Radiation BioPhysics

at TIFPA

Trento Institute for
Fundamental Physics
and Applications

Elettra V. Bellinzona & RBP Group
elettra.bellinzona@tifpa.infn.it

FONDAZIONE CARITRO
CASSA DI RISPARMIO DI TRENTO E ROVERETO

UNIVERSITÀ DI TRENTO

TIFPA
Trento Institute for
Fundamental Physics
and Applications

Azienda Provinciale per i Servizi Sanitari
Provincia Autonoma di Trento

Biophysics is an interdisciplinary science that applies approaches and methods traditionally used in physics to study biological phenomena.

Medical physics, a branch of biophysics, is any application of physics to medicine or healthcare.

History

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- 1780 - Luigi **Galvani**

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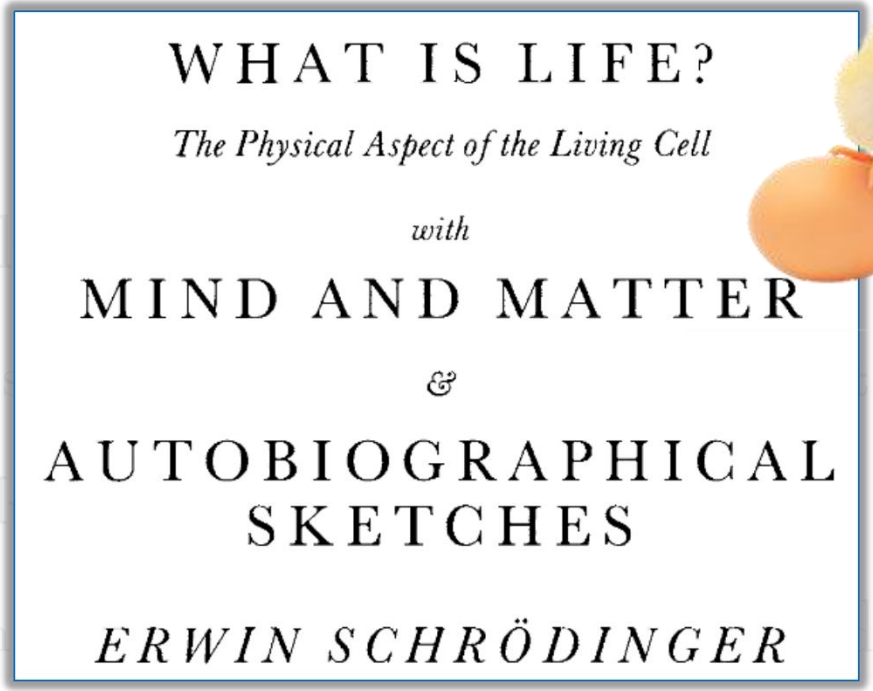

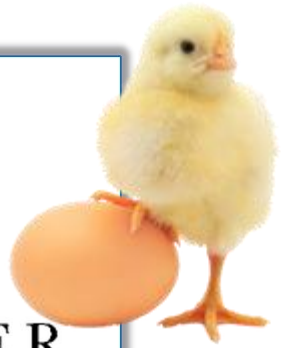

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- 1957 - first Biophysical Society

Radiation Bio Physics

Among the several field of this discipline, we will focus on radiation bio-physics.

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Study of the effects of radiation on cells, tissues, bio-molecules, and living organisms.

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So that some concept about radiation interaction with biological matter will follow

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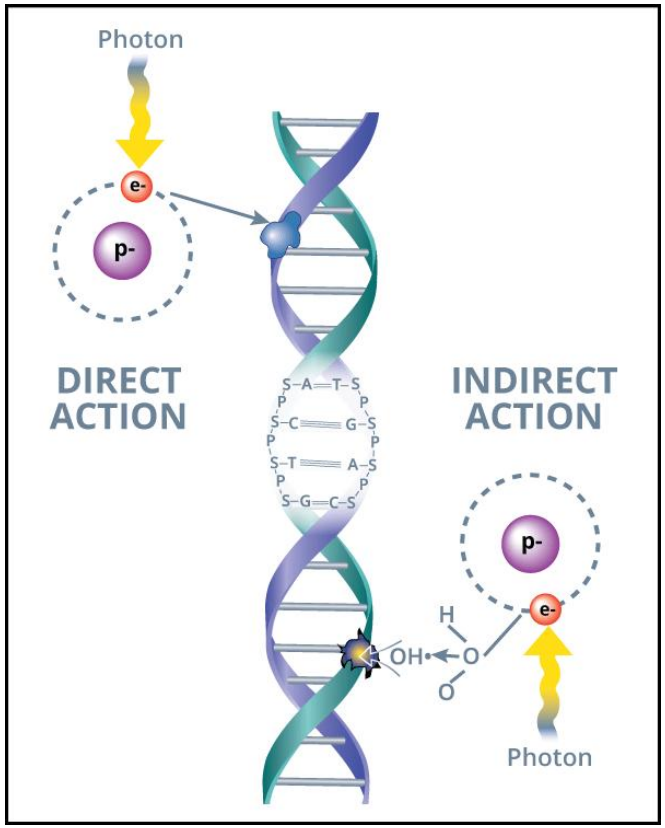
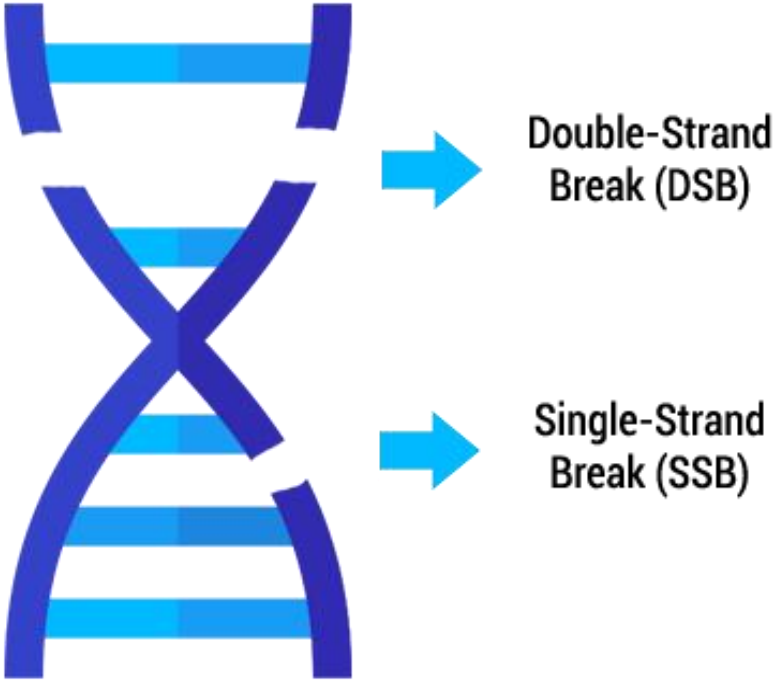
Ionizing only!

Radiation interaction with biological matter



Radiation interaction with biological matter

II



Radiation interaction: quantities

III

Radiation interaction: quantities

III

Linear Energy Transfer (LET)
Energy locally imparted to the medium over the length interval dl.

$$LET = \frac{dE}{dl}[KeV/\mu m]$$

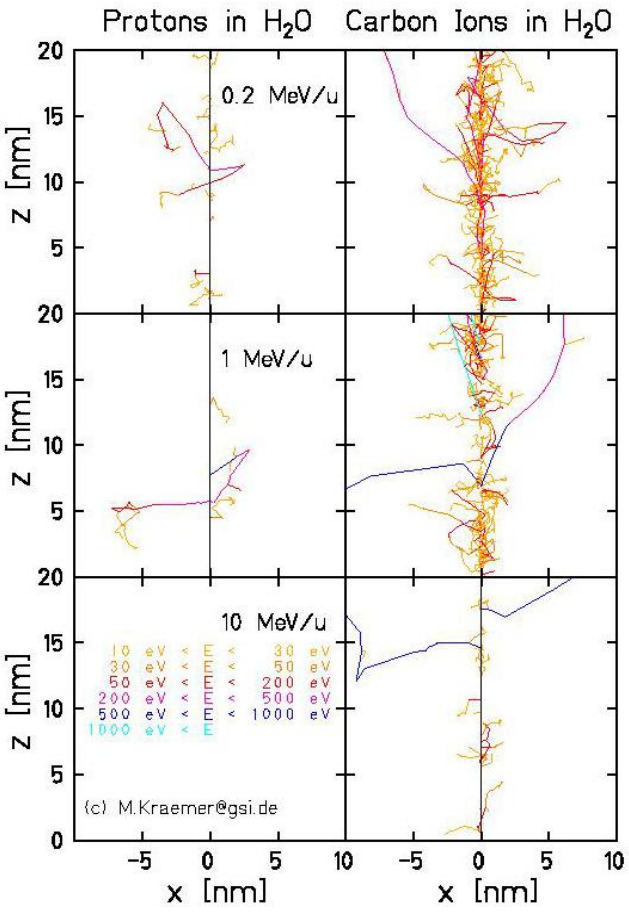
Dose:
Energy deposited per unit of mass

$$Dose = \frac{dE}{dm}[Gy]$$

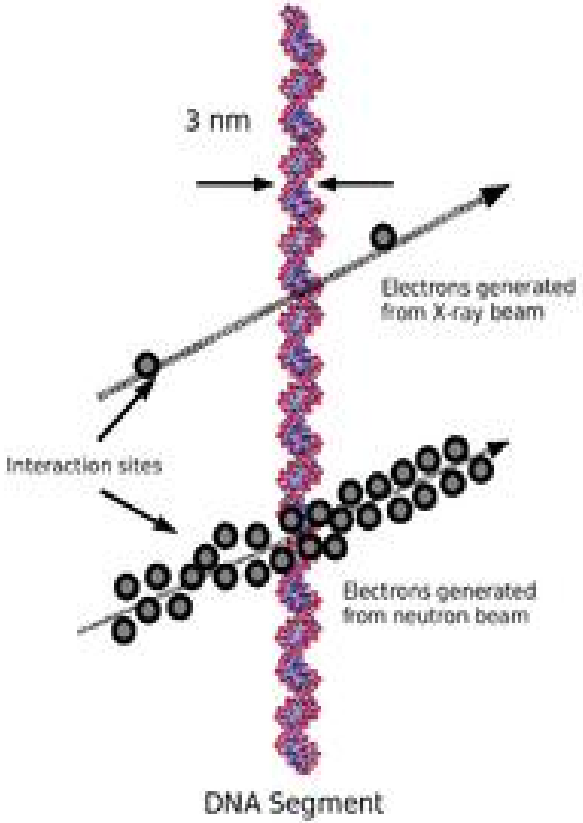
Relative biological effectiveness (RBE):
ratio of the dose required by two radiations to cause the same level of effect.

