Toward Portable Gamma-Neutron Imaging: A Two-Stage Compton Camera for Environmental Monitoring

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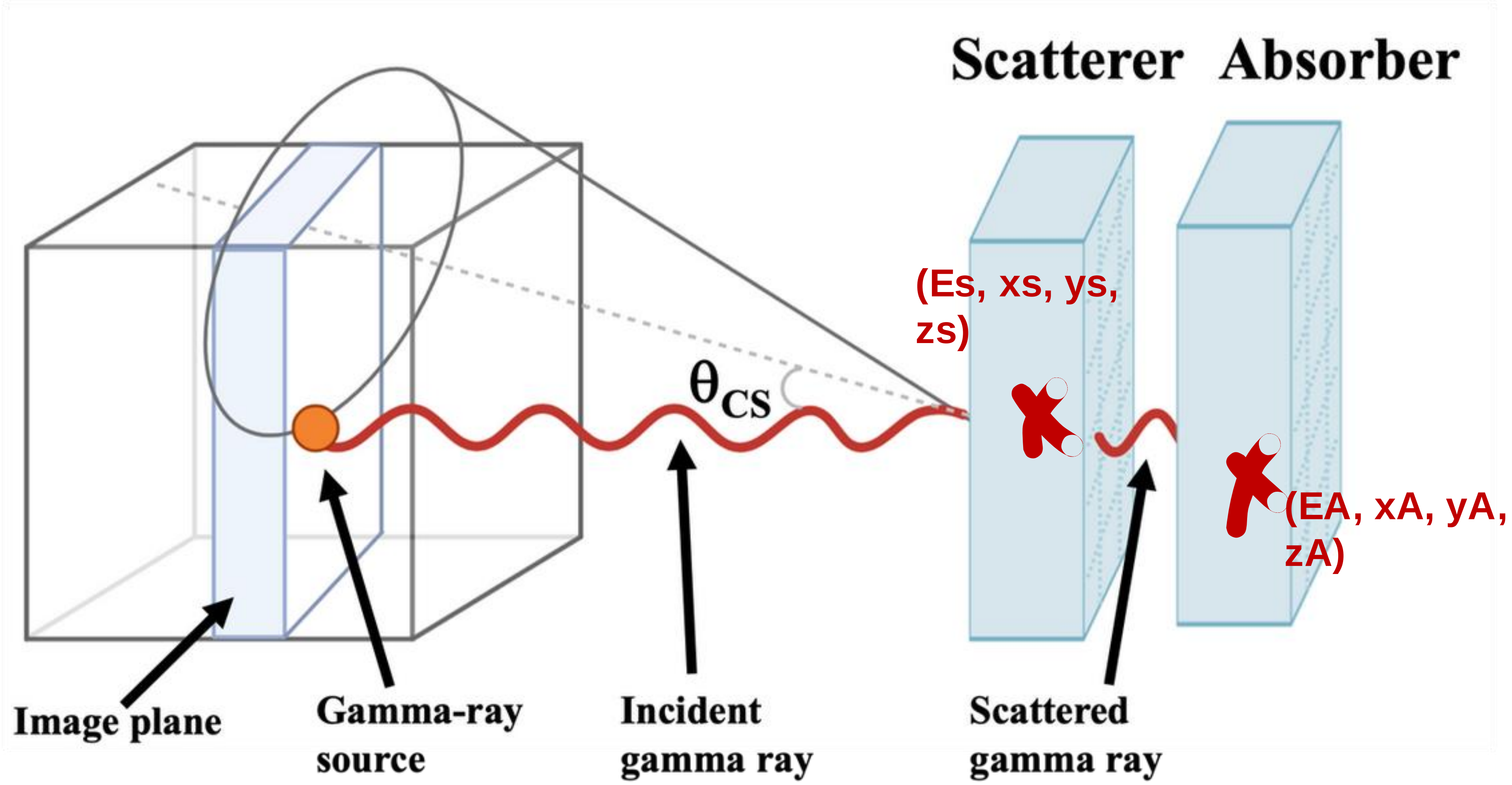
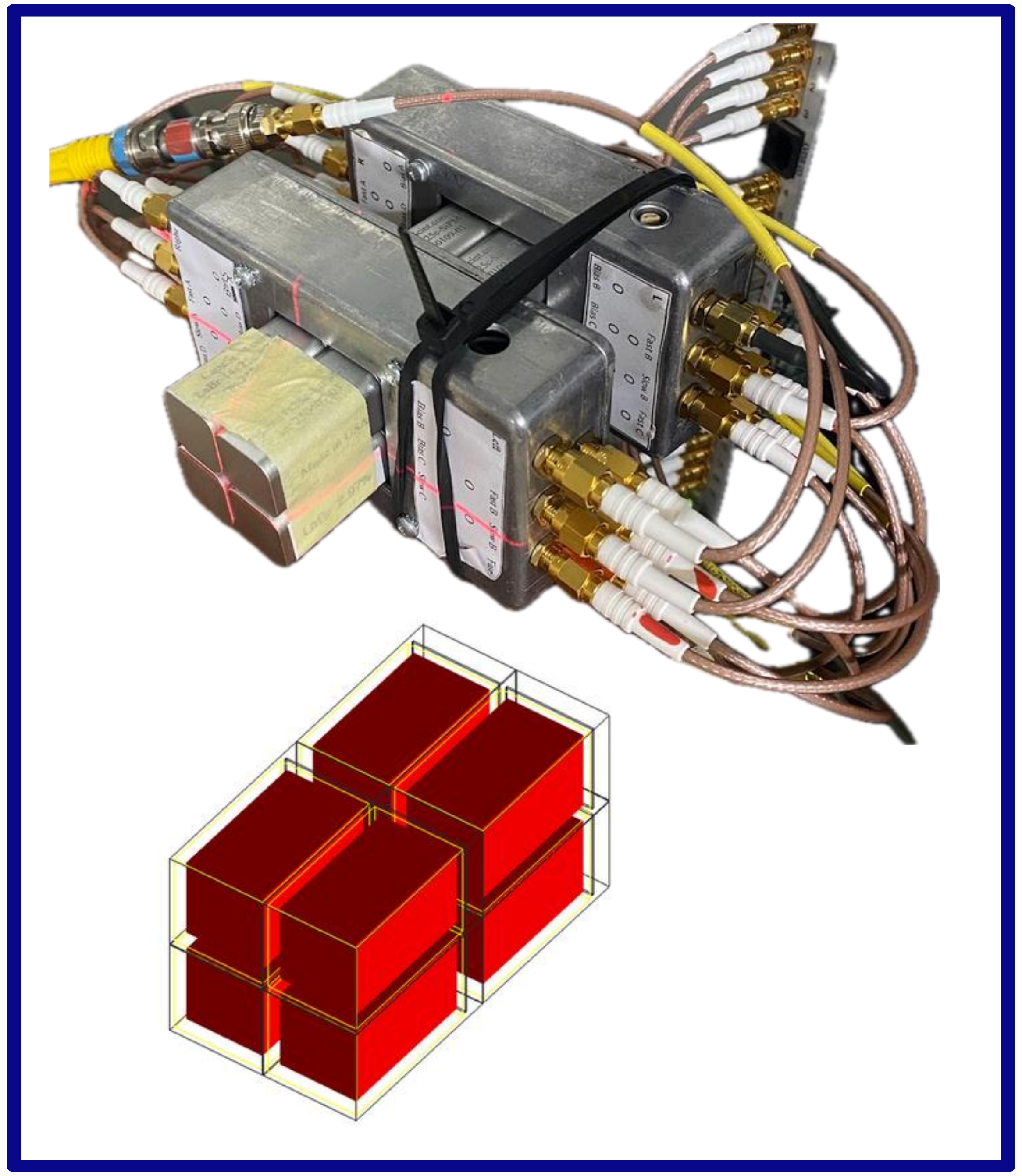
07 July 2026

Compton Camera Principle



$$\theta_{CS} = \cos^{-1}[1 - m_e c^2(\frac{1}{E_A} - \frac{1}{E_S + E_A})]$$

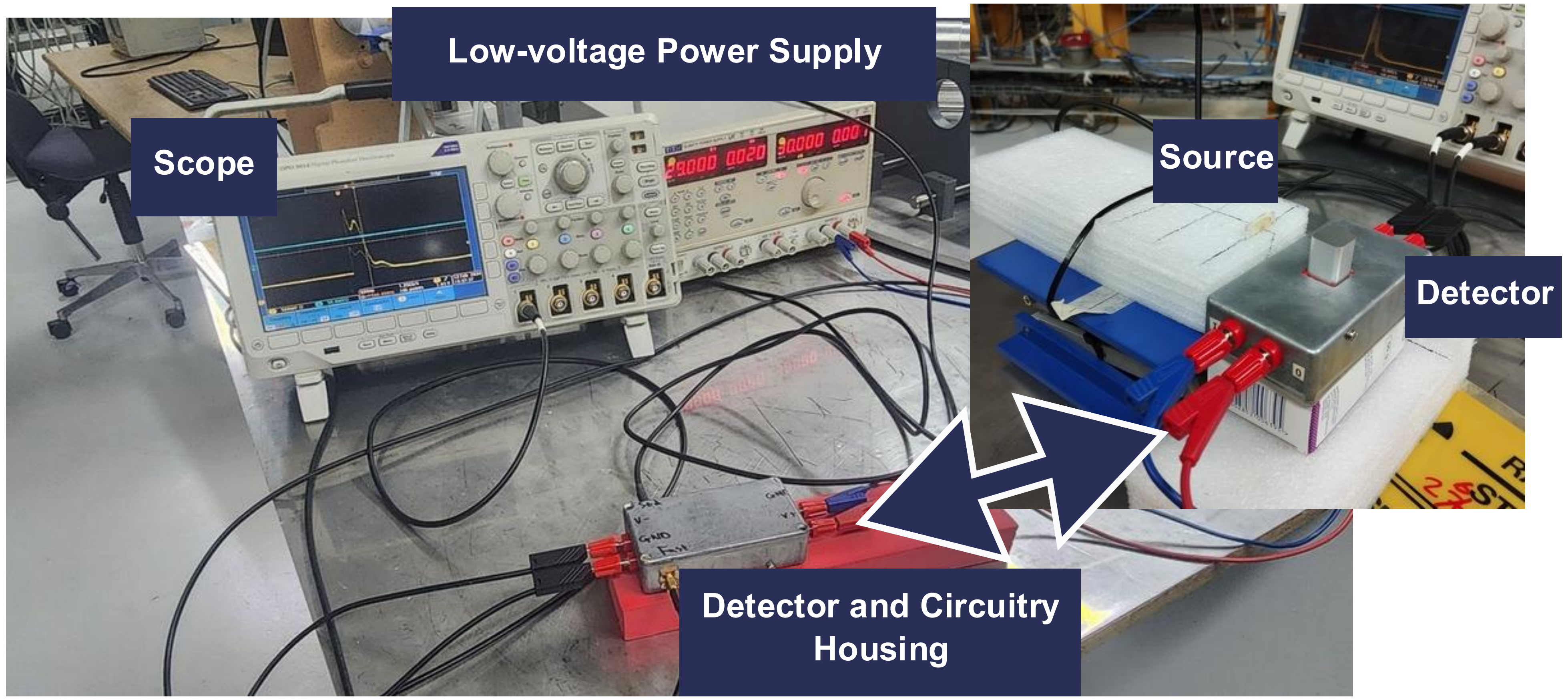


CC **Scatterer and Absorber - MacroPixel LB-14x25c-SiPM-T $LaBr_3$:Ce detector assemblies in two stacked 2 x 2 arrays.**

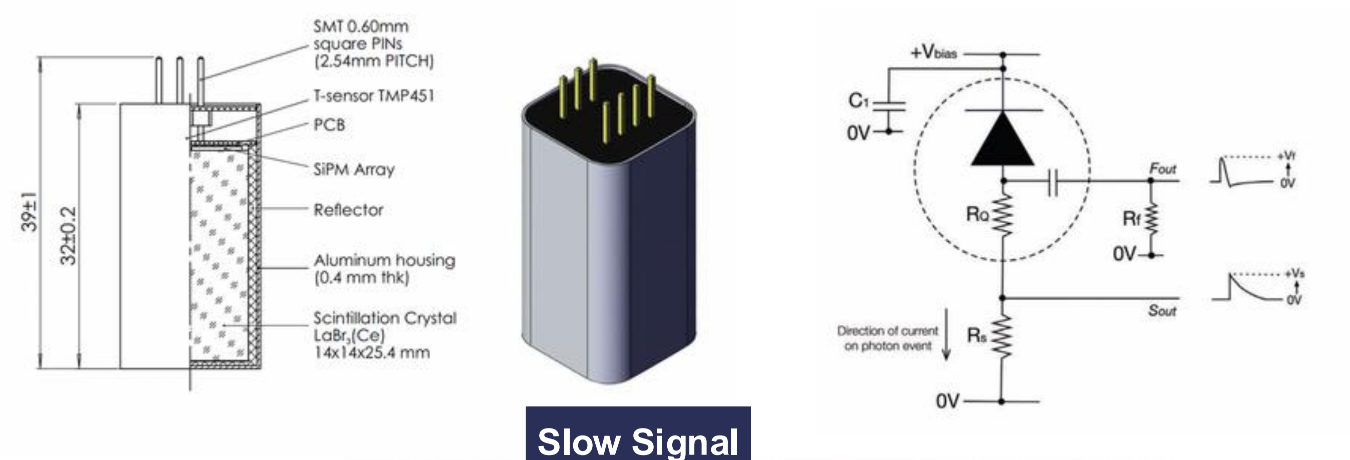
CC: Characterisation

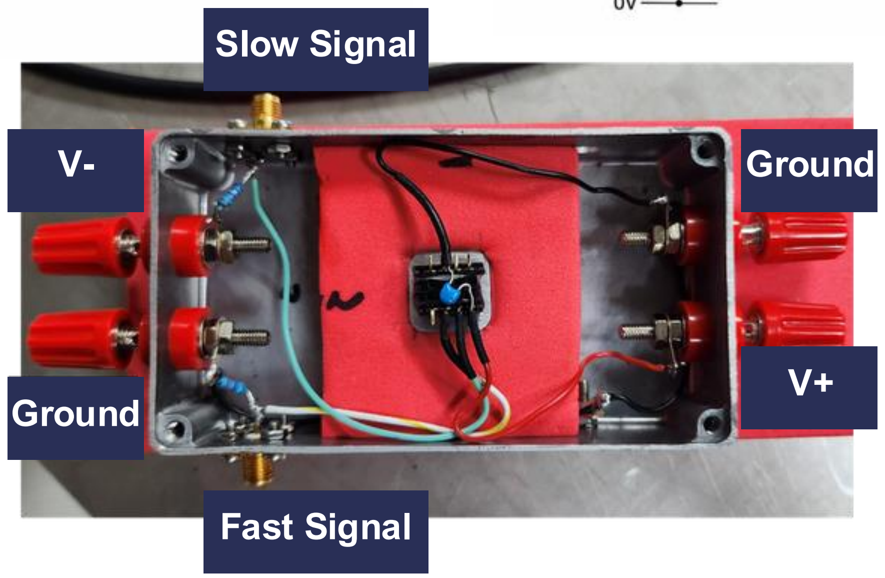
Macropixel detector assemblies (14 x 14 x 25.4 mm³) coupled to a **2x2 MicroFJ-60035-TSV SiPM** array and **TMP451** temperature sensor packed in an aluminium canister. Manufactured by **CapeScint** (MA,USA).

