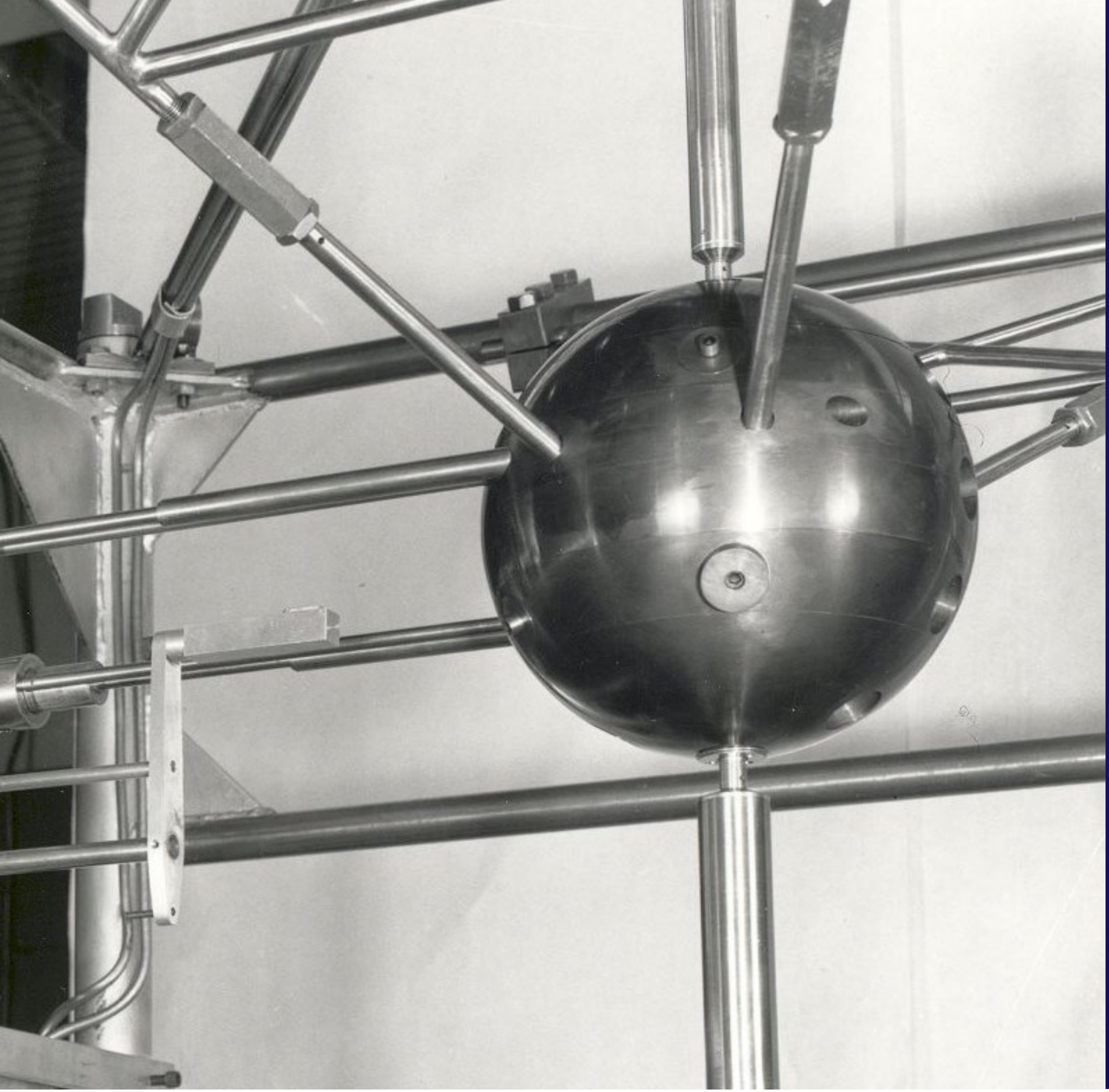


Los Alamos
NATIONAL LABORATORY
EST. 1943

Delivering science and technology
to protect our nation
and promote world stability

