Muon Imaging for Dry Cask Storage Verification

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Introduction and Motivation

- Dry-cask storage containers are the only form of long-term storage in the U.S.
- The amount of shielding required to reduce dose rates causes difficulties for x-ray and neutron imaging.
- Cosmic-ray muons are a natural source of highly energetic and highly penetrating particles.

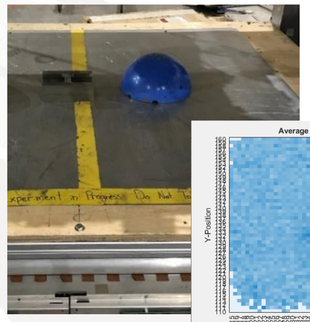
MMT imager supermodules placed on opposite sides of the Westinghouse MC-10 Fuel Cask at INL [Poulson, 2019].

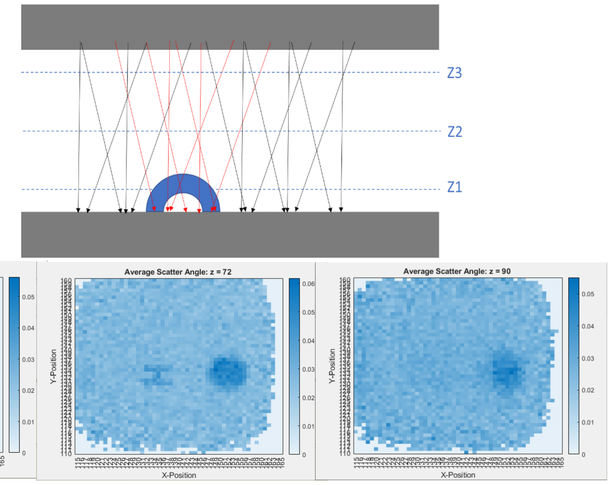
Technical Approach

This work utilizes the Mini-Muon Tracker, developed by Detection Sciences and used by the Threat Reduction Team, LANL.

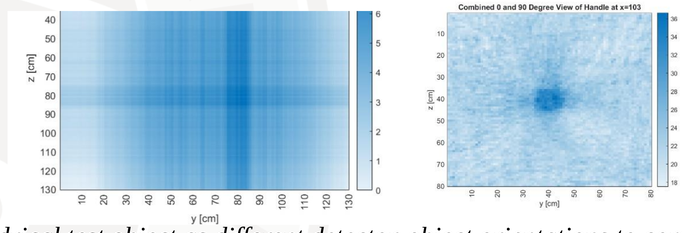
- Consists of two drift tube arrays (supermodules), placed on either side of object of interest
- Each array is made up of alternating stacks of drift tubes, allows for muon tracking in three-dimensions.
- For muons that interact with both supermodules, position and trajectory information is stored for each array.
- Position and trajectory data from both supermodules used for reconstruction.

3D plenoptic imaging From one direction!



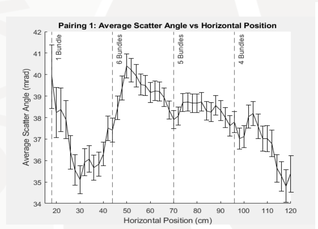


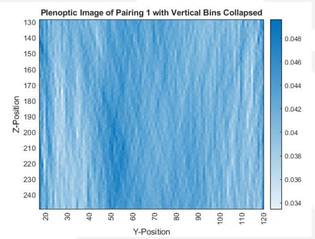
(Left) Pb hemisphere and tungsten H in imager. (Top right) Drawing of high (red) and low (black) scatter angle muons that can be tracked to different positions at different distances from the bottom (or top) detector array, similar to plenoptic camera. The scattered muons converge at the height that they encountered the high density object. (Bottom series) Deconstruction of image at different heights, in focus at the correct height.

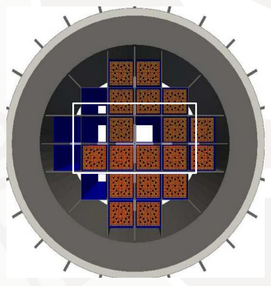


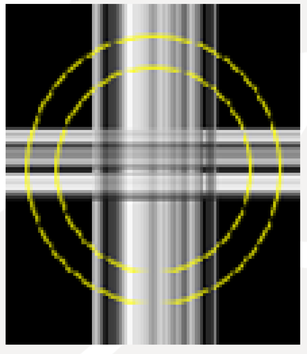
We used a cylindrical test object as different detector-object orientations to compare with (left) traditional backprojection tomography and (right) a tomographic reconstruction using two orientations using plenoptic information. The plenoptic depth field imaging approach converges very quickly, which should allow field imaging with much less data.

Cask Results









(Top left) One-dimensional projection scatter intensity image of test MC-10 Fuel Cask. ~10-day measurement. Differences in scatter intensity are clear between different numbers of fuel bundles muons pass through. (Bottom left) Schematic of fuel bundle fill in the test cask. (Bottom right) Combination of intensity profiles from the top figure and a 90º orientation using traditional backprojection tomography. The rectangle marked on the schematic shows where the backprojections overlap. (Top right) Plenoptic depth field image of MC-10 cask, using same data as one-dimensional scatter intensity image.

MTV Impact

- Impact
  - 3D muon based imaging
  - Image converges faster, less data needed, faster imaging
  - MTV PhD student fellow Jesus Valencia is supported by this work
  - What is the impact of the MTV on your development?
- Personnel transitions: Plans for future relationship with national labs
  - Collaborating with Matthew Durham and Daniel Poulson from LANL
  - Plan to perform cask measurements at INL and/or SRNL

Mission Relevance

Muon Imaging techniques can be used to prevent nuclear weapons proliferation by

- Maintaining continuity of knowledge of spent fuel in dry-cask storage
- Identify if nuclear material has been removed from storage containers

Conclusion and Next Steps

- Using a very limited number of views, around the cask, we can extract information showing the loading profile of a dry-cask storage container.
- Apply these methods to new cask measurements.

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