Status of Forward Silicon detector on BM@N

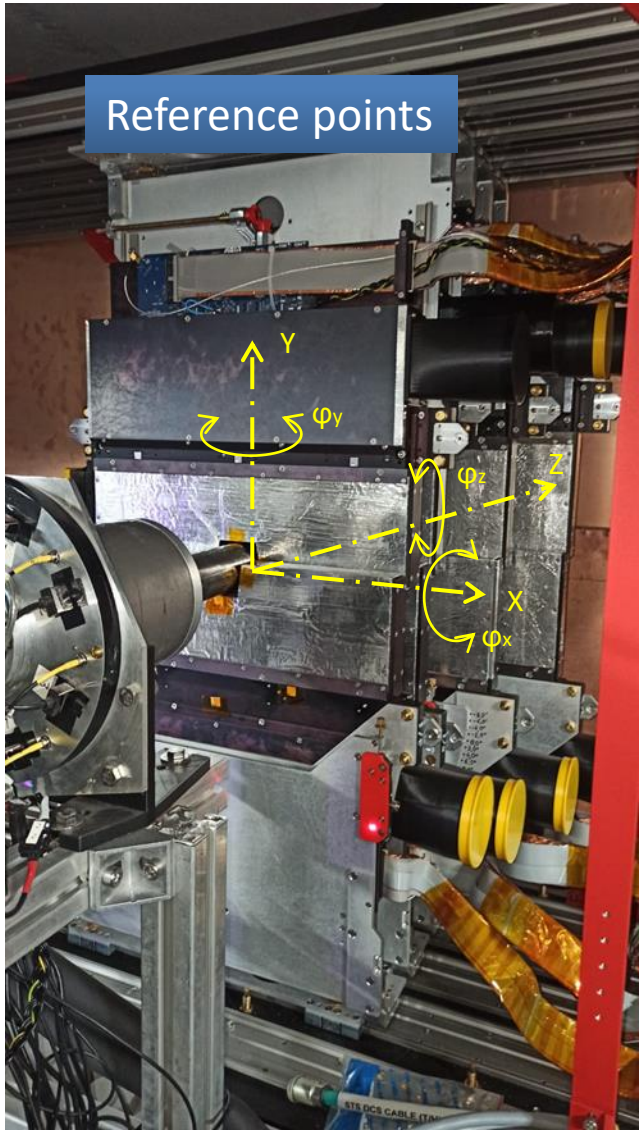
N. Zamyatin *on behalf of Forward Silicon Detector team*

Analysis and Detector Meeting of the BM@N Experiment at NICA, 04-05 March 2025

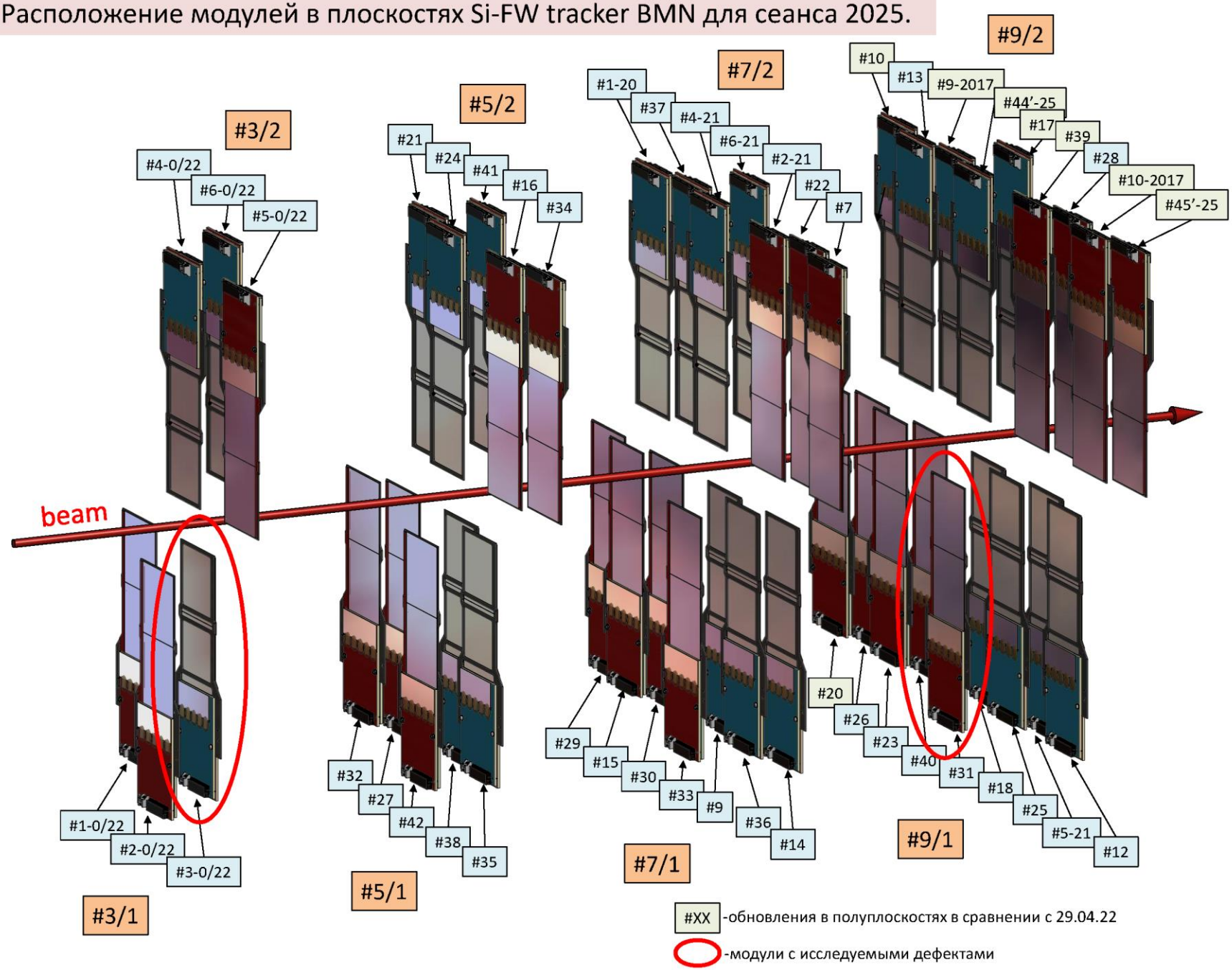
FWD-Si relative to the target on the BM@N experimental hall for the April-June-2025 session

All 8 FSD planes were installed and adjusted in the SP-41 magnet:

- After preliminary positioning of each half-plane relative to the beam pipe, the coordinates of the reference points on the planes in the coordinate system of the installation were measured using laser geodesy and the reversals (distortions) of the planes around the axes (ϕ_x; ϕ_y; ϕ_z) were determined;
- Adjustments were made to minimize distortions (the difference between the corresponding coordinates of the two reference points is no more than 0.3 mm) and the final measurement of the coordinates of the reference points (with an accuracy of +/-0.01 mm).

