MPGDs face2face with art and industry

- EDXRF imaging system

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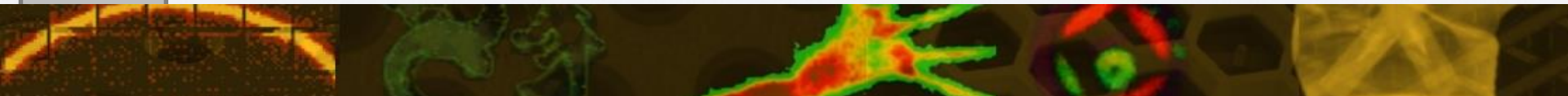
OUTLINE

- Motivation
- MPGDs and 2D-imaging
- EDXRF imaging system
- Applications/Proof of concept - face2face with art and cultural heritage
- Next step - portable prototype / applications for industry



MOTIVATION

What we know about X-RAY FLUORESCENCE IMAGING?

… It is a powerful and non-destructive technique to obtain **elemental map distributions in materials**.

Requires …

- **Spatial-resolved** information for elemental mapping;
- **Energy-resolved** information for elemental identification;

Are commonly based on …

- Scanning systems;
- FF-XRF systems

MOTIVATION

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PROBLEM ?!

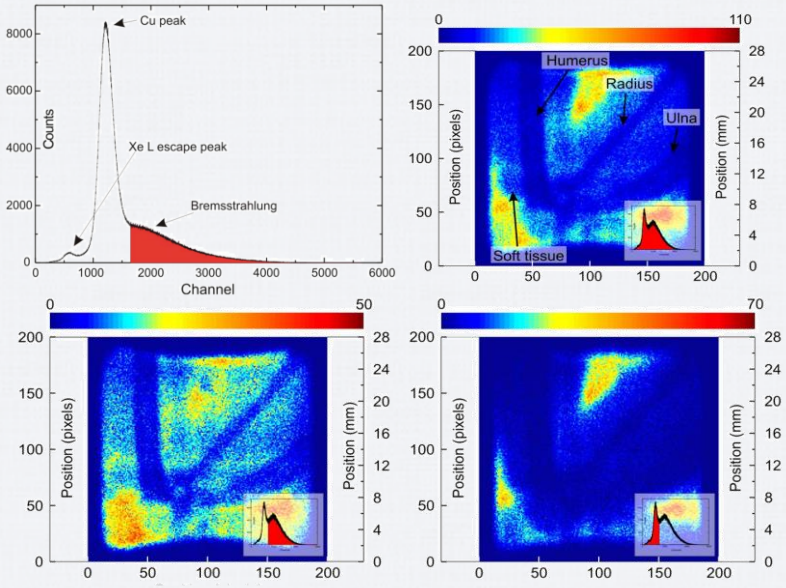
- Expensive !
- Small active area !
- Some systems require low temperature operation !

MOTIVATION

- **MPGDs present excellent single photon counting imaging capabilities:**

MOTIVATION

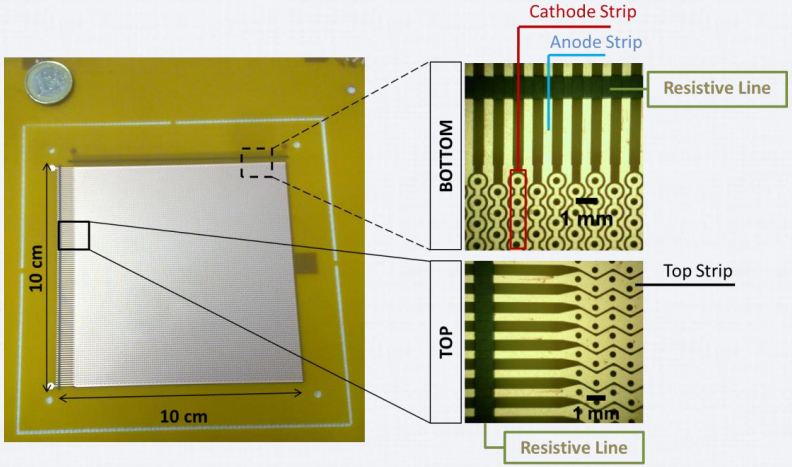
MPGDs present excellent single photon counting imaging capabilities:



- Full field of view imaging operation (2D)
- Possible Rp>50 um
- No noise (set threshold)
- High counting rate capability
- Large area (up to 50x50 cm2)
- Very soft X-rays detection capability (<1keV), due to its high gain
- Room temperature operation
- Versatility and portability
- Low cost and low complexity

