

Nuclear Data Measurement and Analysis at RPI

2018 Report at CSEWG

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CSEWG meeting, November 7, 2018 @ BNL

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Summary of Measurements and Analysis

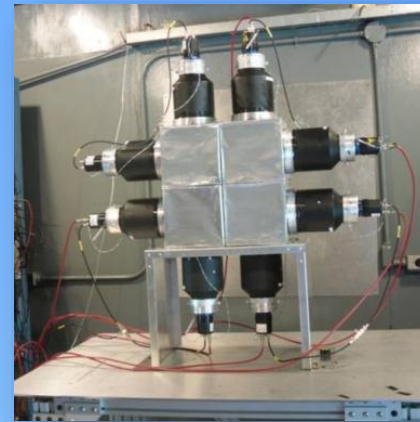
- Completed Measurements:
 - Capture: **Ta** - 10 eV - 100 keV, 45m flight path
 - Transmission: **Hf** - 0.5 – 20 MeV, 100m flight path
 - Scattering: **Cu** – 0.5 – 20 MeV neutron scattering and angular distributions
- Data analysis:

Measured	Sample	Status
High Energy 0.5 – 20 MeV	Ti, Ta, Zr, ⁵⁶ Fe, W, Cu, Pb, Hf	Submitted to NSE. Transmission, Internal report in progress. Data analysis in progress.
RRR and URR Transmission, Capture and fission	Cs ^{98,100} Mo Ta	R. C. Block, et al., Accepted to NSE K. E. Remley et al., Annals of Nuclear Energy, vol. 122, pp. 23 - 36, 2018 Transmission and capture data analysis in progress
Scattering	Cu Zr ²³⁵ U, ²³⁹ Pu	Data analysis in progress KeV scattering system construction in final stages. Progress was presented in recent WINS meeting. RPI will host the next one in 2020. Measurements at LANL completed, Analysis in progress.
Thermal Scattering	Polyethylene Lucite Quartz Ice	Kemal Ramic et al., Annals of Nuclear Energy, vol. 120, pp. 778 - 787, 2018 Kemal Ramic et al., Submitted for publication Completed Ramic PhD thesis. Completed Ramic PhD thesis.
PFNS	²⁵² Cf	Analysis of E _n >7 MeV data in progress



