Application of the Cohn-α Method on Bare Highly Enriched Uranium Using Organic Scintillators

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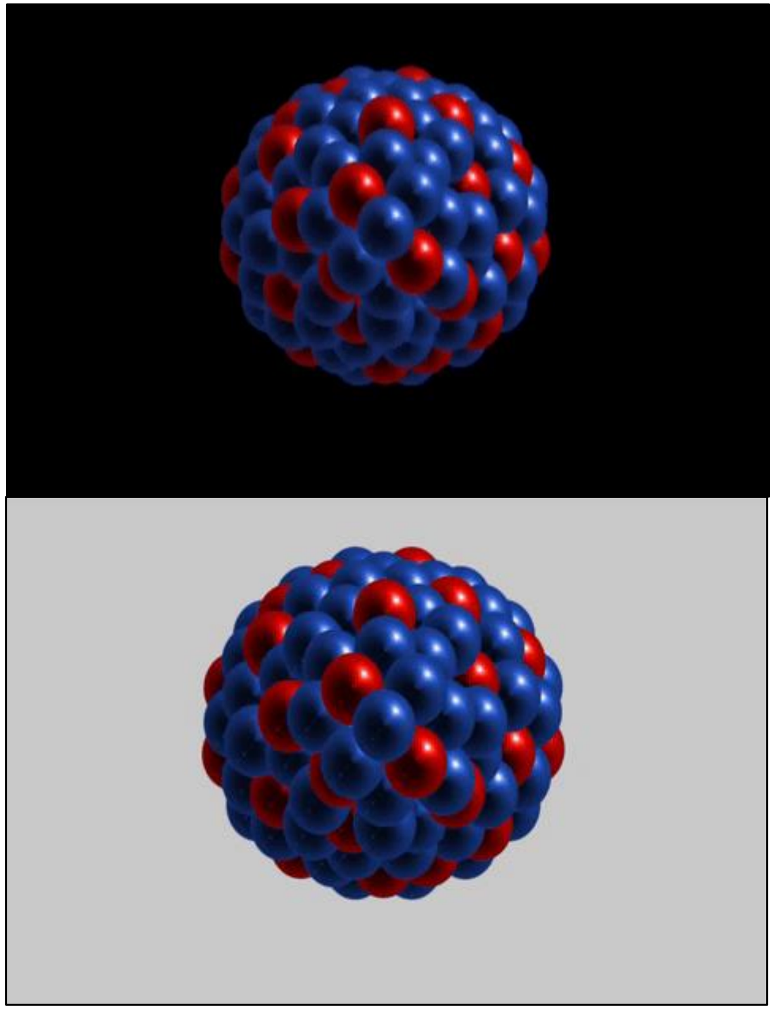
Introduction and Motivation

