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

Gregory Siemers[1], Y. Danon[1], S. Singh[1], A. Daskalakis[2], P. Brain[1,3], K. Cook[1,2], B. Wang[1], M. Rapp[2], D. Barry[2]

[1]*Gaerttner LINAC Center, Rensselaer Polytechnic Institute, Troy, NY – 12180*
[2]*Naval Nuclear Laboratory – Niskayuna, NY 12309*
[3]*Los Alamos National Laboratory – Los Alamos, NM 87544*

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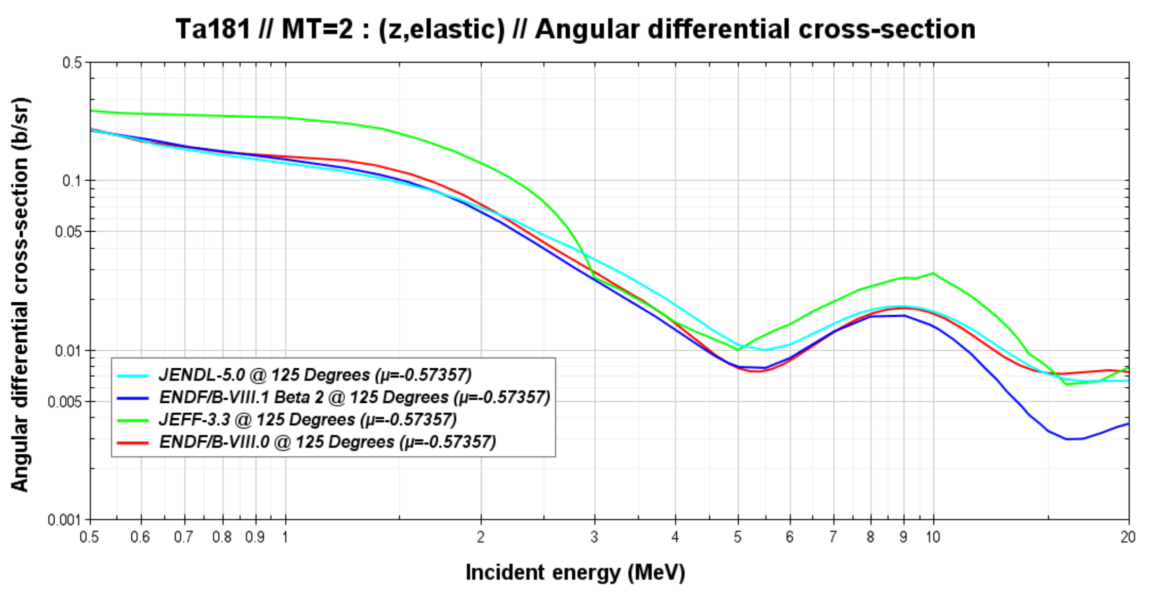
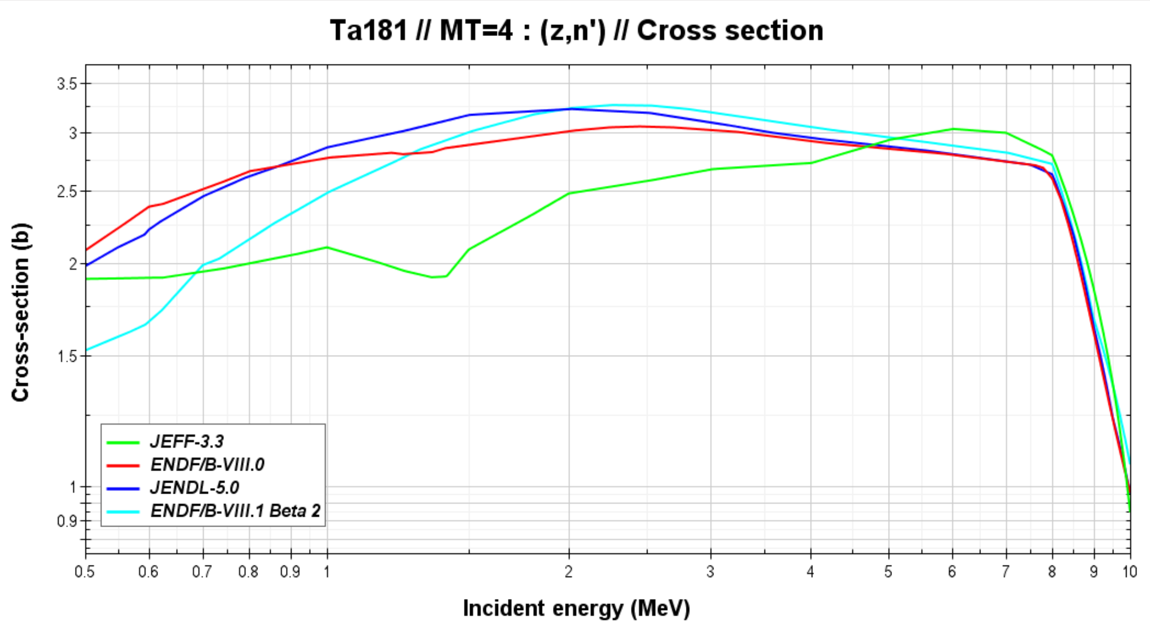
Presentation Overview

1. Motivation for performing ^{181}Ta and ^{19}F high energy quasi-differential neutron emission measurements
    i. Discussion of significant pulse digitization upgrade
2. Quasi-Differential methodology and importance for validating nuclear data
3. Preliminary results from ^{181}Ta and ^{19}F
4. Discussion and future studies

Motivation for RPI Tantalum Experiment

- 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]
- Validation of new ^{181}Ta evaluation in upcoming ENDF/B-VIII.I library

