Data Evaluations in Support of NCSP

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2024 TPR Meeting
Santa Fe, New Mexico
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Outline

1. Report on data evaluations and Benchmark Testing in response to criticality safety needs
2. Performance of Hf evaluations using the new integral benchmark experiments: TEX-Hf
3. Remarks

Note: All tasks presented are listed in Appendix B of the NCSP five-year plan

Evaluation and Benchmark Testing

Isotope	Energy range	RR + RPC Evaluations	Target date for delivery the evaluation
^{51}V	Thermal to 200 keV	RR + CV	Complete (paper presented at ANS – Vegas)
^{103}Rh	Thermal to 8 keV	RR + URR (NNL) + CV	Complete (paper accepted for publication at NSE)
^{95}Mo	Thermal to 5 keV	RR + CV URR + CV (ongoing)	Complete (paper presented for the ANS – Orlando)
Hf (^{174}Hf, ^{176}Hf, ^{177}Hf, ^{178}Hf, ^{179}Hf, ^{180}Hf)	TEX-Hf integral benchmark experiments test with several existing evaluations		
Gd isotopes	Use of integral benchmark experiments to improve evaluations		
Zr (^{91}Zr, ^{92}Zr, ^{94}Zr)	Work in progress		
^{19}F	Inelastic data are needed (109.9 keV and 197.2 keV)		
^{56}Fe	a) Address issues with inelastic data b) Refine angular data fitting above 850 keV c) Incorporate new data if available d) Perform benchmark testing: criticality and shielding		

Zirconium Evaluation at ORNL

Some observations:

a) Examination whether extension of resolved resonance energy region is needed;

b) Inclusion of capture data in the fitting as they become available;

c) Inclusion of coherent and incoherent scattering in the resonance fitting;

Remarks

- Lack of experimental data may be an issue for completing the Zr task and other isotopes;
- Hopefully complete the evaluation for other Mo isotopes;
- Expected to complete the Gd evaluation using ENDF/B-VIII.1 information;
- Work on the Hf evaluation;
- Evaluations are tested with benchmark calculations;
- Evaluations will include covariances;

Testing Existing ^{177}Hf Evaluations TEX-Hf Benchmark Experiments

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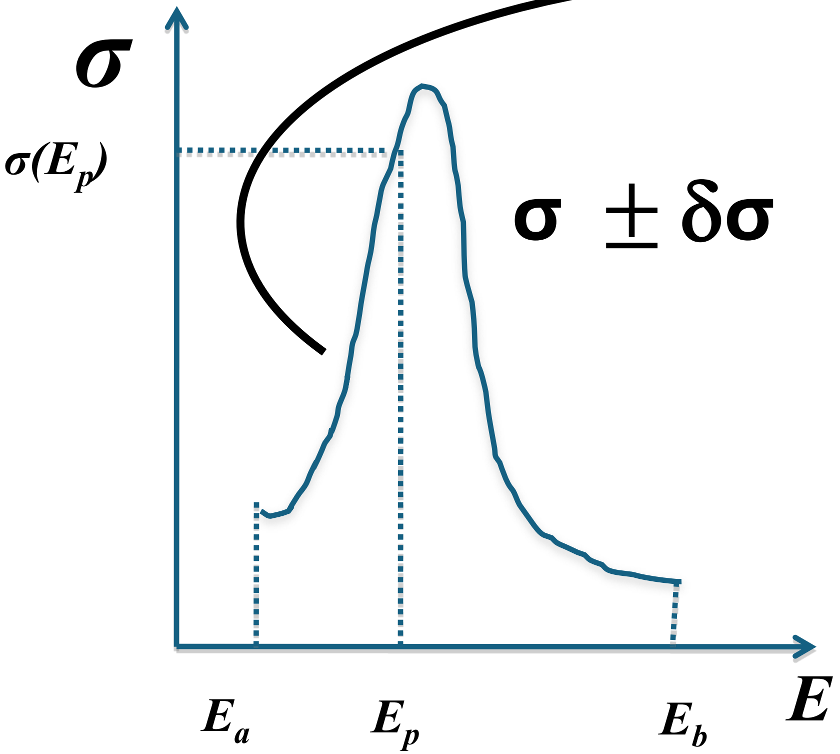
Motivation

- Review existing Hf evaluations, ENDF/B-VII.1, ENDF/B-VIII.0, ENDF/B-VIII.1, JEFF3.3, and JENDL5
- Start with the ^{177}Hf evaluation
- Perform benchmark calculations using the ORNL SCALE/CE_KENO tool
- Test the ^{177}Hf evaluation with the TEX-Hf benchmark

EXFOR
Data Evaluation
Data Library (ENDF)