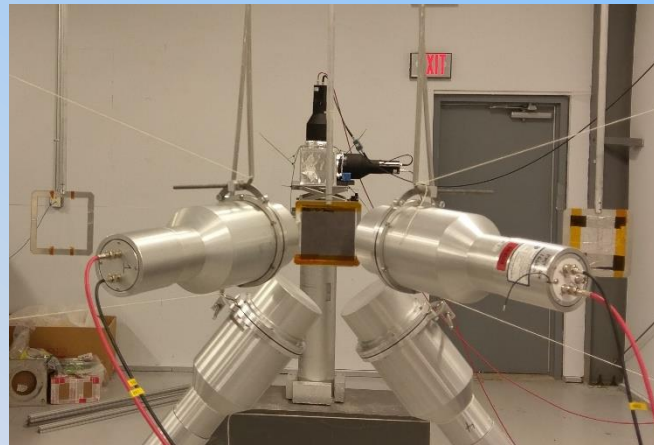


35 m Li-Glass Neutron Detector



100 m modular Li-Glass Neutron Detector

Resonance Region Measurements

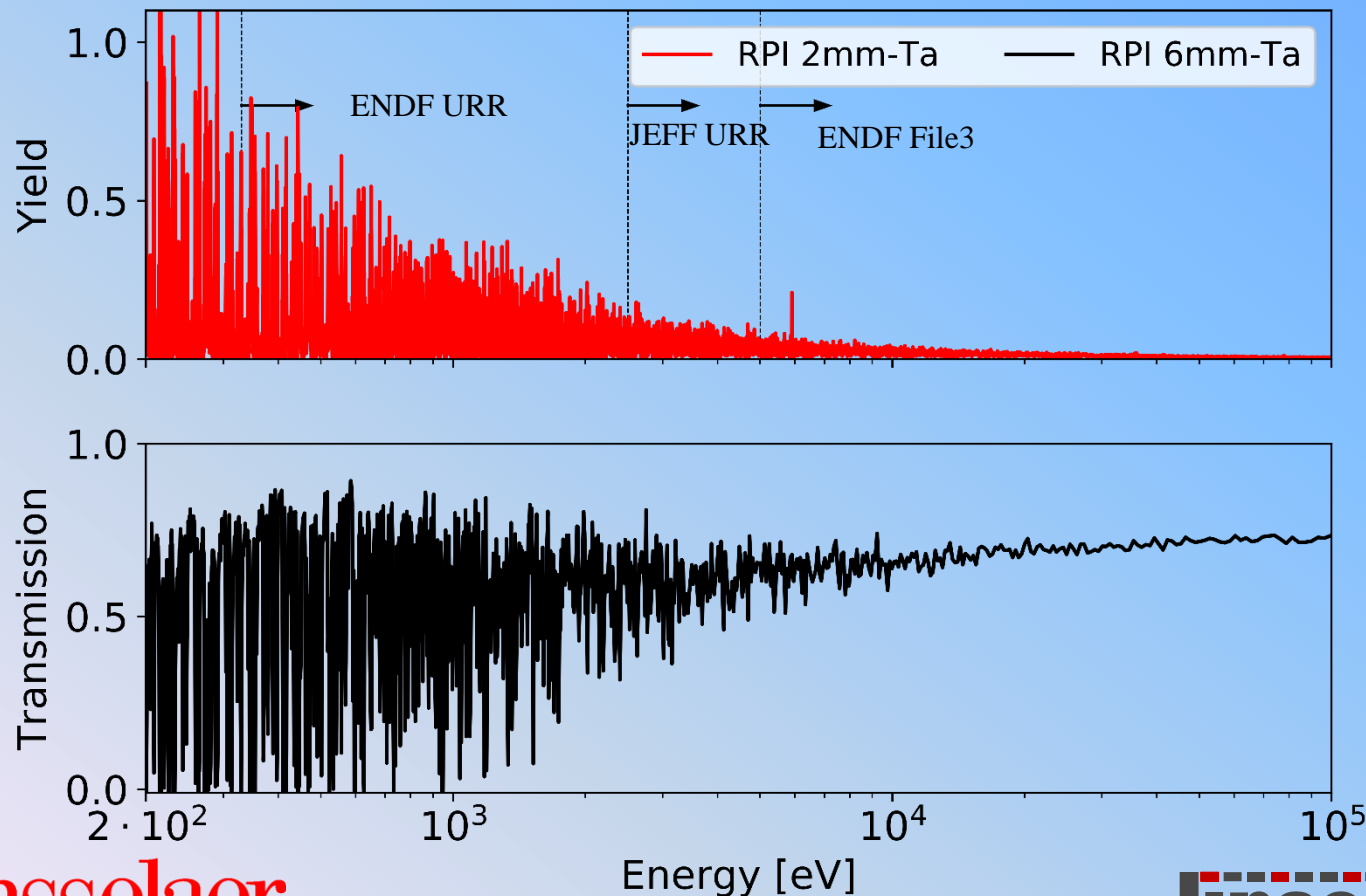


45 m capture detector array



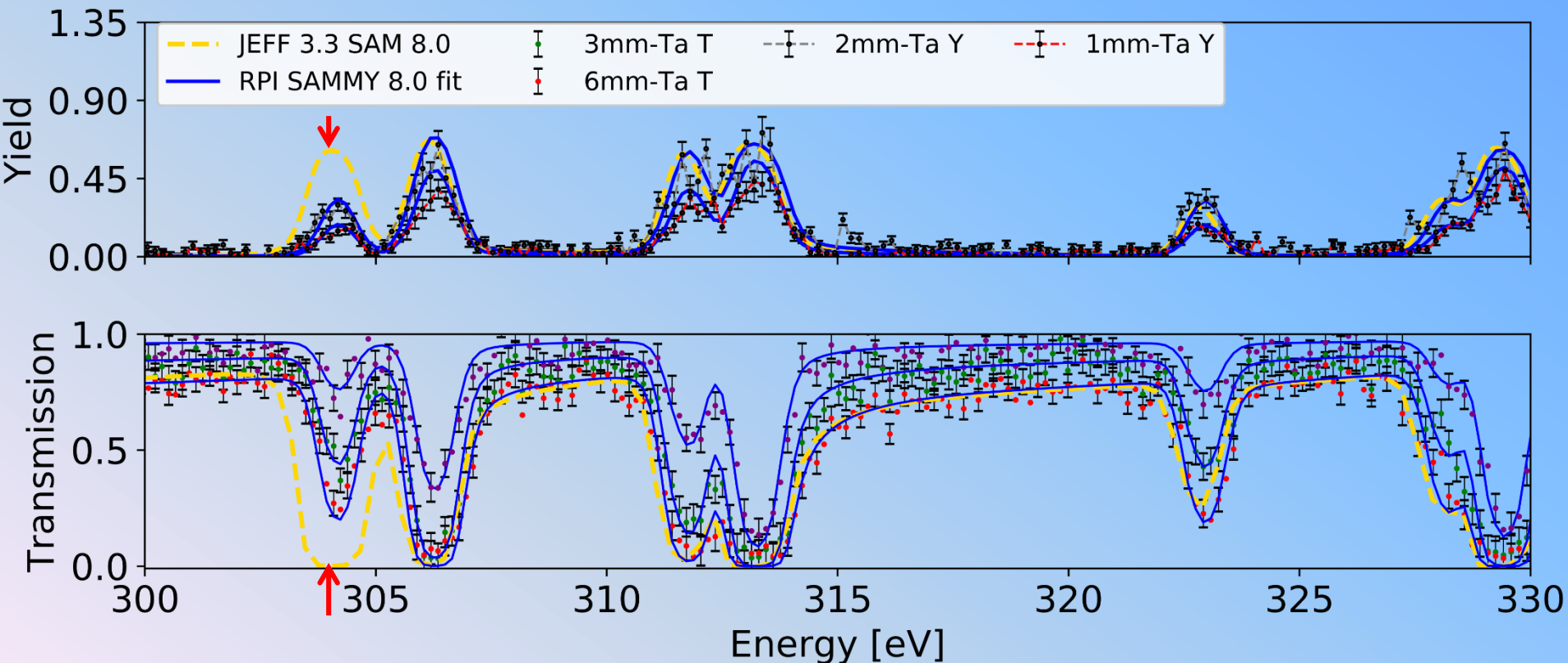
Ta Transmission and Capture Measurements

- Used 100m flight station for transmission and 45m for capture
 - Sample thicknesses included: 1, 3, 6 mm Ta.
- High resolution data resolving resonance structure up to 10 keV
- URR self-shielding test using transmission through a thick 12mm Ta sample



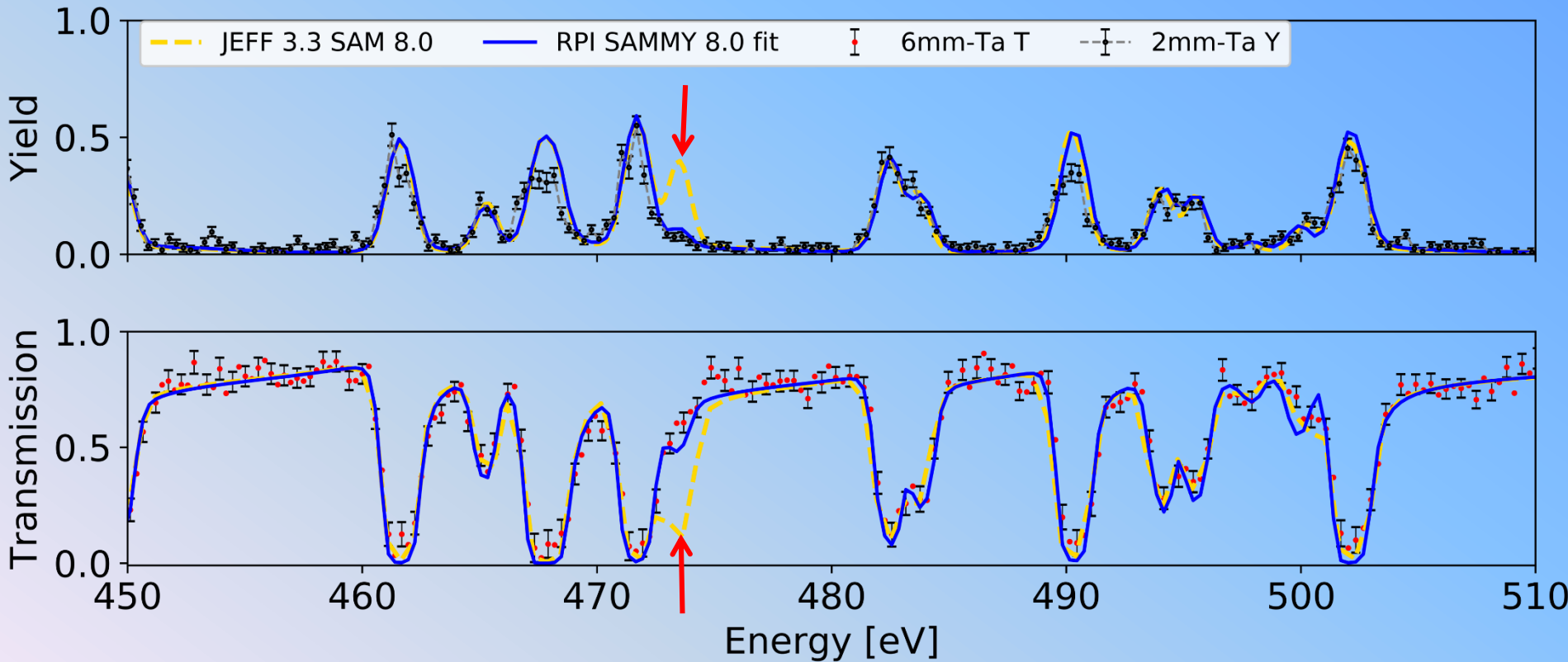
Ta results: RRR

- Generally the experiment is in better agreement with JEFF-3.2/JENDL-4.0 compared to ENDF/B-VIII.0.
- Some discrepancies with JEFF-3.2/JENDL-4.0



