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Updates on: IER 518 Joint Laboratory High-Multiplication Measurements IER 153 Prompt Fission Uranium Neutron Spectrum (PFUNS)

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Outline

- IER 518 Joint laboratory high multiplication measurements
  - Background
  - Measurements at Sandia SPRF/CX facility
  - Results and preliminary data analysis
  - Continuing work
- IER 153 Prompt Fission Uranium Neutron Spectrum (P**FUN**S)
  - Background
  - Godiva IV preliminary measurements and results
  - Rocky Flats shells approach to critical and irradiations on Planet
  - Continuing work
- Questions

IER 518 Project Goals

- Gather list-mode (time-tagged) data for configurations exceeding 20-100 M
- Provide inter-comparison between LLNL, LANL, and IRSN detector systems on SNL assembly
- Overlap and extend previous subcritical M measurements
- Create fundamental physics benchmark greater than about M=20
  - None over a multiplication of about 20 published *yet*

LEU-COMP-THERM-078

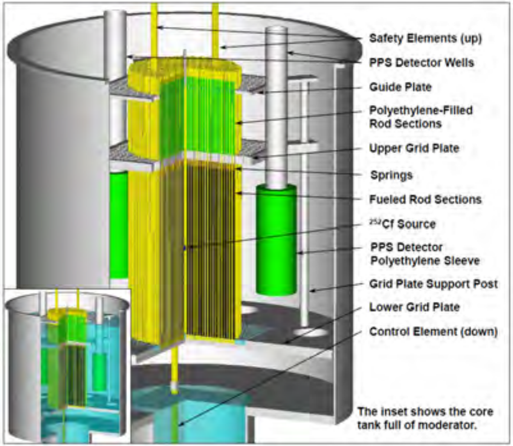
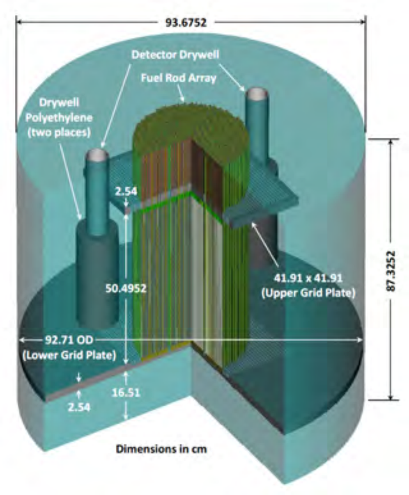


Figure 3. Cut-away View of the Critical Assembly Core Tank (Case 2).

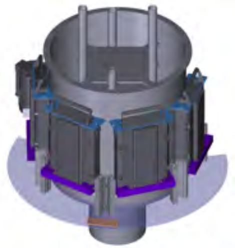
IER 518 Project Goals

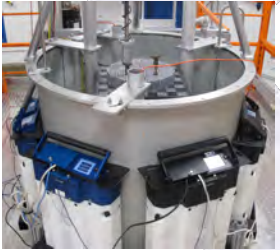
- Leverage existing experiment and detector systems to limit cost, etc.
  - LANL choice: NoMAD/MC-15 & SNAP-IV neutron detection system, added org. scint
- Leverage existing benchmark:
  - LCT-COMP-THERM-078 critical benchmark chosen, performed at the Sandia SPRF/CX facility on ‘7uPCX’ assembly
  - Loading pattern for LCT-COMP-THERM-078 chosen as basis for subcritical measurements

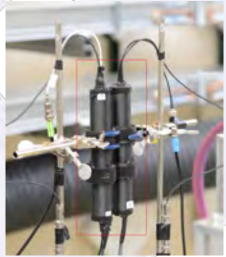


7uPCX reactor and detector systems

- Initial viability questions - where do we put the NoMAD, SNAP-IV? We've put them inside the core before in water (RPI), but not outside - Can we even get enough counts for good statistics? Lots of simulations answered the question: **Yes, and if the new source has arrived it would be even better!**
- **two detector systems per configuration measured** we accomodated *in-core* organic scintillator measurements (mini RAM-RODD), helps characterization efforts for other experiments and direct comparison for *ex-core* NoMAD analysis

