Evaluation of double-sided silicon microstrip sensors as tracker components for FOOT experiment

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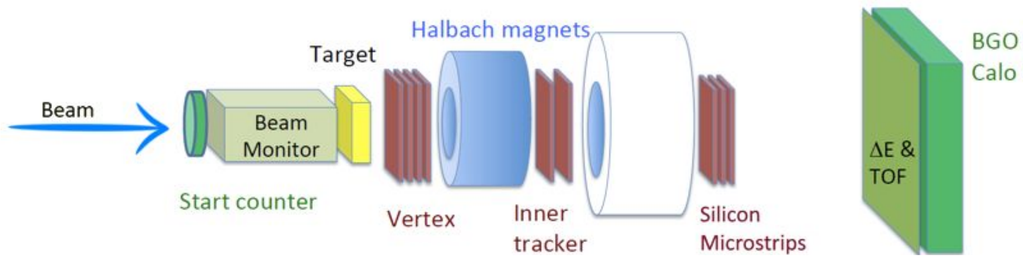
INTRODUCTION TO FOOT AND MICROSTRIP DETECTORS

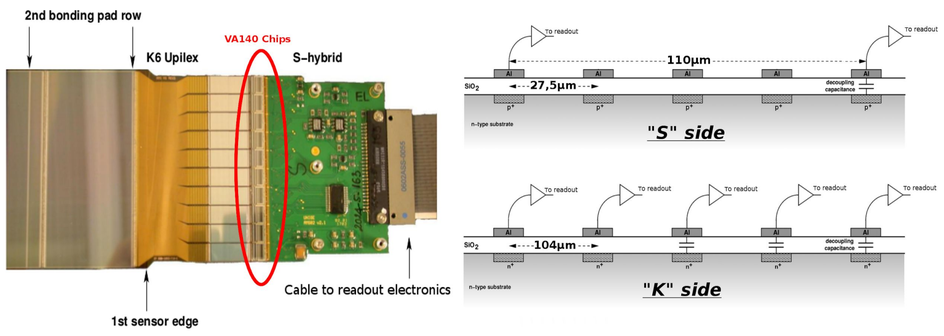
The goal of the FOOT (FragmentatiOn Of Target) experiment is to measure the fragmentation cross section of protons impinging on H, C, O targets at beam energies of interest for hadrontherapy. Given the short range of the fragments, an inverse kinematic approach has been chosen, hence requiring precise tracking capabilities for charged ions. One of the experiment subsystems will be the MSD (Microstrip Silicon Detector), composed of three x-y measuring planes. 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 (tenths of μm accuracy) will be obtained.

