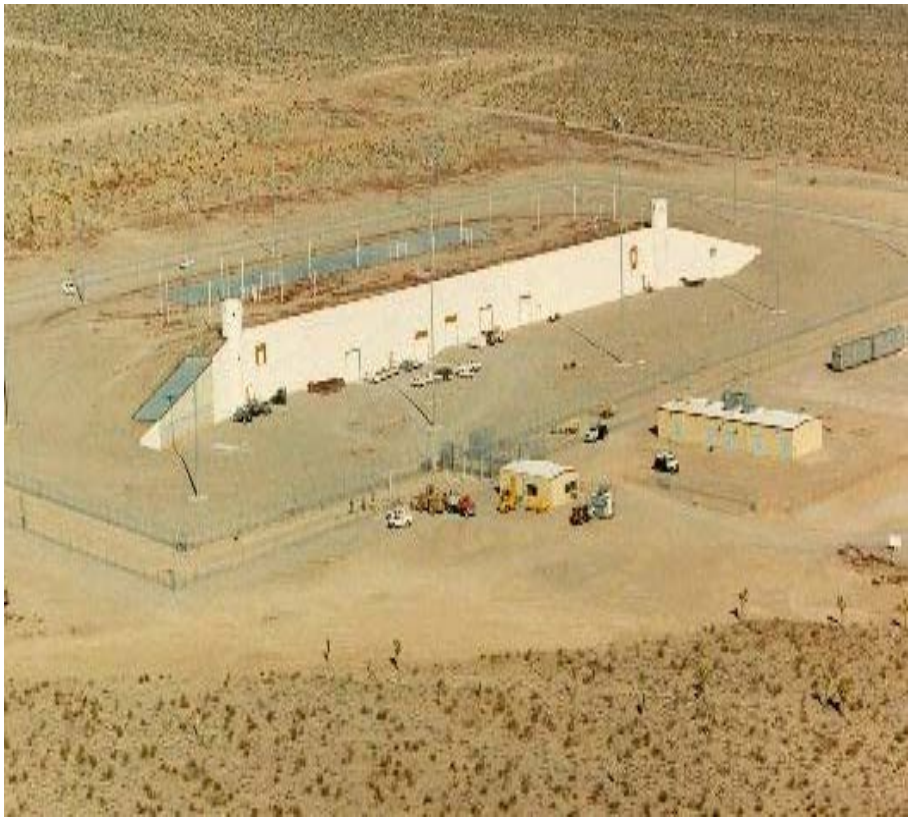
LA-UR-14-21819



Measurement of Prompt Neutron Decay Constant in a Highly Enriched Uranium Copper Reflected System

George McKenzie, Travis Grove,

Rene Sanchez, and John Bounds

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Outline

- Purpose
- Theory behind the experiment
- Description of the Experiment
- Experimental Results
- Conclusions

