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Office of Defense Nuclear Nonproliferation Research and Development

University Program Review (UPR) 2019 Meeting

An Optically Segmented Single-Volume Scatter Camera for Compact, High-Efficiency Neutron Imaging

NSSC – Nuclear Science & Security Consortium

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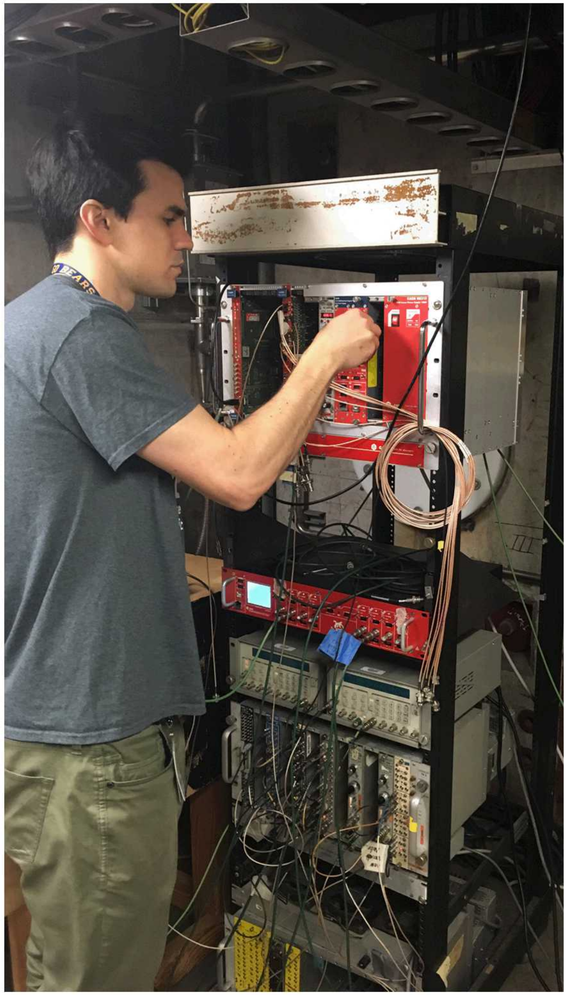
Introduction

Postdoctoral Scholar/NSSC Affiliate



Bethany Goldblum

(Nuclear Engineering)

Erik Brubaker

(California)

Optically Segmented Single-Volume Scatter Camera

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

Focus Area: **Radiation Detection and Instrumentation**

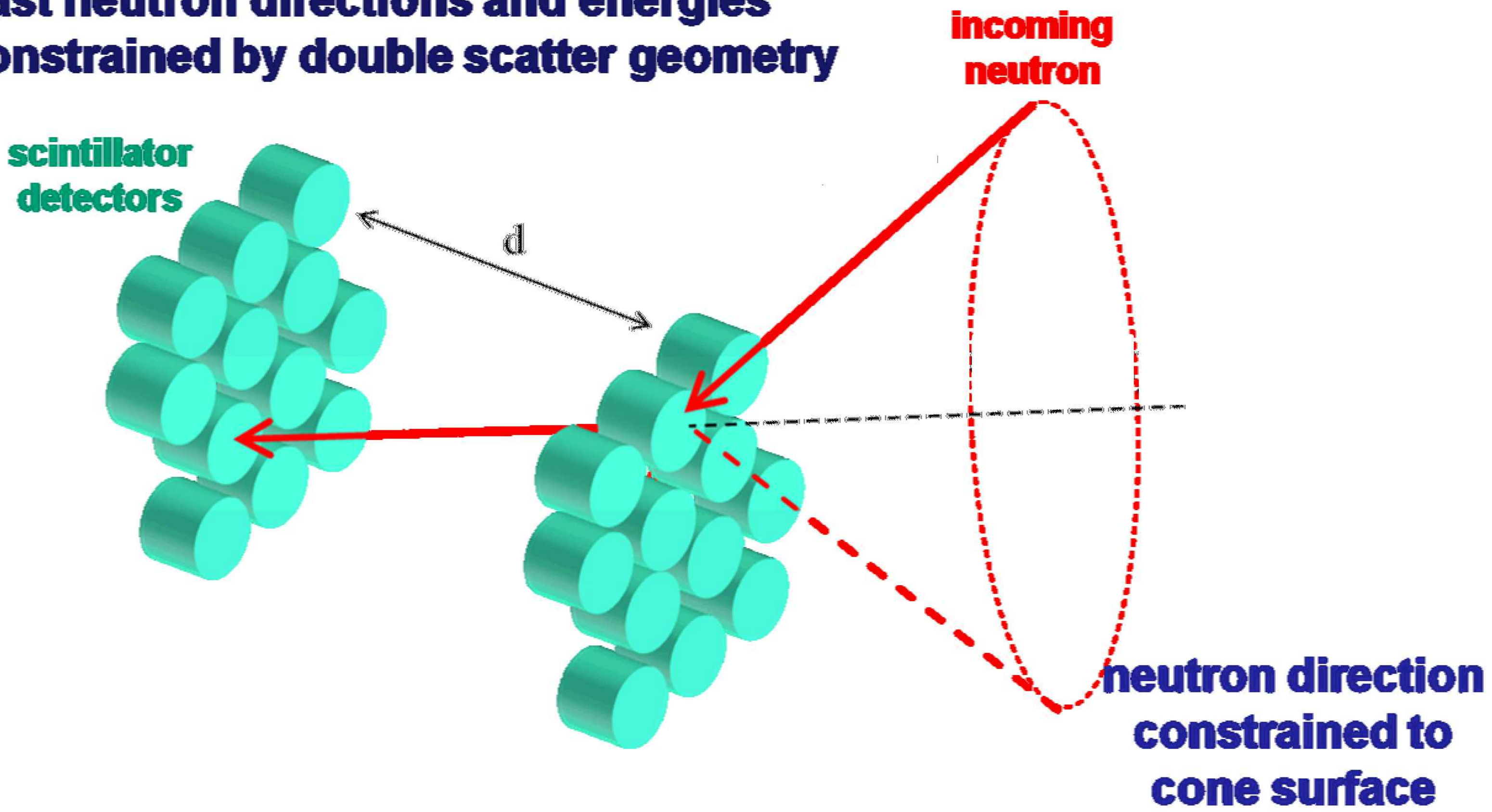
Crosscutting Area: **Modeling and Simulation**

