ΙΑΤΡΙΚΗ ΦΥΣΙΚΗ

Π. Παπαγιάννης & Ε. Στυλιάρης
ΠΑΝΕΠΙΣΤΗΜΙΟΝ ΑΘΗΝΩΝ
2013-2014

Single Photon Emission CT (SPECT)

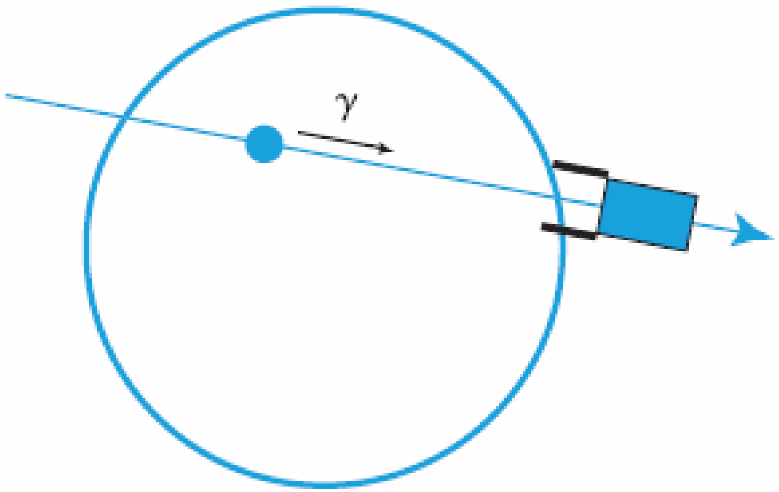
- Αρχή Λειτουργίας
- γ-Camera
- Προβολικές Λήψεις
- Ανακατασκευή Τομογραφικής Εικόνας

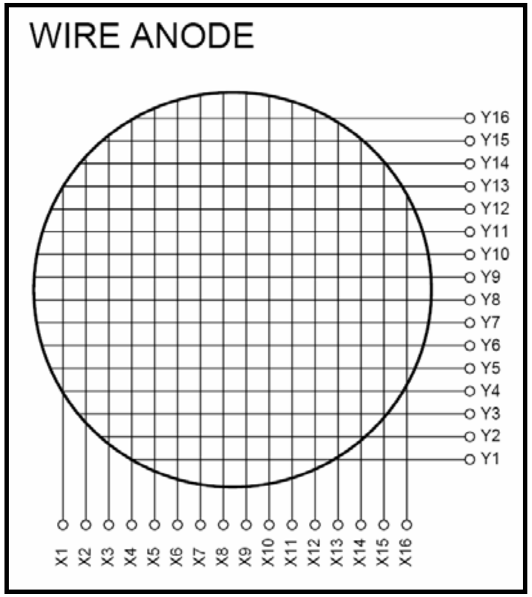
Positron Emission Tomography

- Αρχή Λειτουργίας
- Γεωμετρία Διάταξης
- Ανακατασκευή Τομογραφικής Εικόνας

Single Photon Emission CT (SPECT)

Ανίχνευση γ Ακτινοβολίας



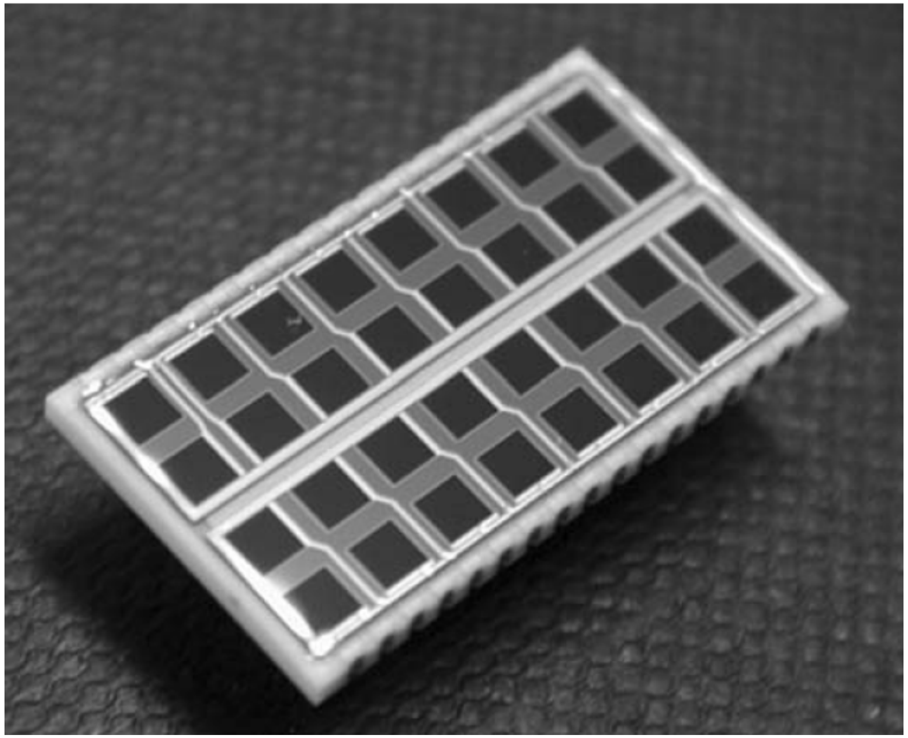


Single Photon Emission CT (SPECT)

	Na(Tl)	BGO	LSO(Ce)	GSO(Ce)	CsI(Tl)	BaF_2	$LaBr_3$	Plastic
Density (g/cm^3)	3.67	7.13	7.40	6.71	4.51	4.89	5.29	1.03
Effective atomic number (Z)	50	74	66	59	54	54	46	12
Decay time (ns)	230	300	40	60	1,000	0.8, 620	26	2
Photon yield/keV	38	8	20–30	12–15	52	10	63	10
Index of refraction n	1.85	2.15	1.82	1.85	1.80	1.56	1.90	1.58
Hygroscopic	Yes	No	No	No	Slightly	No	Yes	No
Peak emission λ_{max} (nm)	415	480	420	430	540	225, 310	380	Various

Πίνακας των κυριότερων υλικών που χρησιμοποιούνται σαν σπινθηριστές στην ανίχνευση γ-ακτινοβολίας.

Single Photon Emission CT (SPECT)

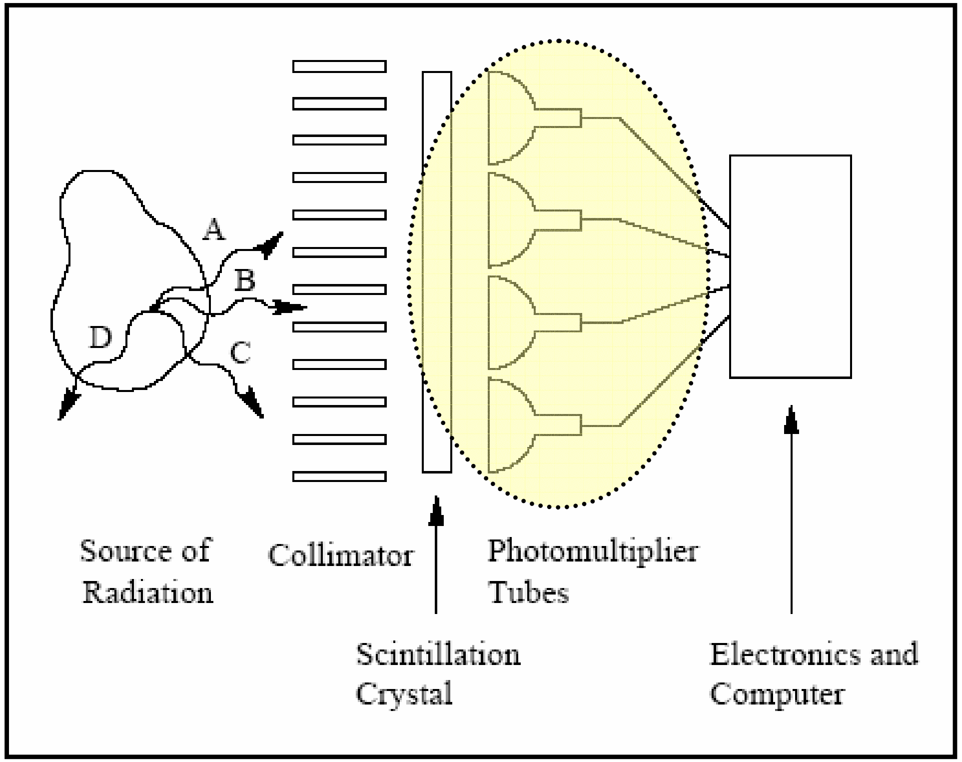


	PMT	APD	SiPM
Photon detection efficiency (PDE) in blue	20%	50%	20–70%
Gain	10^6	100	10^6
Bias voltage (V)	~1,000	~400	<100
Sensitivity in magnetic field	Yes	No	No
Rise time (ns)	~1	~5	~1

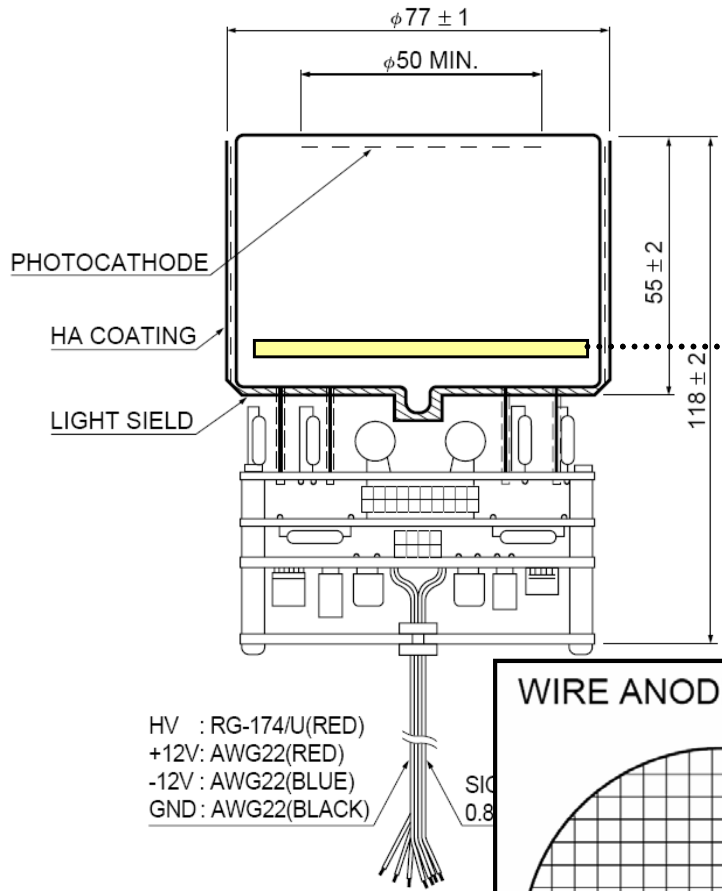
Πλεονεκτήματα φωτοδιόδων και SiPM έναντι των συμβατικών φωτοπολλαπλασιαστών.