Differential and Integral

ICSBEP
IRPhEP
SINBAD



$$\sigma \pm \delta\sigma$$

σ(E) as a function of energy

Differential

$$R = \int_{E_a}^{E_b} \sigma(E)\varphi(E)dE$$

$$R \pm \delta R$$

R **is the reaction rate (measured quantity)**

Integral

Hf Evaluations

Isotope	Abundance (%)	Spin	σ_γ (b) (ATLAS)	I_γ (b) (ATLAS)
^{174}Hf	0.16	0+	549 ± 7	307 ± 15
^{176}Hf	5.26	0+	23.5 ± 3.1	708 ± 15
^{177}Hf	18.60	7/2−	375 ± 10	7200 ± 200
^{178}Hf	27.28	0+	84 ± 4	1882 ± 20
^{179}Hf	13.62	9/2+	41 ± 3	630 ± 30
^{180}Hf	35.08	0+	13.04 ± 0.07	33.0 ± 1.0

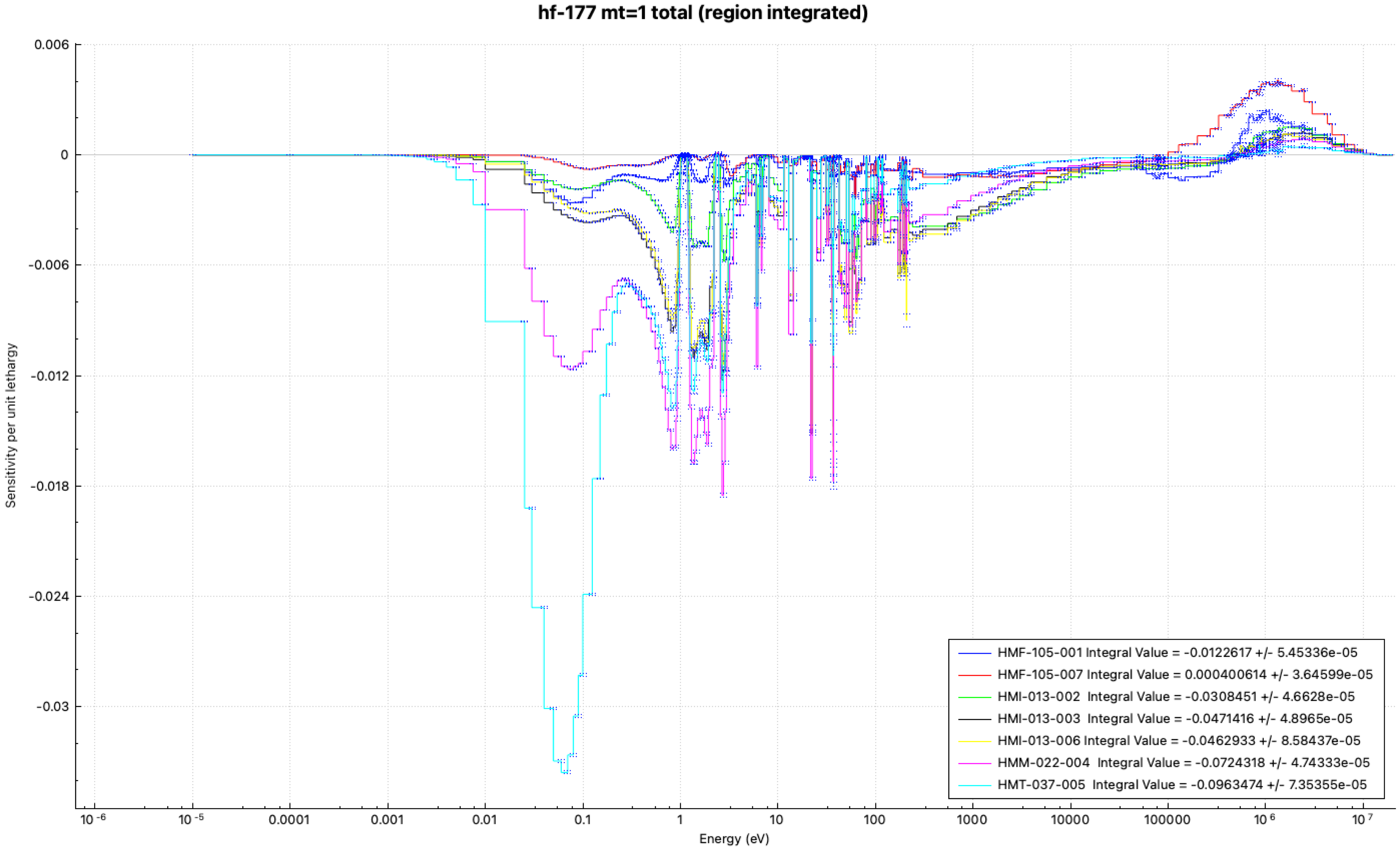
^{177}Hf Evaluations

Isotope	Resolved resonance upper limit (eV)	Unresolved resonance upper limit (keV)	σ_γ (b)	I_γ (b)	Resonance parameter covariance
ENDF/B-VII.1	510	50	373.59	7213.1	No
ENDF/B-VIII.0	510	50	373.59	7213.3	No
ENDF/B-VIII.1	250	50	371.89	7215.8	No
JENDL5	250	50	371.89	7210.8	No
JEFF3.3	1000	112	371.24	7167.9	Yes

