CsI.C.C Update – DAMSA

SPE Calibration & Na-22 Spectrum Analysis

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Experimental Setup/DAQ Updates

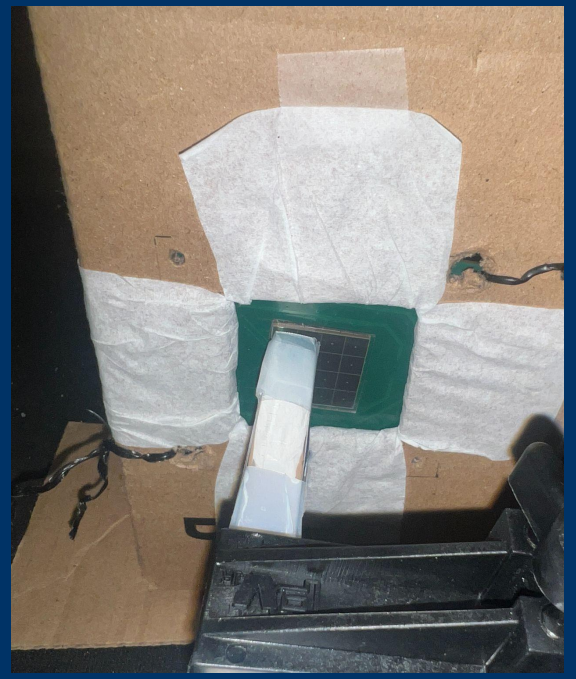
Silicon Pad Coupling

Attached an extra medium of silicon padding in between the SiPM the CsI Crystal

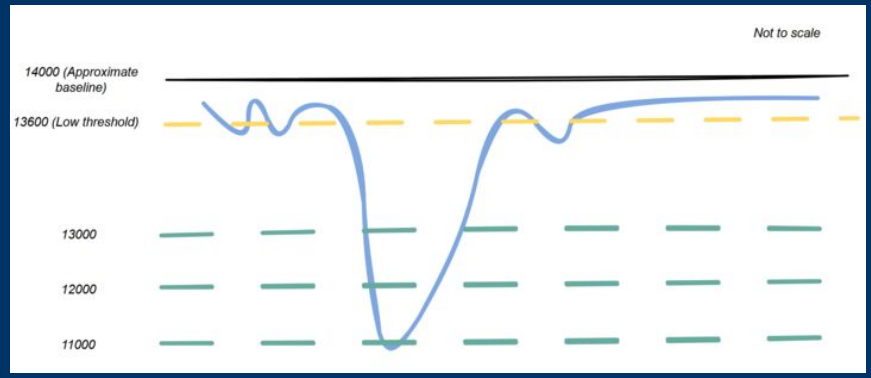
- reduce air gap
- less reflection

MIDAS DAQ

Updated some parameters and triggering settings including trigger on event and the ADC thresholds



Na-22 Gamma Source



The Objective

Phase 1: Apply Calibration

Find the SiPM's "conversion factor" (Gain). We answer the question: “How much charge corresponds to a single photoelectron (PE)?" We use a dark run to measure individual dark counts/”background”

Phase 2: Analysis of Light Yield

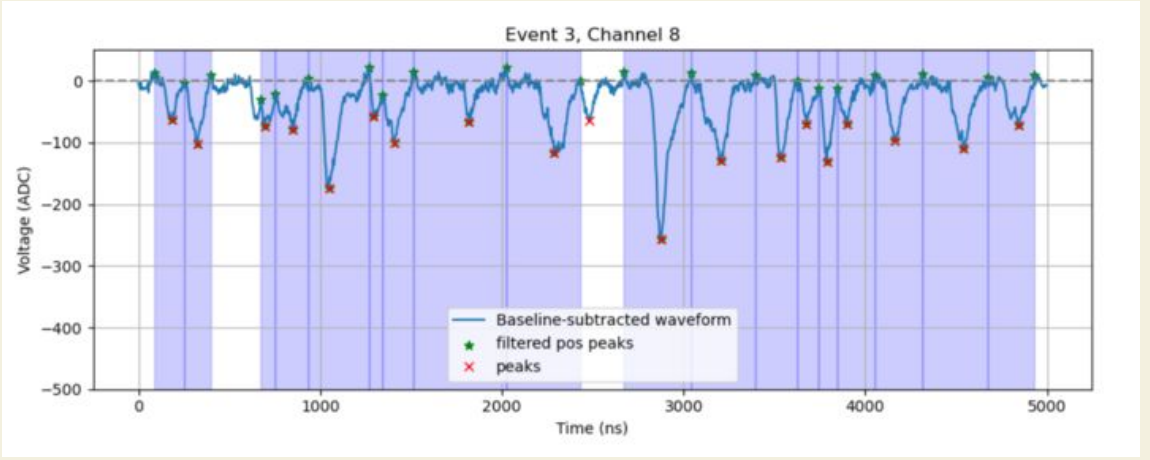
Use the Gain to calibrate a Na-22 source run. We answer the question: "What is the photoelectron yield (PE/keV) of our crystal?" This involves cleaning our source spectrum and measuring the calibrated energy spectrum.

