Muon Tomography Optimization for Dry Cask Spent Nuclear Fuel Storage Imaging

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Background

- Dry-cask storage containers are the only form of commercial long-term spent fuel storage in the U.S.
- The amount of shielding required to reduce dose rates causes difficulties for x-ray and neutron imaging techniques.
- Cosmic-ray muons are naturally created, highly energetic, and highly penetrating particles.

Muon tracking supermodules placed on opposite sides of the Westinghouse MC-10 Fuel Cask at Idaho National Laboratory.
[Durham et al, 2018. DOI: 10.1103/PhysRevApplied.9.044013]

Goals

- Utilize lessons learned from prior cask and lab measurements to optimize future spent fuel cask measurements.
- Minimize the amount of muon data needed to generate informative reconstruction images.

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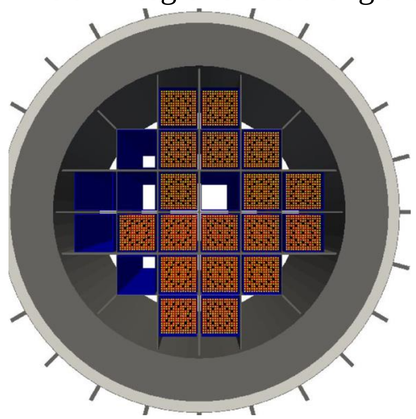
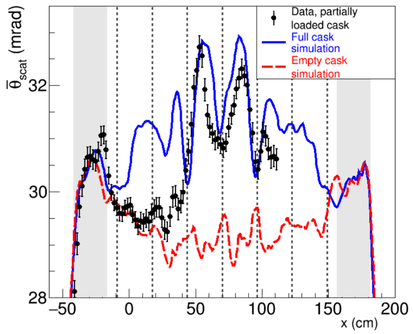
• Cask Measurements

- Muon positions and trajectories are recorded in supermodules, before and after interacting with cask.
- Overall deflection is used to distinguish high atomic number material regions from low atomic number regions. Fuel vs vacant regions. Deflection is an integral effect along the path.



Schematic of fuel bundle fill in the measured MC-10 cask. Orange regions are locations where fuel is loaded.



One-dimensional scatter intensity projection image of MC-10 Fuel Cask. Approximately 30-days of measurement data.

[Durham et al, 2018. DOI: 10.1103/PhysRevApplied.9.044013]

- **1D image shows differences in scatter intensity between different numbers of fuel bundles muons pass through.**
- **We lack sufficient statistics for the depth of field (plenoptic) reconstruction to resolve materials, so we seek to improve muon tomographic imaging reconstruction and collection.**

Lab Data

- Using a 10-gallon steel drum filled with concrete, muon tracks were collected at LANL.
- Brass, lead and tungsten wedges were placed in different position in the barrel.
- The drum was rotated in 15-degree intervals between measurements to give 24 views around the barrel.

Multiple plenoptic tomography and traditional backprojection tomography methods were compared

- Plenoptic depth of field reconstruction method created better images, using less detector views and less muons per view.