Hyper Pure Germanium (HPGe) detector

Group - IG

January 26, 2019

Motivation

- Energy measurement of photons in MeV range with better resolution than a scintillation detector.
- Sources: ^{60}Co, ^{152}Eu

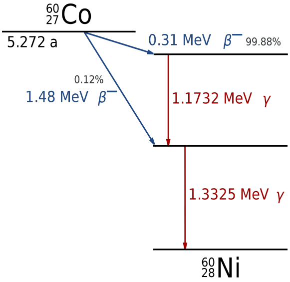


Figure: $https://commons.wikimedia.org/wiki/File:Cobalt-60_Decay_Scheme.svg$

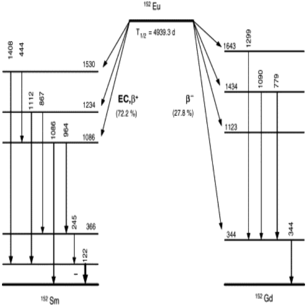
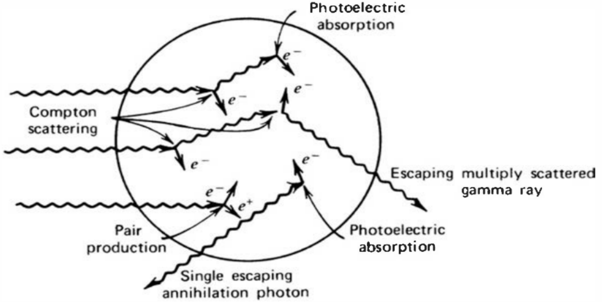


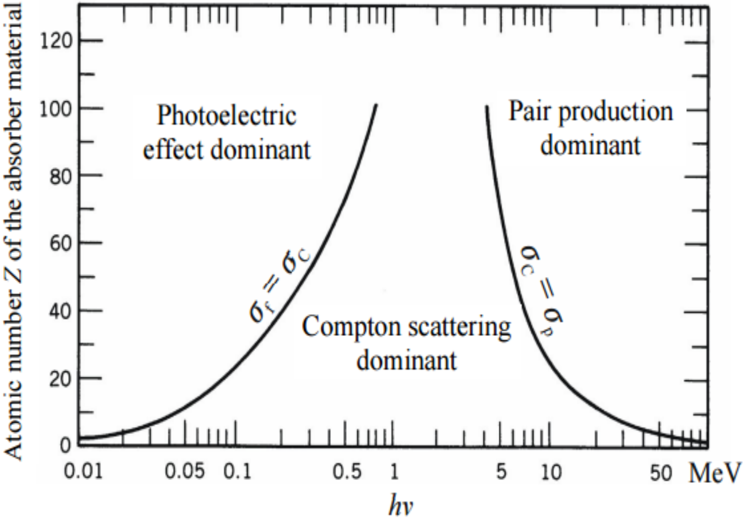
Figure: https://doi.org/10.1016/S0969-8043(01)00200-7

Introduction – Light-matter interaction



1. Photoelectric effect
   - $E_e = h\nu - \phi_e$
   - Complete absorption of incident photon energy.
2. Compton scattering
   - $E_e = \frac{E_\gamma^2(1-cos\theta)}{m_e c^2 + E_\gamma^2(1-cos\theta)}$
   - Photon typically leaves with non-zero energy.
3. Pair production
   - $E_\gamma \geq 1.02$ MeV

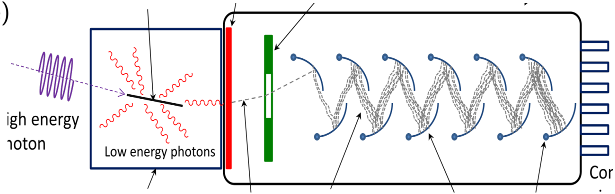
Light-matter interaction (contd.)



Introduction — Detectors

1. **Scintillation detectors**

- $LaBr_3(Ce)$



- Part 1: Incident photon → excites e^- from VB to CB → hole left in VB ionizes activator/dopant ground state → activator/dopant gets de-excited → visible $(1 - 2$ eV$)$ scintillation photon.
- Part 2: Photocathode emits corresponding intensity of electrons.
- Part 3: Photomultiplier amplifies the electron signal to a measurable extent $(10^7 - 10^{10}$ electrons$)$.

▶ Many inefficient steps.

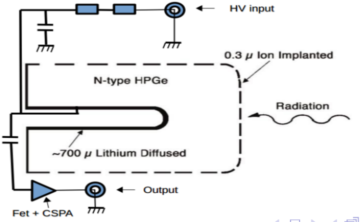
▶ For one photoelectron: ~ 100 eV

▶ No. of photoelectrons in a typical radiation interaction $\sim< 1000 \Rightarrow$ large statistical fluctuations!

