The Effect of Detection Threshold on Rossi-alpha Measurements

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Introduction, Motivation, and Mission Relevance

Nonproliferation and Criticality Safety
↓
Goal: Measure and monitor k_{eff}
↓
Use Rossi-α measurements of α to infer k_{eff}
↓
Utilize organic scintillators that offer capabilities beyond ^{3}He detectors
↓
Set detector thresholds for practical purposes
↓
Study the effect of threshold on Rossi-α measurements

- k_{eff} multiplication factor is the average number of neutrons from fission that induce another fission
- k_{eff} cannot be directly estimated but can be inferred from Rossi-α measurements of the prompt neutron decay constant, α, or its inverse value, α^{-1}
- ^{3}He filled gas proportional counters are insensitive to α^{-1} for neutron measurements
- Look to organic scintillators with better capabilities including improved timing
- Thresholds set for practical considerations, e.g. noise mitigation
- Need to solve any problems with scintillators before deploying
- If variance is found, must correct for it or choose threshold ideal for experiment
- If no effect, then no correction needed

IAEA safeguard inspectors[1]

$$k_{eff} \begin{cases} < 1 & subcrtical \\ = 1 & critical \\ > 1 & supercritical \end{cases}$$

Expected and MTV Impact

Results confirm accuracy of organic scintillator estimates of k_{eff} for variable threshold, improving nuclear criticality safety, and nonproliferation.

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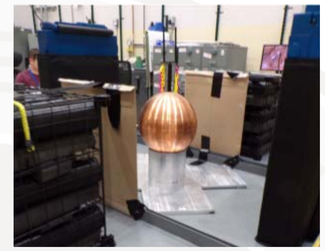
Collaborations with LANL/DAF

Procedure

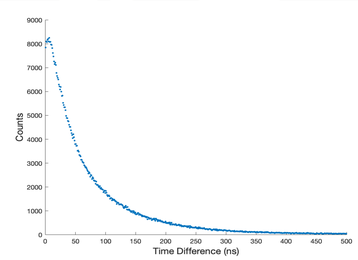
BeRP ball reflected by 7.62 cm of tungsten[2]



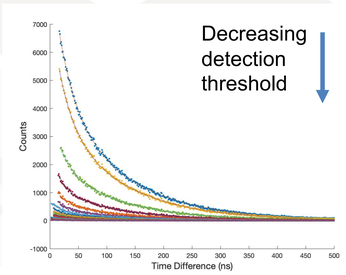
BeRP ball reflected by 7.62 cm of copper[2]

Use 12 *trans*-stilbene detectors measuring BeRP ball reflected by 7.62 cm of tungsten and 7.62 cm of copper and measure neutron detection times.
Tungsten: 30-min measurement
Copper: 20-min measurement

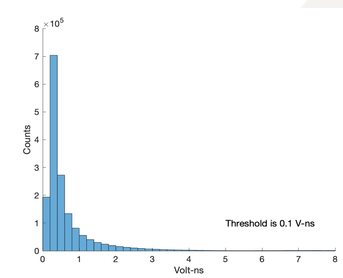
The 12 trans-stilbene organic scintillator detection system coupled to photomultiplier tubes[2]



Calculate time difference between neutron detections < 1000 ns



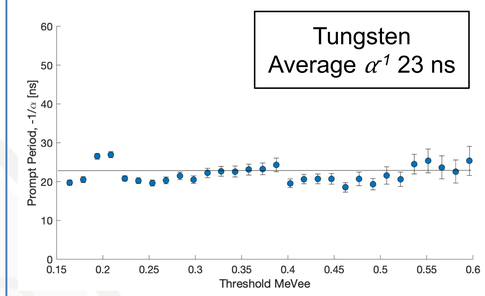
Create and fit Rossi-alpha histogram of time difference between neutron detections for different thresholds



Create pulse integral distributions for different threshold files

Goal: Acquire fit parameters, α, and standard deviations. Create α^{-1} vs threshold plot to study invariance.

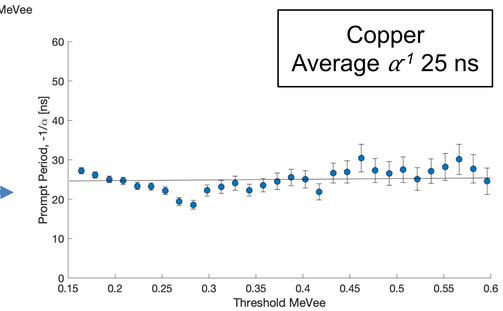
Results

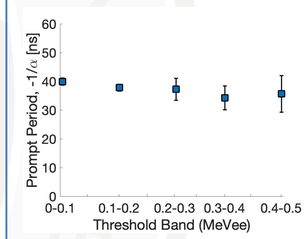


The Rossi-α measurements are not affected by threshold for both the copper and tungsten material experiments using organic scintillators

α^{-1} as a function of threshold for the tungsten measurements

α^{-1} as a function of threshold for the copper measurements





Prompt period as function of energy bands for copper

Conclusions

- Work demonstrates Rossi-α measurements are invariant of detection threshold.
- Corrections do not need to be applied and threshold can be chosen to optimize the organic scintillator performance.
- Prioritize lower thresholds for precision purposes

References:
[1] Calma, Dean, IAEA Safeguards inspectors (17-21 January 2005)
*[2] M.Y. Hua, C.A. Bravo, A.T. MacDonald, J.D. Hutchinson, G.E. McKenzie, B.C. Kiedrowski, S.D. Clarke, S.A. Pozzi, "Rossi-alpha measurements of fast plutonium metal assemblies using organic scintillators," Nuclear Instruments and Methods in Physics Research Section A, **959**, 2020.*

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