

# PET/CT vizsgálatok szervezési sajátosságai

# Sequence of events for a PET scan



Isotope production



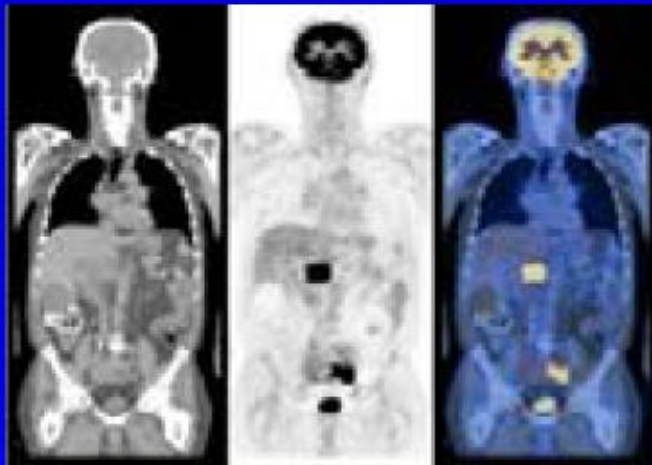
Radiochemistry



Quality control



PET/CT scanning <sup>\$2004</sup>



Results



# A pozitron bomló izotópok előállítása: a ciklotron

www.zdsoft.com



# Positron Emitting Isotopes

<u>Isotope</u>	<u>Half-Life</u>	<u>Production</u>
Carbon-11	20.3 min	$^{14}\text{N}(\text{p},\alpha)^{11}\text{C}$
Nitrogen-13	10.0 min	$^{16}\text{O}(\text{p},\alpha)^{13}\text{N}$
Oxygen-15	2.0 min	$^{14}\text{N}(\text{d},\text{n})^{15}\text{O}$
<b>Fluorine-18</b>	<b>110 min</b>	$^{18}\text{O}(\text{p},\text{n})^{18}\text{F} (\text{F}^-), ^{20}\text{Ne}(\text{d},\alpha)^{18}\text{F} (\text{F}_2)$
Gallium-68	68 min	Daughter of Ge-68 (271days)
Rubidium-82	1.3 min	Daughter of Sr-82 (25days)

- Small elements (C,N,O,F) allow “real” biochemistry
- Short half-lives make tracer production an integral part of PET



## A PET vizsgálatok várólista-nyilvántartása

[Belépés a nyilvántartásba](#)  
*(regisztrált felhasználóknak)*

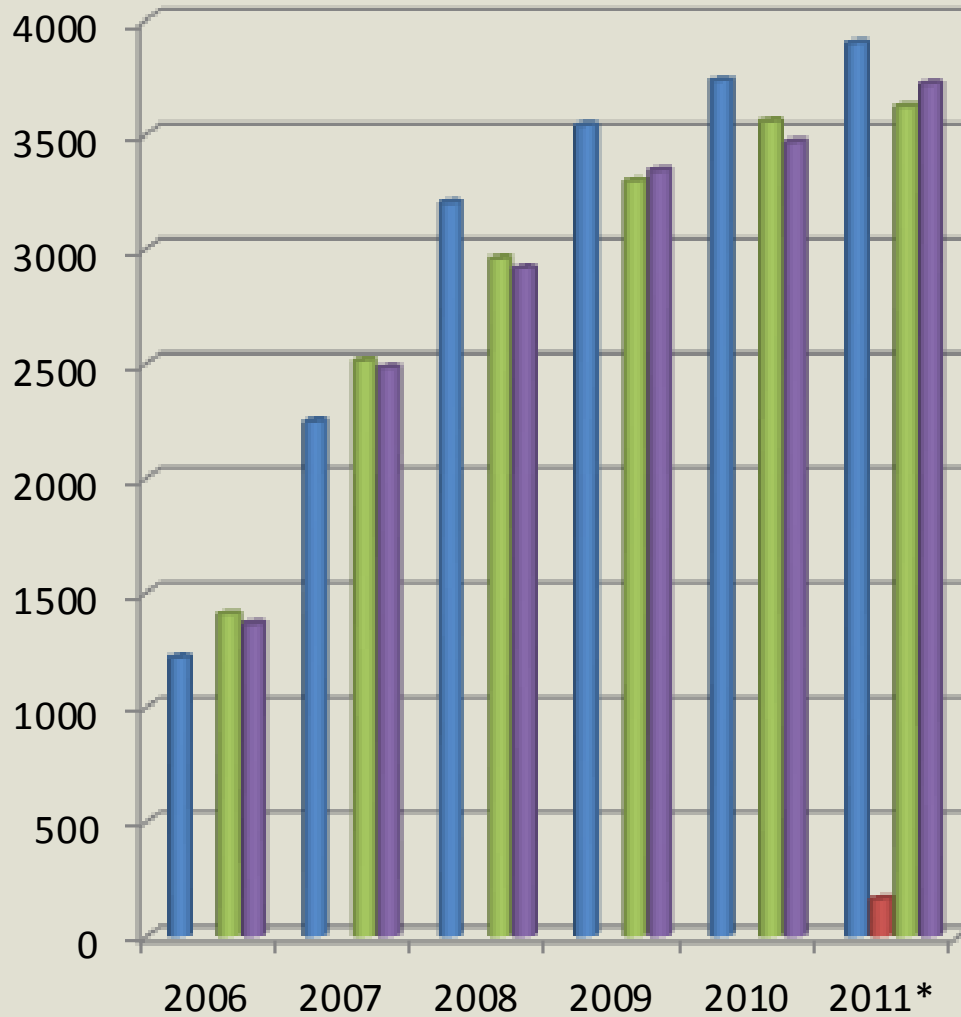
[Publikus várólista](#)

[Új felhasználó](#)  
*(vizsgálatkérő orvos)*  
[regisztrációja](#)

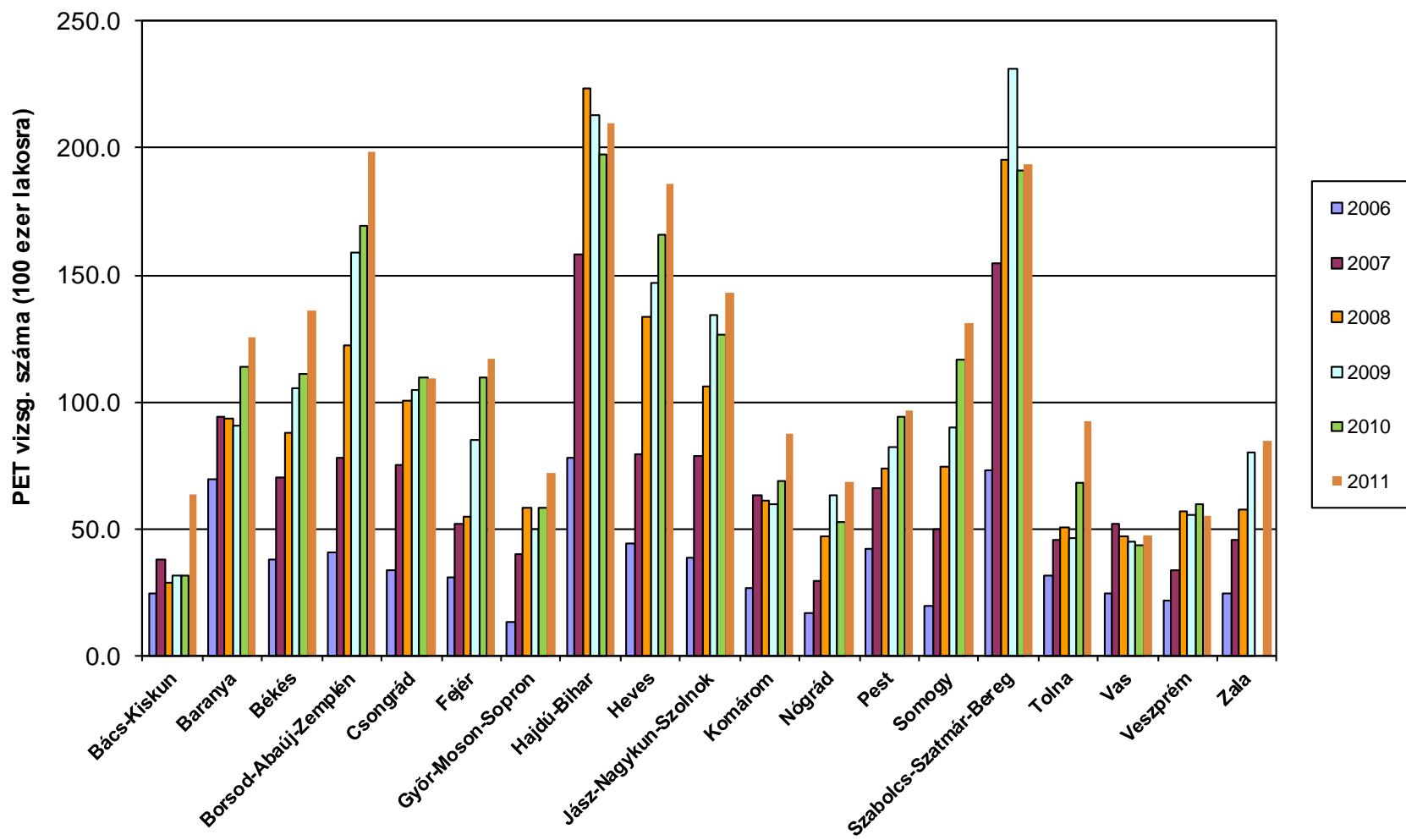
### Általános információk

Az egészségügyi miniszter 46/2006. (XII.27) EüM. rendelete alapján 2007 január 1.-től a PET vizsgálatok várólista vezetését az [Országos Vérellátó Szolgálat Központja](#) irányítja. E változás eredményeképpen 2007 május hónaptól kezdődően a PET várólista nyilvántartásának használata néhány pontban megváltozott.

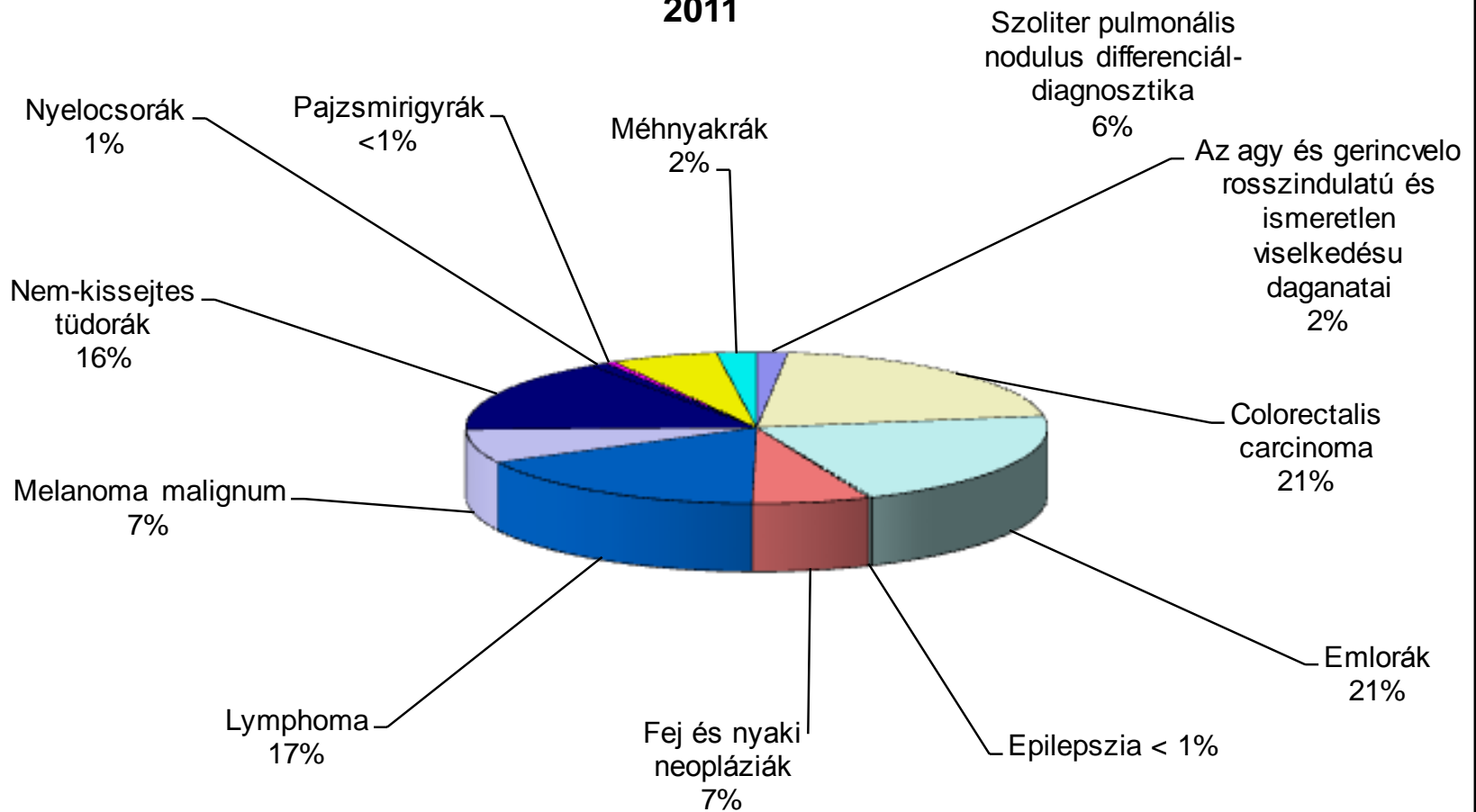
- Ettől a hónaptól kezdődően lehetőség van arra, hogy a beküldő orvosok is regisztrálhassanak vizsgálatkéréseket a honlap segítségével, csökkentve ezzel a PET vizsgálatok indikálásához szükséges adminisztratív munkát.
- Megváltozott a nyilvántartásban szereplő "Beutaló Intézetek" tábla is, ami most már az OEP hivatalos intézeti listáját tartalmazza az intézetkódokkal együtt, amely automatikusan beíródik az intézet kiválasztása után. A hivatalos intézeti lista több mint 30ezer intézetnevet tartalmaz, ami nehezen lenne kezelhető, ezért a vizsgálatkérő űrlapon található "legördülő" listában csak a korábban már kiválasztott intézetek szerepelnek. A teljes lista excel formában [innen](#) letölthető. Ha a legördülő listában nem szereplő beutaló intézetet kellene választani, akkor



- DE OEC Nukleáris Medicina Intézet
- PET/CT Központ Kecskemét
- Pozitron Diagnosztika Kft, PET/CT központ
- ScanoMed Orvosi Diagnosztikai Kft (OITI)



2011





# PET-CT kamerák



Siemens Biograph HiRez

## Discovery STE Making the best even better

- Everything Discovery delivers today...  
• New technology - Innovate, get, build a purpose  
• Clinical choice - Only PET/CT offering 2D, 3D & 4D acquisition modes  
• Continuum™ - Setting the standard for resolution and diagnostic precision  
• Streamlined design - Enabling efficient installation  
...With like clinical performance of tomorrow  
• Voxel Point Reconstruction - Exceptional image quality  
• ADIC - More diagnostic information for motion in one scan  
• Real Re - Improved workflow and CT flexibility  
• Clinical Performance Package - Sustaining imaging quality without compromise



## Discovery Dimension Console Integrating innovation

The heart of Discovery STE is the Discovery Dimension Console - the first truly integrable PET/CT operator's environment designed to improve clinical results and streamline workflow. Together, Discovery STE and the Discovery Dimension Console represent the state-of-the-art from which we are delivering value and clinical improvements that solve some of your biggest needs.

