Parker D. Lewis

Dr. Paul King

Nuclear Grad Lab

9/10/24

Tutorial Analysis assignment

1.

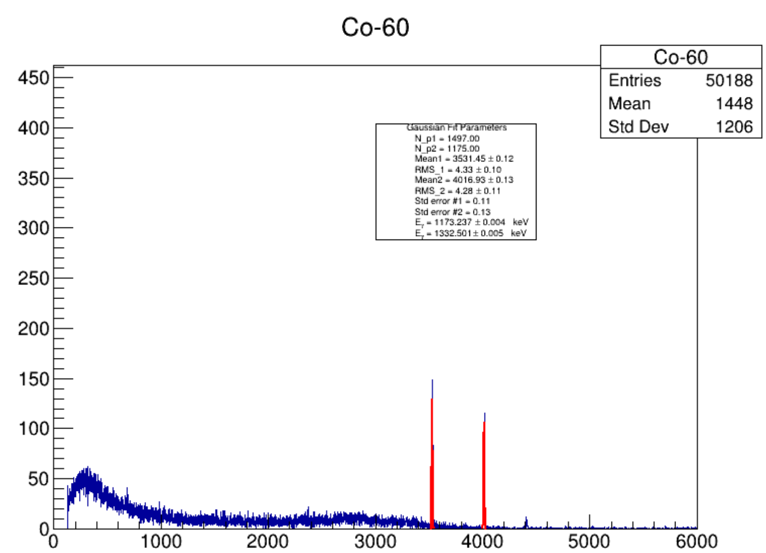

Fig 1. Cobalt-60 Data and Histogram.

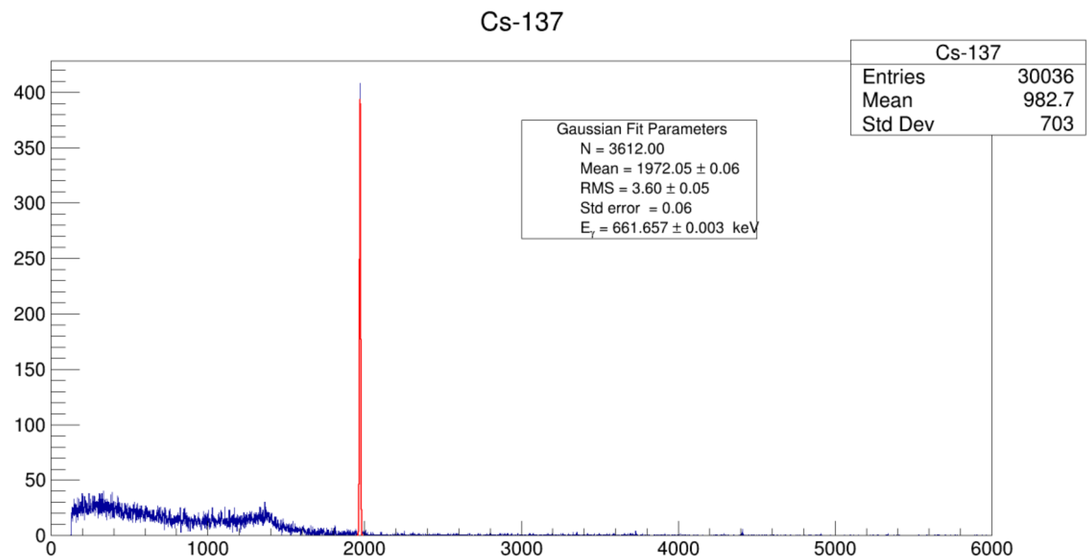

Fig 2. Cesium-137 Data and Histogram.