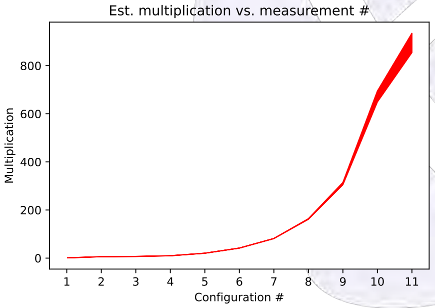






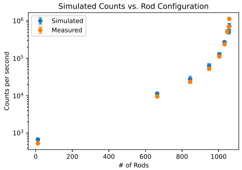
Continuity of measurements between labs

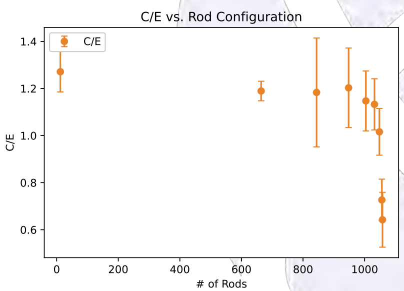
Configuration	Rods	est. M	Participants		
1	12	1	LANL	IRSN	LLNL
2	492	6		IRSN	
3	564	7		IRSN	
4	664	10	LANL	IRSN	
5	844	20	LANL	IRSN	
6	948	42	LANL	IRSN	LLNL
7	1004	82	LANL	IRSN	LLNL
8	1032	163	LANL		LLNL
9	1048	310	LANL		LLNL
10	1056	672	LANL		LLNL
11	1058	895	LANL		LLNL

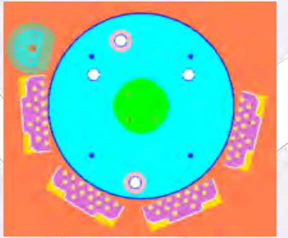


Preliminary data analysis - NoMAD/SNAP IV detectors

- *Simple* fixed source simulation w/ MCNP model updated to include ‘as-measured’ positions for detectors/drywells etc.
- Trend moves from over predicted to under predicted counts as M ↑, PTRAC time-tagged simulation coming soon to compare measured moments, etc.
- Small changes at near-critical/high multiplication dramatically impact count rate, ’worst’ C/E at 0.64 is still decent!







Continuing work

- Comparison of simulated to the measured moments, Feynman-Y, Rossi-α, etc for **both the organic scintillators (4x) and NoMADs(4x)/SNAP-IV**
- Comparison of neutron noise analysis using organic scintillator w/ pulse shape discrimination (PSD) to NoMAD ^{3}He system
  - This effort may also aid characterization of system for MUSIC, EUCLID etc.
- Challenge: MCNP PTRAC simulation required for 1-to-1 comparison of NoMAD measurements is computationally intensive - high source strength, large amount of moderator between fuel and detectors
- Solutions: MCNP 6.3 updates allow parallelization of PTRAC routine, previously serialized
- Papers: ICNC (2): neutron noise analysis/results, MCNP6.3 PTRAC validation (Mike Rising), ANS Student Conference initial analysis

IER 518 acknowledgements

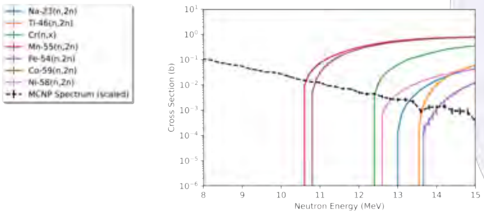
- Special thanks to: the SPRF/CX crew at Sandia National Labs - Beth Hanson, Patrick Ward, and Jason Soares, as well as Gary Harms
- LLNL for administrative, planning, etc.: Jesse Norris et al.
- the LANL measurement team and my student: Jesson Hutchinson, Rob Weldon, Geordie McKenzie, Mark Nelson, Eric Sorensen, and Tanner Heatherly (Oregon State University)
- Chris Romero for his instrumental assistance in designing the measurement apparatus

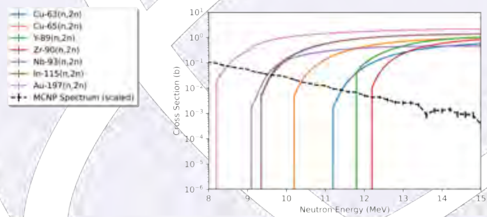
Background - IER 153 Prompt Fission Uranium Neutron Spectrum (PFUNS)

- Experiment originally proposed in 2011 to reduce uncertainties in the prompt-fission neutron spectrum (PFNS) in ^{235}U, especially above 5 MeV, using threshold neutron detectors/activation foils
- Critical experiment proposed to use the Rocky Flats HEU shells as source of neutrons
  - designed such that the spectrum is as close to unperturbed ^{235}U PFNS as possible
- By choosing materials with threshold reactions spanning the high energy region, spectral adjustment can be performed to infer an updated PFNS
- The data gathered can provide an integral validation of ^{235}U PFNS gathered during chi-nu experiment at LANSCE, potential help in updated PFNS evals.

