Experimental Validation of Neutron Capture γ-Cascades

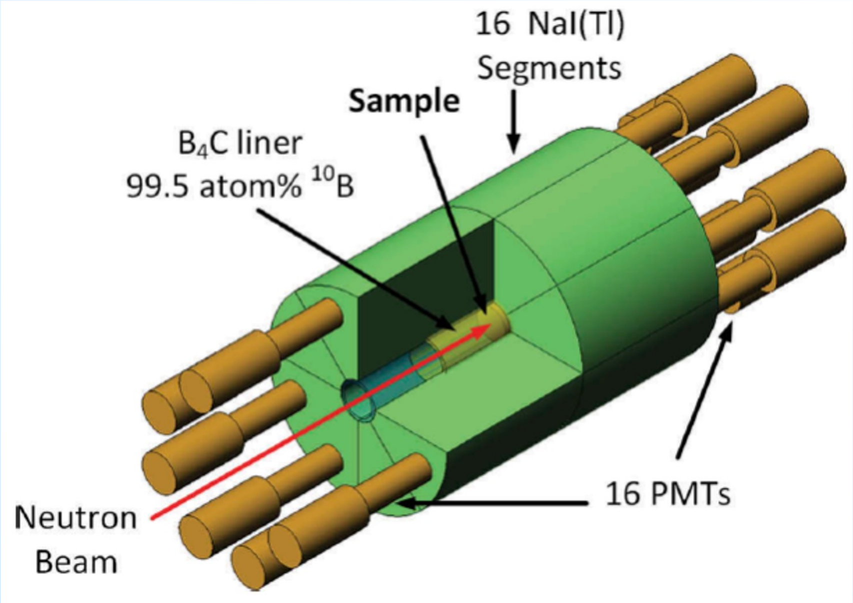
Katelyn Cook[1], Yaron Danon[1] and Amanda Lewis[2]

[1]Gaerttner LINAC Center, Rensselaer Polytechnic Institute, Troy, NY
[2]Naval Nuclear Laboratory, Schenectady, NY

NSAC Long Range Plan Town Hall Meeting on Nuclear Structure, Reactions and Astrophysics
Nuclear Data Working Group
November 15, 2022

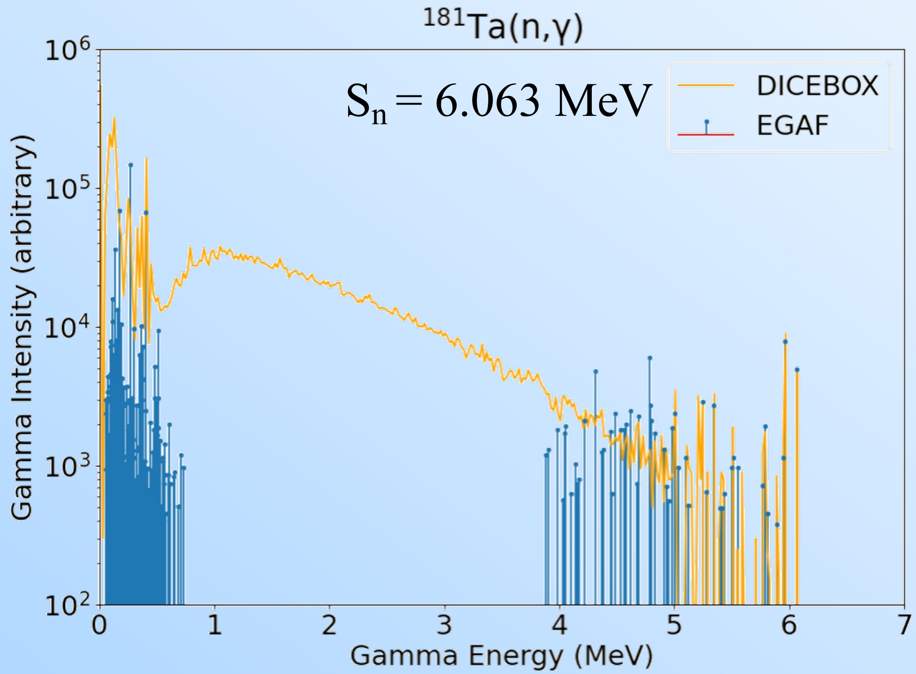
RPI γ-Multiplicity Detector

- 16 segment NaI(Tl) detector for <u>neutron capture yield and γ-spectra measurements</u>
  - Total volume: 20 L of NaI(Tl) surrounding the sample
  - Inside of the detector is lined (~1 cm) with a B_4C ceramic sleeve which is enriched 99.5 atom% in ^{10}B to absorb scattered neutrons from the sample
  - Up to 96% efficiency for detecting γ-cascades
  - **Incident neutron energies: 0.01 eV – 3 keV**



Motivation for Capture γ-spectra Measurements

- Understand **γ-heating** in nuclear reactors
- Characterize γ-emission spectra for **non-proliferation** applications
- Improve the current models used to **simulate γ-emission spectra**
- Increase the accuracy of nuclear data for **reactor and shielding calculations** (constrain physics models used)



