Neutron and Gamma Imaging with a Novel Organic Glass-Based Imager

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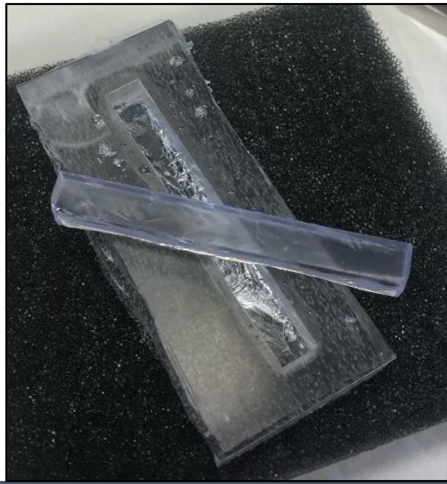
Introduction and Motivation

- Concerns in nuclear verification and nonproliferation fields include accounting for nuclear material
  - Deployable instrumentation
  - Small form factor → user-friendly
- Particle imagers are a powerful tool in use
  - Neutrons + gamma rays important signatures of U, Pu, etc.
- Novel organic glass scintillator (OGS) material developed by Sandia National Labs
  - High light-output and detection efficiency
  - Can be melt-cast into a variety of geometries



NNSA Mission Relevance

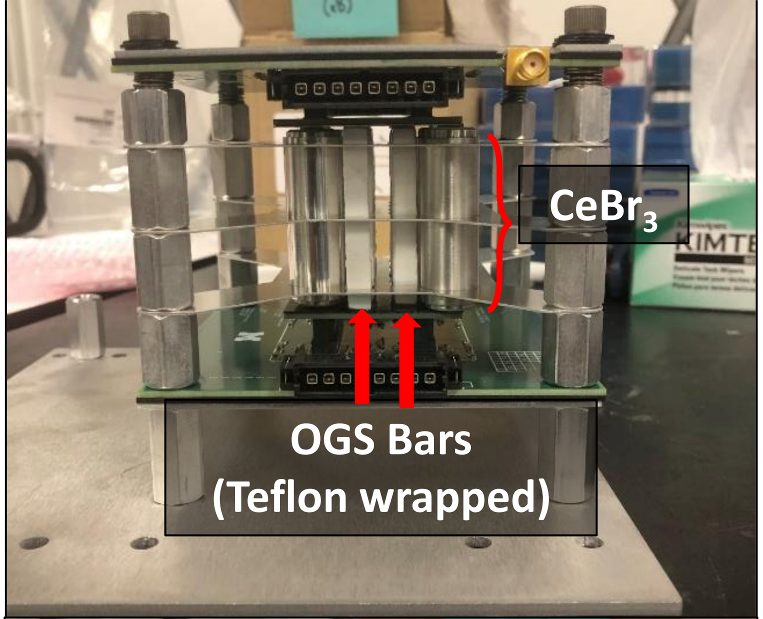
- NNSA's Office of Nonproliferation and Arms Control (NPAC)
  - "…detect and deter diversion of nuclear material or illicit use of nuclear facilities"
- NNSA's Office of Nuclear Verification (ONV)
  - "…deployment to locations worldwide where U.S.-led on-site monitoring and/or verification activities are required."

