

Photon detection with position sensitive thick-hole based MPGDs: from VUV to gamma

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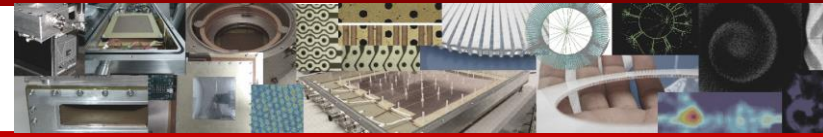
DRIM – Radiation Detection and Medical Imaging Group



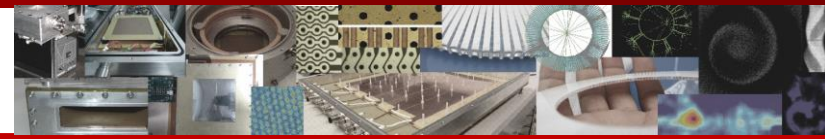
universidade de aveiro



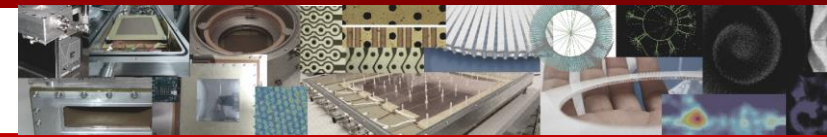
RD51 Academia-Industry Matching Event
Special Workshop on Photon Detection with MPGDs
CERN, 10-11 July 2015



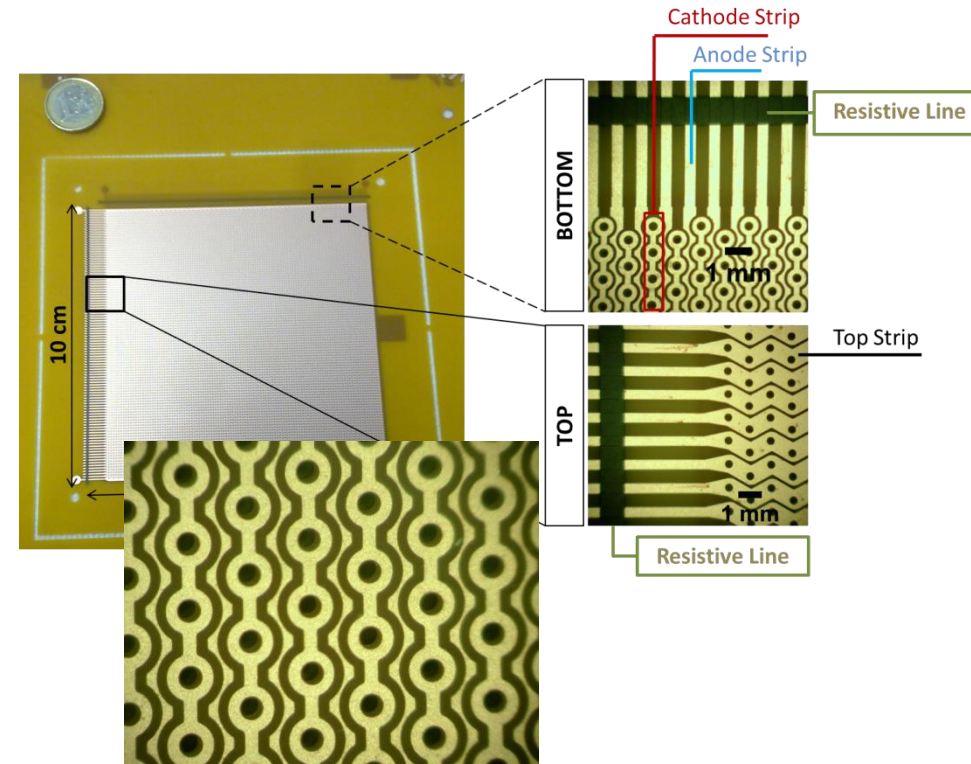
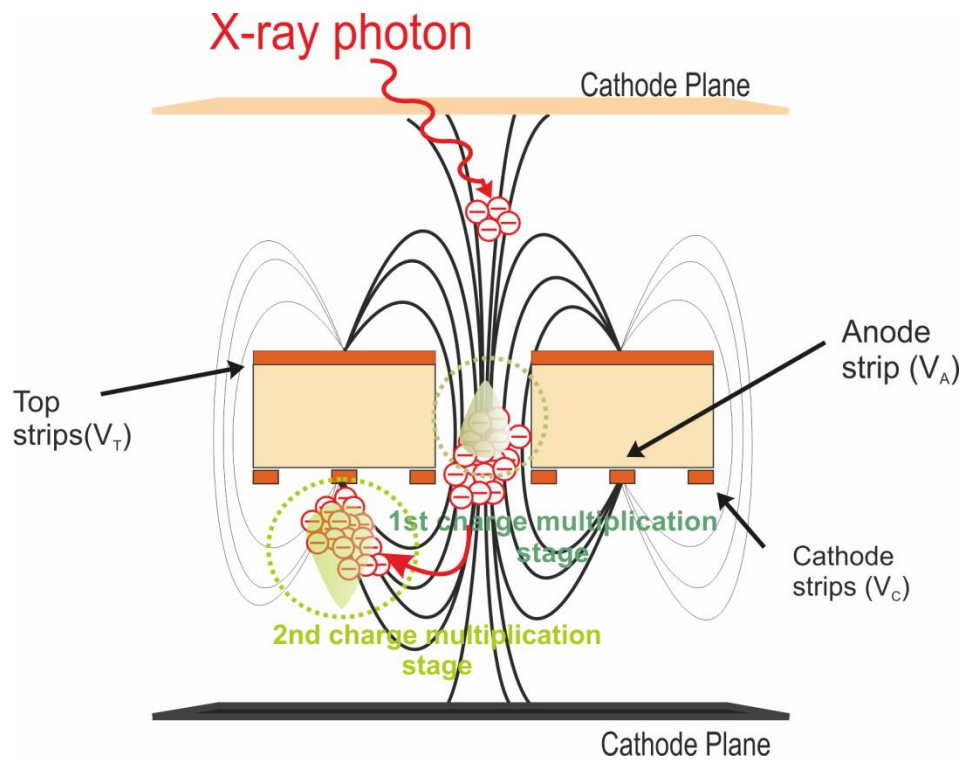
- X-ray detection – some considerations
- X-ray imaging - THCOBRA
 - X-ray panels
 - CT
 - EDXRF imaging
- VUV Gaseous photomultipliers - THGEM+THCOBRA
- Gamma detection – THGEM+ THCOBRA



- X-ray detection with THCOBRA
 - Detector gain
 - Detection efficiency
 - Energy resolution
 - Position resolution limits



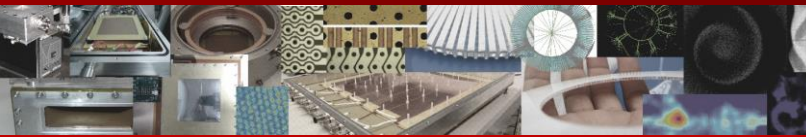
- **Operation principle**



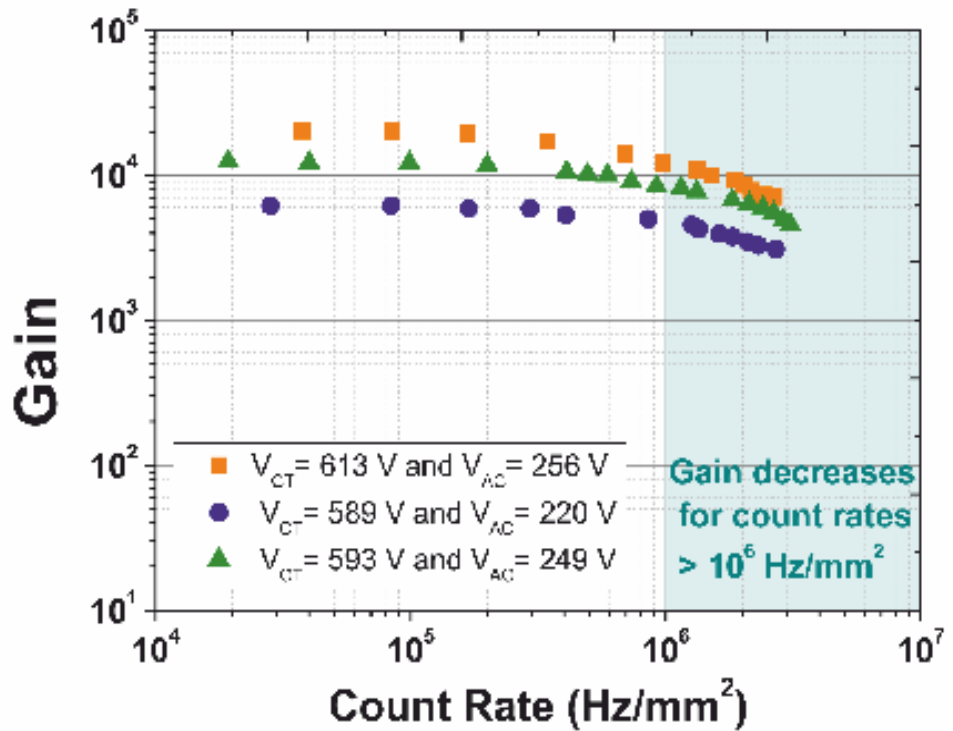
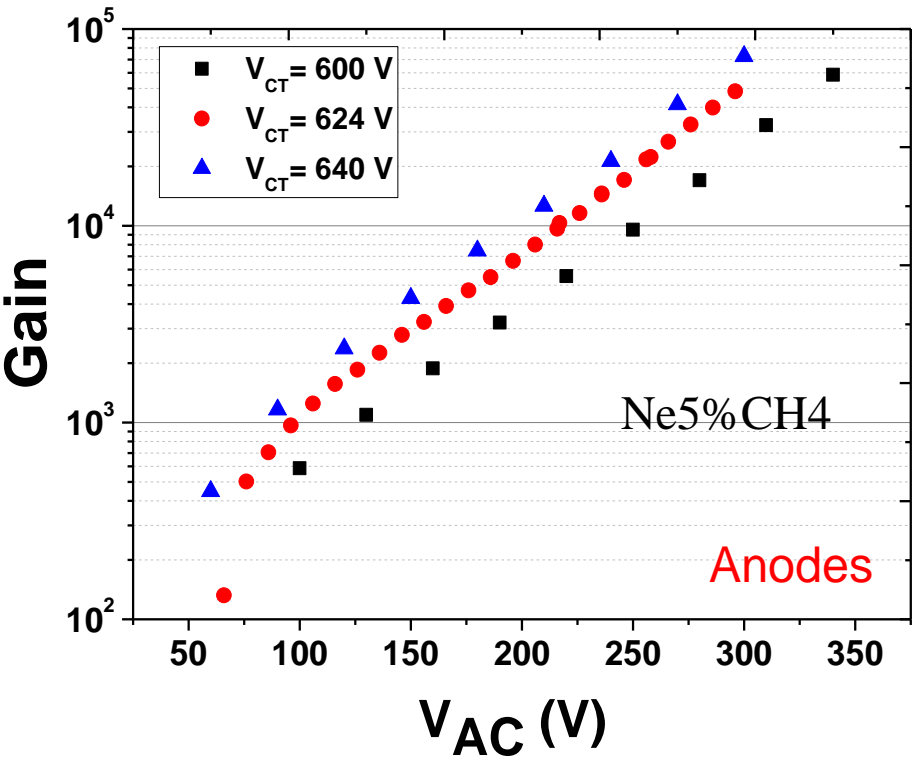
- based on THGEM technology
- large areas
- good resistance to discharges
- 2 multiplication stages – high gain

F. Amaro et al., JINST 5(2010); JFCA Veloso et al. NIM A639(2011)

Gain

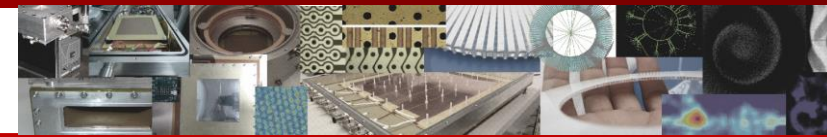


- Gain is important for:
- low energy detection
 - signal to noise ratio → energy and position resolution

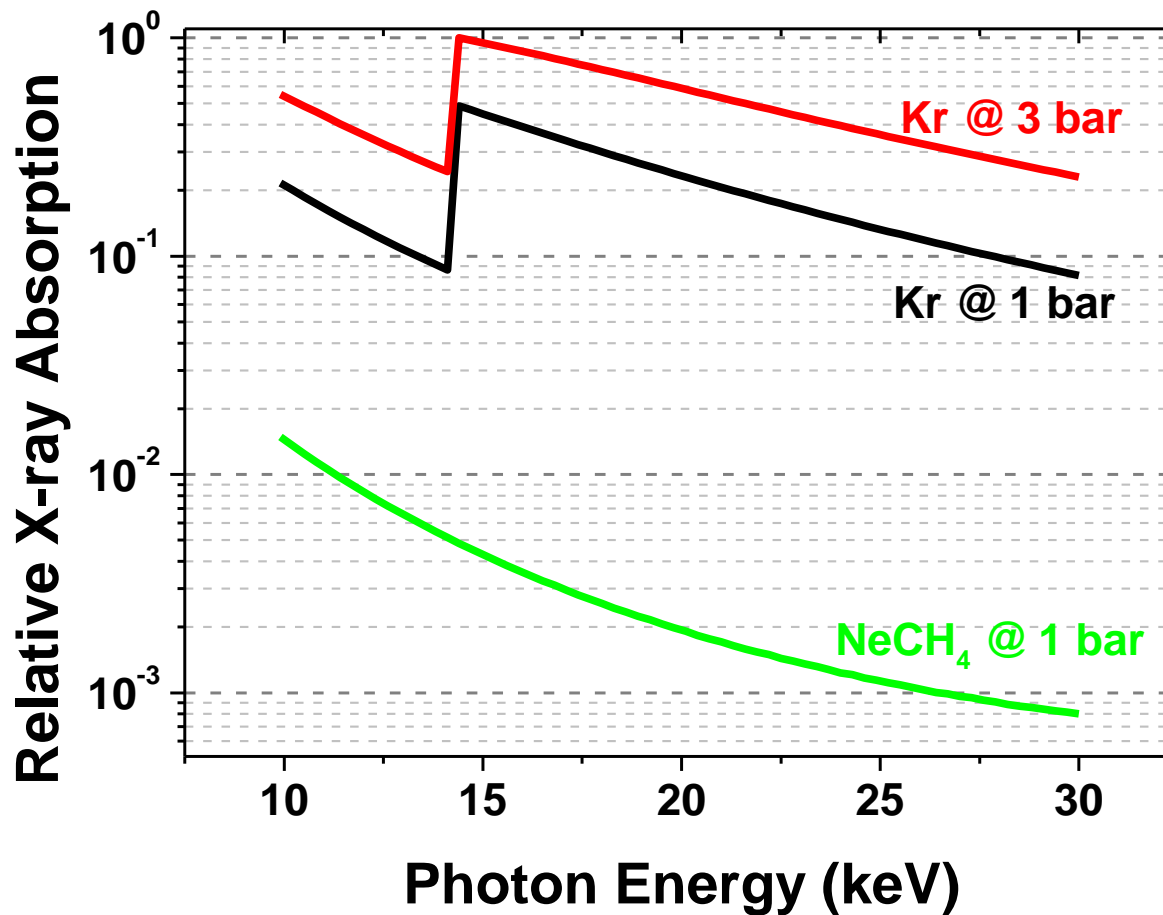


A. Silva et al. JINST 8(2013)P05016

- high gain - $G \sim 10^5$
- count rate(8 keV) $> 10^6$ Hz/mm²



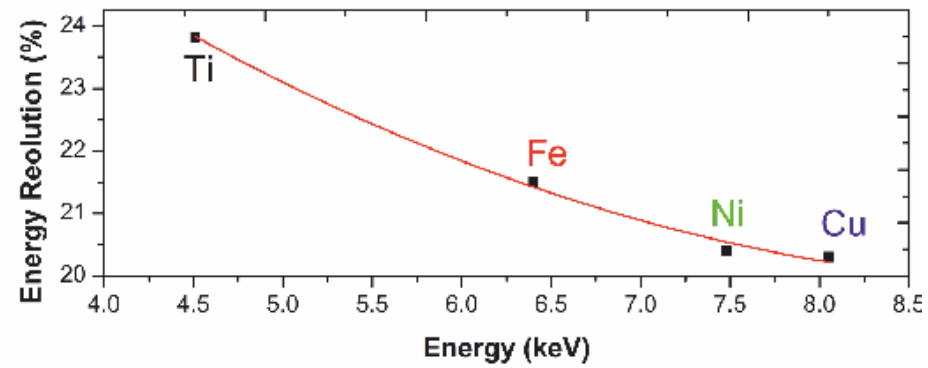
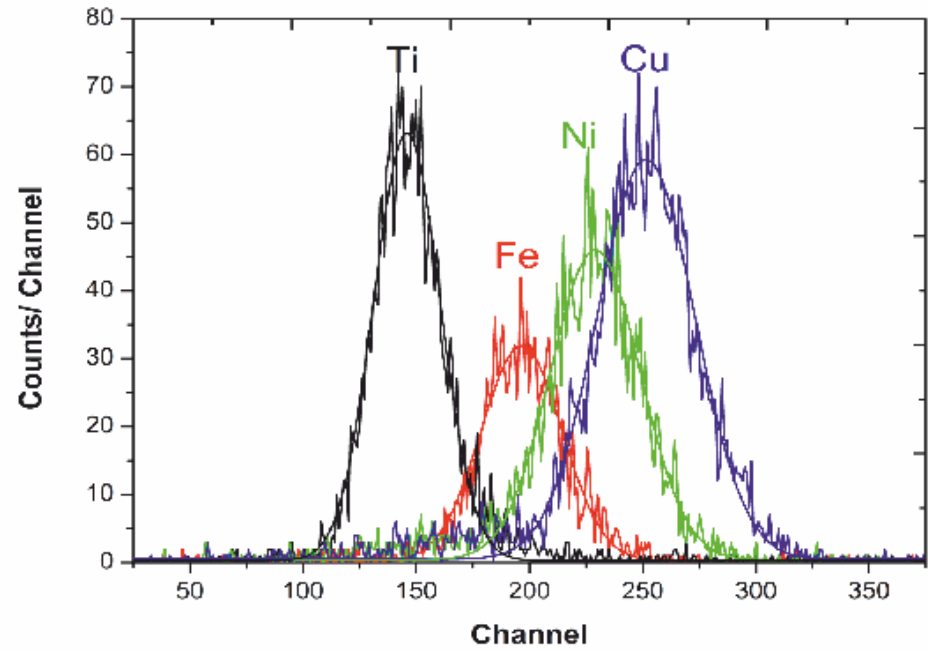
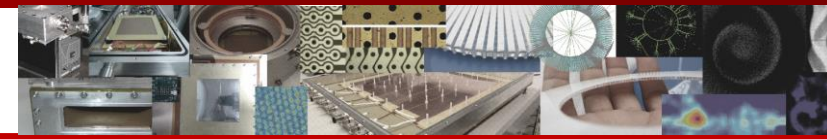
Absorption Efficiency

