

# University of Pennsylvania experience with Anger-logic detectors for PET

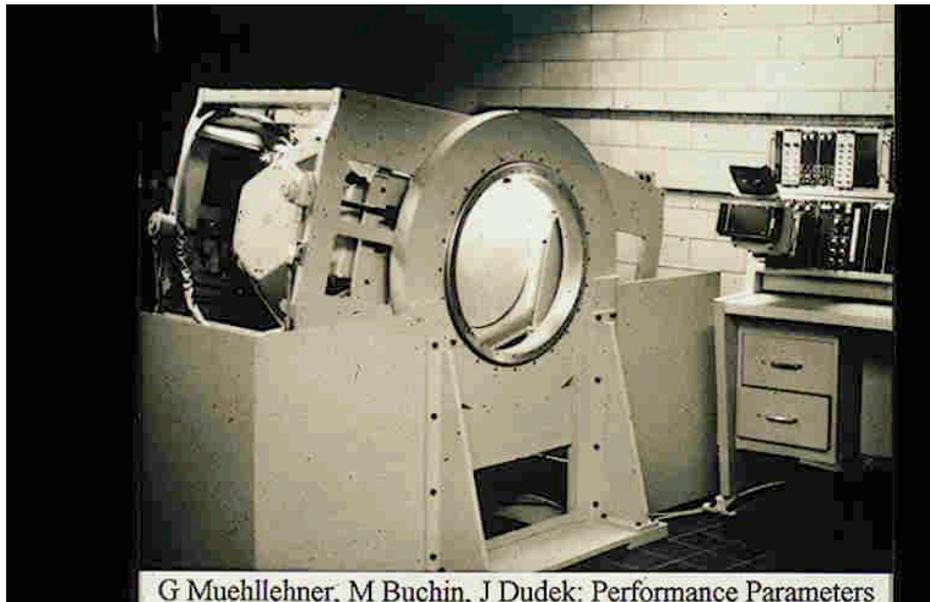
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Suleman Surti  
Rich Freifelder

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Chris Kyba  
Rony Wiener  
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# Coincidence Imaging (PET) with 2 rotating Anger Cameras

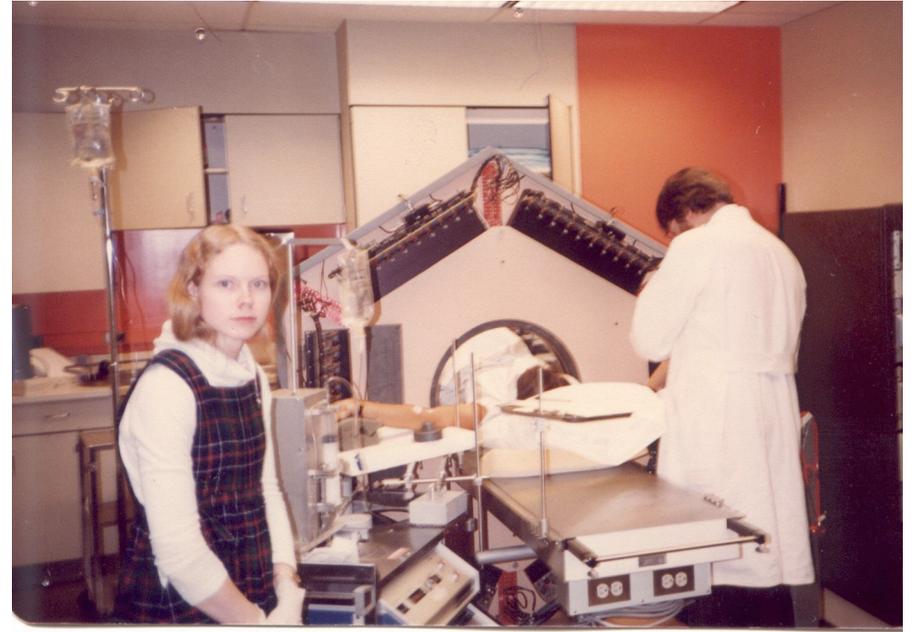
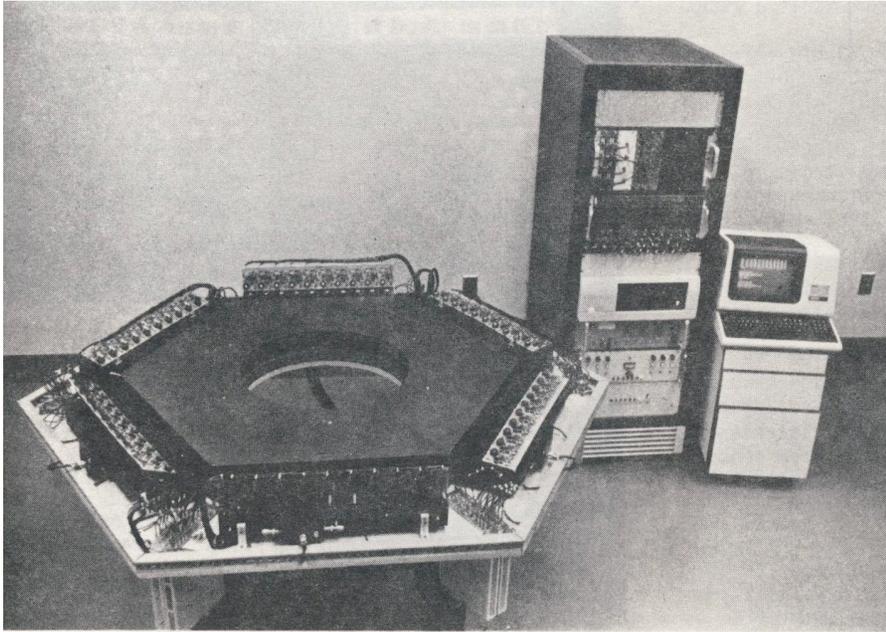


