New ^{239}Pu Resonance Region Evaluation

Working Party on International Nuclear Data Evaluation Co-operation (WPEC)
NEA Headquarters, May 24-25

Outline

- Motivation for revising ^{239}Pu evaluation in the resonance Region;
- New evaluation description;
- Benchmark calculations: ORNL, CEA, LANL contributions;
- Approach used in the evaluation process: Combining differential and integral data;
- Benchmark results;
- Concluding remarks;

Motivation for revising ^{239}Pu Resonance Evaluation

- Existing H. Derrien resonance evaluation divided into three disjoint resonance parameter sets (computer limitations at the time ~ 1986) :

  1.0×10^{-5} eV - 1 keV, 1 keV - 2 keV, 2 keV - 2.5 keV;

Issues are:

- Cross section mismatch at the energy boundaries;
- Not easy to generate uncertainty for the whole energy region (zero correlations between energy regions);
- Solve long standing problem for thermal benchmark;

New Evaluation (still H. Derrien at ORNL)

- One set of resonance parameter:

  1.0×10^{-5} eV - 2.5 keV;

- Cross section mismatch at the energy boundaries gone!
- Uncertainty for the whole energy region generated with correlations properly determined!!
- Does it solve the problem of thermal benchmark?

EXPERIMENTAL DATA

Reference	Energy Range (eV)	Facility	Measurement
Bollinger et al. (1956)	0.01 – 1.0	Chopper	Total Cross Section
Gwin et al. (1971)	0.01 – 0.5	ORELA	Fission and Absorption at 25.6 m
Gwin et al. (1976)	1.0 – 100.0	ORELA	Fission and Absorption at 40.0 m
Gwin et al. (1984)	0.01 – 20.0	ORELA	Fission at 8 m
Weston et al. (1984)	9.0 – 2500.0	ORELA	Fission at 18.9 m
Weston et al. (1988)	100.0 – 2500.0	ORELA	Fission at 86 m
Weston et al. (1993)	0.02 – 40.0	ORELA	Fission at 18.9 m
Wagemans et al. (1988)	0.002 – 20.0	GELINA	Fission at 8 m
Wagemans et al. (1993)	0.01 – 1000.0	GELINA	Fission at 8 m
Harvey et al. (1985)	0.7 – 30.0	ORELA	Transmission at 18 m
Harvey et al. (1985)	30.0 – 2500.0	ORELA	Transmission at 80 m

Issues with ORNL Evaluation

- Results of plutonium solution calculations indicate no improvement using ORNL evaluation. Longstanding problem persists!!

- In some case the good results from previous ^{239}Pu evaluation deteriorated

- Can ORNL, LANL and CEA together solve the problem?

