Development of a High-Energy Two-Component Gamma Calibration Source

Junwoo Bae

Postdoc, University of Michigan

C. Graham[1], K. Ogren[2], S. Dazeley[3], I. Jovanovic[1]

[2]Los Alamos National Laboratory, [3]Lawrence Livermore National Laboratory

Introduction and Motivation

- Water-based Cherenkov detectors with Gd doping are one of the promising technologies for practical remote monitoring of nuclear reactors.
- Gamma-ray calibration sources with high energy points (>5 MeV) are required for these detectors.
- The (α, n) reaction on ^{13}C target can be utilized to produce an excited state of ^{16}O, emitting a 6.13 MeV gamma ray.

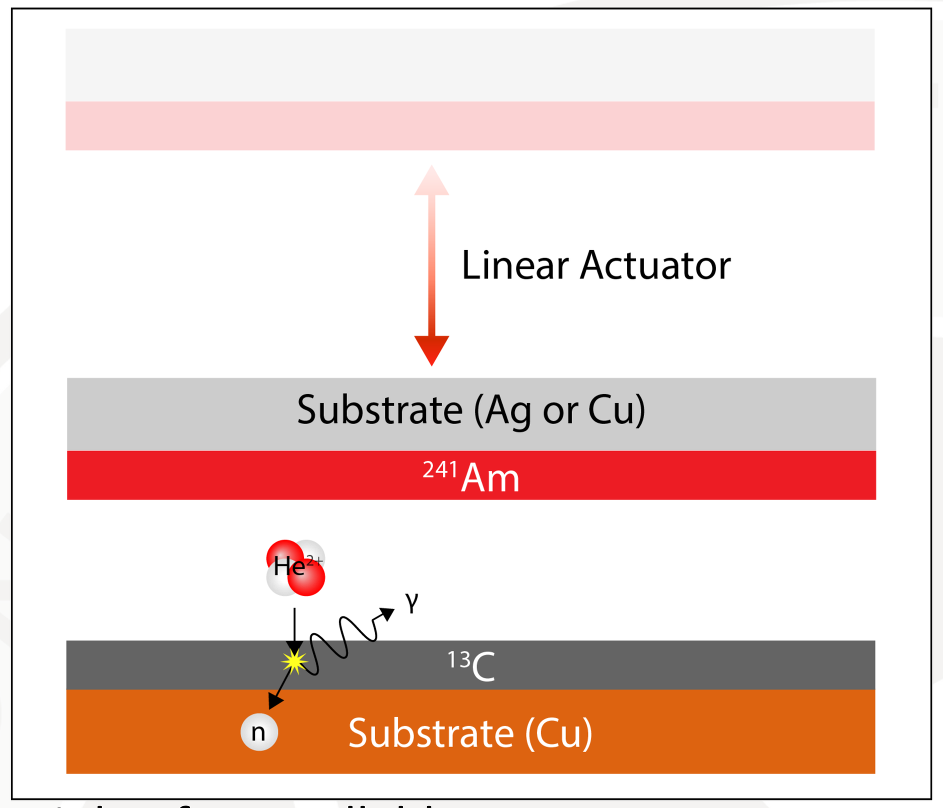
$$\begin{cases} E_\alpha < 5.12\ MeV: \quad {}^{4}_{2}He + {}^{13}_{6}C \rightarrow {}^{16}_{8}O + {}^{1}_{0}n \\ \quad Q = 2.22\ MeV \\ E_\alpha > 5.12\ MeV: \ {}^{4}_{2}He + {}^{13}_{6}C \rightarrow {}^{16}_{8}O + {}^{1}_{0}n + \gamma\ (6.13\ MeV) \\ \quad Q = -3.91\ MeV \end{cases}$$

- To avoid unnecessary shielding, a switchable source with two components (source and target) has been designed.

