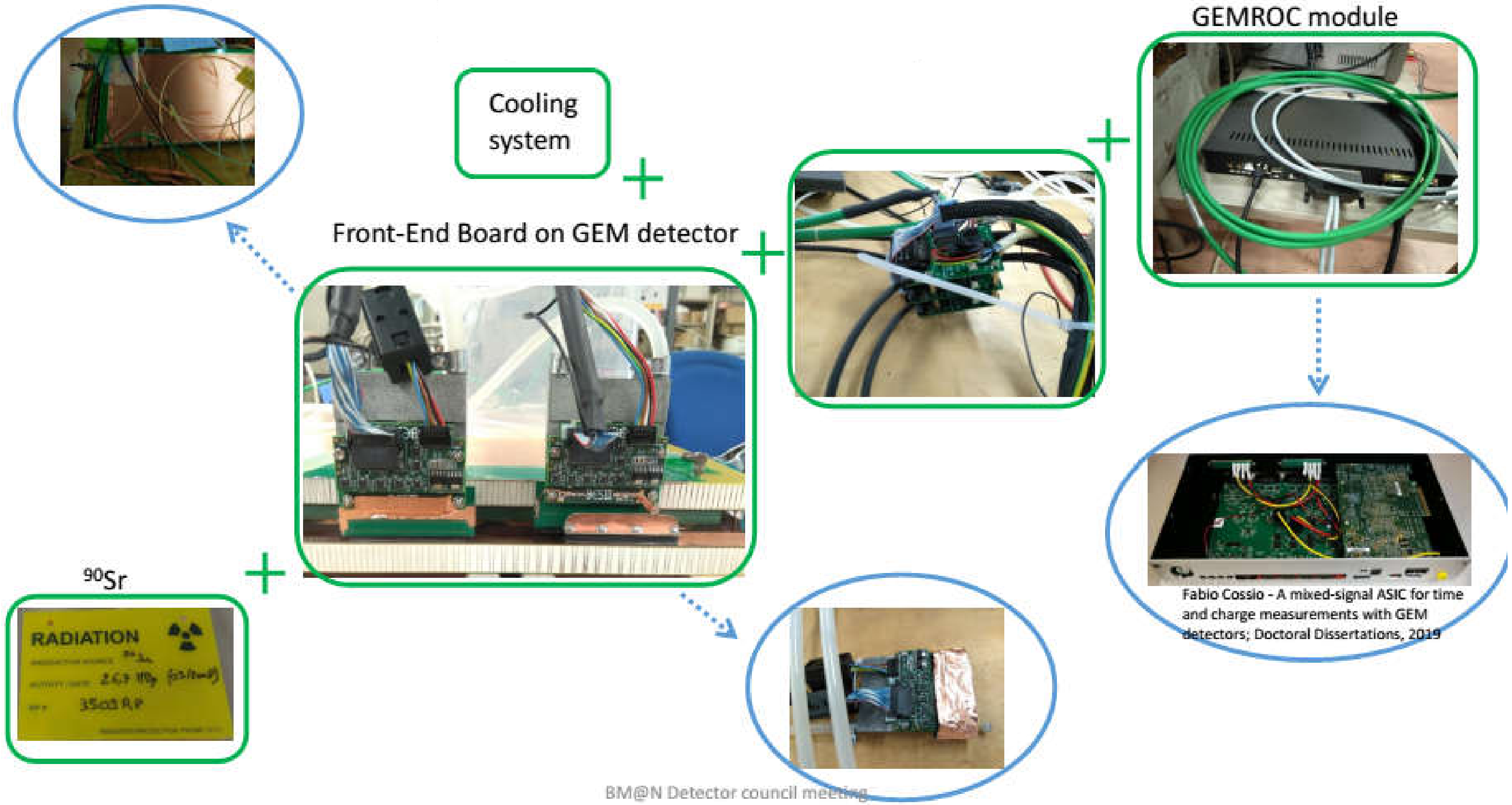
05.2020 – development of the mechanics design (Pelcom Dubna) and mechanics production for GEM planes precise installation inside the magnet.

09.2020 – integration of the full GEM planes into the experimental setup (electronics based on the VA-163 chips, ~90000 readout channels)

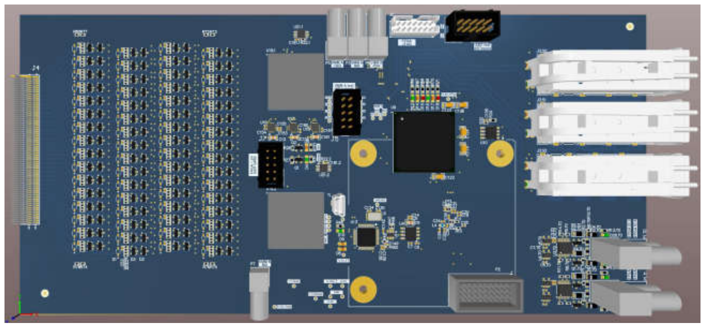
2022 - Development, tests and integration of FEE based on VMM3/TIGER ASICs.

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 are planned on March 2020 at JINR.



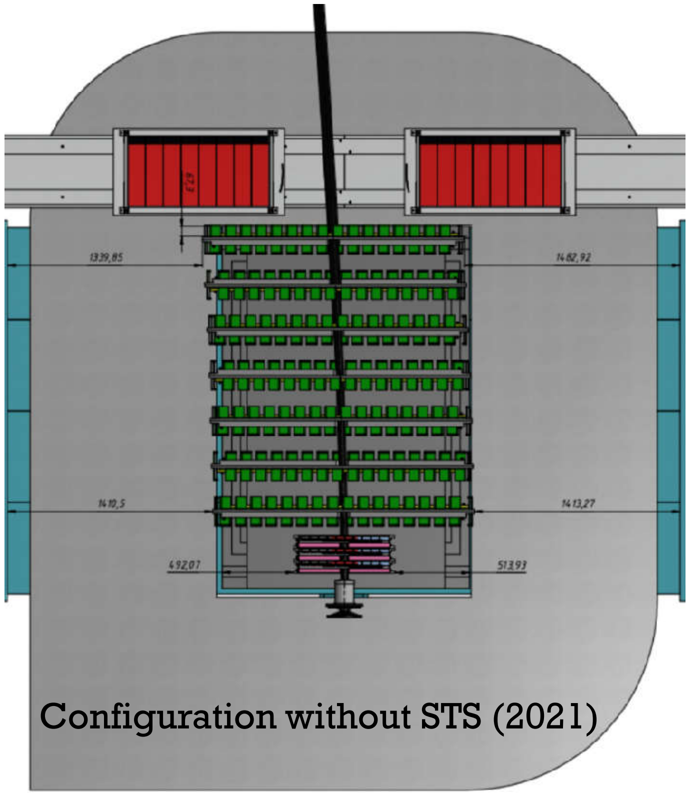
Kintex7 based 128ch GEM evaluation board was designed for **VMM3a** tests.



