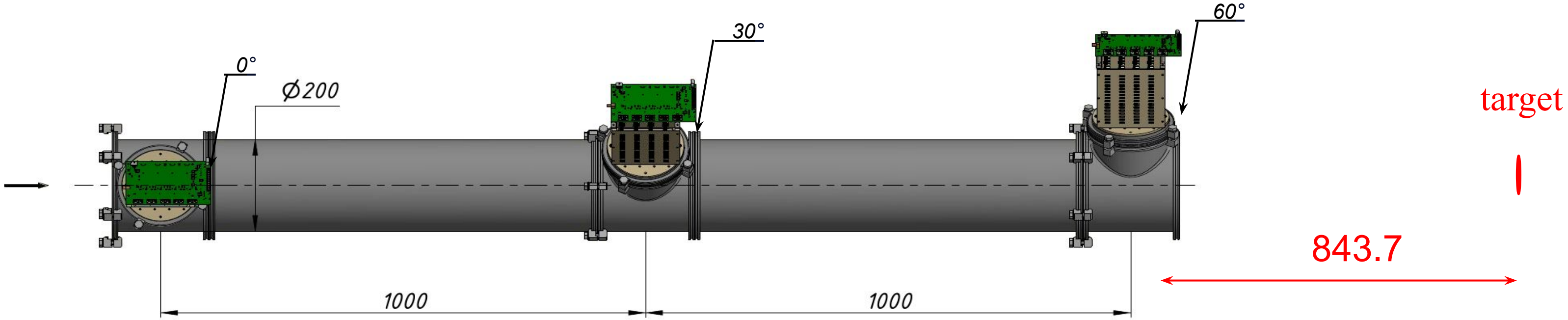
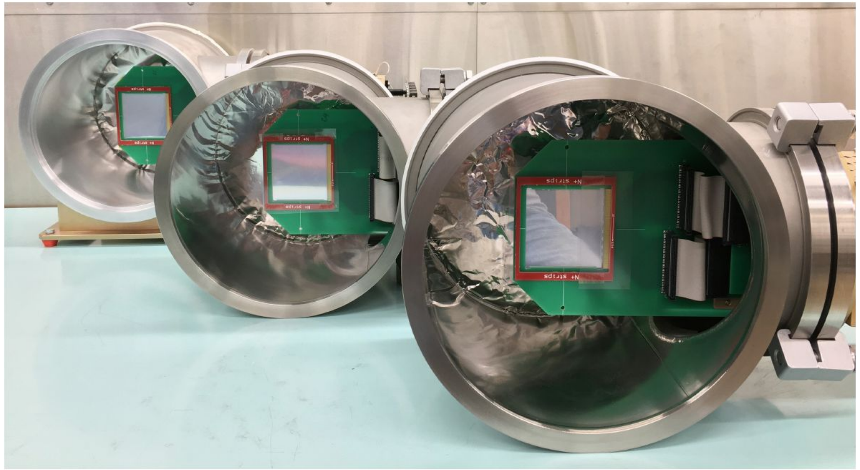
Beam tracker status

