Resolution Study of a γ-Camera System for SPECT at Preclinical Level

Despoina Zarketan

L. Koutsantonis, M.-E. Tomazinaki, E. Stiliaris

Department of Physics & Medical School

National & Kapodistrian University of Athens, Athens, Greece

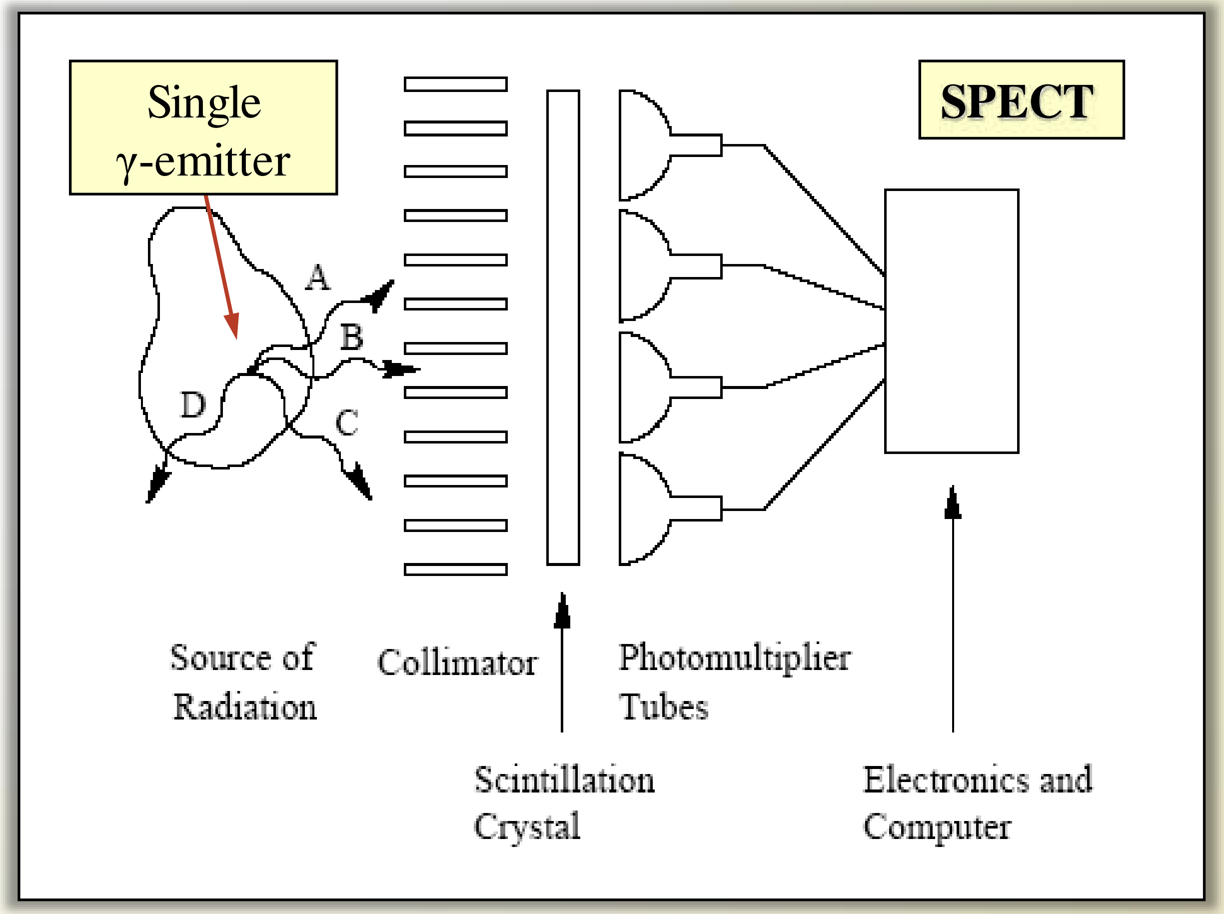
HINPw5
5th Hellenic Institute of Nuclear Physics Workshop
12-13 April 2019, Aristotle University of Thessaloniki

Introduction

- Single Photon Emission Computed Tomography (SPECT) at :

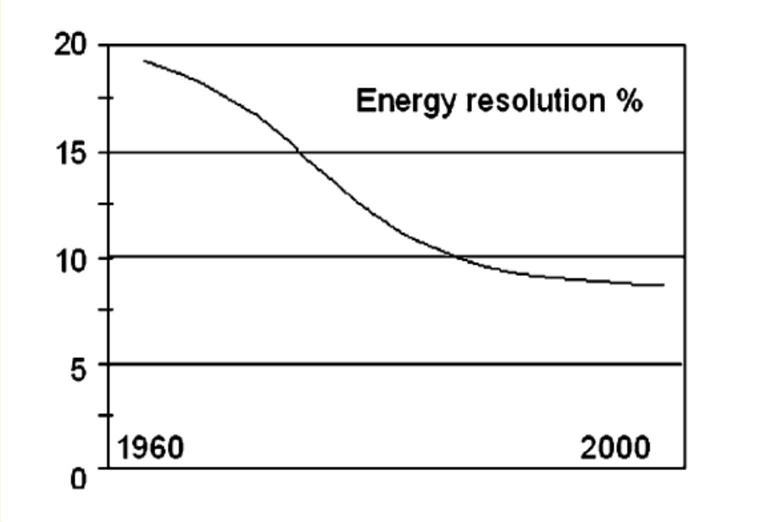
✓ Clinical Level

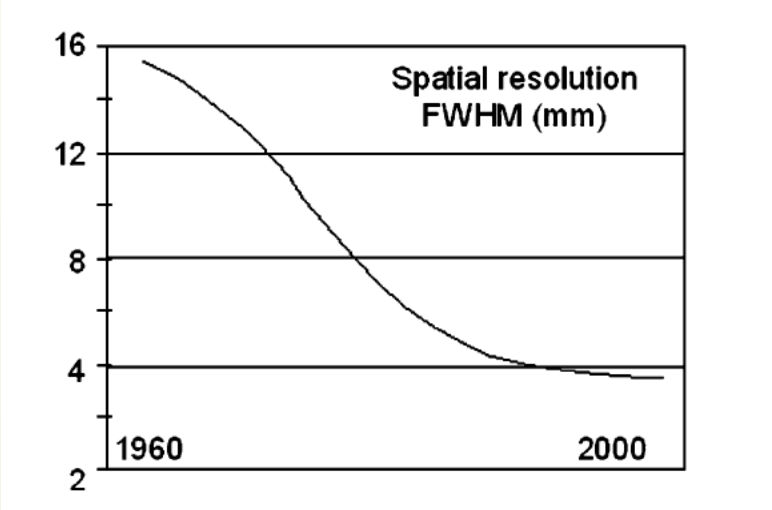
✓ Preclinical Level

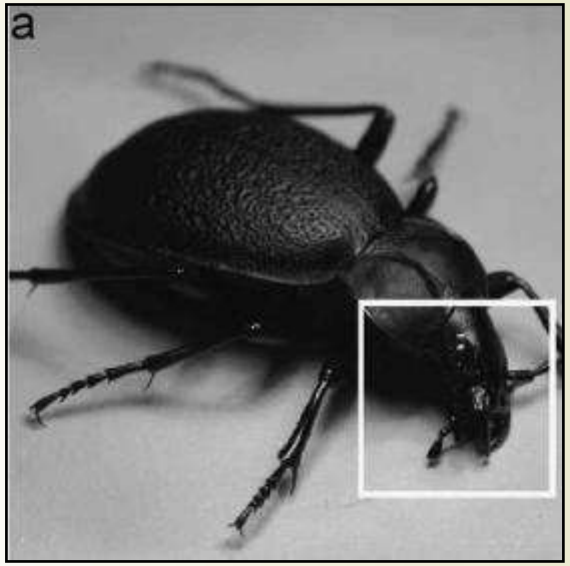


Introduction

Evolution of the Energy and Spatial Resolution for Clinical γ-Camera Systems







Outline of the Presentation

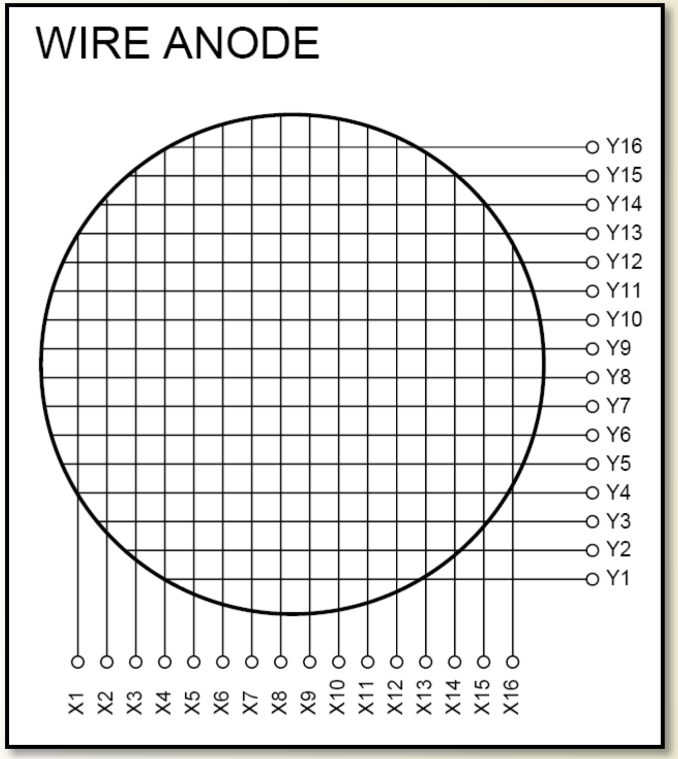
- Position Sensitive Photomultiplier Tube (PSPMT)
  - Operating Principle
  - PSPMT Characterization with LED pulses