$$RBE = \frac{D_\gamma}{D_{rad}}|_{isoeffect}$$

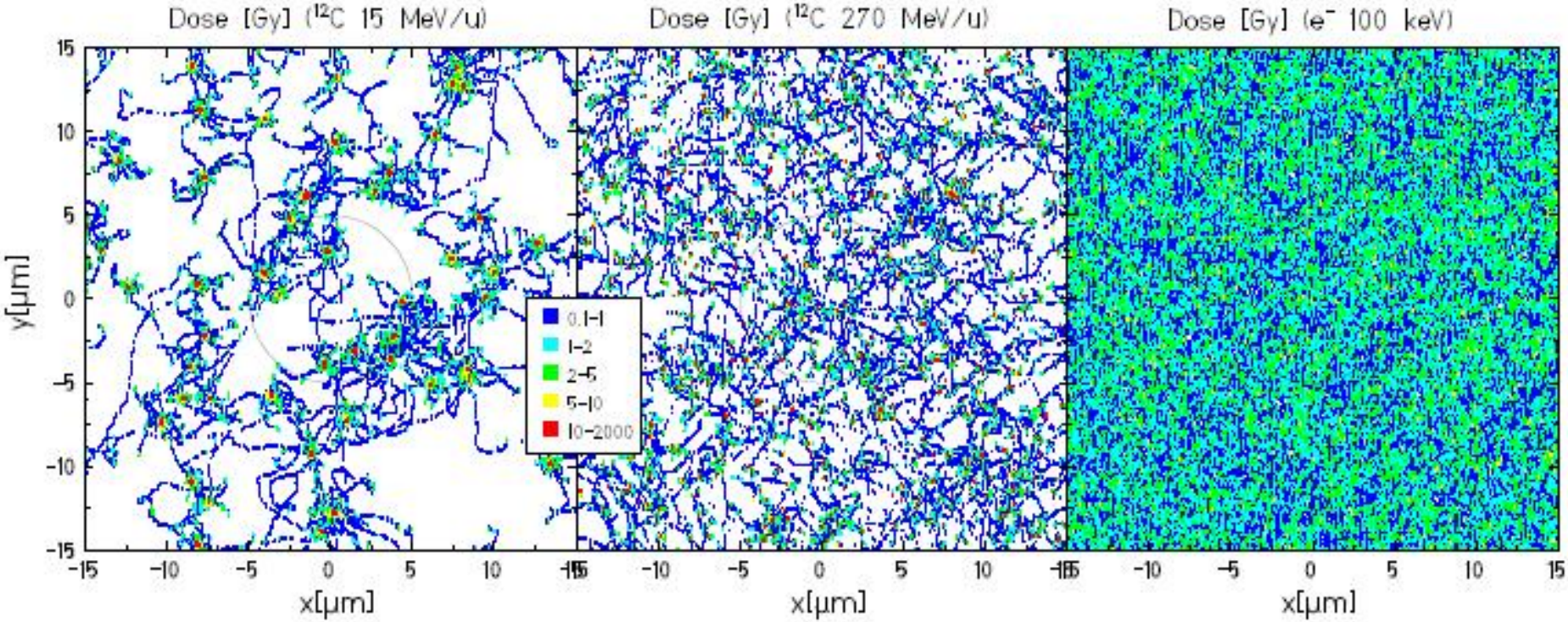
LET


Protons in H_2O
Carbon Ions in H_2O
0.2 MeV/u
1 MeV/u
10 MeV/u
z [nm]
x [nm]
10 eV < E < 30 eV
30 eV < E < 50 eV
50 eV < E < 200 eV
200 eV < E < 500 eV
500 eV < E < 1000 eV
1000 eV < E
(c) M.Kraemer@gsi.de

TRAX (GSI)


3 nm
Electrons generated from X-ray beam
Interaction sites
Electrons generated from neutron beam
DNA Segment

Dose


Dose [Gy] (12C 15 MeV/u)
Dose [Gy] (12C 270 MeV/u)
Dose [Gy] (e- 100 keV)
0.1-1
1-2
2-5
5-10
10-2000
y[μm]
x[μm]
x[μm]
x[μm]

RBE

Relative biological effectiveness depends on:

- radiation quality
- radiation energy
- tissue

RBE

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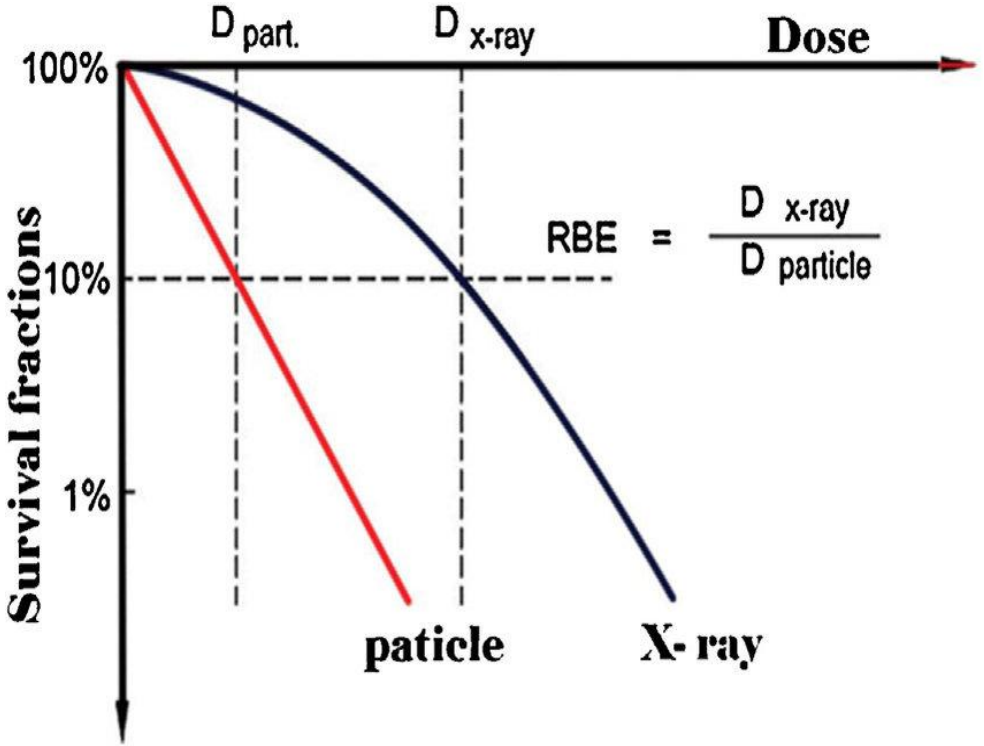
- radiation energy
- tissue

Several models available to predict survival, the most diffused is the **Liner Quadratic model**

$$-\ln S = \alpha D + \beta D^2$$



RBE

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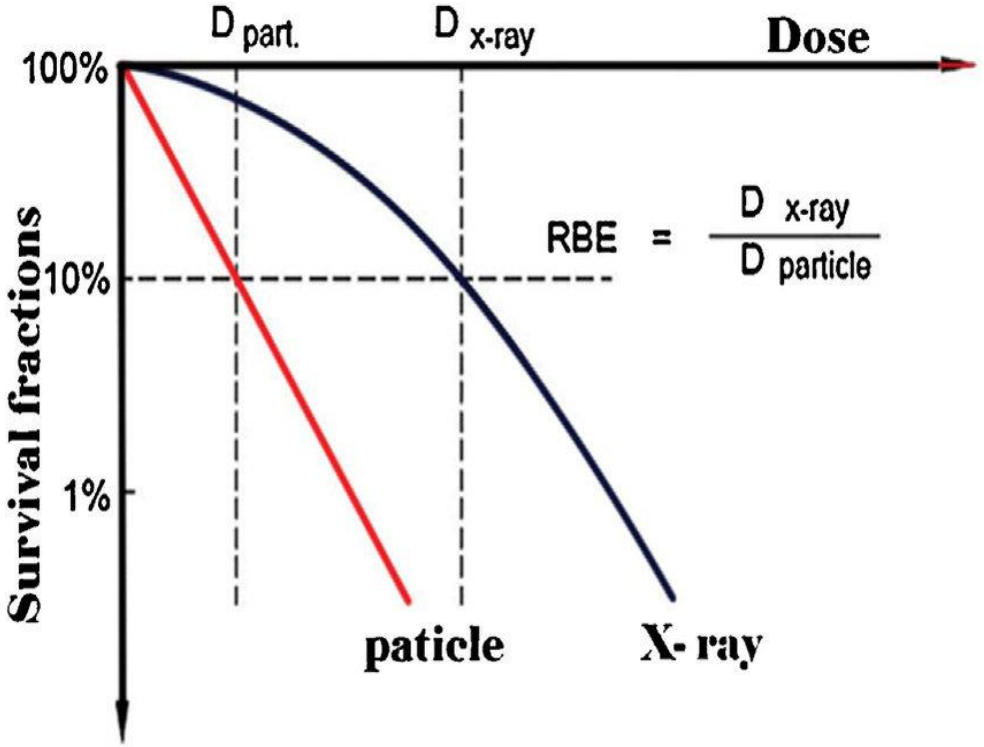