IRDFF threshold reactions

- Goal is to be able to get favorable γ-counting statistics on very high energy threshold reactions - easier said than done!
- Challenge is that as neutron energy increases, neutron population at that energy drops by orders of magnitude
- Combined with low interaction probability, half-lives, high power is absolutely necessary





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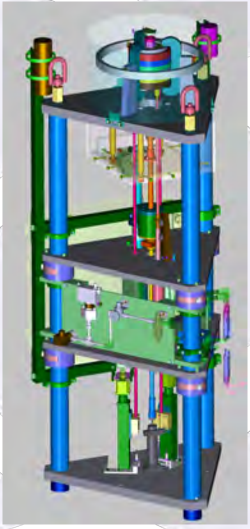
Preliminary Godiva IV irradiation

- Godiva IV served as a test platform prior to PFUNS Rocky Flats irradiations on Planet
- Exercise process of foil selection, retrieval, counting, and subsequent analysis to be used in the PFUNS experiment
- Validate activation foil prediction tools - crucial to the planning process to ensure sufficient statistics for Rocky Flats irradiations



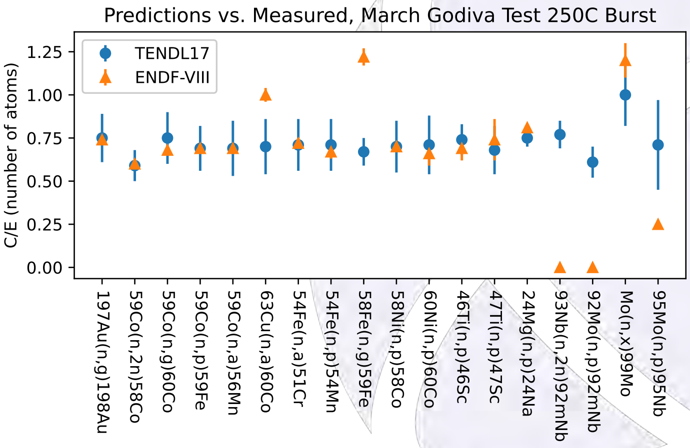
Godiva IV test irradiation foil selection

- Foils chosen based on documentation and availability, International Reactor Dosimetry Fusion File (IRDFF) cross section, high E threshold reactions
- Recent IRDFF updates include more reactions in foils that benefit this work

Foil material	mass (mg)	avail. IRDFF reactions
Gold (Au)	126.8 ± 0.1	2
Cobalt (Co)	66.0 ± 0.1	3
Copper (Cu)	141.3 ± 0.1	3
Iron (Fe)	124.8 ± 0.1	5
Nickel (Ni)	281.1 ± 0.1	3
Titanium (Ti)	141.9 ± 0.1	7*
Magnesium (Mg)	28.6 ± 0.1	1
Niobium (Nb)	298.2 ± 0.1	3
Molybdenum (Mo)	90.6 ± 0.1	1

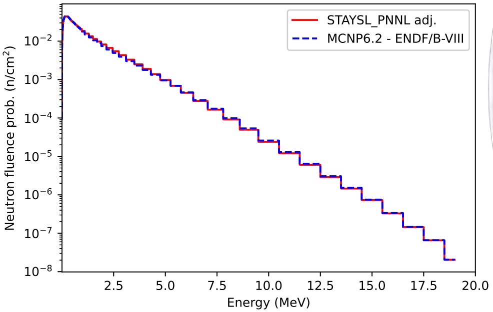
Foil activation measured vs. predicted results

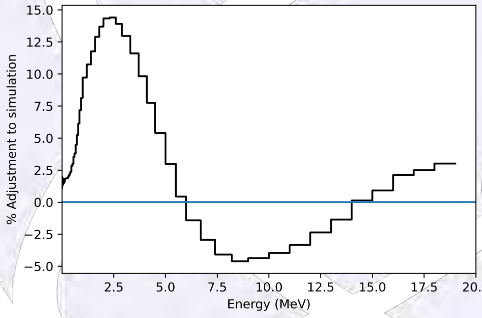
C/E results contain uncertainty: systematic, counting, and cross sections in FISPACT-II (not total uncertainty) avg. 0.70 $\pm$ 0.05 (minus outliers)



Godiva IV spectral adjustment results with STAYSL_PNNL

- STAYSL_PNNL uses dosimetry data to adjust a well-informed guess (*a priori*) to the most likely (*a posteriori*) neutron spectrum using generalized linear least-squares approach
- Fit below is from 15 IRDFF standard reactions, norm. χ^2 (fitness) = 0.84766





