The ΔE-TOF detector of the FOOT experiment: characterization and first results

Riccardo Ridolfi

on behalf of the FOOT collaboration

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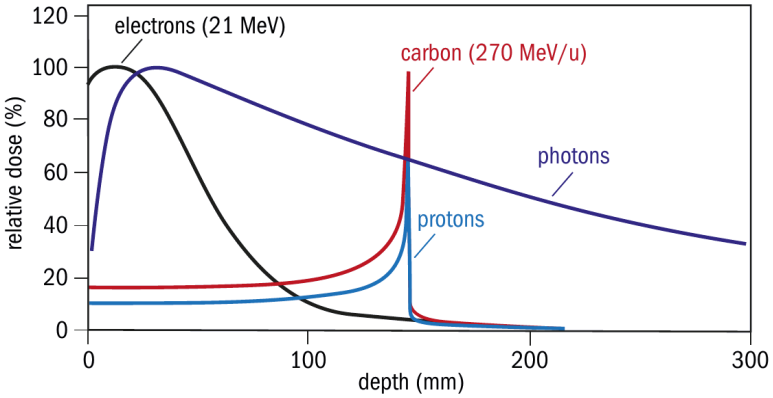
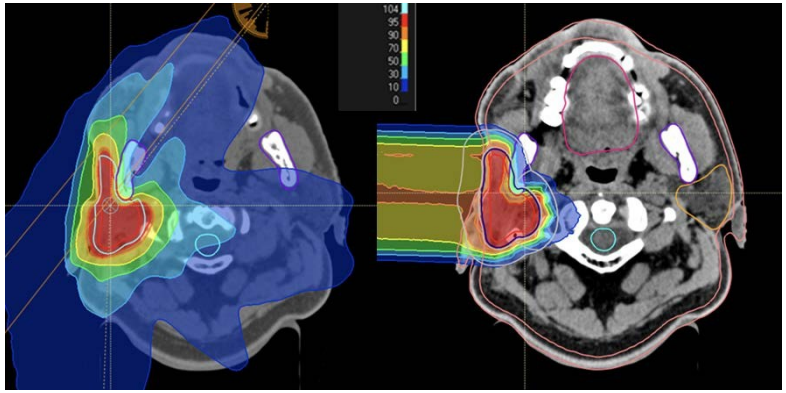
Pros and cons of Hadrontherapy