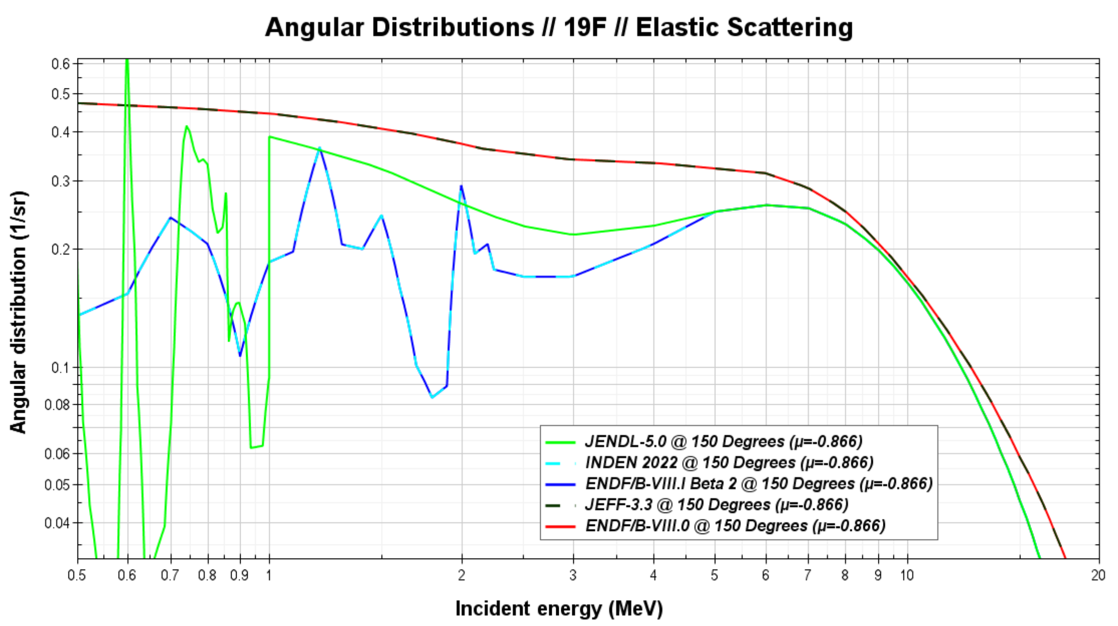


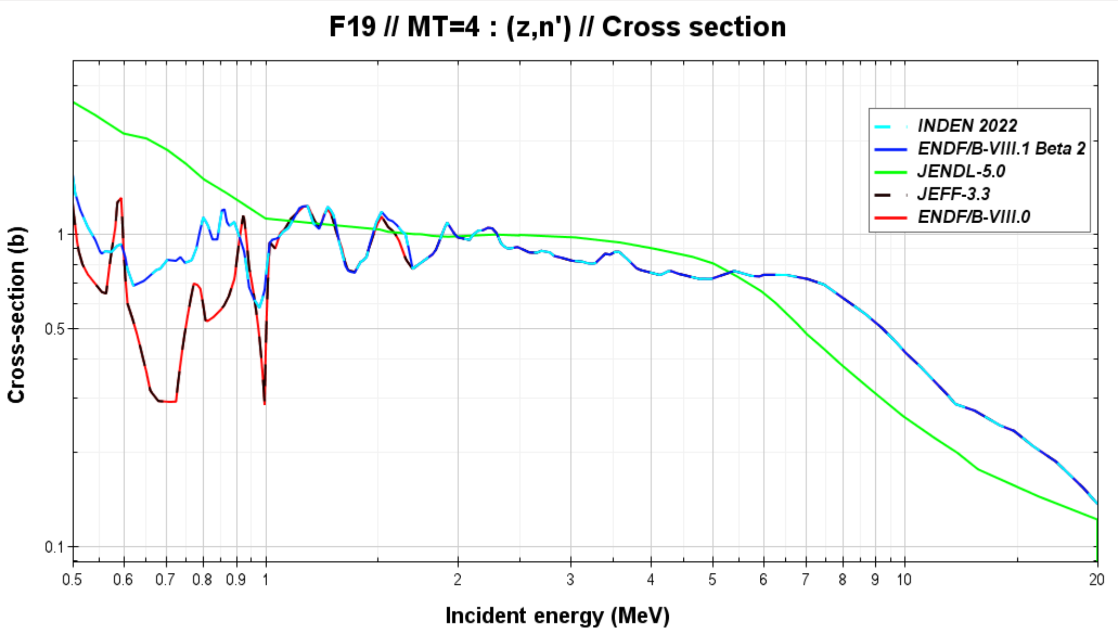


[1]Chambers, A. (2023) - *Five Year Execution Plan – United States Department of Energy Nuclear Criticality Safety Program FY2024 though FY 2028*

Motivation for RPI Teflon (CF_2) Experiment

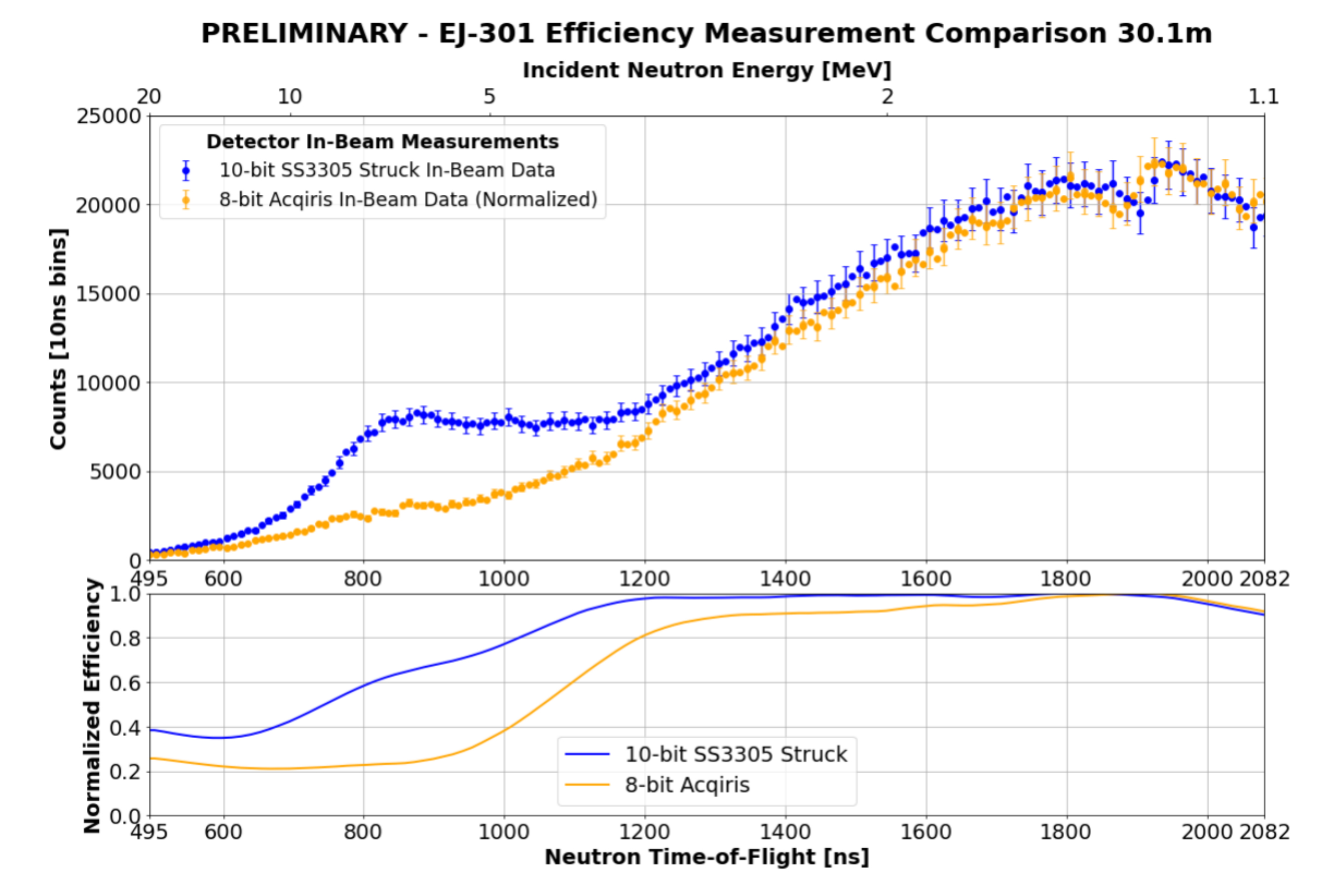
- Measuring Teflon allows for validation of the ^{19}F evaluations
- Fluorine is relied on heavily in salts for Generation – IV reactor concepts:
  - Kairos Power – FHR
  - TerraPower – SFR and Natrium
  - Flibe LFTR (blanket and coolant)
- Fluorine is an integral component of Uranium manufacturing/enrichment (UF_6)
- Criticality safety, design, and operation of these reactor concepts are highly dependent on ^{19}F neutronics





Upgrade to Struck SIS-3305 10-bit Digitizer

- 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 increase in relative neutron detection efficiency of the system, largest gains in efficiency observed from 2 MeV – 20 MeV
- Comparison generated using pulse shape discrimination methods[1] different from the results presented in this work