Phase 1 Method: "Strict Isolation"

Challenge & Solution

Dark runs are noisy, filled with cross-talk and after-pulses. To get a clean signal, we developed a "Strict Isolation" algorithm.

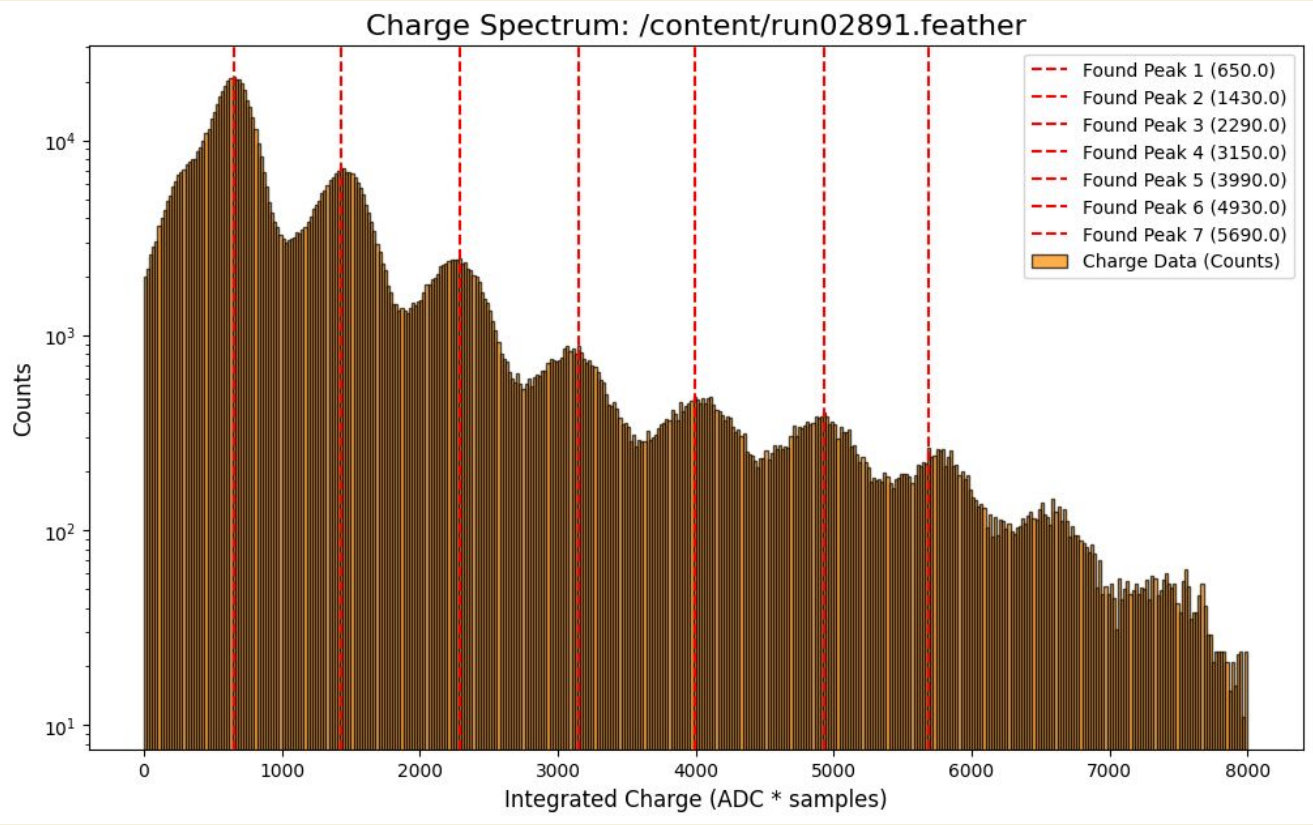
- Identify all negative (SPE) and positive (boundary) peaks.
- Only accept PE peaks if they are "strictly isolated" between two positive-going boundaries.
- This effectively filters out noise, leaving a clean multi-PE signal.



