NE 204 Lab 0 - Energy Calibration with Reproducible Workflows

Darrell Stepter

September 17, 2018

What kind of signal is the MCA digitizing?

Introduction

The purpose of Lab0 is to practice generating lab reports using the reproducible work flow required for NE204: Advanced Concepts in Radiation Detection. Energy calibration of a High Purity Germanium (HPGe) detector, a ubiquitous task in radiation detection laboratories, was used for practicing the work flow. Energy calibration is a necessary step for every radiation detector. This is especially true for HPGe Detectors that are able to achieve high-energy resolution beyond what other detectors, such as scintillators, are capable of. Precise calibration ensures the accuracy and the quality of the results. Without a proper calibrations, there is no way to tell how the channels/bins from a Multi-Channel Analyzer (MCA) correlate to energy. In Lab0 this energy calibration was done using a two-point linear calibration between two gamma-ray photopeaks of ^{137}Cs and ^{241}Am. Subsequently, the calibration model was "verified" by applying it to the gamma-ray spectrum from ^{133}Ba, which has five distinct photopeaks. This report details the process and results of a two-point linear calibration.

evaluated

Methods

The data for this lab was collected by collected by Dr. Ross Barnowski. Dr. Barnowski used a HPGe detector and a 13-bit resolution MCA, yielding 8192-bin spectra. It is assumed that each of these measurements were taken with each source at the same location and distance from the detector. The sources used to generate the spectrum are shown in Table 1.

This assumption is correct... can you think of why this consideration would impact the energy calibration process?

Delta implies a reference level... what are you using for your reference?

Good practice making a table in LaTeX, but doesn't contain much relevant info... for example, consider adding info about the energies of the most prominent gamma-rays emitted by each source.

Table 1: Sources for Lab0

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

Not specific enough... polyfit can fit any model to any data... describe the model you are using for this analysis.

The energy calibration was performed using a two-point linear fit between ^{137}Cs and ^{241}Am. To perform the calibration, a simple python peak detection script searched the raw spectrum data of ^{137}Cs and ^{241}Am looking for the channel containing largest number of counts (photopeak) within the spectrum. The program iterated over the spectrum by channel trying to identify a large delta (40000) in the counts. Because ^{137}Cs and ^{241}Am have single gamma ray photopeaks, a large delta ensures no other noise in the signal could be misconstrued as photopeaks.

A more concrete discussion of the advantages and drawbacks of this approach would be good.

Once the ^{137}Cs and ^{241}Am peaks were discovered, the python function polyfit was used to plot a linear line. The inputs to polyfit were the channel of the peak and the actual gamma-ray photopeak energy as listed in the LBNL Nuclear Data Search [1]. The polyfit output was a slope and intercept that can be used to translate channel to energy. Next, the peak detection script was used to find the multiple photopeaks in the ^{133}Ba spectrum. Lastly, the polyfit "calibration" was applied to the ^{133}Ba photopeaks and spectrum to calculate approximation error and display the full ^{133}Ba spectrum.

Good

You keep referencing the "polyfit", but this doesn't convey the relevant information. Items of interest include what model you are using to fit peaks to determine their centroid, and the model you are using for the energy calibration itself. Your text implies that the model is linear, but this should be made explicit rather than focusing so much on the particular fitting tool.

Results

The peak detection script found the ^{241}Am photopeak in channel 208 and the ^{137}Cs photopeak in channel 2354. The documented energies for these photopeaks are 59.541 keV and 661.657 keV, respectively. The identified photopeaks of ^{241}Am and ^{137}Cs are depicted in Figure 1.

References to nuclear data wouldn't hurt.

