Nuclear Physics applied to Particle Therapy: a possible proposal for a next experiment

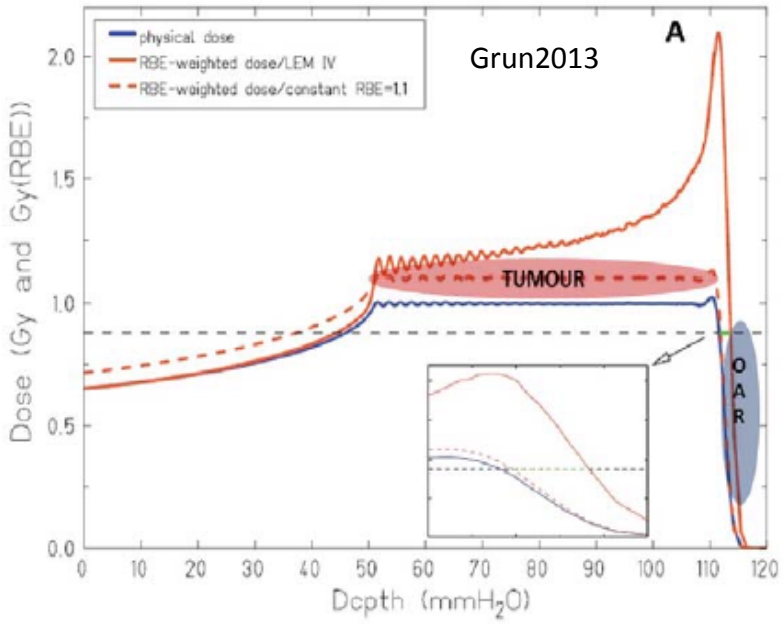
Cancers 2015,7 Tommasino & Durante

Proton RBE

In clinical practice protons **RBE = 1.1**

BUT

at the tissue-cellular-subcellular levels protons show **different physical and biological properties** wrt to gammas
→ **RBE ≠ 1.1**
(Girdhani2013, Tommasino2015)