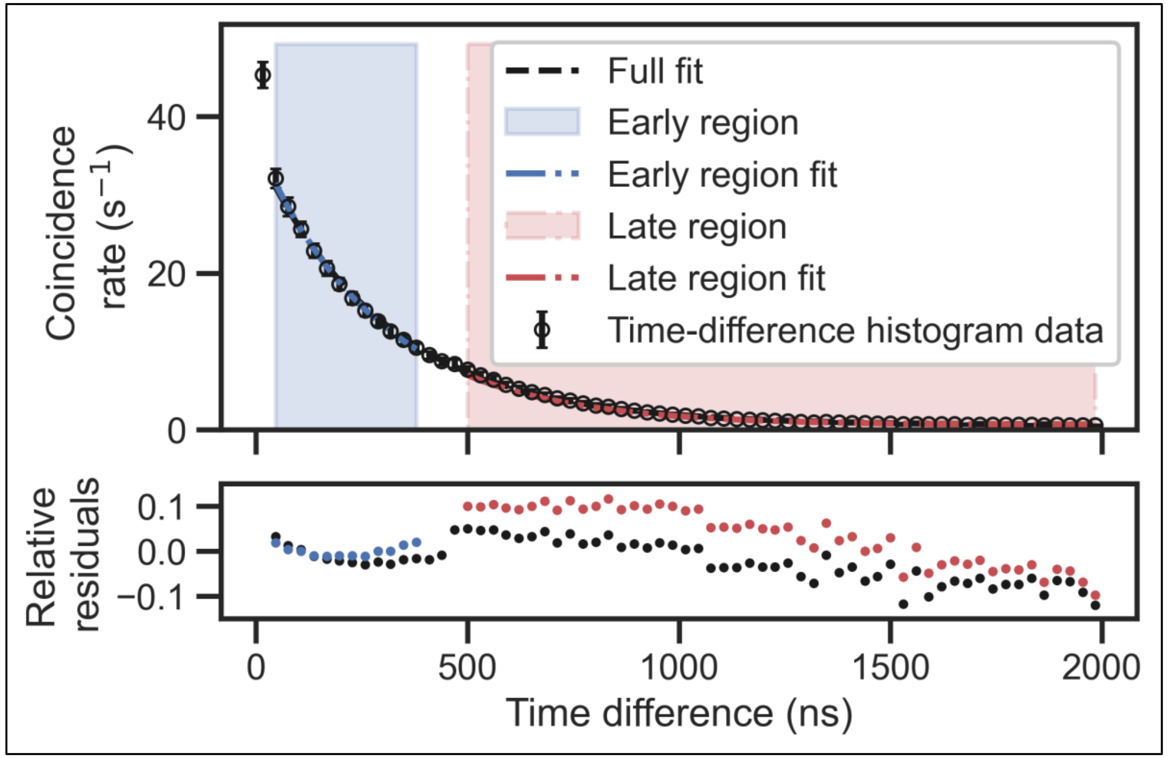
- Monitoring fission chain kinetics is vital to nuclear nonproliferation
- Estimate prompt neutron decay constant (α)
  - The rate prompt neutrons in a chain-reacting system change
  - Methodology determines α at or near delayed critical
- Can use α to monitor fissile systems to infer the multiplication factor k_{eff}
- Organic scintillators have been validated for fast assemblies
  - Previous methods used are Rossi-α



MTV, fission chain

Introduction and Motivation

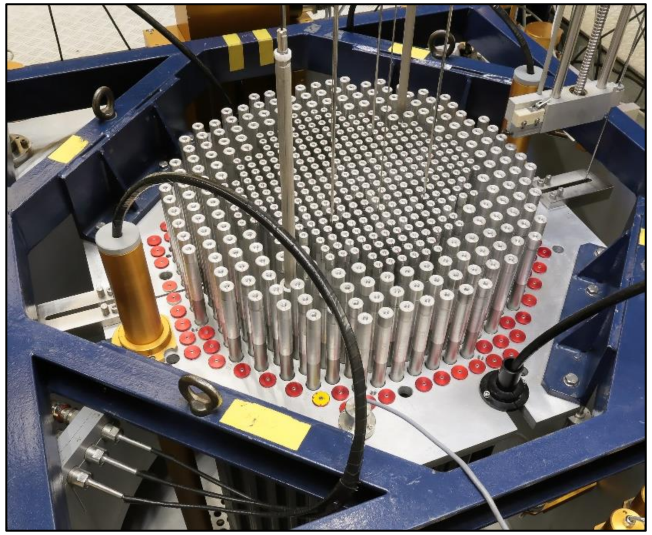
- Systems with saturated count rates complicate analysis
  - High-multiplying systems overwhelm electronics
  - Rossi-α shows discontinuities when estimating α
- Creates motivation to apply Cohn-α methodology to similar data
  - Continue validation using organic scintillators for neutron noise analysis
  - Validate Cohn-α method using fast bare systems of uranium

