Characterizing the Directional Dependence of Organic Scintillators from a Fission Source

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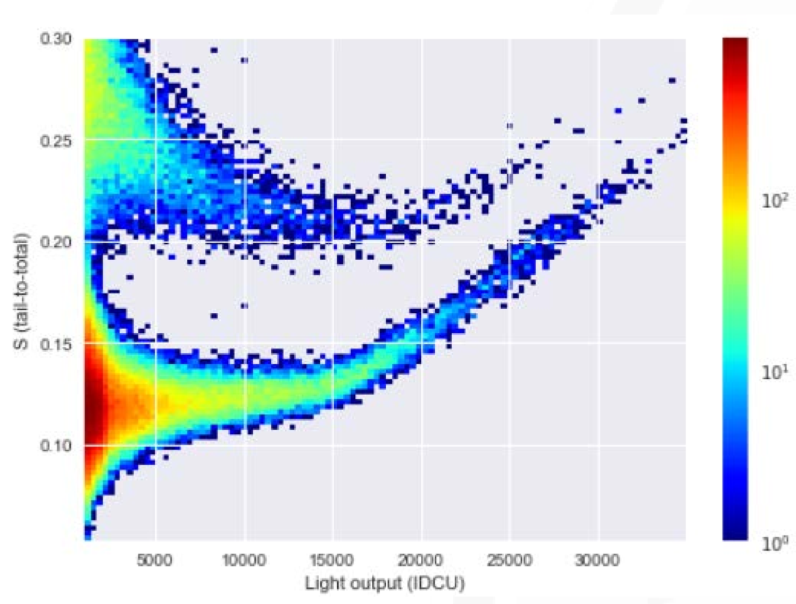
Introduction and motivation:

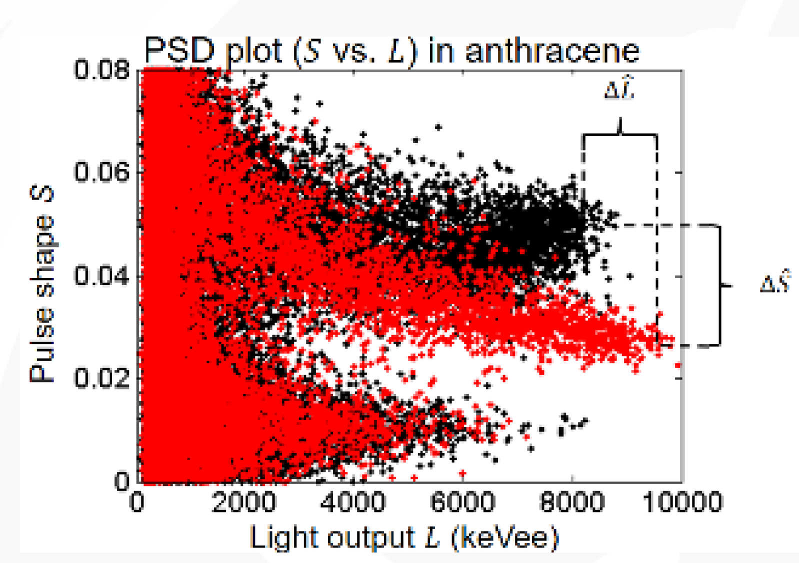
- Organic scintillators important for nuclear security:
  - Ability to detect, discriminate n vs. γ
  - Relatively affordable and robust
- Efforts to produce a new generation of materials with improved performance:
  - Understanding of internal processes governing light production incomplete
- Study the effect of anisotropy on light output production and pulse shape to better understand the internal processes.
- What are the methods used to characterize anisotropy from:
  - Mono-energetic neutron source
  - Fission source

Dependence on particle type, pulse shape discrimination (PSD)

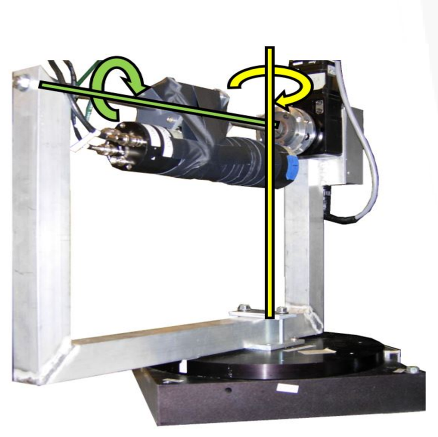
Pulse shape distribution measured from a Cf252 source