- Small Field γ-Camera System
  - Collimator – Scintillation Crystal
  - Planar Projections of a Phantom with ^{99m}Tc Capillaries
  - Correction Algorithm for Spatial Distortions

- γ-Camera System Check
  - Tomographic Reconstruction of a Complicated Geometrical Phantom
  - Small Mouse Imaging

- Conclusions

Position Sensitive Photomultiplier Tube (PSPMT)



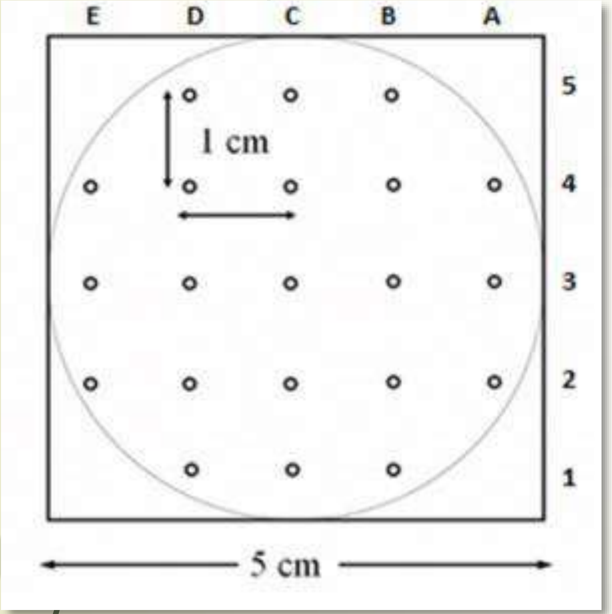
$$X_{pos} = \frac{\sum_{i=1}^{N} X_i S_i}{\sum_{i=1}^{N} S_i} \qquad Y_{pos} = \frac{\sum_{i=1}^{N} Y_i S_i}{\sum_{i=1}^{N} S_i}$$

$$E = \sum_{i=1}^{N} S_i$$

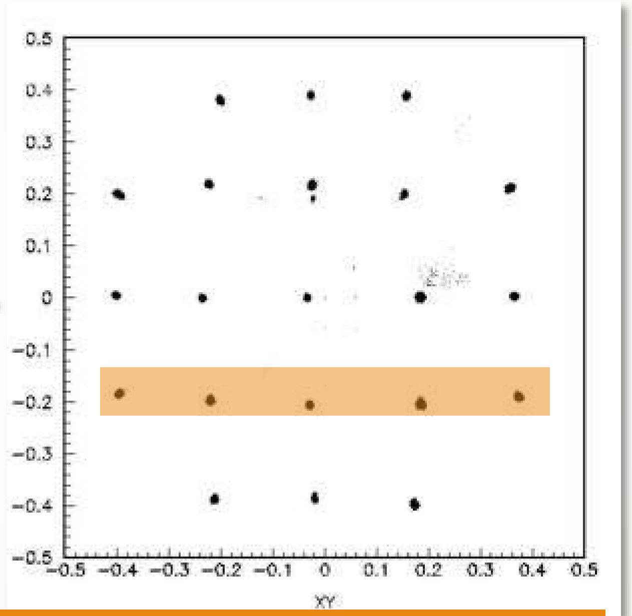
The crossed-wired anodes that give 16 X and 16 Y different signals

Position Sensitive Photomultiplier Tube (PSPMT)

PSPMT characterization with LED pulses



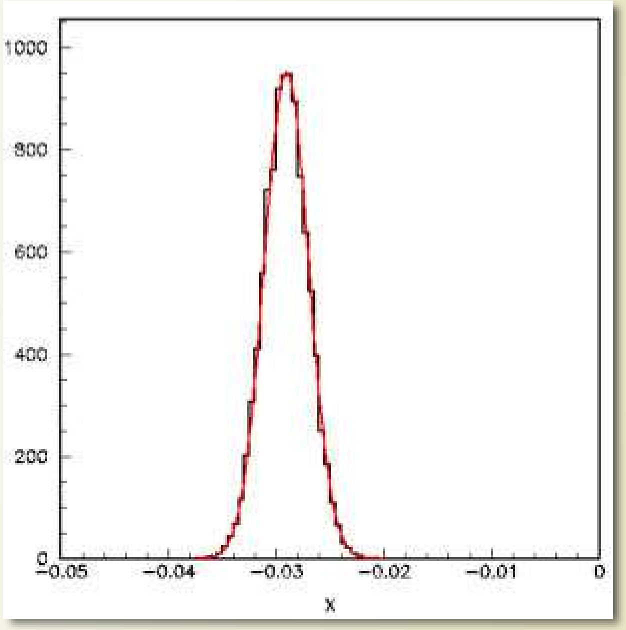
Plexiglass support
for LED fiber



$\langle FWHM \rangle_x = 0.124 \pm 0.009$mm

&

$\langle FWHM \rangle_y = 0.123 \pm 0.051$mm



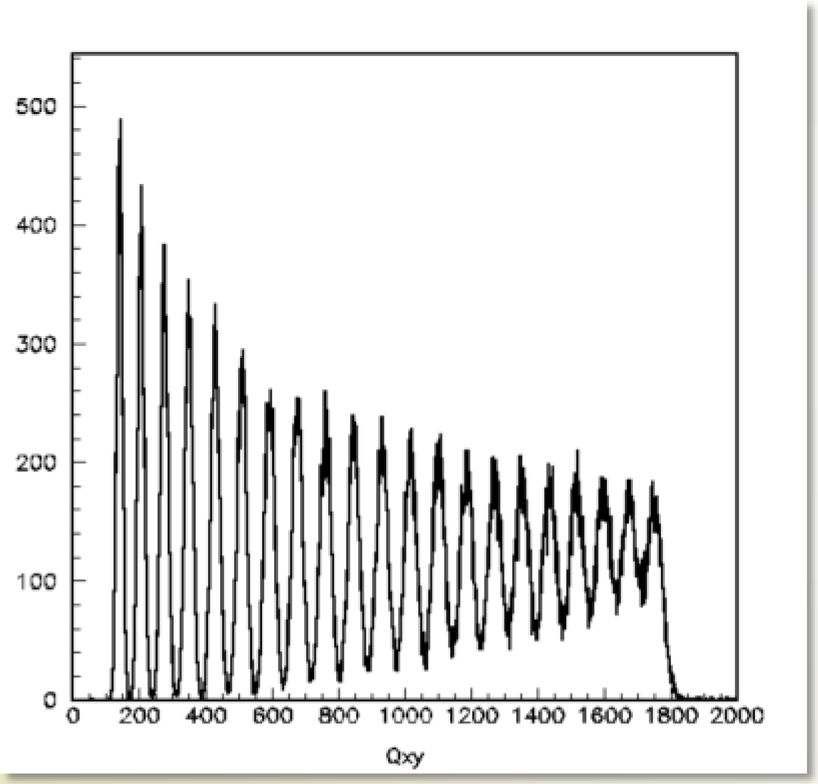
X projection of the slice

D. Zarketan, MSc Thesis (2019), University of Athens

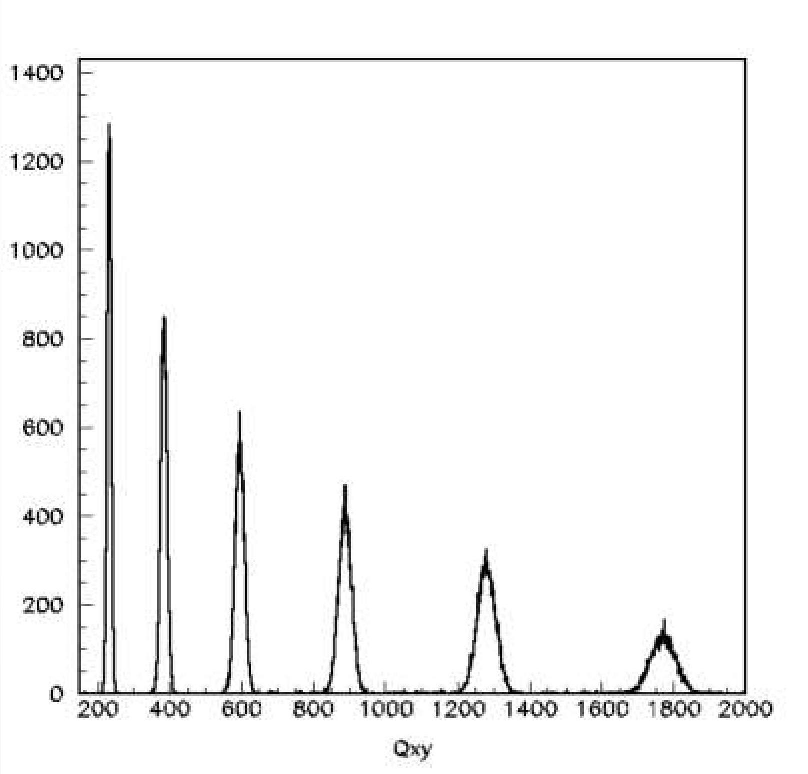
Position Sensitive Photomultiplier Tube (PSPMT)

PSPMT characterization with LED pulses

Q(T)



Q(H.V.)

