NAVAL NUCLEAR
LABORATORY

TEX-Hf Benchmark Analysis

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November 4-7, 2024

CSEWG Meeting, Brookhaven National Laboratory

Background

- TEX (Thermal and Epithermal eXperiments) series of experiments conceived in 2012
    - Design influenced by Prometheus critical experiments designed by NNL circa 2004-2005
    - Initial concentration on TEX-Pu and TEX-Ta
    - Next priority was TEX-HEU and TEX-Hf

- 7 benchmark quality delayed critical configurations completed between August-October 2022 (requiring 7 NCERC weeks)

- ICSBEP Benchmark Evaluation included in 2024 ICSBEP Handbook

NEA/NSC/DOC(95)03/II
Volume II

HEU-MET-INTER-013

TEX-HF ASSEMBLIES: HIGHLY ENRICHED URANIUM PLATES WITH HAFNIUM USING POLYETHYLENE MODERATOR AND POLYETHYLENE REFLECTOR

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Configurations
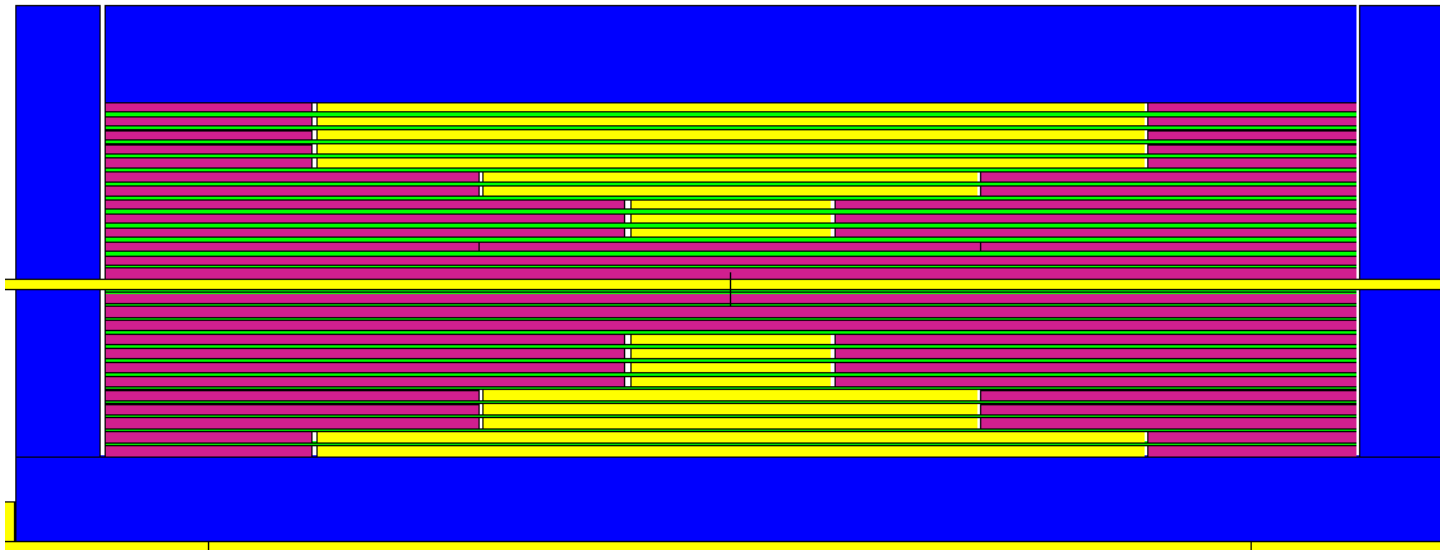
- Seven (7) configurations
    - 1 fast spectrum   (case01)
    - 3 intermediate spectrum   (case02, case03, case06)
    - 1 mixed spectrum   (case04)
    - 1 thermal spectrum   (case05)
    - 1 fast Hf (axially) reflected   (case07)

- Two stacking units
    - Standard (HEU, Hf, HDPE)
    - Sandwich (HEU, HDPE, Hf, HDPE)

- 1 inch thick HDPE axial/radial reflector to decouple assembly from Comet assem
  machine and reduce room return

Case	Calculated Fission Fractions *		
	Thermal (<0.625 eV)	Intermediate (0.625 eV - 100 keV)	Fast (>100 keV)
1	0.072	0.180	0.738
2	0.093	0.510	0.397
3	0.159	0.547	0.294
4	0.317	0.480	0.203
5	0.598	0.277	0.125
6	0.133	0.572	0.295
7	0.015	0.136	0.849

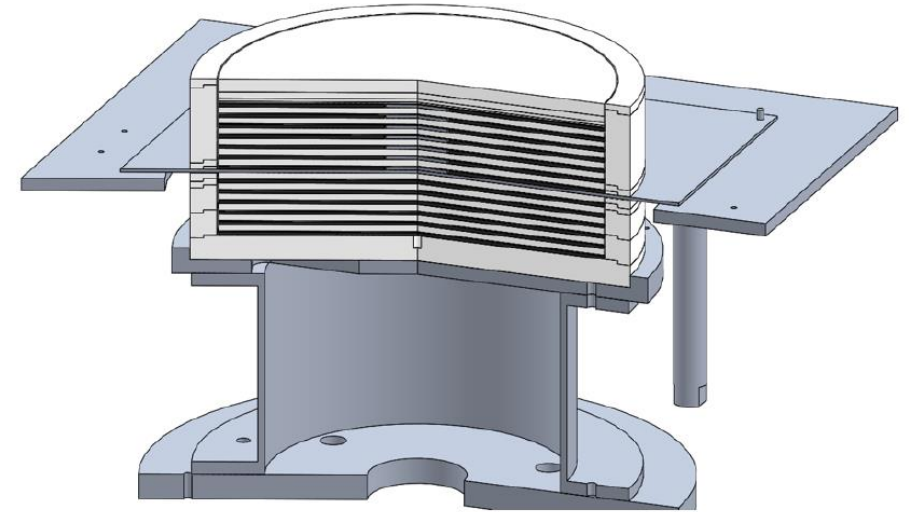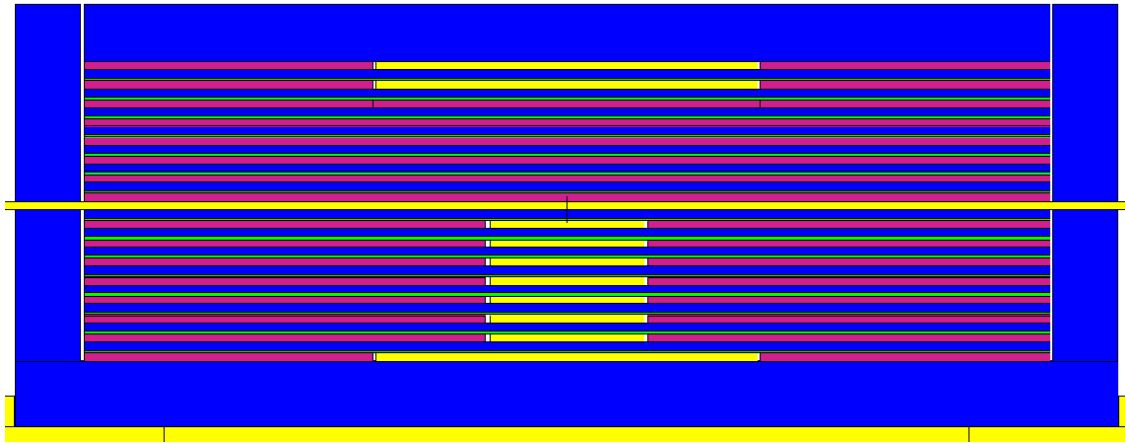* Using MCNP 6.2 with ENDF/B-VIII.0 cross-sections
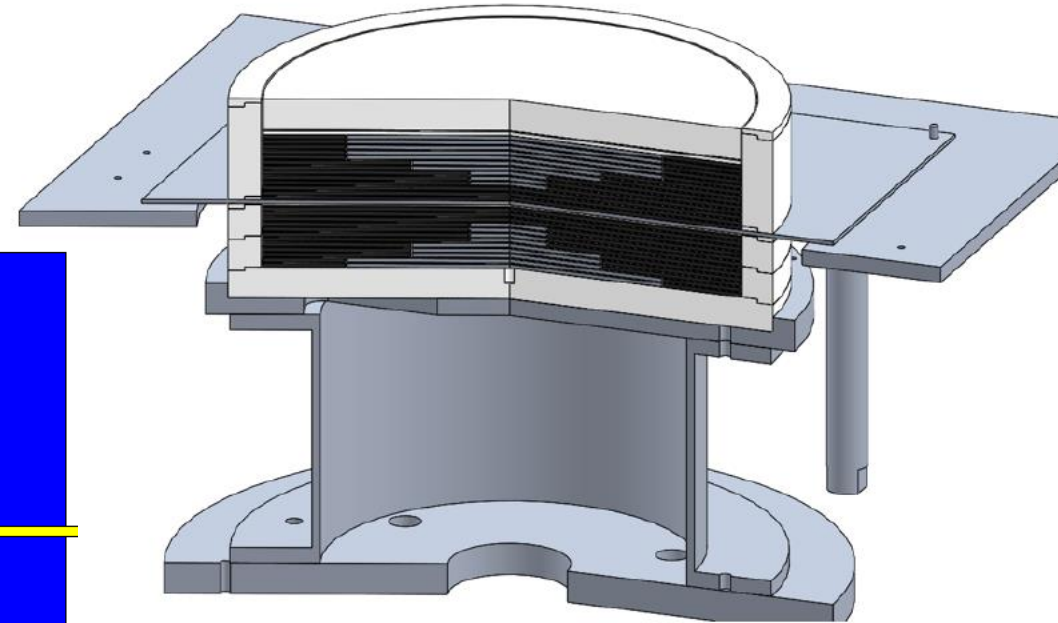
Case 1 – unmoderated
(HEU in pink, hafnium in green, polyethylene in blue, and aluminum in yellow)
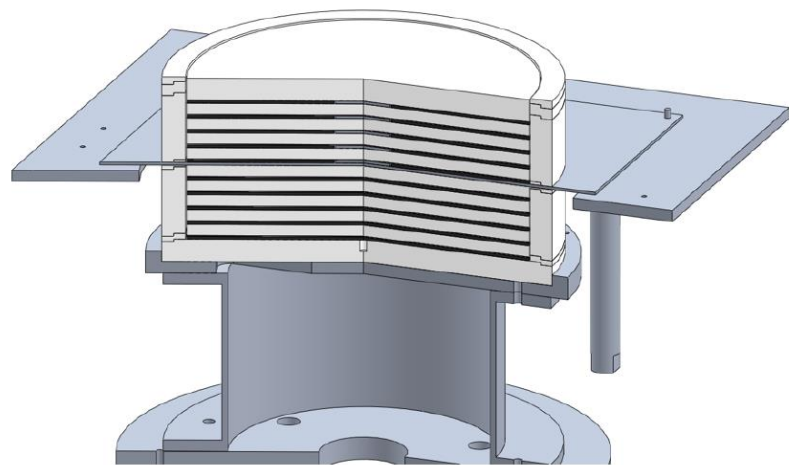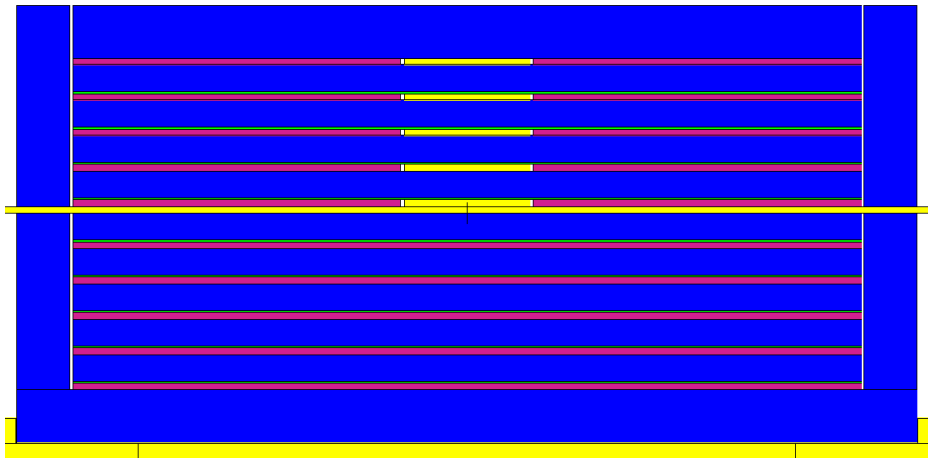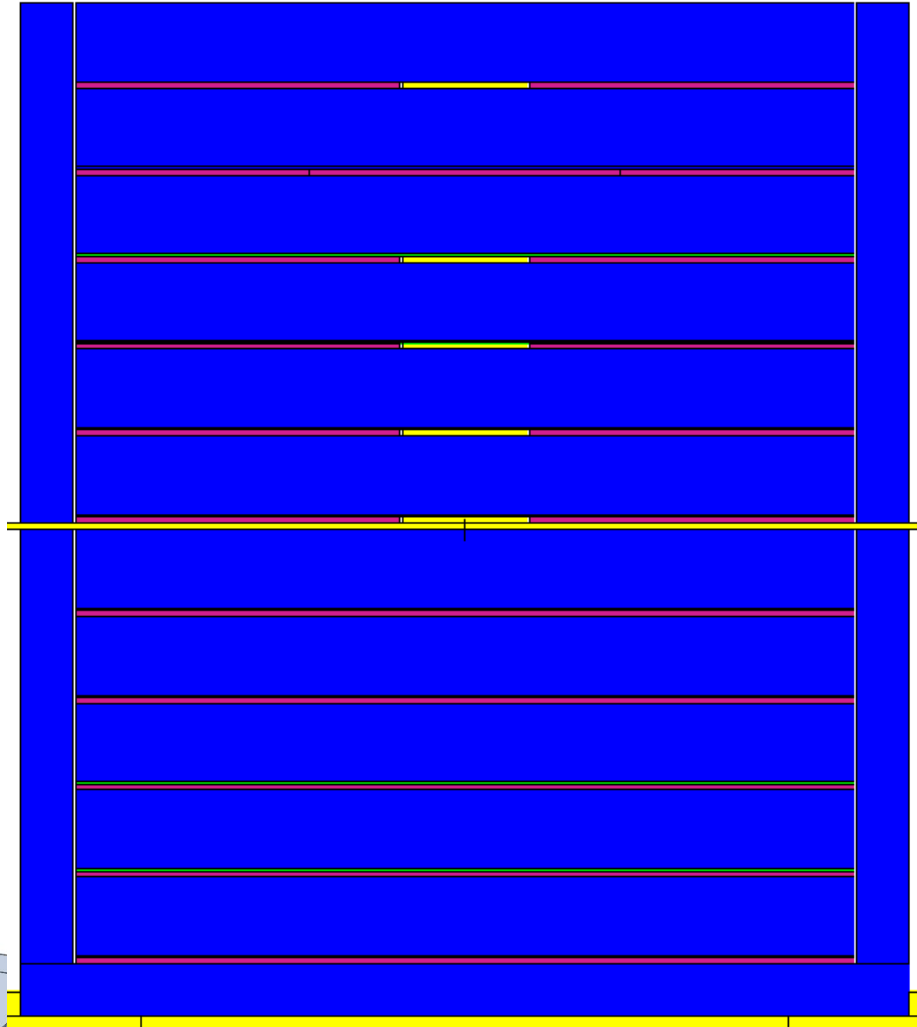
Configurations

