SAND2020-4487PE

Melt-Cast Organic Glass

MTV Workshop, 2020

March 10, 2020

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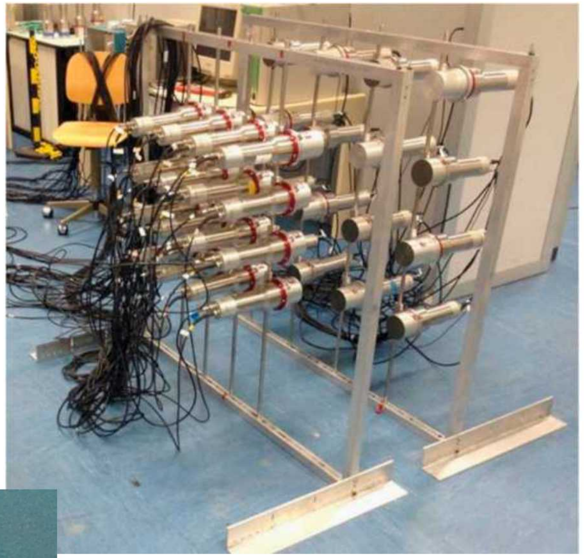
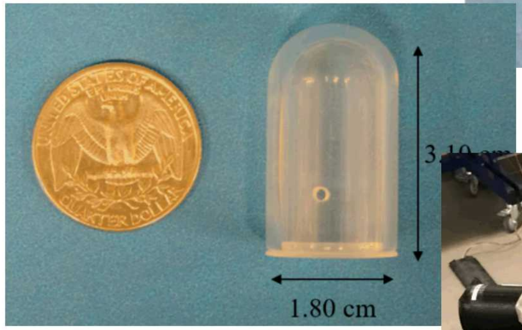
Introduction and Motivation

- Organic scintillator detectors can be used to accomplish important mission items
  - Neutron and gamma-ray detection for nuclear nonproliferation
  - Nuclear explosion monitoring
- Current organic scintillators have notable drawbacks
  - *Trans*-stilbene: Expensive, fragile, anisotropic scintillation response
  - Plastics: Poor light output and pulse shape discrimination (PSD)
- Enter: Organic glass



Dual-particle imager



Plastic beta cell

Fast neutron multiplicity counter

Background

- Developed by researchers at Sandia National Laboratories[1]

- Organic <u>glass</u>: it's amorphous
    - No anisotropic effects
    - Can readily accept dopants (Sn, ^{10}B, etc.)
    - No intermolecular order lost during heating
    - Manufactured via a **bulk melt-cast** procedure

- PSD-capable

- Reported higher light output than *trans*-stilbene[2]

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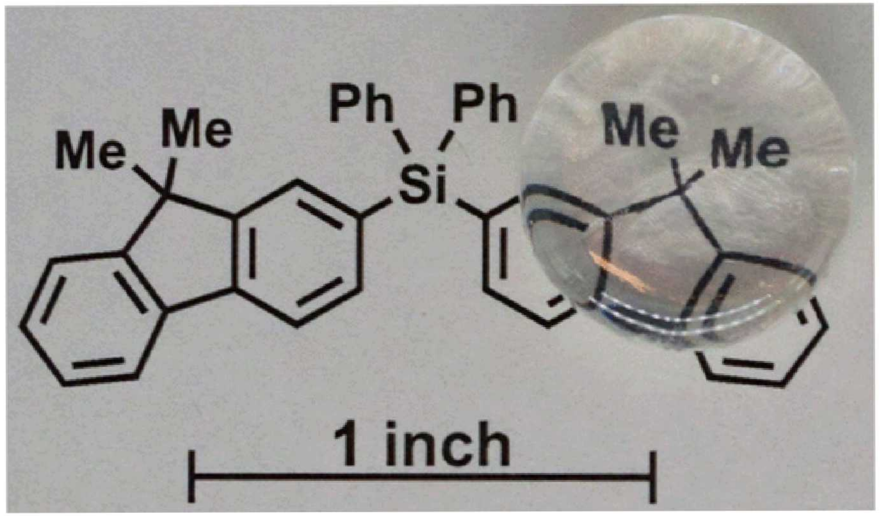


Primary fluor structural formula and 2g glass sample[1]

Mission Relevance

"Preventing nuclear weapons proliferation and reducing the threat of nuclear and radiological terrorism around the world are key U.S national security strategic objectives that require constant vigilance.