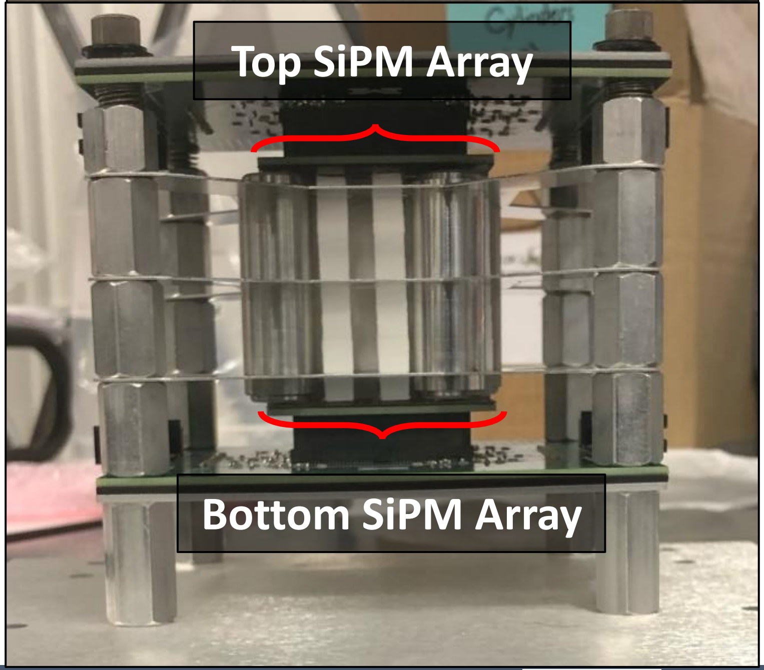
- **Both objectives benefit from equipping personnel with particle imagers capable of source isolation and identification**

Technical Approach

- University of Michigan's scatter-based OGS imager consists of:
  - 12 OGS bars ($6x6x50$ mm^3) wrapped in Teflon
  - 8 $CeBr_3$ inorganic scintillators
  - Silicon photomultiplier arrays
- OGS composition developed at Sandia National Laboratories and **sensitive to both neutrons and gamma rays**
- Reconstruct double scatter events

