Status of the beam line and beam detectors

Sergey Sedykh for the BM@N

BM@N Detector Advisory Committee
February 05, 2020

Outline

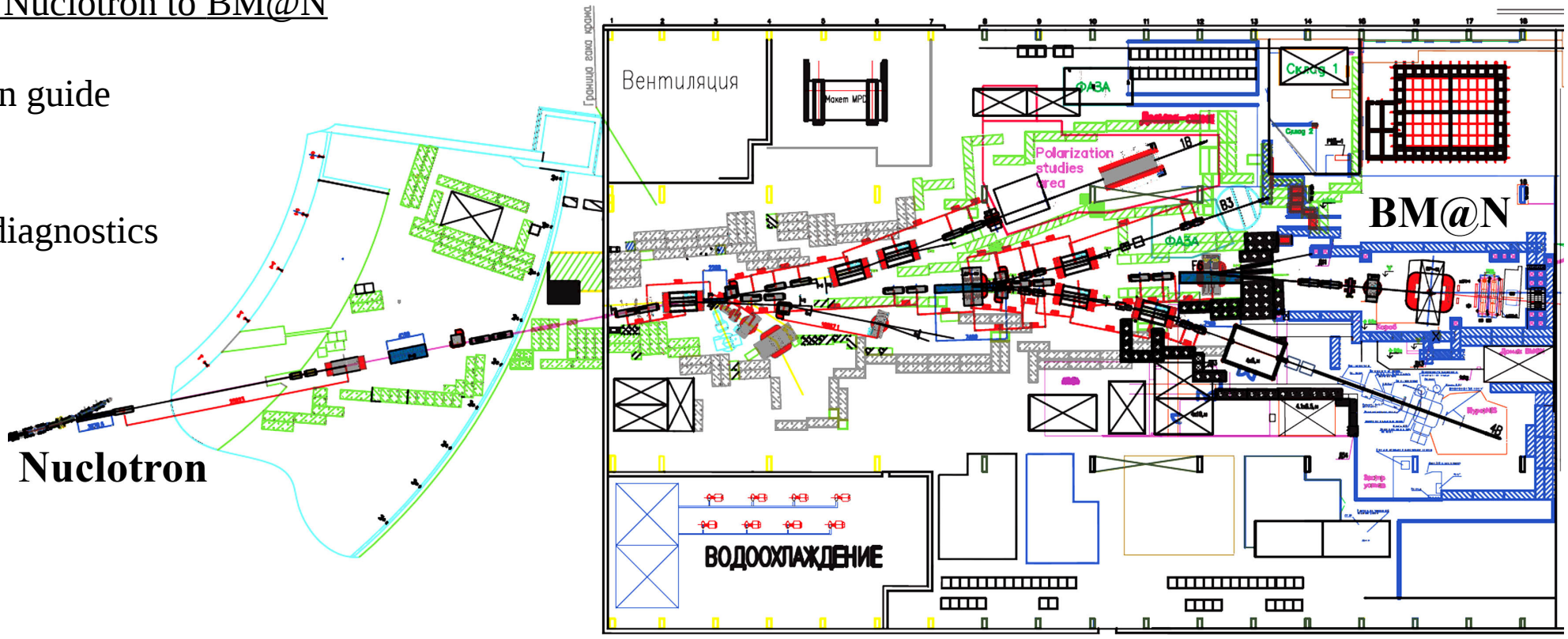
- *Beam transport line from Nuclotron to BM@N*
- *Beam tracking and profile detectors*
- *Beam counters (BC1, BC2, VC)*
- *Target area and trigger multiplicity detectors*
- *Ideas about T0 for TOF at high intensity Au+Au*

Vacuum ion transport line from Nuclotron to BM@N

Radiation Physics Laboratory of Belgorod State University
Head: A. Kubankin

Continuous vacuum from Nuclotron to BM@N

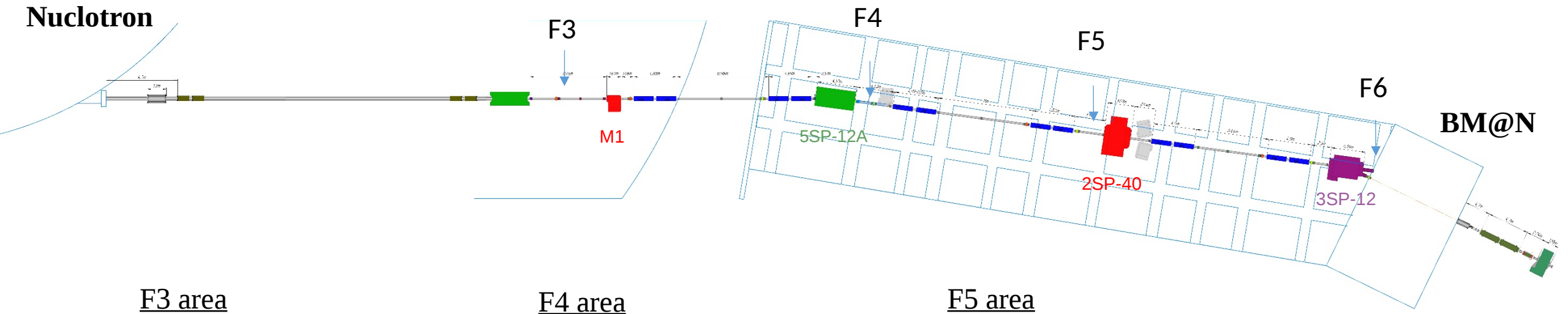
– 110 m of modernized ion guide
– 6 magnets
– 17 quadrupole lenses
– 14 points for ion beam diagnostics
– 4 focus areas (F3-F6)



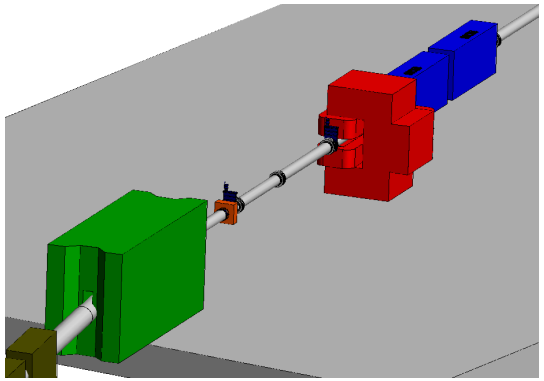
Nuclotron ← 138 m lenght of the ion guide → **BM@N**

Vacuum ion transport line from Nuclotron to BM@N

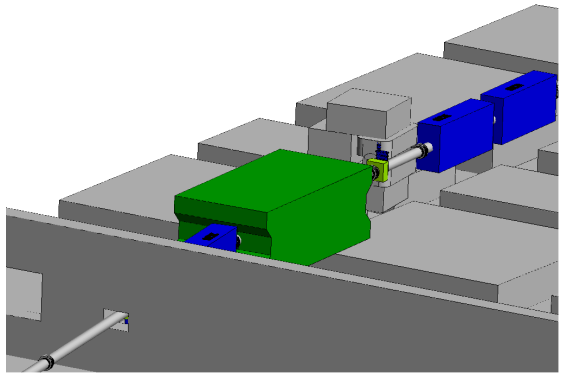
Detailed 3D model of the ion guide
(Done in Feb-Mar 2019)



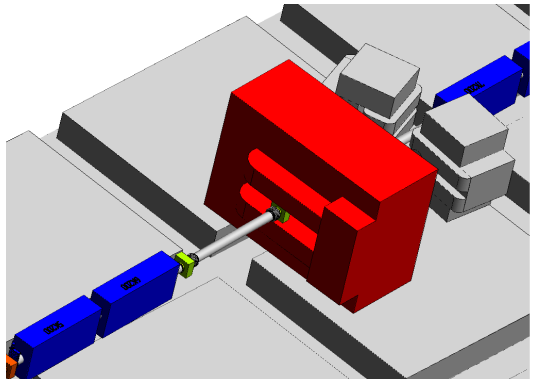
F3 area



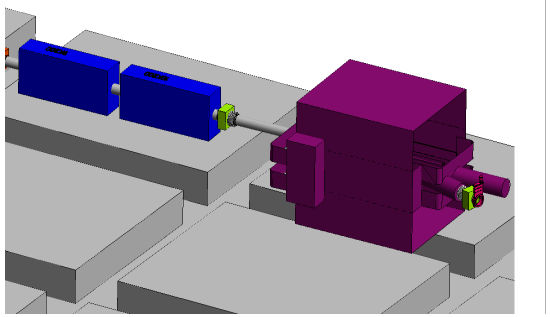
F4 area



F5 area

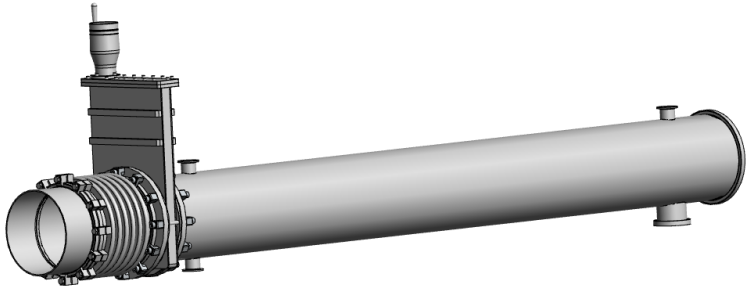


F6 area

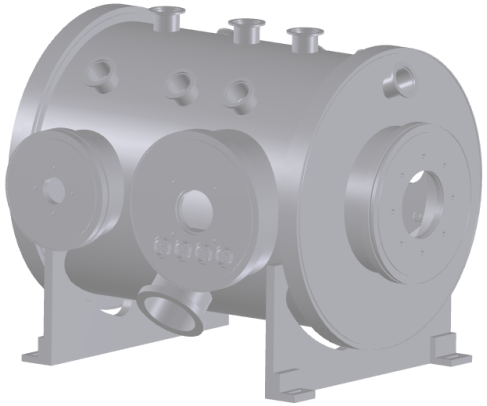


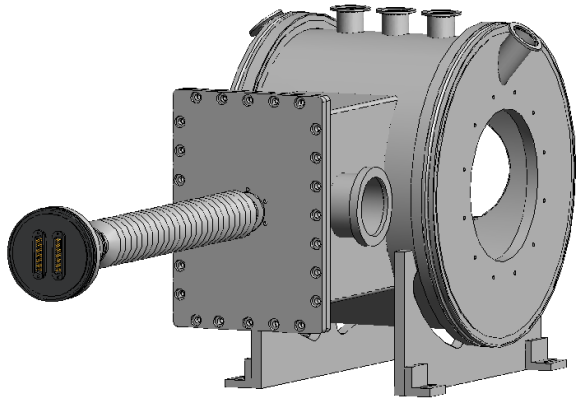
Vacuum ion transport line from Nuclotron to BM@N

Examples of designed parts of the ion guide

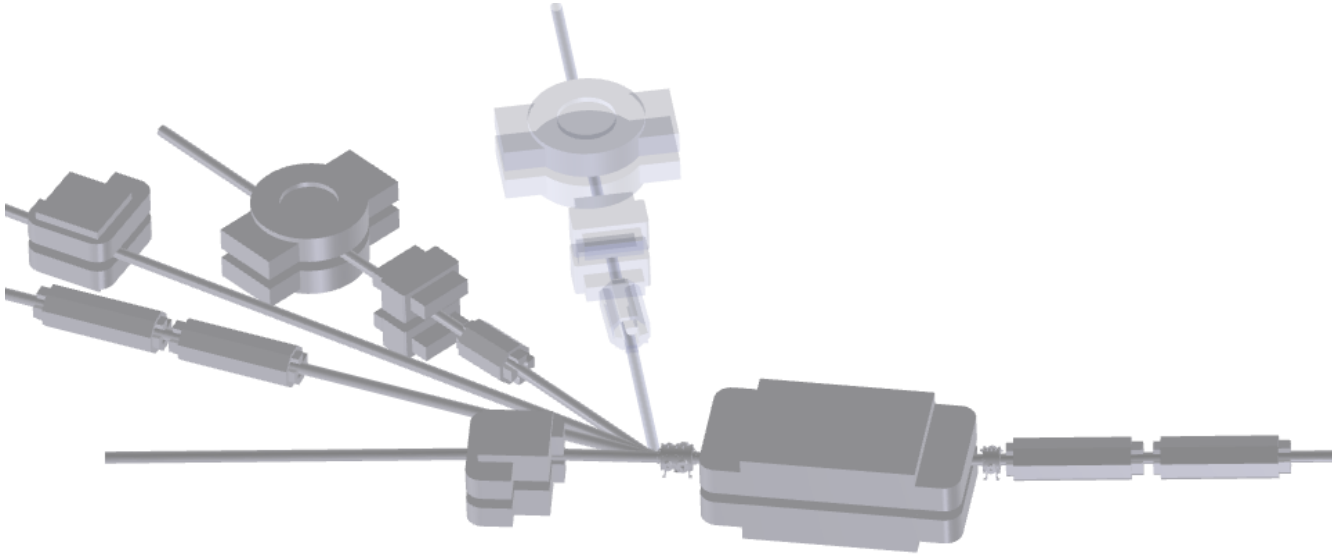


Basic part of the ion guide - vacuum pipe with ISO-K, KF flanges assembled with bellow and gate valve