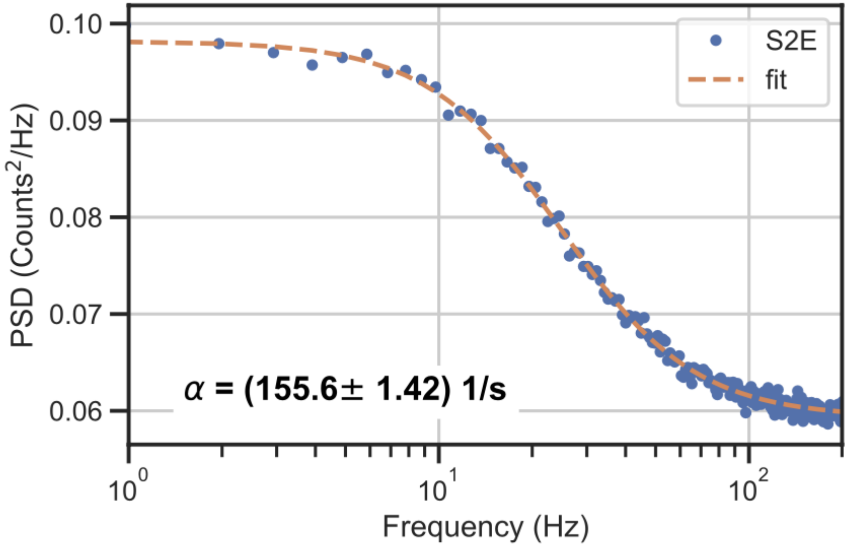


F. Darby, et. al. INMM & ESARDA 2023

Mission Relevance

- Neutron Noise analysis can be used to:
  - Monitor fissile systems such as nuclear reactors
  - Improve criticality safety standards
  - Contribute to benchmarks
- Reactor monitoring verifies reactor start-up or shutdown
  - "*implement international safeguards obligations and detect and deter diversion of nuclear material or <u>illicit use of nuclear facilities</u>*"
- Previous work by our group validates the method for thermal systems

