Characterization of FS-3: a detection system for neutron-photon correlations in fission

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Isabel Hernandez
University of Michigan
Nuclear Engineering and Radiological Sciences
Undergraduate Student Fellow
Professor Sara Pozzi

Leah Clark, Eoin Sansevero, Stephan Okar, Stefano Marin, Shaun Clarke

National Nuclear Security Administration

Introduction and Motivation

Neutron and photon emission from fission fragments is highly correlated

System response accounts for large biases of experimental results

Need to determine the sensitivity/system response to correlation measurements in Fission Sphere (FS-3)

By simulating the FS-3 system and comparing to experimental results, the system response/sensitivity may be deduced

Mission Relevance

NNSA Mission

Preventing nuclear weapons proliferation and reducing the threat of nuclear and radiological terrorism around the world are key U.S national security strategic objectives that require constant vigilance.

Fissionable material releases unique correlated signatures

Special Nuclear Material (SNM) characterized by these observables

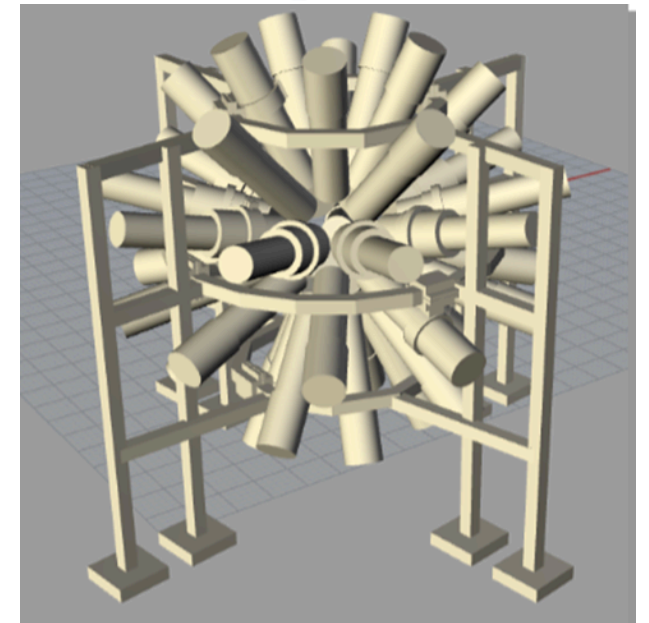We want to know the accuracy of FS3 to correlations

Fission Sphere Design

40 organic scintillation detectors
- 30 stilbene crystals
- 10 EJ-309

Distinguish particles using Pulse Shape Discrimination and Time of Flight

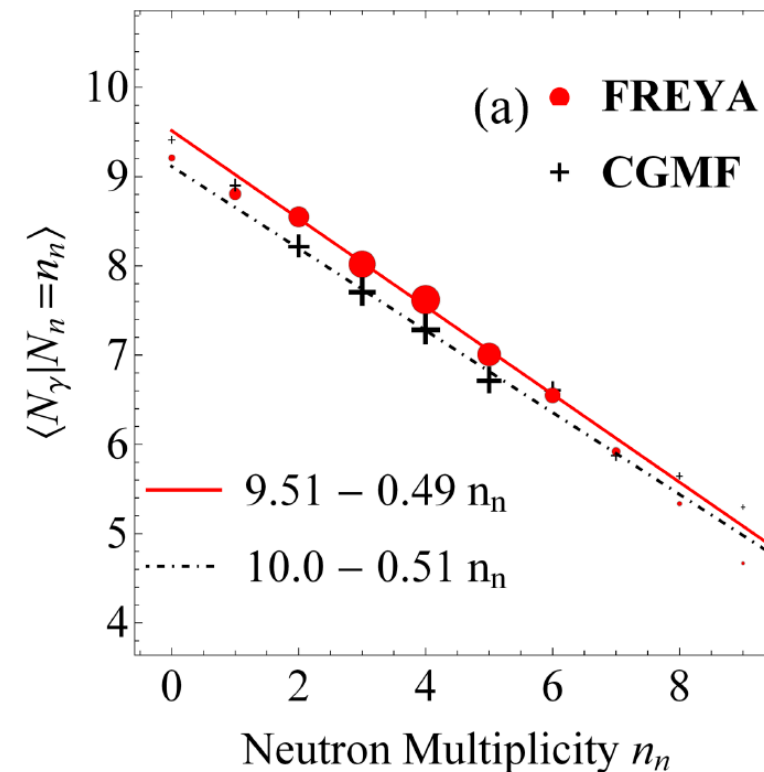Total absolute efficiency of 15% for neutrons and for photons

Correlations
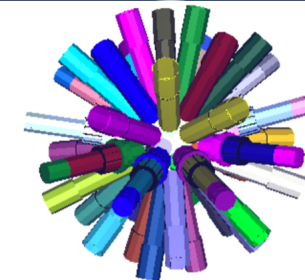
Multiplicity-multiplicity

- Neutron and gamma ray multiplicity

Energy-multiplicity

- Neutron multiplicity and average neutron energy

Marin, S., et al. "Event-by-event neutron-photon multiplicity correlations in ^{252}Cf(sf)", Nucl. Instrum. Methods Phys. Res. A 968 (2020) 163907