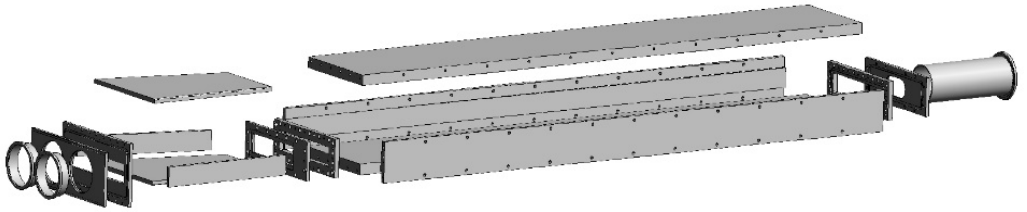




Multitask vacuum boxes for modern beam diagnostics tools and experimental research



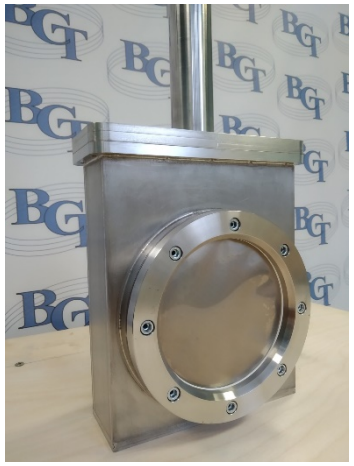
F4 focus area with MARUSYA experimental setup



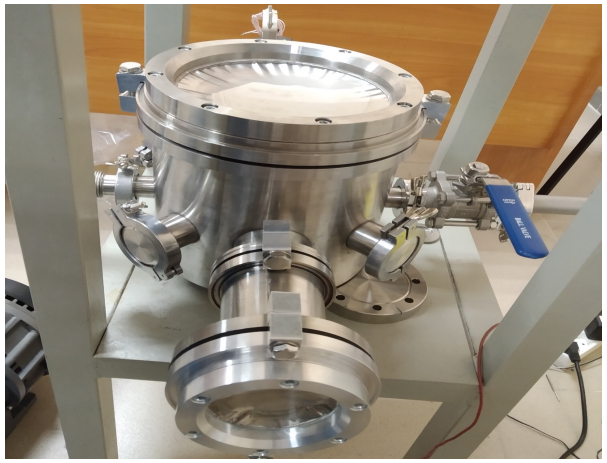
Vacuum box of a magnet

Maufactured prototypes of the pipe parts

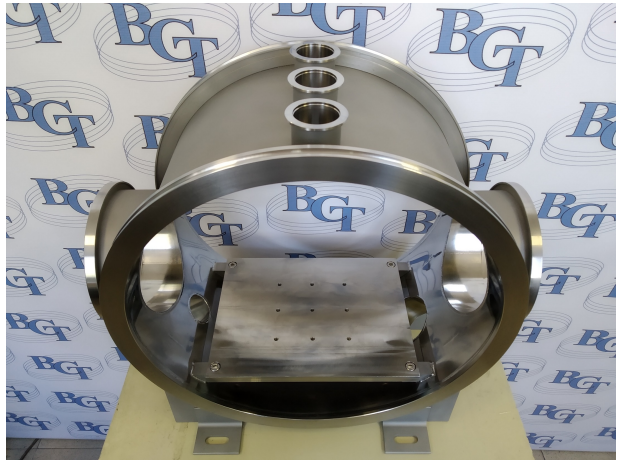
Motorized translator stages for detectors and targets



Vacuum box with thin titanium window for diagnostics detectors

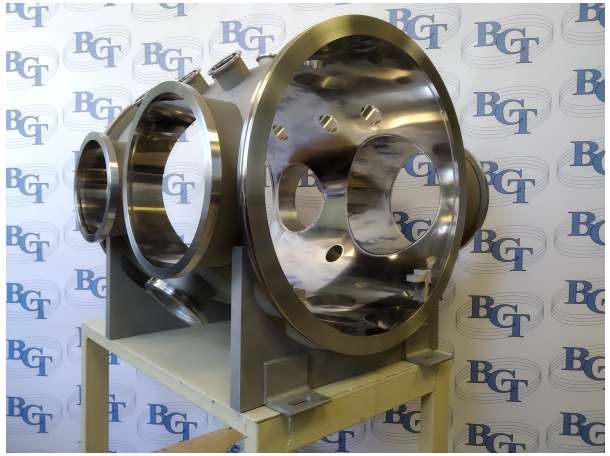


Setup for thin windows testing



Vacuum chamber for diagnostics tools

Vacuum parts of the beam pipe



Vacuum chamber for diagnostics tools and targets

Beamline from Nuclotron to BM@N

Overview of the current status

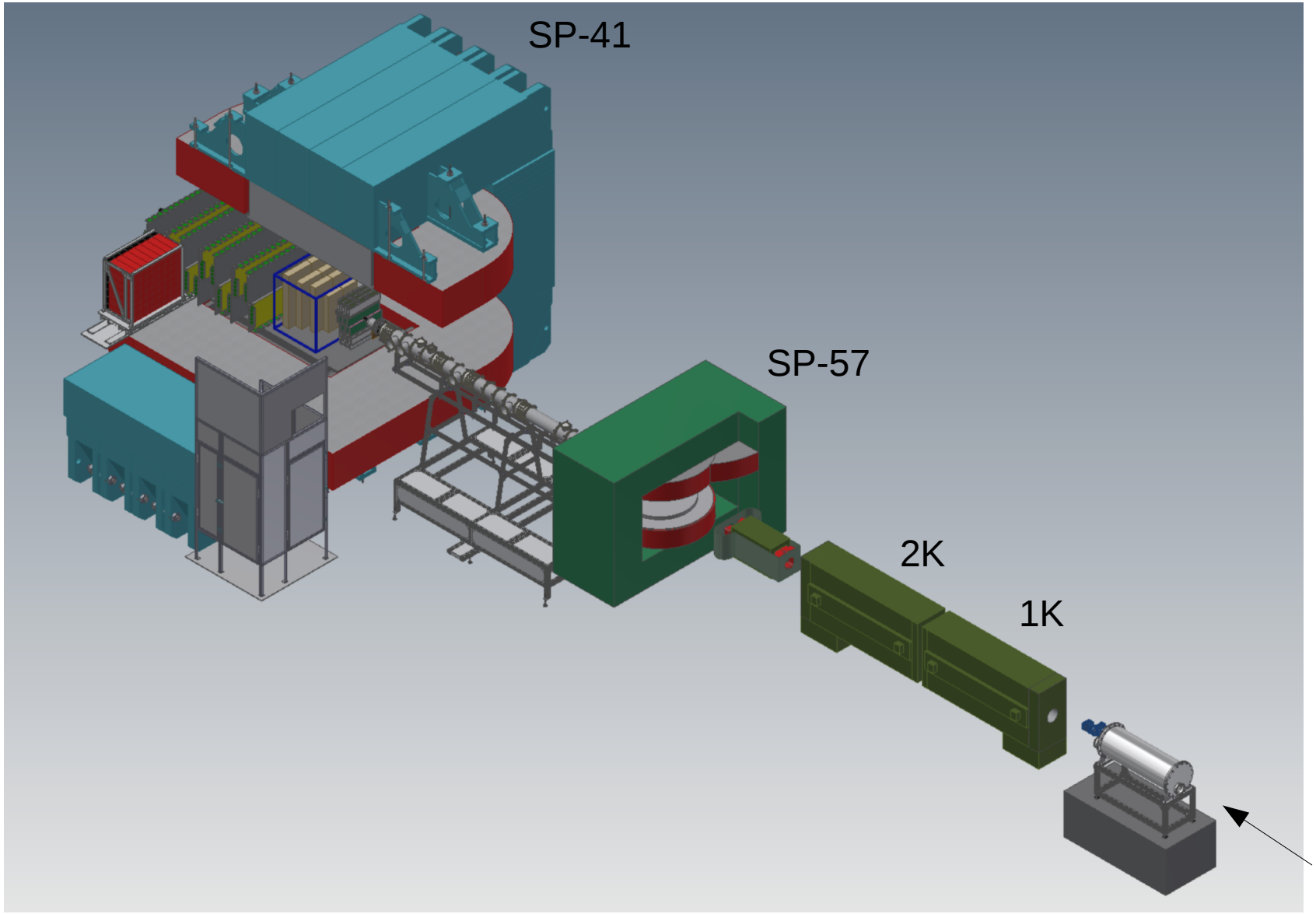
- *Measurement of the beamline components with 3D model (done)*
- *Technical documentation and design of major components (done)*
- *Prototypes of all major components (manufactured and tested)*
- *Formal official contract (in progress, exp. completion 03/2020)*

- *Expected start of production: shifted 08/2019 → 03/2020*
- *Expected completion of parts production: shifted 05/2020 → 01/2021*
- *Expected overall assembly and testing: early 2021*

- *Manufacturing of vacuum parts for two SP-12 magnets upstream of BM@N (in progress, exp. assembly by the end of Feb.2020)*

Beam pipe in BM@N before the target

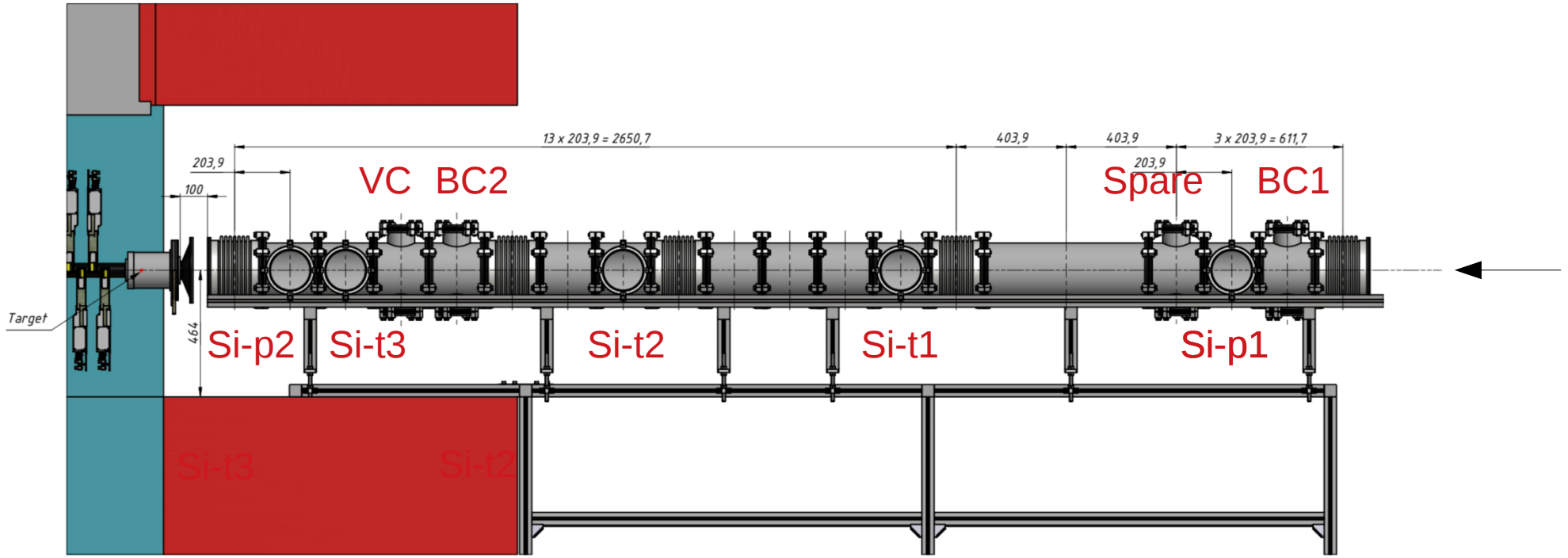
S. Piyadin et al., BSU Group



- So far work was done for area between SP-57 and SP-41 where all beam detectors are placed
- Vacuum elements upstream of SP-57 are planned for later stages
- Lenses of 1K and 2K will need special treatment

