

L'ANTI-MATIÈRE : UN OUTIL DE LUTTE CONTRE LE CANCER



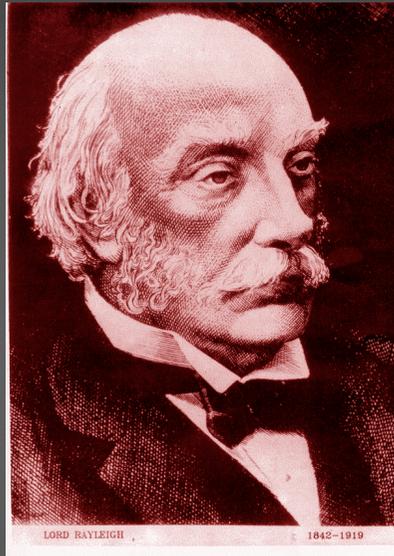
Denis MARIANO-GOULART
Département de biophysique et médecine nucléaire
Faculté de médecine de Montpellier

PLAN

- ① L'anti-matière
- ② La médecine nucléaire
- ③ La Tomographie par Emission de Positons
- ④ Exemples cliniques
- ⑤ Perspectives pour un futur proche...

Découverte des anti-particules

La physique après Newton et Maxwell ?

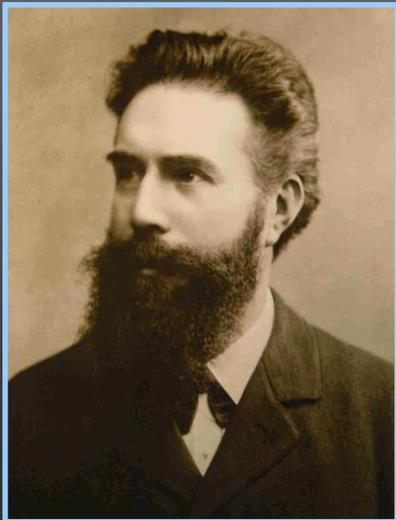
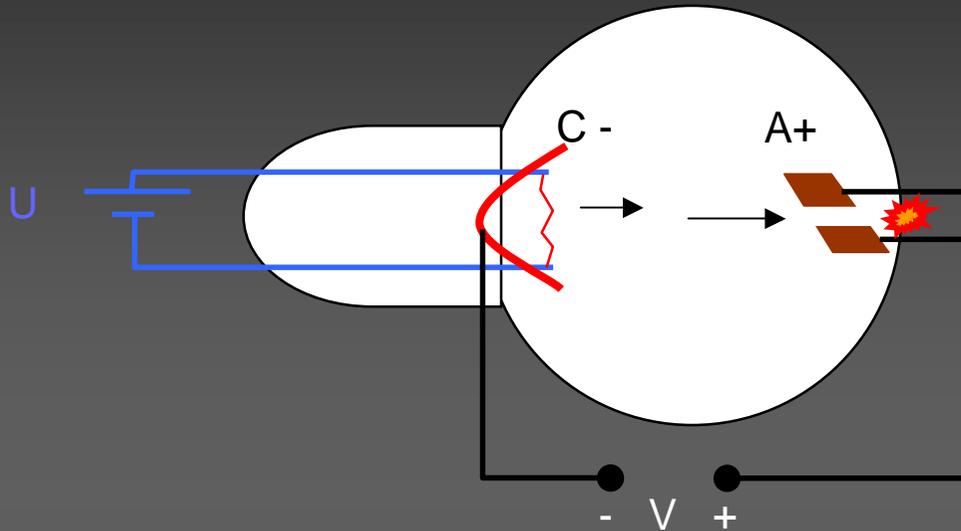


Lord Rayleigh, 1898 :
« la physique est pratiquement terminée..., il ne reste que deux petites choses à examiner et ce sera l'affaire des années suivantes... »



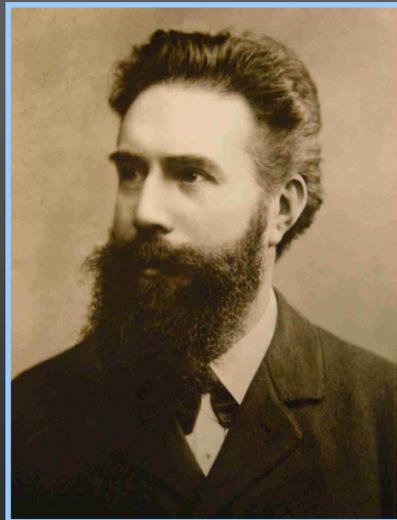
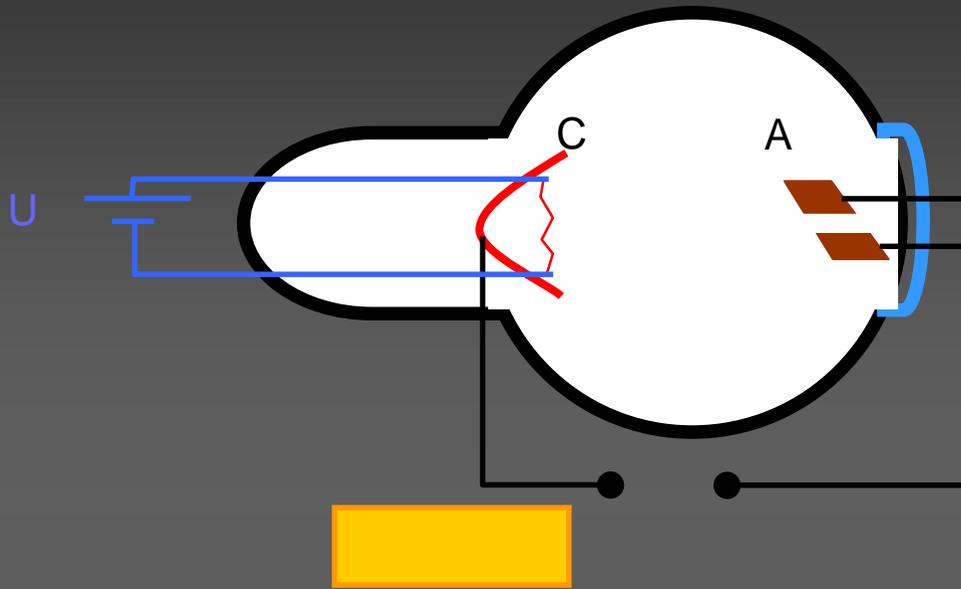
D. Hilbert, 1900
Le 6° des 23 problèmes :
« L'axiomatisation de la physique »

Une ampoule à rayons cathodiques...



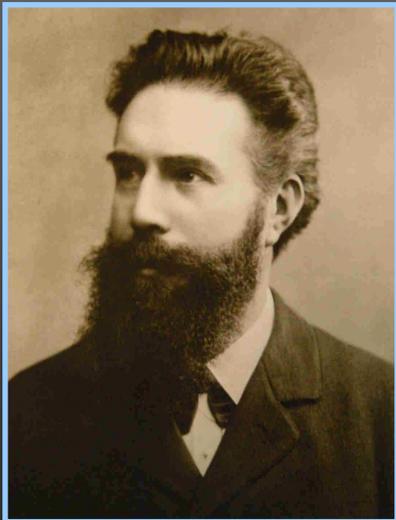
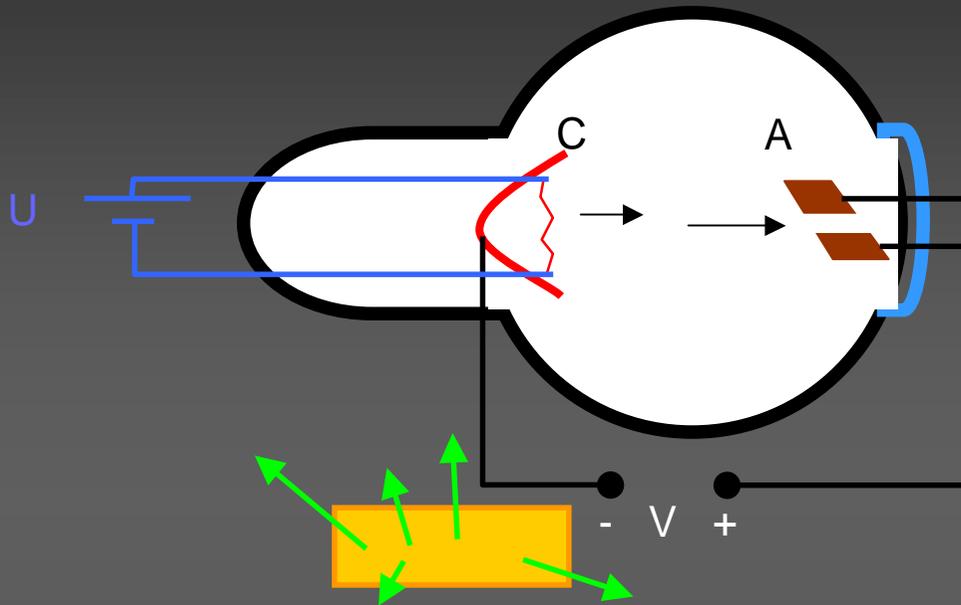
Röntgen 1895

...qui ménage des surprises...



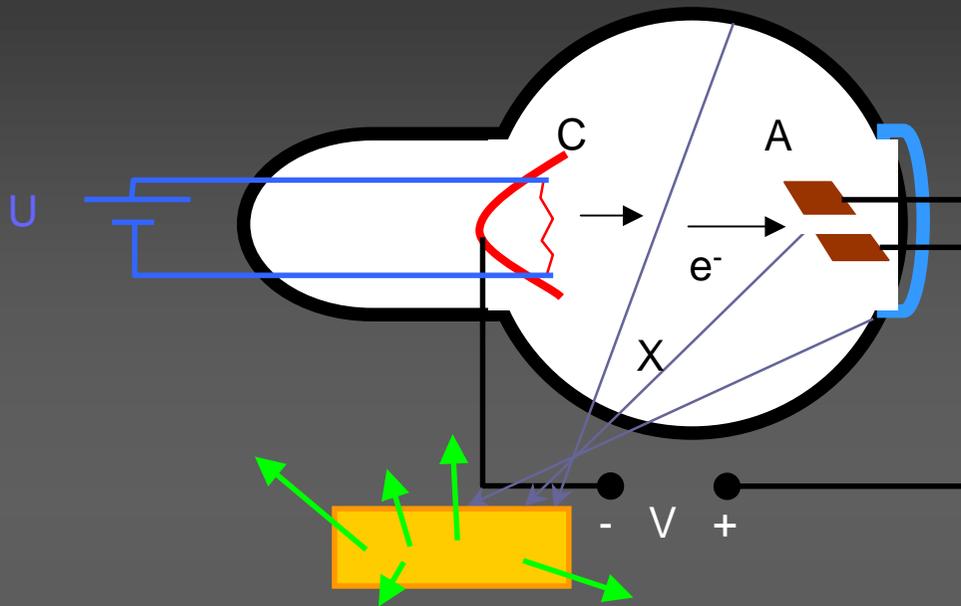
Röntgen 1895

...qui ménage des surprises...



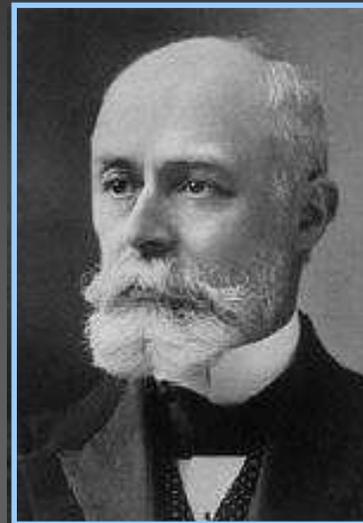
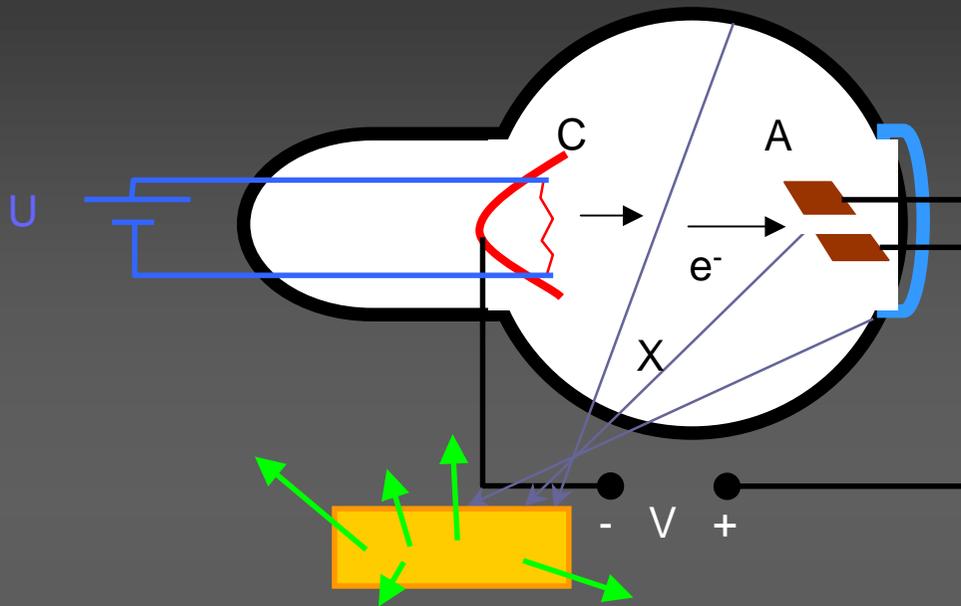
Röntgen 1895

... fait découvrir les rayons X, ...

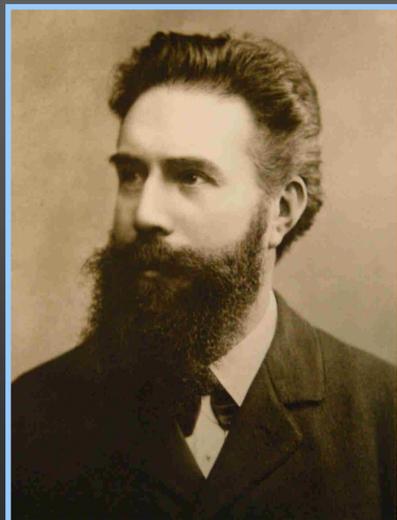
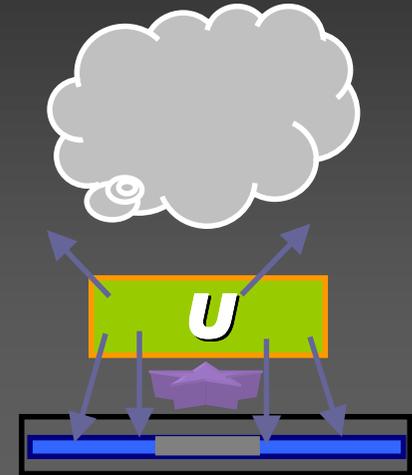


Röntgen 1895

...et la radioactivité naturelle.

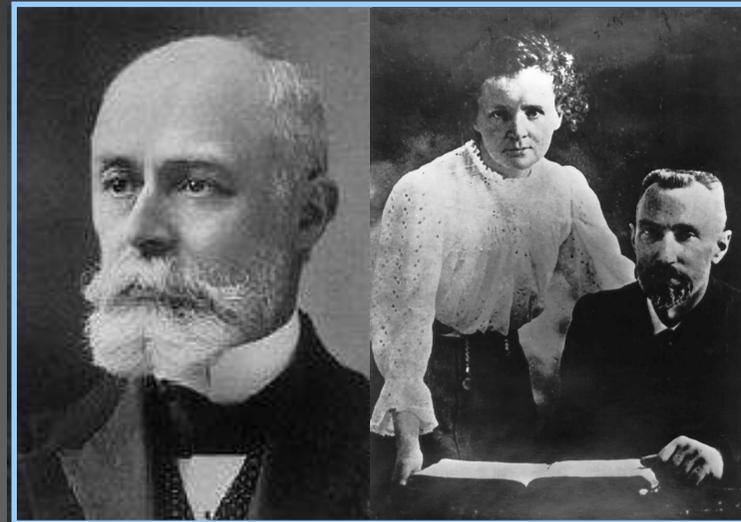
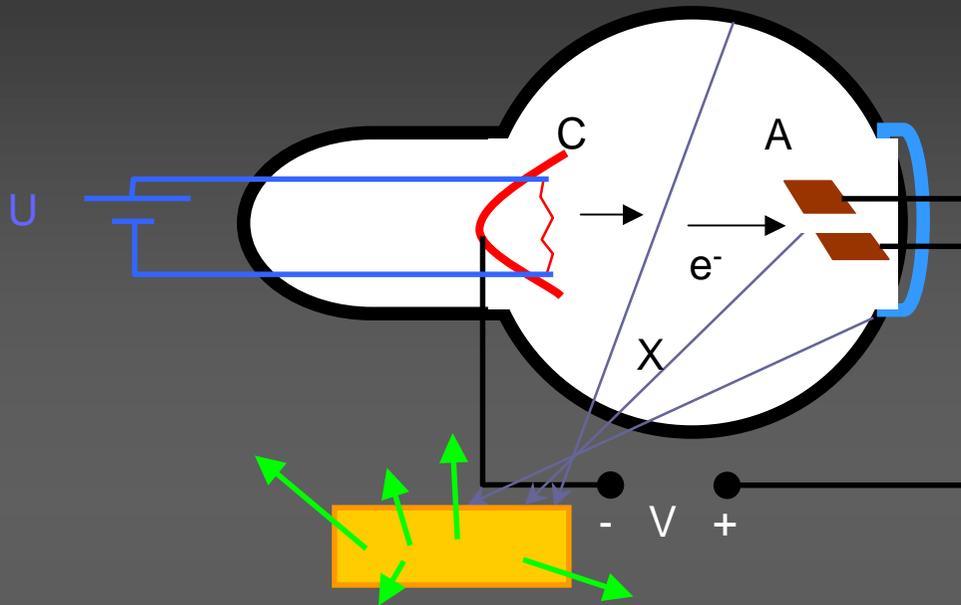


