Updates on Nuclear Data Measurement Validation and Analysis at RPI

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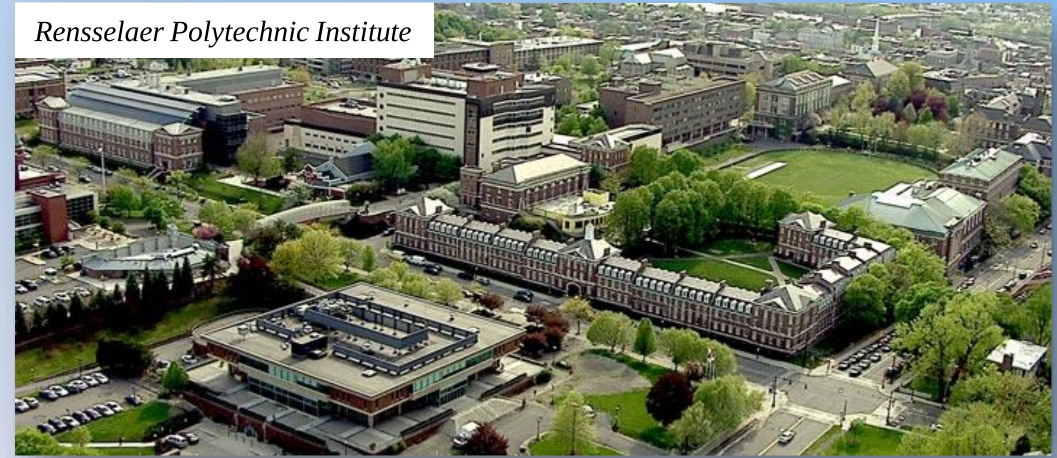

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Mini- CSEWG meeting at LANL, August 13-15, 2024

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Outline

- Validation of Cu evaluations
- Validation of capture gammas from Mn-55 and Cd-113
- Impact of experimental covariance on RRR fits in Fe-54

Copper keV quasi-differential scattering measurement (~2019)

- Was on the NCSP list
- Zeus benchmark
  - Intermediate energy benchmark with HEU and graphite plates and a copper reflector
  - Discrepancies in the critical benchmark
  - Possible issues in the angular distribution
- Experiment at the RPI LINAC
  - 3 cm natural copper sample
  - 7 cm carbon sample as reference
  - 1 keV to 1 MeV energy range
  - Measured keV neutron scattering at 4 angles (2 detectors at each angle)
  - 35, 70, 115, 150 deg
  - Upgraded digitizer (SIS3316, 16 ch, 4 ns)