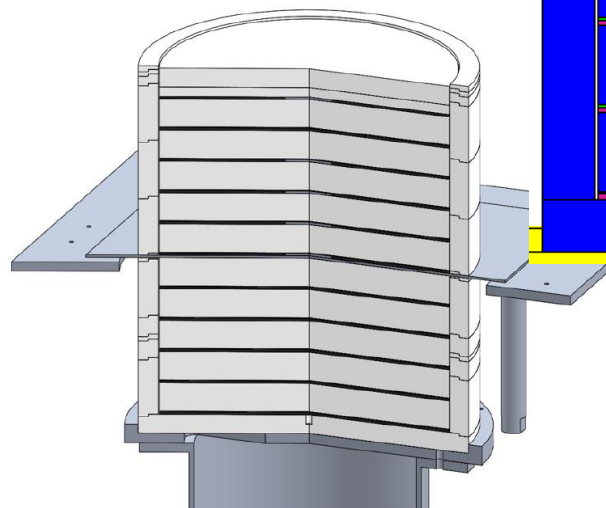Case 2 – 0.125 inch HDPE moderation
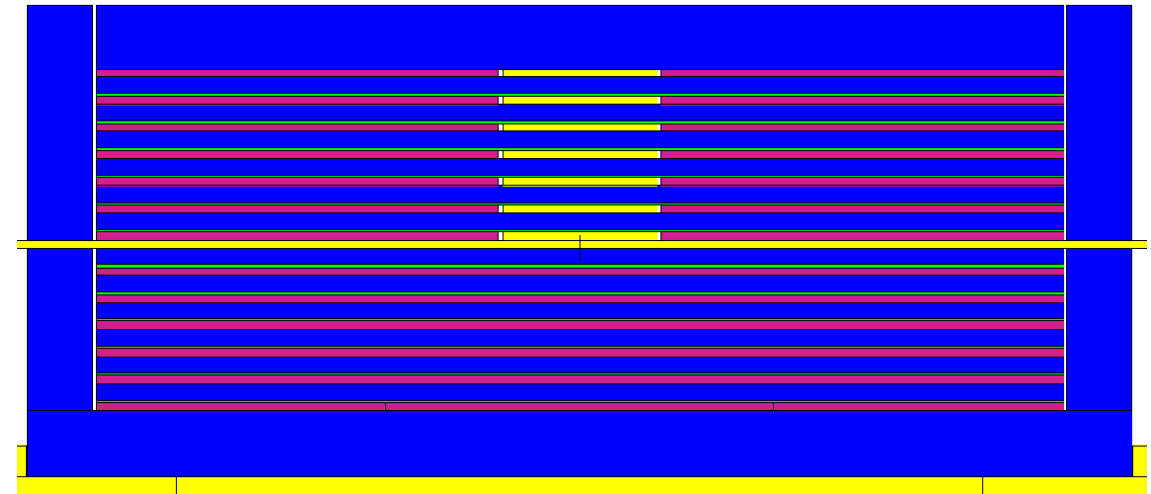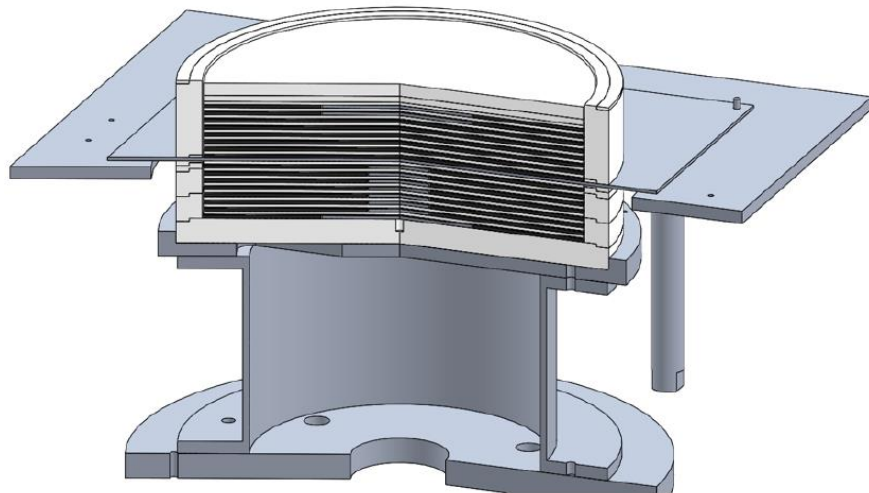
Case 3 – 0.25 inch HDPE Moderation

Configurations

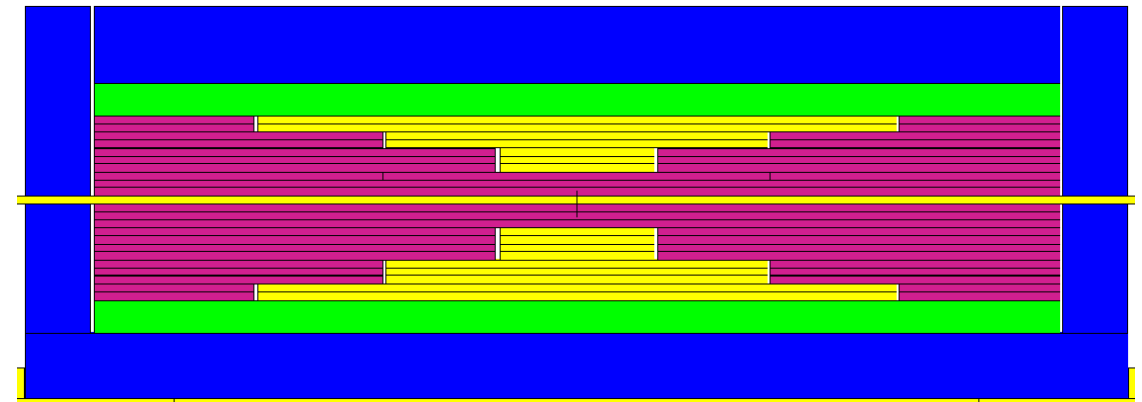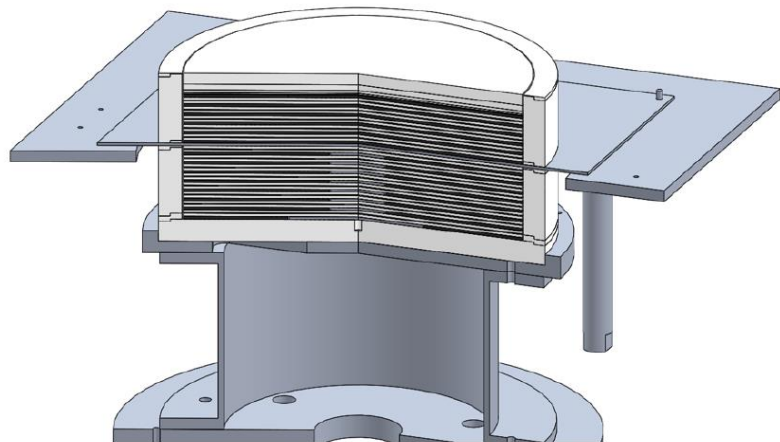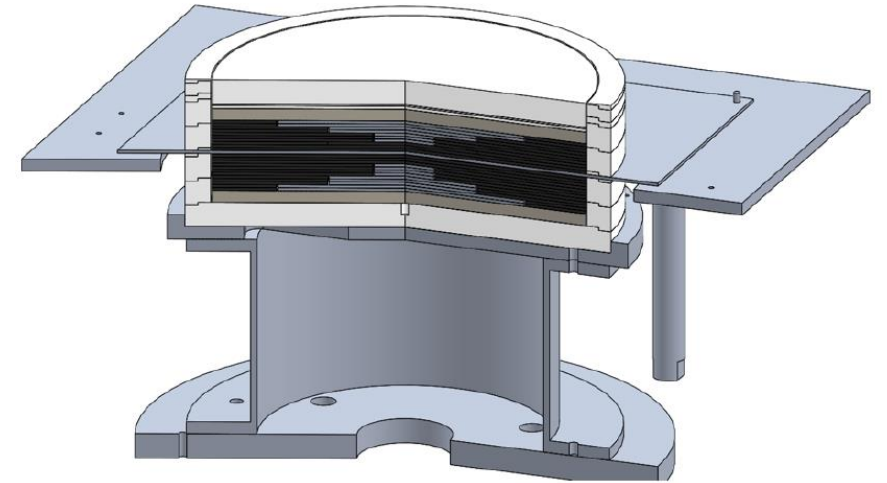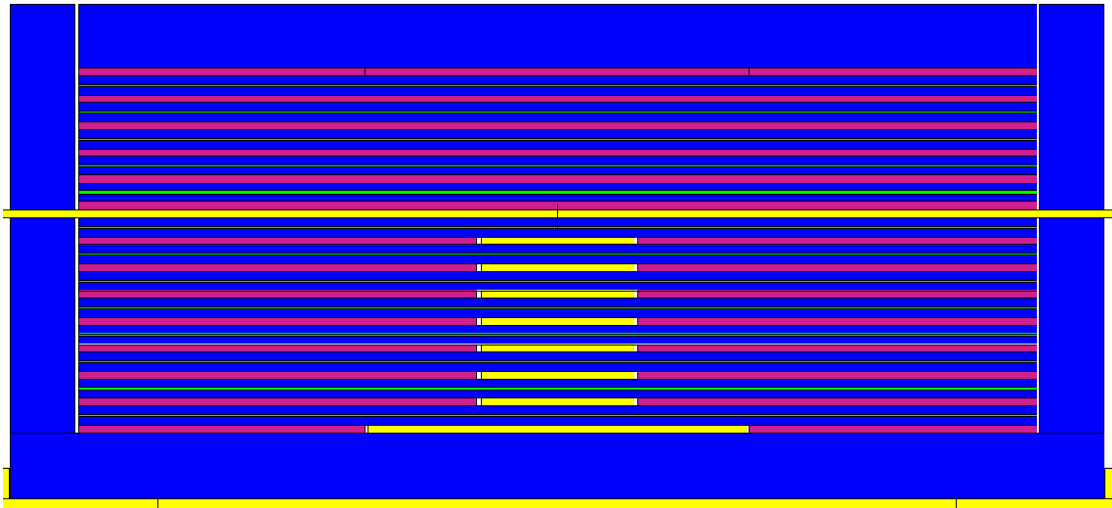Case 4 – 0.5 inch HDPE Moderation (mixed spectrum)

Case 5 – 1.5 inch HDPE moderation (thermal spectrum)

Configurations

Case 6 – 0.25 inch HDPE Moderation
Sandwich Stacking
(intermediate spectrum)

Case 7 – Bunched stacking,
0.48 inch Hf axial reflector

HMI013 Hf Analysis Results

- Calculated using MC21

- Run Strategy:
  - Histories: 1,000,000
  - Discards: 100
  - Active Batches: 1,000
  - Average Eigenvalue Uncertainty: <5pcm
  - Reference Temperature: 293.6K

