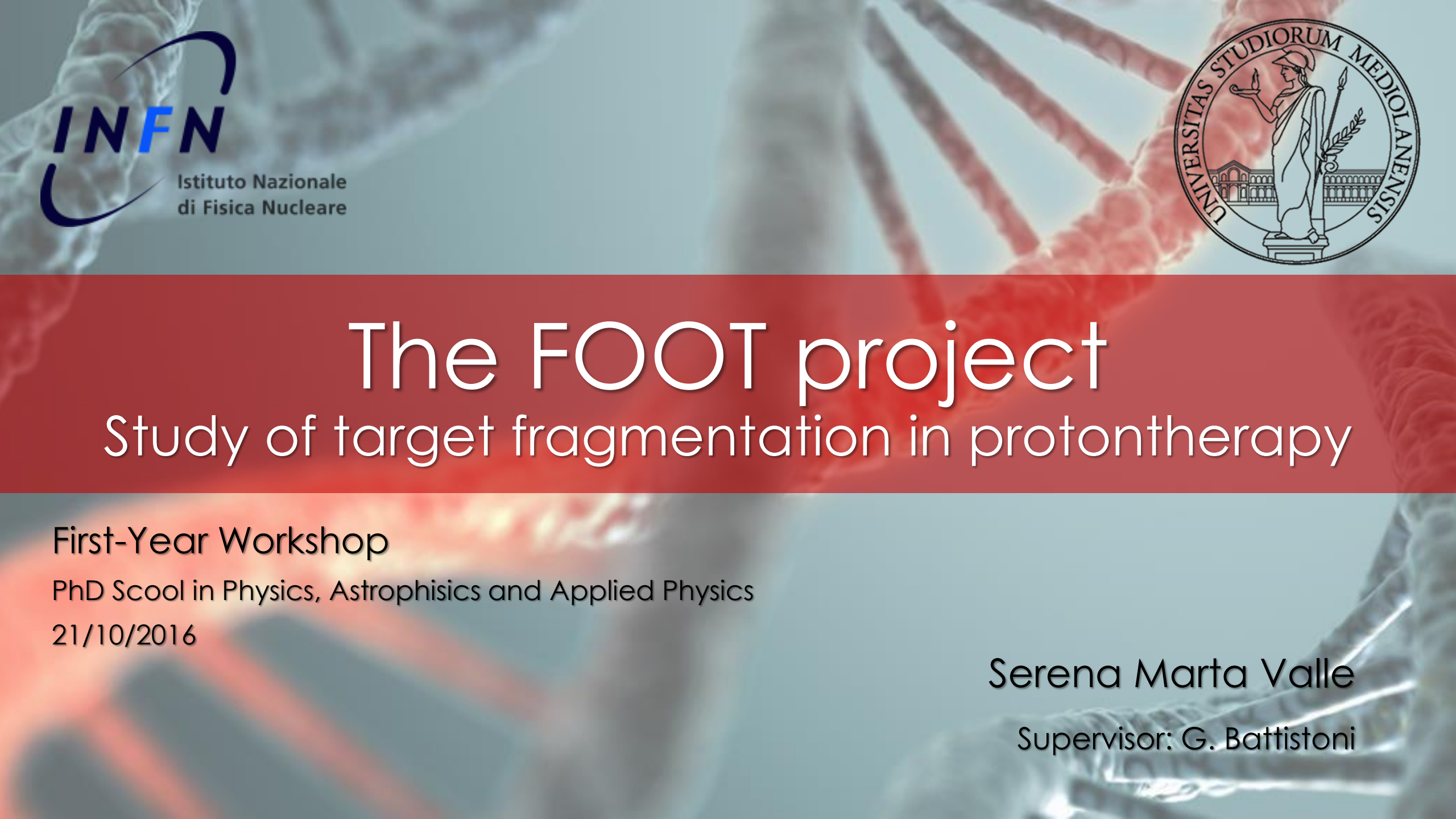


The FOOT project

Study of target fragmentation in protontherapy

First-Year Workshop

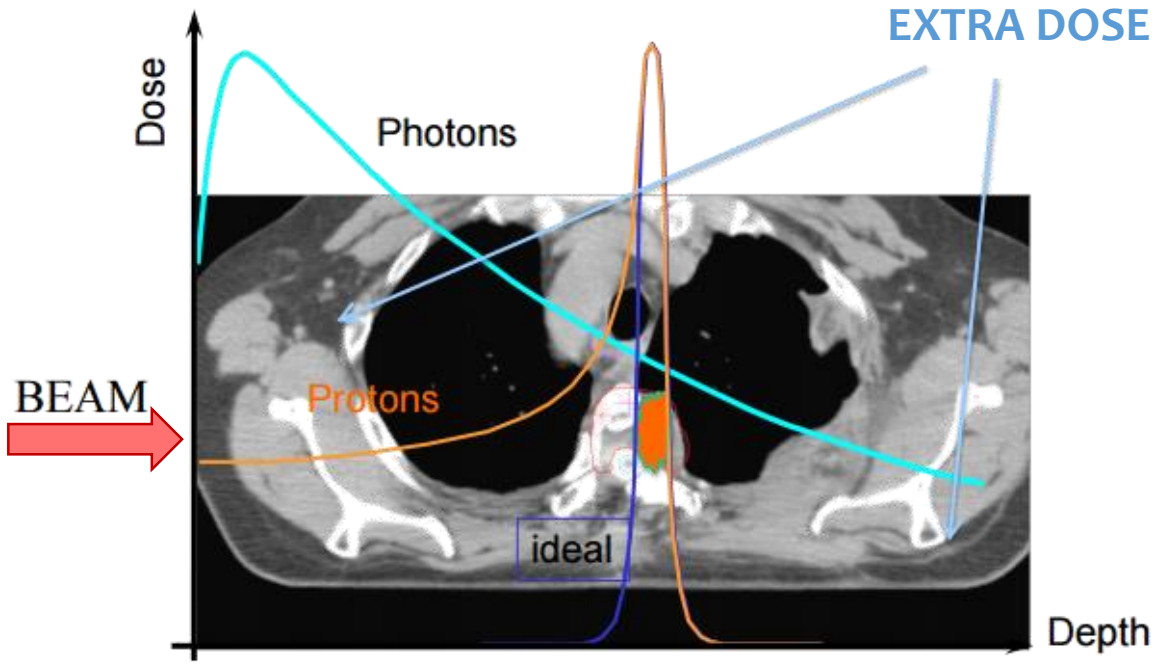
PhD Scool in Physics, Astrophisics and Applied Physics

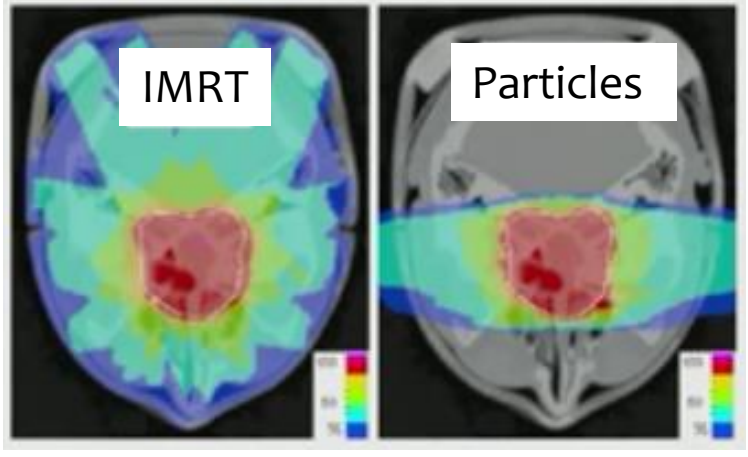
21/10/2016

Serena Marta Valle

Supervisor: G. Battistoni

Why particle therapy?





Better **tumor local control** because of:

Physical selectivity
- higher conformity of dose to the target volume
- smaller lateral scattering

→ better sparing of normal tissues

Biological selectivity
- greater biological effectiveness in radioresistant tumors

But:

More complex and expensive instrumentation is needed

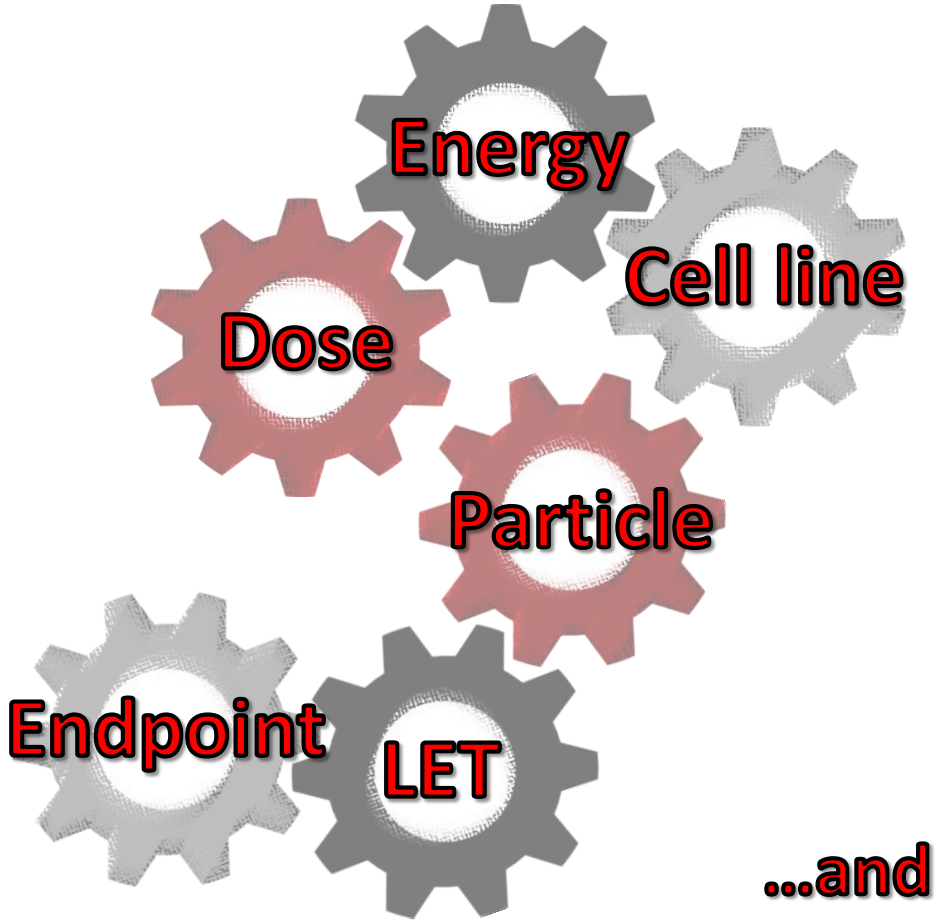
Sensitive to target motion

Relative biological effectiveness

Relative biological effectiveness (RBE)

$$RBE = \frac{D_X}{D_{ion}}$$

$$D_{bio} = RBE * D_{phys}$$



…and other factors…

Relative biological effectiveness

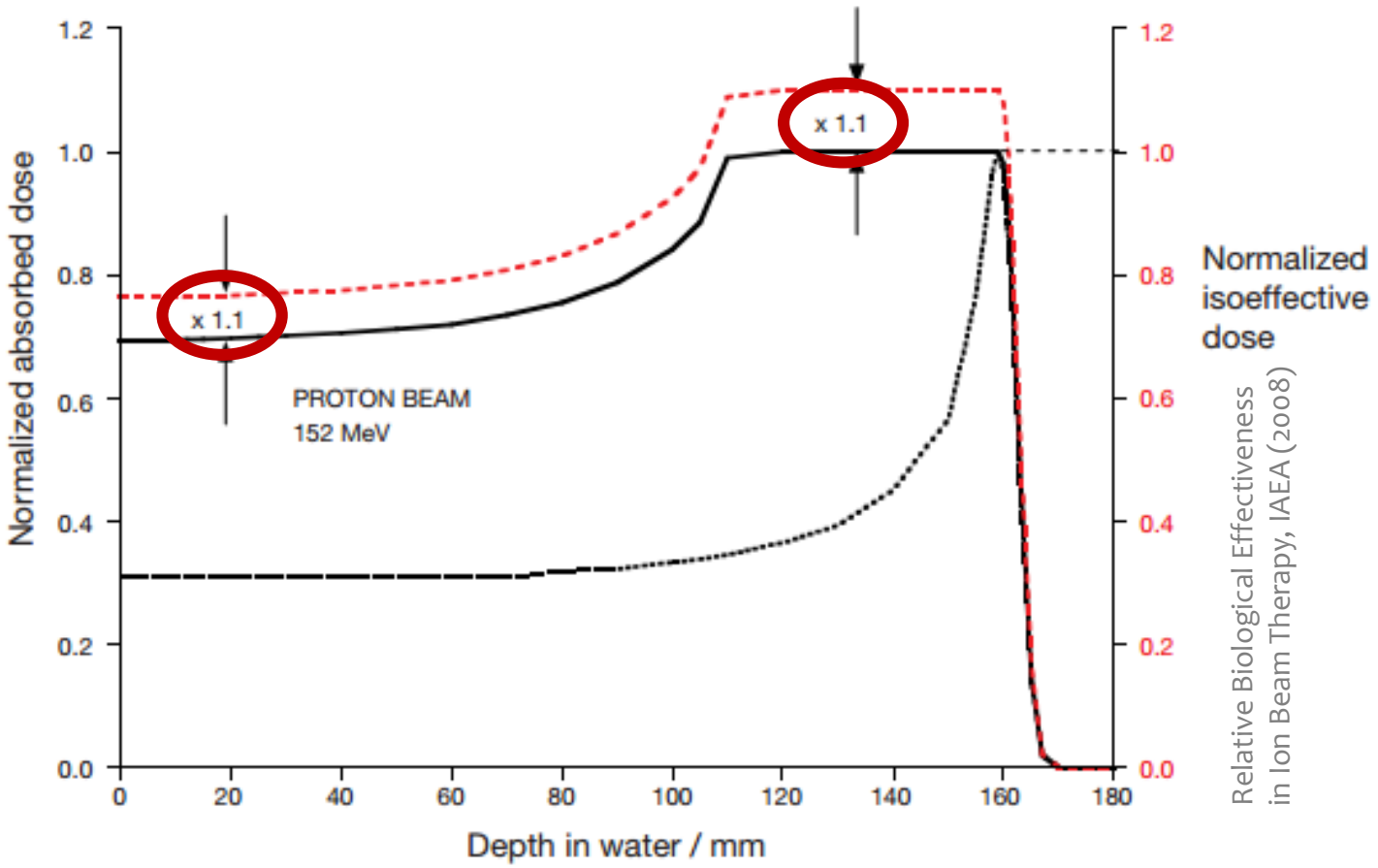
Relative biological effectiveness (RBE)

