Recent Nuclear Data Research at RPI

2017 Report at CSEWG

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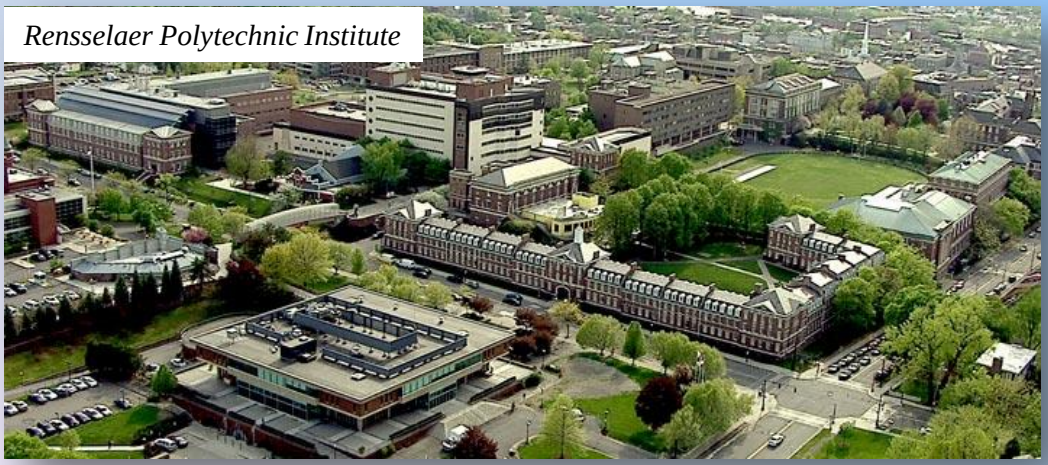
Rensselaer Polytechnic Institute



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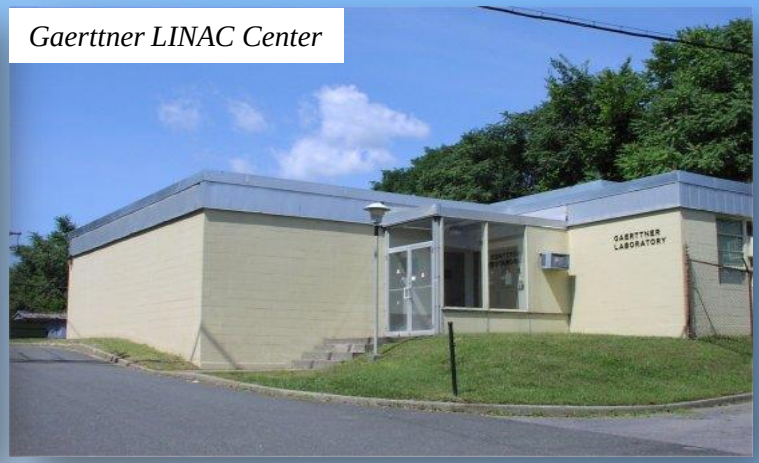

CSEWG meeting, November 8, 2017 at BNL

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Summary of measurements and analysis

- **Completed Measurements**
  - **Capture**
    - Ta - 10 eV - 100 keV, 45m flight path
  - **Transmission**
    - Ta – 10 eV – 100 keV, 100m flight path
- Data analysis:

Measured	Sample	Status
High Energy 0.5 – 20 MeV	Ti, Ta, Zr, ^{56}Fe, W, Cu, Pb	Publication in internal review. Transmission, Internal report in progress.
RRR and URR **Transmission, Capture and fission**	Cs Re Ta ^{164}Dy ^{161,162,163,164}Dy $^{92/94,95,96,98,100,nat}$Mo Cd ^{235}U ^{252}Cf	Resonance analysis in progress. B. E. Epping, et al. Progress in Nuclear Energy, vol. 99, pp. 59 - 72, 2017. B. J. McDermott, et al., Phys. Rev. C, vol. 96, pp. 014607, Jul 2017. R. C. Block, et al., Prog. Nucl. Energy, vol. 94, pp. 126-132, jan 2017 S.G. Shin et al., Eur. Phys. J. A vol. 53 pp.203, 2017 ^{96}Mo – J. M. Brown et al., published in AccApp 2017. Leinweber e al., published in AccApp 2017. Y. Danon, et al., Nuclear Science and Engineering, vol. 187, no. 3, pp. 291-301, 2017. E. Blain, et al. Phys. Rev. C, vol. 95, pp. 064615, Jun 2017.
Scattering	Fe	A. M. Daskalakis, at al., Annals of Nuclear Energy, vol. 110, pp. 603 - 612, 2017.
LSDS	Ta, Ni, Ag, Nb, Sn, Zr, In, Co, Mo, C	Capture rates, Nicholas Thompson, PhD thesis.
Thermal Scattering	polyethylene quartz Lucite	Publication under internal review Analysis in progress Analysis in progress

Resonance Region Measurements

Cs capture and total cross section

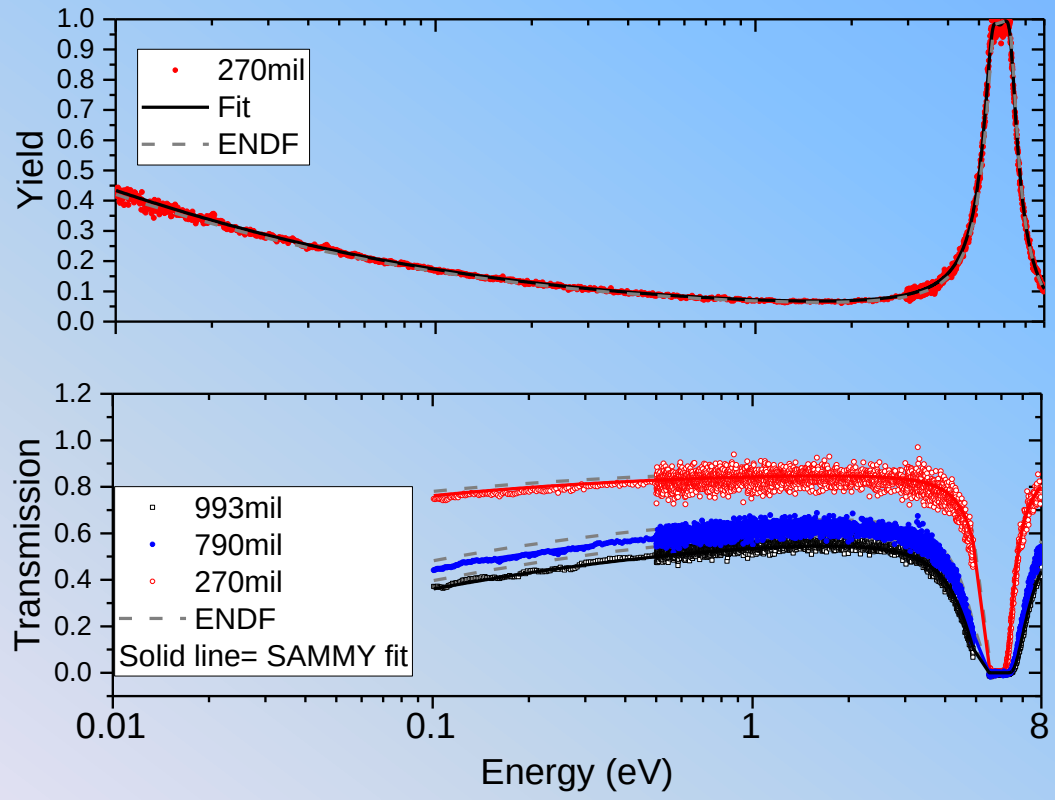
- Cs has one isotope; Cs-133

- Use CsF crystals with several thicknesses for the thermal region (0.01 – 25 e)
  - Bragg peaks prevented analysis of total cross section below 0.1 eV
  - In the SAMMY analysis ENDF/B-VII.1 value for F was used.

- Used Cs_2CO_3 liquids for the low resonance region
  - In the SAMMY analysis ENDF/B-VII.1 values for C and O were used.
  - Use D_2O filled quartz cells as blank for both transmission and capture.

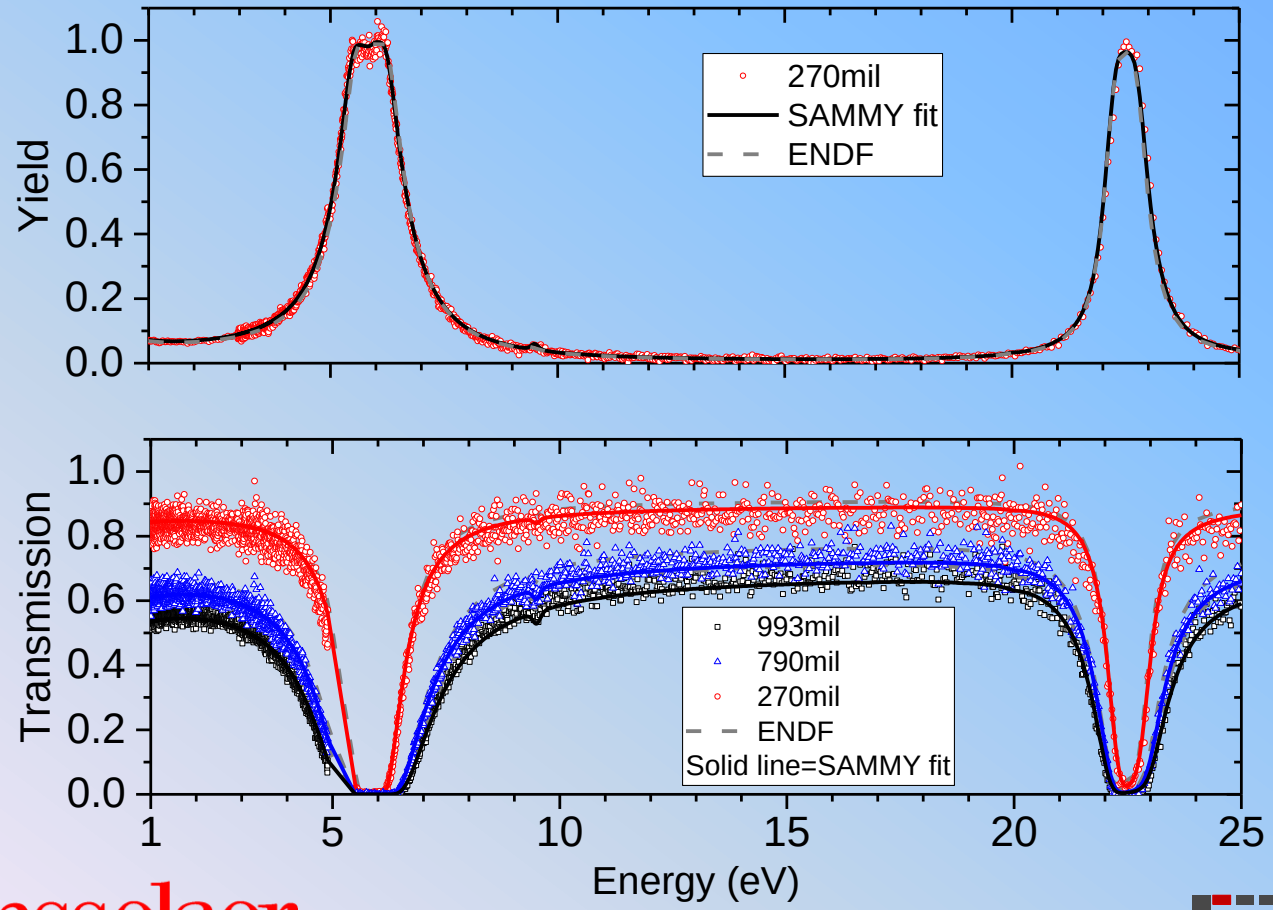
CsF thermal data

- Capture is in good agreement with ENDF/B-VII.1
- For E< 1 eV the total cross section is higher by about 10% compared to ENDF/B-VII.1
  - Thus scattering was increased



