# Test of a prototype Microstrip Silicon Detector for the FOOT experiment

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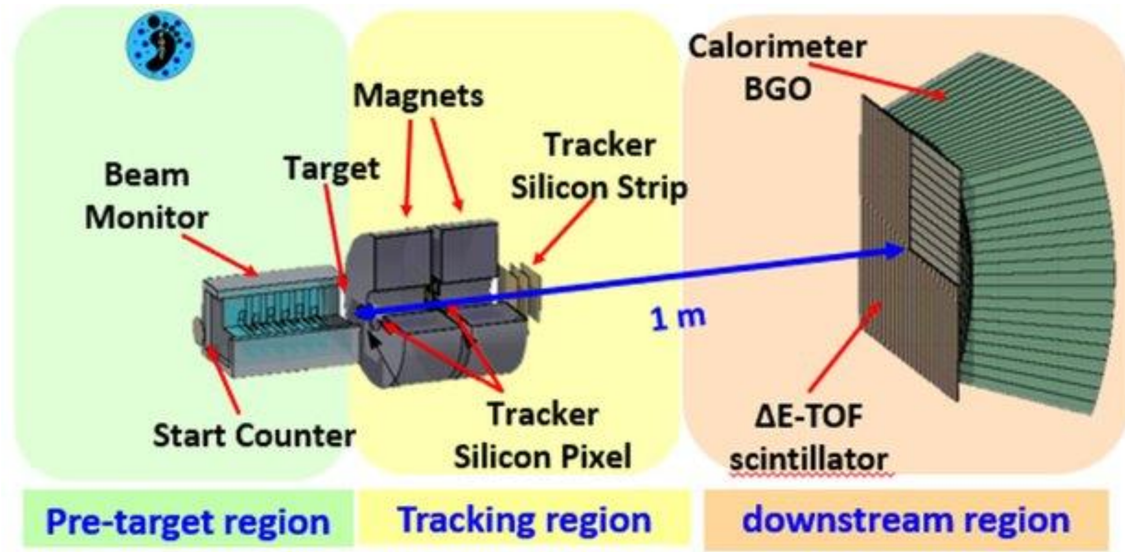
## THE FRAGMENTATION OF TARGET EXPERIMENT

