The ΔE-TOF detector of the FOOT experiment: experimental tests and Monte Carlo simulations

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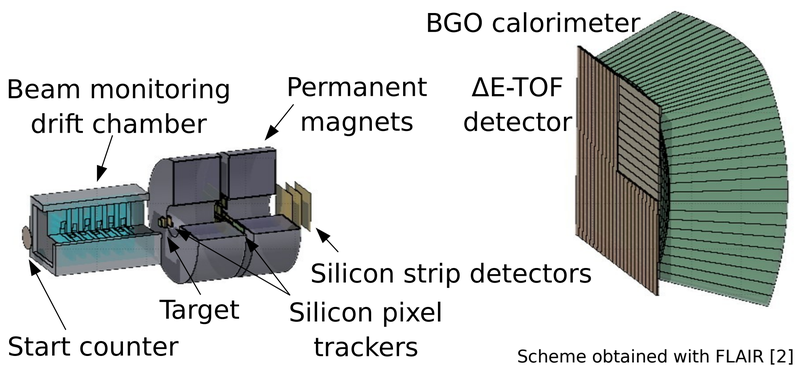
FragmentatiOn Of Target

The FOOT experiment

- **Identification** of the **fragments** produced in the human body during **hadrontherapy** and measurement of their production **cross-section** [1]
- **Radioprotection** in **space**



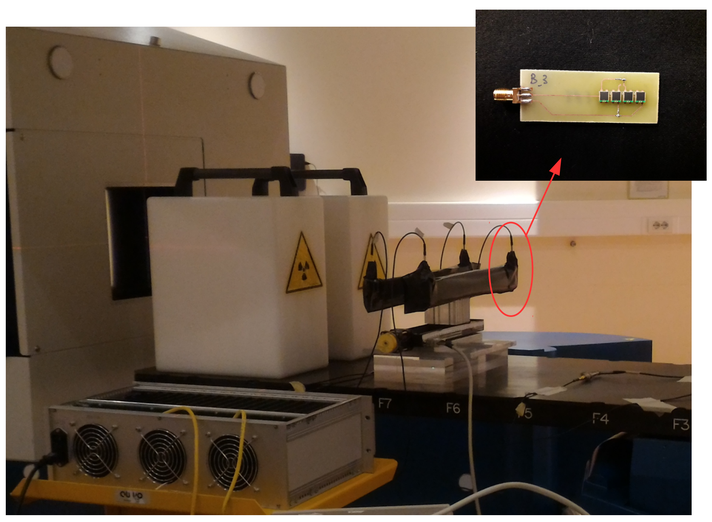
Scheme obtained with FLAIR [2]

ΔE-TOF detector

- Two layers of orthogonal plastic scintillator bars coupled to SiPMs at both ends
- Measures energy deposition in detector **ΔE** and Time of Flight **TOF**
- Contributes to provide velocity **β** and atomic number **Z** of the fragment
- The FOOT Monte Carlo simulation suggests a **Z resolution** of **2-6%** for the ΔE-TOF detector

Experimental setup

- Two **EJ200** bars @ 11 cm relative distance (400 mm × 20 mm × 3 mm)
- **Aluminum** and black tape wrapping
- 4 Hamamatsu **SiPMs** coupled to each end
- **WaveDREAM** for bias & readout [3]
- **Proton** and **carbon** ion beams irradiations of different **energy** and **position** @ CNAO

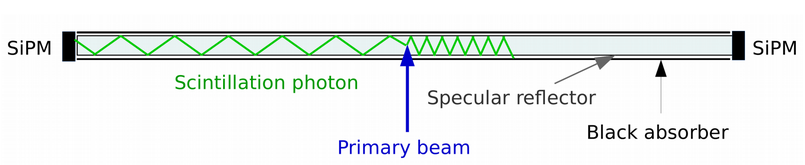


Monte Carlo simulations

- **Proton** energy deposition as input (FLUKA)
- **Scintillation** emission spectrum (Matlab)
- **Geometry** & **optical transport** (Geant4, [4])
- SiPM photon **detection** efficiency (Matlab)

$$\overline{N}_{ph,det} = \overline{N}_{ph,\,gen} \cdot PDE \cdot \varepsilon_{geom,transport}$$

$\overline{N}_{ph,\,gen} = \Delta E \cdot Y$ (10^4 ph/MeV) · PDE ~23% · $\varepsilon_{geom,transport}$ ~10% per side @ detector center

