ICOR – Compton Imaging in Radionuclide Therapy

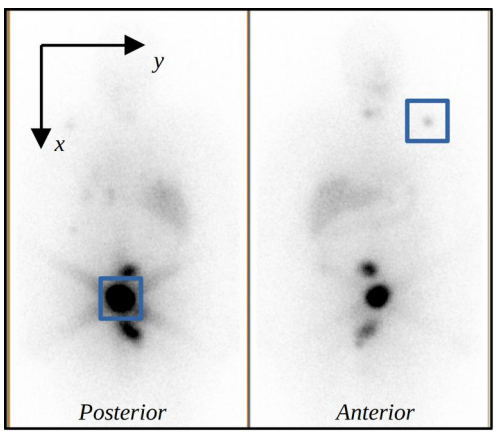
Gabriela Llosá on behalf of the IRIS group and collaborators.

Instituto de Física Corpuscular IFIC (CSIC-UV), Valencia, Spain.

ASTROHEP-PPCC24. Zaragoza, 5-7 June 2024.

Imaging in radiopharmaceutical therapy

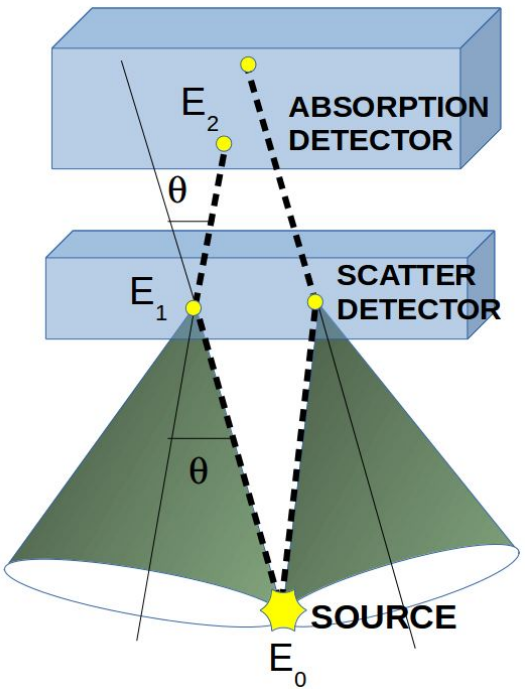
- The interest on radiopharmaceutical therapy is rapidly increasing.
- Imaging can be used to visualize the distribution of radionuclides in the body and carry out dosimetry employing secondary gamma radiation.
- More challenging than diagnostic imaging since photon energies and activities are not optimized for gamma cameras, in particular for alpha emitters.
- Compton cameras can complement gamma cameras in this task.
  - Higher efficiency.
  - Better performance at high energies.
  - Better suited for multi-gamma imaging.



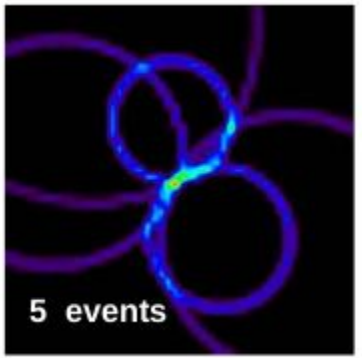
Gamma camera images of a patient treated with ^{131}I-NaI

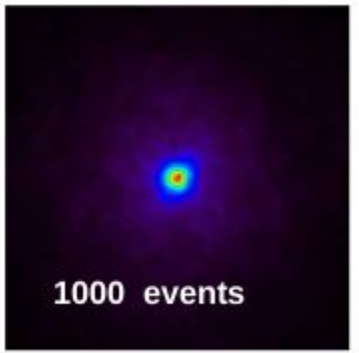
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Compton camera



Backprojection:





+ Image reconstruction

$$\cos\varphi = 1 - m_0 c^2 \left(\frac{1}{E_{\gamma'}} - \frac{1}{E_\gamma} \right)$$

$$E_\gamma = E_{e^-} + E_{\gamma'}$$

List mode ML-EM

$$\lambda_j^{n+1} = \frac{\lambda_j^n}{s_j} \sum_{i=0}^{N} \frac{t_{ij}}{\sum_k t_{ik} \lambda_k^n}$$

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

ICOR

ICOR GOALS:

- Improvement of Compton camera performance with scintillators.
- Development of a Compton camera with a silicon scatterer.
- Tests in hospitals.

PI: G. Llosá (IFIC, Valencia)

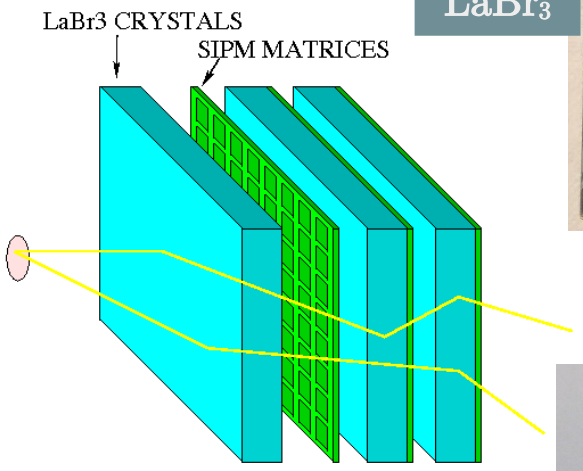
Co-PI: Irene Torres-Espallardo (La Fe Hospital, Valencia)

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Financiado por la Unión Europea NextGenerationEU
GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Plan de Recuperación, Transformación y Resiliencia
GENERALITAT VALENCIANA Conselleria de Educación, Universidades y Empleo
GVANEXT Fondos Next Generation en la Comunitat Valenciana

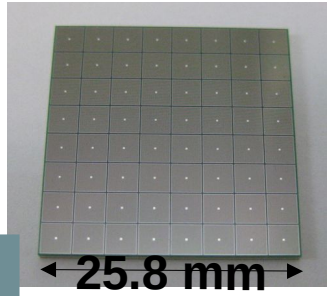
MACACO III (Medical Applications CompAct COmpton camera)

Detectors



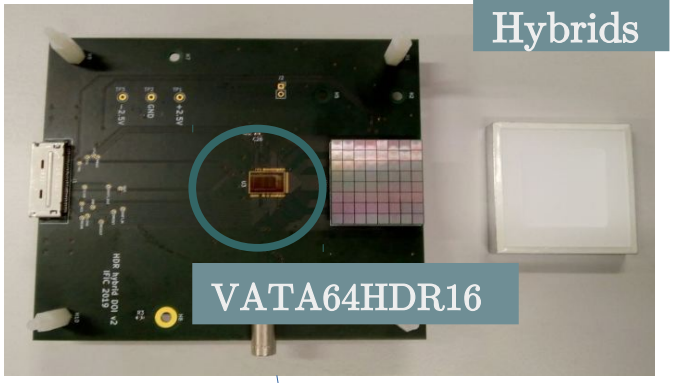
2/3 planes
+ absorption not required

LaBr$_3$

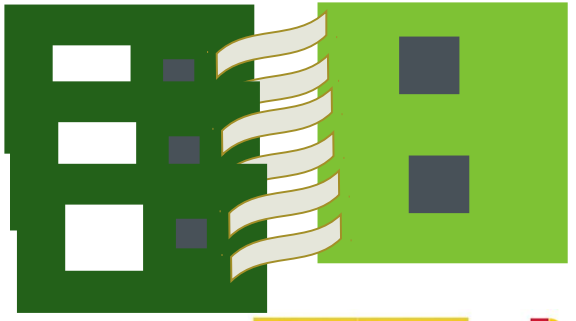


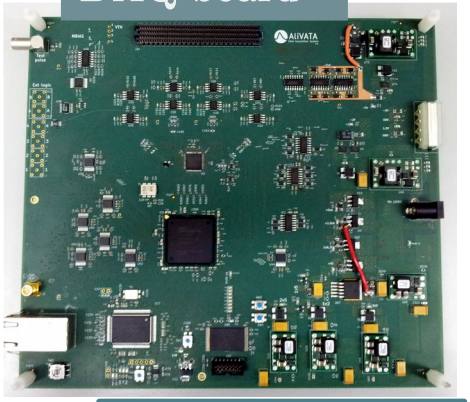
SiPMs

Readout



Hybrids





AliVATA DAQ board

Commercialized by Alibava Systems S. L.