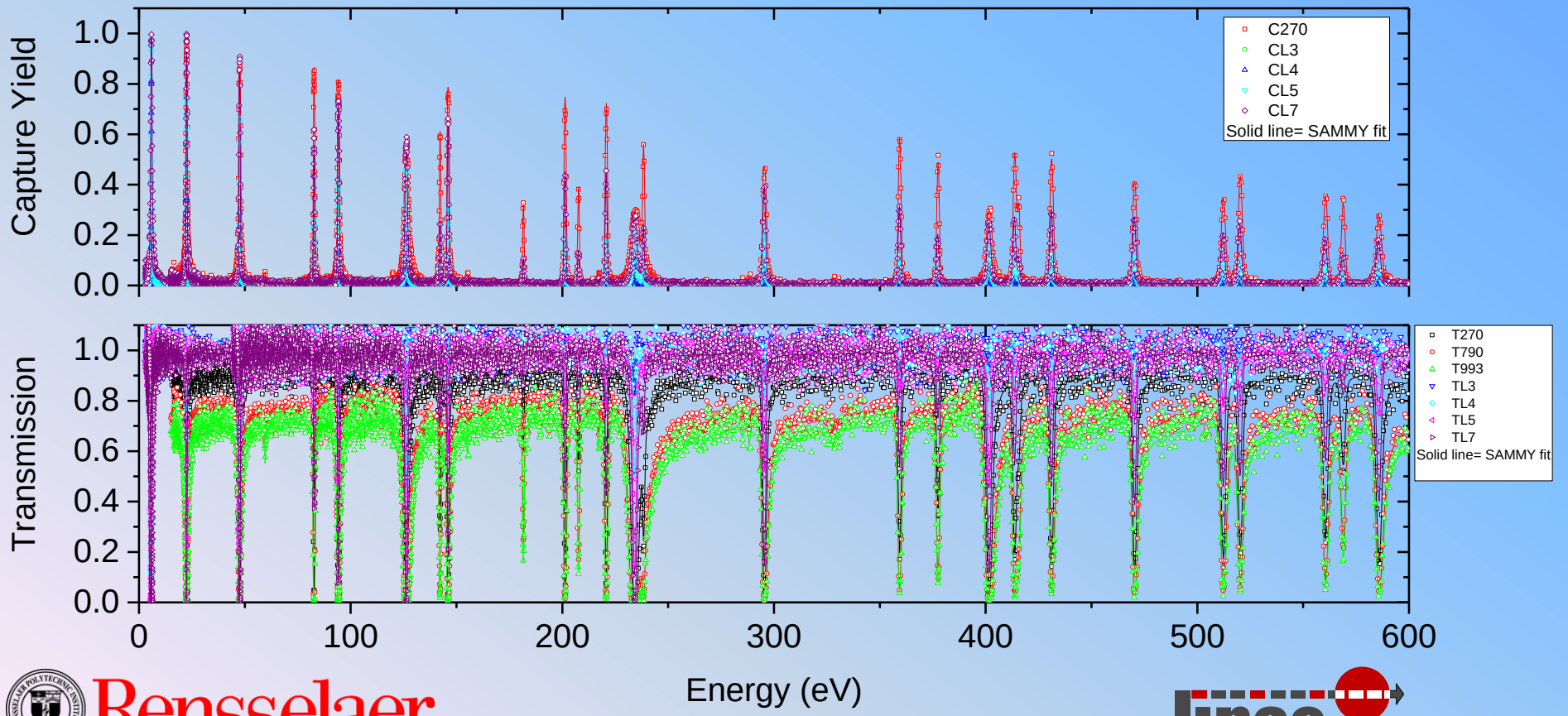
CsF low-energy resonance region

- Overall good agreement with ENDF/B-VII.1
- Slightly higher cross section between resonances



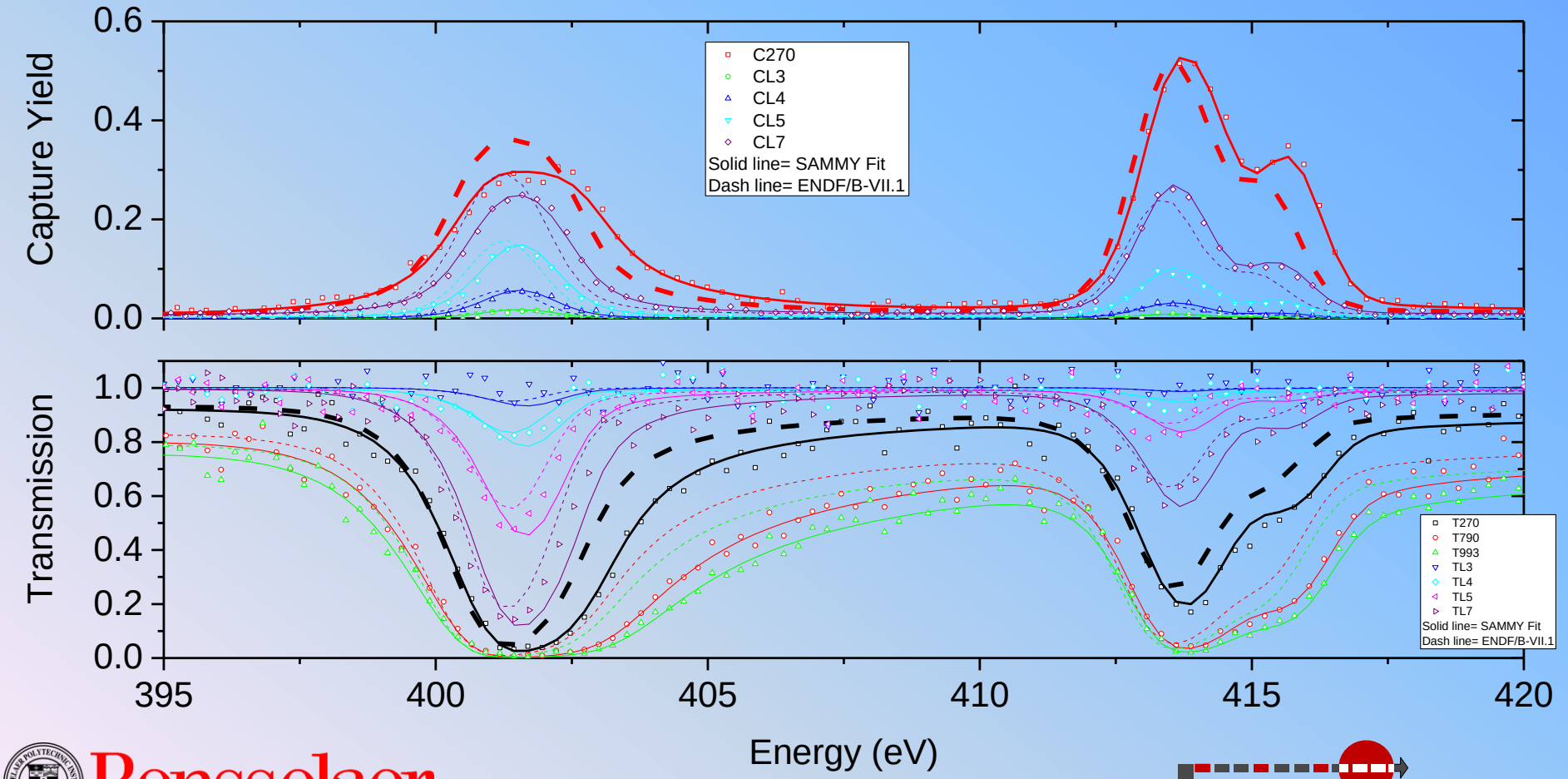
Cs epi-thermal transmission and capture

- Epi-thermal data use 3 CsF sample thicknesses and 4 Cs_2CO_3 liquid samples
- All data (epi-thermal and thermal) were simultaneously fitted with SAMMY to result in a new set of resonance parameters



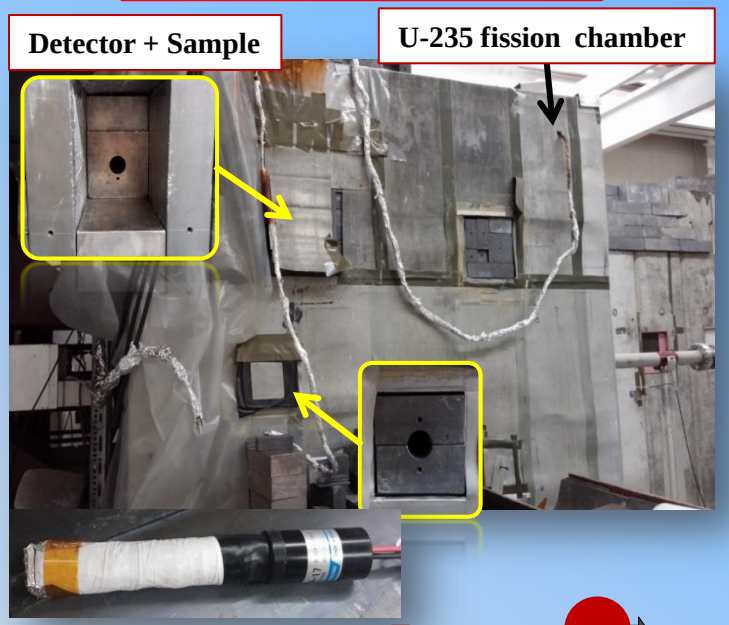
Cs epi-thermal transmission and capture

- Comparison with ENDF/B-VII.1 shows differences
- Will change resonance integral



Assessment of capture cross section with the Lead Slowing Down Spectrometer

- Use the **high neutron flux** of the Lead Slowing Down Spectrometer (LSDS) to assess the accuracy of capture cross section
  - Insert the sample and YAP scintillator in the LSDS
  - Measure with and without the sample of interest
  - LINAC runs at very low power (< 5W)
  - Measurements take about 30 minutes.
- Compare the measurements with simulations that use different evaluations
- Similar to work of Perrot et al.
- PhD thesis published



Nicholas Thompson, Measuring and Validating Neutron Capture Cross Sections Using a Lead Slowing-Down Spectrometer, PhD Thesis, Rensselaer polytechnic Institute, 2017.