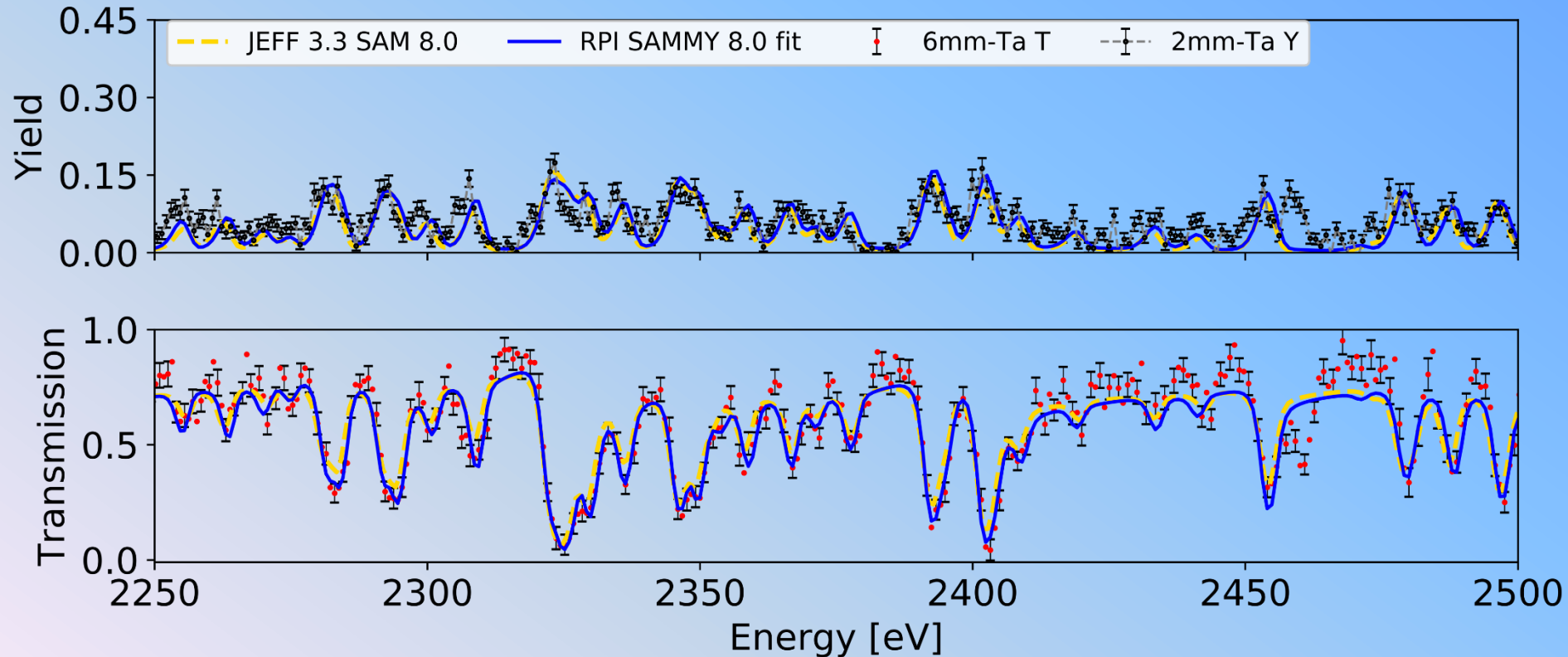
Ta results: RRR

- Above 330 eV (end of ENDF/B-VIII RRR) strong resonances are still well resolved in both transmission and capture experiments



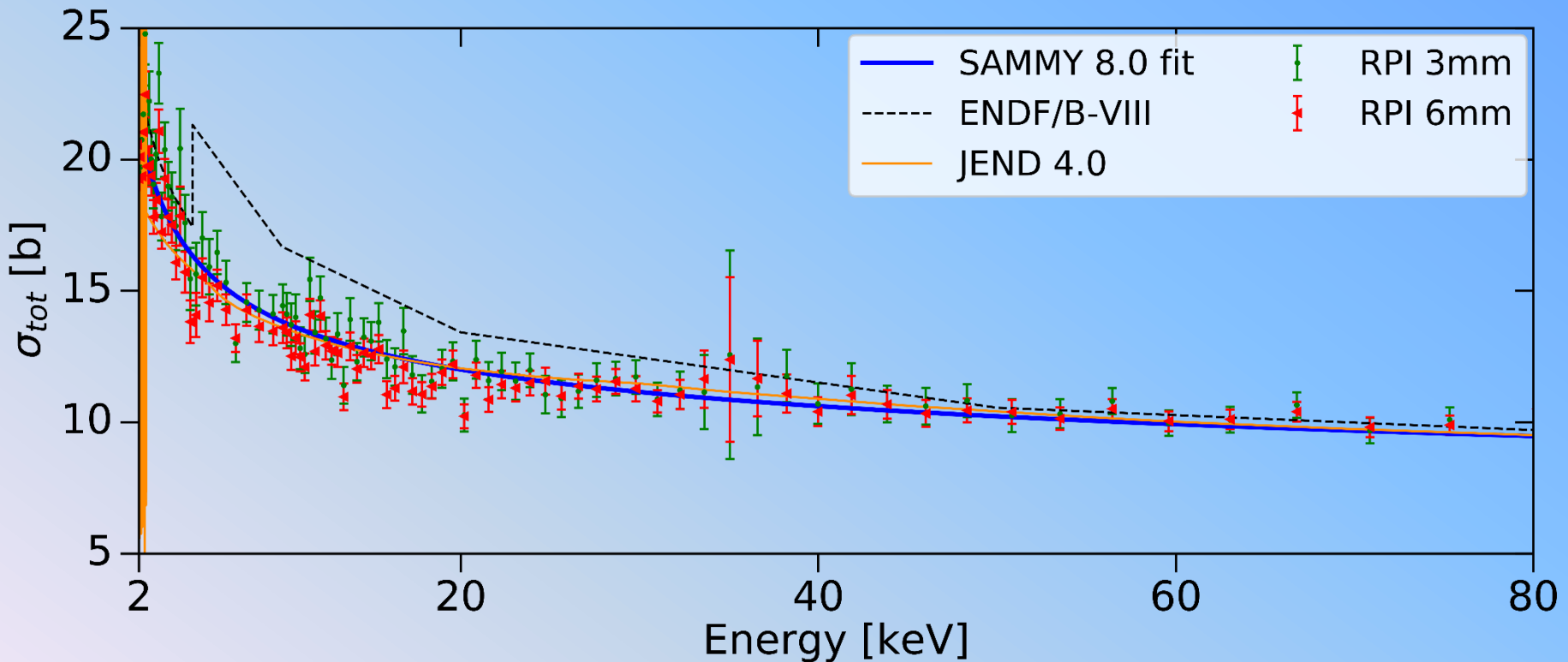
Results: RRR

- At the end of JEFF RRR treatment recreates the cross section reasonably well
- However, weak resonances could easily be missed



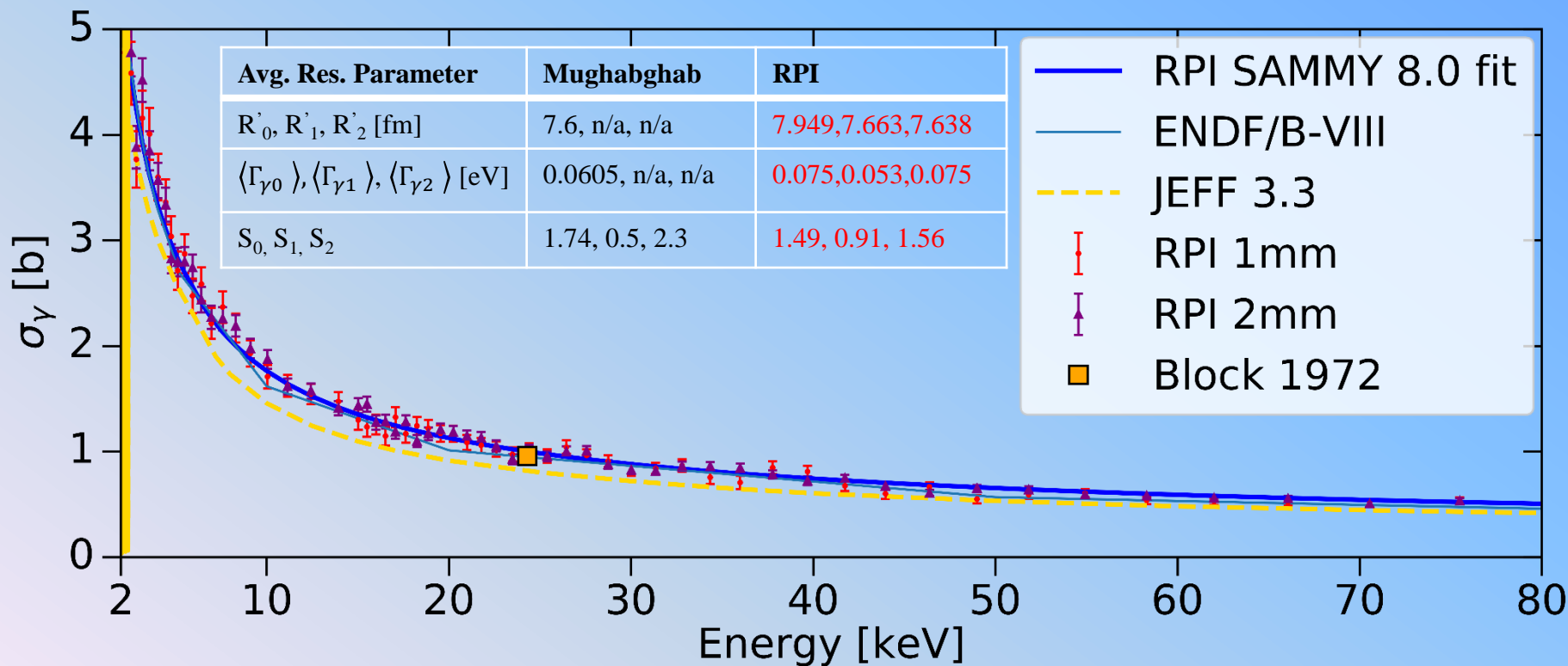
Ta results: URR σ_t

- SAMMY/FITACS total cross section matches JEFF & JENDL evaluation for a URR treatment between 2-80 keV



