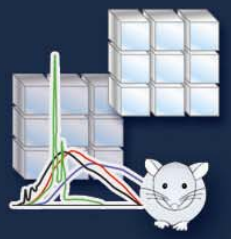

Design, construction and characterization of a benchtop microPET system based on LYSO crystal arrays and Hamamatsu H8500 PS-PMTs

Mercedes Rodríguez-Villafuerte

H. Alva-Sánchez, A. Martínez-Dávalos, E. Moreno-Barbosa, B. Hernández-Reyes, T. Murrieta, C. Ruiz-Trejo, M.E. Brandan

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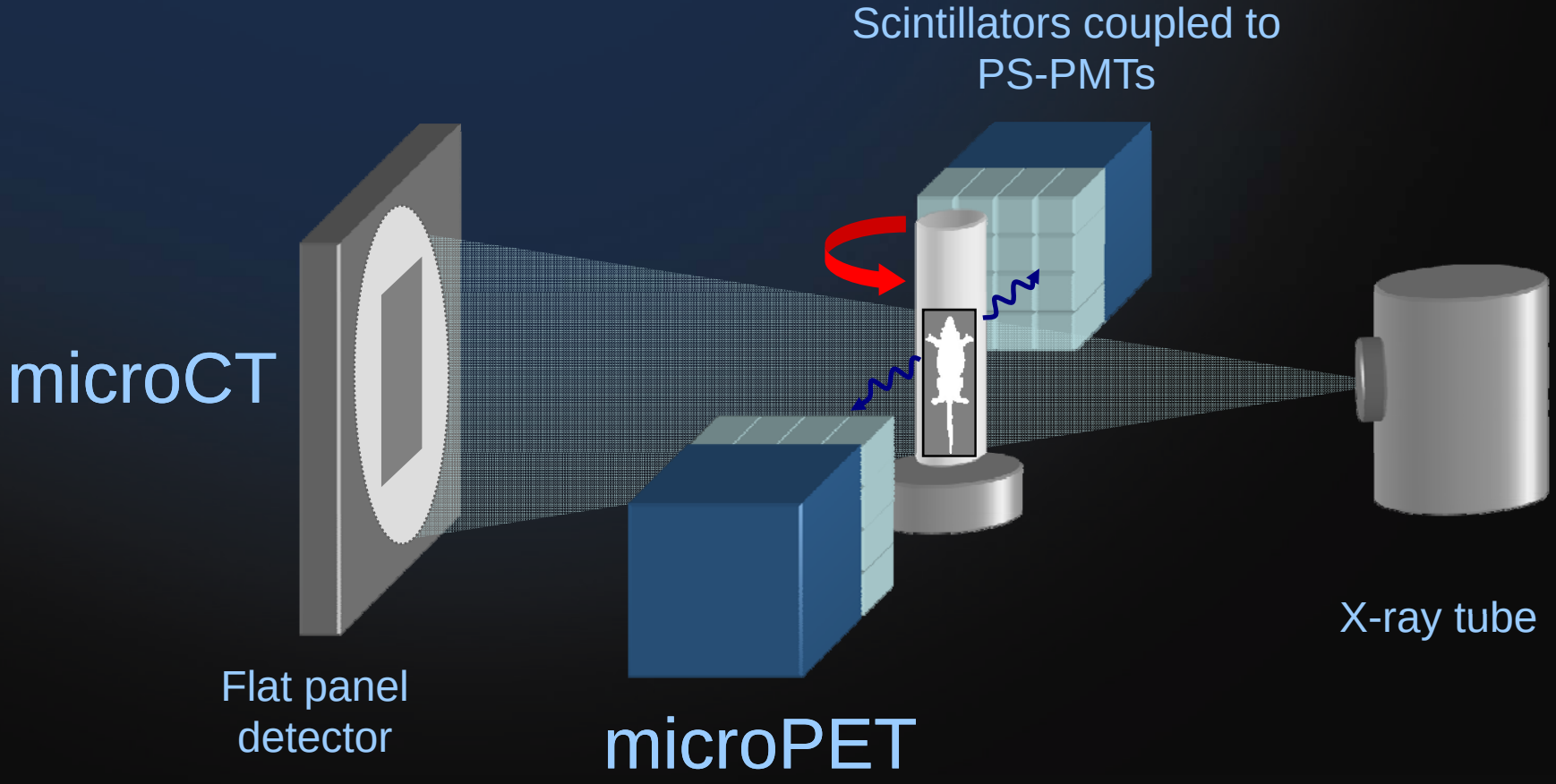
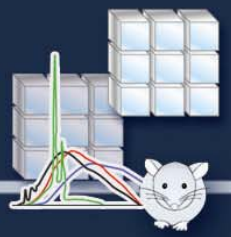
Sistema Bimodal de Imágenes (SIBI)





Aims

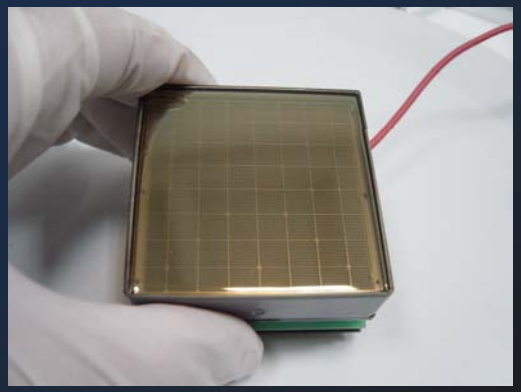
- To develop radiological imaging systems for small rodents using state of the art technologies for basic research purposes
- To integrate different imaging techniques in order to provide both anatomical and functional information
- To provide advanced training in all related areas (radiation detection, nuclear techniques, imaging, preclinical studies, etc.)
- To collaborate in basic biomedical research using *in vivo* molecular imaging techniques