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

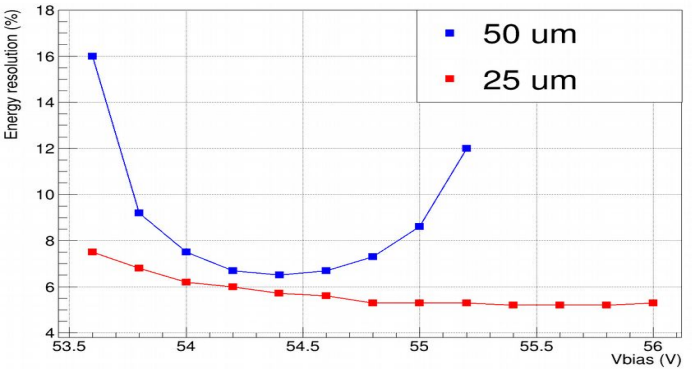
MACACO III detectors

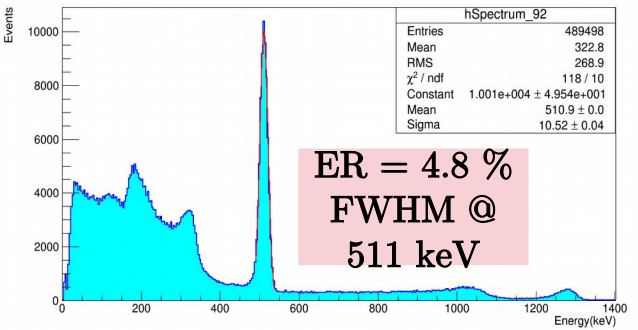
S13360-3025CS (25 µm)

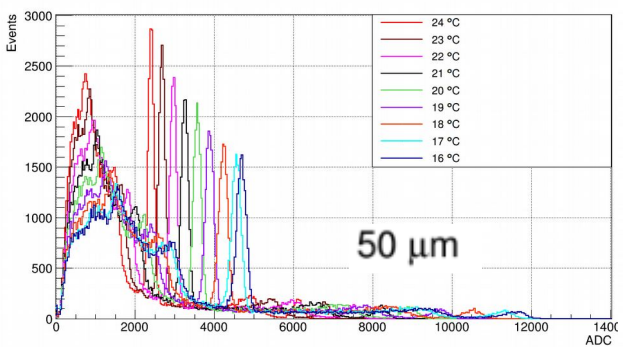
vs

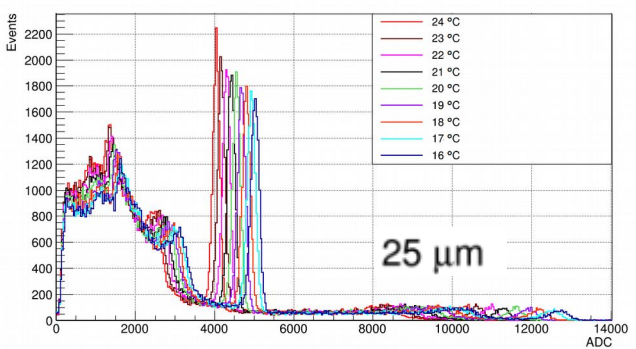
S13361-3050AE-08 (50 µm)

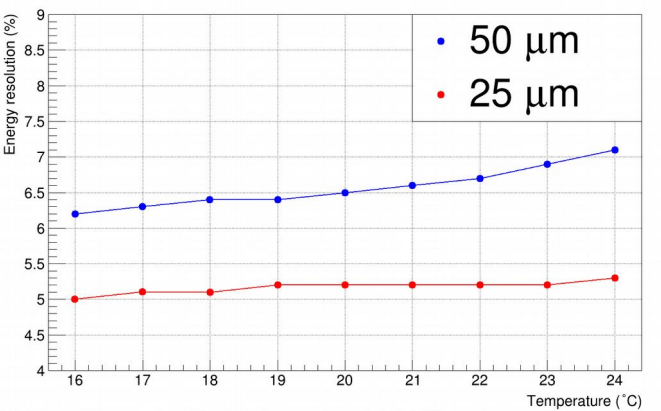
Now commercial product









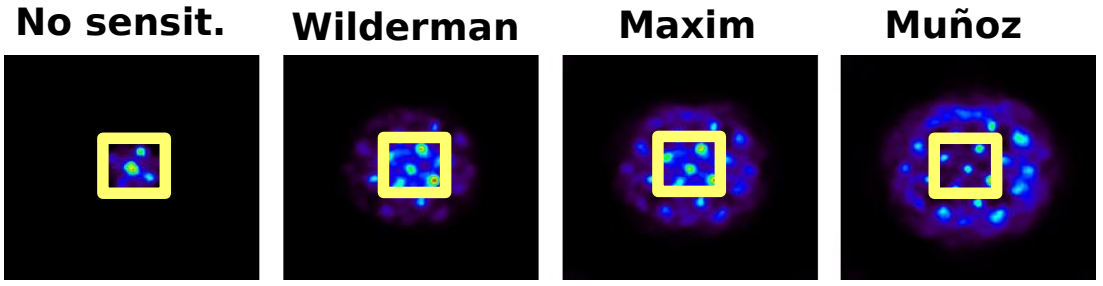


L. Barrientos et al. Rad. Phys. Chem. 2023

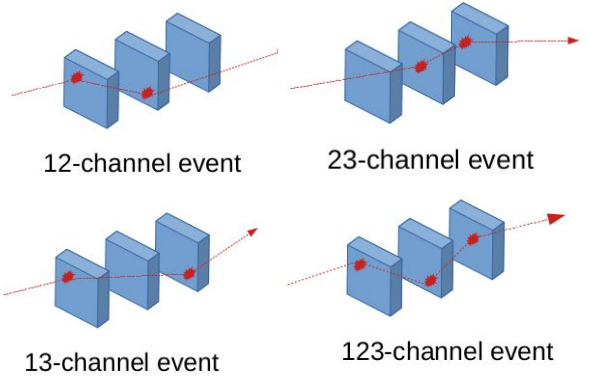
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Image reconstruction: list-mode MLEM