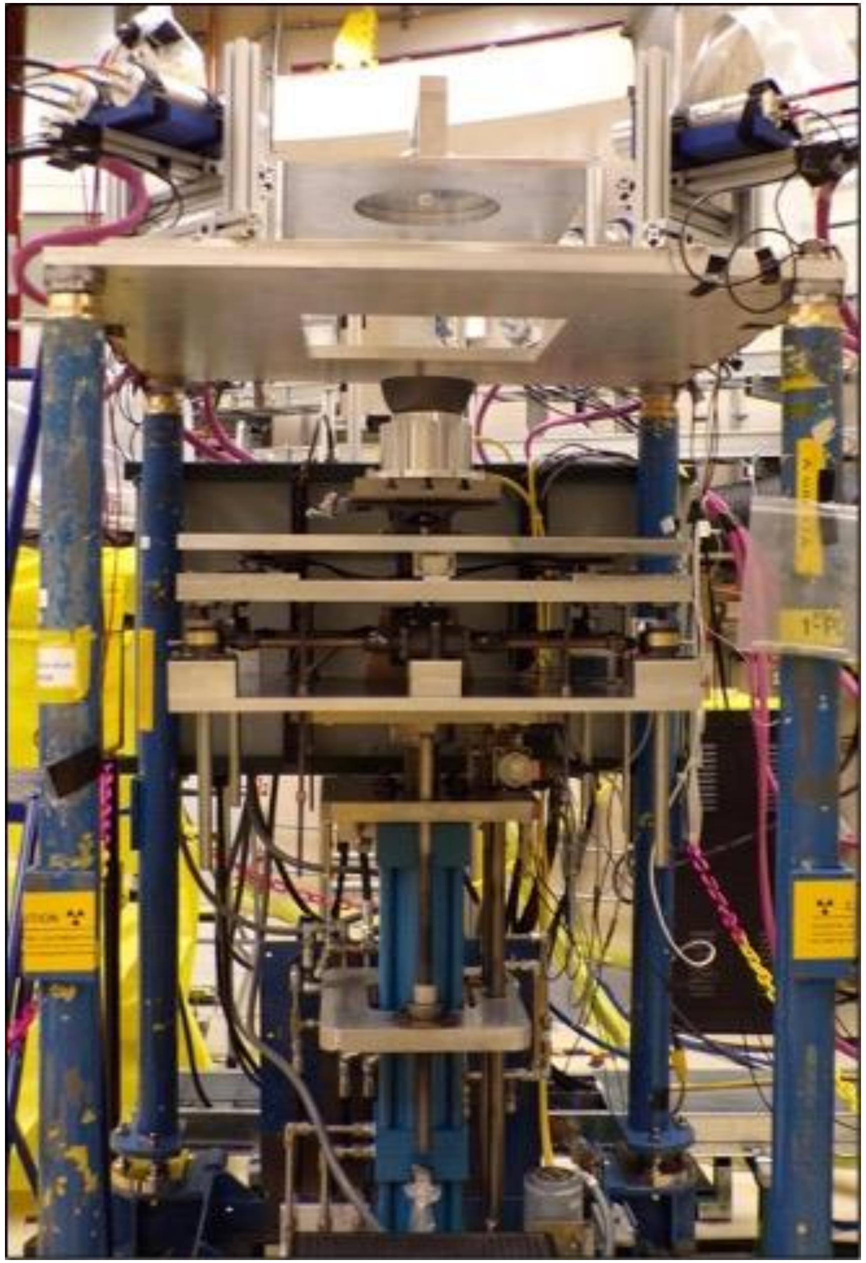




Darby, et. al. https://doi.org/10.1109/TNS.2023.3337657

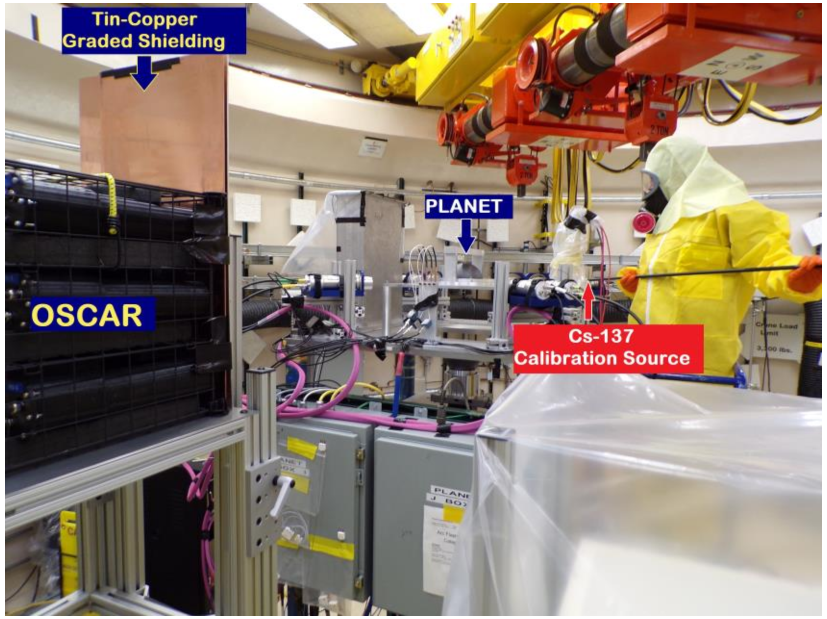
Technical Approach

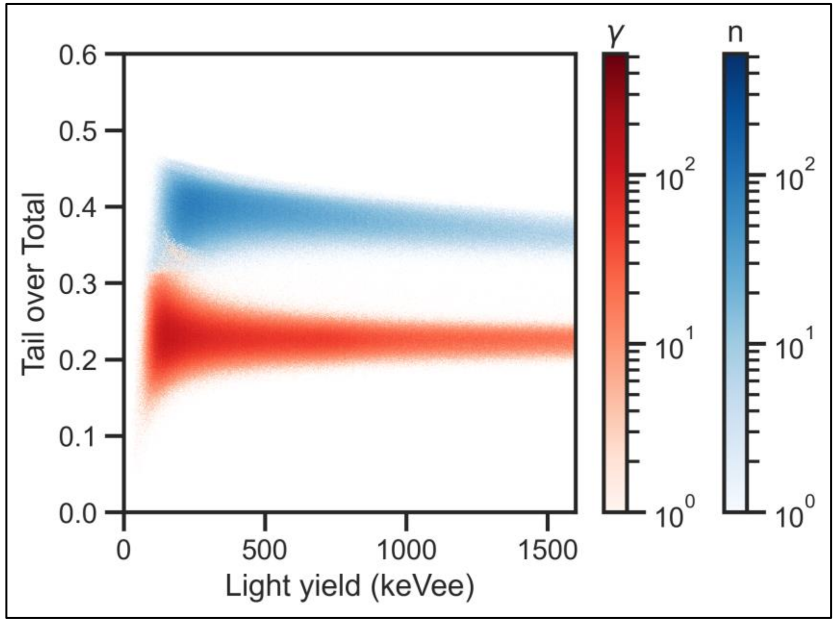
- Data was acquired through collaboration with Los Alamos National Laboratory (LANL)
- Data comes from a series of measurements of a fast bare uranium system
  - Measurement of Uranium Subcritical and Critical (MUSiC)
  - Led by LANL's NEN-2 group at NCERC
  - Subcritical and critical benchmark
  - Variable mass of HEU (93% ^{235}U)
  - Uranium geometry is stackable half hemi-shells



Technical Approach

- Was done on the PLANET critical assembly platform
- Measured with organic scintillator array (OSCAR)
  - 3 x 4, 5.08 cm × 5.08 cm diameter trans-stilbene organic scintillator array
- Isolate neutron time-series data using pulse shape discrimination
  - Organic scintillators are dual particle-sensitive
  - Quantify the ratio of prompt and delayed light output
  - $R = \frac{\text{tail}}{\text{total}}$