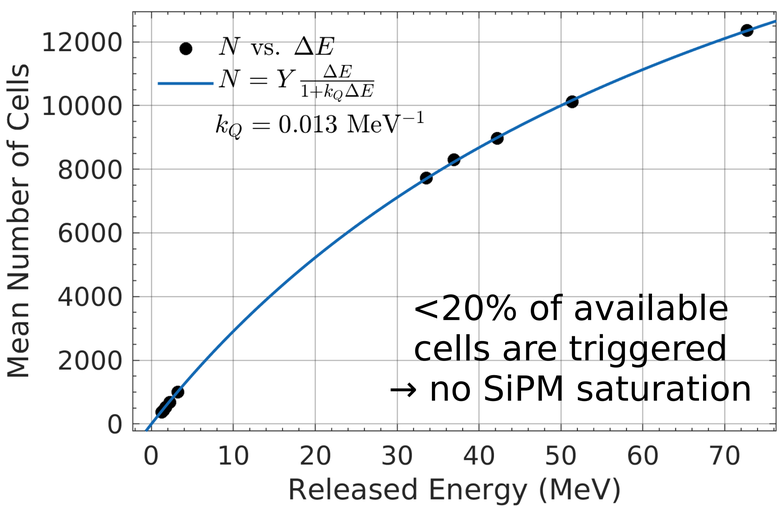


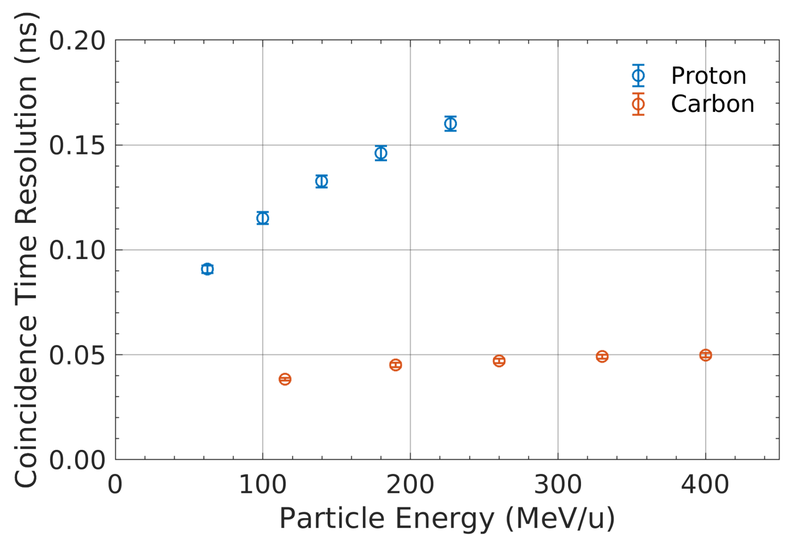
Highlights

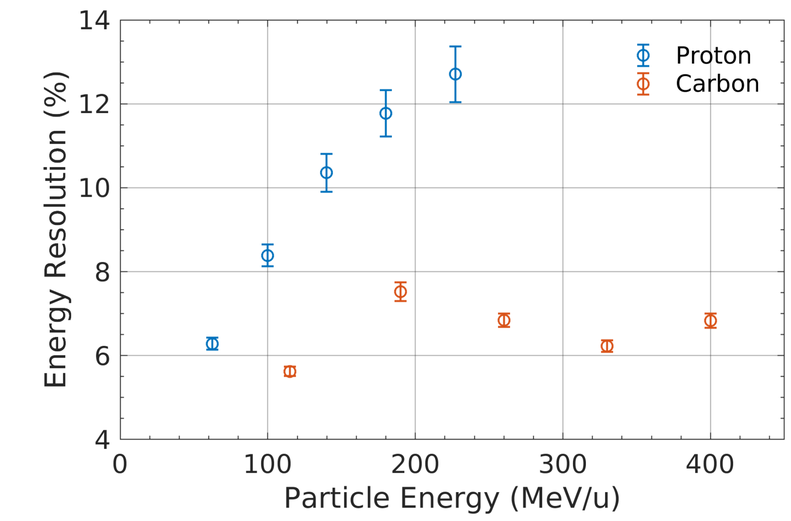
- A ΔE-TOF detector **prototype** was irradiated with **proton** and **carbon** ion beams
- Coincidence **time** resolutions (**40-160 ps**) compatible with the FOOT requirements were obtained
- **Energy** resolutions of **5-13%** were measured
- The predictive capability of the Monte Carlo simulation of the **optical transport** was tested
- The Monte Carlo can predict the light **attenuation** in the bar and the **number of detected photons**

