



Dosimetry Radiotherapy-Hadrontherapy Radiobiology

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The Dose definition

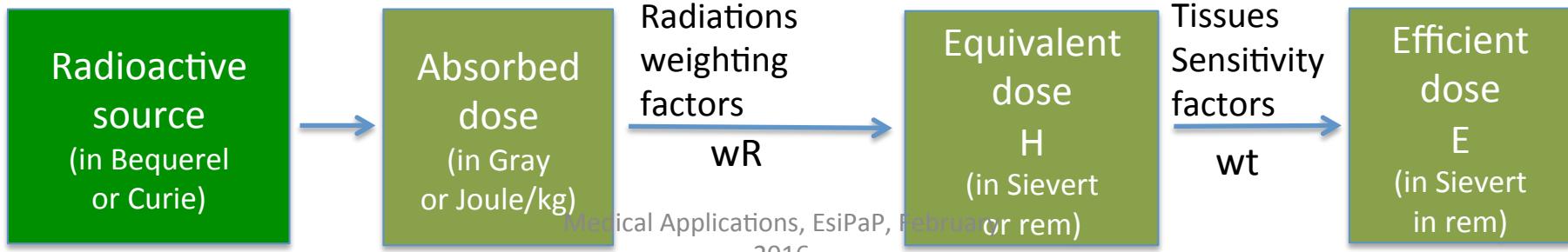
- The absorbed dose D by an organism is defined as the energy (Joules) deposited in a mass unit (Kg).

$$D = dE/dm$$

In the international system unit, the dose unit is the Gray (Gy):

$$1 \text{ Gy} = 1 \text{ J/kg.}$$

- The Gray is a unit that represents only the pure physical aspect of the dose. When the biological effect of a radiation has to be evaluated, we talk about the efficient dose and its unit is the Sievert (Sv).



Physics basis

Particle range (Distance after which the particle is stopped) : $R = \int_0^{E_0} \frac{dx}{dE} dE$

Bethe-Bloch Formula:

$$-\frac{dE}{dx} = \frac{z^2 e^4 n Z}{4\pi \epsilon_0^2 m_e v^2} \left[\ln\left(\frac{2m_e v^2}{I}\right) - \ln\left(1 - \frac{v^2}{c^2}\right) - \frac{v^2}{c^2} \right]$$