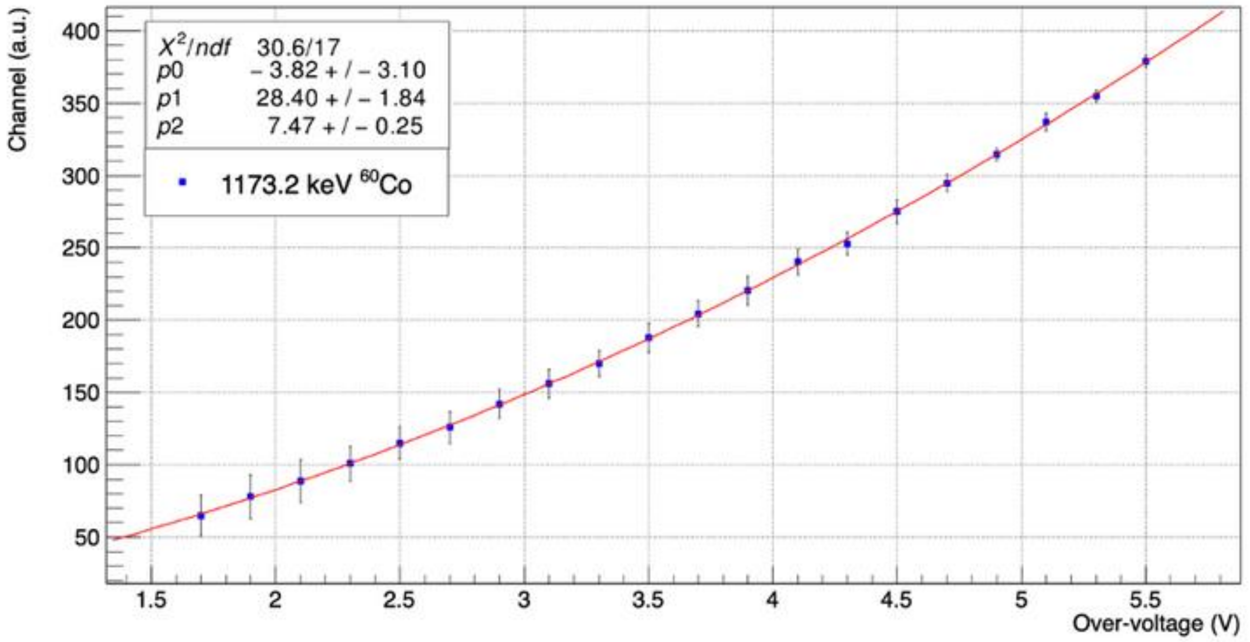
Material	Light Yield [ph/MeV]	Emission λmax [nm]	En. Res. at 662 keV [%]	Density [g/cm³]	Decay Time [ns]
$LaBr_3$:Ce	63,000	360	3	5.1	17
SrI_2:Eu	80,000	480	3–4	4.6	1500
CLYC:Ce	20,000	390	4	3.3	1 CVL 50, ~1000

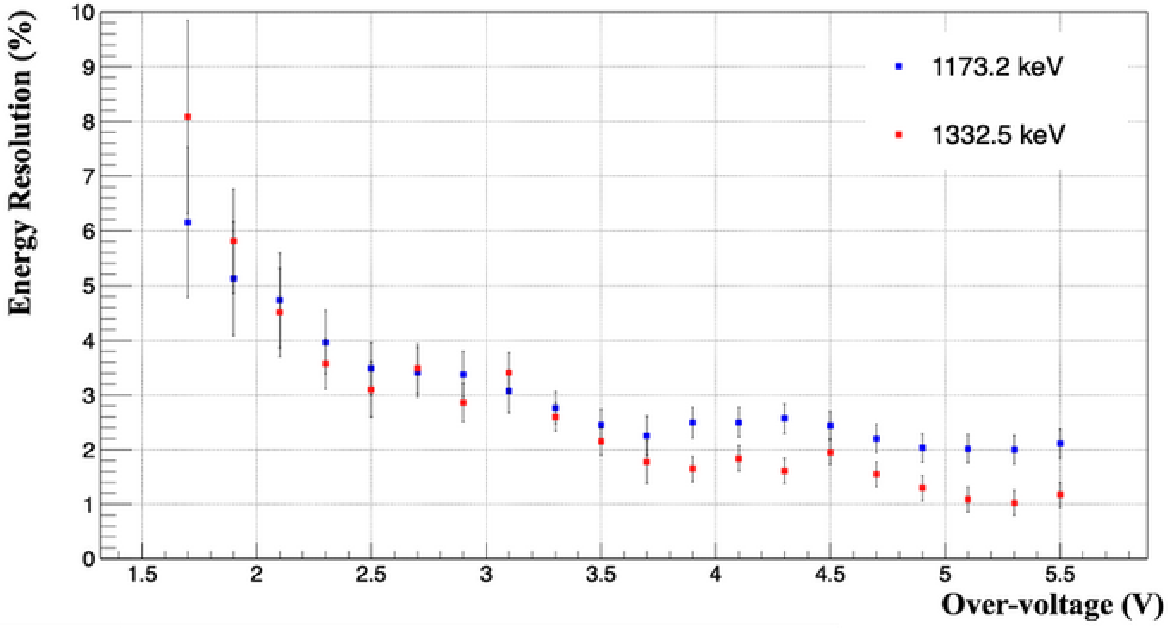


Operational voltage chosen to be 30 V (5.3 V overvoltage)





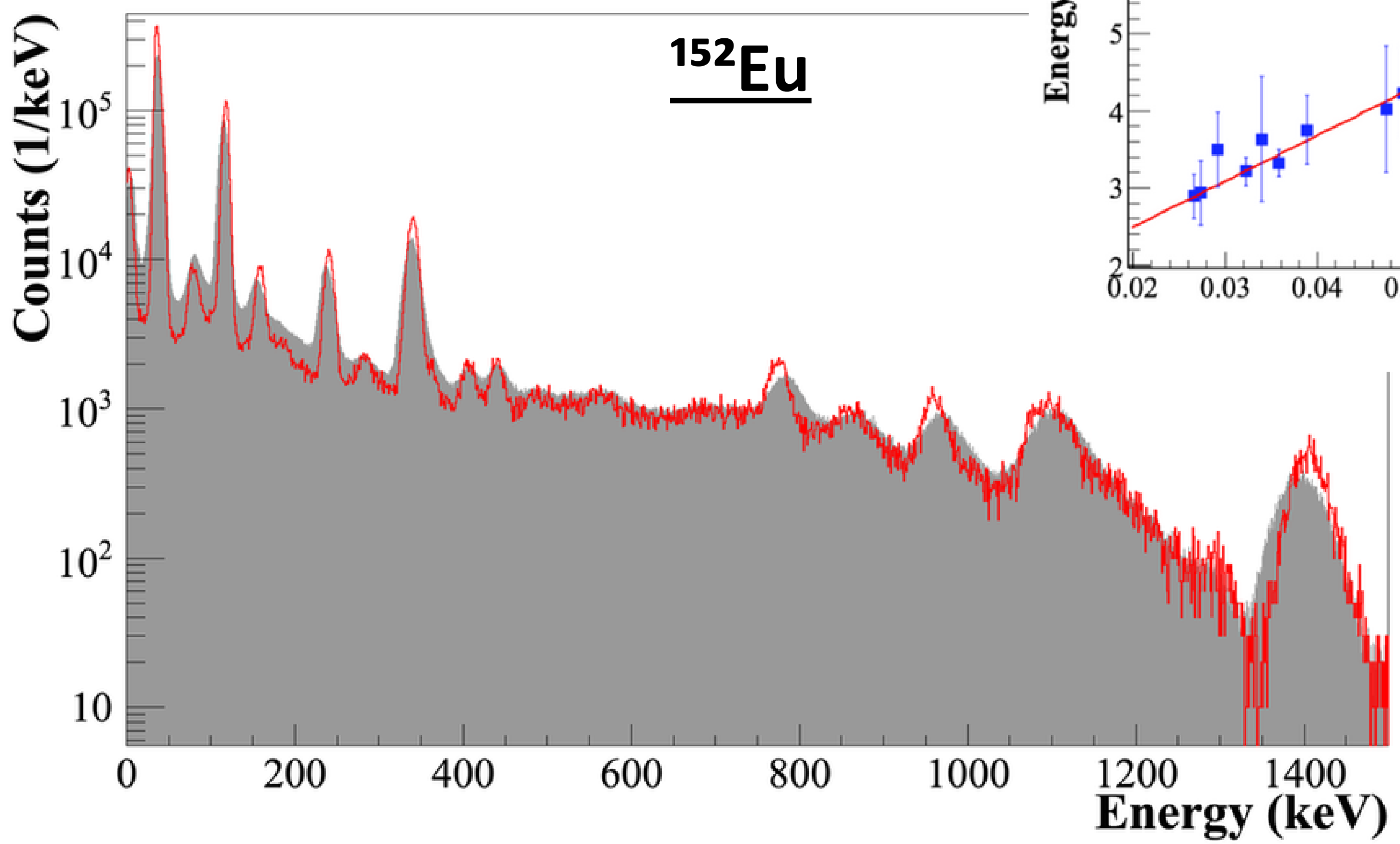


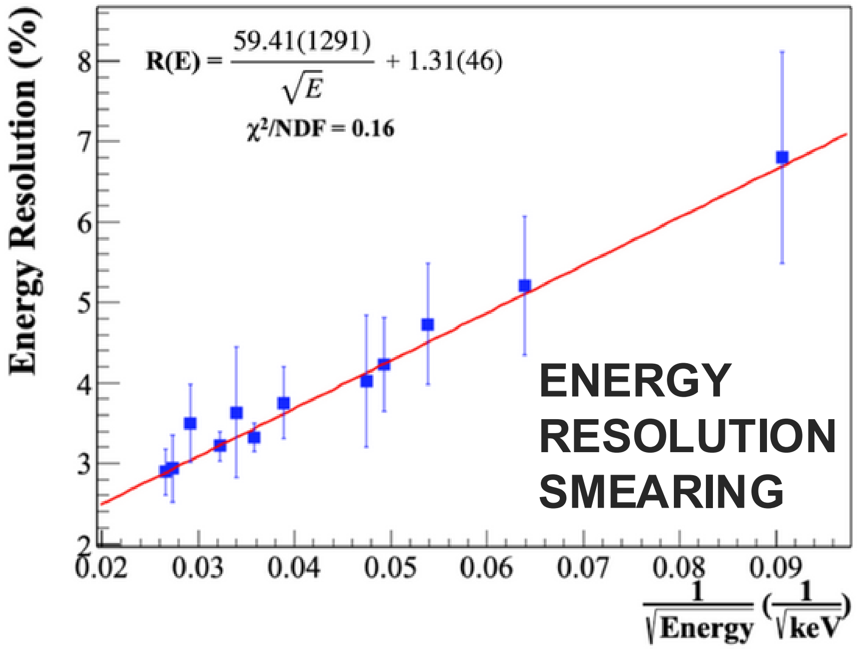


CC: Simulation Validation

TOPAS Geant4
TOPAS MC Inc is a proud user of the Geant4 Simulation Toolkit

LaBr$_3$:Ce-SiPM



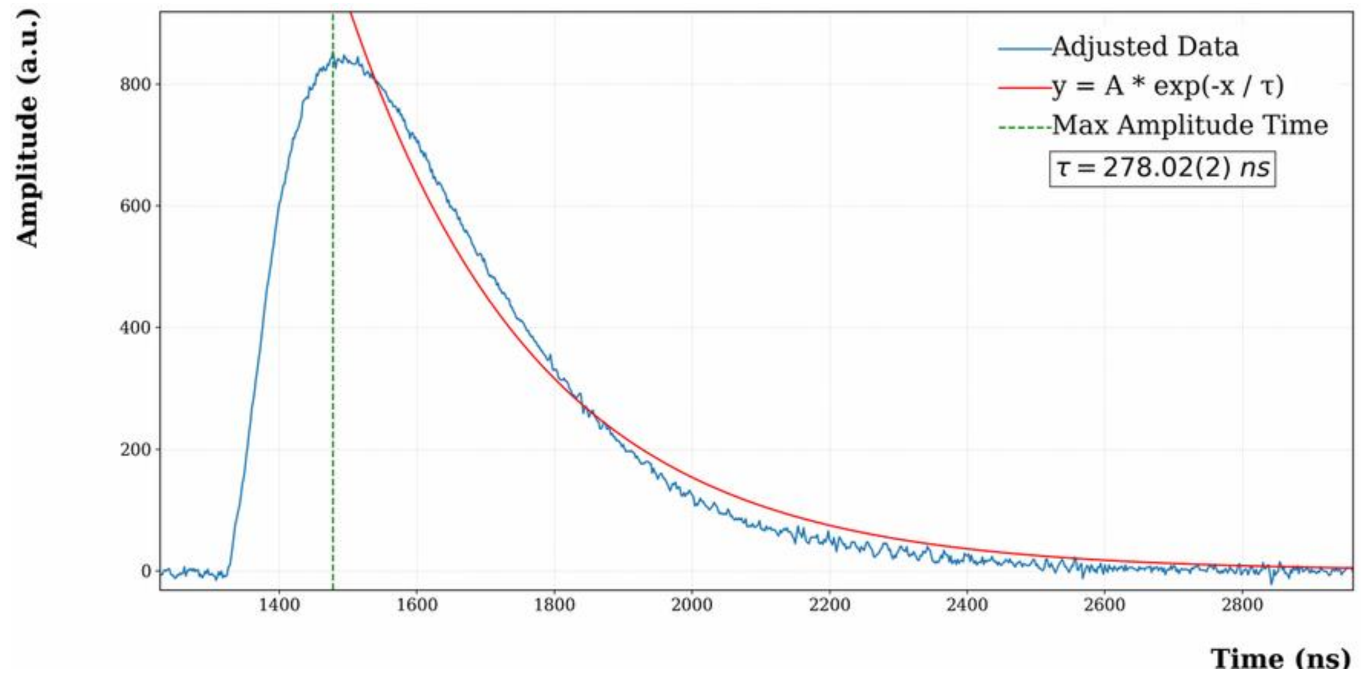


High efficiency for Compton scattering at low energies. Good candidate for addback.

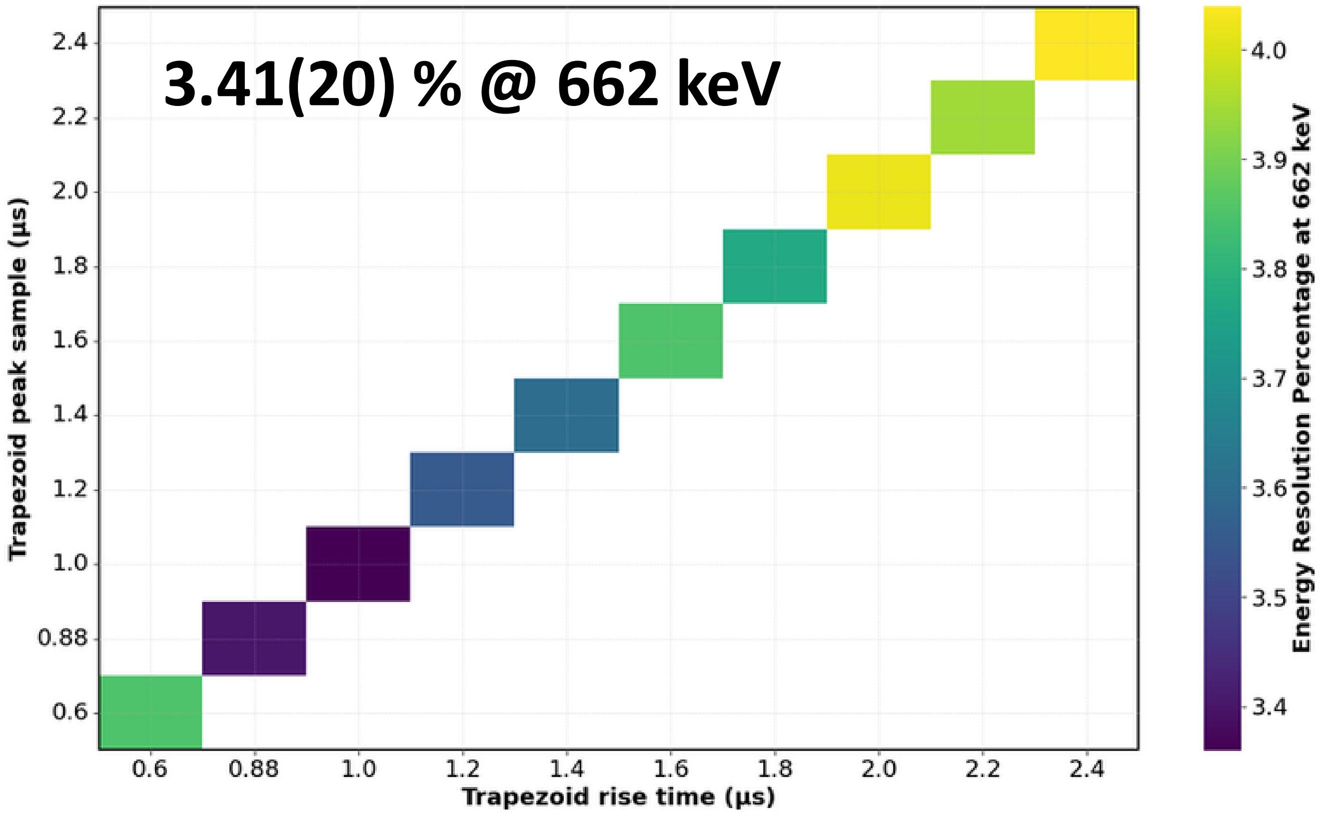
Distance (mm)	344.28 keV			968.08 keV		
	$\epsilon_{EXP,FEPE}$ (%)	$\epsilon_{SIMU,FEPE}$ (%)	Agreement (σ)	$\epsilon_{EXP,FEPE}$ (%)	$\epsilon_{SIMU,FEPE}$ (%)	Agreement (σ)
10.0	1.38(19)	1.50(10)	0.56	0.223(63)	0.196(13)	0.42
30.0	0.332(142)	0.449(90)	0.70	0.123(31)	0.078(21)	1.20
50.0	0.141(16)	0.204(53)	1.14	0.042(39)	0.039(12)	0.074
100.0	0.043(7)	0.044(9)	0.088	0.009(17)	0.009(10)	0

Table 2

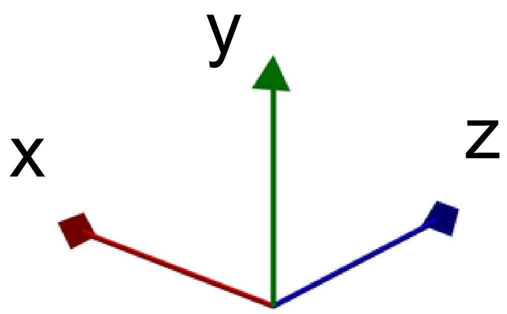
Comparison of experimental and simulation for the LaBr$_3$:Ce DA absolute full-energy peak efficiencies and associated uncertainties for gamma-ray energies 344.28 keV and 968.08 keV at various source-to-detector distances.

