High Energy Quasi-Differential Neutron Emission Measurements of ^{181}Ta and ^{19}F

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Presentation Overview

1. Motivation for performing ^{181}Ta and ^{19}F high energy quasi-differential neutron emission measurements
2. Quasi-Differential methodology and importance for validating nuclear data
3. Discussion on results from the ^{181}Ta and ^{19}F measurements

Tantalum (Ta)	RPI	RPI					
Basis	Fast quasi-differential scattering measurements will be performed by RPI to assess the adequacy of Ta elastic and inelastic scattering data. Tantalum is used at Y-12 for recovering uranium from machine turnings and at LANL for Pu casting operations in PF-4 where it may provide modest moderation and reflection of fissile material. Tantalum is chosen due to its material properties, as it is one of the few materials that can contain molten plutonium metal. Due to this characteristic, tantalum is often used as crucible, distributer, launder, or molds for plutonium casting operations. The wall thickness of these materials varies from a few mm all the way up to a few cm.						

Fluorine (^{19}F)			ORNL	ORNL			
	RPI	RPI					
Basis	Measurement of the ^{19}F inelastic scattering reaction channels at GELINA that appear to be underestimated in the current evaluation. Analysis and evaluation of the angular distributions in the RRR. Errors in fluorine may be contributing to bias in ^{233}U benchmarks. Fluorine is used in the uranium enrichment process and molten salt reactor coolants. This measurement also support the resolution of the bias observed in the Teflon $(C_2F_4)_n$ moderated configurations in the recently completed Curie critical experiment. RPI will perform a fast quasi-differential scattering measurement on Teflon.						

Motivation for RPI and Tantalum and Teflon Experiments

Tantalum

- Validation of new ^{181}Ta evaluation in upcoming ENDF/B-VIII.1 library
- Due to special material and nuclear properties ^{181}Ta is relied on for the following applications:
  1. Neutron-producing targets for linear accelerators
  2. Recovering Uranium from fuel reprocessing[1]
  3. Casting of molten Plutonium metal[1]

Teflon (^{19}Fluorine)

- Validation of the new ^{19}F evaluation in upcoming ENDF/B-VIII.1 library
- Fluorine is relied on heavily in salts for Generation – IV reactor concepts:
  - Kairos Power – FHR
  - TerraPower – SFR and Natrium
  - Flibe LFTR (blanket and coolant)
- Criticality safety, design, and operation of these reactor concepts are highly dependent on ^{19}F neutronics

[1]Chambers, A. (2023) - *Five Year Execution Plan – United States Department of Energy Nuclear Criticality Safety Program FY2024 though FY 2028*

Quasi-Differential Experimental Methodology and Impact

Rensselaer

NCSP
NUCLEAR CRITICALITY SAFETY PROGRAM

NAVAL NUCLEAR LABORATORY

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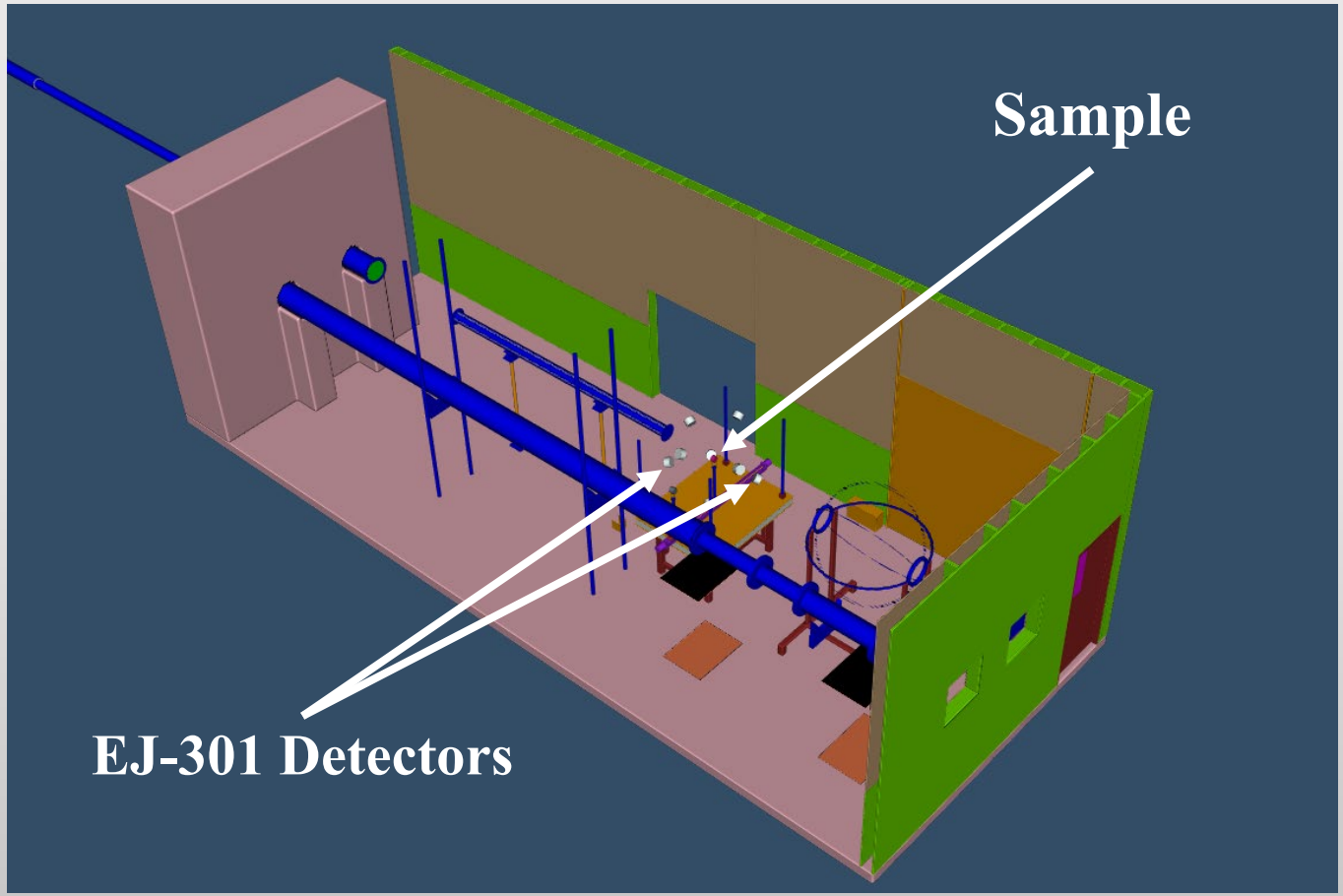
Quasi-Differential Measurement Methodology

1. Conduct differential neutron time-of-flight experiment on sample of interest, validation sample, and open beam
   - Due to sample size, the experiment is dominated by multiple scattering interactions
2. Perform MCNP transport calculation of validation (Carbon) measurement using measured neutron flux and detector efficiencies
   - This validates experimental geometry and reproduction of known validations sample
3. Perform MCNP transport calculation of sample of interest measurement using measured neutron flux and detector efficiencies
   - Differences present in nuclear data evaluations of the sample of interest are compared to the experimental data to validate performance or show needs for improvement