Riccardo Ridolfi

High **conformity** to the tumour volume ✓





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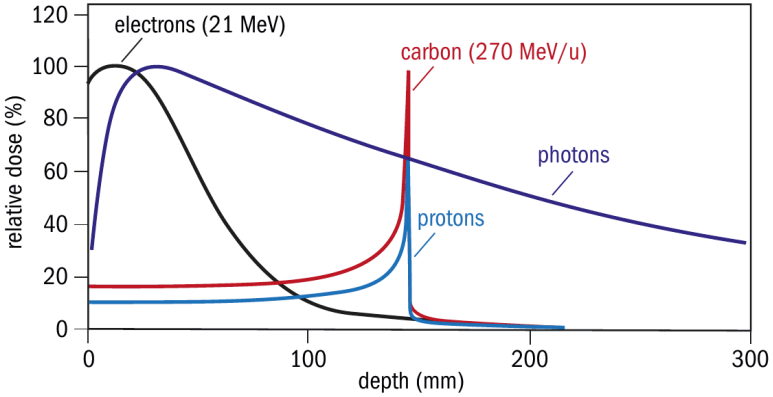
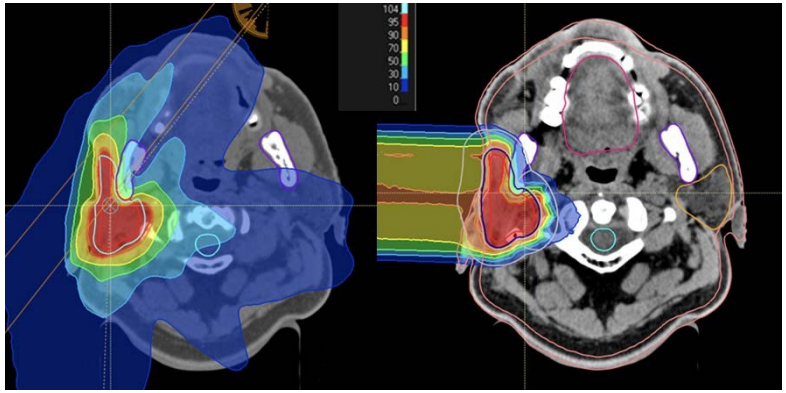
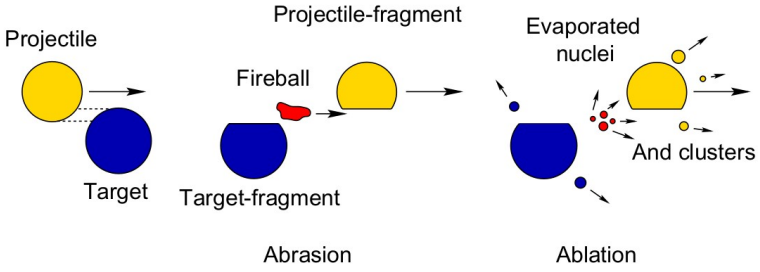
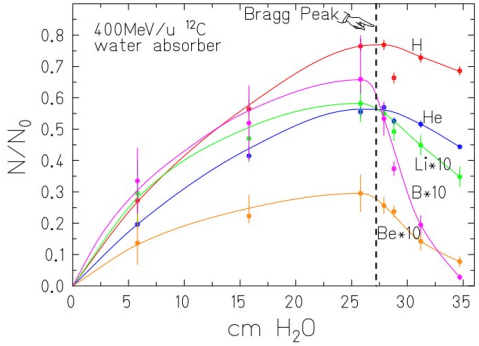




Nuclear fragmentation of the **projectile** and of the **target** ✗





Space radioprotection

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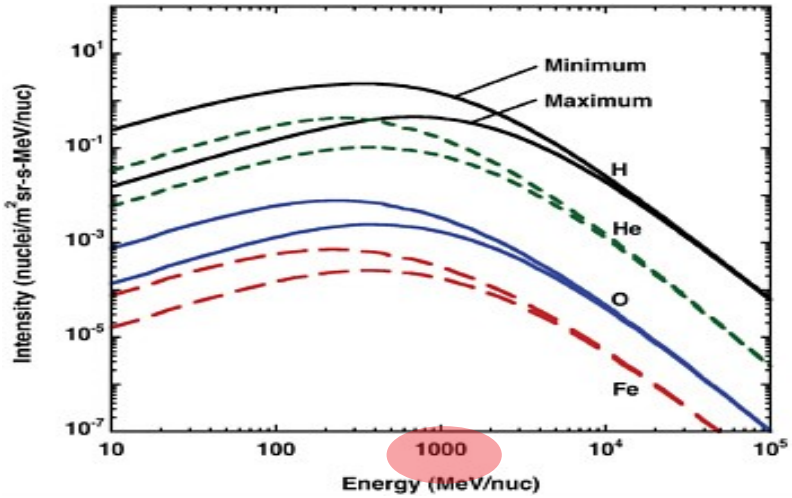
Mars and Moon has
NO magnetosphere
and a **very thin** atmosphere

→ **NO protection** against GCR and SPE

Travel: 1.8 mSv/day (GCR + SPE)
On Mars: 0.64 mSv/day
On Earth: 2.64 mSv/year

→ ~ 1 Sv (increase the cancer probability of ~3%)