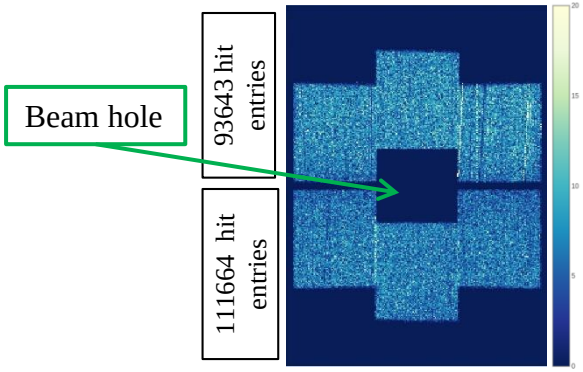


Расположение модулей в плоскостях Si-FW tracker BMN для сеанса 2025.

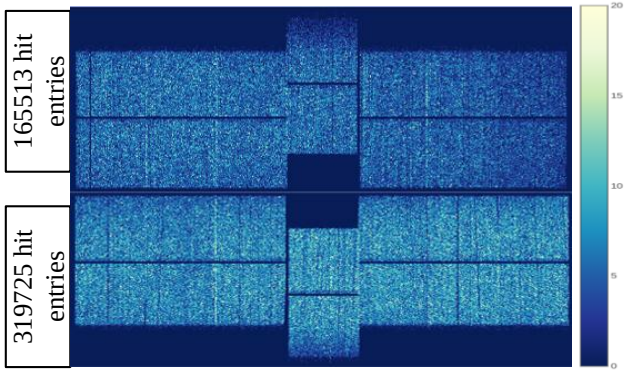


FSD: after replacing

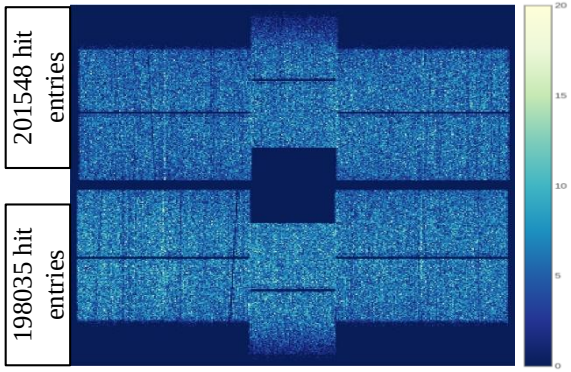
Cosmic tests station 1



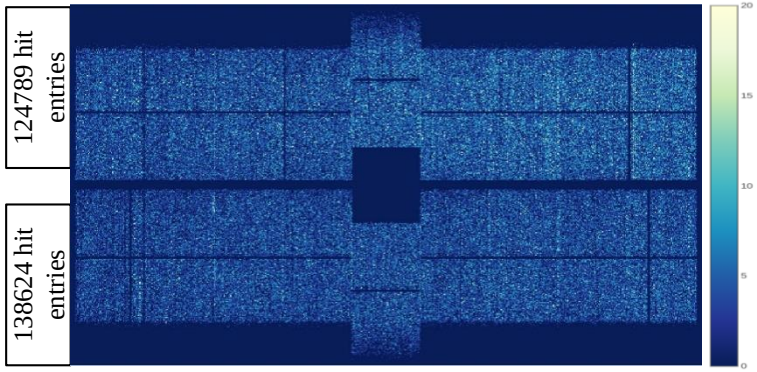
Cosmic tests station 3



Cosmic tests station 2



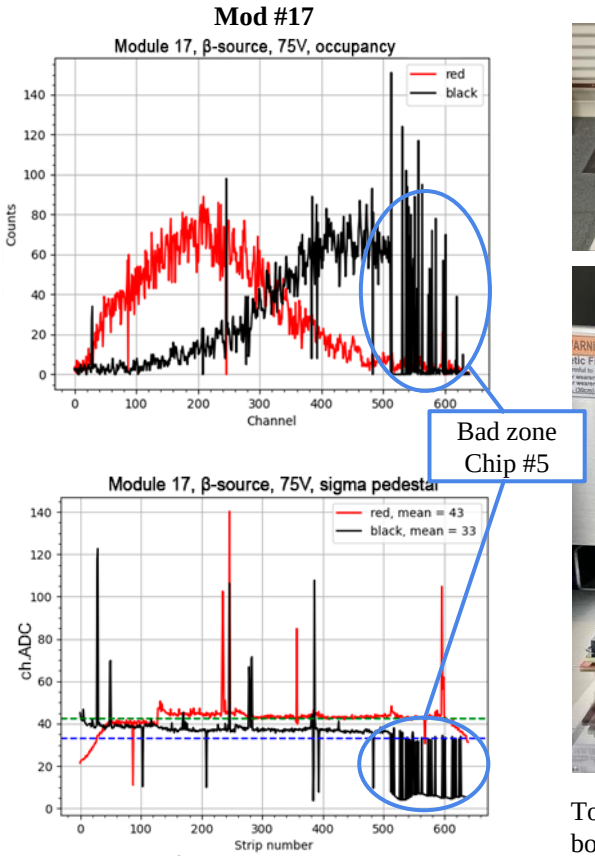
Cosmic tests station 4



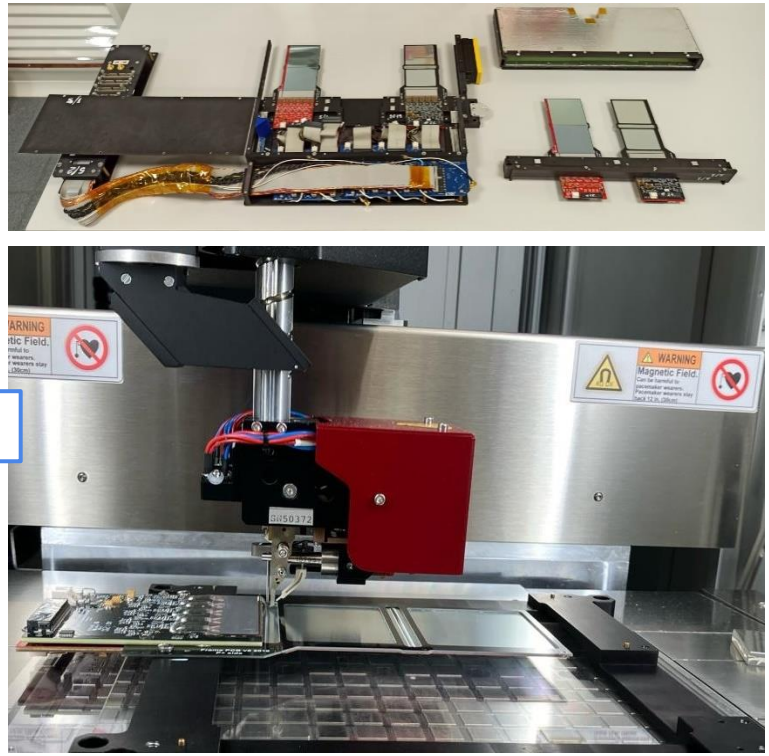
All dead zones have been eliminated!