Phase 1 Result: Multi-PE Spectrum

Finding the Peaks

After analyzing 70,000 events from our dark run (“run02891.feather”), the isolation method produced the following charge spectrum. Distinct, quantized peaks are clearly visible for 1-7 photoelectrons. This proves the calibration method is working and the detector is stable.



Phase 1 Analysis: The Linearity Fit

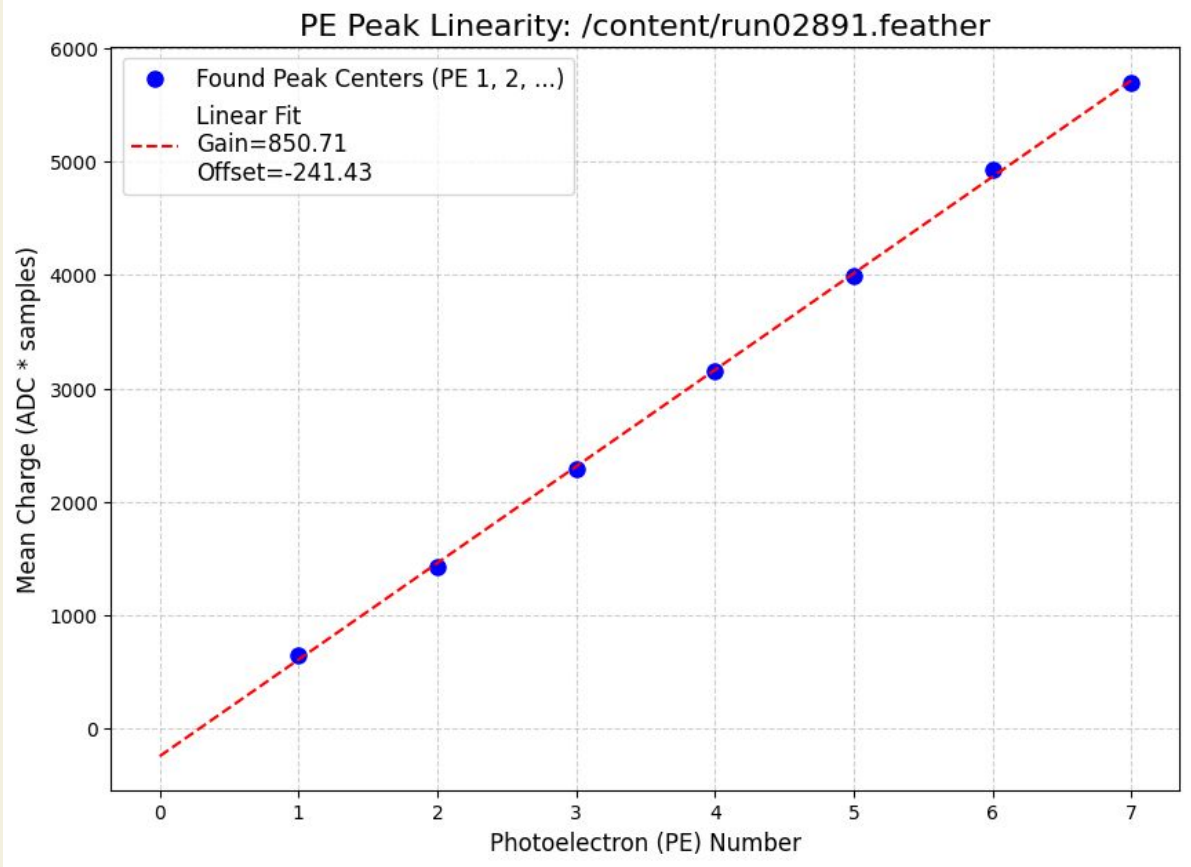
Calculating the Gain

We found the charge center of each of the 6 PE peaks and plotted them against their PE number (1-6).

The result is a perfectly straight line, confirming the detector's high linearity. The slope of this line is our **Gain**, the most critical calibration constant.

