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LOW ENERGY LIGHT YIELD OF FAST PLASTIC SCINTILLATORS

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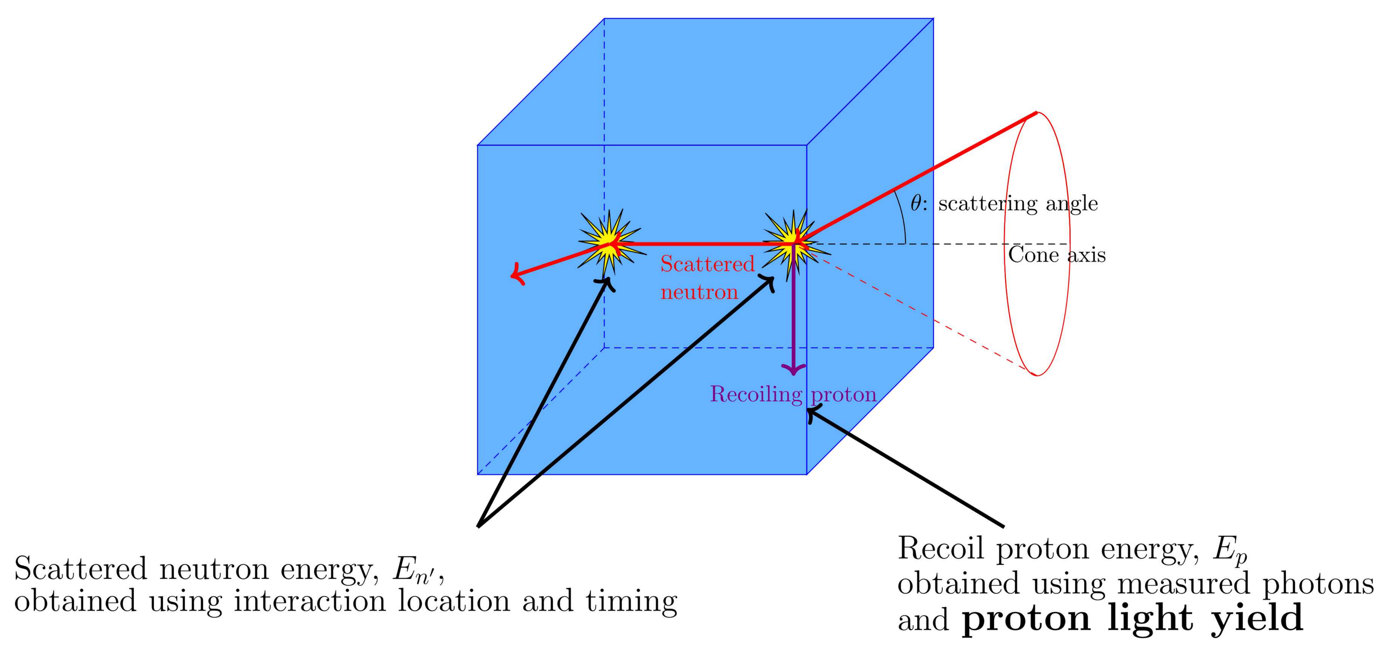
MOTIVATION

A **compact double scatter neutron imager** is being developed as part of a multi-institution collaboration led by Sandia National Laboratories for **weak threat source detection** and other **nuclear security applications**.



The Single Volume Scatter Camera (SVSC) concept allows reconstruction of the incoming neutron energy and direction:

$$E_n = E_{n'} + E_p \quad \text{and} \quad \theta = \arccos(\sqrt{E_{n'}/E_n})$$

Eljen Technology's fast plastic scintillators EJ-200, EJ-204 and EJ-208 are potential candidates for the SVSC:

- fast rise time ($\leq$1 ns)
- long optical attenuation length ($\sim$1.5 - 4 m)