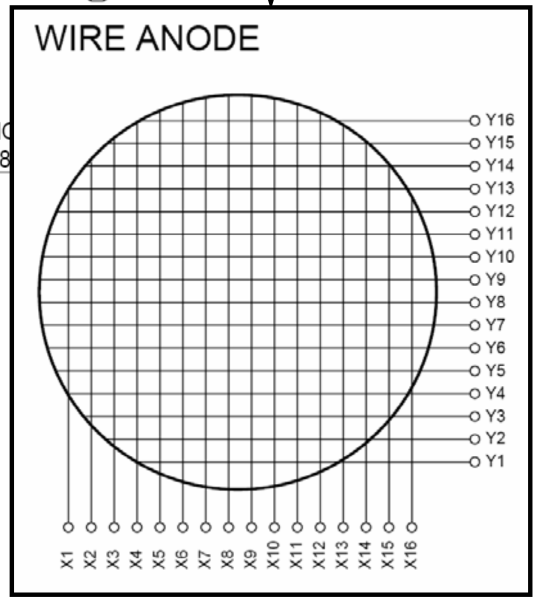
Single Photon Emission CT (SPECT)

From the Anger Camera to Position Sensitive Photomultiplier Tubes (PSPMTs)



Anger Camera

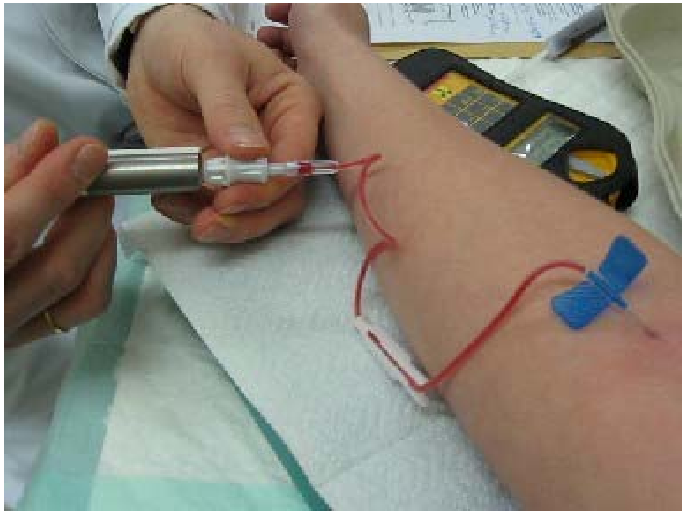


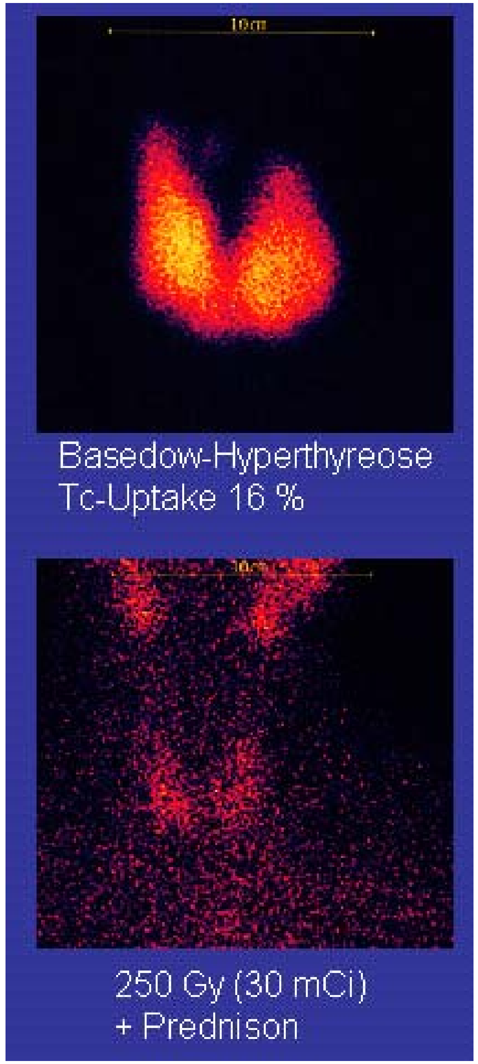


PMT array substituted by a multi-wire anode grid

H. Anger: "*A new instrument for mapping gamma-ray emitters*",
Biol. Med. Quart. Rep. UCRL (1957) 3653

Single Photon Emission CT (SPECT)





$$^{99m}_{43}\mathrm{Tc} \xrightarrow[6\ \mathrm{h}]{\gamma\ \ 141\ \mathrm{keV}} {}^{99}_{43}\mathrm{Tc} \xrightarrow[211\ 000\ \mathrm{y}]{\beta^-\ \ 249\ \mathrm{keV}} {}^{99}_{44}\mathrm{Ru}$$

Παραγωγή ^{99m}Tc από την έκλουση ^{99}Mo και ενδοφλέβια χορήγηση.

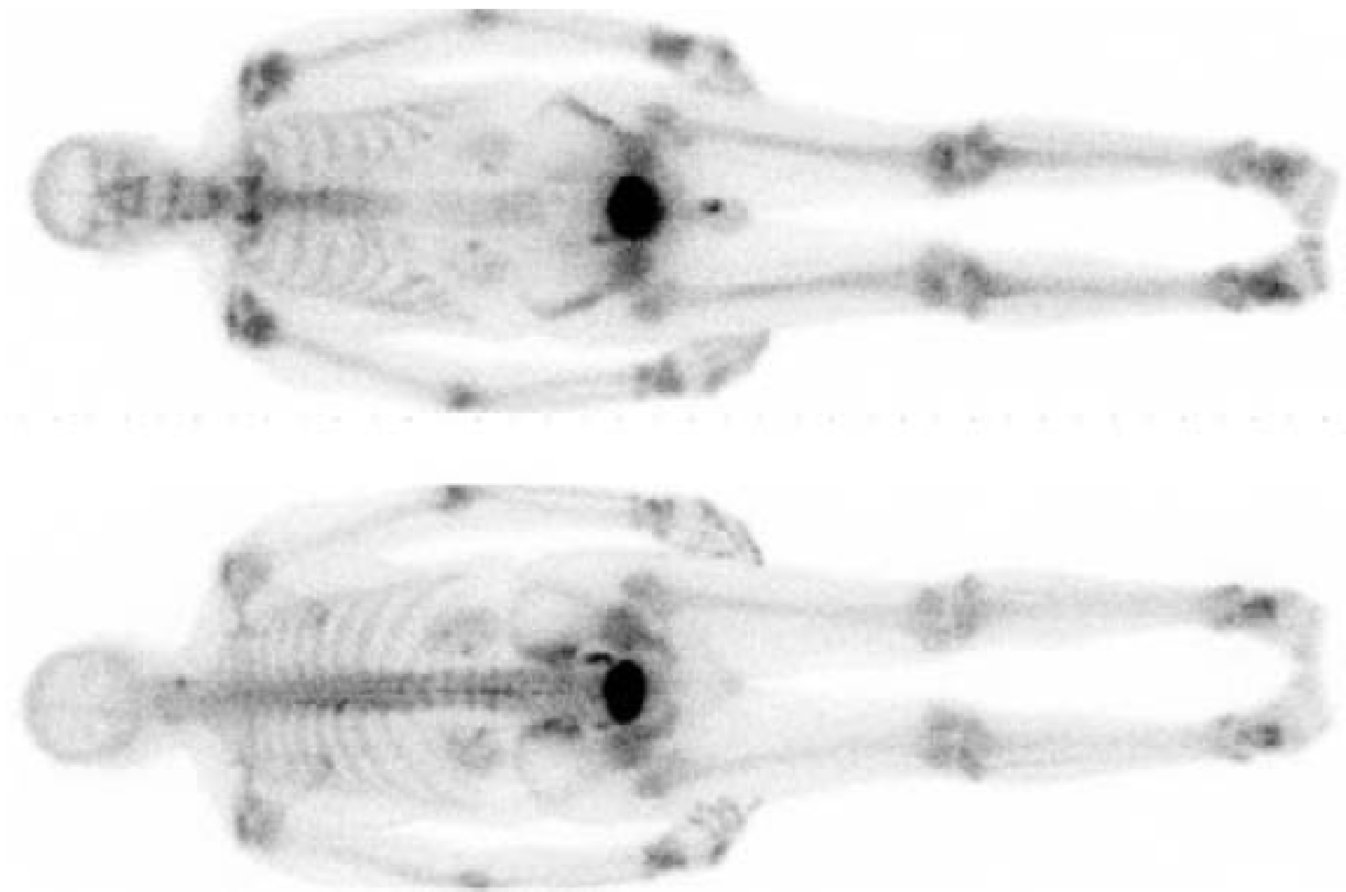
Single Photon Emission CT (SPECT)

(a)

(b)

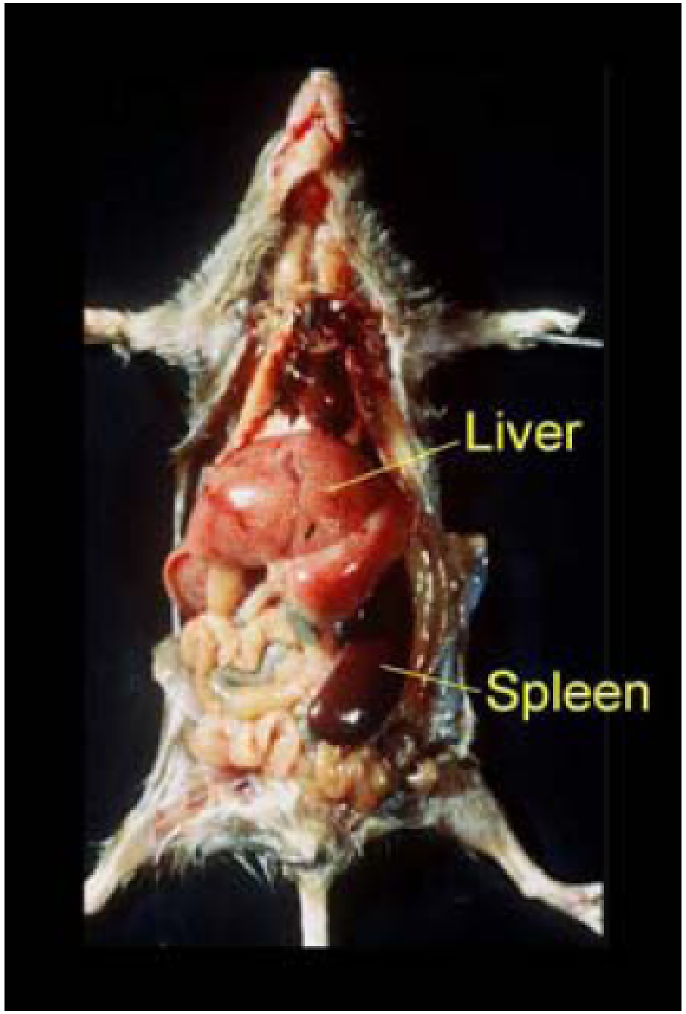
(a) Gamma camera and SPECT scanner with two large crystal detectors. (b) System with three detector heads. If the gamma camera rotates around the patient it behaves like a SPECT scanner.

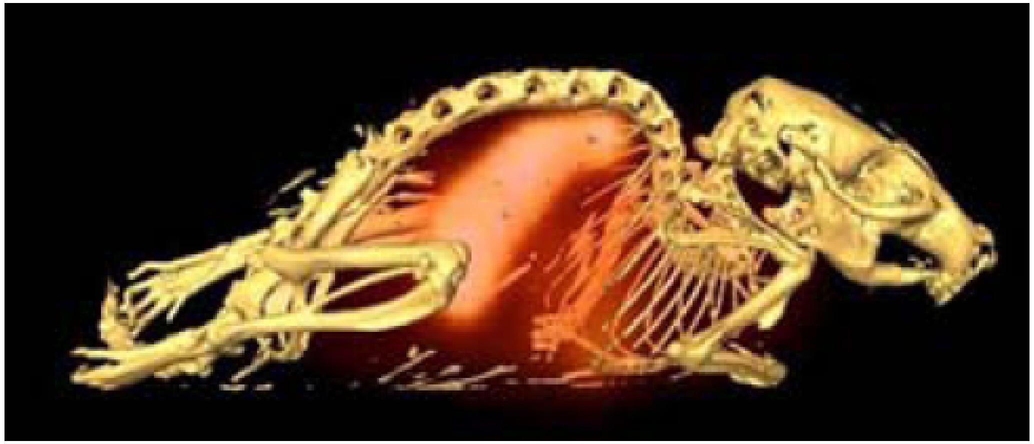
Single Photon Emission CT (SPECT)



^{99m}Tc-MDP study acquired with a dual-head gamma camera. The detector size is about 40 × 50 cm, and the whole-body images are acquired with slow translation of the patient bed. MDP accumulates in bone, yielding images of increased bone metabolism. As a result of the attenuation, the spine is more visible in the lower, posterior image.