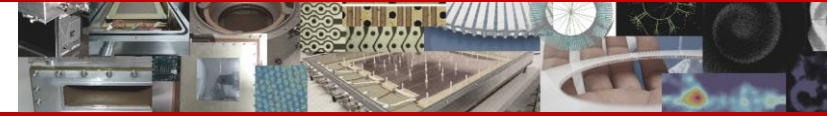


Kr @ 3 bar

- 78% for 17 keV
 - (34% for Kr @ 1 bar)
 - (0.3% for NeCH₄)

Energy resolution





IMAGING CAPABILITY AND POSITION RESOLUTION

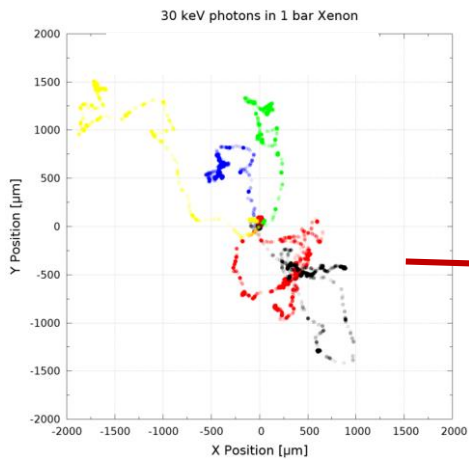
Depends on...

Signal-to-Noise Ratio – related with the type of detector

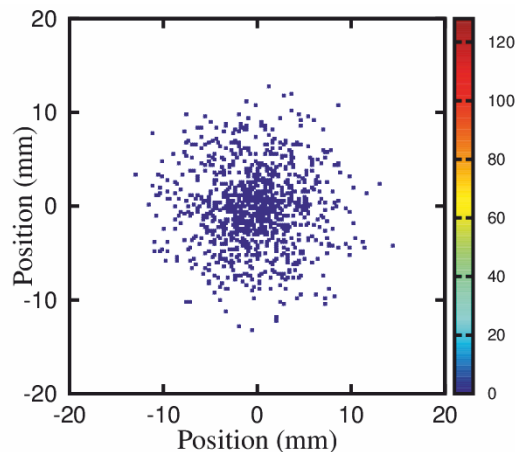
Photoelectron range

SIMULATIONS -Degrad

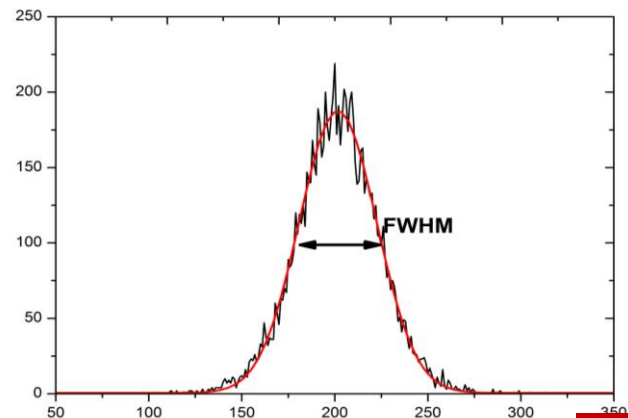
primary cluster spatial distribution
in gas mixtures for X-rays



Average
Position

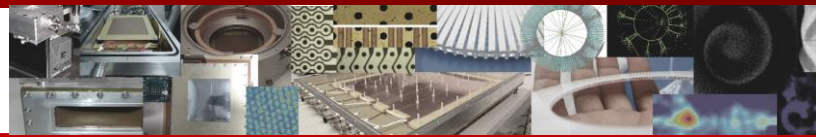


1D
Projection

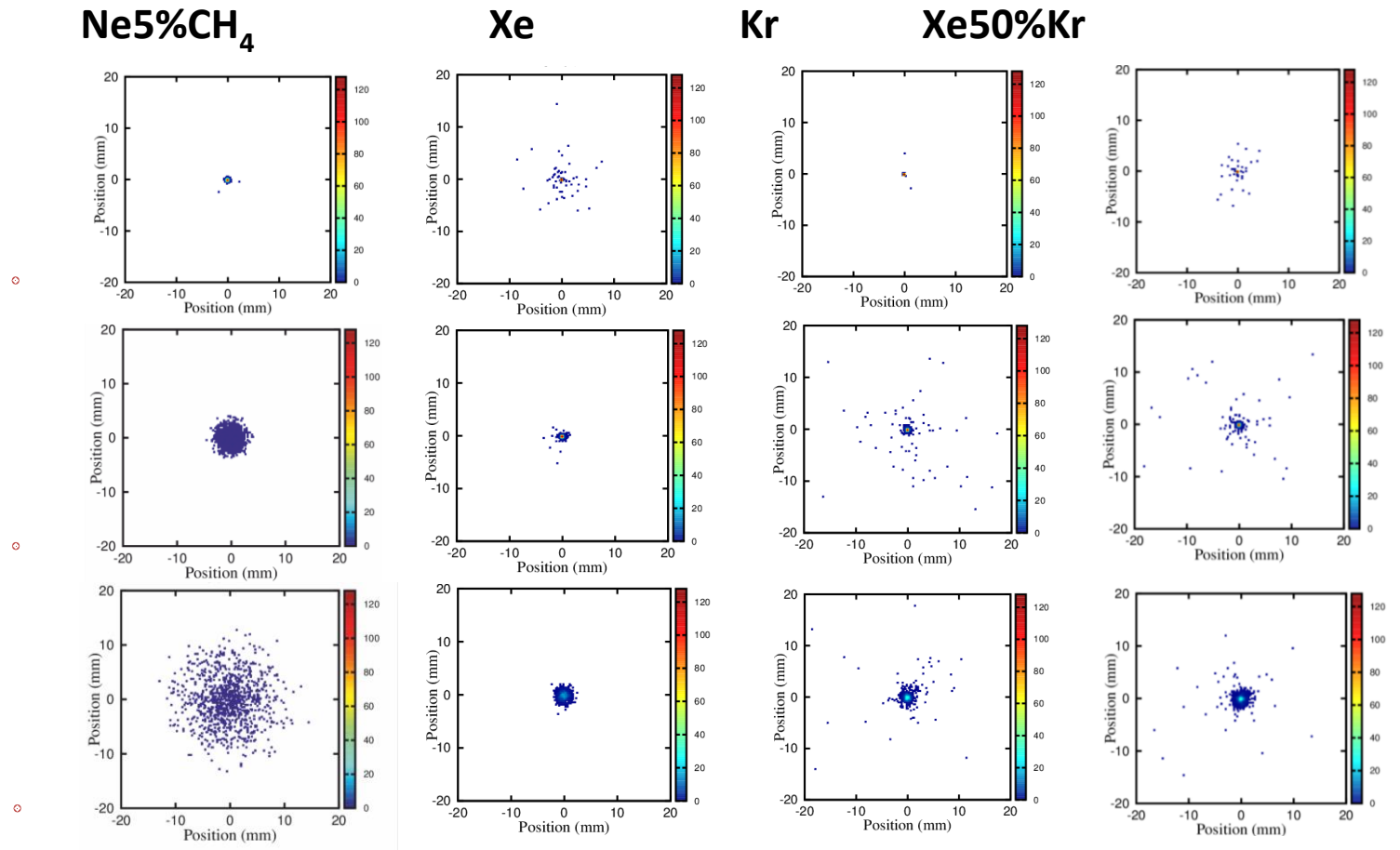
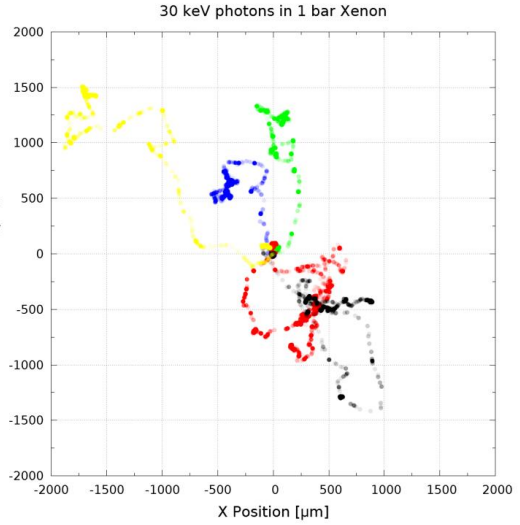


Gaussian distribution FWHM
uncertainty in the position of interaction.

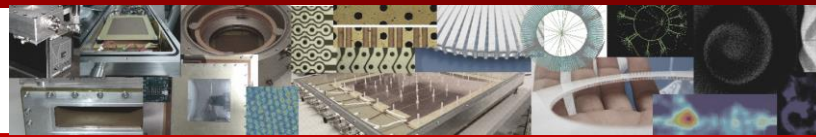
Position resolution limits in GD – x-rays



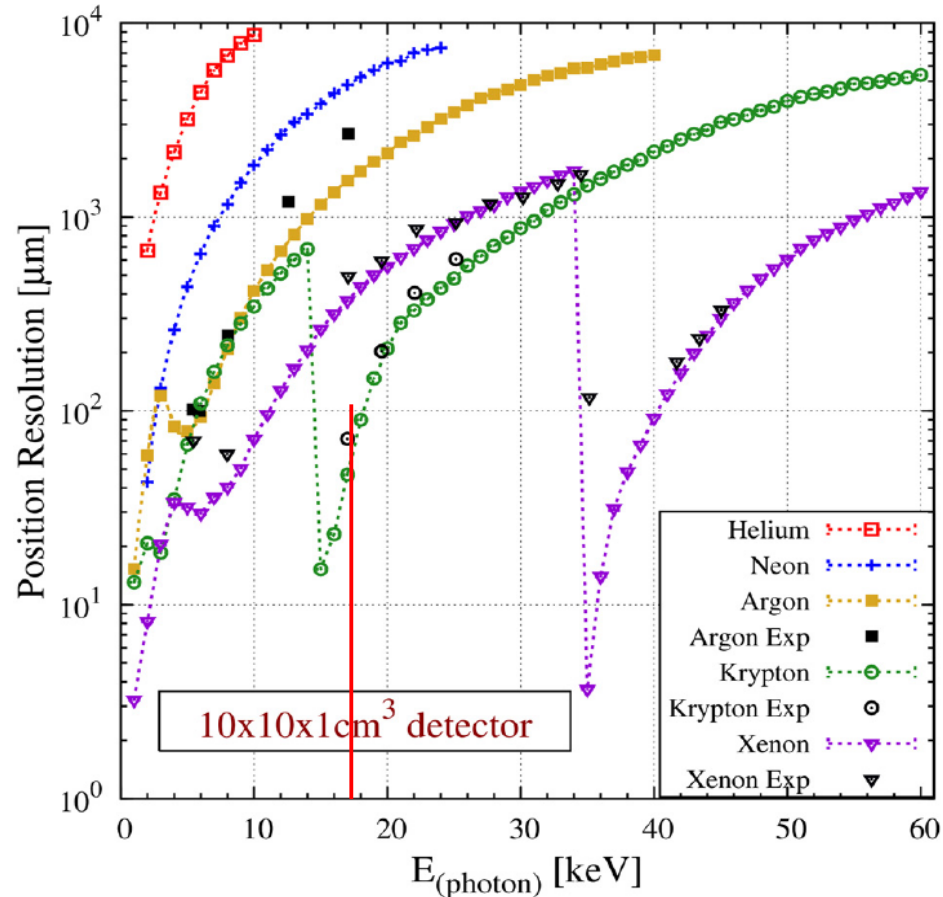
- Degrad
- Cluster distribution* as a function of X-ray energy and filling gas



Position resolution limits in GD – x-rays



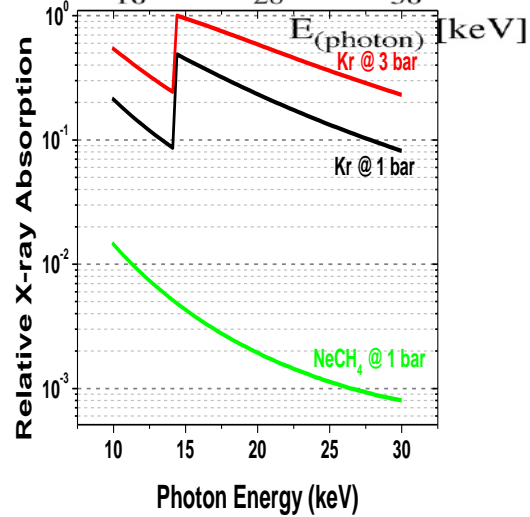
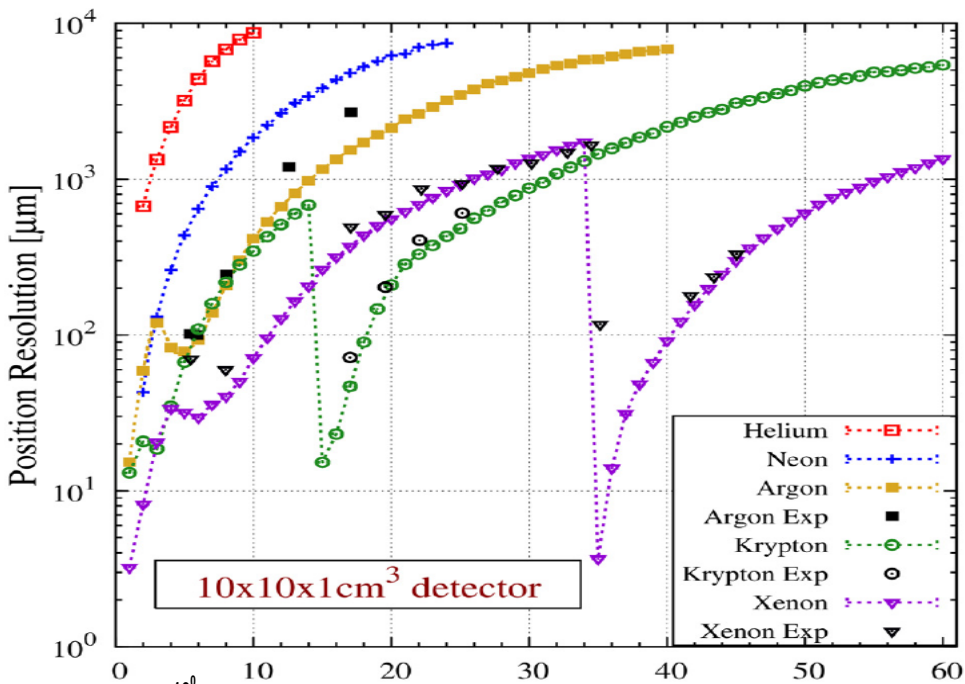
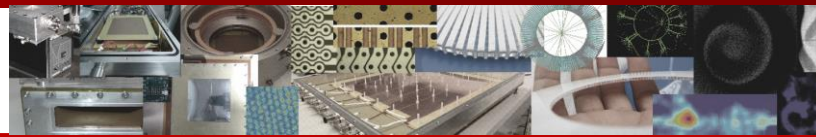
Position resolution limits for X-rays in He, Ne, Ar, Kr and Xe; 1atm
-Detector: $1 \times 10 \times 10 \text{ cm}^3$ – it can be computed for any detector configuration