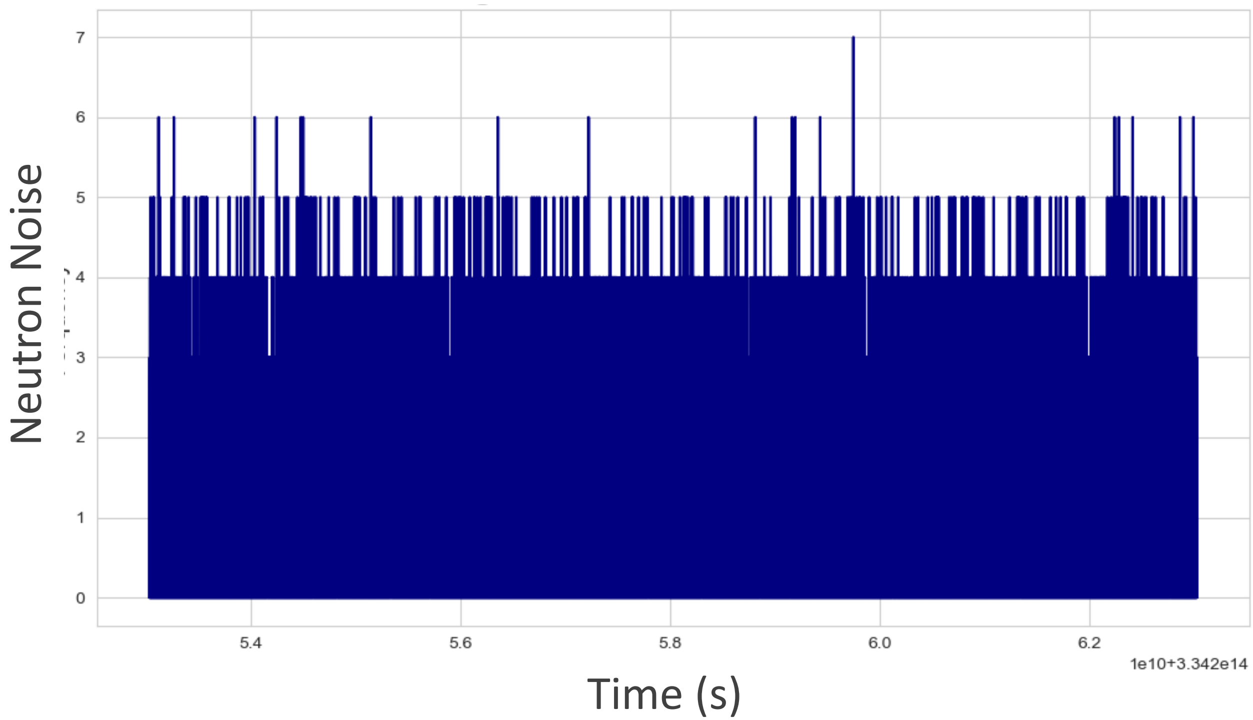


Technical Approach

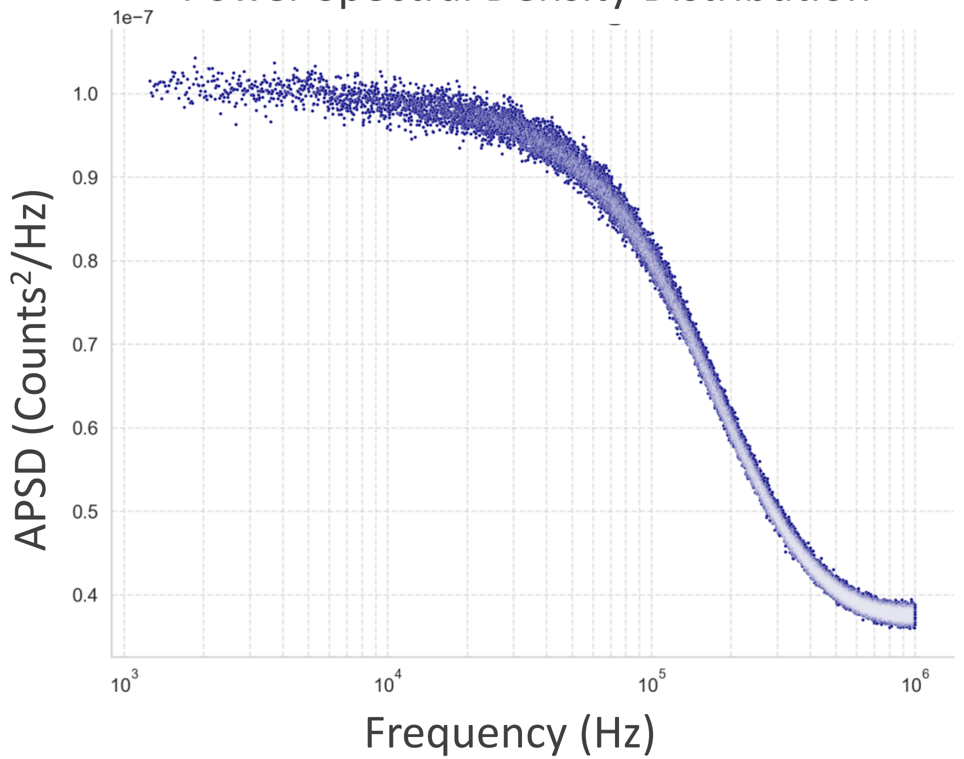
$$G_{ii}(\omega) = \frac{\epsilon_i^2 F_o D_v}{(\beta_{eff} - \rho)^2} \cdot \frac{1}{1 + \frac{\omega^2}{\alpha^2}} + \epsilon_i F_o$$

