

BENCHMARK RESULTS BY JAEA

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1. Calculation and Adjustment Conditions

- Nuclear data: JENDL-4.0
- Covariance data: JENDL-4.0
- Base calculation: Continuous energy Monte Carlo method
- Corrective factors: Given (practically ZPR6-7 only)
- Analytical modeling uncertainty: Statistical one with the Monte Carlo method
- Adjusted parameters (complements)
 - Total fission spectrum (not prompt)
 - Total Nu-bar (not prompt)
 - Energy-averaged delayed neutron fraction (not delayed Nu-d)

Changed from the previous calculations

1. Calculation and Adjustment Conditions

- Correlation Coefficients of Critical Mass -

For experimental uncertainty

Core	JEZEBEL-Pu239	JEZEBEL-Pu240	FLATTOP-Pu	ZPR6-7 standard	ZPR6-7 High Pu-240	ZPPR-9	Joyo MK-I
JEZEBEL-Pu239	1						
JEZEBEL-Pu240		1					
FLATTOP-Pu			1				
ZPR6-7 standard				1	0.8	0.6	
ZPR6-7 High Pu-240					1	0.6	
ZPPR-9						1	
Joyo MK-I							1

For analytical modeling uncertainty

Core	JEZEBEL-Pu239	JEZEBEL-Pu240	FLATTOP-Pu	ZPR6-7 standard	ZPR6-7 High Pu-240	ZPPR-9	Joyo MK-I
JEZEBEL-Pu239	1						
JEZEBEL-Pu240		1					
FLATTOP-Pu			1				
ZPR6-7 standard				1	0.8	0.8	
ZPR6-7 High Pu-240					1	0.8	
ZPPR-9						1	
Joyo MK-I							1

Detail on experimental uncertainty among ZPR6-7s and ZPPR-9

Core and component			ZPR6-7 High Pu-240			ZPPR-9		
			Geo.	Comp.	Total	Geo.	Comp.	Total
			0.041	0.068	0.086	0.035	0.112	0.154
ZPR6-7 standard	Geo.	0.042	1.0	0.0	-	0.0	0.0	-
	Comp.	0.075	0.0	1.0	-	0.0	1.0	-
	Total	0.087	-	-	0.9*	-	-	0.6
ZPR6-7 High Pu-240	Geo.	0.041	-	-	-	0.0	0.0	-
	Comp.	0.068	-	-	-	0.0	1.0	-
	Total	0.086	-	-	-	-	-	0.6

Geo.: Geometry, Comp.: Composition

*: Reduced to 0.8 by assuming unknown error component

1. Calculation and Adjustment Conditions

- Correlation Coefficients of Spectral Indices -

For experimental uncertainty

Core and characteristics		JEZEBEL-Pu239			FLATTOP-Pu		ZPR6-7 standard			ZPPR-9		
		F28/F25	F49/F25	F37/F25	F28/F25	F37/F25	F28/F25	F49/F25	C28/F25	F28/F25	F49/F25	C28/F25
JEZEBEL-Pu239	F28/F25	1	0.4	0.4								
	F49/F25		1	0.5								
	F37/F25			1								
FLATTOP-Pu	F28/F25				1	0.3						
	F37/F25					1						
ZPR6-7 standard	F28/F25						1	0.3	0.3			
	F49/F25							1	0.5			
	C28/F25								1			
ZPPR-9	F28/F25									1	0.3	0.3
	F49/F25										1	0.5
	C28/F25											1

For analytical modeling uncertainty

Core and characteristics		JEZEBEL-Pu239			FLATTOP-Pu		ZPR6-7 standard			ZPPR-9		
		F28/F25	F49/F25	F37/F25	F28/F25	F37/F25	F28/F25	F49/F25	C28/F25	F28/F25	F49/F25	C28/F25
JEZEBEL-Pu239	F28/F25	1	0.4	0.4								
	F49/F25		1	0.5								
	F37/F25			1								
FLATTOP-Pu	F28/F25				1	0.3						
	F37/F25					1						
ZPR6-7 standard	F28/F25						1	0.4	0.4			
	F49/F25							1	0.5			
	C28/F25								1			
ZPPR-9	F28/F25									1	0.4	0.4
	F49/F25										1	0.5
	C28/F25											1

Detail on analytical modeling uncertainty for JEZEBEL and FLATTOP

JEZEBEL-Pu239							
Index and component		F49/F25		F37/F25			
		F25	Total	F25	Total		
		0.0027	0.0038	0.0027	0.0040		
F28/F25	F25	0.0027	1.0	-	1.0	-	
	Total	0.0047	-	0.4	-	0.4	
F49/F25	F25	0.0027	-	-	1.0	-	
	Total	0.0038	-	-	-	0.5	

FLATTOP-Pu					
Index and component		F37/F25			
		F25	Total		
		0.0022	0.0035		
F28/F25	F25	0.0022	1.0	-	
	Total	0.0042	-	0.3	

1. Calculation and Adjustment Conditions

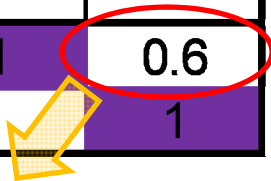
- Correlation Coefficients of Na Void Reactivity (ZPPR-9) -

