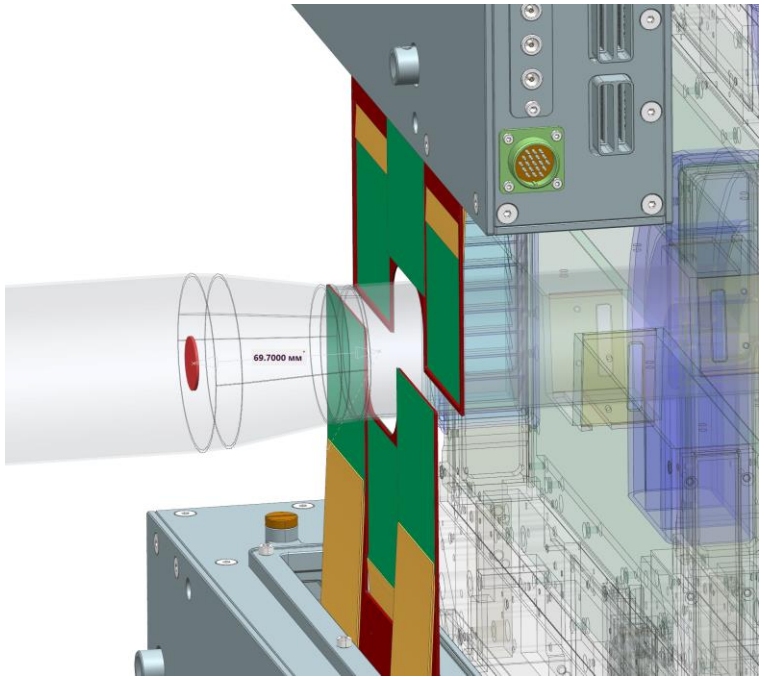
Исследование характеристик трековых модулей на основе DSSD-сенсоров на ускорителе СЦ-1000 для эксперимента BM@N

Владимир Леонтьев (ОЯИ НИИЯФ) для группы STS

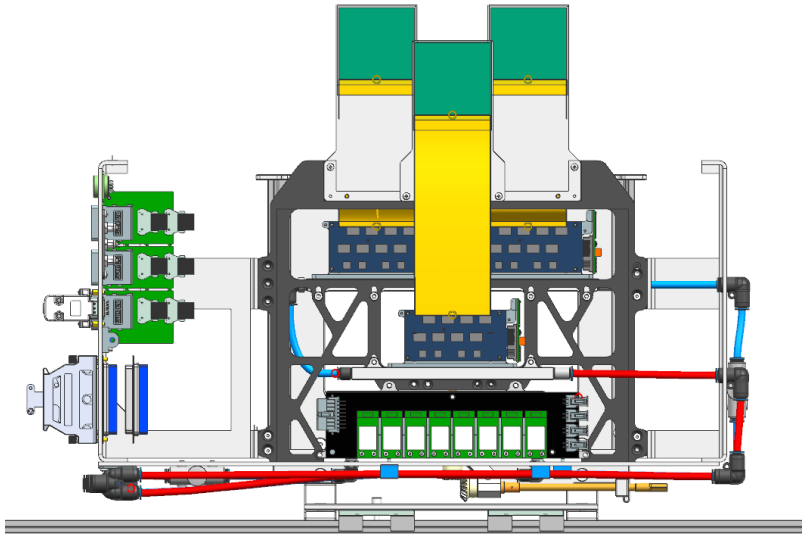
a) Joint Institute for Nuclear Research, Dubna, Russia
D.Dementev, A.Kolozhvari, Yu.Murin, I.Rufanov, A.Sheremetev, M.Shitenkov
a, b) Moscow State University, Moscow, Russia
V.Leontyev
a, c) Center of Technological Applications and Nuclear Development, Havana, Cuba
R.Arteche Diaz, C.Ceballos Sanchez, A.Rodriguez Alvarez

Vertex Si-plane for BM@N experiment

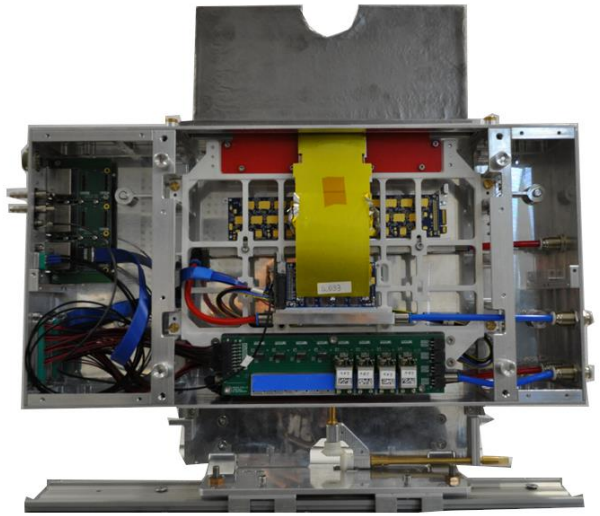
Motivation



Si-station with 6 STS modules



Half-station with 3 STS modules



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

DSSD module

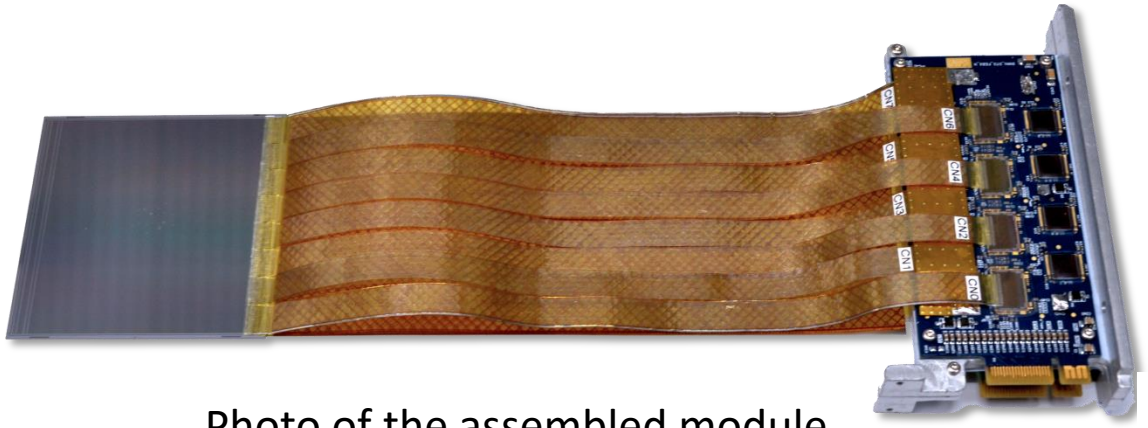
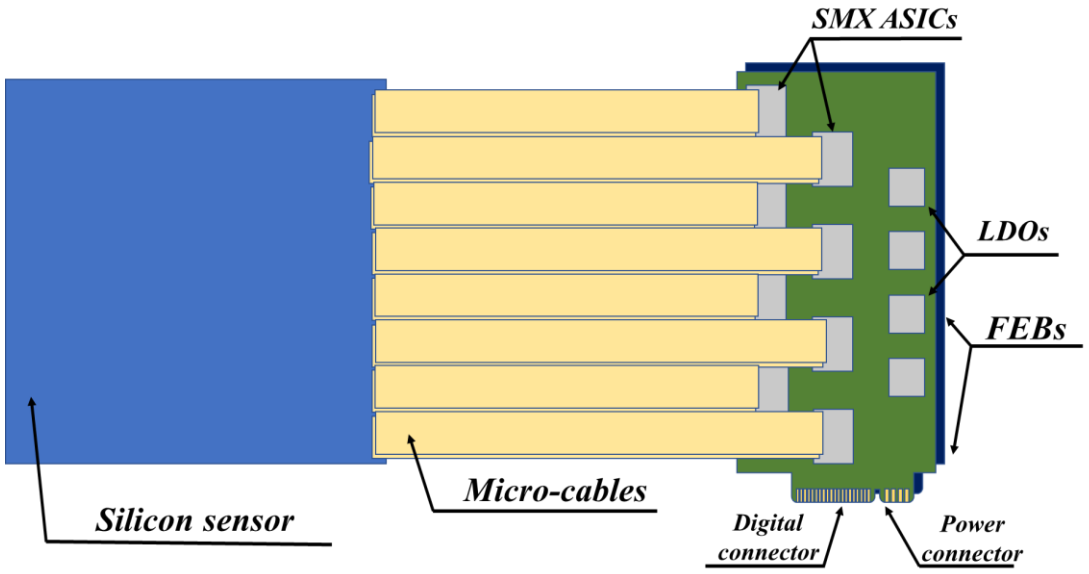
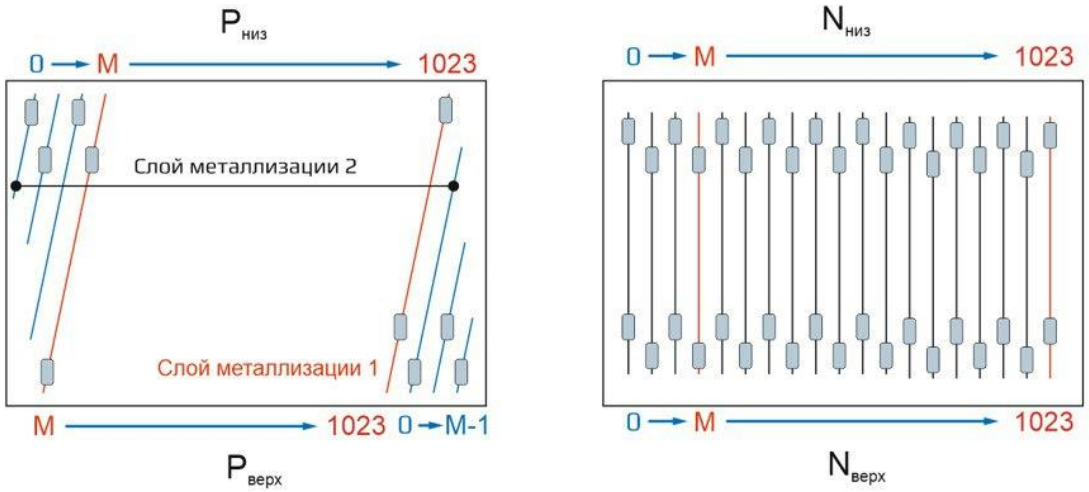


