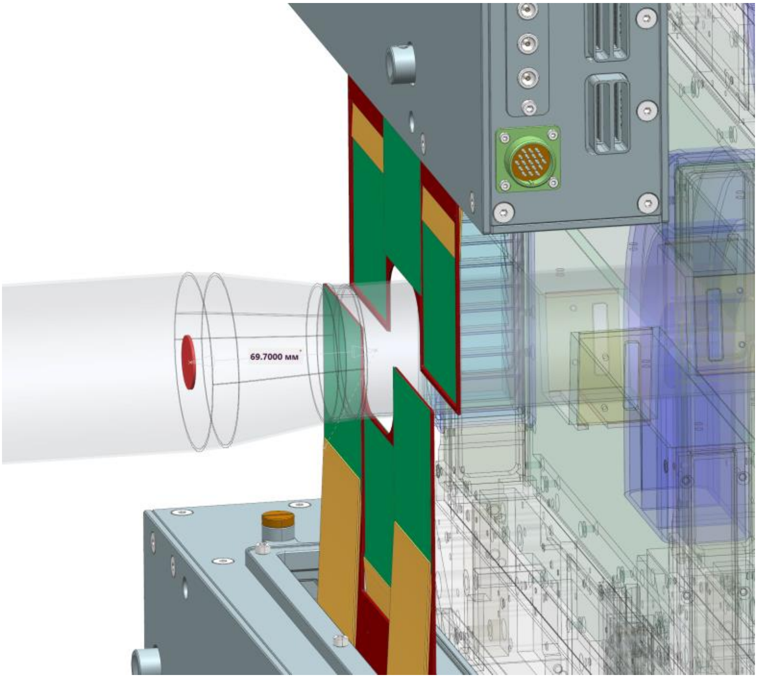
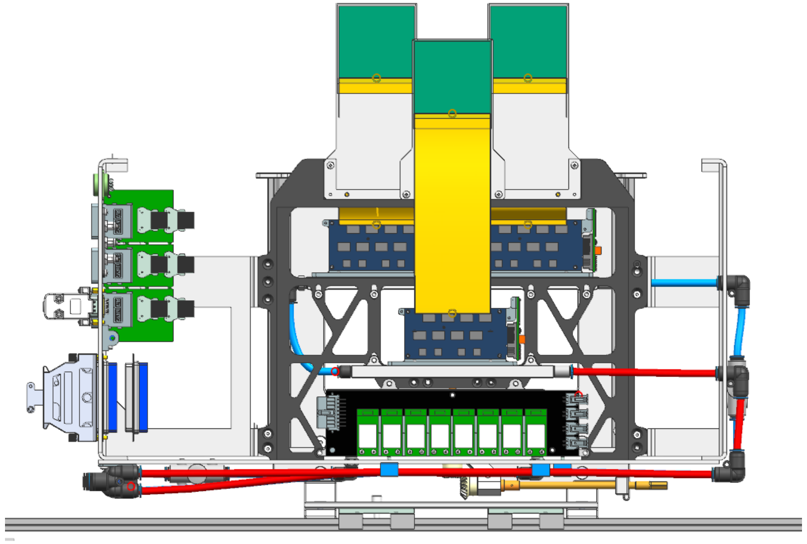
IN-BEAM TESTS OF DOUBLE-SIDED SILICON STRIP DETECTOR MODULES FOR THE BM@N EXPERIMENT

D. Dementev, R. Arteche Diaz, C. Ceballos Sanchez, A. Kolozhvari, V.Leontyev, N. Maltsev, Yu. Murin, A. Rodriguez Alvarez, I. Rufanov, A. Sheremetev, M.O Shitenkov, V. Zherebchevsky

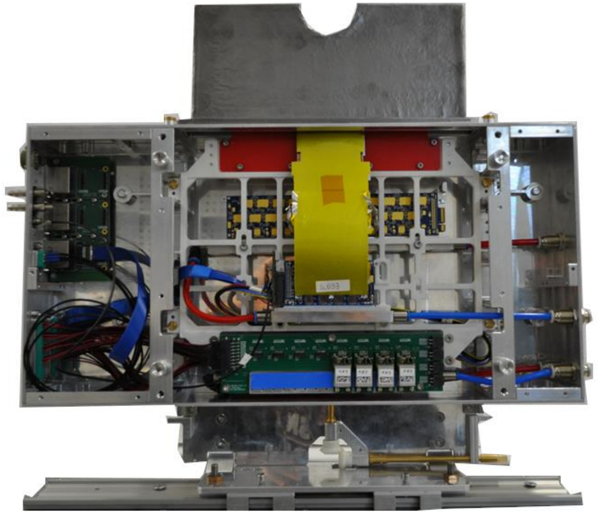
Vertex Si-plane for BM@N experiment



Si-station with 6 STS modules



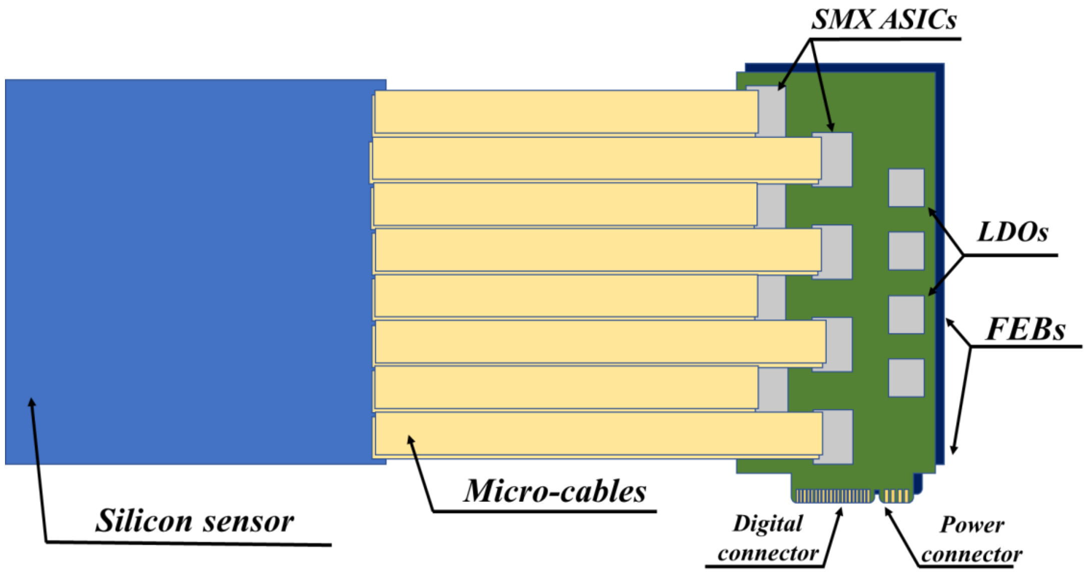
Half-station with 3 STS modules



A new vertex Si-plane based on STS modules will be installed in front of FwdSi with the aim to improve vertex and track reconstruction efficiency for the low-momentum particles