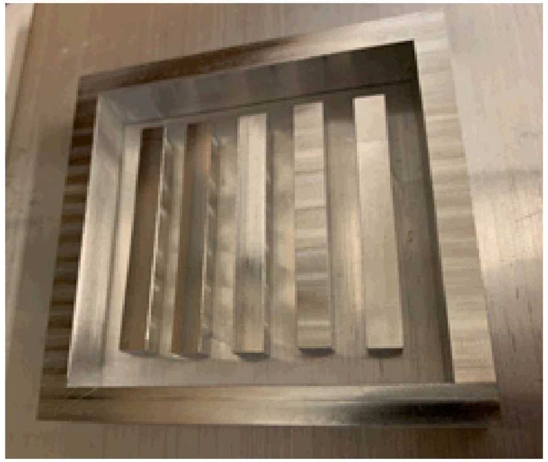
NNSA's Office of Defense Nuclear Nonproliferation works globally to prevent state and non-state actors from developing nuclear weapons or acquiring weapons-usable nuclear or radiological materials, equipment, technology, and expertise."

- Improve upon existing radiation detection systems for nuclear nonproliferation
- Evaluate this new material for use in future instruments

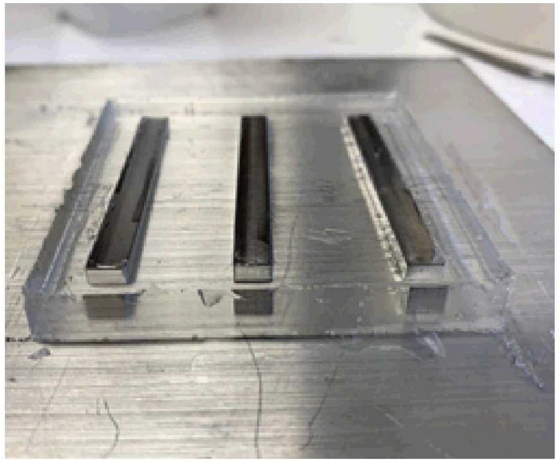
Casting Scintillators

Process developed at Sandia, implemented at Michigan

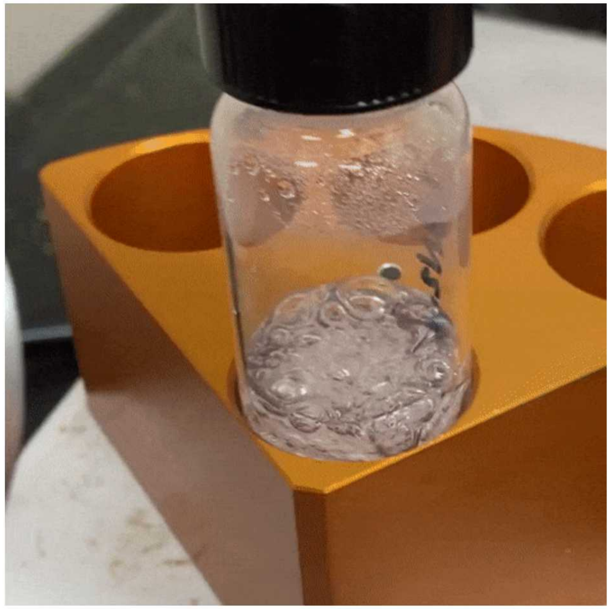
1. Create a mold
2. Cast the glass
    - Heat under vacuum
    - Pour into mold
    - Anneal and extract