L. Perrot, A. Billebaud, R. Brissot, A. Giorni, D. Heuer, J.-M. Loiseaux, O. Méplan, J.-B. Viano, "**Precise Validation of Database (n,γ) Cross Sections Using a Lead-Slowing-Down Spectrometer and Simulation from 0.1 eV to 30 keV: Methodology and Data for a Few Elements**", Nuc. Sci. and Eng., Vol. 144, No. 2, June 2003

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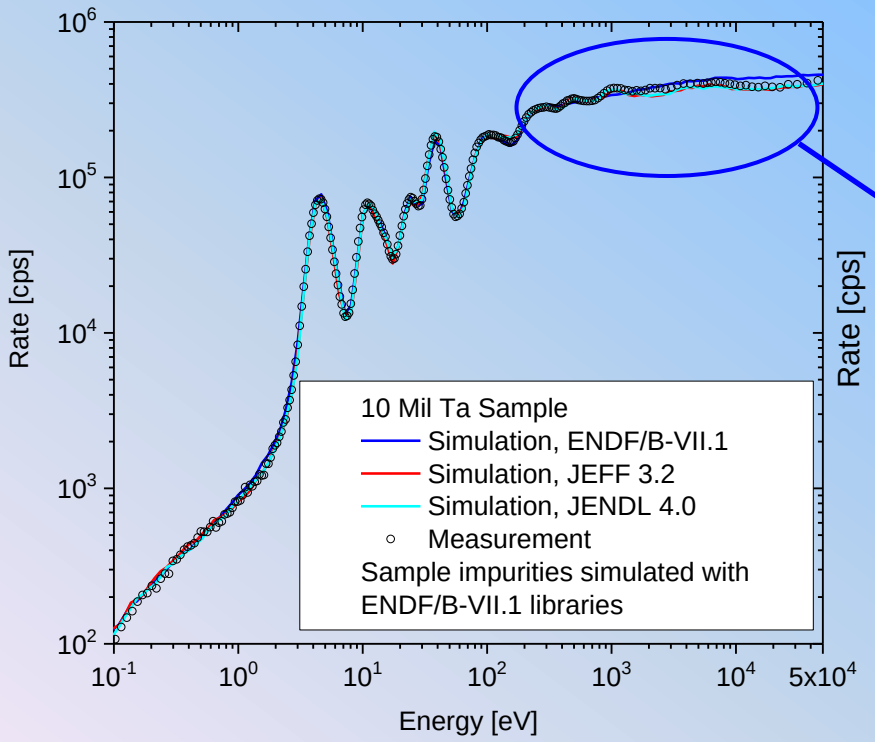
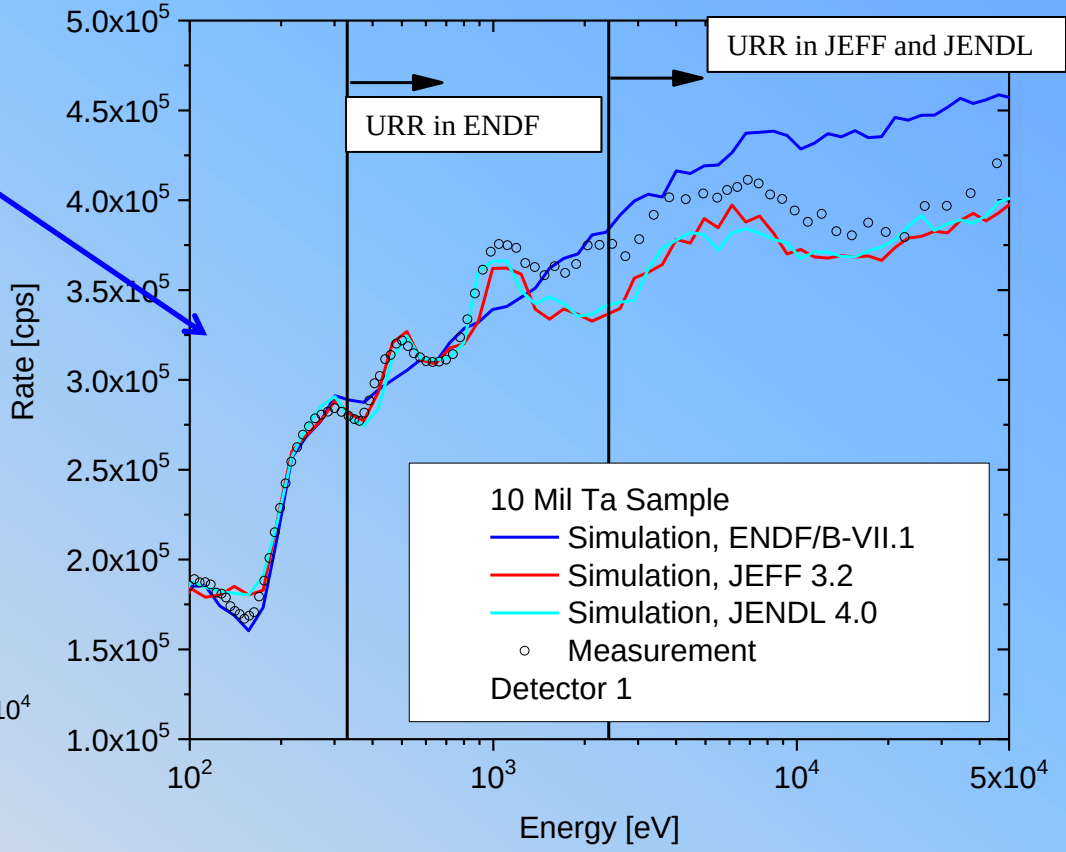
Results - Ta

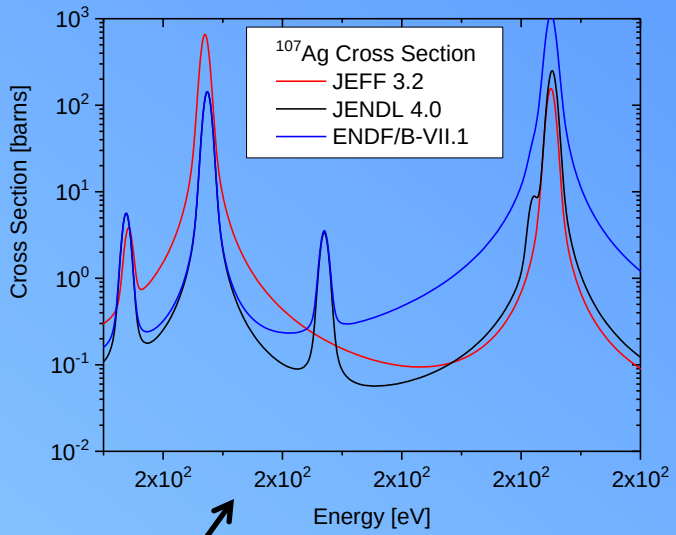
- Good agreement up to 300 eV
  - Some disagreement in the ENDF/B-VII unresolved resonance region
  - RPI is working on high resolution measurements to improve the Ta cross section

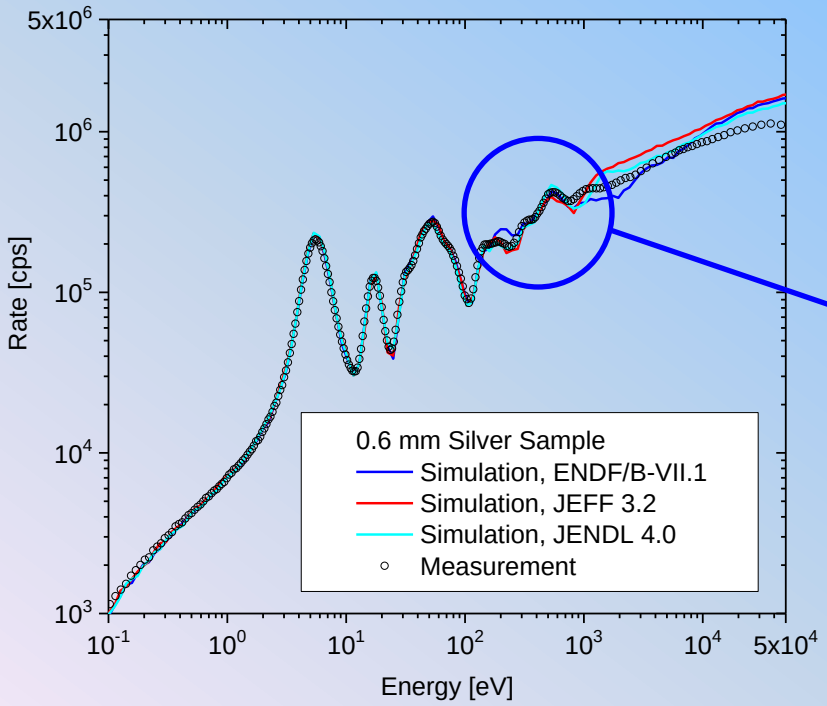


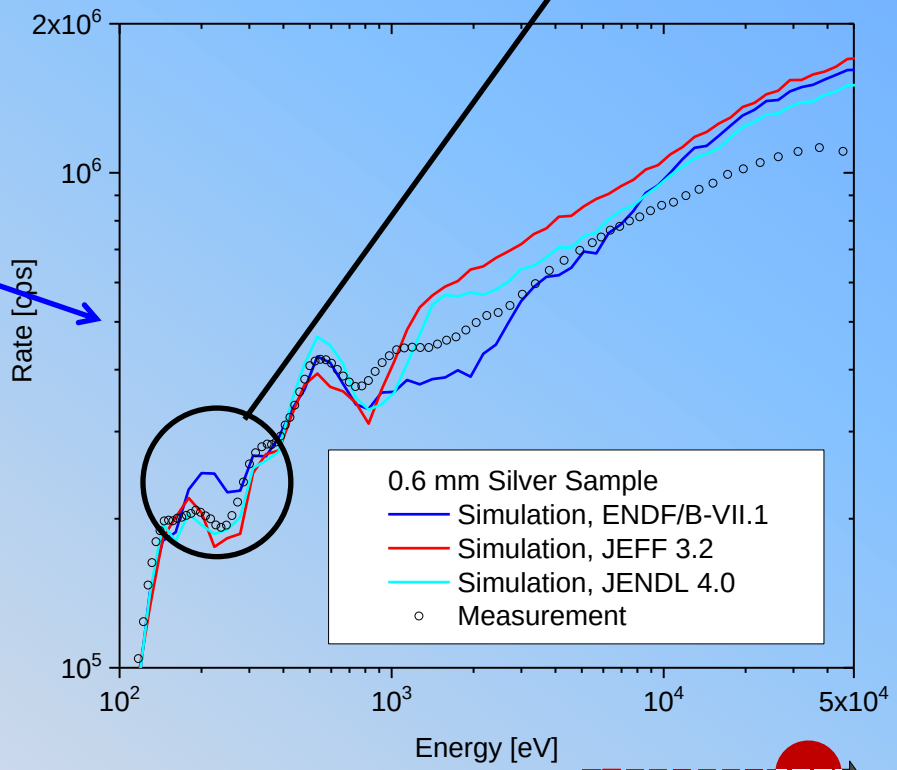


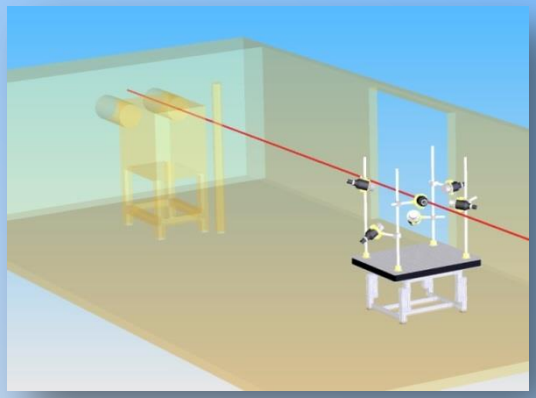
Results - Ag

- Problem with ^{107}Ag resonances near 200 eV
- Large differences between libraries above 1 keV