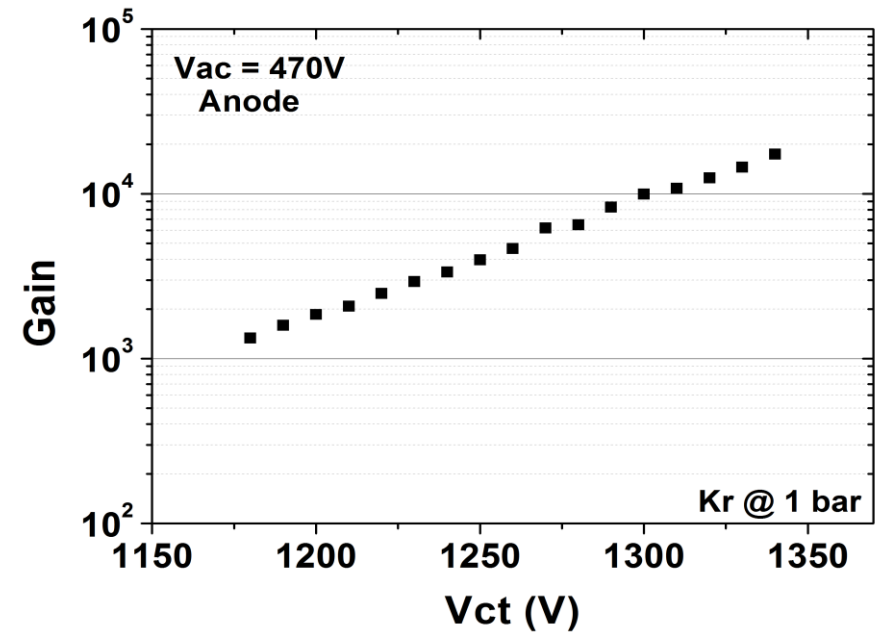
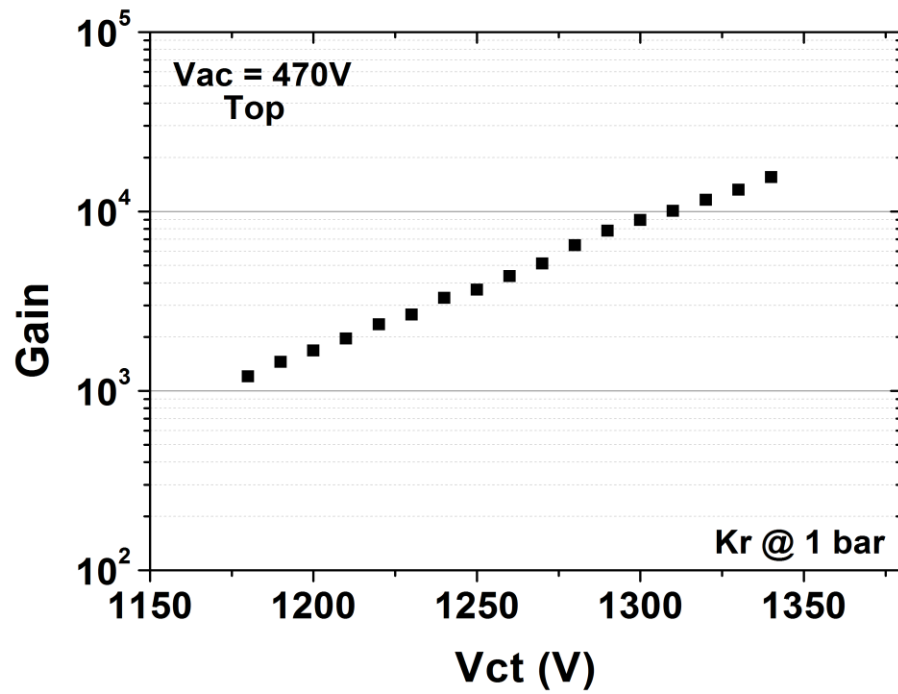
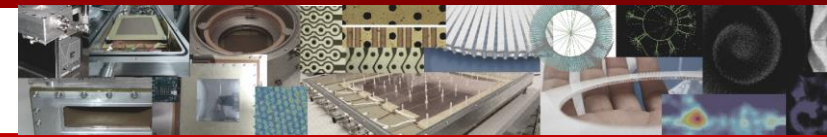
- Excellent agreement with experimental results
- Kr at 17.5 keV → Mo anode imaging

C. Azevedo et al., PLB 741(2015)272; Exp. - G. Smith 2013

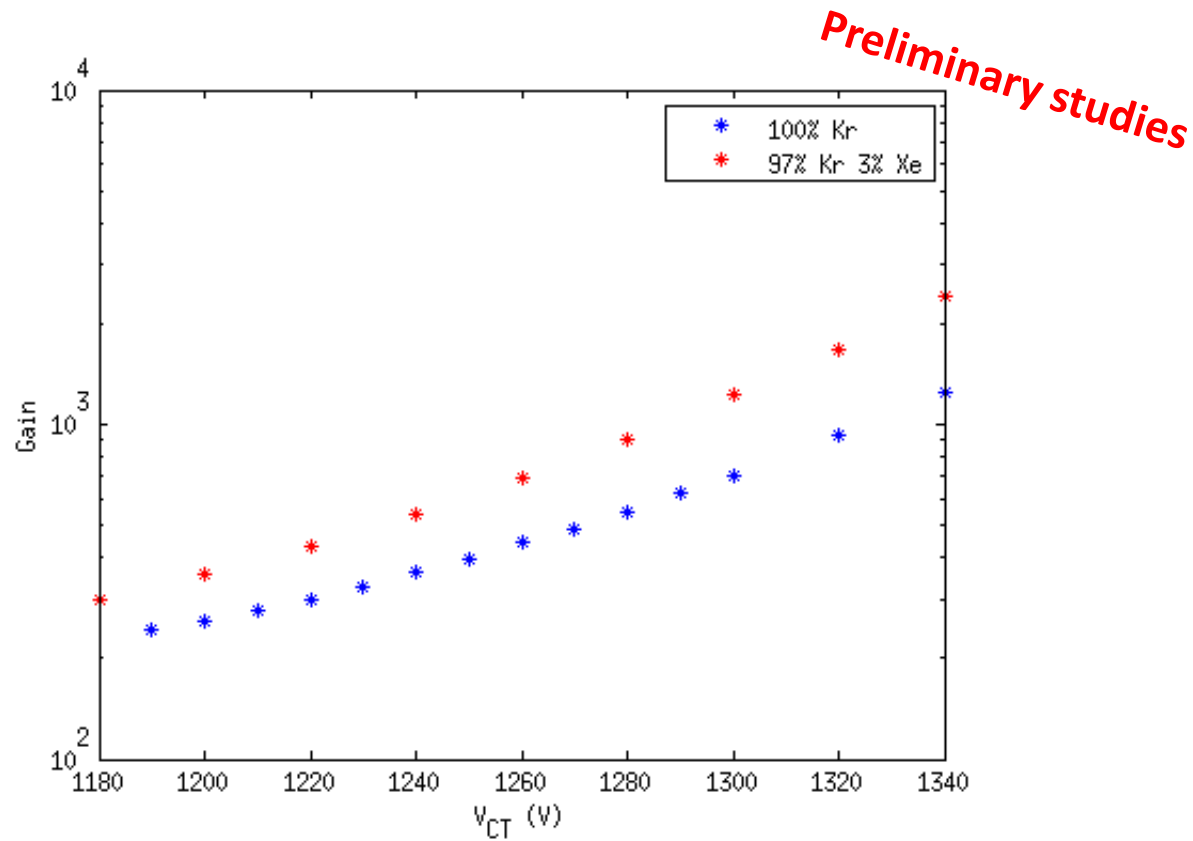
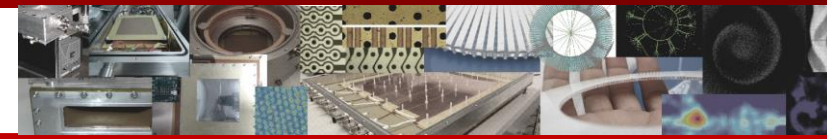
Kr – Position resolution vs detection efficiency



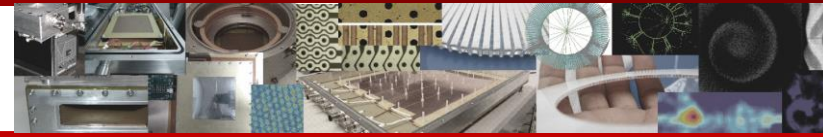
Region of:
 higher efficiency = better Rp



Very stable operation even for high rate

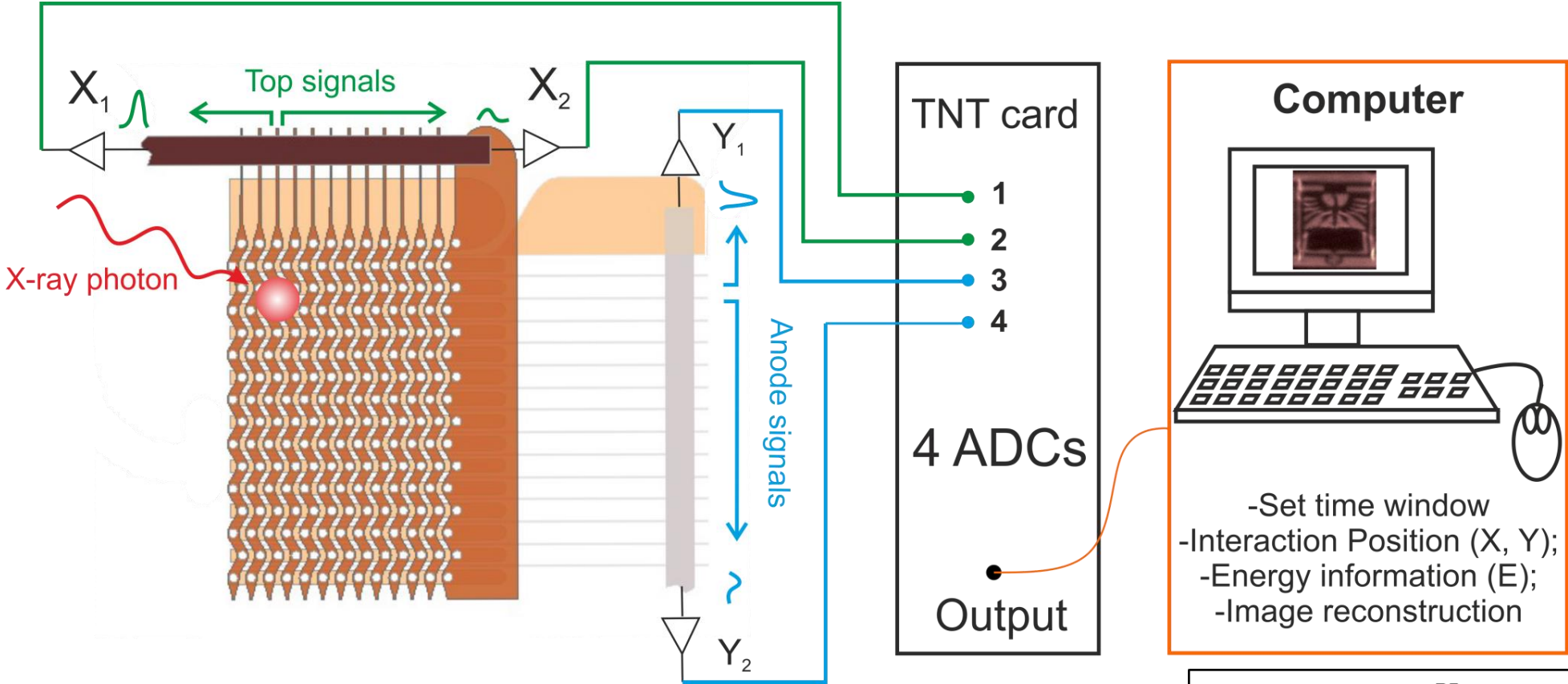
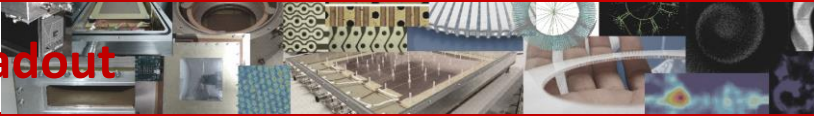


- A small addition of Xe in Kr increases the gain – penning effect
- systematic studies with Kr-Xe mixtures are ongoing



- Energy Resolved X-ray Imaging
 - X-ray panels
 - Computed Tomography
 - EDXR fluorescence imaging

