Temperature Dependence of Organic Scintillator Detectors

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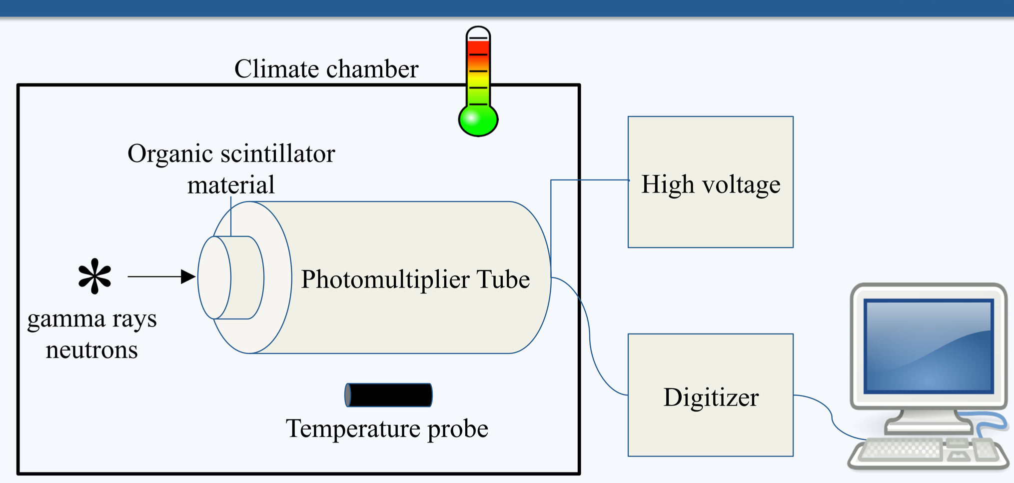
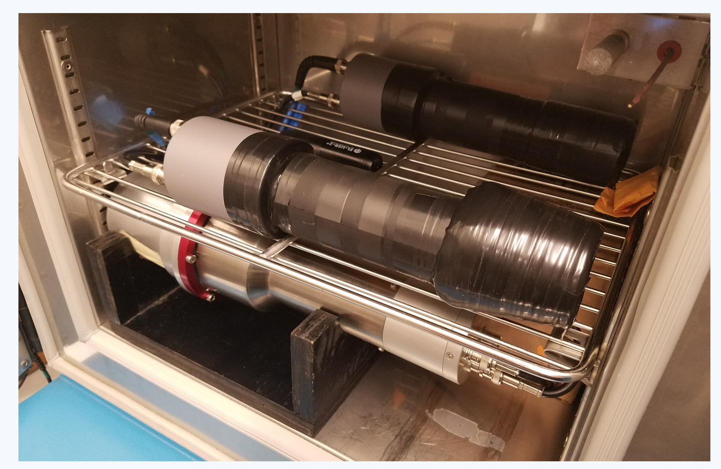
Background

- Organic scintillator detectors are commonly used in field-deployable radiation detection systems
- Field deployable detection systems include MINER, RadMAP, UTK & Oak Ridge National Laboratory's mobile trailer-based system
- Temperature dependence observed in anthracene organic scintillator detector [1]
- **Objective: characterize temperature dependence of stilbene and EJ-309 liquid organic scintillator detectors**