For experimental uncertainty

Characteristics	Na void (Step 3)	Na void (Step 5)
Na void (Step 3)	1	0.4
Na void (Step 5)		1

For analytical modeling uncertainty

Characteristics	Na void (Step 3)	Na void (Step 5)
Na void (Step 3)	1	0.6
Na void (Step 5)		1



Detail on analytical modeling uncertainty

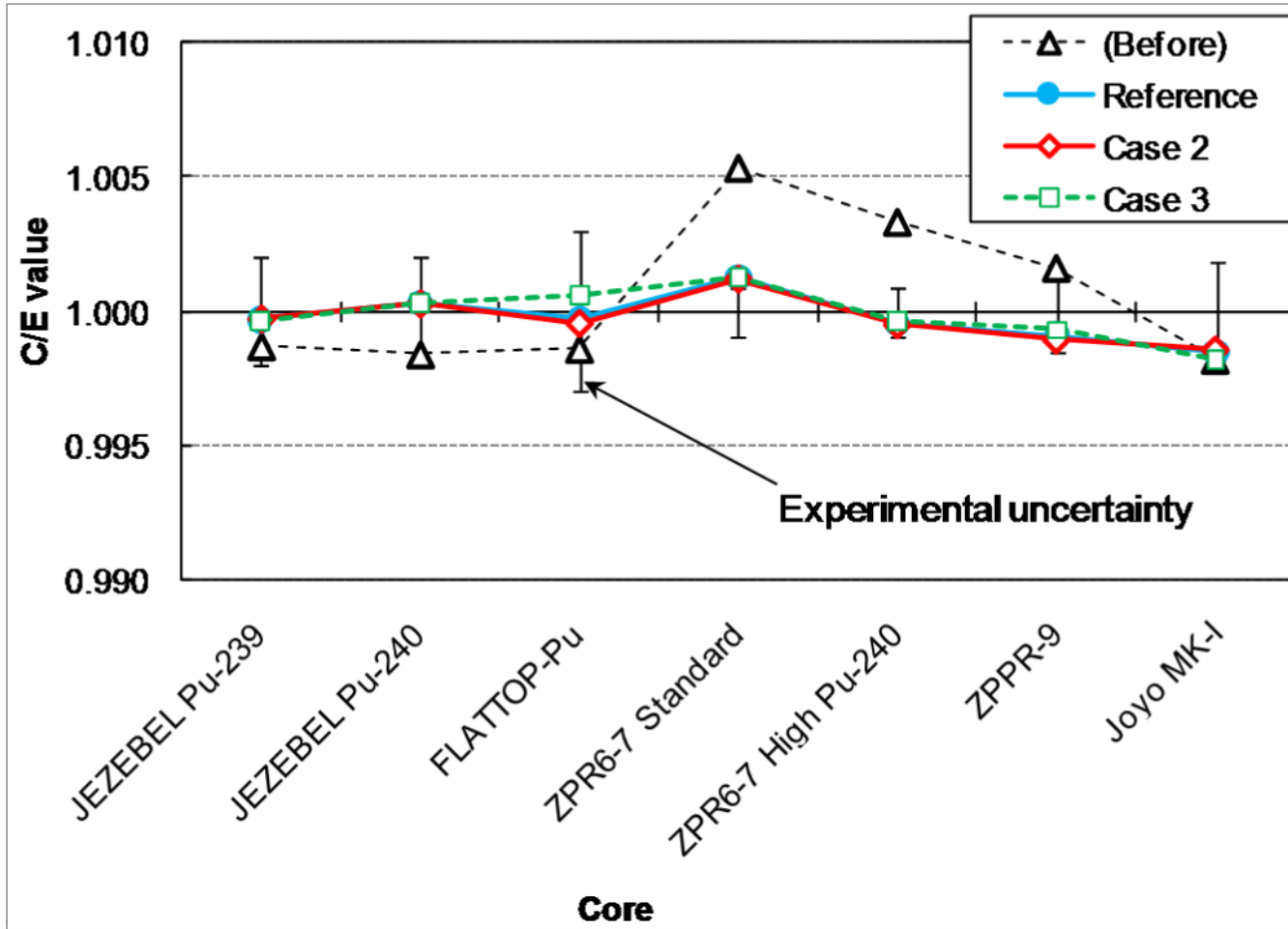
Na void step and component			Step 5		
			Non-leakage	Leakage	Total
			0.0142	0.0476	0.0497
Step 3	Non-leakage	0.0085	1.0	0.0	-
	Leakage	0.0038	0.0	1.0	-
	Total	0.0093	-	-	0.65

