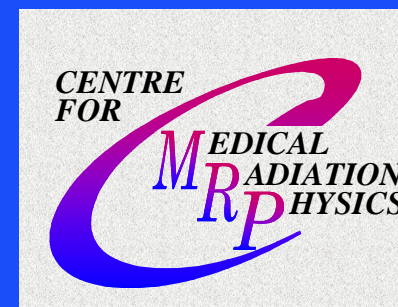


University of Wollongong

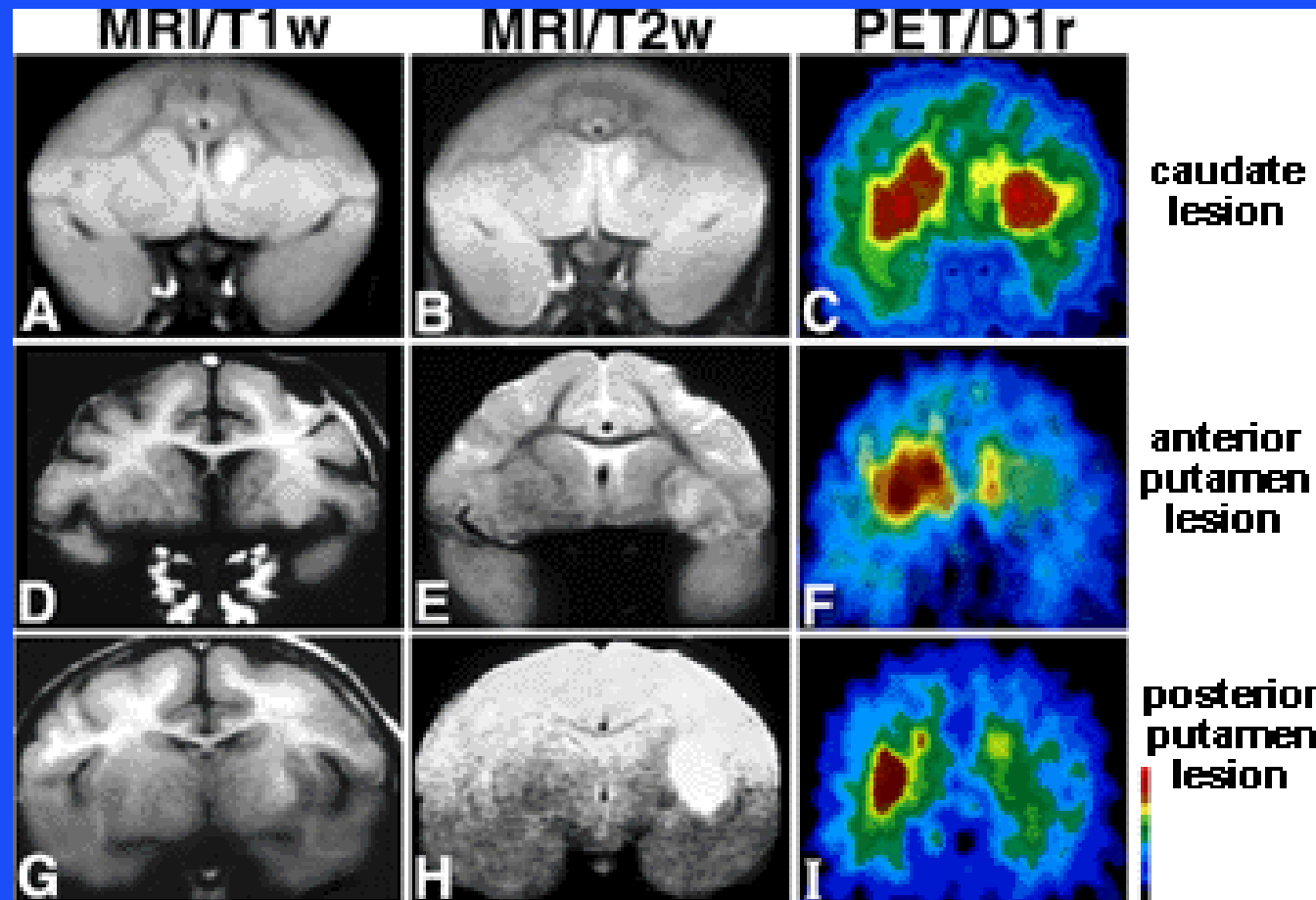
# Future Directions in PET Instrumentation



A.B Rozenfeld<sup>1</sup>, M.L.F. Lerch<sup>1</sup>, R. Ward, P.E. Simmonds<sup>1</sup>,  
S. Meikle<sup>2</sup>, B. McBride<sup>1</sup>, G.J. Takacs<sup>1</sup>, V. Perevertailo<sup>1</sup>,  
G. Moorhead<sup>3</sup>, J. Culpepper<sup>3</sup>, and G. Taylor<sup>3</sup>

1. Centre for Medical Radiation Physics, University of Wollongong, Australia,
2. PET and Nuclear Medicine Department, Royal Prince Alfred Hospital, Sydney,
3. High Energy Physics Department, University of Melbourne,

# Introduction



Huntington's disease studies

<http://neurosurgery.mgh.harvard.edu/pet-hp.htm>

# Introduction

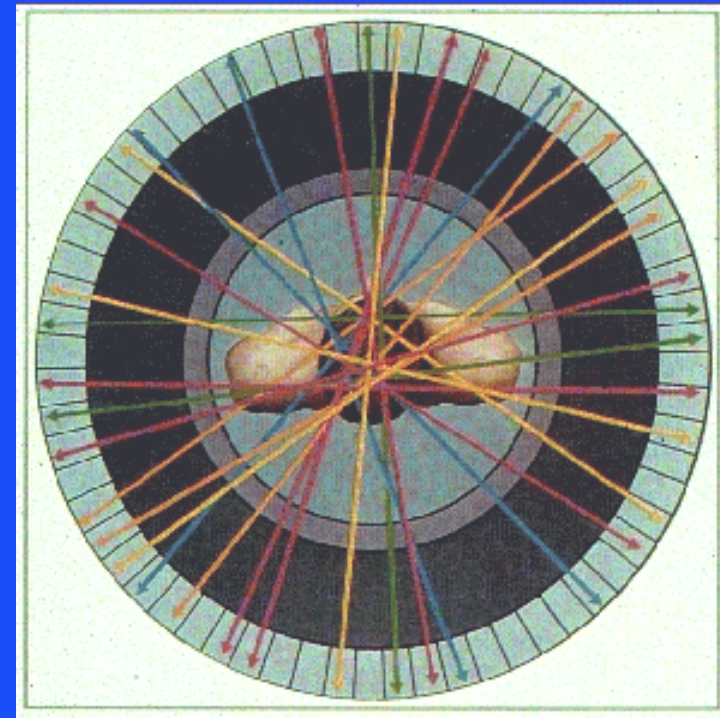


## *Advantages of PET*

- ◆ Measures level of radiotracer uptake
- ◆ High sensitivity to small lesions

## *Disadvantages of PET*

- ◆ Poorer spatial resolution (5-8 mm) than other anatomical imaging techniques such as MRI (1 mm)



