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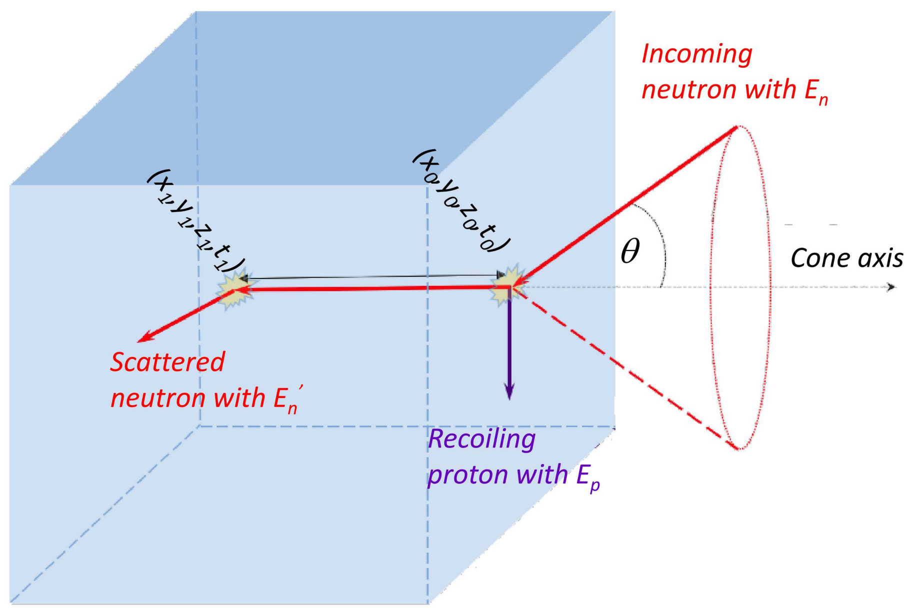
Scintillator Characterization for the Single Volume Scatter Camera

Project Number (SL17-ML-MIND-PD3Jb)

Thibault Laplace on behalf of the Single Volume Scatter Collaboration

National Nuclear Security Administration

Goals and Objectives



Provide the Single Volume Scatter Camera (SVSC) project with necessary characteristics of prospective and employed scintillators of interest. These Include:

Relative Proton Light Yield across a broad range of energies

$$E_n = E_{n'} + E_p \qquad E_{n'} = \frac{1}{2}m_n\left(\frac{d_{10}}{t_{10}}\right)^2$$

$$\theta = \arccos\left(\sqrt{\frac{E_{n'}}{E_p}}\right)$$

Kinematic Imaging requires the proton light yield relation to relate the detected light to the proton energy

Proton energy dependent pulse shape measurements with resolution better than the anticipated temporal resolution of the detection system

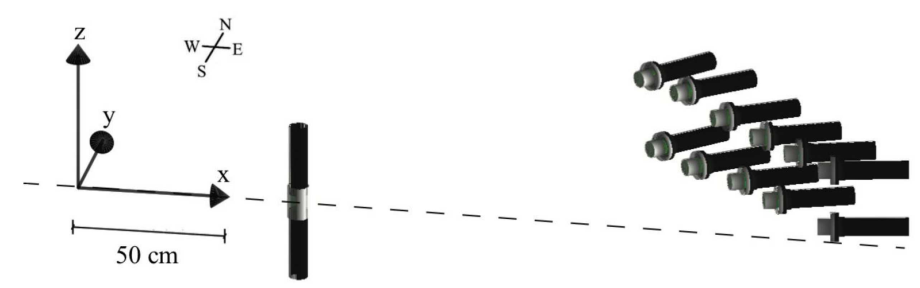
$$\mathcal{L} = \frac{e^{-\mu}\mu^n}{n!}\prod_{i=1}^{n}\sum_{j=1}^{N}\frac{\mu_j}{\mu}P_j(\vec{x_i})$$

$$P_j(\vec{x_i}) = \frac{\cos\phi_{ij}}{4\pi d_{ij}^2}.e^{\frac{-d_{ij}}{\lambda}}.f\left(t_i - t_j - \frac{d_{ij}}{c_p}\right)$$

The likelihood reconstruction algorithm for the monolithic detector concept requires the original pulse shape of the scintillation emission to extract position and times of multiple interactions