DSSD module

Photo of the assembled module



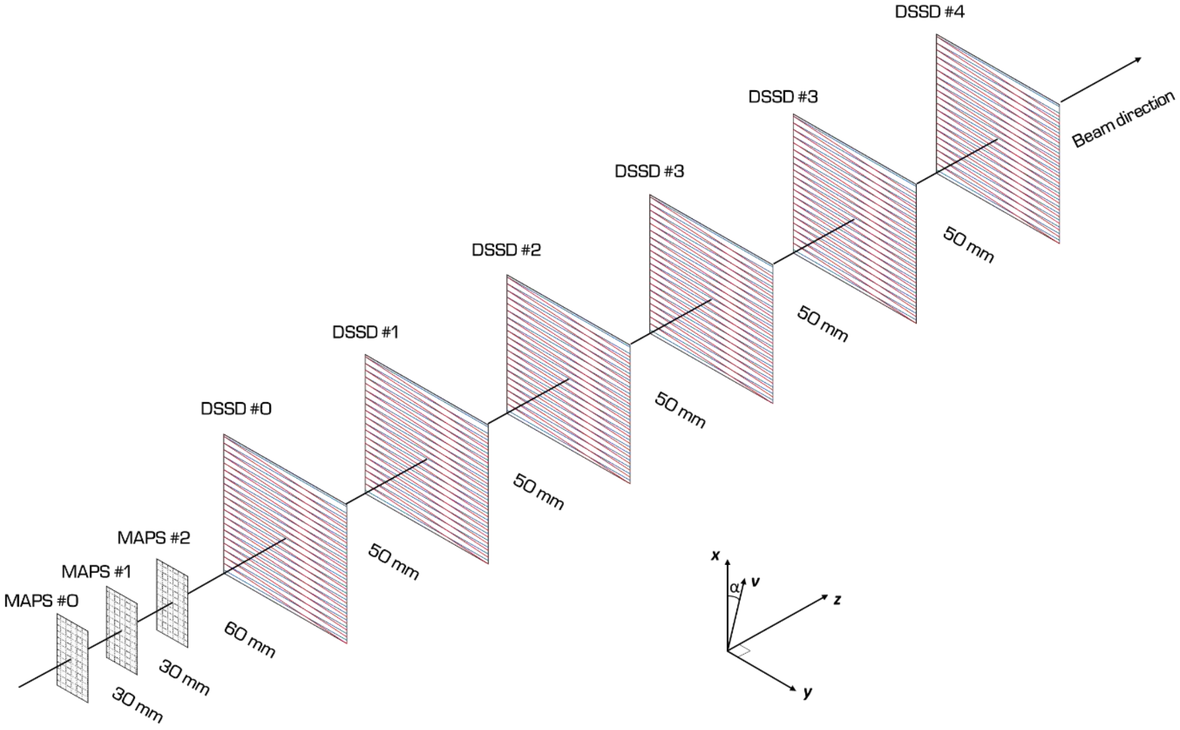
Sensor parameters:

• Sensor size:	62×62 mm²;
• Strip pitch (P/N side):	58 µm/58 µm;
• Num. of strips per side:	1024;
• Stereo-angle:	7.5°;
• Thickness:	300 µm;

Front-end electronics:

- STS-XYTER ASIC:
- Free streaming readout architecture;
- 5 bit ADC + 14 bit TDC;
- Channel throughput: 1.8 × 10^3 Hits /s

Beam telescope



Tests with 1 GeV proton beams at SC-1000:

- ➢ Study of the tracking performance of DSSD modules;
- ➢ Merging of the data from two different subsystems

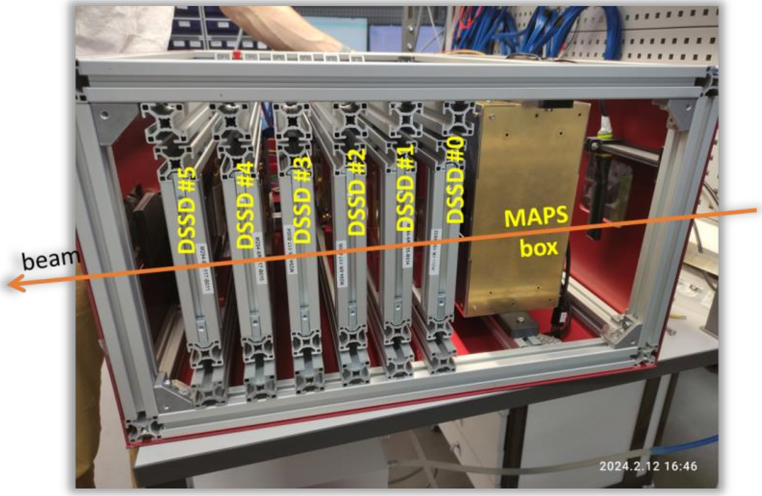
DSSD

• Sensor size:	62×62 mm²;
• Strip pitch (P/N side):	58 µ/58 µm;
• Num. of strips per side:	1024;
• Stereo-angle:	7.5°;
• Thickness:	300 µm.

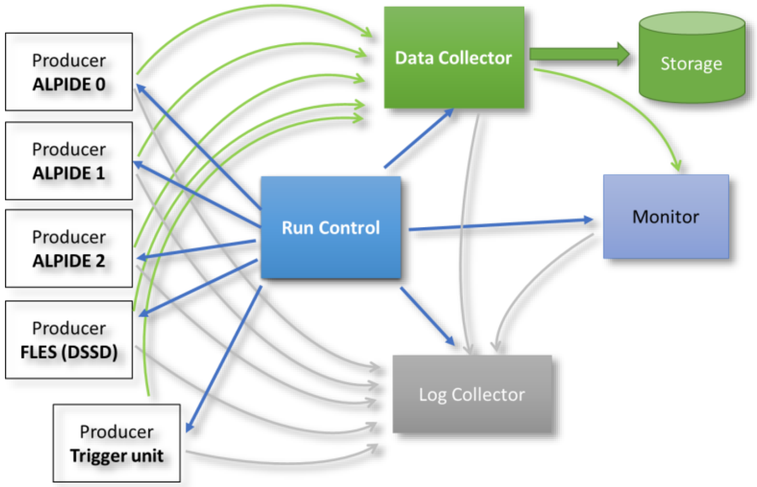
MAPS

• Sensor size:	15×30 mm² (X×Y);
• Number of pixels:	1024 × 512 (X×Y);
• Pixel size:	29.24 µm × 26.88 µm (X×Y);
• Thickness:	50 µm.

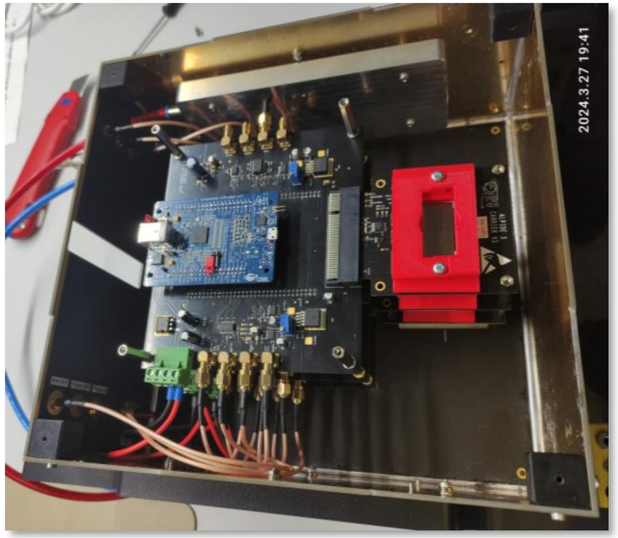
DAQ system of the telescope



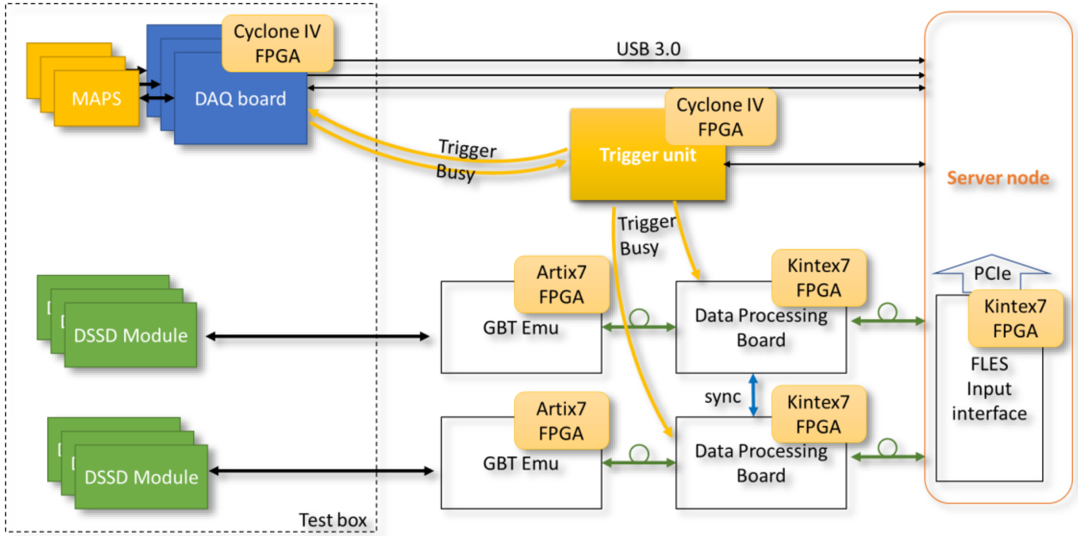
Telescope mechanics (A. Sheremetev)