# Simulations Full Array

|	
• Correlated ^{252}Cf(sf) source	• Uncorrelated ^{252}Cf(sf) source
Fission Reaction Event Yield Algorithm (FREYA) used to produce correlated emission • Lawrence Livermore National Laboratory physics-based event generator	MCNPX-PoliMi contains an IPOL option for uncorrelated fission generation • IPOL(1) = 10 IPOL generator used to produce uncorrelated emission

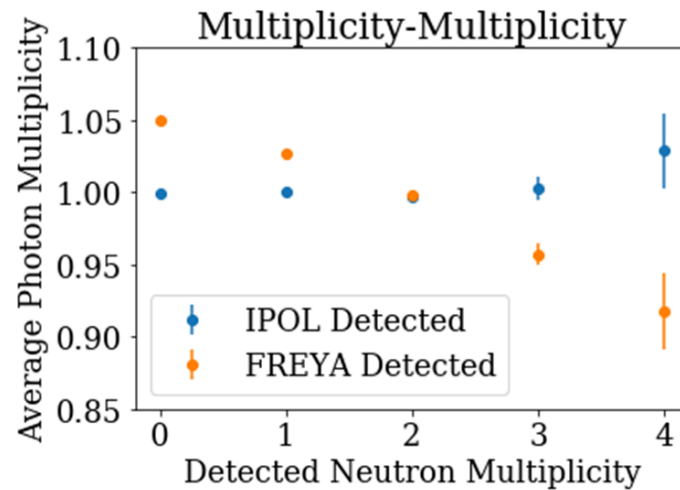Events generated by FREYA and IPOL propagated onto model with MCNPX-PoliMi
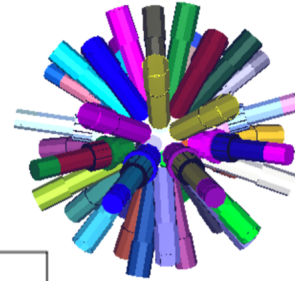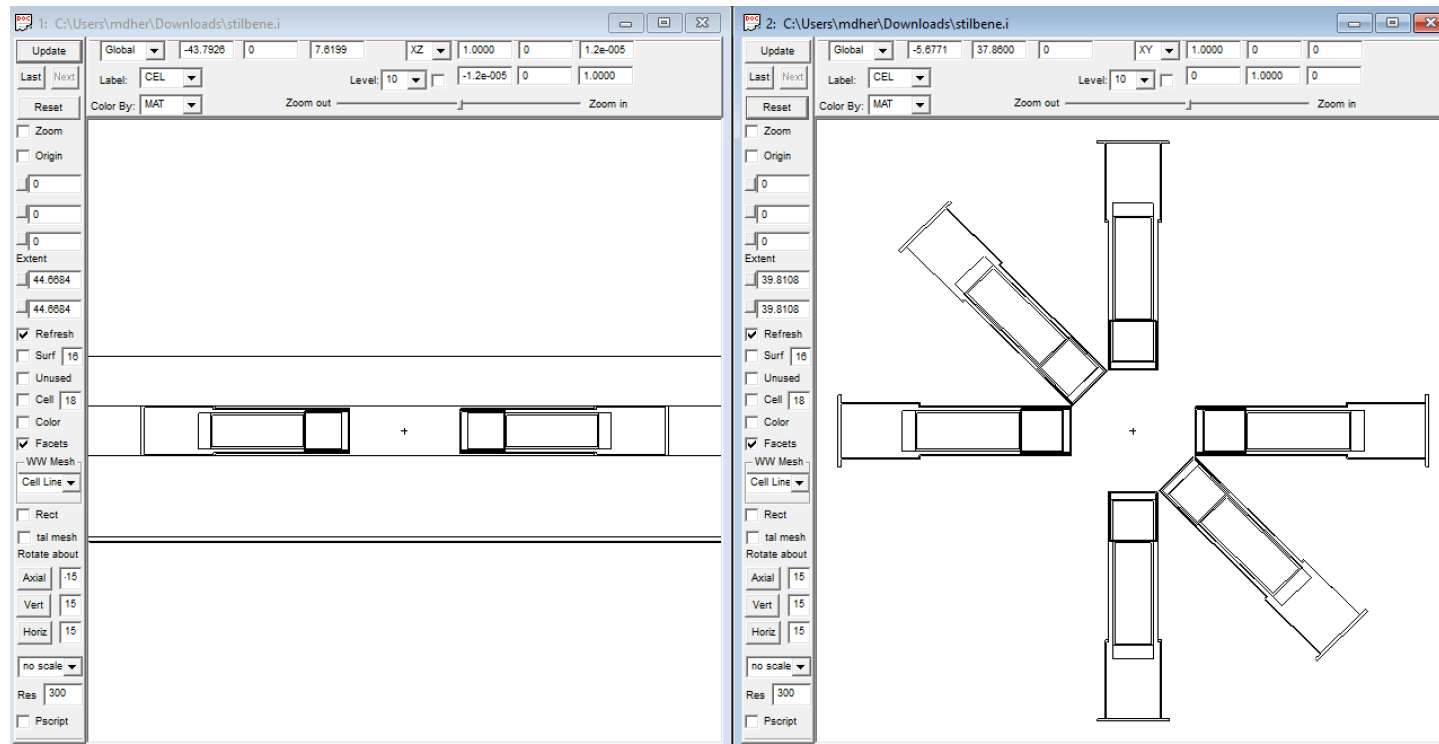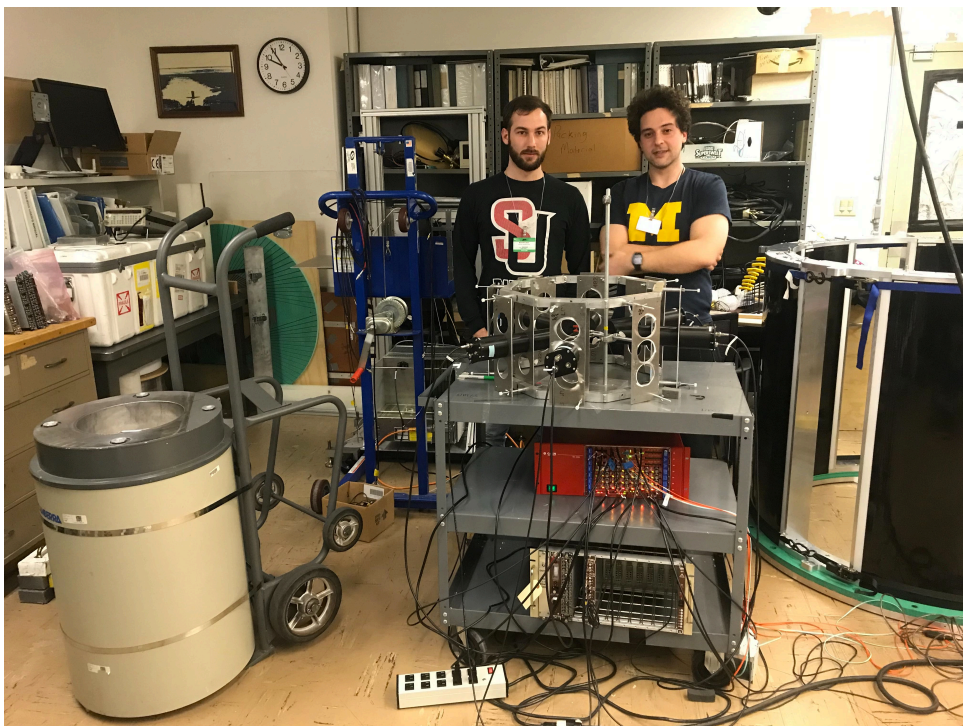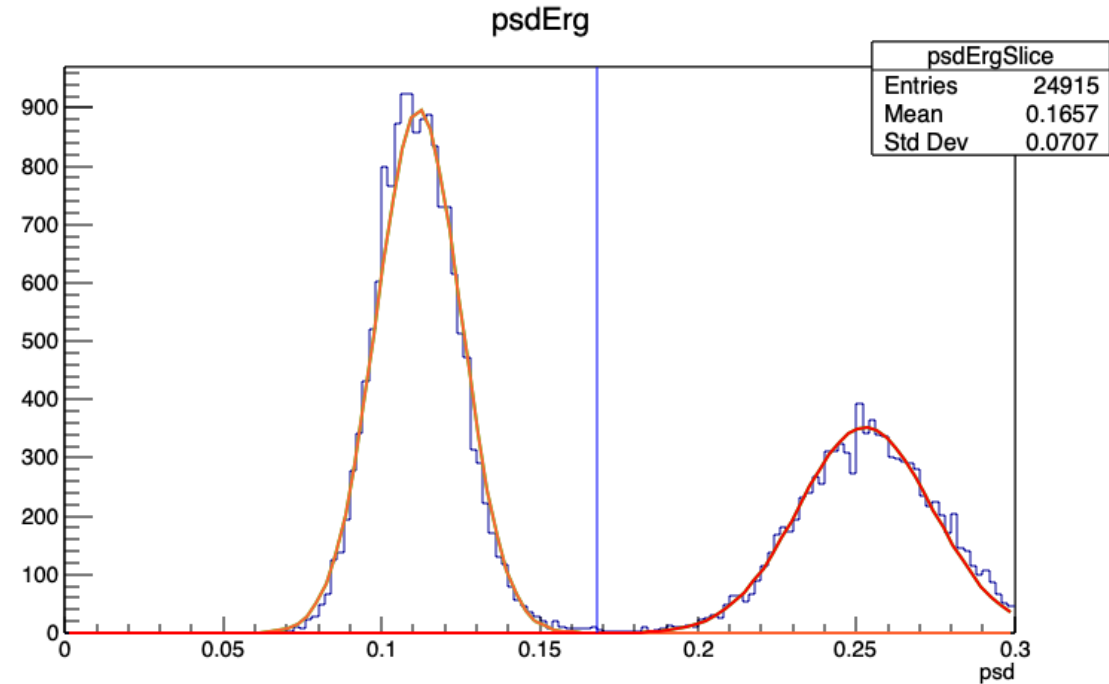
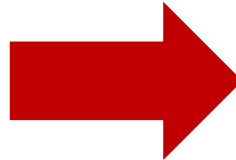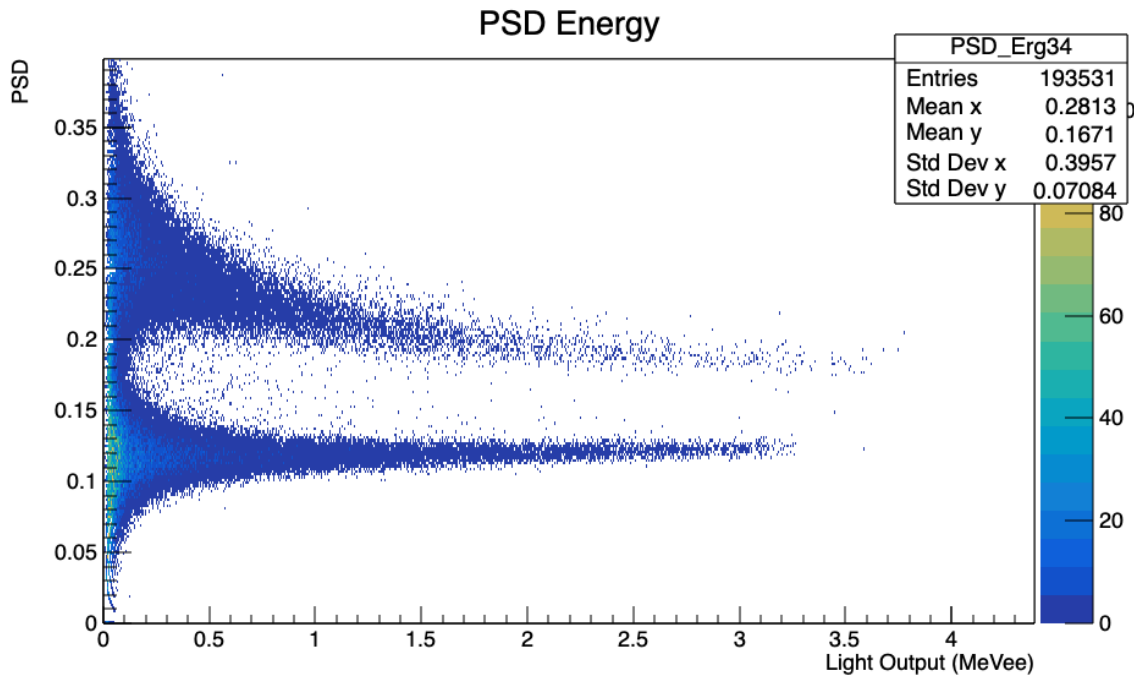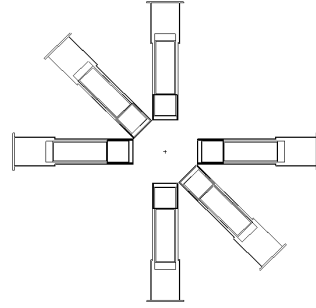# Simulations Full Array Results

