# Forward Silicon Tracker (FSD) status

Oleg Tarasov on behalf of Forward Silicon Tracker team

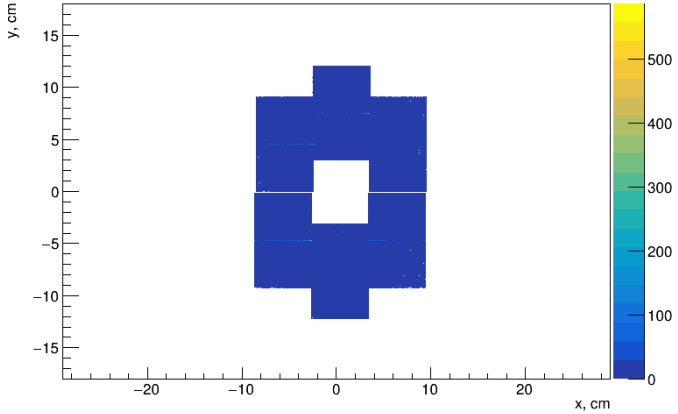
**12th Collaboration Meeting of the BM@N Experiment at the NICA Facility**
**May 13 – 17, 2024**

Content of the report:

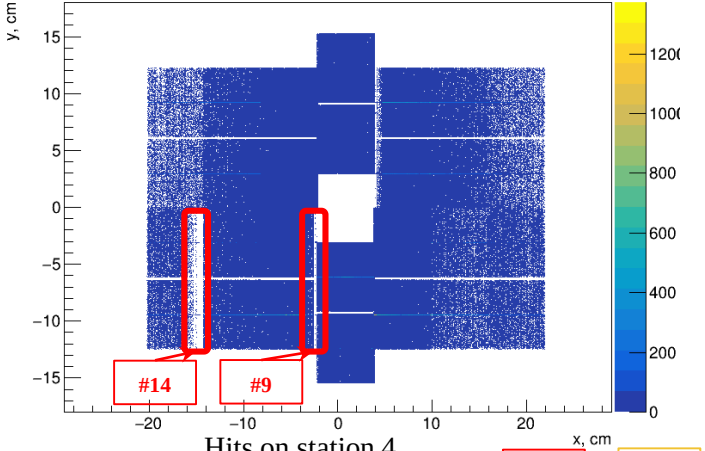
1 Diagnostics and elimination of defects in FSD-planes.
2 Coordinates of modules (Si-detectors) after disassembly-assembly of FSD-planes.
3 Refinment of FSD-planes positioning device in the BM@N experemental hall.
4 Conclusion.

# FSD: before replacing (Run 8305, 30.01.2023)

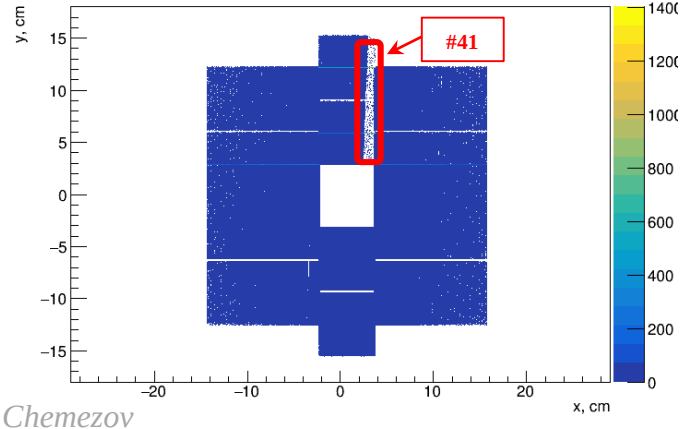
Hits on station 1
6 modules, DSSD 63×93 mm$^2$



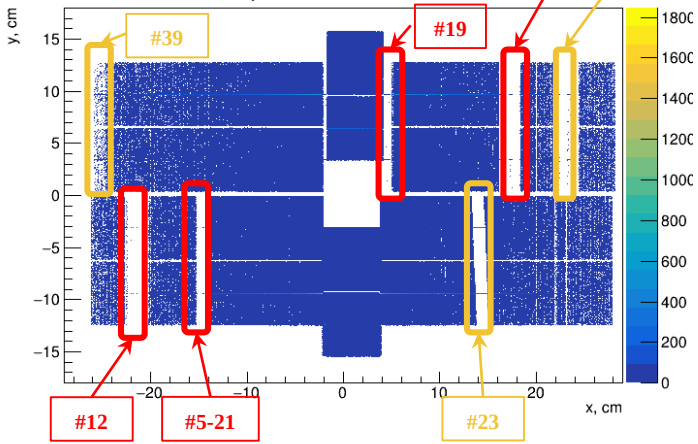

Hits on station 3
14 modules, DSSD 63×63 mm$^2$




Hits on station 2
10 modules, DSSD 63×63 mm$^2$




Hits on station 4
18 modules, DSSD 63×63 mm$^2$



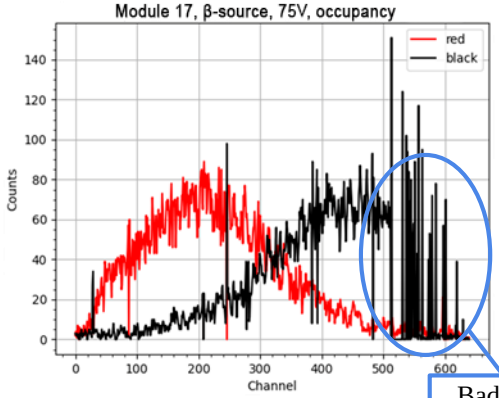

| Run | 8305 |
|---|---|
| Beam | Xe |
| Energy | 3.8 Gev/n |
| Target | CsI (2%) |

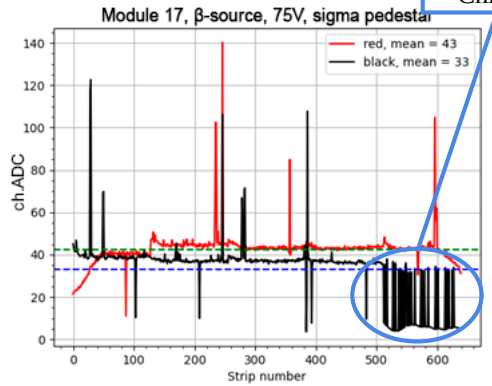
Summary:
10 dead zones, 3 were discovered before the run and 7 occurred during the run

| Module | Chip |
|---|---|
| #41 | 5Y |
| #14 | 5X |
| #9 | 5X |
| #39 | 1X |
| #19 | 5X |
| #13 | 4X, 5X |
| #17 | 4X, 5X |
| #12 | 4X, 5X |
| #5-21 | 5X |
| #23 | 4Y |