2D – imaging with resistive lines readout

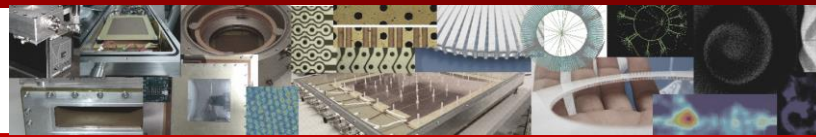


Allows for Position and Energy determination

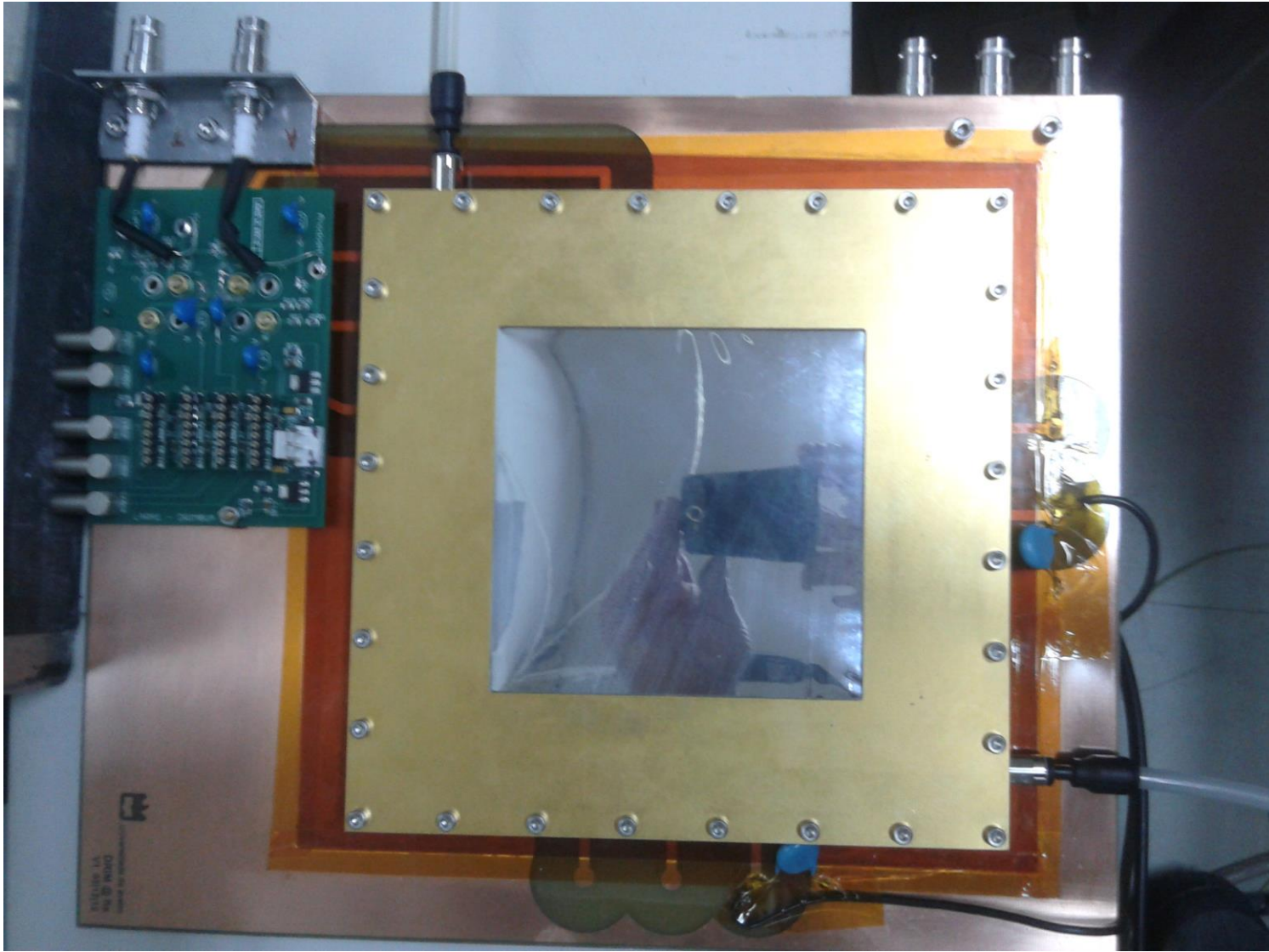
$$X = k \frac{X_1}{X_1 + X_2}$$

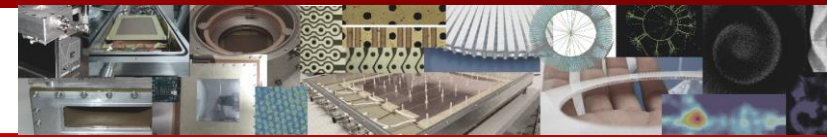
$$E = Y_1 + Y_2$$

Energy resolved X-ray imaging

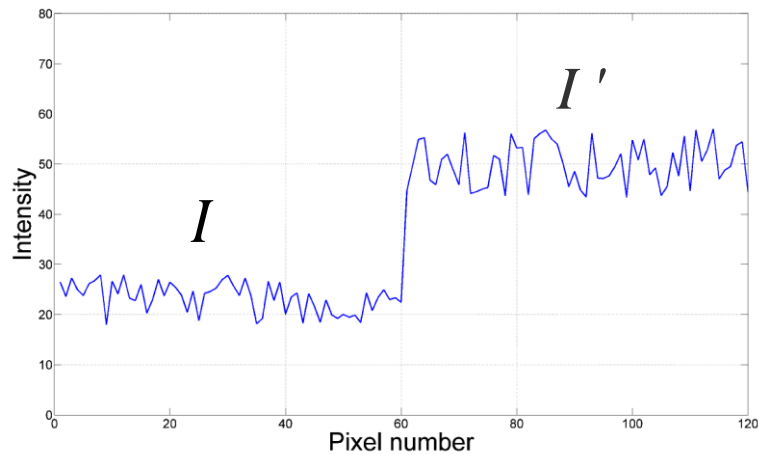


X-ray panels with integrated electronics – HV will be integrated





Energy Weighting Technique



$$\tilde{I} = \sum_i^n I_i \cdot w_i$$

J. Giersch et al., NIM A531(2004)68

- Integrating

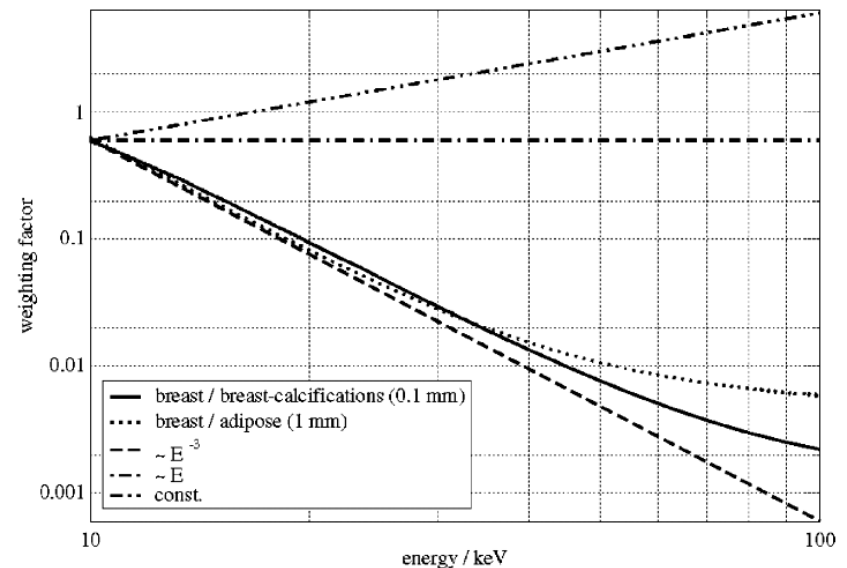
$$w_i \propto E_i$$

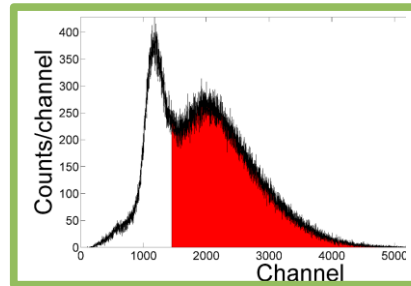
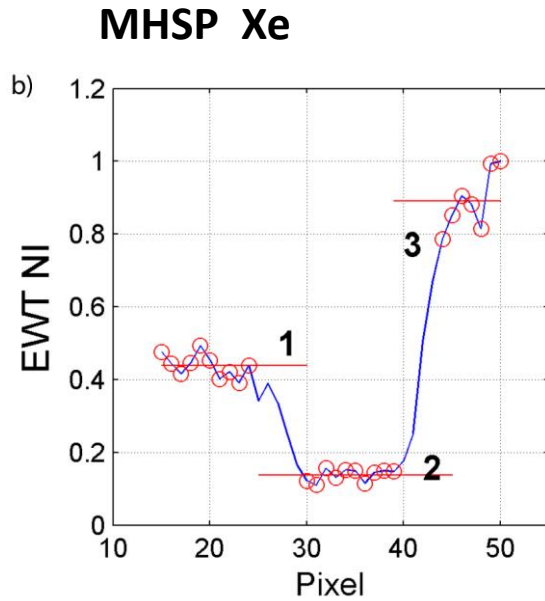
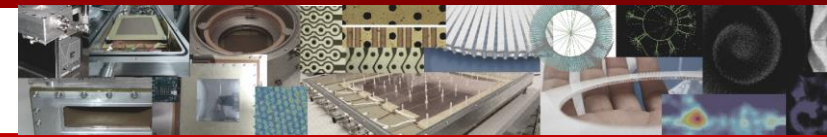
- Counting

$$w_i = 1$$

- EWT

$$w_i = \frac{1}{E_i^3}$$

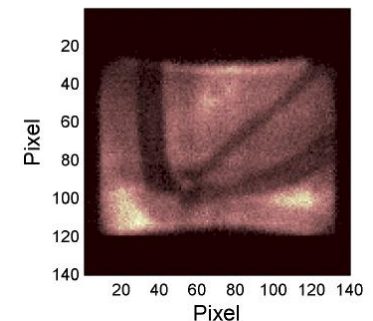
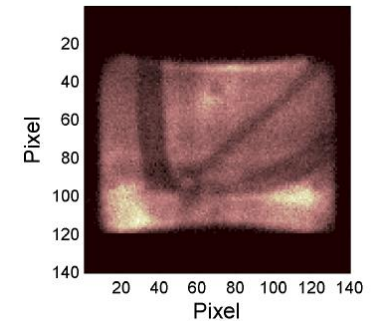
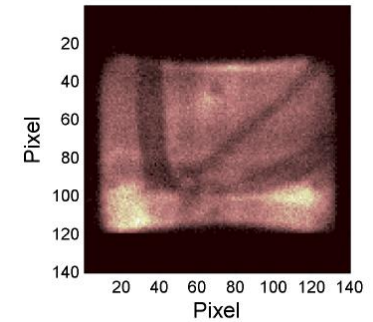




Integrating

Counting

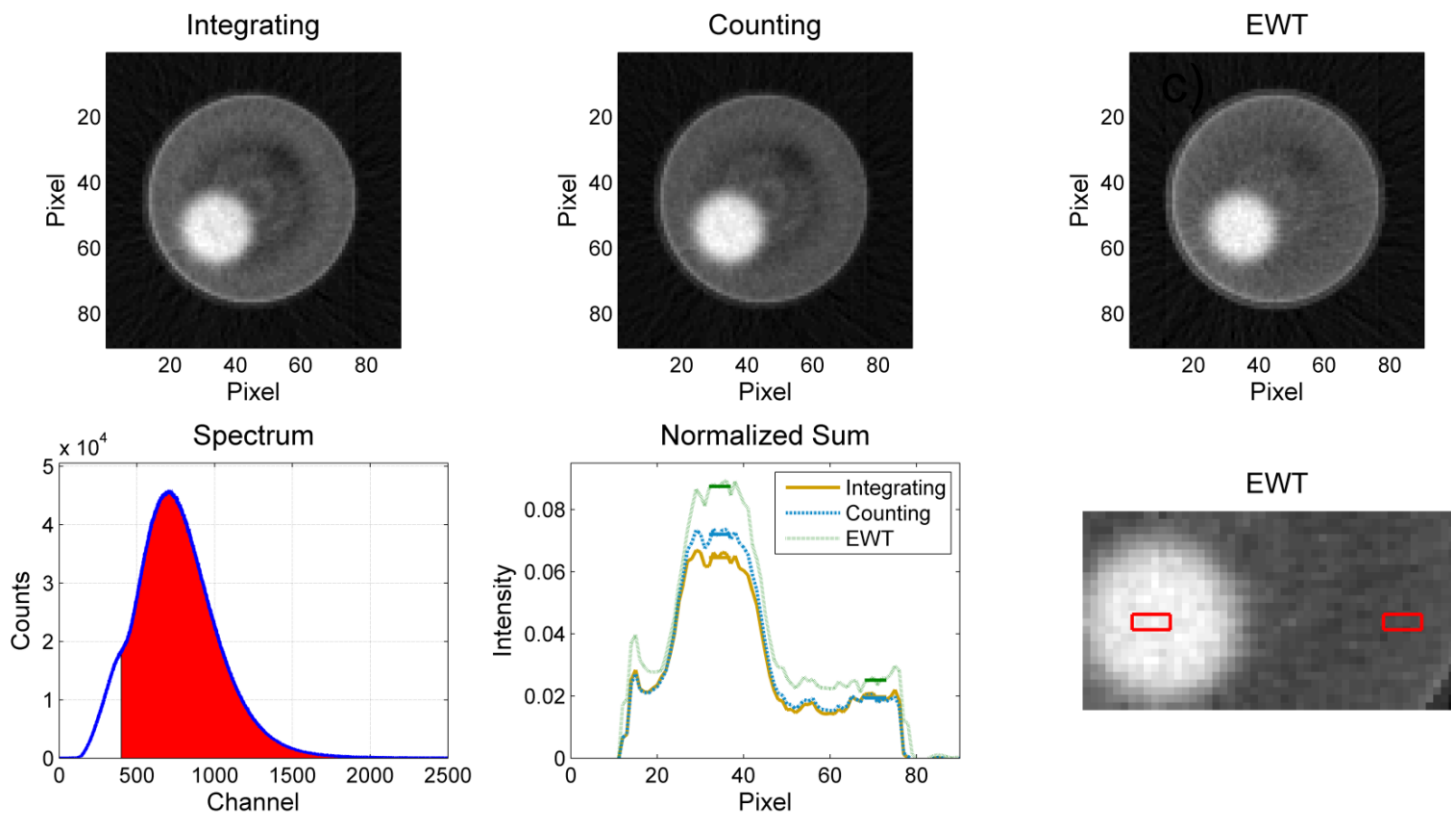
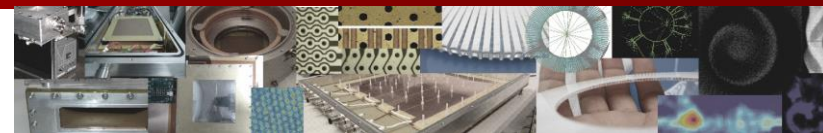
EWT



Technique compared with Integrating	Step	Contrast Enhancement
Counting	1 st	1.046 ± 0.009
	2 nd	1.092 ± 0.003
EWT	1 st	1.17 ± 0.01
	2 nd	1.265 ± 0.004

C.A.B. Oliveira et al. IEEE TNS 57(2010)938

Energy Resolved Computed Tomography



PMMA
air
chalk

$T_{acq_view} = 2s$

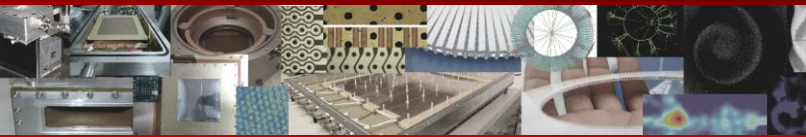
$N_{views} = 200$

Slit
 $0.5 \times 25mm^2$

Integrating to	Contrast Enhancement	SNR Enhancement	CNR Enhancement
Counting	8%	10%	11%
EWT	23%	22%	31%

L. F. N. D. Carramate et al JINST 6(2011) C02002

WG3 – multislice CT Imaging



- Sea snail (20 mm)



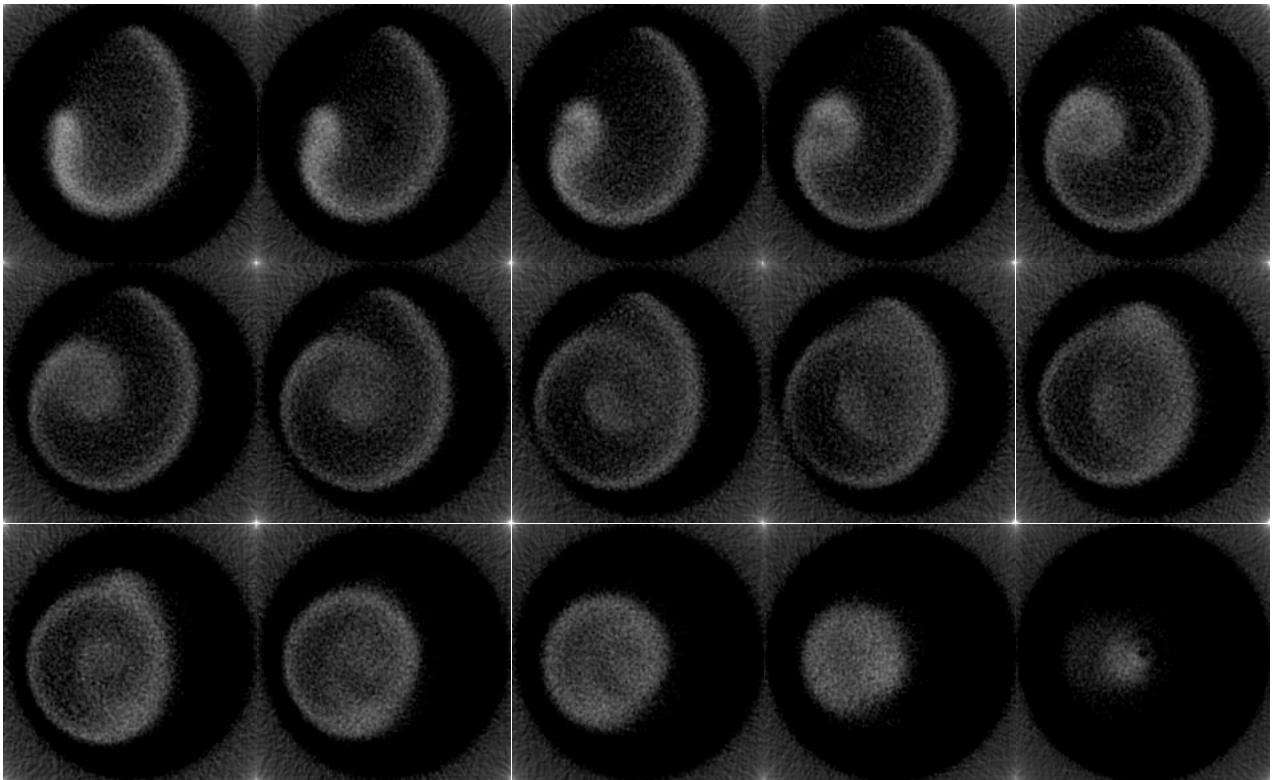
2D-THCOBRA

X-ray tube

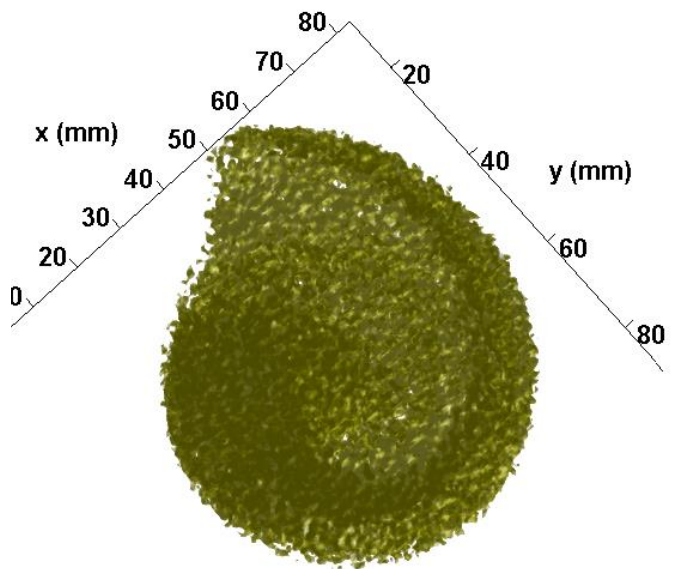
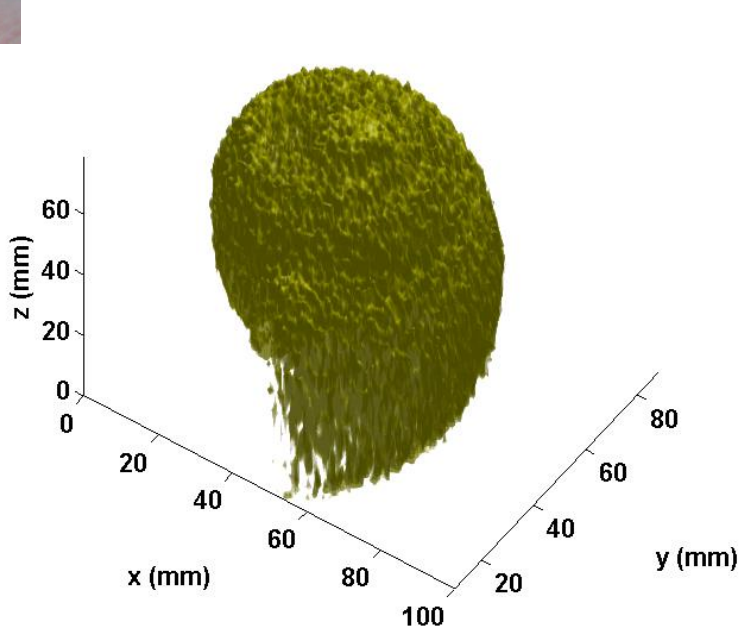
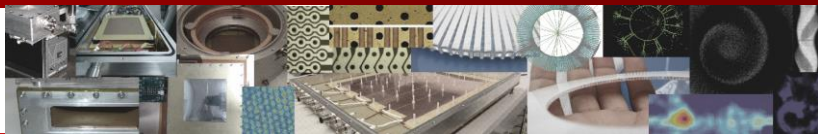
- 50 kVp
- 6 μ A