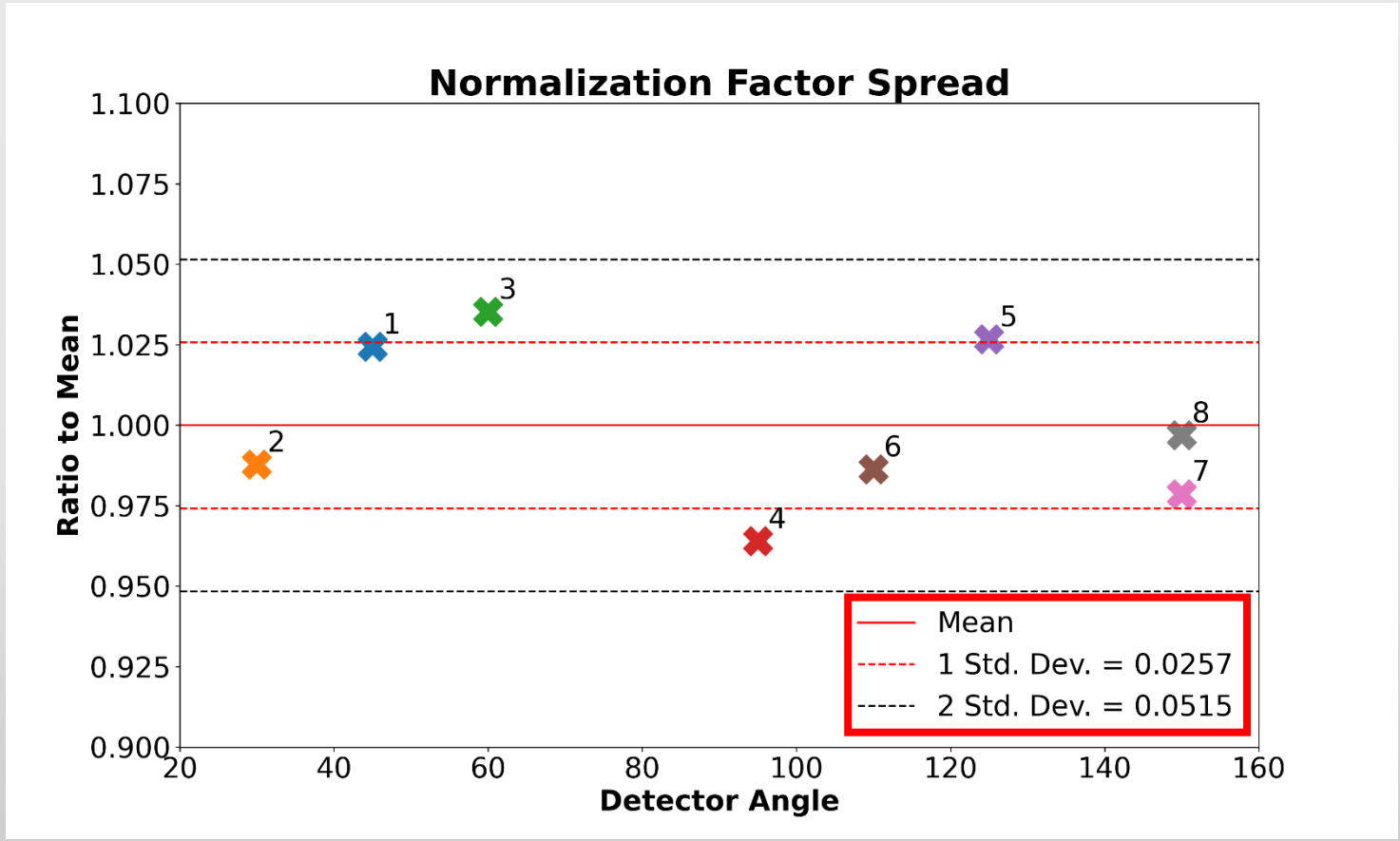
Upgrades to RPI High Energy Scattering System

- System upgraded from Agilent-Acqiris AP240 8-bit to Struck SIS-3305 10-bit digitizer
  - Dynamic range of pulses increased from 256 bits to 1024 bits
  - Sampling resolution increased from 1.0*ns* to 0.8*ns*
- Upgrade yields 2x increase in relative neutron detection efficiency in 3 MeV – 20 MeV region
- RPI high energy neutron scattering system MCNP model overhauled more increased accuracy



Systematic Uncertainty Quantification

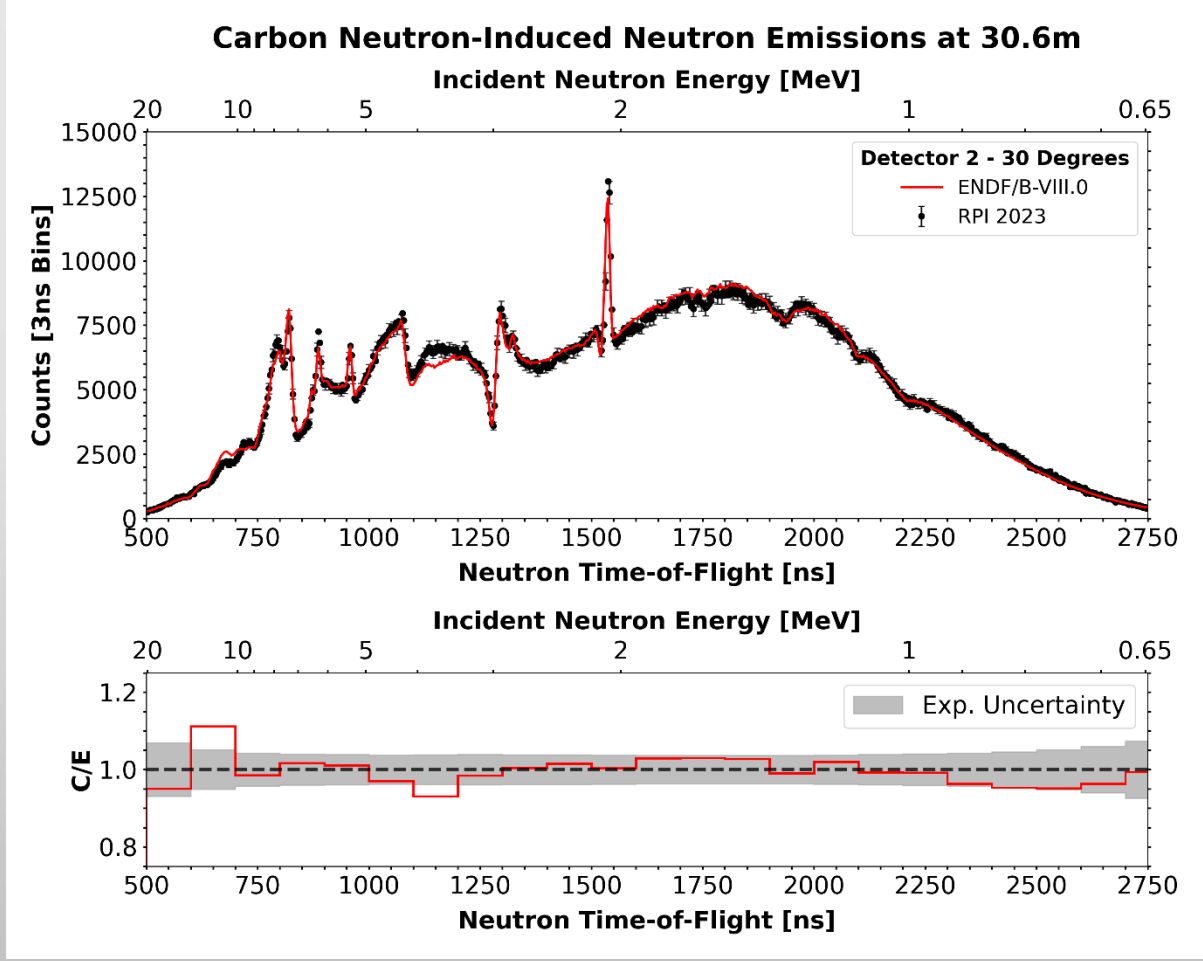
- Systematic uncertainty has been reduced to 2.6%, and 3.1% for the Teflon and ^{181}Ta experiments respectively
  - Previous measurements[1,2] arrived at systematic uncertainty of 6%
- Detector efficiencies determined from in-beam measurements
- Deadtime correction utilized legacy RPI algorithms recently validated for SIS-3305 digitizer[3]