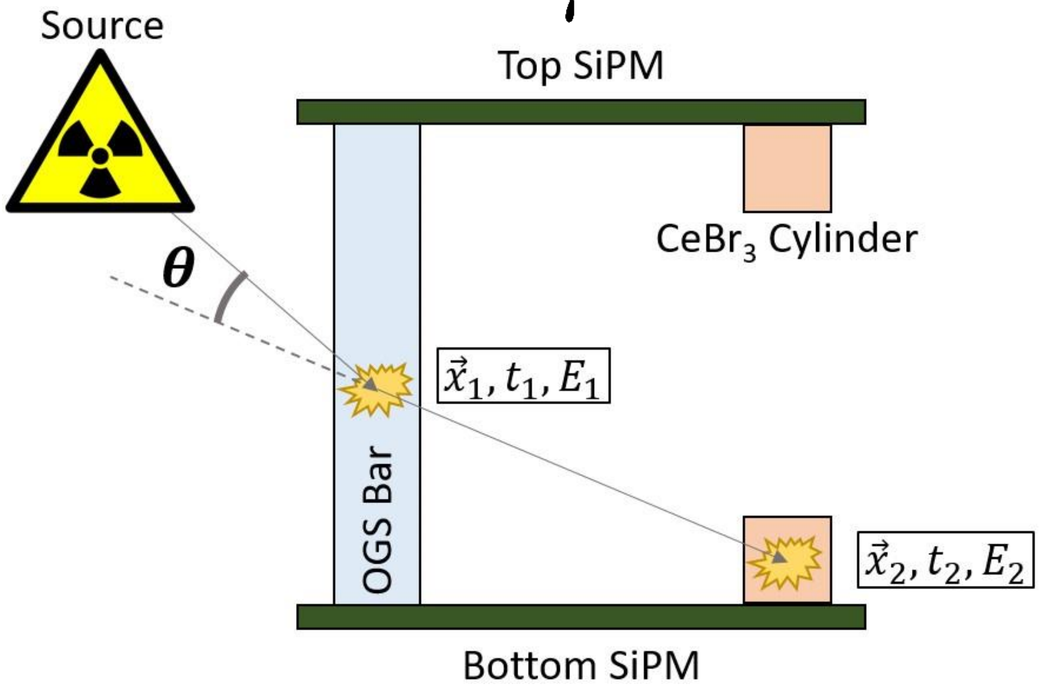
  ↳ apply converging algorithm





Gamma-Ray and Neutron Imaging

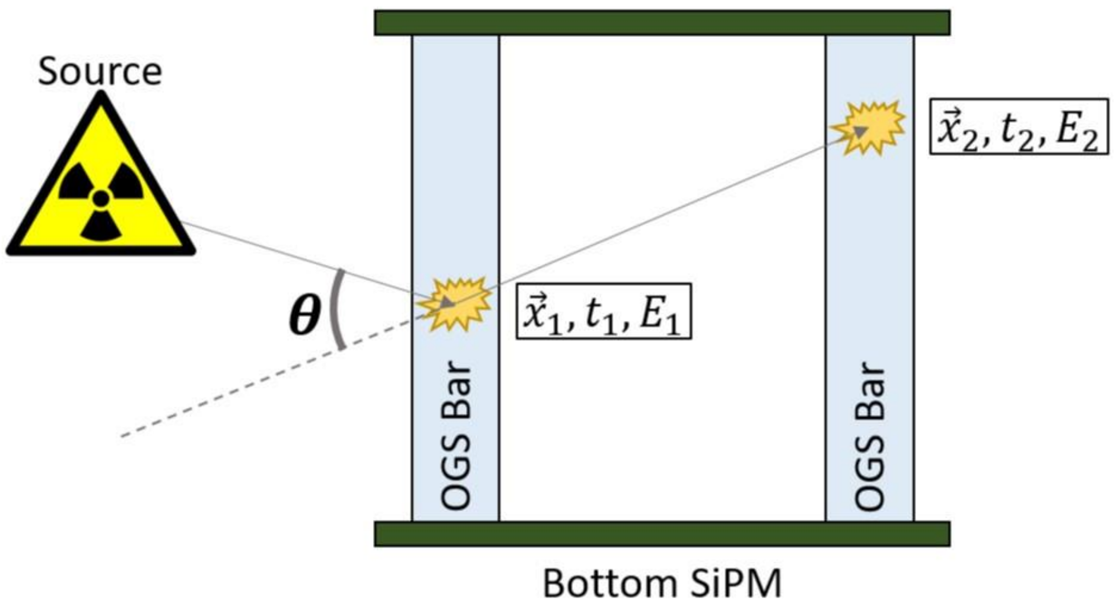
γ



$$\cos\theta^2 = \left(1 + m_e c^2 \left[\frac{1}{E} - \frac{1}{E_2}\right]\right)^2$$