Bar mold hardware



Set silicone bar mold

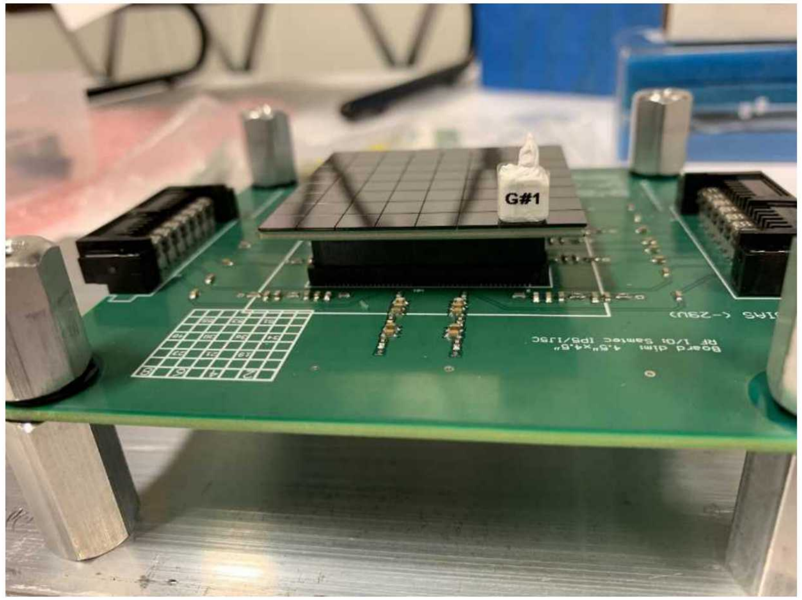


Glass heating & degassing

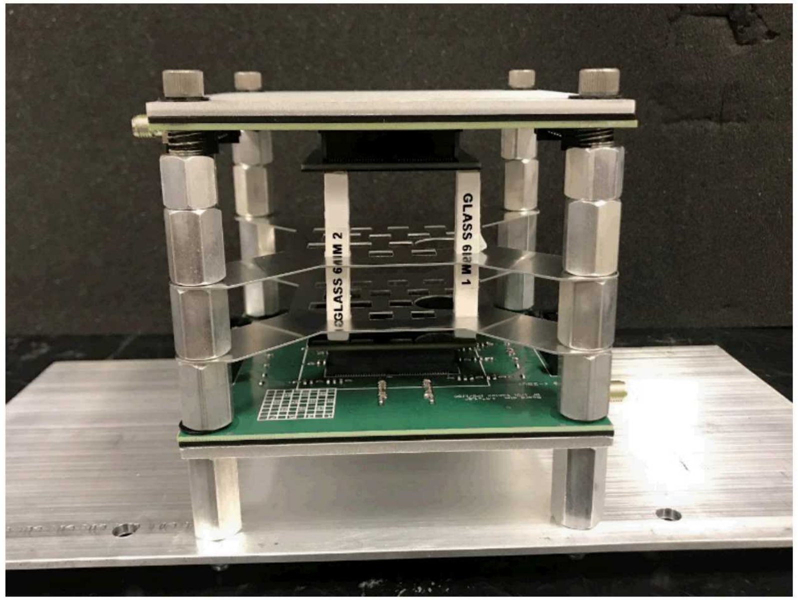
Annealed organic glass bars

Sample Characterization

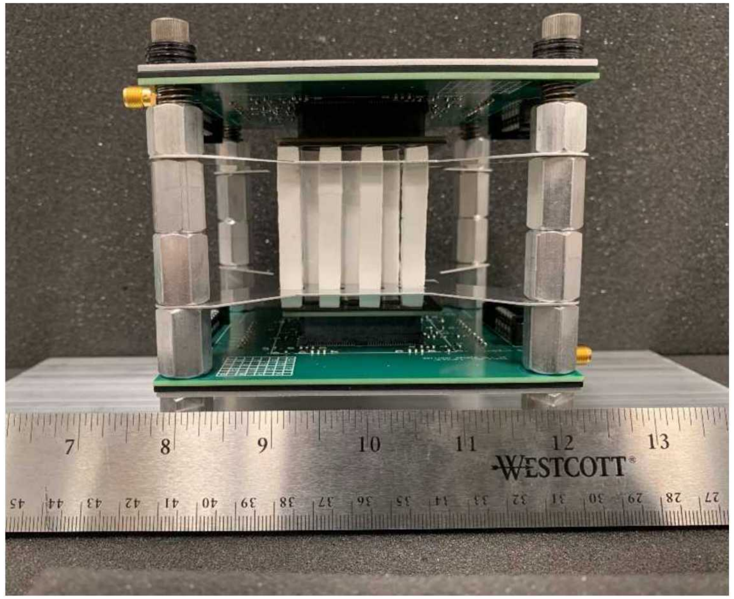
- Produced several organic glass scintillators at U. Michigan
- Wrapped in PTFE and coupled to SiPM array
- Compared response to equivalent stilbene measurements