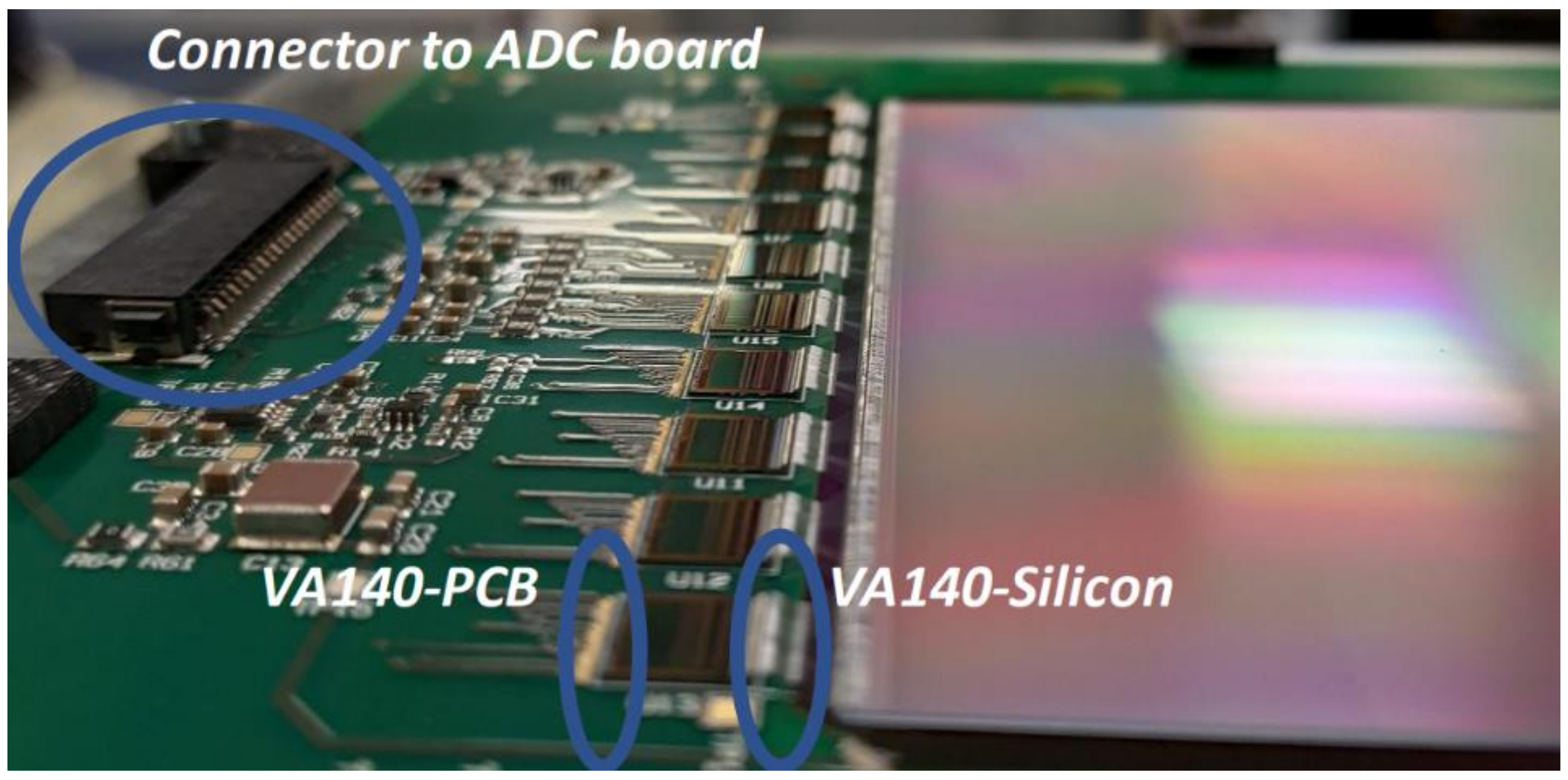
The goal of the FOOT (FragmentatiOn Of Target) experiment is to measure the fragmentation cross section of protons impinging on H, C, O targets at beam energies of interest for hadrontherapy. [1]

Given the short range of the fragments, an inverse kinematic approach has been chosen, hence requiring precise tracking capabilities for charged ions. One of the experiment subsystems will be the MSD (Microstrip Silicon Detector), composed of three x-y measuring planes. [2]

Charged particles passing through the MSD will ionize the silicon layer and, reading the charge collected by the strips, a precise reading of the impact point (tens of µm accuracy) can be obtained. [3]




## SILICON MICROSTRIP DETECTORS




Semiconductor track detectors are basically a set of p-n junction diodes operated at reverse bias to form a sensitive region depleted of mobile charge carriers and sets up a strong electric field. When a ionizing particle crosses the depleted zone it produces several electron-hole pairs along its path that are then collected by readout electrodes. In order to minimize the number of acquisition channels needed typical readout schemes are based on alternating connections every n strips (the charge collected on not connected strips is capacitively transmitted to the neighbor readout strip) in a configuration called *"floating strip readout"*. [4]

Each FOOT MSD detector is made of one AC-coupled silicon microstrip sensor, read-out by ten VA140 (now IDE1140) low noise/low power high dynamic range ASICs. [5]

