Upgrade of the beam pipe, beam detectors and trigger system

Sergey Sedykh for the BM@N

BM@N Detector Advisory Committee
January 19, 2021

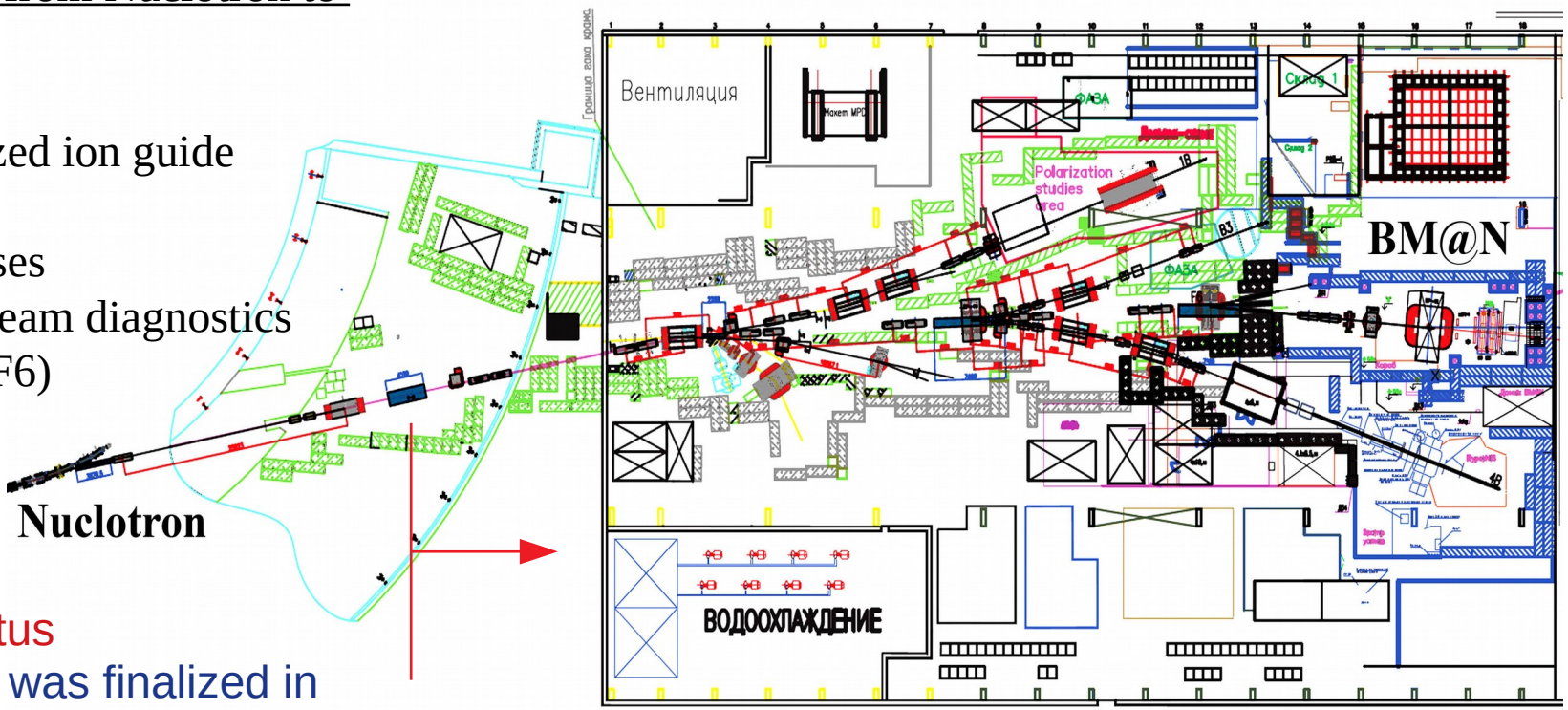
Outline

- *Beam transport line from Nuclotron to BM@N*
- *Beam tracking and profile detectors*
- *Beam counters (BC1, BC2, VC)*
- *Target area and trigger multiplicity detectors*
- *Trigger options with downstream detectors*

Vacuum ion transport line from Nuclotron to BM@N

Continuous vacuum from Nuclotron to BM@N

– 110 m of modernized ion guide
– 6 magnets
– 17 quadrupole lenses
– 14 points for ion beam diagnostics
– 4 focus areas (F3-F6)



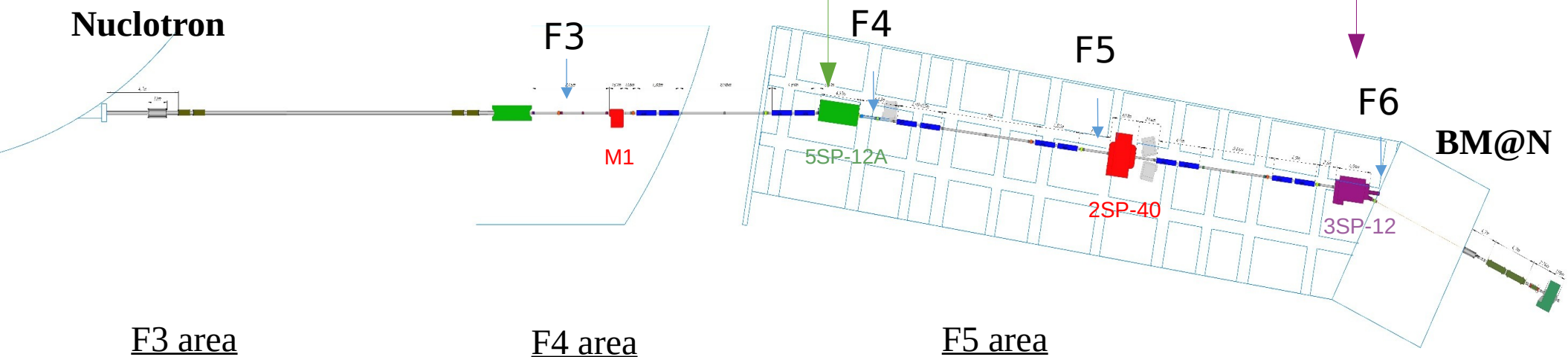
Current status

– formal contract was finalized in 12.2020 for most of the beamline

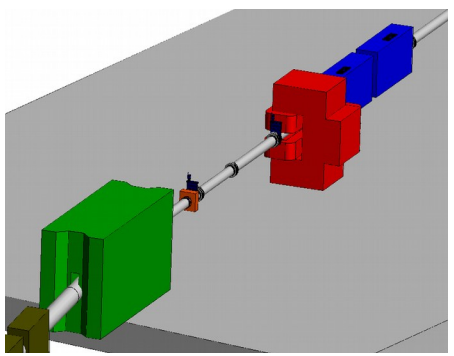
– additional contract will be organized for the remaining section

Vacuum ion transport line from Nuclotron to BM@N

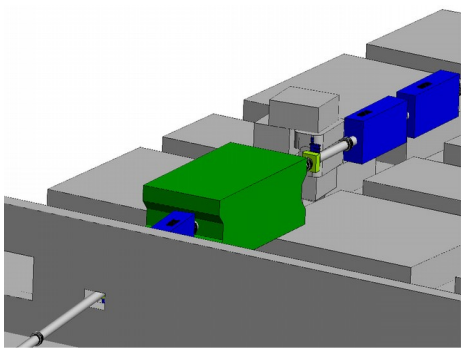
– detailed 3D model of the ion guide done in Feb-Mar 2019
– in March 2020 vacuum chamber was installed in SP-12 in F6
– in Nov-Dec 2020 vacuum box in 5SP-12A was renewed



