# Investigation of Organic Glass Scintillators for Improved Energy Resolution for Radioxenon Detection

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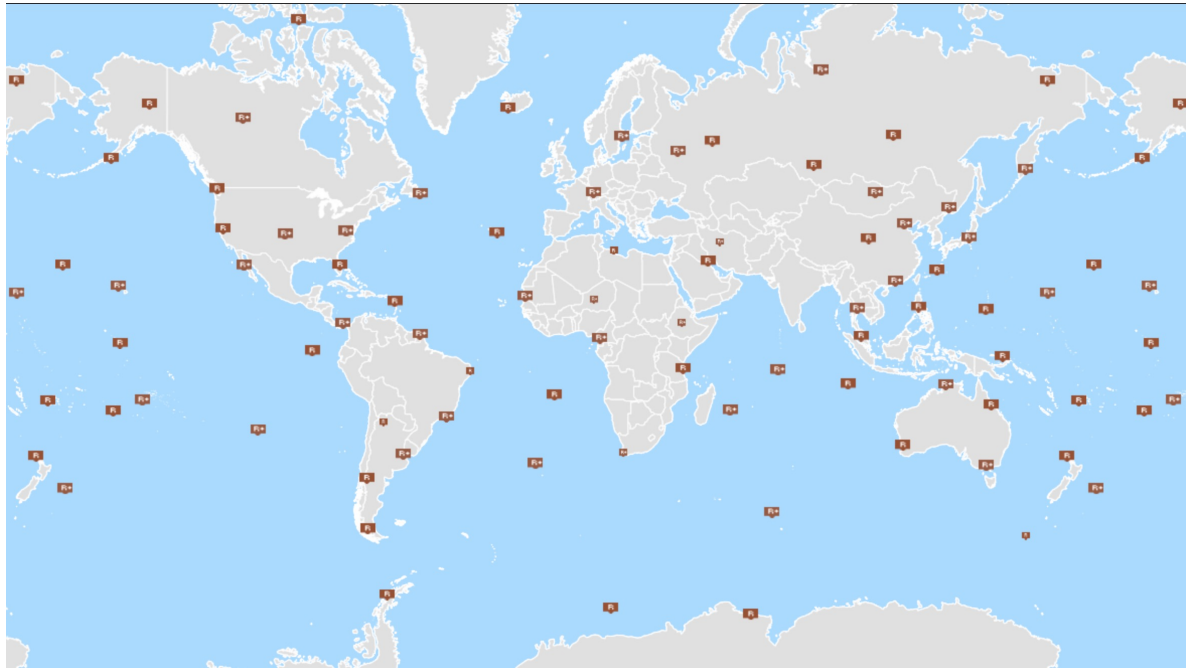
# Introduction and Motivation

- The Comprehensive Nuclear-Test-Ban Treaty prohibits nuclear explosions around the world
  - Verification regime includes International Monitoring System (IMS)
- IMS utilizes four areas of detection
  - Hydroacoustic, seismological, infrasound, **radionuclide**
- Radioxenon isotopes $^{131m}Xe$, $^{133}Xe$, $^{133m}Xe$, and $^{135}Xe$ produced during fission
- Beta-gamma coincidence detectors used to verify radioxenon prominence
  - Currently use plastic scintillators
  - Exhibit memory effects and poorer energy resolution

