

Gamma-Ray Imaging with a GeGI Device



Matti Kalliokoski

GammaRay X Webinar

21/10/2021

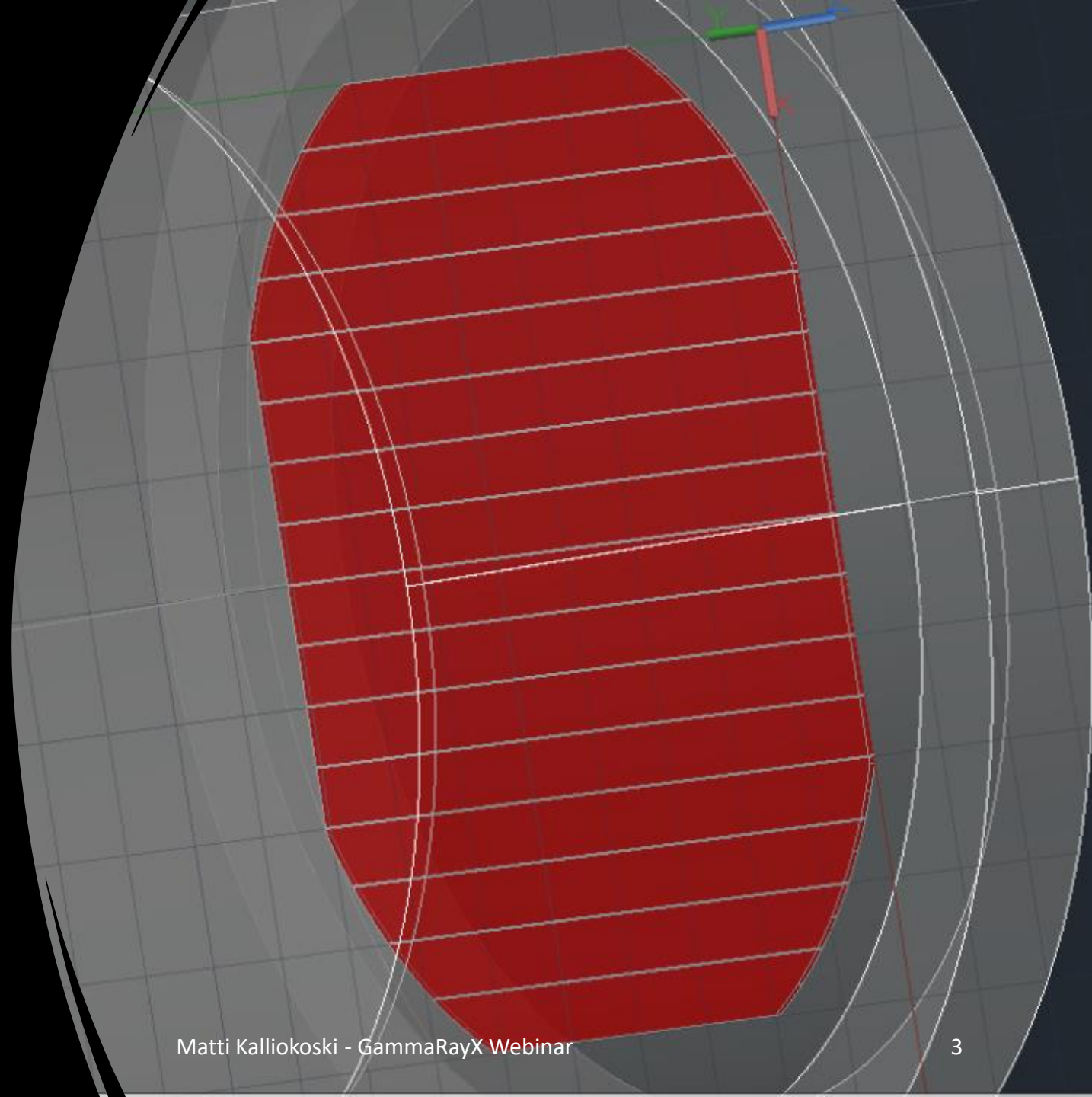
Germanium Gamma-Ray Imaging Spectrometer, GeGI

- HPGe detector
 - Ge-crystal diameter 90 mm, thickness 11 mm
- Active detector area of 61 cm²
- Imaging range from 10 cm to over 50 meters
- Spectral range from 30 keV to over 3 MeV (extends to 10 MeV)
- Stirling cooling
 - Cable or battery powered
 - Batteries allow operation of 2-3 hours



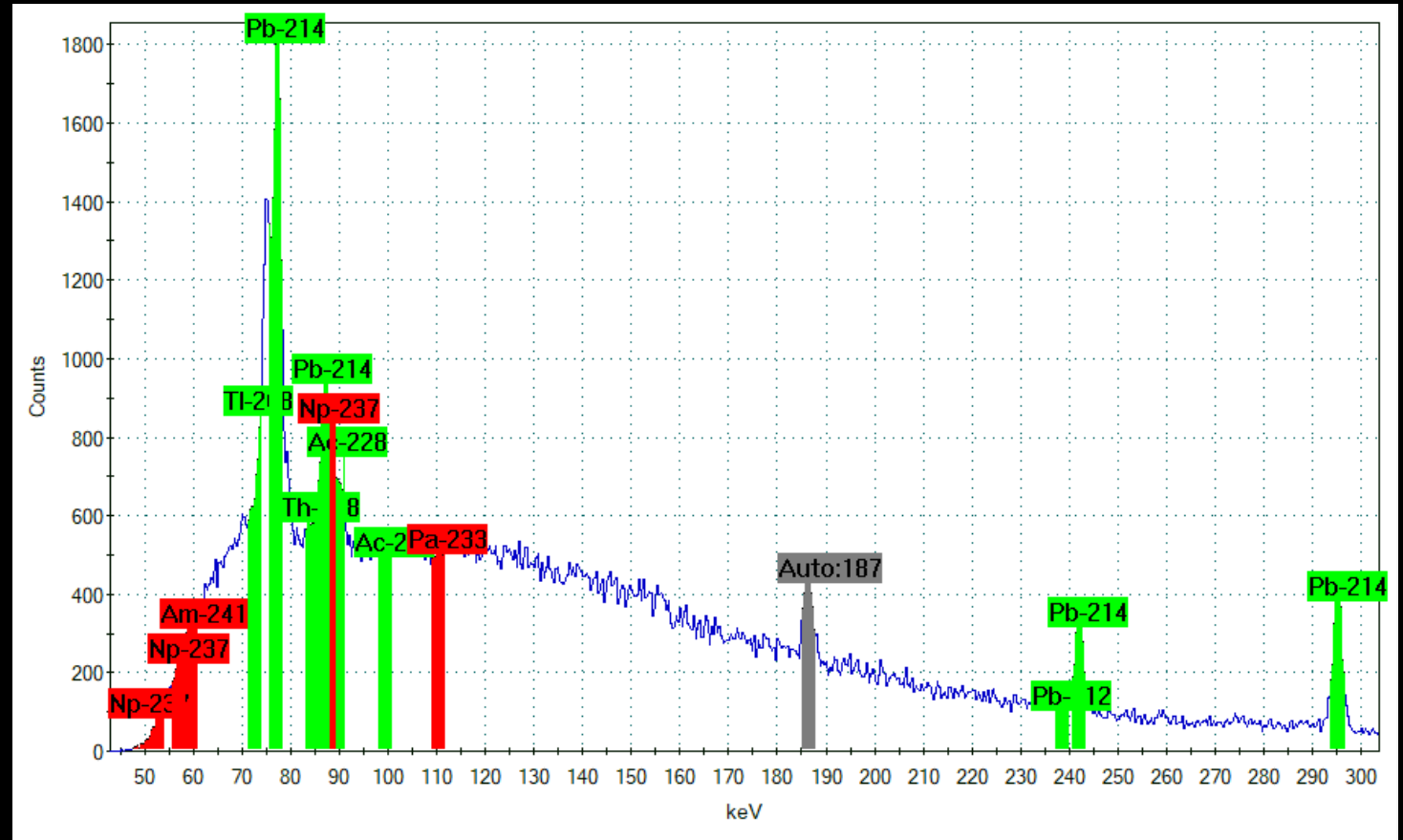
Germanium Gamma-Ray Imaging Spectrometer, GeGI