E.V. Martovitsky; D.D. Chemezov

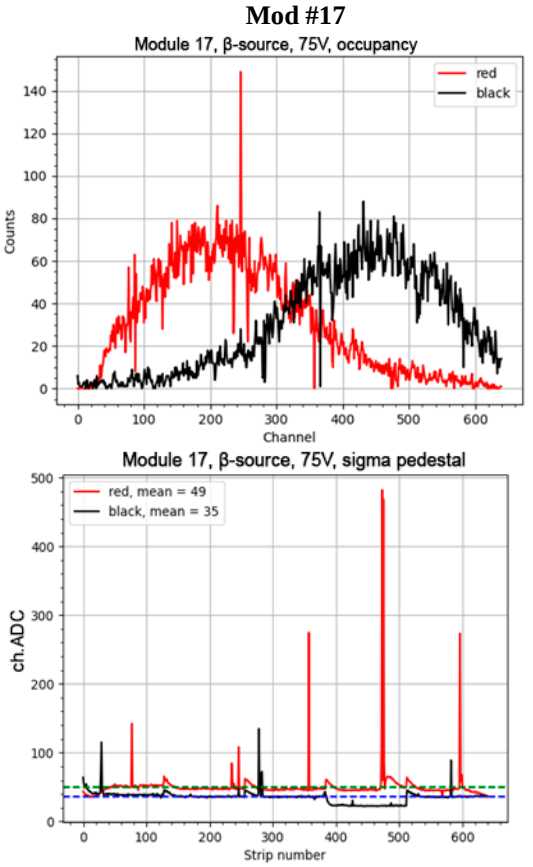
FEE board replacing



Before replacement



To eliminate the dead zones it was necessary to assemble a new FEE board completely, 5 ASICs were spent to eliminate each of defects. The old boards were disconnected from the modules and replaced with a new ones. Total: 9 new black boards (p+ strips) were built, 45 VATAGP 7.2 ASICs were used (30 spare ASICs available).