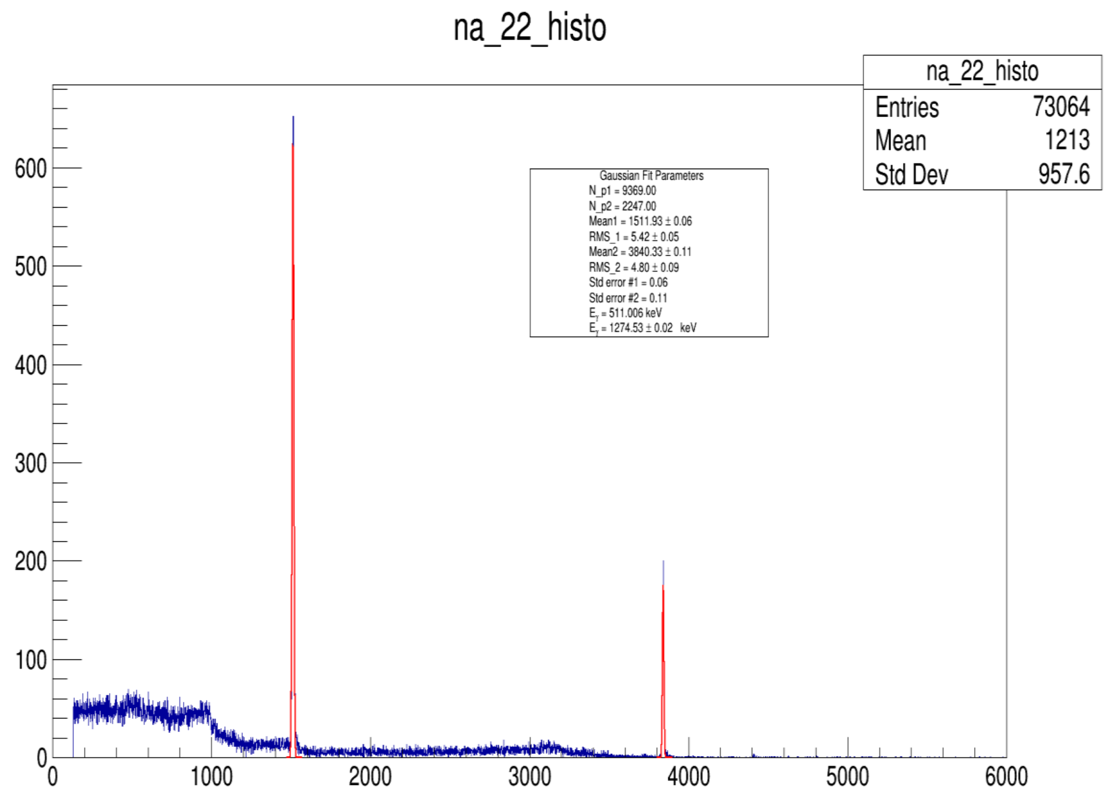

Fig 3. Sodium-23 data and histogram.

- For all three histograms, I found the parameters and needed values by taking the information from the gaussian fits. I also used the integral method in root to find my number of counts and defined the formula of error of the mean to get those values of my peak. I used the Idaho National Labs source for the gamma energies.

2.

	Variable	Value	Error
0	Slope (a)	0.328	1.31e-05
1	Intercept (b)	15	0.032
2	Chi2	83.1	
3	NDf	3	
4	Edm	6.1e-12	
5	NCalls	24	
6	p0	0.328	1.31e-05
7	p1	15	0.032
8	Covariance Matrix (0,0)	1.72e-10	
9	Covariance Matrix (0,1)	-3.89e-07	
10	Covariance Matrix (1,0)	-3.89e-07	
11	Covariance Matrix (1,1)	0.00103	
12	Calibration error (Channel 3531.45)	0.0205	
13	Calibration error (Channel 4016.93)	0.0259	
14	Calibration error (Channel 1511.93)	0.0156	
15	Calibration error (Channel 3840.33)	0.0239	
16	Calibration error (Channel 1972.05)	0.0127	
17	New Energy value (Channel 3531.45)	1.17e+03	
18	New Energy value (Channel 4016.93)	1.33e+03	
19	New Energy value (Channel 1511.93)	511	
20	New Energy value (Channel 3840.33)	1.27e+03	
21	New Energy value (Channel 1972.05)	662	
22	Calibration Formula	E = a * channel + b	
23	Error Propagation Formula	sigma_f(x)^2 = x^2*sigma_a^2 + sigma_b^2 + 2*x*cov(a,b)	
24	Calculated error for channel 3531.45	0.0205	
25	Calculated error for channel 4016.93	0.0259	
26	Calculated error for channel 1511.93	0.0156	
27	Calculated error for channel 3840.33	0.0239	
28	Calculated error for channel 1972.05	0.0127	