Photo of the assembled module



Sensor parameters:

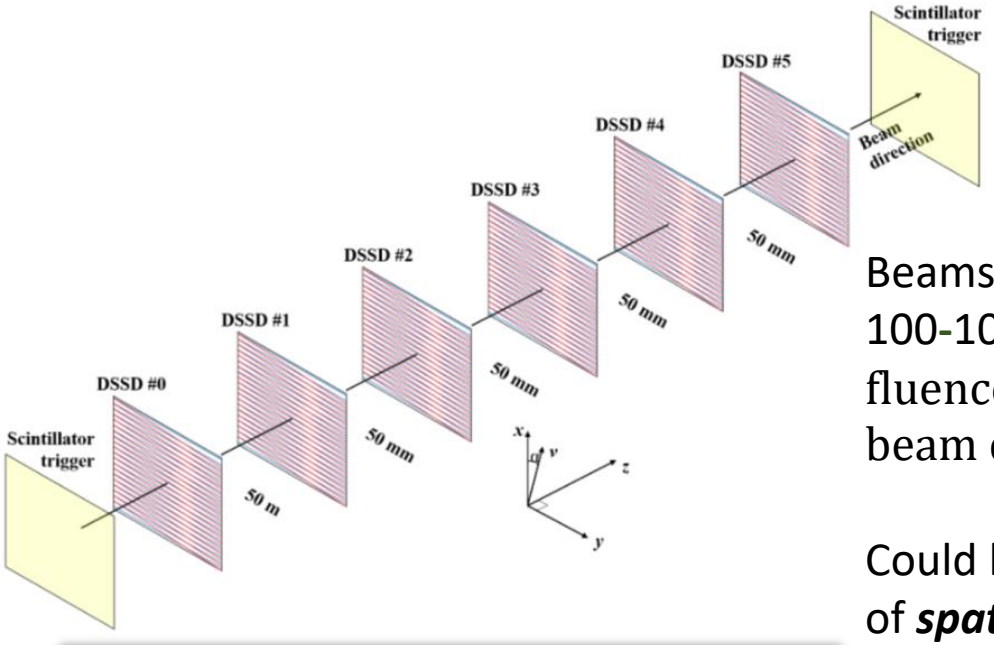
- Sensor size: 62×62 mm²;
- Strip pitch (P/N side): 58 µm/58 µm;
- Num. of strips per side: 1024;
- Stereo-angle: 7.5°;
- Thickness: 300 µm;

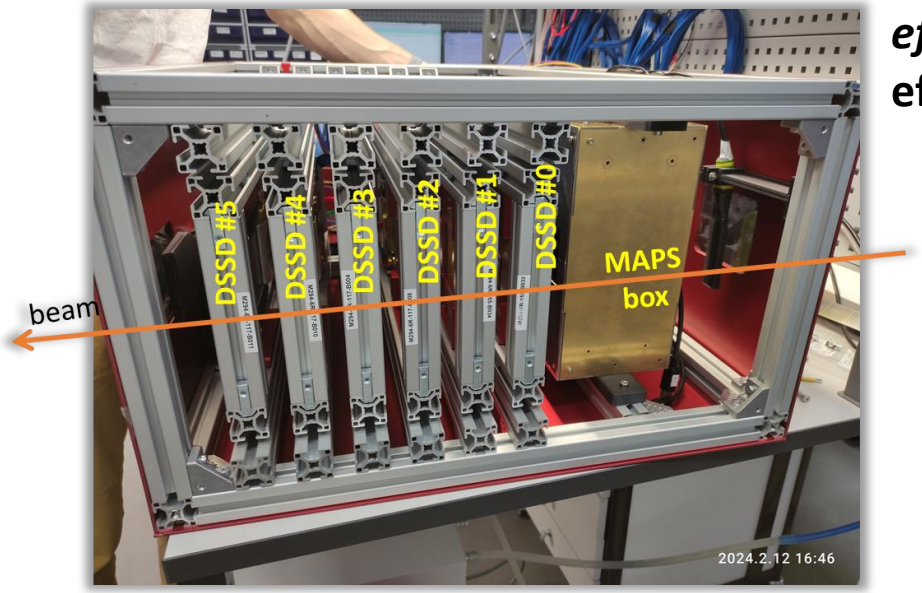


Front-end electronics:

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

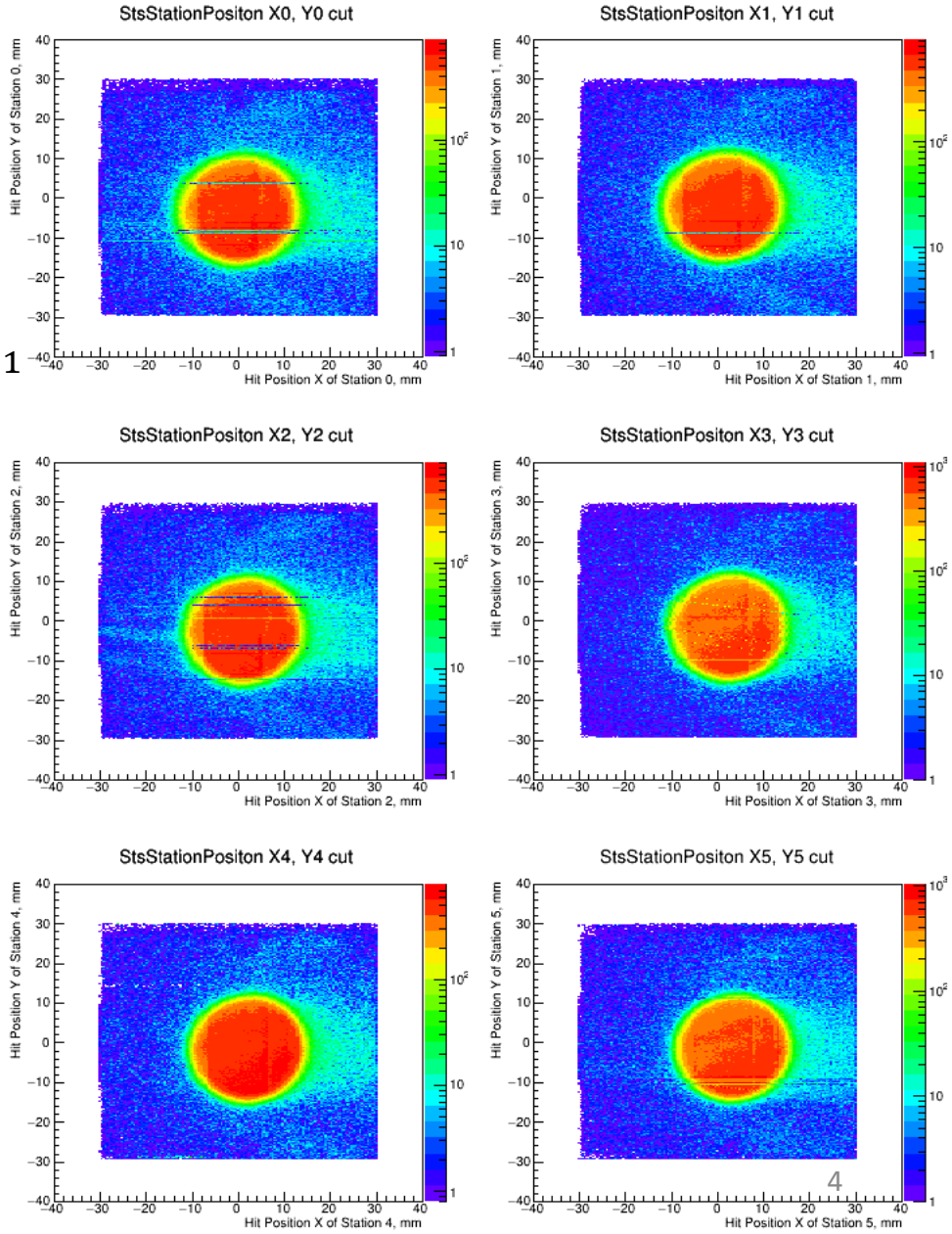
Beam telescope





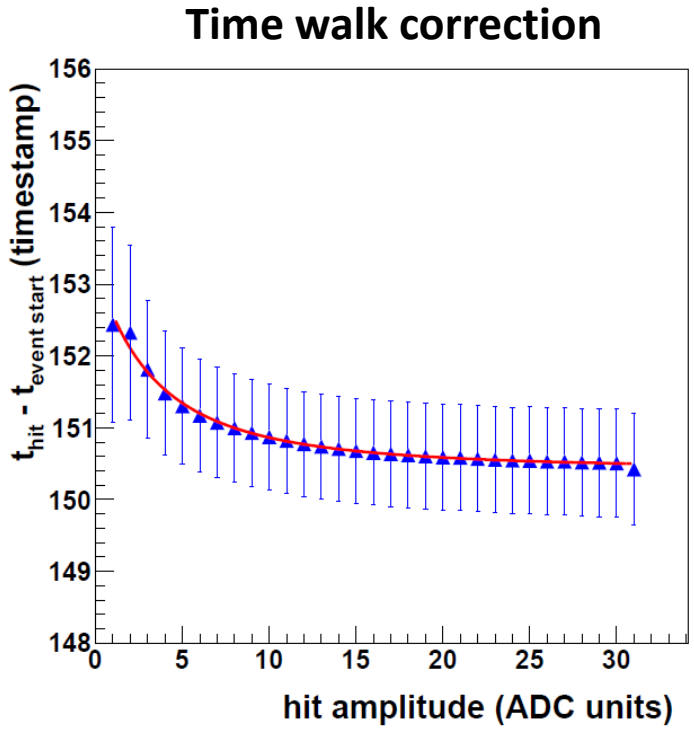
Beams of
100-1000 MeV protons,
fluence $10^4 - \ 10^8\ cm^{-2}s^{-1}$
beam diam. 25 mm;

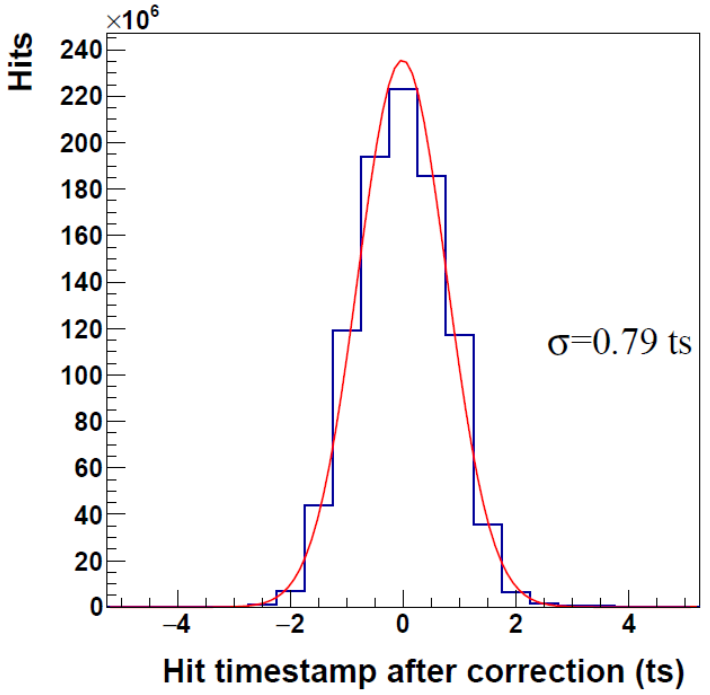
Could be used for the study of ***spatial resolution, efficiency, charge sharing*** **effects**, etc.



