Passive Time Coincidence Measurements with HEU Oxide Fuel Pins

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49th Annual Meeting of the Institute for Nuclear Materials Management

July 13 – 17, 2008

Managed by UT-Battelle
for the Department of Energy

OAK RIDGE National Laboratory

Passive Time Coincidence Measurements with HEU Oxide Fuel Pins

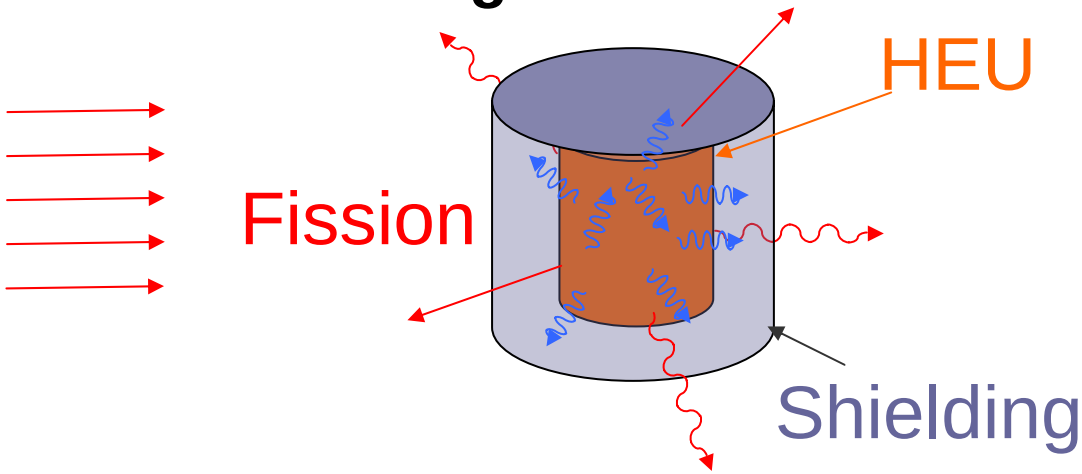
- **Passive measurements are part of a larger project to actively detect SNM**
- **Collaborators**
  - **Idaho National Laboratory**
    - **J. Jones, B. Blackburn, S. Watson, J. Johnson**
  - **Los Alamos National Laboratory**
    - **C. Moss, K. Ianakiev, L. Waters**
  - **Oak Ridge National Laboratory**
    - **J. Mihalczo, P. Hausladen, S. McConchie**
  - **Idaho State University/Idaho Accelerator Center**
    - **A. Hunt, S. Thompson, M. Kinlaw**

Passive Measurements Purpose

- **Project goal**
  - **Evaluate the ability to actively determine the presence of SNM using both pulsed and CW operational accelerator modes**
  - **Distinguish HEU from DU**
- **Compare HEU detection capabilities of passive and active measurements**
- **Passive HEU and DU measurements with ^{3}He detectors presented here**

