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Physics 3700

Lab 4 Report

The goal of this lab was to perform the maximum likelihood fit for plots of gamma energy versus voltage. We recorded gamma ray spectra of Co-60, Cs-137, and Na-22 using equipment such as an MCA, NaI Amplifier and Calorimeter, an Interface, and a PM Controller. The results for the spectra of Co-60, Cs-137, and Na-22 are shown on Figures 1, 2, and 3, respectively. It is important to note that these three materials only have a total of five peaks, since the voltages less than about 0.5V are attributed to the standard cosmic background radiation, X-rays, and more (not the gamma rays we are looking for). The peak at about 1.6V for Na-22 is due to positron annihilation. This process results in the creation of two gamma particles, in which only one is picked up by the NaI crystal. This process occurs when an electron and positron collide with an almost nonzero momentum, yielding two gamma particles. This system needs to satisfy the conservation of momentum, and therefore if one gamma particle heads towards the NaI crystal, then the other must travel away from the detector. Thus, only one of the gamma rays is picked up by the detector. The energy values for the five peaks are indicated in Figures 1-3 for each material. Using literature, we found the gamma ray energies of each of these peaks and plotted them as an energy calibration curve versus the voltage on Fig. 4. Using both Excel and LabPlot2, we used the formulas of the maximum likelihood method to linearly fit the data (the formulas used can be found in Appendix A). Both LabPlot2 and Excel found coefficient values of $A = -0.03$ and $B = 0.34$ for a line in the form of $E = A + BV$, where E is the gamma ray energy and V is the voltage. This line is plotted on Fig. 4 as well. The results of both software are comparable since they both effectively yield the same coefficients for the linear fit.