- Average CoE-1 [pcm]
  - ENDF: 62
  - ENDF w JEFF: -130
  - ENDF w JENDL: 102

C/E-1 by Case

ATFF Ratio by Case

ATLF Ratio by Case
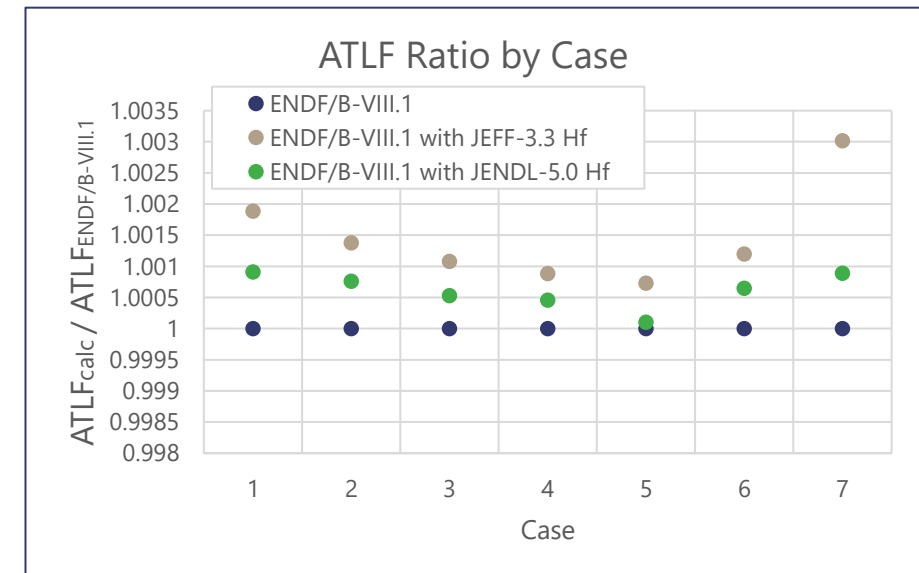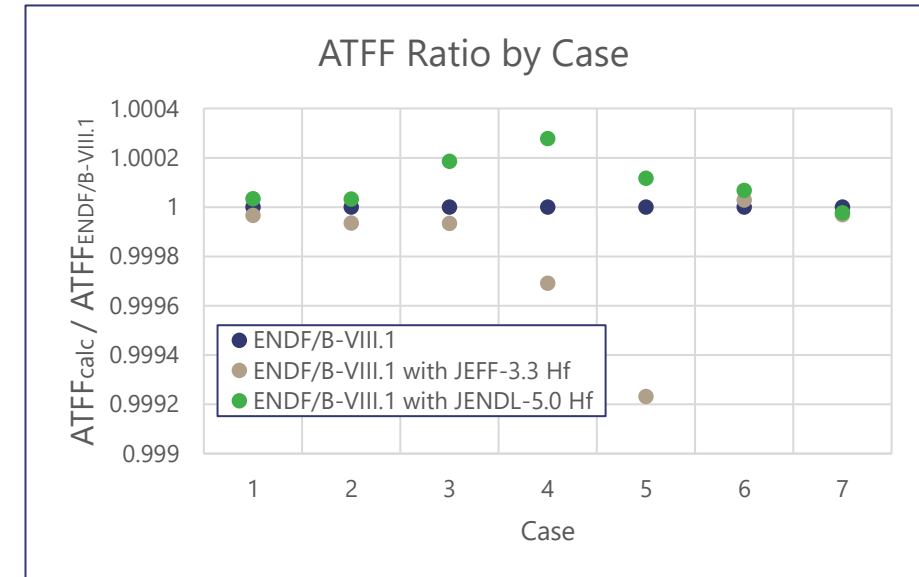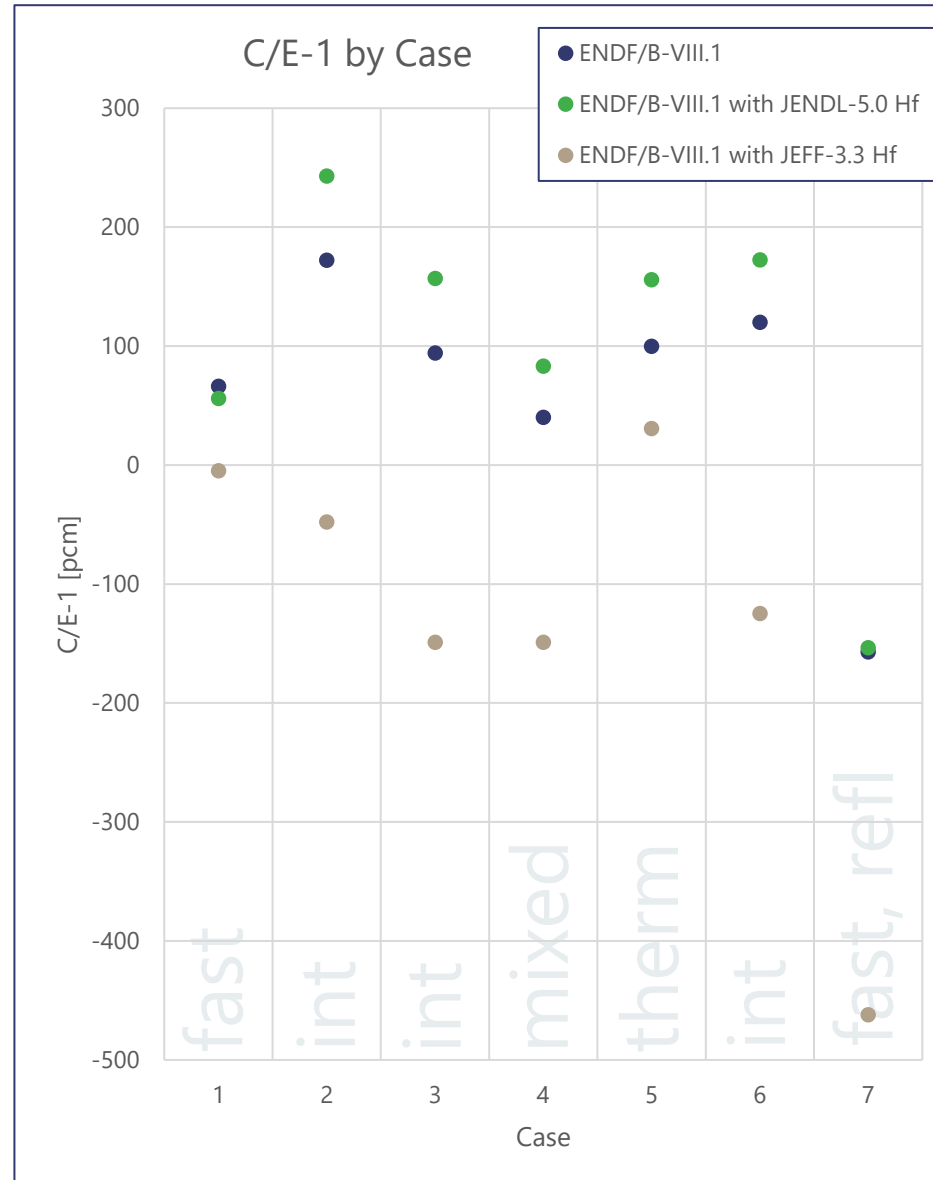
HMI013 Hafnium Analysis

- Figure of Merit:
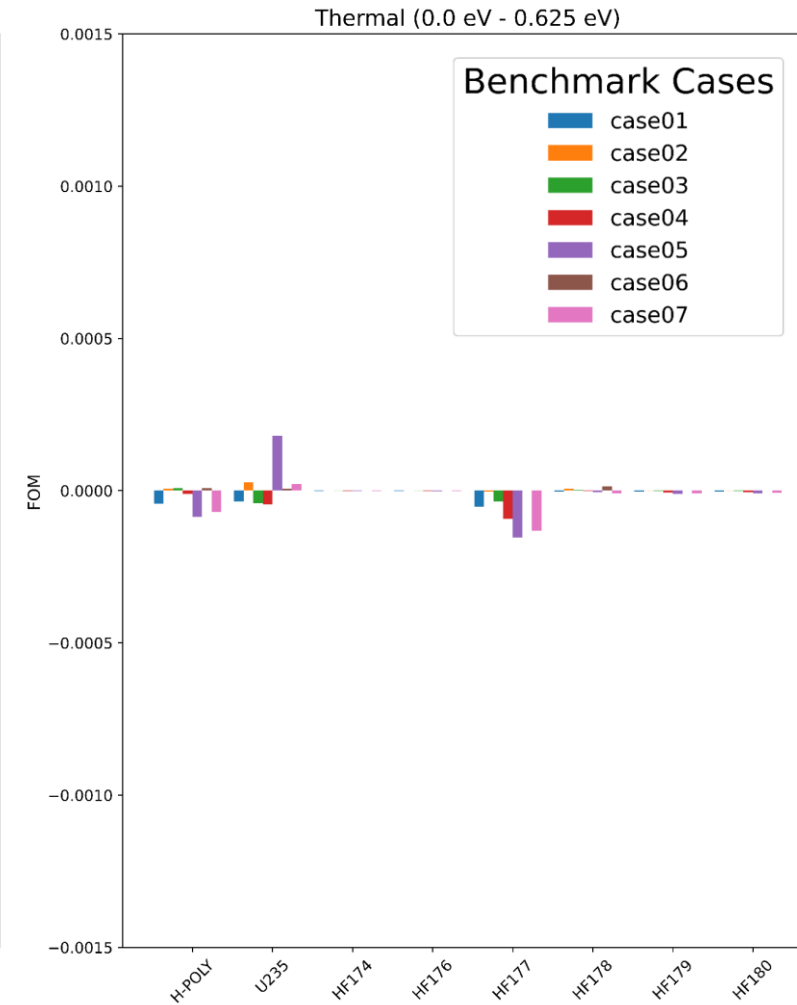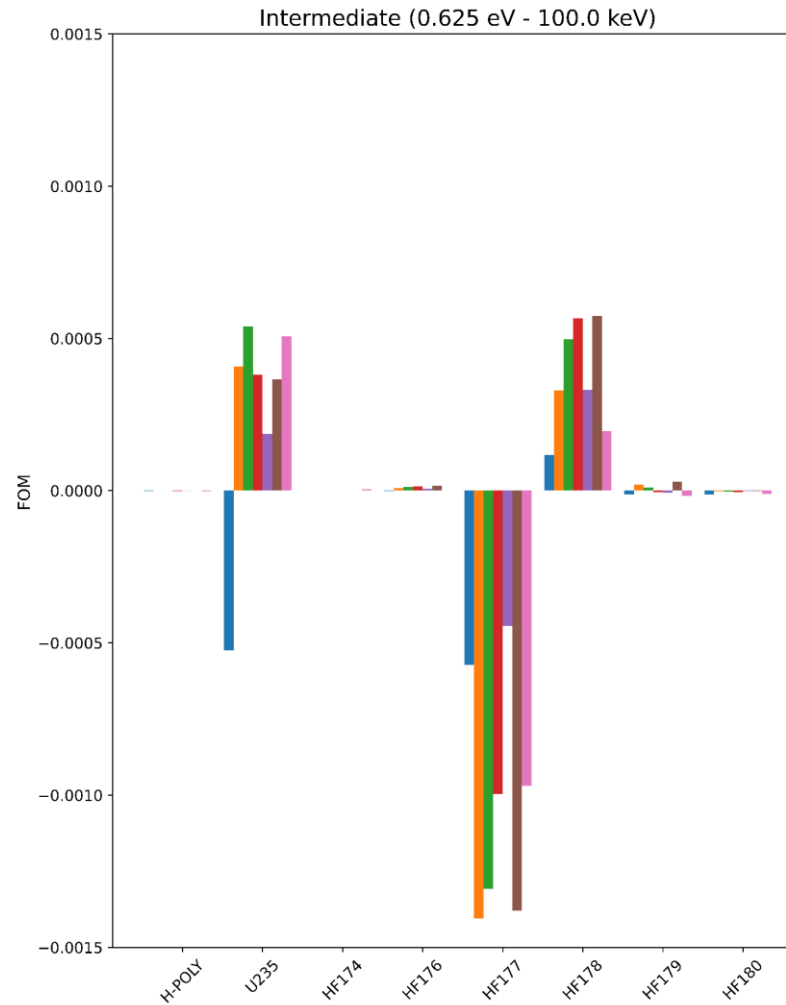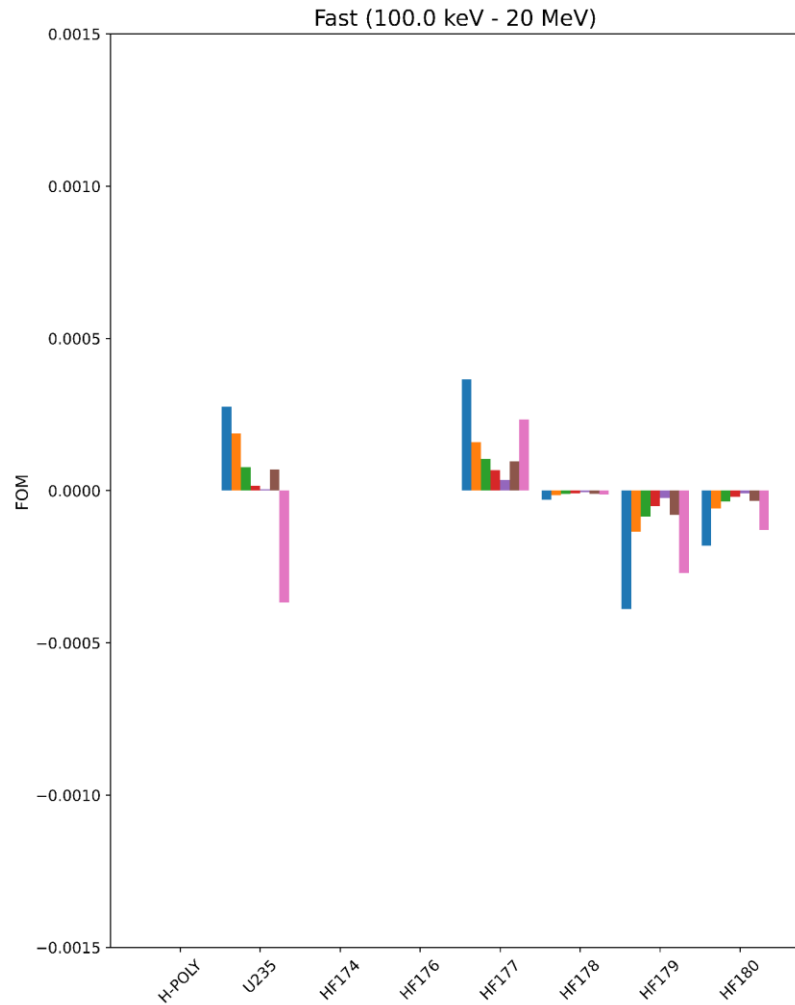 - Nuclide absorption fraction * nuclide absorption percent difference between dataset and ENDF/B-VIII.1

$$FOM = \frac{nuclide\ absorptions_{ENDF8.1\ with\ JENDL5\ Hf}}{total\ absorptions_{ENDF8.1\ with\ JENDL5\ Hf}} * \left(\frac{nuclide\ absorptions_{ENDF8.1\ with\ JENDL5\ Hf}}{nuclide\ absorptions_{ENDF8.1}} - 1 \right)$$