NNSA
National Nuclear Security Administration
Managed by Triad National Security for the U.S. Department of Energy's NNSA

Prompt Neutron Decay Constant Measurements on a Copper Reflected Intermediate Enrichment Uranium System with Lead Interstitial

G. McKenzie, T. Grove, and R. Sanchez

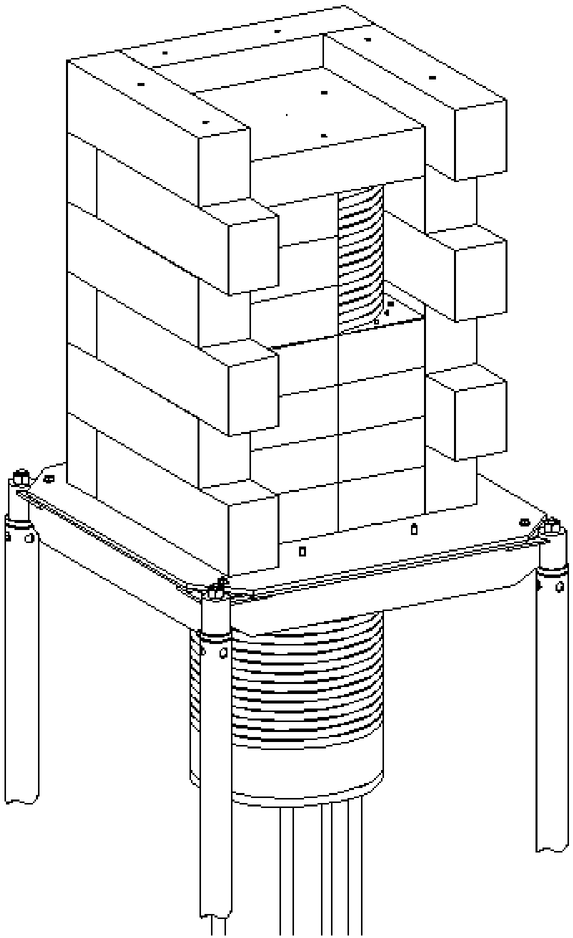
Los Alamos National Laboratory

ANS Winter Meeting
Washington DC
November 2019

Experiments at National Criticality Experiments Research Center (NCERC) in Nevada

NCERC is the only Security Category 1, US Criticality Experiments Capability

- **Focus on using existing fuel on Comet to produce comparable data for JAEA**
- **US has interest in lead cross section for data libraries**
- **This series of measurements occurred as part of larger three part campaign to measure lead void reactivity coefficients**
  - All three series are planned to be included in ISCBEP as benchmarks



Experiments at NCERC

Comet

- Vertical Assembly Machine
- Lower fuel is placed on moveable platen and lifted towards an upper fuel stack.

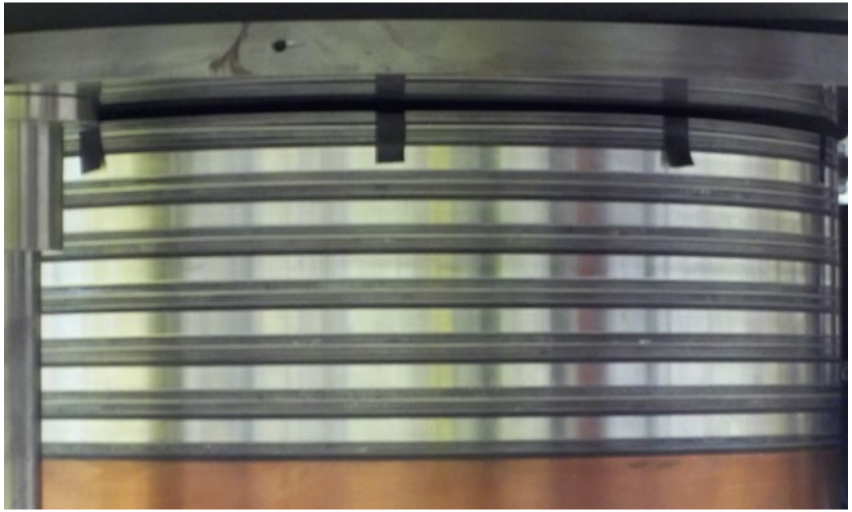
Zeus Series of Experiments

- Copper reflector
- HEU fuel
- Various interstitial material (graphite, iron, poly) to modify spectrum