where : *z is the particle charge*

e is the electron charge

n is the number of atoms per volume unit

Z is the atomic number of the target media

ϵ_0 is the media permittivity

m_e is the electron mass

v is the particle velocity

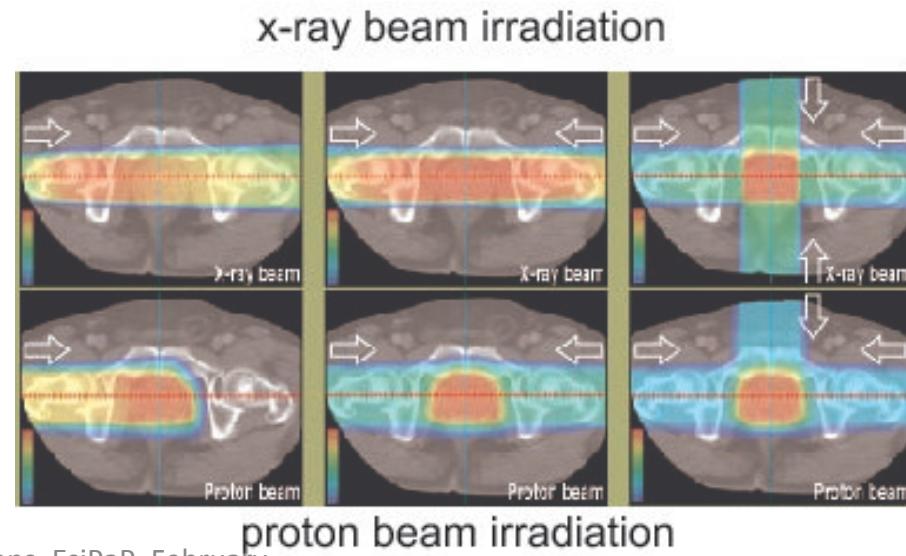
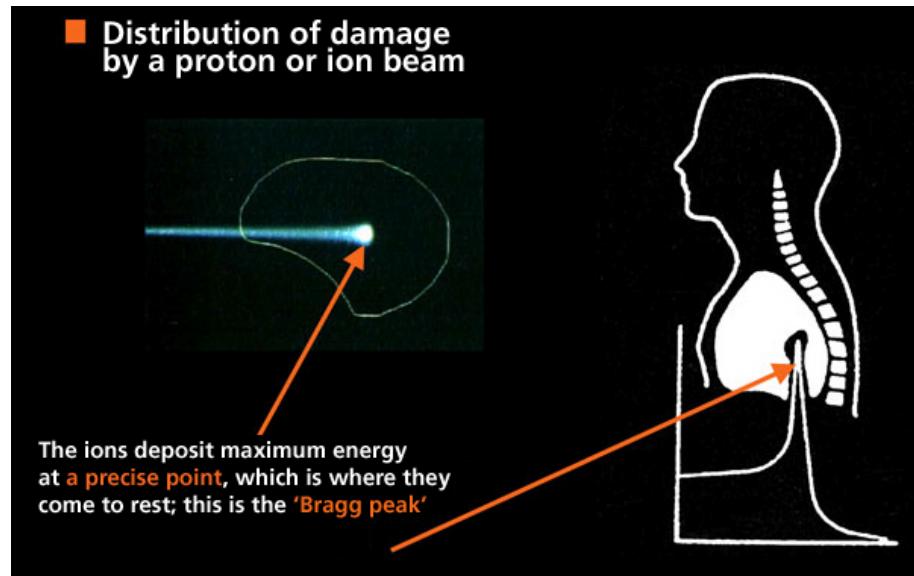
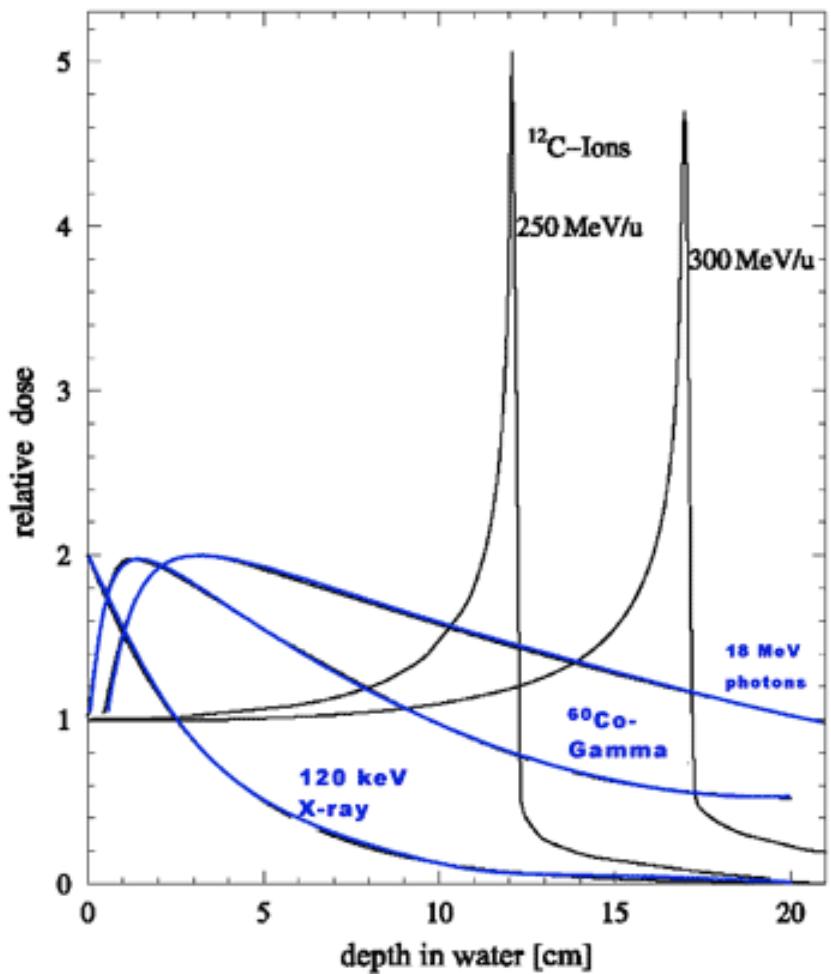
I is the ionisation or excitation potential that depends of the media