Results: URR σ_γ

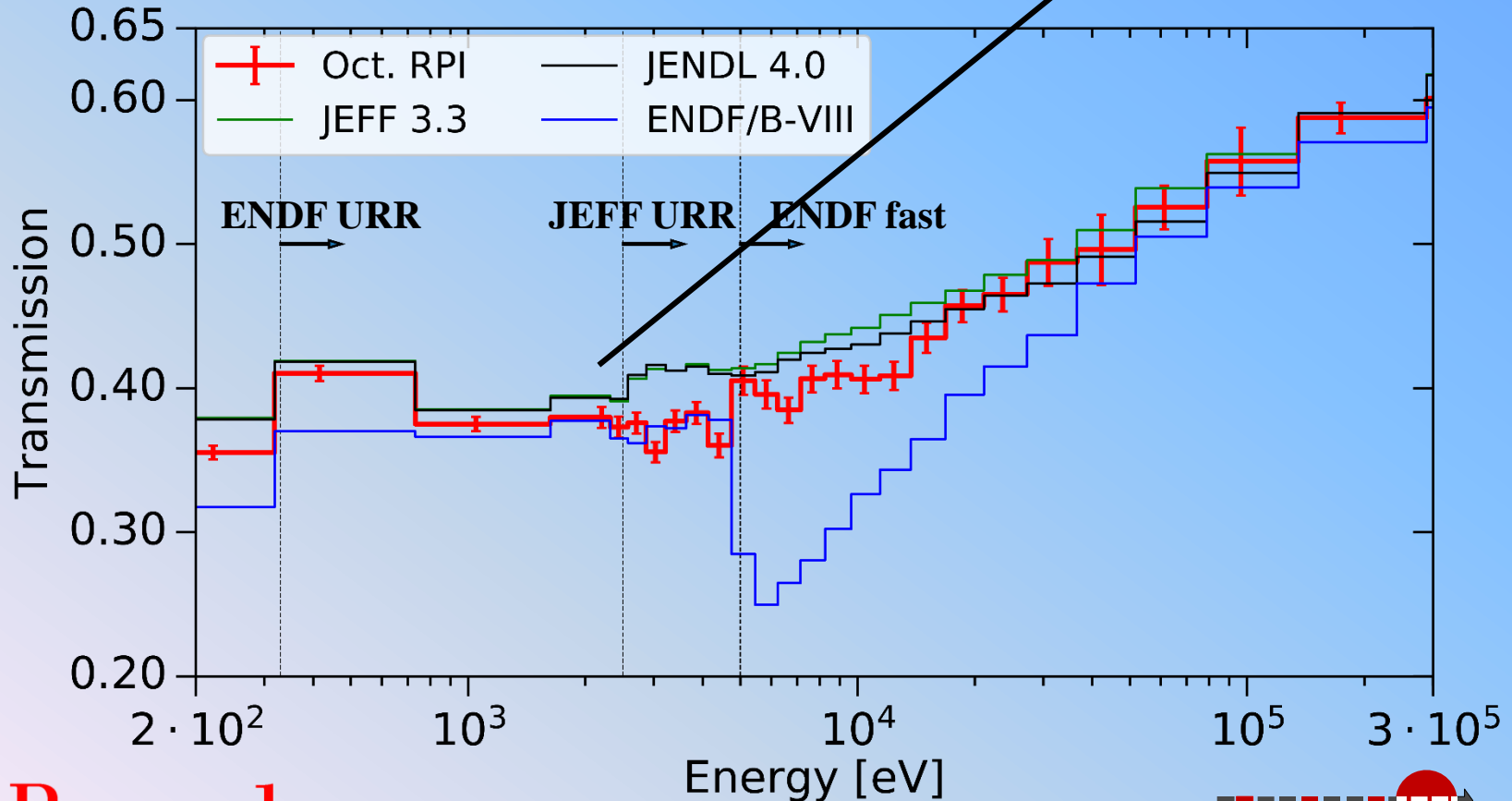
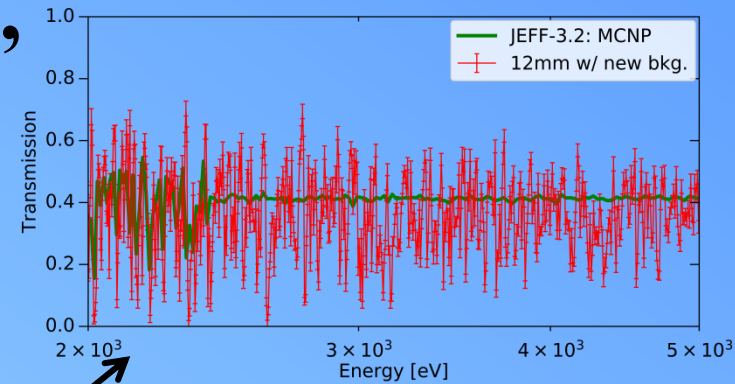
- Capture cross section is higher than JEFF & JENDL evaluation for a URR treatment between 2-80 keV, closer to ENDF/B-VIII
- Agrees with trusted RPI measurement at 25 keV by Block



Self-Shielding “Benchmark”

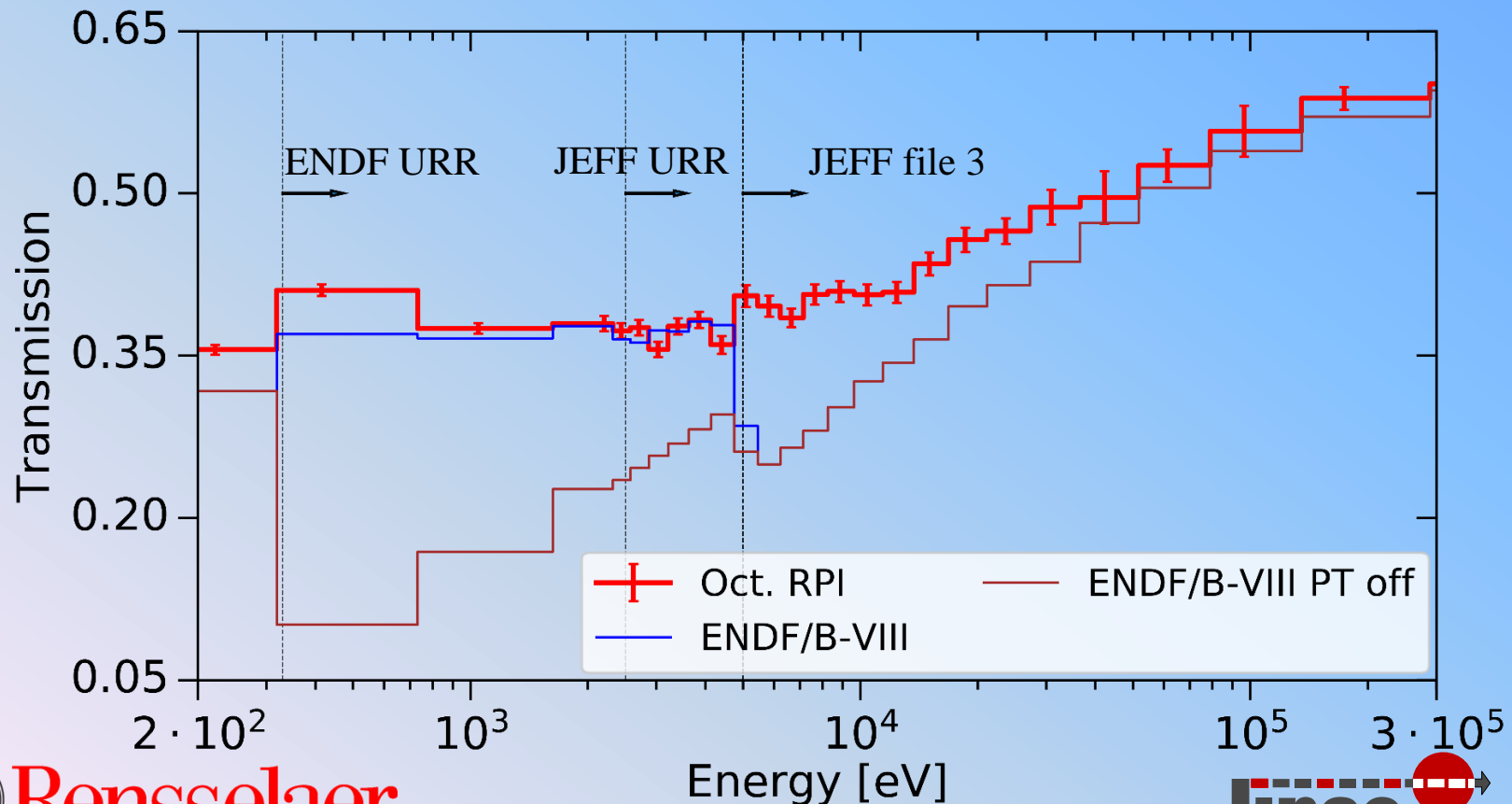
(Transmission through a thick sample)