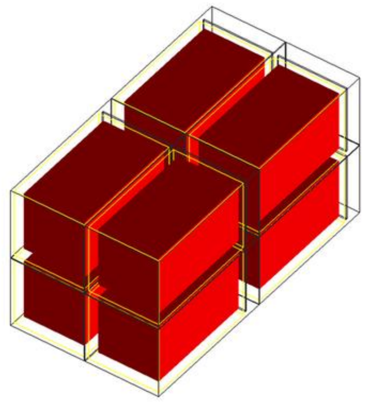


Triangular Optimisation of slow signal (Flat top = 0 µs)



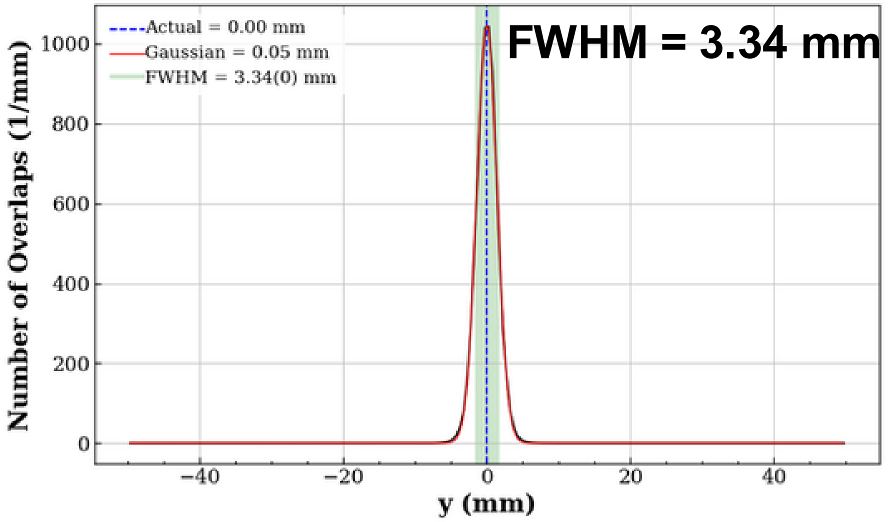
CC: Simulation Results

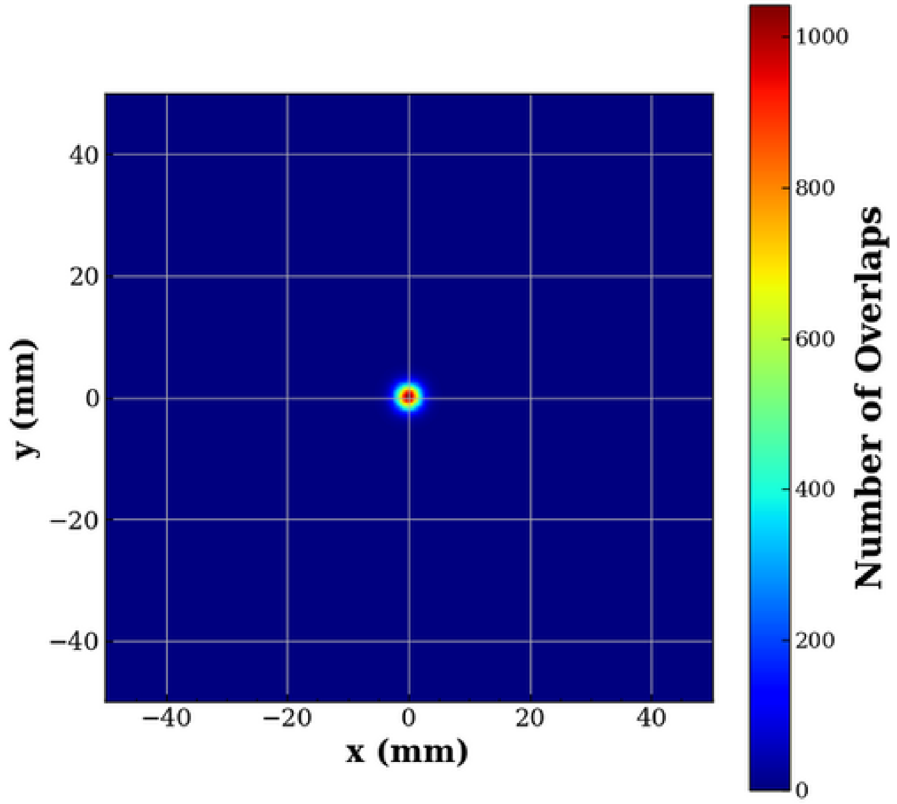




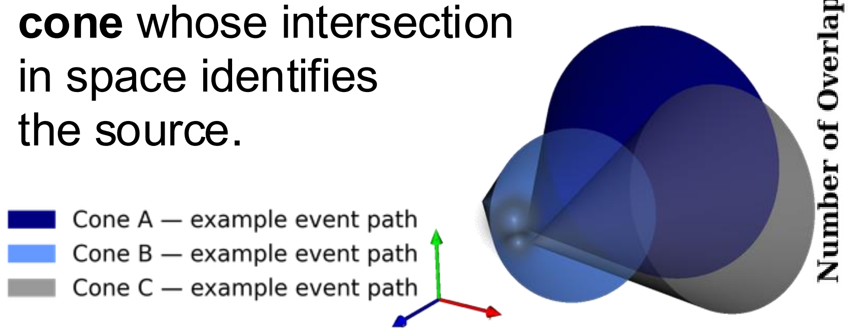
^{137}Cs source at (0,0,10) mm from scatterer face

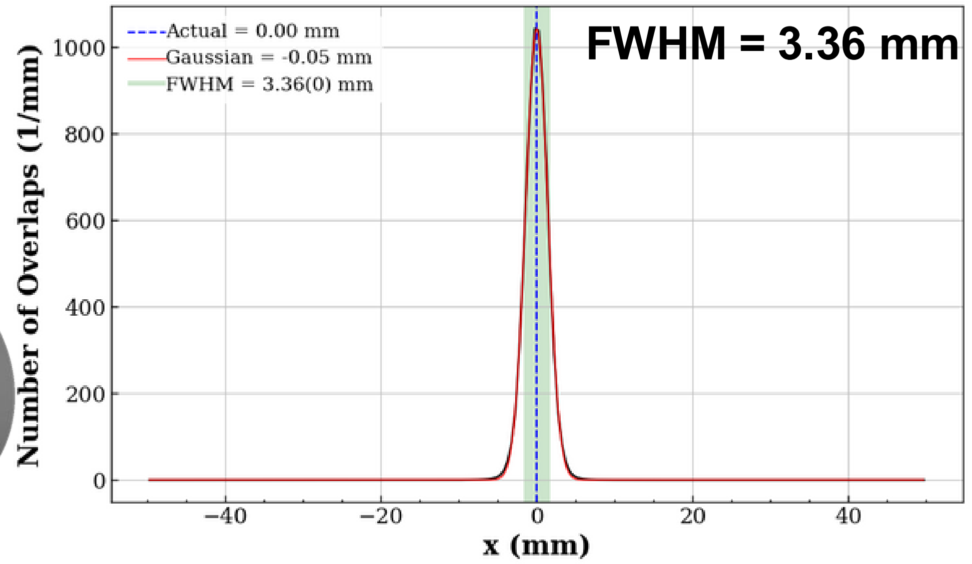
Image Resolution



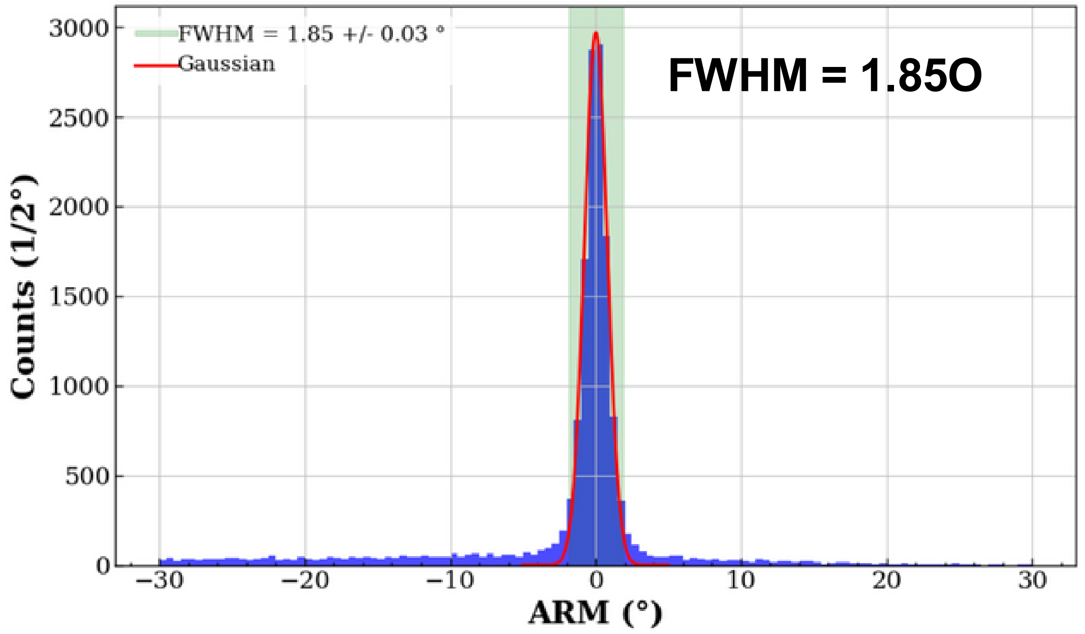


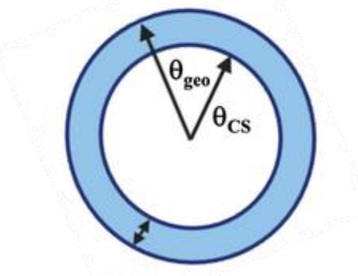
3D iterative filtered back-projection algorithm applied to simulated Compton events.
Each valid event defines a **Compton cone** whose intersection in space identifies the source.





Angular Resolution Measurement





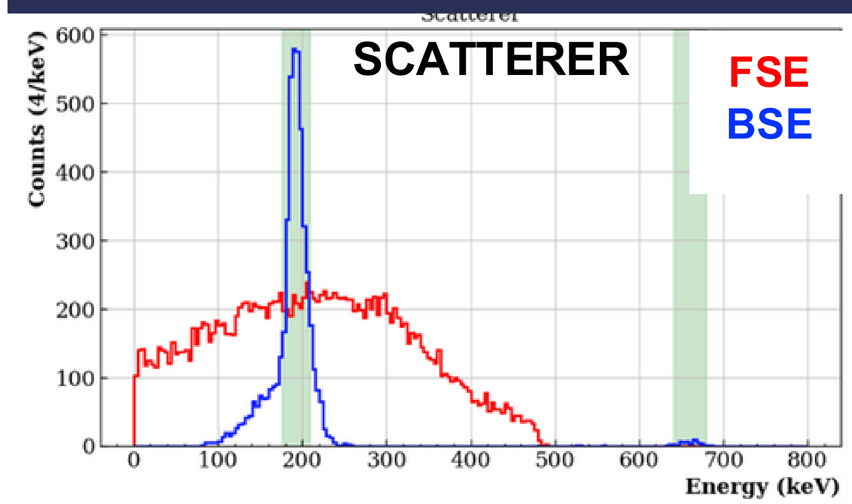
$\mathrm{ARM} = \theta_{geo} - \theta_{CS}$

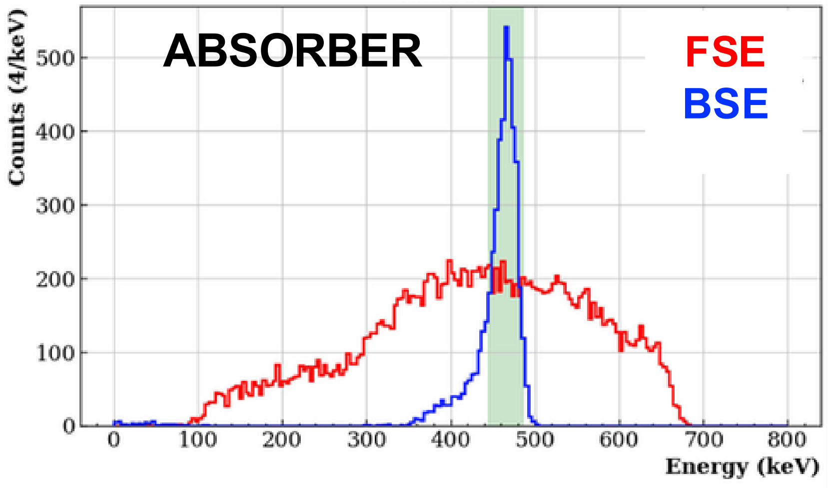
$$\theta_{geo} = cos^{-1}\left(\frac{(r_S - r_0)\cdot(r_A - r_S)}{|r_S - r_0|\cdot|r_A - r_S|}\right)$$

$$\theta_{CS} = cos^{-1}\left(1 - m_e c^2\left(\frac{1}{E_A} - \frac{1}{E_S + E_A}\right)\right)$$

$$m_e c^2 = 510.9989461\ \mathrm{keV}$$

Effect of CC Backscattering

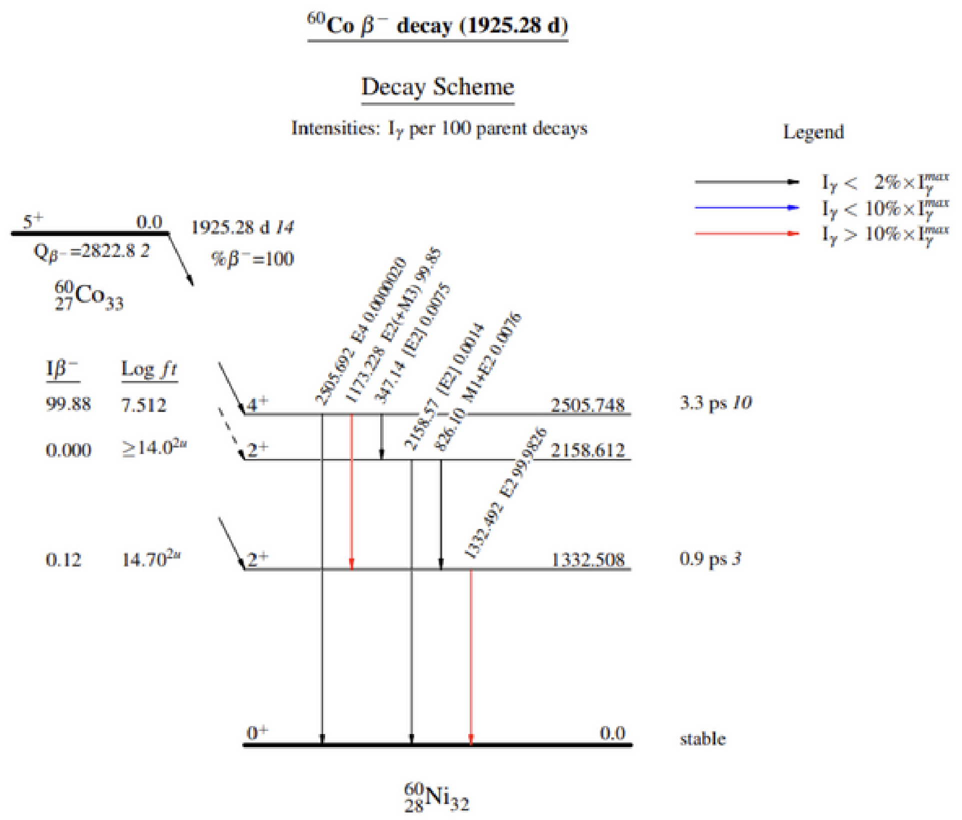




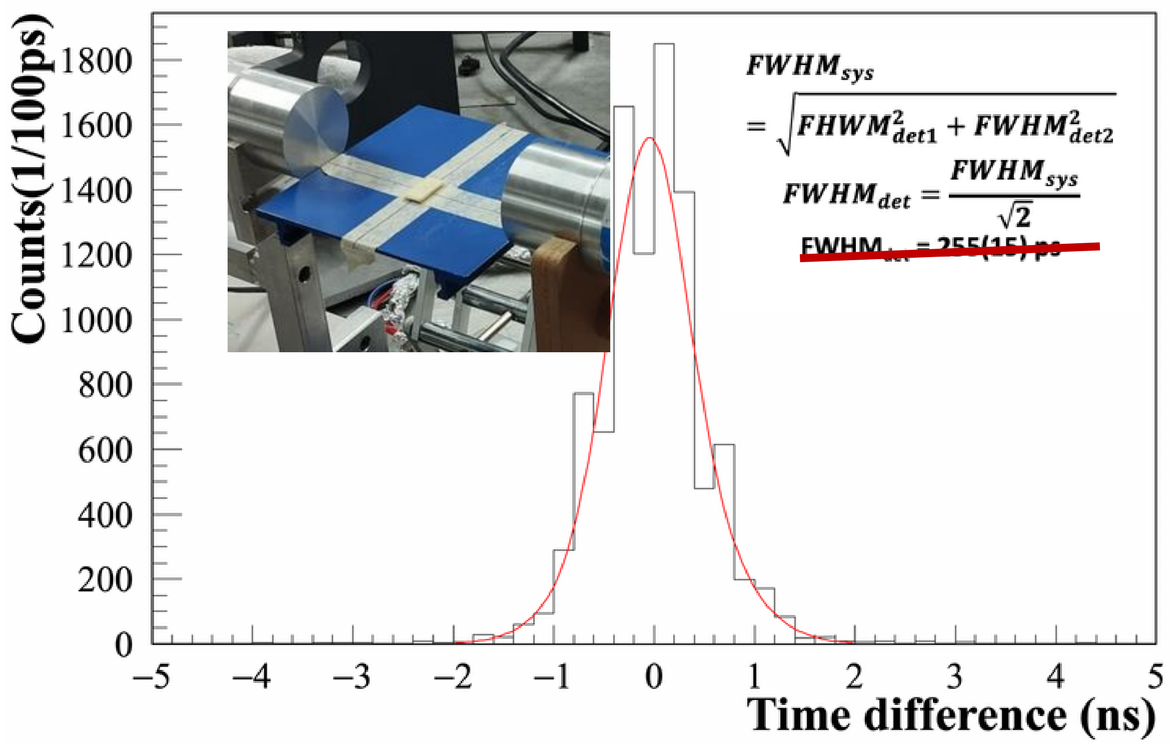
CC: DA Fast-Timing Performance

Calculated by gating on the ^{60}Co prompt-gamma decays. The time interval between the **1173 keV** and **1332 keV** emissions is **<0.9 ps**, effectively instantaneous compared to detector resolution.

