A Study of the Quality of CsI Detectors and Pulse-Shape Discrimination of Scintillators for α-Particles, ɣ-Particles, and Neutrons

K. Salyer[1,3], E.Hudson[2,3], J. Hooker[3], G. Rogachev[3]

[1]*Department of Physics, University of Notre Dame, Notre Dame, IN 46556*

[2]*Department of Physics, Swarthmore College, Swarthmore, PA 19081*

[3]*Cyclotron Institute, Texas A&M University, College Station, TX 77843*

Motivation and Background

The focus of the first part of this project was to test a Cesium Iodide (CsI) detector's accuracy across its entire surface area (25 cm^2). CsI is of interest as it will be used in Texas Active Target (TexAT) at Texas A&M University in experiments involving rare isotope beams. The second part of the study investigated pulse-shape discrimination (PSD) methods for scintillators to be used in the Mitchell Institute Neutrino Experiment at Reactor (MIνER) at Texas A&M University, and its ability to recognize α-particles, ɣ-particles, and neutrons.

Scintillators fluoresce when struck by a particle with high energy. Their data can be collected with photomultiplier tubes (PMTs), which convert photons to electrons via the photoelectric effect. PMTs then multiply the electrons through a series of potential differences between their anodes and output the amplified signal as an electrical pulse.

CsI Experimental Setup

The experiment to test the surface uniformity of the CsI detector was conducted with an α-source consisting of ^{148}Gd, ^{239}Pu, ^{241}Am, and ^{244}Cm. The CsI detector (Figure 1) was covered with a 3D printed mask (Figure 2). Only one hole of the mask was exposed at a time. The data was collected at vacuum (Figure 3) because α-particles lose energy very quickly in air.

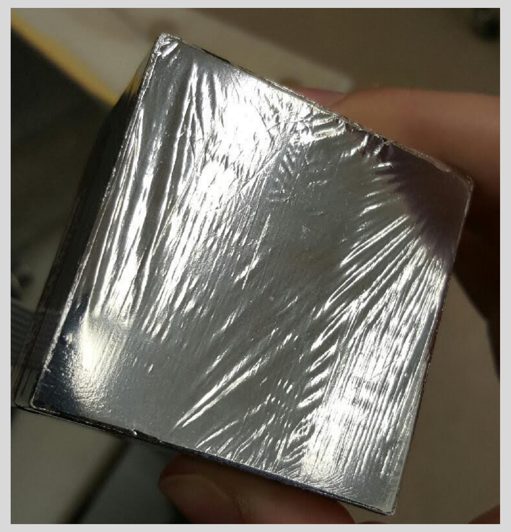


Figure 1: CsI detector

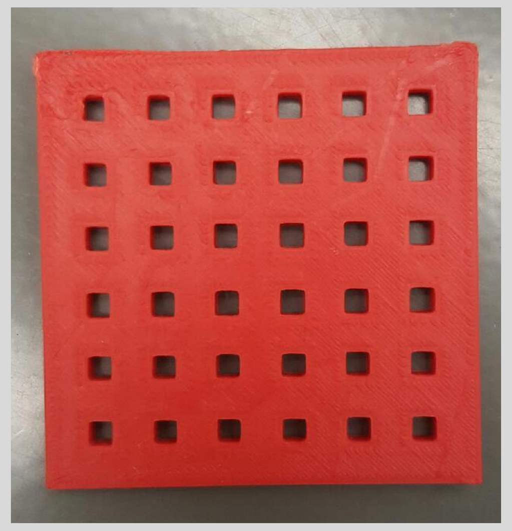


Figure 2: CsI mask

Figure 3: Experiment Setup

CsI Data Analysis

Four Gaussian peaks, one for each of the isotopes in the α source, were expected in the data output (Figure 4). The means, sigmas, and resolutions (Figure 5) were then extracted from this data and graphed. There is a slight non-uniformity, contributing to the overall resolution. However, it is reliable, with a resolution as low as 4%.