# FEE board replacing

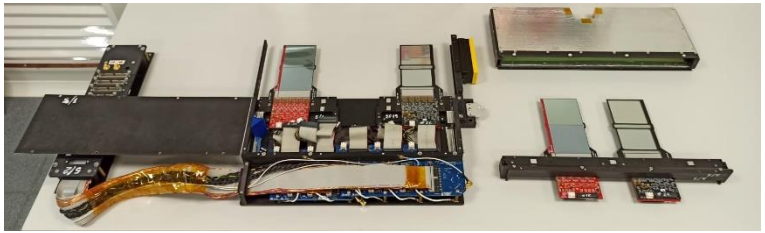
**Mod #17**

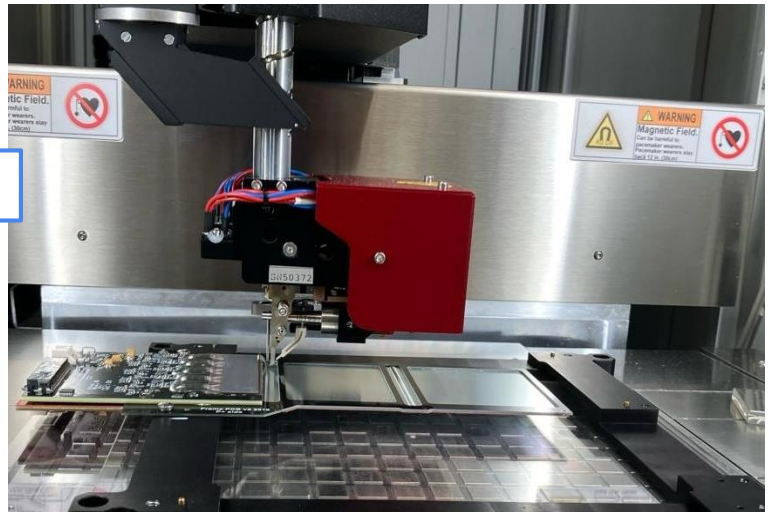



Bad zone
Chip #5

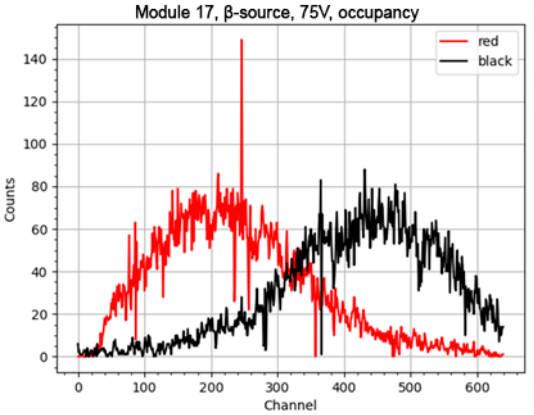
Before replacement

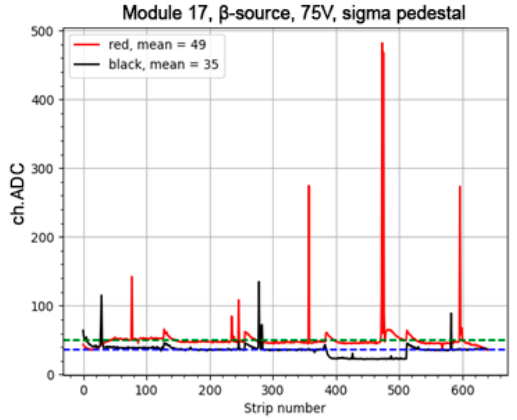





To eliminate the dead zones it was necessary to assemble a new FEE board completely, 5 ASICs were spent to eliminate each of defects. The old boards were disconnected from the modules and replaced with a new ones. Total: 9 new black boards (p+ strips) were built, 45 VATAGP 7.2 ASICs were used (30 spare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

**Mod #17**



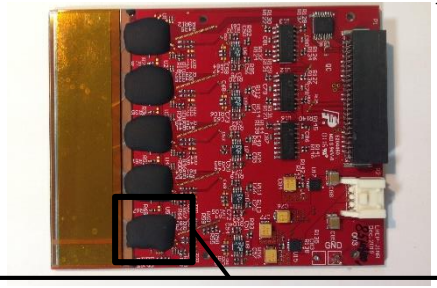



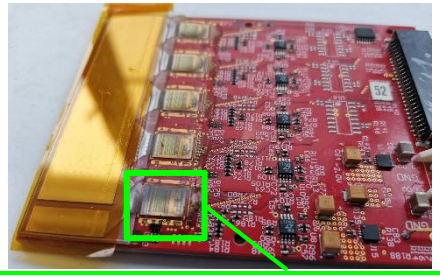

After replacement



*Yu.A. Kopylov; O.G. Tarasov*

# Repairable FEE boards with new compound





Black **BE-08** encapsulant (polarization temperature 100°C)

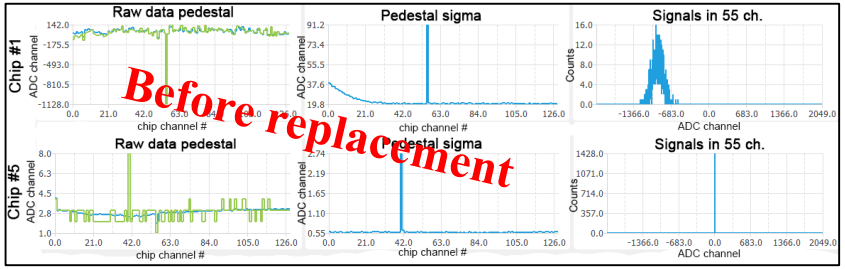
- an additional optical shield for chips
- **Not removable** mechanically or with chemical solvents (dimethyl sulfoxide, dimethylformamide, $CH_2O_2$)

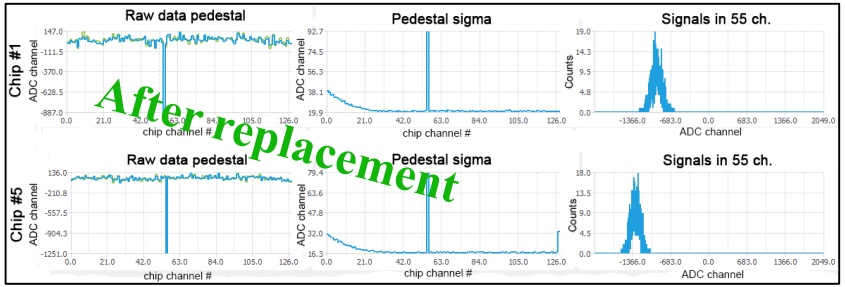
Ultra Light-Weld 9008 Flexible, UV-Curable Encapsulant

- Does not create an additional optical shield
- Can be mechanically removed so **FEE boards are repairable**

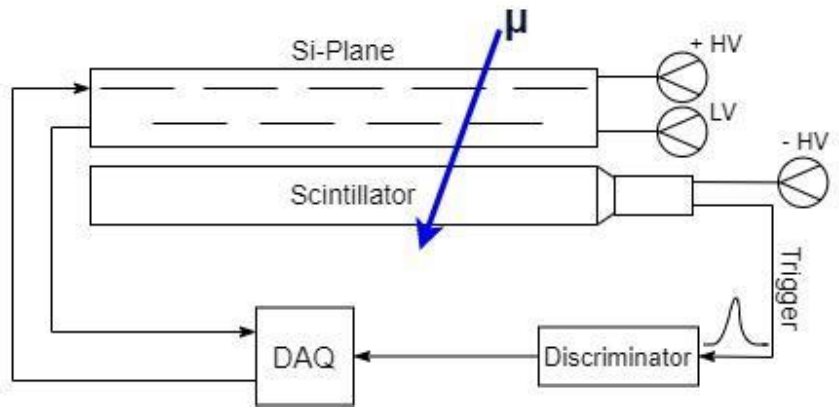
Replacement of one chip:

removed chip



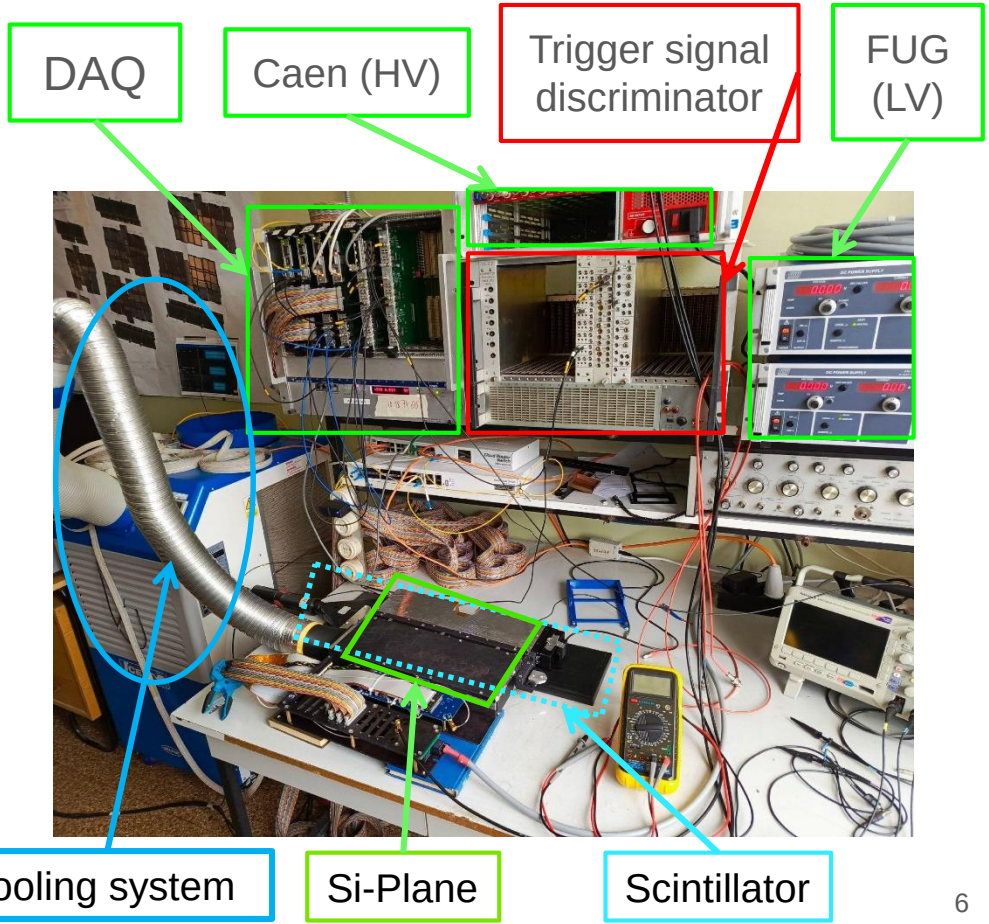



# Cosmic tests of FSD



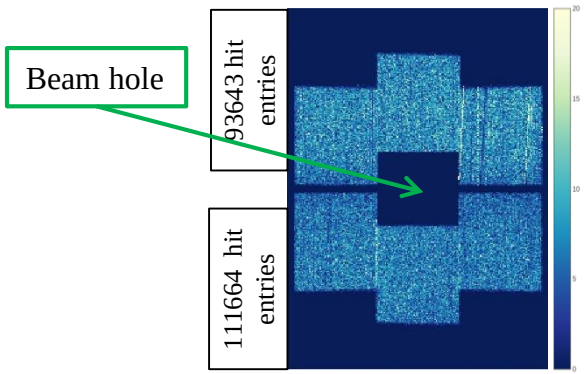

Dimensions:

- Scintillator: 150x600 mm$^2$
- Station-1, half-plane: 93x180 mm$^2$
- Station-2, half-plane: 126x300 mm$^2$
- Station-3, half-plane: 126x420 mm$^2$
- Station-4, half-plane: 126x540mm$^2$