Event builder based on EUDAQ (A. Kolozhvari, V. Leontyev)

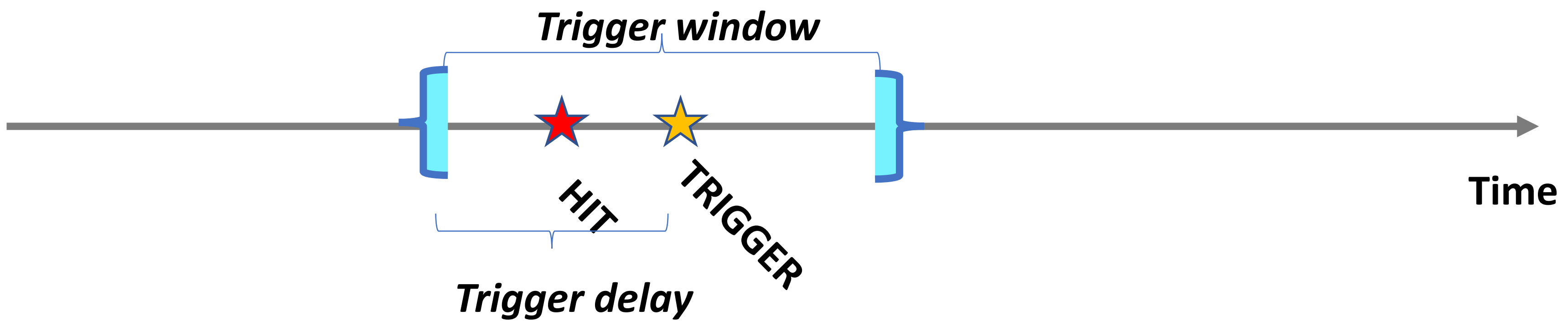


MAPS Readout (R.A. Diaz)



Time slice selection based on trigger signal

- The front-end readout electronics of STS operates only in the self-triggered mode therefore the data filtering according to the trigger decision is implemented in the DPB;
- Due to the free-streaming readout scheme DPB provides the functionality of the time-based data sorting. The sorters store the data for the sufficient amount of time (up to 96 μs) and thus provides the possibility to implement also trigger-based data filter.



Trigger window and trigger delay parameters could be configured within the specified range:

Trigger latency <= 7 us;

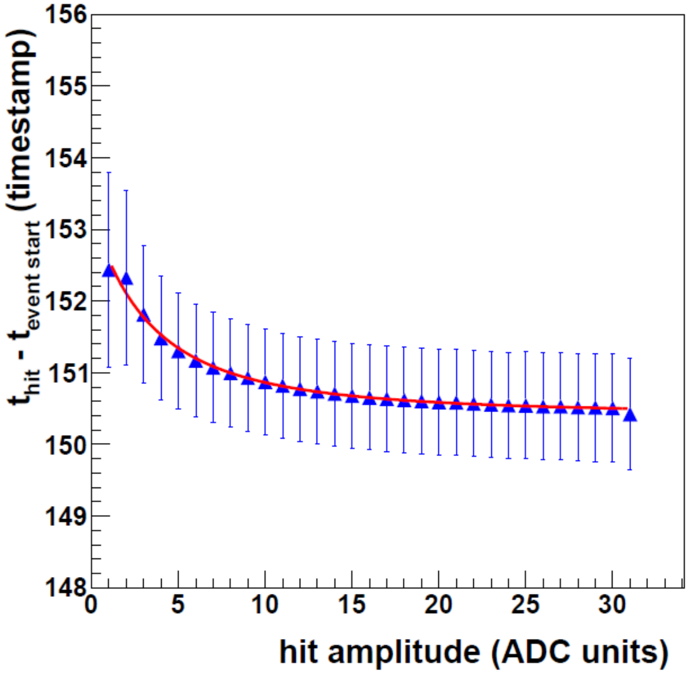
Trigger window <= 7 us;

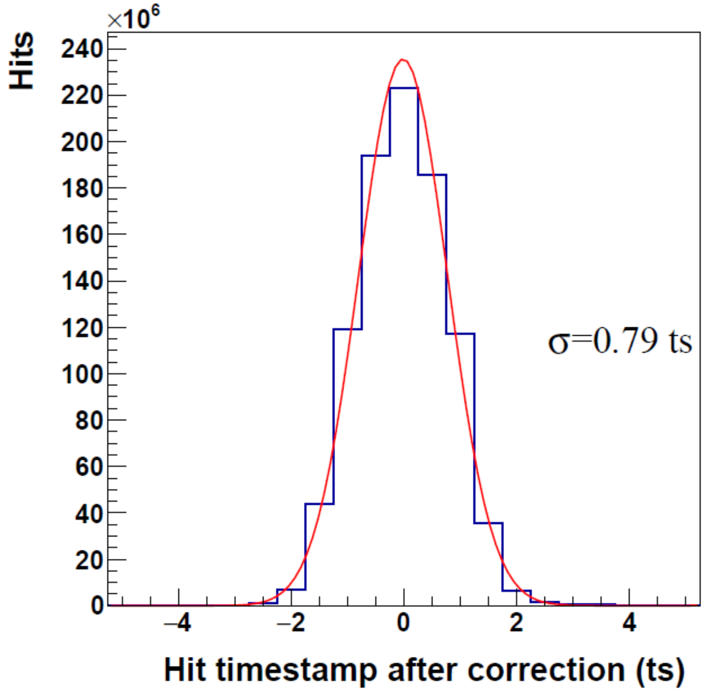
Min time between triggers: 20 us.

Time resolution

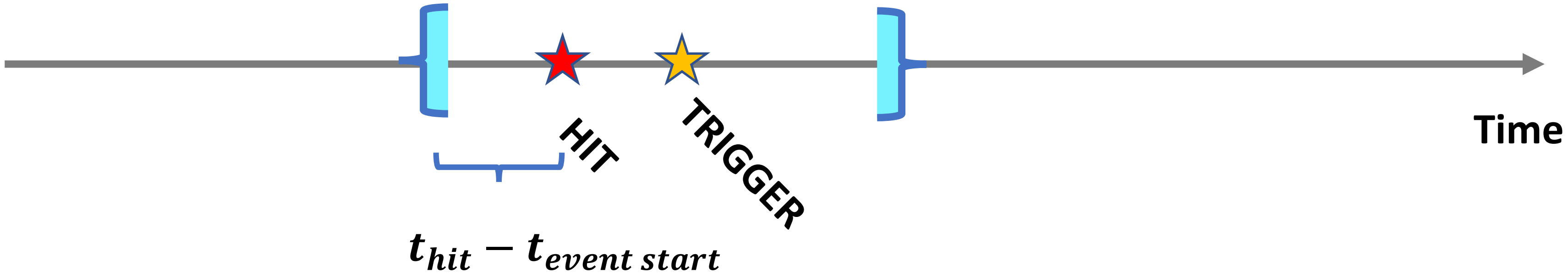
$$\sigma_{tot} = \sigma_{Jitter} \oplus \sigma_{TDC} \oplus \sigma_{Time\,Walk}$$