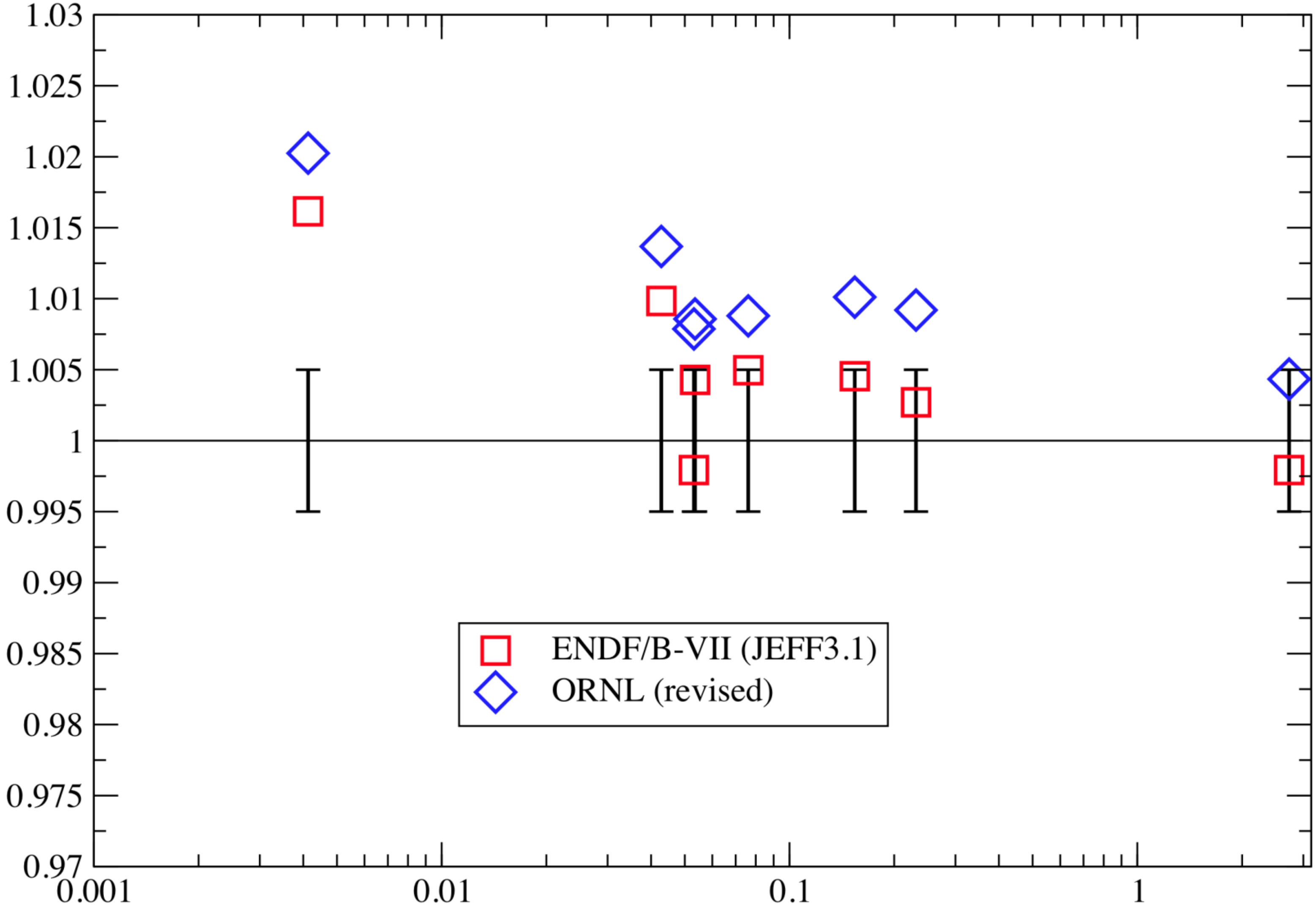
Choice of Benchmarks

- Benchmark from the ICSBEP;
- Plutonium Solution Systems;
- A good choice would be those benchmark experiments spanning the energy region from 0.004 eV to 3 eV
- Choice based on the Average Neutron Lethargy Causing Fission (EALF)

Benchmark problem from ICSBEP

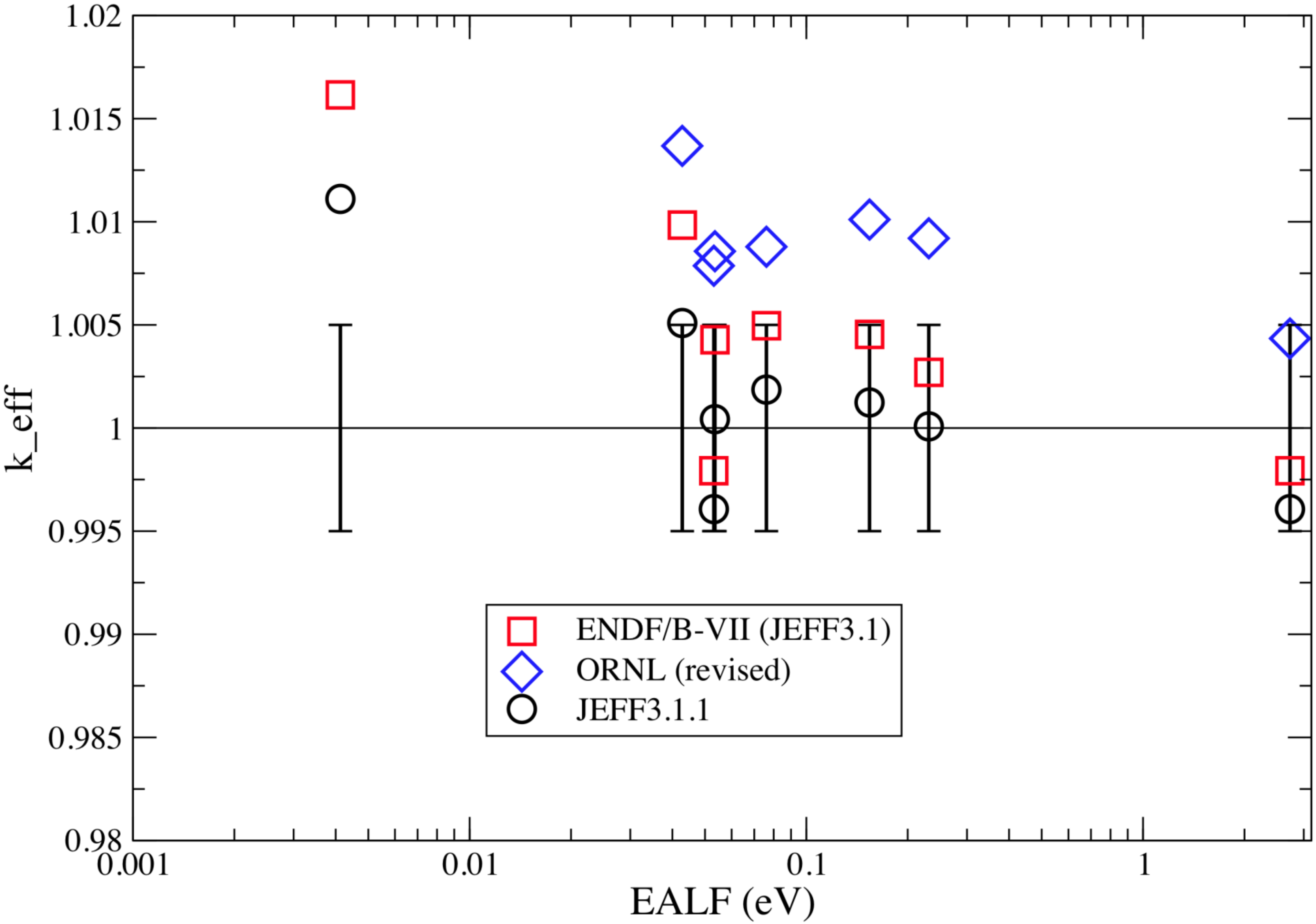
Benchmark	Experimental Keff	EALF(eV)	Contents
PST9.1	1.0000 ± 0.0050	0.00413	2.5 % ^{240}Pu
PST12.13	1.0000 ± 0.0047	0.0428	19.0 % ^{240}Pu
PST4.1	1.0003 ± 0.0033	0.0531	0.5 % ^{240}Pu
PST12.10	1.0000 ± 0.0047	0.0535	25 % ^{240}Pu
PST18.6	1.0000 ± 0.0047	0.0761	43 % ^{240}Pu
PST1.4	1.0000 ± 0.0047	0.154	5 % ^{240}Pu
PST34.4	1.0000 ± 0.0047	0.231	116g Pu/L, 1.42g Gd/L
PST34.15	1.0000 ± 0.0047	2.730	363 g Pu/L, 20.25g Gd/L