PFUNS Rocky Flats shells irradiations on Planet

- First: a short irradiation/calibration with 9 Nickel foils, 2 Gold, 1 Indium, and 1 Mn-Cu
- These foils correlate what is measured in the control room and the neutrons on foils - very important for newly built/measured systems
  - (1) Amps to fissions/sec or power and (2) Amp-sec to total fissions or neutron fluence on foils
- Data gives estimate of 4.1×10^{18} fissions/Amp-sec
- 2 Gold foils within about 1%, 9 Nickel foils within about 3% of each other
- Second irradiation: uniform fluence b/w sample locations? Data showed: **Yes!**
- Plan to use over 20 foils for final irradiation(s)

Continuing work on PFUNS

- Presentation of Godiva IV work to international community at 17th Int. Symp. on Reactor Dosimetry (ISRD) in May
- Power supply and stepper motor controller successfully relocated in order to avoid rad damage - temp mod made permananent
- Continuing dose rate predictions for both (1) foil retreival (2) electronics using information gathered from dosimetry during EUCLID experiment
  – Have worked collaboratively with colleagues in rad. prot. at LANL
- Steady-state Rocky Flats shells heat transfer simulations: time-dependent/transient from Bob Kimpland (NEN-2)
  – These simulations informed the first runs' correlation of amps to fissions!
- Additional foils with Cd covers - helps with constraining the dosimetry informed spectral adjustment with STAYSL_PNNL

Acknowledgements

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What questions do you have for me?

Thank you for listening

Email: nhwhitman@lanl.gov

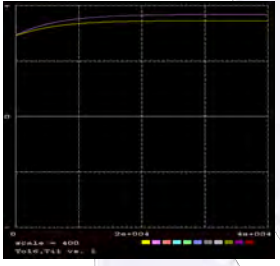
Supplemental

Example steady state calculation to determine excess reactivity needed

Q (Watts)	Amps	$T_{i,1}$(C)	$T_{o,16}$(C)	ΔR ($)
100	7.60E-07	353.8	336.2	0.17
200	1.50E-06	403.8	368.6	0.3
300	2.30E-06	449.4	396.6	0.42
400	3.00E-06	492	421.6	0.53
500	3.80E-06	532.4	444.3	0.63
600	4.60E-06	570.9	465.2	0.73

Supplemental

Example transient heating calculation



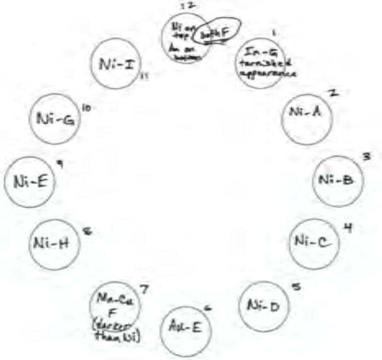
Q (Watts)	Amps	$T_{i,1}$(C)	$T_{o,16}$(C)	ΔR ($)
5000 (1.4 hr)	334.3	322.2	0.11	2.05E+16
10000 (2.8 hr)	353.9	336.3	0.17	4.10E+16
20000 (5.6 hr)	366.7	345.2	0.2	8.20E+16
40000 (11.1 hr)	369.5	347.2	0.21	1.64E+17

Supplemental

Run 0

Notes:

- Indium - G vs. Nickel - G → Indium should have a darker appearance: Nickel is quite shiny.
- Same with Mn-Cu-F vs. Nickel F.
- Nickel - F + Gold - F go together w/ Nickel on top.
- #12 - Au on bottom Nickel on top.



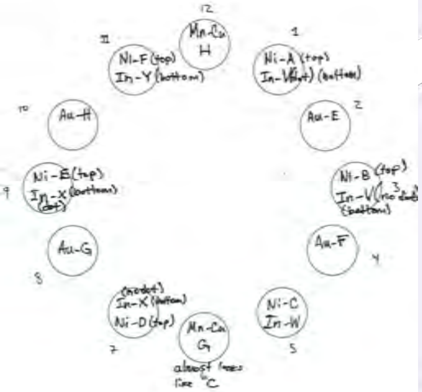
Supplemental

Run 1

Notes:

* There are duplicate Indium Foils designated "V" and "X". Please ensure that Indium-V with a dot goes into position 1 and Indium-X with a dot goes into position 9. The labels also include "dot" → if applicable.

* If position has Nickel + Indium, place Nickel on top.



Supplemental

Indium Nickel Gold Manganese-copper alloy DU (U238) Zinc Iron Zirconium Niobium Cobalt Magnesium Titanium HEU (U235) Copper Yttrium Aluminum Molybdenum Tantalum Vanadium Silver