Characterization of the Microstrip Silicon Detector for the FragmentatiOn Of Target experiment

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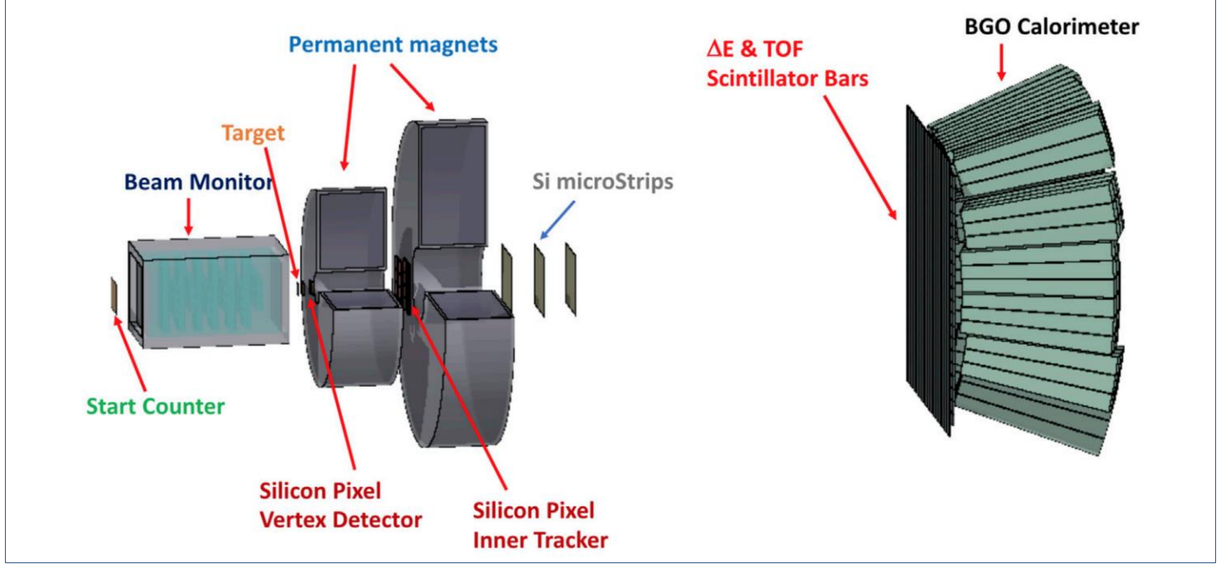
THE FOOT (FRAGMENTATION OF TARGET) EXPERIMENT

- The main objective of the *FOOT (FragmentatiOn Of Target)* experiment is the measurement of the double differential cross-sections with respect to kinetic energy and emission angle of fragments produced in nuclear interactions at energies of interest for hadrontherapy (up to 400 MeV/u) [1].
- Secondary particles produced by beam and target fragmentation have very high LET and therefore high RBE and contribute to the total dose released especially in healthy tissues on the path to the tumor region.
- Since the fragments produced by the interaction of the beam with the target nuclei have a short range (e.g. order of 10 to 100 μm) in the energy ranges considered, the *FOOT* experiment uses the inverse kinematics technique, i.e. sending the ions on targets rich in protons and Carbon. Cross sections can then be extracted from data obtained using a pure C target [2].
- The experimental setup will be exposed to ion beams in two configurations: one with electronic detectors *(Fig. 1)* for the measurement of heavier fragments and one based primarily on an emulsion chamber for the measurement of lighter fragments [3].

