Dosimetry
Radiotherapy-Hadrontherapy
Radiobiology

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The Dose definition

ZONE CONTROLÉE
ACCES REGLEMENTÉ

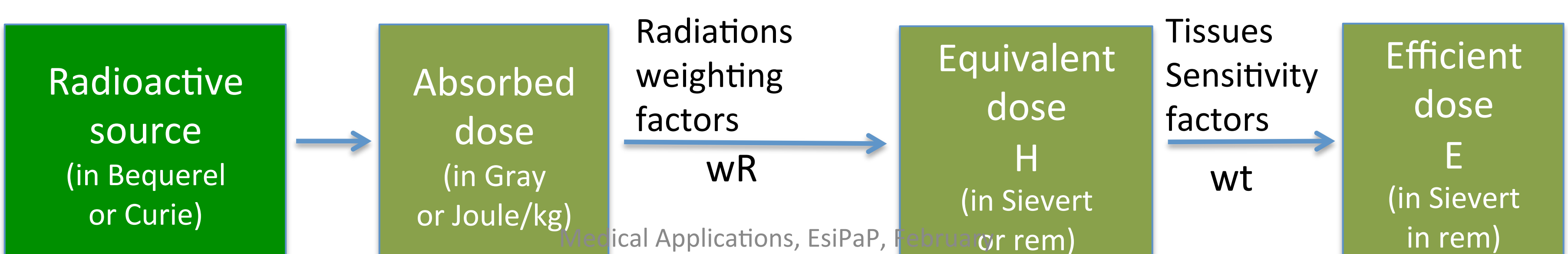
- The absorbed dose D by an organism is defined as the energy (Joules) deposited in a mass unit (Kg).

$$D = dE/dm$$

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:

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

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*

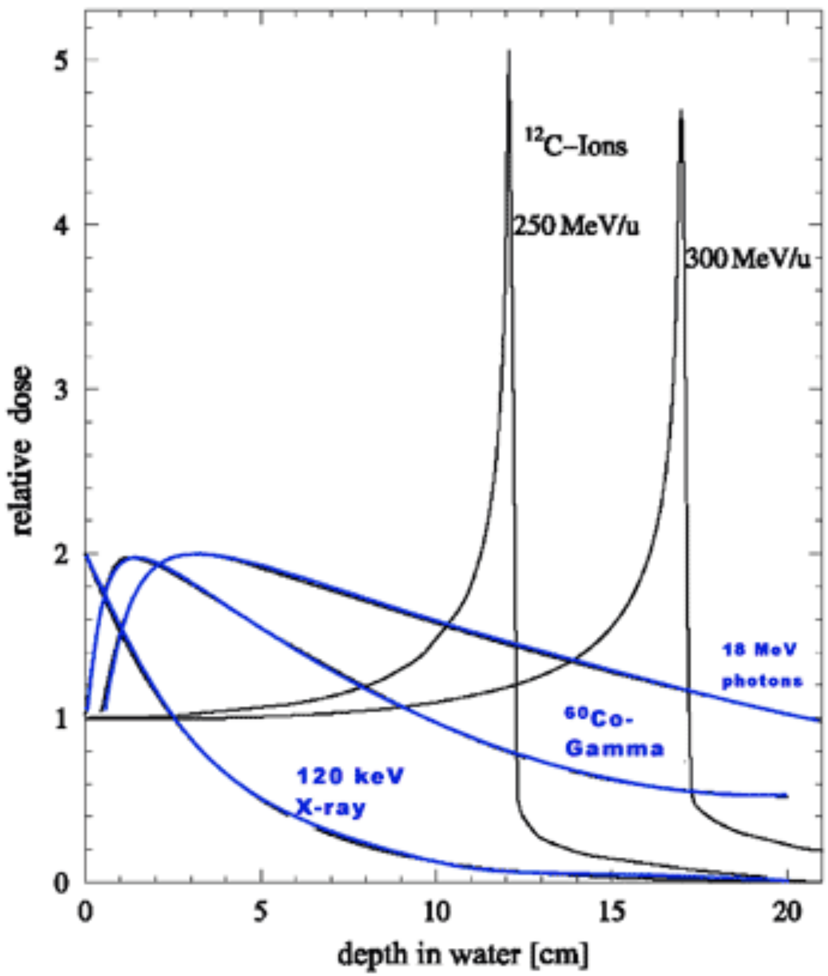
I *is the ionisation or excitation potential that depends of the media*