Passive shielding is needed but it contributes to the dose



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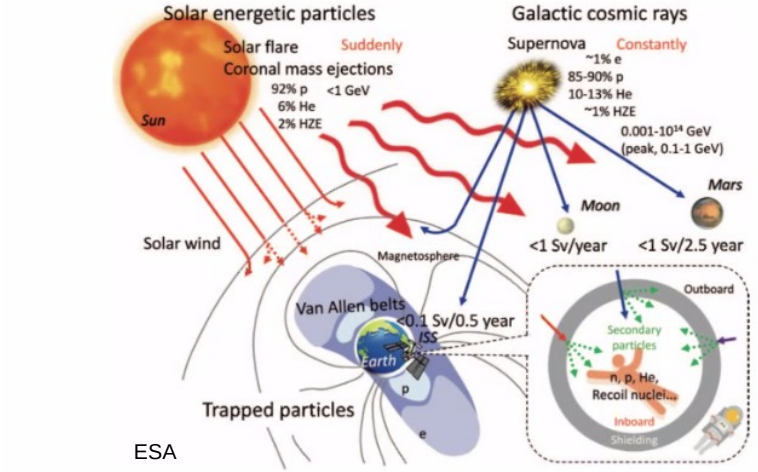

The FOOT experiment

The ΔE-TOF detector of the FOOT experiment

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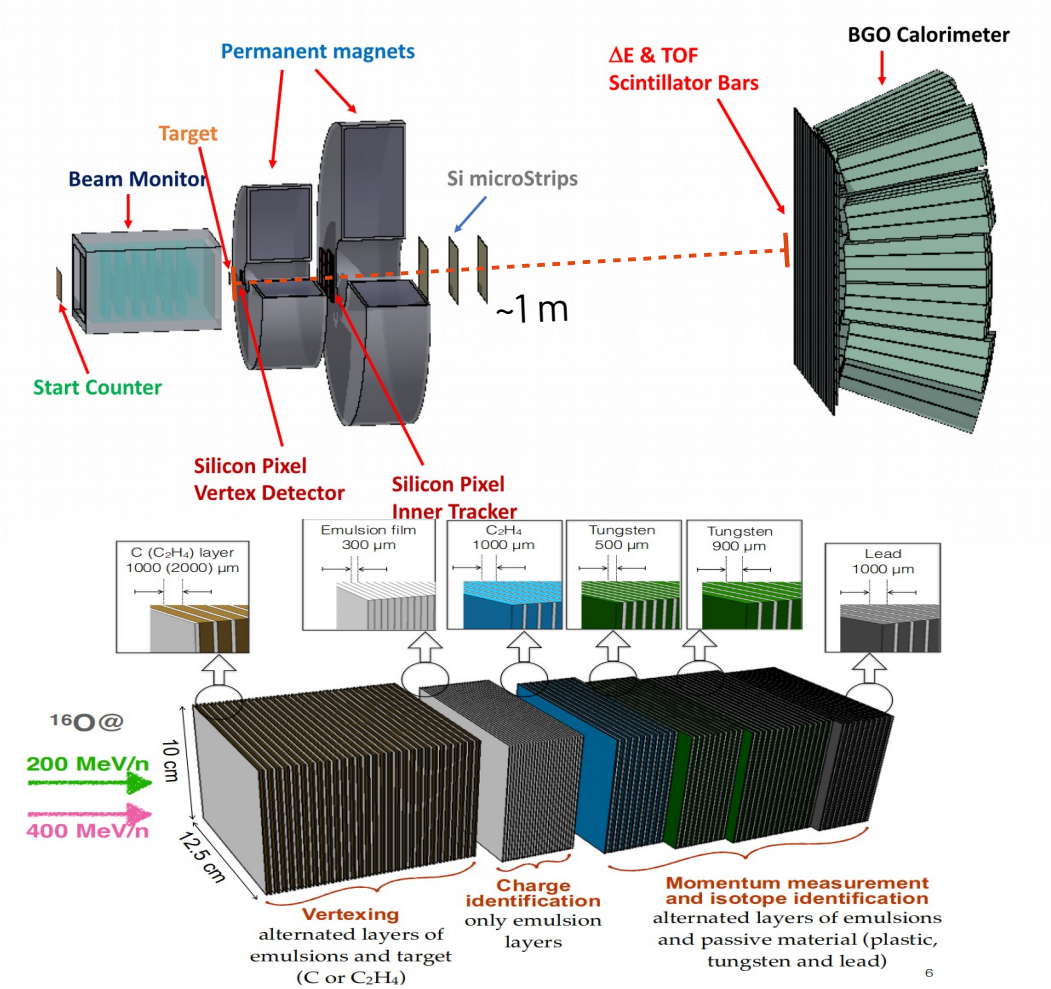

