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FY2018 Preparation for the NeSO Subcritical Experiment

NCSP Technical Program Review 2019

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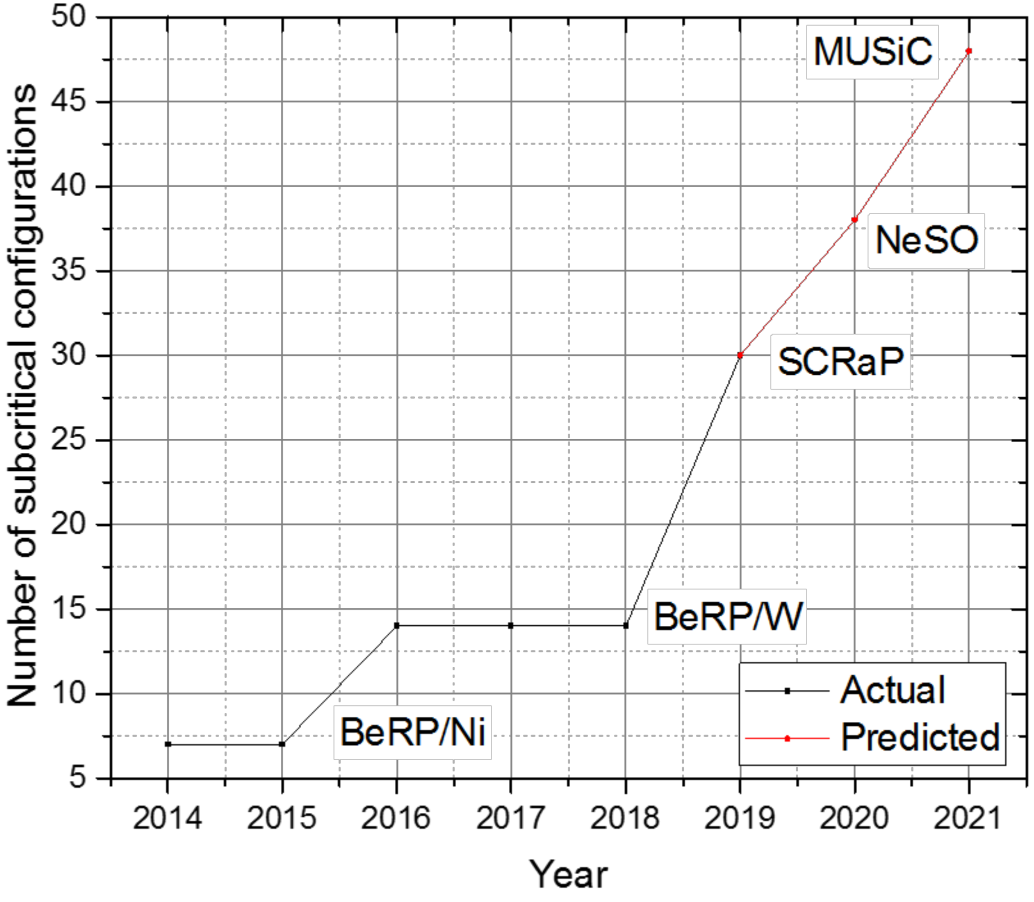
Outline

- Motivation
- What is NeSO?
- Status at Beginning of FY18
- Preliminary Measurements
- Composition Troubles
- Current and Future Work

Motivation

- Limited ICSBEP benchmarks related to Neptunium
- Help validate ^{237}Np nuclear data, and subcritical measurement methods
  - Create a benchmark much more sensitive to ^{237}Np cross sections than any already in existence
- ^{237}Np is a byproduct of power reactors
  - (n,γ) reactions of ^{235}U or (n,2n) reactions involving ^{238}U
  - ^{241}Am α-decay
- Np sphere exists to better understand ^{237}Np critical mass
  - Subject of previous critical benchmarks
- Add to steadily growing group of NCERC subcritical benchmark measurements



