Actinide Nuclear Data Evaluation for JENDL-4

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Actinides in JENDL-4.0 (79 nuclides)

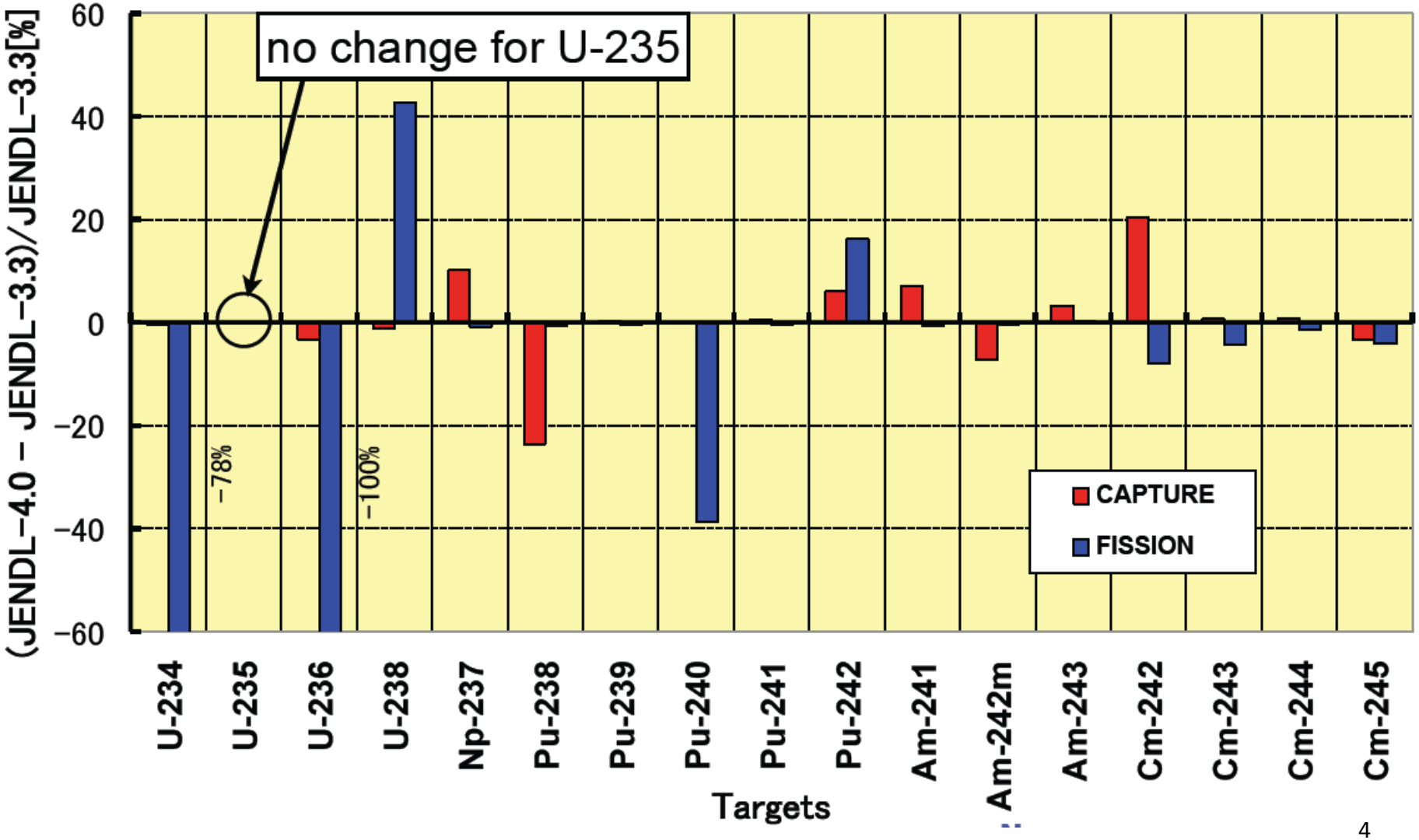
high ← priority → low

	A	B	C	D	E (new)
Ac				225, 226, 227	
Th	232		228, 229, 230	227, 233, 234	231
Pa			231, 232, 233		229, 230
U	233, 235, 238	232, 234, 236	237		230, 231
Np		237	236, 238, 239	235	234
Pu	239, 240, 241	242	238, 244	236, 237, 246	
Am	241, 243	242m	242	244, 244m	240
Cm		242, 244, 245	243, 246, 247,248, 250	240,241,249	
Bk			247	249, 250	245, 246, 248
Cf			249, 250	251, 252, 254	246, 248, 253
Es					251, 252,

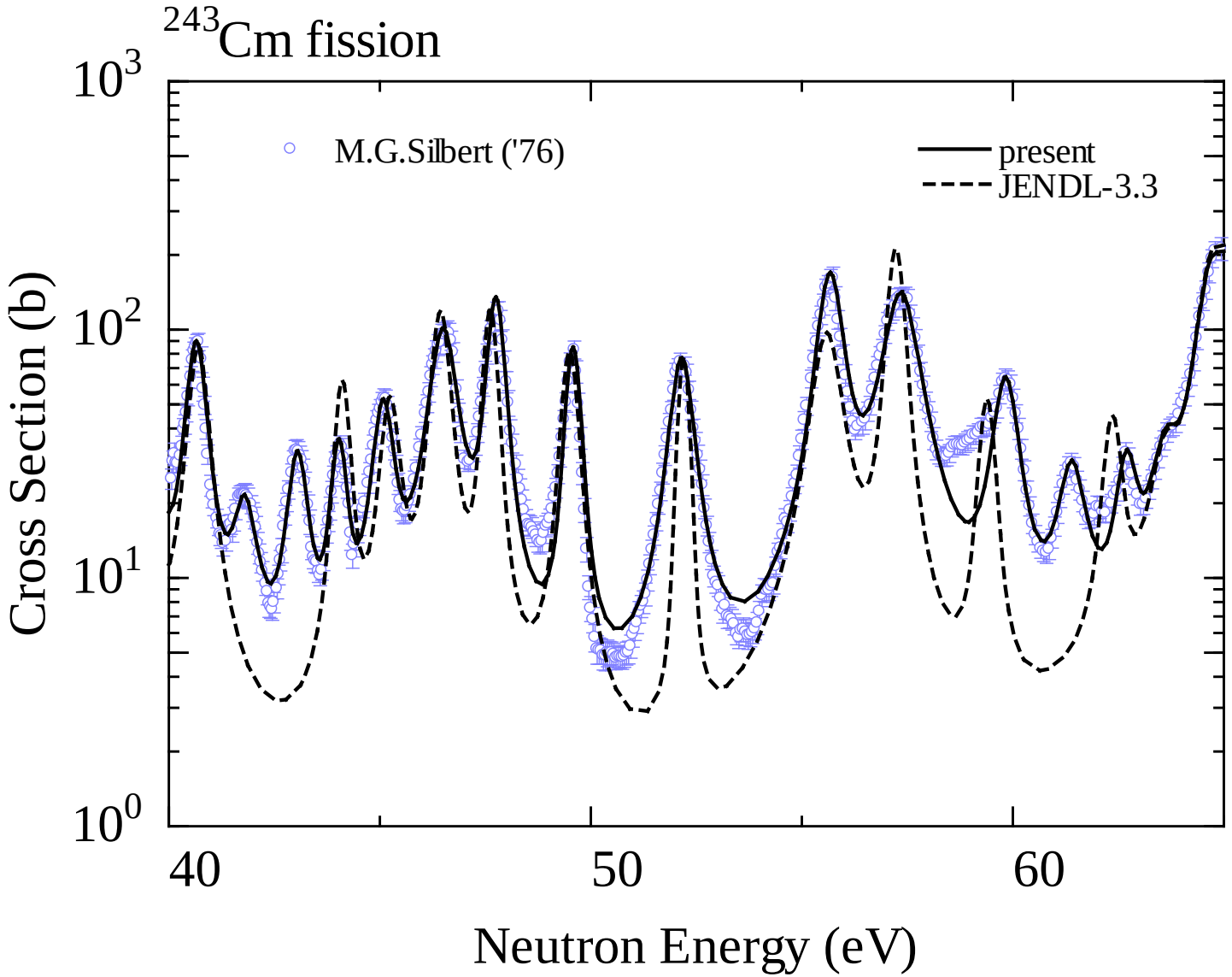
Resonance region

- Thermal cross section
  - Fission and capture cross sections
  - Re-evaluated
- Resonance parameter
  - Major actinide
    - Th-232, U-233, U-238, Pu-241: ENDF/B-VII.0
    - U-235: JENDL-3.3, Upper boundary 2.25keV → 500 eV
    - Pu-239: Derrien '07
    - Pu-240: JENDL-3.3 slightly modified + background C.S. (1 - 2.7keV)
  - Minor actinide
    - Np-236, 238: Furutaka (JAEA) SAMMY analysis
    - others: MLBW formula, adjusted based on experimental data.

Thermal cross sections



Revised resonance parameter



Cross sections in fast region

- Fissoin cross section: least-squares fitting of experimental data
  - Simultaneous evaluation: SOK code (Kawano)
    - U-233, U-235, U-238, Pu-239, Pu-240, Pu-241
    - En=10 keV to 20 MeV
  - GMA code (Poenitz, S. Chiba)
- Other cross sections: nuclear model calculation by CCONE code
  - Model
    - CC(rotational) + DWBA(vibrational) + Exciton ($\pi+\nu,\gamma$) + Hauser-Feshbach(WFC, n+p+d+t+h+α+f+γ)
  - OMP(CC)
    - Total, shape elastic, direct inelastic cross sections
    - transmission coefficients
    - Soukhovitskii(2005), Kunieda(2007), adjusted
  - Level density
    - Fermi-gas + constant temperature, Shell energy correction (Ignatyuk), Collective enhancement

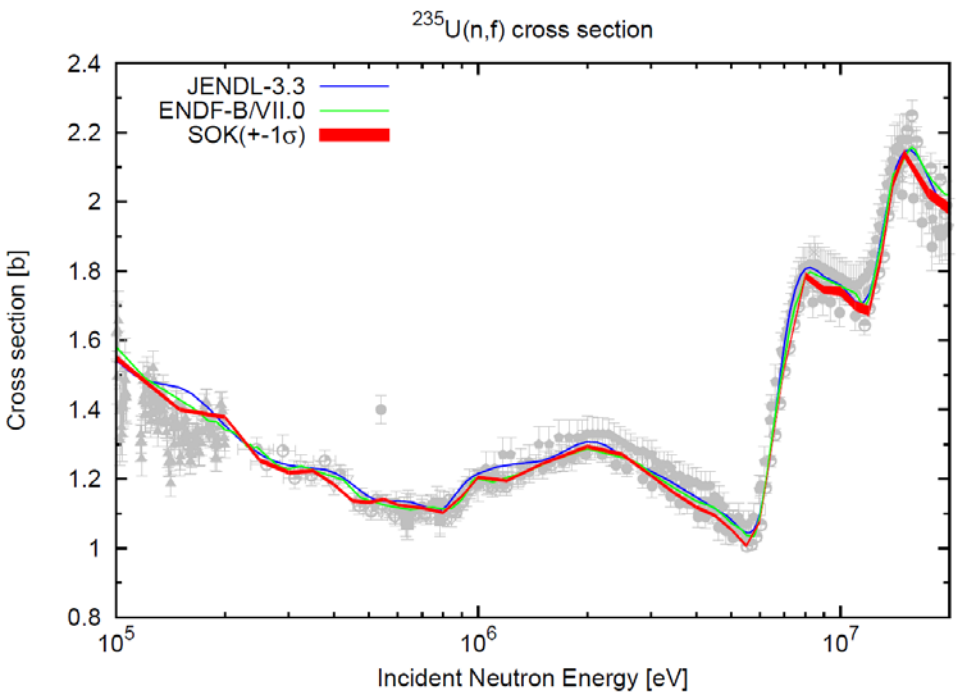
Simultaneous evaluation of fission cross section

- Least-squares fitting
  - SOK code (Kawano)
  - First order spline
- Experimental data

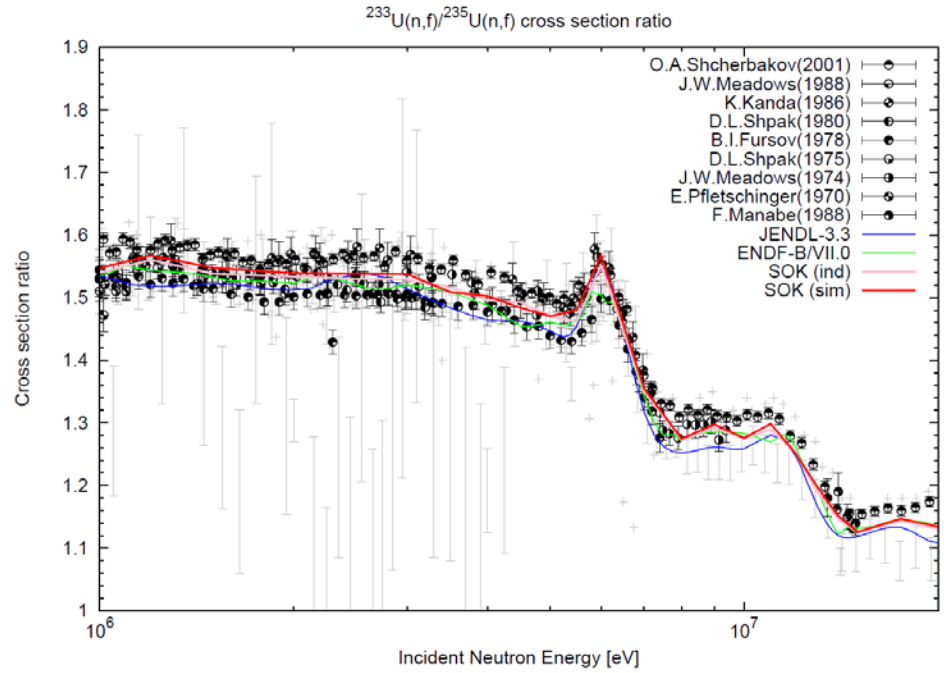
Reaction	sets	Reaction	sets
^{233}U	13	^{233}U/^{235}U	9
^{235}U	17	^{238}U/^{233}U	1
^{238}U	9	^{238}U/^{235}U	18
^{239}Pu	16	^{239}Pu/^{235}U	14
^{240}Pu	4	^{240}Pu/^{235}U	12
^{241}Pu	6	^{240}Pu/^{239}Pu	1
		^{241}Pu/^{235}U	4