FIG. 1

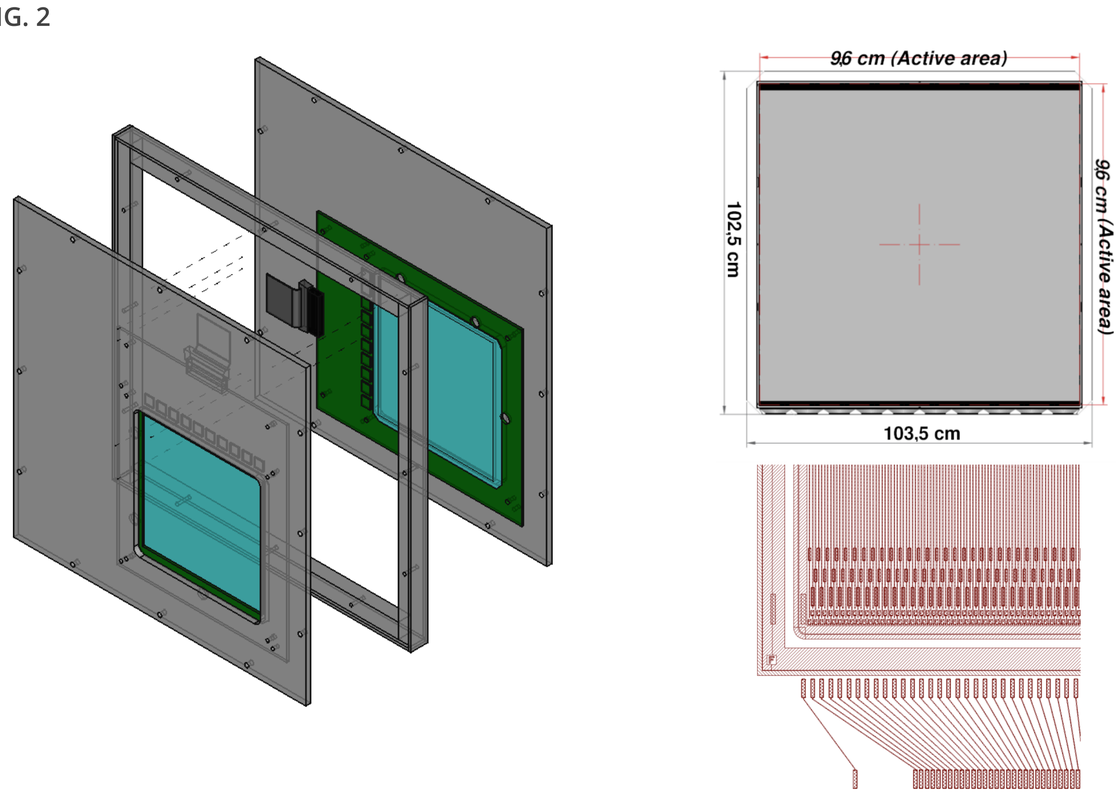
The FragmentatiOn Of Target magnetic spectrometer



THE MICROSTRIP SILICON DETECTOR

- The *Microstrip Silicon Detector* (MSD) is the last station of the FOOT magnetic spectrometer, composed of three layers of silicon microstrip detectors placed after the two permanent magnets.
- It will be mainly used to reconstruct the position of the fragments with a spatial resolution < 35μm, to match the reconstructed tracks with the downstream scintillator and calorimeter hits, with the possibility to also give a redundant measurement of the energy release dE/dx of the particles.
- The tracking apparatus consists of three MSD X-Y stations *(Fig. 2, left)* with an active area of 9.6 × 9.3 cm2, separated by a 2 cm gap along the beam direction, to ensure the needed angular acceptance to measure ions with Z > 2.
- In order to reduce the amount of material needed, two perpendicular *Single-Sided Silicon Detector* (SSSD) sensors thinned down to 150 μm *(Fig. 2, right)* are used for each MSD X-Y plane, each glued on a hybrid PCB that provides the needed mechanical support and the interface with the readout, and with light tightness of each plane ensured using only the metallized sensors backplane.

