The FOOT experiment

FragmentatiOn Of Target

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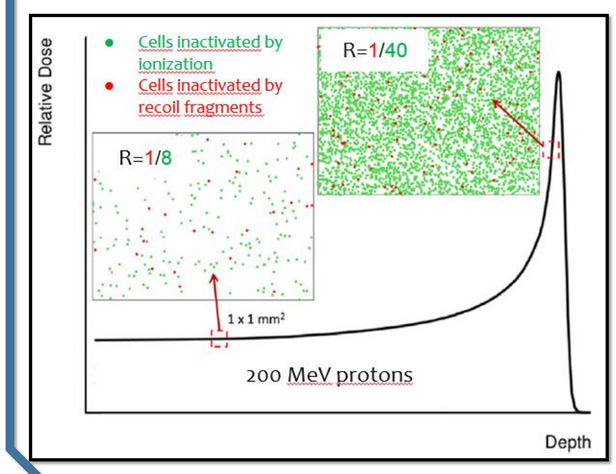
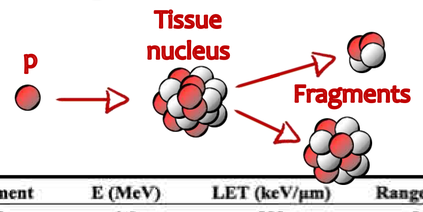
NUCLEAR INTERACTIONS IN HADRONTHERAPY

Particle therapy uses proton or ^{12}C beams for the treatment of deep-seated solid tumors exploiting the characteristic energy deposition of charged particles. **Nuclear interactions** between beam and patient tissues induce fragmentation both of projectile and target. In proton treatment the target fragmentation produces **low energy, short range fragments** along all the beam range. Their biological effectiveness is greater with respect to protons.





Fragment	E (MeV)	LET (keV/μm)	Range (μm)
^{15}O	1.0	983	2.3
^{15}N	1.0	925	2.5
^{14}N	2.0	1137	3.6
^{13}C	3.0	951	5.4
^{12}C	3.8	912	6.2
^{11}C	4.6	878	7.0
^{10}B	5.4	643	9.9
^{8}Be	6.4	400	15.7
^{6}Li	6.8	215	26.7
^{4}He	6.0	77	48.5
^{3}He	4.7	89	38.8
^{2}H	2.5	14	68.9

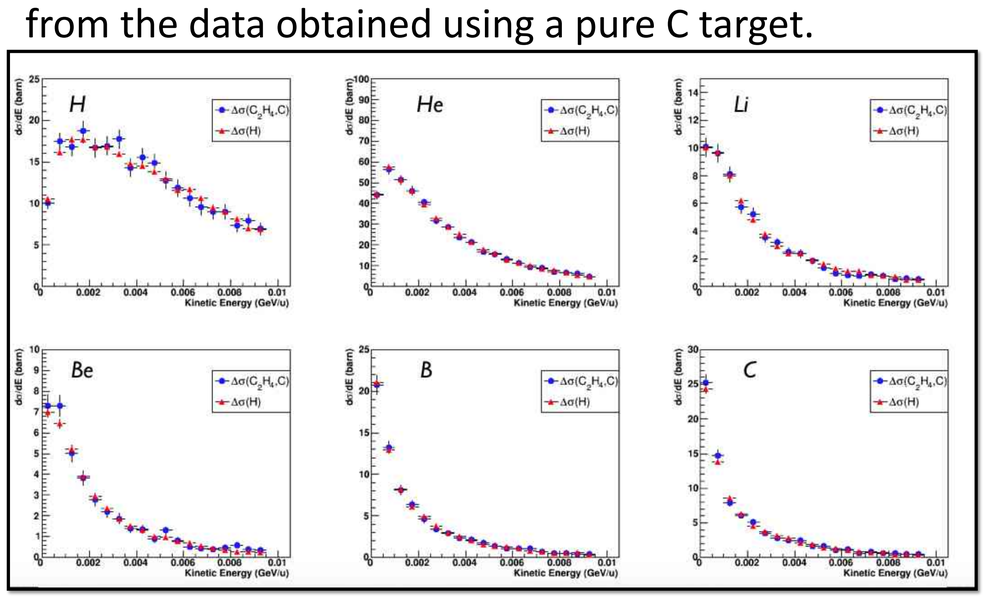
Tommasino e Durante 2015

EXPERIMENTAL STRATEGIES

The main experimental difficulty in the measurement of the target fragmentation induced by proton beams is due to the short range (~tens of μm) of produced fragments.

