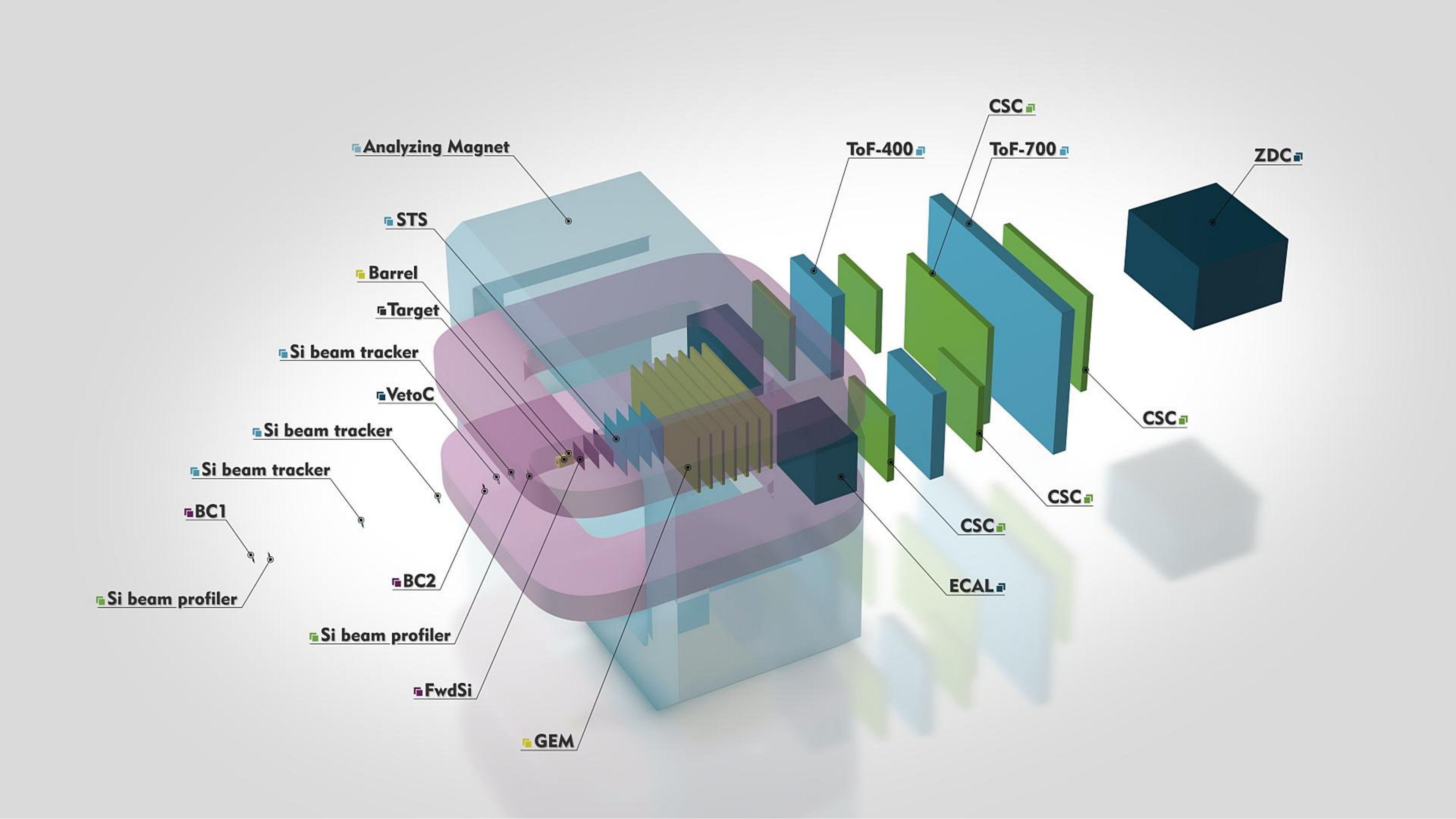
Upgrade of the BM@N detectors

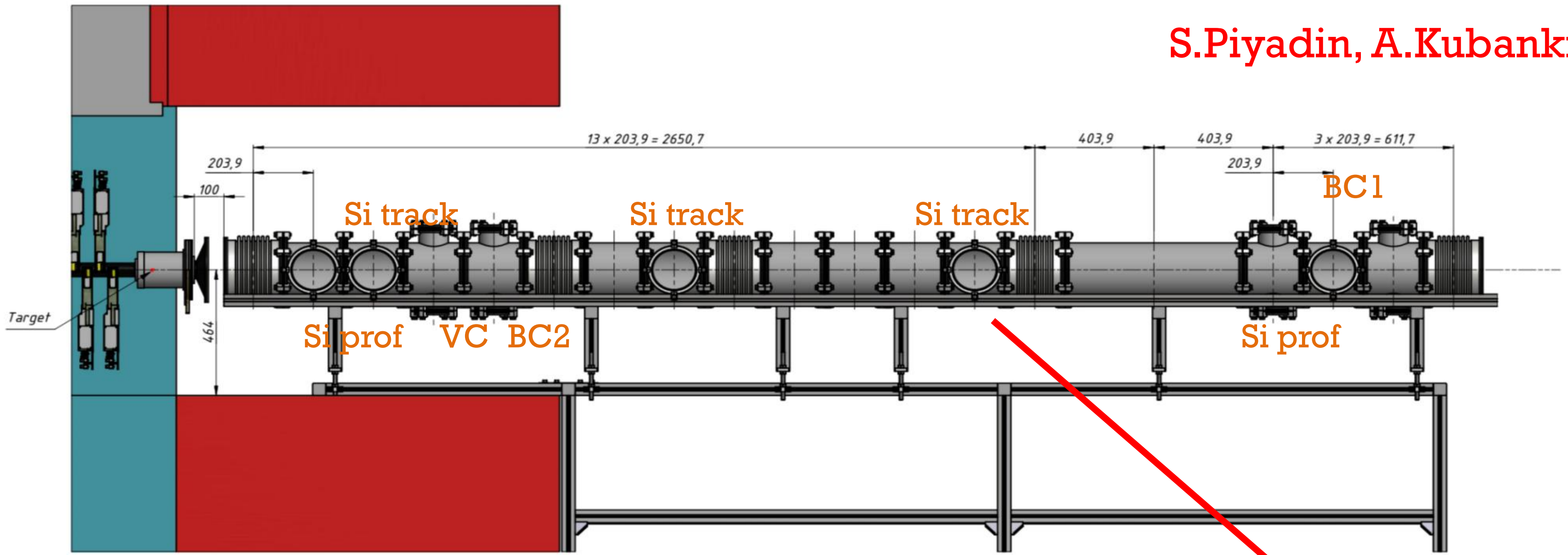
Anna Maksymchuk on behalf of the BM@N Collaboration
14/10/2019

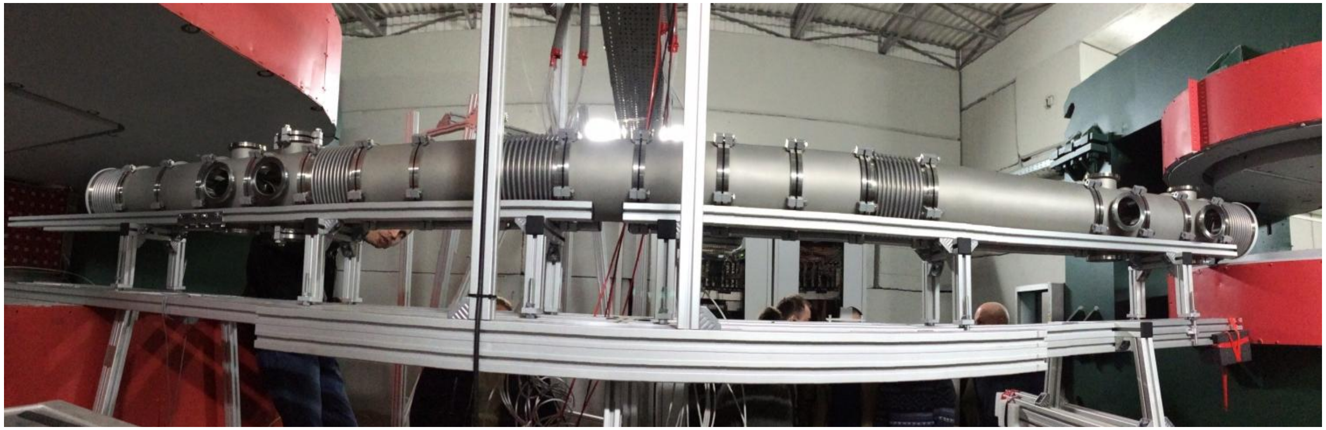
BM@N Experimental Setup

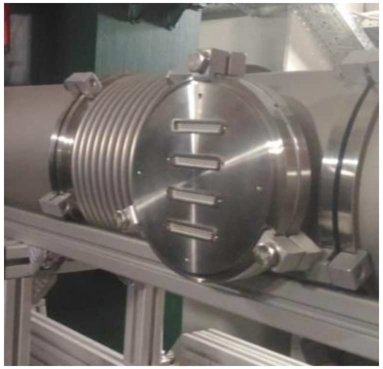


Beam pipe before the target

S.Piyadin, A.Kubankin



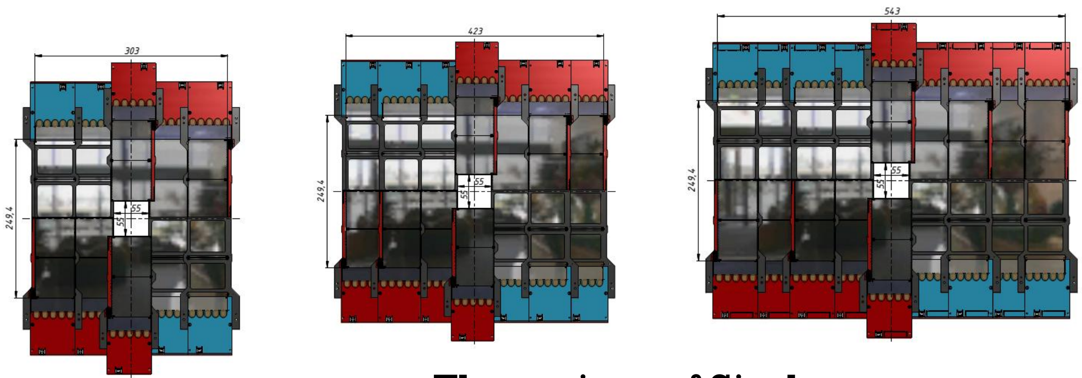




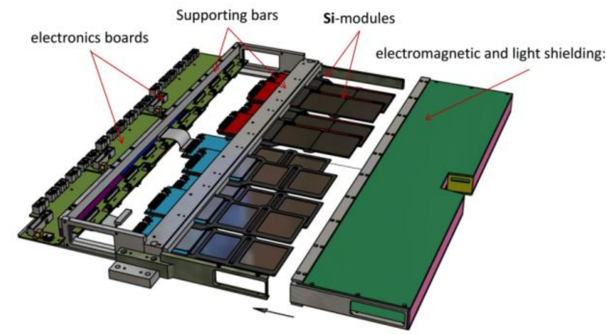
See talk of S.SEDYKH

Production of the beam pipe: Belgorod University

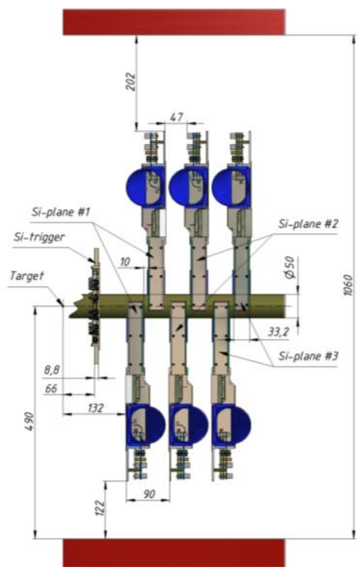
Upgrade of the forward Si tracking detectors