Becquerel 1896



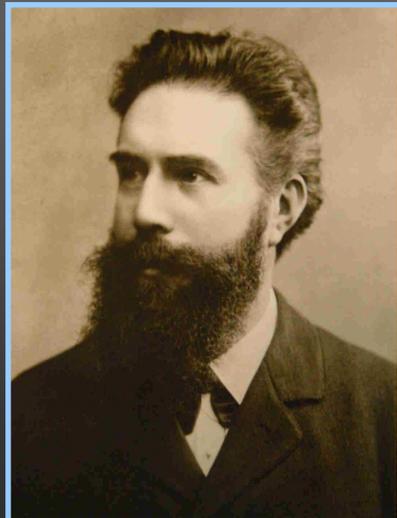
Röntgen 1895

Des rayonnements pénétrants et détectables

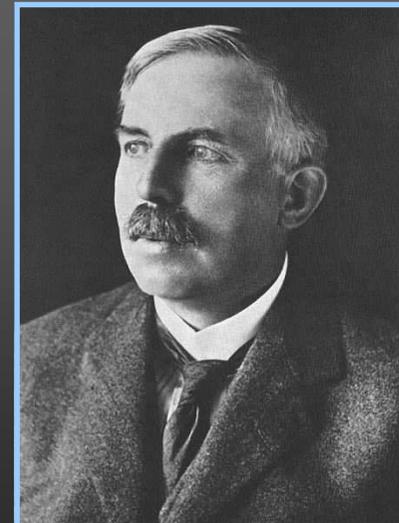


Becquerel 1896

Curie 1898



Röntgen 1895

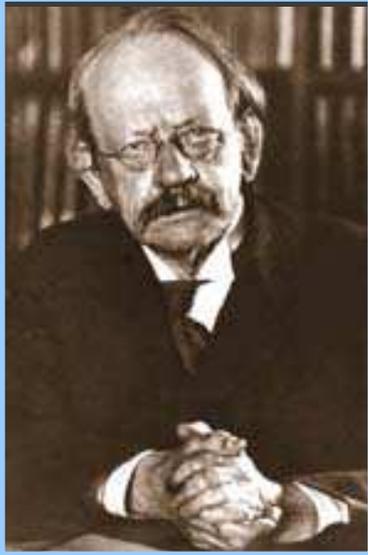


Rutherford 1899



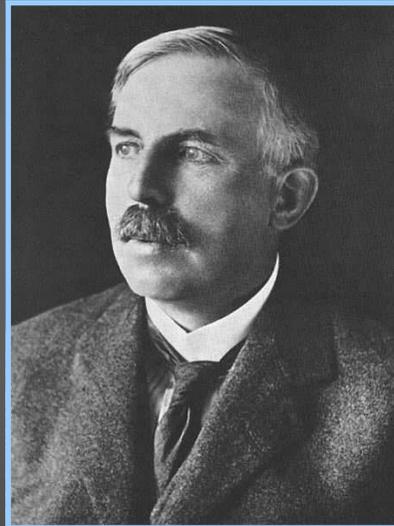
Villard 1900

Découverte de la structure de l'atome...



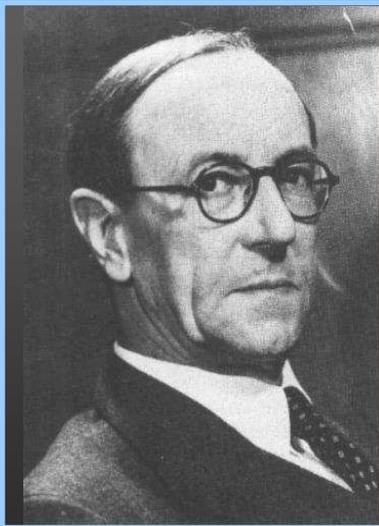
Thomson 1897

e^-



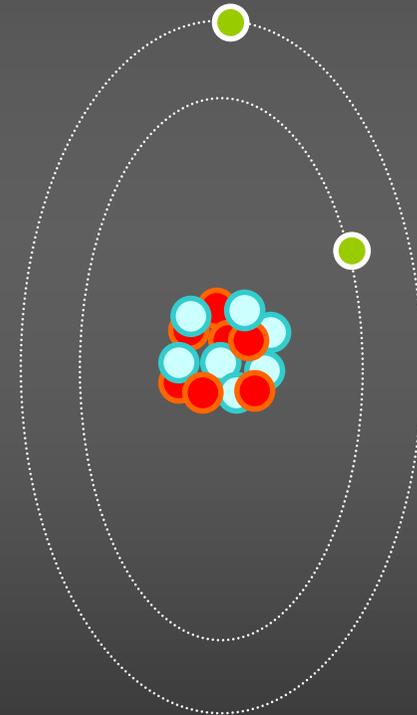
Rutherford 1919

p

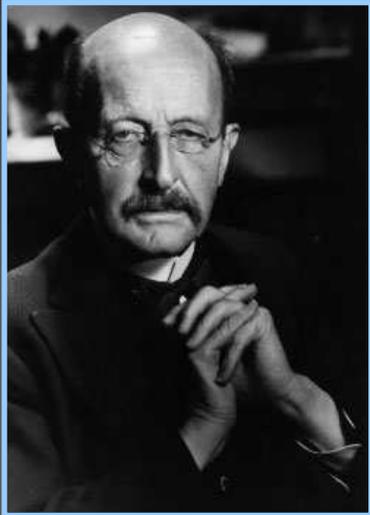


Chadwick 1932

n



Renouveau de la physique théorique



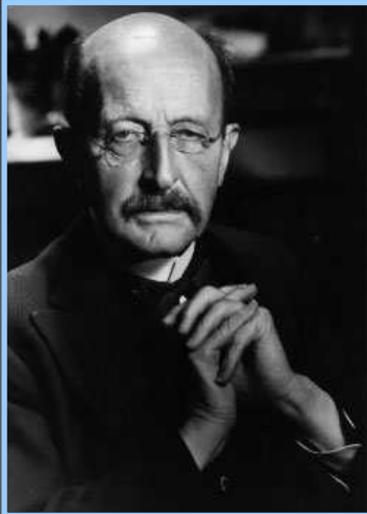
1900 : M. Planck



1905 : A. Einstein

$$E = m.c^2$$

Renouveau de la physique théorique



M. Planck



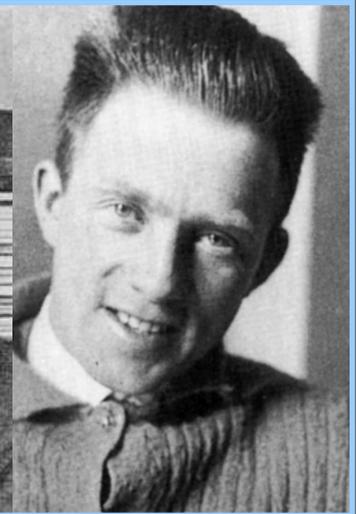
N. Bohr



E. Schrödinger



L. de Broglie



W. Heisenberg



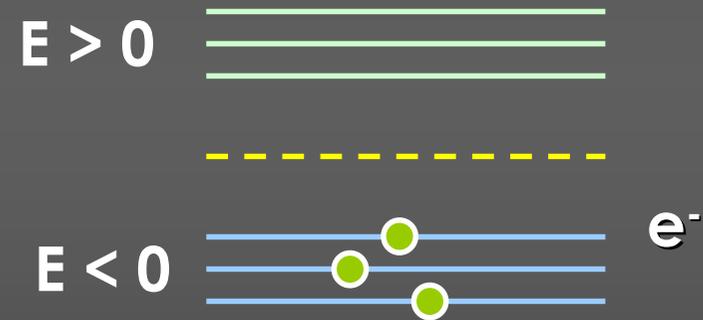
A. Einstein

$$E = m.c^2$$

Renouveau de la physique théorique



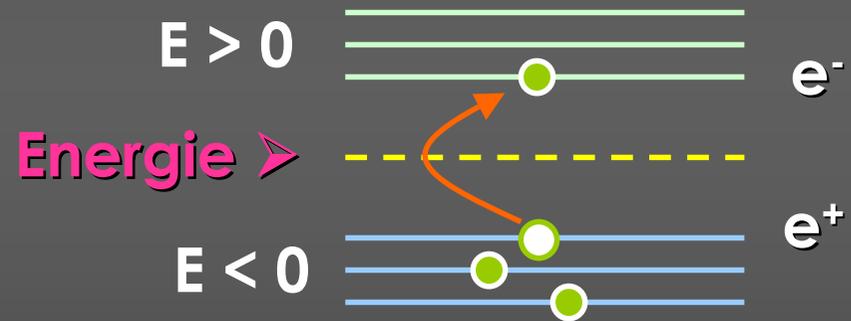
1929: PAM Dirac : $E = \pm \sqrt{p^2c^2 + m^2c^4}$
Théorie Quantique et relativiste de l' e^-



Renouveau de la physique théorique



1929: PAM Dirac : $E = \pm \sqrt{p^2c^2 + m^2c^4}$
Théorie Quantique et relativiste de l' e^-

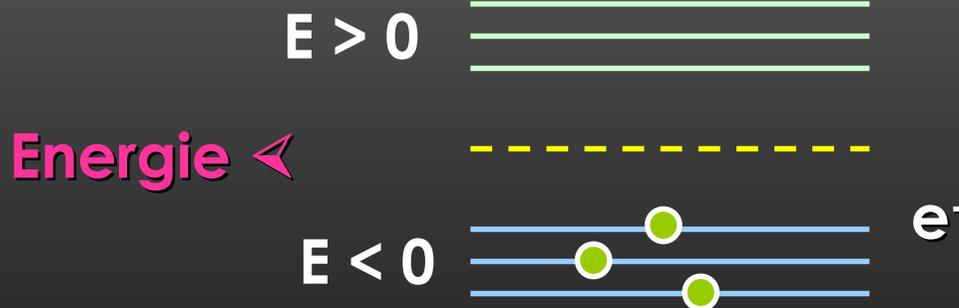
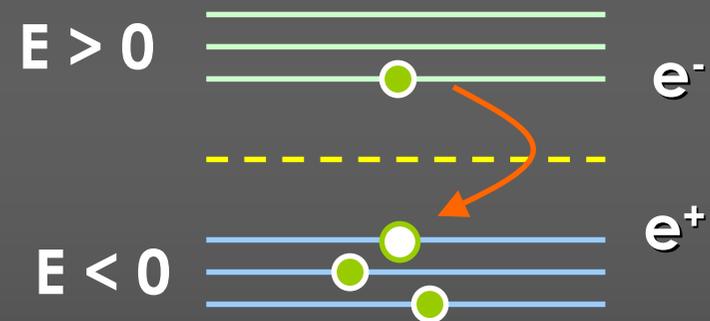


Energie \rightarrow $e^- + e^+$

Renouveau de la physique théorique

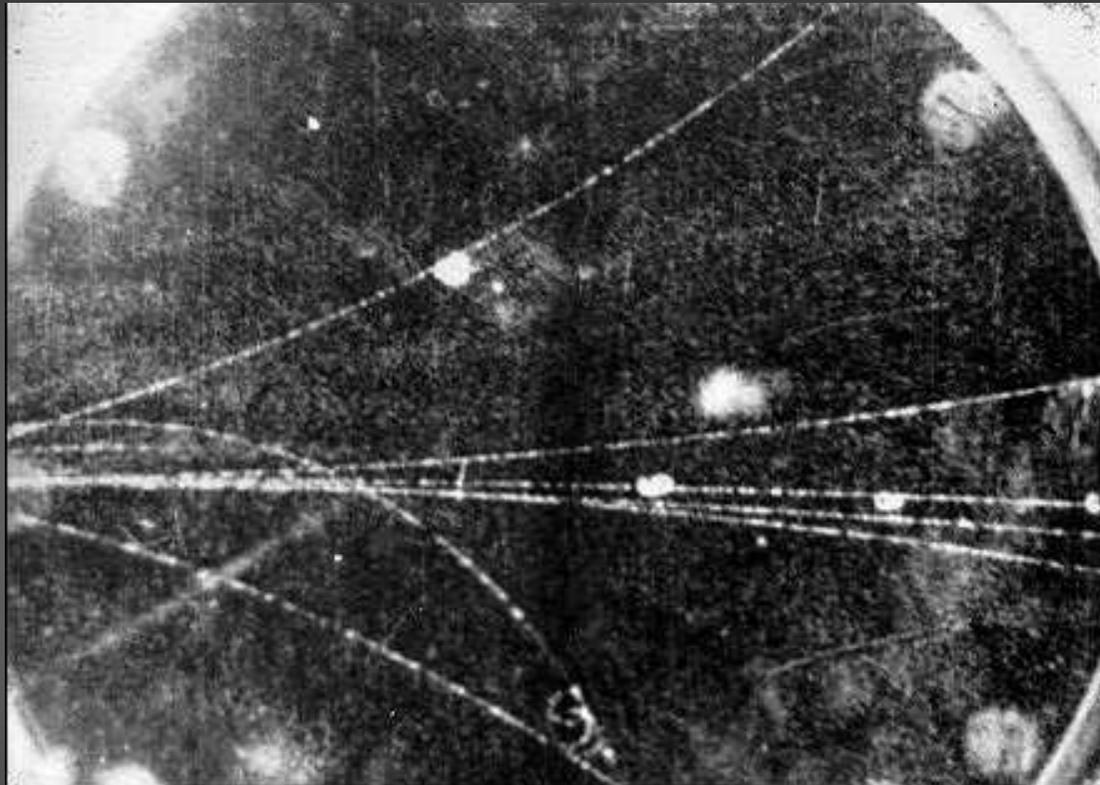
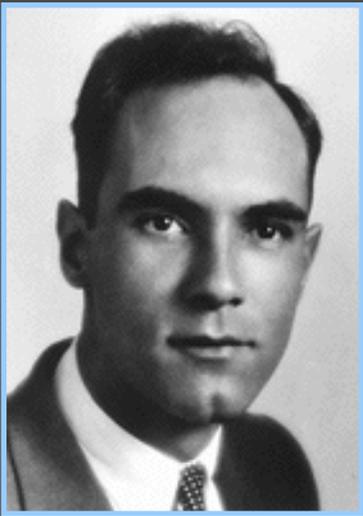


1929: PAM Dirac : $E = \pm \sqrt{p^2c^2 + m^2c^4}$
Théorie Quantique et relativiste de l' e^-



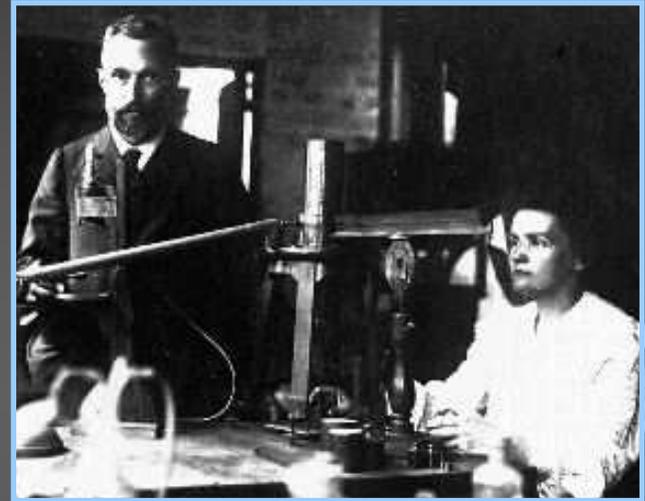
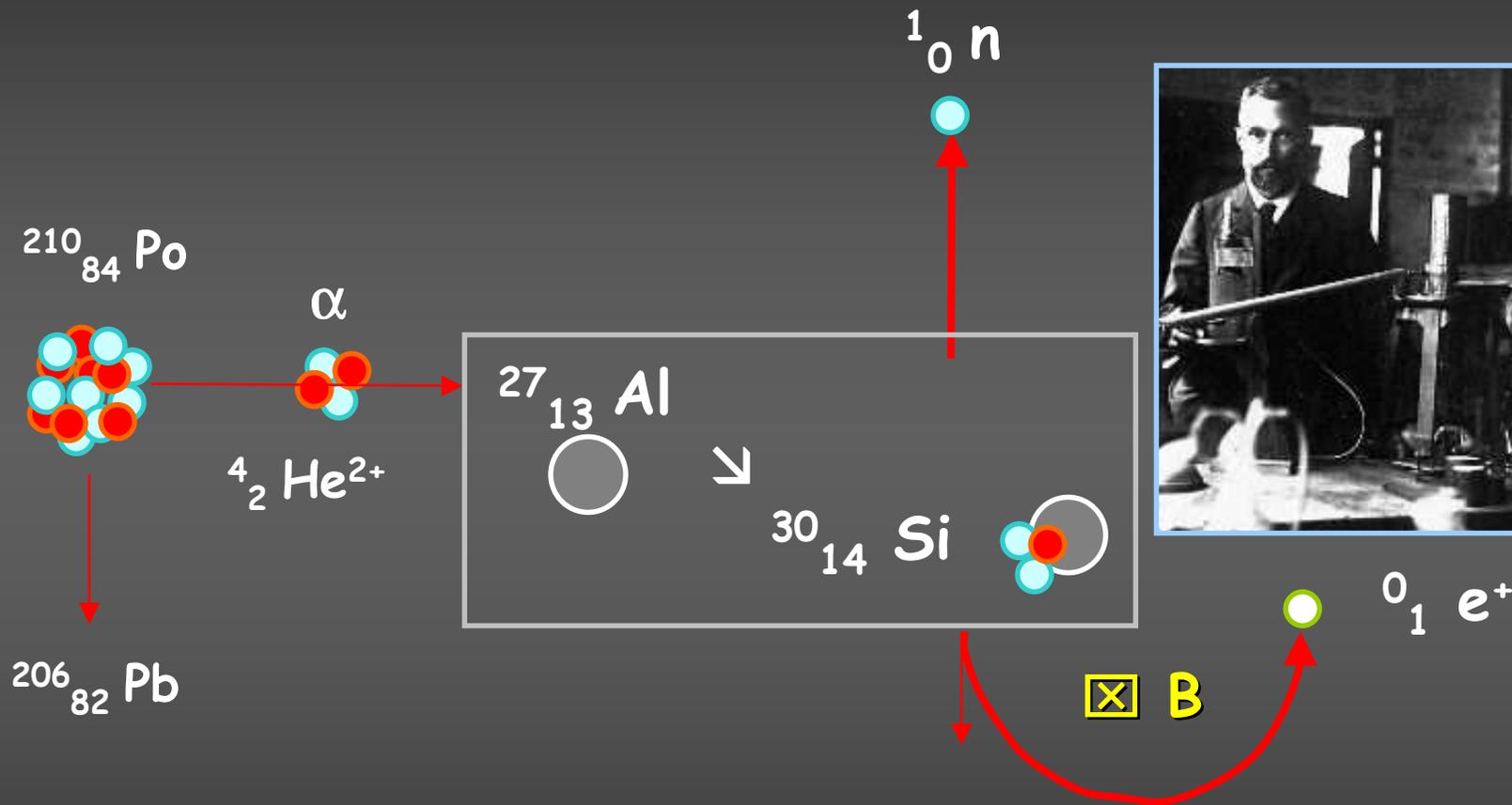
$e^- + e^+ \rightarrow \text{Energie}$