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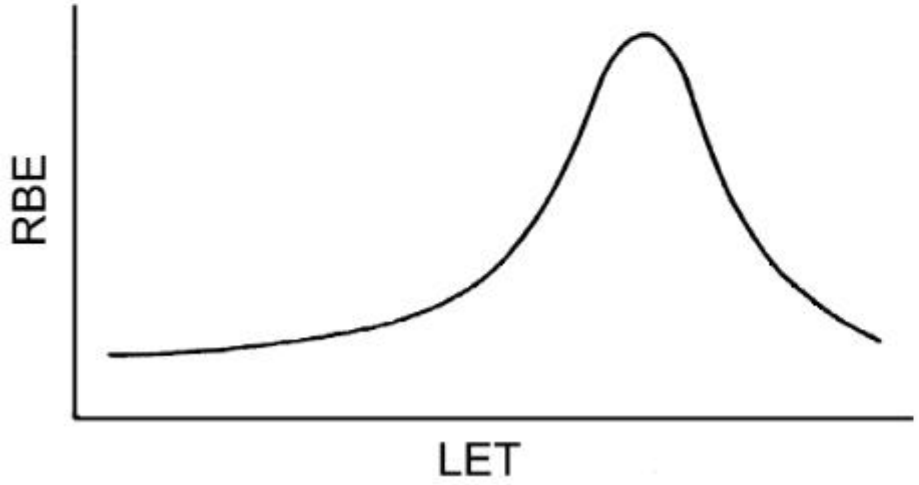
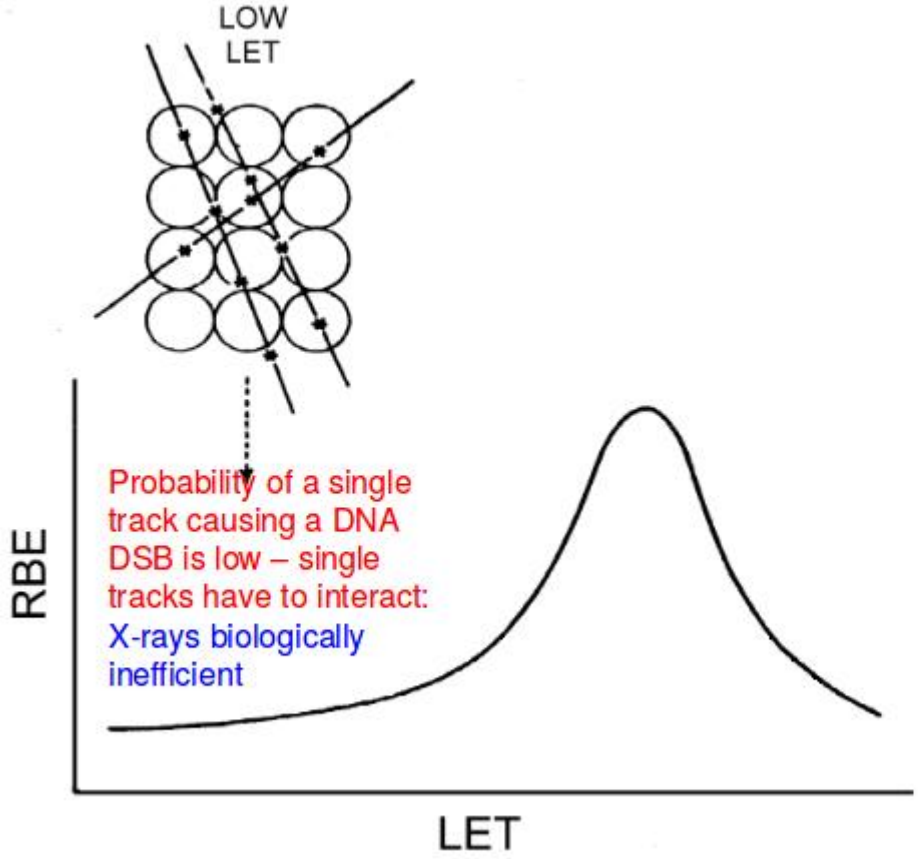
Hot topic

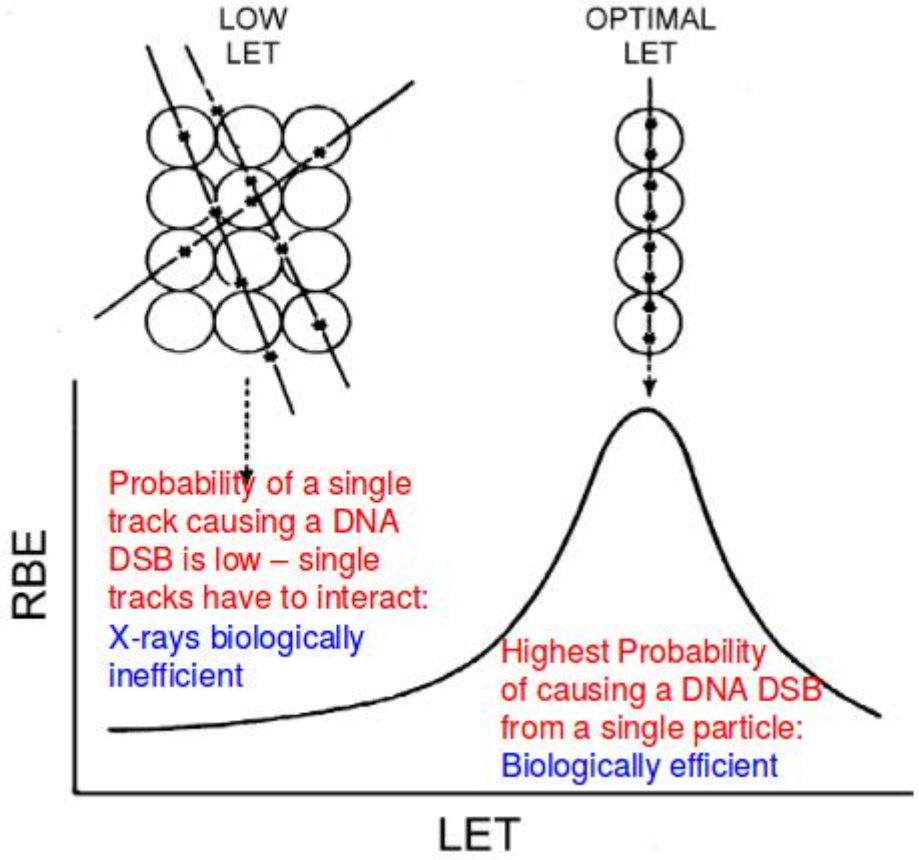
LET vs RBE



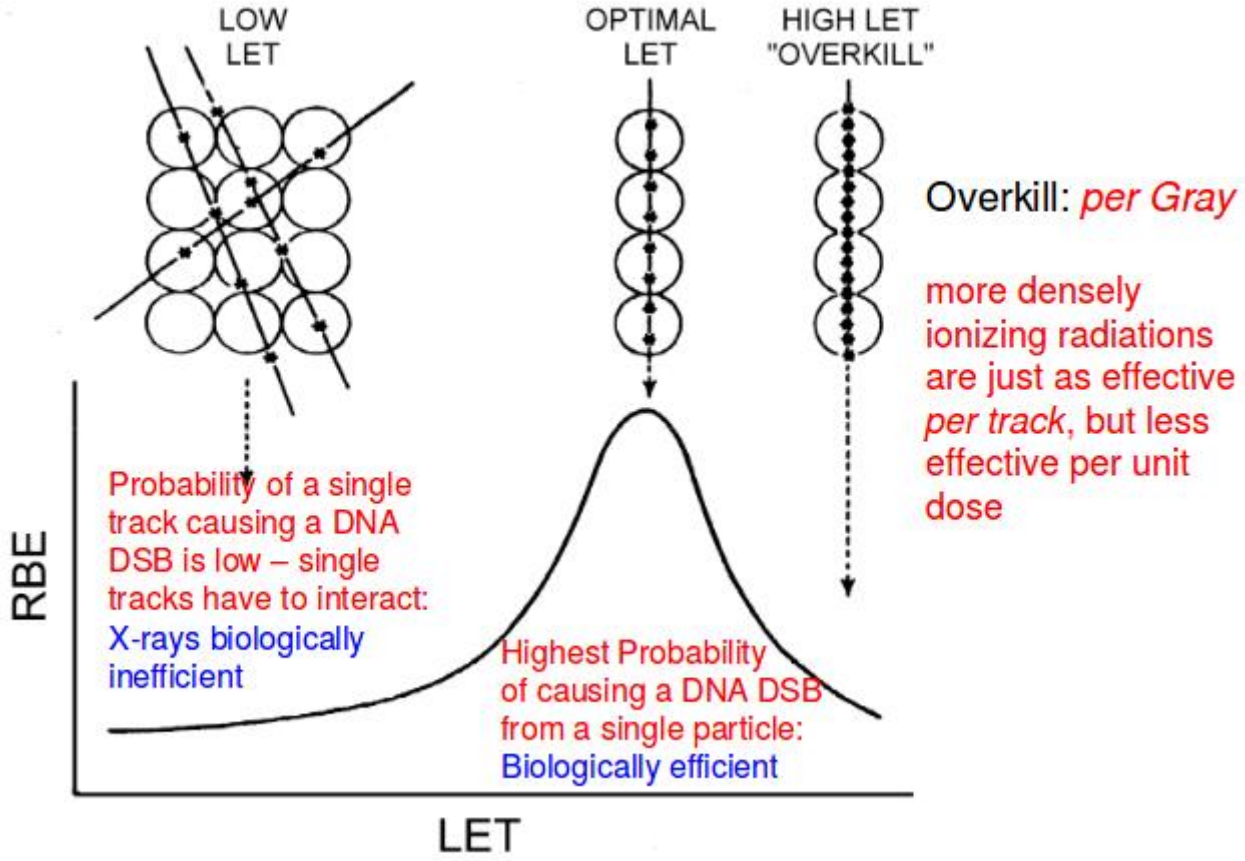
LET vs RBE


LOW
LET
Probability of a single track causing a DNA DSB is low – single tracks have to interact:
X-rays biologically inefficient
RBE
LET

LET vs RBE


LOW
LET
OPTIMAL
LET
Probability of a single track causing a DNA DSB is low – single tracks have to interact:
X-rays biologically inefficient
Highest Probability of causing a DNA DSB from a single particle:
Biologically efficient
RBE
LET