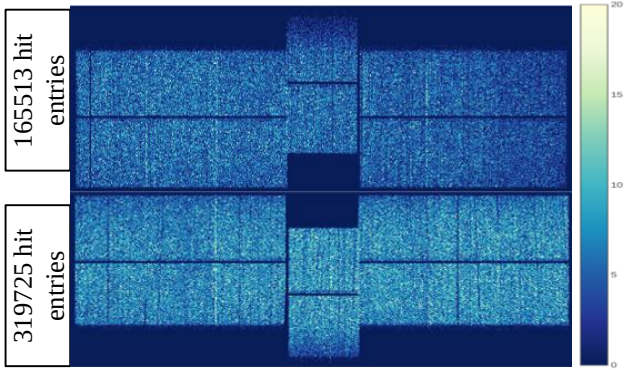


# FSD: after replacing

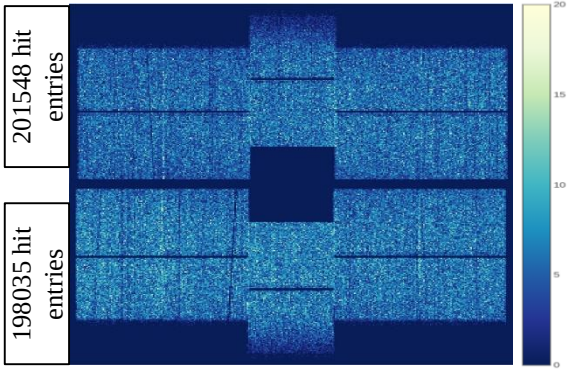
Cosmic tests station 1



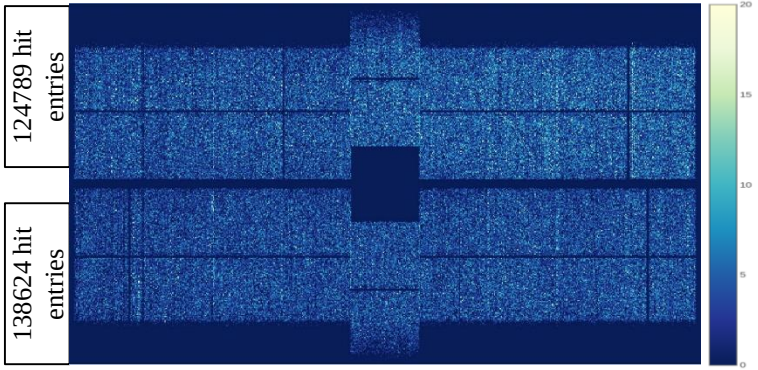

Cosmic tests station 3



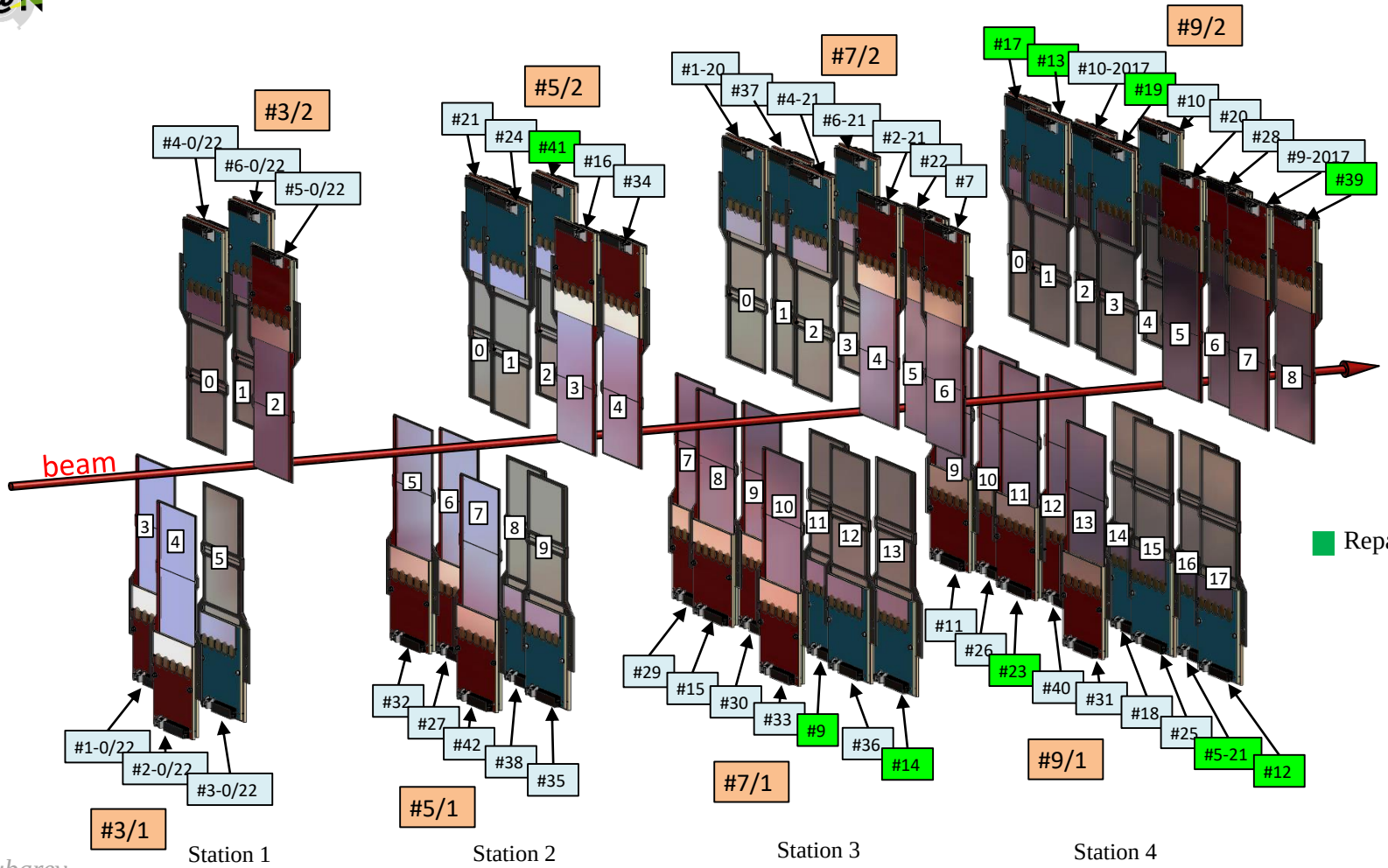

Cosmic tests station 2



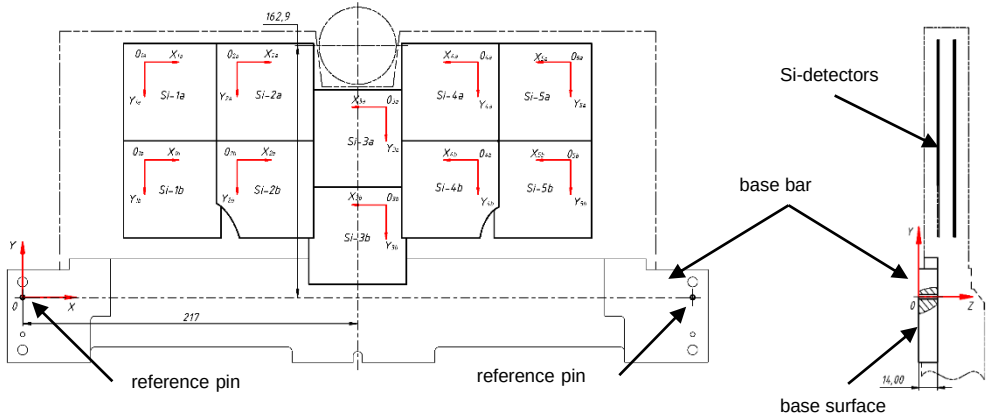

Cosmic tests station 4

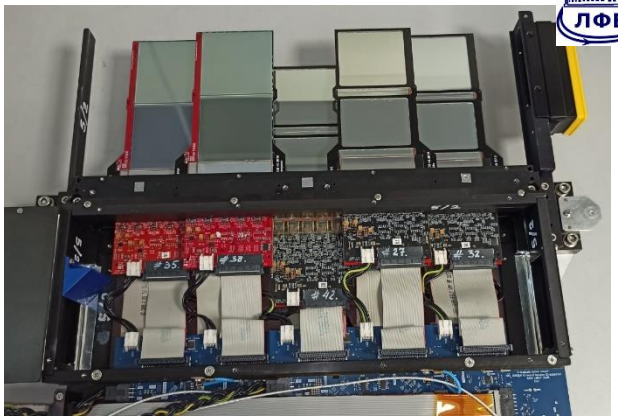



All dead zones have been eliminated!


#3/2
#4-0/22
#6-0/22
#5-0/22
#5/2
#21
#24
#41
#16
#34
#7/2
#1-20
#37
#4-21
#6-21
#2-21
#22
#7
#9/2
#17
#13
#10-2017
#19
#10
#20
#28
#9-2017
#39
beam
#1-0/22
#2-0/22
#3-0/22
#3/1
#32
#27
#42
#38
#35
#5/1
#29
#15
#30
#33
#9
#36
#14
#7/1
#11
#26
#23
#40
#31
#18
#25
#5-21
#12
#9/1
Station 1
Station 2
Station 3
Station 4
Repaired modules
(10 pcs)

# Coordinates of modules (Si-sensors) after disassembly-assembly FSD-planes.



**Position of Si-sensors in half-plane # 5/2 (25.03.24) after repair**

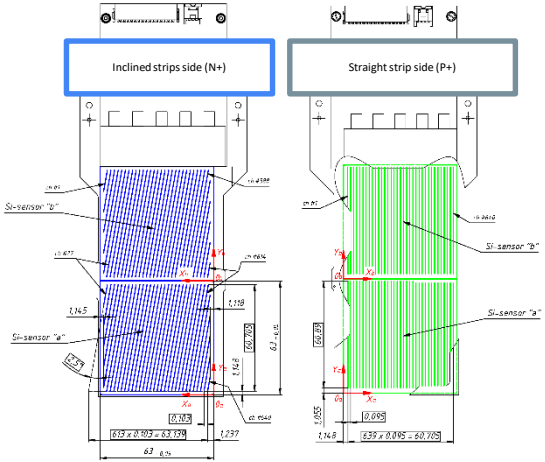
| Sensor position | X±0.02* (mm) | Y±0.02* (mm) | Turn in 0XY plane (deg.)** | Z±0.2*** (mm) | Module serial number |
|---|---|---|---|---|---|
| Si-1a | 65.55 | 164.23 | -0.03 | 16.0 | #34 |
| Si-1b | 65.59 | 101.25 | 0.01 | 15.7 | |
| Si-2a | 125.45 | 164.21 | 0.04 | 27.6 | #16 |
| Si-2b | 125.55 | 101.26 | -0.01 | 27.6 | |
| Si-3a | 248.63 | 134.21 | -0.04 | 14.0 | #41 repair |
| Si-3b | 248.57 | 71.22 | -0.03 | 13.9 | |
| Si-4a | 308.42 | 164.24 | -0.01 | 25.8 | #24 |
| Si-4b | 308.46 | 101.26 | 0.0 | 25.9 | |
| Si-5a | 368.64 | 164.25 | -0.06 | 14.2 | #21 |
| Si-5b | 368.56 | 101.26 | -0.03 | 14.0 | |

**Difference in Si-sensors position data in half-plane # 5/2 (25.03.24 compared to 06.07.22)**

| Sensor position | ΔX (mm) | ΔY (mm) | Changin of turn (deg.)** | ΔZ (mm) | Module serial number |
|---|---|---|---|---|---|
| Si-1a | -0.08 | -0.02 | 0.0 | 0.1 | #34 |
| Si-1b | -0.05 | -0.01 | 0.0 | 0.0 | |
| Si-2a | -0.09 | -0.02 | 0.0 | 0.1 | #16 |
| Si-2b | -0.06 | 0.0 | 0.0 | 0.1 | |
| Si-3a | -0.06 | -0.02 | -0.02 | -0.5 | #41 repair |
| Si-3b | -0.03 | -0.01 | 0.0 | -0.3 | |
| Si-4a | -0.08 | -0.01 | 0.0 | -0.3 | #24 |
| Si-4b | -0.05 | 0.0 | 0.0 | -0.1 | |
| Si-5a | -0.07 | -0.02 | 0.01 | -0.2 | #21 |
| Si-5b | -0.05 | -0.01 | 0.0 | -0.2 | |

Changing of Si-sensors positions after disassembly and reassembly does not exceed:
- 100 μm for X-coordinate
- 50 μm for Y-coordinate

*-position of the origin point of the Si-sensors in the coordinate plane 0XY (tied to the outer reference pins).
**-the distance from the base surface of the base bar to the middle of the Si-sensors surface farthest from it.