Tacq_{view} = 10 s

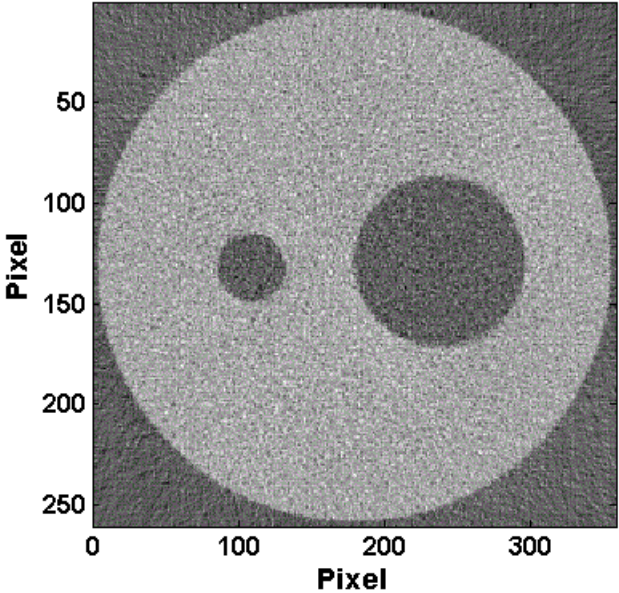
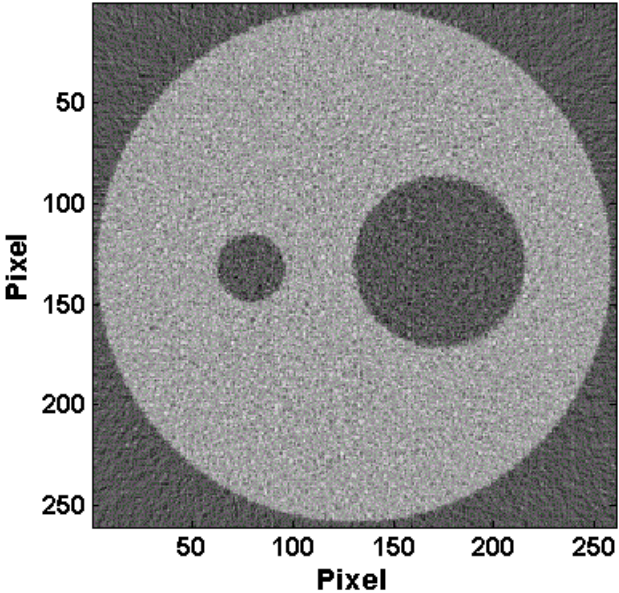
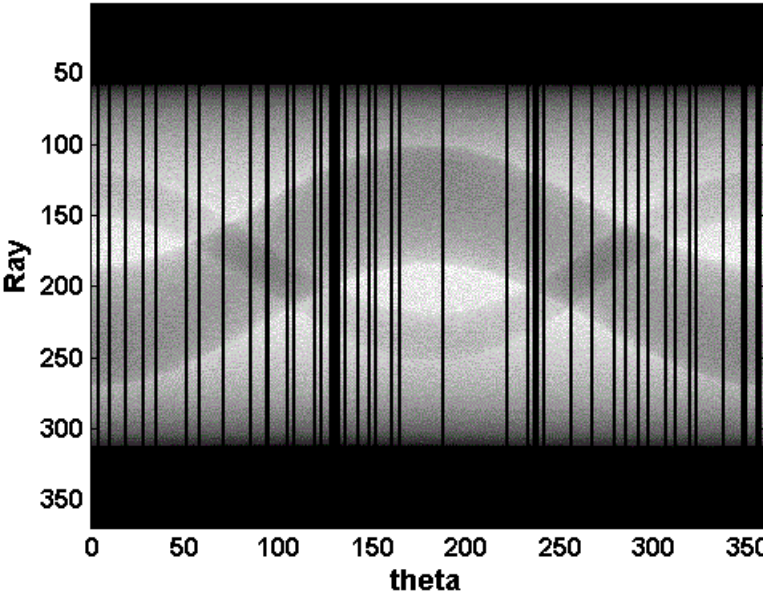
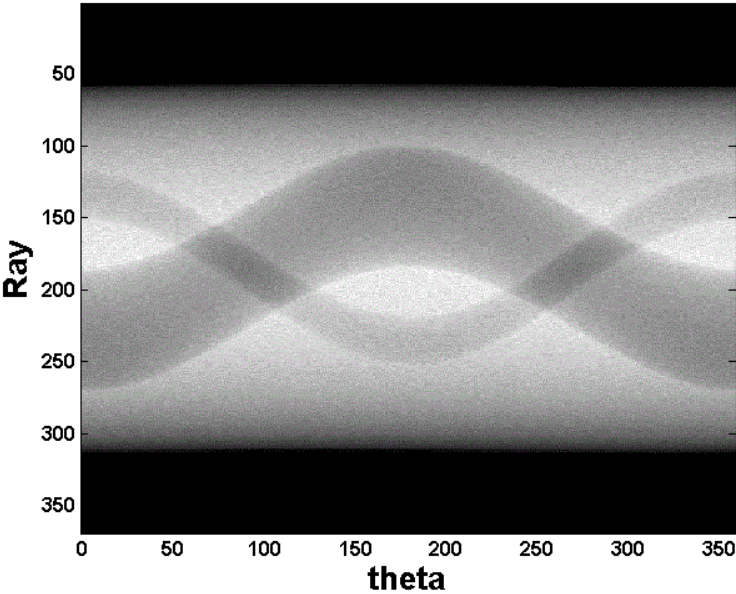
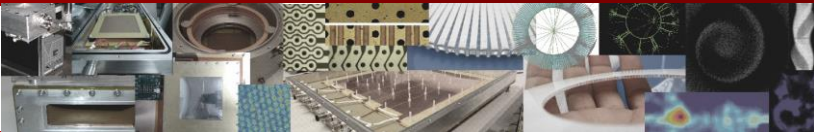
Slice = 1.3 mm

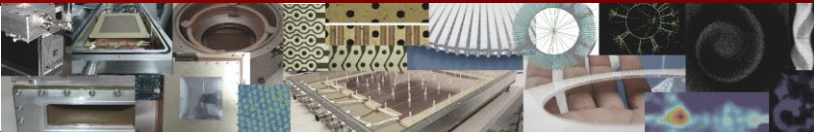


CT Imaging -3D reconstruction

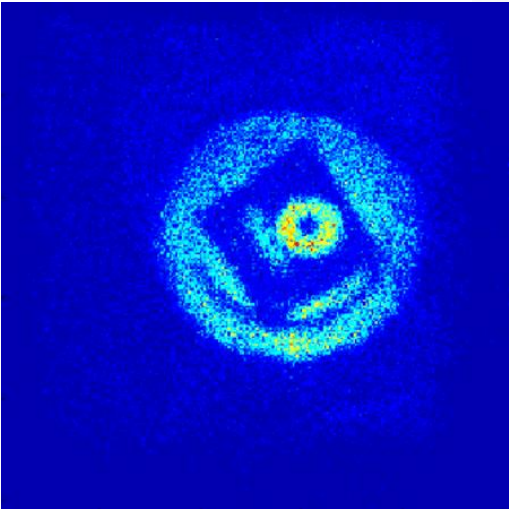
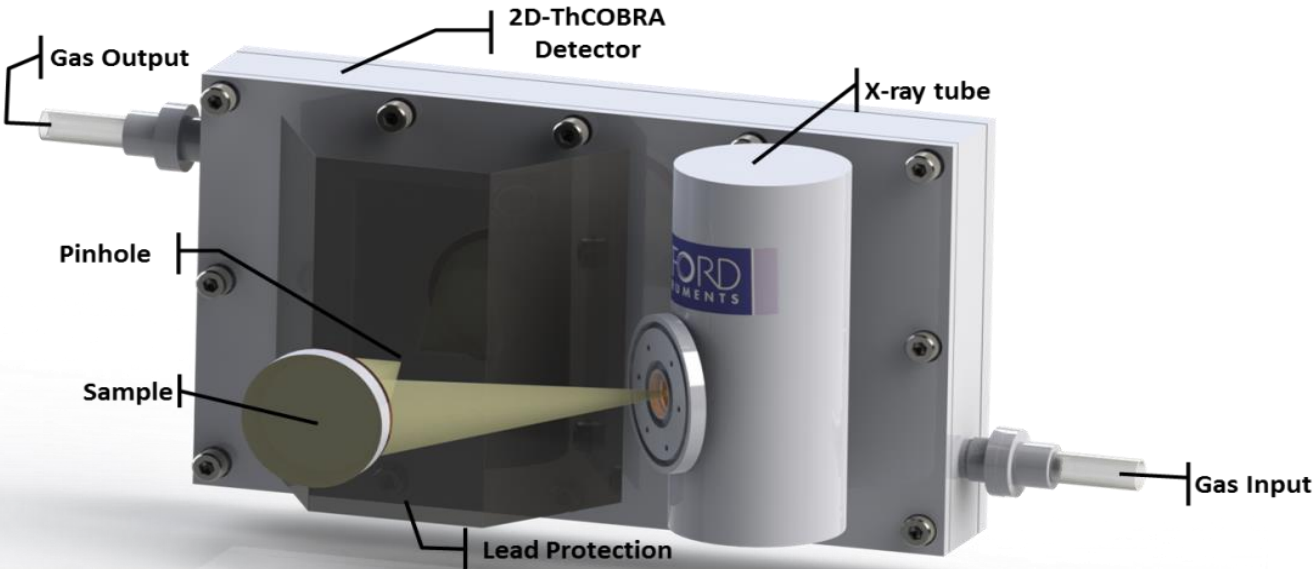
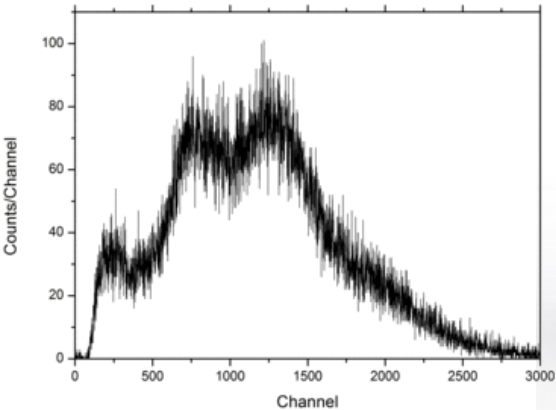


Discharge effect in image quality

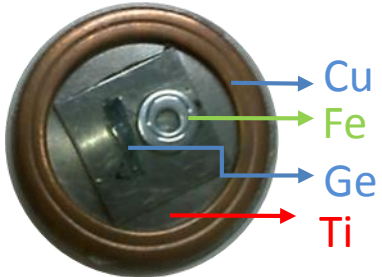




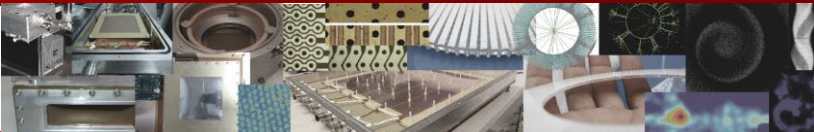
Pinhole - 500 μm



Multi-elemental Sample

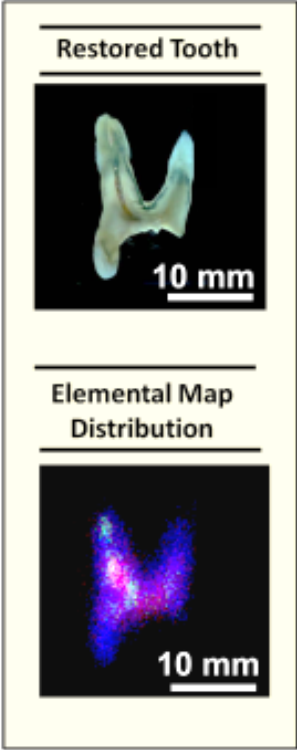
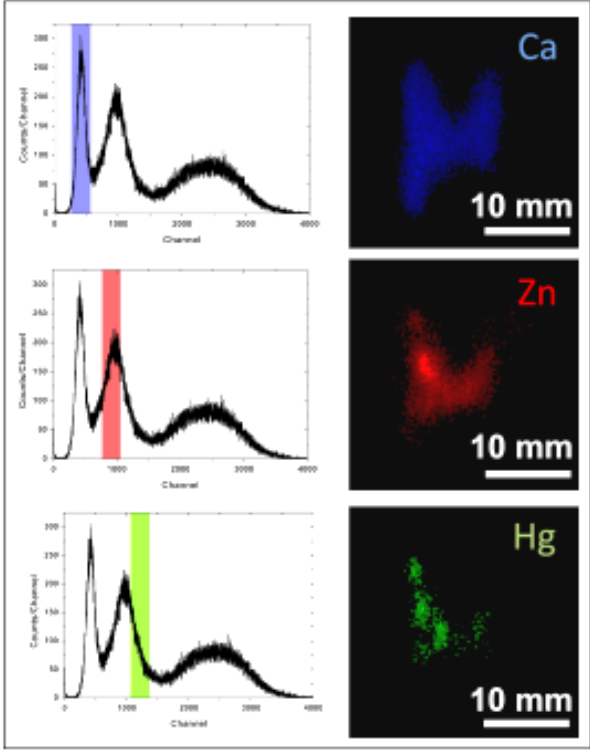


- **X-ray tube**
($V < 50\text{kV}$; $I < 1\text{mA}$)
- **Pinhole: Pb**
- **Magnification**



