Antineutrino fingerprinting of dry storage casks

MTV Kickoff Meeting

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Introduction and Motivation

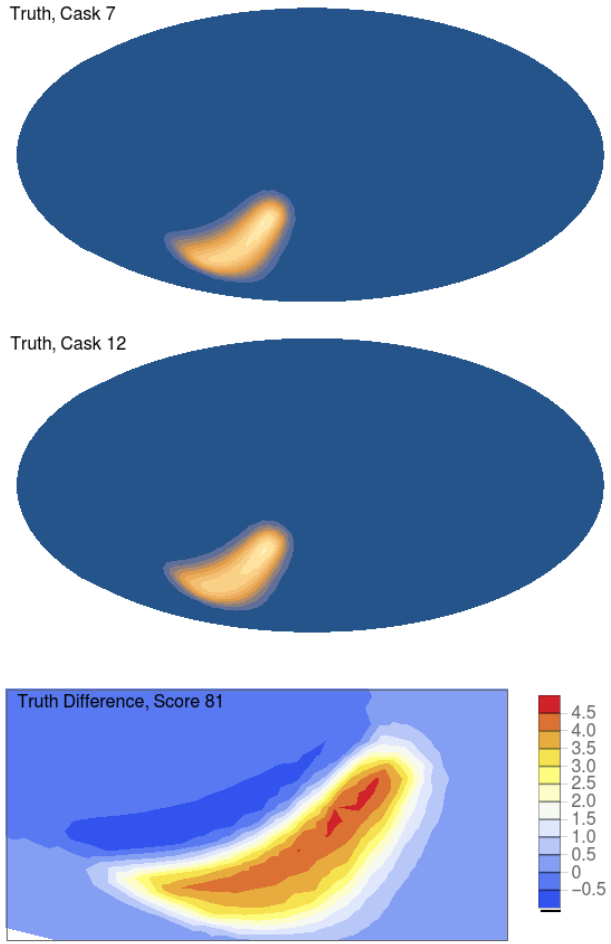
- Bulk of spent nuclear fuel in dry storage.
- Verification of cask contents using usual radiation signatures difficult due to cask design and self-shielding.
- Antineutrinos are not attenuated by the cask or contents.
- Detector technology made significant progress over the last 5 years.
- As did analysis techniques based on machine learning.

Mission Relevance

- Antineutrino technology (AT) would allow to directly measure the total fission fragment content of a cask.
- AT may also be able to determine the spatial distribution of fission fragment content, which could serve as a unique identifier of a given cask.
- This addresses the NNSA goal to develop technologies and implement approaches to monitor and verify compliance in the context of non-proliferation safeguards.

Exploratory studies

- Axial burn-up for several dozen BWR fuel elements from NUREG/CR-7224.
- Generate neutrino source terms based on Brdar, Huber, Kopp, Phys.Rev.App. **8** 054050 (2018).
- Randomly “fill” casks to make library of reference casks.
- Fast detector MC to map to neutrino signal.
- Comparison of statistical similarity.



Technical Work Plan

- Expand source term calculation to include both antineutrino and conventional signatures (gamma, neutron) in collaboration with VT's NSEL (Y1).
- Close past collaboration with LLNL on AT and potential applications. Unique detector R&D and simulation expertise at the lab will ensure realism in detector modeling (Y2&5).
- Improve detector simulation and data generation (Y2).
- Increase size and diversity of cask library (Y2).
- Develop machine learning for cask ID based only on AT and in combination with conventional signatures (Y3&4).
- Derive detector R&D targets (Y5).

Expected Impact

- Demonstrate that AT fingerprinting is feasible given the “right” detector.
- Indicate R&D pathways to the “right” detector.
- Lay scientific groundwork for the necessary detector R&D.
- Experimental demonstration of fingerprinting with a prototype detector within 5 years of the conclusion of MTV.
- Field deployable system a decade from today.

MTV Impact

- MTV will provide a framework to collaborate with LLNL and in particular to have students spent time at the lab.
- Good success in the past with internships of students at national labs turning into job offers: student supported by LLNL during academic year, summer internship at LANL, postdoc position at LANL. Hope to replicate.
- MTV contains unique expertise in radiation detection and we hope for collaboration to study the interplay of conventional techniques and AT.

Conclusion

- If AT fingerprinting is shown to be theoretically feasible, and experimental demonstration concludes favorably, this could provide an answer for safeguarding the bulk of spent nuclear fuel effectively.
- This would globally strengthen the accounting of plutonium in spent nuclear fuel prior to emplacement into geological repositories, which is just starting.

Acknowledgements

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