University of Chicago  
Muehllehner et al 1975

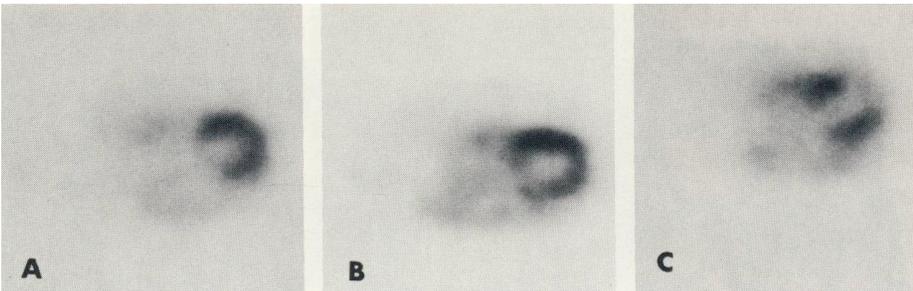
ADAC Laboratories  
MCD 1995



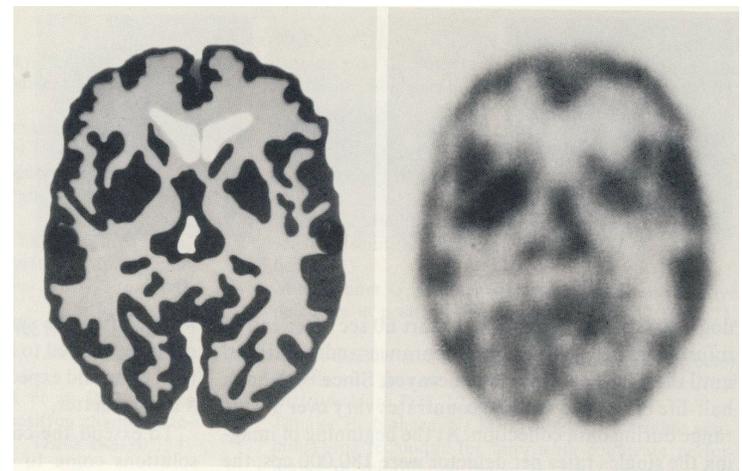
# Single-slice Penn-PET 1984



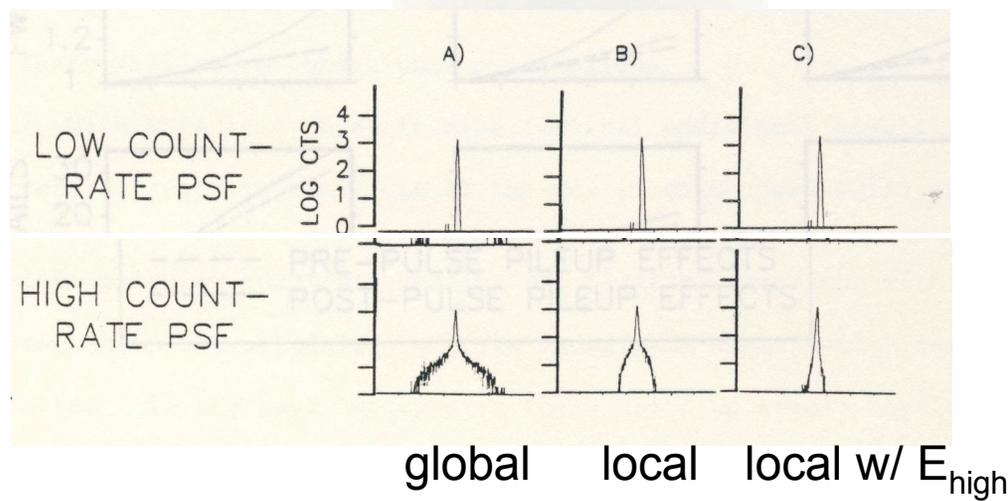
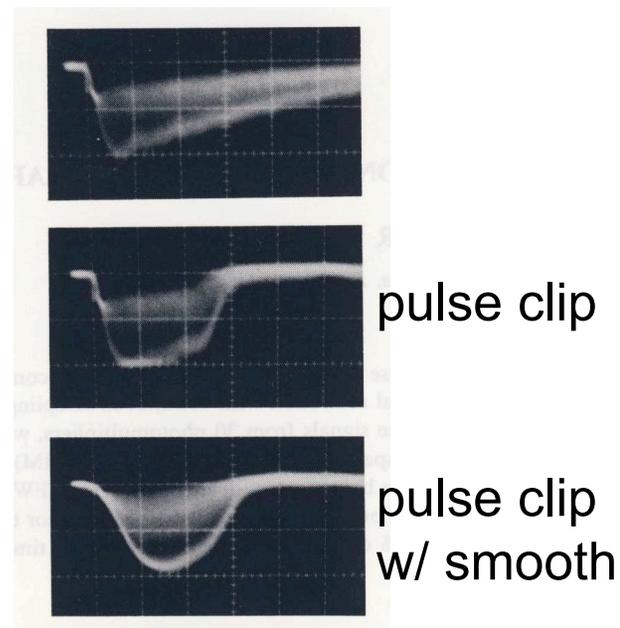
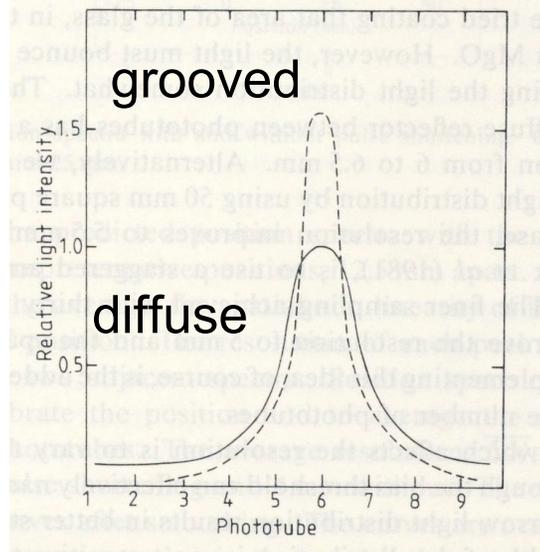
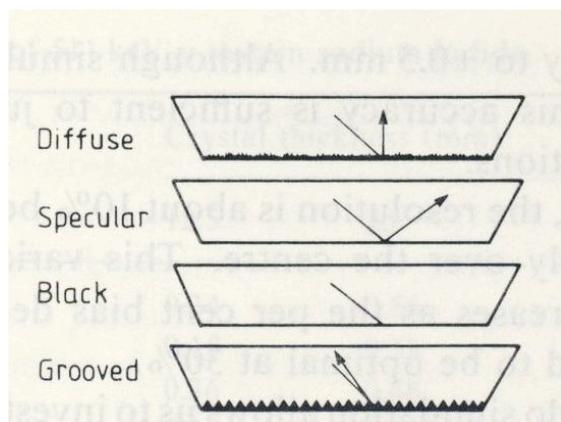
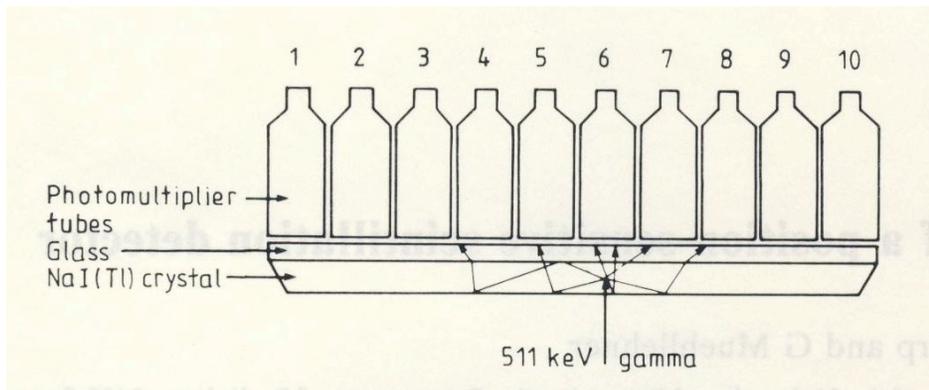
## Dog studies - $^{82}\text{Rb}$