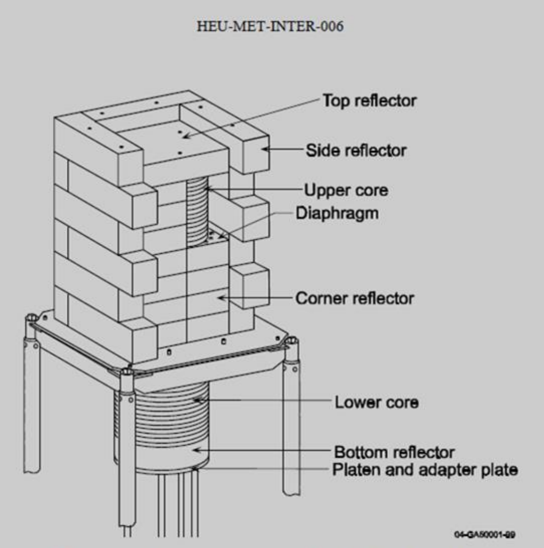
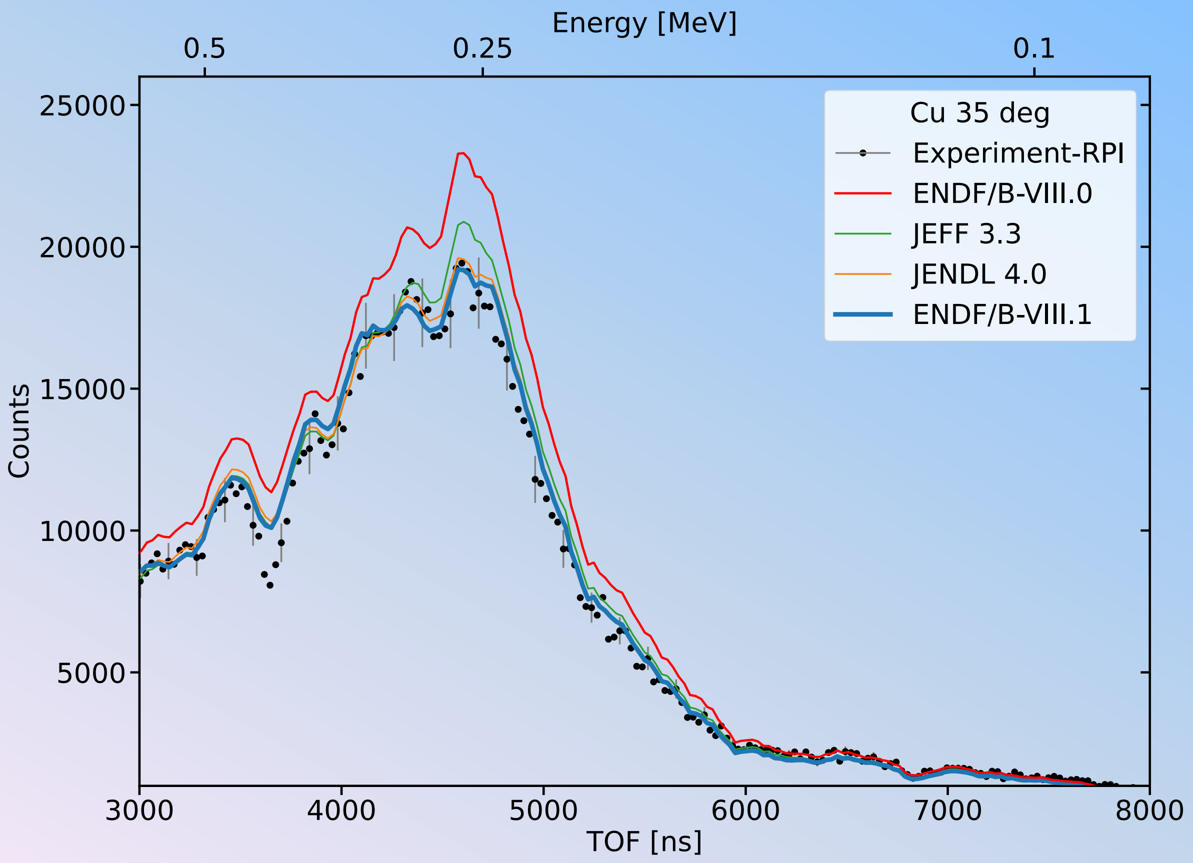
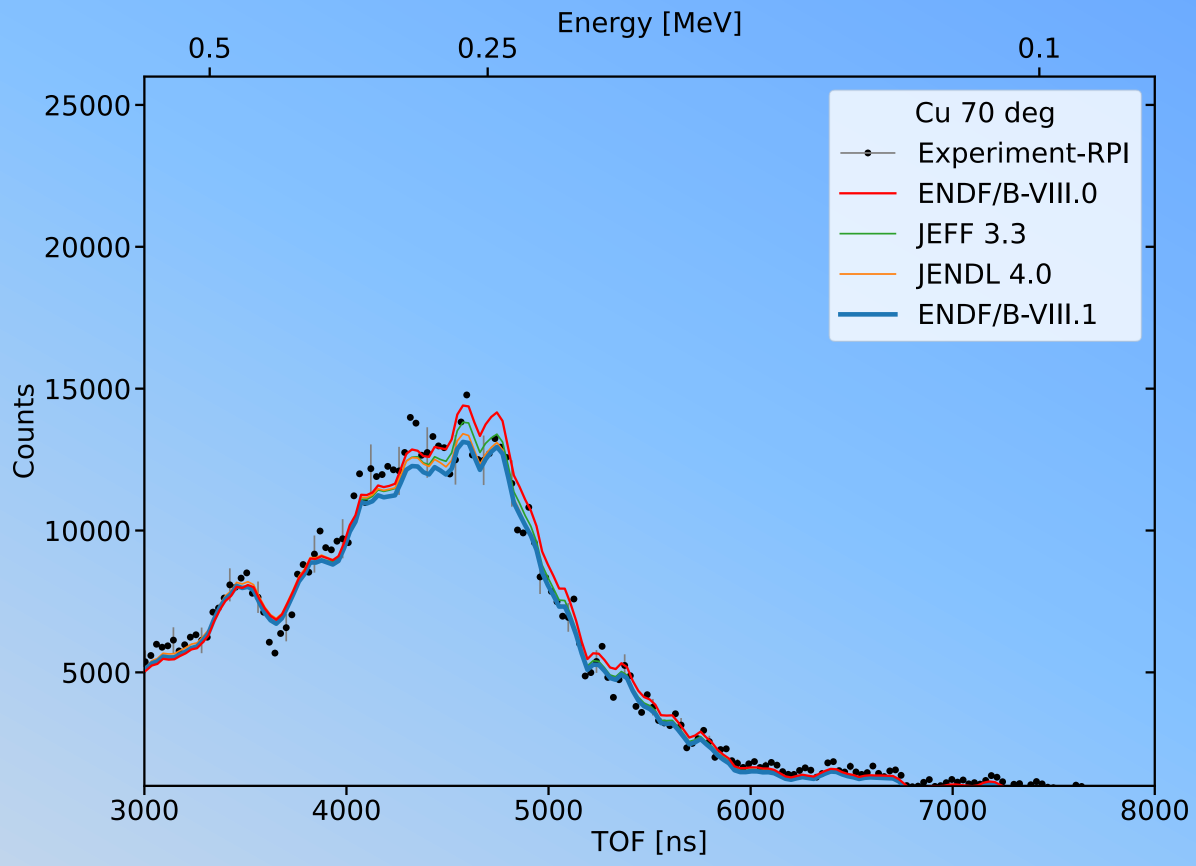


Figure 6. Schematic Cutaway of Zeus before Assembly.

