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MONTE CARLO FITTING OF THE AMLI NEUTRON SPECTRUM

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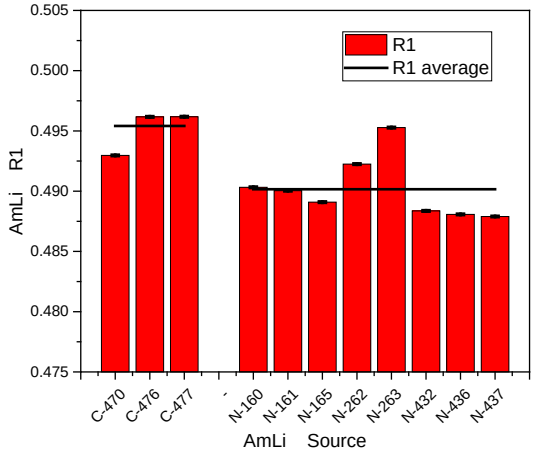
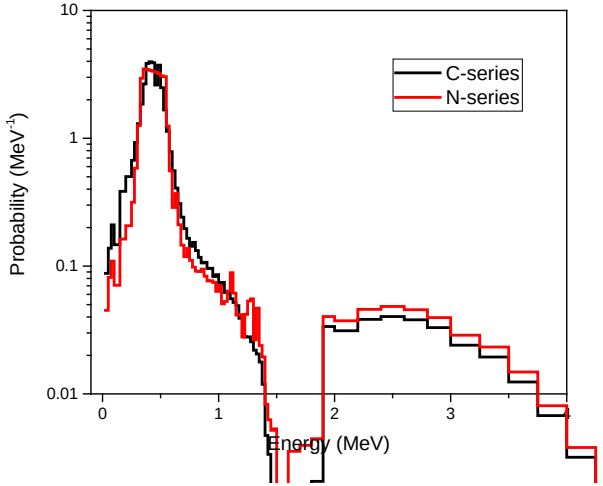
Novel Outcomes

- Characterization of the differences between AmLi sources

- Spectra specific to different series of AmLi sources, and to individual sources





OUTLINE

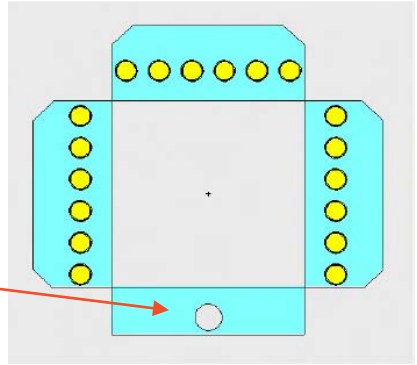
- AmLi applications – Active neutron interrogation
- Physics considerations
- Current AmLi spectra
- Measurements – Source variations
- Simulations
- Spectra fitting
- Limitations

APPLICATIONS

- The IAEA uses an AmLi source in the Uranium Neutron Coincidence Collar (UNCL) to verify compliance with nonproliferation treaties

- The UNCL requires calibration with known uranium samples. The AmLi spectrum isn't known well enough to allow simulated calibrations