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Purpose

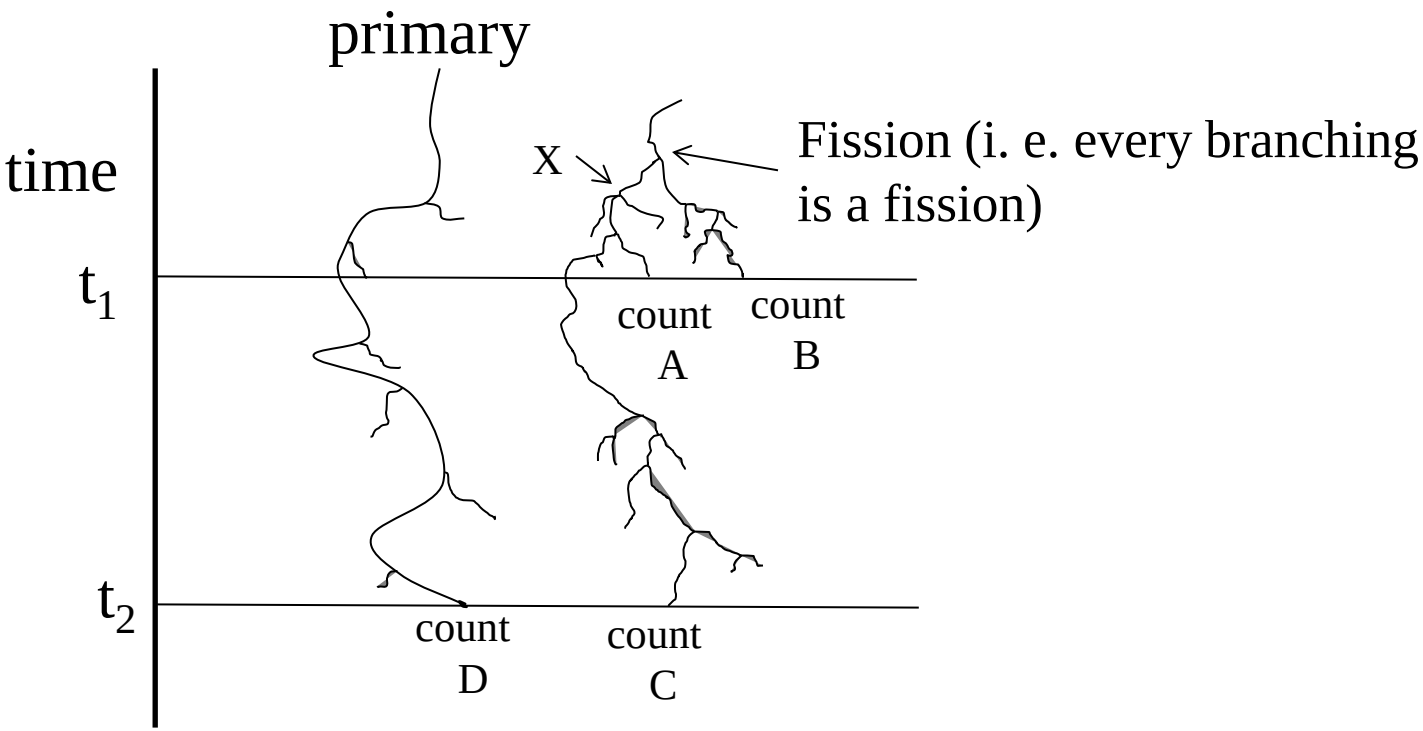
- **Prompt Neutron Decay Constants**

  Purpose:

  - To provide information regarding the neutron lifetime, β_{eff} of the system, and $k_{eff.}$
  - Indicators of the neutron energy spectrum
  - Benchmarks

Reference
Statistical Aspects of Pile Theory
Frederic de Hoffman

Primary Neutrons



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Theory

$$\dot{N} \alpha N \qquad \frac{\partial N}{\partial t} = \alpha N \qquad N(t) = N_0 e^{\alpha t}$$

$\varepsilon \frac{dt}{\tau_f}$ Probability of any neutron present being detected and producing a count in ^{3}He detector at t_1 or t_2

Fdt_0 Probability that a fission occurs at t_0 in dt_0

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Theory (cont.)

$\nu e^{-\alpha(t_1 - t_0)}$ Expected number of neutrons at t_1 due to neutrons created at t_0

$(\nu - 1) e^{-\alpha(t_2 - t_0)}$ Expected number of neutrons at t_2 due to neutrons created at t_0

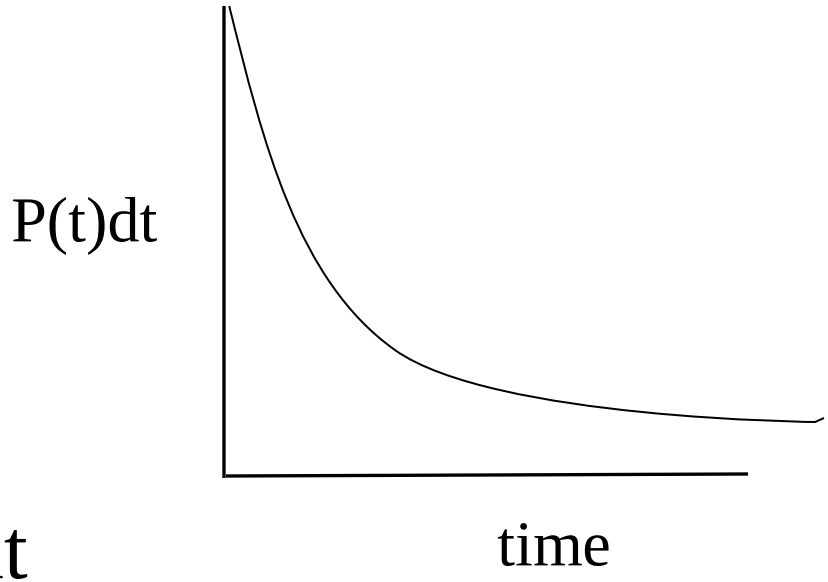
$\int_{-\infty}^{t_1} (\nu - 1) e^{-\alpha(t_2 - t_0)} \varepsilon \frac{dt_2}{\tau_f} \nu e^{-\alpha(t_1 - t_0)} \varepsilon \frac{dt_1}{\tau_f} F dt_0$ Probability of correlated counts

$F\varepsilon dt_1 F\varepsilon dt_2$ Probability of uncorrelated counts

Theory (cont.)