SIBI

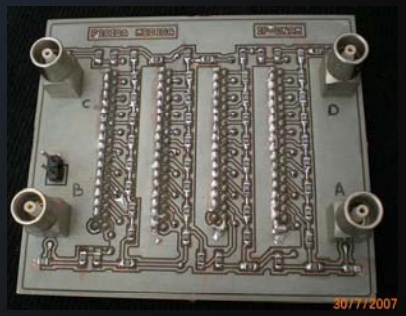
microPET modules design

Scintillator crystal

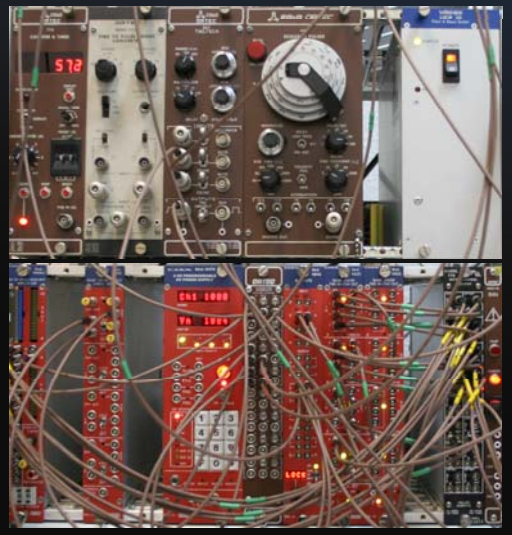
PS-PMTs



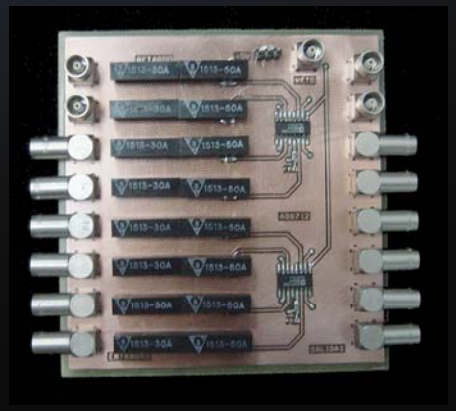
Resistive chain



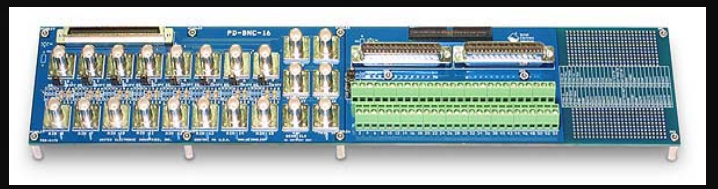
NIM modules



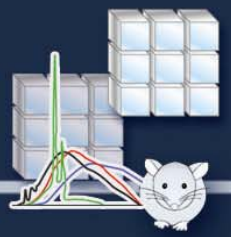
VETO



Data acquisition board

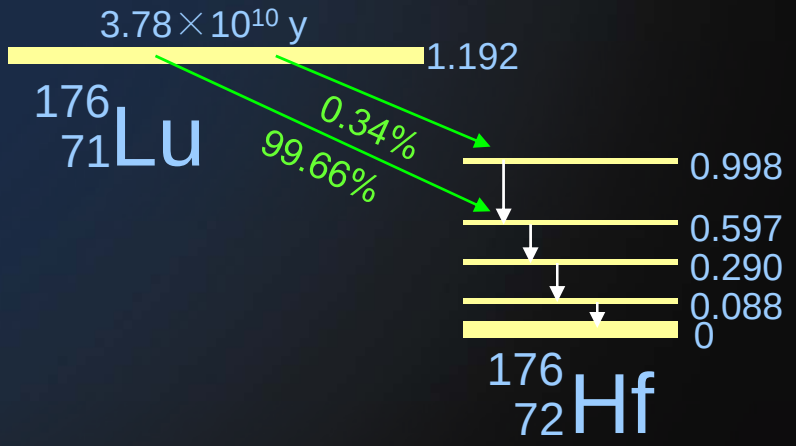


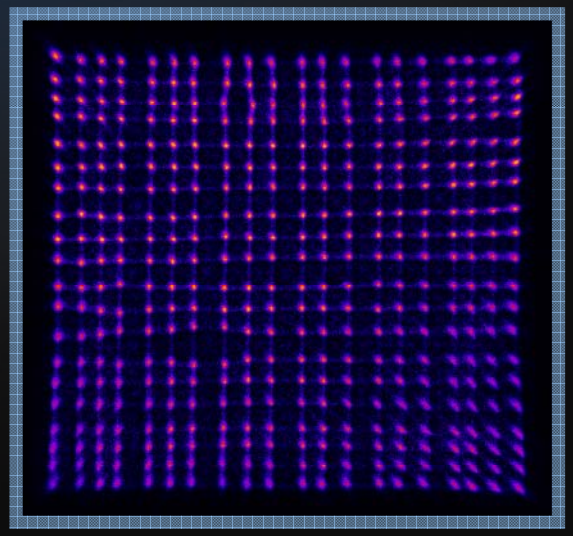
The benchtop microPET

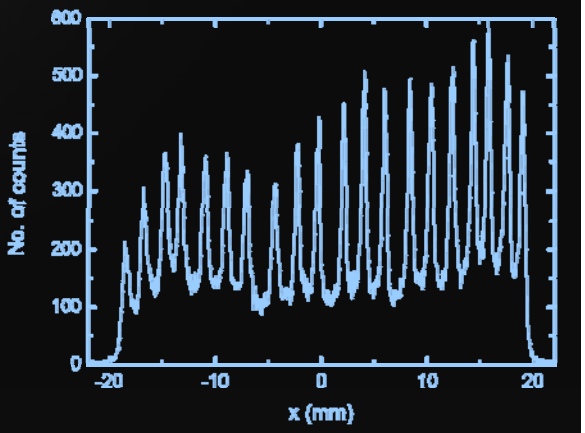


Scintillator Crystal

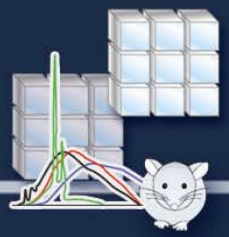
- $Lu_{2(1-x)}Y_{2x}SiO_5$:Ce (LYSO†)
  - Density: 7.1 g/cm^3
  - Effective atomic number: 60
  - Decay constant: 41 ns
  - Photon yield: 0.80 wrt NaI
  - Refraction index: 1.81
  - Peak wavelength: 420 nm
  - 1/μ @ 511 keV: 1.16 cm
- 2×2×10 mm^3, 2.075 mm pitch
- Ground crystals, 75 μm VM 2000 reflective layer
- Radioactive







†Proteus, Inc., 120 Senlac Hills Drv., Ohio 44022, USA

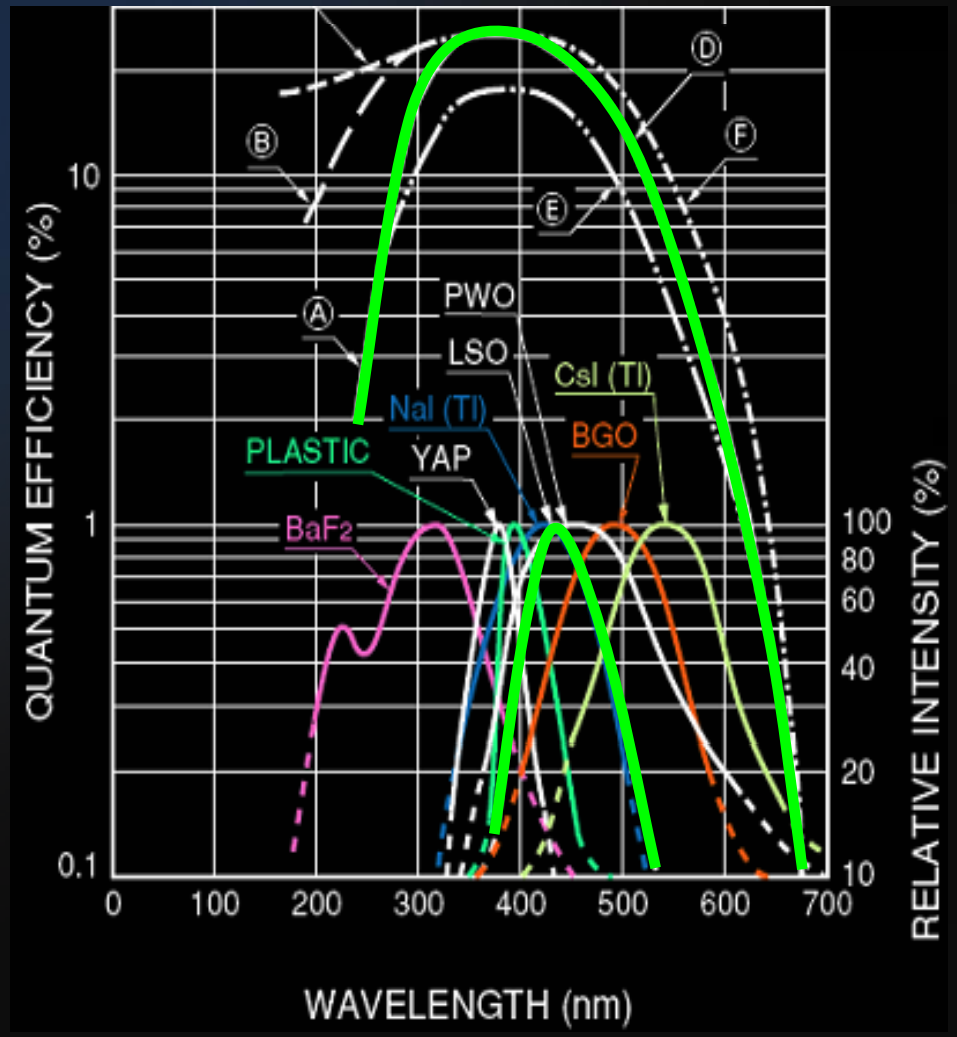


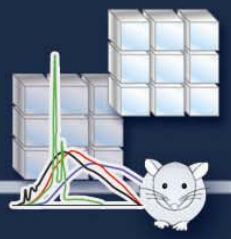
PS-PMT Hamamatsu H8500

- Bialkali photocathode
- Spectral response 300-650 nm
- Peak wavelength: 420 nm
- 8×8 anodes, 5.8×5.8 mm^2
- 49×49 mm^2 effective area