AmLi source

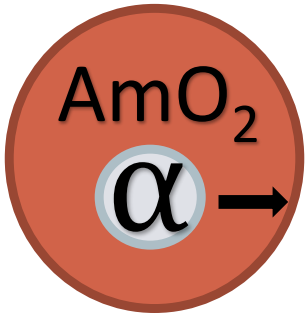


UNCL

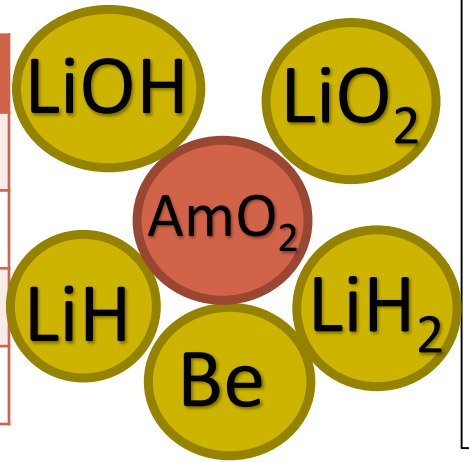
UNCL with fuel

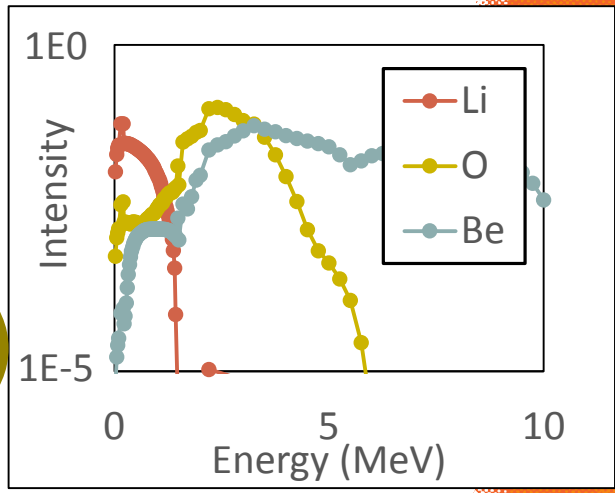
Physics Considerations

- Alphas lose energy traveling through AmO_2 particle of unknown size
- Energy reduction below Li threshold enhances O contribution
- Unknown Li matrix material affects neutron production and thermalization
- Large variation in spectra from each element



Isotope	Energy (MeV)
Am-241 (α)	5.486, 5.443
Li-7 (α,n)	4.38
O-18 (α,n)	0.85
U-238 (n,f)	~1