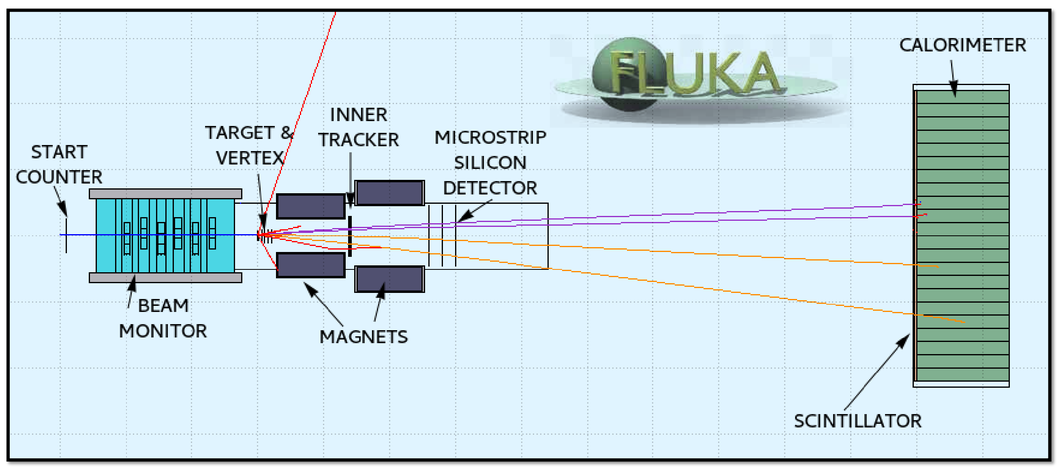
In an **inverse kinematic approach** we will study the fragmentation of different ions beams (C, O, Ca..) onto H enriched target, such as CH_2 [1]: secondary fragments will have boosted energy and longer range.

The cross section on H can be extracted by **subtraction** from the data obtained using a pure C target.



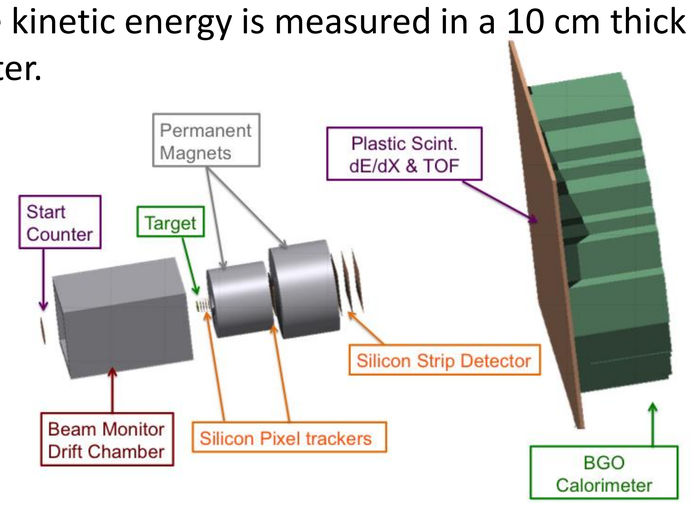
FLUKA simulations [2]

EXPERIMENTAL SETUP



The setup aims to the identification and measurement of fragments heavier than the ^4He and covers an angular acceptance up to 10÷20 degrees with respect to the beam axis. The detector can be divided in three different regions:

- **Target region**. A thin plastic scintillator counter provides trigger information and the TOF start. A drift chamber acts as beam monitor, tracks the beam direction and position. The target is the last element of this region.
- **Magnetic spectrometer**. A telescope of pixel trackers provides the vertex reconstruction and the fragments initial tracking. Then two permanent dipole magnets (Hallbach geometry) provide the ~0,8T magnetic field. Two additional layers of silicon pixel trackers and a telescope of silicon microstrips are placed between and at the end of the magnets respectively. All these tracking elements allow the measurement of the momentum.
- **Calorimeter region**. A detector made of two orthogonal planes consisting of 3mm thick plastic scintillator rods measures ΔE and TOF . The kinetic energy is measured in a 10 cm thick BGO crystal calorimeter.