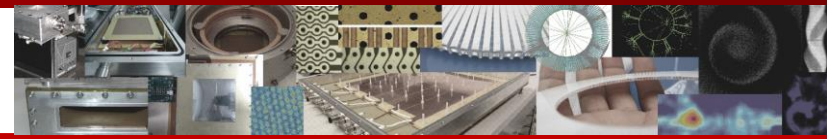
Biomedical application

Hg distribution of a restored tooth with metallic amalgam

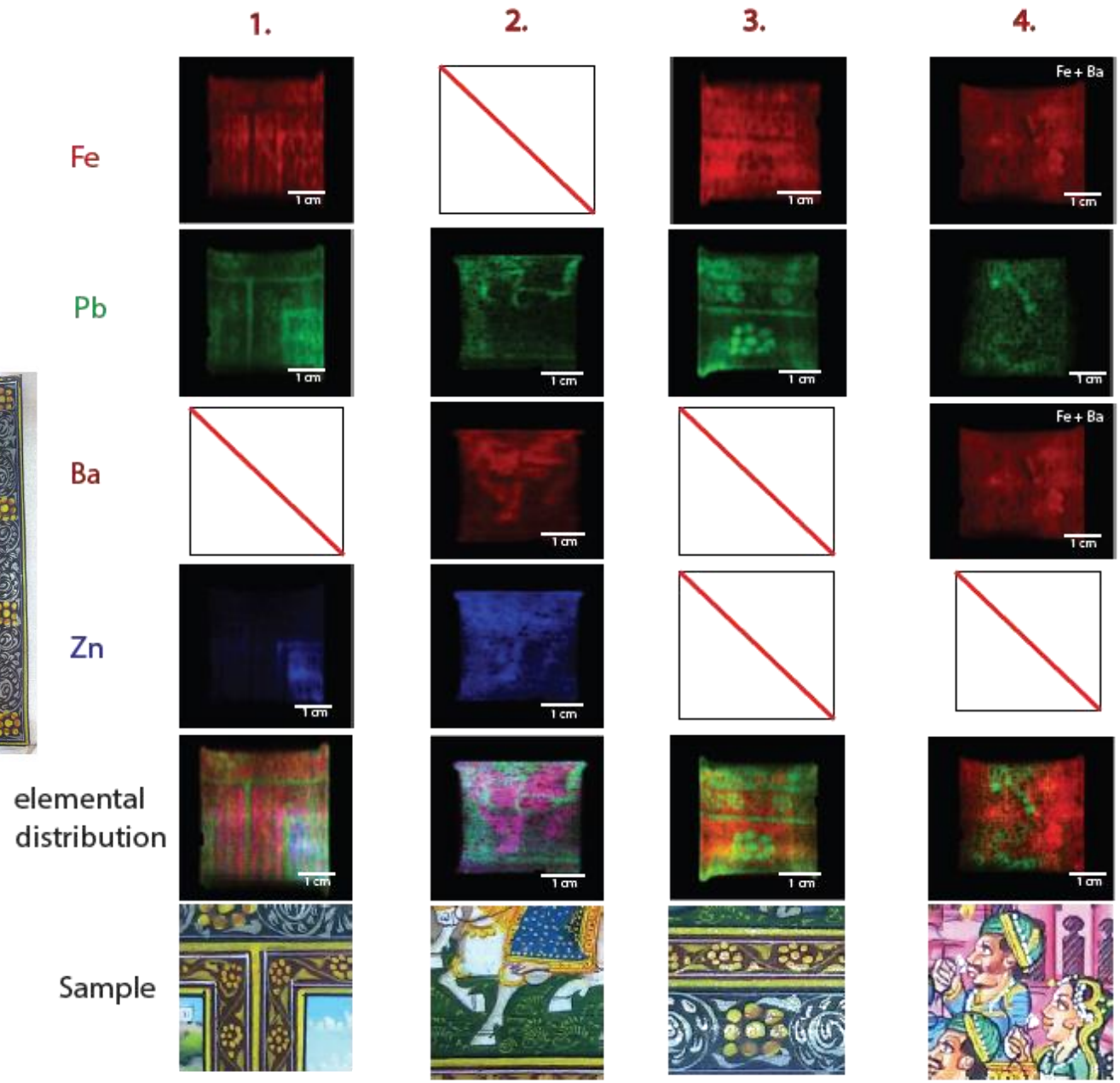


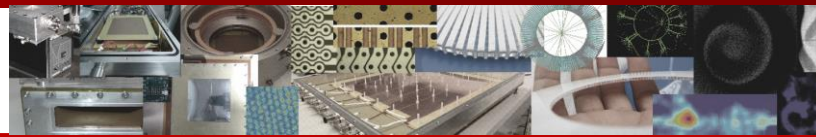
10 mm

A. L. M. Silva et al., Spectrochimica Acta B (2013)



Indian Miniature





Volume 30 Number 2 February 2015 Pages 317–528

JAAAS

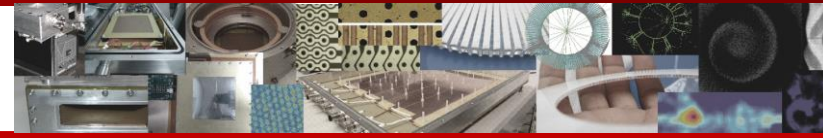
Journal of Analytical Atomic Spectrometry
www.rsc.org/jaas



ISSN 0267-9477



PAPER
A. L. M. Silva *et al.*
A large area full-field EDXRF imaging system based on a THCOBRA gaseous detector

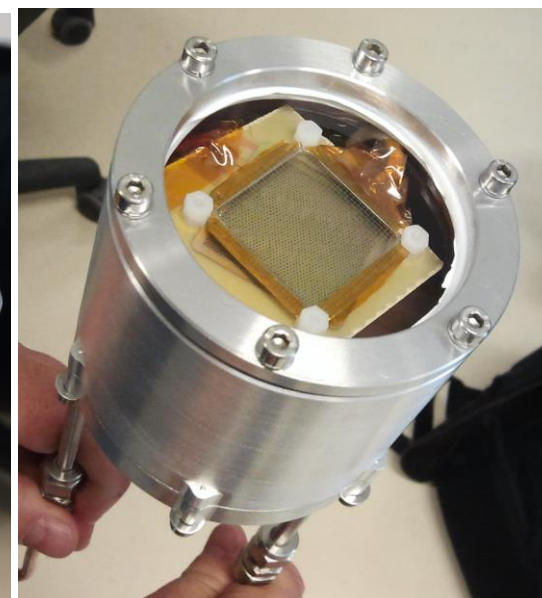
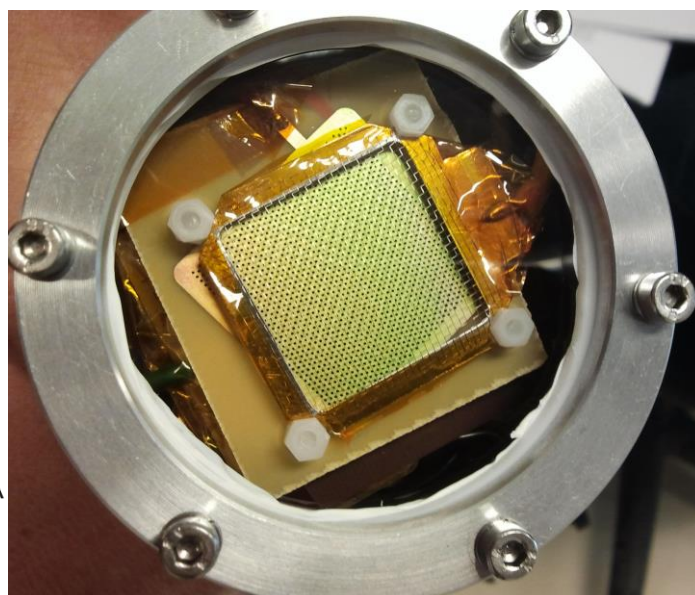
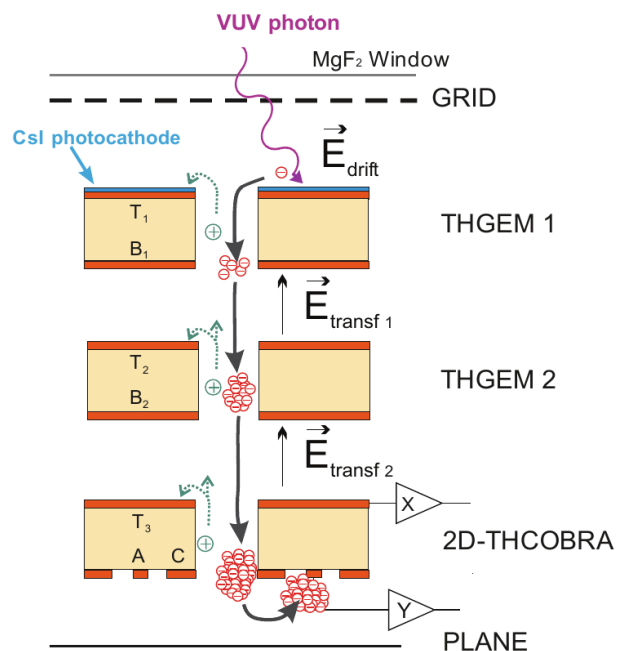


Gaseous photomultipliers

Sensitivity:

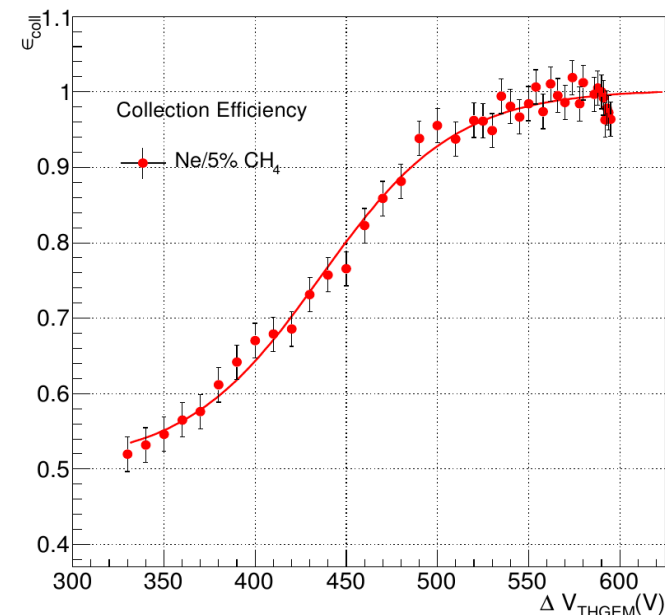
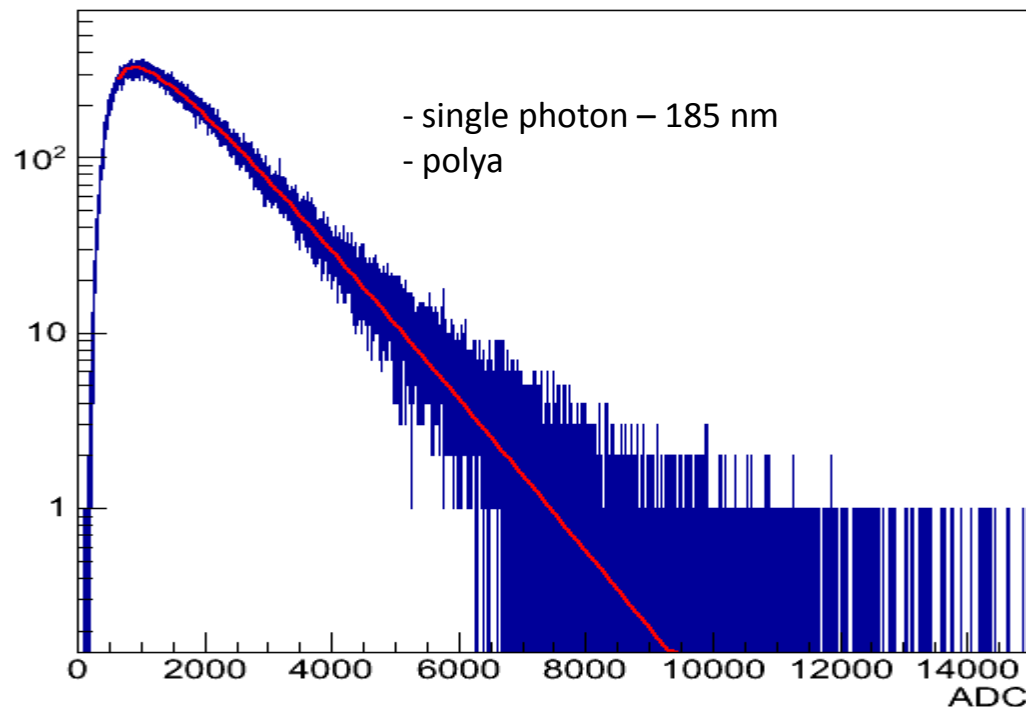
- Single photon
- VUV
- Position

UVV - GPM sensível à posição



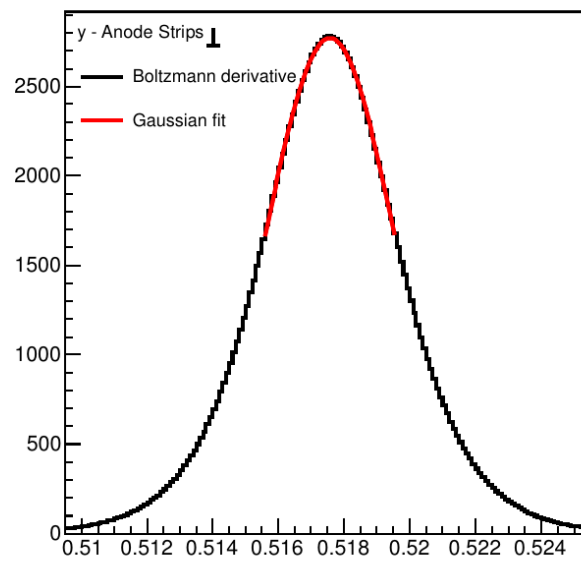
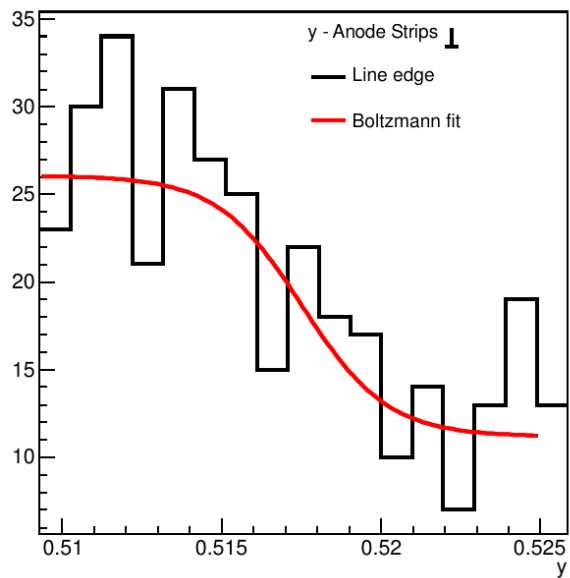
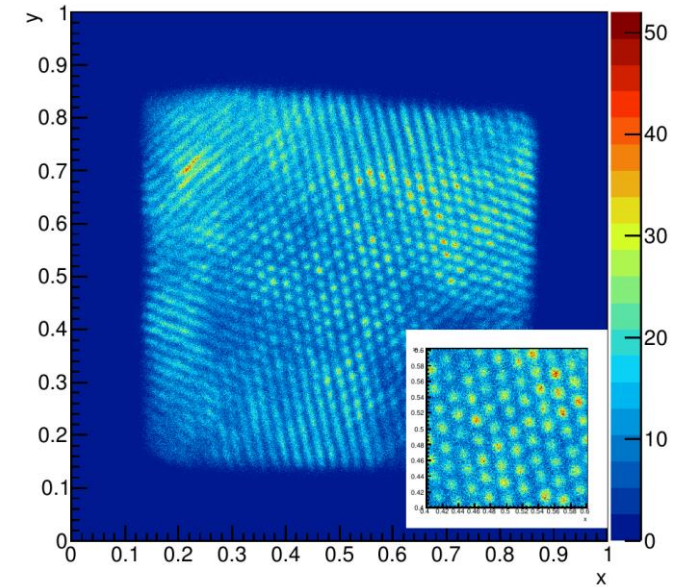
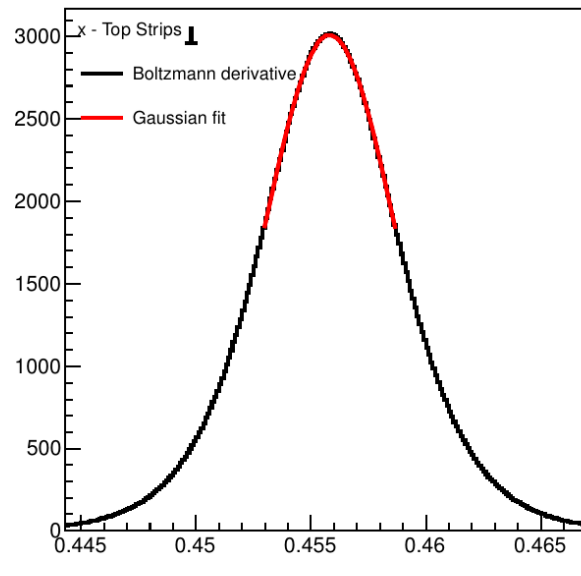
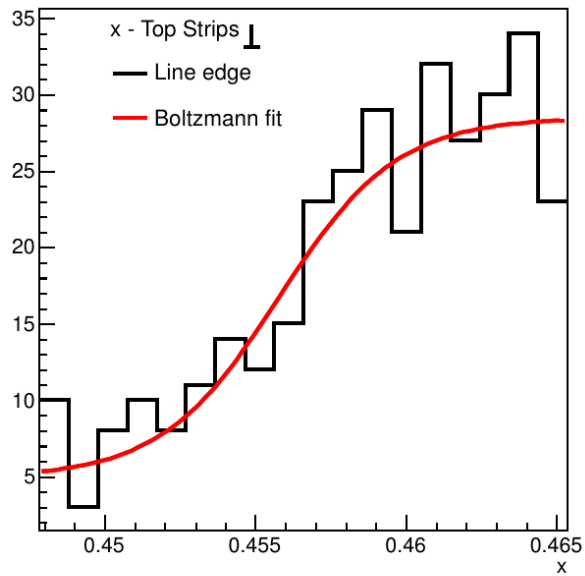
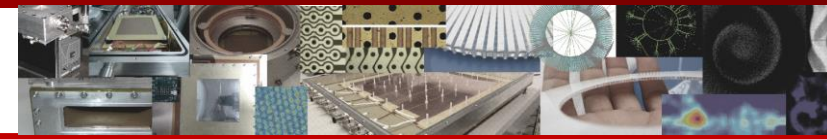
- Built for cryogenic environment
- MgF window - (LAr light – 110 nm)
- Filling gas – Ne5%CH₄