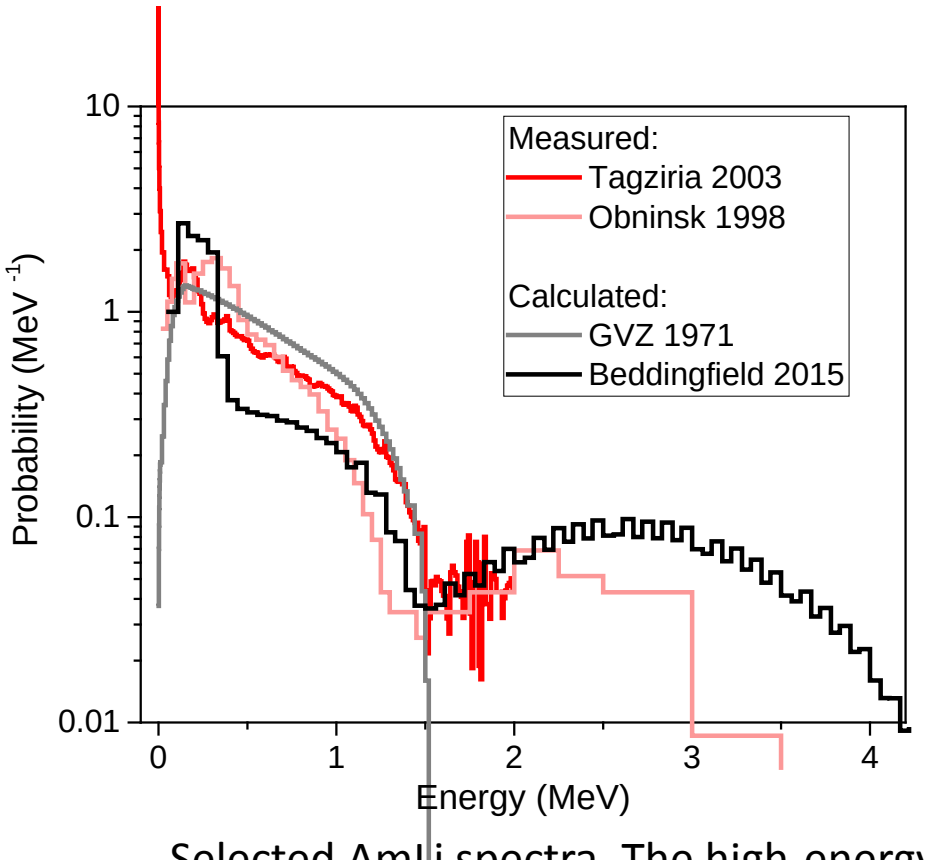




Current Spectra

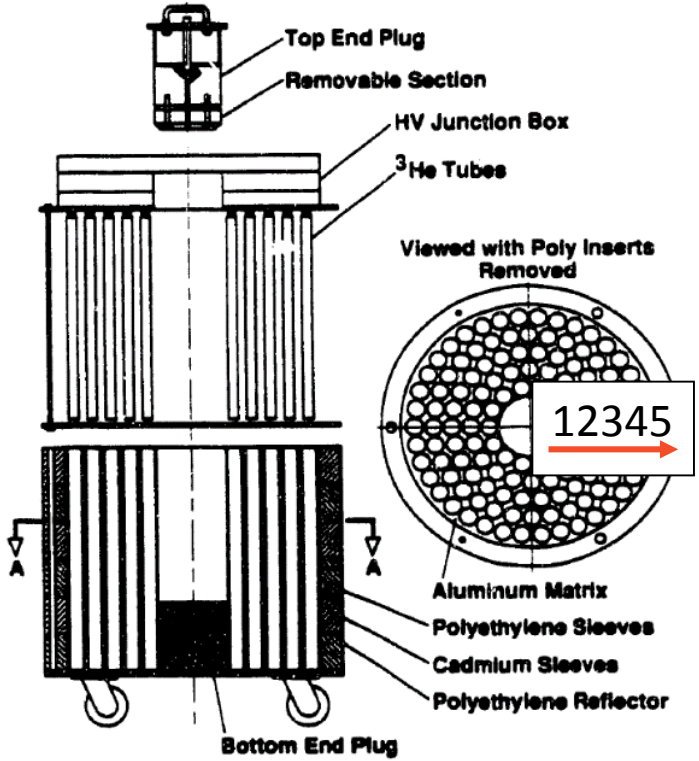
- Measured single sources
  - Tagziria 2003 2004
  - Obninsk 1998
  - Birch 1984
  - Ing 1981
  - Owen 1982
  - …and more

- Calculated initial spectra
  - Geiger and van der Zwan 1971
  - Tagziria 2012
  - Beddingfield 1999 2015