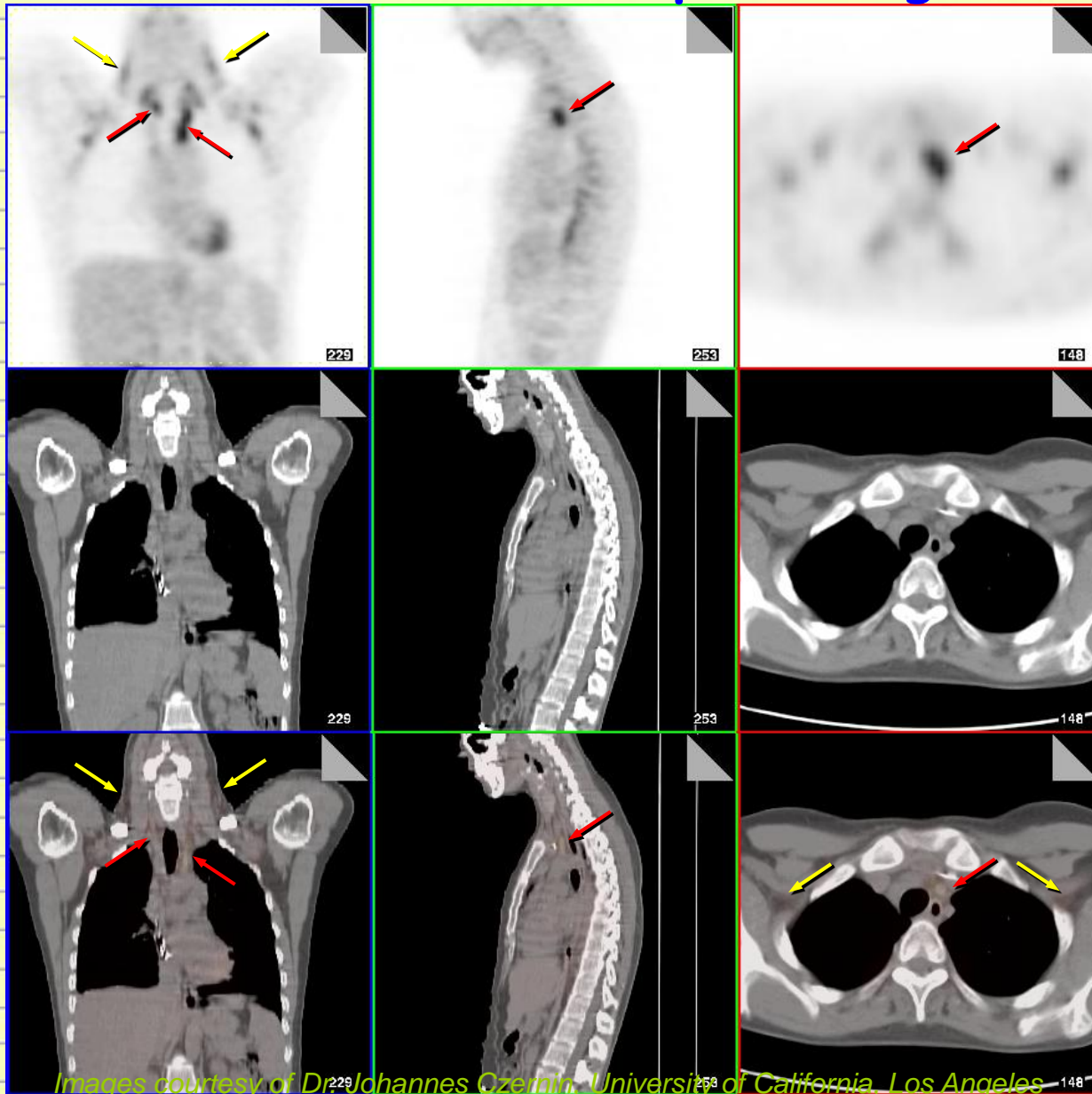
GE Discovery ST Elite





Philips Gemini GXL/TF

# Az együttes vizsgálat előnyei:

## 1. a lokalizálás pontossága



 Normal  
 Lymphoma

PET	(6 min)
FDG	15 mCi
Bed	1 min
CT	(1 min)
KVs	130 kV
mAs	75 mA
Slice	5 mm

Images courtesy of Dr. Johannes Czernin, University of California, Los Angeles

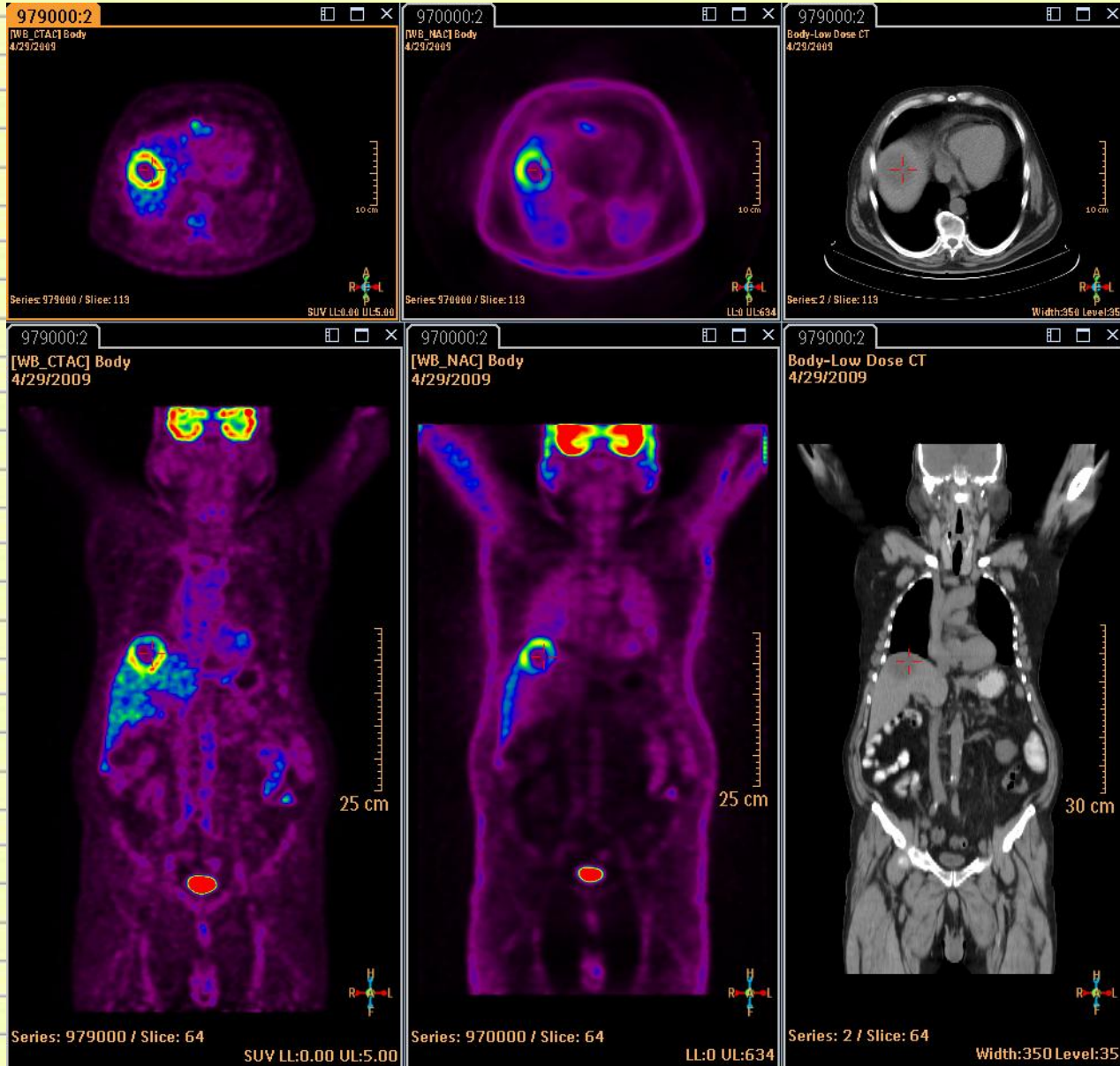


# Az együttes vizsgálat előnyei:

## 2. Tökéletesebb korrekciók a PET képrekonstrukció során

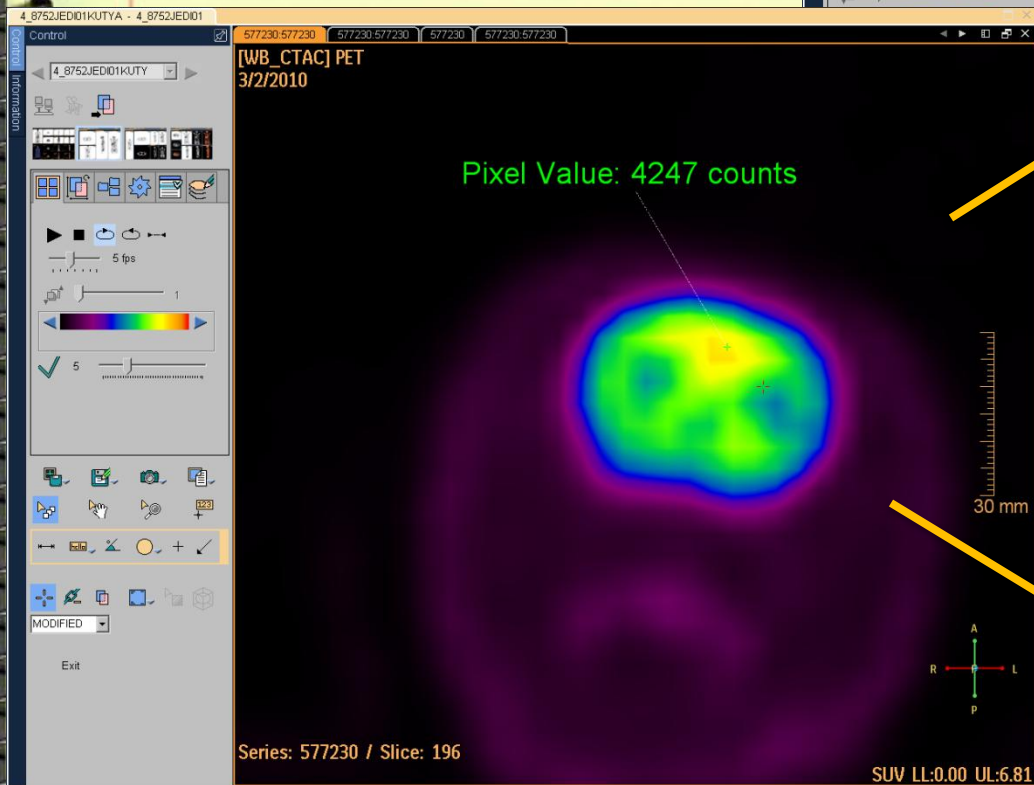
corrected

no corrections

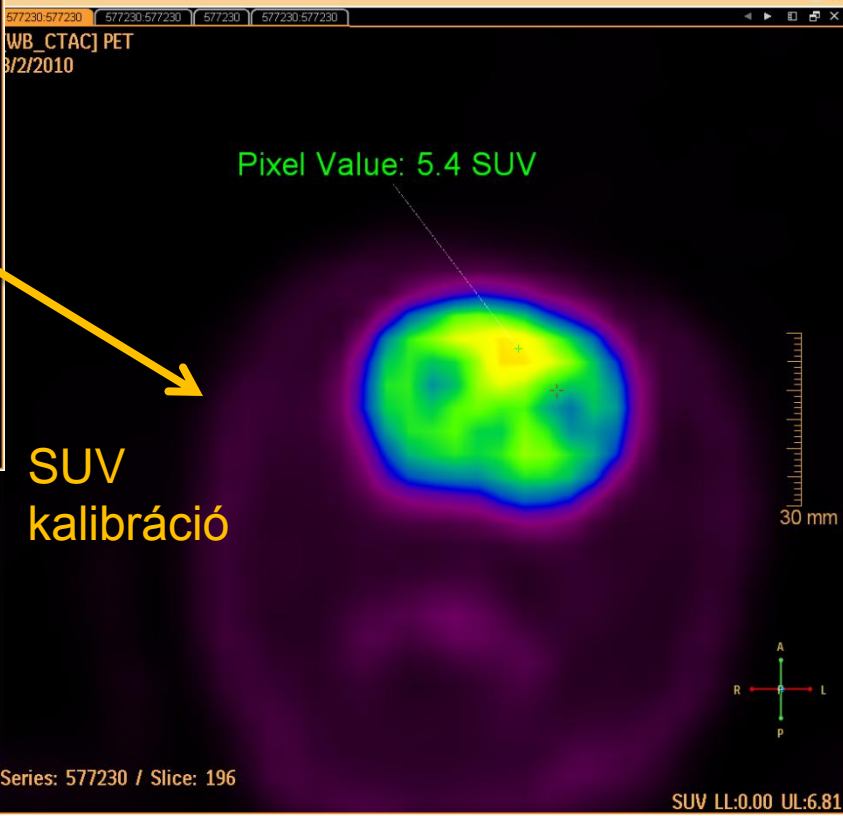




# A PET kamera kalibrációja



Aktivitás  
koncentráció  
kalibráció



SUV  
kalibráció

# Standard uptake value (SUV)

Az aktivitás koncentrációban kifejezett PET kép  
praktikus „tovább skálázása”

$$SUV_{(1,t_2)} = \frac{\text{ROI aktivitás koncentráció}_{(1,t_2)}}{\text{beadott aktivitás / testsúly kg}}$$

$$SUV_{(1,t_2)} = \frac{\text{pixel aktivitás koncentráció}_{(1,t_2)}}{\text{beadott aktivitás / testsúly kg}}$$

Megmutatja, hogy egy kiválasztott régióban  
mérhető aktivitás hányszorosa annak, amit a  
radiofarmakon feltételezett egyenletes szöveti  
eloszlása esetén mérhetnénk

# A SUV számolás előnyei, tulajdonságai

- Egyszerű
- Összehasonlíthatóvá teszi a vizsgálatokat (terápia ellenőrzés)
- Feltételezi, hogy a páciensben a radiofarmakon globális metabolizmusa nem változik a két vizsgálat között (gyakran kérdéses hogy a kiválasztás valóban egyforma-e, vagy pl változó gyulladáisos folyamat nem történik-e, ...)
- A pontosság további feltételei: a PET kamerát időközönként kalibrálni kell; a leképzés időzítése szigorúan protokoll szerint kell hogy történjen



Akkumulált FDG aktivitásigény (mCi)

FDG betegenként [mCi] =

10

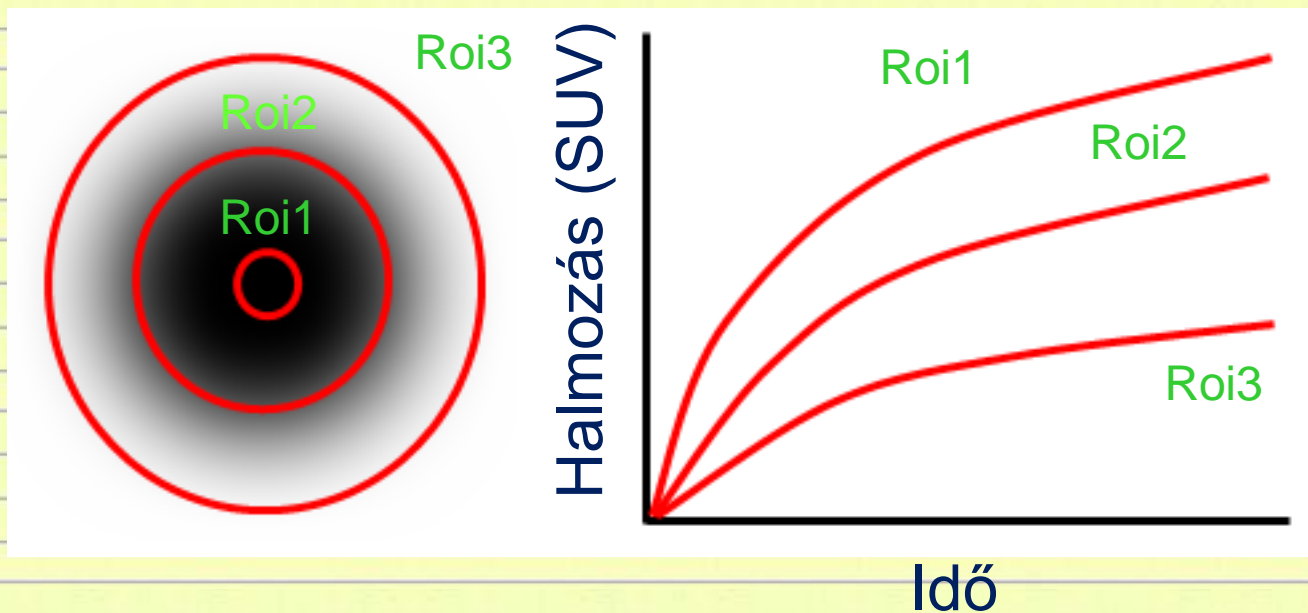
ScanTime [min] =

35

First scan start time - FDG ready time

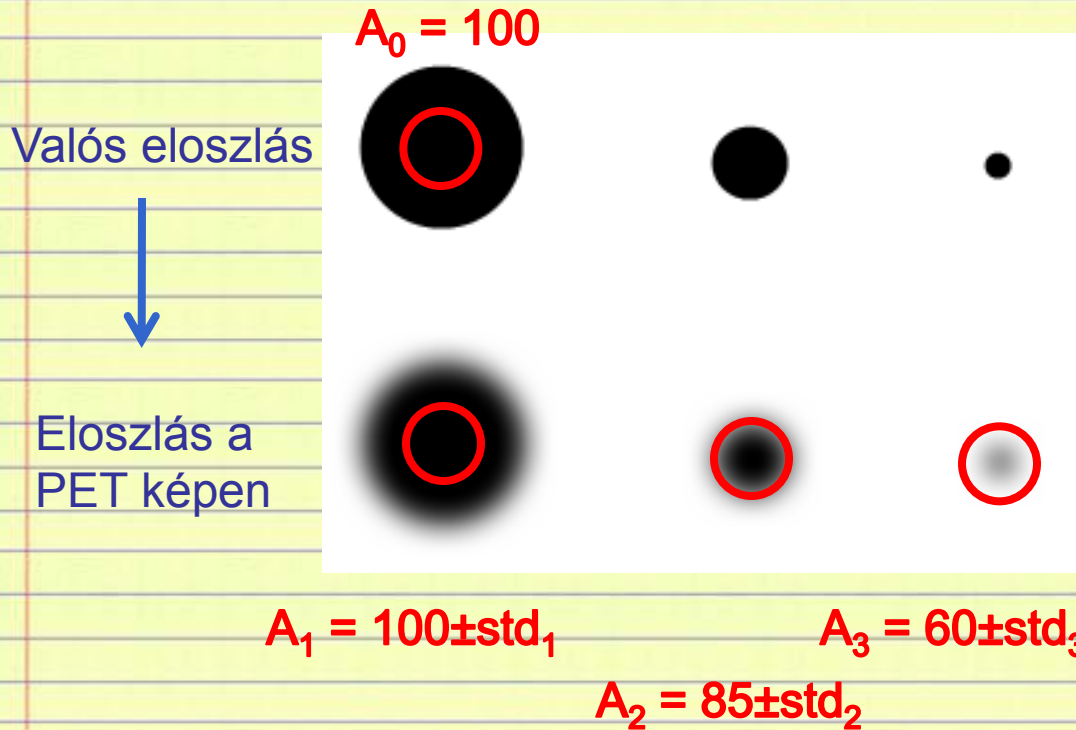
vizsgálatok sorszáma	Scan start (óra)	0	150
1	0.00	10	26
2	0.58	22	58
3	1.17	38	98
4	1.75	57	148
5	2.33	82	210
6	2.92	112	287
7	3.50	149	384
8	4.08	196	505
9	4.67	254	655
10	5.25	327	842
11	5.83	418	1076
12	6.42	531	1367
13	7.00	672	1730
14	7.58	848	2182
15	8.17	1067	2746
16	8.75	1341	3450
17	9.33	1681	4327
18	9.92	2106	5420
19	10.50	2636	6784
20	11.08	3297	8483

# Region of interest (ROI) és a target terület méretének hatása a SUV-ra



$$SUV_{(t_1, t_2)} = \frac{ROI \text{ aktivitás koncentráció}_{(t_1, t_2)}}{\text{beadott aktivitás / testsúly kg}}$$

# ROI és target(szerv) méret viszonyának hatása



Ha a target „nagy” és a ROI ennél kisebb, akkor a halmozás becslése kis hibával lesz terhelve

Ha a target „kicsi”, akkor a ROI-val történő halmozás- mérés mindig alul becsüljük (az alulbecslés mértéke függ a target és ROI méretétől)

$$SUV \langle t_1, t_2 \rangle = \frac{\text{ROI aktivitás koncentráció} \langle t_1, t_2 \rangle}{\text{beadott aktivitás / testsúly kg}}$$

