

Compton Camera Based on Timepix3 for Nuclear Decommissioning

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GEFÖRDERT VOM

Bundesministerium
für Bildung
und Forschung



PTKA

Projektträger Karlsruhe

Karlsruher Institut für Technologie

Agenda

- Motivación
- Detectores contadores de fotónes
- Reconstrucción de imágenes basadas en Compton
- Resultados
- Conclusiones

NEWS

Home War in Ukraine Climate Video World UK Business Tech Science Entertainment & Arts

Asia China India

Fukushima disaster: What happened at the nuclear plant?

23 August

Fukushima nuclear disaster



BASE TOPICS NEWS

NUCLEAR SAFETY

Nuclear Facilities - Reportable Events - Decommissioning - Nuclear Accidents



Homepage > Topics > Nuclear Safety > Nuclear phase-out

Overview: Nuclear Safety

The nuclear phase-out in Germany

The Bundestag resolution on 30 June 2011 laid the foundation for the new search for a final repository

10 years of nuclear phase-out: great success, but still a lot to do

The decision of the German Bundestag on 30 June 2011 to phase out nuclear energy has paved the way for an orderly withdrawal from this high-risk technology in Germany. At the same time, the phase-out allowed a recommencement of the search for a final repository for high-level radioactive waste.

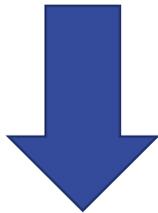
The lifetimes of the remaining nuclear power plants

- All German nuclear power plants that had gone into operation up to and including 1980

Motivación

Cese de operaciones en Abril del 2023 !

Gran cantidad de plantas nucleares en proceso de desmantelamiento



Sin número de oportunidades para la innovación en el reciclaje y clasificación de material nuclear

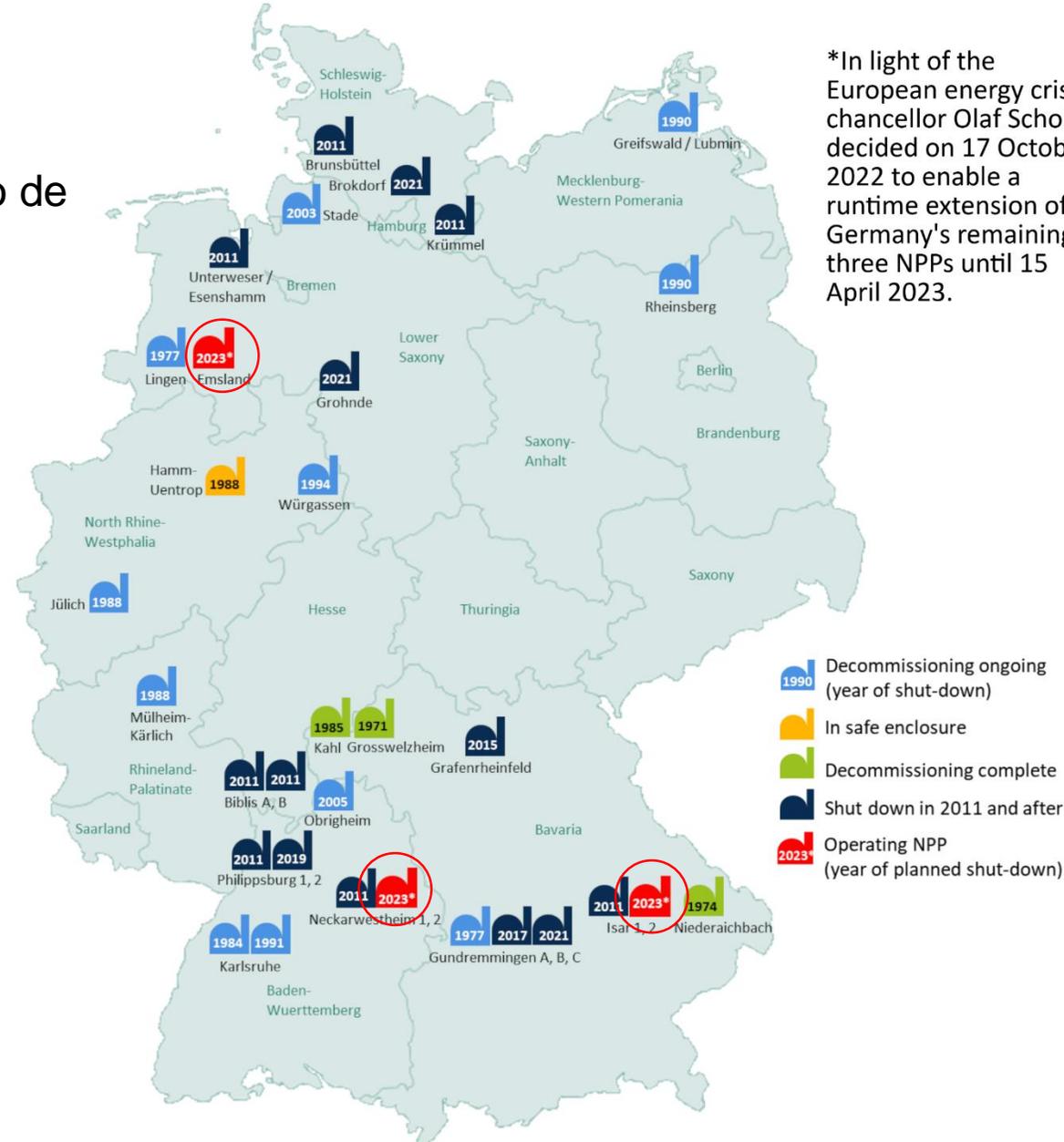


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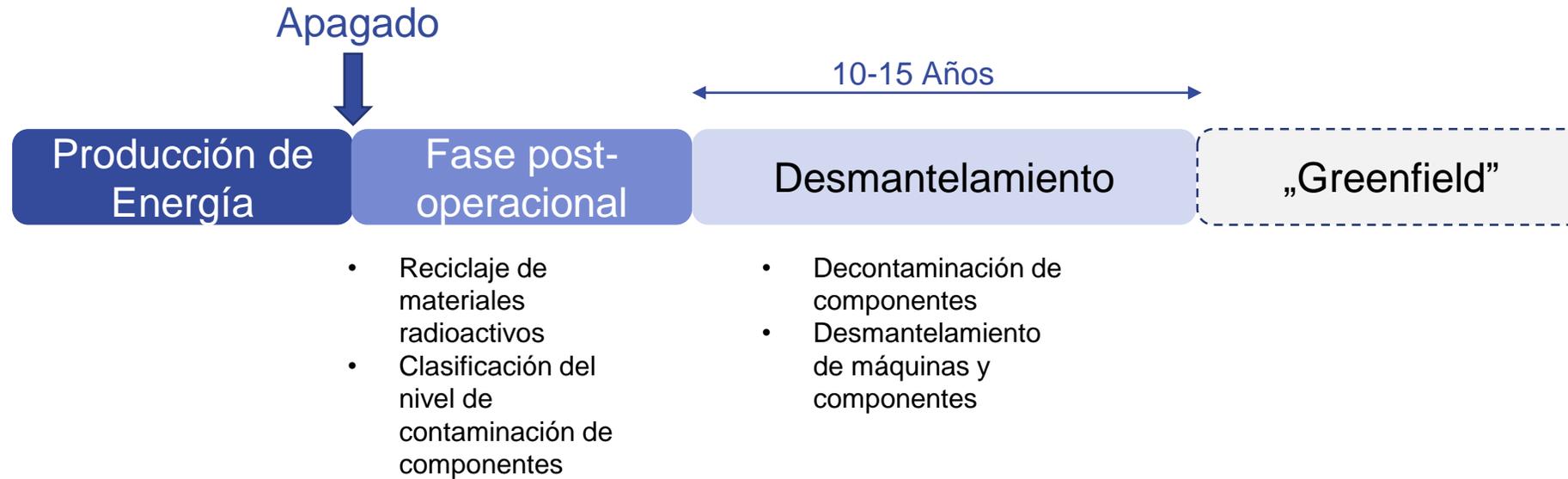
Location and status of Germany's nuclear power stations and year of (planned) shut down.

Data: BASE 2022, federal government 2022.



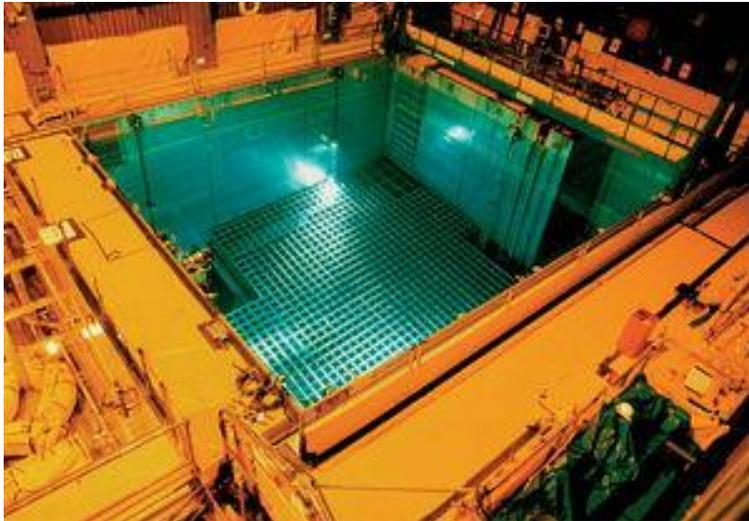
Motivación

Ciclo de vida de una central nuclear:



Motivación (Desmantelamiento)

1) Decarga de combustible nuclear



Reprocesamiento



- Enriquecimiento de Uranio
- Combustible MOX

Almacenamiento definitivo

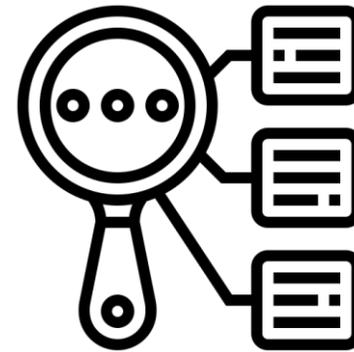


Motivación (Desmantelamiento)

2) Segmentación de components de la planta



3) Clasificación por niveles de radioactividad



Alto



Almacenamiento
temporario (in-situ)

Medio



- Almacenamiento definitivo
- Reciclaje

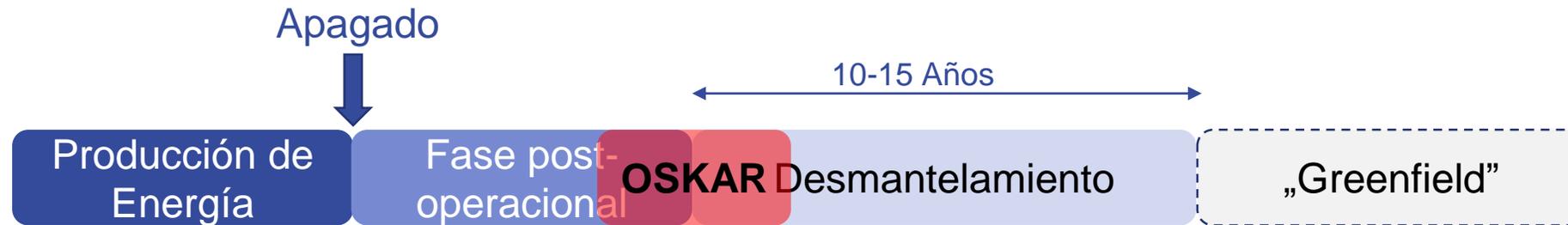
Bajo

Chernobyl (Bóveda de contención)



Motivación

Ciclo de vida de una central nuclear:



- Reciclaje de materiales radioactivos
- Clasificación del nivel de contaminación de componentes

- Decontaminación de componentes
- Desmantelamiento de máquinas y componentes



Presencia de focos de radiación ?



Identificación de isótopos radioactivos ?



Medición de los niveles de radiación ?