E.V. Zubarev

# FSD: New coordinates of Si-sensors in the plane

Position of Si-sensors in plane # 5/2 (25.03.24) after repair

| Sensor position | X±0.02* (mm) | Y±0.02* (mm) | Turn in 0XY plane (deg.)** | Z±0.2*** (mm) | Module serial number |
|---|---|---|---|---|---|
| Si-1a | 65.55 | 164.23 | -0.03 | 16.0 | #34 |
| Si-1b | 65.59 | 101.25 | 0.01 | 15.7 | |
| Si-2a | 125.45 | 164.21 | 0.04 | 27.6 | #16 |
| Si-2b | 125.55 | 101.26 | -0.01 | 27.6 | |
| Si-3a | 248.63 | 134.21 | -0.04 | 14.0 | #41 repair |
| Si-3b | 248.57 | 71.22 | -0.03 | 13.9 | |
| Si-4a | 308.42 | 164.24 | -0.01 | 25.8 | #24 |
| Si-4b | 308.46 | 101.26 | 0.0 | 25.9 | |
| Si-5a | 368.64 | 164.25 | -0.06 | 14.2 | #21 |
| Si-5b | 368.56 | 101.26 | -0.03 | 14.0 | |

Position of Si-sensors in plane # 7/1 (27.03.24) after repair

| Sensor position | X±0.02* (mm) | Y±0.02* (mm) | Turn in 0XY plane (deg.)** | Z±0.2*** (mm) | Module serial number |
|---|---|---|---|---|---|
| Si-1a | 65.47 | 164.14 | 0.03 | 28.6 | #14 repair |
| Si-1b | 65.48 | 101.11 | 0.04 | 28.0 | |
| Si-2a | 125.39 | 164.27 | 0.06 | 16.2 | #36 |
| Si-2b | 125.48 | 101.29 | 0.05 | 15.8 | |
| Si-3a | 185.42 | 164.13 | 0.05 | 28.0 | #9 repair |
| Si-3b | 185.47 | 101.12 | 0.04 | 27.8 | |
| Si-4a | 308.46 | 134.28 | -0.04 | 14.2 | #33 |
| Si-4b | 308.41 | 71.31 | 0.03 | 14.0 | |
| Si-5a | 368.43 | 164.21 | 0 | 25.8 | #30 |
| Si-5b | 368.41 | 101.21 | 0.02 | 26.1 | |
| Si-6a | 428.48 | 164.27 | -0.02 | 14.5 | #15 |
| Si-6b | 428.46 | 101.27 | -0.01 | 14.2 | |
| Si-7a | 488.57 | 164.18 | -0.06 | 25.7 | #29 |
| Si-7b | 488.50 | 101.18 | -0.06 | 26.0 | |

Position of Si-sensors in plane # 9/1 (10.04.24) after repair

| Sensor position | X±0.03* (mm) | Y±0.05* (mm) | Turn in 0XY plane (deg.)** | Z±0.2*** (mm) | Module serial number |
|---|---|---|---|---|---|
| Si-1a | 65.46 | 164.28 | 0.03 | 15.0 | #12 repair |
| Si-1b | 65.59 | 101.21 | 0.05 | 15.3 | |
| Si-2a | 125.48 | 164.31 | 0.04 | 26.4 | #5-21 repair |
| Si-2b | 125.56 | 101.18 | 0.02 | 27.2 | |
| Si-3a | 185.54 | 164.36 | 0.01 | 15.2 | #25 |
| Si-3b | 185.60 | 101.35 | 0.00 | 15.3 | |
| Si-4a | 245.39 | 164.34 | 0.06 | 26.7 | #18 |
| Si-4b | 245.50 | 101.13 | 0.06 | 27.2 | |
| Si-5a | 368.46 | 134.37 | -0.02 | 14.4 | #31 |
| Si-5b | 368.48 | 71.37 | 0.01 | 14.0 | |
| Si-6a | 428.42 | 164.35 | 0.00 | 25.8 | #40 |
| Si-6b | 428.48 | 101.35 | 0.01 | 25.9 | |
| Si-7a | 488.61 | 164.35 | -0.03 | 13.7 | #23 repair |
| Si-7b | 488.59 | 101.34 | -0.05 | 13.7 | |
| Si-8a | 548.45 | 164.37 | 0.01 | 25.7 | #26 |
| Si-8b | 548.49 | 101.38 | 0.01 | 25.8 | |
| Si-9a | 608.60 | 164.32 | -0.04 | 14.7 | #11 |
| Si-9b | 608.60 | 101.29 | -0.02 | 14.3 | |

Position of Si-sensors in plane # 9/2 (17.04.24) after repair

| Sensor position | X±0.03* (mm) | Y±0.05* (mm) | Turn in 0XY plane (deg.)** | Z±0.2*** (mm) | Module serial number |
|---|---|---|---|---|---|
| Si-1a | 65.58 | 164.27 | 0.01 | 16.2 | #39 repair |
| Si-1b | 65.59 | 101.28 | 0 | 15.8 | |
| Si-2a | 125.45 | 164.23 | 0.05 | 27.2 | #9-2017 |
| Si-2b | 125.49 | 101.11 | 0.04 | 27.4 | |
| Si-3a | 185.41 | 164.22 | 0.07 | 16.2 | #28 |
| Si-3b | 185.49 | 101.22 | 0.06 | 15.9 | |
| Si-4a | 245.51 | 164.29 | 0.03 | 27.8 | #20 |
| Si-4b | 245.53 | 101.28 | 0.01 | 27.7 | |
| Si-5a | 368.44 | 134.32 | 0.01 | 14.1 | #10 |
| Si-5b | 368.43 | 71.32 | 0.02 | 13.9 | |
| Si-6a | 429.39 | 164.32 | 0.01 | 26.5 | #19 repair |
| Si-6b | 428.39 | 101.33 | 0.02 | 26.2 | |
| Si-7a | 488.58 | 164.31 | -0.06 | 14.5 | #10-2017 |
| Si-7b | 488.51 | 101.30 | -0.04 | 14.2 | |
| Si-8a | 548.50 | 164.31 | -0.01 | 25.9 | #13 repair |
| Si-8b | 548.47 | 101.29 | -0.01 | 25.9 | |
| Si-9a | 608.62 | 164.29 | -0.07 | 14.2 | #17 repair |
| Si-9b | 608.54 | 101.28 | -0.04 | 14.0 | |

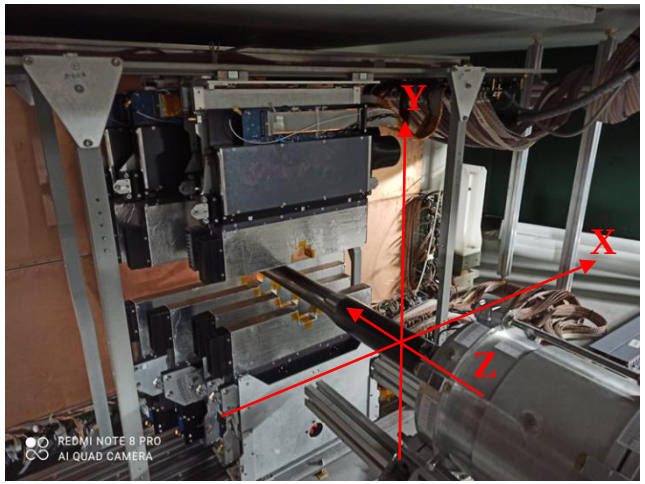

Measurement of Si-detectors position coordinates in 2024y were carried out on a new tooling for plane fixation on the table of video-measuring microscope "NORGAU" NVM II-5040D (3 points of support).

*- New coordinates were entered into the data table for positions of detectors in FSD-planes*

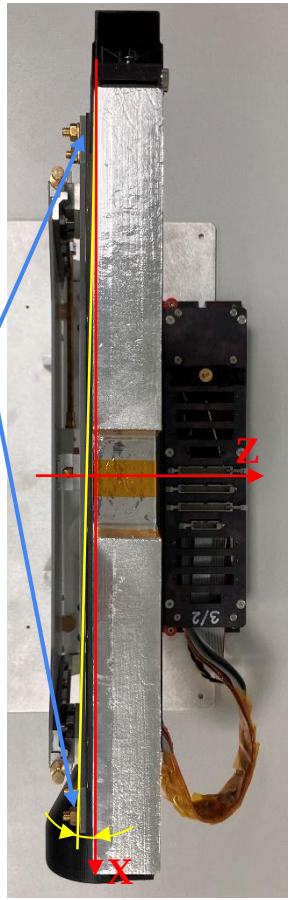


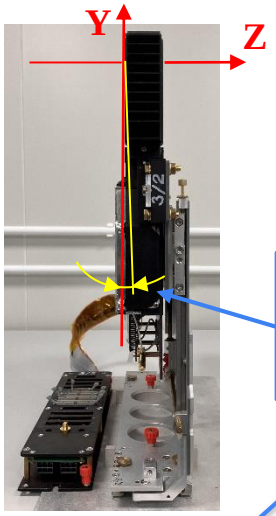
E.V. Zubarev

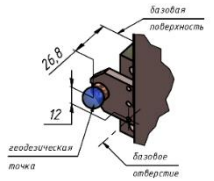
# Refinement of FSD-planes positioning device in the BM@N experemental hall.