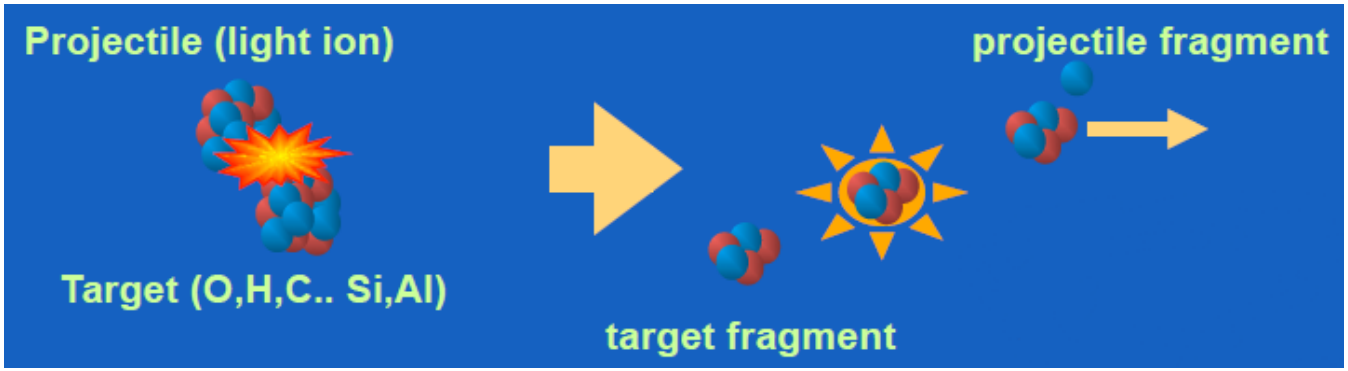


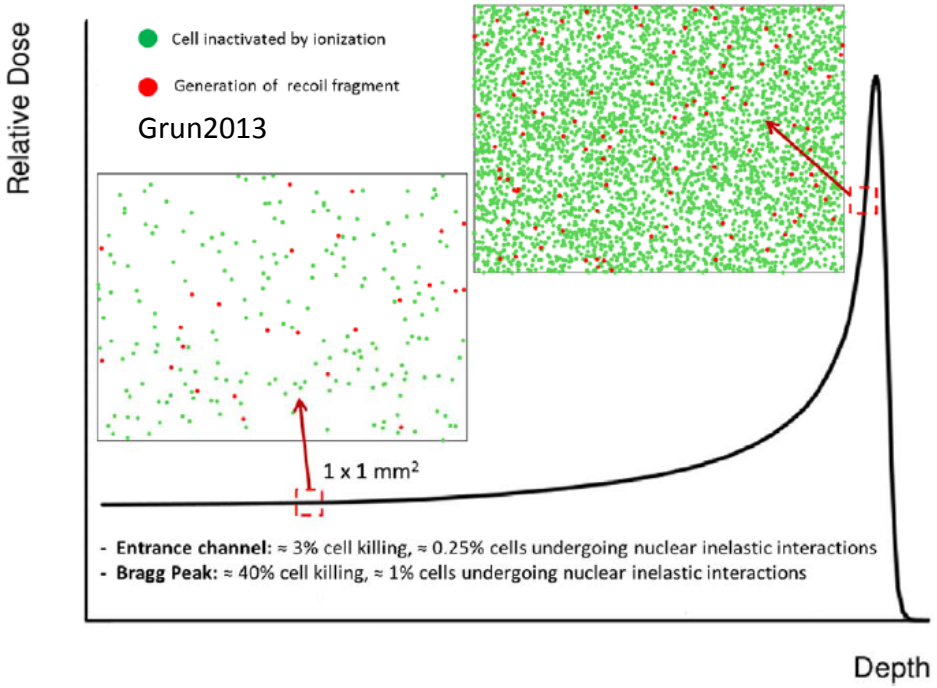
eventually
RBE>>1 in OAR

At the distal edge of SOBP → LET ↑ / dose ↓ → RBE ↑ → greater RBE uncertainty especially in the distal SOBP (Grun2013)

Possibly due to **target fragmentation**

Target fragmentation





He, C, O, N

↓

higher RBE

↓

Secondary fragments cause ~10% of the biological effects in the entrance channel (Grun2013)

↓

NTCP

Methods & aim of the FOOT project

Target fragments have a low energy and have a very short range in tissue

→ no experimental data about nuclear fragmentation in a human tissue target

How???
Twin targets (~mm):
C and hydrocarbon
Fragmentation cross sections can be obtained by subtraction

FOOT project

INVERSE KINEMATICS

a beam of heavy tissue-like ions (*i.e.* O and C) hitting a proton target

↓

secondary fragments would have a boosted energy and a longer range

↓

easier detection

↓

Particle ID

→

- Better definition of peak-to-entrance ratio
- Evaluation of side effects in the entrance channel (NTCP) and dose to target (TCP)
- Prediction of secondary cancer risks
- TP with a variable RBE → possibly better results in PT (Wedenberg2014)

Istituto Nazionale di Fisica Nucleare

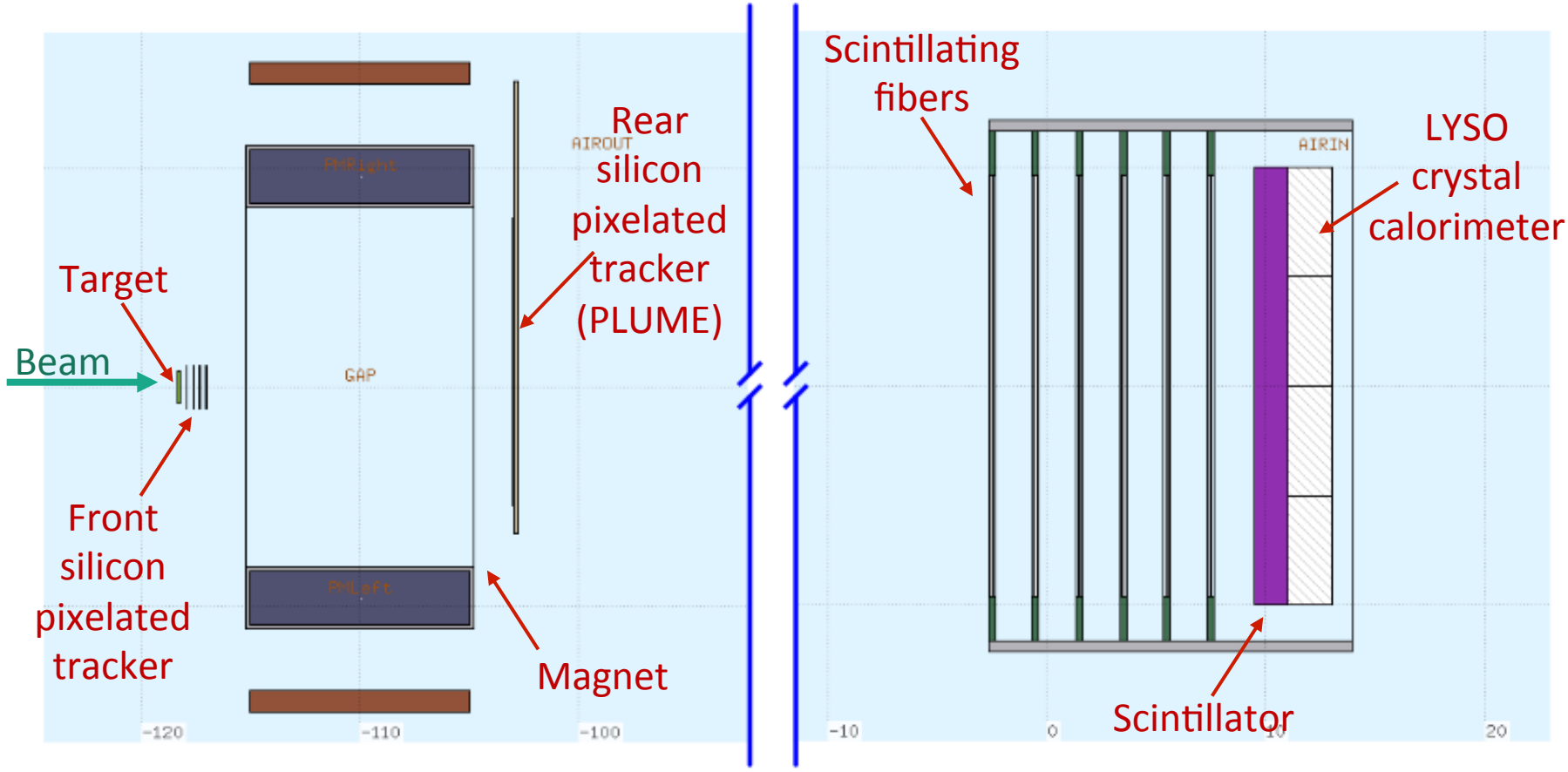
Trento Institute for Fundamental Physics and Applications