2. Calculation Results (Before Adjustment)

Core	Characteristics	C/E value	Relative uncertainty		
			Experiment	Calculation	Sum
JEZEBEL-Pu239	Critical mass	0.9987	2.00E-03	1.33E-04	2.00E-03
	S-Index (F28/F25)	0.9686	1.08E-02	4.72E-03	1.18E-02
	S-Index (F49/F25)	0.9837	8.90E-03	3.77E-03	9.66E-03
	S-Index (F37/F25)	0.9794	1.42E-02	4.02E-03	1.48E-02
JEZEBEL-Pu240	Critical mass	0.9984	2.00E-03	1.33E-04	2.00E-03
FLATTOP-Pu	Critical mass	0.9986	3.00E-03	1.63E-04	3.00E-03
	S-Index (F28/F25)	0.9773	1.11E-02	4.18E-03	1.19E-02
	S-Index (F37/F25)	0.9925	1.40E-02	3.46E-03	1.44E-02
ZPR6-7 standard	Critical mass	1.0053	8.67E-04	1.03E-04	8.73E-04
	S-Index (F28/F25)	0.9891	3.00E-02	6.76E-03	3.08E-02
	S-Index (F49/F25)	0.9790	2.10E-02	2.14E-04	2.10E-02
	S-Index (C28/F25)	1.0167	2.40E-02	1.09E-03	2.40E-02
ZPR6-7 High Pu-240	Critical mass	1.0033	8.55E-04	9.90E-05	8.61E-04
ZPPR-9	Critical mass	1.0016	1.54E-03	4.46E-05	1.54E-03
	S-Index (F28/F25)	0.9575	2.65E-02	8.86E-03	2.79E-02
	S-Index (F49/F25)	0.9867	2.12E-02	4.78E-03	2.17E-02
	S-Index (C28/F25)	1.0233	1.73E-02	6.13E-03	1.84E-02
	Na void (Step 3)	1.1174	1.22E-02	5.33E-02	5.47E-02
	Na void (Step 5)	1.0480	1.14E-02	4.19E-02	4.34E-02
Joyo MK-I	Critical mass	0.9982	1.80E-03	1.40E-04	1.80E-03

3. Adjustment Results in C/E Values

- Critical Mass -

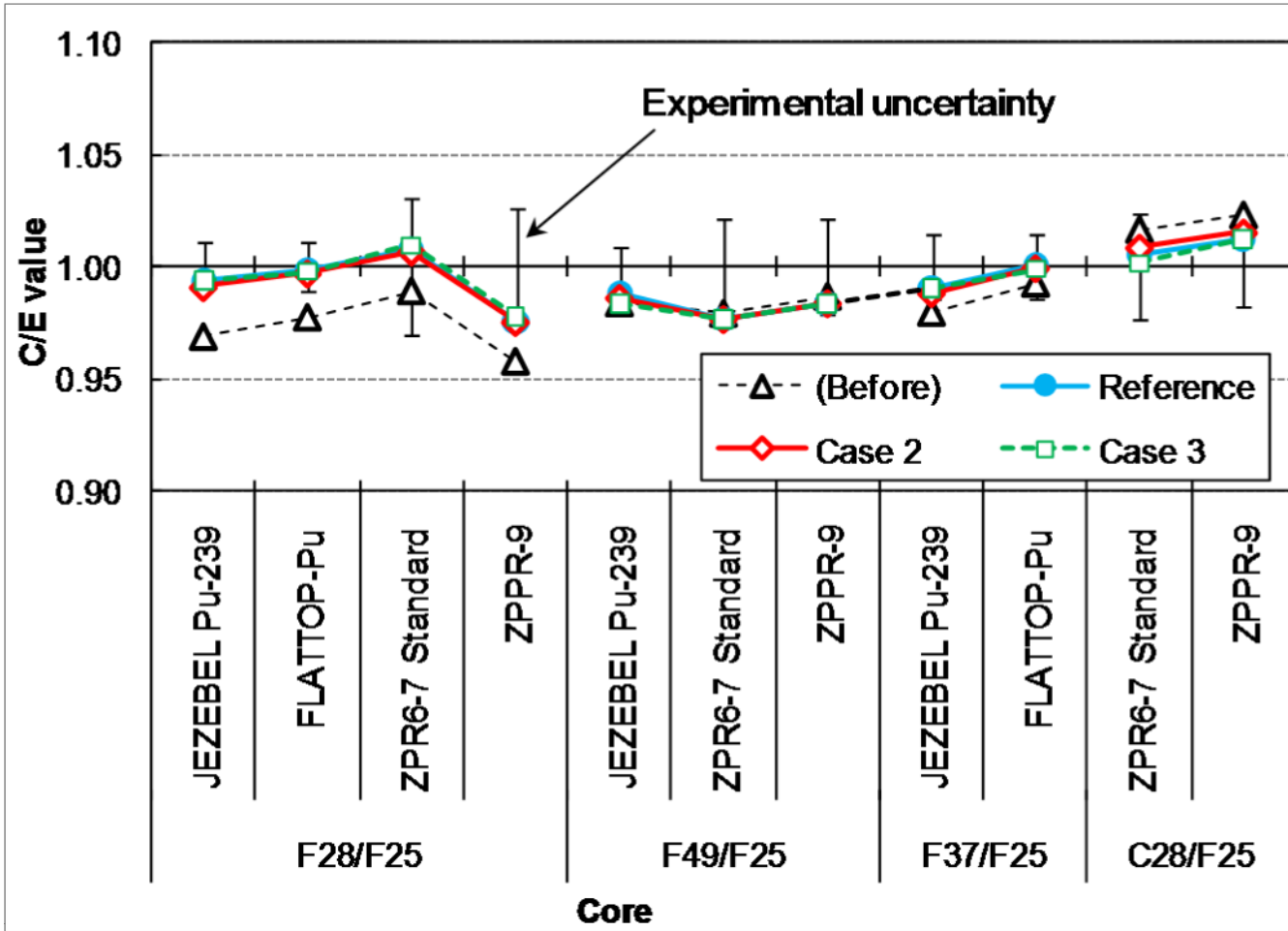


- Reference: $\chi^2/d=1.6$
 - Case 2: $\chi^2/d=1.2$
(3 times of analytical modeling uncertainty)
 - Case 3: $\chi^2/d=2.5$
(No analytical modeling uncertainty)
- [d: Degree of freedom (=20)]