For JAEA experiments

- Perform similar experiment with lead
- This one in particular lowered enrichment using natural uranium plates
- Began in 2017

LEU/Lead Experiment: Core

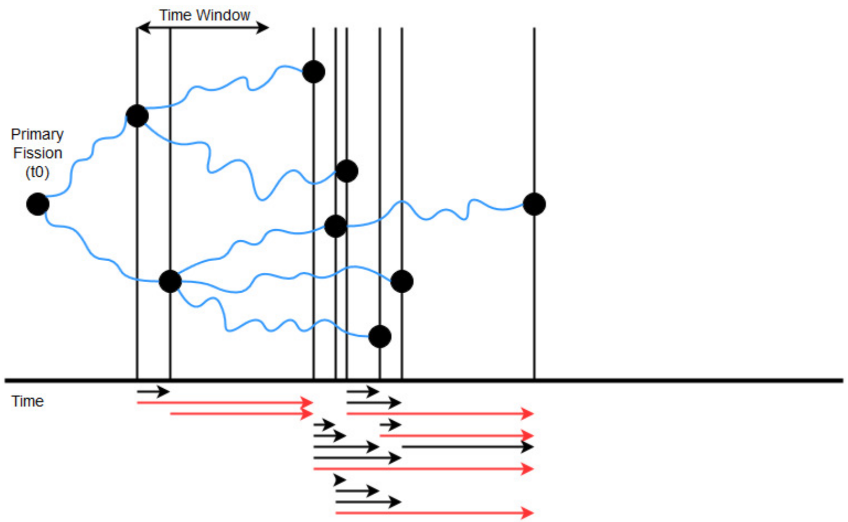


LEU Core

- Natural uranium plates interleaved with HEU plates
- Effective enrichment ~21%
- Similar measurements to HEU core
- Lower NU plates surrounded by Al rings
- Positive Void Coefficient for Lead (HEU system has negative coefficient)

Prompt Neutron Decay Constant Measurements

- **The Rossi-α method is used to measure the prompt neutron decay constant**
- **Measures correlations between neutron detections to assess prompt neutron population decay in a sub-prompt system**
  - Using a list-mode time tagging system