$$\alpha = \frac{k_p - 1}{l}$$

$$\alpha_{dc} = \frac{1 - \beta - 1}{l} = \frac{-\beta}{l}$$



$$P(t)dt = Cdt + Qe^{\alpha t}dt$$

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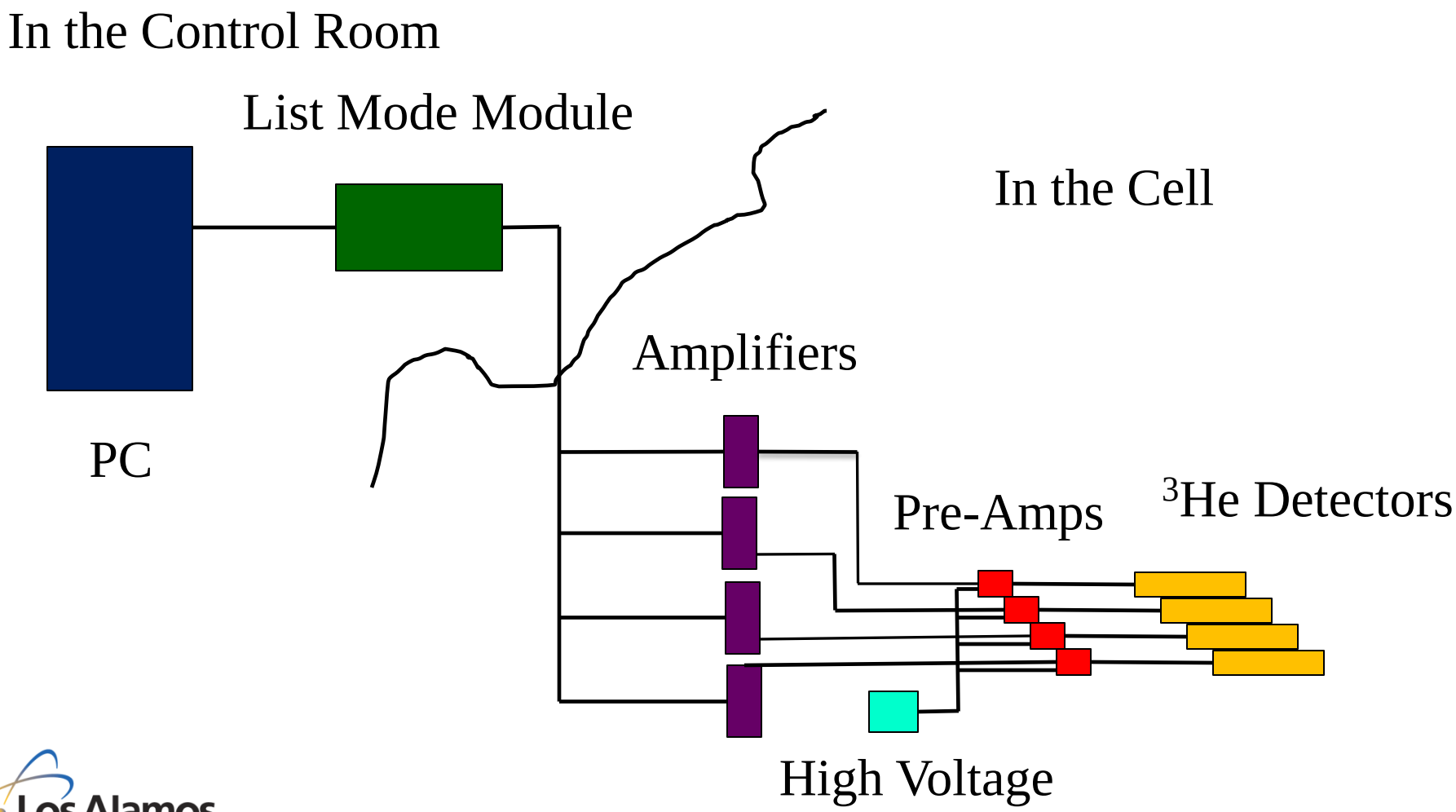
Detection System



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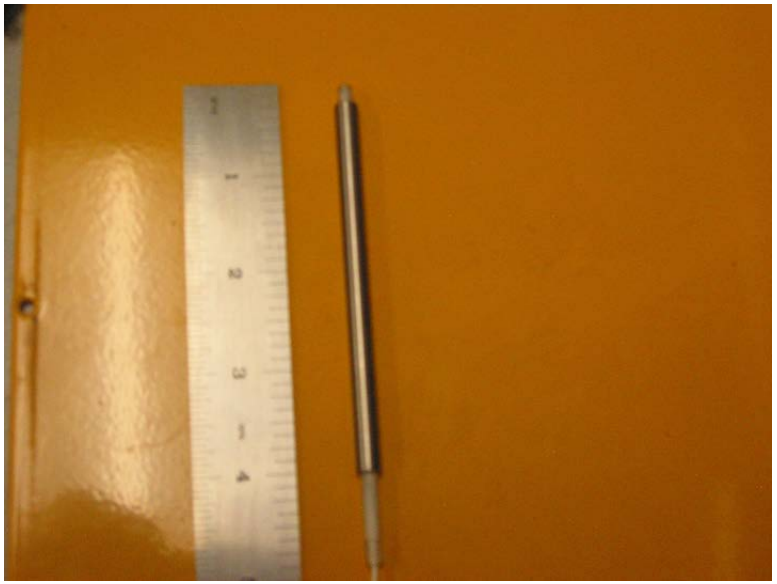
^{3}He Detectors