Scheme of the FOOT experiment setup

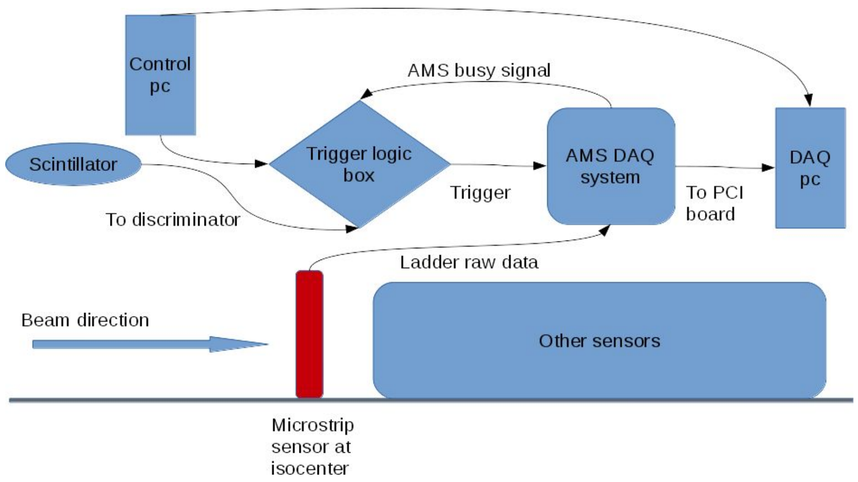


SETUP AND GOAL OF THE TEST

The test was conducted at the Trento Proton Therapy facility in December 2017. For this test, a MSD sensor derived from the ones used in AMS-02 experiment was positioned at the beam isocenter. Proton beams at 7 different energies (50MeV, 70MeV, 80MeV, 112MeV, 159MeV, 200MeV, 228MeV) were used in order to explore possible saturation effects of electronics for low energy beams on a detector designed to work with minimum ionizing particles.



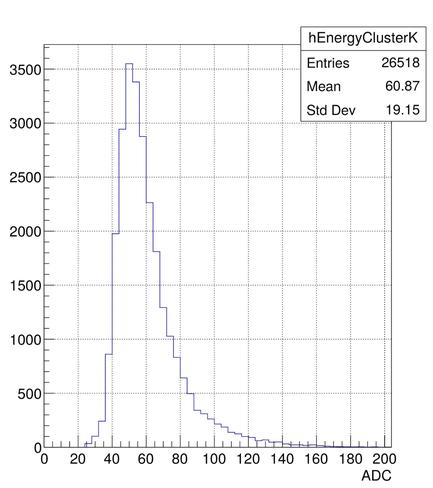
On “S” side, there is some loss in charge collection efficiency due to the floating strips. Hence that data is used just to clean-up data sample.
Only "K" side is used for signal saturation studies.

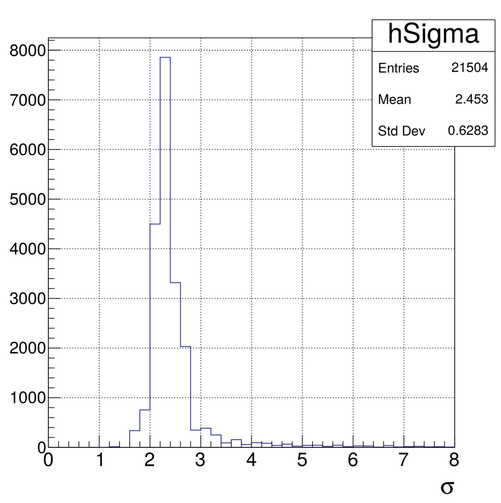


Data selection: only events with a single particle are selected (exactly one cluster for each side).

DETECTOR PERFORMANCE

Reading the signal collected by all the strips it’s possible to reconstruct particle clusters: thresholds used to distinguish real signal from noise depend on S/N (ADC of strip / fluctuation of the strip value with no signal).
A low noise, high dynamic range readout electronics is used for the MSD.
Signal distributions of reconstructed clusters are compatible with the expected distributions for such detectors.

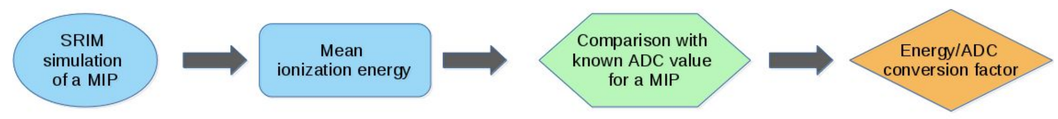




SIMULATION PROCEDURE

A specific simulation of a MIPs beam to correctly convert mean ionization energy to ADC counts has been performed (Step 1). To compare data taken during the test, a series of simulations of proton beams at the energy used onto 300μm thick silicon were then made (Step 2).
The same simulations were also run for a 150μm thick silicon, to test the response to proton beams with respect to standard noise levels of the electronics.
Finally, simulations were run for Carbon ions beams at the same energies on 150μm thick silicon, to test for possible saturation effects of the electronics.