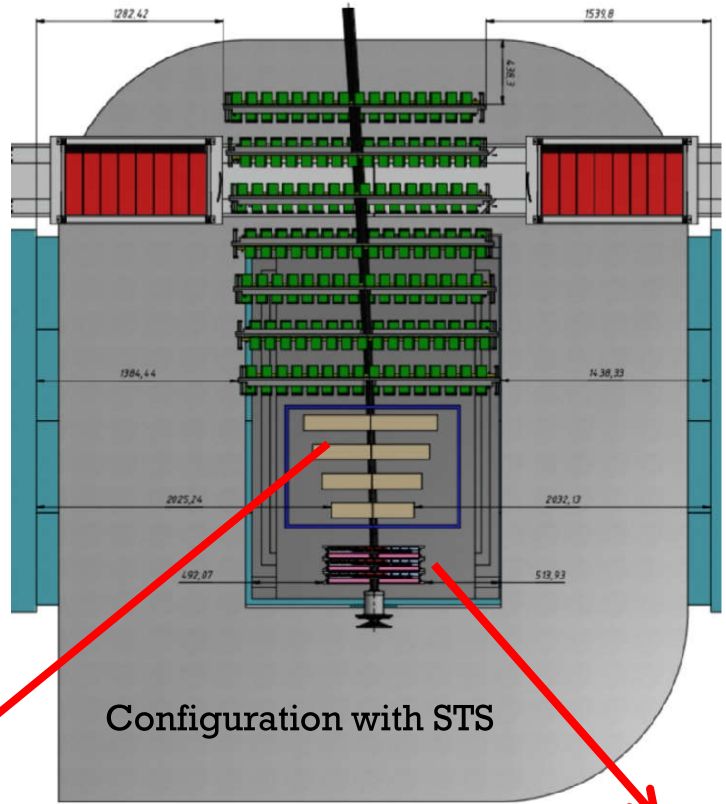
Forward Si+ STS +Gem configuration

Four configurations of the tracking detectors are foreseen:

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

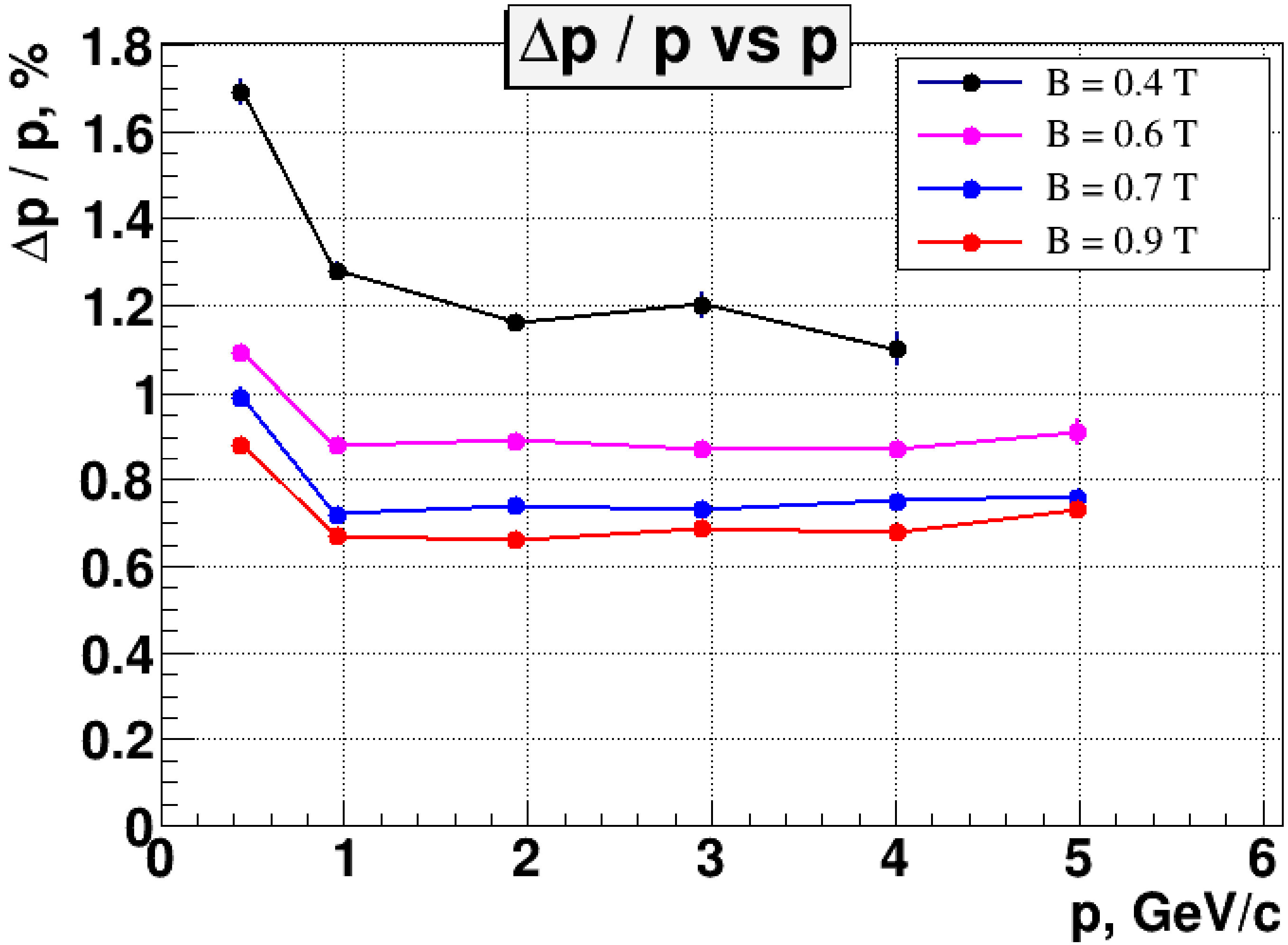


Configuration with STS

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)

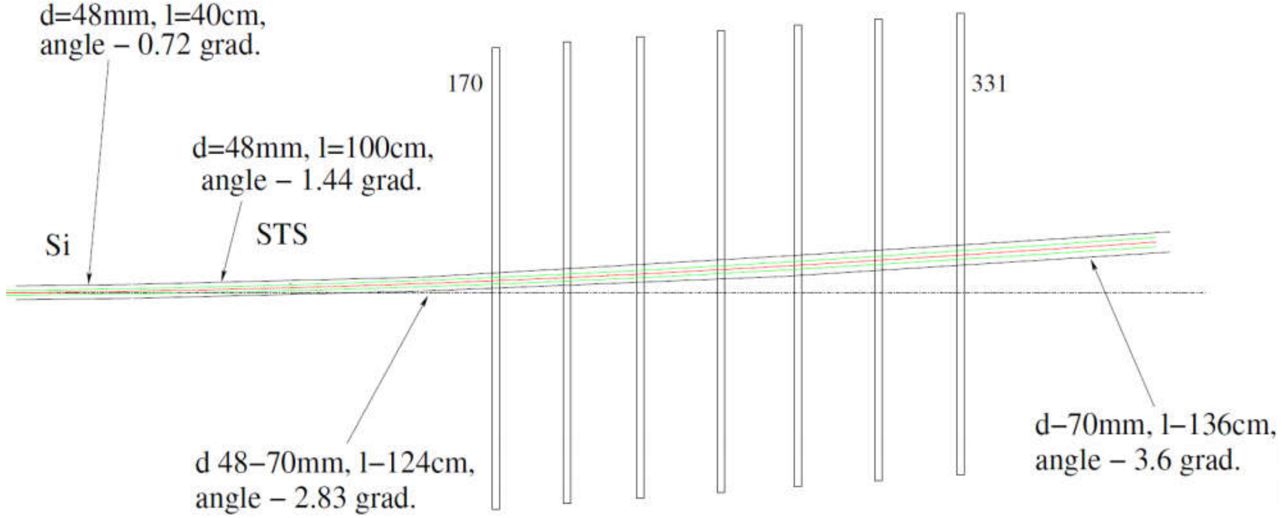
Hybrid central tracker STS+GEM momentum resolution for different magnetic field values