Project Team

- Project title: “**Single-Volume Scatter Camera Development**”
- Participants: Six institutions
  – SNL/CA (lead): E. Brubaker, M. Sweany, J. Brown, J. Steele, B. Cabrera-Palmer, et al.
  – ORNL: P. Hausladen, K. Ziock, M. Febbraro, M. Folsom, J. Nattress, et al.
  – ANL: J. Elam, A. Mane, M. Gebhard, A. Letorneau
  – U Hawaii: K. Nishimura, J. Learned, A. Druetzler, A. Galindo Tellez, R. Dorrill, K. Keefe, N. Kaneshige, et al.
  – UC Berkeley/LBNL: B. Goldblum, T. Laplace, J. Manfredi, et al.
  – NCSU: J. Mattingly, K. Weinfurther, M. Mishra, A. Moustafa

Classic approach to neutron imaging

Fast neutron directions and energies constrained by double scatter geometry

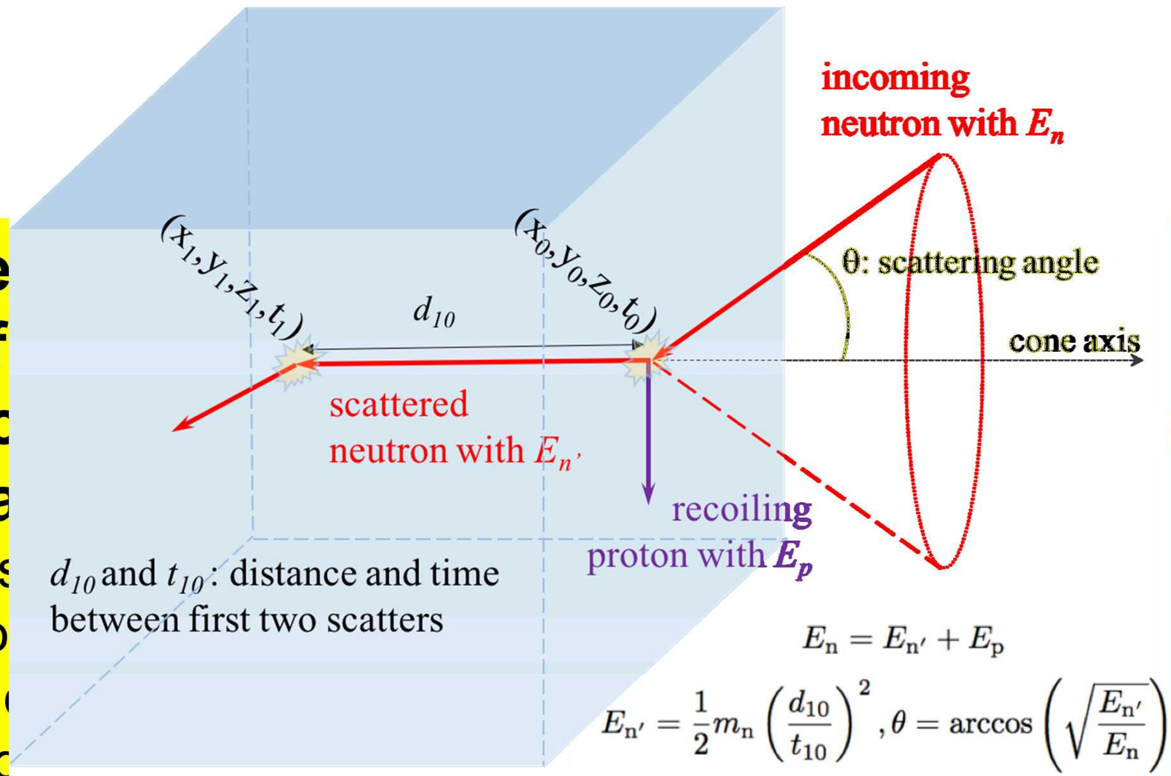


Single-volume approach

- **Two planes → single volume**

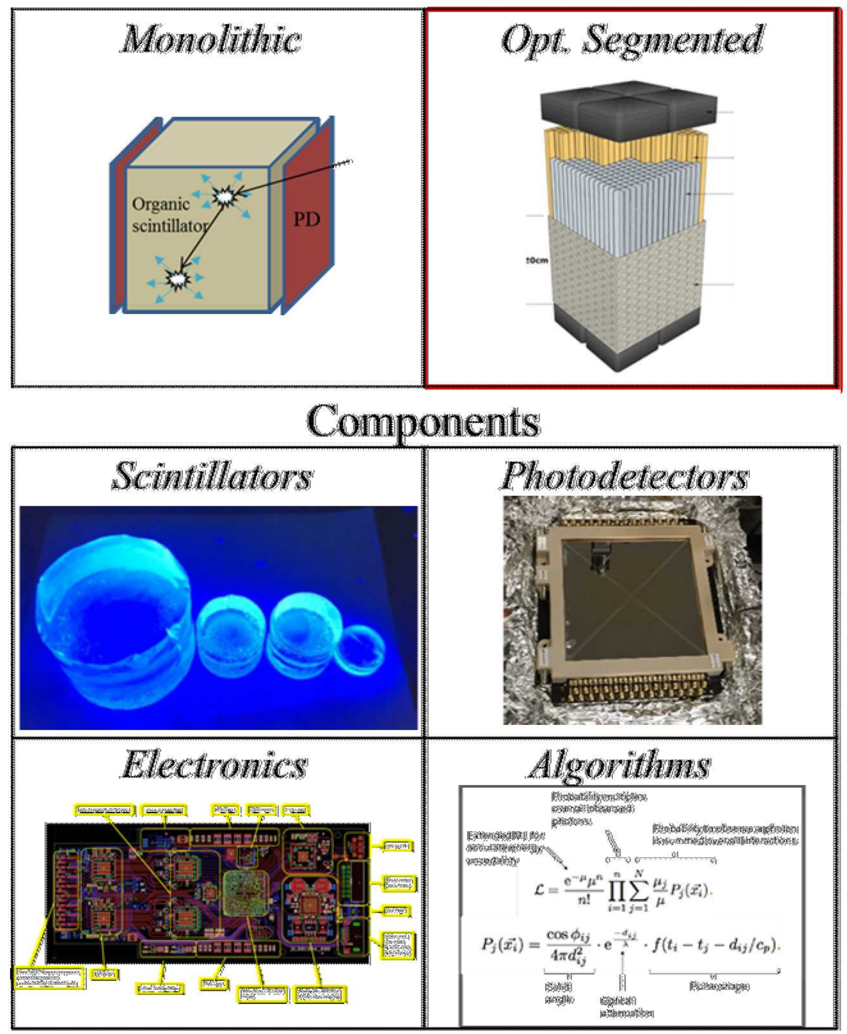
Relevance

- **High eff**
- **Compac … pproach**
- **Potentia**
  - SNM s
  - Cargo
  - Arms
  - Emerg