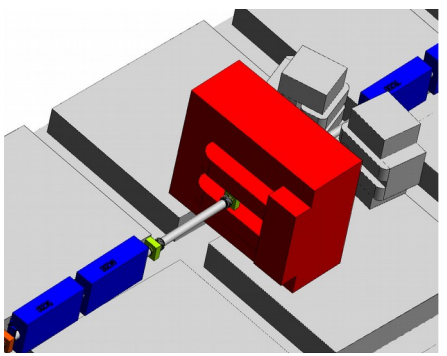
F3 area



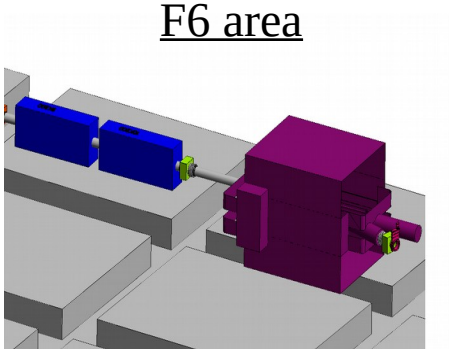
F4 area



F5 area

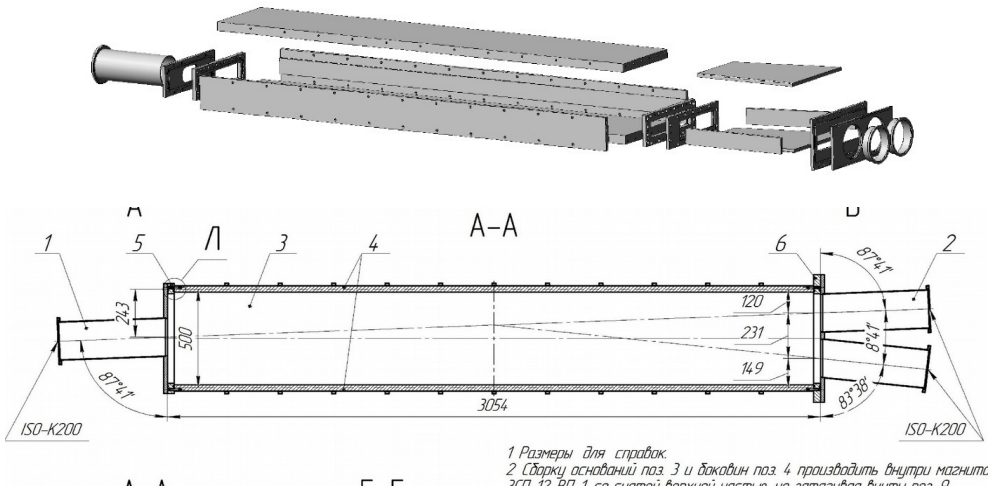


F6 area



R&D VACUUM

Vacuum chamber for SP12 in F6



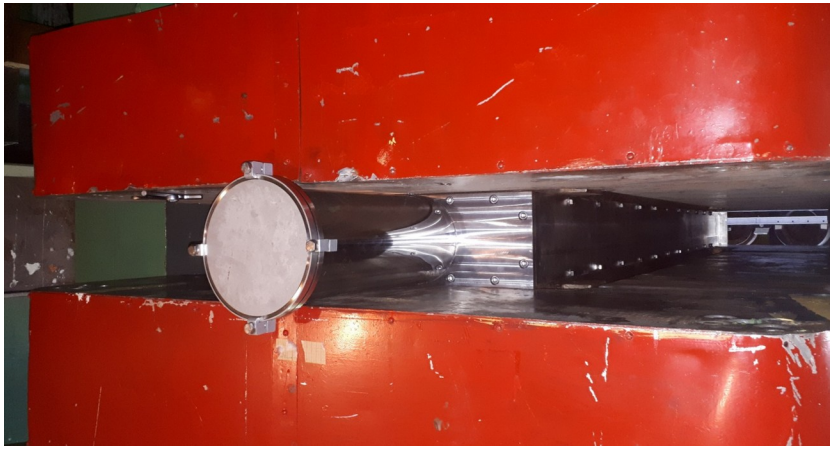
Sketch and final design of the vacuum chamber

Requirements and parameters

– inner part from the steel same to the poles
– should fill vertically the whole magnet
– vacuum <10^{-2} Torr
– side parts from stainless steel, no welding
– length ~4m; weight ~1.5t

Installation of vacuum chamber for SP12 in F6

A.Kubankin ea (BSU Group), S.Anisimov ea (LHEP),
P.Rukoyatkin (Beam Transport), S.Piyadin (BM@N)



Installation steps

– removal of RP concrete blocks
– lifting of the upper part of the magnet (32 t)

Similar operation will be used for some other dipole magnets

Control tests of vacuum chamber for SP12 in F6

Results of the tests

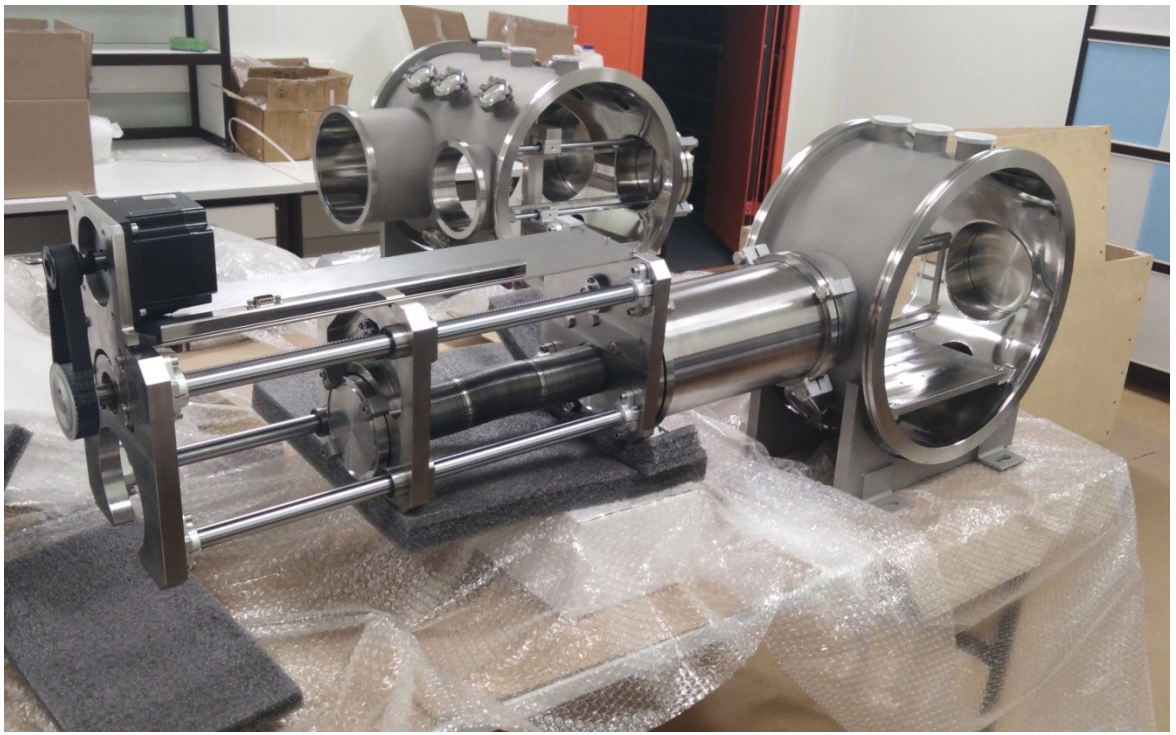
– $5 \cdot 10^{-3}$ Torr reached in ~30 min with vacuum pump Pfeiffer Duo 35, (pressure measured with Pfeiffer Vacuum D-35614)

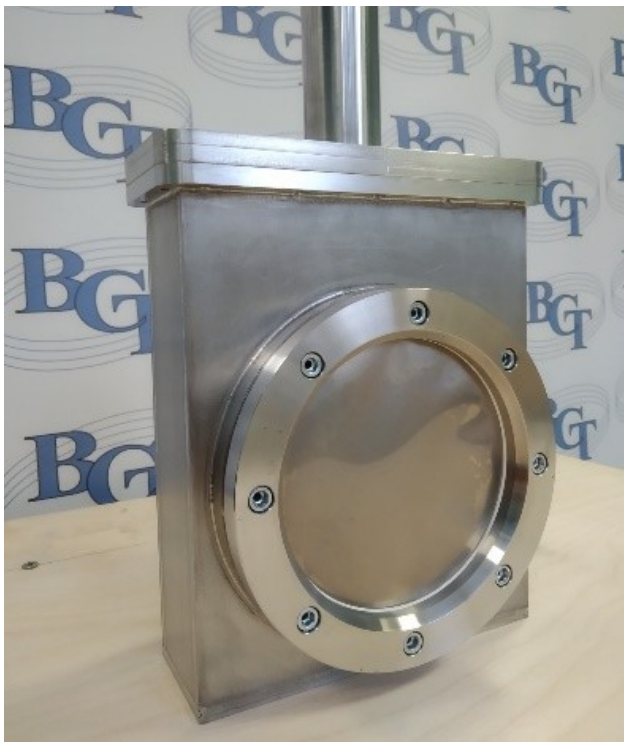
– less than $3 \cdot 10^{-10}$ Pa·m^3/s leakage measured with Pfeiffer ASM 340 detector

– when the chamber was left closed, after 17 hrs, pressure went up to 10^{-1} Torr (acceptable rate)

R&D VACUUM

Prototype of the vacuum box with movable ionization chamber profilometer





Overall assembly:
- vacuum box ~40 cm dia.
- sensitive area of the ionization chambers
  ~18 cm dia. (4 stations)
  ~10 cm dia. (5 stations)