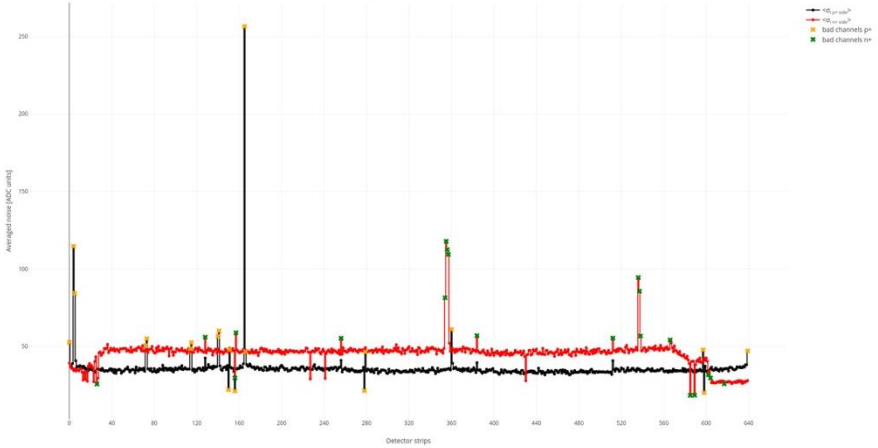


After replacement

Yu.A. Kopylov; O.G. Tarasov

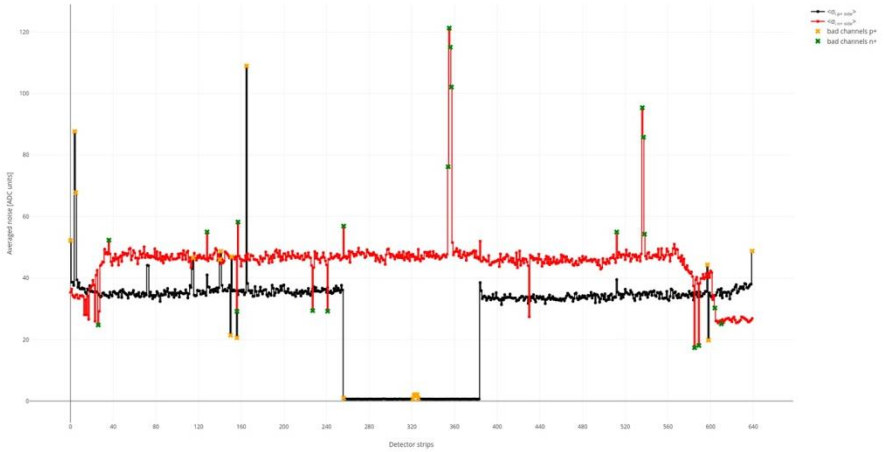
27.02.2025, 14:56

Station #1, module #3-0/22

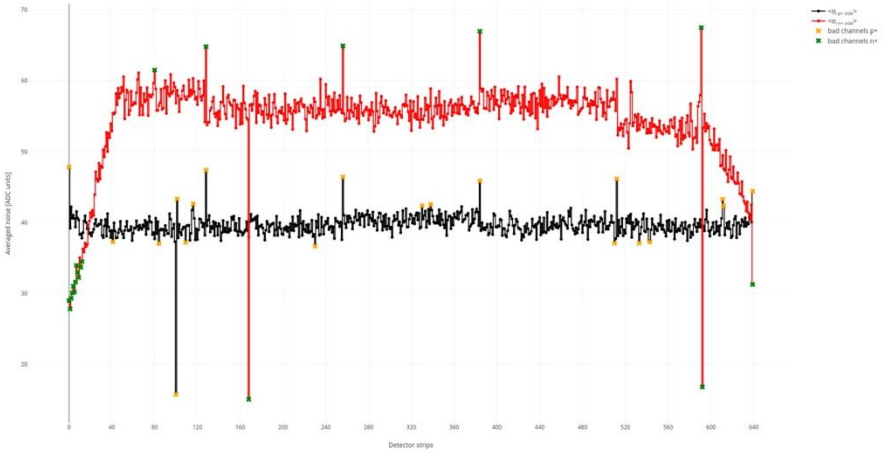


27.02.2025, 16:44

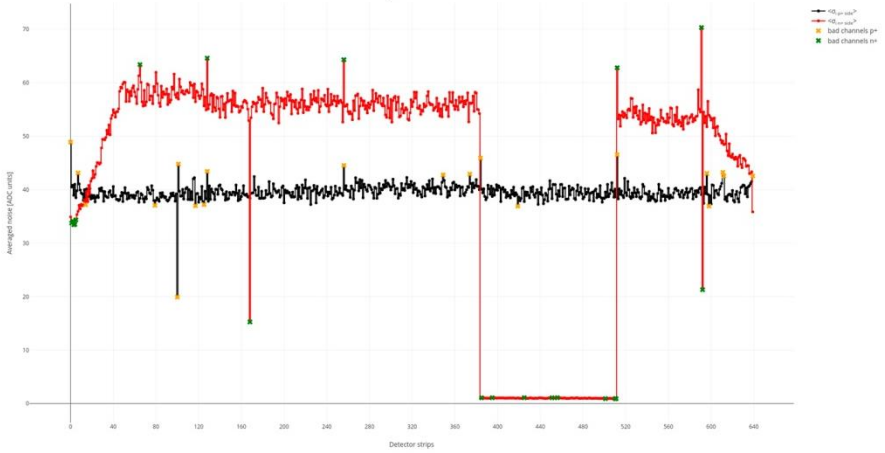
Station #1, module #3-0/22



Station #4, module #31

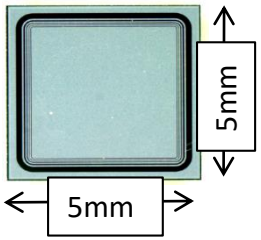


Station #4, module #31



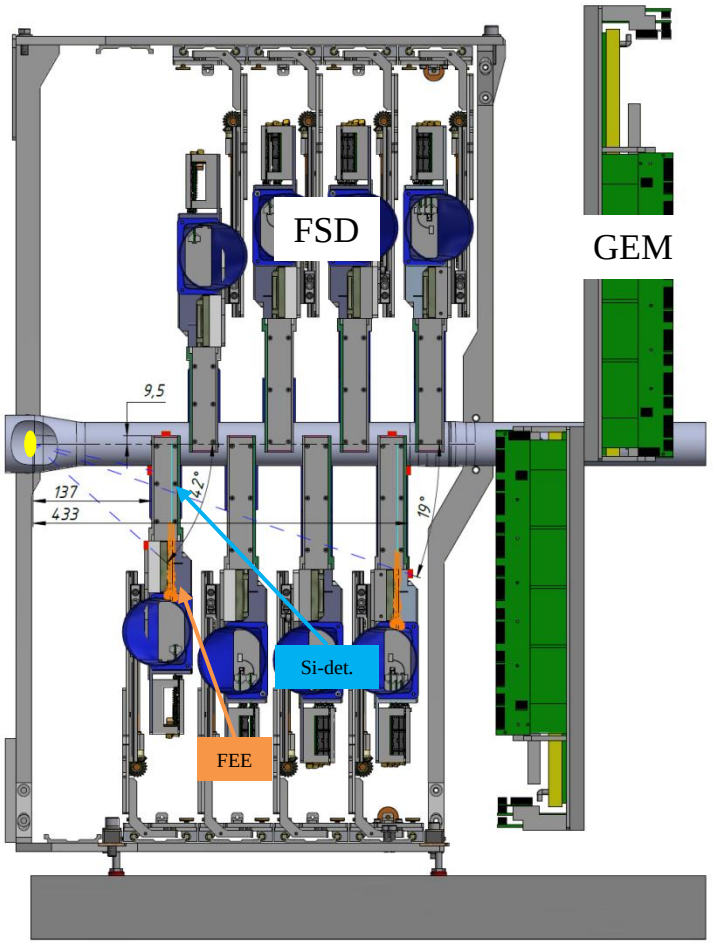
Radiation Si-monitors on FSD region for equivalent neutron fluence measurement

Si- pin-detector (rad_monitor) :
- Detectors size**: (5×5×0,3) mm^3**
- Detectors thickness: **300 µm**
- Active area: **13 mm^2**



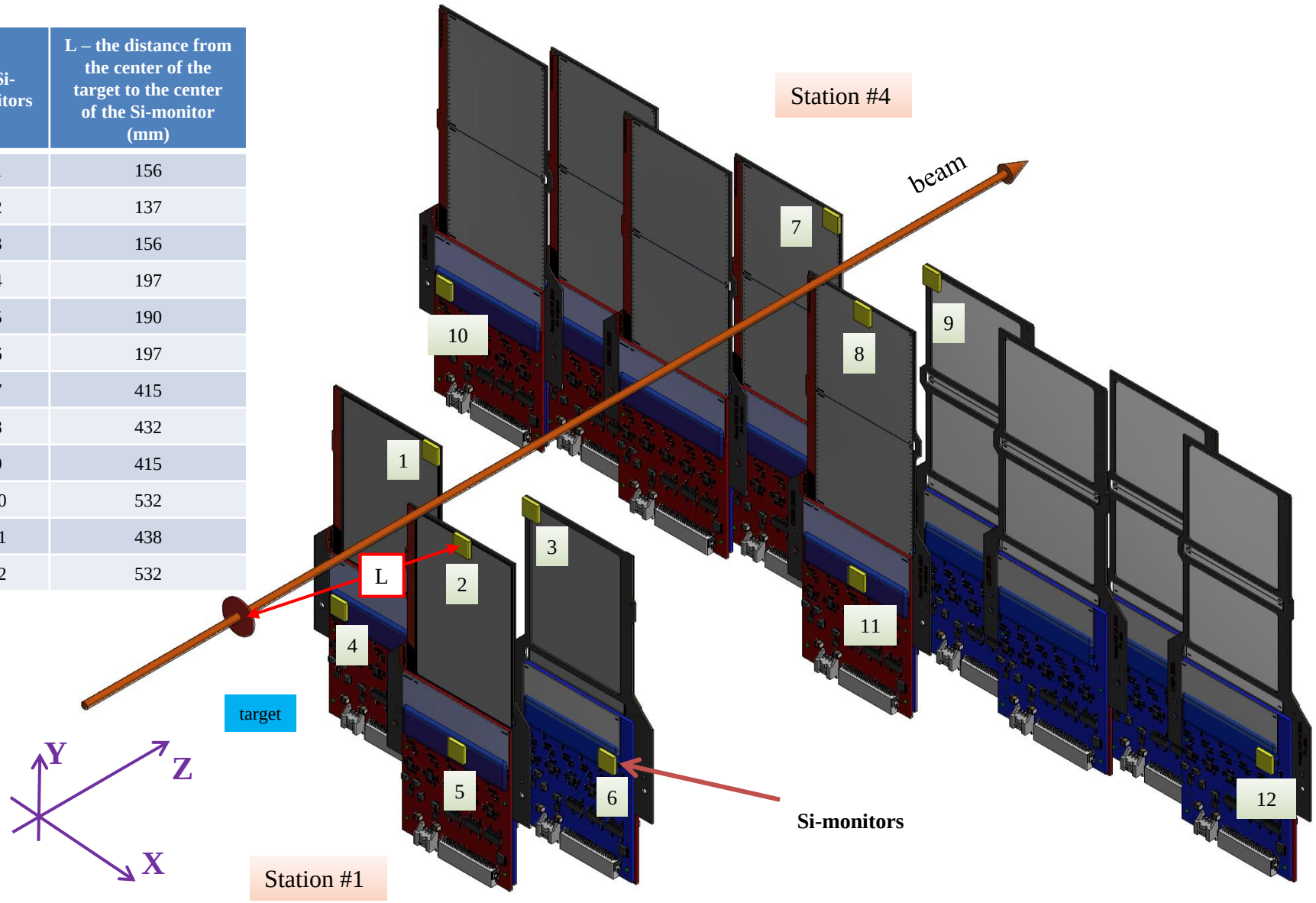
$$\Delta I = \alpha_I \times V \times \Phi$$

$\Delta I = I_\phi - I_0$, (A):
- **I_ϕ** – dark current after irradiation;
- **I_0** - dark current before irradiation;
- **α_I** = $(5\pm0,5)\cdot10^{-17}$ (A×cm^{-1}) – radiation damage constant-Si (for neutrons 1MeV at +20°);
- **V**, (cm³) – volume of SCR (spice charge region at U_{fd});
- **Φ,** (cm^{-2}) – eq. neutron fluence (1 MeV)