"Welch" Approximation

Fluctuations In Counts vs Time



Power Spectral Density Distribution

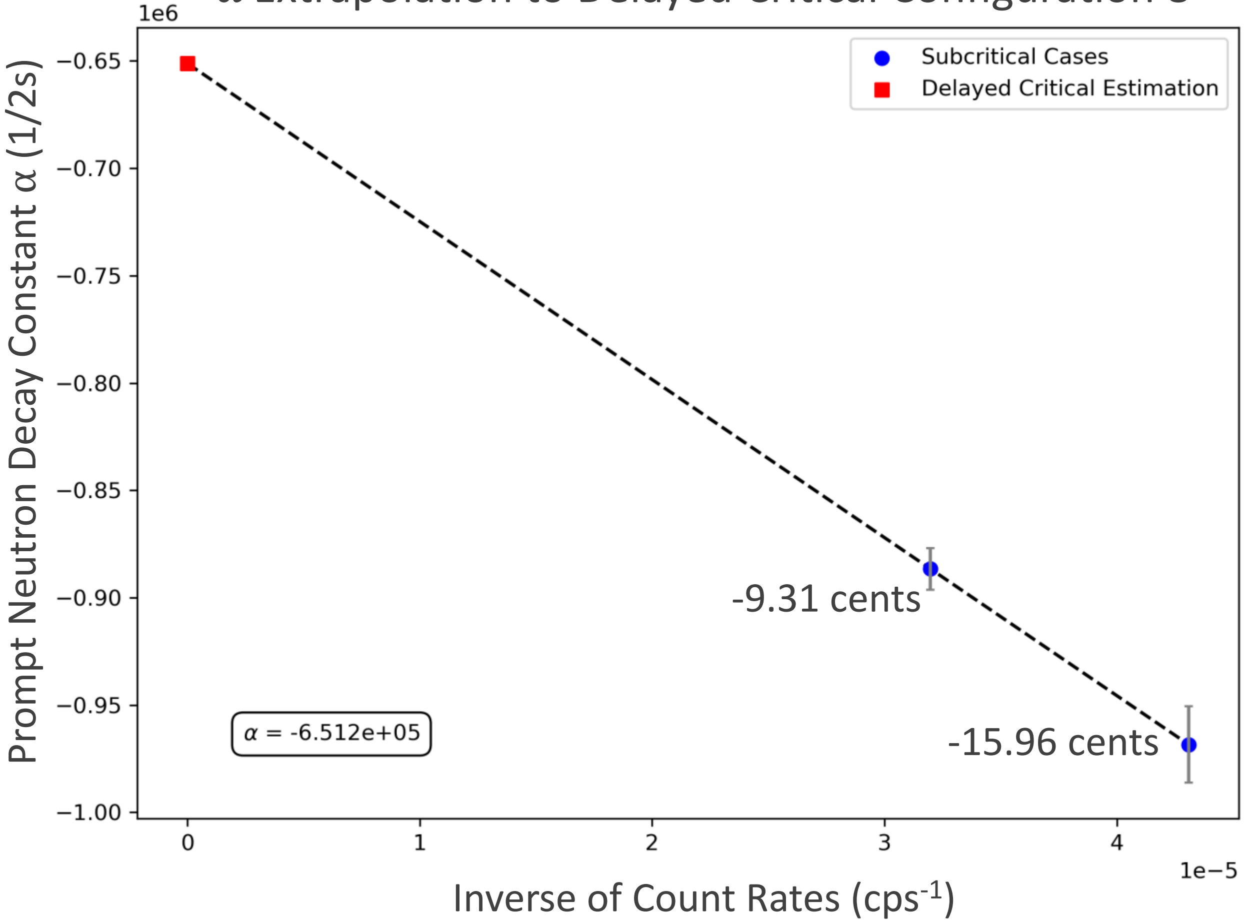


Results

- Configurations 8 and 9 were analyzed
  - These data are all subcritical
- 2 subcritical cases per configuration
- α can be plotted as a function of the inverse count rate
  - Can extrapolate to 0 to estimate α at delayed critical
  - This method assumes accurate count rates
- Can compare directly to simulation