FragmentatiOn Of Target

A Preliminary study

Geometry

Simulated ^{16}O beam 200 MeV/n
with realistic transversal spreading

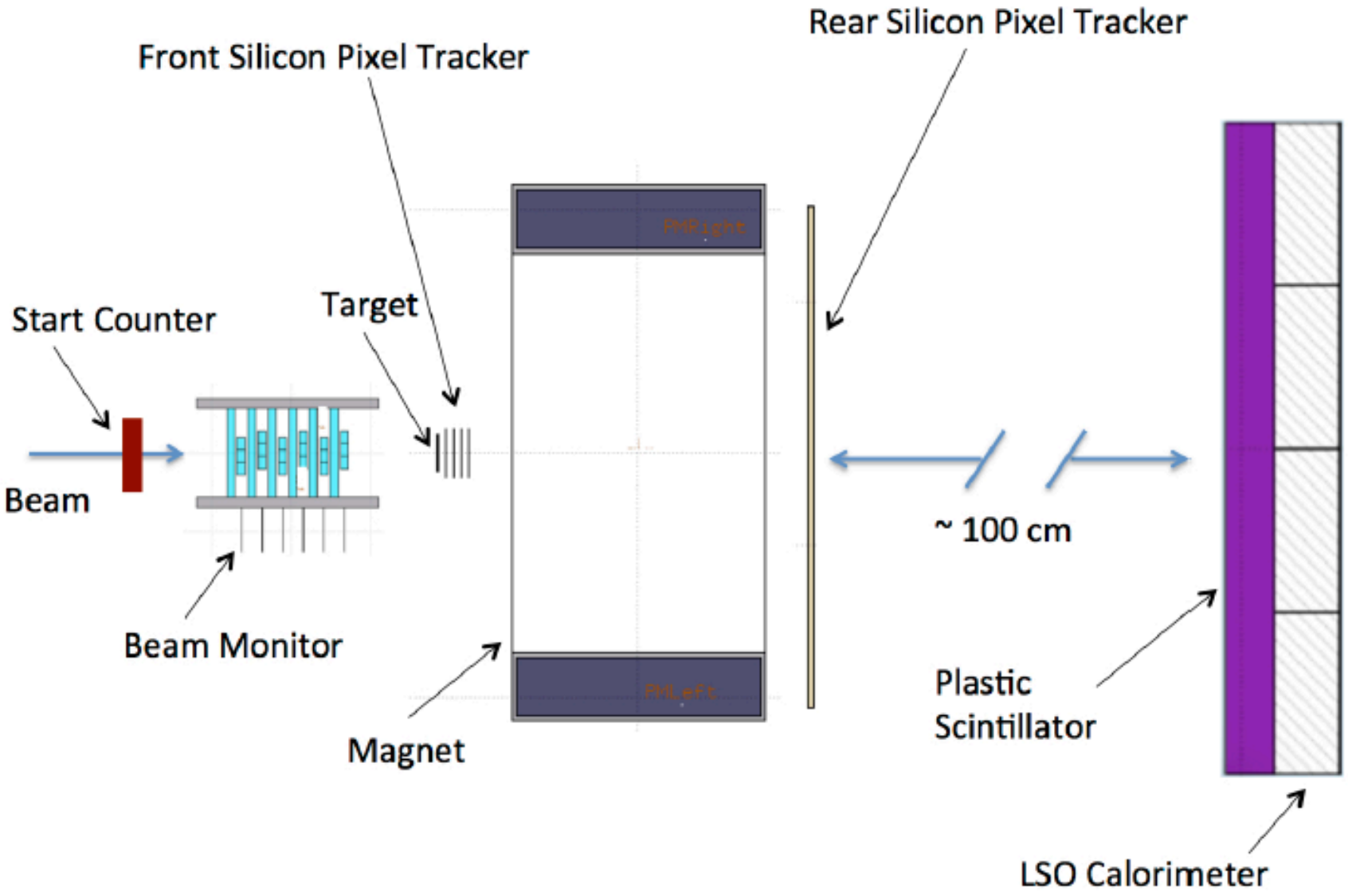


Prin2015: Proton On Patient (POP)

Evaluation of the clinical impact of the nuclear fragmentation induced by proton beam in tumor hadrontherapy

V. Patera & M. Durante

con G. Battistoni, A. Sarti, A. Sciubba, E. Spiriti, F. Tommasino,….


