Position resolution via color gradient in UV-cured scintillators

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Nuclear Science & Security Consortium

Introduction

- Conventional position resolution (PR) is achieved through comparing relative light output and/or timing offsets in signals from two photodetectors on opposite ends of a scintillator
- Simulations suggest mixed material scintillators have the potential to improve PR by as much as 10x using a segmented, color-gradient design[4]
- The goal of this work is to experimentally interrogate this claim using custom plastic scintillating media and source-based position resolution measurements

Workstation Capabilities

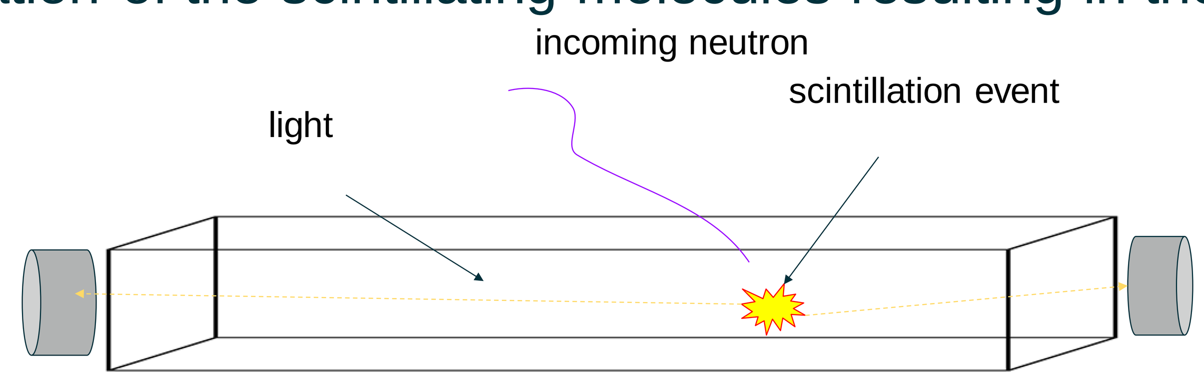
- Established a workstation for scintillator development at the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory
- Assembled chemical inventory necessary to explore multiple wavelength shifters and fluors
- Working in conjunction with existing BANG scintillator characterization capabilities

Equipment from left to right: UV Curer and chemical cabinet, Glovebox, Hot Plate, UV Curer, Digital Scale and Ultrasonic Bath

