MUSIC Leakage Multiplication with Organic Scintillators

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Leakage Multiplication Definition

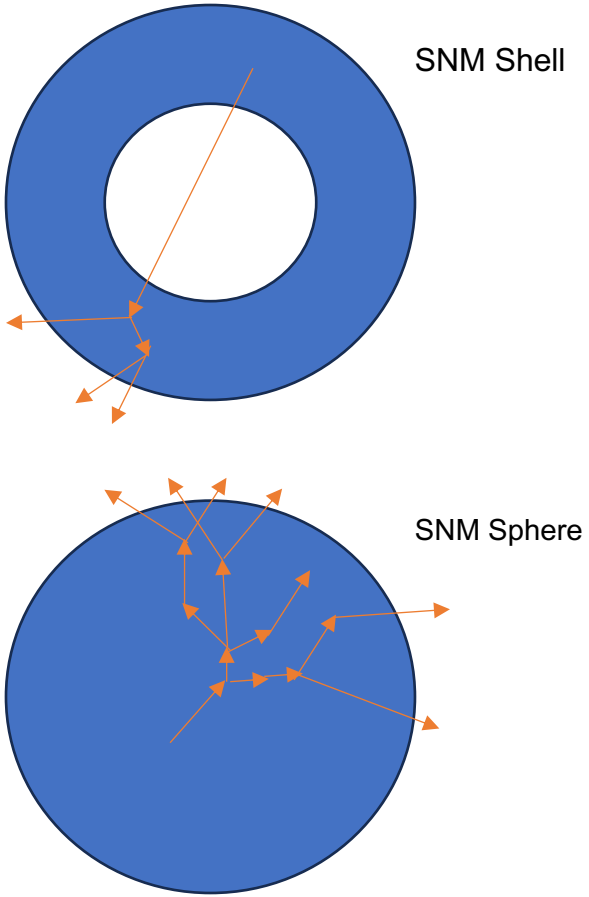
- M_T: Total Multiplication
- M_L: Leakage Multiplication

$$M_T = 1 + Q_{F,n}\bar{\nu} = \frac{1}{1-k}, \qquad k < 1$$

$$M_L = 1 + Q_{F,n}\left(\bar{\nu} - 1 - \frac{\Sigma_c}{\Sigma_f}\right)$$

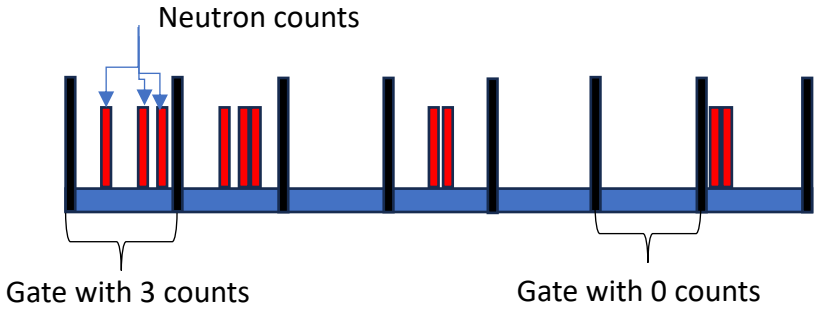
$$M_L = M_T * \rho$$

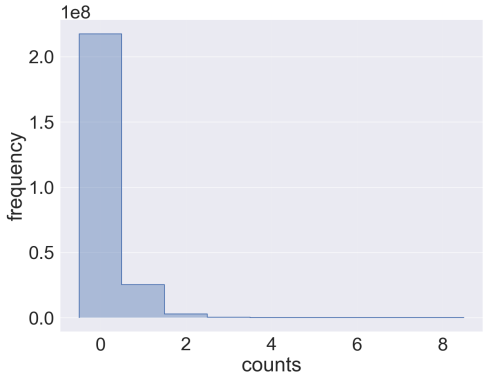
- Avoids issue of self-shielding
- Accomplished by measuring time correlation of neutron emission and comparing to total count rate