DICEBOX models full γ-cascades using primary intensities from ENSDF

EGAF shows experimentally measured γ-ray lines

(does not represent the full cascade)

Neutron capture γ-cascade data is incomplete

Simulated vs. Experimental γ-spectra for ^{181}Ta(n,γ)

MCNP-6.2/ENDF/B-VIII.0

Extracts γ-ray data from ENDF/B-VIII.0 files

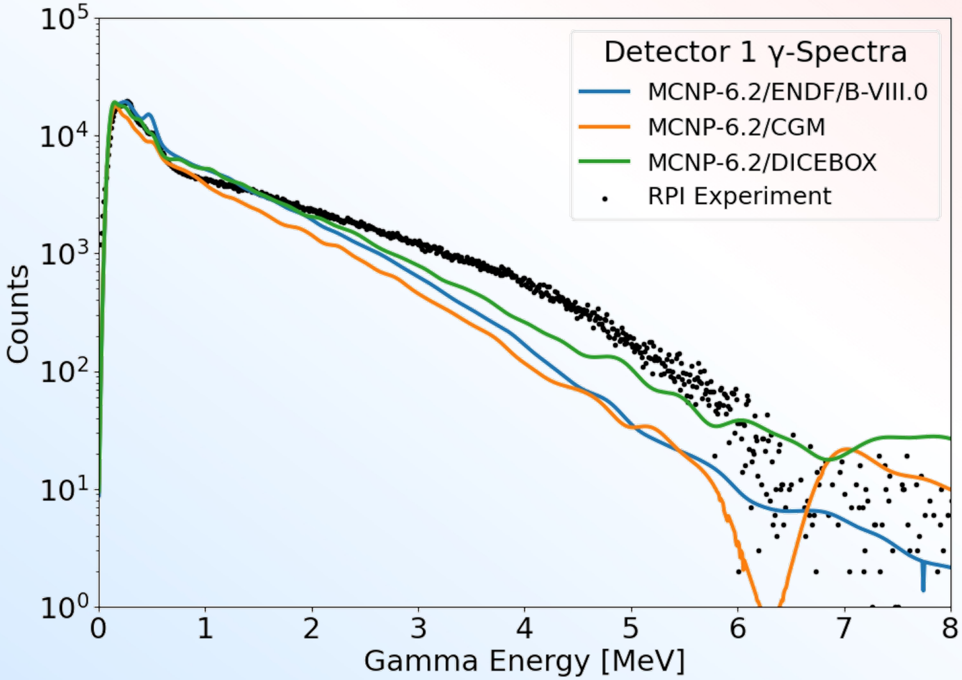
MCNP-6.2/CGM

(Cascading Gamma-Ray Multiplicity)
Produces correlated secondary γ-emissions

MCNP-6.2/DICEBOX

1. γ-cascades are generated using DICEBOX
2. For each capture event, a cascade is transported though the detector geometry
3. γ-energy deposition in each of the 16 detector segments is tallied which enables event-by-event analysis including coincidence

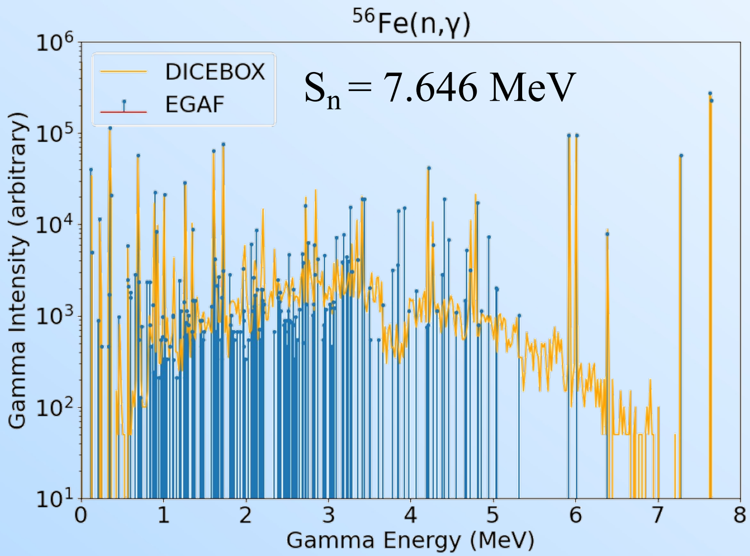
* Working with LANL to implement this capability for all MCNP users

