Nuclear Science and Security Consortium
Virtual Scholar Showcase 2020

Organic Scintillator Characterization for Neutron Detection

June 3, 2020

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Introduction

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(Nuclear Engineering)

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(California)

Optically Segmented Single-Volume Scatter Camera

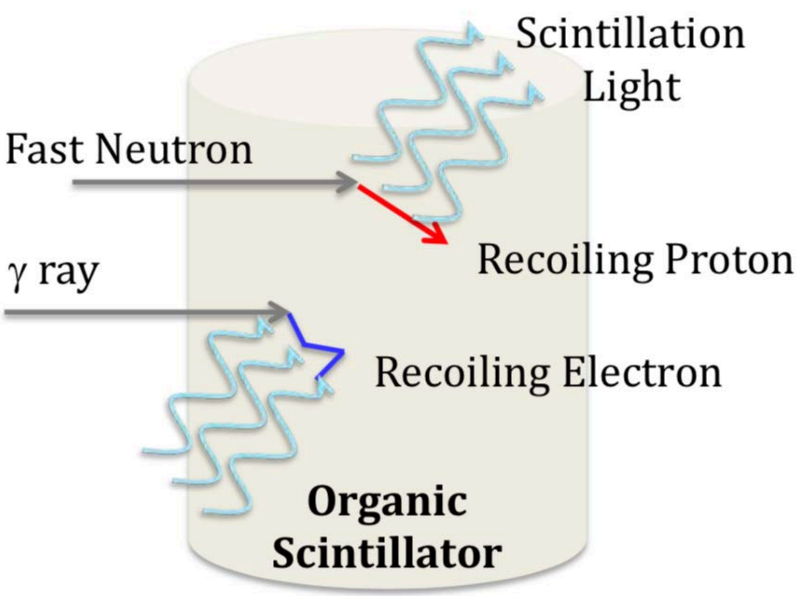
- Scintillator characterization (UCB/LBNL)
- Simulation and imaging studies (SNL)

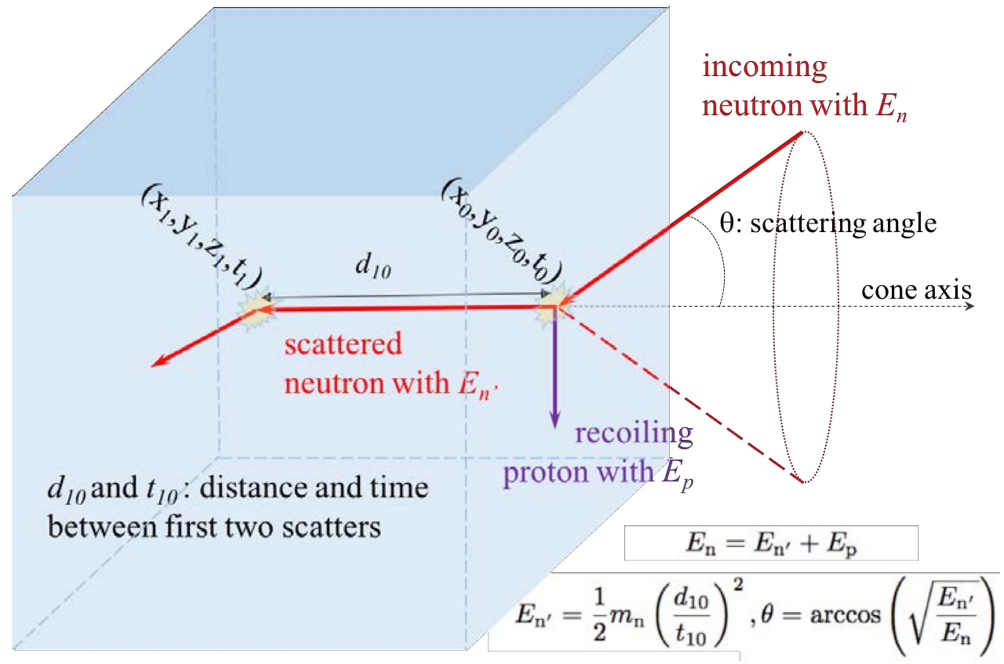
Focus Area: **Radiation Detection and Instrumentation**

Crosscutting Area: **Modeling and Simulation**

Organic scintillators for national security

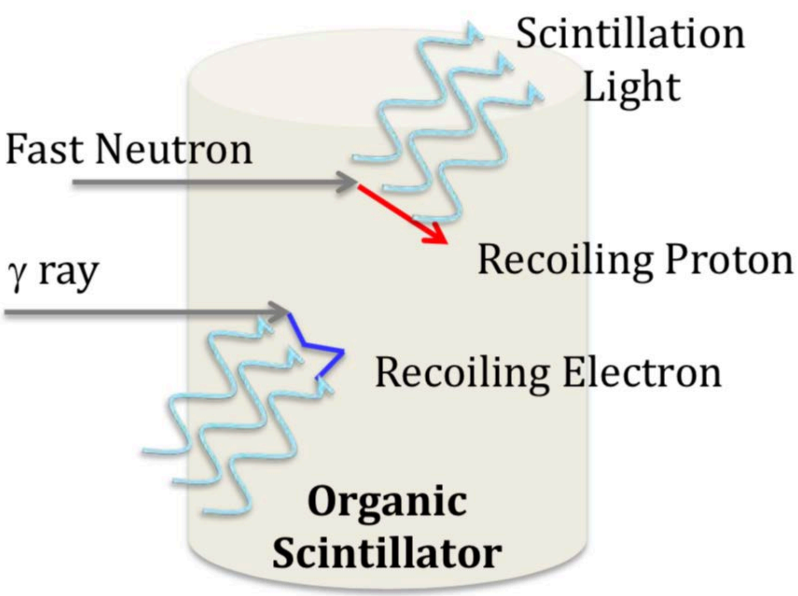
- Organic scintillators can detect fast neutrons via np-elastic scattering
- Fast neutron detection central to NNSA Mission (SNM search/standoff detection, imaging, cargo screening, arms control, emergency response)
  - e.g., Single Volume Scatter Camera (Sandia, Brubaker)