Movable part with thin titanium windows

Beamline from Nuclotron to BM@N

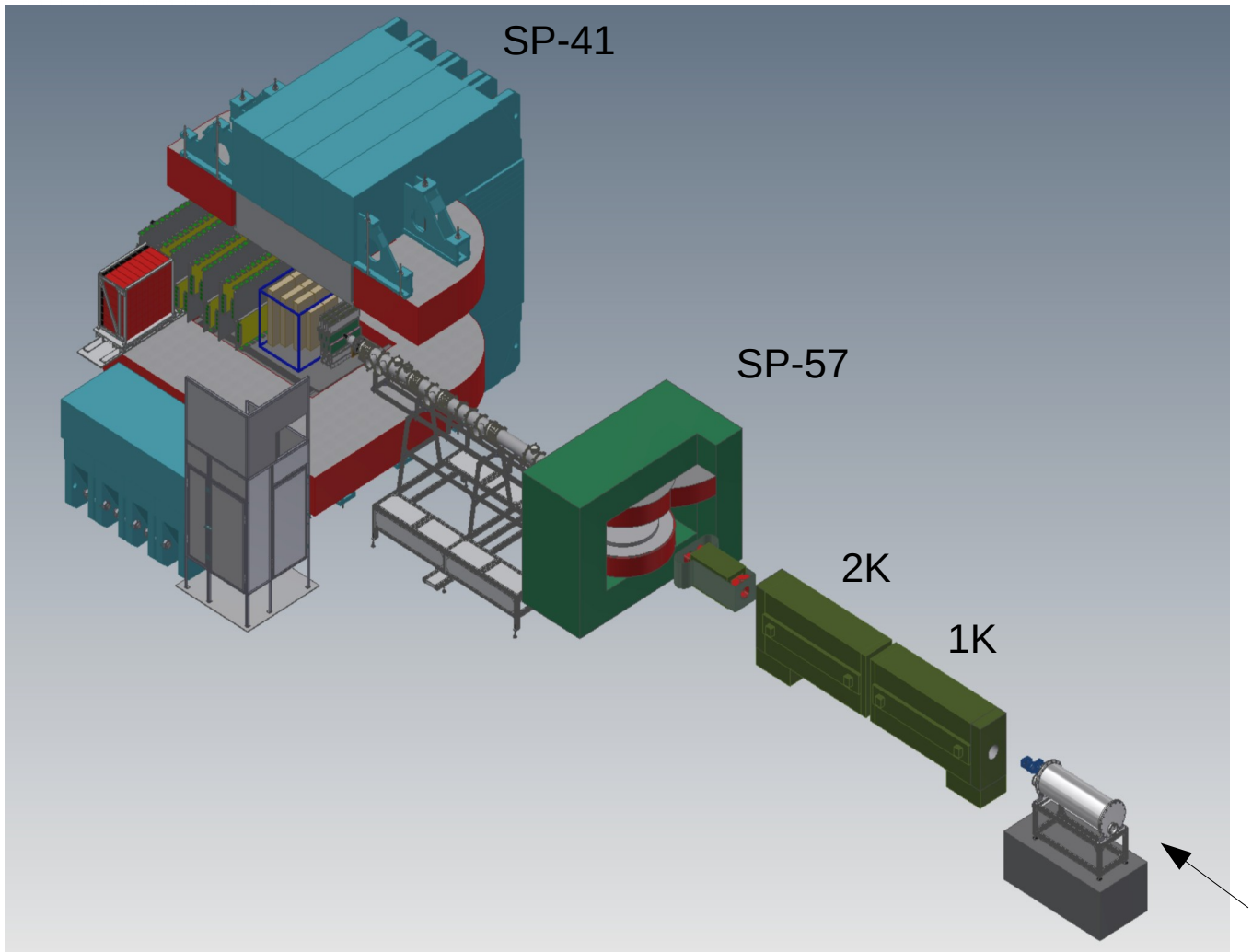
Overview of the current status

– *Measurement of the beamline components with 3D model (done)*
– *Technical documentation and design of major components (done)*
– *Prototypes of all major components (manufactured and tested)*
– *Chambers for SP-12 and SP-12A magnets upstream of BM@N (done)*
– *Formal official contract (done for most of the beamline)*

– *Technical design for the whole beamline (March 2021)*
– *Production of components (March – August 2021)*
– *Installation and testing: (June – September 2021)*

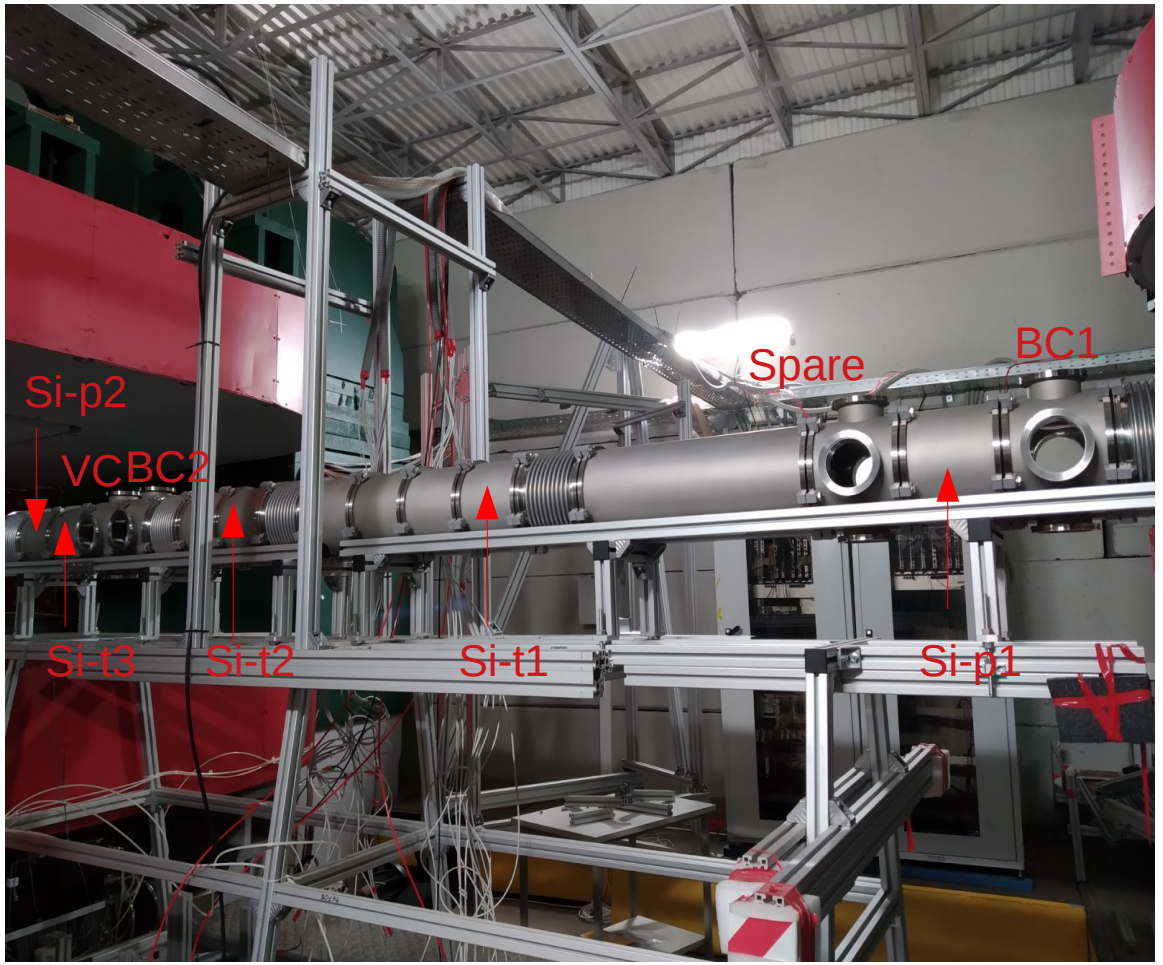
Beam pipe in BM@N before the target

S. Piyadin et al., BSU Group



- Vacuum pipe for 1K-2K lenses was produced and tested in 2020
- Non-standard diameters:
  – inner >192 mm
  – outer <198 mm
  should be machined and welded
- Joints without flanges
- Mechanically the test was successful, but some induced magnetization found. Currently under investigation, how to proceed

