How Well Do You Know Your Neutron Source?
Neutron Yield of Thermo Scientific P385 D-T Neutron Generator vs. Current and Voltage

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Introduction and Motivation

- Thermo Scientific™ P385 Neutron Generator is a compact and portable neutron source known to be with the maximum neutron yield of $5 \times 10^8\ n/s$ (A3082 tube at 70 µA and 130 kV) and $8 \times 10^8\ n/s$ (A3083 tube at 90 µA and 140 kV) from deuteron-trition (DT) fusion reactions.
- To better characterize the source for future applications, it is important to understand the dependence of neutron production rate on the accelerator current and voltage.
- There has been no previous studies on a TRIM-based calculation of the neutron yield of accelerator-based neutron source.

Mission Relevance

- D-T neutron generators have been proposed for warhead verification.
- This study on neutron source characterization can help the NNSA mission on nuclear verification, as a part of developing the technical means to monitor the compliance of a nuclear arms control treaty or other international agreement.

MTV Impact & Expected Impact

- Close collaboration with Princeton Plasma Physics Laboratory (PPPL) enabled neutron experiments in a safe and seamless manner.
- Dr. David Chichester (INL) and Dr. Jim Simpson (Thermo Scientific) gave us useful comments on accelerator-based neutron sources.
- This study will set a baseline for any studies using DT neutron generators, including zero-knowledge protocol verification.

Technical Approach

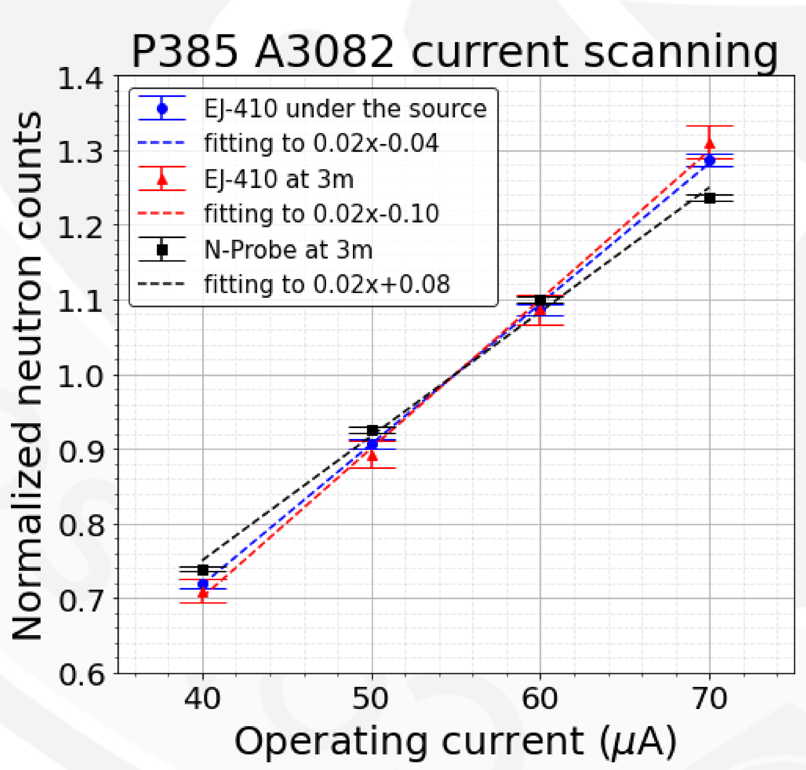

- Source: P385 A3082 & A3083 tube
- Detectors: Nested Neutron Spectrometer (NNS, ^{3}He with poly shells), BTI N-Probe (liquid scintillator), EJ-410 (ZnS(Ag) scintillator)
- Calculation: MCNP, Python code using SRIM/TRIM
  – Mixture of 10% atomic (D+, T+) and 90% molecular (DD+, DT+, TT+) beam