Sensitivity model for 2- and 3- interacion events



Joint reconstruction of all channels

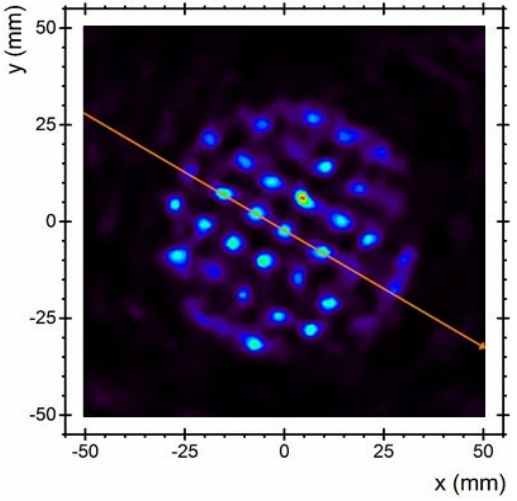


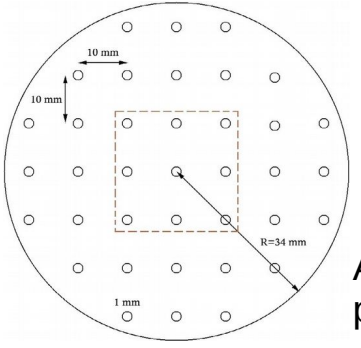
E. Muñoz et al. Phys. Med. Biol. 2018

E. Muñoz et al. Phys. Med. Biol. 2020

J. Roser et al. Phys. Med. Biol. 2020

J. Roser et al. Phys. Med. Biol. 2022





Array of 37 Na-22 point-like sources

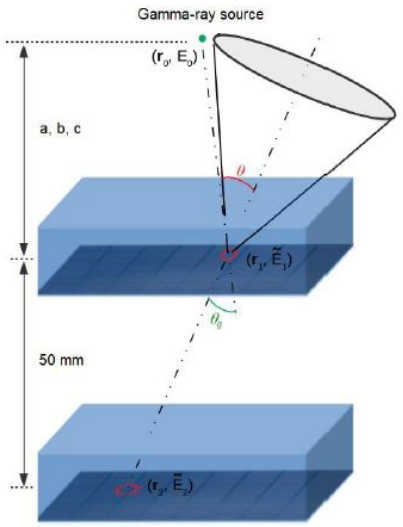
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

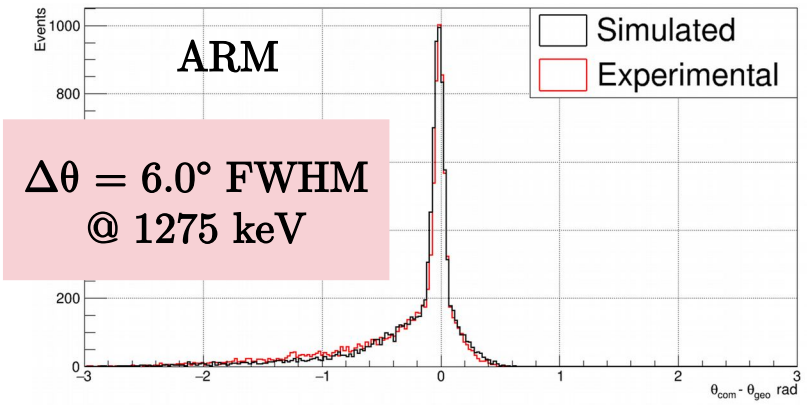
Simulations validation

Excellent agreement between experimental results and GATE v8.2 simulations.

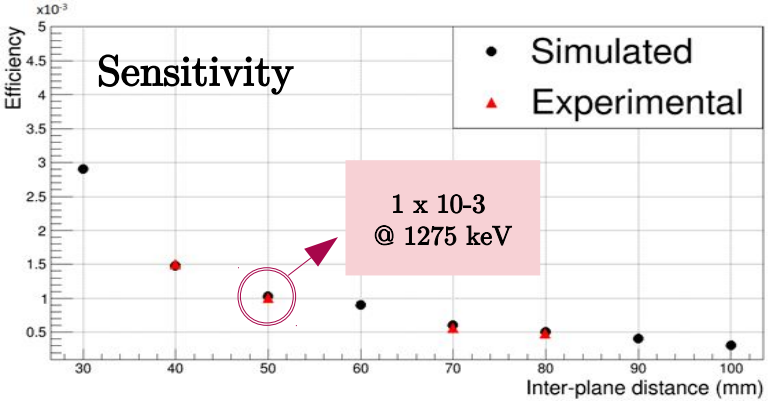
Angular resolution

$$ARM = \theta c - \theta g$$

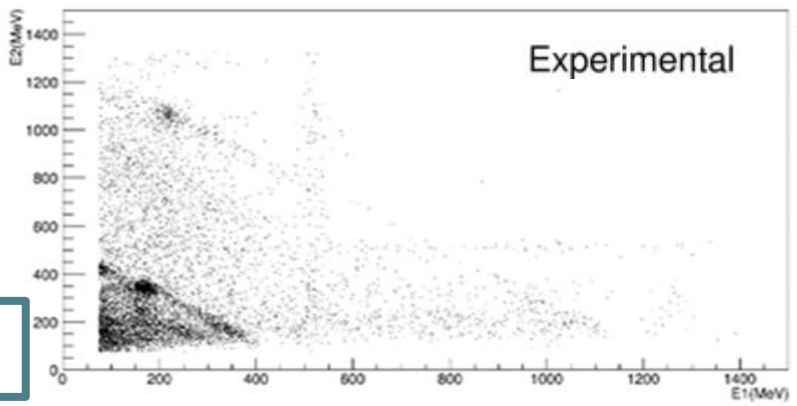


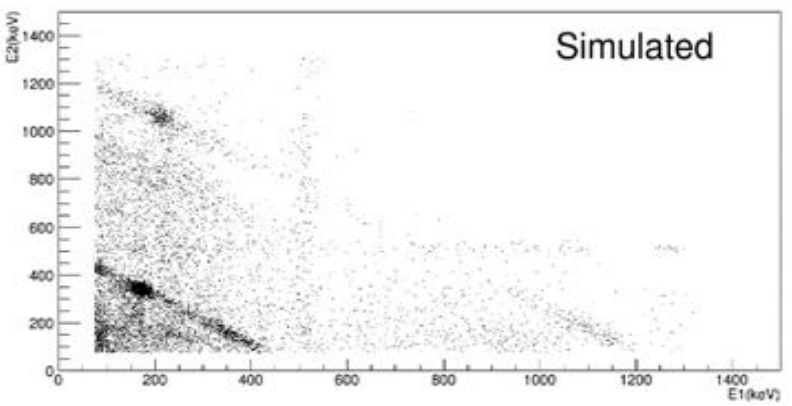


$\Delta\theta = 6.0°$ FWHM
@ 1275 keV



1 x 10-3
@ 1275 keV



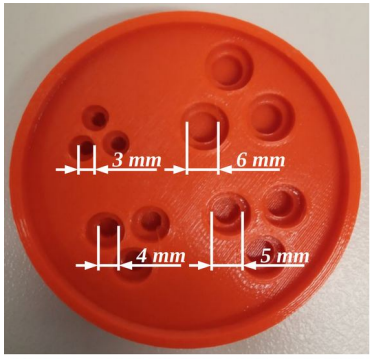


L. Barrientos et al.
Rad. Phys. Chem. 2023

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

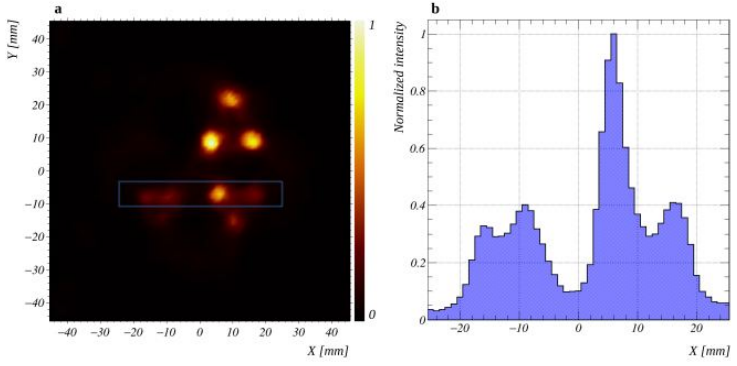
Tests in La Fe hospital (Valencia)

3D printed Derenzo-like phantom



^{18}F-FDG (511 keV)