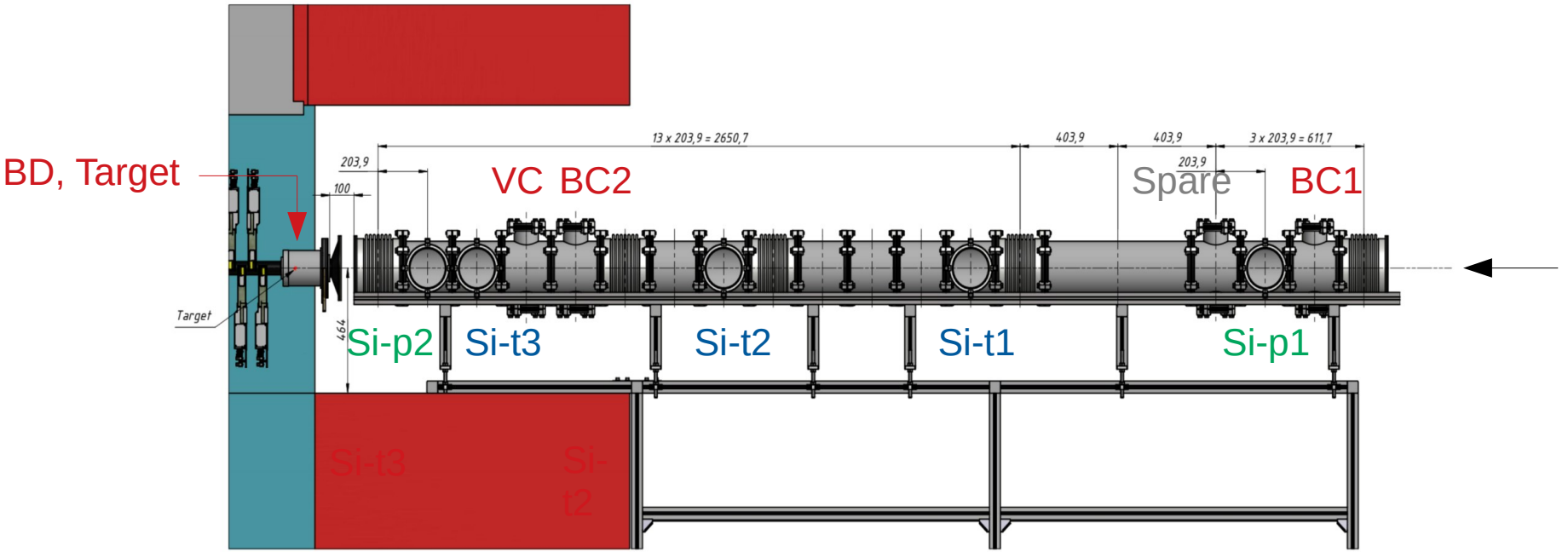
Vacuum components in BM@N area between SP-57 and SP-41



Current status:

- all components were made and tested in the BSU Lab (specs. ~10^{-3} Torr); delivered and assembled at BM@N in Oct.2019
- magnetization of components was found after welding and machining, therefore, one bellow and parts for Si-p2, Si-t3 and VC were remade of aluminum in 2020
- mechanics of Si-p1, Si-p2 was tested and sent back to Belgorod for further improvements

BM@N beam pipe before the target



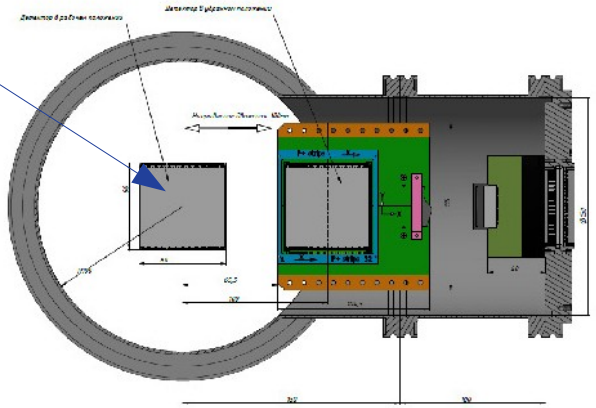
BC1, BC2, VC beam counters

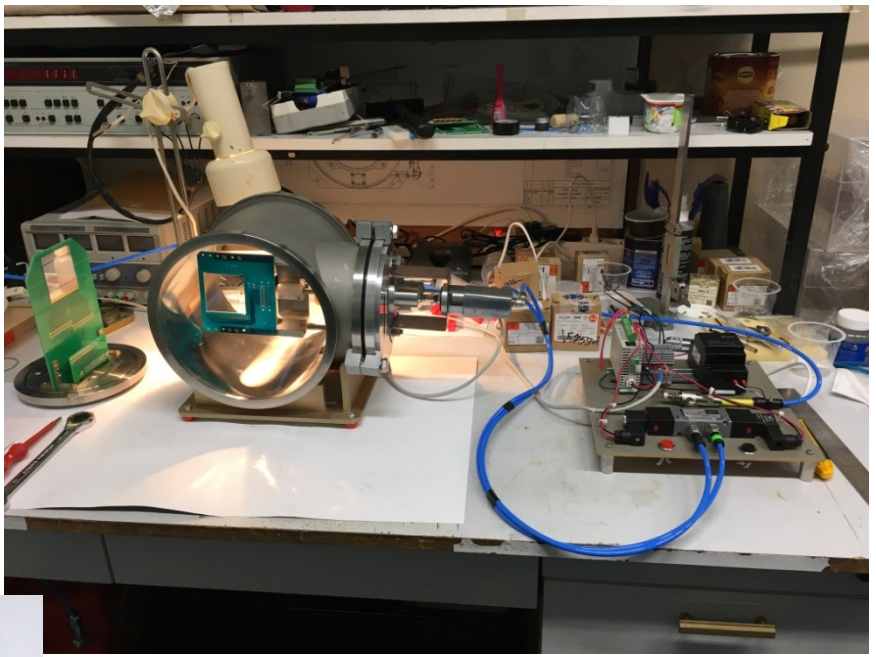
Si-p1, Si-p2 beam profile detectors
(removed after beam tuning)

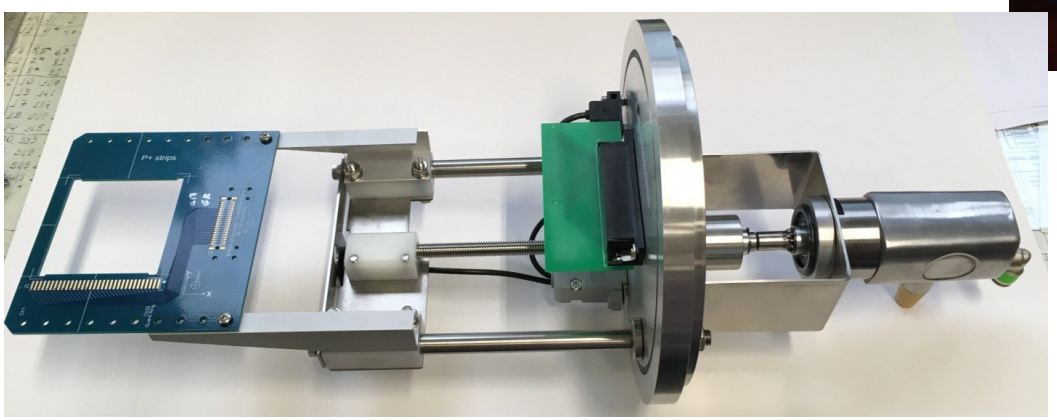
Si-t1, Si-t2, Si-t3 beam tracker detectors

Silicon Beam Profile Detectors
test of mount and pneumatic actuator

DSSD:
60 x 60 mm^2
pitch 1.87 mm
32 x 32 strips
175 μm thick







– not yet tested in a magnetic field, but has no magnetic parts
– full shift by 10 cm

– some adjustment is needed
– software for remote control is under development

Silicon Beam Profile Detectors

current status of DSSD and FEE

– *Ordered and obtained 10 detectors (done, 2019)*

– *Dark current tests of all 10 detectors (done, 2019)*

– *Tests with ^{241}Am source of 4 detectors mounted on PCB (done, 2020)*

– *FEE design with two ASICs (in progress)*

VA163+TA32 Dyn. Range ±750 fC (<Q_C>= 96 fC; <Q_{Ar}>= 866 fC)

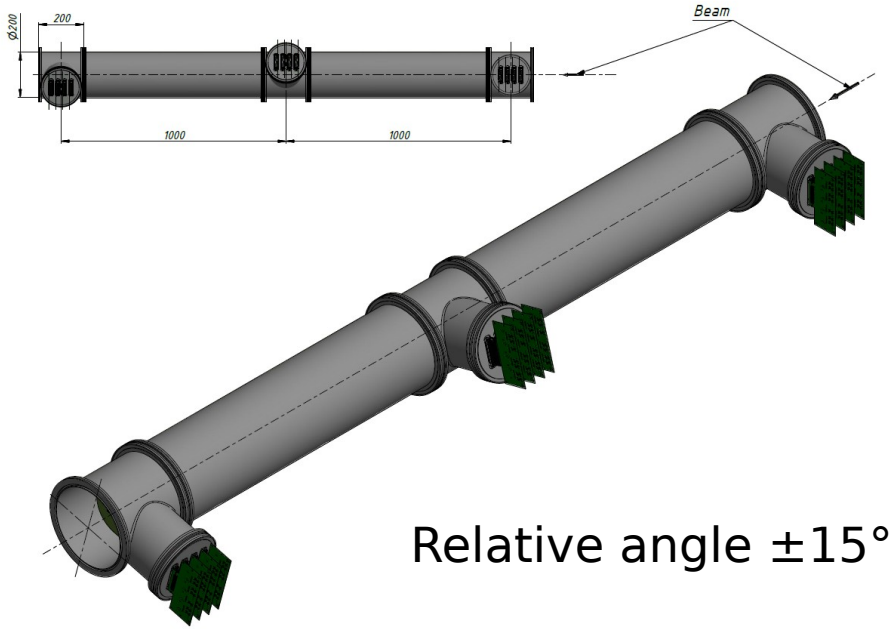
VA HDR16+TA32 ± 30 pC (<Q_{Kr}>= 4 pC; <Q_{Au}>= 18 pC)

