Laboratory Report 8

Dane Sabo
dane.sabo@pitt.edu

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NUCE 2113

1 Equipment

- ULTRA™ Charged Particle Detector (Model BU-014-050-100)
- Ortec Model 142A Preamplifier
- 4001A/4002D NIM Bin and Power Supply
- Ortec Model 575A Spectroscopy Amplifier
- Ortec Model 807 Vacuum Chamber
- ALPHA-PPS-115 Portable Vacuum Pump Station
- Ortec Model 710 Quad Detector Bias Supply
- Ortec Model 480 Pulser
- Easy-MCA-8K Multichannel Analyzer and a Desktop PC running MAESTRO32
- Tektronix Model TDS3032C Oscilloscope
- Assorted RG-62A/U and RG-59A/U coaxial cables (BNC/SHV connectors)
- Flat-bladed screwdriver for control adjustments
- Alpha source set: ^{241}Am, ^{228}Th, ^{230}Th, ^{244}Cm
- Latex or nitrile gloves

2 Experiment 8.1: Simple Alpha Spectrum and Pulser Calibration

2.1 Procedure

A silicon charged-particle detector (BU-014-050-100) was mounted in the Model 807 vacuum chamber lid. The chamber was connected to a vacuum pump (ALPHA-PPS-115) to achieve a pressure under 100 mTorr, ensuring minimal energy loss of alpha particles in air. A short (6-inch) RG-62A/U coaxial cable was used to connect the detector output to the Ortec 142A Preamplifier input to reduce stray capacitances.

Before power was applied, the shaping time of the Ortec 575A Amplifier was verified to be $1.5\,\mu$s, and its input polarity was set to `POSITIVE`. The 710 Quad Bias Supply voltage dials were initially set to zero, and the range switches set to `DISABLE`, thereby protecting the detector from sudden high voltage.

An ^{241}Am source was placed at approximately 1.5 cm from the detector inside the vacuum chamber, and the chamber was evacuated to below 100 mTorr. The detector bias voltage was slowly increased to 60 V once the chamber was at the proper vacuum level. The gain on the 575A amplifier was adjusted so that the most prominent alpha peak from ^{241}Am (~ 5.486 MeV) produced a signal of about +5.5 V on the oscilloscope.

A Pole-Zero adjustment (PZ) was then performed to ensure pulse return to baseline without undershoot. Finally, the ^{241}Am alpha spectrum was acquired using MAESTRO32, with a collection long enough to accumulate at least 900 counts in the main alpha peak. The centroid channel number, C_0, was recorded.

2.1.1 Observed Data

- Centroid channel, $C_0 = 4160$
- Peak maximum: 107 counts
- Left half-maximum at channel 4155 (52 counts)

- Right half-maximum at channel 4165 (47 counts)
- Thus, FWHM in channels, $\delta = 4165 - 4155 = 10$

The pulser (Ortec Model 480) was then connected through its `ATTEN OUTPUT` to the preamplifier test input, with a $100\,\Omega$ terminator on its `DIRECT OUTPUT`. The pulser amplitude was adjusted so that its pulses matched the amplitude of the ^{241}Am peak (around +5.5 V). The pulser dial was set to $\frac{548}{1000}$ to represent 5.48 MeV.

The ^{241}Am source was removed (with bias first turned to zero and the chamber vented), the vacuum chamber sealed again, and bias reestablished to 60 V. A short 20-second run with the pulser alone was used to verify alignment at channel C_0. Pulser data at multiple dial settings (in steps of 100 from 100 to 700) were then acquired, and each centroid channel was measured.

2.1.2 Exercise 8.1

Fill in any missing data for the above table, plot *Energy (MeV)* vs. *Centroid Channel*, and compare it to the example provided in the laboratory document. *"Please show this in your report."*

Pulser Dial Setting	**Measured Centroid (channels)**
700 (i.e. 7.00 MeV)	5316
600 (6.00 MeV)	4554
500 (5.00 MeV)	3799
400 (4.00 MeV)	3041
300 (3.00 MeV)	2282
200 (2.00 MeV)	1522
100 (1.00 MeV)	761