EALF: Average Neutron Lethargy Causing Fission


1.03
1.025
1.02
1.015
1.01
1.005
1
0.995
0.99
0.985
0.98
0.975
0.97
0.001
0.01
0.1
1
ENDF/B-VII (JEFF3.1)
ORNL (revised)

JEFF3.1.1 Evaluation

- Improves substantially prediction of keff for thermal systems;
- Work started based on the JEFF3.1 (ENDF/VII.1)
- Three sets of resonance parameters in the range 1.0×10^{-5} eV - 2.5 keV;

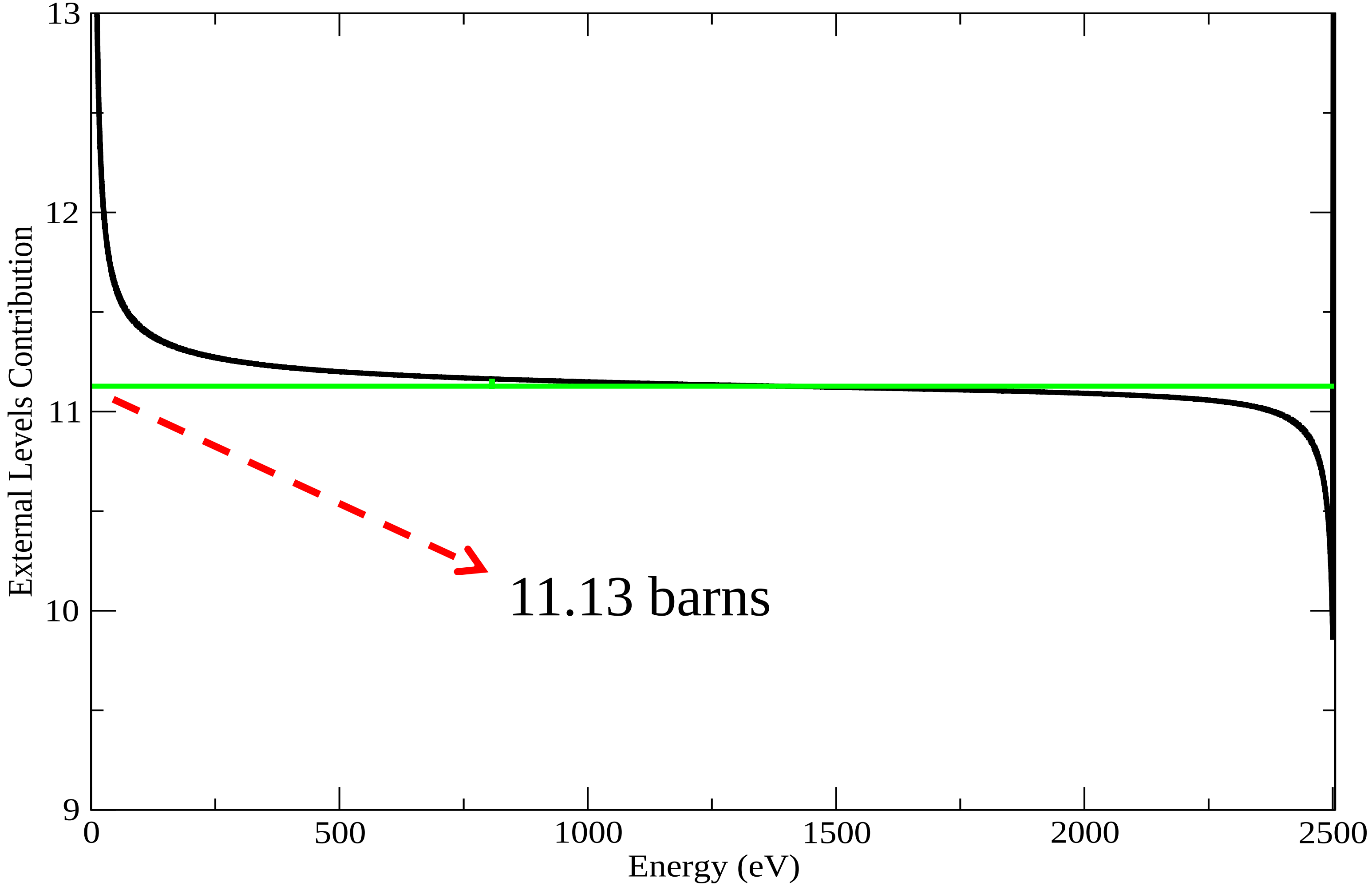


k_eff
EALF (eV)
1.02
1.015
1.01
1.005
1
0.995
0.99
0.985
0.98
0.001
0.01
0.1
1
ENDF/B-VII (JEFF3.1)
ORNL (revised)
JEFF3.1.1