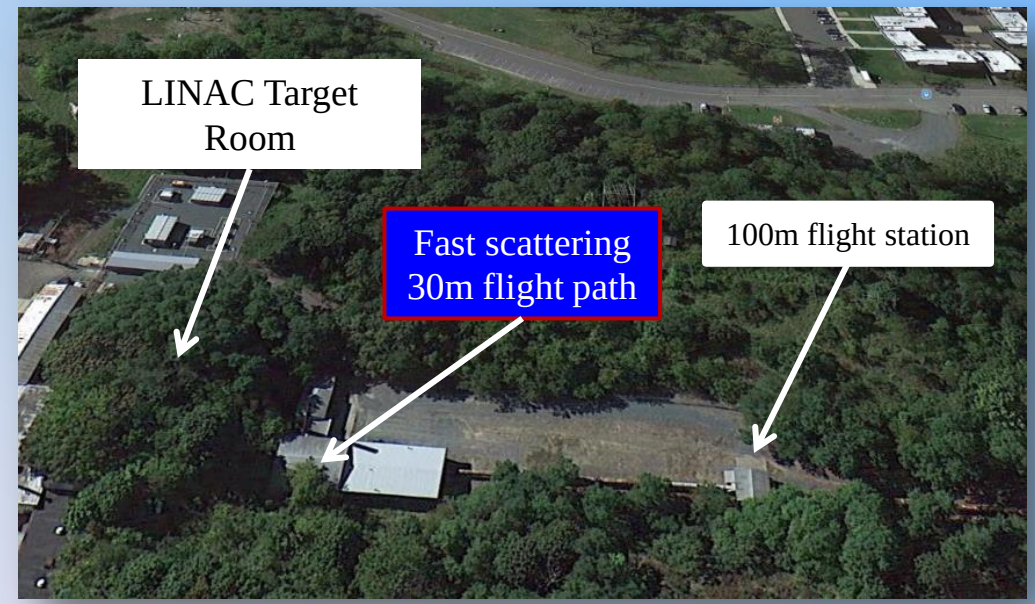






Neutron scattering benchmark of Fe-56 evaluations

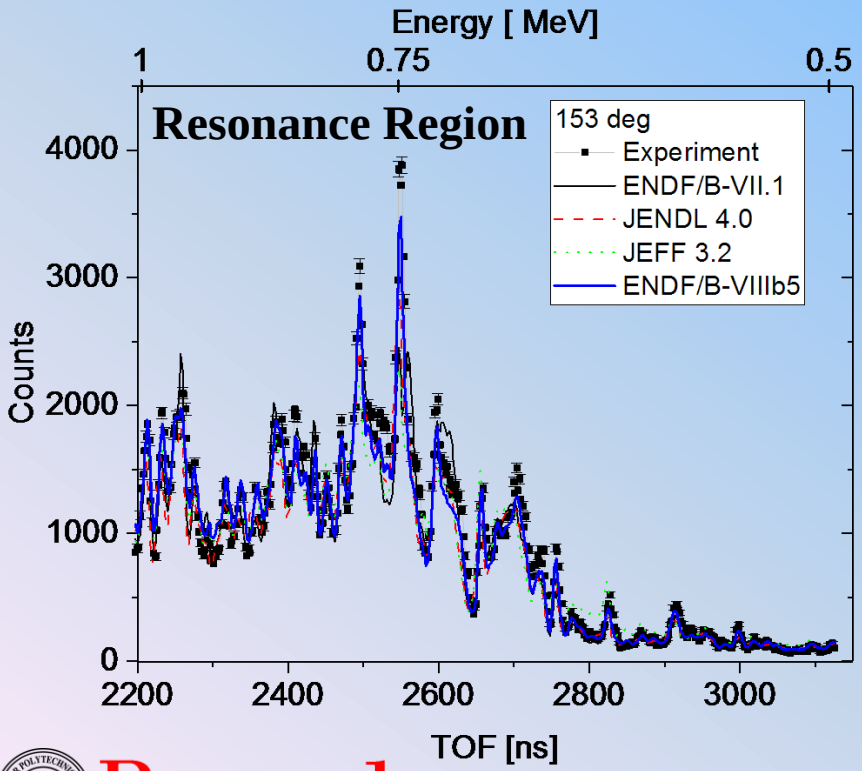
Quasi-differential neutron scattering and angular distributions.

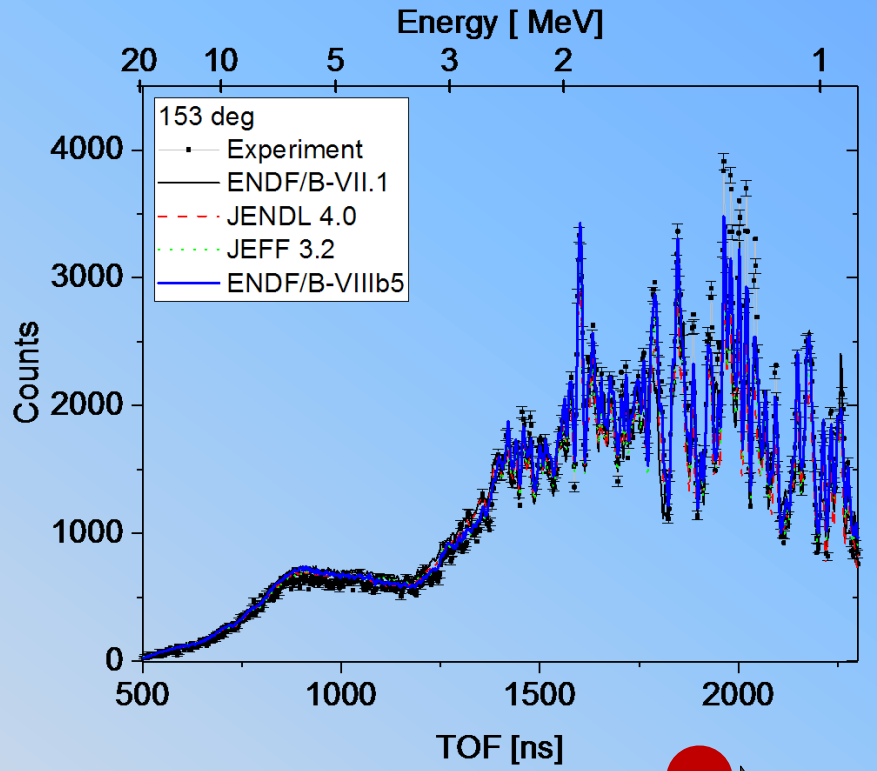


Iron scattering

- Measured the total scattering and compared with detailed simulation
- Method was verified with graphite

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.





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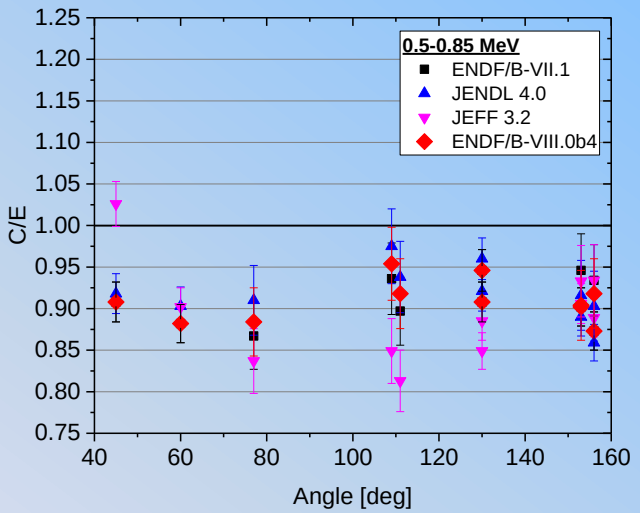
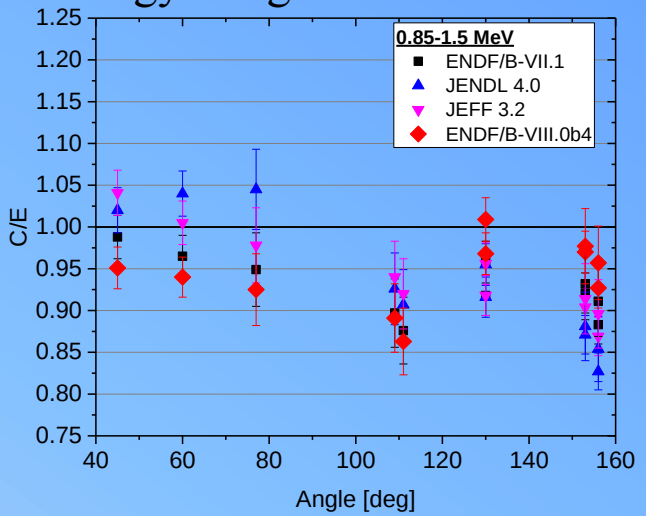
C/E energy dependence

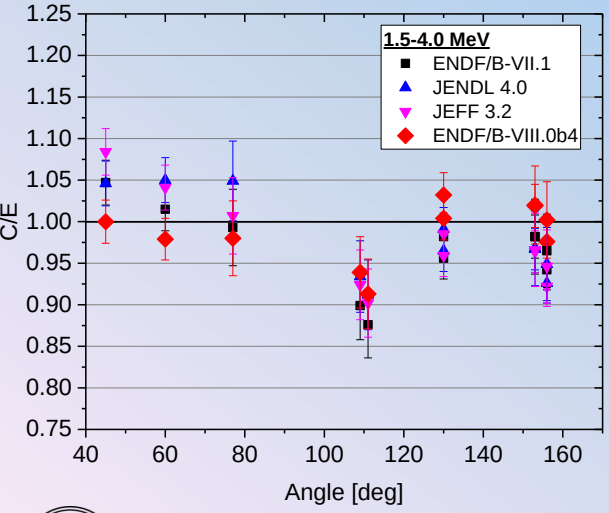
- Ratio of the sum of counts for a given "incident neutron" energy range