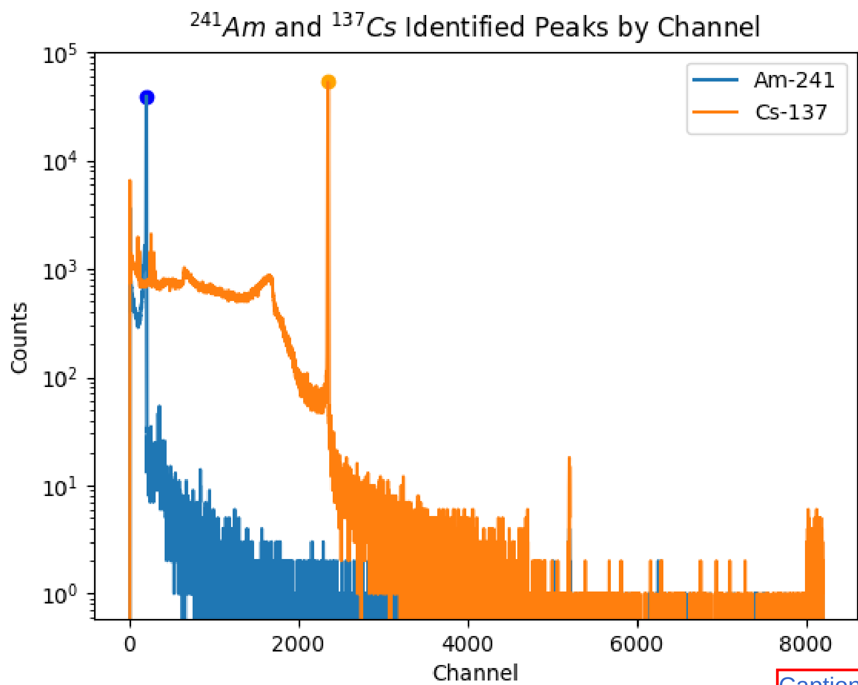


Figure 1: Photopeaks of ^{241}Am and ^{137}Cs

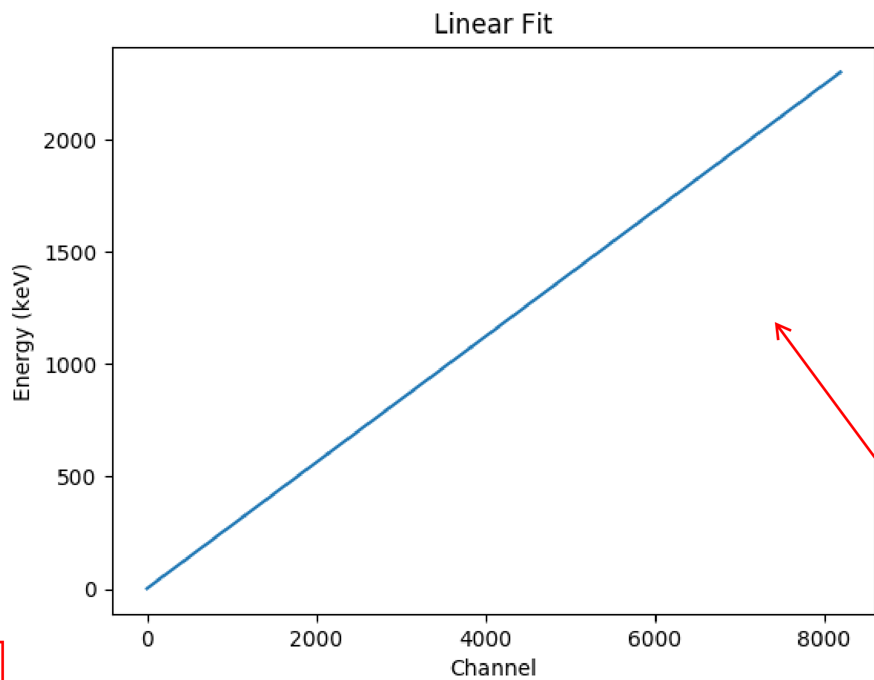
Caption should be more detailed... these are not just photopeaks but full energy spectra that *contain* full-energy peaks

The polyfit function found the linear relationship between channel and energy to be

$$E_{calib} = 0.2805759552656106 \cdot C + 1.1812013047530752 \tag{1}$$

where E_{calib} is energy in keV and C is channel number. Figure 2 depicts this linear calibration.

Should point out the linear model you are using in the methods section



Good practice for creating a plot, but doesn't convey any meaningful information... superfluous in this context

Why only integer values here? How does the quantization error effect the energy determination?

Figure 2: Linear Fit of Channel to Energy

The peak detection script found the ^{133}Ba photopeaks in channels 13, 105, 284, 981, 1075, 1265, and 1364. However, the first two channels could be excluded from the data set because they are indicative of low energy noise and the 31 keV X-ray emitted by ^{133}Ba. Figure 3 depicts the photopeaks found in ^{133}Ba.

Are they? This is the type of claim that could use a figure (e.g. a zoomed-in shot of the Ba-133 spectrum in the low-energy region) to support it. Is your energy calibration not valid for X-ray peaks? why or why not?