Compare evaluations to the experiment at forward angles

- ENDF/B-8.1 is an improvement from ENDF/B-8.0, similar to JENDL 4.0





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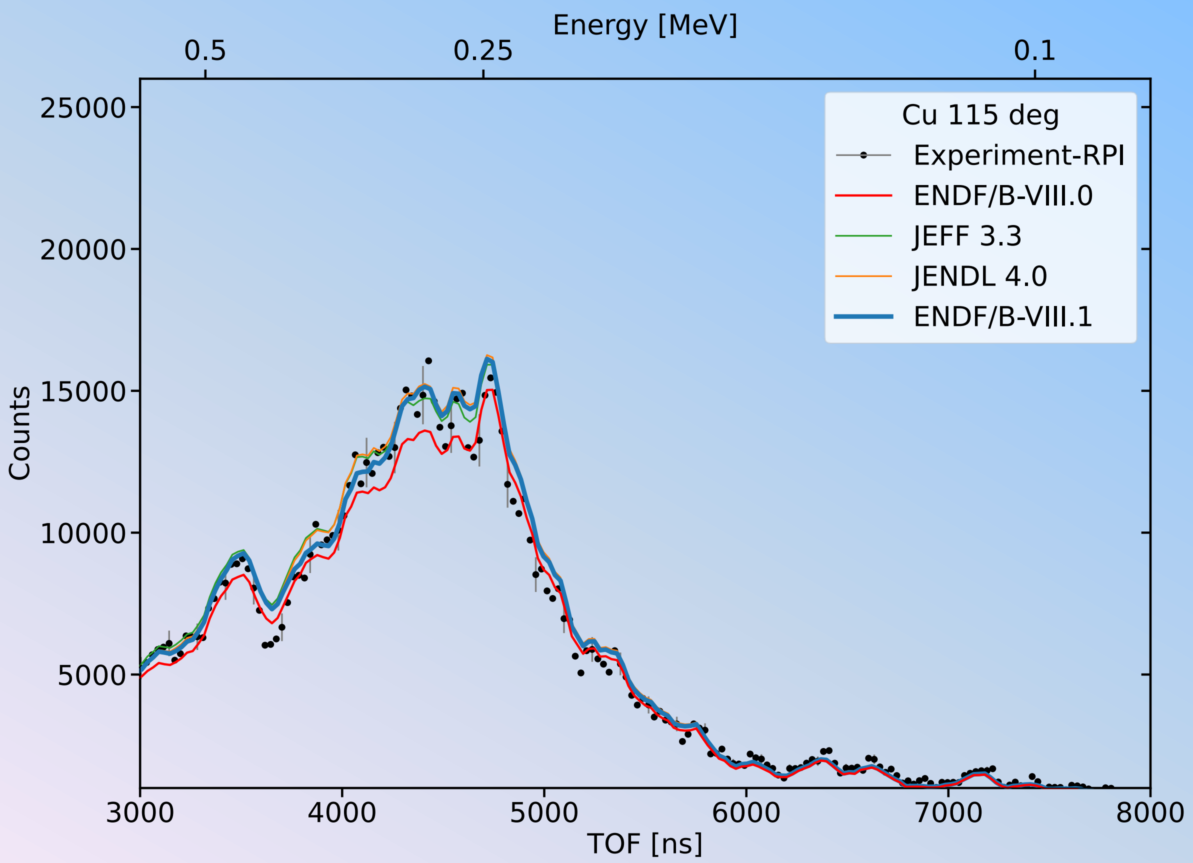
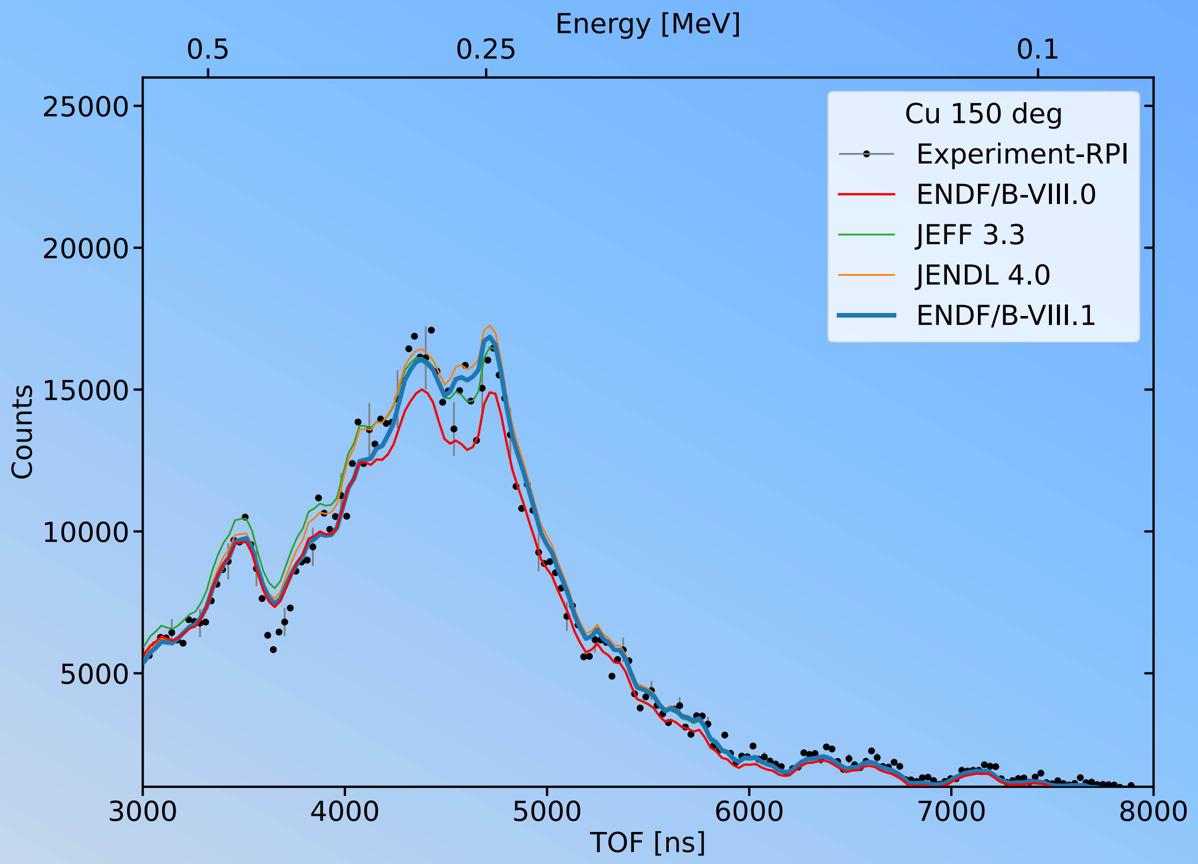
Compare evaluations to the experiment at back angles