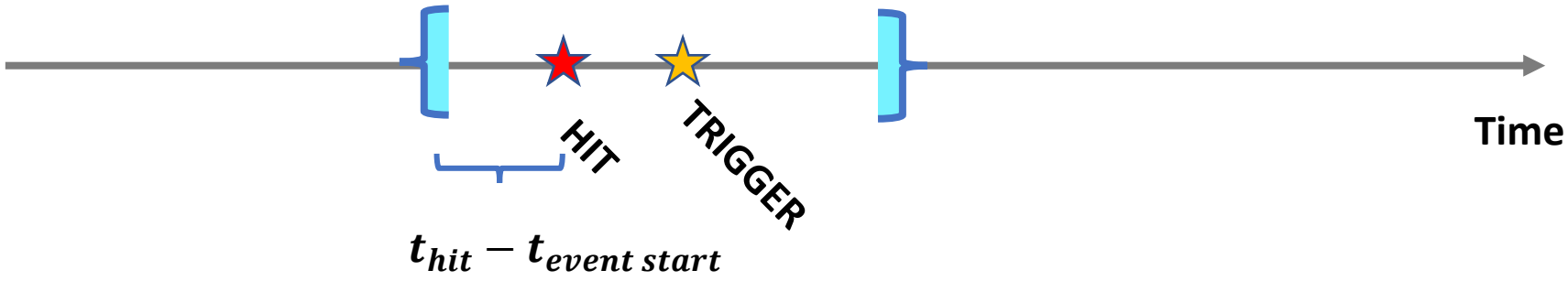
Time resolution

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



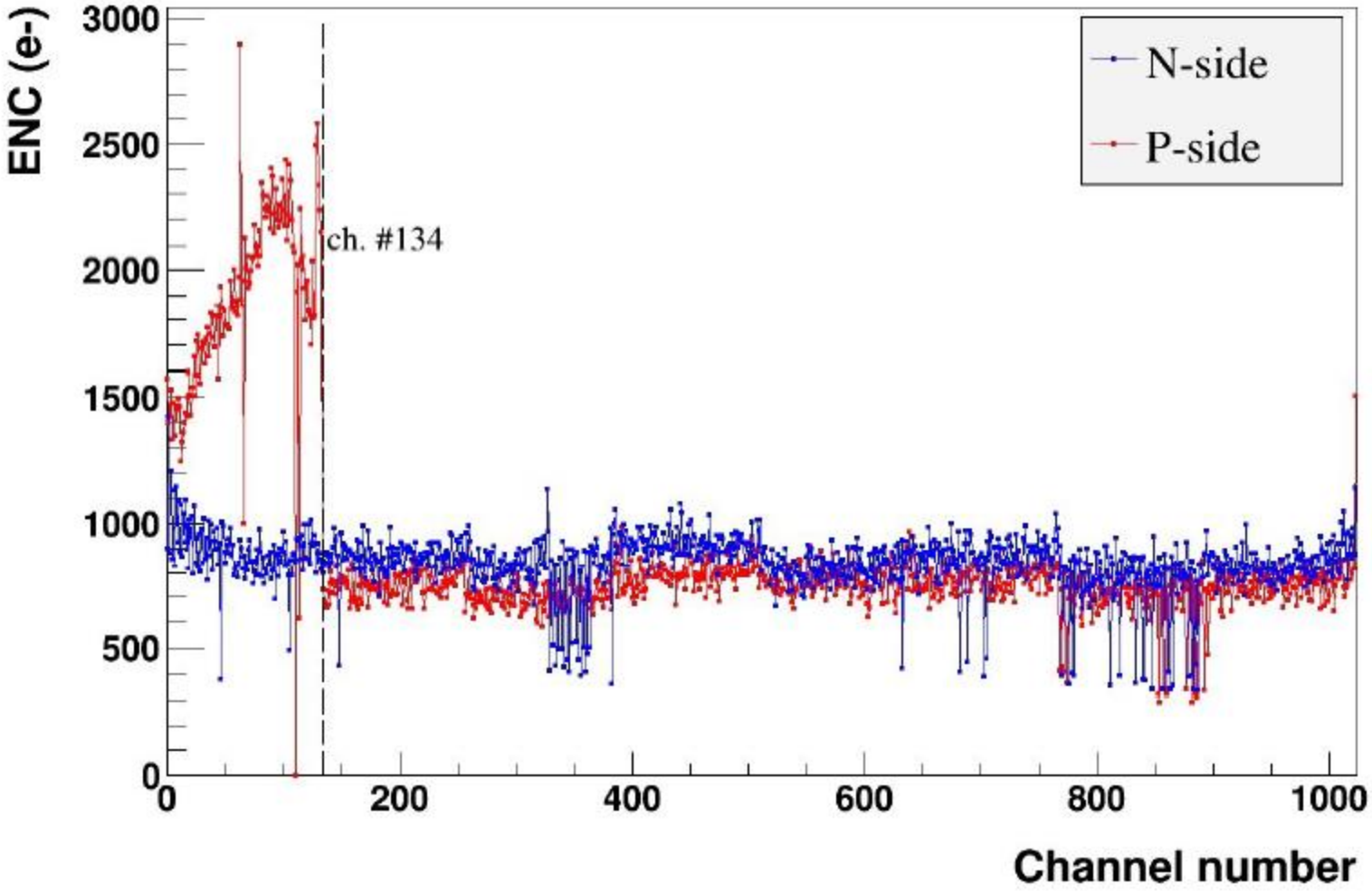


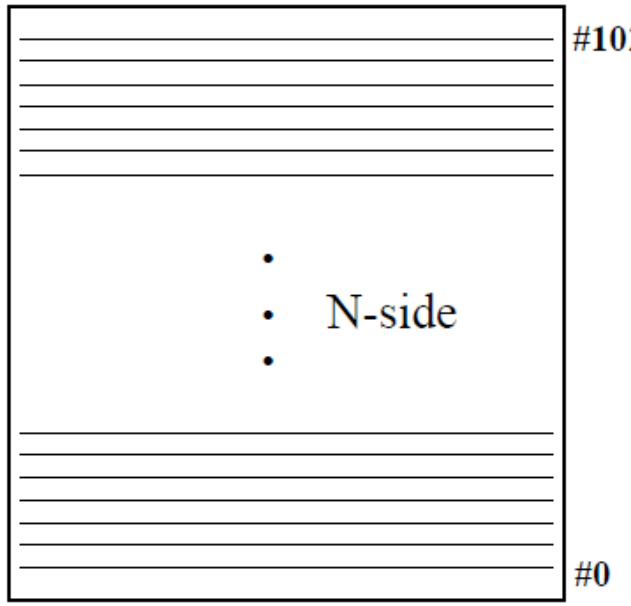
$\sigma_{tot} = 9.9$ ns

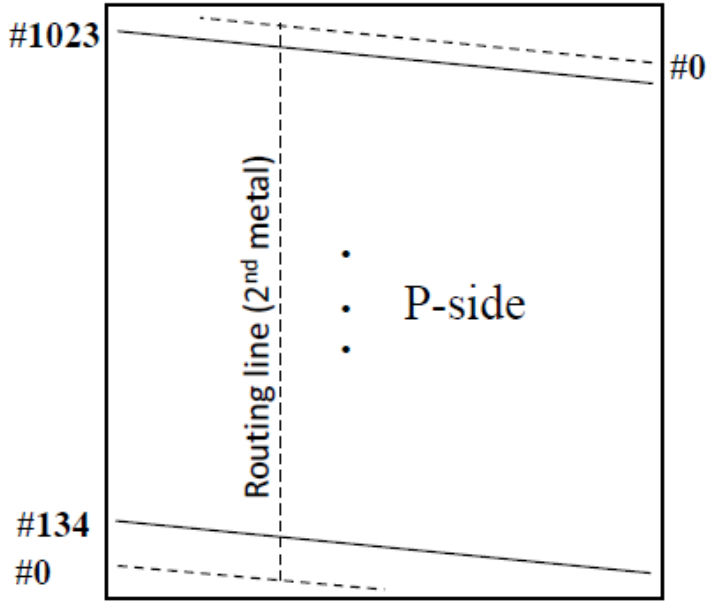


$t_{hit} - t_{event\ start}$

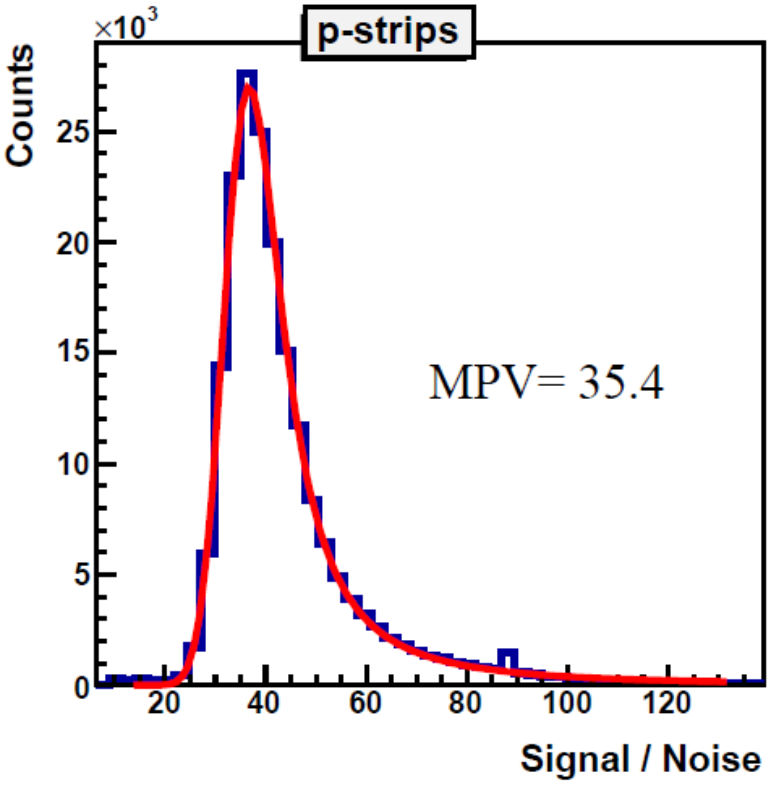
Noise distribution