Selected AmLi spectra. The high-energy tail is key for a good fit

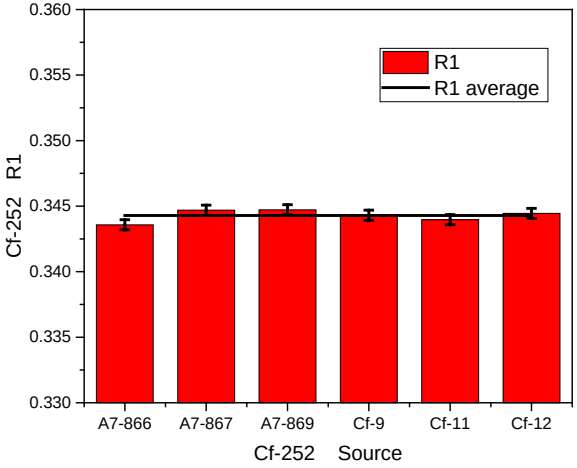
Measurement Overview

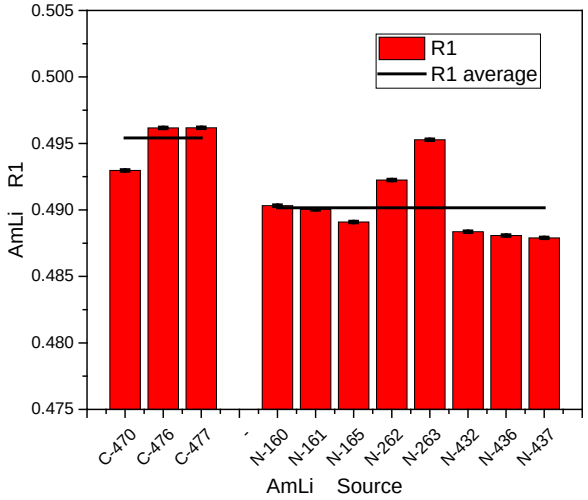


Sources	Type
Cf-252	3 A7-series
	3 Cf-series
AmLi	3 Gammatron C-series
	8 Gammatron N-series

- 5-Ring Multiplicity Counter (5RMC) gives singles rate by ring
- Higher neutron energy is required to reach the outer rings

Measurement results – Variation between sources





Cf-252 inner ring ratios

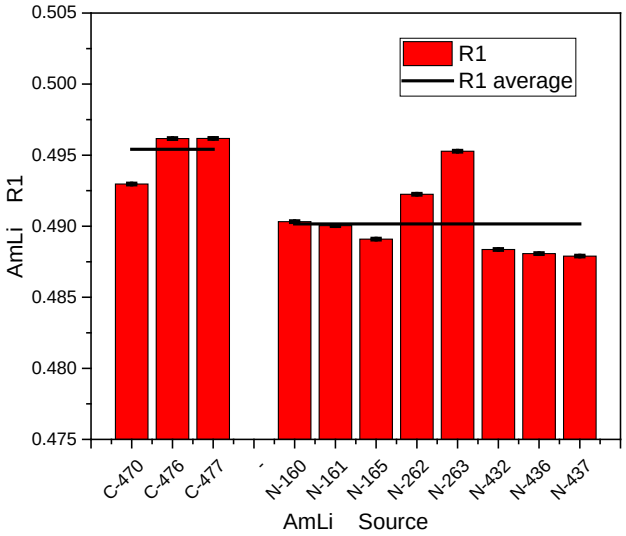
$$\chi^2 = \sum_{r=1}^{5} \left(\frac{individual - average}{relative_i * error_i * error_a} \right)_r^2$$

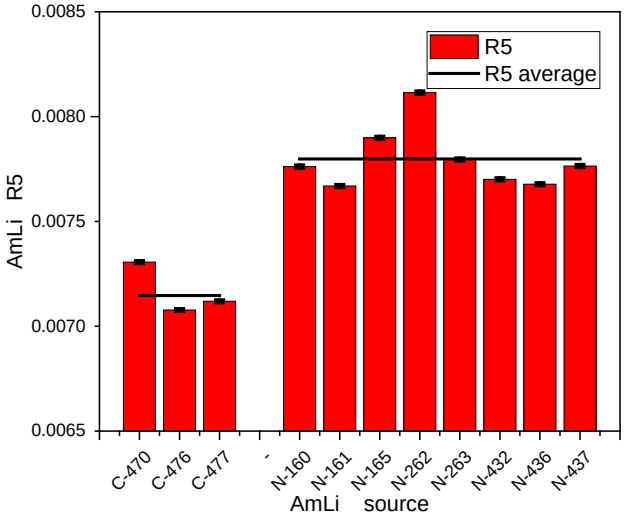
Statistical uncert.	0.11%
Standard deviation	0.12%
Chi-squared	1.41 E-6

AmLi inner ring ratios

Statistical uncert.	0.01%
Standard deviation	0.63%
Chi-squared (C)	1.73 E-5
Chi-squared (N)	6.22 E-5

MEASUREMENT RESULTS – TARGETS FOR SPECTRA FITTING





AmLi inner ratios

Ratio	C-series	N-series
R1	0.495414	0.490165
R2	0.353878	0.354726
R3	0.114653	0.117043
R4	0.028918	0.03027
R5	0.007147	0.007798