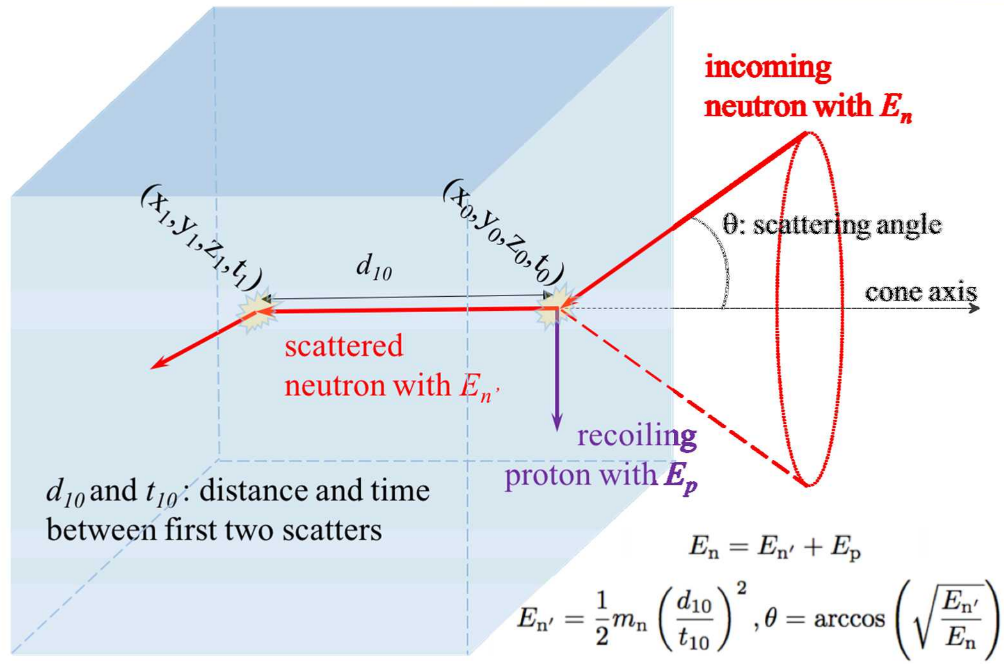
Single-Volume Scatter Camera (SVSC)

- **Two configurations:**
  - Monolithic scintillator (reconstruct positions and times from isotropically emitted photons)
  - Optically segmented scintillator (photon propagation constrained within specific channel)
- **Prototyping underway in concert with component development**



Proton Light Yield

- To calculate incoming neutron angle we must know the mapping between measured light and proton recoil energy (E_p), called the **relative proton light yield relation (PLY)**
- Previously measured PLY for the OS-SVSC candidate scintillators EJ-200, EJ-204, EJ-208: see Laplace, et al. NIM A (2018)
- **Presented here: PLY for EJ-230, EJ-232, and EJ232Q**



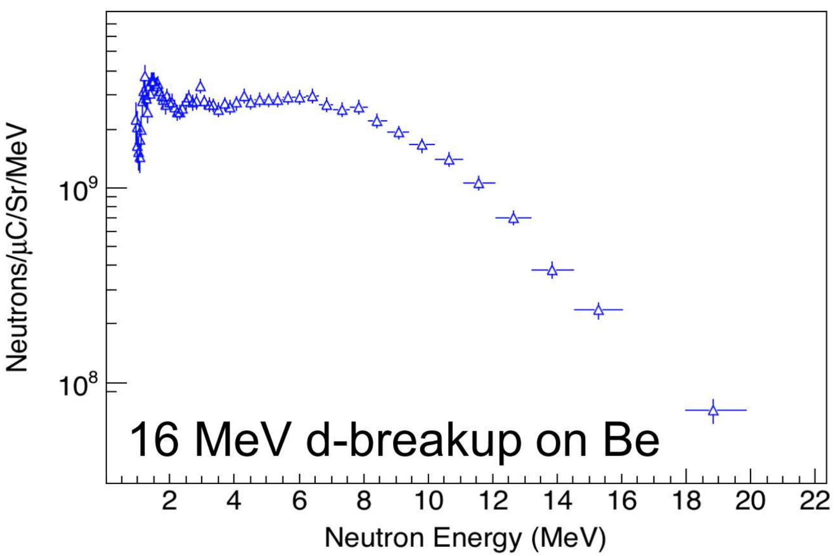
Material	Scintillation Efficiency (photons/MeVee)	Rise Time (ps)	Decay Time (ns)	Commercial Equivalents
EJ-230	9700	500	1.5	BC-420
EJ-232	8400	350	1.6	BC-422, NE-111A
EJ-232Q*	2900	110	0.7	BC-422Q