- Test URR treatment
- ENDF is performing poorly



Resonance Self-Shielding effect

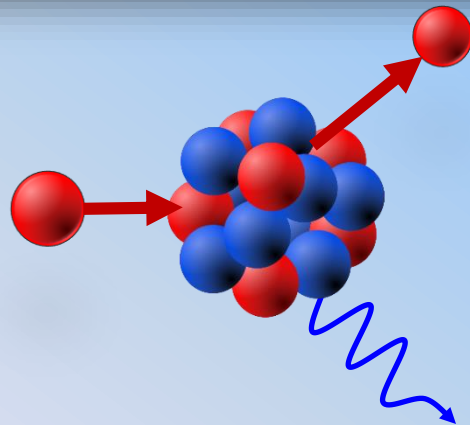
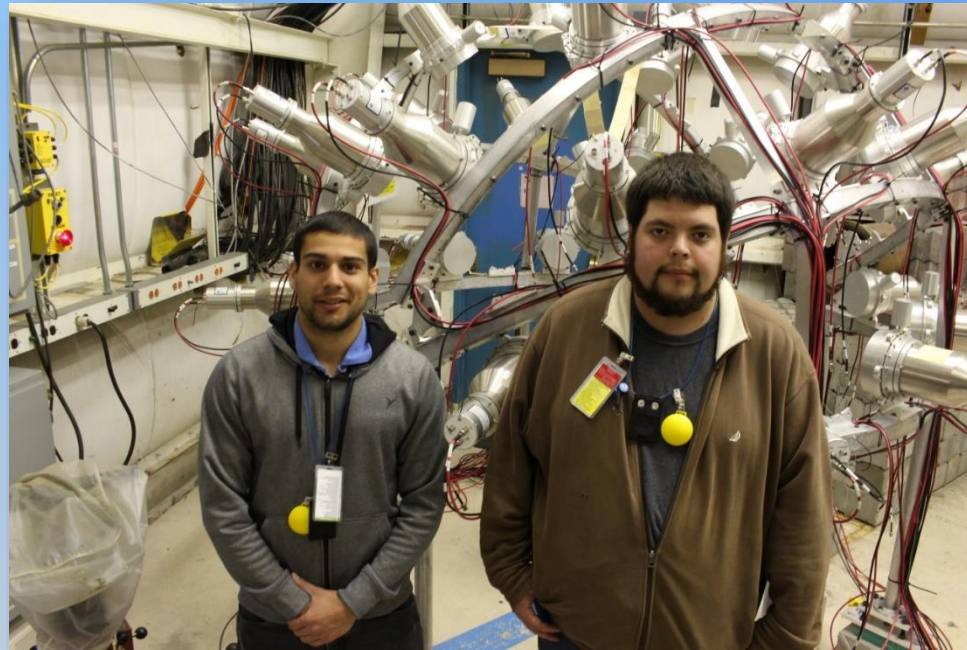
- The effect of self shielding is shown by turning off the URR treatment in MCNP
- Near 400 eV self-shielding reduces the transmission by a factor of about 4.
Considering such large effect, the evaluations are reasonable but the new data will help improve



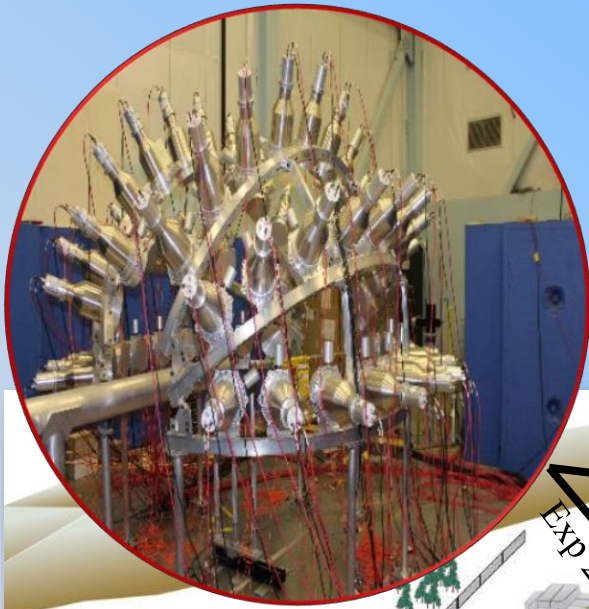
Fast Neutron Scattering



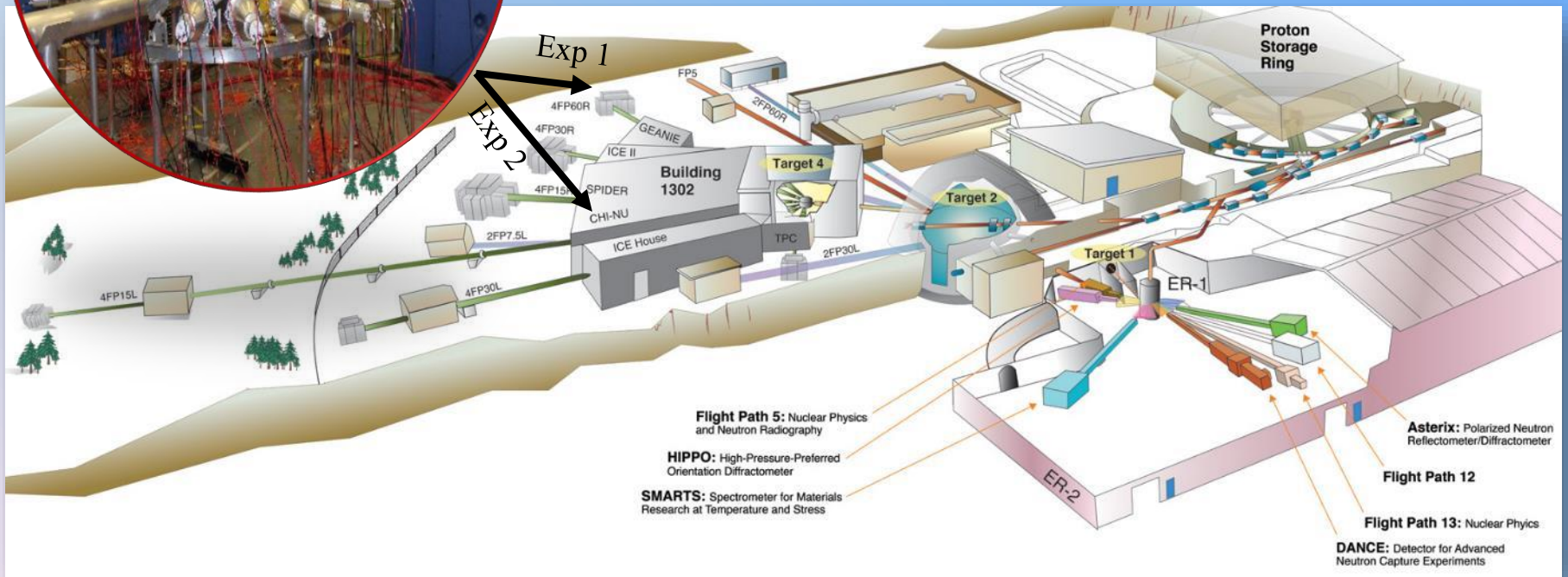
^{235}U and ^{239}Pu Quasi Differential Neutron Induced Neutron Emission at WNR