Renouveau de la physique théorique



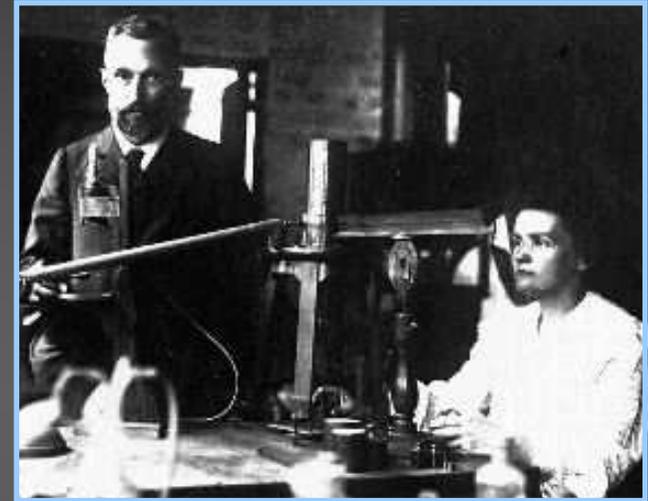
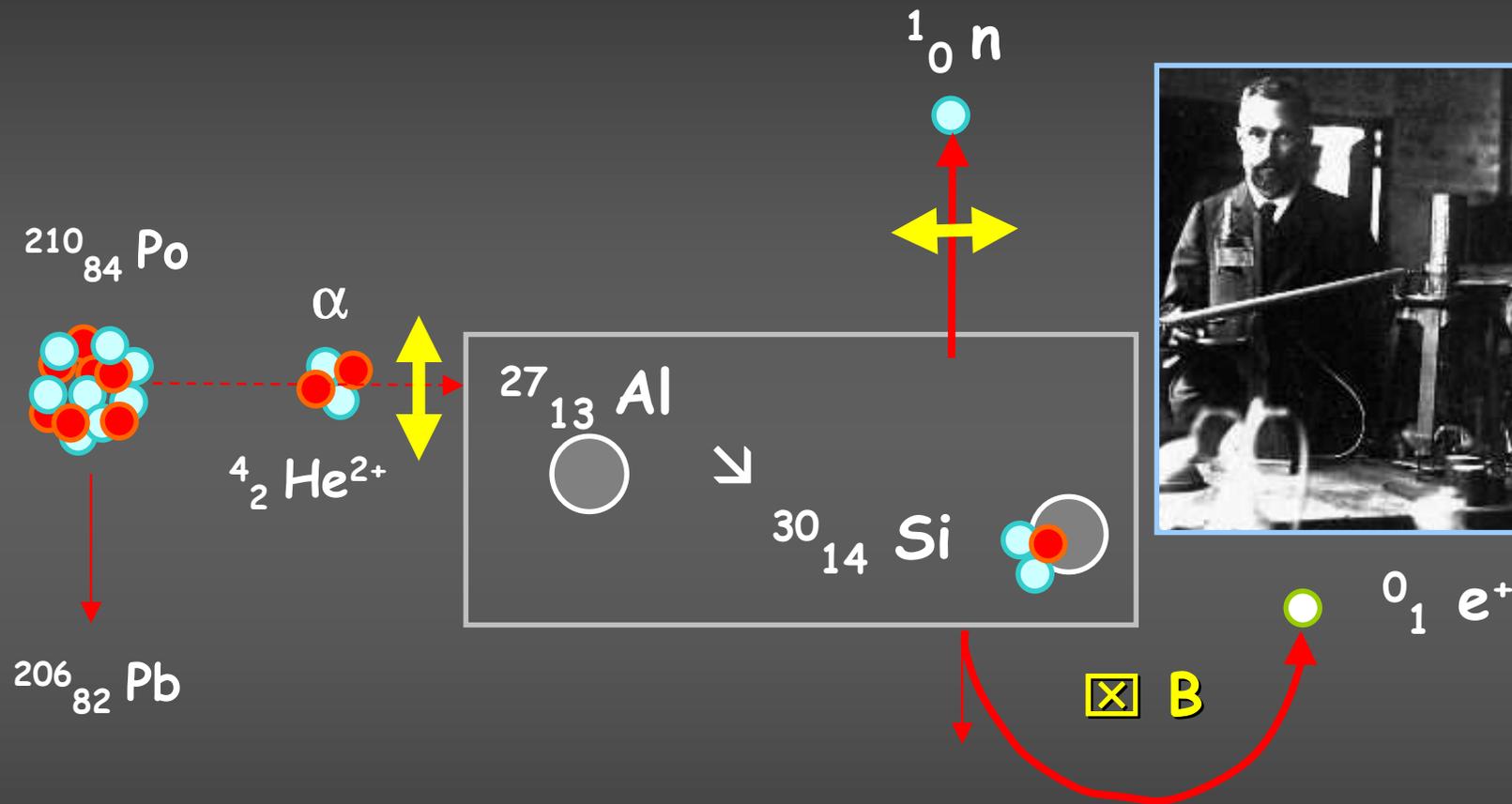
1932: C. Anderson :
Découverte d' e^+ dans le rayonnement cosmique

Les Curie, des alchimistes...

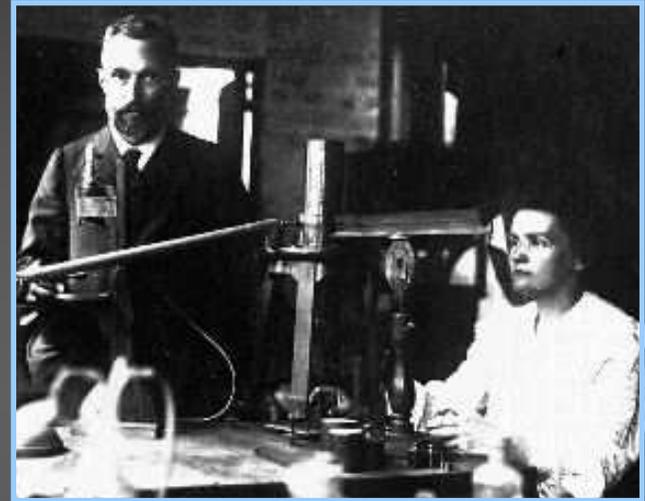
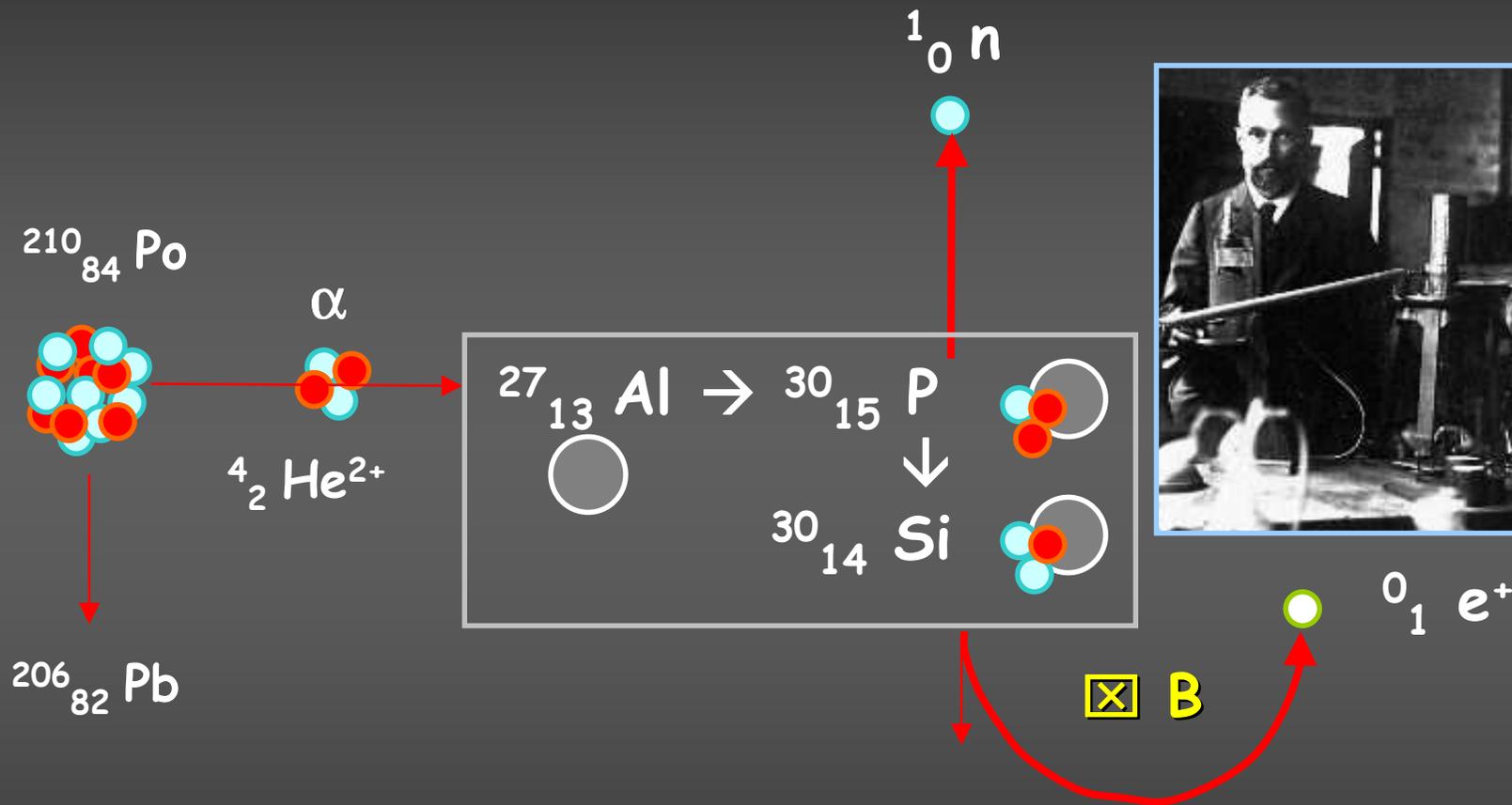


Reprise de l'expérience initiale de Bothe et Becker

...qui découvrent (aussi)...

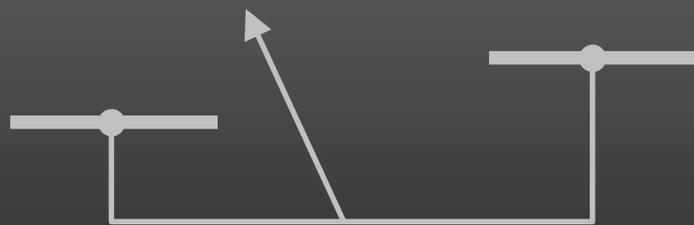
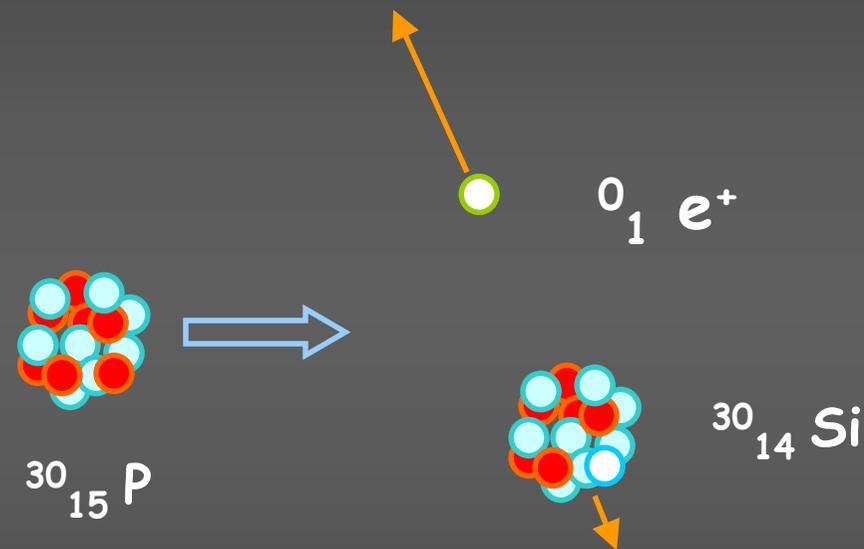


... la radioactivité artificielle

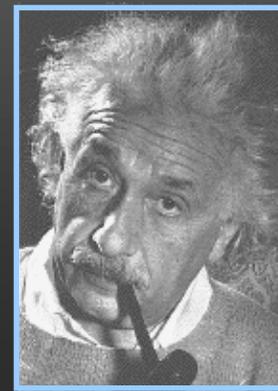


CRAS 15/1/1934 : RA artificielle et désintégration β^+

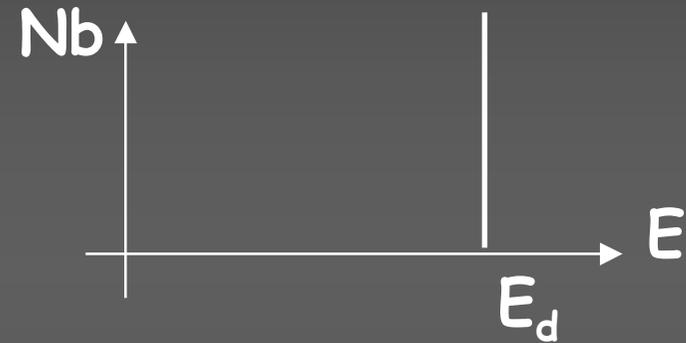
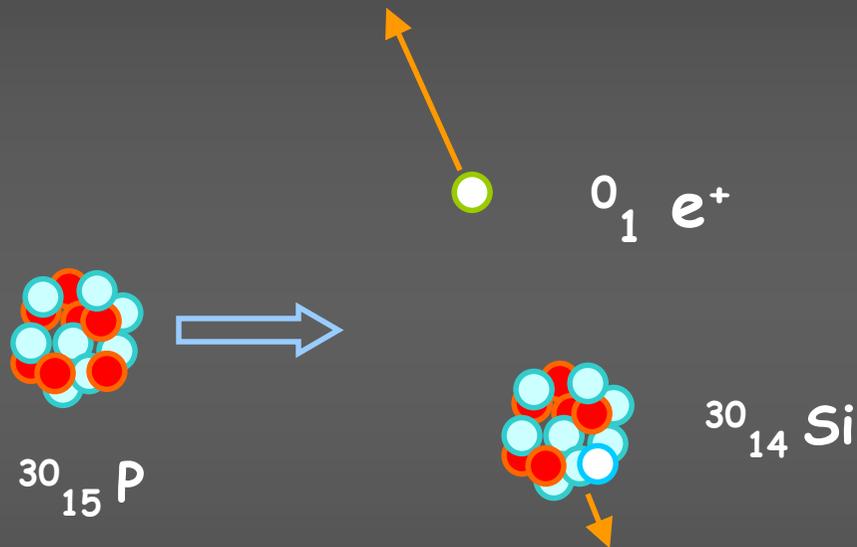
L'énergie du positon ...?



$$E_d = \{ M(\text{P}) - [M(\text{Si}) + m(e^+)] \} \cdot c^2$$

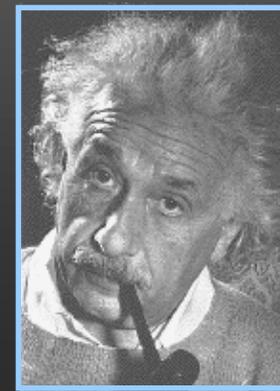


L'énergie du positon ...?