Overview of NeSO

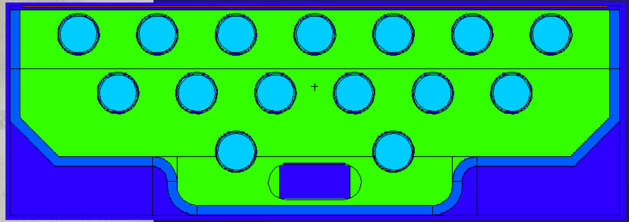
- Subcritical experiment with a 6kg sphere of Neptunium (“Np sphere”)
- Includes configurations with both the bare sphere and varying amounts of nickel reflection
  - Nickel increases multiplication of system, leading to configurations spanning a variety of multiplication levels
- Performed at National Criticality Experiments Research Center (NCERC) at the Nevada National Security Site (NNSS)
- Goal is inclusion in International Criticality Safety Benchmark Evaluation Project (ICSBEP) Handbook

The Neptunium Sphere

- Cast in 2001
- Total mass: 6070.4 grams
  - ^{237}Np: 6060 grams
- Radius: 4.149 centimeters
- Includes Tungsten and Nickel cladding
  - Meant to decrease dose from ^{233}Pa γ-rays
  - Tungsten is 0.259 cm thick
  - Two layers of nickel, total 0.381 cm thick
- Composition shown in table on right, from analysis of the surface
  - Taken from previous critical benchmark
    - SPEC-MET-FAST-008, Np sphere surrounded by HEU
  - May not be representative of other parts of the sphere
  - Low emission rate
    - Spontaneous fission yield from PANDA Manual

Nuclide	Mass (g)	S.F. yield (neutrons/s)
^{237}Np	6.06×10^{3}	6.90×10^{-1}
^{233}U	2.17×10^{-1}	1.87×10^{-4}
^{234}U	3.48×10^{-2}	1.75×10^{-4}
^{235}U	1.66	4.96×10^{-4}
^{236}U	9.28×10^{-3}	5.09×10^{-5}
^{238}U	1.87×10^{-1}	2.54×10^{-3}
^{238}Pu	9.83×10^{-2}	2.55×10^{2}
^{239}Pu	1.95	4.25×10^{-2}
^{240}Pu	1.40×10^{-1}	1.43×10^{2}
^{241}Pu	3.77×10^{-3}	1.88×10^{-4}
^{242}Pu	1.95×10^{-2}	3.35×10^{1}
^{241}Am	4.04×10^{-4}	4.76×10^{-4}
^{243}Am	1.12×10^{1}	-
Total	6.07×10^{3}	4.32×10^{2}