  - Shows nuclide absorption contribution difference
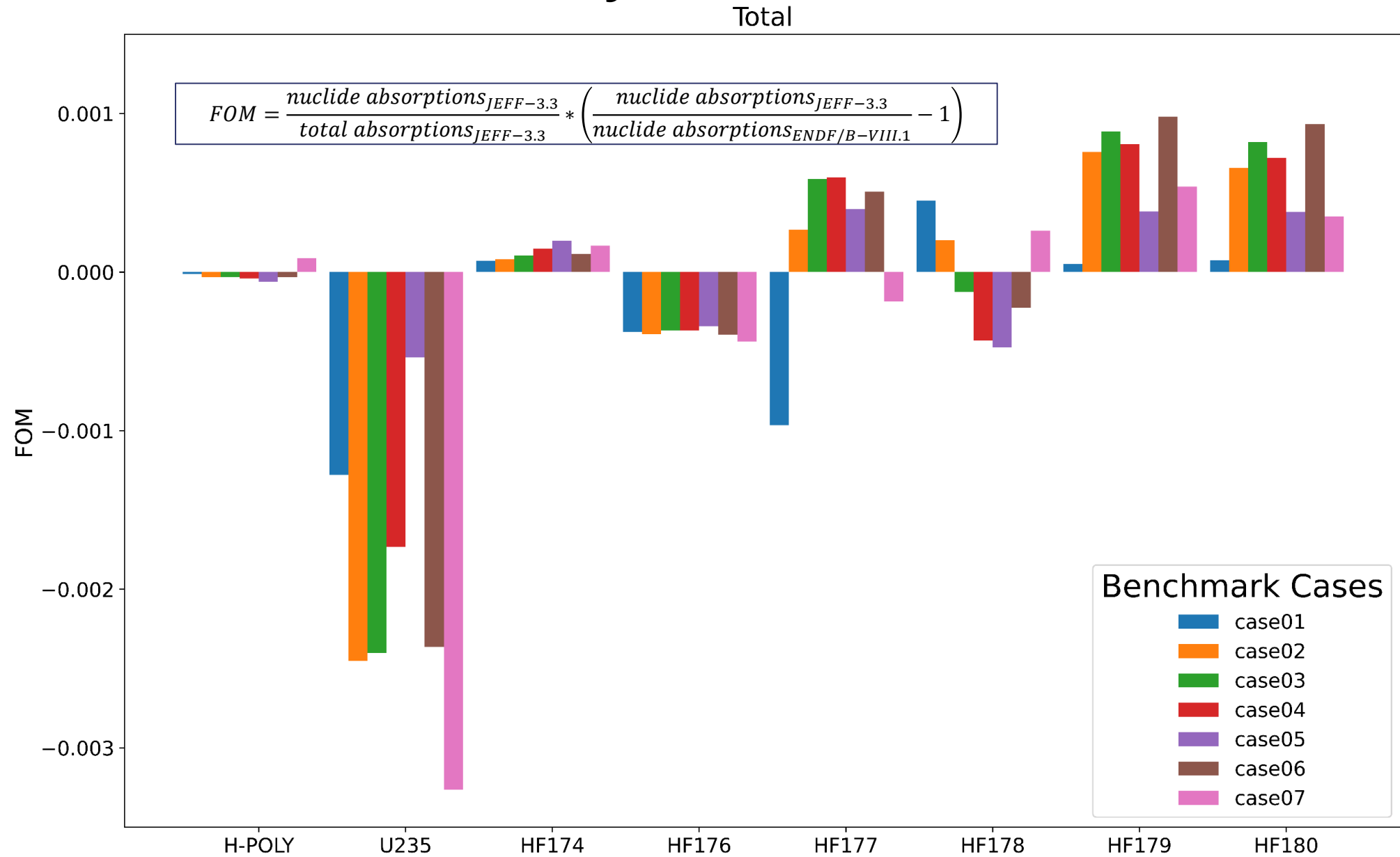 - Weighted by nuclides absorbing more

HMI013 Hafnium Analysis

Total

$$FOM = \frac{nuclide\ absorptions_{JENDL-5.0}}{total\ absorptions_{JENDL-5.0}} * \left(\frac{nuclide\ absorptions_{JENDL-5.0}}{nuclide\ absorptions_{ENDF/B-VIII.1}} - 1 \right)$$

Benchmark Cases

- case01 Fast
- case02 Int
- case03 Int
- case04 Mixed
- case05 Therm
- case06 Int
- case07 Fast-Refl

HMI013 Hafnium Analysis

$$FOM = \frac{nuclide\ absorptions_{JENDL-5.0}}{total\ absorptions_{JENDL-5.0}} * \left(\frac{nuclide\ absorptions_{JENDL-5.0}}{nuclide\ absorptions_{ENDF/B-VIII.1}} - 1 \right)$$

Case	Calculated Fission Fractions		
	Thermal (<0.625 eV)	Intermediate (0.625 eV - 100 keV)	Fast (>100 keV)
1	0.057	0.179	0.764
2	0.085	0.511	0.404
3	0.155	0.551	0.294
4	0.311	0.487	0.203
5	0.598	0.279	0.123
6	0.129	0.575	0.296
7	0.015	0.136	0.849

Fast (100.0 keV - 20 MeV)

Intermediate (0.625 eV - 100.0 keV)

Thermal (0.0 eV - 0.625 eV)

Benchmark Cases
- case01
- case02
- case03
- case04
- case05
- case06
- case07

HMI013 Hafnium Analysis

Total

$$FOM = \frac{nuclide\ absorptions_{JEFF-3.3}}{total\ absorptions_{JEFF-3.3}} * \left(\frac{nuclide\ absorptions_{JEFF-3.3}}{nuclide\ absorptions_{ENDF/B-VIII.1}} - 1 \right)$$

Benchmark Cases
- case01
- case02
- case03
- case04
- case05
- case06
- case07

HMI013 Hafnium Analysis

$$FOM = \frac{nuclide\ absorptions_{JEFF3.3}}{total\ absorptions_{JEFF3.3}} * \left(\frac{nuclide\ absorptions_{JEFF3.3}}{nuclide\ absorptions_{ENDF/B-VIII.1}} - 1 \right)$$

Case	Calculated Fission Fractions		
	Thermal (<0.625 eV)	Intermediate (0.625 eV - 100 keV)	Fast (>100 keV)
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TEX-Hf Analysis Summary

- ENDF/B-VIII.1
  - showing on average closest agreement to benchmark k_{eff}
- ENDF/B-VIII.1 with JENDL-5.0 hafnium
  - consistently higher eigenvalue, close to ENDF/B-VIII.1
  - Driven heavily by Hf-177. Contributions by Hf-178, Hf-179, and Hf-180
- JEFF-3.3
  - Consistently lower C/E's when compared to ENDF/B-VIII.1 and ENDF/B-VIII.1 with JENDL-5.0
  - Driven by all hafnium nuclides
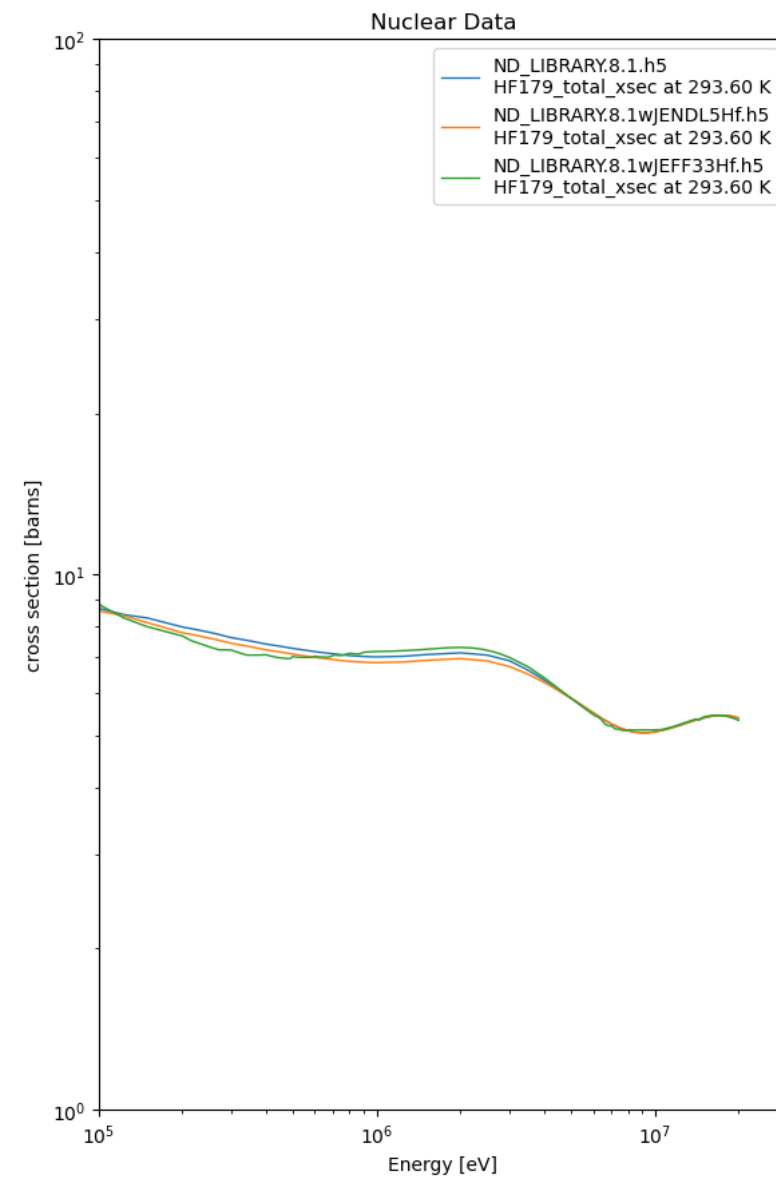 - Expanded resolved resonance regions