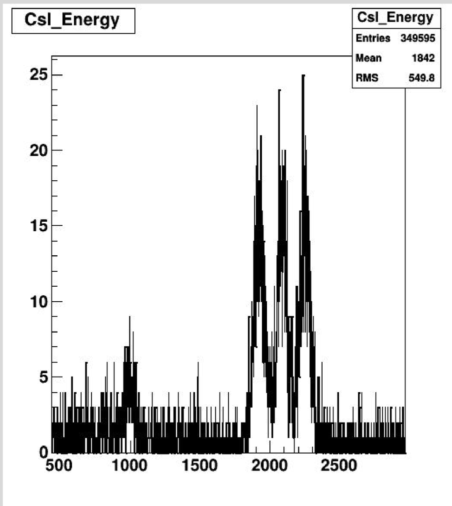


Figure 4: Gaussian peaks output from the detector

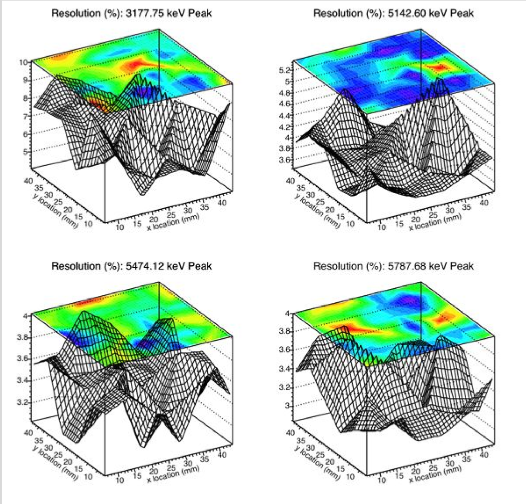
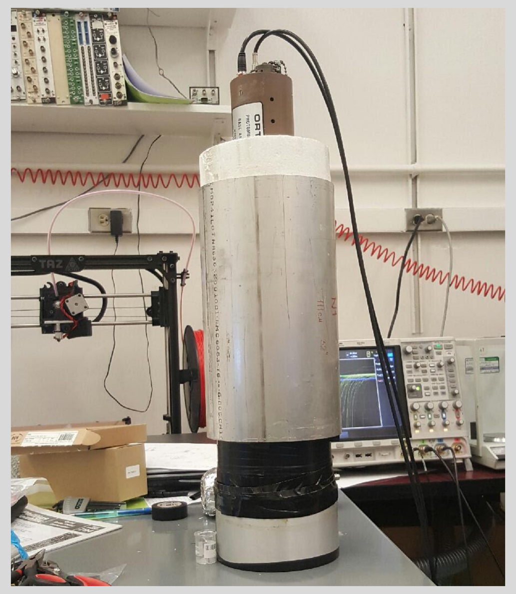


Figure 5: Resolutions of each Gaussian peak at corresponding location on detector

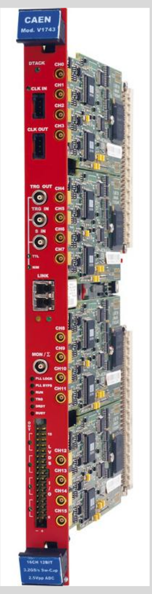
PSD Experimental Setup

For the second project, PSD methods were tested using a Stilbene scintillator with ^{60}Co and ^{252}Cf. The PMT (Figure 6) was connected to an oscilloscope, for monitoring output, and a CAEN waveform digitizer (Figure 7) to collect the information. The digitizer connected to a waveform emulator, allowing for outputting data to a file. The pulse was then fit with a function made of two Gaussians. Their amplitudes and left sigmas were extracted and plotted against each other as a form of PSD.



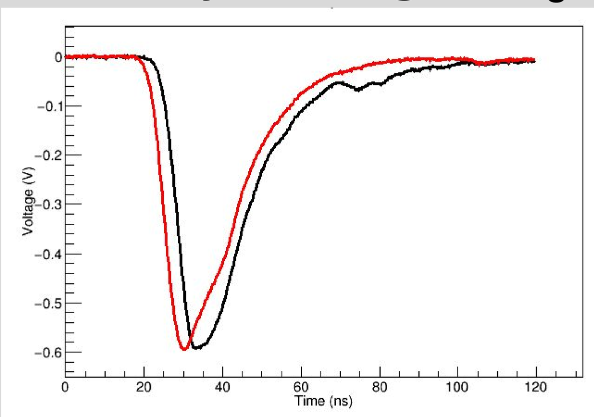
(Left) Figure 6: Experiment Setup, PMT is at the top, with cords connecting it to high voltage and data collection, Stilbene is at the bottom with ^{252}Cf

(Right) Figure 7: CAEN V1743 Waveform Digitizer



PSD Data Analysis

The separation of ɣ-particles and neutrons of ^{252}Cf (Figure 9) was tested by looking at a ɣ only source, ^{60}Co (Figure 10).