Results of SOK

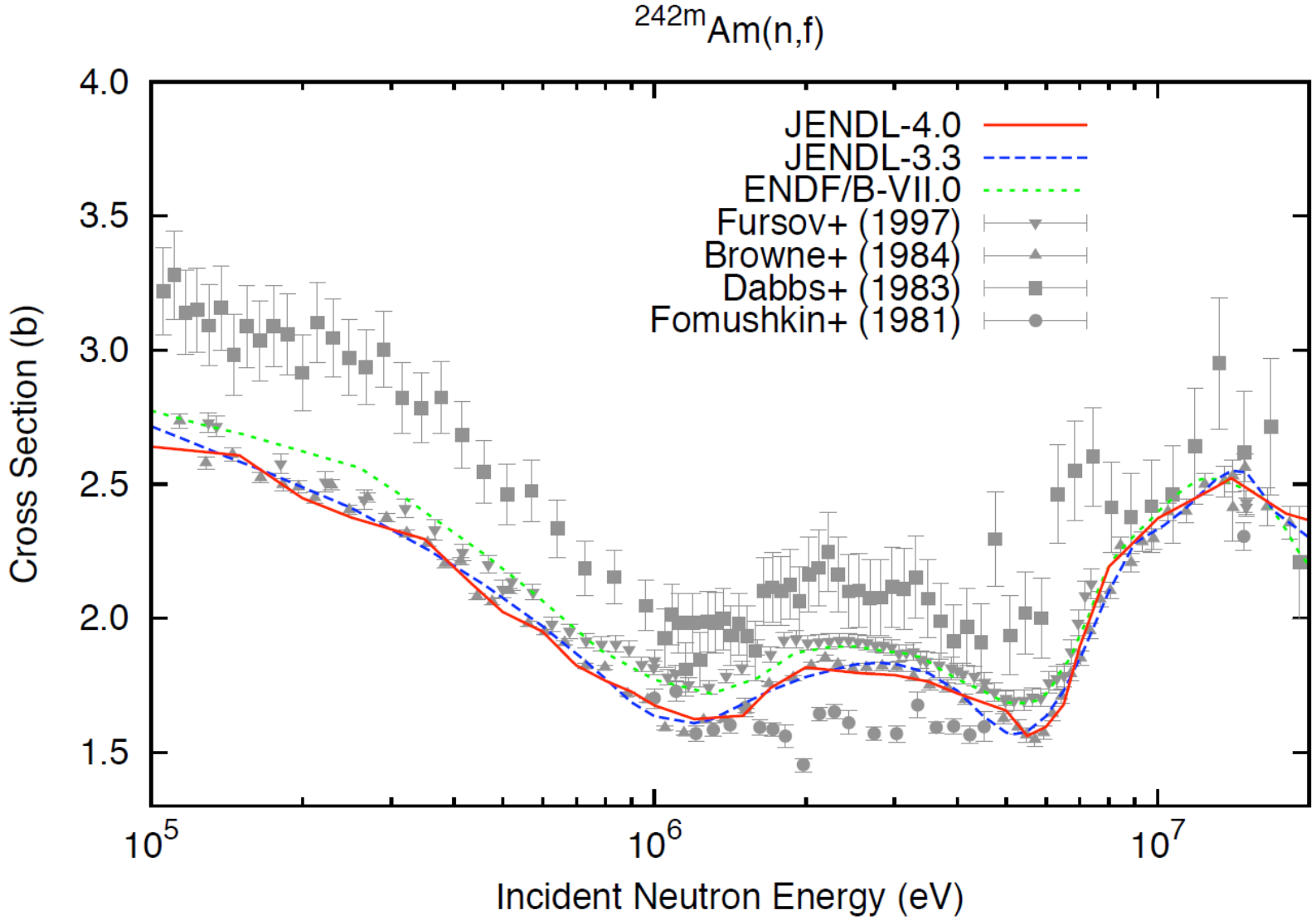
^{235}U (n,f)



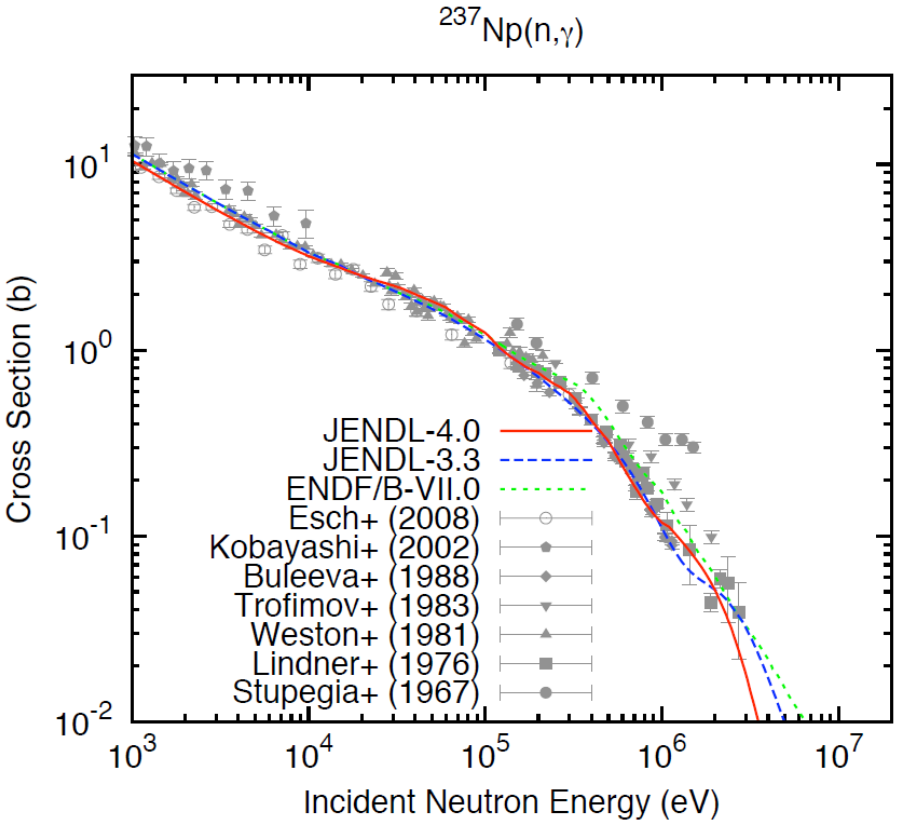
U-233(n,f)/U-235(n,f)