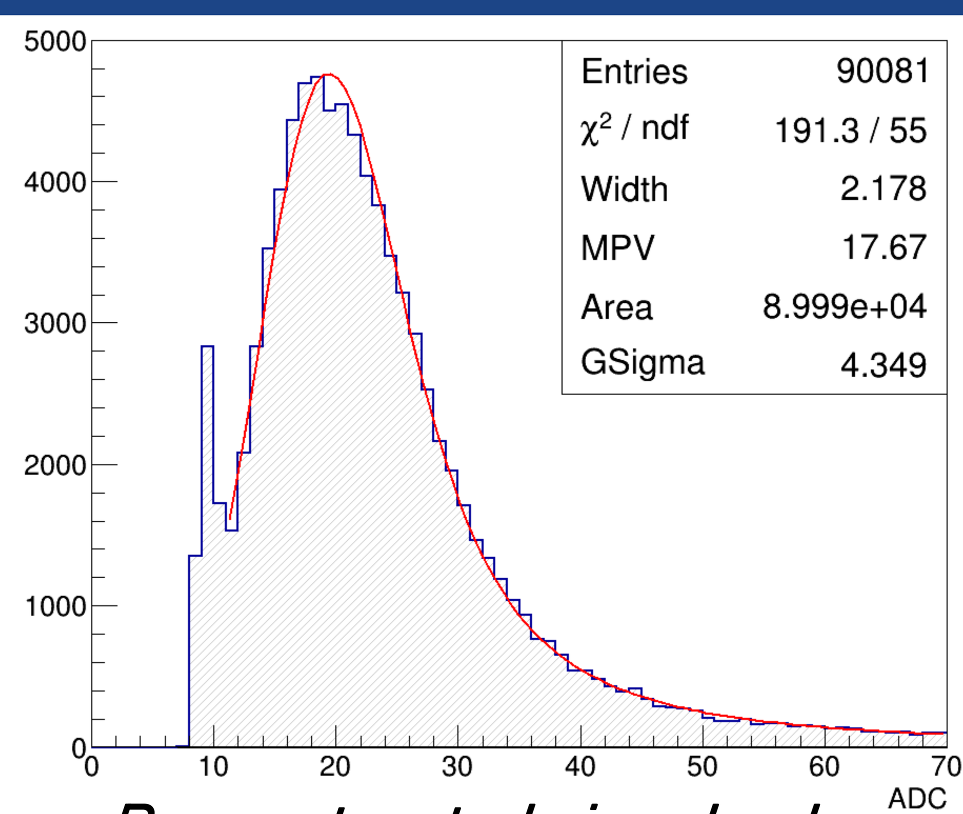
The silicon sensors, made by Hamamatsu Photonics are 150 µm thick, much less than the typical thickness to reduce the effect of Multiple Coulomb Scattering.

## DETECTOR PERFORMANCE

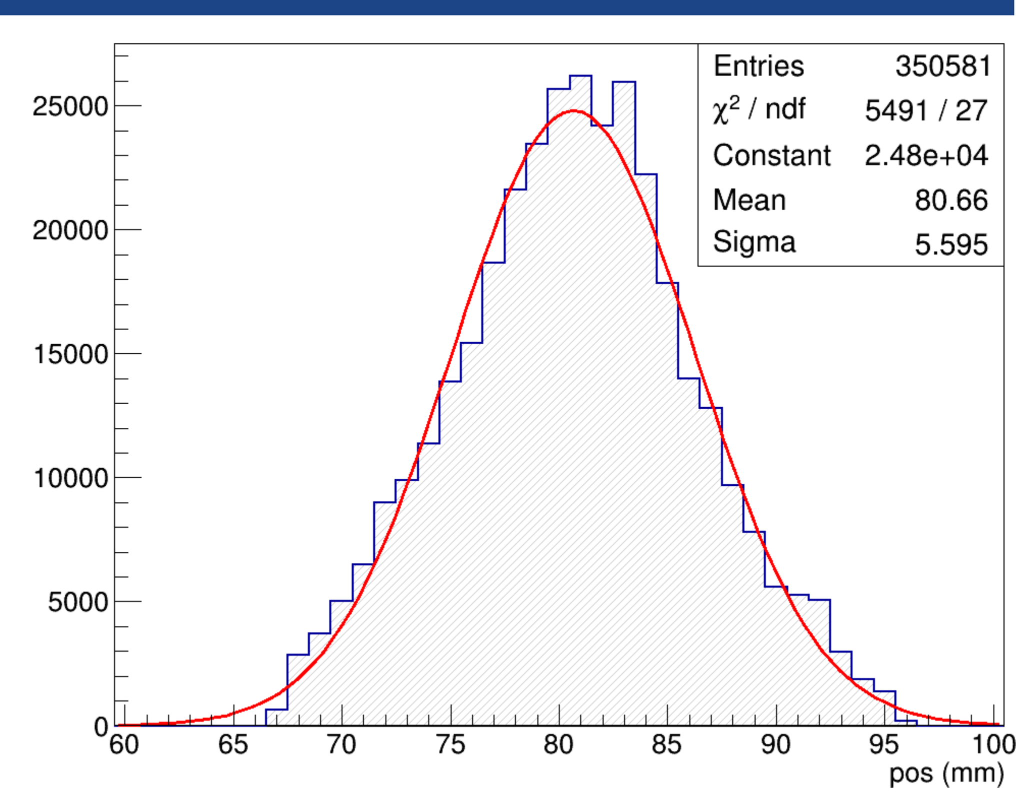
To detect charged particle signals it's of fundamental importance to characterize the noise of the detector. Test were performed over long time periods (several hours) to verify the stability of noise parameters like channel pedestals (channel base-level without particle signal).