Time walk correction

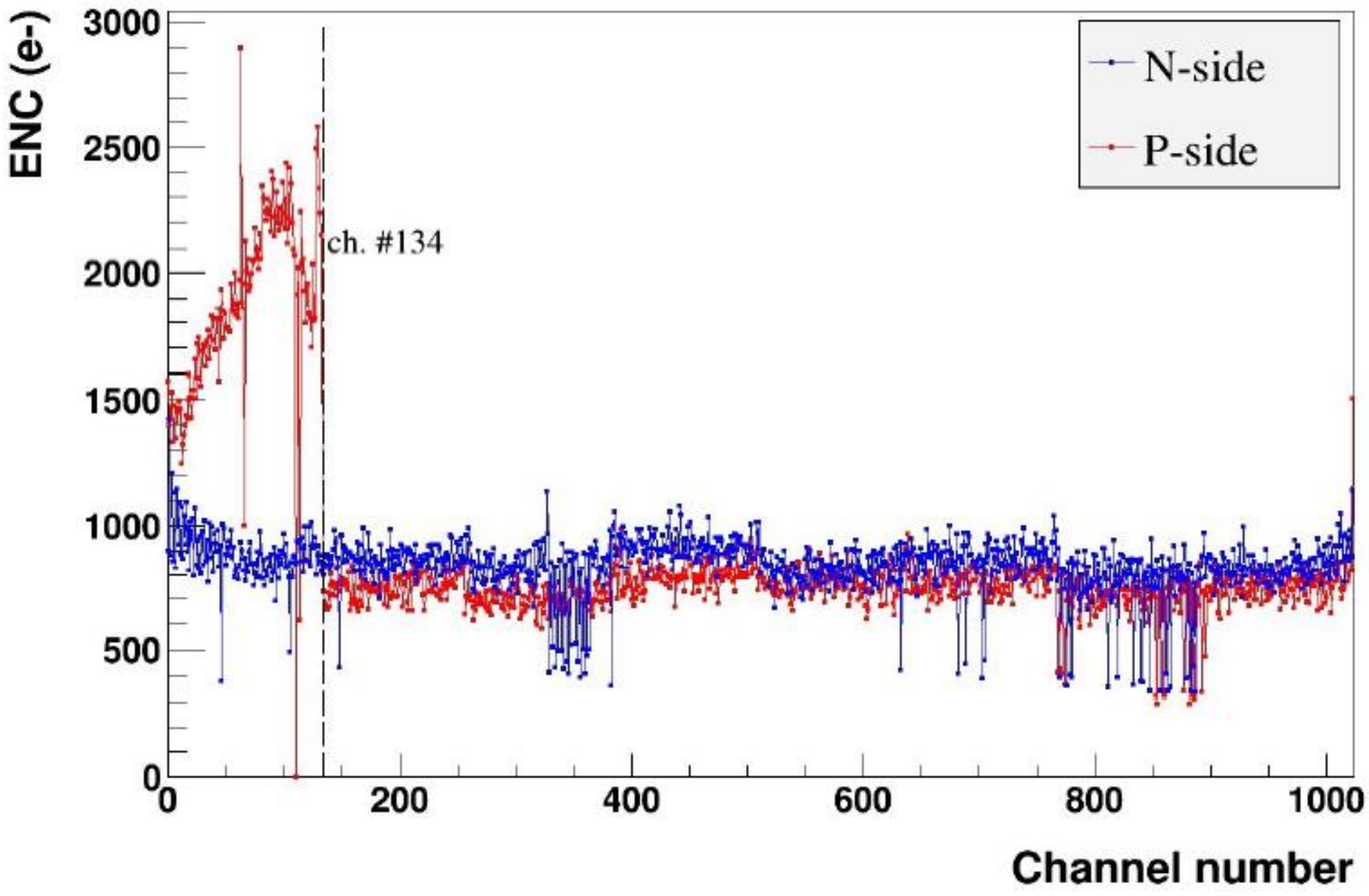


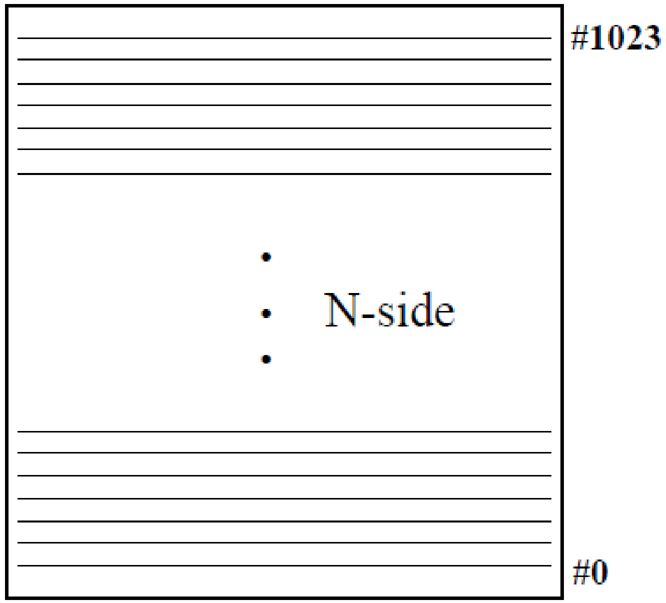


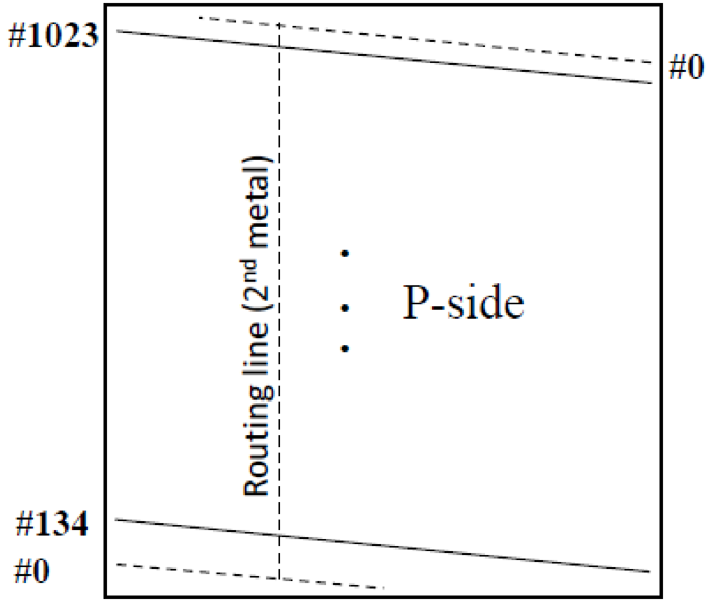
σ_{tot} = 9.9 ns



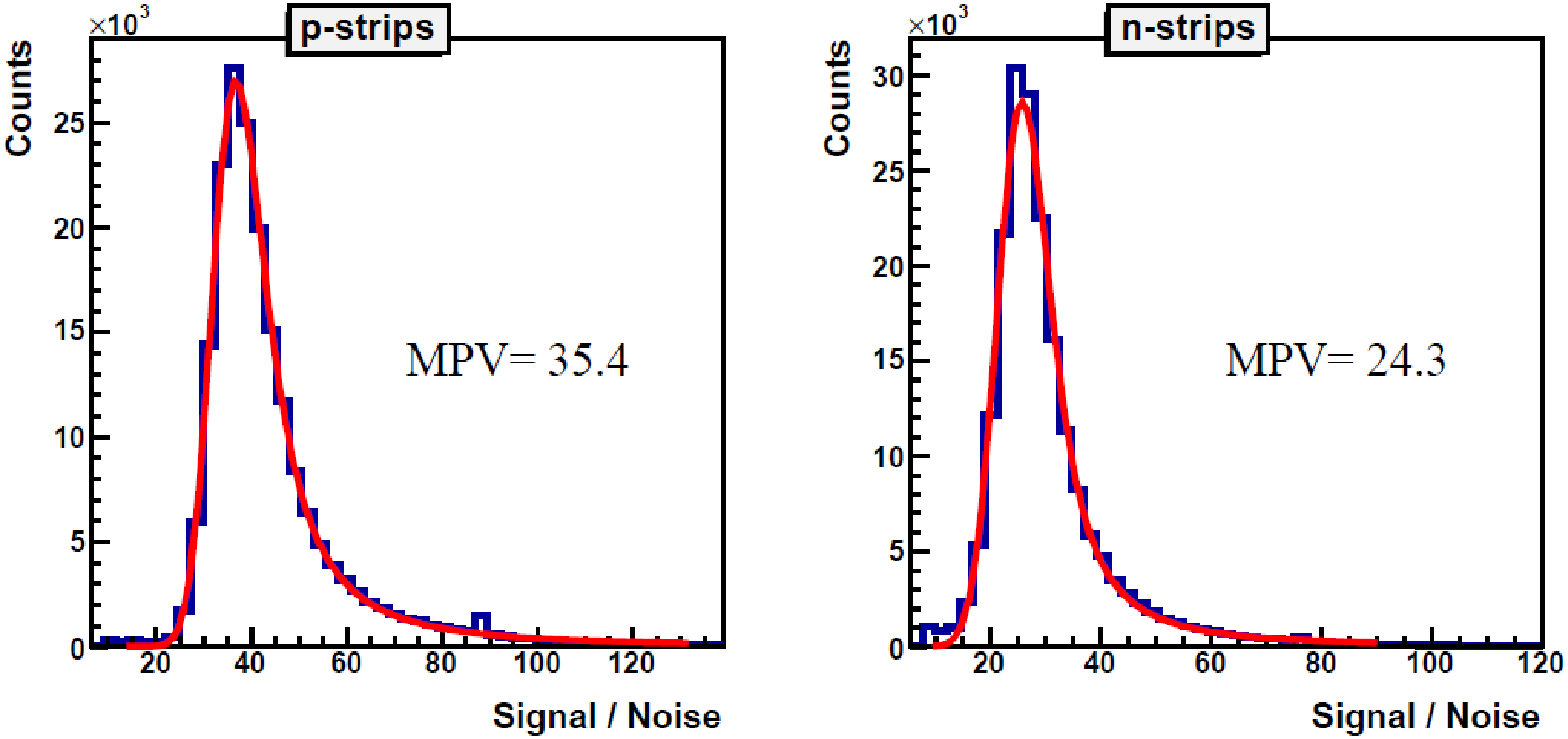
Noise distribution







Signal/Noise

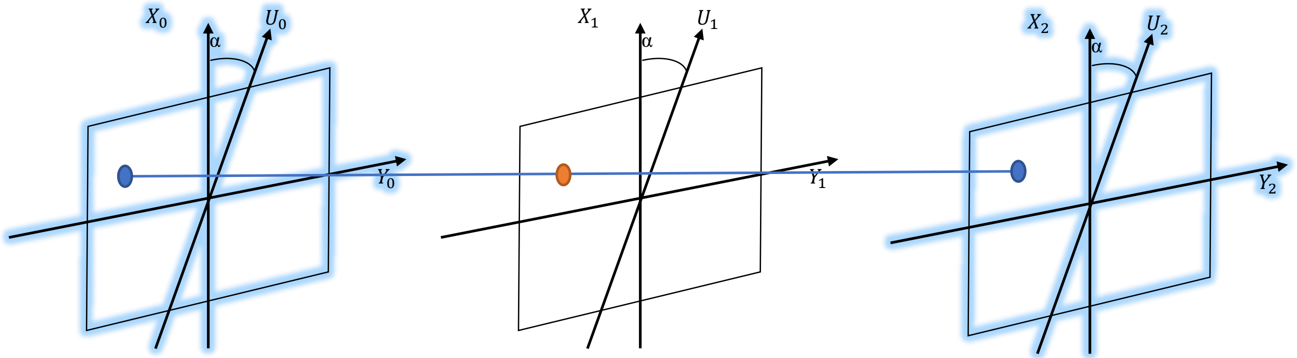


Signal/Noise distribution for 1GeV protons

SRIM: $Signal_{MIP} = 0.92 \times Signal_{1\ GeV\ protons}$

- ***p*-strips SNR_{MIP}: 28 - 30.5;**
- ***n*-strips SNR_{MIP}: 21 - 24.5;**
- ***z*-strips SNR_{MIP}: 8 – 13;**