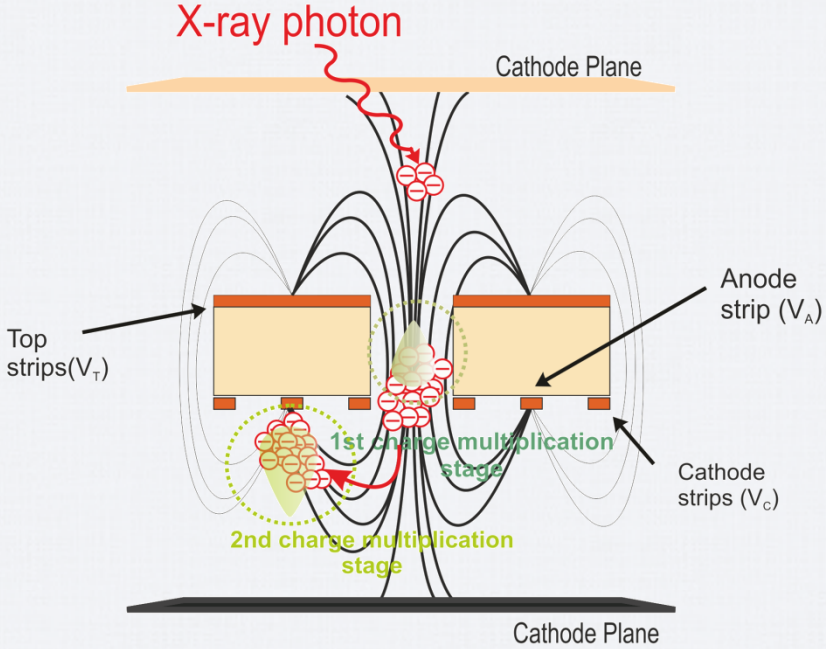
MPGDs and 2D-imaging

Example - THCOBRA detector (10x10 cm²)



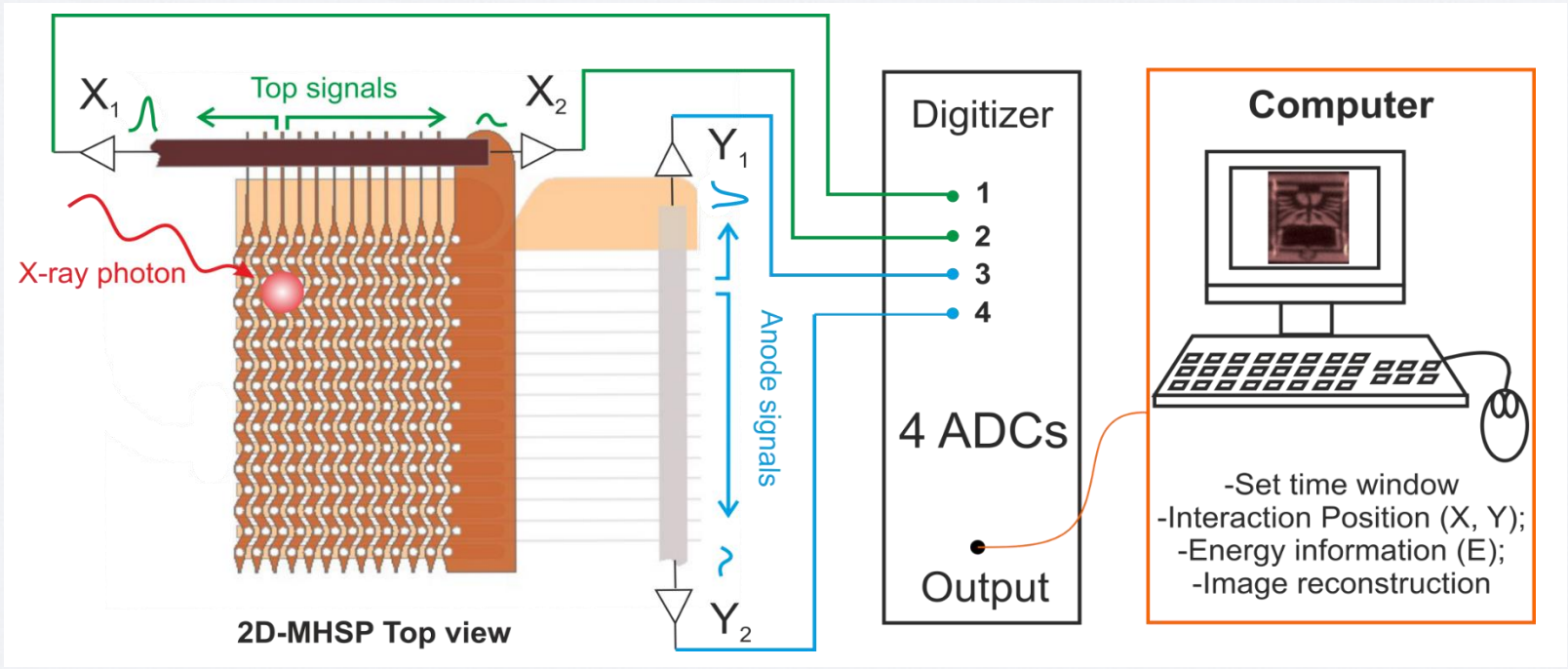
- Double side structure
- Substract: PCB 400 µm
- Holes ø = 300 µm
- Cathodes 200 µm
- Anodes 200 µm
- Pitch 1 mm