70	68	71	71	68	69	65	56
70	76	82	87	85	89	92	94
66	80	80	80	84	90	100	95
64	76	74	69	72	77	83	78
55	67	66	65	63	65	72	65
54	62	60	62	60	64	65	59
52	56	60	61	63	67	71	66
39	48	53	55	58	61	66	70

Anode uniformity





Data acquisition board

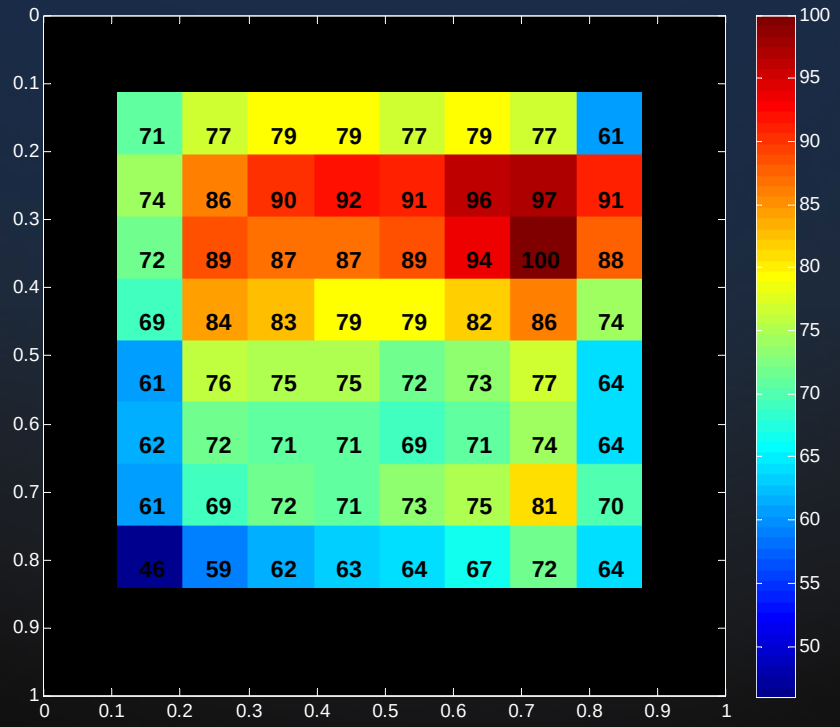
- United Electronics† PD2-MFS-8-2M/14
- PCI bus
- 8 single-ended simultaneous sample/hold A/D channels
- 14 bit resolution, 2 MS/s sampling rate
- Two 12-bit analog outputs; 32 digital I/O lines; three 16 bit-counter/times
- Simultaneous operation of all subsystems
- Stream-to-disk capability

SIBI

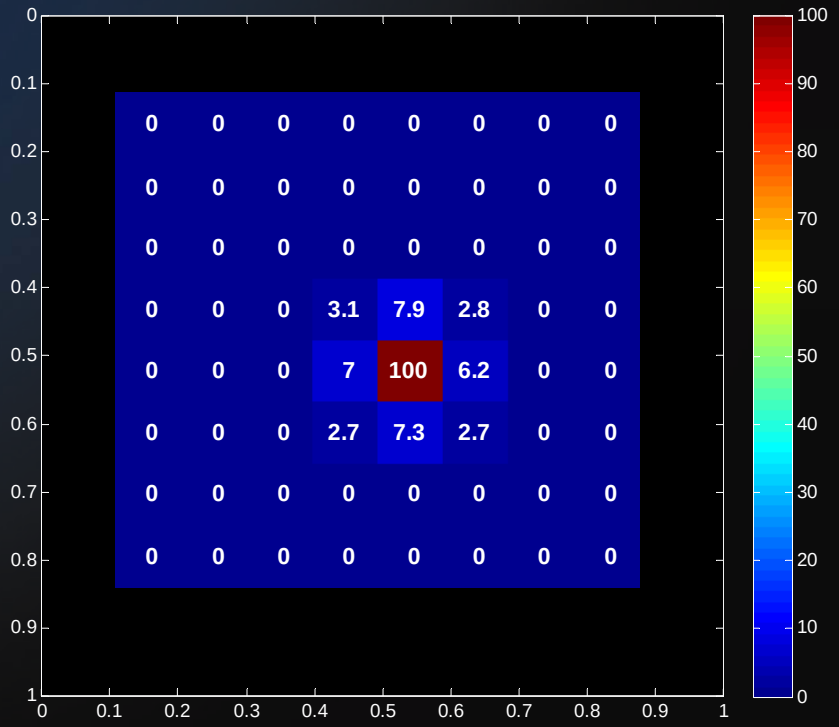
†United Electronic Industries, Inc. 611 Neponset St., Canton, MA 02021, USA

H8500 characterization

Uniformity (within 20%)



Crosstalk (<3%)

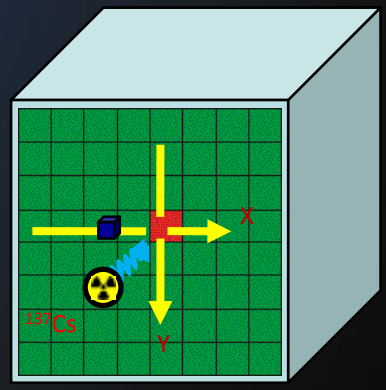


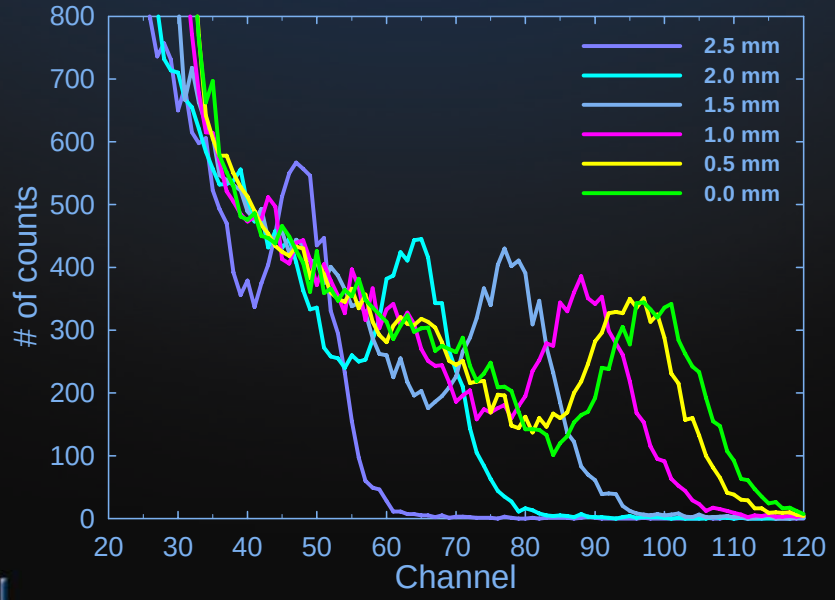
1.1 mm Ø fiber optic, λ= 428 nm (blue LED), MCA Amptek 8000A
Anode uniformity: All anodes
Crosstalk: Only anode #29