Spatial resolution



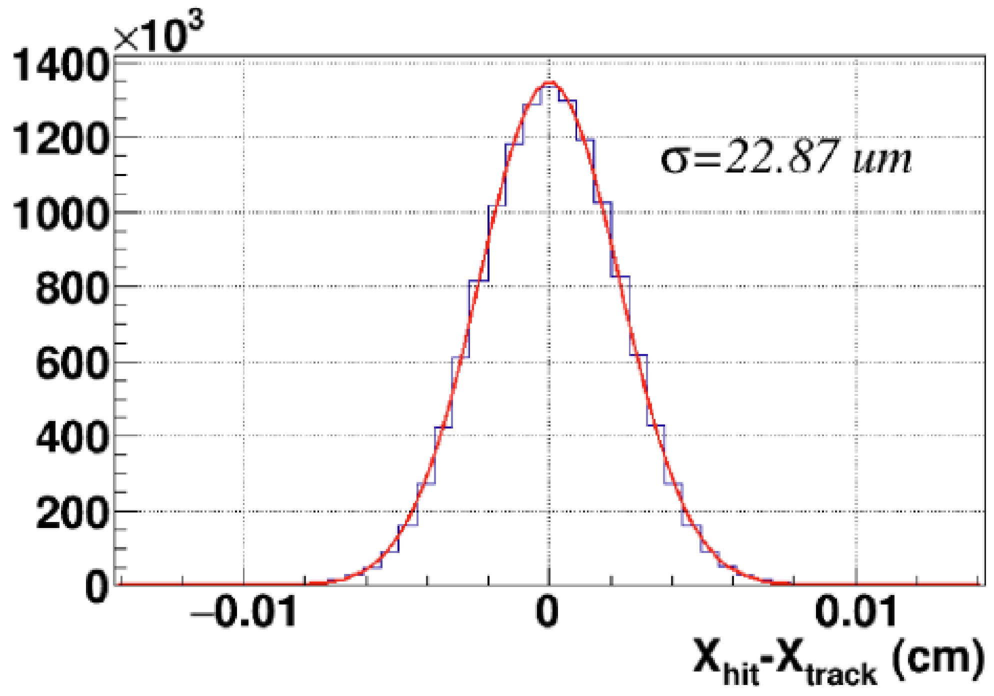
$$\sigma_{res} = \sigma_{sp.res.} \oplus \sigma_{line} \oplus \sigma_{mcs}$$

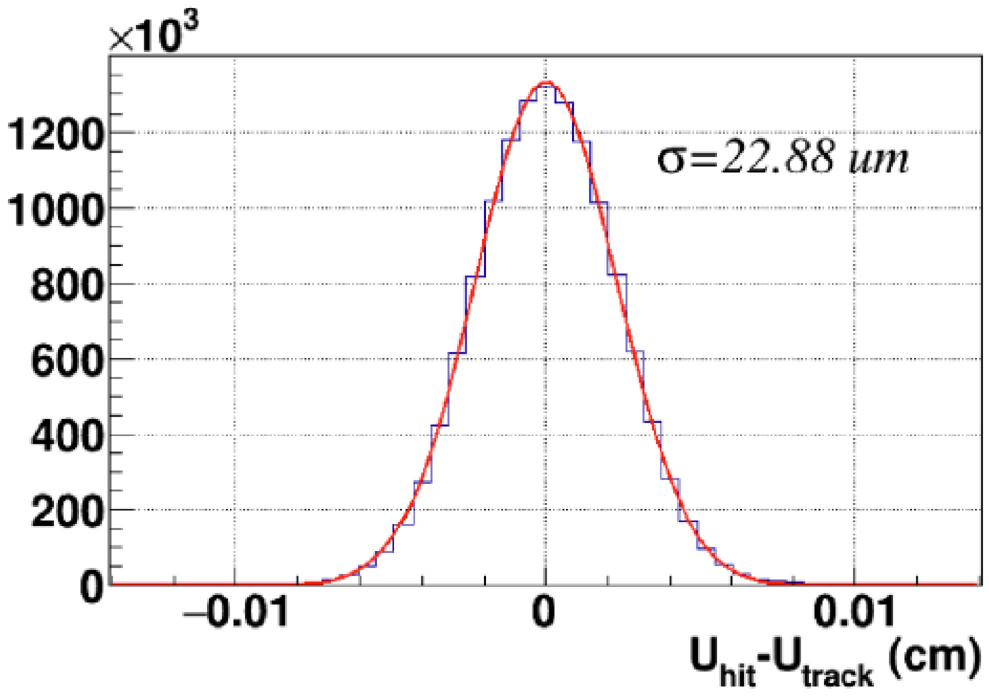
$$\sigma_{line} = \frac{1}{\sqrt{2}} \sigma_{sp.res.}$$

σ_{MCS} = 11.6 μm (GEANT)

σ_{res} - Measured residuals;
$\sigma_{sp.res.}$ - Spatial resolution of the detector;
σ_{line} - Inaccuracy of the straight-line track interpolation
σ_{mcs} - Uncertainties induced by Multiple Coulomb Scattering.