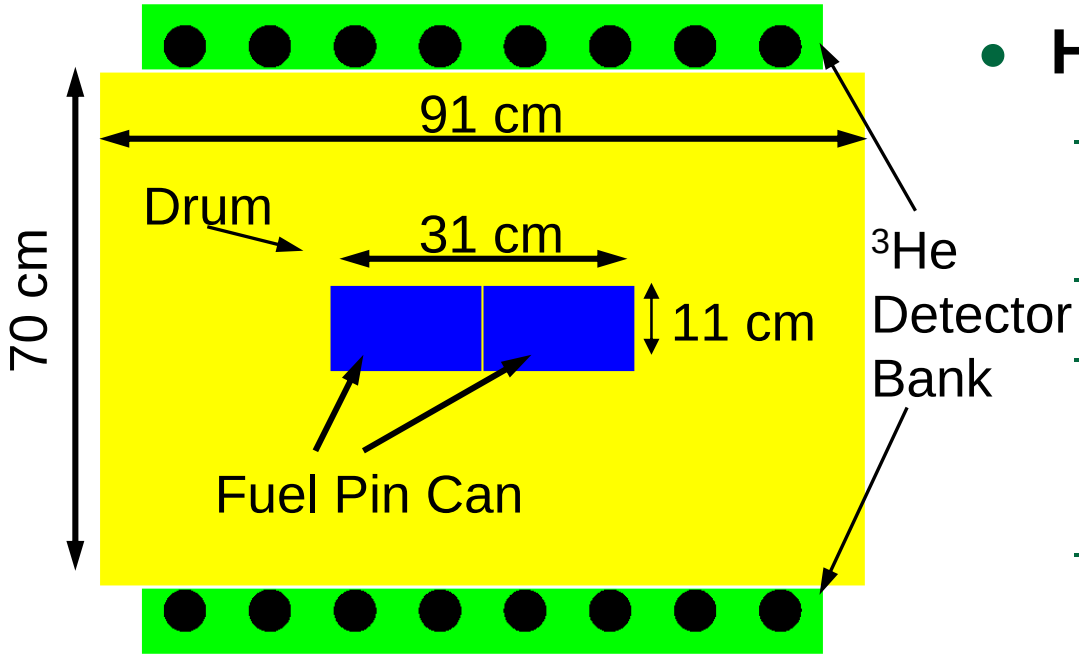
Passive Detection Signatures

- **Active measurements induce fission on ^{235}U to emit multiple neutrons and gammas correlated in time**



- **Passive detection of HEU is possible with either fissions or decays**
  - **^{235}U fission emits multiple neutrons and gammas initiated by spontaneous fission (1.6×10^{-1} fissions s^{-1} kg)**
  - **^{235}U decay yields 186 keV gamma (8×10^{7} γ s^{-1} kg^{-1}) difficult to detect through shielding**

Experimental Setup

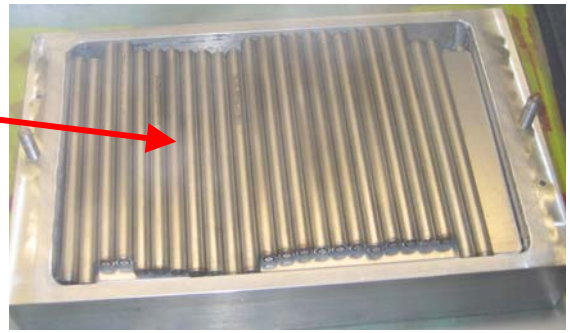


- **HEU samples:**
  - **Unirradiated U_3O_8 fuel pins with 46 wt% ^{235}U**
  - **1 kg, 4 kg, and 8 kg ^{235}U**
  - **Single steel can (11 cm diam., 15.5 cm length) contains 4 kg sample**
  - **Two cans placed next to each other to give 8 kg sample**

- **HEU samples surrounded by foam in 55 gal drum**
- **31 kg DU sample used for comparison**
- **2 banks of 16 poly moderated ^{3}He detectors**
  - **2.5 cm diameter**
  - **Located 35 cm from center of drum**