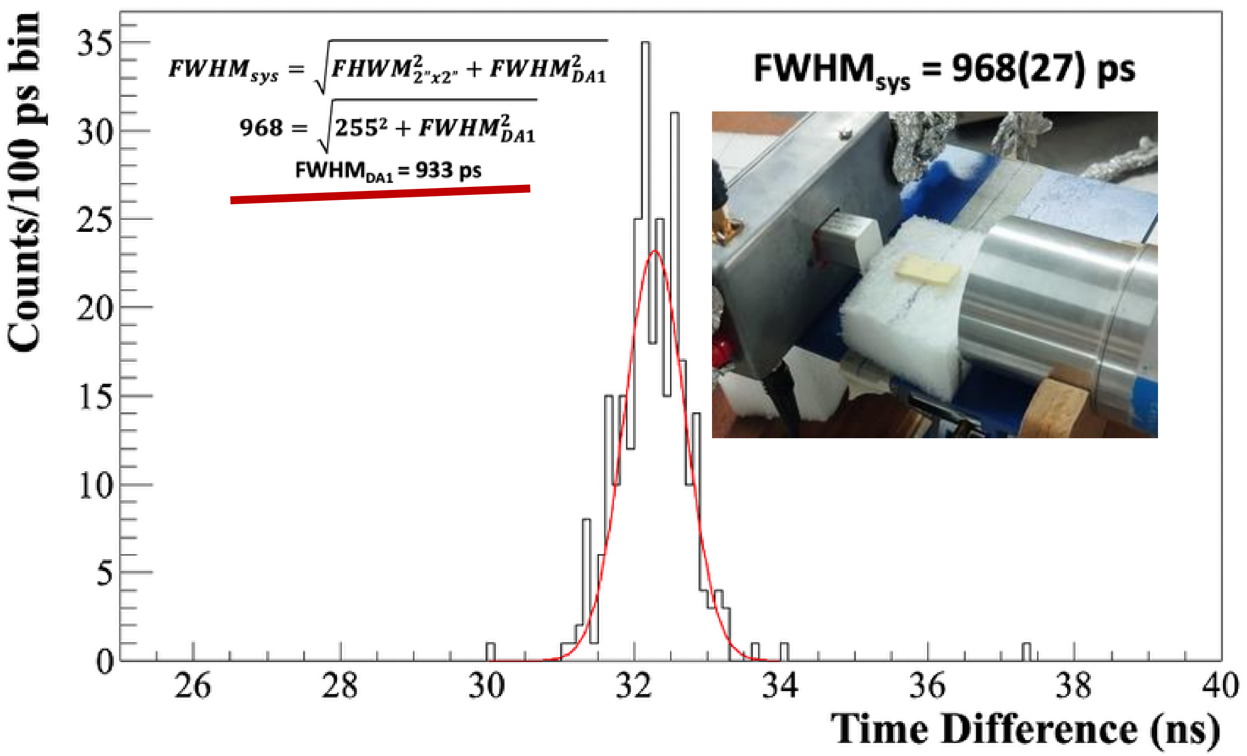
Measurements performed using the **14-bit XIA PIXIE-16 500 MHz** data acquisition system, exploiting the use of the **digital CFD** for fast timing.



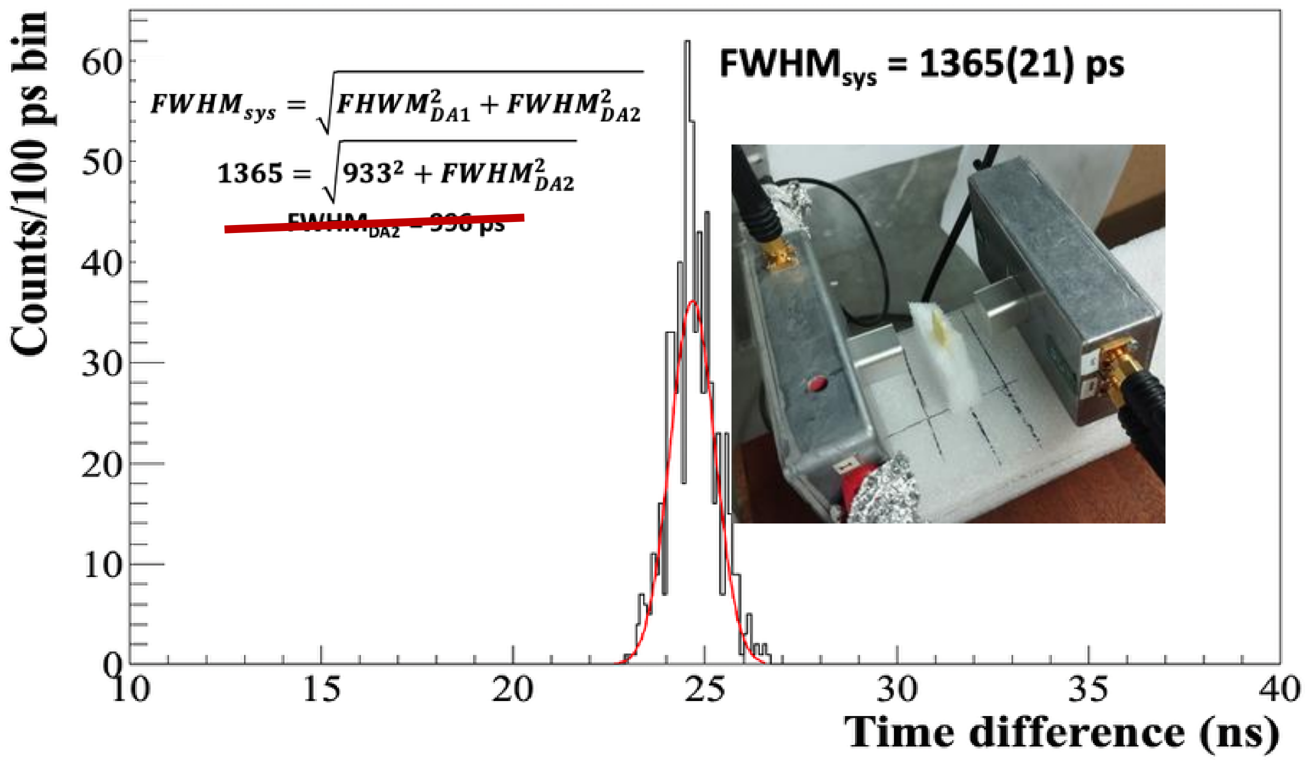
Two 2” x 2” LaBr$_3$:Ce detectors



2” x 2” LaBr3:Ce and LaBr$_3$:Ce-SiPM DA



Two LaBr$_3$:Ce-SiPM DAs



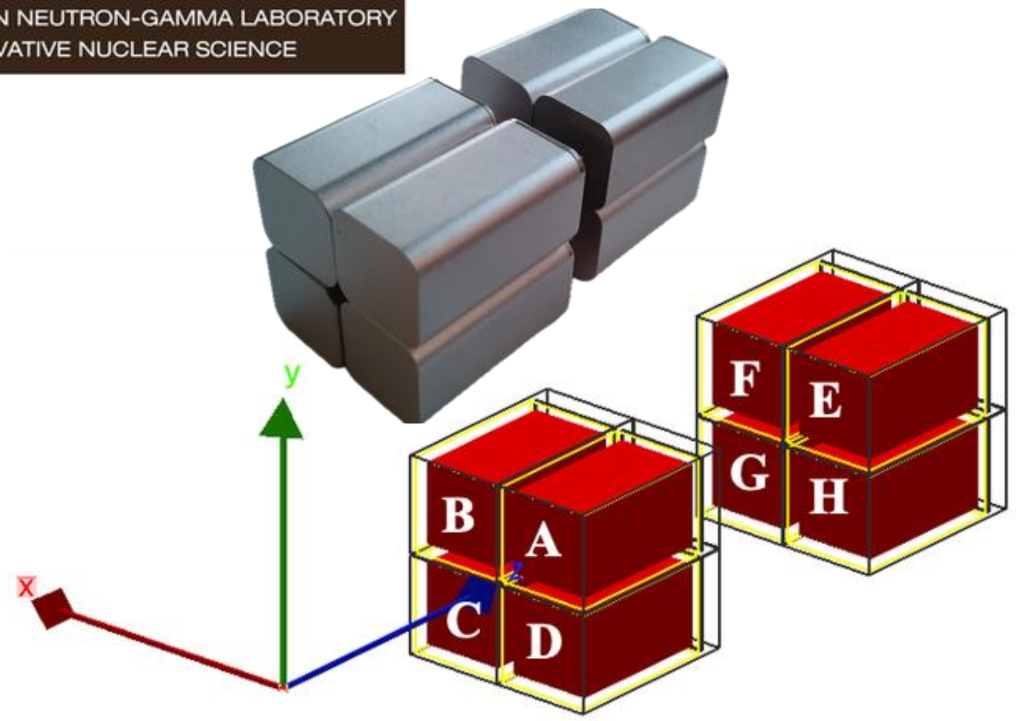
Postdoctoral Research

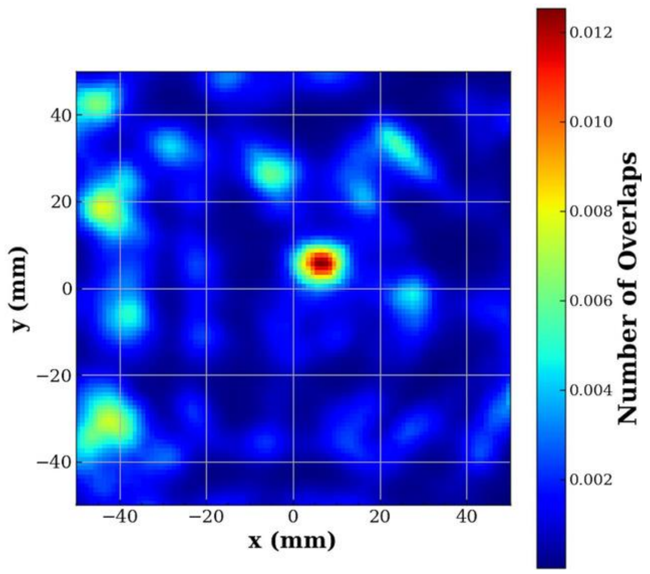
DASSIE

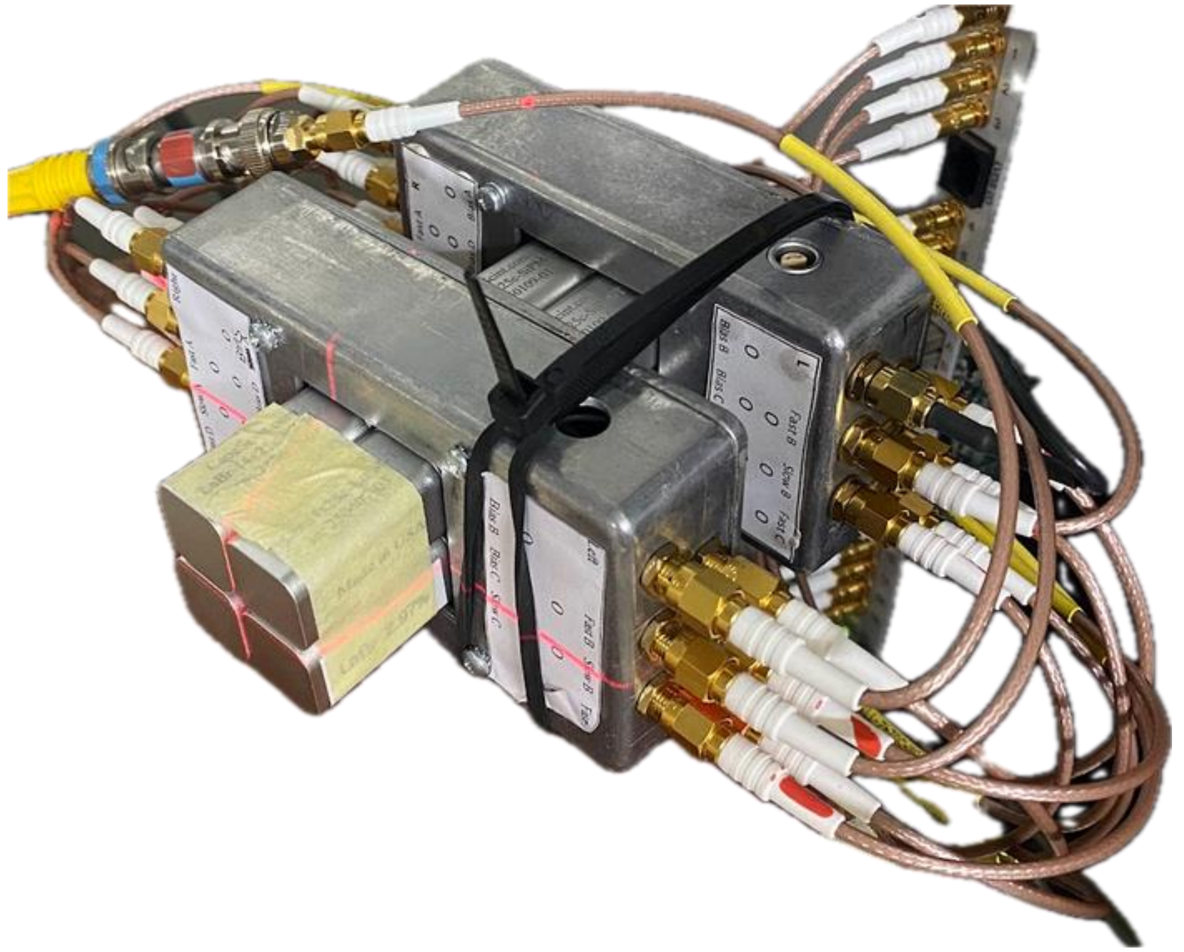
PANGOLINS
PORTABLE AFRICAN NEUTRON-GAMMA LABORATORY FOR INNOVATIVE NUCLEAR SCIENCE

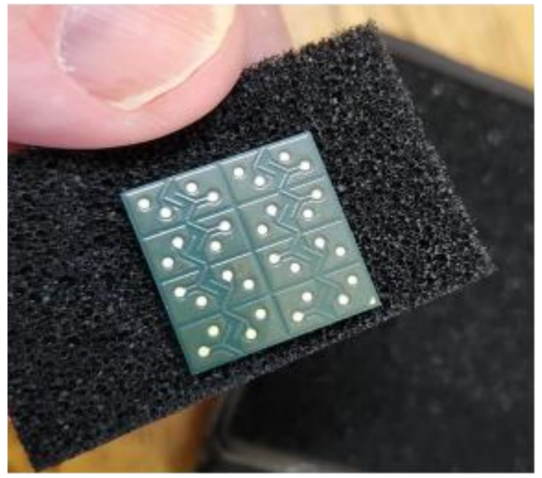
Current & Upcoming Work

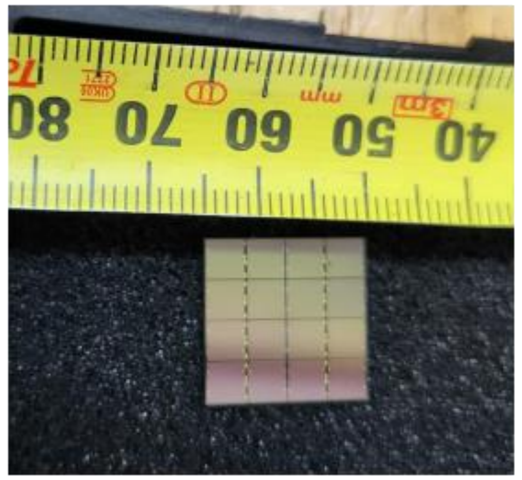
- **Position-sensitive detection in $LaBr_3$:Ce scintillators**
- Improving spatial resolution using **Broadcom AFBR-S4N44P164M 4×4 SiPM arrays**
- **Custom development boards** currently in production
- **Enhanced Geant4 simulations**
- Realistic performance modelling for detector optimisation
- **Drone-based deployment** of Compton Cameras
- Environmental monitoring and mapping applications
- **In-beam proton testing**
- Evaluation with **70 MeV and 200 MeV proton beams** for medical imaging