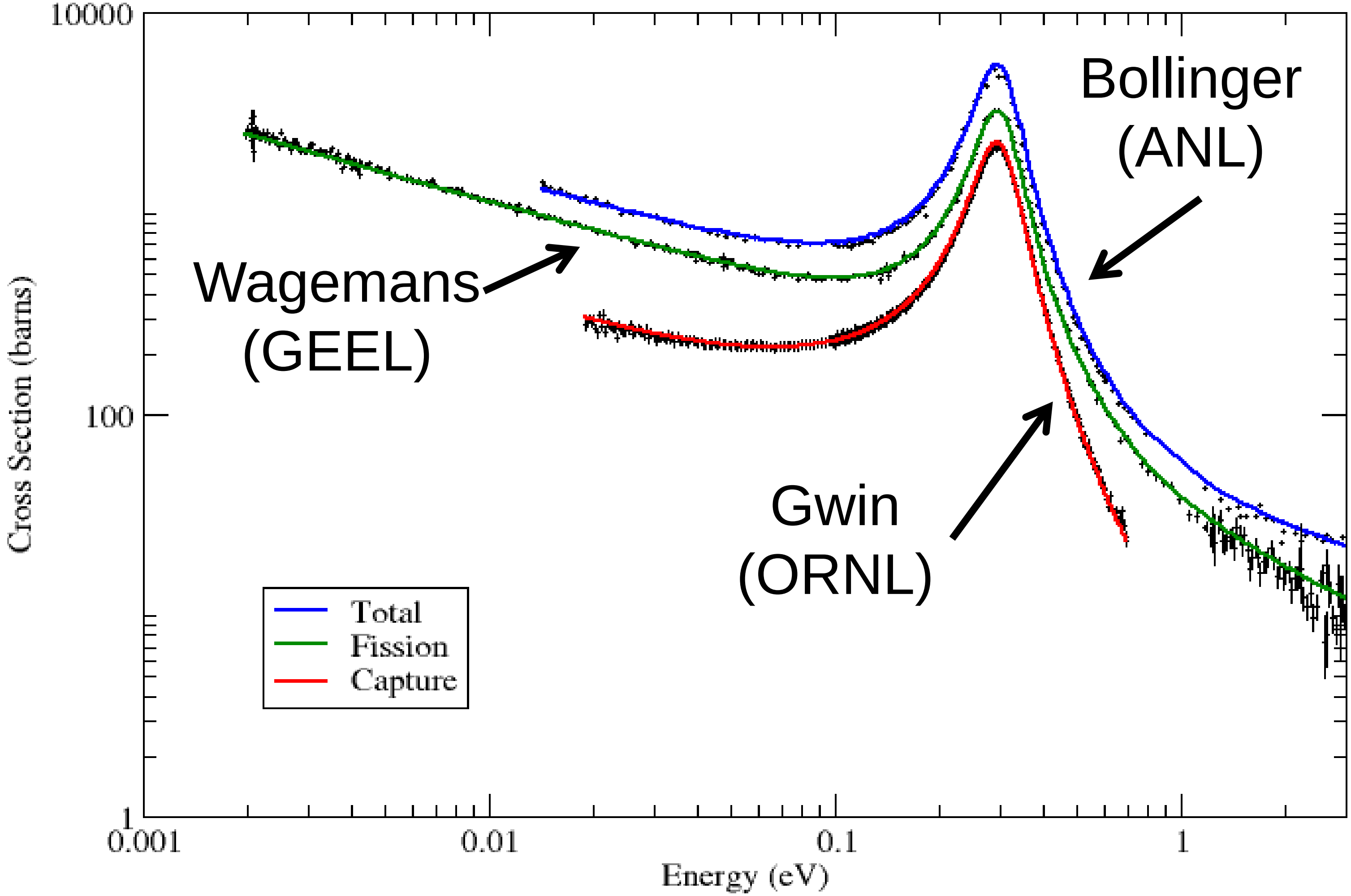
Work Strategy

- Use the SAMMY code to perform resonance analysis with the best selected set of experimental time-of-flight data;
- Generate cross-section library with the NJOY code for use in benchmark calculations with the MCNP code;
- Generate cross-section library with the GALILEE (NJOY+CALENDF) code for use in benchmark calculations with the TRIPOLI (point energy) and APOLLO (multigroup SHEM) codes;
- Use a selected set of experimental benchmarks with average of neutron lethargy causing fission spanning the energy range from 0.004 eV to 3 eV;
- Use MISTRAL and FUBILA experiments (MOX fuel) performed at the EOLE facility to test the evaluation;
- Evaluate nu-bar to improve benchmark results;

External Levels Determination



Cross Section Fitting



Integral Quantities:

- ✓ Benchmark experiments sensitive to the fission, capture cross sections, nu-bar
- ✓ A right combination of capture-to-fission ratio (alpha) may lead to an improvement on the k_{eff};
- ✓ Eta (η) and K1
    - ✓Eta (η): six factor form
    - ✓ K1: from first-order perturbation theory

System Multiplication Factor: k_{eff}

$$\frac{\text{Production}}{\text{Absorption+Leakage}}$$

k_{eff}

- > 1 (supercritical)
- = 1 (critical)
- < 1 (subcritical)