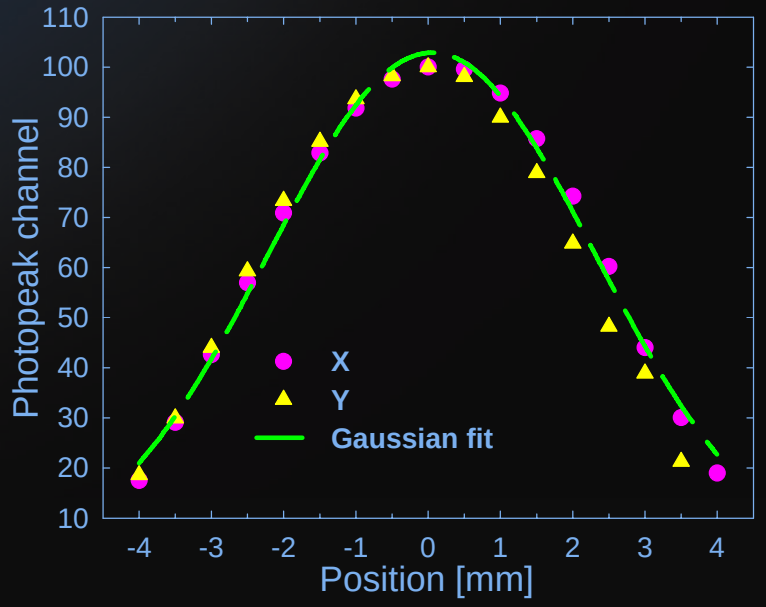
B. Hernández, MSc thesis, Graduate Program in Medical Physics, UNAM, 2008