Proyecto OSKAR

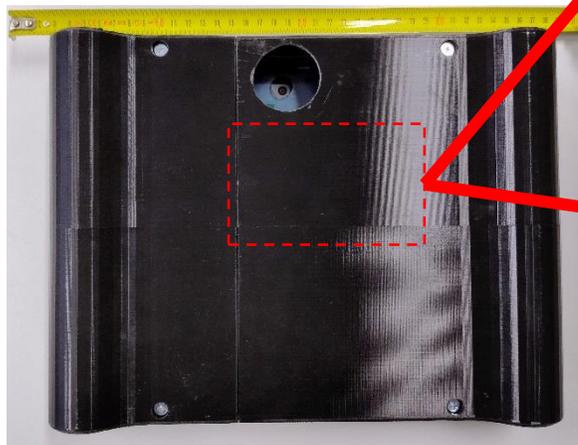
OSKAR



Ortsaufgelöste Strahlungskamera mit Radionuklididentifikation
“Cámara para la localización e identificación de isótopos radioactivos”

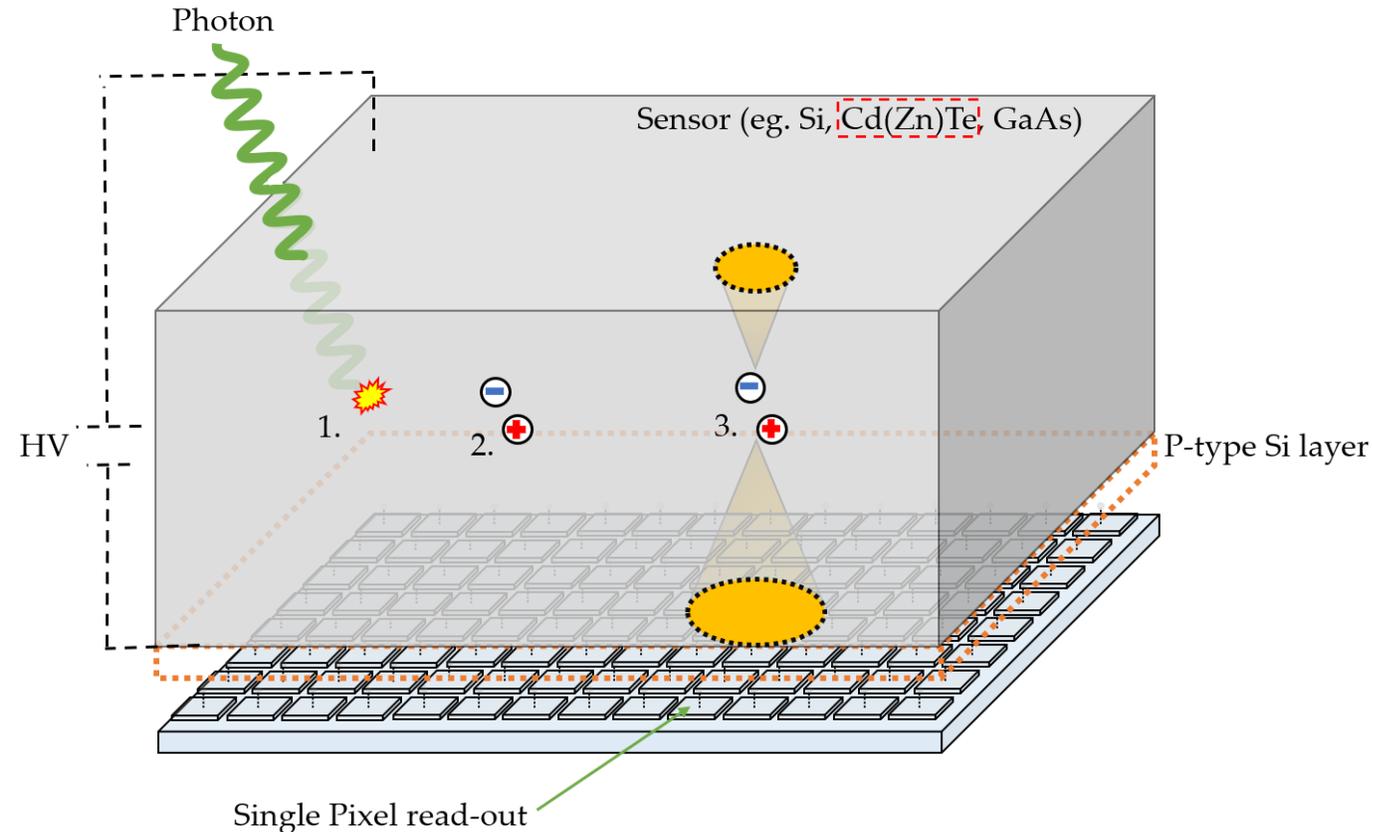


- Portabilidad
- Facilidad de uso
- Basada en un detector **contador de fotones** (Timepix 3)
- Usar el **efecto Compton** para la localización de la radiación



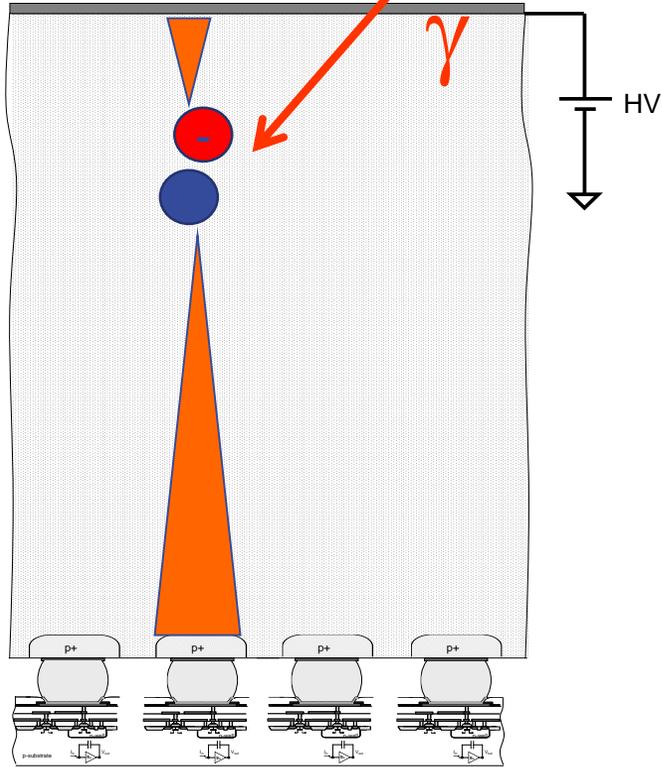
Detectores contadores de fotones

Detectores contadores de fotones



Timepix 3	
Pixel matrix / size	256 x 256 / 55 μm x 55 μm
Technology	CMOS 130 nm
Measurement modes	<ul style="list-style-type: none"> Simultaneous 10 bit TOT and 14 + 4 bit TOA 14 + 4 bit TOA only 10 bit PC and 14 bit integral TOT
Readout type	<ul style="list-style-type: none"> Data driven Frame based
Dead time (pixel, data driven)	>475 ns (pulse processing + packet transfer)
Output bandwidth	40 Mbits/s – 5.12 Gbits/s
TOA Precision	1.56 ns

Timepix3 - Data-driven ToT+ToA Mode

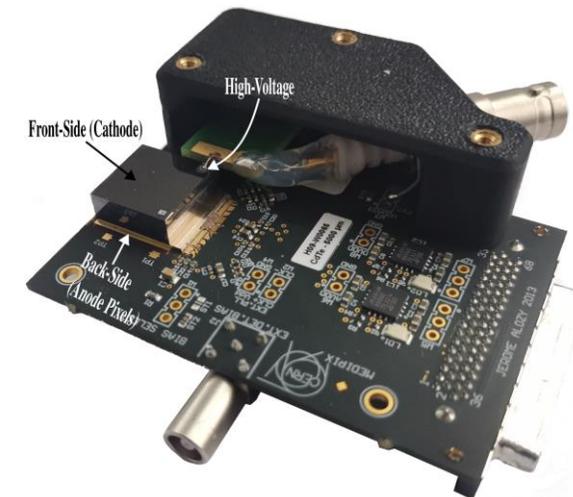
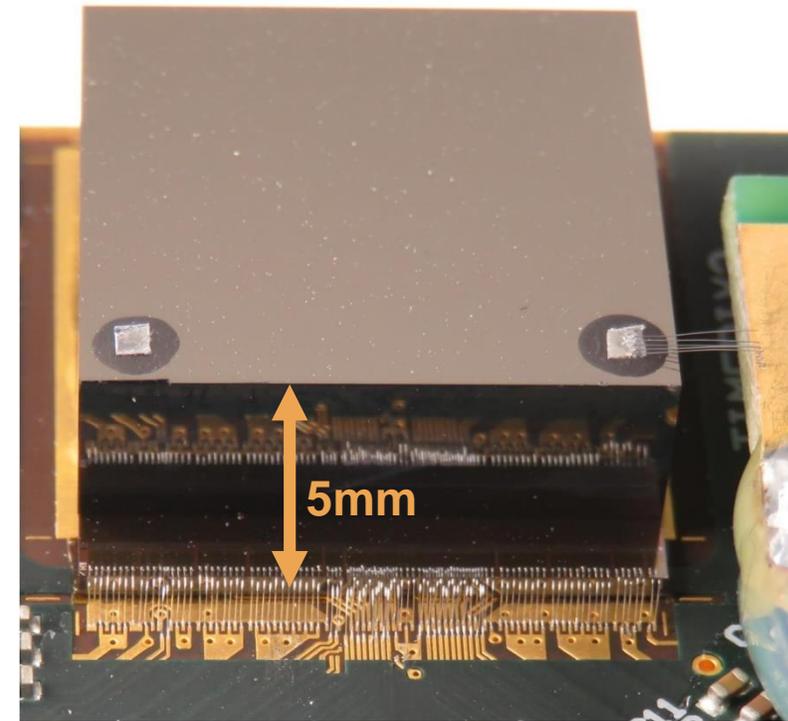
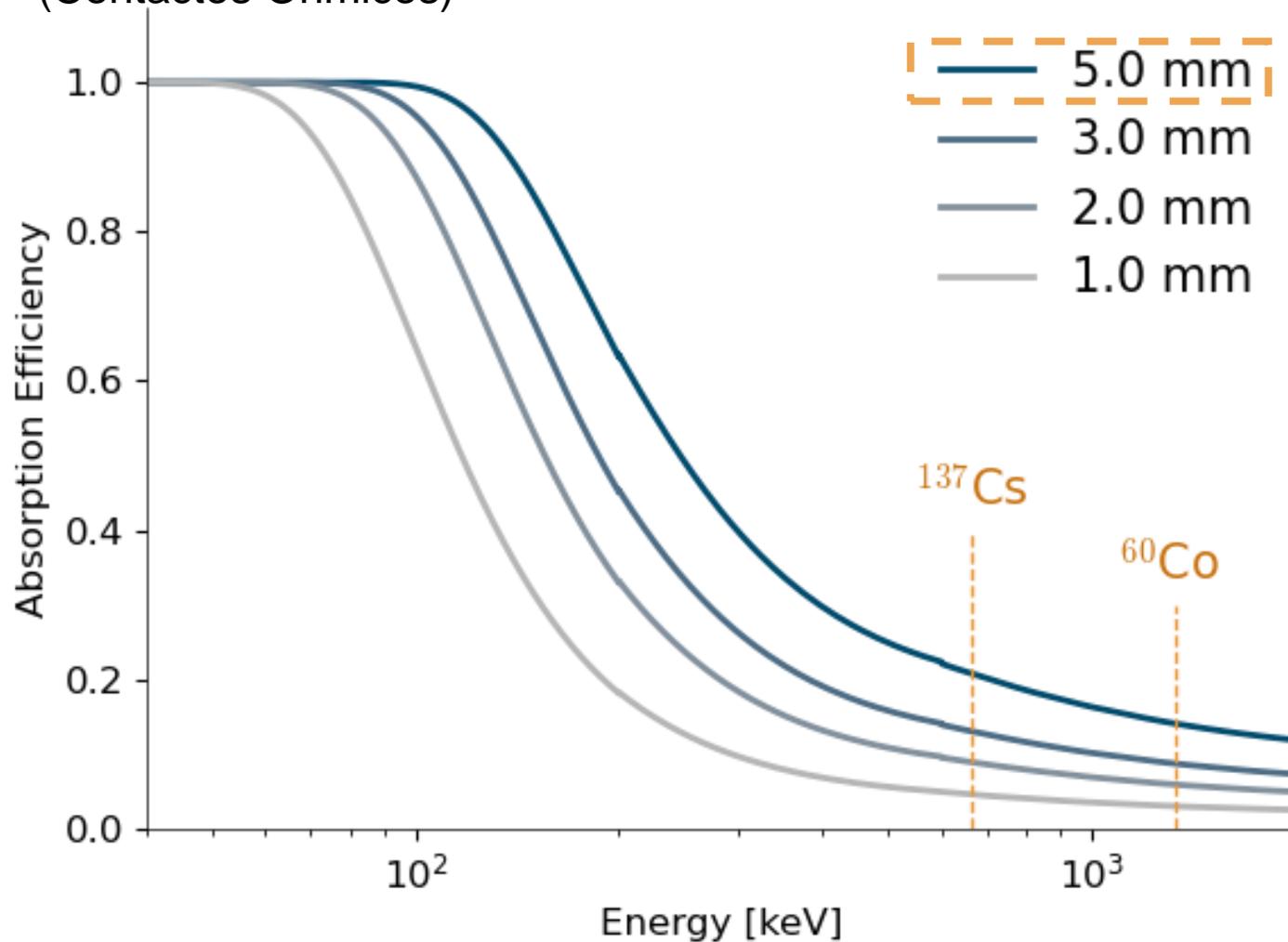


R. Ballabriga et al.,
"Characterization of the
Medipix3 Pixel Readout
Chip", IWORID 2010

Photon Counting detectors

Un grosor de **5mm** tiene una mayor probabilidad de absorción a las energías requeridas en un una planta nuclear.