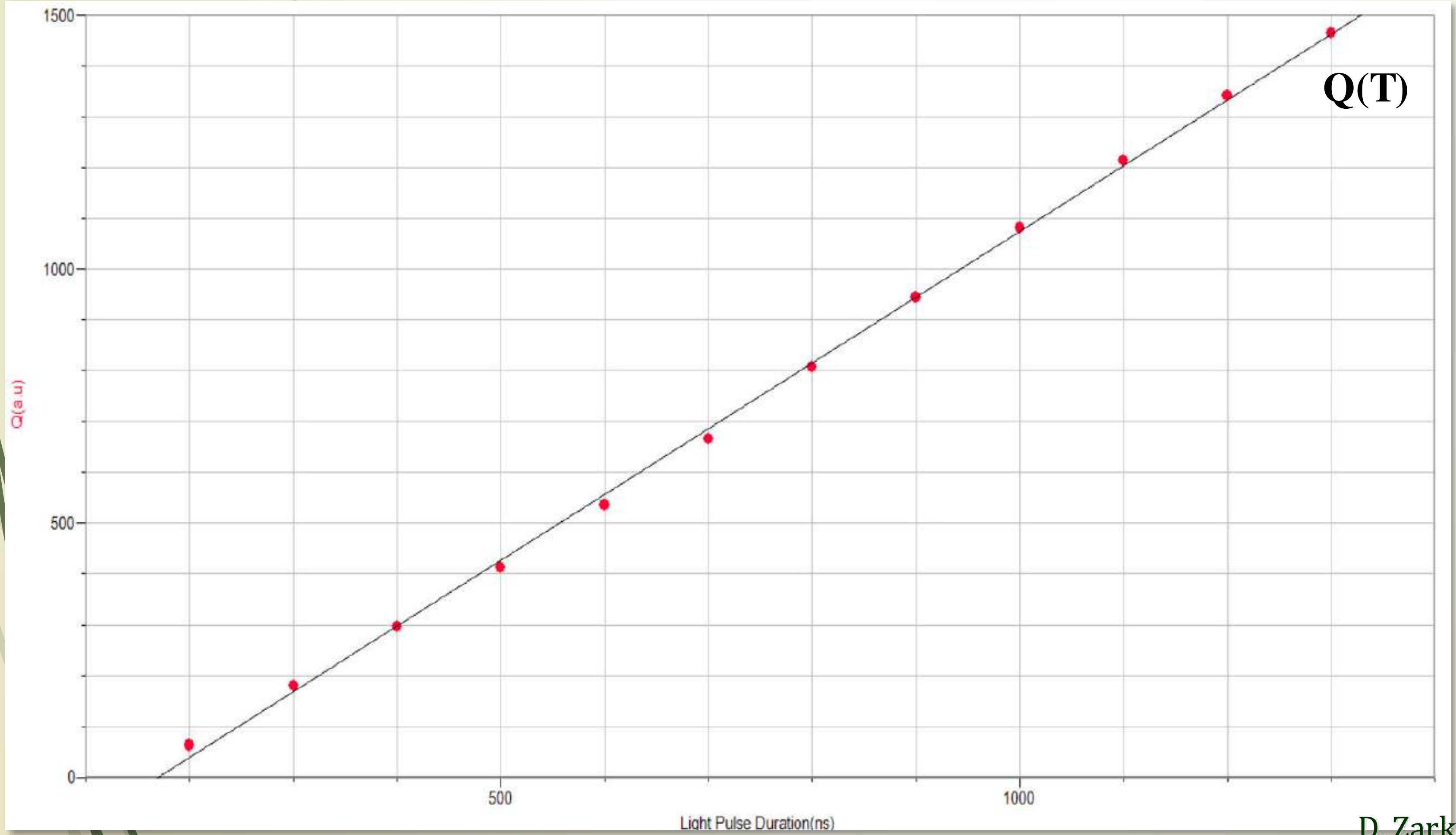


Accumulated anodic charge for applied Pulse Durations (left) and High Voltages (right)

D. Zarketan, MSc Thesis (2019), University of Athens

Position Sensitive Photomultiplier Tube (PSPMT)

PSPMT characterization with LED pulses



Incident Photons – Charge Linearity

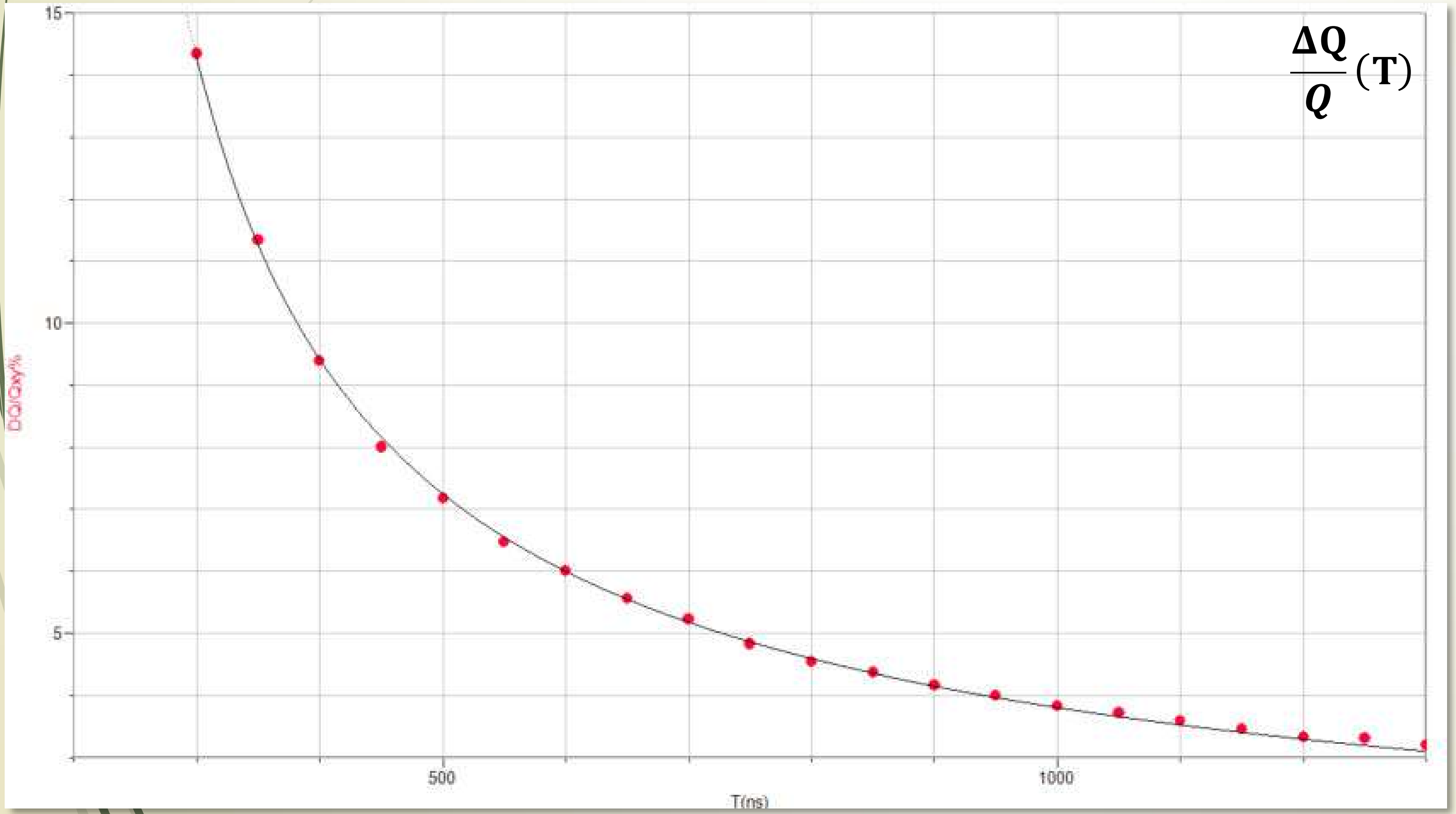
Q=aT+b

a=1.295 ± 0.012 ns^{-1}
b=-220.0 ± 9.982

D. Zarketan, MSc. Thesis (2019), UOA, Athens, Greece

Position Sensitive Photomultiplier Tube (PSPMT)

