High resolution gamma spectroscopy using High Purity Germanium detectors

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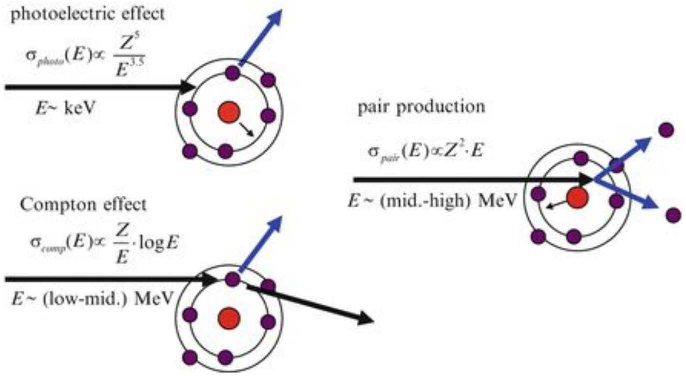
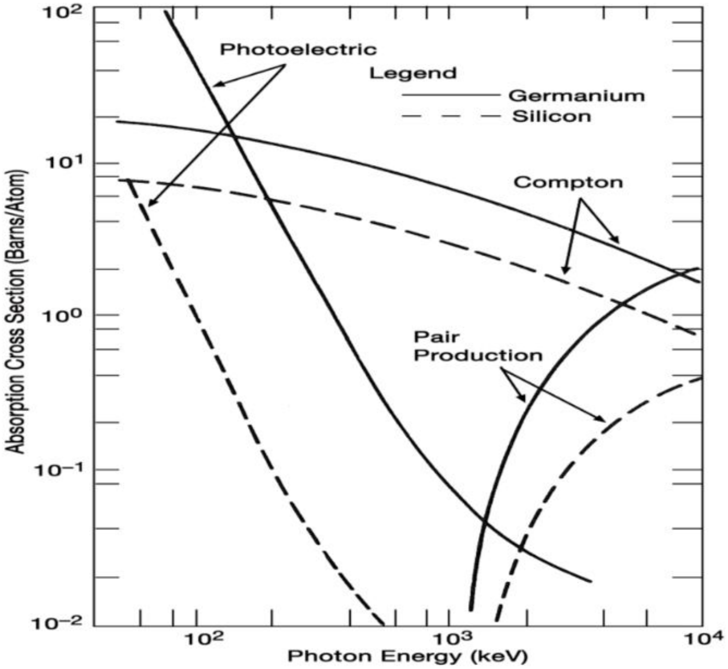
Gamma ray spectroscopy: An overview (1)

3 light-matter processes:

- Compton Scattering
- Photoelectric absorption
- Pair production



3 processes related to light-matter interactions



Photon energy against cross section, from *G. F. Knoll, Radiation Detection and Measurement, 4th edition*

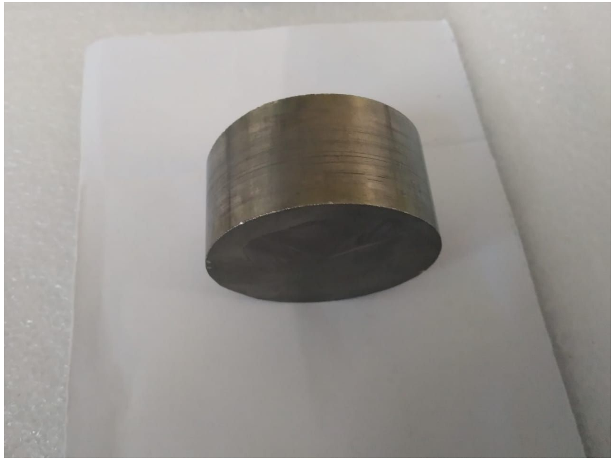
Gamma ray spectroscopy: An overview (2)

Many different materials that can detect these processes:

- Semiconductors
- Scintillators

We will be considering detection of gamma rays from radioactive materials via use of a **High Purity Germanium detector (HPGe)**, and will calculate relative characteristics of the detector (resolution, efficiency).