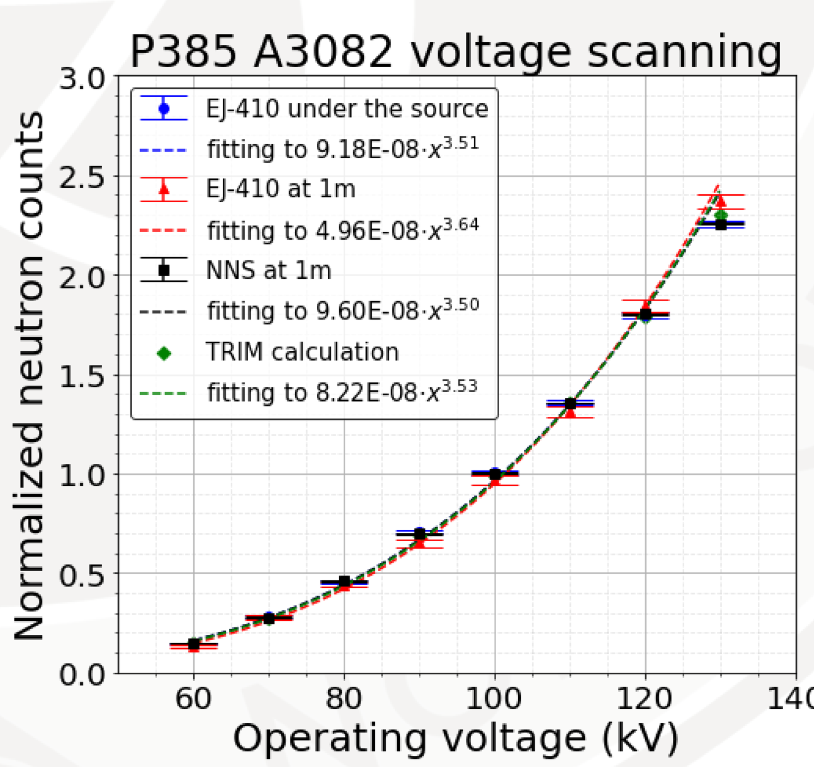
- TRIM calculation

$$f = n_t \sum_i \Delta l_i\, \sigma_{fus,i}$$

  – i: individual steps by the beam ions
  – n_t: target density
  – Δl_i: length of the i[th] step
  – $\sigma_{fus,i}$: fusion cross-section for the beam and target species, using the beam energy at the i[th] step.

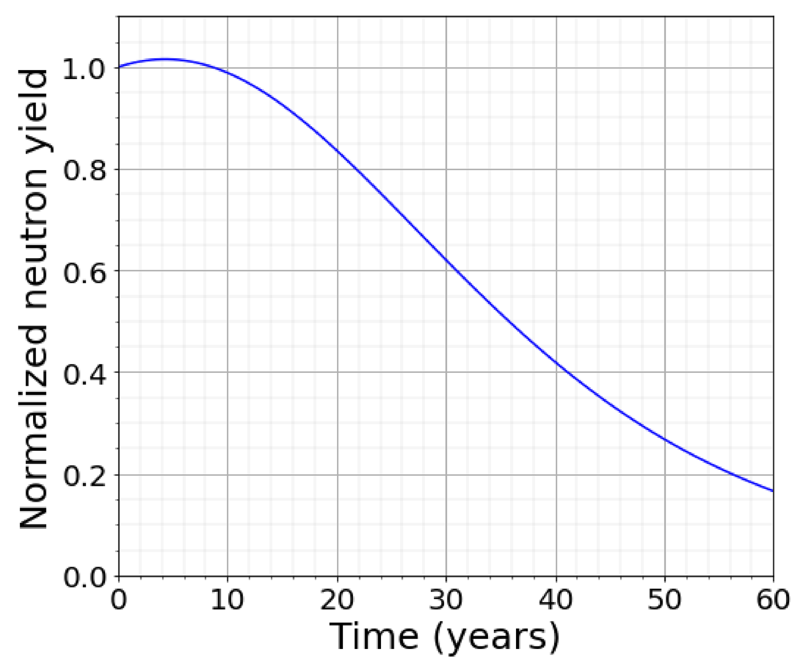
Results





- **Current dependency**: linear @ 130 kV, 40-70 µA (A3082)
- **Voltage dependency**:
  – Power of 3.5-3.64 @ 70 µA, 60-130 kV (A3082)
  – Power of 3.58-3.71 @ 70 µA, 60-140 kV (A3083)
  – Developed a code using TRIM and it gave us the power of 3.53 (A3082) and 3.48 (A3083).

- **Absolute (and maximum) neutron source rate**
  – The full set of the NNS → $\sim 8.23 \times 10^8\ n/s$ (A3083)
  – The 6[th] shell of NNS → $\sim 4.5 \times 10^8\ n/s$ (A3082)
  – N-Probe with A3082 → $\sim 4.48 \times 10^8\ n/s$ (A3082)
- **Tritium decay (half-life 12.3 yrs) calculation**
  – Same number of beam ions for the same current
  – Supposed the number of D or T per Ti is conserved by the beam.
  – Could not explain the ratio of A3083 (~1.44 yrs) to A3082 (~8.44 years): theoretically 0.7% but experimentally 3-17%.
  – Tritium decay decreased the neutron yield very little in calculation, due to replacement of T with D and the cross-section of T(D,n)He is greater than D(T,n)He at the same ion energy.



Conclusion

- Experimental and theoretical results showed the linear dependence to the operating current and ~3.5 power dependence to the voltage.
- N-Probe, NNS measurements and MCNP calculation showed that the A3083 and A3082 tube can give us the maximum neutron yield of $\sim 8.23 \times 10^8\ n/s$ and $\sim 4.5 \times 10^8\ n/s$, respectively.
- We calculated the effect of tritium decay on neutron generator performance, and found that the effect of tritium depletion was less than would be naively expected. The ~ 10% improvement in the A3083 tube relative to the older A3082, at a given voltage and current, could not be explained by this effect. We speculate that design improvements in the new tube or accumulation of helium in the older tube could be responsible.

Next Steps

- The results are drafted as a peer-review journal paper, and it will be submitted soon.

This work was funded in-part by the Consortium for Monitoring, Technology, and Verification under DOE-NNSA award number DE-NA0003920

National Nuclear Security Administration