Fig 4. Energy Calibration Formulas, Parameters, and Errors.

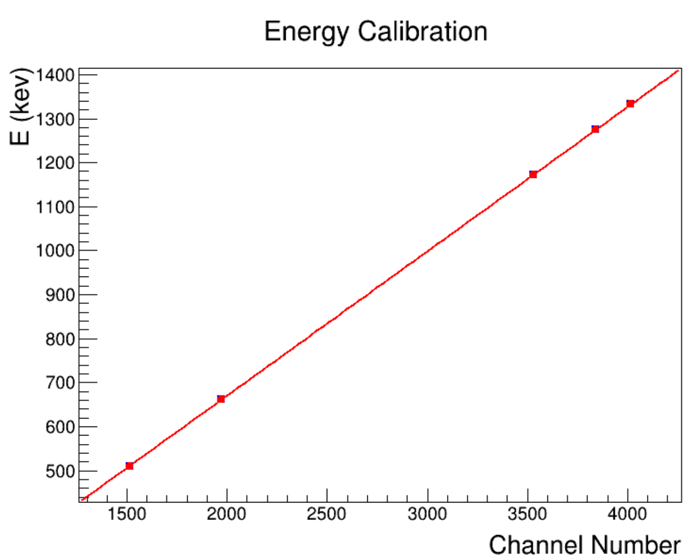

Fig 5. Energy Calibration Plot.

- Using gamma energies, mean channel numbers, uncertainties of both, I used TGraphErrors, and linear fitting to get a calibration plot, calibration formula, uncertainty relations, formula, and the rest of the parameters requested.

3.

Cobalt Energy residual	Sodium Energy residual	Cesium Energy residual	Residual_error
-0.027	-0.109	0.139	0.021
-0.071	-0.02		0.026
			0.016
			0.031
			0.013

Fig 6. Energy Residual and Uncertainties of Na-22, Cs-137, Co-60.

$$\sigma = \sqrt{\sigma_f + \sigma_L} \quad (1)$$

Fig 7. Residual Uncertainty.

- The residual has higher value than the calibration error values. This means that other factors like systematic errors in measurements, lack of consistency within a model to predict behavior and fit a data set.

4.