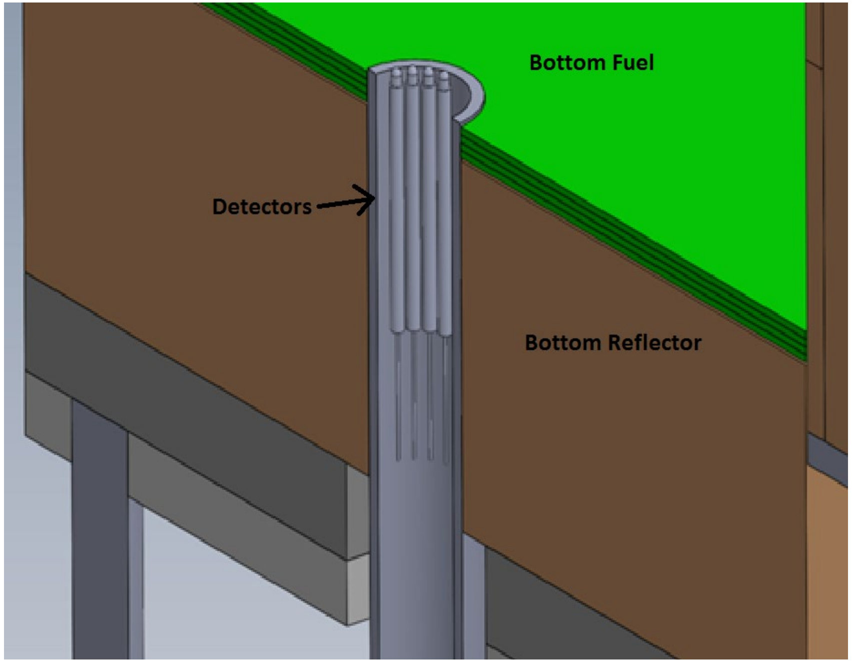


Prompt Neutron Decay Constant Measurements

- **Prompt neutron decay constants are used to benchmark neutron lifetime for critical experiments**
  - Easy single parameter comparison
- **Prompt neutron decay constants can be used to establish the mass increment between delayed critical and prompt critical**

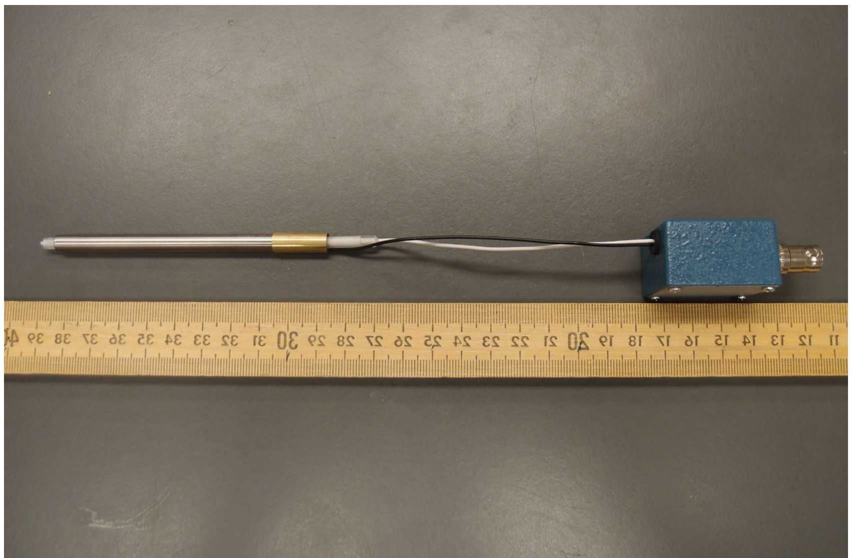
- **Give valuable nuclear kinetics information about the system**
- $\boldsymbol{p(t) = A + Be^{\alpha t}}$
  - Where alpha is the prompt neutron decay constant
  - A is the uncorrelated source rate
  - B is the magnitude of the correlated source rate

Measurements



- The detectors used to measure the prompt neutron decay constant placed near the center of the assembly
- Inside a section called the spindle (or alignment tube)
- Access from the top and bottom to locate detection system and associated wiring
- Center of the assembly is ideal for measurements
- Four detectors used to reduce system dead-time