[1]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

Quasi-Differential Experimental Methodology and Impact

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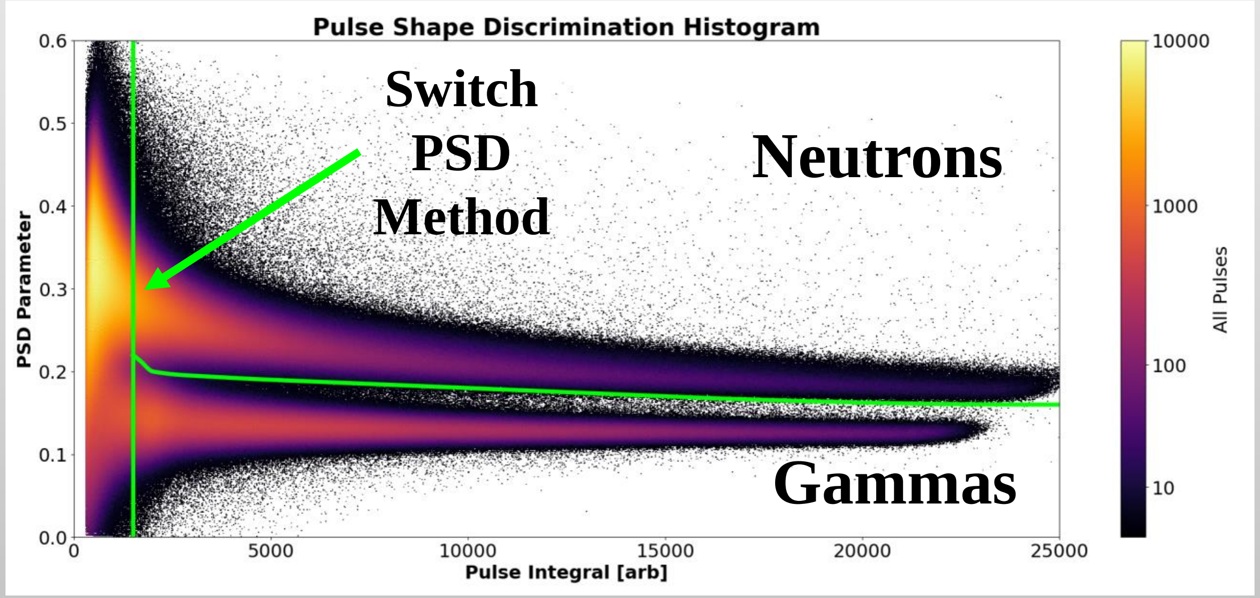
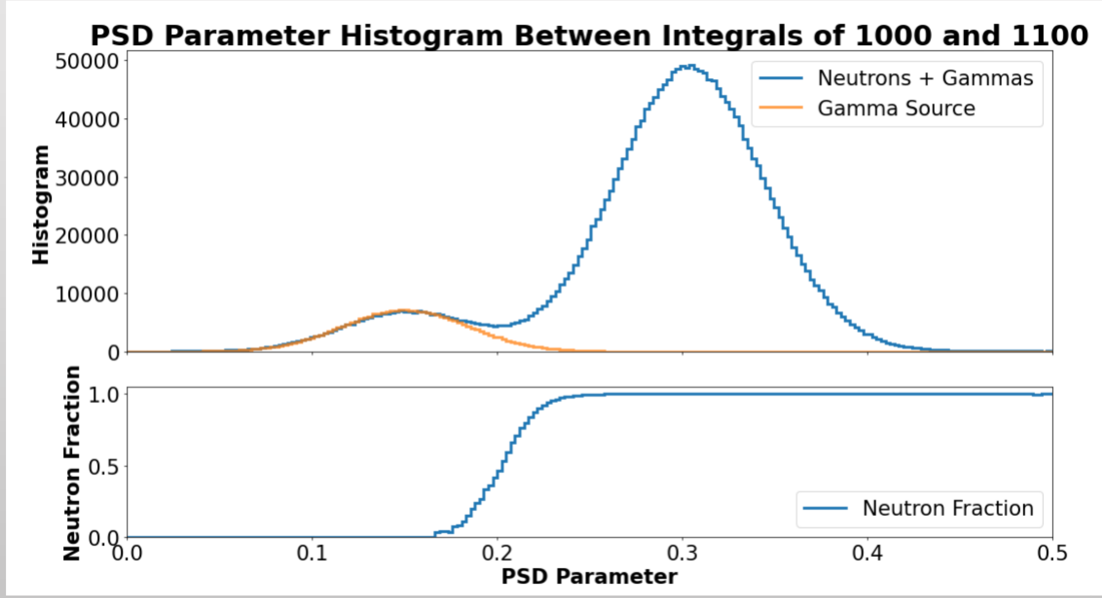
Quasi-Differential Measurement Methodology

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

Pulse Shape Discrimination

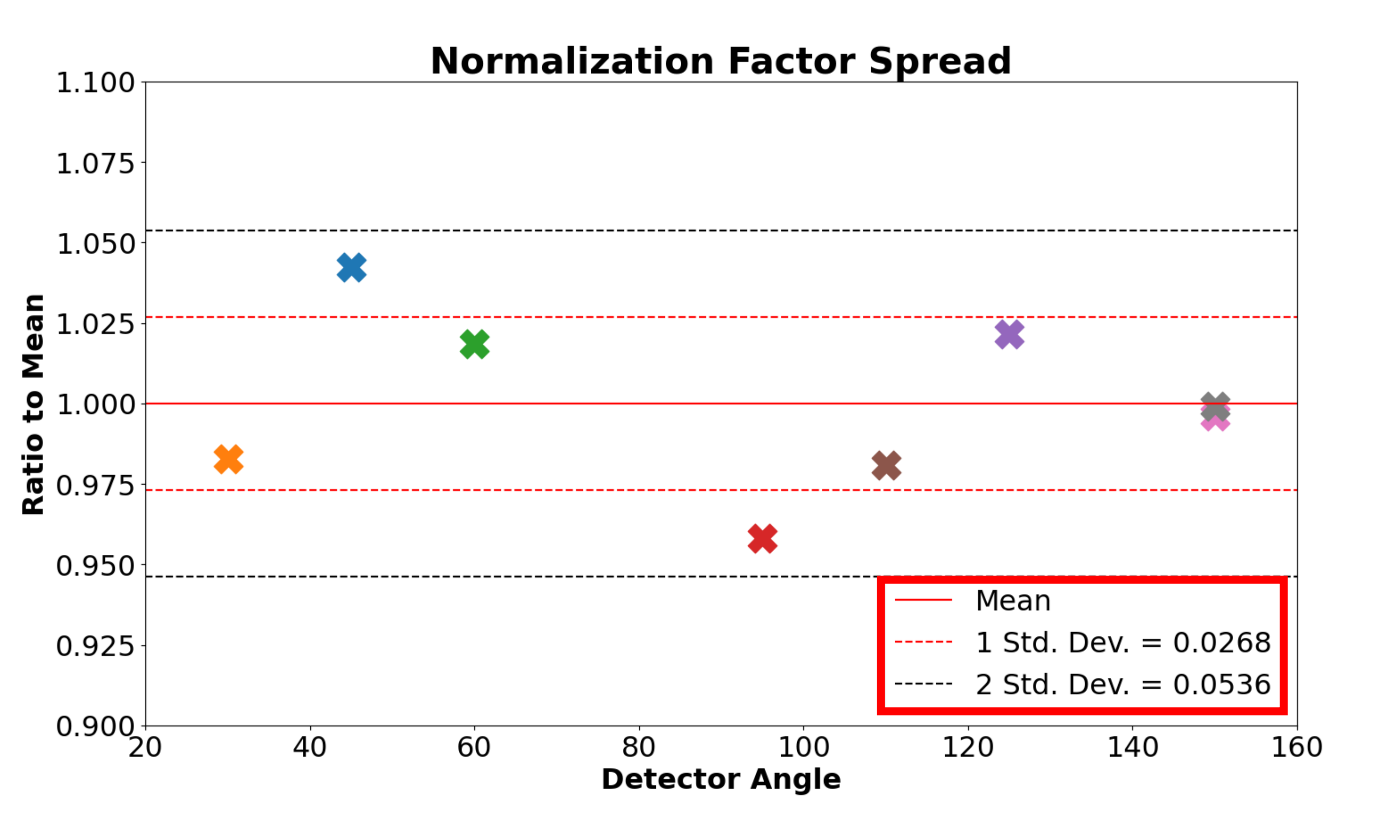
- Neutron and gamma pulses were separated based by the ratio of the tail integral of the pulse to the integral of the whole pulse
- Below a pulse integral of 1500 *a priori* detector responses to gamma rays used to predict and remove gamma ray portion of detector response