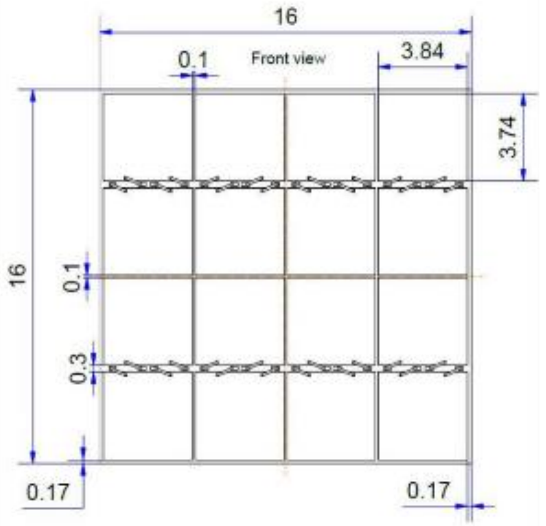












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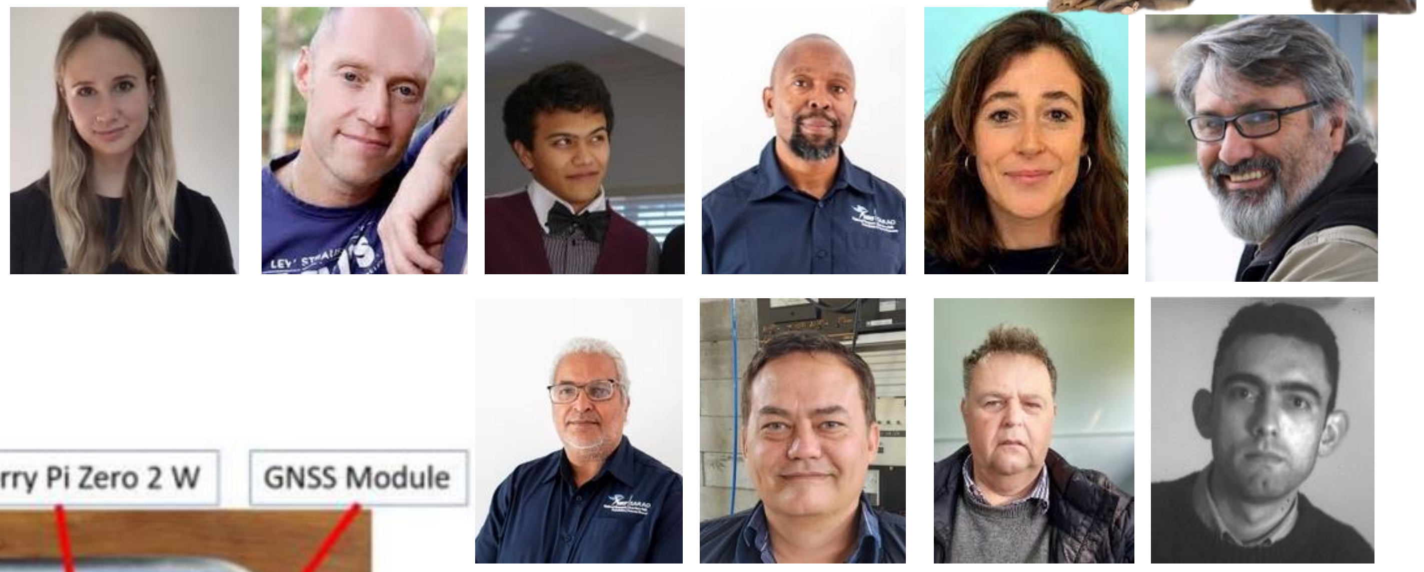
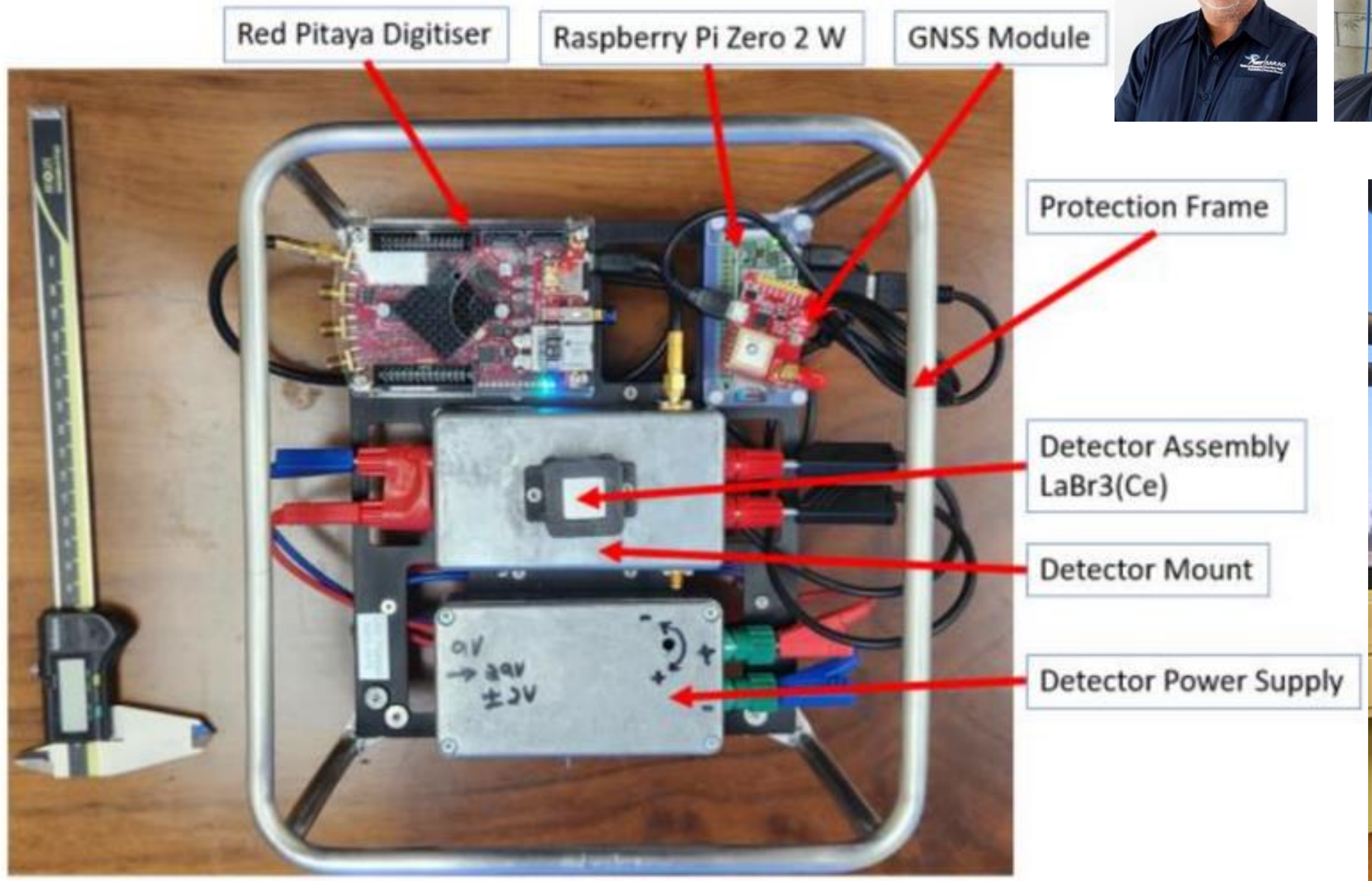
PORTABLE AFRICAN NEUTRON-GAMMA LABORATORY FOR INNOVATIVE NUCLEAR SCIENCE

The **P**ortable **A**frican **N**eutron-**G**amma **L**aboratory for **I**nnovative **N**uclear **S**cience



Milestones

- Reduce footprint of the Mobile Radiation Detection Unit
- Adopt **next-generation detectors**
  → $LaBr_3$, SrI2, CLYC-6 (Cs_2LiYCl_6)
- Enable **neutron sensitivity** with effective gamma–neutron discrimination
- Transition from photomultipliers to **SiPMs**
  → Compact, low-power silicon avalanche photodiodes
- Eliminate high-voltage requirements
  → Shift to stable **low-voltage** operation
- Characterise and deploy advanced **measurement systems**
- Expand field testing
  → On-foot and **drone**-based in-situ deployments



Completed payload (Mass: 1.1 kg compared with the 3.8 kg of its predecessor)

PANGoLINS: In-situ work

Development of a mobile gamma-ray $LaBr_3$:Ce detector unit for in-situ radionuclide analysis at TENORM contamination sites

by

Ferdinand van Niekerk

UNIVERSITY OF CAPE TOWN

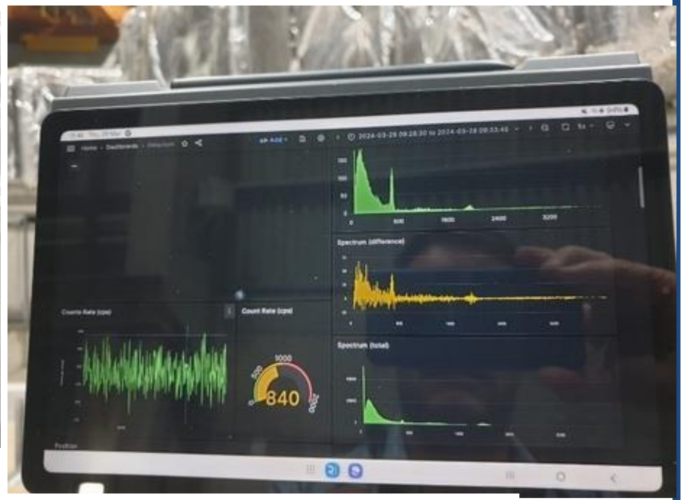
PANGoLINS PhDs

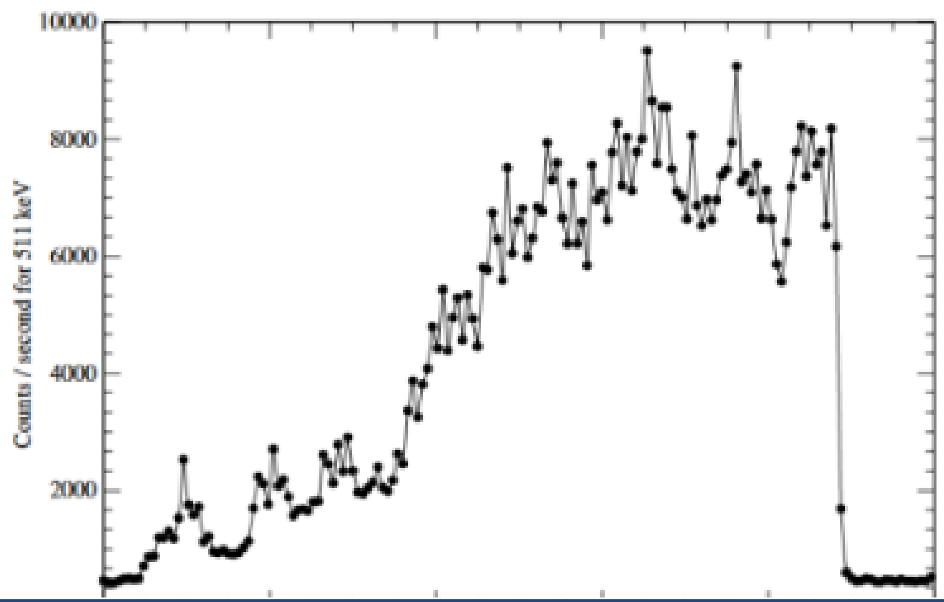
Building a Hybrid Compton Camera System for Improving Proton Therapy Imaging

Orphan ^{226}Ra source (< Ci) - \$70k / gram

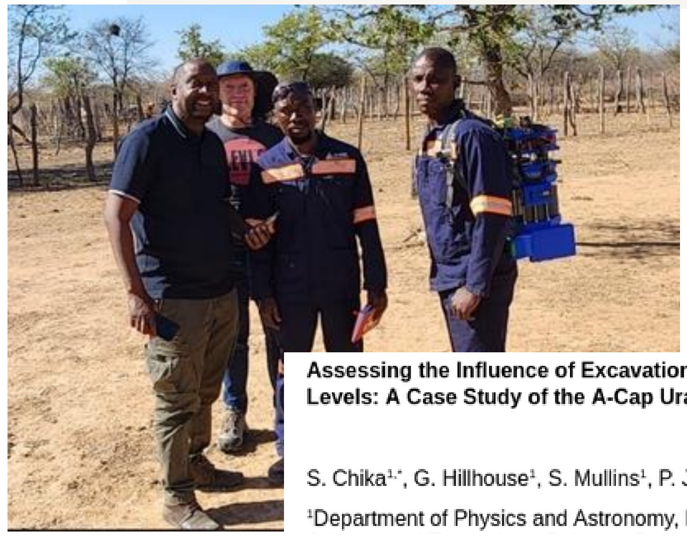
SAIF SOUTH AFRICAN ISOTOPE FACILITY

Investigating ^{15}O in SAIF cooling water





LOTUS RESOURCES



Radiation consequences in mining

Assessing the Influence of Excavation Practices on Background Radiation Levels: A Case Study of the A-Cap Uranium Mining Lease Area in Botswana

S. Chika[1,*], G. Hillhouse[1], S. Mullins[1], P. Jones[2]

[1]Department of Physics and Astronomy, Botswana International University of Science and Technology, Palapye, Botswana

[2]iThemba LABS, Separated Sector Cyclotron Laboratory, P. O. Box 722, Somerset West 7130, South Africa

Radiation in deep-sea cables

In-situ gamma and neutron spectroscopy

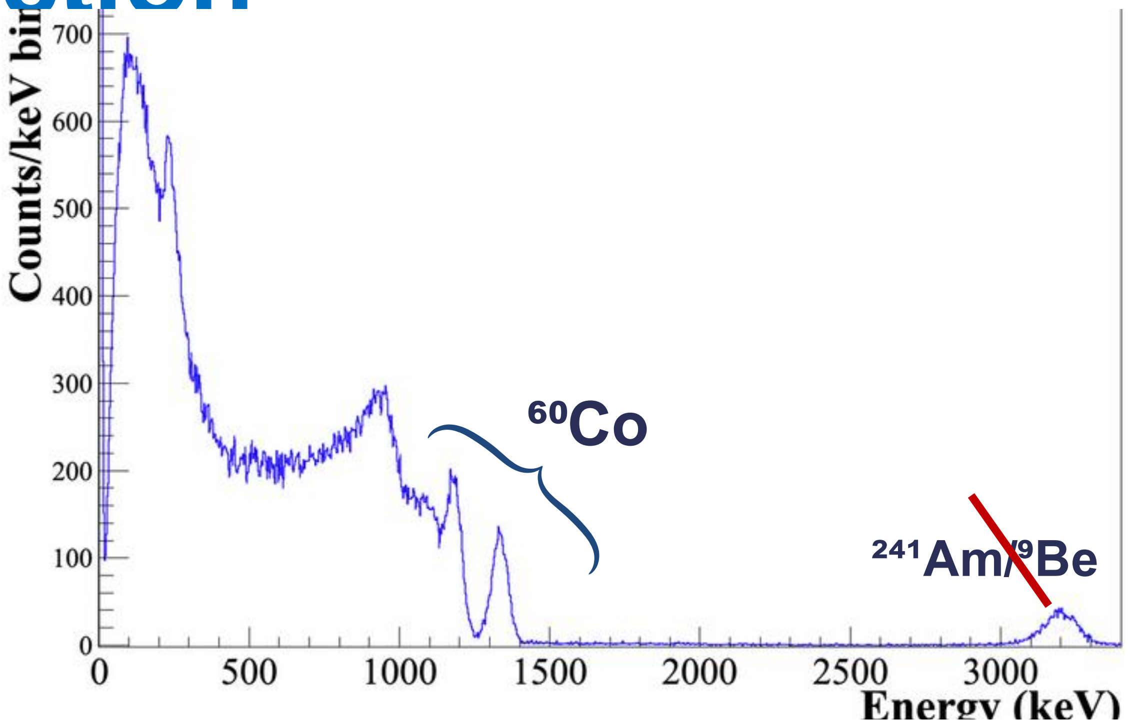
PANGoLINS: CLYC-6 for Thermal Neutron Detection

Measurements

$^{241}Am/^{9}Be$ neutron source (6.9 GBq) and **^{60}Co gamma source**
PIXIE-16 500 MHz DAQ
Elpasolite crystal Cs_2LiYCl_6:Ce (^{6}Li = 95%) detector **slow signal**.