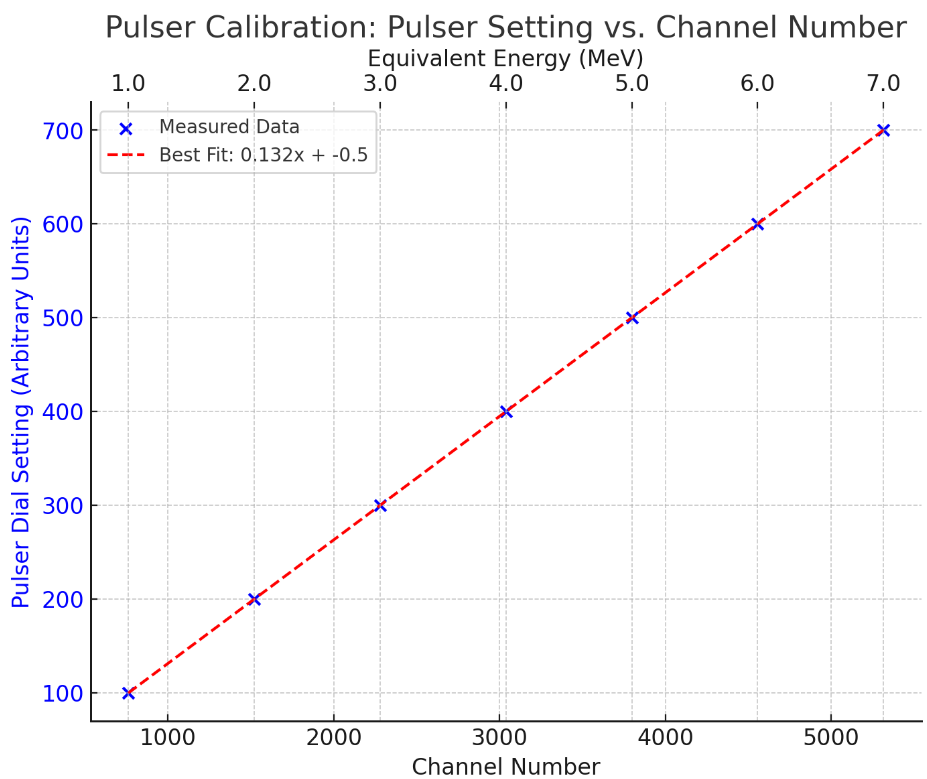


Figure 1: The data collected plotting the centroid channel compared to the pulser dial setting. A best fit line is produced and annotated on the graph

Our graph is similar to figure 8.6, albeit with a different slope and scale for numbers of channels. We see what is defintely a linear correlation.

2.1.3 Exercise 8.2

"The slope of the calibration curve, $\Delta E/\Delta C$, is the energy per channel. Determine this slope in keV/channel for your data."

Our slope was observed to be 0.132 Pulser Dial Setting / Channel Number. When converting this to keV/channel, we obtain a value of 1.32 keV/channel.

2.1.4 Exercise 8.3

"The energy resolution in a spectrum is calculated as:

$$\text{Resolution (keV)} = \left(\frac{\Delta E}{\Delta C}\right) \times \delta$$

where δ is the FWHM in channels. Calculate the FWHM in keV for the 5.486 MeV alpha peak and assess whether it meets the detector datasheet specification (¡14 keV). Discuss the factors that can worsen resolution:

- *Dirt/fingerprints on detector or source*
- *Source thickness*
- *Source window*
- *Amplifier shaping time constant*
- *MCA resolution limitations*

"

In our data:

$$\delta = 10 \text{ channels}, \quad \Delta E/\Delta C \approx 1.32$$

Hence,

$$\text{Resolution (keV)} = \left(\frac{\Delta E}{\Delta C}\right) \times 10 = 13.2\text{keV}.$$

This is within the guaranteed resolution of the detector.

For the first three items (dirt, source thickness, window thickness...) the thickness of material that the alpha particle must get through has a huge impact on the amount of alpha radiation that is able to get to the sensor. Alpha radiation has a very very low penetrating power, such that any small interference can damage a measurement.

The last two items (the amplifier shaping and MCA resolution limitations) will affect the resolution due to analog to digital measurement conversion losses due to discretization. The equipment we use will lose some of the precision of the raw instrument in order to turn it into a digital value that a computer can process.

3 Experiment 8.2: Energy Calibration with Two Alpha Sources

3.1 Procedure

After the first calibration, the detector bias was turned to zero, the vacuum chamber vented, and a ^{244}Cm source installed. The chamber was again evacuated to below 100 mTorr, and the bias restored to 60 V. A spectrum was acquired to locate the main alpha emission near 5.805 MeV (77 % intensity), and its centroid channel was measured (observed to be 4398). The spectrum was saved.

The ^{244}Cm source was replaced with ^{230}Th, and its 4.688 MeV peak centroid was recorded at channel 3549. This combined spectrum was likewise saved.