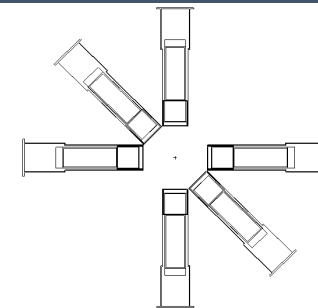Emission
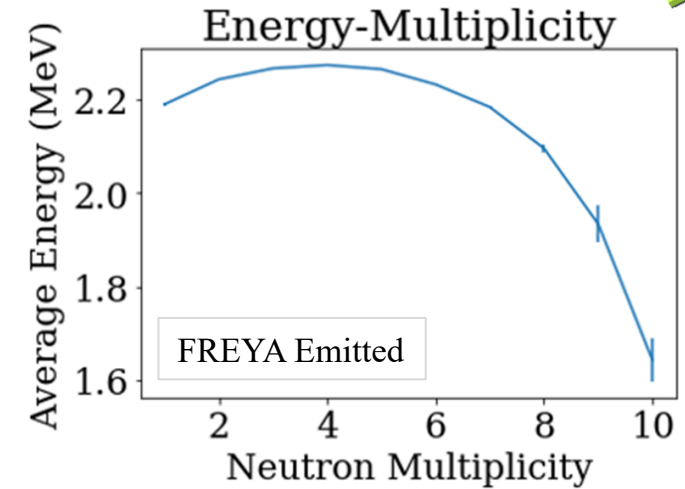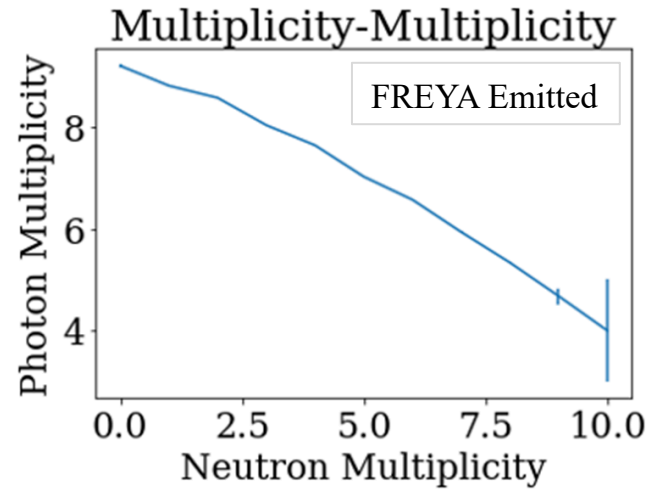
Detection
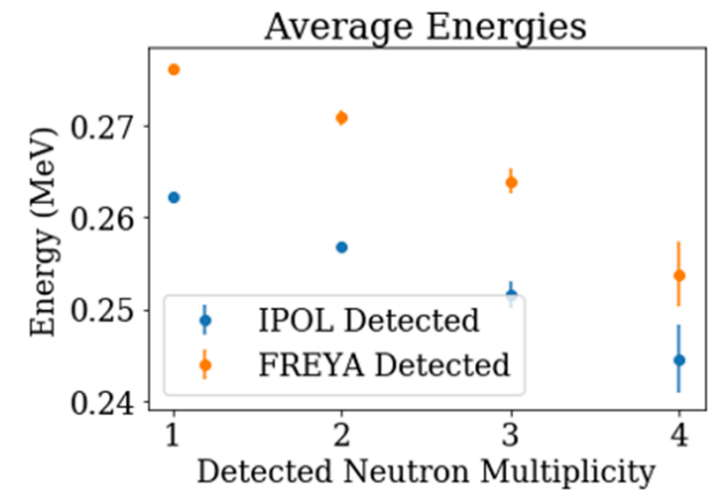
Experimental Setup