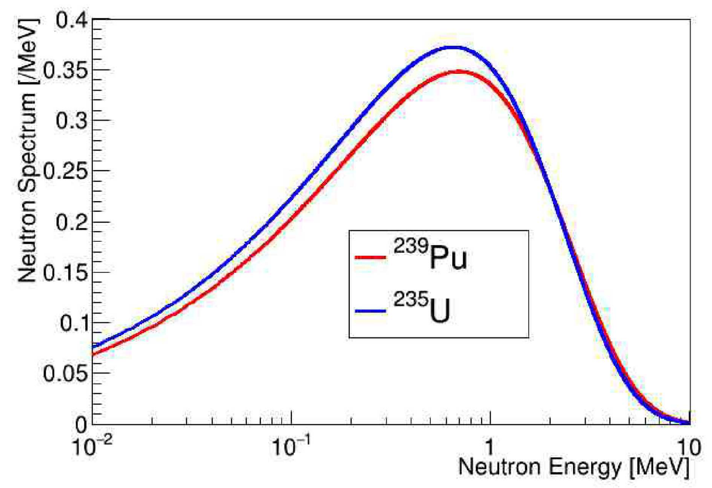
Material equivalence

EJ-200	BC-408	Pilot F
EJ-204	BC-404	NE-104
EJ-208	BC-412	NE-110

LOW ENERGY FOCUS

Current state: Existing physics-based models of **proton light yield** give unreliable extrapolation to low energies

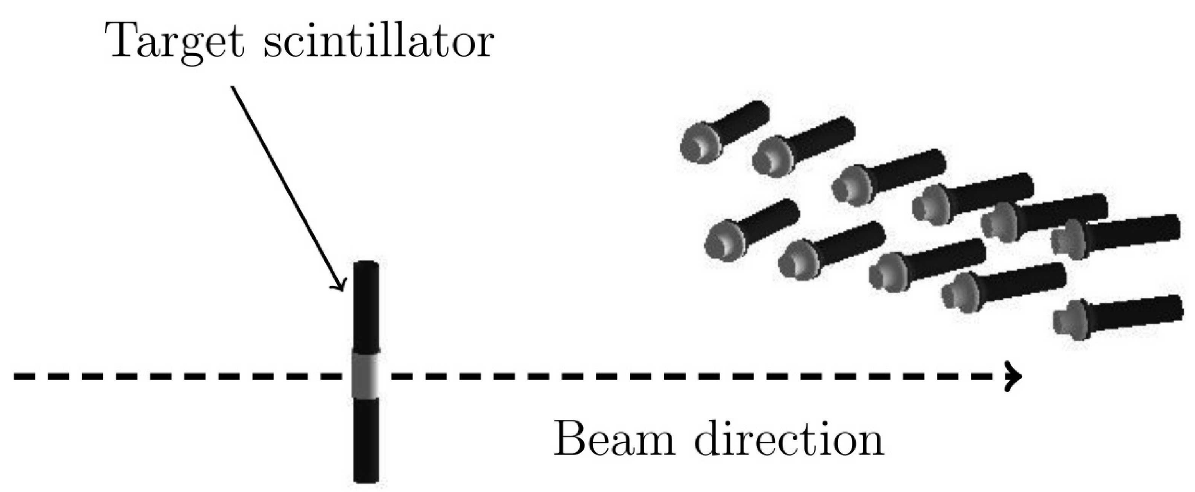
- Accurate assessment of scintillator light yield is a key input to double-scatter kinematic image reconstruction
- Passive neutron spectrum from SNM has significant contribution from low energy neutrons