(Contactos Ohmicos)

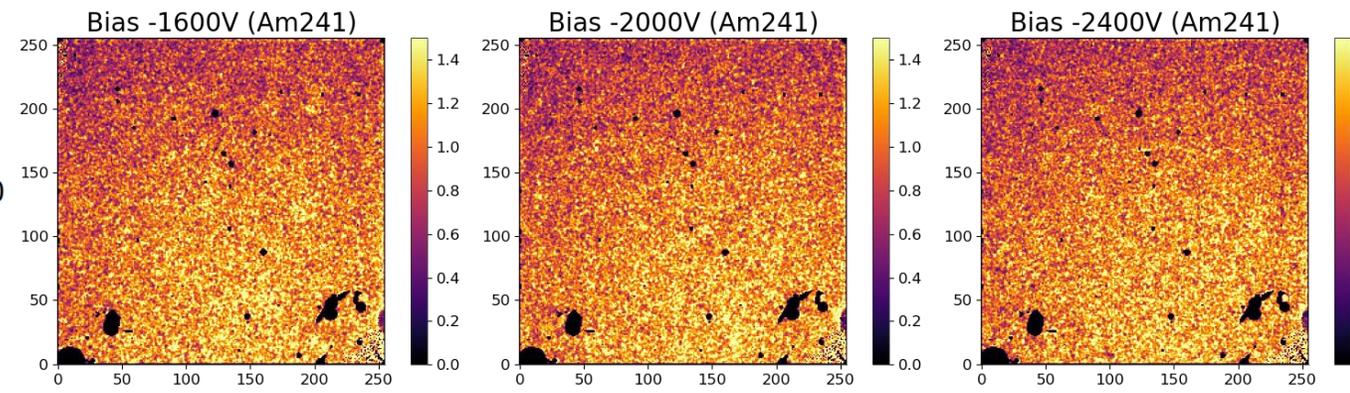
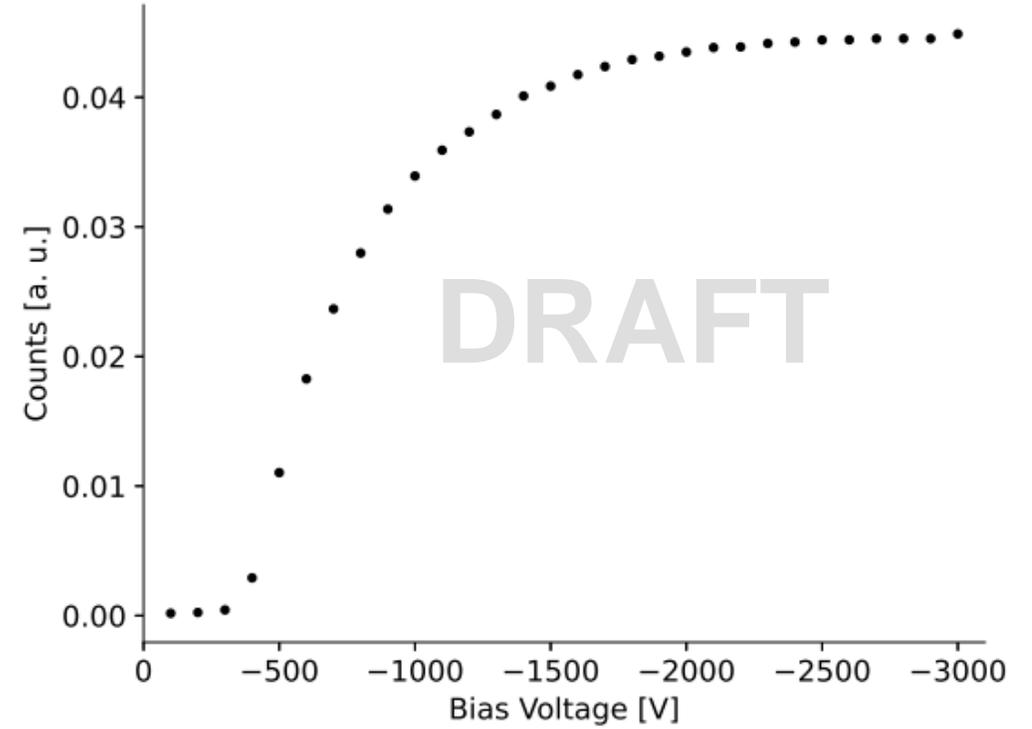
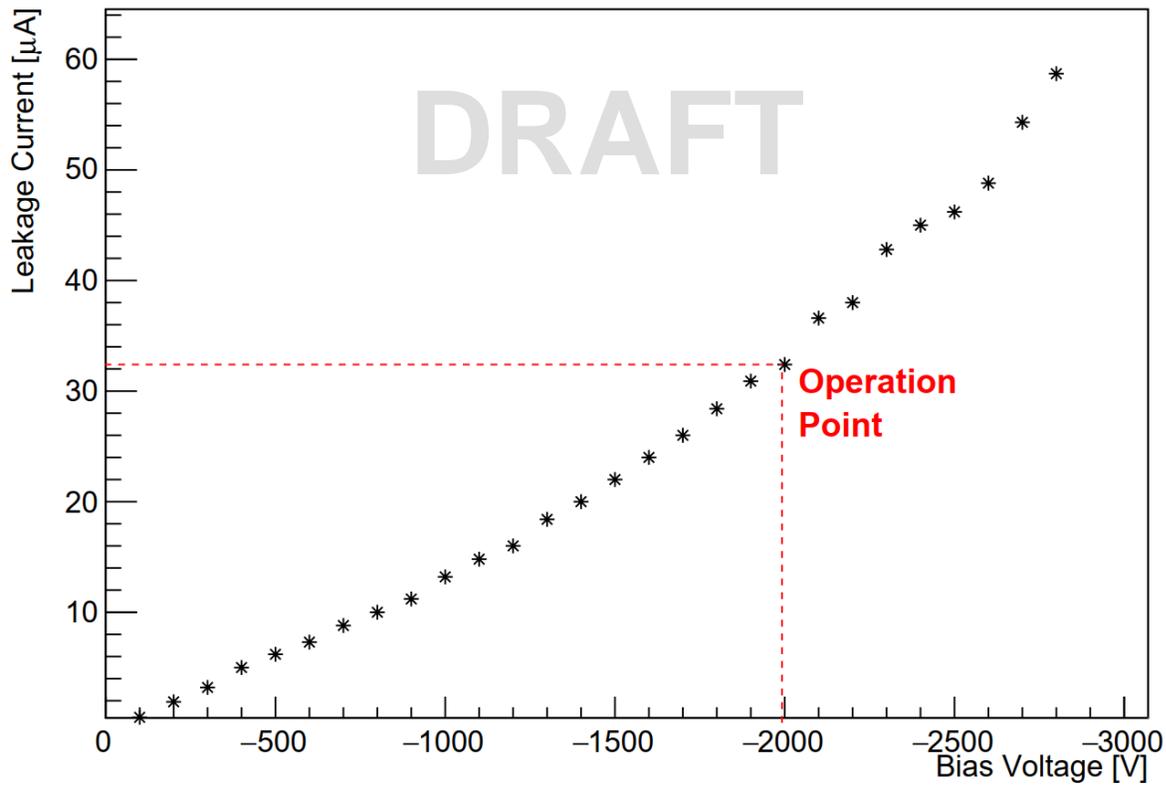


Caracterización



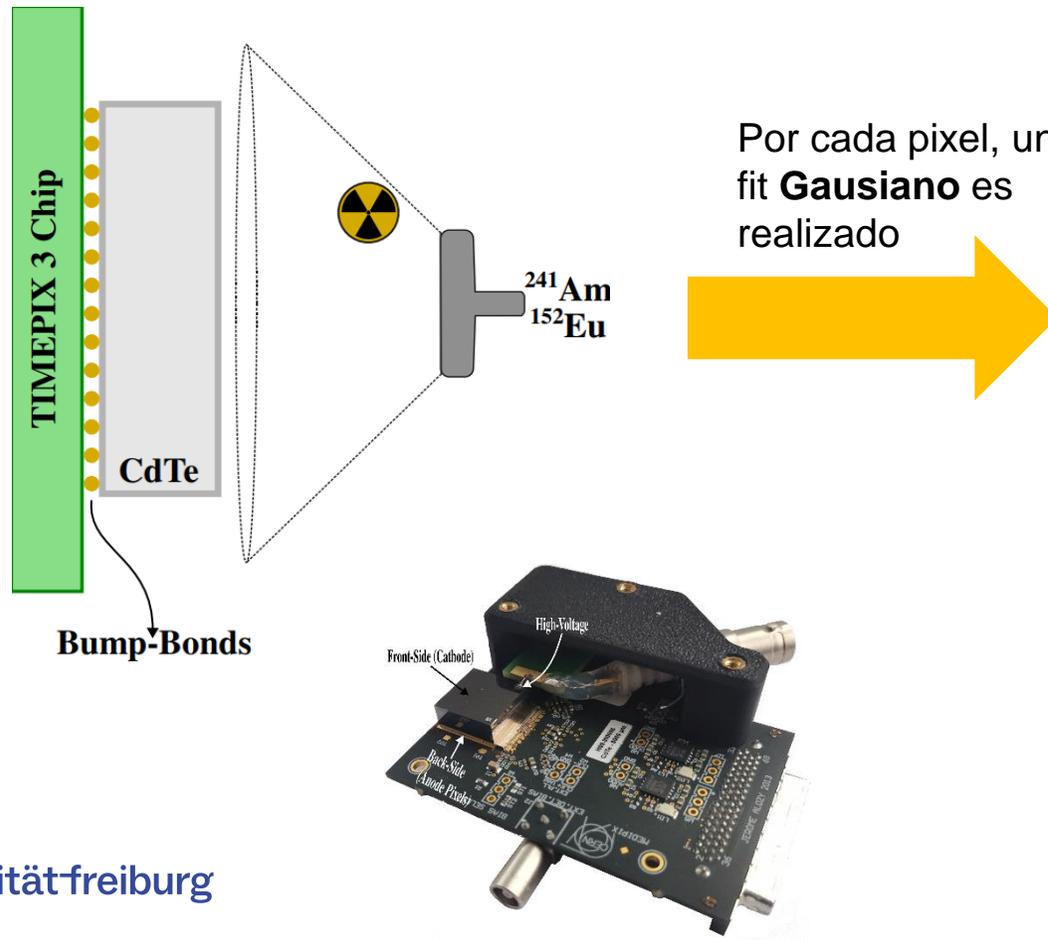
Caracterización

El voltaje de operación es seleccionado a partir de la **minimización** de la corriente de fuga y la **maximización** de los conteos registrados