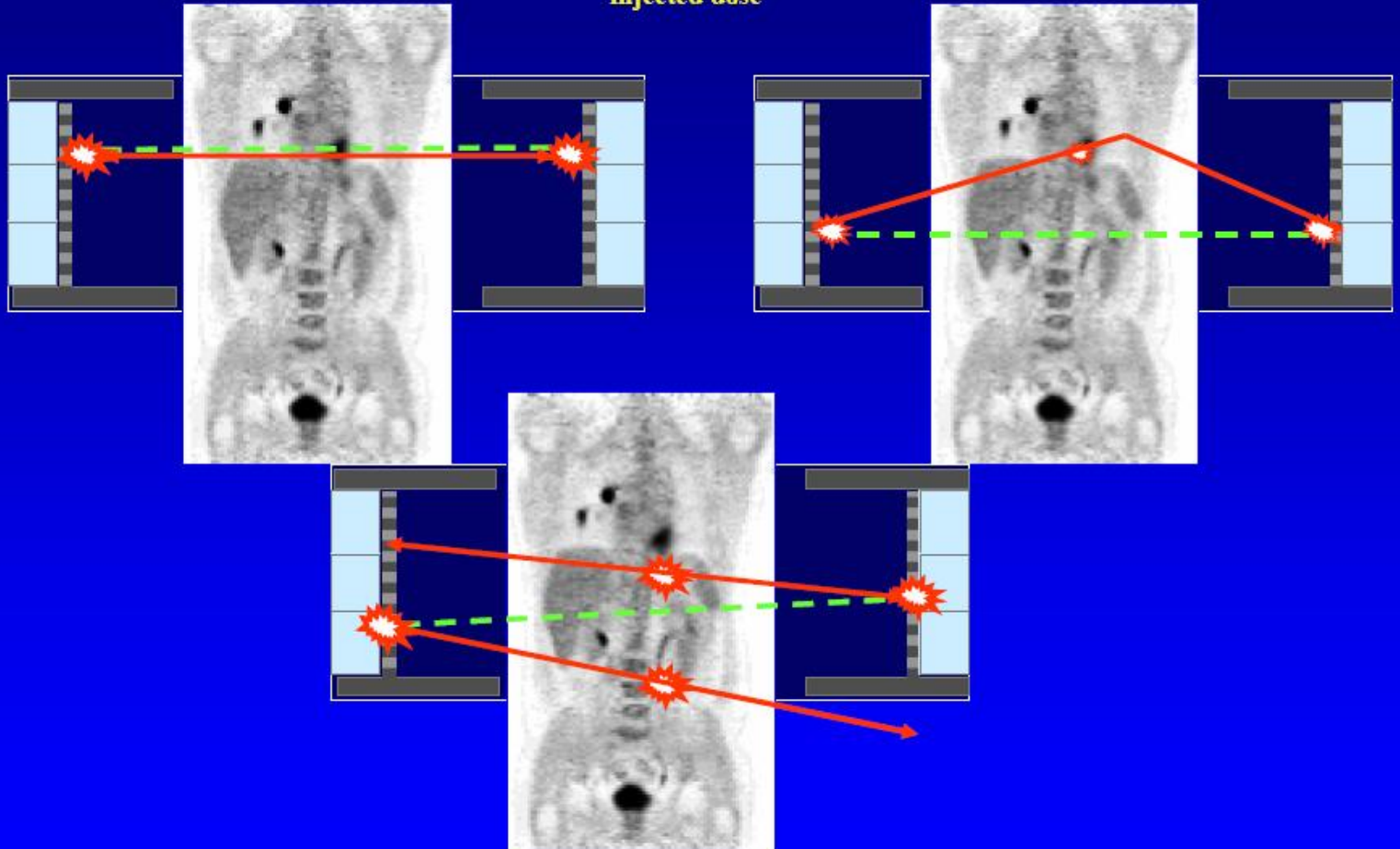


# Zavaró, torzító hatások a PET-ben

**Trues Coincidence**

**Scatter Coincidence**

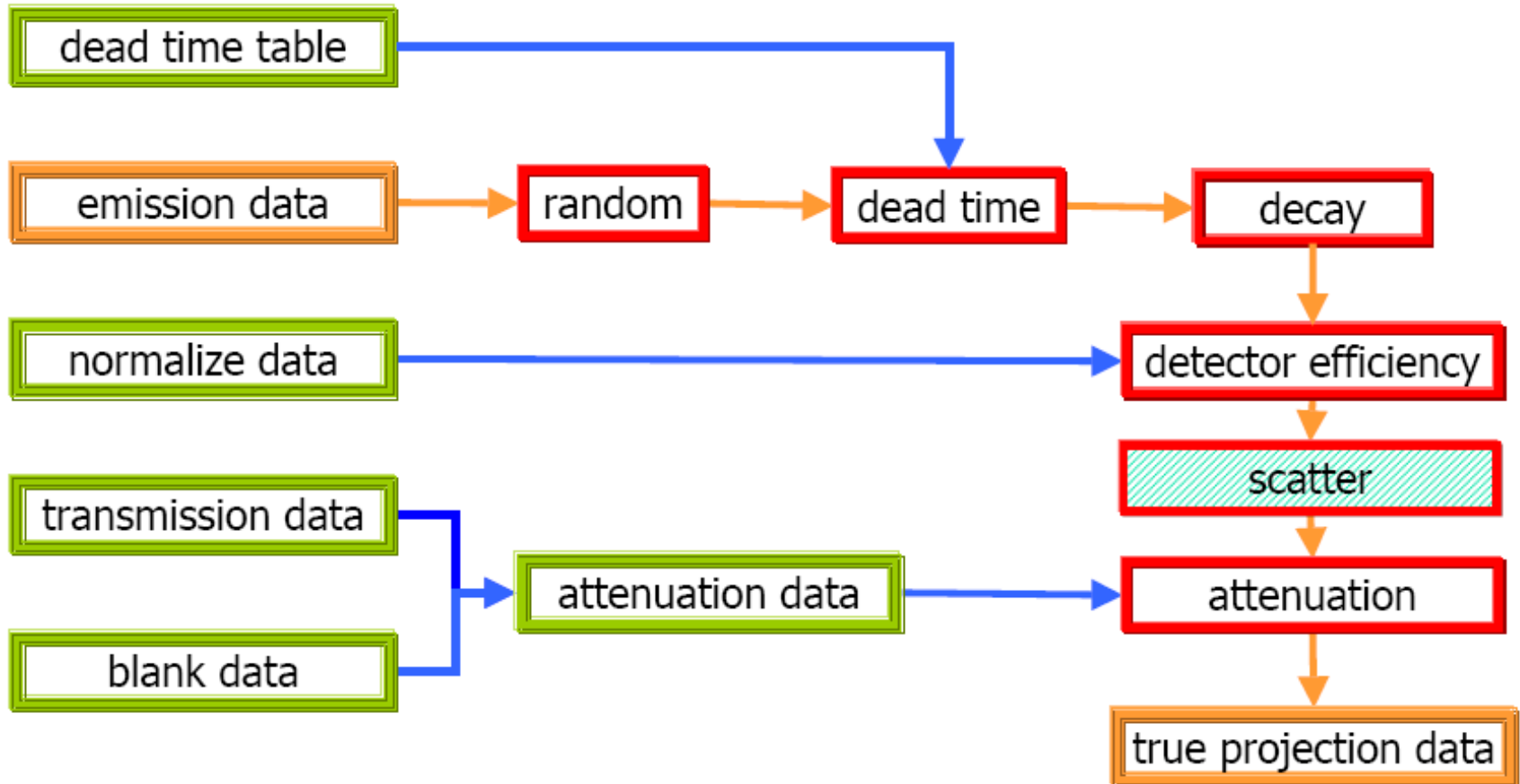
Vary linearly with  
injected dose



**Random Coincidence**

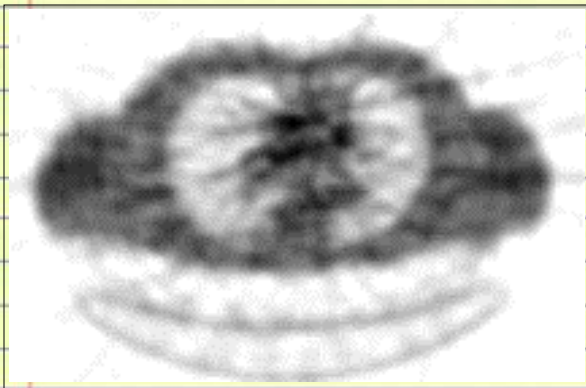
Vary quadratically with injected dose

# What are needed to obtain true projection data



# Gyengítési korrekció módszerei

## A transzmissziós képek típusai



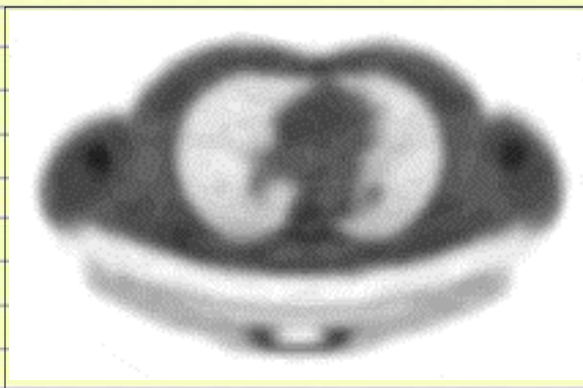
Coincident photon Ge-68/Ga-68 (511 keV)

high noise

15-30 min scan time

low bias

low contrast



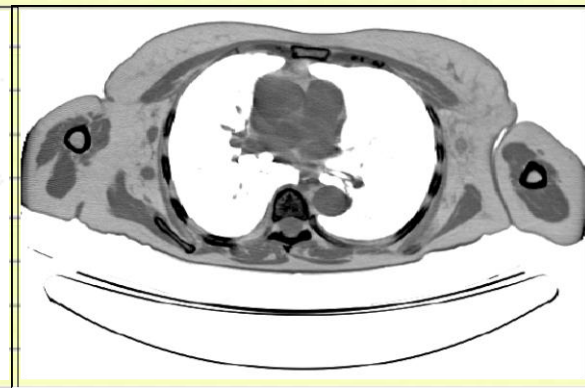
Single photon Cs-137 (662 keV)

lower noise

5-10 min scan time

some bias

lower contrast



CT (~30-140kVp)

no noise

1 min scan time

potential for bias

high contrast



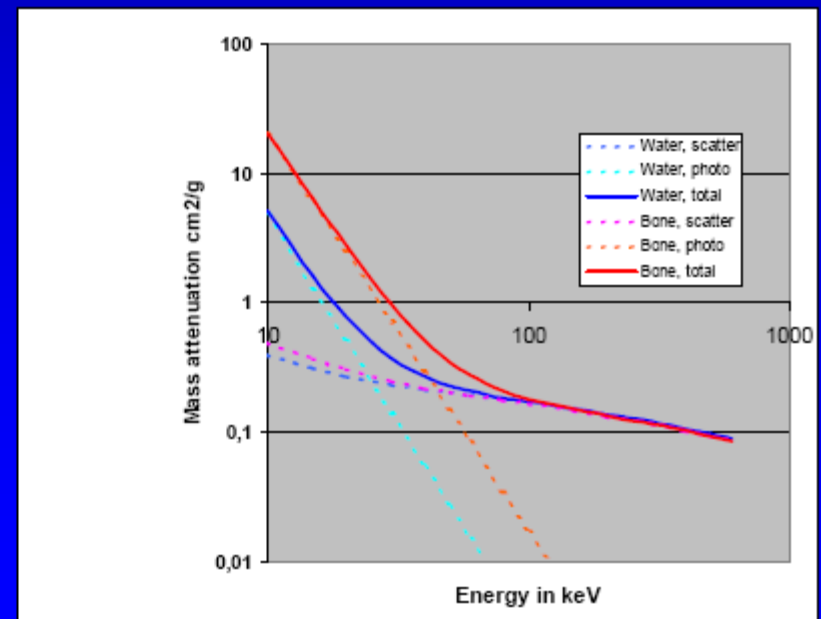
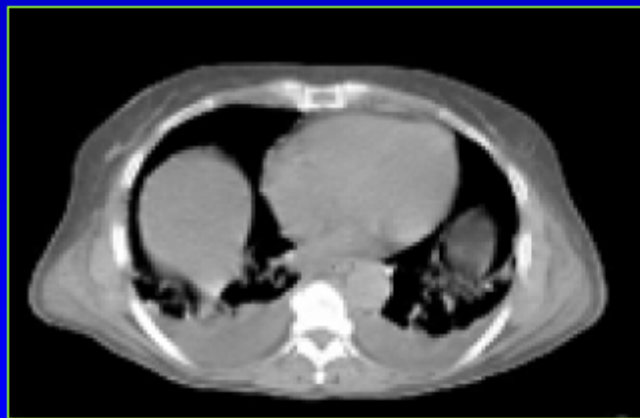
A CT scan IS a  $\mu$ -map (expressed in HU)

- can be used for attenuation correction
- essentially noise free (except artefacts)

But:  $\mu(511 \text{ keV}) \neq \mu(80 \text{ keV})$ , therefore a scaling is required

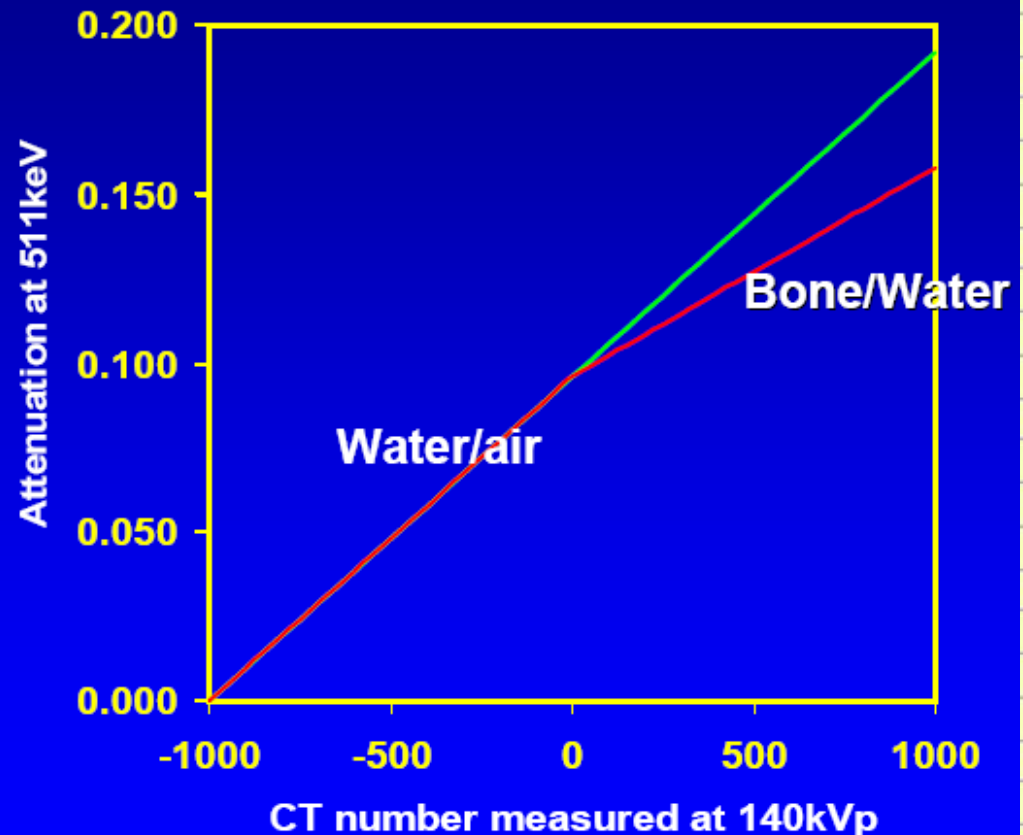
Soft tissue and bone (and contrast) scale **differently**

$\Rightarrow$  only minor errors in quantitation of PET images



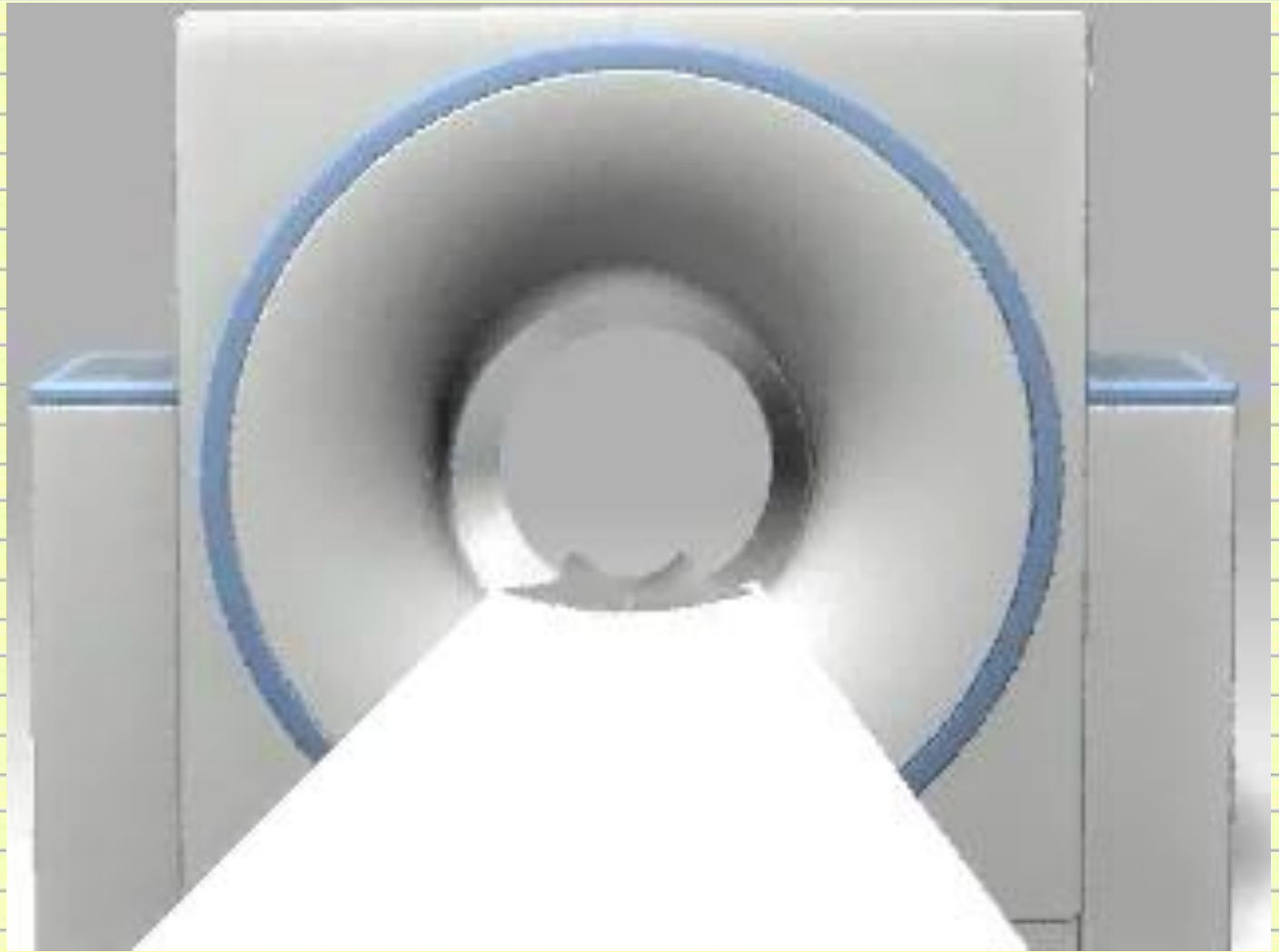
# Converting CT Numbers to Attenuation Values

- For CT values  $< 0$ , materials are assumed to have an energy dependence similar to water
- For CT values  $> 0$ , material is assumed to have an energy dependence similar to a mixture of bone and water
- The green line shows the effect of using water scaling for all materials



## CT (SOMATOM Emotion DUO)

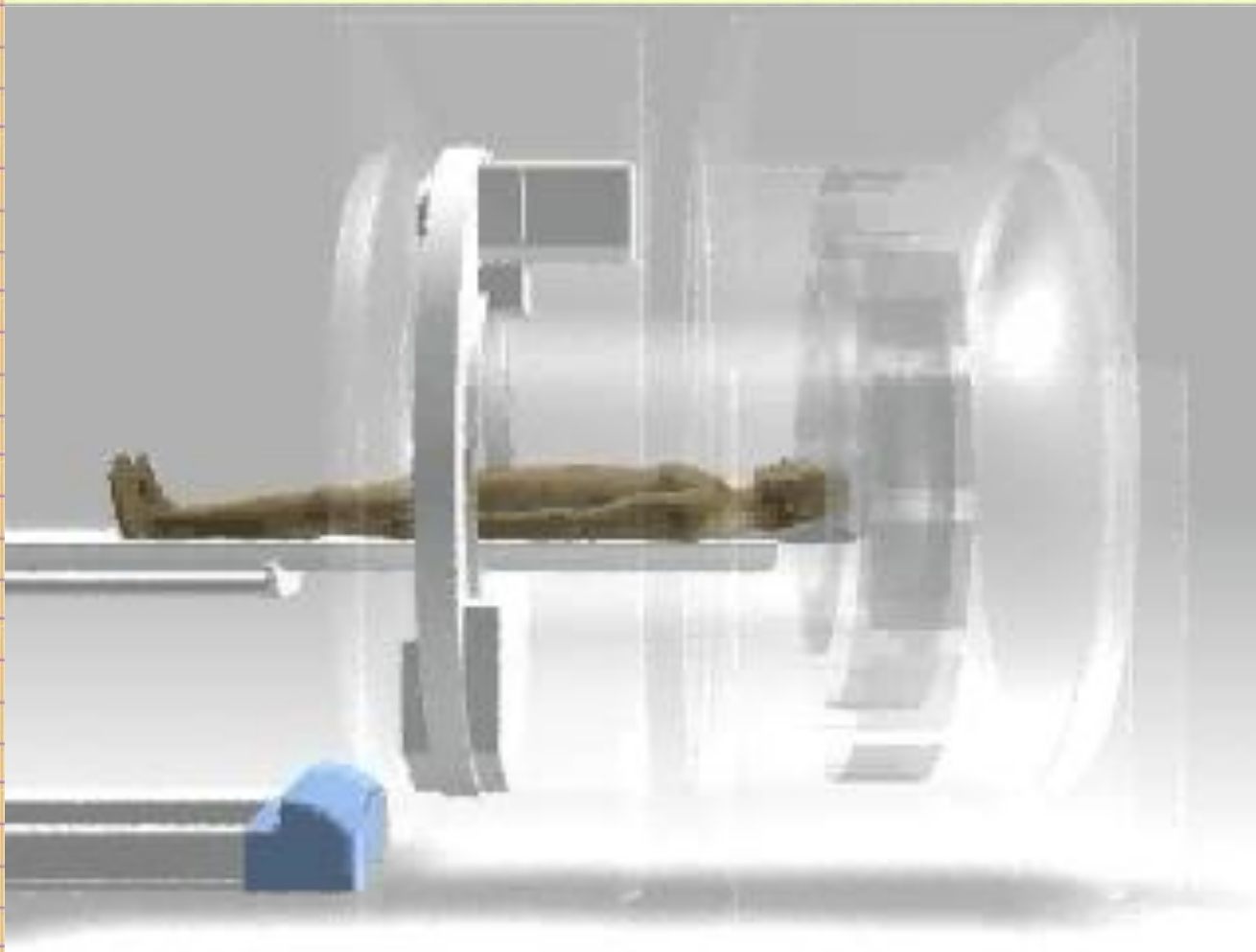
- Topogram (scout)
- Spiral scan (<1 min)