A.Zinchenko

Beam pipe inside the SP-41 magnet

S. Piyadin, V. Spaskov



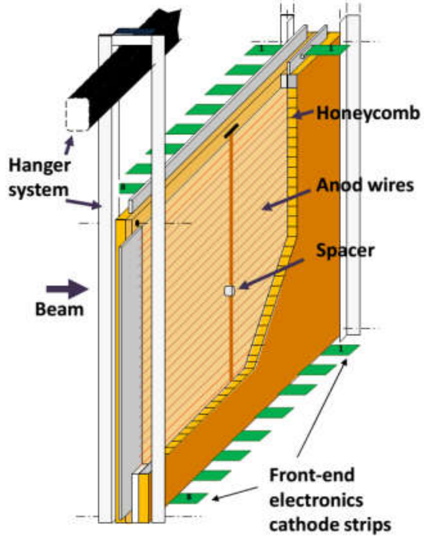
Test sample of the carbon beam pipe

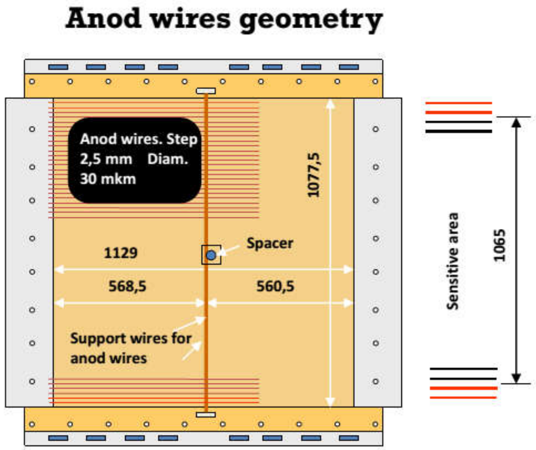
- DD "Arkhipov" (Moscow, Russia) – 1m test sample of carbon beam pipe is ready
- Agreement on cooperation to be signed with "SYNTEZ-PROJECT" LLC (Moscow, Russia) for flange connections design
- Vacuum tests of the sample are to be performed this week.

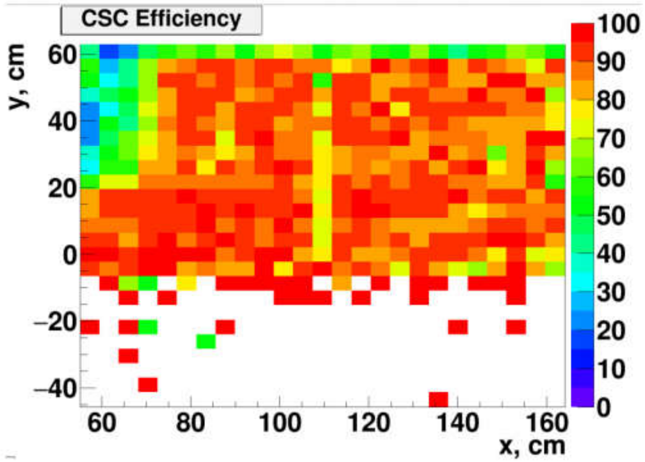
1065x1065 mm^2 CSC chamber

CSC group

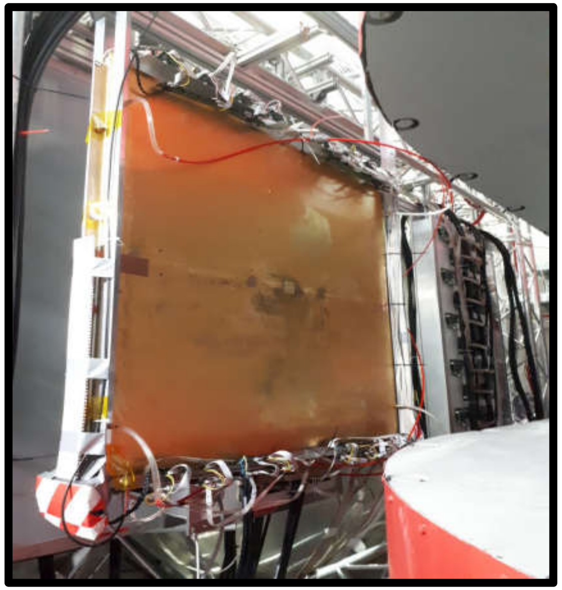
C, Ar and Kr runs in March 2018: CSC chamber is installed in front of ToF-400 to check its performance as outer tracker for heavy ions







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



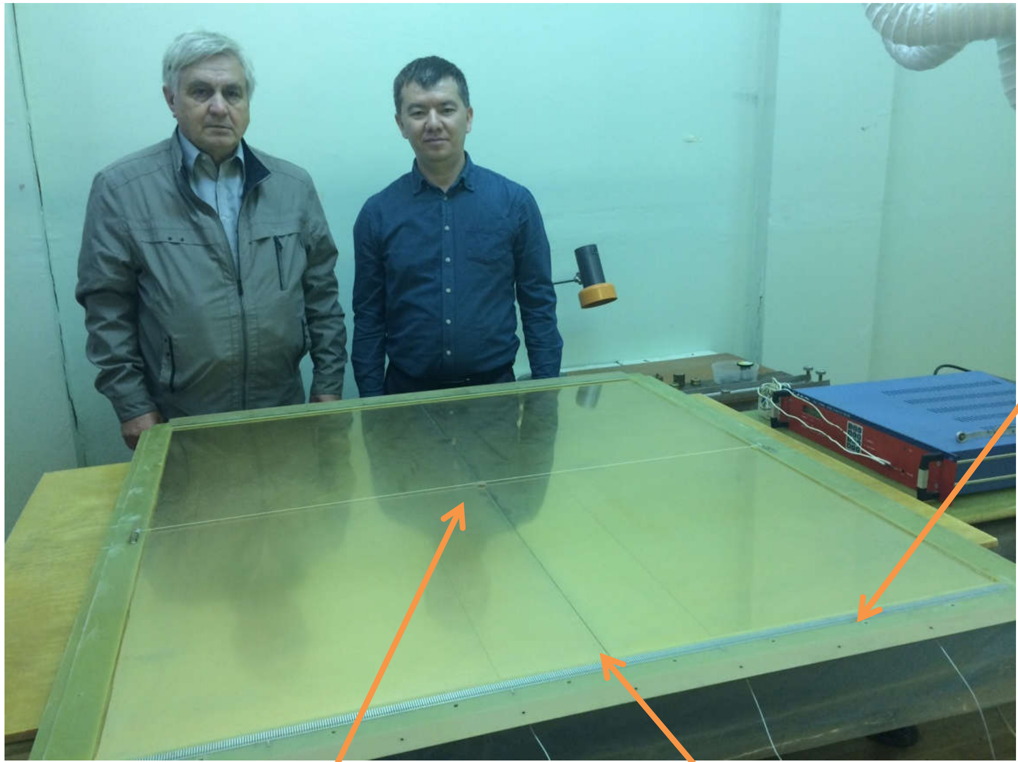
One CSC 1065x1065 mm^2 is produced and tested at Nuclotron beam.

Plans:

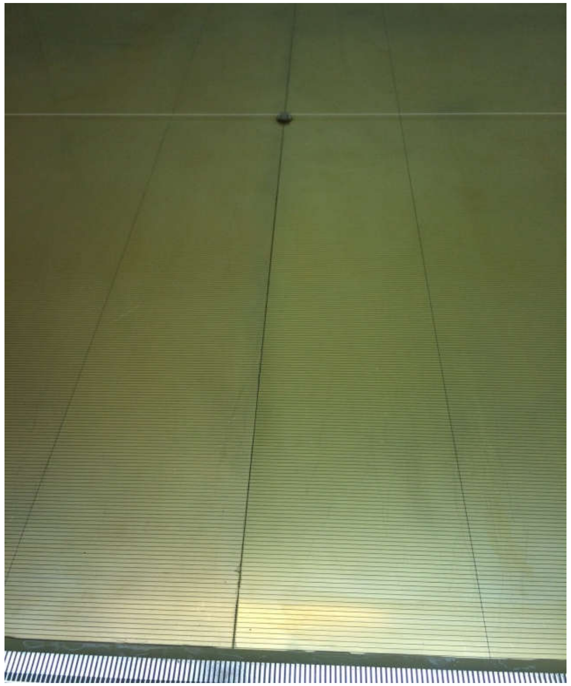
- assembly of the three1065x1065 mm^2 chambers is at the final stage