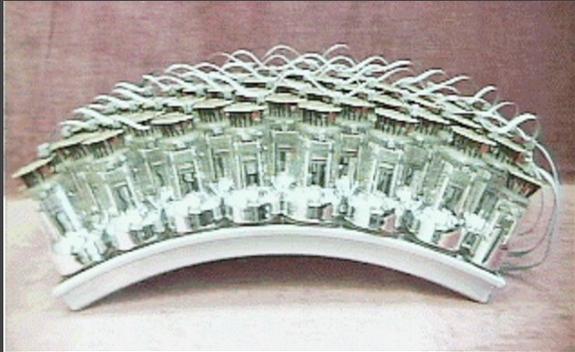
infarct



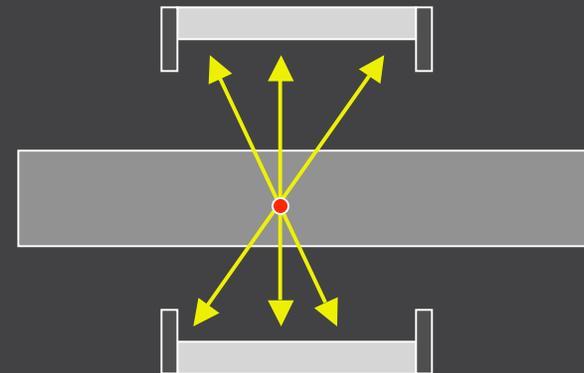
# Position-sensitive Anger-logic detector for PET *thick crystal, high count-rate*