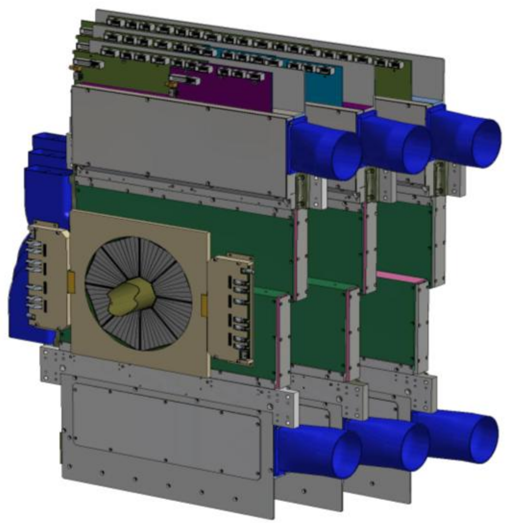


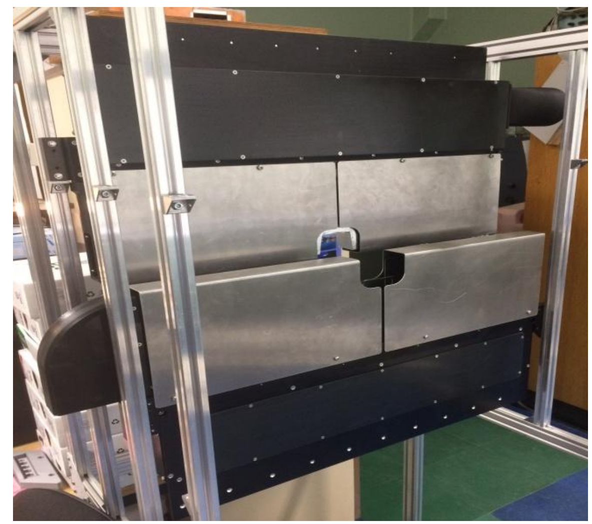
Three sizes of Si-planes



Half-plane design





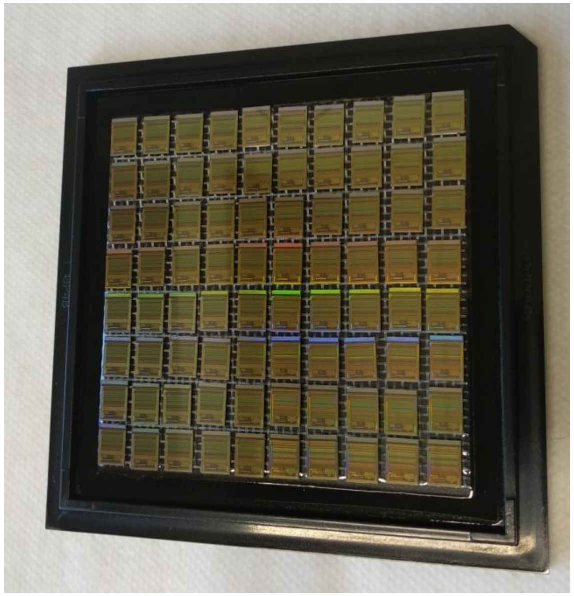


Design of the Si-planes
on the BM@N beam-channel

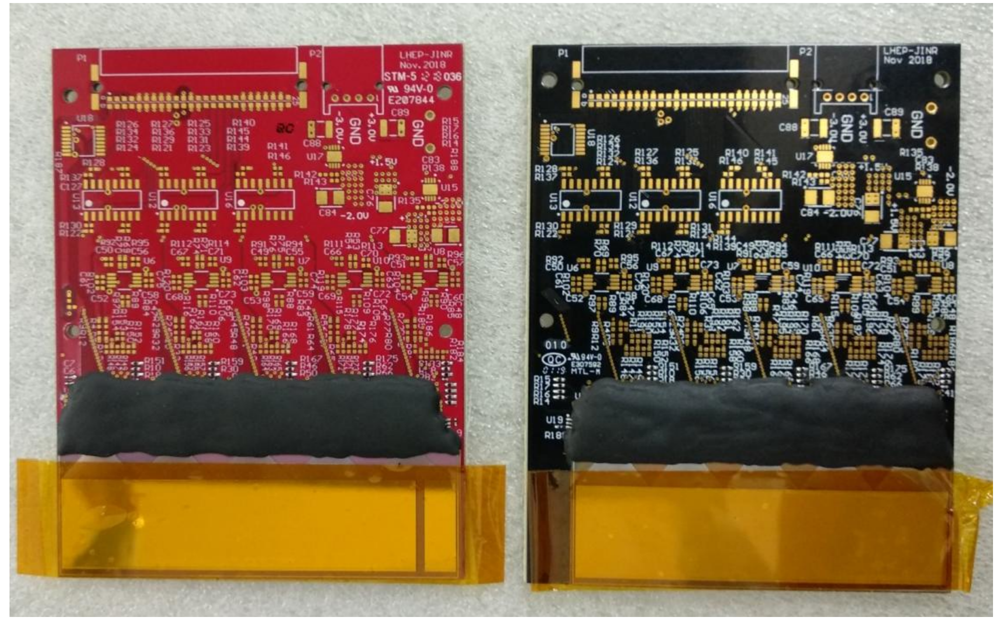
Station#	Number of DSSD modules	DSSD station square	Number of Readout channels
Station1	10	720 cm^2	12800
Station2	14	1008 cm^2	17920
Station3	18	1296 cm^2	23040
Total	***42***	***~0.3 m^2***	***53760***

group of N.Zamiatin

Upgrade of the forward Si tracking detectors



ASIC VATAGP7.1 are delivered to JINR



First FEE based on VATAGP7.1 are ready for testing

Readout ASIC VATAGP7.1.
Number of sensitive pre-amplifier (CSA) inputs - 128
Input charges (dynamic range) - -30fC ÷ +30fC
Peaking time (slow shaper) - 500ns (typ.)
Good linearity for charges up to +/- 15fC
Reading clock - 4,6MHz

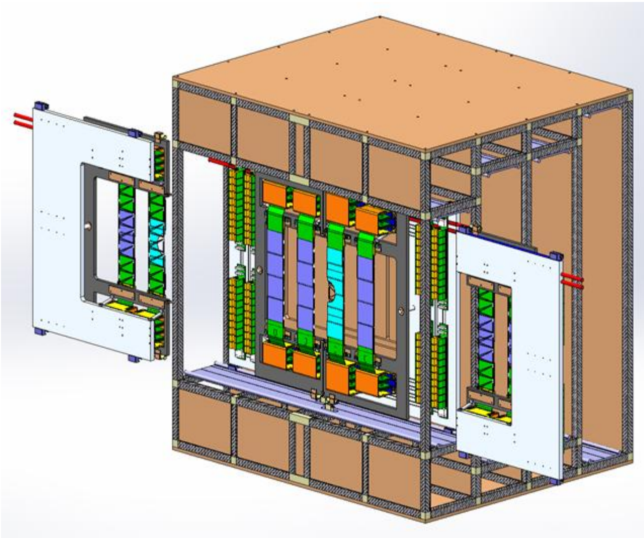
Plans:
2020 – integration of the Si forward tracking detectors into BM@N setup

See talk of B.Topko

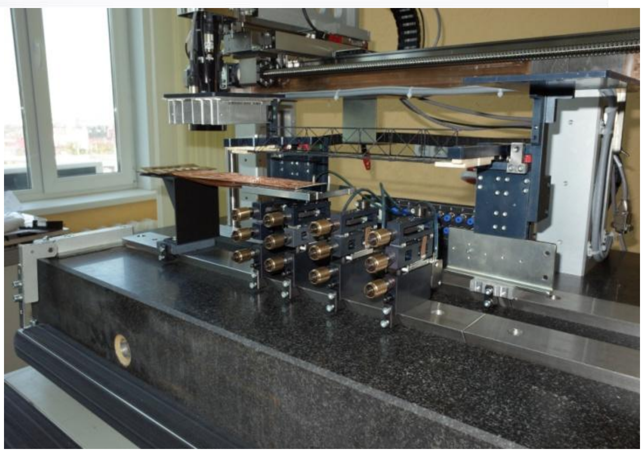
Status of BM@N STS

STS group

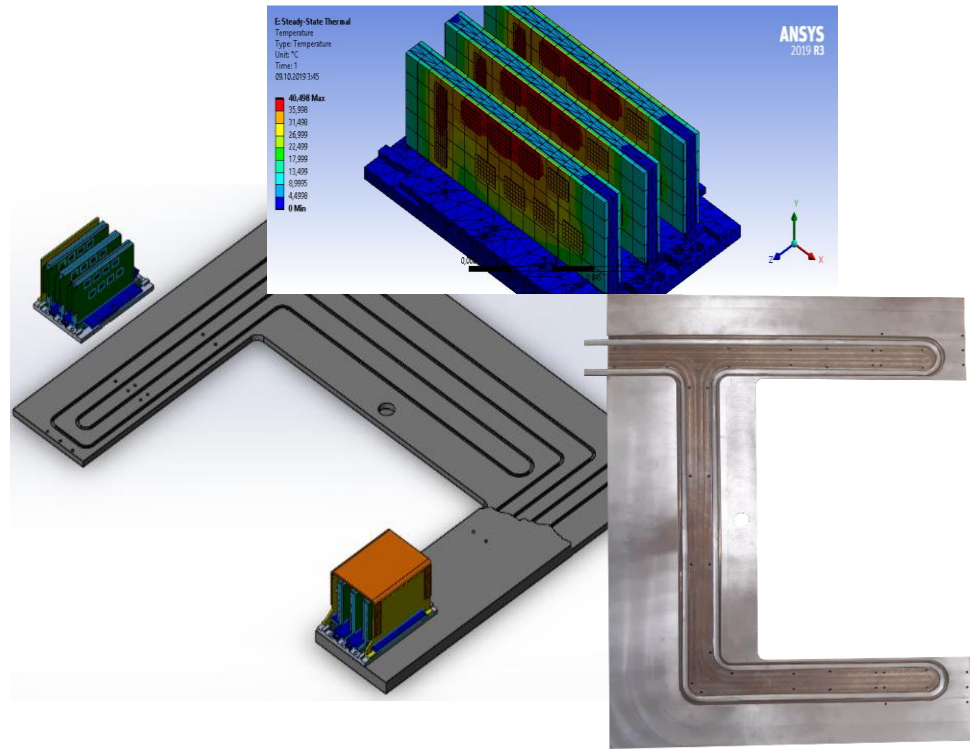
See talk of D.Dementev



- ❑ Design of the mainframe is ready
- ❑ Will be produced by ltd. Hydromania (Minsk, Belorussia)



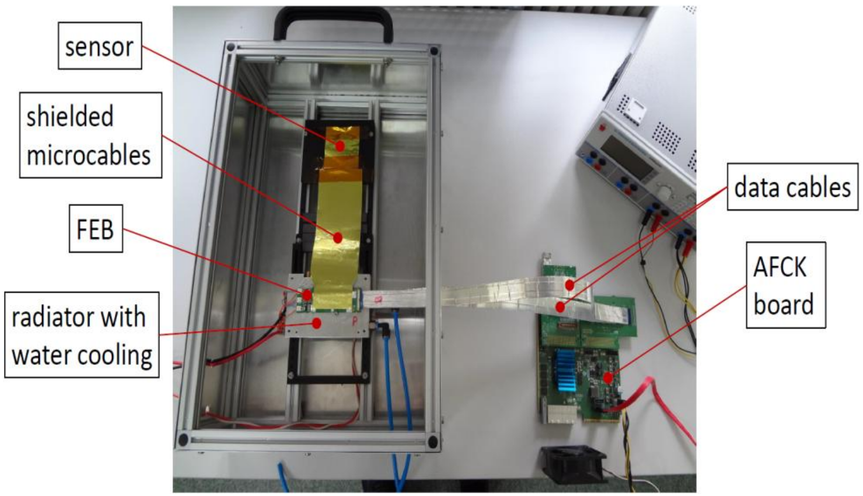
- ❑ Ladder assembly device was produced at Planar factory (Minsk)
- ❑ FAT in Oct 2019
- ❑ SAT in Nov 2019



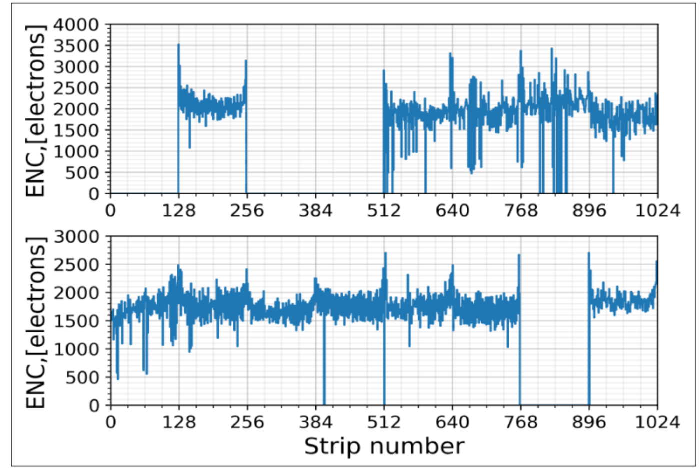
- ❑ FEB cooling is under development
- ❑ Heat exchanger for the first quarter station was produced by Artmash (Minsk) and tested

Status of BM@N STS

STS group

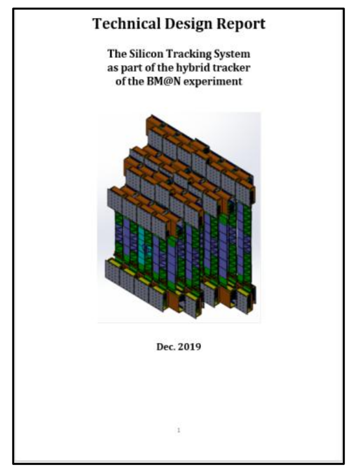


Test bench for the functional tests of assembled modules



Noise measurements, module N01.