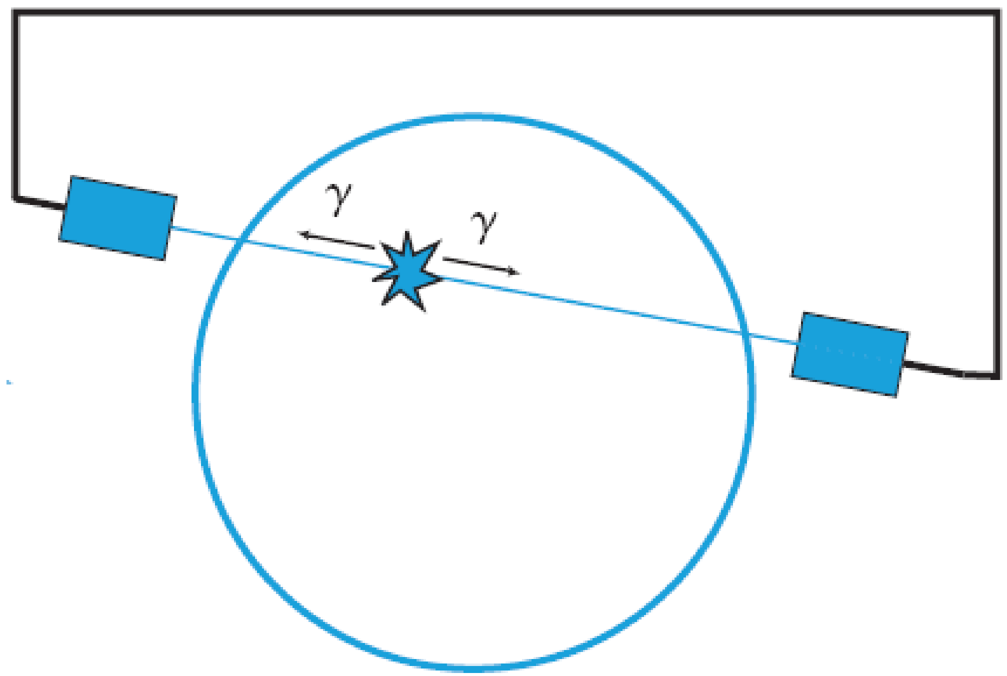
SPECT / CT Dual Modality

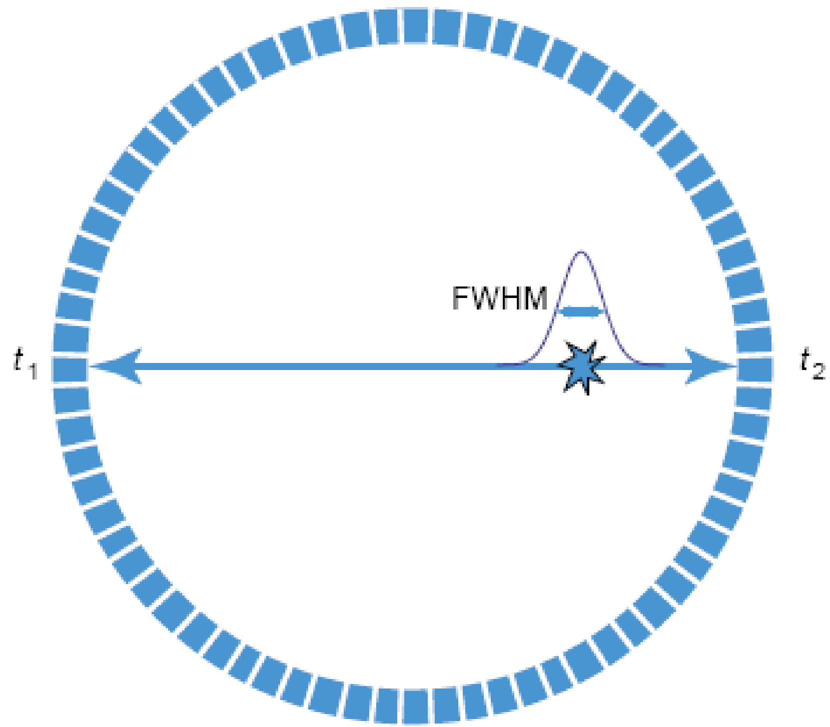




Mouse with AA-amyloidosis (left). Note the enlarged spleen and discoloration of the liver. Pseudo-colored SPECT image overlaid on top of co-registered CT image (top, right) and surface-rendered skeleton CT image (bottom, right). Bright object (high specific activity) is splenic amyloid, while cloudy object represents liver deposits.

Positron Emission Tomography (PET)





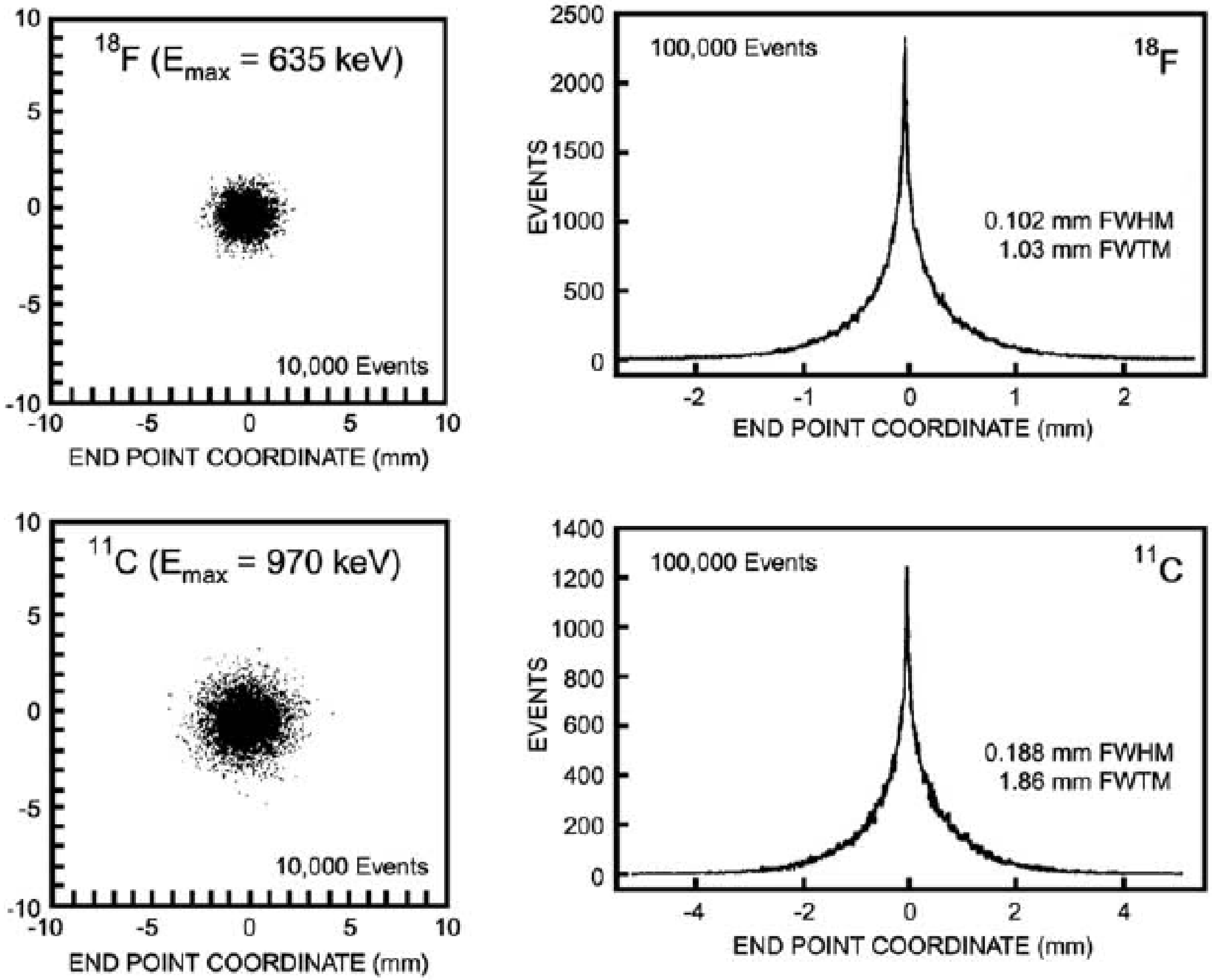
Αρχή λειτουργίας Ποζιτρονικού Τομογράφου.

Positron Emission Tomography (PET)

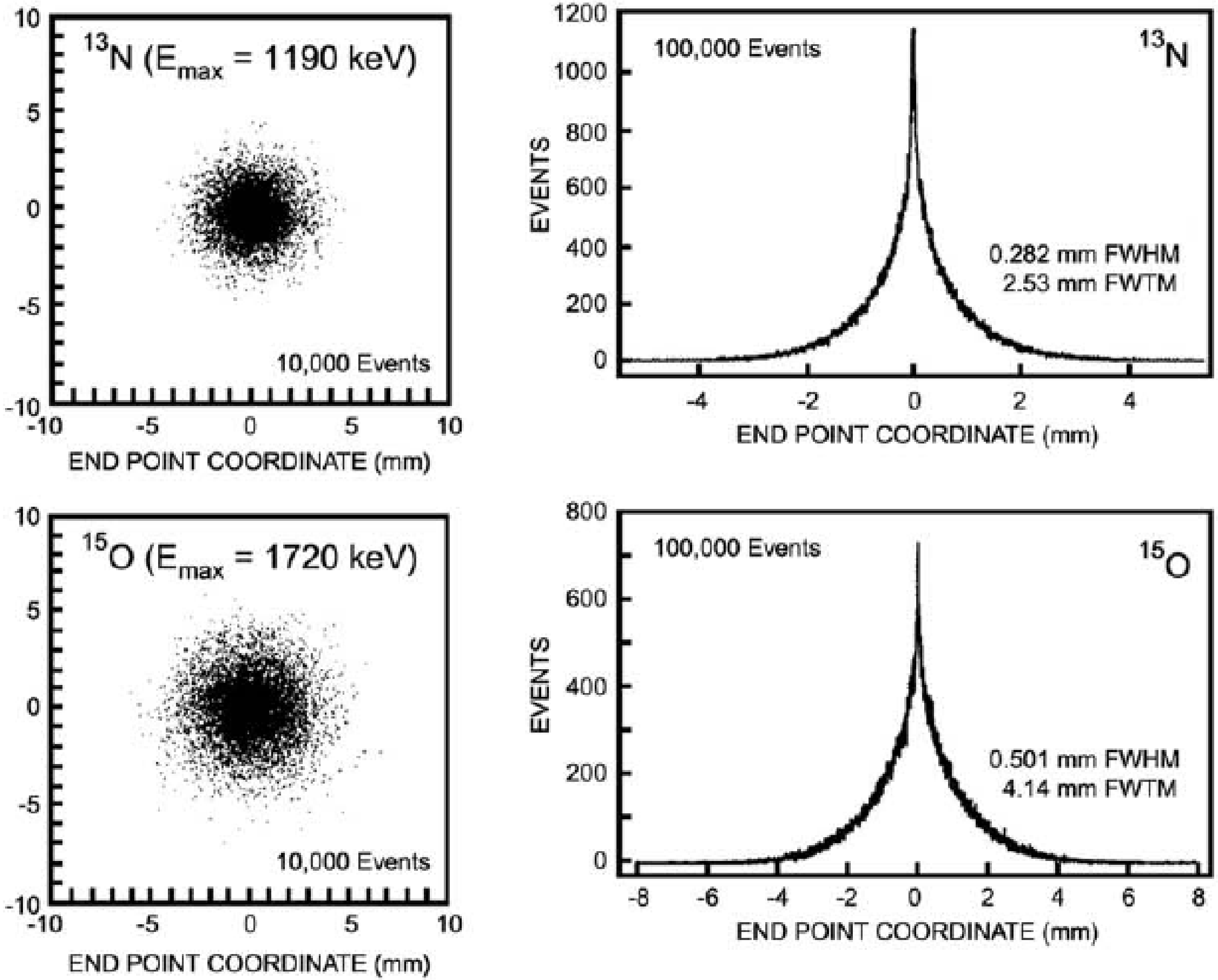
Radionuclide	Half-life (minutes)	Radiotracer	Clinical applications
^{18}F	109.7	^{18}FDG	oncology, inflammation, cardiac viability
^{11}C	20.4	^{11}C-palmitate	cardiac metabolism
^{15}O	2.07	$H_2{}^{15}O$	cerebral blood flow
^{13}N	9.96	$^{13}NH_3$	cardiac blood flow
^{82}Rb	1.27	$^{82}RbCl_2$	cardiac perfusion

Radionuclide	$E(\beta^+)_{max}$ [keV]
^{18}F	635
^{11}C	970
^{13}N	1190
^{15}O	1720
^{82}Rb	3180