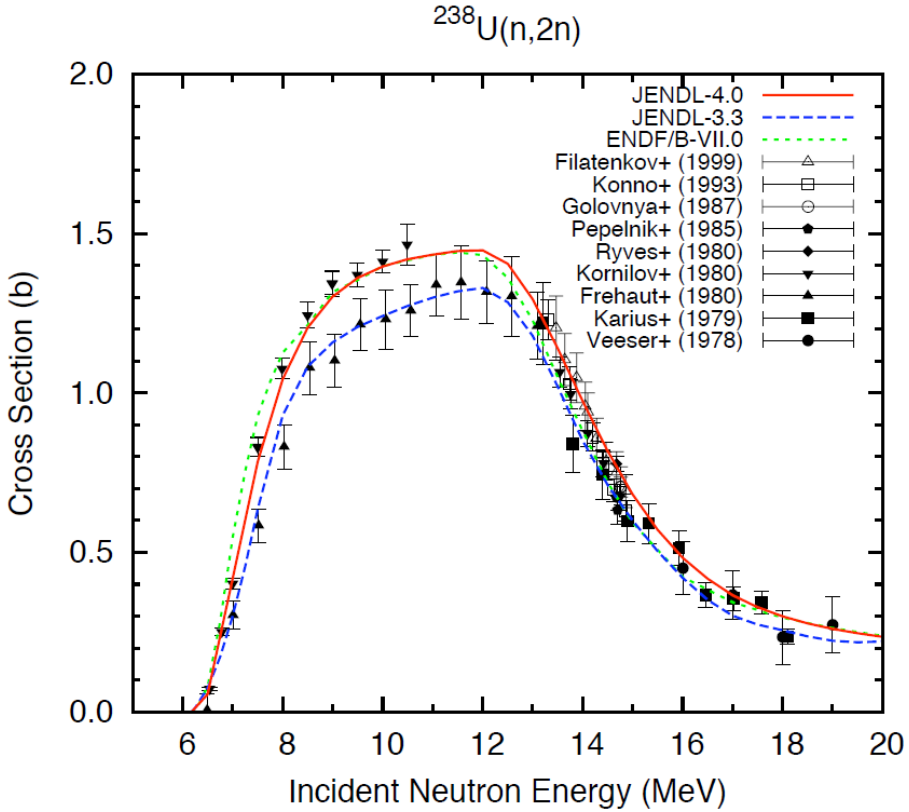


Result of GMA

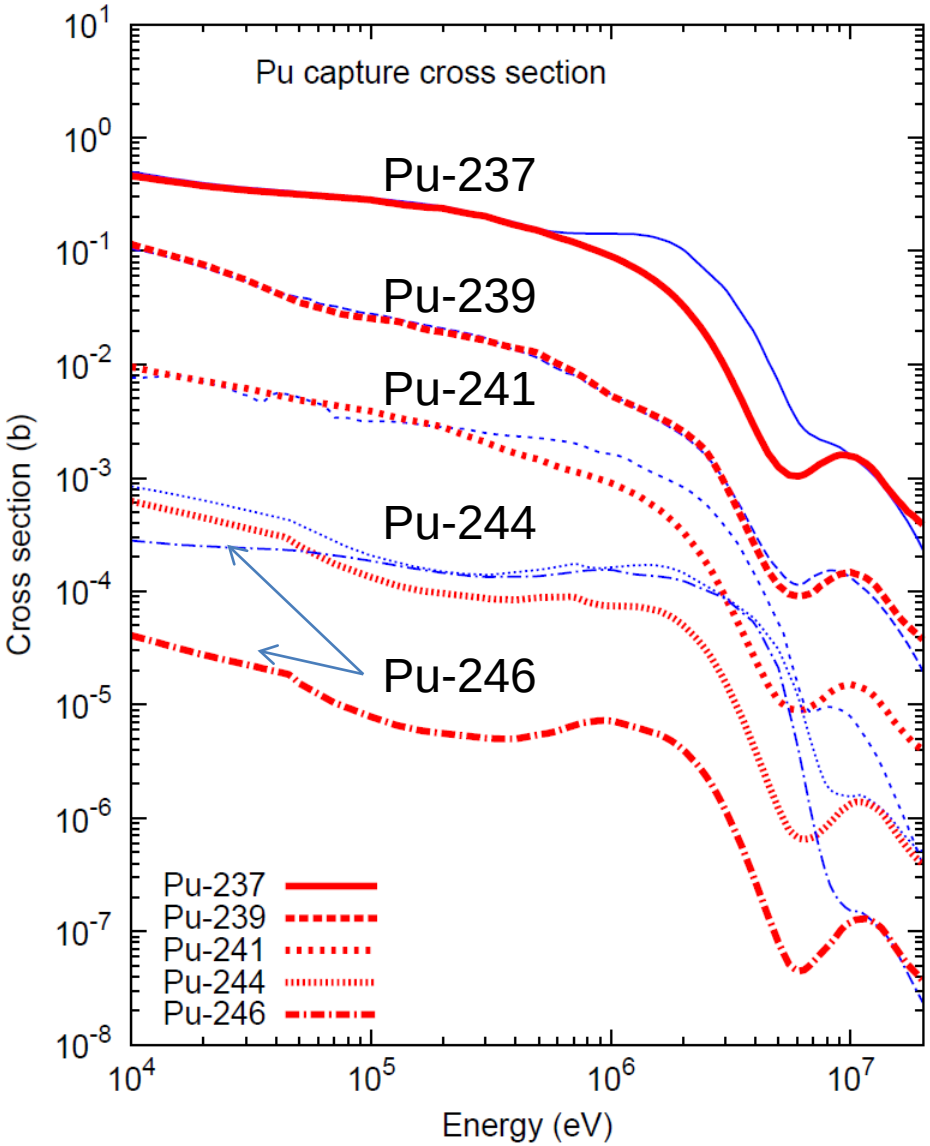


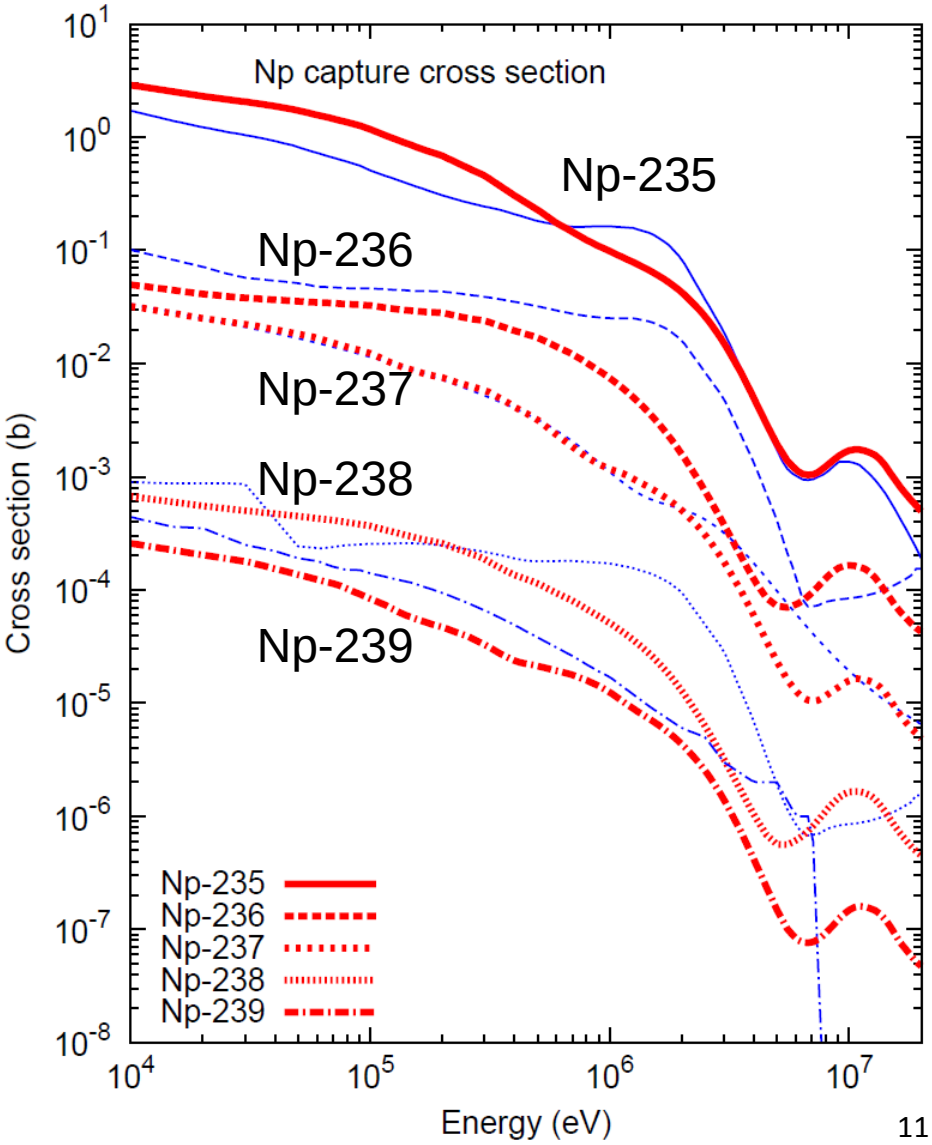
CCONE calculations



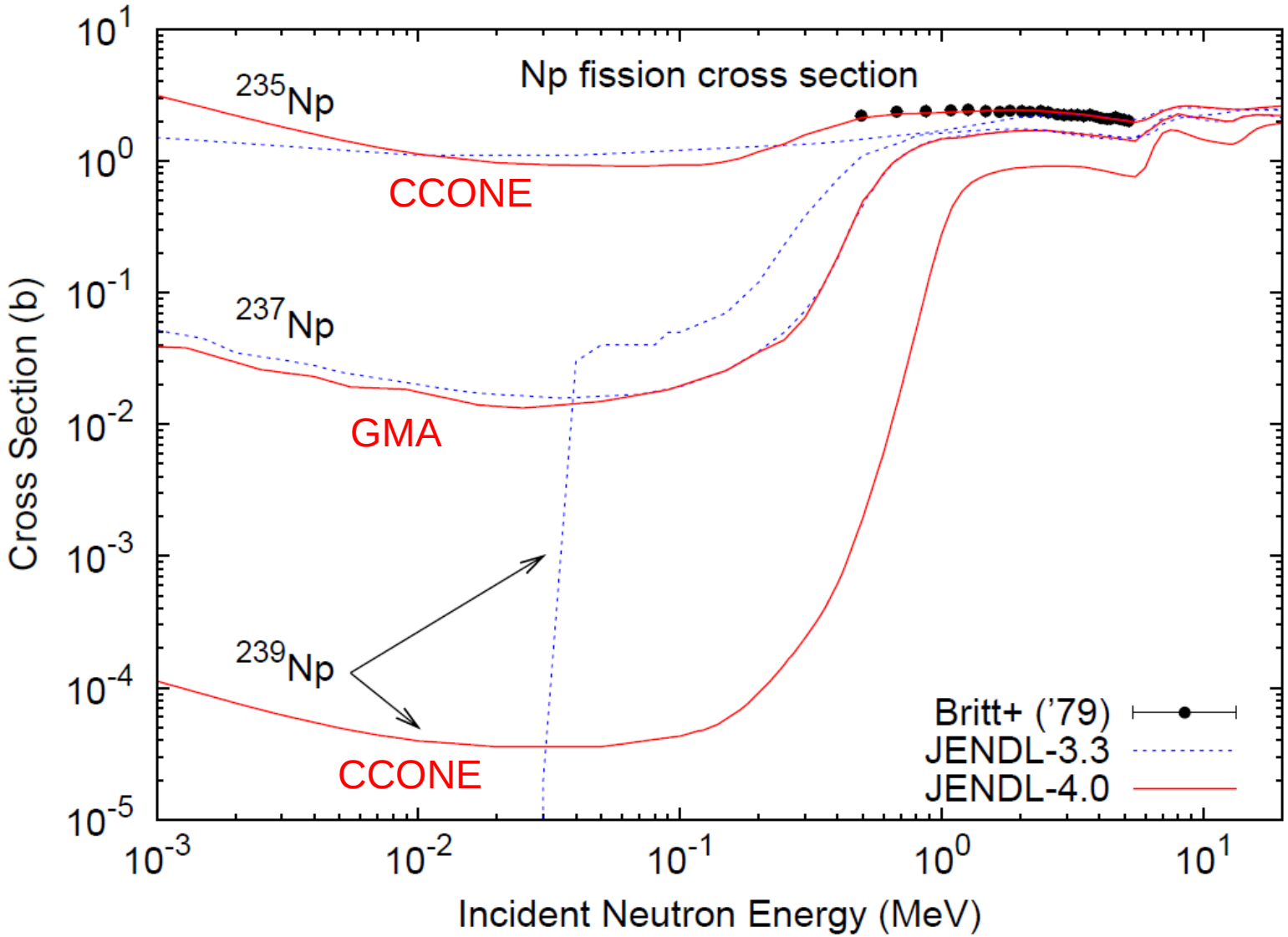


Capture cross sections





Fission cross section

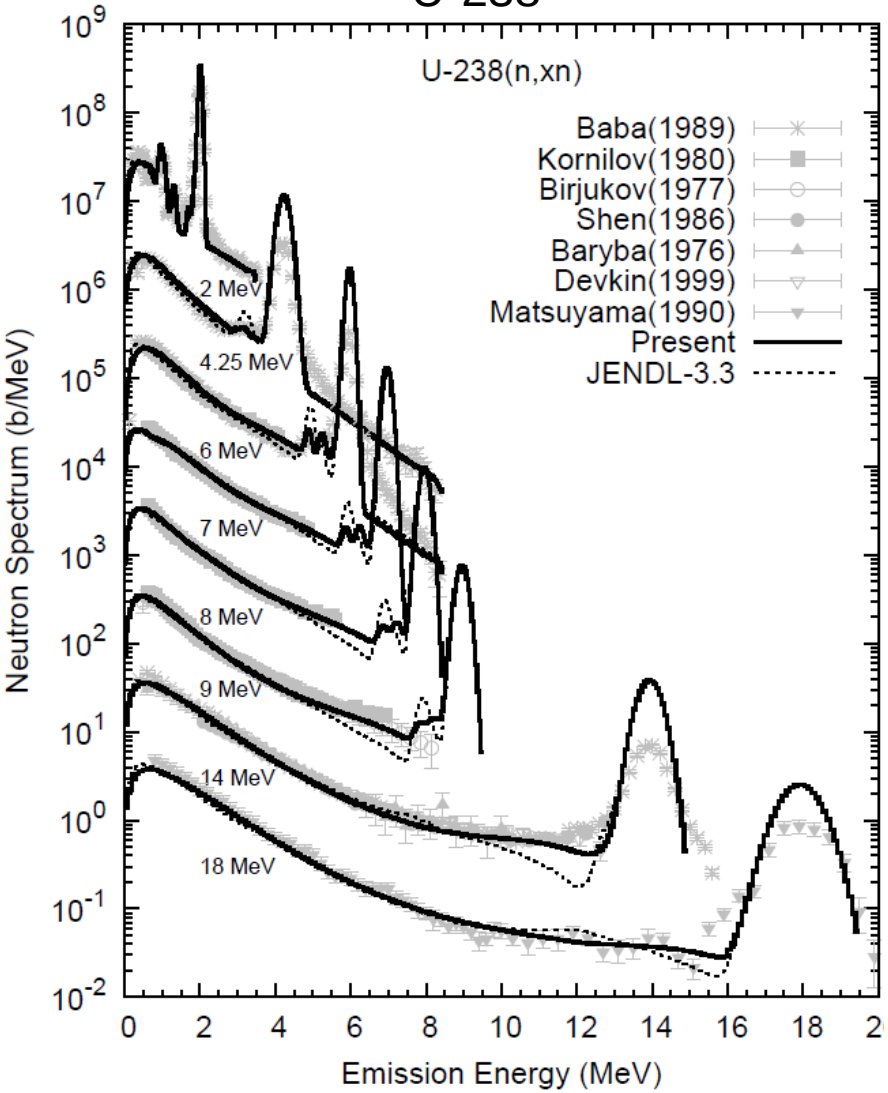


Spectra

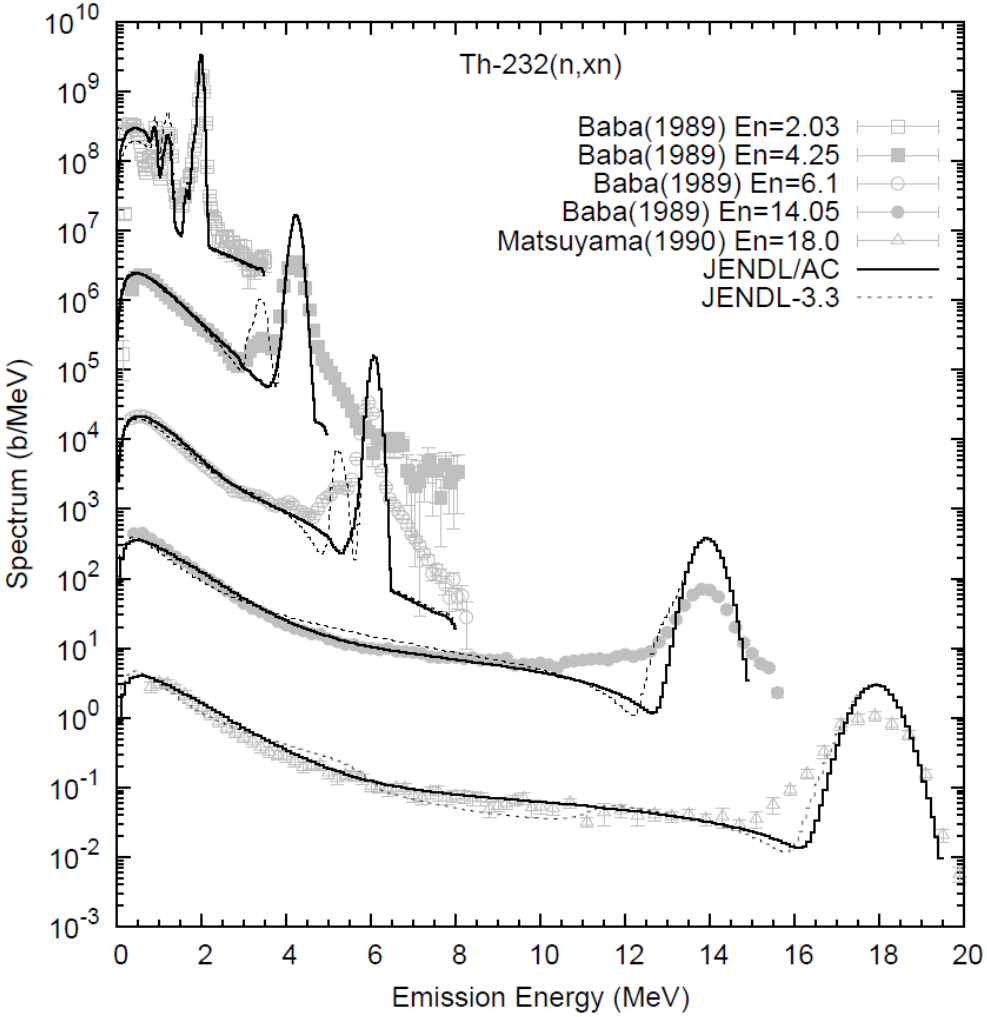
- Neutron
  - prompt fission
    - multi-modal Los-Alamos model (Ohsawa)
    - Systematics of simplified Los-Alamos model (Iwamoto ’08)
  - pre-fission and other reactions
    - CCONE calculation
- Gamma
  - prompt fission
    - shape: Verbinski (’73: U-235, Pu-239) for all
    - multiplicity: (total gamma energy)/(average gamma energy)
  - pre-fission and other reactions
    - CCONE calculation

