Development of $^{241}Am^{13}C$ Calibration Source for a Large Water Cherenkov Detector

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Introduction and Motivation

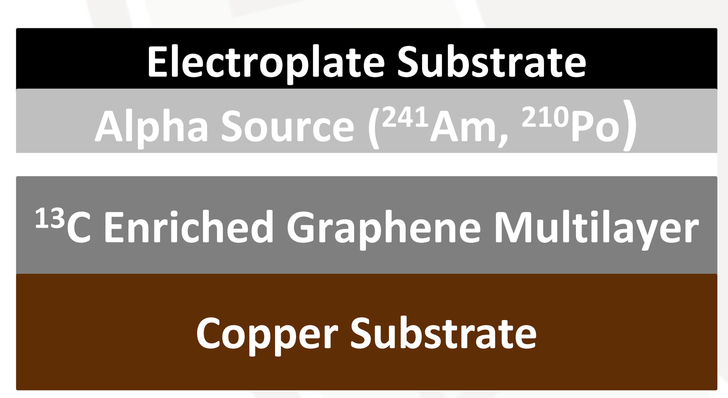
- Large-scale gadolinium-doped water Cherenkov detectors, *e.g.*, WATCHMAN, require correlated high-energy gamma calibration sources
- We are developing a 6.1-MeV gamma-ray source based on the $^{13}C(\alpha,n)^{16}O^*$ reaction and seek
  - High emission rate of gamma rays per volume
  - High ratio of gamma emission to neutrons

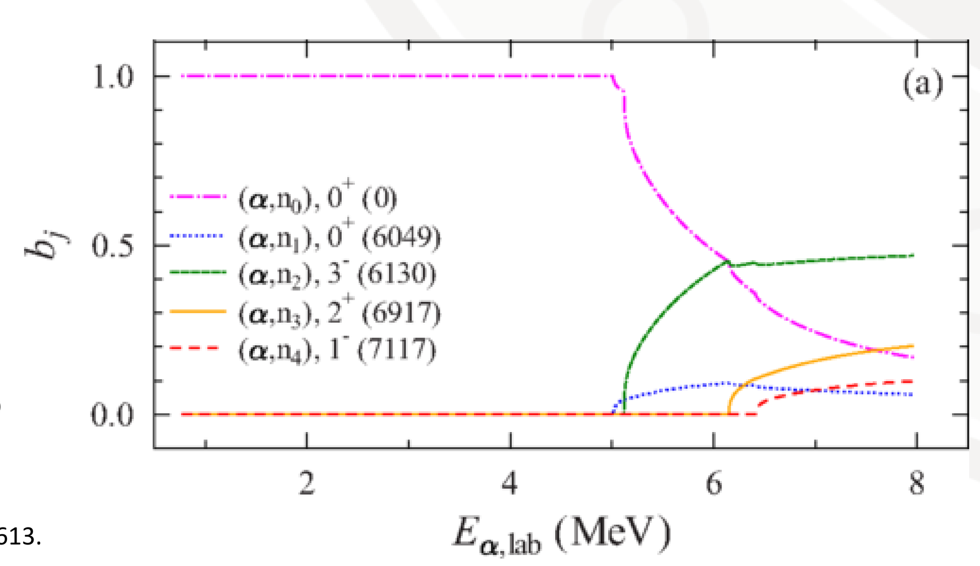
Mission Relevance

- Antineutrino detection nonproliferation applications:
  - Remote monitoring of reactor power and fuel composition [1]
  - Spent fuel monitoring [2]
  - Discovery or exclusion of undeclared reactors [3]

Technical Approach

- Simulation of production and detection of gamma-ray and neutron signal
- Simulation performed with standard Monte Carlo codes and semi-analytical calculation