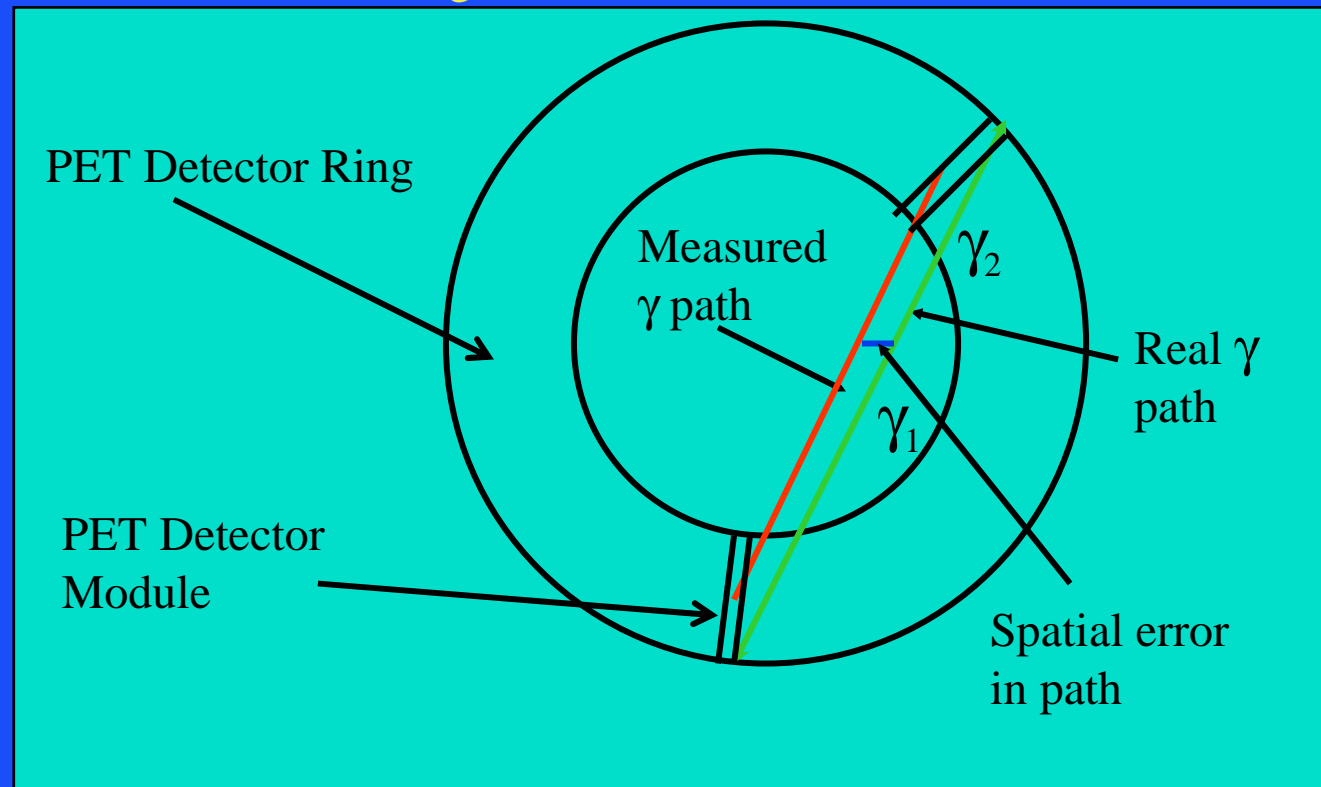
<http://www.nucmed.buffalo.edu/>



# Resolving the Spatial Resolution Problem



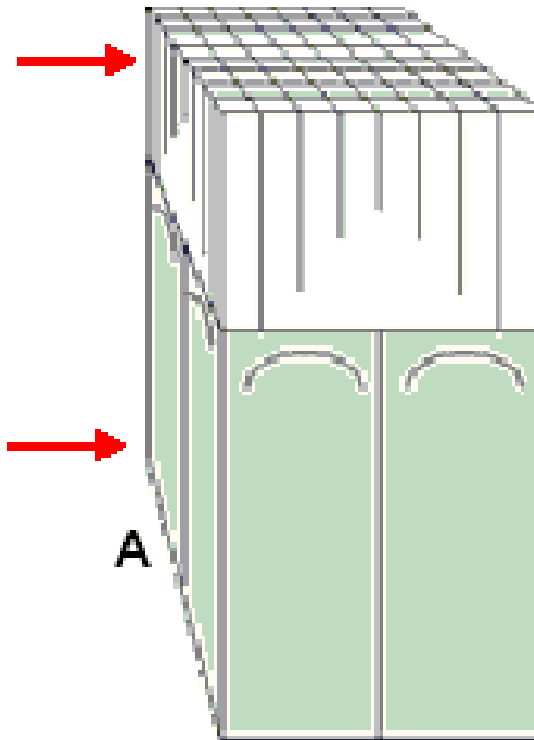
- u Lack of DOI information leads to errors in the lines of response that indicate the original gamma ray paths.
- u These errors significantly contribute to the degradation of the final reconstructed PET image



# Anger Logic in PET



Scintillator  
array



PMTs

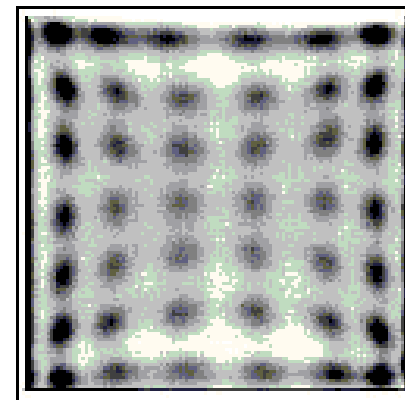
A

B

D

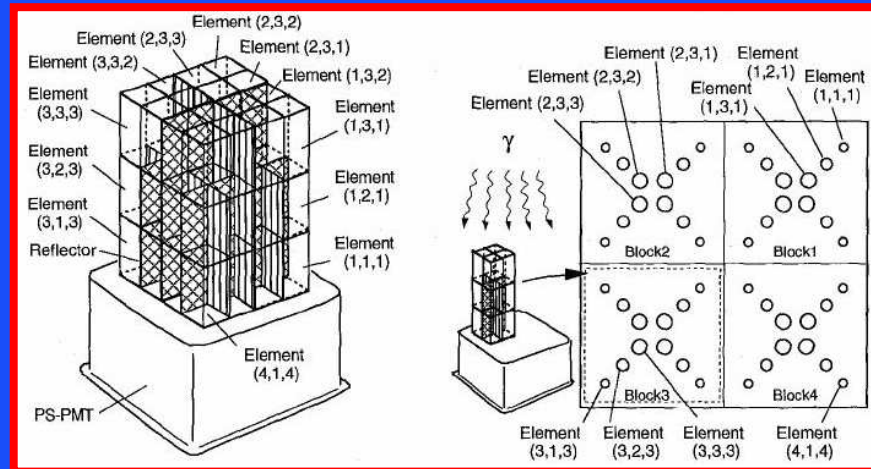
$$X = \frac{A + B - C - D}{A + B + C + D}$$