International Monitoring System



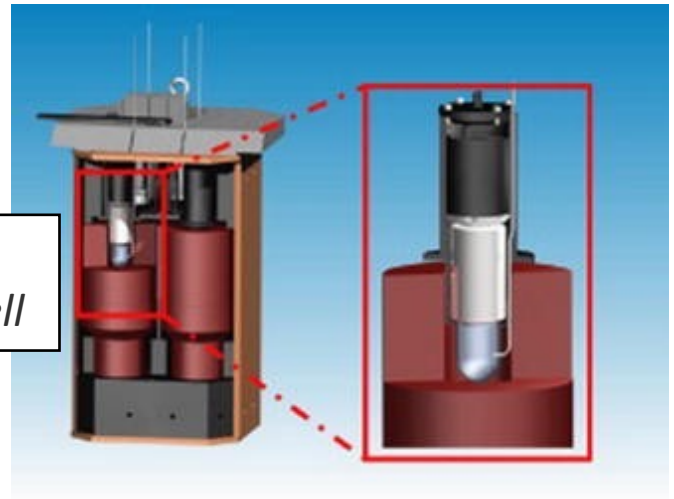
Ctbto.org

All Facilities
337 Total – 302 Certified

Radionuclide:
80 Total – 72 Certified
40 detect noble gases

# Mission Relevance

- Radionuclide IMS detection can identify an explosion as nuclear
- Past investigations of plastic and stilbene cells for beta-gamma coincidence measurements
  - Stilbene reduced **memory effect**, comparable **energy resolutions**
  - Difficult machining of stilbene, expensive
- Investigate small-molecule organic glass scintillating material as replacement to plastic scintillator



*Coincidence detector with rounded plastic cell*

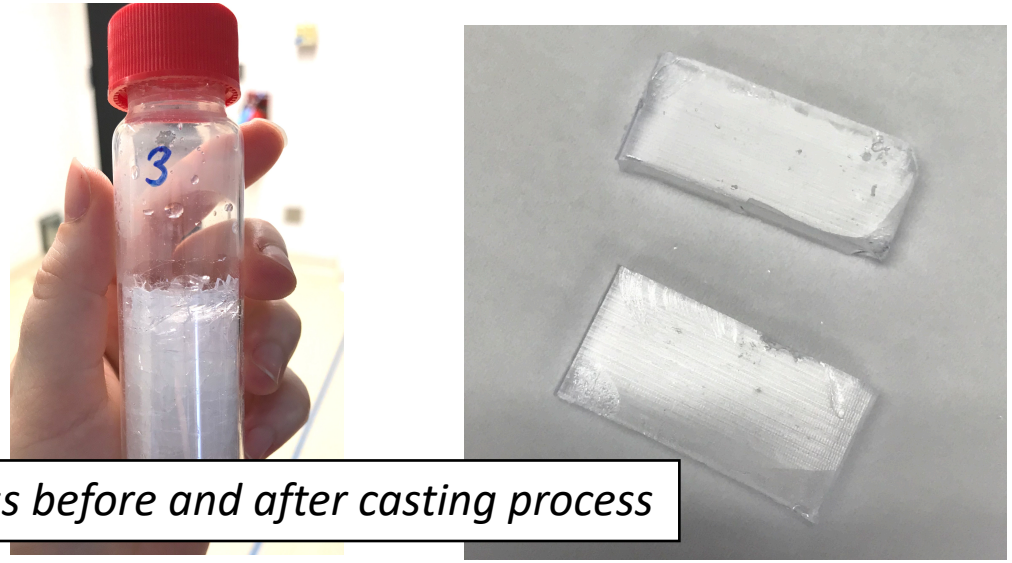
*SPALAX noble gas system*



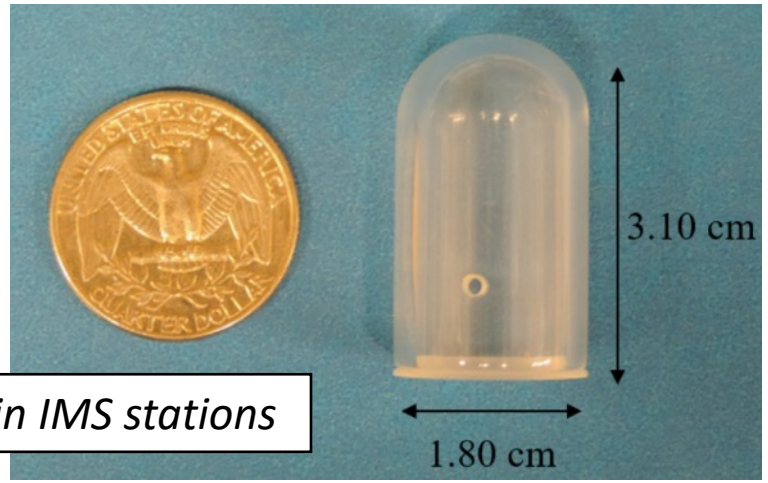
C. Sivels, J. McIntyre, A. Prinke, A. Day, C. Lynch, S. D. Clarke, and S. A. Pozzi, "Stilbene Cell Development to Improve Radioxenon Detection," Nuclear Instruments and Methods in Physics Research Section A, vol. 923, pp. 72-78, 2019.