Danil Chemezov on behalf of Forward Silicon Tracker team

Analysis & Software Meeting of the BM@N Experiment,
12-13 September 2023

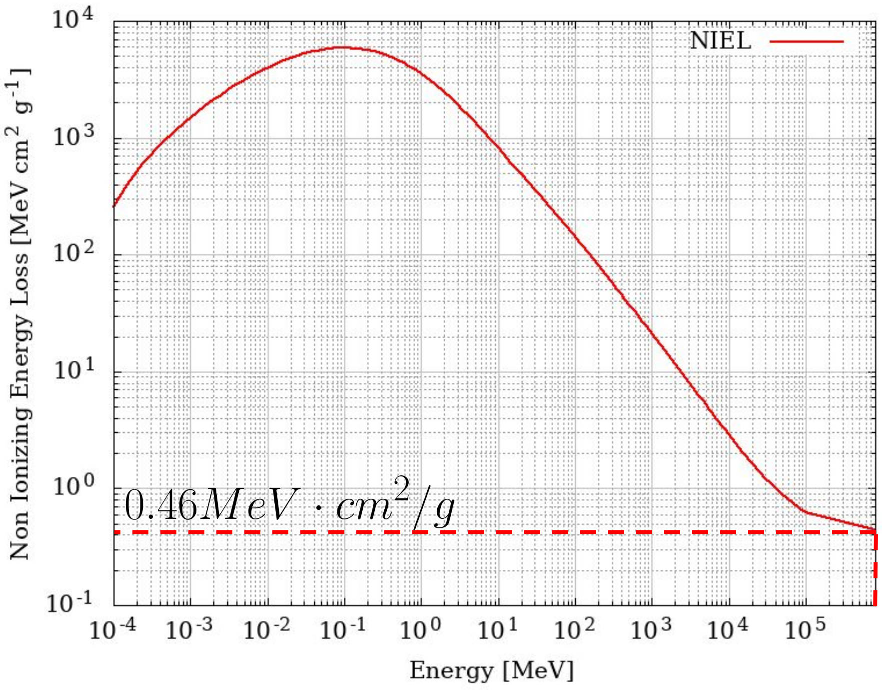
Beam Tracker





- **Physical purpose**: determination of the reaction plane, refinement of the vertex definition, beam profilometry
- **detector:** DSSD, 128×128 strips, pitch p+ / n+ strips 0.47 mm, thickness 175 μm, active area 61×61 mm^2
- **FEE**: based on VATA64HDR16.2 (64 ch, dynamic range: -20 pC ÷ +50 pC; programmable shaping time: 50, 100, 150, 300 ns)

NIEL simulation of ^{124}Xe in 175 μm silicon



NIEL of Xe in 175 μm Si

Non-ionizing energy losses (NIEL) are used as a measure of the degree of radiation damage.
Using GEANT4 with the SR-NIEL library, NIEL of Xe in 175 μm Si values were obtained.

NIEL from 1 MeV neutron in Si (ASTM Standard E722-19):

$$NIEL_n = 0.0016 MeV \cdot cm^2/g$$

NIEL from 4 A*GeV Xe:

$$NIEL_{Xe} = 0.458 MeV \cdot cm^2/g$$

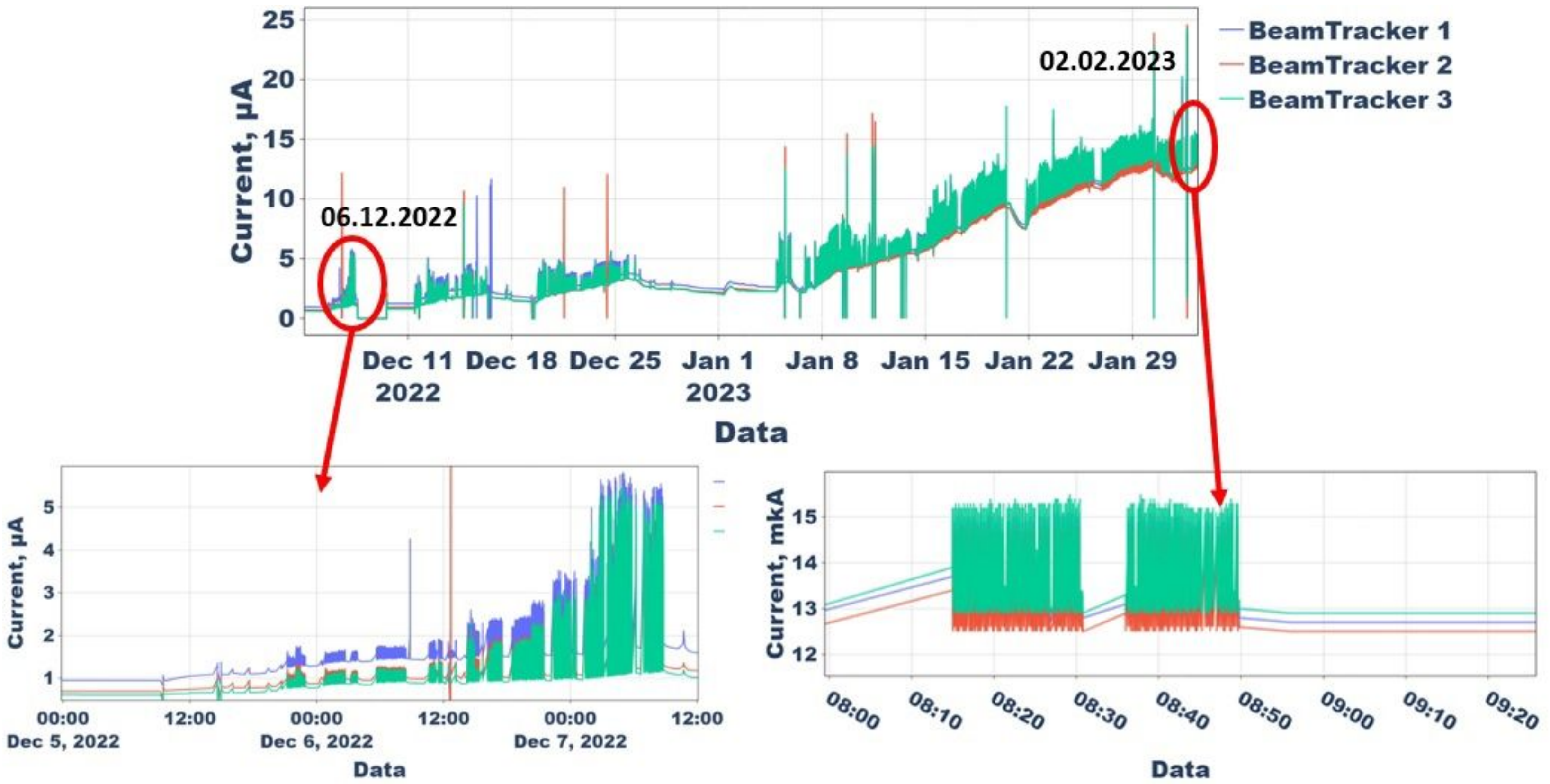
Hardness factor of 4A*GeV Xe:

$$NIEL_{Xe}/NIEL_n \approx 276 \Rightarrow \Phi_n = \Phi_{Xe} \cdot 276$$

For example:

- hardness factor of 4A GeV gold is 470;
- hardness factor of 3.6A GeV carbon is 3

Increasing the dark current of beam trackers during Xe run



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

Run stop, <I> = 12.7 µA; t = +26.8°C

Method of measuring the fluence using silicon detectors

	I_{d0}, μA/+20 V/+22.5°C 04.12.2022 (run start)	$I_{d(s)}$, μA/+20 V/+26.8°C 2.02.2023 (run stop)	$\Delta I = I_{d(s)} - I_{d0}$, μA **(at +20 °C)**
BT1	0.965	12.7	6.3
BT2	0.692	12.5	6.4
BT3	0.626	12.9	6.7
Mean	0.761	12.7	6.44

Fluence can be estimated by the empirical formula:

$$\Delta I = \alpha \cdot \Phi_n \cdot V_{det} \ , \alpha = 3 \cdot 10^{-17} \ A \cdot cm^{-1}, V_{det} = 61 \cdot 61 \cdot 0.175 \ mm^3$$

, α - bulk radiation damage constant, Φ_n is the equivalent fluence of 1 MeV neutrons, related to the fluence of xenon by the relation:

$$\Phi_n = k \cdot \Phi_{Xe}$$

, k - hardness factor of 4 A*GeV Xe, k =276

Using the calculated hardness factor and experimentally obtained increases of currents we obtain:

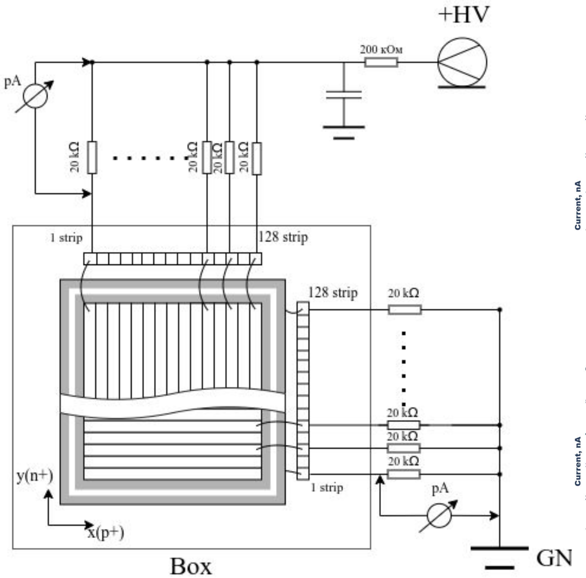
Based on the obtained fluence, we can estimate the number of xenon nuclei that passed through the detectors during the run:

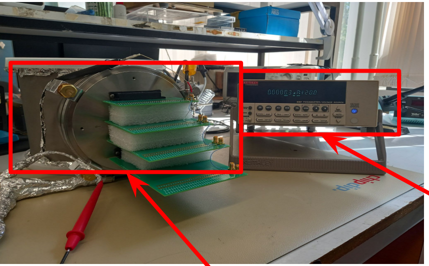
$$N_{Xe} = \Phi_{Xe} \cdot S_{det}$$

$$S_{det} = 37.2 \ cm^2$$

	Fluence of 1 MeV neutrons, cm^{-2}	Fluence ^{128}Xe, cm^{-2}	Number of xenon nuclei
BT1	$3.21 \cdot 10^{11}$	$1.16 \cdot 10^{9}$	$4.33 \cdot 10^{10}$
BT2	$3.27 \cdot 10^{11}$	$1.18 \cdot 10^{9}$	$4.41 \cdot 10^{10}$
BT3	$3.41 \cdot 10^{11}$	$1.23 \cdot 10^{9}$	$4.60 \cdot 10^{10}$
Mean	$3.30 \cdot 10^{11}$	$1.19 \cdot 10^{9}$	$4.44 \cdot 10^{10}$

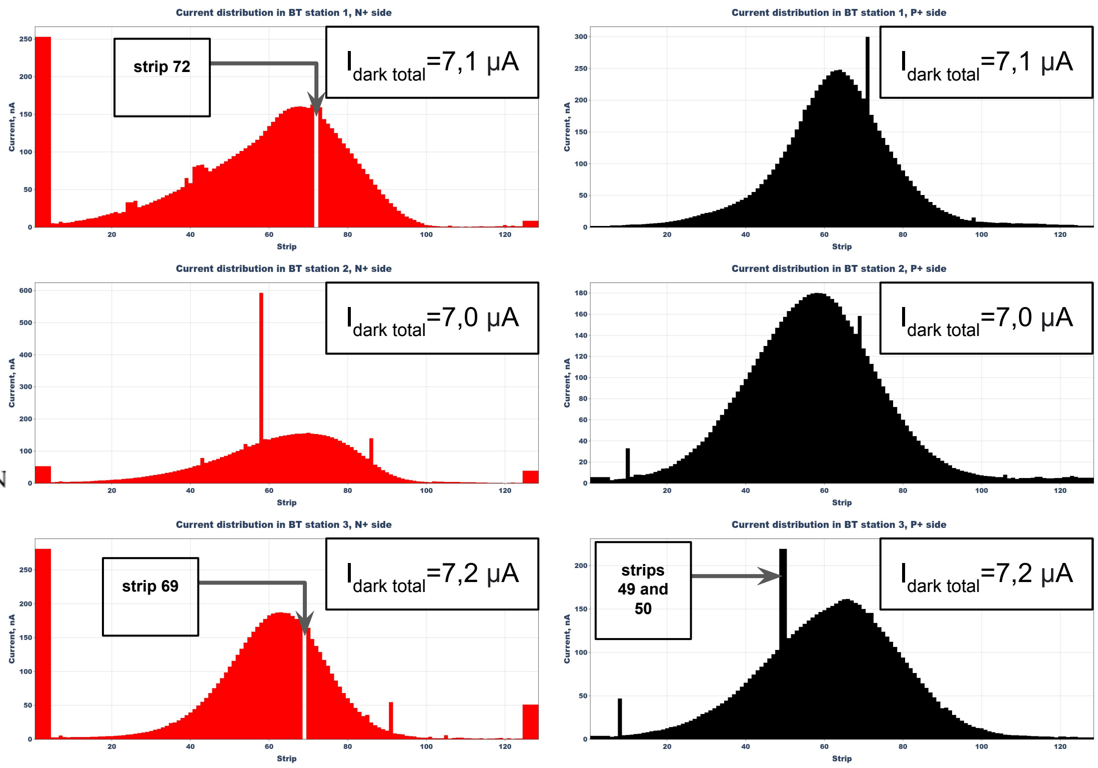
Dark current for each strip after Xe run