– *Stand-alone DAQ based on 16ch ADC (design in progress)*

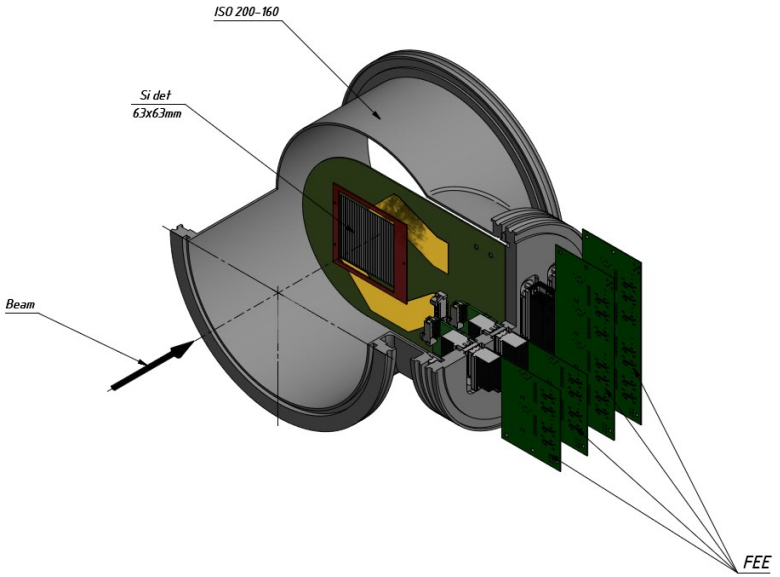
– *Tests of the overall assembly (Jun.-Aug. 2021)*

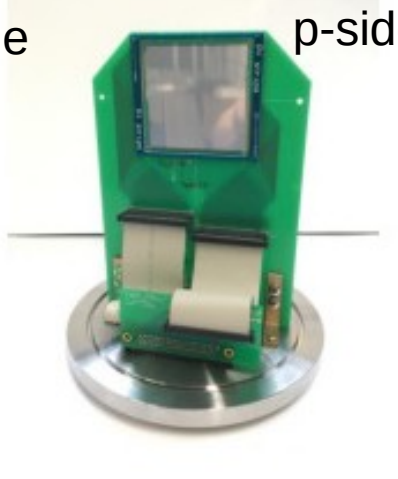
Silicon Beam Tracker Detectors

Group of N.Zamjatin



Relative angle ±15°



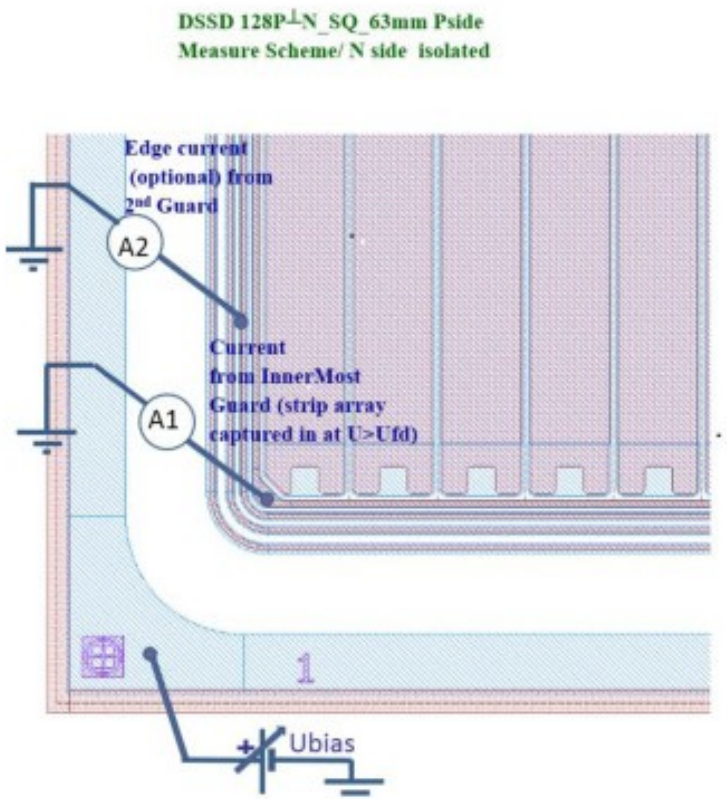


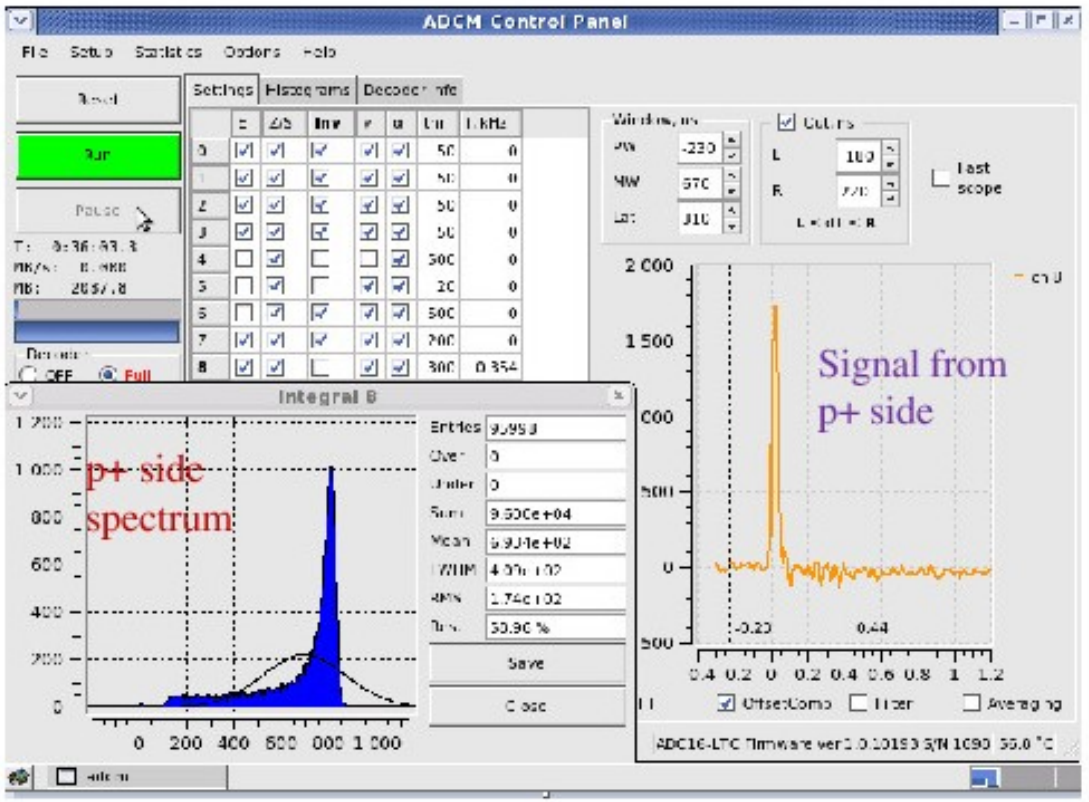
Detector:

– double-sided
– active area 63x63 mm^2
– pitch 475 μm
– 128 x 128 strips
– thickness 175 μm

Silicon Beam Tracker Detectors

First test of beam tracker Si detector





6th BM@N Coll. Meeting, talk of Bogdan Topko

Silicon Beam Tracker Detectors

current status of DSSD and FEE

– *Ordered and obtained 15 detectors (done, 2019)*

– *Dark current tests of all 15 detectors (done, 2019)*

– *Tests with ^{241}Am source of 3 detectors mounted on PCB (done, 2020)*

– *FEE design with two ASICs (in progress)*

VA163+TA32 Dyn. Range ±750 fC (<Q_C>= 96 fC; <Q_{Ar}>= 866 fC)

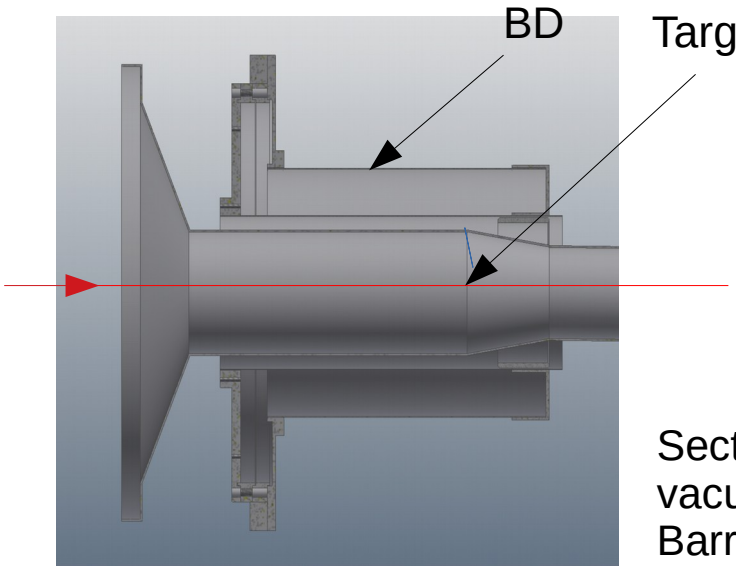
VATA64HDR16.2+TA32 -20..+50 pC (<Q_{Kr}>= 4 pC; <Q_{Au}>= 18 pC)