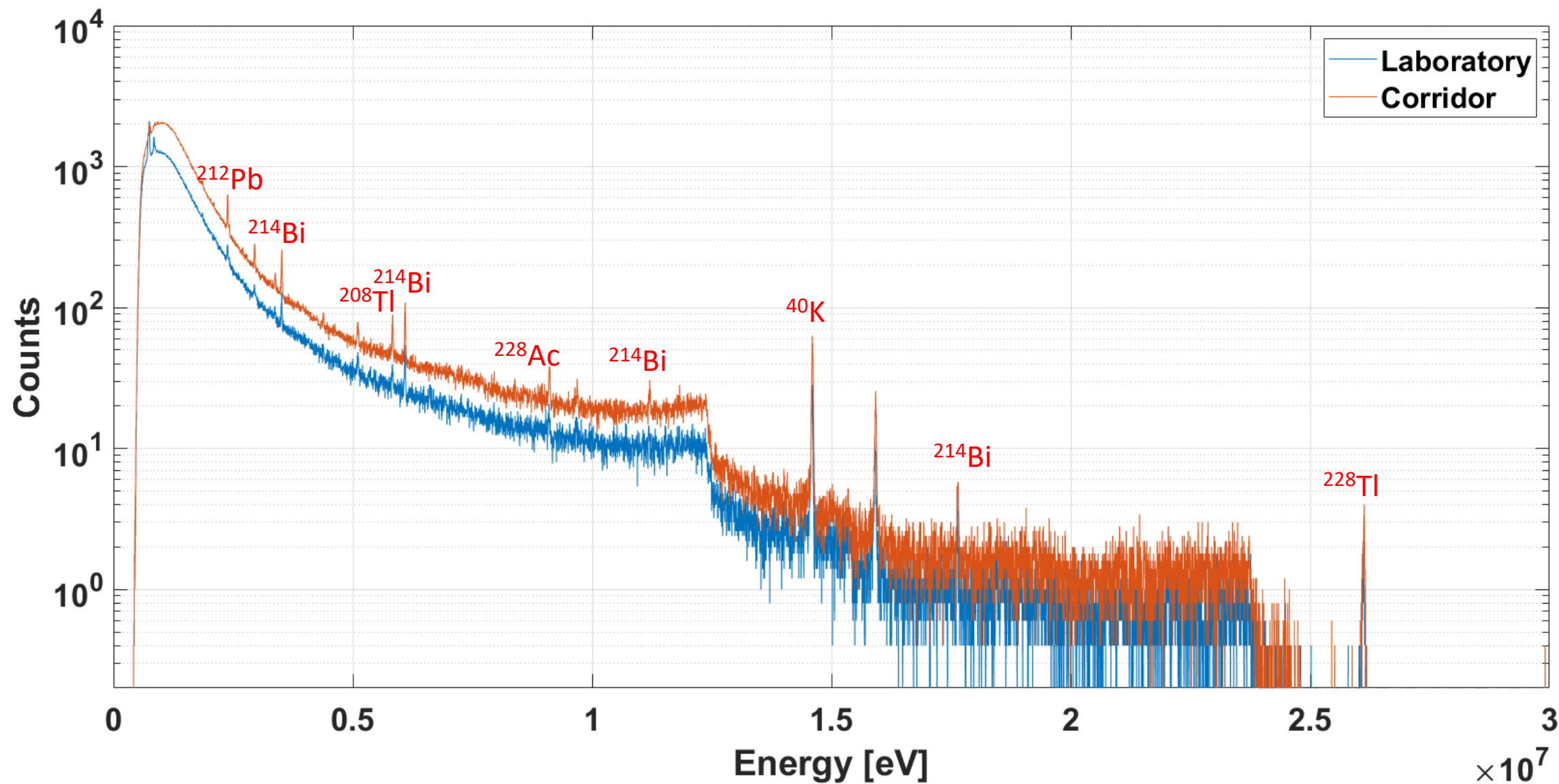
- 32 strips on both sides of the detector bulk
 - 16 on top and 16 on bottom with 90 degrees of rotation between each other
 - Strip width, strip pitch
 - Each strip is connected to an individual MCA



Spectrometry

- Measured peaks are analyzed by GeGI Imager32 application
- Internal library is used to identify the measured peaks
 - ~400 isotopes,
~25 000 gamma rays



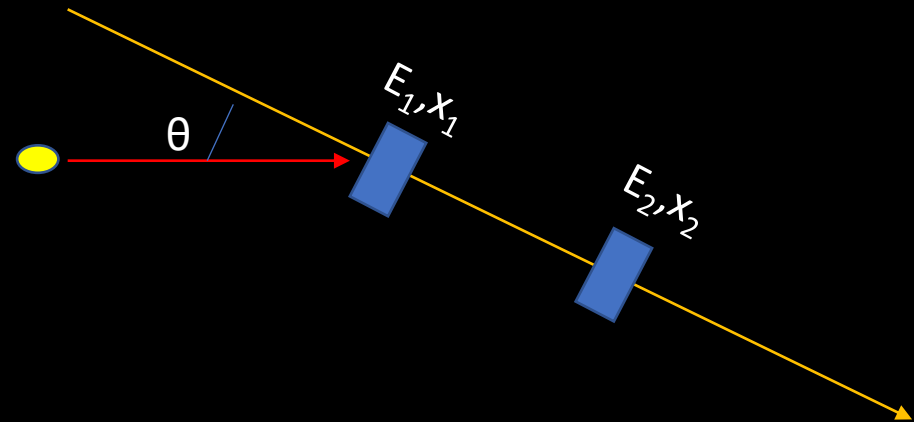


1 hour measurements at basement (corridor) and at 3rd floor (laboratory)

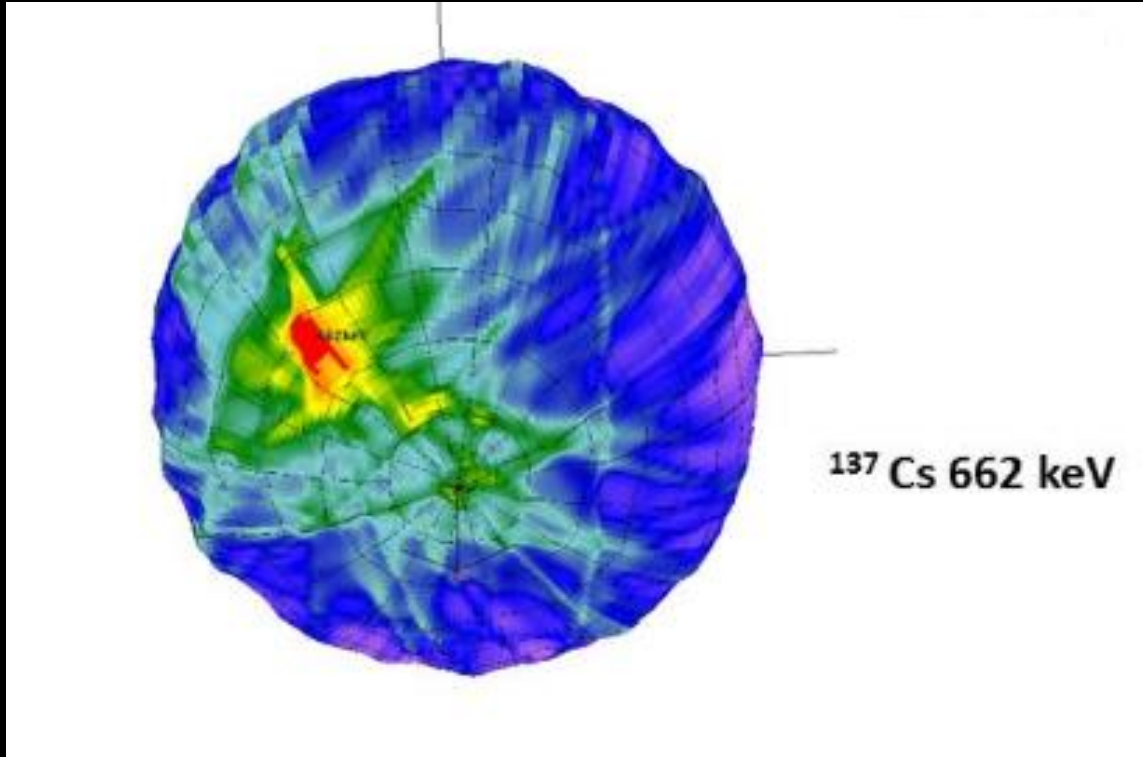
Compton Imaging Mode

- Basic collimator-less imaging mode
- Segmented detector allows to reconstruct the path of a photon interacting in the bulk
 - Photon scatters through an angle θ between the incident and scattered photon
- Gives information about the deposited energy
 - Source identification
- Allows selection of threshold of interest for the Compton centroid
- Uses both energy spectroscopy and angular information from Compton image to calculate activity at 2π field of view
 - Requires material information from user

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



Compton Imaging Mode



- Angular bounds of Compton image is a function of energy
 - Parametrized from 136 keV to 2614 keV
- Angular resolution improves with energy $1/E$
- Resolution dependent on photoelectric absorption within a single pixel