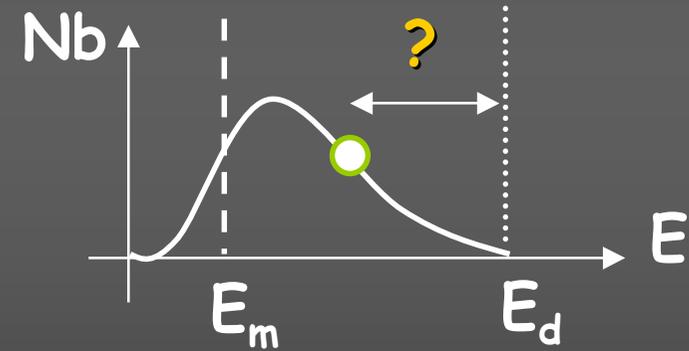
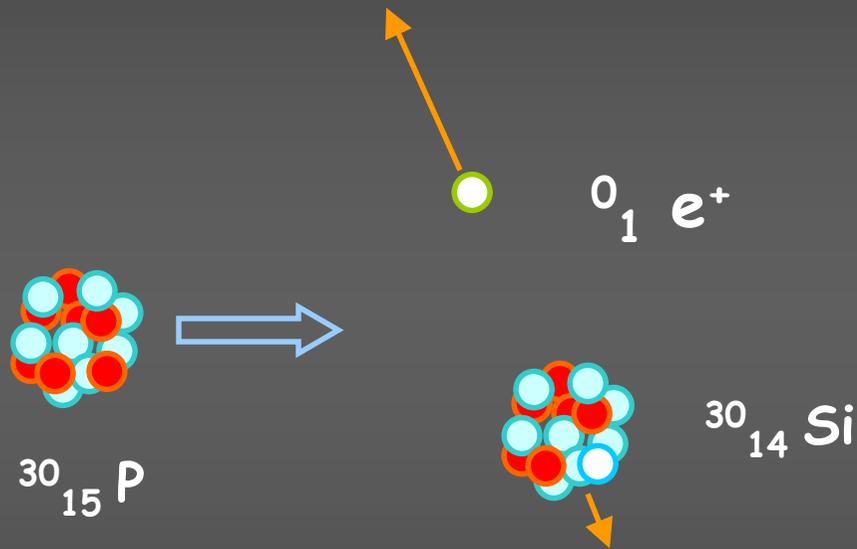


$$E = \frac{M_{\text{Si}}}{M_{\text{Si}} + M_e} E_d \approx E_d$$

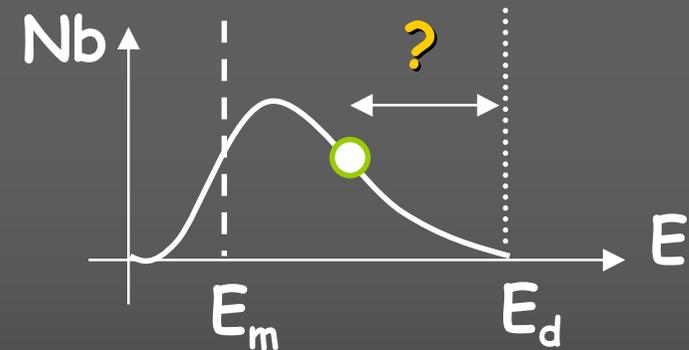
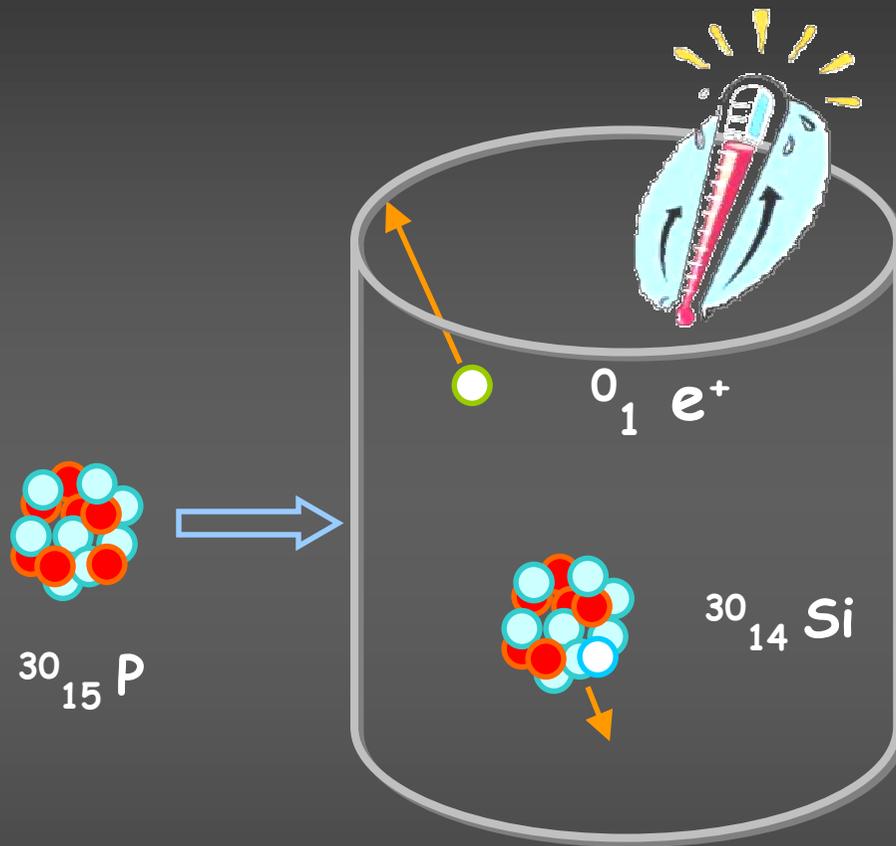
$$E_d = \{ M(\text{P}) - [M(\text{Si}) + m(e^+)] \} \cdot c^2$$



...est elle perdue ?...



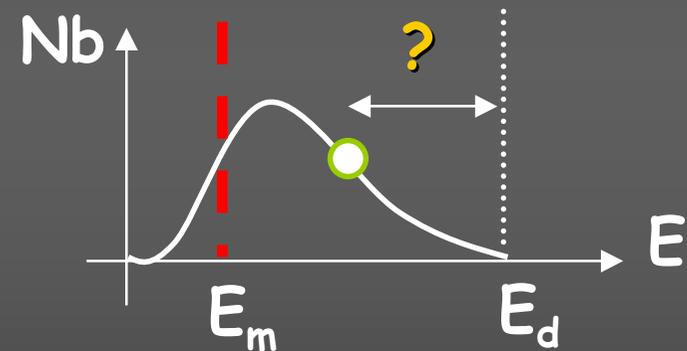
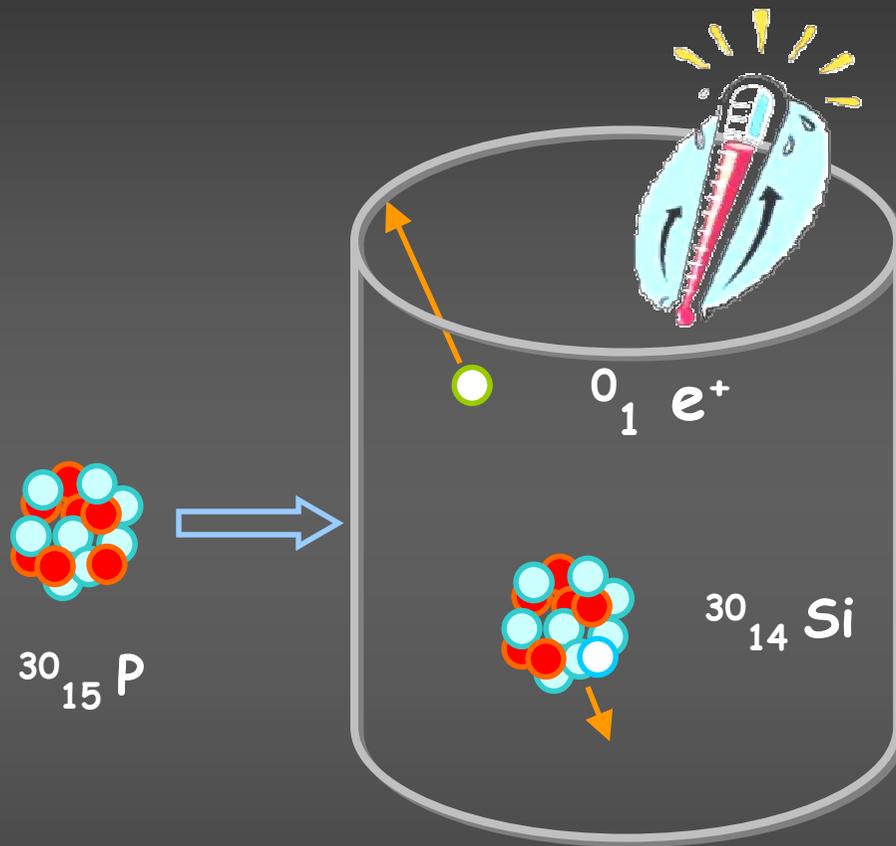
...est elle perdue ?...



1922, Meitner : ralentissement des e^-
1925, Ellis et Wooster : calorimétrie



...est elle perdue ?...



1922, Meitner : ralentissement des e^-
1925, Ellis et Wooster : calorimétrie $\Rightarrow E_m \approx E_d / 3$



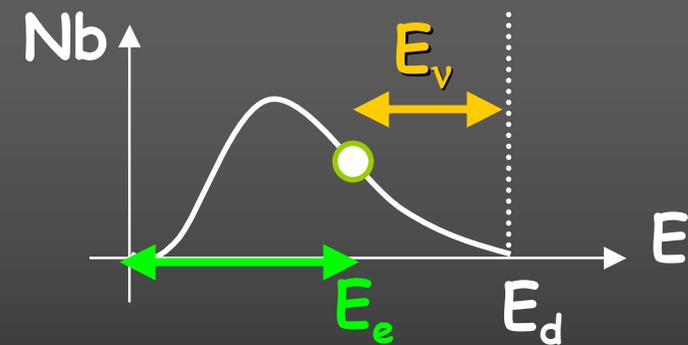
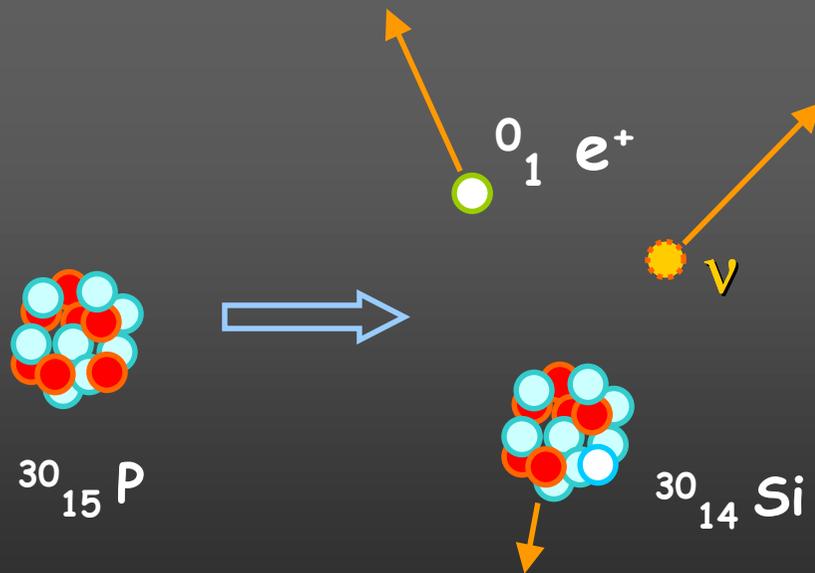
La lettre de Pauli à Meitner et Geiger



W. Pauli : 1930

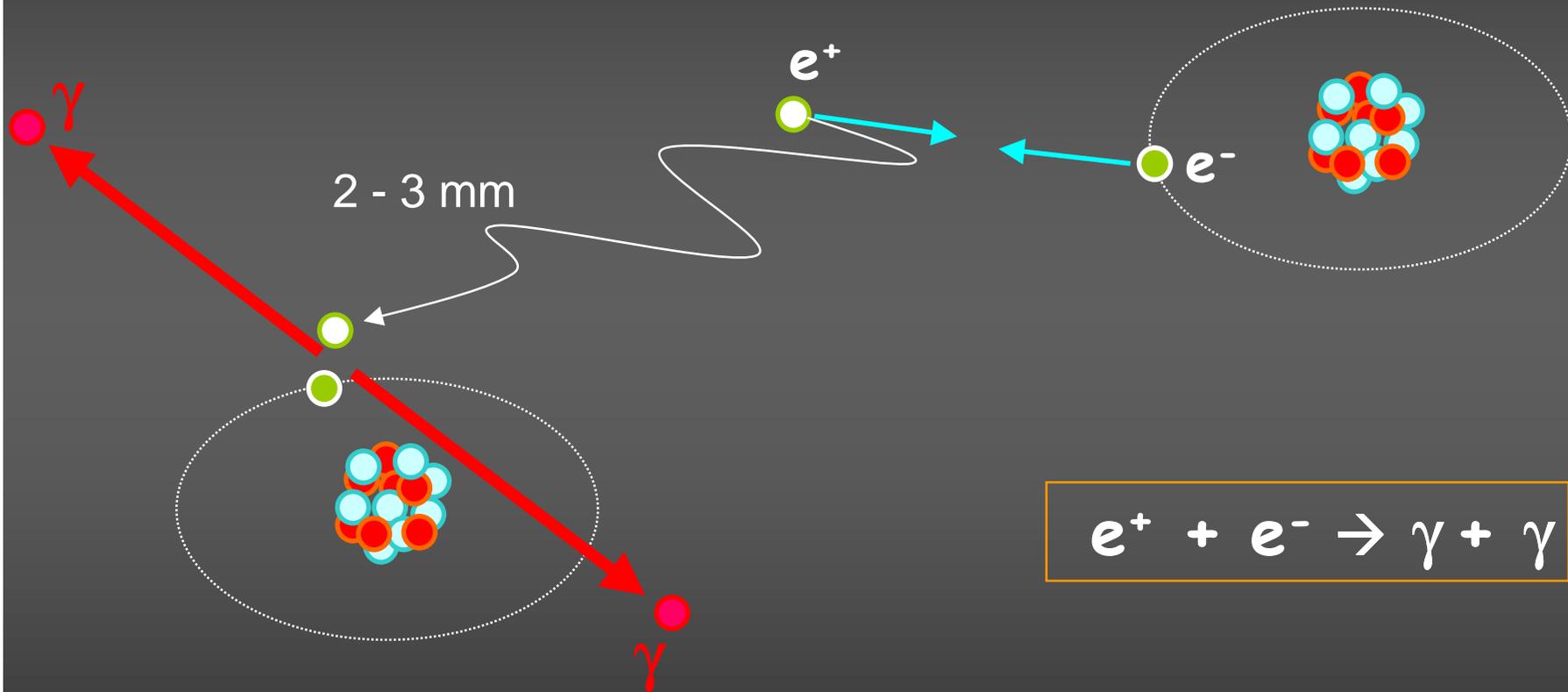


E. Fermi : 1934



ν : neutrino,
de masse et de charge nulle

Que devient le positron émis ?

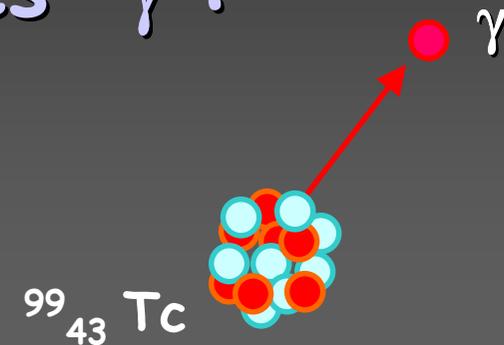


2 PHOTONS partant a 180°
d'énergie $E = 511 \text{ keV} = m_e c^2$

Donc, 2 familles d'émetteurs γ :

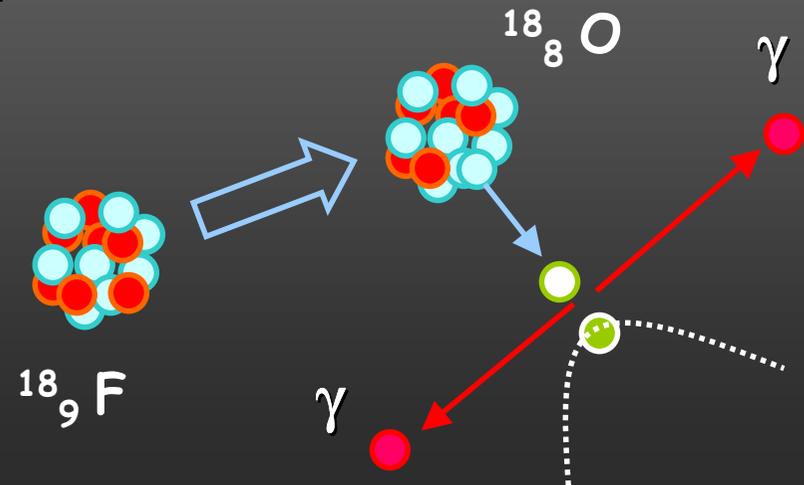
- Emetteurs de photons uniques γ :

- Tc, (Xe, Kr, Ga, Tl, In ...)



- Emetteurs de positons β^+ :

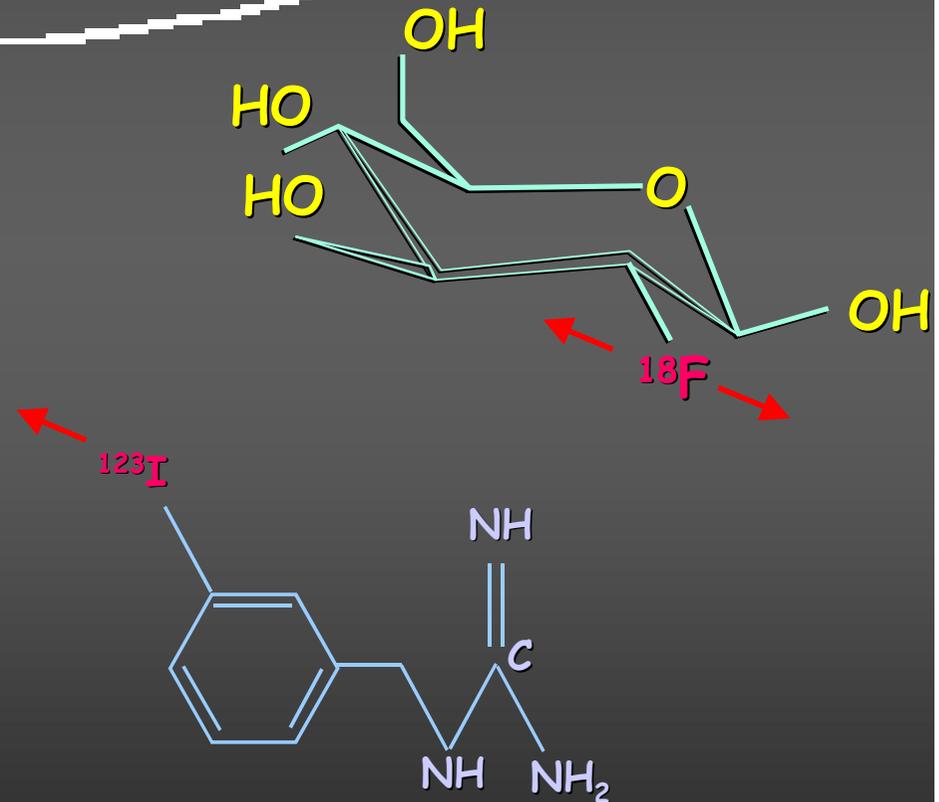
- F, (C, N, O, ...)



Principes de la médecine nucléaire



Si on accroche
un atome radioactif γ ou β^+ (**marqueur**)
à une molécule biologiquement active (**vecteur**) ...
On obtient un
TRACEUR METABOLIQUE DETECTABLE



On pourra alors
créer une
image
FONCTIONNELLE...

...et même irradier
in situ des tumeurs !

...mais il faut
produire
des isotopes...



...et détecter
les photons γ !