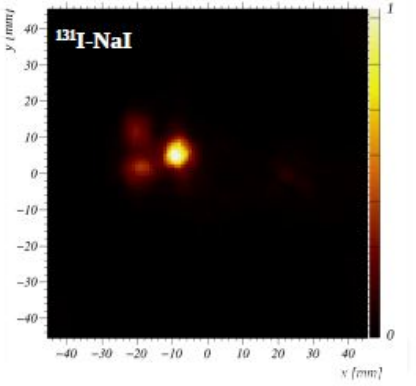
Compton camera



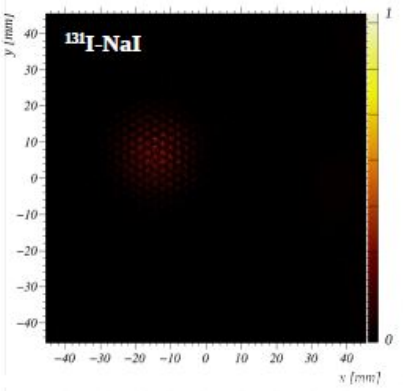
^{131}I-NaI (364 keV)

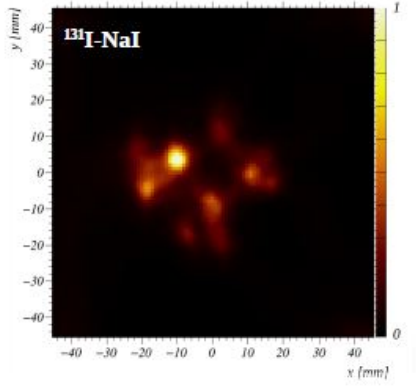
Compton camera

Gamma camera
Bright View XCT (Philips)

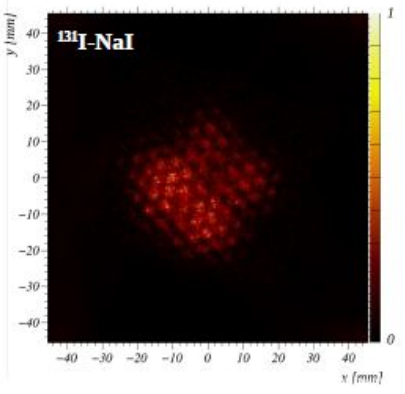


One sector





All sectors

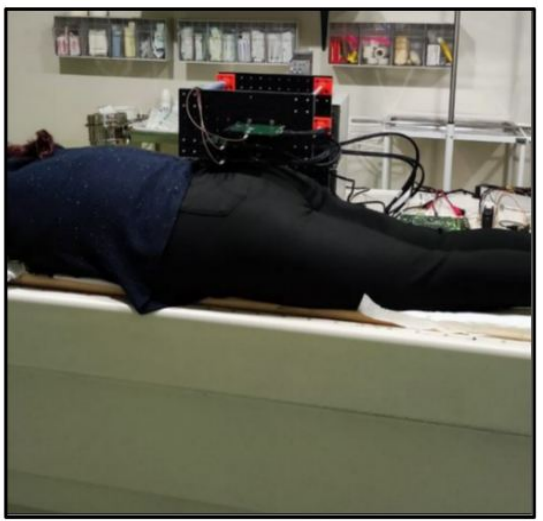


In collaboration with Irene Torres-Espallardo, José Manuel Calatayud, Pilar Bello and Stefan Prado from La Fe.

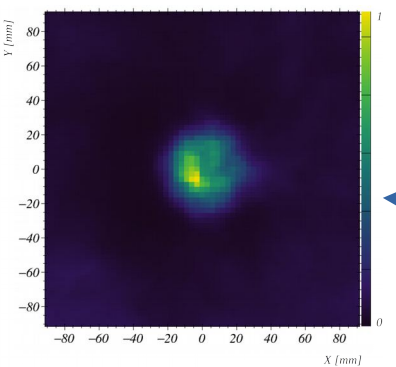
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Tests in La Fe hospital (Valencia)

- Metastatic lesions from patients treated with ^{131}I-NaI after thyroid gland resection
- Initial activity (total): 150 mCi
- MACACO III @ ~70 mm.