- ❑ First modules were assembled and tested
- ❑ QA procedure during module assembly was established
- ❑ Glue for the Glob top of the ASIC was found to be the reason of brakes of wire bonds due to the thermal expansions
- ❑ New glues were tested, Dymax 9008 was chosen for the glob top

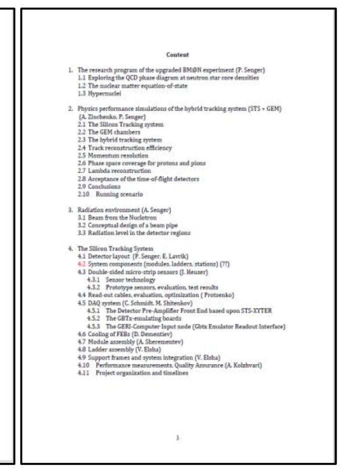


Technical Design Report

The Silicon Tracking System
as part of the hybrid tracker
of the BM@N experiment

Dec. 2019

1



Content

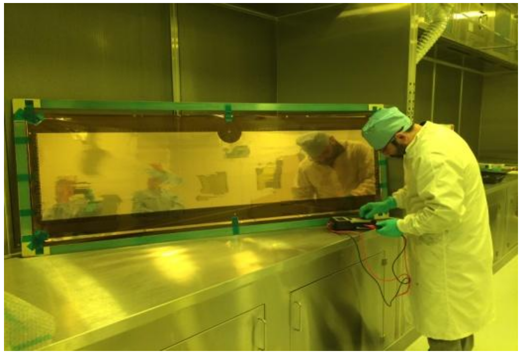
3

First draft of BM@N STS TDR is now available (some chapters are still at work)
Final version will be ready by the end of 2019

See talk of P.Senger

GEM central tracking system

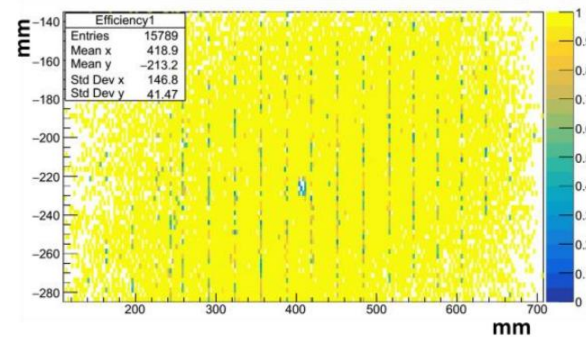
GEM group

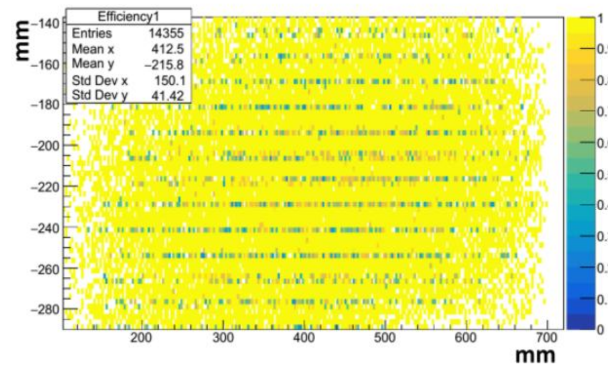


1632x390 mm^2 GEM chamber assembly process

1632x450 mm^2 GEM chambers at BM@N experimental setup

Stand for cosmic tests

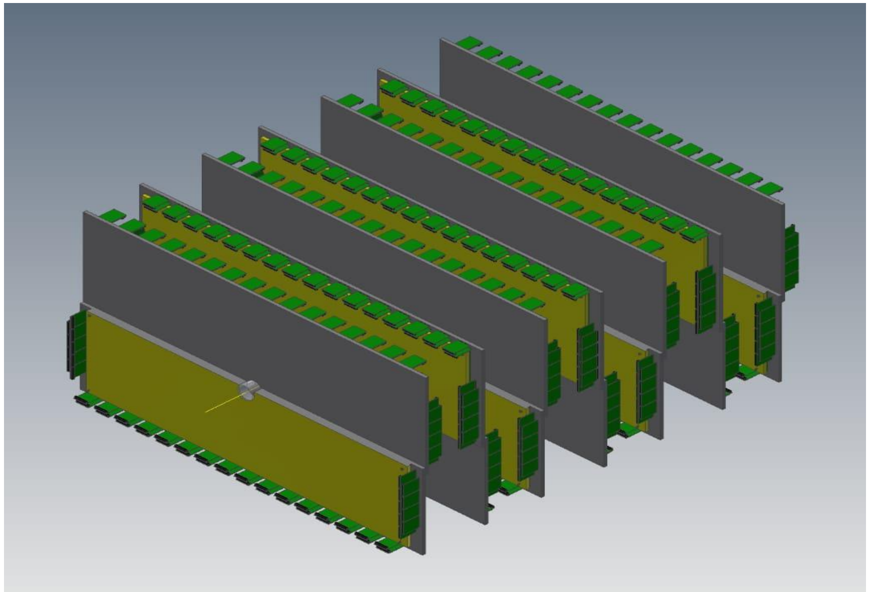


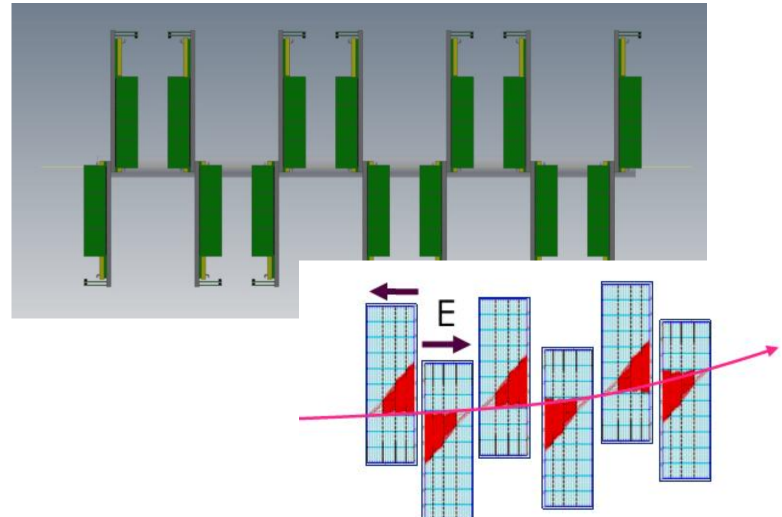


Spatial efficiency for different sector design

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

Scheme of the GEM full planes configuration inside the magnet





Scheme of the GEM planes installation inside the SP-41 magnet

Upgrade plans:

03.2020 – development of the mechanics design (Pelcom Dubna) and mechanics production for GEM planes precise installation inside the magnet.

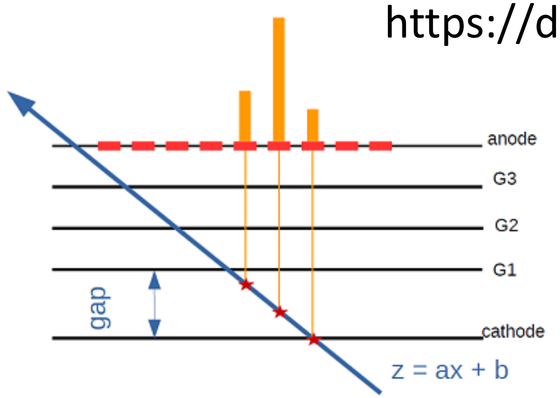
12.2019 year - production of 4 GEM chambers of size 1632 mm × 390 mm to cover full vertical acceptance of analyzing magnet

03.2020 – 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.

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

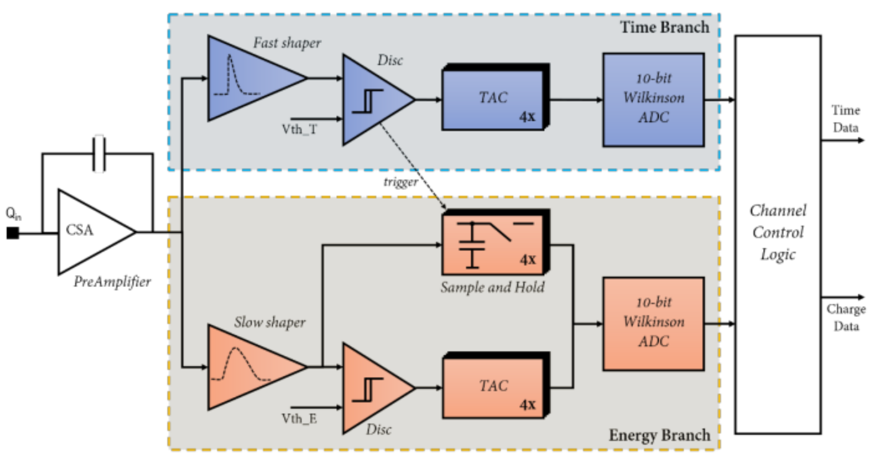
https://doi.org/10.1016/j.nima.2018.09.010



- 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%

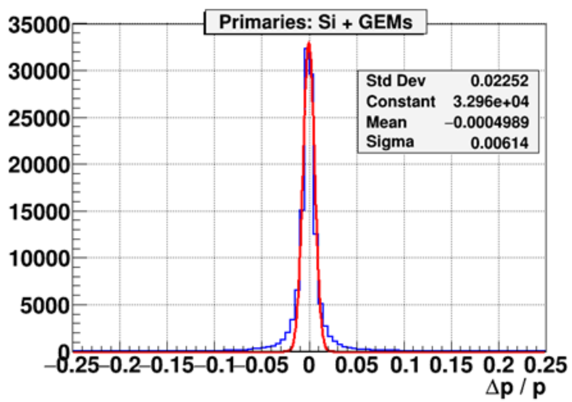
Noise floor (ENC) 1500 $e-$

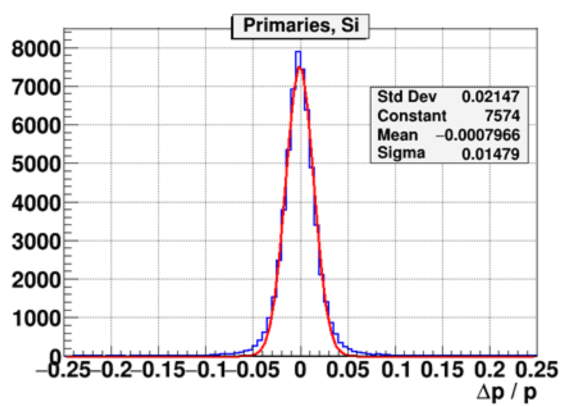
Noise slope 10 $e-$/pF

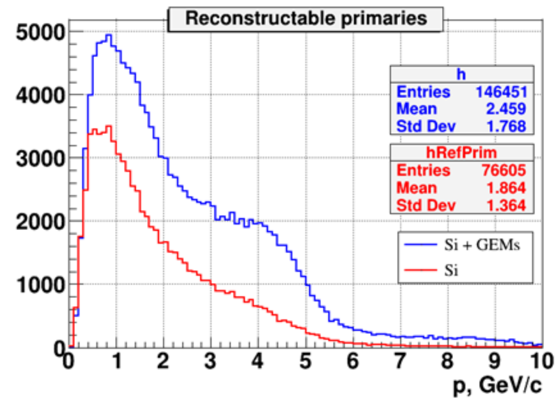
Maximum power consumption 12 mW/ch

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

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



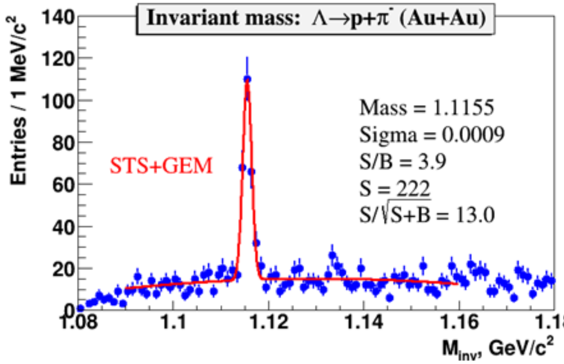


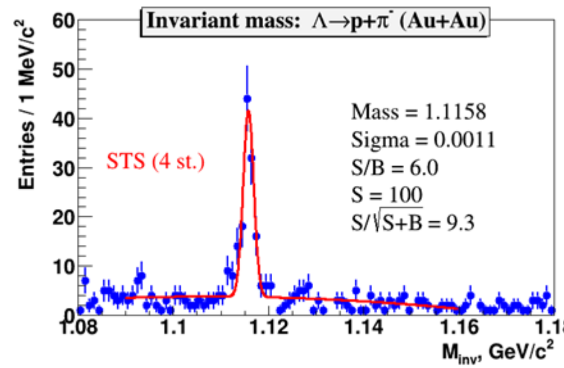


Hybrid STS + GEM tracker:

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

►2 times better momentum resolution



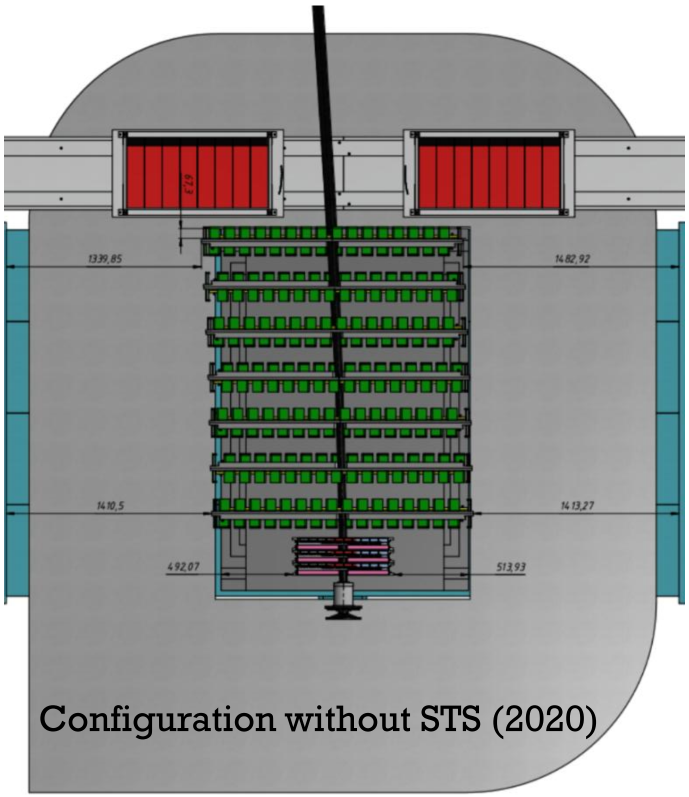


A. Zinchenko, P. Senger

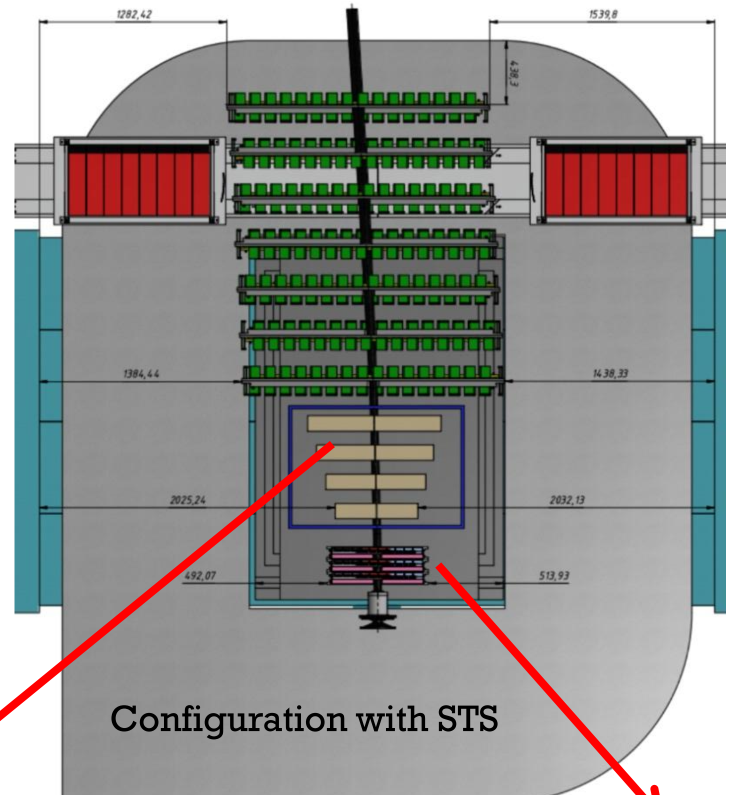
Forward Si+ STS +Gem configuration

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 , 2021
- Forward Si + 4 STS stations + 7 GEMs: beam intensity few 10^5 Hz, 2022
- 4 STS stations + 7 GEMs (fast FEE): high beam intensity few 10^6 Hz, 2022-