FOOT goal:

Fragments **energy spectrum** resolution at the level of **~1-2 MeV/u**

Heavy fragments (Z>2) **cross section** with maximum **uncertainty of 5%**

The ΔE-TOF system

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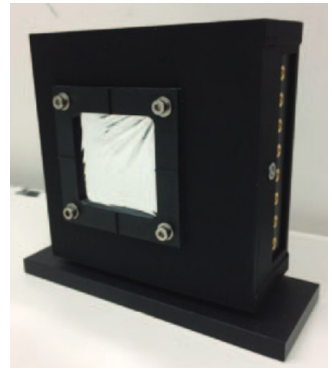
Start counter 250 um thick plastic scintillator (5x5 cm^2, EJ-228)
TOF wall 2 layers of 20 bars each (44x2x0.3 cm^3, EJ-200)

Readout with **SiPMs** and fast digitizer (**WaveDream,** DRS4 chip up to 5 GSPS)



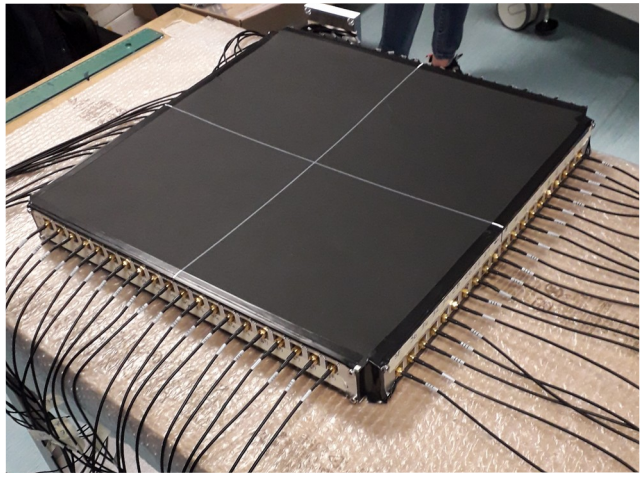
The system provides two measurements:

Energy loss **ΔE**
Time of Flight via **β**

→ Bethe Bloch → Charge **Z**

For hadrontherapy energy:
σ(ΔE)/ΔE at level of **4-5%**
σ(TOF) < 100 ps

→ **σ(Z)/Z** at level of **2-6%**



Beam test@CNAO

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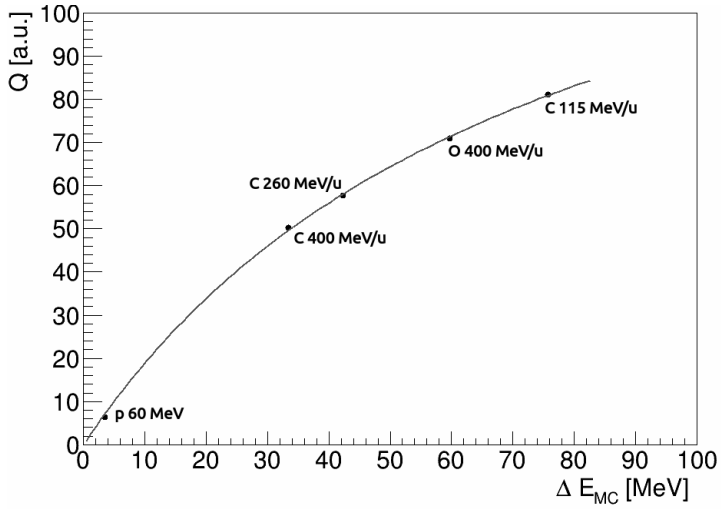
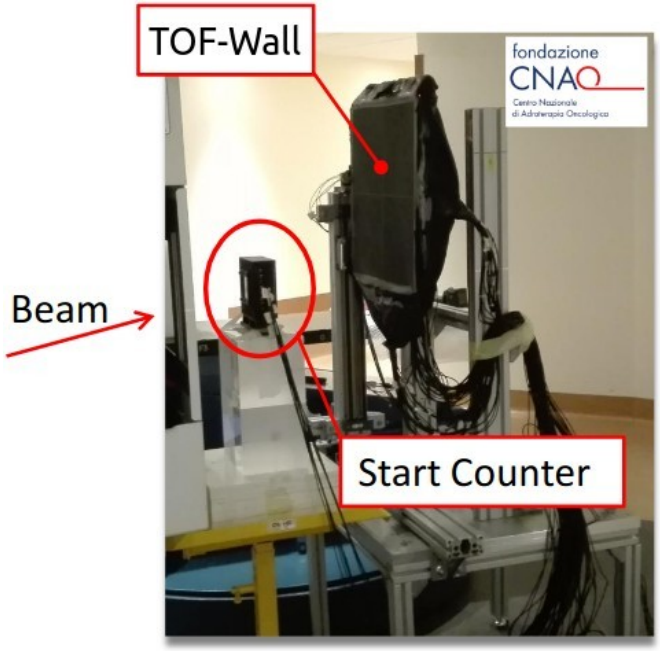
First test of the full ΔE-TOF setup at CNAO (March 2019)
SC-TW distance: ~40 cm