Detector diameter 0.25 inches

Detector length 3.75 inches

Sensitive length 3.0 inches

Fill pressure of 40 atmospheres of ^{3}He

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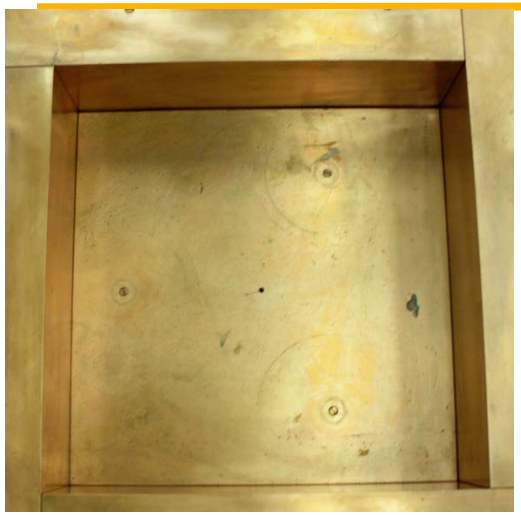
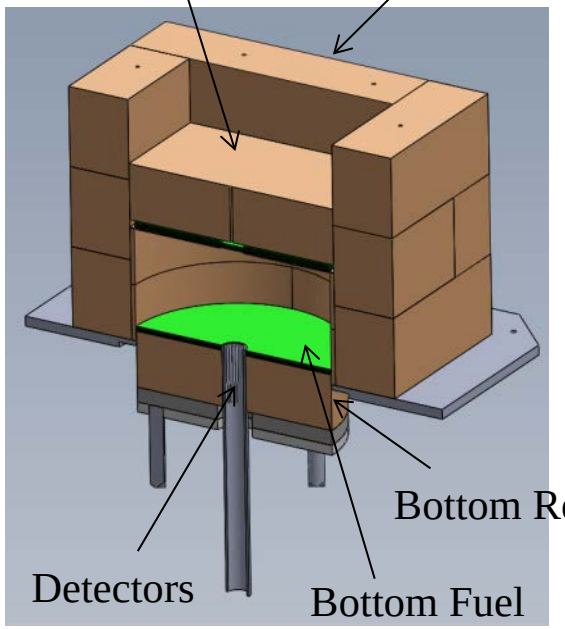
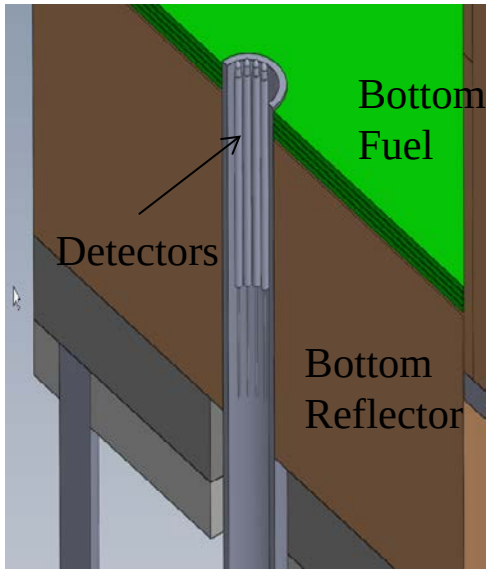
The HEU core surrounded with copper