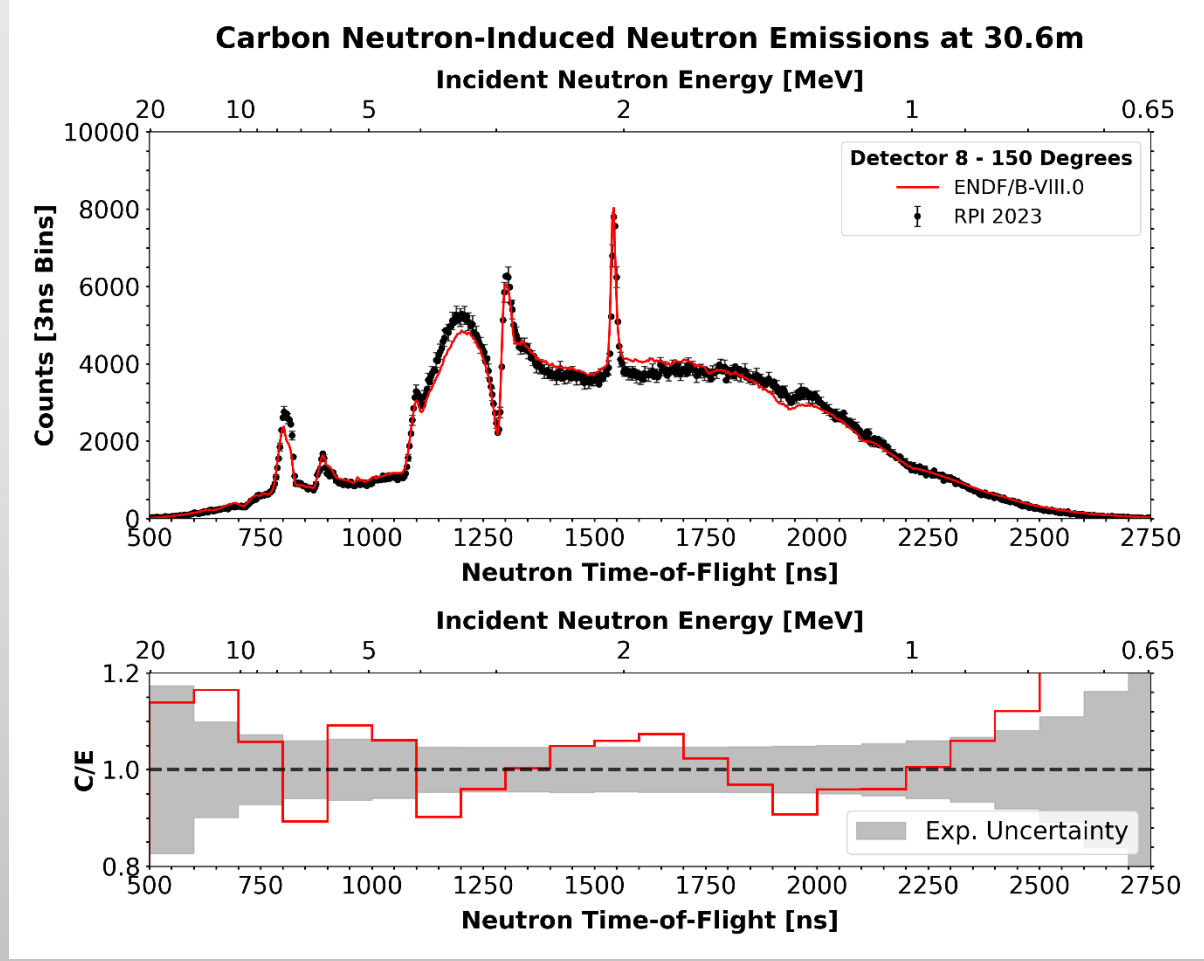
1. E. Blain, Y. Danon, D. P. Barry, B. E. Epping, A. Youmans, M. J. Rapp, A. M. Daskalakis and R. C. Block, "Measurements of Neutron Scattering from a Copper Sample Using a Quasi-Differential Method in the Region from 2 keV to 20 MeV", *Nuclear Science and Engineering*, vol. 196, no. 2, pp. 121-132, 2022, DOI:10.1080/00295639.2021.1961542
2. A. M. Daskalakis, E. J. Blain, B. J. McDermott, R. M. Bahran, Y. Danon, D. P. Barry, R. C. Block, M. J. Rapp, B. E. Epping and G. Leinweber, "Quasi-differential elastic and inelastic neutron scattering from iron in the MeV energy range", *Annals of Nuclear Energy*, vol. 110, pp. 603 - 612, 2017, DOI:10.1016/j.anucene.2017.07.007
3. B. J. McDermott, *RESONANCE REGION CAPTURE CROSS SECTION MEASUREMENTS IN IRON AND TANTALUM USING A NEW C6D6 DETECTOR ARRAY, Ph.D. Thesis, Rensselaer Polytechnic Institute (2016)*

Carbon validation measurement shows agreement within experimental uncertainty observed for all detectors, beside 150 degrees, between 0.65 MeV and 20 MeV.