Experimental Setup at LANL

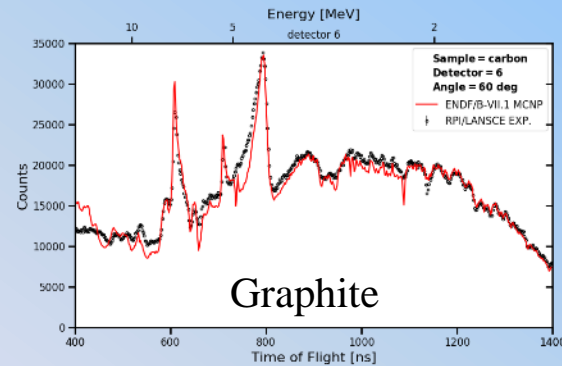
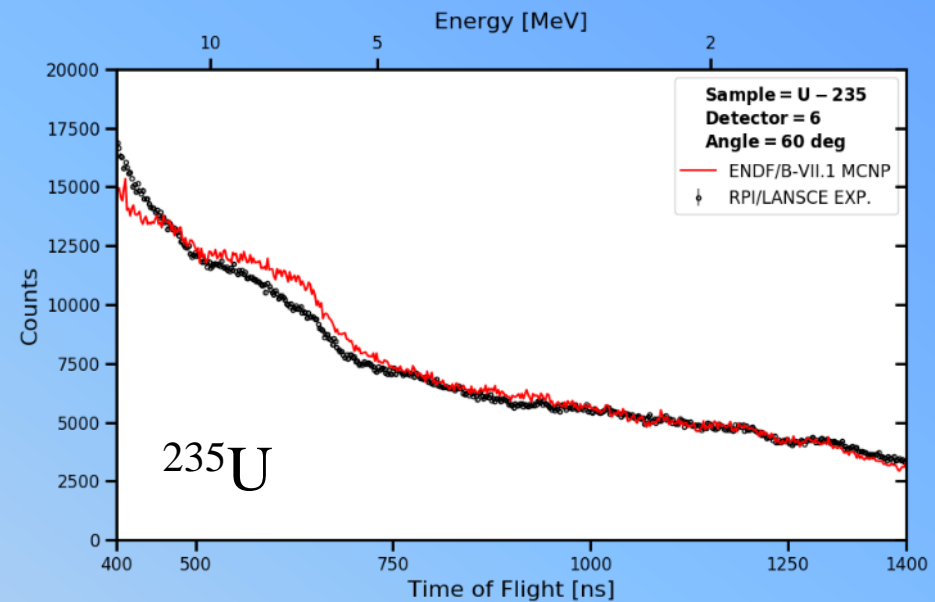
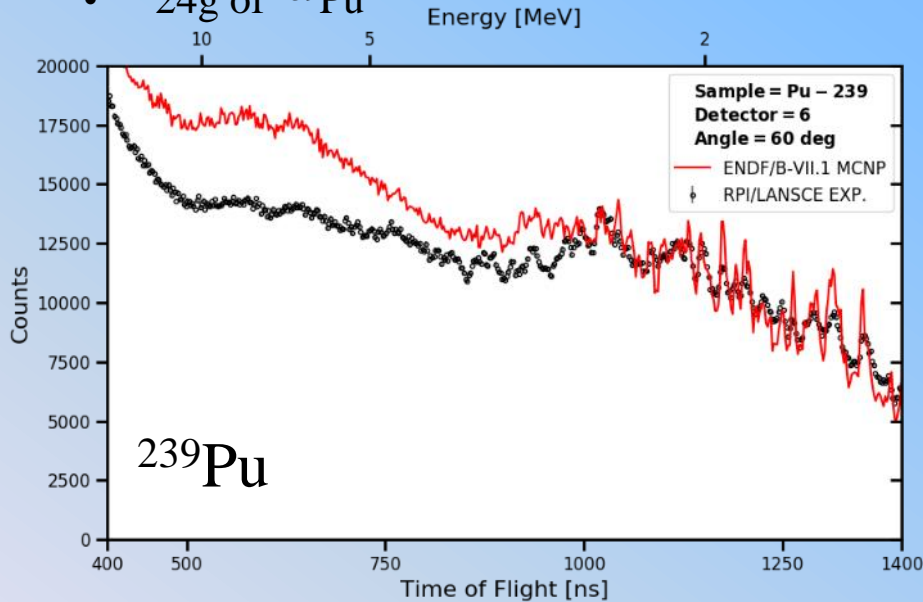


- **Motivation U-235 and Pu-239**
- Used the Chi Nu EJ-309 detector array
 - 54 detectors, arranged in 2 “quarter-spheres”
 - 9 detector slots per row starting at 30 degrees spaced 15 degrees apart spanning 150 degrees encompassing the sample
- Detectors were connected to digitizers
 - Pulse shape analysis using long and short gate
 - Full event pulse was also saved



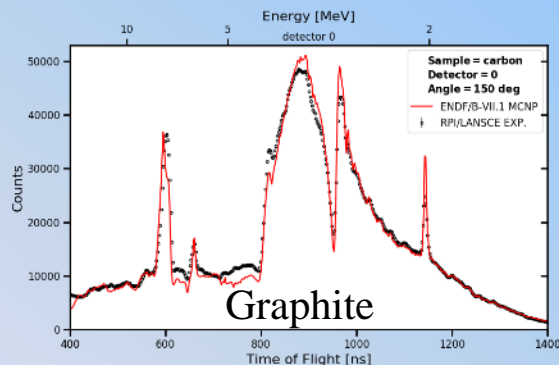
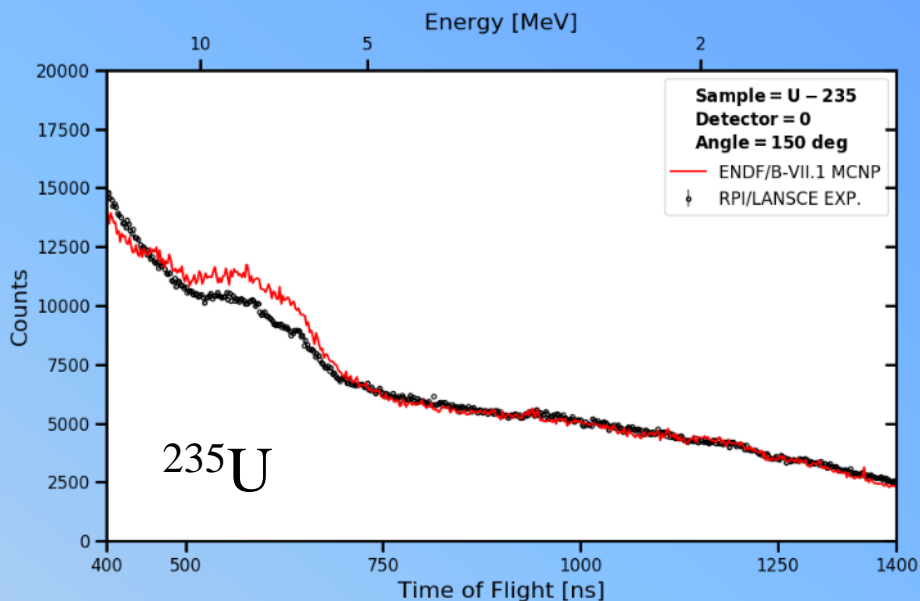
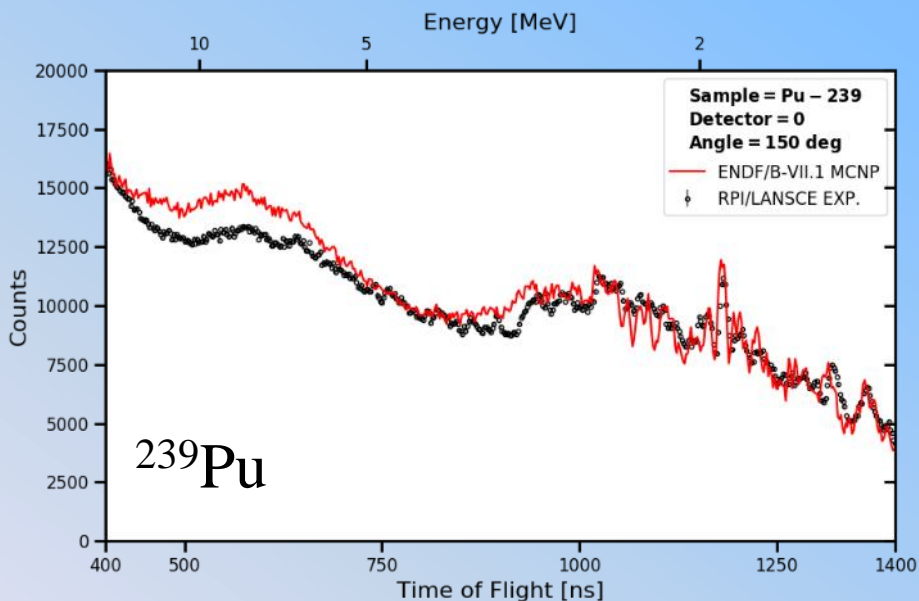
Preliminary Results – ^{235}U and ^{239}Pu at 60 deg