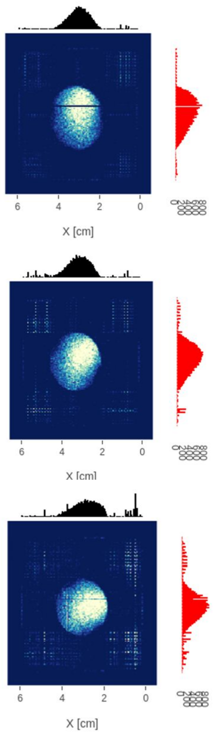




beam tracker and boards to read the current from each strip

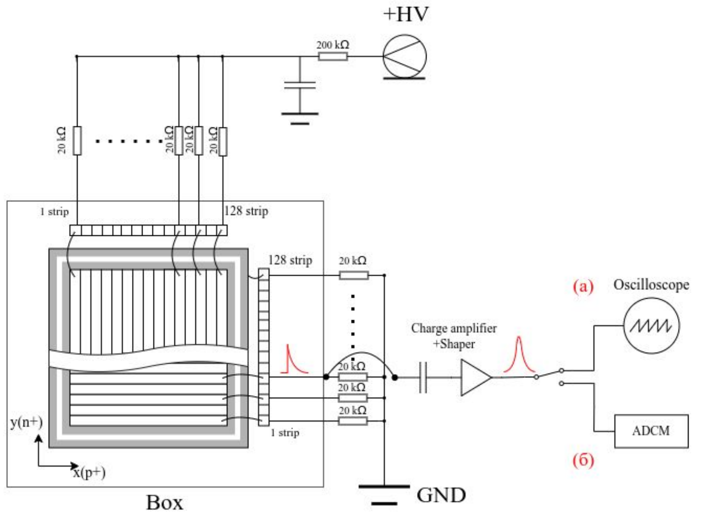
picoammeter/voltage source



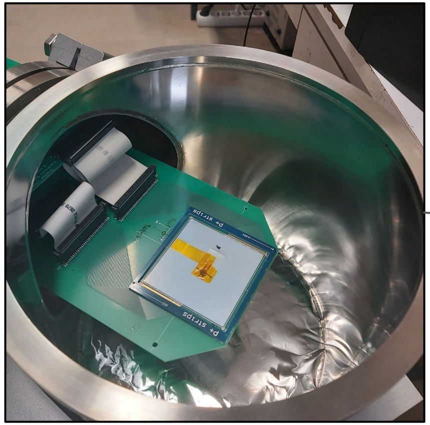


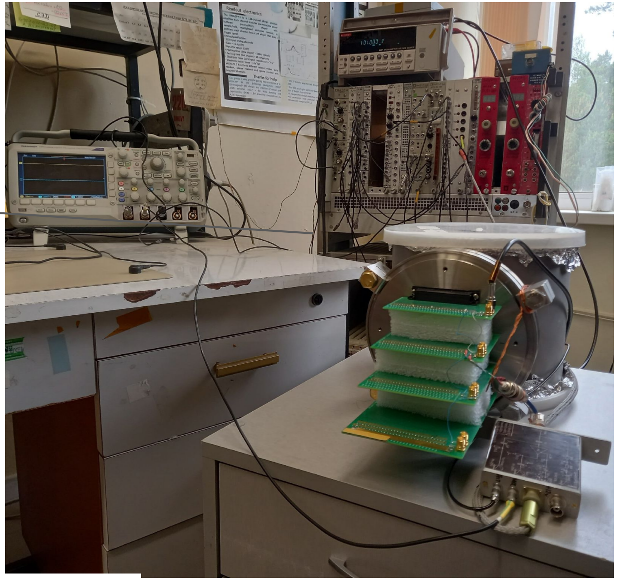