AmLi outer ratios

Ratios also exist for individual sources

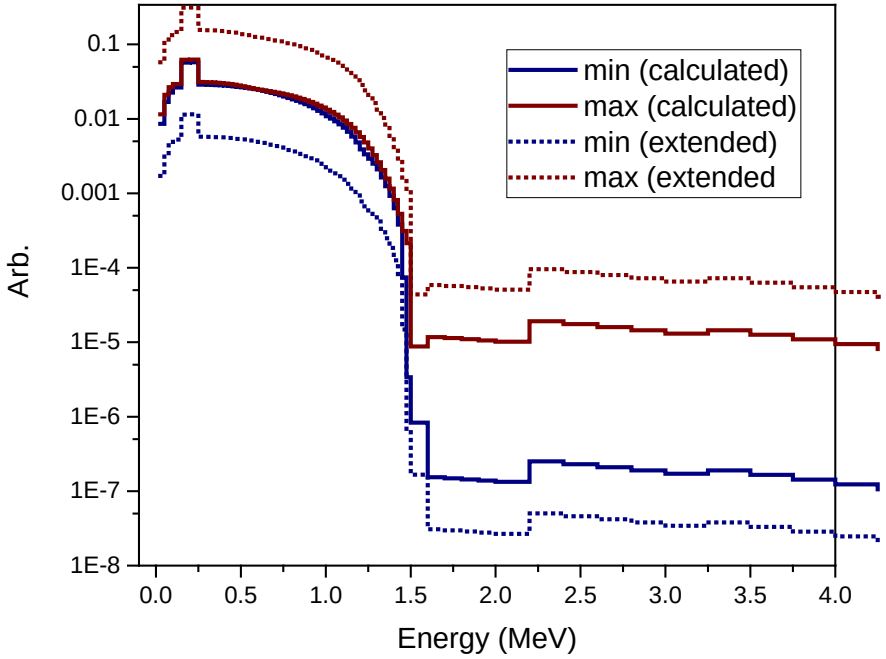
SIMULATIONS

- 5RMC MCNP model benchmarked to Cf-252 measurements
  Chi-squared ring ratio agreement of 9.0E-6
- 5RMC neutron energy 100-bin monoenergetic **response function** for AmLi matrix – MCNP6

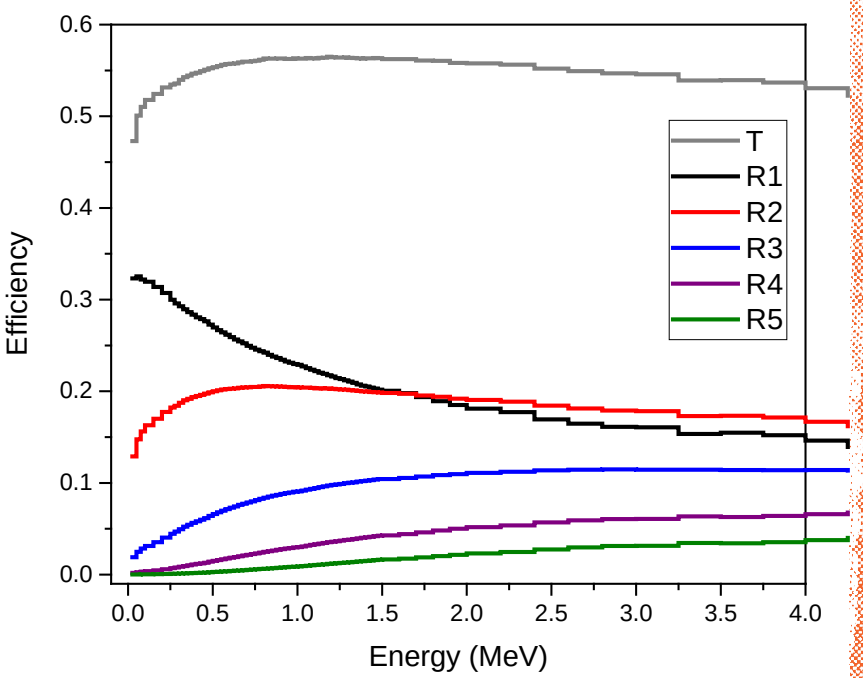
- Alpha energy for different particle sizes – MCNP6
- Li (α,n) neutron **energy spectra** for different particle sizes – SOURCES4C