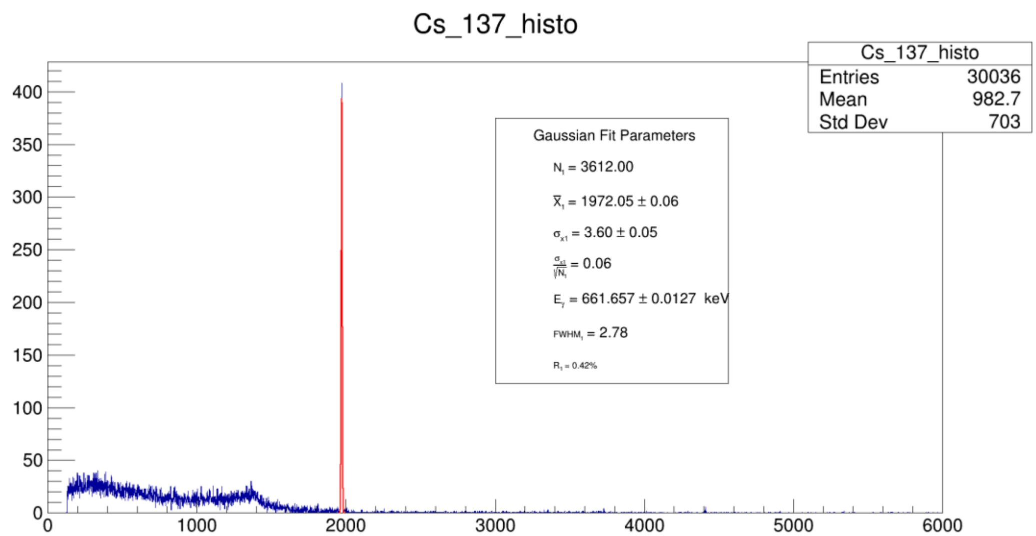

Fig 8. Cs-137 Parameters, FWHM, Resolution.

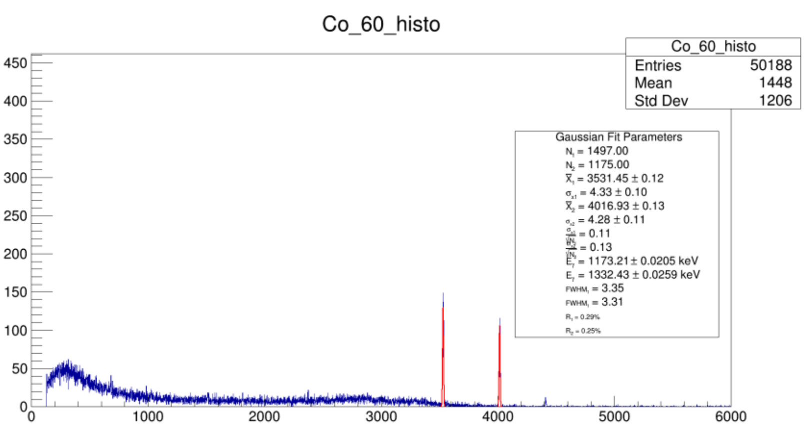

Fig 9. Co-60 Parameters, FWHM, Resolution.

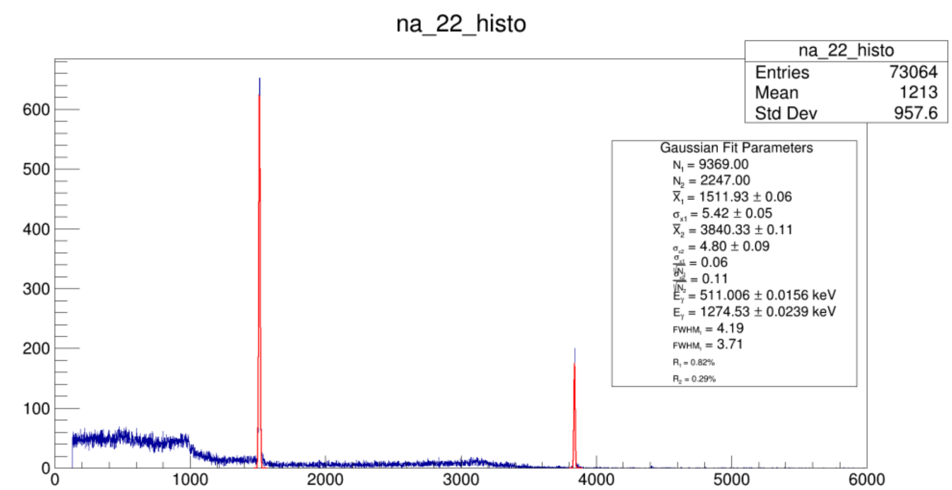

Fig 10. Na-22 Parameters, FWHM, Resolution.