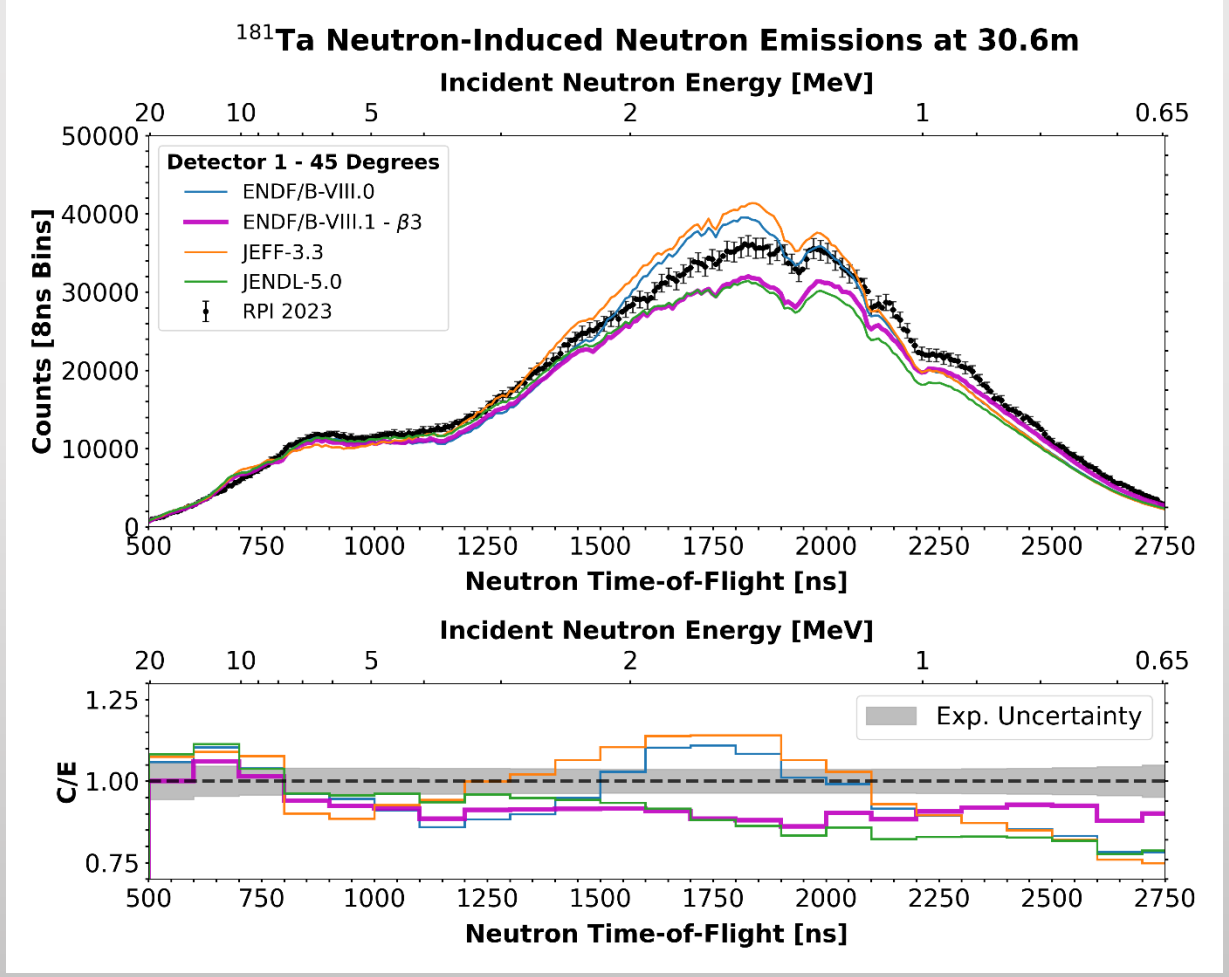
Teflon Experiment

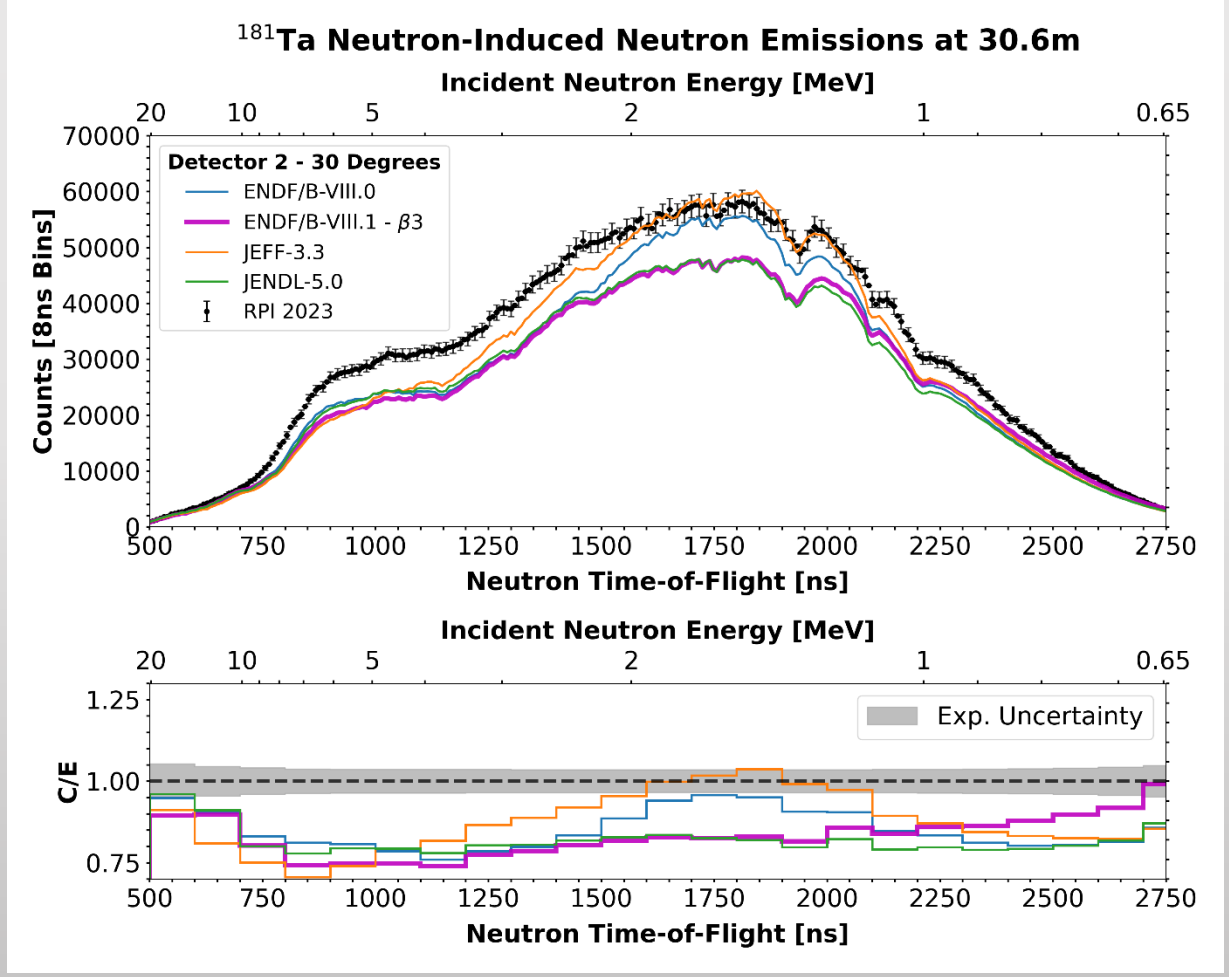


^{181}Ta Experiment

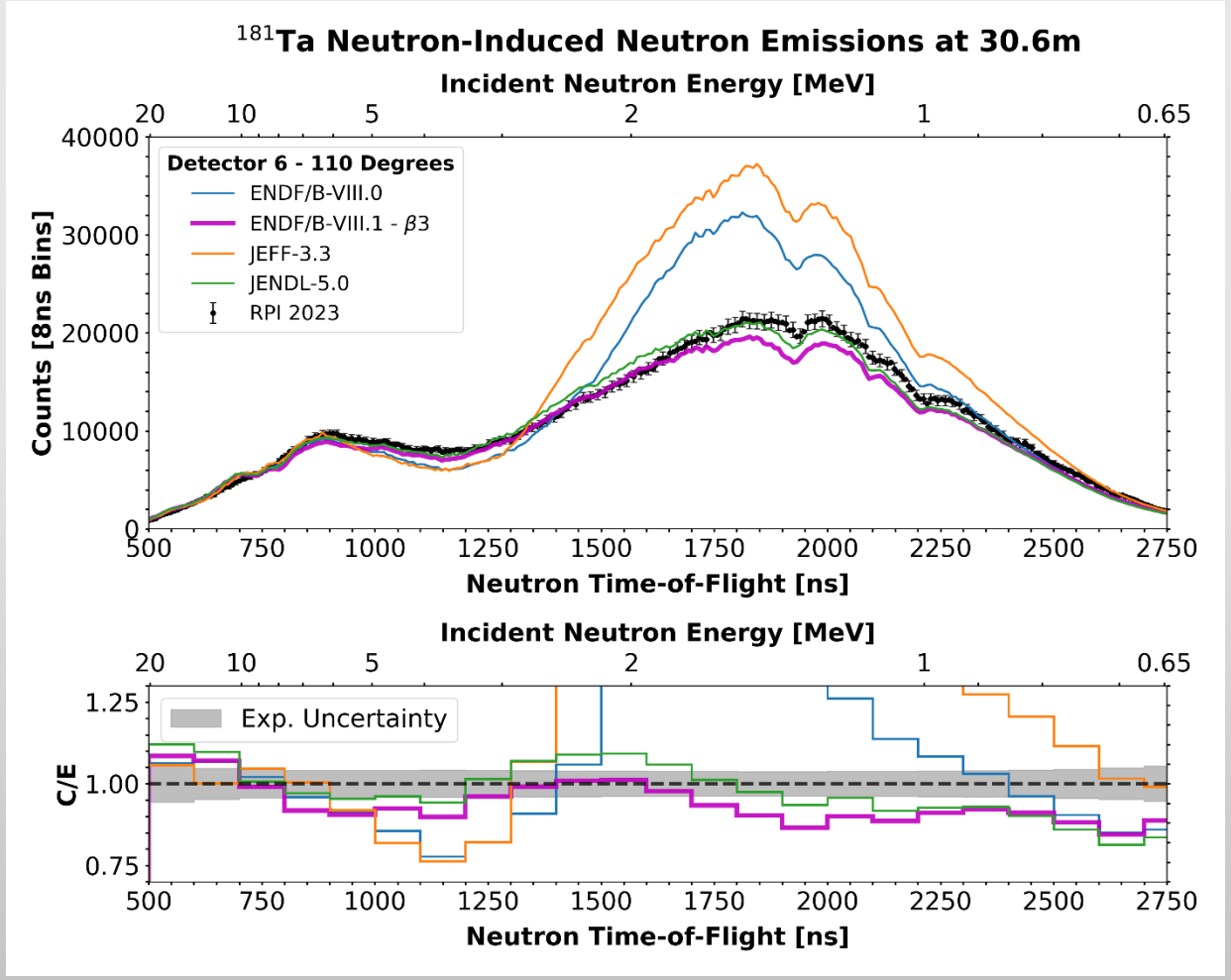