Configuration without STS (2020)



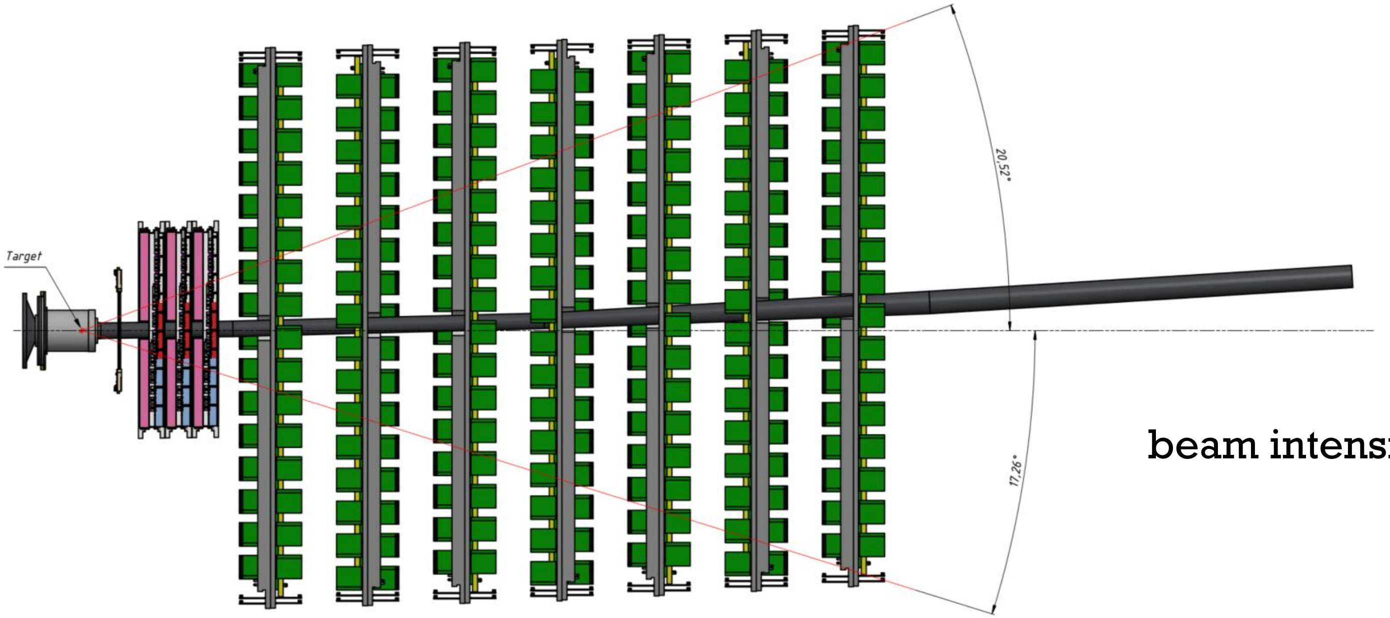
Configuration with STS

2021 year – “pilot” configuration
2022 year – full configuration

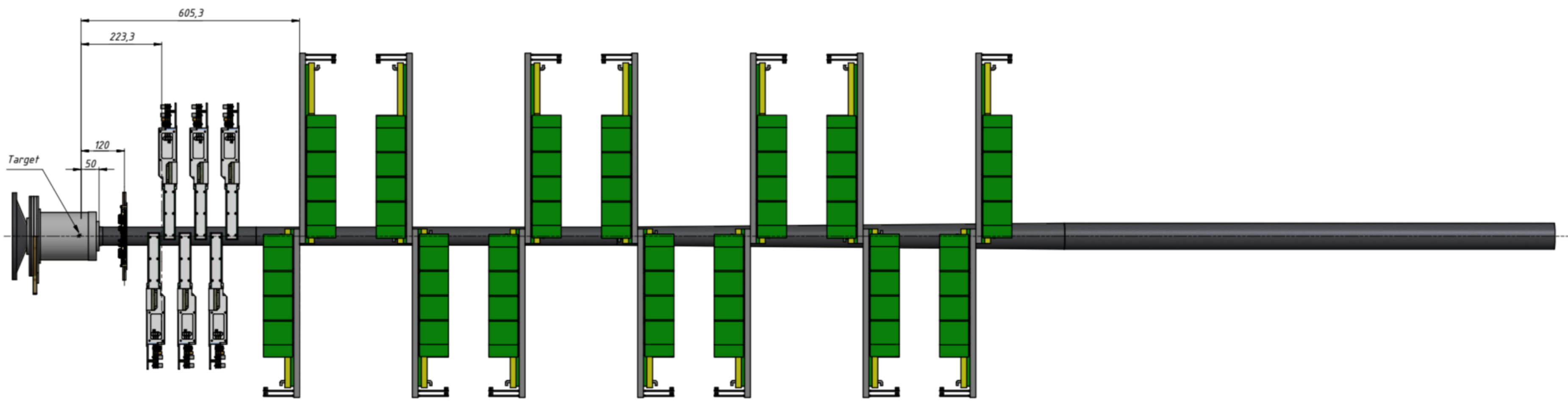
Forward Si will be removed after integration of STS full configuration into BM@N setup (2022 year, high beam intensity - few 10^6 Hz)