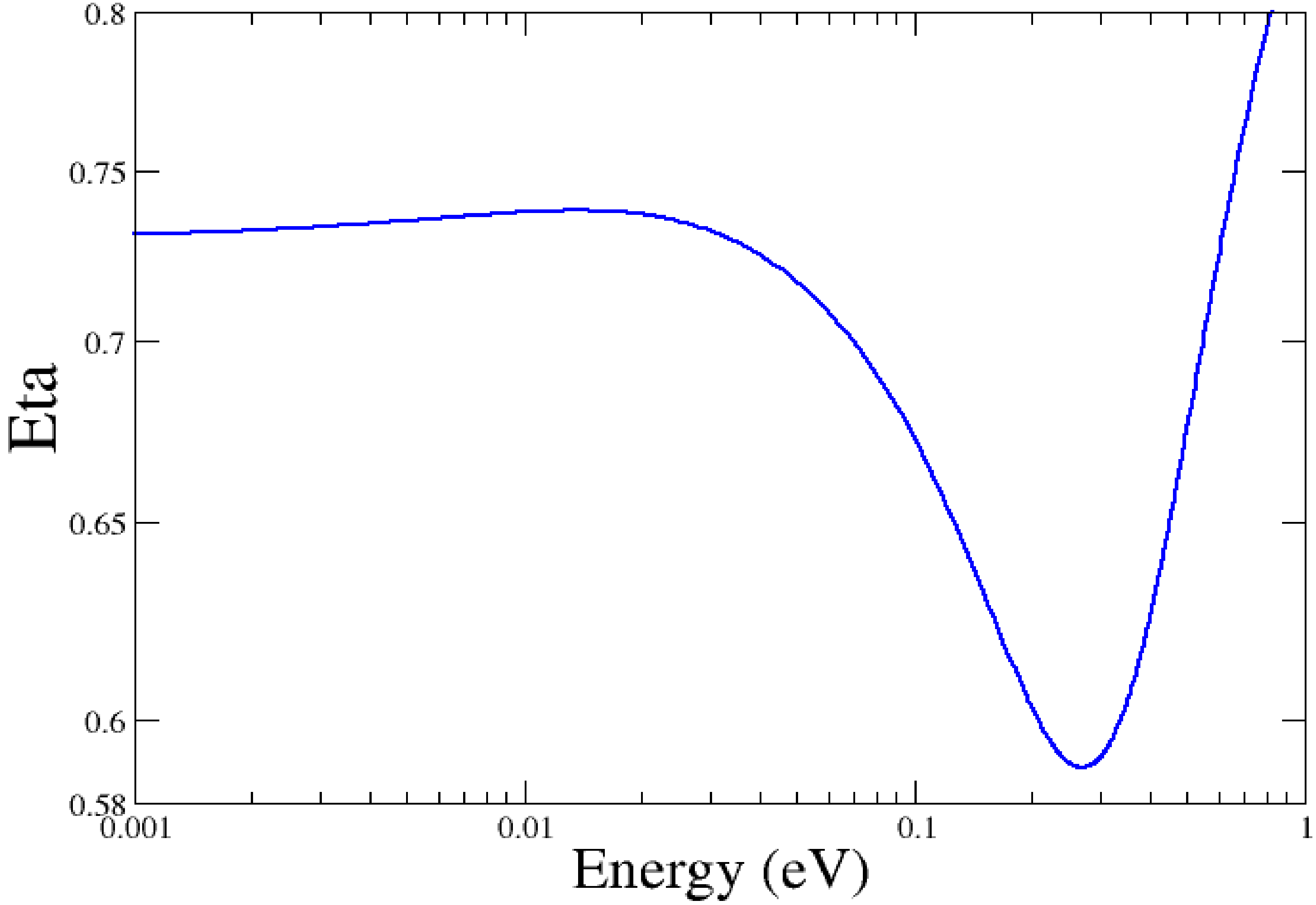
Multiplication Factor: k_∞

Leakage $\longrightarrow$ *0*

$$\frac{\text{Production}}{\text{Absorption}}$$

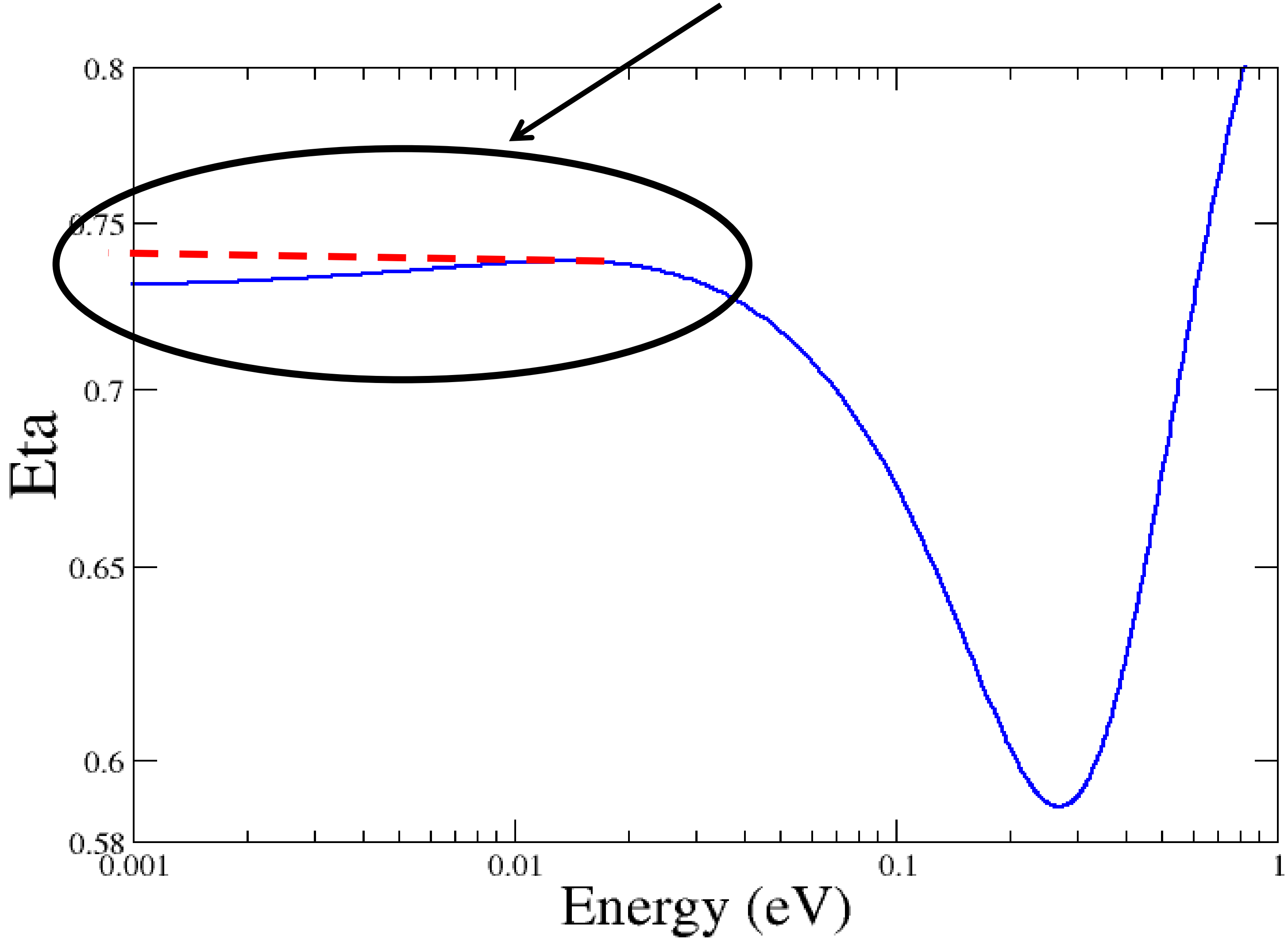
$$k_\infty \propto \eta = \frac{\nu\Sigma_f}{\Sigma_a}$$

Eta: η



Eta: η (first negative resonance with very low $\wp_n$)