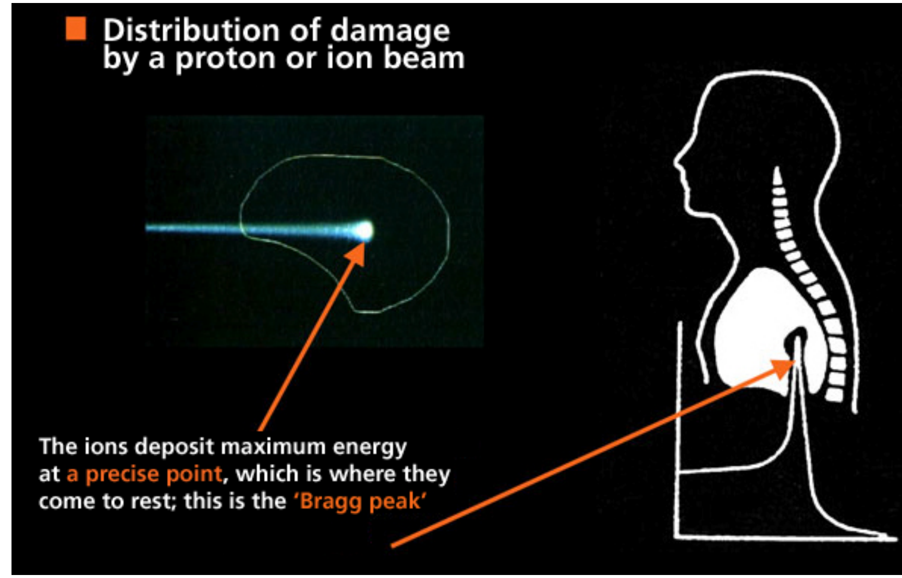
c *is the light velocity*

Hadrontherapy

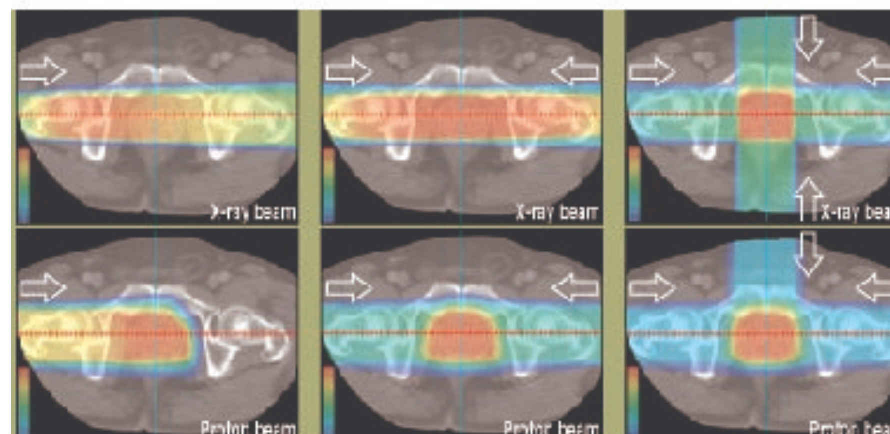
- Radiotherapy technique that consists in using heavy ions (protons, carbon ions) beams to kill cancer cells.
- Advantage with respect to classical X-rays radiotherapy:
  1. High balistic precision: hadrons stop at the level of the tumor produce less damage to healthy tissues.
  2. High treatment efficiency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