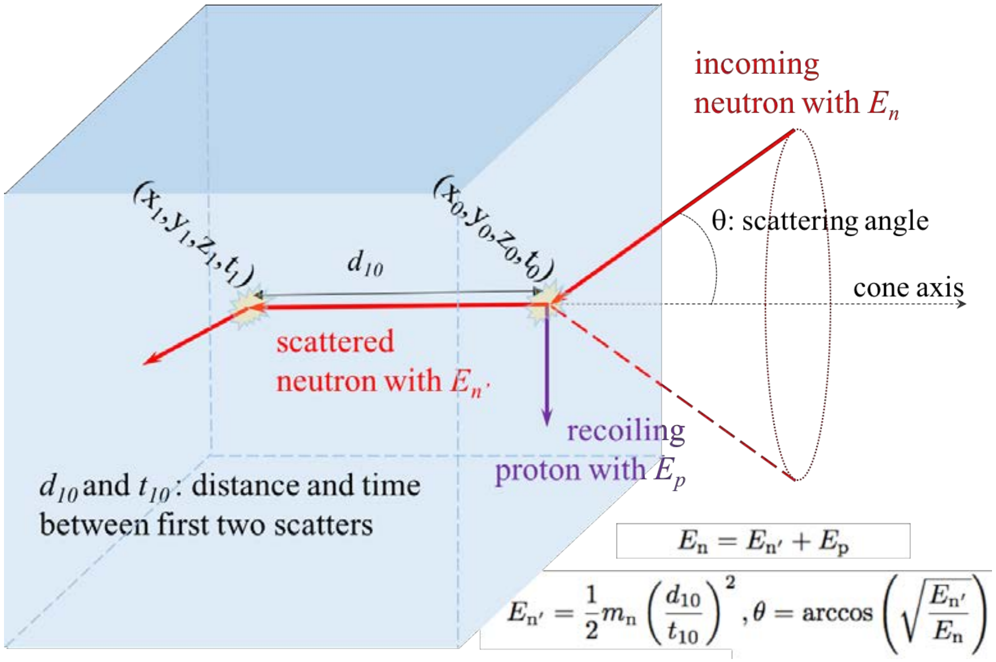




Organic scintillators for national security

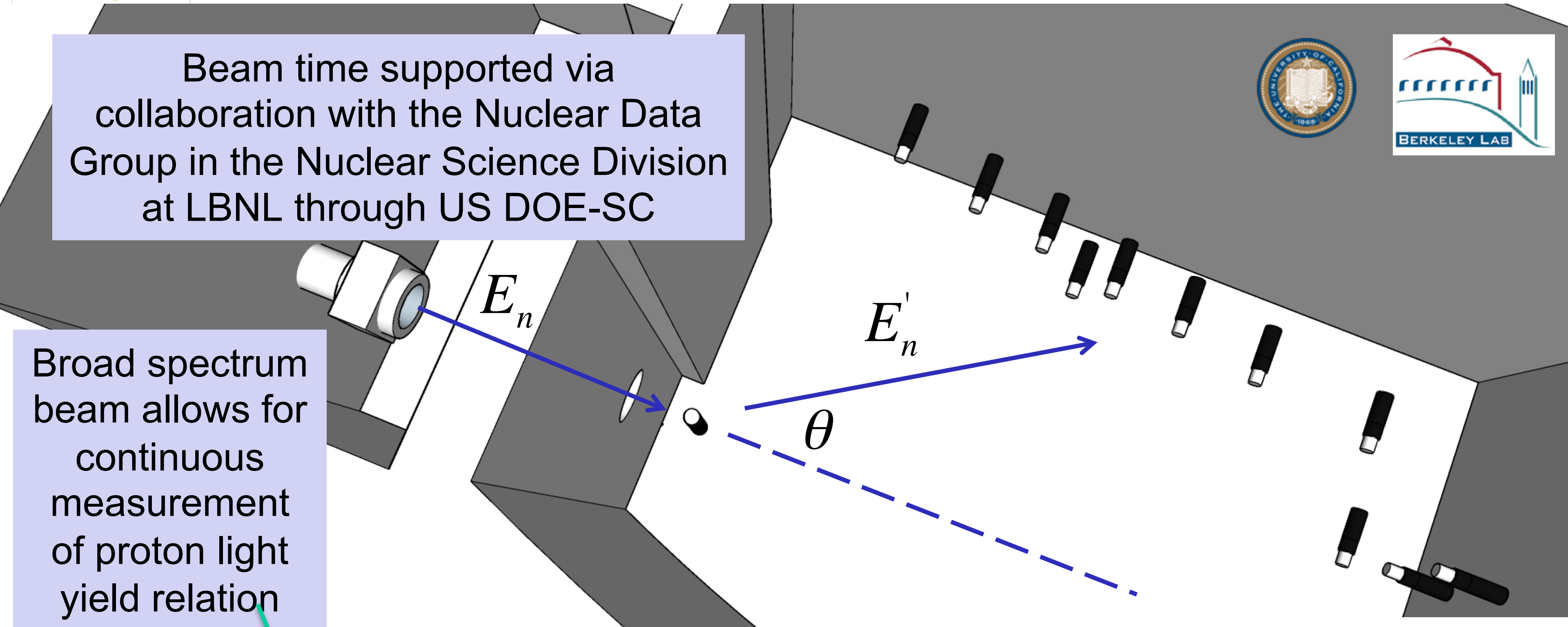
- In this talk, I will discuss three different research efforts related to the characterization of organic scintillators
  - Proton light yield of several SVSC candidate materials
  - Novel organic glass from Sandia
  - Pulse height vs. pulse integral for proton light yield