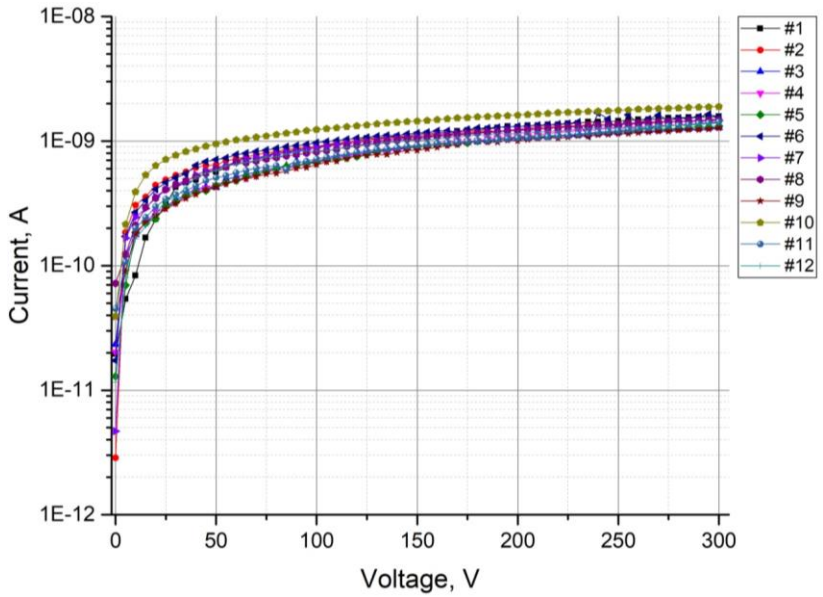
Radiation Si-monitors on FSD region for equivalent neutron fluence measurement

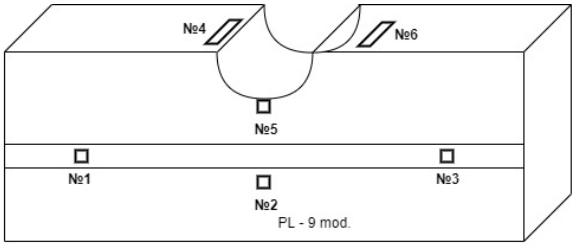
# Si-monitors	L – the distance from the center of the target to the center of the Si-monitor (mm)
1	156
2	137
3	156
4	197
5	190
6	197
7	415
8	432
9	415
10	532
11	438
12	532

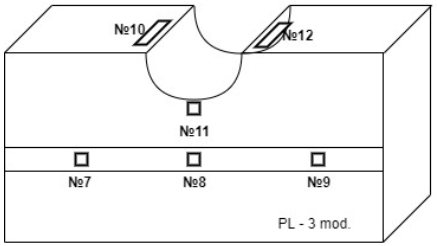


PAD detectors-monitors are installed on the FSD planes №1 and №4

Detector's number	d, mm	S, mm^2	V, mm^3	I, nA (V_{op}= 100V) (before irradiation)	Expected Φ, cm^{-2}	Expected ΔI, nA (after irradiation)
1	0,248	13	0,003224	0,898	1×10^{10}	1,61
2	0,250	13	0,00325	0,885		1,63
3	0,242	13	0,003146	0,691		1,57
4	0,248	13	0,003224	0,673		1,61
5	0,241	13	0,003133	0,671		1,57
6	0,249	13	0,003237	0,970		1,62
7	0,241	13	0,003133	0,882		1,57
8	0,249	13	0,003237	0,816		1,62
9	0,238	13	0,003094	0,646		1,55
10	0,253	13	0,003289	1,23		1,64
11	0,250	13	0,00325	0,719		1,63
12	0,242	13	0,003146	0,835		1,57



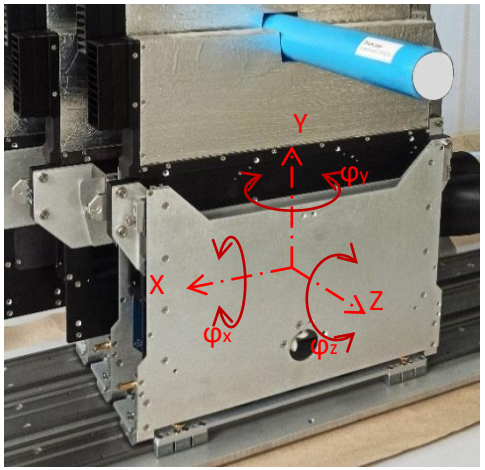


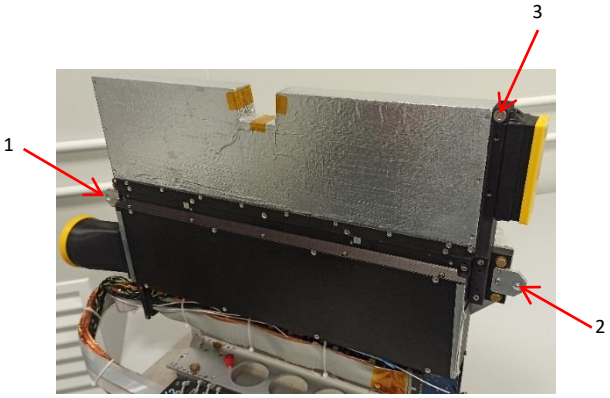


Current situation on FSD installation and tests on BM@N experimental hall, list of works to be done

1. In February-2025, FSD assembly, alignment and tests were performed on the BM@N experimental hall. By using of the developed device for coordinate planes position adjustment the alignment accuracy of 0.3 mm with XYZ axes was achieved. The accuracy of measurement of the reference points of the planes relative to the zero of the BM@N coordinate system is +/- 10 μm.
2. During tests (pedestal noise) after alignment, two “dead” chips (128 channels FEE=1 ch.ADC each) were found in half-plane Pl-(3-1) and half-plane Pl-(9-1), these half-planes have been removed from the experimental hall and will require re-alignment on the channel + repeat tests.
3. The behavior of defects in time is unstable (flickering), which indicates the operability of all electronic components of the module, we hope that this is a defect of PCB mounting contacts.
4. Disassembly of half-planes and removal of modules with defects will be required. After troubleshooting, the modules will be installed in the half-planes, and work on reassembling and adjusting the planes should be completed by early April 2025.

Backup

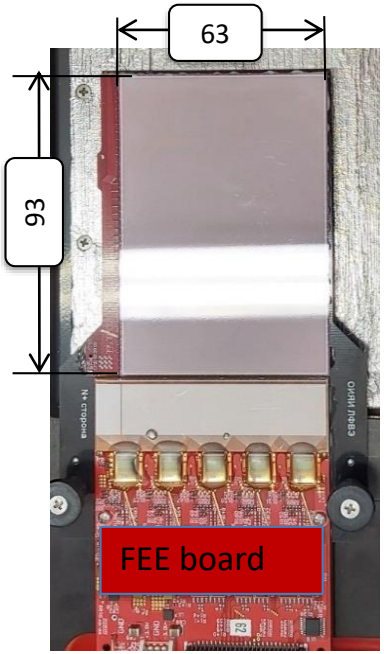




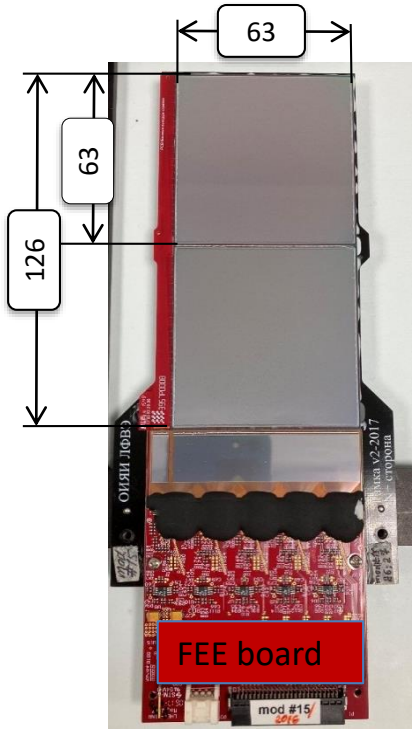
После предварительного позиционирования каждой полуплоскости относительно трубы с помощью лазерной геодезии измерялись координаты ее трех реперных точек (1; 2; 3) в системе координат установки и определялись ее развороты вокруг осей (φ_x; φ_y; φ_z) (перекосы). Производилась регулировка для минимизации перекосов (разница соответствующих координат двух реперных точек не более 0.3 мм) и окончательный замер координат реперных точек (с точностью 0.01мм).