Fission neutron spectra of ^{235}U and ^{239}Pu

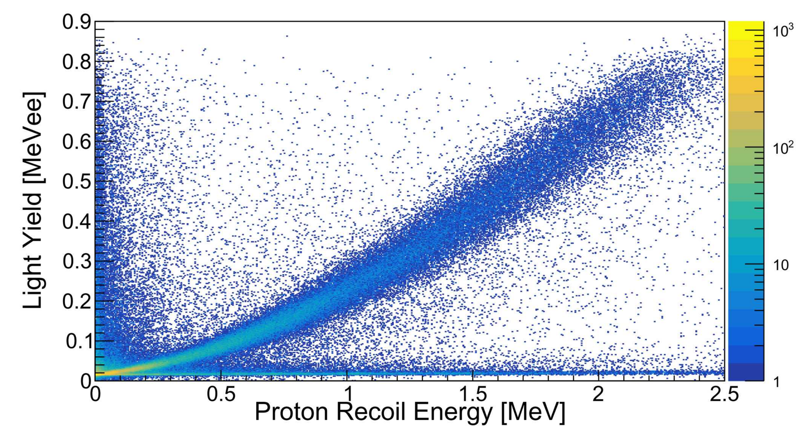
PROTON LIGHT YIELD MEASUREMENT

- 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 scintillators
- Proton recoil energy obtained using **kinematics**
- Digital acquisition (CAEN V1730 500 MS/s) recording full waveforms



This double time-of-flight technique and broad spectrum source allows for:

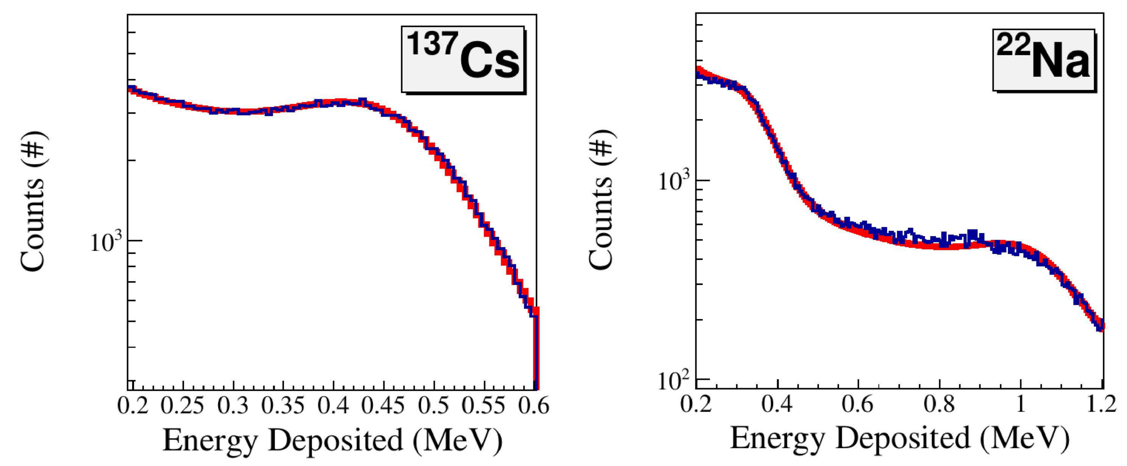
- Kinematically over-constrained system
- Broad range of energies without changes to experimental setup
- Continuous, model-independent light yield measurement



MEVEE CALIBRATION

The pulse integral was calibrated to an electron-equivalent energy scale by simultaneous minimization of γ-ray spectra and GEANT4-simulated distributions convolved with the detector resolution function.