Le Pic de Bragg



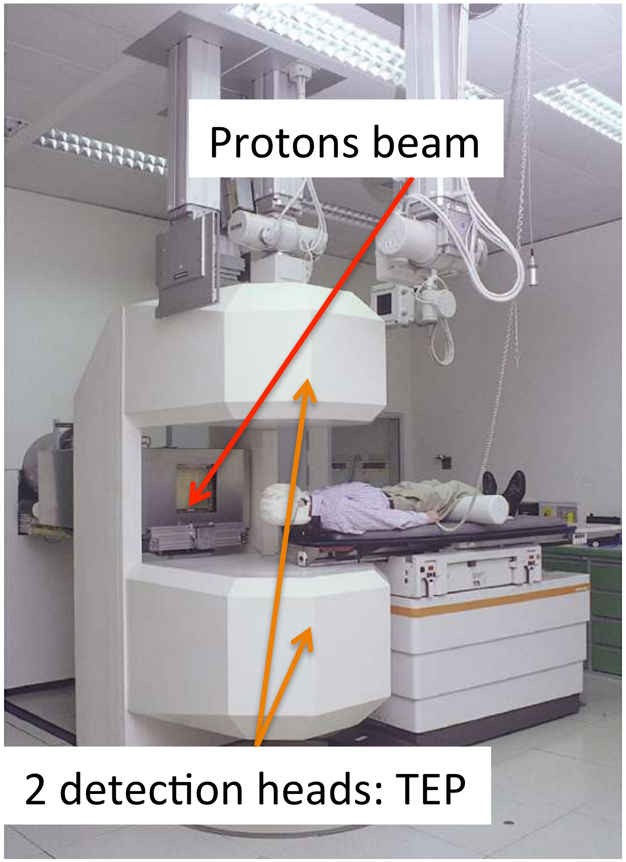


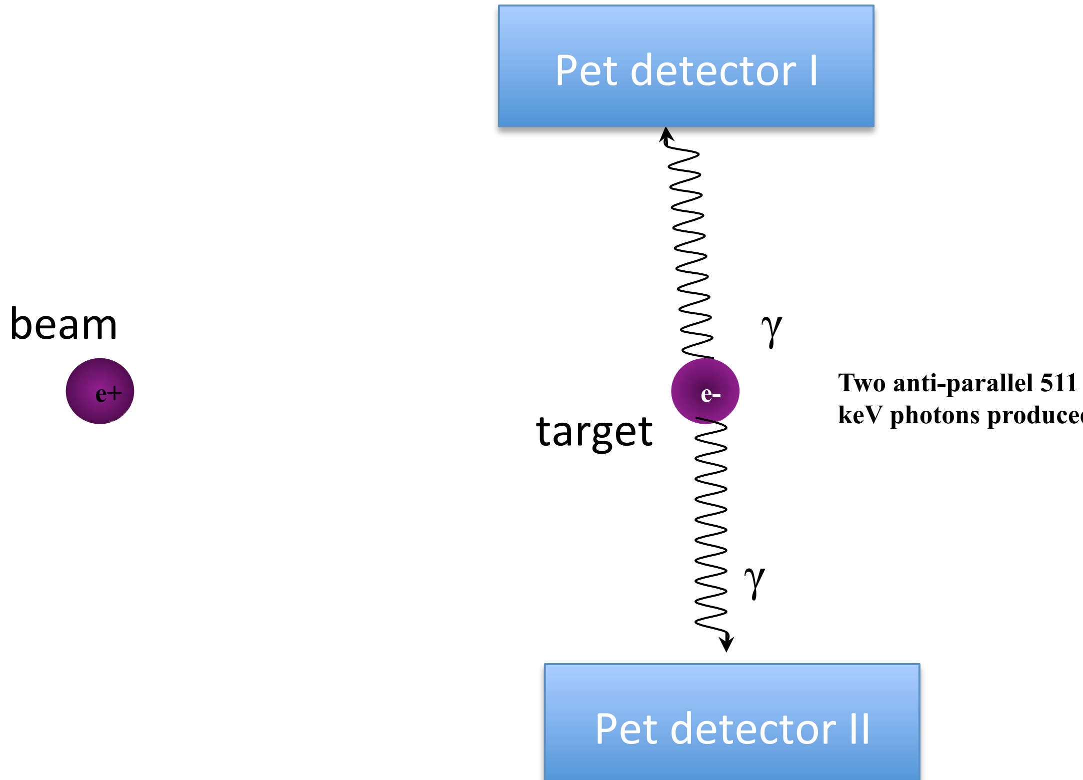
x-ray beam irradiation



proton beam irradiation

In situ dose control : inBeam PET



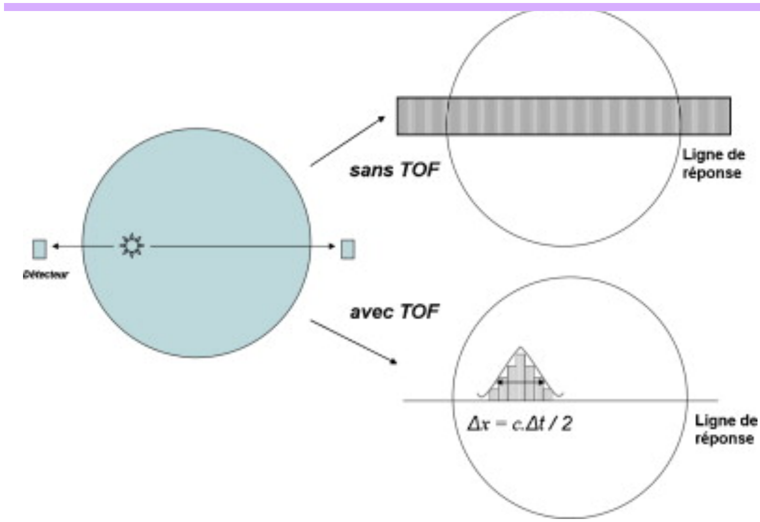


InBeam PET problem:

1. Short periods 11-C (20 min), 15-O (2min), 10-C (10s)