Two type of Si-modules for Forward Si detector

Station1
DSSD 63x93mm^2
6 modules



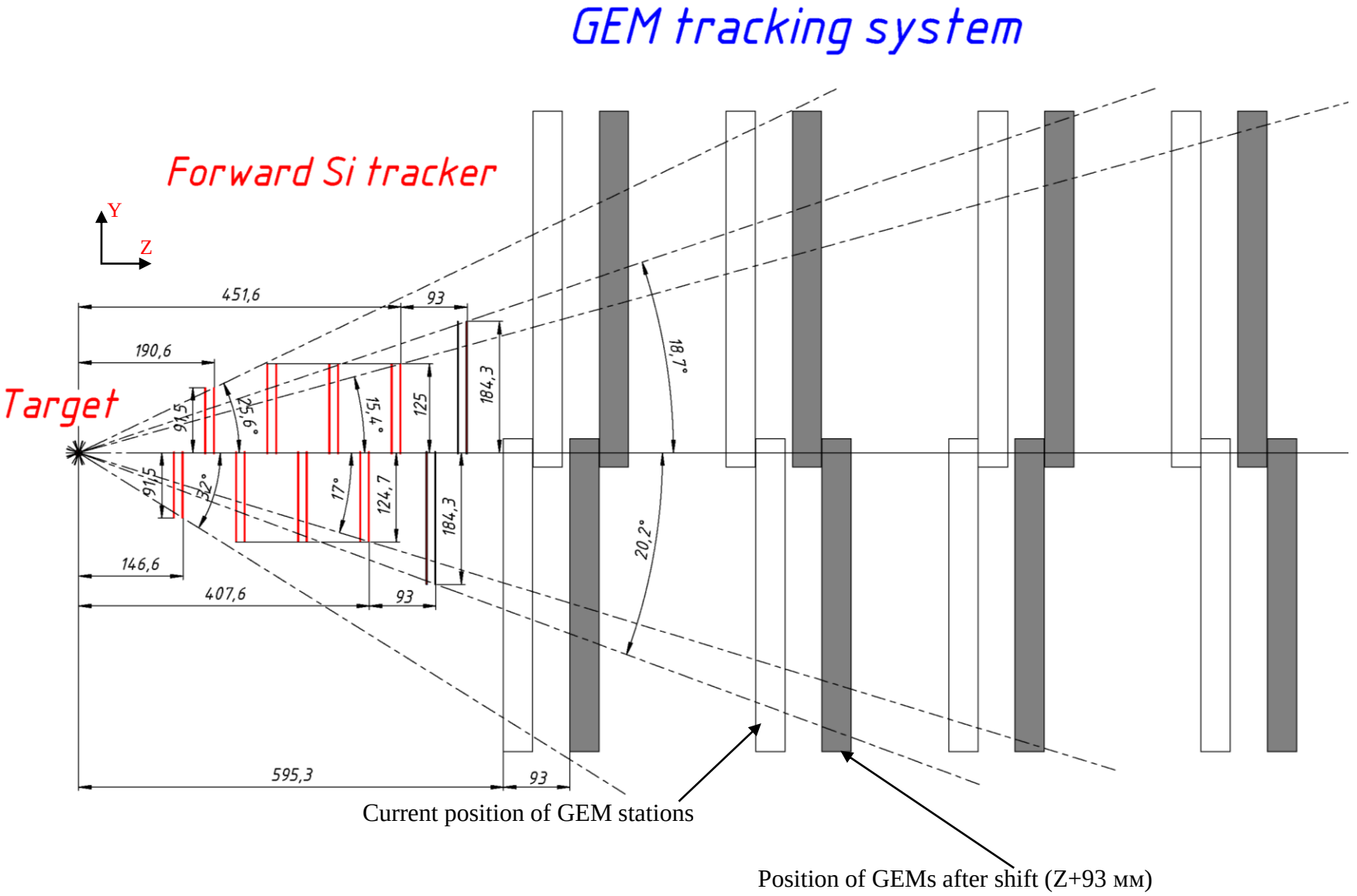
Detectors size: 63x93x0,3 mm^3 (on 6” – FZ-Si-n wafers)
Topology: double sided microstrip (DSSD) (DC coupling)
Pitch p^+ strips: 95 μm;
Pitch n^+ strips 107,1 μm;
Stereo angle between p^+/n^+ strips: 2.5^0
Number of strips/DSSD: 640 (p^+)×603(n^+)
Number of strips/module: 640 (p^+)×640(n^+)



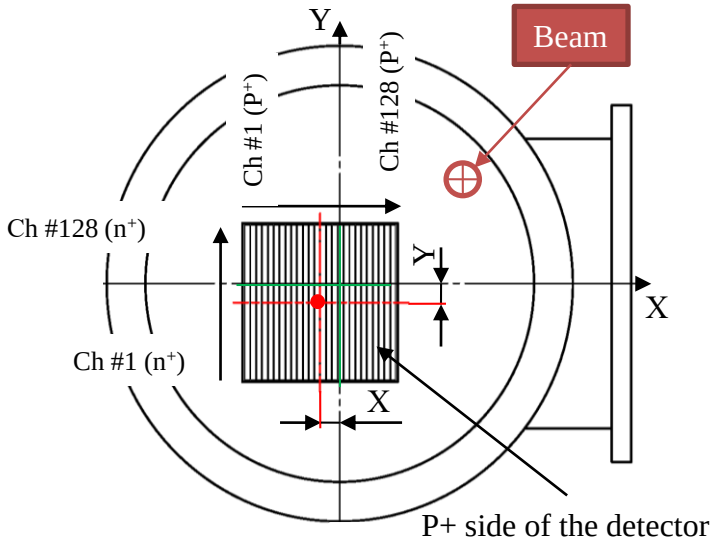
Station 2,3,4
DSSD 63x63mm^2
42 modules

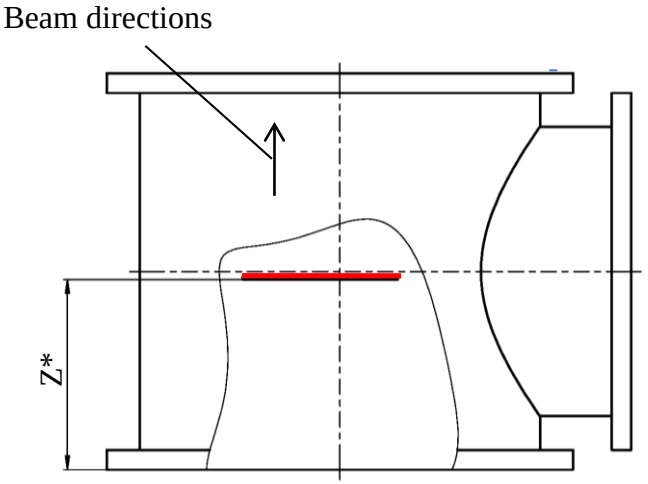
Detectors size: 63x63x0,3 mm^3 (on 4” – FZ-Si-n wafers)
Topology: double sided microstrip (DSSD) (DC coupling)
Pitch p^+ strips: 95 μm;
Pitch n^+ strips 103 μm;
Stereo angle between p^+/n^+ strips: 2.5^0
Number of strips/DSSD: 640 (p^+)×614(n^+)
Number of strips/module: 640 (p^+)×640(n^+)