c is the light velocity |

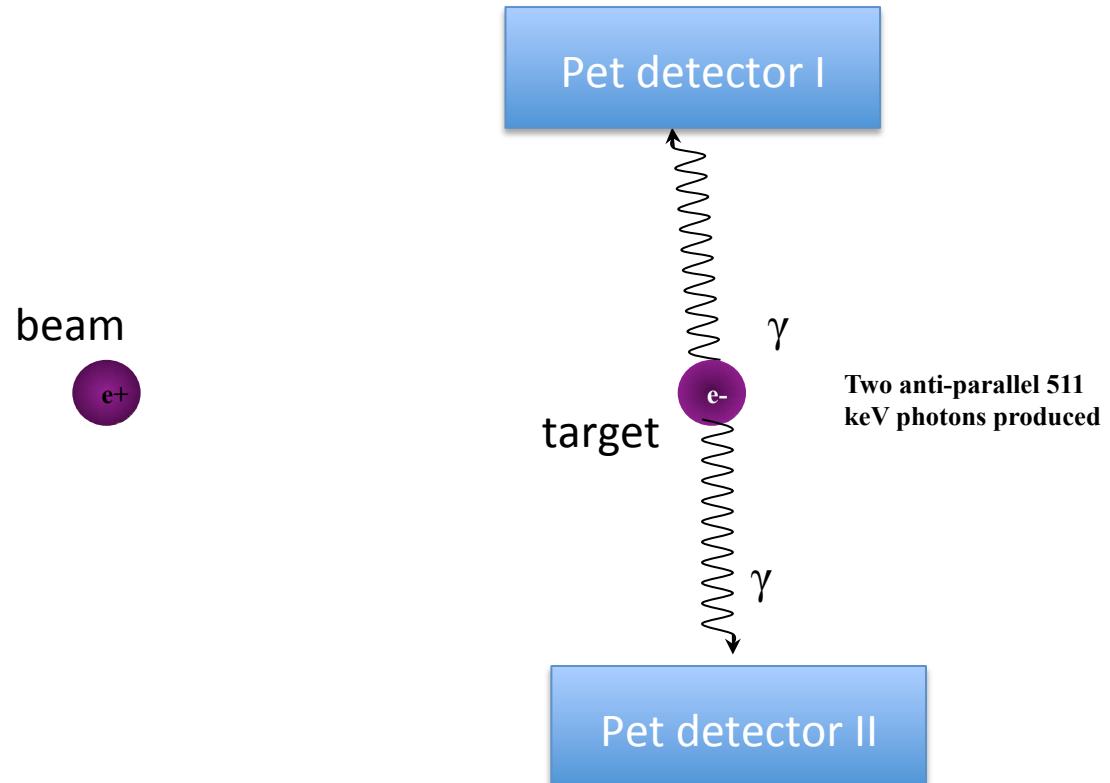
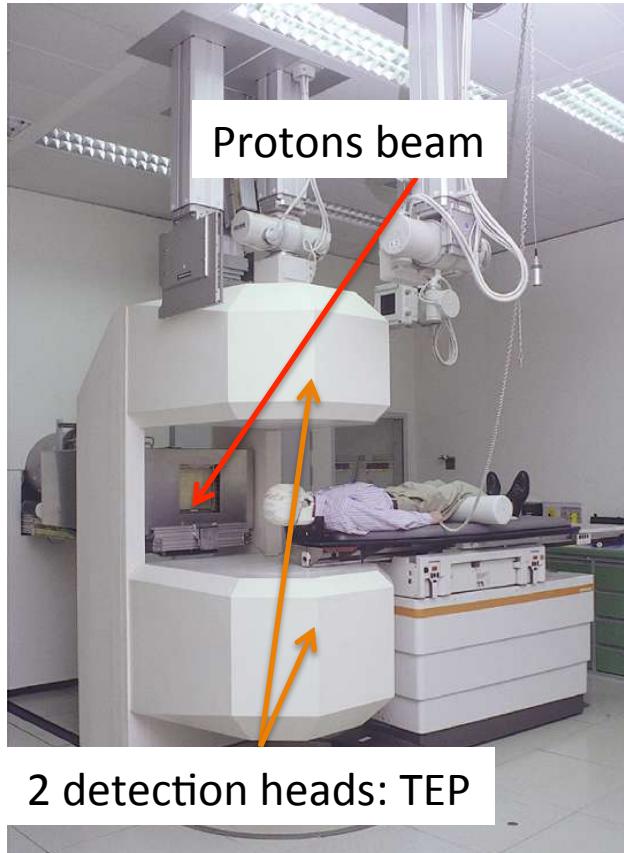
Hadrontherapy