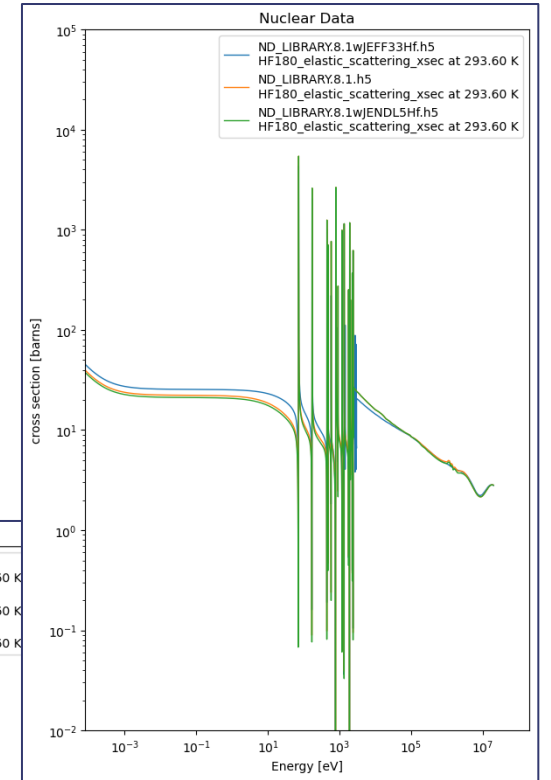# Hafnium-176 Total Cross-Section
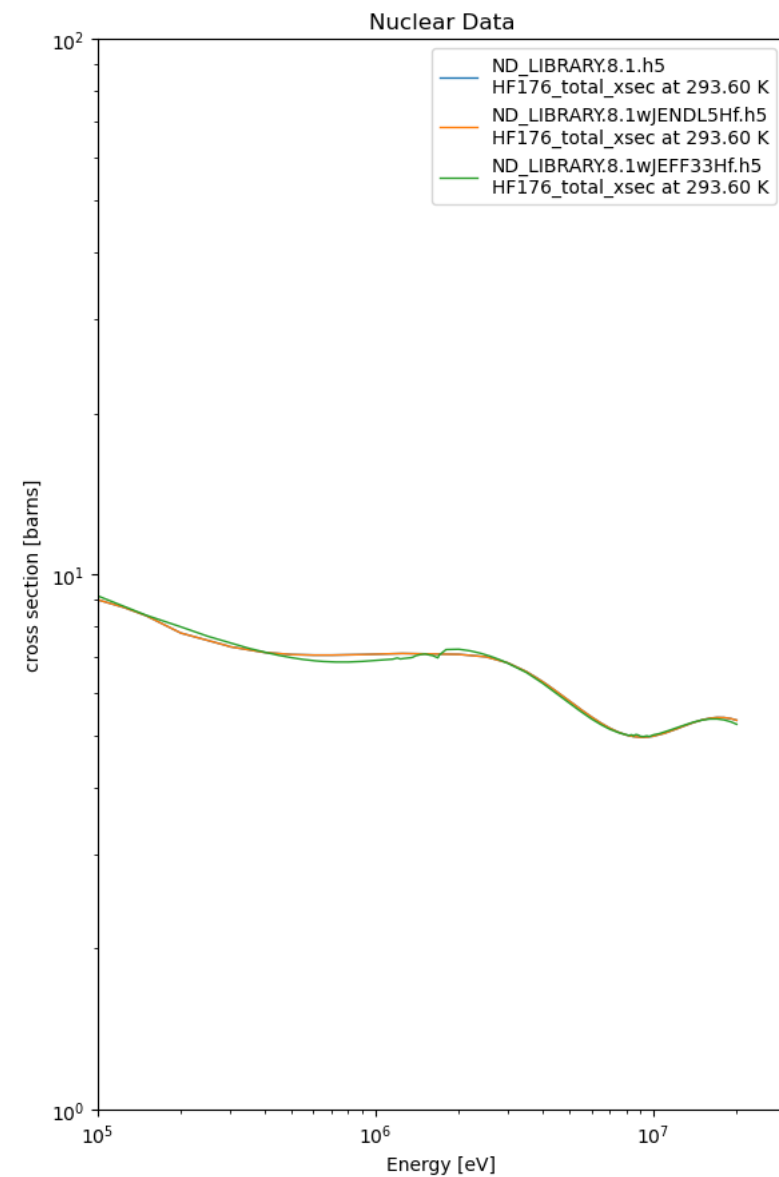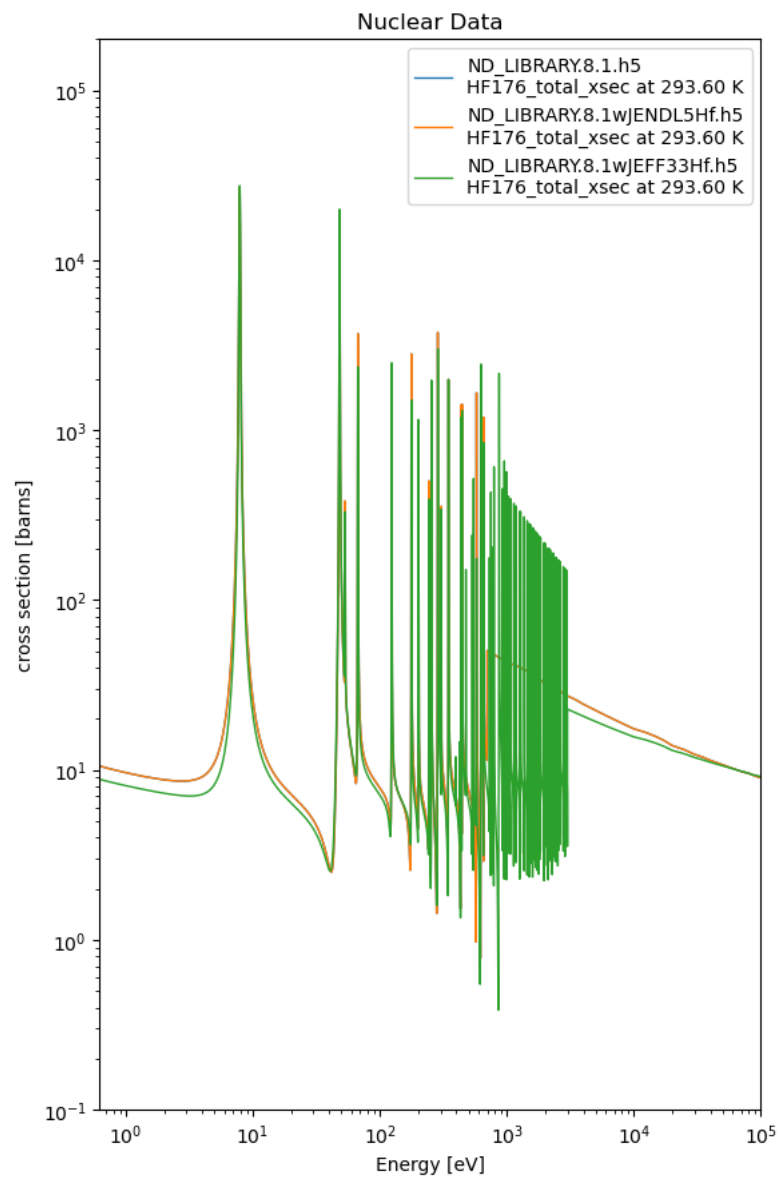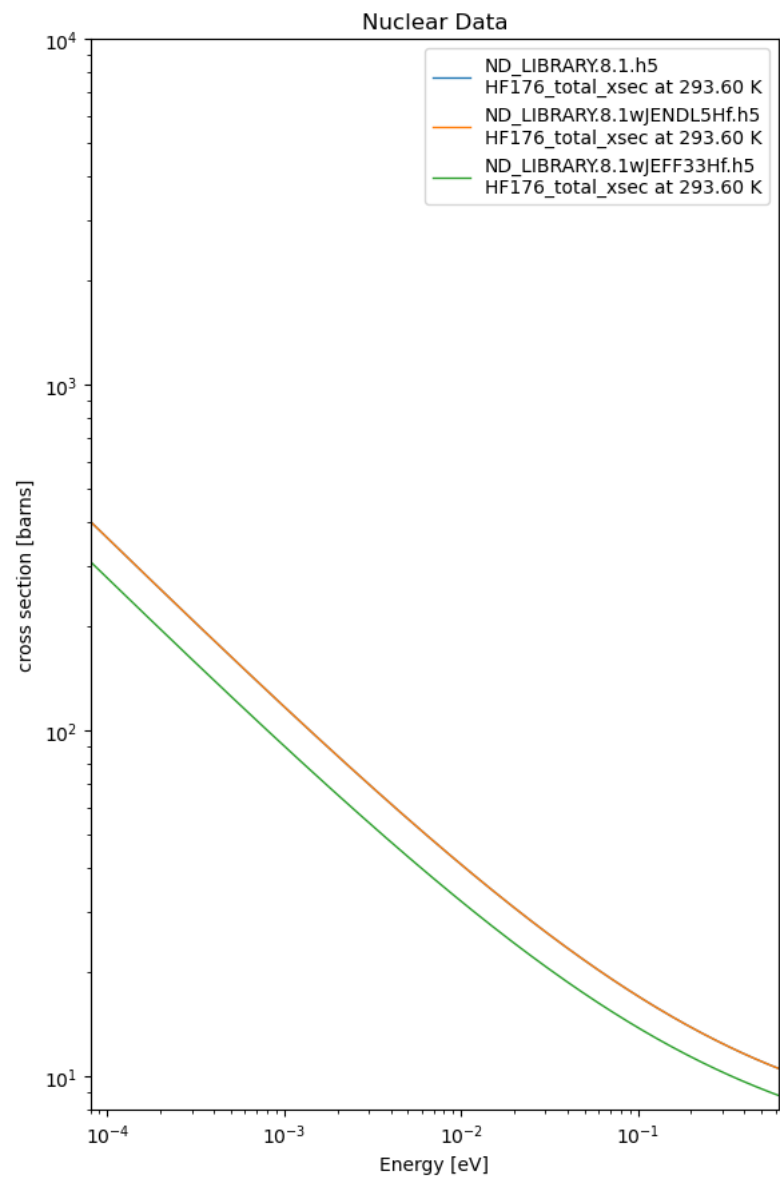
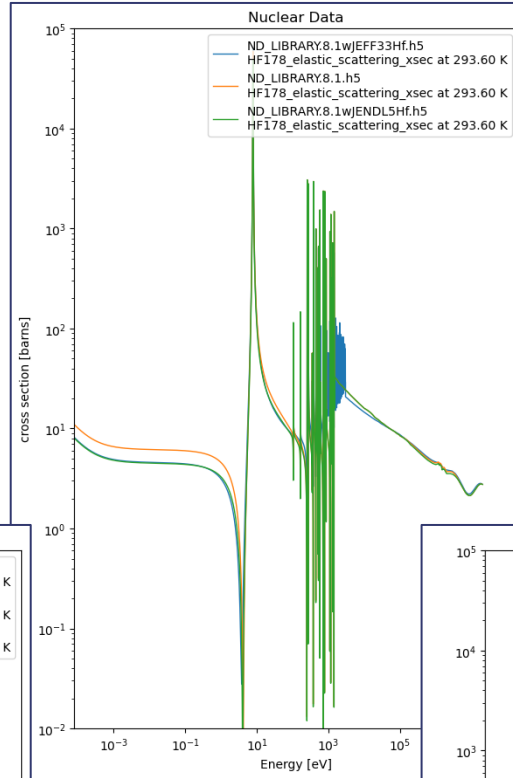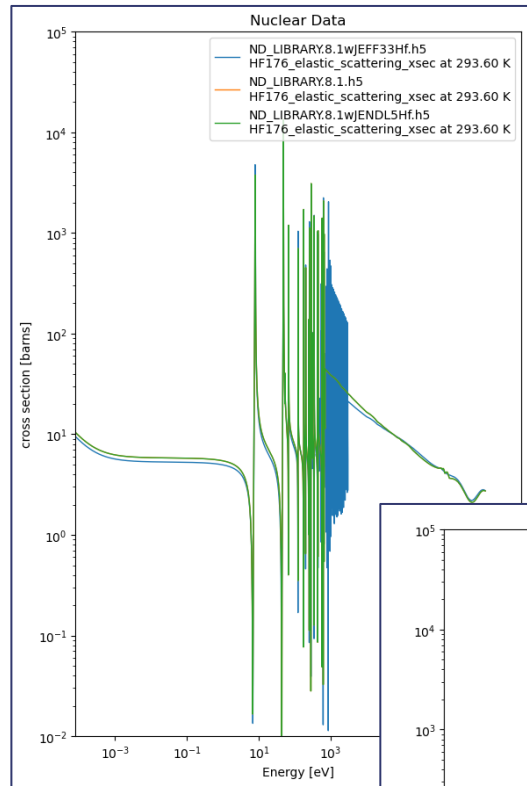# Hafnium-177 Total Cross-Section