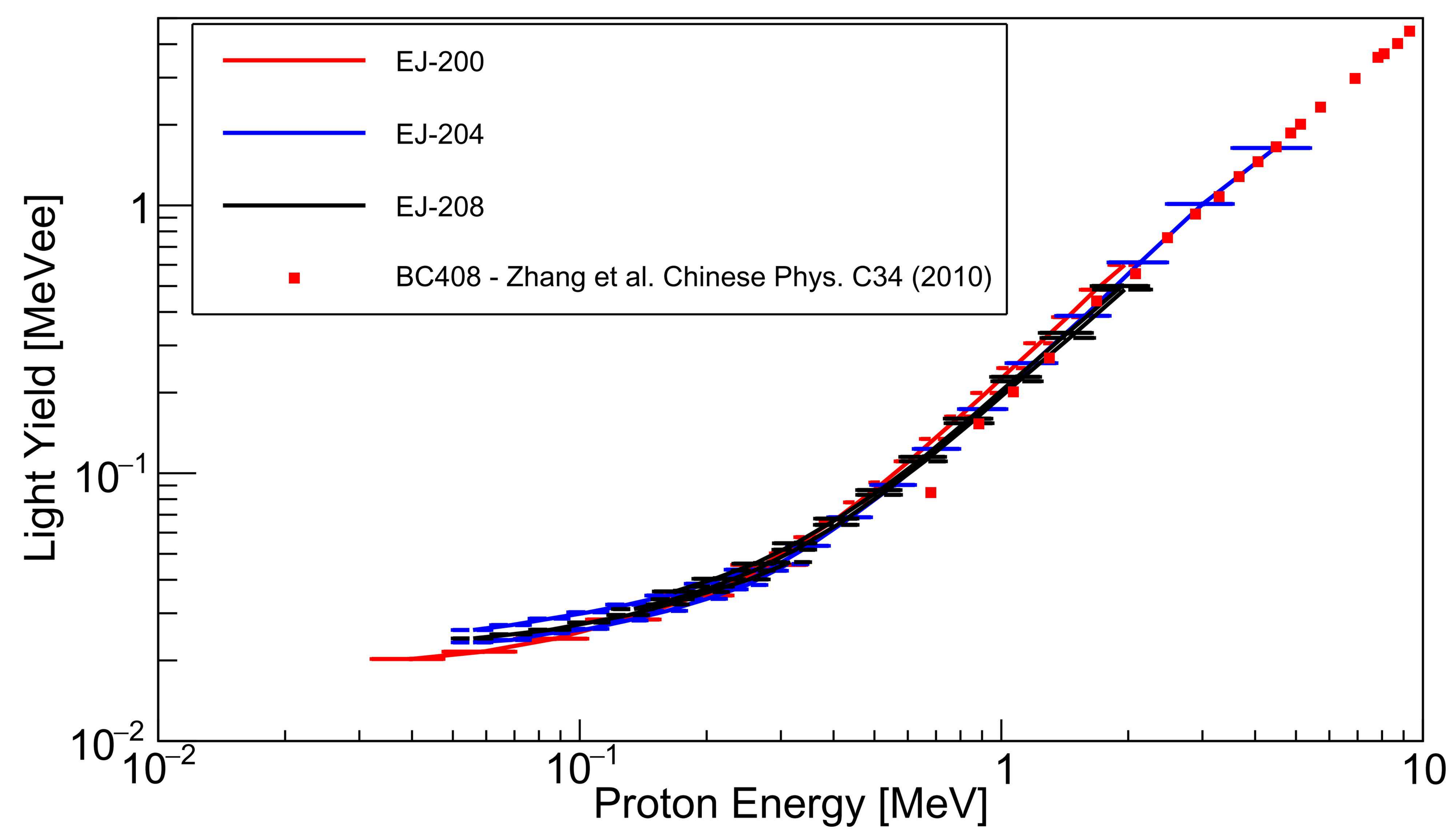
$L = A(E - E_0)$, where L is the measured light, E is the electron energy equivalent, A is a scaling parameter and E_0 is an energy offset.



Calibration in electron equivalent units using γ rays from ^{137}Cs and ^{22}Na sources

Independent measurement of the electron light yield non-linearity allows anchoring of the offset parameter $E0$.

RESULTS



Proton light yield curve for EJ-200, EJ-204, EJ-208 fast platic scintillators

- EJ-200 proton light yield measured from 30 keV up to 2 MeV - provides new low energy limit for proton light yield measurements in fast plastic scintillators (previous limit for this material was 500 keV)
- EJ-204 proton light yield data from 60 keV to 4.5 MeV - provides new low energy limit for proton light yield in this material (previous was 300 keV)
- EJ-208 proton light yield data from 60 keV to 2 MeV - first known proton light yield measurement of this material

CONCLUSIONS AND FUTURE WORK

Low energy proton light yield measurements of organic scintillators provides data for improvement of physics-based models down to low energies, which can in turn help with:

- Design of new scintillator materials
- Improved accuracy and neutron energy resolution of SVSC

Future work includes:

- Monte Carlo of the systematic uncertainties in the measurements
- Characterization of other candidate scintillators: EJ-230, EJ-232, and EJ-232Q

ACKNOWLEDGEMENTS

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