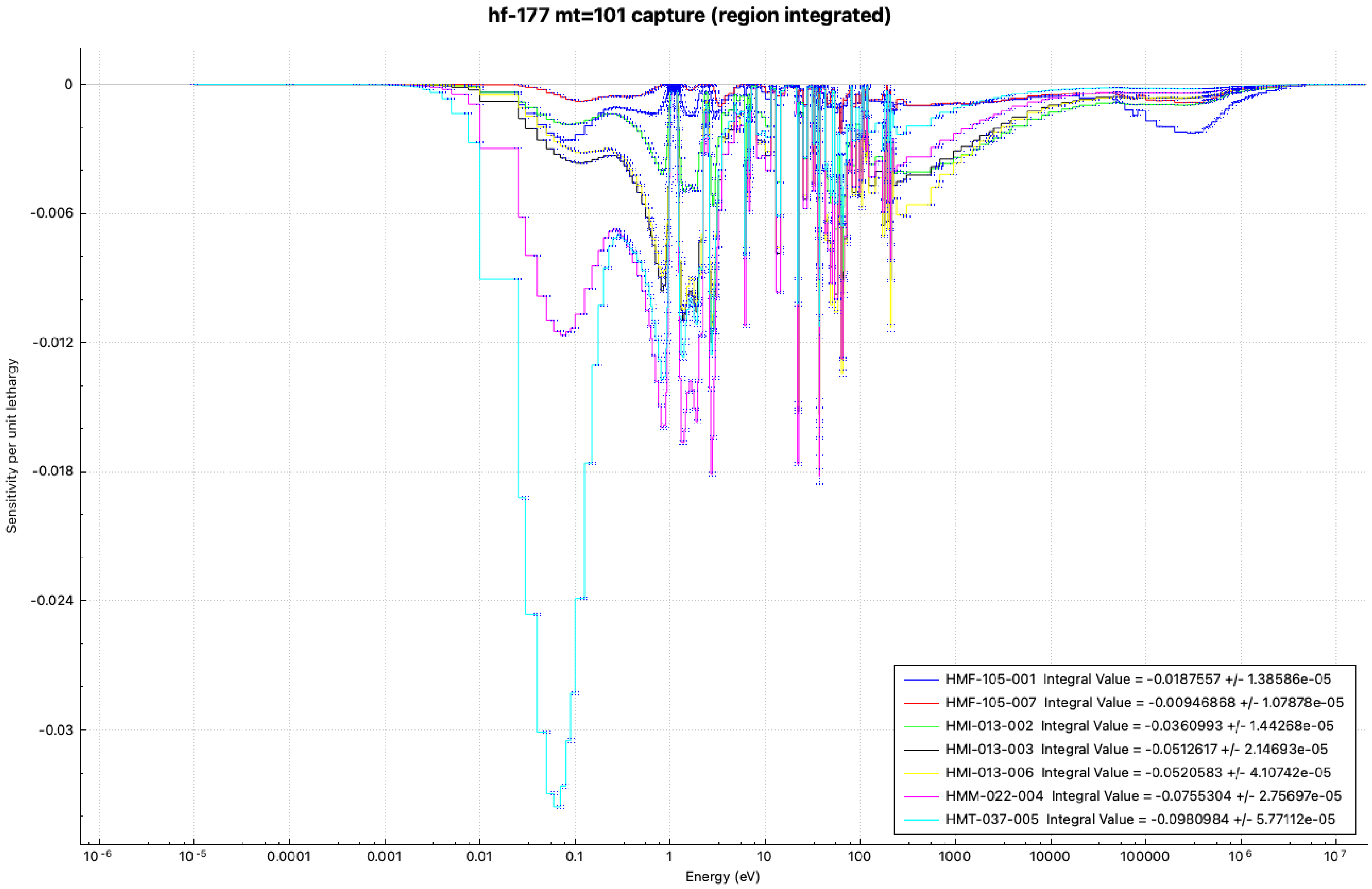
Seven Critical Experiments Sensitive to the Hafnium Cross Sections

Benchmark	Energy of average lethargy causing fission (eV)
HEU-MET-THERM-037-005	3.82
HEU-MET-MIXED-022-004	88.65
HEU-MET-INTER-013-003	930.06
HEU-MET-INTER-013-006	1178.60
HEU-MET-INTER-013-002	6097.69
HEU-MET-FAST-105-001	1.22×10^5
HEU-MET-FAST-105-007	3.51×10^5