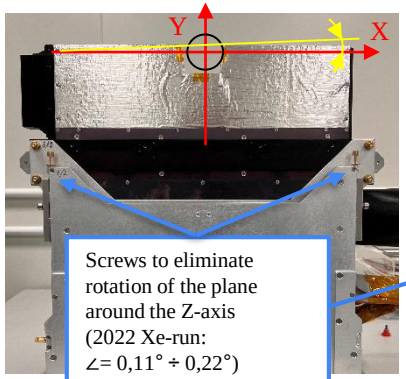

Adjustment shims to eliminate plane rotation around the Y axis.
(2022 Xe-run:
∠= 0,11° ÷ 0,74°)



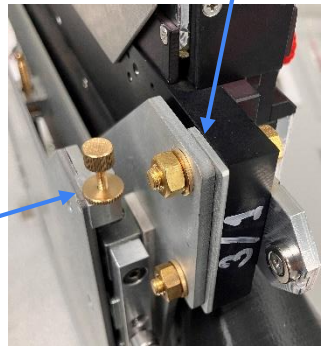



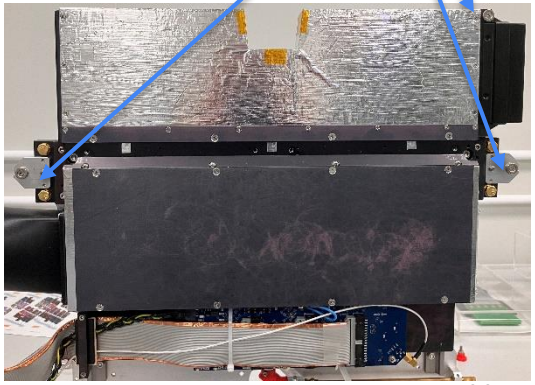




Added a 3rd geodetic marker to control the inclination of the plane around the X axis




Screws to eliminate rotation of the plane around the Z-axis
(2022 Xe-run:
∠= 0,11° ÷ 0,22°)







E.V. Zubarev

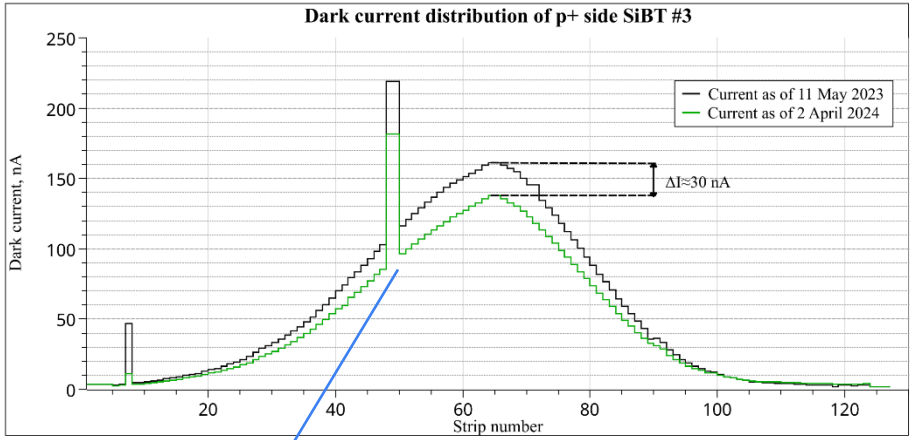
## Conclusion

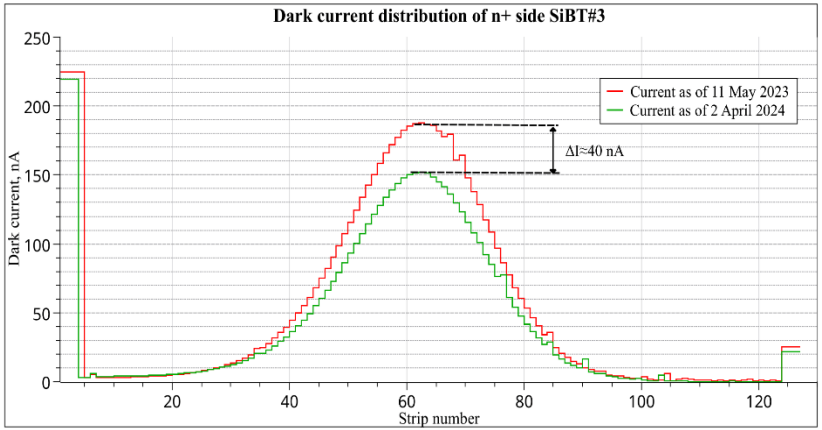
- Eliminated defects in FSD-planes, all defects were related to FEE-chips failures. At the end of Xe-run (February 2023) number of problematic chips were 2,7% (from 480 pC.), at the moment - 0%.
- FSD-planes are ready to installation and alignment in BM@N experimental hall .
- True coodrinates of Si-detectors in FSD half-planes after disassembly-assembly during defects repair were measured with accuracy ± 50μm.
- Refined FSD-planes positioning devices for alignment in BM@N experimental hall (added a 3-rd geodetic marker).

**Thank you for your attention!**

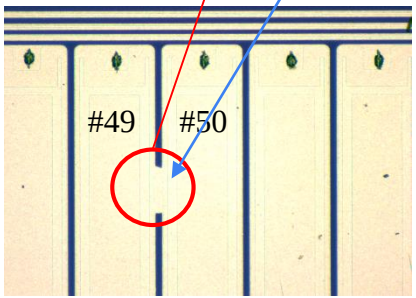
Additional slides

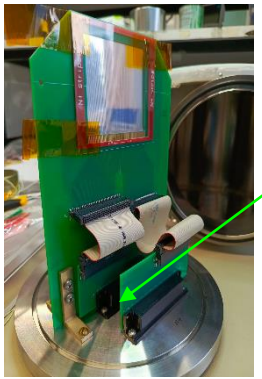
# SiBT station #3 status




49 and 50th strips are shorted out on the detector. Irreparable defect



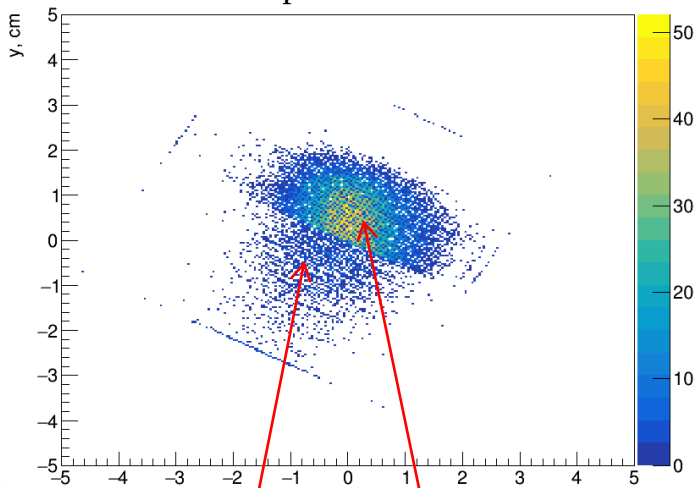
There was no contact on the connector. The defect was eliminated by cleaning the connectors

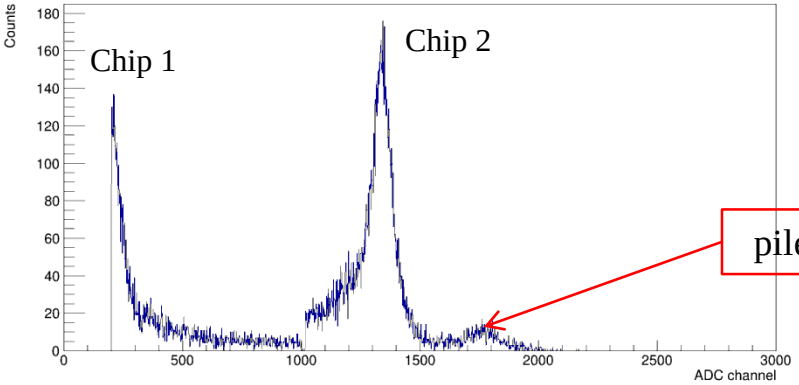
| | $I_{max}$, nA | $I_{\Sigma}$, μA |
|---|---|---|
| May 2023 | 182 | 7.1 |
| April 2024 | 219 | 5.9 |
| Delta | ≈40 | 1.2 |