- ENDF/B-8.1 is an improvement from ENDF/B-8.0





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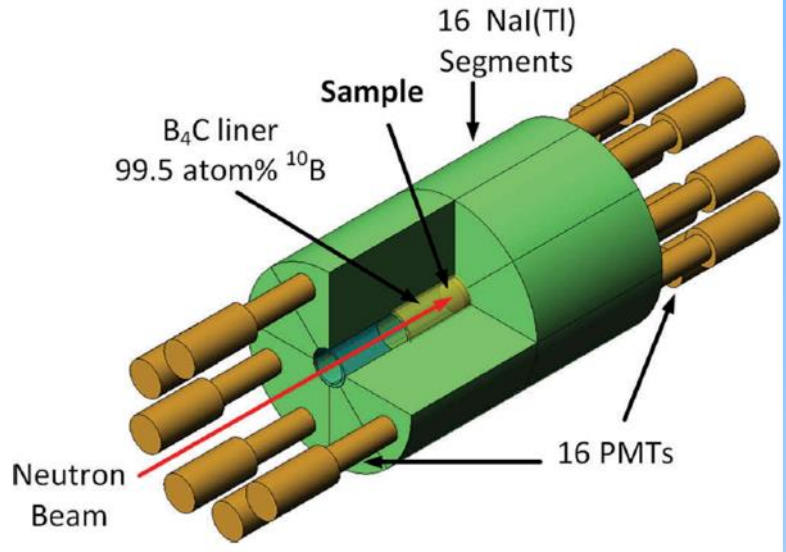
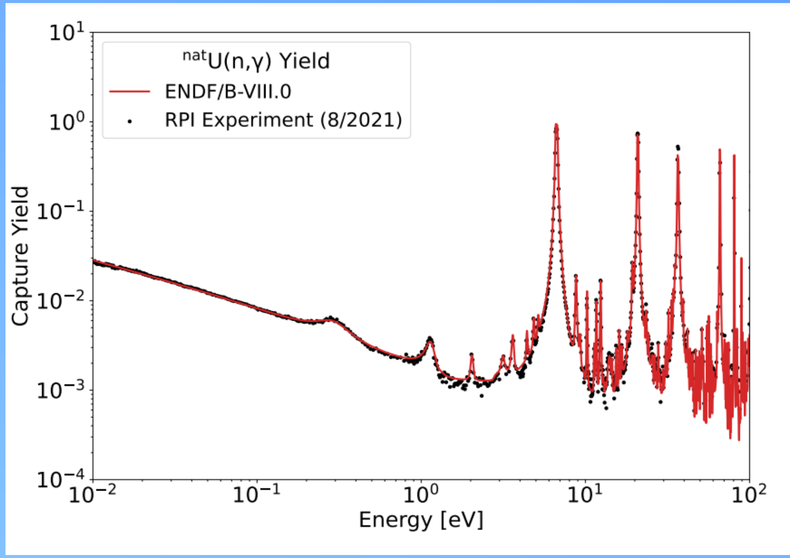
Neutron capture yield and γ-ray cascade spectra measurements

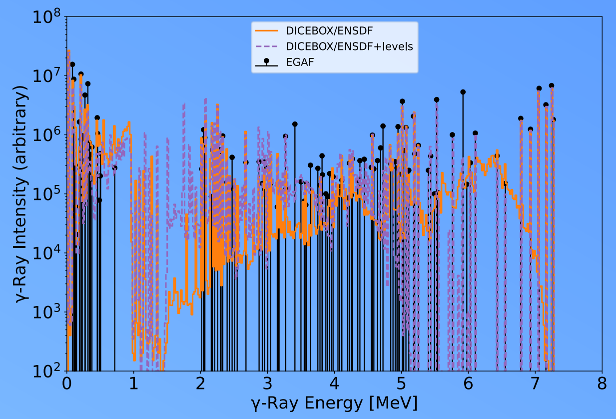
RPI Capture γ-Ray Multiplicity Detector





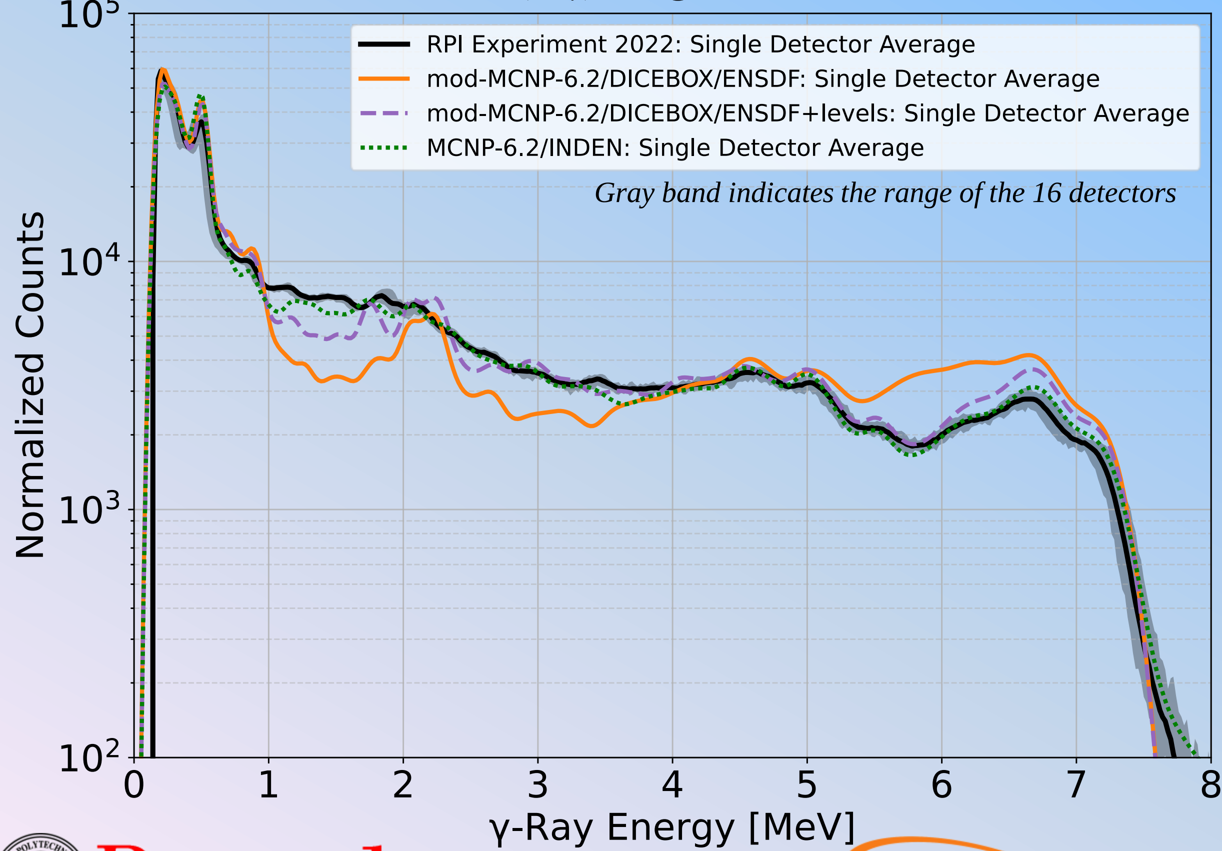
- **16 segment NaI(Tl) γ-ray multiplicity detector**
  - Total volume: 20 L of NaI(Tl) surrounding the sample
  - Inside of the detector is lined (~1 cm) with a B_4C ceramic sleeve which is enriched 99.5 atom% in ^{10}B to absorb scattered neutrons from the sample
  - Up to 96% efficiency for detecting γ-ray cascades
  - Located 25 m from the neutron-producing tantalum target
- **Used for neutron capture yield and γ-ray spectra measurements**
  - Incident neutron energies: 0.01 eV – 3 keV
- **16 Channel 250 MHz 14-bit Digitizer (SIS3316-250-14)**
  - Digitize pulses generated for each event on all 16 detectors to determine the energy deposited in each detected event