- 49.5 g of U enriched to 93% ^{235}U ,
- 24g of ^{239}Pu



Preliminary Results – ^{235}U and ^{239}Pu at 150 deg

- Similar results at back scattering angles, possible issues with both ^{235}U and ^{239}Pu



Thermal Scattering

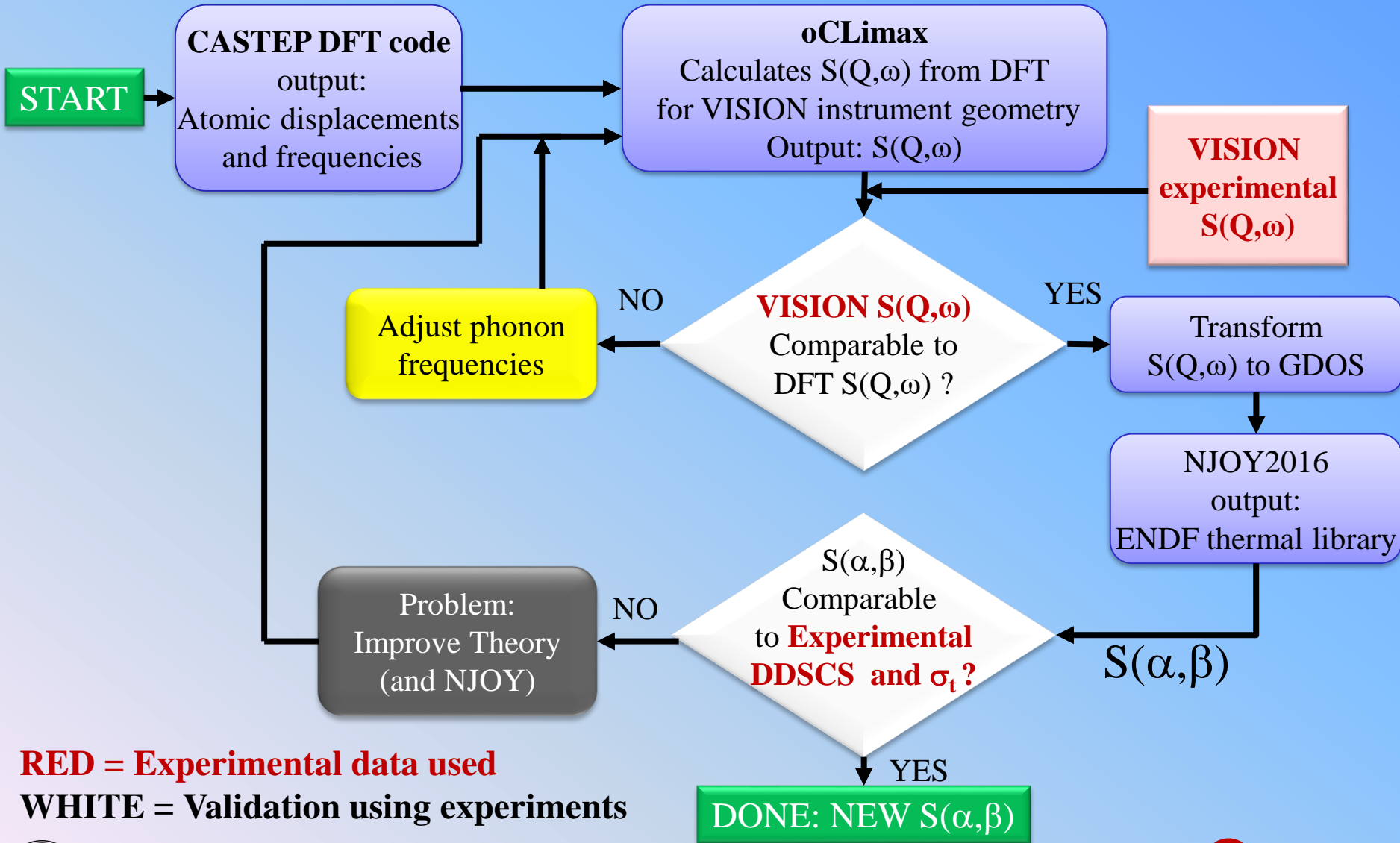


Completed Experiments

Moderators	SEQUOIA (Ω : 3-58° in 1° increments)	ARCS (Ω : 3-125° in 1° increments)	VISION (at 5 K)
Light Water (H ₂ O)	E _f : 55, 160, 250, 600, 1000, 3000, 5000 meV Temp: 300 K		YES
Polyethylene (CH ₂)	E _f : 55, 160, 250, 600, 1000, 3000, 5000 meV Temp: 300 K	E _f : 50, 100, 250, 700 meV Temp: 5, 295 K	YES
Quartz (SiO ₂)		E _f : 50, 100, 250, 700 meV Temp: 5, 295, 573, 823, 873 K Thickness: 3.175, 6.35 mm	YES
Teflon ((C ₂ F ₄) _n)		E _f : 50, 100, 250, 700 meV Temp: 5, 300, 500 K	NO
Lucite (C ₅ O ₂ H ₈)		E _i : 50, 100, 250, 700 meV Temp: 5, 300, 400 K	YES
Concrete (mixture)		E _i : 50, 100, 250, 700 meV Temp: 5, 300 K	NO