$\chi^2/d=3.3$ (preliminary adjustment in no analytical modeling uncertainty case presented in the 3rd meeting)

3. Adjustment Results in C/E Values

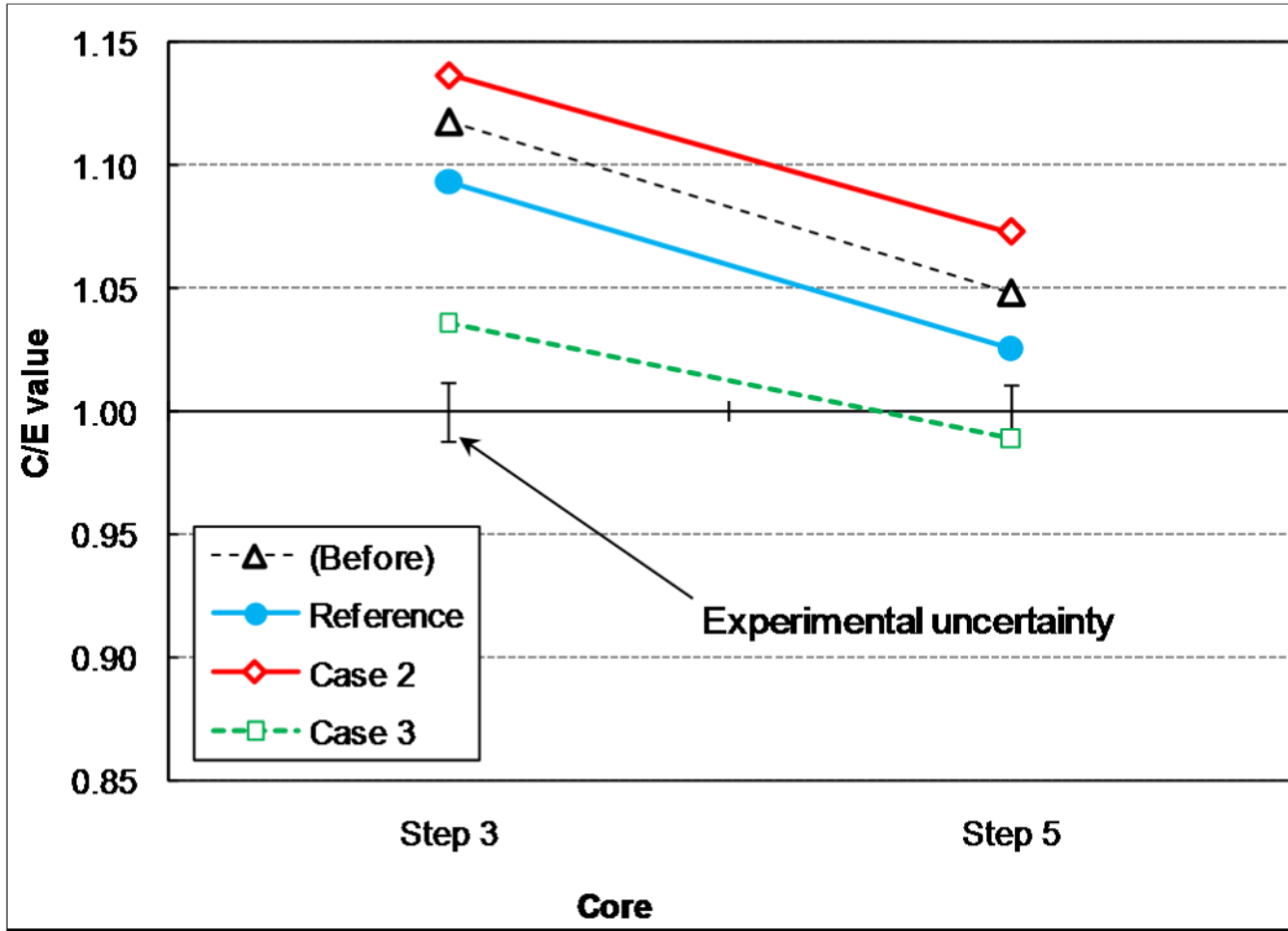
- Spectral Indices -



- Reference: $\chi^2/d=1.6$
 - Case 2: $\chi^2/d=1.2$
(3 times of analytical modeling uncertainty)
 - Case 3: $\chi^2/d=2.5$
(No analytical modeling uncertainty)
- [d: Degree of freedom (=20)]