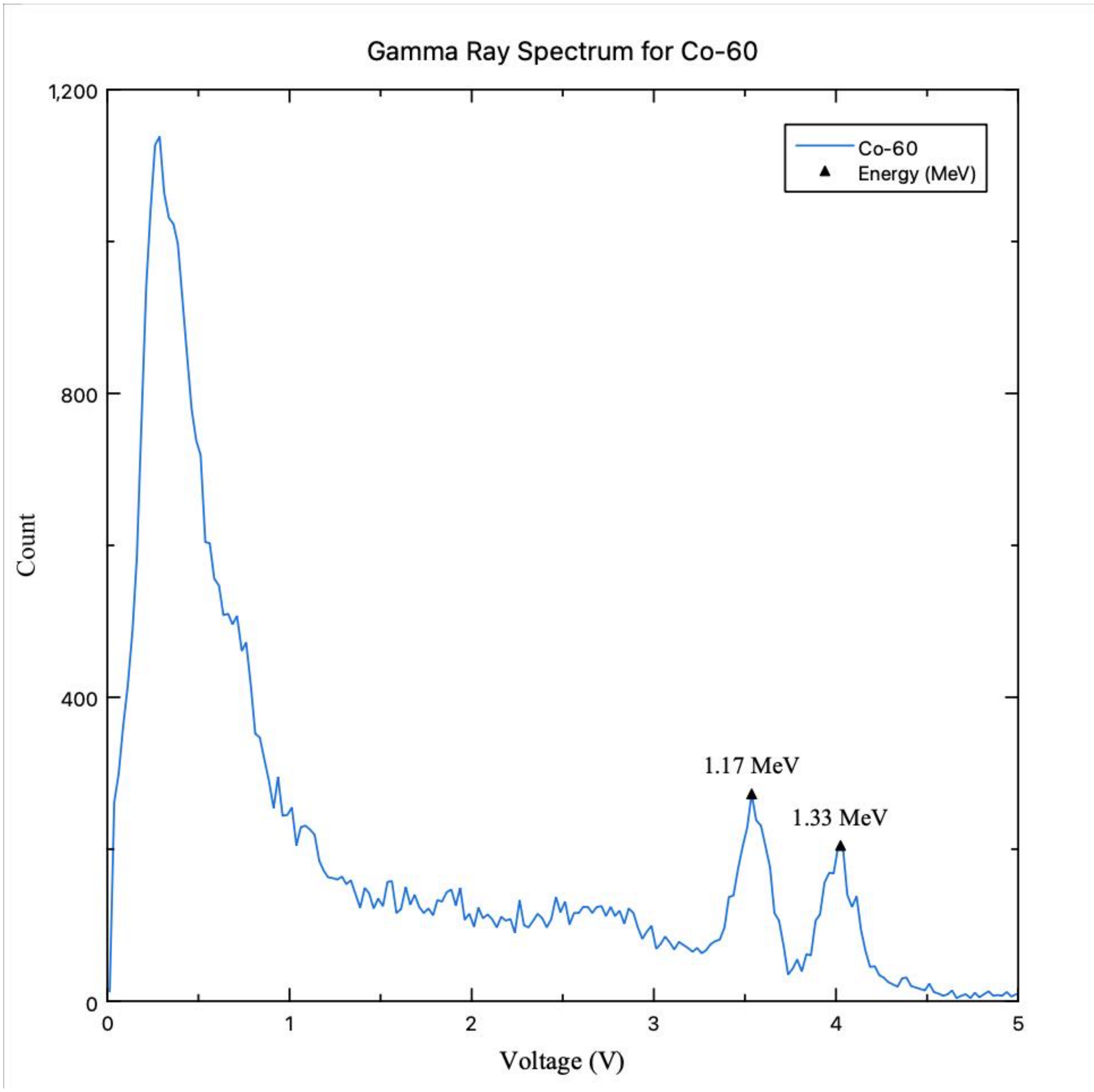

Figure 1: Gamma Ray Spectrum for Co-60

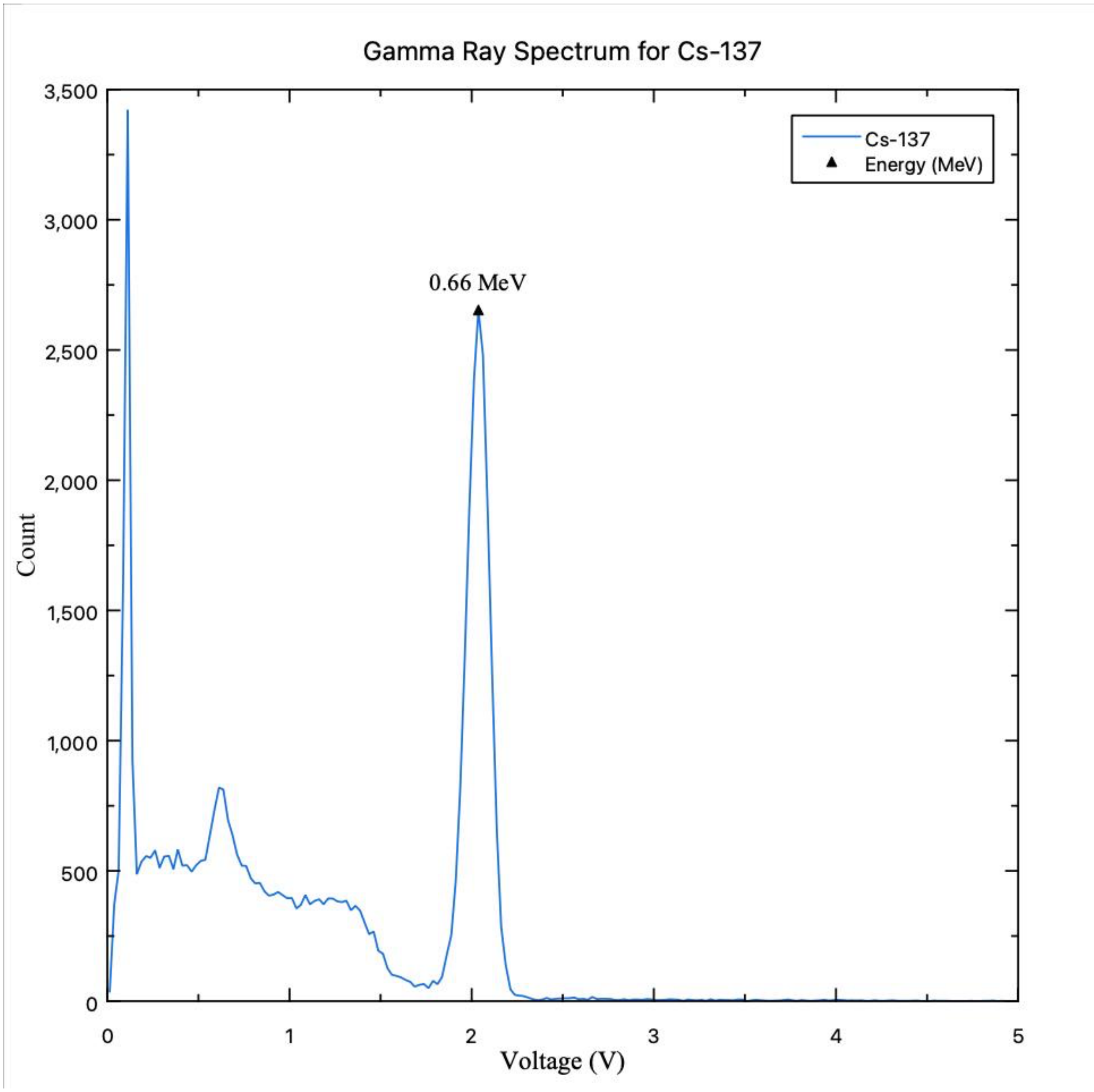

Figure 2: Gamma Ray Spectrum for Cs-137

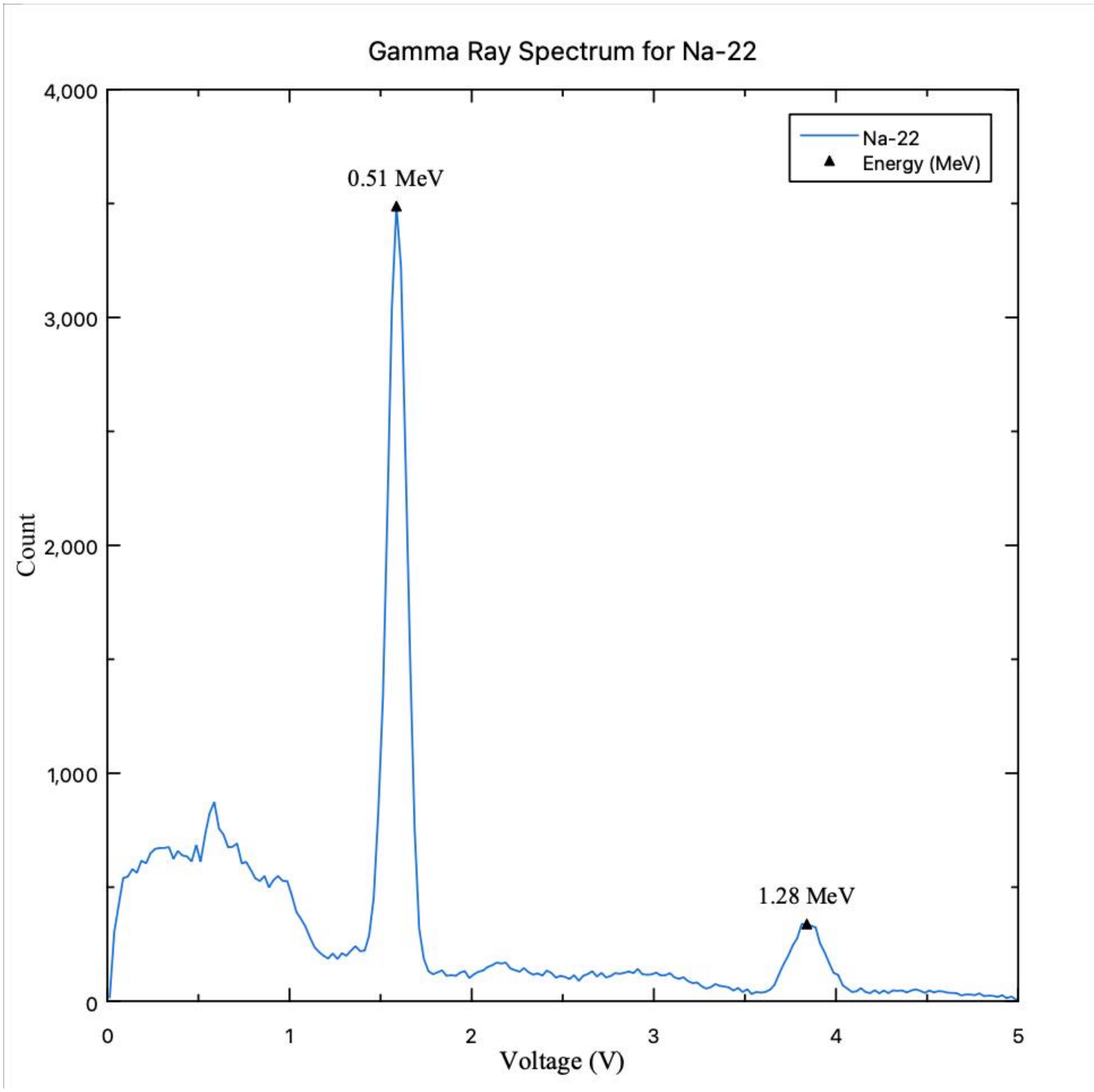

Figure 3: Gamma Ray Spectrum for Na-22

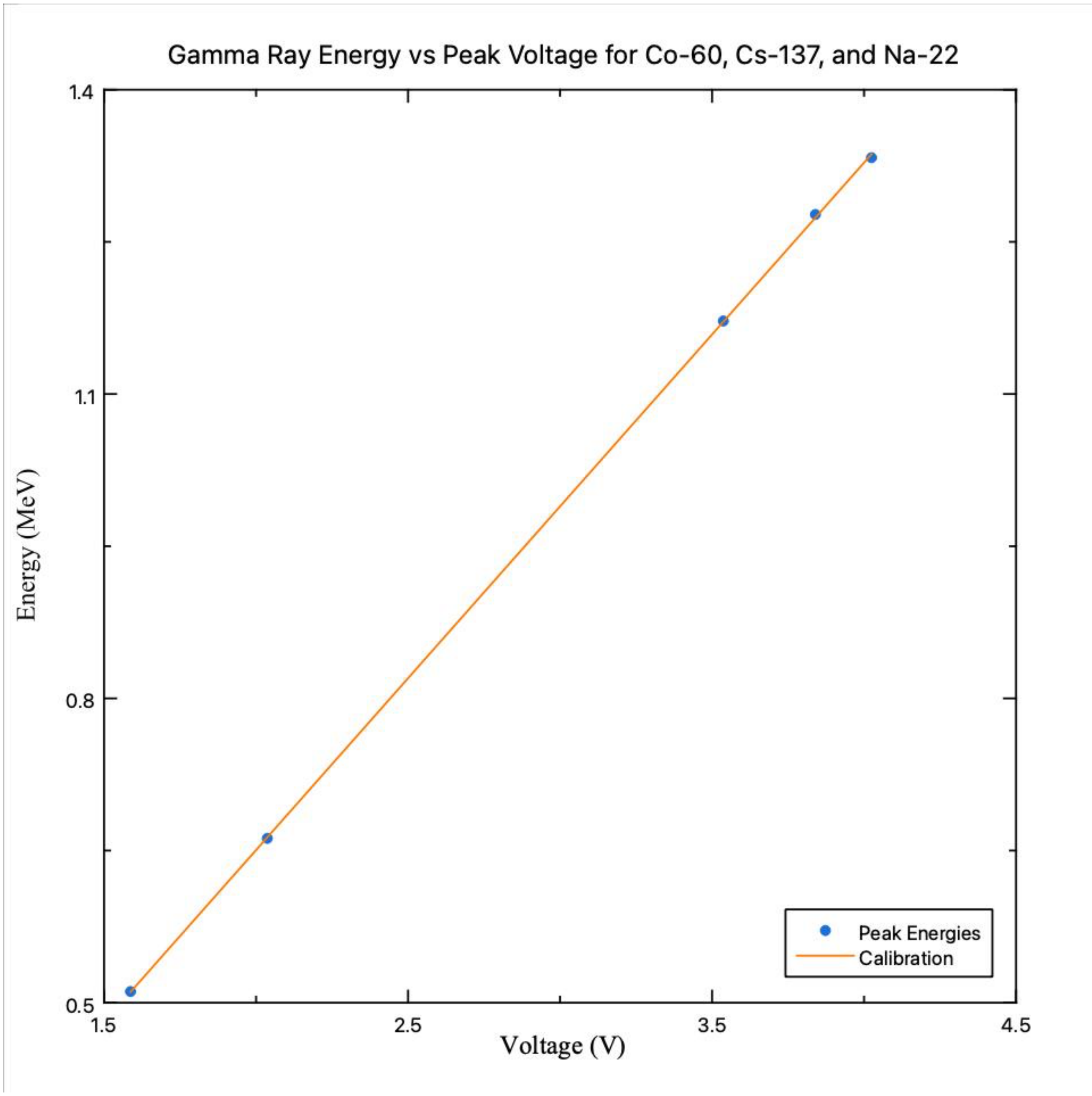

Figure 4: MLM Calibration Curve for Gamma Ray Energy vs. Peak Voltage (LabPlot2)

Appendix A: Equations for Coefficients of MLM Fit

Coefficients in Matrix Form:

$$\begin{bmatrix} \sum_{i=1}^{n} y_i \\ \sum_{i=1}^{n} x_i y_i \end{bmatrix} = \begin{bmatrix} n & \sum_{i=1}^{n} x_i \\ \sum_{i=1}^{n} x_i & \sum_{i=1}^{n} x_i^2 \end{bmatrix} \begin{bmatrix} A \\ B \end{bmatrix}$$

(This form adapted from Lecture 4 Notes)

Direct Solutions for Coefficients:

$$A = \frac{\sum_{i=1}^{n} x_i^2 \sum_{i=1}^{n} y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} x_i y_i}{\Delta}$$

$$B = \frac{n \sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{\Delta}$$

$$\Delta = n \sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i \right)^2$$

(These equations are adapted from Taylor 8.10-8.12)

These equations solve for a Maximum Likelihood fit in the form of $y = A + Bx$, with n representing the total number of measured (x_i, y_i) data points.