Design of "light" ion option will be started after testing the "heavy" one

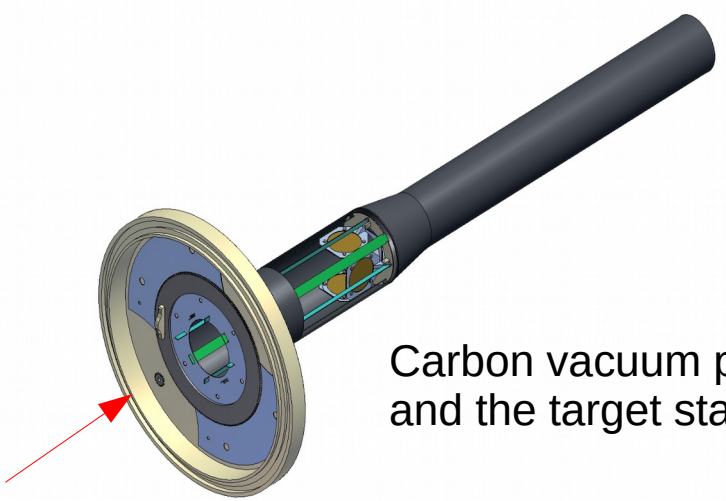
– *Tests of the overall assembly (Jun.-Oct. 2021)*

Target station

S.Piyadin, Yu.Gusakov,
BSU Group



Section of carbon vacuum pipe and Barrel Detector

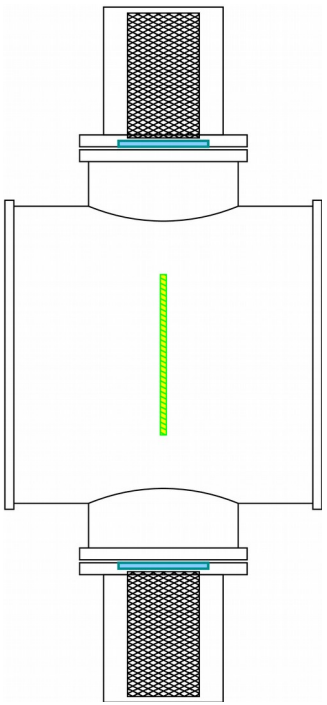


Carbon vacuum pipe and the target station

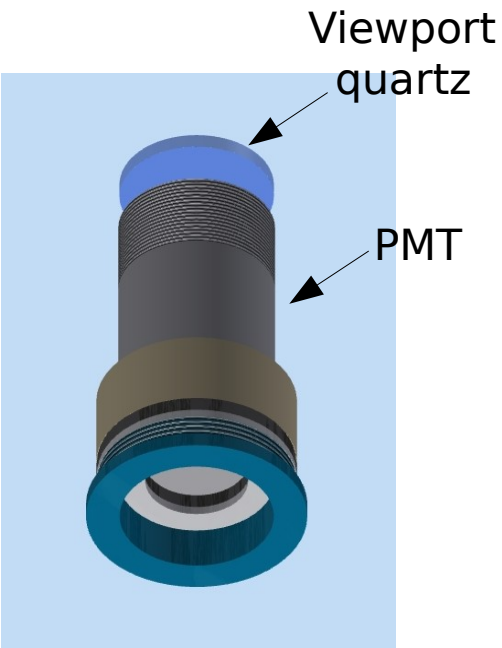
Current status

– developed and tested
– no magnetic materials
– should be able to operate in the magnetic field

Beam Counters: BC1, VC



Sketch of vacuum box for BC1 and VC



Design of PMT mount for BC1 and VC

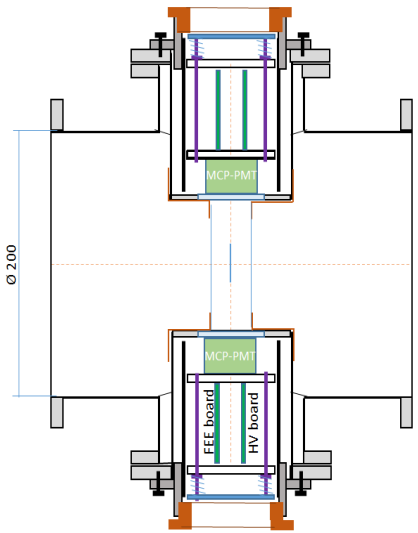
Current status

PMTs:
- Hamamatsu R2490-07 operate in magnetic field <1T (available ~14 PMTs, 1 base)
- testing with laser system is planed
- design of PMT mounts (completed)

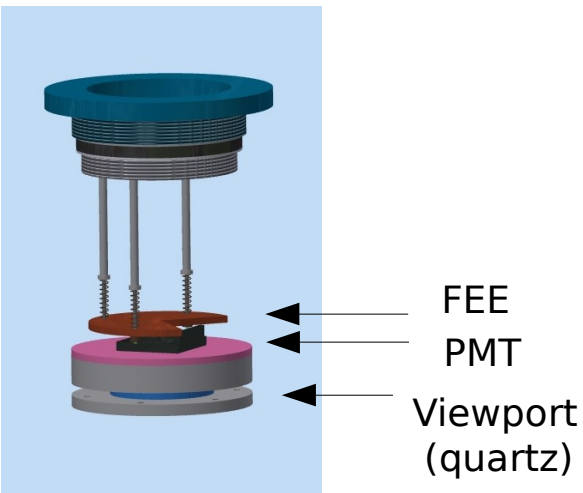
Scintillators (BC400B):
- 100x100x0.25mm^3 (BC1)
- dia.100x10mm with hole 27 mm (VC) (available)

Scintillator mounts (design is scheduled for Spring 2021)

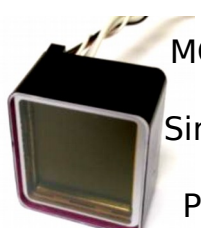
Beam Counters: BC2



Sketch of vacuum box



Design of PMT mount



MCP-PMT XPM85112/A1-Q400
(Photonis)
Similar to FFD PMT but smaller

Photocathode: 25 × 25 mm^2

Current status

MCP-PMT XPM85112/A1-Q400
operate in magnetic field <1T
(available)

PMT + FEE mounts
(design is close to completion)

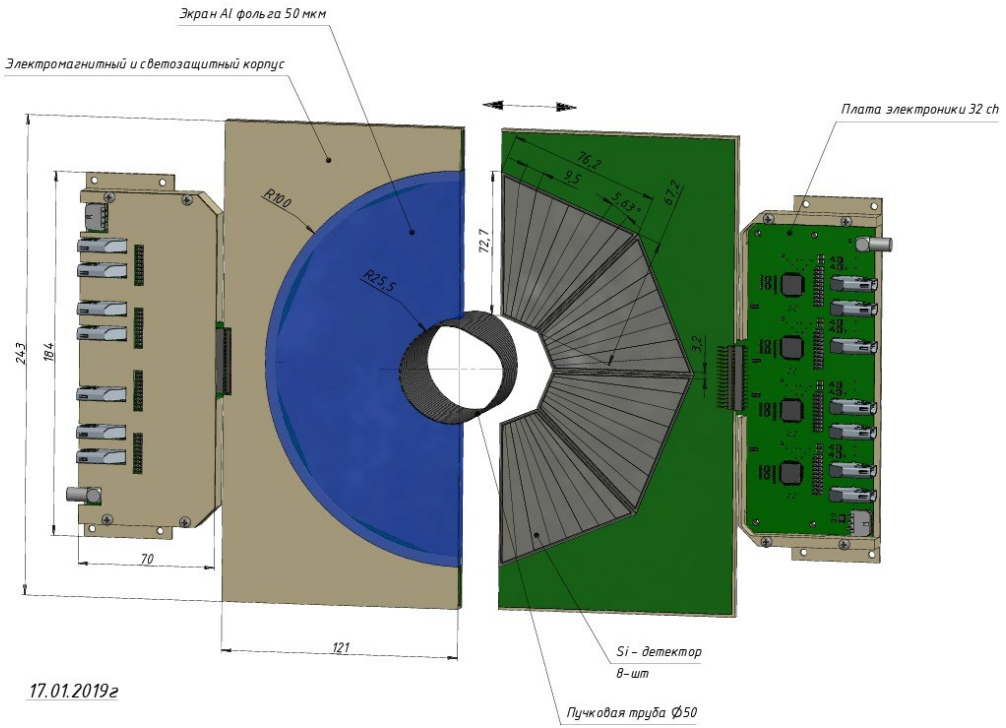
FEE (design is ready, production
scheduled for Spring 2021)