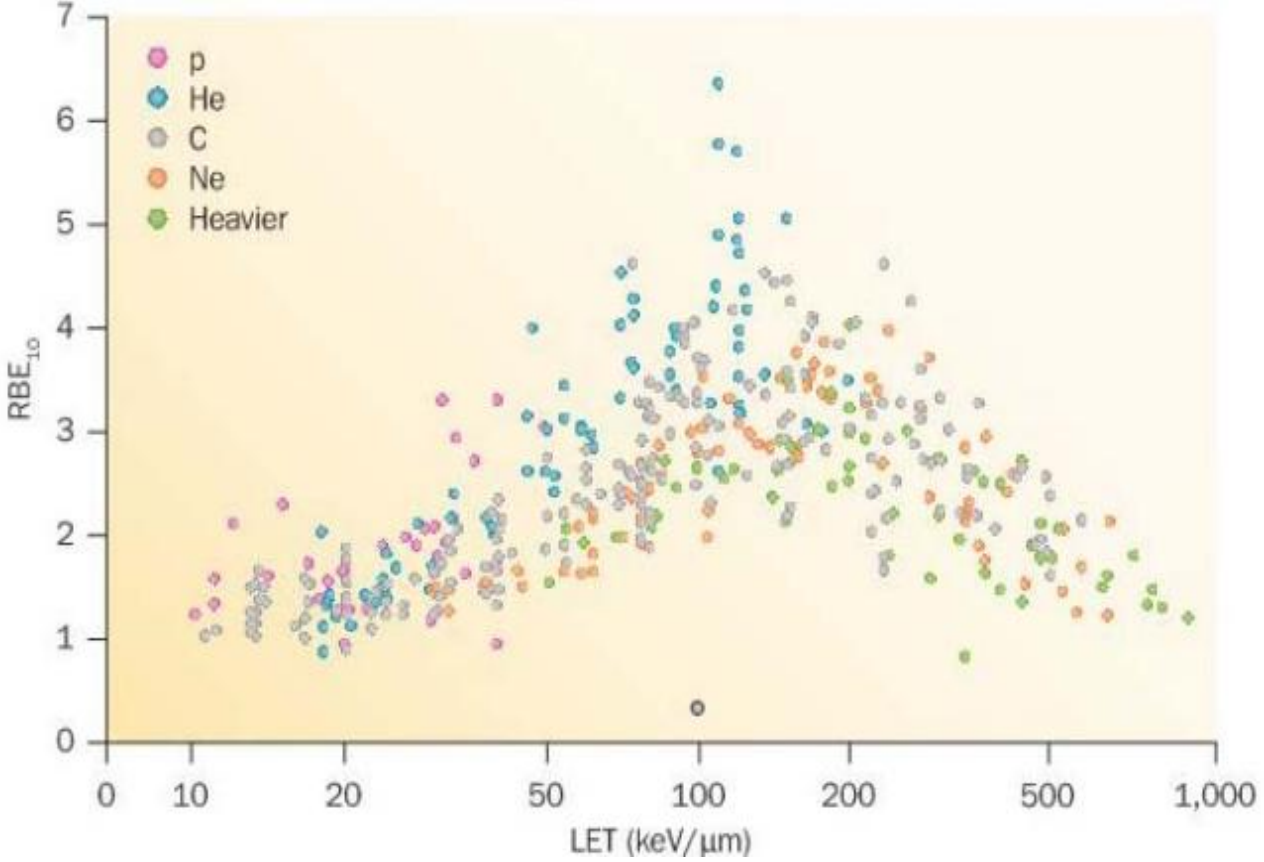
LET vs RBE



Overkill: *per Gray*

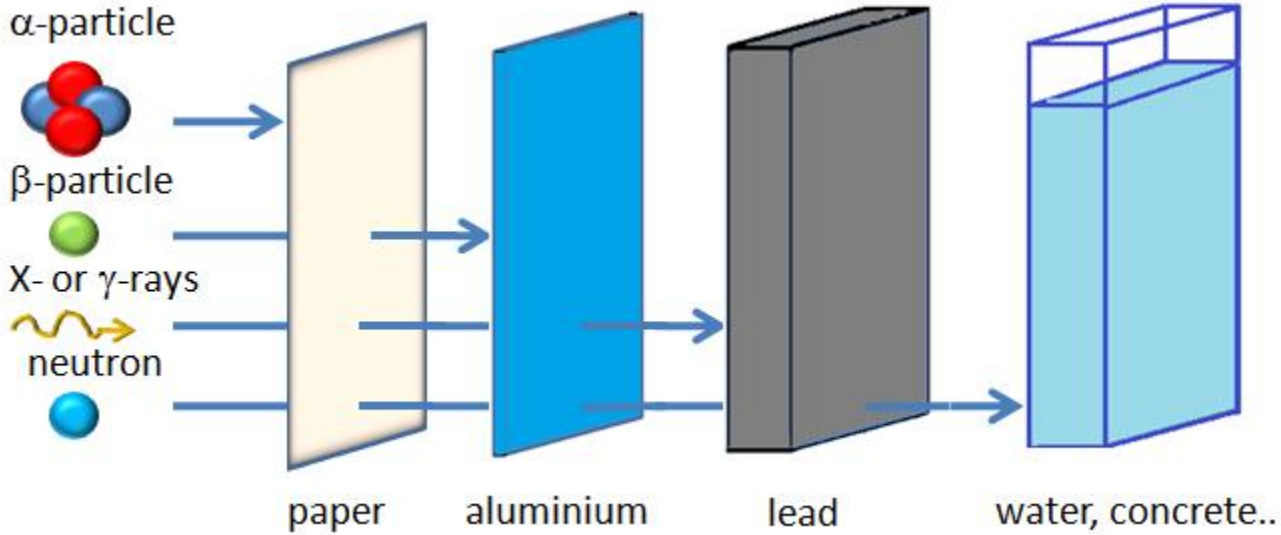
more densely ionizing radiations are just as effective *per track*, but less effective per unit dose

LET vs RBE


p
He
C
Ne
Heavier
RBE10
0
1
2
3
4
5
6
7
0
10
20
50
100
200
500
1,000
LET (keV/µm)

Radiation type

Radiation type



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BioPhysics

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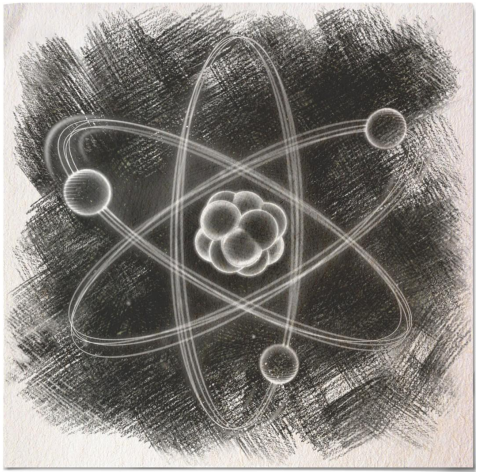
Proton
therapy



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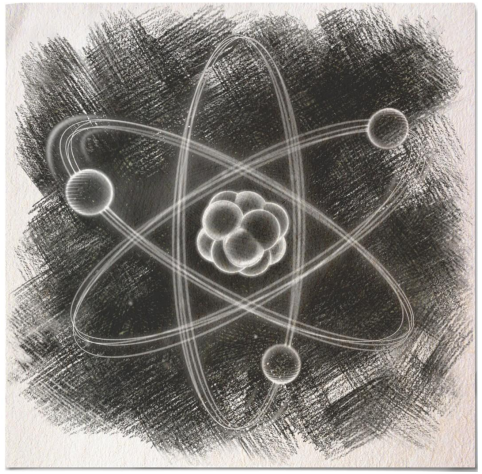
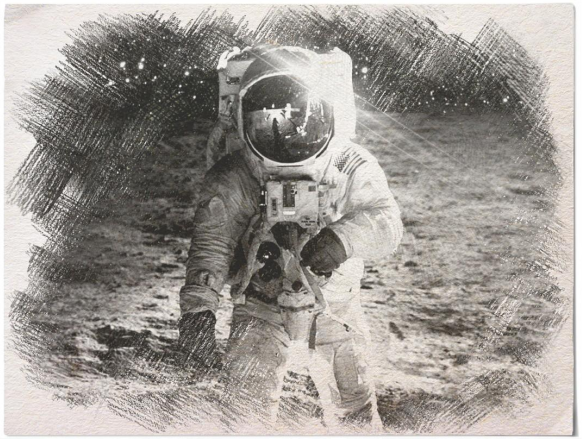
Radiation BioPhysics

Proton therapy





Space radiation

Iontherapy

Iontherapy

Cancer treatment by using charged particles.
Within electromagnetic and nuclear interactions , as they slow down energy deposited per depth unit (LET) increases until particle comes to halt, and there is sudden peak of energy (**Bragg peak**)