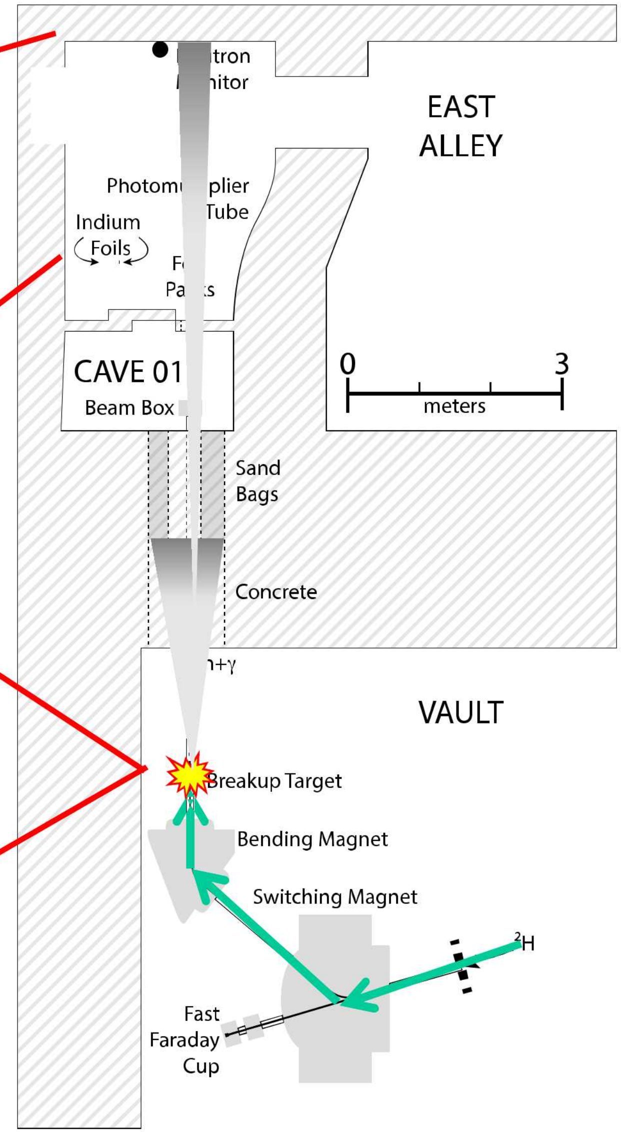
* 0.5% Benzophenone.

Sweany, et al. NIM A 927 (2019).

D-Breakup Neutrons at the 88-Inch

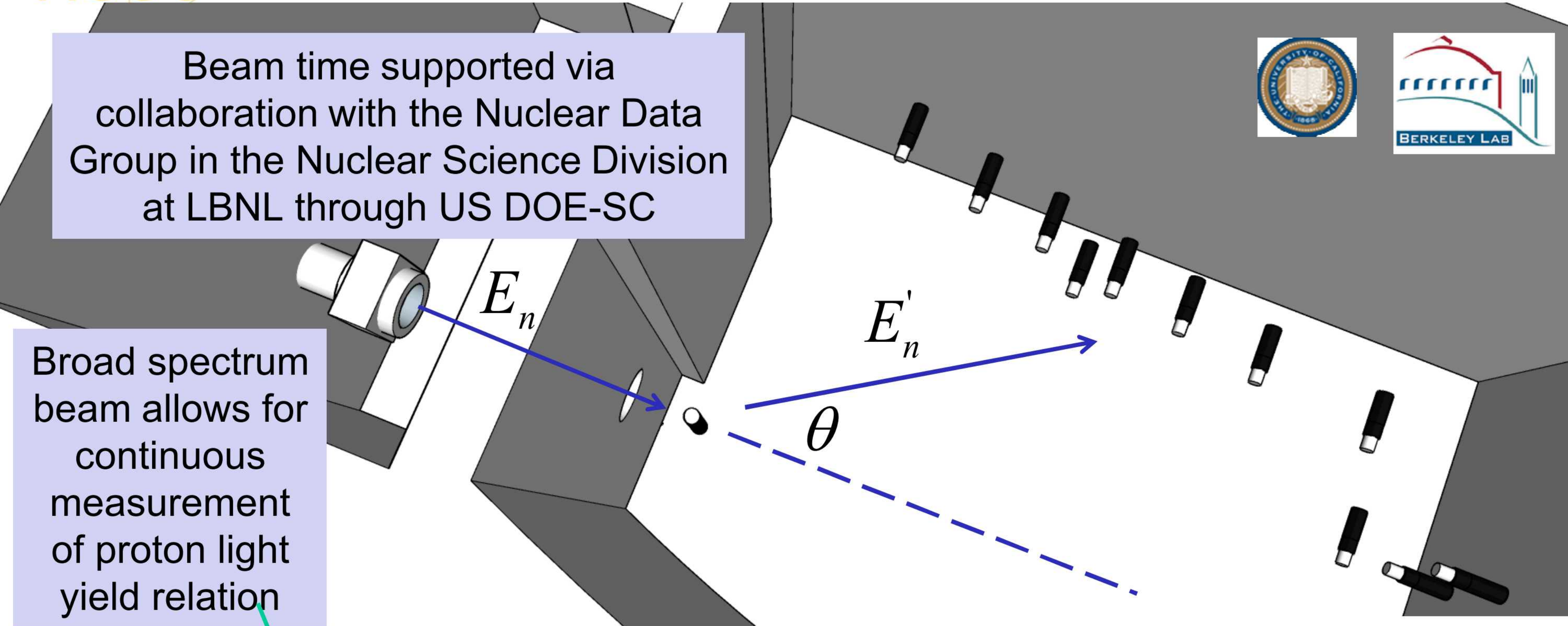
K.P. Harrig , B.L. Goldblum, et al., Nucl. Instrum. Meth. (2017).