6mm glass cube coupled to SiPM array



6x6x50mm^3 glass bars coupled to SiPM arrays

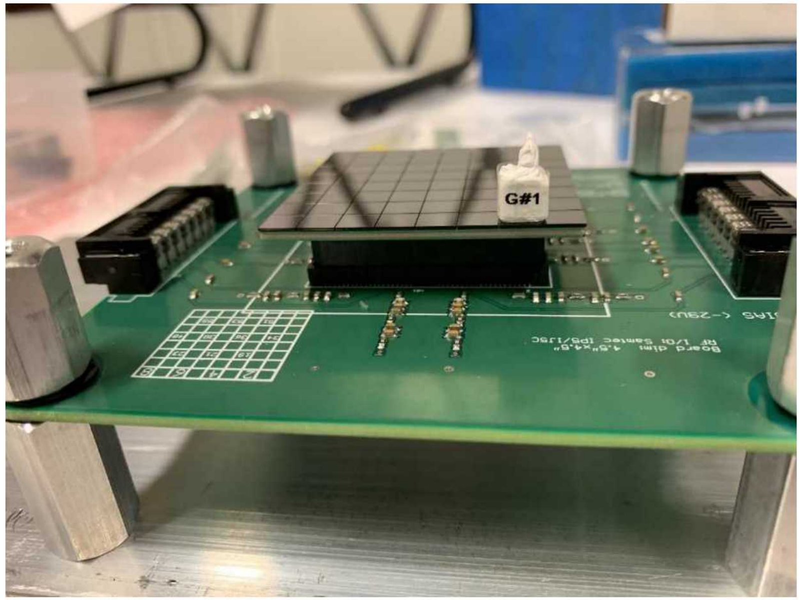


Organic glass imaging prototype

Light Output

Measurement

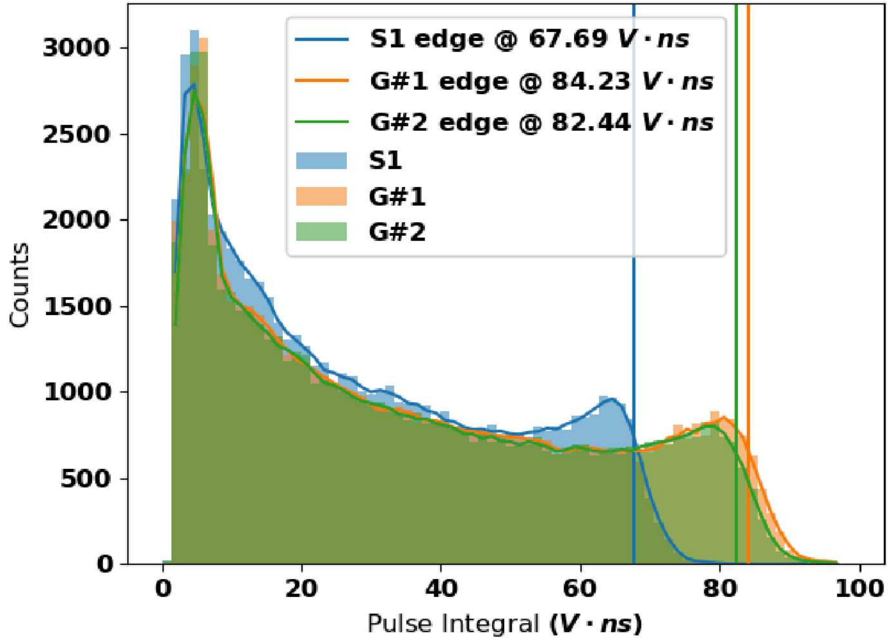
- 6mm glass and stilbene cubes
- ^{137}Cs monoenergetic gamma-ray source



6mm glass cube coupled to SiPM array

Light yield

- 2x glass cubes (O, G), 1x stilbene cube (B)
- ≈25% higher light output in glass at 477 keV