(Left) Figure 8: An example of a neutron pulse (black) and a ɣ pulse (red)
Neutron pulses have a larger sigma than ɣ pulses

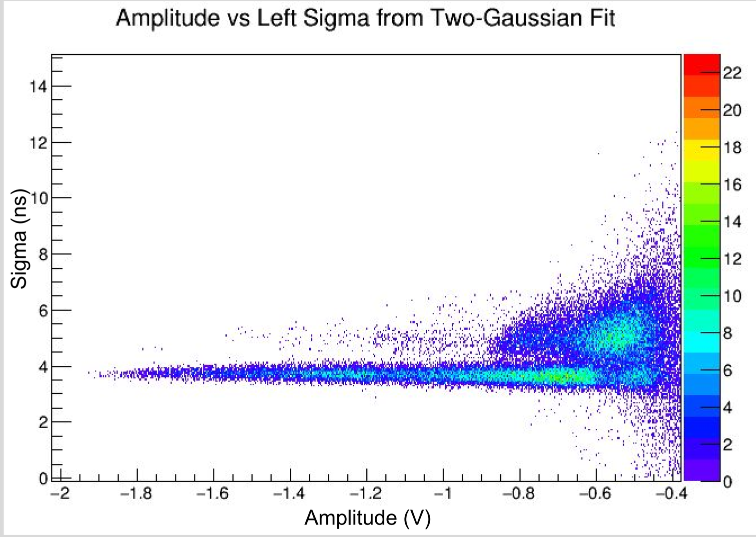


Figure 9: Results of ^{252}Cf

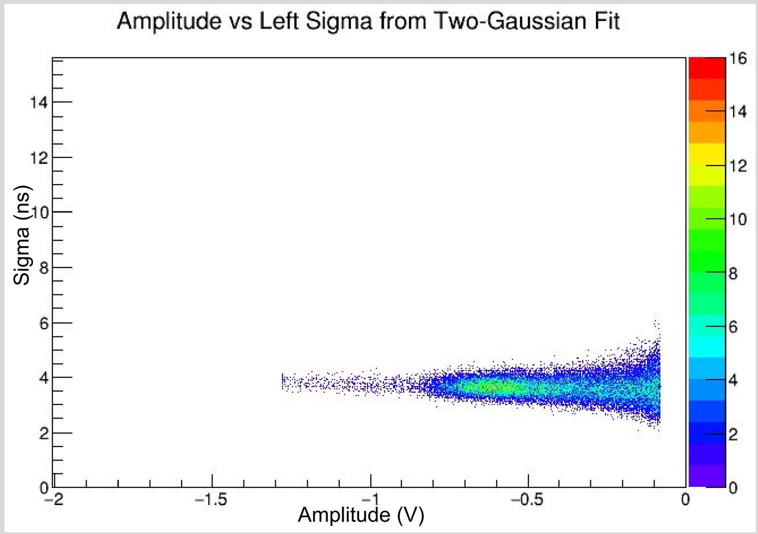


Figure 10: Results of ^{60}Co

Conclusions

- Resolution across the CsI detector is slightly non-uniform, though the overall resolution is as low as 4% for higher energy α-particles. An overall resolution this low shows that this is a reliable detector.
- The best PSD was achieved by plotting amplitudes versus left sigmas. It showed a distinct separation of the ɣ-particles and neutrons of ^{252}Cf. These methods will be applied to p-Terphenyl for MIνER.

Acknowledgements

This research was conducted with support from the National Science Foundation (PHY-1263281) and the US Department of Energy (DE-FG03-93ER40773). I would like to thank Josh Hooker and Dr. Rogachev for their mentorship. I am also very thankful to the Cyclotron Institute and their REU program for affording me the opportunity to conduct this research.