H8500 aperture function

- ^{137}Cs source (662 keV)
- LYSO (2×2×15 mm^3)
- MCA Amptek 8000A

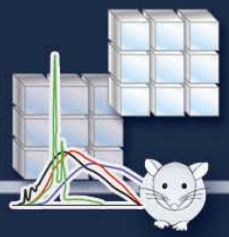


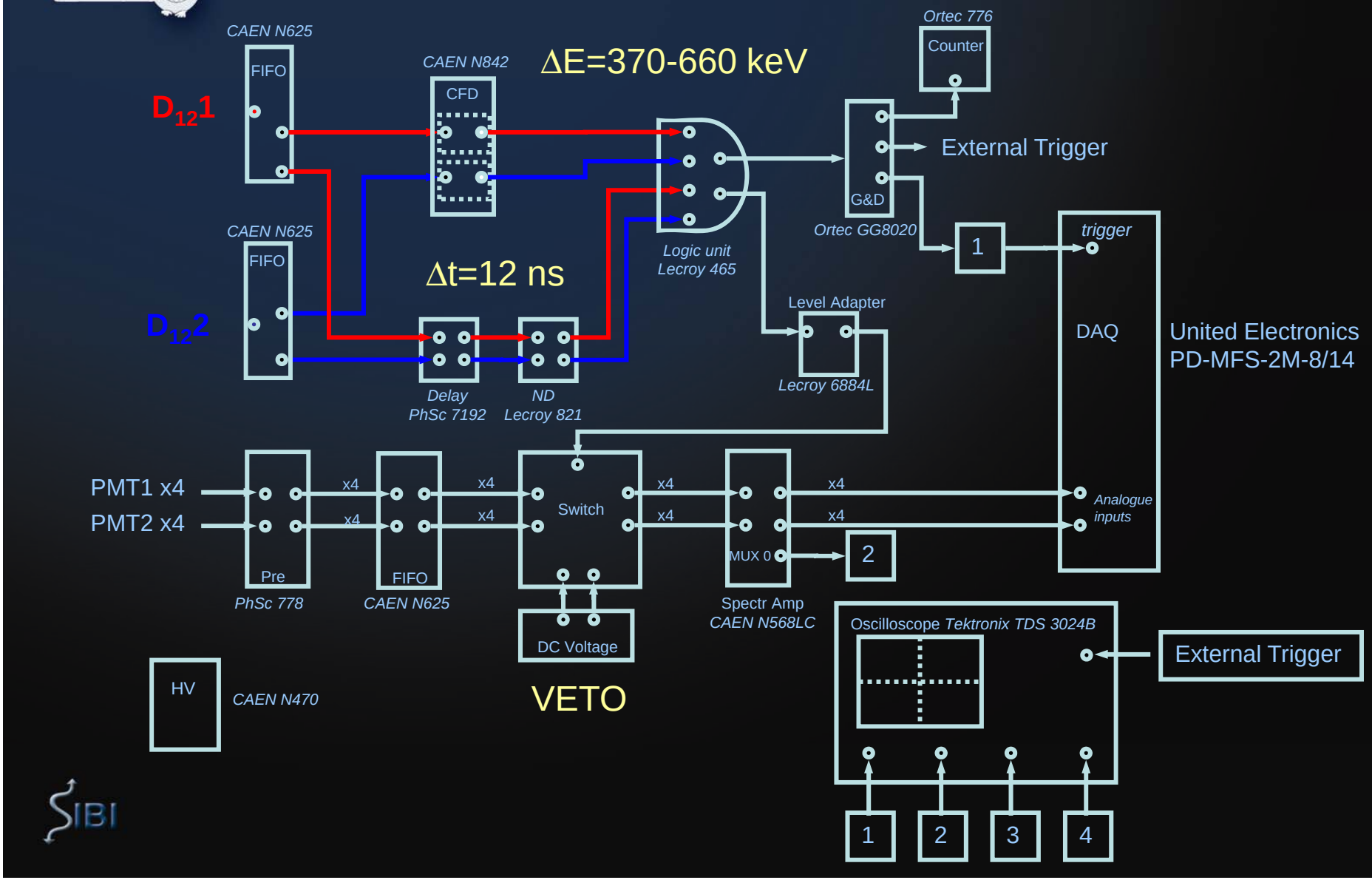




Inadama N, Murayama H, Watanabe M, et al. IEEE Trans Nucl Sci 51-1 (2004) 58-62

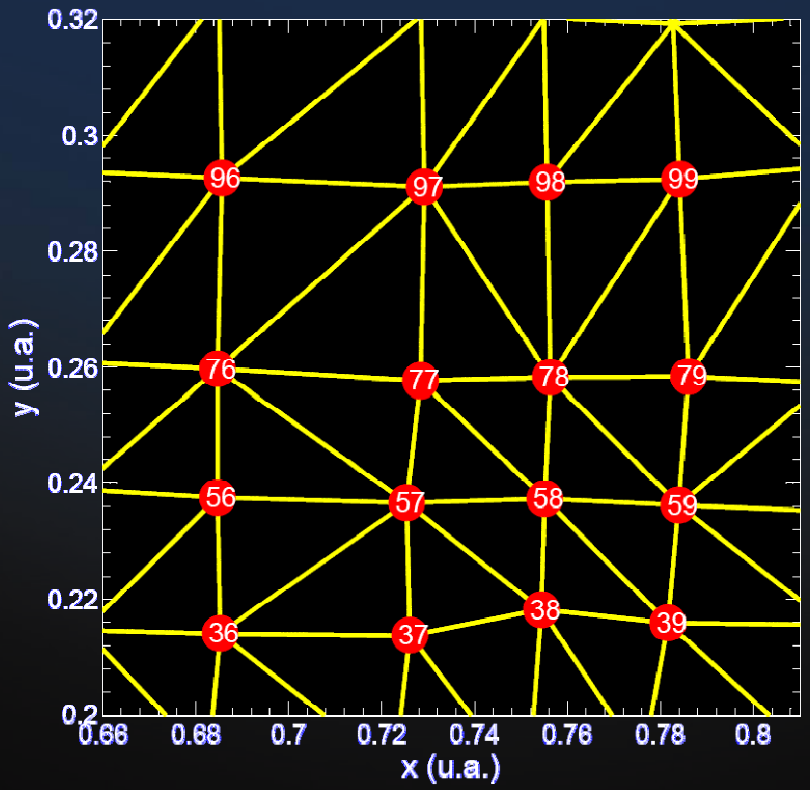
Electronics diagram



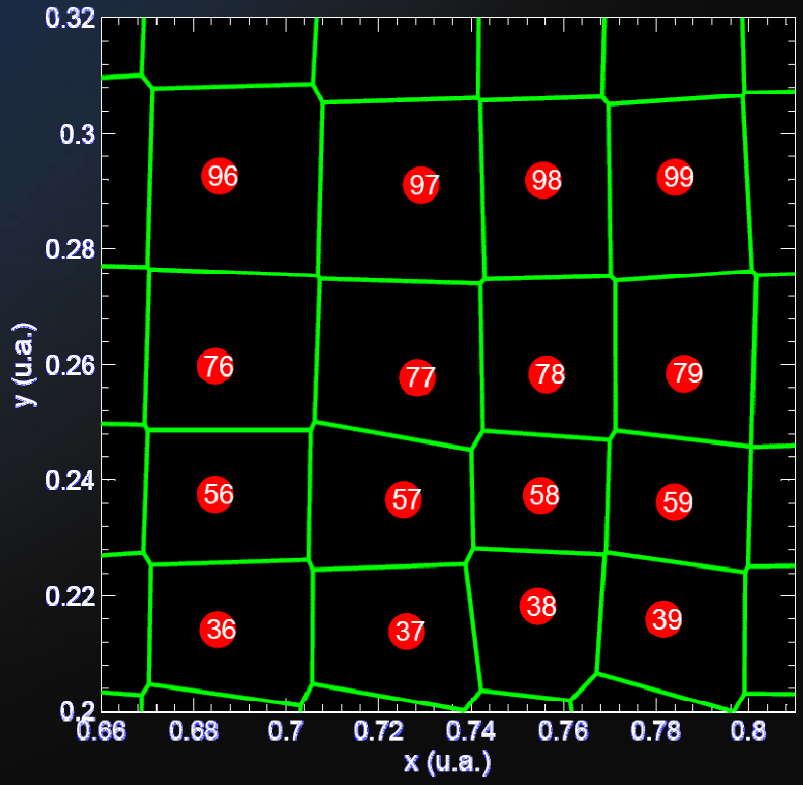


Crystal map

Delaunay triangulation



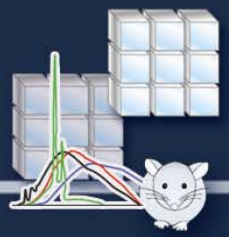
Voronoi diagrams

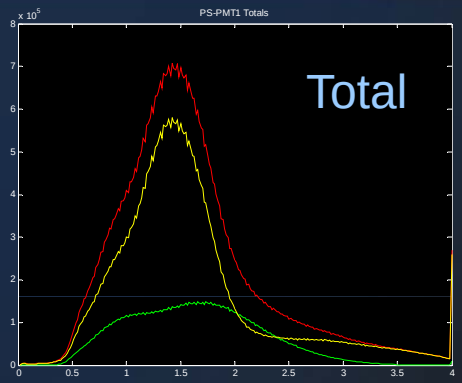


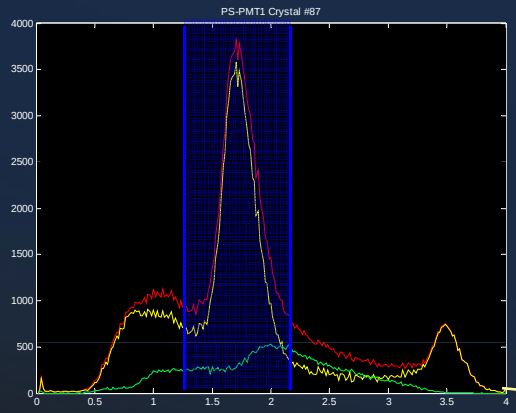
SIBI

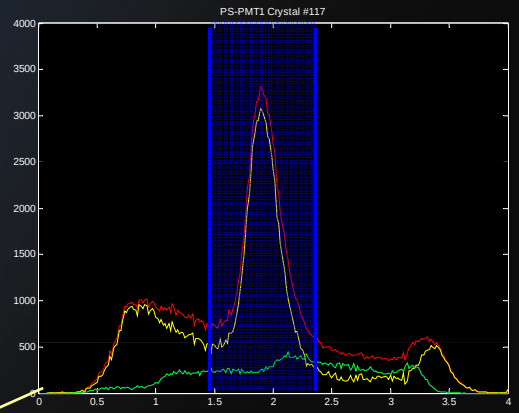
H. Alva et al., Energy calibration of individual crystals in a LYSO pixelated array for microPET detection modules, in press NIMA, 2008