Saved File



Time: 3604 DT: 0.7%

Saved File

CPS: 0 19

uR/hr



66



Temp (K): 88.7



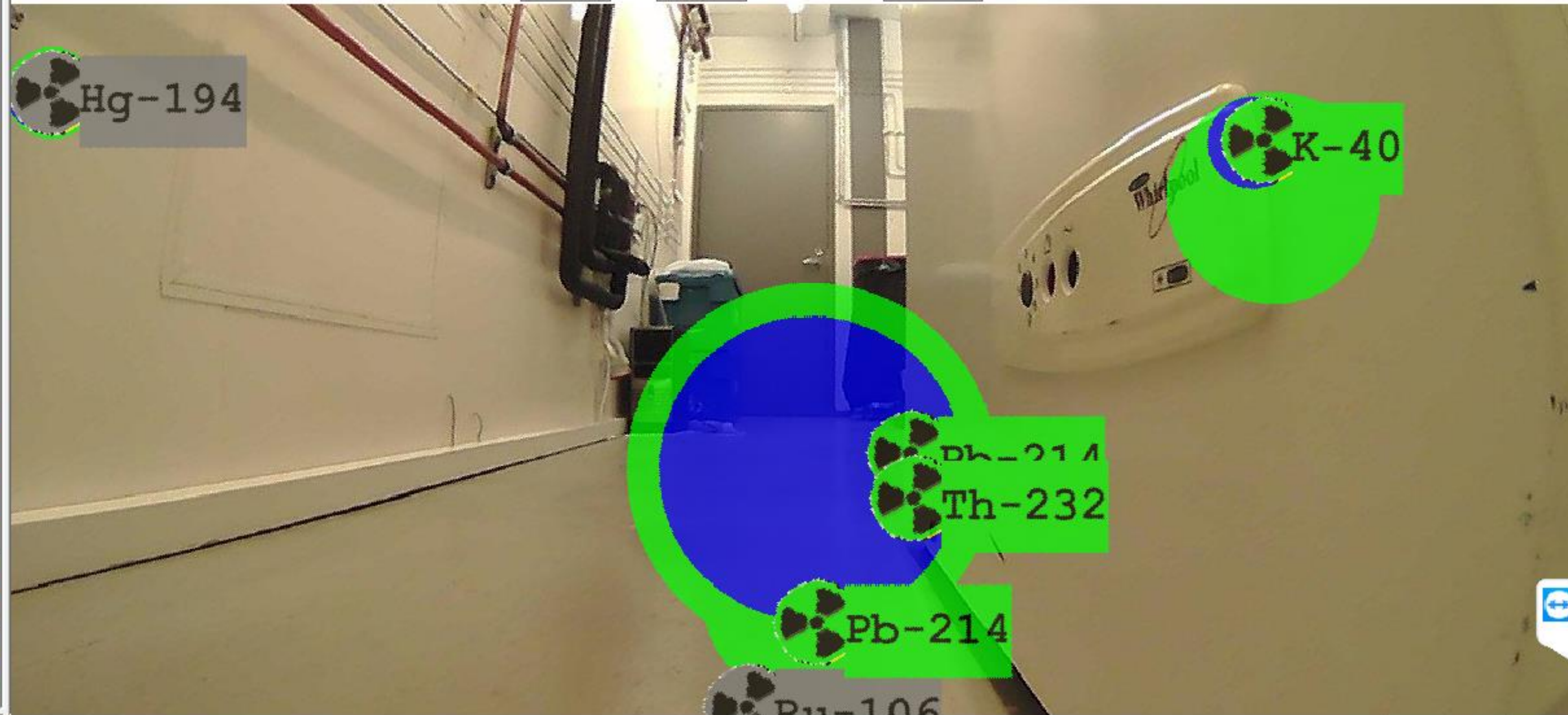
All Energy Windows

Distance(m) 0.500 +/-

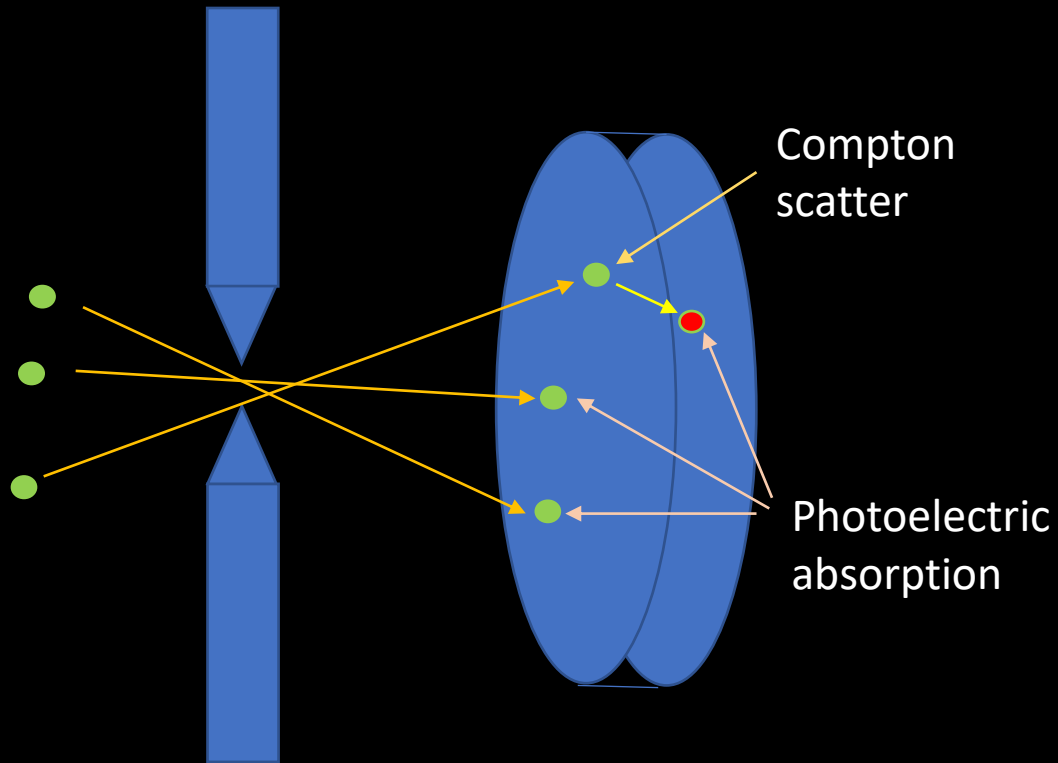
Events 2017

Switch to Analysis View

Width 30 %



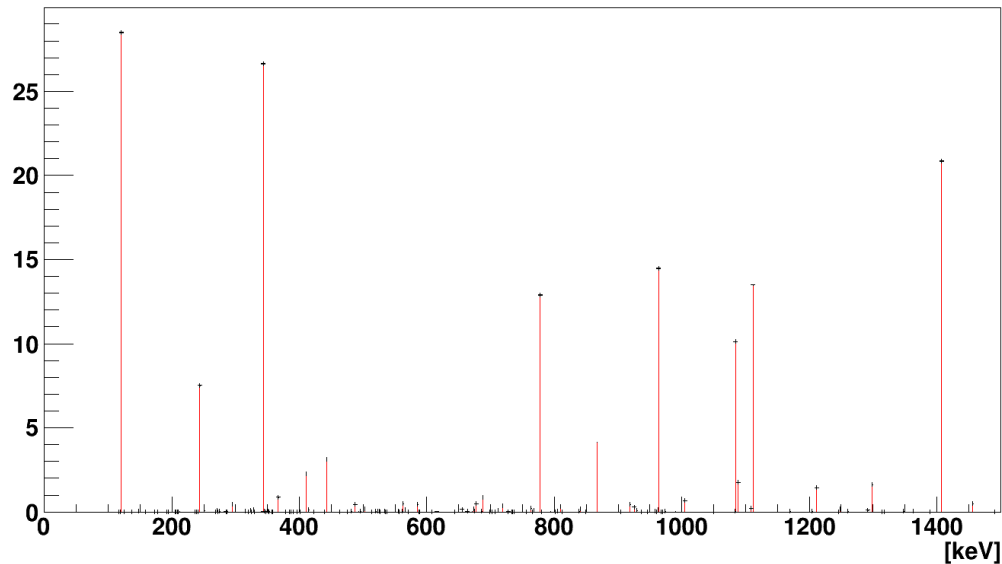
Pinhole Aperture Imaging



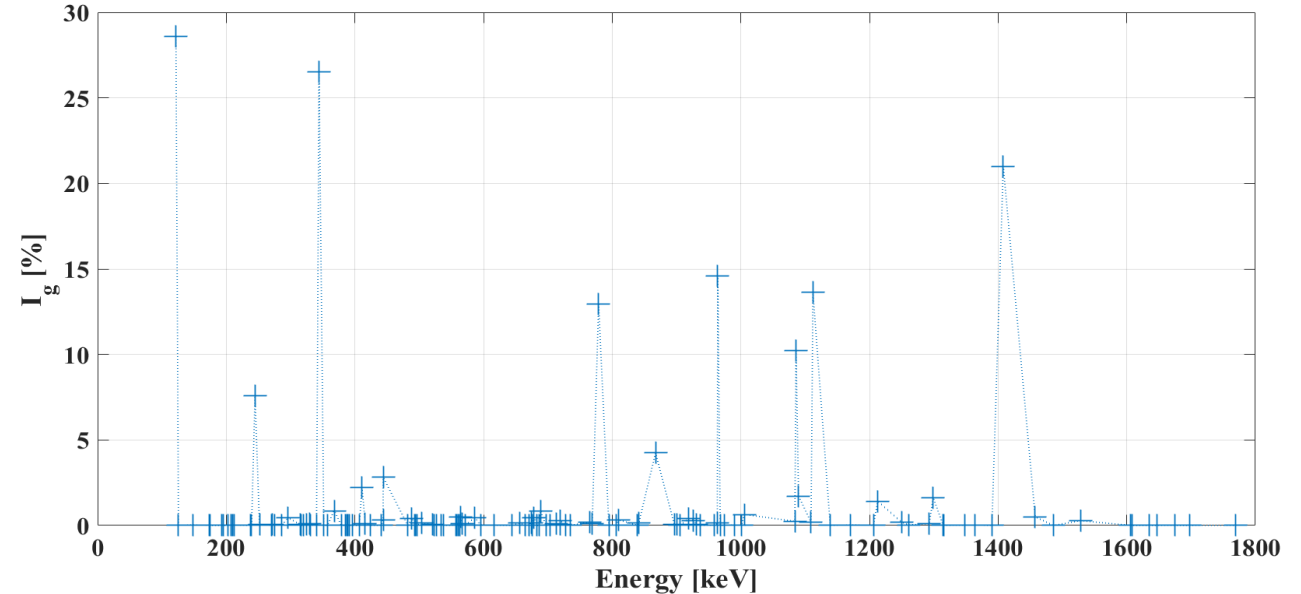
- Pinhole aperture imaging allows creation of high detailed object images
 - Shape and substructure are visible
- Spectral-statistical peak search on a pixel-by-pixel basis
- Angle within 60° field of view is used