Experimental Setup - Photographs

Fuel Pins



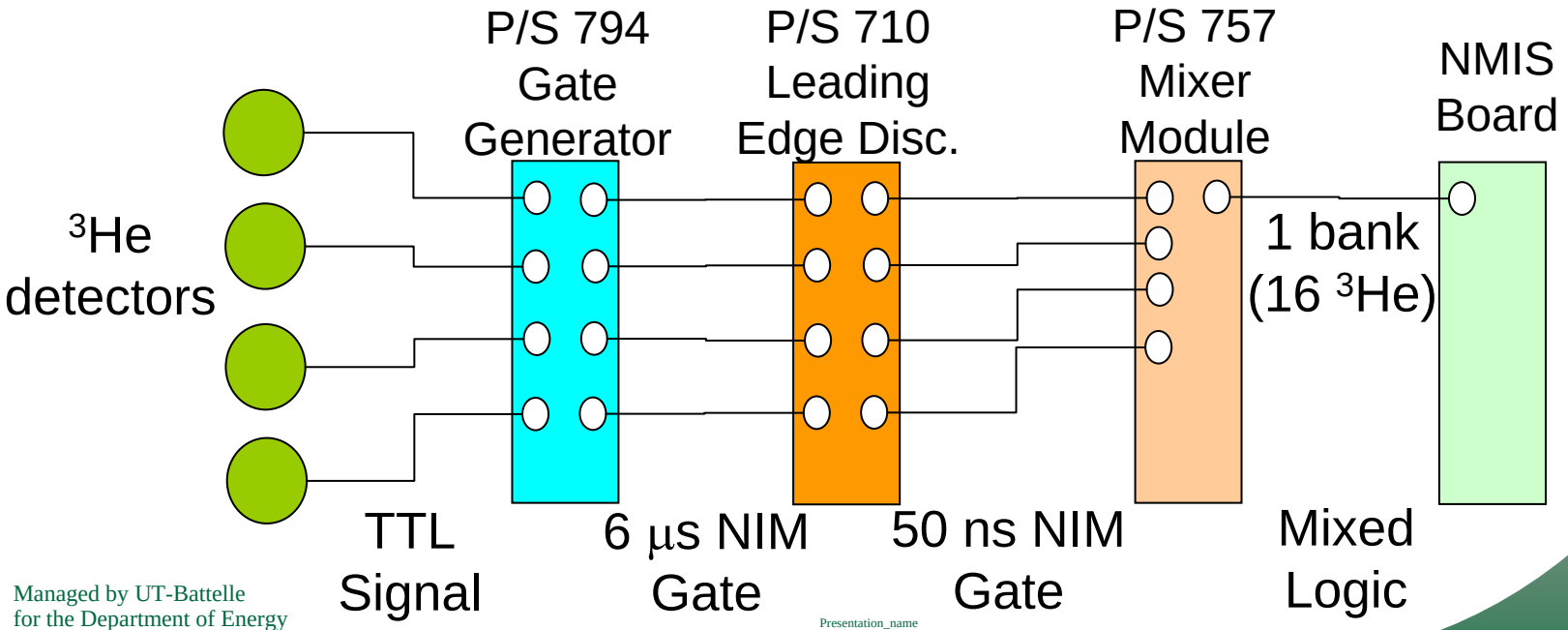
Fuel Pin Can

Sample drum

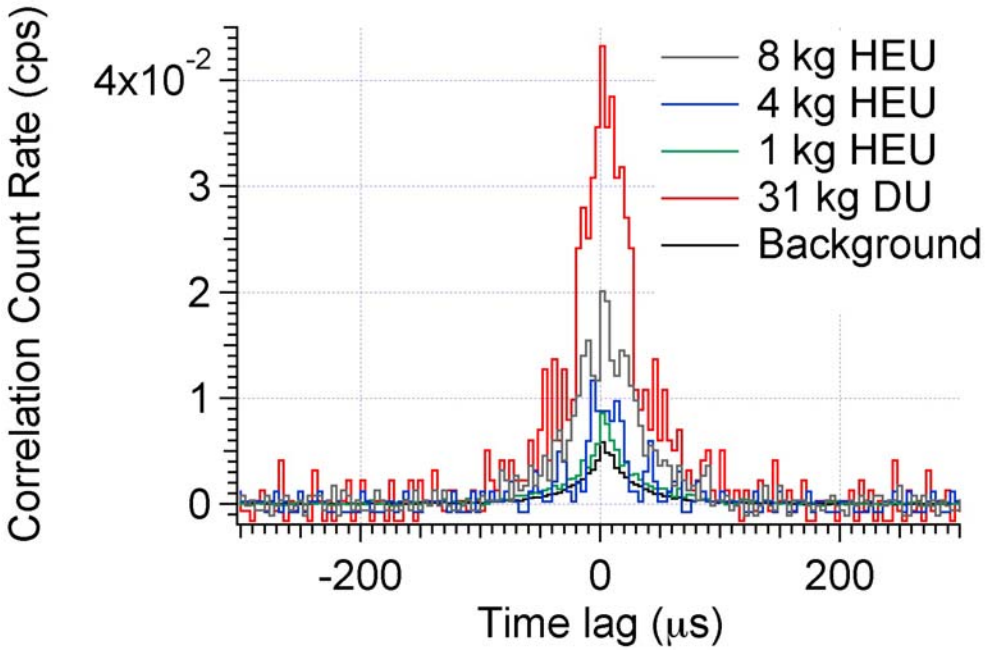
Bank of 8 moderated ^{3}He detectors

Electronics Setup with NMIS

- **Fast (1 GHz) online 10-channel time correlation processing with simultaneous list mode acquisition**
  - **2 dual card boards in PC with appropriate NMIS software**
  - **Online analysis gives time correlation functions, Feynman variance, multiplet rates, and multiplet probability distributions for an input time window**
  - **Offline analysis used to determine correlation functions and multiplet distributions for arbitrary window size and to calculate Feynman variance as a function of window size**