850.71

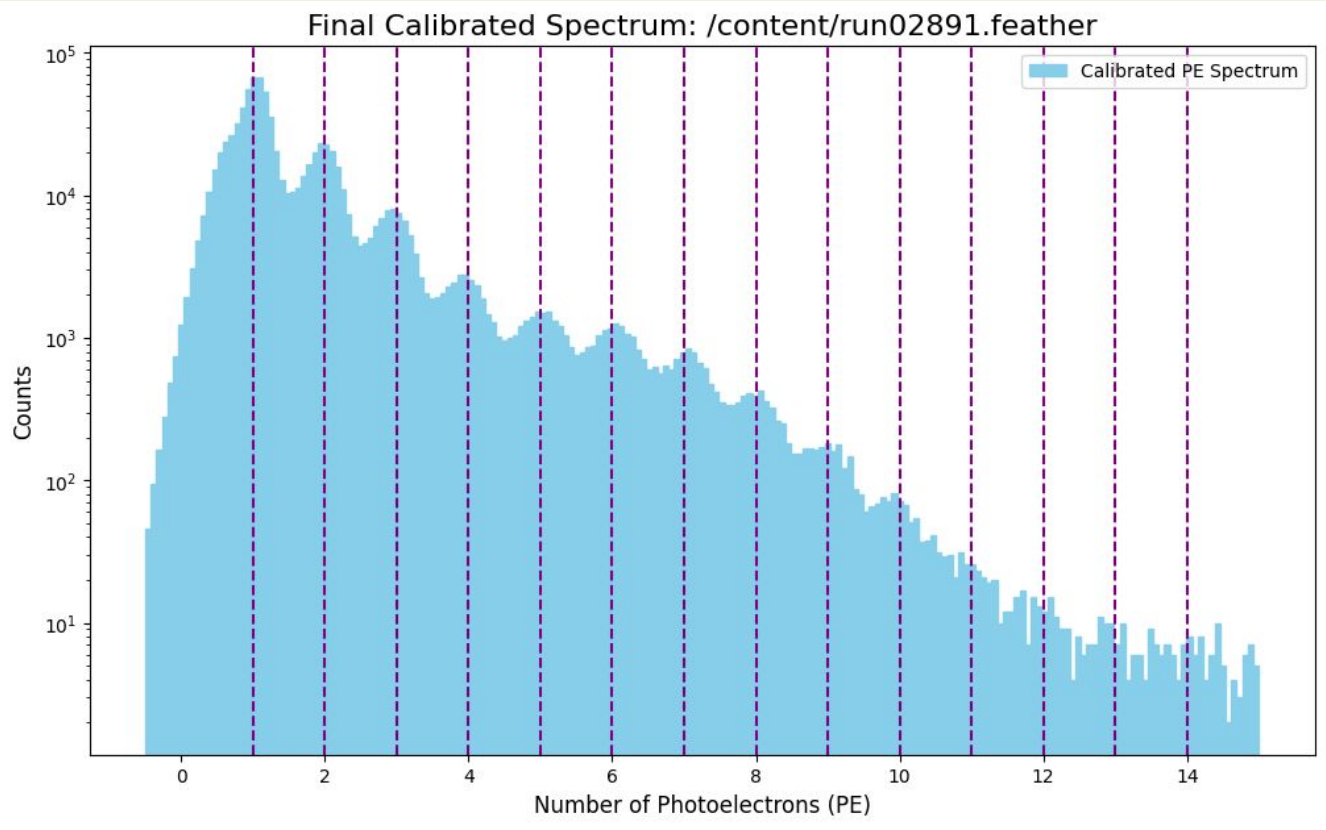
ADC*samples / PE (The Gain)



Phase 1 Analysis: PE Distribution

Calculating the Gain

We found the charge center of each of the 6 PE peaks and plotted them against their PE number (1-6).