3. Adjustment Results in C/E Values

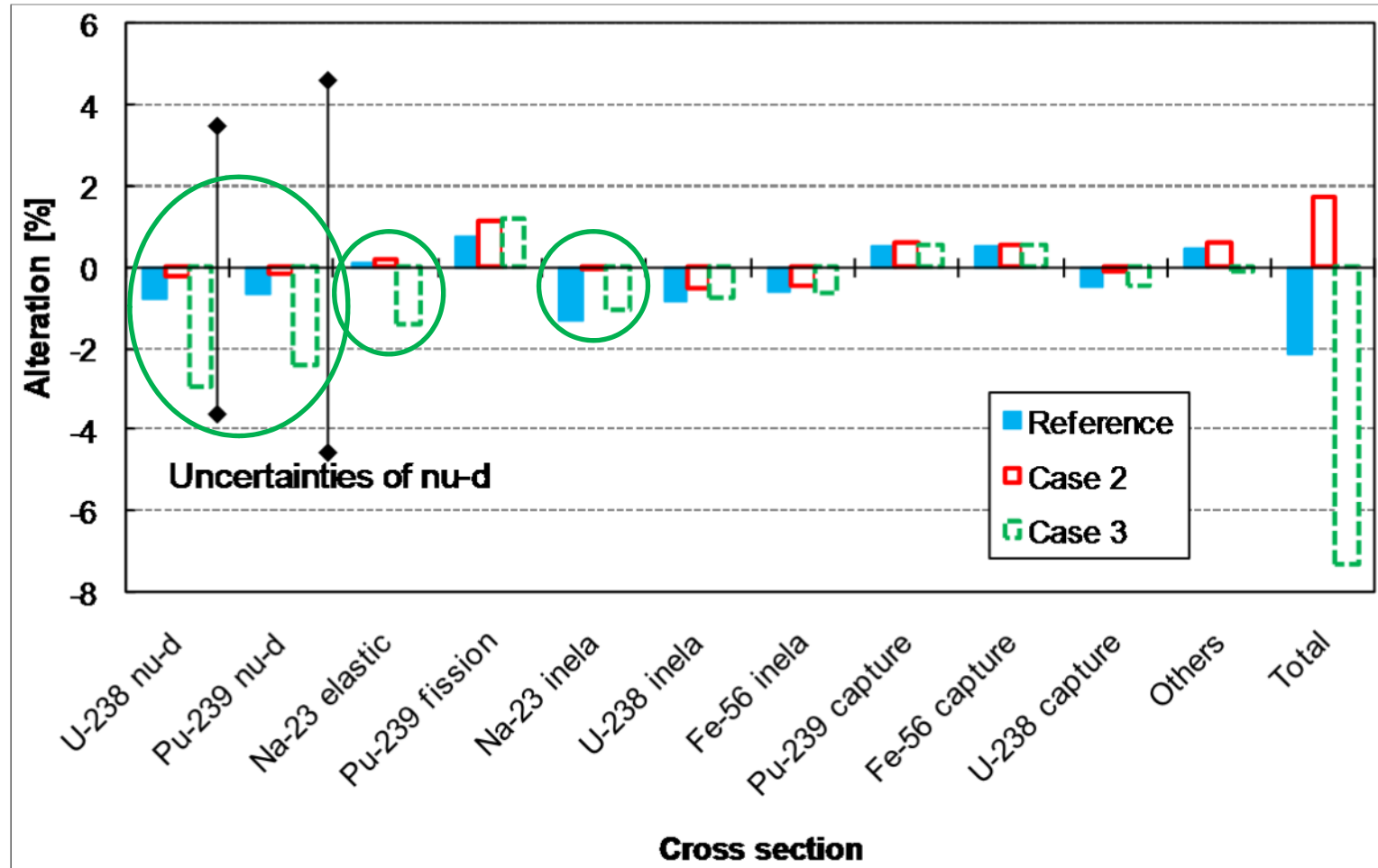
- Na Void Reactivity -



- Reference: $\chi^2/d=1.6$
 - Case 2: $\chi^2/d=1.2$
(3 times of analytical modeling uncertainty)
 - Case 3: $\chi^2/d=2.5$
(No analytical modeling uncertainty)
- [d: Degree of freedom (=20)]

