Special Nuclear Material Experiments with a Dual-Particle Imager and Visualization in Mixed Reality

MTV Workshop, 2023

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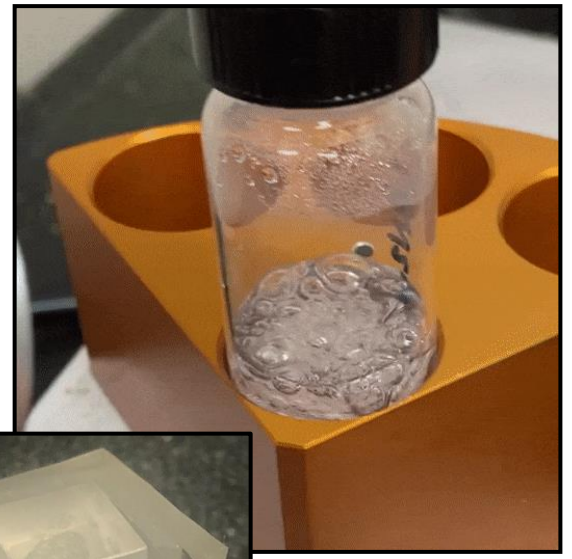
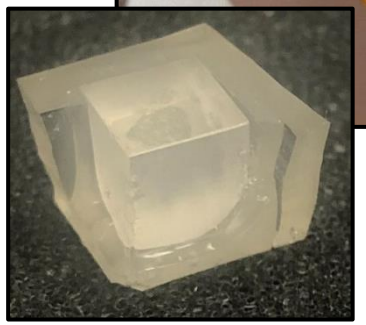
Introduction and Motivation

- Concerns in nuclear verification and nonproliferation fields include accounting for nuclear material
  - Deployable equipment w/ small form factor + user-friendly
- Particle imagers are a powerful tool
  - Neutrons + gamma rays important signatures of U, Pu, etc.
- Organic glass scintillator (OGS) material developed by Sandia National Labs
  - Melt-cast & comparable to other scintillators in performance
- Mixed reality has become more accessible and can convey information in a new medium for users





OGS 6 mm cube cast sample

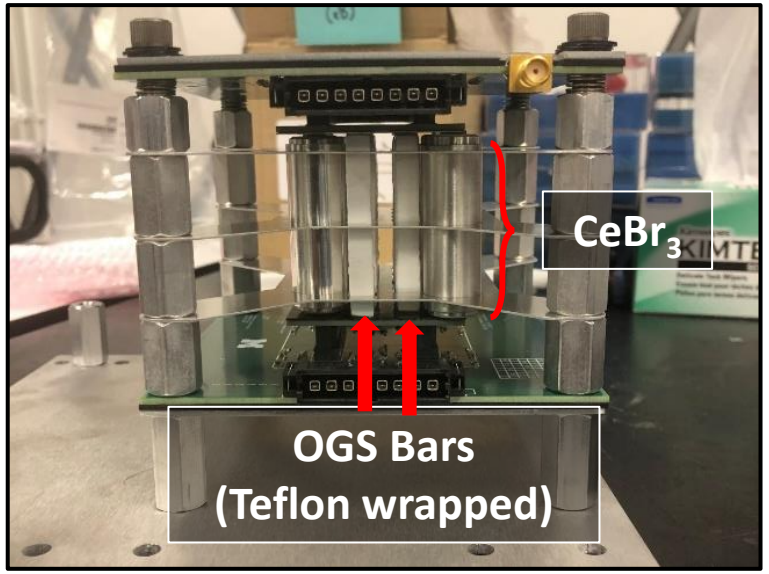
NNSA Mission Relevance

NNSA Office of Defense Nuclear Nonproliferation

- "…build the capacity of the International Atomic Energy Agency (IAEA) and partner countries to implement international safeguards obligations and detect and deter diversion of nuclear material or illicit use of nuclear facilities"

This work is developing equipment capable of source localization while also improving the user experience for personnel.