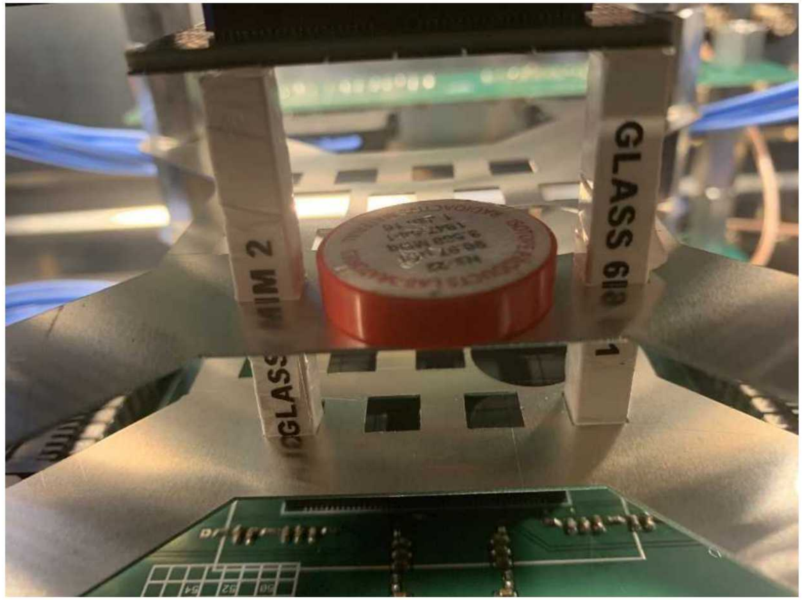


^{137}Cs spectra for glass and stilbene 6mm cubes

Time Resolution

Measurement

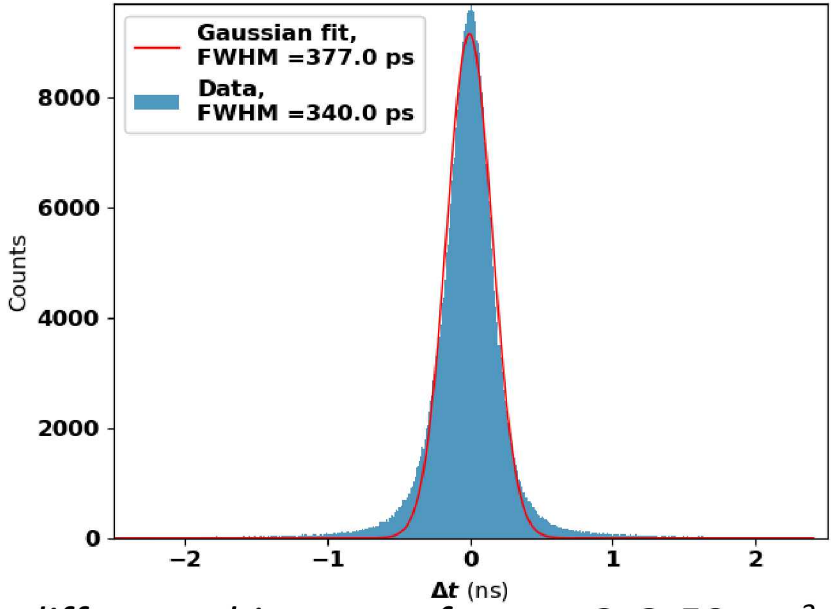
- Two 6x6x50mm^3 glass bars
- ^{22}Na annihilation photon source between bars



^{22}Na measurement with 6x6x50mm^3 glass bars

Time resolution

- Histogram of reconstructed time difference between coincident events
- 340ps FWHM (vs. 510ps for stilbene)