# Advantages of Organic Glass

- PSD-capable
- High light output
  - Improved energy resolution
- Easily moldable
  - Amorphous glass and can be melted and cast into ideal shape
- Inexpensive and performs well




*Glass before and after casting process*




*Plastic beta cell used in IMS stations*

# Technical Approach

- Sandia National Laboratories develop organic glass used in project as well as foundational work with casting process

- Ongoing collaboration with Pacific Northwest National Laboratory in radioxenon monitoring and developed of new detection systems

- Experimental and Simulation Aspects
  1. Characterize properties of organic glass
  2. Utilize Geant4 simulations for beta cell geometry
  3. Produce organic glass beta cell comparable to plastic cell

# Geant4 Cell Geometry Simulations

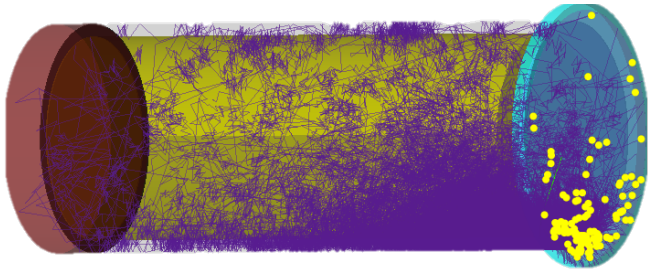
- Geant4 model of organic glass beta cell for geometry optimization for maximum detection efficiency and energy resolution

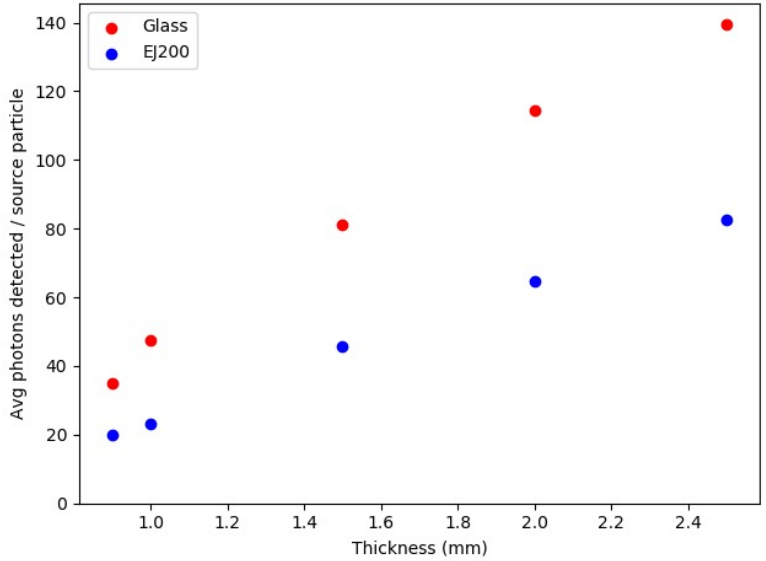
- Plastic (EJ200) vs glass simulations
  - Diffuse reflector – 99% reflective
  - Wall thickness – 0.9 to 2.5 mm
  - 129 keV CE from $^{131m}$Xe decay

- Specular vs diffuse wrappings
  - Wall thickness – 1 to 2.5 mm
  - 129 keV CE from $^{131m}$Xe decay

*Geant4 model of beta cell*
*Two-piece beta cell w/ hollow cylinder and endcap*

*Scintillation light production and transport from single 129 keV CE from $^{131m}$Xe decay*