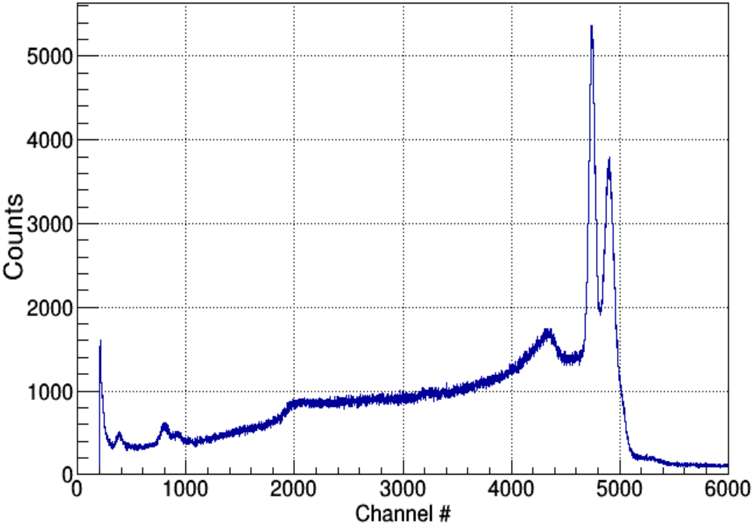
Introduction – Detectors

2. **Semiconductor detectors (HPGe)**
   - Z(Ge) $>$ Z(Si), E_g(Ge) $\approx$ 0.7eV
   - p-n junction reverse biased
   - Depletion width, $d = \left(\frac{2\epsilon V}{eN}\right)^{1/2}$

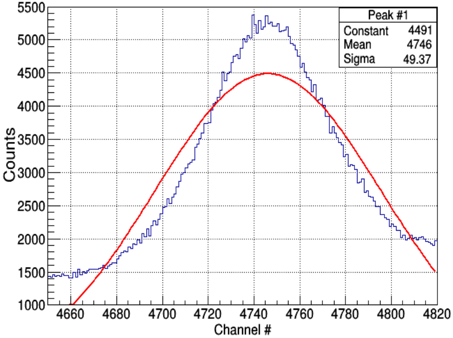
   where, V: reverse bias voltage, N: impurity concentration.
   - Normal purity: Maximum depletion width within breakdown voltage $\sim 2 - 3$ mm
   - High purity: wider depletion region $\Rightarrow$ larger active volume $\Rightarrow$ more number of e$^-$-hole pairs $\Rightarrow$ larger signal!

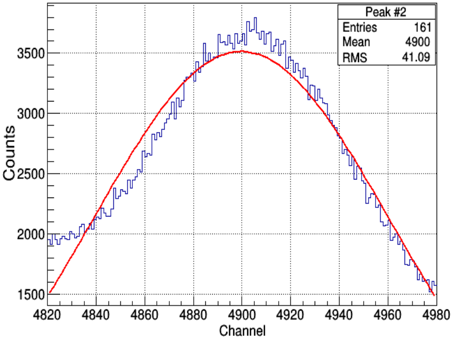


Cobalt-60 (^{60}Co) – (LaBr$_3$)



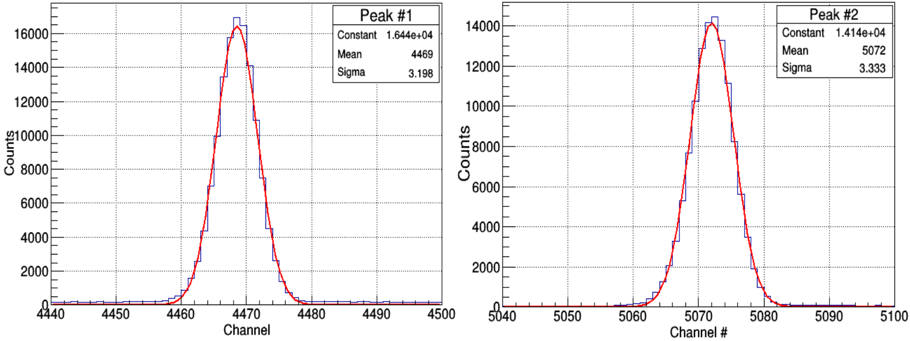
Cobalt-60 (^{60}Co) – (LaBr$_3$(Ce)) Two-point-calibration





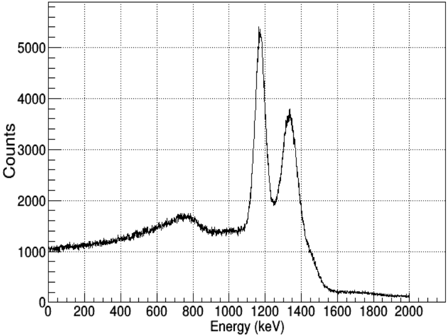
- $E(\text{keV}) = (1.03 \times \mathit{channel}\#)$ - 3715.4