3.1.1 Exercise 8.4

"Plot the known energies (5.805 MeV for ^{244}Cm and 4.688 MeV for ^{230}Th) vs. their measured channel numbers on the same calibration graph from Experiment 8.1. Do the alpha points agree with the pulser-based calibration?"

This plot has been created in figure 2.

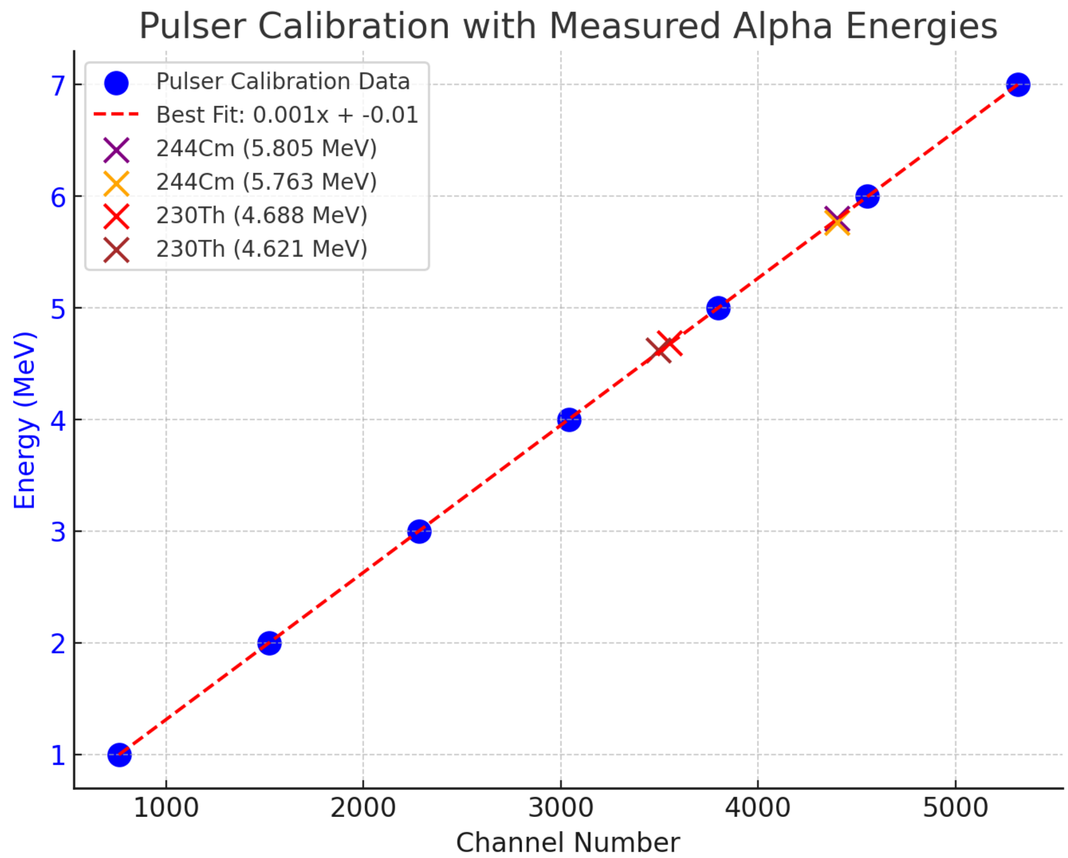


Figure 2: The measurements closely align with our calibration, to the point you will likely have to zoom in to see the difference.

3.1.2 Question 8.2

"Do the points from the alpha particles fall on the pulser calibration curve?"

Yes. They do very closely, as shown in figure 2.

3.1.3 Exercise 8.5

"Use the MAESTRO-32 'energy calibration' feature with the data from ^{241}Am, ^{244}Cm, and ^{230}Th. Compare that new slope (keV/channel) to the slope from the pulser-based calibration. What are the strengths and weaknesses of each method?"

Our slope obtained from the MAESTRO-32 software yielded a slope of 0.862 keV/channel. This value is significantly smaller than our calibration from the pulse height method.

- **Pulser-based calibration:** only uses several alpha-energy matches, and covers a much larger dynamic range. Data is also spaced out evenly across channels.
- **Multi-alpha calibration:** uses real data from multiple known alpha energies, and as such is not susceptible to human setup errors. That being said, slight variations may cause significant calibration changes especially if extrapolation is attempted.

3.1.4 Exercise 8.5a

A separate ^{241}Am spectrum was reacquired. The MAESTRO-32 software reported an FWHM of ~ 16.35 keV at 5.481 MeV.