$$E = E_1 + E_2$$

n

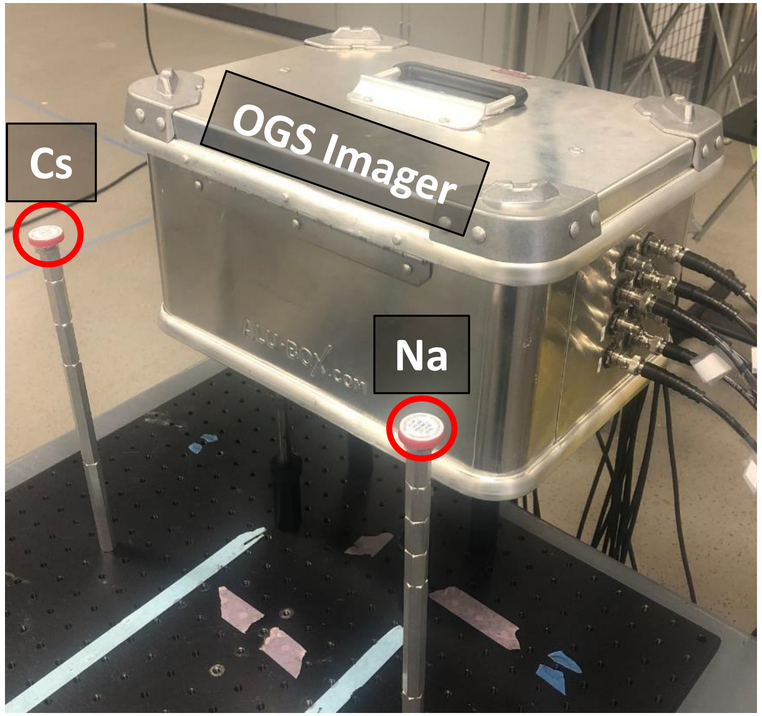


$$v = \frac{\|\vec{x_2} - \vec{x_1}\|}{t_2 - t_1}, \quad E_{TOF} = \frac{1}{2} m_n v^2, \quad \cos^2(\theta) = \frac{E_{TOF}}{E_1 + E_{TOF}}$$