In collaboration with Oak Ridge National Laboratory:
Paul Hausladen, Jason Nattress

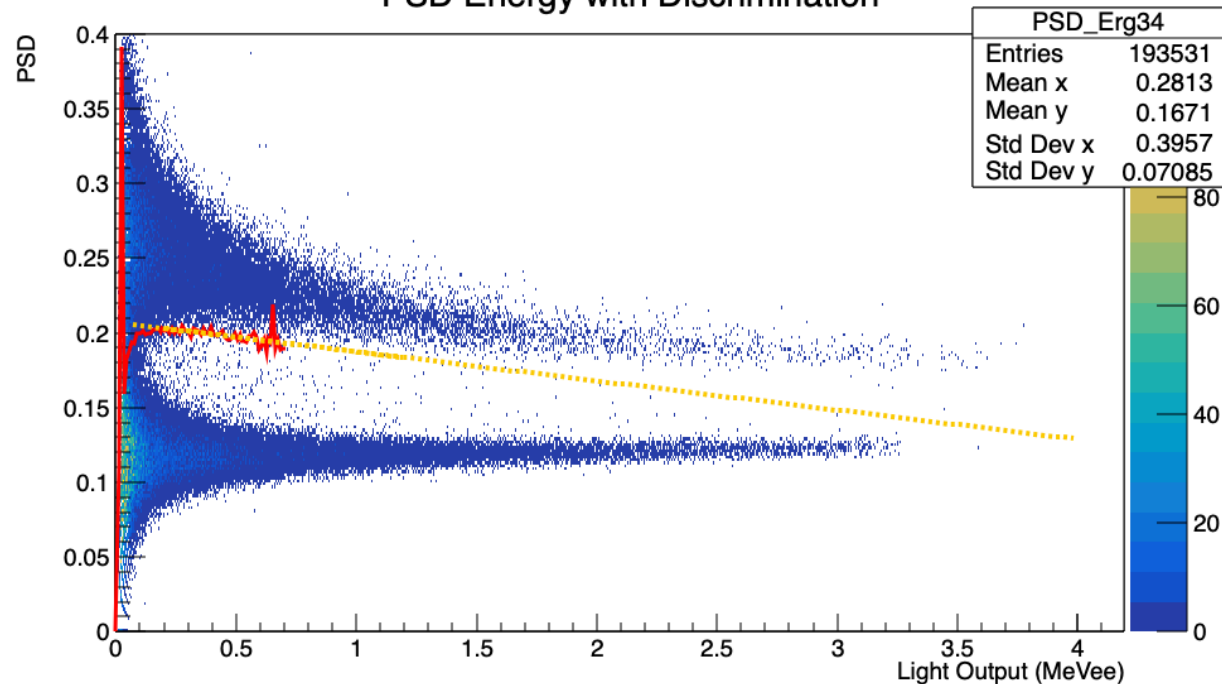# PSD Fitting

Higher Order Calibrations
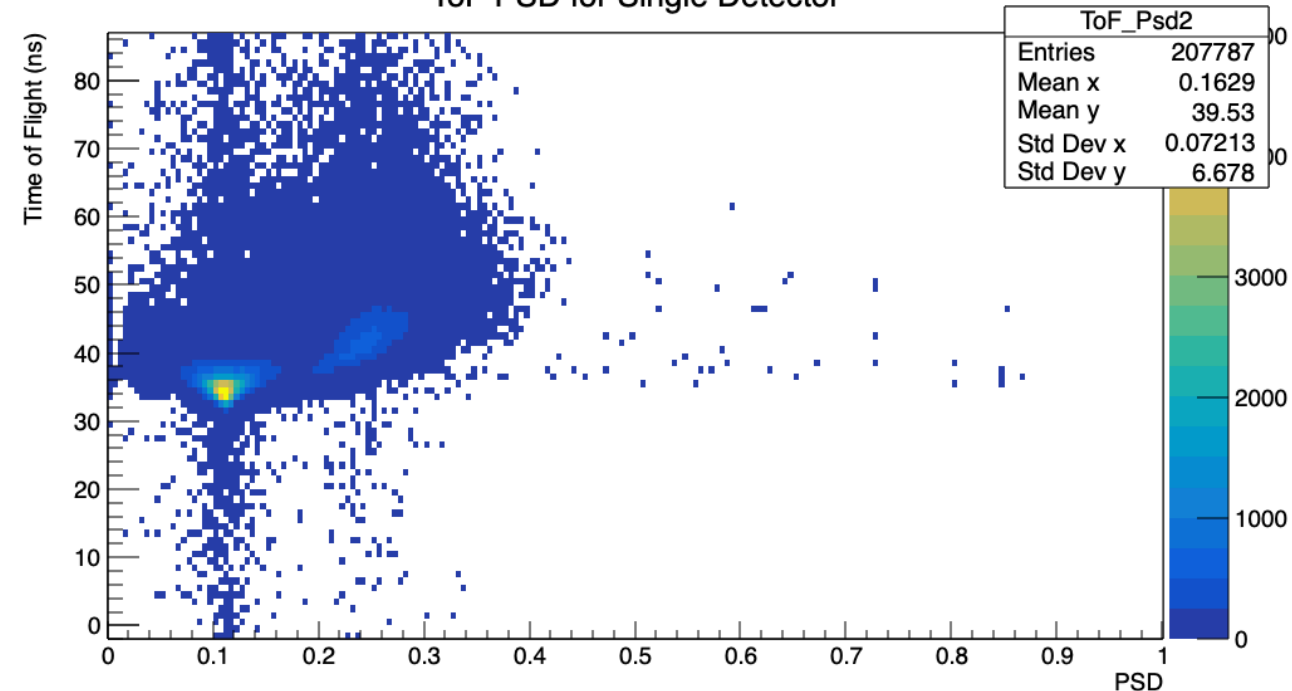