operation principle



MPGDs and 2D-imaging

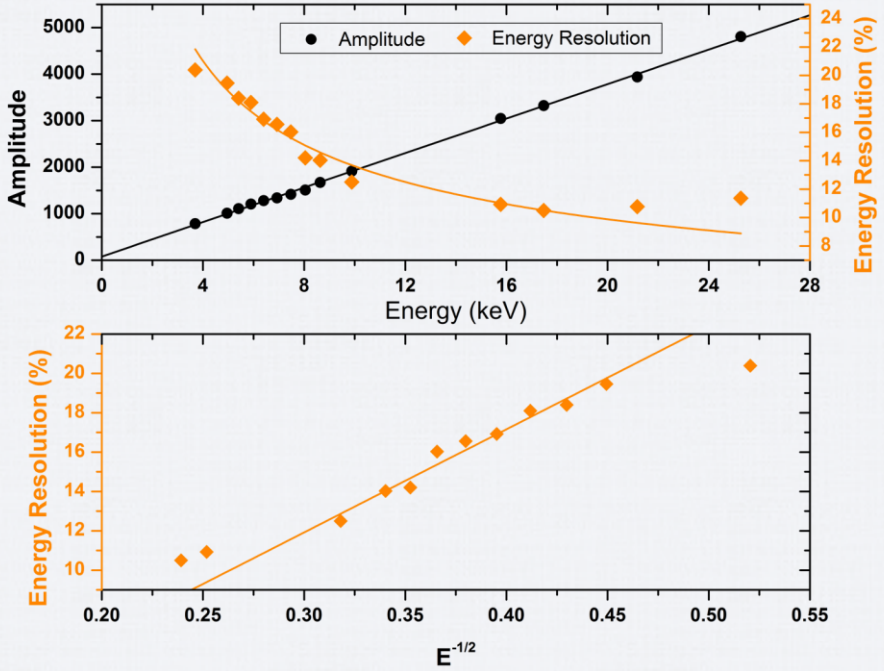
MPGDs and 2D-imaging



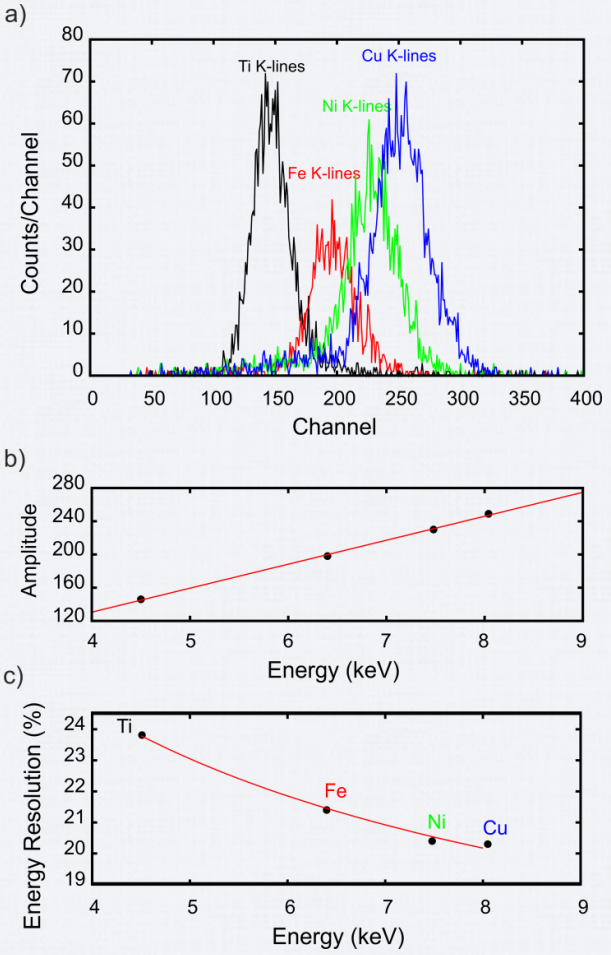
MPGDs and 2D-imaging

- Energy Resolution and linearity

MHSP - Xe @ 1 bar



THCOBRA - Ne/5%CH_4@ 1 bar



MPGDs and 2D-imaging

- Position resolution

Depends on…

Signal-to-Noise Ratio $\sigma_x = \frac{l}{\sqrt{2}}\left(\frac{1}{2}+\frac{Z}{R}\right)\frac{N}{S}$

Photoelectron range – gas dependence

MPGDs and 2D-imaging

- Position resolution

Depends on…

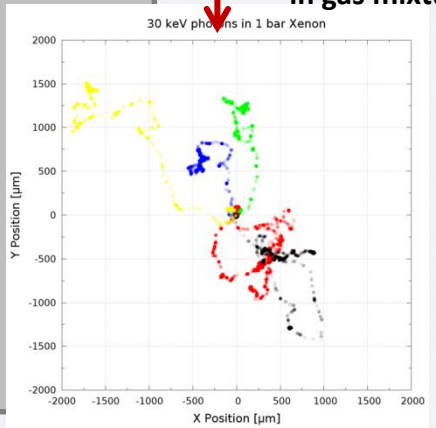
Signal-to-Noise Ratio $\sigma_x = \frac{l}{\sqrt{2}}\left(\frac{1}{2}+\frac{Z}{R}\right)\frac{N}{S}$

Photoelectron range – gas dependence

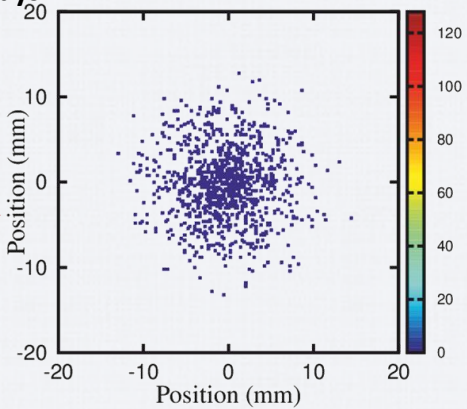
SIMULATIONS - Degrad

primary cluster spatial distribution in gas mixtures for X-rays

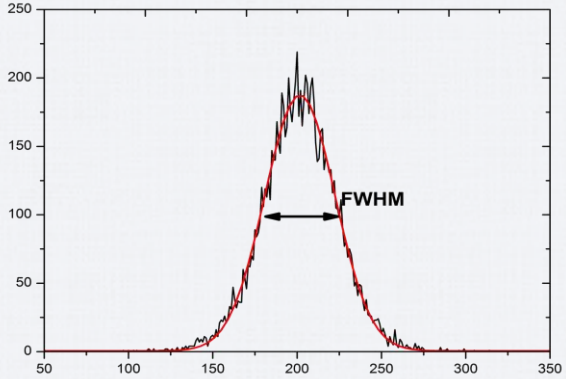
Gaussian distribution FWHM
uncertainty in the position of interaction.