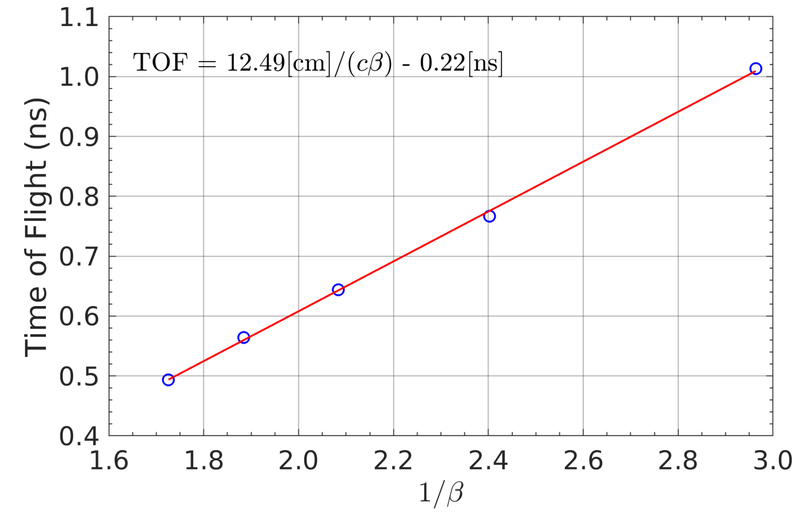
Experimental results

Scintillator quenching (Birks' law)



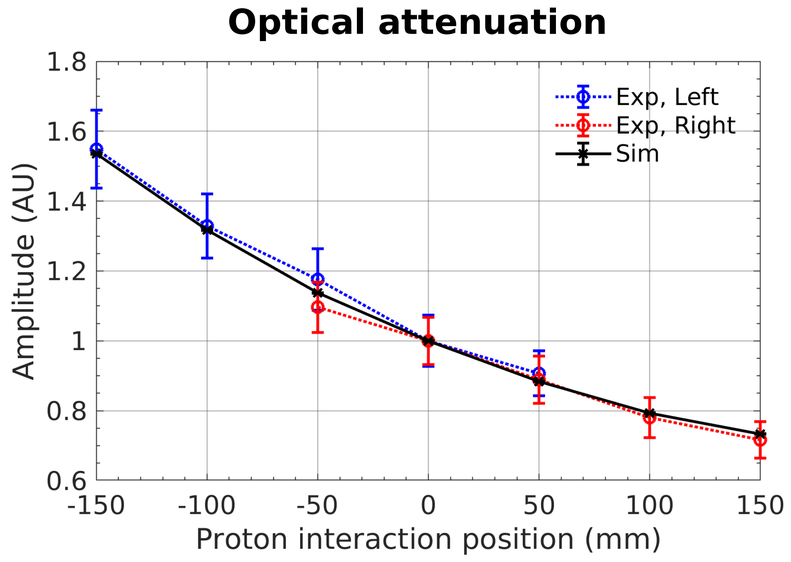




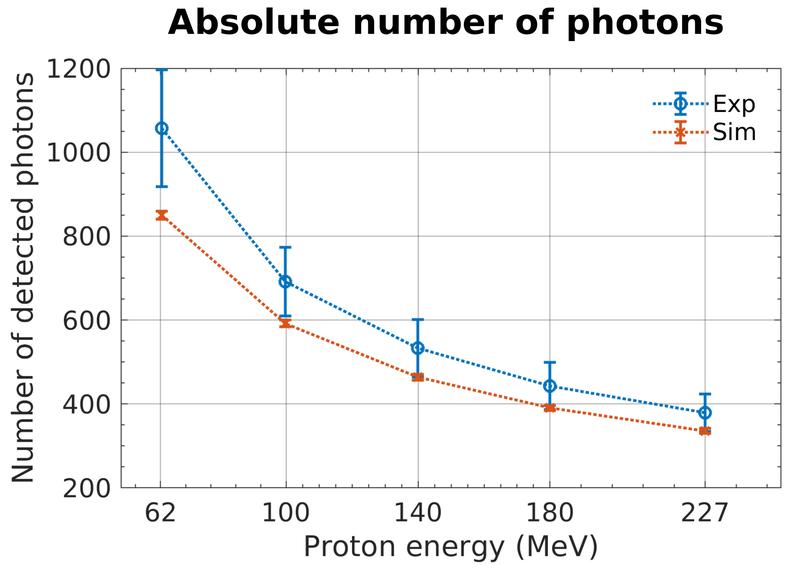


Monte Carlo simulation test and future applications

Optical attenuation



Absolute number of photons



Future MC applications

- Investigate the **impact** on the detector time and energy resolution of **geometrical** factors, such as:
  - the **thickness** of the plastic scintillator **bar**
  - different **SiPM arrangements** (number of SiPMs, micro-cell size)
  - uncertainties in the **SiPM position** wrt the plastic scintillator bar (e.g., angle, misalignment)
- Predict the energy and time **resolution** of the **final** ΔE-TOF detector

References

[1] Patera V et al. "The Foot (Fragmentation Of Target) Experiment", 2017

[2] Vlachoudis V. "FLAIR: a powerful but user friendly graphical interface for FLUKA", 2009

[3] Galli L. poster @ this conference

[4] Agostinelli S et al. "GEANT4—a simulation toolkit", 2003

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