Mission Relevance

- Calibration of antineutrino detectors for monitoring nuclear reactors, contributing to the NNSA's nuclear nonproliferation mission.
- Easy deployment (no shielding in transport) for calibration of gamma and neutron detectors used in other NNSA applications

Technical Approach

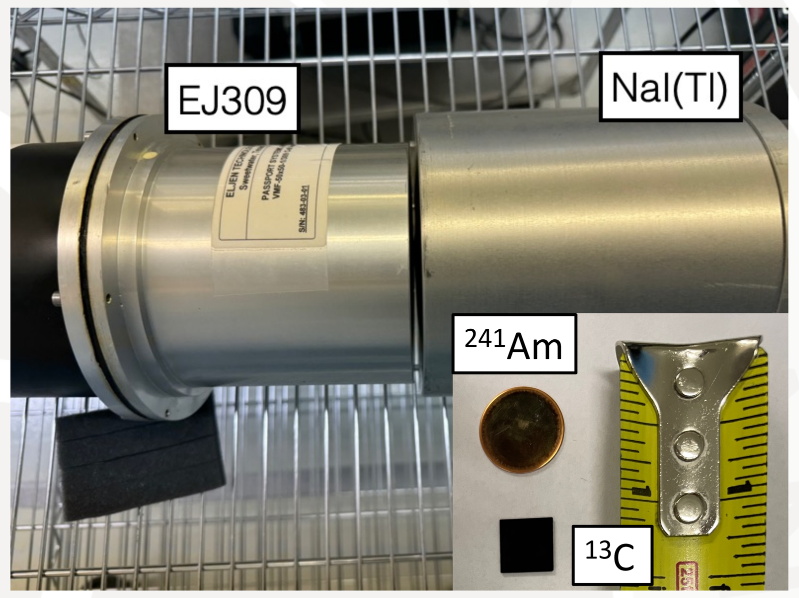


Principle of controllable two-component gamma source with actuator

– Actuator: move source component far from target

- Two source components:
  – **^{13}C**: deposited on Cu substrate using plasma enhanced chemical vapor deposition (Collab with Penn State Univ.)
  – **^{241}Am**: electrodeposition on Ag substrate (collab with Univ. of Cincinnati)

- Output measured using a PSD-capable organic scintillator (EJ-309) and NaI(Tl) detector.

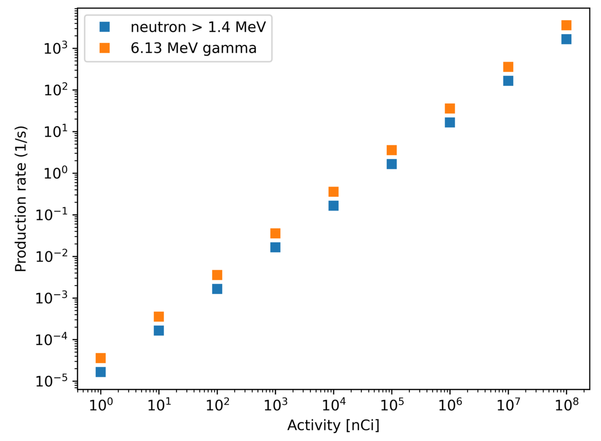


Detector setup and prepared ^{241}Am and ^{13}C deposited layers

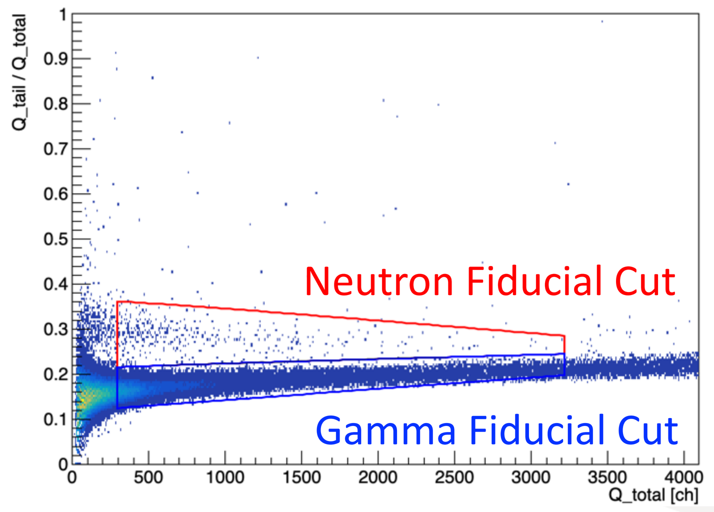
Results

The production rate for 1 cm^2 of a is estimated with different activities of ^{241}Am.