- Radiotherapy technique that consists in using heavy ions (protons, carbon ions) beams to kill cancer cells.
- Advantage with respect to classical X-rays radiotherapy:
 1. High ballistic precision: hadrons stop at the level of the tumor produce less damage to healthy tissues.
 2. High treatment efficiency for some tumors (radio-resistant cells, Radiobiological effect)

Le Pic de Bragg



In situ dose control : inBeam PET

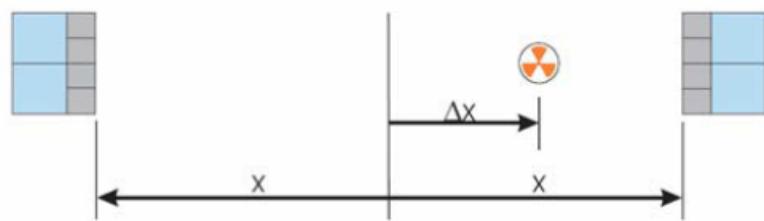
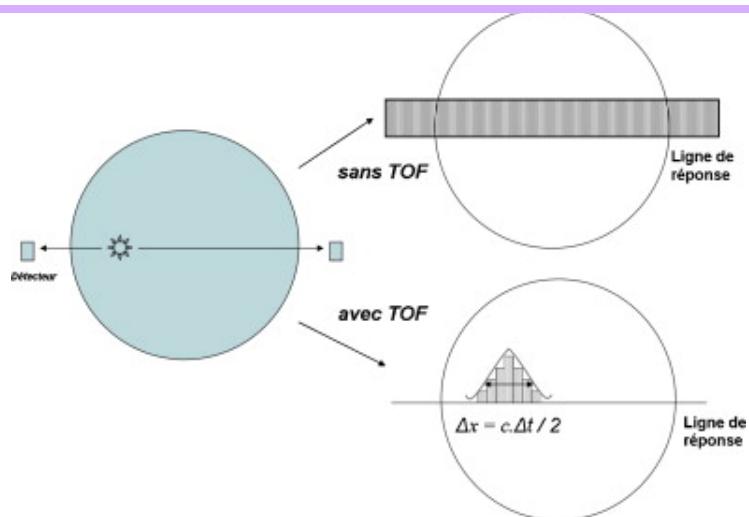


InBeam PET problem:

1. Short periods ^{11}C (20 min), ^{15}O (2min), ^{10}C (10s)
2. Low activities ($\sim 10 \text{ kBq}$), (Clinical PET $\sim 250 \text{ MBq}$)
3. Static mode acquisition (3D ?)