Cobalt-60 (^{60}Co) − (HPGe) Two-point-calibration



- $E(\text{keV}) = (0.26 \times channel\#)$ - 5.48

Cobalt-60 (^{60}Co) LaBr$_3$(Ce) vs. HPGe



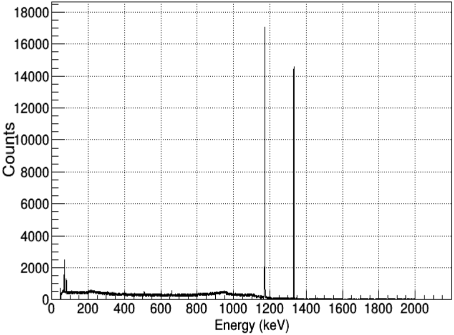
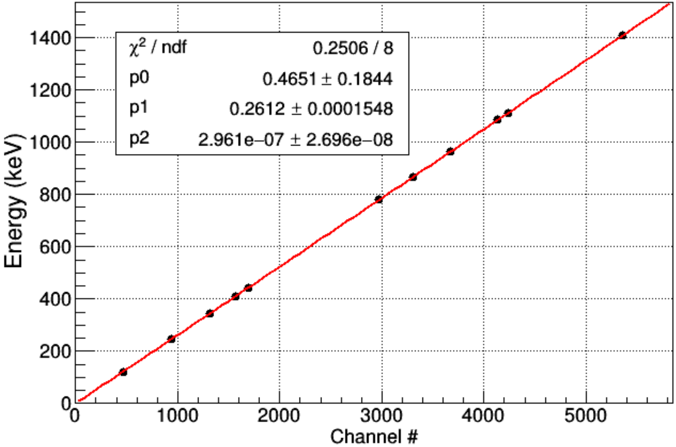


Table: FWHM (keV)

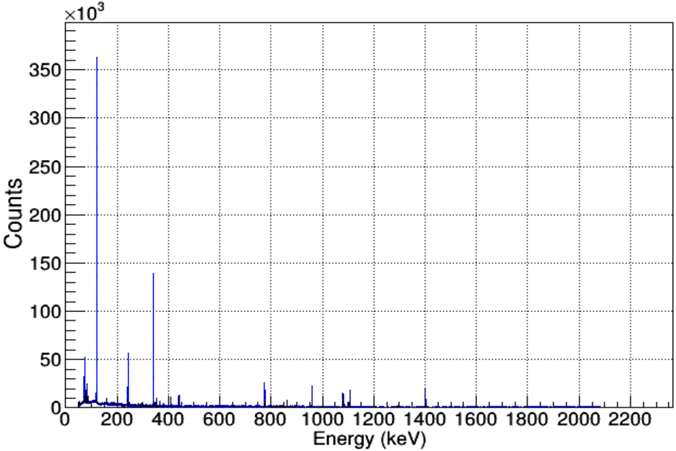
	LaBr$_3$(Ce)	HPGe
Peak 1	87.12 ± 1.16	1.74 ± 0.04
Peak 2	122.72 ± 1.48	1.86 ± 0.02

Europium − (HPGe) Calibration



- E(keV) $= (2.96 \times 10^{-7} \times (channel\#)^2) + (0.26 \times channel\#) + 0.46$

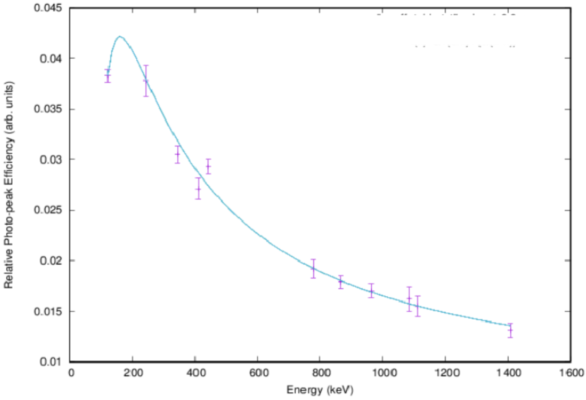
Europium – (HPGe) Photopeaks



Europium – (HPGe)
Photopeak efficiency

- Photopeak efficiency $(\epsilon_i) = \frac{F_i}{F_i^S}$

where, F_i: fractional area of the i^{th} photopeak obtained using HPGe set-up
F_i^S: fractional area of the i^{th} photopeak from the standard spectrum.



Results & Conclusion

- Calibrated $LaBr_3$(Ce) and HPGe detectors.
- Energy resolution of HPGe is about 50 times that of $LaBr_3$.