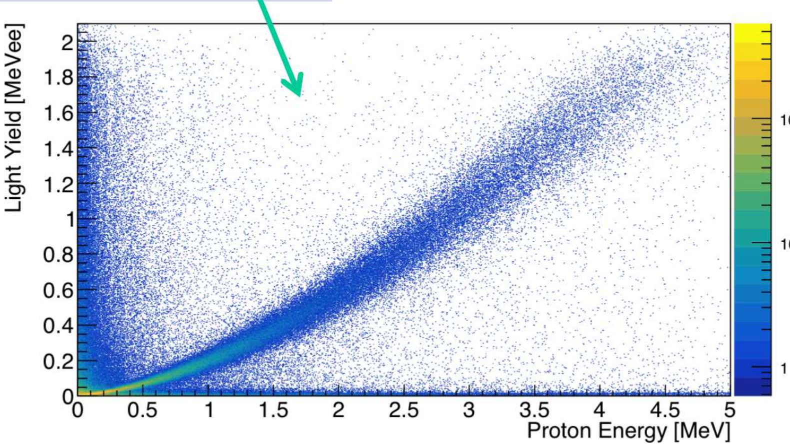


PLY Measurements at UCB/LBNL

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

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

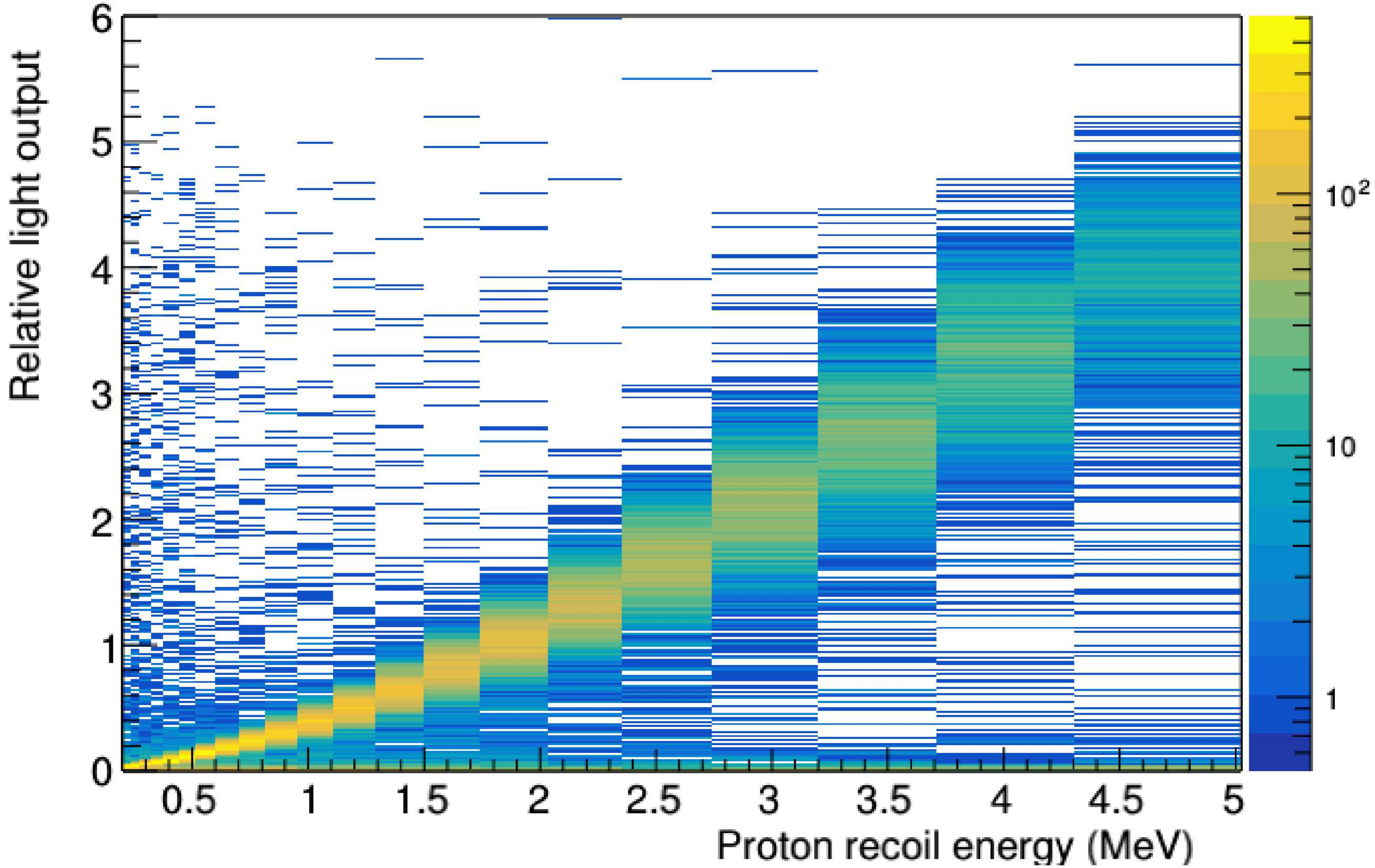
$$E_p = E_n \sin^2 \theta$$

$$E_p = E_n - E_n'$$

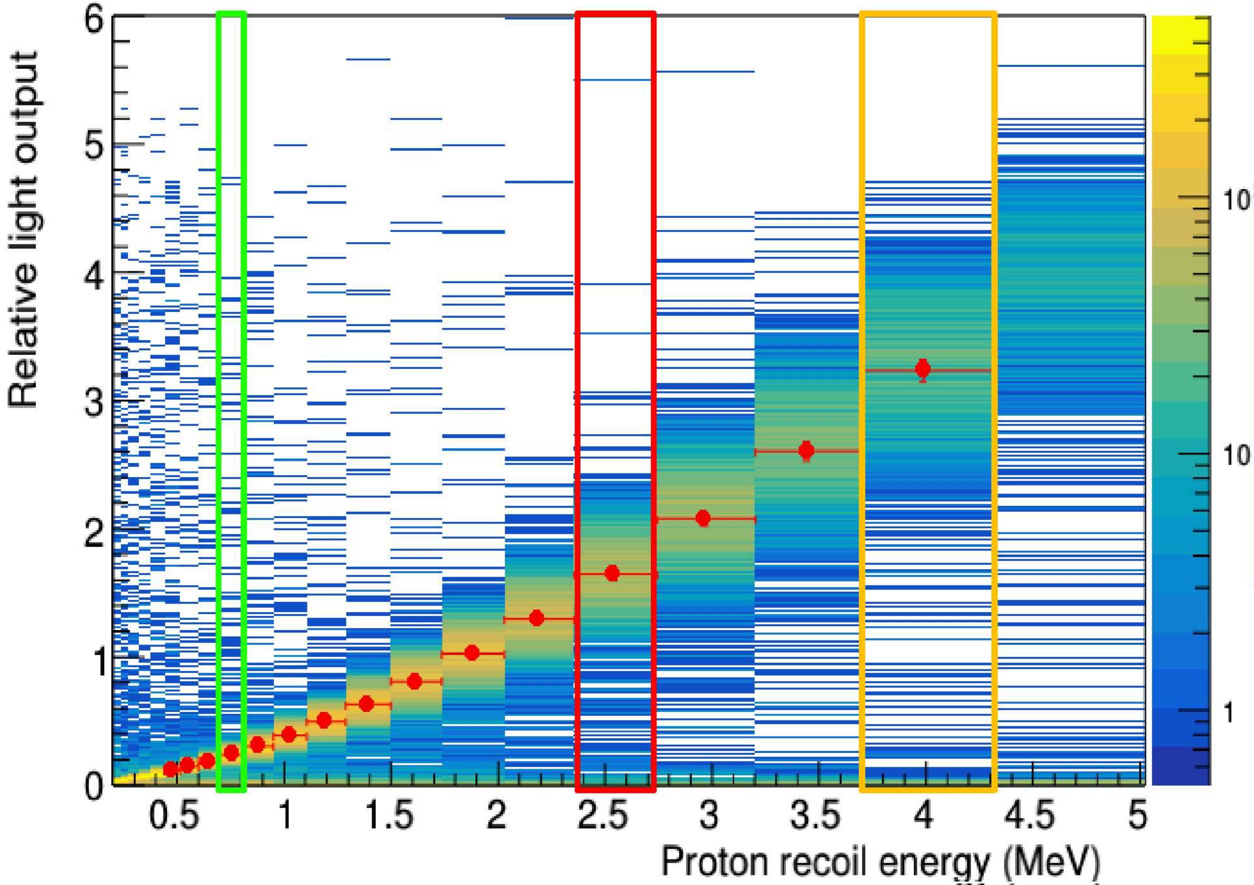