Change in pulse shape distribution for DT neutron generator measurements

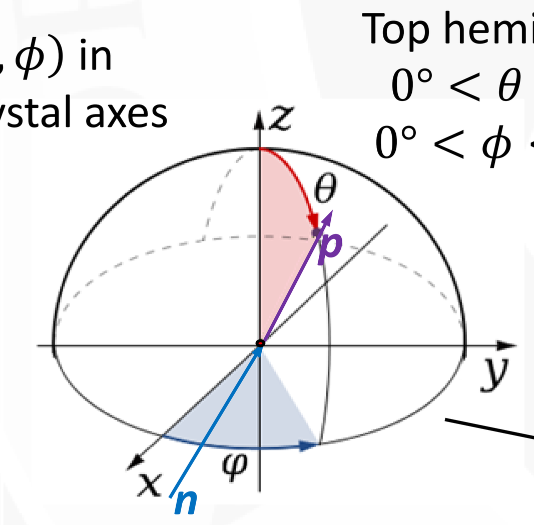


Dependence on interaction direction (of heavy charged particle)



Rotational stage positions four crystals at all possible (ϕ, θ) orientations

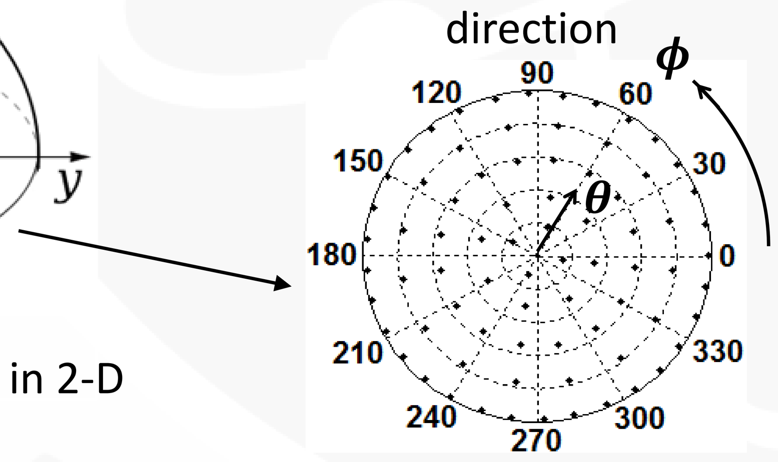
(θ, ϕ) in crystal axes



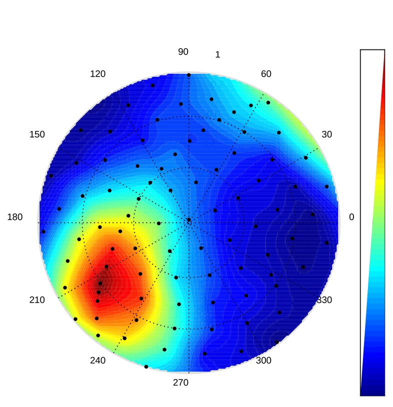
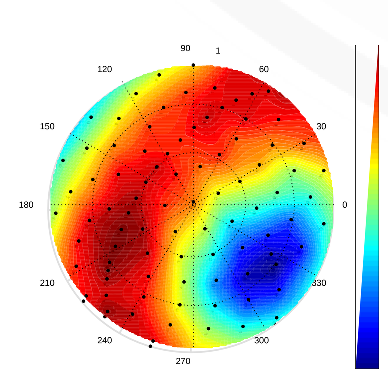
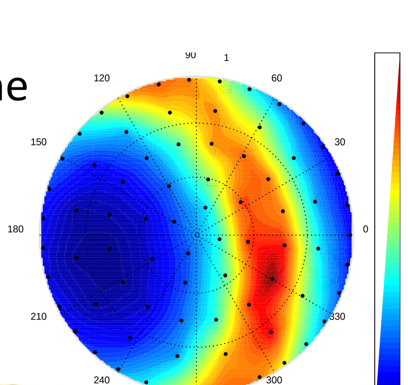
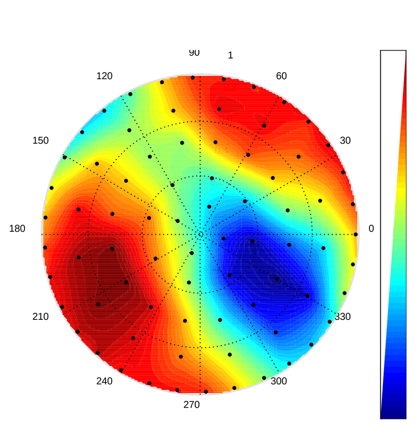
Represent directions in 2-D