Measurements

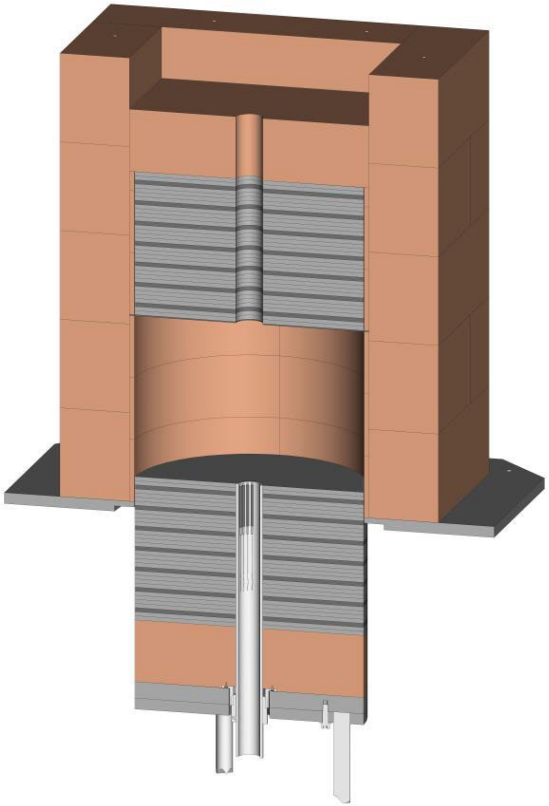


- The Rossi-α experiment can be performed using a number of different neutron detectors
- This experiment used Reuter-Stokes He-3 tubes
- These tubes contain 40 atm of the He-3 inside a ¼” casing
- The tubes are 4 inches long with an active length of 3 inches
- These are ideal for these measurements because they are insensitive to gammas and can be placed inside the assembly

Measurements

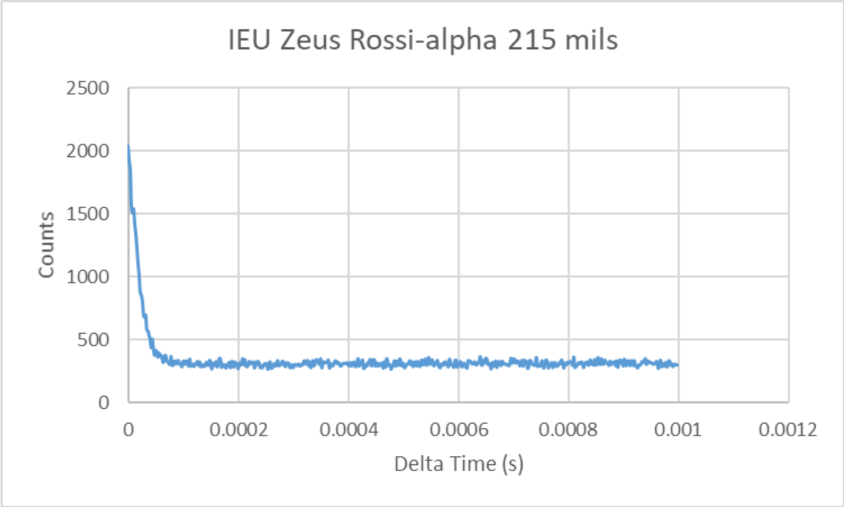
Measurements were taken on several configurations

- **All subcritical**
- **The configurations adjusted reactivity (multiplication) through separation of the top and bottom fuel sections**
- **Measurements taken at 185, 200, and 215 mil separations**
- **These measurements used to extrapolate value at delayed critical**



Measurements

- An example of the Rossi-α histogram from a single measurement is shown to the right
- Ten measurements were completed on each configuration to help assess statistical uncertainty in the measurement
- Average values were used to assess the prompt neutron decay constant at delayed critical



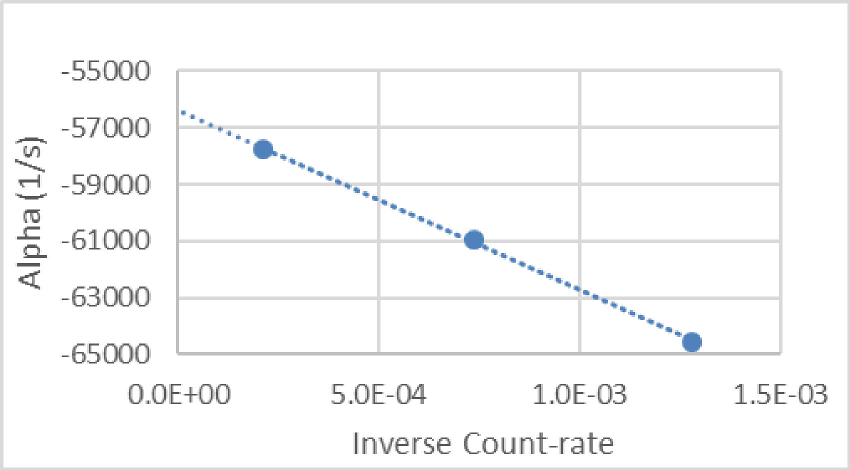
Results

- The measured value of the prompt neutron decay constant for each of the three configurations is shown in the table on the right
- As expected, the trend of these values moves toward zero as multiplication increases
- These values are then used to extrapolate the prompt neutron decay constant at delayed critical