Once the stability in terms of noise for each channel have been assessed, the detector and its DAQ system were set up to acquire signals from an external $^{90}Sr/^{90}Y$ radioactive source: beta electrons deposit their energy along the full path in the detector before reaching a triggering scintillator. The cutoff in energy for the $e^-$ to reach the scintillator is 0.85 keV, hence they are very close to a Minimum Ionizing Particle. [6]

Signals are correctly identified over the detector readout noise. Signal values correctly follow a Landau-like distribution (with additional Gaussian noise contribution), and the reconstructed position has a shape and width compatible with the known values for the used radioactive source.




*Reconstructed signal value*

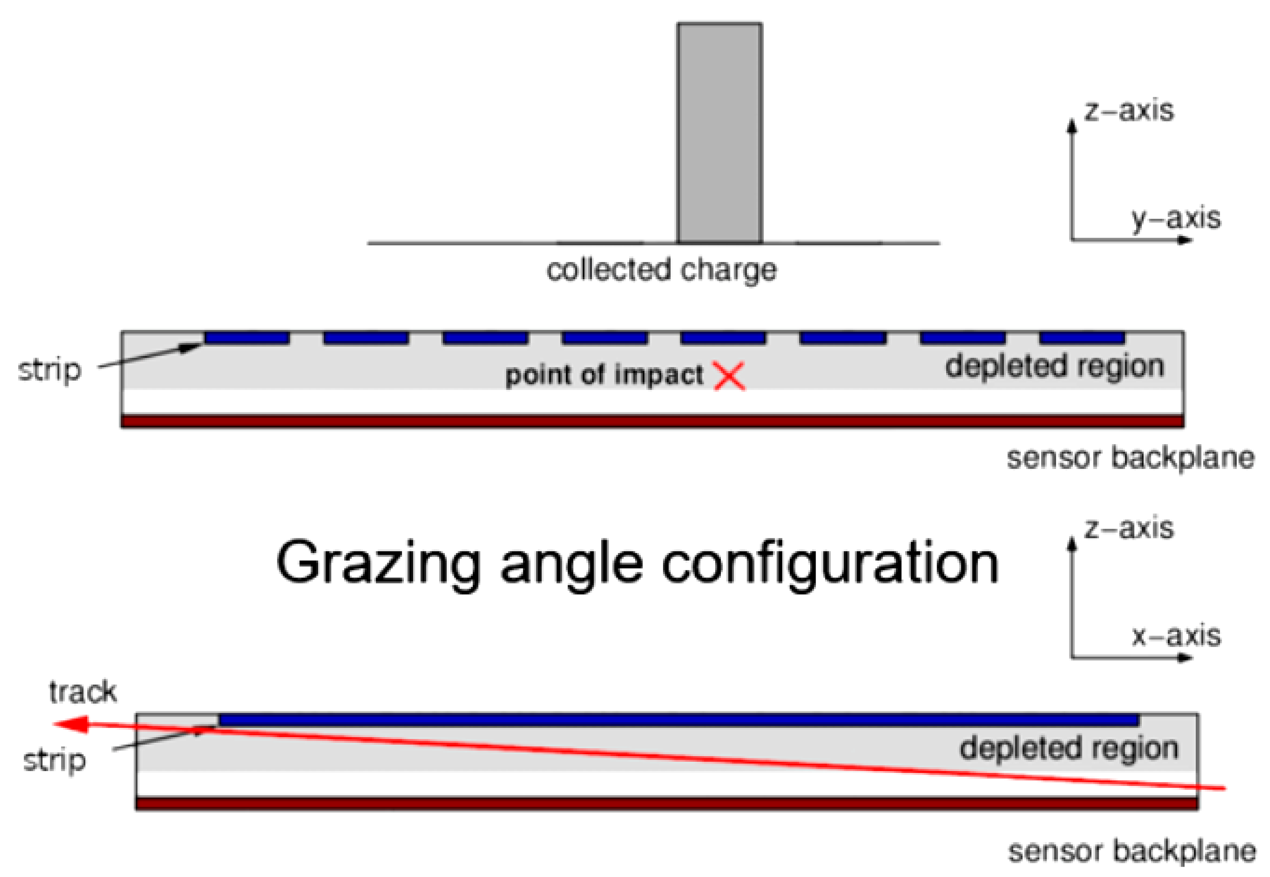


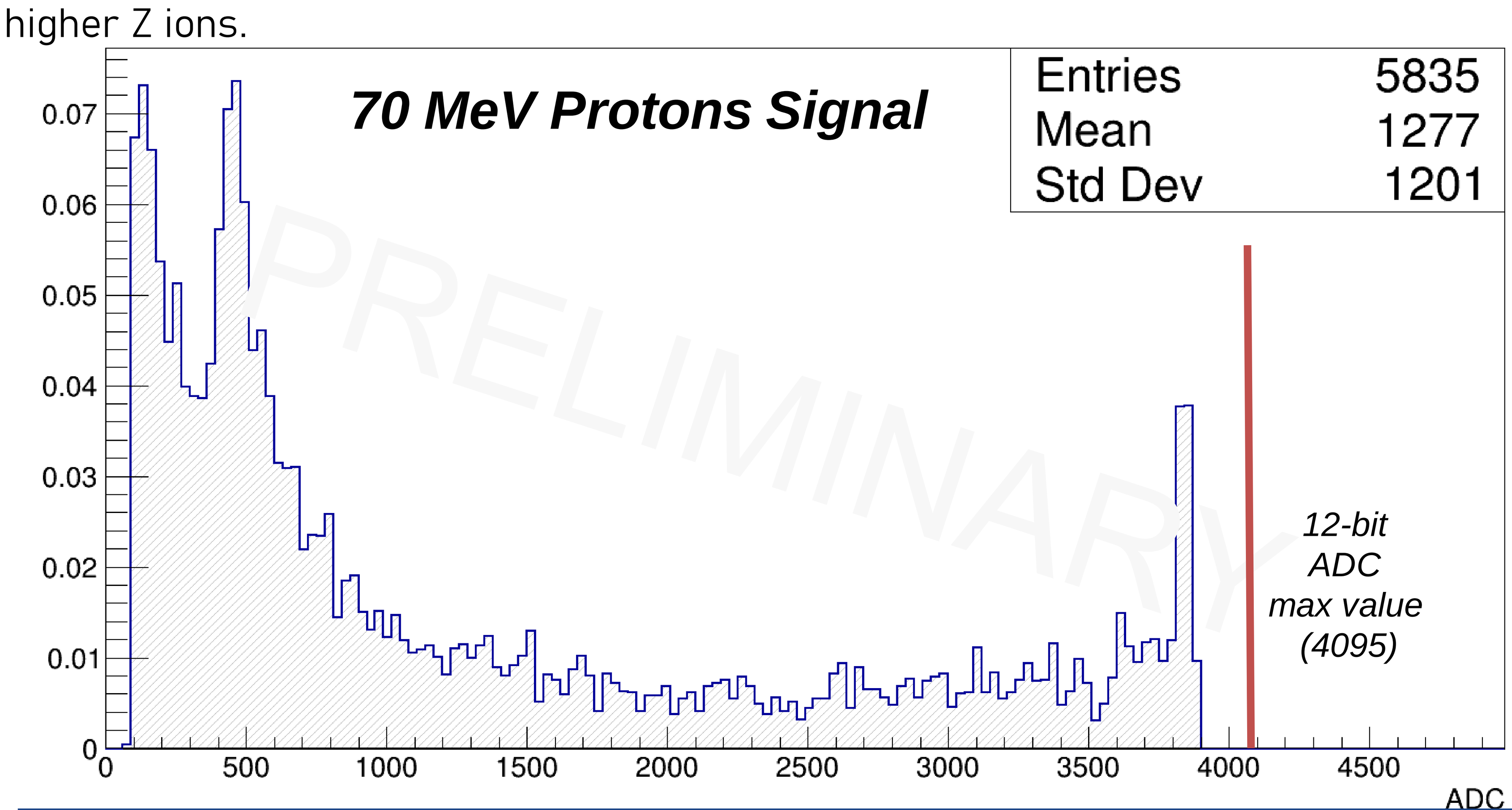

*Reconstructed signal position*