Sensitivities to the ^{177}Hf Total Cross Sections



Sensitivities to the ^{177}Hf Capture Cross Sections



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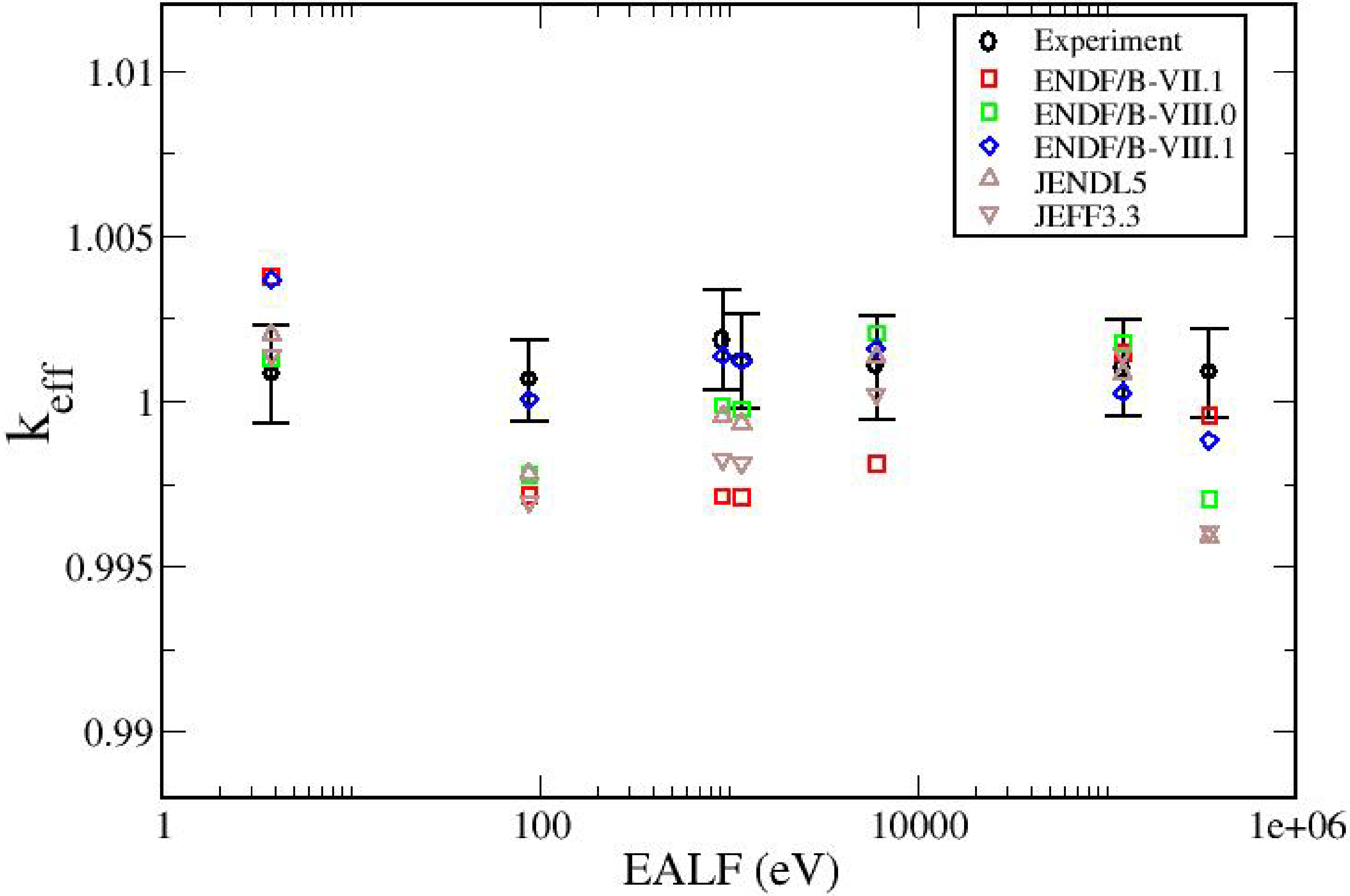
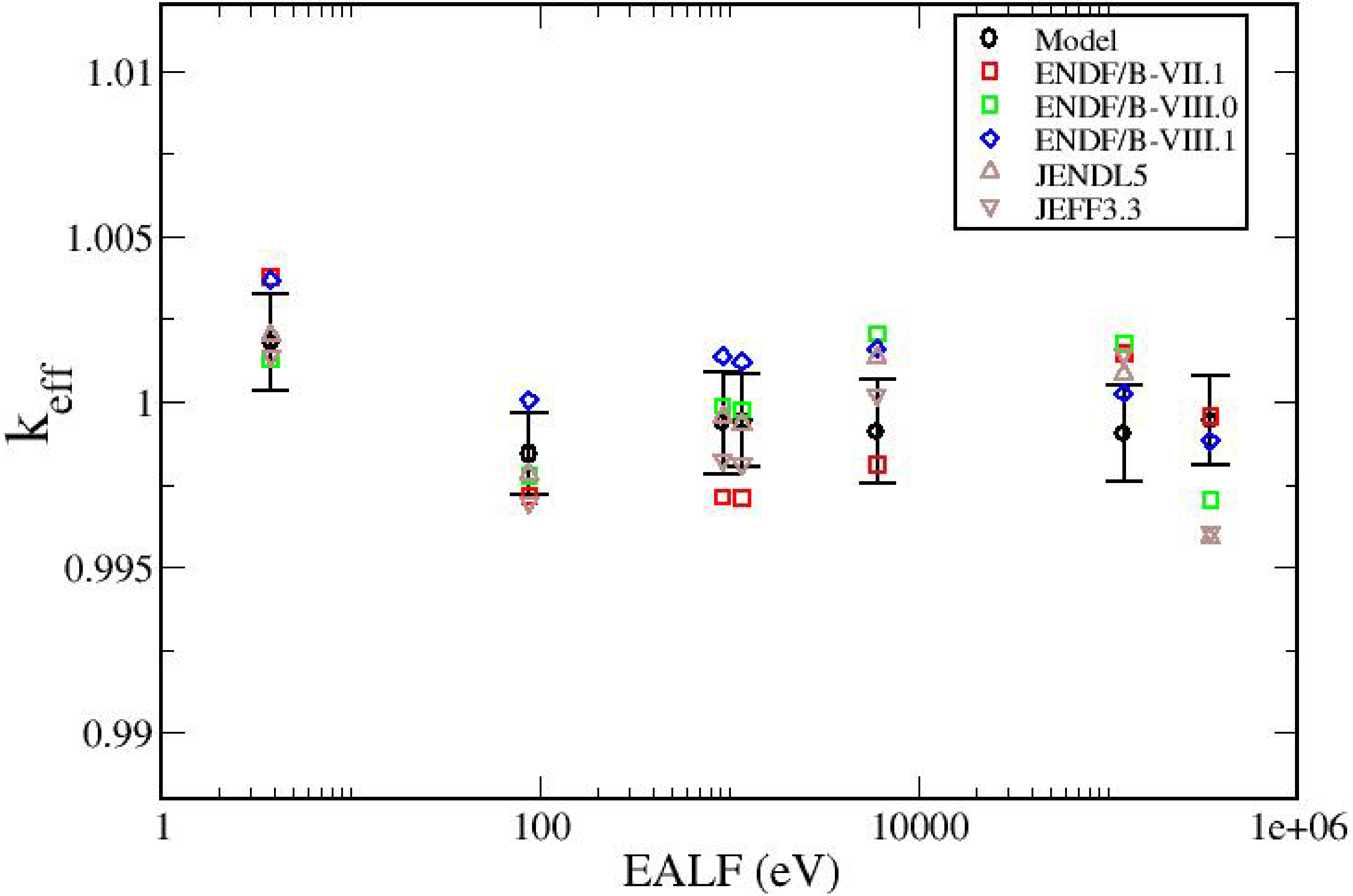
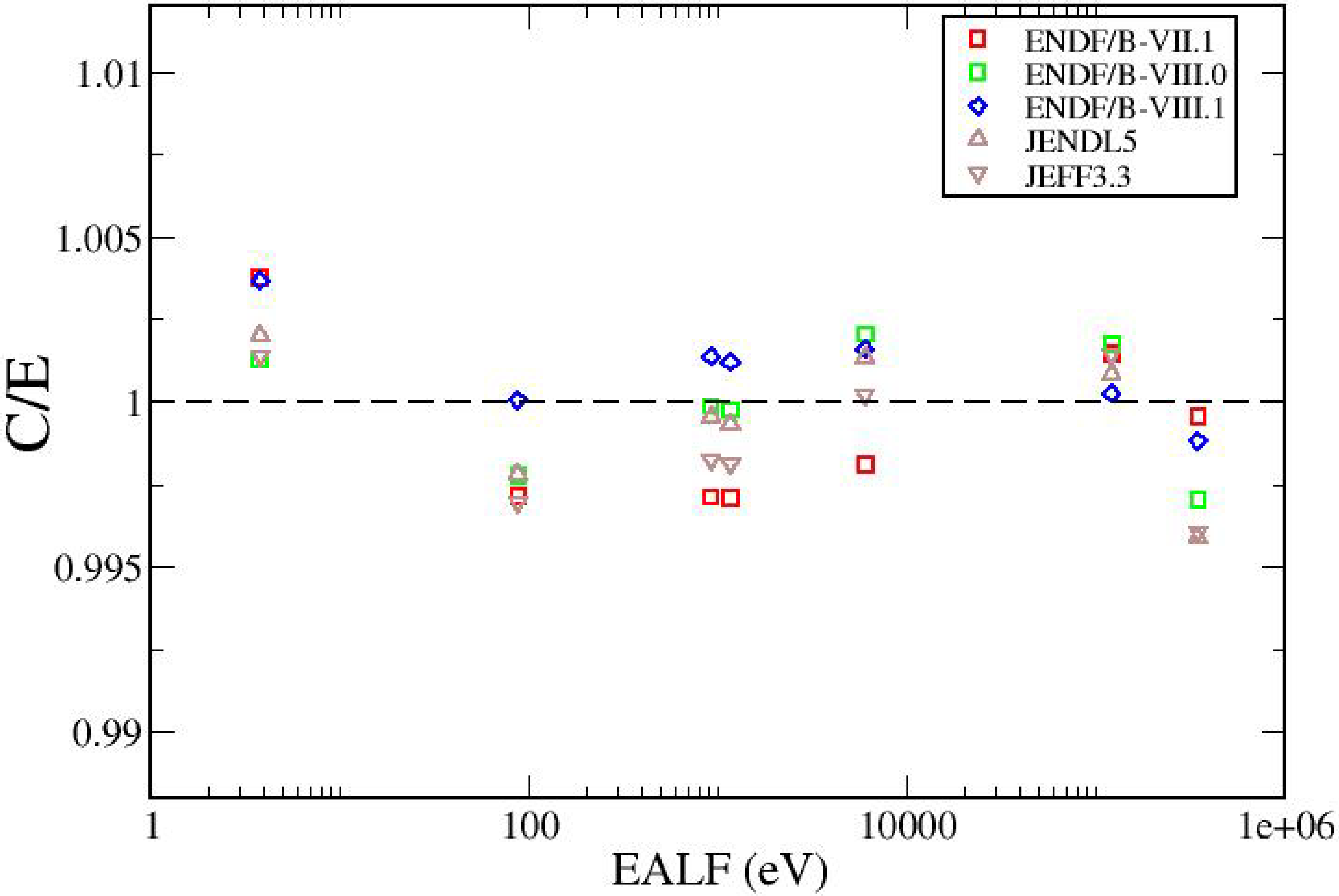
Benchmark Results (Experiment)