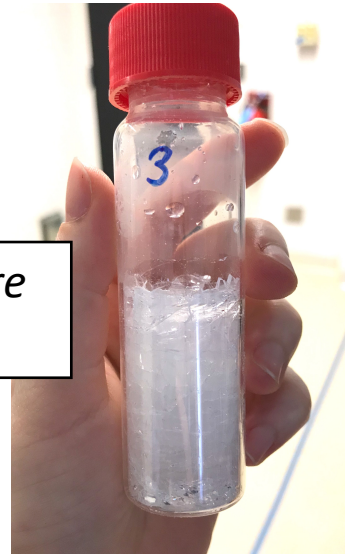





*Average number of photons detected per 129 keV electron vs wall thickness*

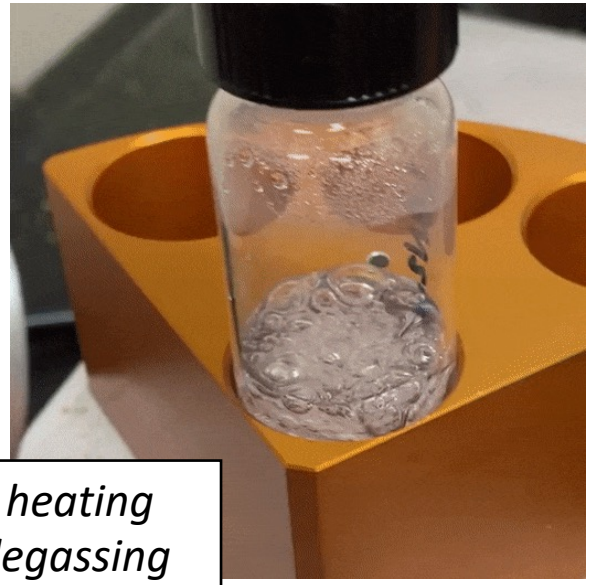
# Organic Glass Casting

1. Prepare custom mold for desired shape
2. Solid glass provided by Sandia National Laboratories heated and vacuum sealed to remove oxygen
3. Quickly cast with the custom mold and set for 14 hours
4. Delicate process to remove glass from mold