Front Silicon Pixel Tracker
Rear Silicon Pixel Tracker
Start Counter
Target
Beam
Beam Monitor
PMRight
PMLeft
Magnet
~ 100 cm
Plastic
Scintillator
LSO Calorimeter

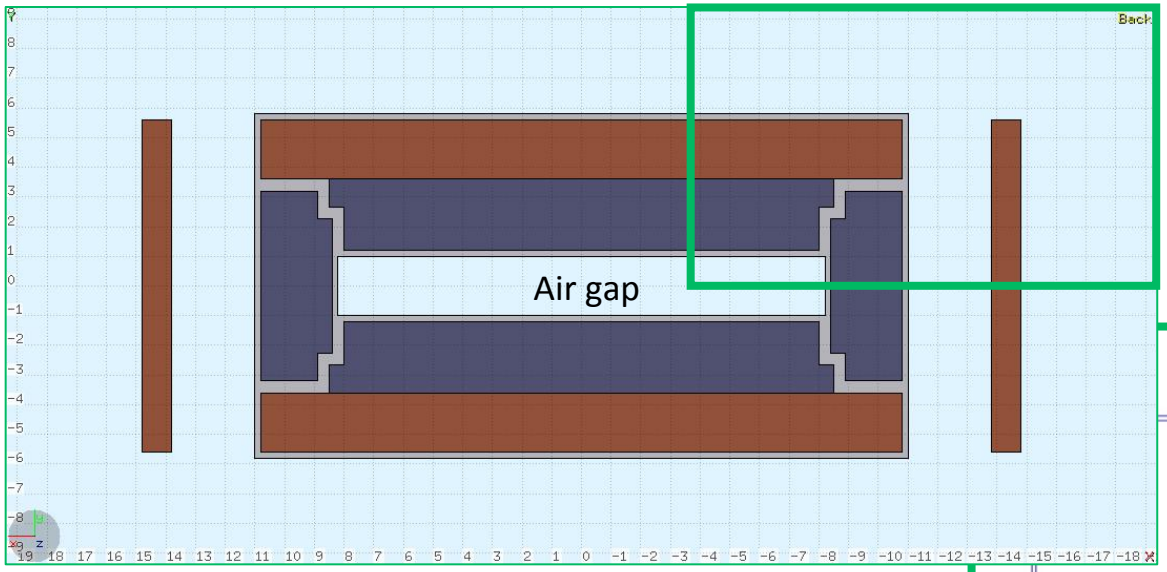
Magnets

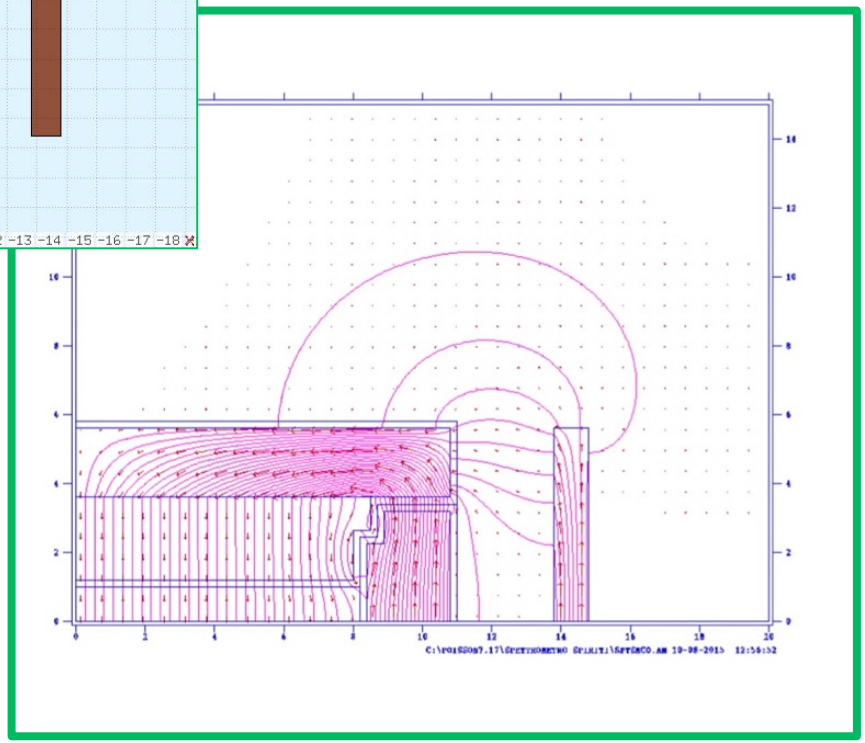
Iron

Permanent magnets (SmCo)