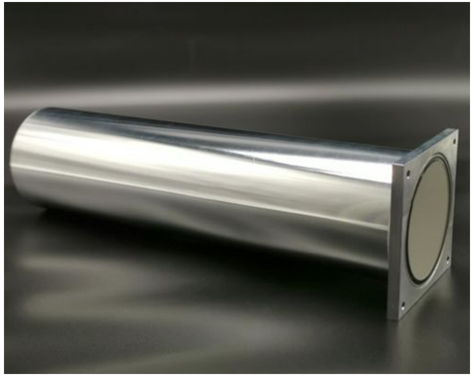
Germanium crystal used in this experiment



Gamma ray spectroscopy: Scintillator vs Semiconductor

Scintillator

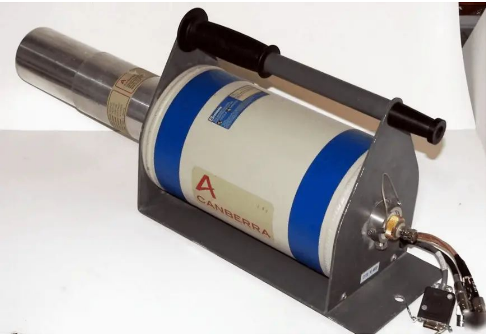
- Light detected via ionisation of materials
- Impurities deliberately added to ensure emitted light is within visible/detectable region
- Low cost, poorer resolution
- Eg: NaI(Tl)



NaI Scintillator

Semiconductor

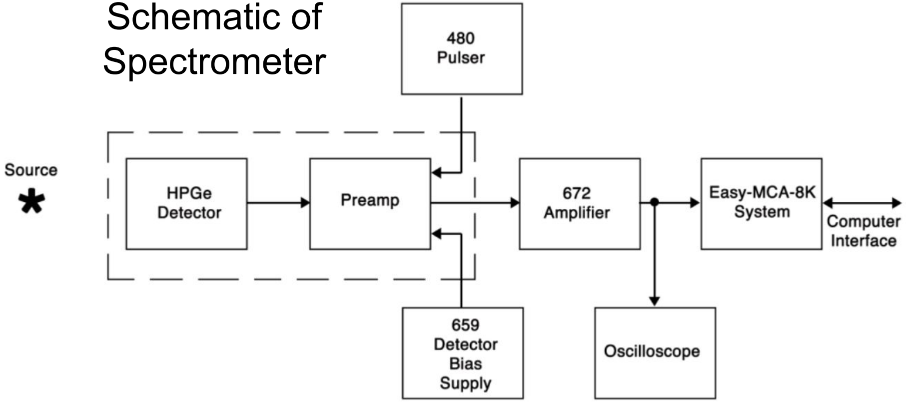
- Ionisation particle produces eh pairs that provide a signal via the application of an electric field
- Impurities need to be removed to improve the depletion region (and consequently detector performance)
- High cost, greater resolution
- Eg: HPGe