Top hemisphere:
$0° < \theta < 90°$
$0° < \phi < 360°$

Use full energy event from n generator
↓
control p energy, direction

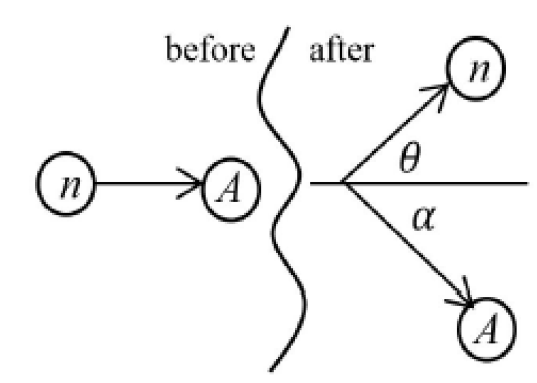


Measure expected light output $\hat{L}$ and pulse shape $\hat{S}$ in Stilbene for 14 MeV proton recoil vs. p recoil direction. Quantify effect as $A_L = \frac{L_{max}}{L_{min}}$, $A_S = \frac{S_{max}}{S_{min}}$.

	$\hat{S}$	$\hat{L}$	
Stilbene			All in sync $A_{\hat{L}} = 1.182 \pm 0.006$ $A_{\hat{S}} = 1.081 \pm 0.001$
Anthracene			Min, Max out of sync Saddle in sync $A_{\hat{L}} = 1.155 \pm 0.006$ $A_{\hat{S}} = 1.798 \pm 0.006$

Prior Method to Characterizing the Effect

-Need to know the direction and energy of the proton recoil
- For mono-energetic sources, select proton recoil events in the forward direction.
- This will make energy and direction of proton recoil s known

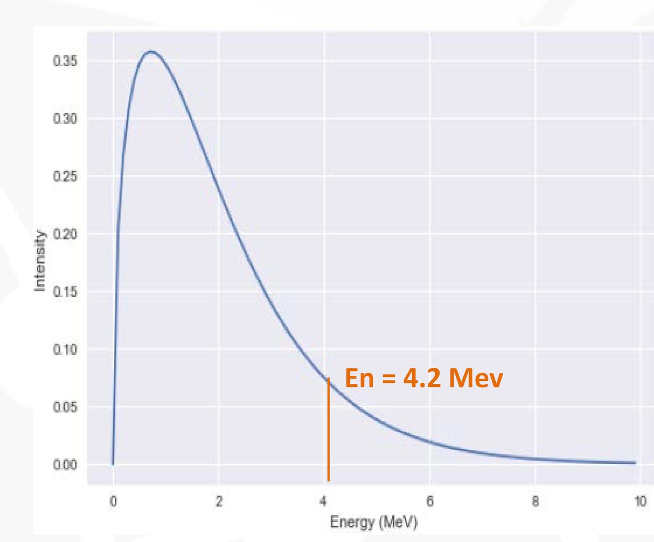


$$E_{\text{recoil}} = E_n \cos^2 \alpha$$

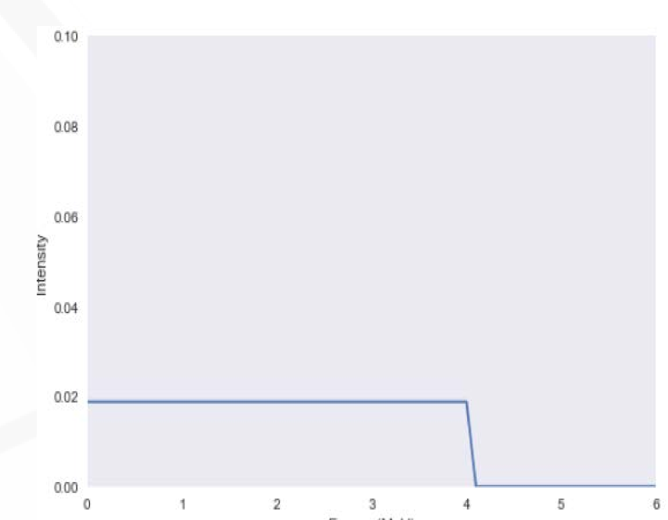
Unique direction of proton recoil when:

$$E_{\text{recoil}} = E_n$$

Cf-252 Fission Spectrum



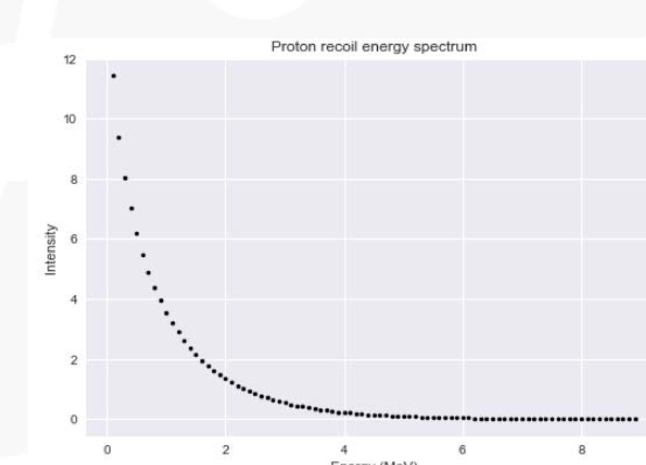
Light Output Spectrum from a Mono-energetic Source



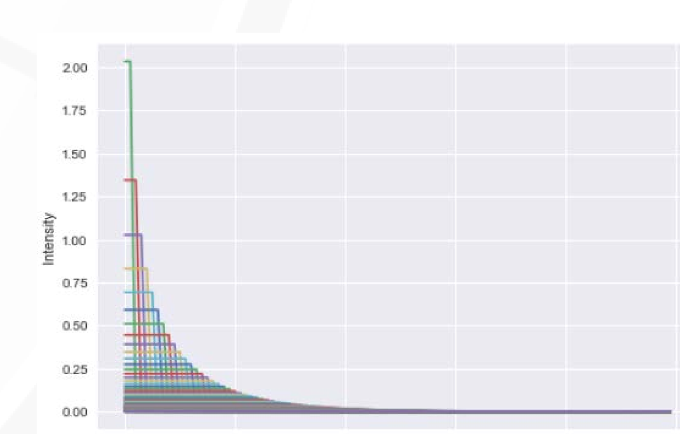
Research Question:
How does the anisotropy effect appear for measurements of distributed energy neutron sources, such as Watt-spectrum fission sources?

- When using a fission source, direction and energy of proton recoil are no longer known.
- The light output response from a fission source is a decaying exponential.
- The response could be viewed as a multiple mono-energetic light output responses produced by each neutron in the f in the Cf-252 spectrum

Light Output Spectrum from Cf-252



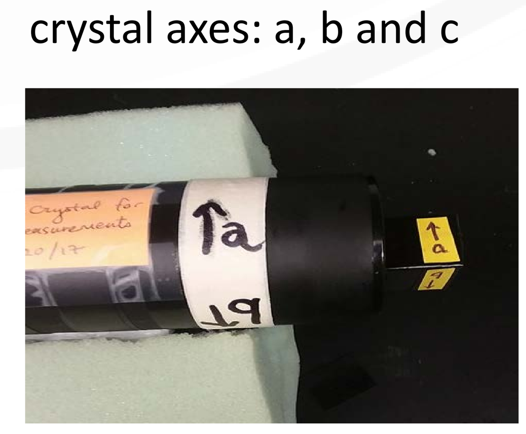
Treat Spectrum as Multi-Mono-Energetic Sources



Research Plan

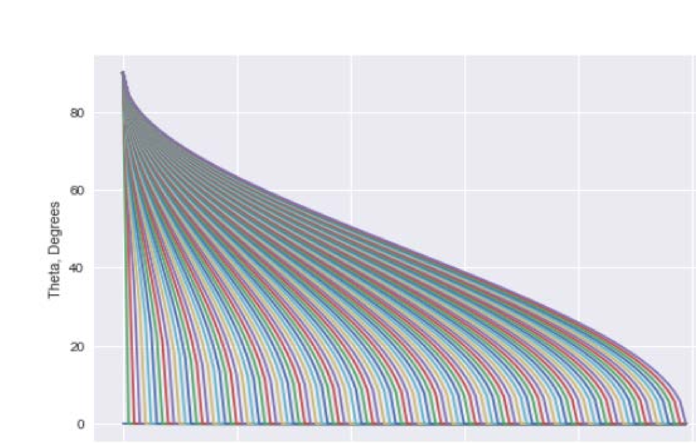
Measurements

- Take measurements along each of the known crystal axes: a, b and c



Calculations

- Analyze produced distributions for presence of anisotropy
- Develop a simulation of the experiment and compare results



As E of proton recoil increases → it's scattering angle decreases

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