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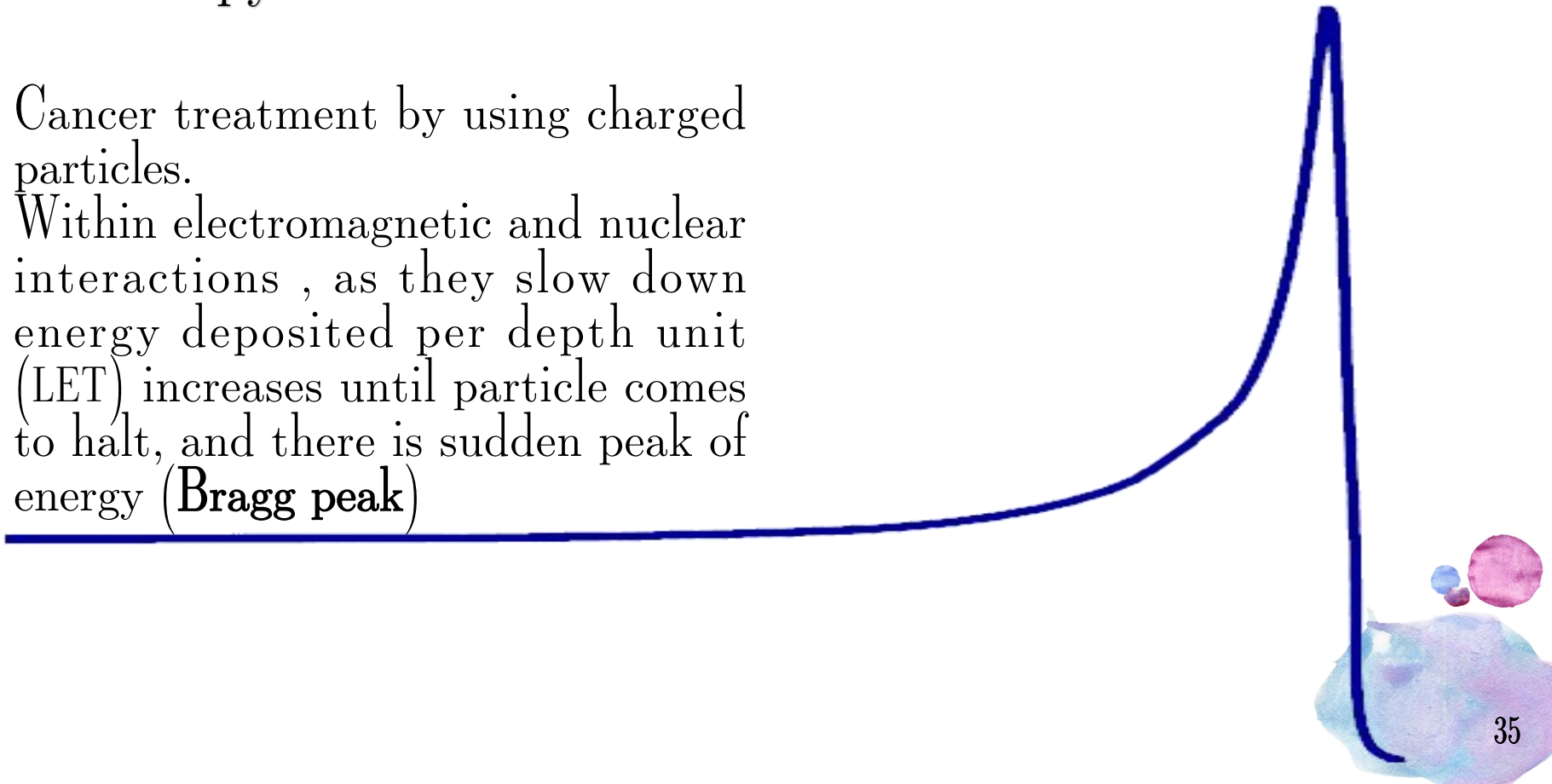
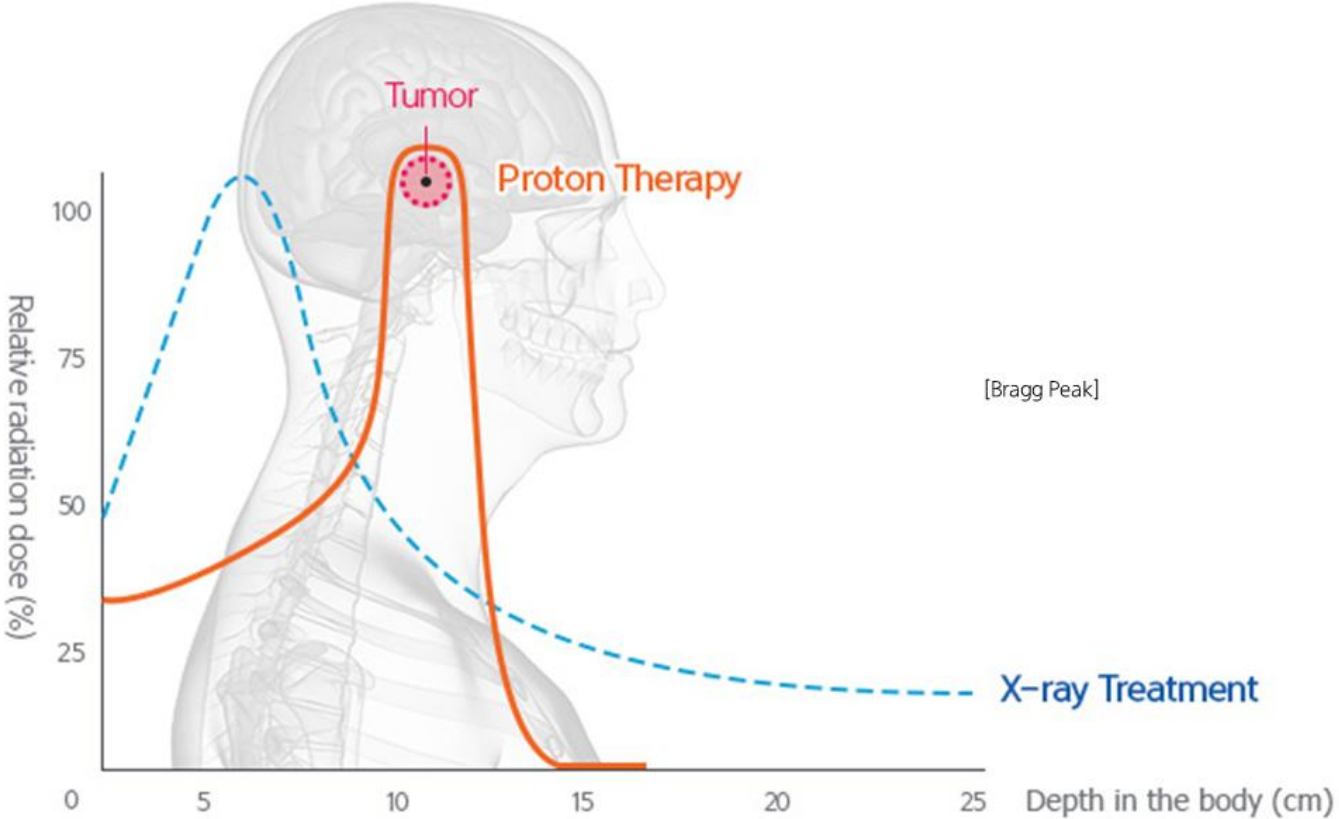
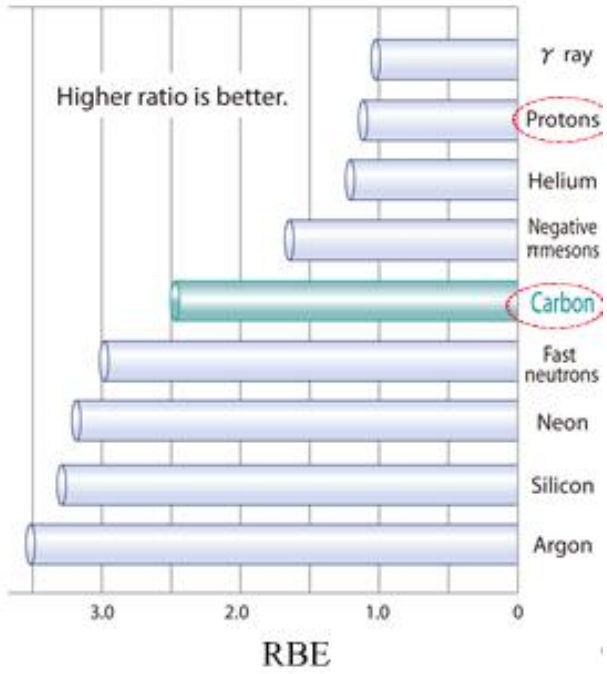
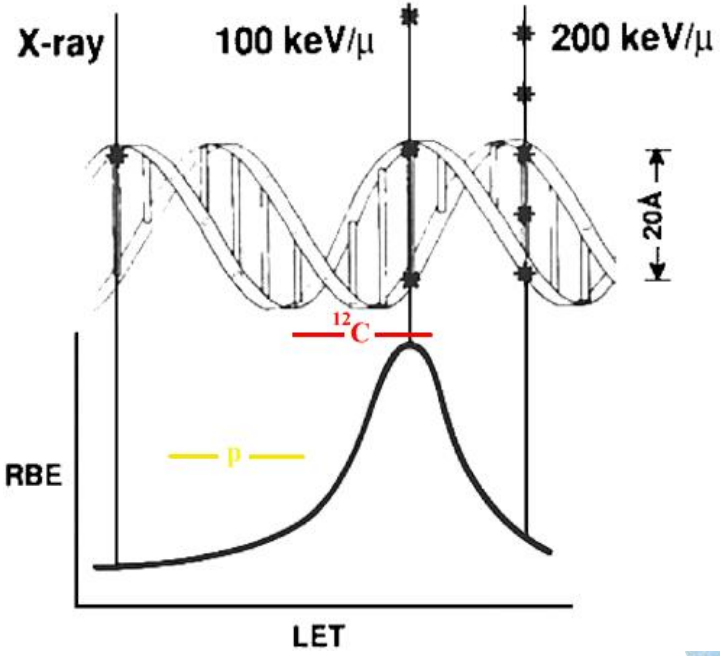