$$RBE = \frac{D_X}{D_{ion}}$$

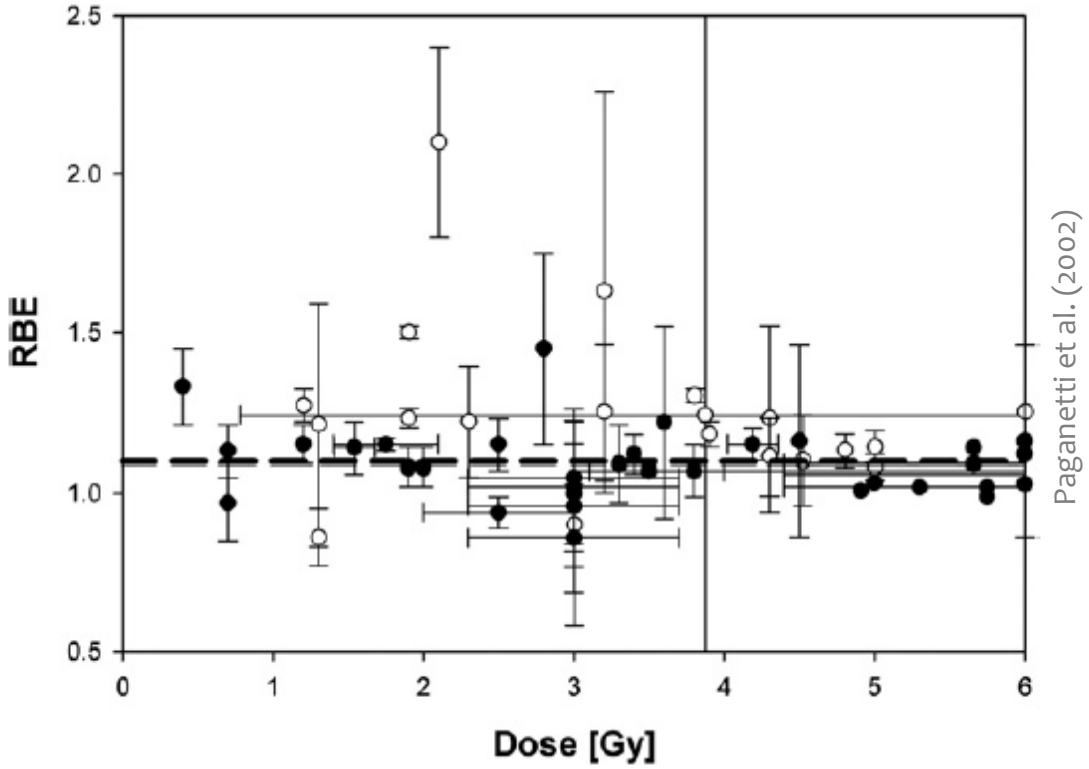
$$D_{bio} = RBE * D_{phys}$$

In clinical practice :