Average Position

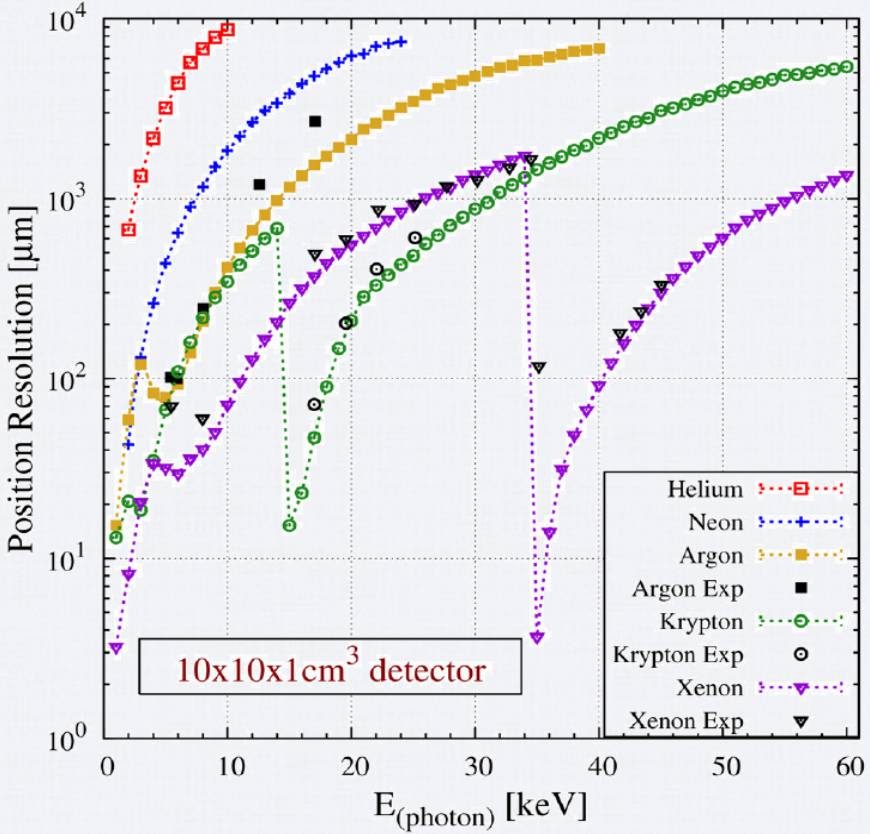


1D Projection



MPGDs and 2D-imaging

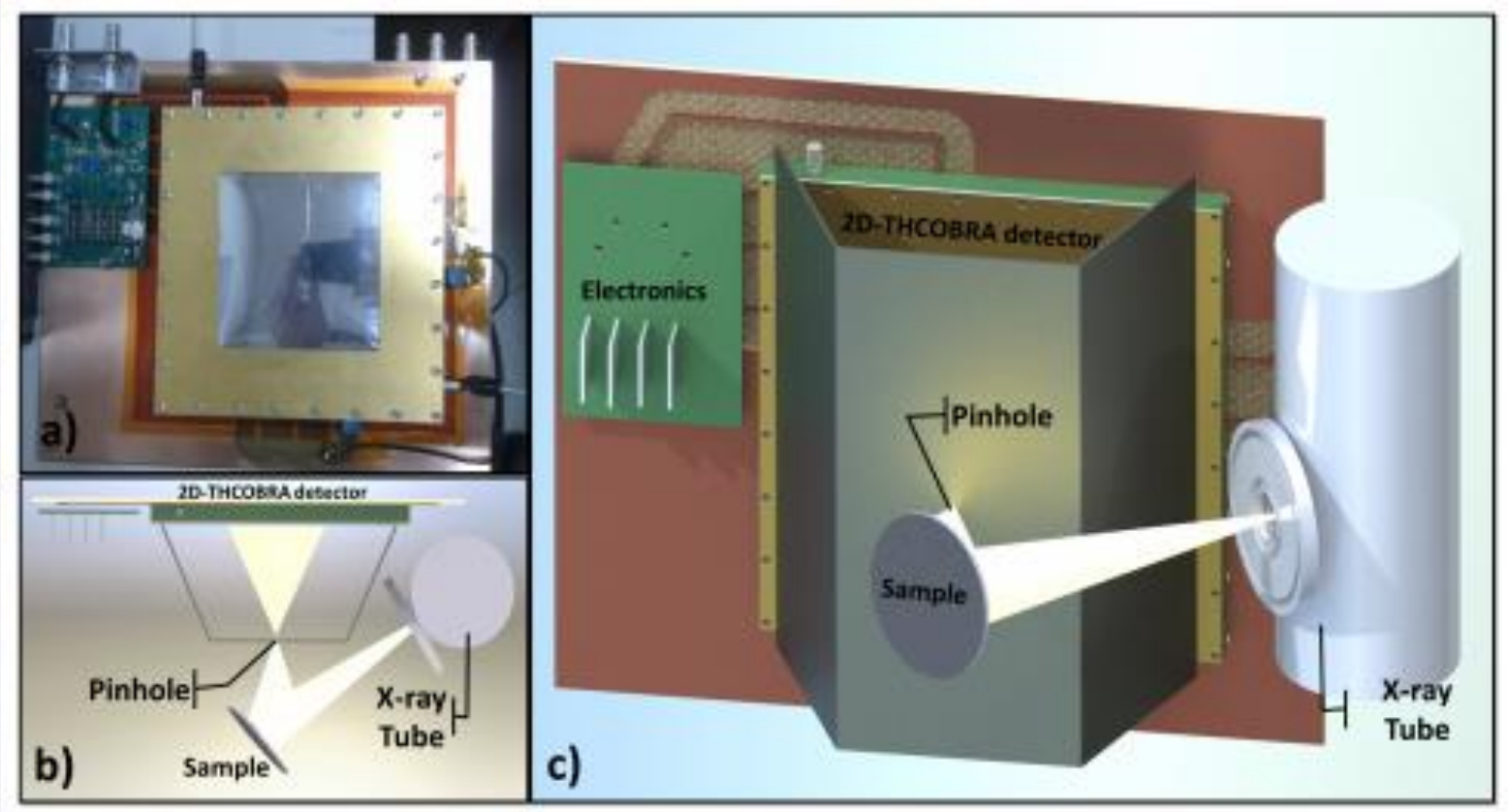
- Imaging Capability and Spatial Resolution **for X-rays** in He, Ne, Ar, Kr and Xe; 1atm
  Detector: 1 x 10 x 10 cm³