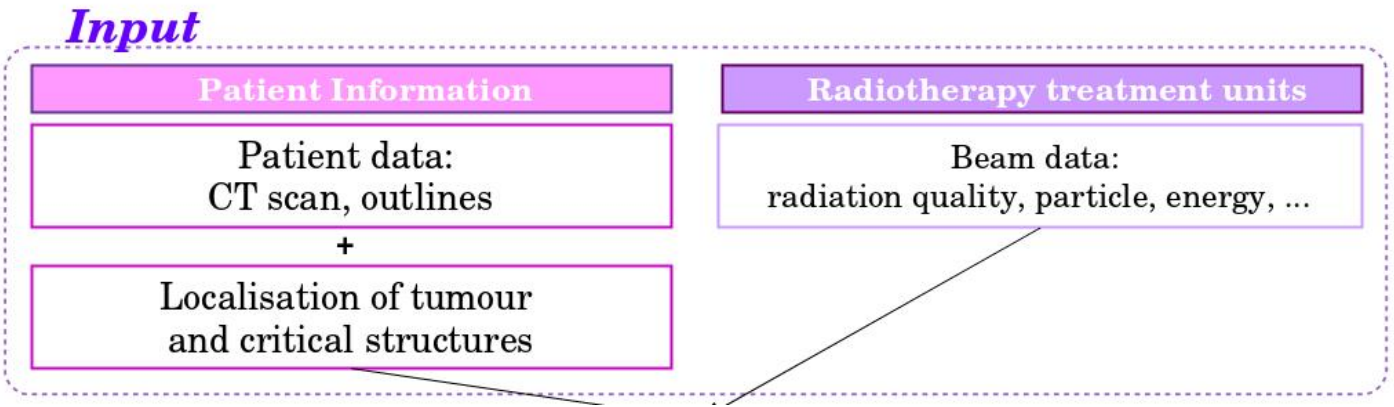
Iontherapy: physical advantages



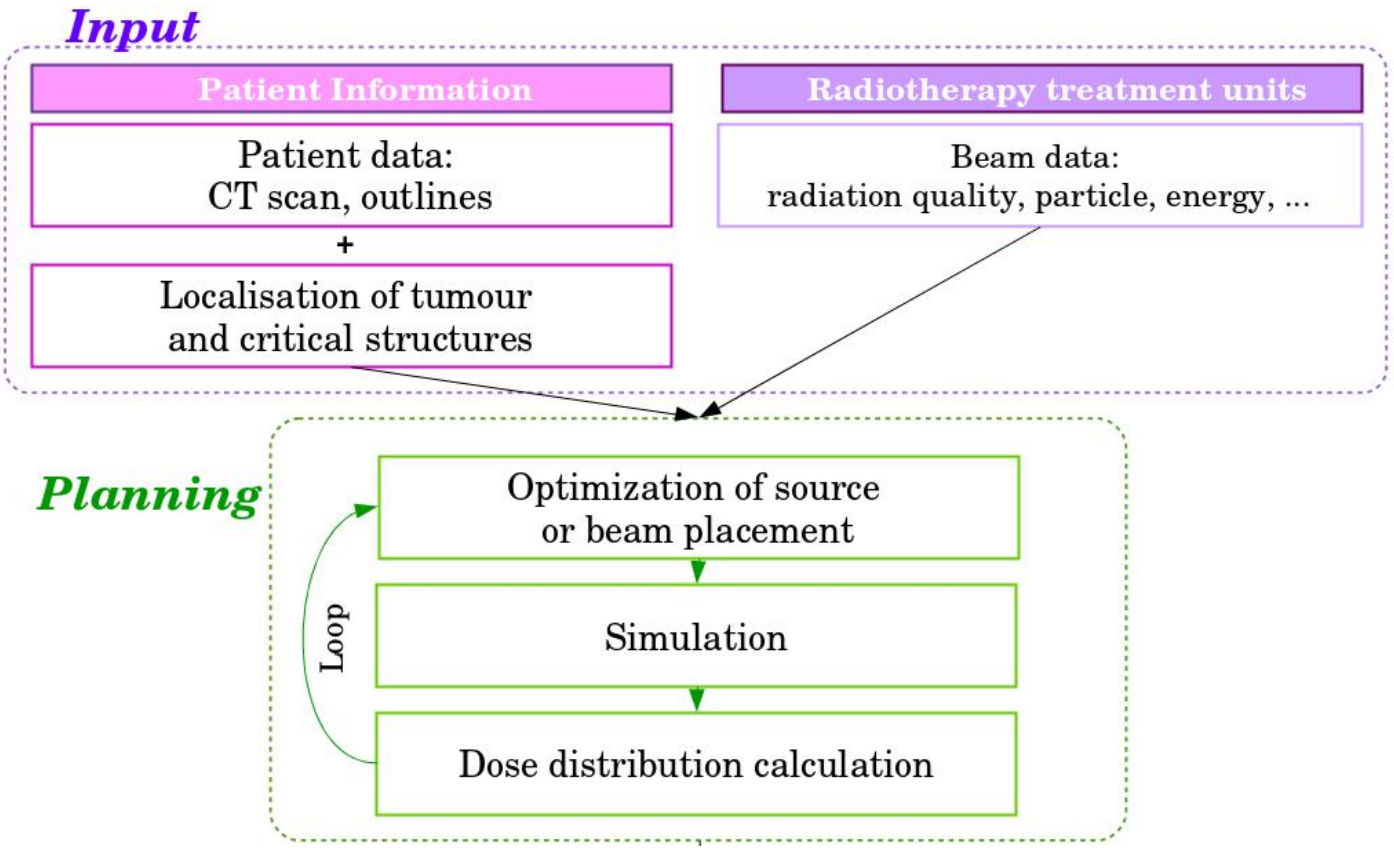
Iontherapy: biological advantages



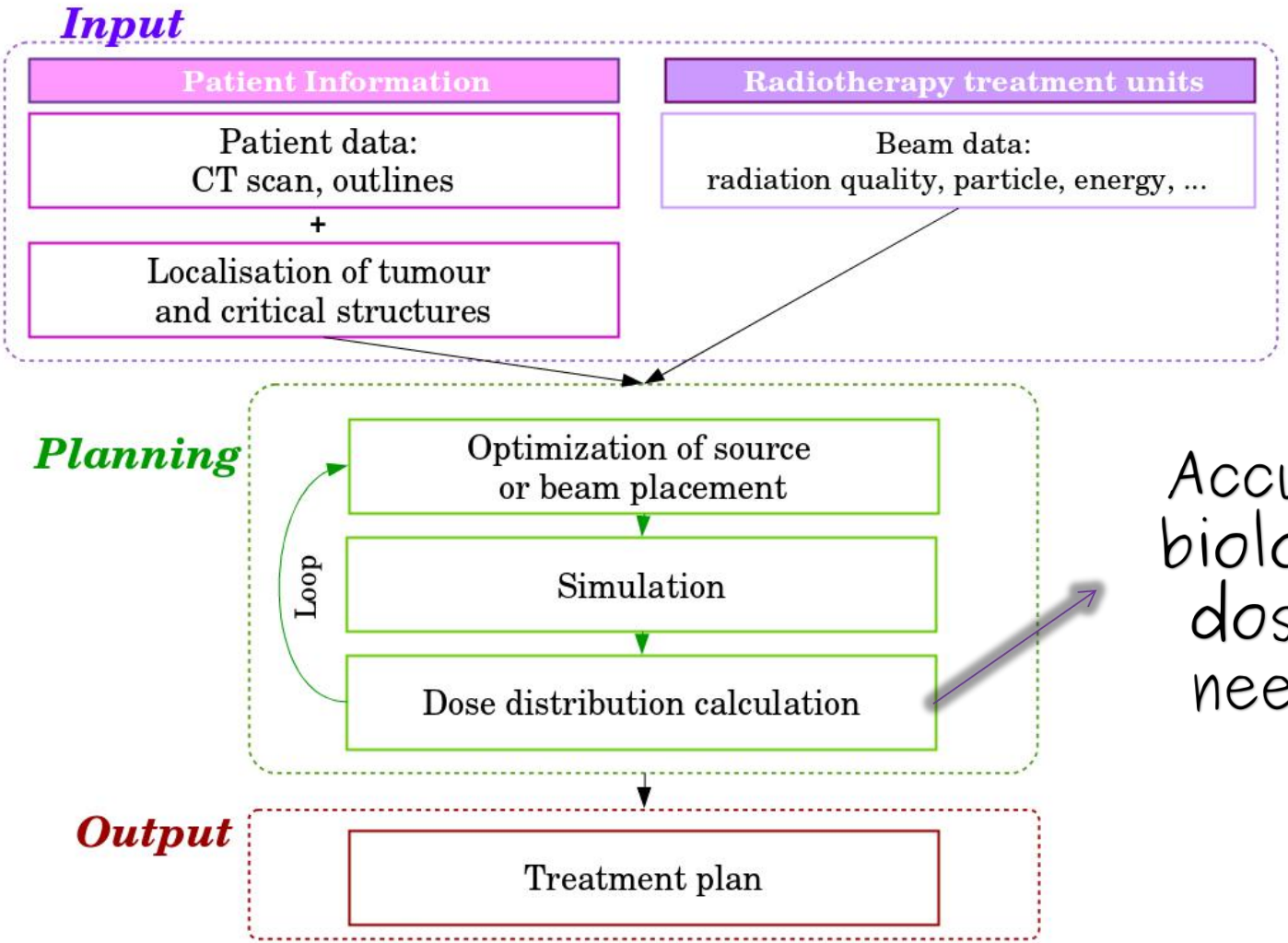



Input
Patient Information
Radiotherapy treatment units
Patient data:
CT scan, outlines
+
Localisation of tumour
and critical structures
Beam data:
radiation quality, particle, energy, ...