BM@N beam pipe before the target

S. Piyadin et al.



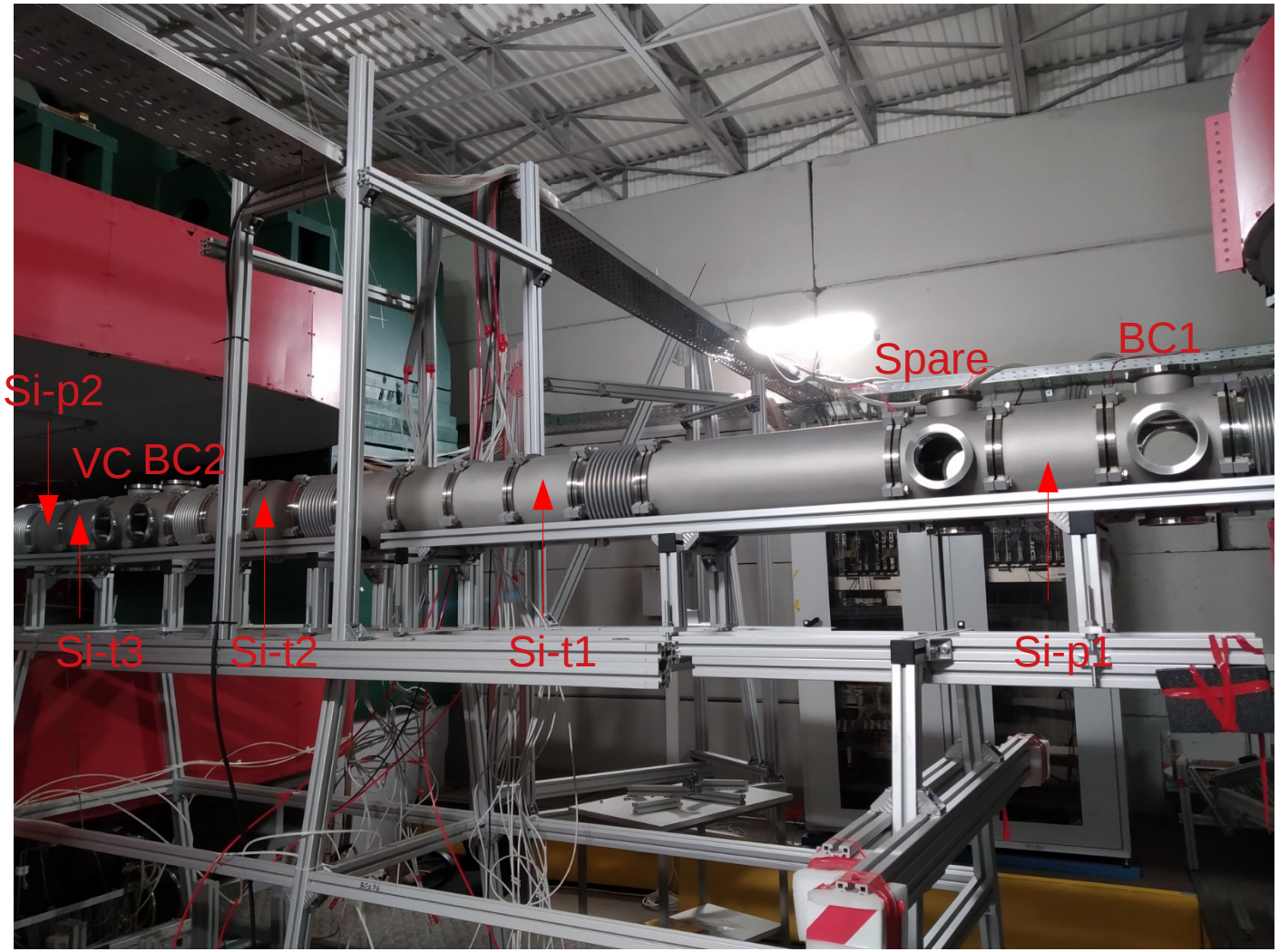
BC1, BC2, VC beam counters

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

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

– Vacuum boxes are 20 cm long in Z (non standard)
– Si-p1, Si-p2 and Si-t1, Si-t2, Si-t3 are similar in design
– BC1, VC have the same design
– BC2 the same vacuum box but different PMT mounts

Beam pipe in BM@N before the target

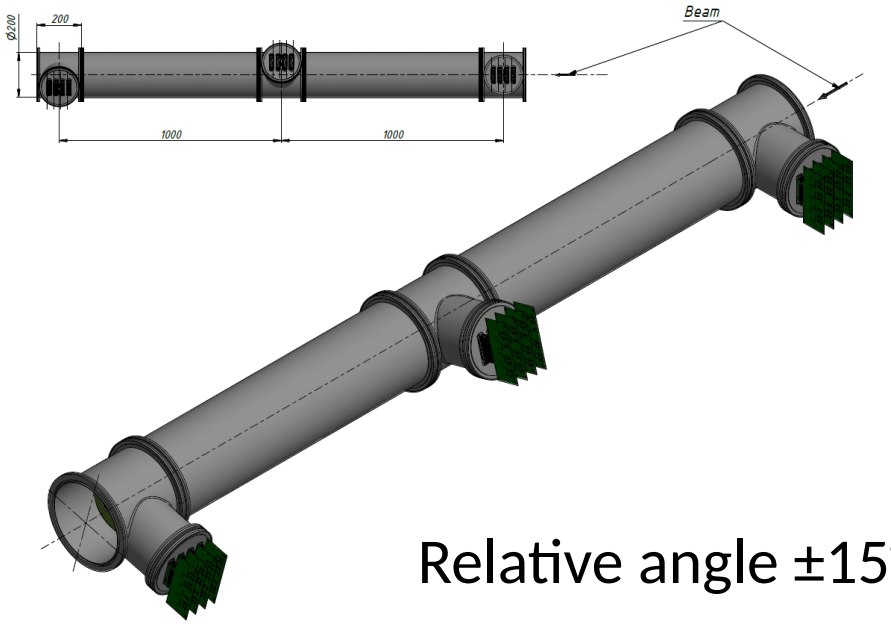


Current status:

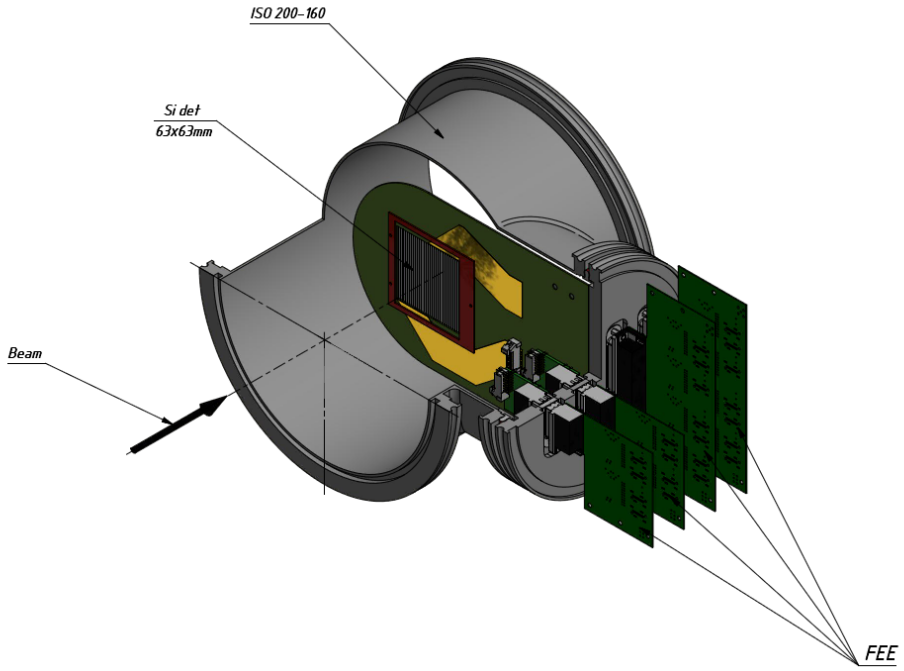
- all ordered components were made and tested in the BSU Lab (specs. 10^{-3} Torr, actual 10^{-6} Torr)
- delivered and assembled at BM@N in Oct.2019
- magnetization of components after welding and machining, therefore, one bellow and parts for Si-p2, Si-t3 and VC will be remade of aluminum
- tests of the whole line is foreseen after complete assembly
- design of mechanics for moving Si-Profile detectors in and out of the beam is in progress

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

Status of DSSD and FEE:

– 15 detectors ordered and delivered (NIIMV, Zelenograd)

– 20 VATA64-HDR16 purchased

– PCB design is in progress

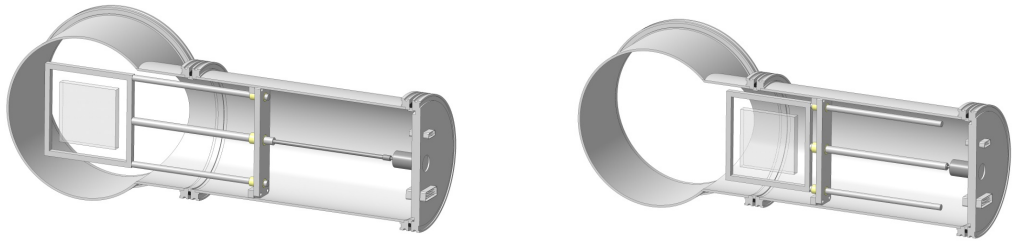
Status of vacuum components:

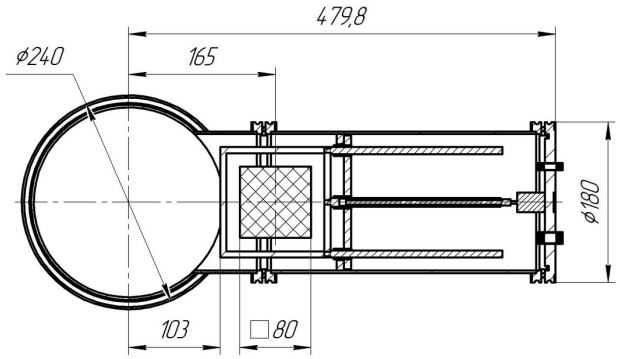
– Si-t1, Si-t2 are ready,
Si-t3 is being remade of aluminum

– one flange with connectors is available for testing

Silicon Beam Profile Detectors

Group of N.Zamjatin,
S. Piyadin,
BSU Group





Tentative design (by BSU Group) of moving mechanics for Si Beam Profile Detectors

Current status of vacuum parts:

– Si-p1 box is completed,
Si-p2 box is being remade of aluminum
– moving mechanics design is ready,
some details need final approval
– proposal to use Phytron motors,
open question is operation in the magnetic field for Si-p2
– flanges with connectors are ready for testing

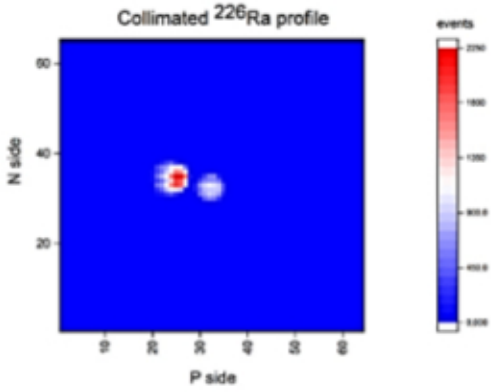
Status of DSSD and FEE:

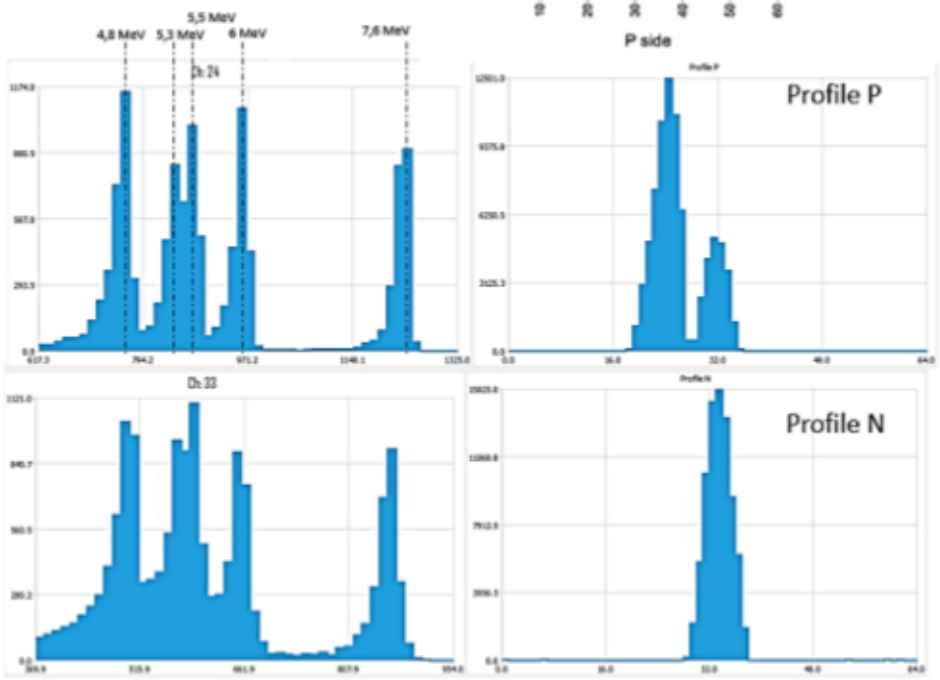
– 10 detectors ordered and delivered (NIIMV, Zelenograd)
– VA163 and VA32HDR11 available
– PCB design is in progress

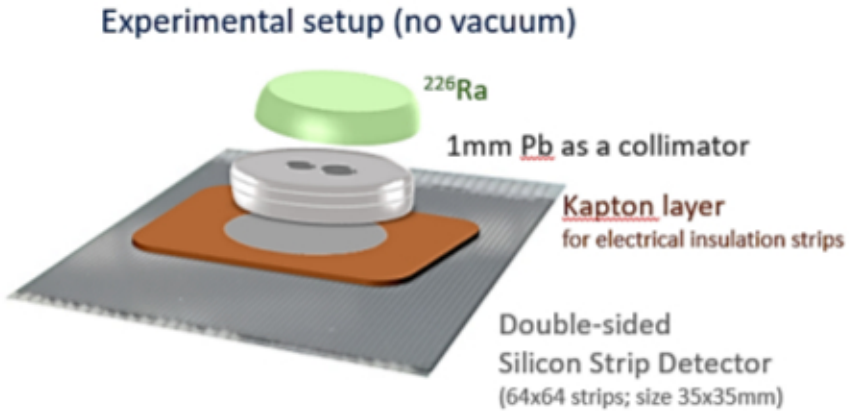
Silicon Beam Profile Detectors
Tests of prototype

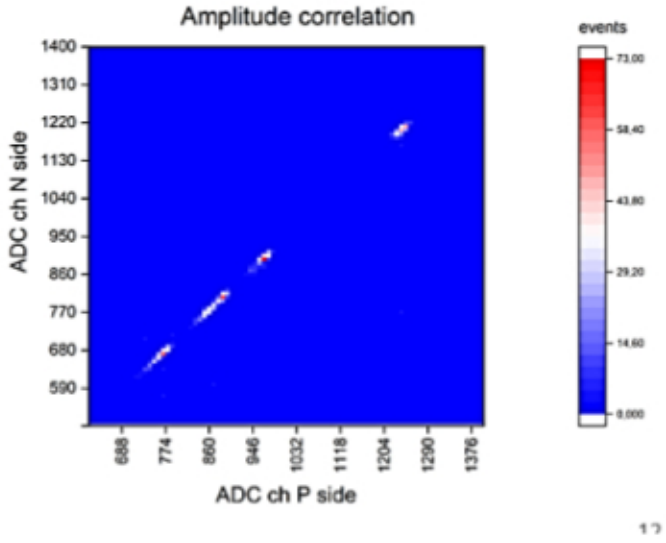
Group of N.Zamjatin

Test with collimated ^{226}Ra (VA162)









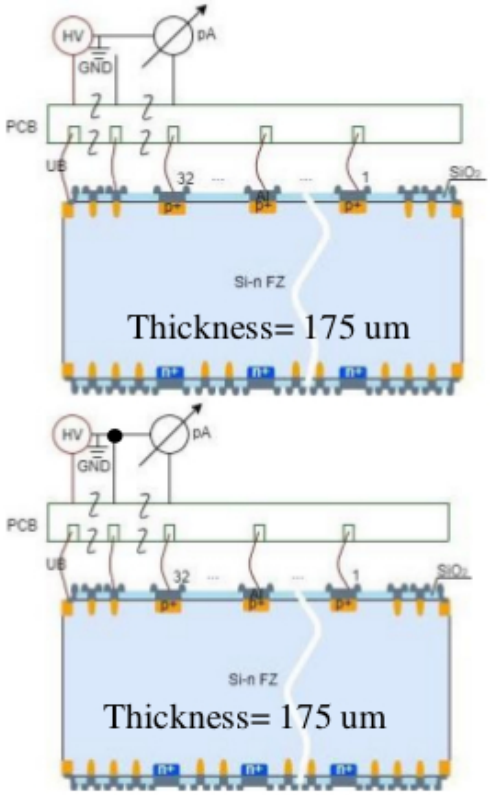
Prototype

– area 32 x 32 mm^2
– pitch 0.5 mm
– 64 x 64 strips
– thickness 300 μm
– ASIC VA162

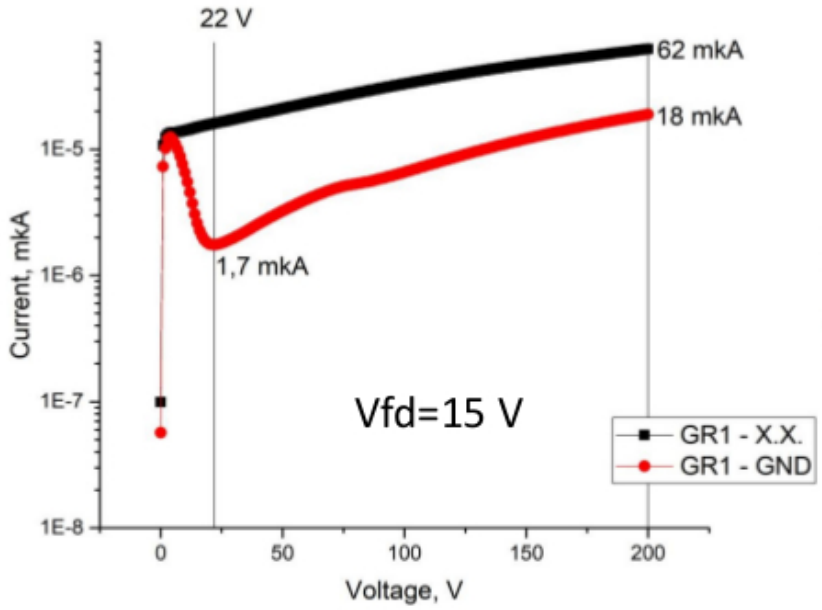
Beam Profile

– area 60 x 60 mm^2
– pitch 1.87 mm
– 32 x 32 strips
– thickness 175 μm
– ASICs:
VA163 (0.7 pC,^{12}C),
VA32HDR11 (30 pC, Kr and Au)

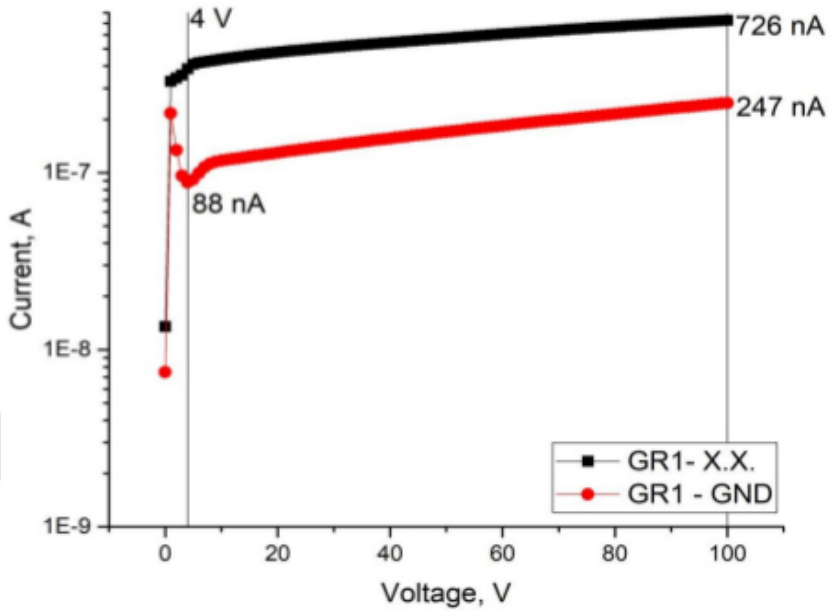
IV-tests for beam profilometer and tracker DSSDs



Measurement scheme of summary dark current beam profilometer and beam tracker DSSDs, Inner guard ring at floating (top), Inner guard ring at GND (bottom).



Summary beam profilometer DSSD Dark Currents, Inner GR at floating (black) Inner GR at GND (red) at T= +24,2 ºC



Summary beam tracker DSSD Dark Currents, Inner GR at floating (black) Inner GR at GND (red) at T= +24,1 ºC

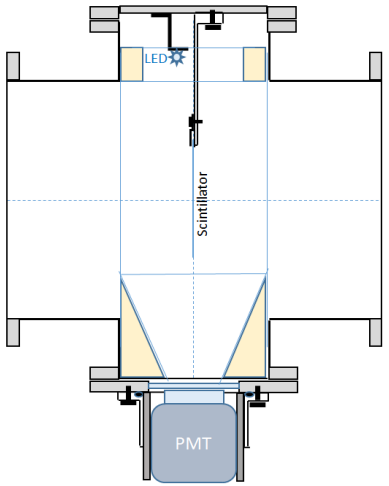
Beam Profile and Tracker Detectors

Group of N.Zamjatin

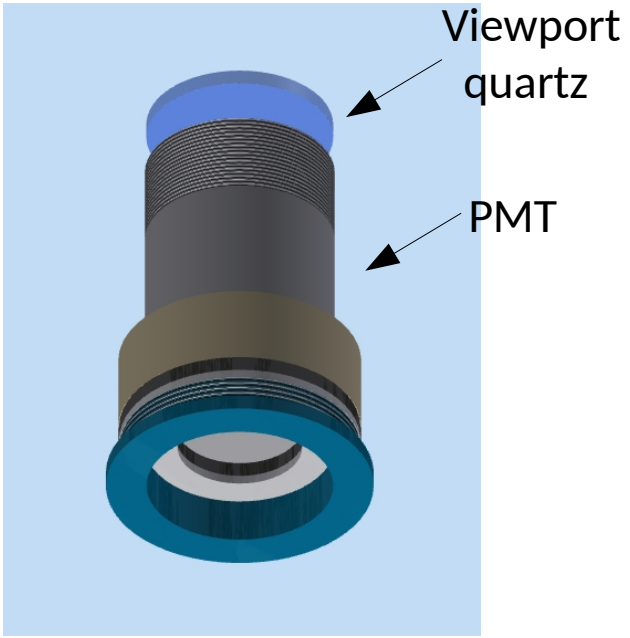
planned actions and schedule

- *tests of vacuum flanges with connectors (resp. O.Tarasov, 03/2020)*
  final production (resp. O.Tarasov and BSU group, 05/2020)
- *design of PCBs (resp. S.Khabarov, 02-03/2020)*
  order of PCBs for production (resp. S.Khabarov, 03-04/2020)
- *assembly and tuning PCB+FEE (S.Khabarov, Yu.Ivanova, Yu.Kovalev, 04-09/2020)*
- *tests of DSSD mounted on plates (O.Tarasov, N.Zamjatin 06/2020)*
- *tests of trackers with BM@N DAQ (09/2020)*
- *tests of beam profile detectors with stand-alone read-out (09/2020),*
  profile distribution copy to beam transport group (+P.Rukoyatkin, 09-12/2020)
- *full assembly with vacuum parts (12/2020)*