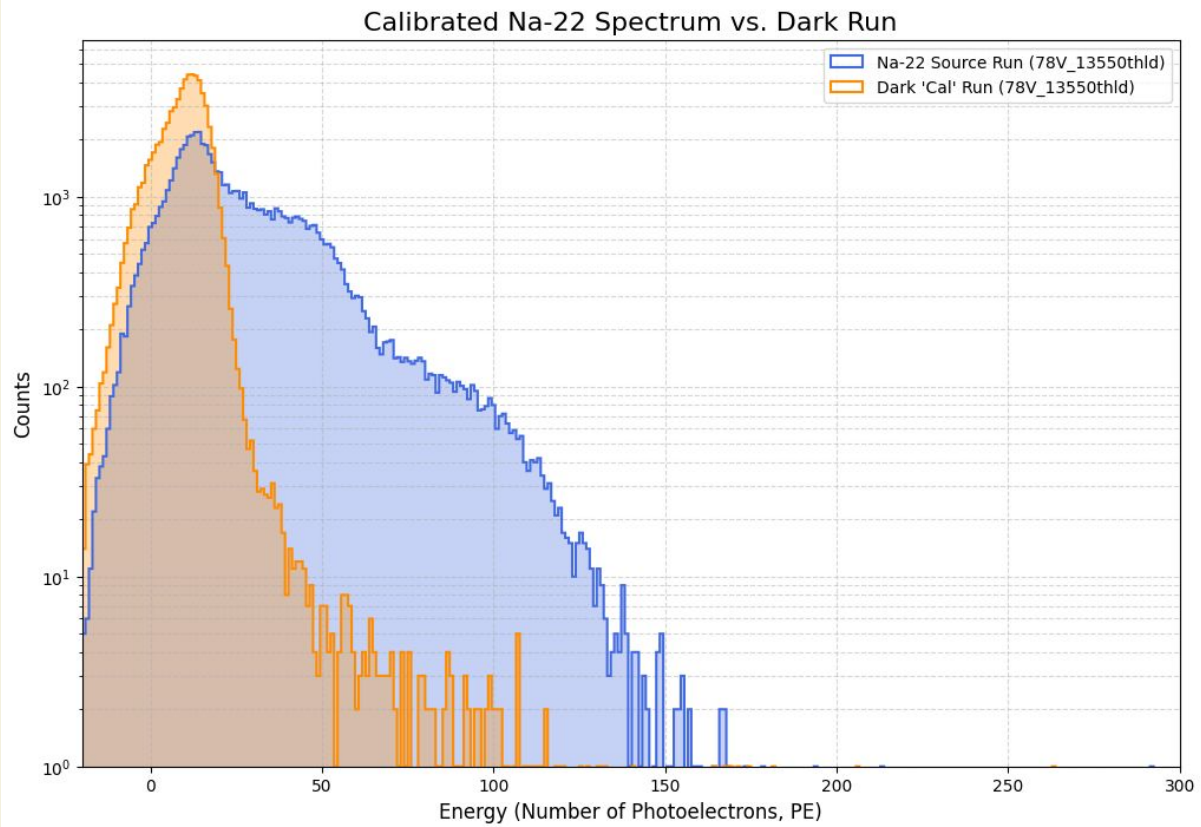


Phase 2 Analysis: Signal vs. Background

Identifying the Signal

With the correct window, we overlaid the Source Run and the Dark Run.

- **Dark Run (Orange):** Shows the 0-PE pedestal and natural background at higher ends (cosmic rays, K-40, muons?)
- **Source Run (Blue):** Shows the same background *plus* a clear, broad signal shoulder. This is the Na-22.