^{55}Mn Thermal Neutron Capture

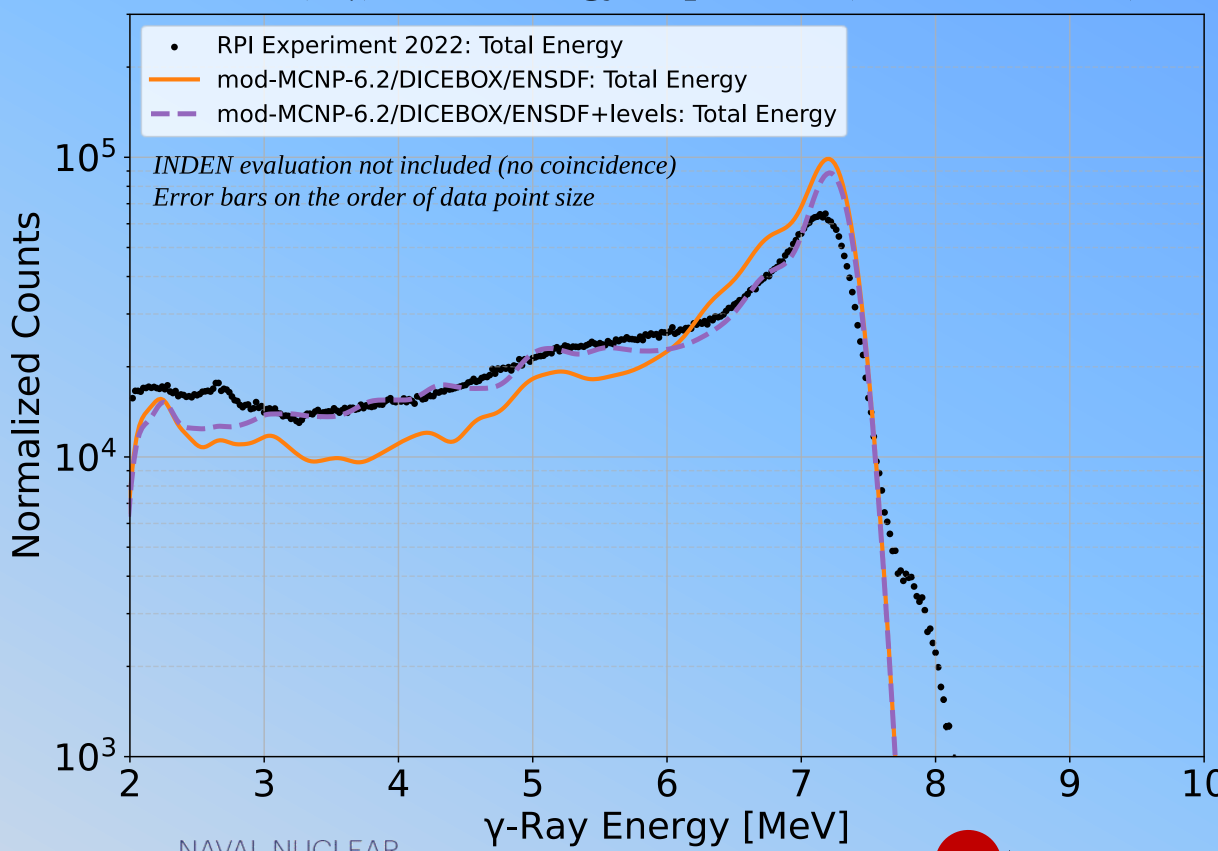


- ENDF/B 8.1 improve in single detector response

^{55}Mn(n,γ) Single Detector



^{55}Mn(n,γ) Total Energy Deposition (all 16 detectors)