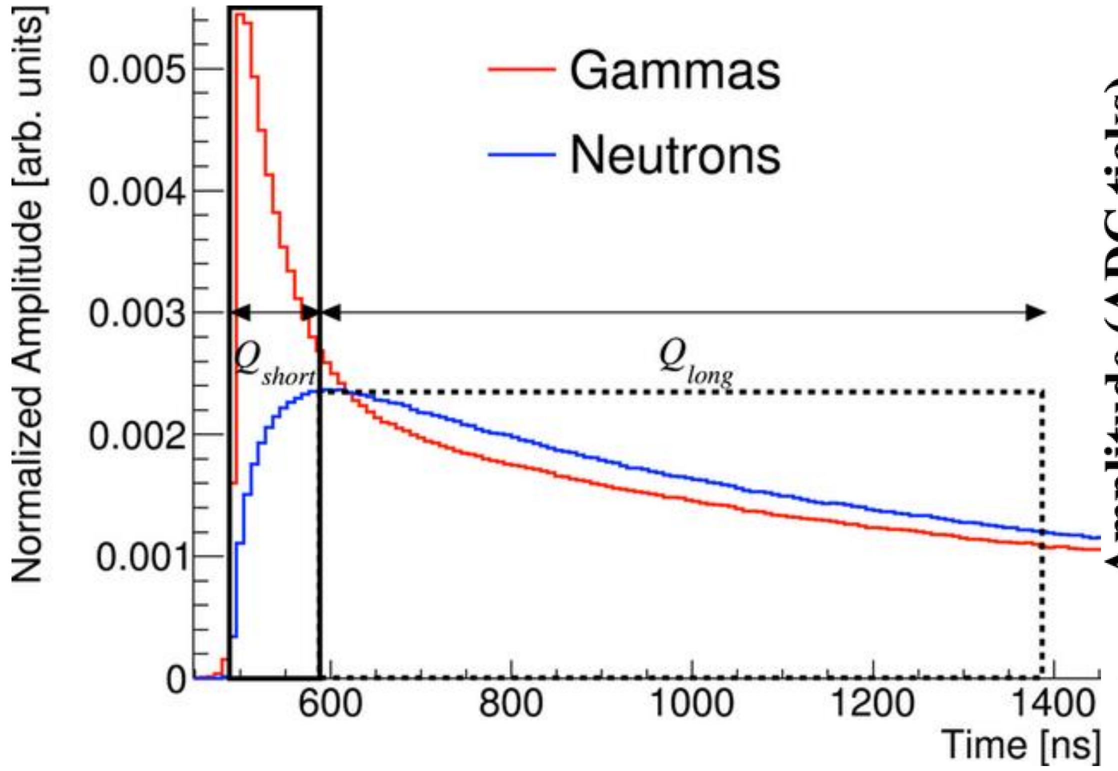
$^{6}Li + n \rightarrow {}^{3}H(2.73\ \text{MeV}) + \alpha(2.05\ \text{MeV})$ Q-value = 4.78 MeV, σ = 940 barns at En = 0.025 eV.
$^{35}Cl + n \rightarrow {}^{35}S + p$

3.2 MeV thermal neutron peak observed due to quenching effects.

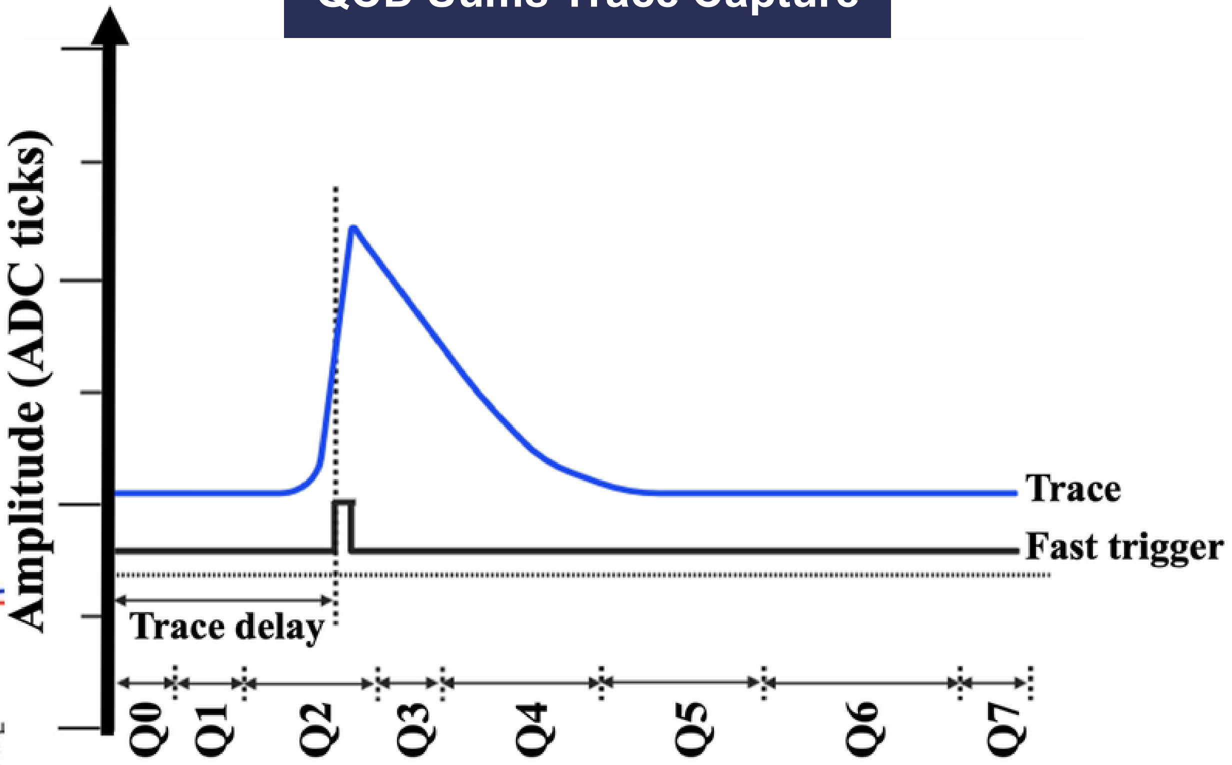


PSD is based on the difference in the scintillation decay response to gamma and neutrons

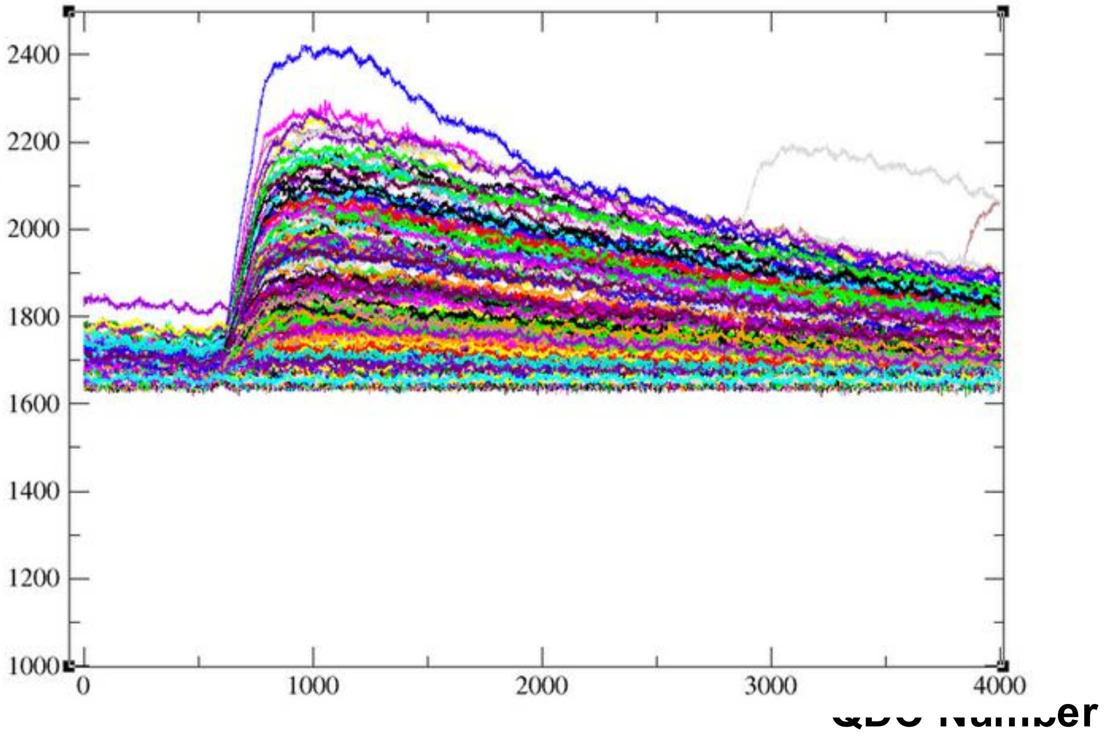
Signal Rise Times



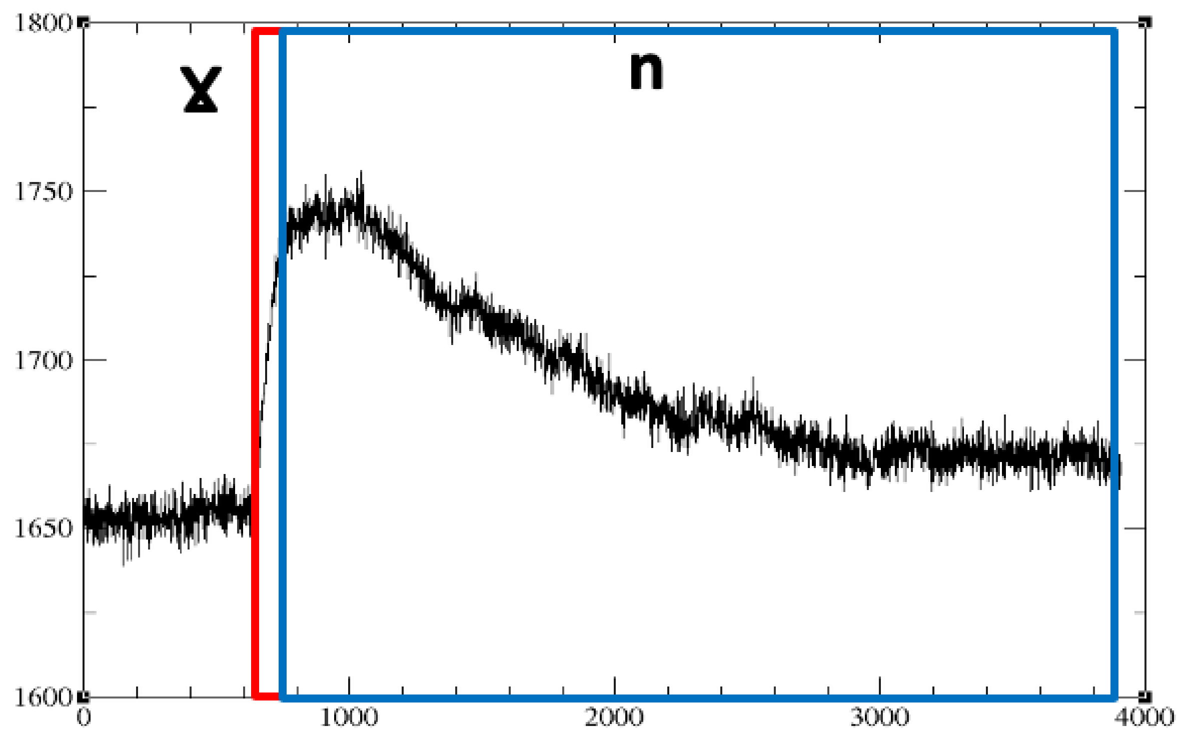
QCD Sums Trace Capture

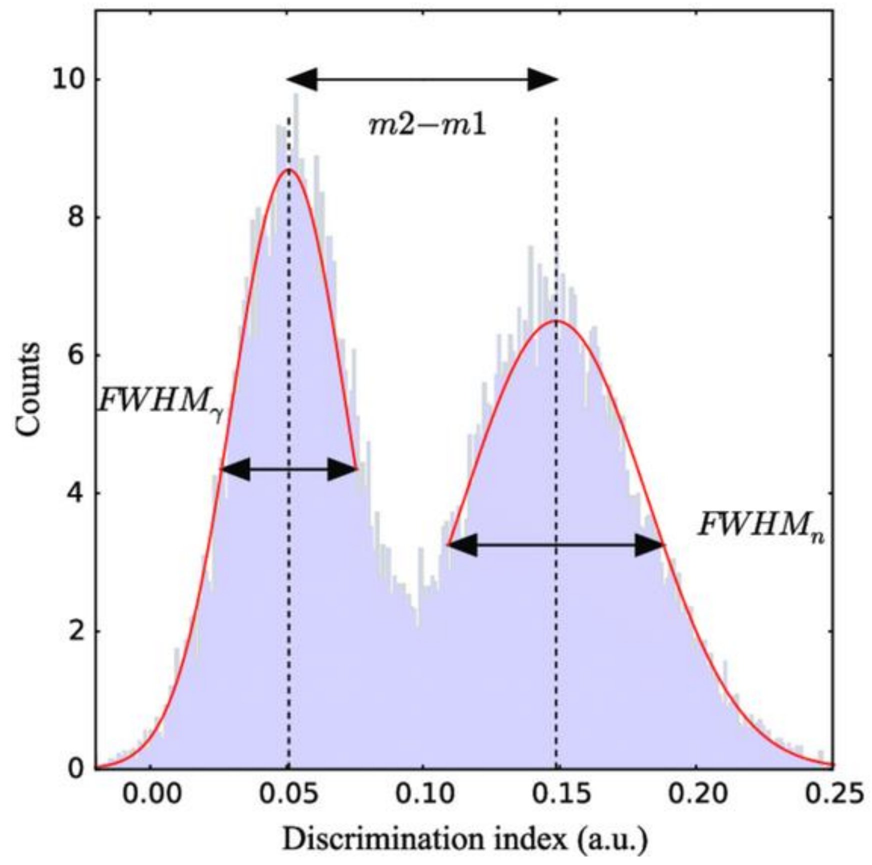


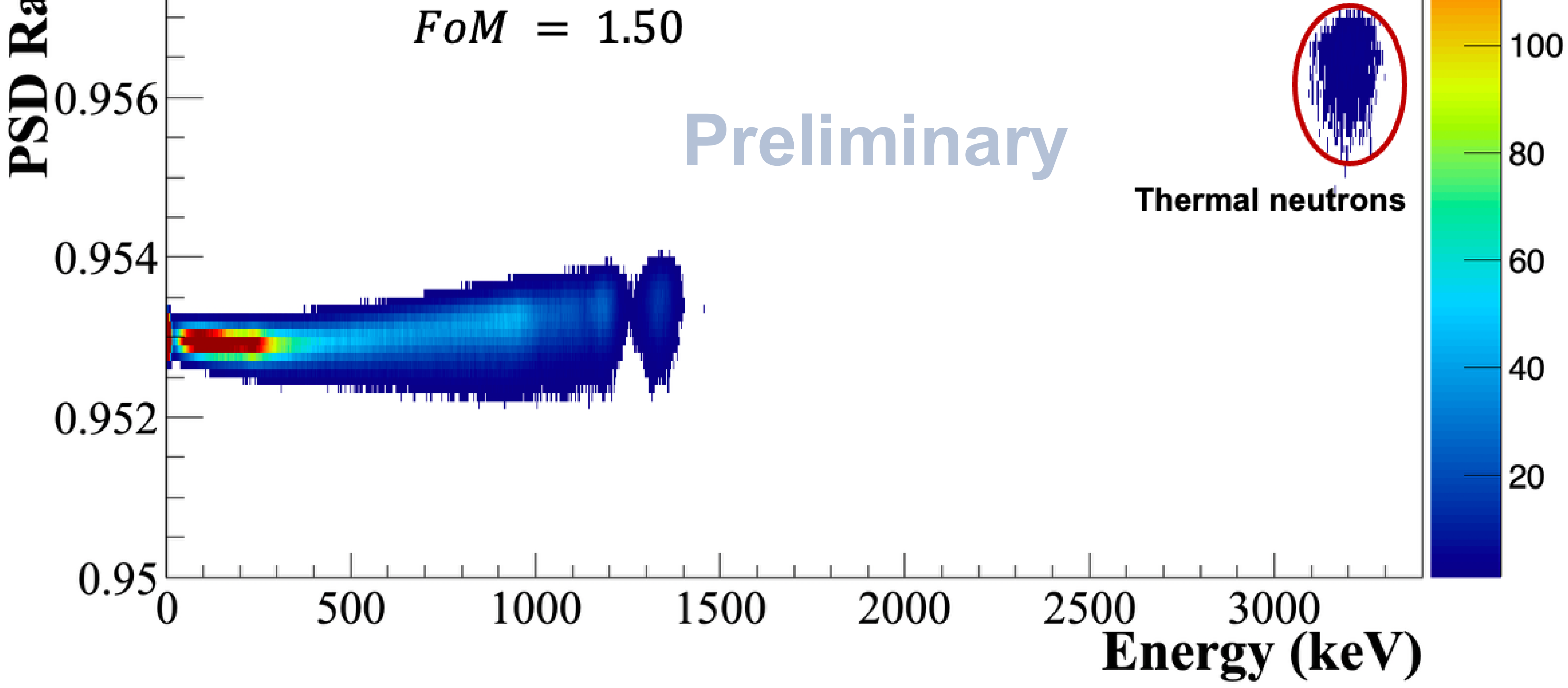
CLYC Traces



PANGoLINS: CLYC-6 for Thermal Neutron Detection







$$FoM = \frac{m_2 - m_1}{FWHM_y + FWHM_n}$$

$$FoM = 1.50$$

Acknowledgements

Collaborators & Contributors

Dr. Pete Jones
Assoc. Prof. Luna Pellegri
Prof. Steve Peterson
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Dr. Philippos Papadakis
Mr. Moschos Kogimtzis
Dr. Carl Unsworth
Dr. Matthew Russell
Dr. Marc Labiche

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Technology Innovation Agency (TIA)

National Research Foundation

Science and Technology Facilities Council

Southern African Institute for Nuclear Technology & Sciences

technology innovation AGENCY
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Supported 2023-24 under Grant number 14606/01

Thank you for your attention

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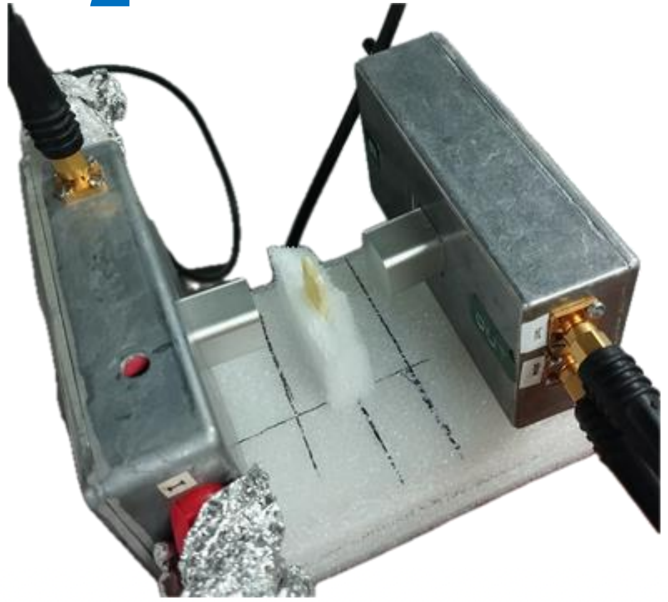
Questions?