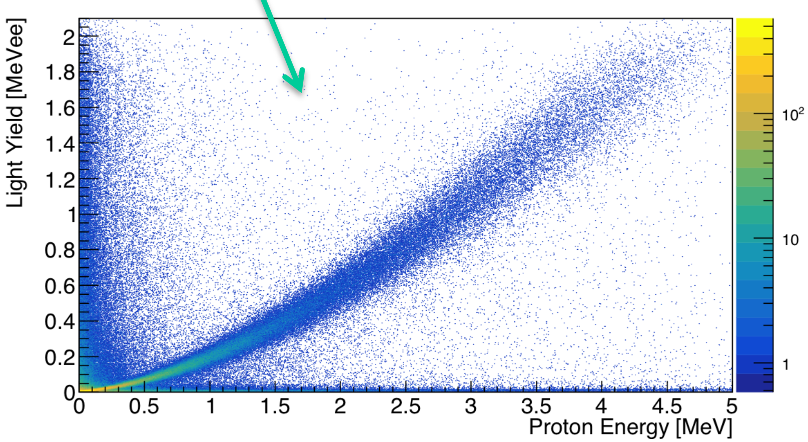


PLY measurements at UCB/LBNL

Beam time supported via collaboration with the Nuclear Data Group in the Nuclear Science Division at LBNL through US DOE-SC



Broad spectrum beam allows for continuous measurement of proton light yield relation