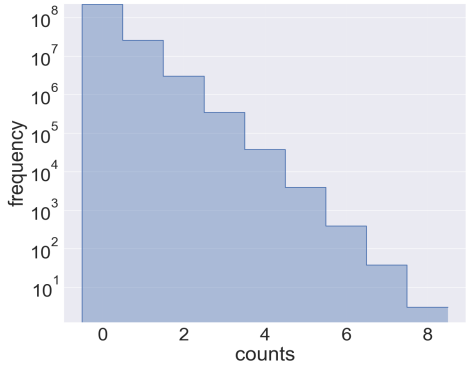


Neutron Counting

- Time series data stream broken into “gates” of width Δt
- Record multiplets and histogram to build counting distribution
- Optimize gate width to maximize real and minimize background coincidence





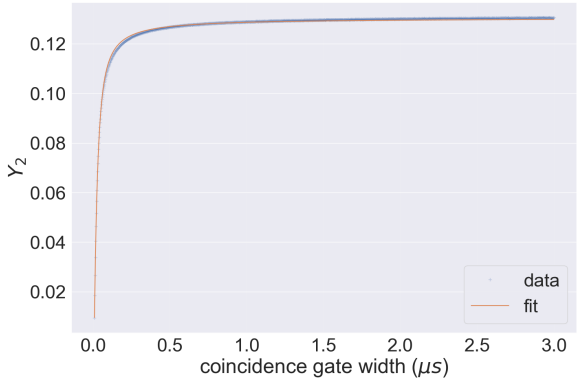


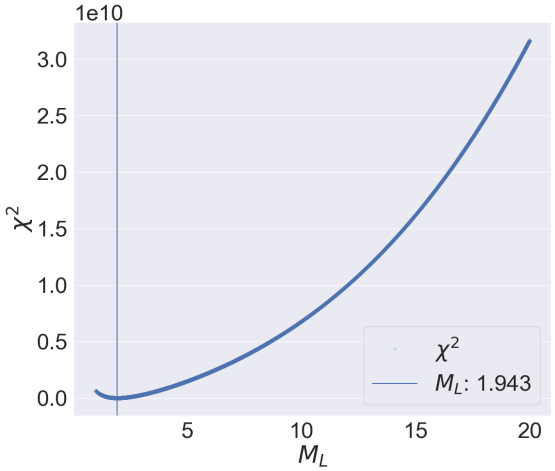
Two Methods:

- Feynman-Y with Robba et al.[1]:

$$Y = \frac{\sigma_C^2}{\bar{C}} - 1$$

  - $C \equiv$ measured counting distribution
  - Calculate Y for many gate widths
  - Fit Ys with model where M_L is a parameter
- Cifarelli, Hage [2]:
  - $R_n \equiv$ number of combinations of n counts from N correlated counts
  - Calculate $R_1, R_2, R_3 (if\ necessary)$ for a single gate width
  - Minimize χ^2 for fit to R_n used.