Neutron Coincidence Time Distributions

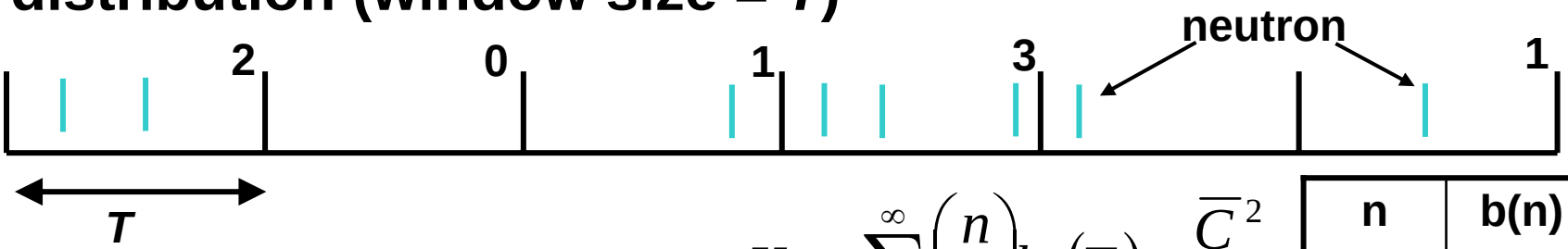


Sample	Measurement Times (min)
8 kg HEU	35.0
4 kg HEU	17.5
1 kg HEU	346.5
31 kg DU	17.5
Background	3495.3

- **Neutron efficiency determined to be ~1% using Cf-252 fission chamber**
- **Difference in doubles rate evident from HEU and DU neutron coincidence time distributions**
- **1 kg sample barely distinguishable from background**

Feynman Variance (Y2F)

- **Feynman variance (Y2F) is related to the probability that two neutrons are from the same fission chain**
- **Calculated from the "random" gate multiplicity distribution (window size = *T*)**



- **The efficiency, fission rate, and multiplication can be estimated from *A***
- **Passive measurements on an HEU sphere have been performed at LLNL using this framework[1]**

$$Y_2 = \sum_{n=2}^{\infty} \binom{n}{2} b_n(T) - \frac{\overline{C}^2}{2!}$$

$$\overline{C} = \sum_{n=1}^{\infty} n b_n(T)$$

$$Y_{2F} = \frac{Y_2}{\overline{C}} = A\left(1 - \frac{1-e^{-\lambda T}}{\lambda T}\right)$$

n	b(n)
0	0.2
1	0.4
2	0.2
3	0.2

[1]Verbeke, et al, UCRL-PROC-231582, 2007.