- **Energy spectra * response function = ring ratios**

SIMULATIONS



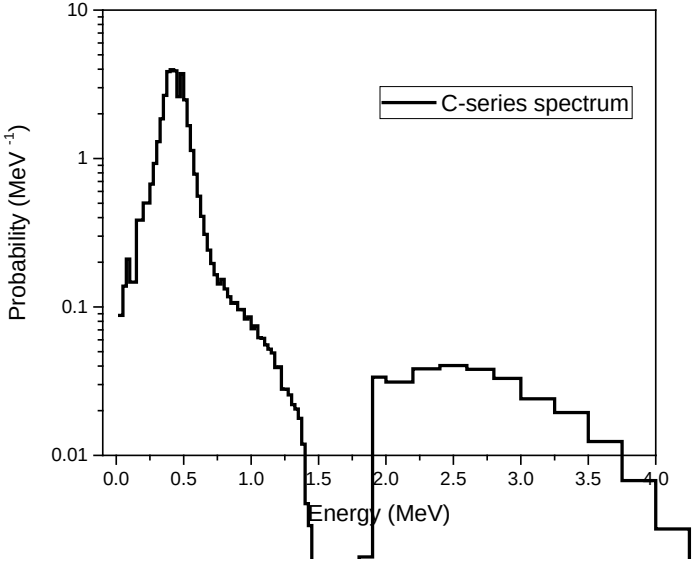
Li (α,n) neutron energy spectrum range between 1 and 7 microns

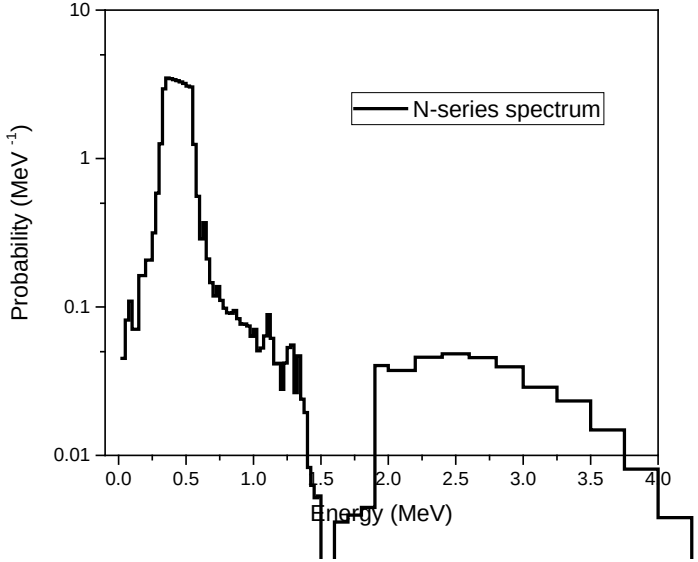


5RMC response function

SPECTRA FITTING

- Minimize chi-squared of simulated and measured ring ratios - adjust oxygen contribution and spectra within expanded limits





Parameter	C-series	N-series
Oxygen contribution	6.7%	8.1%
Chi-squared fit	1.3 E-6	1.4 E-6

LIMITATIONS

- Chi-squared value only relates to Cf-252 agreement, no physical meaning
- MCNP model bias of chi-squared 9.0 E-6, with 1.4 E-6 disagreement between Cf-252 sources
- We assume the spectra fitting accounts for the unknown AmO_2 particle size, matrix composition, other effects
- Need to benchmark simulations to UNCL measurements and characterize spectrum effects on U-235 mass in a UNCL