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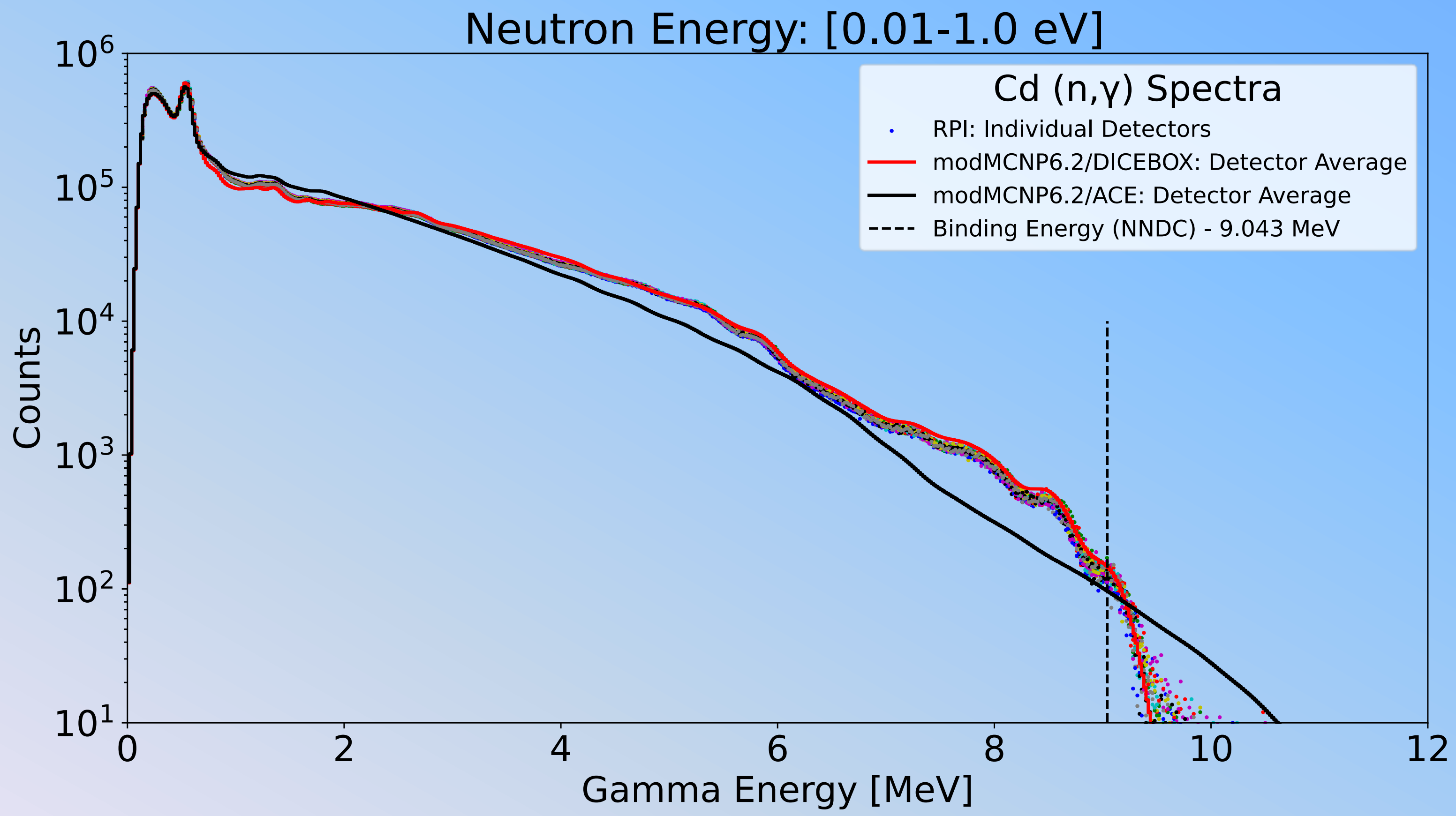
Cd-113 capture gammas

- ENDF/B-8.0 does not have any capture gammas
- ENDF/B-8.1 includes capture gammas, agreement with experiment can be improved



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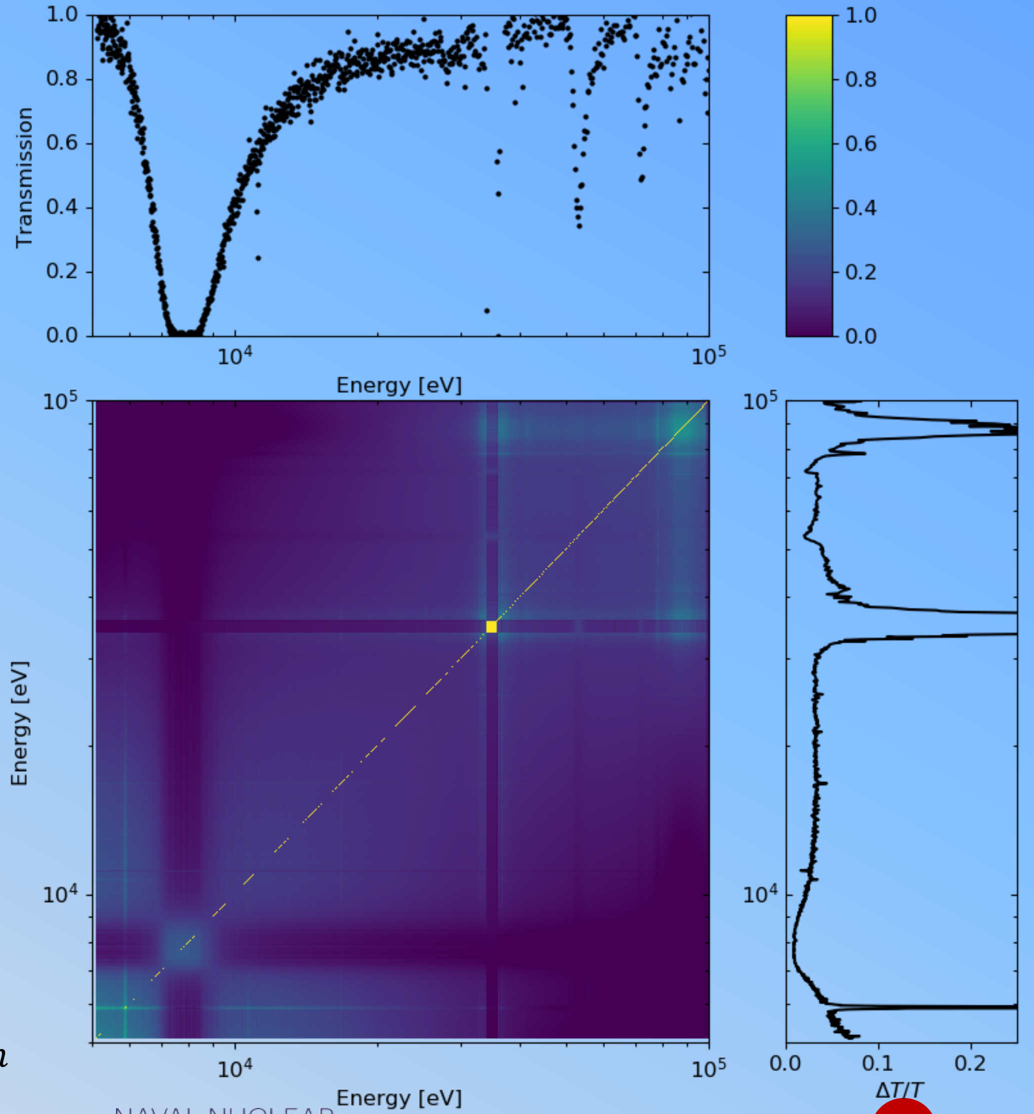
Fe-54 Experimental covariances in RRR