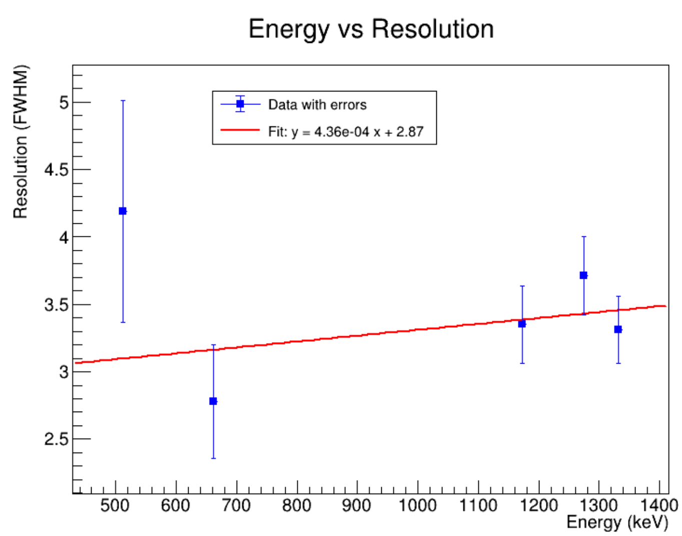

Fig 11. Energy vs. Resolution Plot.

- I analyzed the energy resolution for isotopes such as Cobalt-60, Cesium-137, and Sodium-22 by using Gaussian fits on their respective energy histograms. From these fits, I extracted key parameters like the full width at half maximum (FWHM) and peak positions. I then used these values, along with their uncertainties, to plot the relationship between energy and resolution.
- I incorporated error bars to represent uncertainties in both energy and resolution. To further understand the relationship, I applied a linear fit to the data points, creating a model to describe how resolution varies with energy.
- Since The plot is flat it’s keen to say that Energy resolution doesn’t vary much with energy or dependent on it.

5.

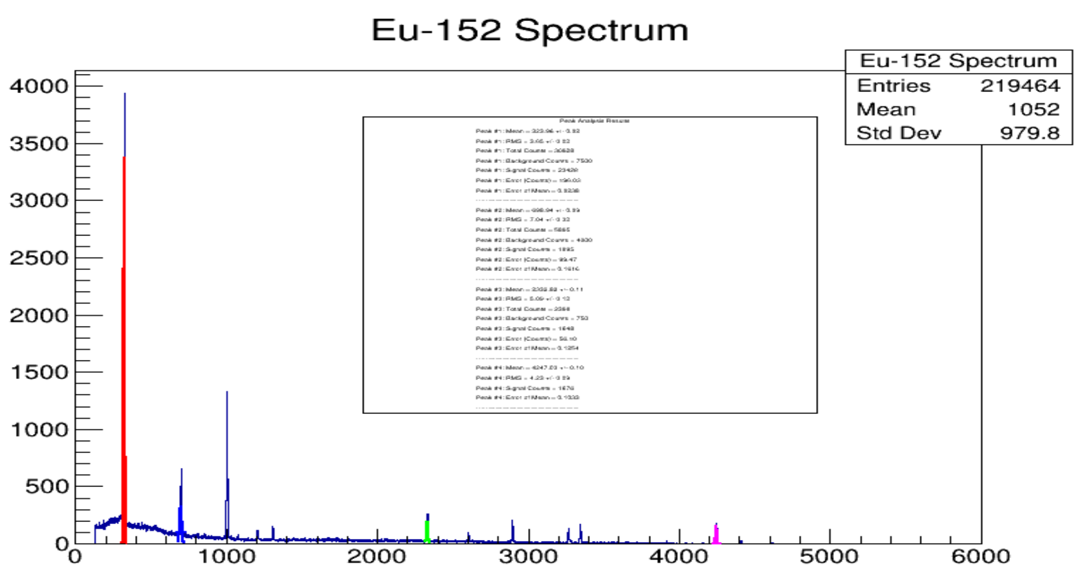

Fig 12. Parameters of Eu-152 Spectrum.