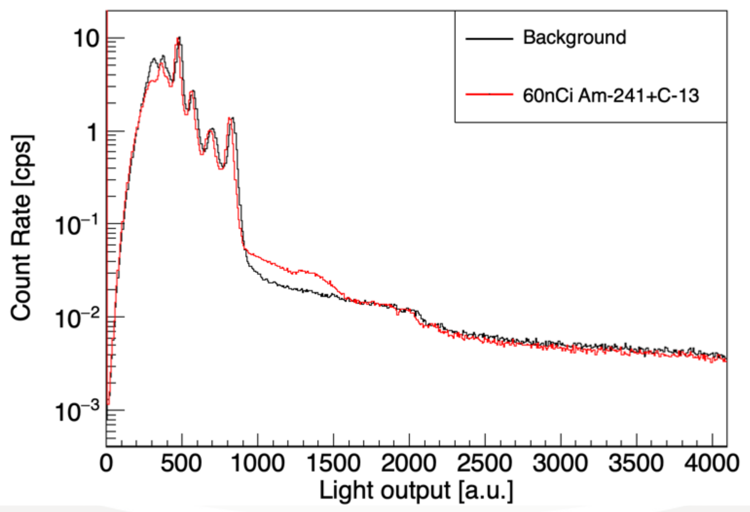
	Neutron (cph)	Gamma (cph)
BKG	14.6±0.8	2383±10
^{241}Am+^{13}C	17.0±0.8	2522±10



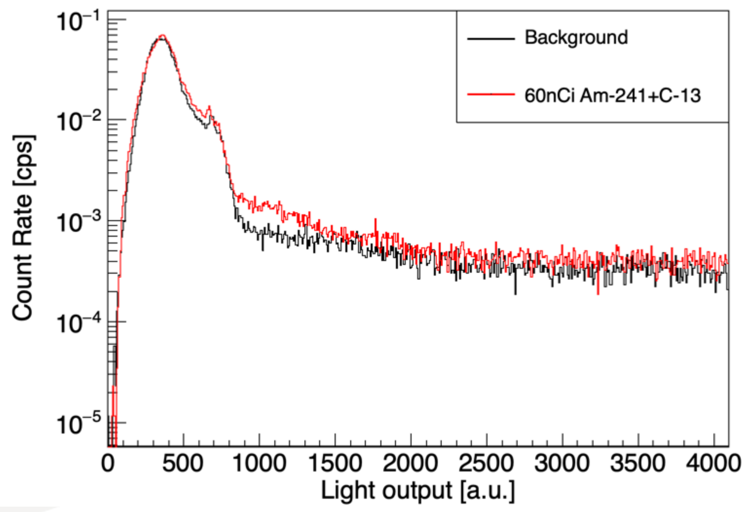
Estimated neutron and gamma ray production rate



Source output measured by an EJ-309 detector



Full spectrum



Time coincidence applied

Gamma ray spectra from NaI(Tl)

The gamma ray count rate is elevated in the 3–5 MeV region.

Expected Impact

- The developed source can be used for the calibration of detectors that utilize gamma rays of O(10 MeV), such as water-based Cherenkov detectors, and for neutron active interrogation.

MTV Impact

- We work with LLNL and the UK/US BUTTON collaboration to establish the required source size, gamma-ray production rate, practical actuators, and future deployment in the BUTTON experiment (Boulby, UK).

Conclusion

- Calculations and measurements of neutron and gamma-ray production for thin layers of ^{13}C and ^{241}Am were performed.
- Both the neutron count rate and the gamma-ray spectrum show promising differences from the background level.

Next Steps

- Prepare a higher activity source and obtain statistically significant spectral difference.
- Test the controllability using an actuator

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