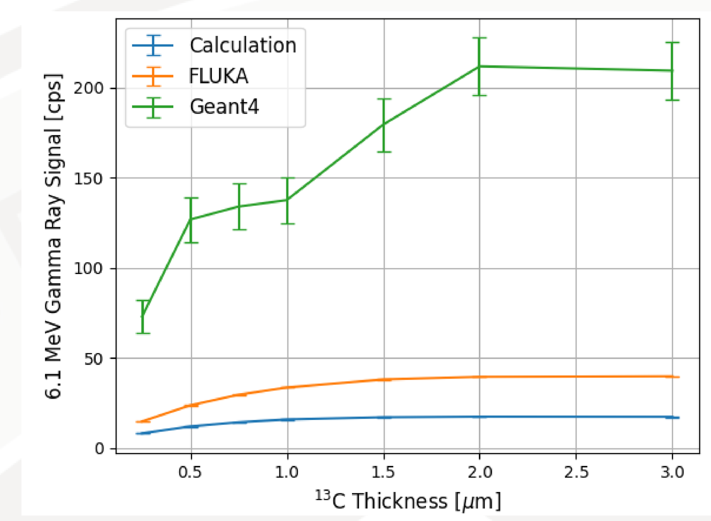




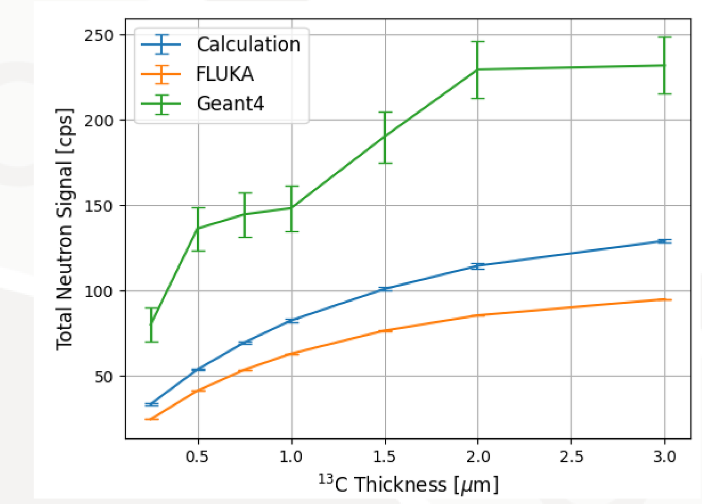
P. Mohr, "Revised cross section of the 13C(α,n)16O reaction between 5 and 8 mev," Phys. Rev. C, vol. 97, p. 064 613, 6 Jun. 2018. doi: 10.1103/PhysRevC.97.064613. [Online]. Available: https://link.aps.org/doi/10.1103/PhysRevC.97.064613.