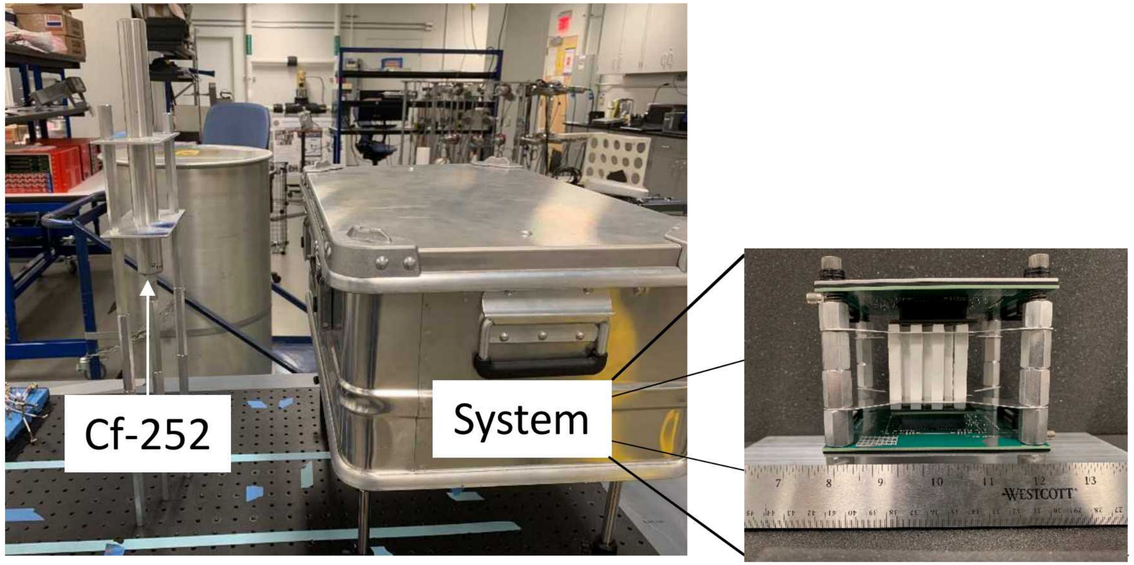


Time difference histogram for two 6x6x50mm^3 glass bars

Pulse Shape Discrimination

Measurement

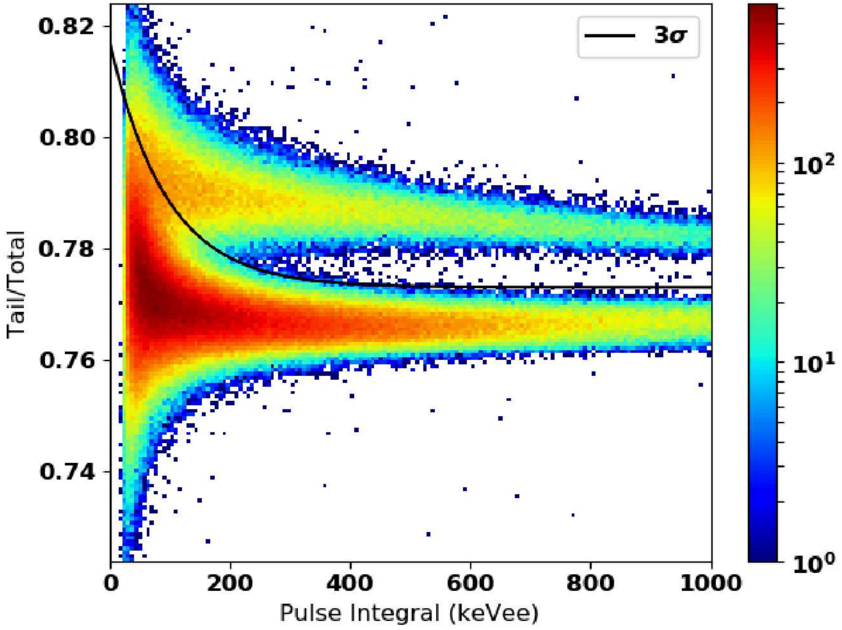
- Four 6x6x50mm^3 glass bars
- ^{137}Cs light output calibration
- ^{252}Cf spontaneous fission source



^{252}Cf measurement with imaging prototype

Pulse shape discrimination

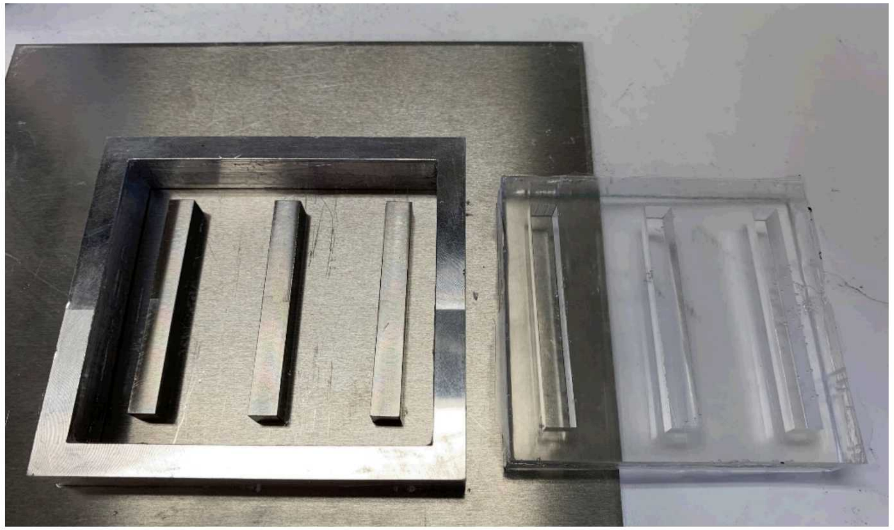
- Charge integration of tail vs. total
- 3σ gamma-ray discrimination line shown