# A topogram





PET (LSO)

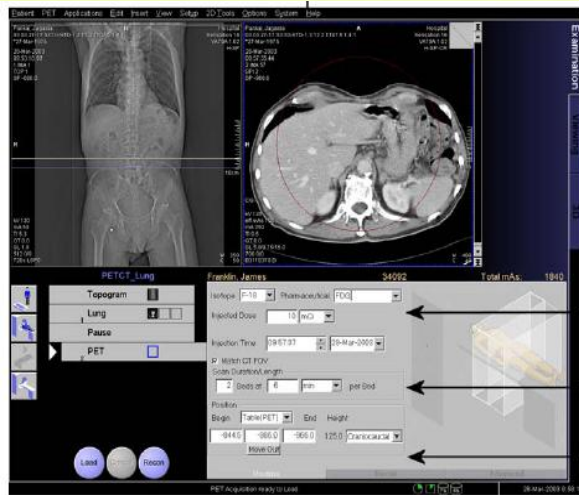
- 1 to 4 min/ bed position
- 7 bed positions

# Operátorok, kezelők





# Adatgyűjtő „szoftver”



Siemens Biograph Hirez



GE Discovery ST Elite



Philips Gemini GXL

# A képmegjelenítés módjai I

[WB\_CTAC] Body  
4/29/2009

[WB\_CTAC] Body  
4/29/2009

[WB\_CTAC] Body  
4/29/2009

[WB\_CTAC] Body  
4/29/2009

Series: 979000 / Slice: 113  
SUV LL:0.00 UL:5.00

Series: 979000 / Slice: 69  
SUV LL:0.00 UL:5.00

Series: 979000 / Slice: 68  
SUV LL:0.00 UL:5.00

979000:2  
Body-Low Dose CT  
4/29/2009

979000:2  
Body-Low Dose CT  
4/29/2009

979000:2  
Body-Low Dose CT  
4/29/2009

Series: 979000 / Slice: 15  
unitless LL:0.00 UL:2600.00

Series: 2 / Slice: 113  
Width: 350 Level: 35

Series: 2 / Slice: 80  
Width: 350 Level: 35

Series: 2 / Slice: 68  
Width: 350 Level: 35

Movie  
5 fps

40 cm

15 cm

30 cm

30 cm

30 cm

30 cm

30 cm

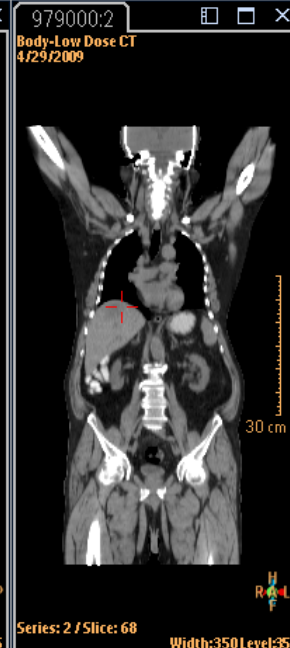
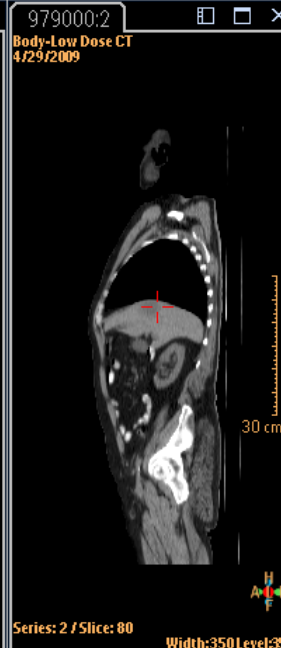
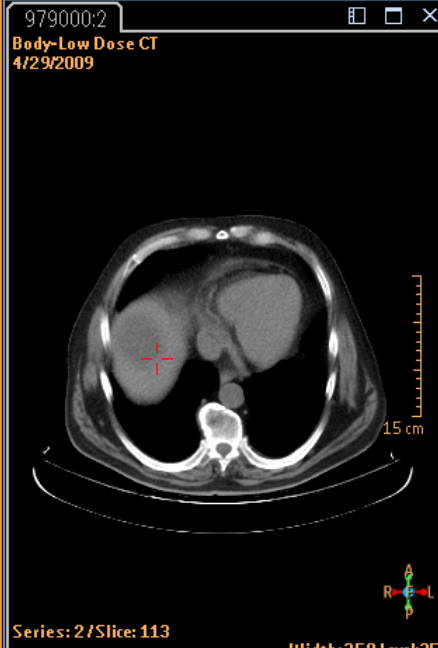
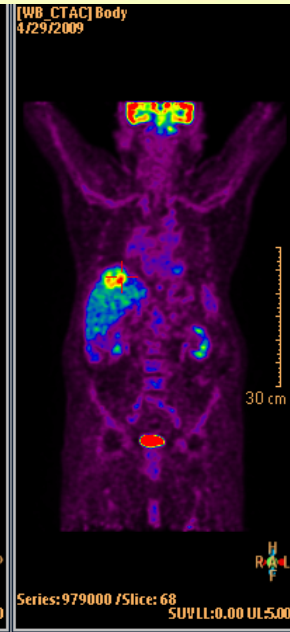
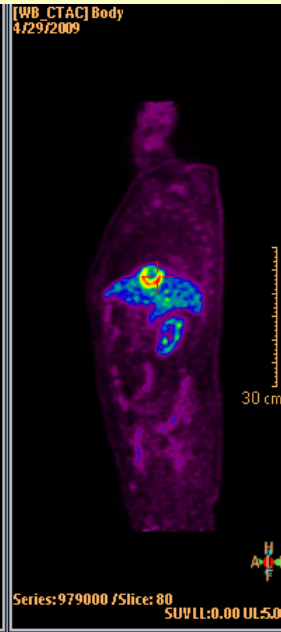
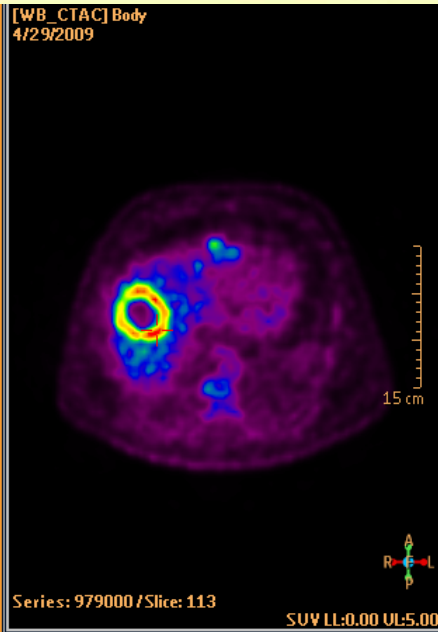
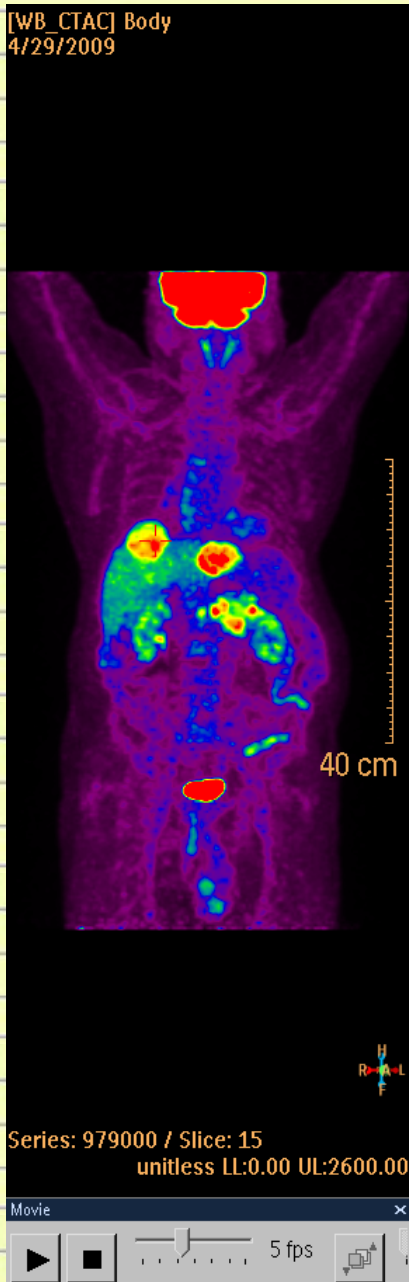
15 cm

30 cm

30 cm

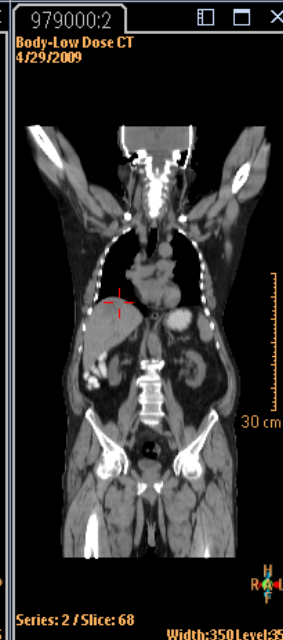
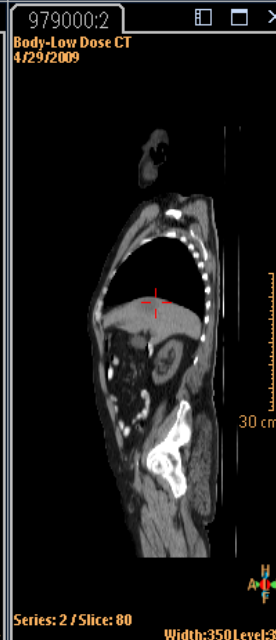
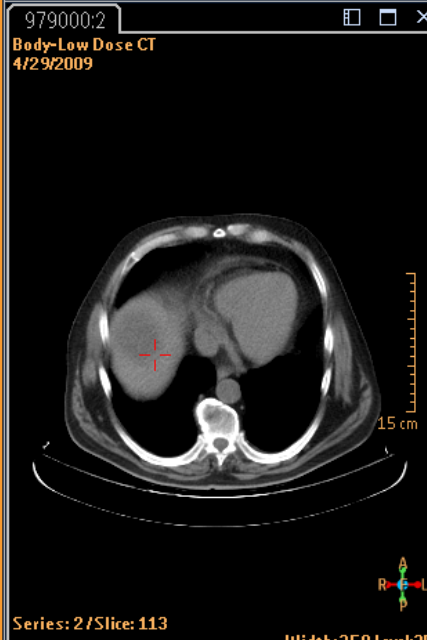
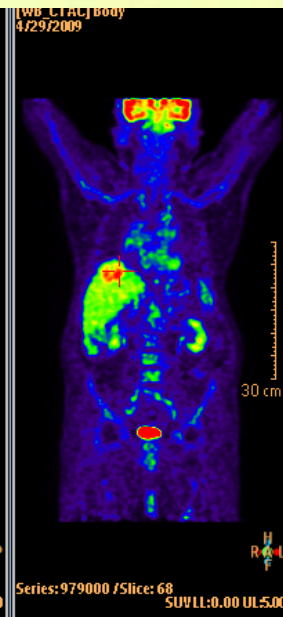
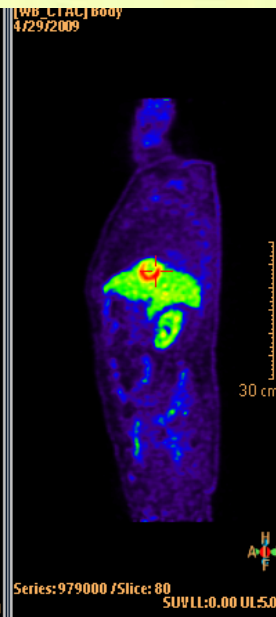
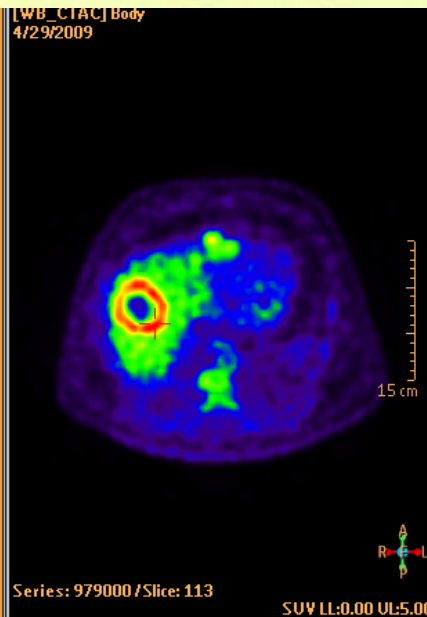
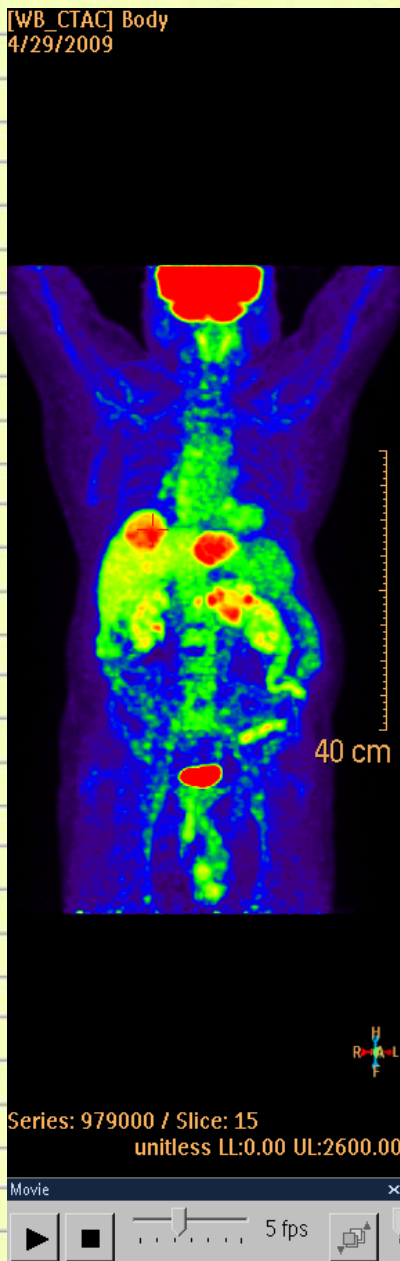


# A képmegjelenítés módjai II

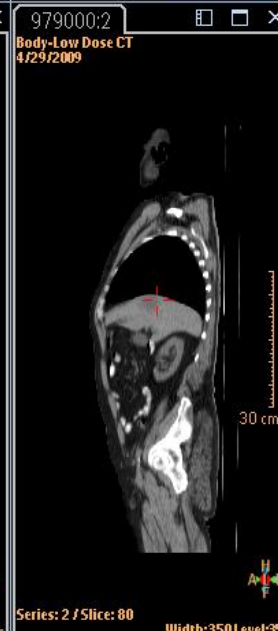
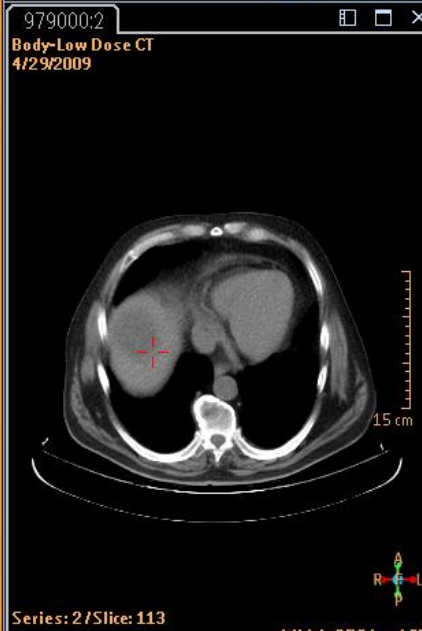
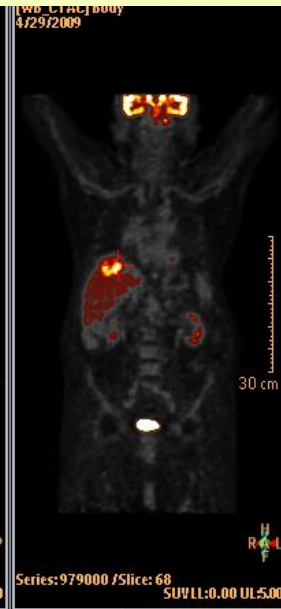
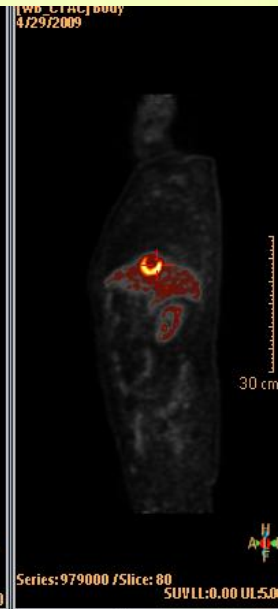
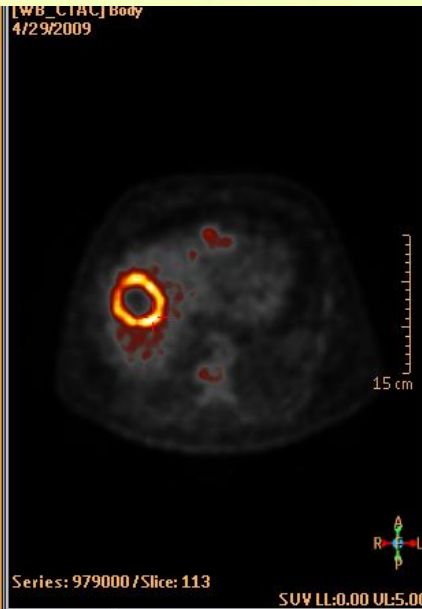
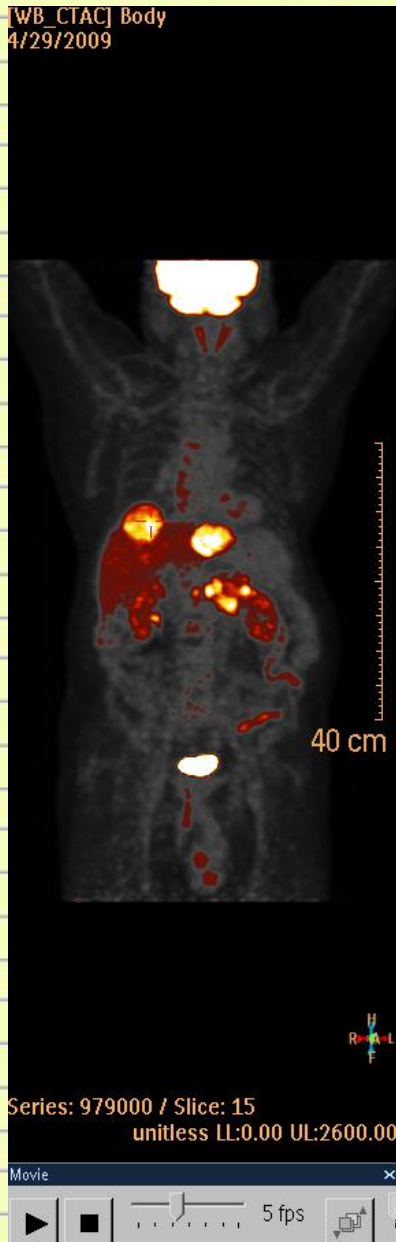