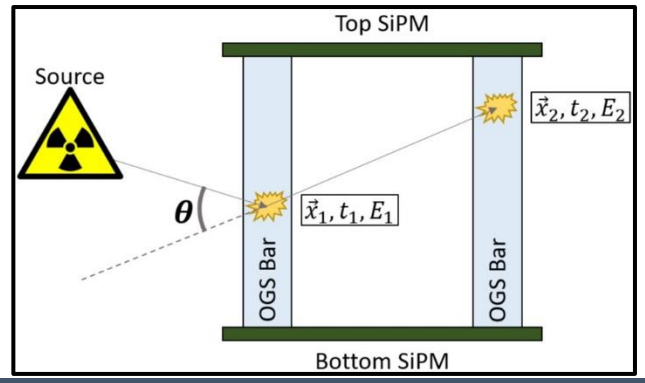
Technical Approach – Imaging

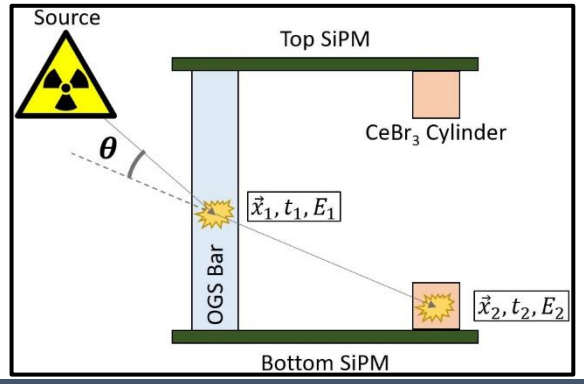


- Scatter-based OGS imager consists of:
  - 12 OGS bars (6x6x50 mm^3) w/ diffuse reflector
  - 8 $CeBr_3$ (6 mm height, 6 mm Ø) cylinders
  - Silicon photomultiplier arrays for output
- OGS composition **can discriminate neutrons and gamma ray events**
- Reconstruct double scatter events using simple backprojection then apply converging algorithm (LM-MLEM)

Neutron Imaging

(Elastic scattering)