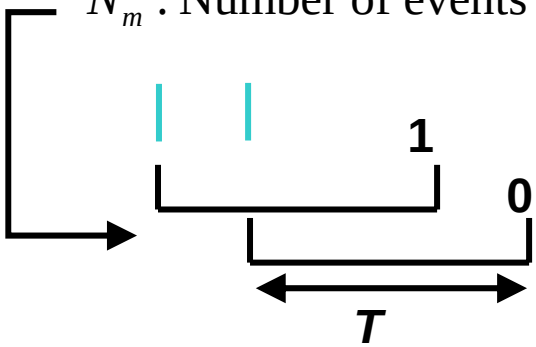
Multiplet Distribution

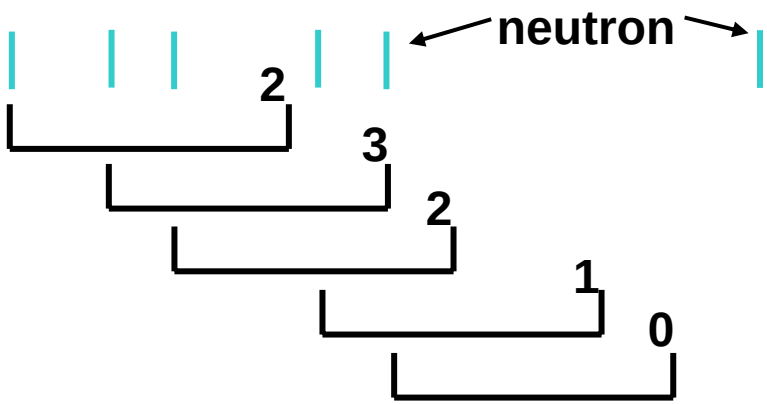
- **Multiplets[2] of order *m*, R_m, are the number of times *m* events occur in a time window, *T***

$$R_m = \frac{1}{B_0}\left(\sum_{\upsilon=0}^{\infty} B_\upsilon\right)\left[N_m - \sum_{\upsilon=0}^{\infty} R_{m-\upsilon} B_\upsilon \left(\sum_{i=0}^{\infty} B_i\right)^{-1}\right]$$

B_m : Number of events with m signals in a randomly triggered inspection interval

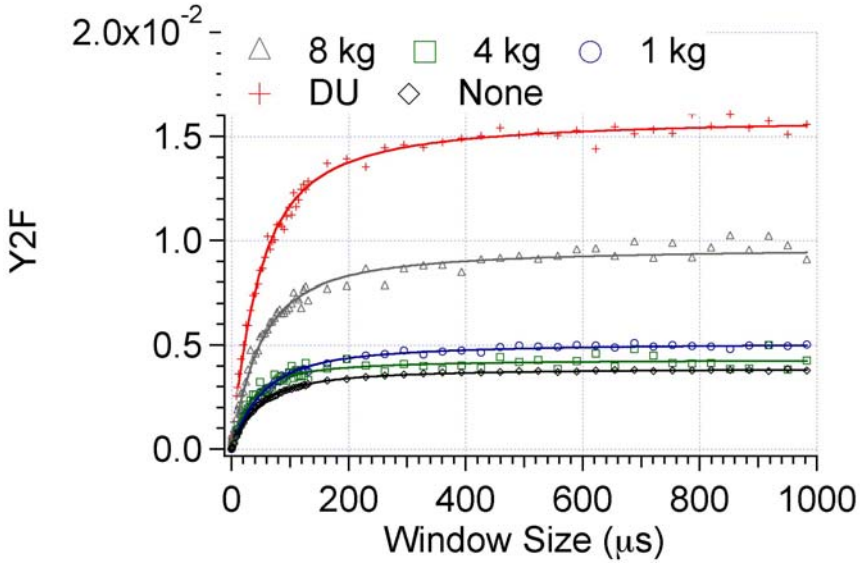
N_m : Number of events with m signals inside an event triggered inspection interval