Kinematically over-constrained system provides systematic check

$$E_p = E_n' \tan^2\theta$$

$$E_p = E_n \sin^2\theta$$

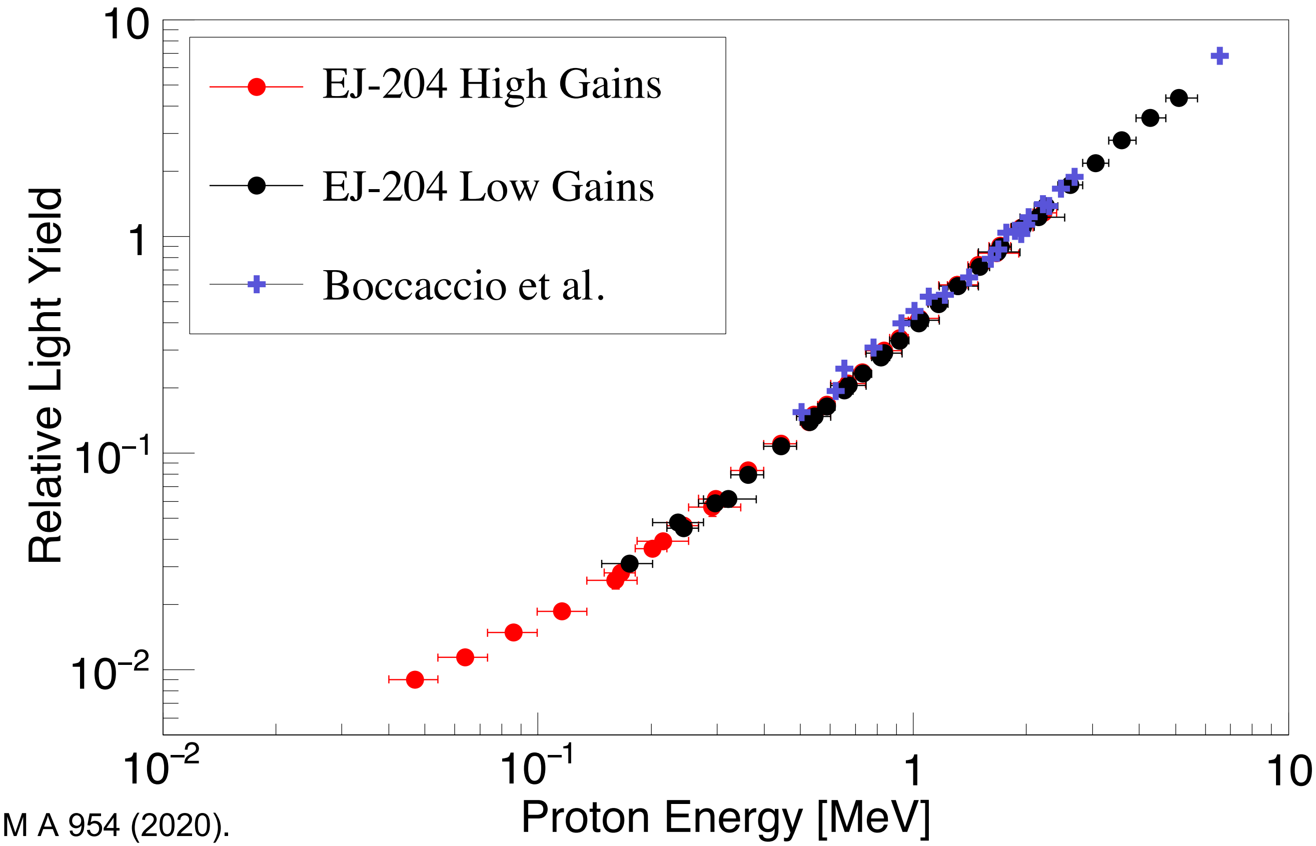
$$E_p = E_n - E_n'$$

J.A. Brown, PhD Thesis, UC Berkeley 2017.

J.A. Brown, et al. Journal of Applied Physics 124, 045101 (2018).

Proton light yields: EJ-20X

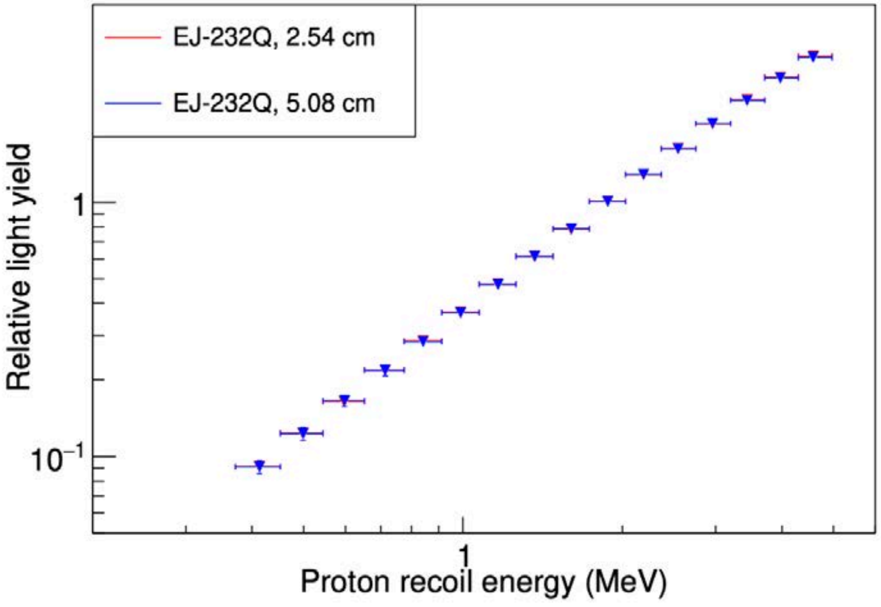
- Several plastic scintillators from Eljen that are considered candidate materials for the SVSC were measured: EJ-200, **EJ-204**, EJ-208
- Results show similar light yields for all three (due to shared PVT base)
- Light yield was measured from **50 keV** to 5 MeV, allowing for constraints on physics-based scintillation models

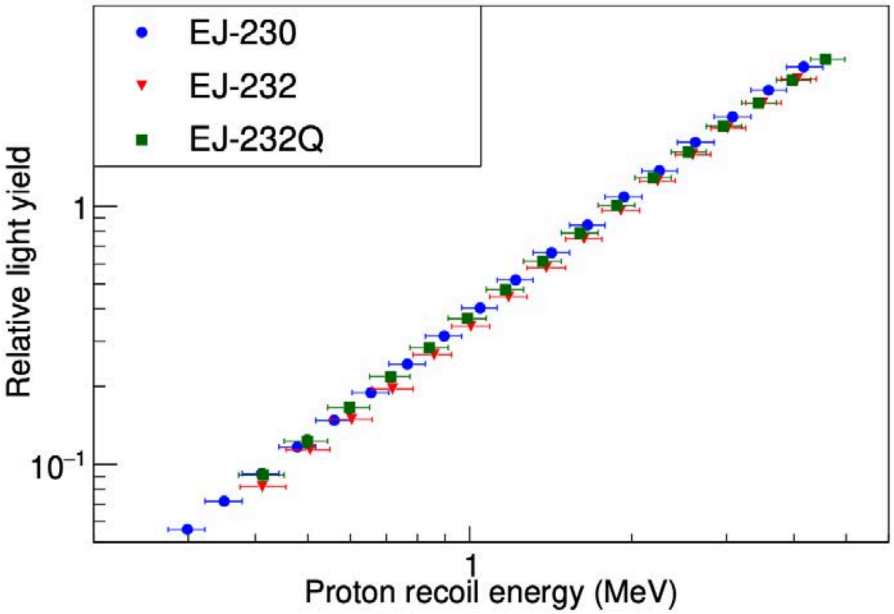


Laplace, et al. NIM A 954 (2020).