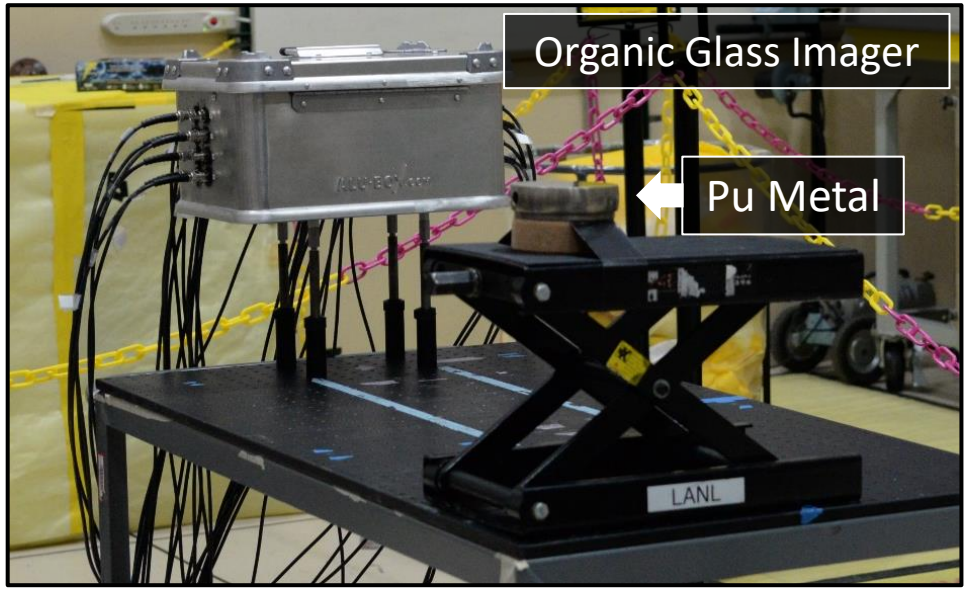


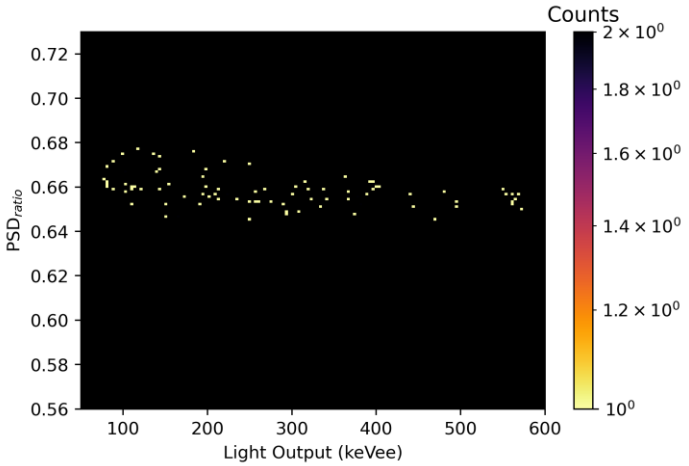
Gamma Imaging

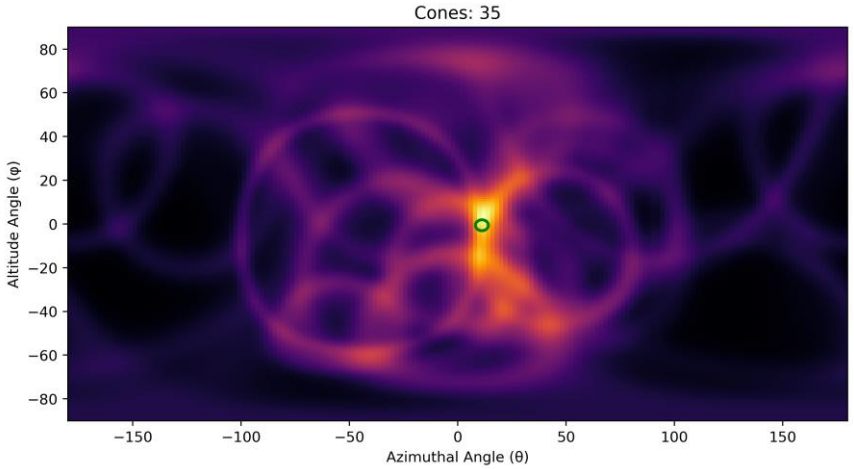
(Compton scattering)

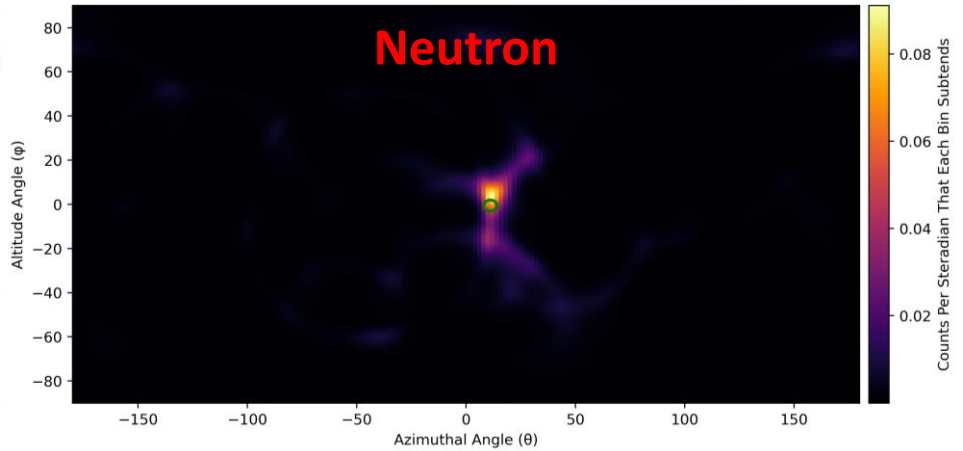
Plutonium Metal: Neutron & Gamma Imaging