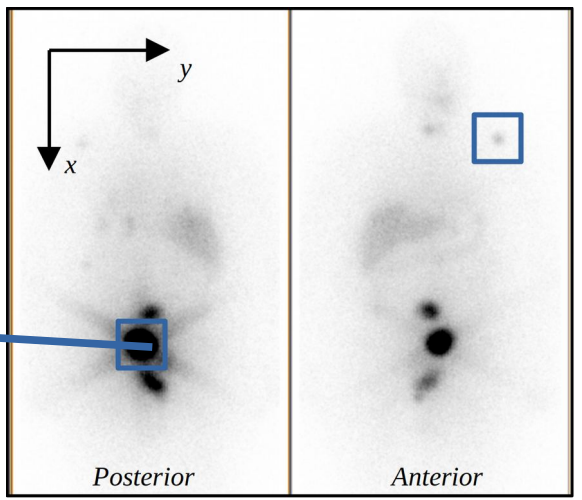


MACACO III



Sacrum lesion

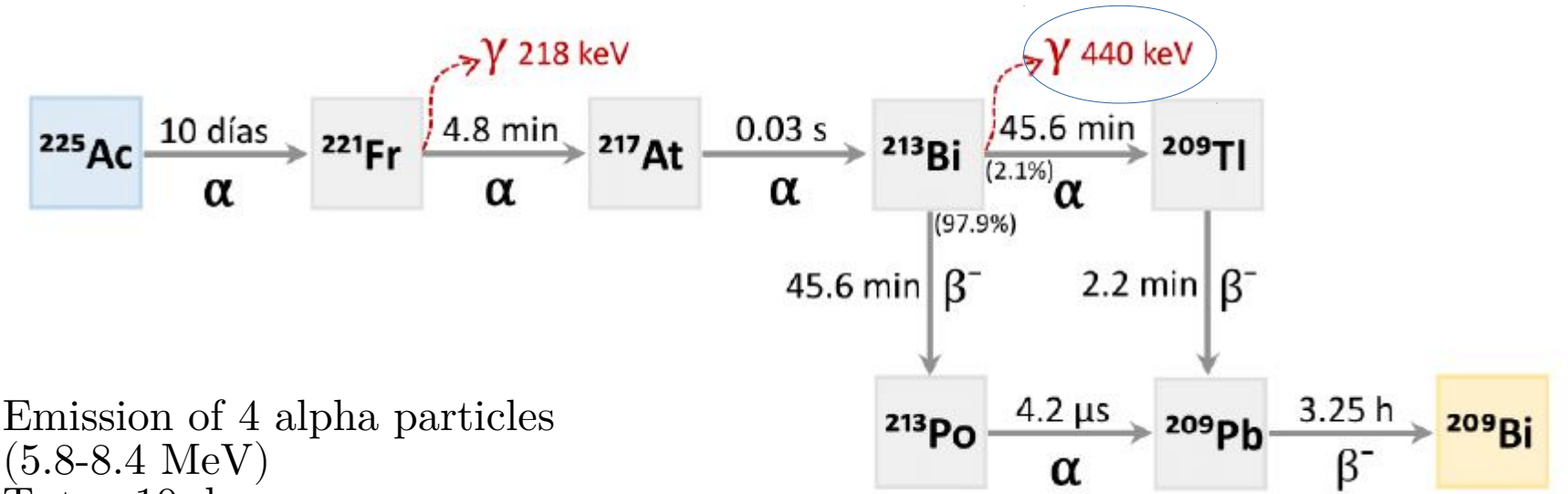
Gamma camera



J. Roser et al. In preparation.

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

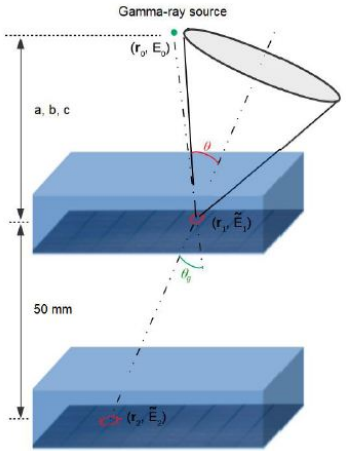
Ac-225



- Emission of 4 alpha particles (5.8-8.4 MeV)
- $T_{1/2}$= 10 days

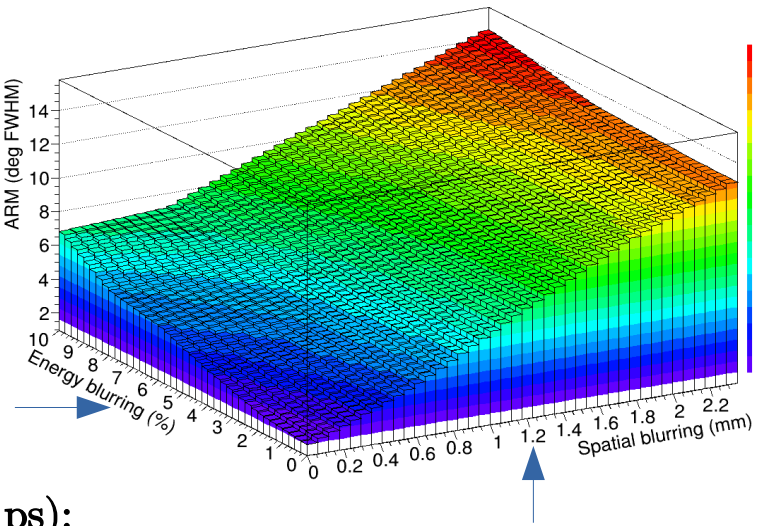
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Performance estimation with GATE simulations



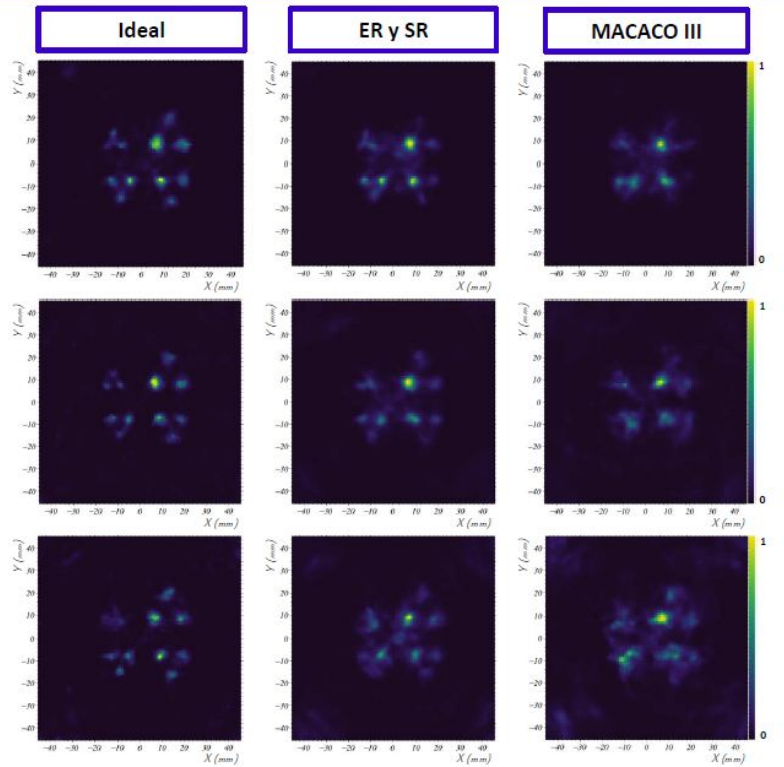
Angular resolution @440 keV

$$ARM = \theta Compton - \theta geometrical$$



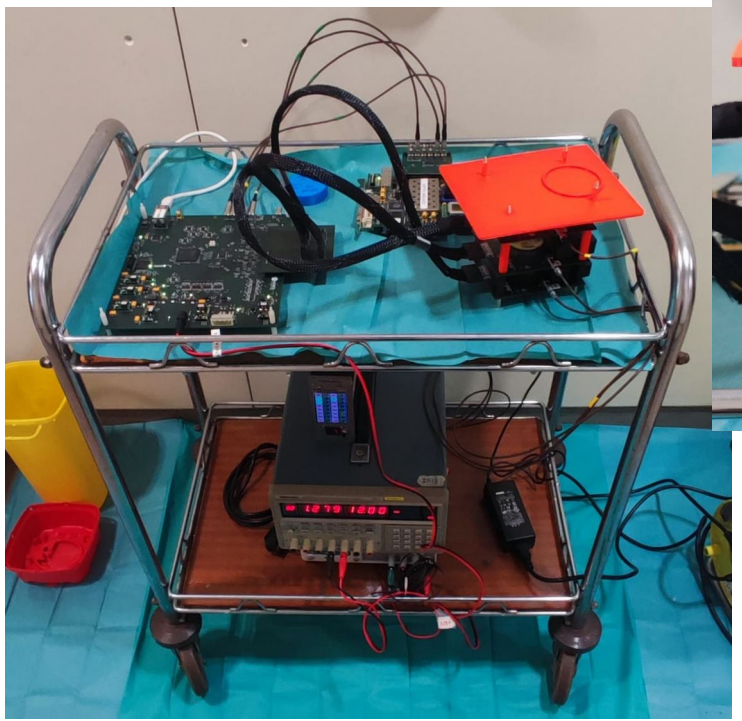
Fast timing (< 200 ps):
- Background reduction
- Determination of interaction sequence.

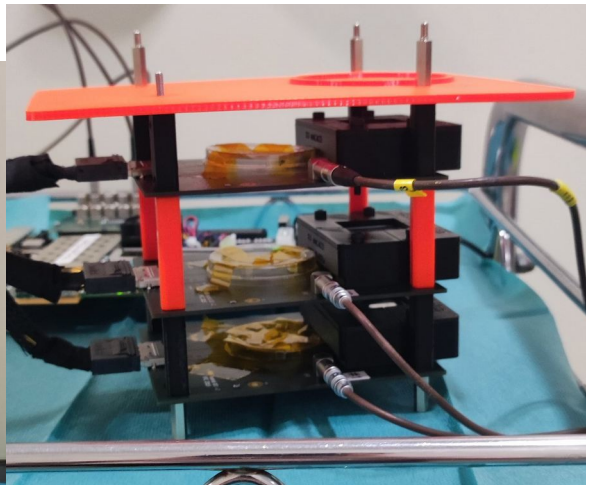
Ac-225 Simulations with MACACO III

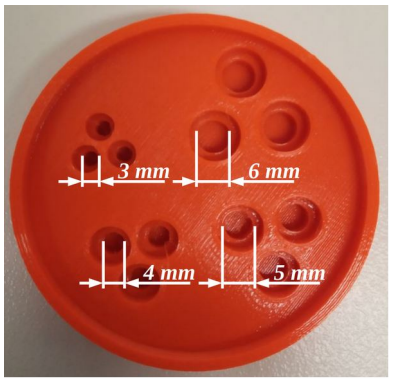


The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Ac-225 Measurements at Léon Bérard hospital (Lyon)