- in March-April 2020 assembled chambers are to be tested with r/a source and at cosmic stand

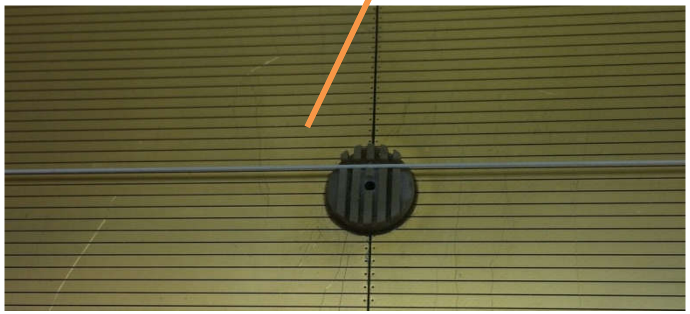
1065x1065 mm^2 CSC chamber assembly process



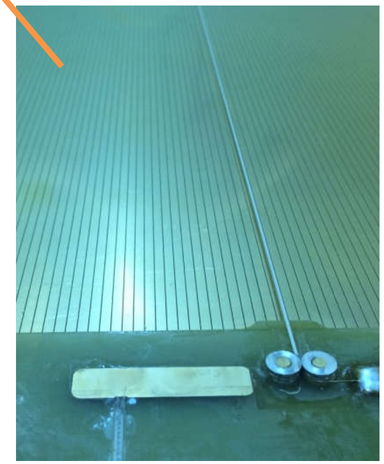
Marks for wires precise positioning



Cathode plane
is ready for wire soldering



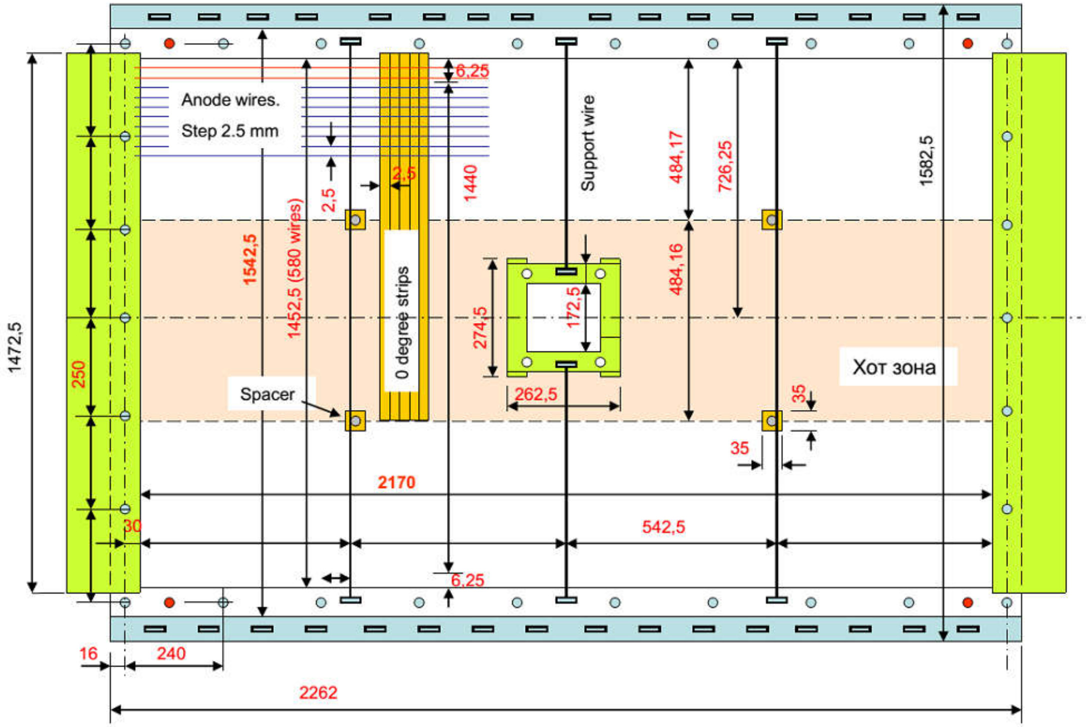
Spacer

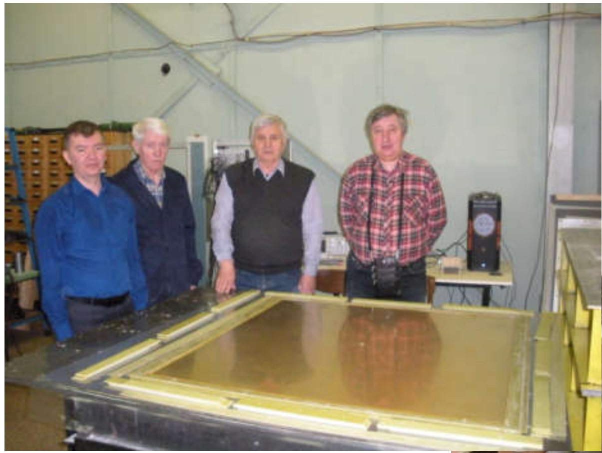


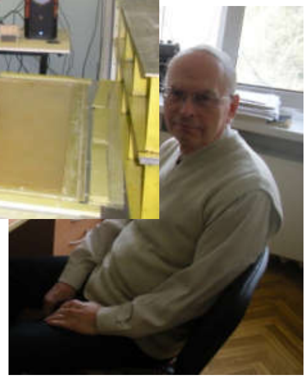
Support wire

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.

Production plans:

- 06.2020 – design and production of the cathode planes for 2190x1453 mm^2 CSC chambers

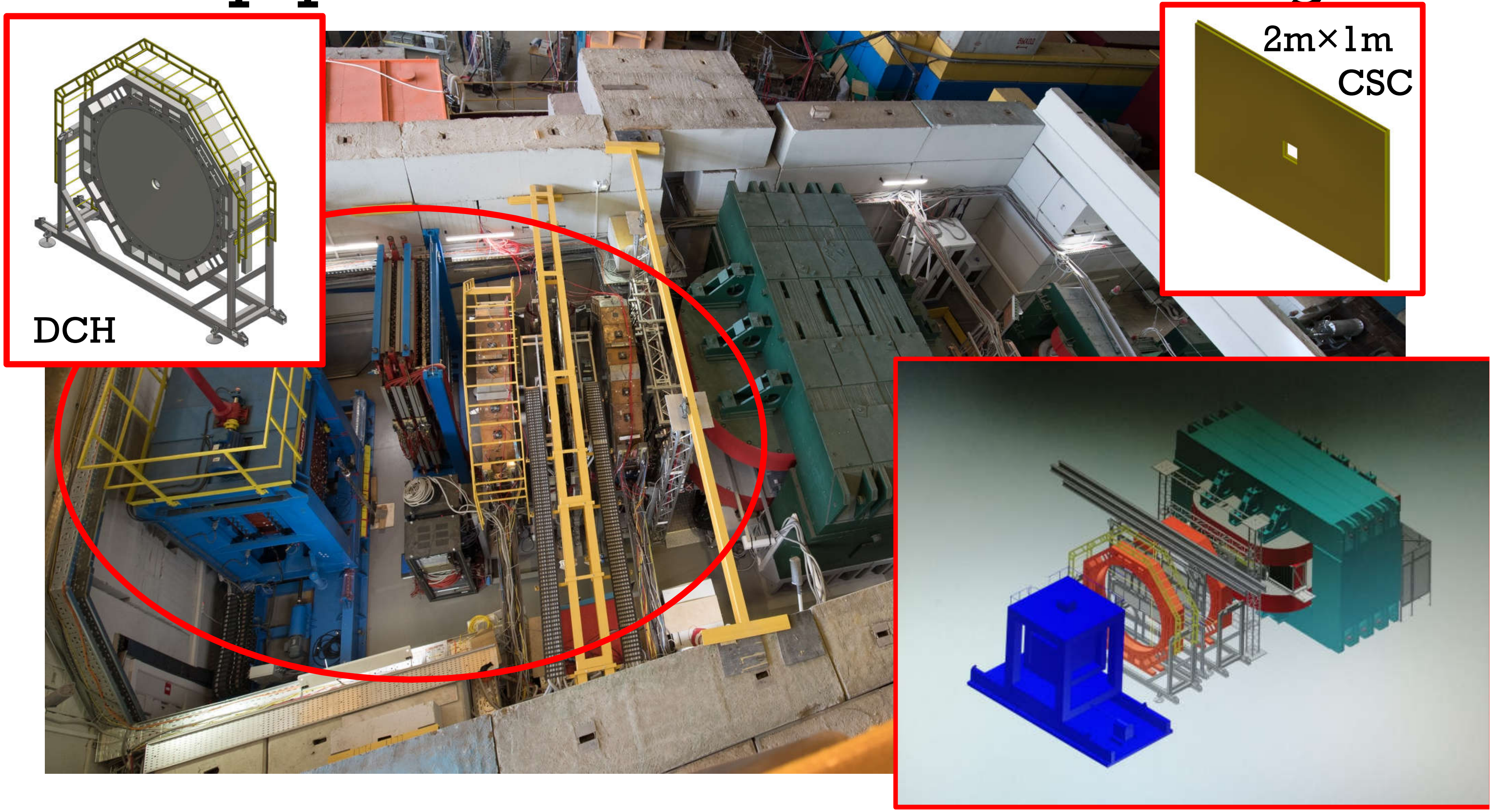
- 03.2021 – Assembly of the 2190x1453 mm^2 CSC