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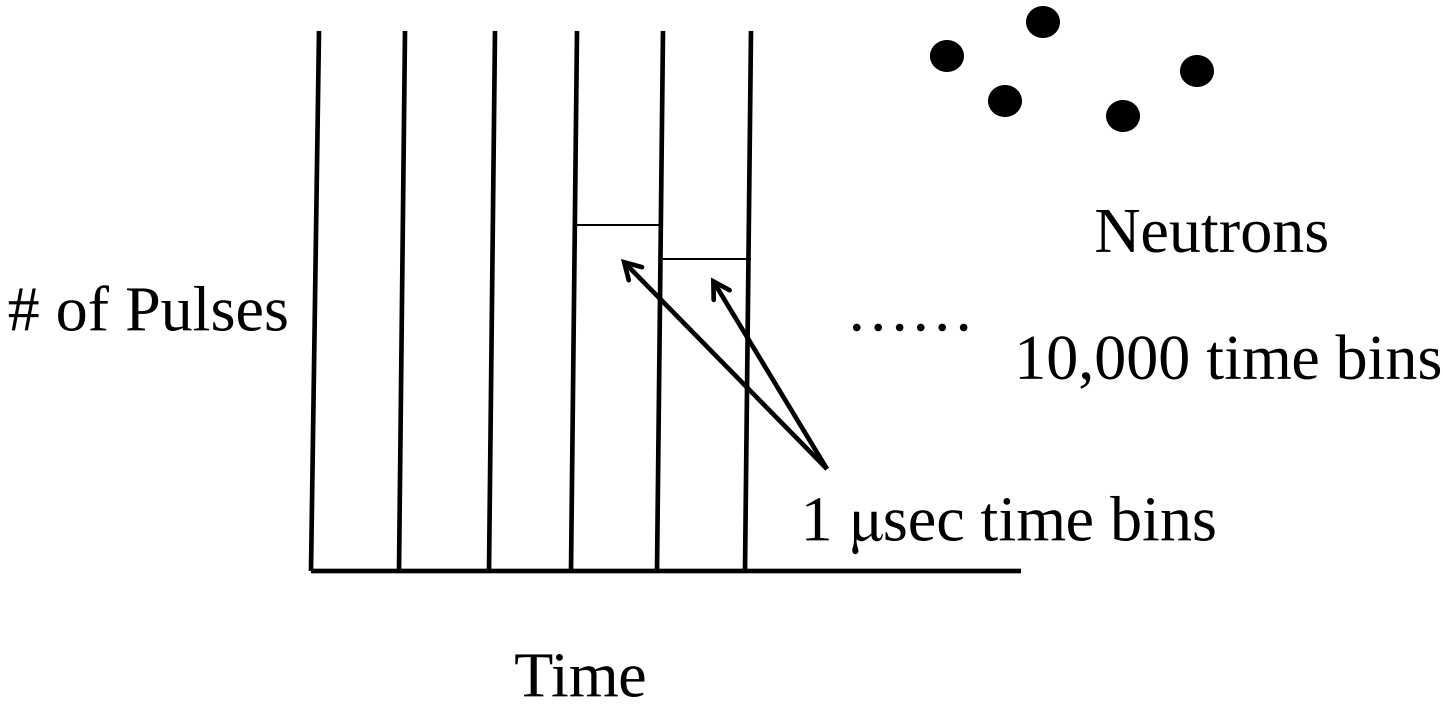
Recording of Neutron Pulses



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Analysis of the Data (-0.10 $)

$P1 := genfit(Time\mu s, Pt\Delta t, vg1, F)$

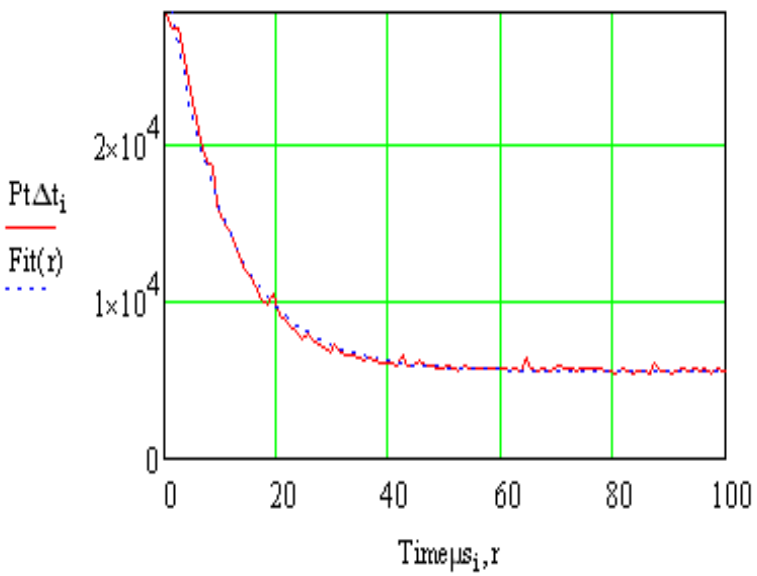
$$vg1 := \begin{pmatrix} \frac{\max(Pt\Delta t)}{2} \\ \max(Pt\Delta t) \\ alphaguess \end{pmatrix}$$

$$F(t,u) := \begin{bmatrix} u_0 + u_1 \cdot \exp(-u_2 \cdot t) \\ 1 \\ \exp(-u_2 \cdot t) \\ -t \cdot (u_1) \cdot \exp(-u_2 \cdot t) \end{bmatrix}$$