OGS Imaging Experiments

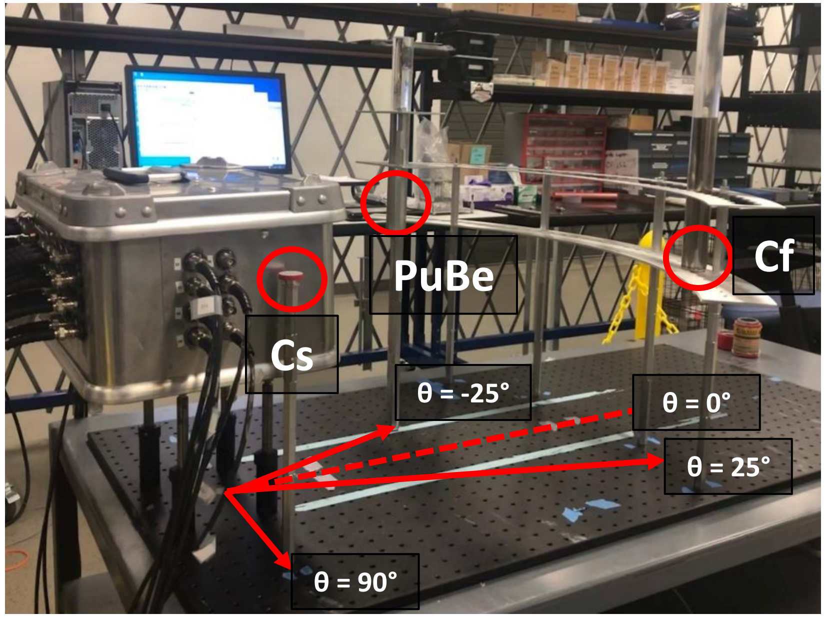
Gamma Ray Measurement

- ^{137}Cs at (50°, 0°) [23.4 cm distance]
- ^{22}Na at (-50°, 0°) [23.4 cm distance]



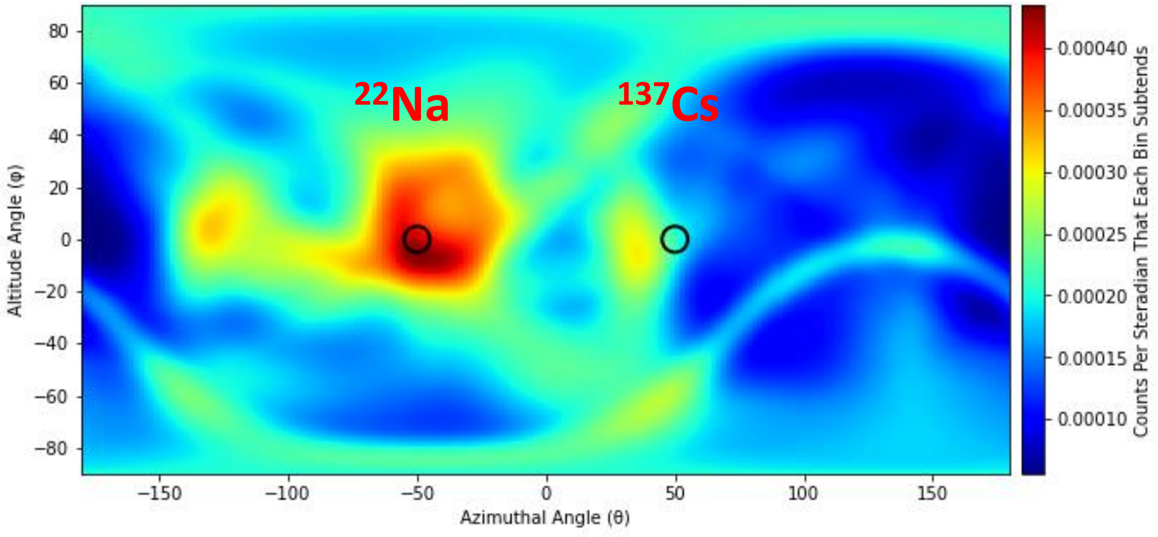
Neutron Measurement

- ^{137}Cs at (90°, 0°) [20.3 cm distance]
- ^{252}Cf at (25°, 0°) [58.4 cm distance]
- PuBe at (-25°, 0°) [36.4 cm distance]