Improves Reactivity Temperature Coefficient Results



K1 Factor: first-order perturbation theory

Reactivity change: dr

$$dr = \frac{< f^{+}, DHf >}{< f^{+}, Pf >}$$

$$\Delta H = \text{Production} - \text{Absorption}$$

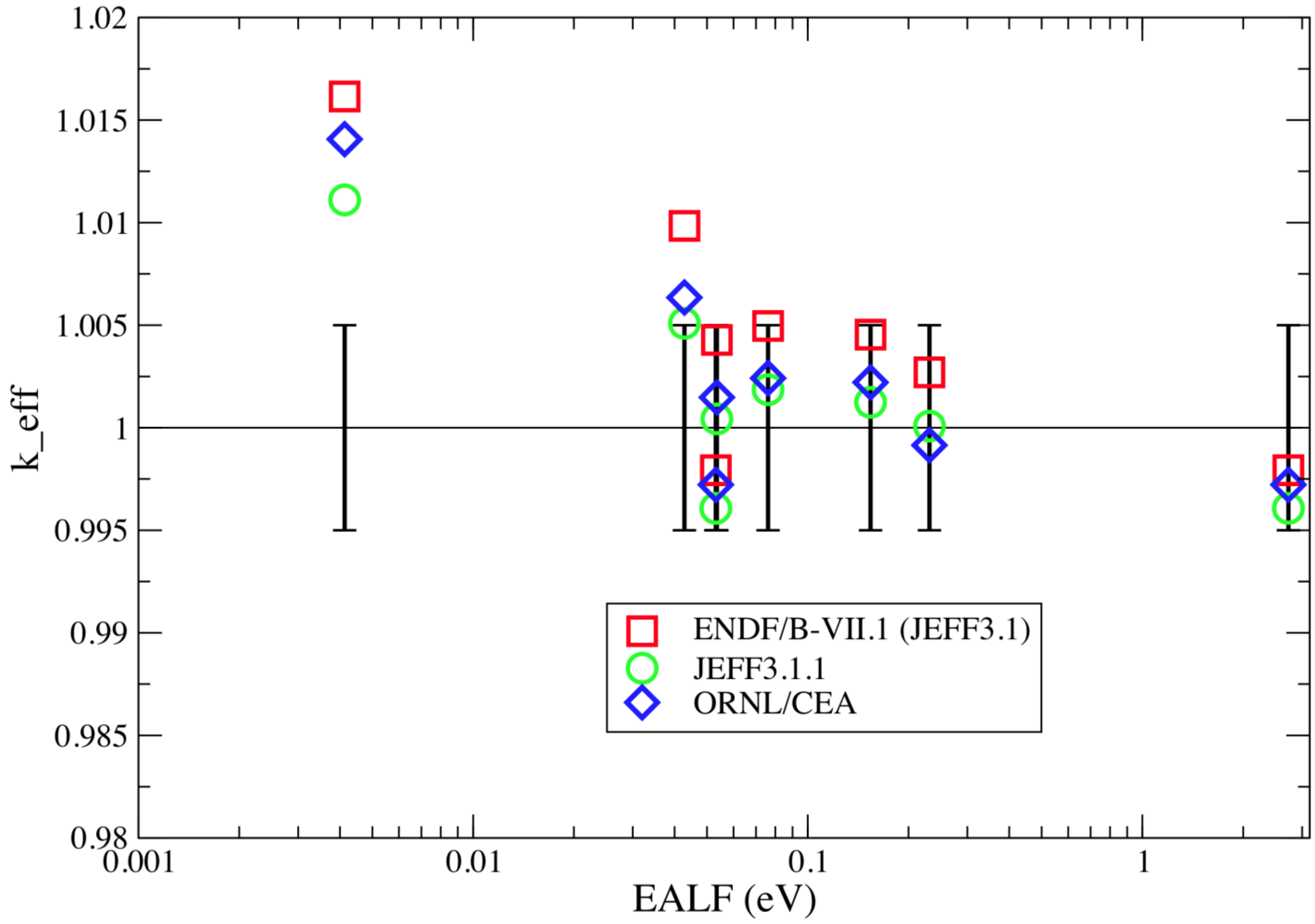
Equivalent K1

$$K1 = \nu\sigma_f - \sigma_a$$

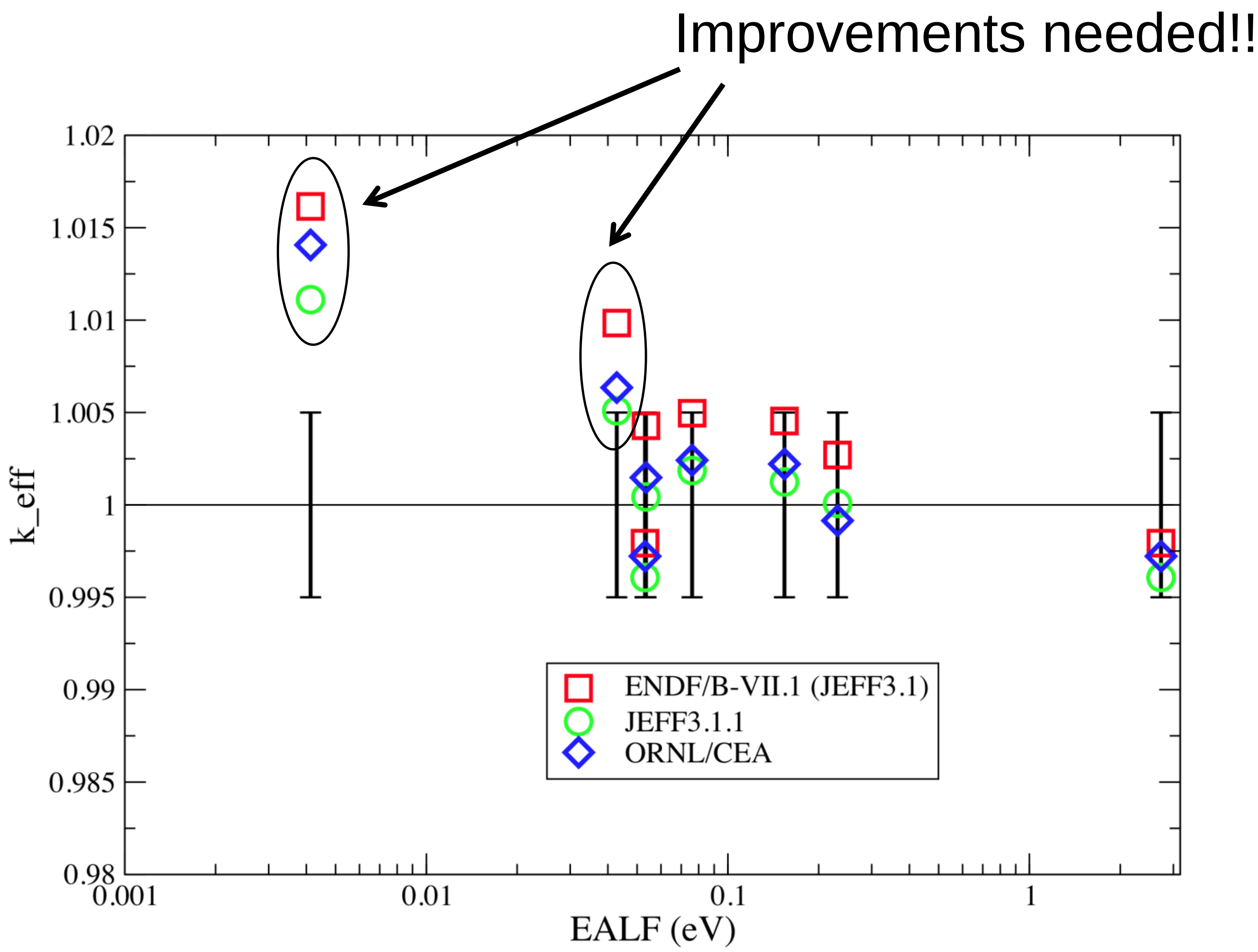
Thermal values and integral quantities calculated with SAMMY