$$Y = \frac{A - B + C - D}{A + B + C + D}$$

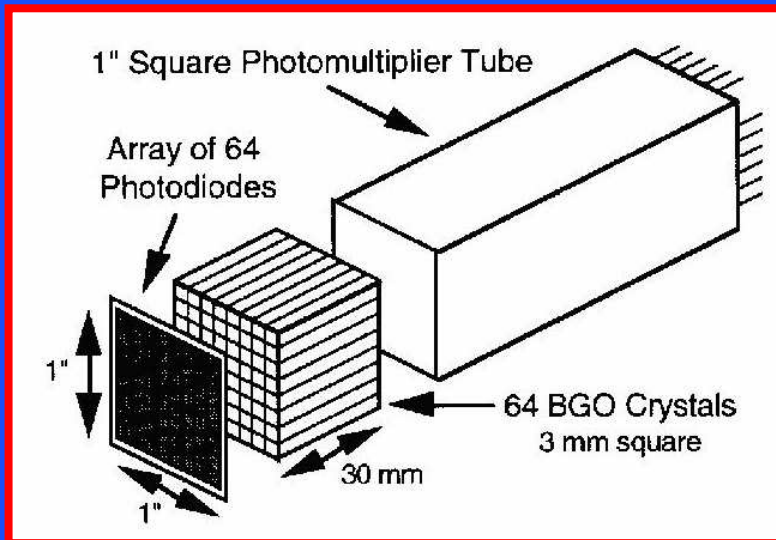


Histogram

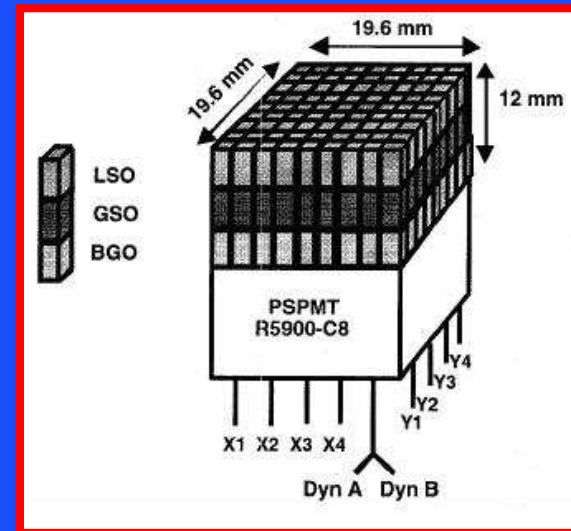
# Previous DOI encoding approaches



*Murayama, Ishibashi, Ucida, Omura, and Yamashita, (2000).*

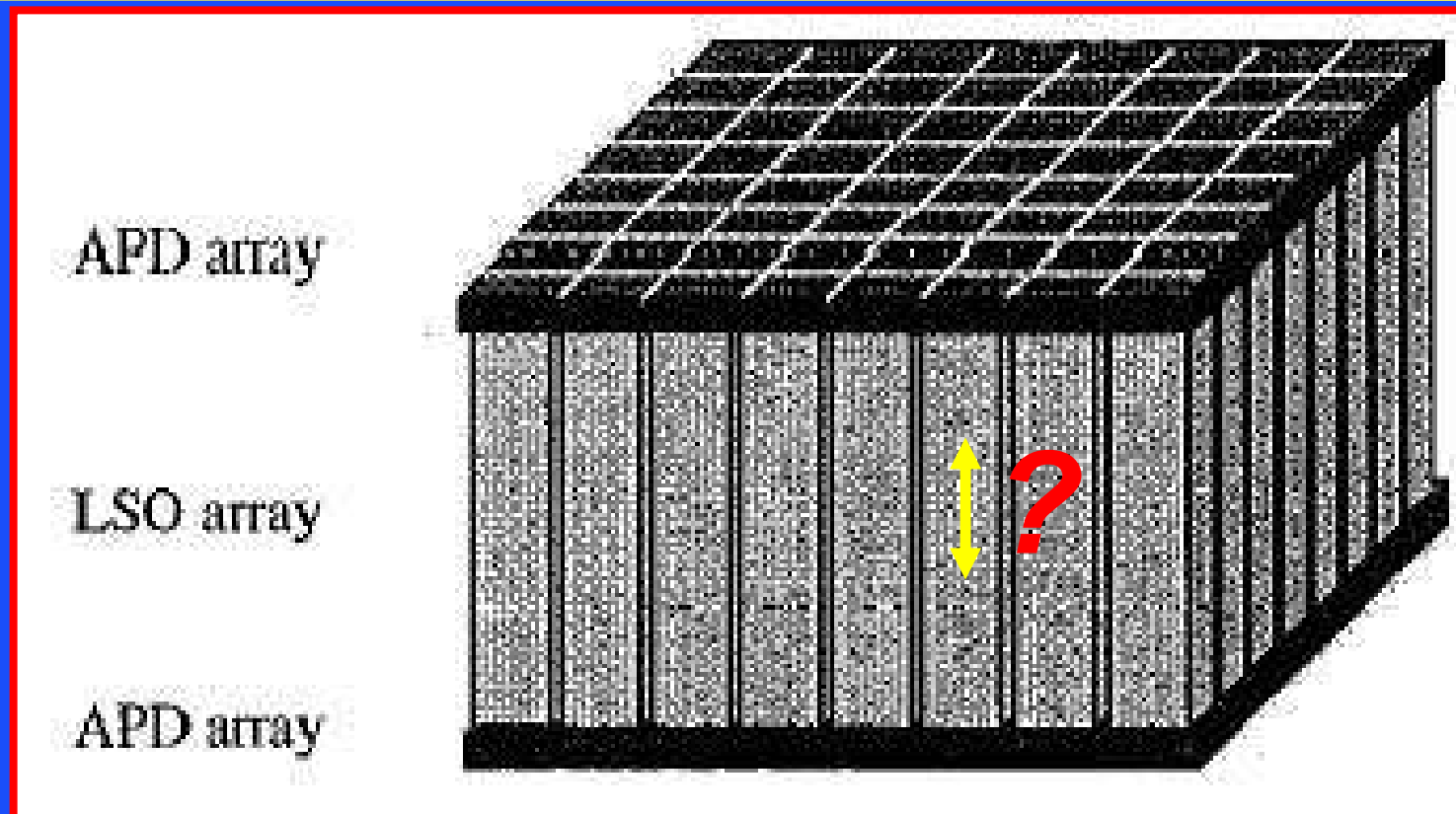


*Moses and Derenzo (1994)*



*Seidel, Vaquero, Siegal, Gandler and Green (1999).*  
PET-RPA-2002

# Previous DOI encoding approaches



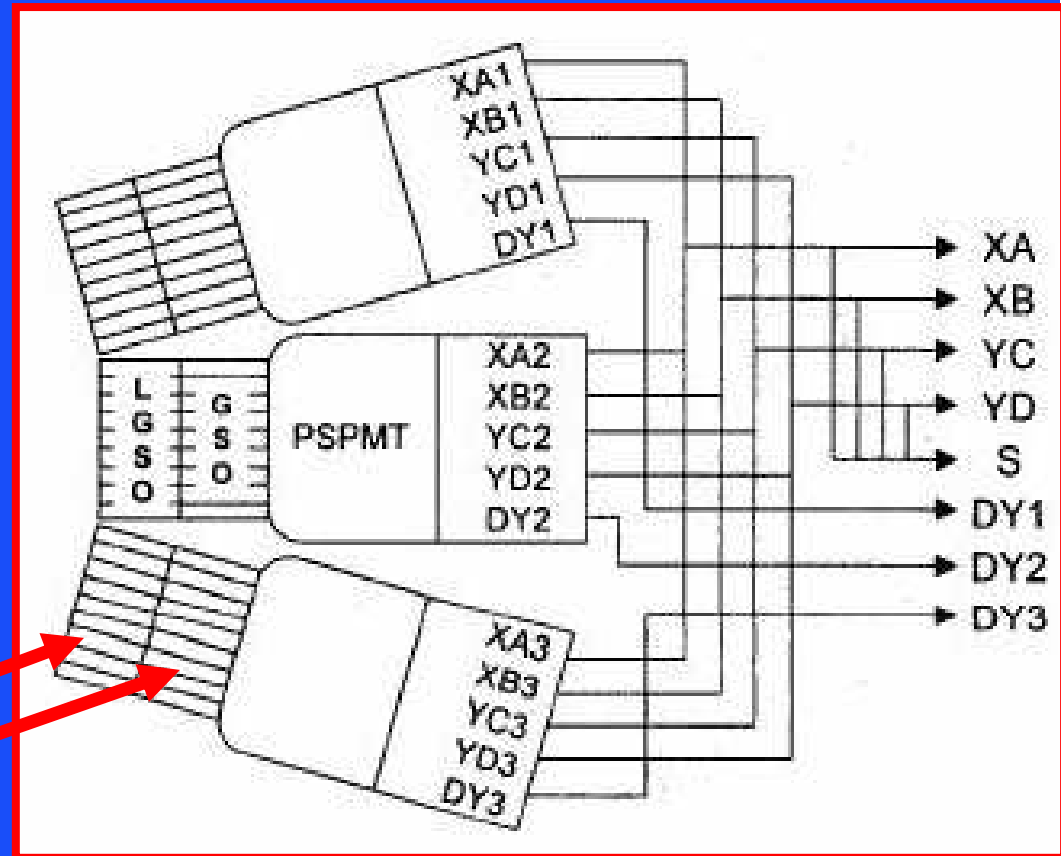
**“DOI accuracy of between 4 and 6.5mm”**

*(Diagram from Shao, Silverman, Farrell, Cirignano, Grazioso, Shah, Visser, Clajus, Tumer, and Cherry, 2000, p. 1051).*