2021:Forward Si + 7 GEMs

S.Piyadin

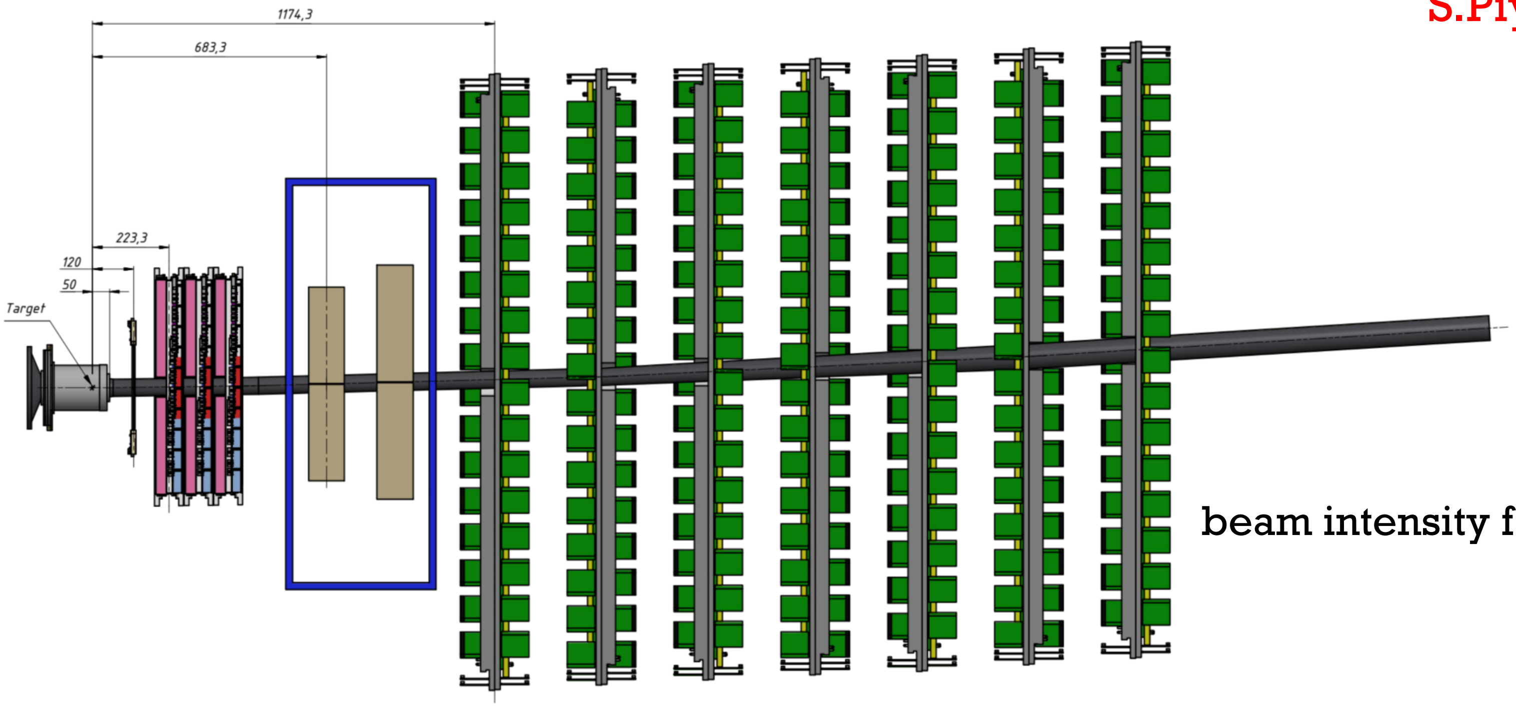


beam intensity few 10^5 Hz

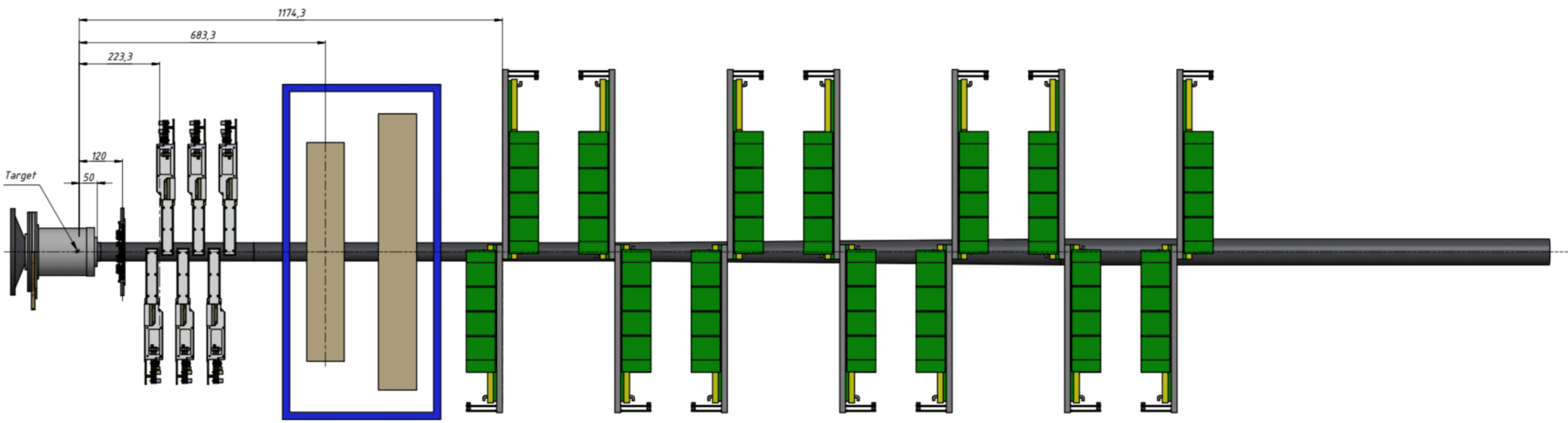


2021-22: Forward Si + "Pilot STS" + 7 GEMs

S.Piyadin

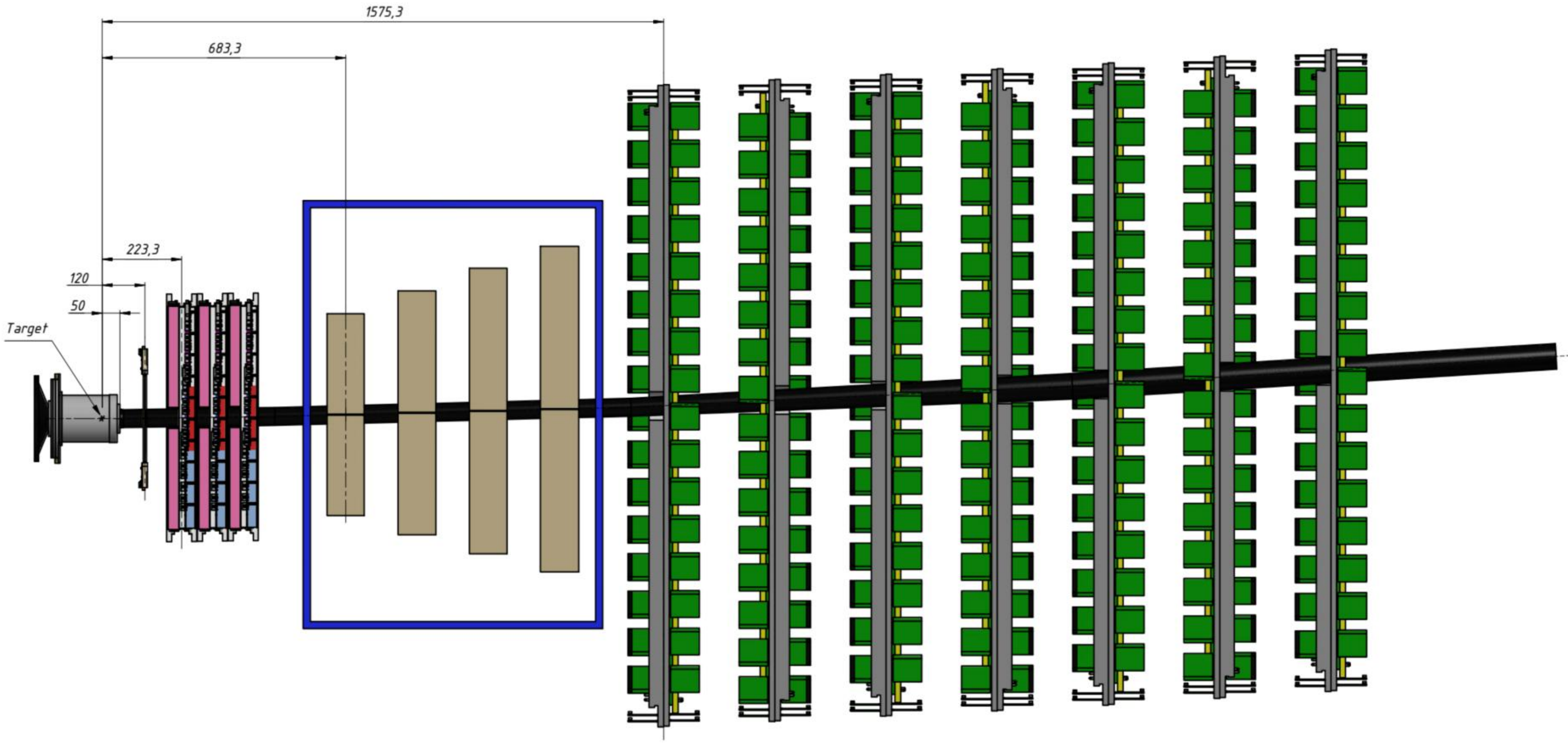


beam intensity few 10^5 Hz



2022: Forward Si + STS + 7 GEMs

S.Piyadin

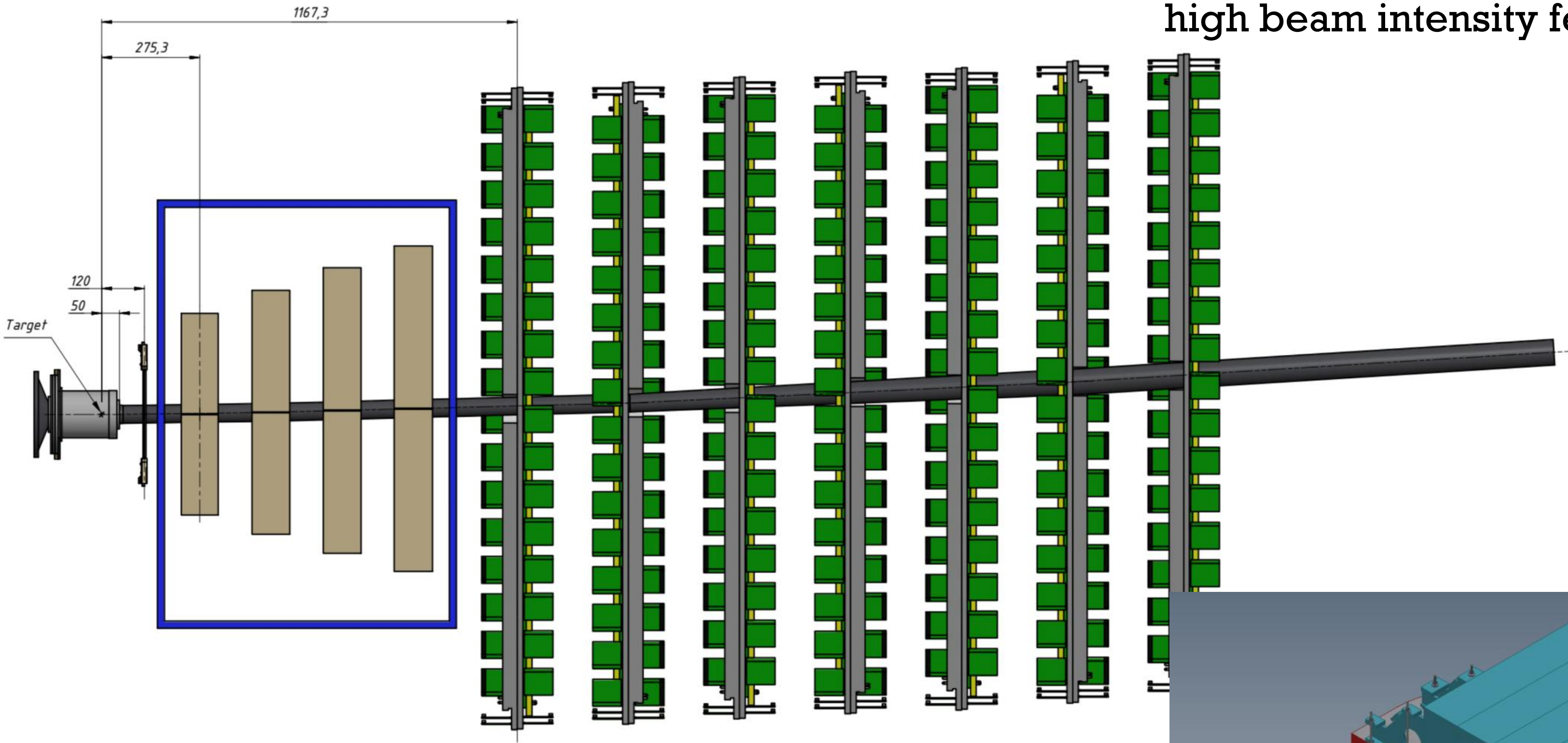


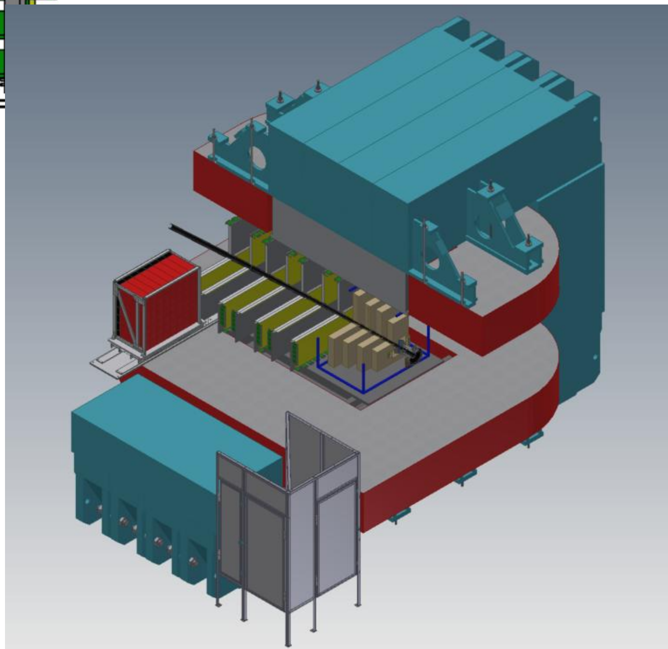
beam intensity few 10^5 Hz

2022- : STS + 7 GEMs

S.Piyadin

high beam intensity few 10^6 Hz

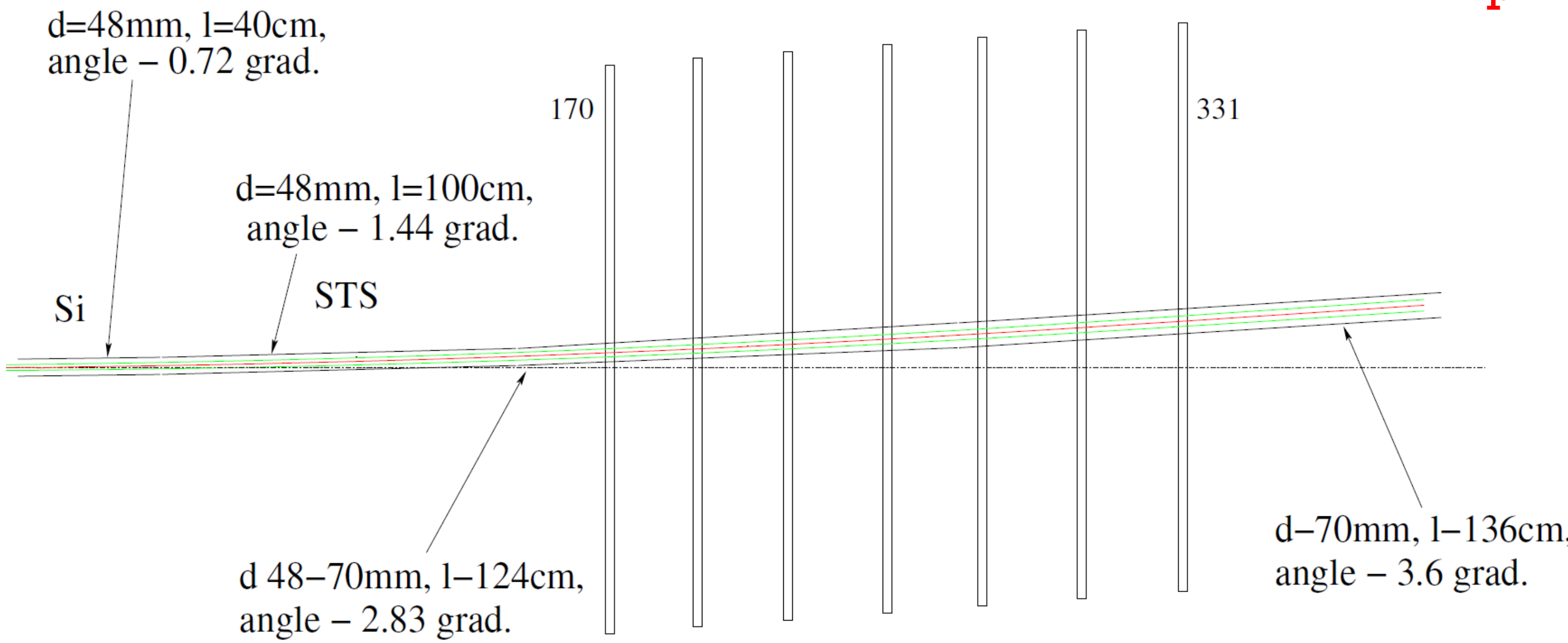




Precise measurements of the SP-41 magnet geometry were performed and
3D model of the tracking detectors installation in the SP-41 magnet was done

Beam pipe inside the SP-41 magnet

S. Piyadin,
V. Spaskov



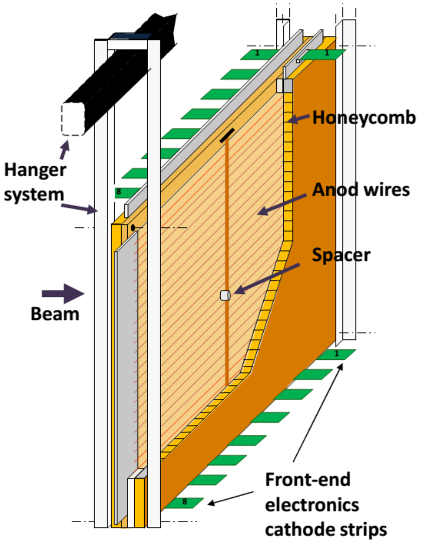
Two companies are taking part in tender to perform the carbon beam pipe production:

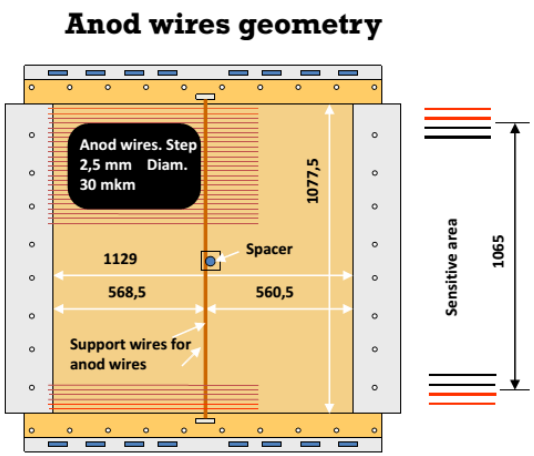
- DD "Arkhipov" (Moscow, Russia) – the drawings of the ion beam test sample are ready
-"SYNTEZ-PROJECT" LLC (Moscow, Russia)