Beam: **60 MeV** protons, **115, 260, 400** MeV/u Carbon ions





Calibration with **Birks**' law $Q = p_a \frac{\Delta E_{mc}}{1 + p_b \Delta E_{mc}}$

Beam test@CNAO

The ΔE-TOF detector of the FOOT experiment

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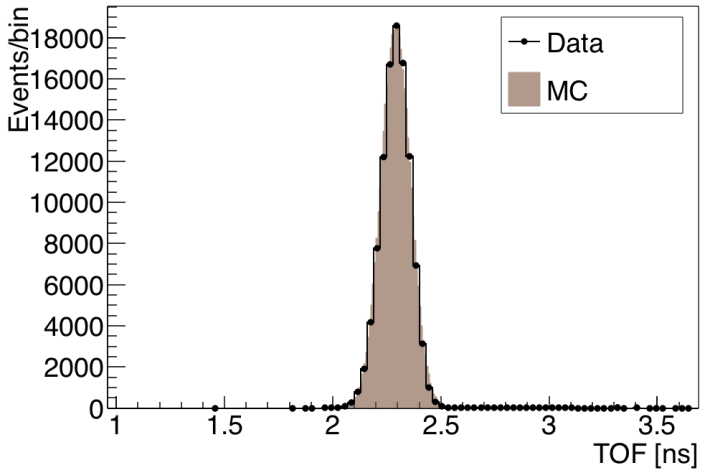
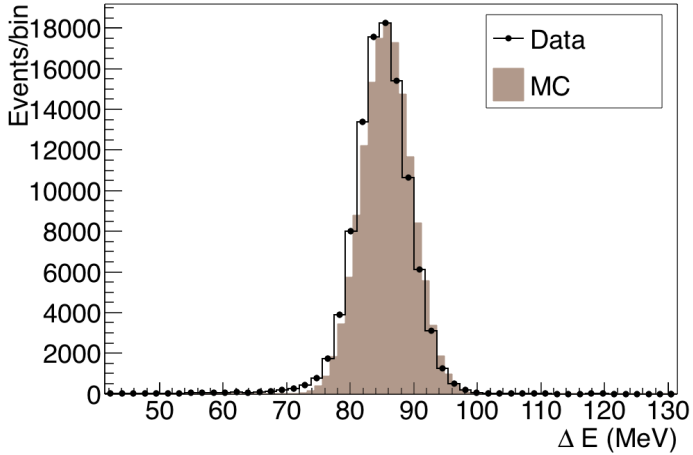
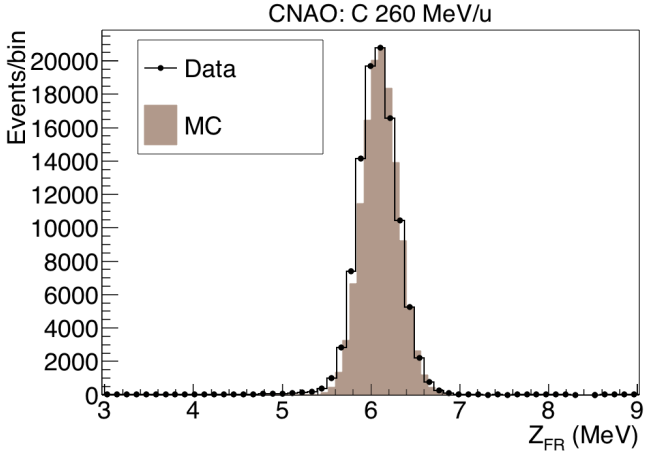