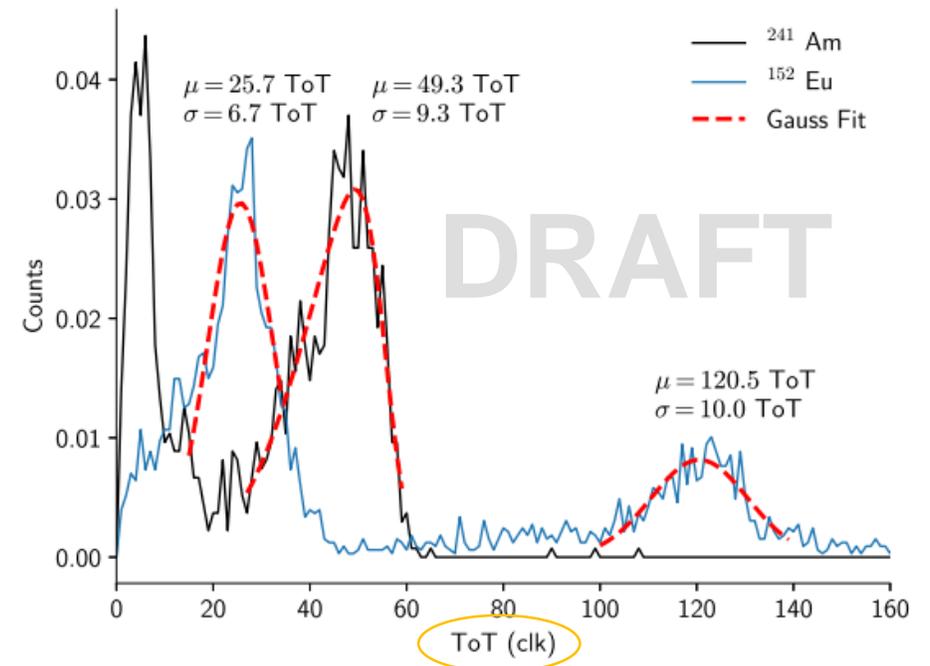
Calibración de la Energía

Calibración **Per-Pixel**, realizada desde el **Cátodo (Frente)**.



Por cada pixel, un fit **Gausiano** es realizado

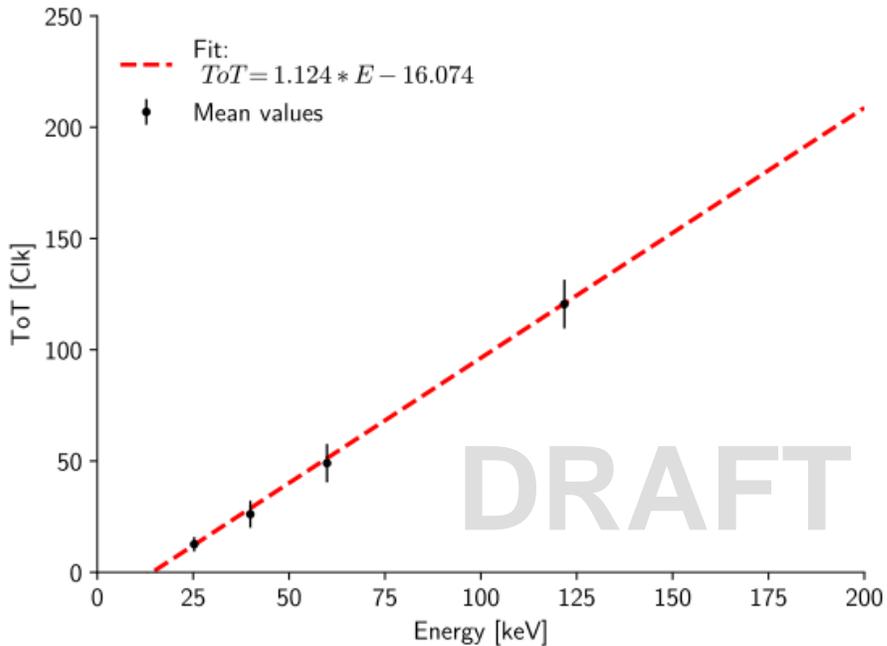
Pixel 37585



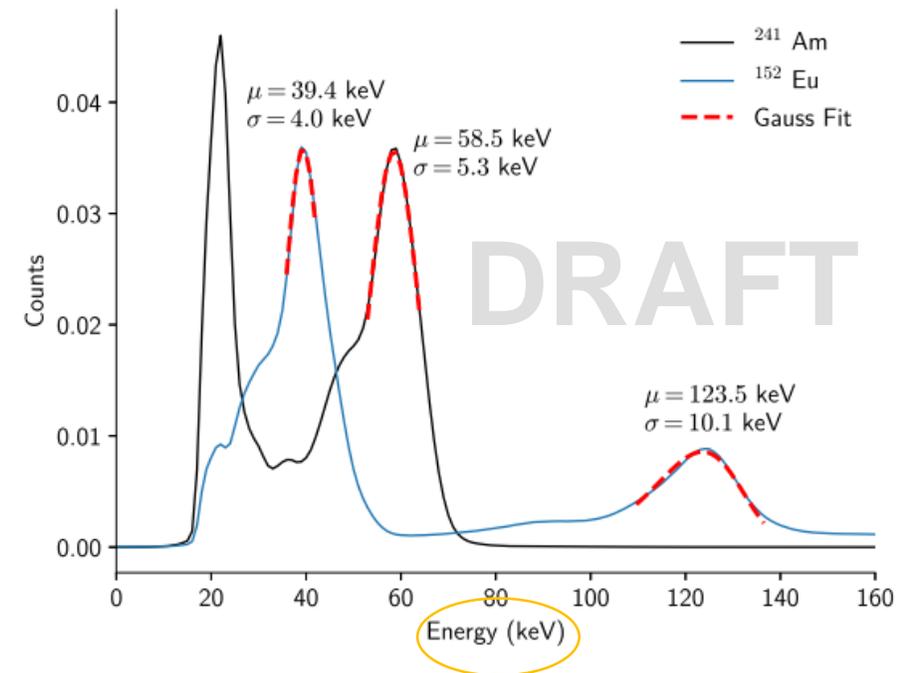
Calibración de la Energía

Cada pixel tiene una función **lineal** de calibración.

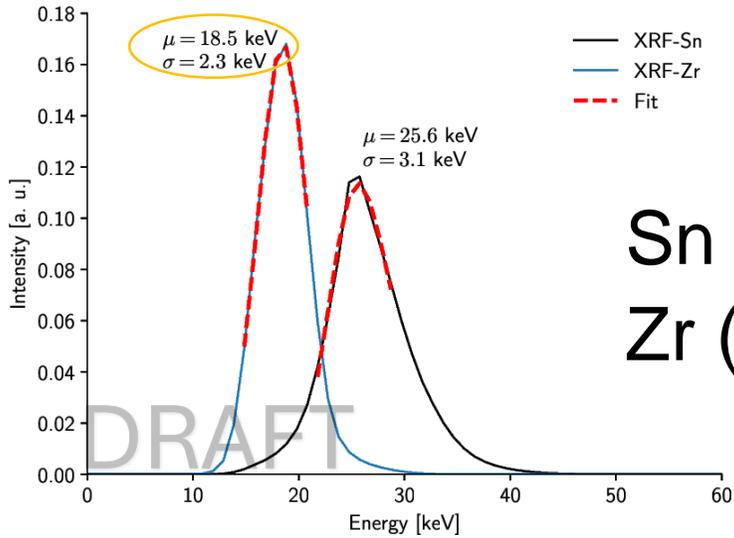
Pixel 37585



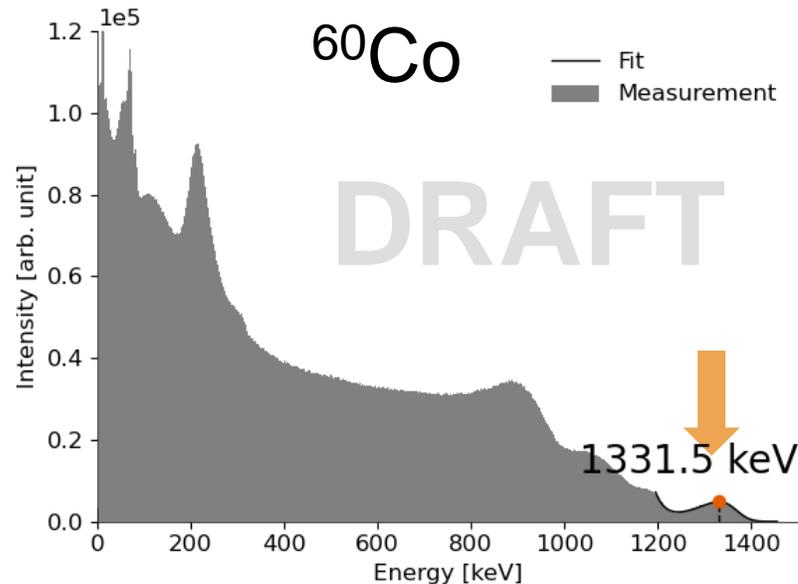
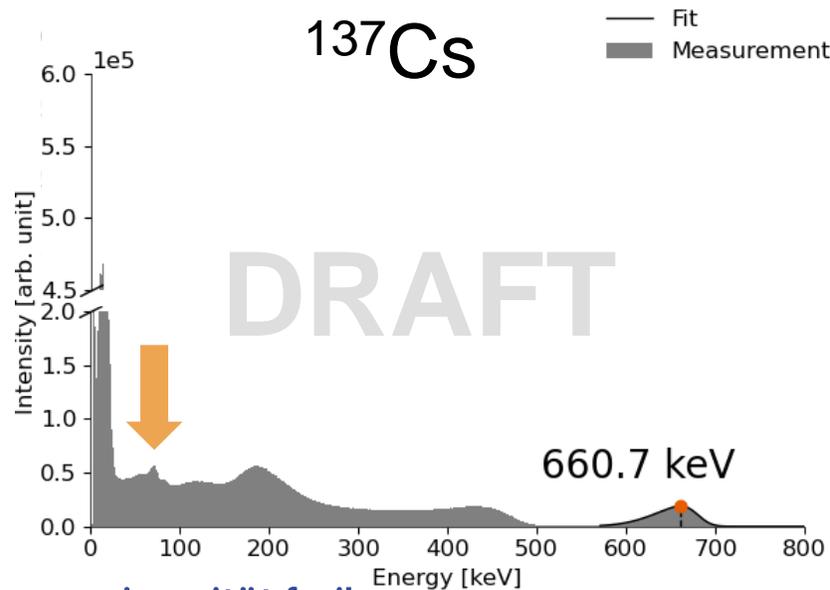
Full-detector