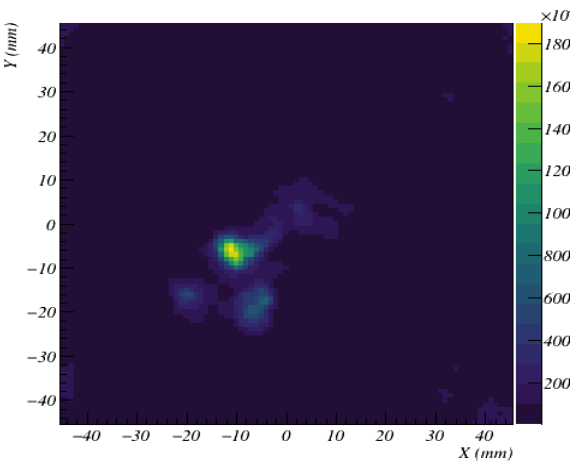






6 mm diameter rods reconstructed

70 kBq /rod

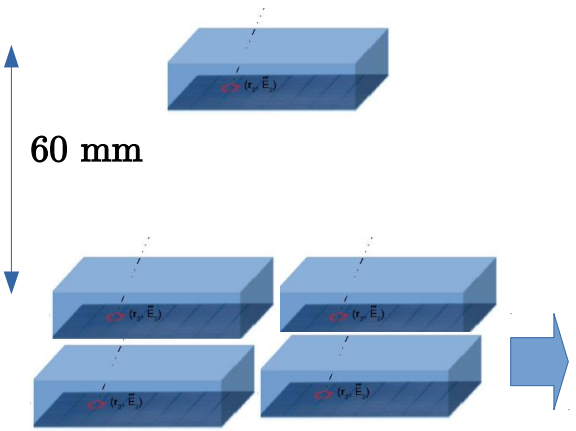


In collaboration with Ane Etxebeste, David Sarrut, Jean Noël Badel from Creatis and Léon Bérard hospital (Lyon).

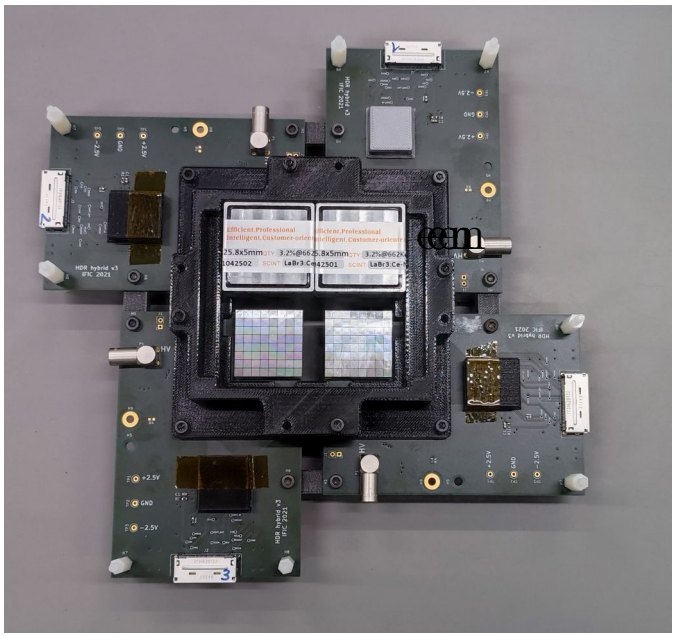
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

MACACO III+

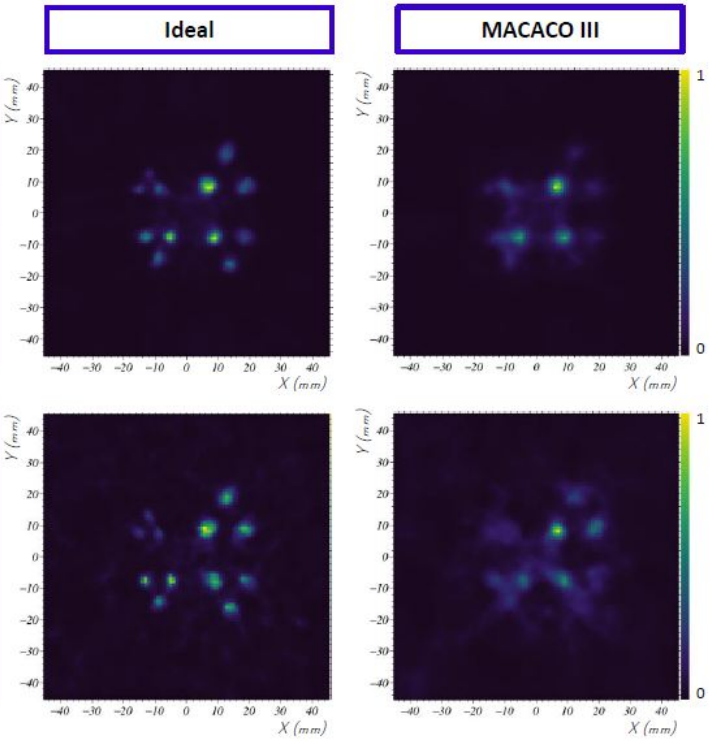
MACACO III+



4x larger 2nd plane
to increase sensitivity



Ac-225 Simulations with MACACO III+

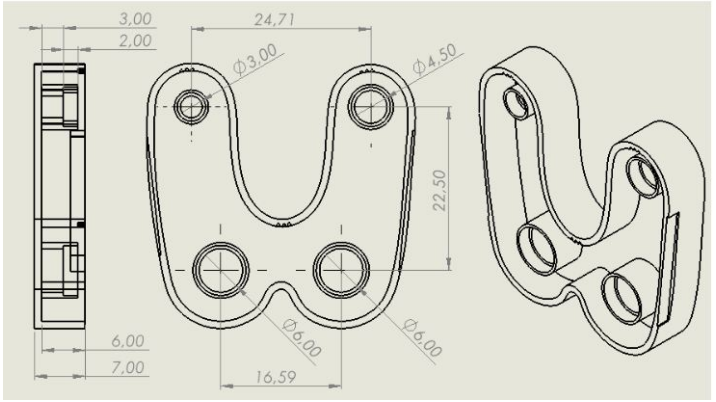


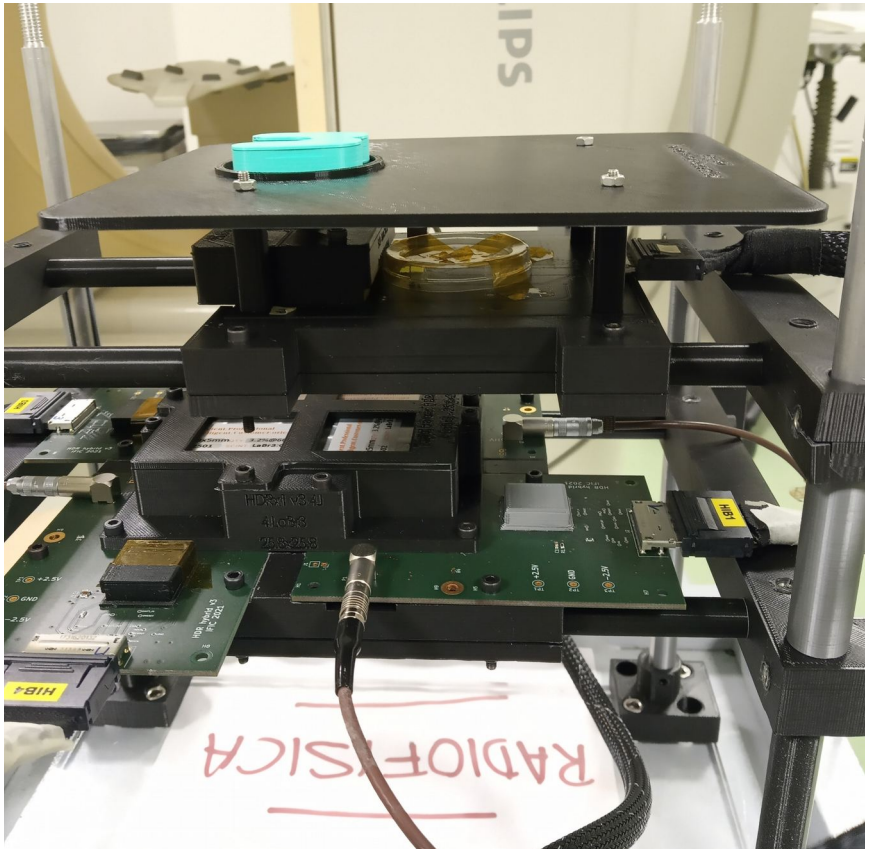
Further Ac-225 measurements foreseen with MACACO III+