Proton light yields: EJ-23X

- Measurements of fast plastic materials also being considered for the SVSC (EJ-230, EJ-232, EJ-232Q) show proton light yield consistent with EJ-20x series (same PVT base)



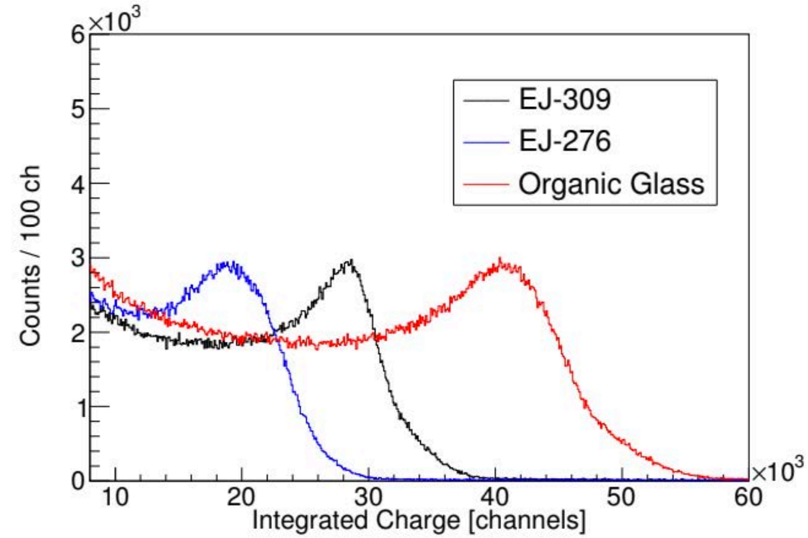


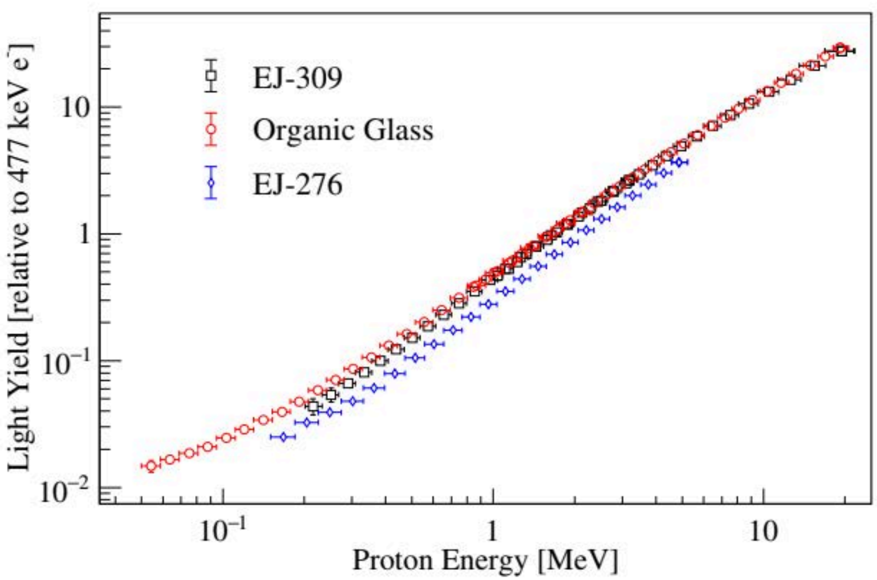
- Does scintillator size affect the relative proton light yield?
- EJ-309 measurement in Enqvist, et al. NIM A 715 (2013) said yes
- Our work shows that there is no size dependence for EJ-232, EJ-232Q (which have short attenuation lengths)

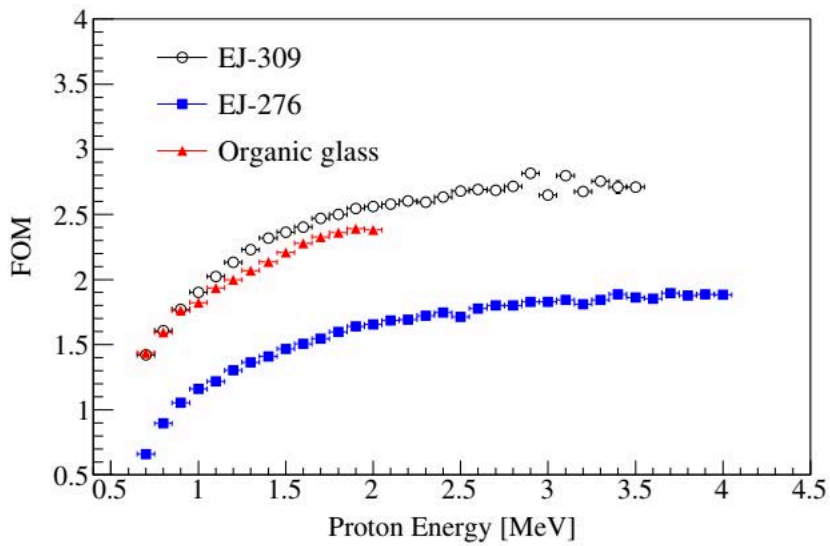
J.J. Manfredi, et al. IEEE Trans. Nucl. Sci. 67 (2020).