Branching Ratio into Excitation State of ^{16}O

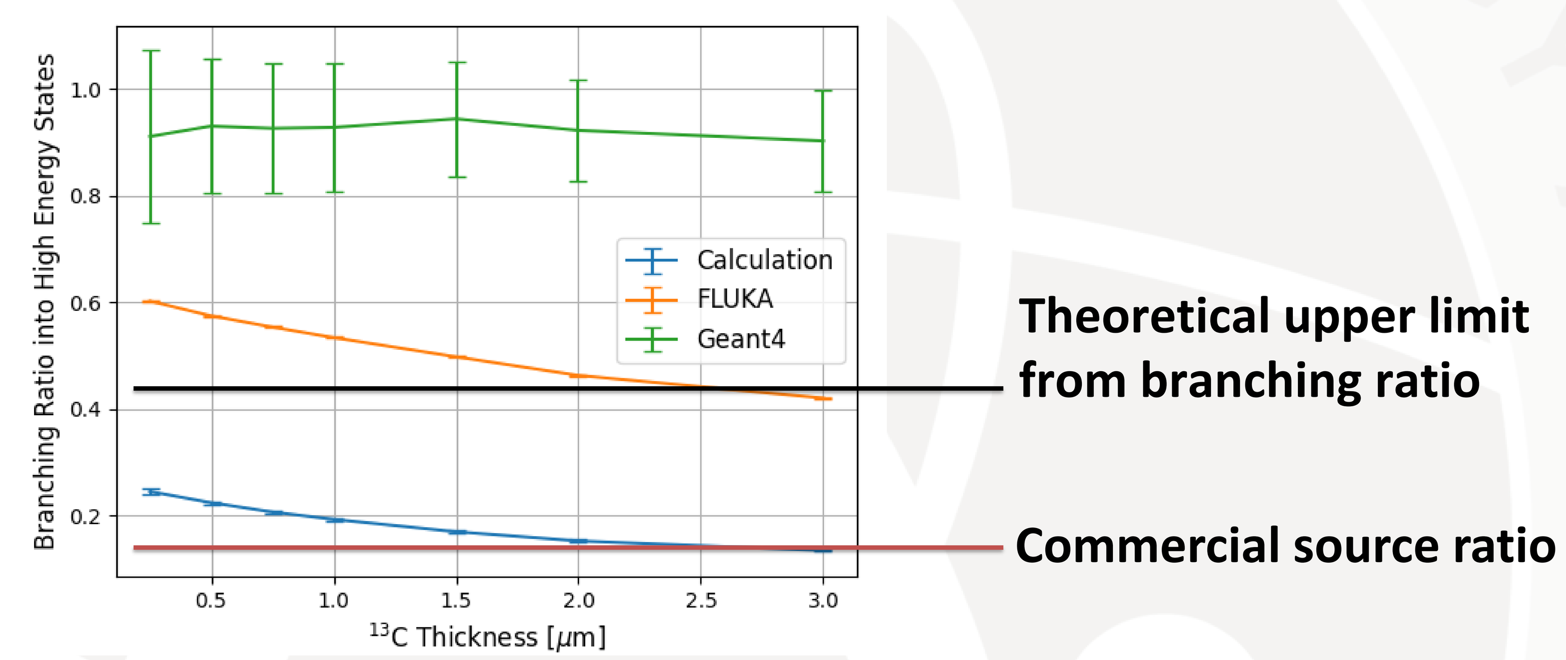
Results



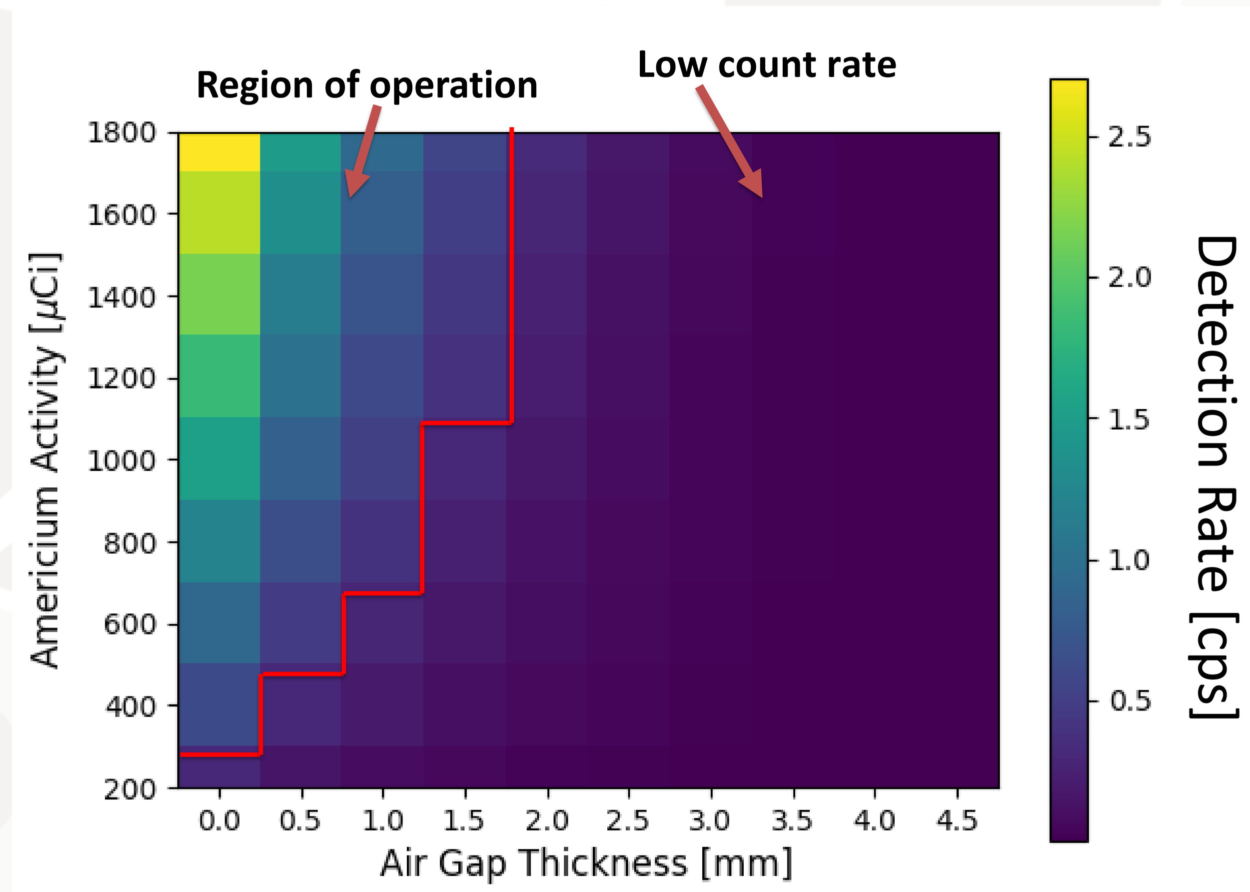
Gamma production rate for 1 mCi ^{241}Am



Neutron production rate for 1 mCi ^{241}Am



Ratio of gamma to neutron production rate



Heat map of detection rate of AmC source based on activity and air gap with 3"x5" NaI detector

Expected Impact

- Developed source and simulation model which can be used for calibration of future large water-based detectors

MTV Impact

- Work is partially supported by Lawrence Livermore National Lab and is done in framework of WATCHMAN collaboration
  - US and UK collaborators
  - 3 US national labs (LLNL, PNNL, BNL)

Conclusion

- Conducted simulations to design a 6.1-MeV gamma ray source
- Developed a simulation framework that more closely matches known physics than available Monte Carlo radiation transport codes
- Work advances the development of antineutrino detectors for remote monitoring

Next Steps

- Survey commercially available alpha sources to determine applicability
- Validate simulation modeling by comparison against measurement
- Construct and test a prototype source

[1] Yu. V. Klimov, V. I. Kopeikin, L. A. Mikaélyan, K. V. Ozerov V. V. Sinev, "Neutrino method remote measurement of reactor power and power output," Atomic Energy, vol. 76, pp. 123-127, Feb. 1994, 10.1007/BF02414355 [2] V. Brdar, P. Huber, and J. Kopp, "Antineutrino monitoring of spent nuclear fuel," Phys. Rev. Applied, vol. 8, p. 054 050, 5 Nov. 2017. doi: 10.1103/PhysRevApplied.8.054050. [Online]. Available: https://link.aps.org/doi/10.1103/PhysRevApplied.8.054050 [3] A. Bernstein, N. Bowden, B.L. Goldblum, P. Huber, I. Jovanovic, J. Mattingly, "Colloquium: Neutrino detectors as tools for nuclear security," Review of Modern Physics, vol. 92, pp. 011003, Mar. 2020, 10.1103/RevModPhys.92.011003

This work was funded in-part by the Consortium for Monitoring, Technology, and Verification under Department of Energy National Nuclear Security Administration award number DE-NA0003920

National Nuclear Security Administration