# SiBT FEE during Xe-run

This slide shows SiBT FEE operation in XE-run on example of SiBT #2 (run 8387, 1.02.2023). The gains of FEE-chips on n+ side were not tuned for signals on the order of 10.9 pC (energy losses of Xe with energy 3.8 GeV/n are 245.5 MeV). Because of this signals from one of FEE-chips were below th threshold and were not written (in this case – chip 1 (channels 0 – 63)

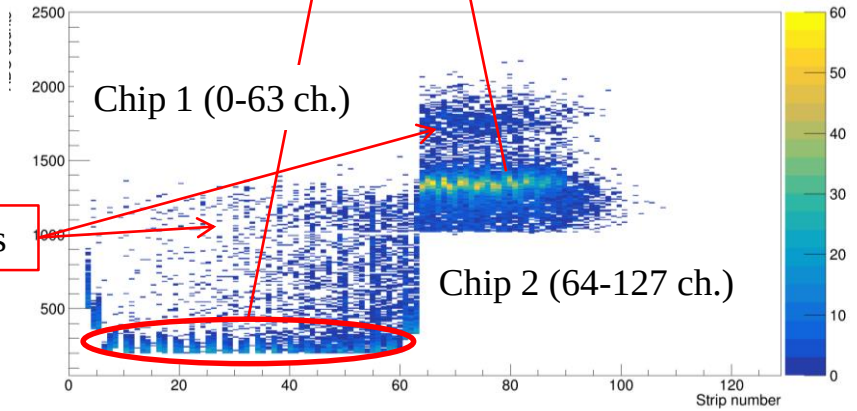
Hit plot SiBT #2




Amplitude distribution (SiBT #2 n+ side)

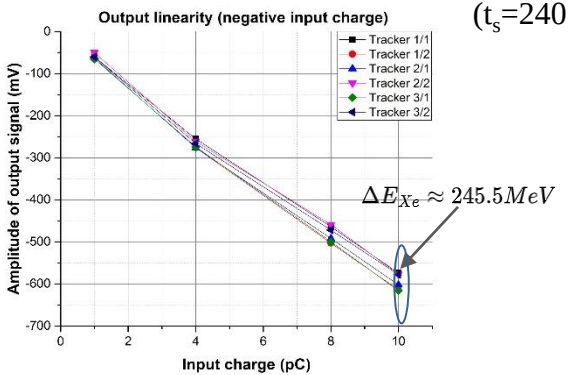
pileups

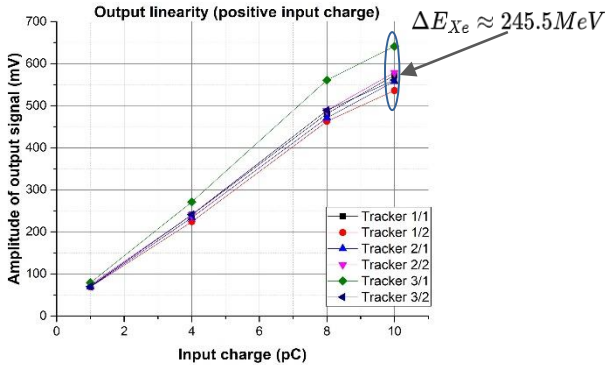



Channel distribution of amplitudes (SiBT #2 n+ side)

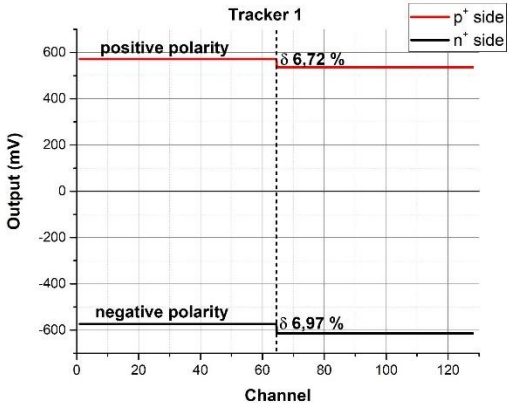
# SiBT FEE status

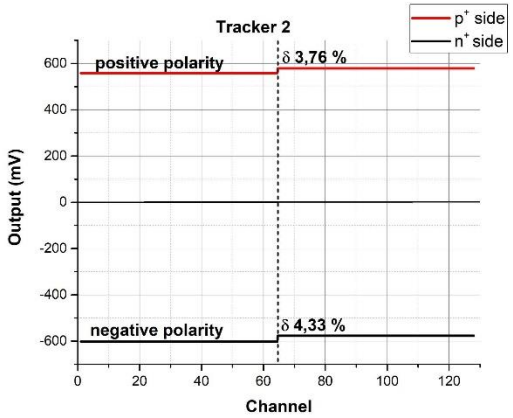
Linearity of ASICs after PCB tuning ($t_s$=240 nS)

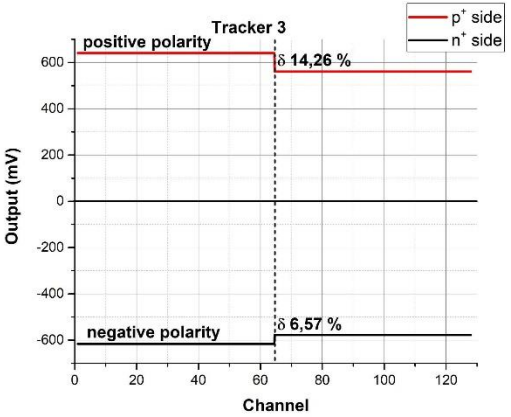


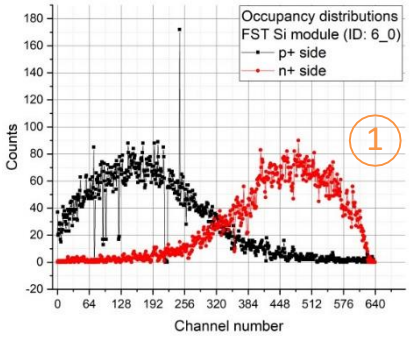

The gain spread of ASICs (input 10 pC, $t_s$=240 ns+120 ns)