Novel organic glass developed at Sandia

- Novel melt-cast organic glass material has been developed at Sandia Livermore
- Relative electron light yield, proton light yield, and PSD have been characterized and compared to EJ-309 and EJ-276







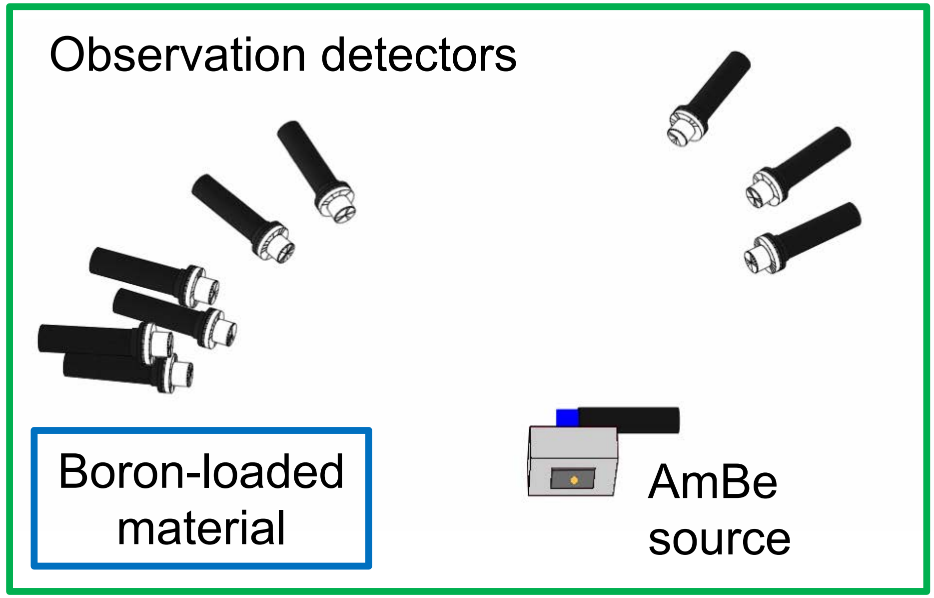
J.S. Carlson and P.L. Feng, NIM A 832 (2016).
T.A. Laplace, et al., IEEE Trans Nucl Sci (submitted).

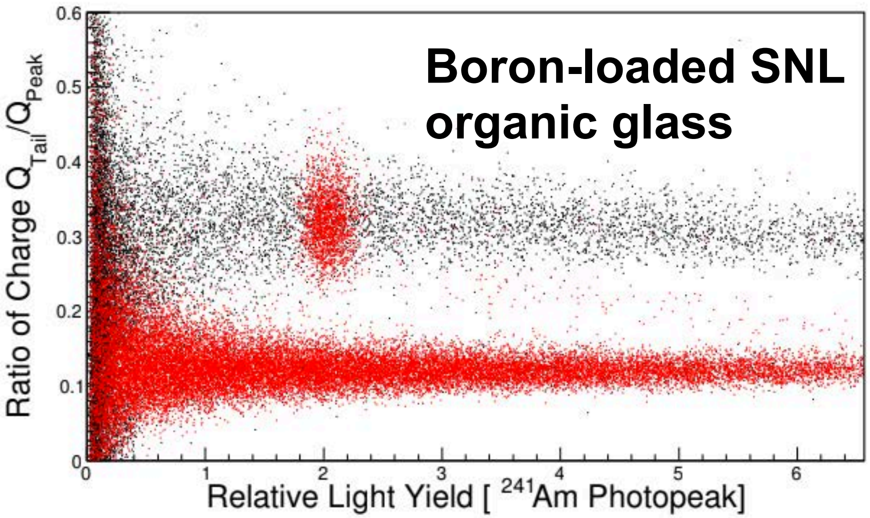
Boron-loaded organic glass

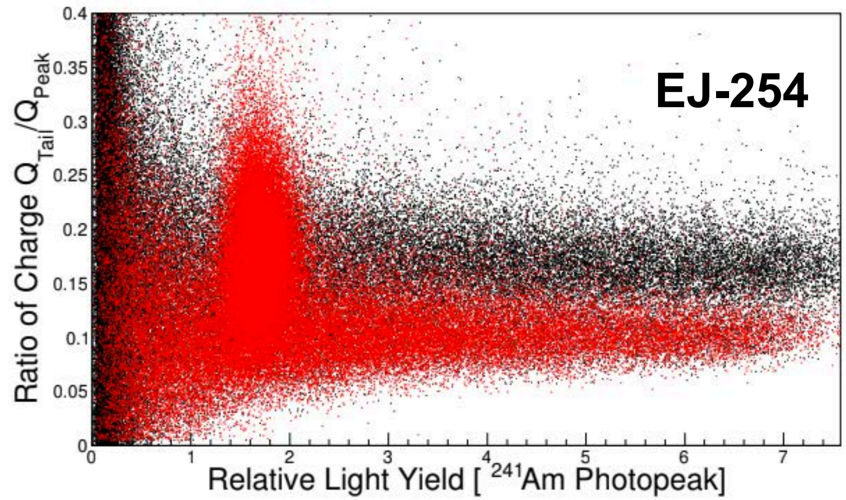
- SNL glass can be loaded with boron to add thermal neutron detection via:

$$^{10}B + n = \begin{cases} ^{7}Li + \ ^{4}He, & \text{Q= 2.792 MeV, 6\%} \\ ^{7}Li + \ ^{4}He + \gamma(477.6\ \text{keV}), & \text{Q= 2.310 MeV, 94\%} \end{cases}$$