Aluminium covering

Air gap ($16.4 \times 2 \times 10{,}4\,cm^3$) → magnetic field



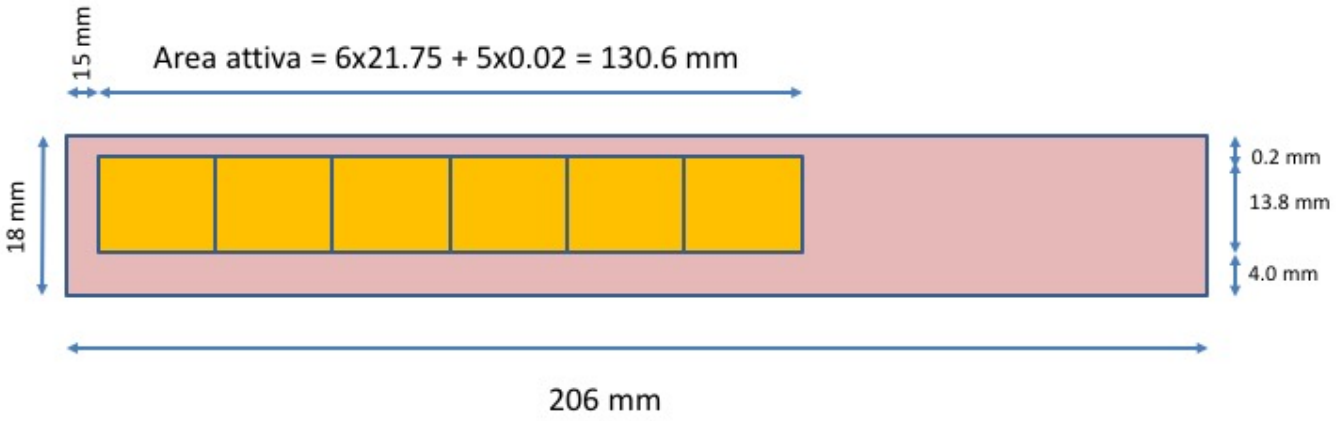


B=0,5 T

(at present assumed uniform)

Fringe magnetic field outside the gap parametrizable as an erf or a Fermi-Dirac

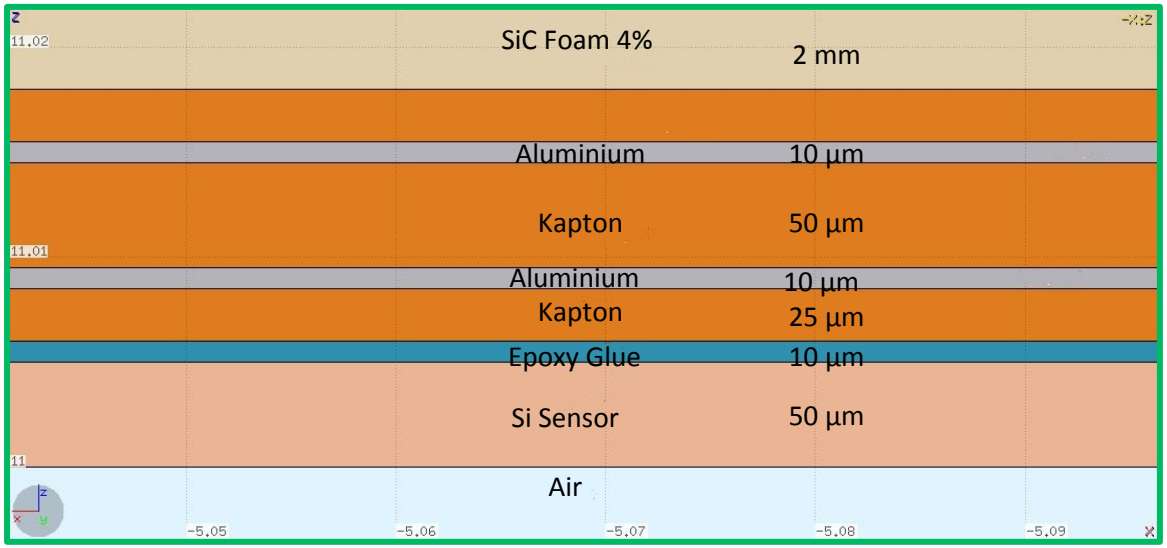
Rear tracker: PLUME



Sensor active zone:
576x1152 pixel matrix

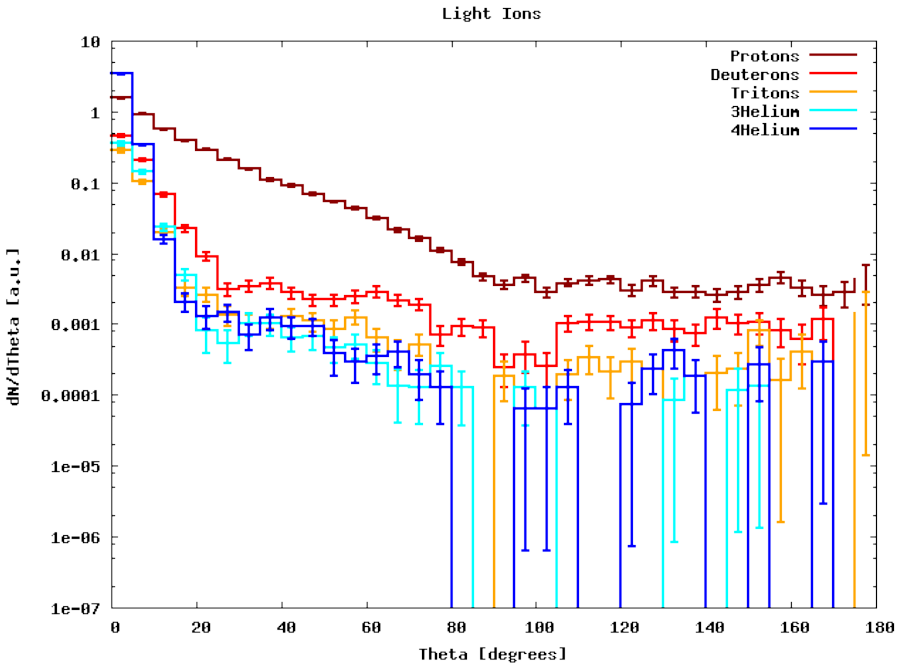
Dimension of the active zone:
(576x18.4)x(1152x18.4)=
10598.4x21196.8 µm