# A képmegjelenítés módjai III

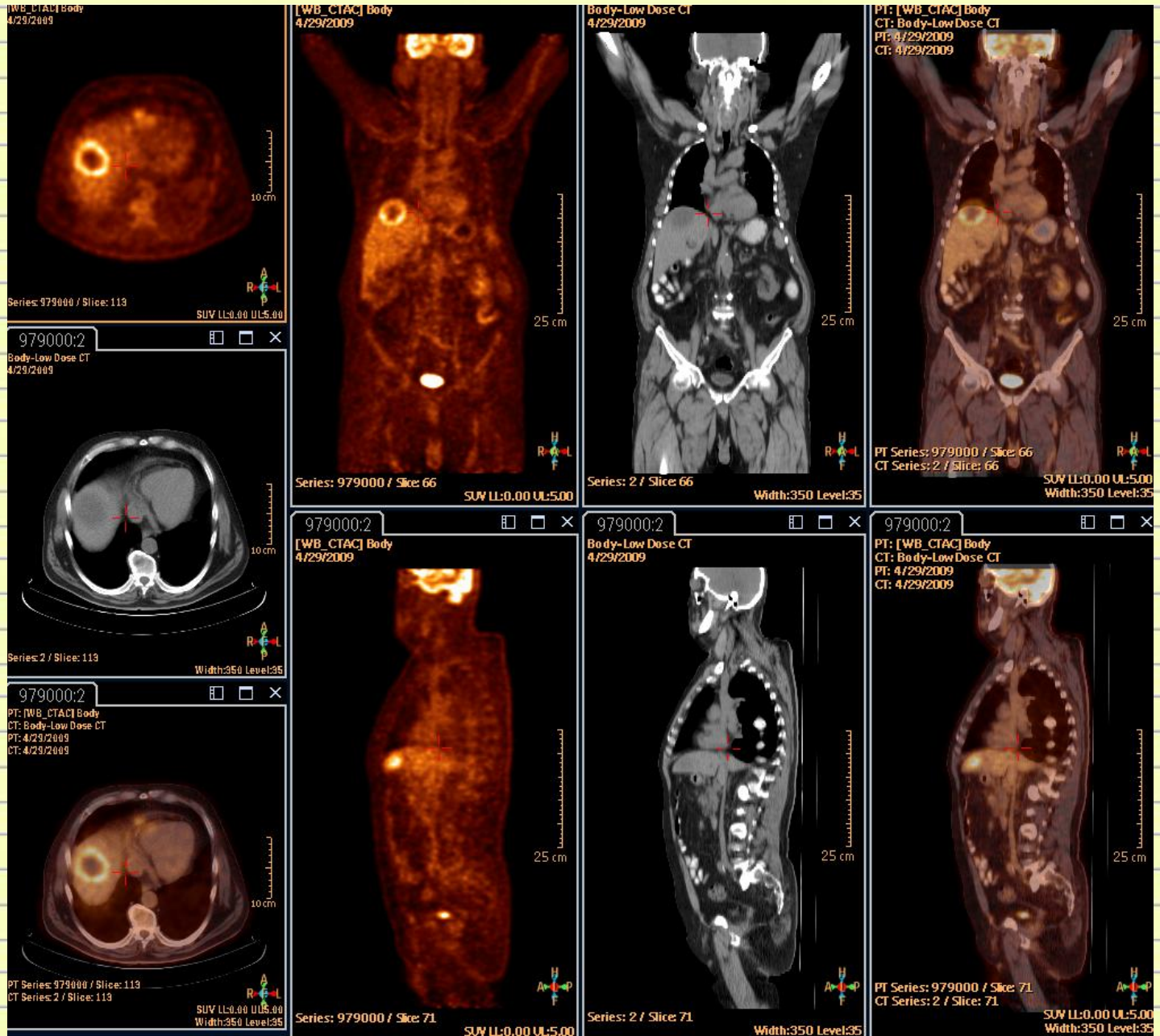


# A képmegjelenítés módjai IV





# A képmegjelenítés módjai V





# A képmegjelenítés módjai VI

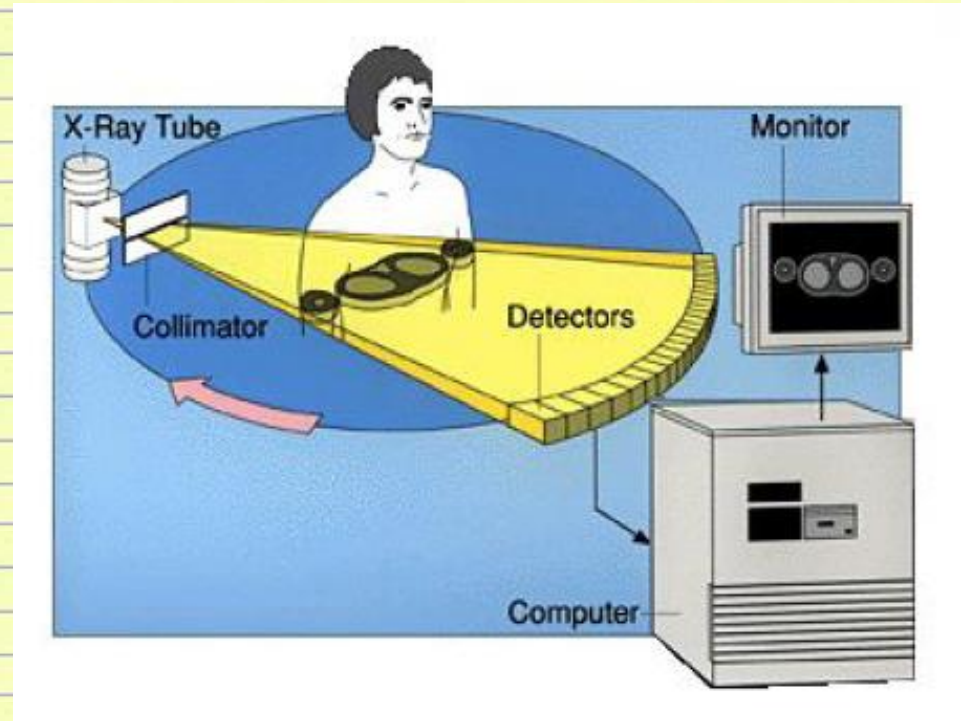
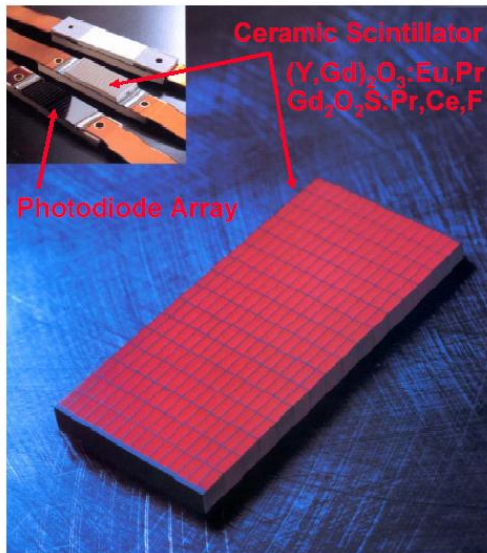
MIP: maximal intensity projection



# A PET és a CT kamerák felbontása



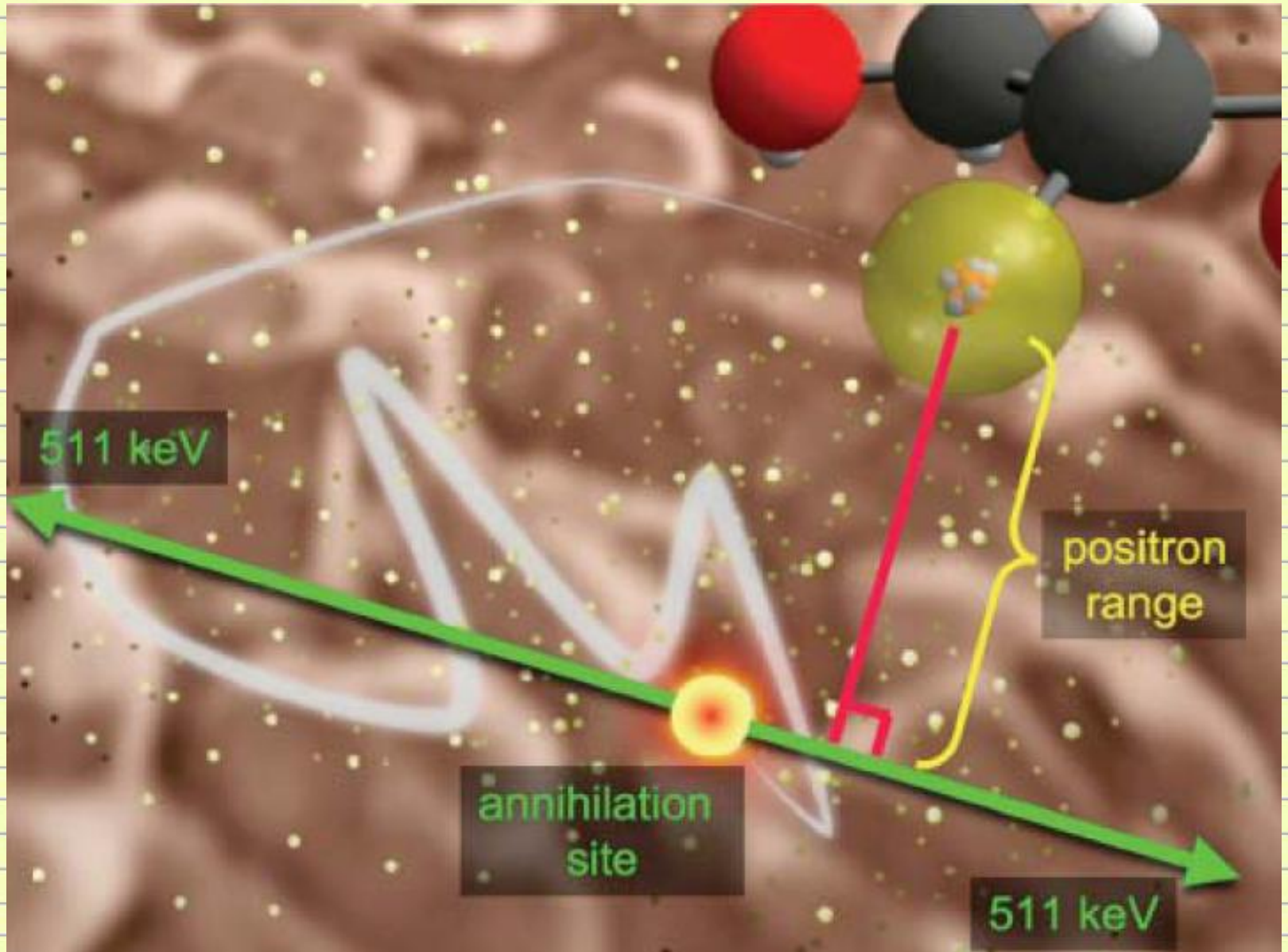
## Typical Sensor for X-Ray CT



A CT felbontása homogén a látótéren belül. (Részterfogat hatás fogalma azonban itt is használatos, de mást jelent: axiális átlagolási hiba).



# Térbeli Felbontás I

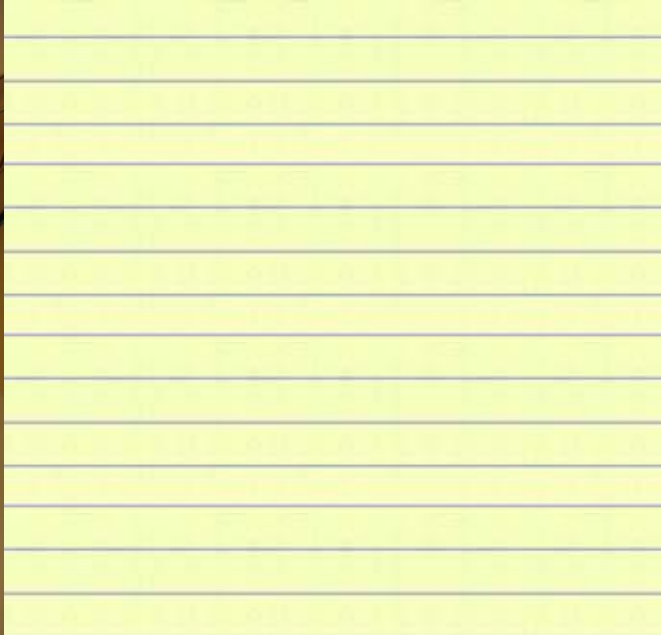




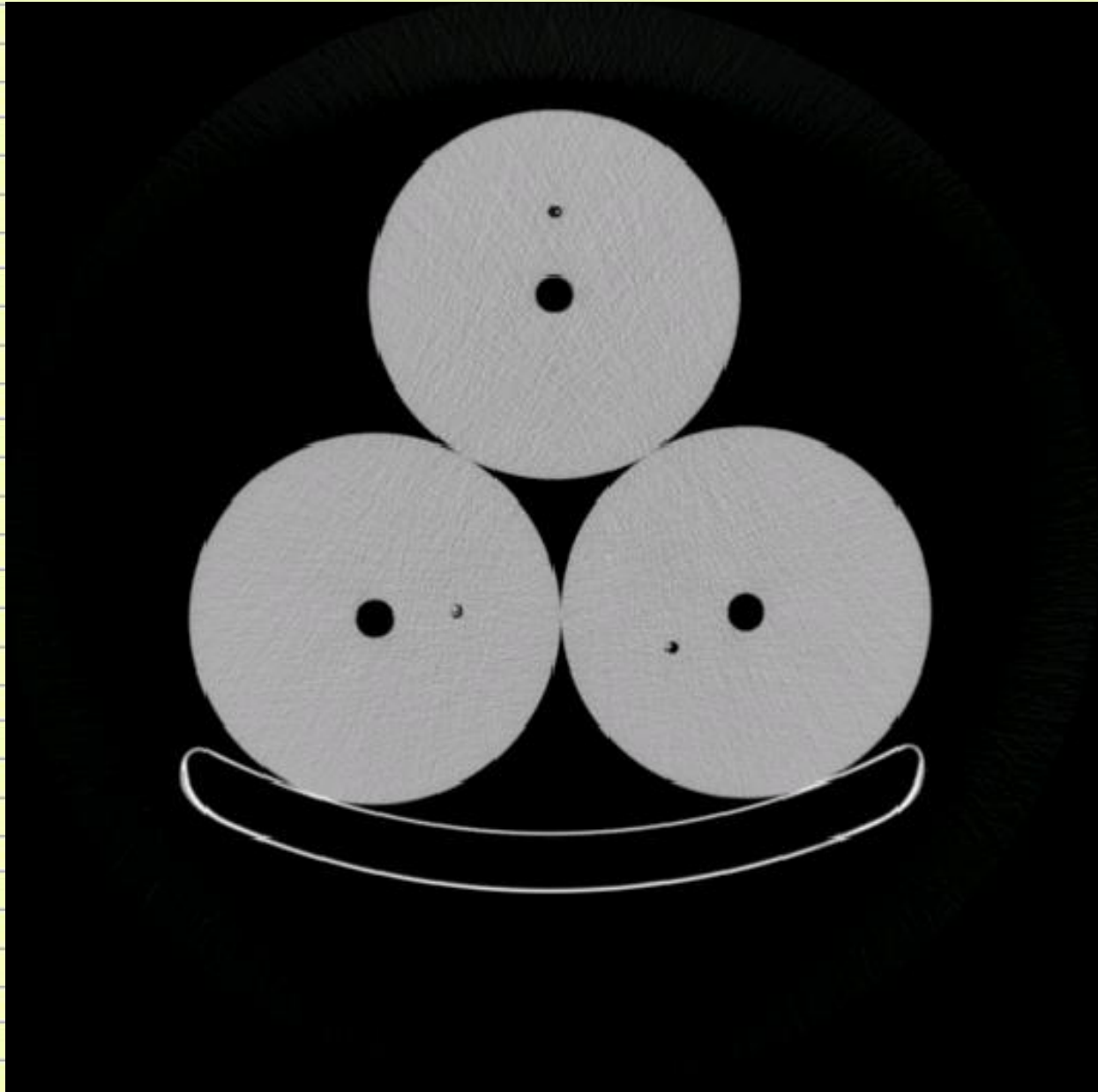
# A PET és a CT kamerák felbontása III

Tehát elvileg mindkét modalitás képes a detektorméretnél kisebb léziók megjelenítésére, ha a detektált jel elegendő a képalkotáshoz. A pont mérete azonban a rekonstruált képen a detektor mérete szerint elkent lesz. Csináljunk kísérletet!