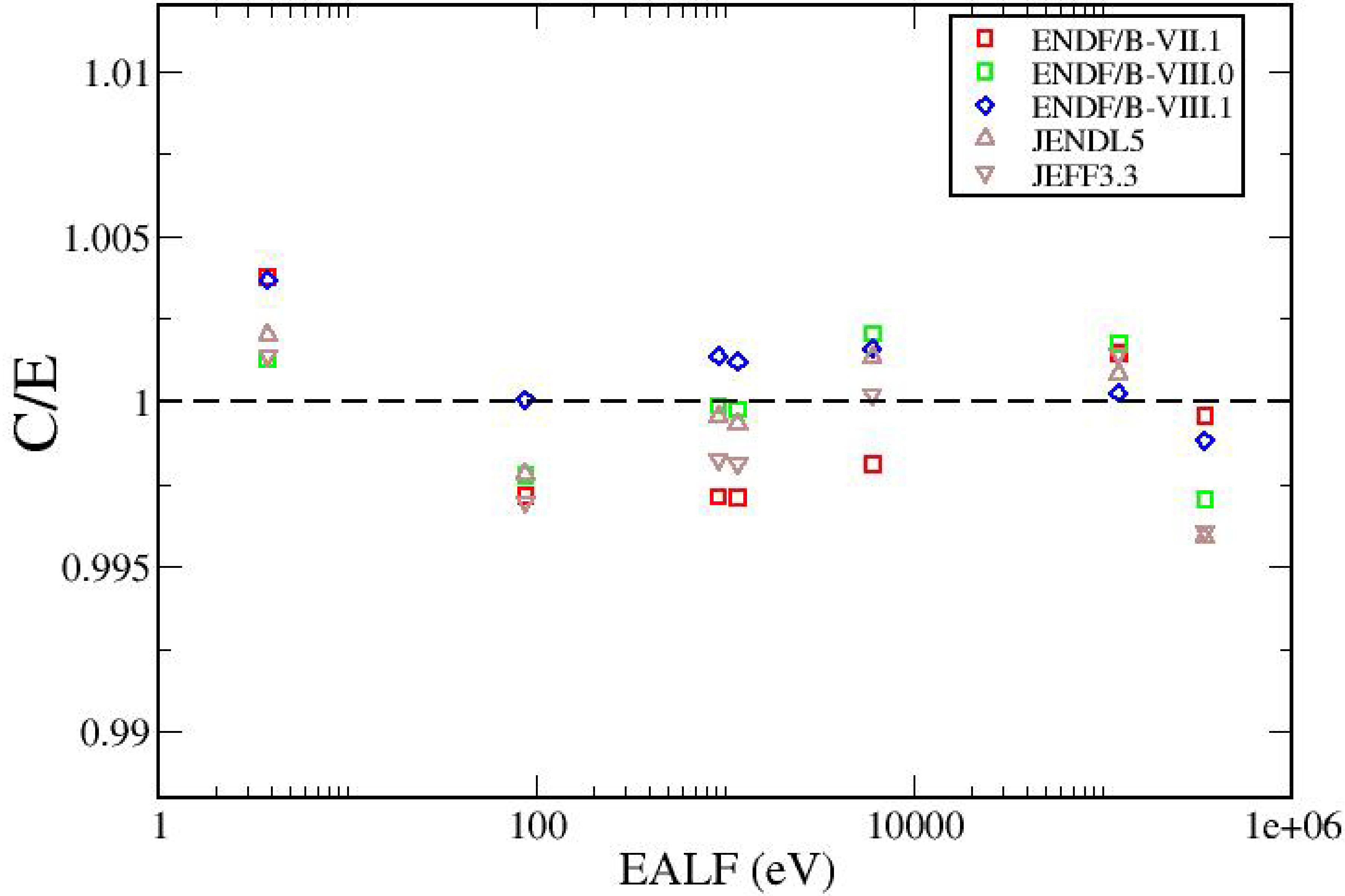
Benchmark Results (Model)