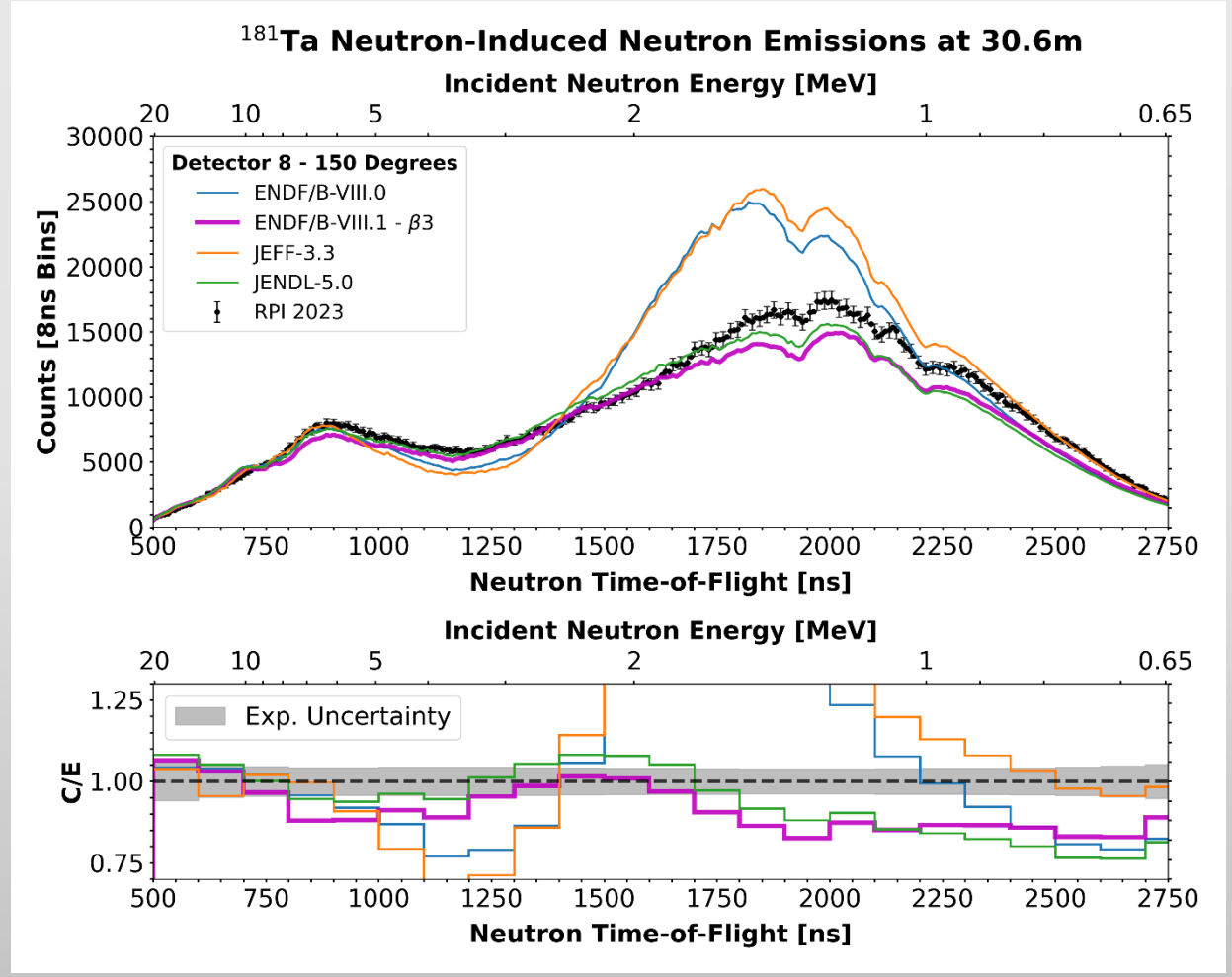
ENDF/B-VIII.1 (β3) evaluation resolves spectra shape issues, but appears to have magnitude issues, particularly at very forward angles.