Respuesta en Energía

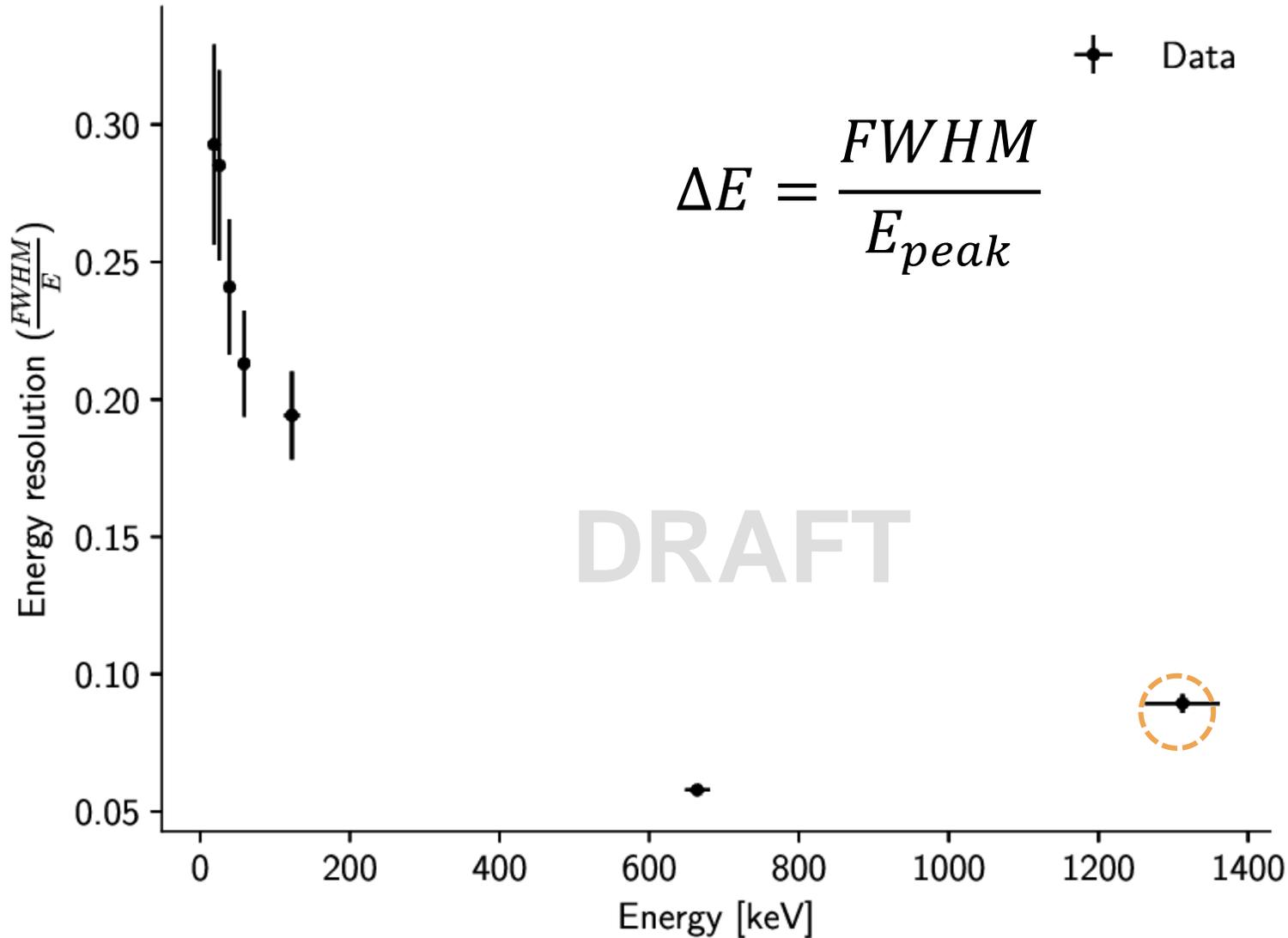


- **Sobre estimación** de valores de energía bajos, fuera del rango de calibración
- Reconstrucción incompleta de eventos a baja energía
- Fluorescencia (X-Ray) de Pb



Isotope	Photopeak Energy [keV]	Meas. Energy [keV]
Zr (K_{α_1})	15.8	18.5 ± 2.3
Sn (K_{α_1})	25.3	25.6 ± 3.1
^{241}Am	59.9	58.5 ± 5.3
^{152}Eu	121.8	123.5 ± 10
^{137}Cs	662	661.8 ± 26.6
^{60}Co	1332	1331.5 ± 49.8

Resolución Energética



Disminución de la resolución con la energía



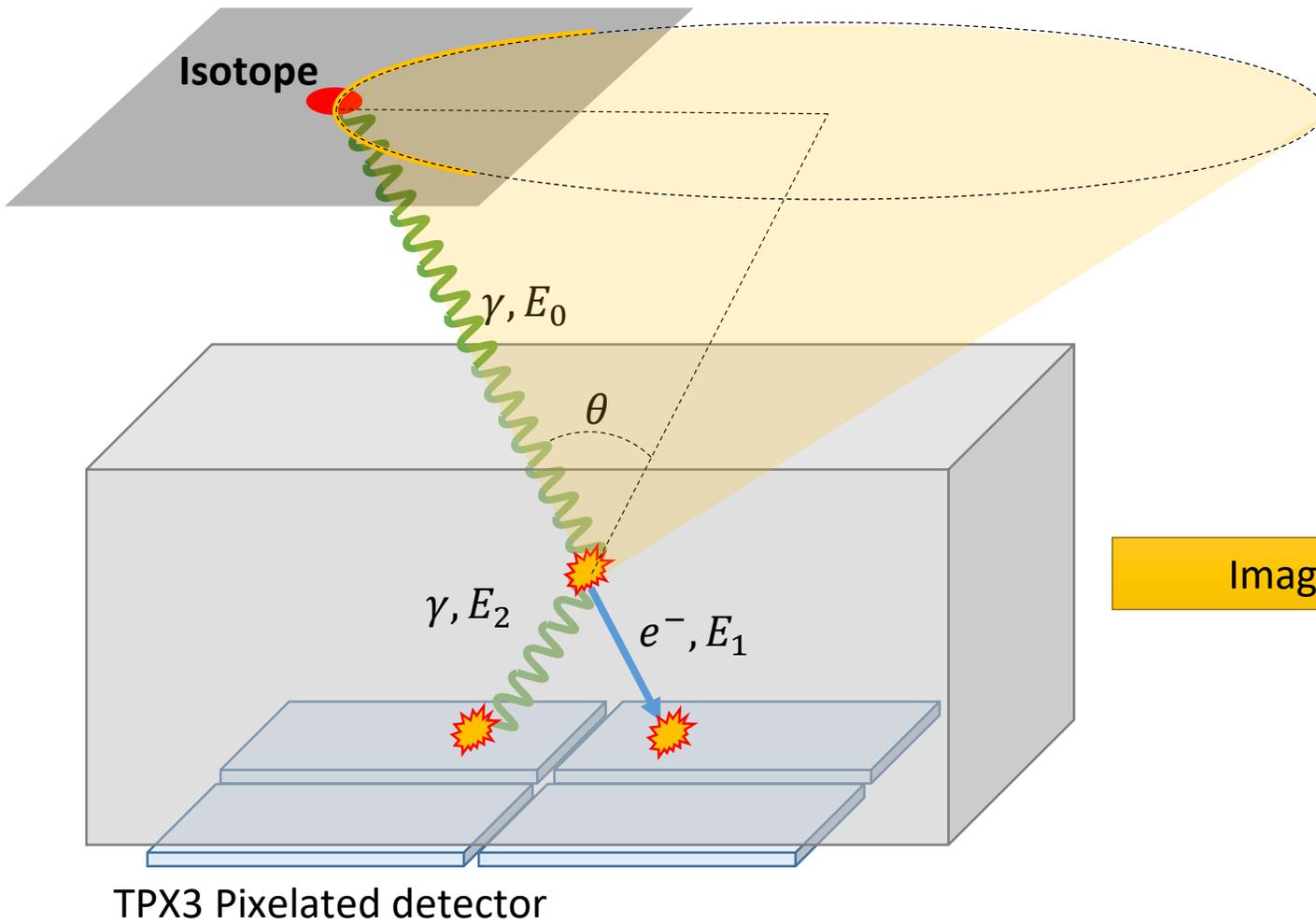
Mejor definición de los picos a altas energías

● ^{60}Co afectado por el “ruido” generado por el pico a 1117 keV.