# “ATLAS”



## “Advanced Technology Laboratory Animal Scanner” (NIH)



GLSO = 40ns

LSO = 60ns

*(Seidel, Vaquero, and Green, 2001).*

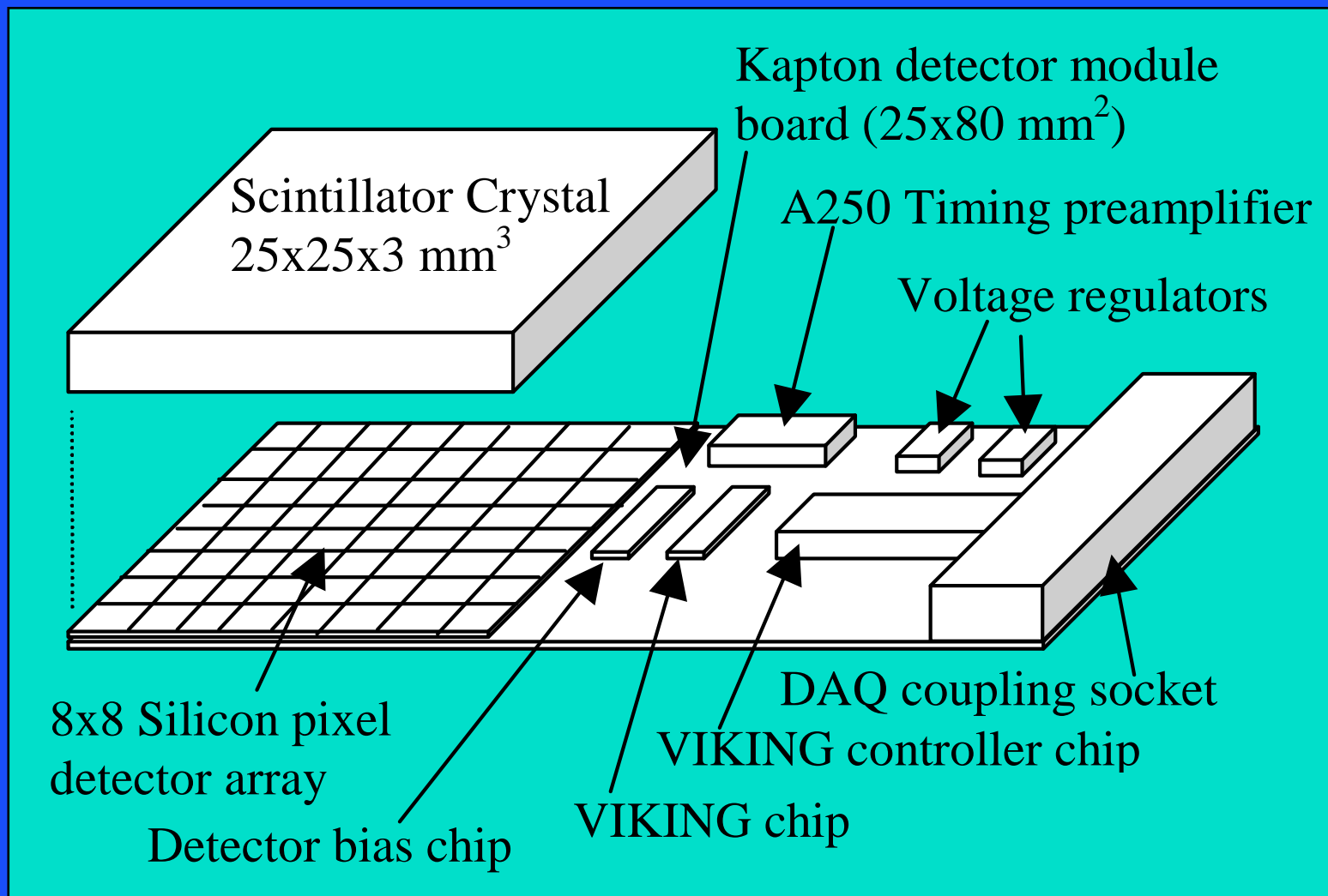
# MicroPET II



**No DOI capability - short crystal**

*(Chatziioannou, Tai, Doshi and Cherry, 2001).*

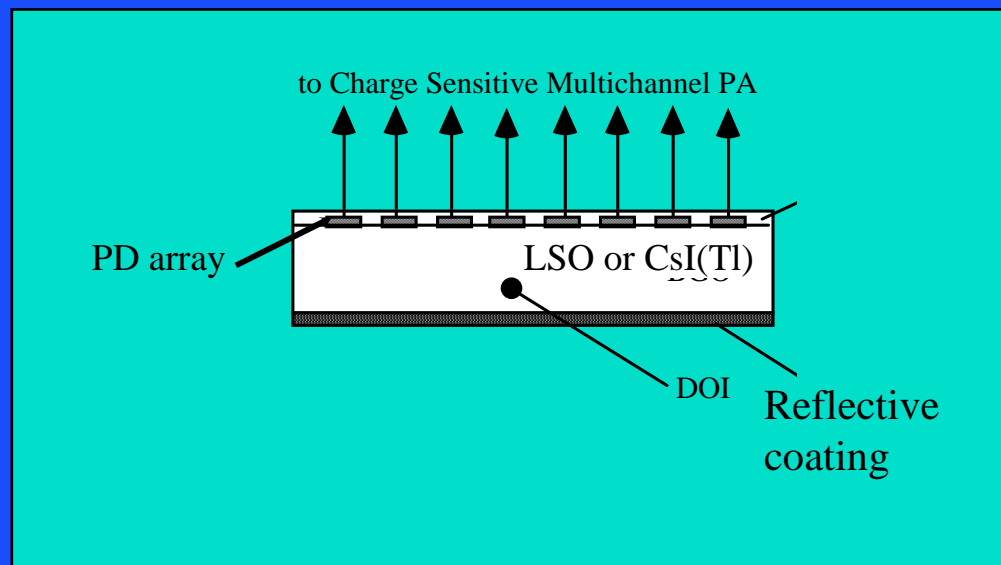
# New Detector Module Design



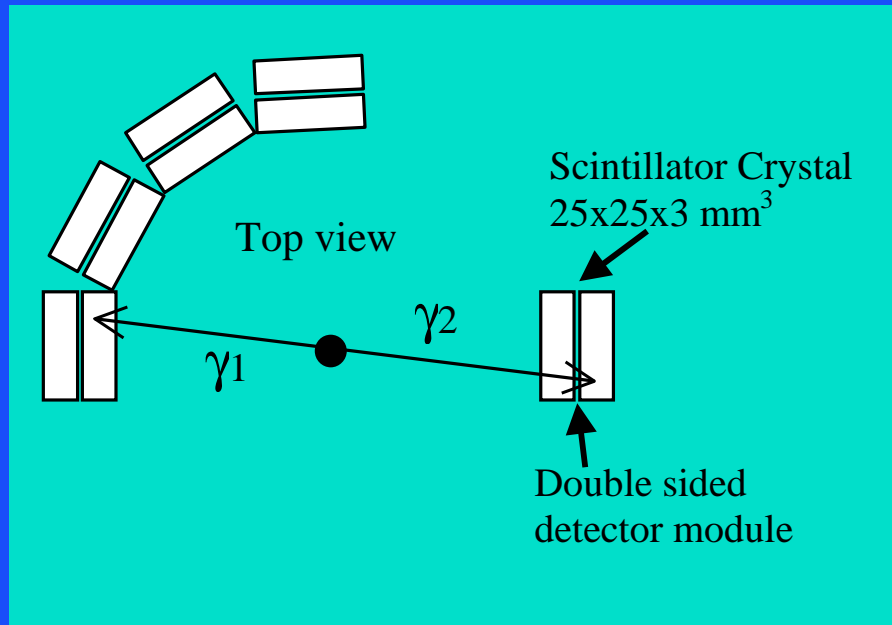
# Basic Detector Module Concept



- u Replace PMTs with silicon pixel photodetectors
- u Optically couple the array on the side of the scintillator
- u Determine the position of gamma ray interaction (POI) in the x-y plane of the array.
- u Reduce the uncertainty of the POI in the z-direction
- u Maximise the light incident on the array.