Configuration 8 α [1/s]	Configuration 9 α [1/s]
-6.512×10^5	-8.766×10^5

α Extrapolation to Delayed Critical Configuration 8



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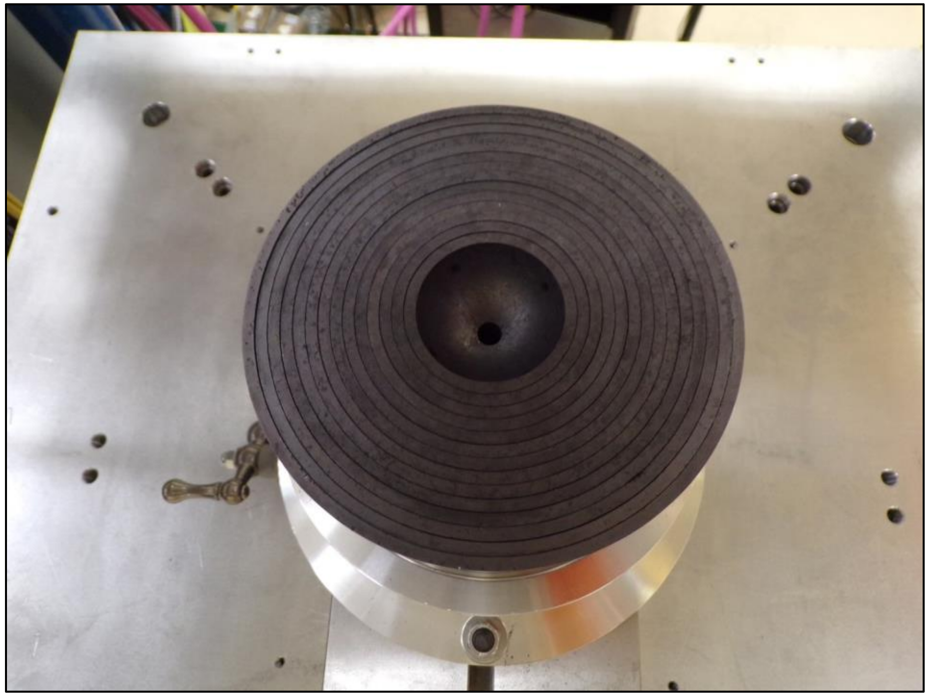
Expected Impact

- Successful estimations of α using Cohn-α avoid discontinuities seen in Rossi-α
  - Specifically, with highly multiplying systems
- Contribution to benchmark validation of MUSiC
  - Use α as benchmark value
- Further validates use of organic scintillators for fast bare systems
  - Alternative to He-3 detector



MTV Impact

- Working directly with staff scientists at LANL
  - Validating research during weekly check-ins
  - Continuation of work into a summer internship at LANL
- NEN-2 contacts assisting in research
  - Mentored by Alex McSpaden from NEN-2
  - Guidance from Jesson Hutchinson, George McKenzie, and Rene Sanchez
- Apply Cohn-α to different datasets and standardize the algorithm in collaboration with LANL.

Los Alamos NATIONAL LABORATORY

Conclusion

- Current estimations can be compared with detailed simulations
- α can be estimated in simulation as a benchmark value
  - Compare to measured values using methods such as Cohn-α
- α can be used to monitor thermal and fast fissile systems for verification of startup and shutdown
  - This method may be applied to next-generation fast modular reactors

Next Steps

- Explore additional methods for Cohn-α uncertainty
  - Efficiently estimate measurement uncertainty and compare
- Compare delayed critical estimate to simulation
- Continue research with LANL to analyze other datasets
  - Improve the algorithm and compare results of varying material

Acknowledgements

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