2. Low activities (~10 kBq), (Clinical PET ~250 MBq)
3. Static mode acquisition (3D ?)

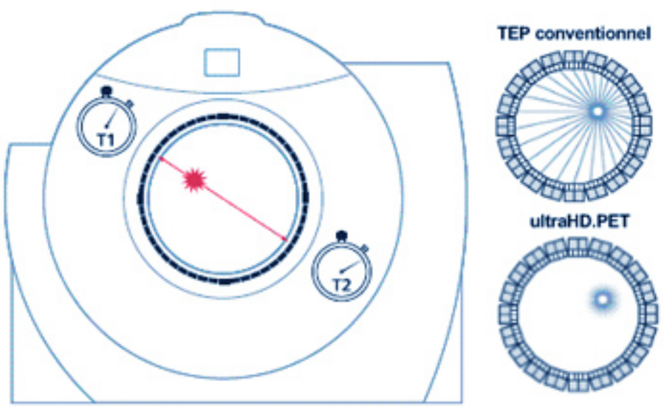
Time Of Flight technology (TOF) improves the signal to noise ratio

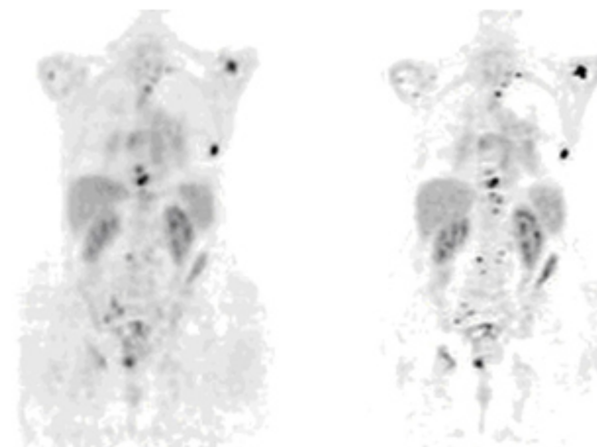
Improving spatial resolution using the Time Of Flight