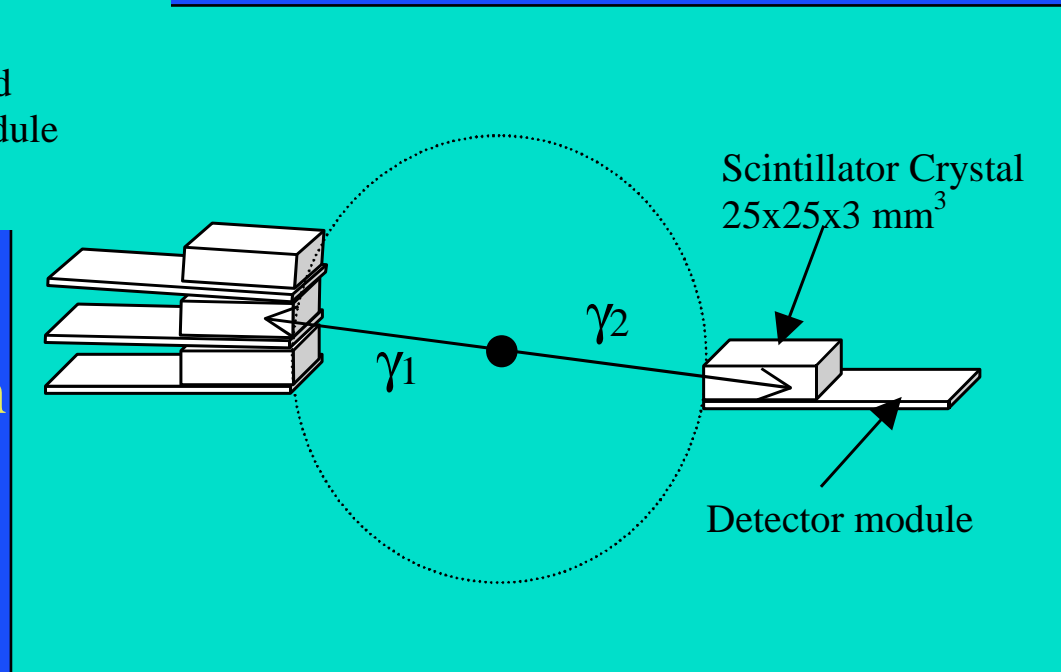


# Potential Module Configurations



High spatial resolution with  
medium gamma ray sensitivity

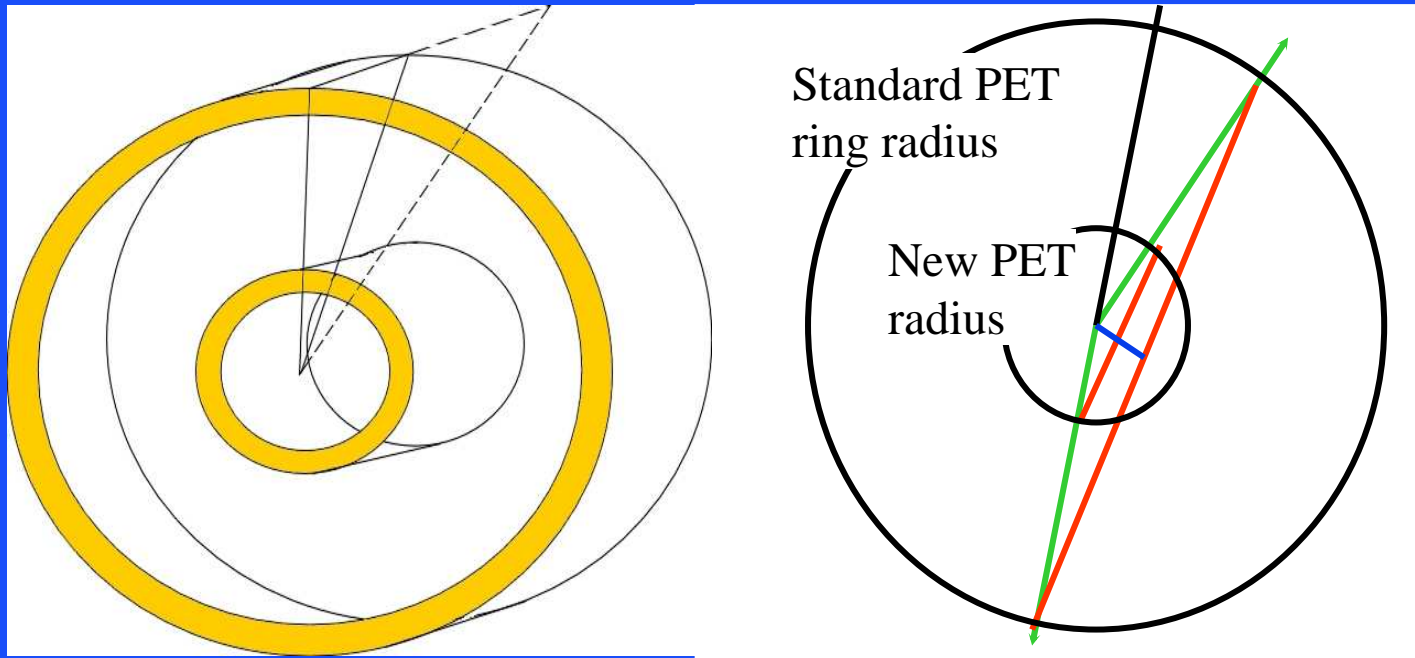
High spatial resolution with  
high gamma ray sensitivity



# Advantages of the New Detector Module



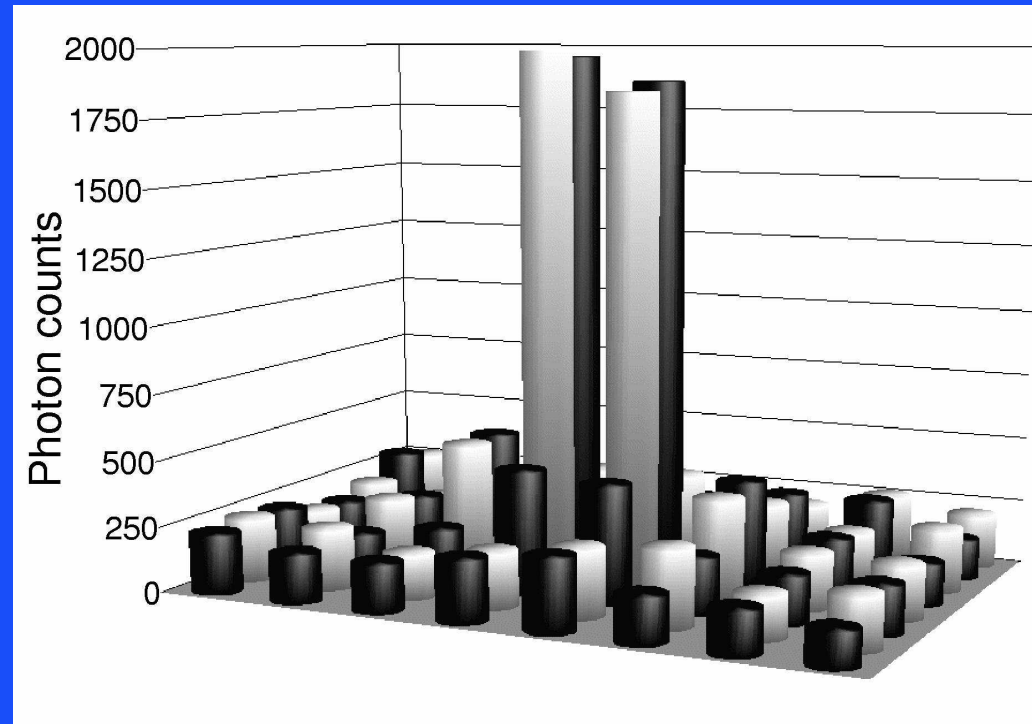
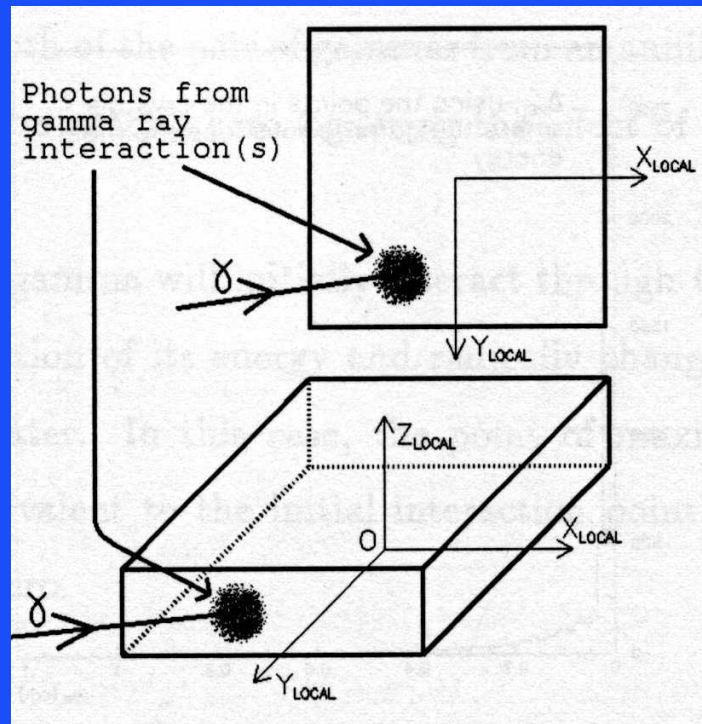
- u Good spatial resolution
- u Constant spatial resolution over the whole tomograph field of view
- u Reduced dead time, therefore can reduce diameter of detector ring
- u Improved photon counting statistics and reduce non-collinearity errors
- u Lower power consumption 1:2000