Fabrication des isotopes

Séparation isotopique des produits de fission : ^{99}Tc , ^{131}I , ^{133}Xe

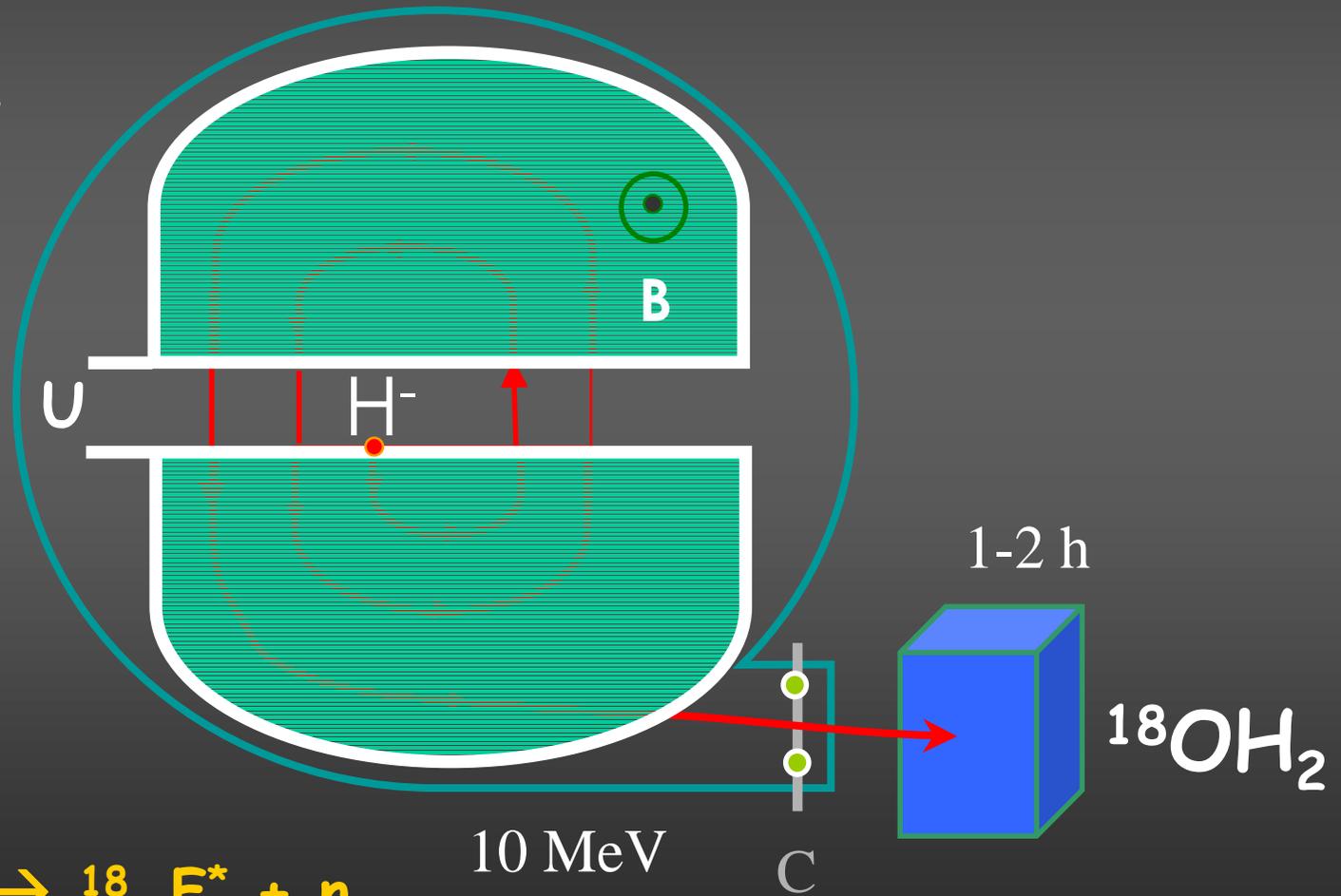


Bombardement particulaire : ^{18}F , ^{201}Tl , ^{123}I , ^{111}In , ^{67}Ga

• **CYCLOTRON** : Exemple du $^{18}_9\text{F}$

Le cyclotron (E Lawrence 1930)

$$evB = mv^2/R$$



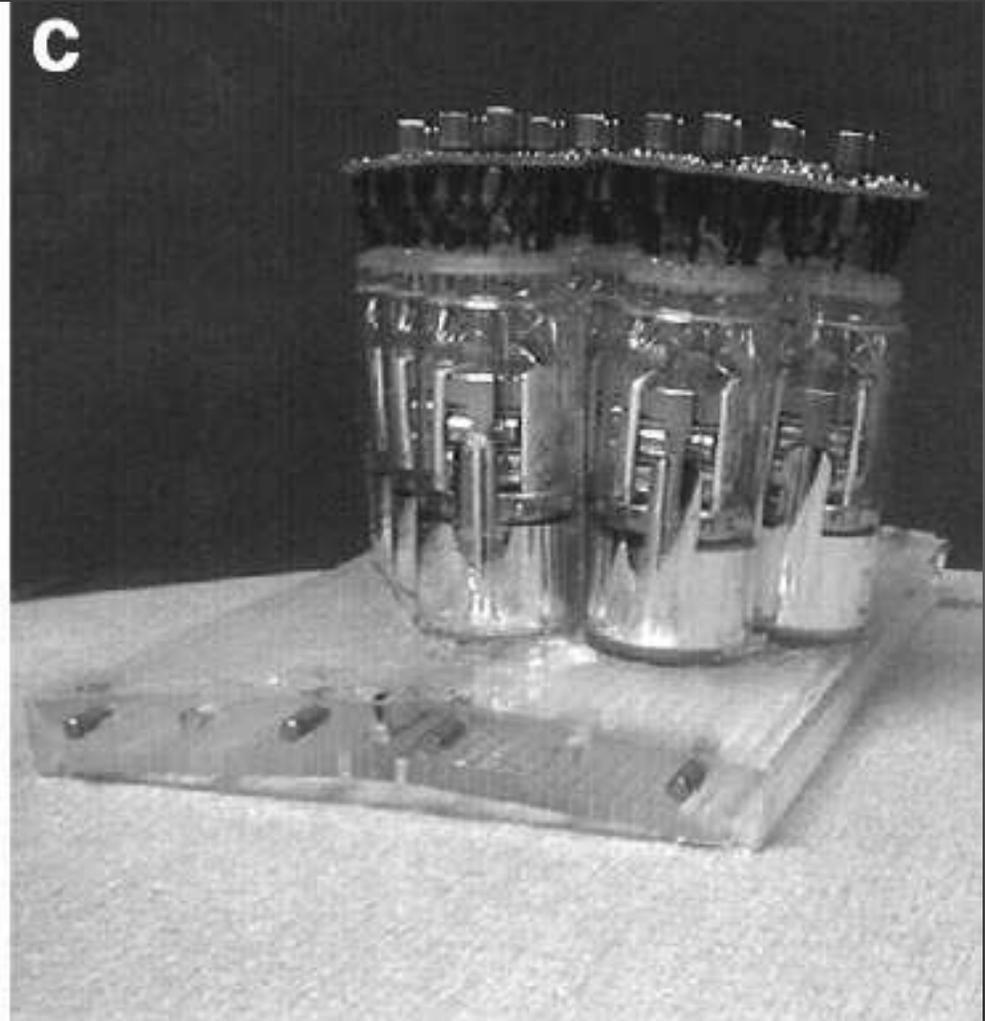
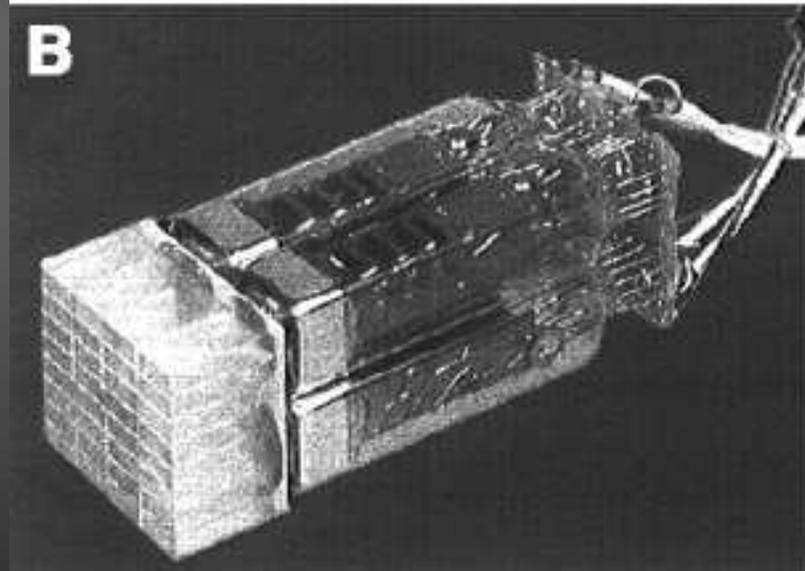
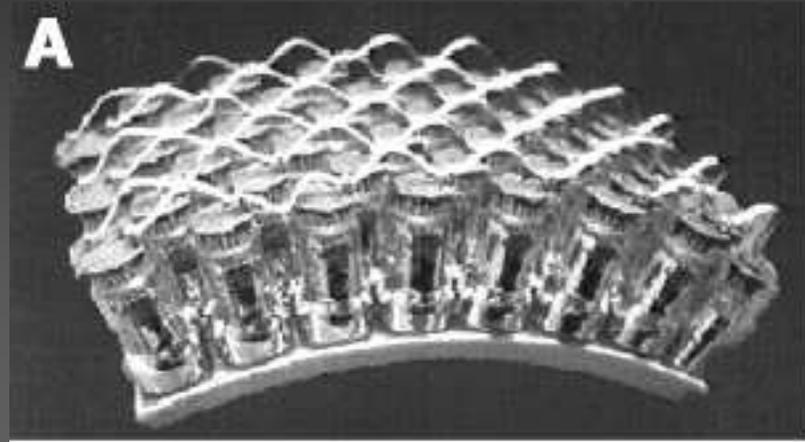
10 MeV

C

1-2 h

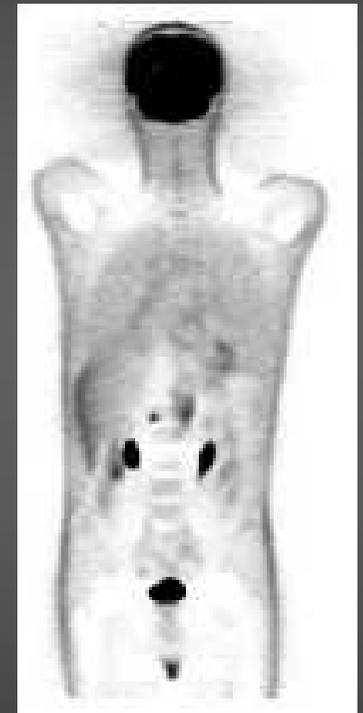
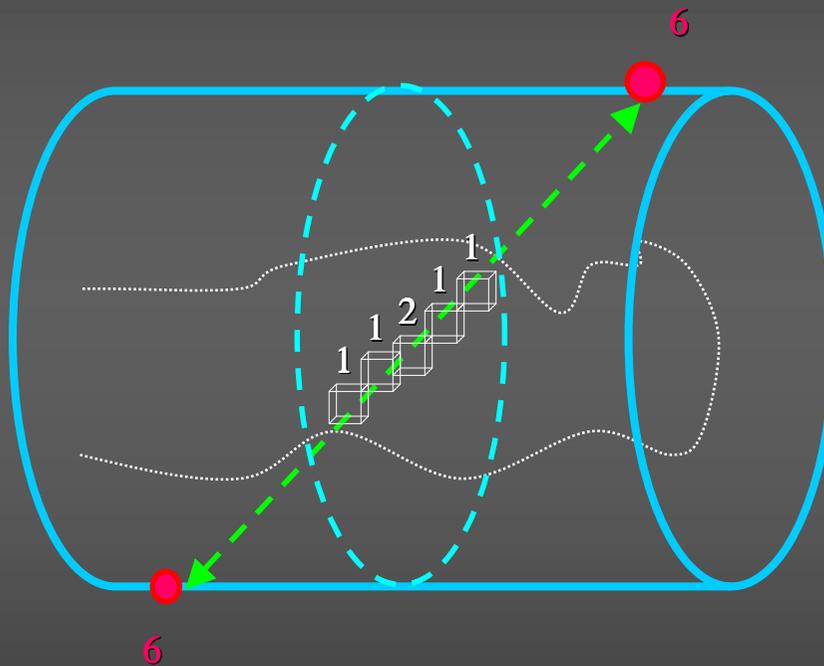
$^{18}OH_2$

Détecteurs de photons γ (Anger 1956)