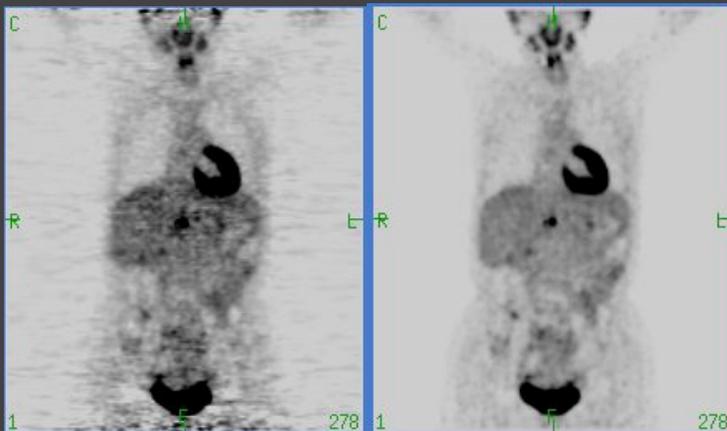
# Penn-PET Scanner development



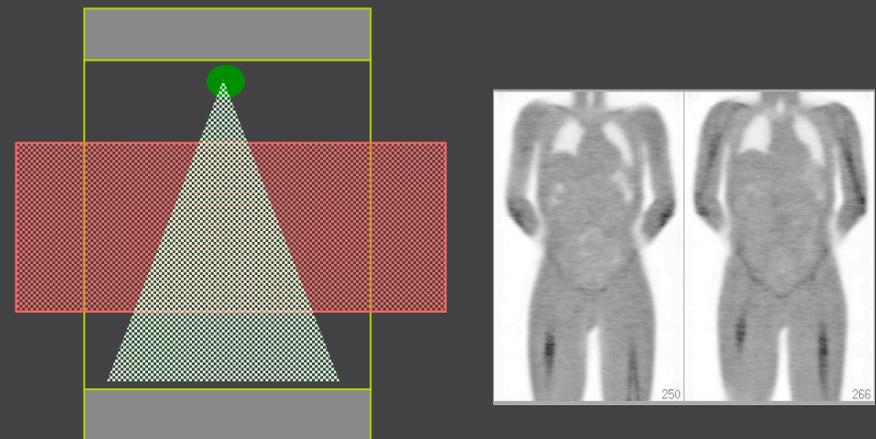
2D curve-plate detectors for PET



3D imaging (no septa)  
Large axial FOV

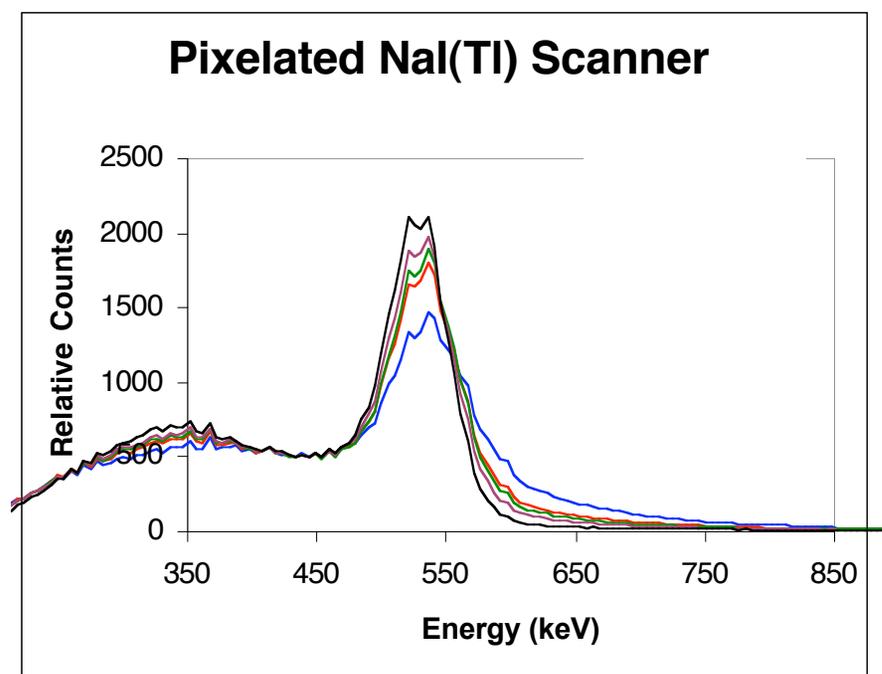
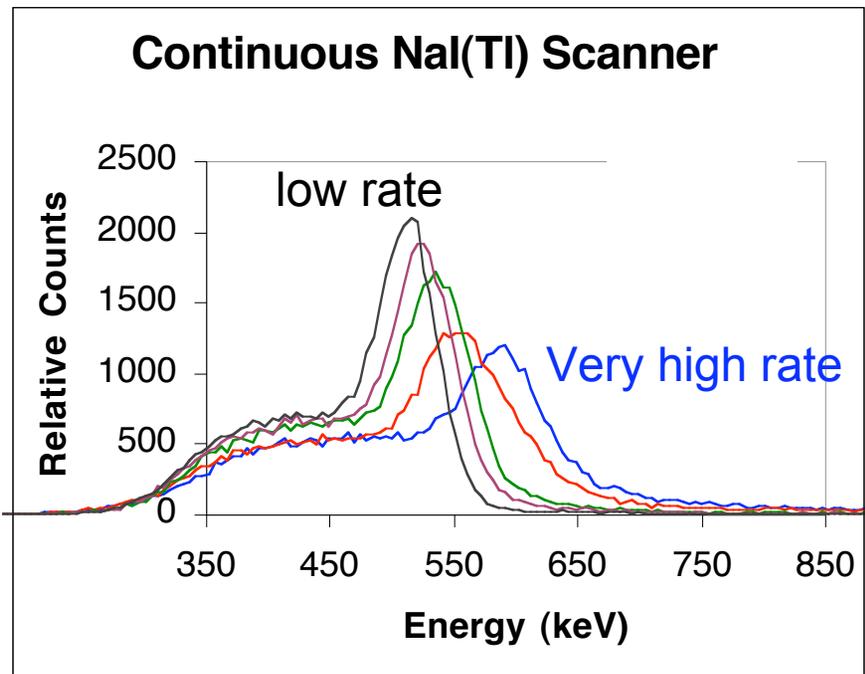
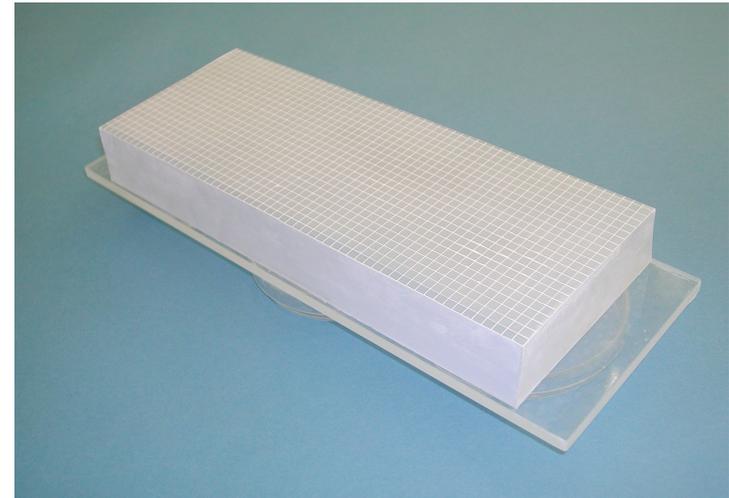
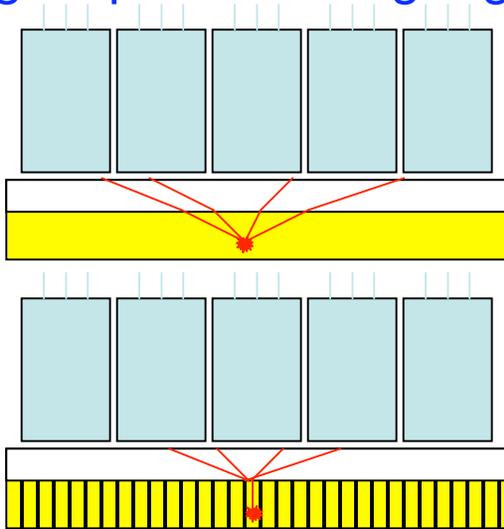


FBP -> Iterative



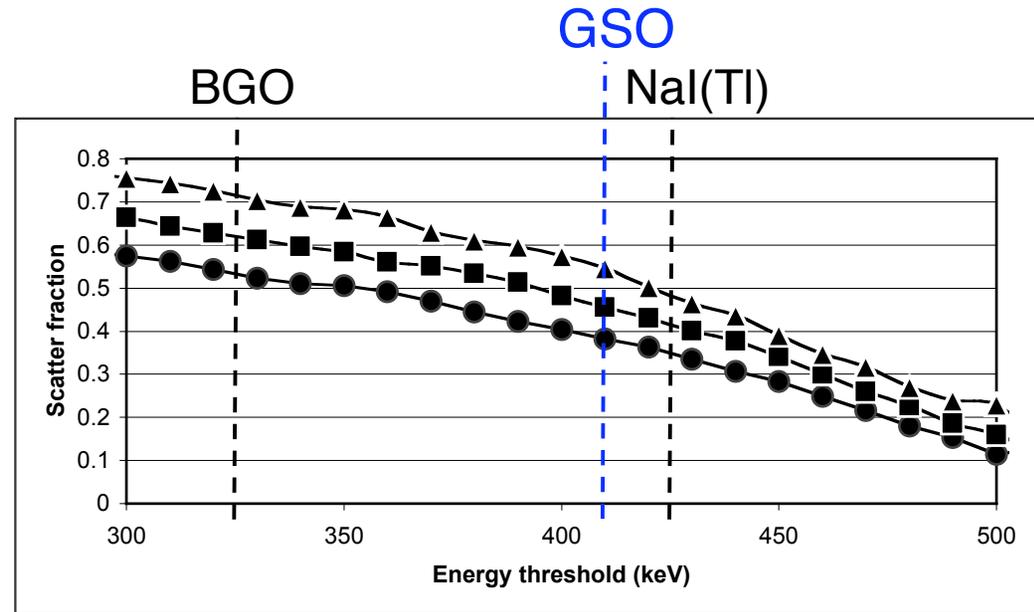
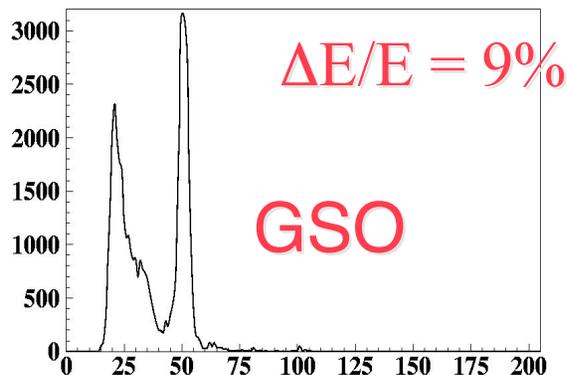
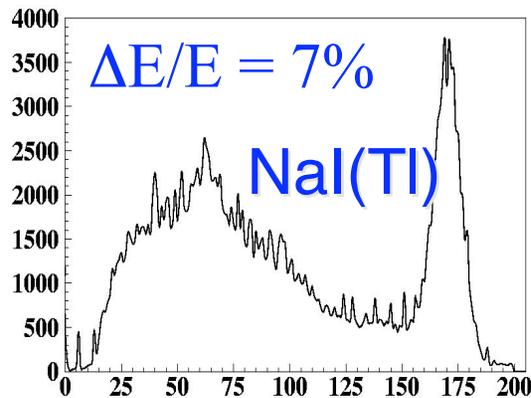
Transmission with Cs-137 source