Preliminary Experimental Uncertainty Quantification

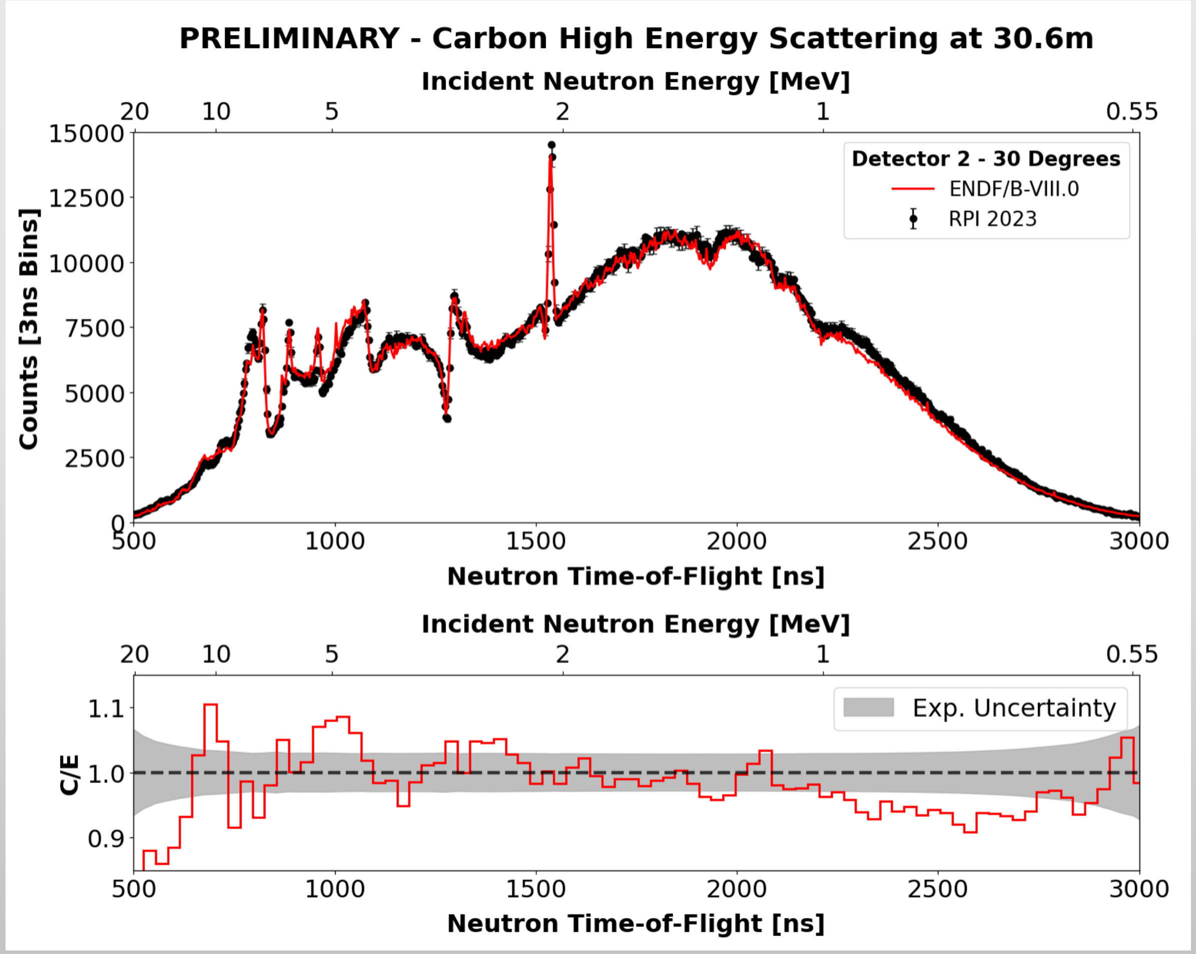
- Preliminary analysis suggests approximate systematic uncertainty has been reduced to approximately 2.5% – 3.5%
  - Previous measurements[1,2] arrived at systematic uncertainty of 6%
- Detector efficiencies determined from in-beam measurements
- Digitizer latency (33.6*ns*) and PSD techniques used for deadtime correction



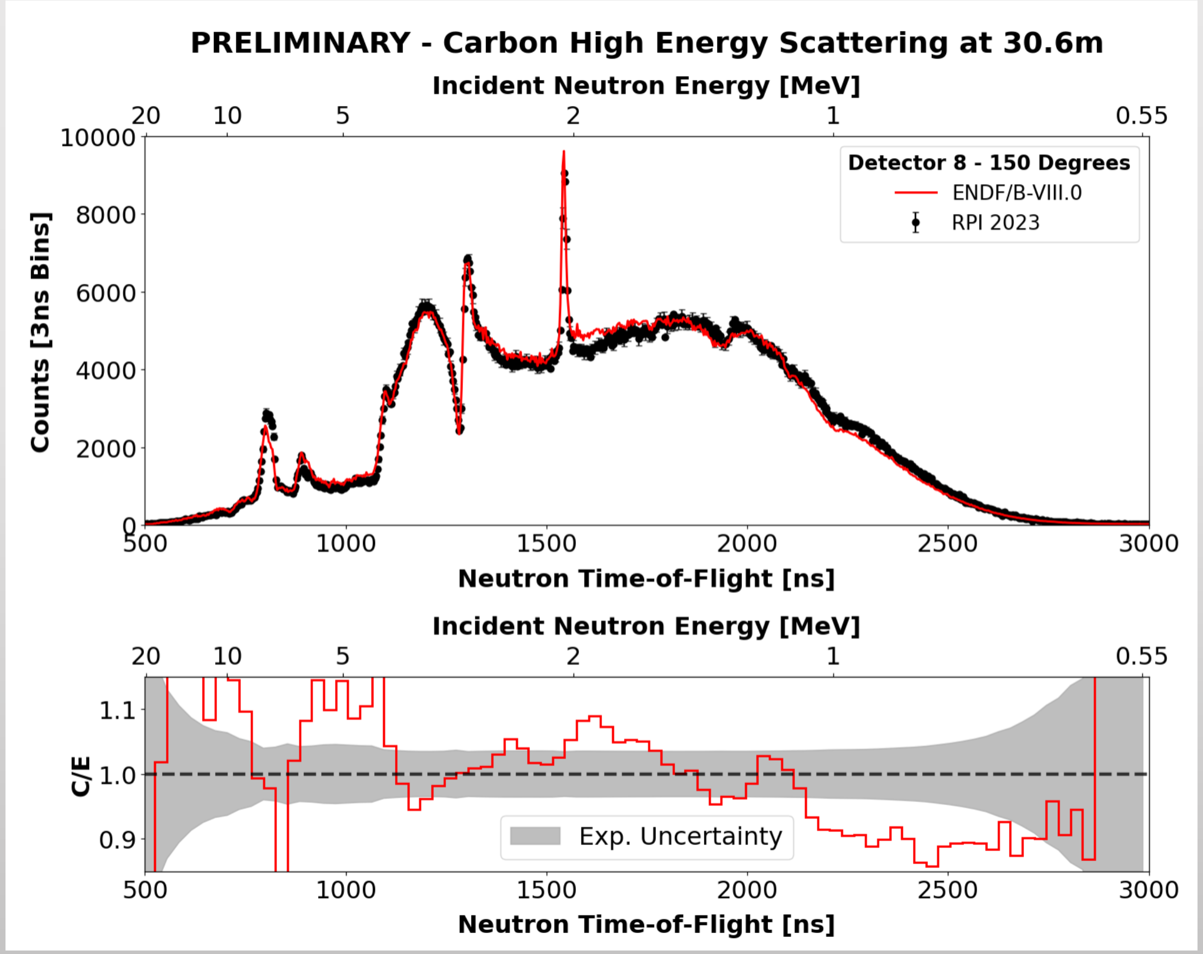
1. E. Blain, Y. Danon, D. P. Barry, B. E. Epping, A. Youmans, M. J. Rapp, A. M. Daskalakis and R. C. Block, “Measurements of Neutron Scattering from a Copper Sample Using a Quasi-Differential Method in the Region from 2 keV to 20 MeV”, *Nuclear Science and Engineering*, vol. 196, no. 2, pp. 121-132, 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

Carbon validation measurement shows simulation near agreement within experimental (~3%) uncertainty observed for all detectors between 1 MeV and 5 MeV.