$$P1 = \begin{pmatrix} 5513.951 \\ 26373.493 \\ 0.093 \end{pmatrix}$$

$$alpha1 := P1_2 \cdot 10^6$$

$$alpha1 = 9.333 \times 10^4$$



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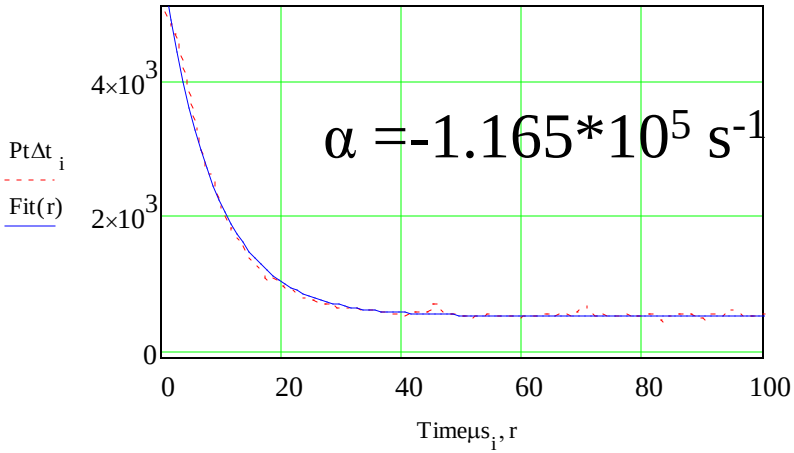
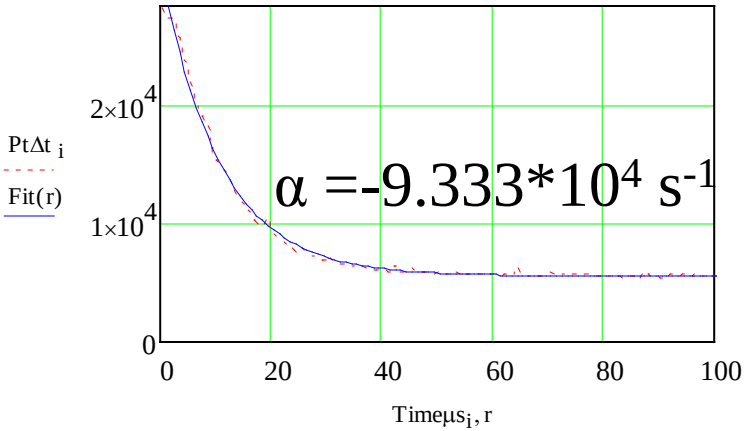
Other Reactivities