Benchmark Results (Experiment)



Benchmark Results (Model)



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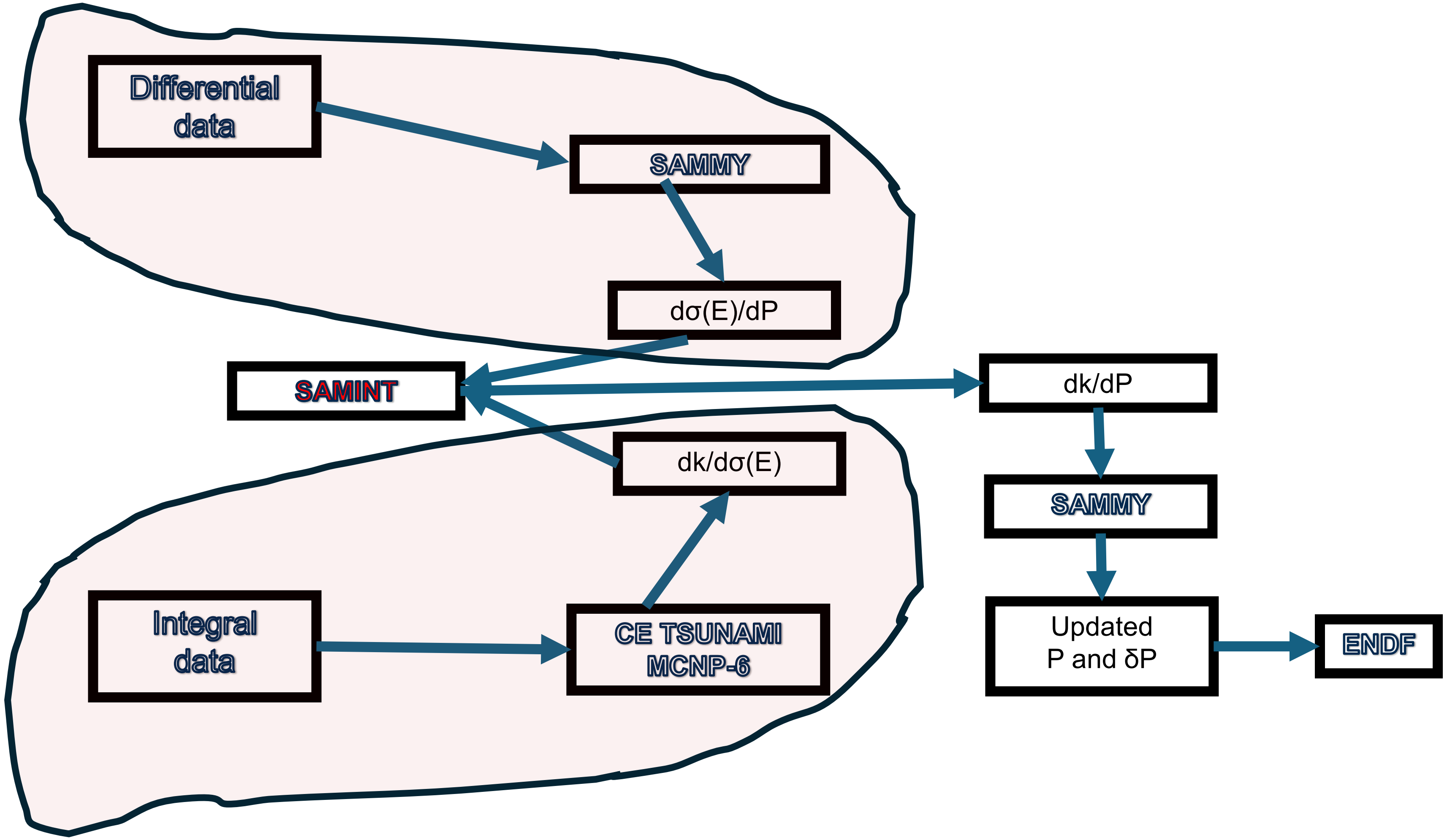
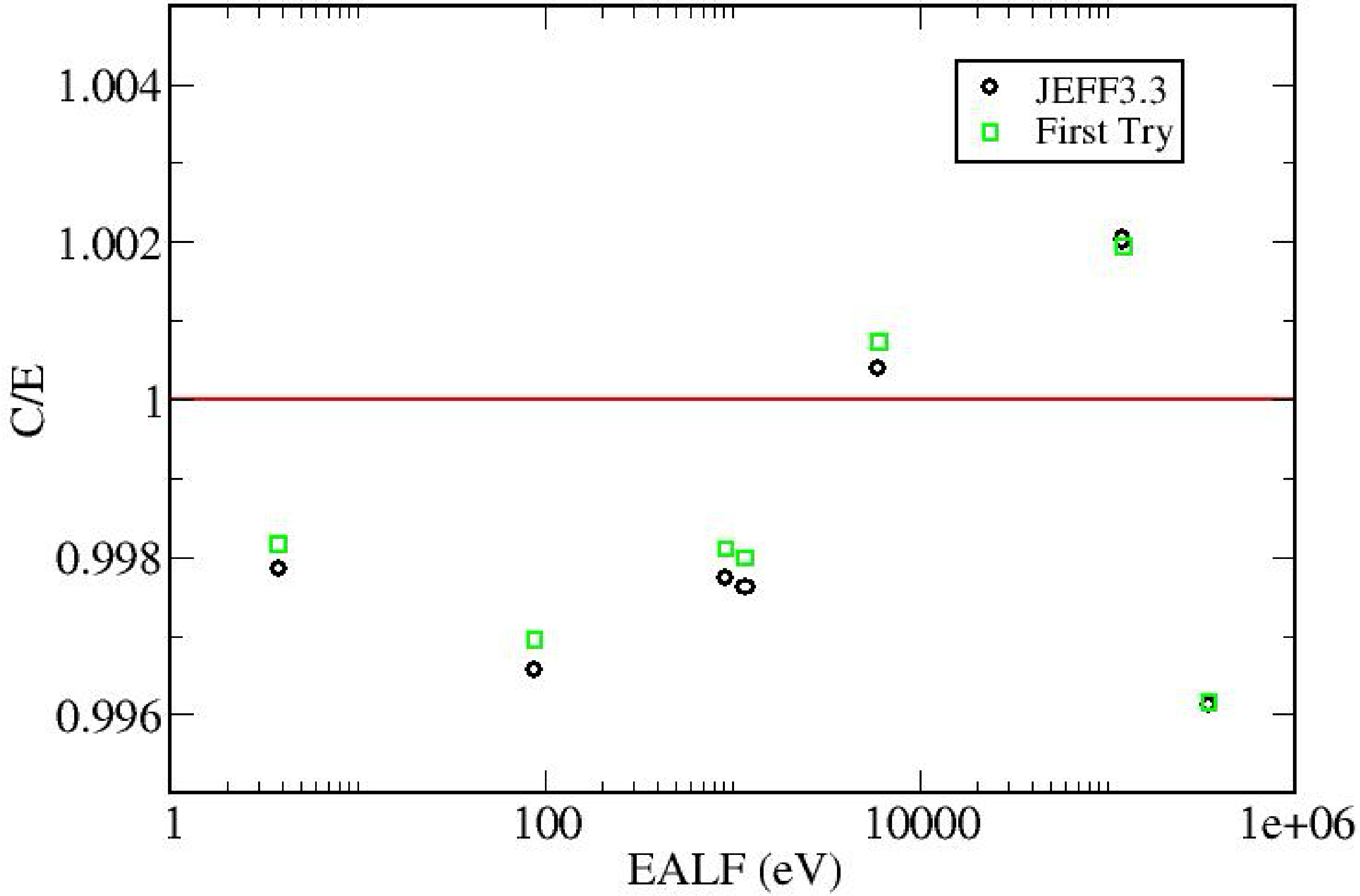
SAMINT Methodology for Differential and Integral Data Treatment