VUV position sensitive gaseous photomultiplier



- $G > 10^6$
- collection efficiency $\sim 100\%$
- $R_{p(\text{anode})} = 60 \mu\text{m}$
- $R_{p(\text{top})} = 90 \mu\text{m}$
- only a few discharges for several months even for high photon flux

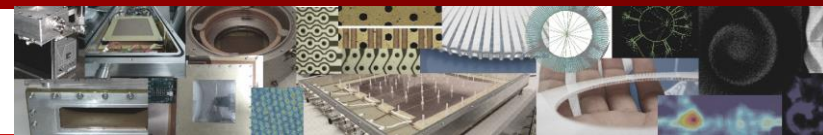
VUV position sensitive gaseous photomultiplier



- $R_{\rho(\text{top})} = 90 \mu\text{m}$

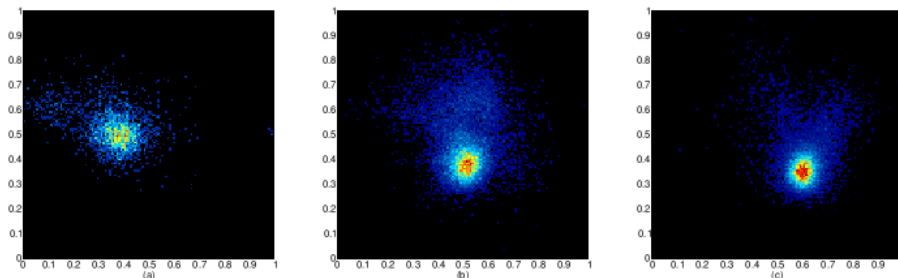
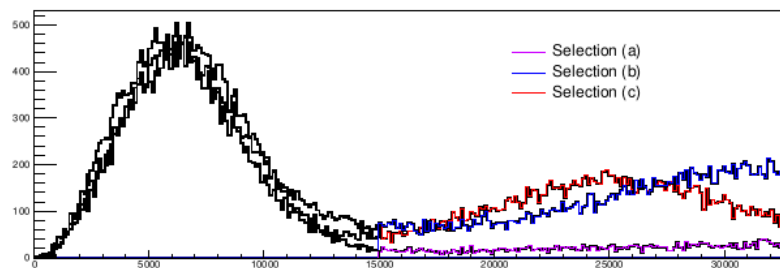
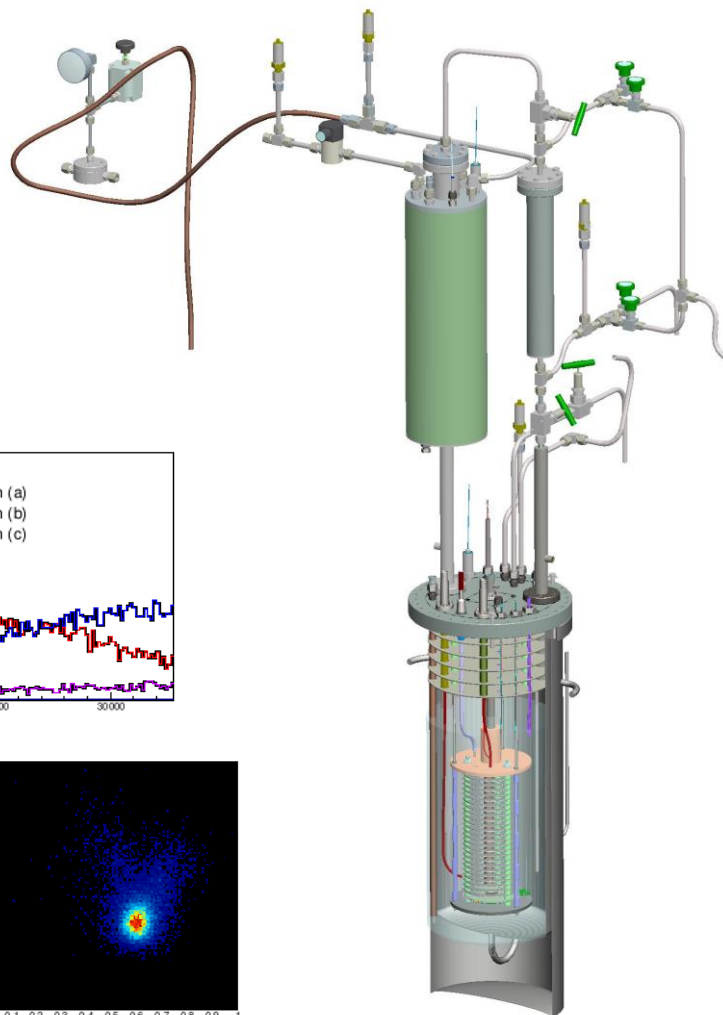
- $R_{\rho(\text{anode})} = 60 \mu\text{m}$

e.g. - B. Paredes et al. JINST (2005), in press

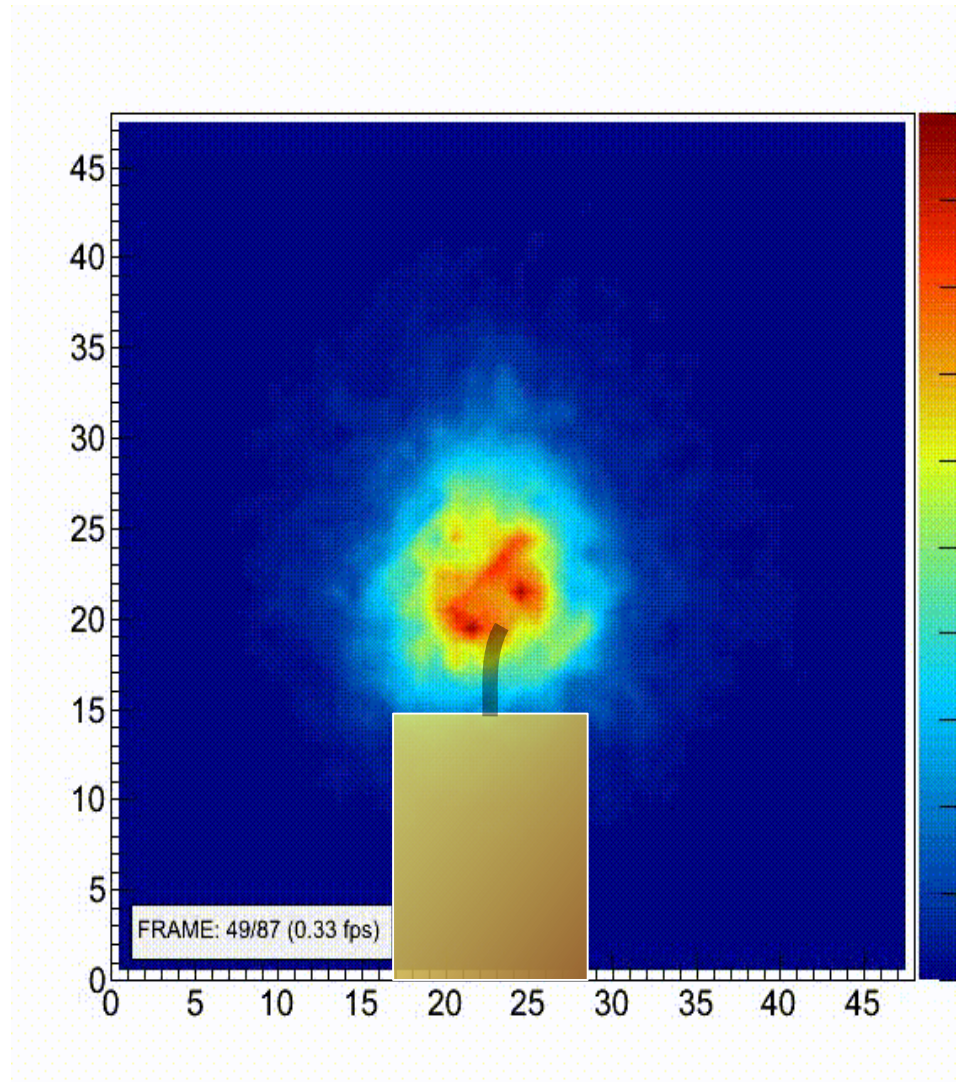
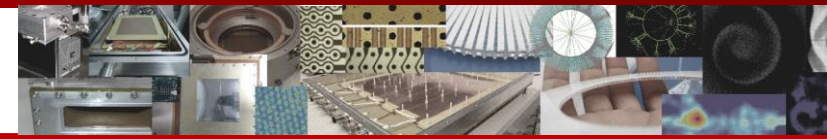


LAr Med Project (Sheffield & Aveiro)

- Cryogenic tests with N₂
- VUV source at 20 cm (3 cm step)
 - Tens of photons/pulse
 - (~1 MeV in LAr)

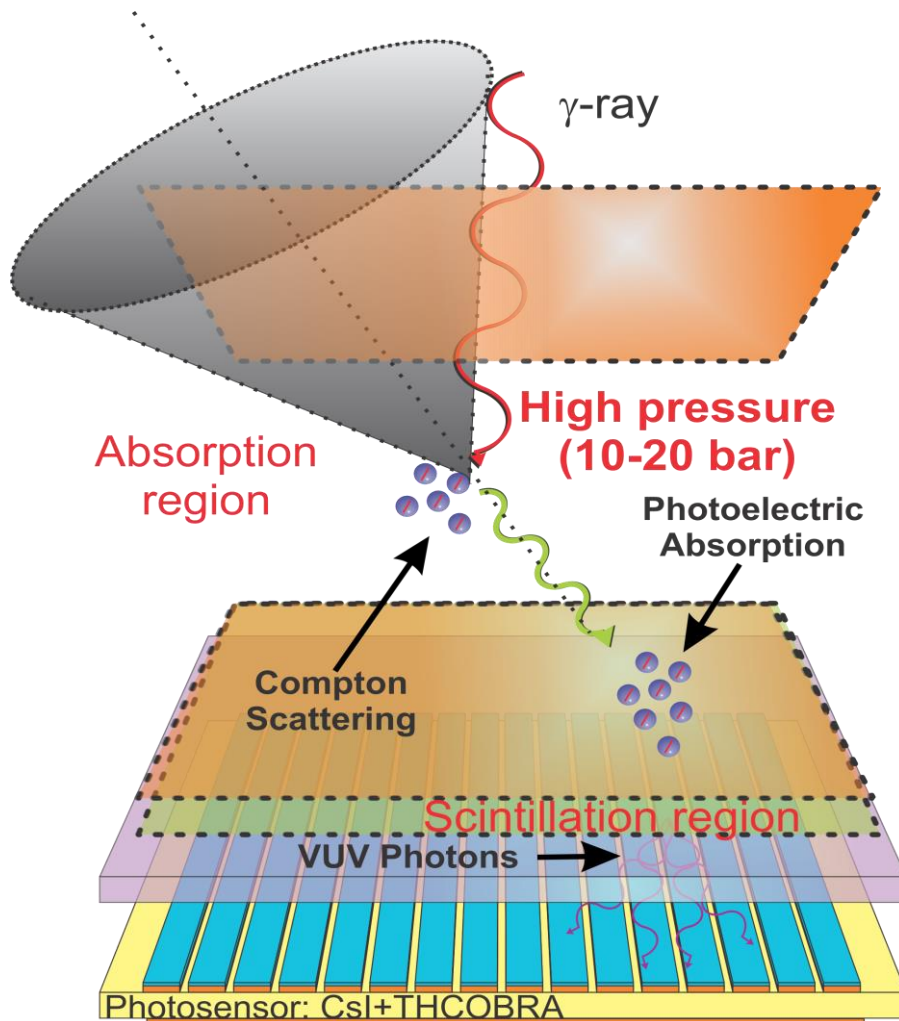


VUV light emitted by a candle - single photon





Self triggered Compton Camera

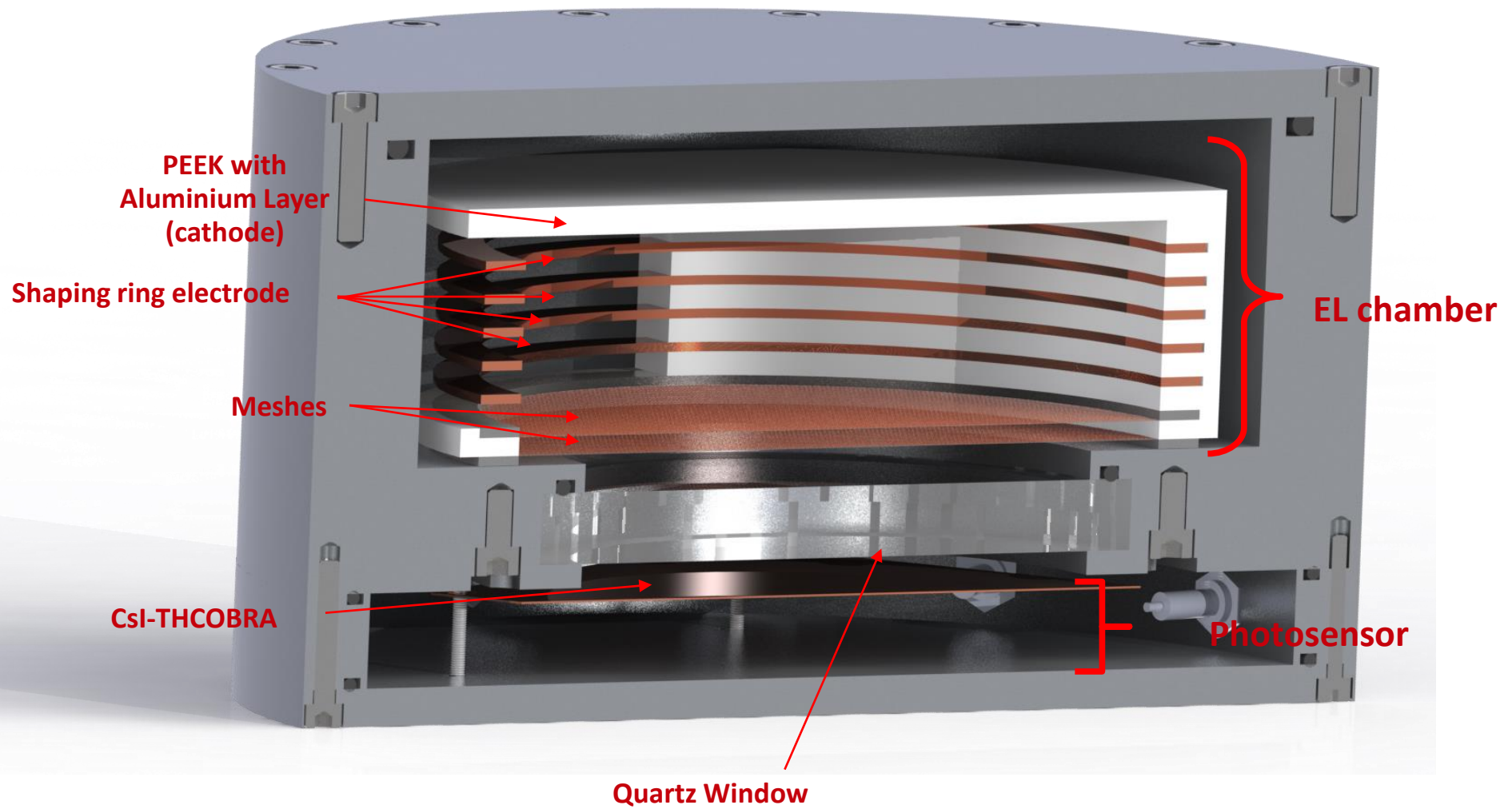
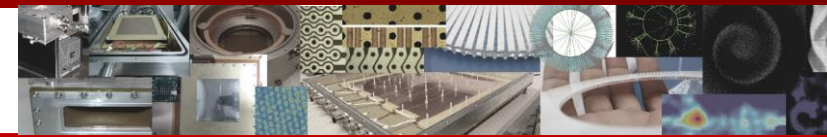


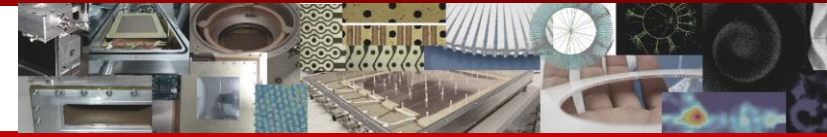
- **Trigger:**
Primary Scintillation
- **3D position discrimination:**
Electron Drift time
- **Dead time:**
Drift distance