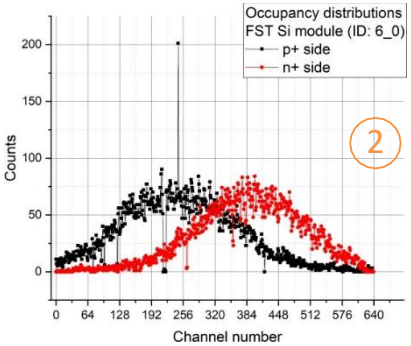


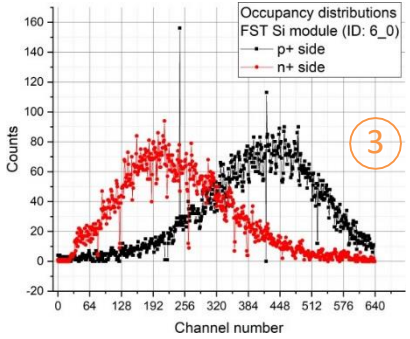



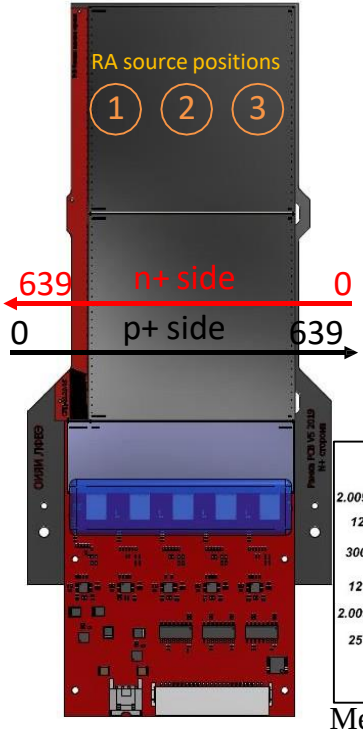



# FST Si module test results

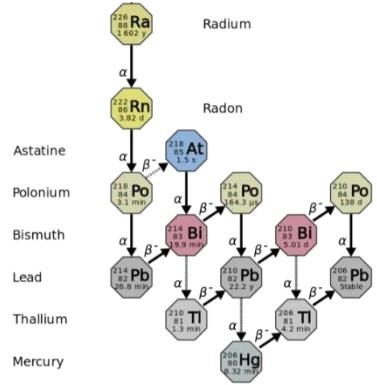


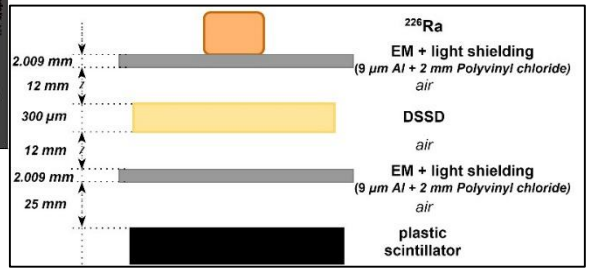




Ufd = 30 V

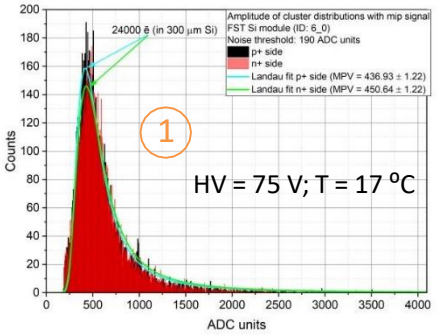


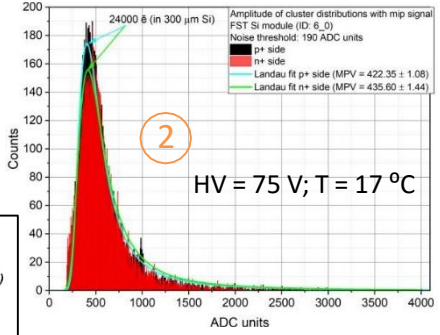

Electron end-point energy up to 3.27 MeV ($^{214}_{83}Bi$)

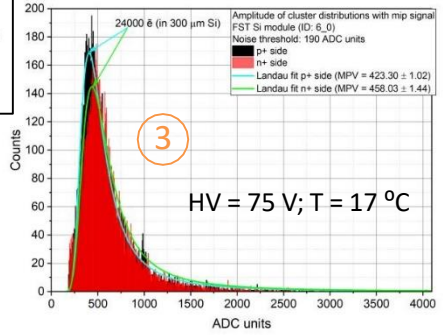



Measurement with RA source cross-section
(trigger rate: 150 Hz)

| Module ID | <ENCp+> ē RMS | <ENCn+> ē RMS | SNR p+ side | SNR n+ side | Bad channels ratio, % |
|---|---|---|---|---|---|
| 6_0 | 1963.60 | 2 237.88 | 12.22 | 10.72 | 1.25 |

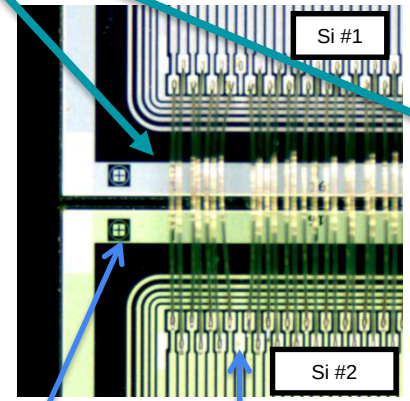


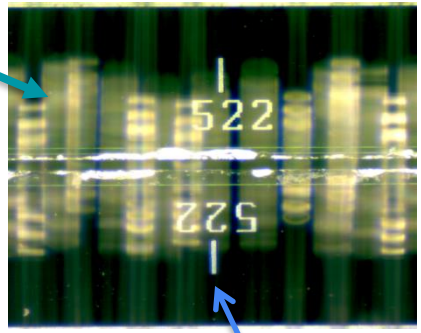



Измерения положения Si-детекторов в модулях и плоскостях проводились на бесконтактном видеоизмерительном микроскопе «NORGAU» NVM II-5040D.


| «NORGAU» NVM II-5040D | |
|---|---|
| Диапазон перемещений по осям X и Y (мм) | 500 x 400 |
| Диапазон перемещений по оси Z (мм) | 250 |
| Допускаемая абсолютная погрешность линейных измерений по осям X и Y (мкм)* | ±(2.5+L/200) |
| Допускаемая абсолютная погрешность линейных измерений по оси Z (мкм)* | ±(2.5+L/100) |
| * L –измеряемая длина в мм | |

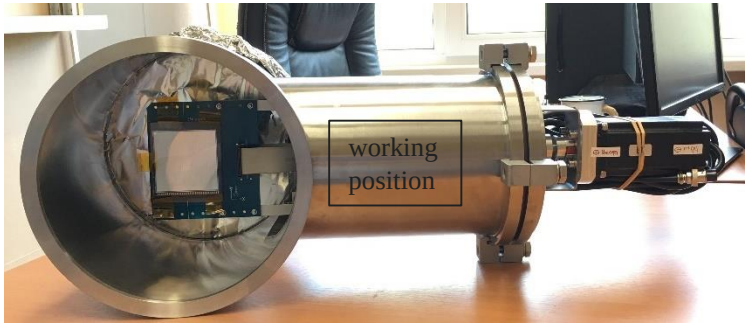




реперный крест детектора

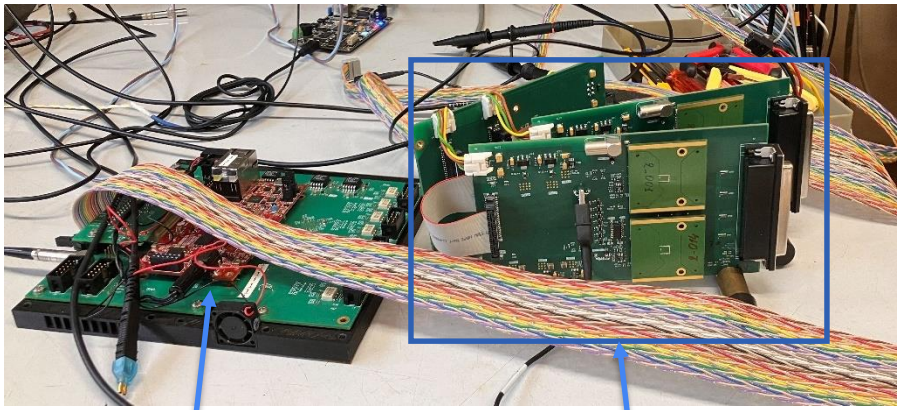
отсутствие сварки

Топологические знаки на детекторе можно использовать в качестве реперов

# Beam profilometer upgrade



Beam tracker Cross-board


Beam profilometer
standalone DAQ

New readout electronics for beam profilometer

## Beam profilometer

**is necessary for beam tuning (alignment of the center beam with the center of the target)**

- **detector:** DSSD, ($128p^{+}\times128n^{+}$), strips pitch = 475 μm, thickness (Si) -175 μm, active area (61 × 61) $mm^2$. Strips are combined in pairs on detector board. Total have ($64p^{+}\times64n^{+}$), pitch = 950 μm
- **mechanical design:** the plane of the profilometer is automatically removed from the beam zone to the parking position
- **FEE** based on two VA32HDR11 ASICs. Total number of channels are 64 for X and 64 for Y coordinate. Dynamic range -35pC - +25pC. Peaking time 800ns. Self trigger mode based on TA32cg2 ASICs
- **current status:**
  FEE have been designed, manufactured and tested. Next step is testing FEE with Si detector placed in flanges with alpha-source (5.5 MeV) and standalone DAQ subsystem.