Set Up

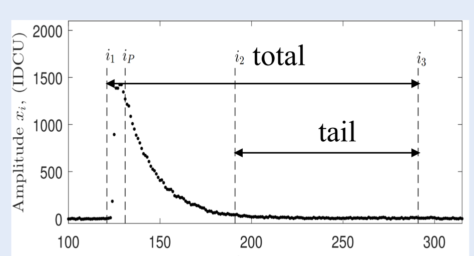




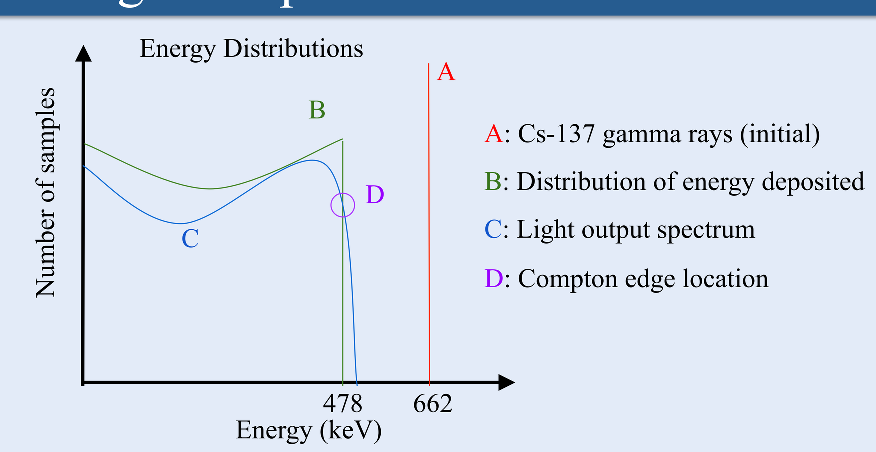
Analysis Methods

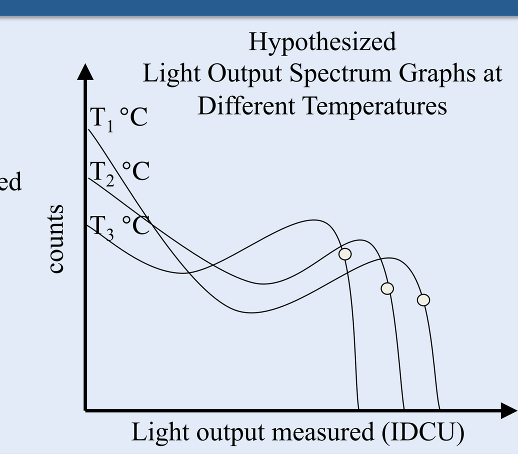
Light Output

- Light output spectrum is a histogram of L values
- Compton edge used as a reference point to determine if the light output spectrum changes as a function of temperature



$$L = \sum x_i$$

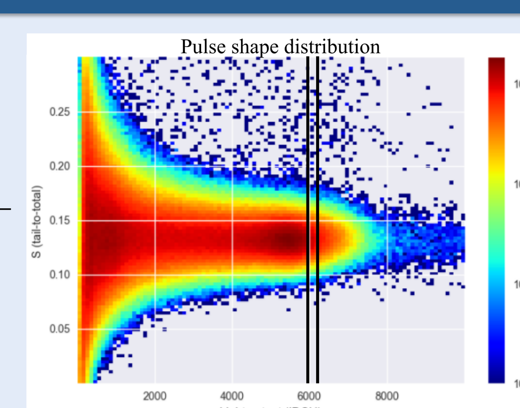


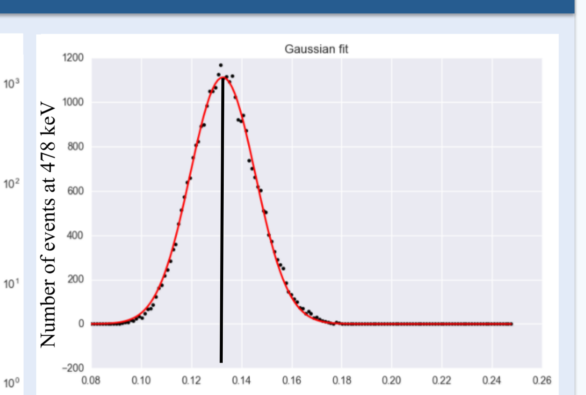


Pulse Shape

- Pulse shape distribution: 2D histogram of S value vs. L value
- Get S distribution by taking all events at 478 keV (Compton edge position)
- Gaussian fit to find the centroid value
- Use centroid value as a reference point to measure expected pulse shape of events at 478 keV as a function of temperature