Geant4 model

- To study the efficiency of the GeGI device a simple G4 model is developed
- Radiation is simulated by using gamma decay datasets or by G4RadioactiveDecay class



G4RadioactiveDecay of ^{152}Eu



^{152}Eu decay data from The Lund/LBNL Nuclear Data Search

CPS:

0

12

uR/hr

66

Temp (K):

88.7

All Energy Windows

Distance(m)

0.400

+/-

Events

248

Switch to Analysis View

Width

90 %

Ready

21/10/2021

type here to search

Matti Kallioikoski - GammaRayX Webinar

10:48 PM

10/18/2021



All Energy Windows

Distance(m)

0.500 +/-

Events

879

Switch to Tactical View

Width 50 %

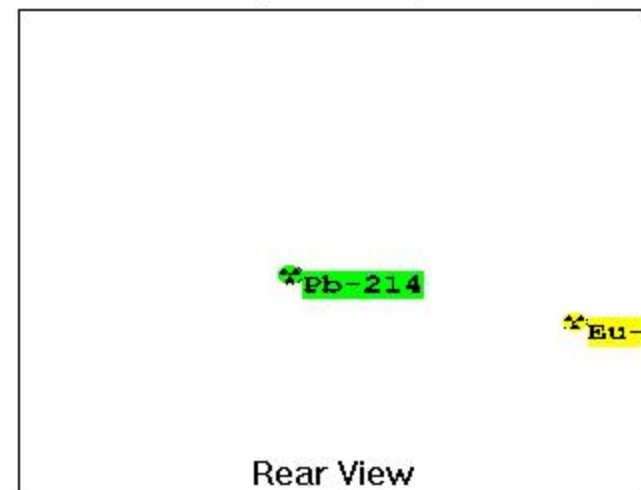
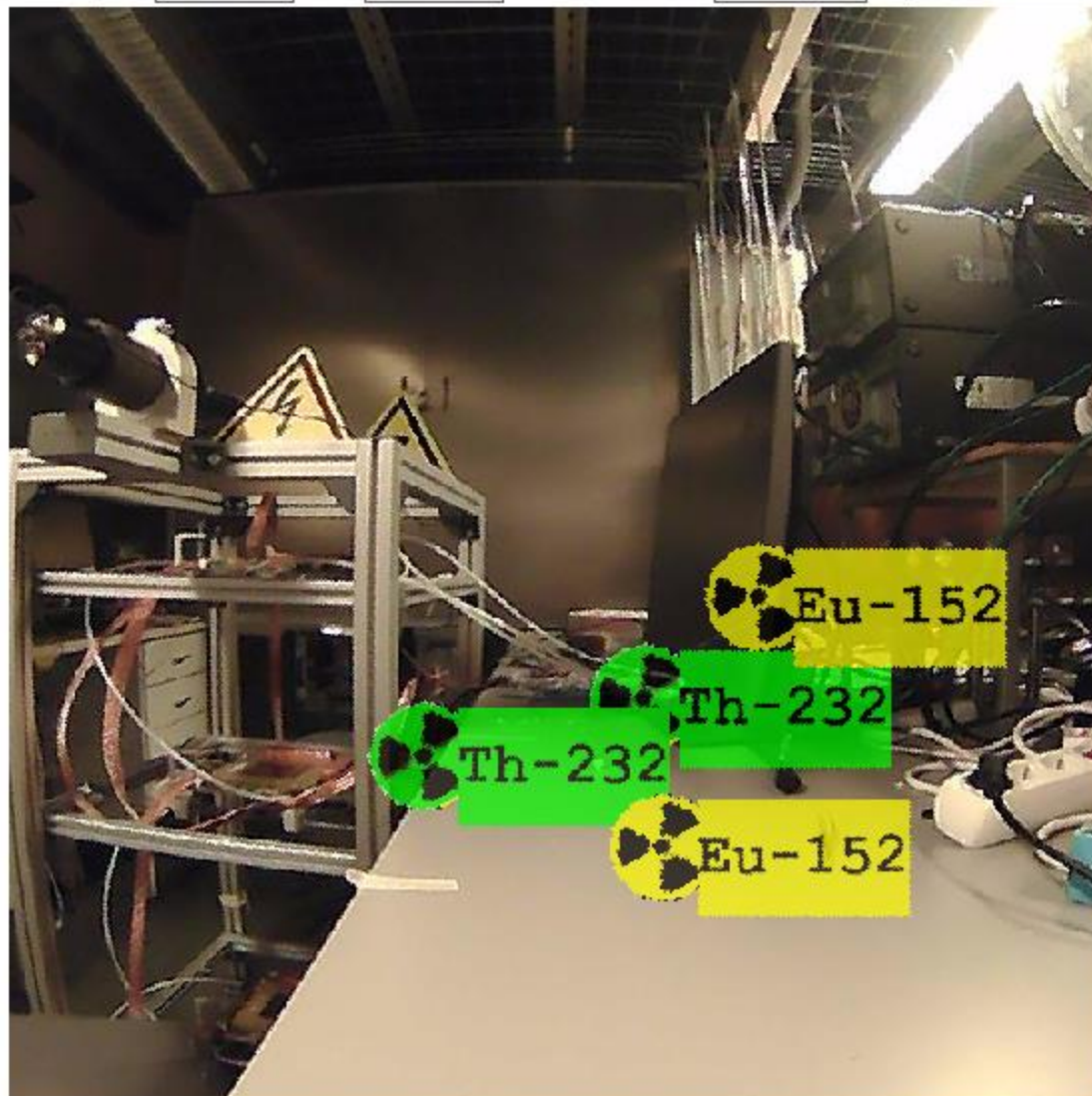
Isotope	Energy (k...	Events
☒ Th-232	238.6	62
☒ Bi-214	609.3	14
☒ Ru-106	511.8	7
☒ Pb-214	351.9	33
☒ Bi-205	511.5	3
☒ K-40	1460.8	10
☒ Th-232	1580.5	1
☒ Th-232	583.2	14

Intervening Materials

Material	Density(g...	Thick(c...

ROI Materials

ROI	Material	Density(g...	Thick(c...
There are no items to show in this view.			



Activity Units

Becquerel (Bq)

Isotope	Energy	Count	Activity (Bq)
Th-232	238.6	106	2.64e+03 +/- 2.5
Th-232	338.3	26	4.31e+03 +/- 8.4
Eu-152	344.3	4000	2.90e+05 +/- 4.5
Eu-152	244.7	1563	2.29e+05 +/- 5.8

Time: 299 DT: 1.0%
CPS: 0 12
uR/hr 66
Temp (K): 88.7

All Energy Windows
Distance(m) 0.400 +/-
Events 248
Switch to Tactical View
Width 40 %

Isotope	Energy (k...	Events
☒ Th-232	238.6	19
☒ Bi-214	609.3	6
☒ Ru-106	511.8	4
☒ Pb-214	351.9	14
☒ Bi-205	511.5	0
☒ K-40	1460.8	9
☒ Th-232	1580.5	0
☒ Th-232	583.2	7

Intervening Materials

Material	Density(g...	Thick(c...