3. Adjustment Results in C/E Values

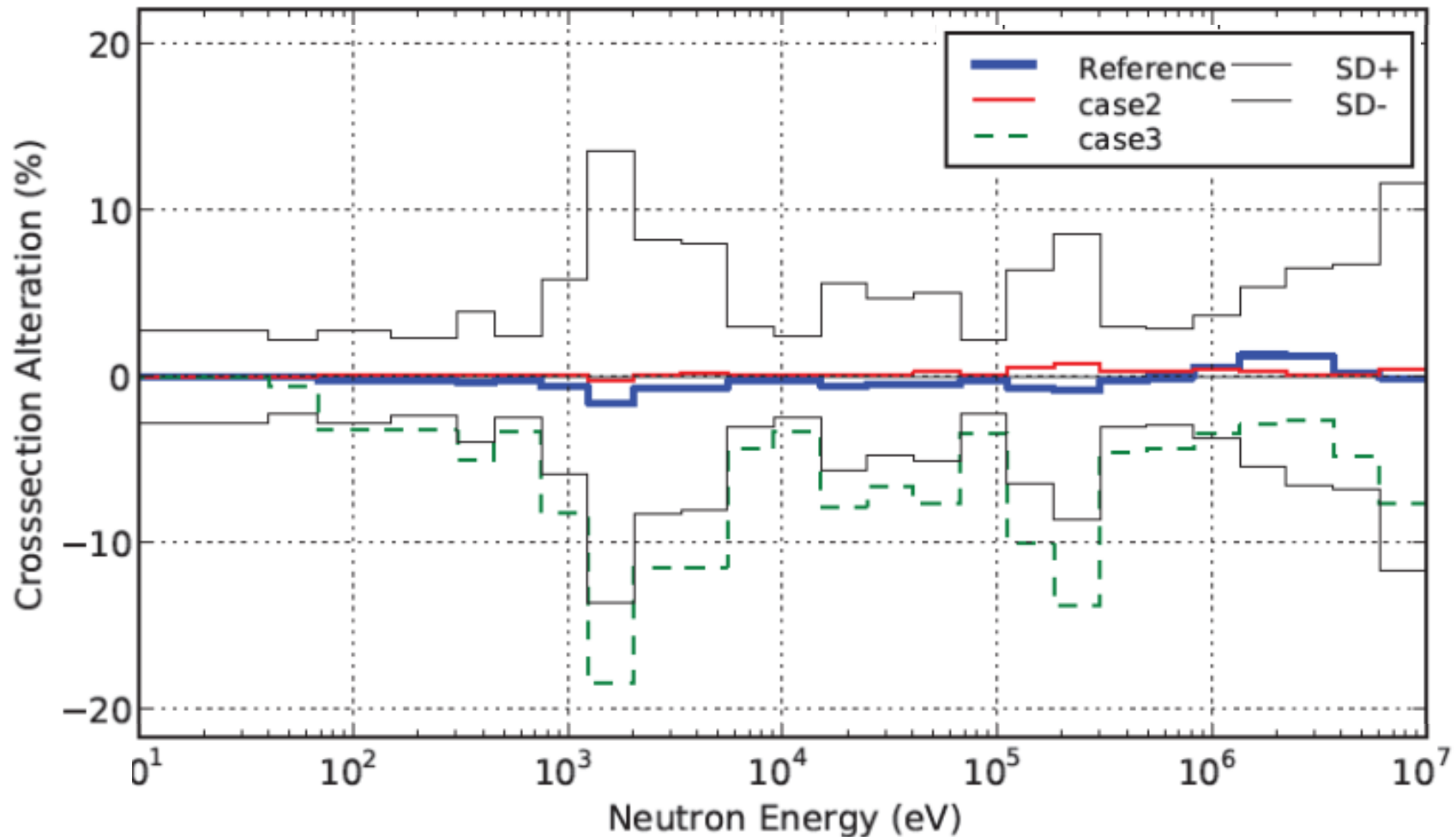
- Components of Na void reactivity (Step 3) -



4. Adjustment Results in Cross-sections

- Na-23 elastic scattering cross-section data -

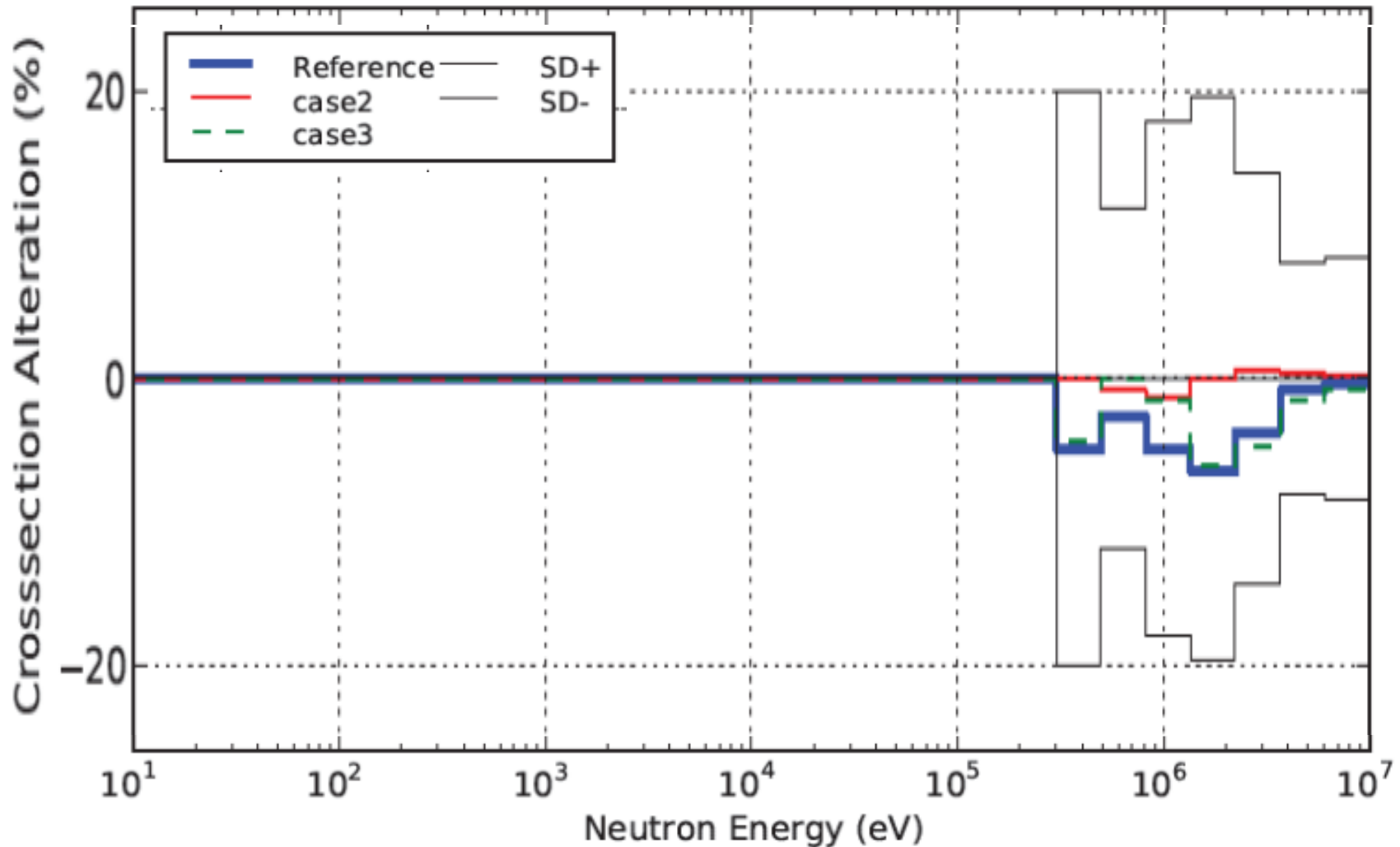
Fig. (Na-23, elastic_scattering)