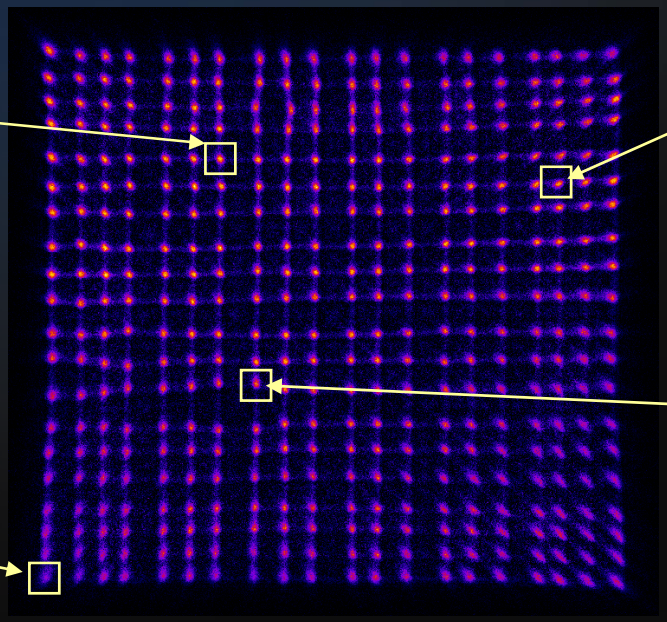
Energy calibration

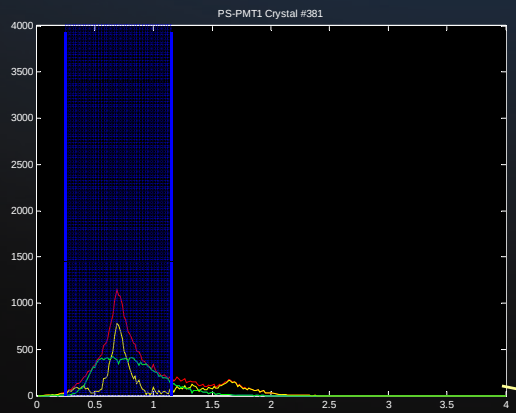


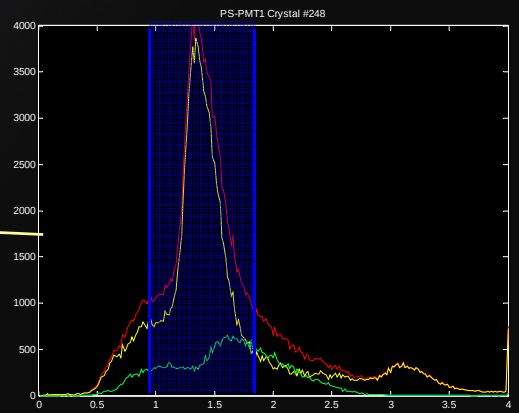




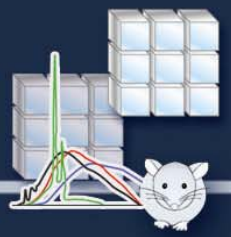




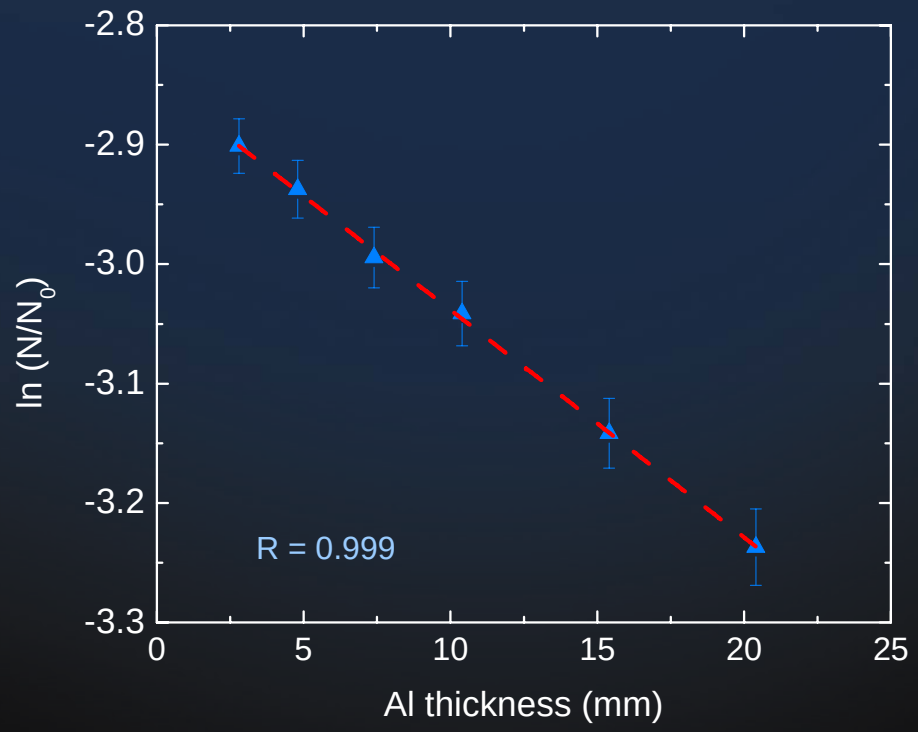




Photopeak position variations as high as 50% are observed.
Energy resolution @ 511 keV goes from 7% to 15%.



Sensitivity



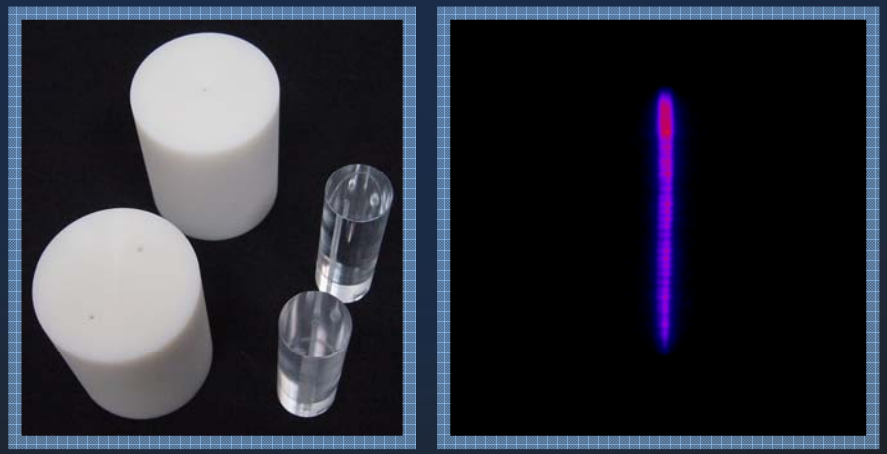
	This work (370-660 keV)	NIST
μ_{Al} (cm^{-1})	0.19 ± 1%	0.22

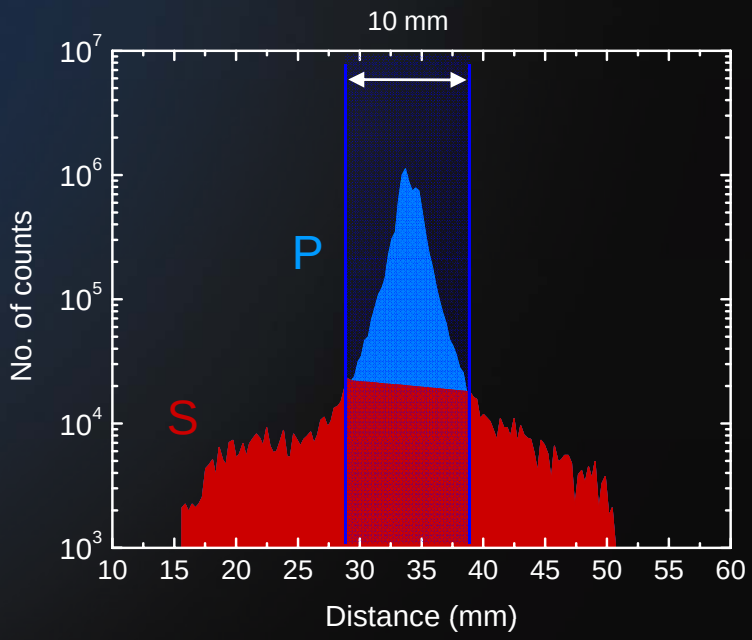
- A_o= 144 µCi (5.32 MBq)
- Distance between detectors: 15 cm
- 2D parallel beam geometry
- Absolute sensitivity: 0.06%

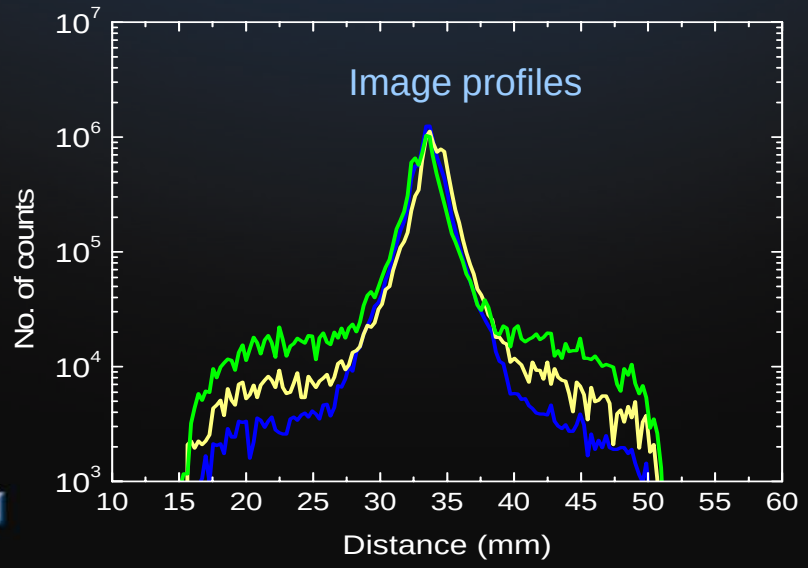
Bailey DL et al., Eur. J. Nucl. Med. 18 (1991) 374-379.