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

EDXRF Imaging System

X-RAY FLUORESCENCE IMAGING - THCOBRA



EDXRF Imaging System

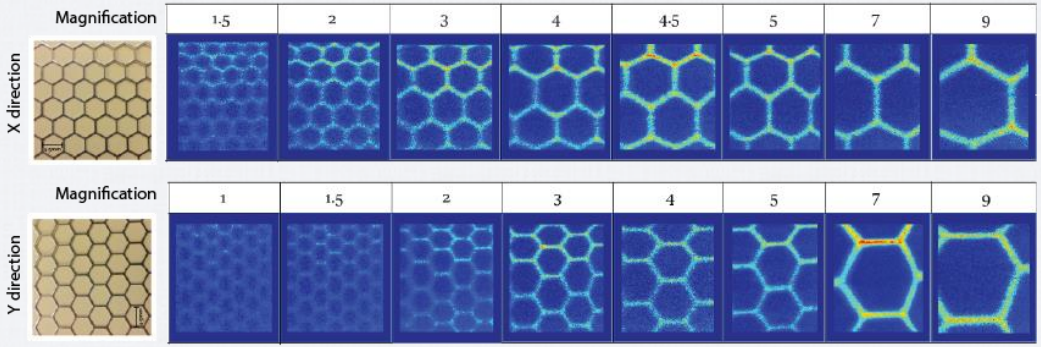
- Pinhole influence on the system spatial resolution:

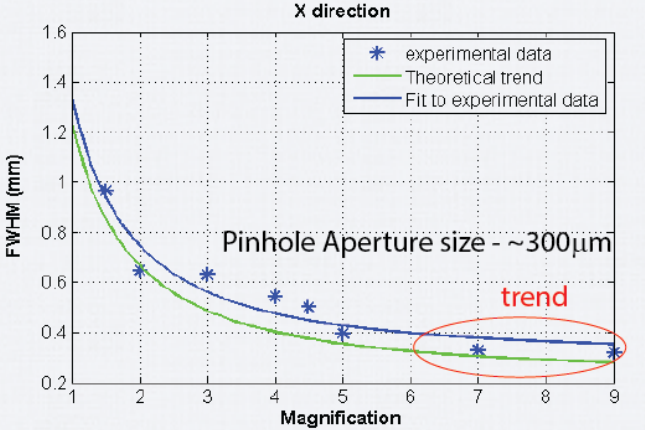
$$\lambda_s = \sqrt{\lambda_g^2 + \lambda_i^2} = \sqrt{d_p^2\left(1+\frac{1}{M}\right)^2 + \frac{FWHM_i^2}{M^2}}$$