Compton Imaging

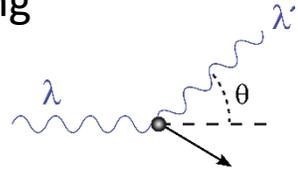


Compton Imaging

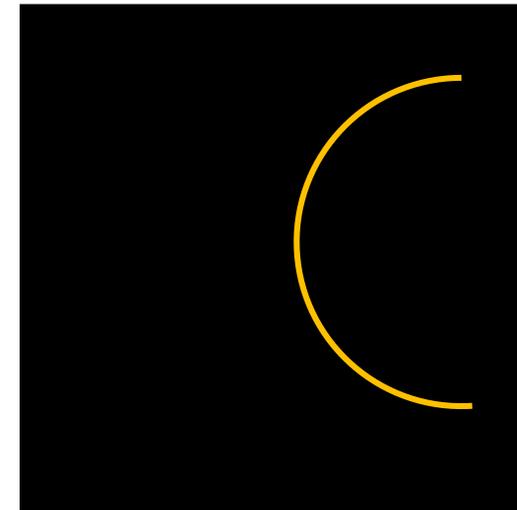


- Basada en Compton scattering

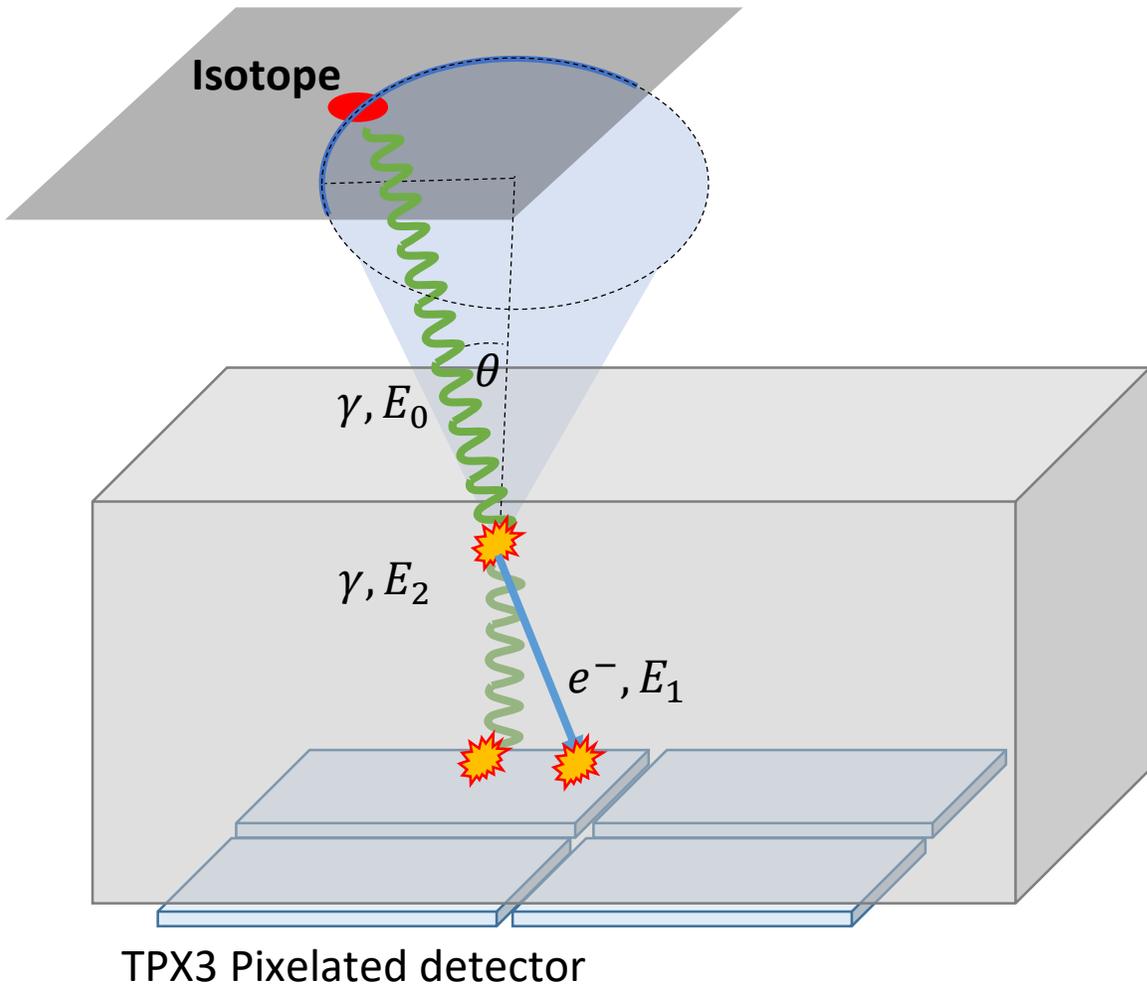
$$E_0 = E_1 + E_2$$



$$\cos \theta = 1 - \frac{m_e c^2 E_1}{E_2 (E_1 + E_2)}$$



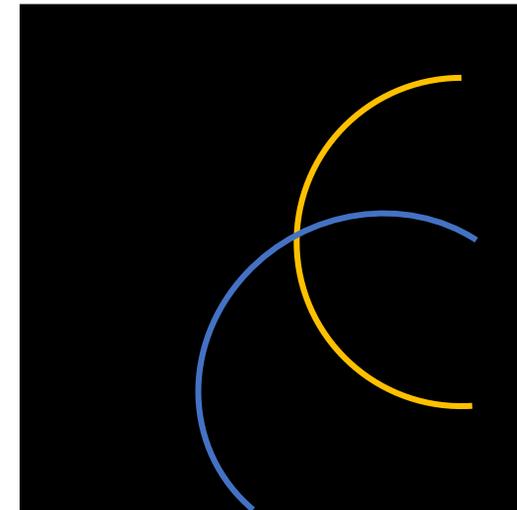
Compton Imaging



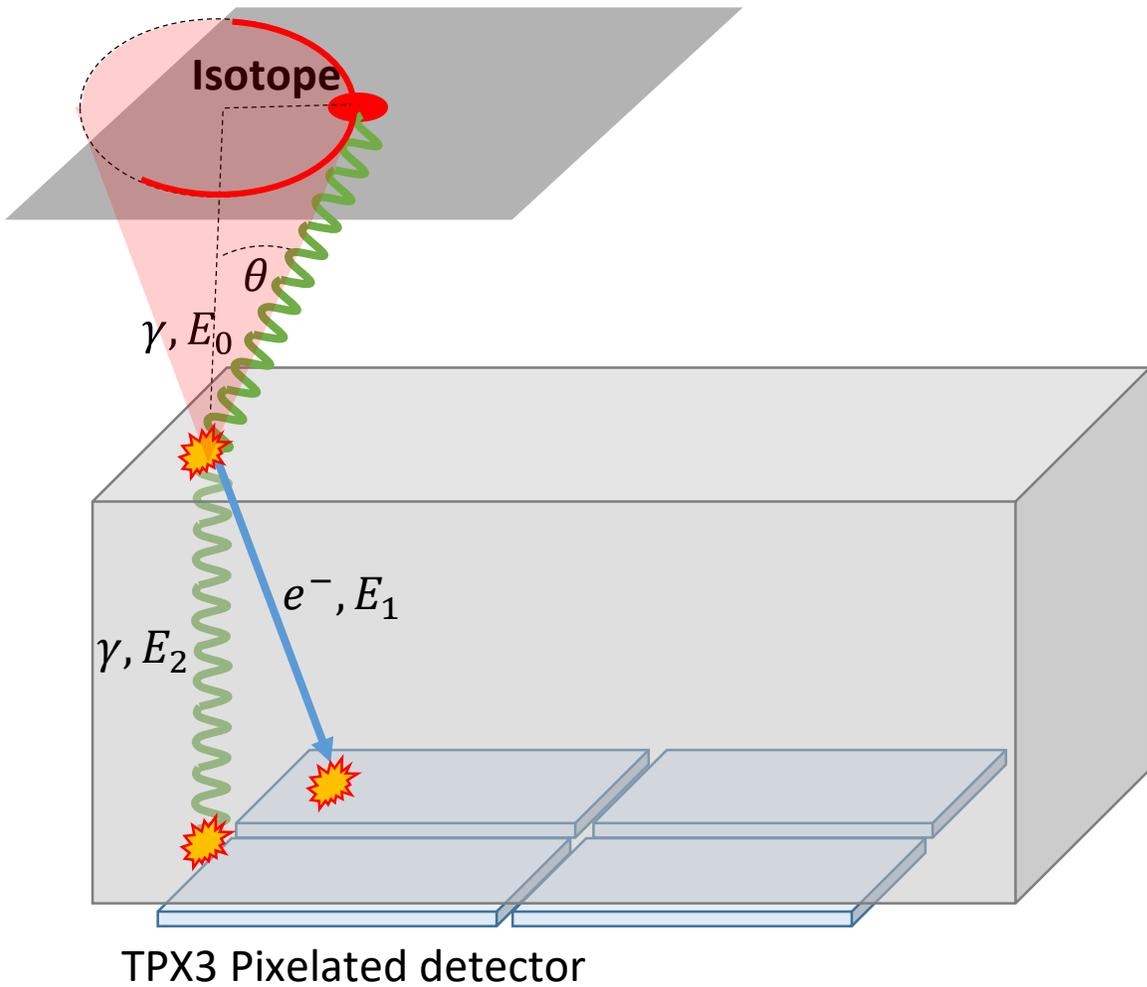
- Based on Compton scattering

$$E_0 = E_1 + E_2$$

$$\cos \theta = 1 - \frac{m_e c^2 E_1}{E_2(E_1 + E_2)}$$



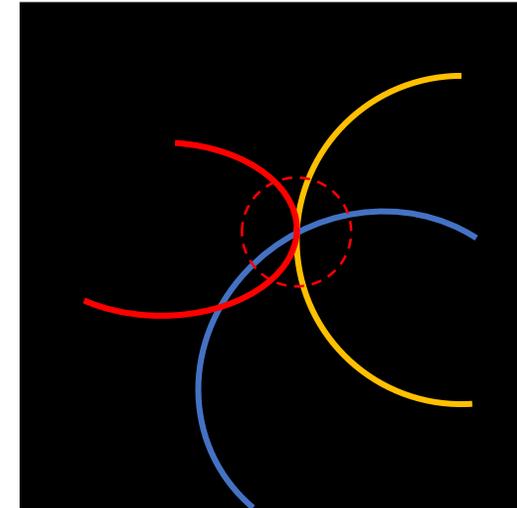
Compton Imaging



- Based on Compton scattering

$$E_0 = E_1 + E_2$$

$$\cos \theta = 1 - \frac{m_e c^2 E_1}{E_2 (E_1 + E_2)}$$



Compton Imaging



Imagen Fotográfica

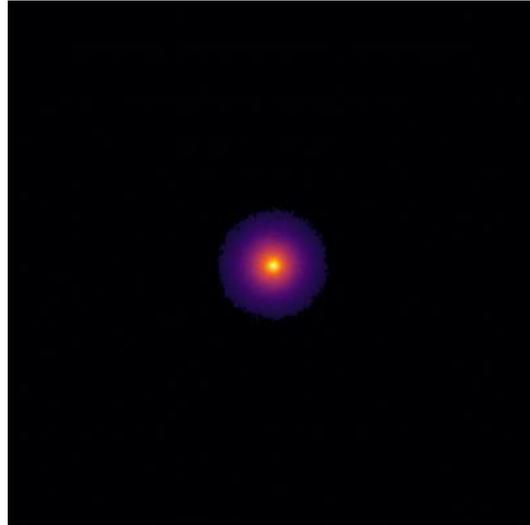


Imagen de Compton

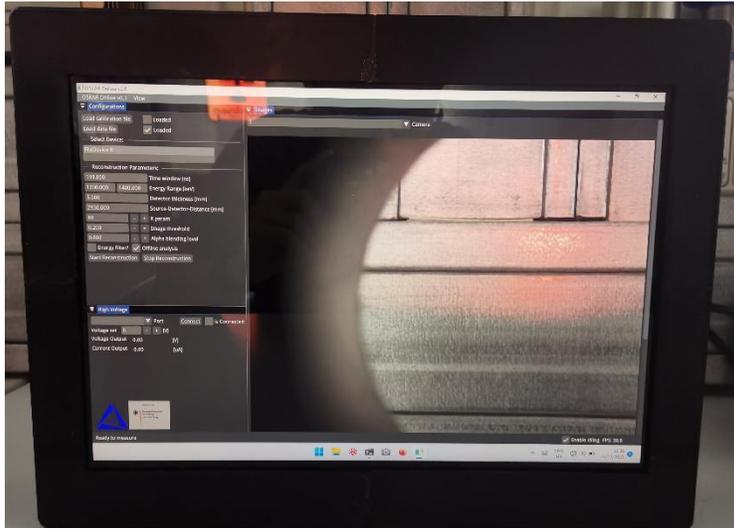


Superposición

Prototipo Final



Prototipo Final



OSKAR v0.2

OSKAR v0.2 View

Online Offline

Load calibration file Loaded C:\Users\OSKAR\Desktop

Save data file C:\Users\OSKAR\Desktop

Save image

Configurations

Reconstruction Parameters:

Apply Energy Filter

1050.000 1400.000 Energy Range [keV]

500.000 Source-Detector-Distance [mm]

Image Options:

0.200 - + Image threshold

0.900 - + Transparency level

Start Reconstruct Stop Reconstruct Clear Image

High Voltage

Connect is Connected

Voltage set 0 - + [V]

Detector Temp (°C): 46.60

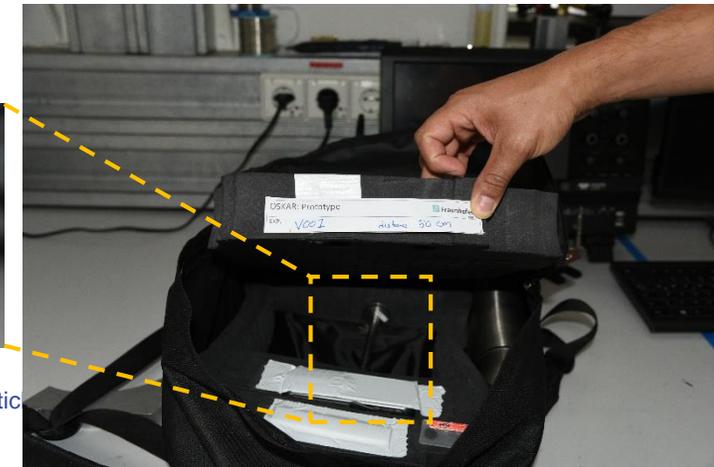
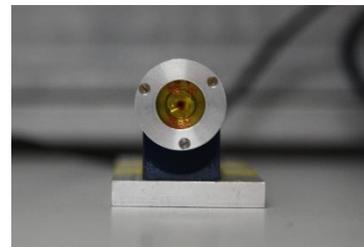
Enable idling FPS: 11.1

Images Hits Mask

Energy Histogram:

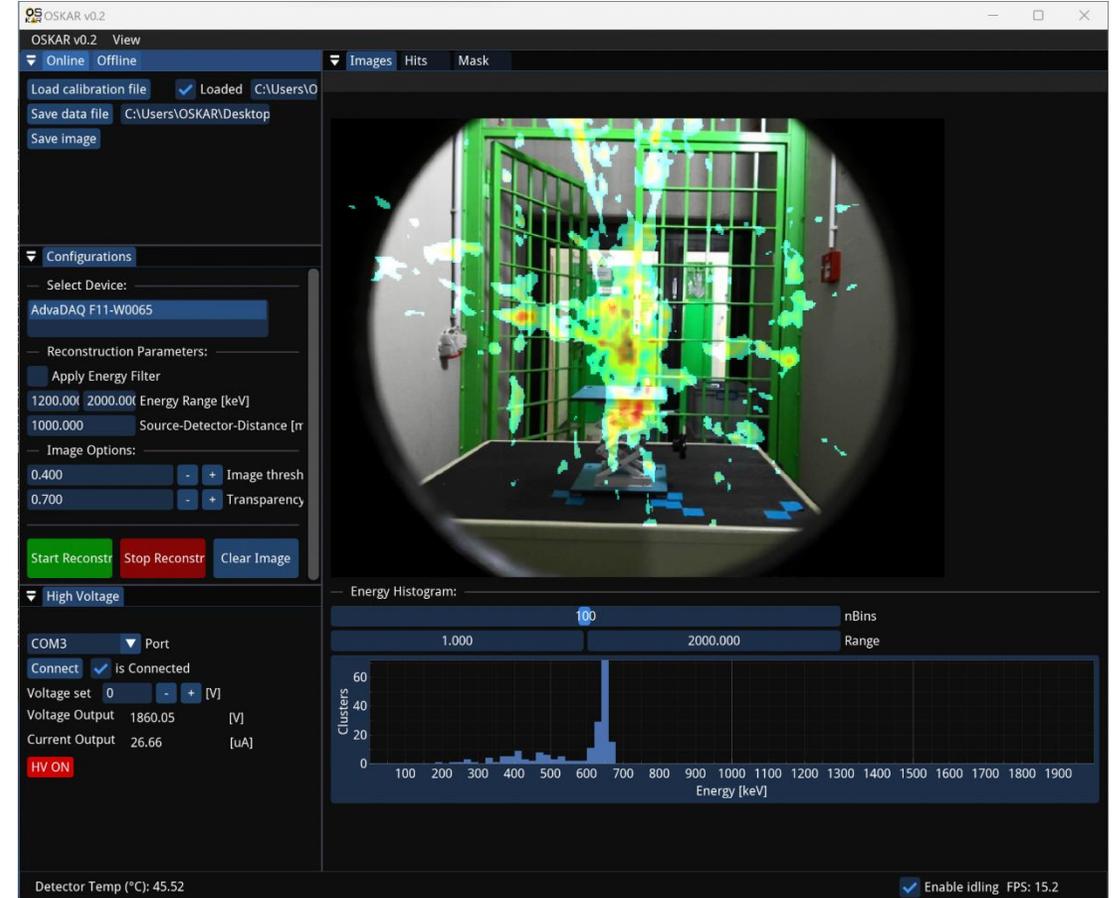
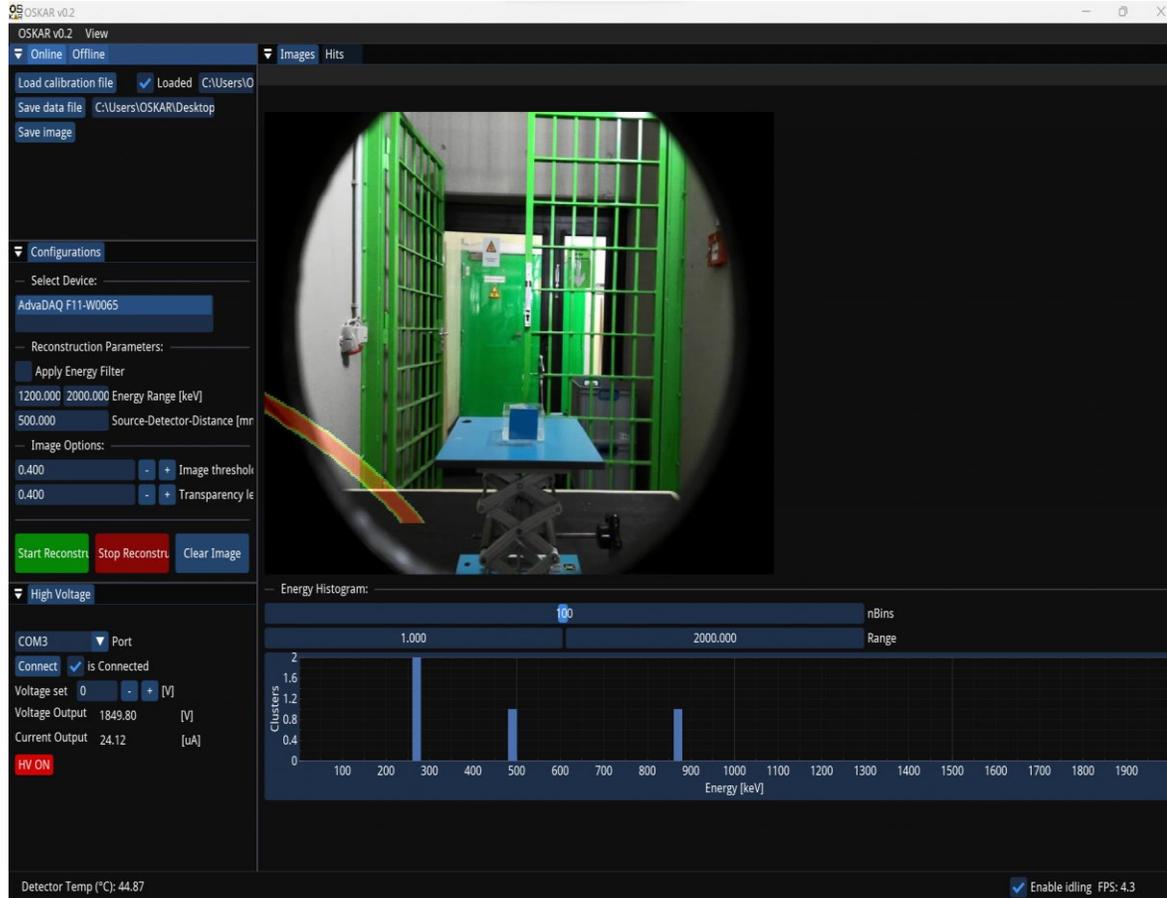
103 nBins

1.000 2000.000 Range



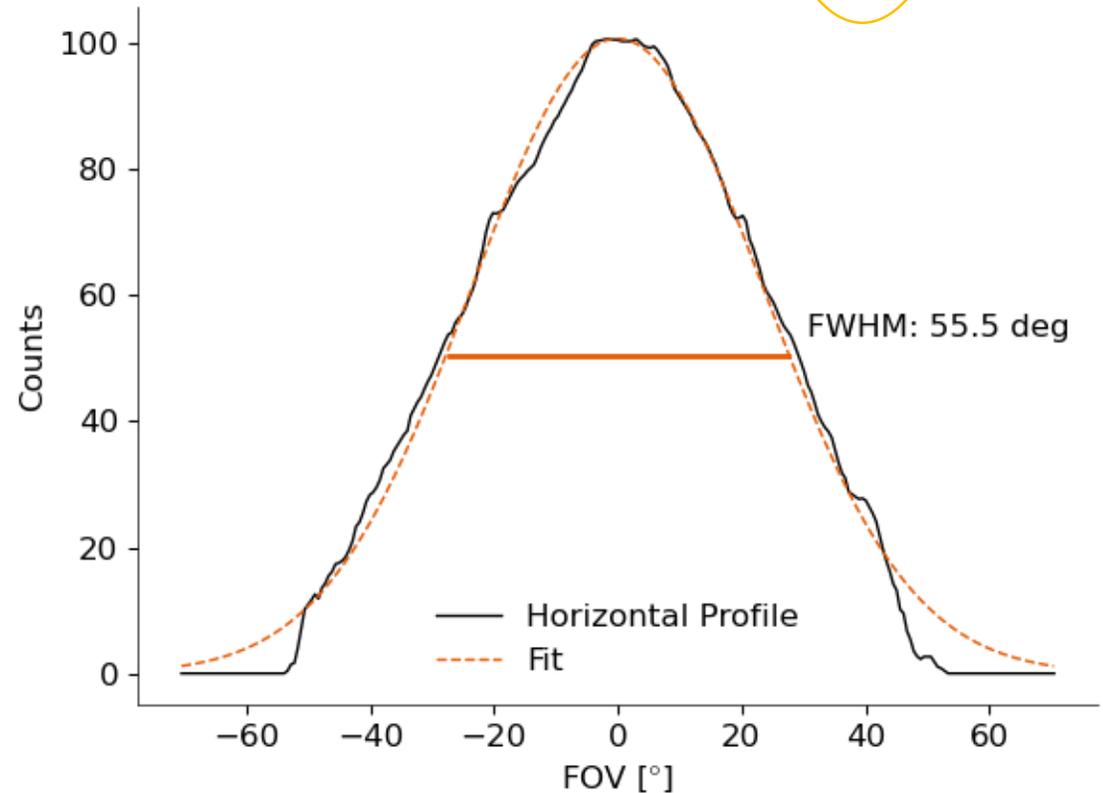
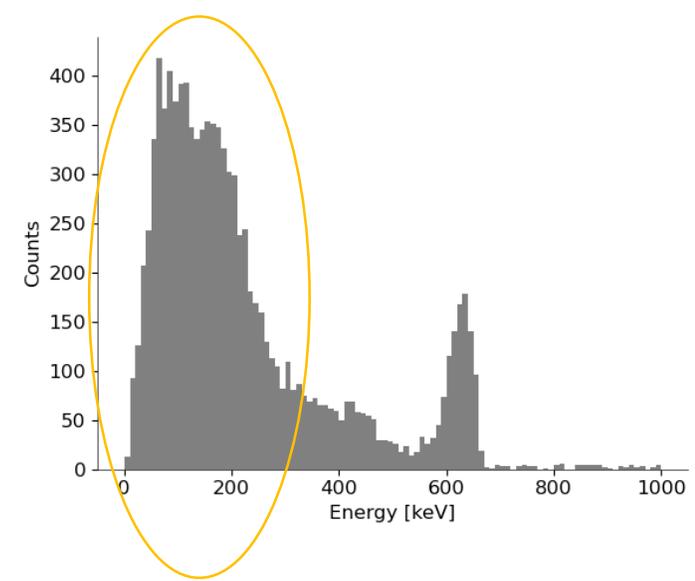
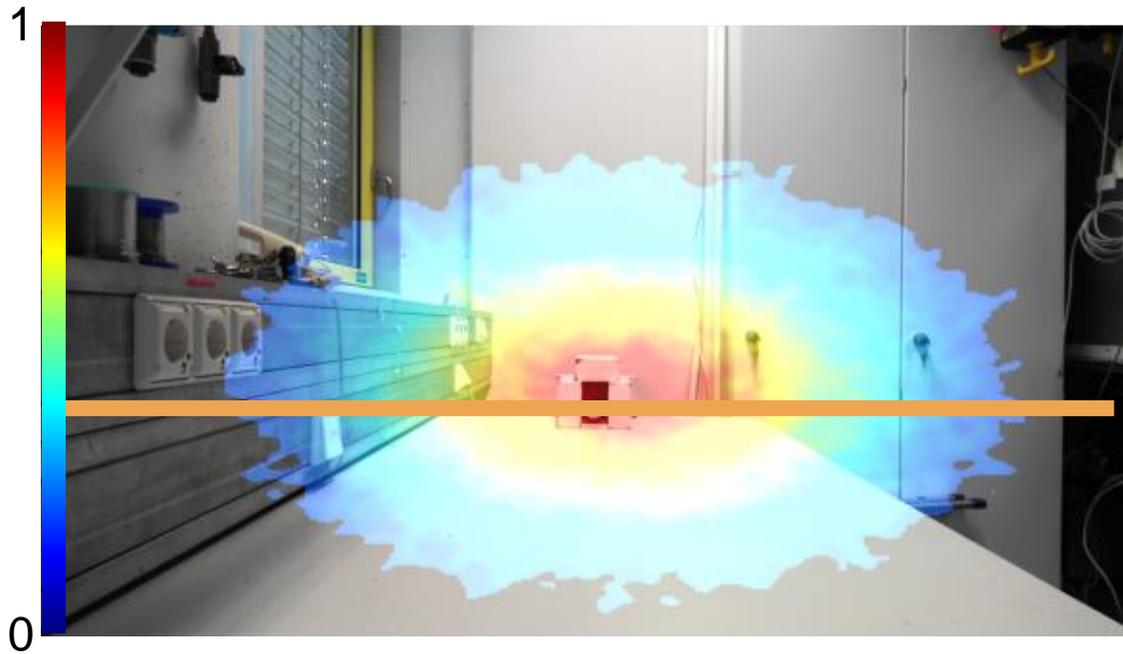
Prototipo Final