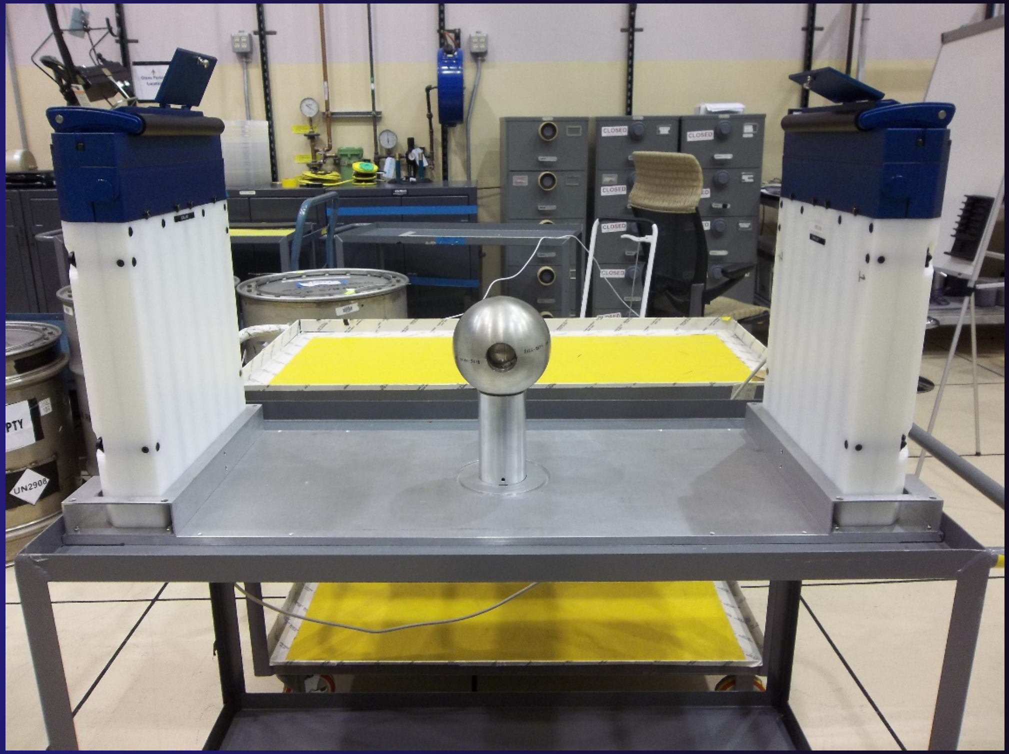
Detectors & Analysis Method



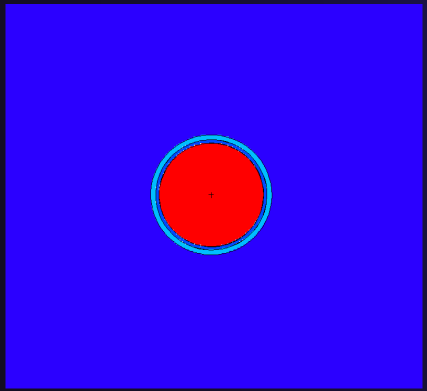
- Neutron Multiplicity Array Detector (NoMAD)
  - 15 ^{3}He tubes surrounded by polyethylene
  - Creates list-mode data
  - Two will be placed at 30 cm from the center of the sphere
- Data will be analyzed with Hage-Cifarelli formalism of Feynman Variance-to-Mean technique
  - Same as previous NCERC subcritical measurements
  - Allows for the inference of leakage multiplication (M_L)
    - M_L – number of neutrons that leave the system per starter neutron

Final Configurations

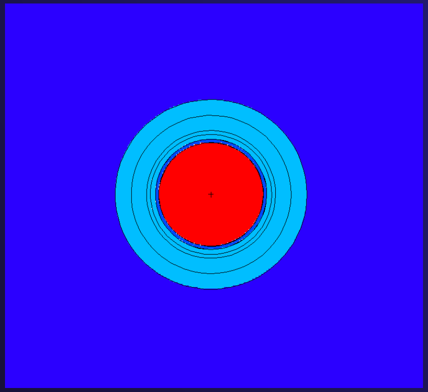
- Bare (no added nickel), 0.6”, 1.1”, 2.1”, 3.6” Nickel
  - A range of distinct M_L values
  - Smaller range than previous benchmarks, but still distinguishable
- Nickel reflection from nesting spherical shells
  - Similar in style to previous subcritical benchmarks