"Compare this to your earlier resolution. Provide reasons for any differences (e.g. changes in shaping time, source positioning, vacuum, or random variance)."

This resolution is slightly worse than our previous measurement. For this measurement, due to the low activity of the source, we had to move the source very close to the detector, which may have contributed to some resolution loss. That being said, the loss in resolution is not severe.

3.1.5 Question 8.3

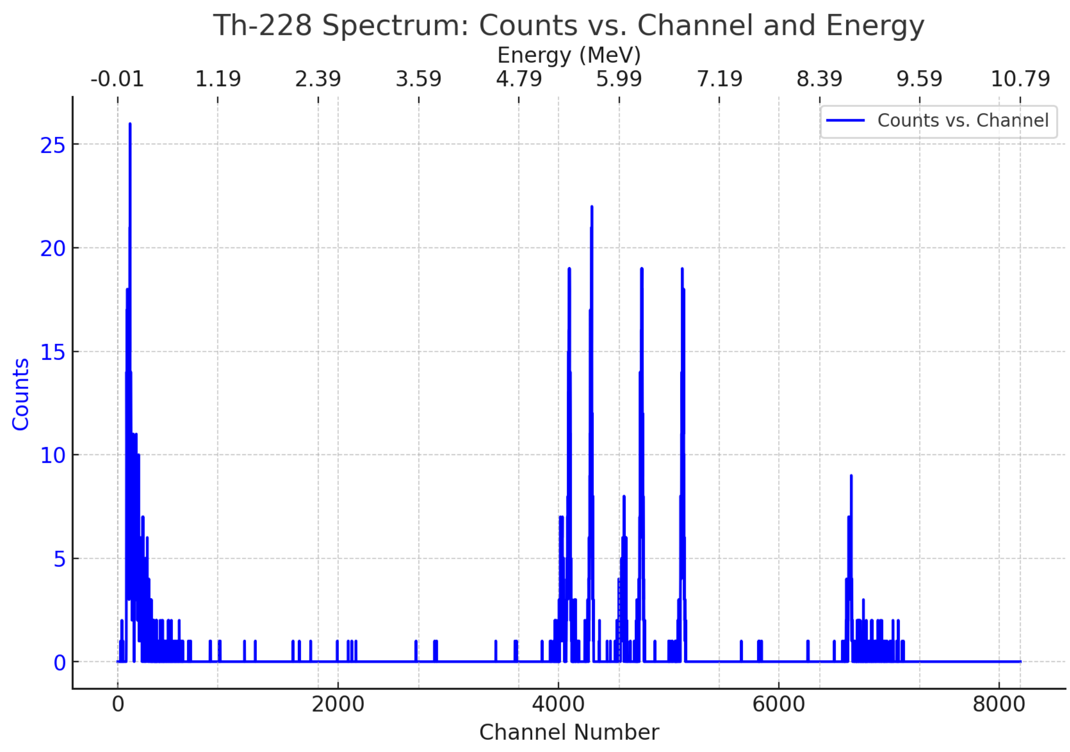
"A finite source thickness or an inadequate vacuum causes alpha particles to lose differing amounts of energy before reaching the detector. The resulting peaks are asymmetric (lower-energy tail). Under these conditions, why is it inadvisable to use the centroid for energy calibration?"

Because the peak no longer has a symmetric Gaussian shape, the centroid is shifted lower. The true peak energy is better approximated by the steep high-energy edge or the *maximum* channel rather than the centroid when low-energy tailing dominates.

4 Experiment 8.3: ^{228}Th Decay Series Identification

4.1 Procedure

An accurate energy calibration was confirmed. The vacuum chamber was vented, and the ^{228}Th source installed. With the bias restored to 60 V at a vacuum below 100 mTorr, the ^{228}Th spectrum was accumulated until its peaks were well-defined. Each alpha peak above 4 MeV was identified by comparing the measured energy to tabulated data for ^{228}Th and its daughter nuclides.



4.1.1 Exercise 8.6

"Plot the ^{228}Th spectrum. Label each prominent peak with:

- *its measured (apparent) energy,*
- *the corresponding known energy from the reference table, and*
- *the daughter/parent isotope identification.*

Please show this in your report."

Channel	Counts	Measured Energy (MeV)	Known Energy (MeV)	Isotope
4017	7	5.289	5.340	228Th
4100	19	5.398	5.423	228Th
4303	22	5.665	5.685	224Ra
4758	19	6.265	6.288	220Rn
5123	19	6.746	6.778	216Po
6657	37	8.768	8.784	212Po

Table 1: Prominent Peaks in the Spectrum with Updated Energy Calibration