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Measurements with ^{131}I with MACACO III+

3D printed thyroid-shaped phantom filled with ^{131}I-mIBG





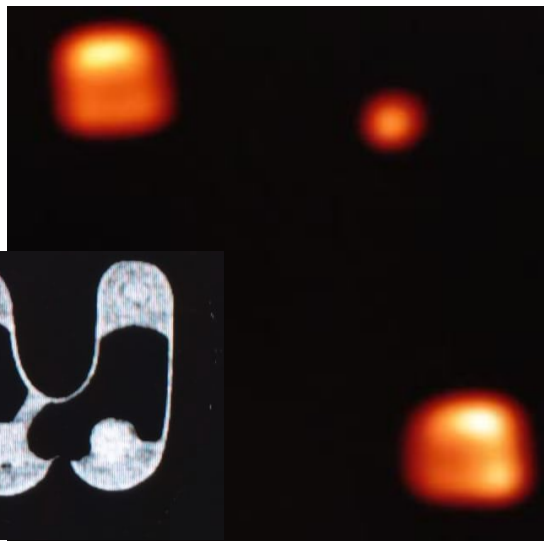
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Measurements with ^{131}I with MACACO III+

3D printed thyroid-shaped phantom filled with 131I-mIBG

Background: ~3 ml
Rods:
3: 0.021 ml
4: 0.047 ml
5: 0.084 ml

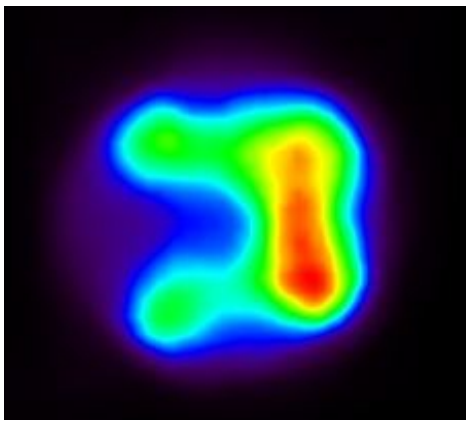
Gamma camera images



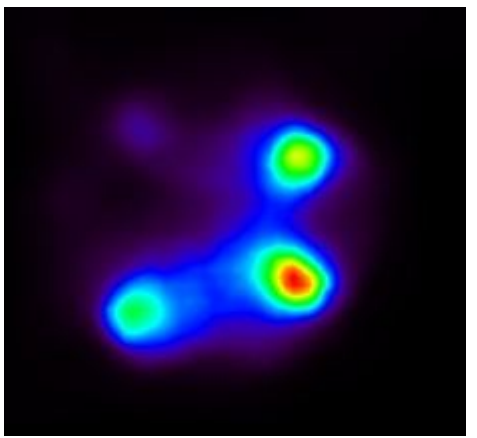
CT images

Compton camera images

PRELIMINARY



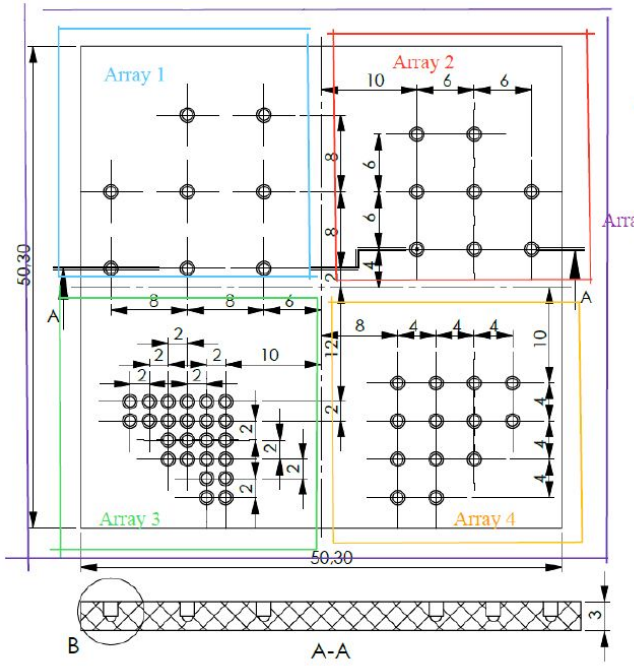
'Uniform' filling.
~ 0.5 MB/ml

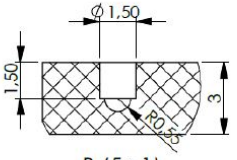


Background + hot rods at 10:1 activity concentration (0.1 : 0.01 MBq/ml)

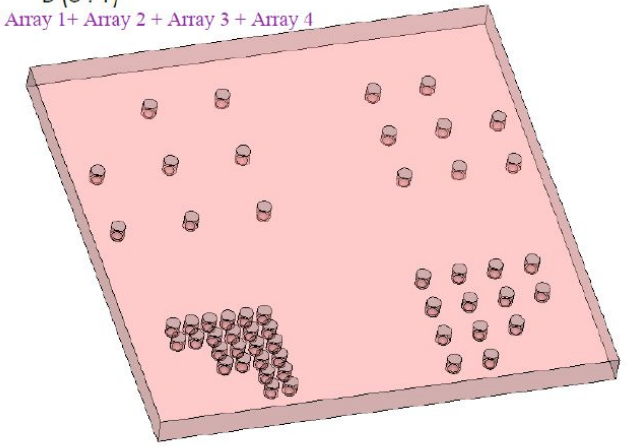
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

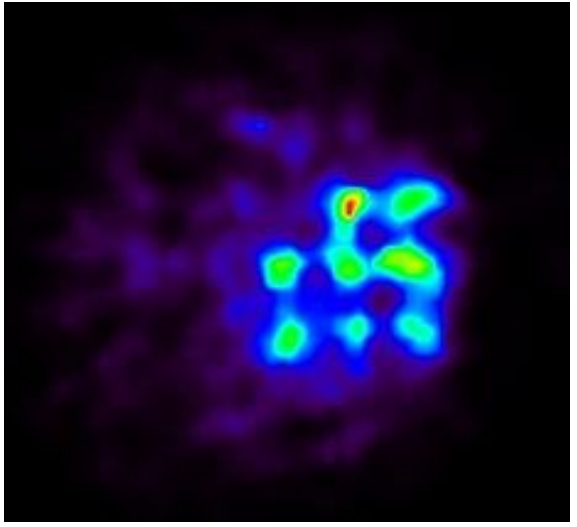
Measurements with MACACO III+ - new array