Y-Z cross section of central tracker



Position of double-coordinate Si-detectors relative to the axis of the ion guide





*Distance between the flange surface and the detector surface.
Detector rotation in the coordinate plane no more than 0.5^0

Beam tracker detector center coordinates relative to the ion guide axis (mm)

#	X	Y	Z*
#1	0.0	0.9	94.7
#2	2.7	-0.3	96.9
#3 (Al)	0.4	0.1	94.9

Strip pitch in the detector: 0.45 mm
Number of strips: 128x128
Thickness: 175 μm
Size: 63 x 63 mm^2

Beam profilometer detector center coordinates relative to the ion guide axis (mm)

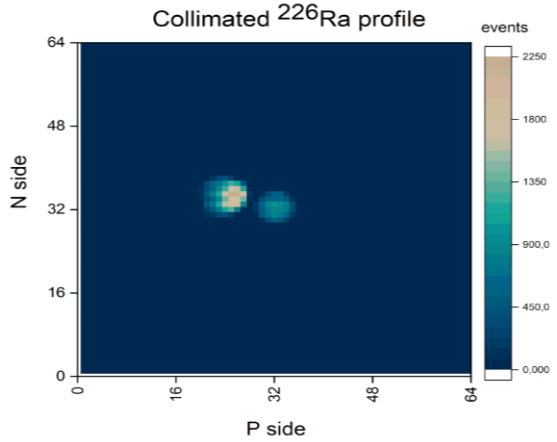
#	X	Y	Z*
#1 (electric)	-1.3±0.1	0.7±0.1	99.7
#2 (pneumatic)	-2.7±0.5	1.4±0.2	100.7

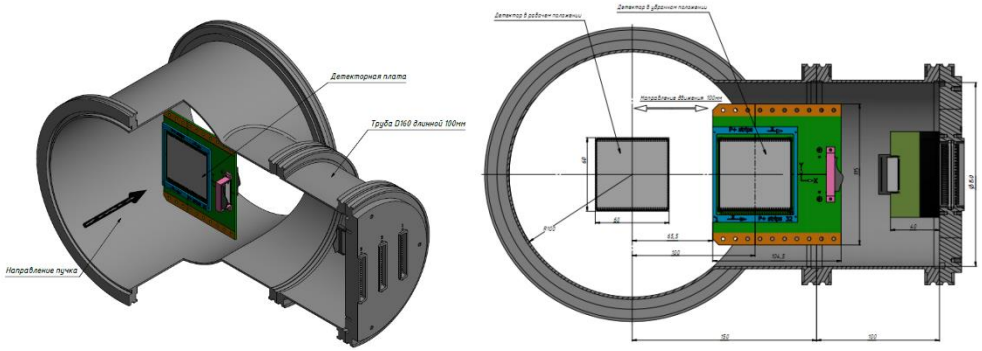
Strip pitch in the detector: 1.87 мм
Number of strips : 32x32
Thickness: 175 μm
Size: 60 x 60 mm^2

New beam profilometer (64×64) strips for heavy ions (Xe, Au, Bi)

На рис. результаты тестов-2022 с альфа источником Si – профилометра:

- такую же картину мы хотели получить при работе с пучком, но не удалось из-за наложений при «медленной» электронике (ИС-VA163);
- оба профилометра были убраны в положение «парковка» и не использовались в сеансе;
- наши планы и действия – ведется новая разработка (С.Хабаров+О.Тарасов) конструкции плоскости детектора (128x128) стрипов превращаем в (64x64) стрипа + новая FEE на основе ИС HDR64/VA, чипы есть в наличии, детекторные платы разработаны, изготовлены и готовы к сборке детекторов, FEE-PCB в разработке (С.Хабаров), детекторы есть и тестируются (Е.Стрелецкая+Ю.Копылов), готовность – осень_23.