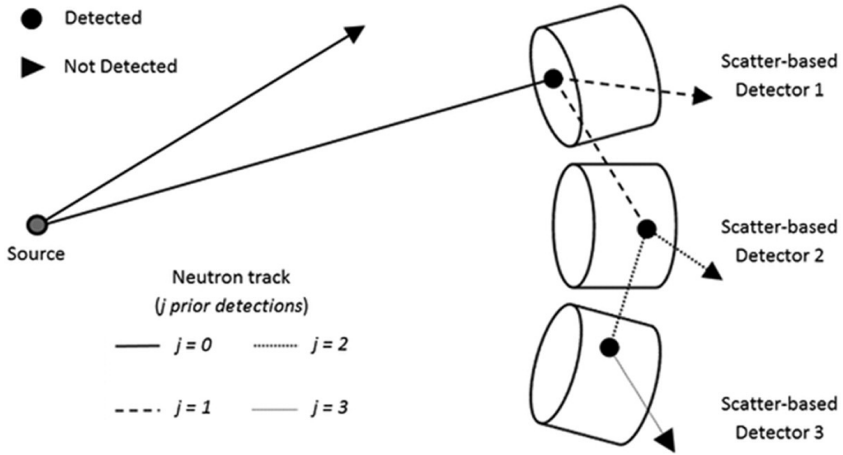


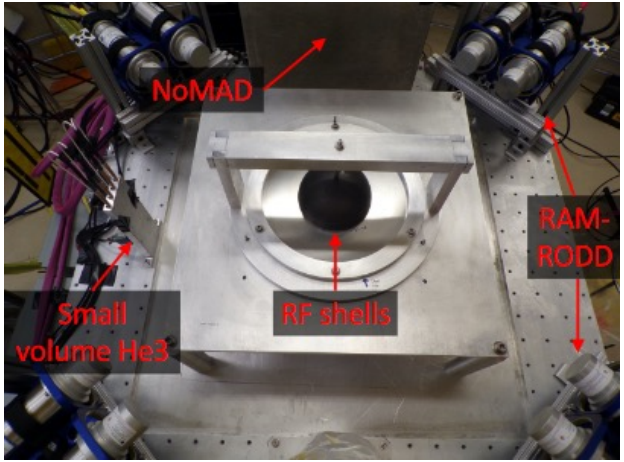


[1] Robba et al. “Neutron Multiplication Measurements Using Moments of the neutron Counting Distribution”, NIM, 1983
[2] Cifarelli, Hage, “Models for a three-parameter analysis of neutron signal correlation measurements for fissile material assay”, NIM, 1986

Cross Talk and Return

- Cross talk: same neutron scattering in multiple detectors
  - Practically non-existent in non-adjacent and negligible in adjacent detectors
- Post detection return: same neutron gets detected then returns to sample
  - Small contribution and can be treated by adjusting ν in systems with higher contribution



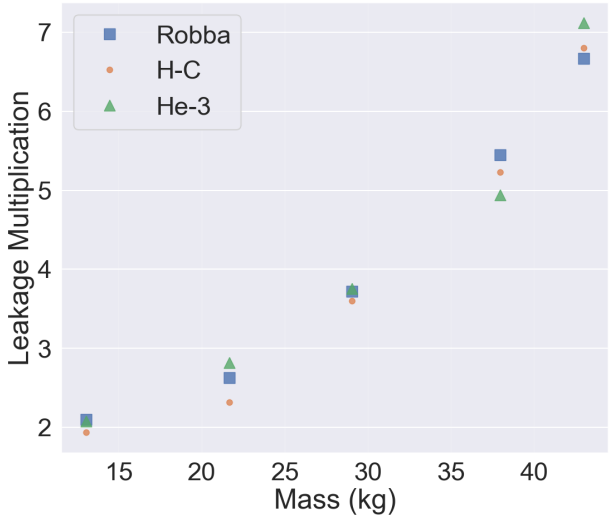


[top] Image of cross talk from Shin et al. "**Neutron Multiplicity Counting Moments for Fissile Mass Estimation in Scatter-Based Neutron Detection Systems" NIM, 2017 https://doi.org/10.1080/00295639.2017.1354591**
[bottom] MUSiC experiment setup

Results

- Preliminary agreement between methods and with NoMAD system
- Comparison to simulated results and possible adjustments from literature to come
- Underestimated uncertainty using propagation as compared to bootstrapping

	Organic Scintillator M_L		
Configuration	Robba	H-C	^{3}He ML
1	2.10 ± 0.002	1.94	2.08 ± 0.01
2	2.63 ± 0.002	2.32	2.82 ± 0.01
3	3.72 ± 0.003	3.60	3.76 ± 0.02
4	5.45 ± 0.005	5.23	5.49 ± 0.04
5	6.76 ± 0.005	6.80	7.12 ± 0.05



Conclusion/Summary

- Applied two methods of calculating M_L with organic scintillators
- Compared to ^{3}He detector results and found agreement with preliminary results
- Shown organic scintillator detection systems can be used effectively to measure M_L
- Can account scattering detection effects with experimental design or post processing correction

Acknowledgements

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