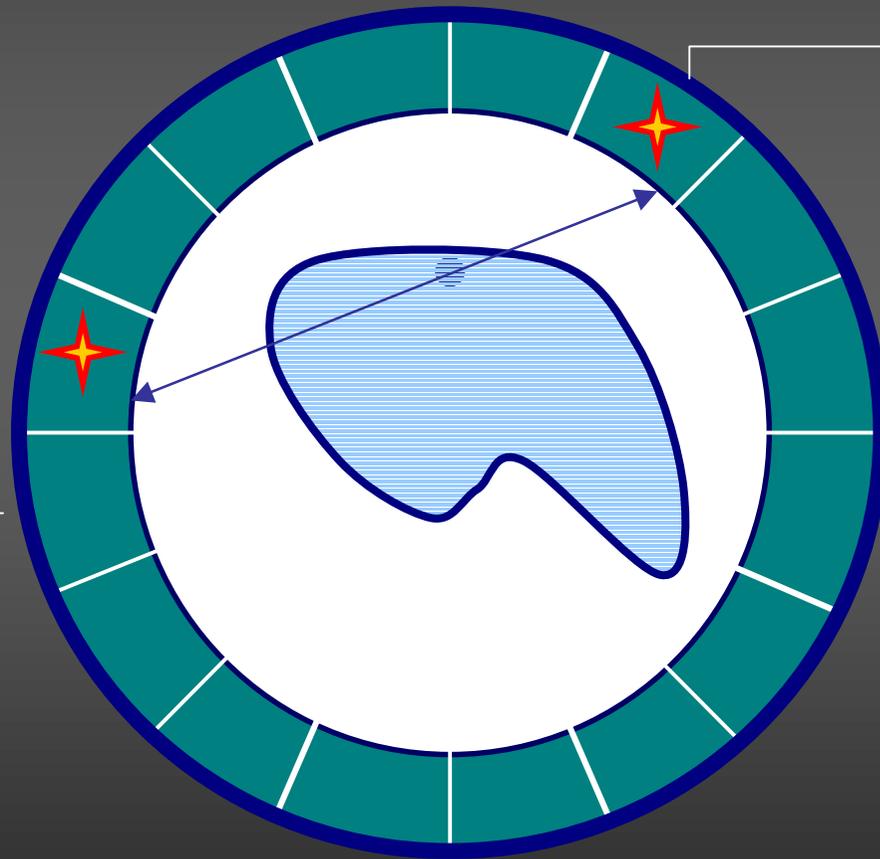


Le tomographe par émission de positons

Tomographie par émission d'e⁺

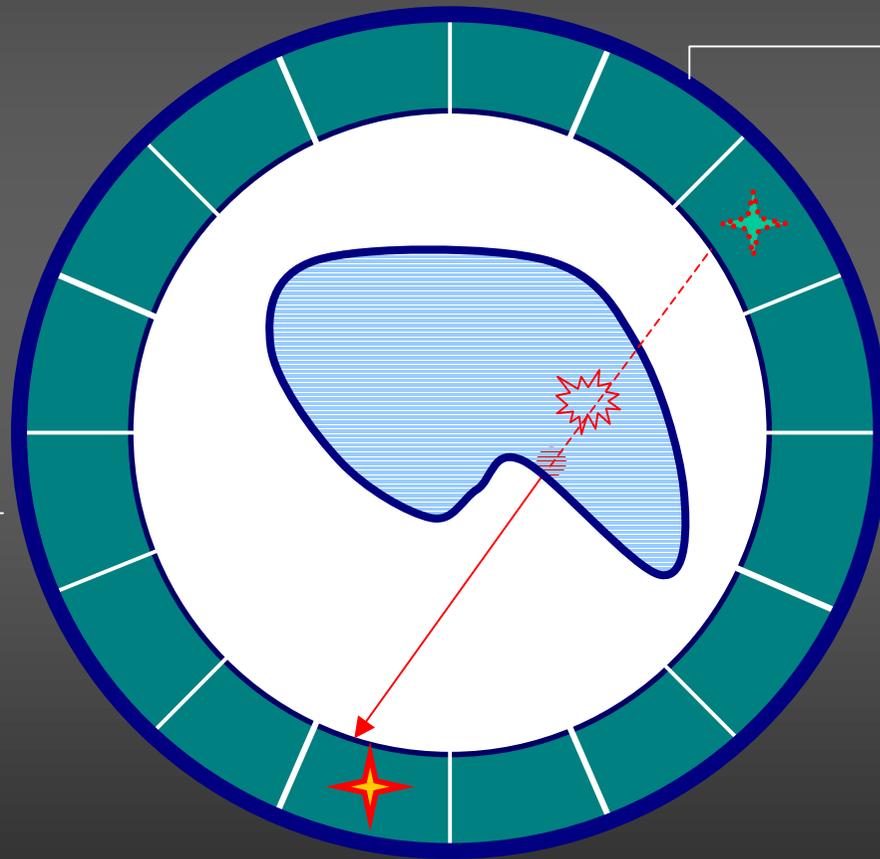


Artefacts de détection



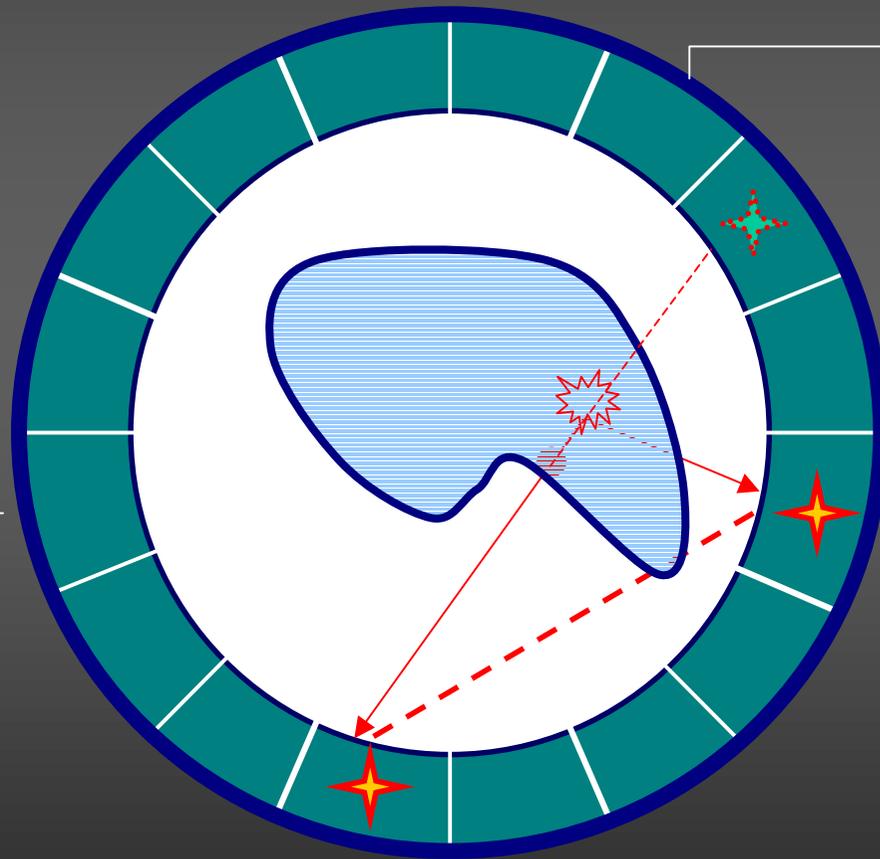
Fenêtre de détection des coïncidences

Artefacts de détection



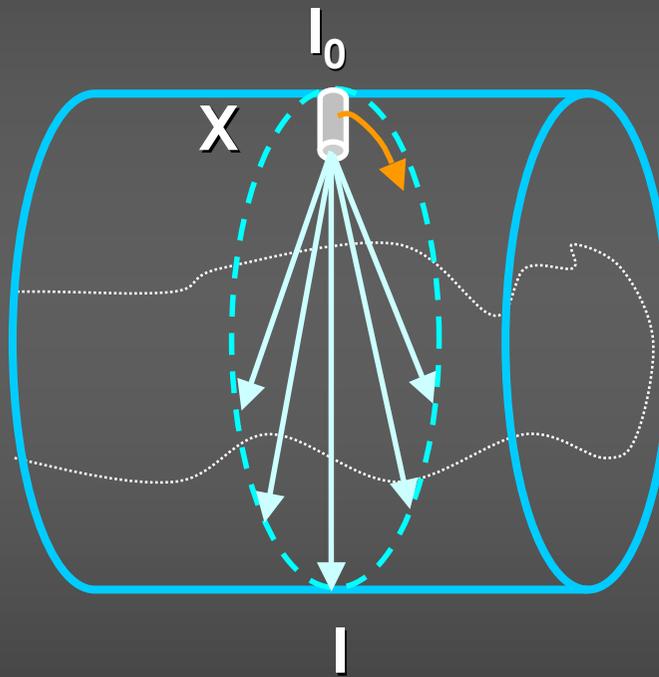
Fenêtre de détection des coïncidences

Artefacts de détection



Fenêtre de détection des coïncidences

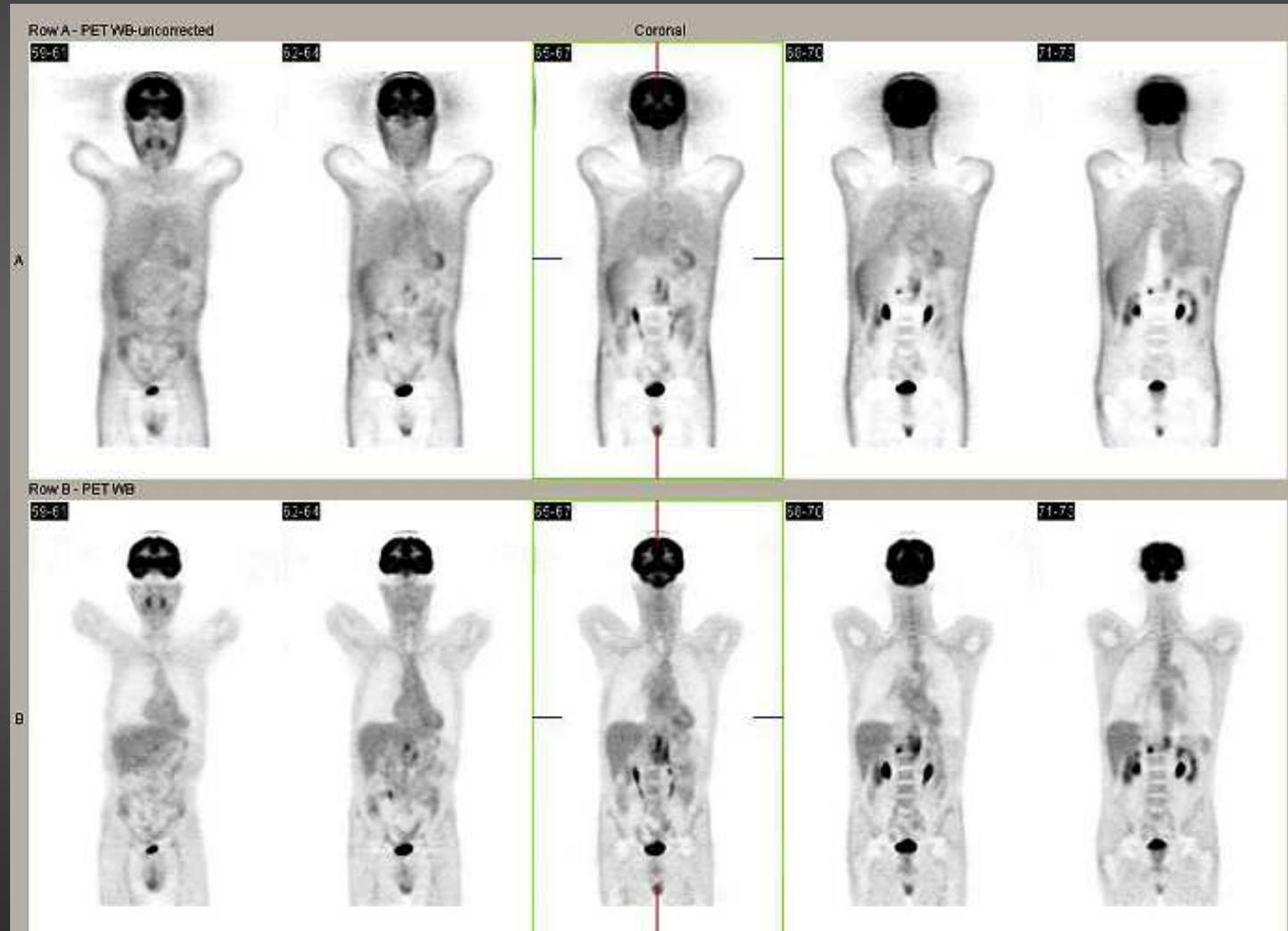
Tomographie de transmission



$$\ln\left(\frac{I}{I_0}\right) = k.(\rho_1 + \rho_2 + \dots + \rho_n)$$

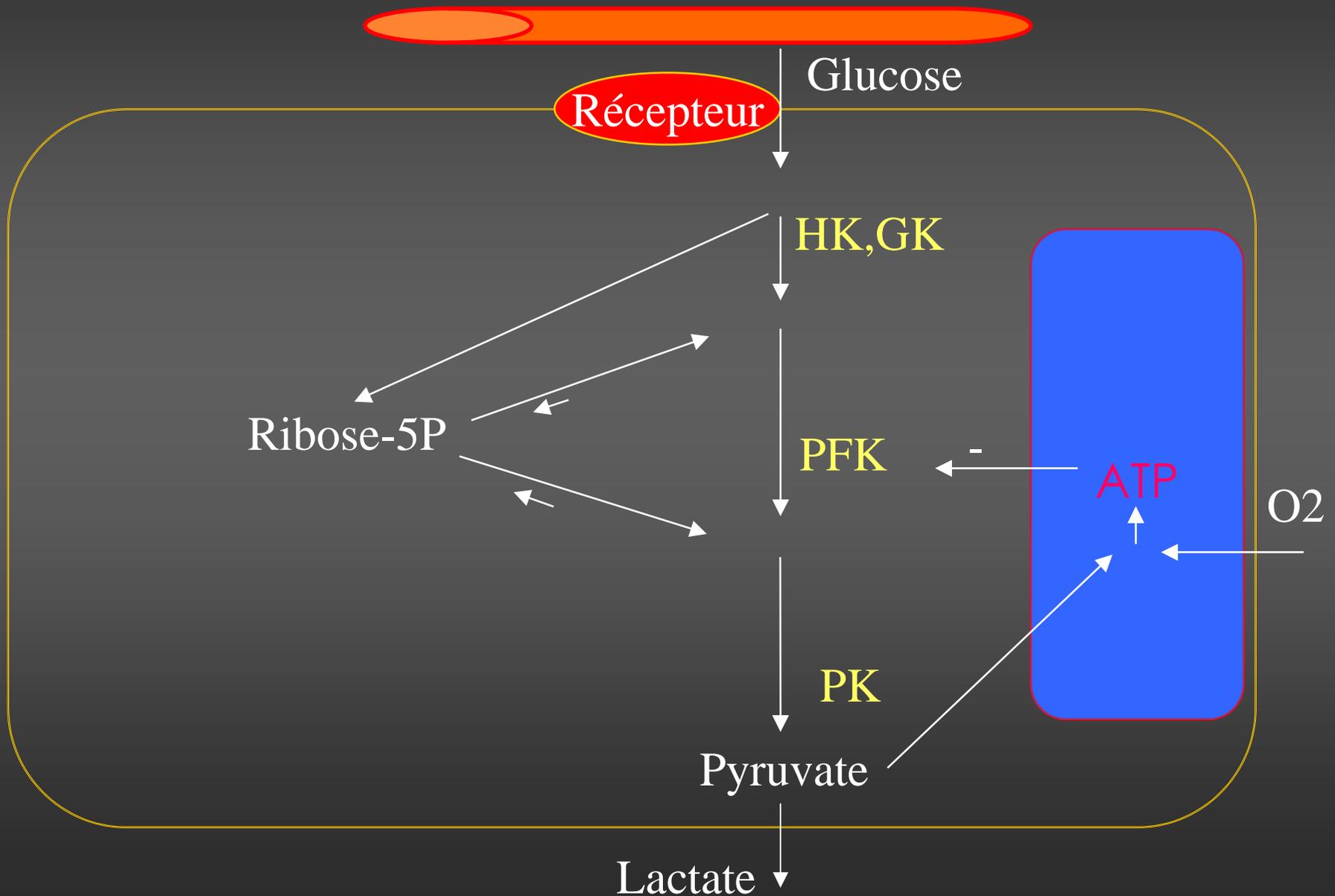
Imagerie TEP-TDM (PET-SCAN)

- Correction d'artefacts
- Localisation anatomique

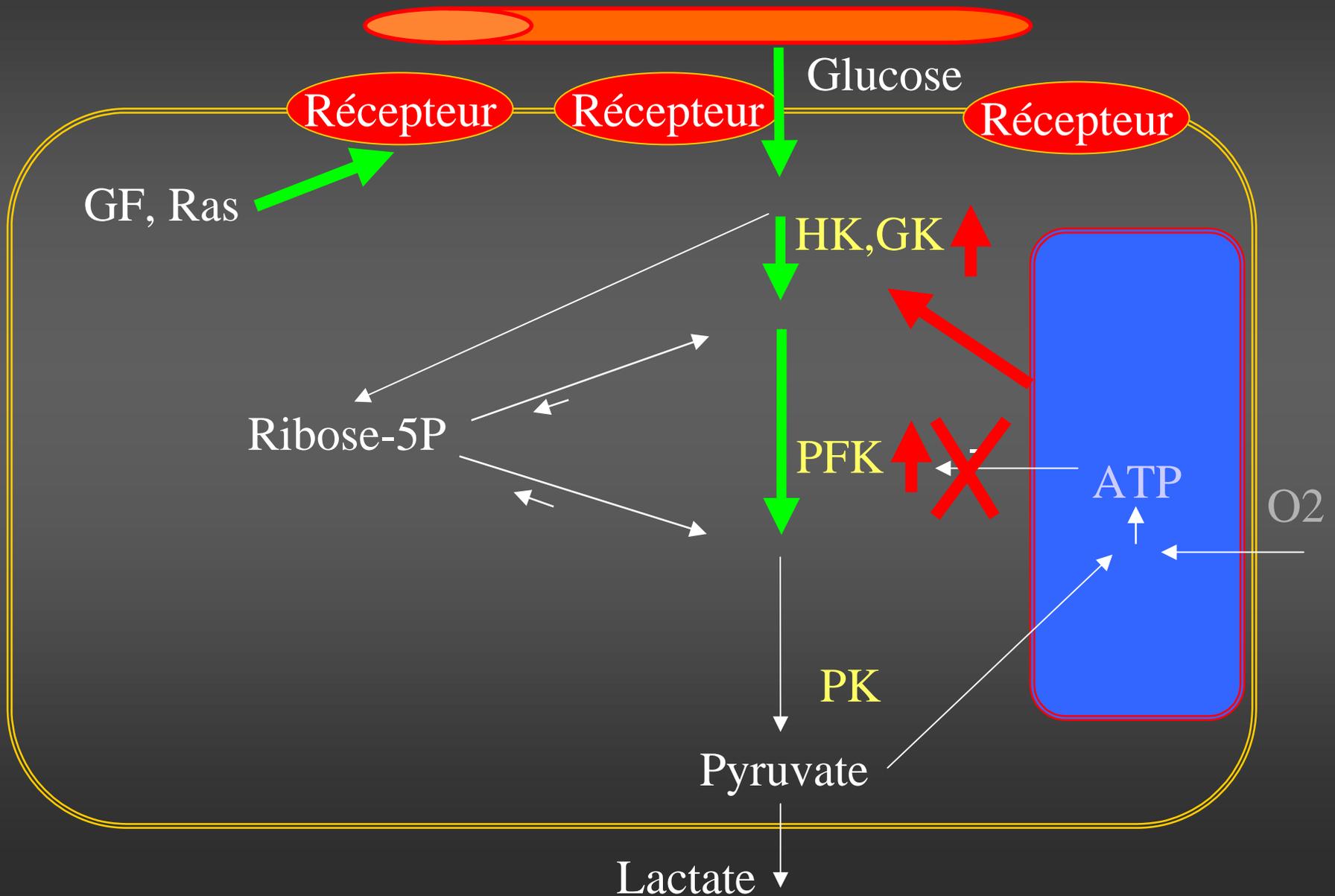


Exemples cliniques en cancérologie

Métabolisme cellulaire du glucose



Cas d'une cellule cancéreuse

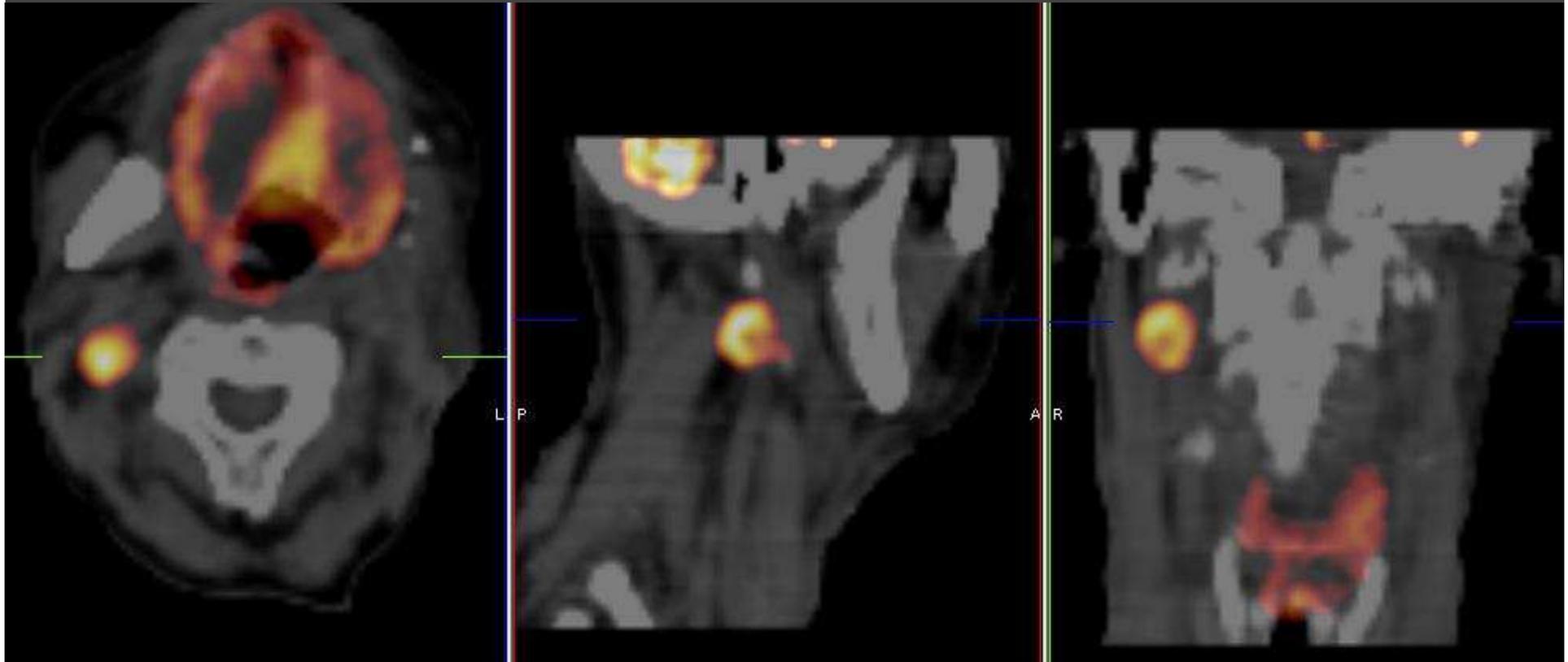


Fixation normale du FDG

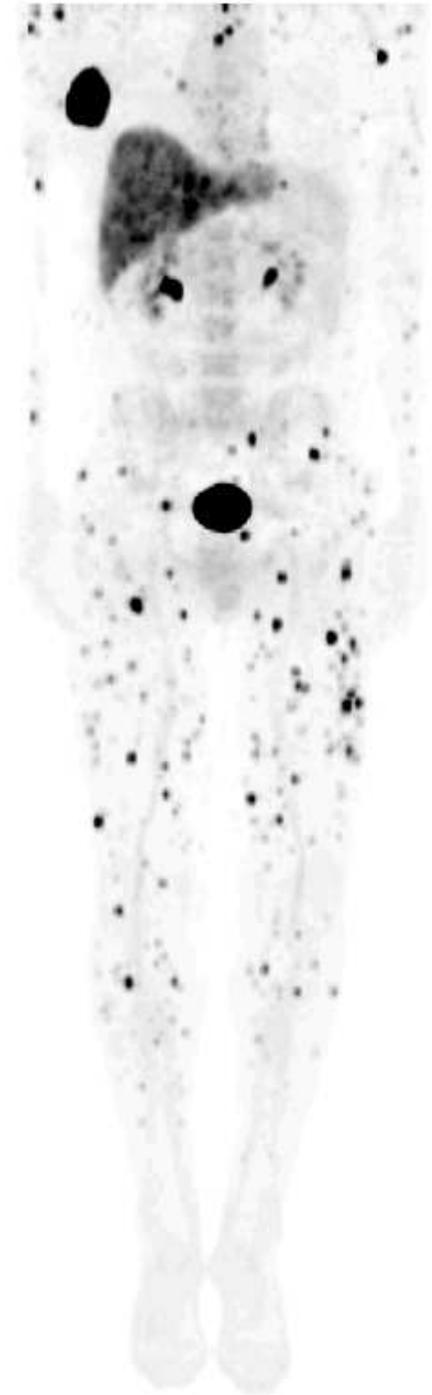
Cerveau
Tissu lymphoïde
Cœur
Urine
± Foie, rate