- Using 478 keV gamma + observation PSD, **neutron scatter events** and **capture/gamma scatter events** can be separated in target PSD (below)



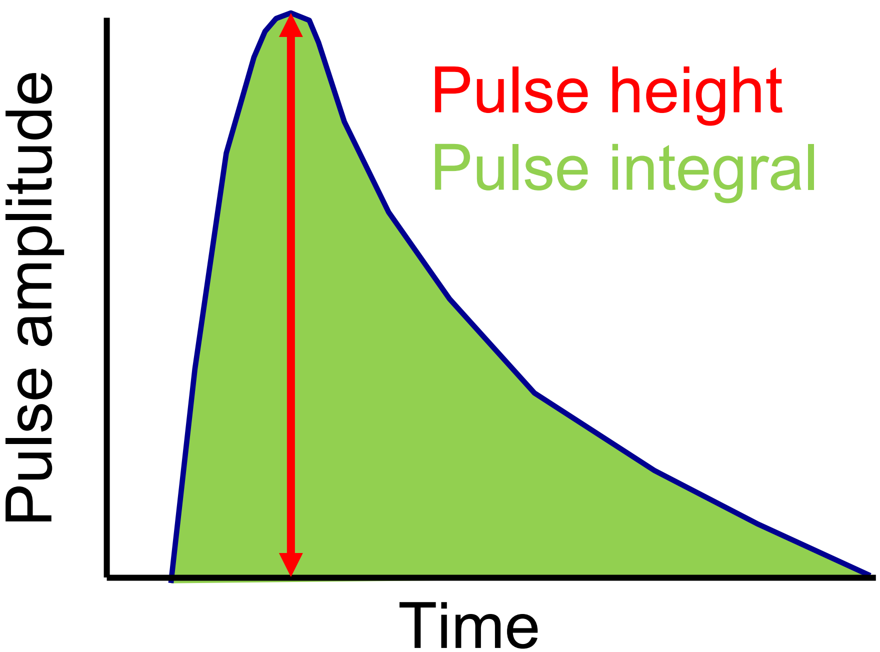


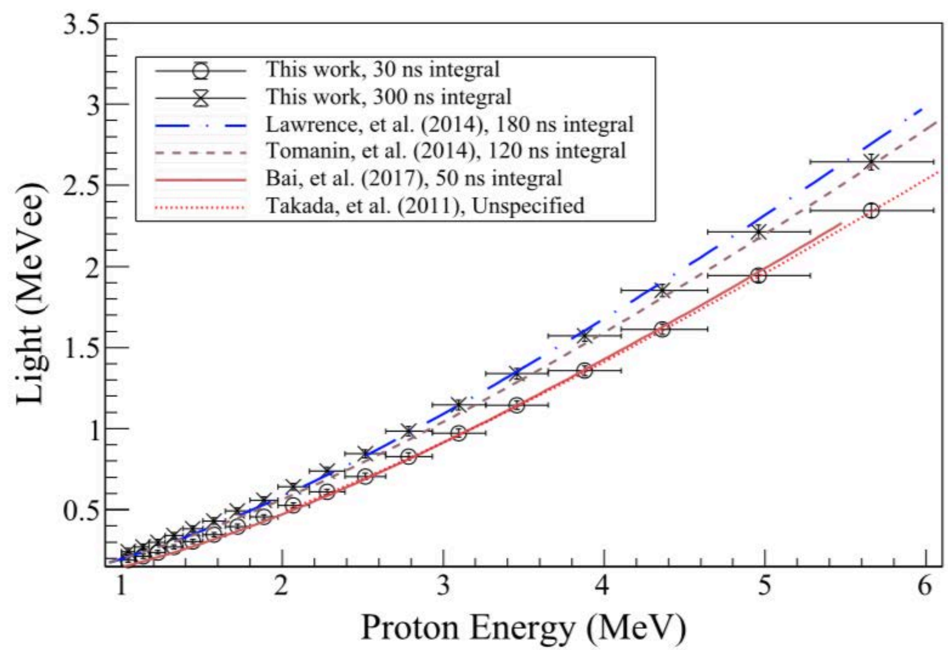


G. Gabella, et al., in preparation.

Pulse height vs. pulse integral

- Light yields are sometimes reported using the pulse height (PH) of the digitized photodetector trace (or with a short integration length)
  - Strictly speaking, only the total pulse integral (PI) of a digitized trace is proportional to the number of scintillation photons
- Literature shows discrepancies in proton light yield for EJ-309
  - Wide range of integration lengths used