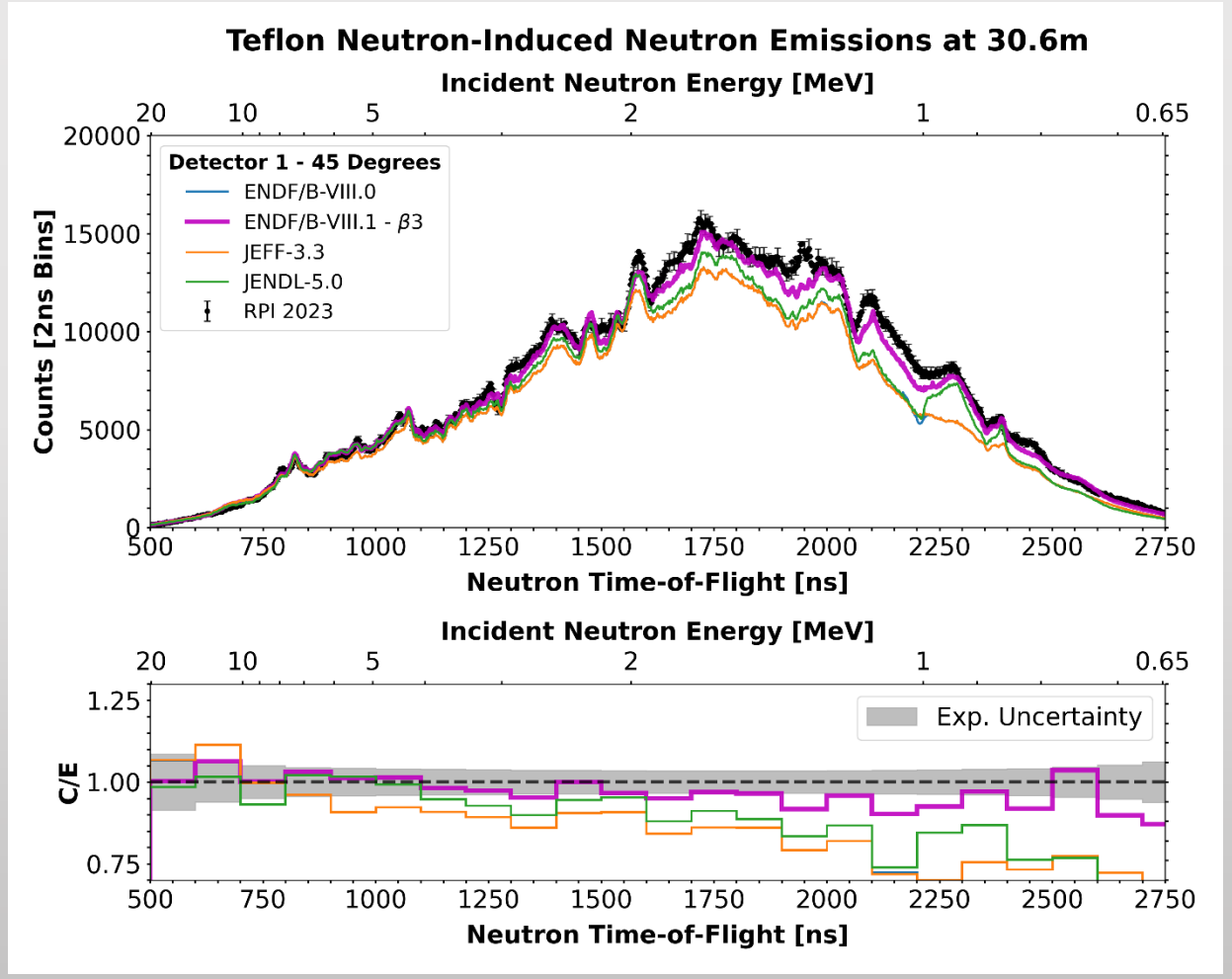


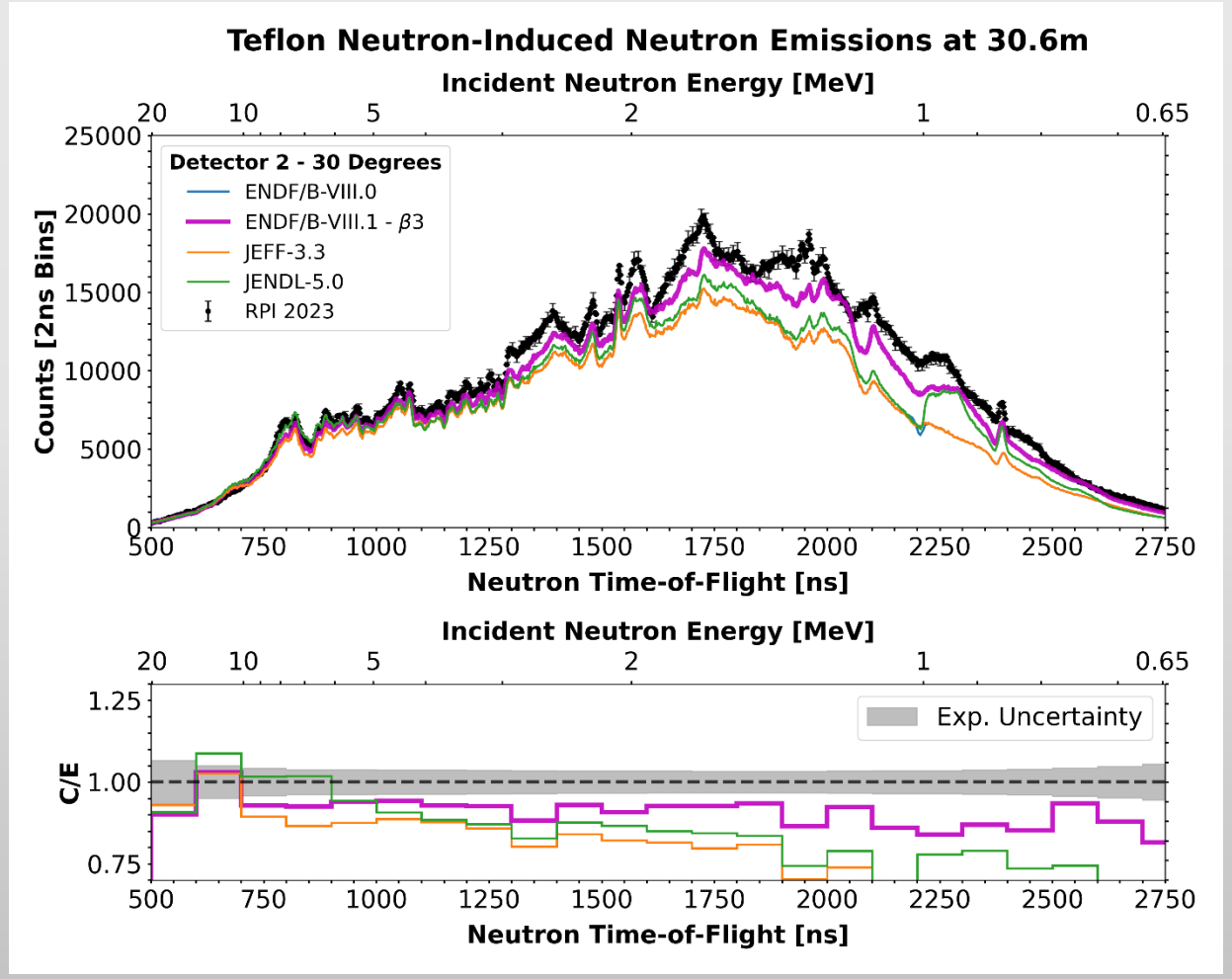
ENDF/B-VIII.1 (β3) evaluation resolves significant overprediction by ENDF/B-VIII.0 evaluation. Underprediction observed below 2.5 MeV.



