# NE 204: Advanced Concepts in Radiation Detection and Measurement

## Experiment 2: Digital Signal Processing in HPGe - Timing and Pulse Shape Analysis

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## Purpose

This lab expands on the digital signal processing techniques applied in the first experiment for applications in gamma-ray spectroscopy. In this lab, digital signal processing techniques are investigated for other applications in pulse shape analysis and high-rate counting scenarios. Investigating digital techniques for extracting timing information is encouraged but not required.

## Approach

The digitized preamplifier voltage signals are used as the bases for determining the radial position of interaction of the gamma-ray within the detector volume. Pulse shape analysis techniques for deconvolving multiple gamma-ray interactions will be investigated. The application of event-selection filters will be evaluated in terms of the overall spectral response, including the peak-to-Compton (PC) and peak-to-total (PT) ratios. In addition, the trade-off between pulse pile-up and optimal SNR performance will be evaluated for high-rate gamma-ray spectroscopy.

### Pulse Shape Analysis: Spectral Response vs. Signal Timing

Develop techniques to correlate the interaction history of individual gamma-rays in the detector to the corresponding preamplifier signal. Consider parameterizing the time profile of the rising edge of the signal in terms of fractions of total induced charge. For example, the rise-time of a signal is usually defined as the time it takes for the signal to rise from 10% of maximum to 90% of maximum, or $t_{rise} = t_{90} - t_{10}$. Create energy spectra using only signals within various ranges of rise time: comment on variations in the PC and PT ratios. Given these correlations (if any), can you devise a simple gamma-ray event-selection filter to improve the PC ratio?

#### Required

- Devise an event selection filter based on signal shape and quantitatively evaluate its effect on gamma-ray energy spectra in terms of total counts and PC ratio. Provide a theoretical justification for the event selection procedure you are proposing.

### Optional

- Evaluate and compare multiple event selection filters and quantify their impact on gamma-ray spectra.

## Pulse Shape Analysis: Predict Signal Shape

### Required

- Use the Shockley-Ramo theorem and conventional electrostatics to predict the signal shape for a single gamma-ray interaction at **one** radial location in the detector. Using a collimated gamma-ray source, experimentally validate your predicted signal shape. Thoroughly discuss any simplifications employed for the signal formation calculation, and discuss how well the observed signal agrees with your prediction.

### Optional

- Repeat the above procedure for multiple radial locations.
- Predict signal shapes resulting from multiple gamma-ray interactions. Can you find examples in your experimental data that match these predicted shapes?

## Rate Effects: Pile-up in Spectroscopy

One of the several mCi $^{137}Cs$ sources can be used to investigate gamma-ray spectroscopy in high-rate scenarios. Pile-up can be investigated using off-line digital filters on saved data, or directly using the fast-filter configuration options in the SIS3302 firmware.

### Optional

- Using a strong gamma-ray source, evaluate the trade-off between energy resolution and pile-up (or throughput) for triangular/trapezoidal shaping filters with various peaking & gap times.