# Light Collection Simulations



- u Monte Carlo Simulations were performed by G. Takacs to:
  - determine the ideal crystal geometry so as to maximise the light output
  - optimise detector pixel size to improve the DOI measurements.

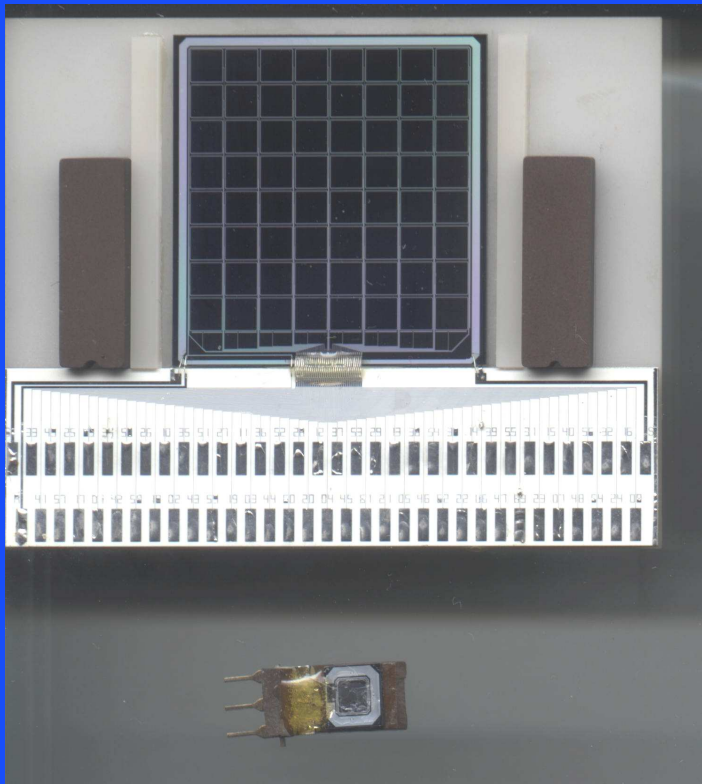


Interaction point above the corner of four pixels

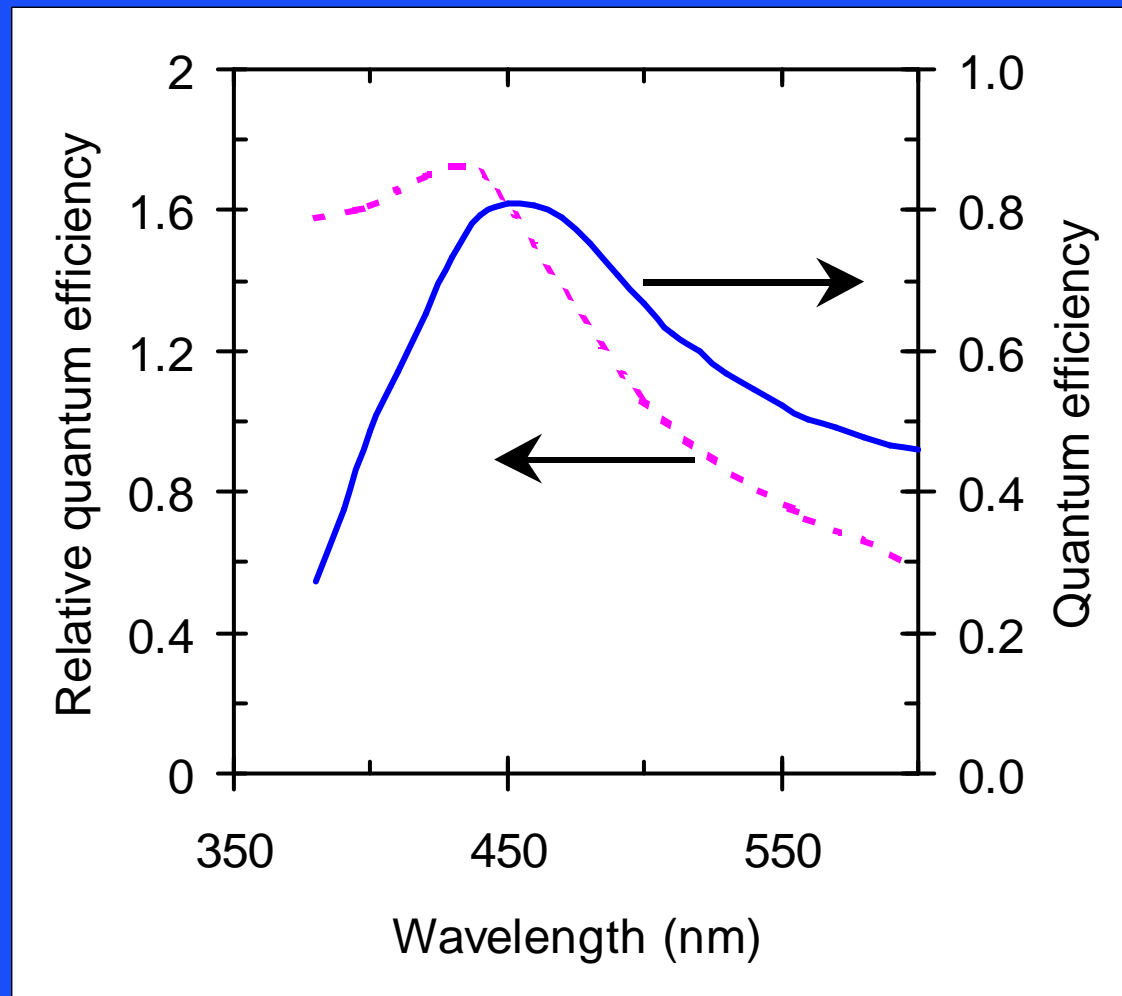
# Current status of detector module



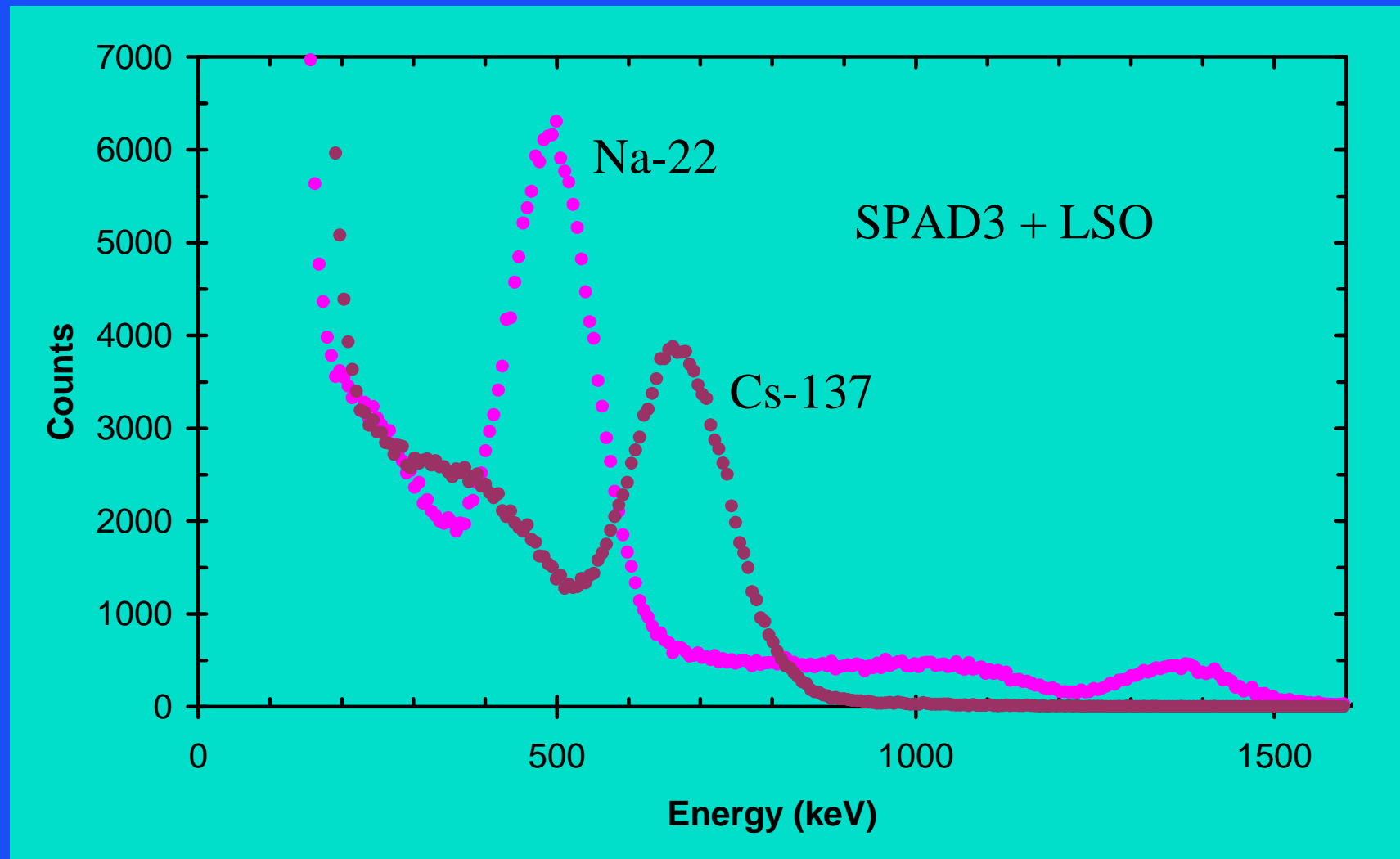
- u New pixel detectors have been manufactured
- u First prototype detector module board has been designed and built in collaboration with the HEP department, Melbourne University.