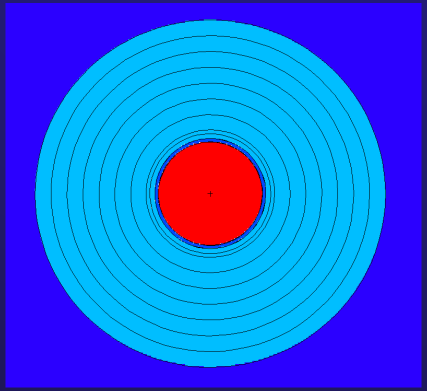
Bare – M_L 1.94



1.1” Ni – M_L 2.10



3.6” Ni – M_L 2.21



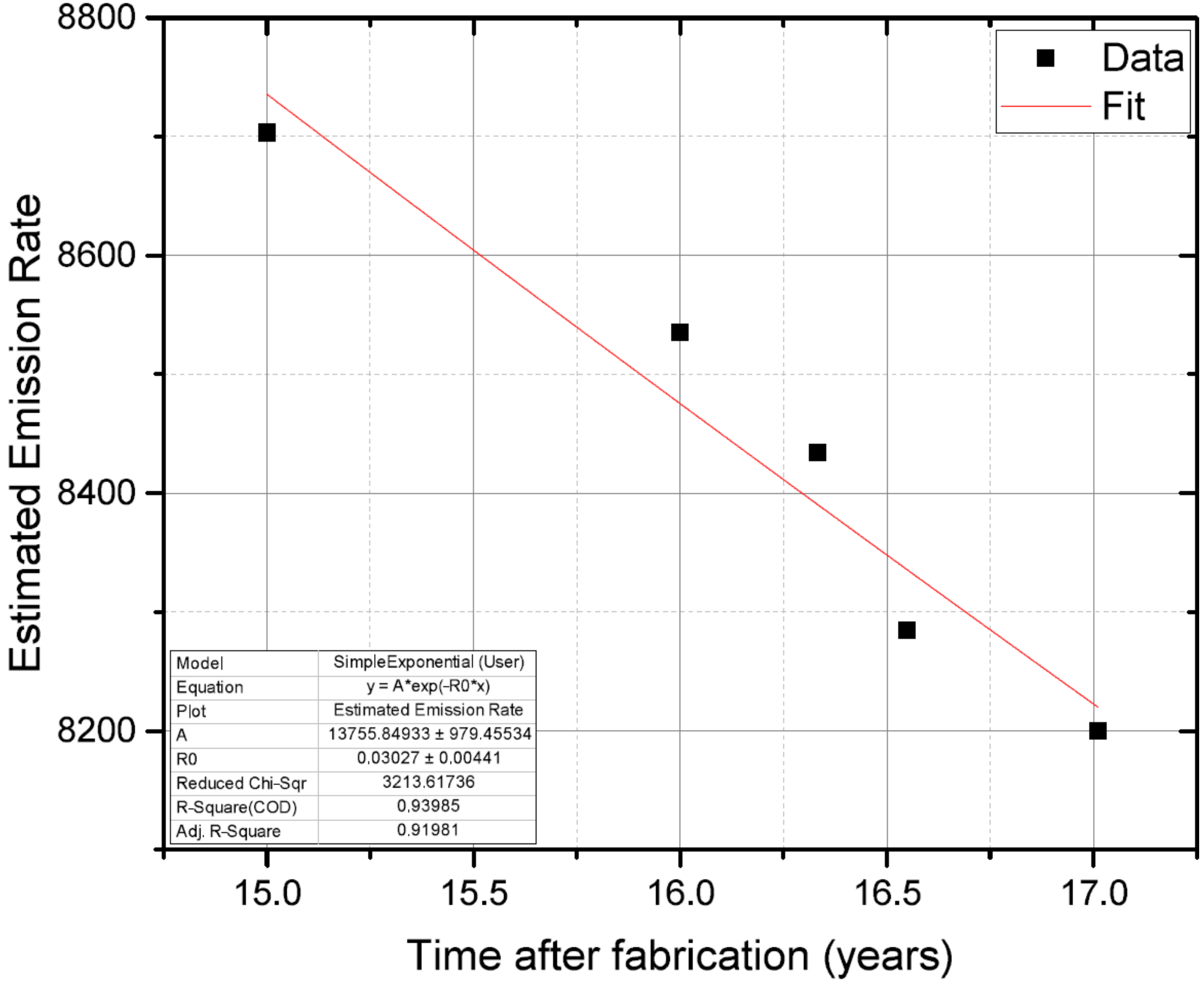
Statistical uncertainties ≤ 0.0005

Preliminary Measurements

Date	Estimated Emission Rate (n/s)
February 2017	8,703
February 2018	8,535
June 2018	8,434
August 2018	8,284
February 2019	8,199

- A series of preliminary measurements have been performed over the past couple of years
  - Show decline in neutron emission rate over time
  - See the effect of moving the neutron hotspot