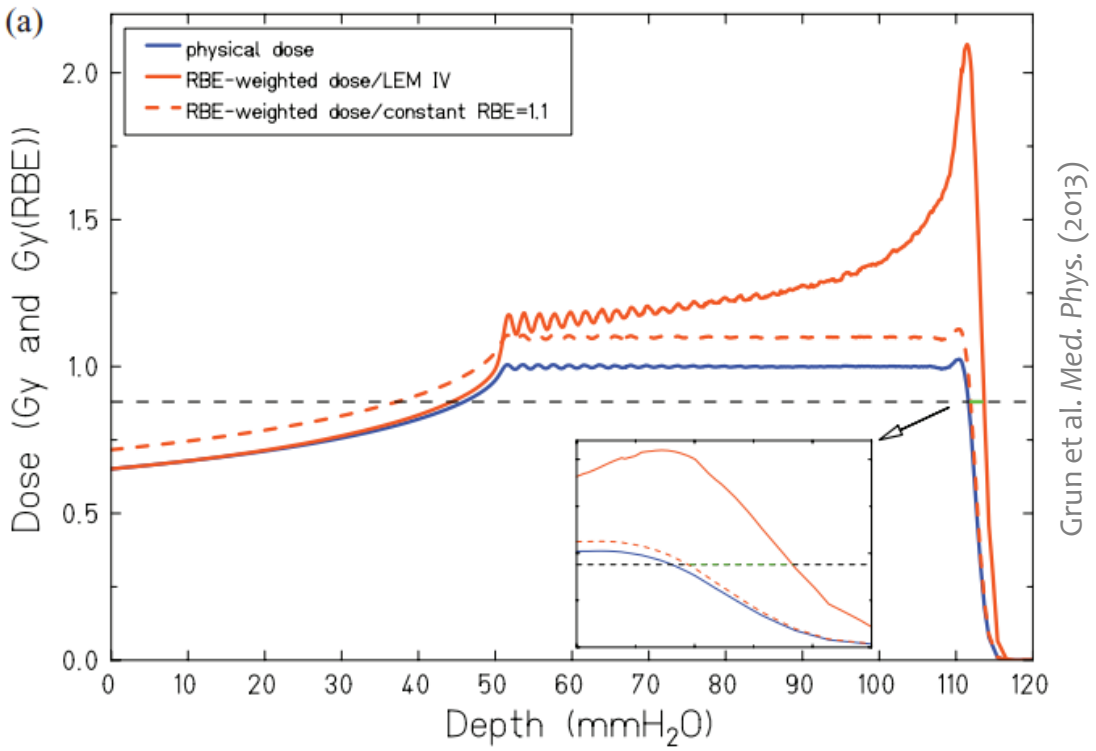
proton RBE =1.1



Proton effectiveness



Paganetti et al. (2002)



Grun et al. *Med. Phys.* (2013)

Experimental findings:

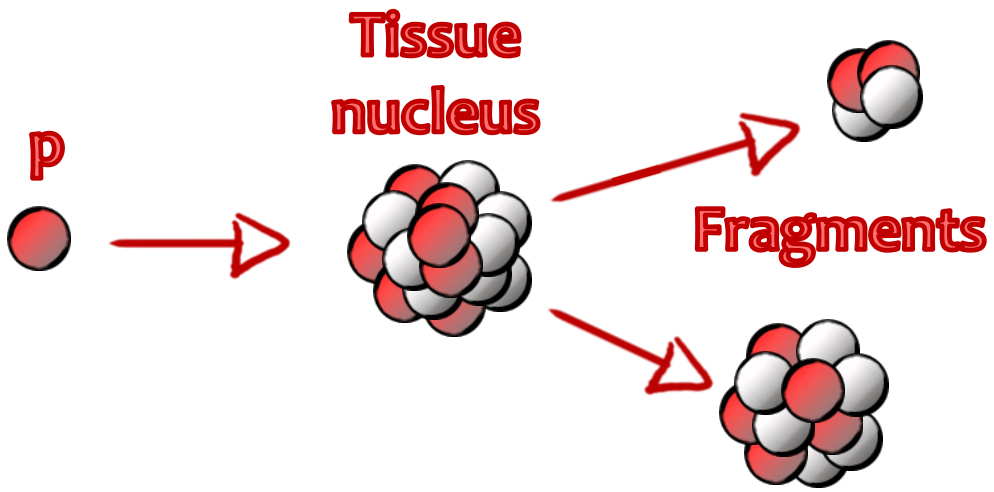
proton RBE not constant

Different RBEs

↓

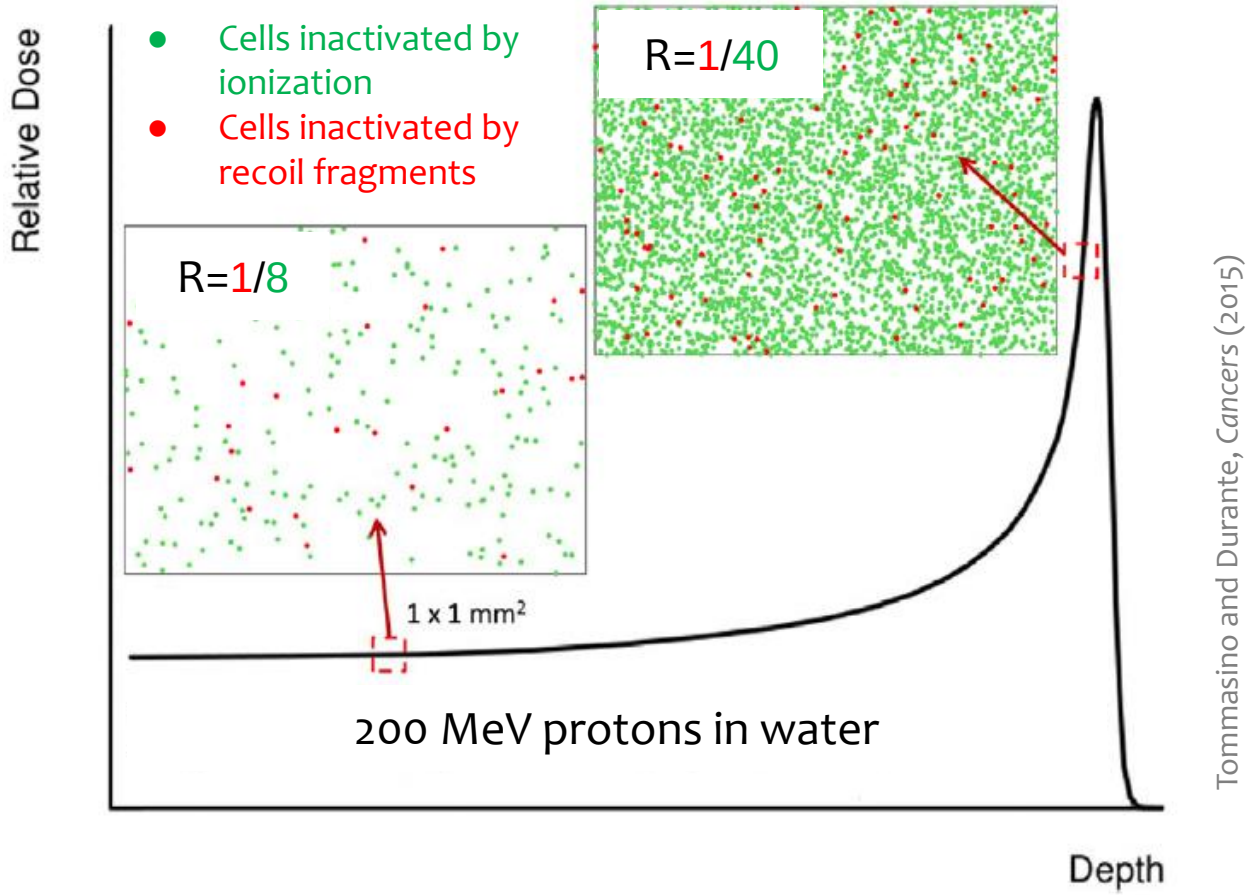
Different biological doses delivered to the patient