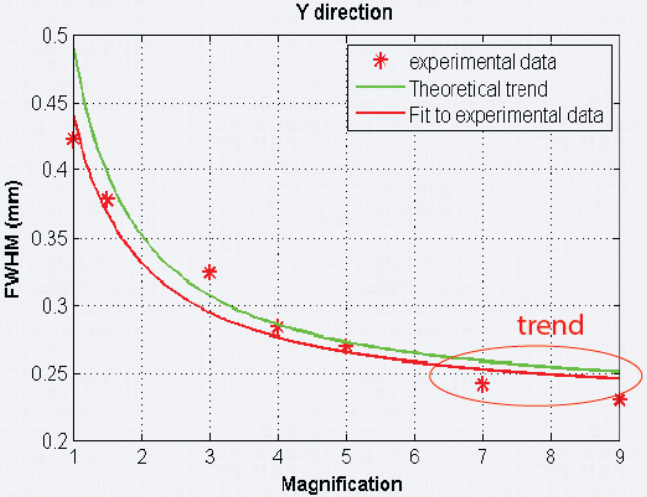
λ_g - Pinhole Contribution

λ_i - Detector Contribution

R. Accorsi, S. D. Metzler
IEEE TRANSACTIONS ON MEDICAL IMAGING, VOL. 23, NO. 6, JUNE 2004

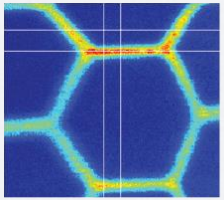




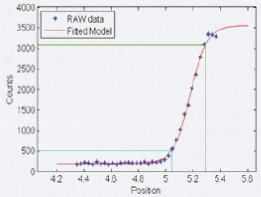


Method

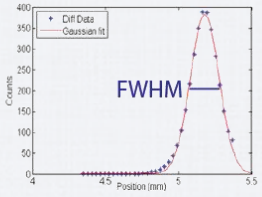