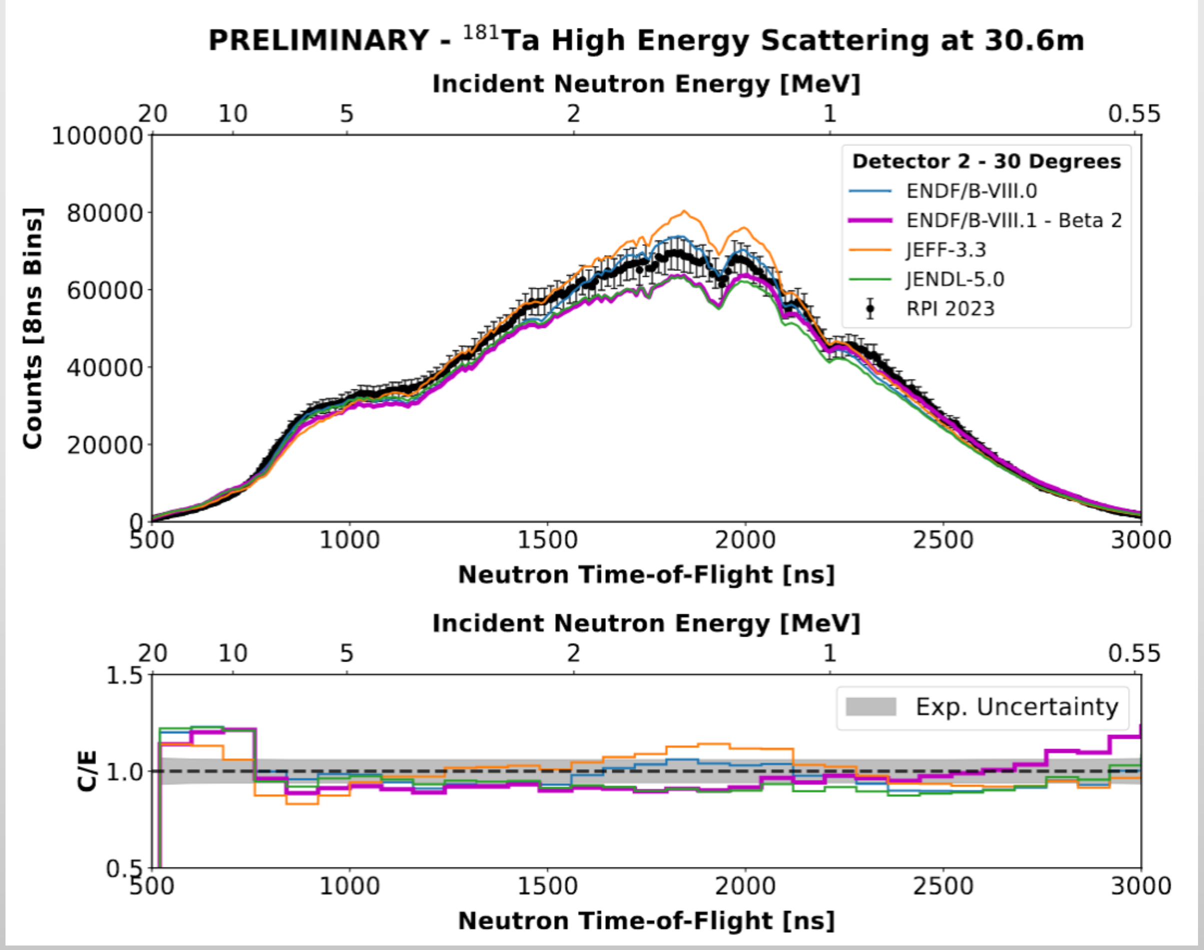
Teflon Experiment

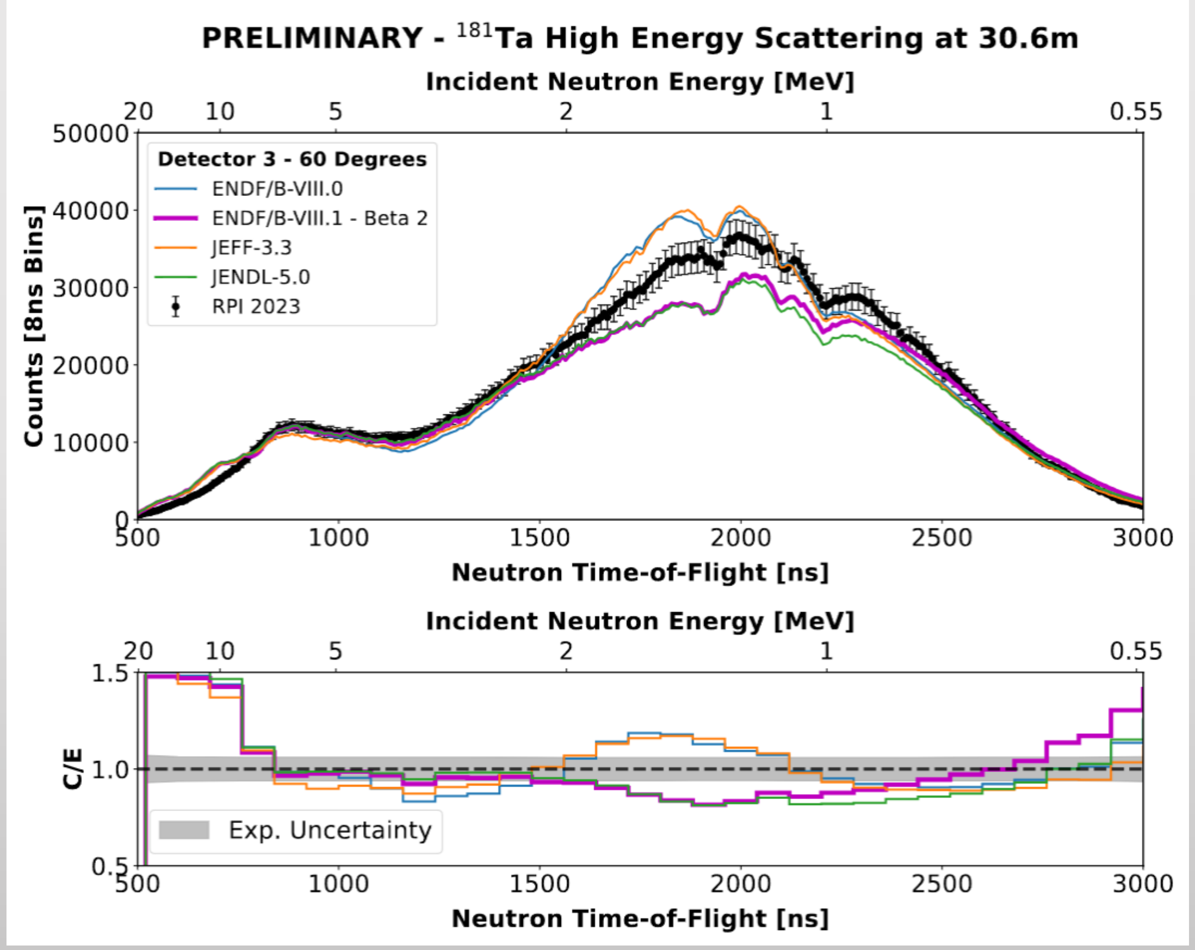


^{181}Ta Experiment

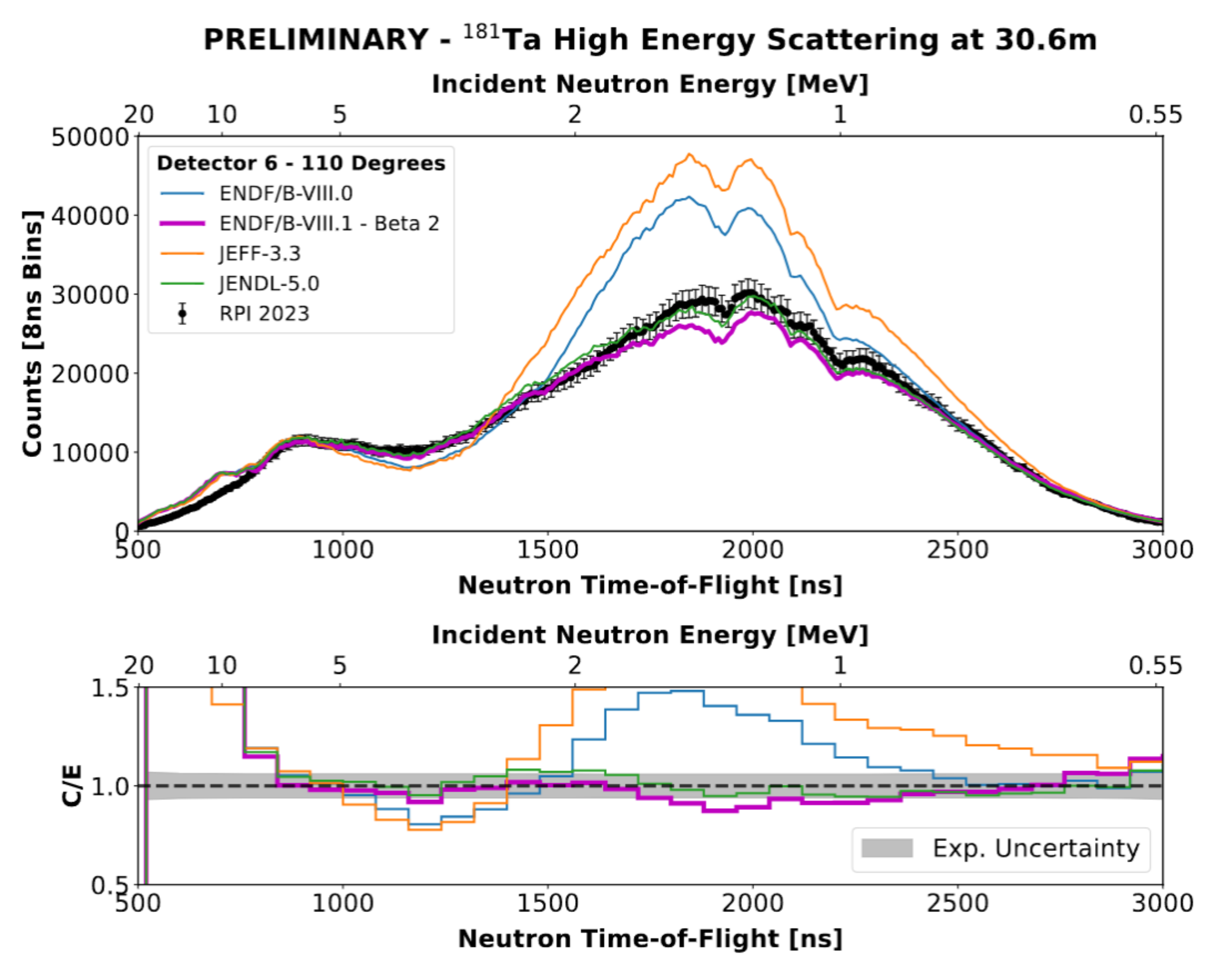