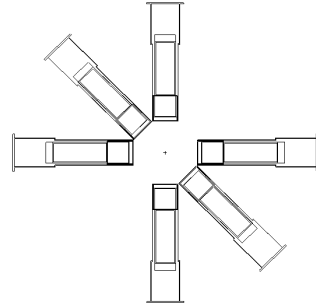PSD Energy with Discrimination

PSD_Erg34	
Entries	193531
Mean x	0.2813
Mean y	0.1671
Std Dev x	0.3957
Std Dev y	0.07085
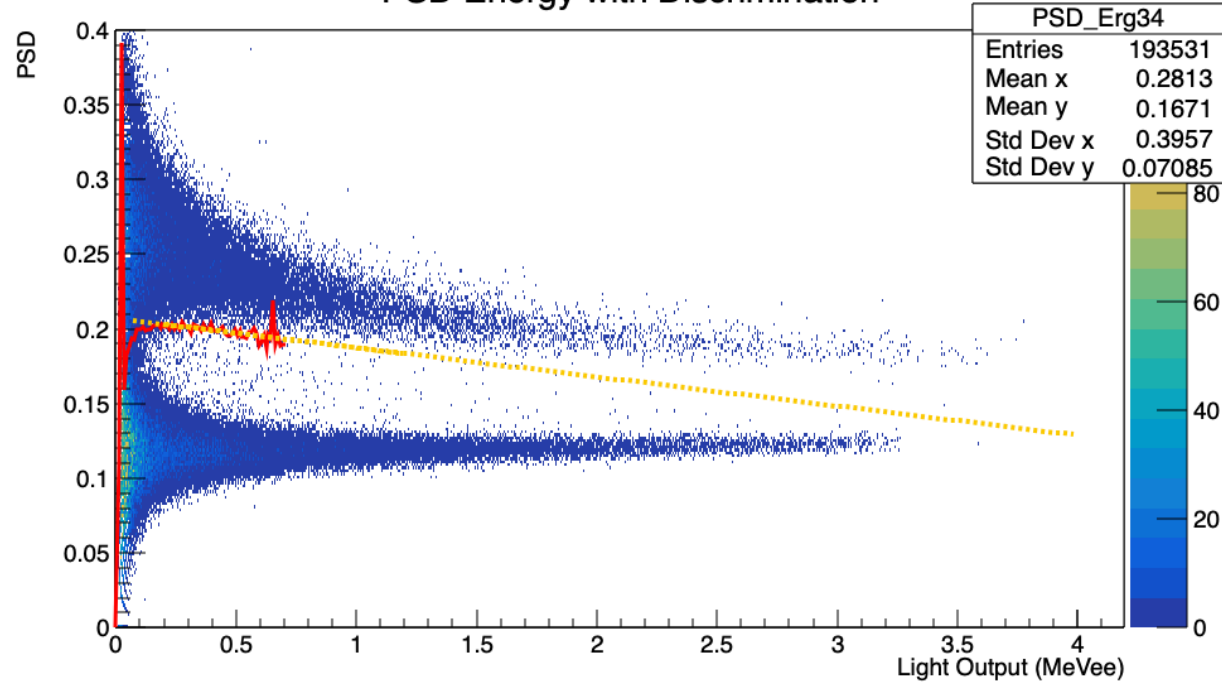
ToF PSD for Single Detector