Cancer ORL



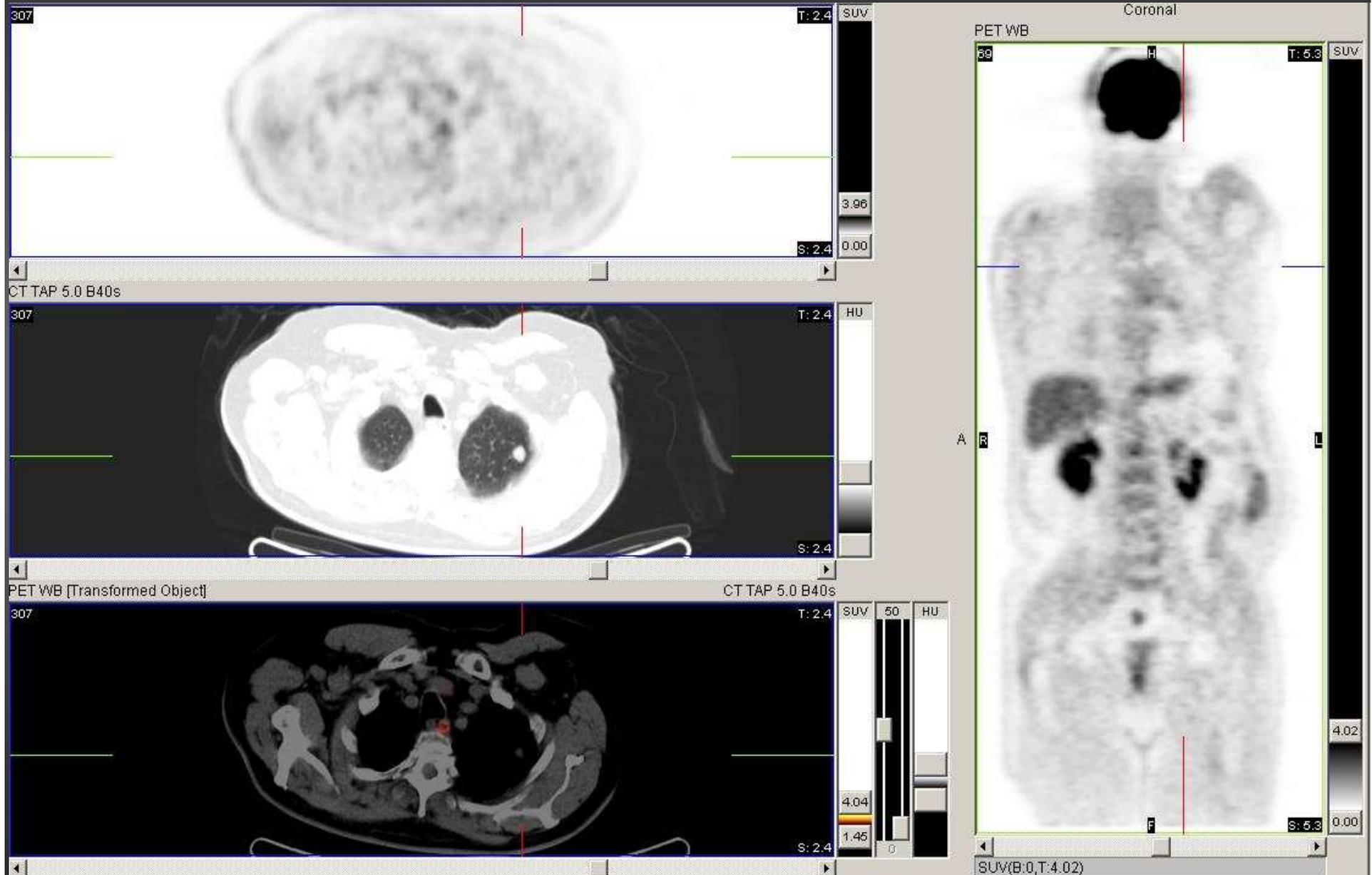
Mélanome



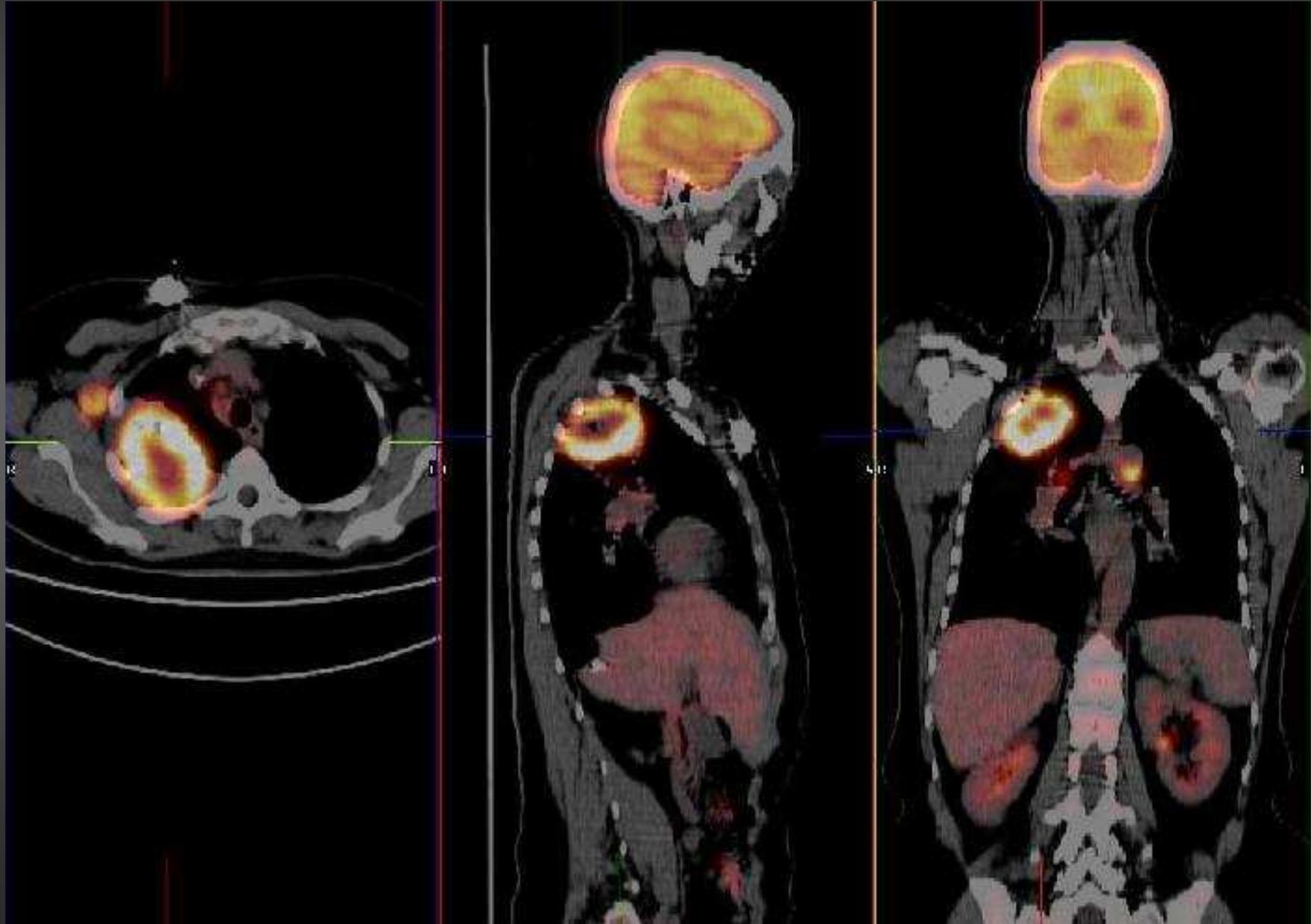
Lymphome agressif



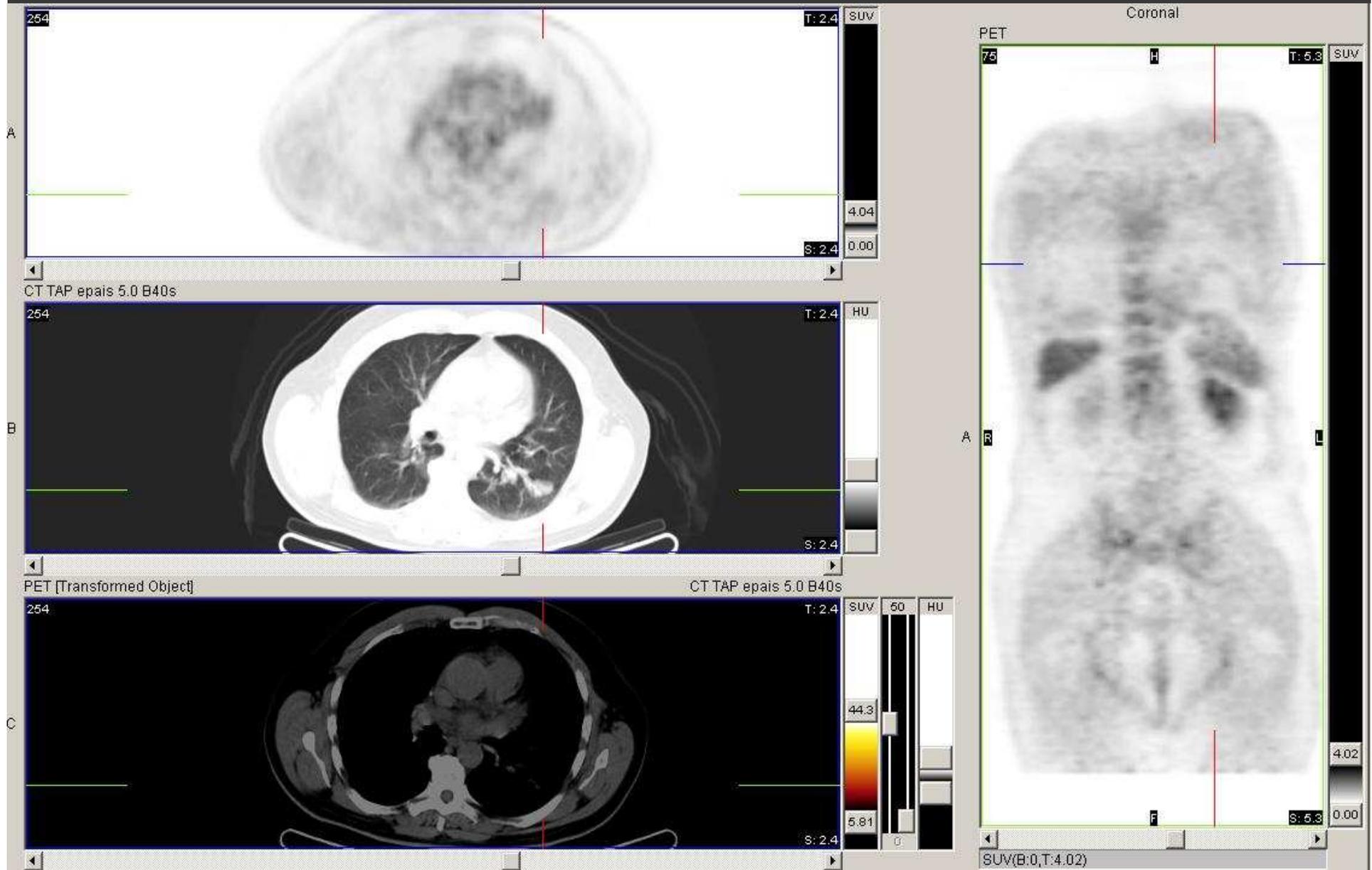
Poumon : nodule bénin (I)



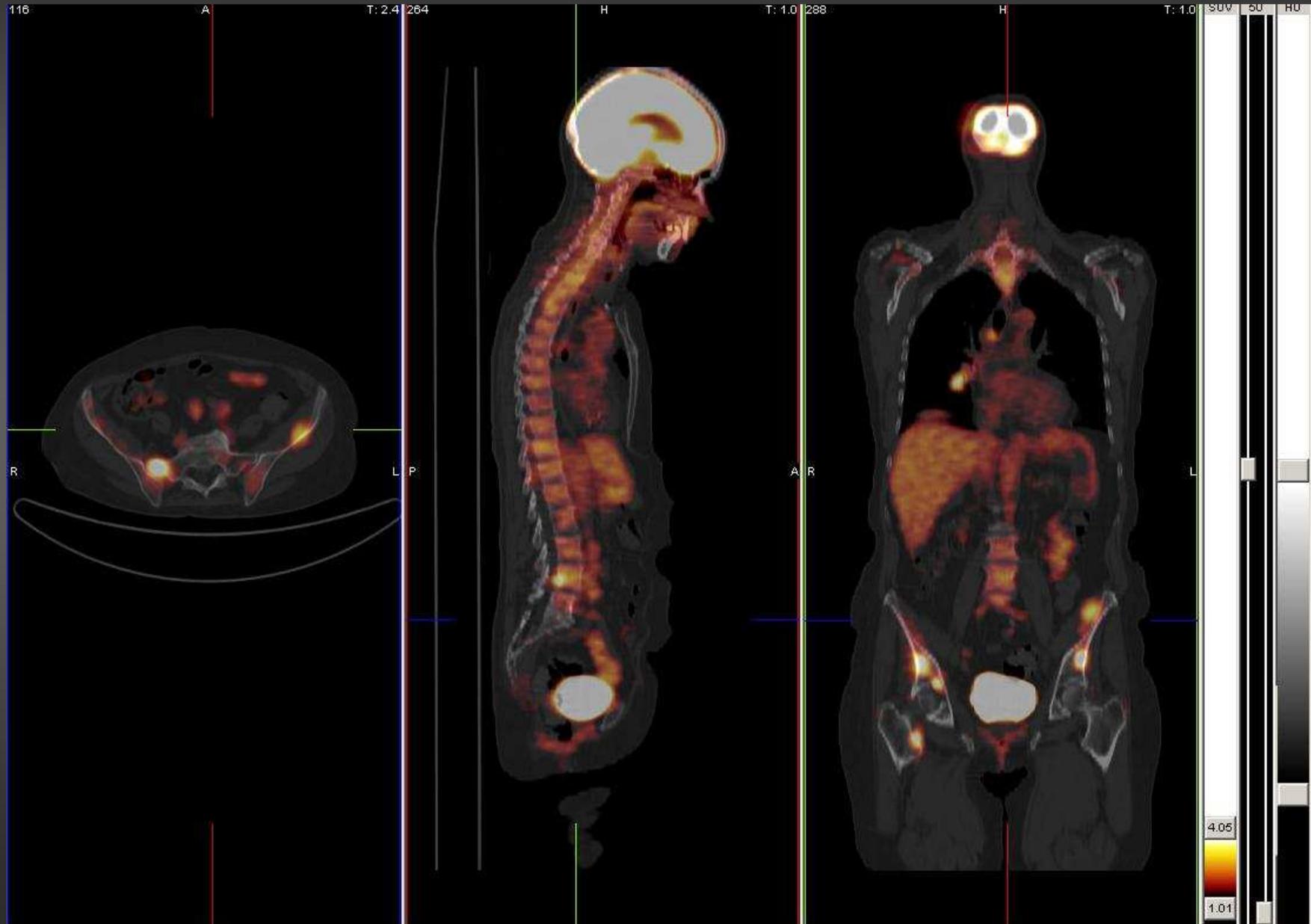
Poumon : ADC (II)



Poumon : CBA (III)