PSPMT characterization with LED pulses

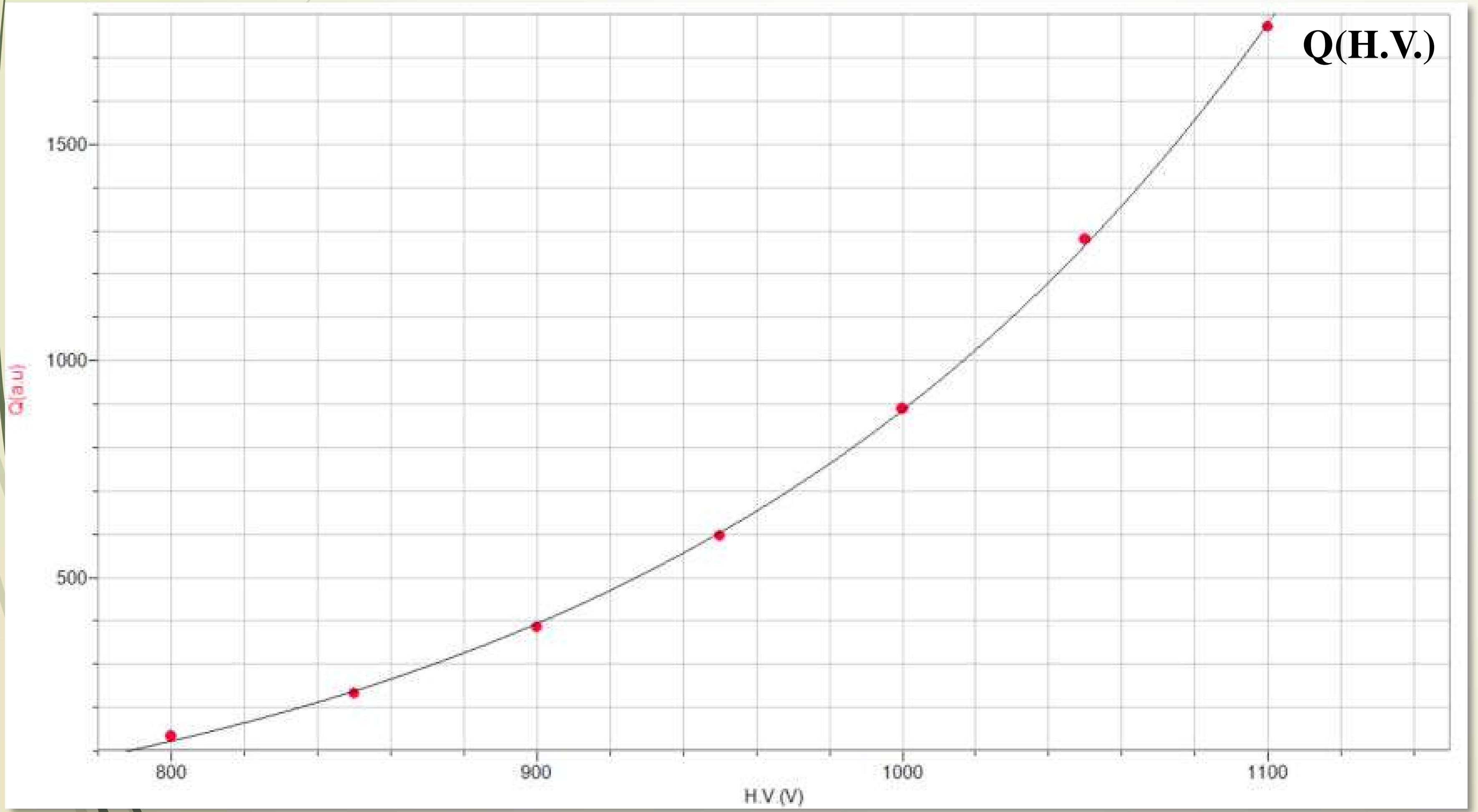


Intrinsic Charge Resolution

$$\frac{\Delta Q}{Q} = \frac{a}{\sqrt{T} + b}$$

Position Sensitive Photomultiplier Tube (PSPMT)

PSPMT characterization with LED pulses



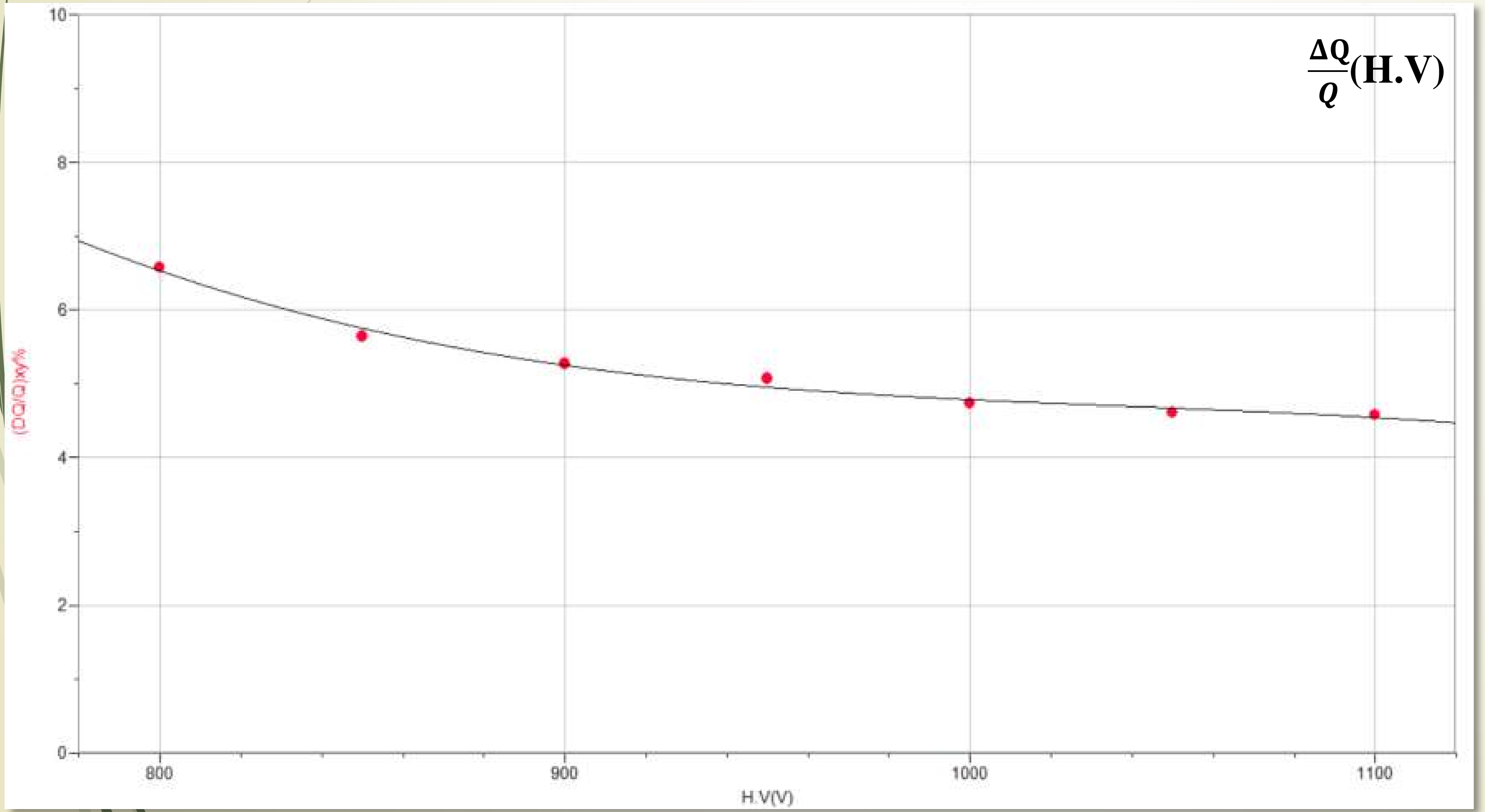
The Charge as an exponential function of the supplied H.V.

Q=a × exp[c(H.V.)]+b

a=2.83 ± 0.7
b= -210.6 ± 31.10
c= $59.6\times10^{-4} \pm 2.0\times10^{-4}$

Position Sensitive Photomultiplier Tube (PSPMT)