FIG. 2

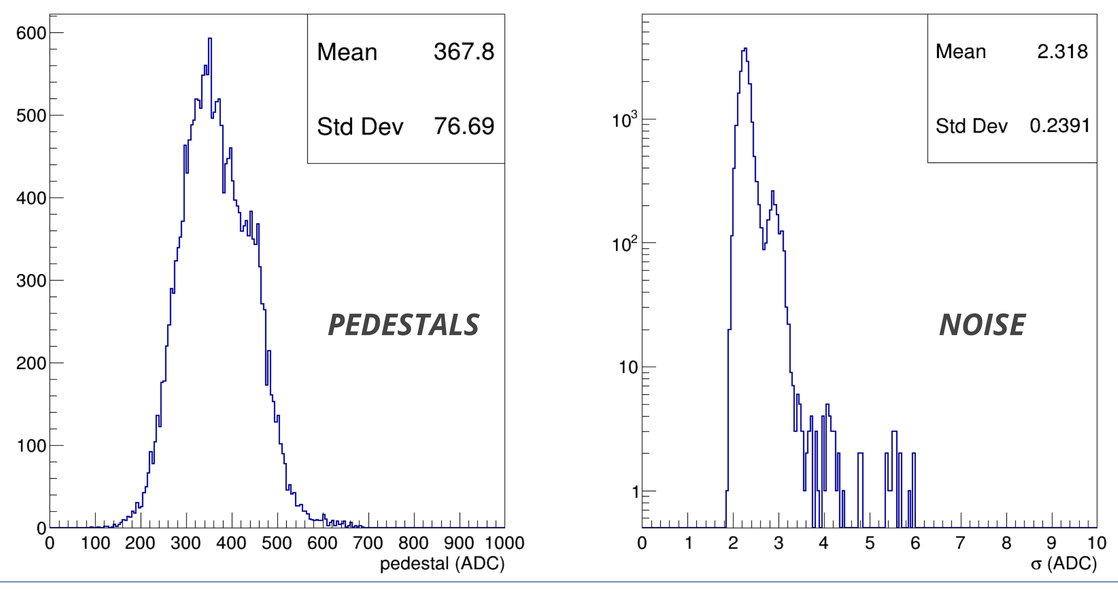


Exploded view of one of the X-Y stations (left) and mechanical drawing of the SSSD with its on-silicon pitch adapter (right)

- Several tests were carried out in the laboratory and on particle beams at accelerators for hadrontherapy in Italy, such as the proton accelerator at the *Protontherapy Centre* in Trento.
- The sensors produced were tested throughout the production chain first in the laboratory to ensure their operation and performance in terms of noise *(Fig. 3)* and signal. When possible, further tests were carried out at the accelerators to test the operation of the complete setup that is used by the FOOT experiment.

FIG. 3

Distributions of pedestal values (left) and single channel noise levels (right) for all the sensors assembled



- The success of the construction from the point of view of performance and integration with the rest of the experiment have allowed to perform the first official data acquisition of the FOOT experiment at the accelerator of the *GSI Helmholtz Centre for Heavy Ion Research* in Darmstadt in July 2021.
- A final test has been carried out at the *Centro Nazionale di Adroterapia Oncologica* (CNAO) in Pavia. The data acquired in these last two campaigns allowed the characterization of the response of the detectors to heavy charged particles such as Carbon *(Fig. 4)* in terms of noise performance, signal, cluster characteristics and spatial resolution *(Fig. 5)*.

FIG. 4

Detector response for Carbon ions as a function of their energy and comparison with predicted values