Experimental Covariance

- Experimental implicit data covariances (IDC) were generated for ^{54}Fe capture + transmission measurements.
- Passes mathematical checks and included systematic + statistical errors.
- For example, transmission is calculated using equation below, and the resulting energy-energy correlation matrix is plotted.

$$T_i = k \frac{R_{s,i} - ae^{bt_i} - B0_s \frac{M_o}{T_o}}{R_{O,i} - ce^{dt_i} - B0_o \frac{M_s}{T_s}}$$

$R_{x,i}$ − *Sample or open detector count rates*
ae^{bt_i} − *Sample time dependent background*
ce^{dt_i} − *Open time dependent background*
$B0_x$ − *Sample or open constant background rate*
$\frac{M_o / T_o}{M_s / T_s}$ − *Monitor to trigger ratio*
k − *Unity* ± *uncertenty, systematic uncertainty from monitor normalization*



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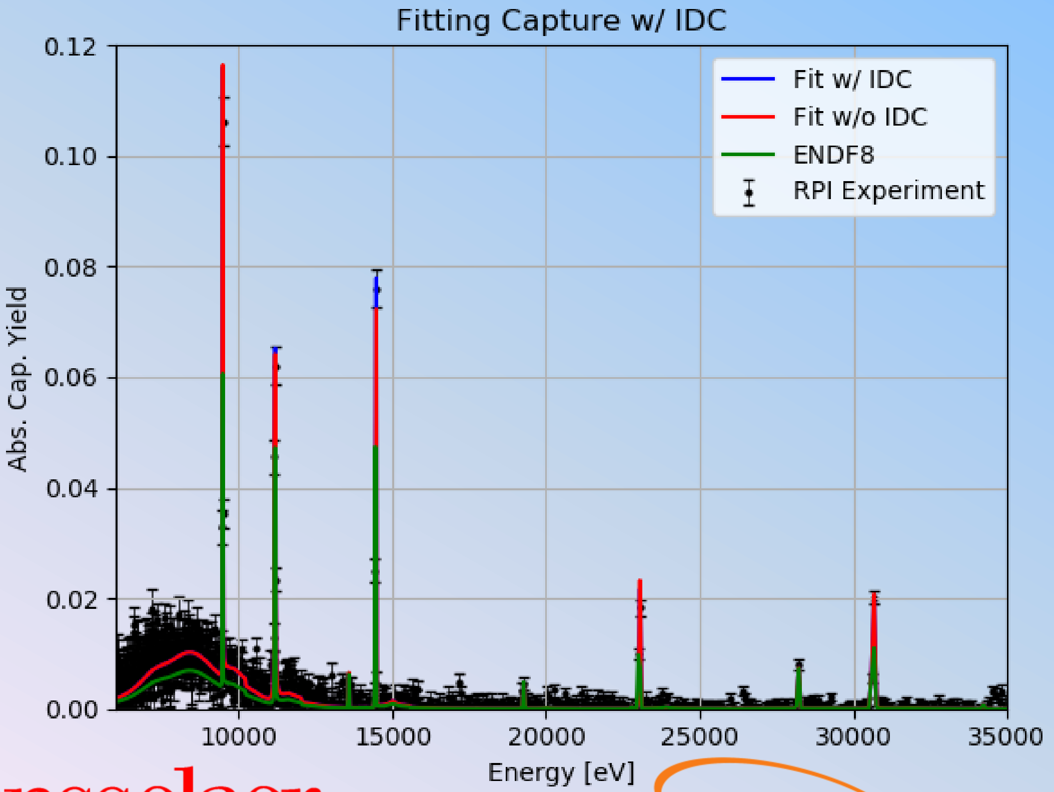
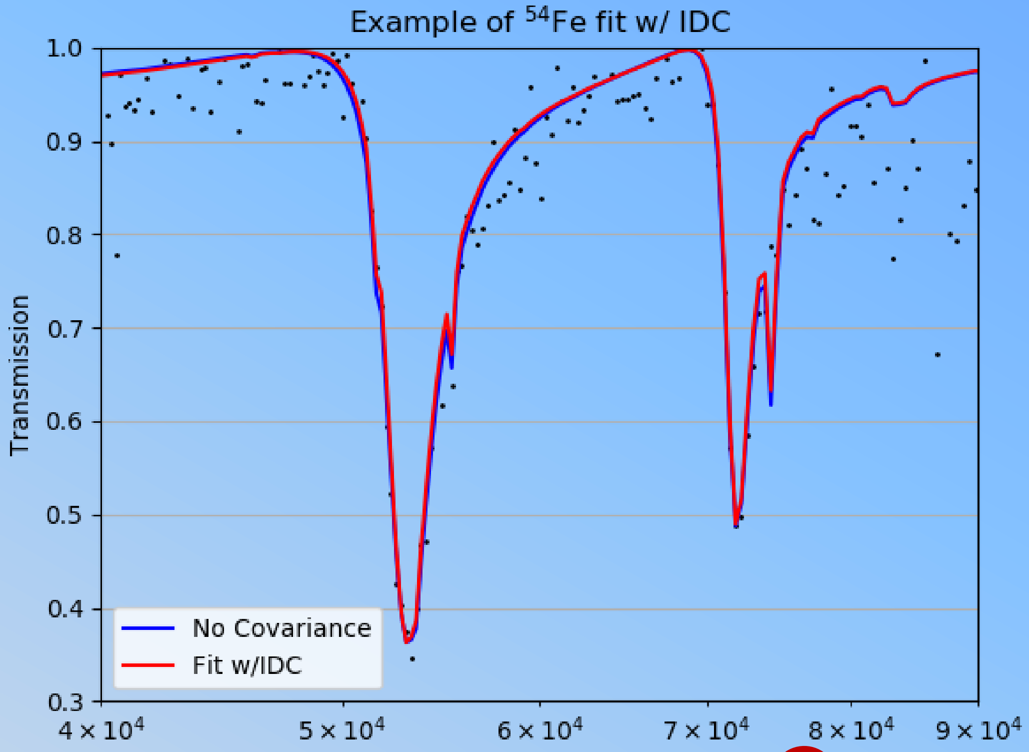
Experimental Covariance Impact on SAMMY Fits