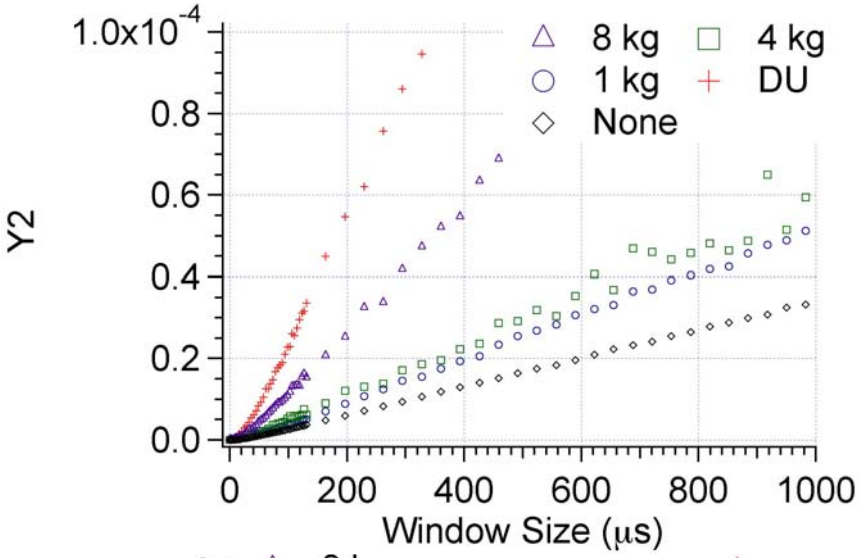




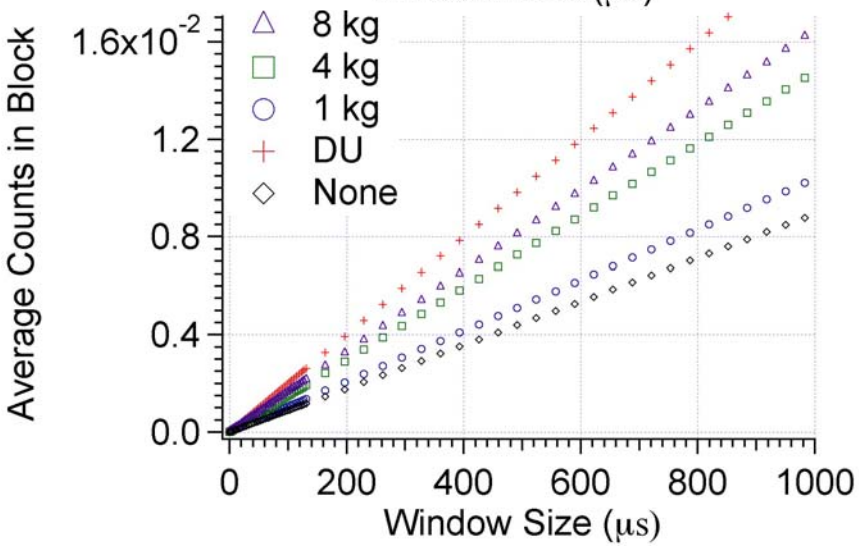
[2]R. Dierckx and W. Hage, Nucl. Sci. and Engr. 85, 325-338 (1983).