Scatter fraction

Mouse & rat-size phantoms





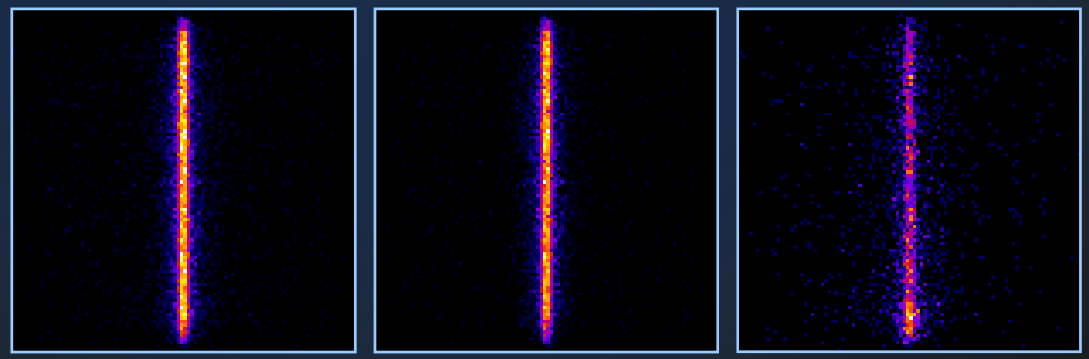


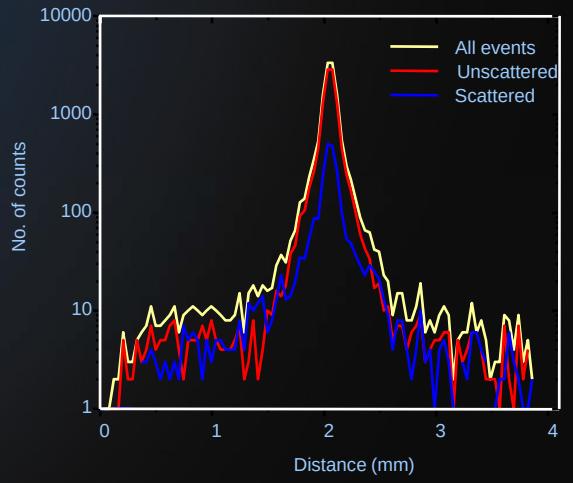
SF=S/(P+S)	This work (370-660 keV)	Yang 2006 (350-750 keV)
Capillary in air	11%	6%
Mouse phantom	14%	11%
Rat phantom	21%	37%

Yang et al., IEEE Trans Nucl Sci 53-1 (2006) 127-132.

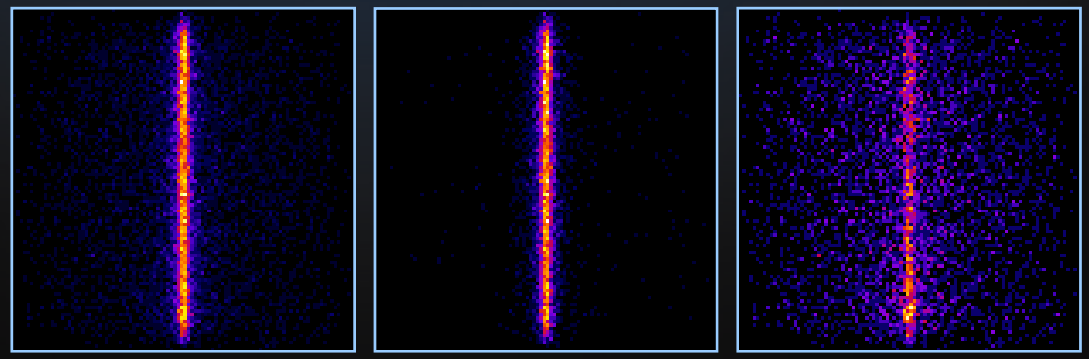
Monte Carlo (PENELOPE)