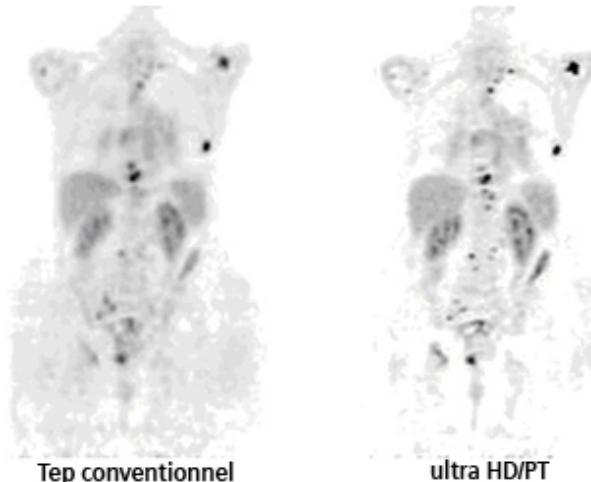
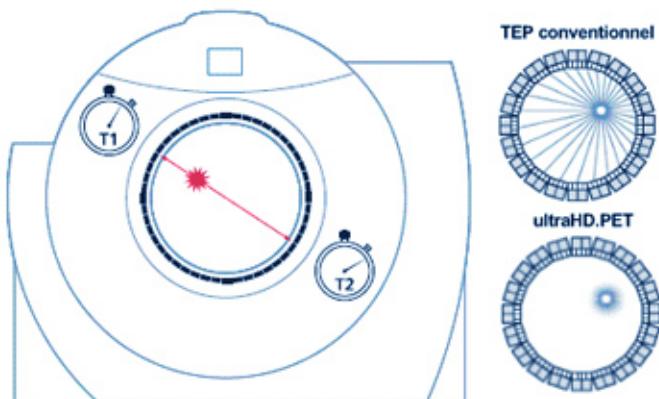
Time Of Flight technology (TOF) improves the signal to noise ratio

Improving spatial resolution using the Time Of Flight



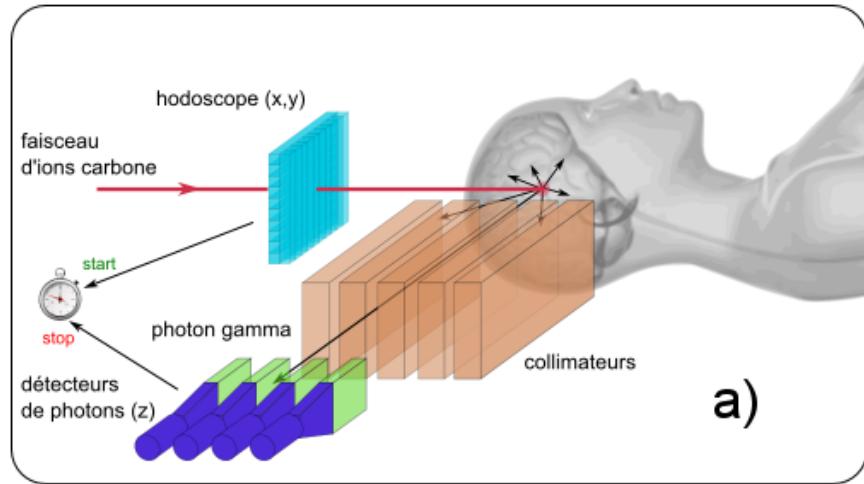
$$\Delta t = \frac{(x + \Delta x)}{c} - \frac{(x - \Delta x)}{c} = \frac{2\Delta x}{c}$$

