IL NUOVO CIMENTO **42 C** (2019) 141
DOI 10.1393/ncc/i2019-19141-7

COLLOQUIA: EuNPC 2018

# Track reconstruction in the FOOT experiment

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received 5 February 2019

**Summary.** — The FOOT experiment is a fixed target experiment aiming for high precision (better than 5%) measurement of fragmentation cross section for hadrontherapy and space radioprotection purposes. Both target and projectile fragmentation are studied by using mainly proton, Carbon and Oxygen ion beams in both direct and inverse kinematic regime, alternatively. A good track reconstruction and momentum measurement is of fundamental importance for precise fragment identification and cross section measurement.

## 1. – The detector

The project of the FOOT detector [2] [3] foresees a compact and modular design as pictured in figure 1. The main sub-detectors for tracking purposes are:

- the silicon **Vertex Detector** (VTX) is formed by 4 layers of a single 2x2 cm$^2$ MIMOSA28 pixel sensor, 50 $\mu$m thick and with 20 $\mu$m pitch. VTX is the closest sub-detector to the target, with a foreseen spatial resolution of 6 $\mu$m.
- **the Silicon Inner Tracker** (ITR) is formed by 2 layers of a 4x4 array of MIMOSA28 sensors each (total dimension 8x8 cm$^2$), with a foreseen spatial resolution of 6 $\mu$m.
- **the MicroStrip Detector** (MSD) is made of 3 planes of 9x9 cm$^2$ double layer strip 300 $\mu$m thick and with 150 $\mu$m pitch. MSD is placed at 30 cm from the target, with a foreseen spatial resolution of 10 $\mu$m.

## 2. – Reconstruction strategy with Kalman filter

Kalman filter [1] is an iterative method used to estimate the states of a dynamic system starting from a series of measurement points on $N$ surfaces, in the FOOT case $N = 9$. Kalman filter copes for both multiple scattering and energy loss effects. Before applying the Kalman algorithm, a hit preselection is needed to identify the hits (one per detector plane) to be fitted. The method currently under study is to select hits relative to

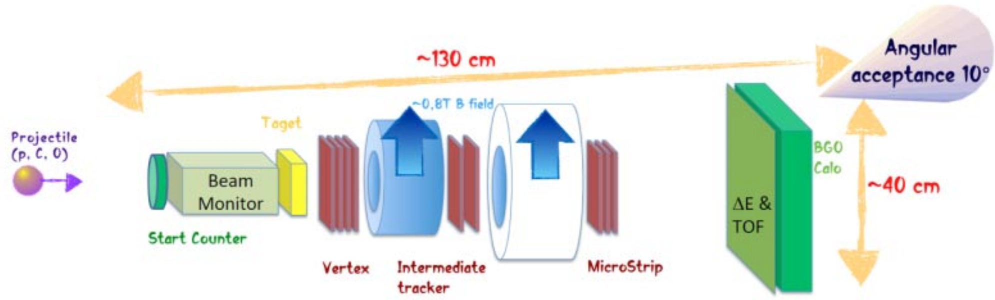


Fig. 1. – FOOT detector design sketch.

each sub-detector separately and to consider them on a straight line. These hits groups are then matched by extrapolating from one sub-detector to the others, taking advantage of the Kalman filter propagation algorithms.

## 3. – Implementation and results

In the FOOT collaboration, a complete reconstruction software (SHOE) is under development, including:

- a common geometrical and material description shared by the FLUKA MC-generator [4] and by the reconstruction algorithms;
- a Kalman filter algorithm from the GenFit package;
- a complete set of other detector routines, particle identification and final cross section measurement codes.