PSD histogram of one bar

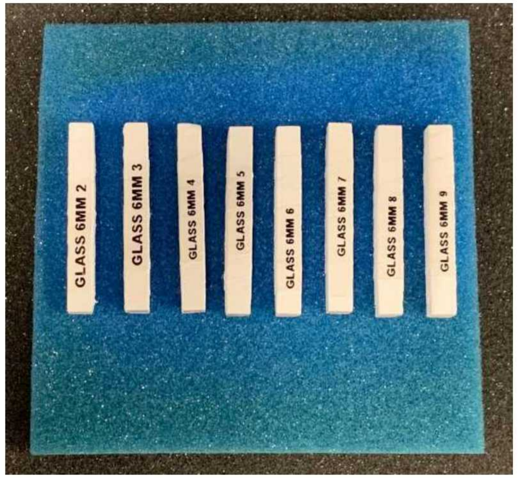
Conclusion

- A facility for casting organic glass scintillators was developed at the University of Michigan
- Initial characterization of Michigan-produced scintillators coupled to SiPMs was performed
  - Light output
  - Time resolution
  - Pulse shape discrimination



Bar casting hardware and mold

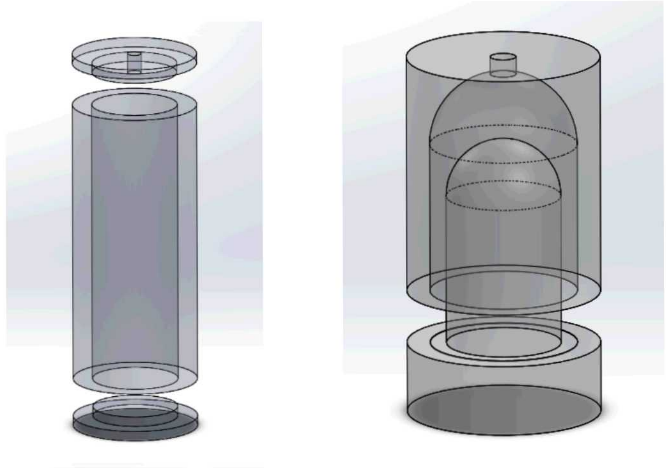
Programmable scientific ovens



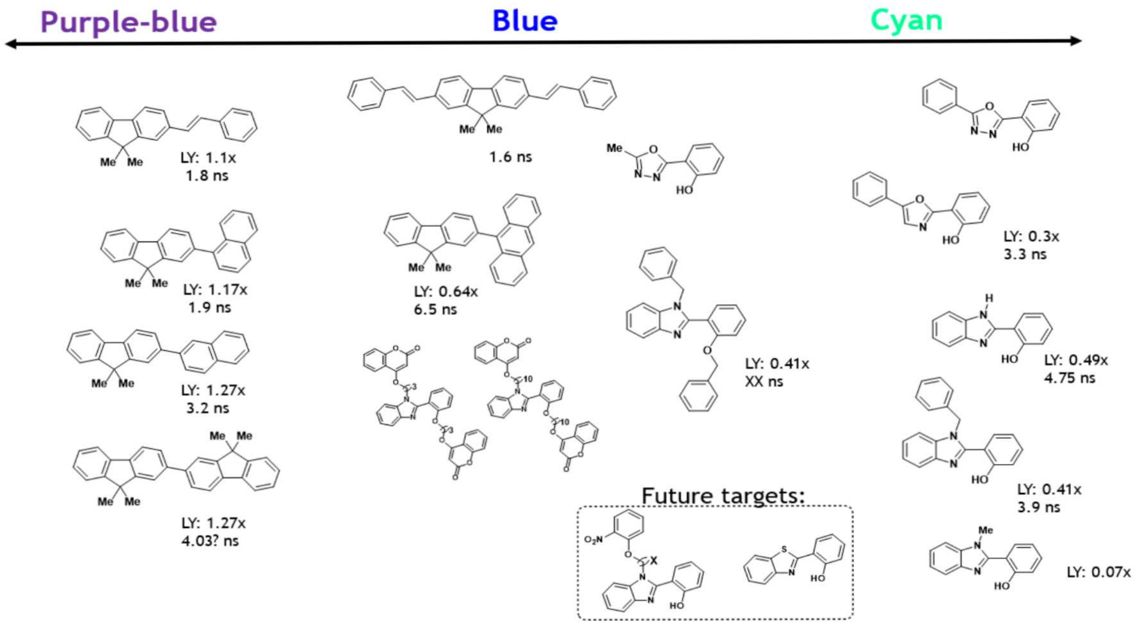
Organic glass bars

Next Steps

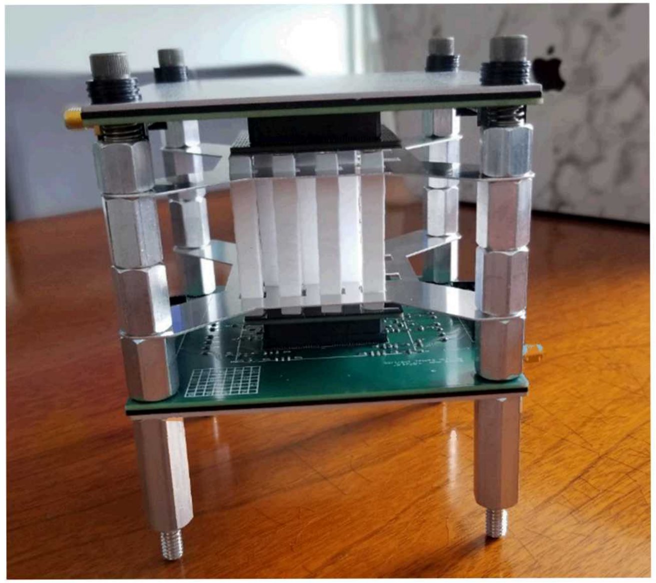
- Radioxenon detection
- Neutron and gamma-ray imaging
- Tuning scintillation properties with wavelength shifters



Glass beta cell casting hardware



Wavelength shifters to be explored



Prototype organic glass imaging system

Expected Impact

- Capability to construct detector systems based on locally-cast organic glass scintillators

- Characterization of relevant properties to a wide application space
  - Pulse shape discrimination
  - Energy resolution
  - Time resolution
  - Neutron light output
  - Interaction position reconstruction

⌀1x1" organic glass cylinder

MTV Impact

- Future collaboration with Pacific Northwest National Laboratories
  - Radioxenon beta cell development
  - Eventual measurement campaign

Pacific Northwest
NATIONAL LABORATORY