$$S = \frac{tail}{total} = \frac{\sum_{i_2}^{i_3}}{\sum_{i_1}^{i_3}}$$



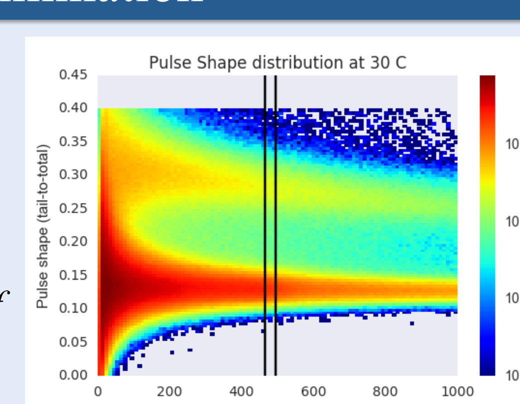


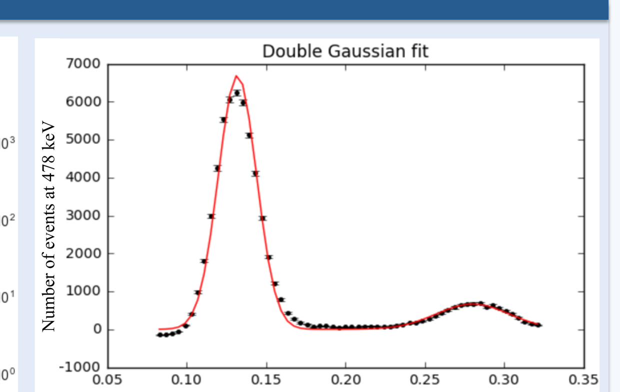
Pulse Shape Discrimination

- Pulse shape distribution obtained from a Cf-252 source
- Get S distribution by taking all events at 478 keV (Compton edge position)
- Double Gaussian fit
- Calculate figure of merit (FOM) and observe how it changes as a function of temperature

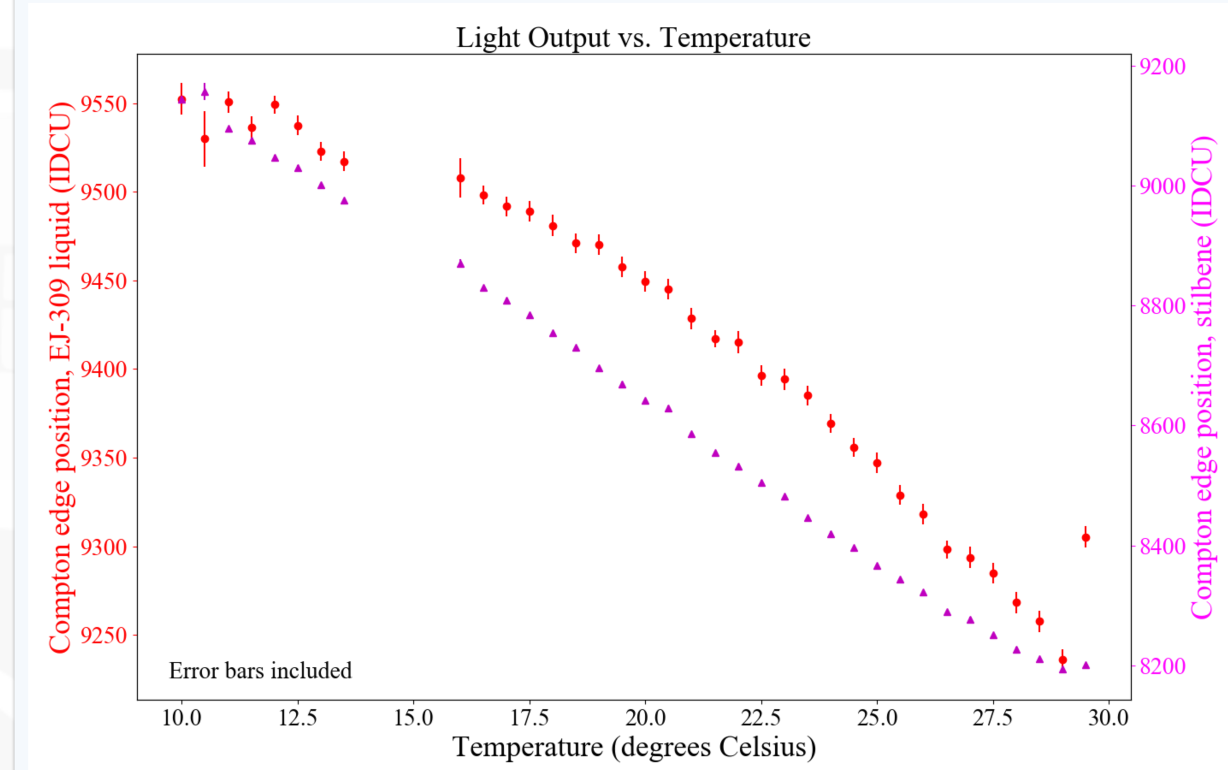
$$FOM = \frac{\mu_2 - \mu_1}{\sqrt{FWHM_2^2 - FWHM_1^2}}$$