J.A. Brown, PhD Thesis, UC Berkeley 2017.

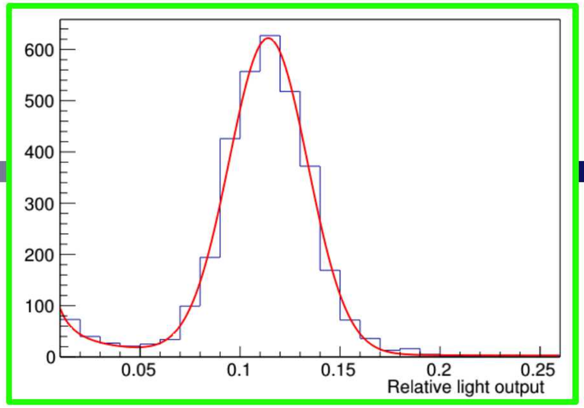
J.A. Brown, et al. Journal of Applied Physics 124, 045101 (2018).

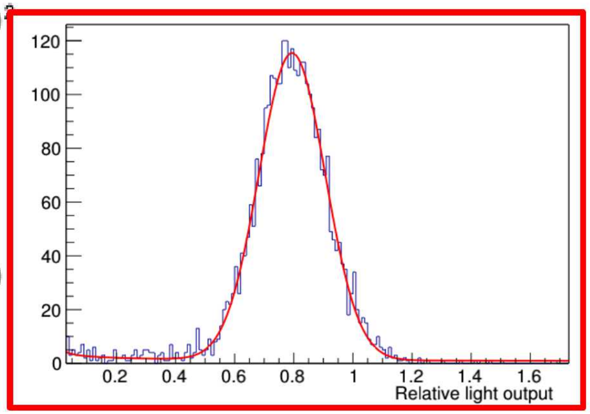
Proton recoil energy vs. light yield (EJ-230)

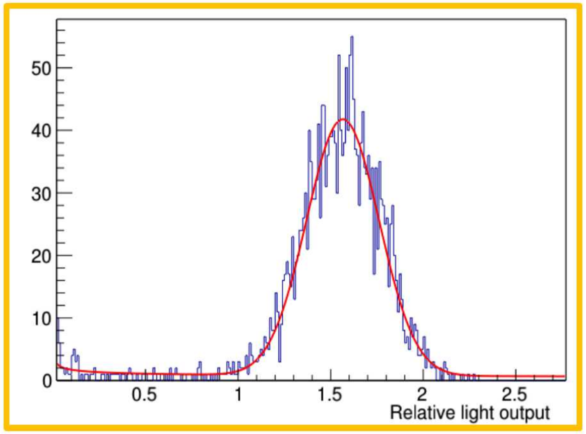


Light-yield fitting (EJ-230)