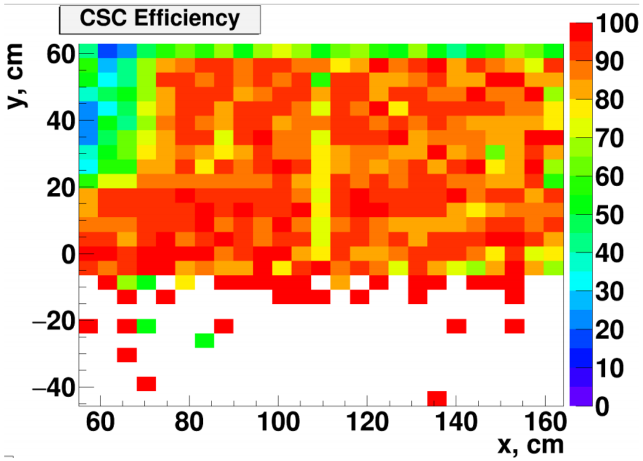
1065x1065 mm^2 CSC chamber

CSC group

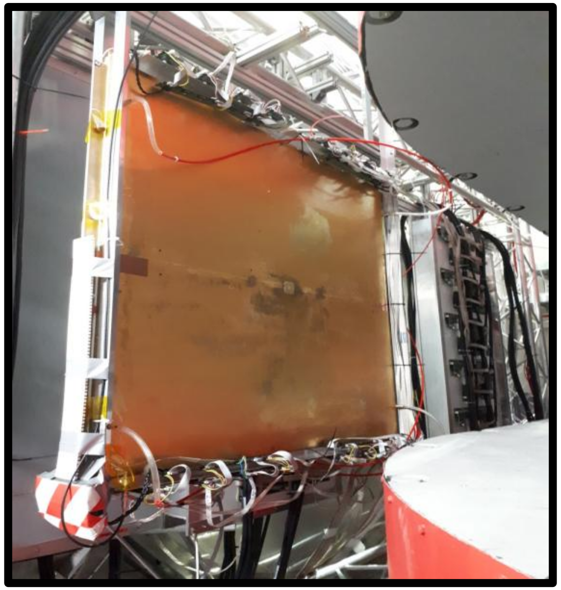
C, Ar and Kr runs in March 2018: CSC chamber is installed in front of ToF-400 to check its performance as outer tracker for heavy ions







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



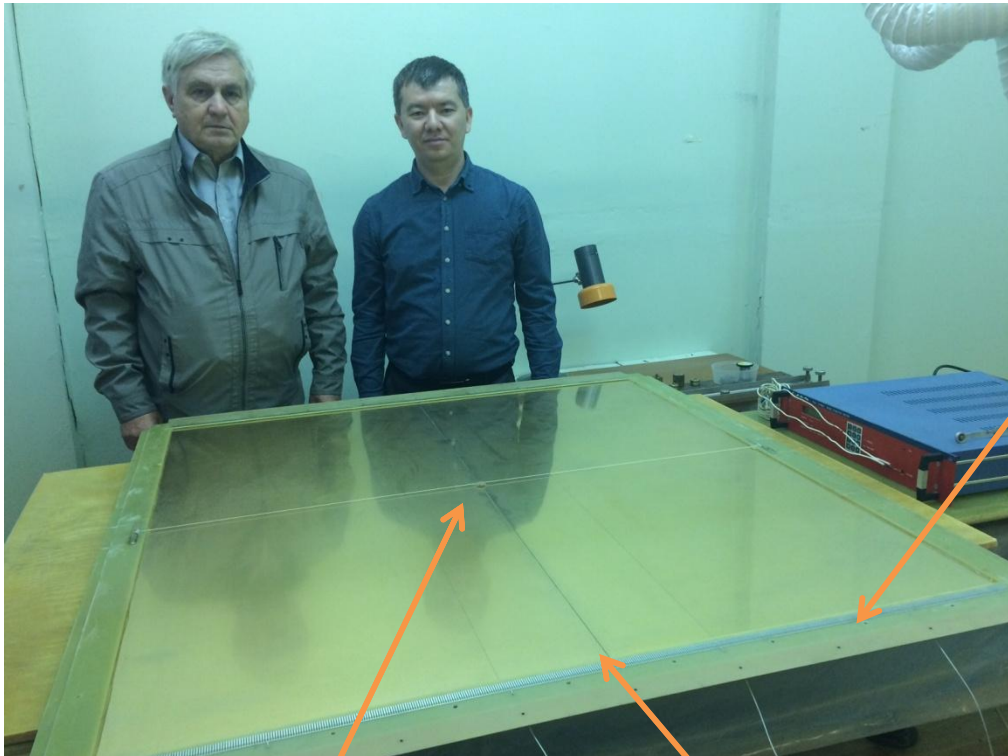
One CSC 1065x1065 mm^2 is produced and tested at Nuclotron beam.

Plans for 2019:

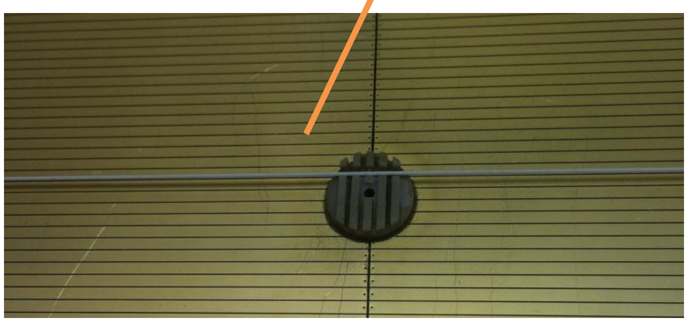
- assembly of the three1065x1065 mm^2 chambers

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

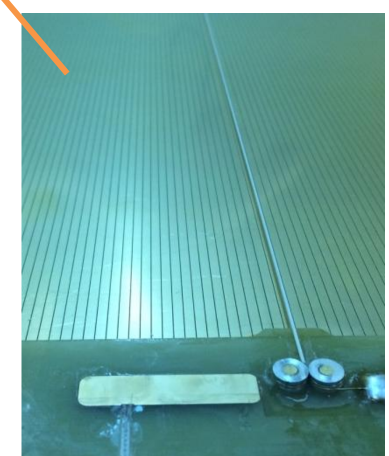
1065x1065 mm^2 CSC chamber assembly process



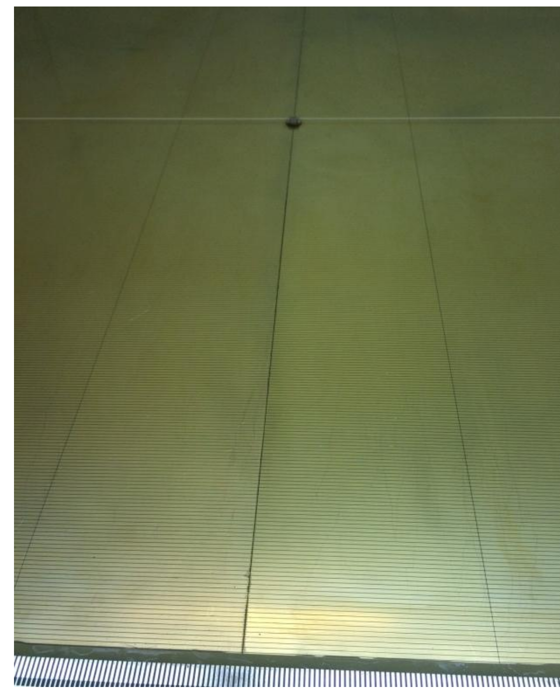
Marks for wires precise positioning



Spacer



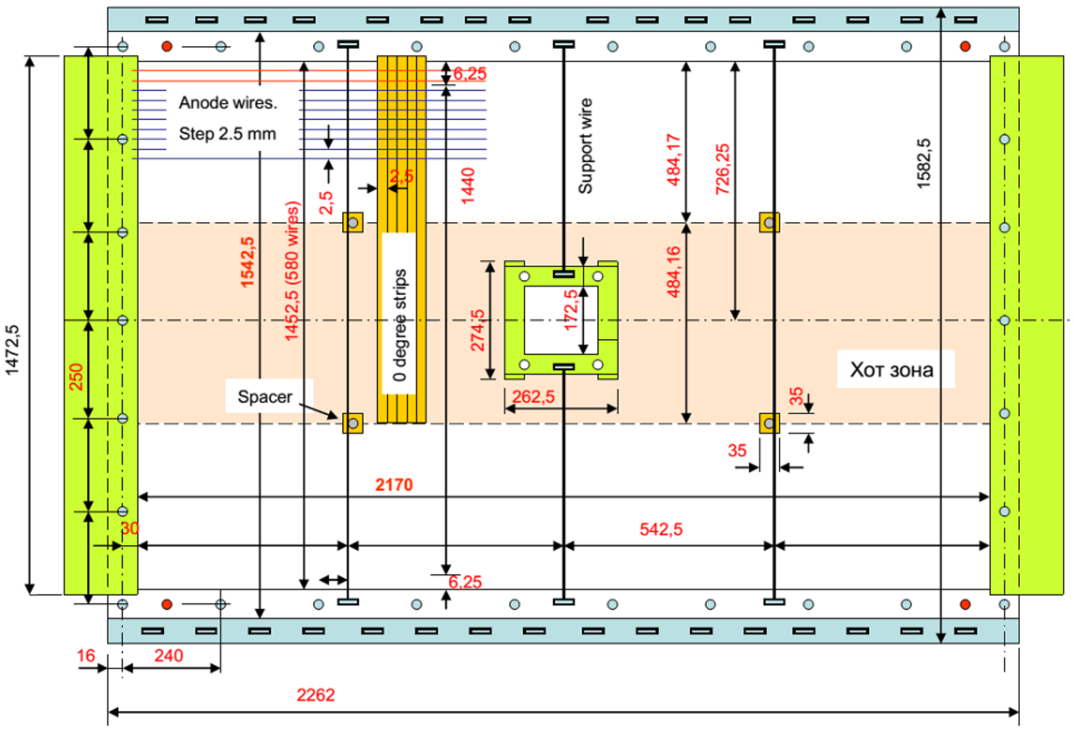
Support wire

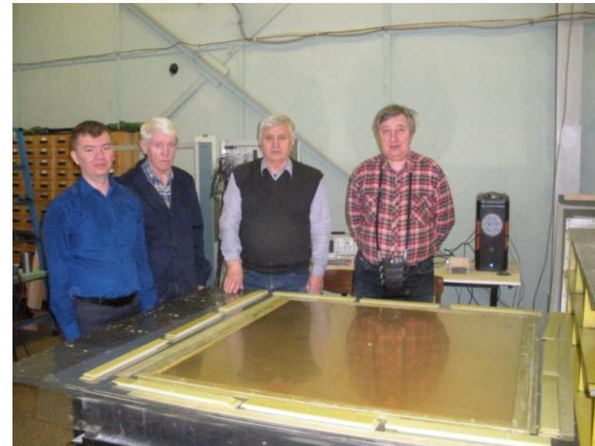


Cathode plane
is ready for wire soldering

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.

Two 2190x1453 mm^2 CSC chambers are to be installed before and after ToF-700

Design and assembly – JINR LHEP

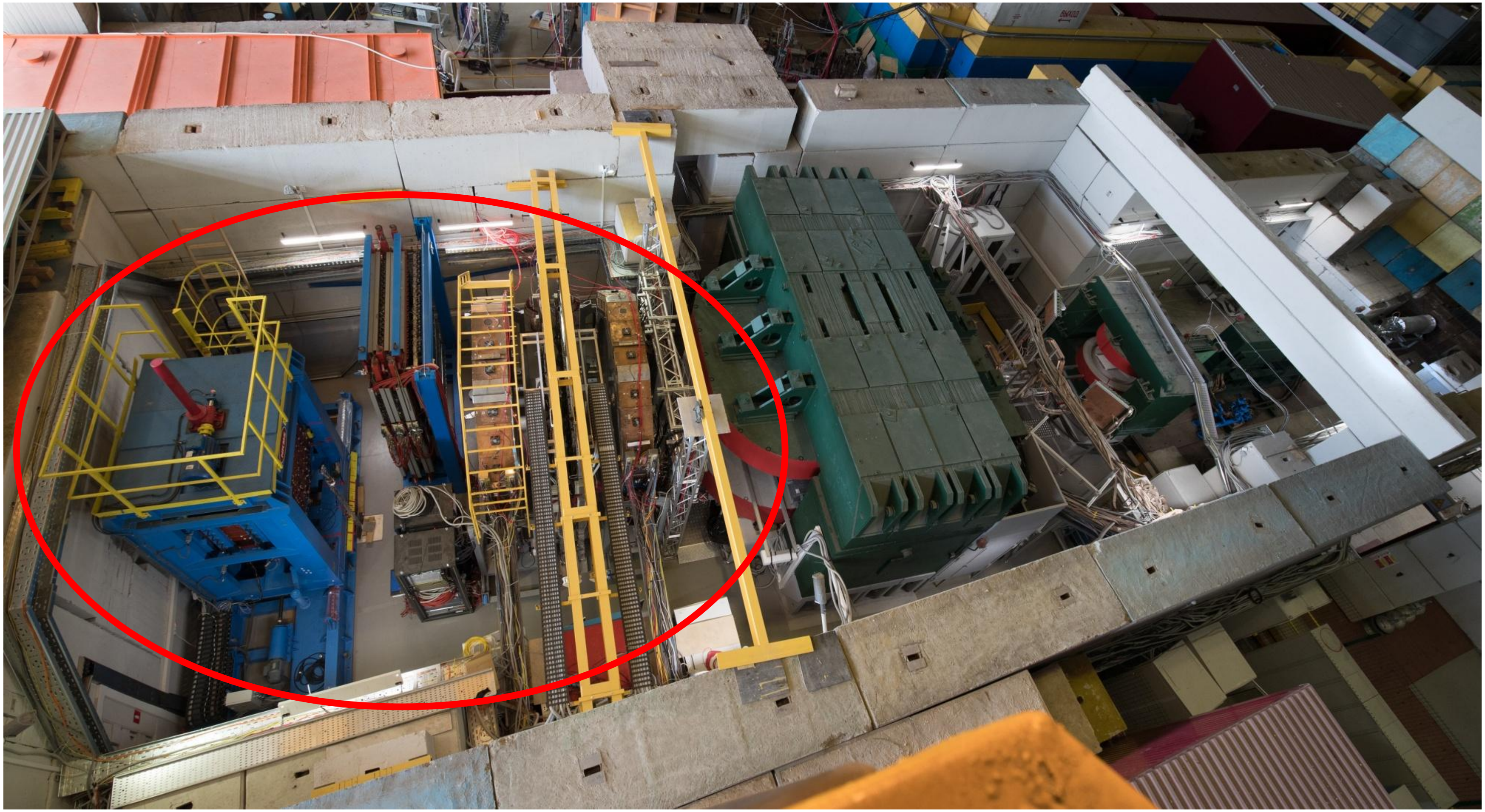
Production plans:

- 06.2019 – design and production of the cathode planes for 2190x1453 mm^2 CSC chambers

- 12.2020 – Assembly of the 2190x1453 mm^2 CSC

- 06.2021 – All chambers are integrated into the BM@N experimental setup

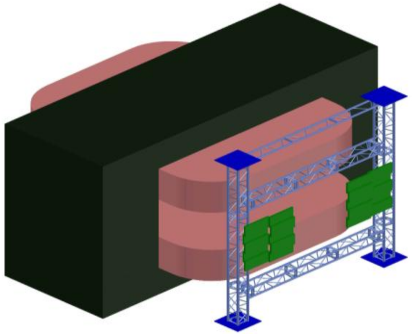
Beam pipe downstream the SP-41 magnet



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

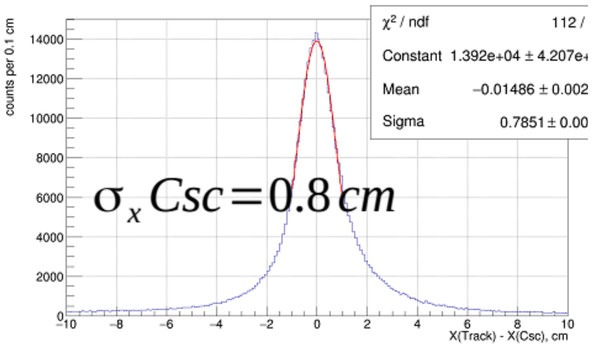
S. Piyadin

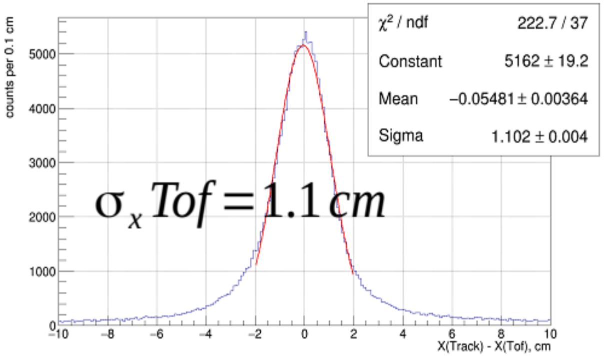
Status ToF-400



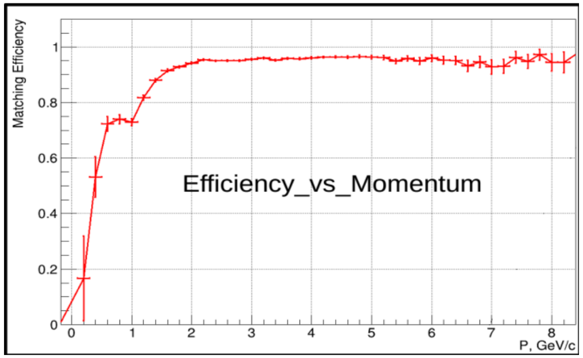
ToF-400
+ V.Plotnikov
+M.Rumyantsev

Residuals of CSC and ToF-400

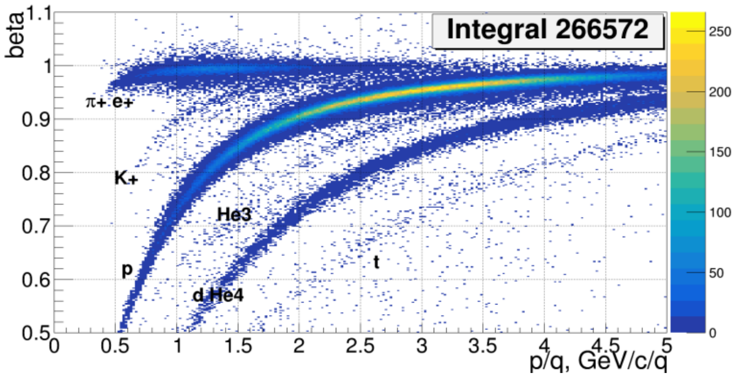


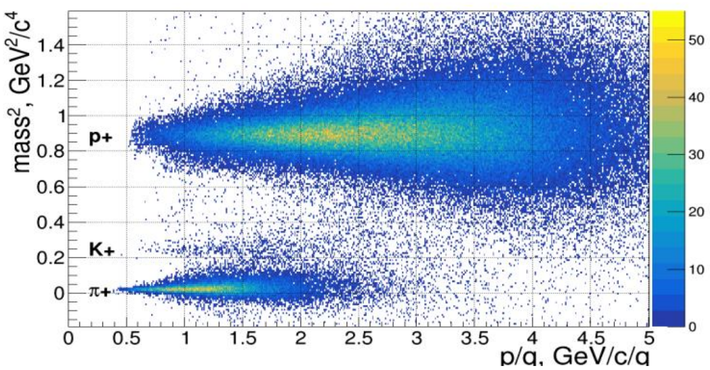


Matching efficiency of GEM+CSC track to ToF-400



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

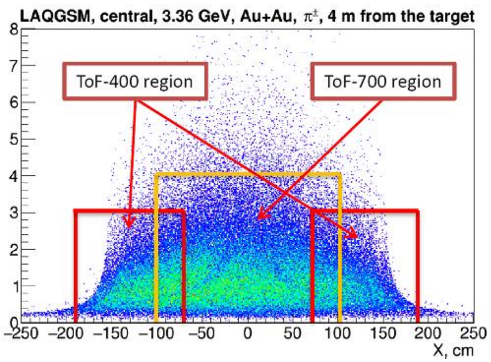


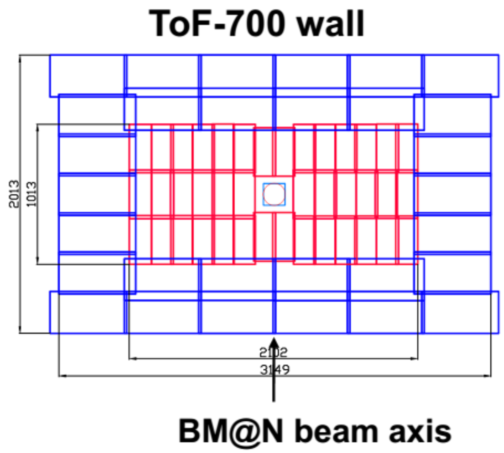


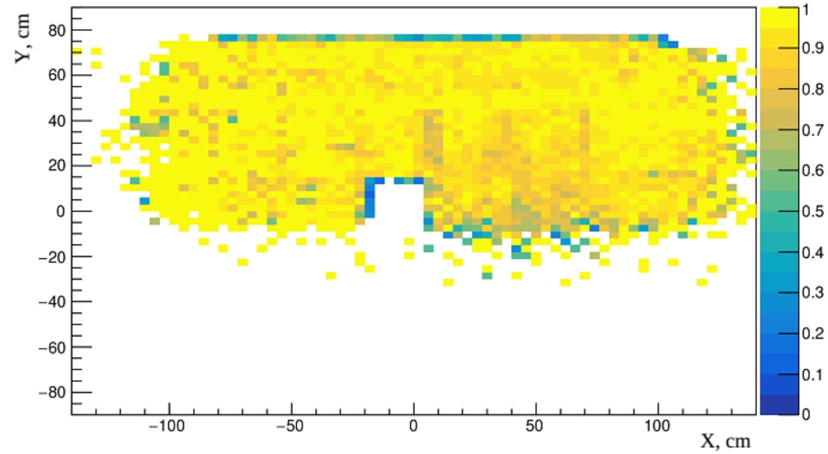
Proton Mass^2 = 0,894 +- 0,081 GeV^2/c^4, Pion Mass^2 = 0,021 +- 0,016 GeV^2/c^4

Status ToF-700

Yu.Petukhov, L.Kovachev

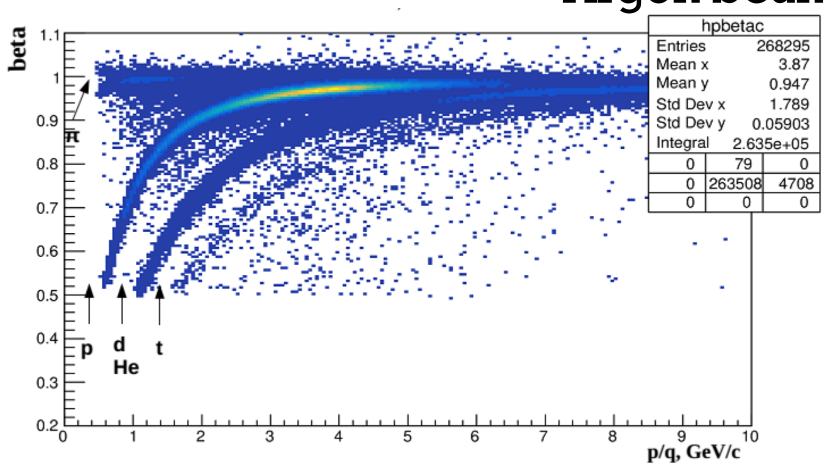


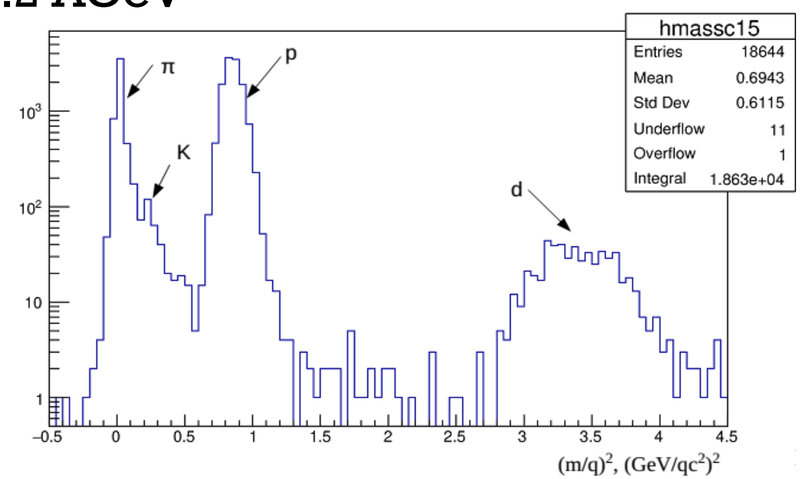




ToF-700 efficiency, DCH1+DCH2 tracks

Argon beam, 3.2 AGeV





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

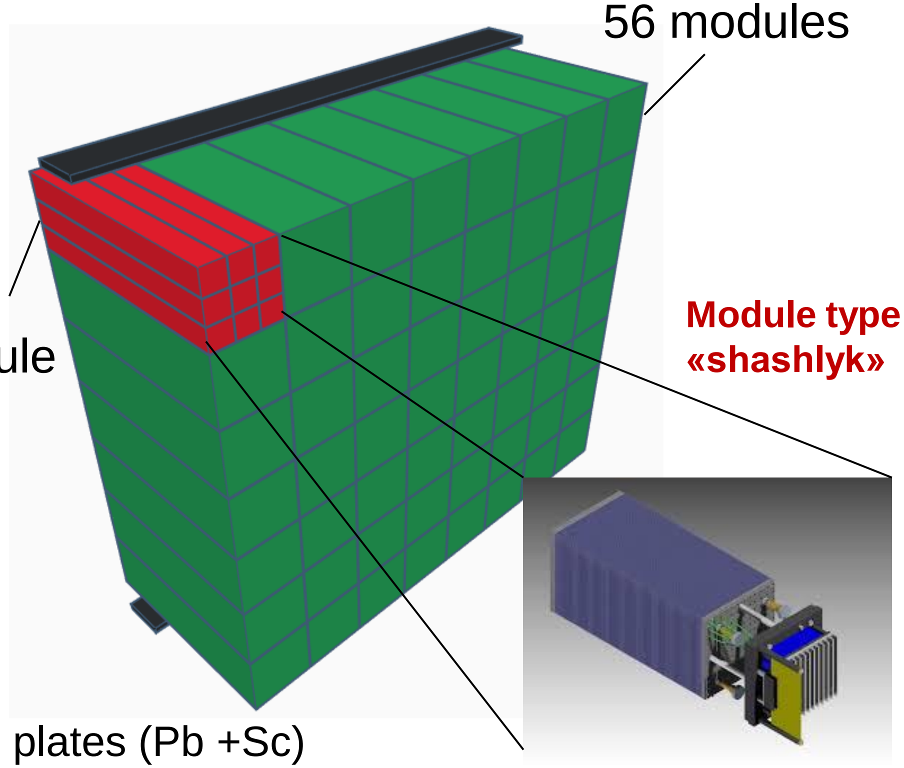
ToF-700 time calibration procedure was developed. Final tests of the algorithm are performed.