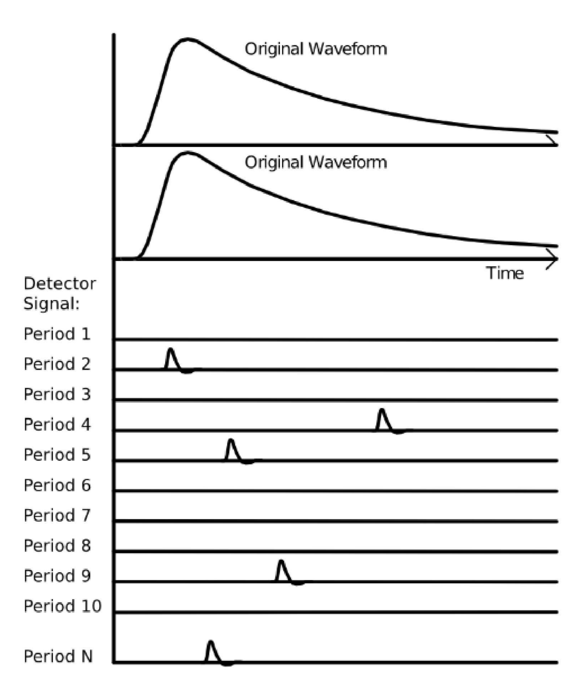
Methods

Broad Spectrum Proton Light Yield Measurements

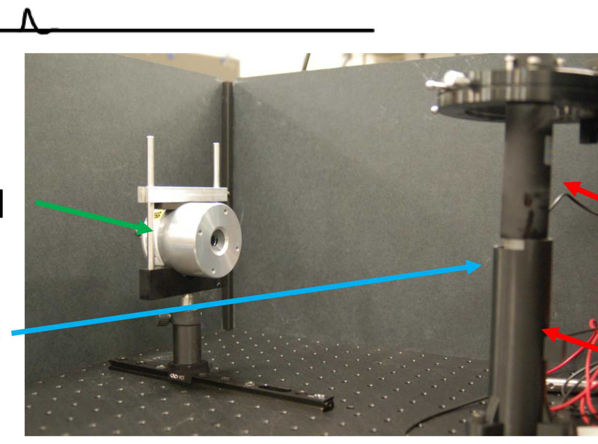


- Pulsed ^{9}Be(d,n) beam at LBNL 88-Inch Cyclotron
- Scintillator coupled to dual PMT to reject dark current
- Coincidences between In-beam scintillator of interest and 11 Out-of-beam
- PSD-capable out-of-beam scintillators
- Proton recoil energy obtained using kinematics
- Digital acquisition (CAEN V1730 500 MS/s) recording full waveforms

Time Correlated Photon Counting with sub 100 ps Resolution

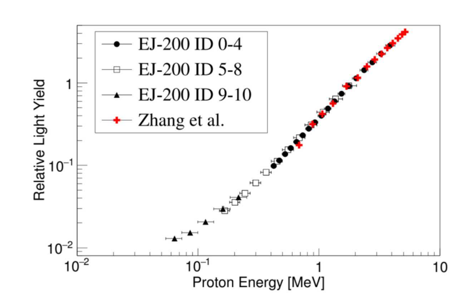


Sources of systematic uncertainty in classic measurement were explored and a system was developed to address them

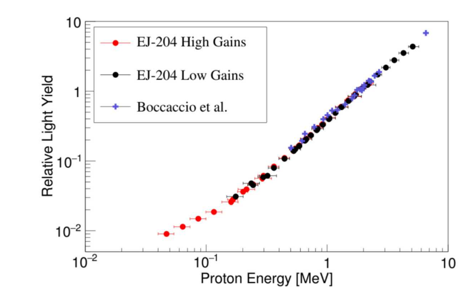


Results

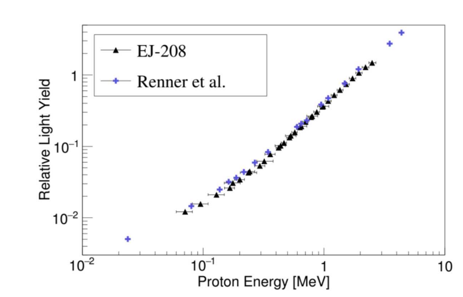
Publication of Light Yield Measurements of ELJEN 200 series fast plastic scintillators



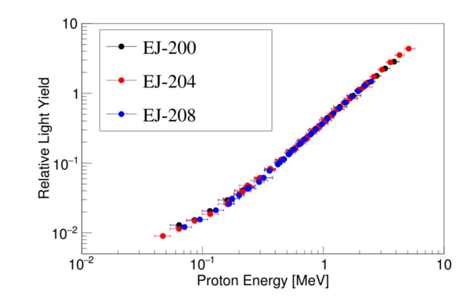
Relative light yield of EJ-200 as a function of proton recoil energy