SAMINT flowchart



P = resonance parameters (e.g., E_λ, Γ_γ , Γ_n , Γ_f)

First attempt to improve benchmark results starting with the JEFF3.3



Some Observations

- Measurements of Hf transmission and capture cross sections are needed
- Resolved and unresolved energy region require evaluation
- Resonance parameter covariance needed

Some relevant publications

- L. Leal, N. Leclaire, V. Jaiswal, "Impact of experimental effects on a resolved resonance evaluation for practical applications," Annals of Nuclear Energy 208 (2024) 110795;
- Luiz Leal, Goran Arbanas, Nicolas Leclaire, Klaus Guber, Peter Schillebeeckx, Stefan Kopecky, Carlos Paradela, and Ettore Marcello Mafucci, "A Resolved Resonance Evaluation for ^{51}V with Resonance Parameter Covariance," 2024 ANS Annual Conference June 16–19, 2024, Las Vegas, Nevada(best paper).
- Luiz Leal, Nicolas Leclaire, Travis Greene, Marco T. Pigni, and Klaus Guber," Resolved Resonance Evaluation for ^{95}Mo from thermal to 5000 eV," 2024 ANS Winter Conference and Expo, November 17–21, 2024, Orlando, Florida.
- Luiz Leal, Nicolas Leclaire, Frédéric Fernex, Devin Barry, Peter Schillebeeckx, and Stefan Kopecky, "Resolved Resonance Evaluation for Neutron Interactions with ^{103}Rh Up to 8 keV," *Nuclear Science and Egineering*, November 2024.