- 09.2021 – All chambers are integrated into the BM@N experimental setup

Design of the first PCB is finished.

Design and assembly – JINR LHEP

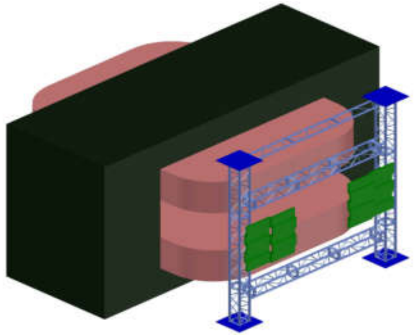
Beam pipe downstream the SP-41 magnet



Possible candidate for development and production of the aluminum beam pipe downstream the SP-41 magnet is A. Kubankin group (Belgorod University).
3D model development of the detectors after the SP-41 magnet is at the final stage.

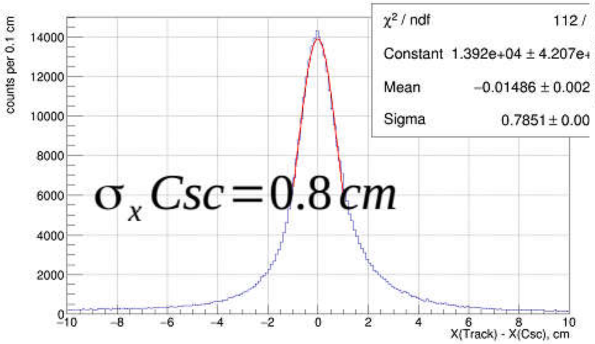
S. Piyadin

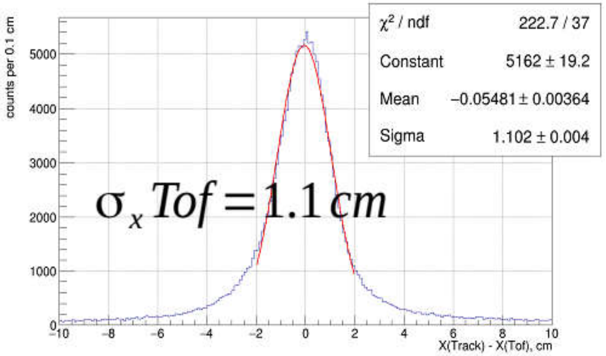
Status ToF-400



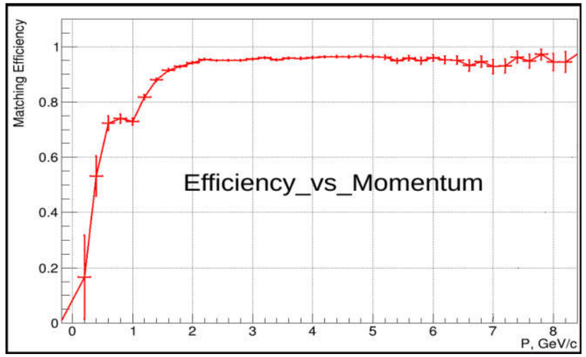
ToF-400
+ V.Plotnikov
+M.Rumyantsev

Residuals of CSC and ToF-400

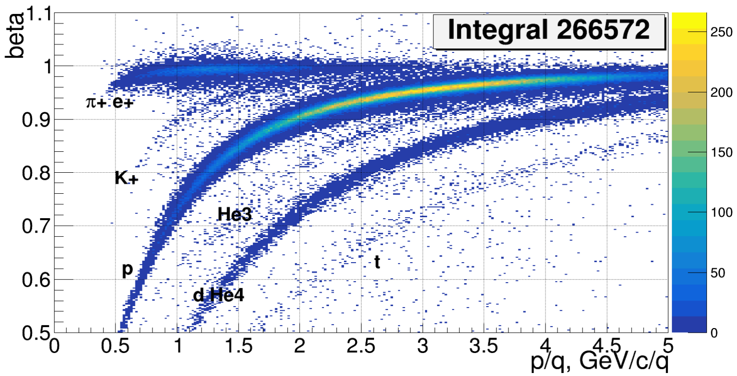


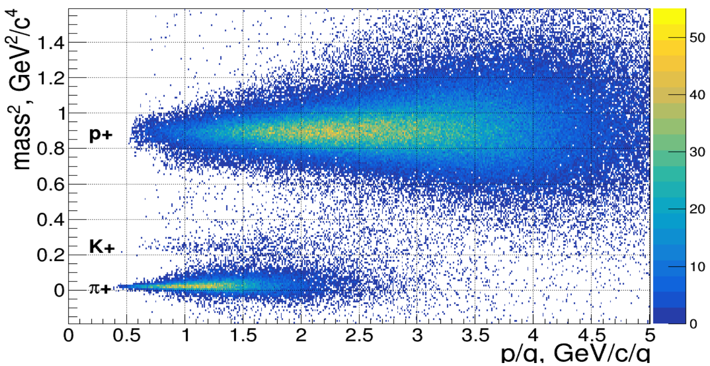


Matching efficiency of GEM+CSC track to ToF-400



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

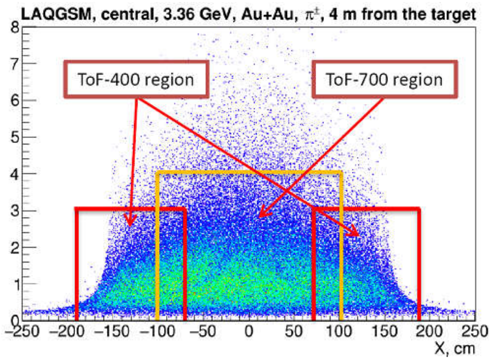




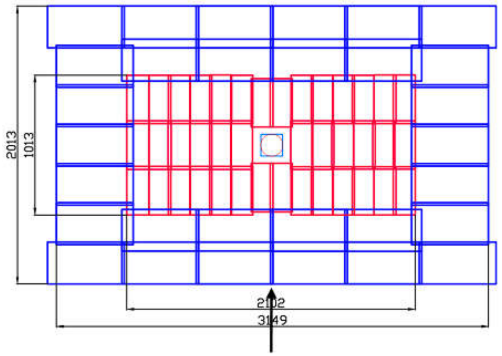
Proton Mass^2 = 0,894 +- 0,081 GeV^2/c^4, Pion Mass^2 = 0,021 +- 0,016 GeV^2/c^4