260 MeV/u
^{12}C





σ(TOF) **54 – 74 ps** for Carbon, **265 ps** for protons
σ(ΔE)/ΔE **4% – 4.7%** for Carbon, **5.7%** for protons

σ(Z)/Z **2.5% – 3.8%** for Carbon, **6%** for protons

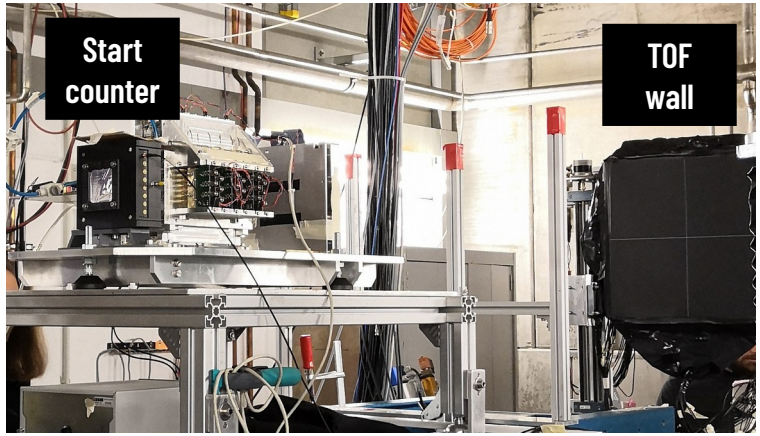
Beam test@GSI

Riccardo Ridolfi

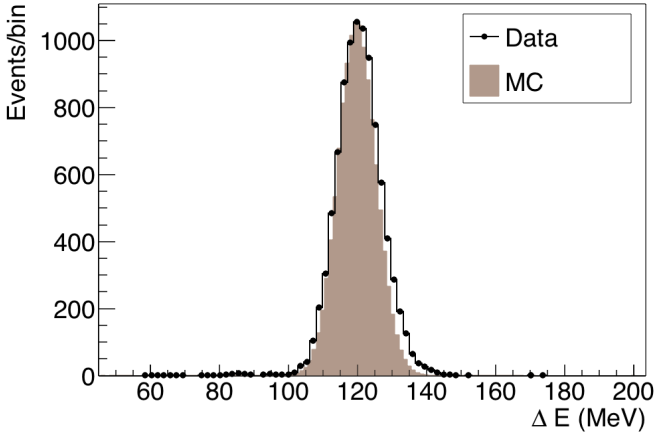
First test of a reduced setup of the FOOT experiment at GSI (April 2019)