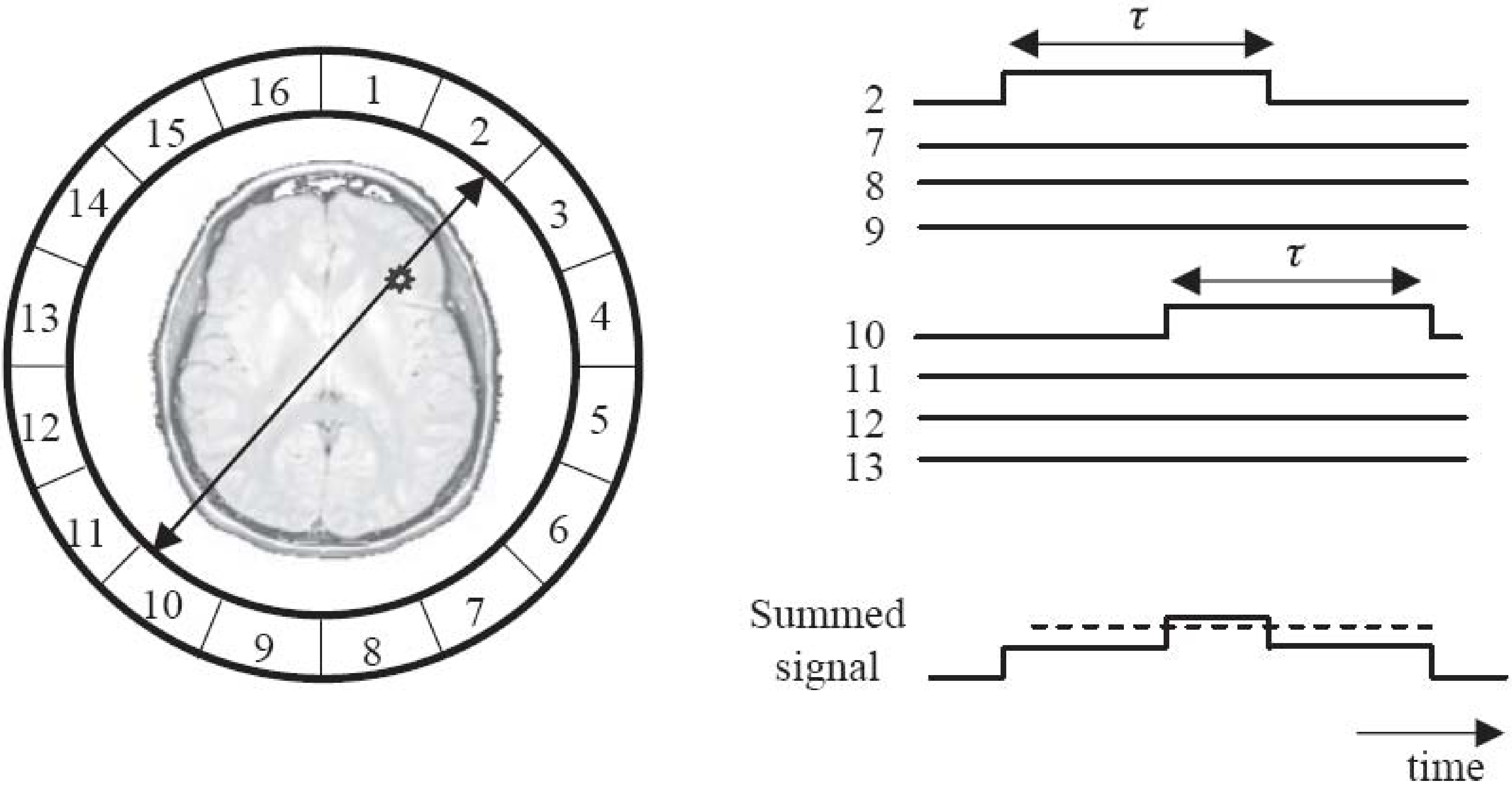
Positron Emission Tomography (PET)



Positron Emission Tomography (PET)



Positron Emission Tomography (PET)



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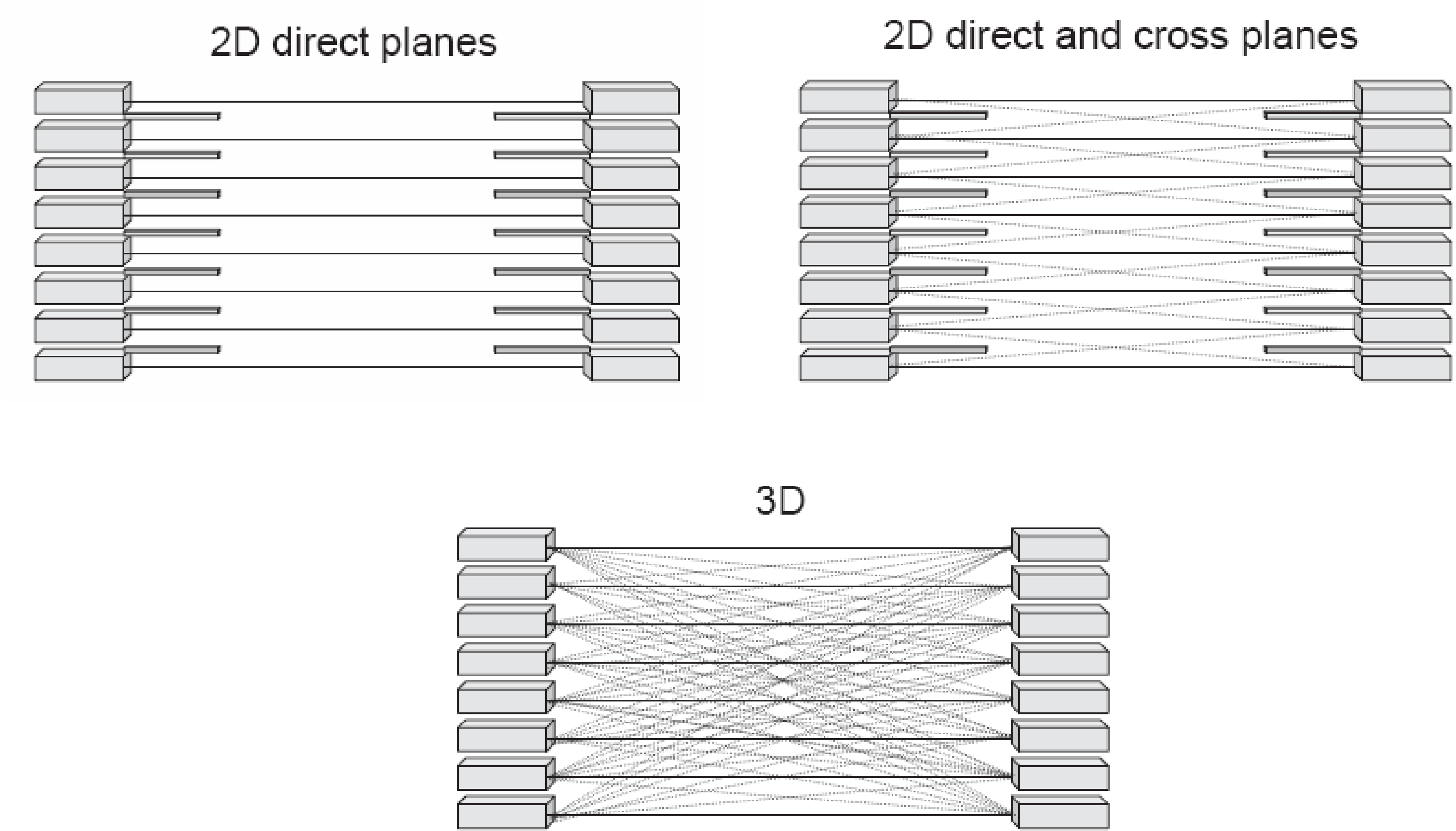

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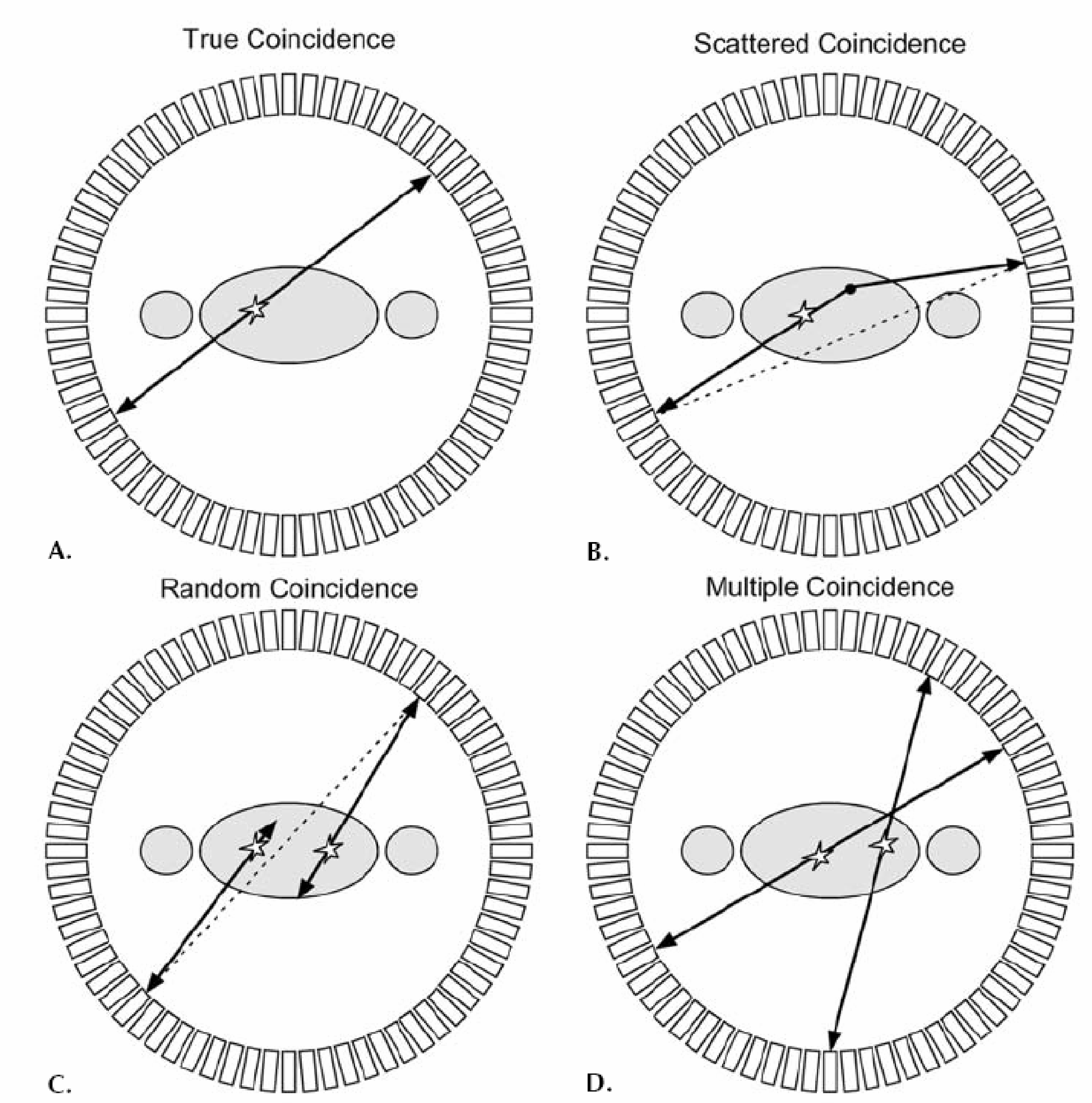
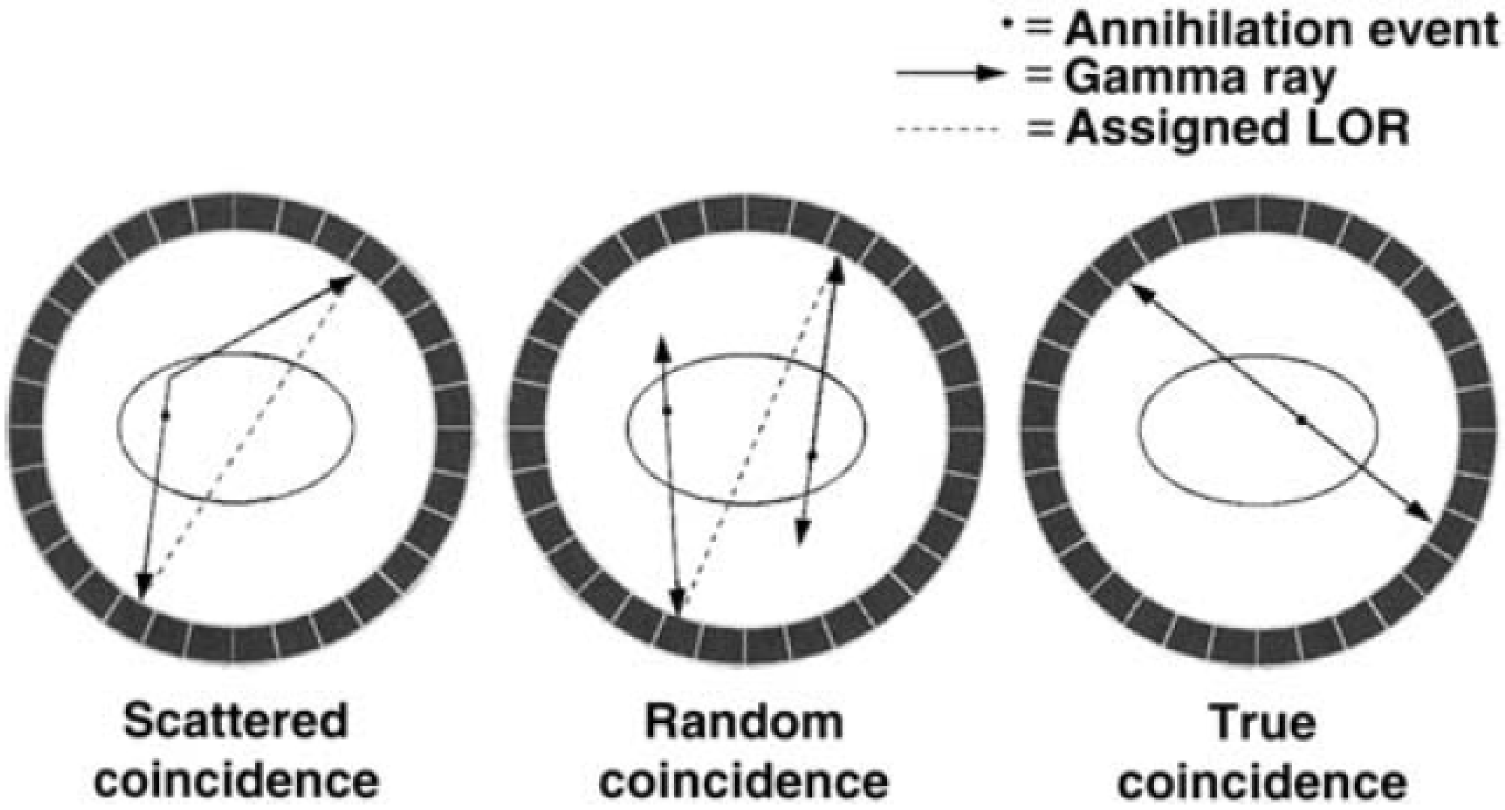