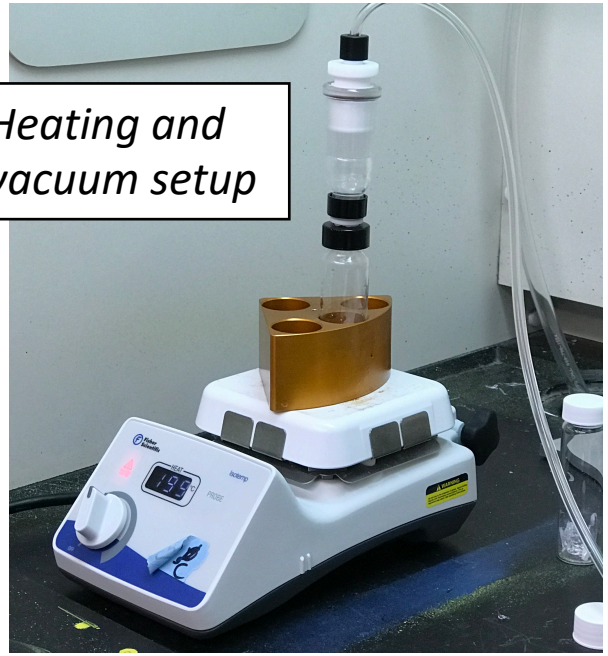



*Glass before casting*

*Mold for slabs of varying thickness*



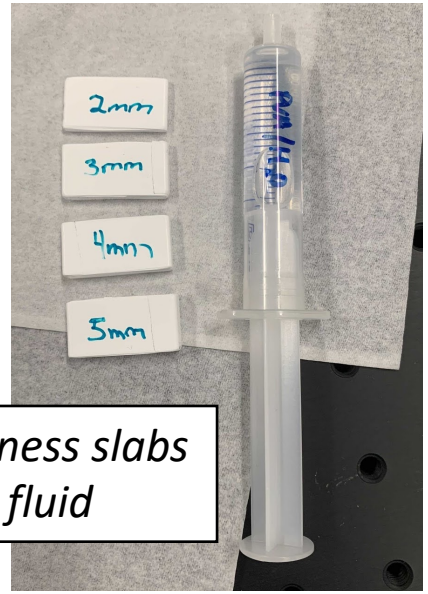
*Glass heating and degassing*



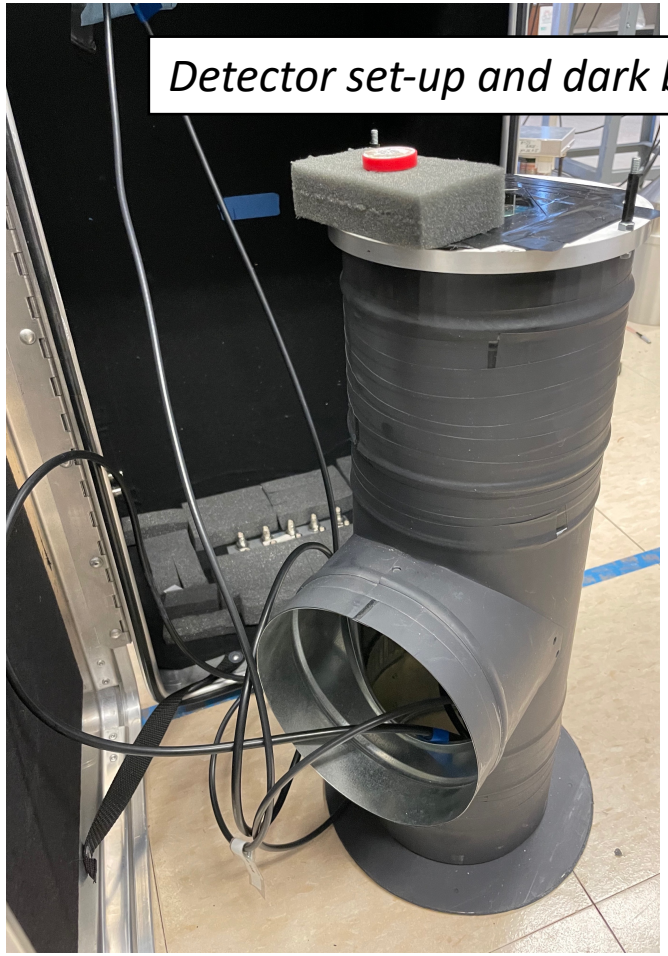
*Heating and vacuum setup*

# Experimental Setup

- Organic glass slabs, mimic "unwrapped cell" of varying thickness 2 to 5 mm
- High aspect ratio, 25.4 x 12.7 x thickness $mm^3$
- Measured $^{137}Cs$ spectra: bare and diffuse reflective tape