Neutron emission spectrum

U-238



Th-232



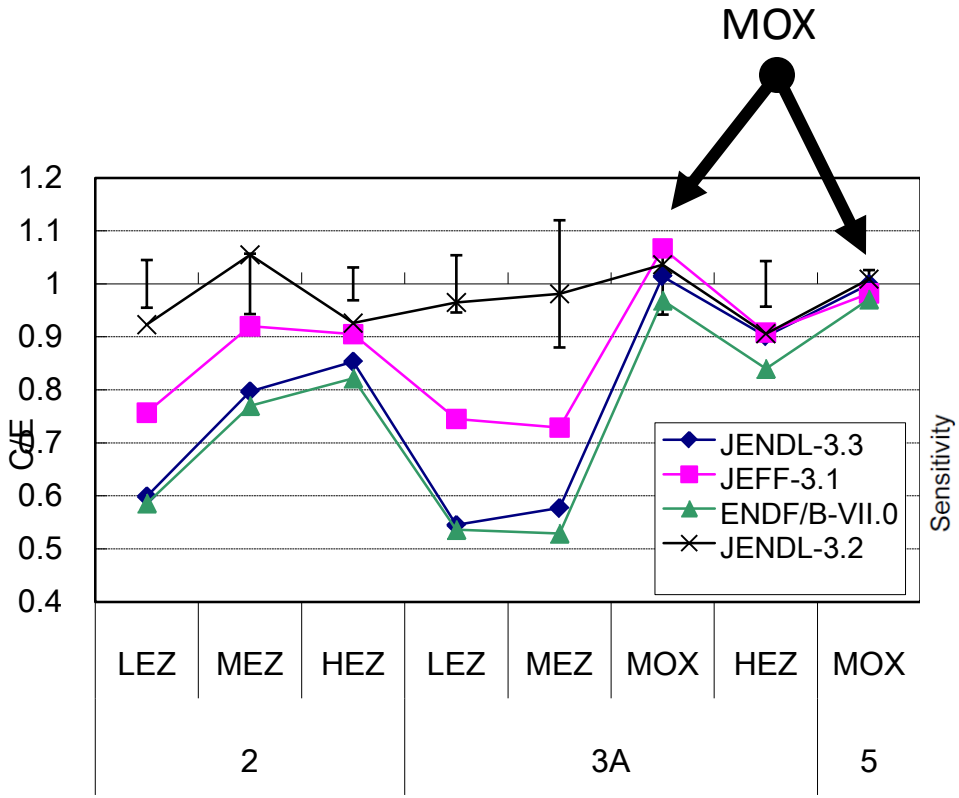
Summary

- Almost all of data for 62 nuclides in JENDL-3.3 were updated. New 17 nuclide data were added.
  - resonance parameter
  - cross section
    - fission cross section by least-squares method: SOK, GMA
    - nuclear model calculation: CCONE
  - neutron and gamma emission spectra
    - prompt fission neutron: Los-Alamos model

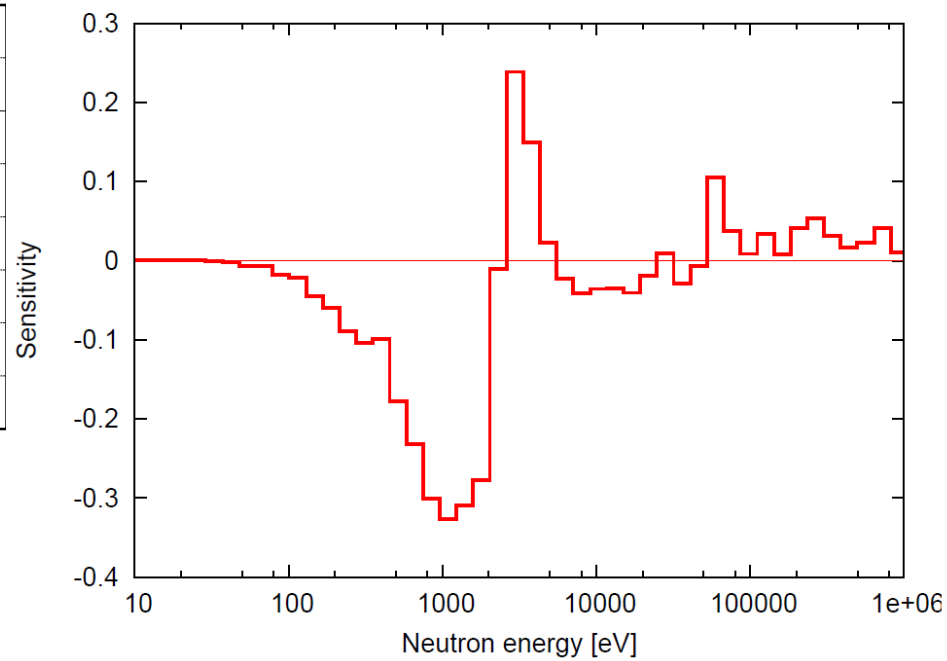
U-235 Capture Cross Section in the keV to MeV Energy Region

WPEC Subgroup 29

Problem of integral experiment (1) sodium voided reactivity in BFS

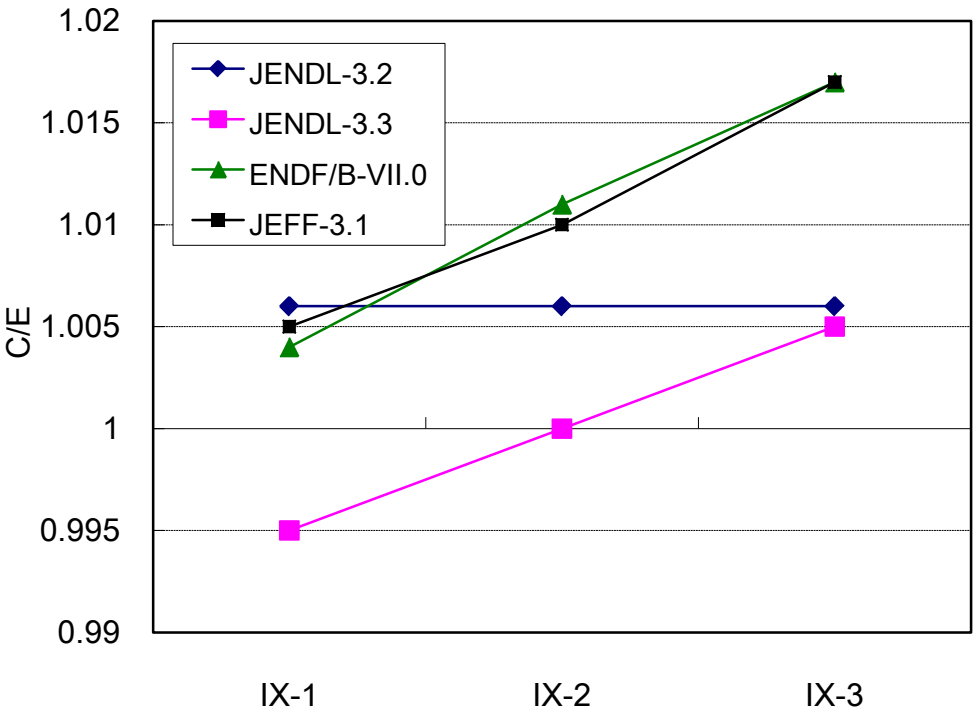


sodium voided reactivity

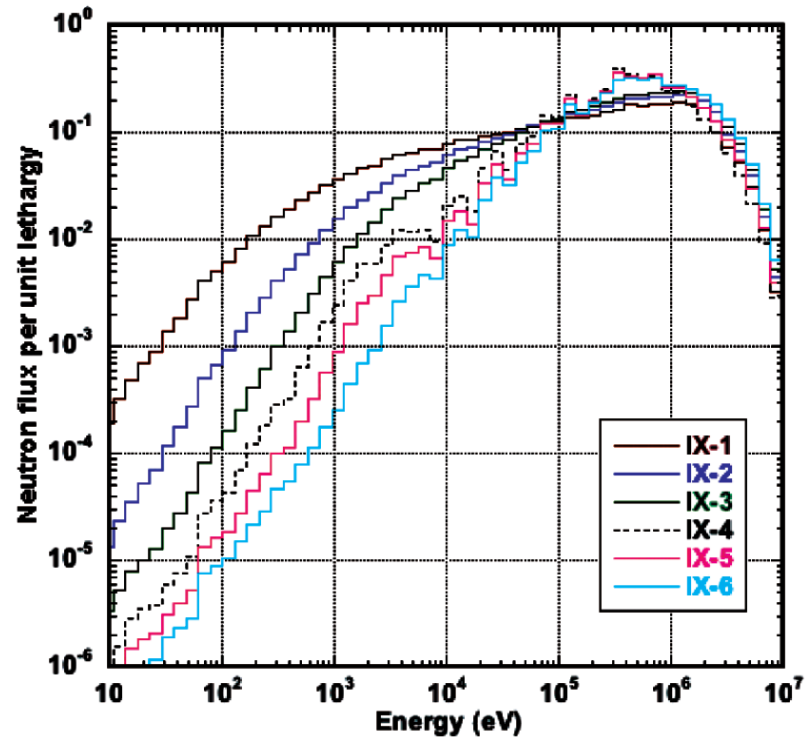


Sensitivity of ^{235}U capture cross section

Problem of integral experiment (2)
FCA experiment (enriched U + C)



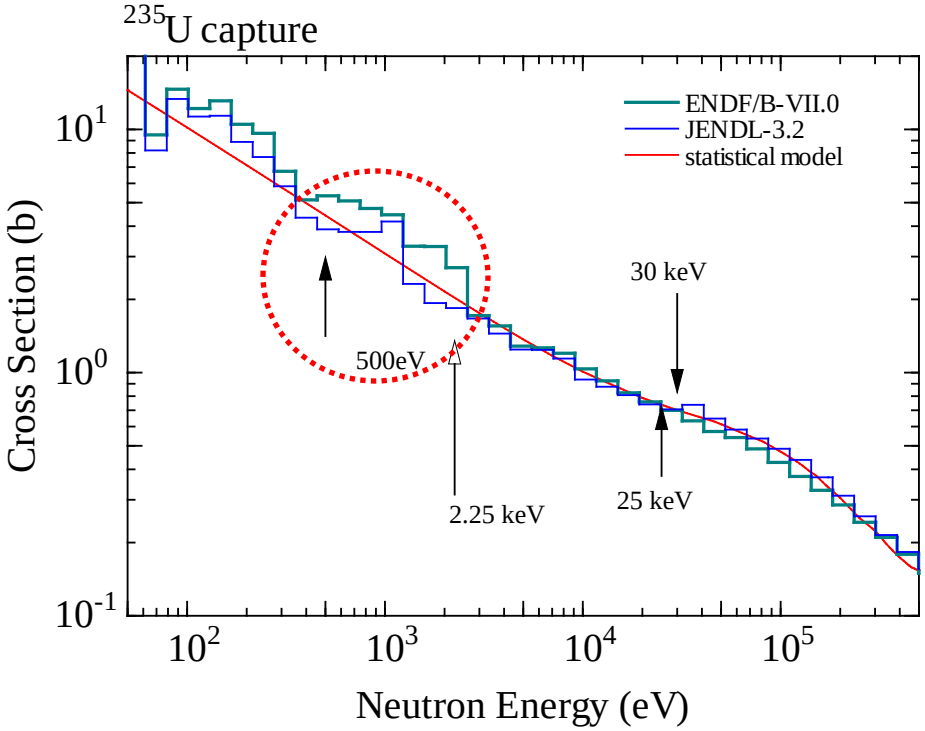
criticality of FCA IX assemblies



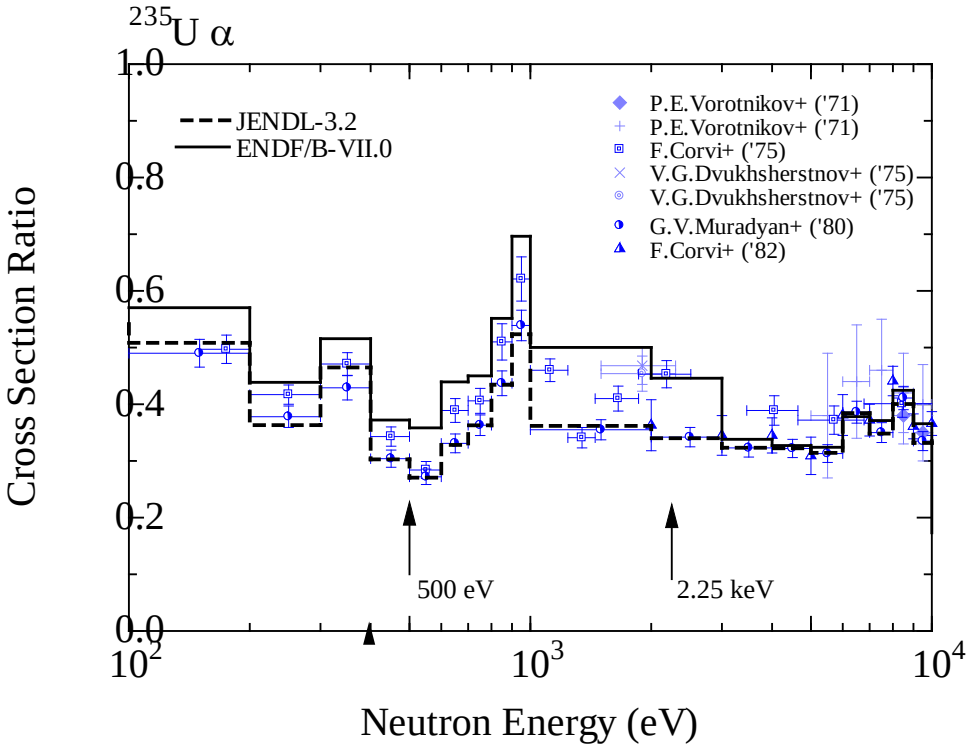
Neutron spectra

Possible overestimation of capture cross section of U-235

U-235 capture cross section



capture cross section/ fission cross section



U-235 test libraries

Case #	1.0e-5 eV – 500 eV	500 eV – 2250 eV	2250 eV – 25 keV	25 keV – 30 keV
(base)	RR	RR	URR	File 3
1	RR	RR	URR	URR
2	RR	URR	URR	URR
3	RR	URR	URR	File 3
4	RR	RR	URR	File 3
5	RR	URR	URR	File 3
6	RR	RR	URR	File 3
7	RR	RR	URR	File 3
8	RR	URR	URR	URR