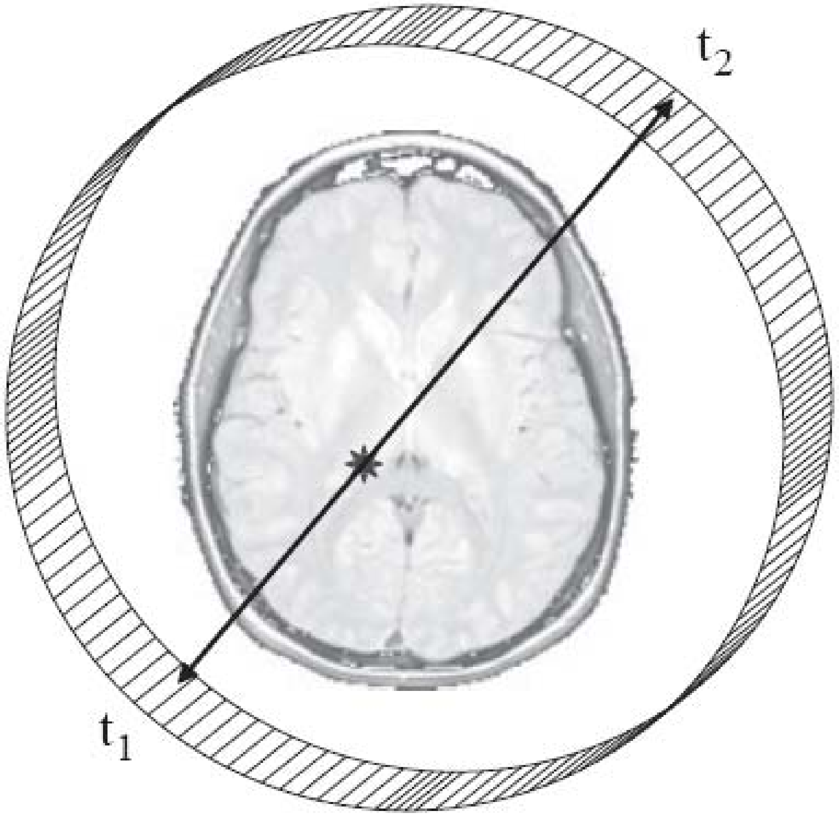
Positron Emission Tomography (PET)

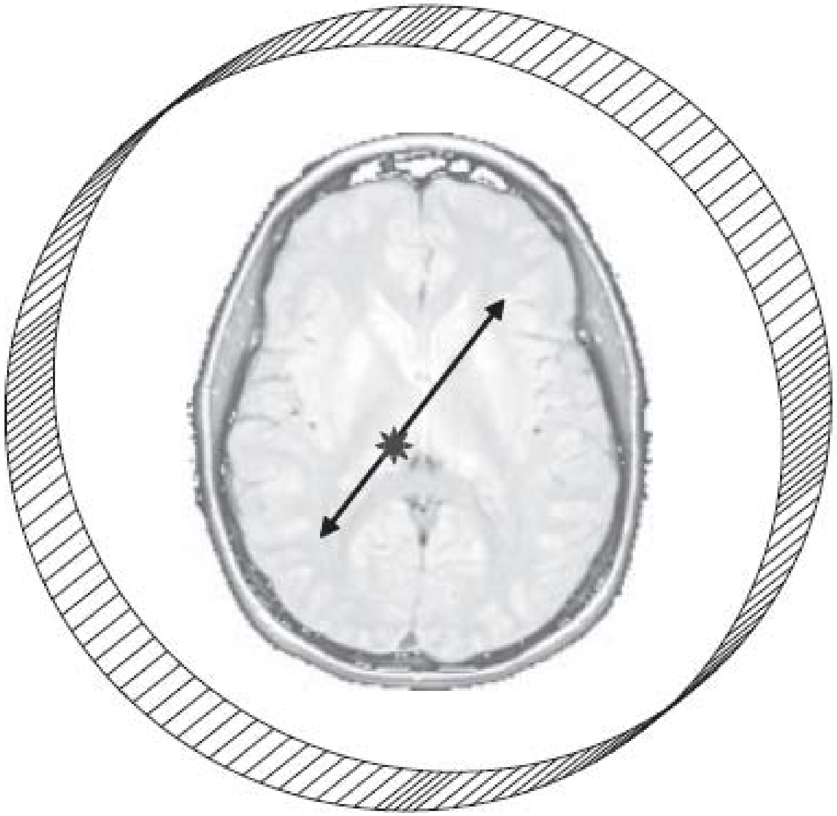


The three types of coincidence events measured in a PET scanner.

Positron Emission Tomography (PET)

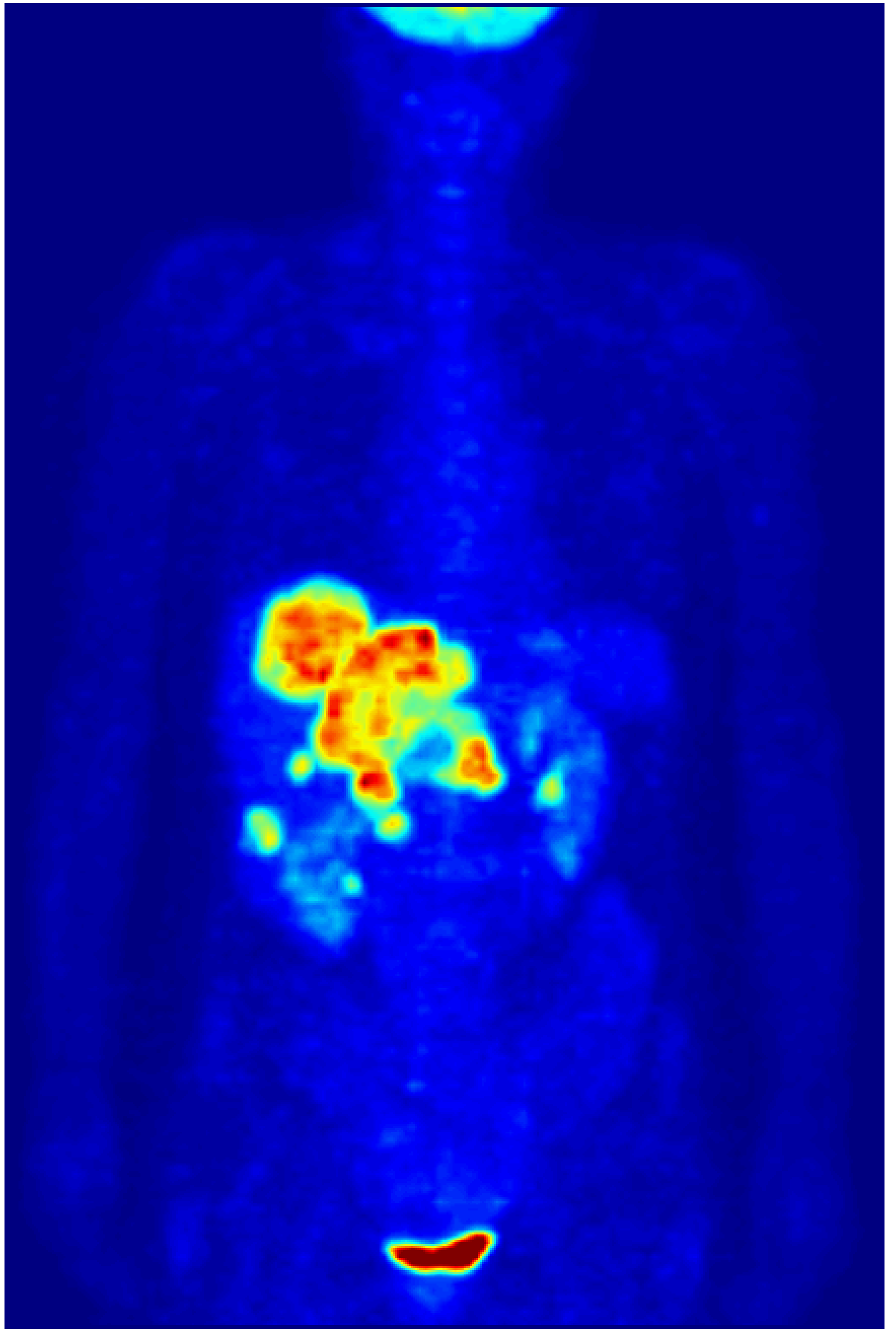
Time of Flight (ToF) PET Scanners





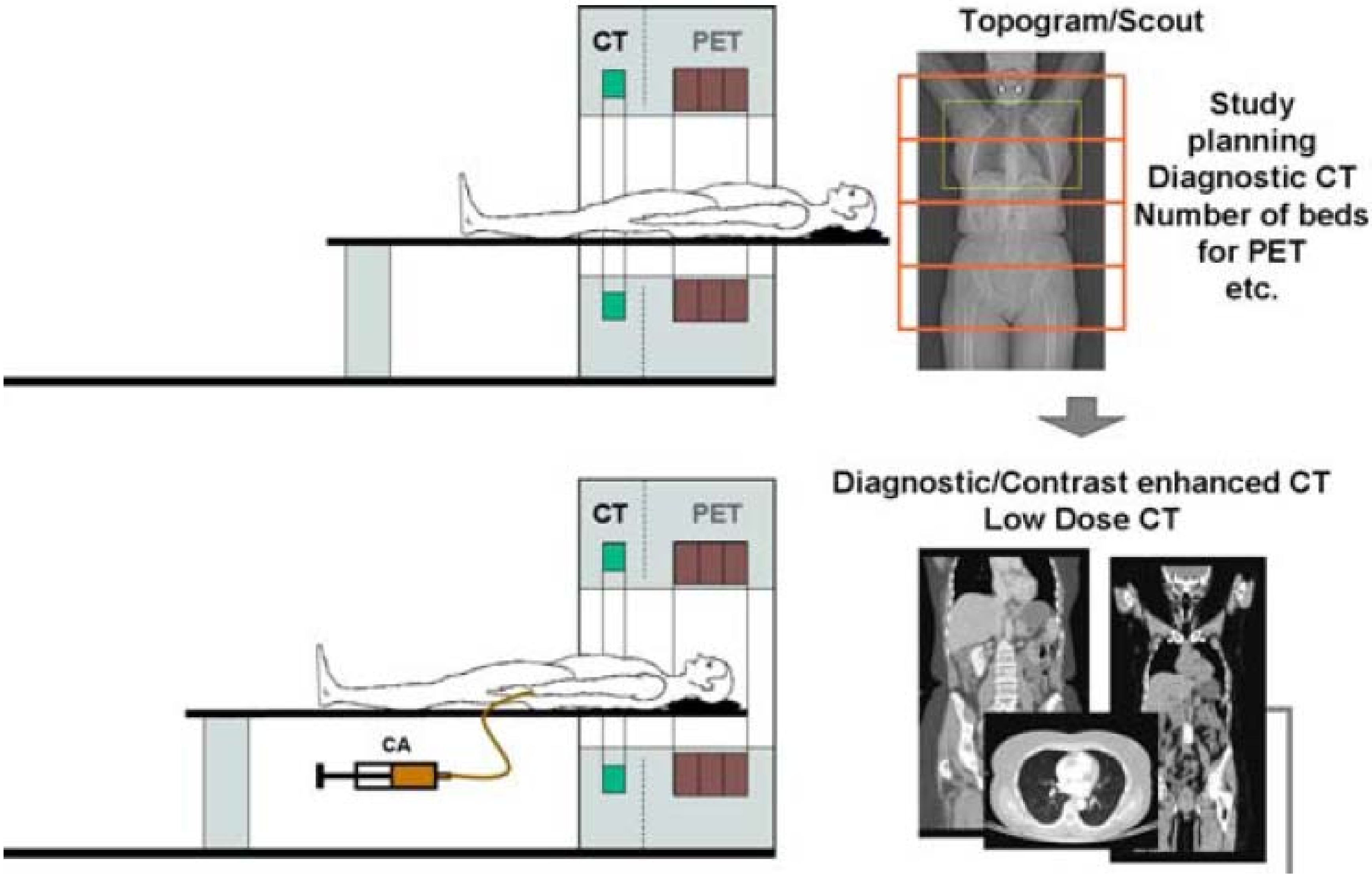
A timing resolution of 500 ps corresponds to a spatial resolution of ~7.5 cm. Therefore, it would appear that TOF PET offers no advantages over conventional PET since the latter already has a spatial resolution of the order of several millimetres. However, being able to constrain the length of the LOR from its value in conventional PET to 7.5 cm reduces the statistical noise inherent in the measurement.