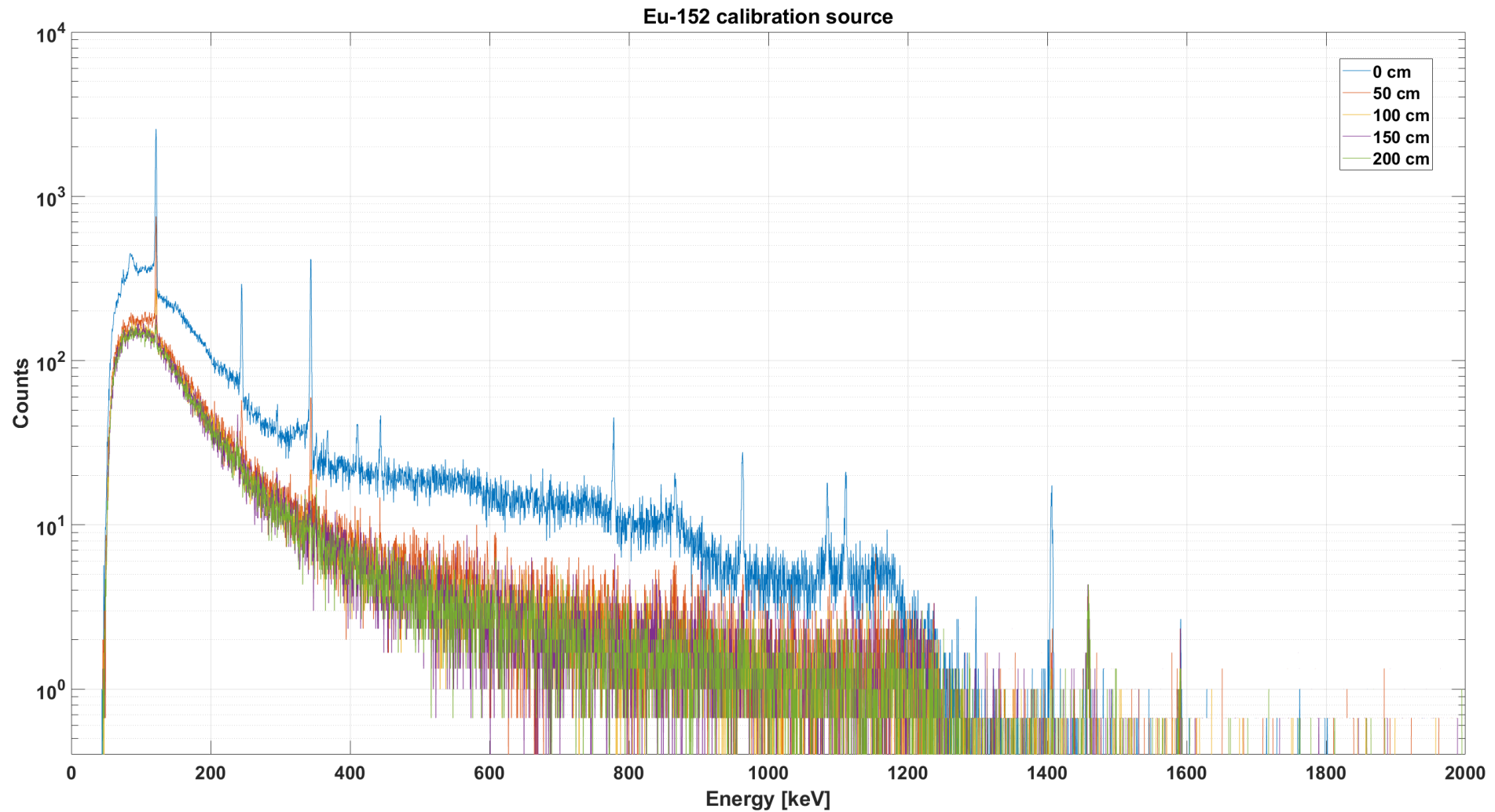
ROI Materials

ROI	Material	Density(g...	Thick(c...
There are no items to show in this view.			

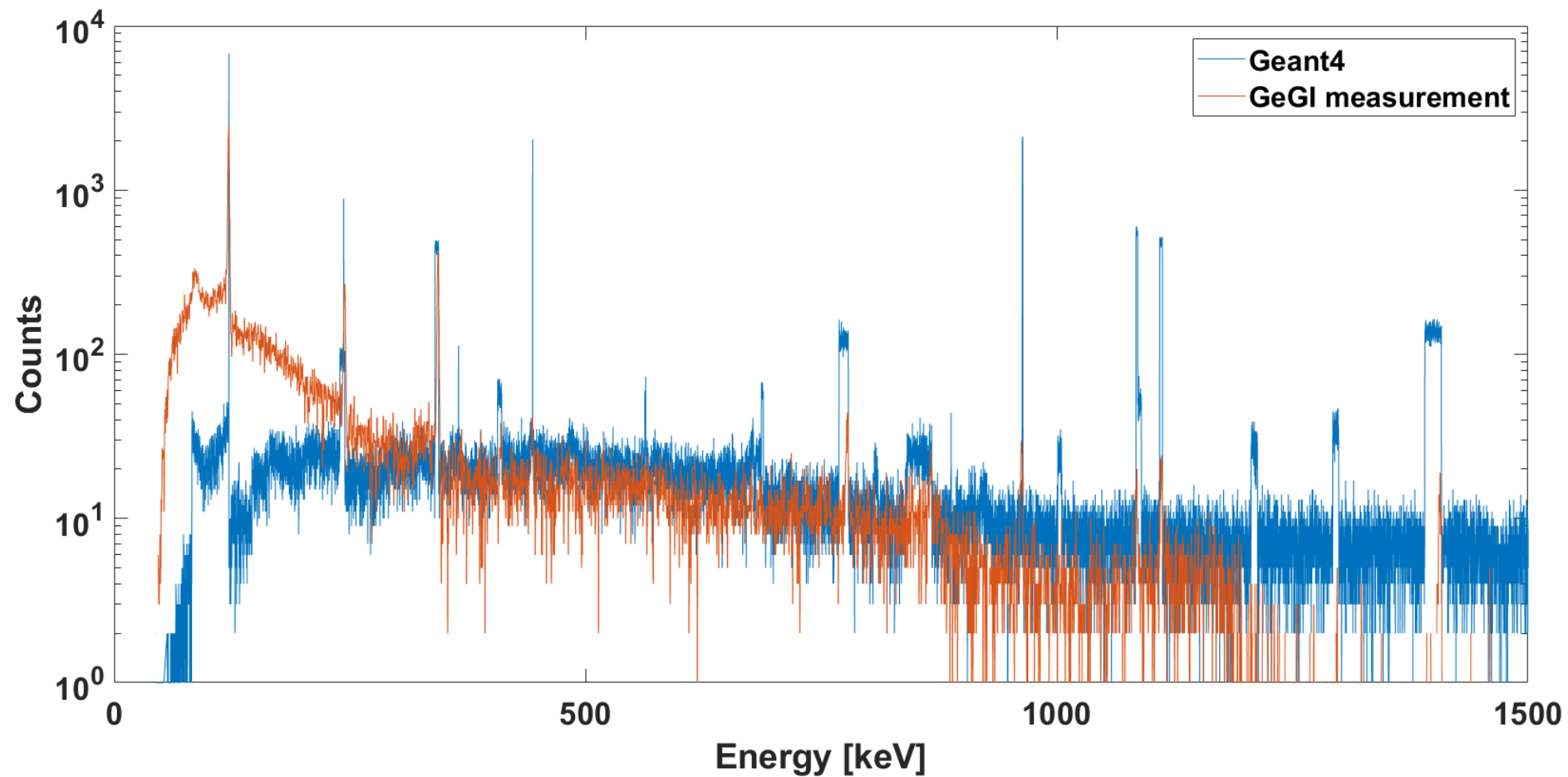
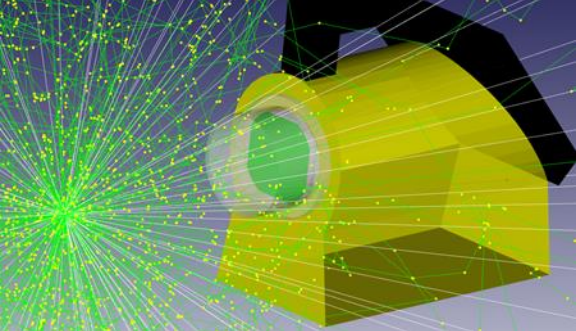
Rear View

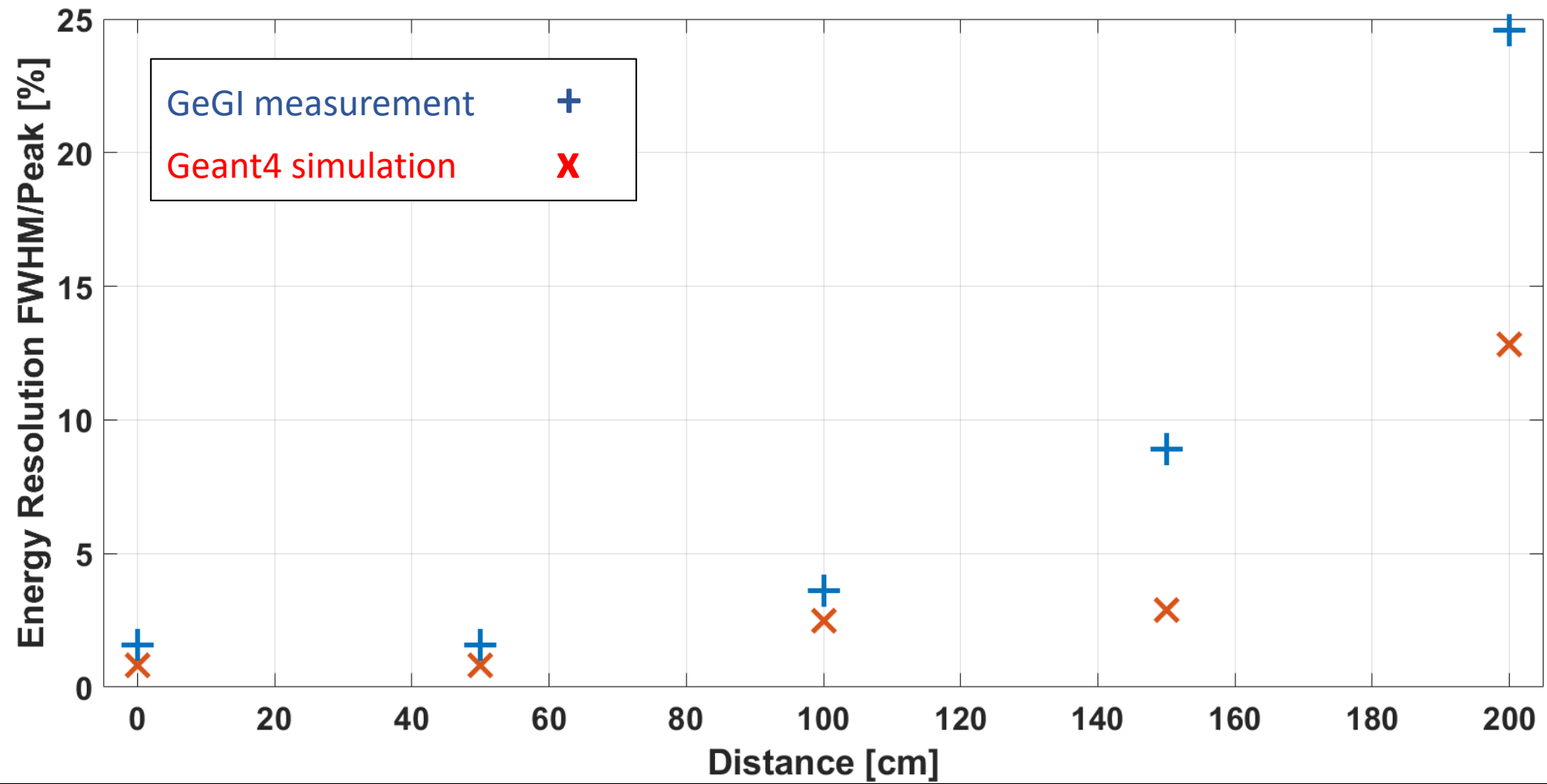
Activity Units Becquerel (Bq)