LUBW Mediciones con ^{137}Cs



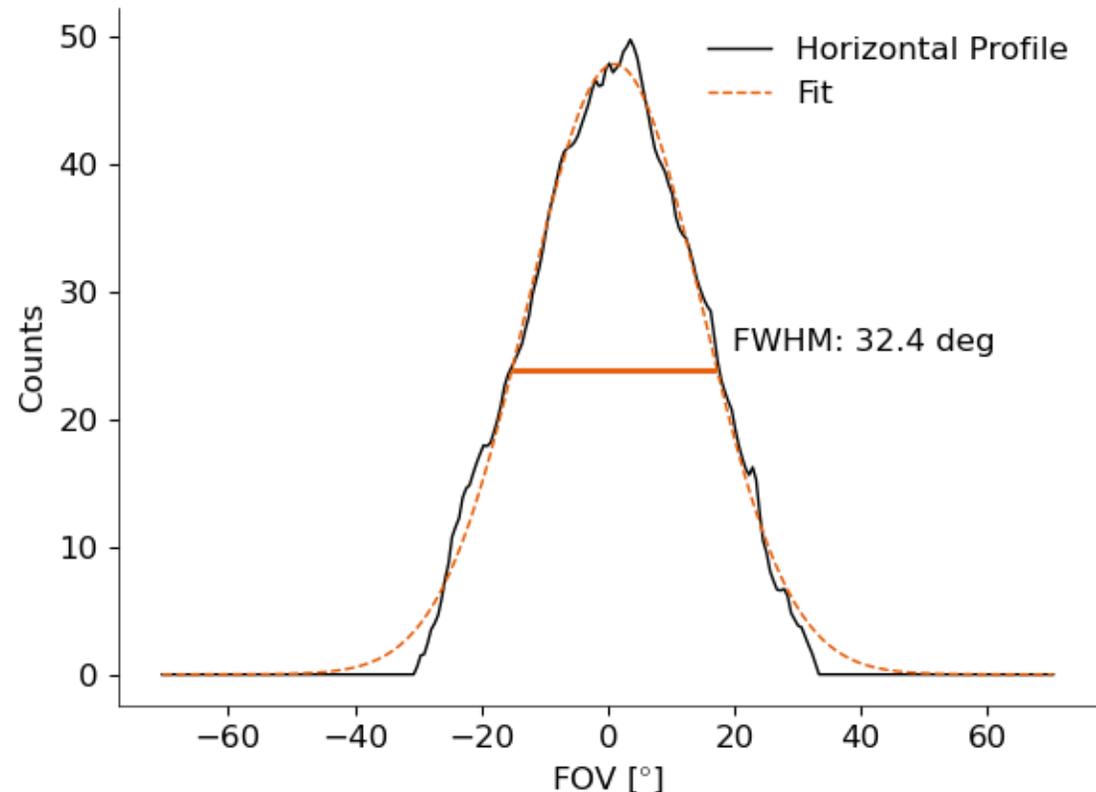
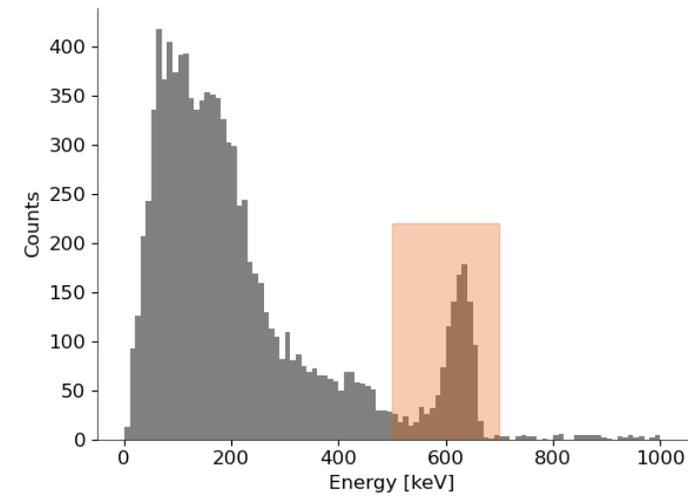
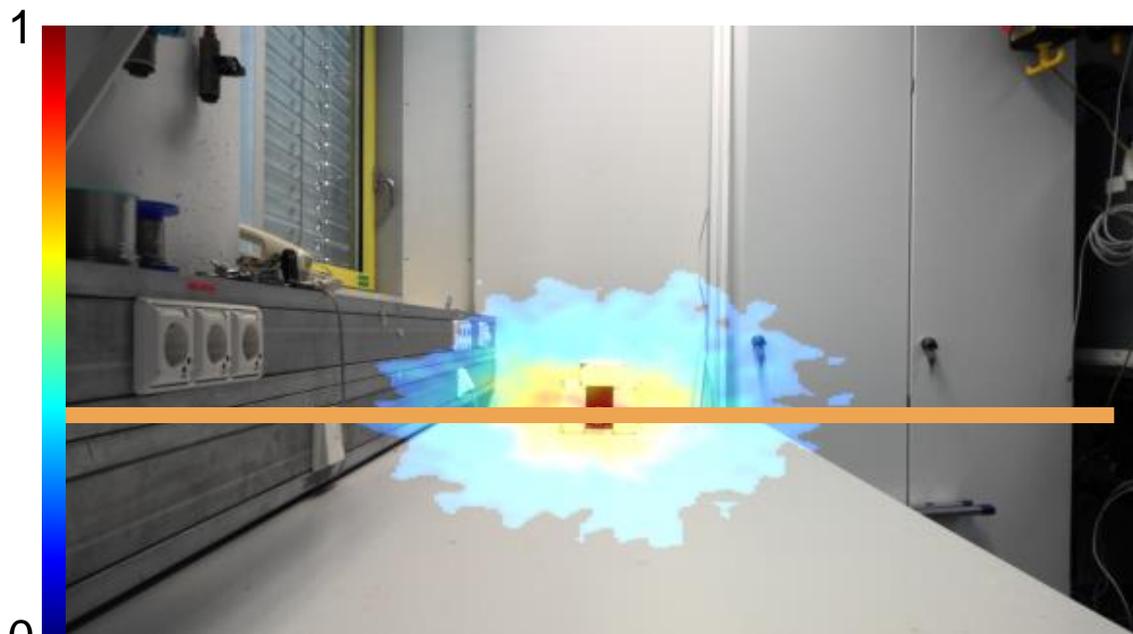
Resolución Angular

^{137}Cs (3.3MBq) a una distancia de 1.68m

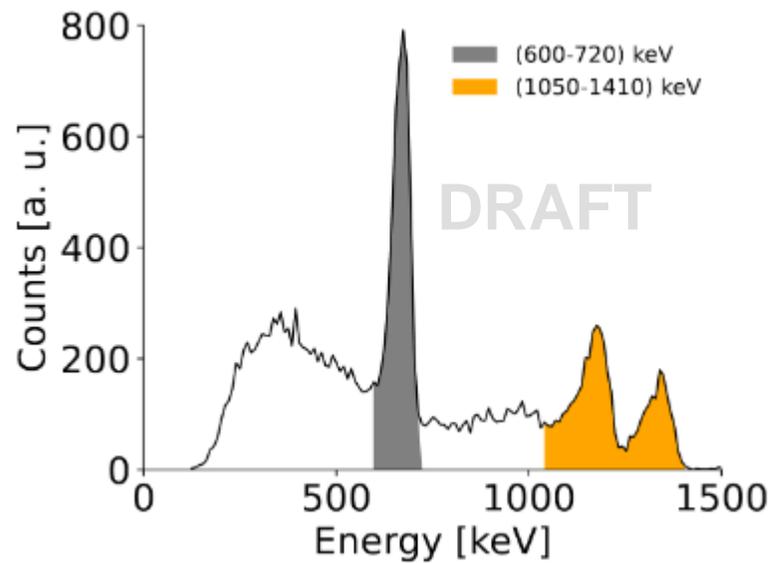
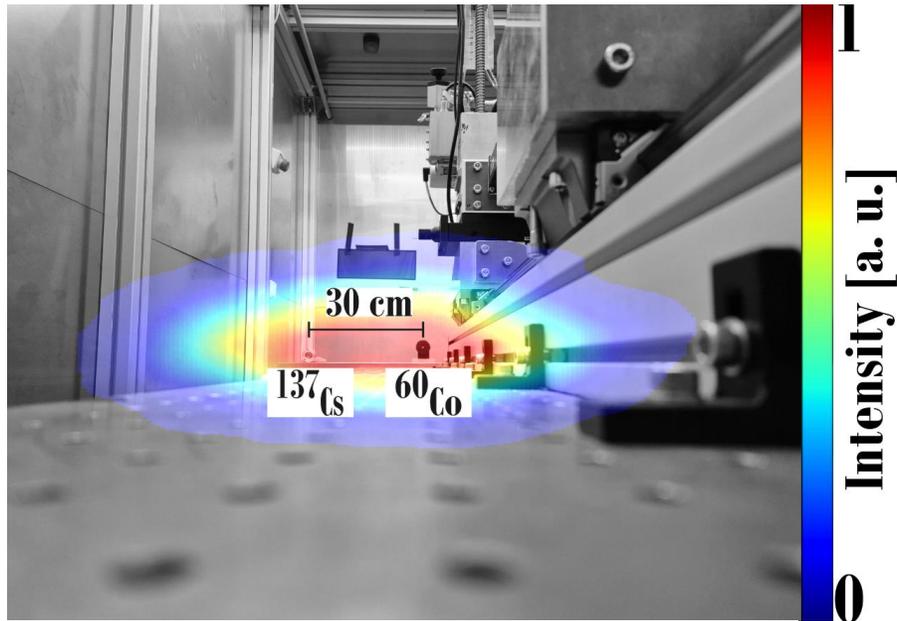


Resolución Angular

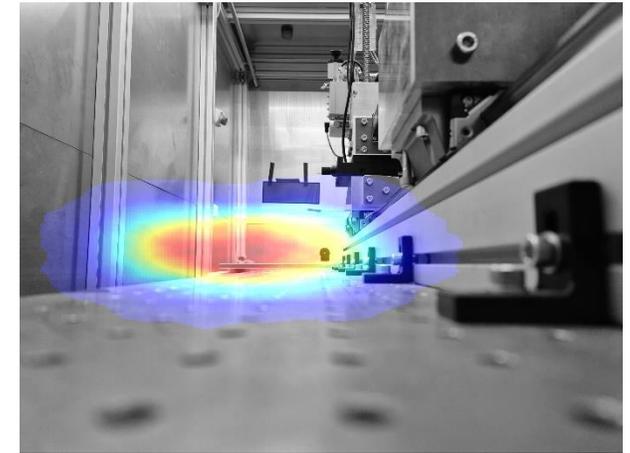
42% Aumento de la resolución al filtrar el photo-peak



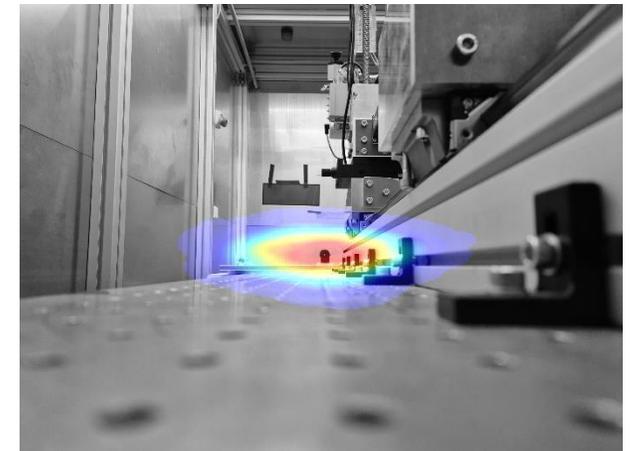
Mediciones con más de una Fuente radioactiva



^{137}Cs



^{60}Co



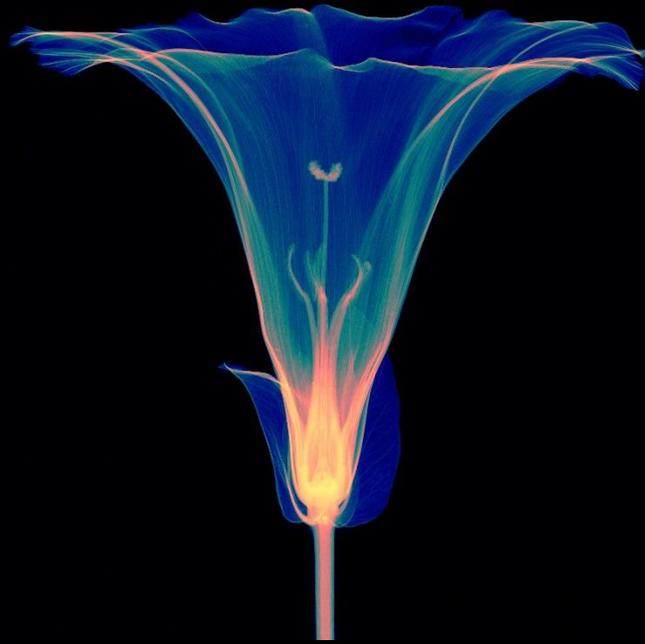
Conclusiones

- **Alta** resolución de energía en el rango estudiado. Observación del del pico ^{60}Co
- **Localización** de isótopos radioactivos por medio del efecto Compton con una resolución angular de $\sim 32^\circ$
- **Prueba exitosa** del software desarrollado
- Implementación de la **identificación** de isótopos está en desarrollo

Acknowledgment



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*Gracias por su
atención!*