Decay in Emissions



Based on these measurements, estimated half-life is fit to 22.9 $\pm$ 3.3 years

Procurement of Reflector Shells

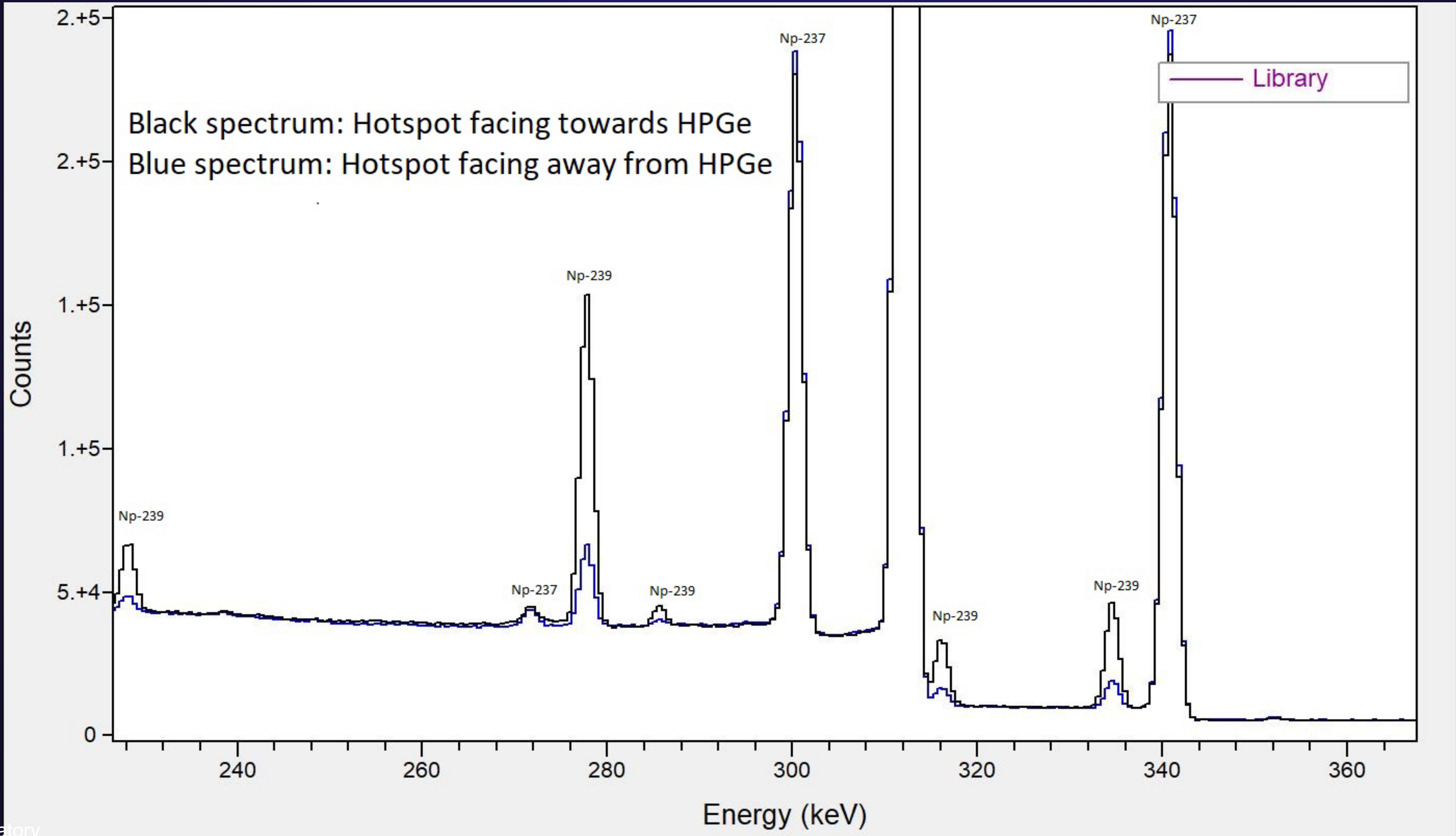
- Nickel Reflectors were received for the experiment in September of 2018

Benchmark Measurement Campaign

Everything that follows is *preliminary*.