4. Adjustment Results in Cross-sections

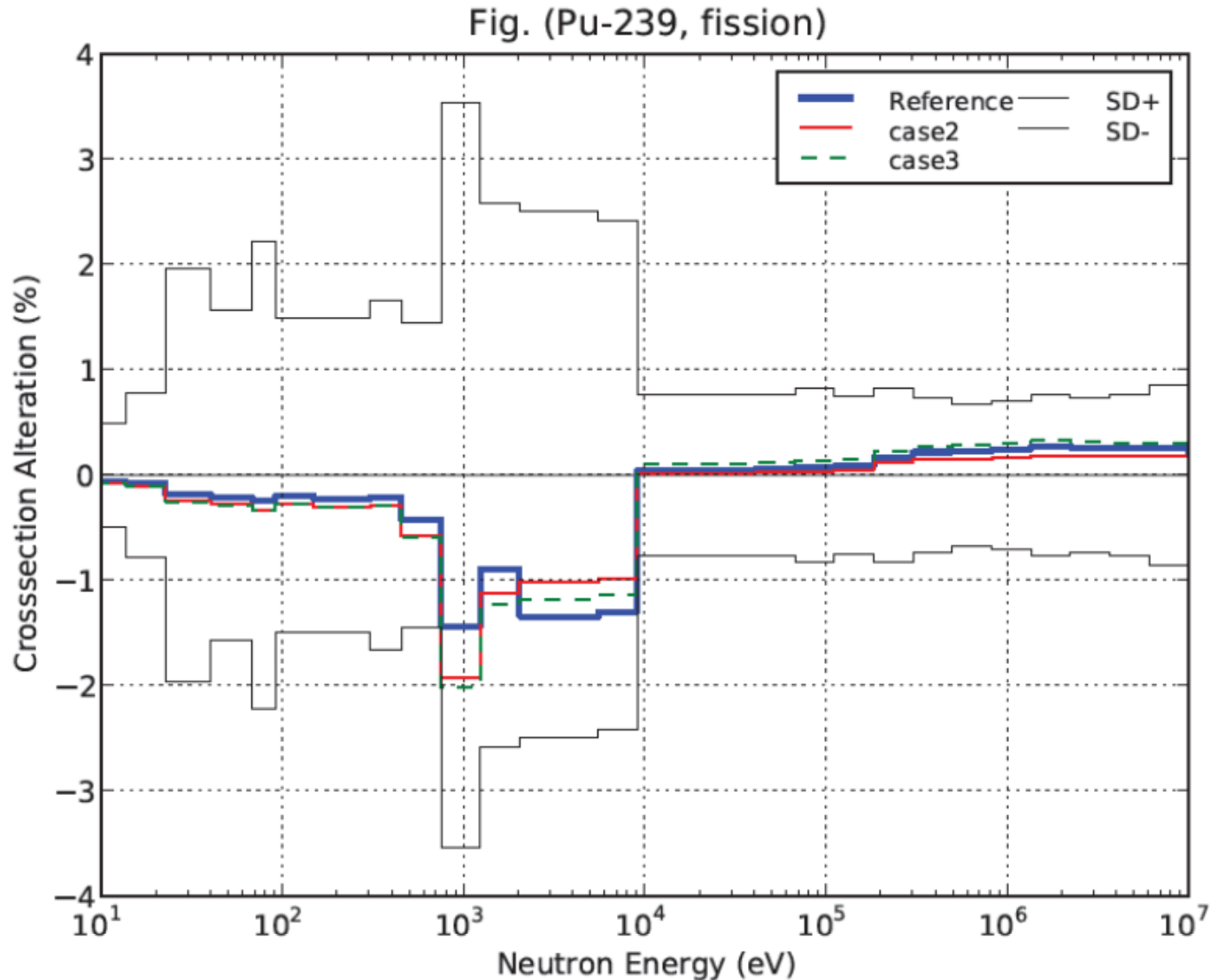
- Na-23 inelastic scattering cross-section data -