- 4 kg ^{239}Pu δ–phase metal @ 1m
  - (94.9 wt % ^{239}Pu, 5.1 wt % ^{240}Pu)
- ^{239}Pu emissions of interest for gamma imaging:
  - 375/414 keV
  - 646 keV



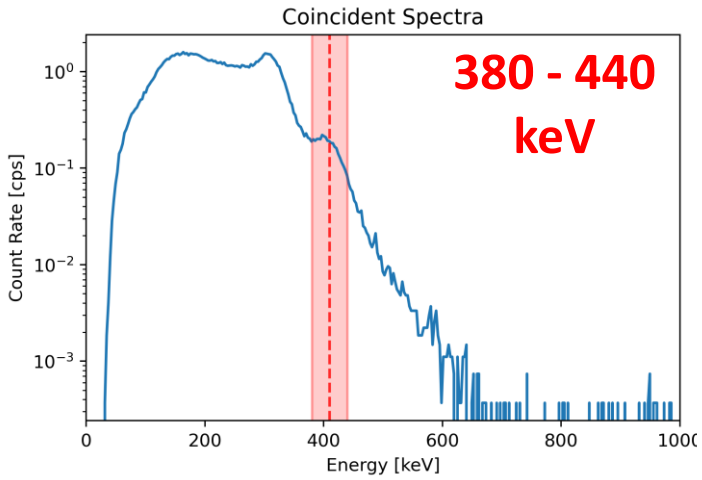


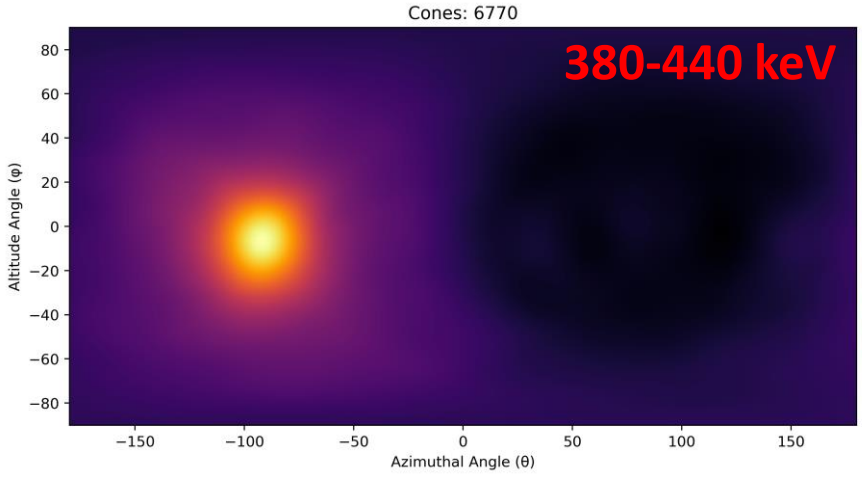