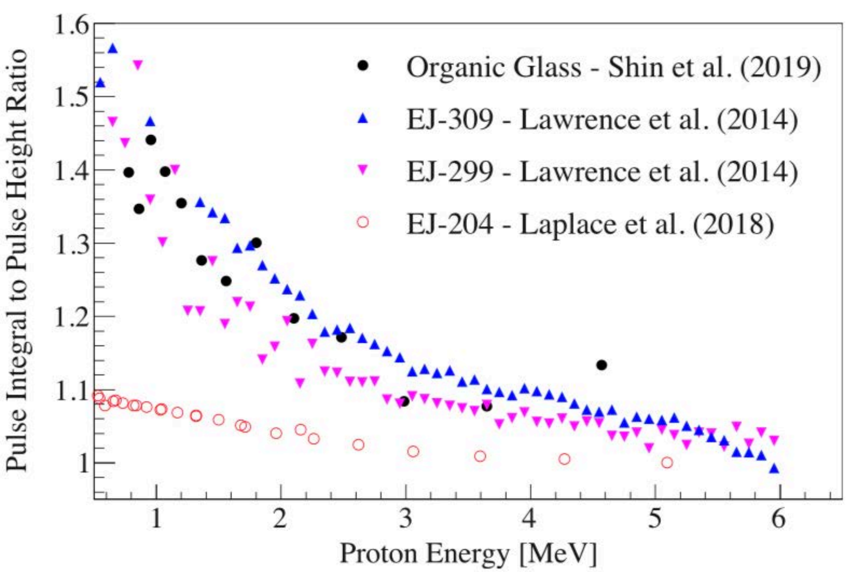


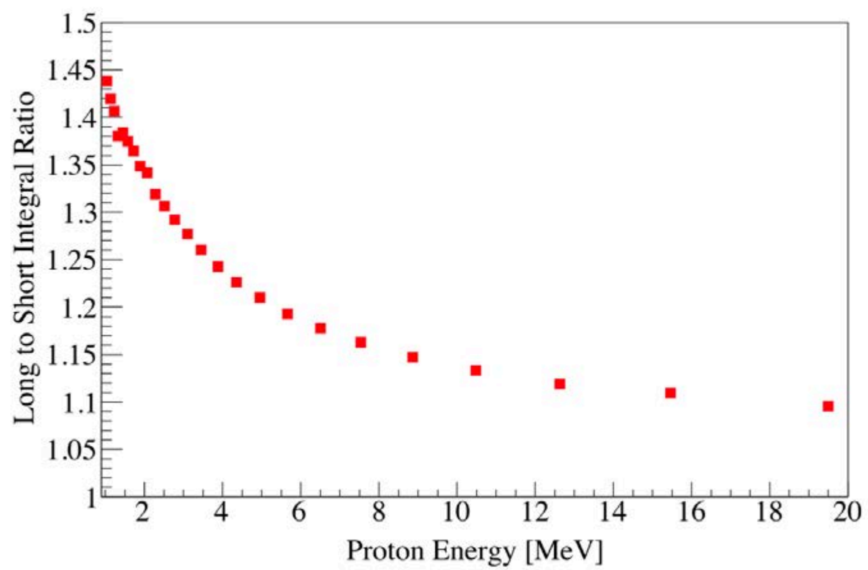


J.A. Brown, et al. Journal of Applied Physics 124, 045101 (2018).

Pulse height vs. pulse integral

- In organic scintillators pulse can be dependent on both particle and energy, implying that PH and PI are not proportional
- Comparison of proton light yields from PI and PH (or short integration length PI) show clear energy-dependent bias in relevant energy range
- Light yield measured with digitizer should use PI!



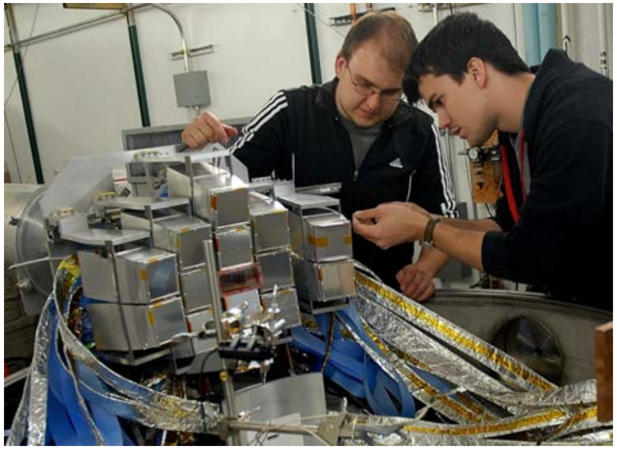


T.A. Laplace, et al. NIM A 959 (2020).

Summary

- **Relative proton light yield for several organic scintillators**
  - Consistent results across different materials with same PVT base
  - No size dependence found for EJ-232, EJ-232Q
- **Novel organic glass from Sandia Livermore**
  - Performs favorably (electron light yield, proton light yield, PSD) compared to commonly used PSD materials
  - Boron-loading allows for thermal neutron capture signal and outperforms commercially available EJ-254
- **Pulse height vs. pulse integral**
  - Proton light yields should be calculated using pulse integral, even for non-PSD materials

NSSC Experience + History



May 2012, BA in Mathematics, Physics from WUSTL

August 2012, NSCL Fellow at MSU

September 2013, NNSA Stewardship Science Graduate Fellowship

Summer 2014, Practicum at LLNL

July 2018, PhD in Physics from MSU

August 2018, Postdoctoral Scholar at UCB (in collaboration with LBNL, SNL)

June 2019, presented at UPR

May 2020, NSSC Postdoctoral Fellow at UCB

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