ToF_Psd2	
Entries	207787
Mean x	0.1629
Mean y	39.53
Std Dev x	0.07213
Std Dev y	6.678

isabelhz@umich.edu

Higher Order Calibrations
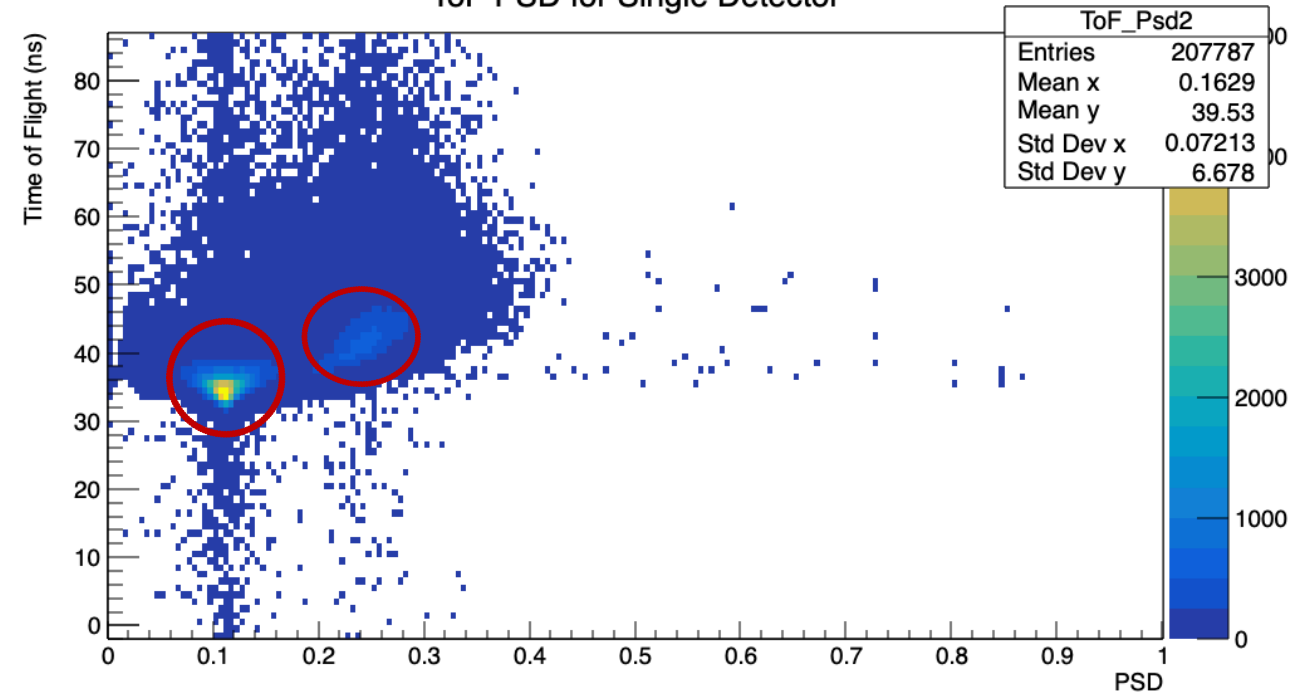
Timing Considerations

kinematic

	P	
Entries		248183
Mean x		38.19
Mean y		0.2991
Std Dev x		4.361
Std Dev y		0.3963