# Pixelated detector (with continuous optical coupling): control light spread with light-guide thickness, independent of crystal thickness



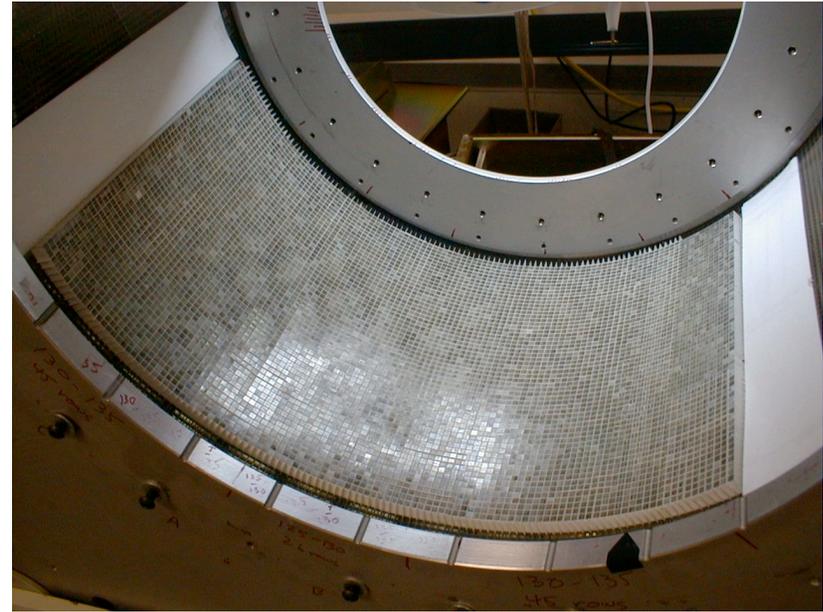
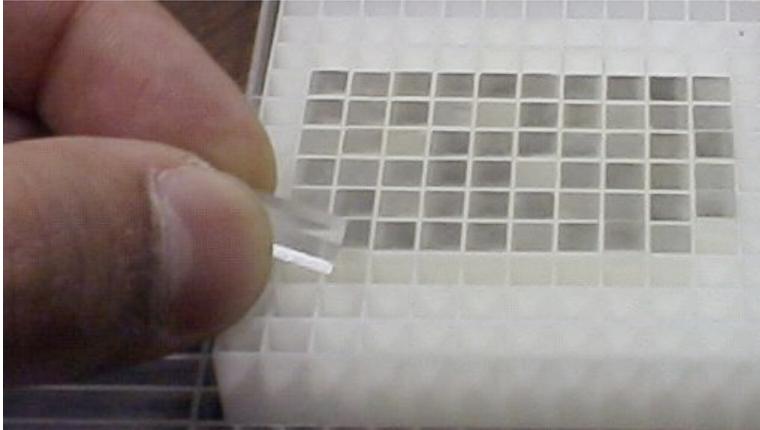
# Scintillators for PET circa 1990's

Scintillator	NaI(Tl)	BGO	GSO	LSO
$\tau$ (ns)	230	300	60	40
$\mu$ (cm <sup>-1</sup> )	0.35	0.95	0.70	0.86
photons (per MeV)	41,000	7000	10,000	26,000