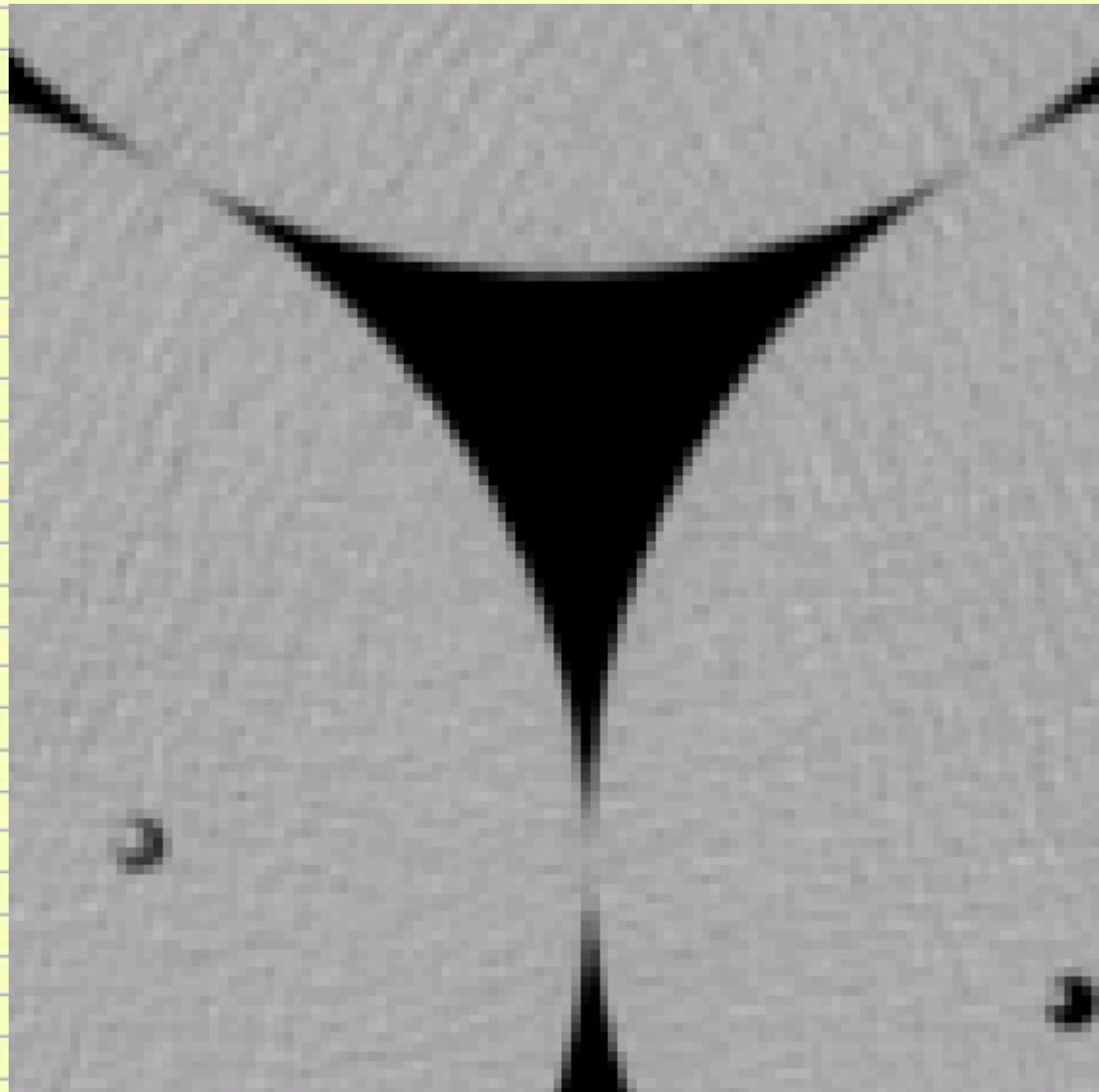


# A fantom CT képe



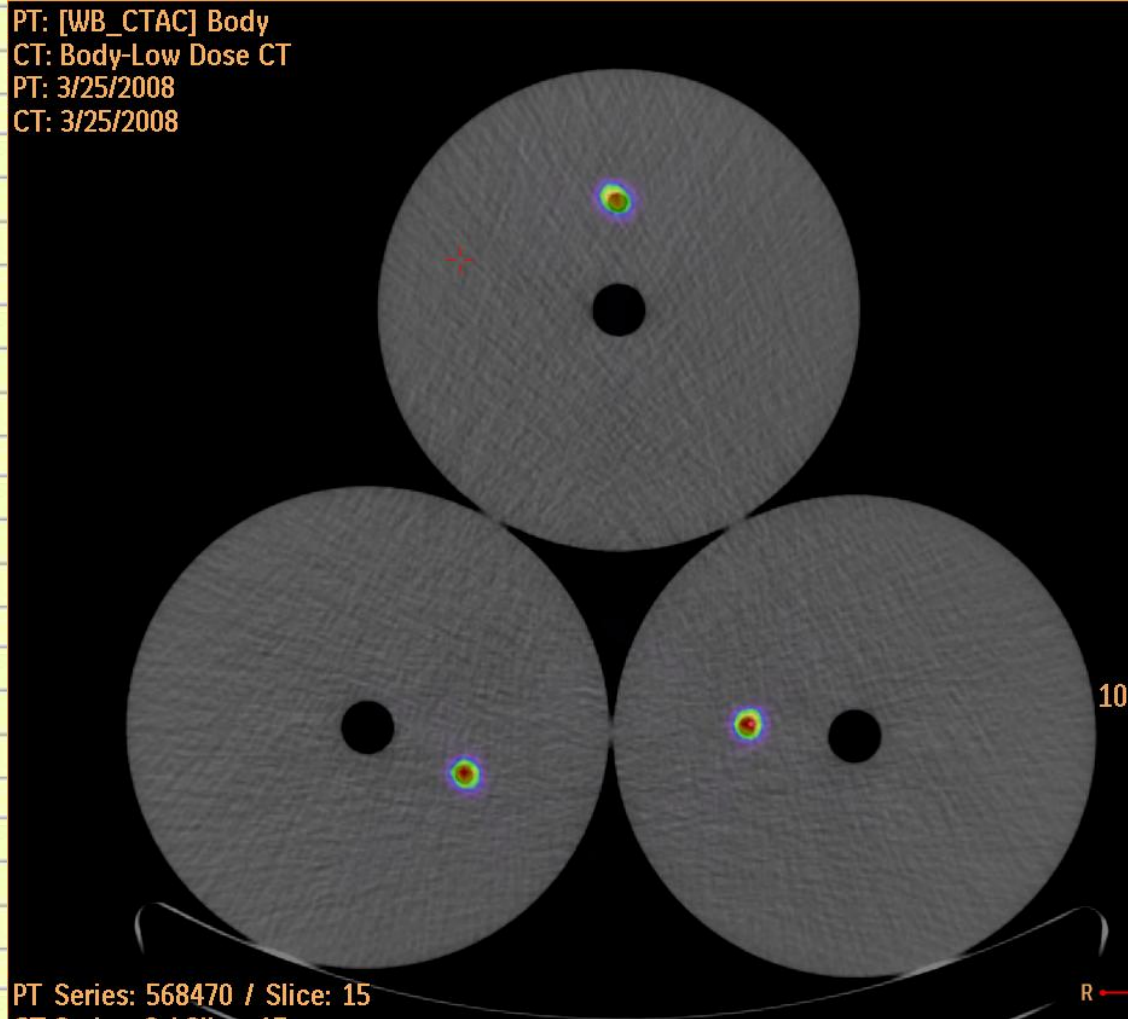


# A fantom „zoomolt” CT képe



# A fantom PETCT képe I

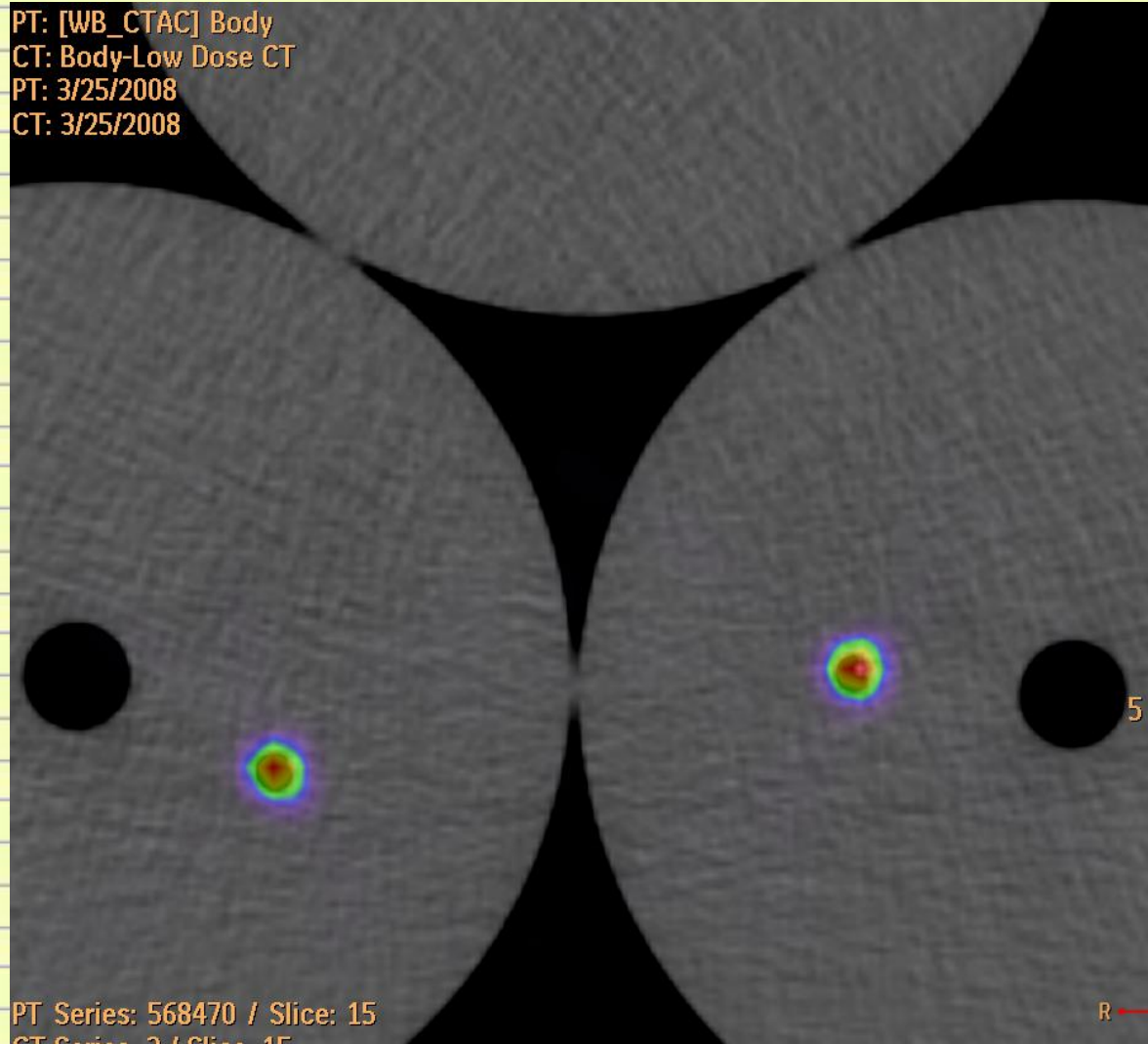
Az aktivitás koncentráció a start időpontban  $\sim 0.8$  mCi/ml (32MBq/ml) volt. Egy normál FDG egésztest vizsgálat esetén az átlagos koncentráció  $\sim 10\text{mCi}/5000\text{ml} = 0.002$  mCi/ml



Frame time = 1 min

# A fantom PETCT képe I

Az aktivitás koncentráció a start időpontban  $\sim 0.8$  mCi/ml (32MBq/ml) volt. Egy normál FDG egésztest vizsgálat esetén az átlagos koncentráció  $\sim 10\text{mCi}/5000\text{ml} = 0.002$  mCi/ml





# Új technikai elemek a PETCT készülékekben: „TruePoint”, „TrueV”, „TrueFlight”, „Vue Point” .....

## HD Uniformity + HD Resolution + HD Contrast = HD Clarity

### HD Uniformity:

Images are distortion-free throughout the entire field of view, from center to edges, enabling more accurate visualization of fine detail no matter where you look.

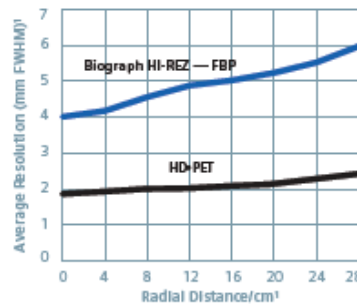


Without HD•PET

With HD•PET

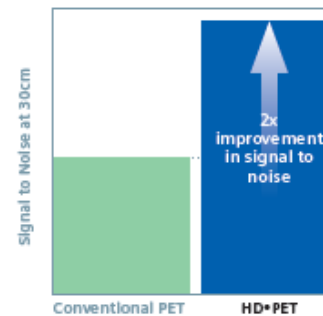
### HD Resolution:

HD•PET offers 2 mm uniform resolution across the entire field of view for enhanced detectability and the highest level of detail.

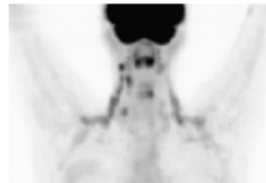


### HD Contrast:

With an unprecedented 2x improvement in signal to noise ratio, HD•PET reveals sharper images, as well as greater distinctness within the image.

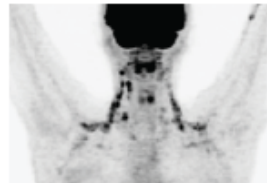


Conventional PET



Data courtesy of the University of Erlangen.

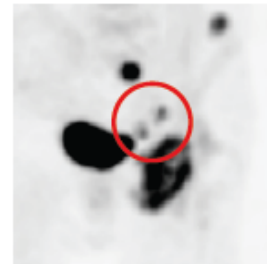
HD•PET



### HD Clarity:

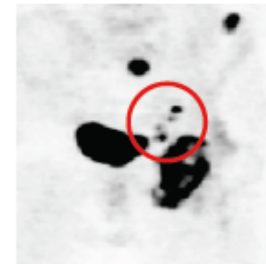
Greater specificity and accuracy deliver crystal-clear results for more confident diagnoses, and earlier, more targeted treatment.

Conventional PET

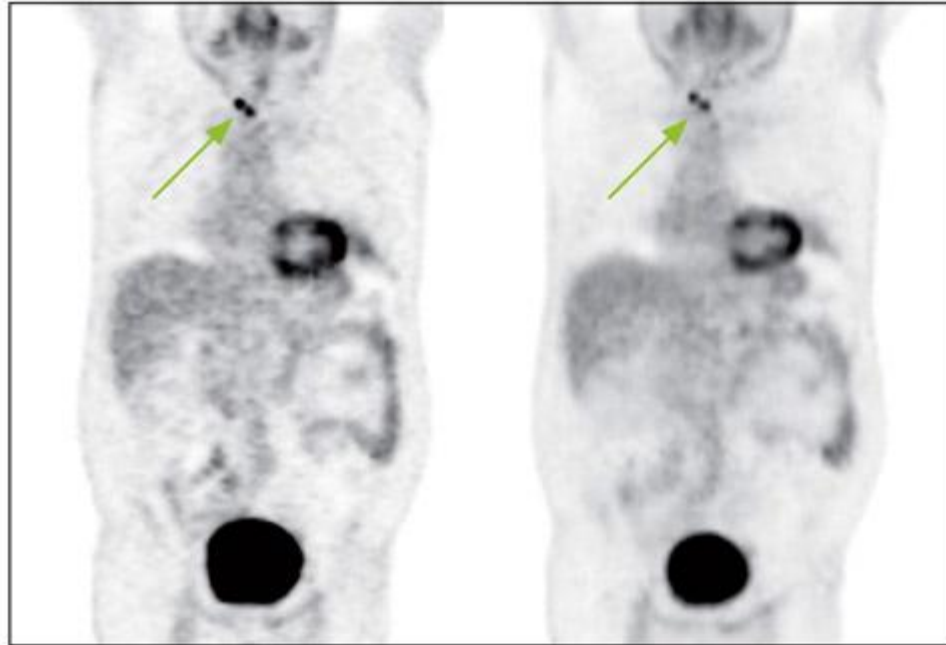


Data courtesy of the University of Erlangen.

HD•PET



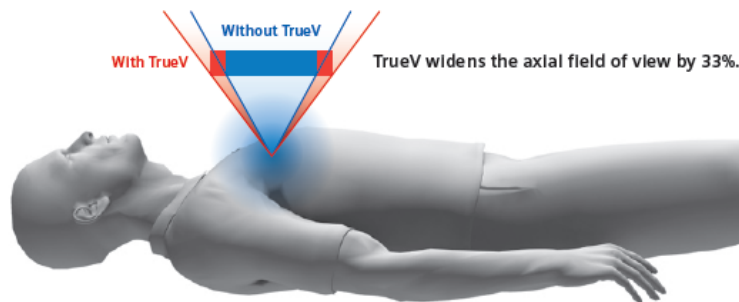
# Új technikai elemek a PETCT készülékekben: „TruePoint”, „TrueV”, „TrueFlight”, „Vue Point” .....



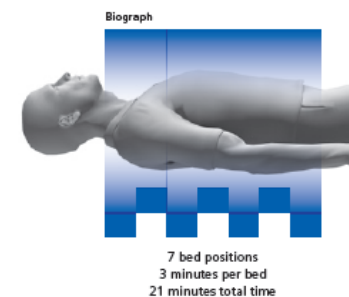
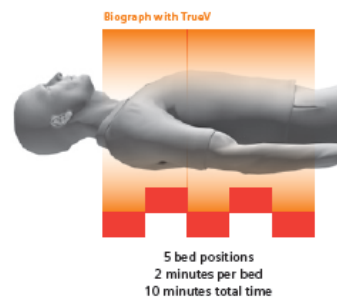
See the distinct separation of the two lesions located in the neck region on both 2D and 3D imaging modes.

# Új technikai elemek a PETCT készülékekben: „TruePoint”, „TrueV”, „TrueFlight”, „Vue Point” .....

## TrueV: Extended Field of View

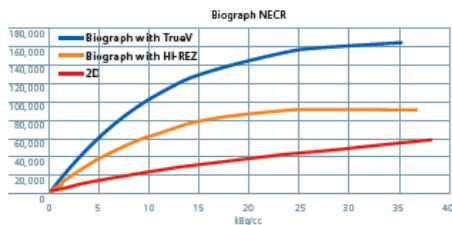


TrueV enables the fastest whole-body scans possible.



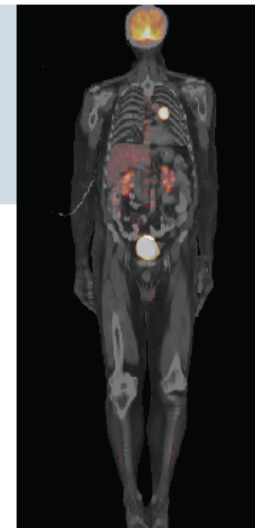
“TrueV extended PET field of view from Siemens has raised all of our expectations as to what PET•CT should be and what it can do to help our patients.” — Dr. David Townsend, University of Tennessee

Feature	Biograph	Biograph with TrueV
Axial bed coverage	162 mm	216 mm
Sensitivity	4.4	7.9
NECR	96 kcps	165 kcps
Resolution	4.2 mm	4.2 mm
Total number of detector elements	24,336	32,448
Total number of detector rings	39	52



TrueV widens the axial field of view (FOV) by 33%, which increases count rate performance by more than 70%, giving you the clinical flexibility to lower dose rates or scan times by 50%. To make the most of the additional FOV, the acceptance angle in the 3D PET acquisition is increased. In this way, more lines of response can be measured per a given unit of time. By increasing the lines of response and thereby, the count rate, scanning protocols can be more flexible. With TrueV you can improve image quality while shortening scan time or reducing the injected dose. Shortened scan time results in less patient motion and fewer artifacts and more time for dedicated CT scans.

- TrueV enables:
- More than a 70% higher noise effective count rate (NECR) for better image quality
  - 2x faster PET•CT for faster imaging
  - Half the injected dose



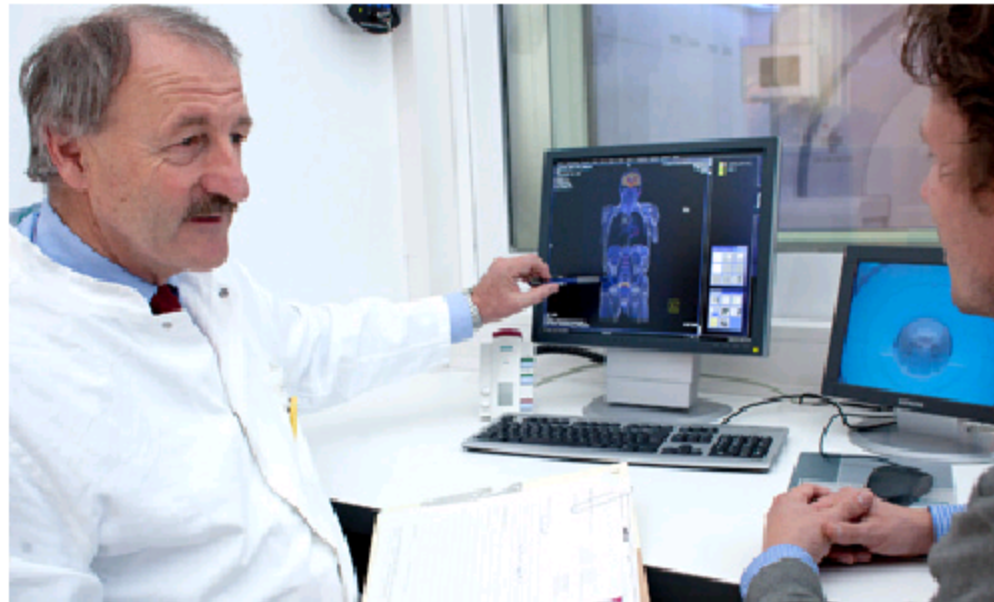


A world's first in imaging – integrated whole-body molecular MR system available for clinical use testing

Siemens unveils Biograph mMR\* whole-body integrated MR and PET system capable of simultaneous data acquisition. First system already undergoing clinical use testing in Munich, Germany.

Erlangen, Germany, 2010-Nov-19

**Today, Siemens Healthcare unveils its new system, Biograph mMR, the world's first integrated whole-body molecular MR with simultaneous data acquisition technology, currently undergoing clinical use testing. This revolutionary system comprises a magnetic resonance (MR) scanner and an integrated PET (Positron Emission Tomography) detection system with an architecture that performs as one. In the new 3-tesla hybrid system, Siemens developers have succeeded for the first time in simultaneously capturing MR and PET data with a whole-body system. The Biograph mMR system has been installed at the university hospital Klinikum rechts der Isar of the Munich Technical University, Germany.**



## Introducing Biograph **mMR**.

Meet the world's only simultaneous, whole-body molecular MR system. Biograph **mMR**. For the first time, MR and PET are together in a single scanner. Empowering you to redefine the way you visualize, diagnose, treat and manage disease.



two is now one.