Scintillators BC400B 30x30x0.15mm^3
(available)
Quartz 40x40x0.2 mm^3 (available)

Scintillator mounts
(design is scheduled for Spring 2021)

Upgrade of Si Multiplicity Detector

Group of N.Zamjatin



Current status

– trapezoidal detectors
(tested, ready for mount on PCB)
– 2 PCBs (design in progress)
– 2 FEE boards 32 ch each
(ready, used in 2018)
– light and EM schielding
(design in progress)
– mechanical support
(design in progress)

Exp. overall completion July 2021

Detector parameters:
– opening for the beam. Dia. 28 → 50 mm
– 8 trapeziodal detectors
– 64 strips in total
– 525 μm thick

BD Shielding Optimization

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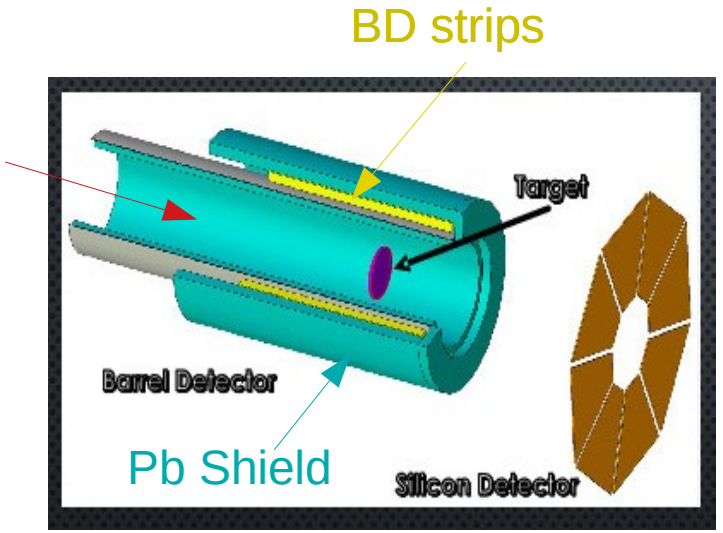
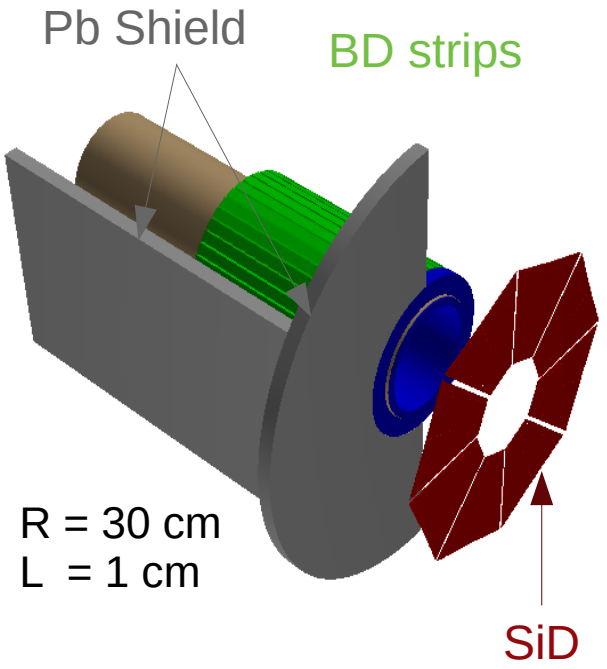
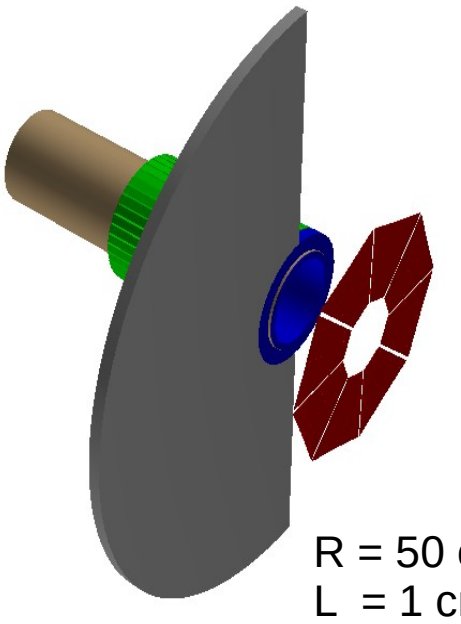
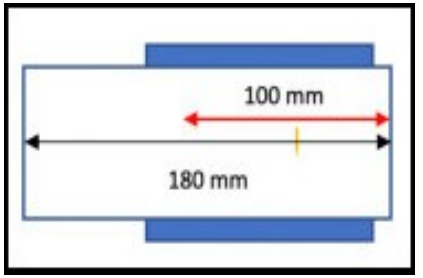






Criteria:

– sufficient background suppression;
– reduce material for potential detectors at high *θ;*
– put Pb only where it's needed;
– convenient mounting;



Inner shield (5mm thick)
Reduction in length 180→100 mm results in 1.53 increase in background rate
(Au+Au, 4GeV/n, 300μm)

Centrality selection with BD and Si triggers

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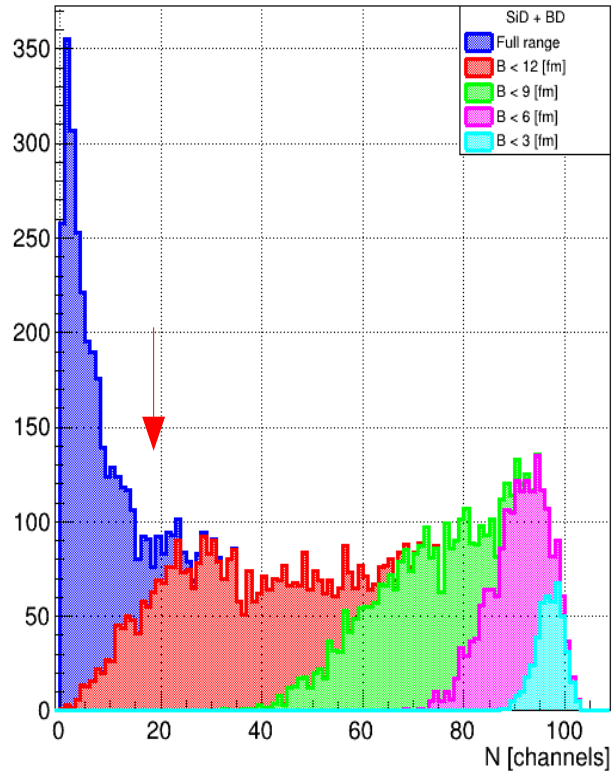
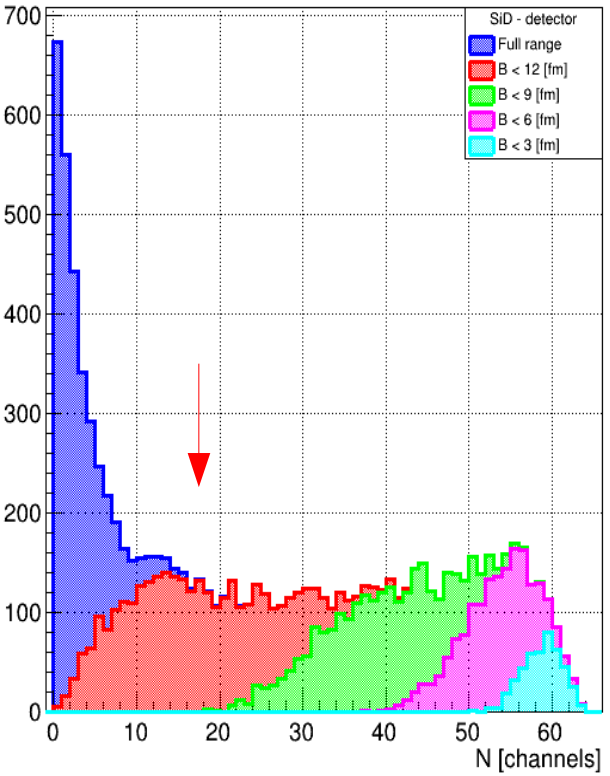
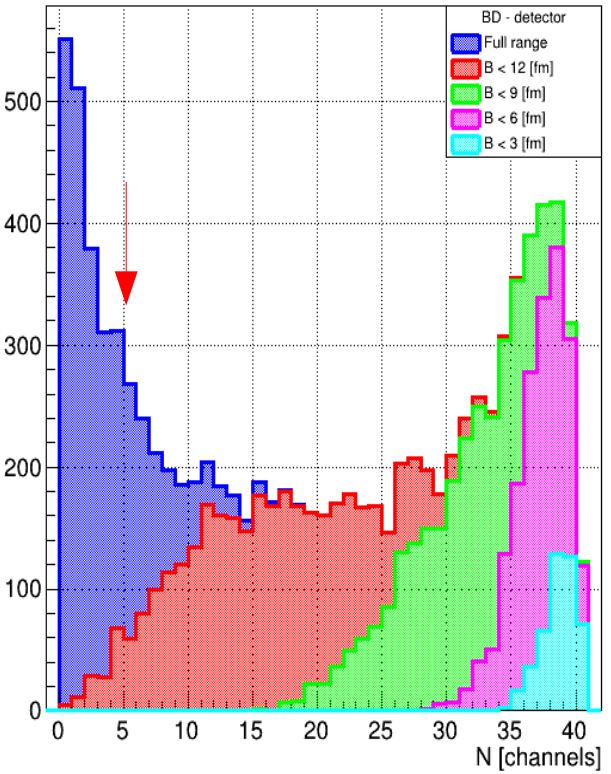
DCM QGSM, Au+Au, 4GeV/n, 300μm