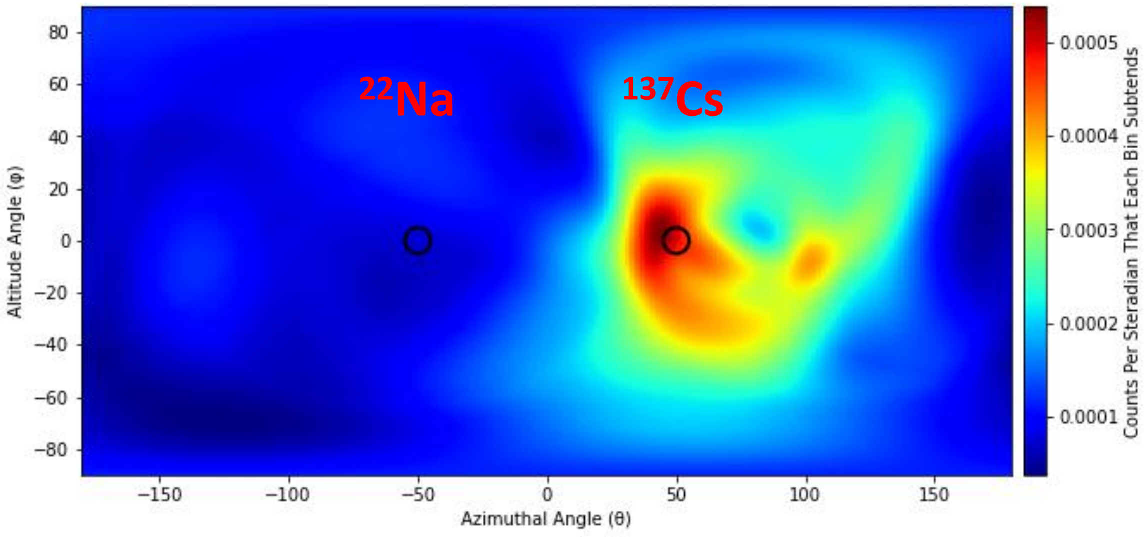


Gamma-Ray Localization Results

Energy gate applied:
511.0 ± 33.0 keV



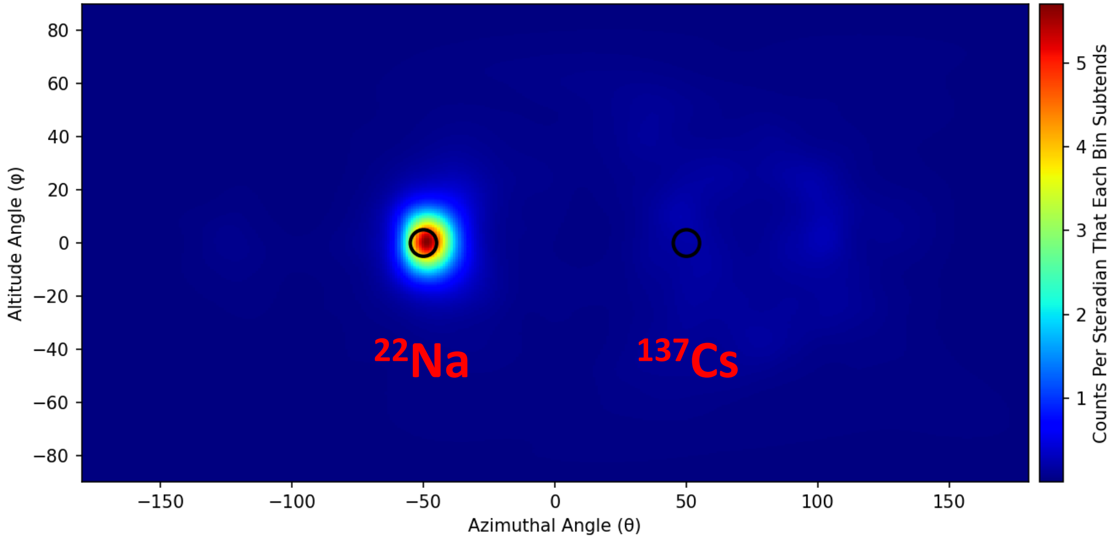
Energy gate applied:
661.7 ± 36.9 keV



Can begin to **image and differentiate** the two gamma-ray sources within **18 seconds** of starting measurement

Gamma-Ray Imaging Results

Energy gate applied:
511.0 ± 33.0 keV

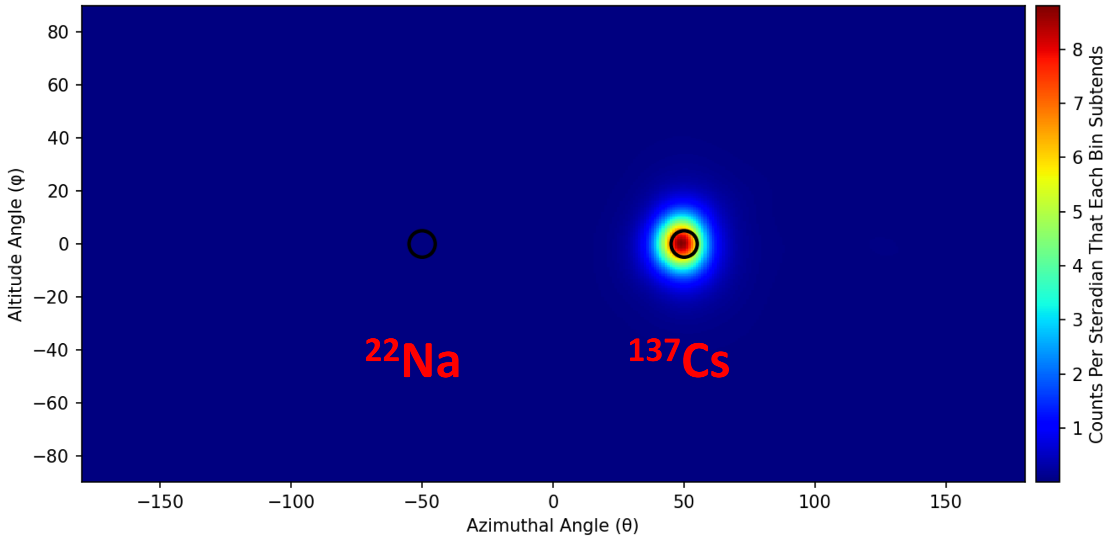


Source Location

Actual: (-50°, 0°)

Converged: (-48.64°, 0.25°)