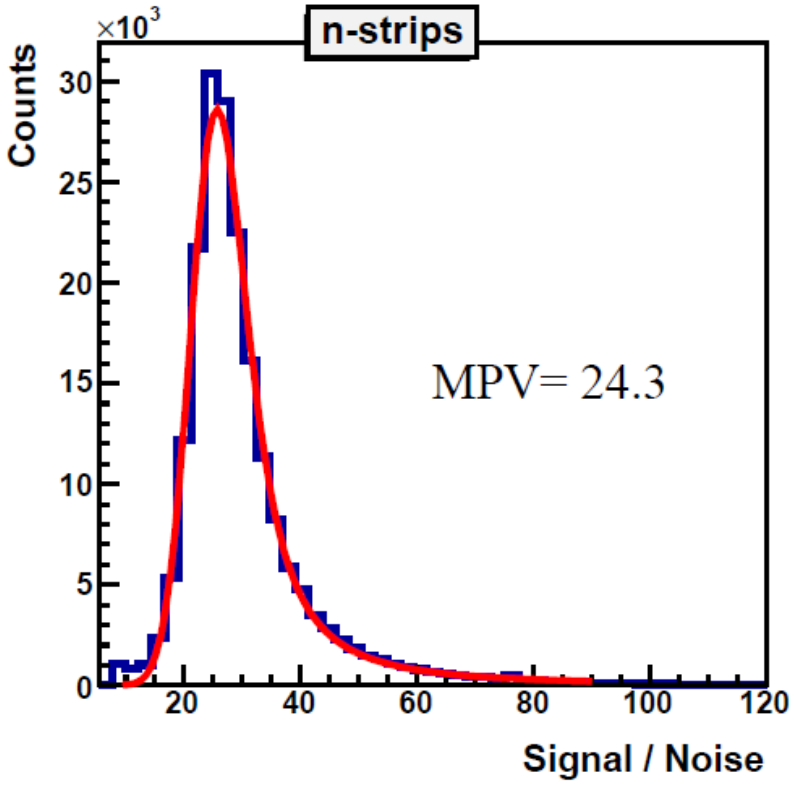


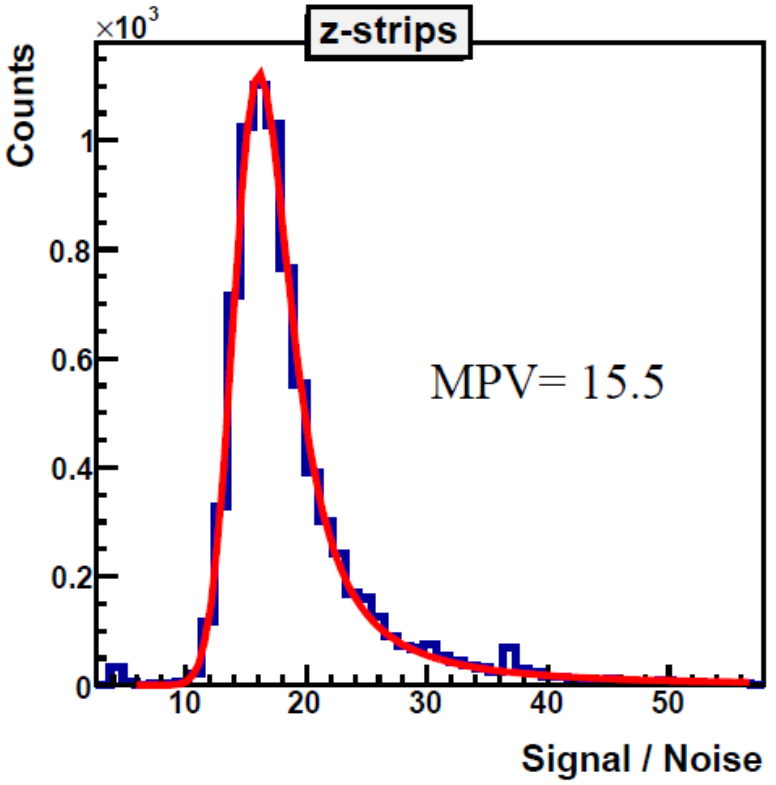




Signal/Noise





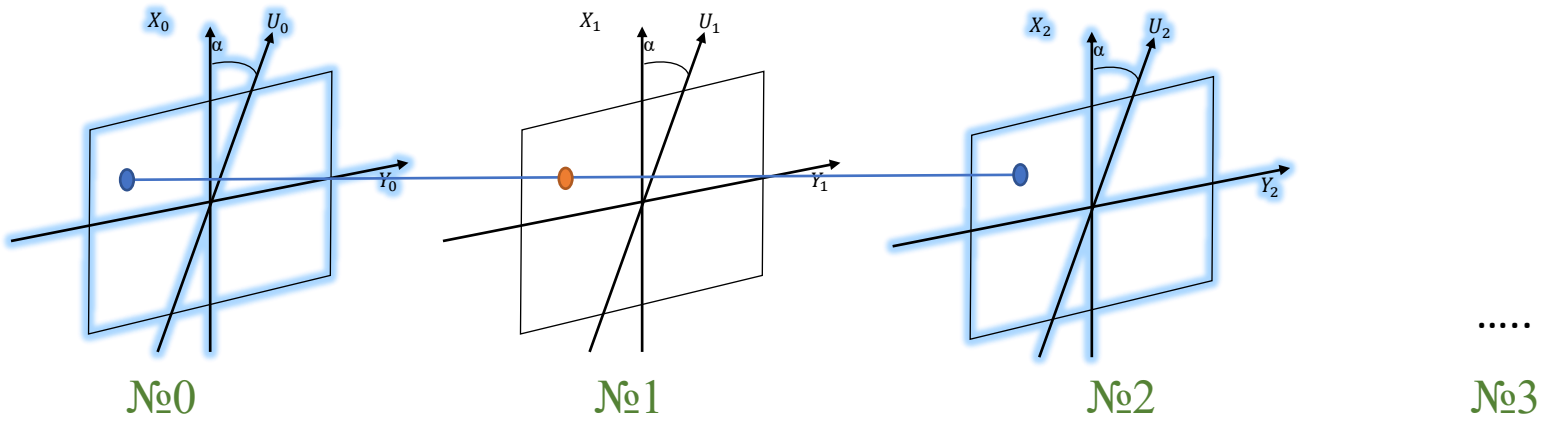


Signal/Noise distribution for 1GeV protons

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



.....

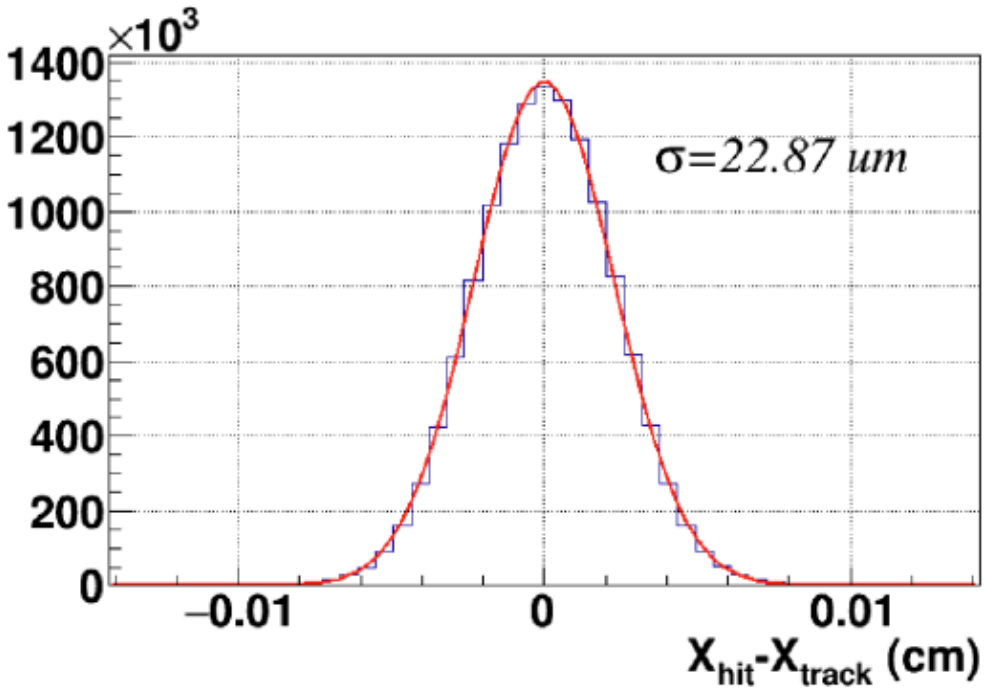
$$\sigma_{res} = \sigma_{sp.res.} \oplus \sigma_{line} \oplus \sigma_{mcs}$$