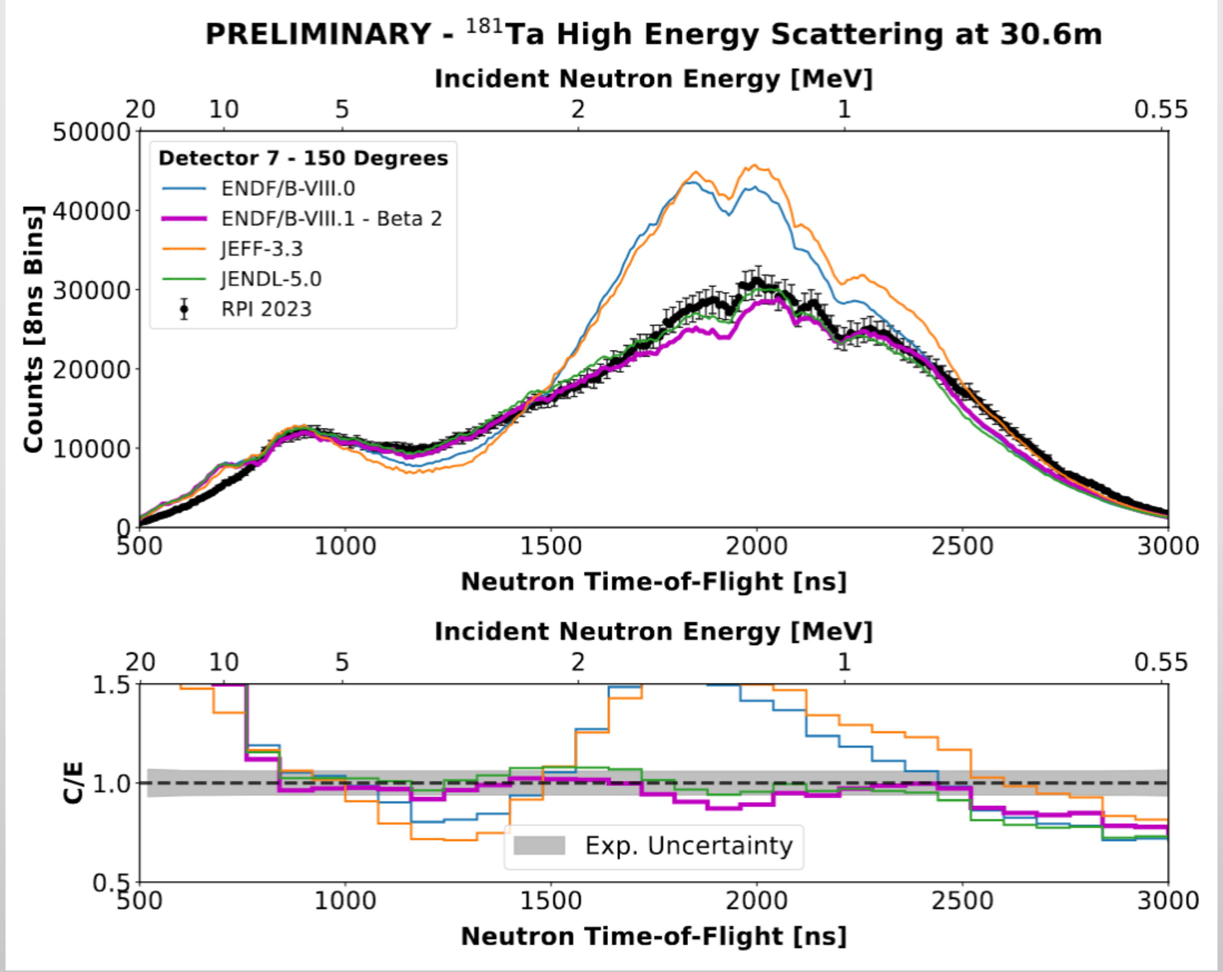
ENDF/B-VIII.I – Beta 2 and JENDL-5.0 show good agreement to each other, but underpredict experimental data 0.75 MeV – 3 MeV at forward angles.