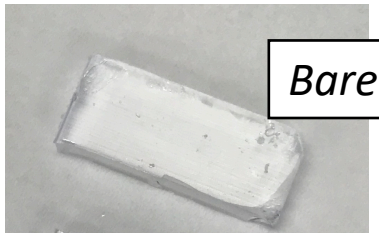



*Various thickness slabs and coupling fluid*



*Detector set-up and dark box*

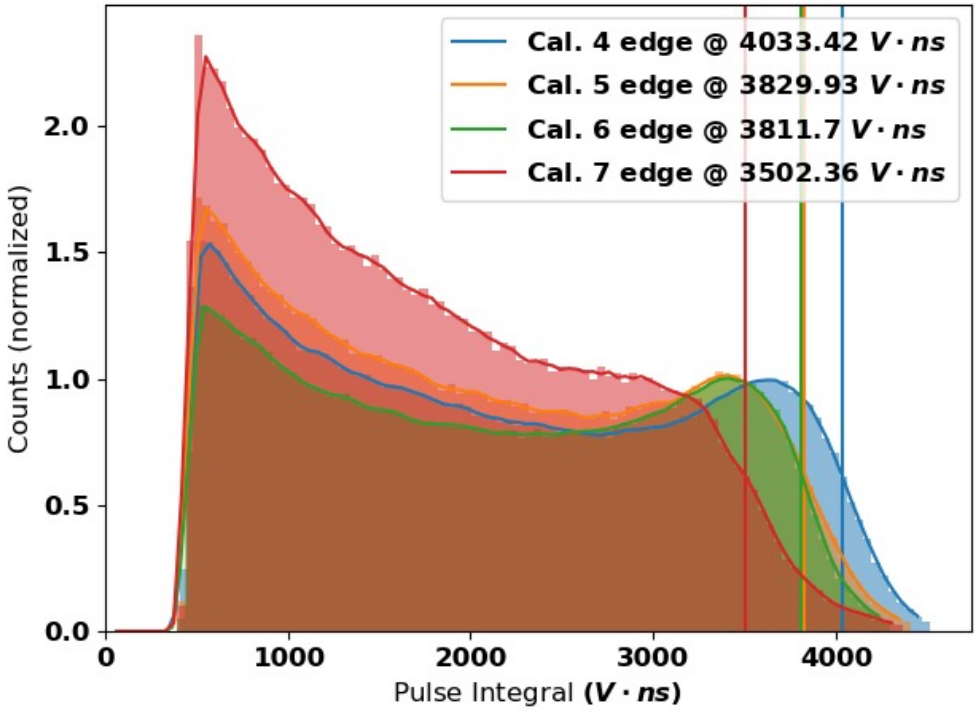
*Scintillator coupled to PMT*



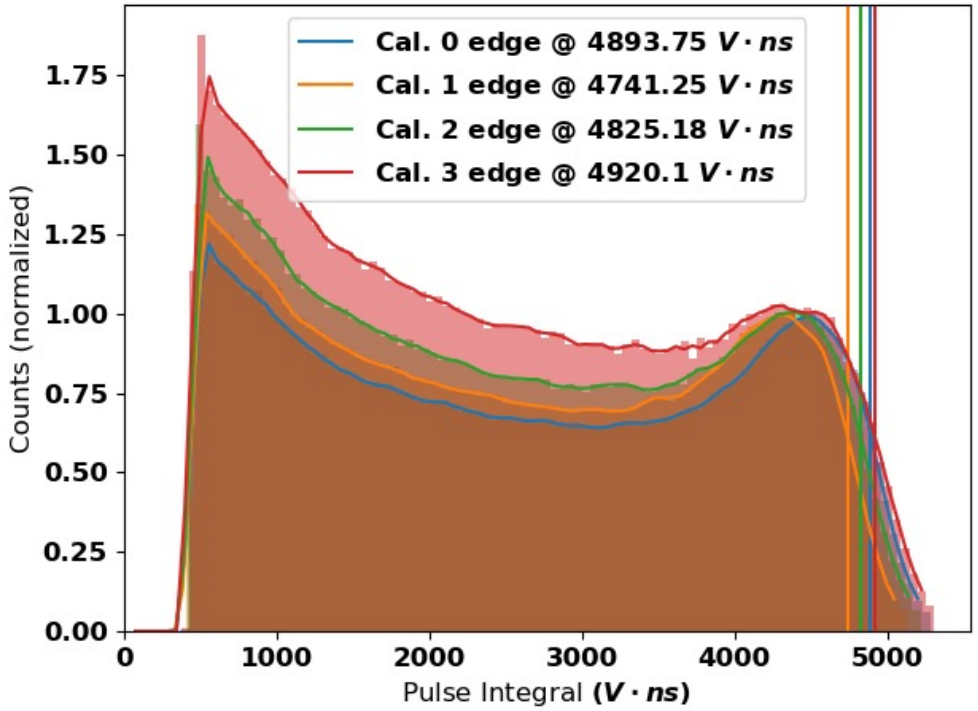
*Bare*

*Diffuse*

# Results – *Organic Glass Experiment*




*Bare slab Cs-137 spectra*

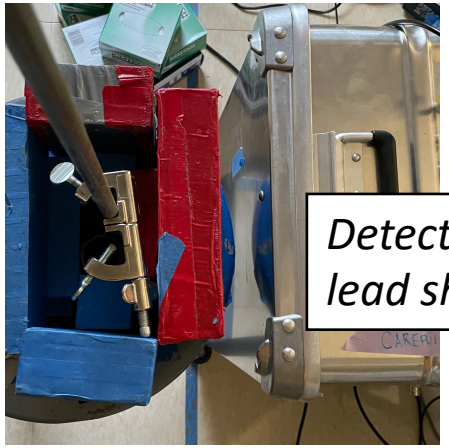