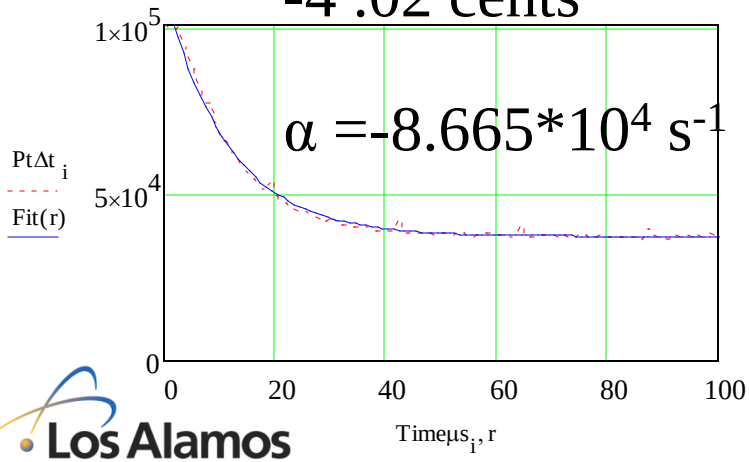
-38.58 cents



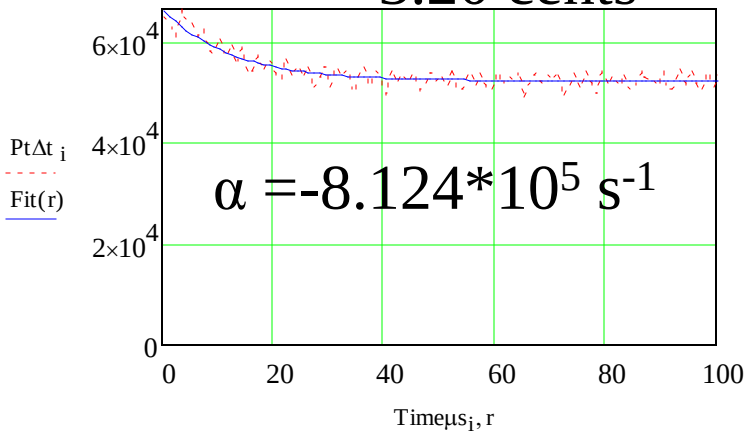
-10.45 cents



-4 .02 cents



+3.20 cents



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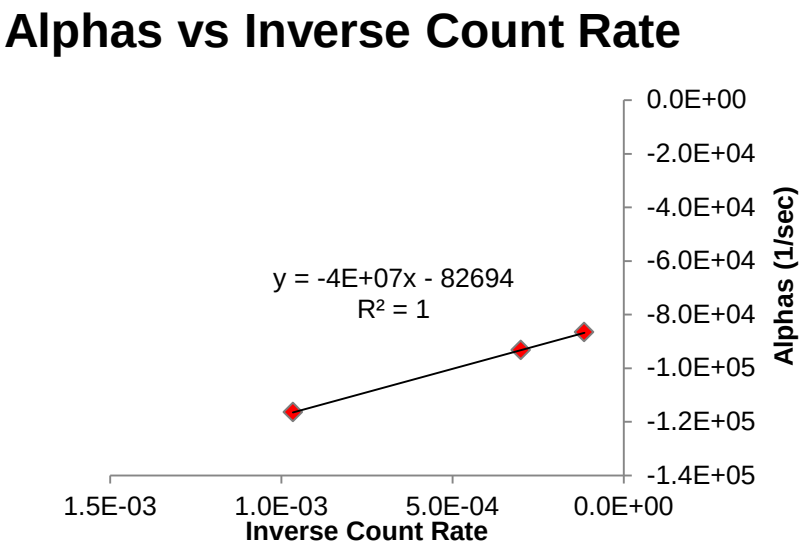
Alpha at Delayed Critical



$\alpha(dc) = -82694\ s^{-1}$

$$\alpha = \frac{k_p - 1}{l}$$

$$\alpha_{dc} = \frac{1 - \beta - 1}{l} = \frac{-\beta}{l}$$

β =0 0.0065

$$l = \frac{-\beta}{\alpha(dc)} = 7.86e^{-8}\ \text{sec}$$

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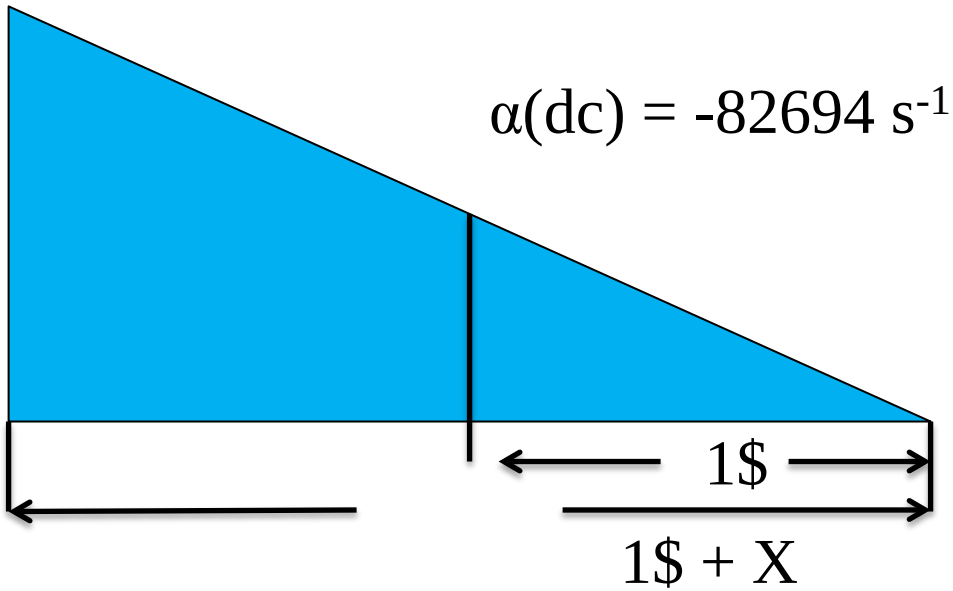
Reactivity

$\alpha = -9.333e^{+4}\ s^{-1}$



$$\frac{-82694}{1\$} = \frac{-9.333e^{+4}}{1\$ + X}$$

$$(1\$ + X)(-82694) = -9.333e^{+4}$$

$$X(-82694) = -9.333e^{+4} + 82694 \Rightarrow X = \frac{-9.333e^{+4} + 82694}{-82694}$$