LEGEND:

- ENDF/B-VII
- JENDL-3.2
- ENDF/B-VII (-3% Γg)
- ENDF/B-VII (-10% Γg)
- JENDL/AC-2008 URR

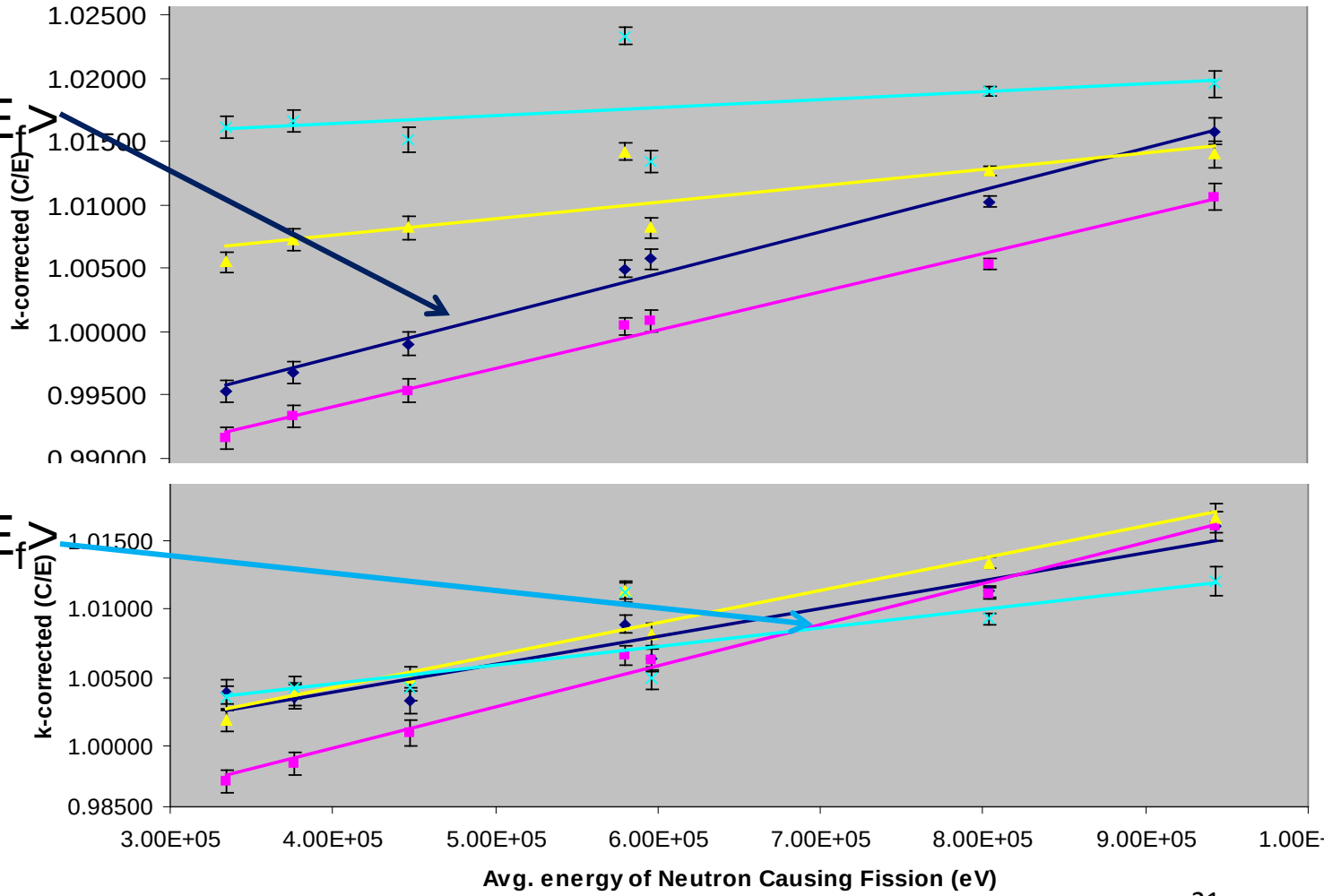
FCA-IX and HMI-006 (Zeus) Eigenvalue Trends

ENDF/B-VII.0

0.98+3.3e-8 $\langle E_f \rangle$

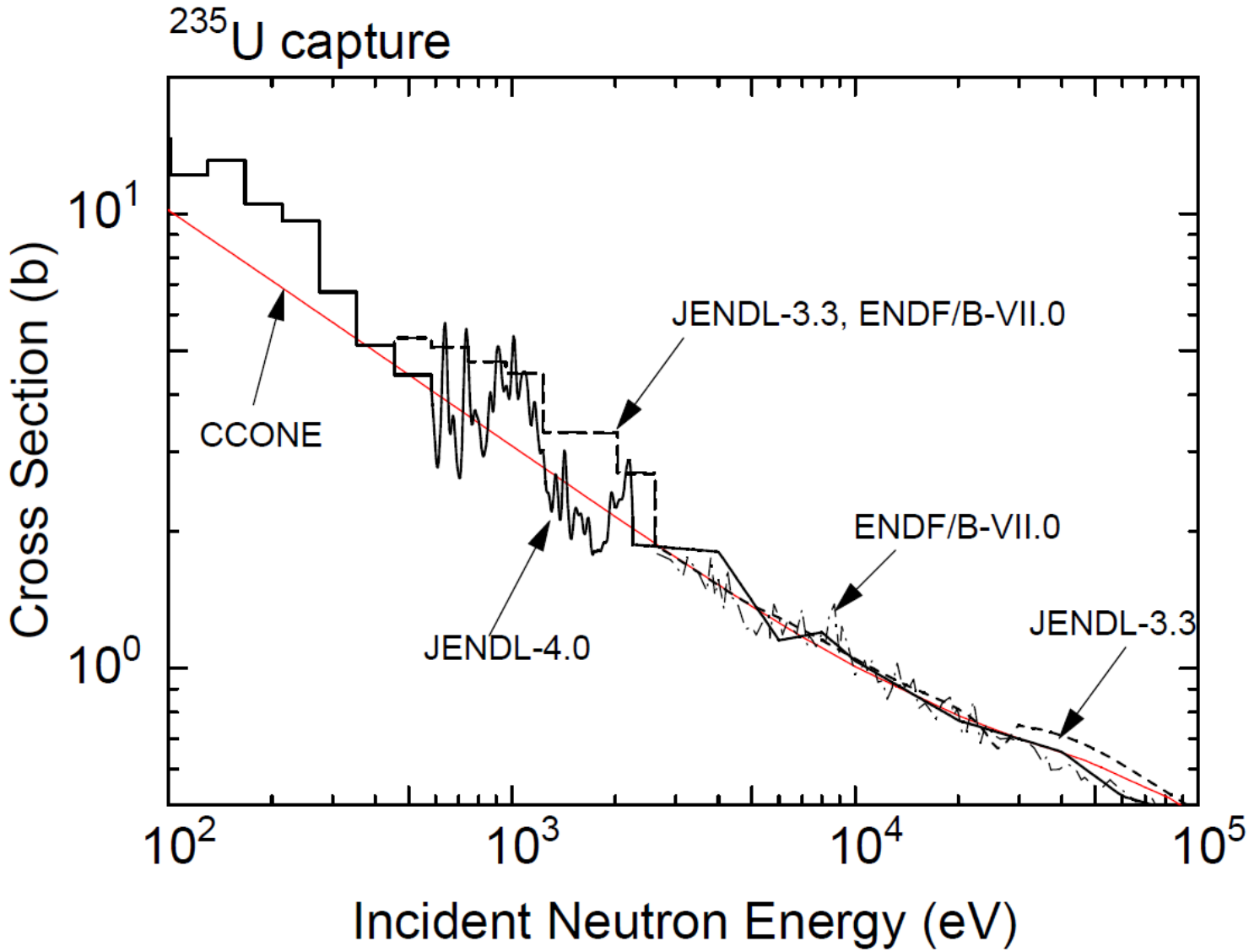
ENDF/B-VII.0 + JENDL/AC

1.00+1.4e-8 $\langle E_f \rangle$

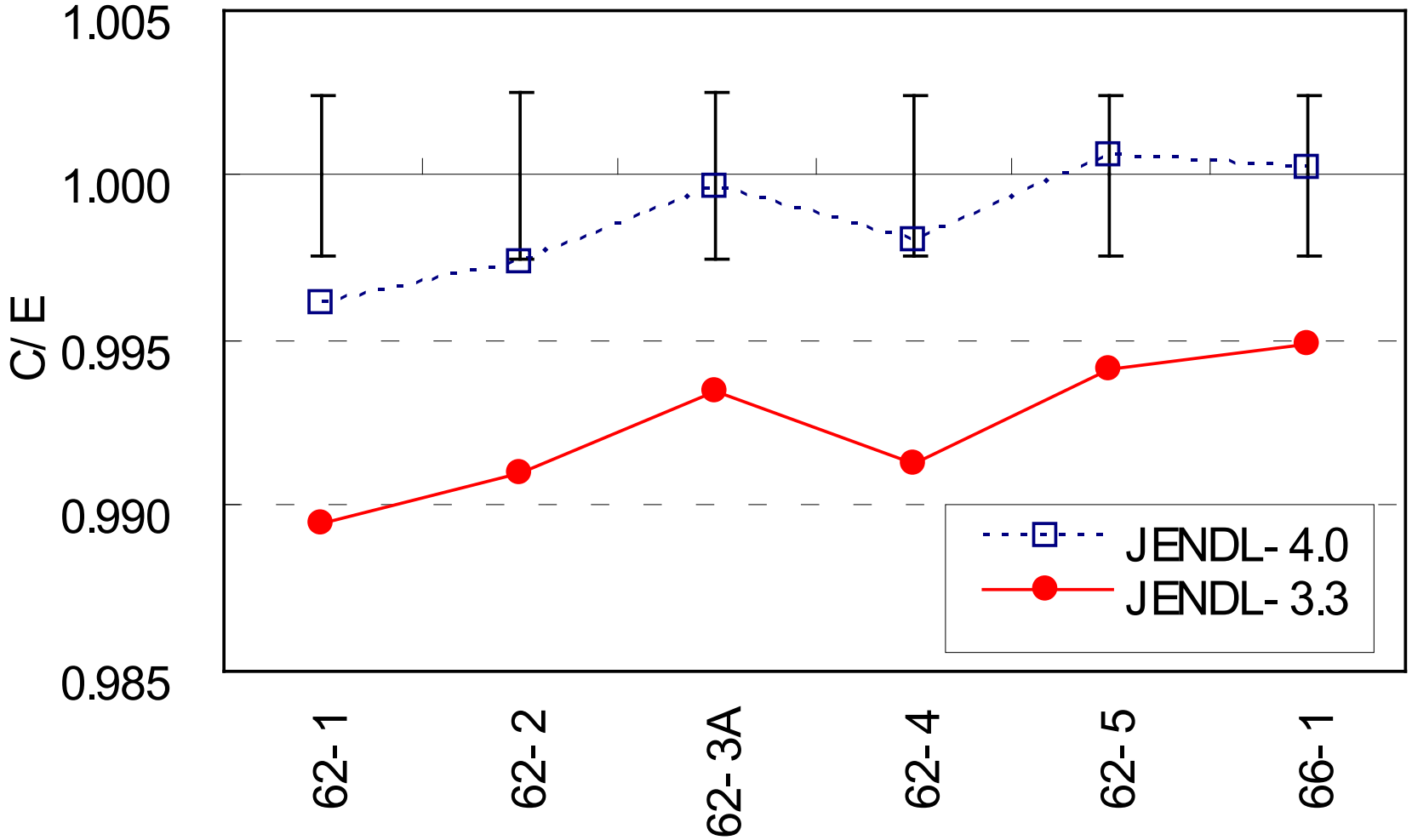


$\langle E_f \rangle$

JENDL-4.0
(released in May 2010)