PSPMT characterization with LED pulses

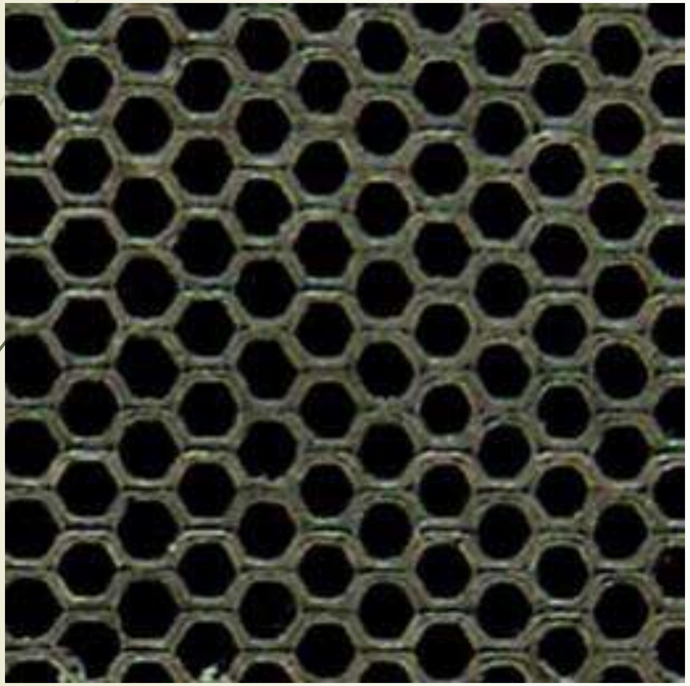


Intrinsic Charge Resolution

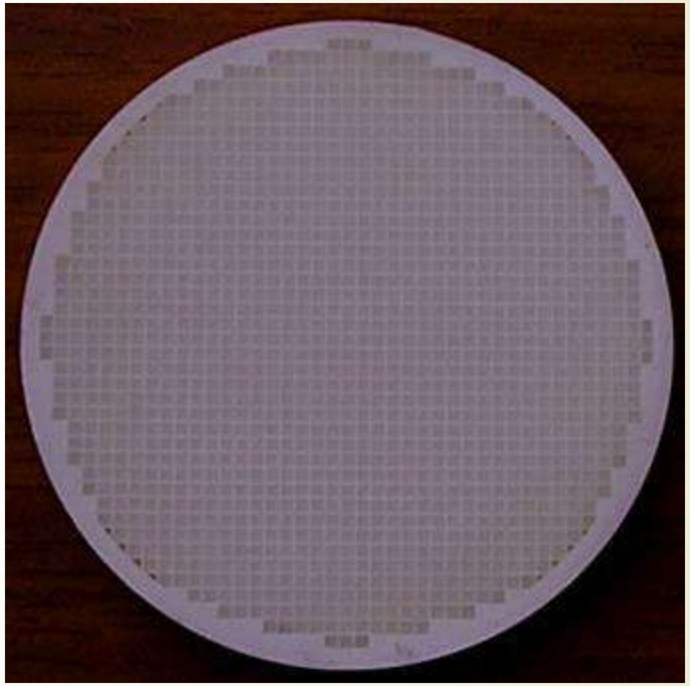
Only 2% optimization for 300V increase (from 800V to 1100V) in the dynamic range of the PSPMT.

Small Field γ-Camera System

Collimator and Scintillation Crystal



The parallel-hole Pb collimator (hexagonal type)

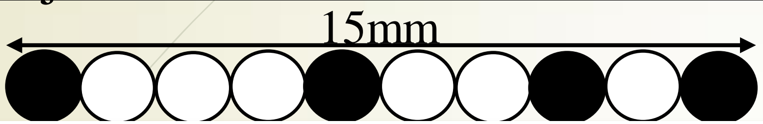


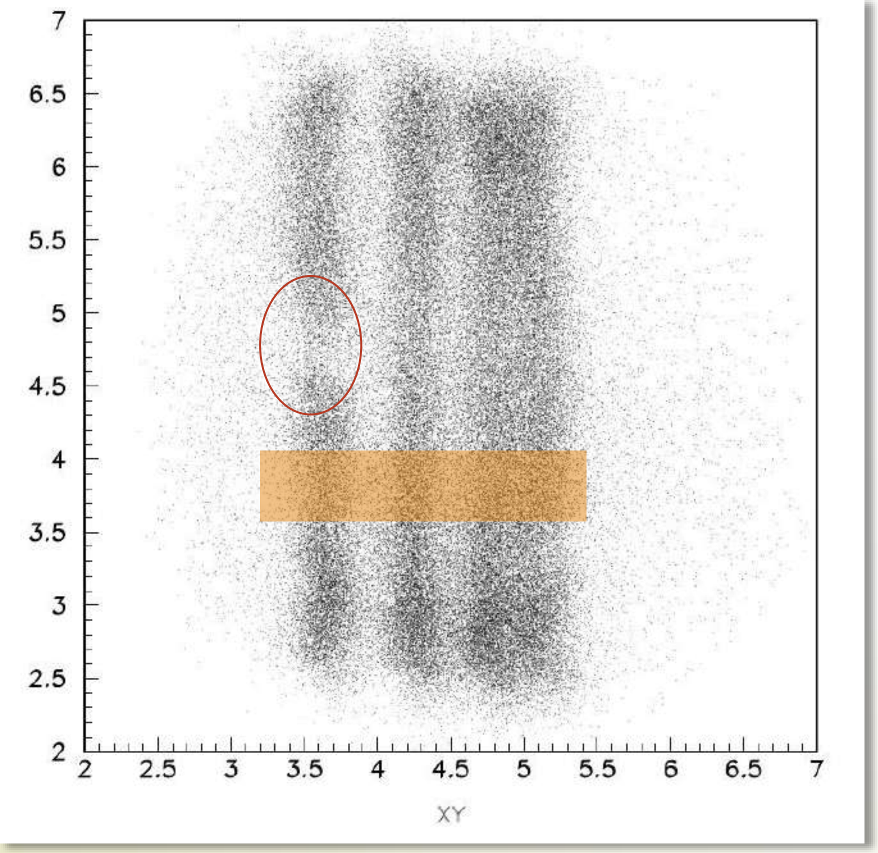
4mm CsI(Tl) pixelated scintillation crystal

Pixel size: 1mm × 1mm
separated by 0.1 mm epoxy

Small Field γ-Camera

Planar Projections of a Phantom with ^{99m}Tc Capillaries

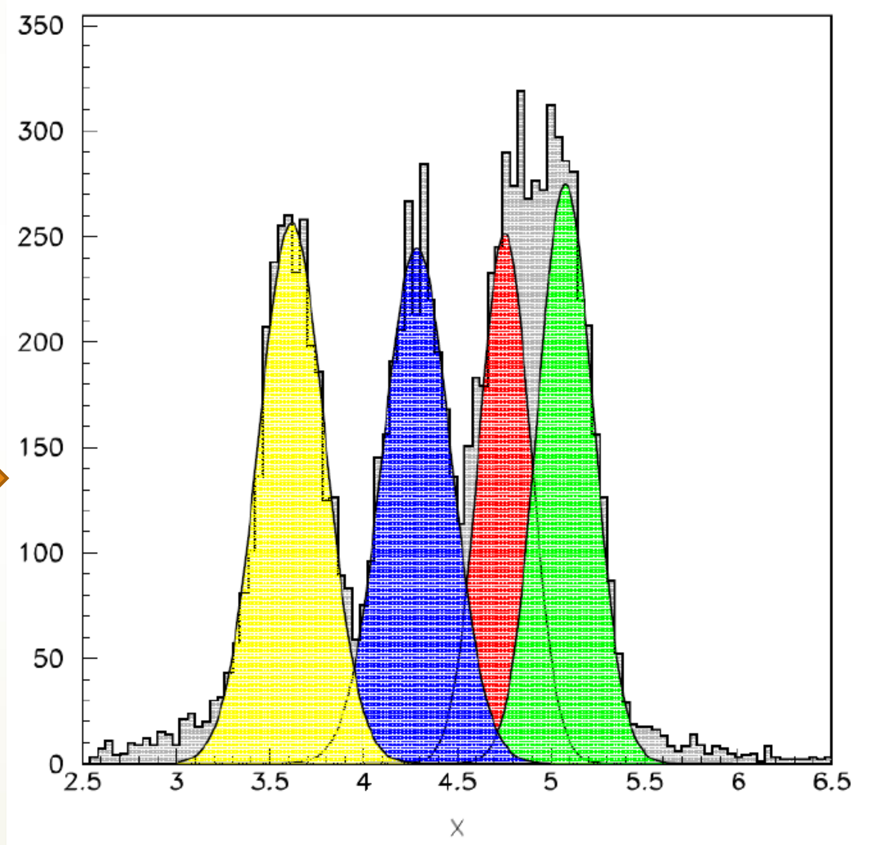




Phantom vertically orientated

$\langle\sigma_X\rangle = (1.49 \pm 0.08)$ mm

$\langle\sigma_Y\rangle = (1.58 \pm 0.18)$ mm



X-Projection of a slice

D. Zarketan, MSc Thesis (2019), University of Athens

Small Field γ-Camera

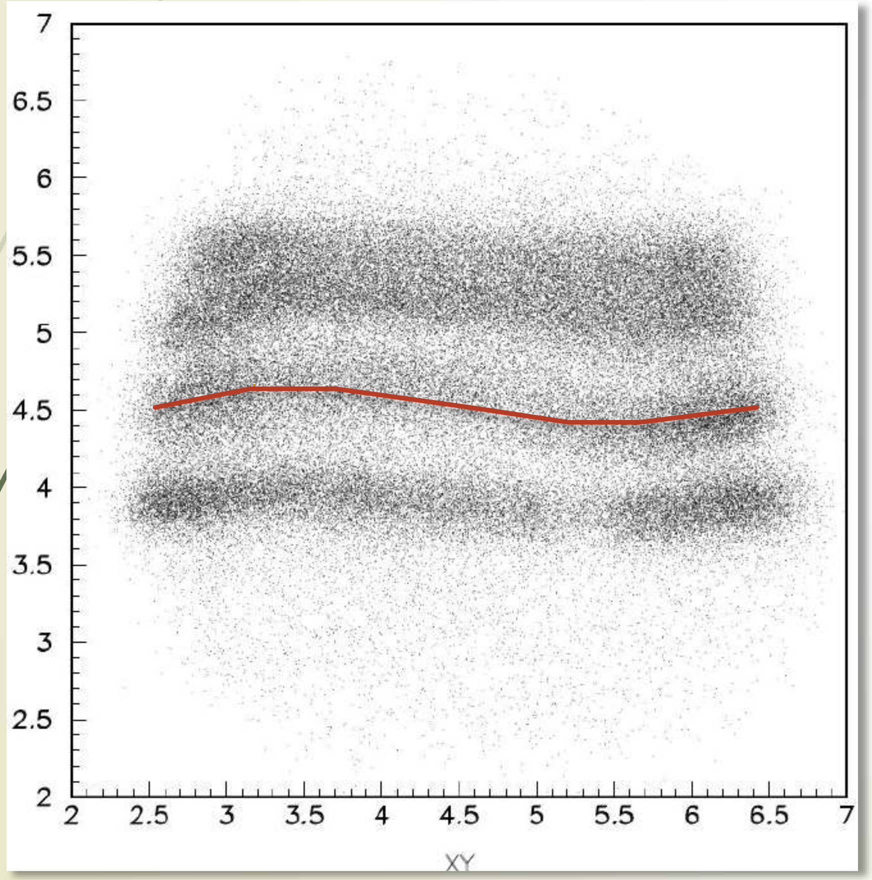
<u>Correction Algorithm for Spatial Distortions</u>