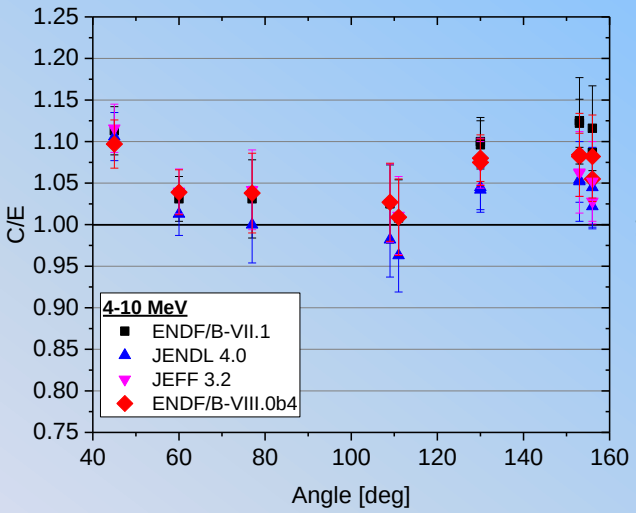


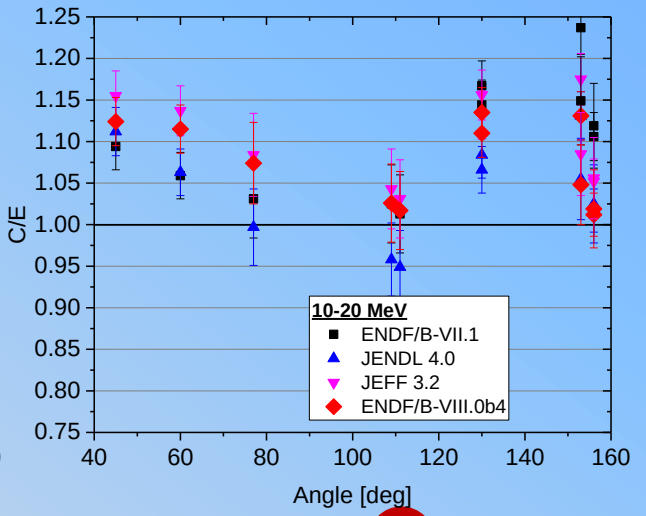
C/E of the new evaluations are closer to 1 compared with ENDF/B-VII.1

For some energy regions (4-10 MeV and 10-20 MeV) JENDL 4.0 is in slightly better agreement with the experiment









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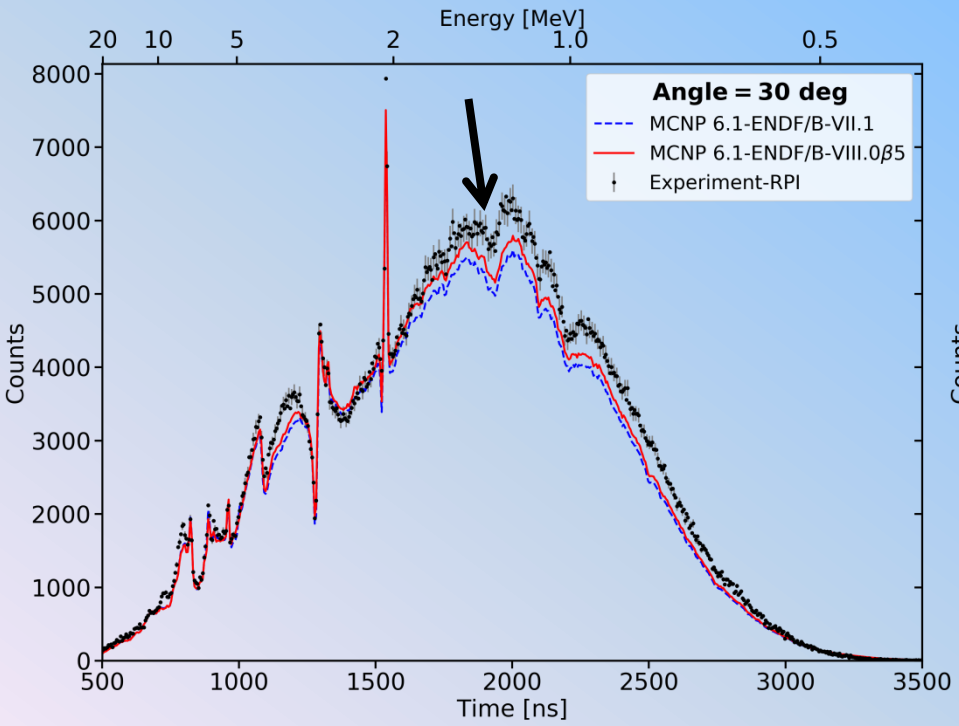
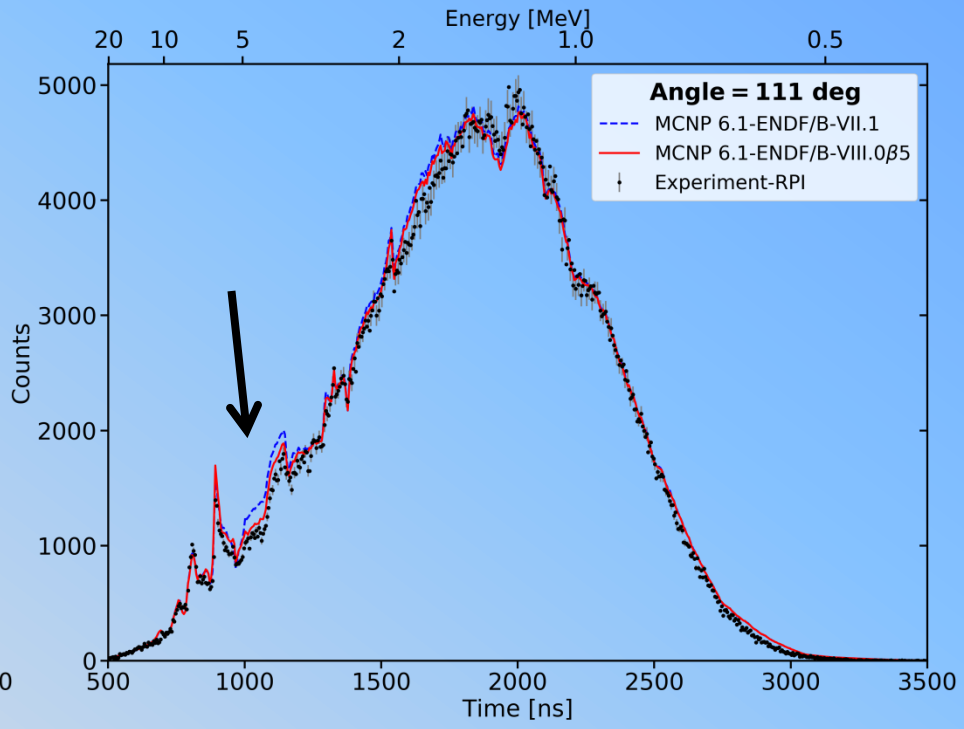
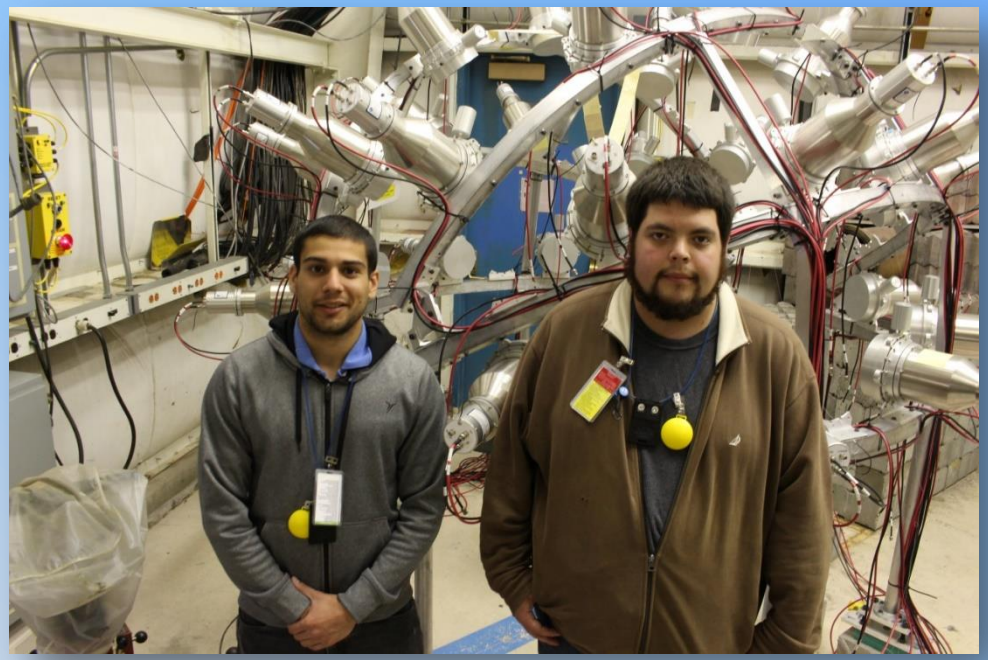
Carbon scattering

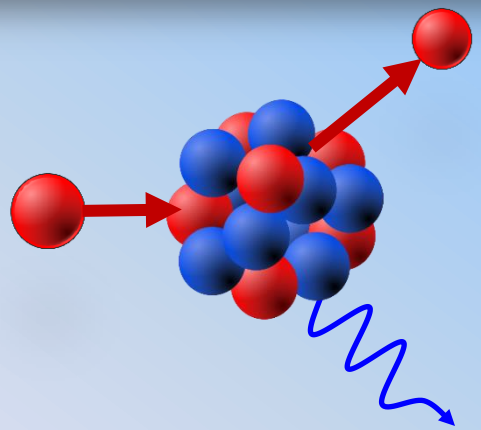
- Small difference between ENDF/B-II.1 to ENDF/B-III.0b5 generally the new evaluation is closer to the experiment
- Overall the normalization of the simulation at all angles to the experiment is better. The standard deviation was reduced from 5.2% to 3.8%.