Array 5= Array 1+ Array 2 + Array 3 + Array 4

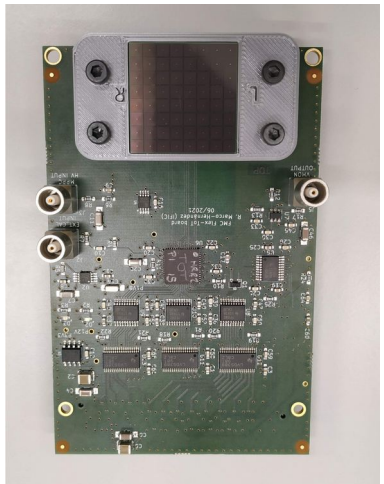




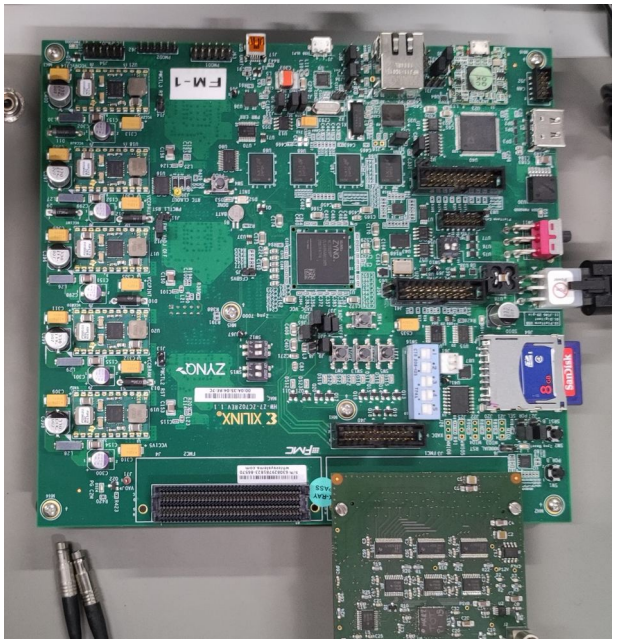
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

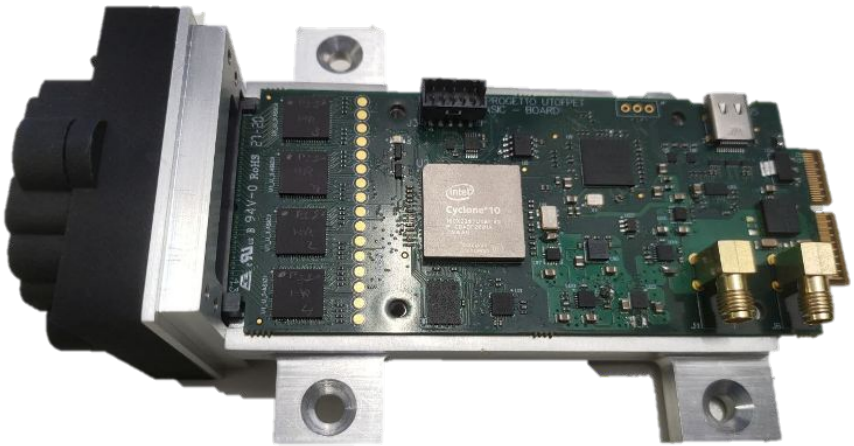
Improvement with scintillators

- Contact with Luxium (Saint Gobain crystals) for improved crystal-photodetector coupling.
- Tests with alternative ASICs: HRFlexTOT (UB), GAMMA (Politecnico di Milano).



HRFlexTOT Valencia (R. Marco)



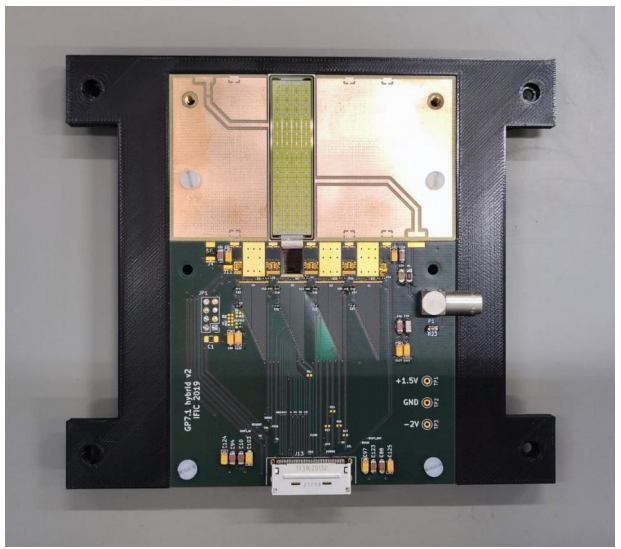


HRFlexTOT Univ. Pisa

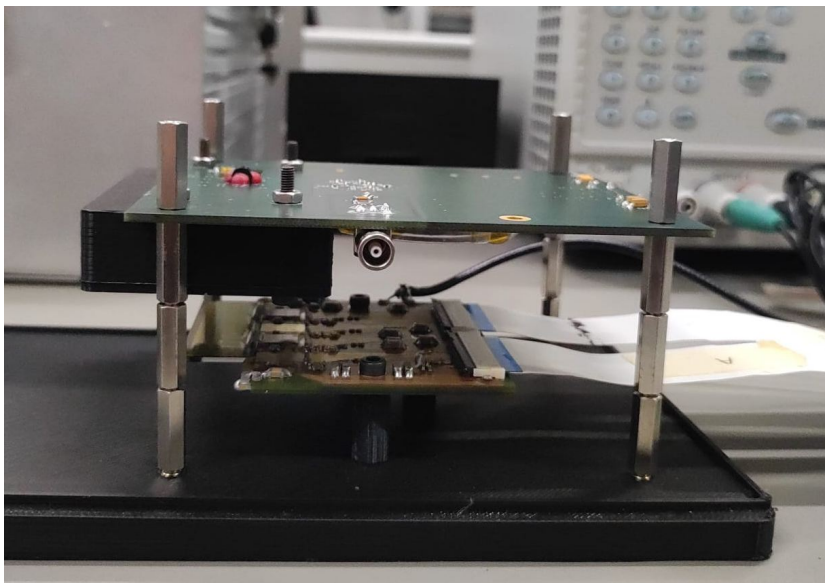
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Tests with silicon detectors

- Silicon detectors as scatterers for improved energy resolution.
- Specific design of thick detectors with IMB-CNM.



Silicon pad detectors, 0.5 and 1 mm thick.



CC setup. Data analysis ongoing.

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Conclusions

- The IRIS group has developed a Compton camera suitable for photon imaging in the range of 300 keV – 7 MeV.
- Initial results in collaboration with La Fe hospital in Valencia and Léon Bérard hospital in Lyon are very encouraging.
- Detector improvements are possible and can lead to better system performance.
- Further system performance improvements and test in clinical sites are ongoing.

Compton cameras show potential for this application

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

G. Llosá

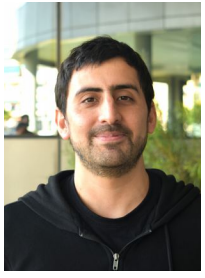
A. Ros

F. Hueso-Glez

K. Brzezinski

http://ific.uv.es/iris

J. Roser

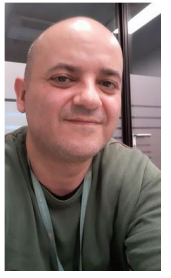


L. Barrientos

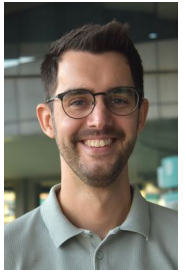
M. Borja-Lloret

R. Viegas

J. Pérez Curbelo



C. Senra



J. V. Casaña

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Acknowledgements

This work was supported by:

- MCIN /AEI (PID2019-110657RB-I00).
- MCIN /AEI 10.13039/501100011033 (PDC2021-121839-I00).
- Support from the MCIU with funding from theEuropean Union NextGenerationEU and Generalitat Valenciana in the call Programa de Planes Complementarios de I+D+i (PRTR 2022). Project ICOR, reference ASFAE/2022/019.

Group members are supported by GVA Excellence programmes, UVEG Atracció de Talent and GVA Grisolía contracts.

9-13 June 2025

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Thank you

Gabriela.llosa@ific.uv.es

http://ific.uv.es/iris