Energy gate applied:
661.7 ± 36.9 keV



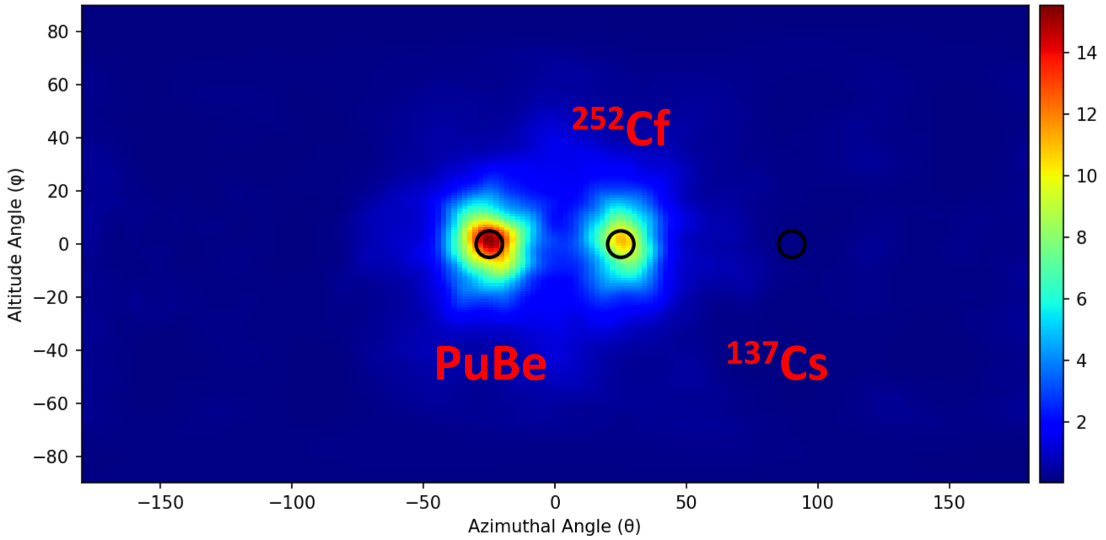
Source Location

Actual: (50°, 0°)

Converged: (48.64°, 0.25°)

Neutron Imaging and Spectrometry Results

Imaging Neutron Sources

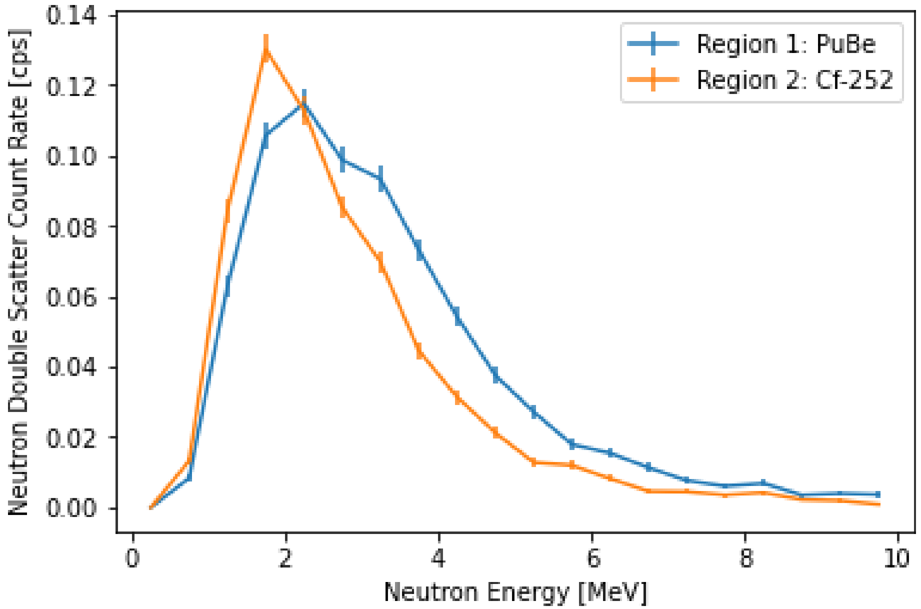


<u>Source Location</u>

Actual: (-25°, 0°) & (25°, 0°)

Converged: (-25.14°, 1.51°) & (25.14°, 1.51°)