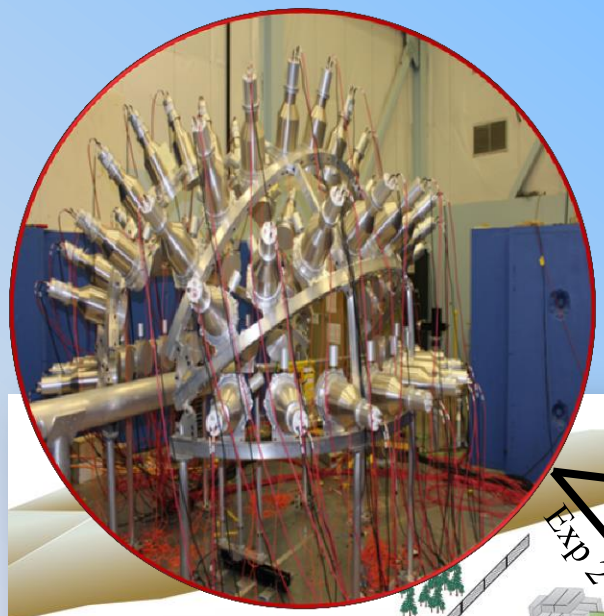


^{235}U and ^{239}Pu Quasi Differential Neutron Induced Neutron Emission at WNR

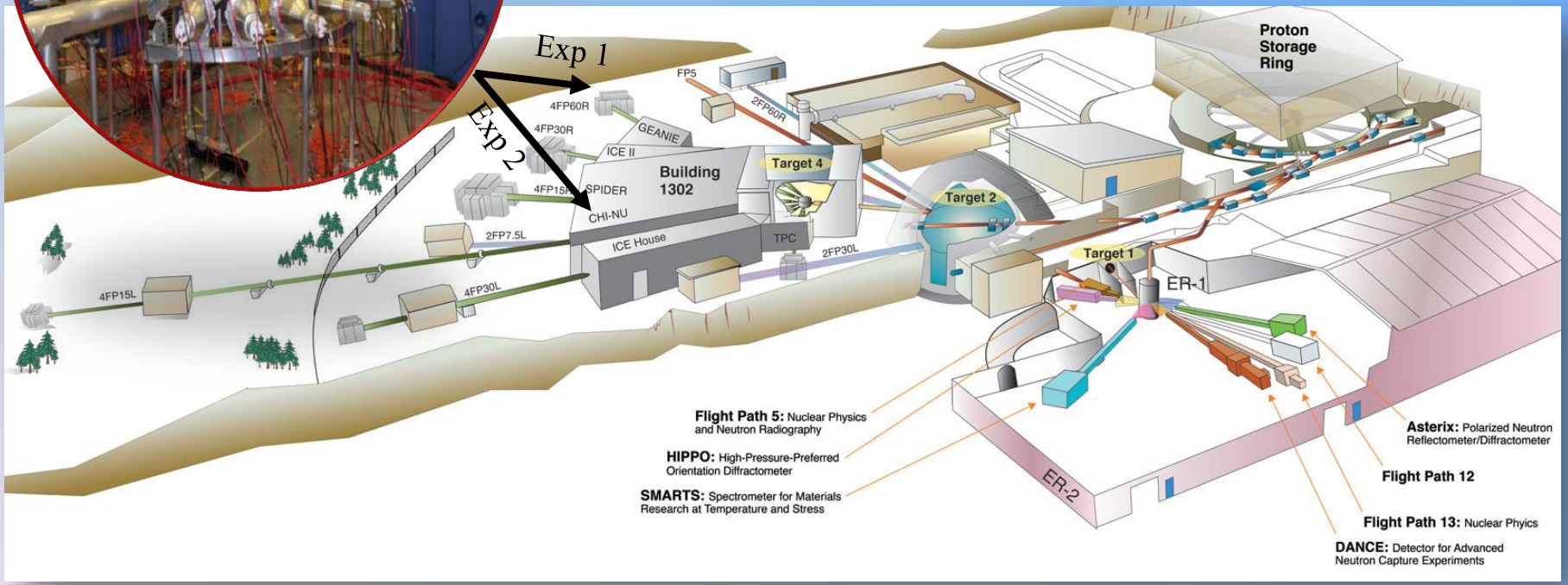




Experimental Setup at LANL

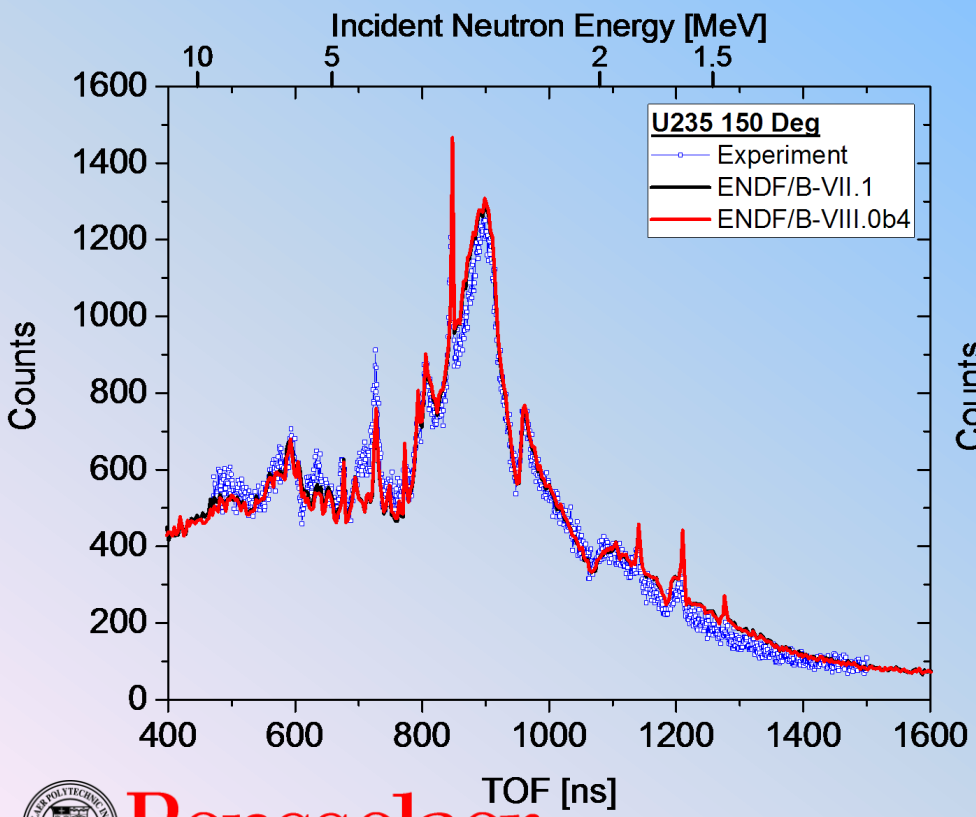


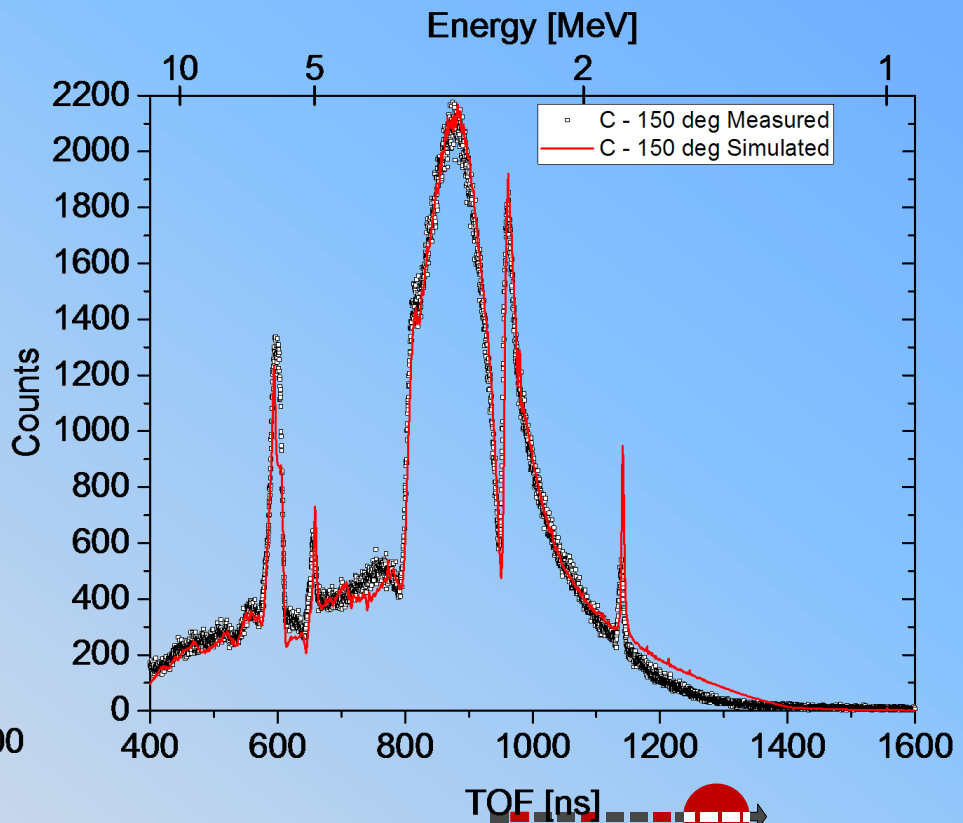
- **Motivation: U-235 and Pu-239**
- Used the Chi Nu EJ-309 detector array
  - 54 detectors, arranged in 2 “quarter-spheres”
  - 9 detector slots per row starting at 30 degrees spaced 15 degrees apart spanning 150 degrees encompassing the sample
- Detectors were connected to digitizers
  - Pulse shape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



Preliminary Results – ^{235}U Scattering

- Experiments done using Chi-Nu at LANL
- 35g of U enriched to 93% ^{235}U
- Includes contribution from plastic laminate (C and H)