Selected Region



ESF

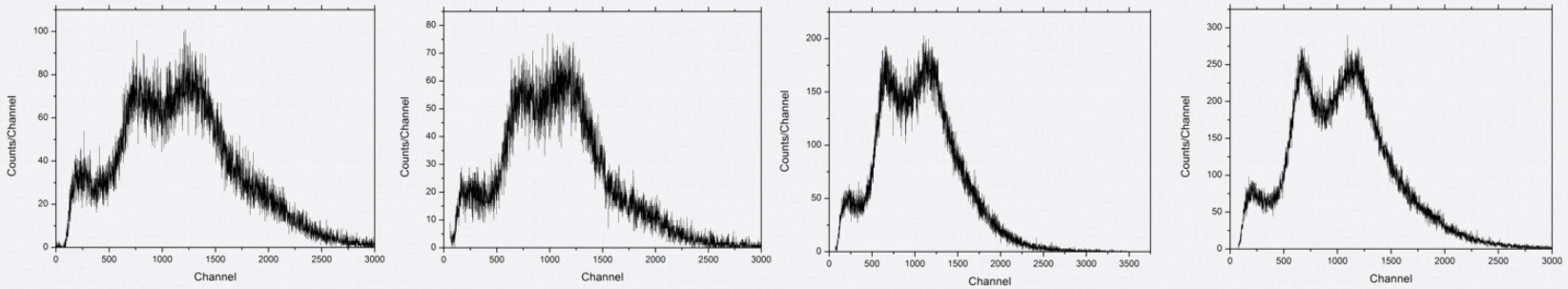


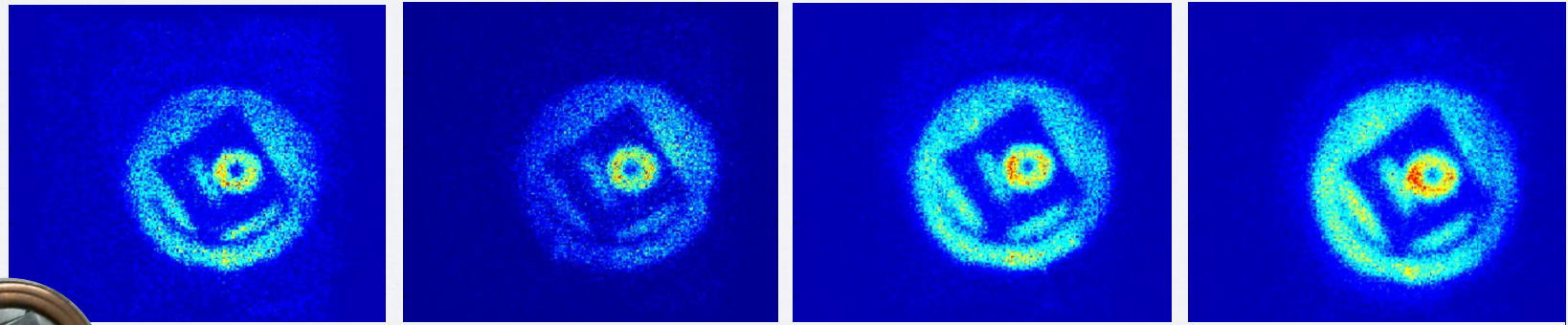
LSF

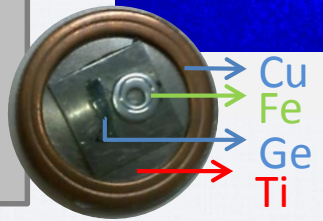


EDXRF Imaging System

500 µm	1 mm	1.6 mm	2 mm







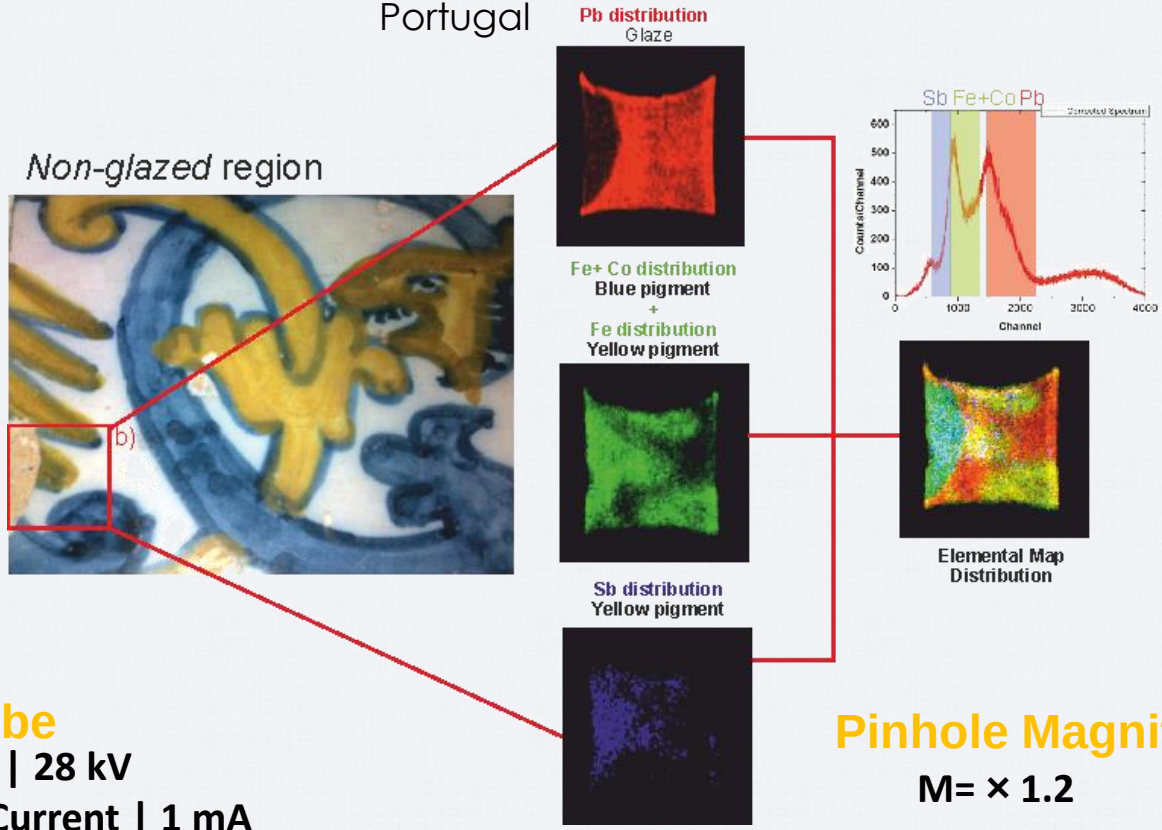
Higher pinhole efficiency – More photons detected per second