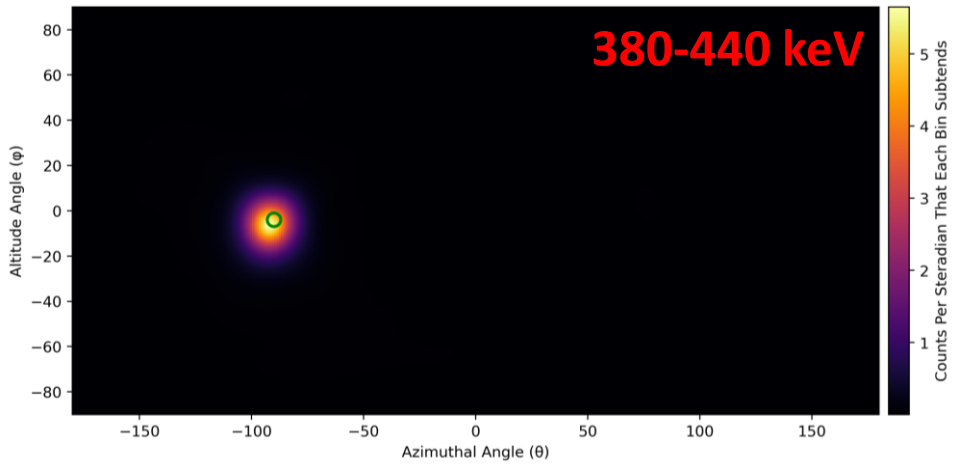


^{237}Np Metal: Gamma Imaging

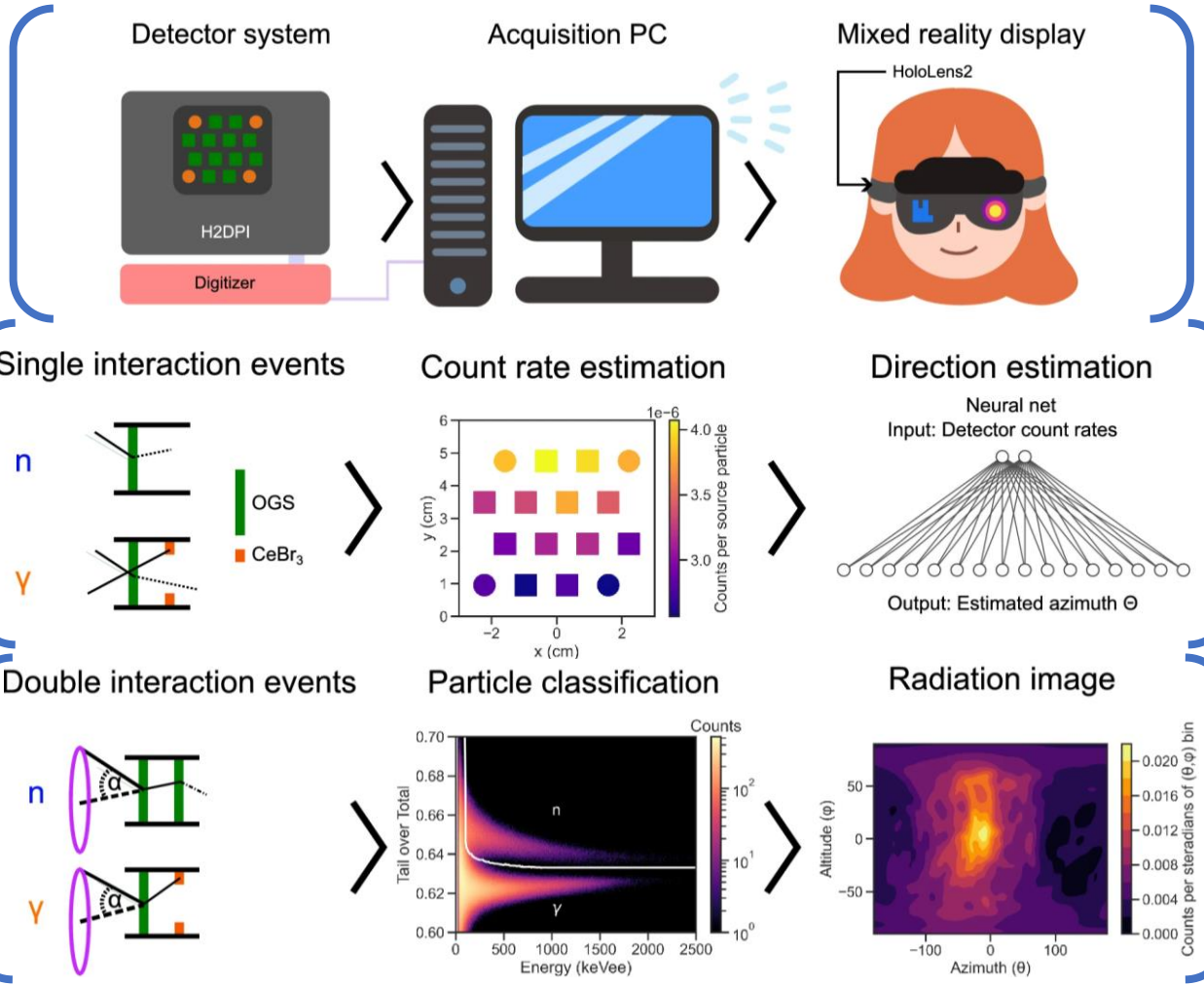
- 6 kg ^{237}Np sphere (98.8 wt % Np)
- ^{233}Pa emissions of interest for imaging:
  - 300/312 keV
  - 398/416 keV
- 1 m distance