Isotope	Energy	Count	Activity (Bq)
Eu-152	344.3	443	2.09e+04 +/- 9.9
Eu-152	244.7	242	2.35e+04 +/- 1.5



- Measurement time 3 x 5 minutes for each distance
- The resulting plots are obtained from average values of each measurement

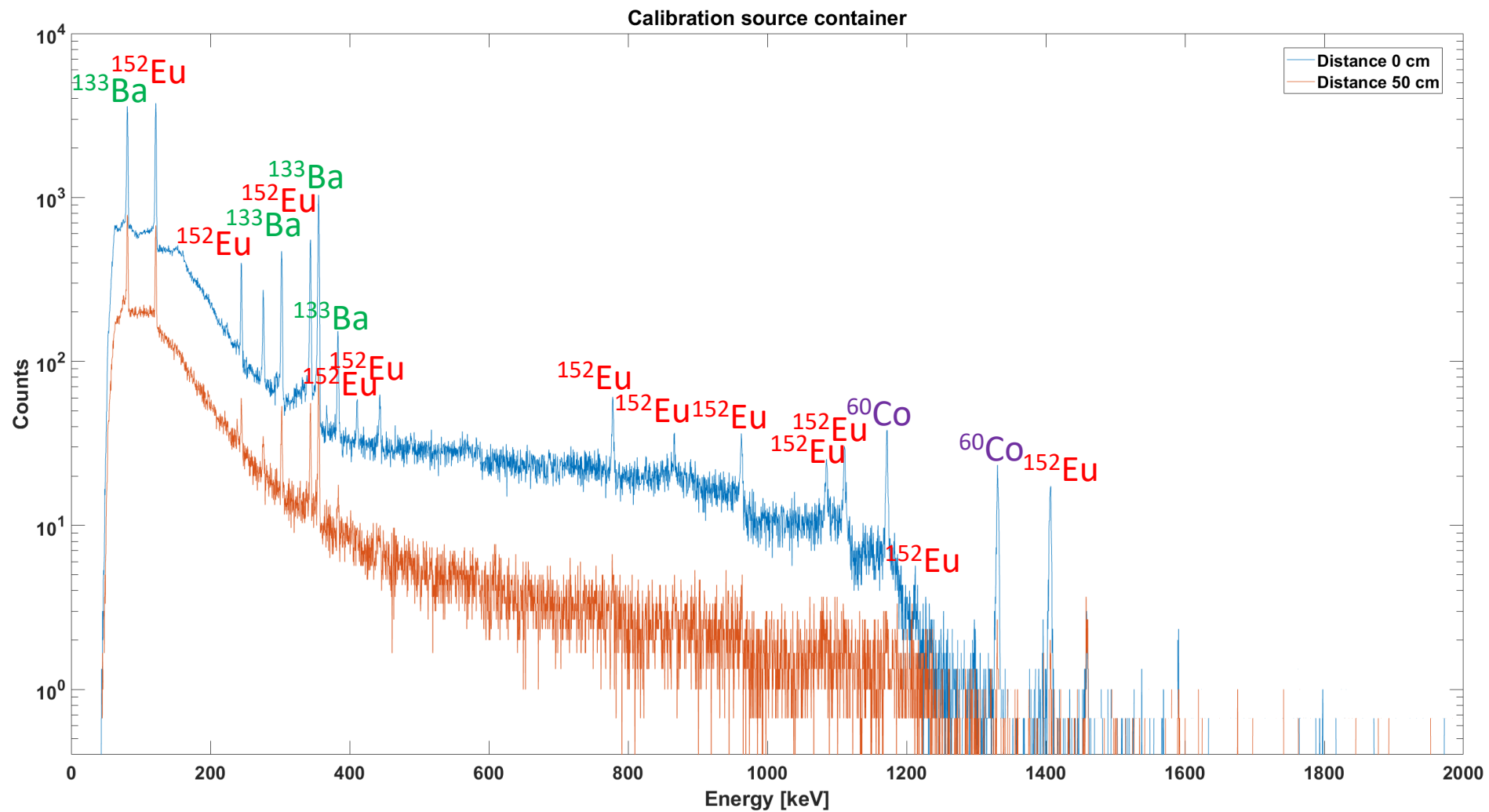


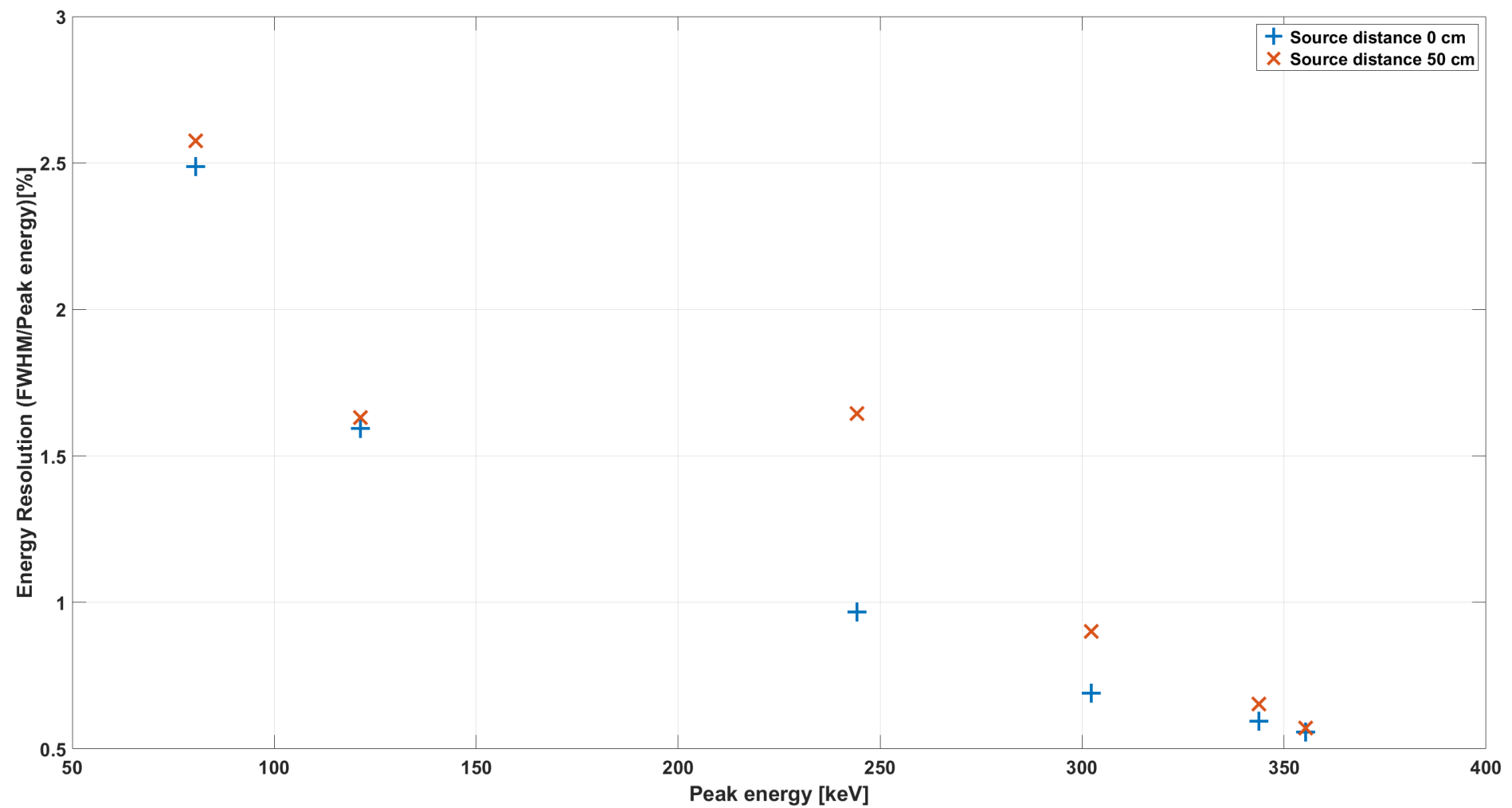


Calibration sources



- 3 active gamma calibration sources in a container
 - ^{60}Co , ^{133}Ba and ^{152}Eu