The apparatus' momentum resolution is currently evaluated using Monte Carlo (MC) simulations of Oxygen beams at different energies. The hits produced by the same fragments having a momentum $p_{true}$ are grouped together and processed by the Kalman filter algorithm measuring the fragment momentum $p_{meas}$. The quantity $|p_{meas} - p_{true}|/p_{true}$ is then evaluated in bins 200 MeV wide and a gaussian fit is performed. The $\sigma$ parameter of the fit corresponds to the momentum resolution at different momentum values. The momentum resolution found ranges from 4.5% to 2.5% depending on the fragment type and on the beam energy. Results are shown in figure 2.

## 4. – Possible high energy configuration

FOOT measurements are also interesting for radioprotection in space, as NASA and other space agencies are studying the risk assessment for astronauts in view of long duration space missions. The design of spacecraft shielding requires a detailed knowledge of fragmentation processes also at higher energies (ideally up to 3 GeV) than hadrontherapy ones, ranging from $\sim$150 to $\sim$400 MeV/n.

At projectile kinetic energies around 700 MeV/n (currently available ion beam energies), it is fundamental for particle identification to increase the momentum resolution to cope with the decreasing precision of the calorimetric system. A possible solution is to enlarge the distance between the tracking detectors in order to have a higher lever arm with an improvement evaluated from MC simulations, as shown in figure 3.

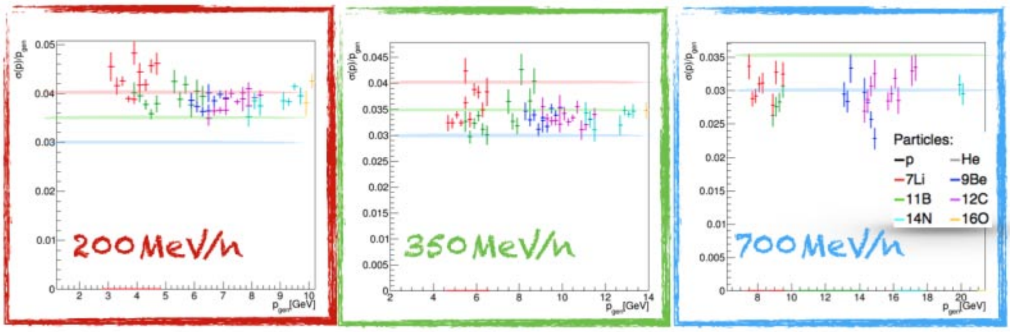


Fig. 2. – Momentum resolution from MC simulations at beam energies of 200, 350, 700 MeV/n respectively (left to right). Different colors of the points corresponds to different element of the reconstructed fragment.

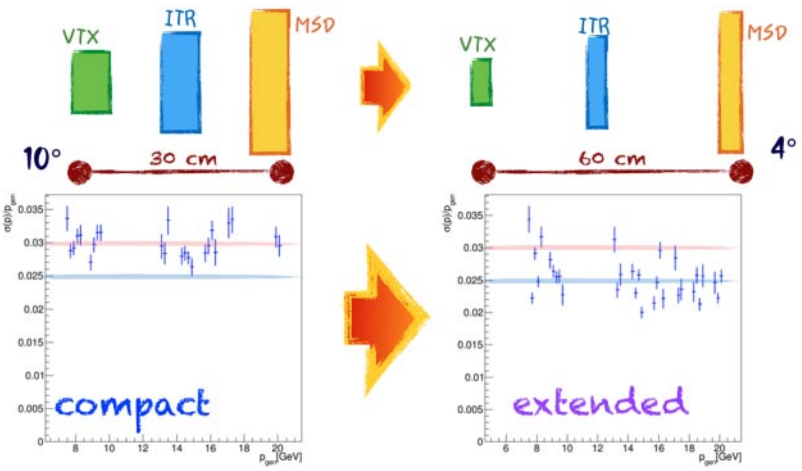


Fig. 3. – Momentum resolution comparison between the compact configuration (left) and the extended one (right), with a sketch of the position of the tracking detectors.

This would lead to a smaller angular acceptance but fragments produced at higher energies are more collimated. The possibility of an elongating mechanic system could also allow to repeat the same measurement in both the compact and the extended configurations.

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