Scatter fraction vs. Energy threshold

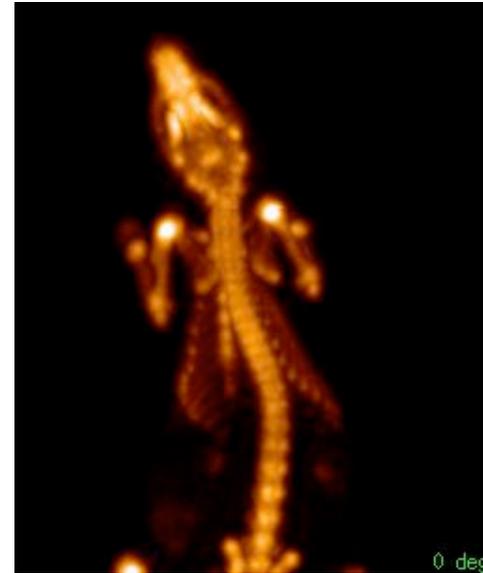
# GSO Brain scanner



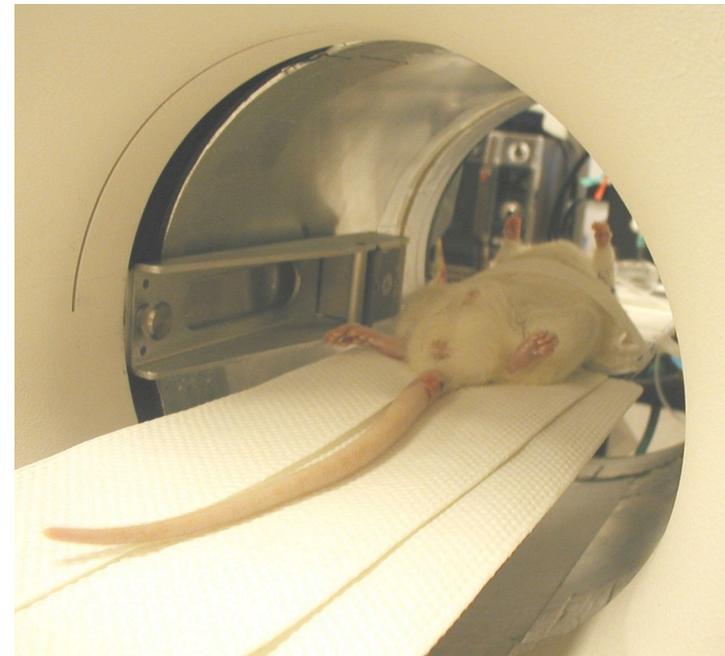
# Small Animal scanner

## GSO -> LYSO

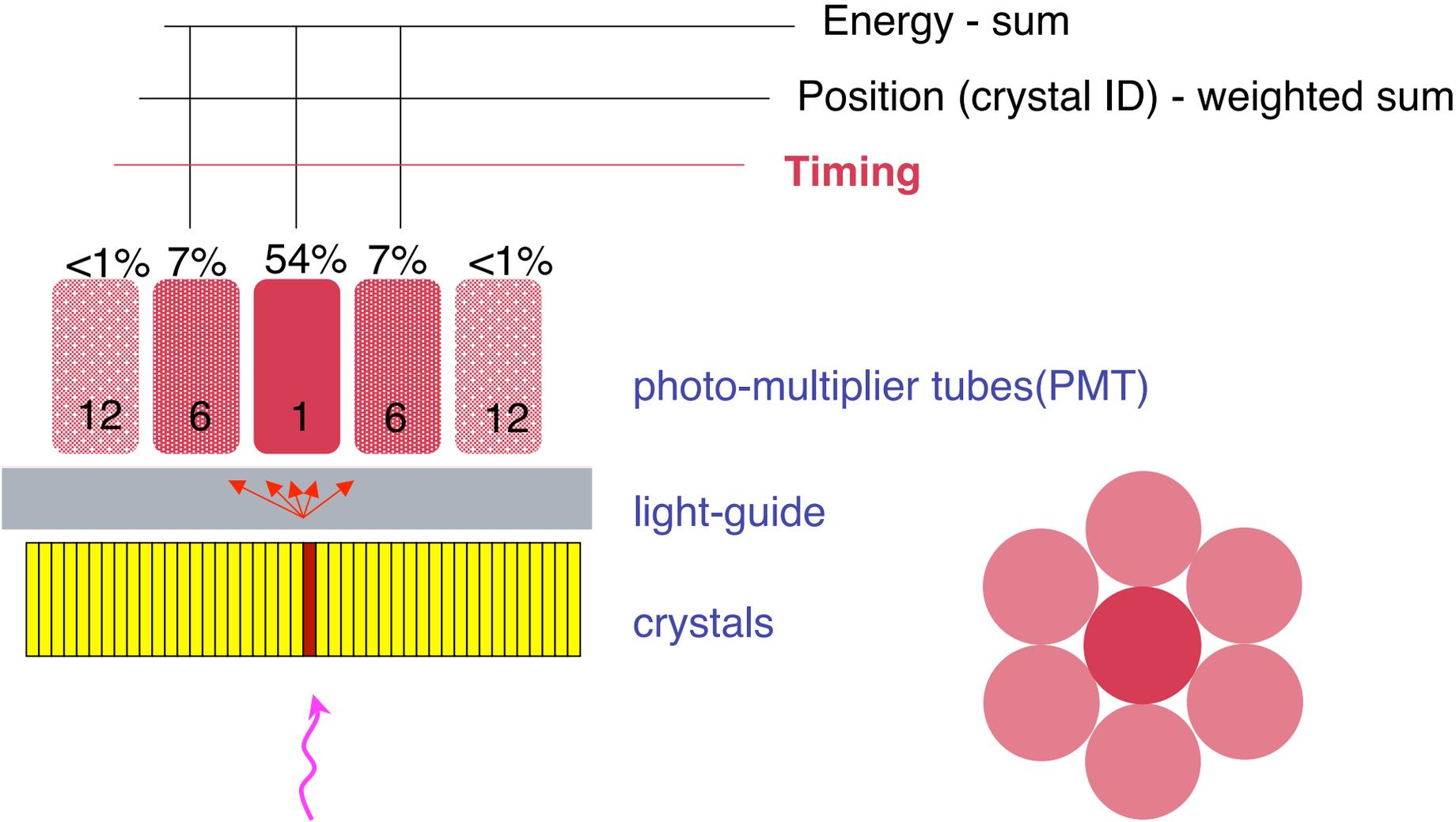
Sensitivity x2



$^{18}\text{F}$   
bone scan



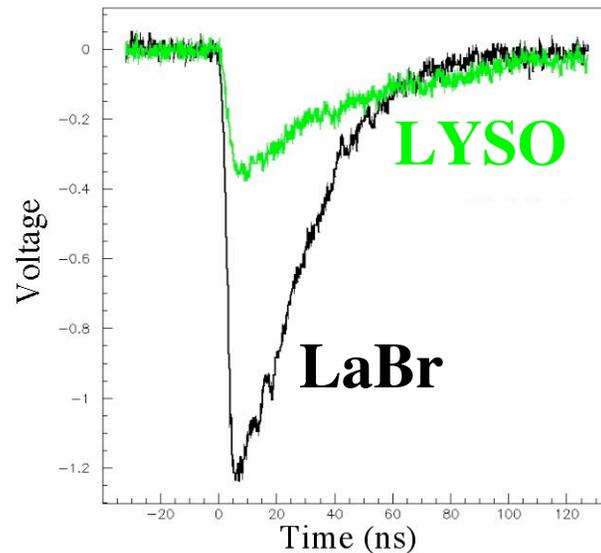
# Pixelated Anger-logic Detectors



# Scintillators for TOF

*Fast enough for TOF*

Scintillator	NaI(Tl)	BGO	GSO	BaF <sub>2</sub>	LSO/LYSO	LaBr <sub>3</sub>
$\tau$ (ns)	230	300	60	2	40	21
$\mu$ (cm <sup>-1</sup> )	0.35	0.95	0.70	0.45	0.86	0.47
photons (per MeV)	41,000	7000	10,000	2000	26,000	60,000