Iontherapy: TPS



Iontherapy: TPS



Accurate biological dose is needed

APSS & Experimental room

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Open to external users, PAC for proposal evaluation
http://www.tifpa.infn.it/sc-init/med-tech/p-beam-research/

Courtesy of F. Tommasino

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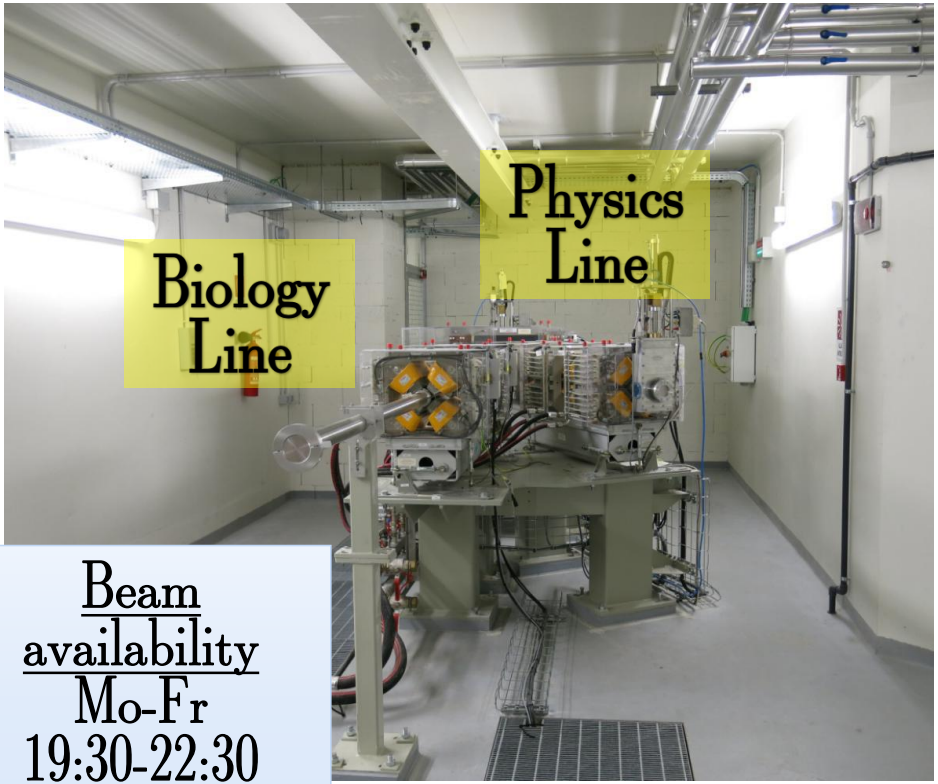


Beam Production:
- Isochronous Cyclotron IBA Proteus 235
- Energy Range: 70-225 MeV
- Beam Current: up to 320 nA
- Typical Efficiency: ≈55%

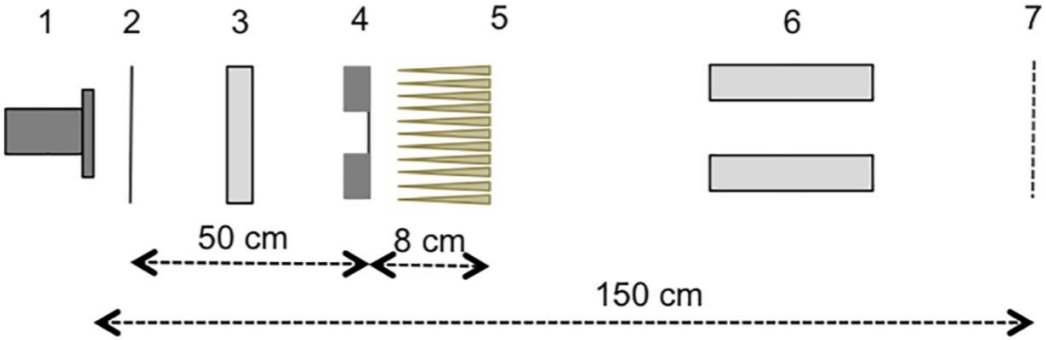
- 54 Proposals received since 2016
- Main activities: detector testing, radiation hardness, radiobiology

Beam availability
Mo-Fr
19:30-22:30
Sat 8:00-14:00

Courtesy of F. Tommasino

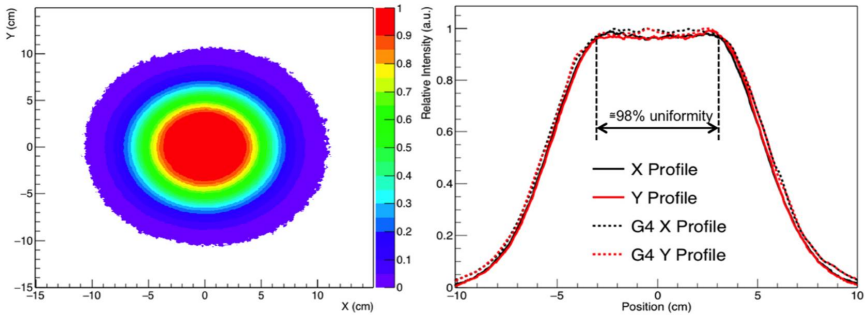
APSS & Experimental room: passive scattering line for Radiobiology

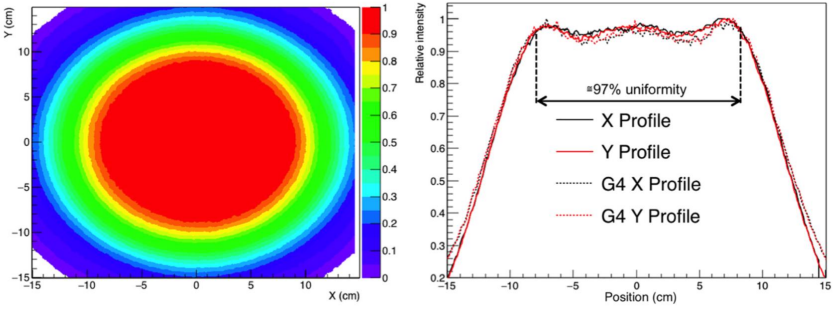
Dual-ring setup for beam shaping + Range modulator



1 Beam pipe	5 Range Modulator
2 First Foil	6 Collimation (optional)
3 Monitor Chamber	7 Target Position
4 Dual Ring	

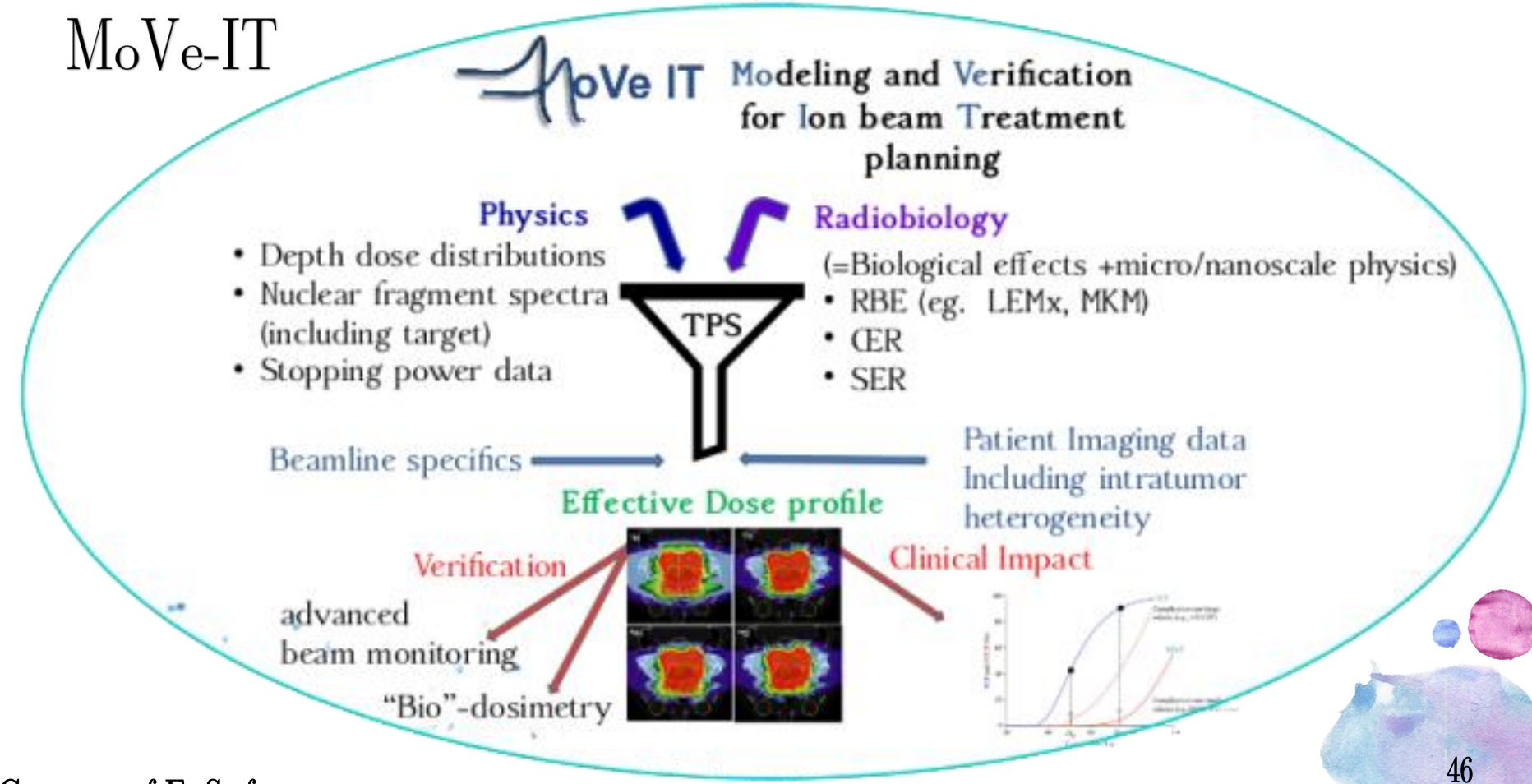
Two large-field setups:
- Setup 1: 6 cm "target" radius
- Setup 2: 16 cm "target" radius