- u Pixel performance tests are currently under way.



# QE of SPAD3 and SPAD1



# Gamma Ray Spectroscopy - LSO



# Gamma Ray Spectroscopic Details



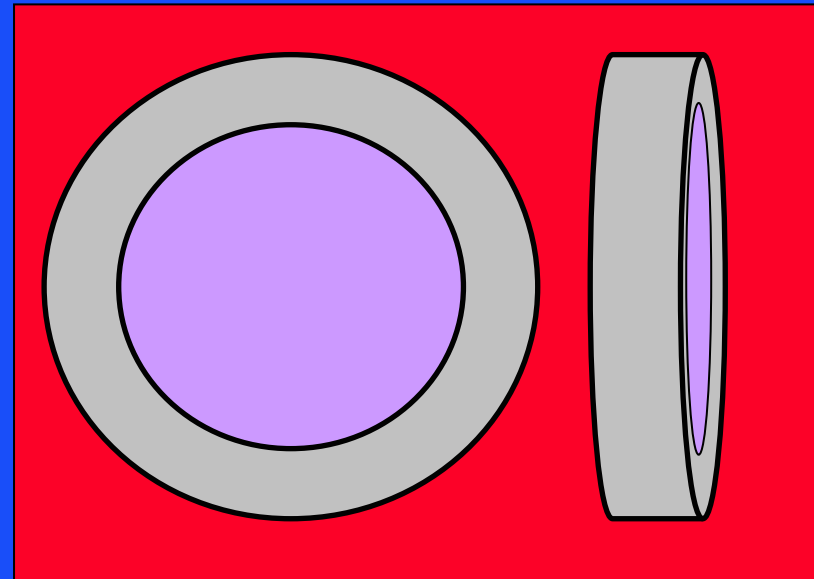
	Energy Resolution		ADC Peak Channel	
	Na-22	Cs-137	Na-22	Cs-137
Detector	(511 keV)	(662 keV)	(511 keV)	(662 keV)
SPAD3	20.8%	16.5%	98	127
SPAD1	25.8%	20.5%	89	117

The results for SPAD3 are some of the best ever reported for these type of photodetectors

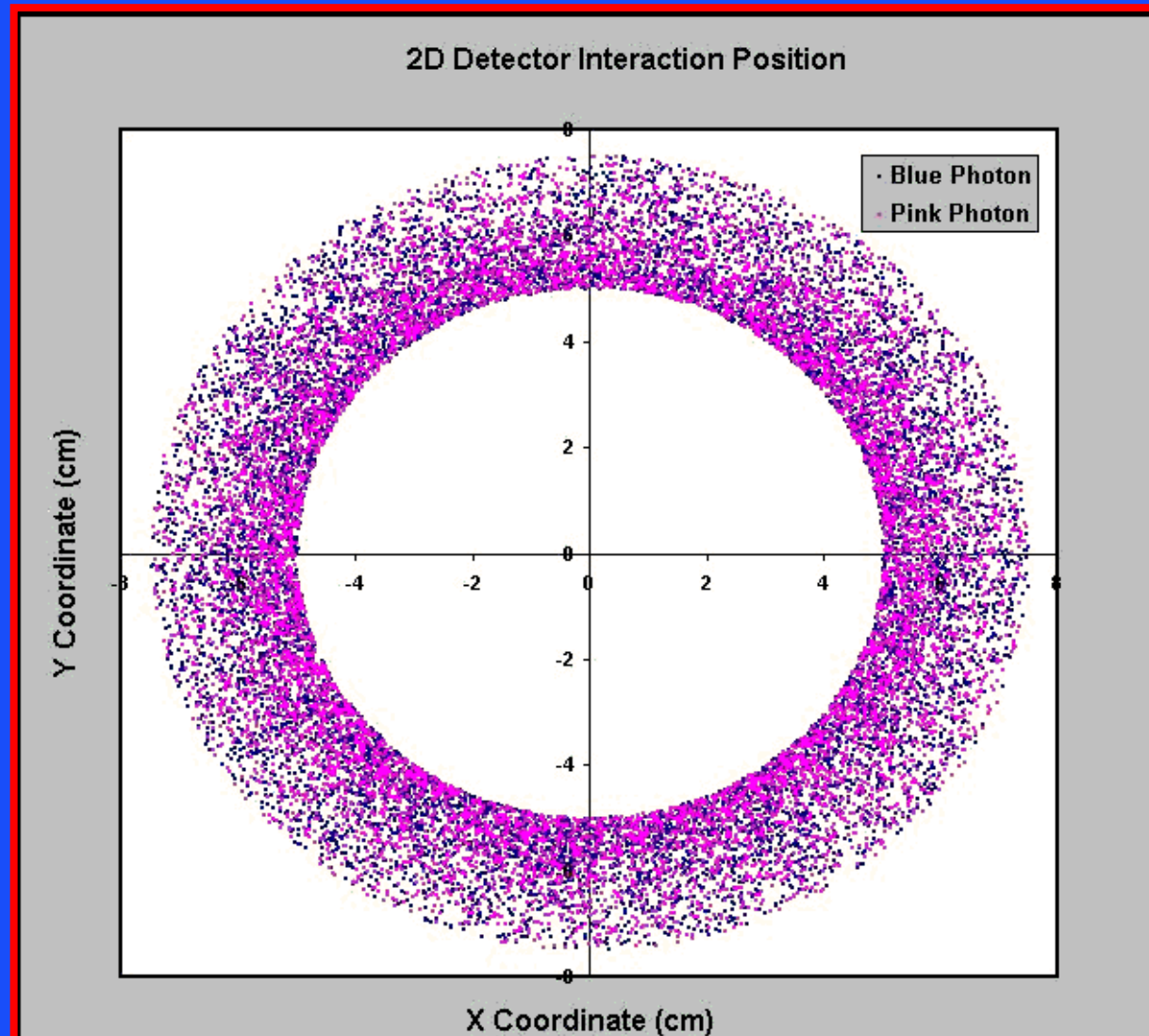
# SimSET - Simulation System for Emission Tomography