EXPECTED PERFORMANCES

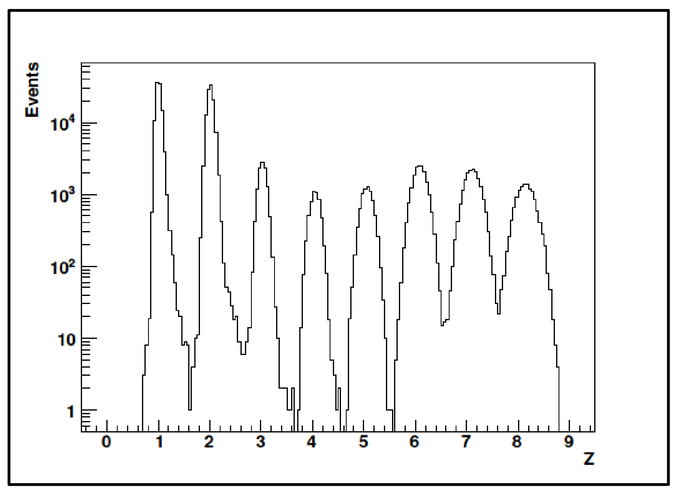
To contribute to a better radiobiological characterization of protons, the FOOT final goals are:

- measure the heavy fragments cross section (max uncertainty of 5%)
- measure the fragment energy spectrum in the "patient" reference frame (resolution 1-2 MeV/u)
- charge and isotopic identification (at the level of 4 2-3% and 5% respectively)

Setup requested performances:

- $\sigma(TOF)$~100 ps
- $\sigma(p)/p$ ~5%
- $\sigma((E_k)/E_k$ ~2%
- $\sigma(\Delta E)/\Delta E$ ~2%

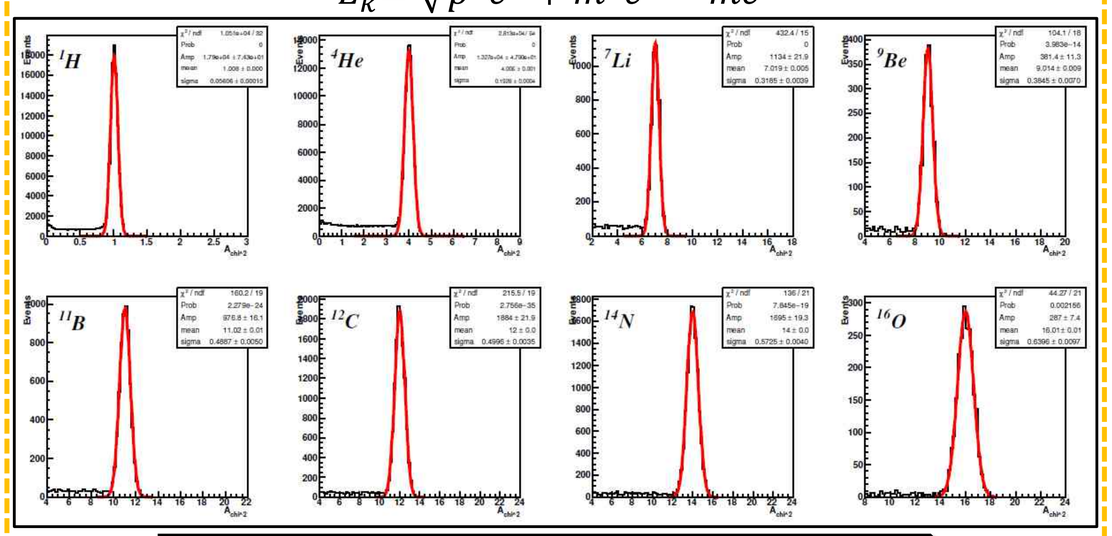
$\Delta E + TOF$



Z-Id

A-Id

$$p = mc\beta\gamma \quad E_k = mc^2(\gamma - 1)$$
$$E_k = \sqrt{p^2c^2 + m^2c^4} - mc^2$$



Fragment	^1H	^4He	^7Li	^9Be	^{11}B
A_{χ^2}	1.01 ± 0.05	4.02 ± 0.18	7.03 ± 0.30	9.03 ± 0.37	11.03 ± 0.47

Fragment	^{12}C	^{14}N	^{16}O
A_{χ^2}	12.01 ± 0.49	14.01 ± 0.56	16.02 ± 0.63

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[1] Dudouet J. et al. *Physical Review C* 88.2 (2013): 024606.
[2] Ferrari A. et al. CERN 2005-10, INFN/TC_05/11, SLAC-R-773L (2005)