Courtesy of F. Tommasino

MoVe-IT



Courtesy of E. Scifoni

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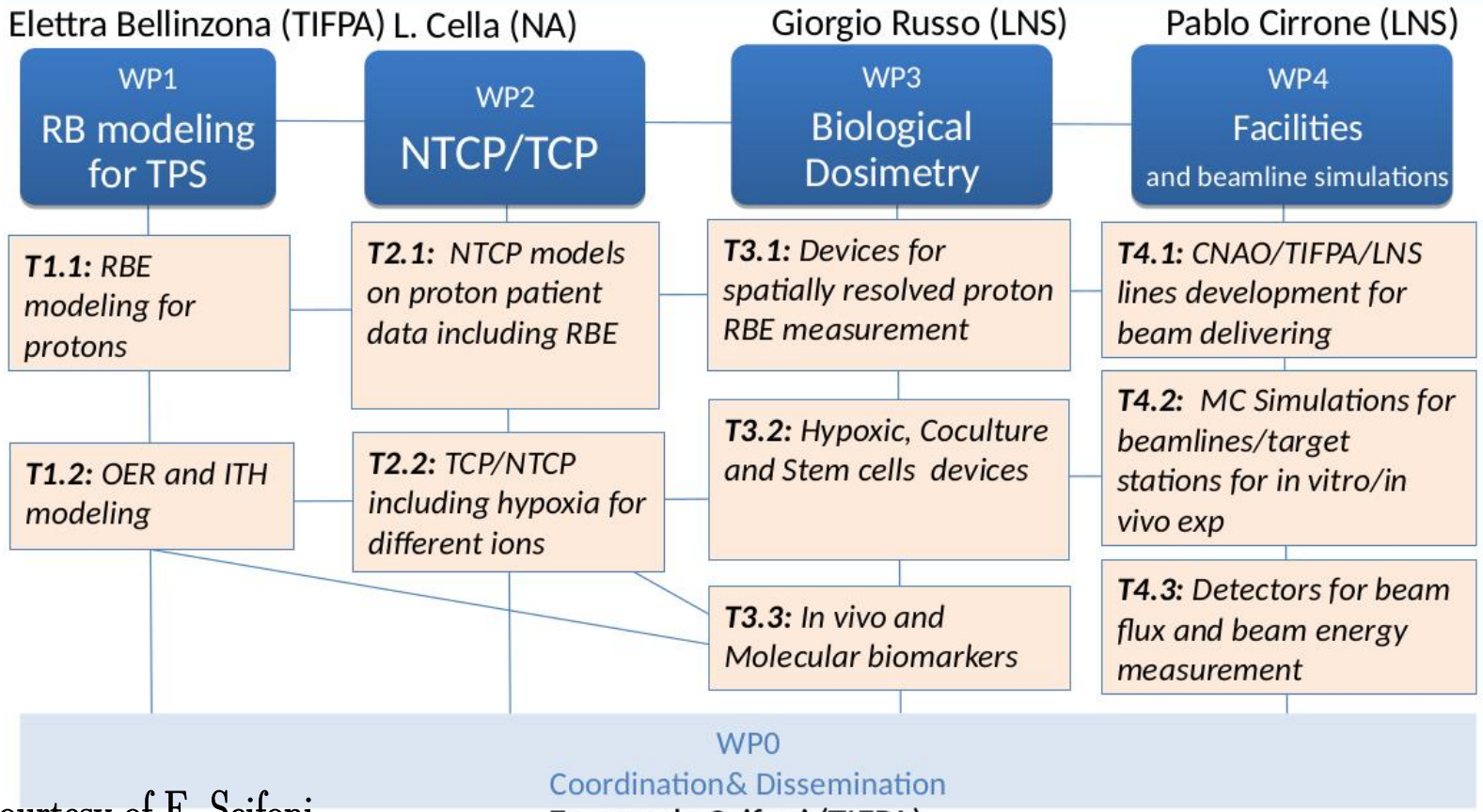


Courtesy of E. Scifoni

FOOT

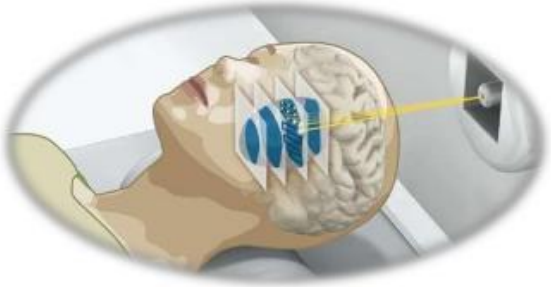
Characterization of the fragments generated in the target to improve the knowledge of the p->patient (p->H,C,O) interaction at therapeutic energies

Fragmentation double differential cross-section $\frac{d^2\sigma}{d\Omega dE}$

- Charge
- Mass
- Momentum
- Generation angle

Particle therapy

Data used to improve the accuracy of the **TPS** (Treatment Planning System)

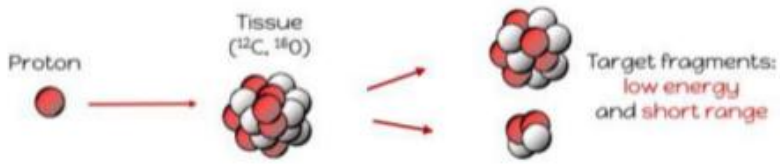


Courtesy of S. Colombi

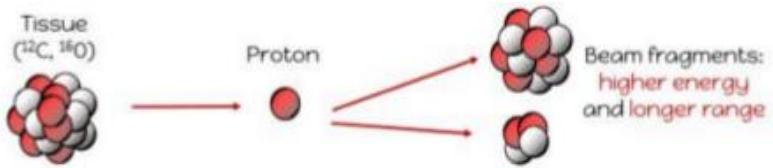
FOOT

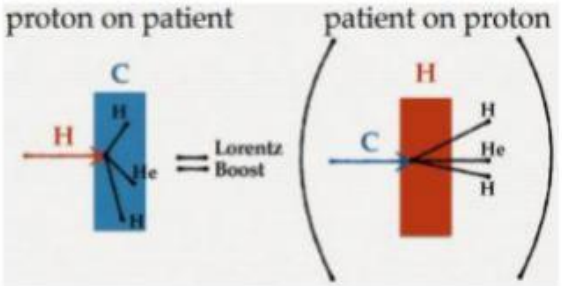
Shooting a proton on a patient (i.e., at 98% a C, O, H nucleus) could not be the right choice.
A possible work around is to **shoot a patient** (i.e., 0, C beam) **on** a target made of **protons** and measure the fragments

Direct kinematics



Inverse kinematics

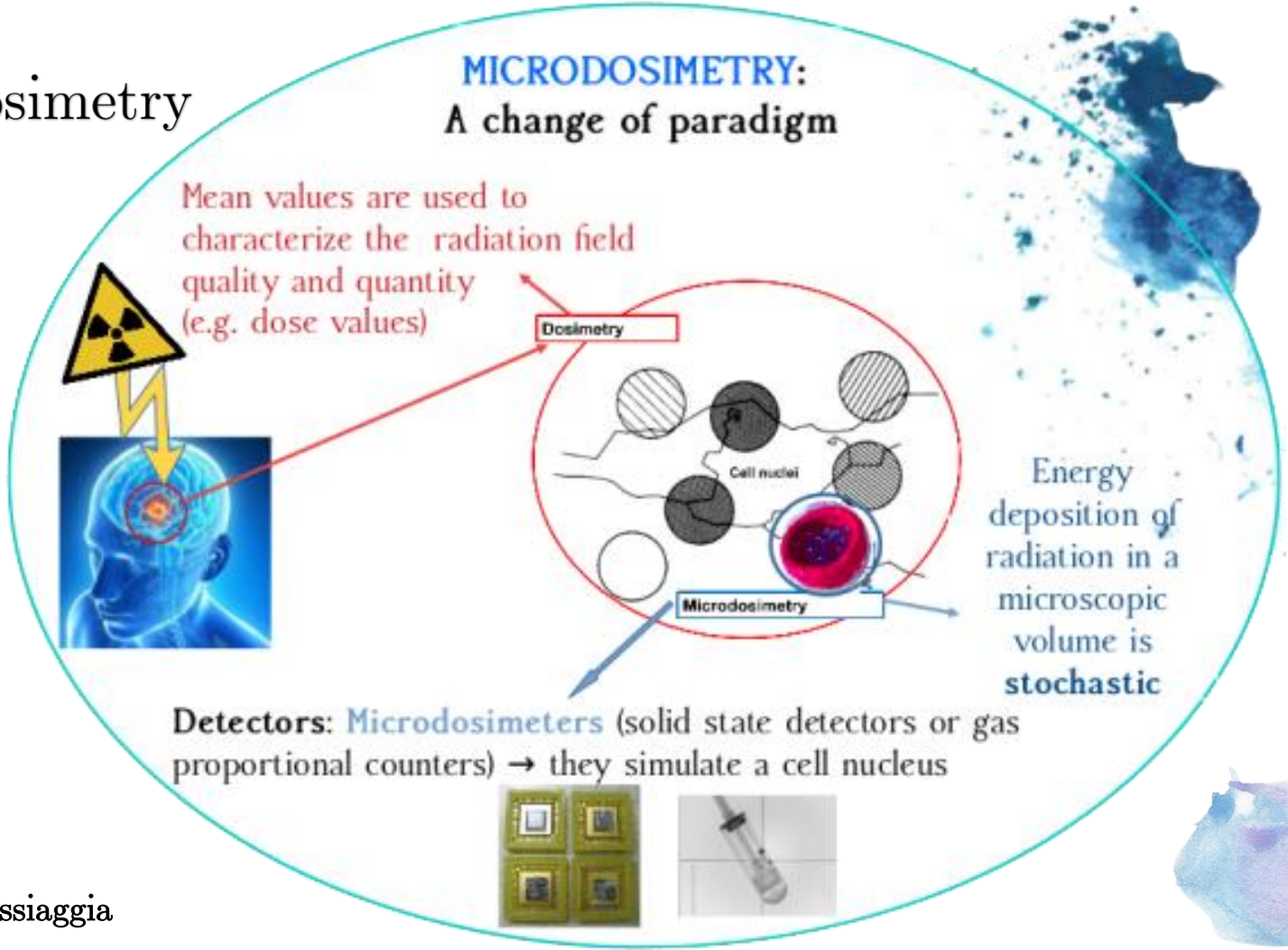




By applying the Lorentz transformation it is possible to switch from *the laboratory frame* to the *patient frame*

Courtesy of S. Colombi

Microdosimetry



Courtesy of M. Missiaggia

Space radiation

2019 African Nuclear Physics Conference
ANPC, June 30 - July 5, Kruger, South Africa

Courtesy of C. La Tessa

Space radiation

Health in Deep Space

1. Protection from space radiation (particularly very high energy heavy ions)
2. Psychosocial and behaviour problems
3. Physiological changes caused by microgravity

Courtesy of C. La Tessa

Space radiation

Radiation research topic

- Ground based experiments for characterizing the space radiation field
- Optimization of shielding materials
- Dose estimation and risk evaluation for any kind of space missions

Courtesy of C. La Tessa

The common issue: space & radio-therapy

In both fields, one of the fundamental questions is:
What is the risk associated to the exposure on the radiation environment?
The parameters involved are the same (LET, RBE medical outcomes..)

Ions used in radiotherapy represent an important subset of the radiation environment found in space

The accurate knowledge of the radiation quality and the biological effect is crucial for both

Courtesy of C. La Tessa

Thanks