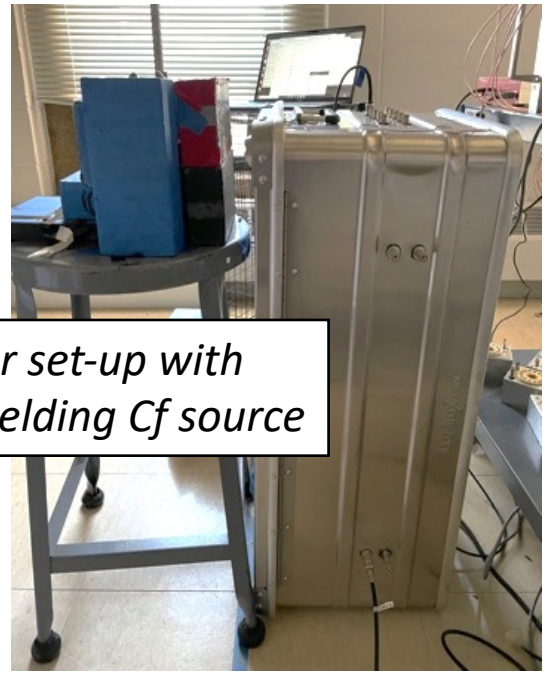

*Diffuse wrapped slab Cs-137 spectra*

*Thickness = 2, 3, 4, 5 mm*

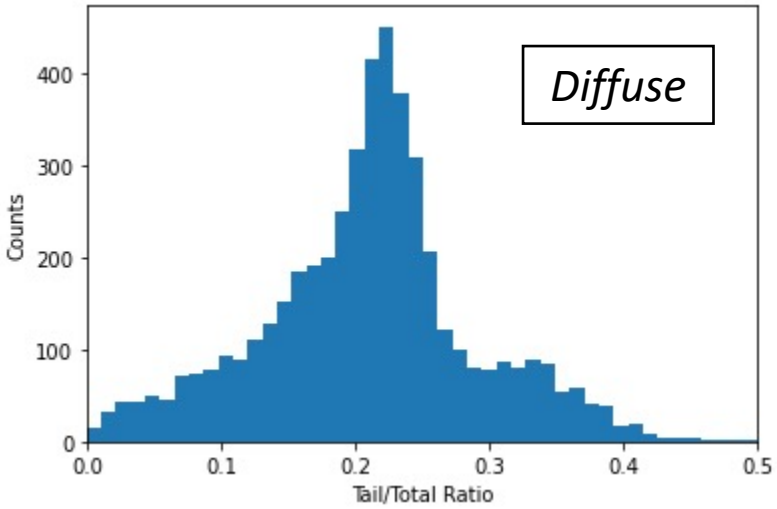
# Demonstrating PSD Capability

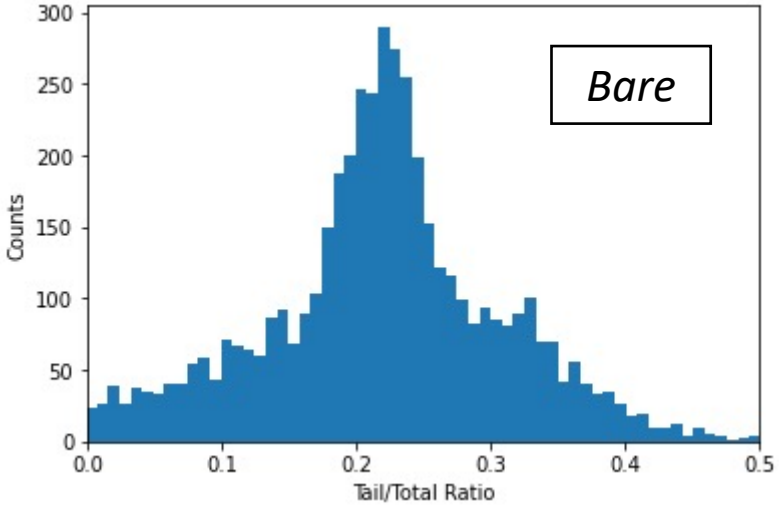
- Preliminary results for PSD investigation
- Measured $^{252}$Cf with lead shielding
- Comparison of diffuse-wrapped and bare glass slabs, both 5 mm thickness