Image Quality – Spatial Resolution increases

face2face with cultural heritage - MHSP detector

Cultural heritage Application

Glazed tile from the XVII century, Odivelas Convent, Portugal



X-ray tube

Voltage | 28 kV

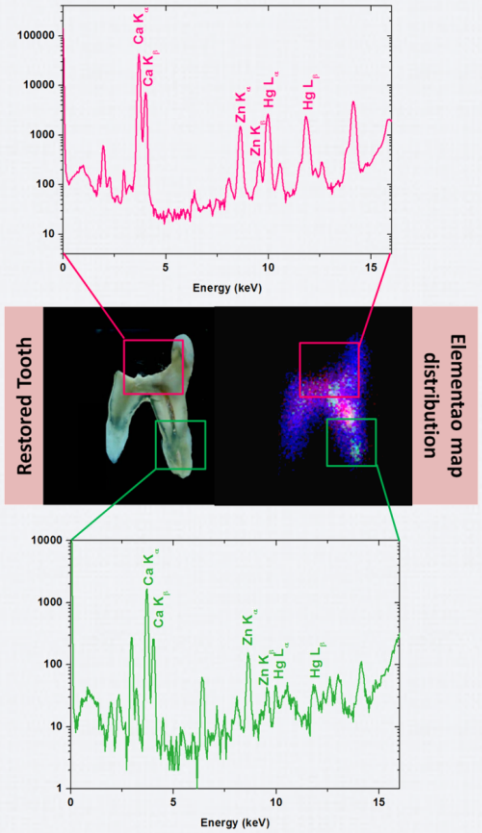
Anode Current | 1 mA

Pinhole Magnification

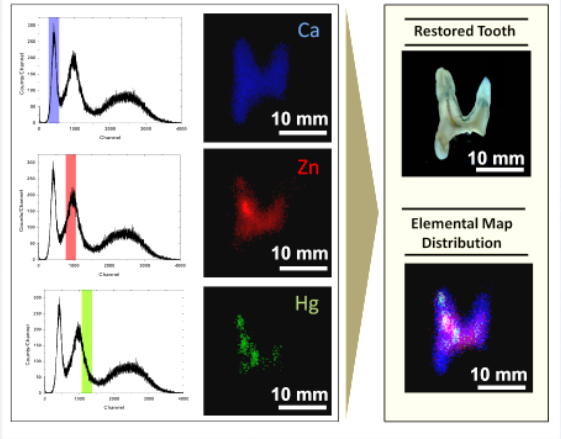
M= × 1.2

face2face with biomedical applications - MHSP detector

Biomedical Application



Distribution **of** **Hg** due to the metallic amalgam treatment



Magnification **M= × 1**

X-ray tube **Voltage | 27.5 kV**
Anode Current | 1 mA

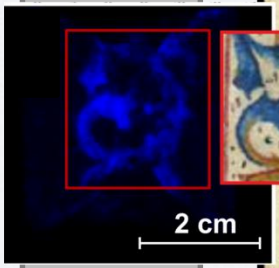
Restored Tooth

Hg in the region surrounding the amalgam, due to contamination

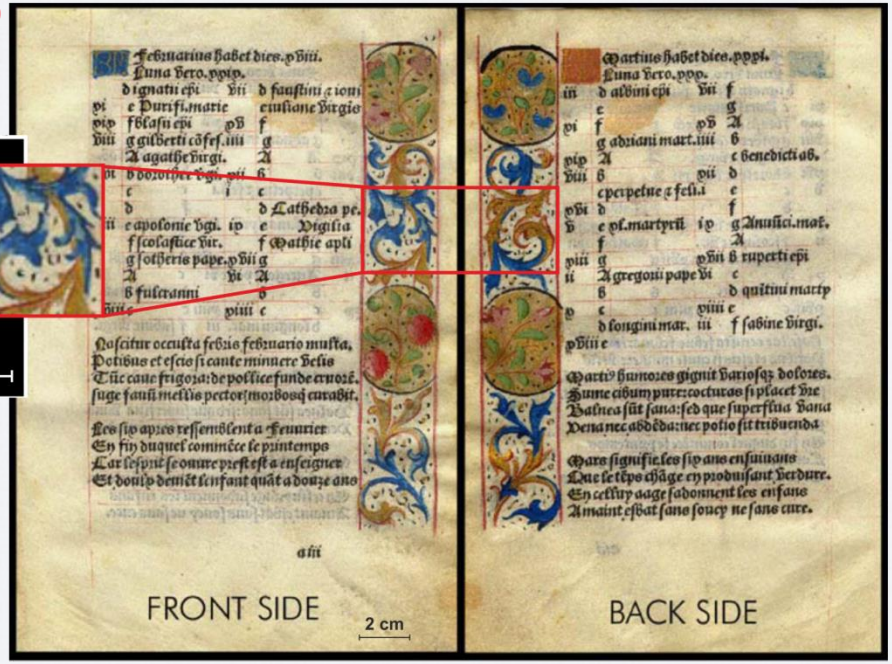
Hg in the root region of the tooth, due to occasional hydroxyapatite network lattice defects

face2face with cultural heritage /art- THCOBRA detector

Sample: Illuminated manuscript from the 15th-16th century



b)

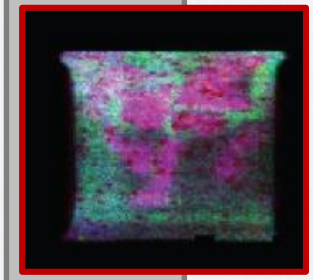


2 cm

FRONT COVER - 2015

face2face with cultural heritage /art- THCOBRA detector

Contemporary Indian Miniature

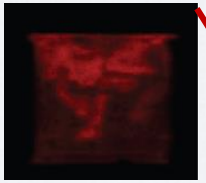


Elemental Distribution

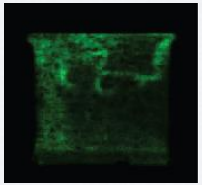
Tube-50 kV; 1 mA
(whole area)
M - x2.7
Acq.time - 1.5 h

=

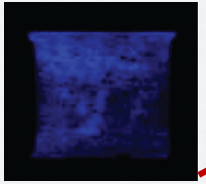
Ba

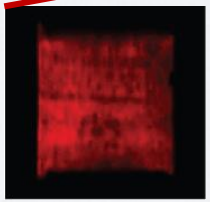


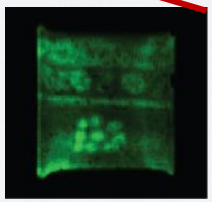
Pb



Zn







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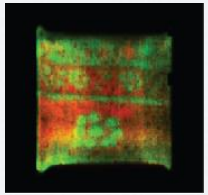


Tube – 50 kV; 1 mA (whole area)
M - x2.7
Acquisition time – 3.5 h

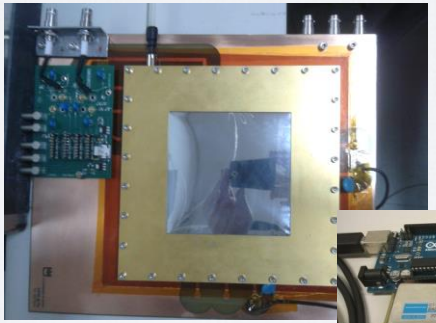
Fe + Zn

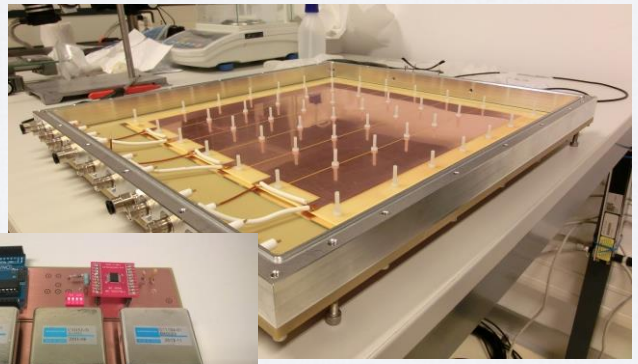
Pb

Elemental Distribution

Next step

- Explore possible applications in Industry – eg. welding point quality evaluation to be applied in the automobile industry.
- Xe/Kr gas mixtures –improve detection efficiency, gain and spatial resolution;
- Multi-pinhole alternatives – increase sensitivity to decrease acquisition time;
- Development of a 30x30 cm2 THCOBRA detector for EDXRF applications
- Portability





- **active area - 30x30 cm^2**

Thank you very much !!