Beam Counters: BC1, VC



Sketch of vacuum box for BC1 and VC



Parts of 3d design of PMT mount for BC1 and VC

Current status

– Hamamatsu R2490-07
operate in magnetic field <1T
(available)

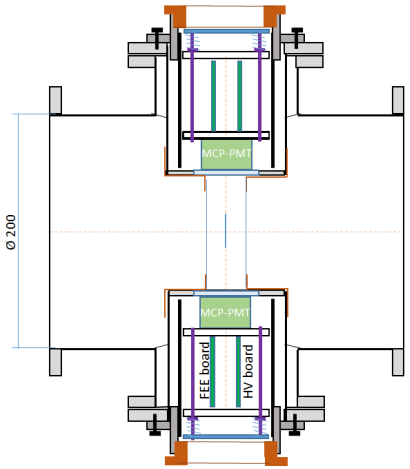
– Vacuum boxes
(BC1 ready, VC in production)

– PMT mounts
(design is close to completion)

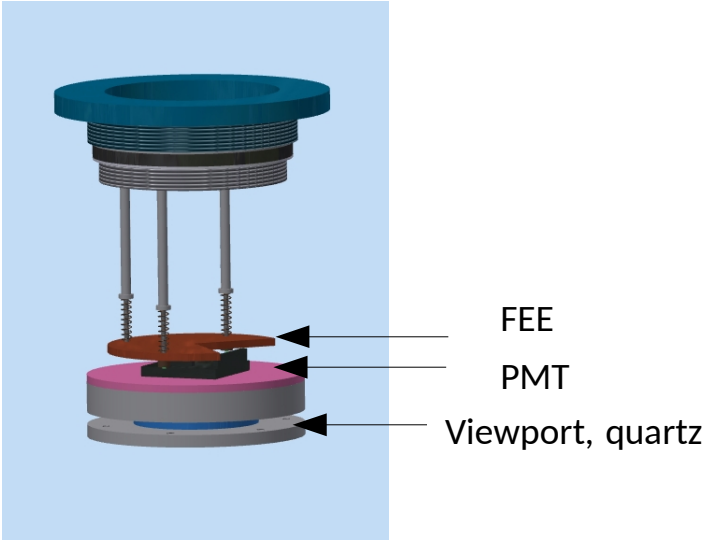
– Scintillator BC400B 100x100x0.25mm^3
(available)

– Scintillator mounts
(design is scheduled for 2020)

Beam Counters: BC2



Sketch of vacuum box for BC2



Parts of 3d design of PMT mount for BC2

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 (delivered, March 2019)

– Vacuum boxes with quartz windows (BSU, delivered October 2019)

– PMT + FEE mounts (design is close to completion)

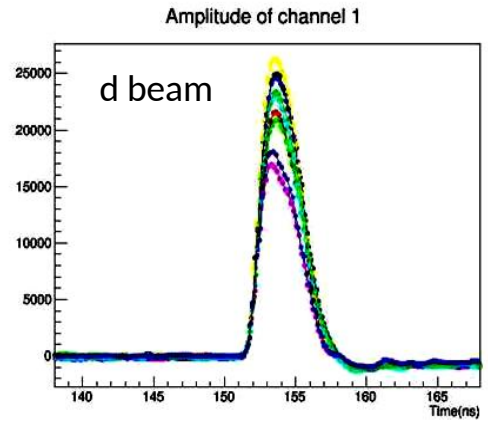
– FEE design and production (scheduled for 2020, ~2 month)

– Scintillators BC400B 10x10x0.15mm^3 (available)

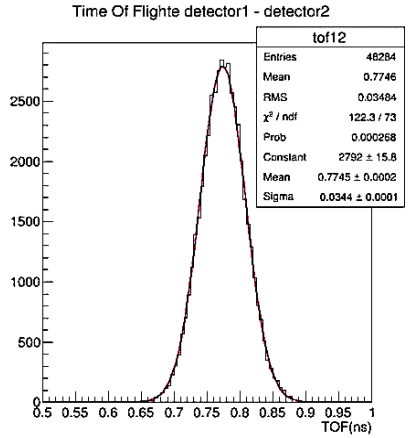
– Scintillator mounts (design is scheduled for 2020)

Relevant to BC2 in BM@N: Time resolution results with FFD prototypes

Ev.B. DRS4 readout

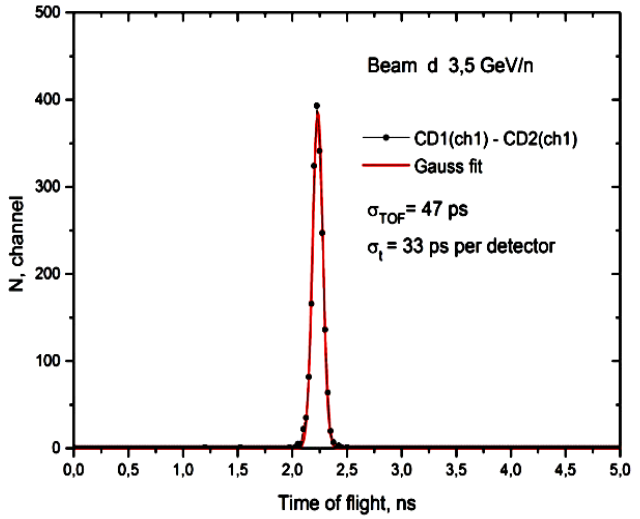


Typical pulses



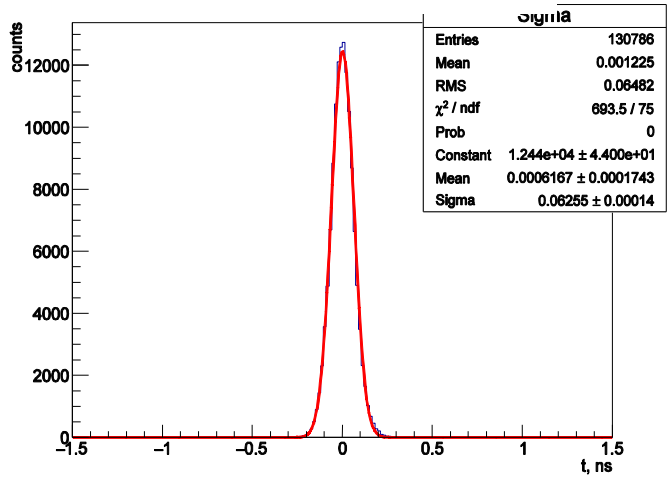
Time resolution (TOF)

CAEN mod.N6742 readout



Time resolution (TOF)

TDC72VHL readout



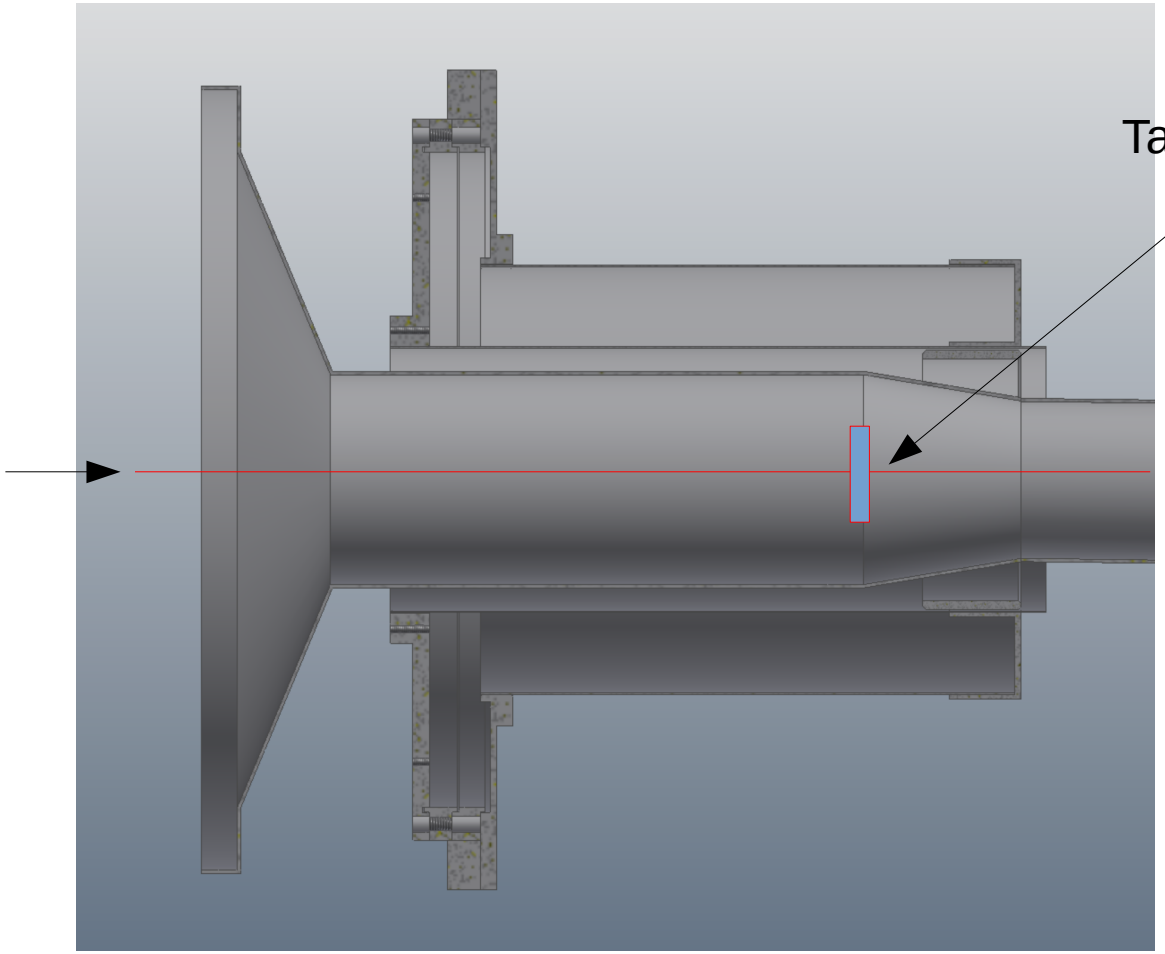
Time resolution (TOF)

Time resolution of FFD module itself	- 21.5 ps
with readout by E.B. DRS4 digitizer	- 24 ps
with readout by digitizer CAEN mod.N6742	- 34 ps
real chain with readout by TDC72VHL	- 44 ps