# Timing Resolution



## 1:1 coupling to PMT

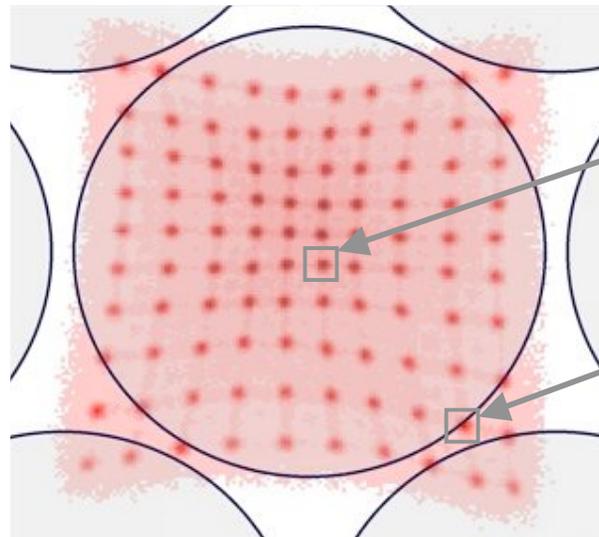
- Best possible light collection

LaBr 160 - 250 ps (coincidence)  
depends on crystal size and PMT



## Crystal array: light sharing

- 4x4x30 mm<sup>3</sup> pixels - 7 Photonis XP20D0 PMTs



LaBr pixel 295 ps

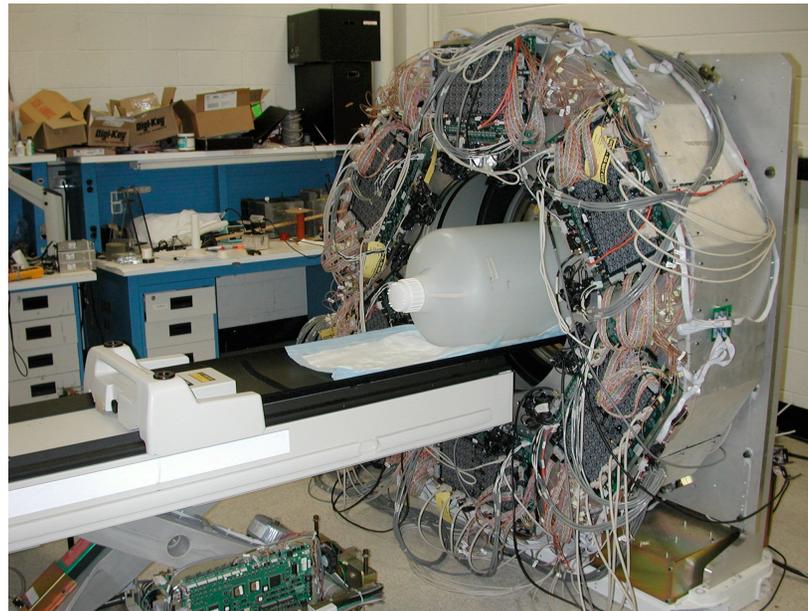
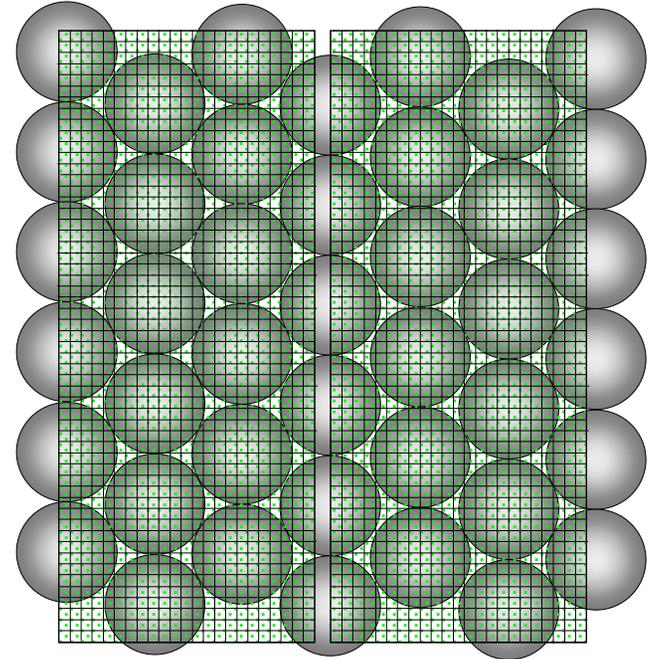
LaBr pixel 335 ps  
(light collected 75%)

# Lanthanum Bromide Detector for TOF



1620 pixels/module

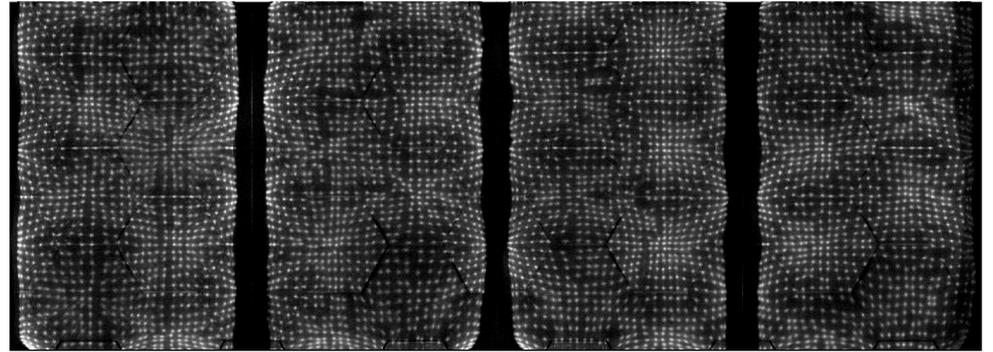
adjacent  
modules  
with  
overlapping  
PMTs