Technical Approach – MR Visualization



For more details see our publication:

O. Pakari, R. Lopez, et al., "Real-time mixed reality display of dual particle radiation detector data," *Sci Rep* 13, 362 (2023). https://doi.org/10.1038/s41598-023-27632-1

General Process

Imaging Mode

- Sends double events
- Fast mode
- Tells to project onto the spatial mesh
- Feeds single event count rates

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Real-time mixed reality display of dual particle radiation detector data

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for colorblindness, etc.

Mixed Reality Radiation Visualization

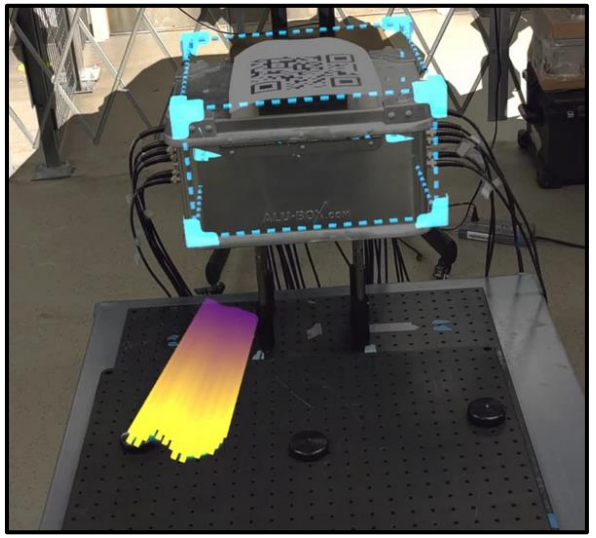
Using HoloLens 2

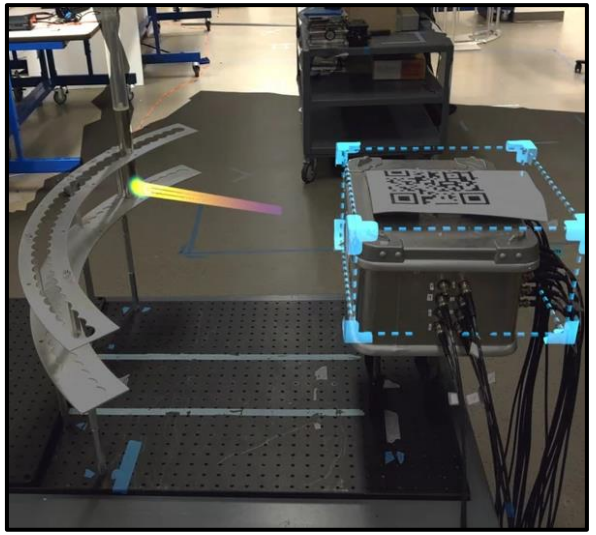
UNIVERSITY OF MICHIGAN

Expected Impact of Work

- Demonstrating feasibility of an OGS-based system → Further increases available tools for safeguards