Quantity	ANR	ENDF/B-VII.1 (JEFF3.1)	JEFF3.1.1	ORNL CEA
σ_γ	269.3 ± 2.9	270.64	272.72	270.06
σ_f	748.1 ± 2.0	747.65	747.08	747.19
g_f	1.0553 ± 0.0013	1.0544	1.0495	1.0516
g_a	1.0770 ± 0.0030	1.0784	1.0750	1.0771
$\bar{\nu}$	2.879 ± 0.006	2.873	2.873	2.873
I_γ	180 ± 20	181.44	181.50	180.09
I_f	303 ± 10	302.60	303.58	309.09
$K1$	1177.25	1166.62	1156.35	1161.30

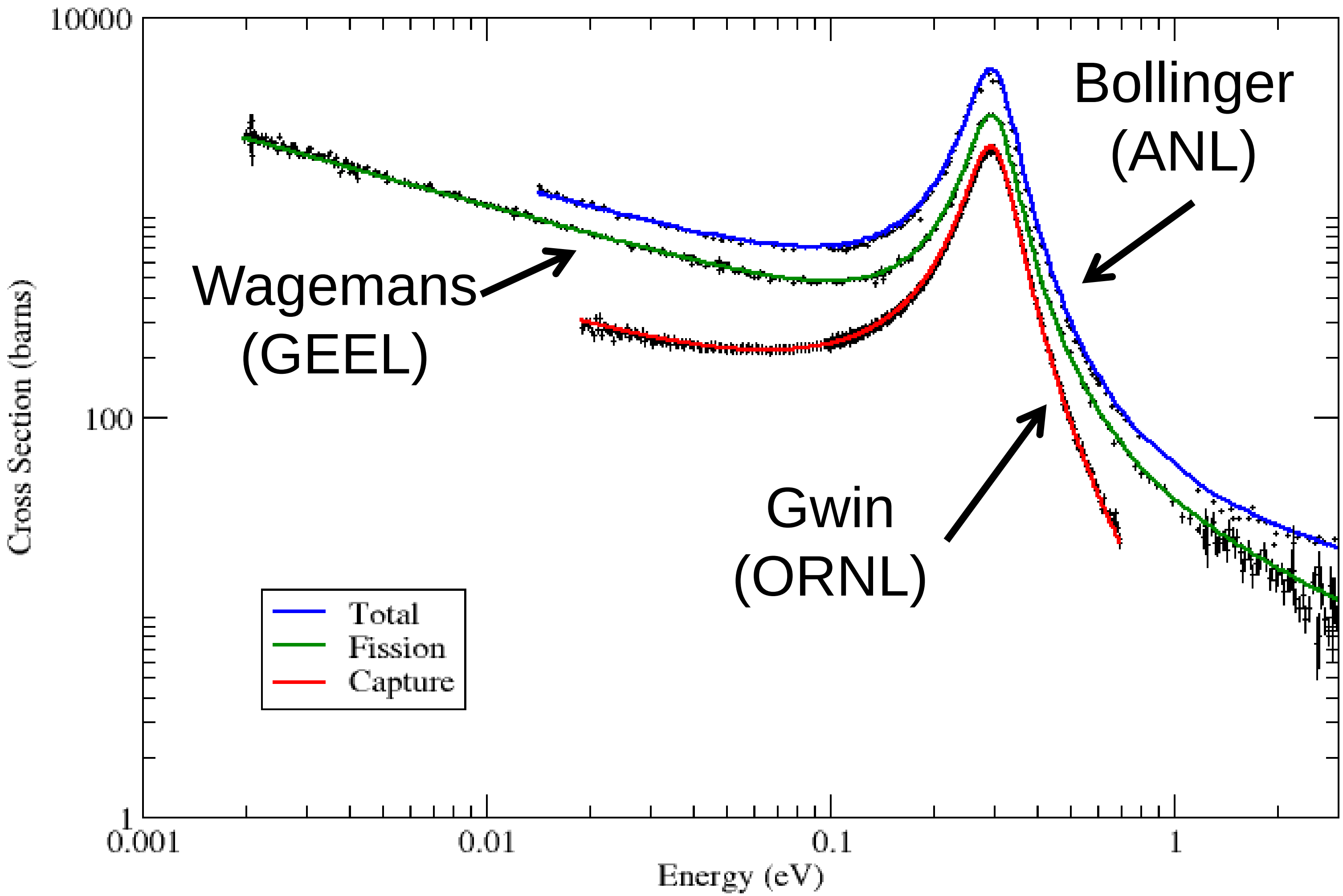
ICSBEP Benchmark Results (everything else from BVII.1)



ICSBEP Benchmark Results (everything else from BVII.1)



Cross Section Fitting



Concluding Remarks

- Work on the re-evaluation of the ^{239}Pu in the resonance region ORNL/CEA (OECD/NEA coordination);
- SAMMY code used to fit differential an integral data (eta and K1);
- ICSBEP benchmark used in testing the resonance parameters;
- CEA benchmark experiment used (Gilles' presentation);
- Resonance parameters will be available for further testing;

Future Work Activities

- ◆Resonance parameter covariance generation including both differential an integral data;

- ◆Re-evaluation of the unresolved resonance region;
- ◆Verify the impact of prompt neutron fission spectrum from IAEA (Coordinate Research Project);

THANKS