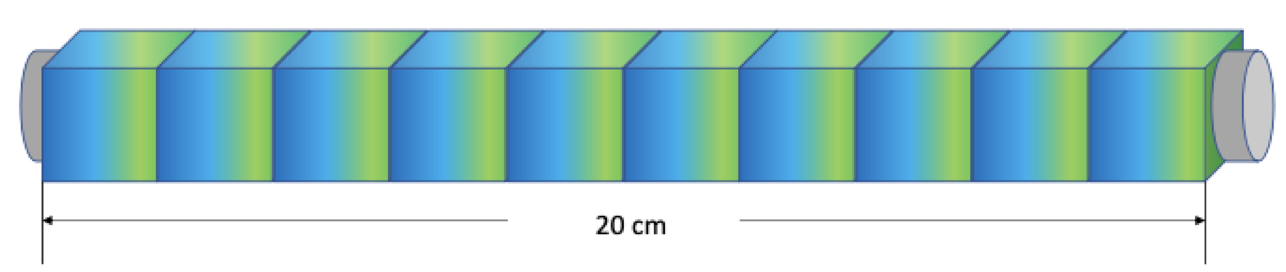
UV Curing in progress

Concepts & Methods

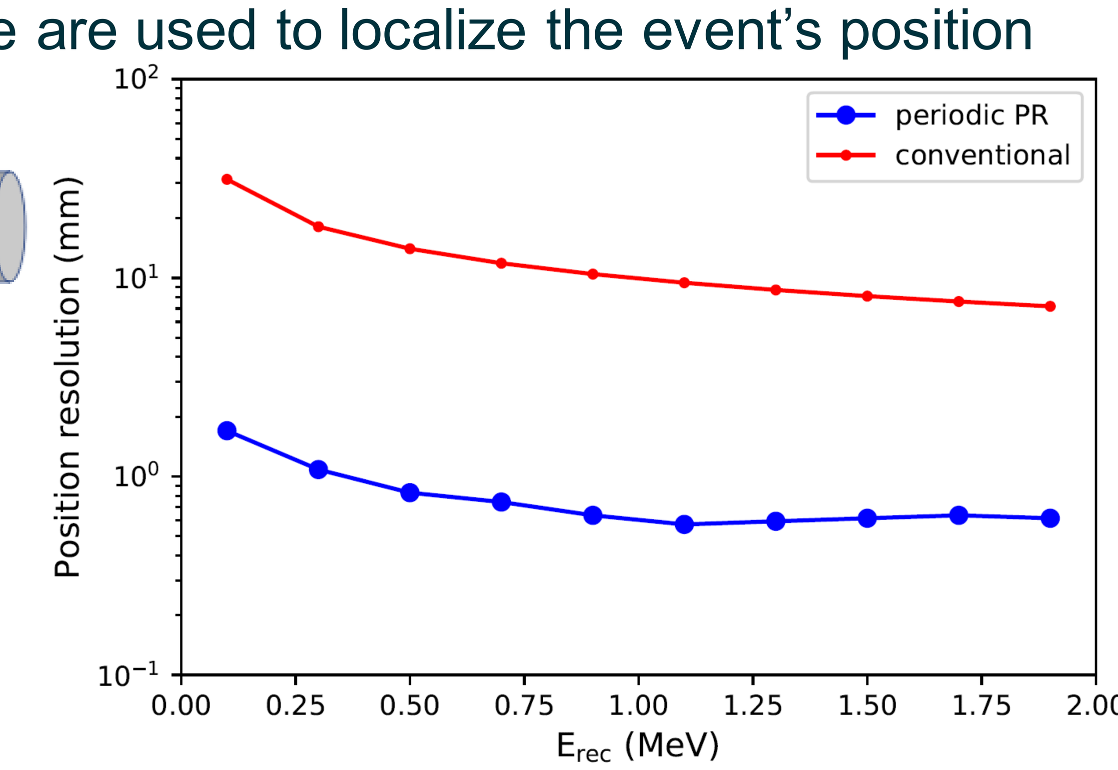
- When a fast neutron elastically scatters in a scintillating medium, recoil protons cause excitation and ionization of the scintillating molecules resulting in the emission of light



- The emitted light will reach the photodetectors on each end at different times and intensities
- The relative light intensity and timing difference are used to localize the event's position within the scintillator



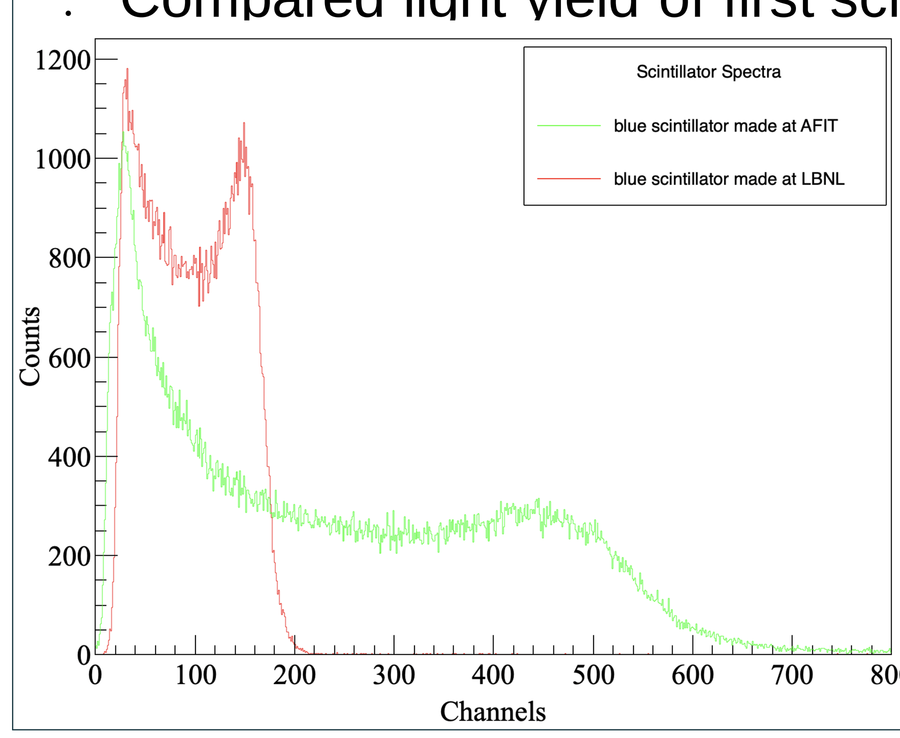
- In a segmented bar with multiple continuous color gradients, the timing difference and relative light intensity provide the segment the event occurred in, while the blue-green color fraction would further localize the event within that segment



