Analysis of Gamma Spectrum with low statistics

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Introduction

Information from gamma detection is very useful in understanding nuclear structure physics. One essential parameter is gamma energy, measured using nuclear detectors.The Full Width at Half Maximum (FWHM) is a key measure that indicates the resolution and accuracy of spectral peaks, directly impacting isotope identification and quantification.

Analyzing gamma spectra can be challenging due to noise and distortions affecting FWHM measurements. To address these issues, smoothing methods are used, but they may introduce deviations from the true FWHM.

This study seeks to compare the Running average, Shrinking, and Savitzky-Golay filter methods to identify the best approach for minimizing deviations from the actual FWHM. The goal is to improve the accuracy and reliability of gamma spectrum analysis, ultimately enhancing the quality of spectroscopic data.

Theory

1. Running Average

The Running average method smooths gamma spectra by averaging points within a sliding window. It helps cut down on noise, but choosing the right window size is crucial. Too large a window can blur the peaks and interfere with Full Width at Half Maximum (FWHM) measurements.

2. Shrinking

Shrinking reduces the number of data points by consolidating them. Instead of averaging, it simply combines nearby points into a single point. This makes the spectrum less detailed, which can affect FWHM accuracy, especially in high-resolution data.

3. Savitzky-Golay Filter

The Savitzky-Golay filter smooths the data using polynomial fitting in a sliding window. It's good at keeping peak shapes intact and provides accurate FWHM measurements, offering a good balance between reducing noise and preserving data quality. [1]

Methodology

Gamma spectra were collected from ^{137}Cs and ^{60}Co sources using a Cesium Iodide Scintillator detector. Additionally, the gamma spectrum of ^{152}Eu was acquired using a High Purity Germanium (HPGe) detector. Since the HPGe data had very low resolution, artificial noise was added to enhance the analysis. The Full Width at Half Maximum (FWHM) of the energy peaks was calculated using Gaussian fitting as a reference point.

The spectra were processed using three techniques: Shrinking, Running averages, and the Savitzky-Golay filter. The spectrum from the scintillator detector was conventionally shrunk by a factor of 4, and the FWHM was remeasured to observe the effect on resolution. Next, the Running average method was applied with various averaging rates based on the original FWHM to determine how different smoothing rates influenced the FWHM. The same averaging rates were used for the window size in the Savitzky-Golay filter, with the polynomial order fixed at 2, and the FWHM for each window size was calculated.

The modified HPGe detector data was processed using these three methods, and the FWHM of the first and last peaks was measured for each method. Given the small original FWHM, it was used as the averaging rate or window size for both the Running average and Savitzky-Golay methods. Finally, the processed data were compared with the original data to identify which method and rate resulted in the least deviation.

Observation

The FWHM values for shrunk ^{60}Co and ^{137}Cs data are 205.9 and 191.3, respectively, which differ from the original FWHM measurements.

TABLE I: FWHM for ^{60}Co (ref FWHM = 205.3)

Averaging	Running Avg	Sav. Golay
1/16 FWHM	205.7	205.3
1/8 FWHM	206.8	205.3
1/4 FWHM	211.5	205.3
1/2 FWHM	223.3	205.7

TABLE II: FWHM for ^{137}Cs (ref FWHM = 190.7)

Averaging	Running Avg	Sav. Golay
1/16 FWHM	191.1	190.7
1/8 FWHM	191.7	190.7
1/4 FWHM	194.4	190.7
1/2 FWHM	203.7	190.0

From Tables I and II, it's clear that as the window size increases with the running average method, the FWHM values drift further from the original measurements. This suggests that larger window sizes cause more distortion in the peak width.

On the other hand, the Savitzky-Golay filter keeps the FWHM values steady regardless of the window size. This stability indicates that the Savitzky-Golay filter is better at maintaining the true peak width.

TABLE III: Comparison of FWHM for ^{152}Eu Using Different Methods

Peak	Actual	Modified	Sav. Golay	Running Avg	Shrink
1	6	5.7	5.9	6.9	6.5
2	9.3	9.05	10.8	11.8	12

From Table III, we see that the FWHM values from the Savitzky-Golay filter are closer to the actual values compared to those from the running average and shrinking methods. This confirms that the Savitzky-Golay filter is more accurate for measuring peak widths.

Conclusion

This study compared Running average, Shrinking, and Savitzky-Golay filter methods for gamma spectrum smoothing and their effects on Full Width at Half Maximum (FWHM) measurements.

The Running average method is effective but sensitive to the averaging rate. Higher rates (e.g., 1/2 FWHM) distort FWHM values, while lower rates (e.g., 1/16 FWHM) better preserve spectral details, making it suitable for spectra with higher FWHM values. The Shrinking technique showed minimal deviation with high FWHM data (^{60}Co, ^{137}Cs) but significant deviation with lower FWHM data (^{152}Eu), indicating it works better with higher resolution data.

The Savitzky-Golay filter maintained accurate FWHM measurements across various window sizes and is especially effective for preserving peak sharpness in high-resolution data.

In summary, the Savitzky-Golay filter is recommended for accurate gamma spectrum analysis due to its superior performance in maintaining precision and smoothing data. The Shrinking technique, while effective with high FWHM data (^{60}Co, ^{137}Cs), showed significant deviation with lower FWHM data (^{152}Eu), suggesting it is less effective with lower resolution data. For the Running average method, an averaging rate of 1/8 FWHM offers a good balance between smoothing and precision. Additionally, the Running Average method is advantageous because it can be easily applied using a simple .xls sheet.

References

[1] A. Savitzky and M. J. E. Golay, "Smoothing and differentiation," *Anal. Chem.*, vol. 36, pp. 1627–1639, 1964.