Lab 0 - Linear Calibration of a High Purity Germanium Detector

Matthew Marshall

September 18, 2018

While you can use the Ba-133 energy spectrum for validation, the energy calibration has much more general application

Abstract

This report details the importance and process of generating a two-point energy calibration using ^{137}Cs and ^{241}Am to produce a calibrated ^{133}Ba.

1 Introduction

The purpose of Lab 0 was to perform a two-point linear calibration between two gamma-ray photopeaks. In gamma-ray spectroscopy, determining which gamma-rays are present is an important aspect of radiation detection, and relying solely on the raw channel output makes it difficult to determine the gamma-ray energies present. By performing an energy calibration, a relationship is formed between peak channel position and the associated gamma-ray energy [1]. This relationship helps with the identification and discernment of gamma-ray photopeaks from noise or spurious results, which has an importance for non-proliferation reasons. Thus, having a properly calibrated spectrum is an essential component of gamma-ray spectroscopy. The following report details the process and results of a two-point linear calibration using ^{137}Cs and ^{241}Am as calibration sources.

Typically we're not worried about noise or other effects in terms of spectral identification - just the ability to identify signatures based on the known energy of gamma-ray emissions from various sources

And many others... nuclear structure, neutron activation analysis, etc.

2 Methods

The data for this lab came from a HPGe detector collected by Dr. Ross Barnowski. The sources used to generate the spectrum are shown in Table 1.

Source
^{241}Am
^{133}Ba
^{60}Co
^{137}Cs
^{152}Eu

Table 1: Gamma-ray lines used in the calibration

The energy calibration was performed using a two-point linear fit between ^{137}Cs and ^{241}Am. To perform the calibration, a python program searched the raw spectrum data of ^{137}Cs and ^{241}Am looking for the largest peaks within the spectrum. The program iterated over the spectrum for the number of gamma-ray energies present since there should only be peaks corresponding to the number of gamma-ray energies present. Before the program iterated over the raw spectrum, the data needed to be "cleaned". Noise from the detector could obscure some of the peaks found from iterating peak heights. With a peak found, the centroid of the peak was recorded, and subsequently, utilizing a pre-defined width that incapsulates the whole peak, the program fit a Gaussian and a linear model to this portion of the data.

After modeling the data with the Gaussian and linear model, the peak was set to zero so during the next iteration the same peak is not found again. The width of the peak was determined from first analyzing the spectrum and establishing the average width of each peak.

Once all of the peaks were discovered, polyfit within python was used to plot a linear line. The inputs for polyfit were the position of the peak and the actual gamma-ray energies. The slope-intercept from polyfit was applied to the channel numbers within the ^{133}Ba spectrum. Finally, to plot the data I did the newly calibrated channel numbers vs the original ^{133}Ba spectrum.

3   Results

The raw spectrum of ^{133}Ba is depicted in Figure 1.
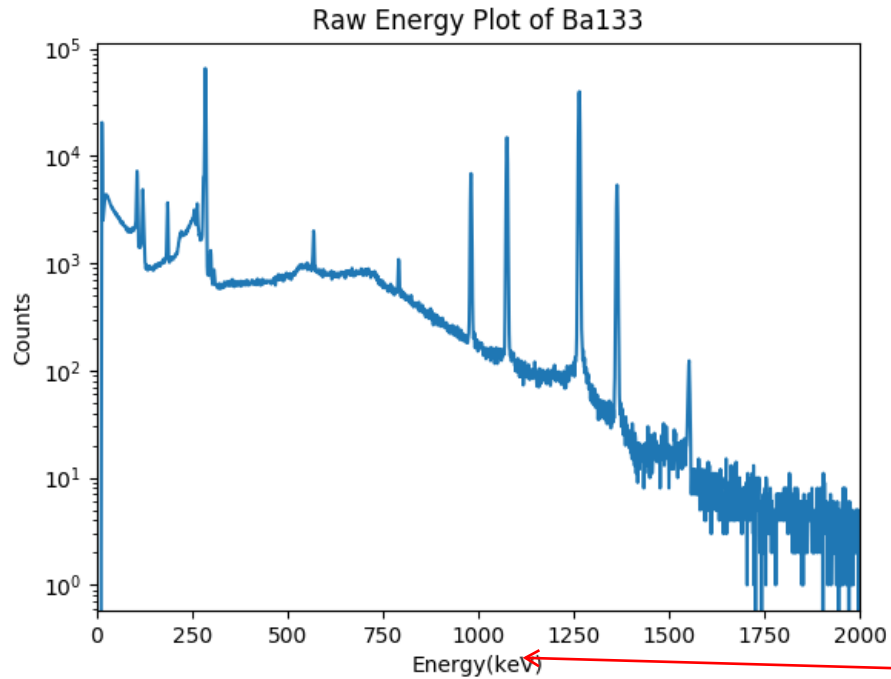
Figure 1: Raw data of ^{133}Ba produced from a HPGe detector.