Status ToF-700

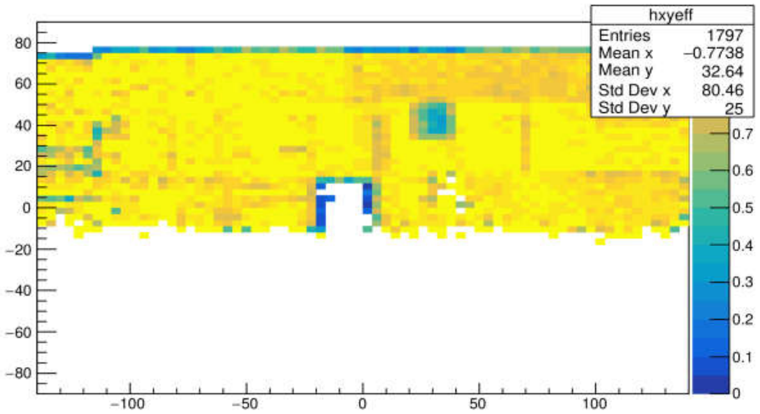
Yu.Petukhov, L.Kovachev



ToF-700 wall

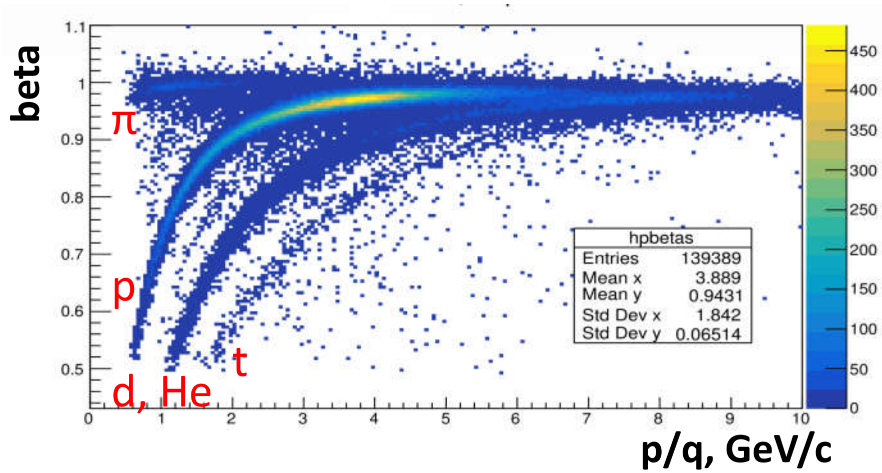


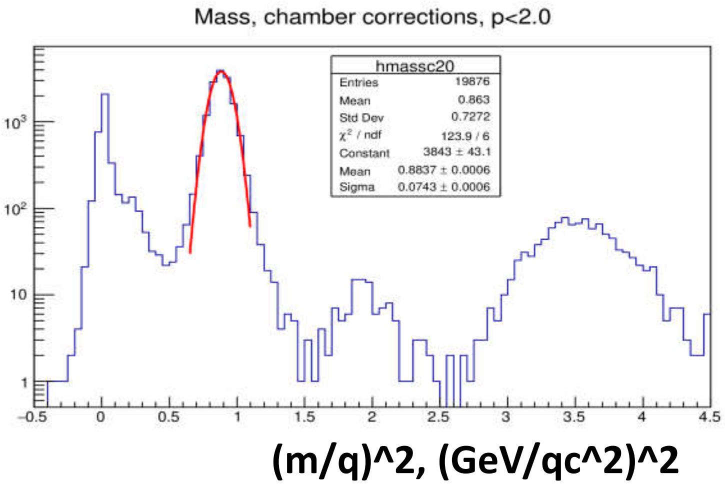
BM@N beam axis



ToF-700 efficiency, GEM+DCH+TOF700 vs GEM+DCH tracks

Argon beam, 3.2 AGeV





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

ToF-700 time calibration procedure was developed. Final tests of the algorithm are performed.

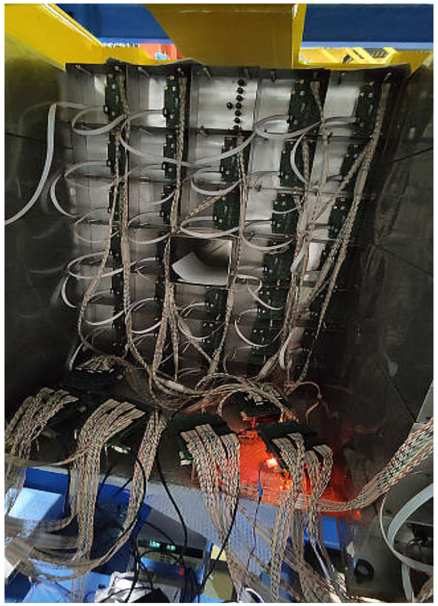
Status of new FHCal at BM@N

group of INR RAS Troitsk

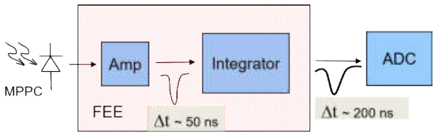
Sep.
2019

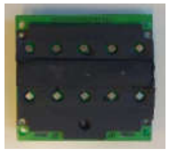
The new FHCal is assembled and installed at BM@N

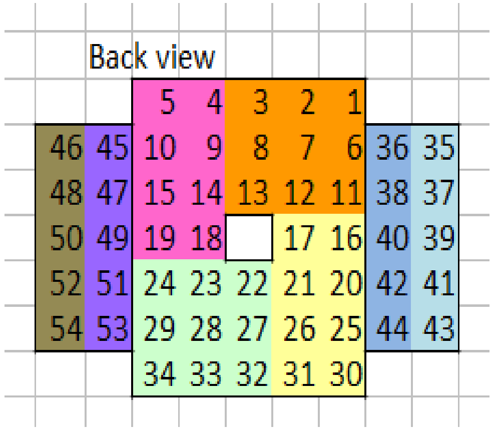
Central part – 34 MPD modules (15x15 cm^2).
Outer part – 20 CBM PSD modules (20x20 cm^2).



438 FEE channels with 8 ADC64WR read-out boards have been installed and tested.

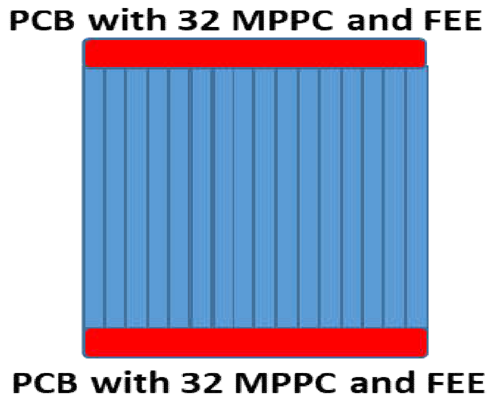


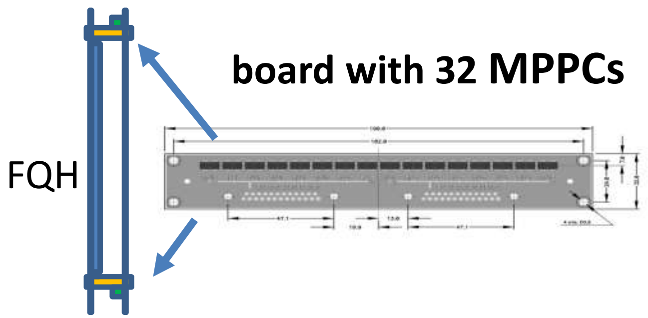




Scheme of modules readout with 8 ADC64

New Forward Quartz Hodoscope (FQH)





- 16 radiation hard quartz detectors with sizes 160 x 10 x 4 mm. Full transverse size 160 x 160 mm.
- FQH will be installed on the beam axis just after the FHCAL and will fully cover the beam hole in the calorimeter.