***not time normalized

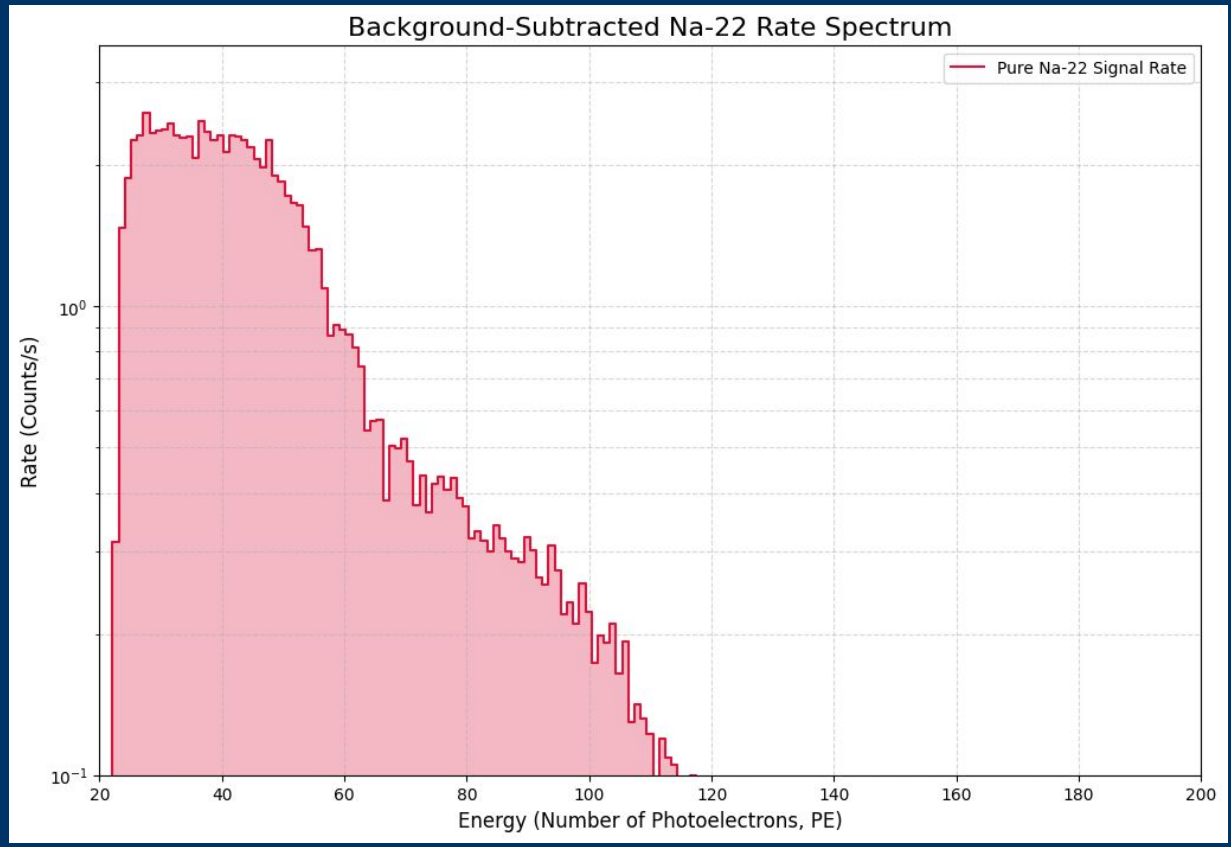
Phase 2: The Solution

Background Subtraction

To isolate the pure Na-22 signal, we must subtract the background.

Method:

- Create histograms for both time-normalized Source and Dark runs
- Subtract the Dark spectrum from the raw Source spectrum.



