Sensitivity of the Antineutrino Source Term on Nuclear Reactor Simulations of Varying Levels of Complexity

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Introduction and Mission Relevance

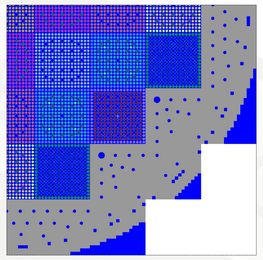
- Antineutrino (AN) detection is a proposed method for monitoring nuclear reactors for plutonium production and diversion
- Antineutrinos are produced in large numbers in the fission process and can be detected in detectors of a variety of scales and distances
- Accuracy of reactor antineutrino monitoring relies on the ability to accurately simulate the antineutrino source term
- Determine how reactor simulation model complexity impacts the antineutrino source term

Technical Approach

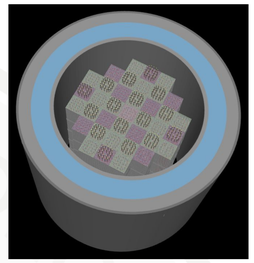
- Simulate 160 MWt NuScale LWR
- Simulated the antineutrino source term for four major isotopes using four models
  - Lattices
  - 2D
  - 3D Fixed TH
  - 3D Full

Increasing Complexity

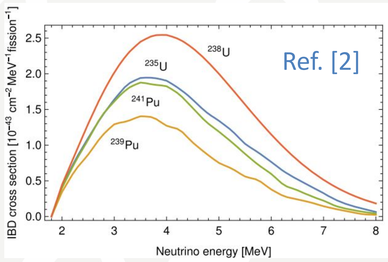
- Use isotopic fission rate, antineutrino spectra [1] and inverse beta decay (IBD) detection cross section [2] to calculate detected neutrino rate

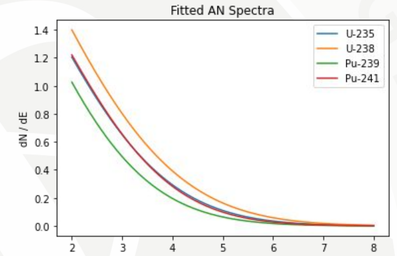


2D Model with Quarter Symmetry

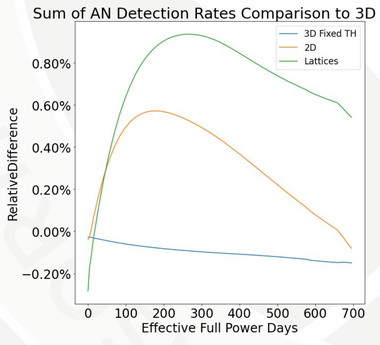


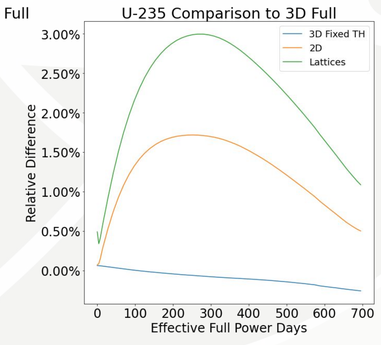
3D Model

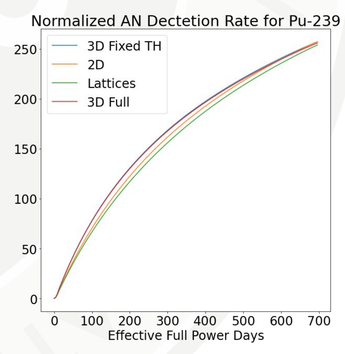




Results







The maximum difference is on the order of 1%.

The difference is dominated by the accuracy in simulating the U-235 fission rate

Impacts

- Quantification of the trade-off between simulation complexity and accuracy that may impact nuclear safeguards and verification using AN detection
- Potential impact on basic research in the neutrino sector

Conclusion and Next Steps

- Higher complexity simulations yield higher accuracy in predicting AN source term
- Accuracy does not necessarily vary monotonously over the operating cycle
- Evaluate the impact in more complex scenarios such as refueling and diversion
- Determine the impact on safeguards variables derived from practical detector measurements

[1] P. Vogel and J. Engel, Phys. Rev. D 39. 3378-3383 (1989)
[2] A. Bernstein, N. Bowden, B. L. Goldblum, P. Huber, I. Jovanovic, and J. Mattingly, Rev. Mod. Phys. 92, 011003 (2020).

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