Positron Emission Tomography (PET)



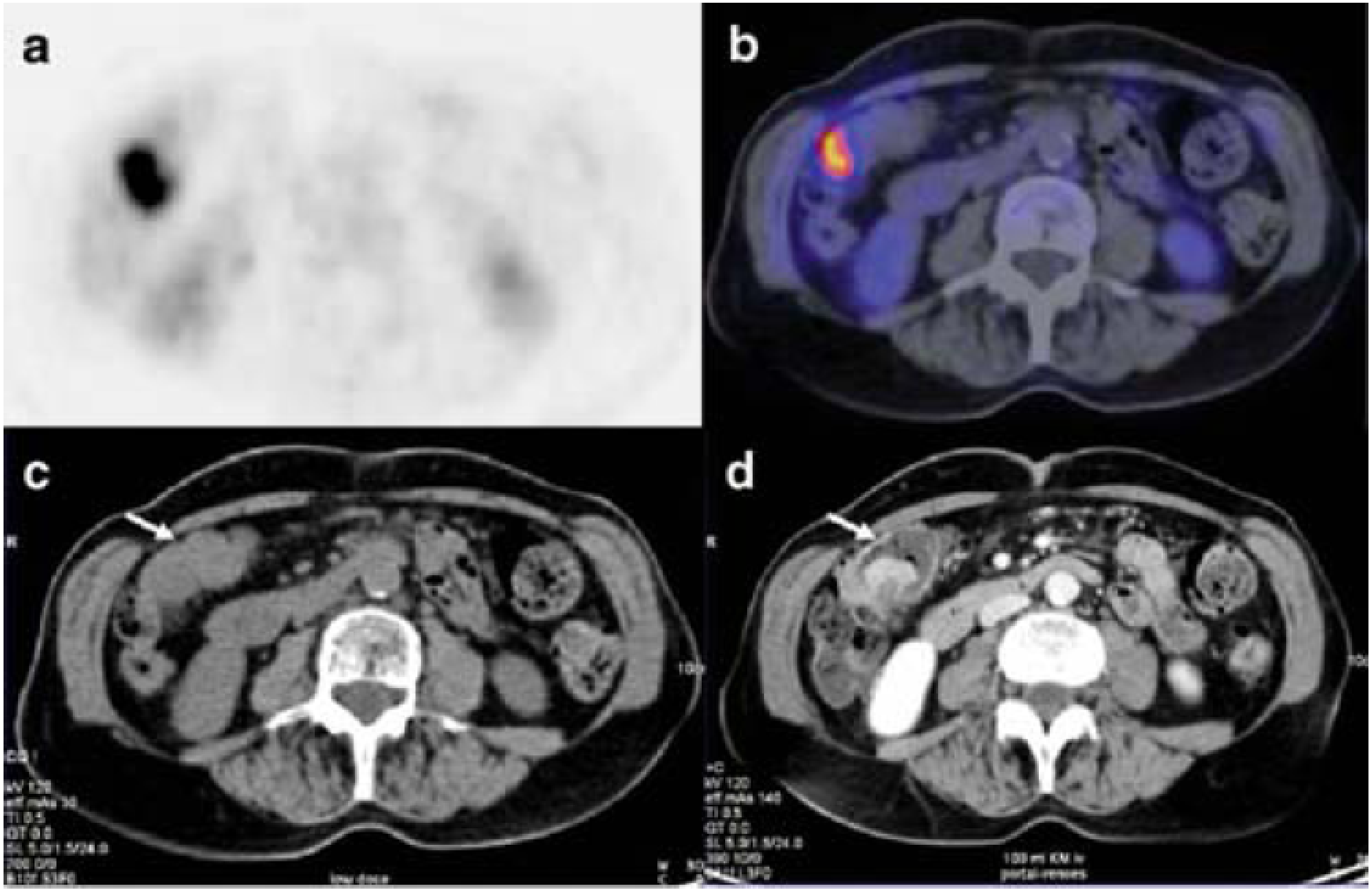
Ολόσωμη απεικόνιση PET με ^{18}F-FDG, όπου διακρίνονται ηπατικές μεταστάσεις του όγκου του παχέος εντέρου.

Positron Emission Tomography (PET)



PET / CT dual-modality scanner and image fusion.

Positron Emission Tomography (PET)



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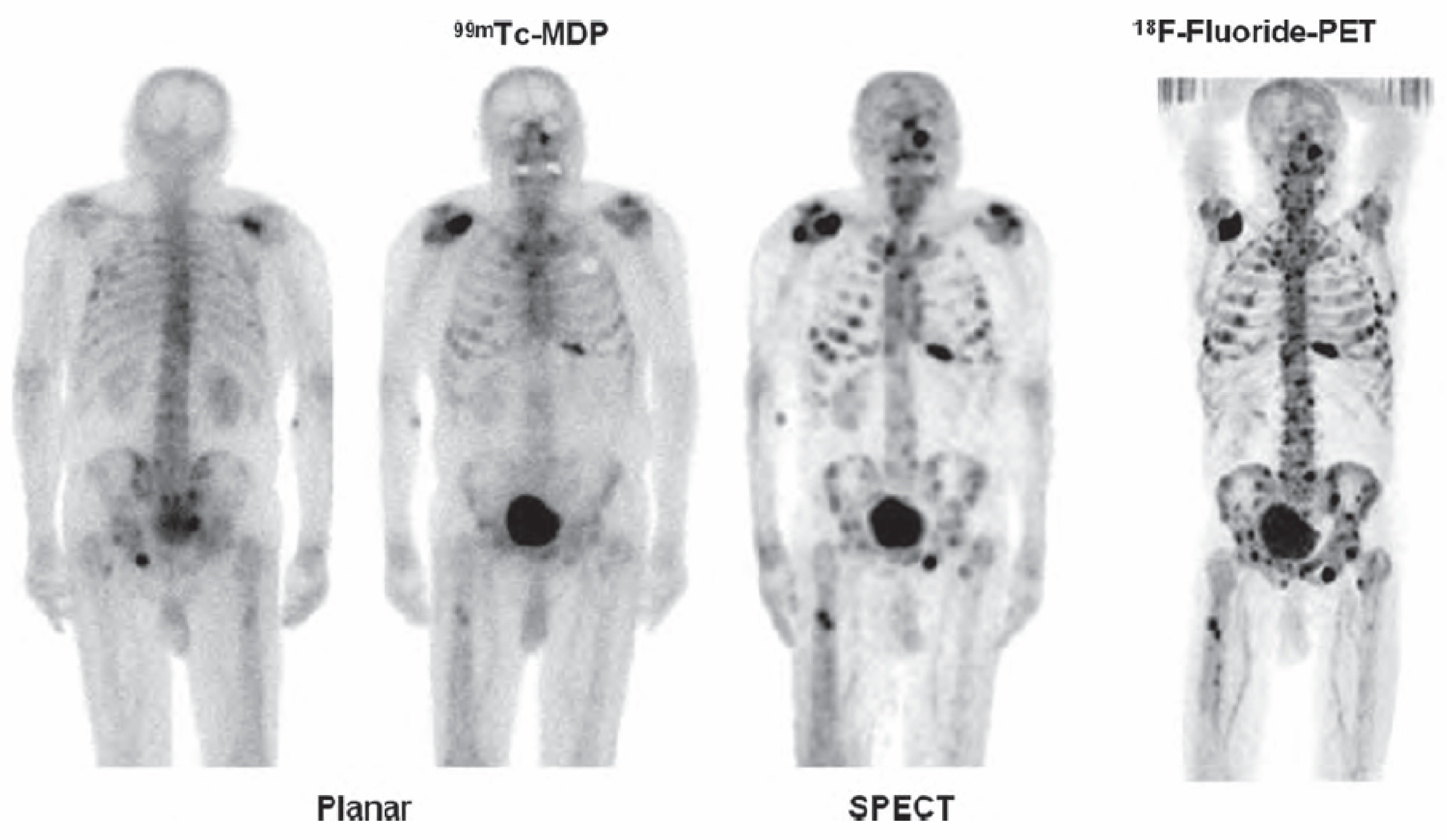


Comparison of [18F]Fluoride-PET with 99mTc-MDP planar and SPECT scintigraphy in a patient with numerous bone metastases. [18F] Fluoride-PET detects more lesions compared to conventional bone scan. (Grant et al. 2008).

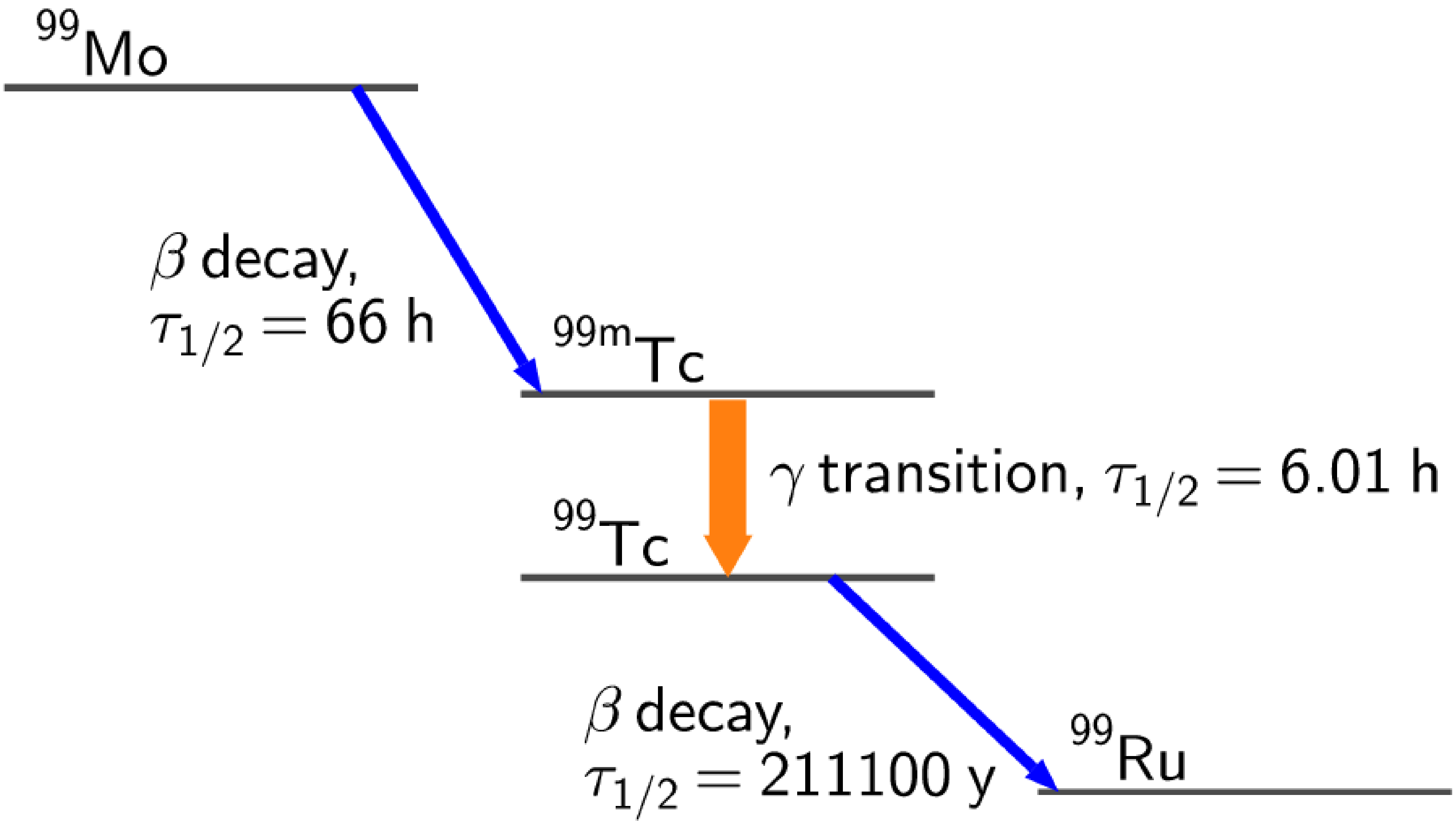
ΠΑΡΑΓΩΓΗ ΡΑΔΙΟΦΑΡΜΑΚΩΝ

Ραδιοφάρμακα στην Μονοφωτονική Τομοσπινθηρογραφία (SPECT)