run 6705, 13.12.2022

Testing with alpha-source



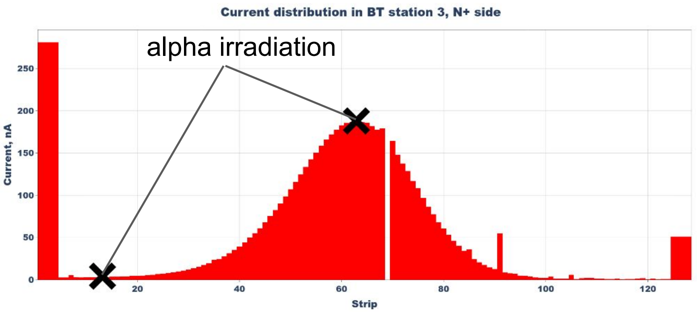
Measurement scheme

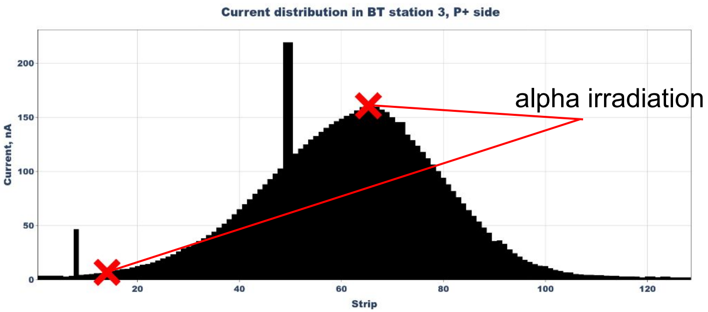




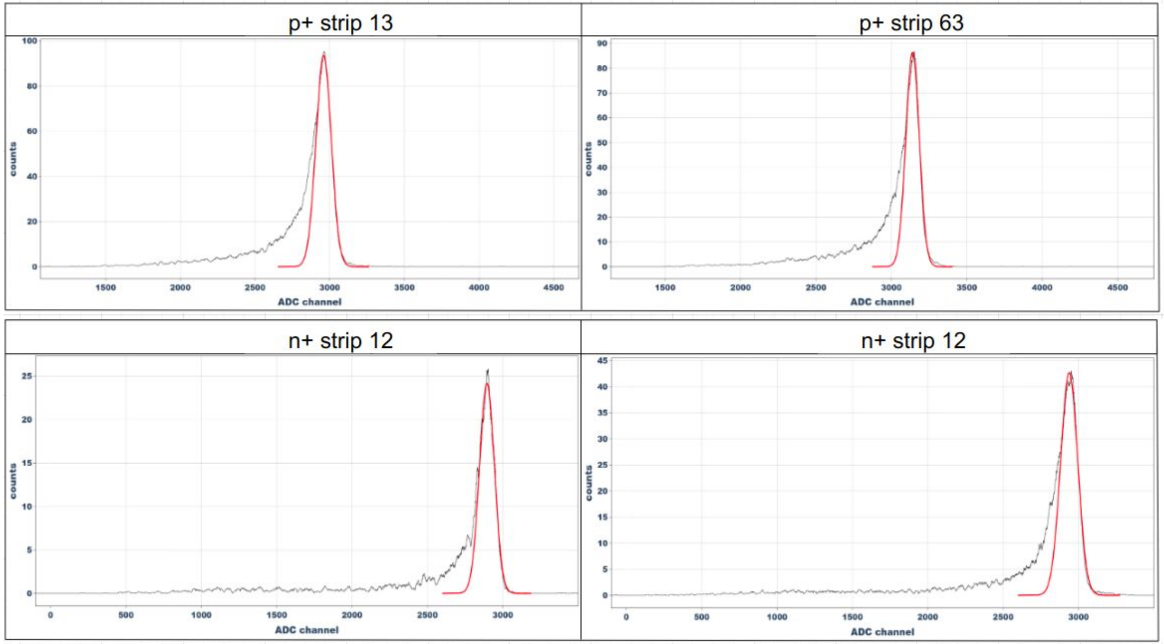
alpha-source: E=5,5 MeV

(energy deposition of 4A GeV Xe: E=245 MeV)