## GRAZING ANGLE METHOD

A series of tests were finally performed to validate a novel "grazing angle" approach, where it is possible to change the track length below a given strip varying the incoming particle's incident angle onto the sensor to test the electronics dynamic range without using high Z ions. A similar method has already been tested with CMOS pixel detectors. [7]

Data acquired at the *Trento Proton Therapy facility* [8] with a proton Beam at 70MeV and 228MeV impinging on the side of the detector with an angle of approximately 84°, so that most particles can traverse the silicon bulk under a single strip, show that the lowest energy particles which deposit the most ionization energy can infact have a track lenght high enough to induce saturation of the single readout channel, without the need for higher Z ions.




## REFERENCES

[1] Tommasino, *et al.* Cancers, 7.1 (2015), pp. 353-381
[2] FOOT CDR Conceptual Design. http://dx.doi.org/10.13140/RG.2.2.28904.78080
[3] Ambrosi, *et al.* Nucl. Instrum. Methods A, 869 (2017), pp. 29-37
[4] Grupen, C., & Shwartz, B. *Particle Detectors*, Cambridge University Press.
[5] https://ideas.no/products/ide1140/ (Accessed in May 2021)
[6] https://radioisotopes.pnnl.gov/isotopes/stronium-90.stm (Accessed in May 2021)
[7] Meroli, *et al.* Nucl. Instrum. Methods A, 650 (2011), pp. 230-234
[8] Tommasino, *et al.* Nucl. Instrum. Methods A, 869 (2017), pp. 15-20

## CONCLUSIONS

- The prototype detector shows excellent performance in terms of electronic noise stability, essential condition for reliable data acquisition
- The new 150 µm silicon from Hamamatsu is thick enough to obtain a high enough Signal to Noise ratio even for Minimum Ionizion Particles
- Results obtained from data acquired with charged particles confirm the suitability of the detector design for the needs of the experiment
- The grazing method provides promising results for an evaluation of the dynamic range of the system without the need for heavy ion beams at the accelerators and it could be in principle be tested also with lab sources

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