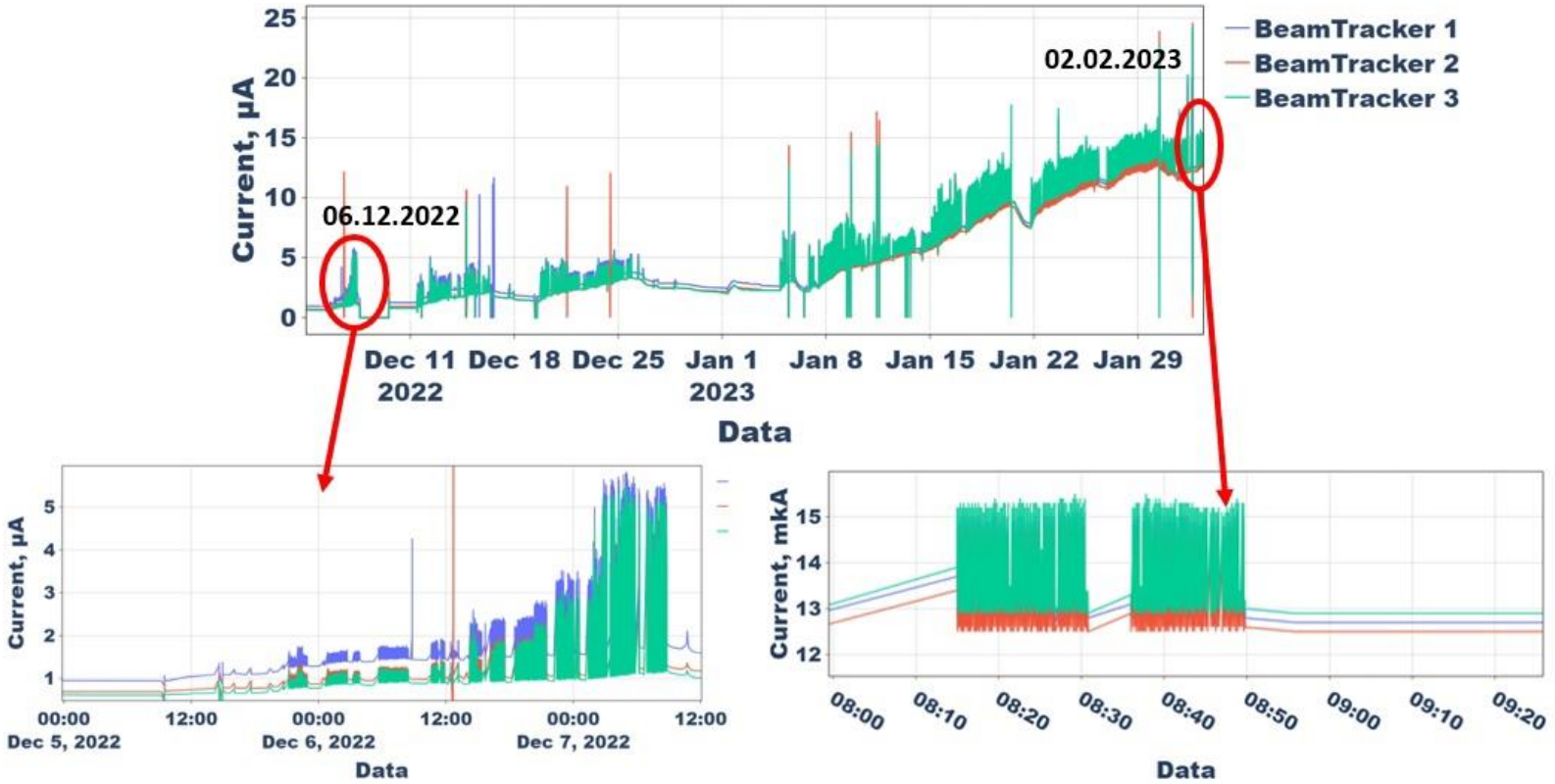


working position

parking position

- **detector:** DSSD, ($32p^+ \times 32n^+$), strips pitch = 1.8 mm, thickness (Si) -175 μm, active area (60 × 60) mm^2;
- **mechanical design:** the plane of the profilometer is automatically removed from the beam zone to the parking position;
- **FEE:** for light ($_6C \div {}_{18}Ar$) ions based on **VA163 + TA32cg2 (32 ch, dynamic range (DR): -750fC ÷ +750fC) desing in progress**;
- **current status:**

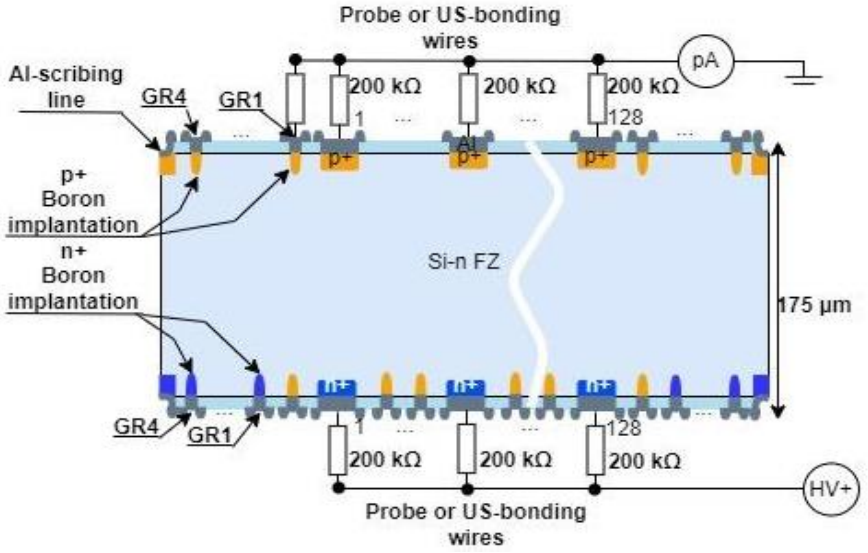
- two vacuum stations with flanges and cable connectors are ready, Silicon Detectors assembled on PCBs and tested with alpha-source (5.5 MeV), autonomus (ADC+DAQ) subsystem ready;
- for heavy (Kr ÷ Au) ions will be developed another version of the FEE with DR = ± 20 pC.



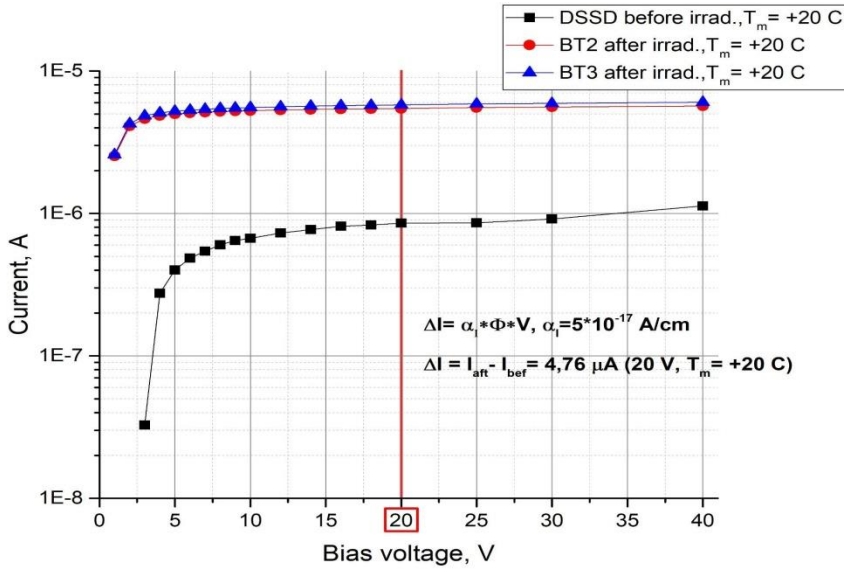
Run start, <I> = 0.761 μA; t = +22.5°C

Run stop, <I> = 12.7 μA; t = +26.8°C

Currents of SiBT(1÷3) detectors at the beginning of the run and at the end of the run:
"substrate" is the dark current created by radiation defects of Xe-ions;
fast pulse component is the ionization current during the spill.



(a)



(b)

Schematic of measurements (a) of the dark current of the double-sided silicon strip detector and I–V curve (b) before and after the session.

Formula for determining the equivalent 1MeV neutron fluence from silicon damage:

$$\Delta I = \alpha_1 \cdot \Phi \cdot V$$

where: α_I – current constant of silicon damage is equal to 5×10^{-17} A/cm, at +20˚C for neutrons with energy of 1 MeV and physically means the current increment in a silicon detector of 1 cm^3 volume from the passage of one neutron (1 MeV),

Φ, cm^{-2} – neutron fluence,

V, cm^3 - detector volume.

	I_{d0}, мкА/+20 В/+22.5°С (04.12.2022 начало сеанса)	$I_{d(ф)}$, мкА/+20 В/+26.8°С (2.02.2023 окончание сеанса)	ΔI = Id(ф) – Id0= αI ·Ф·V, мкА (приведённое к +20 °С)
ВТ1	**0.965**	**12.7**	***4.76***
ВТ2	**0.692**	**12.5**	***4.6***
ВТ3	**0.626**	**12.9**	***4.93***

	Эквивалентный флюенс нейтронов 1 МэВ, $см^{-2}$ (измерен по радиационным повреждениям Si)	**Флюенс ^{128}Xe, $см^{-2}$ расчет через NIEL, *К(^{128}Xe/нейтрон 1МэВ)=276***	**Число ядер ^{128}Xe, прошедших за сеанс через Si-детекторы ВТ(1÷3), S_a=37 $см^2$**
ВТ1	**5.117e+12**	**1.854e+10**	**6.899e+11**
ВТ2	**4.945e+12**	**1.792e+10**	**6.667e+11**
ВТ3	**5.300e+12**	**1.920e+10**	**7.145e+11**
Среднее	**5.117e+12**	**1.854e+10**	**6.899e+11**