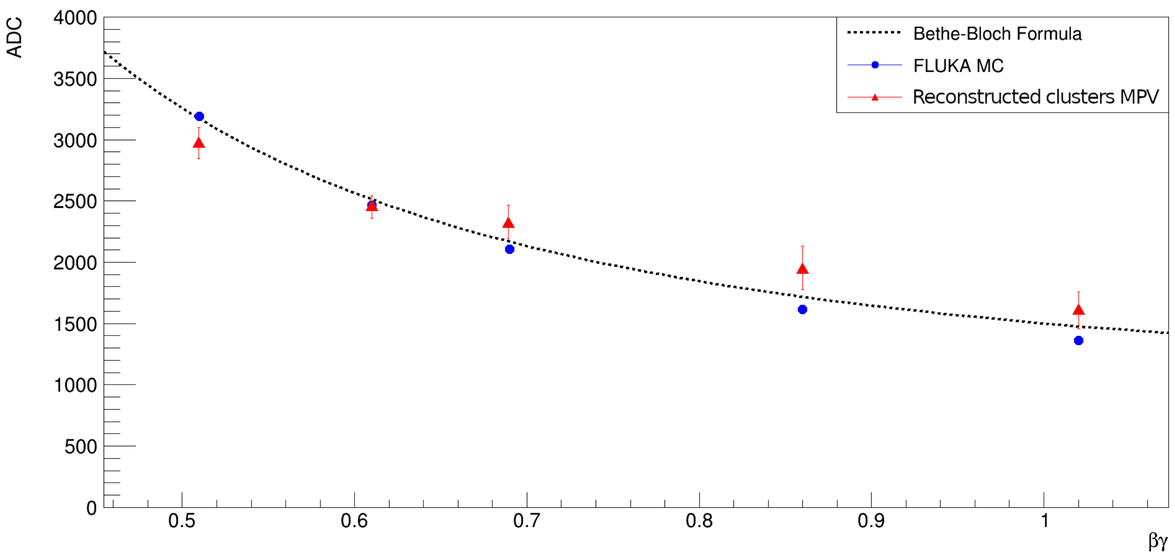
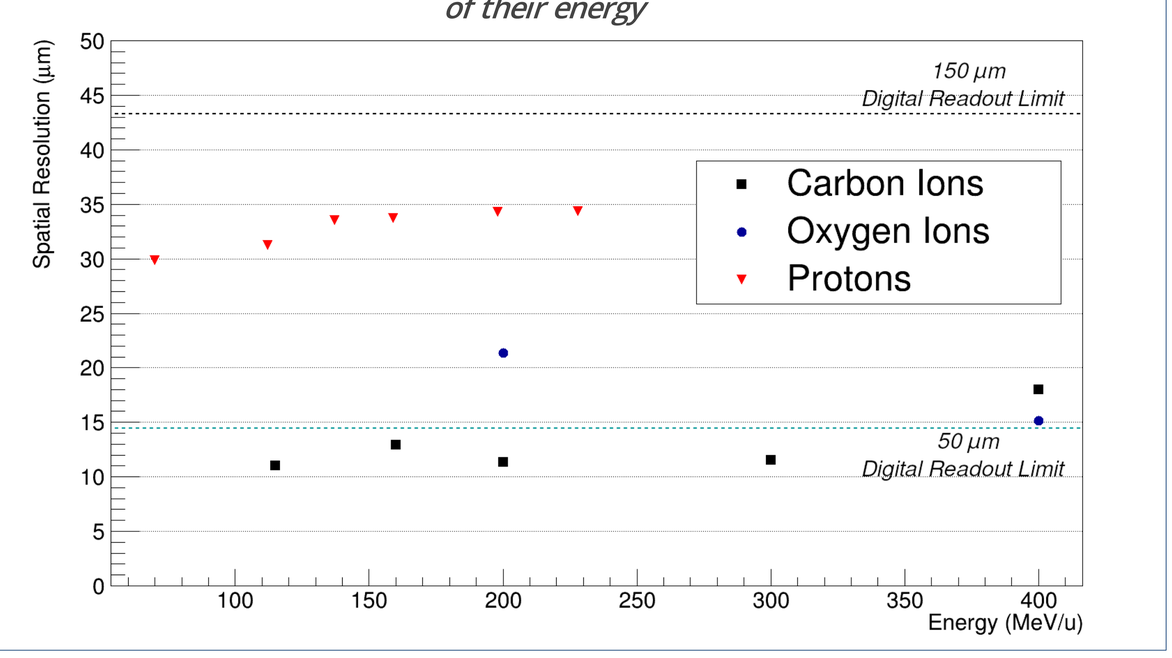


FIG. 5

Computed spatial resolution for different particles as a function of their energy



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