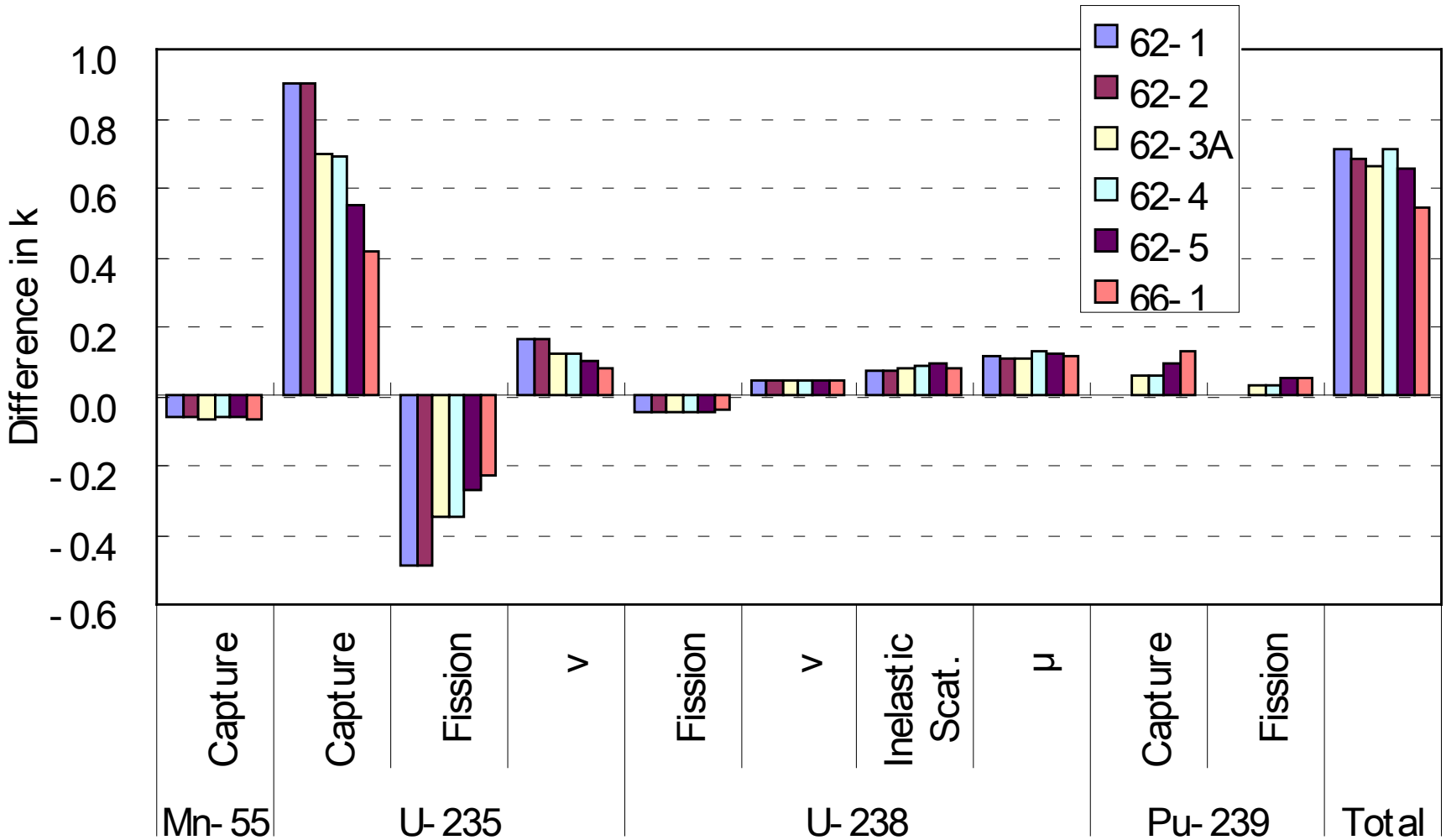


C/E value of BFS criticalities

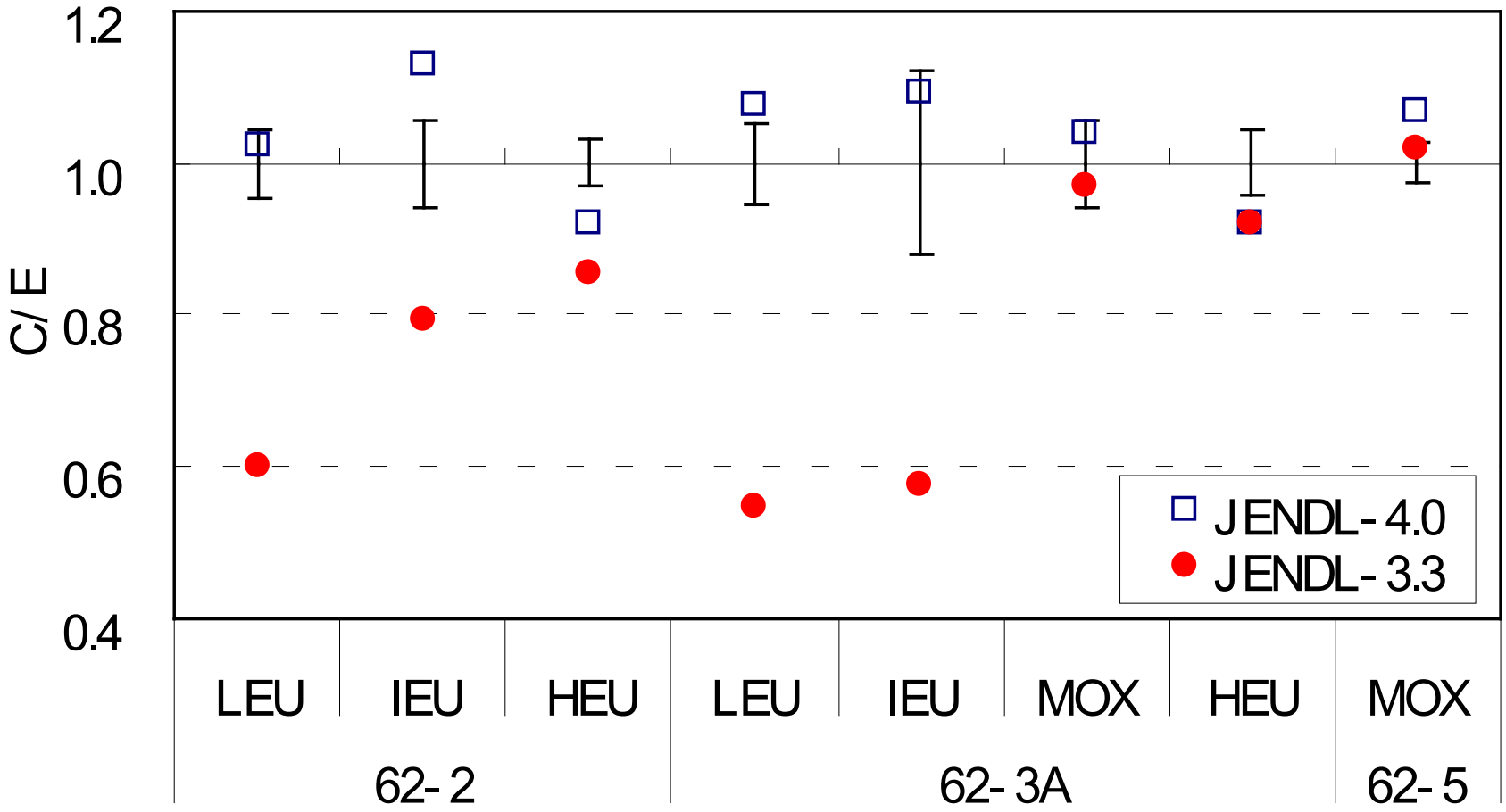


Nuclide-wise contribution to criticality change

[JENDL-3.3 => JENDL-4.0]

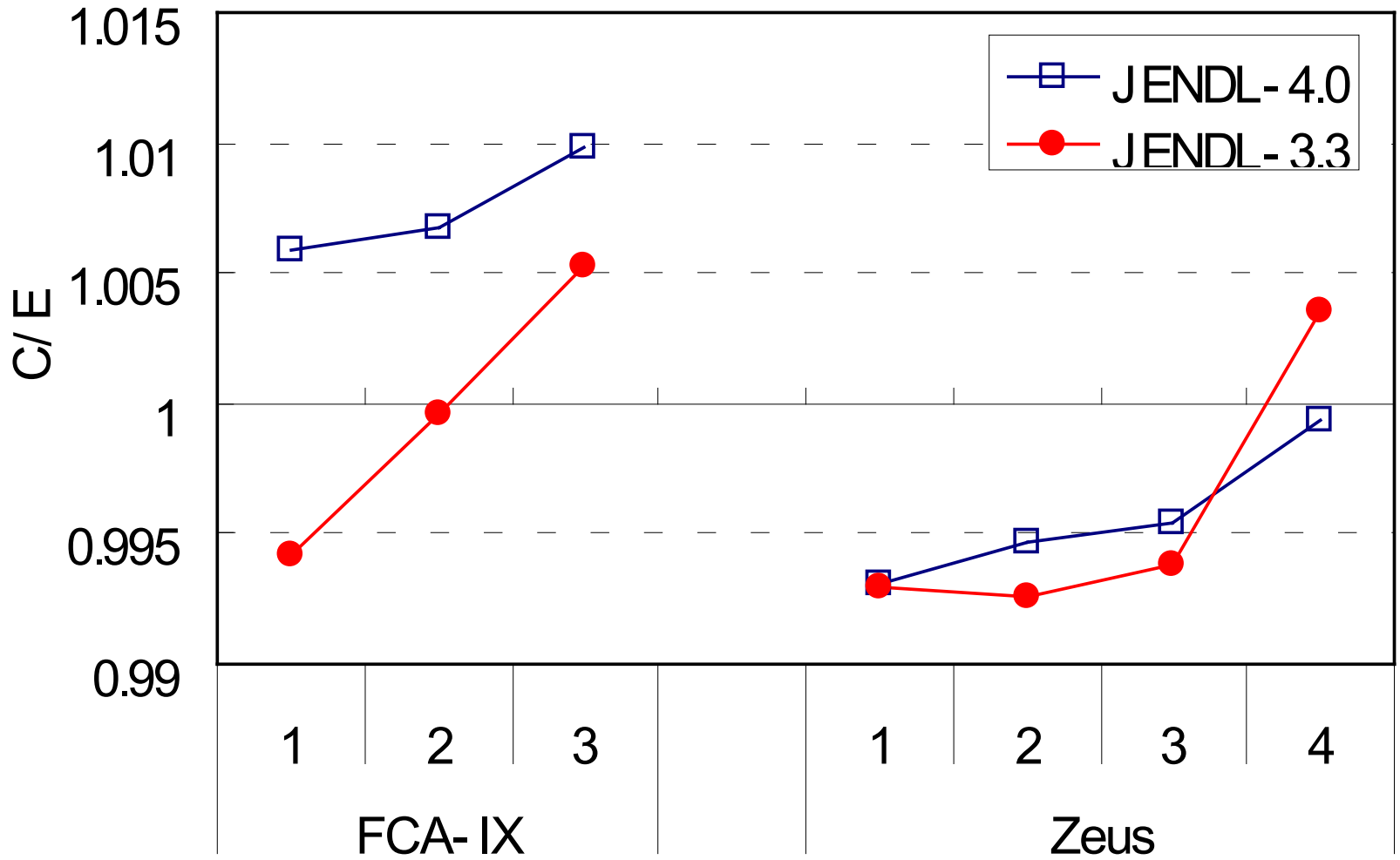


C/E value of BFS sodium void reactivity



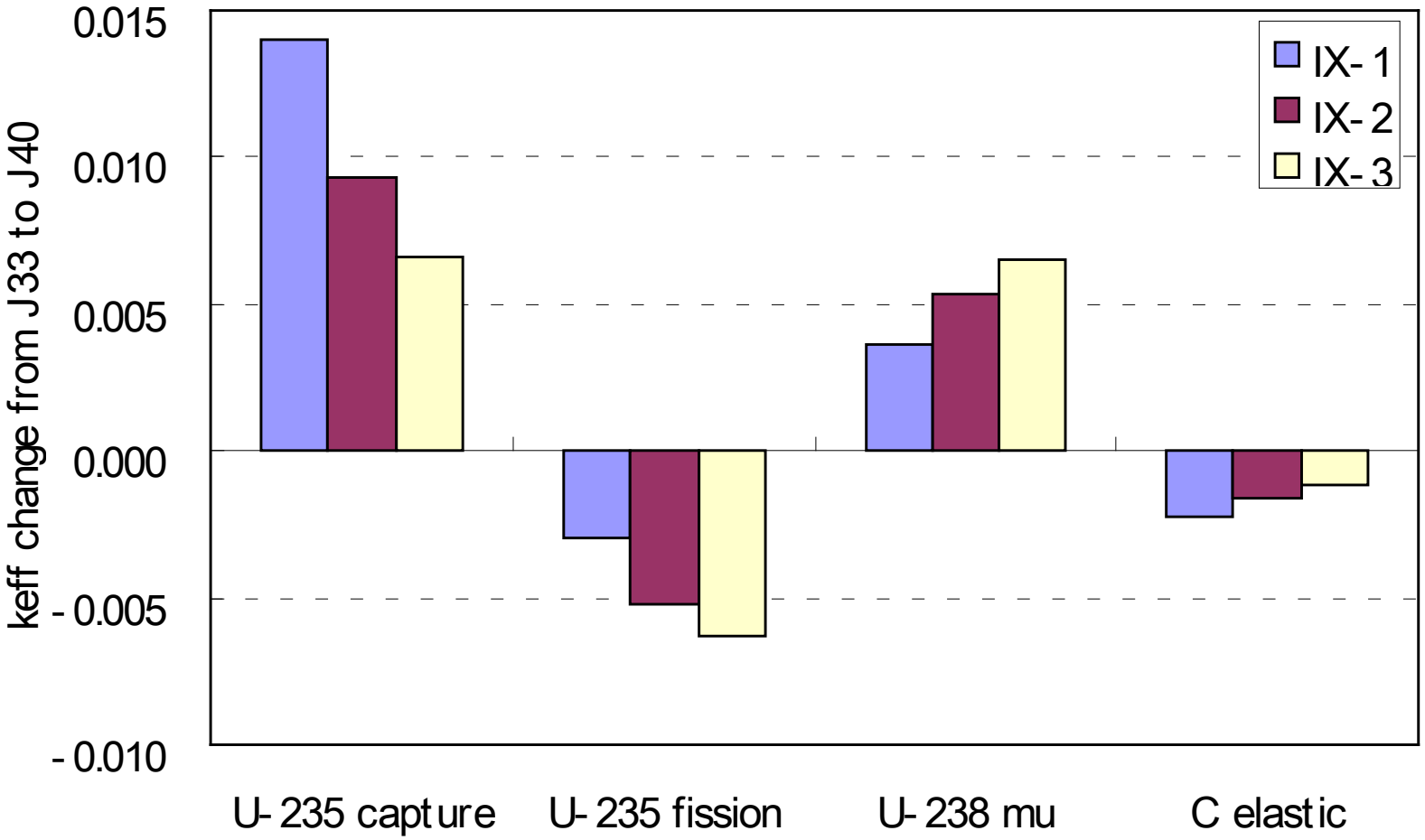
This improvement is due to the revision of U-235 capture cross section in keV region.