Spatial resolution



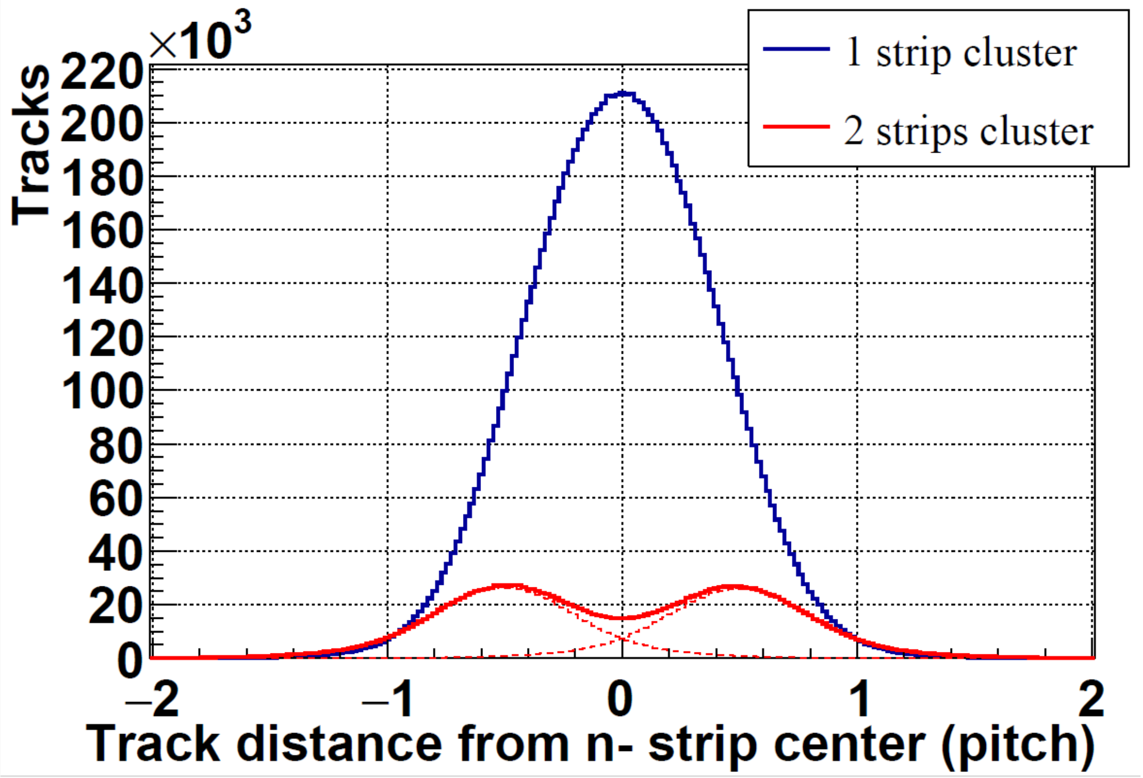


$\sigma_{X,U}$ = 15.4 ± 0.4 μm for regular strips
σ_U = 16.4 ± 0.4 μm for the sensor areas with *z*–strips
σ_Y = 170 ± 4μm

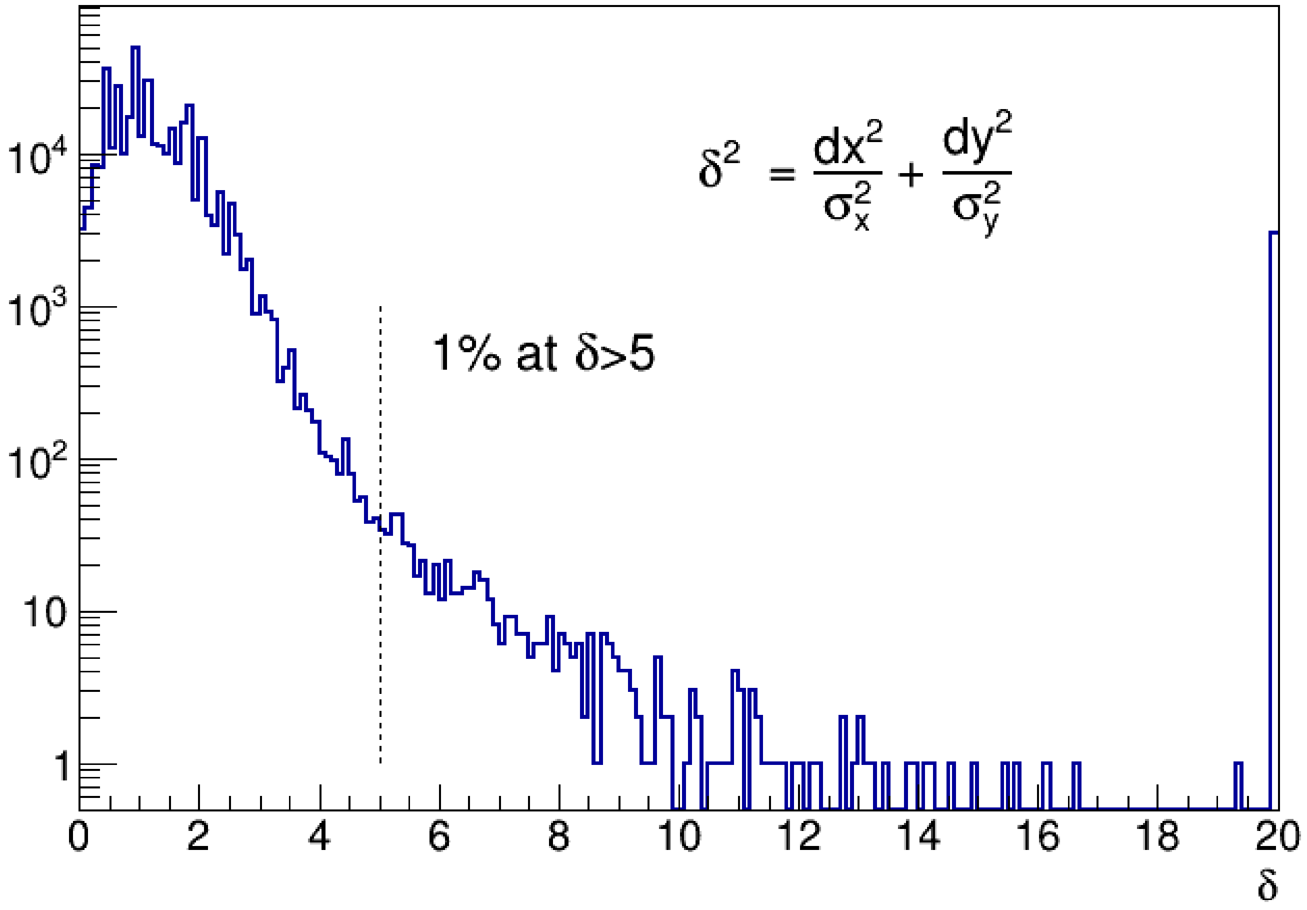
Spatial resolution

RMS of the uniform probability distribution within a strip pitch 58 µm/√12 ≈ 16.74 µm

The calculated spatial resolution is lower due to the impact of two-strip clusters, which are located in the narrow regions between strips. For the tracks of normal incidence ~ 80% of clusters have a size of 1-strip and ~ 18% are 2-strip clusters. The fraction of clusters with a size bigger than 2 strips was negligible.



Efficiency



Event selection:

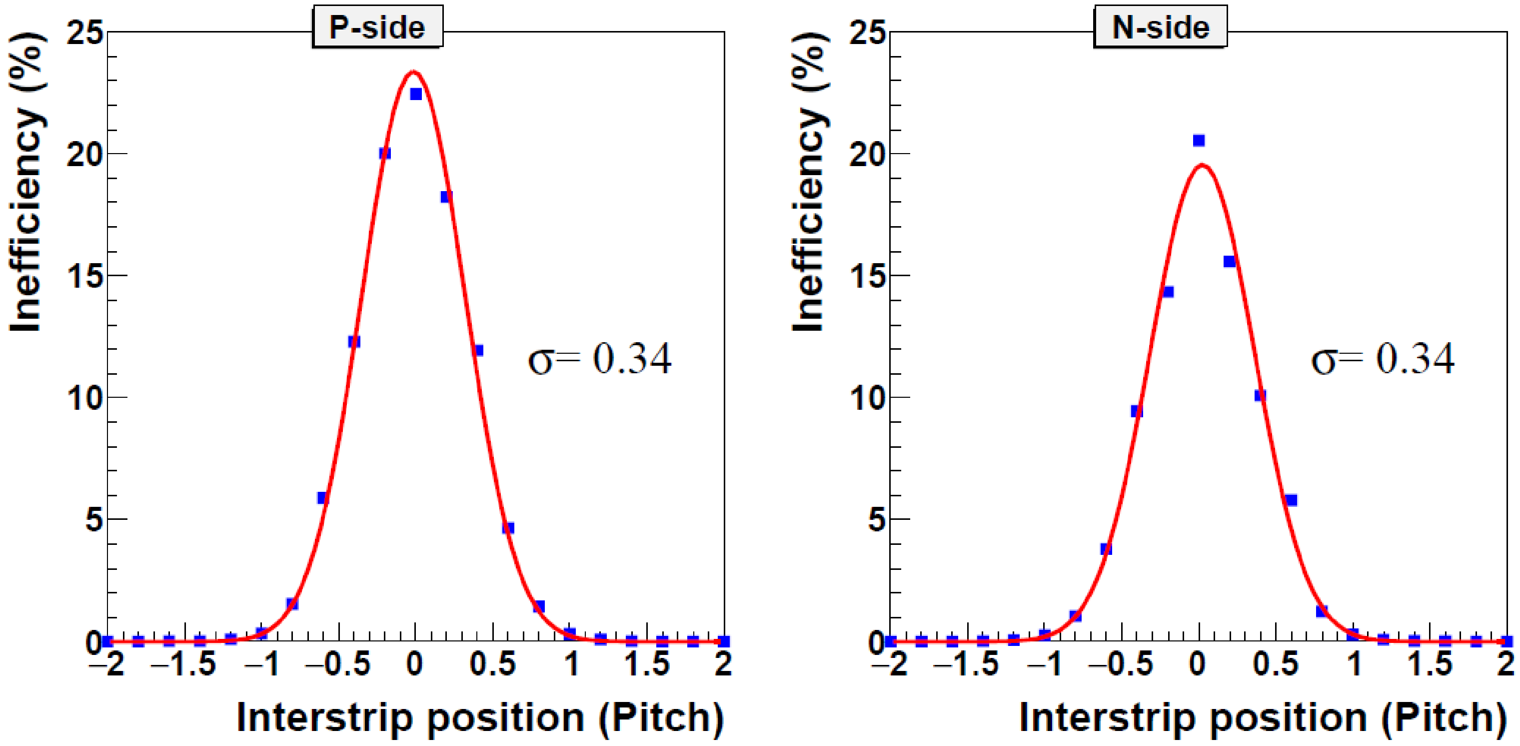
1. **Time window.** ±4 clock cycles (50 ns) around the trigger;
2. **Track quality**. χ^2/Ndf <1;
3. Tracks which have hits in all other modules

Results:

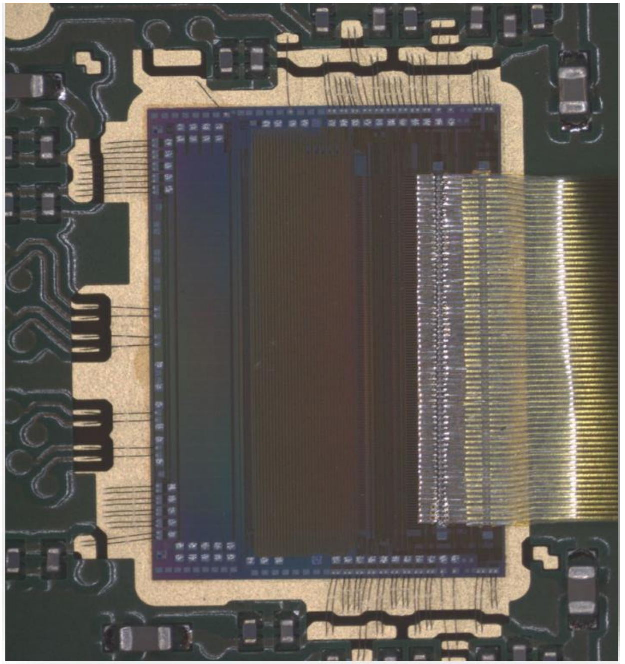
- Average efficiency for the sensor areas with regular strips > 99% for all 4 modules;

- Efficiency of z- strips ~90% .

Side eff. of the areas with not-bonded strips



Inefficiency of not-bonded channels

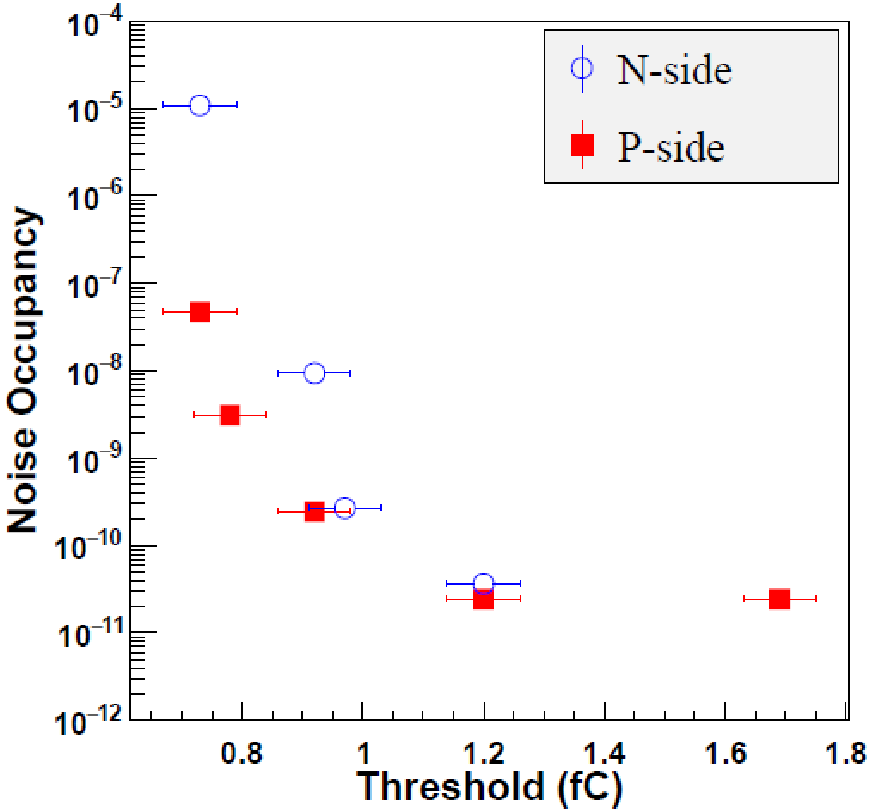


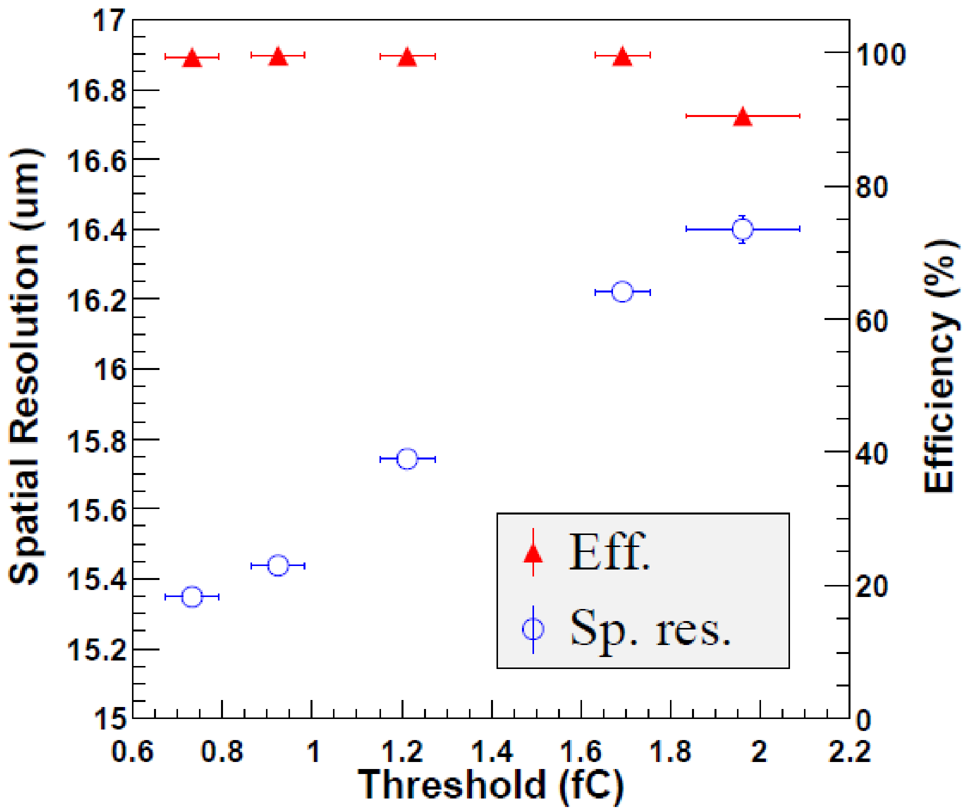
SMX ASIC with bonded micro-cables

The inefficiency was calculated for the selected pitch slice as a ratio of impinging tracks which do not produce hits in the area of ±2 strips around the predicted point