Transversal section

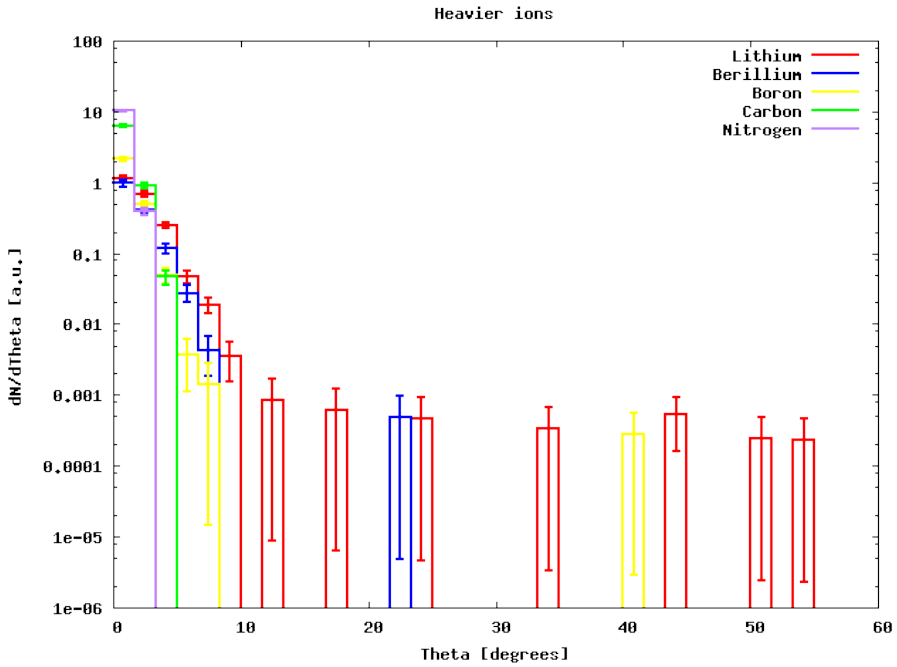


Emission angular distribution

C_2H_4



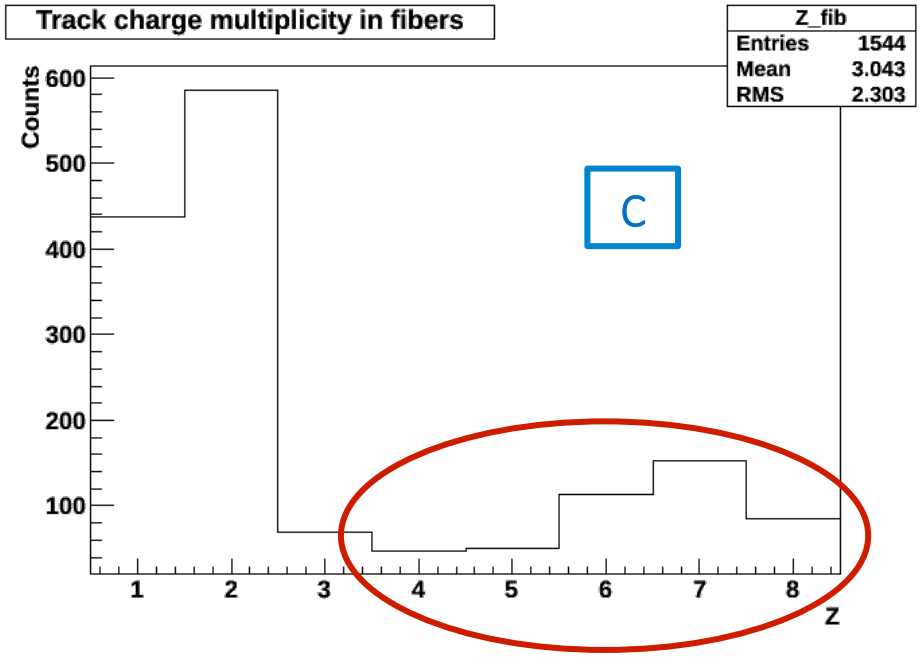
Light fragments also emitted at great angles