Vertical Correction:

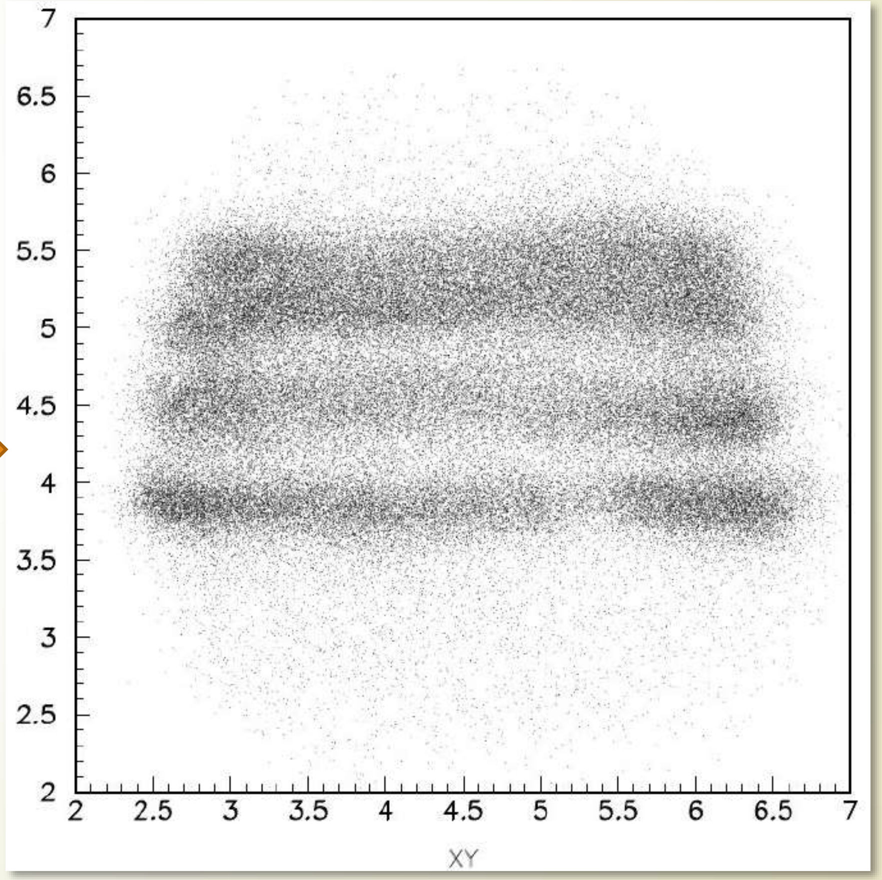
$$\Delta X_i = \frac{Y_i - Y_L}{Y_H - Y_L} * (\Delta X_H - \Delta X_L) + \Delta X_L$$

Horizontal Correction:

$$\Delta Y_i = \frac{X_i - X_L}{X_H - X_L} * (\Delta Y_H - \Delta Y_L) + \Delta Y_L$$



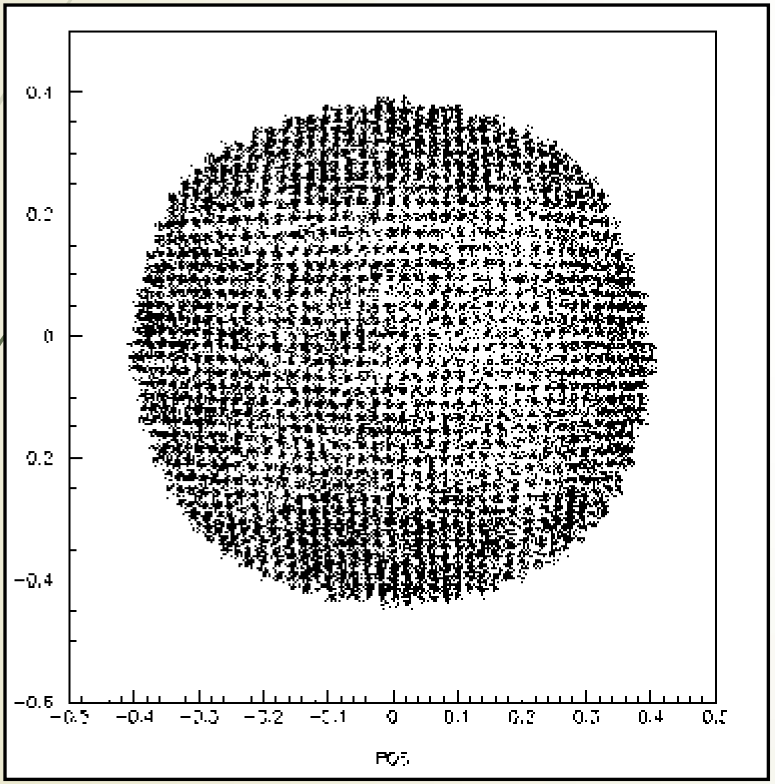
1D Algorithm Correction



D. Zarketan, MSc Thesis (2019), University of Athens

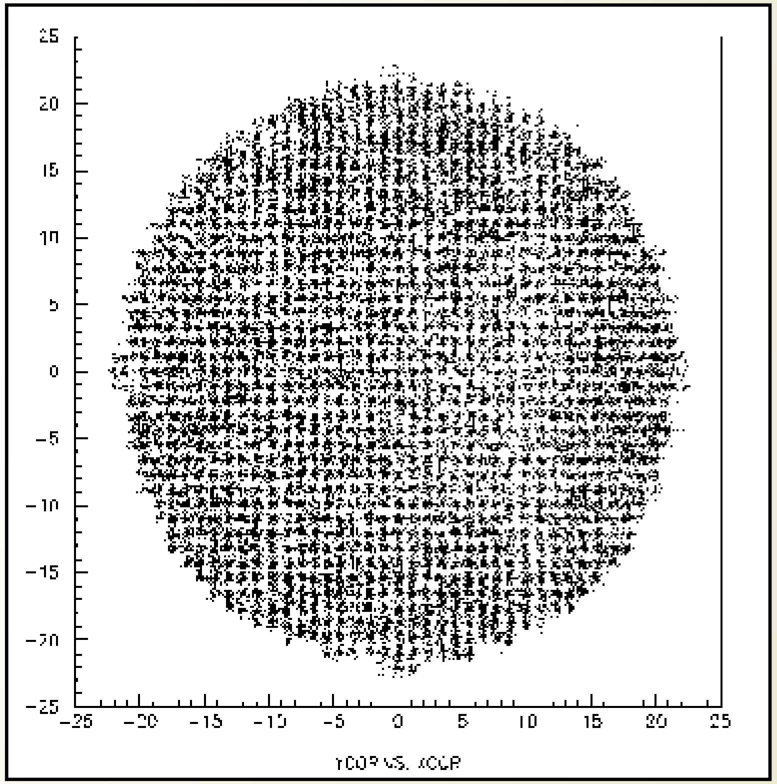
Small Field γ-Camera

<u>Correction Algorithm for Spatial Distortions</u>



Uncorrected Image

2D
Algorithm
Correction

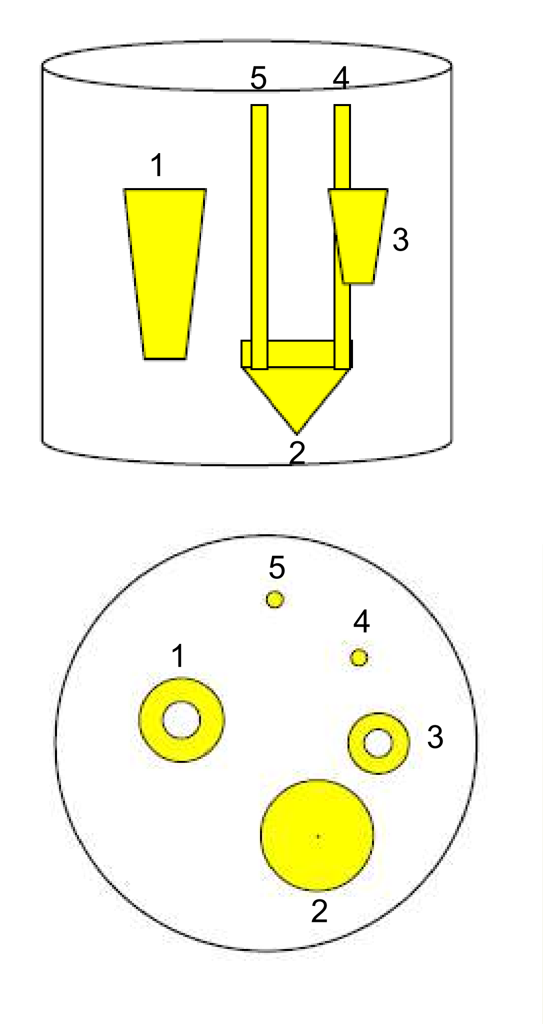


Corrected Image

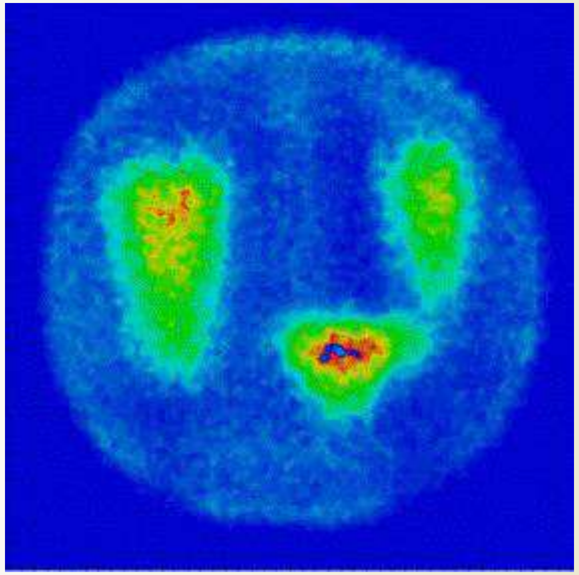
D. Thanasas *et al.*, IEEE NSS-MIC (2008), 3711-3714