Neutron Spectra

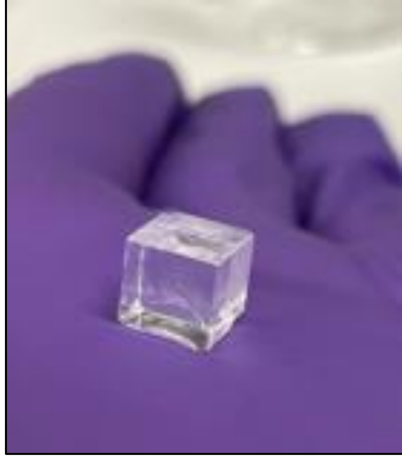


<u>Average Neutron Energy:</u>

PuBe: 3.3 MeV

^{252}Cf: 2.8 MeV

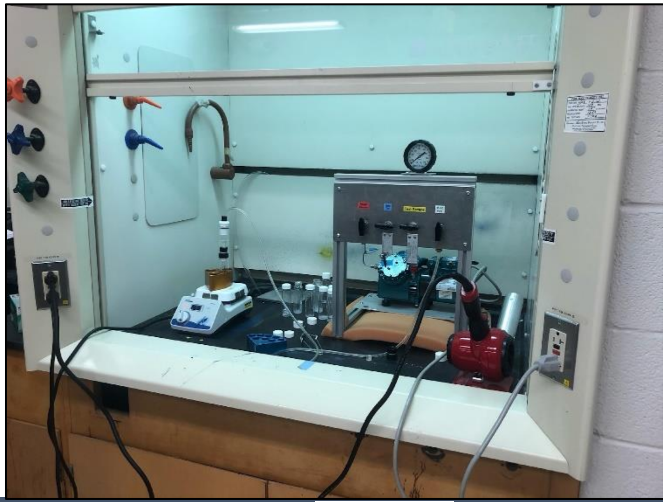
Expected Impact of Work

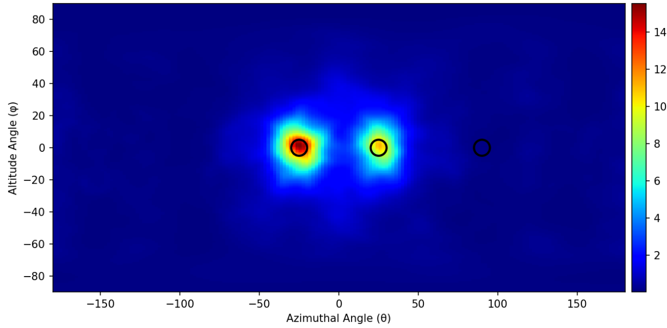


- Significant first step in the implementation of more accessible imaging systems → safeguards scenarios

- Lower costs and high manufacturing scalability of OGS material → more commercially viable

- The success of this work can introduce OGS to more people → find applications in other areas





Conclusion

- Results demonstrate the feasibility of a compact dual particle imager based on an active volume of OGS material
  - **Localize two distinct gamma sources within 18 seconds**
  - **Discriminate (α,n) from fission sources using coarse neutron spectrometry**

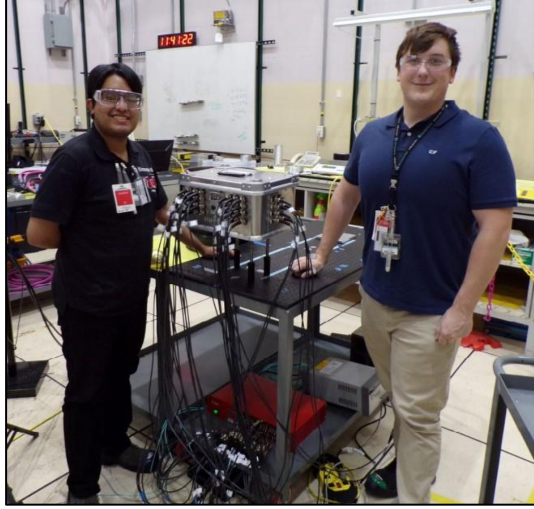
- This work positively impacts the NNSA mission by developing equipment to:
  - Localize sources to detect and deter diversion of nuclear material (NPAC)
  - Characterize sources for on-site monitoring/verification activities (ONV)

Next Steps and Future Work

- Ongoing work includes:
  - Imaging highly enriched uranium and depleted uranium
  - Applying protective coating on OGS to maintain performance in the long term
  - Better characterizing the light output function of the OGS

- Future work includes collaboration with the National Criticality Experiments Research Center (NCERC) for a measurement campaign at the Device Assembly Facility
  - Will image several kilogram quantities of special nuclear material with the OGS imager for the first time

MTV Impact



- I thank MTV for helping to provide the following unique opportunities that have led making important connections over the course of the project:
  - Lab visit to Sandia National Laboratories at Livermore
  - Measurement campaign at Savannah River National Laboratory
  - Measurement campaign at the Nevada National Security Site
- We plan on continuing our collaborative relationship with Sandia
  - Open for more national lab/university collaboration opportunities

Acknowledgements

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