Average efficiency for track actually passing through a full area of not-bonded strip is estimated to be 83% and 85.7% for p- and n- sides respectively

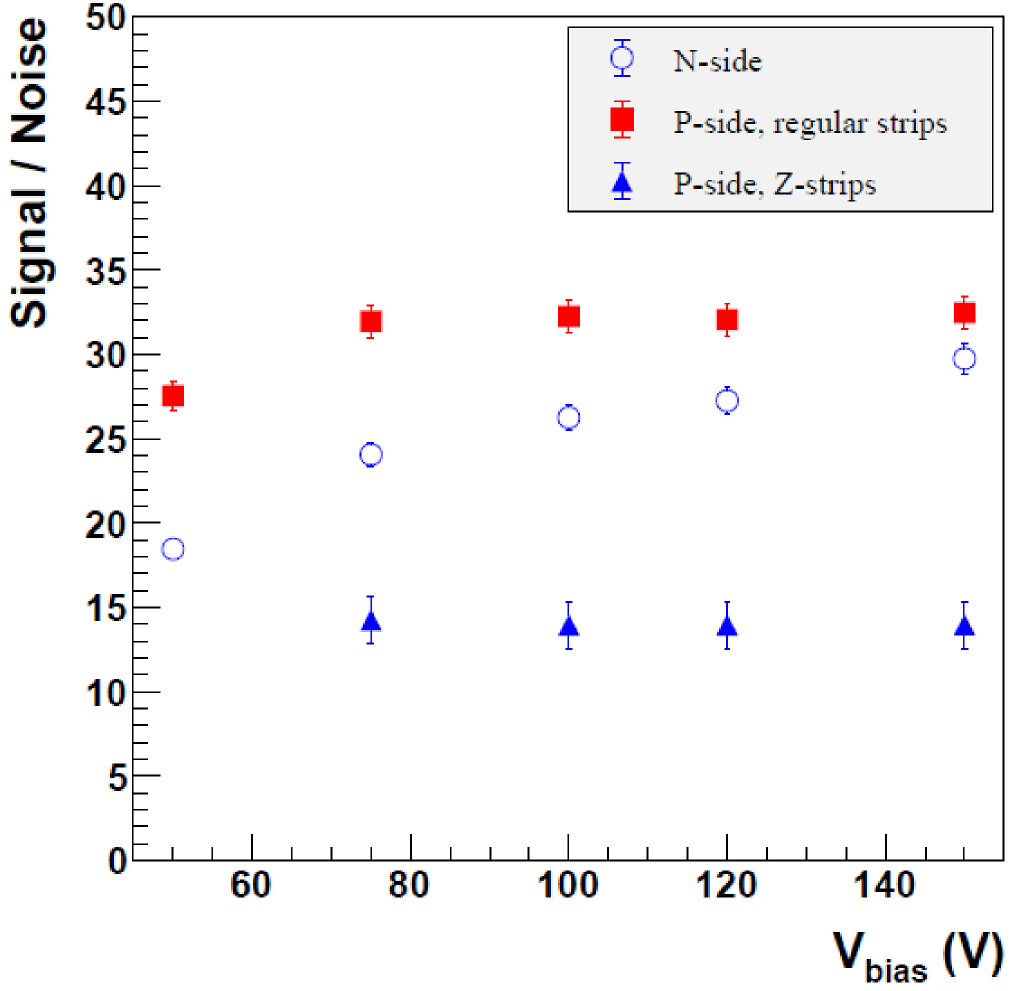
Threshold scan

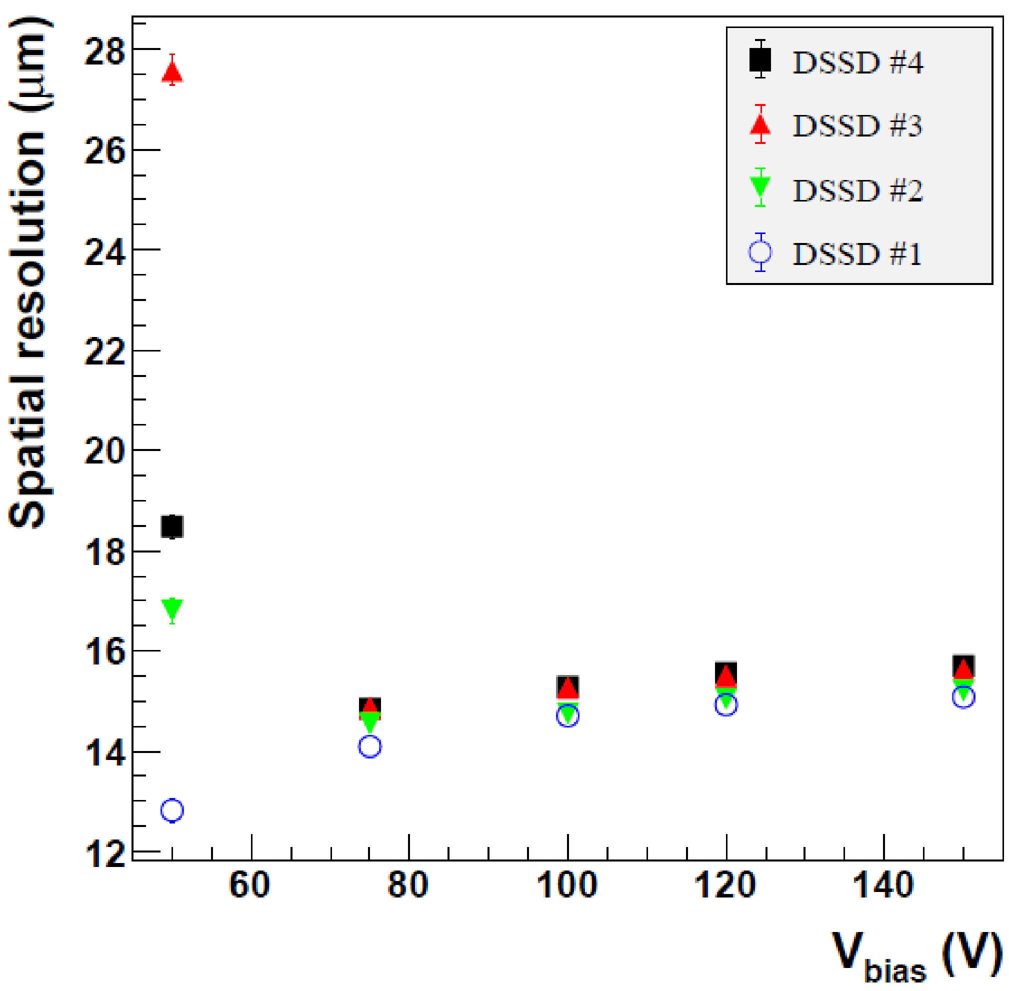




The STS requirements were fulfilled for the operation ADC threshold 0.8-1.5 fC.

Detector bias voltage scan





Conclusion

- Time measurement precision 9.9 ns;
- Regular strips:
  - SNR > 21 for regular strips;
  - Spatial resolution: 15.4 ± 0.4 μm;
  - Efficiency ~99 %;
- Strips with a second metallization layer (z-strips):
  - SNR 8-13;
  - Spatial resolution: 16.4 ± 0.4 μm;
  - Efficiency ~90.5 %;
- The region of 75-100 V of detector bias voltage and 0.8-1.5 fC ADC threshold were selected for the operation of non-irradiated modules in the BM@N setup.