Alpha-test results

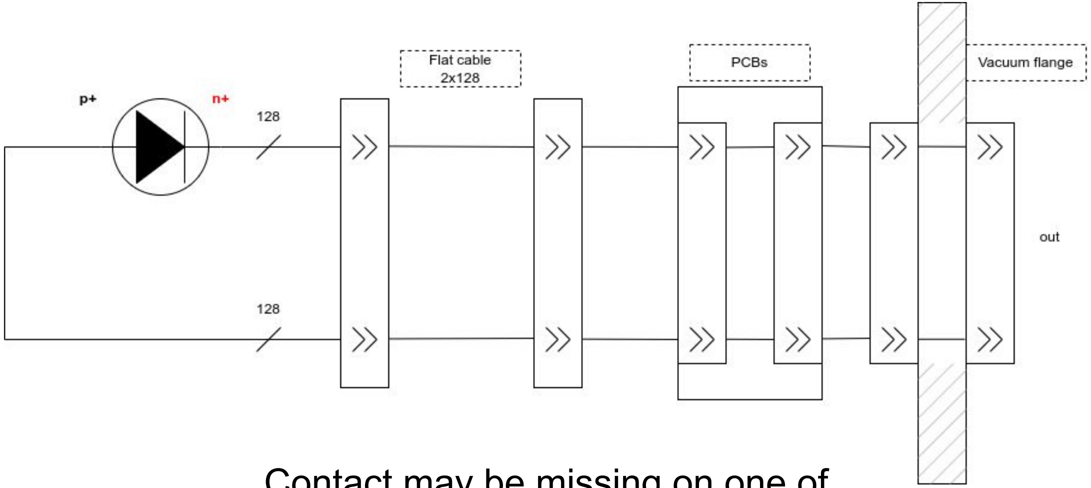


From the obtained data we can conclude that the spectra of alpha particles with energy E=5.5 MeV have approximately the same characteristics in the detector regions subjected to intensive irradiation by xenon nuclei and in the detector regions that were not subjected to irradiation.

	p+ side		n+ side	
	strip 13	strip 63	strip 12	strip 65
mean, ch	2960.0 ±0.2	3146.6 ±0.4	2894.8 ±0.3	2937.9 ±0.4
σ, ch	50.3±0.2	38.2±0.3	49.0±0.4	56.5±0.4

Conclusion

- According to the results of testing with the alpha source, we can say that it is possible to use the beam tracker in next session without replacing the detectors;
- 2 problem areas were found: missing contacts of strip №72 n+ side of detector №1 and strip №69 n+ side of detector №2;



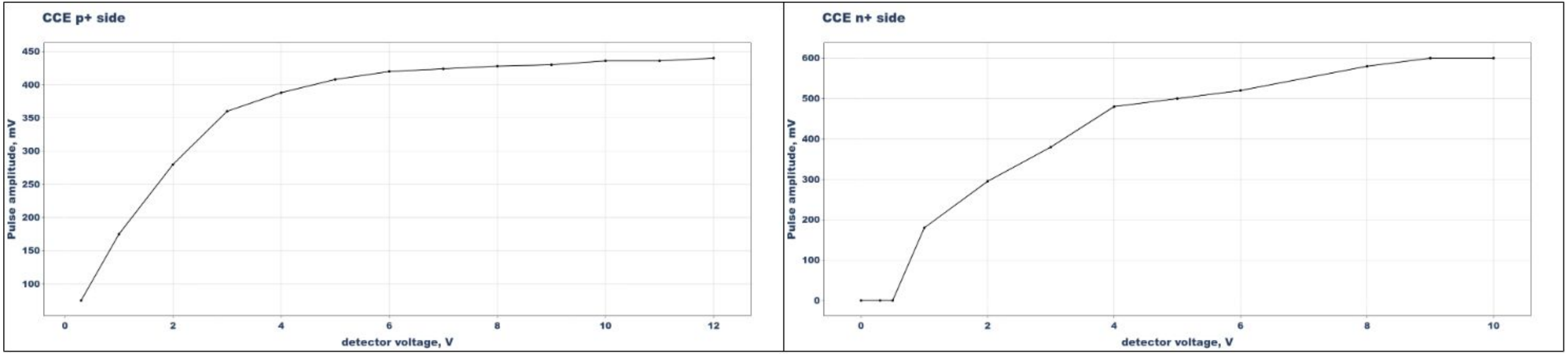
Contact may be missing on one of the connectors

Thank you for your attention!