- I used a Gaussian fit for my 4 peaks to get the RMS, mean, and total counts. I did a constant curve on each peak and applied an integral method to get background count. I got signal count by subtracting total and background, and I did the square root of background and total to get counting error. I then got error of the mean by mean from Gaussian fit divided by square root of signal.

6.

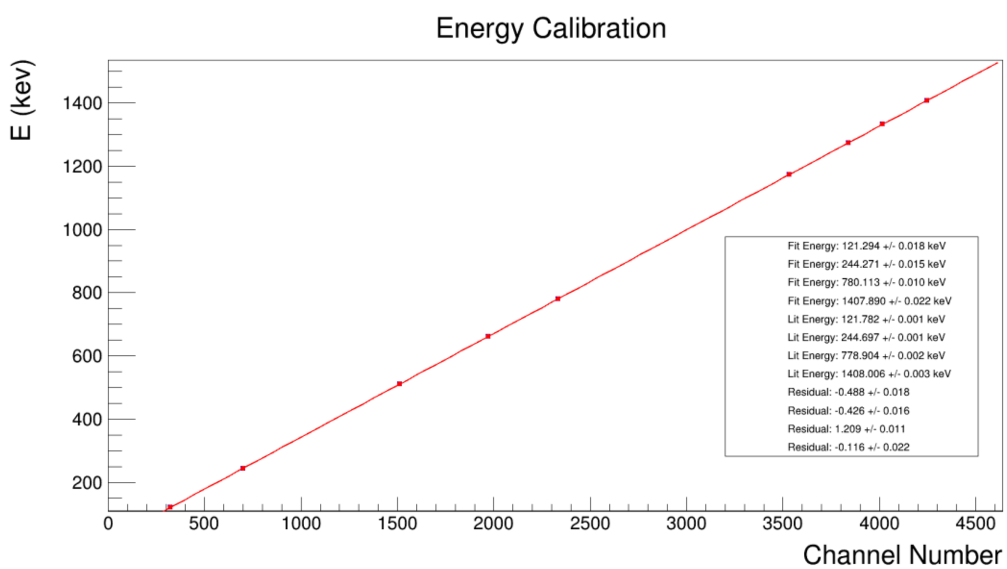

Fig 13. Calibration and Parameters of all Spectra.

- I applied the calibration and uncertainty techniques of questions 2&3 to get the residuals, residual uncertainties, fit energies, and fit uncertainties. I also used the same source of the Idaho page.

7.