Separation (mils)	α (s^{-1})	Std. Dev (s^{-1})
185	-57772.7	1471.6
200	-60954.0	1383.7
215	-64539.8	1224.3

Results

- Using linear extrapolation of each measurement and its corresponding inverse count rate, gives the prompt neutron decay constant at delayed critical
- At delayed critical the inverse count rate goes to zero, so the y-intercept is the prompt neutron decay constant at delayed critical

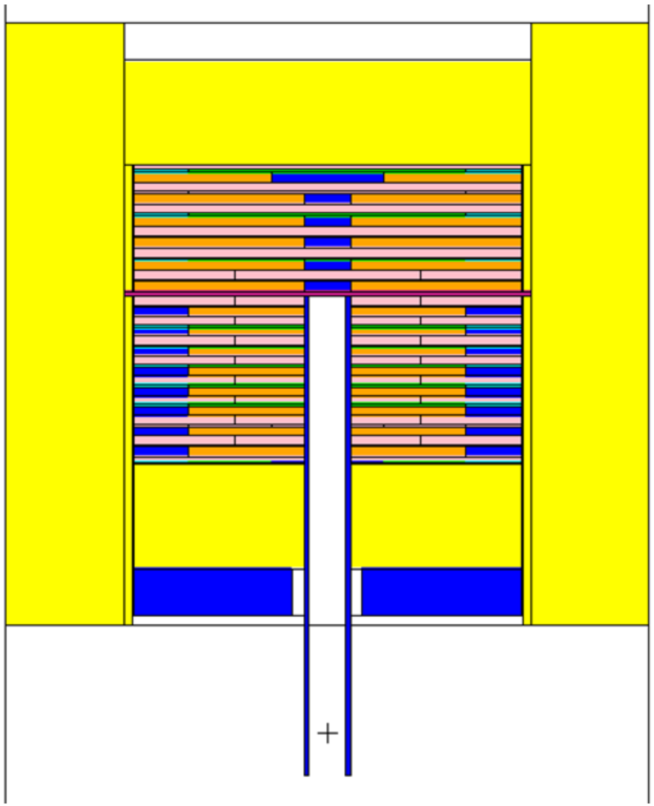


Results

- The extrapolated value at delayed critical is included on the table at the right
- This is the value typically quoted when discussing the prompt neutron decay constant of a particular system
- This is the single value used to compare different critical experiments based on neutron spectrum and lifetime

Separation (mils)	α (s^{-1})	Std. Dev (s^{-1})
DC	-56350.4	552.4
185	-57772.7	1471.6
200	-60954.0	1383.7
215	-64539.8	1224.3

Results



- The prompt neutron decay constant at delayed critical was also obtained using the KOPTs card in MCNP®
- The value obtained is -62286.2 ± 1157.5 s^{-1}
- This has a $\frac{C-E}{E}$ of 0.105 compared to the measurement
- MCNP® and Monte Carlo N-Particle® are registered trademarks owned by Triad National Security, LLC, manager and operator of Los Alamos National Laboratory. Any third party use of such registered marks should be properly attributed to Triad National Security, LLC, including the use of the designation as appropriate.

Conclusions

System	α (s^{-1})
Lady Godiva	-1.1E6
HEU Zeus	-8.9E4
IEU/Pb Zeus	-5.6E4
HEU/Pb Zeus	-3.8E4
Sheba	-2.0E2

- **The prompt neutron decay constant at delayed critical falls where expected when compared to the other Zeus measurements completed**
- **All of which fall into the correct range when compared to other historic measurements**
  - Lady Godiva was an un-reflected HEU experiment and should have the largest magnitude of prompt neutron decay constant
  - Sheba was a HEU solution system which should have the smallest magnitude of prompt neutron decay constant

Acknowledgments

- **This work was supported by the DOE Office of Material Management and Minimization and by the DOE Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the Department of Energy.**