Event discrimination criteria

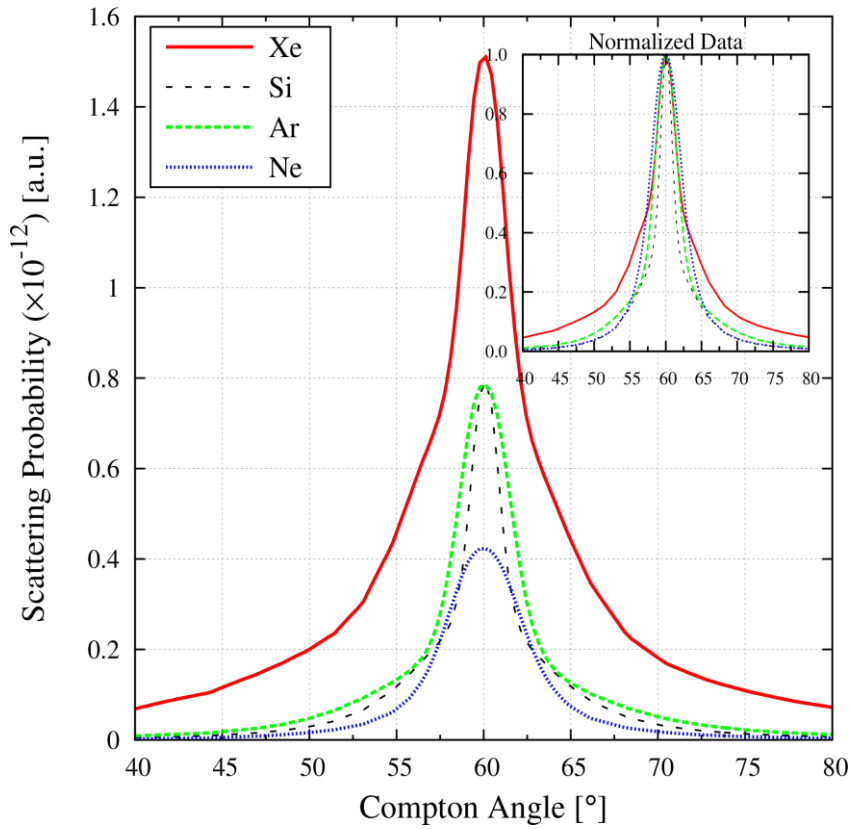
- 3 pulses after trigger
 - Recoil electron
 - Scattered photon
 - Fluorescence photon
- Sum (energy pulses) = Incoming photon energy
- One pulse with energy = Fluorescence photon
- 2 other pulses should lie on Compton kinematics

Hp Compton Camera

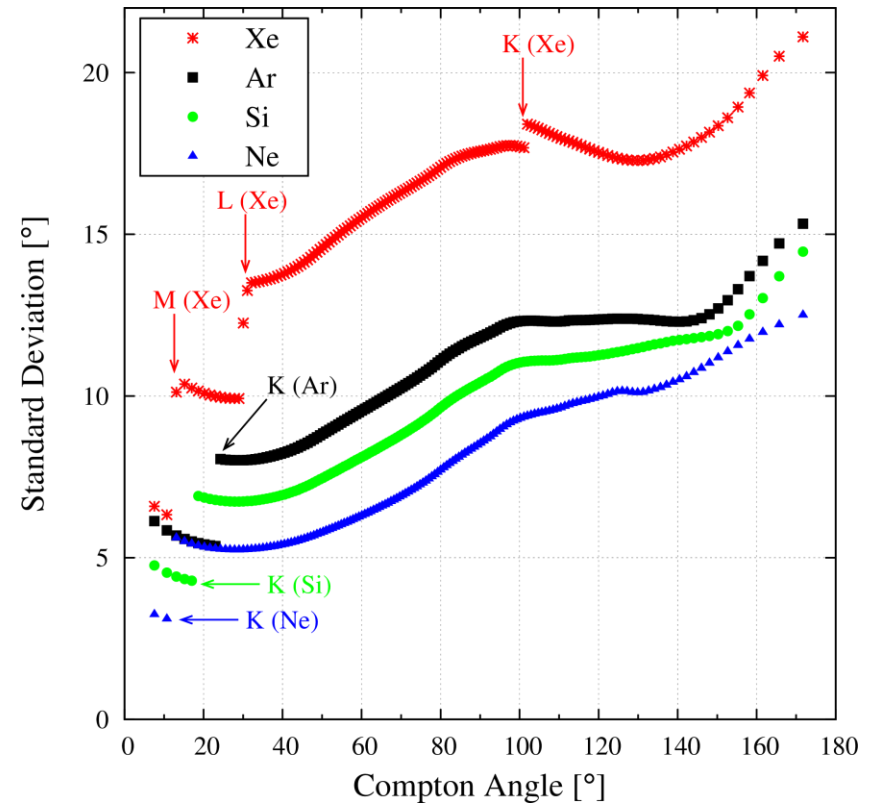


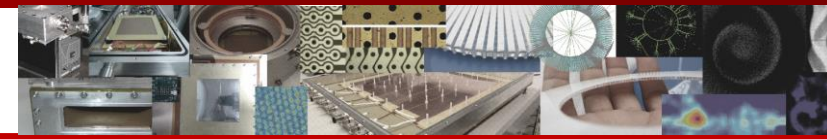


Doppler Broadening in Noble Gases

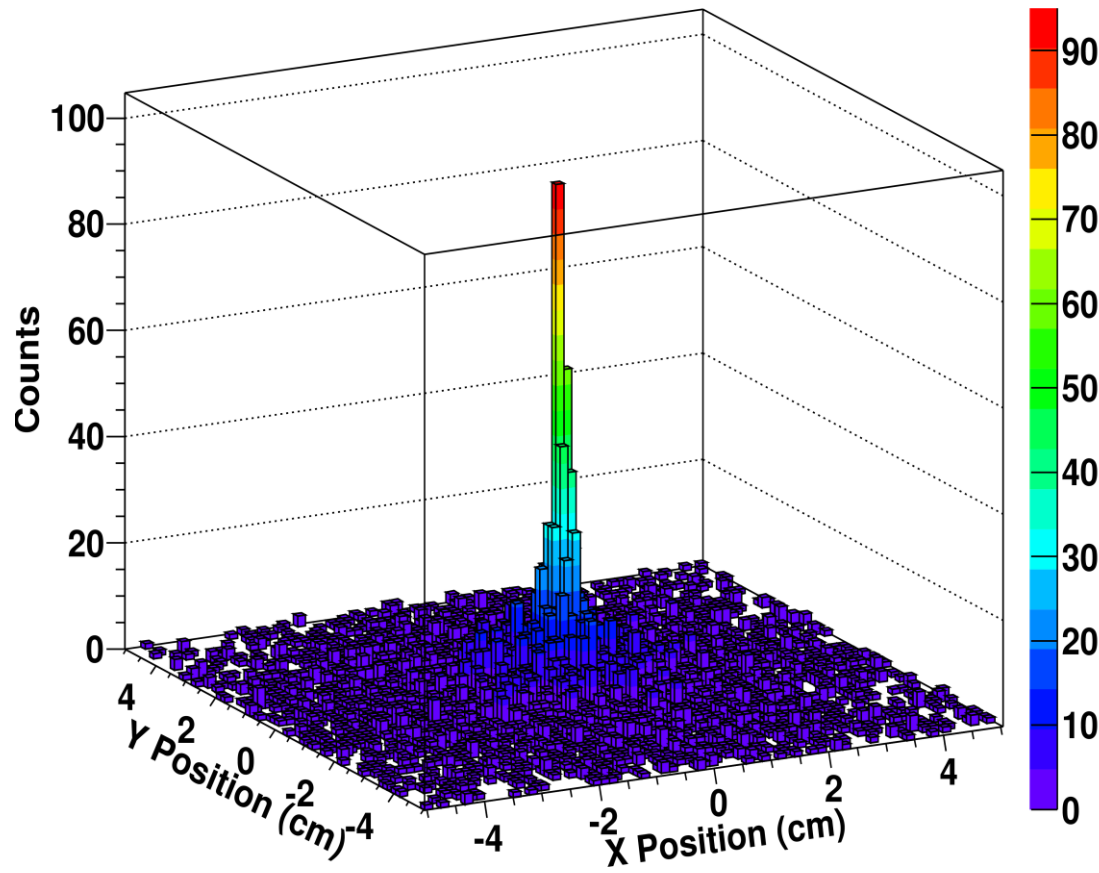


Standard deviation



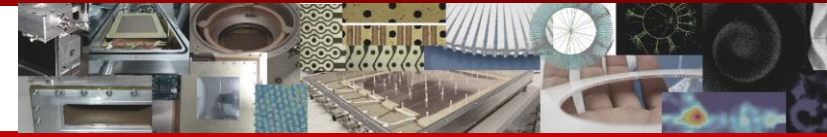


Photon distribution on the photosensor



Simulation of single event
-Full absorption 140 keV
-very precise xy detection

Compton camera



- **Calculated events:**

 - Broadening effect

 - No energy neither position fluctuations

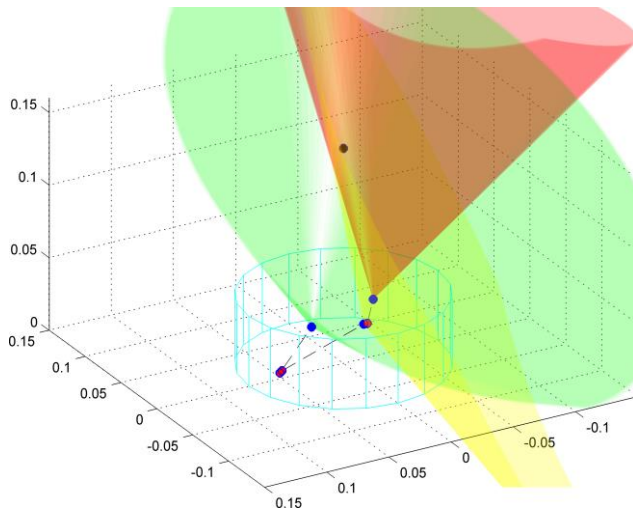
- **Simulated events**

 - Primary electron clouds production

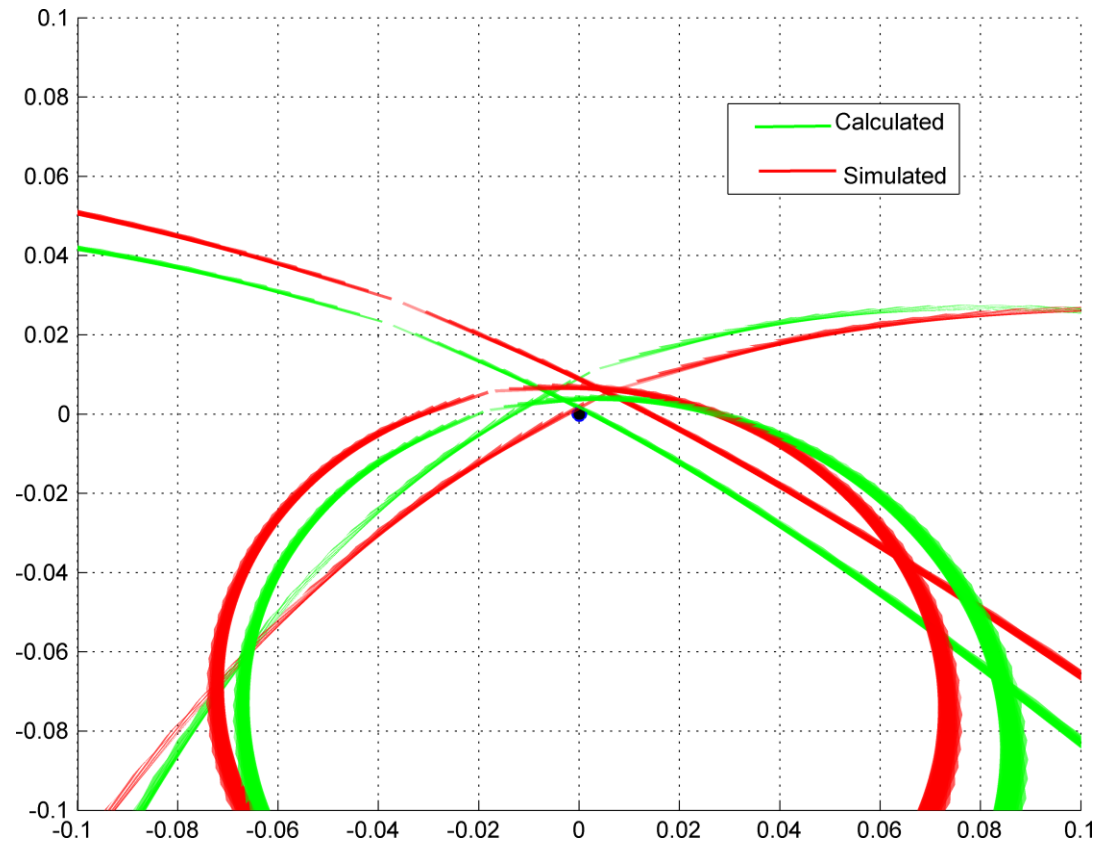
 - Electron drift and diffusion

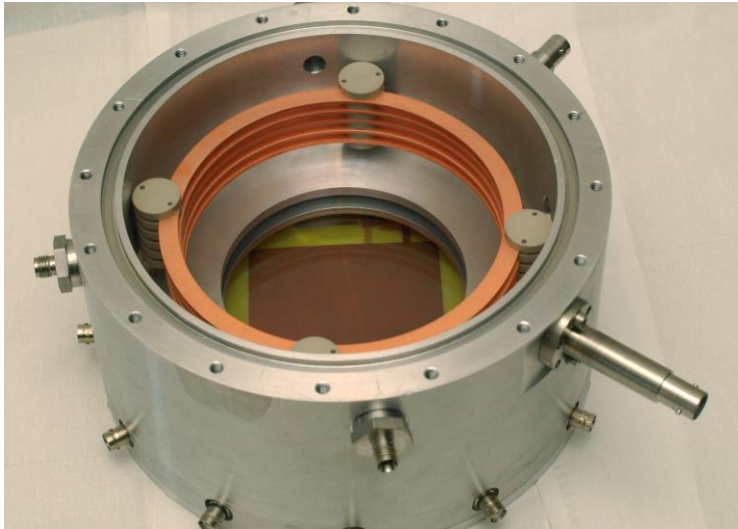
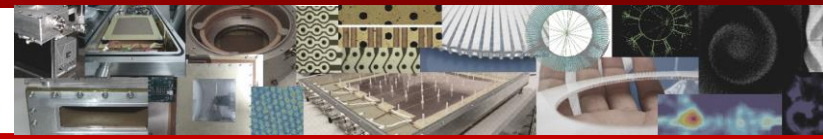
 - Electroluminescence production

 - Photosensor light detection

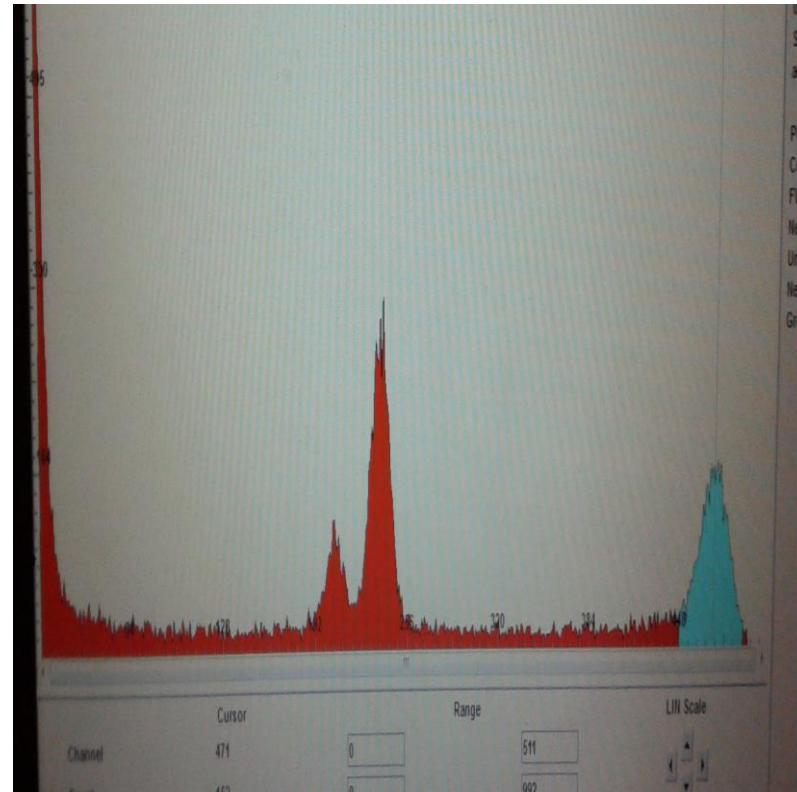


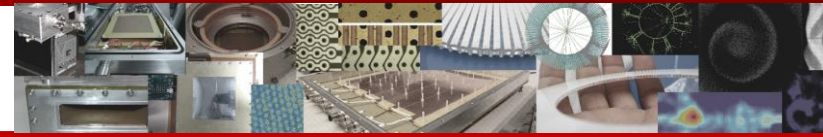
C D R Azevedo et al., NIMA ,





Characterization with a PMT
Xe – 1-5 bar





- MPGDs

- Great potential for photon detection from DUV - gamma

- Applications out from HEP:

- Energy resolved x-ray imaging
- X-ray Computed Tomography (preclinical, material analysis)
- EDXF Imaging
- Fire detection and corona discharge