- Collaboration with Sandia National Laboratories
  - Provided glass materials and guidance on casting process
  - October 2019: Dr. Lucas Nguyen visited from Sandia
  - Continued collaboration on optimizing application-specific formulations

U.S. DEPARTMENT OF ENERGY NNSA

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Acknowledgements

The Consortium for Monitoring, Technology, and Verification would like to thank the NNSA and DOE for the continued support of these research activities.

This work was funded by the Consortium for Monitoring, Technology, and Verification under Department of Energy National Nuclear Security Administration award number DE-NA0003920

National Nuclear Security Administration

References

1. **Taking Advantage of Disorder: Small-Molecule Organic Glasses for Radiation Detection and Particle Discrimination,** Joseph S. Carlson, Peter Marleau, Ryan A. Zarkesh, and Patrick L. Feng, *Journal of the American Chemical Society* **2017** *139* (28), 9621-9626, DOI: 10.1021/jacs.7b03989.
2. **Measured neutron light-output response for *trans*-stilbene and small-molecule organic glass scintillators,** Tony H. Shin, Patrick L. Feng, Joseph S. Carlson, Shaun D. Clarke, and Sara A. Pozzi, *Nuclear Instruments and Methods in Physics Research Section A* **2019** *939* (0168-9002), 36-45, DOI: doi.org/10.1016/j.nima.2019.05.036.