Back-up slides

SrI_2:Eu: Fast-Timing Resolution



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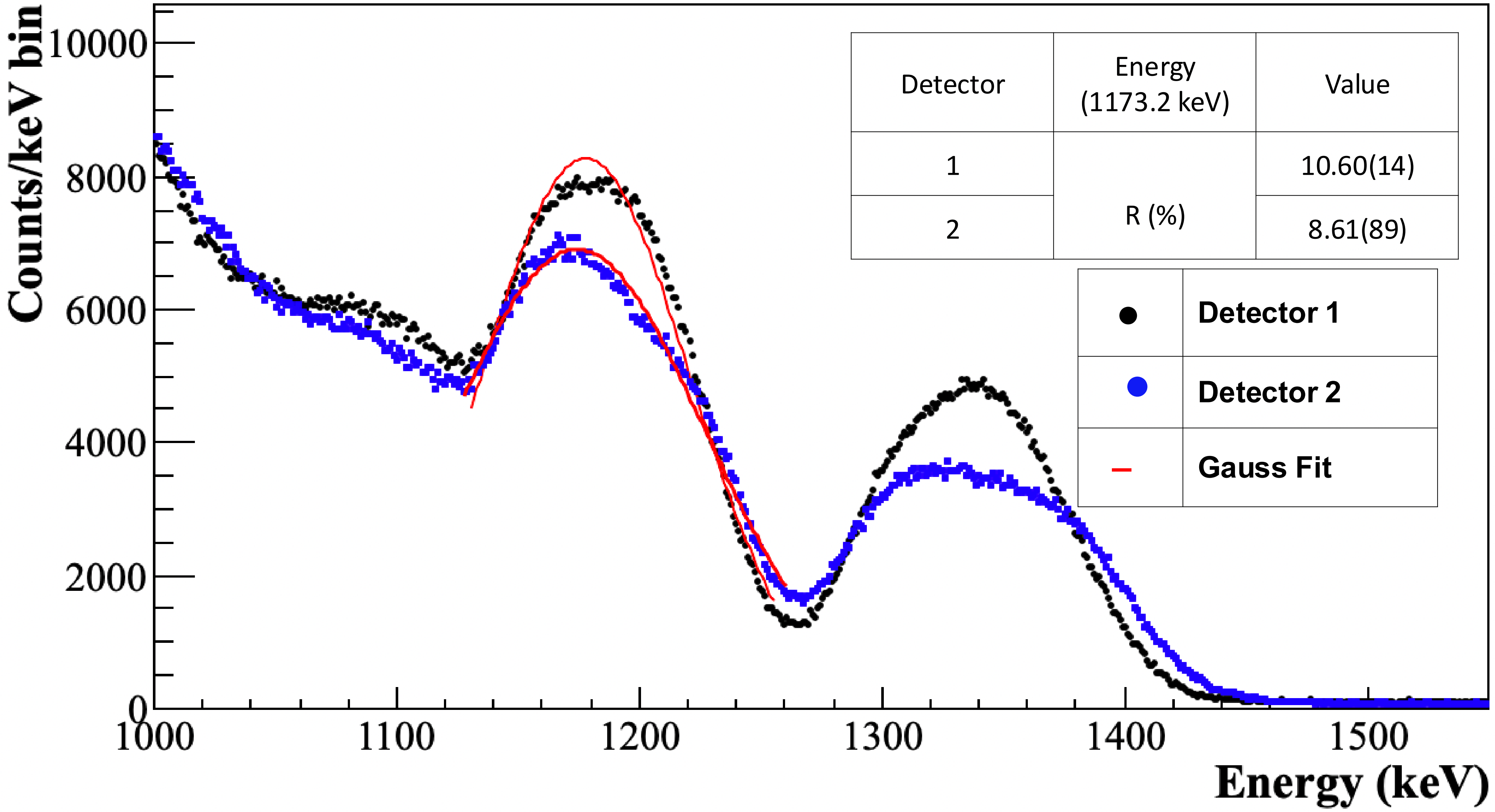


Detector	Energy (1173.2 keV)	Value
1	R (%)	10.60(14)
2		8.61(89)

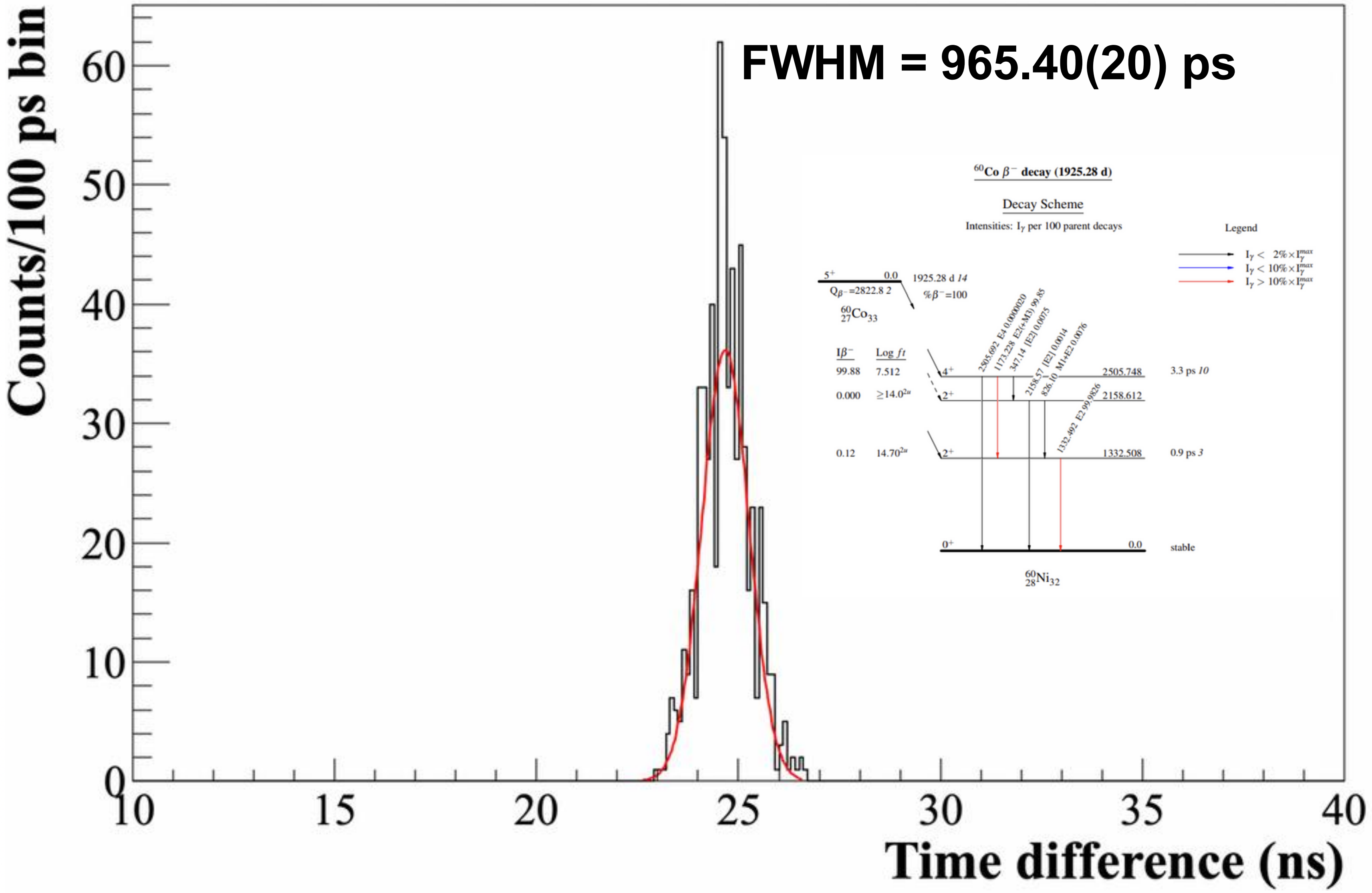
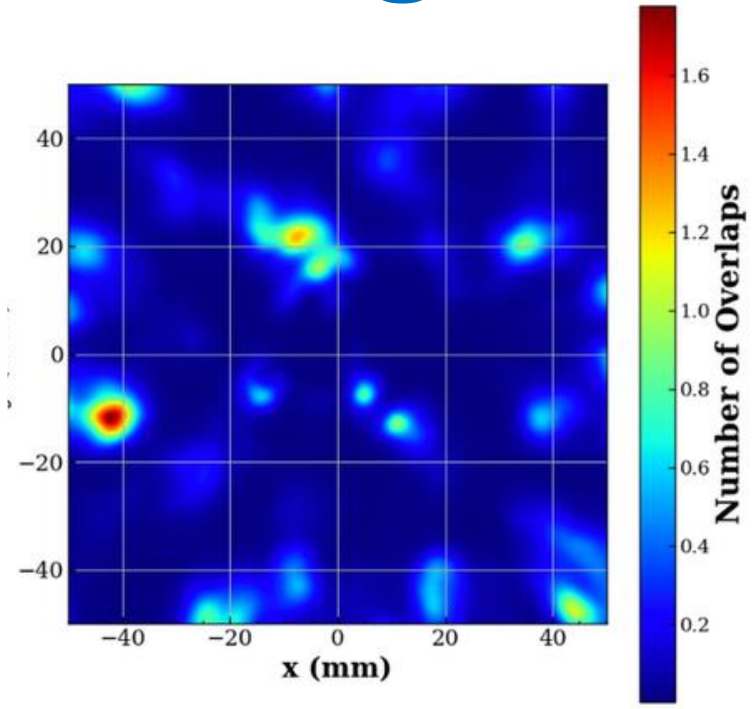
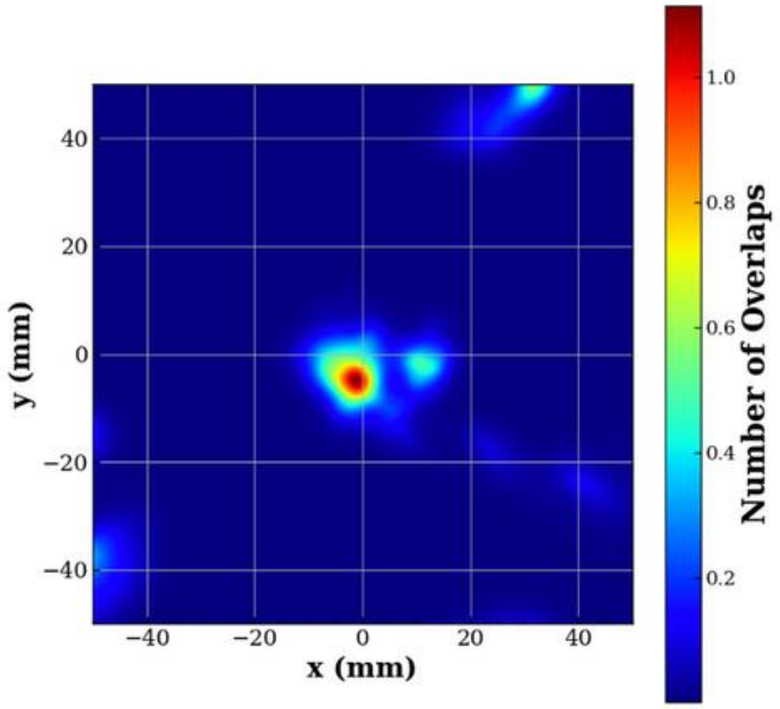


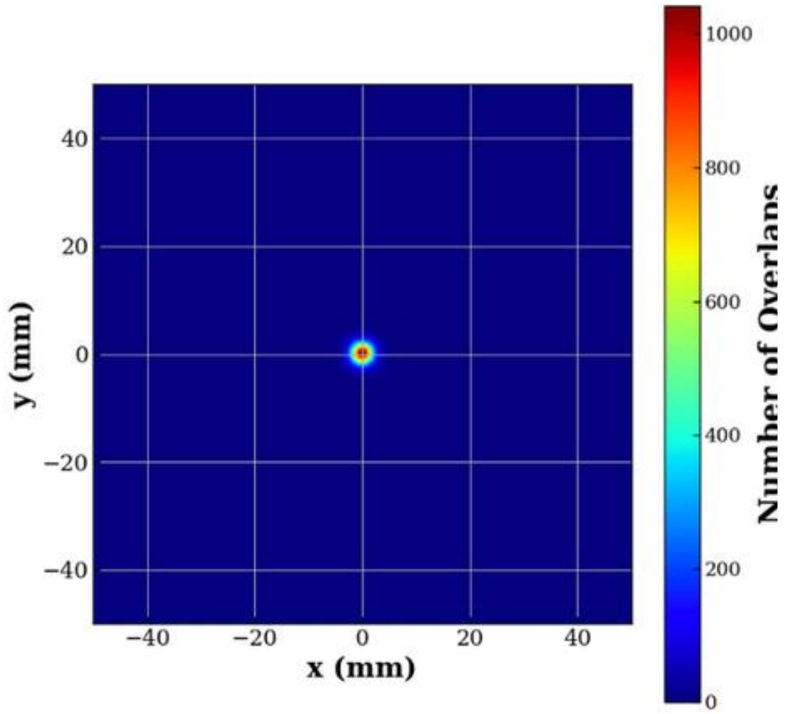
Image Reconstruction: Optimisation



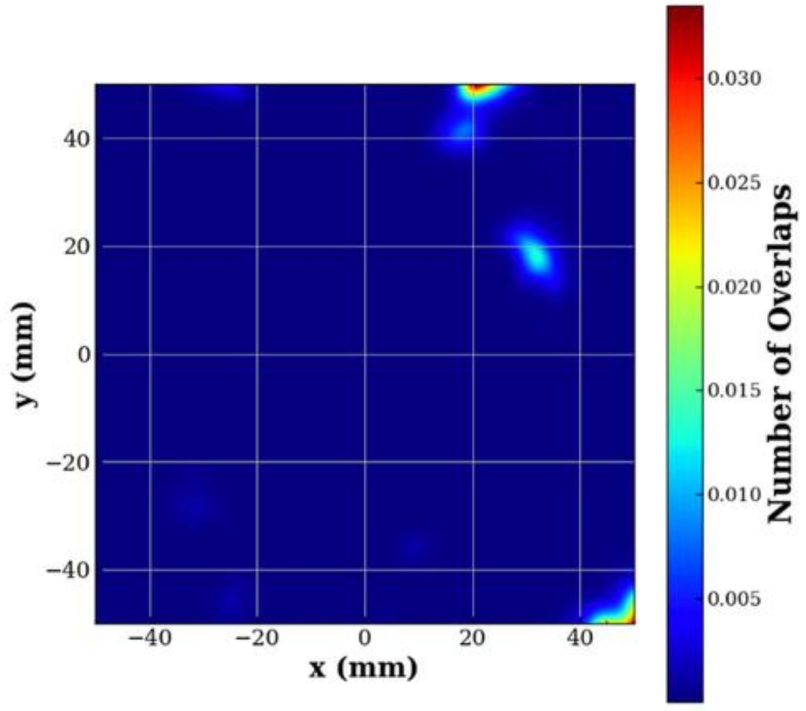
(a)