Thermal scattering – evaluation methodology



RED = Experimental data used

WHITE = Validation using experiments

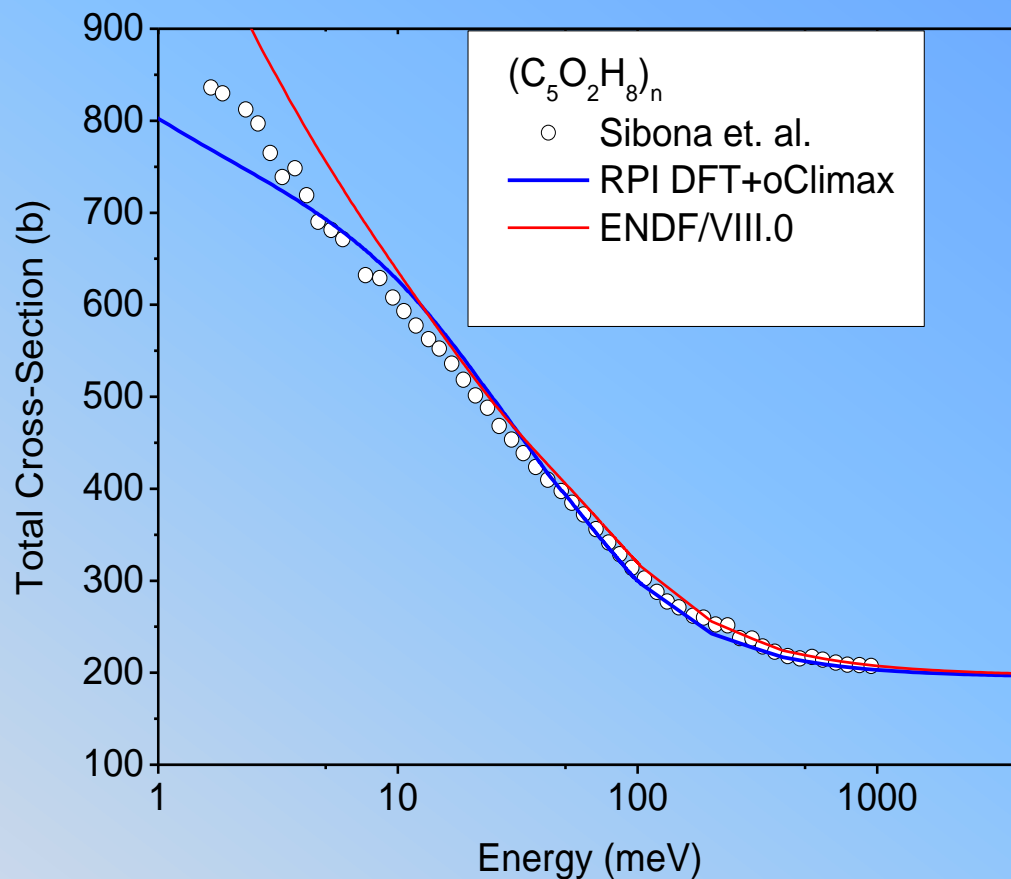
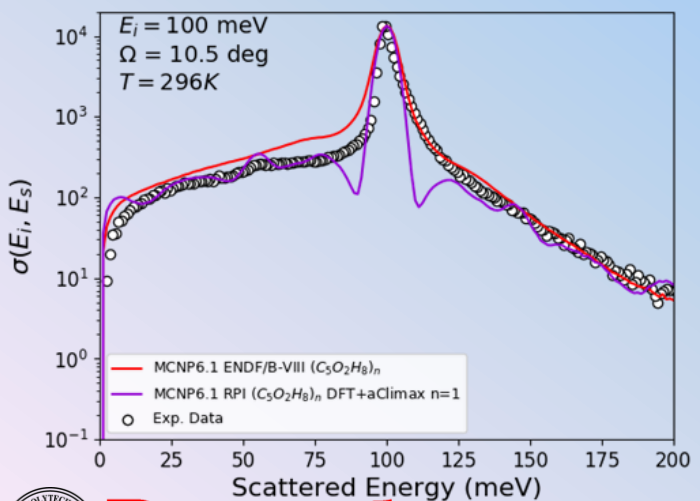
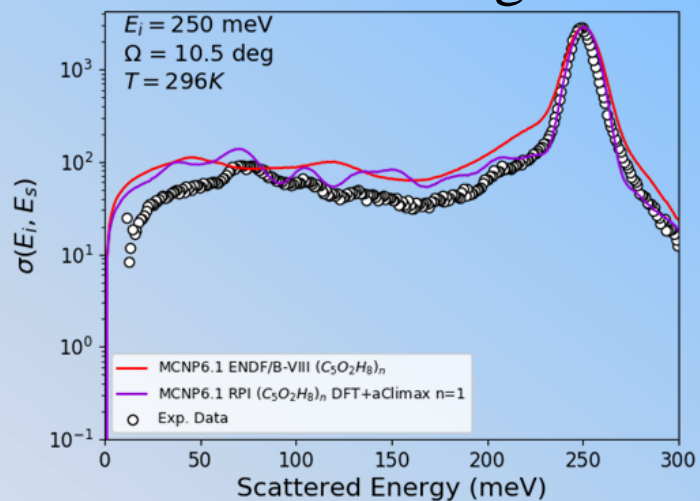
Completed Evaluations

- H and C in C_2H_4 (polyethylene)
- H, C and O in C in $C_5O_2H_8$ (Lucite)
- H and O in ice
- Si and O in quartz

- NJOY 2016 input files and ENDF $S(\alpha,\beta)$ files are available for testing
 - Quartz requires modifications to NJOY that are documented in K. Ramic's PhD thesis

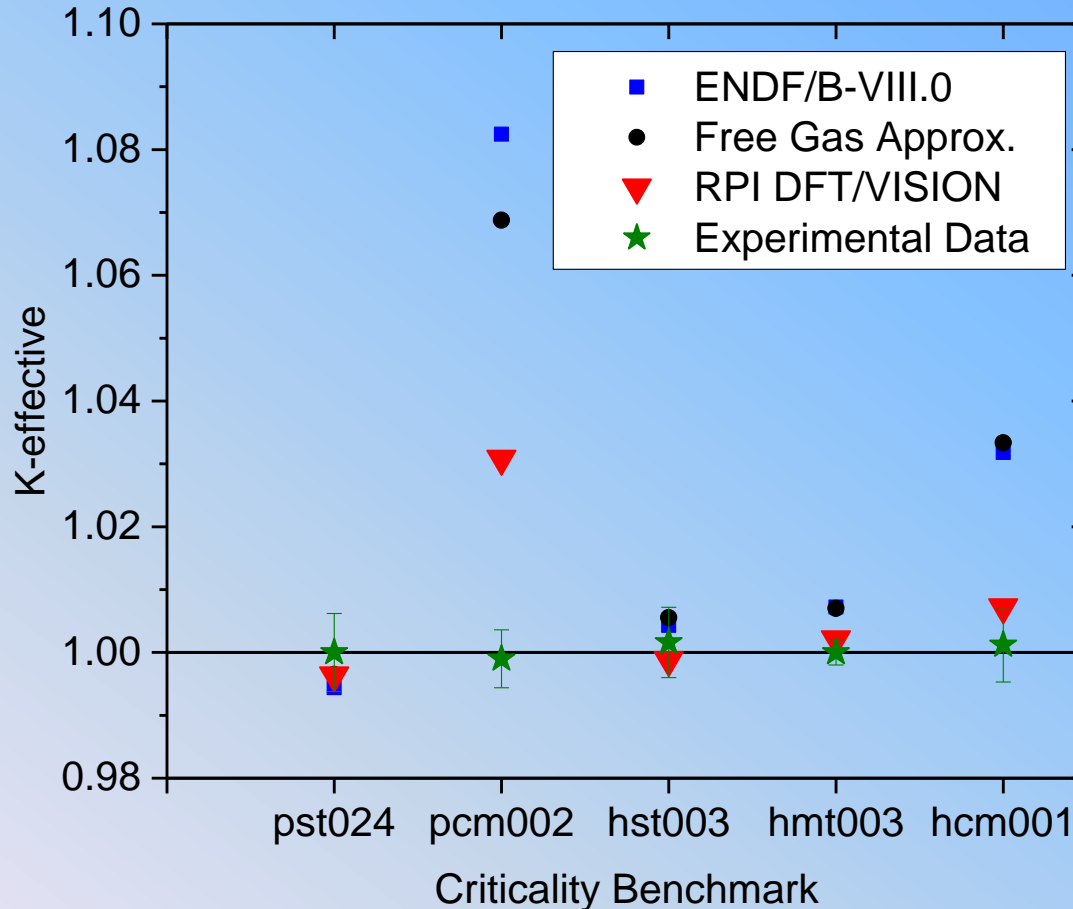
Lucite ($C_5O_2H_8$) DDSCS

- ENDF/B-VIII.0 gives better representation of inelastic region



Lucite Criticality Benchmarks

- RPI TSL file represents a clear improvement to K-effective
- ENDF/B-VIII.0 is similar to free gas treatment



Summary

- Cs paper accepted for publication.
- Analysis of Ta transmission and capture is in progress.
 - SAMMY was modified to handle a weighting function (required for analysis of capture data performed using C_6D_6 gamma detectors)
- Analysis of ^{235}U and ^{239}Pu neutron induced neutron emission is in progress
- Thermal scattering evaluations for polyethylene, quartz, Lucite, and ice were completed.