Threshold N(Si+BD) > 18



Threshold N(Si) > 18



Threshold N(BD) > 6

At these thresholds the background level in triggered events is <10%

Potential additional triggers – I

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Fragment detector near the FHCal

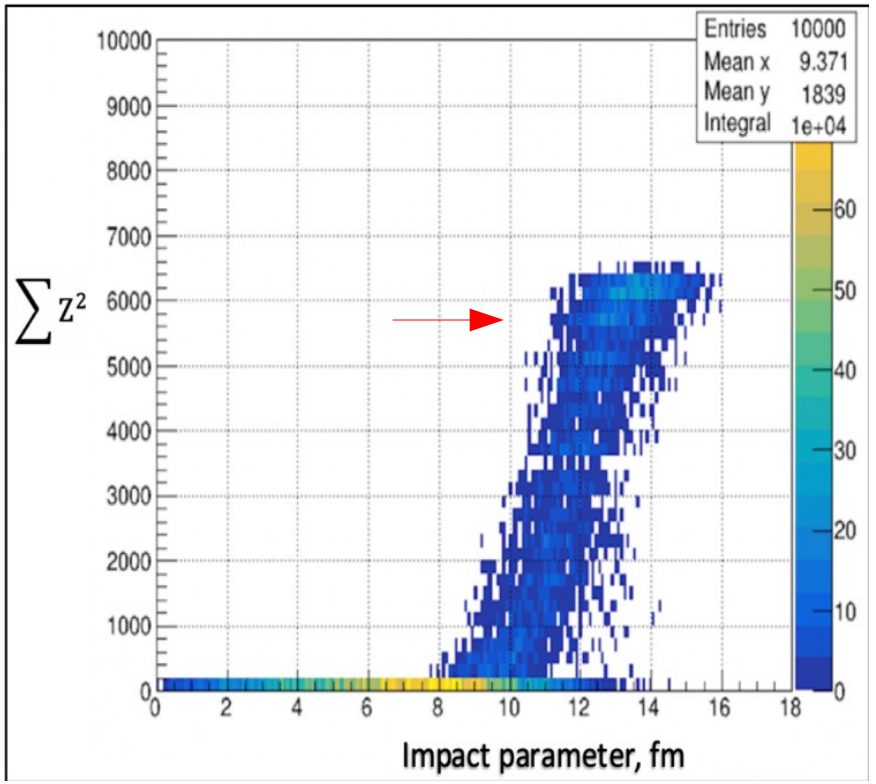
160x160 mm², 4 quartz plates, 160x40x6 mm³ (available)

viewed by 4-5 SiPMs from both sides;

SiPM SensL 6x6 mm² UV sensitive (ordered)

Threshold on summed Z^2 provides either trigger signal or “fast clear”

Simulation DCM QGSM, Au+Au 4GeV/n, 300μm



Potential additional triggers – II

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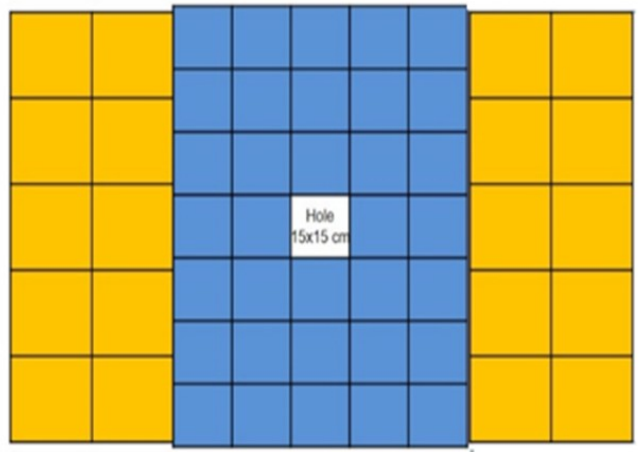
DCM QGSM, Au+Au, 4GeV/n, 300μm

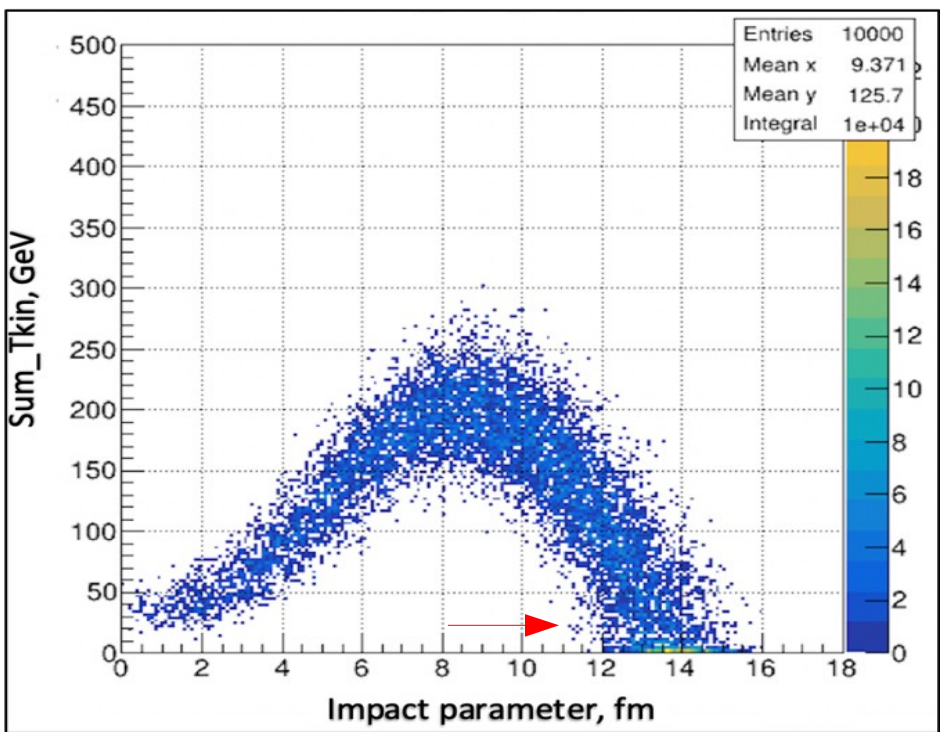
FHCal signals

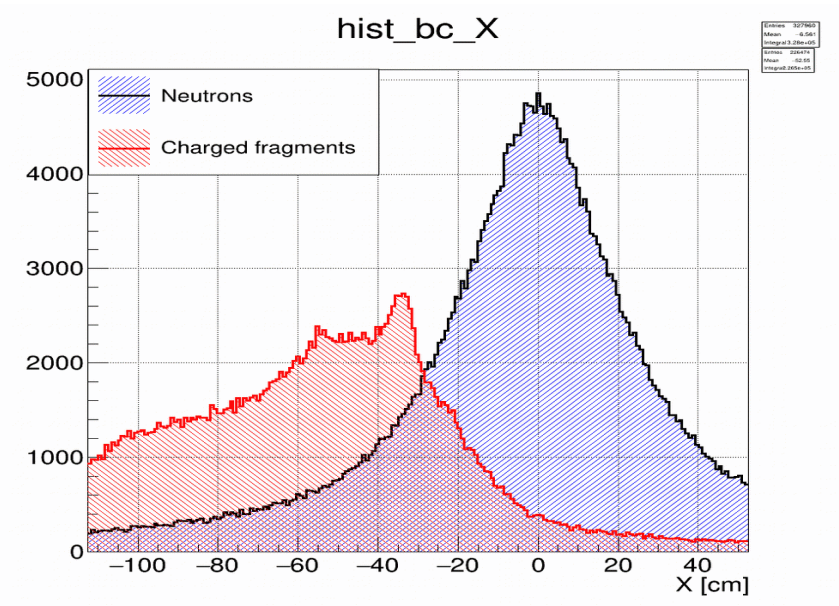
a) neutron zone

b) charged particles zone



Summed energy of all neutrons in FHCal





Thank you for your attention