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

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



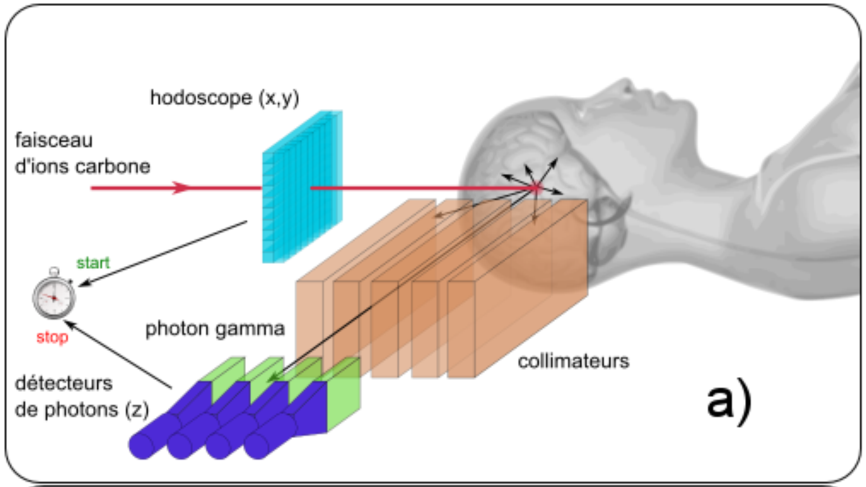


Tep conventionnel ultra HD/PT

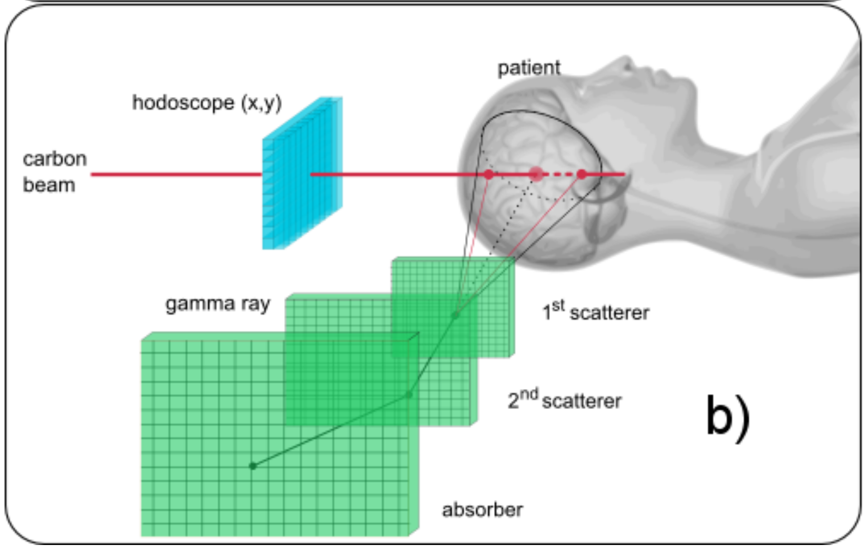
https://www.swe.siemens.com

In situ dose control: gamma prompts detection

Utilising gammas prompts produced by nuclear reactions

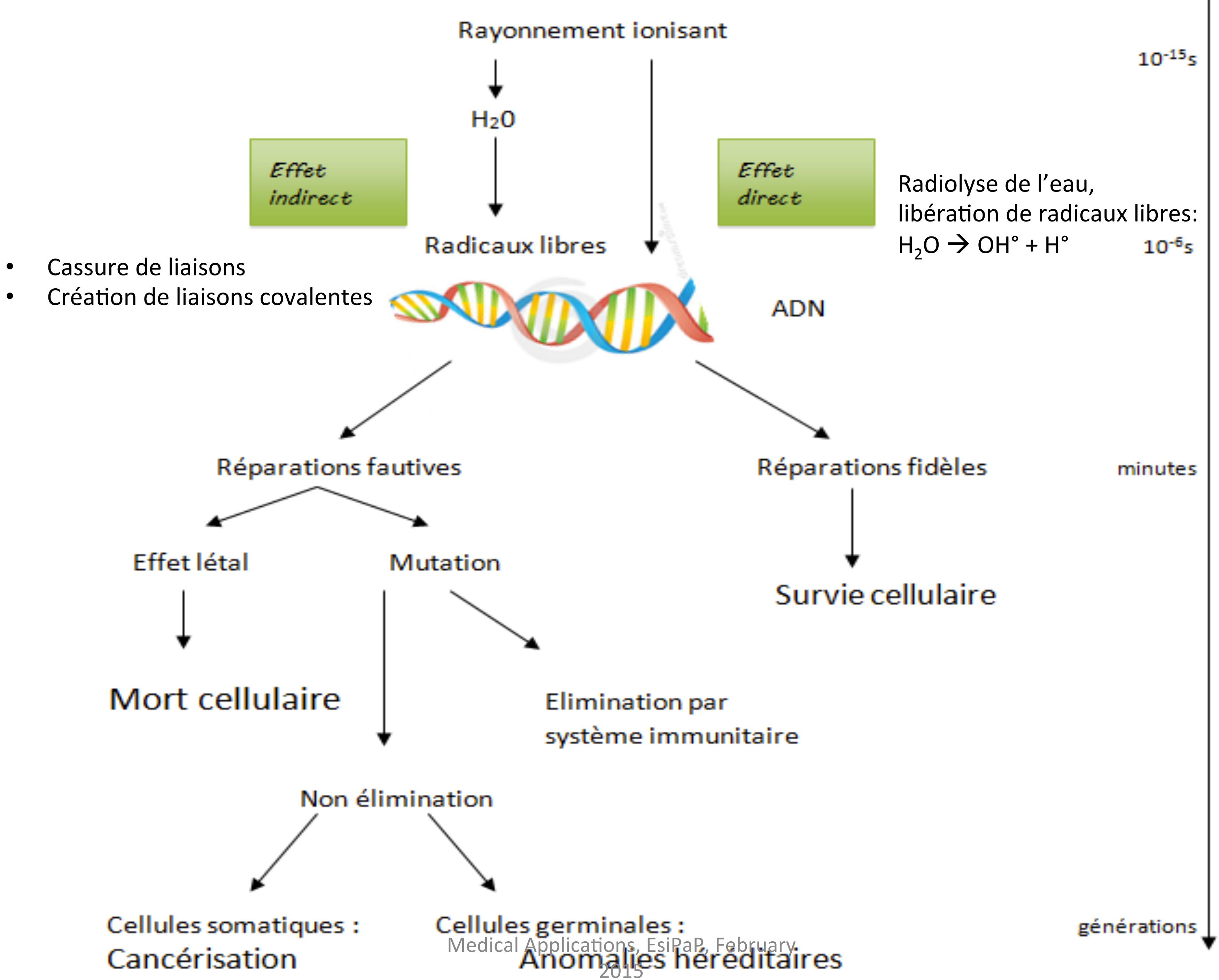


SPECT Technology



Compton Camera

Radiobiology

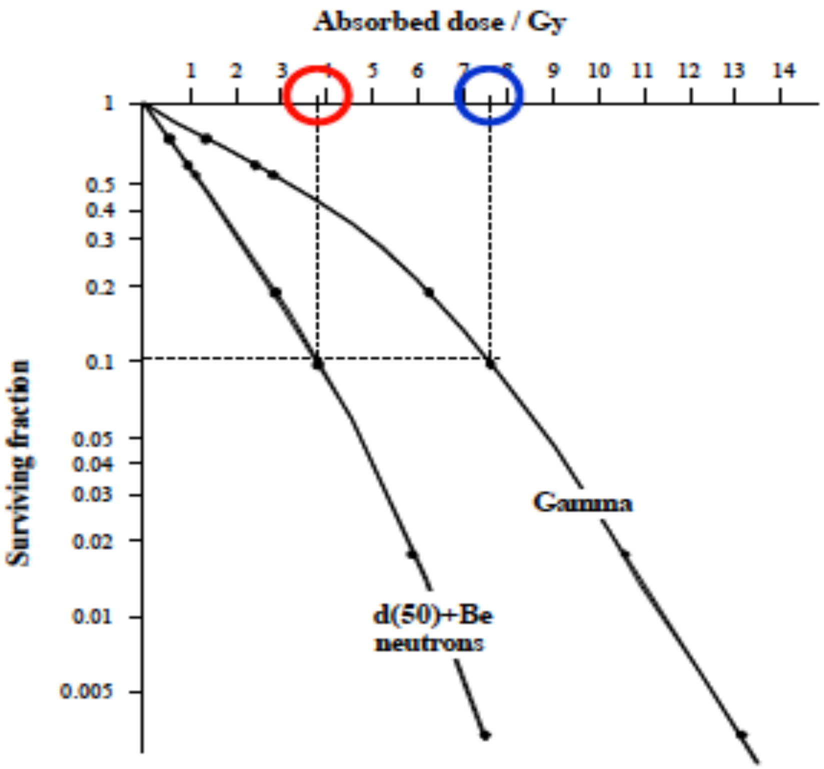

Rayonnement ionisant
10^{-15}s
H_2O
Effet indirect
Effet direct
Radiolyse de l'eau,
libération de radicaux libres:
$H_2O \rightarrow OH° + H°$
10^{-6}s
Radicaux libres
• Cassure de liaisons
• Création de liaisons covalentes
ADN
Réparations fautives
Réparations fidèles
minutes
Effet létal
Mutation
Survie cellulaire
Mort cellulaire
Elimination par
système immunitaire
Non élimination
Cellules somatiques :
Cancérisation
Cellules germinales :
Anomalies héréditaires
générations

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 celles
α/β is low for radio-resistive celles



Iso-dose

Gamma = 7.5 Gy
Neutrons = 3.8 Gy

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.