C/E values of Zeus & FCA-IX criticalities



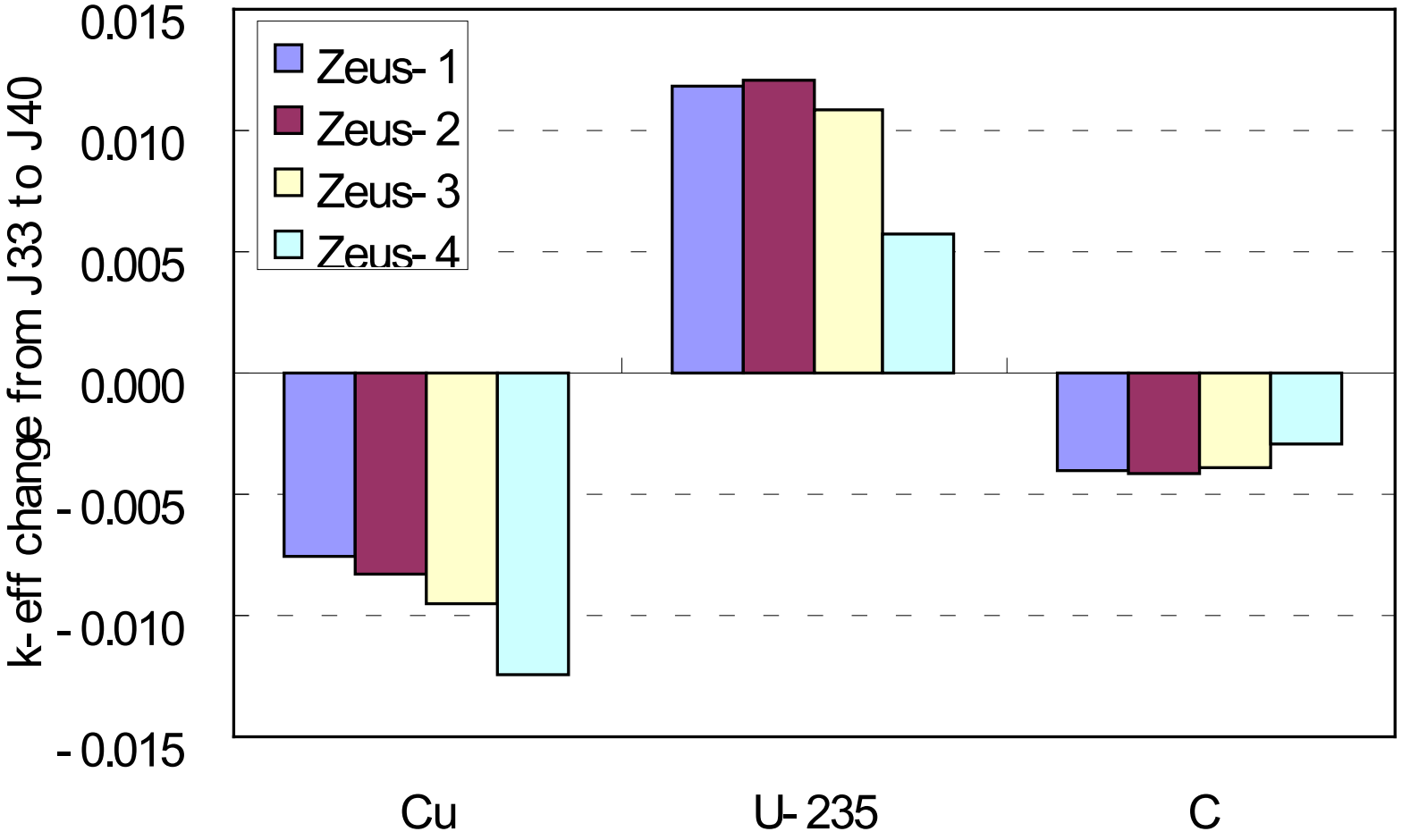
Nuclide-wise contribution to keff change (FCA-IX)

[JENDL-3.3 => JENDL-4.0]

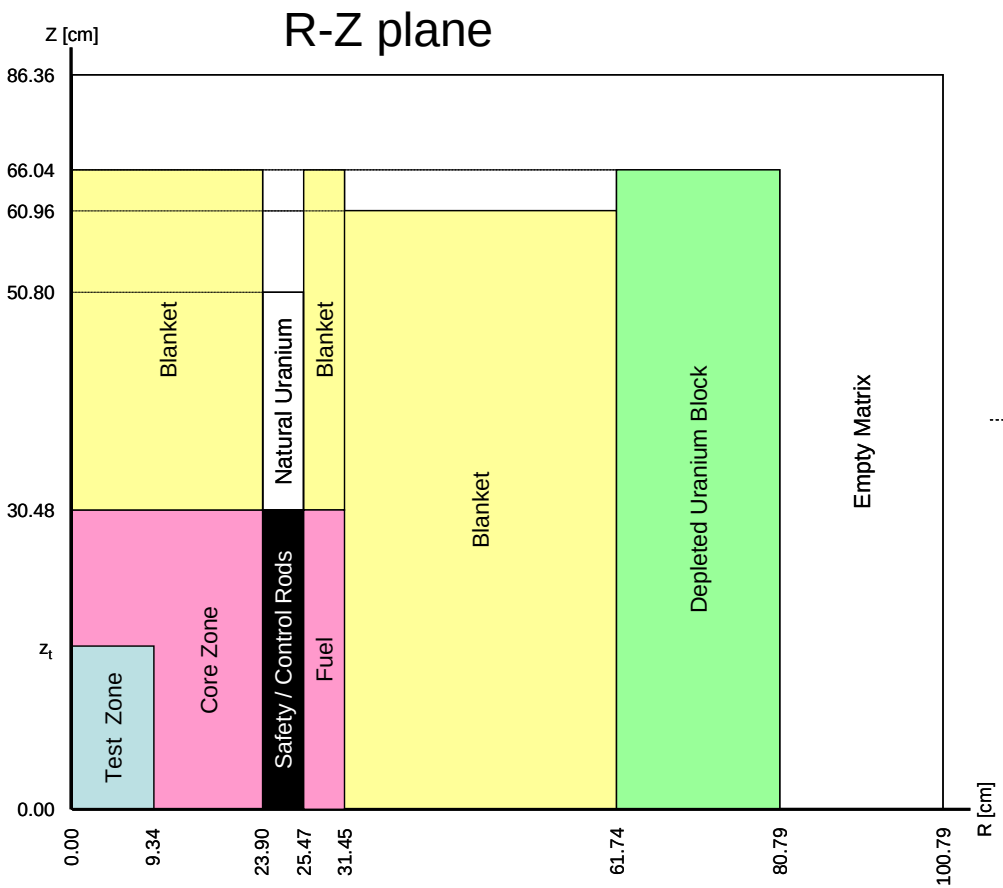


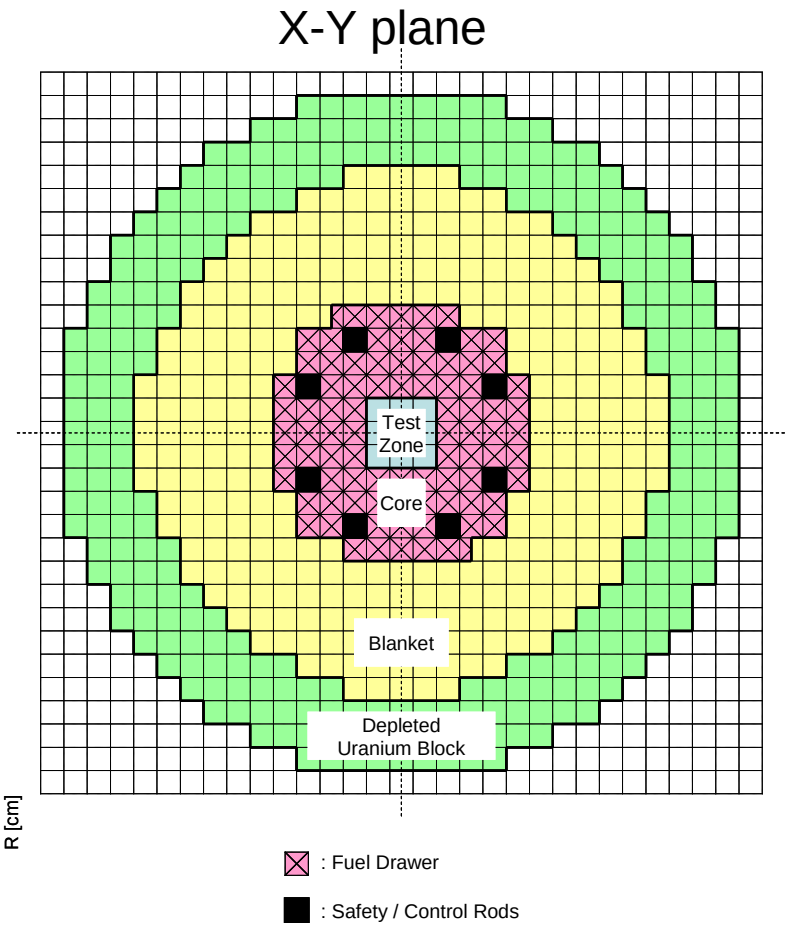
Nuclide-wise contribution to keff change (Zeus)

[JENDL-3.3 => JENDL-4.0]