0.9%

64



66

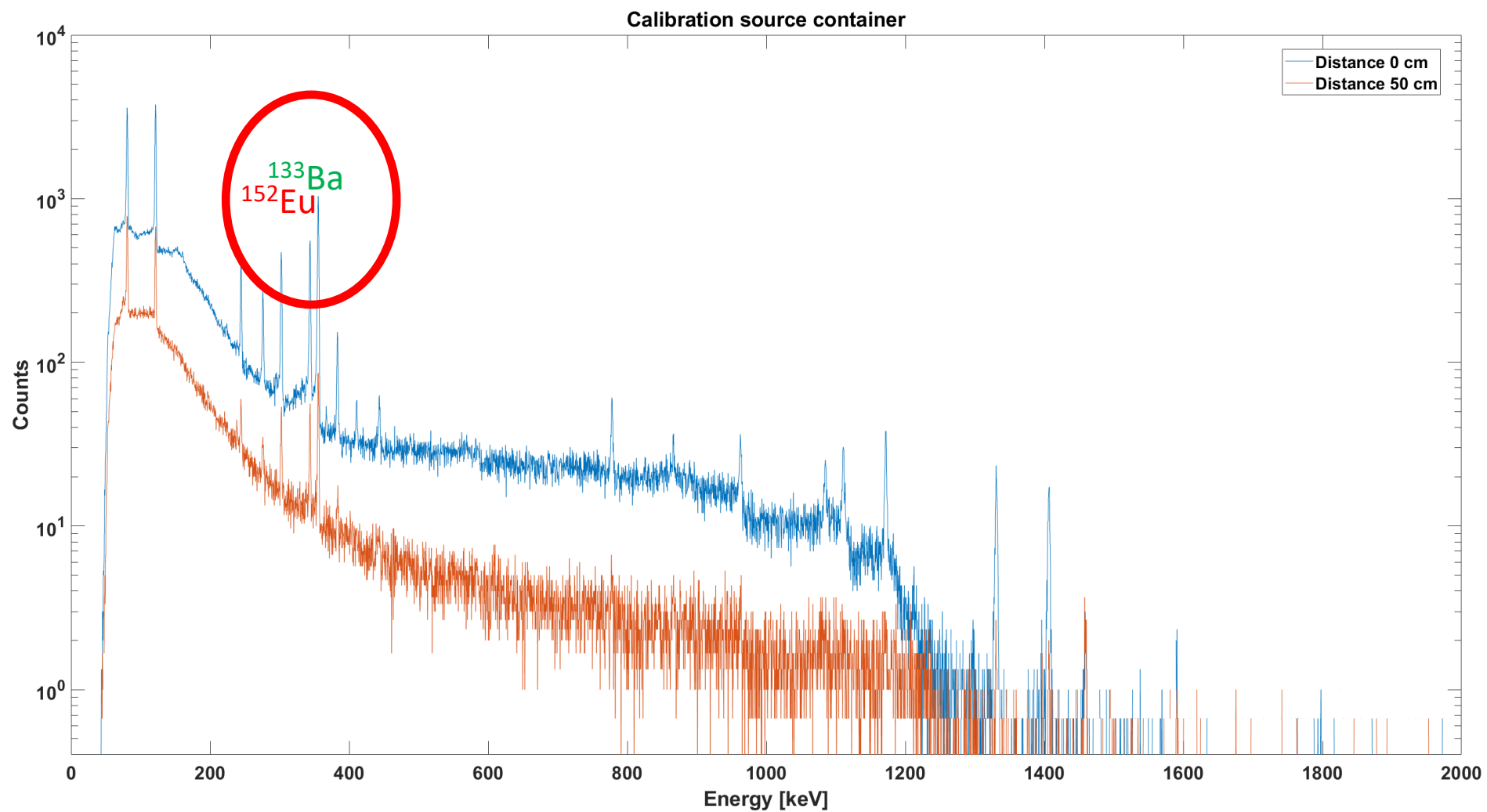
Temp (K) : 88.7

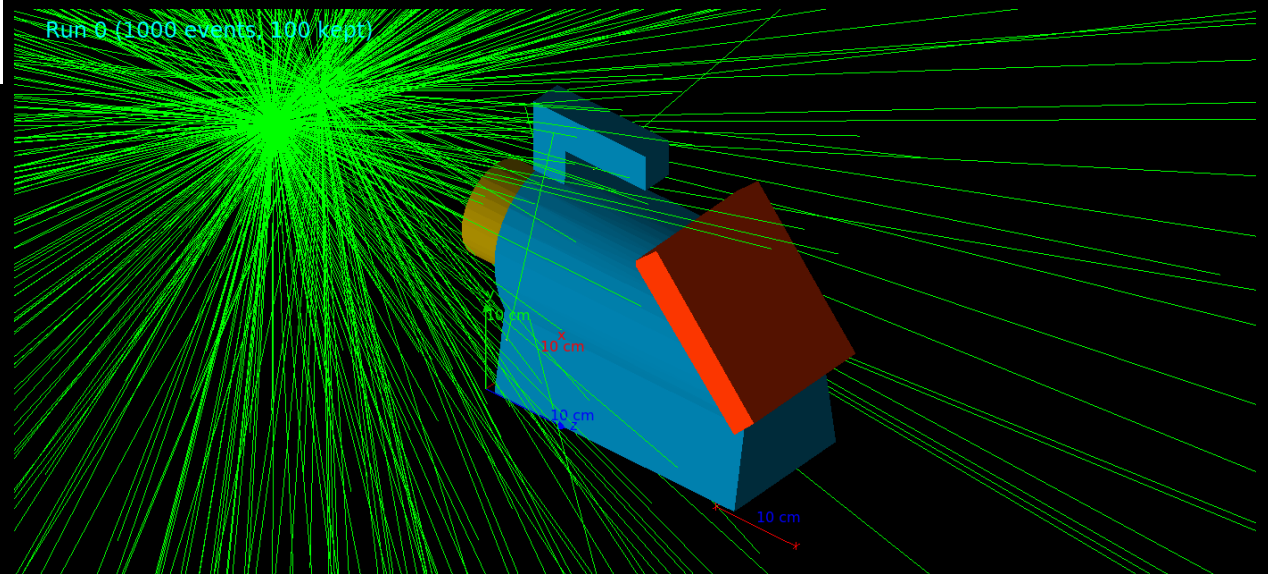
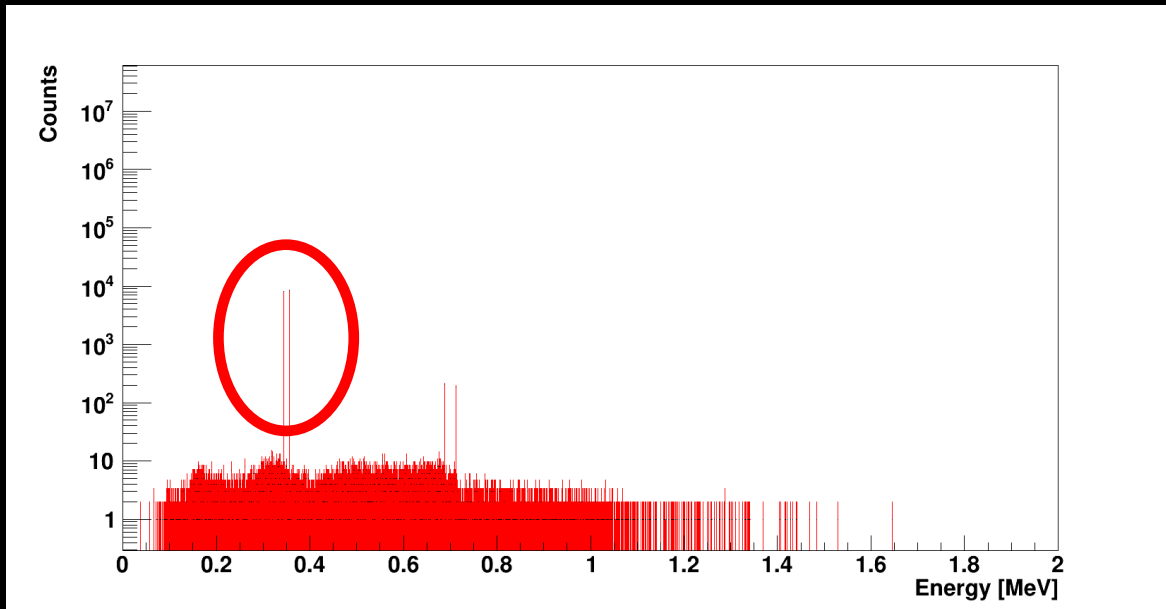
 $+/-$