24 modules

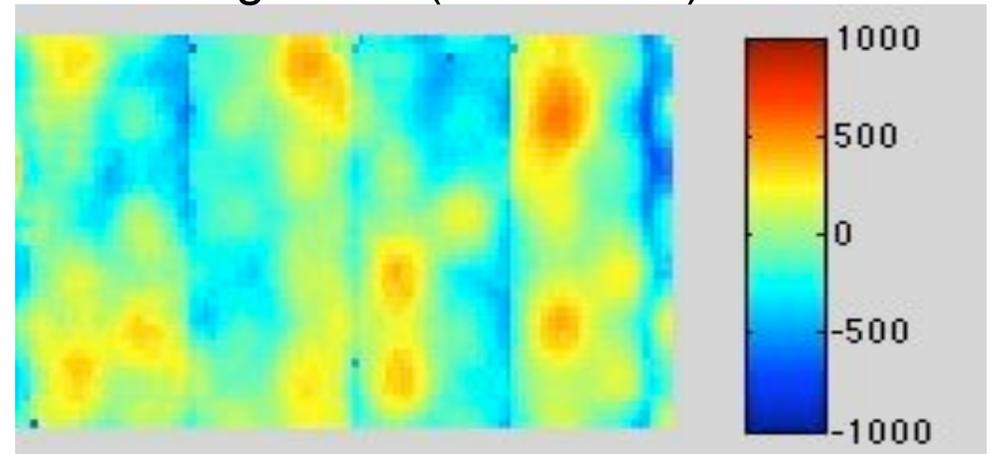
# Calibrations

2D position flood map:  
correct non-linear position



timing offset (4 modules)

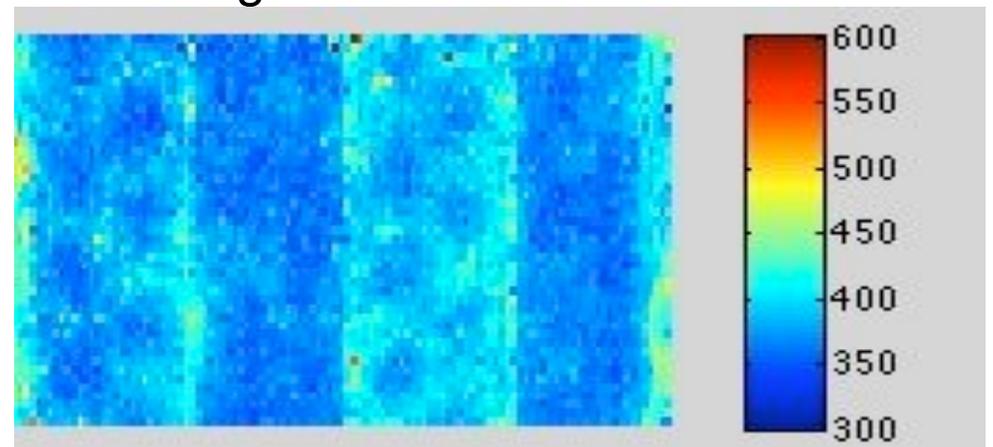
Timing offset map:  
major bias due to PMTs



timing resolution

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System timing resolution  
375 ps



# Philips *Gemini TF*: PET/CT scanner

## PET scanner

70-cm bore  
18-cm axial FOV

## LYSO crystals

4 x 4 x 22 mm<sup>3</sup>  
28,338 xtals/420 PMTs  
600-650ps system timing



## CT scanner

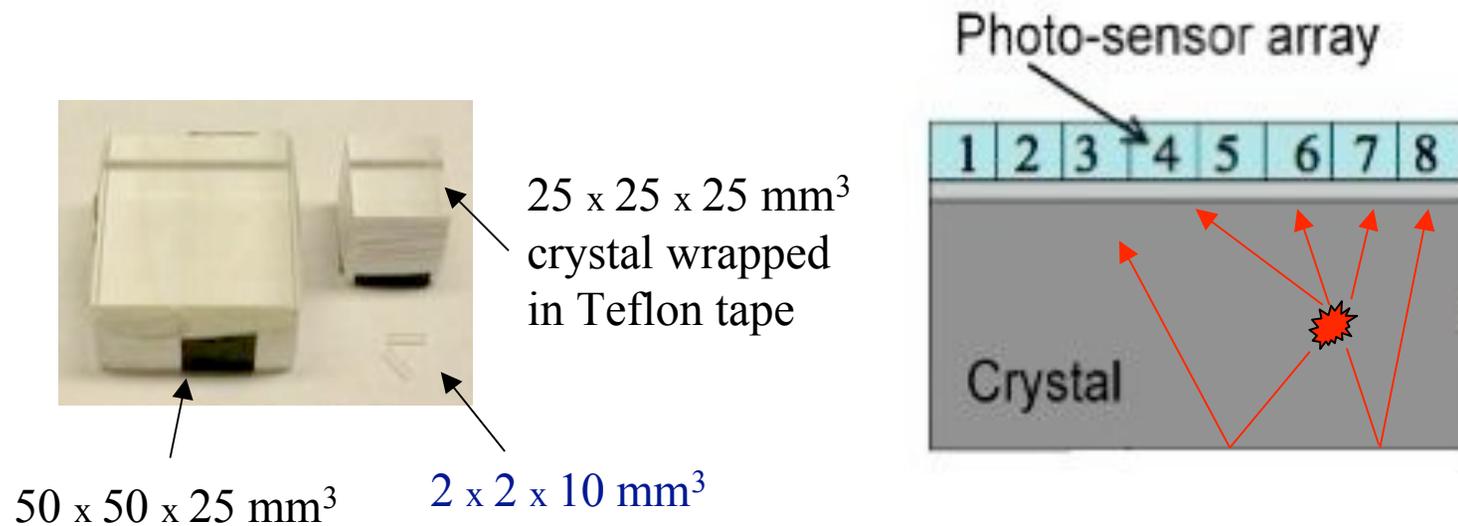
Brilliance 16-slice



PET shows increased FDG uptake in region of porta hepatis

# Continuous block detectors for high resolution and TOF

- spatial, timing resolution - depends on light output/LRF, opportunity for DOI
- cost and performance - less dependent on spatial resolution (i.e. pixel size)



LYSO Crystal	Timing Resolution (off dynode)	$\Sigma$ Anode Energy Resolution
25 x 25 x 25 mm <sup>3</sup>	335 ± 17 ps	9%
50 x 50 x 25 mm <sup>3</sup>	403 ± 20 ps	11%

H8500  
MA-PMT

# Summary - Anger-logic detectors for PET

- Continuous detectors
  - uniform light output leads to good energy resolution
  - entrance surface (grooves, slots) reduces light spread
  - pulse clipping with short integration to reduce pile-up
  - least expensive design
- Pixelated detector (continuous optical coupling to PMTs)
  - control light spread with light-guide thickness
  - improved high count-rate performance
  - minimal edge degradation
  - TOF capability with fast PMTs
- Scintillators
  - high light output
  - fast decay