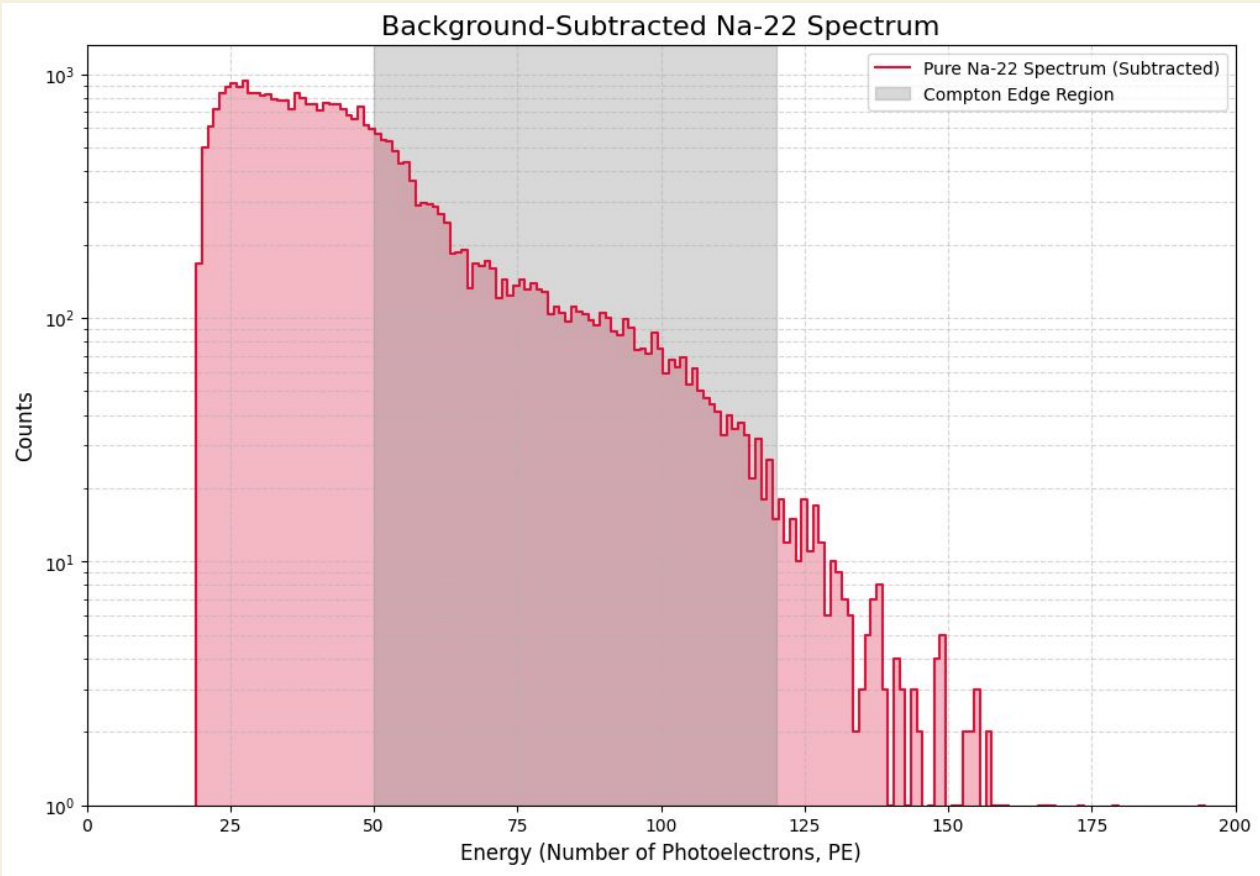
Phase 2 Result: The Compton Edge

Analyzing the Pure Signal

The final, clean spectrum is a classic **Compton continuum. It has no photopeak, as the 511 keV and 1.27 meV gammas scatter and escape the small crystal.

- The key feature is the "cliff" known as the Compton Edge

Eyeballed the edge in the region of 50 and 120 PE for both gamma peaks



Final Calculations: Compton Edge

Derivation for Compton edge $E_{edge} = \dfrac{2E_\gamma^2}{m_e c^2 + 2E_\gamma}$

Compton scattering formula for the scattered photon energy:

$$E'_\gamma(\theta) = \frac{E_\gamma}{1 + \frac{E_\gamma}{m_e c^2}(1 - \cos\theta)}.$$

The energy transferred to the electron is

$$\Delta E(\theta) = E_\gamma - E'_\gamma(\theta).$$

The maximum energy transfer (the Compton edge) occurs when the photon is back-scattered, i.e. $\theta = \pi$, for which $\cos\theta = -1$ and $1 - \cos\theta = 2$. Substituting into the expression for E'_γ:

$$E'_{\gamma,\min} = \frac{E_\gamma}{1 + \frac{2E_\gamma}{m_e c^2}} = \frac{m_e c^2\, E_\gamma}{m_e c^2 + 2E_\gamma}.$$

Thus the maximum kinetic energy given to the electron is

$$E_{edge} = E_\gamma - E'_{\gamma,\min} = E_\gamma - \frac{m_e c^2\, E_\gamma}{m_e c^2 + 2E_\gamma}.$$

Factor out E_γ:

$$E_{edge} = E_\gamma \left(1 - \frac{m_e c^2}{m_e c^2 + 2E_\gamma}\right) = E_\gamma \left(\frac{2E_\gamma}{m_e c^2 + 2E_\gamma}\right).$$

Therefore,

$$E_{loweredge} = \frac{2E_\gamma^2}{m_e c^2 + 2E_\gamma} = 340.7\ keV$$

$$E_{upperedge} = \frac{2E_\gamma^2}{m_e c^2 + 2E_\gamma} = 1061\ keV.$$

Final Calculations: Photoelectron Yield

Our Data

N_pe (from our Na22 spectrum):

50.00 PE and 120 PE

E_dep (from Comp. Edge calculations):

340.7 keV and 1064 meV

The Calculation

Light Yield = N_{pe} / E_{dep}

≈ 0.14 PE/keV

≈ 0.11 PE/keV

Conclusion & Next Steps ****

Success: We calibrated the detector again (Gain = 850.71) and can *eyeball* the Na-22 Compton edge.

- Fitting our Compton Edge for more accurate calculations
- Simulate gamma scattering through Crystal on Geant (possibly)
- More analysis!