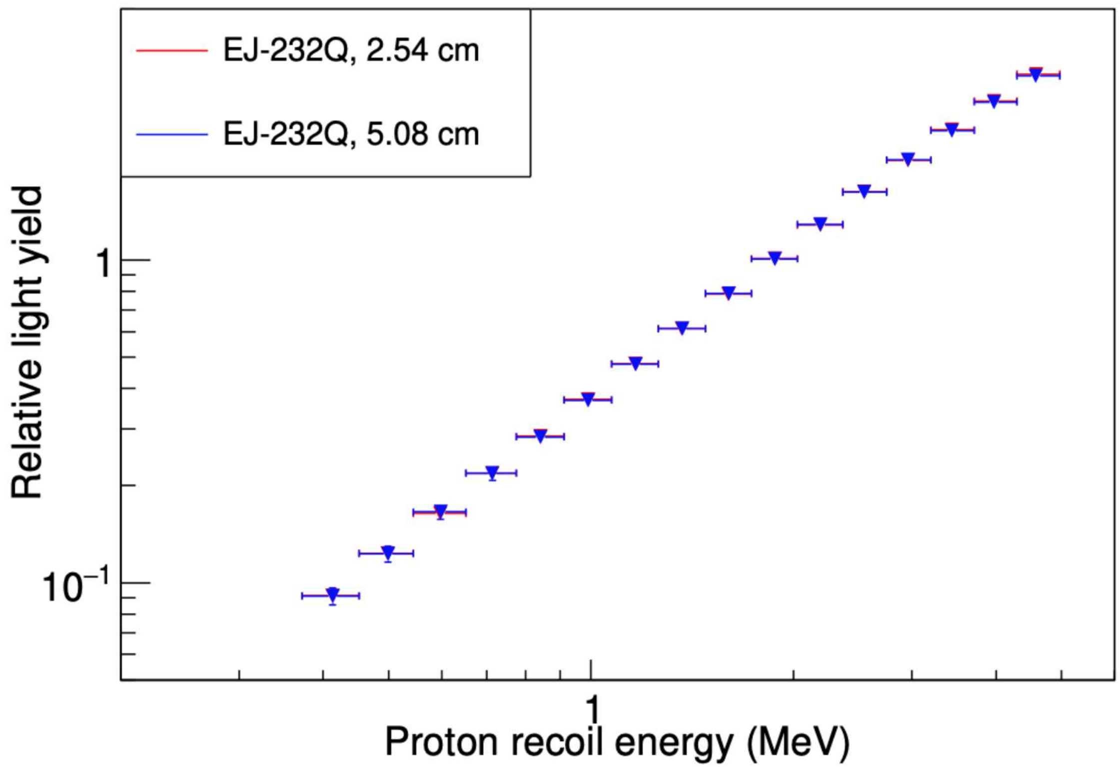






PLY Results

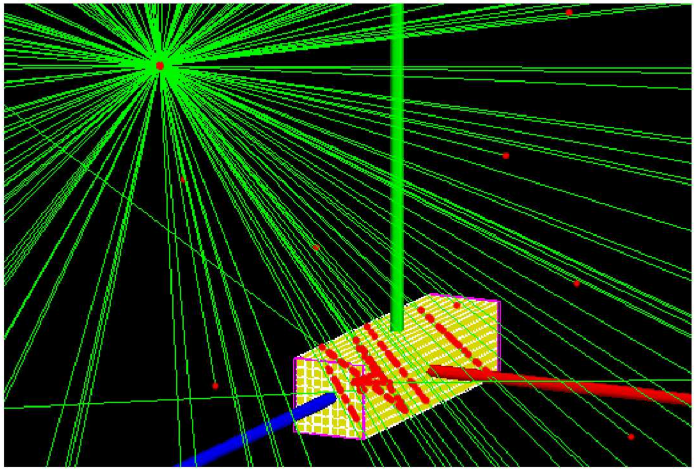
- EJ-23x results consistent with those of EJ-20x, which share the same polymer base and have similar densities, C/H ratios
- EJ-230 result disagrees with previous literature measurement
- Relative proton light yields for 2-inch and 1-inch cells are within error

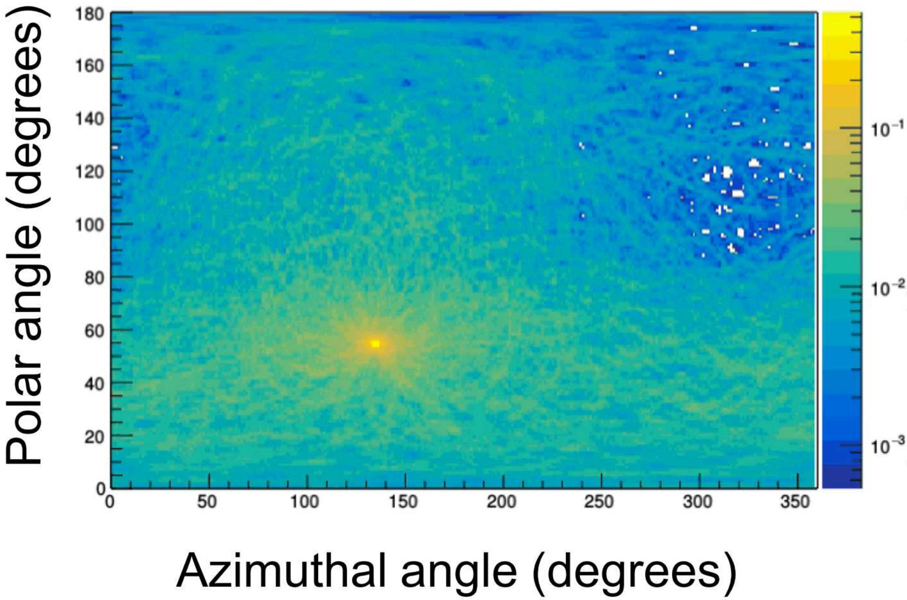


Laplace, et al. NIM A (2018).
Pozzi, et al. NIM A 524 (2004).
Enqvist, et al. NIM A 715 (2013).