- Successful MR visualization can allow for use of imaging systems by wider user base → Nuclear background not necessary to interpret the data from scatter-based imagers



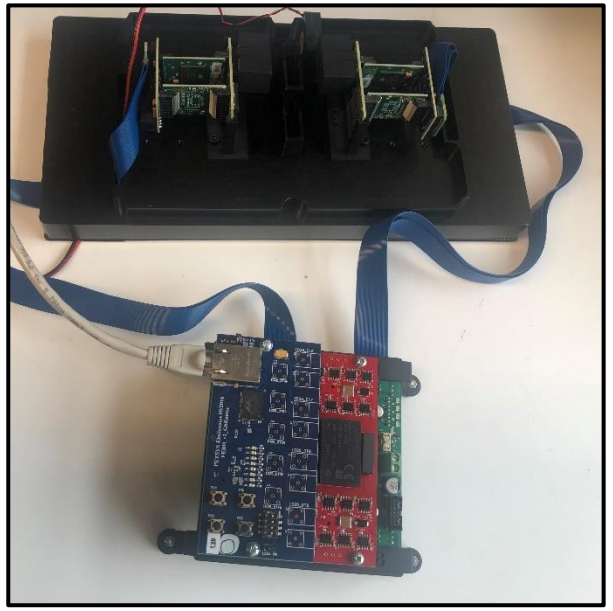


Conclusion

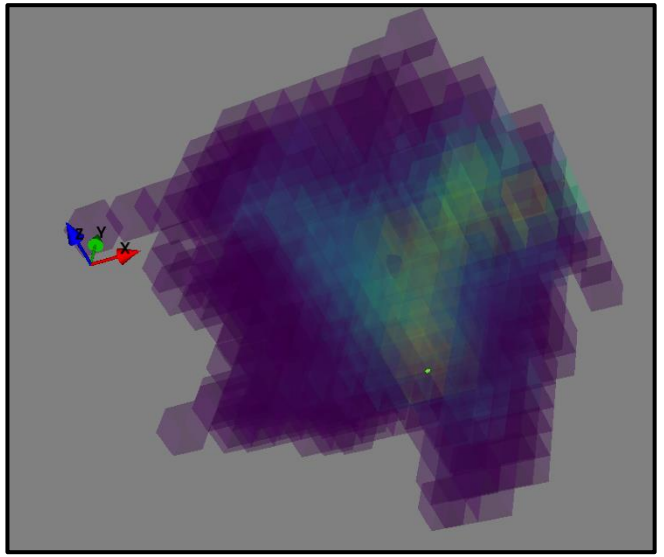
- Results demonstrate the capability of a compact dual particle imager based on an active volume of OGS
  - **Localize kg quantity special nuclear material (Pu) for the first time using n + γ**
  - **Successful gamma imaging of fuel cycle relevant material (Np)**

- Positively impacts the NNSA mission by developing:
  - Equipment that localize sources for on-site monitoring/ verification activities/search, etc.
  - Software that eases burden of data interpretation

Next Steps and Future Work



- Ongoing work includes:
  - Investigating implementation of ASICs in the imaging system
  - 3D imaging algorithm for MR visualization
  - Further characterization of OGS imager



- Future work with imager includes collaboration with:
  - NCERC at the Device Assembly Facility
  - Measurement campaign at Lawrence Livermore National Laboratory

MTV Impact

- I thank MTV for providing the following unique opportunities 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
  - Conference trip to IEEE 2022 in Milano, Italy
- We plan on continuing our collaborative relationship with Sandia + NCERC
  - Open for more national lab/university collaboration opportunities

Acknowledgements

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

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