CONCLUSIONS

- Characterized the variation in AmLi sources compared to Cf-252
- Generation of spectra that are precise enough to distinguish between sources

- Improved accuracy in modeling AmLi active interrogation systems
  Measurement of non-calibrated samples

- Future work – find effects on UNCL measurement results

ACKNOWLEDGEMENTS

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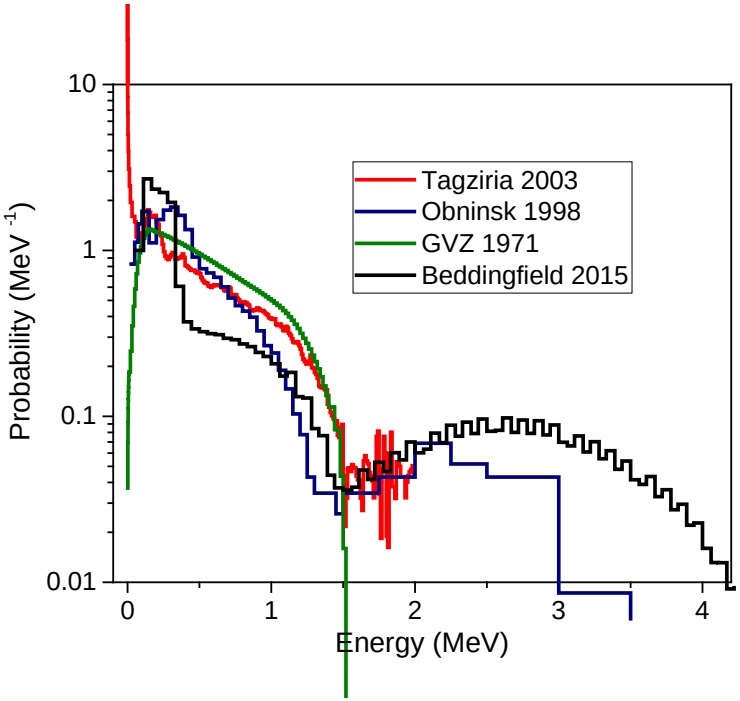
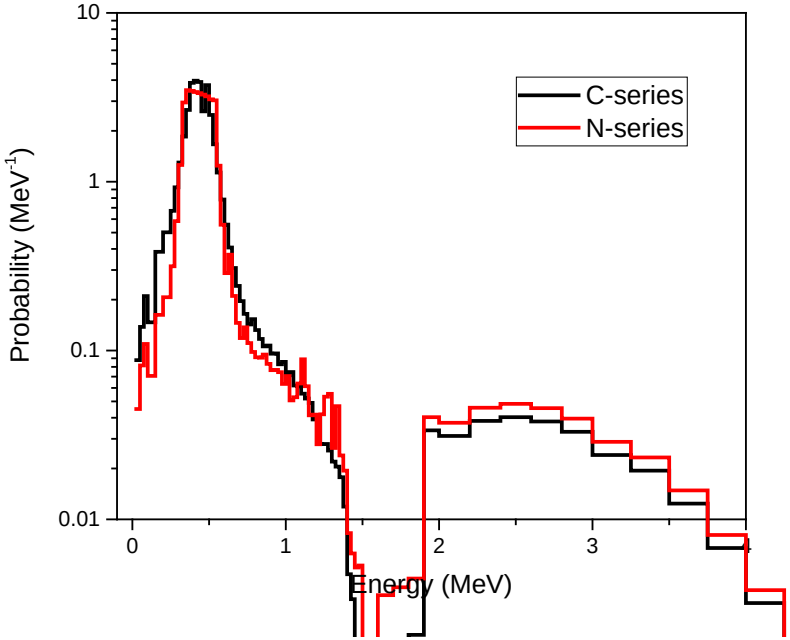
UF UNIVERSITY of FLORIDA