OS-SVSC Simulation Development

- Component characteristics like PLY affect OS-SVSC performance
- **Goal: in simulation space, understand sensitivity of OS-SVSC imaging capabilities to device characteristics (scintillator material properties, electronics, device dimensions, etc.)**
- Lessons from simulation → future prototype development
- **Goal: create ROOT/C++ framework that can analyze both simulation data and experimental data from the OS prototype**





Future Work

- **Big picture: develop → prototype → evaluate → develop …**
  - First generation prototype currently under construction at UH-Manoa
- **Modeling study @UCB/SNL to determine the best path forward for imaging:**
  - How do timing, position, PSD, energy resolution, and threshold map to imaging metrics such as resolution, contrast, artifacts, etc. for a given source and acquisition time?
  - For OS specifically: how do imaging metrics change with source position?
- **Absolute LY measurements of candidate scintillators**

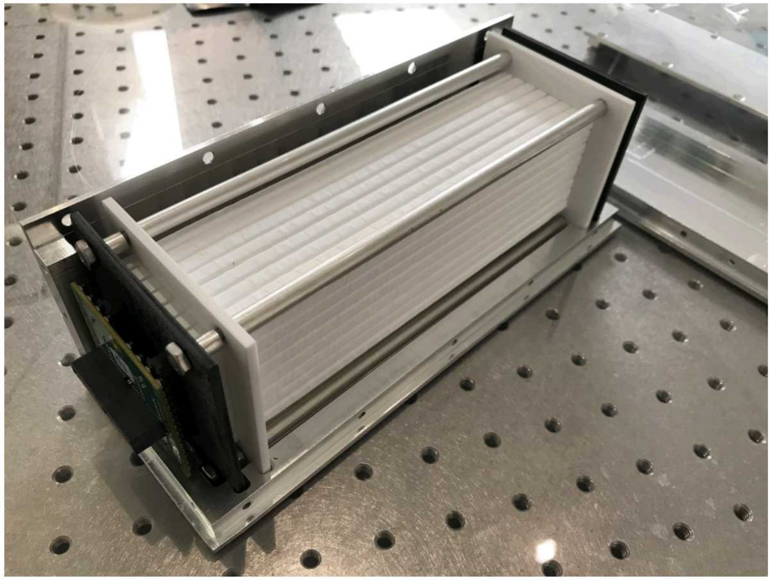


Photo credit: Nathan Kaneshige

Red box: What I will focus on

Acknowledgements

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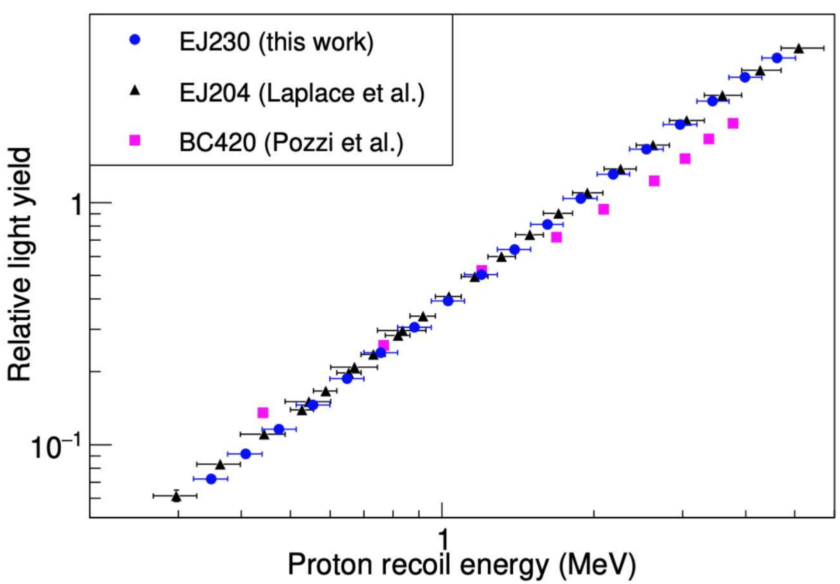
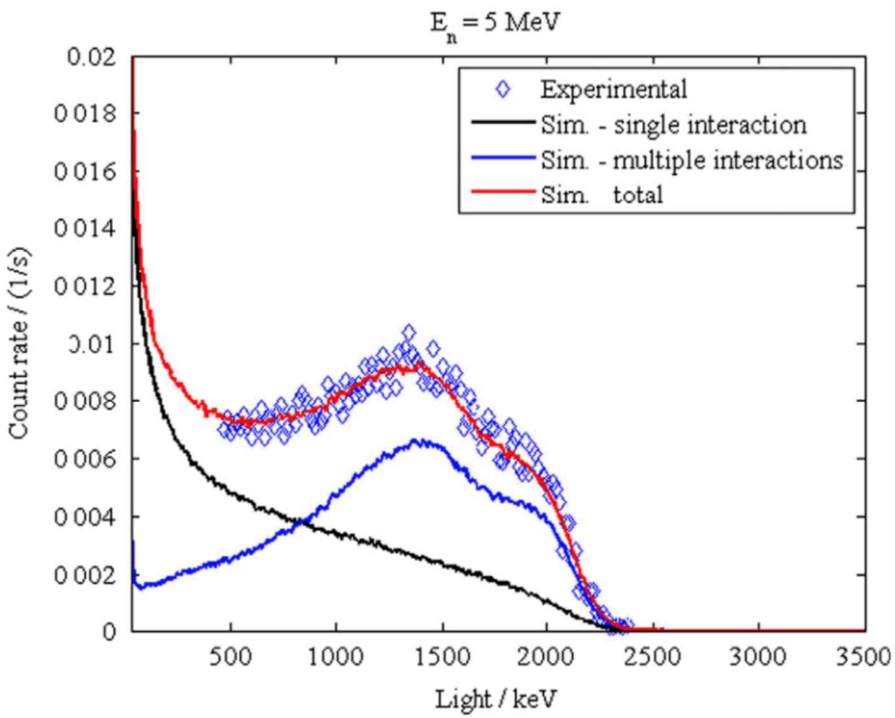
Comparison to literature

- EJ-230 results disagree with previous measurement of commercial equivalent
- Potential issue with Pozzi results: multiple scattering





Pozzi, et al. NIM A 524 (2004).
Tomanin, et al. NIM A 756 (2014).