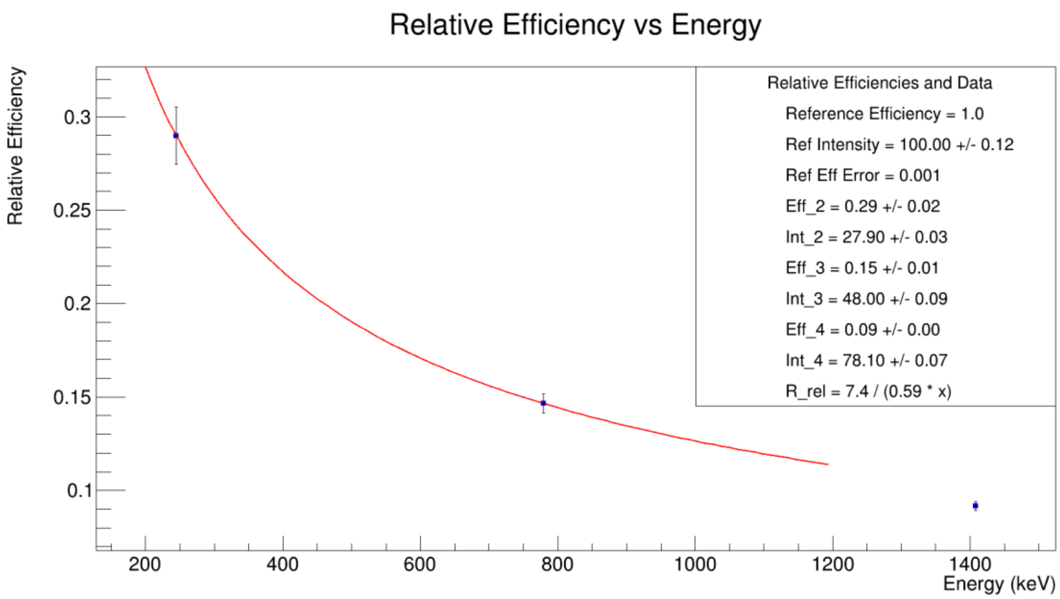

Fig 14. Relative Efficiency Curve and Parameters.

$$\frac{\sigma_{\epsilon_i}}{\epsilon_i} = \sqrt{\left(\frac{\sigma_{N_i}}{N_i}\right)^2 + \left(\frac{\sigma_{N_{\text{ref}}}}{N_{\text{ref}}}\right)^2 + \left(\frac{\sigma_{I_i}}{I_i}\right)^2 + \left(\frac{\sigma_{I_{\text{ref}}}}{I_{\text{ref}}}\right)^2}$$

$$R_{\text{rel}}(E) = \frac{7.4}{E^{0.59}}$$

$$\epsilon_i = \frac{N_i \cdot I_{\text{ref}}}{N_{\text{ref}} \cdot I_i}$$

Fig 14. Equation Schemes for The Analysis.

- I calculated the relative detector efficiency for Eu-152 by analyzing the peak intensities provided by Idaho source and counts of several prominent peaks. First, I defined a reference peak, using its total counts and intensity to compare with other peaks. For each additional peak, I calculated its relative efficiency by comparing the ratio of counts to the reference, adjusted by their respective intensities.

- To propagate uncertainties, I accounted for errors in the counts and intensities of both the reference and the other peaks. Using error propagation formulas, I calculated the uncertainty in the relative efficiency for each peak. The results were then plotted as a function of energy, with error bars representing the efficiency uncertainties. I also fit a polynomial decay functional form to the data to model the relationship between energy and detector efficiency, providing a mathematical description of how the relative efficiency varies with energy.

8.

Description	Value
Efficiency for Na-22 (511 keV)	0.186751
Efficiency for Na-22 (1274.53 keV)	0.108912
Efficiency for Co-60 (1173.237 keV)	0.114365
Efficiency for Co-60 (1332.501 keV)	0.106091
Corrected Na-22 counts for 511 keV	50168.4
Corrected Na-22 counts for 1274.53 keV	20631.4
Corrected Co-60 counts for 1173.237 keV	13089.6
Corrected Co-60 counts for 1332.501 keV	11075.4
Na-22 Peak Ratio (1274.53 keV / 511 keV)	0.411243
Co-60 Peak Ratio (1332.501 keV / 1173.237 keV)	0.846121
Na-22 Intensity ratio	0.56
Co-60 Intensity ratio	1.0

Fig 15. Parameters: Efficiencies, Corrected Counts, and Ratios.

- In this analysis, I measured the event counts for two peaks from the Na-22 and Co-60 calibration spectra and applied a correction using the relative efficiency function derived from prior work. The efficiency for each energy peak was calculated using a power law model, and I corrected the event counts by dividing the measured counts by the respective efficiencies. After obtaining the corrected counts, I calculated the ratio of the two peaks for each isotope. Finally, I compared these ratios to the expected intensity ratios based on literature values to assess how well the corrected data matched the known standards.

- By comparing the ratios, they are off from around a range of 15 to 35 % difference. It could mean in earlier work by pre-corrected counts could be off and maybe with some issues of the power law not totally predicting efficiencies correctly either.

Work Cited

[1]. “Ray Spectrometry Catalog   // .” *Gamma*, gammaray.inl.gov/SitePages/Home.aspx. Accessed 10 Sept. 2024.