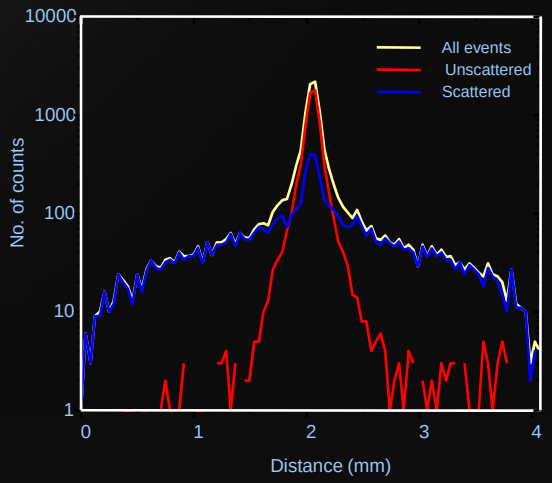
Mouse size phantom: SF = 19.5%





Rat size phantom: SF = 35.0%



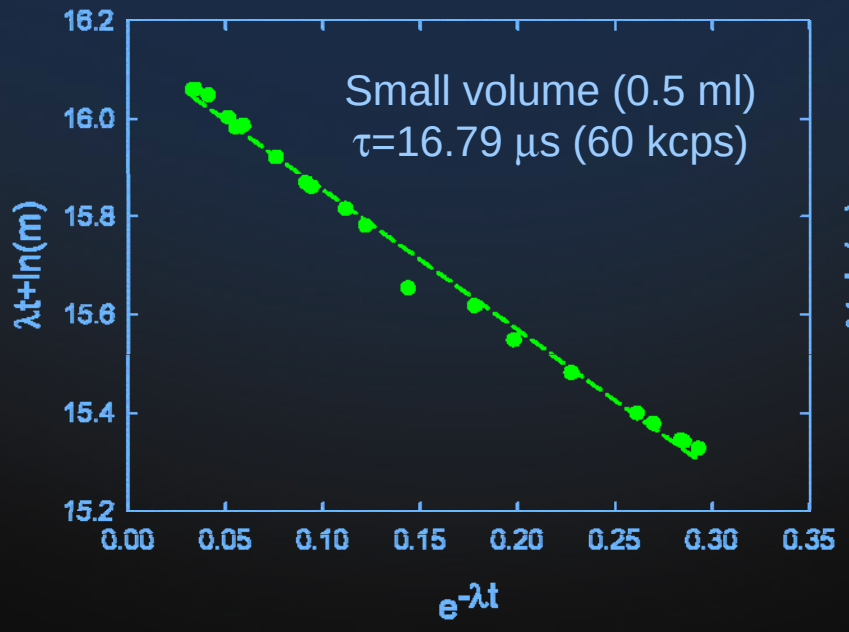


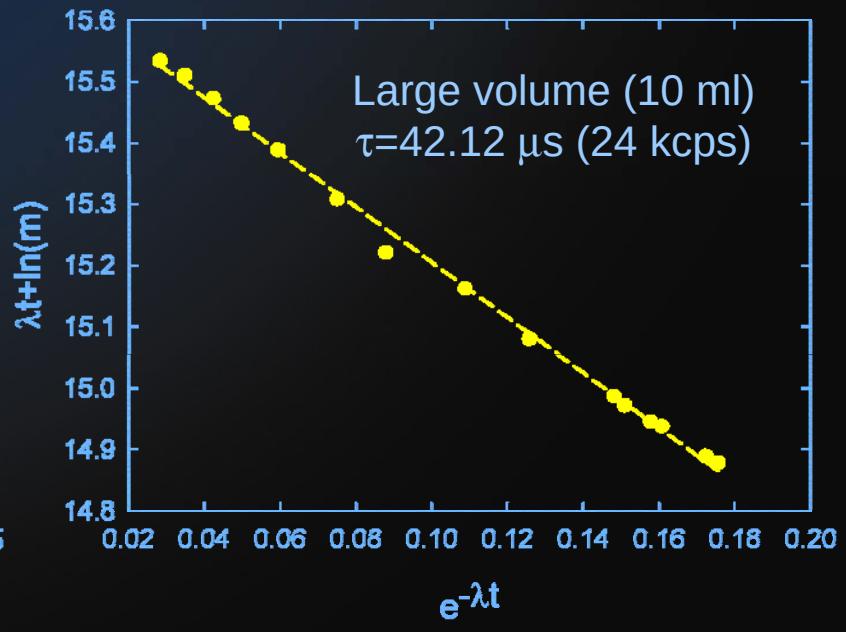
All events Primaries Scattered

Héctor Alva, PhD thesis (in process), Graduate Program in Physics, UNAM, 2008

Dead time

Decaying source method - Paralizable system

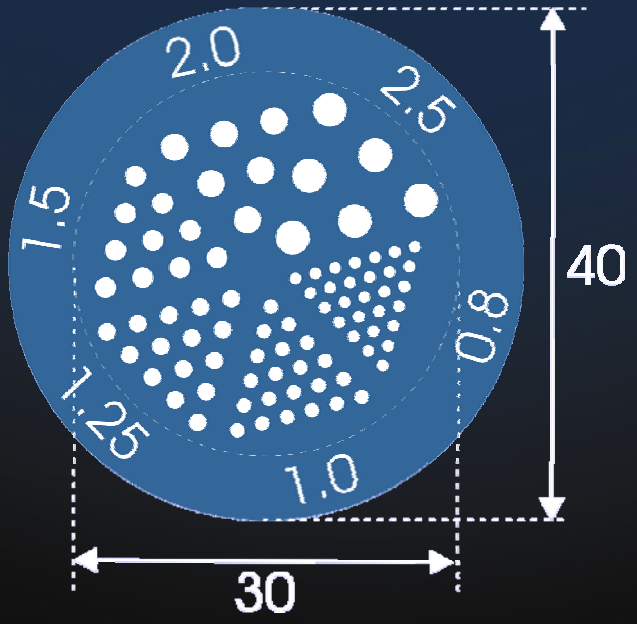




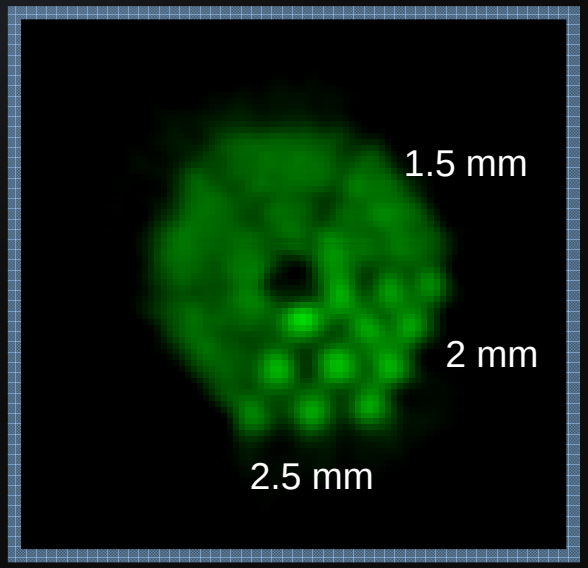
Knoll GF, Radiation Detection and Measurement, Wiley, 2000

Spatial resolution

microDerenzo phantom



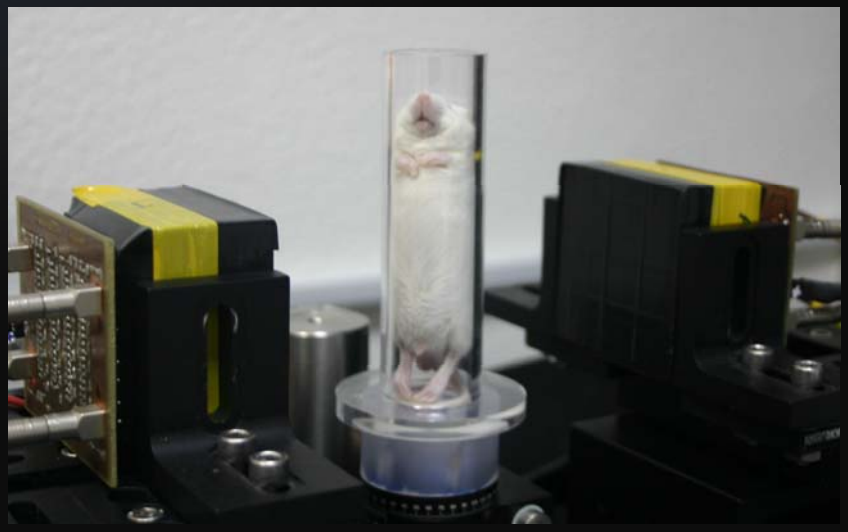
Units in mm



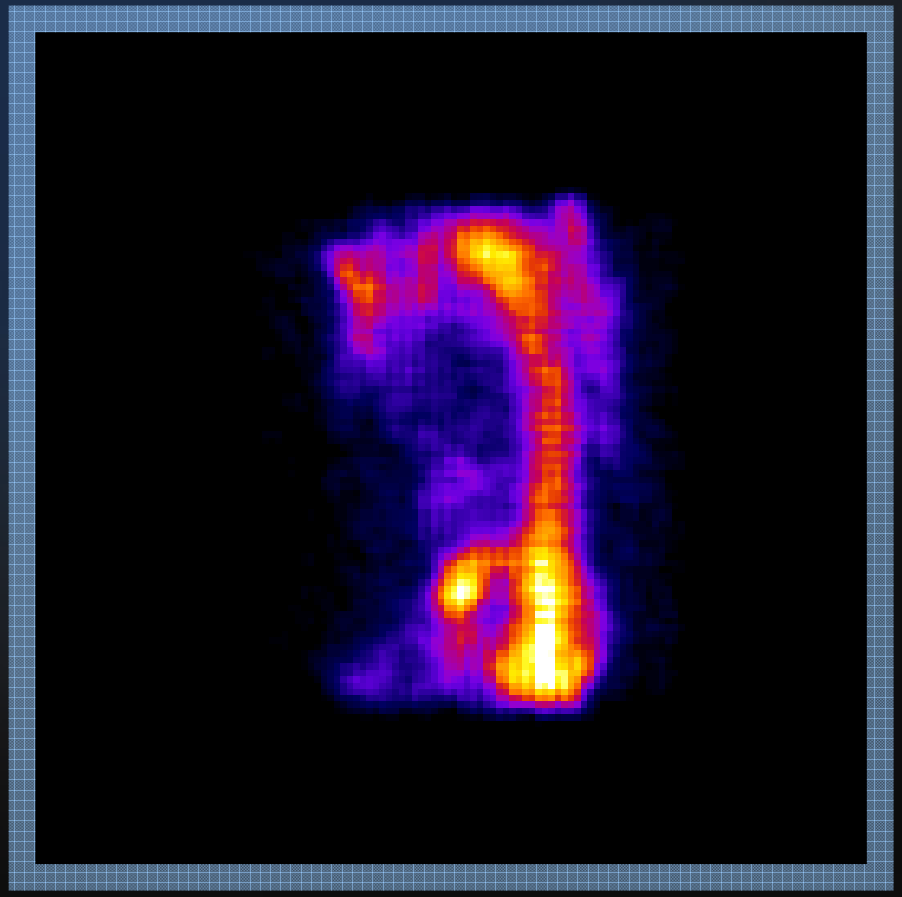
2D FBP

microPET study of a mouse

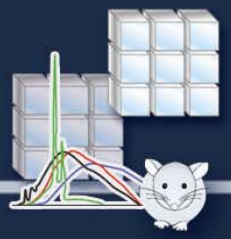
- Bone study, ^{18}F sodium fluoride (NaF)
- 466 μCi
- 360° acquisiton
- 72 projections
- 5×10^5 cpp
- 5 hours



Mouse projection data



Héctor Alva, PhD thesis (in process), Graduate Program in Physics, UNAM, 2008



Conclusions

- Cost effective benchtop microPET (sensitive area: 4×4 cm^2, coincidence time window: 12 ns)
- Useful for basic measurements and Monte Carlo validations
- Energy resolution @ 511 keV of individual crystals: 7%-15%
- Absolute sensitivity: 0.06% in a 2D parallel beam geometry
- Dead time: 17 μs (60 kcps) small volume - 42 μs (24 kcps) large volume
- Scatter fraction (ΔE 370-660 keV): 14% and 21% for mouse and rat phantoms, respectively
- Spatial resolution 1.5 - 2.0 mm

Future work:

- Increase sensitivity
- 3D tomographic reconstruction
- Integration with the microCT system

SIBI

¡Gracias!