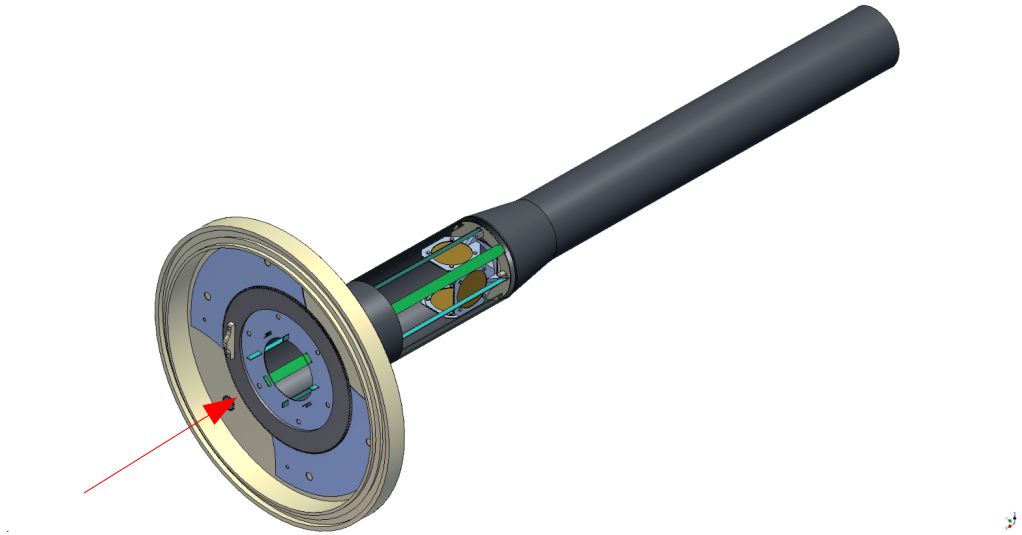
Resolution in C beam (2018):
T0 SRC – 113 ps; BC2 – 57 ps; FFD – 31 ps

Target area with Barrel Detector

S.Piyadin, Yu.Gusakov,
BSU Group



First section of the carbon vacuum pipe and Barrel Detector
Dia. 200 → 66 → 50 mm



Carbon vacuum pipe and the target station

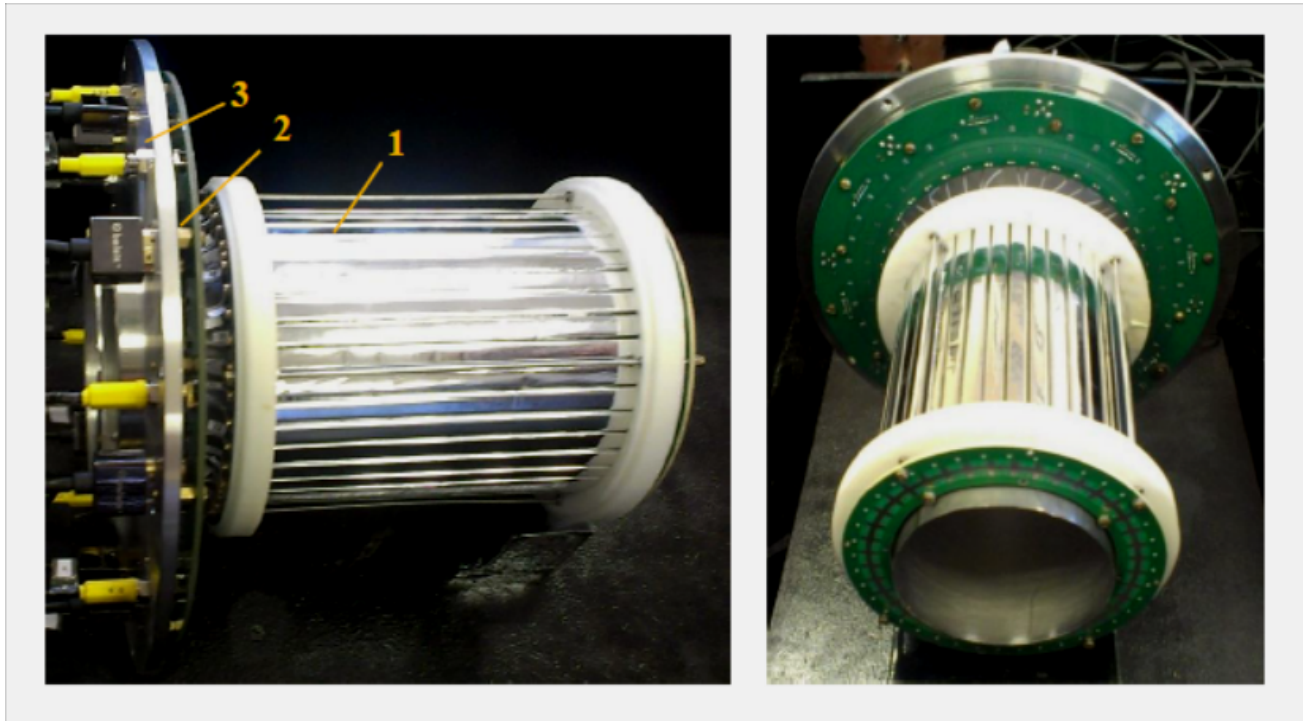
Current status

– mechanical parts
(production started in Belgorod)
– motor operation in magnetic field
(tests are being made in LHEP)

Upgrade of Barrel Detector (BD)

The active area of BD has radius of 45 mm and length of 150 mm and it consists of 40 strips 150 × 7 × 7 mm^3 made from polished scintillator BC418 wrapped by Al- mylar.

Each strip is directly connected with SiPM Micro FC-60035-SMT, 6 × 6 mm^2.



A view of the BD prepared for run 2018:
1 – the scintillation strips, 2 – the board with SiPMs,
3 – the board of front-end electronics.

Planned upgrade for upcoming runs:

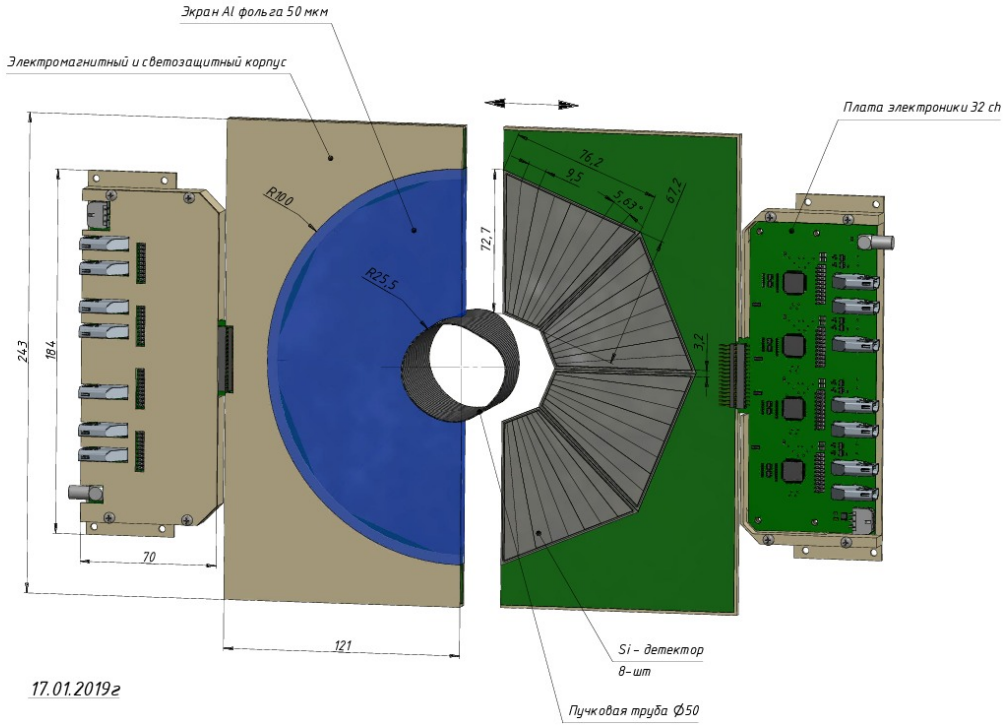
- inner (5 mm) and outer (10 mm) Pb shielding will be added (will be done by the trigger group)

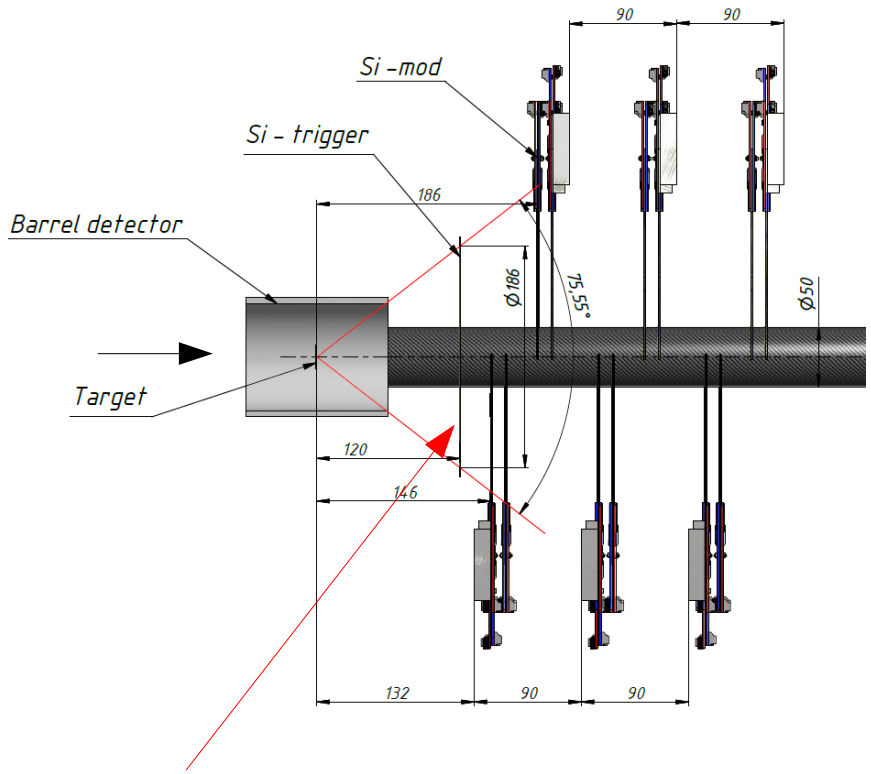
- new FEE (less noise)

Upgrade of Silicon Multiplicity Detector

Group of N.Zamjatin

The Si detector has 64 independent segments / channels and it provides fast determination of multiplicity of charged particles emitted in forward direction by measuring a number of fired segments.





Placement at 12 cm from the target

Reason for the upgrade:

larger opening for the beam. Dia. 28 → 50 mm

Upgrade of Silicon Multiplicity Detector

current status and schedule

– *trapezoidal detectors, 8 strips, 525 μm (NIIMV Zelenograd, 16 delivered 12/2019)*

– *tests and selections of detectors (E.Streletskaya, Yu.Kopylov, 03/2020)*

– *detector frame design including EM and light screens, will be based on experience with Si MD detector of 2018 (O.Tarasov, 02/2020)*

– *design of PCBs (S.Khabarov, 03/2020)*

– *order of PCBs for production, 2x2 half-planes (S.Khabarov, 03-04/2020)*

– *FEE of 2018 will be used with minor corrections (S.Khabarov, 03/2020)*

– *detector assembly, tests and tuning with radioactive source (O.Tarasov, N.Zamjatin 04-07/2020)*

– *integration of signals to trigger logic unit (with trigger group, by 12/2020)*