Relative light yield of EJ-204 as a function of proton recoil energy



Relative light yield of EJ-208 as a function of proton recoil energy

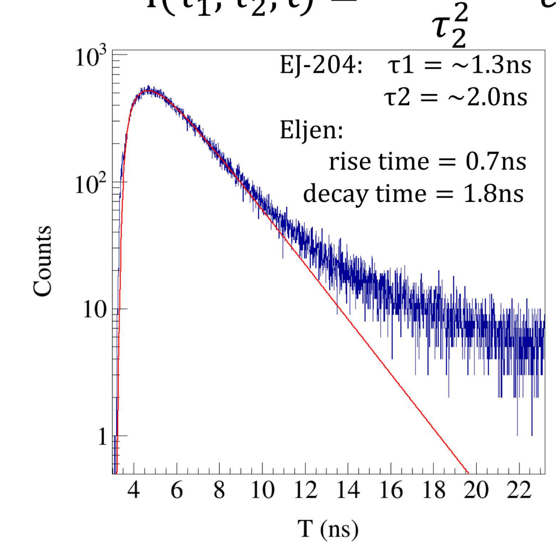


Comparison of the relative light yield between the three materials

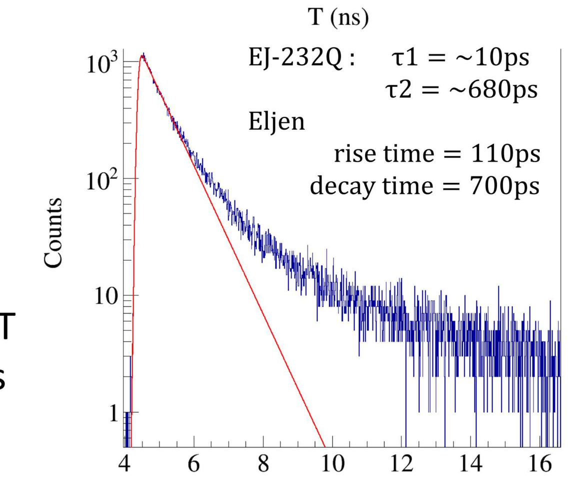
- The proton light yield of EJ-200, EJ-204 and EJ-208 was measured from approximately 50 keV to 5 MeV.
- Similar relative proton light yield for the three materials is reasonable given all use a PVT base

Mixed Field Pulse Shape Measurements

$$I(\tau_1,\tau_2,t) = \frac{(\tau_1+\tau_2)}{\tau_2^2}e^{-t/\tau_2}\left(1-e^{-t/\tau_1}\right)\theta(t)$$



Data were fitted with the empirical relation used to generate scintillation light in GEANT4

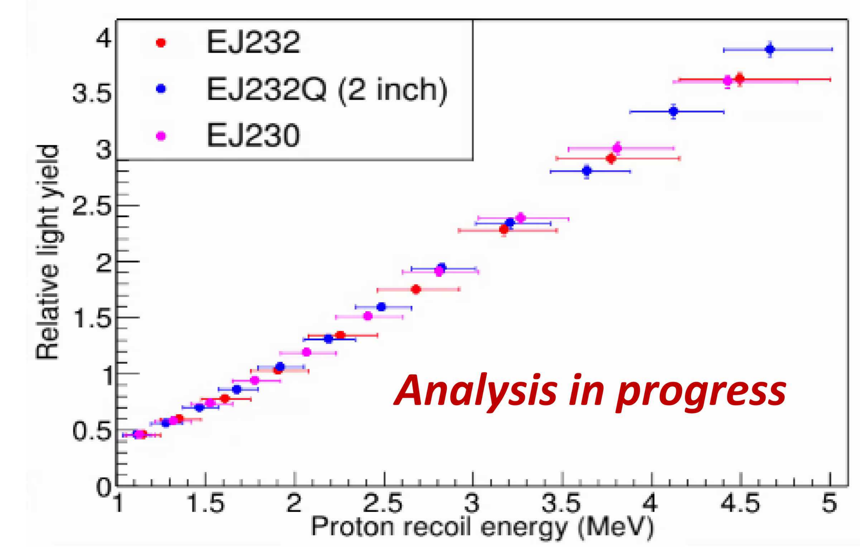


Using manufacturer specified quantities without understanding of their meaning would lead to poor representations of real pulse shapes