Gamma Spectroscopy

- Performed multiple overnight measurements with an HPGe



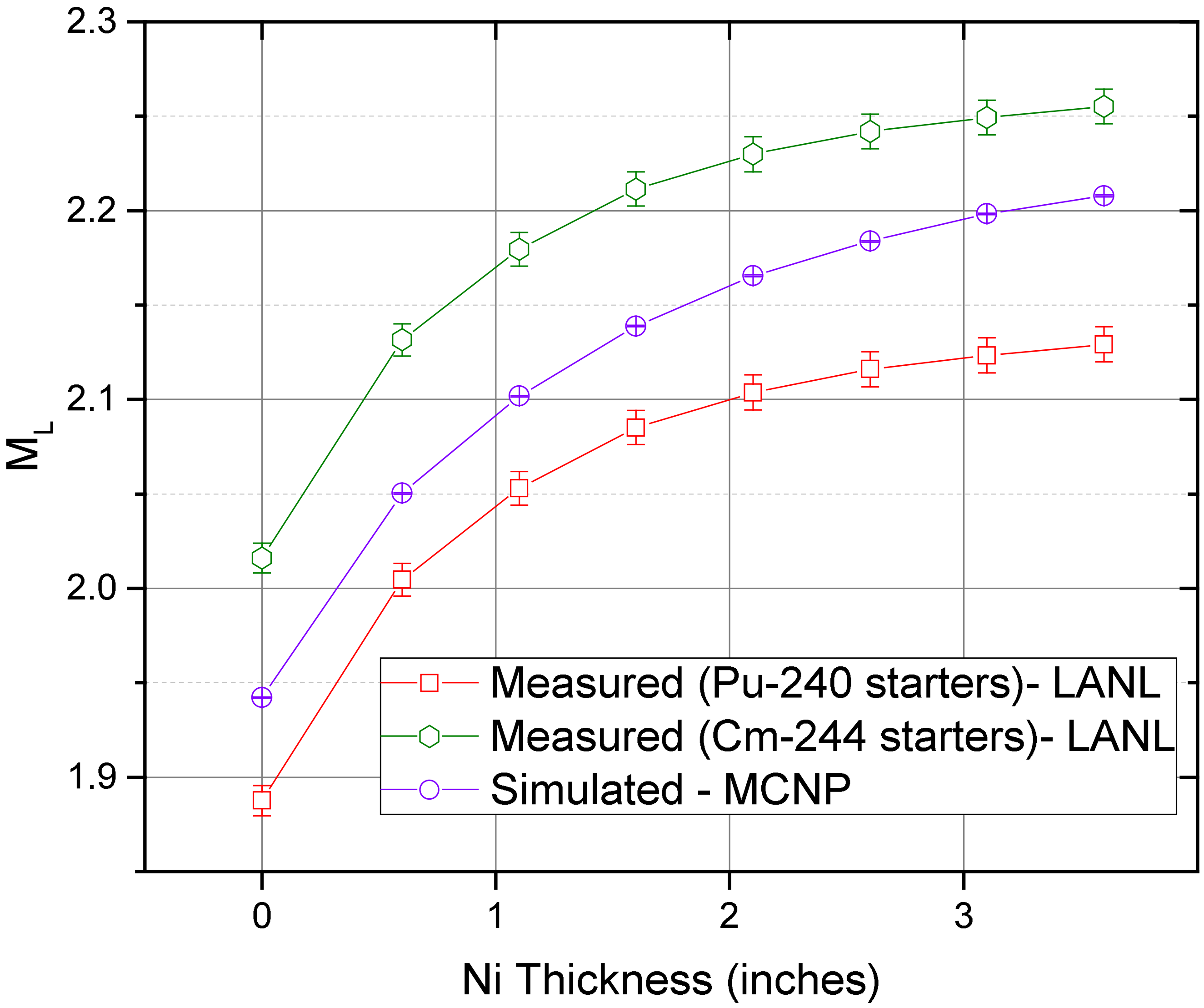
Americium-243

- Gamma Spectroscopy indicates ^{239}Np is present
  - Comes from α-decay of ^{243}Am
- The benchmark composition includes a significant ^{243}Am Content
  - Made through four (n, γ)-interactions on ^{239}Pu
- One Additional neutron capture could explain extra neutron emissions
  - Curium-244!
  - Only milligrams of ^{244}Cm is needed to account for difference in simulated and measured emission rates

241Cm 32.8 D ε: 99.00% α: 1.00%	242Cm 162.8 D α: 100.00% SF: 6.2E-6%	243Cm 29.1 Y α: 99.71% ε: 0.29%	244Cm 18.1 Y α: 100.00% SF: 1.4E-4%	245Cm 8423 Y α: 100.00% SF: 6.1E-7%
240Am 50.8 H ε: 100.00% α: 1.9E-4%	241Am 432.6 Y α: 100.00% SF: 4E-10%	242Am 16.02 H β-: 82.70% ε: 17.30%	243Am 7364 Y α: 100.00% SF: 3.7E-9%	244Am 10.1 H β-: 100.00%
239Pu 24110 Y α: 100.00% SF: 3.E-10%	240Pu 6561 Y α: 100.00% SF: 5.7E-6%	241Pu 14.329 Y β-: 100.00% α: 2.5E-3%	242Pu 3.75E+5 Y α: 100.00% SF: 5.5E-4%	243Pu 4.956 H β-: 100.00%
238Np 2.117 D β-: 100.00%	239Np 2.356 D β-: 100.00%	240Np 61.9 M β-: 100.00%	241Np 13.9 M β-: 100.00%	242Np 2.2 M β-: 100.00%

Preliminary Benchmark Results!