Nuclear interactions



Particles produced in target fragmentation have **lower energy** and **higher Z** than protons

Higher RBE



Target fragmentation

200 MeV/u p on Oxygen

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

No experimental data

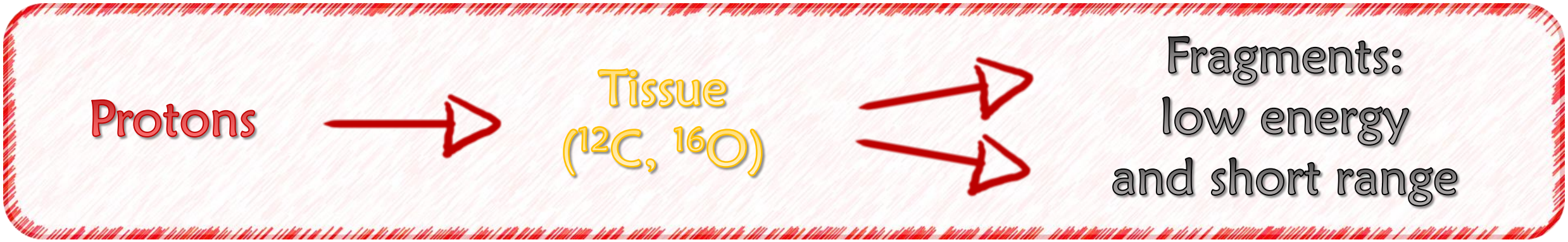
Energies calculated with an approximated analytic method

Tommasino and Durante, *Cancers* (2015)

Cross sections needed:
p → most common nuclei in tissues
(as ^{12}C and ^{16}O)

The FOOT project aims to measure these fragmentation cross sections

Inverse kinematics strategy



Inverse kinematics strategy

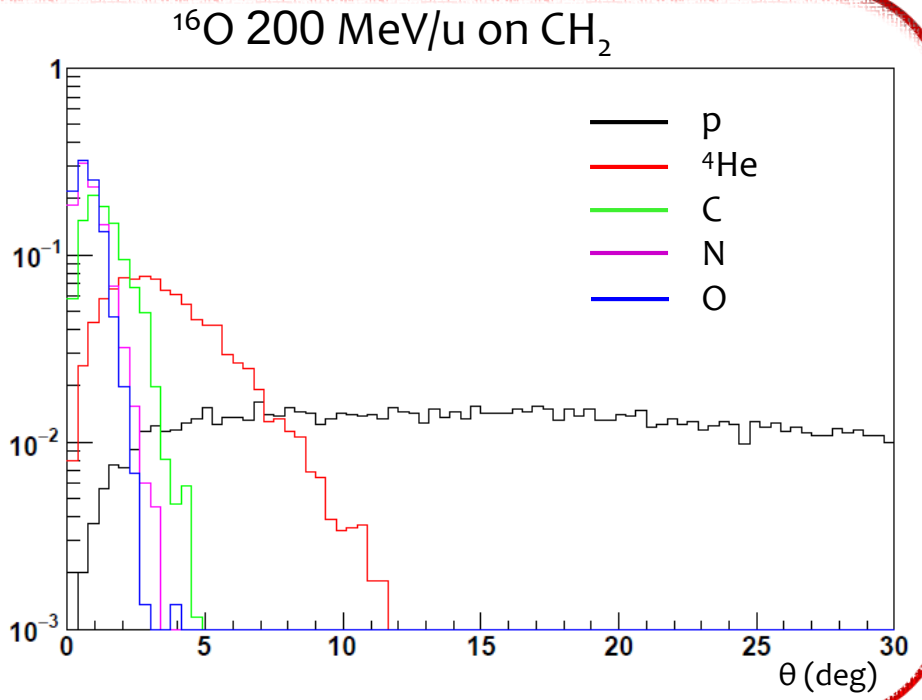
Inverse kinematics strategy

Tissue (^{12}C, ^{16}O) → Protons → Fragments: HIGHER energy and LONGER range

Energies of interest:
^{12}C and ^{16}O @100-250 MeV/u
→ β~0.6

By applying the Lorentz transformation we can switch from the *laboratory frame* to the «*patient frame*»