3522

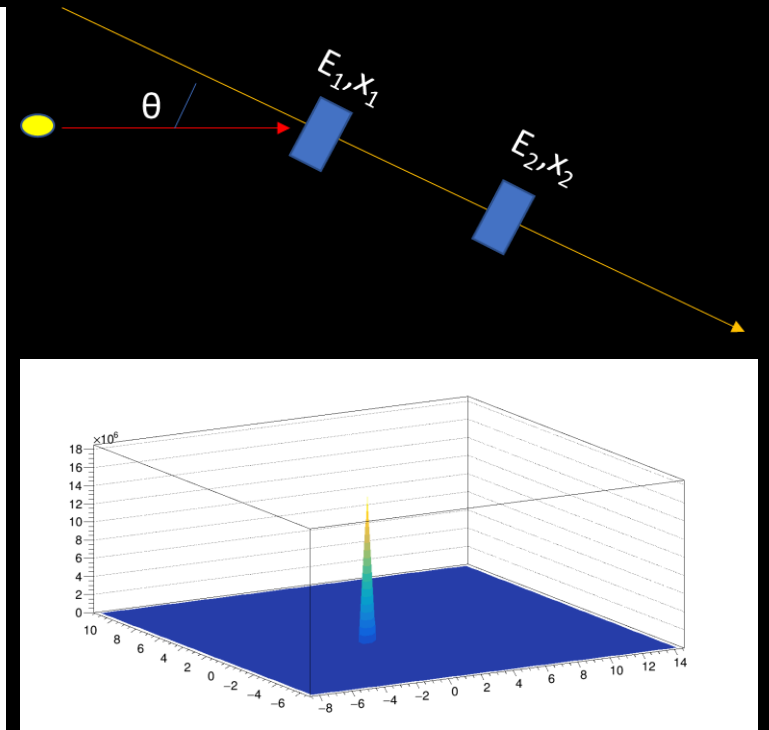
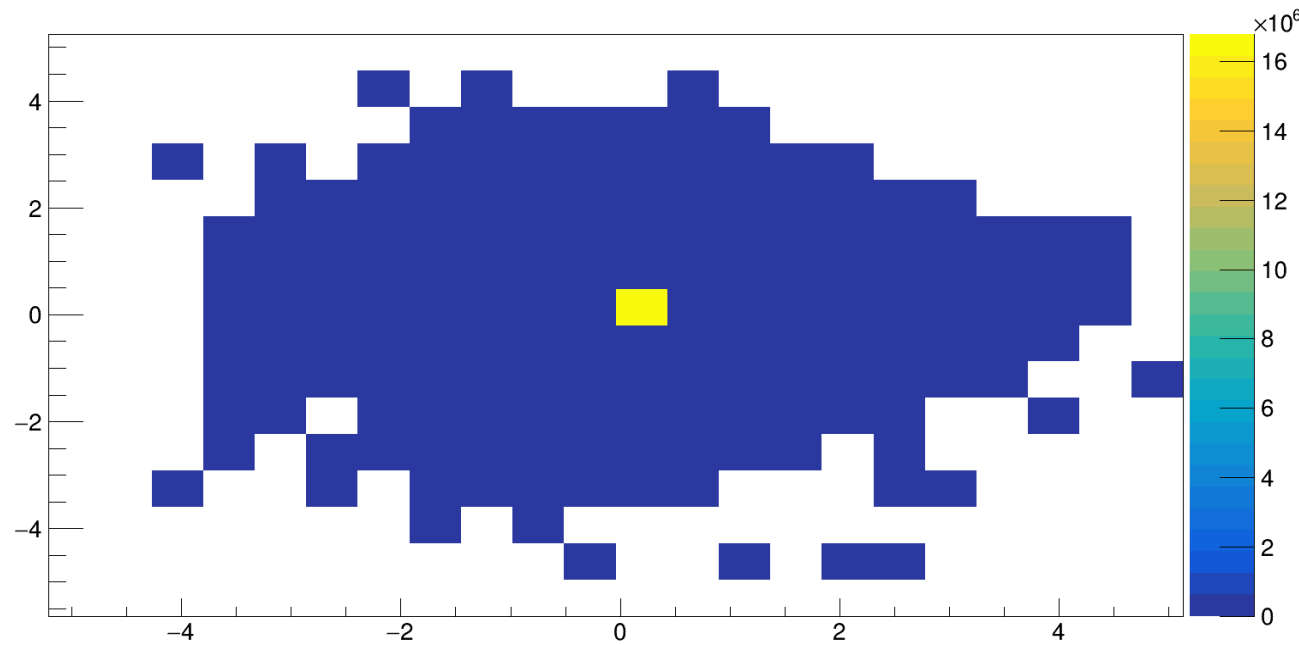
Width 40 %

Activity Units	Becquerel (Bq)		
Isotope	Energy	Count	Activity (Bq)
Pb-214	351.9	217	5.55e+02 +/-
Hg-194	436.8	83	1.52e+06 +/-
Co-60	1173.2	1312	1.29e+04 +/-
Eu-152	344.3	5064	1.77e+04 +/-
Eu-152	244.7	2018	2.20e+04 +/-
Bi-214	964.1	851	1.03e+06 +/-
Ba-133	383.9	1382	1.71e+04 +/-

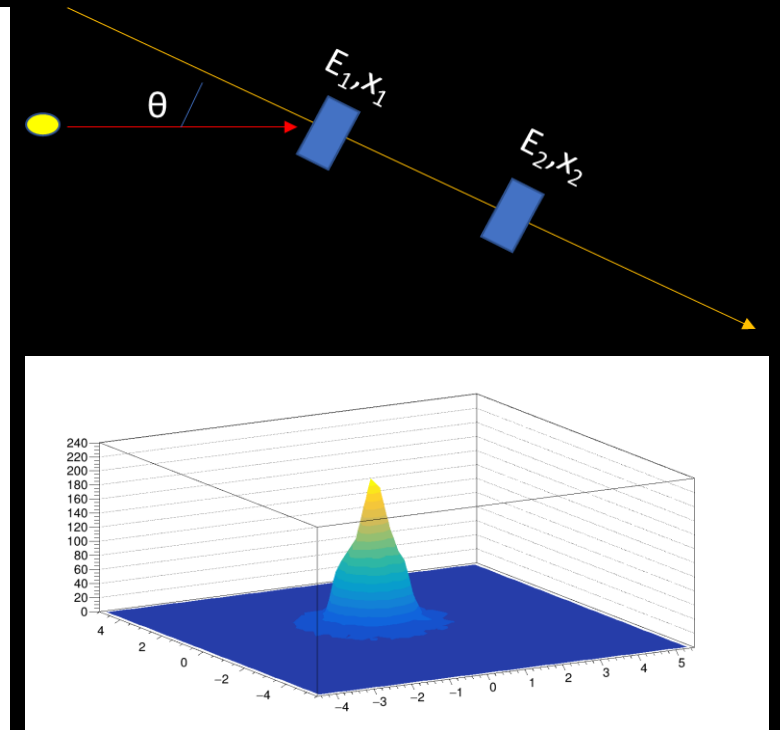
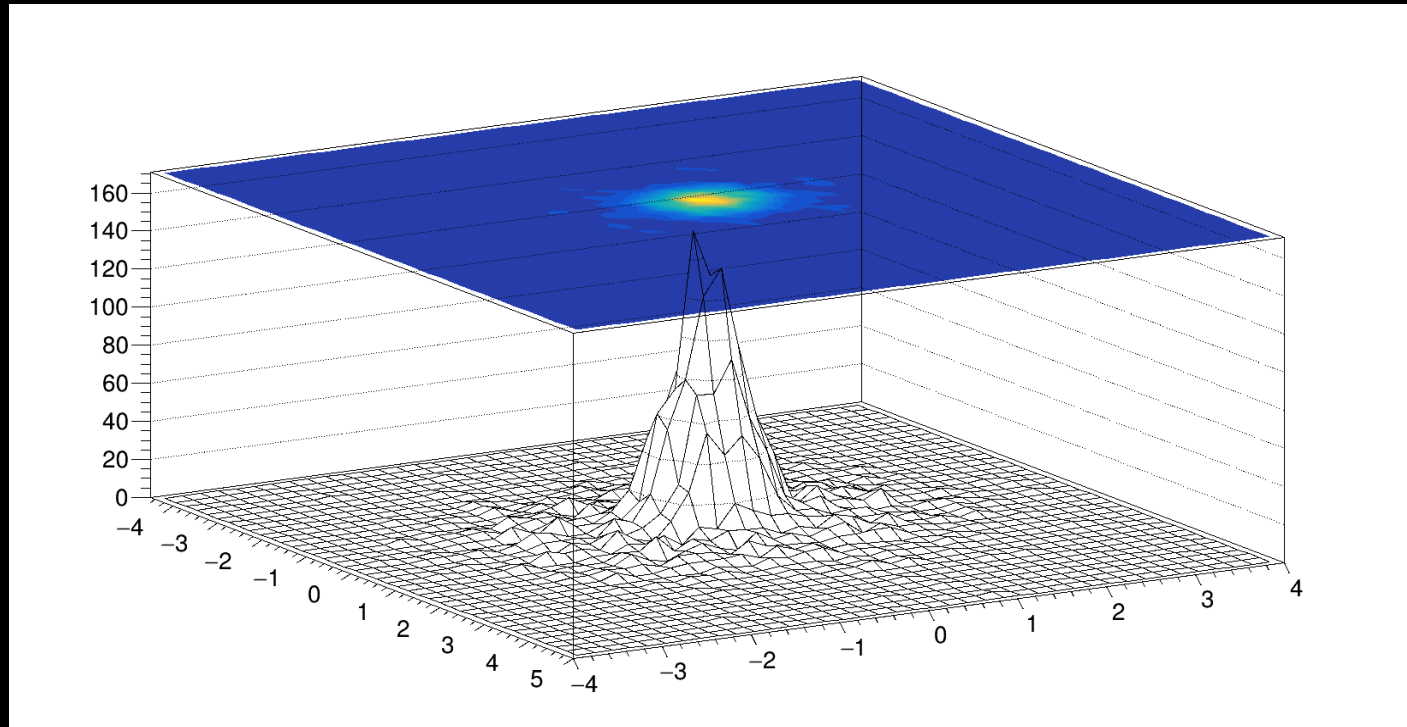




Compton Imaging



Compton Imaging



Summary

- We studied the performance of our GeGI detector at the Detector Laboratory of Helsinki Institute of Physics
 - Measurements are compared to Geant4 simulations
- The device is able to resolve various isotopes and locate sources from a distance within short timeframe
- In addition to source locating, it can be used as a reference for detector development
- By improving Compton model we will be able to better resolve the cone and the angle of incident particle
 - From two hit model to three hit model
 - Geant4 simulations allow to study the required modifications to the analysis algorithms