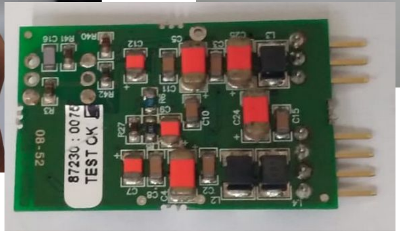
HPGe detector

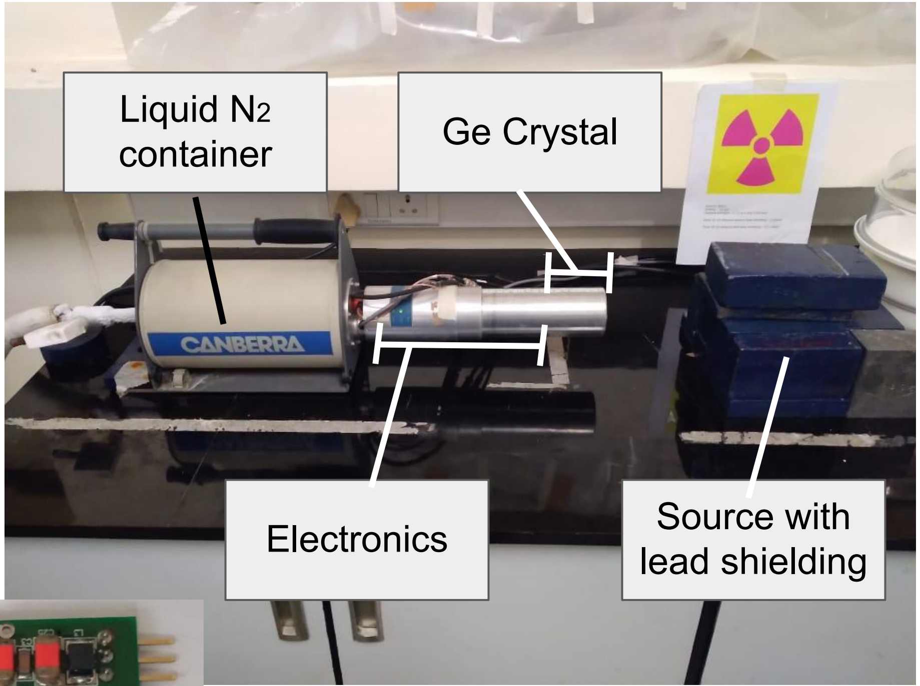
Gamma ray spectroscopy: Experimental Setup

Schematic of Spectrometer



Field effective transistor (FET), capacitor to convert charge to voltage, and preamplifier