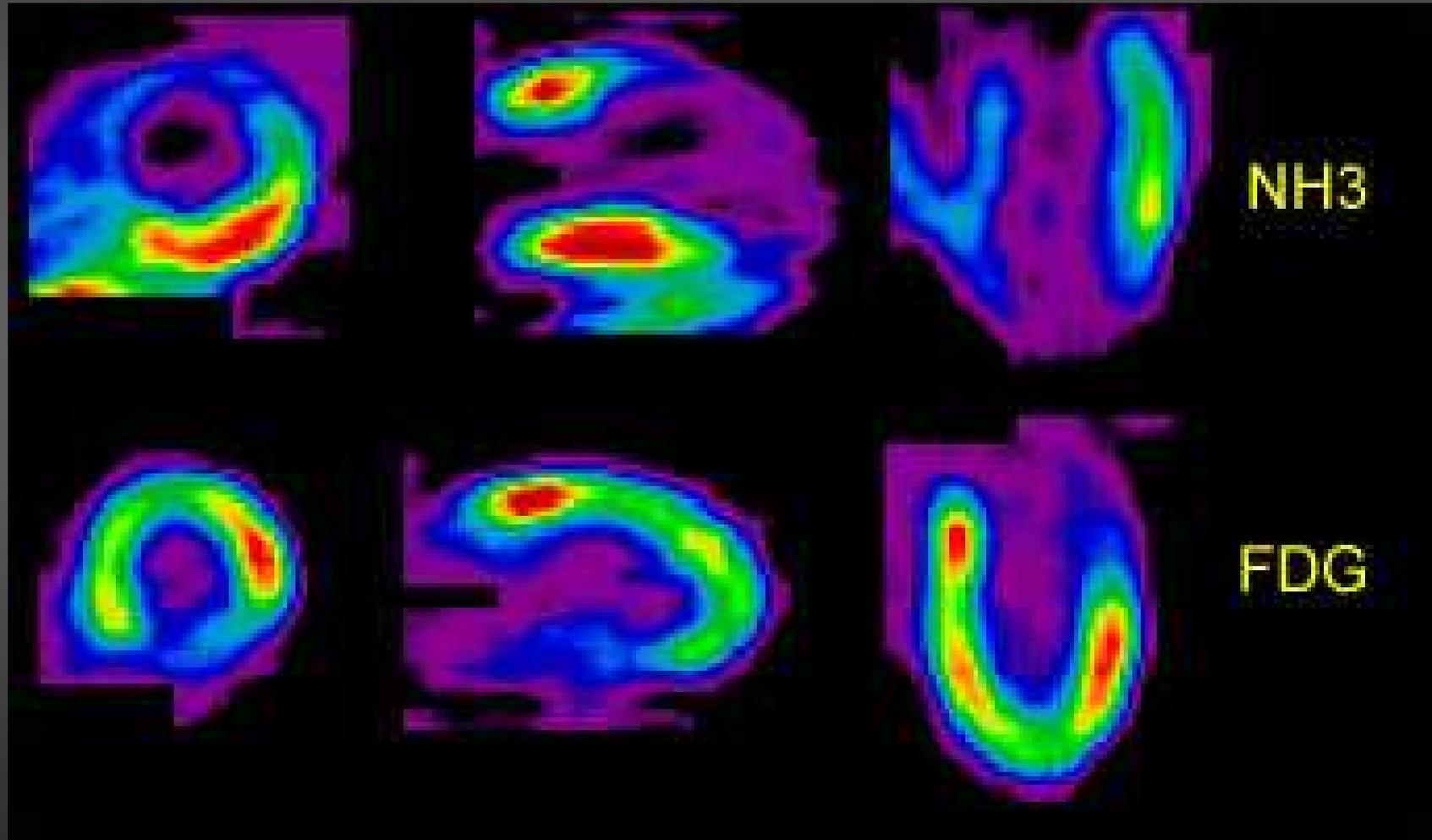


ATCD cancers du rein et du rectum



**Perspectives pour un futur
proche...**

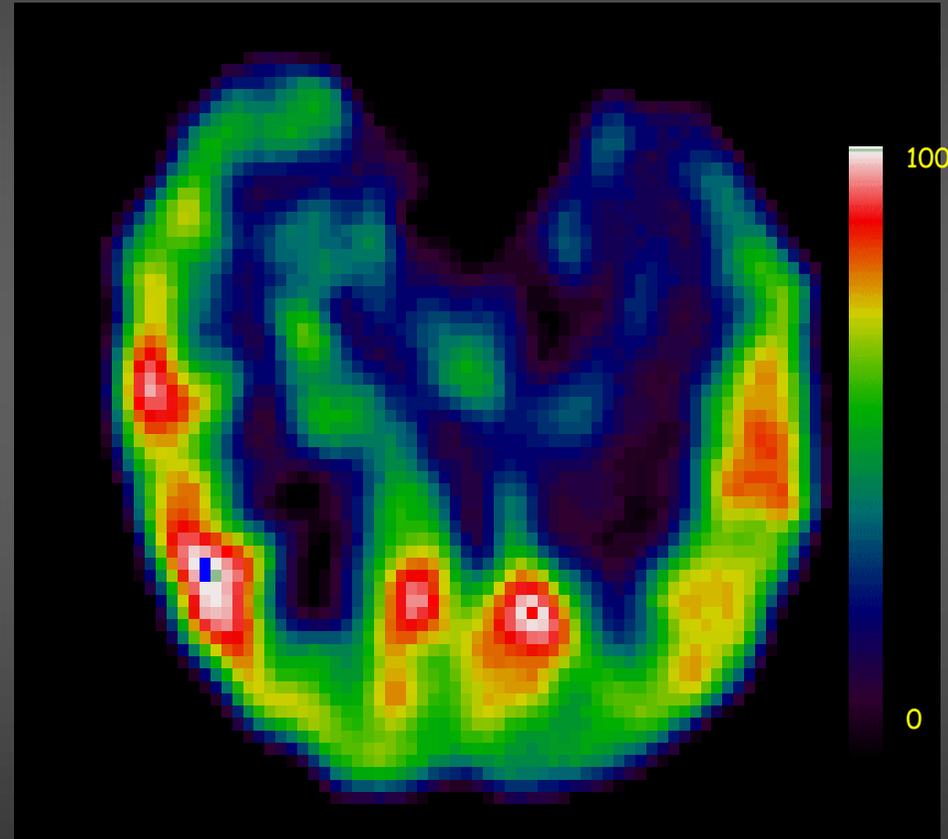
Hibernation myocardique



Epilepsie temporale gauche

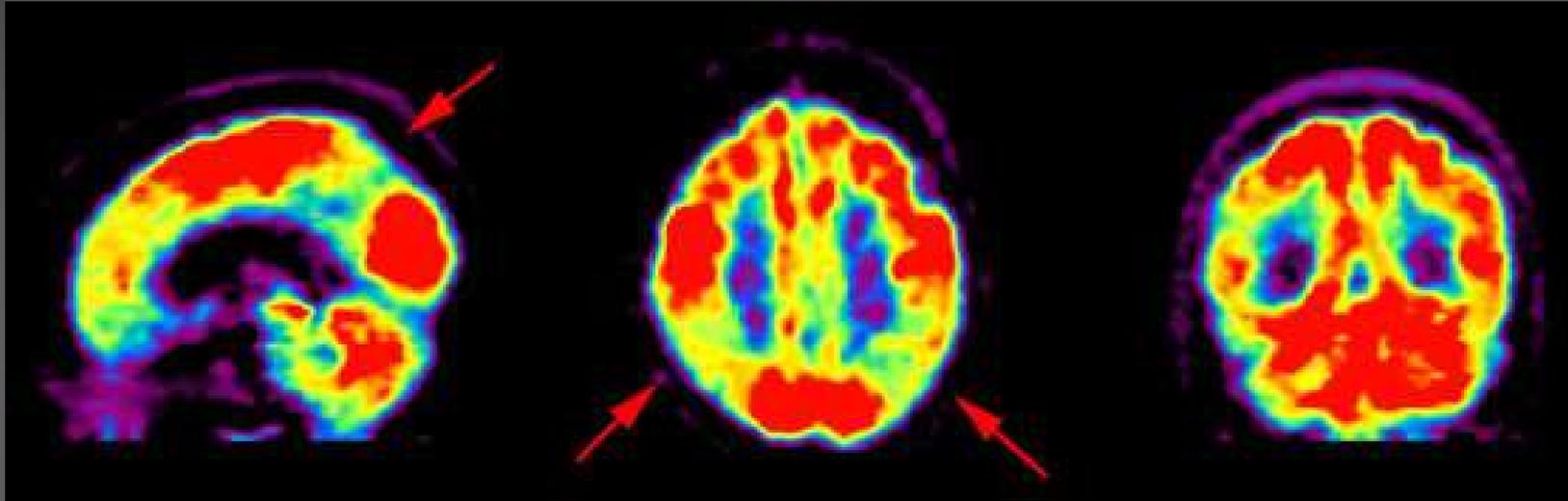


IRM



FDG-TEP

Maladie d'Alzheimer

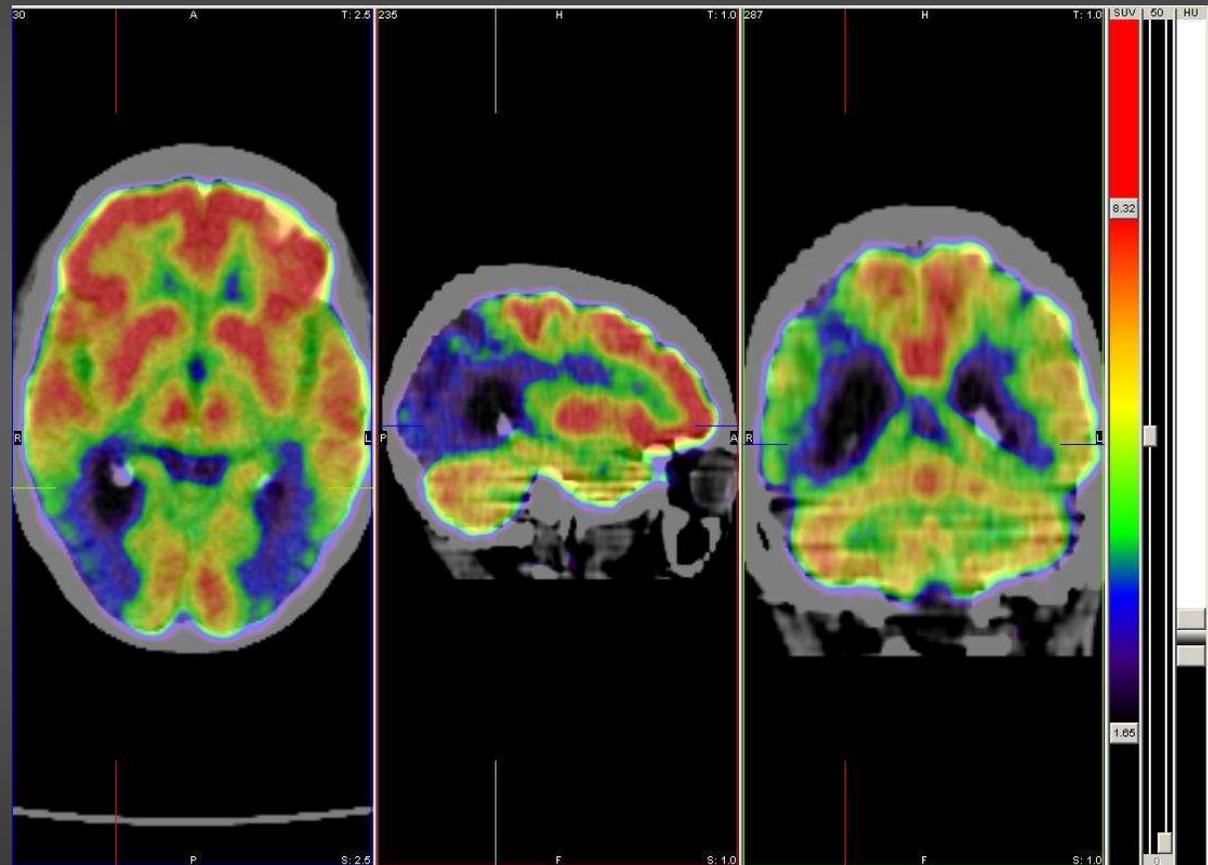


Hypofixation temporo-pariétale du FDG

Paralyse psychique du regard

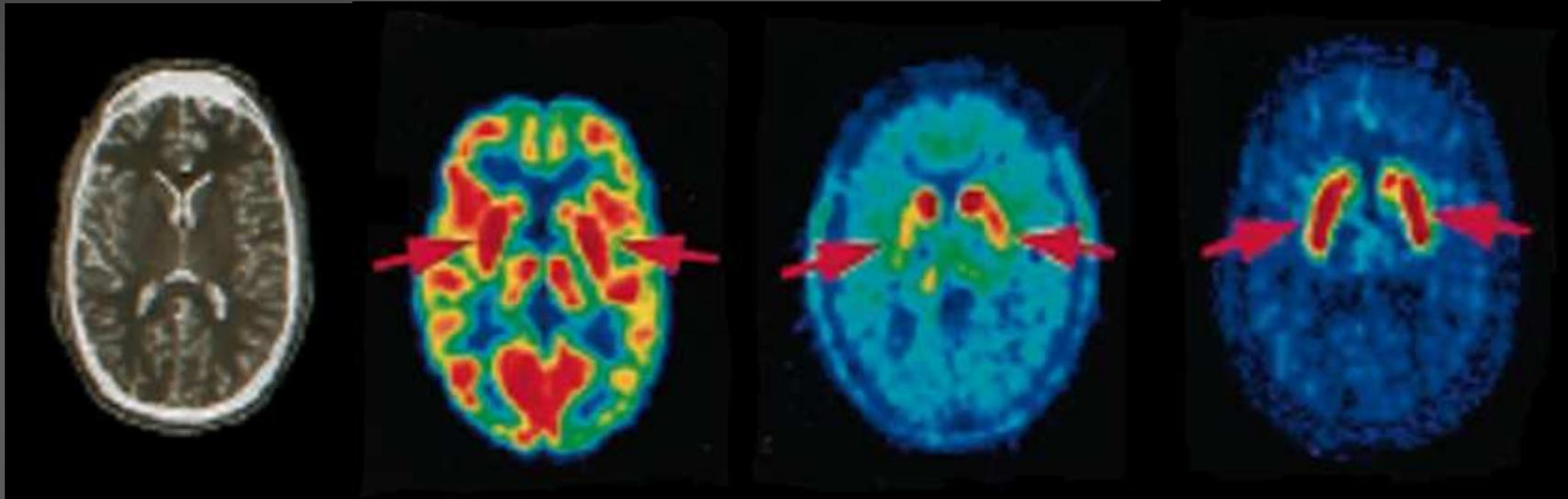
Incapacité à :

- ① orienter le regard
- ② saisir un objet présenté à la vue
- ③ reconnaître plusieurs objets visuellement



« L'imagerie moléculaire »

Hémi Parkinson cliniquement gauche



IRM
 ^1H

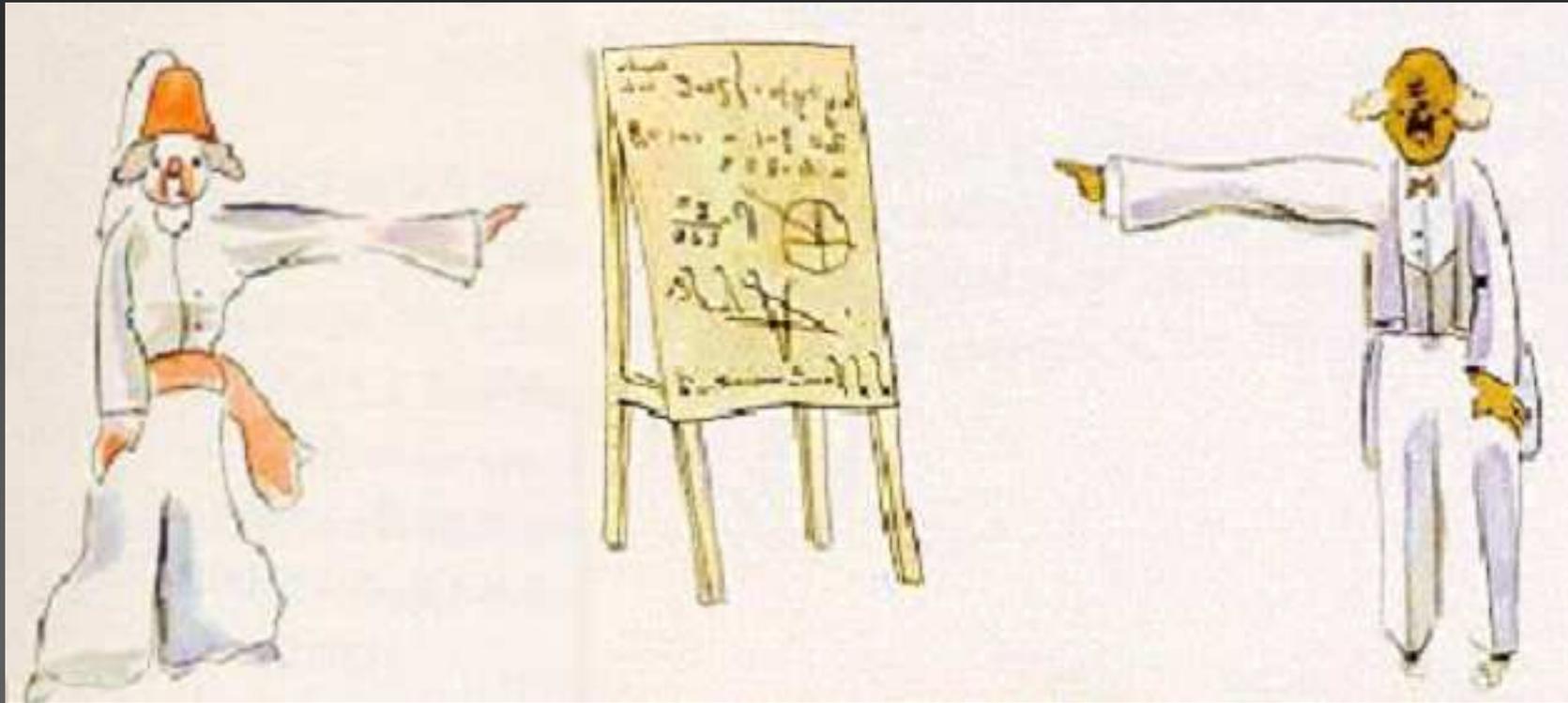
Métabolisme
 ^{18}F FDG

^{18}F -DOPA, voie
Pré-synaptique

Perte
fonction
DaT
Putamen D

^{18}F -Ethyl
Spipérone, voie
Post-synaptique

Pas
d'atteinte
RD2



Merci de votre attention...