$$\Delta x = 1,5 \text{ cm} \rightarrow \Delta t = 0,1 \text{ ns}$$

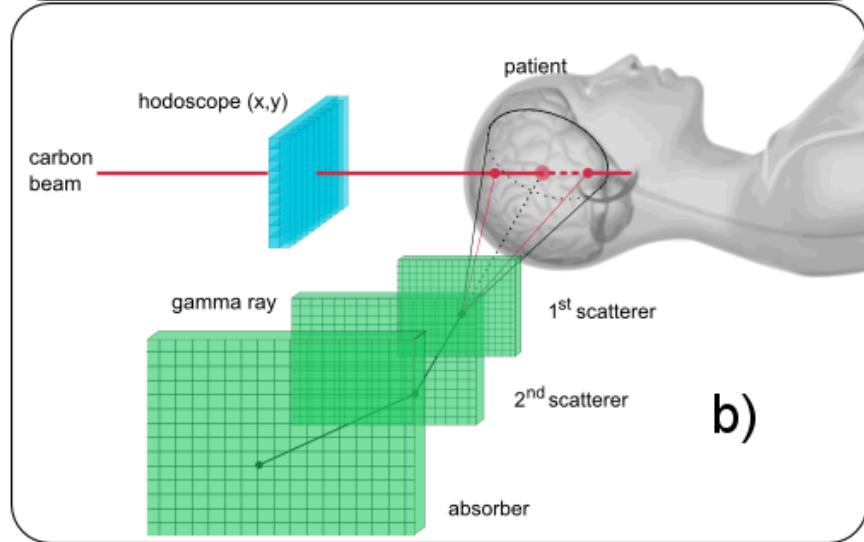


In situ dose control: gamma prompts detection

Utilising gammas prompts produced by nuclear reactions



SPECT Technology



Compton Camera

Radiobiology



Rayonnement ionisant

10^{-15}s



Effet indirect

Radicaux libres

Effet direct



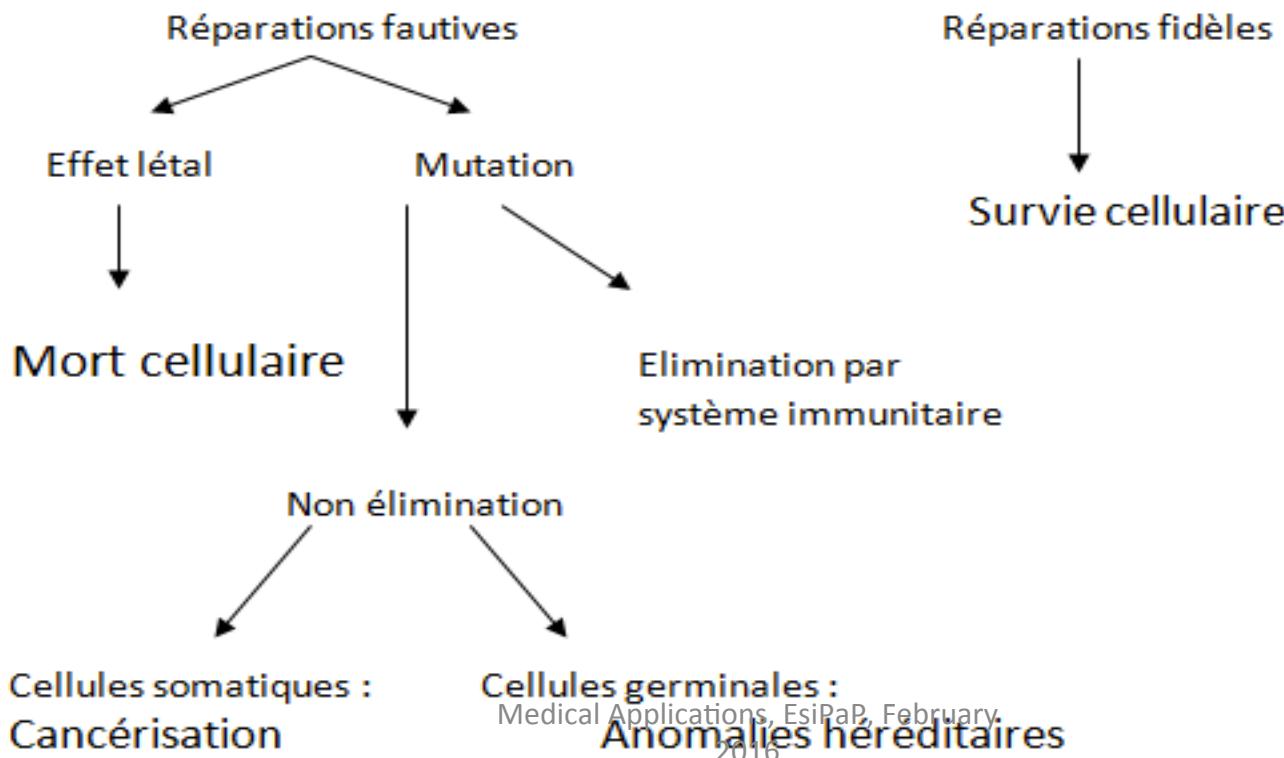
- Cassure de liaisons
- Création de liaisons covalentes