$$X = -12.86 \text{ cents}$$

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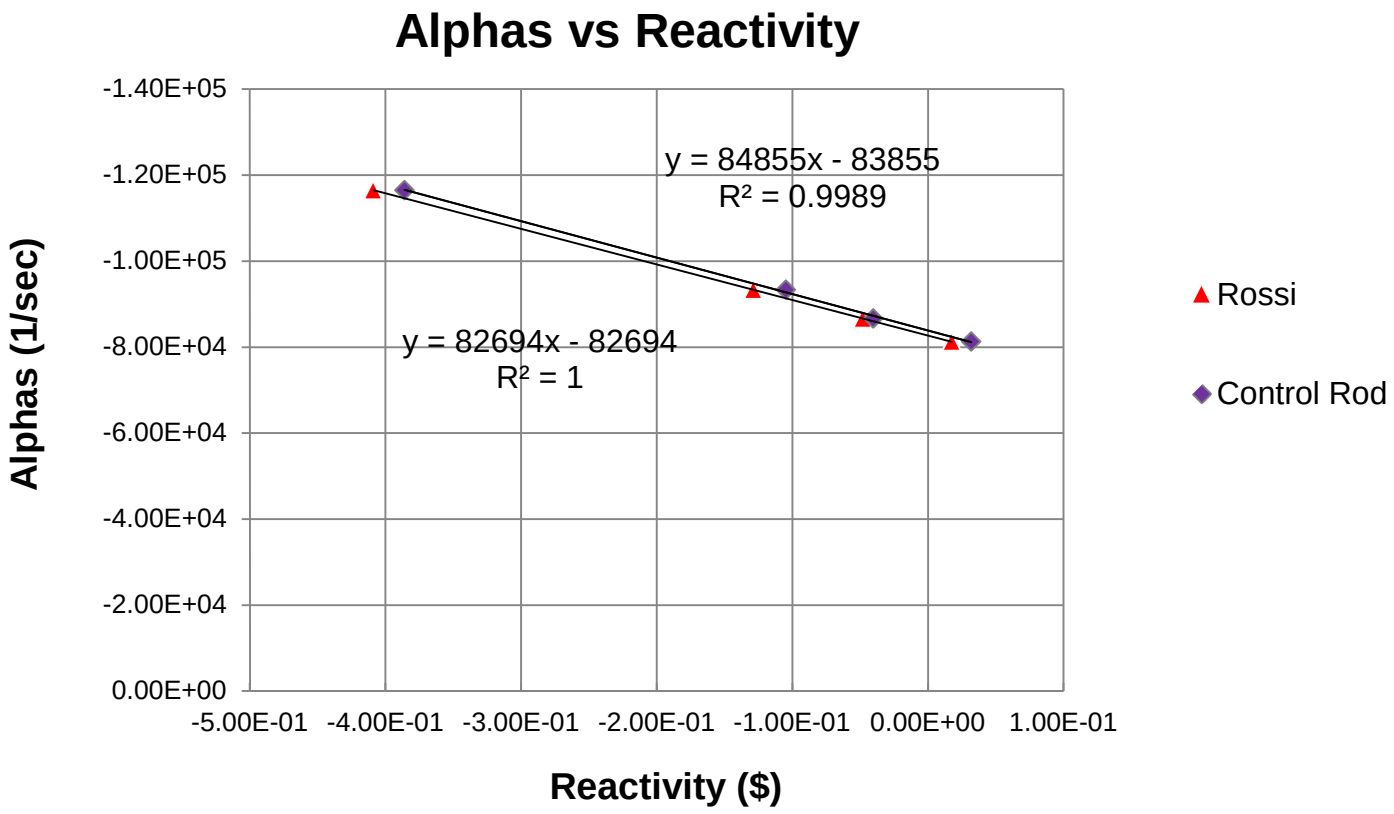
Alphas



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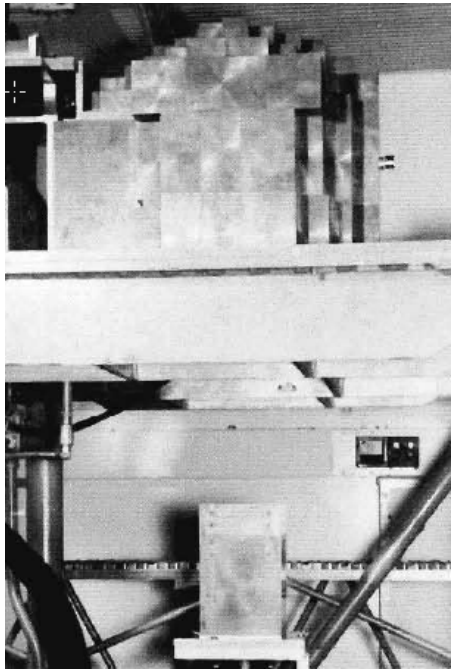
Results and Comparisons

Assemblies	α (dc)	l (neutron lifetime)
Lady Godiva (bare Oy-94)	$-1.1 \times 10^{6}\ s^{-1}$	5.9×10^{-9} s
Godiva IV (bare Oy-93 and 1.5 wt% Mo)	$-8.4 \times 10^{5}\ s^{-1}$	7.7×10^{-9} s
Topsy (Oy-94 in thick NU)	$-3.7 \times 10^{5}\ s^{-1}$	1.75×10^{-8} s
Zeus (all-oralloy reflected with copper	$-8.3 \times 10^{4}\ s^{-1}$	7.86×10^{-8} s
SHEBA (Solution High Energy Burst Assembly	-200	4.0×10^{-5} s



Topsy

Conclusions

- The Rossi-α at delayed critical for this experiment compares quite well with other α's from other assemblies.

- Neutron lifetime compares quite well with those from other assemblies.

- It will be interesting to benchmark this α value with Monte Carlo or any other computational code.

Acknowledgments

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