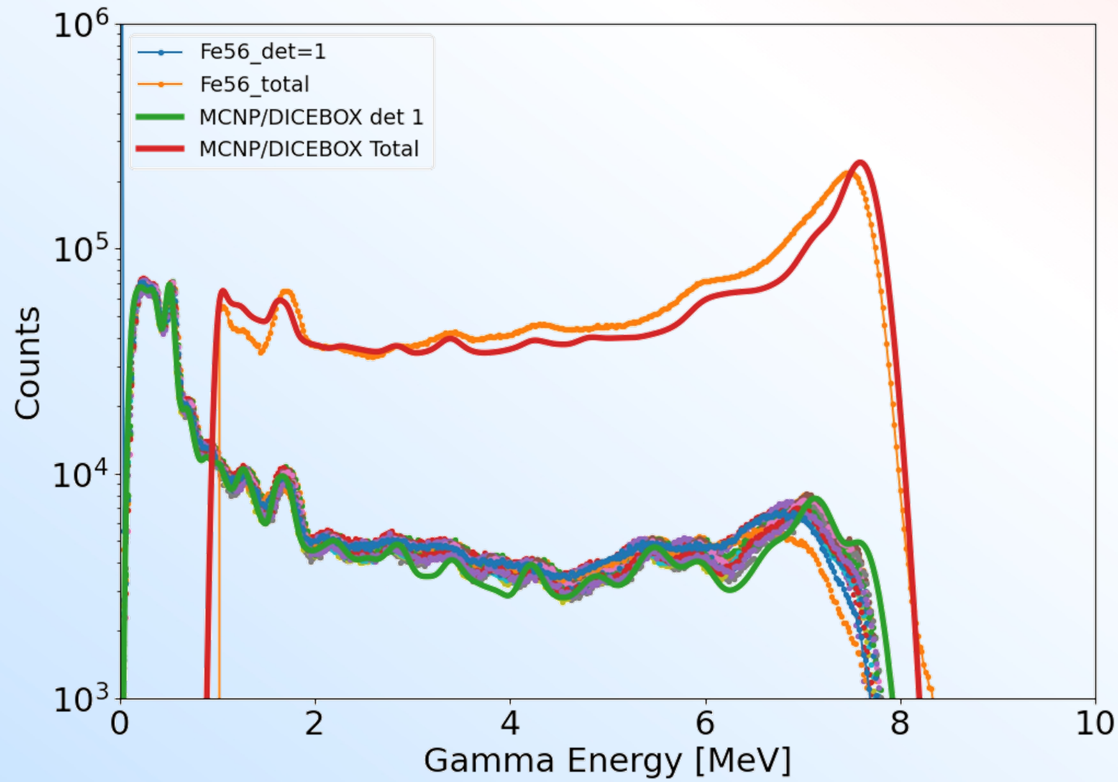


Large discrepancies between experimental and simulated γ-spectra for ^{181}Ta(n,γ)

Need a material with well-known neutron capture γ-ray data that is easy to measure

Measuring an Isotope with well-known γ-ray Data following Neutron Capture: $^{56}Fe(n,\gamma)$

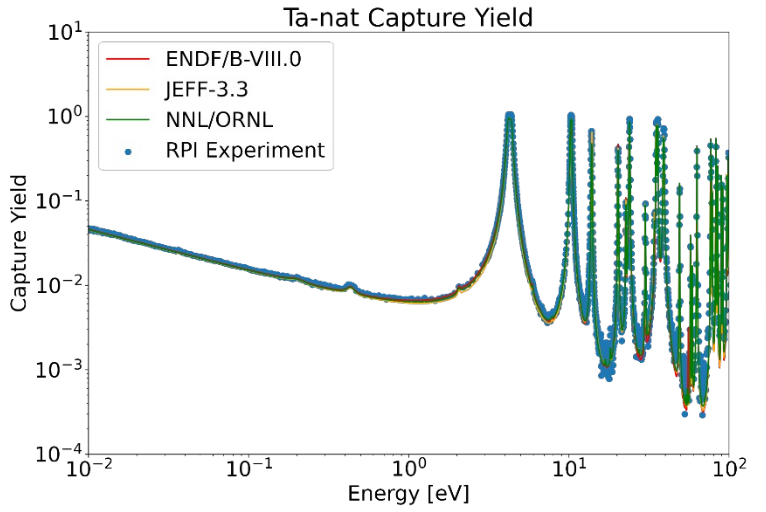




Fewer discrepancies between experimental and simulated γ-spectra for $^{56}Fe(n,\gamma)$

Conclusions

- For isotopes where the neutron capture γ-cascade characteristics are well-known, the experimental system agrees with the γ-emission spectra calculated using modified simulation tools.
- RPI γ-Multiplicity Detector system can provide experimental information for isotopes with deficiencies in **γ-ray data** and simultaneously measure **neutron capture yield**



Future Work

- Develop a robust method for analyzing and adjusting neutron capture γ-cascade data for ^{59}Co, ^{55}Mn and other measured isotopes including **^{181}Ta, ^{238}U and ^{235}U**
- Compare experimental γ-emission spectra with MCNP-6.2/DICEBOX simulations for important nuclear materials: **^{238}U and ^{235}U**
  - Most interesting for reactor applications, most difficult to measure and simulate (due to the fission contribution)