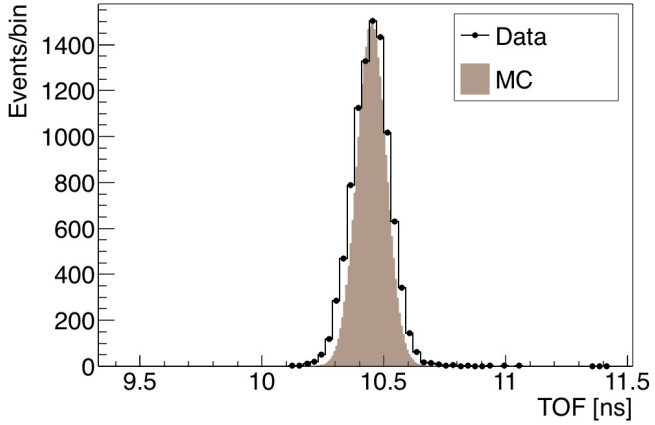
SC-TW distance ~ 230 cm

Beam: **400** MeV/u Oxygen ions



σ(TOF) ~ **75.6 ps**
σ(ΔE)/ΔE ~**5.2%**





Beam test@GSI

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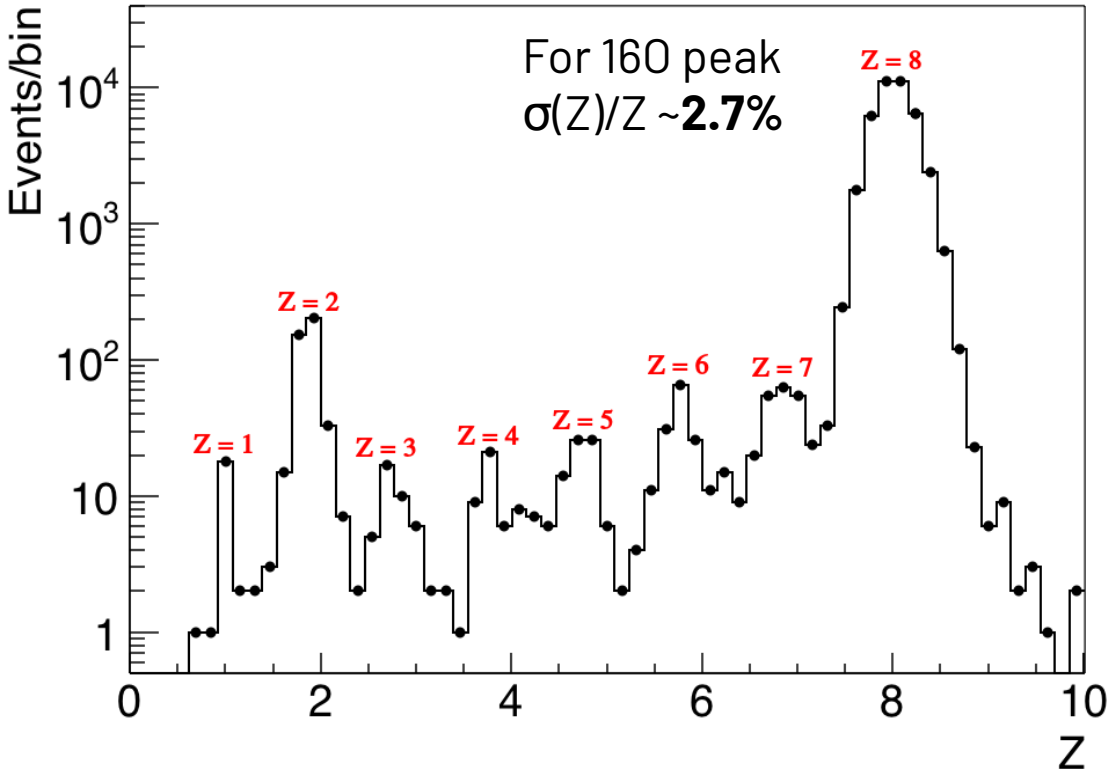
Fragmentation run on a 5 mm thick C target
First fragments identified in FOOT setup!



Conclusions

- A strategy to **calibrate** and **validate** data with MC simulations was developed
- The overall **resolutions** on energy, TOF and charge **satisfy FOOT goals** ($\sigma(\Delta E)/\Delta E \sim$ 4-5%, $\sigma(TOF) <$ 100 ps, $\sigma(Z)/Z \sim$2-6%)
- The charge identification was successfully applied to **fragmentation data**
- **To be published** in NIMA by the FOOT collaboration (Kraan, A.C. and Zarrella R. et al., *Charge identification of nuclear fragments with the FOOT Time-Of-Flight system*)
- Still some room for **improvements**, especially on Start Counter
- Other beam tests and **data taking campaigns** are foreseen (HIT, Trento, CNAO, GSI) despite COVID-19
- **All information** about the FOOT experiment can be found here (The FOOT collaboration, *Measuring the Impact of Nuclear Interaction in Particle Therapy and in Radio Protection in Space: the FOOT Experiment*, Front. Phys., 08 February 2021)

Thanks for your attention!