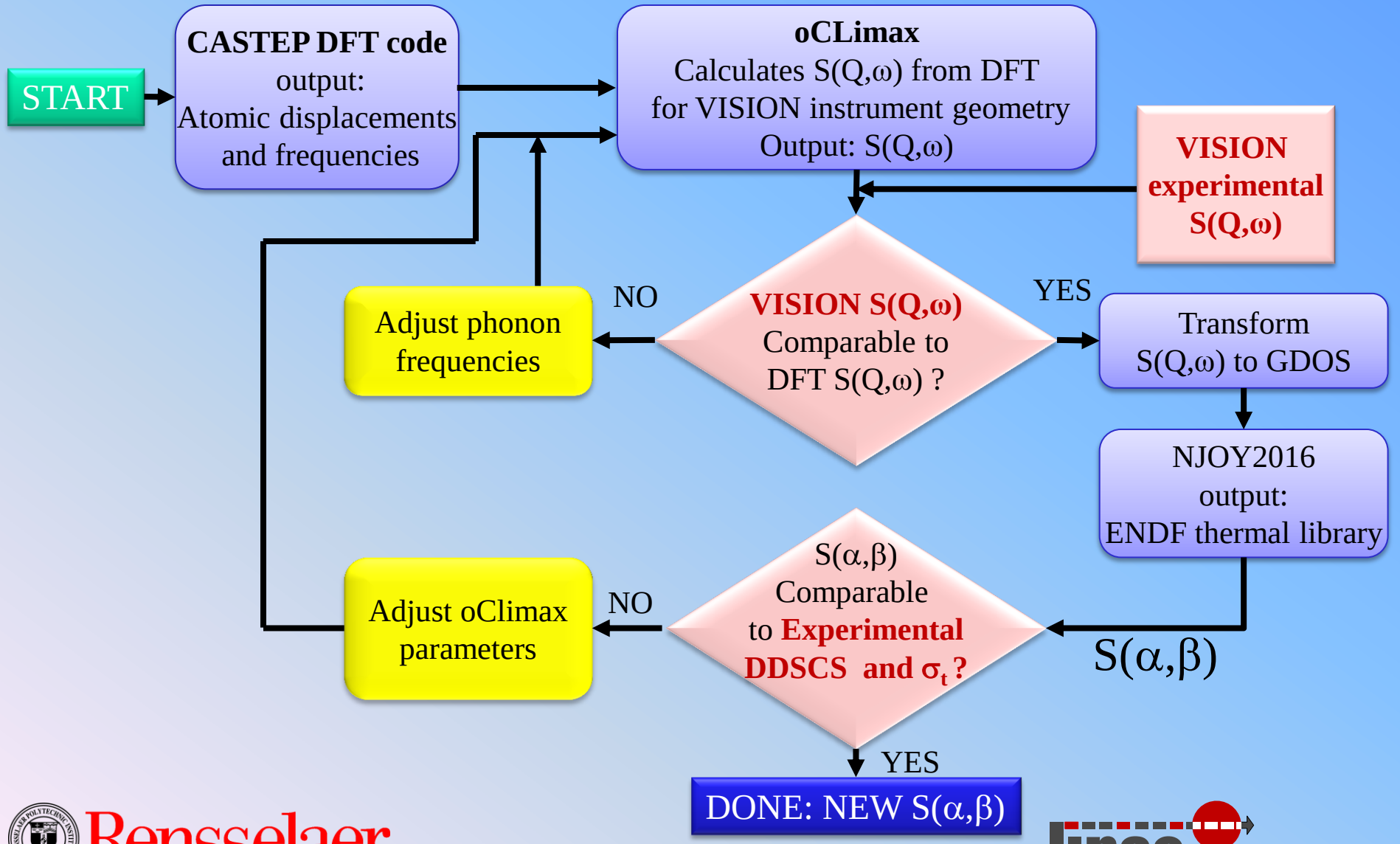




Thermal scattering
completed measurements

- Preformed measurements at SNS:
  - SEQUOIA
    - Water
    - Medium Density Polyethylene (MDPE)
  - ARCS
    - High Density Polyethylene (HDPE) 295 K and 5 K
    - Quartz (SiO_2) at 20, 300 550, 600 °C
  - VISION (measures S(ω))
    - Lucite, Lexan, Polyethylene at 5 K and 295 K
  - ARCS (done Feb. 2017):
    - Lucite ($C_5O_2H_8$) 5 K, 300 K, 400 K
    - Teflon (C_2F_4) 5 K 300 K 500 K
    - Concrete 5 K and 300 K

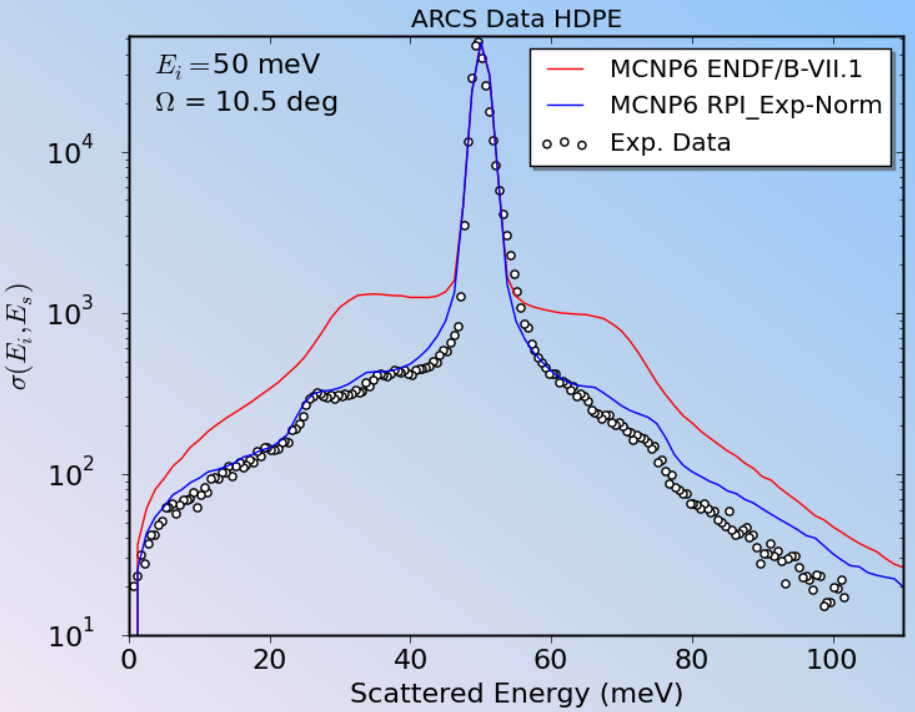
Thermal scattering – evaluation methodology

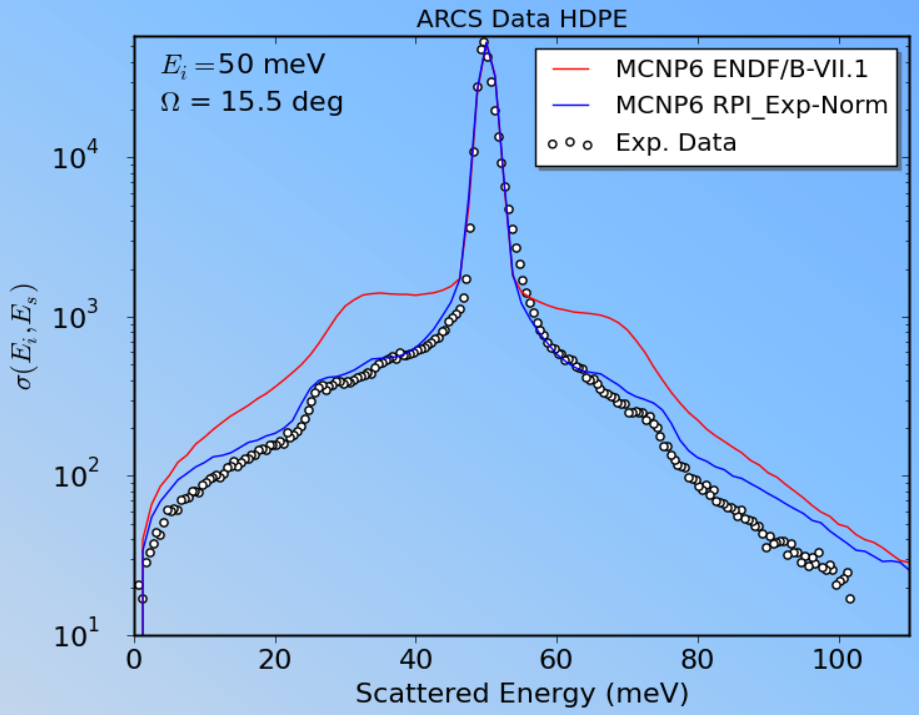


Example for HDPE

Experiment Normalized GDOS

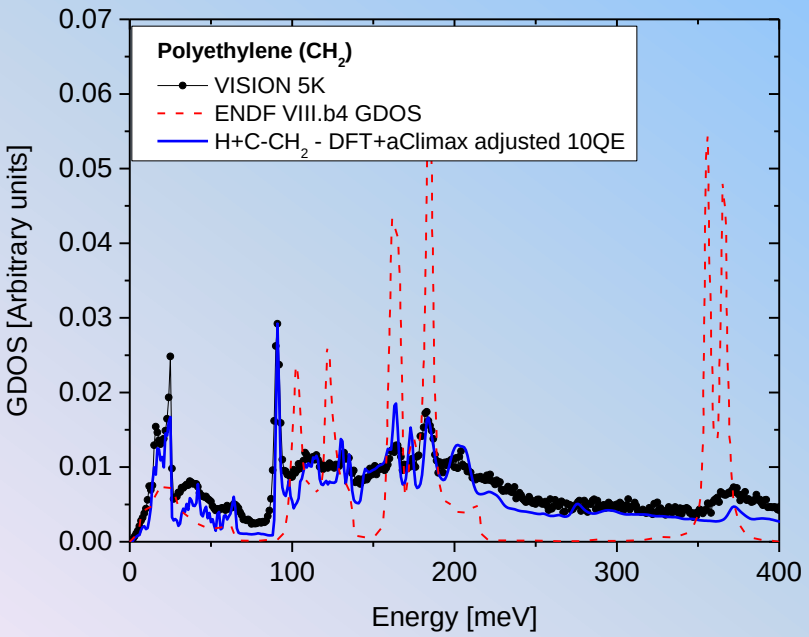
- The phonon spectrum was processed with NJOY 2012
- The experimental response simulated with MCNP 6
- The agreement with the experiment is improved