Backup

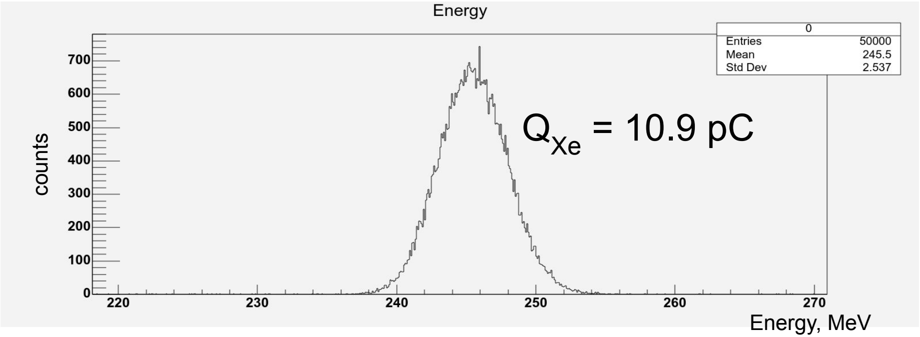
Voltage dependence of signal amplitude

The measured dependences of the magnitude of the collected alpha particle ionization charge on the detector voltage allow us to conclude that the full depletion voltage of the detector changed after its irradiation with heavy xenon ions. For unirradiated p+ strips, non-zero alpha particle signals should be at a voltage of 0 V, in our case 0.3 V is required to be applied. On n+ strips the signal should appear when alpha is illuminated from the n+ side at Ufd = 5 V (in our case already at voltage <1 V signals are observed). These effects confirm that the n+ type detector volume has become more highly resistive and is approaching the point of conductivity type inversion from n-type to p-type.



Signal amplitude dependence from the alpha source on the p+ (left) and n+ (right) sides of the detector. The source is located in the damaged area of the detector

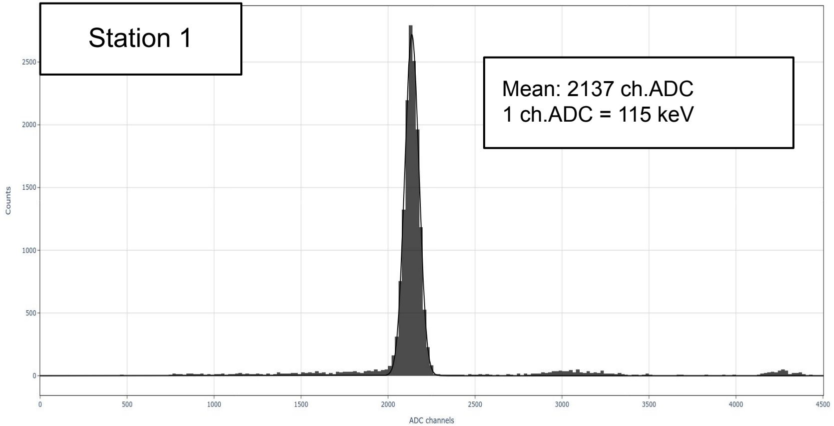
Energy deposition of Xe in 175 µm silicon



Xe 4 AGeV ions deposited energy

- Using the GEANT4 framework, a simulation of Xenon energy loss of 4 AGeV in 175 µm silicon was performed.
- The **ΔE = 245 MeV/175 µm (Si)**, which corresponds to a charge of **10.9 pC**, which falls within the dynamic range of VATA64HDR16.2
- Remind: ($Q_{m.i.p/175µm\ Si}$=2.33 x 10^{-3} pC)

P+ side cluster amplitude distributions, run 8270



The figure above shows the distribution of cluster amplitudes at station 0 with channels 0-63 (first ASIC). The distribution of cluster amplitudes is well described by the Gaussian function, and the mean value was obtained from the fitting results.

Energy deposition of Xe in 175 µm silicon

P+ side cluster amplitude distributions, run 8270