HEU and DU Comparisons – Y2 and Y2F

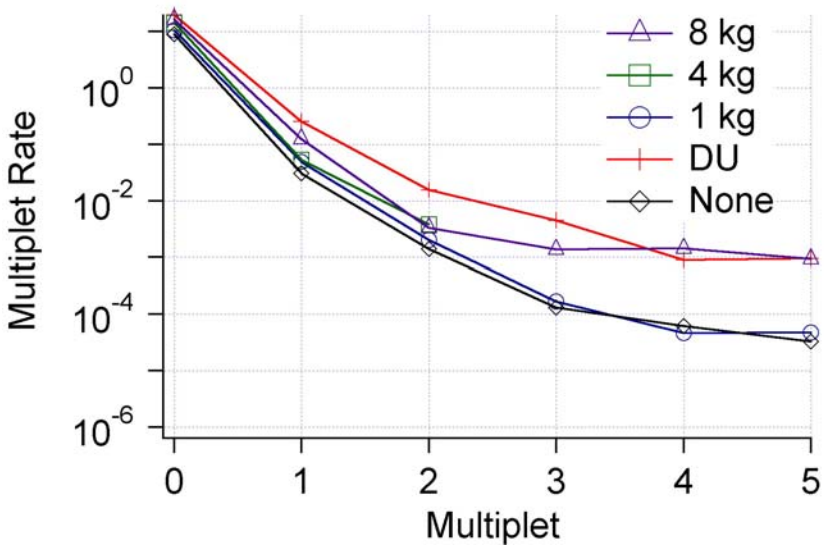


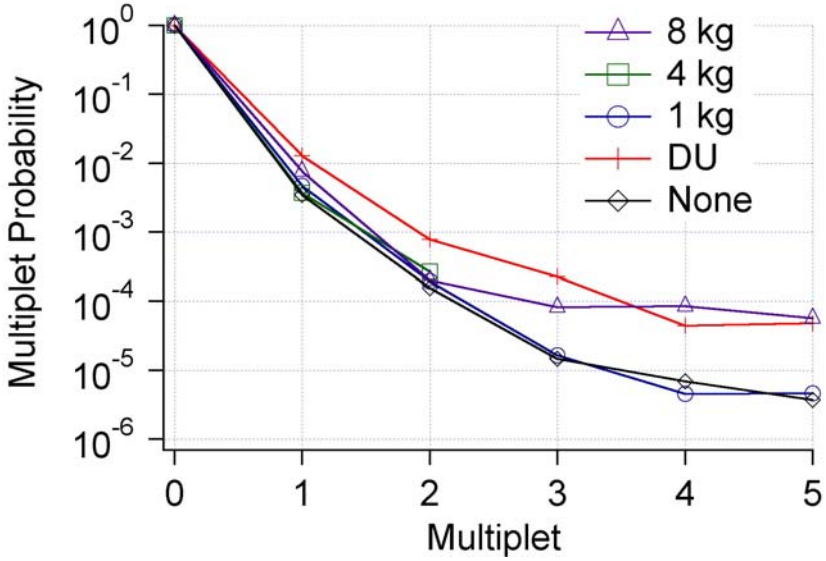


- **Y2F is sensitive sample size but 4 kg is discrepant**
- **Count rate for the 4kg is overestimated**



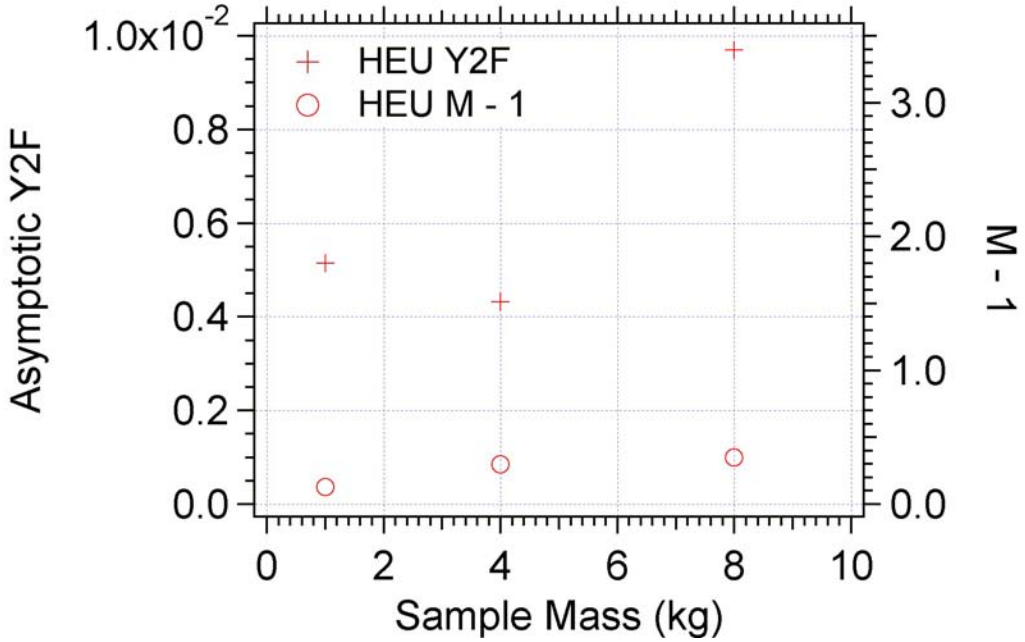
HEU and DU Comparisons – Multiplets





- **HEU amounts distinguishable using rate and probability normalization**
- **Cannot use simple rate argument (doubles, triples, etc.) to distinguish the HEU from DU**

MCNP Simulations



- **Fuel pin geometry modeled in MCNP5 to calculate k_{eff} (multiplication)**
- **Not enough statistics to allow usage of triples rates**
- **Need more data (active or passive) to better measure the multiplication**

Conclusions and Future Work

- **HEU presence is evident in passive measurements**
  - **1 kg sample barely distinguishable from background**
  - **4 kg sample measurements are discrepant**
- **Future work includes:**
  - **Using the point kinetics framework to estimate multiplication and fission rates**
  - **Analyze measurements with fast liquid scintillators (in progress)**
- **Using active measurements, compare passive and active detection capabilities**