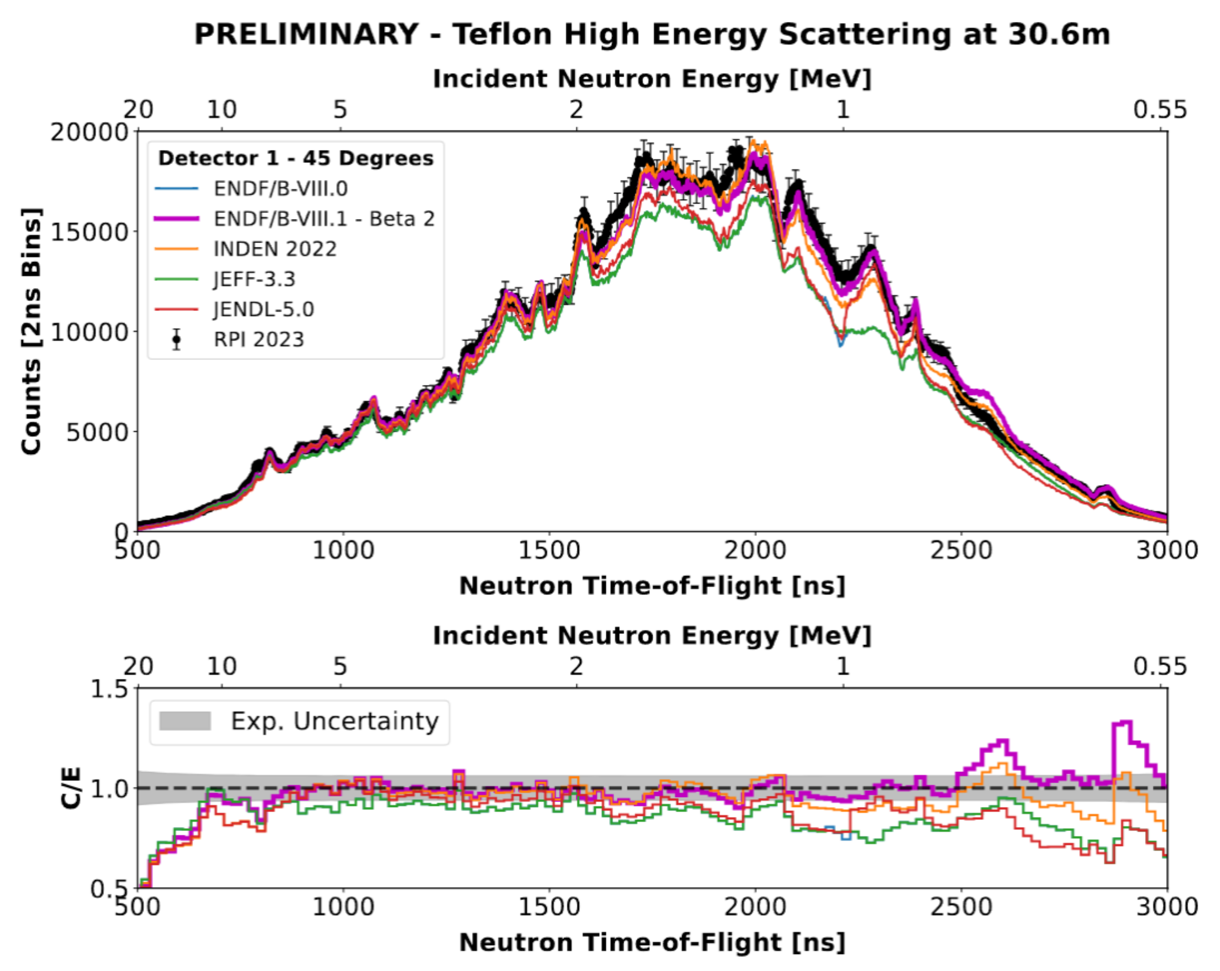


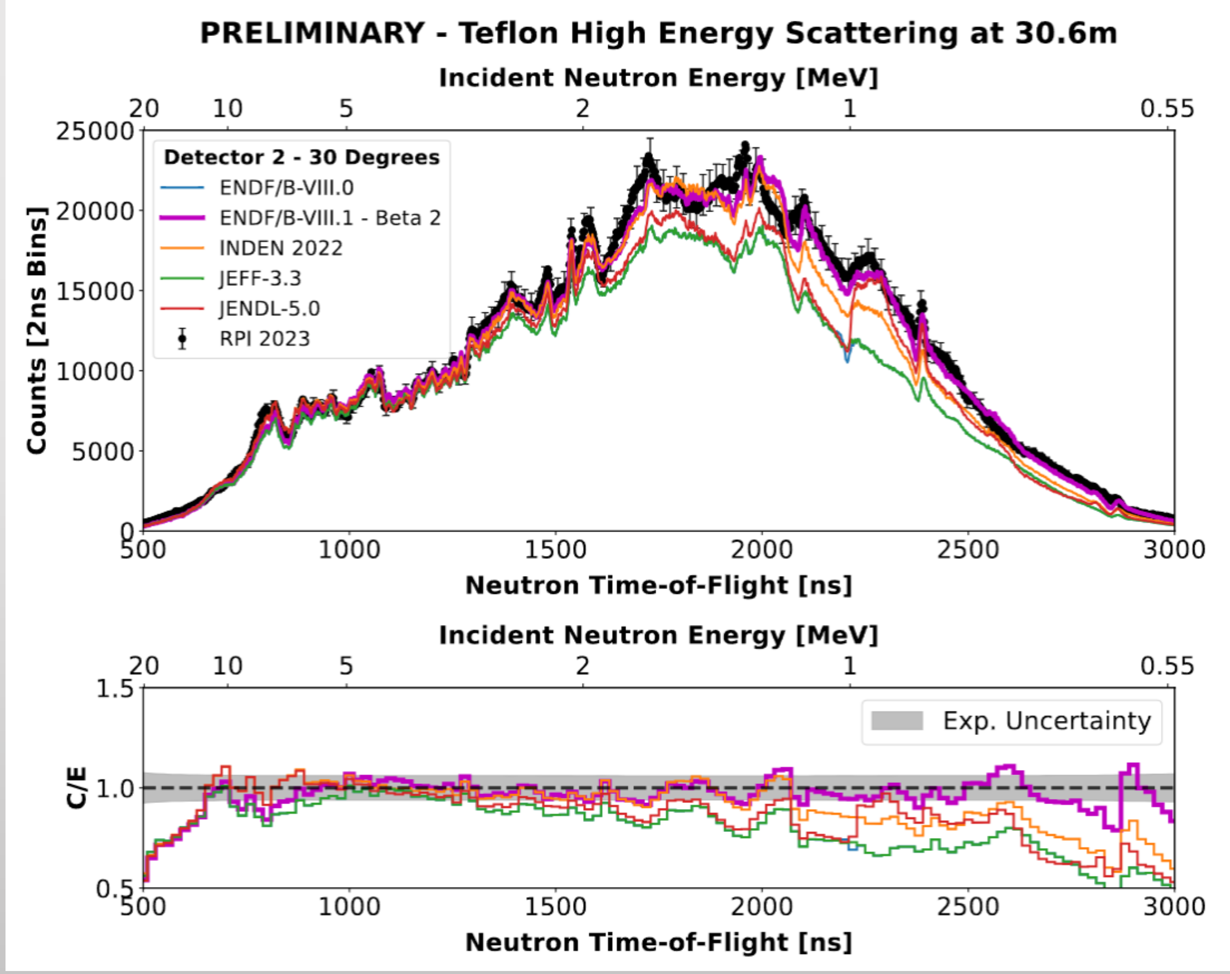
ENDF/B-VIII.I – Beta 2 and JENDL-5.0 show good agreement to experimental data above 2 MeV at back angles. JENDL-5.0 shows best agreement below 2 MeV.





ENDF/B-VIII.I – Beta 2 and INDEN show good agreement to each other, and experimental data at forward angles. Issues observed in specific resonances.