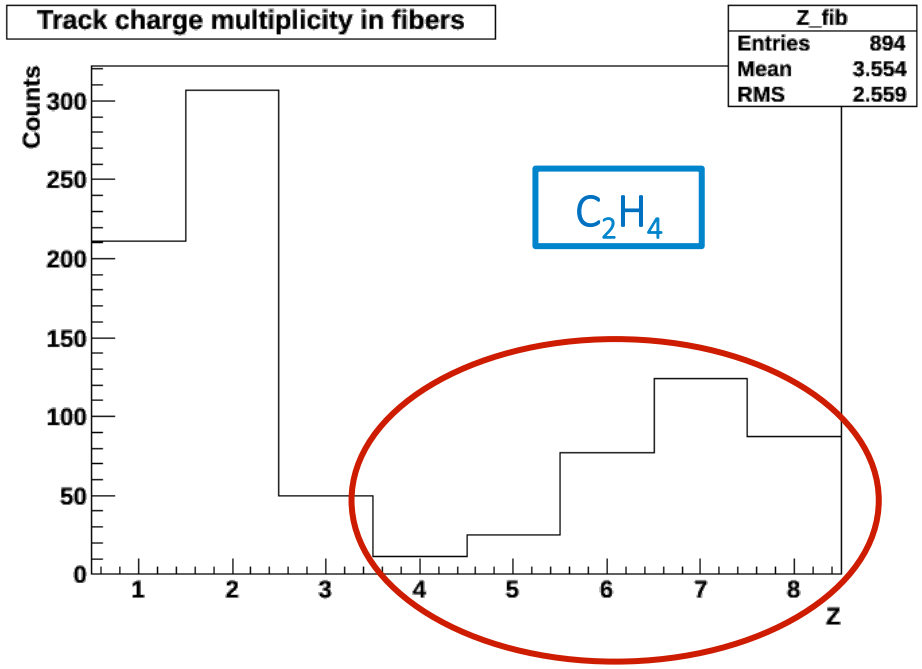


Heavier fragments mostly peaked forward

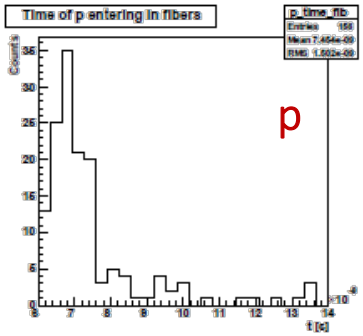
Fragments in the downstream calorimeter

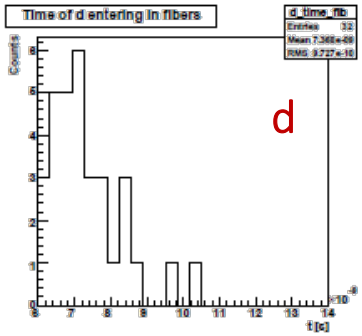
Secondary fragments produced in the target
and tracked in the scintillating fibers