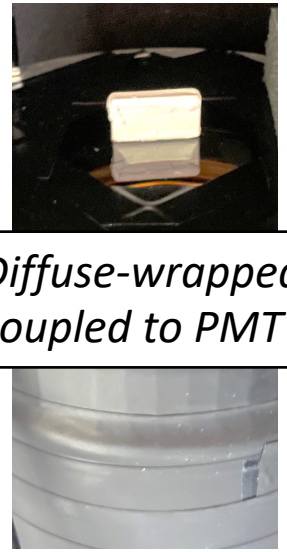




*Detector set-up with lead shielding Cf source*



*Diffuse-wrapped coupled to PMT*

*Bare glass slab*

# Expected Impact

- Easily moldable glass scintillators allow for effective experiments and wider range of lab possibilities
- Organic glass offers a possible drop-in replacement to plastic scintillators
- Improved light output and energy resolution will aid in atmospheric sample measurements

# MTV Impact

- Project built from collaborations with Pacific Northwest National Laboratory and Sandia National Laboratories
- Continued collaborations create opportunities for students
- Opportunities with the CTBTO through workshops and conferences

Pacific Northwest NATIONAL LABORATORY

Sandia National Laboratories

CTBTO PREPARATORY COMMISSION

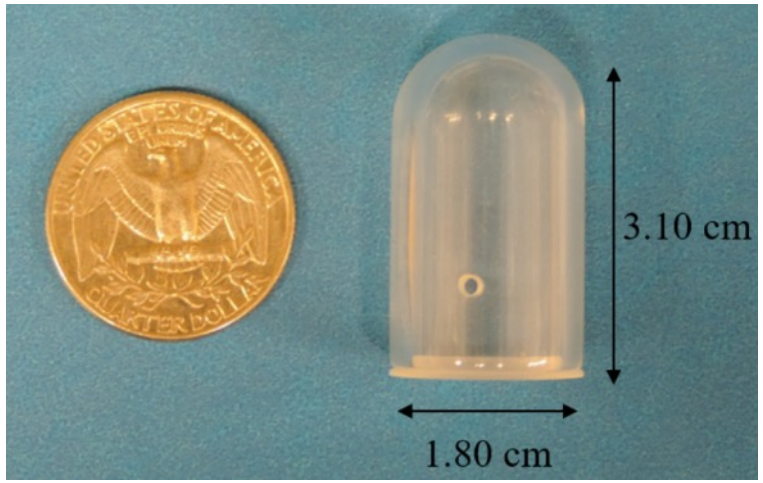
# Conclusion

- From simulations: Organic glass outperforms the plastic scintillators
  - Mean number of detected photons higher in glass than plastic cell

- From experiments: Optimal thickness for experiment can be used when using a reflector without drawbacks
  - Positive correlation between thickness and light collection in bare case
    - Increased thickness enhances light collection efficiency and energy resolution
  - No observed correlation with diffuse reflector

# Next Steps

- Continue characterizing organic glass with various reflectors for optimal geometry for cell
  - Investigate specular experimentally
  - PSD investigation with Cf-252
- Produce a functioning organic glass cell like those seen in the IMS stations
- Investigate memory effect

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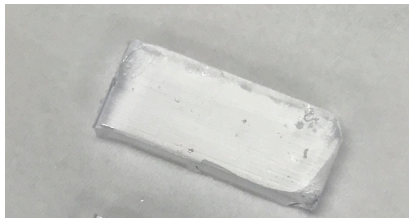

*Bare*

*Diffuse*

*Specular*

# Acknowledgements

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