Next Steps

Proton Light Yield

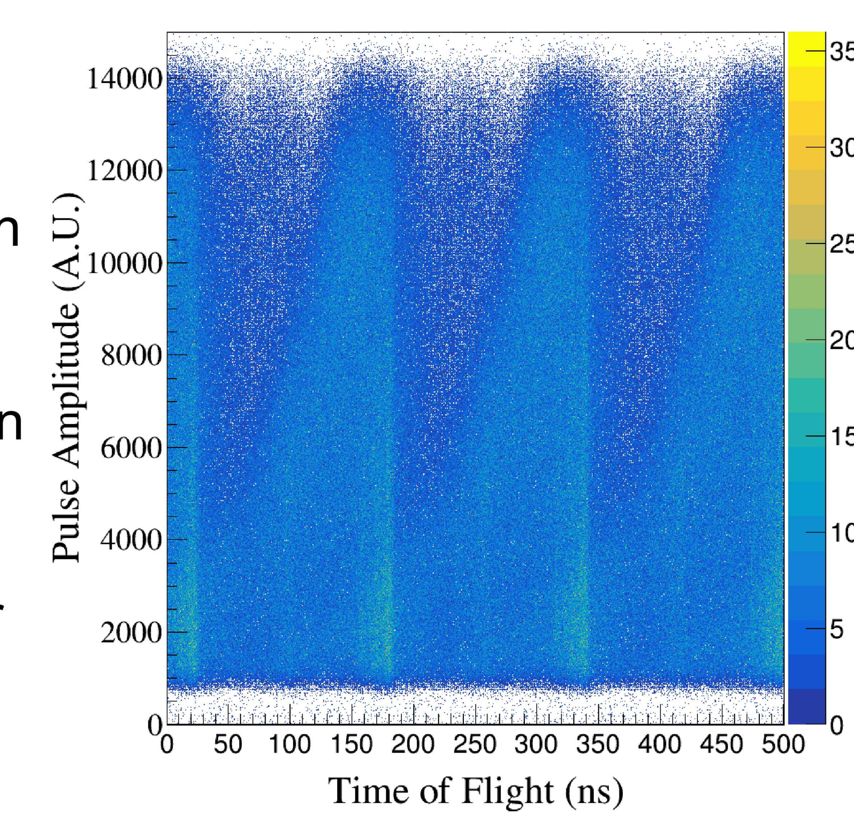
Characterization of other candidate materials: fast and quenched plastics EJ-230, EJ-232 and EJ-232Q



Next Steps

Timing Characterization

Data reduction and analysis for pulsed beam time correlated photon counting experiment conducted at the LBNL's 88-Inch cyclotron enabling neutron pure pulse shapes to be evaluated

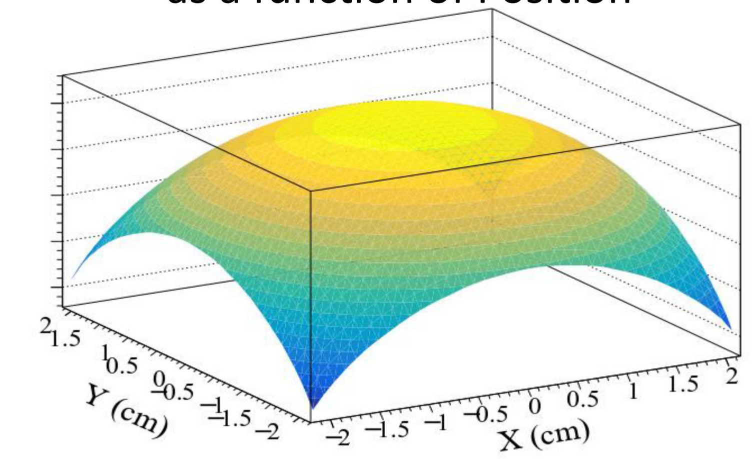


Used in conjunction with the proton light this will enable the determination of pulse shapes for a given scintillator to be evaluated as a function of their proton energies

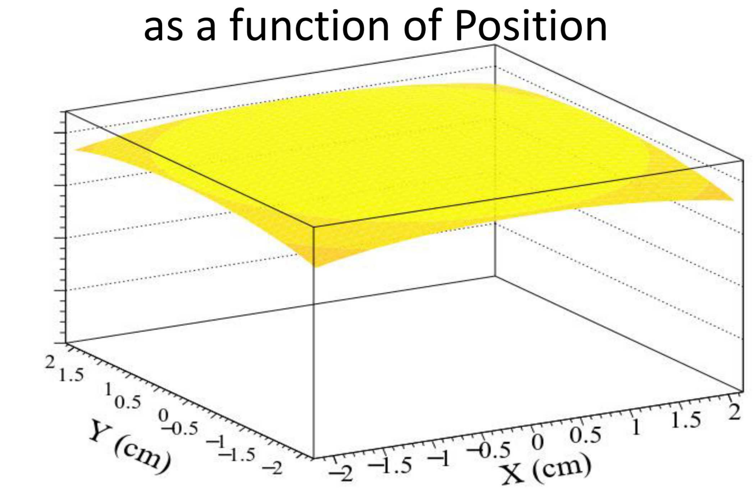
Impact

- A series of scintillator characterizations have been conducted to provide information for the event reconstruction and imaging algorithms of the SVSC project
- The increased knowledge of scintillator performance enables parametric studies for the next iteration of single volume scatter camera prototype
- Publishing the results in the open literature allows the use of the work performed in this project to benefit other detections systems development which require advanced knowledge of scintillator performance

EJ204 Likelihood Surface as a function of Position



EJ232Q Likelihood Surface as a function of Position



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