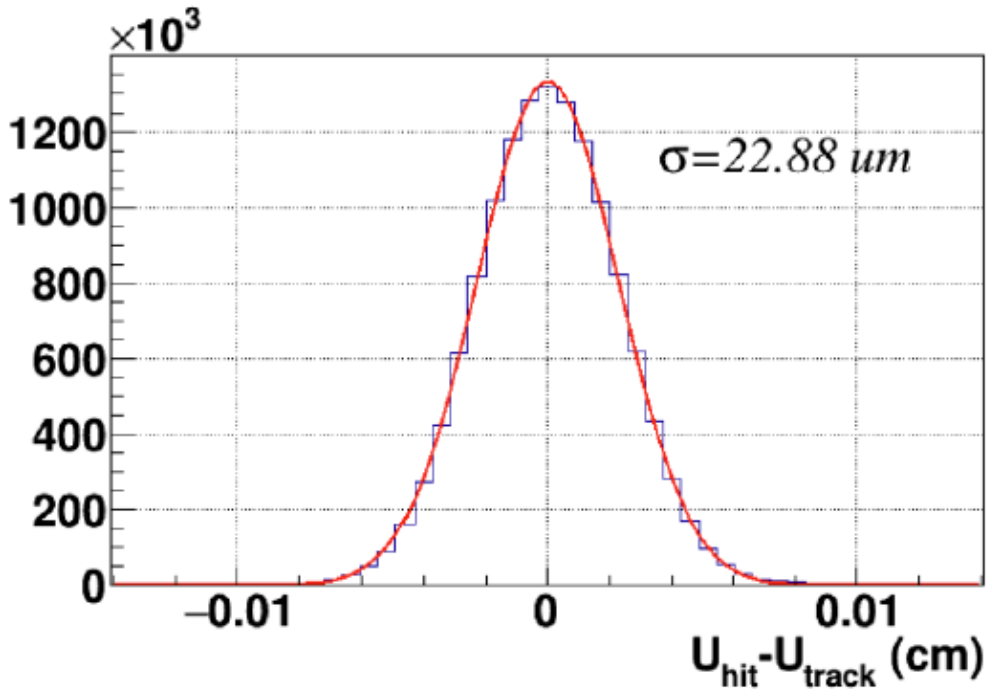
$$\sigma_{line} = \frac{1}{\sqrt{2}} \sigma_{sp.res.}$$

σ_{MCS} = 11.6 μm (**GEANT 4**)

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

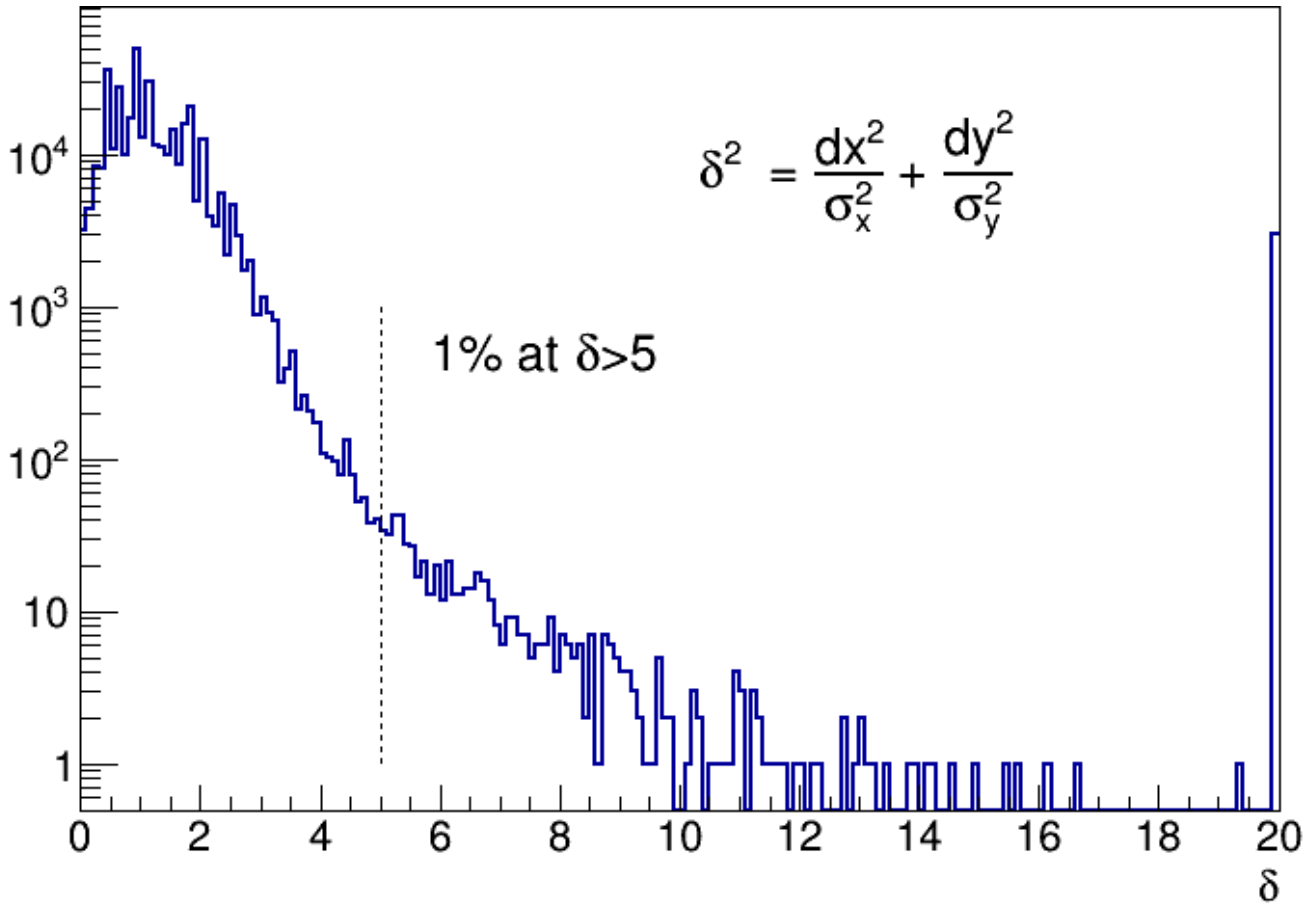




$\sigma_{X,U}$= 15.4 ± 0.4 μm for regular strips
σ_U = 16.4 ± 0.4 μm for the sensor areas with *z*–strips
σ_Y = 170 ± 4μm