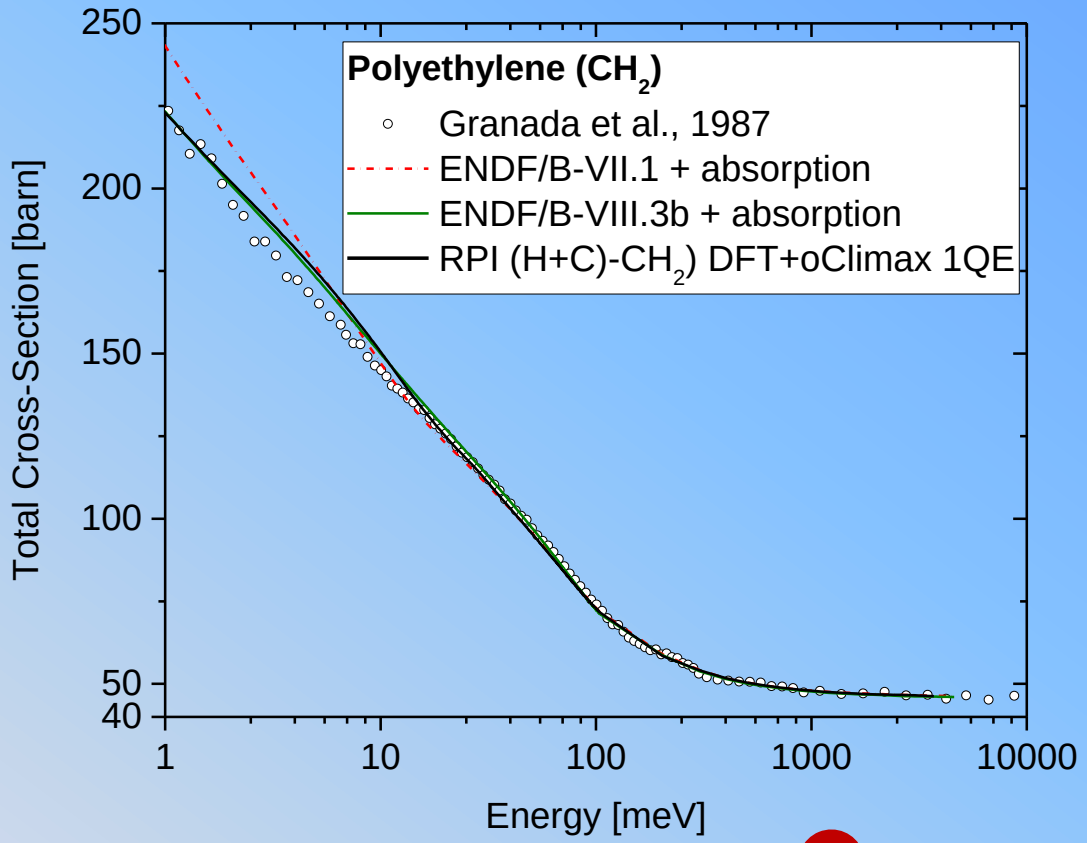




Polyethylene thermal scattering

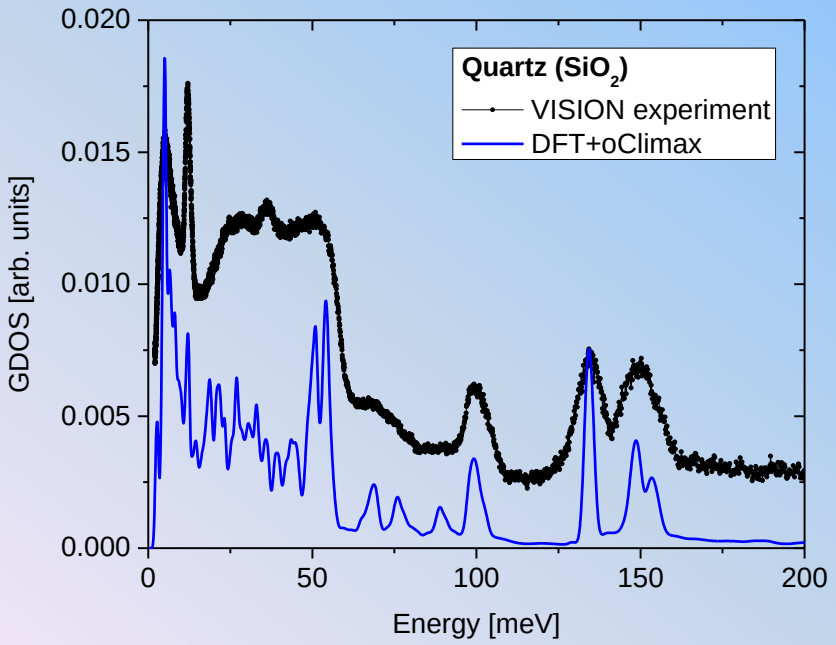
- Frequencies adjusted to match VISION experimental peak locations
- The total cross section calculated using the phonon spectrum is in good agreement with the total cross section measurement.

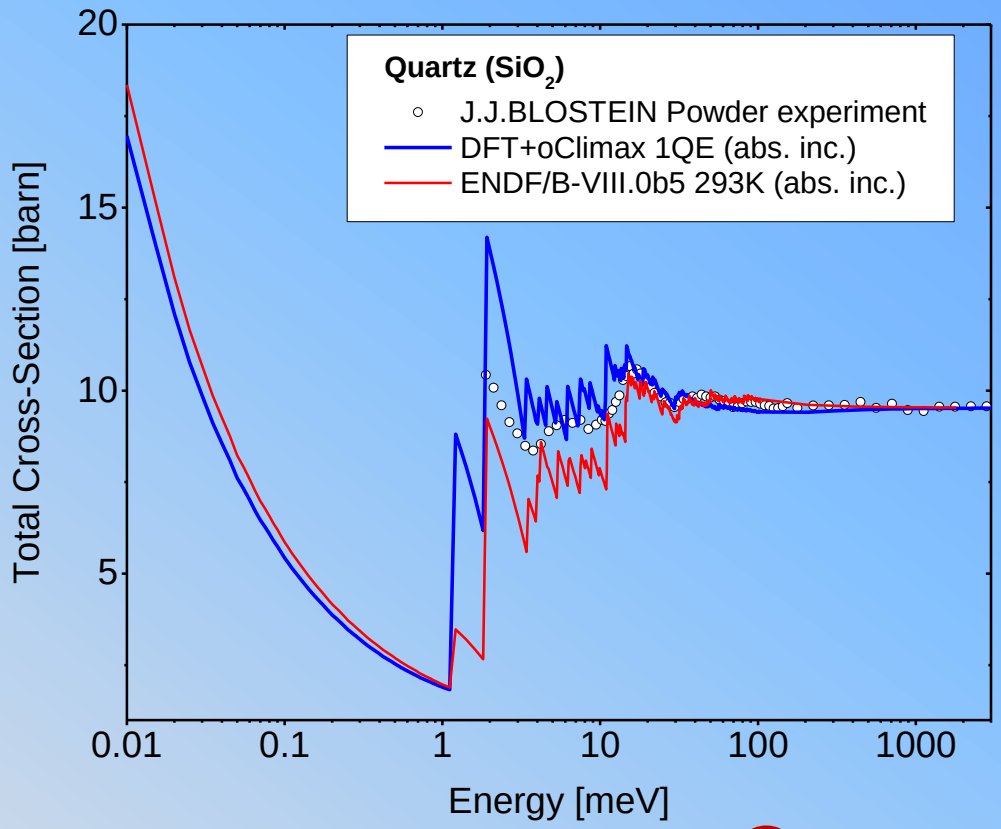




Quartz thermal scattering

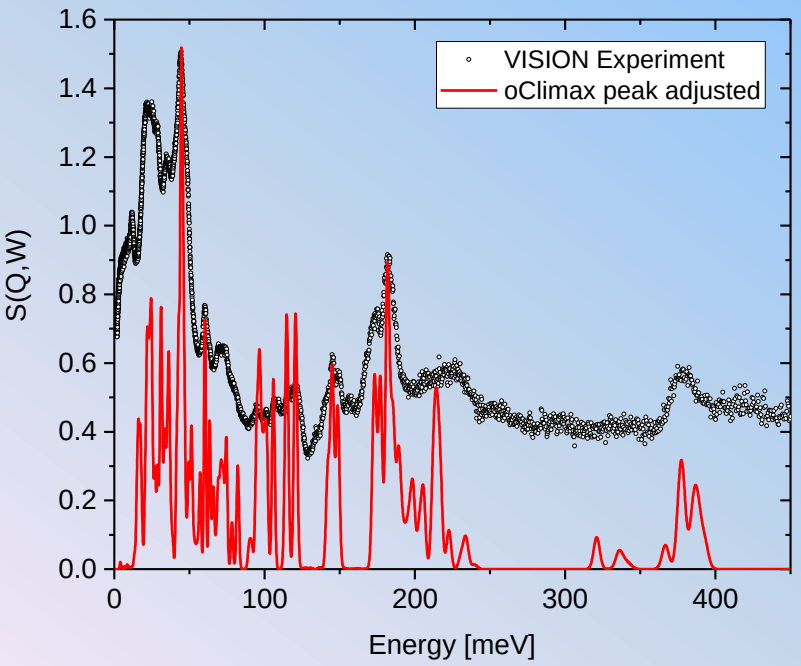
- Measured (VISION) and peak adjusted DFT
  - The adjustment allows to better match the peak location.
- Cross section is in good agreement with available experimental data

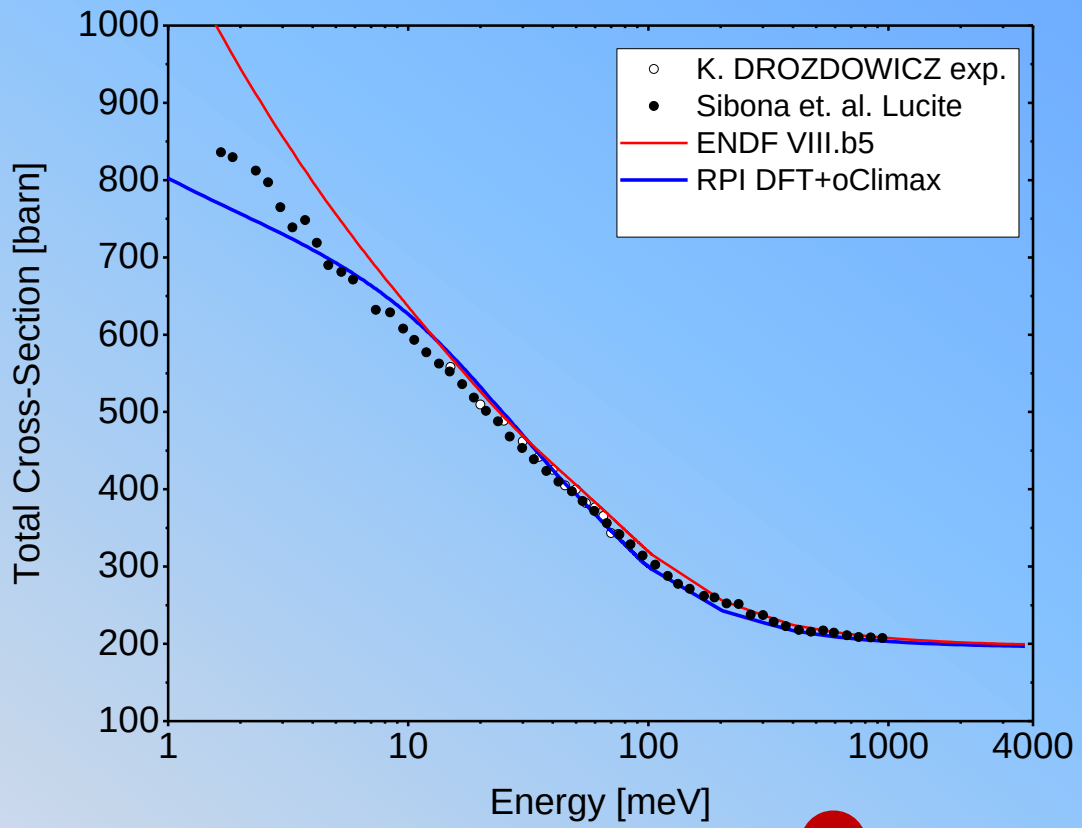




Lucite – thermal scattering

- Frequencies adjusted to match VISION experimental peak locations
- The total cross section calculated using the phonon spectrum available experimental data. Slightly better agreement with the ENDF/B-VIII.0b5 evaluation.





Summary

- **Experiments**
  - Ta transmission and capture experimental data was taken.
  - LSDS capture rates were measured for several samples:
    - Ta, Ni, Ag, Au, Nb, Sn, Zr, In, Fe, Co, Mo, C

- **Data Analysis**
  - Cs resonance parameter analysis in progress.
  - Thermal scattering evaluations for polyethylene, quartz, Lucite, ice and concrete are in progress.
    - Using new experimental data from VISIO, ARCS and SEQUOIA
  - Iron and graphite fast neutron scattering experiments were compared to ENDF/B-VIII.0b5
    - Both shows better agreement with the experimental data.