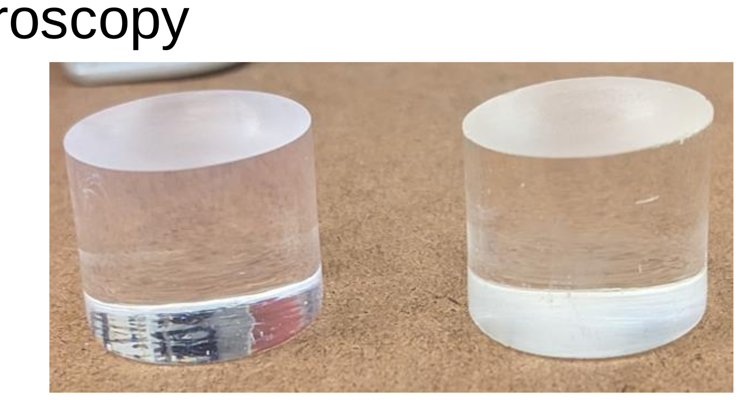
Comparison of position resolution from a periodic color gradient vs end-differential[4]

Progress So Far

- Identified, ordered, and setup equipment for construction
- Two UV curing devices provide capability to adjust curing parameters
- Built and performed initial testing on 6 scintillators
- Compared light yield of first scintillators through gamma spectroscopy



- H1949-51 PMT, -1500Vdc biasing, Cs-137 source
- Two scintillators of identical makeup, constructed in different facilities
- Compton edge positions are not in alignment, more work required



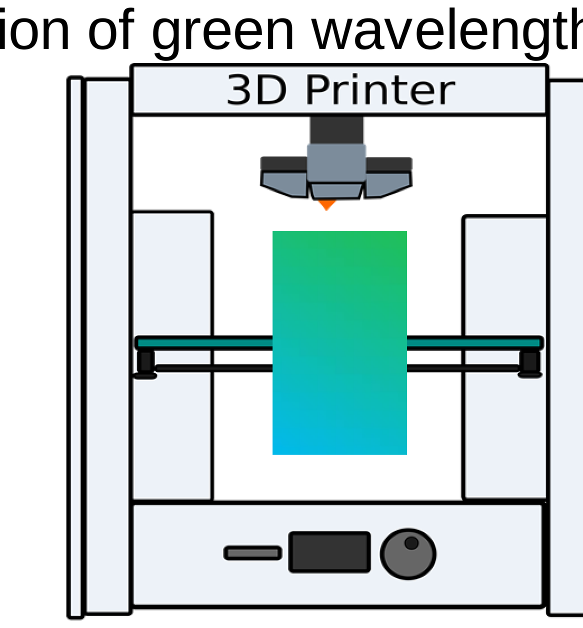
AFIT(left) and LBNL (right) scintillators after curing, sanding, and polishing

Mission Relevance

- Potentially provides an improvement to PR for fast-neutron detection systems such as MoNA-LISA, which currently yields a PR on the order of a few centimeters.
- Fast neutron detection systems have demonstrated superiority in shielded-source detection, directly improving nonproliferation efforts[5]

Next Steps / Future Work

- Establish nitrogen sparging capability - minimize oxygen quenching
- Try plastic vials & zinc stearate - reduce adhesion and minimize meniscus
- Establish PR testing capabilities in lab
- Find PMT alternatives - Look for an adequate photodetector better suited to detection of green wavelengths



- Explore methods for integrating with additive manufacturing capabilities

References

[4]Xianyi Zhang, Jason Philip Brodsky, Elaine Lee, Andrew Neil Mabe, Dominique Porcincula. (2021). The Architected Multi-material Scintillator System: Designs and Modeling. arXiv:2103.02196 **[physics.ins-det]**

[5]R. Chandra, G. Davatz, U. Gendotti and A. Howard, "Fast neutron detection in homeland security applications," *IEEE Nuclear Science Symposuim & Medical Imaging Conference*, Knoxville, TN, USA, 2010, pp. 508-511, doi: 10.1109/NSSMIC.2010.5873813.

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