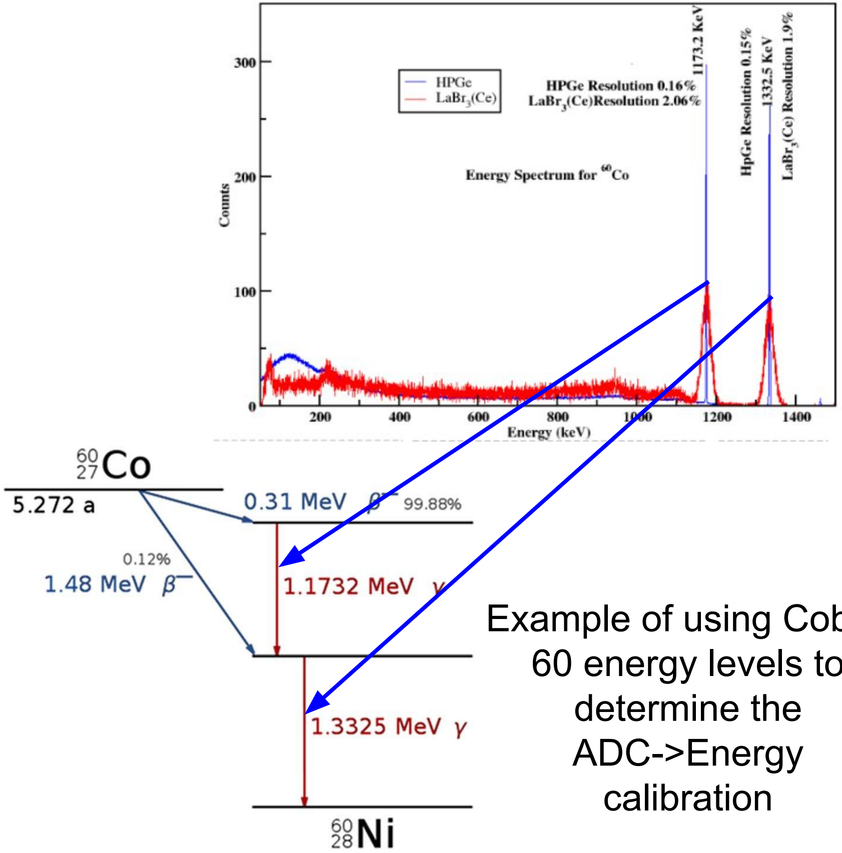




Experimental setup @ LINAC corridor

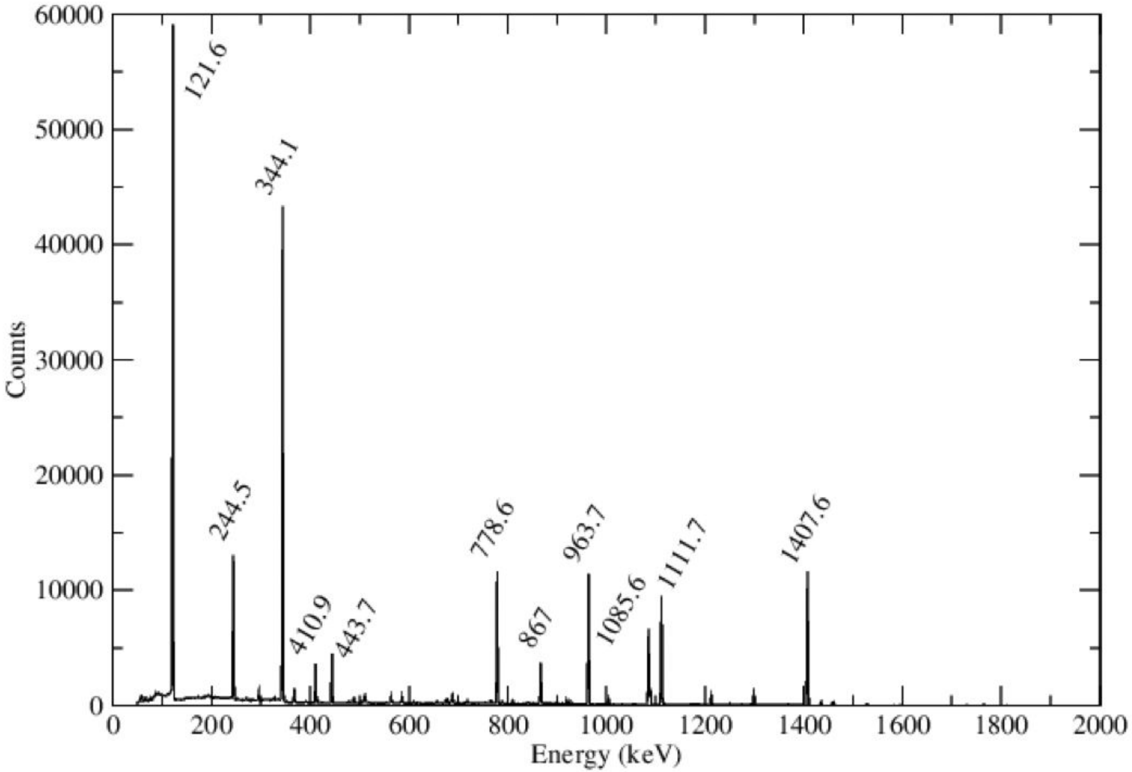
Gamma ray spectroscopy: Experimental Method

- Collect energy data from the emitted gamma rays of Cobalt 60 and Europium 152
- Calibrate the detector using the known Europium 152 gamma ray energy levels.
- Determine the energy resolution of the detector with respect to energy of the gamma rays.
- Determine the relative efficiency with respect to energy of the gamma rays.