SIEMENS

096 level

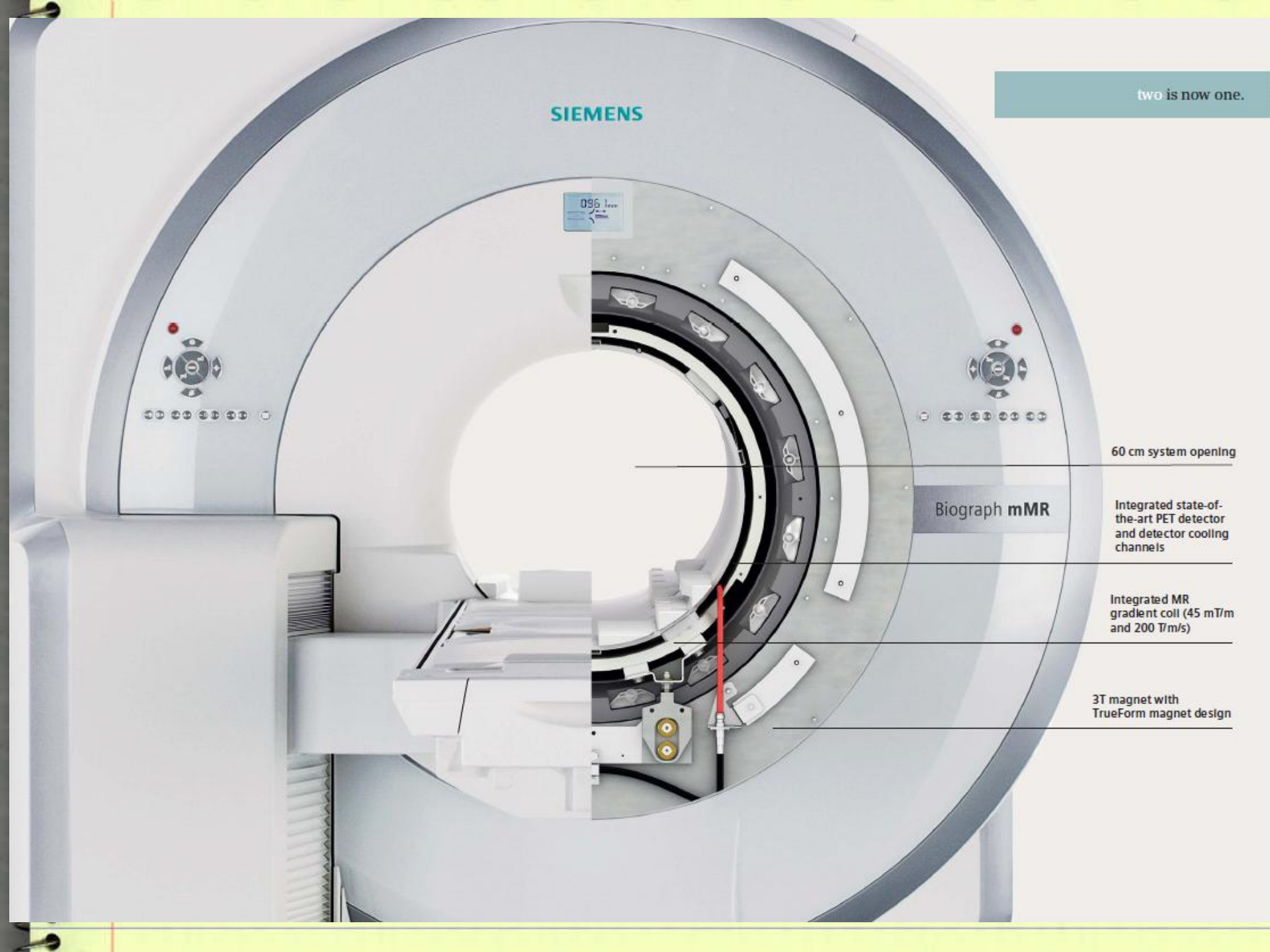
60 cm system opening

Biograph mMR

Integrated state-of-the-art PET detector and detector cooling channels

Integrated MR gradient coil (45 mT/m and 200 T/m/s)

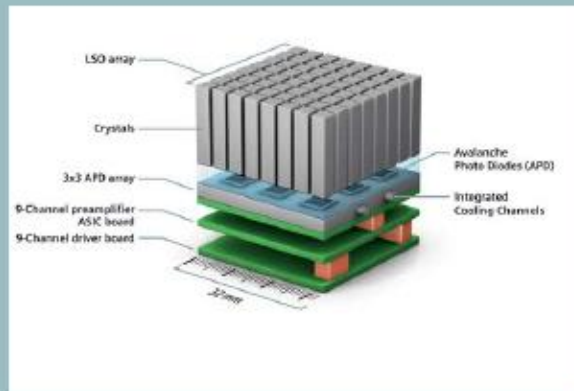
3T magnet with TrueForm magnet design





# The inside story on mMR technology.

As the world leader in both MR and PET, Siemens possesses the engineering expertise to fully integrate the two. It's our understanding of both modalities that has enabled us to bring Biograph mMR to life.



## The first MR-friendly PET detectors.

We've designed the first PET detectors that allow for the full integration of whole-body MR and PET while maintaining the performance of each modality. Our unique mMR PET detector architecture includes integrated cooling features to assure optimal PET performance, as well as specialized shielding to virtually eliminate magnetic field interference in the PET data processing chain.

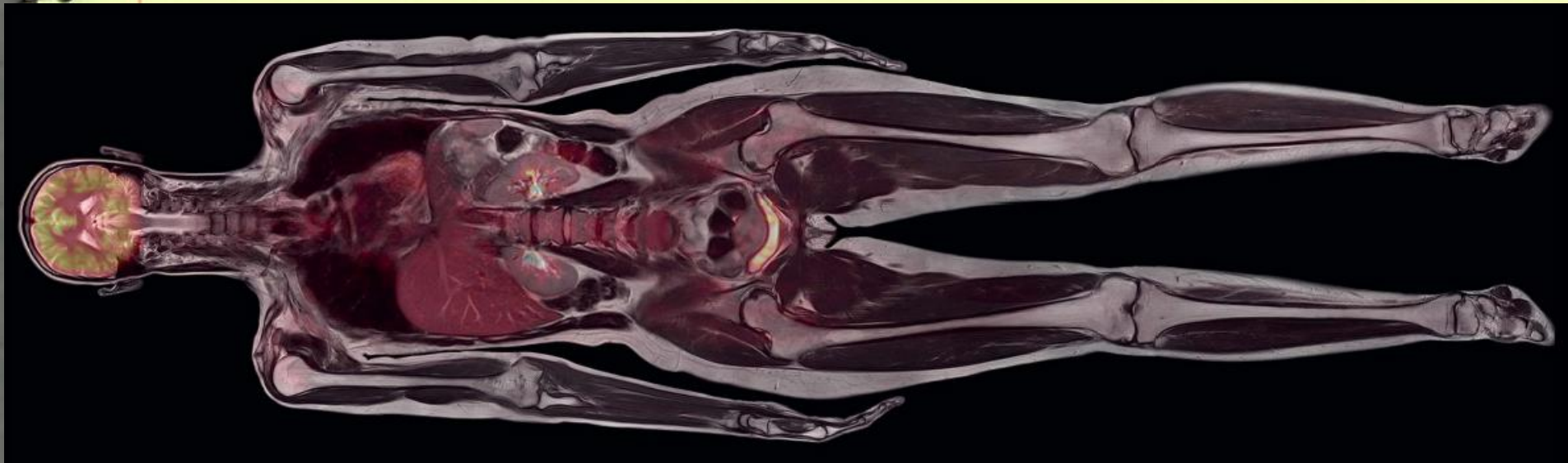
## Optimized for a strong signal.

Attenuation correction of the human body is an essential part of a PET exam. It helps improve the consistency of PET data results across varying tissue densities. With Biograph mMR, attenuation information is collected from MR data during the simultaneous exam. In addition, we've re-engineered every relevant component—from our new, PET-compatible Tim® (Total imaging matrix) coils to the mMR Tim Table designed with low attenuation materials—to further ensure high-quality simultaneous exams.



## Tim delivers state-of-the-art 3T.

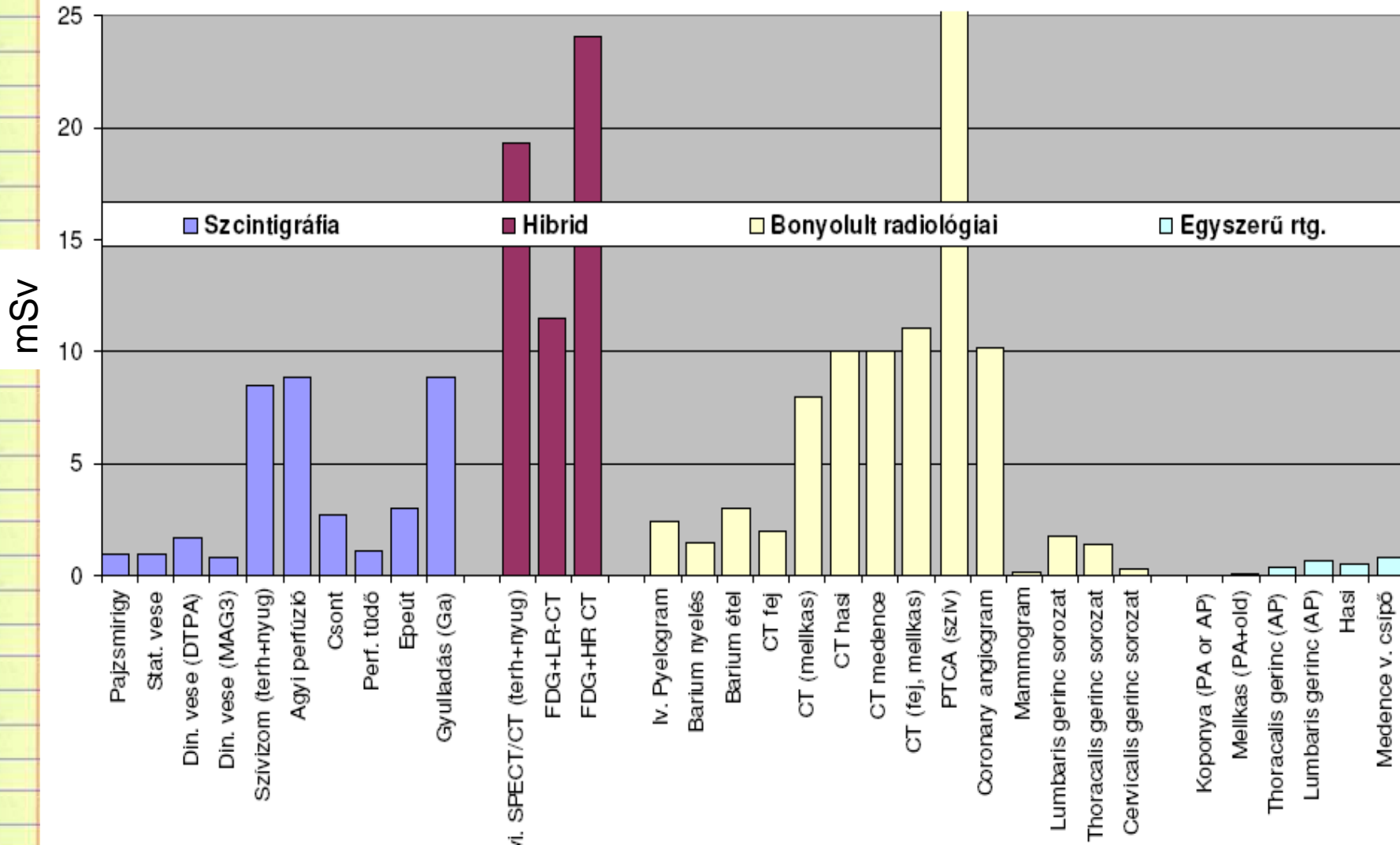
Around the world, Tim (Total imaging matrix) technology has become the new standard in MR coil design. With more than 5000 installations, Tim is proving it every day, with unprecedented flexibility, accuracy and speed. For Biograph mMR, we've optimized the design and incorporated low attenuation materials into the Tim's mMR coils to minimize attenuation of the PET signals. The result is outstanding 3T MRI performance and high resolution PET exams.



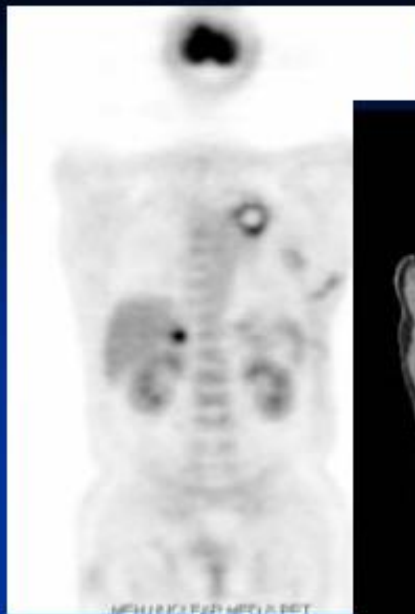
<http://www.siemens.com/mMR>

# Effektív dózisek (mSv)

Éves háttér: 1-2 mSv





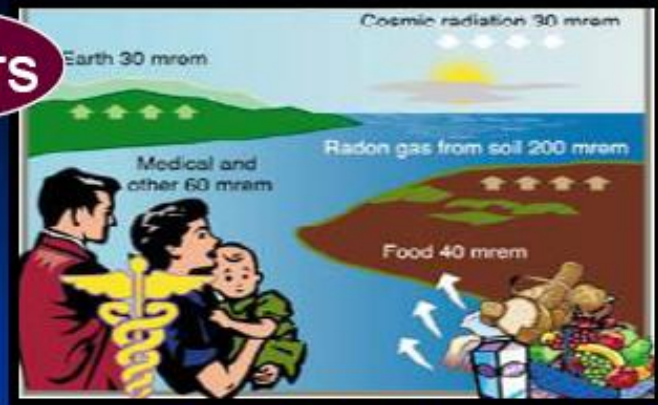


7 mSv



7 mSv

3.5 yrs



2.2 mSv per annum

350



0.02 mSv

1 - 3 yrs



2- 6 mSv per annum

# CT dózisos növekedése II.

1999 - NRPB estimates

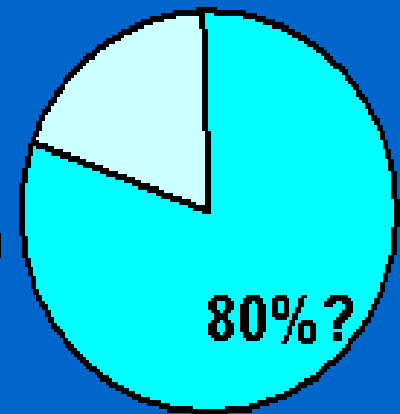
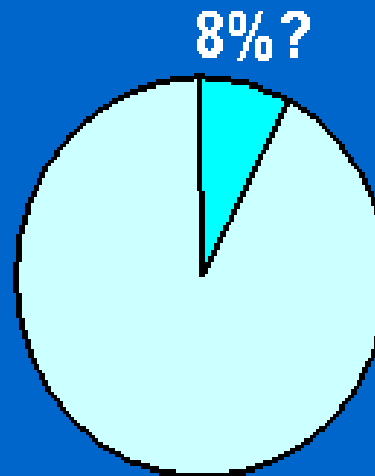
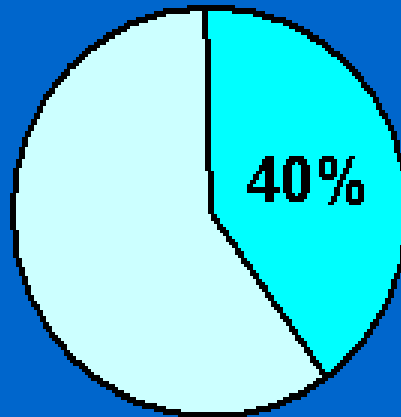
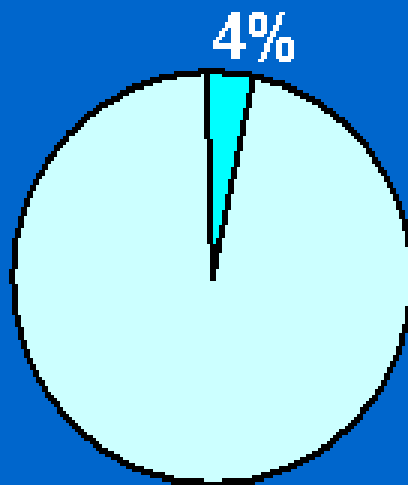
% Examinations

% Dose

2009 ?

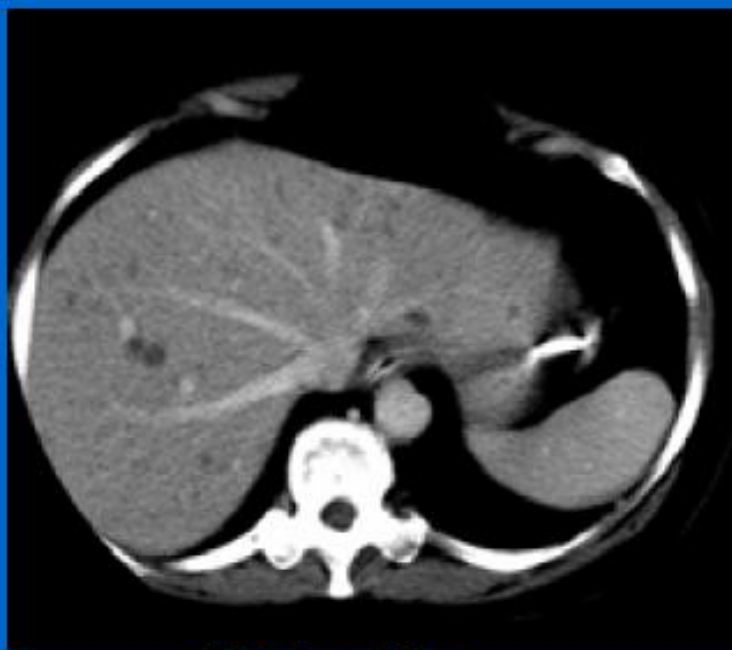
% Examinations

% Dose

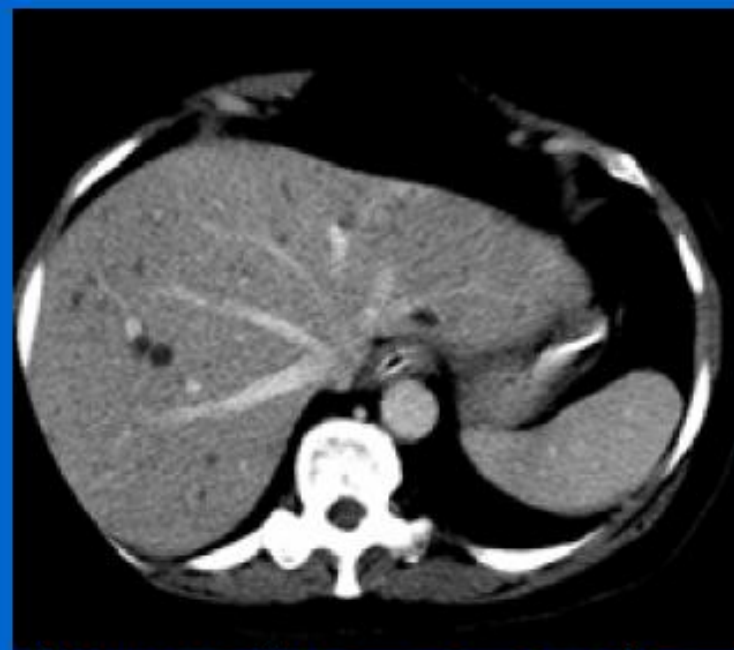


## Thinner slice: improved contrast

- Better contrast for small structures



Wide slice



Narrow slice – same mAs



# A teljes CT vizsgálatra vonatkoztatott dózis

Dose-length product (DLP)