COMPARISON OF SPECTRA

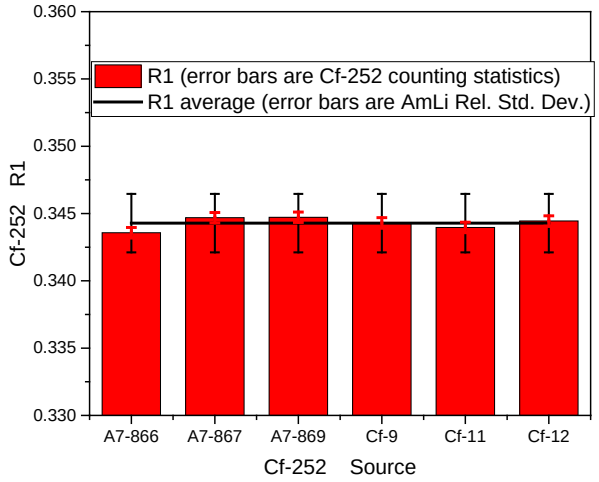


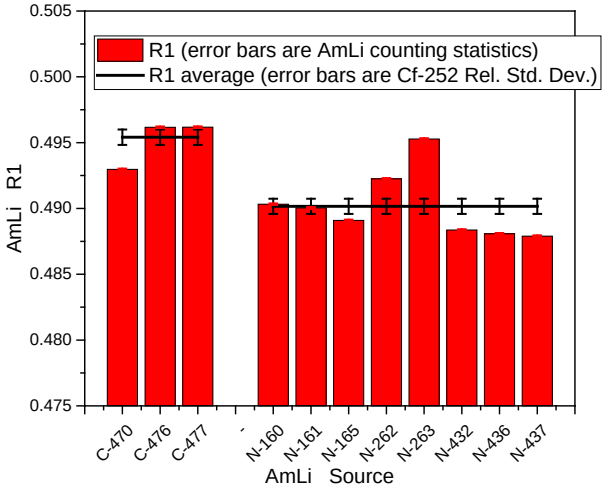


SUMMARY SLIDES FOLLOW:

Monte Carlo Fitting of the AmLi Neutron Spectrum

- AmLi sources are used for active interrogation of fresh uranium fuel for treaty verification
- Characterization of the differences between AmLi sources





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Monte Carlo Fitting of the AmLi Neutron Spectrum

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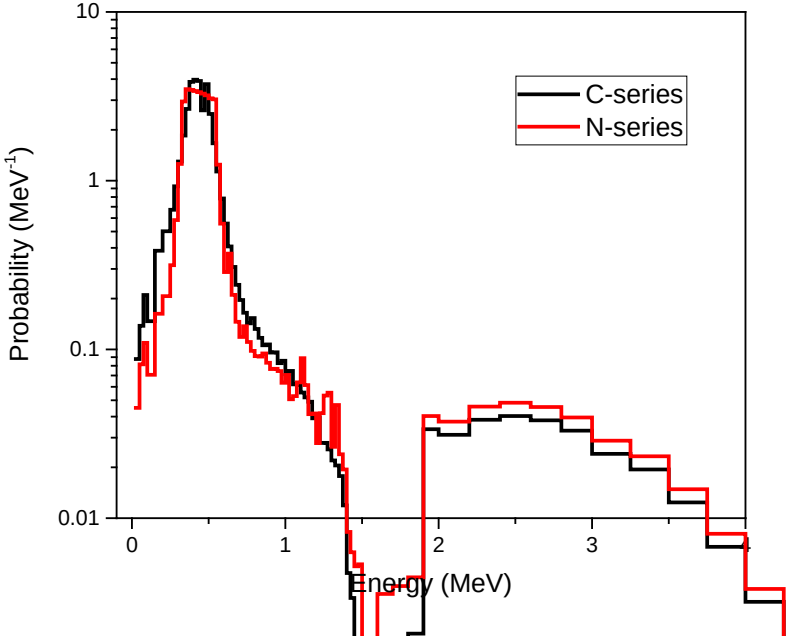
- Improved accuracy in modeling AmLi active interrogation systems



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