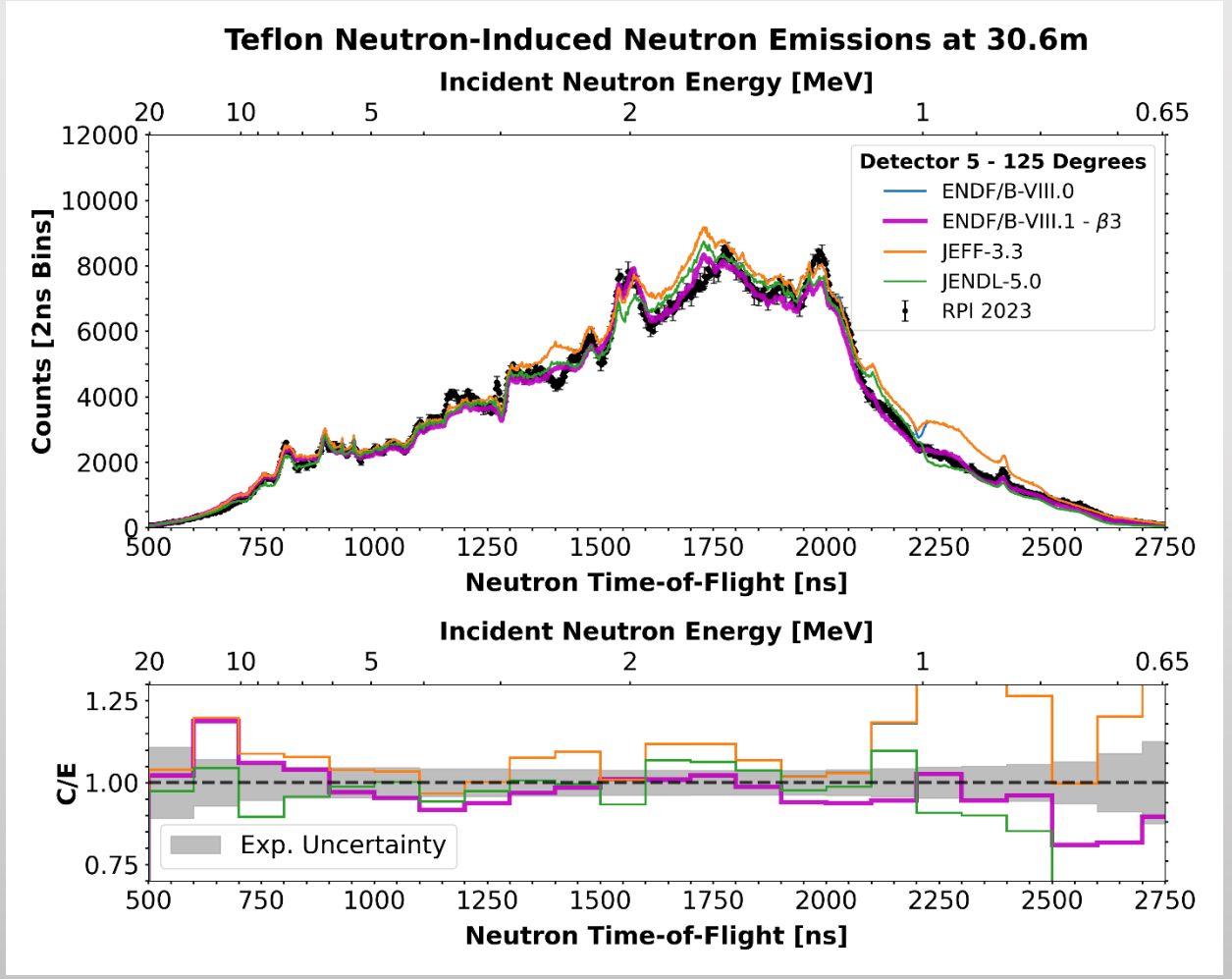


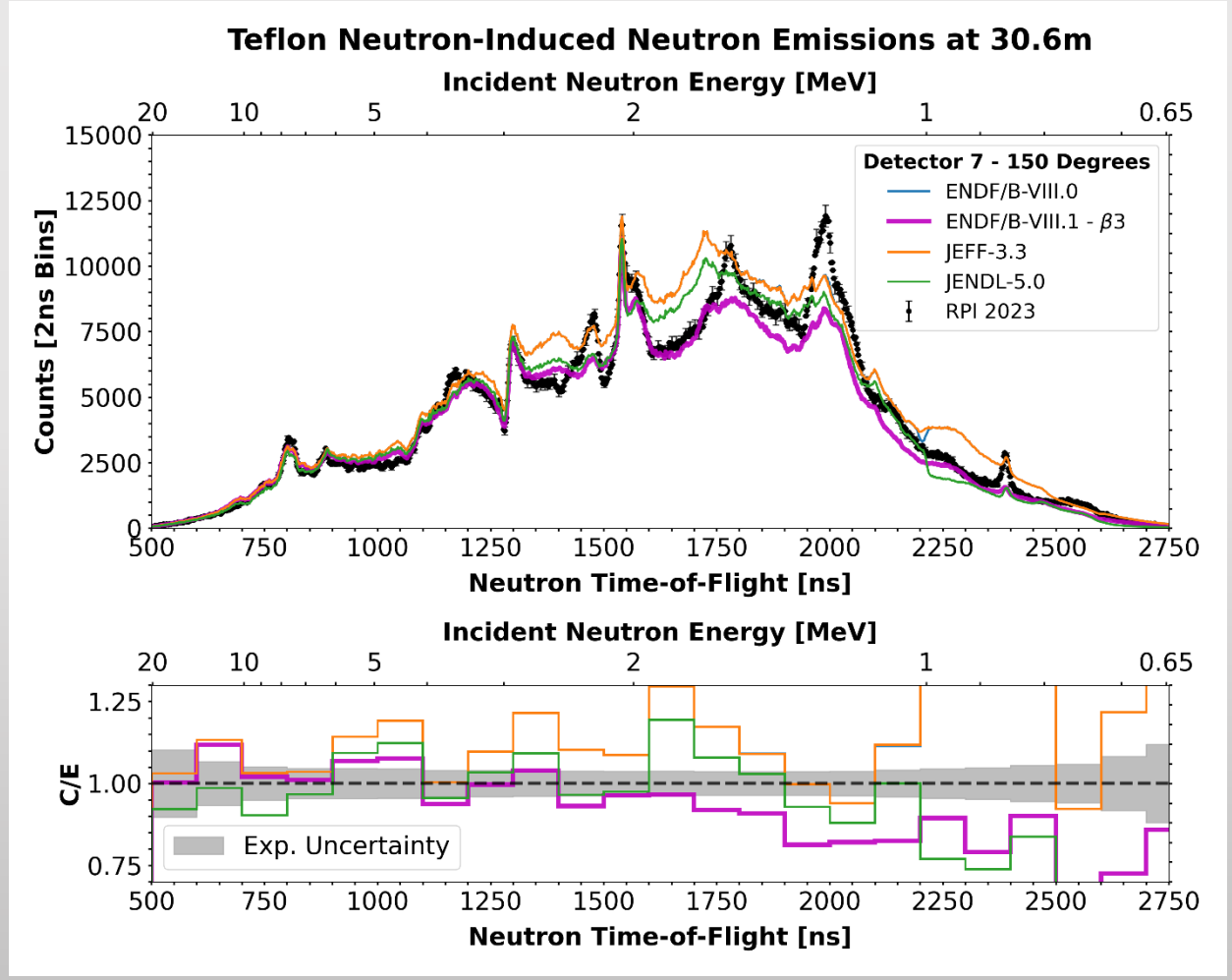
ENDF/B-VIII.1 (β3) provides best prediction of experimental data at forward angles; resolving scattering kernel issues in ENDF/B-VIII.0/JEFF-3.3/JENDL-5.0. Resonance misprediction observed below 3 MeV.