Radiotracer	Half-life (hours)	γ-ray energy (keV)	Clinical application
^{99m}Tc	6.0	140	various
^{67}Ga	76.8	93, 185, 300, 394	tumour detection
^{201}Tl	72	167, 68–82 (X-rays)	myocardial viability
^{133}Xe	127.2	81	lung ventilation
^{111}In	67.2	171, 245	inflammation

$$^{99}_{42}\mathrm{Mo} \xrightarrow{\tau_{1/2}\,=\,66\,\text{hours}} {}^{0}_{1}\beta + {}^{99m}_{43}\mathrm{Tc} \xrightarrow{\tau_{1/2}\,=\,6\,\text{hours}} {}^{99g}_{43}\mathrm{Tc} + \gamma.$$

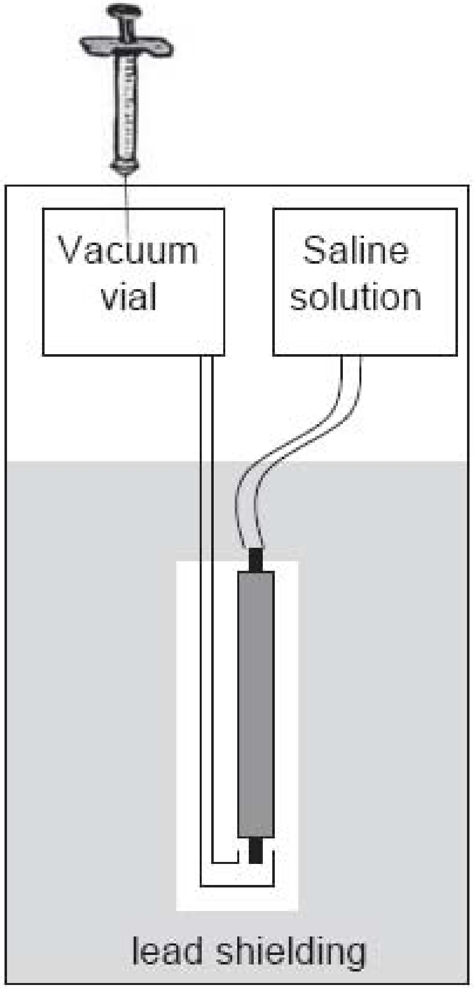
ΠΑΡΑΓΩΓΗ ΡΑΔΙΟΦΑΡΜΑΚΩΝ



$$ {}^{99}_{42}\mathrm{Mo} \xrightarrow{\tau_{1/2}\ =\ 66\,\mathrm{hours}} {}^{0}_{1}\beta + {}^{99m}_{43}\mathrm{Tc} \xrightarrow{\tau_{1/2}\ =\ 6\,\mathrm{hours}} {}^{99g}_{43}\mathrm{Tc} + \gamma. $$

ΠΑΡΑΓΩΓΗ ΡΑΔΙΟΦΑΡΜΑΚΩΝ

Η γεννήτρια Τεχνητίου ^{99m}Tc



$$^{99}_{42}\mathrm{Mo} \xrightarrow{\tau_{1/2} \;=\; 66\,\mathrm{hours}} {}^{0}_{1}\beta + {}^{99m}_{43}\mathrm{Tc} \xrightarrow{\tau_{1/2} \;=\; 6\,\mathrm{hours}} {}^{99g}_{43}\mathrm{Tc} + \gamma.$$

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Η γεννήτρια Τεχνητίου ^{99m}Tc

$$^{99}\mathrm{Mo} \xrightarrow{\lambda_1} {}^{99m}\mathrm{Tc} \xrightarrow{\lambda_2} {}^{99g}\mathrm{Tc}$$

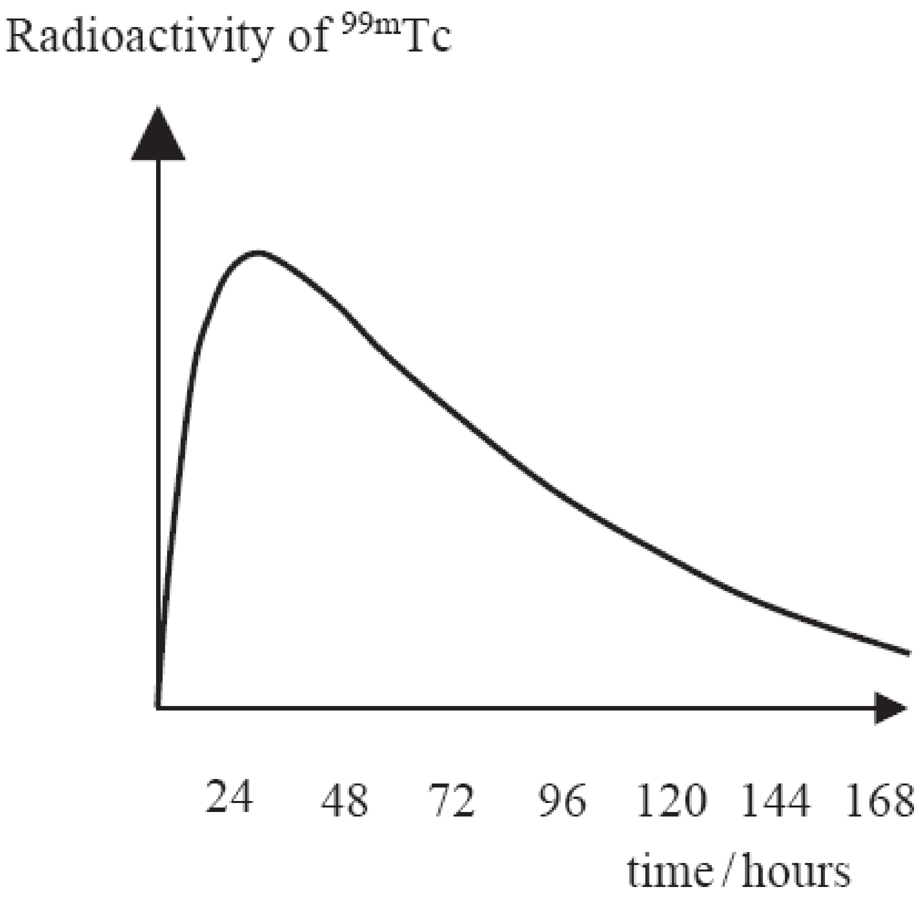
$$(N_1) \qquad (N_2) \qquad (N_3)$$

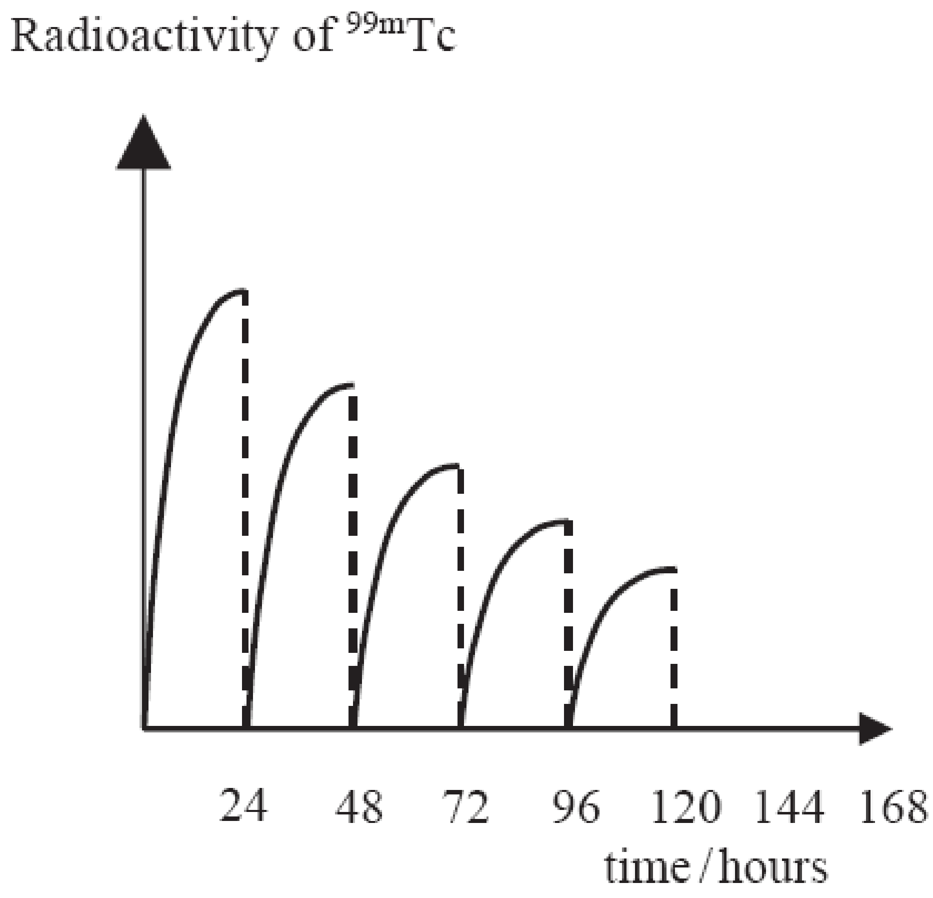
$$\frac{dN_2}{dt} = \lambda_1 N_1 - \lambda_2 N_2 \Rightarrow \frac{dN_2}{dt} + \lambda_2 N_2 = \lambda_1 N_1$$

$$Q_2 = \lambda_2 N_2 = \frac{\lambda_1 \lambda_2 N_0}{\lambda_2 - \lambda_1}\left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)$$