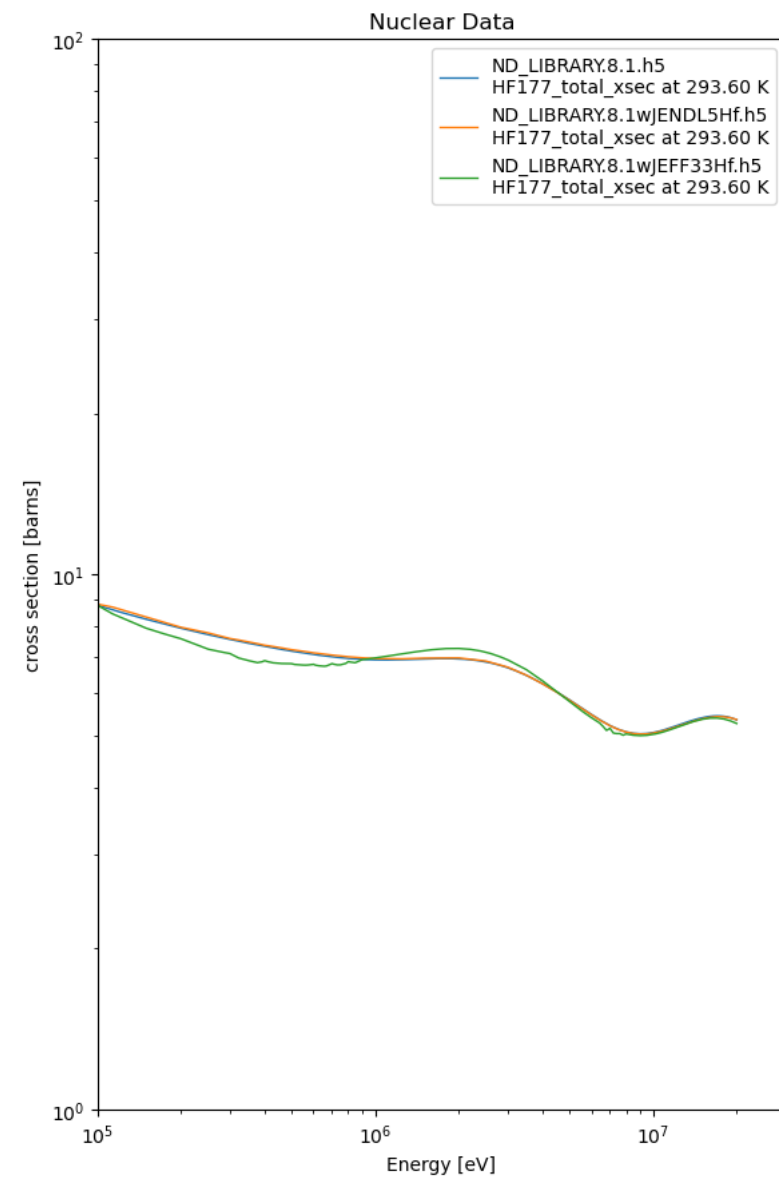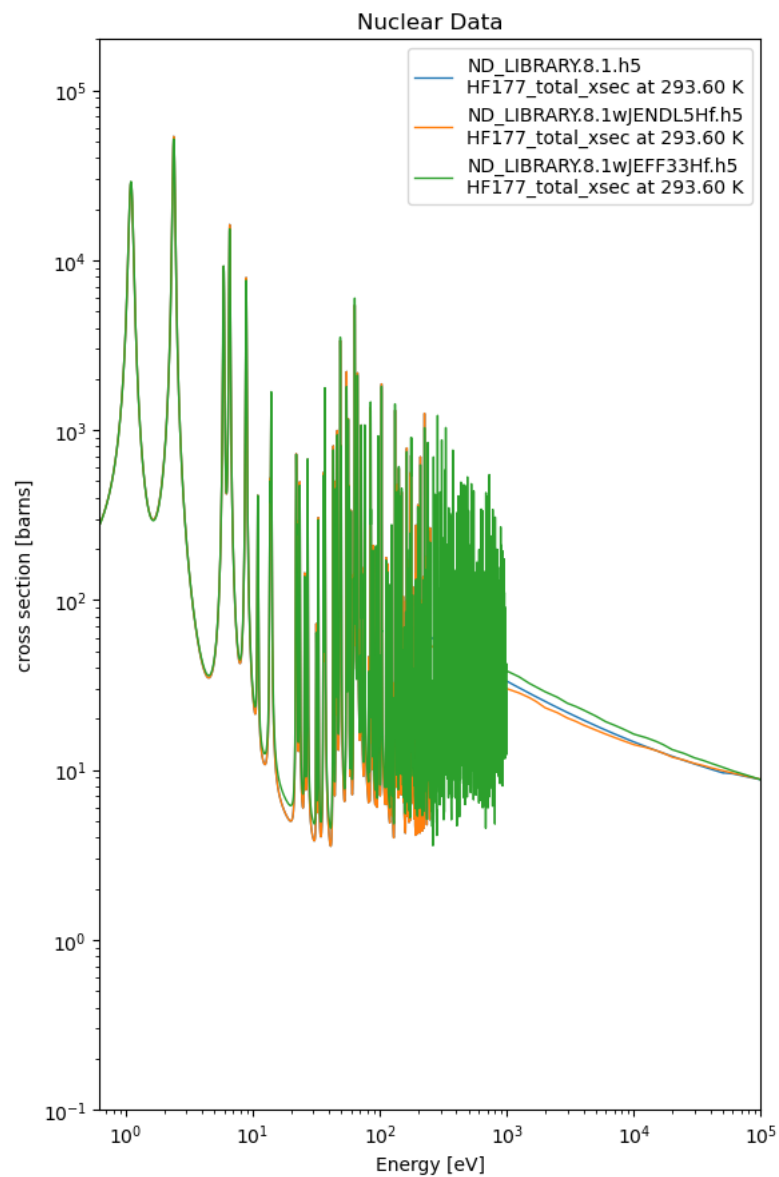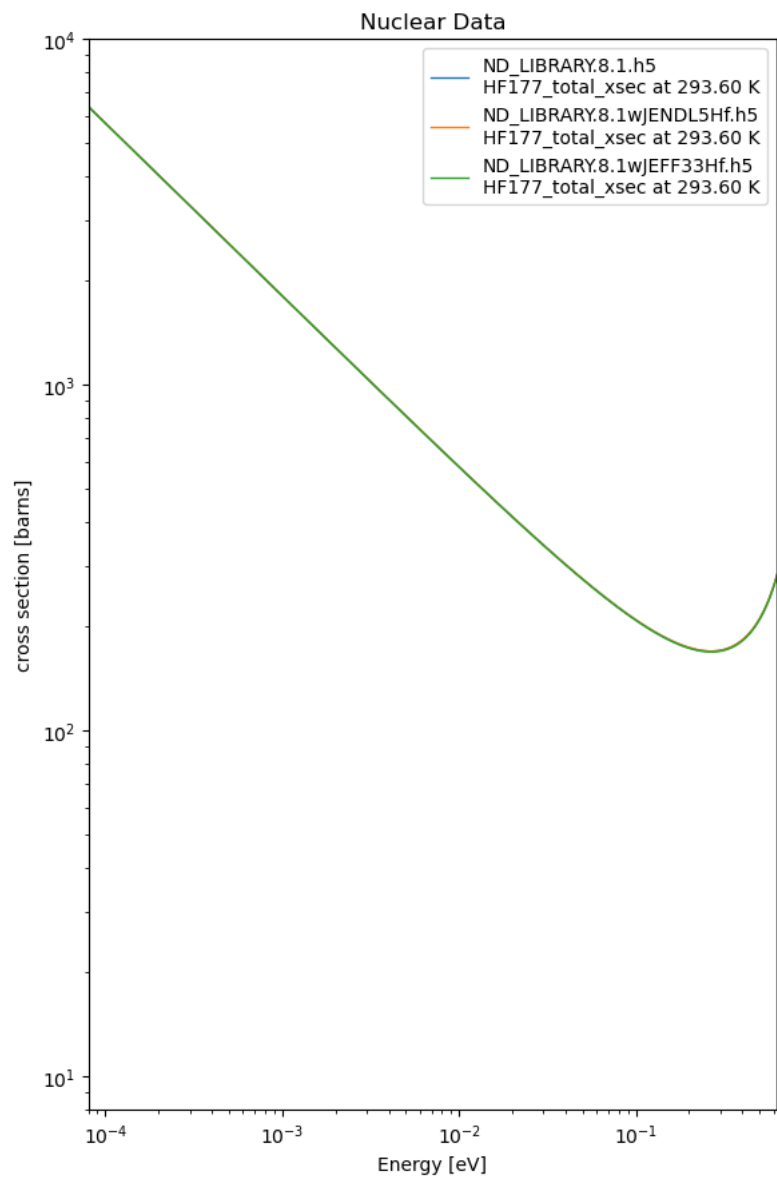
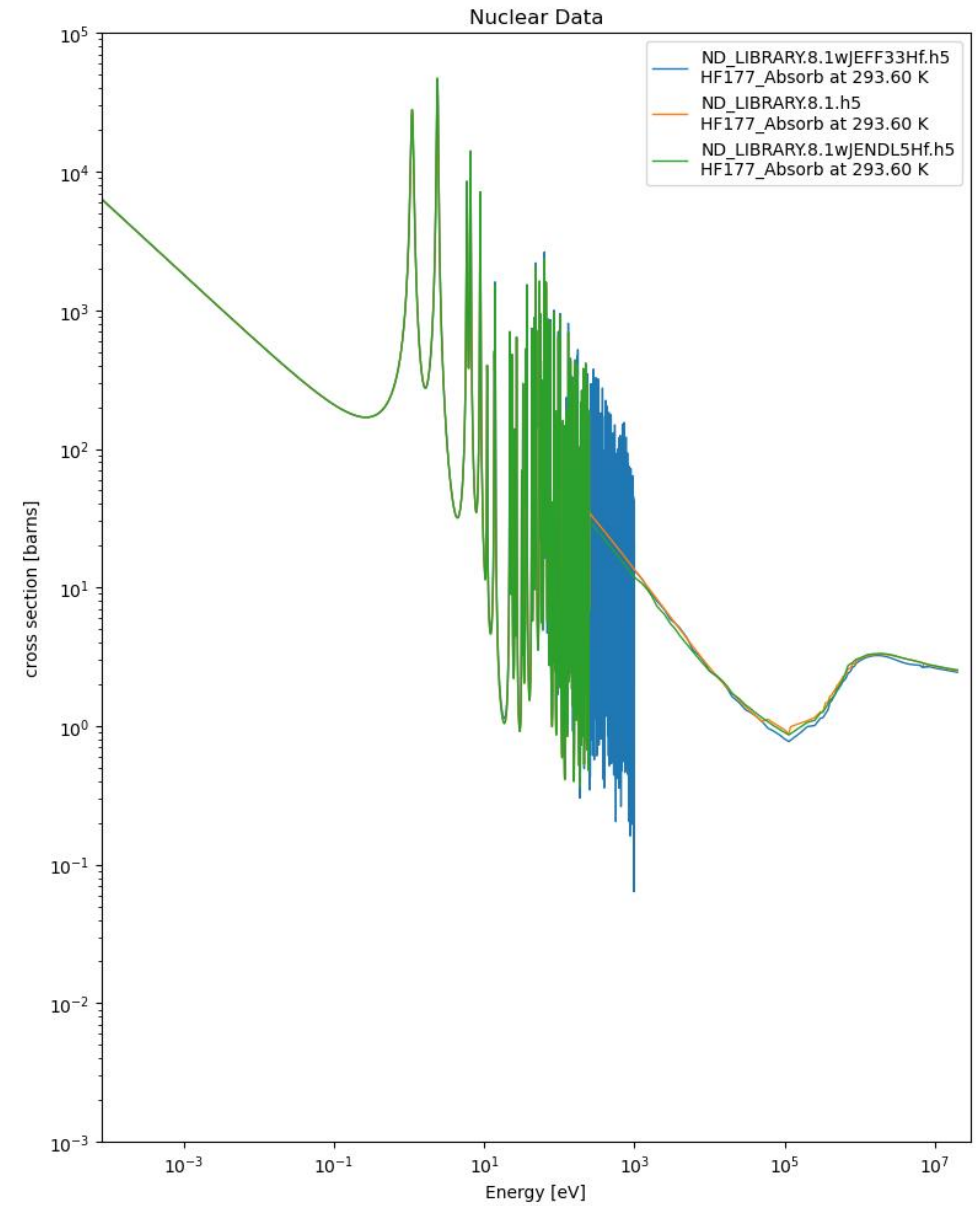# Hafnium-178 Total Cross-Section
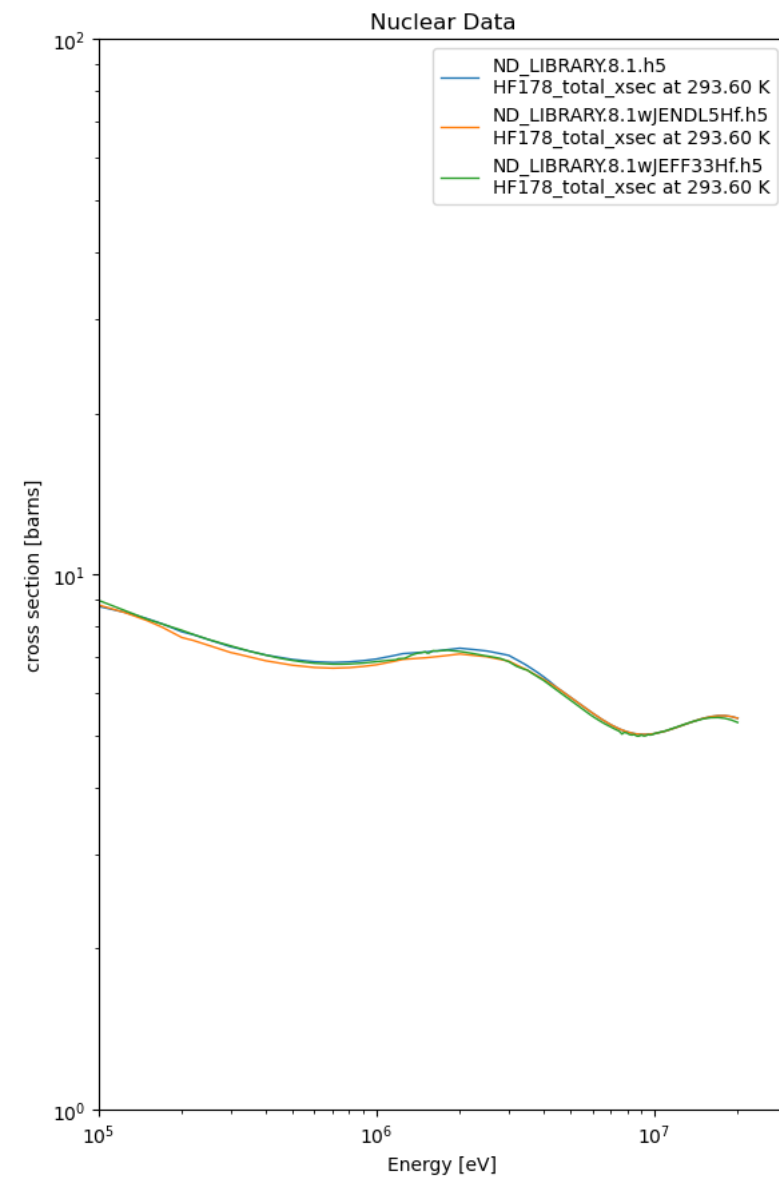