T0 options at high beam intensity, Au+Au, $5 \cdot 10^7$

1) 4 FFD-Type Detectors

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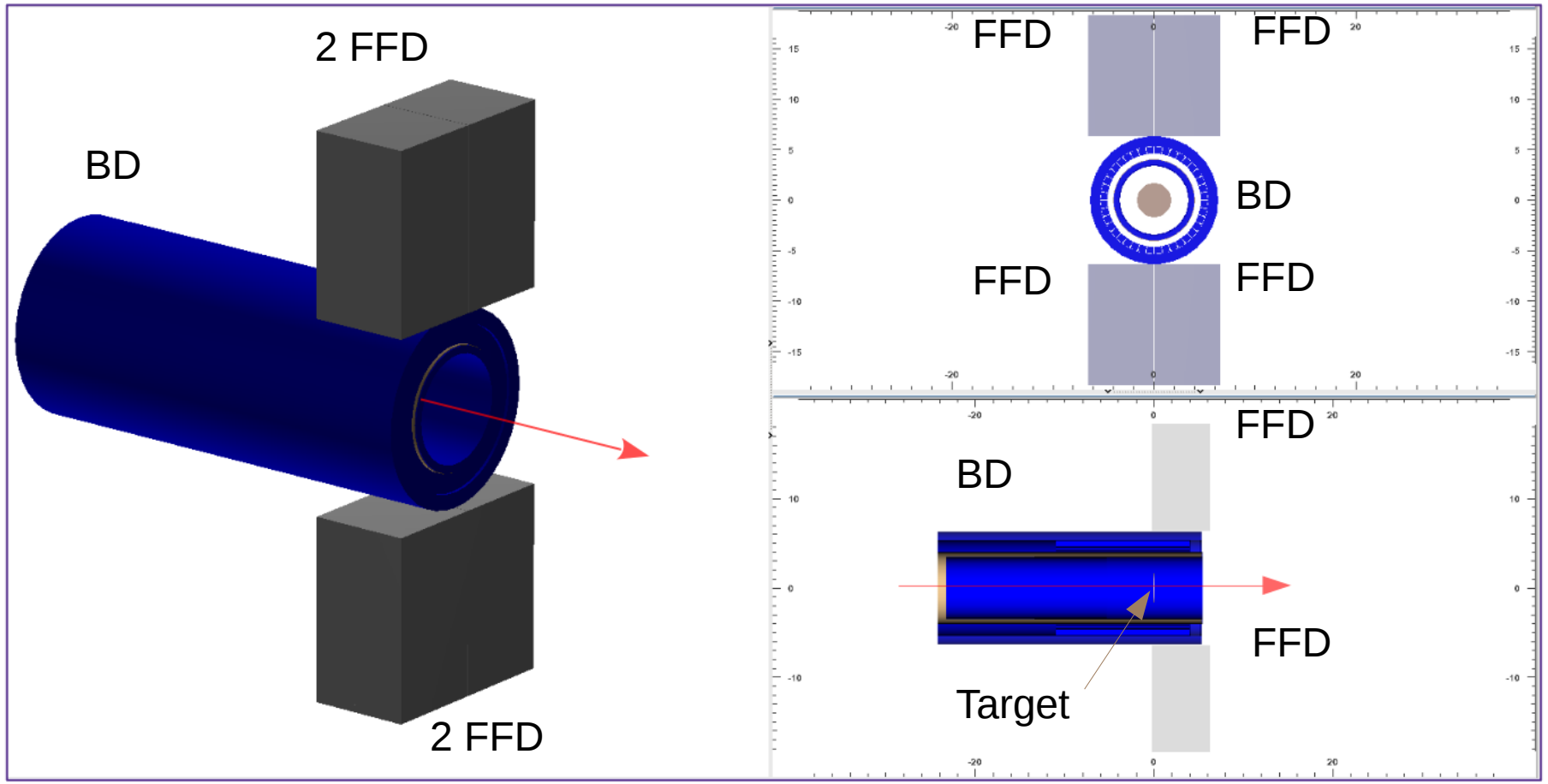
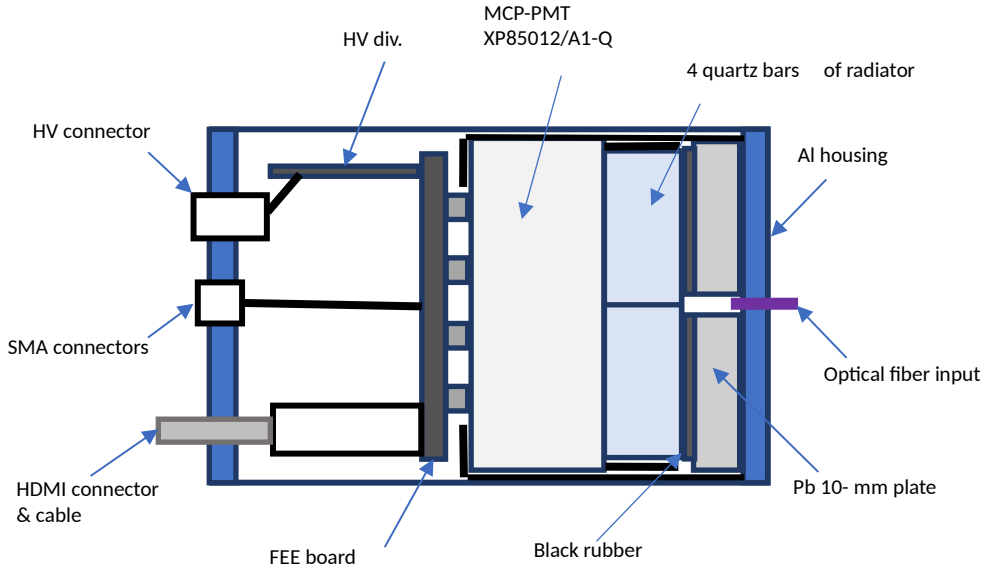
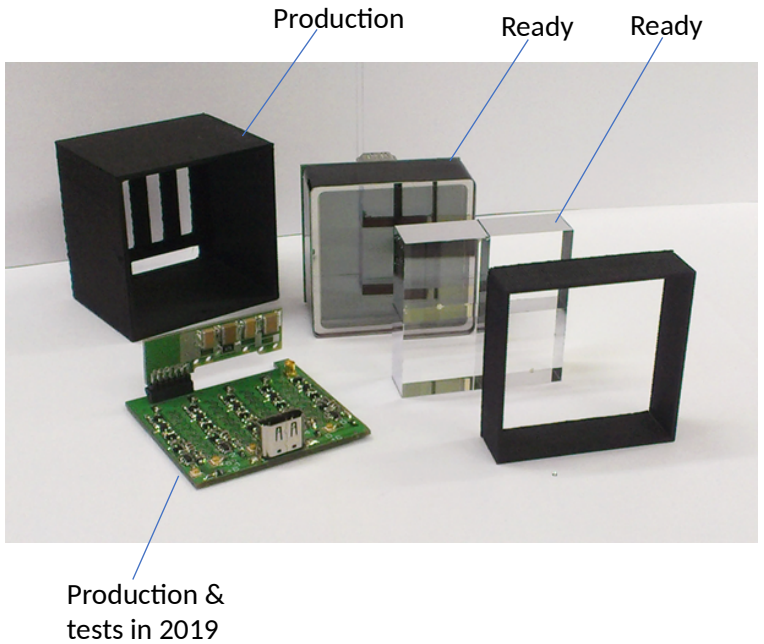
Main idea: put fast counters close to the target and detect β=1 particles



FFD modules





4 quartz bars 28 x 28 x 15 mm^3 in every FFD module
For BM@N trigger the Pb plates in FFD modules can be removed
Pb-Shielding around BD will serve as converter

FFD-Type T0 efficiency simulation: Au + Au, 4 GeV/n

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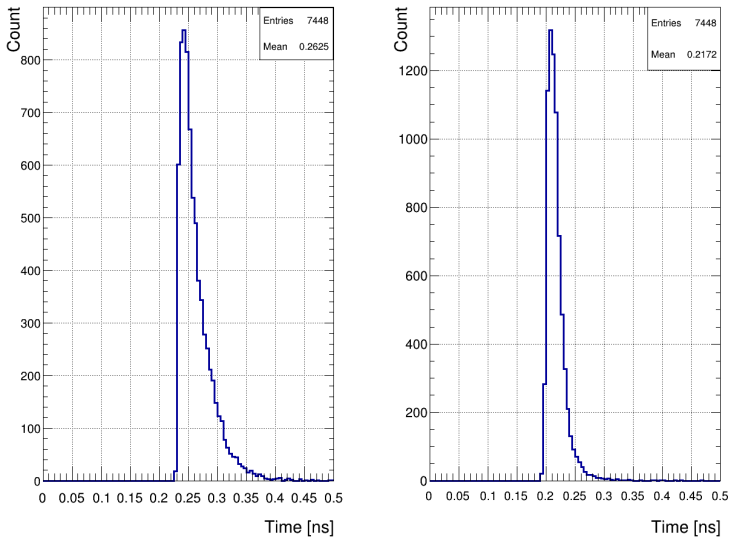
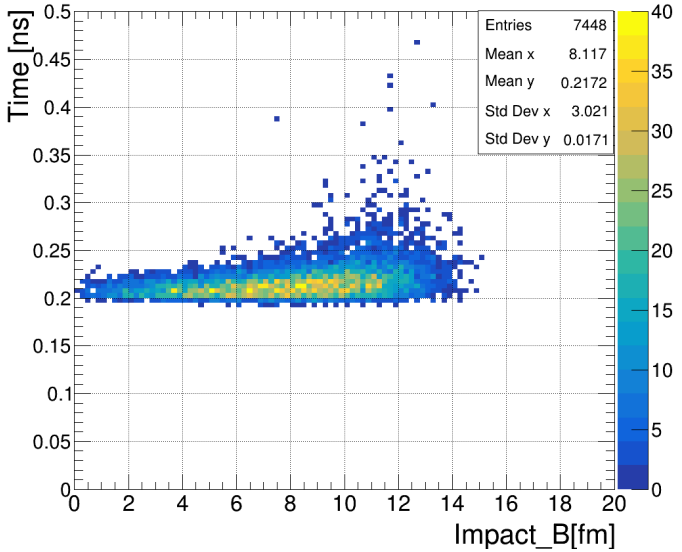
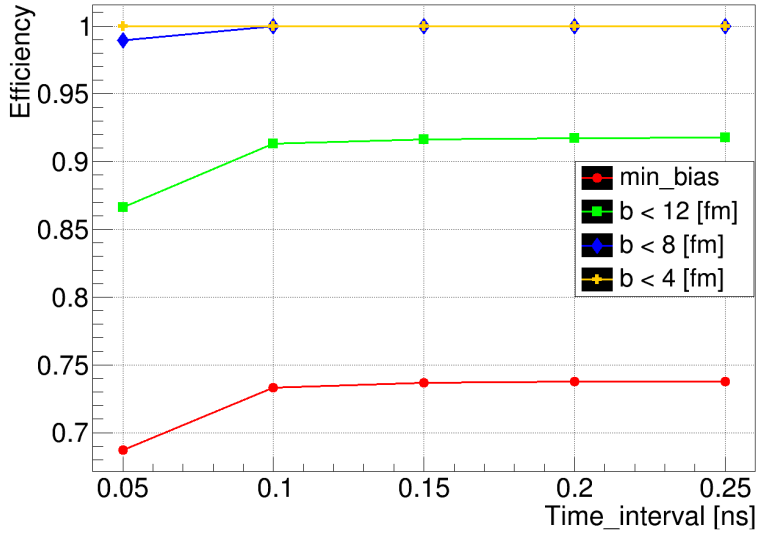