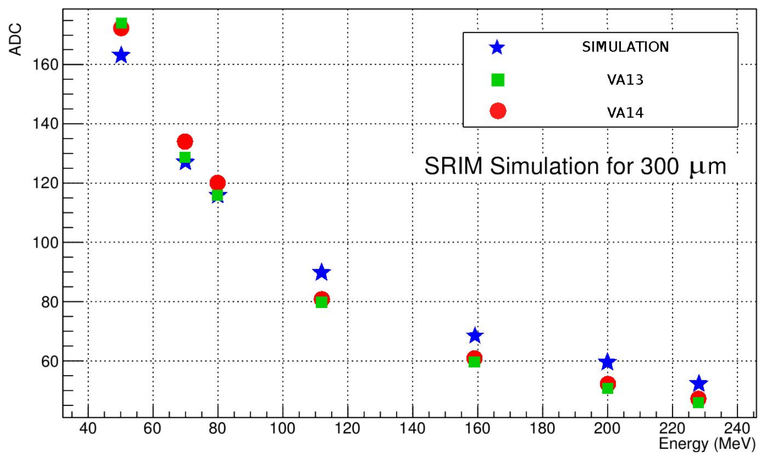
Step 1



Step 2

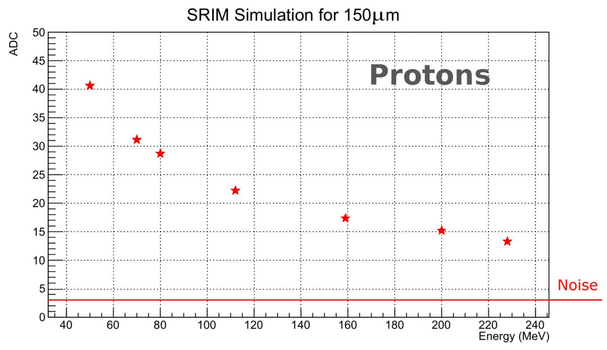
SIMULATION FOR 300μm THICK DETECTOR

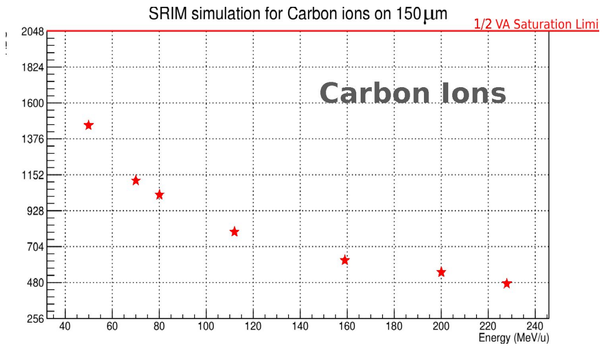
Comparing the experimental results for the two VA140 chips with high statistic with simulations, a good qualitative agreement has been found, validating the use of this simulation.



PREDICTIONS FOR 150μm THICK DETECTOR

To predict the response for 150 μm thick silicon sensor, simulations for Proton and Carbon beams at various energies have been done. We observe that, even for low energy carbon ions, considering the worst case of all charge in one strip, we are far from the effective saturation limit of about 3500 ADC (average pedestal subtracted from dynamic range).





CONCLUSIONS

→ There is a good qualitative agreement between the test-beam data and the simulations; moreover, they agree with measurement from other groups.
→ For carbon ions on 150μm thick silicon we do not predict saturation of the single channels of readout chips.
Given the typical pedestal value of about 600ADC we predict an effective dynamic range of about ±160fC for the readout chip.

REFERENCES

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[1] *Tommasino et al.* Cancers7.1 (2015): 353-381.
[2] FOOT CDR Conceptual Design. 10.13140/RG.2.2.28904.78080.
[3] *Tommasino et al.* NIMA 869 (2017): 15-20
[4] *Ziegler et al.* NIMB 268 (2010): 1818-1823
[5] *Ambrosi et al.* NIMA 869 (2017): 29-37
[6] *Ambrosi et al.* S.Ch.T.S. (2018) 10.1007/s11431-018-9234-9

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