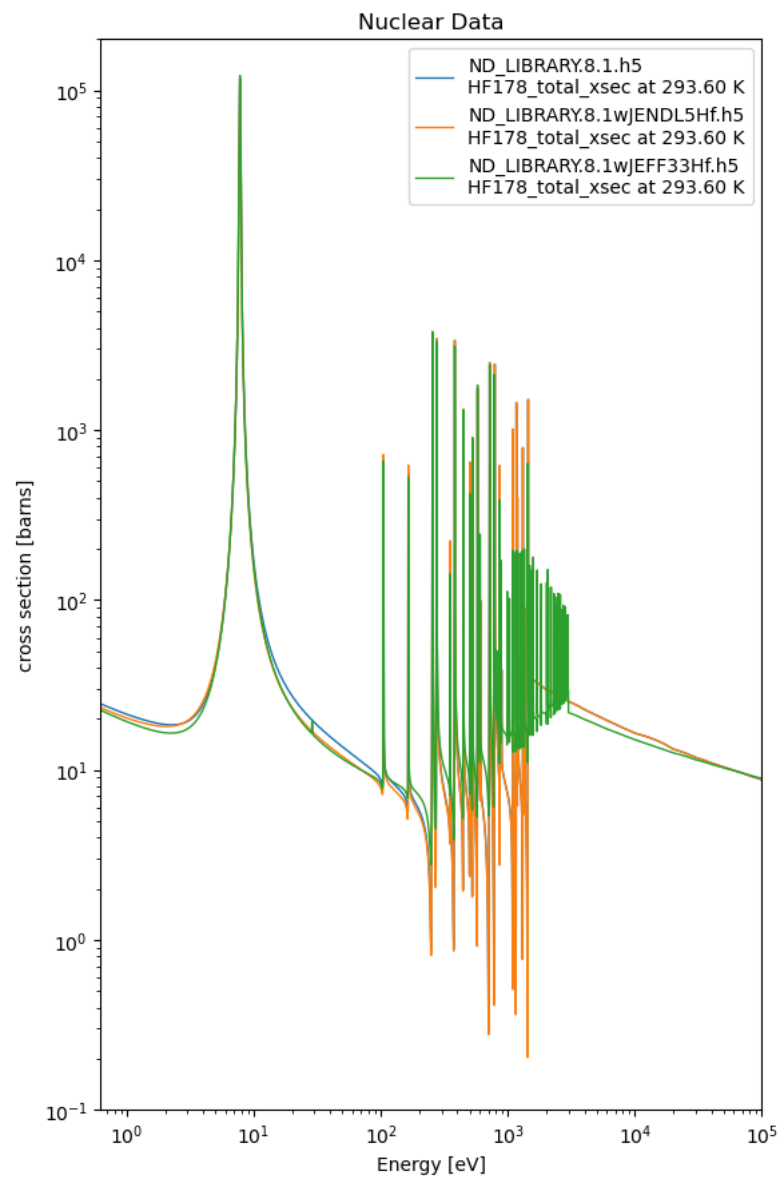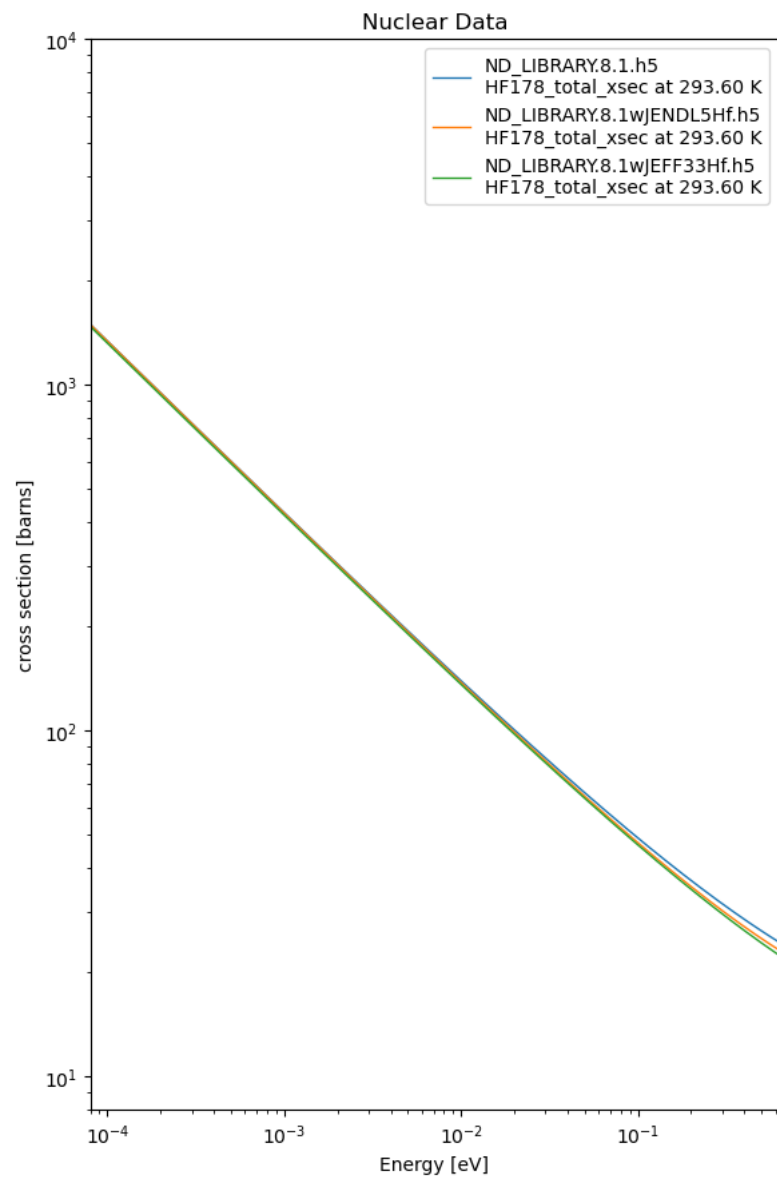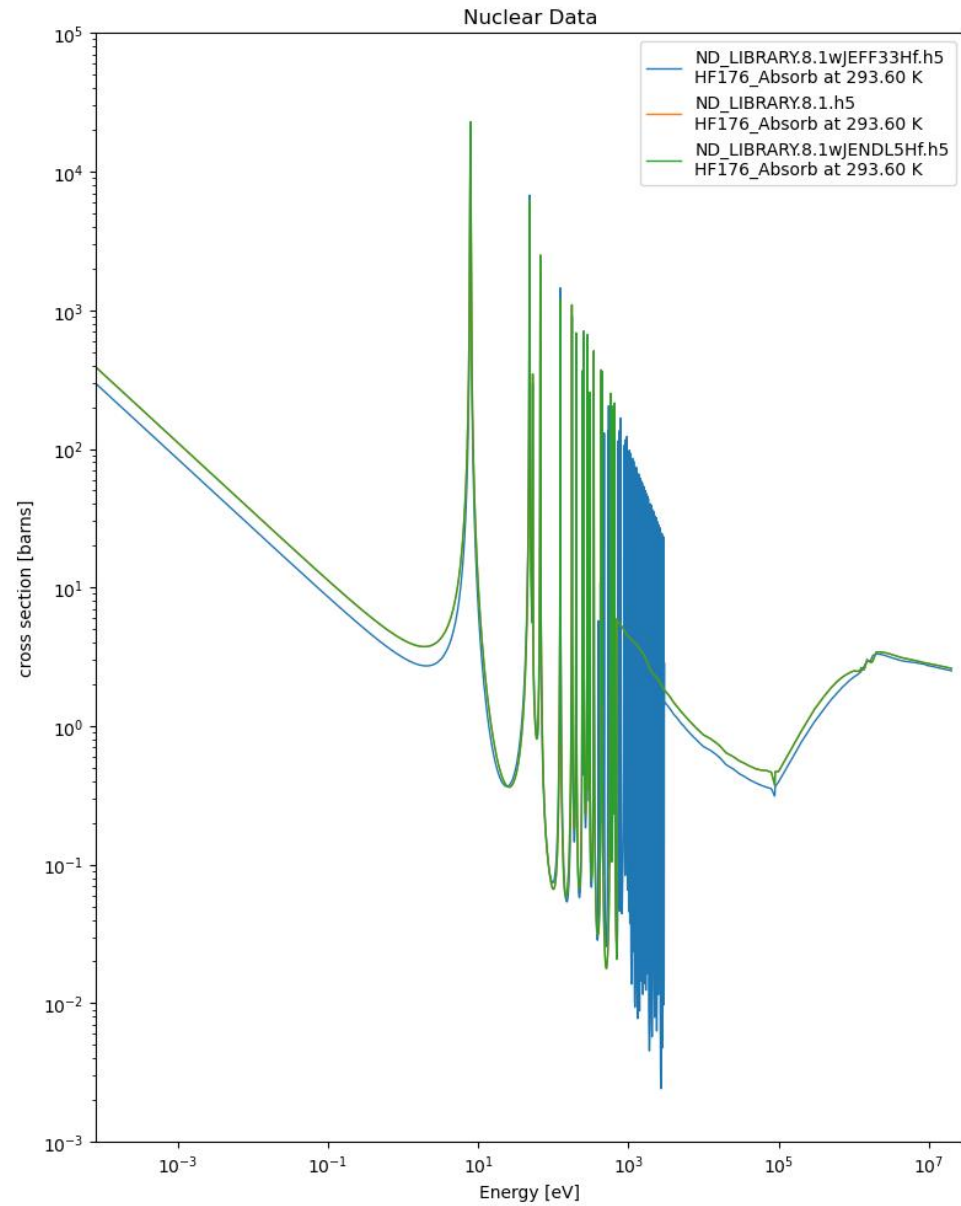
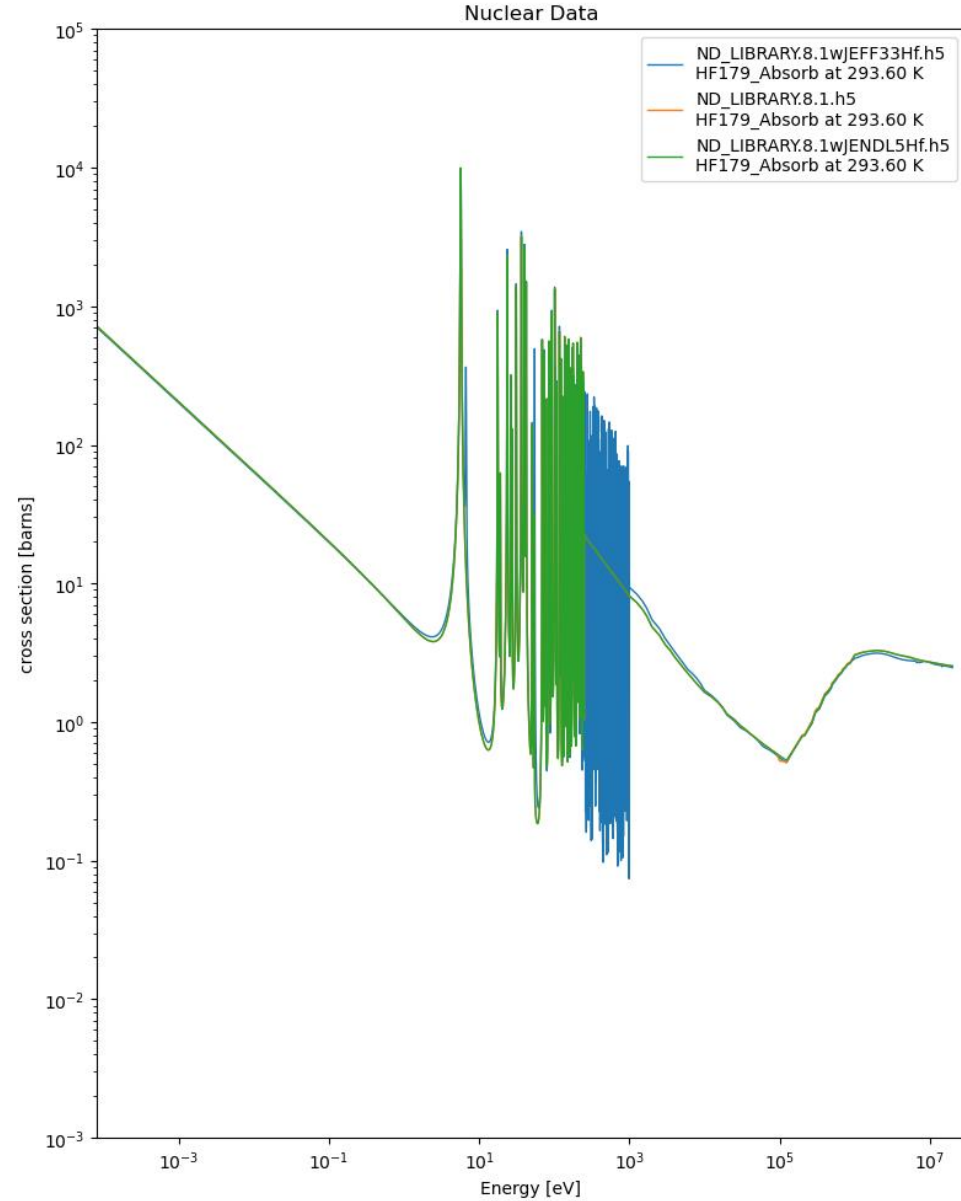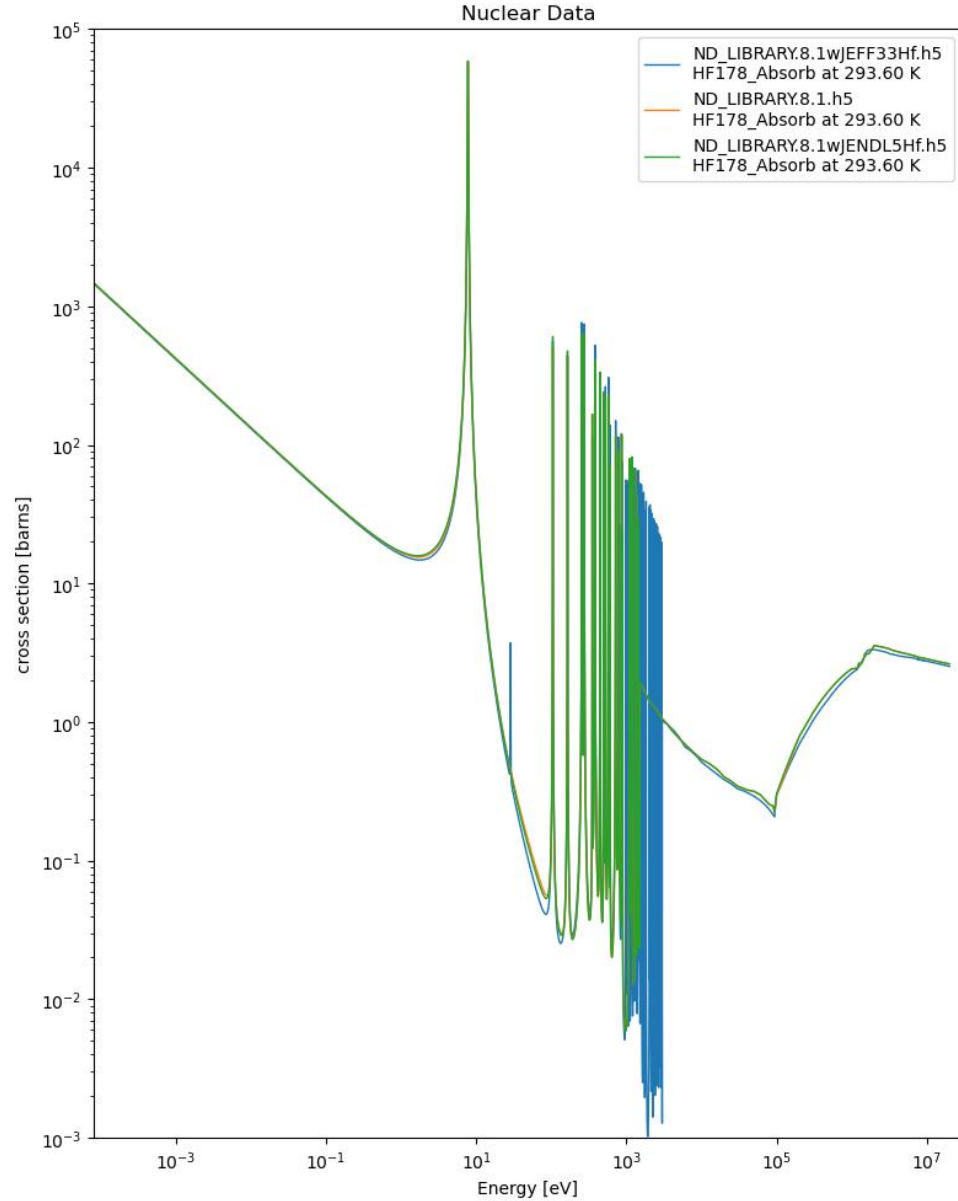# Hafnium-179 Total Cross-Section