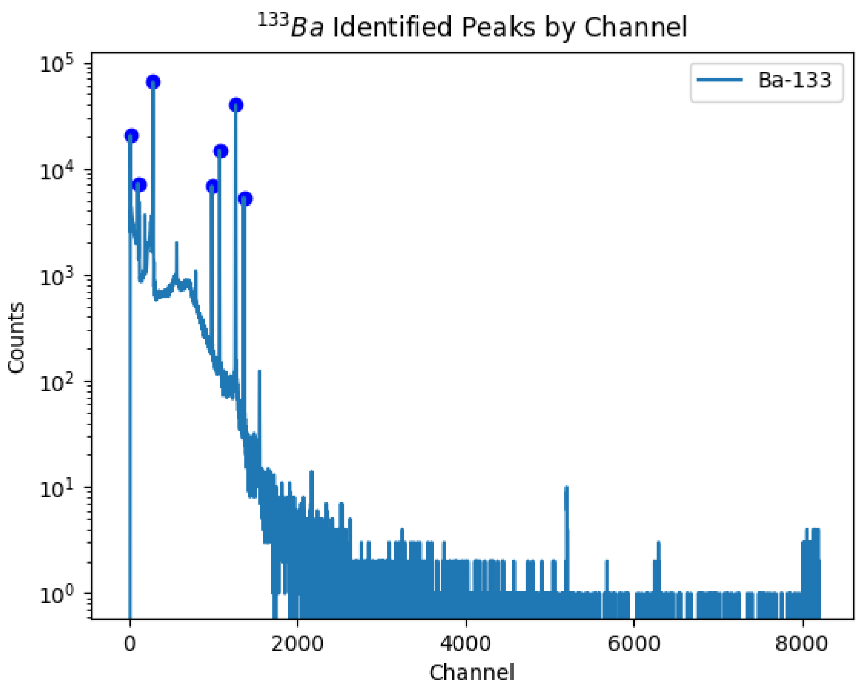
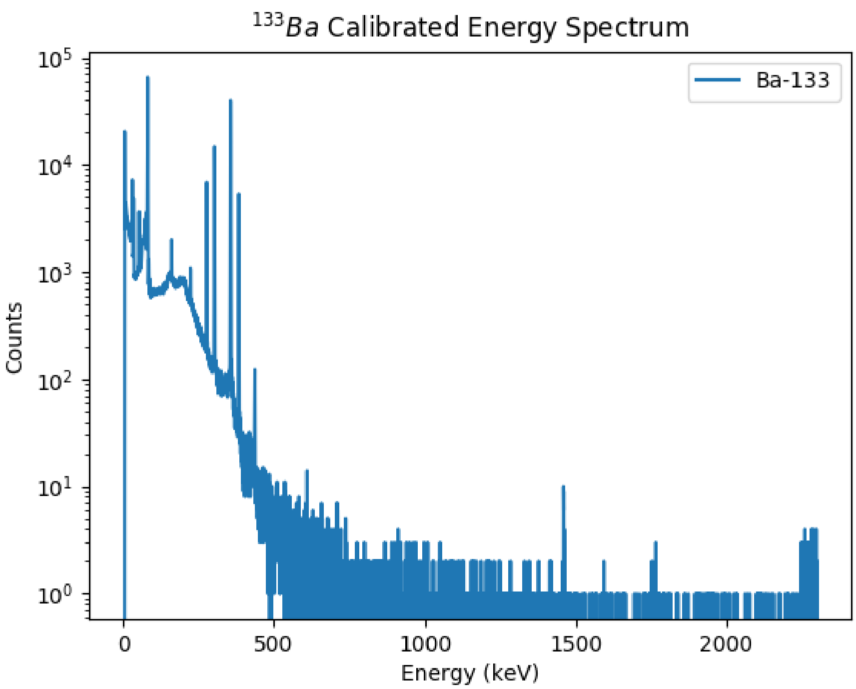


Figure 3: ^{133}Ba Photopeaks

Same comment as above... more descriptive

The photopeaks for ^{133}Ba were calculated using Equation 1. Figure 4 depict the calibrated ^{133}Ba spectrum and Table 2 shows a comparison of the calibrated and known peak energies for ^{133}Ba.

photopeak energies



Careful with this line... what about the 79 keV line?

Figure 4: ^{133}Ba Photopeaks

Table 2: Comparison of Photopeaks for ^{133}Ba

Expected (keV)	Calibrated (keV)
80.9979	80.86477260
276.3989	276.42621342
302.8508	302.80035322
356.0129	356.10978472
383.8485	383.88680429

The approximation error between calibrated and known energy values were quantified by Equations 2, 3, and 4.

$$\epsilon = |E_{calib} - E_{known}| \tag{2}$$

Good, consider plotting these residuals

$$\eta = \frac{|E_{calib} - E_{known}|}{E_{known}} \tag{3}$$

Too many sig figs implies far more precision for your calibration and measured values than you actually have!

These columns show the same thing... redundant! Again, be careful with sig figs!

$$\delta = \frac{|E_{calib} - E_{known}|}{E_{known}} \cdot 100 \quad (4)$$

Table 3: Approximation Error in Calibrated ^{133}Ba Photopeaks

γ Energy	Absolute Error ϵ	Relative Error η	Percent Error δ (%)
80.9979	0.1331273998135174	0.0016435907574581241	0.16435907574581 24
276.3989	0.027313420317000237	9.881884593969163e-05	0.009881884593969163
302.8508	0.05044678471557518	0.00016657306077968155	0.016657306077968153
356.0129	0.09688471575043422	0.00027213821676246627	0.027213821676246627
383.8485	0.038304287045889396	9.979011783526416e-05	0.009979011783526417

linear model

Discussion

A linear energy calibration model for a coaxial HPGe detector was successfully produced using reproducible workflows. The accuracy of the calibration was determined by applying the model to the ^{133}Ba dataset. While Knoll [2] suggests using a polynomial fit, the approximation error between the calibrated and expected energies was insignificant; indicative of a very reliable model. The highest error, a δ of 0.164359(%), occurred at the 80.9979 keV photopeak. This is likely due a large channel width creating an inability to discriminate between the 80.9979 keV and 79.6142 keV photopeaks in ^{133}Ba.

On the right track here... if you recognize this issue, why choose this peak for analysis?

References

[1] S Chu, L Ekstrom, and R Firestone. Decay data search, Feb 1999.

[2] Glenn F Knoll. *Radiation Detection and Measurement*. John Wiley & Sons, 2010.