New Integral Experiment at FCA

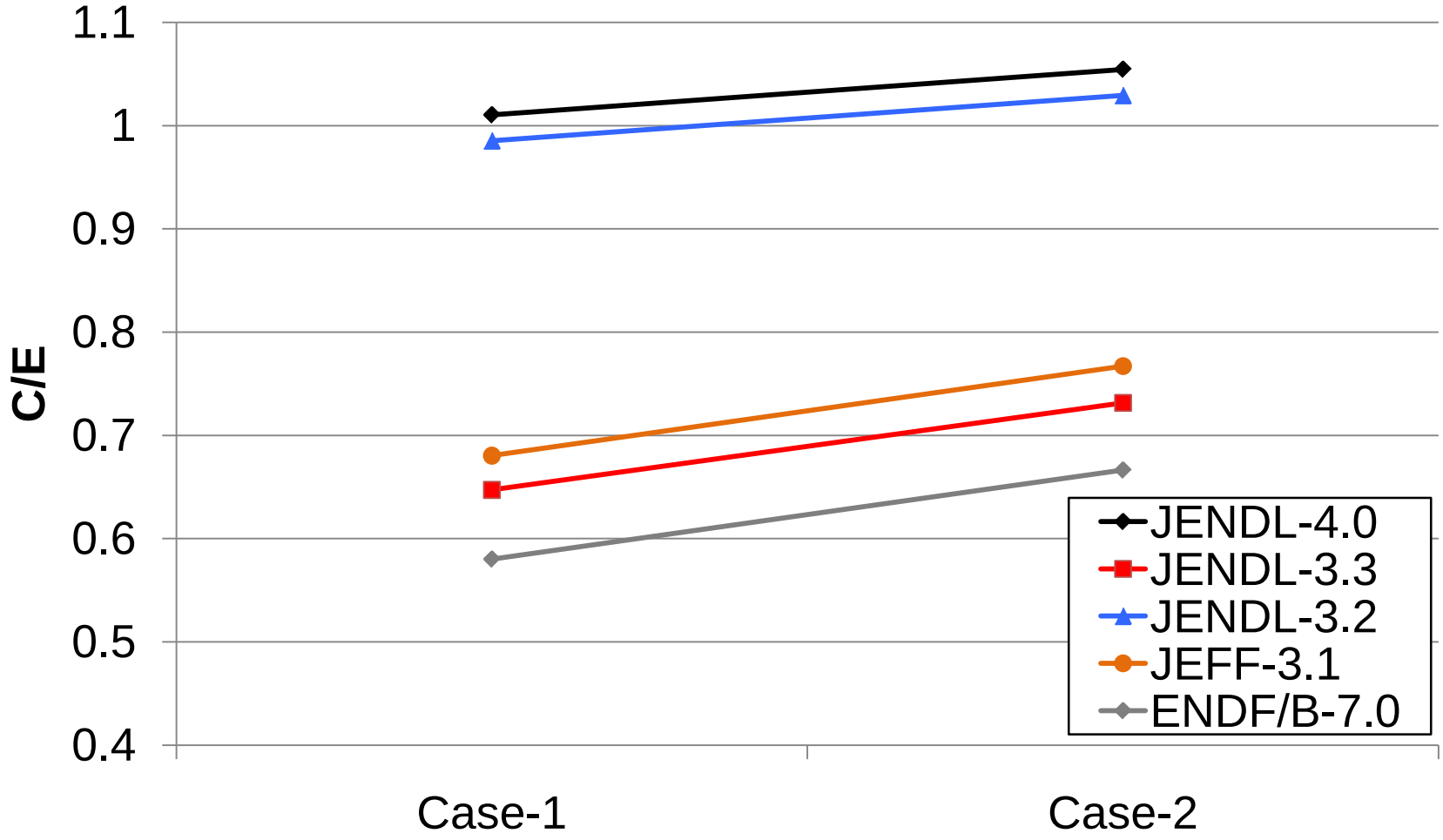




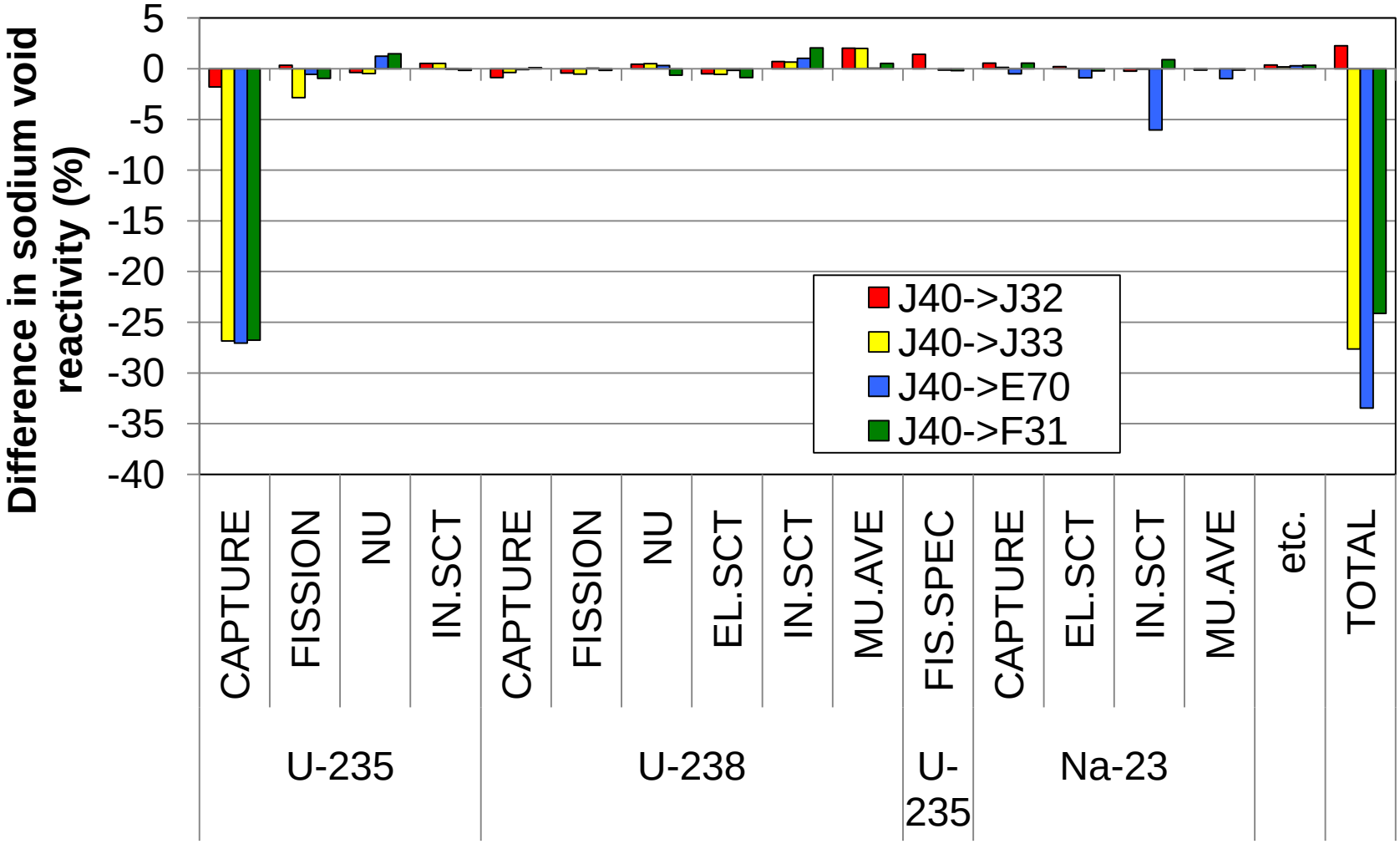
Case	Height of Test Zone z_t x 2 [cm]
1	10.16 x 2
2	15.24 x 2

- The sodium cans at the test zone were replaced with voided steel cans to evaluate the sodium-void reactivities.
- Height of test zone was changed.

C/E of Sodium-Void Reactivity

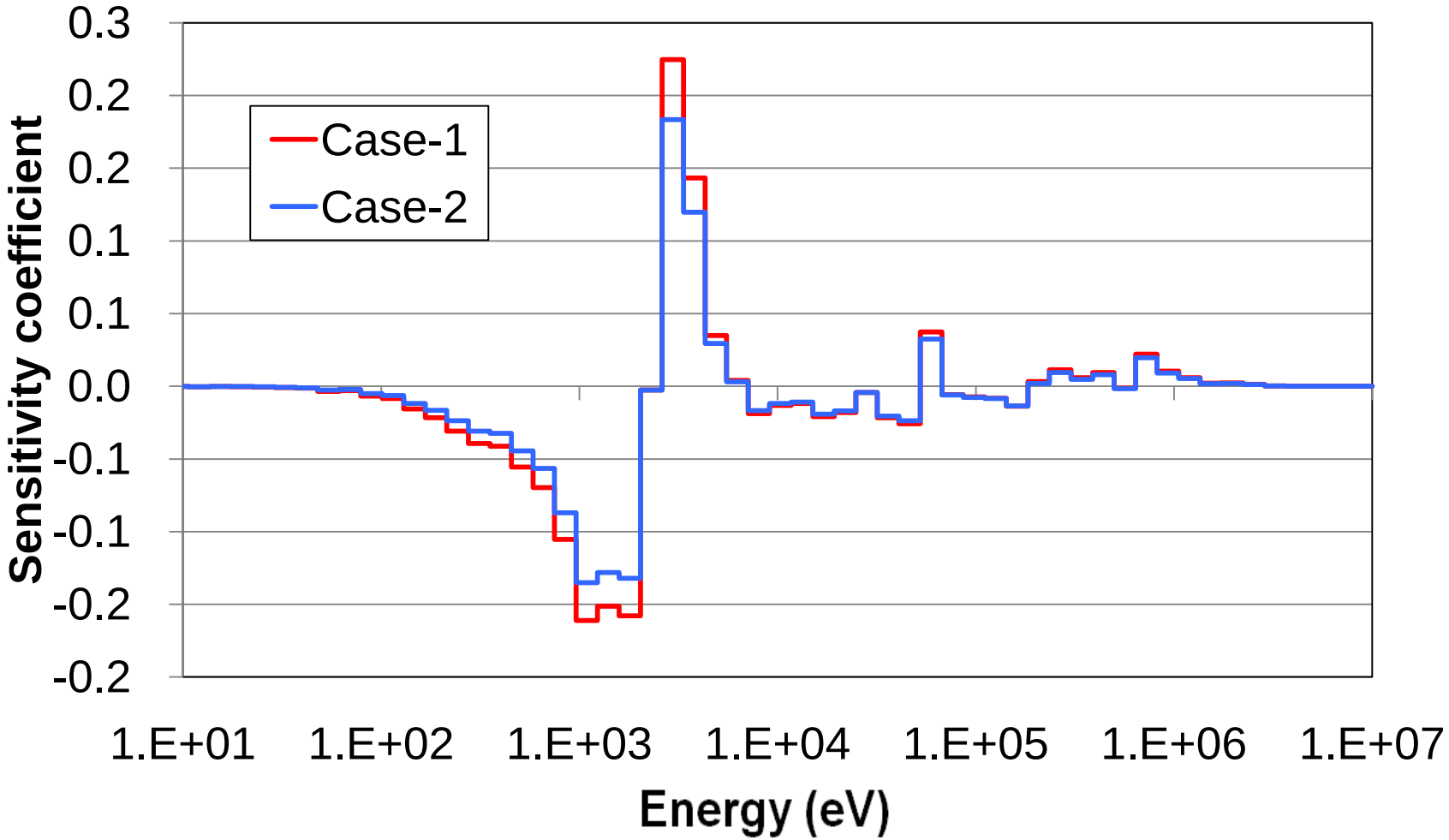


Nuclide-wise contribution to sodium void reactivity change (Case-1)

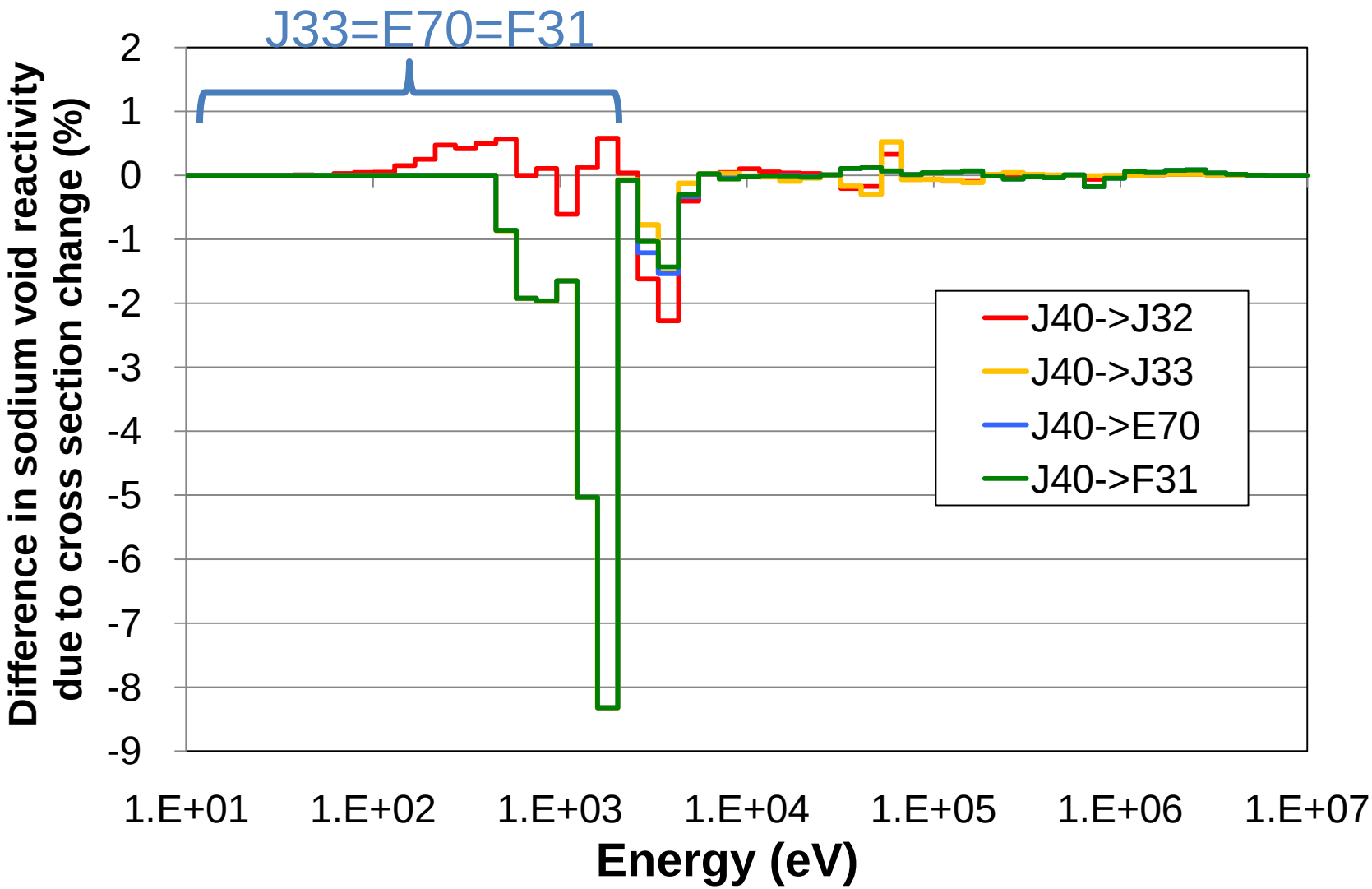


Sensitivity of sodium void reactivity to U-235 capture cross section

(Evaluated with JENDL-4.0)



Energy-wise contribution of U-235 capture cross section to sodium void reactivity change



Conclusions of SG29

- Result:
  - The possible overestimation of U-235 capture cross section in the 0.1 to 2.5 keV is consistent with the alpha measurement and the integral experiments of Na-void reactivity of BFS and FCA, and the criticality trends of FCA and ZEUS.
  - The magnitude of the overestimation could be ~10% or more.
  - However, the problem to overestimate FCA criticalities is remained. It may be needed to consider the other contributions.
- Recommendation:
  - Accurate alpha measurement in keV region
  - New resonance analysis in 0.1 to 2.5 keV region
  - Investigate the reason of the overestimation of criticalities for some benchmarks
- The final report will be prepared within this year.