The fragments (Z>2) are forward peaked: maximum emission angle <10°

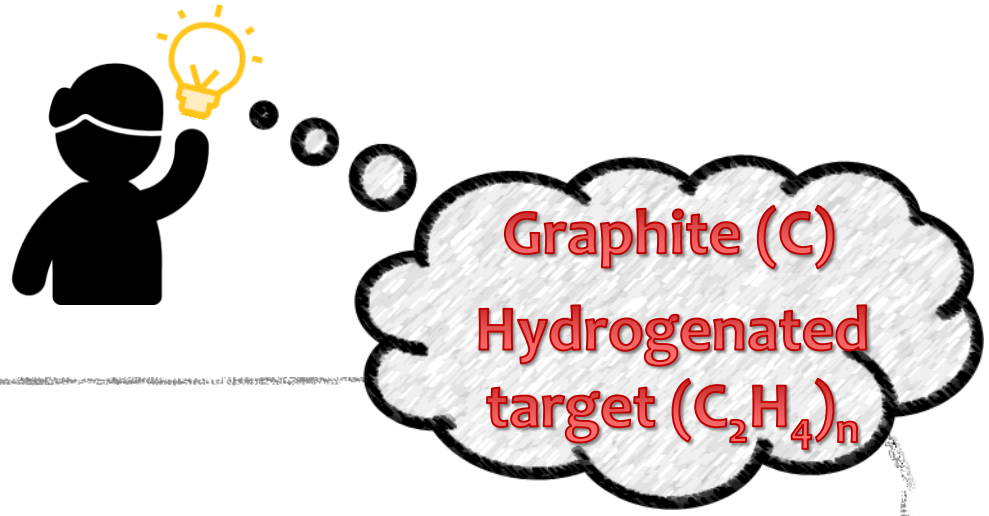


Target choice

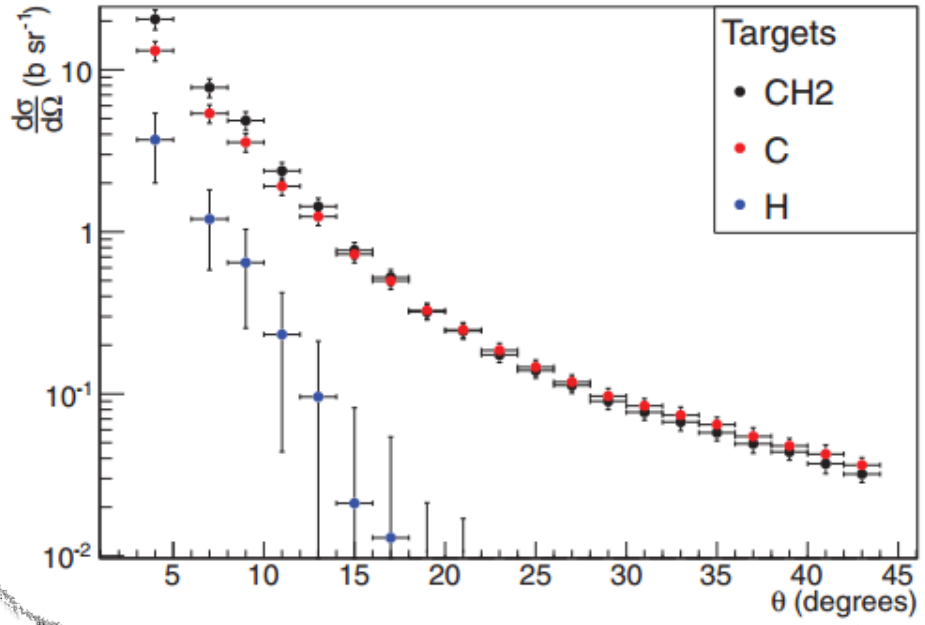
Tissue (^{12}C, ^{16}O) → Hydrogen

Target choice

Tissue (^{12}C, ^{16}O) → Hydrogen



C @95 MeV/u on C and C_2H_4 at GANIL



Dudouet et al., *Phys.Rev.C* (2013)

Fragmentation cross sections on H can be measured by subtracting the cross sections of C and $(C_2H_4)_n$

$$\frac{d\sigma}{d\Omega}(\mathrm{H}) = \frac{1}{2} \times \left(\frac{d\sigma}{d\Omega}(\mathrm{CH_2}) - \frac{d\sigma}{d\Omega}(\mathrm{C}) \right)$$