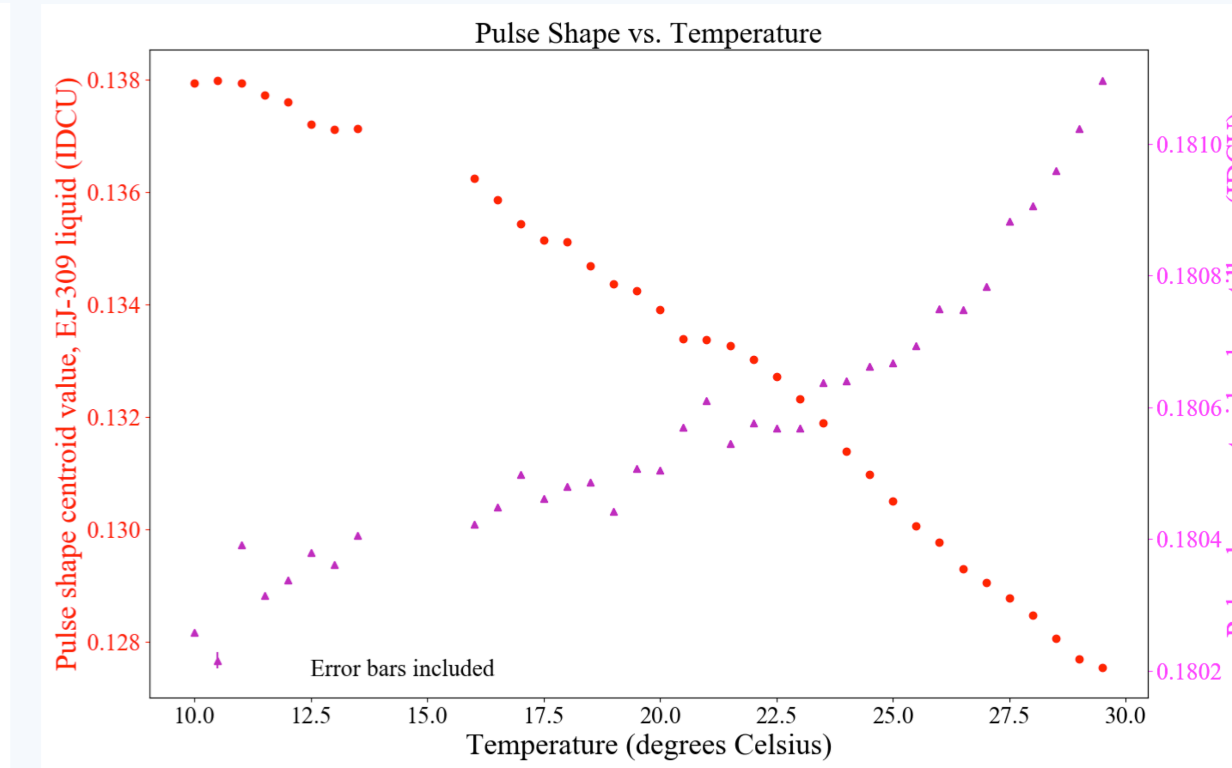
μ = centroid value
FWHM = full width at half maximum





Results





	Percent change, Light Output, 10°C to 30°C	**Percent change, Pulse Shape, 10°C to 30°C**
Stilbene	11.73 %	0.49 %
EJ-309 Liquid	3.43 %	8.18 %

Conclusions and Future Work

- Temperature dependence has been observed in stilbene and EJ-309 in light output and pulse shape
- Pending questions: Why is there a stronger effect in anthracene? Is this a scintillator response or a photomultiplier tube response?
- Future work includes measuring pulse shape discrimination as a function of temperature, measuring pulse shape and light ouput of neutrons as a function of temperature, characterizing the temperature dependence of the newly developed organic scintillator glass [2], and studying the physical properties governing temperature dependence

Author Bio

Aditi Rajadhyaksha is a third year undergraduate student studying Computer Science. She performed this work as a Consortium for Verification Technology fellow this past summer. She also interned at Sandia National Laboratories in Livermore this past summer, where she worked on setting up and characterizing an Active Well Coincidence Counter with Dr. Scott Kiff.

Her future work includes continuing her temperature dependence research by measuring pulse shape discrimination as a function of temperature and measuring the temperature dependence of other scintillator materials. Next semester, she will start working on a kinetic Monte Carlo software to further study the effect of temperature on organic scintillator detectors.

References

1. Schuster, P. & Brubaker, E. (2016). Investigating the Anisotropic Scintillation Response in Anthracene through Neutron, Gamma-Ray, and Muon Measurements. IEEE Transactions on Nuclear Science, 63(3), 1942-1954.
2. Taking Advantage of Disorder: Small-Molecule Organic Glasses for Radiation Detection and Particle Discrimination. Joseph S. Carlson, Peter Marleau, Ryan A. Zarkesh, and Patrick Feng. *Journal of the American Chemical Society* **2017** *139* (28), 9621-9626. DOI: 10.1021/jacs.7b03989

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