Radiolyse de l'eau,

libération de radicaux libres:



10^{-6}s



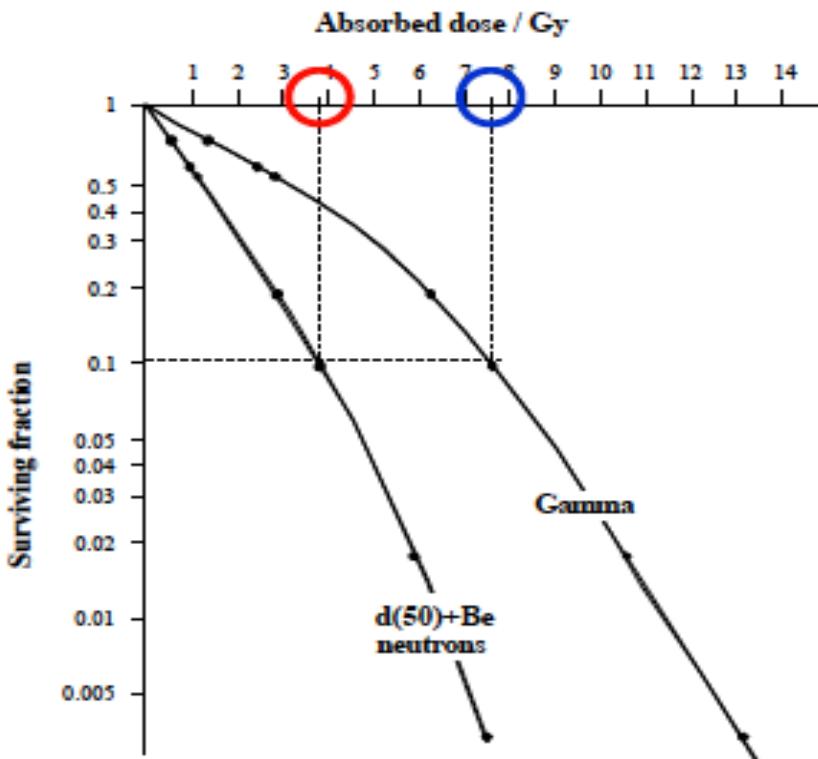
Cell survival (dose, radiation type, tissues)

The cell surviving fraction rate is expressed as :

$$S(D) = \exp(-(\alpha D + \beta D^2))$$

α/β is high for radio-sensitive cells

α/β is low for radio-resistant cells



Iso-dose

Gamma = 7.5 Gy
Neutrons = 3.8 Gy

$$\text{RBE} = 7.5 / 3.8 = 2$$

Efficacité Biologique Relative

EBR (RBE)

Rapport entre les doses d'un rayonnement de référence et du rayonnement étudié qui induisent le même effet.