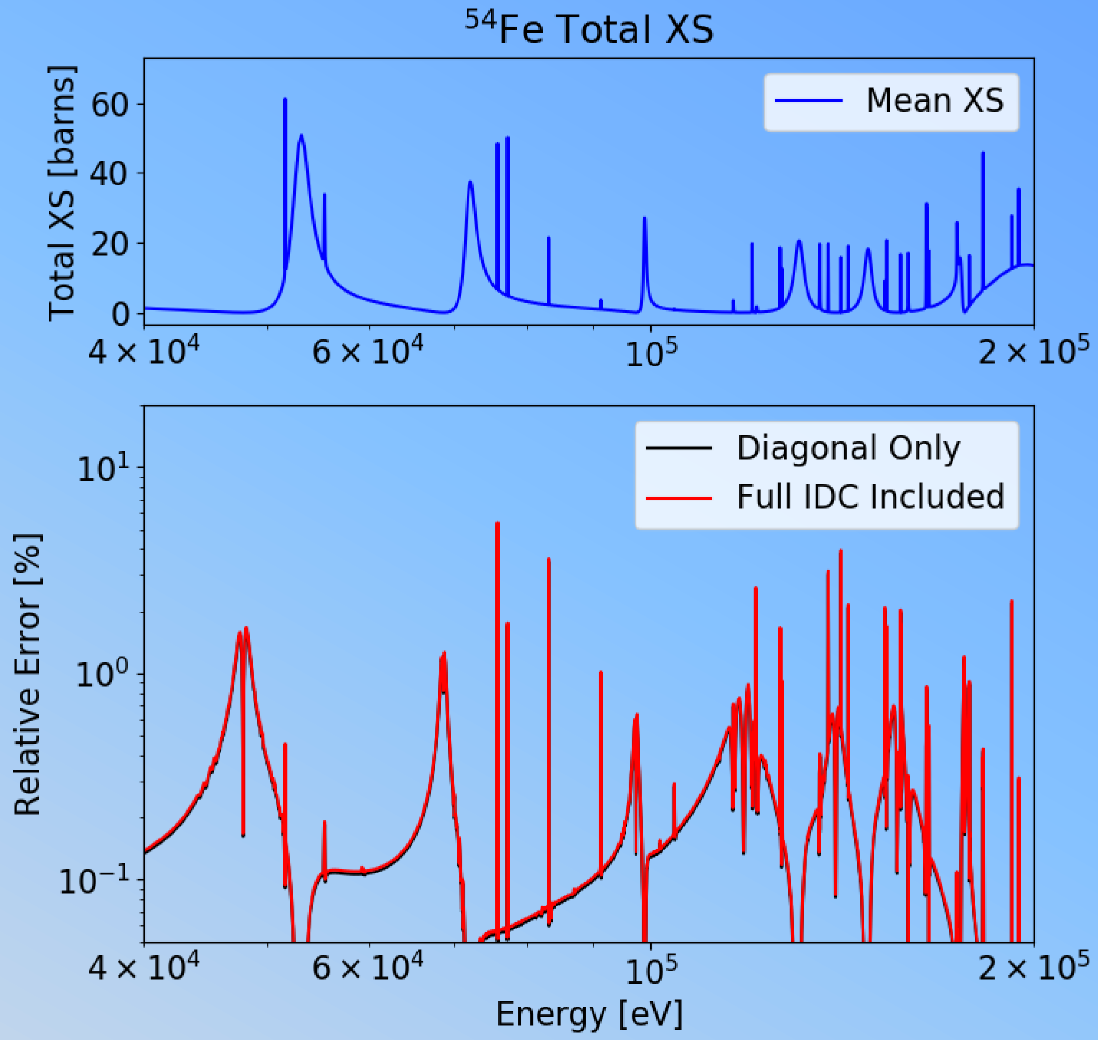
- Using the experimental IDCs, we can now include experimental correlations in SAMMY fits.
- Resulting fits (transmission + capture) are not very different from only including the diagonal element of the IDC (representing only statistical uncertainties), however there are not always strong correlations in the experimental data.
  - The uncertainties in the ^{54}Fe experiments are largely driven by statistics.
  - Fits started with ENDF/B-VIII.0 resonance parameters





Propagation to Cross Section Uncertainty

- To see the impact of the inclusion of **experimental** IDCs in SAMMY fits on the XS uncertainty, a comparison is made on the pointwise XS relative error
  - This was generated using a Monte Carlo resonance sampler developed at RPI
  - Uses an ENDF file as input (no info systematic uncertainty)
- Difference in XS uncertainties is negligible w/ or w/o inclusion of the full experimental IDC in SAMMY fitting
- Full talk to follow in CSEWG w/ more details on generating + testing experimental covariances
- Systematic uncertainties are not propagated in ENDF cover files (need methodology)



Summary

- ENDF/B-8.1 copper evaluation agrees better with keV quasi-differential scattering measured at RPI
  - Large improvement at angle of 35 deg and energy around 250 keV.
  - Small improvements in other angles.

- Mn-55 and Cd-113 ENDF/B-8.1 evaluations of capture gammas perform better than previous ENDF/B-8.0
  - Mn-55 shows good agreement with RPI measured capture gamma spectrum.
  - Cd-133 now has capture gammas which is better than none, agreement with the experiment can be improved.

- In the case of Fe-54 use of full experimental covariance makes a negligible difference on fitted resonance parameters.
  - The have more realistic RRR cross sections uncertainties, need a method for propagating systematic uncertainty solution perhaps file 33 (see CSEWG, Nov 6-8, 2007).
  - In reality (usually) total cross section is known best, capture less well, and scattering is not measured. Can create a problem summing uncertainties in an ENDF file when using file 33.