- Data collection time varied between eight hours and four days
- Difficult to distinguish between some configurations
  – Especially as thickness increases
- Difference between simulated and measured increases with reflection
- We will continue to analyze this data
  – Eventual submission to ICSBEP



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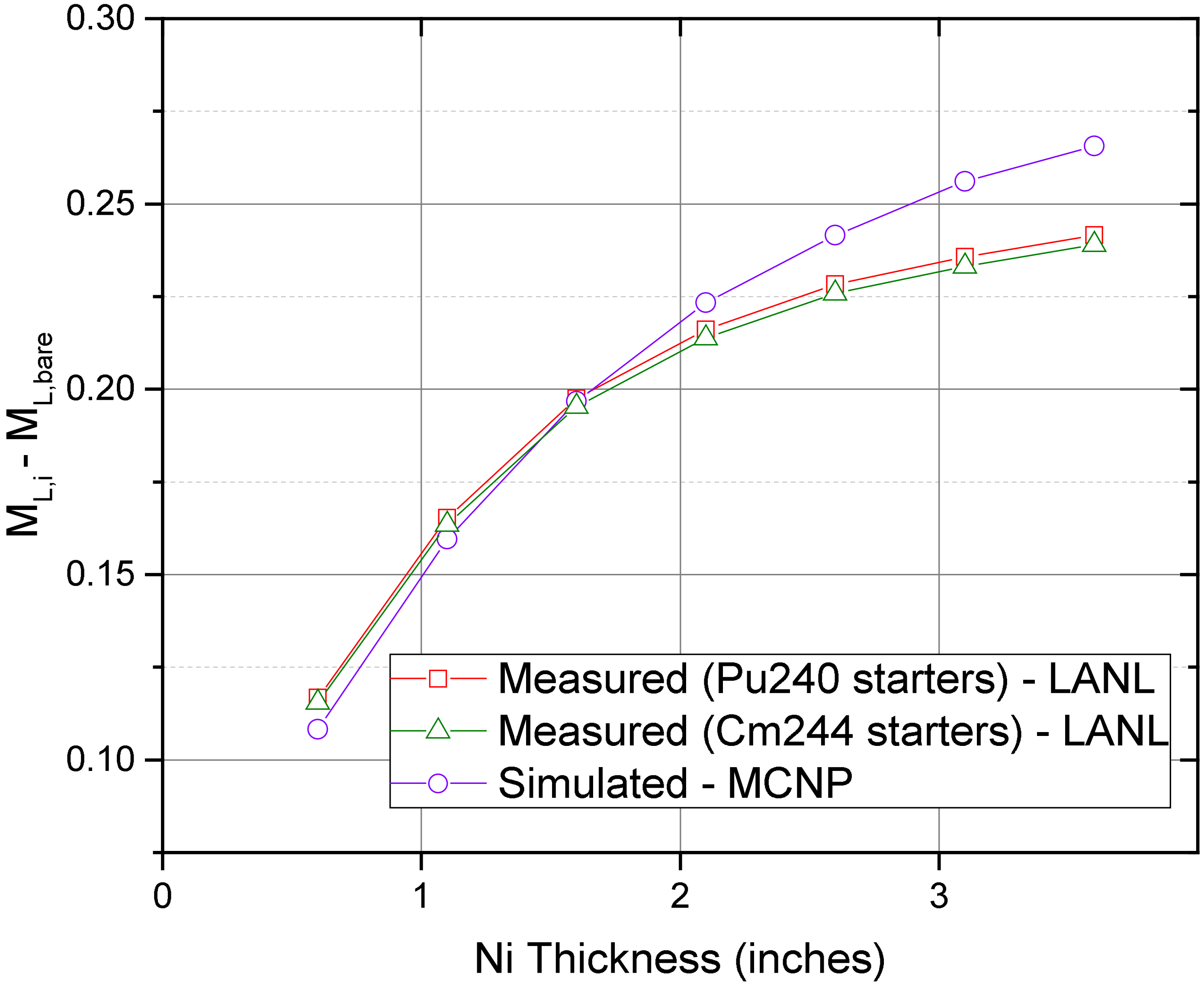

Thank you!

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