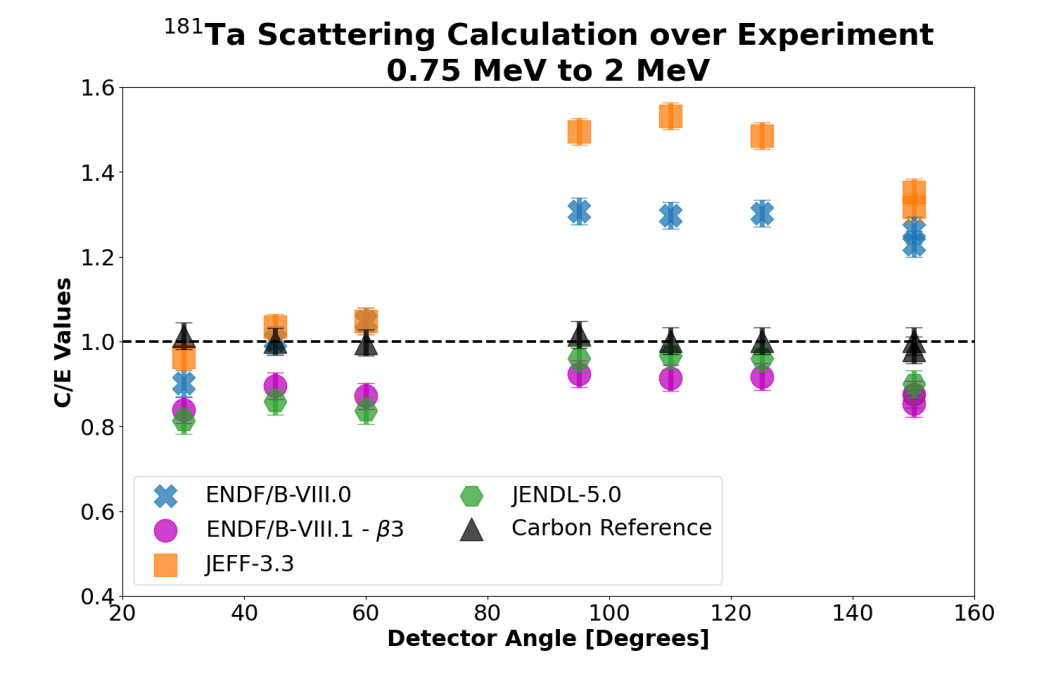
ENDF/B-VIII.1 (β3) provides best prediction of experimental data at backward angles; resolving scattering kernel issues in ENDF/B-VIII.0/JEFF-3.3/JENDL-5.0. Resonance misprediction observed below 3 MeV.

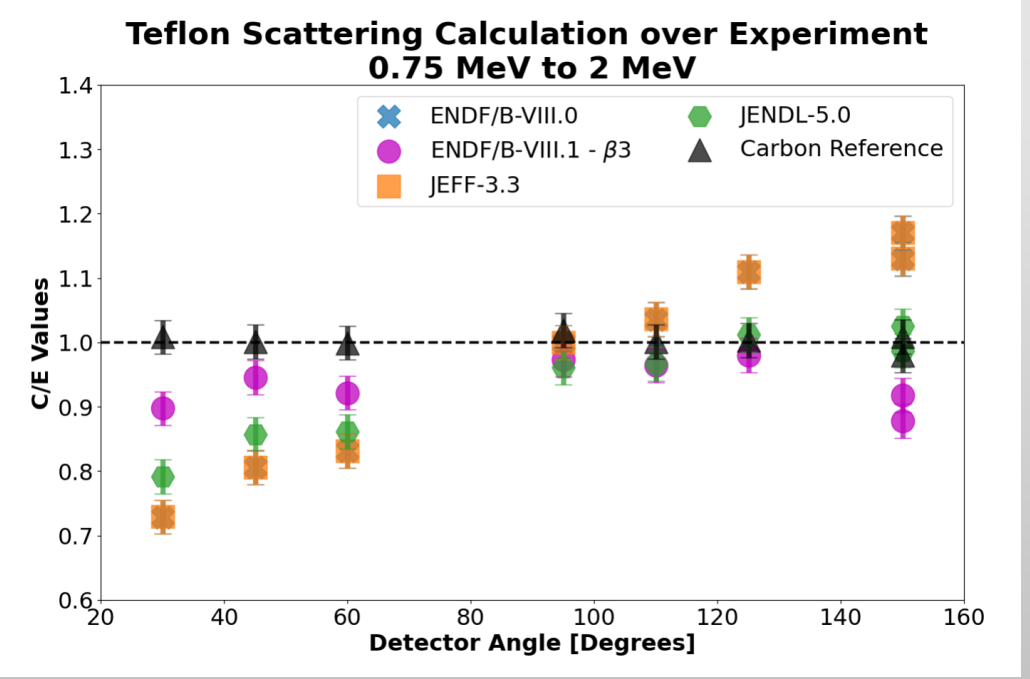




Scattering Kernal Performance

- To test if an evaluation was more forward or backward peaked the C/E values were compared in large energy regions for all angles measured
- The ENDF/B-VIII.1 (β3) evaluation shows a kernel closer to unity compared to ENDF/B-VIII.0 and JEFF-3.3 ^{181}Ta and ^{19}F evaluations





Conclusions and Future Studies

- High energy quasi-differential neutron emission measurements of ^{181}Ta and Teflon have been performed
  - Results provide validation for the performance of the ENDF/B-VIII.1 ^{181}Ta/ ^{19}F evaluations
  - Results also show regions to where improvement is needed for future ^{181}Ta /^{19}F evaluations
- Resonance anisotropy issues in ^{19}F will be investigated by RPI using resonance parameters and the Blatt-Biedenharn formalism as part of Ph.D. thesis
- Manuscript drafts of journal papers are coming for both experiments to be completed this FY

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