ΠΑΡΑΓΩΓΗ ΡΑΔΙΟΦΑΡΜΑΚΩΝ

Η γεννήτρια Τεχνητίου ^{99m}Tc





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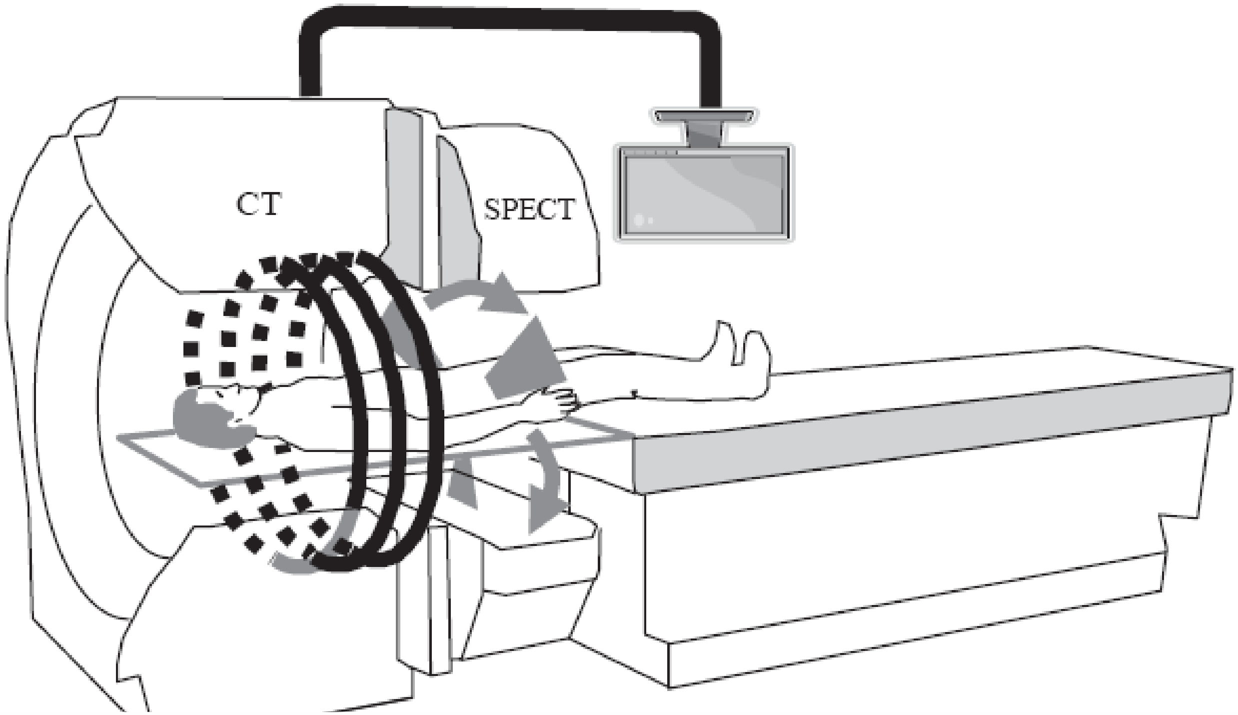
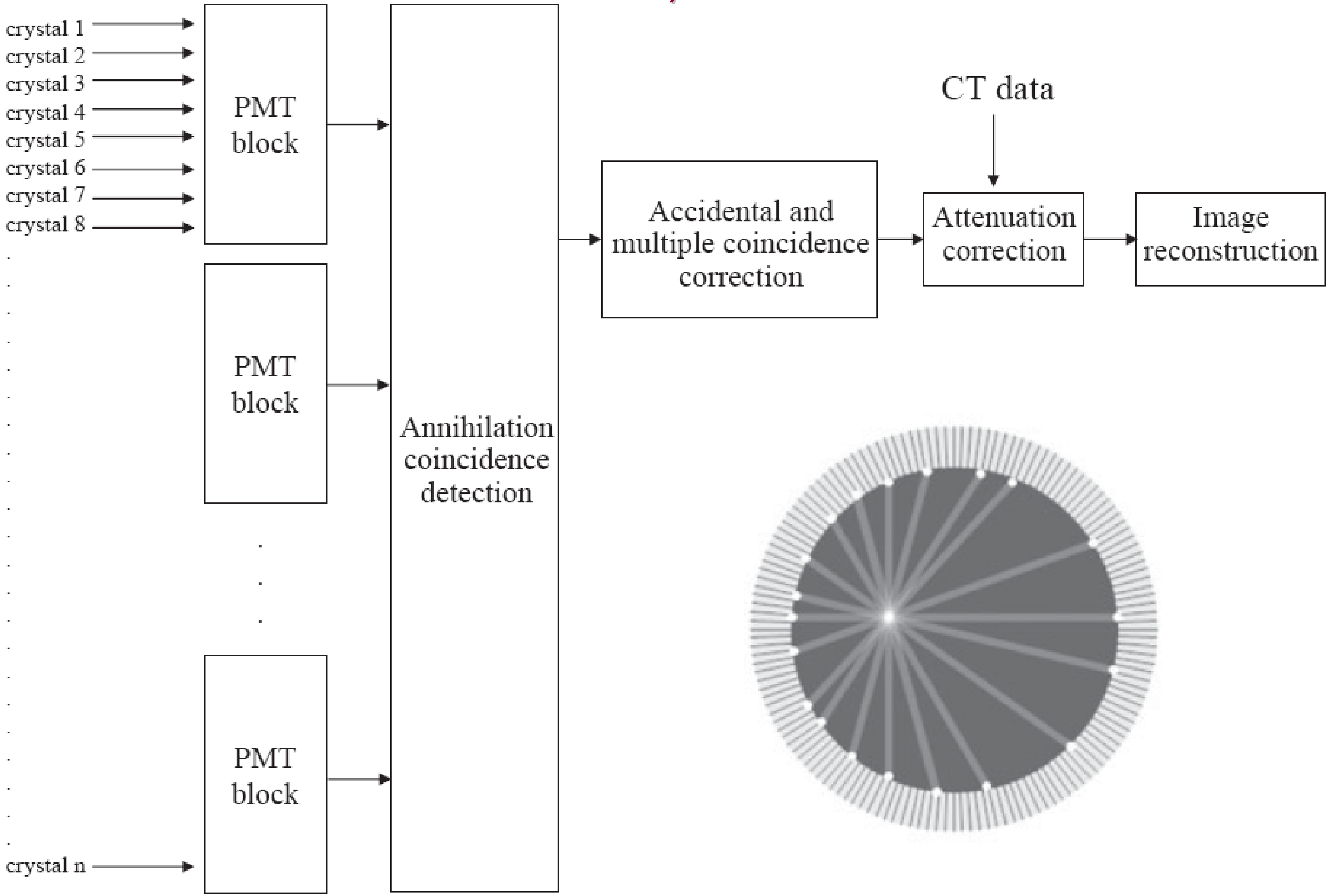
ΕΦΑΡΜΟΓΗ ΠΟΛΛΑΠΛΩΝ ΤΕΧΝΙΚΩΝ

SPECT / CT



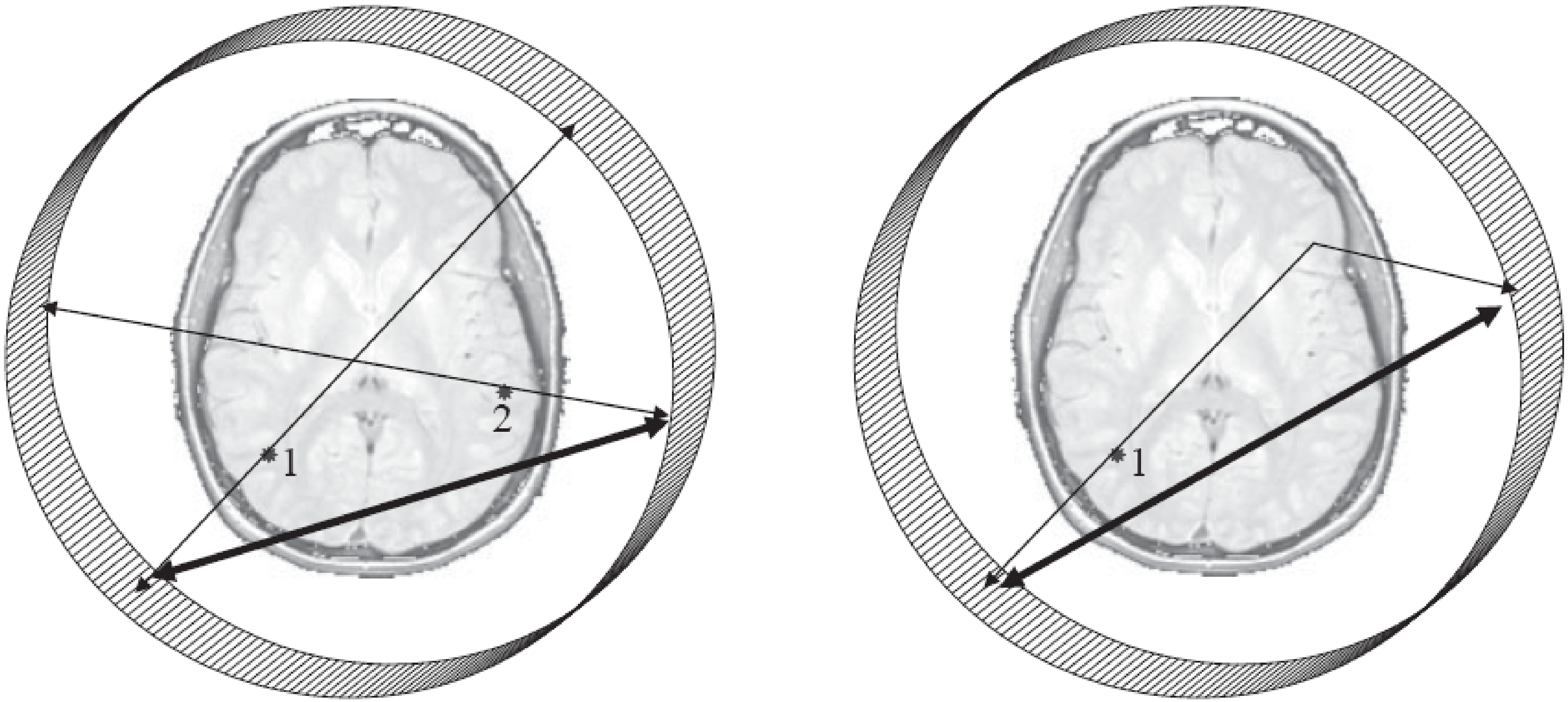
ΕΦΑΡΜΟΓΗ ΠΟΛΛΑΠΛΩΝ ΤΕΧΝΙΚΩΝ

PET / CT



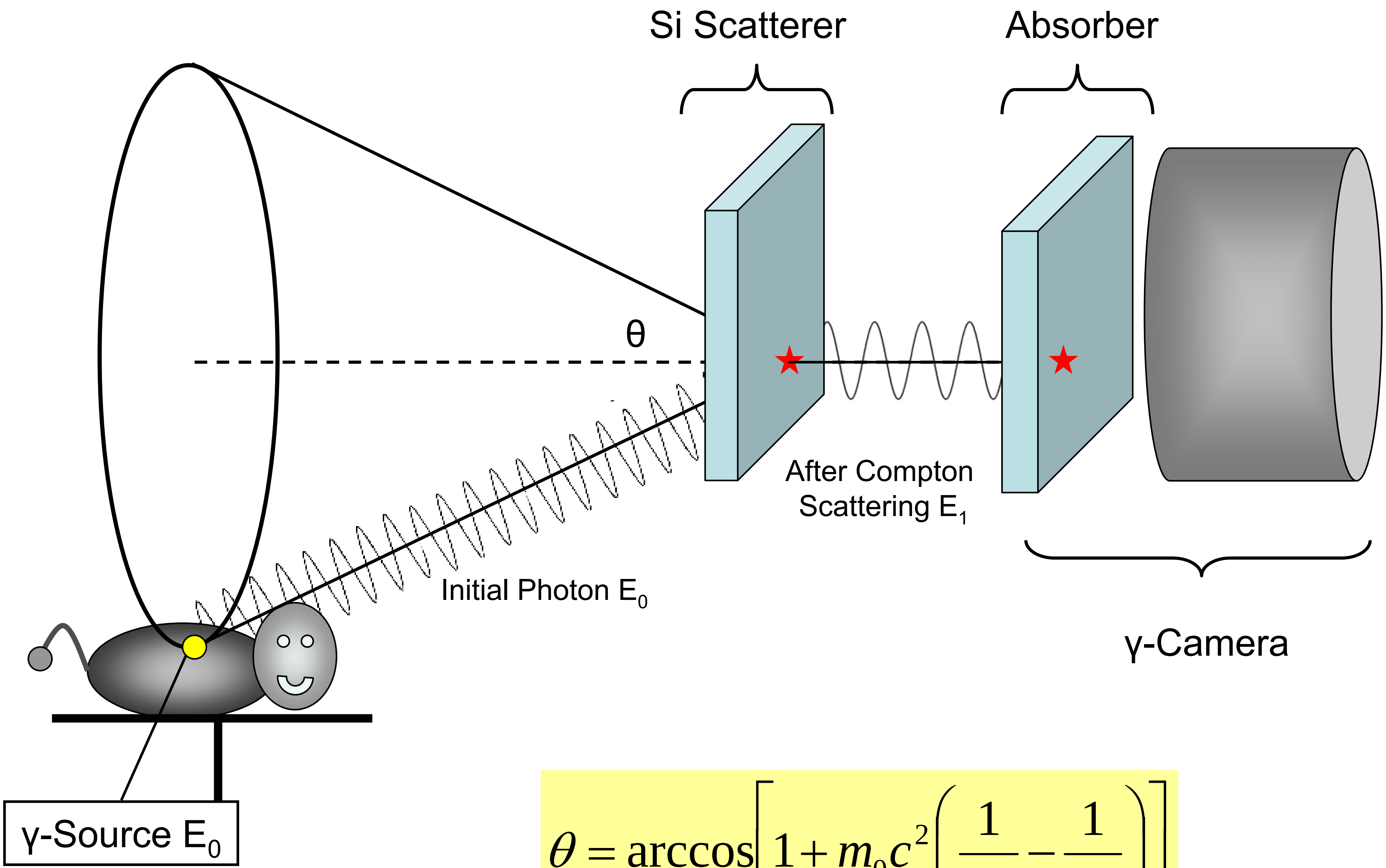
ΕΦΑΡΜΟΓΗ ΠΟΛΛΑΠΛΩΝ ΤΕΧΝΙΚΩΝ

PET / CT



$R^{acc} = 2\tau R_1R_2$

ΕΦΑΡΜΟΓΗ ΠΟΛΛΑΠΛΩΝ ΤΕΧΝΙΚΩΝ



$$\theta = \arccos\left[1 + m_0 c^2 \left(\frac{1}{E_0} - \frac{1}{E_1}\right)\right]$$