Arrival time of the first photon. Alignment



Arrival time of the first photon.
Centrality dependence



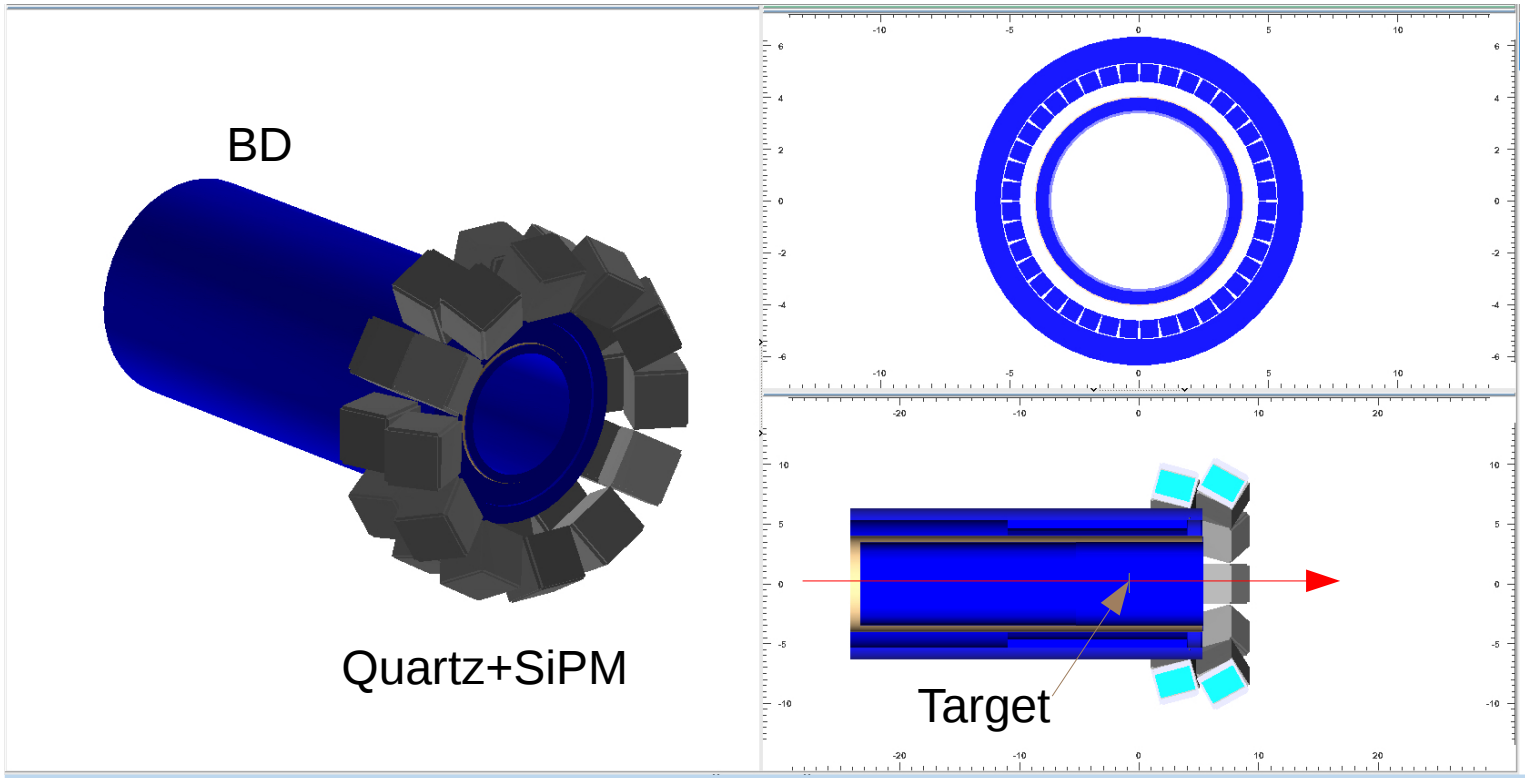
Efficiency vs centrality

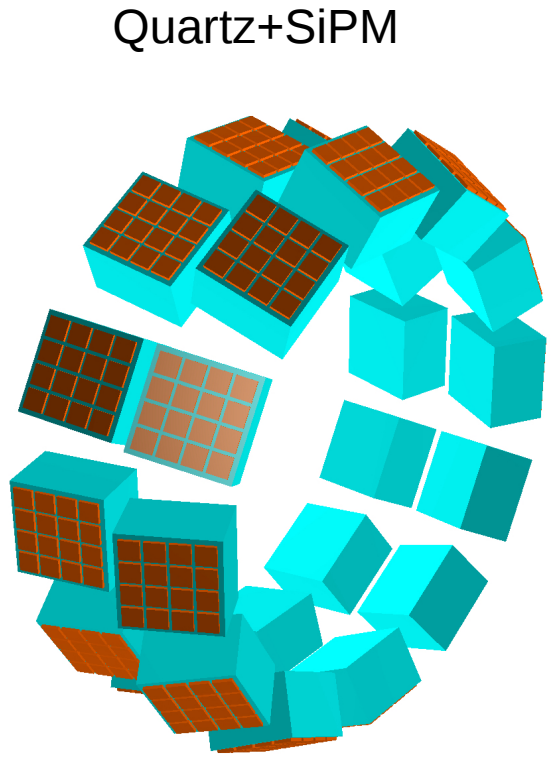
Detection condition:
arrival of more than 800 photons
(sum in all 4 FFD modules)
in 50-250 ps time window
after the first photon

T0 options at high beam intensity, Au+Au, $5 \cdot 10^7$

2) Quartz + SiPM T0

Two rings of 12 quartz radiators 30 x 30 x 20 mm^3 , each viewed by 16 SiPMs 6 x 6 mm^2.
Detection condition: more than N x 100 photons registered by SiPM's (in any of the modules)
in 50-200 ps time window after the first photon.





Quartz+SiPM T0 efficiency simulation: Au + Au, 4 GeV/n

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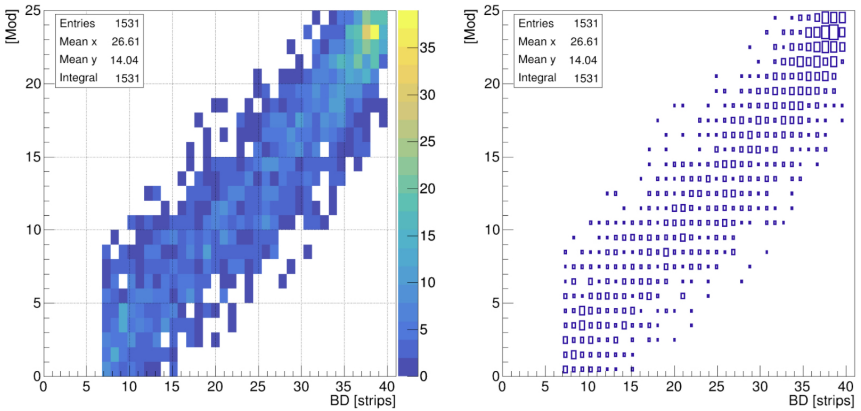
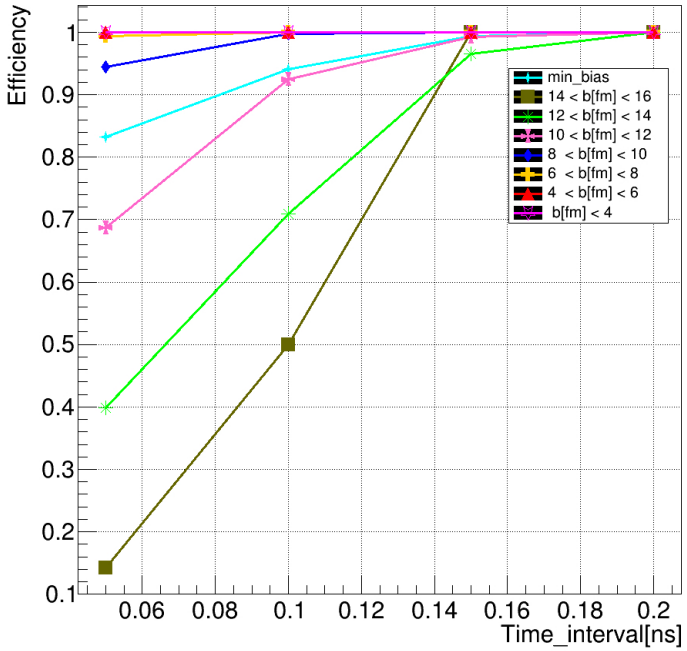
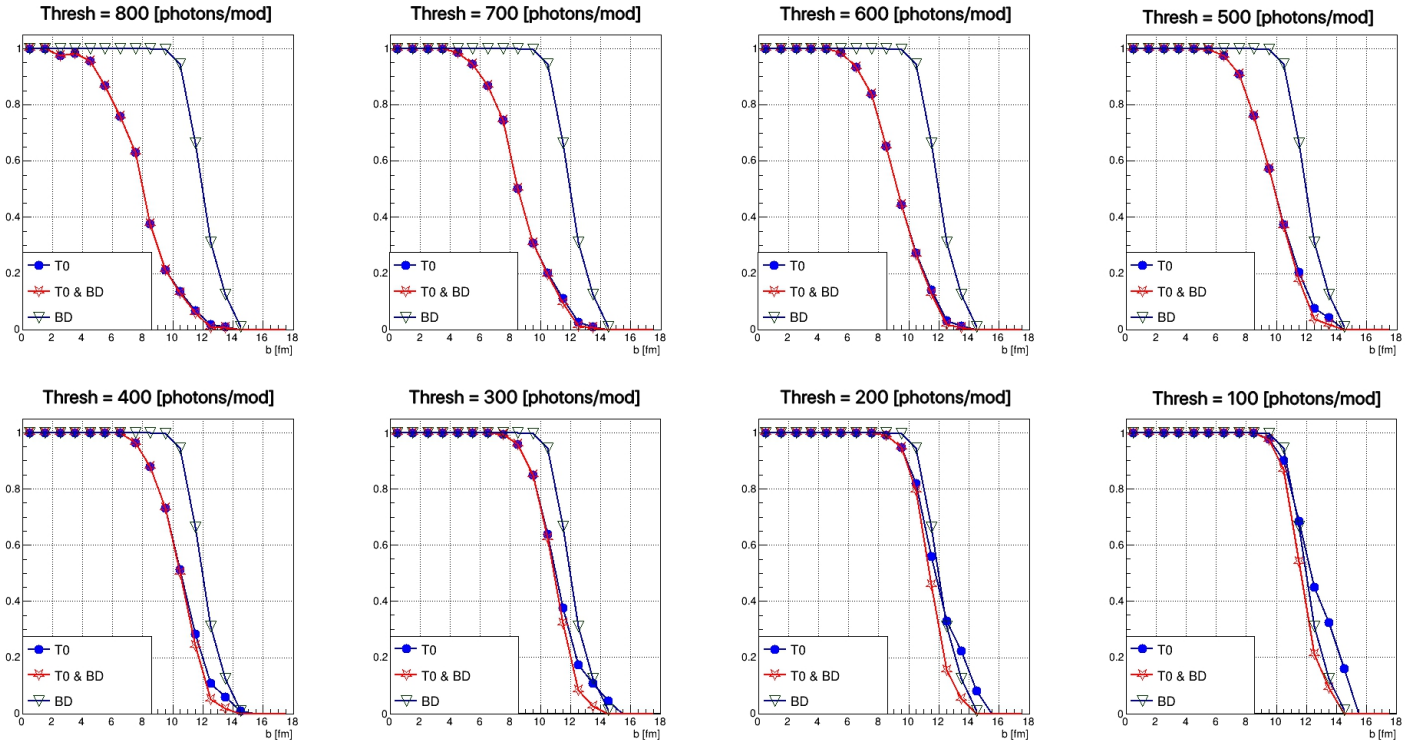


BD counts vs. T0 counts





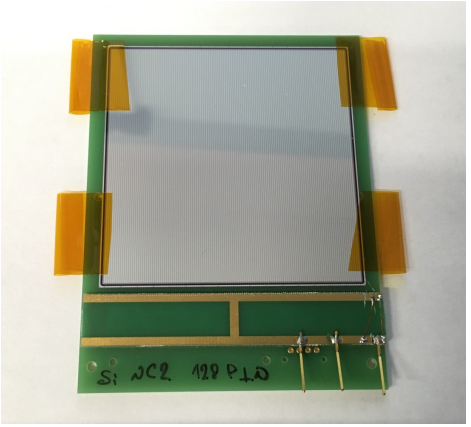
Efficiency vs centrality for different thresholds in T0 modules

Centrality dependence
of T0 efficiency.
More than 100 detected photons
(QE folded in) in time windows
of 50, 100, 150, 200 ps.

T0 options at high beam intensity, Au+Au, >5·10^6

3) Si-tracker detector + TOF Nino chip

Group of N.Zamjatin and TOF Group

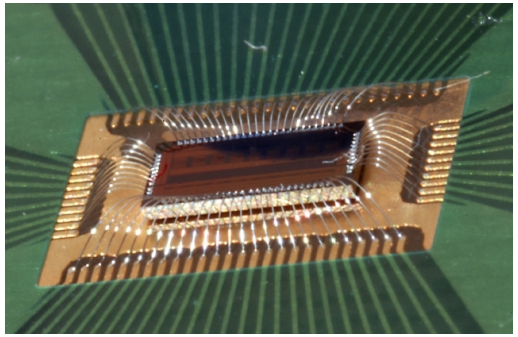


Si Tracker Detector:

– double-sided
– active area 63 x 63 mm^2
(take middle area 30 x 30 mm^2)
– pitch 475 μm
– 128 x 128 strips
(take middle part 64 x 64 strips)
– thickness 175 μm

Current status:

– under discussion
– planned for testing



NINO ASIC:

– 8 channel chips
– developed in CERN for TOF applications
– BM@N TOF Group has positive experience with them
– Basic idea:
Si det. 2x64 signals → 16 NINO cards → 2TDCs

Thank you for your attention