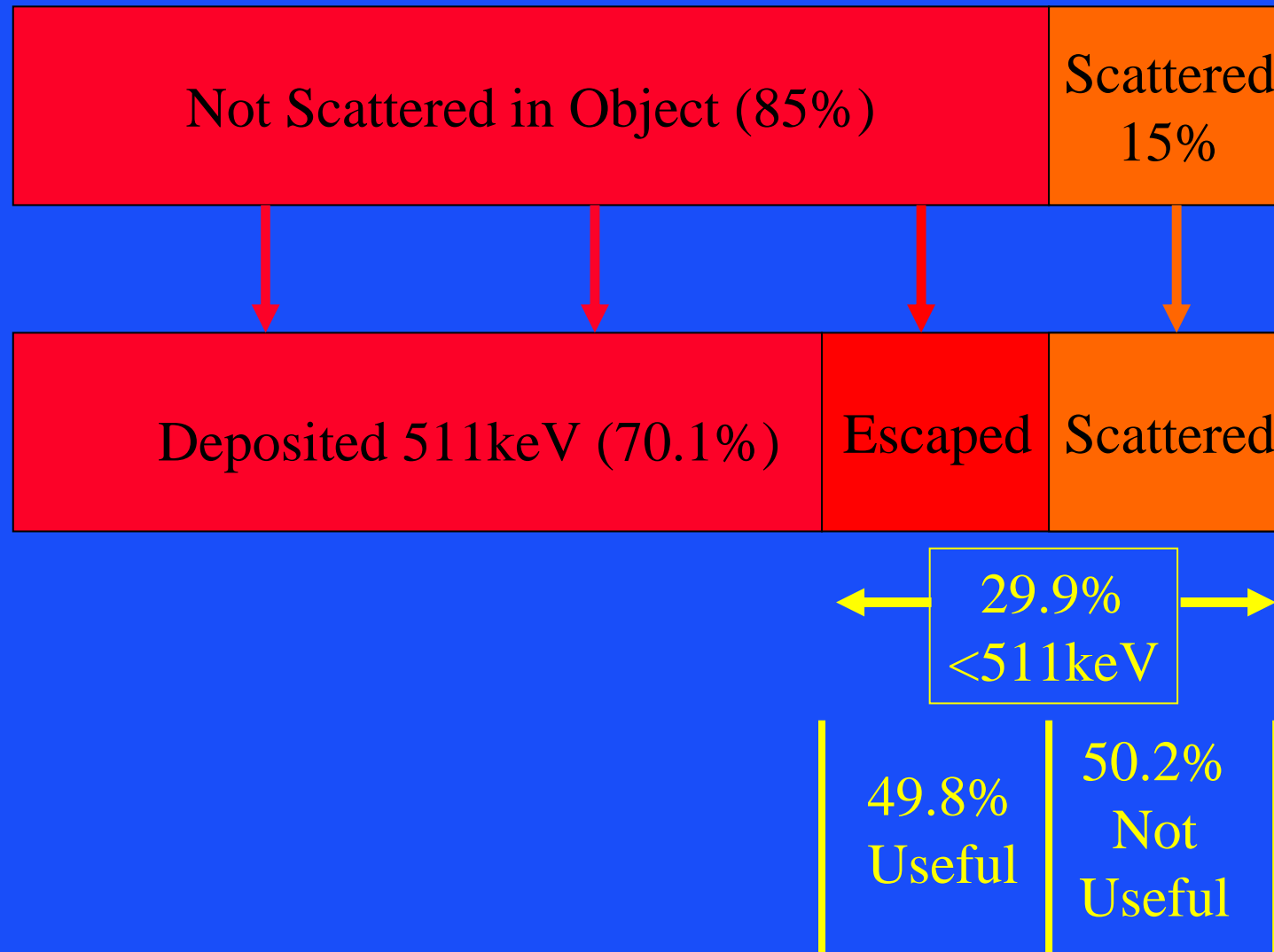
- Ring inner diameter: 100, 120, 140 and 160 mm.
- Detector material: LSO (5600 photoelectrons/511keV)
- Detector type: Cylindrical.
- Collimation: None.
- Detector thickness: 25mm.
- Axial dimension: 25 mm.
  
- Objects simulated
  - Single point sources in air
  - Single line sources in air
  - Multiple line sources in scatter material (water)
  
- 60 million decays per simulation.



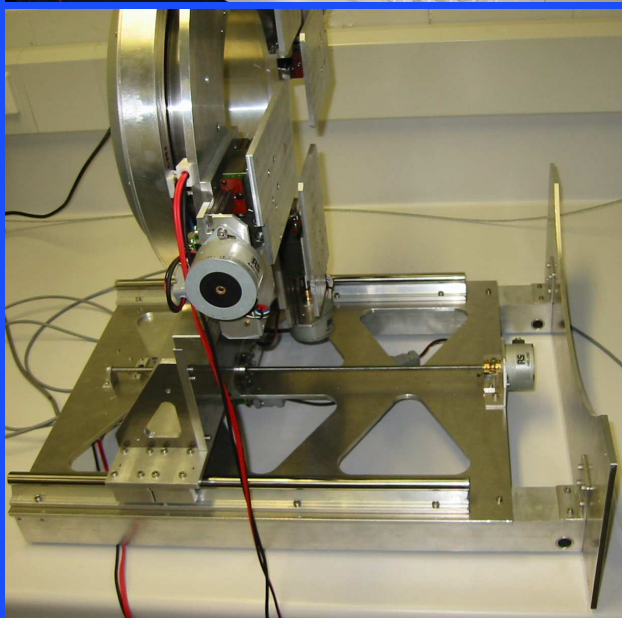
# SimSET modelling of PET scanner



# Assessment of scatter events in the object.



# Module Gantry Development



# Conclusion



- u The Centre for Medical Radiation Physics has developed a new silicon photodetector array.
- u The array displays good spectroscopic properties that make it suitable for use with scintillators that have emission spectra that peak in the blue/violet spectral regions such as LSO.
- u It is planned to use the photodetectors as the basis of a new gamma ray imaging module.
- u The flexibility of the design will allow the same module to be used in a number applications including high resolution human brain PET scanners, scintamamography modules for early detection of breast cancer, and small animal PET scanners for new radiotracer development.

# Acknowledgments

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- u National Health and Medical Research Council (project number 162722)
- u Insight Oceania, Sydney, Australia