γ-Camera System Check

Tomographic Reconstruction of a complicated geometrical phantom



Nr	V (cm^3)	A/V (mCi/cm^3)	A (mCi)
1	0.538	0.25	0.134
2	0.417	0.25	0.104
3	0.180	0.25	0.045
4 - 5	0.073	0.25	0.018

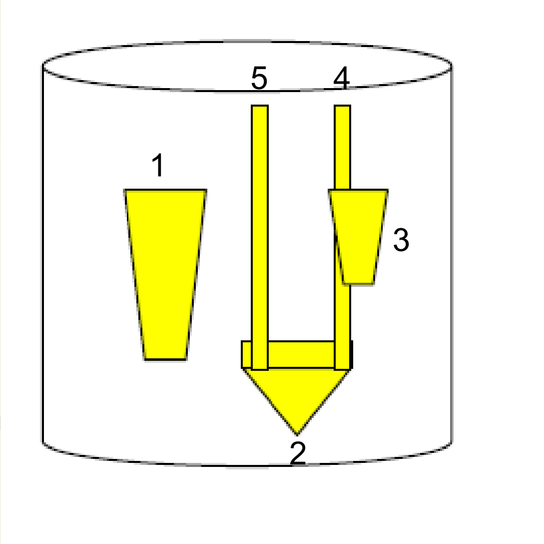


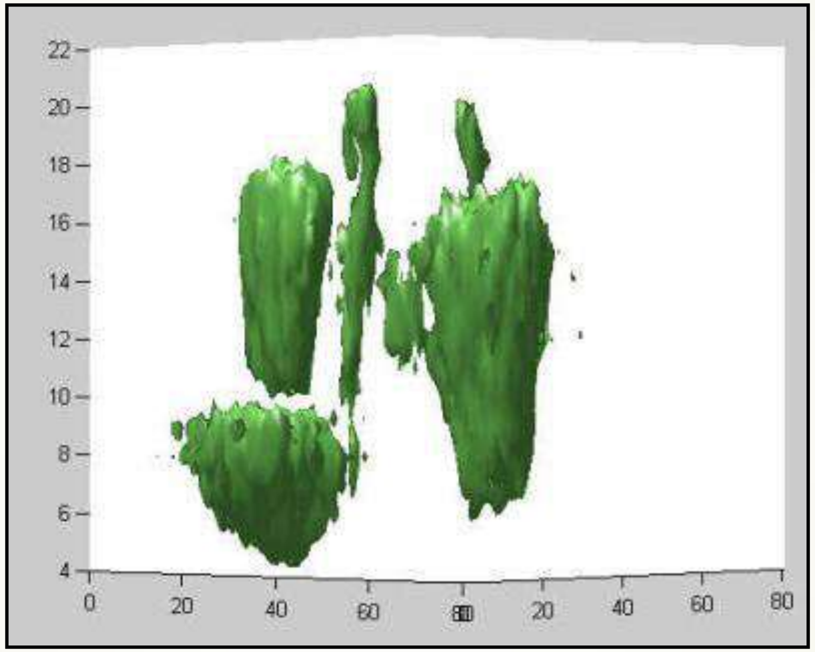
Gel-Phantom
with ^{99m}Tc volumes

24 Projections
15^0 step (0^0... 360^0)

γ-Camera System Check

Tomographic Reconstruction of a complicated geometrical phantom





3D Reconstruction Using ART

Iso-Surface Plot
(20% contour)

Conclusion

Volumes with V > 0.1 cm^3 at specific activity 0.25mCi/cm^3
are easily detectable.

γ-Camera System Check

Imaging Specific Organs of a Targeted Small Mouse

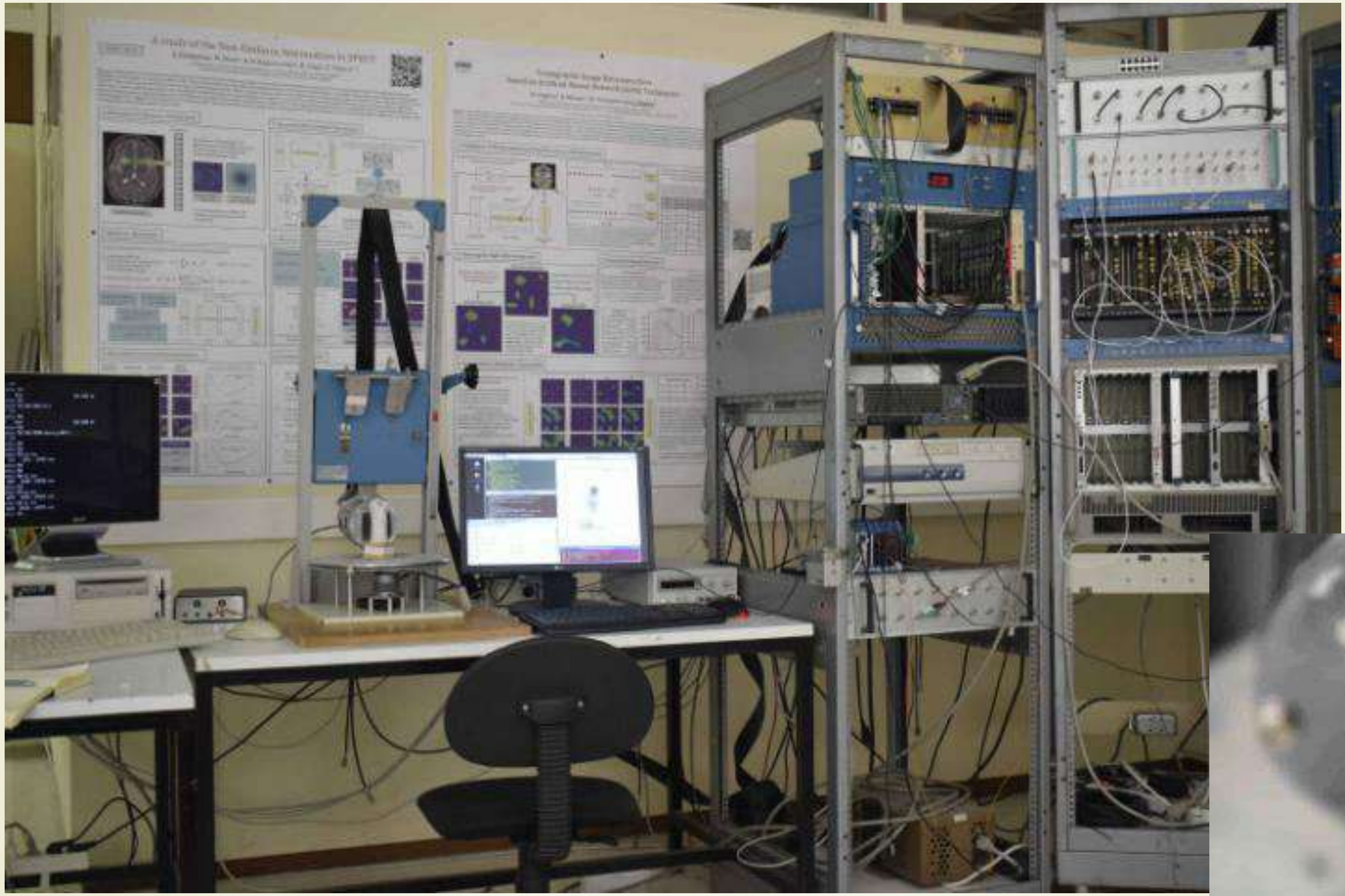
Mice were injected with…

- ^{99m}Tc-DTPA, used in radioisotope renography to evaluate function kidneys
- ^{99m}Tc-MAA (Macro-Aggregates of Albumin), used in lungs imaging