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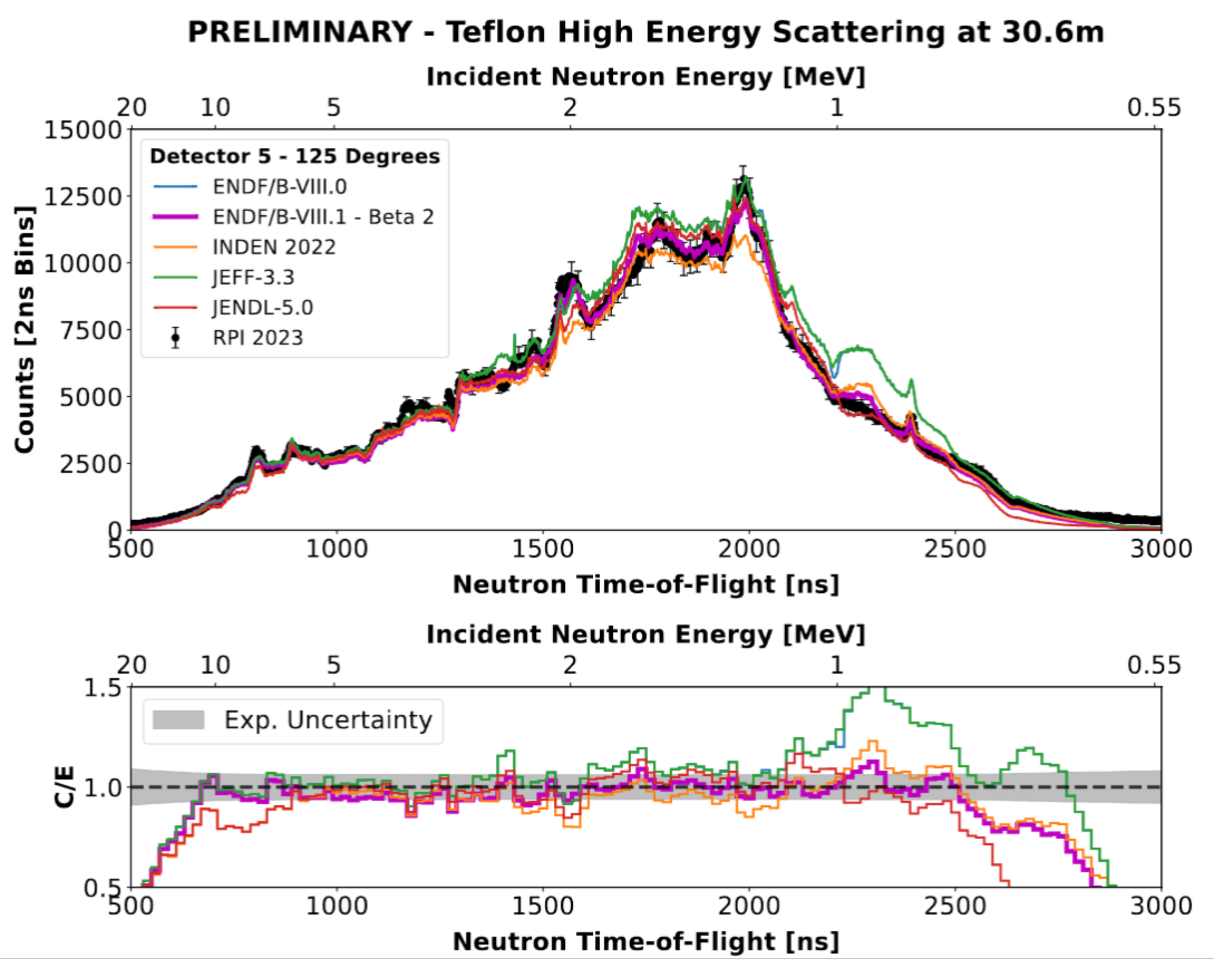
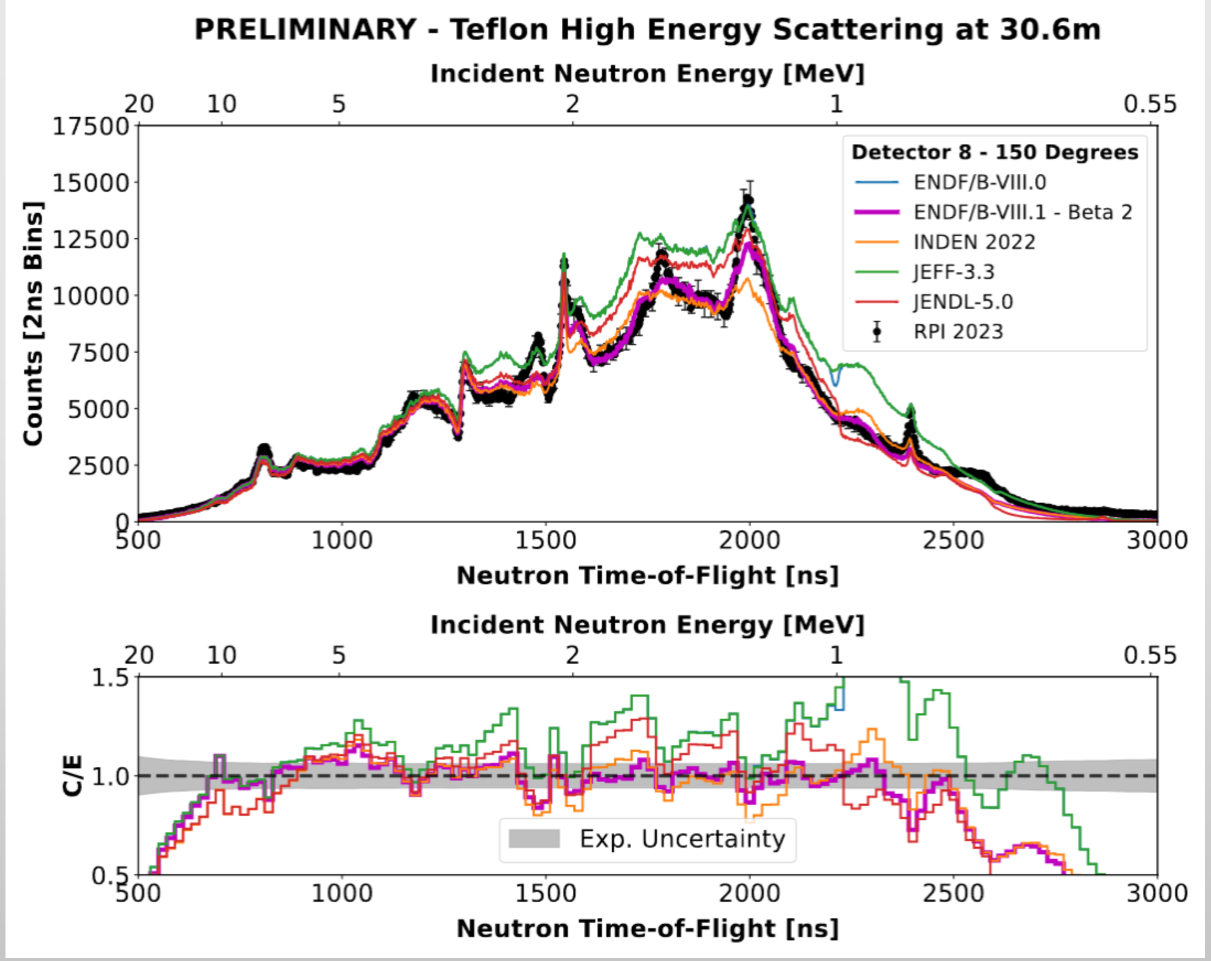




Discussion on **Preliminary** Experimental Findings

- Validation measurement on Carbon sample shows good agreement with evaluation
- **ENDF/B-VIII.1 beta 2 and JENDL-5.0** evaluations observed to have best agreement with experimental **Ta** data
  - Largest improvements seen at back angles
  - Disagreement observed at forward angles with ENDF/B-VIII.I – beta 2 and JENDL – 5.0
  - Disagreements observed at all angles above 10 MeV
- **INDEN and ENDF/B-VIII.1 beta 2** evaluations observed to have best agreement with experimental **Teflon** data
  - General agreement between most evaluations and experimental data seen in forward detectors
  - Back angle detectors highlight issues with angular distributions in resonances at 600 keV, 870 keV, 1.27 MeV, 2.5 MeV, and 3.1 MeV
  - Similar disagreements seen above 10 MeV – suggests data analysis methods issue

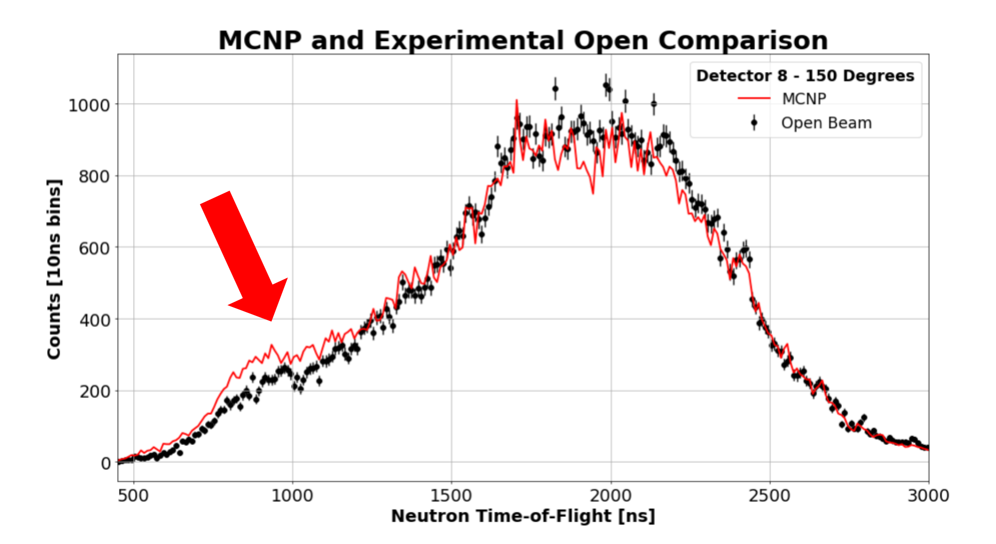
Conclusions and Future Studies

- High energy quasi-differential neutron emission measurements of ^{181}Ta and Teflon have been performed
  - Preliminary results provide validation for ENDF/B-VIII.I ^{181}Ta/ ^{19}F evaluations
  - Preliminary results also show regions to target for improvement of ^{181}Ta /^{19}F evaluations

Coming Soon:

- Improvements to Pulse Shape Discrimination techniques
- Improvements to MCNP modeling
- Improvements to deadtime correction model with digital system
- More investigation of carbon disagreement at low energies, 1.9 MeV, and above 5 MeV
- Journal publications for measurements

Example Area of Improvement



Acknowledgements

This work has been supported in part by:

- U.S. Nuclear Regulatory Commission (NRC-HQ-60-17-G-0006)
- Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the U.S. Department of Energy
- Naval Nuclear Laboratory