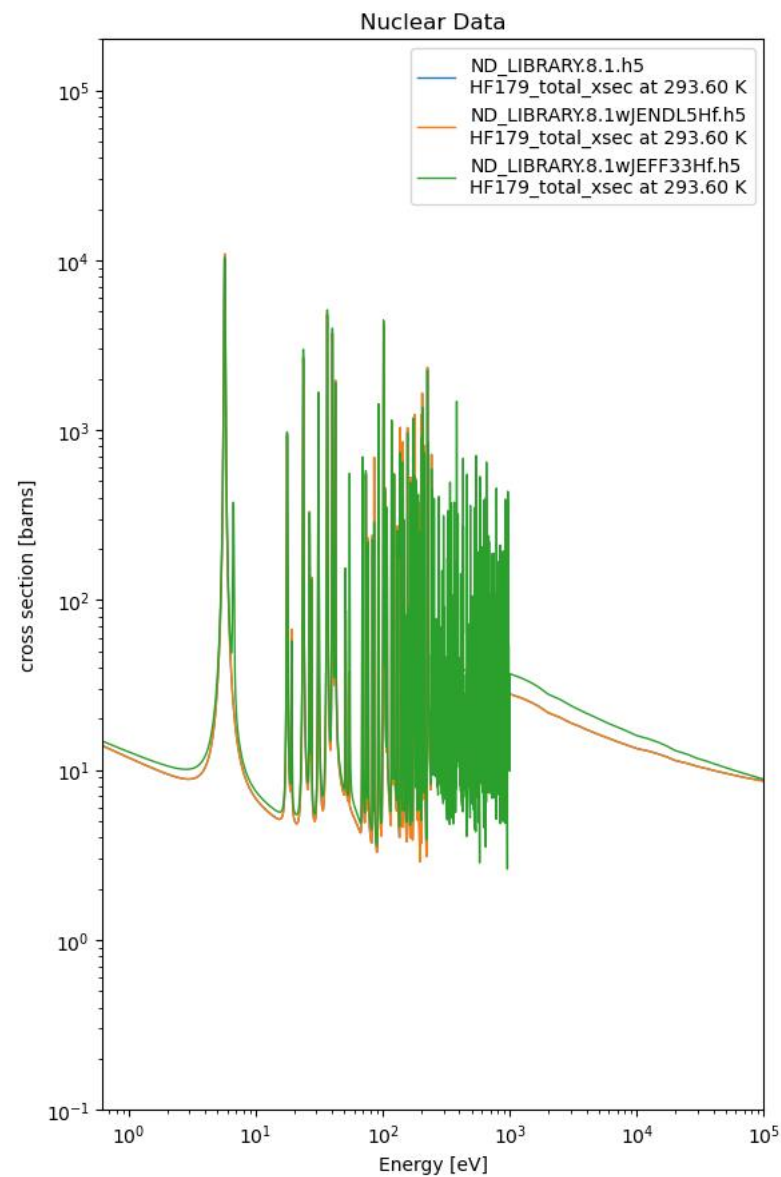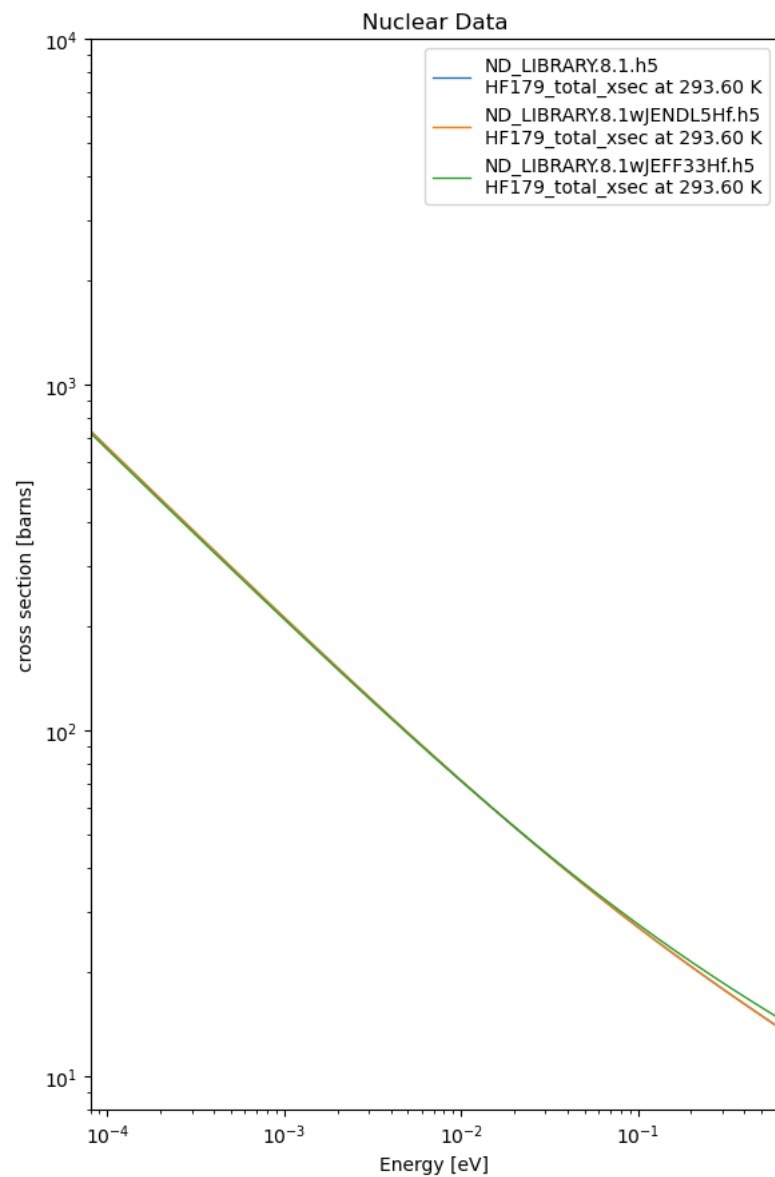
Hafnium-180 Total Cross-Section
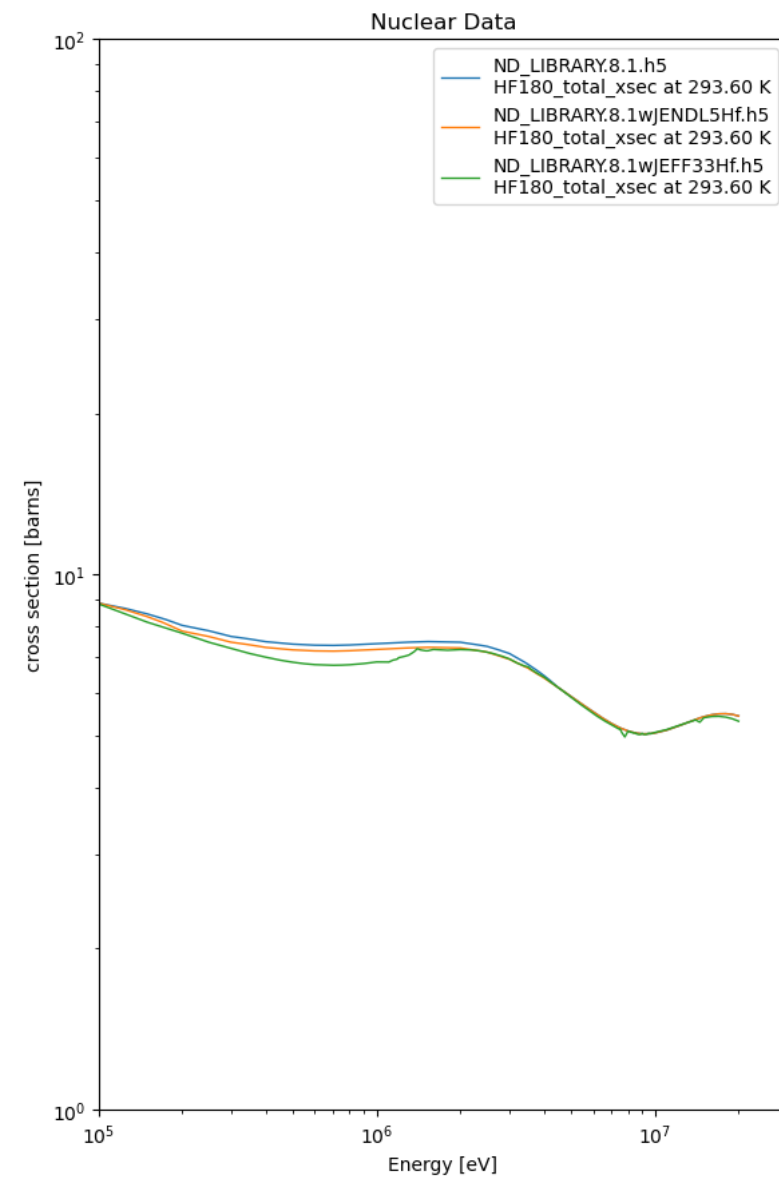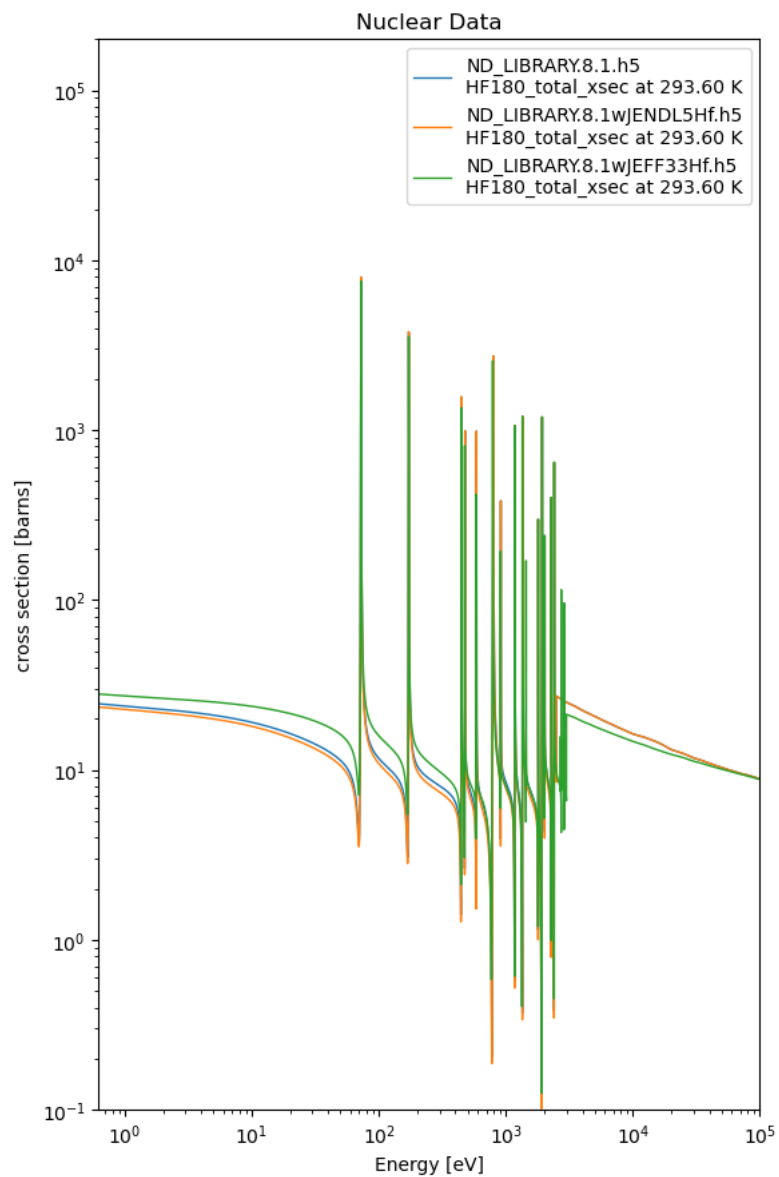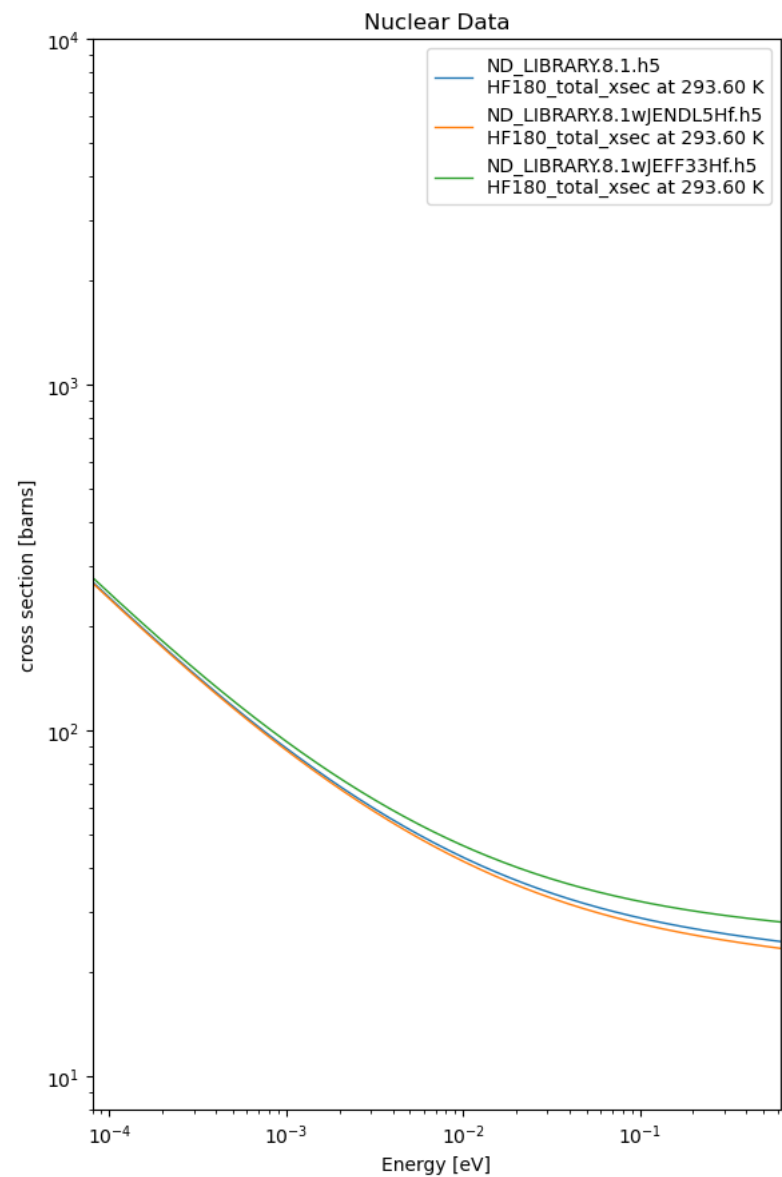
Hafnium Scattering

Hafnium Absorption

Hafnium Absorption

Hafnium Absorption