$$\sigma_t = \frac{\sigma_n}{\left|\frac{dV}{dt}\right|}$$
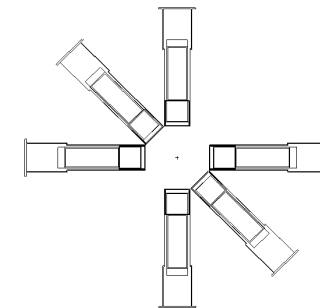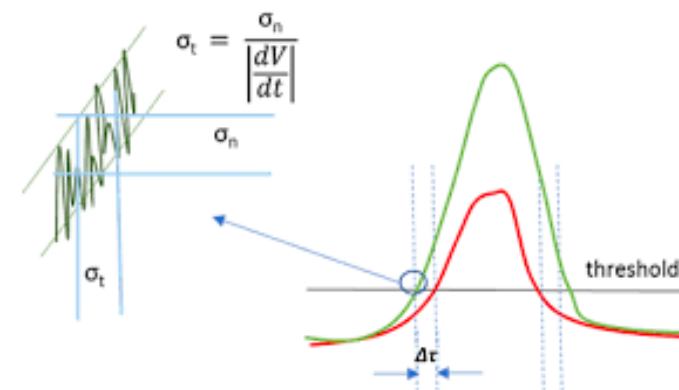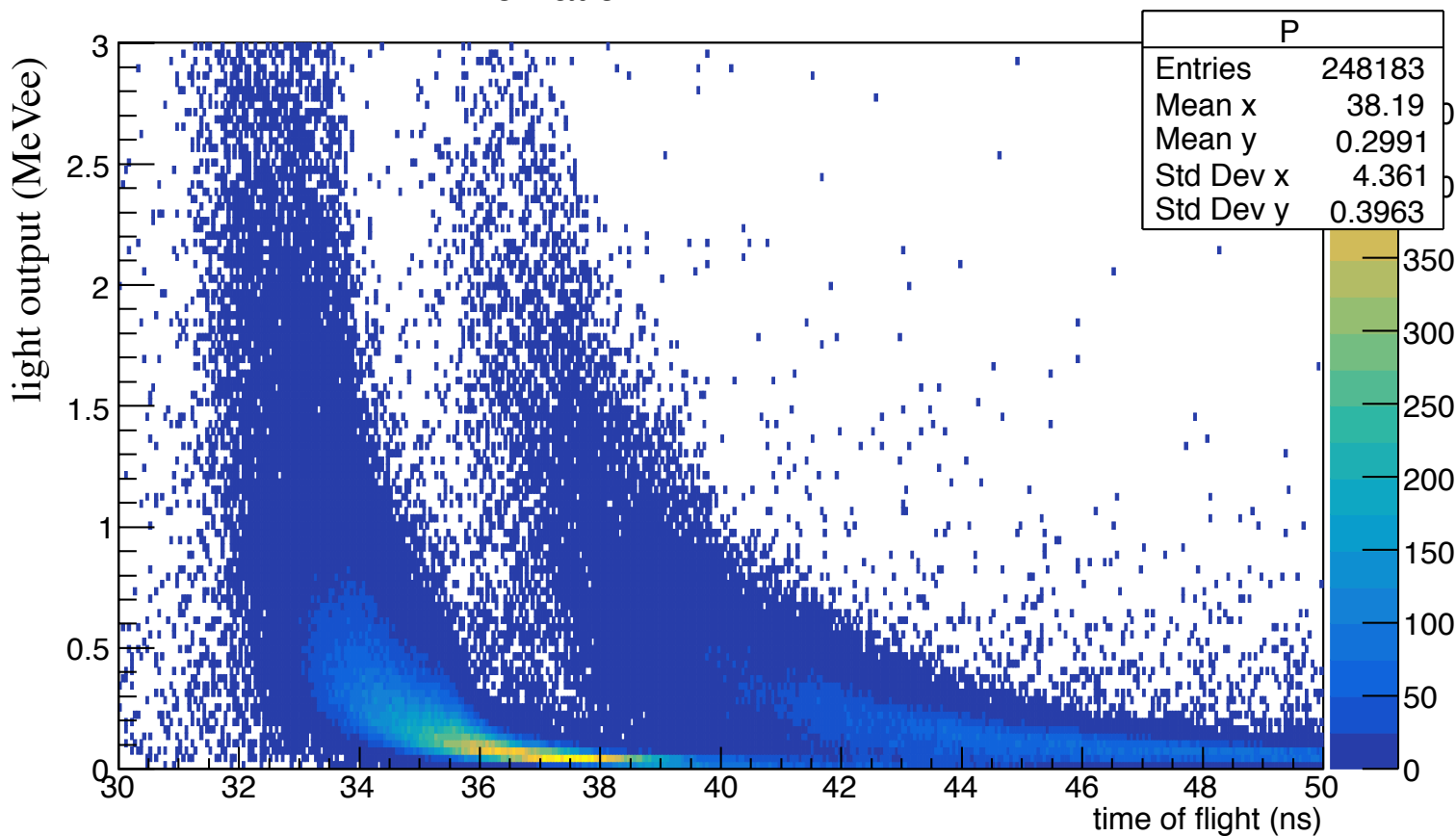
Multi-parametric analysis in discrimination:

- Time of Flight
- Light Output
- Pulse Shape Parameters

Future Work

Include simulated results to compare detection results

Use system response to unfold experimental data
- Sensitivity of FS3 to correlations

Include angular correlations

Provide FREYA error analysis: statistical and physics

MTV Impact

2020 MTV Summer Fellowship

MTV Summer School

Technology transition:

Oak Ridge National Laboratory,
Lawrence Livermore National Laboratory

Personnel transitions:

Los Alamos National Laboratory

Acknowledgements

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