Example of using Cobalt 60 energy levels to determine the ADC->Energy calibration

Energy calibration: ^{152}Eu source



Energy calibration: ^{152}Eu source

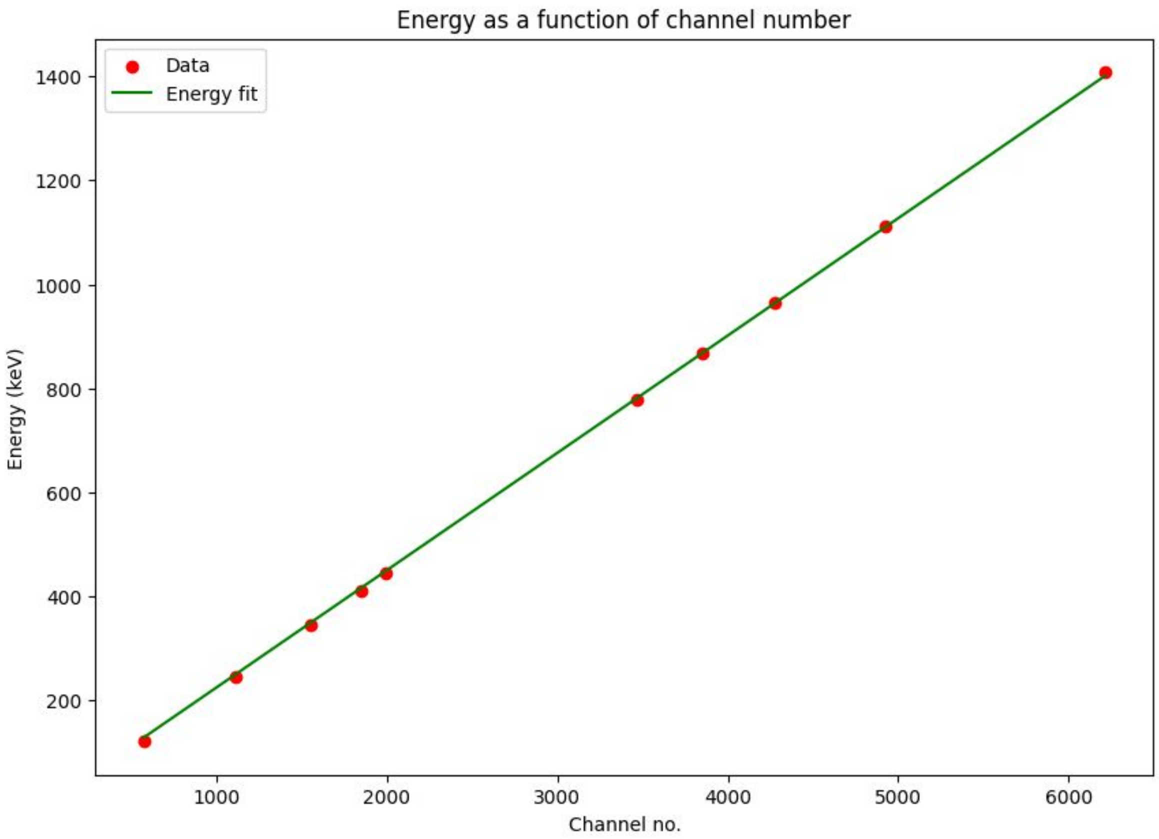
- Fit of the form:

  $E = a + bx + cx^2$
- Parameters:

  a = -7.47 +/- 0.15

  b = 0.23 +/- 0.00011

  c = 2.47 x 10^{-7} +/- 1.56 x 10^{-8}
- Energy increases linearly with channel number.