ECal Design

ECAL group

56 modules

9 cells
In module



Module type
«shashlyk»

Location of Ecal in the magnet
SP-41

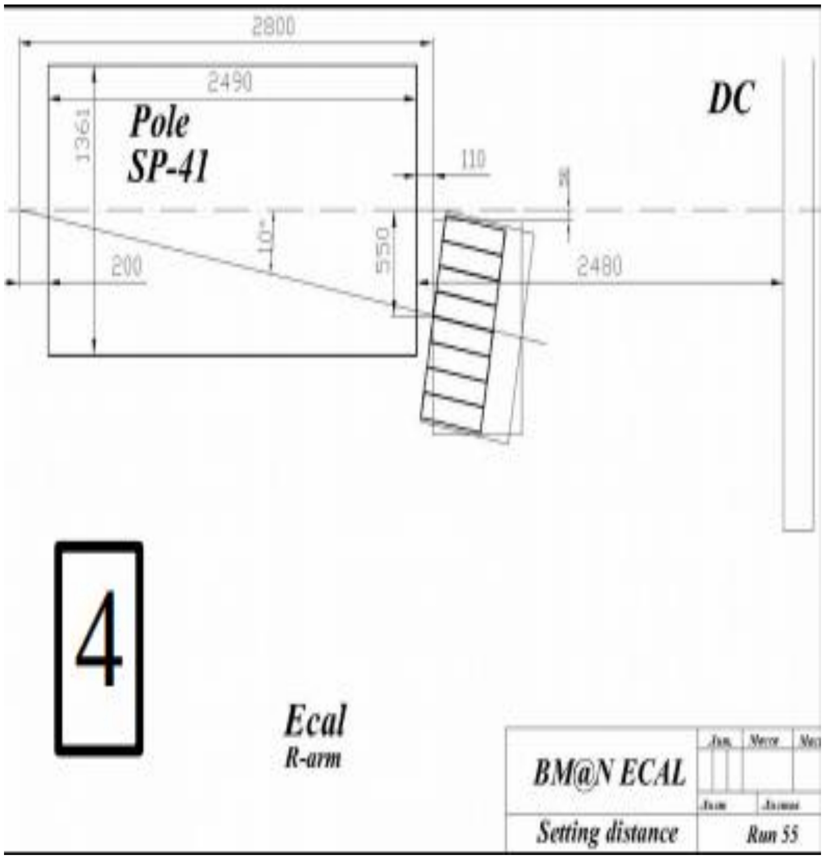
220 plates (Pb +Sc)

504 cells with MPPC
(SiPM) (multipixel photon
counter)

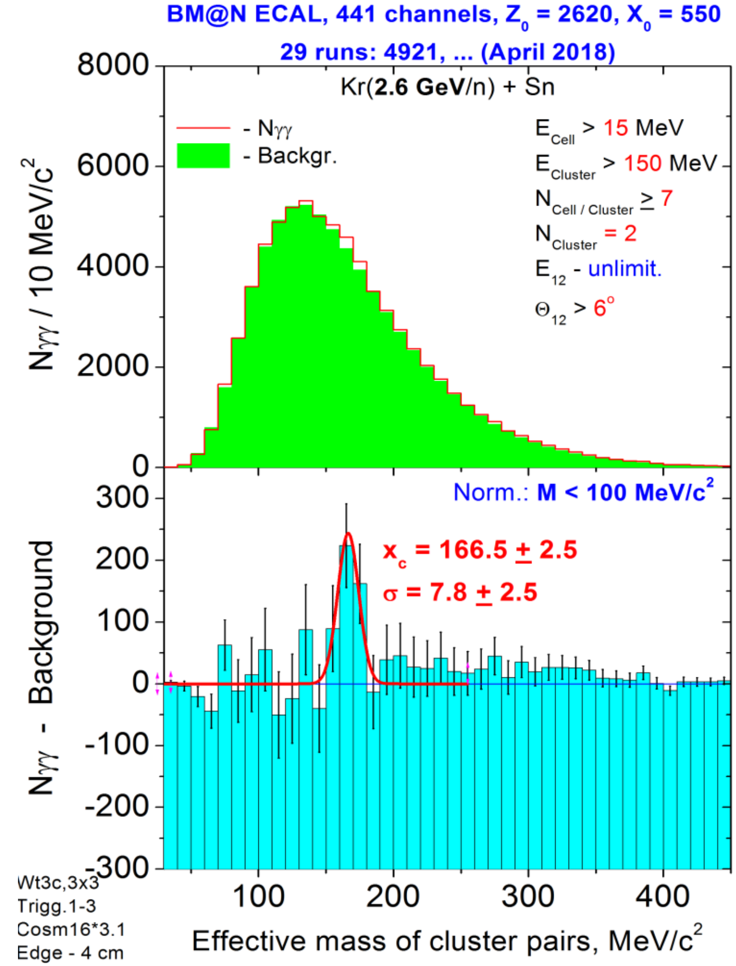
$$\frac{(2.98\pm0.05)\%}{\sqrt{E}} \oplus (2.94\pm0.04)\%$$

Effective mass distributions of photon pairs (pairs of clusters) in the reaction

Kr (2.6 GeV / nucleon) + Sn



Location of the ECAL in the 55th run of the Nuclotron, on a beam of Kr nuclei with an energy of 2.6 GeV per nucleon, using a tin target.



The background is obtained using the event mixing method and normalized to the number of pairs in a range of masses M < 100 MeV/c^2. The curve is the Gaussian approximation of the experimental points in the range M < 260 MeV/c^2 .

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).

Plans until the end of 2019

- Integration of FHCAL readout in the BM@N DAQ + slow control.
- Development of procedure for modules calibration on cosmic muons.
- Start tests and calibration of the FHCAL on the cosmic muons.

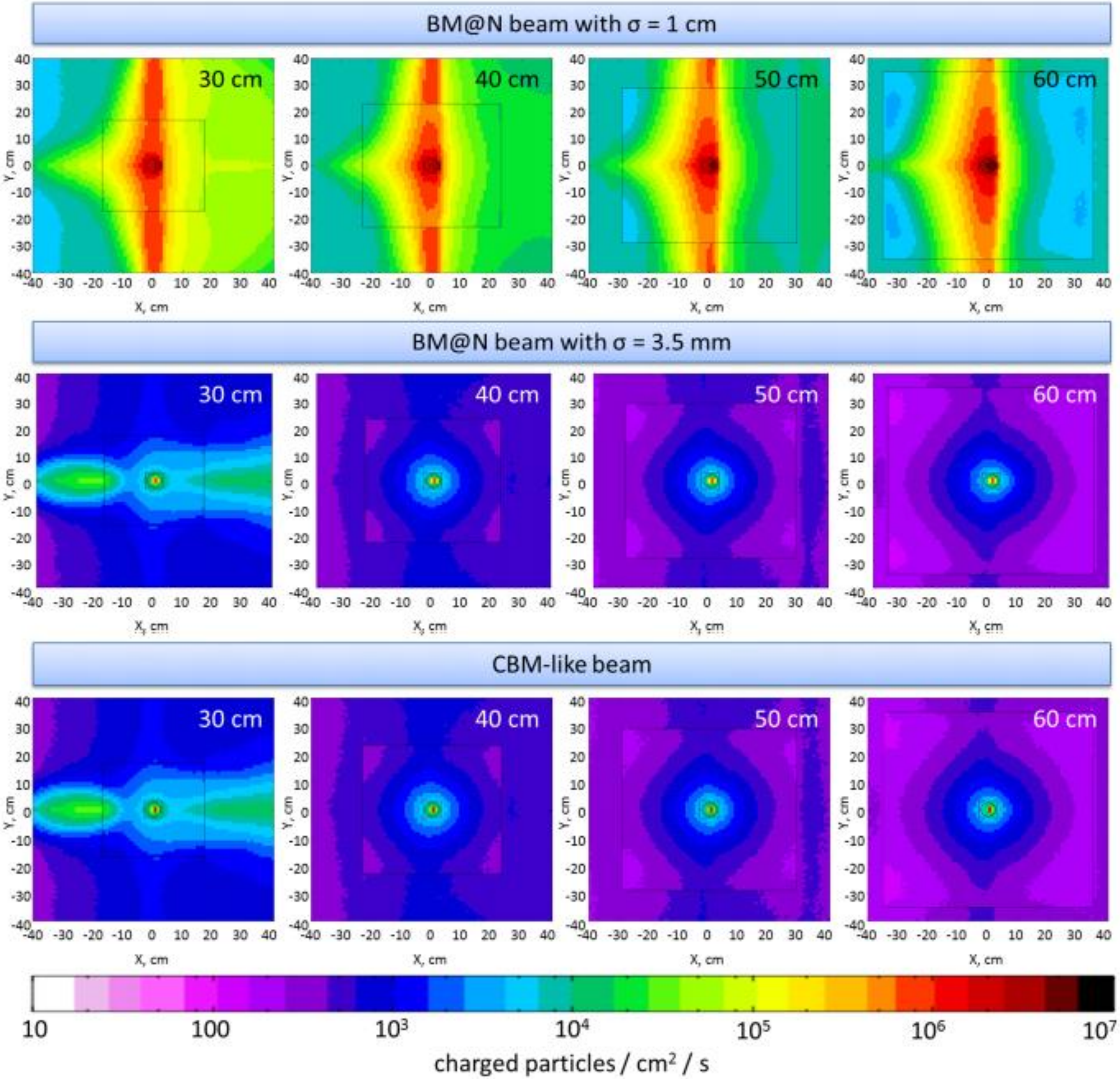
See talk of F.Guber

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 (02.2020)
STS BM@N		42 modules (2021) 292 modules (2022)
GEM	7 top half-planes + 3 bottom half-planes	7 full planes (2019)
CSC	2 chamber 1065x1065 mm^2	4 chambers 1065x1065 mm^2(2019) 2 chambers 2190x1453 mm^2(2020-21)
ECAL	one arm	two arms (2019)
ToF-400	full configuration	
ToF-700	full configuration	
ZDC	ZDC (MPD/CBM type)	

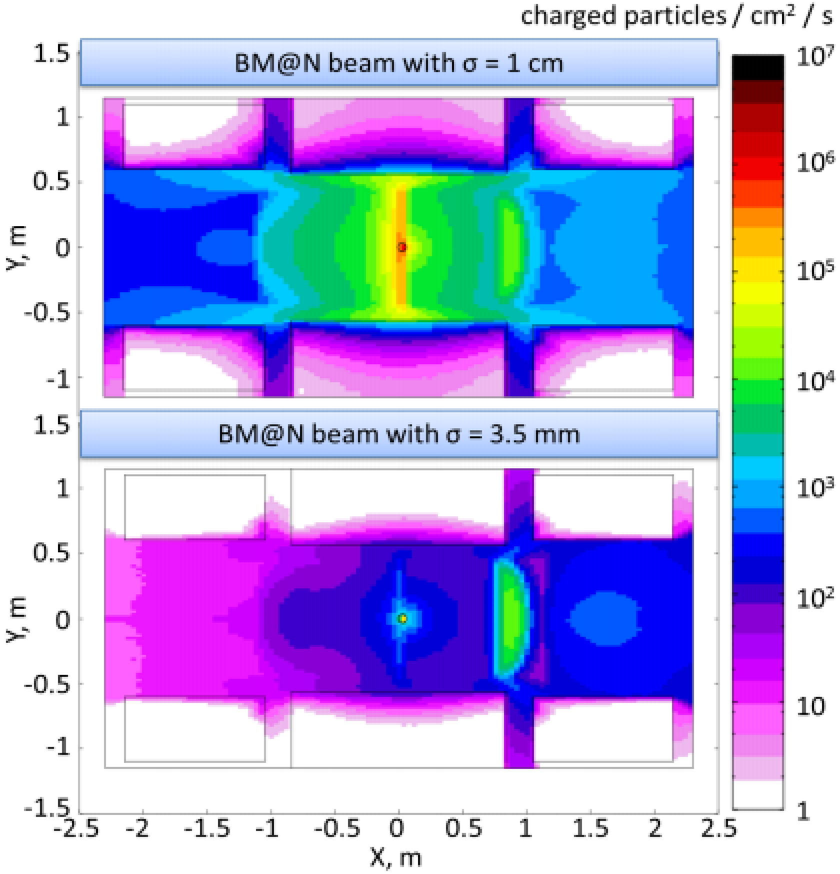
Backup

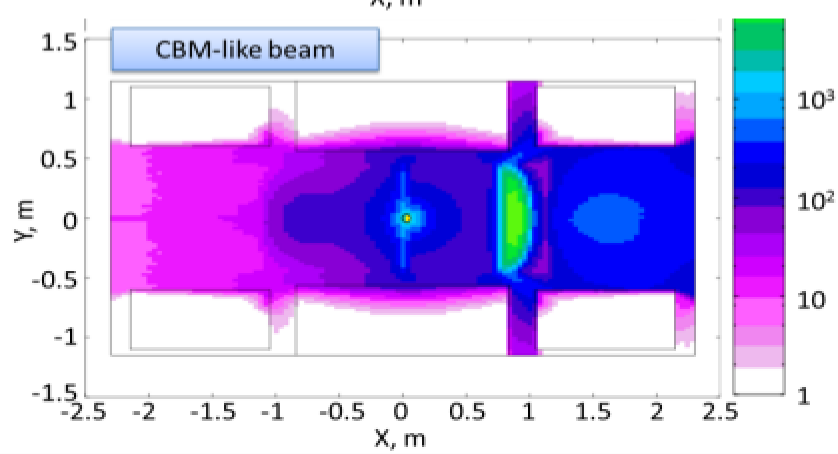
Charged particle densities in the four STS stations



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 %**