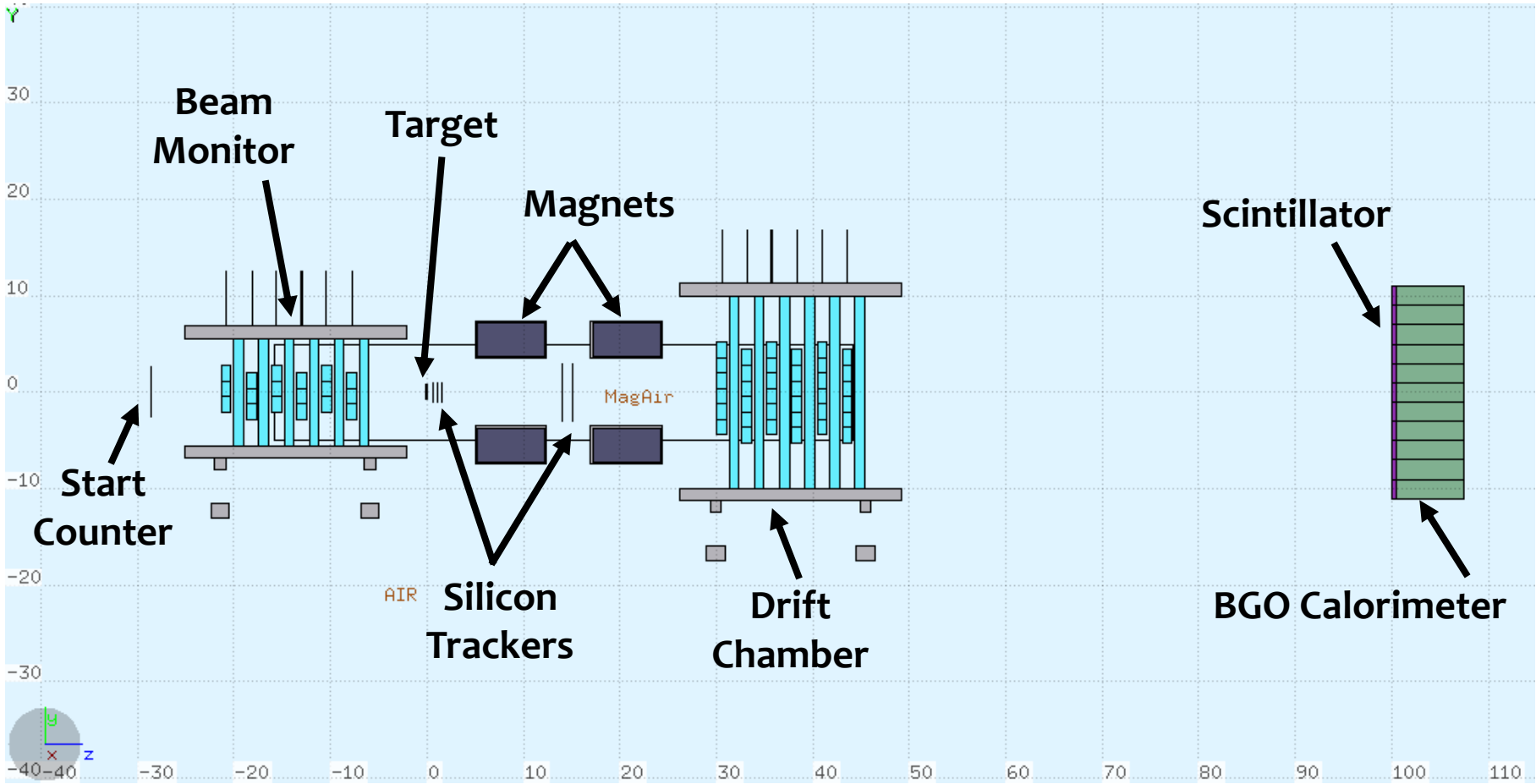
Experimental setup & measurements

Heavy fragments (Z>2) production cross sections (max. uncertainty 10%)

Fragments energy spectrum dσ/dE (resolution ~1-2 MeV/u)

Not needed accurate angular measurement (dσ/dΩ)

- Momentum
- Time of flight
- Energy
- dE/dx



Conclusions

In treatment planning, assuming a constant proton RBE can lead to the deliver of an incorrect dose distribution across the tumor volume and in the surrounding healthy tissues.

The FOOT project aims to provide fragments production cross sections for proton beams, in order to improve protons radiobiological models. Since Carbon and Oxygen beams are currently used in clinical practice, also nuclear cross sections in **direct kinematics** will be studied to better understand the projectile fragmentation. The data taken is forseen in 2018/2019.

In my first year as a PhD student, I worked on the setup FLUKA simulation and optimization of the detectors layout. In the next future, I will help the FOOT collaboration in developing a software framework which will be able to handle both simulated and experimental data.


Thank you!