Inspection of Figure 1 shows that the data has not been calibrated yet. For this analysis, I used 5 peaks from ^{133}Ba detailed in 2 [2].

Table 2: ^{133}Ba Gamma-ray Energies

Source	Energy (keV)
^{133}Ba	80.9979
	276.3989
	302.8508
	356.0129
	383.8485

I excluded 79.6142 keV from the energy list because it blurs together with 80.99 keV into one photopeak due to the energy resolution of the HPGe. A better resolution detector would be needed to distinguish these two peaks.

3

Thus, I removed it so the iterator in the program will not search for a peak that is not present.

After performing the linear calibration with ^{137}Cs and ^{241}Am, a slope-intercept was found.

$$E = 0.28054 * x + 1.26023$$ (1)

The slope and intercept was applied to the channel number of the raw Ba133 data. Figure 2 depicts the two-point calibration.
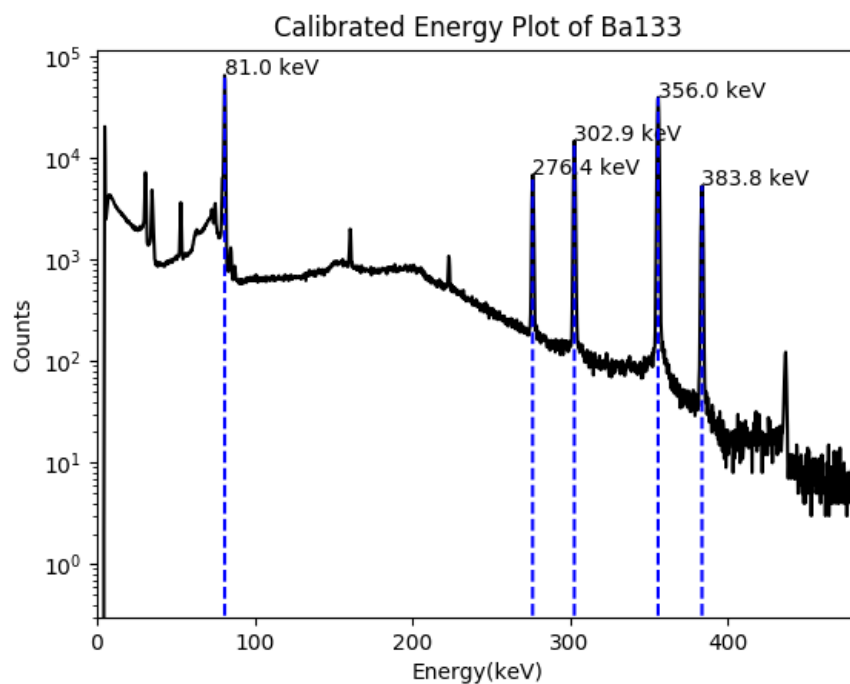

Figure 2: Calibrated ^{133}Ba data with their corresponding gamma-ray energies depicted by dashed blue lines

The difference between the calibrated peak locations and the expected peak are shown in Table 3.

4

Table 3: ^{133}Ba Gamma-ray Energies

Source	Energy (keV)	Calibrated Energy	Difference (%)
^{133}Ba	80.9979 +/- 0.0011	81.0231 +/- 0.02546	0.03108 +/- 0.03147
	276.3989 +/- 0.0012	276.4462 +/- 0.0053907	0.017148 +/- 0.001998
	302.8508 +/- 0.0005	302.8877 +/- 0.008467	0.01217 +/- 0.0028006
	356.0129 +/- 0.0007	356.038 +/- 0.006710	0.0070492 +/- 0.001895
	383.8485 +/- 0.0012	383.8706 +/- 0.009235	0.005751 +/- 0.0024263

Based on Table 3, the percent difference between the actual peak energies and the calibrated spectrum is minute, which would be expected since semiconductors are nearly linear with energy.

4 Discussion

The two-point energy calibration proved to be an effective method to calibrate a spectrum. After cleaning the raw data to remove electronic noise and excluding the 79 keV line for ^{133}Ba, the calibrated data corresponded well with the actual gamma-ray energies. There was a small amount of error between the gamma energies and the photopeaks, but this is expected because I only used a two-point energy calibration. Once more sources are added in to the calibration that span the entire energy range, the photopeaks should correspond better with their corresponding energies.

References

[1] Gordon Gilmore. *Practical gamma-ray spectroscopy*. John Wiley & Sons, 2011.

[2] Recommended gamma-ray energies and emission probabilities ordered by radionuclide. $www-nds.iaea.org/xgamma_standards/genergies1.htm$. (Accessed on 02/01/2018).

> Where are the uncertainty values coming from? In the case of the known energy, I assume this is from the literature - if so, this should be explicitly stated. In the case of the calculated values, no mention is made: quantitative values without the context have very limited value! (whether this shows up in the methods section or in the results/discussion is up to you)

> This is not just the detector itself, but the entire signal processing chain

> Be quantitative... what do the residuals tell you about the calibration. Is there a pattern in delta E vs E?

> This "cleaning" is still not presented