- The light from each of two end faces of quartz FQH - 32 MPPCs with active area 3 x 3 mm^2.
- The FQH will operate at rather high radiation conditions, and the FEE and readout electronics based on TQDC 125 developed at JINR will be located outside of the active FQH region on the distance of 1-1.5 m from beam axis.
- The readout electronics should provide signals digitization of analog 40 nsec width signals with and rate of about 1 MHz.

Recently, one of quartz detector 160 x 10 x 4 mm was tested at electrons beam with energy 400 MeV. Results - light yield is about 2 ph. el. and homogeneity of light collection is on the level of +/-3% if signals from both sides of the detector are readout with 2 MPPCs and are summed.

Plans:

- Construction of FQH and tests of FQH on heavy ions beams at GSI (mCBM) – March – May 2020;
- Implementation of FHCAL and FQH readout and slow control n common BM@N readout/slow control;
- Commissioning and calibration on cosmic.

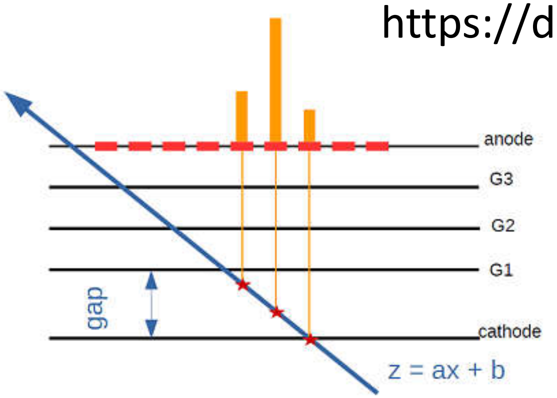
Summary:

Detector Subsystem	Status	Upgrade Status
Beam pipe before the target	installed	
Beam pipe downstream the target, in SP-41 magnet		09.2020
Beam pipe downstream the SP-41 magnet		09.2020
Forward Si detectors	3 small planes	3 full-size planes (09.2020)
STS BM@N		42 modules (2021) 292 modules (2022)
GEM	7 top half-planes + 7 bottom half-planes	
CSC	1 chamber 1065x1065 mm^2	4 chambers 1065x1065 mm^2(03.2020) 2 chambers 2190x1453 mm^2(2020-21)
ECAL	one arm	two arms (2020)
ToF-400	full configuration	
ToF-700	full configuration	
ZDC	ZDC (MPD/CBM type)	

Backup

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

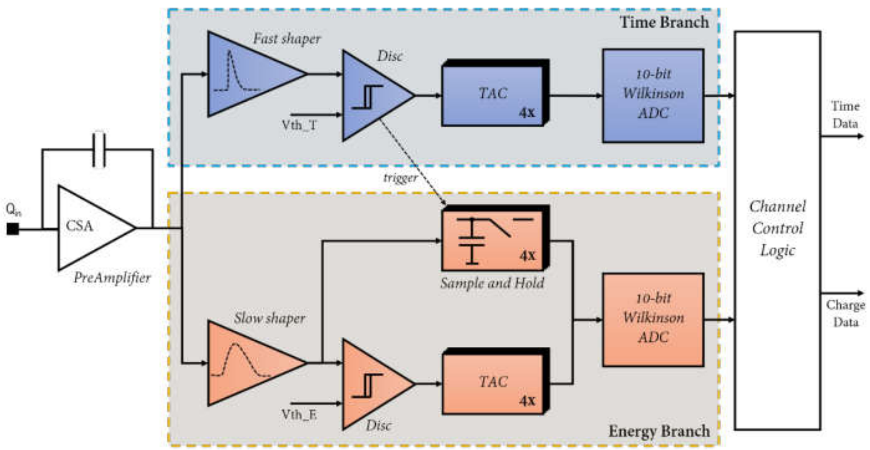
https://doi.org/10.1016/j.nima.2018.09.010



- 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%

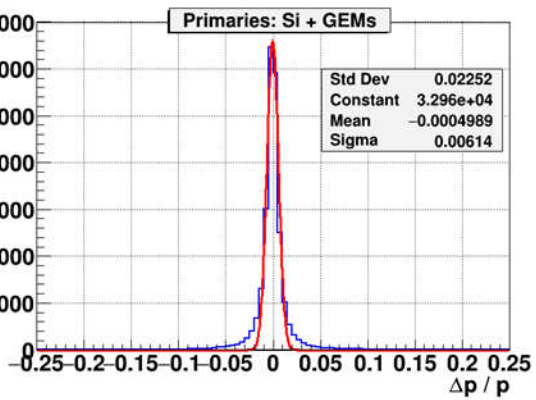
Noise floor (ENC) 1500 $e-$

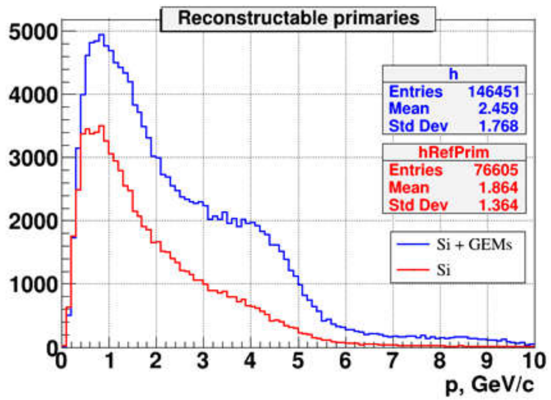
Noise slope 10 $e-$/pF

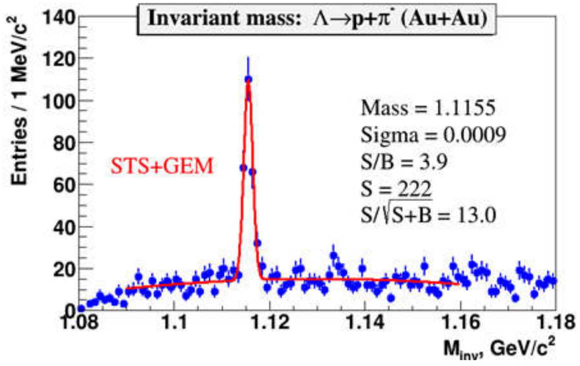
Maximum power consumption 12 mW/ch

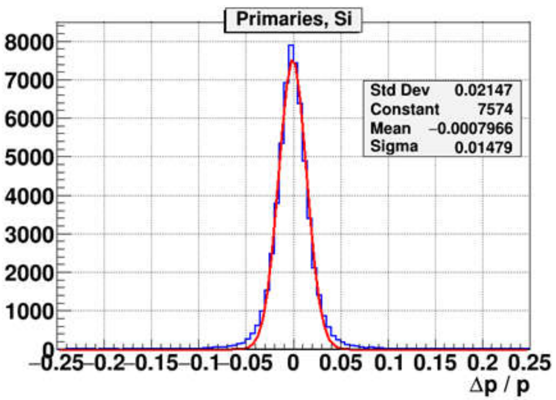
First tests with BM@N GEMs are planed in November 2019 at CERN

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





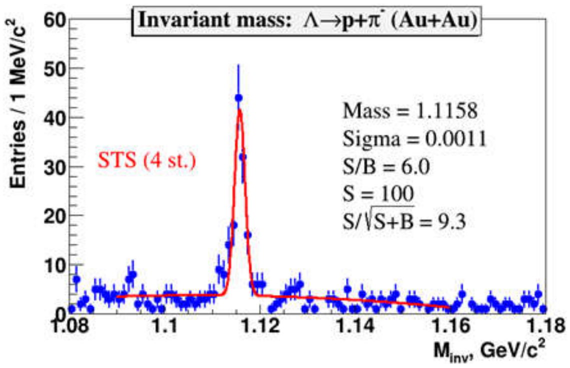




Hybrid STS + GEM tracker:

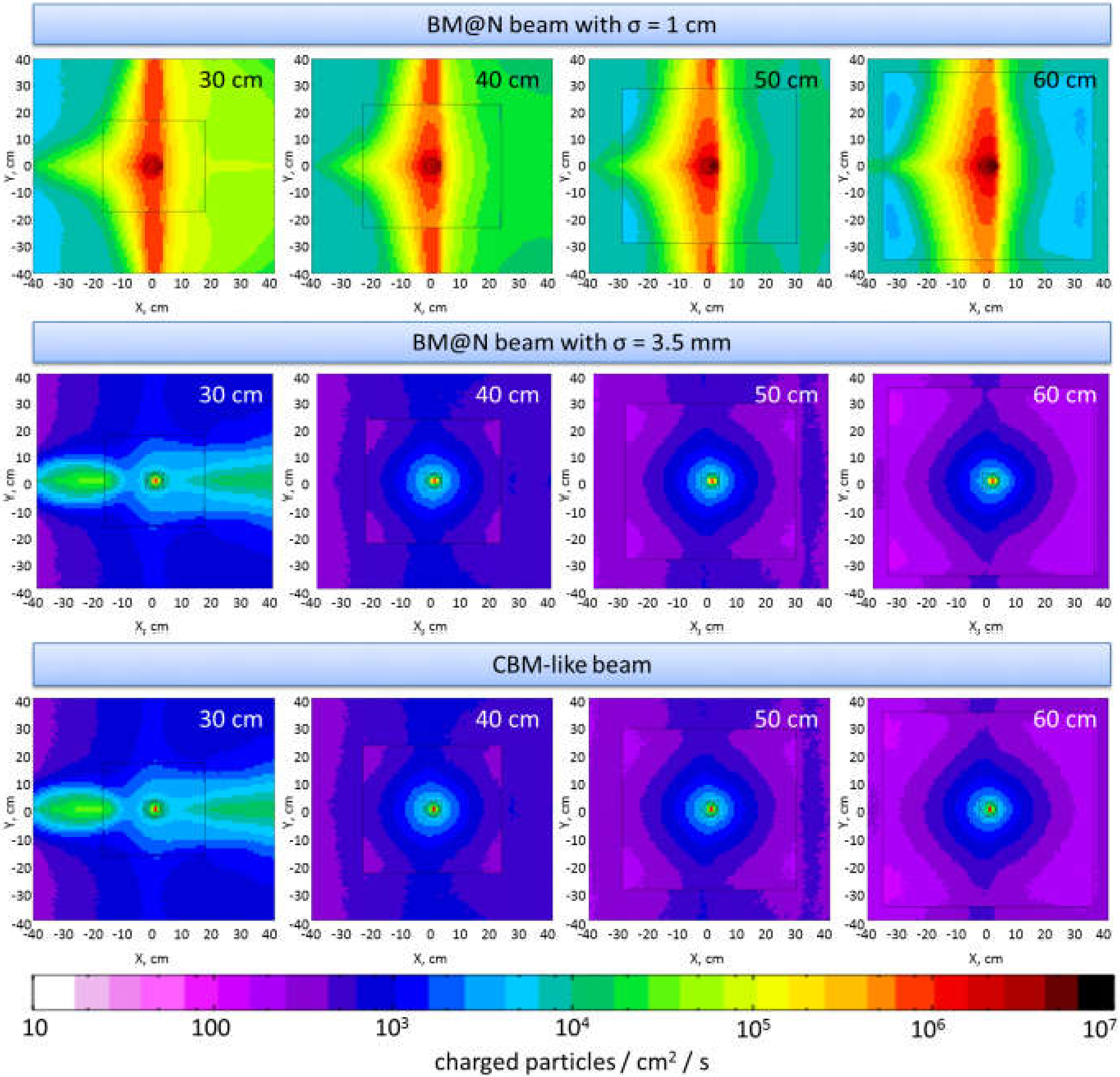
► 2 times increase in number of reconstructed tracks and Λ hyperons

► 2 times better momentum resolution



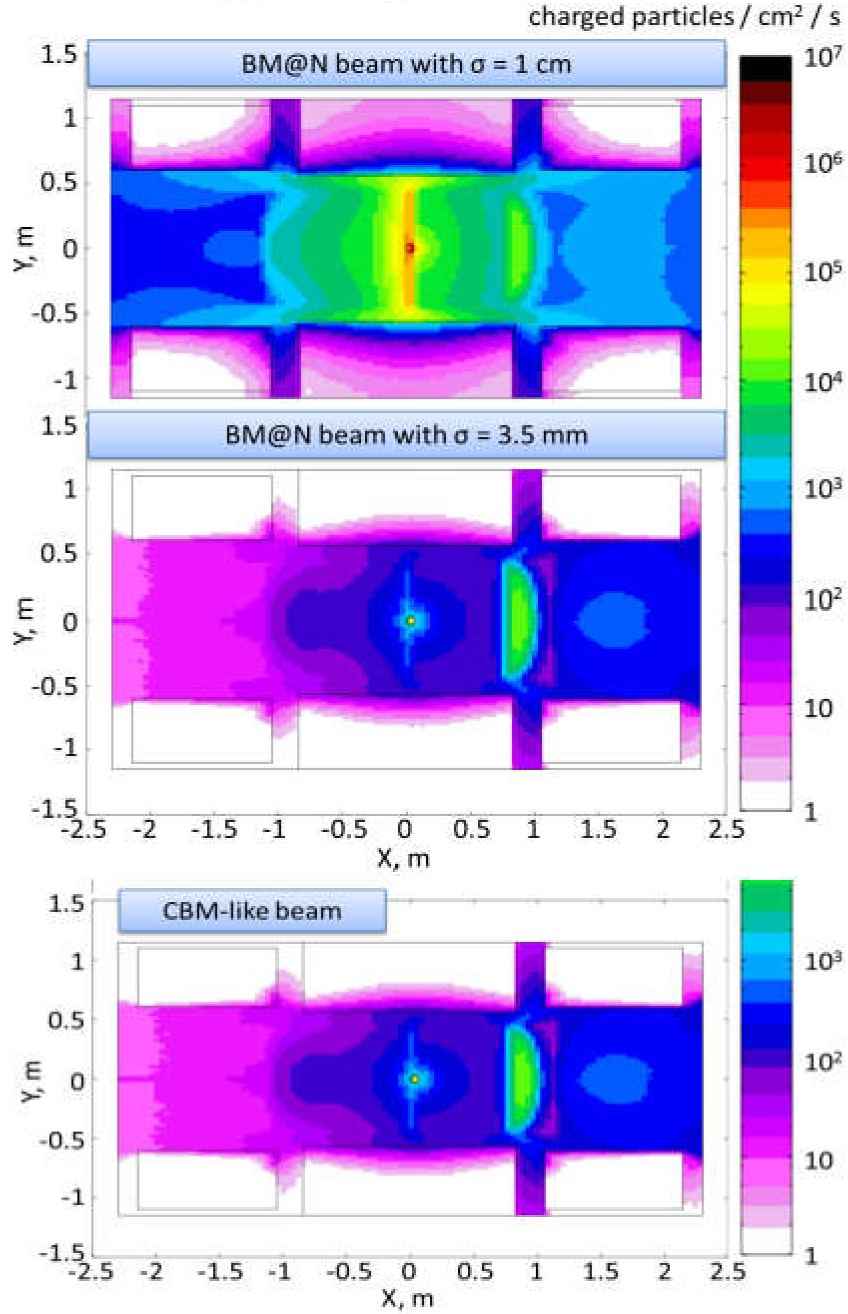
A. Zinchenko, P. Senger

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 %**