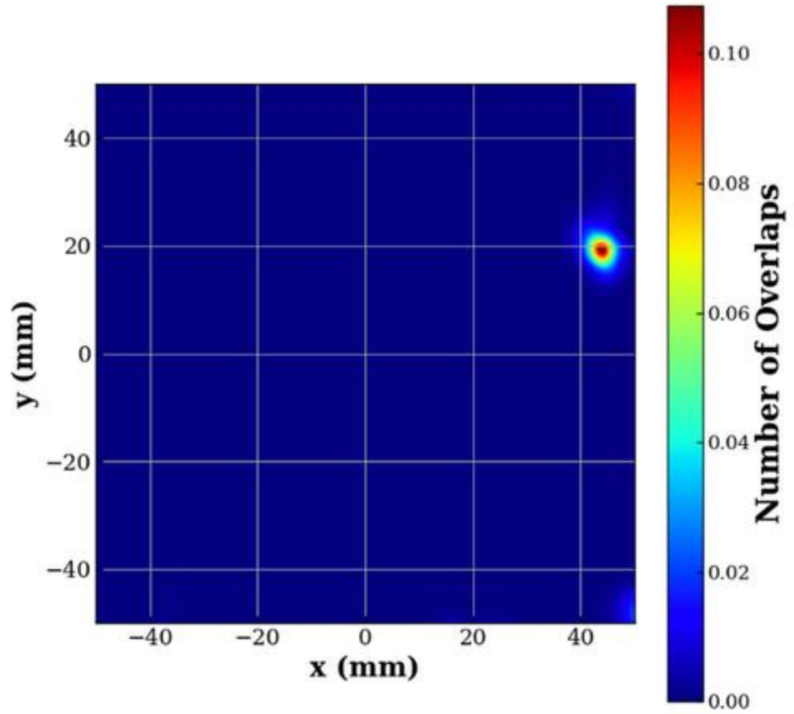


(b)



(c)



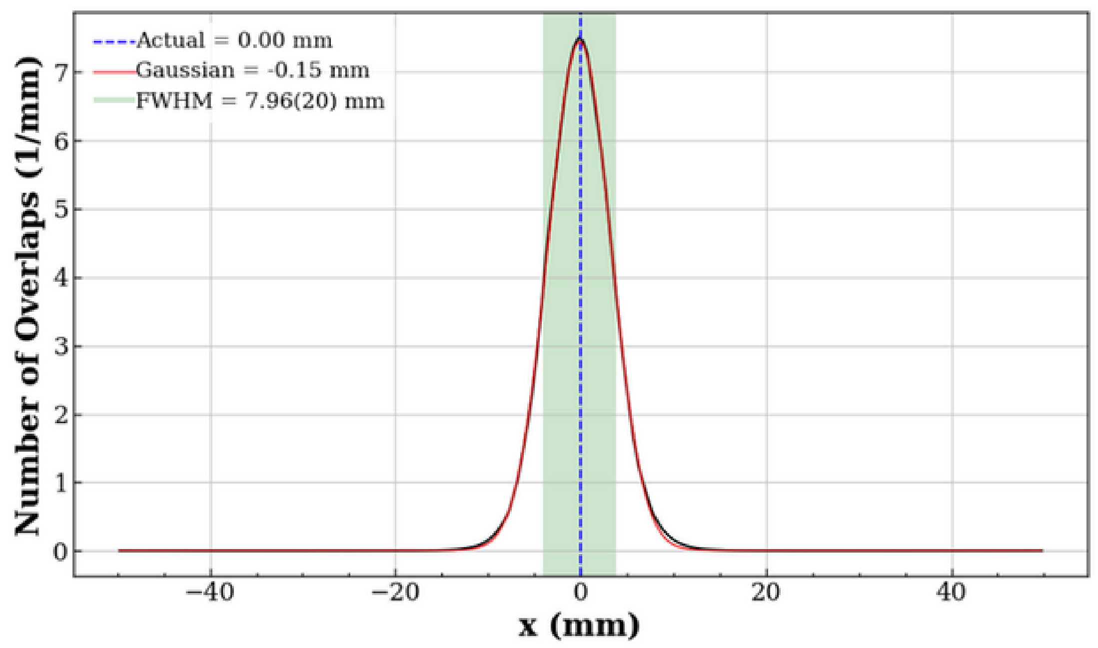


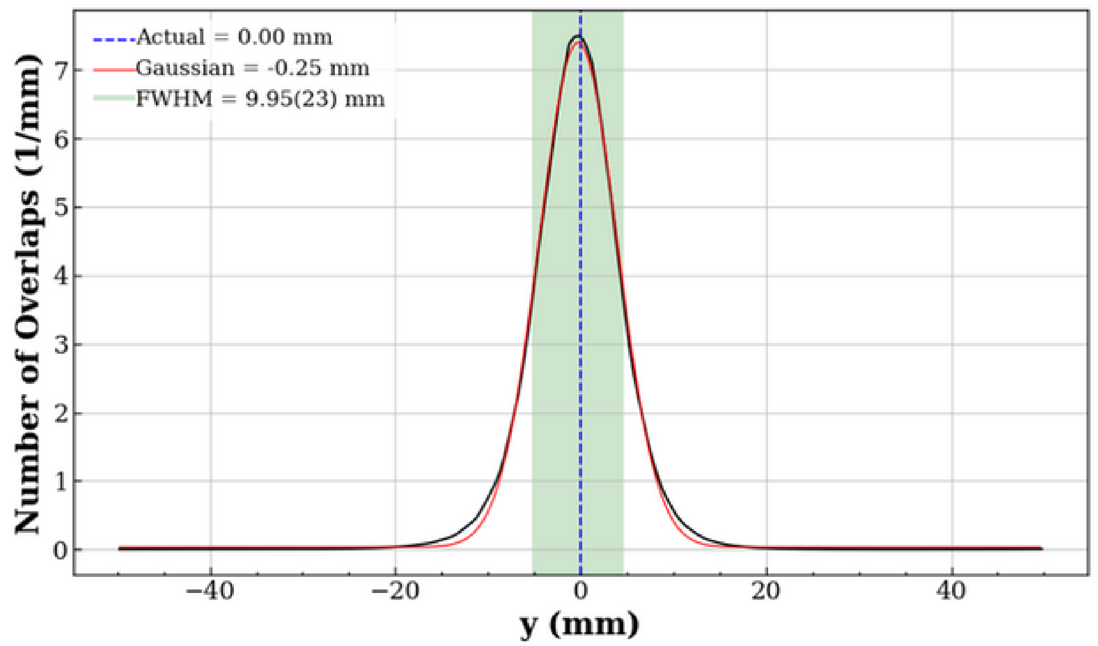
The x-y matrix shown at different z slice values for the same Octane EM reconstruction

Image Reconstruction: Optimisation

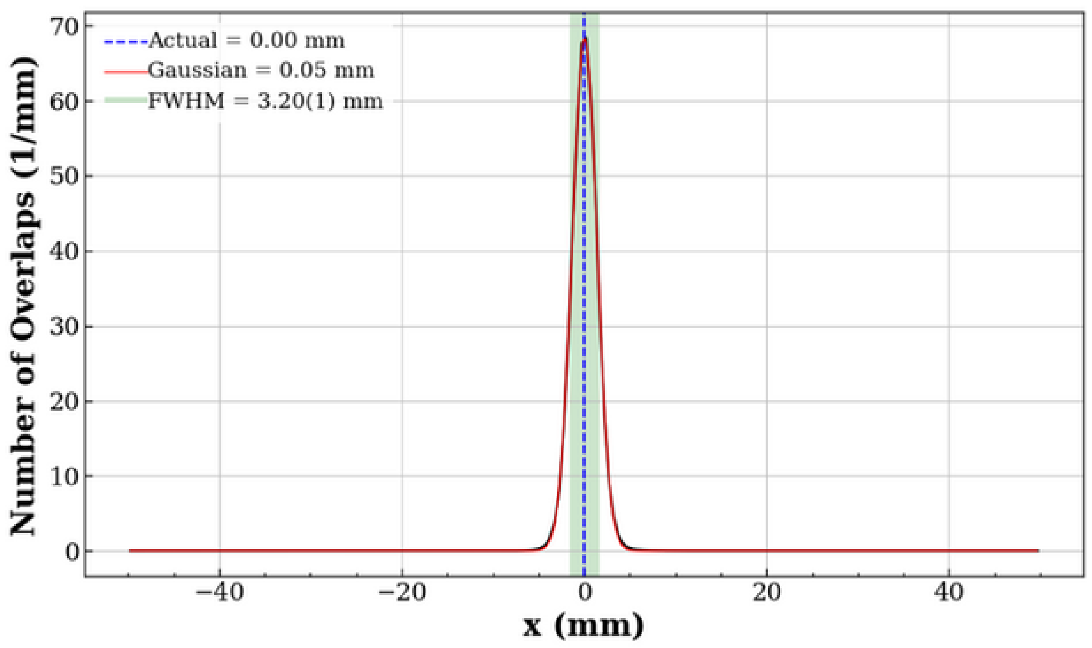
The x and y projections (sliced at the maximum y-z and x-z values respectively) of CC1 shown for different bin width in the Octane EM reconstruction.

5 mm bin width





2 mm bin width



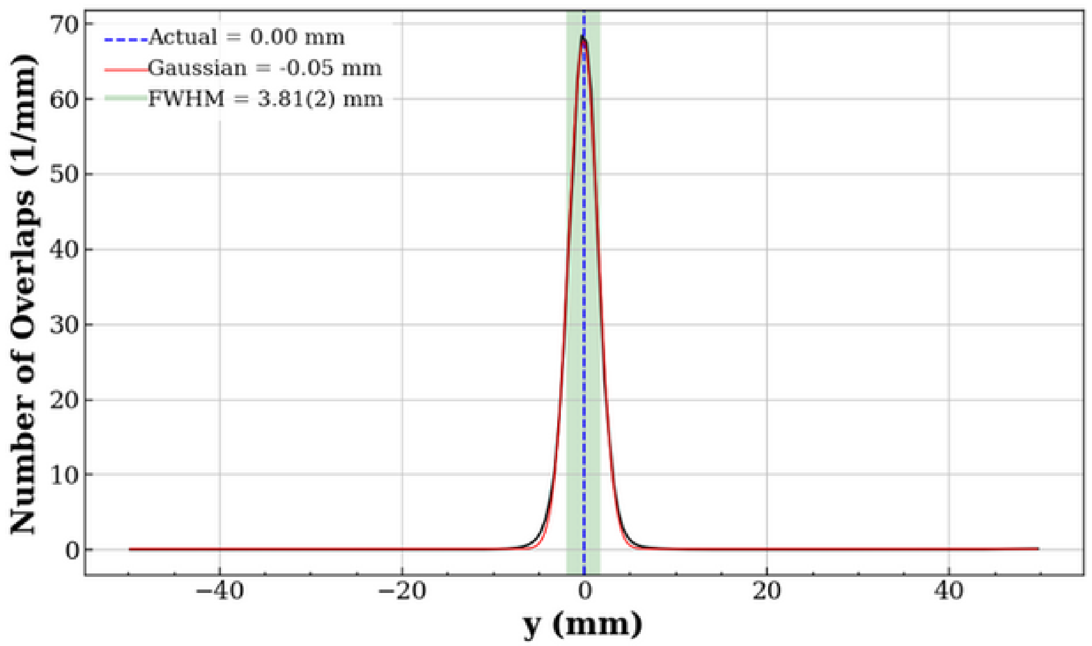
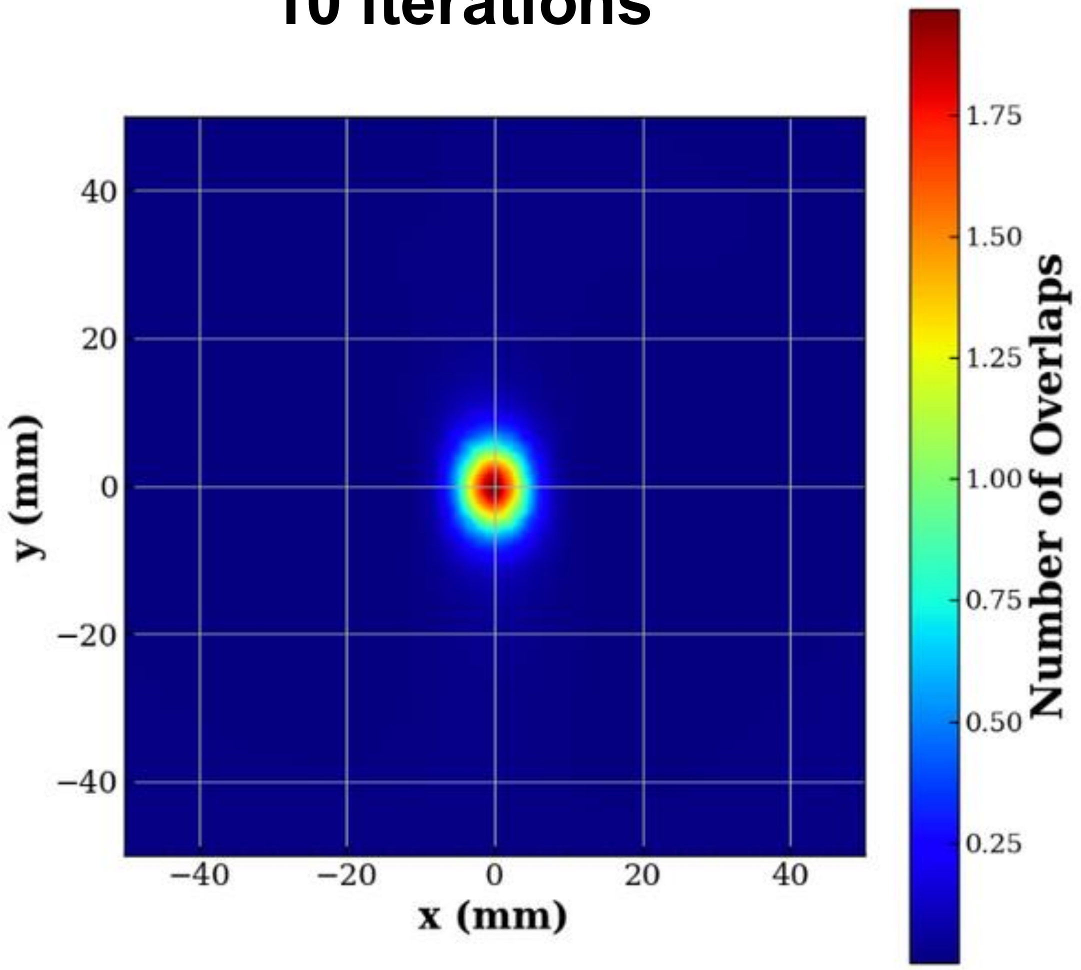


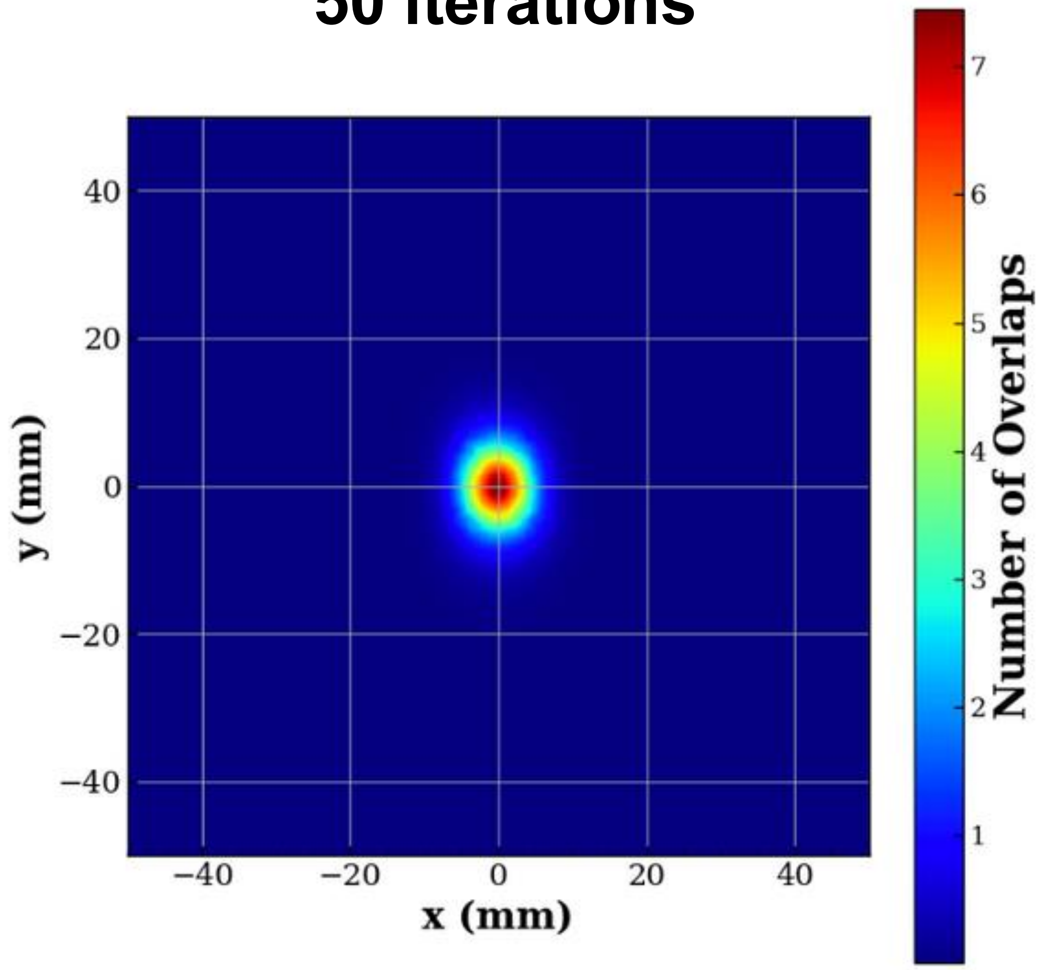
Image Reconstruction: Optimisation

The x and y projections (sliced at the maximum y-z and x-z values respectively) of CC1 shown for different number of iterations in the Octane EM reconstruction.

10 iterations



50 iterations



100 iterations