Energy Resolution

- Resolution calculated by dividing FWHM by energy
- Fit of the form:

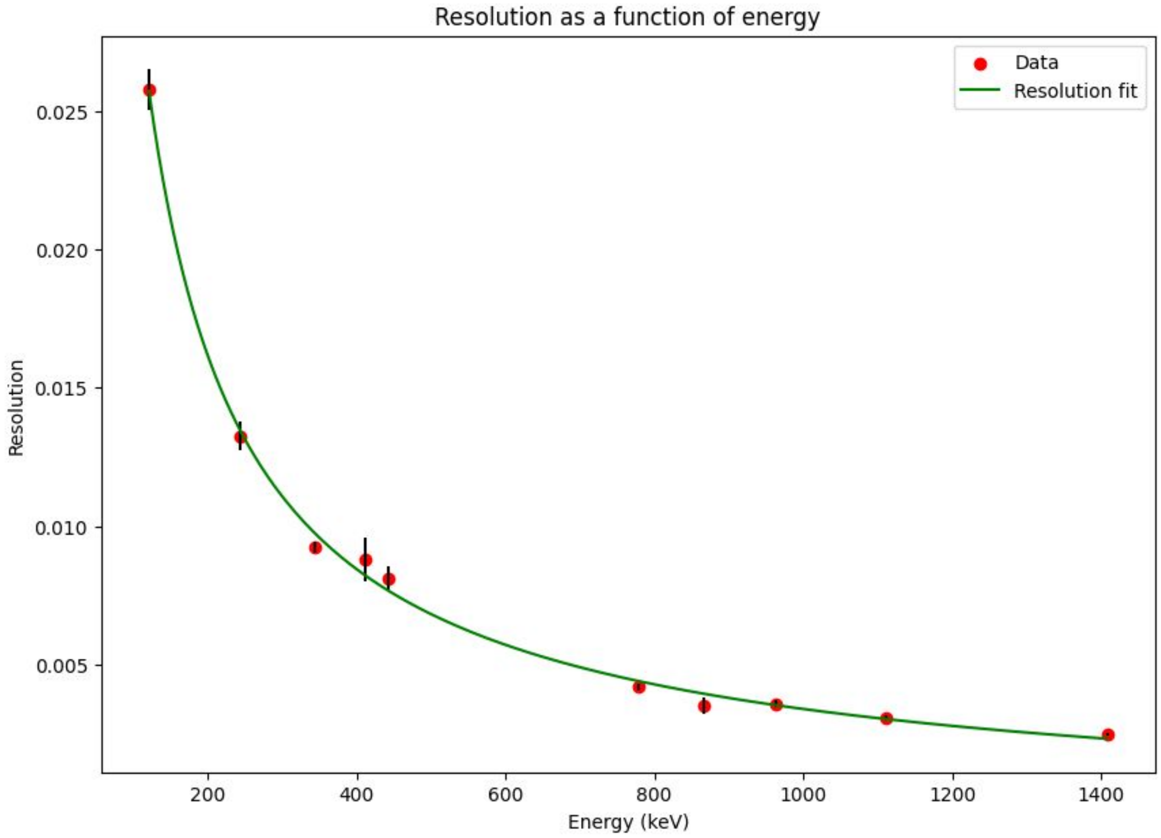
  $$R = a + b/\sqrt{E} + c/E$$

- Parameters:

  a = -0.0013 +/- 0.00098

  b = 0.069 +/- 0.038

  c = 2.53 +/- 0.33



Photopeak Efficiency

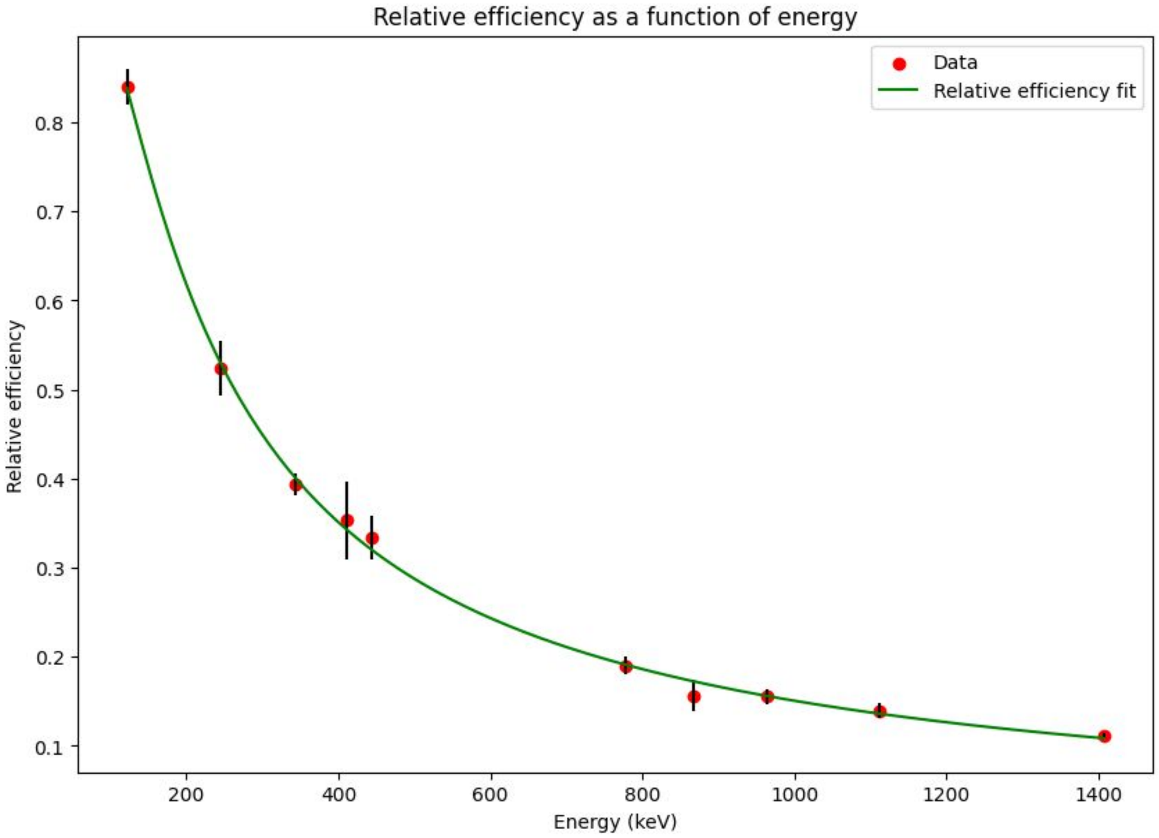
- Relative efficiency calculated by dividing area under photopeak by known intensity weights
- Fit of the form:

  $\eta = a + b/E + c/E^2$
- Parameters:

  a = 0.00024 +/- 0.0083

  b = 157 +/- 5.67

  c = -6701 +/- 628.36



Summary of results

- **Energy Calibration:**
  - Relation between the channel number and energy.
  - To estimate the energy of the unknown source.
- **Energy Resolution:**
  - The ability of the detector to distinguish between gamma rays of different energies.
  - It is important for identifying and characterizing complex gamma-ray spectra, which contain overlapping peaks from multiple sources.
- **Photo peak efficiency:**
  - This is to establish the relationship between the detected gamma ray energy and the number of gamma rays that produced a photopeak in the spectrum.
  - To correct for the loss of gamma rays due to the imperfect detection efficiency of the HPGe detector.

HPGe: Applications

- **Nuclear spectroscopy:** HPGe detectors are widely used for gamma-ray spectroscopy to identify and quantify radioactive isotopes in samples.

- **Environmental monitoring:** HPGe detectors can be used to measure and monitor environmental radiation levels in soil, water, air, etc which would helps to ensure public safety and compliance with regulatory standards.

- **Medical imaging:** HPGe detectors are used in nuclear medicine for imaging and diagnosing various diseases and medical conditions.

- **Material analysis:** HPGe detectors can be used for material analysis, such as in the identification of unknown materials, quality control, and forensic investigations.

- **Astrophysics:** HPGe detectors are used in astrophysics to detect gamma rays emitted from celestial sources, such as supernovae, pulsars, and black holes.

Acknowledgement

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Thank you!

Biswajit, Vishal and us with the clover detector