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

Efficiency



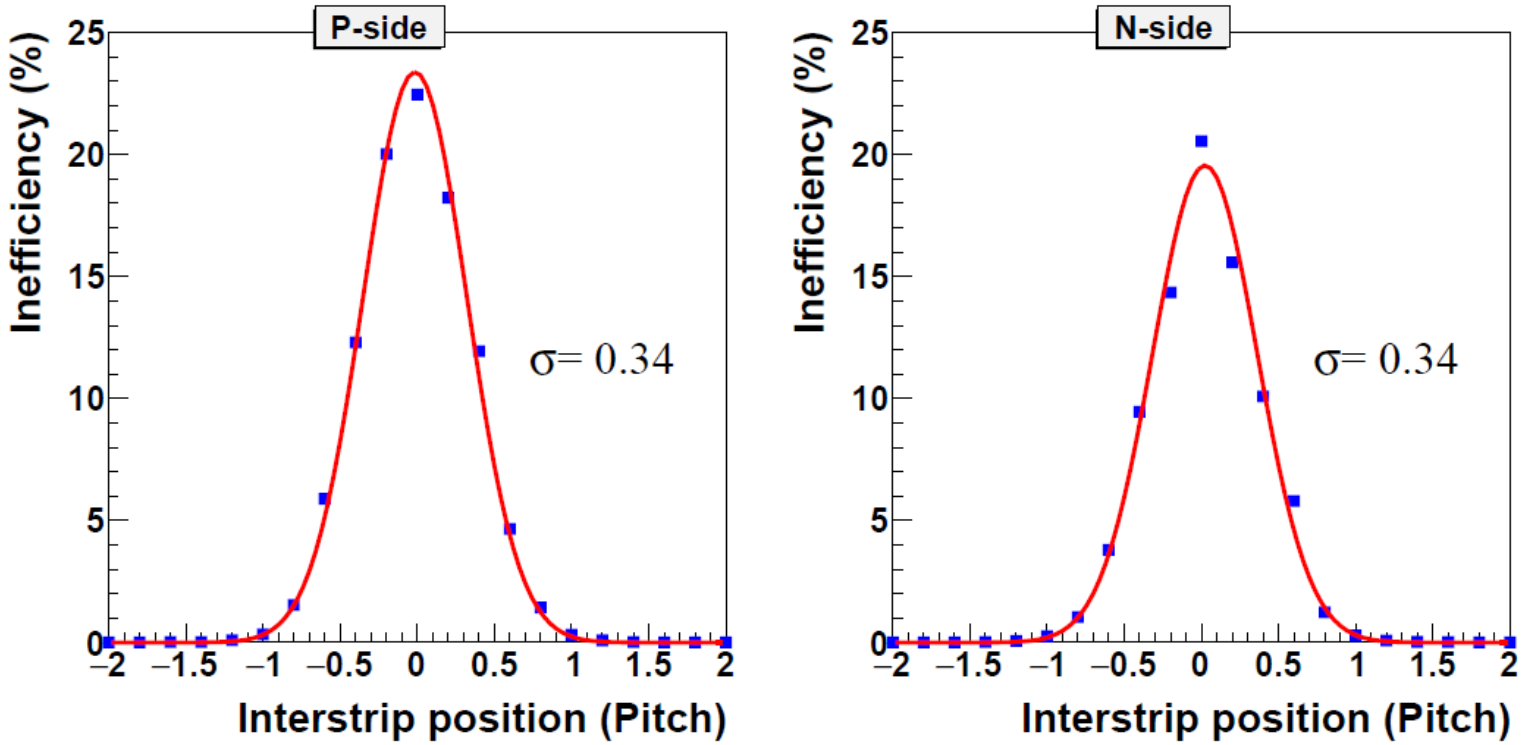
Event selection:

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

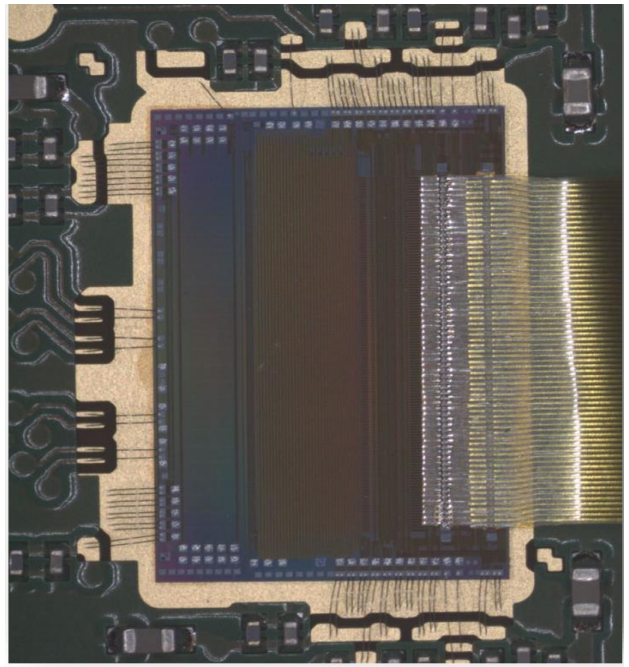
Results:

- 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

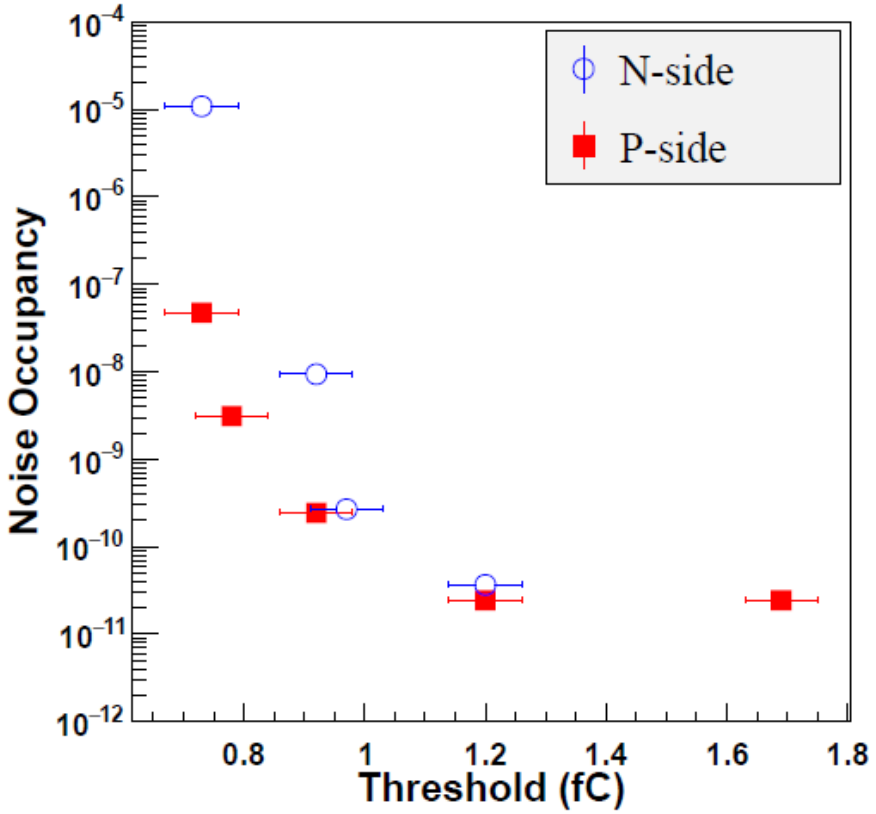


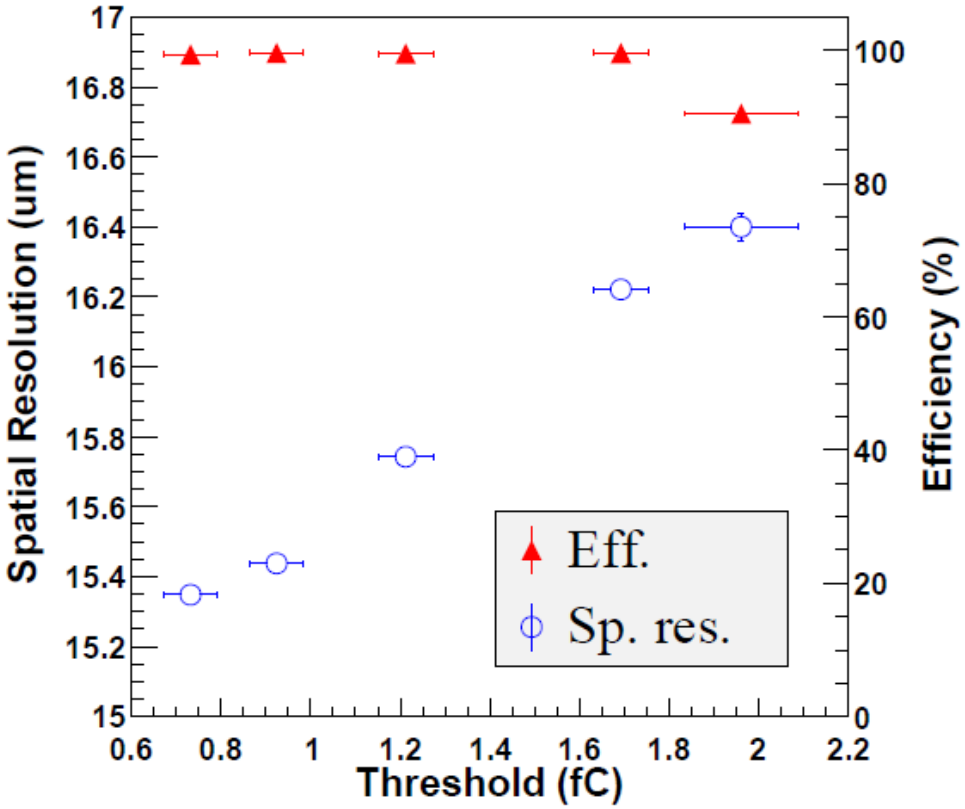
SMX ASIC with bonded micro-cables

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

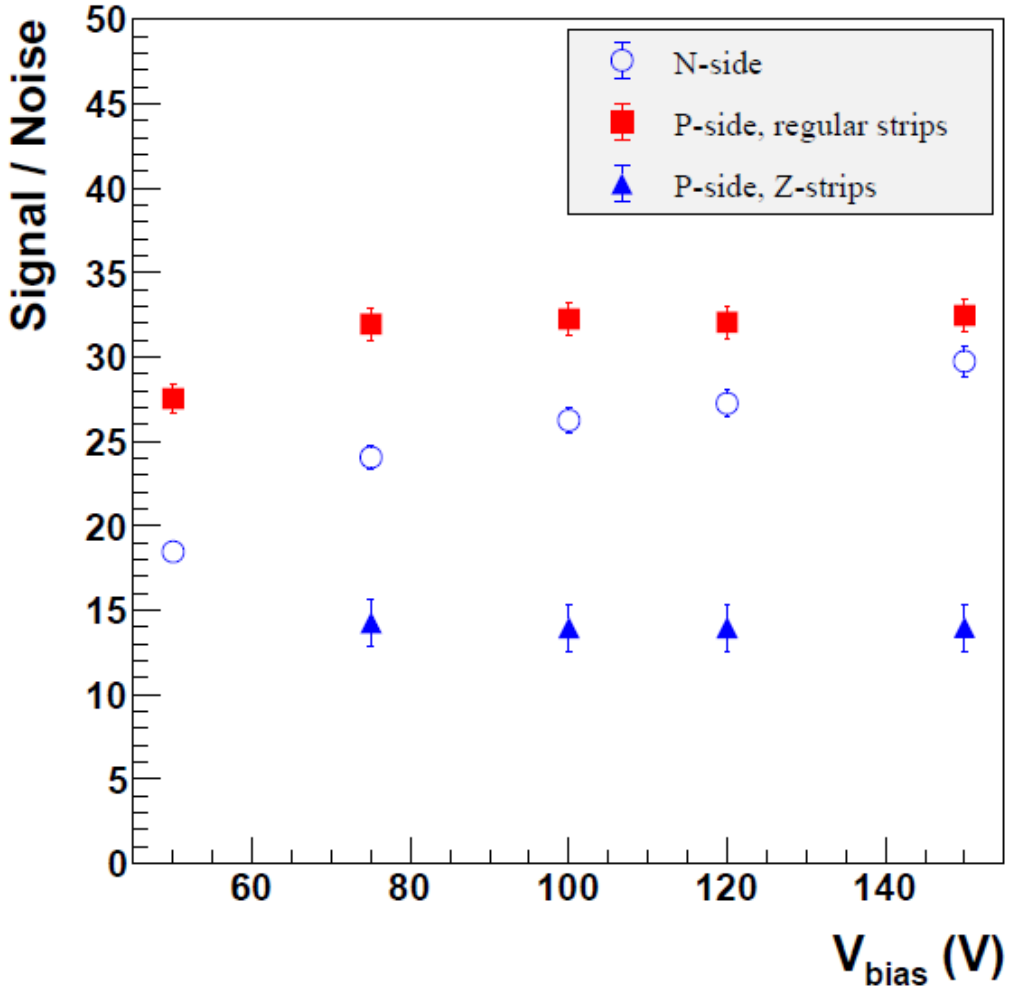
Threshold scan

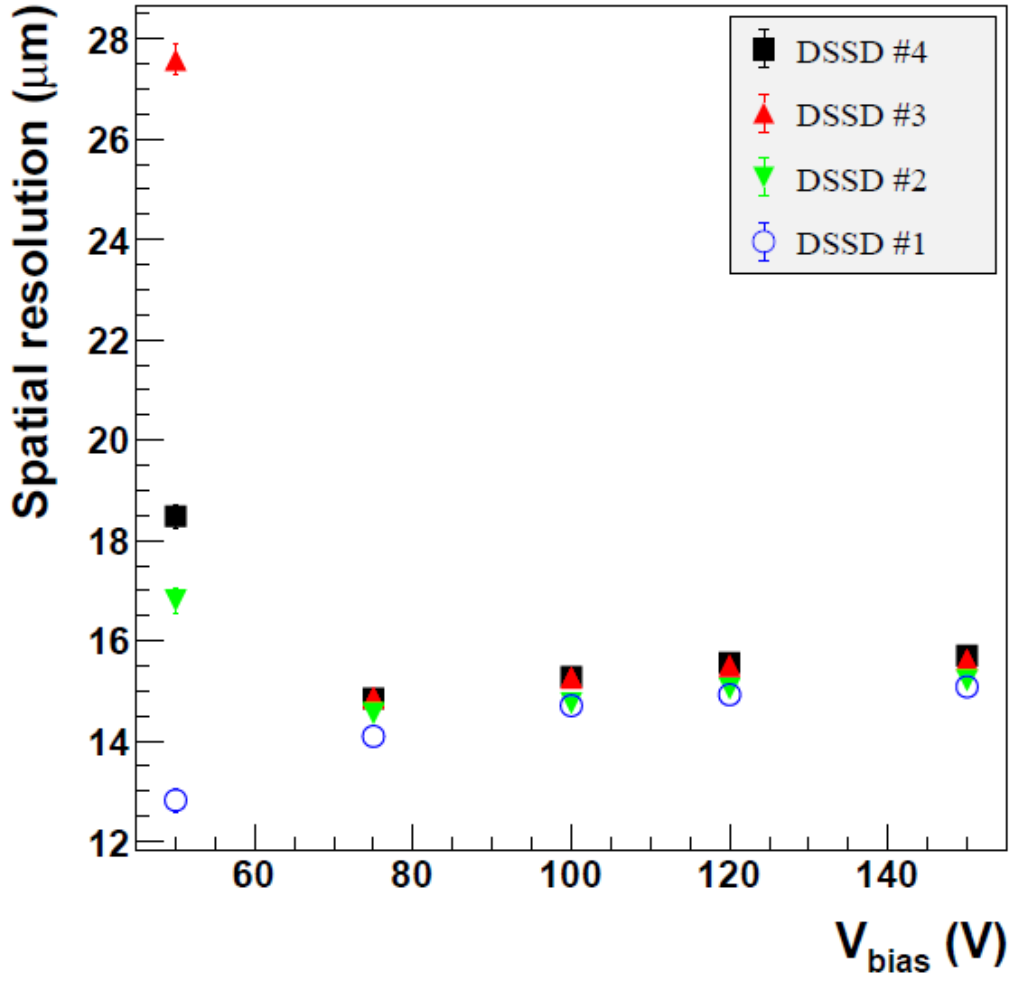




The STS specification requires noise occupancy lower than 2.6×10^{-5} and an efficiency higher than 99% for regular strips and a spatial resolution better than 17 μm. These requirements were fulfilled for the operation ADC threshold 0.8-1.5 fC.

Detector bias voltage scan





Conclusion

- Time measurement precision 9.9 ns;

- Regular strips:
  - SNR > 21;
  - 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 %;

- ***Radiation tests of the data concentrator board based on artix-7 fpga for the silicon tracking system of the bm@n experiment / M. Shitenkov, D. Dementev, V. Leontyev et al. // Instruments and Experimental Techniques. — 2024. — Vol. 67, no. 4. — P. 691–699.***
- ***Technological process of assembly and qa testing of silicone tracking modules with silicon strip sensor / A. D. Sheremetev, V. V. Leontiev, D. V. Dementev et al. // Physics of Particles and Nuclei Letters. — 2024. — Vol. 21, no. 3. — P. 466–480.***
- ***Characterization of tracking modules based on dssd sensors at the sc-1000 accelerator for the bm@n project / D. V. Dementev, A. D. Sheremetev, M. O. Shitenkov et al. // Physics of Particles and Nuclei Letters. — 2024. — Vol. 21, no. 4. — P. 919–927.***

- 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.

Nuclear Instruments and Methods in Physics Research