γ-Camera System Check

Imaging Specific Organs of a Targeted Small Mouse

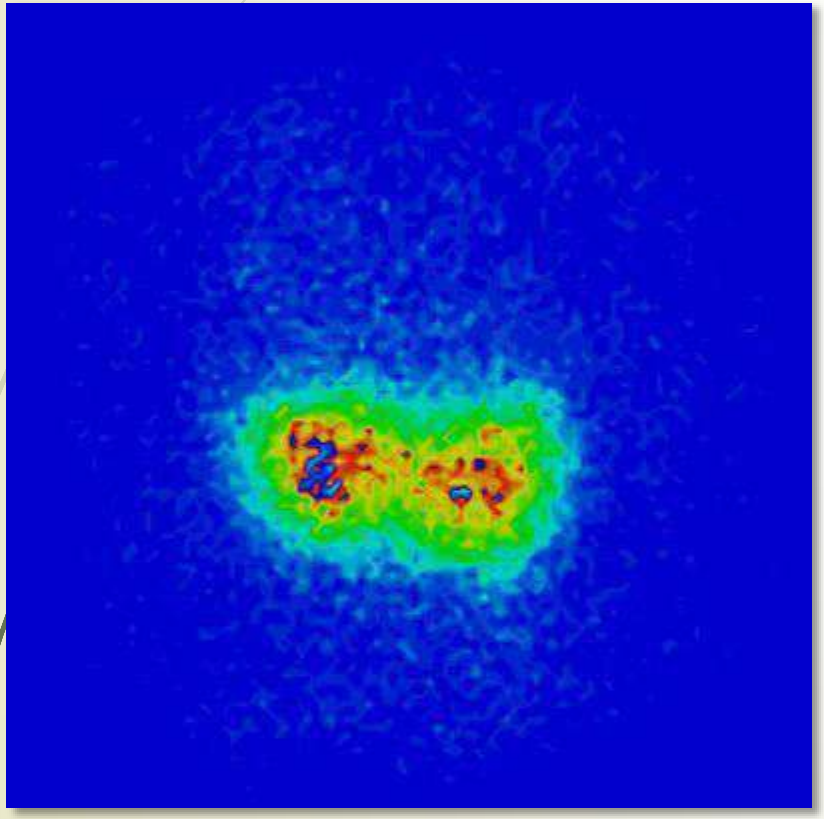
Our SPECT LAB



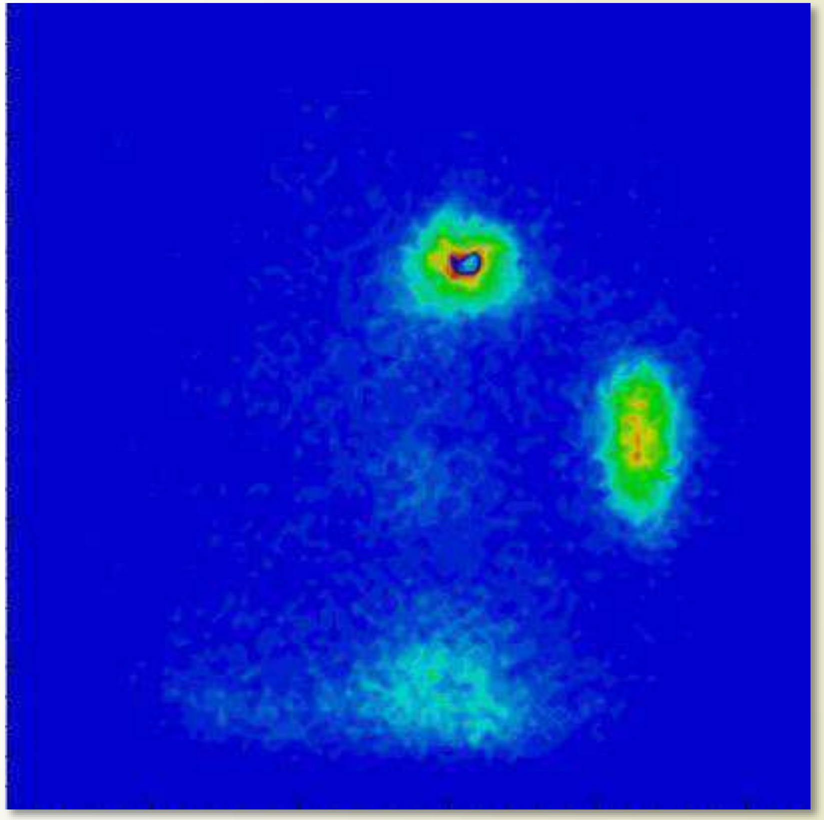
The labelled mouse

γ-Camera System Check

Imaging Specific Organs of a Targeted Small Mouse



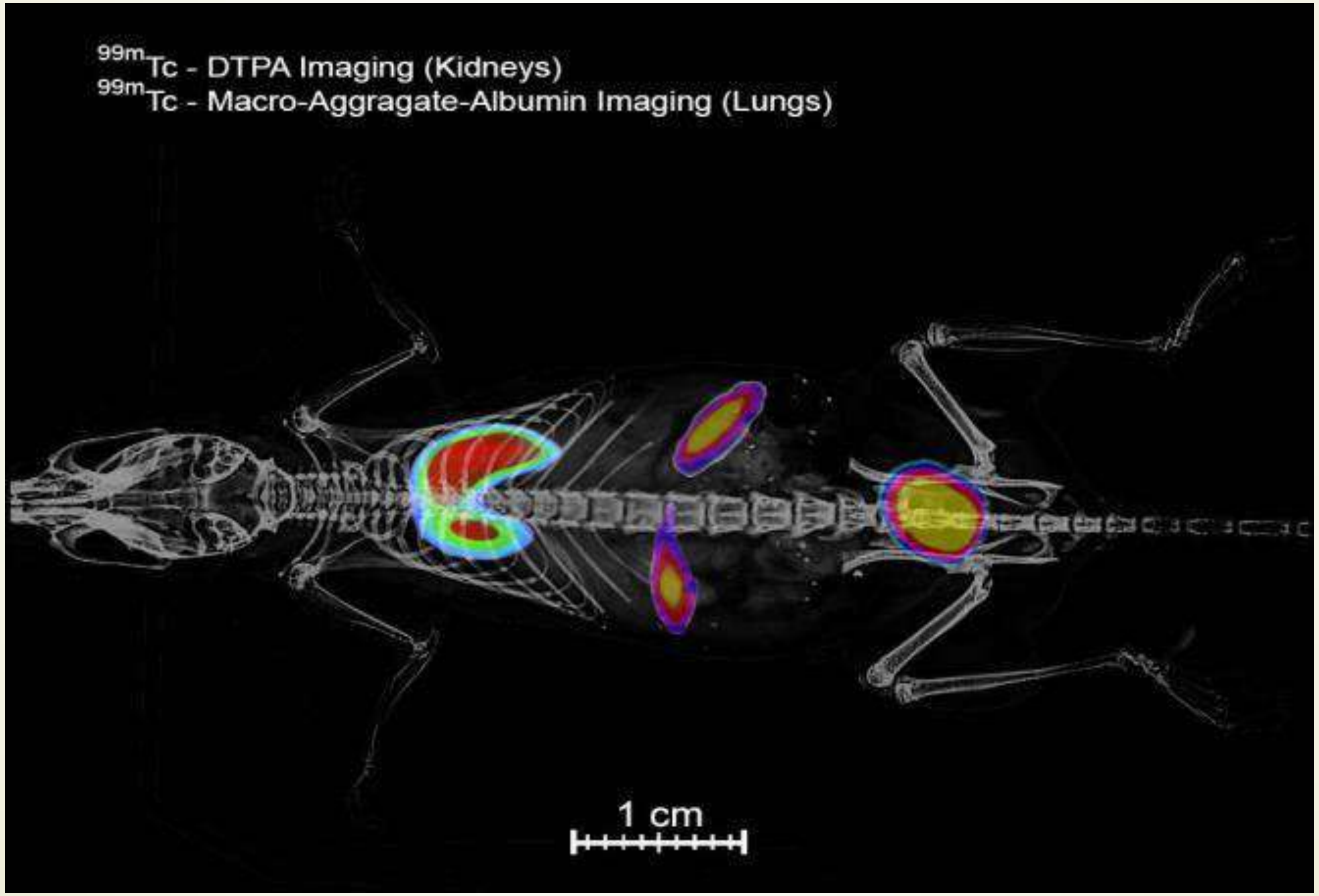
Mouse's lungs imaging with the small field γ-Camera



Mouse's kidneys imaging with the small field γ-Camera

γ-Camera System Check

Imaging Specific Organs of a Targeted Small Mouse



SPECT-CT fusion for the mouse's spots of interest

L. Koutsantonis, PhD Thesis (2019), The Cyprus Institute, Nicosia, Cyprus

Conclusions

- Small field γ-Camera Systems equipped with modern PSPMTs can reach a spatial resolution better than 2mm at planar imaging.
    - Intrinsic PSPMT spatial resolution <150μm
    - The intrinsic PSPMT spatial and energy resolution depends more on the lightness of the scintillation crystal and less on the PSPMT high voltage.
    - γ-Camera System resolution $<\sigma_X> = (1.49 \pm 0.08)$ mm & $<\sigma_Y> = (1.58 \pm 0.18)$ mm

- Planar projections can be corrected even with an 1D correction algorithm, although for more complicated images a 2D is needed.

- Volumes with $V > 0.1\ cm^3$ at specific activity $0.25 mCi/cm^3$ are easily detectable.

- Further studies need to be done, for even better detectability of labelled targets at clinical level.

THANK YOU…!!!