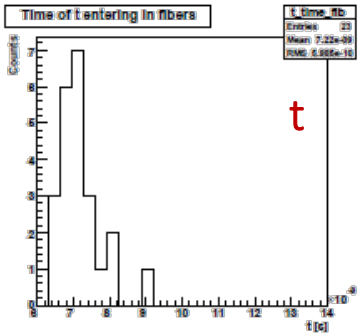


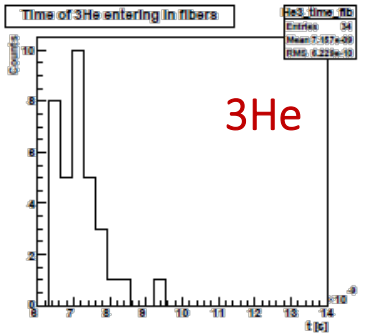


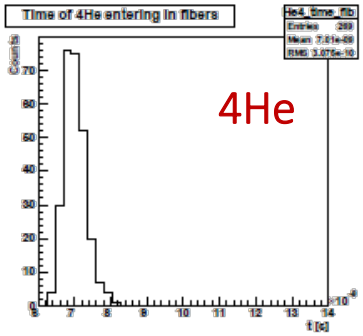
TOF

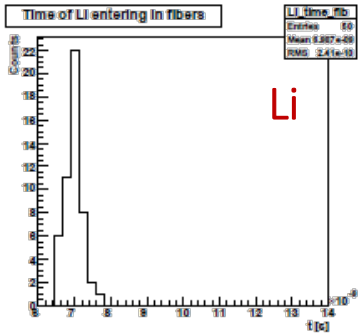


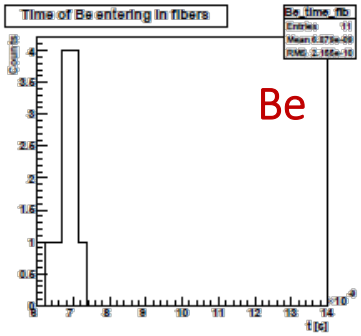


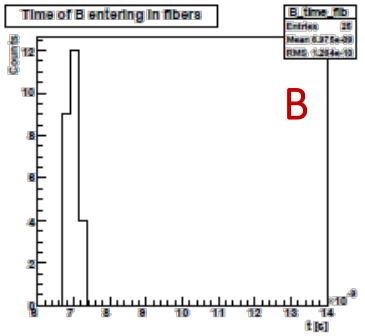


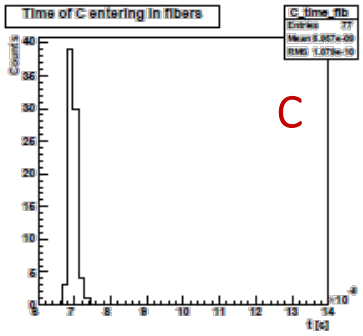


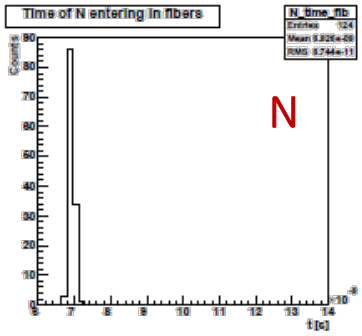


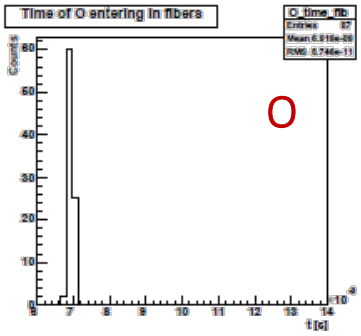








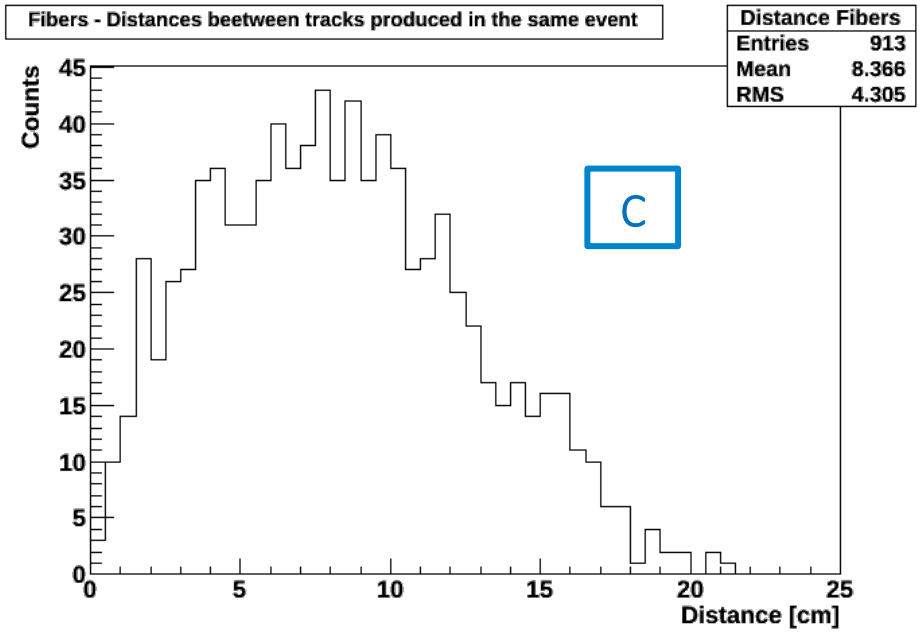


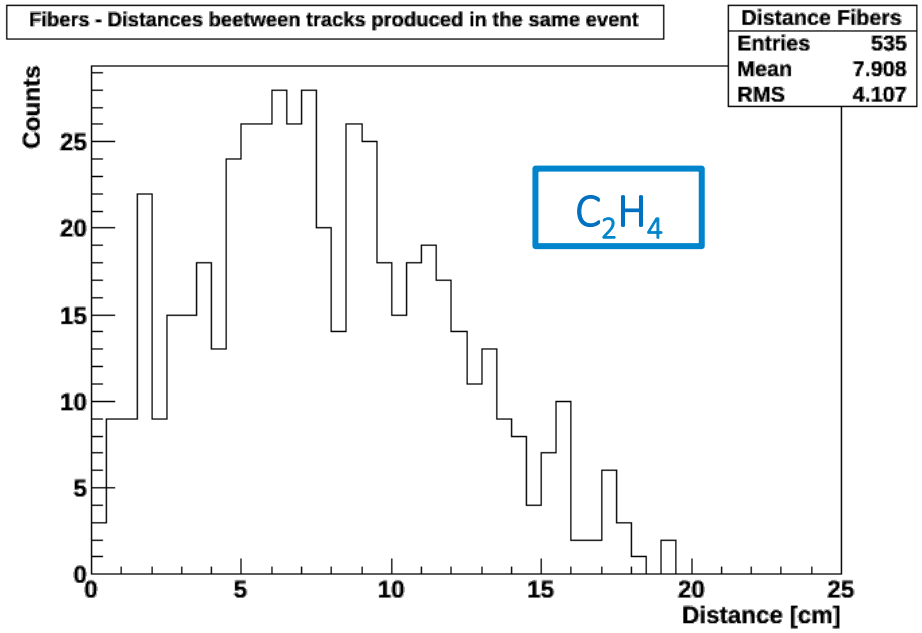


C_2H_4

TOF=6.9-7.5E-11 s

Spatial Tracks separation in downstream calorimeter





Possible Z identification

dE in fibers vs
energy deposition in the calorimeter