$DLP = CTDI_{vol} \times \text{Scan hossz}$

*DLP egysége mGy-cm*

*(A gyártók legfeljebb a DLP-t írják ki!)*

*Az effektív dózis a DLP-vel arányos*

$$E \text{ (mSv)} = w * DLP,$$

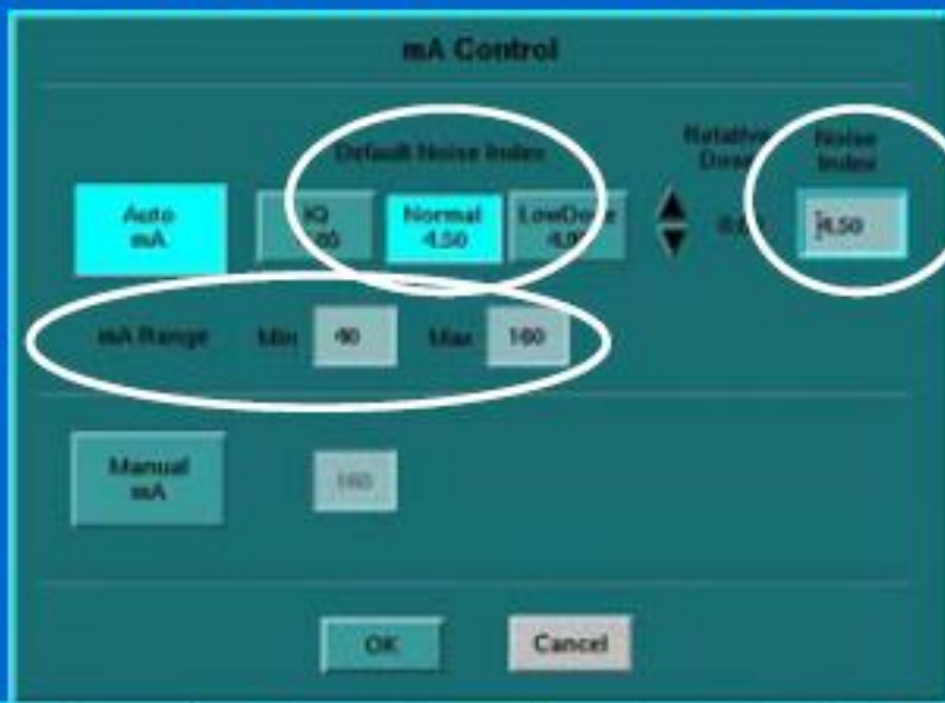
*ahol  $w$  adott anatómiai területekre már ismert állandók.*

# ImPACT: CTdozimetria excel tábla

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
2	<b>ImPACT CT Patient Dosimetry Calculator</b>														
3	version 0.99u, 12/12/2003														
4															
5	Scanner Model:					Acquisition Parameters:									
6	Manufacturer:	Siemens													
7	Scanner:	Siemens Sensation 16													
8	KV:	120													
9	Scan Region:	Head													
10	Data Set	MCSET21	Update Data Set												
11	Current Data	MCSET00													
12	Scan range					Rel. CTDI									
13	Start Position	80	cm	Get From Phantom		Look up	1.00	(assumed)							
14	End Position	94	cm	Diagram		Look up	21.8	mGy/100mAs							
15	Patient Sex:					CTDI (soft tissue)									
16						23.3									
17						mGy/100mAs									
17						nCTDI <sub>w</sub>									
18						16.6									
18	Organ	w <sub>T</sub>	H <sub>T</sub>	w <sub>T</sub> ·H <sub>T</sub>		Remainder Organs					H <sub>T</sub>				
19	Gonads	0.2	#N/A	#N/A		Adrenals					#N/A				
20	Bone Marrow (red)	0.12	#N/A	#N/A		Brain					#N/A				
21	Colon	0.12	#N/A	#N/A		Upper Large Intestine					#N/A				
22	Lung	0.12	#N/A	#N/A		Small Intestine					#N/A				
23	Stomach	0.12	#N/A	#N/A		Kidney					#N/A				
24	Bladder	0.05	#N/A	#N/A		Pancreas					#N/A				
25	Breast	0.05	#N/A	#N/A		Spleen					#N/A				
26	Liver	0.05	#N/A	#N/A		Thymus					#N/A				
27	Oesophagus (Thymus)	0.05	#N/A	#N/A		Uterus					#N/A				
28	Thyroid	0.05	#N/A	#N/A		Muscle					#N/A				
29	Skin	0.01	#N/A	#N/A											
30	Bone Surface	0.01	#N/A	#N/A											
31	#N/A	0.025	#N/A	#N/A		CTDI <sub>w</sub> (mGy)					16.6				
32	Remainder 2	0.025	#N/A	#N/A		CDTI <sub>vol</sub> (mGy)					16.6				
33	<b>Total Effective Dose (mSv)</b>					<b>#N/A</b>									
33						DLP (mGy.cm)									
33						232									

# Automatic exposure control

- Most systems allow users to set a required noise level
  - An image noise index
  - Specifying a reference image with acceptable image quality
- Maximum and minimum mA sometimes specified

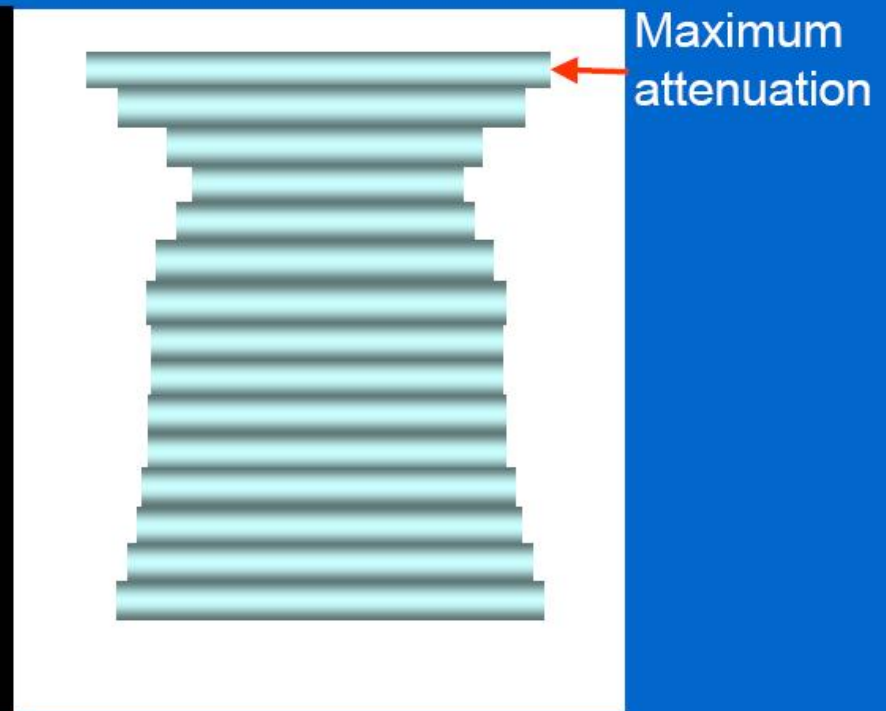
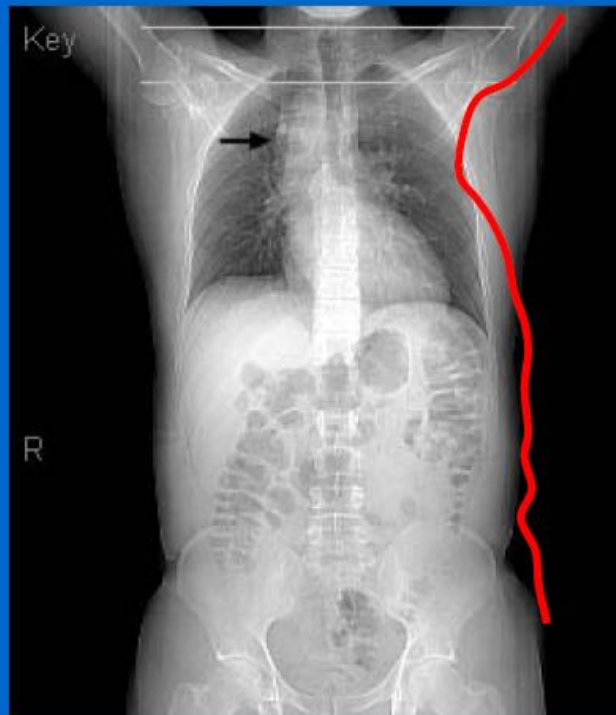




# Principles of AEC: z-axis



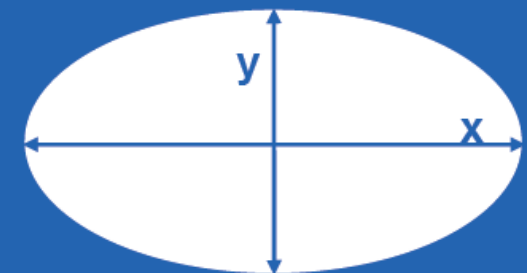
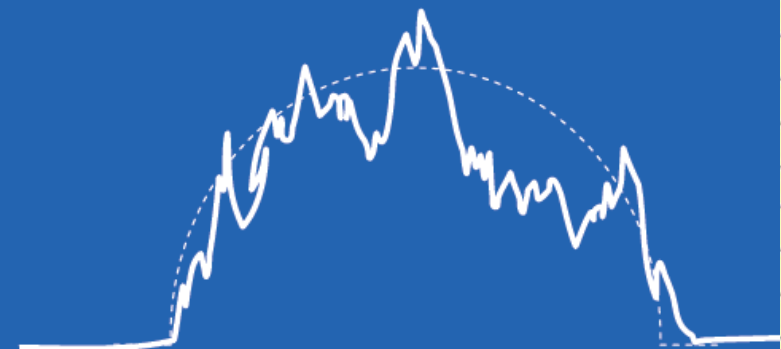
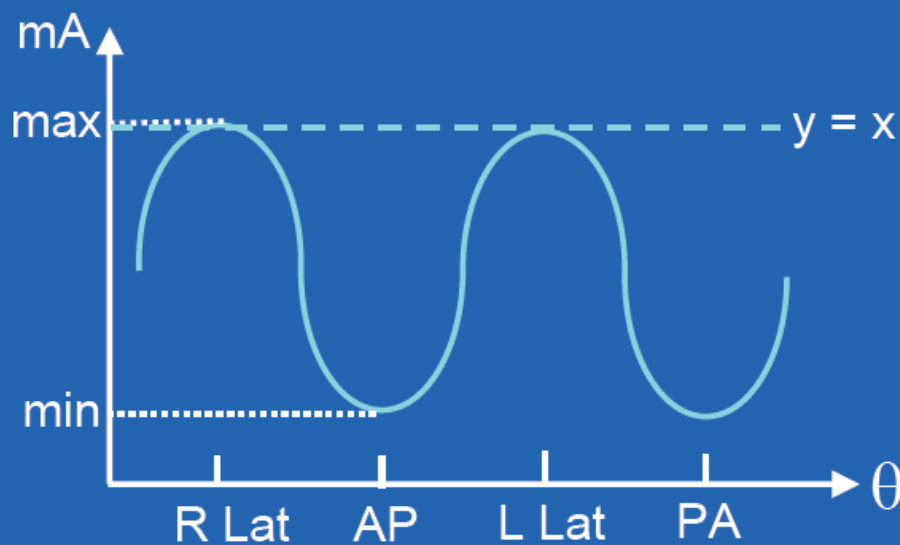
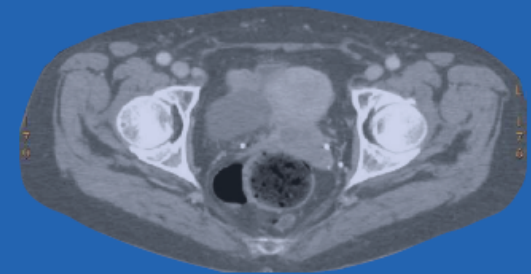
- For z-axis modulation the attenuation at each level is calculated relative to maximum
- For each rotation the appropriate mA will be used



# Principles of AEC: angular

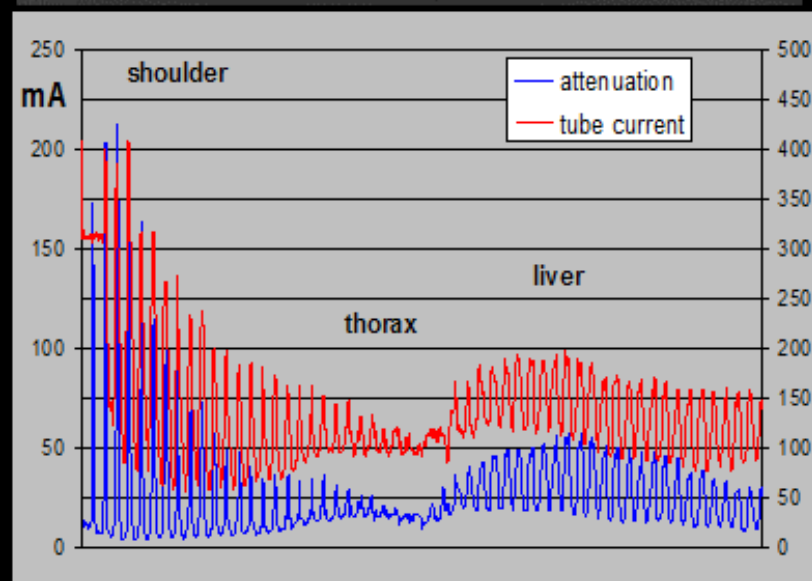
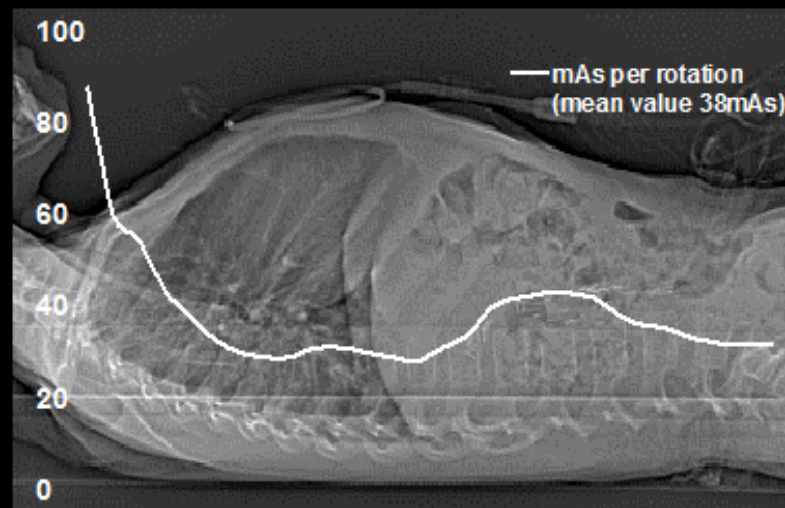


- Method 1: Prospective calculation from SPR
  - x & y dimensions of ellipse calculated from information in attenuation profile
  - tube current varied sinusoidally during rotation



# Care Dose 4D – valós idejű dózismoduláció

- 6 éves gyermek
- Standard protokollal szkennelve (165 mAs)
- Optimális képminőség minimális dózis (átlag 38 mAs).



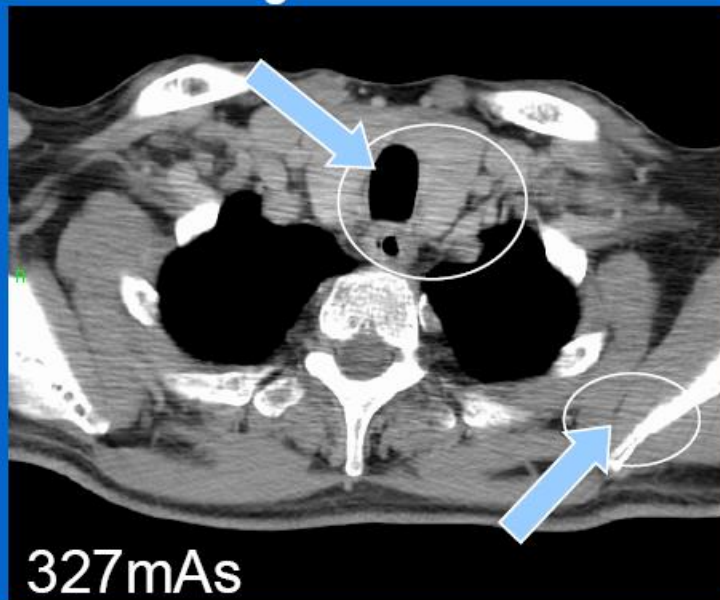


# Principles of AEC: angular

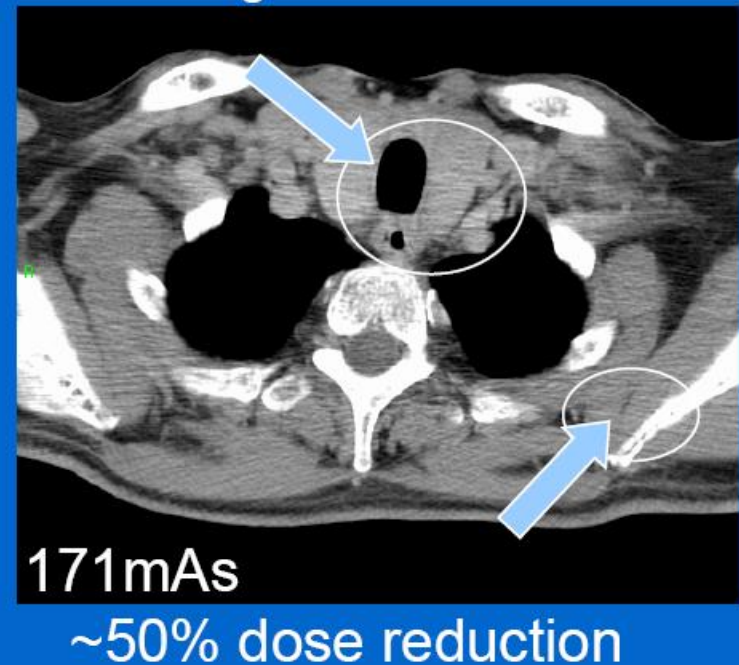


- Noise in image is governed by most attenuating projections
- Reducing mA from AP direction does not change noise significantly but reduces dose

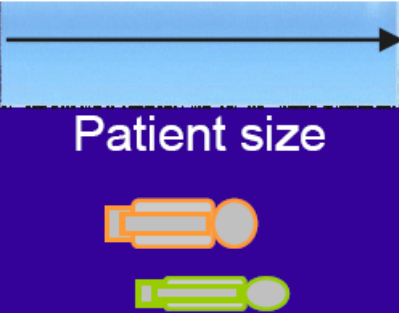
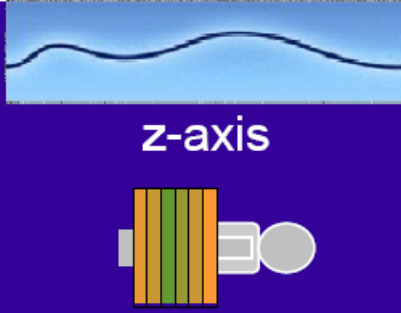
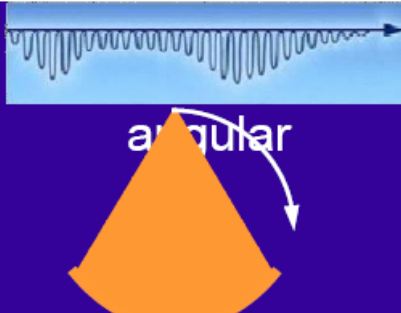
without angular mA modulation



with angular mA modulation



# Implementations of AEC in CT

	 <p>Patient size</p>	 <p>z-axis</p>	 <p>angular</p>
GE	Auto mA		SmartmA
Philips	DoseRight ACS	DoseRight ZDOM	DoseRight DDOM
Siemens	CARE Dose 4D		
Toshiba	SURE Exposure		3D