Fig. (Na-23, inelastic_scattering)



4. Adjustment Results in Cross-sections

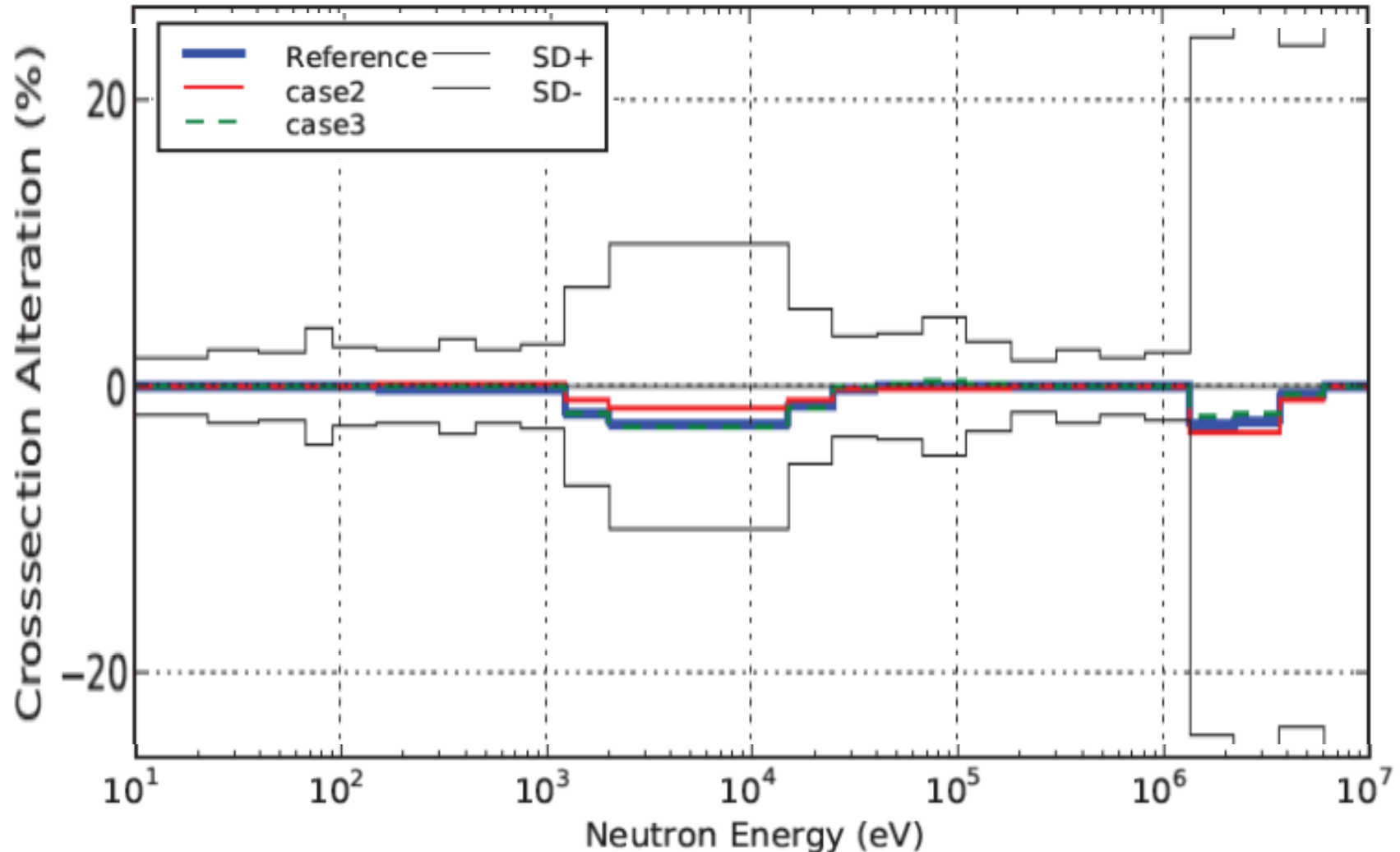
- Pu-239 fission cross-section data -



4. Adjustment Results in Cross-sections

- U-238 capture cross-section data -

Fig. (U-238, capture)



4. Adjustment Results in Cross-sections

- Prediction accuracies for target cores -

Table Prediction accuracies in critical mass for three target cores

	ABR Oxide	ABR Metal	JAEA FBR
(Before)	0.98	0.88	1.06
Reference	0.20	0.29	0.22
Case 2	0.20	0.30	0.22
Case 3	0.20	0.28	0.22

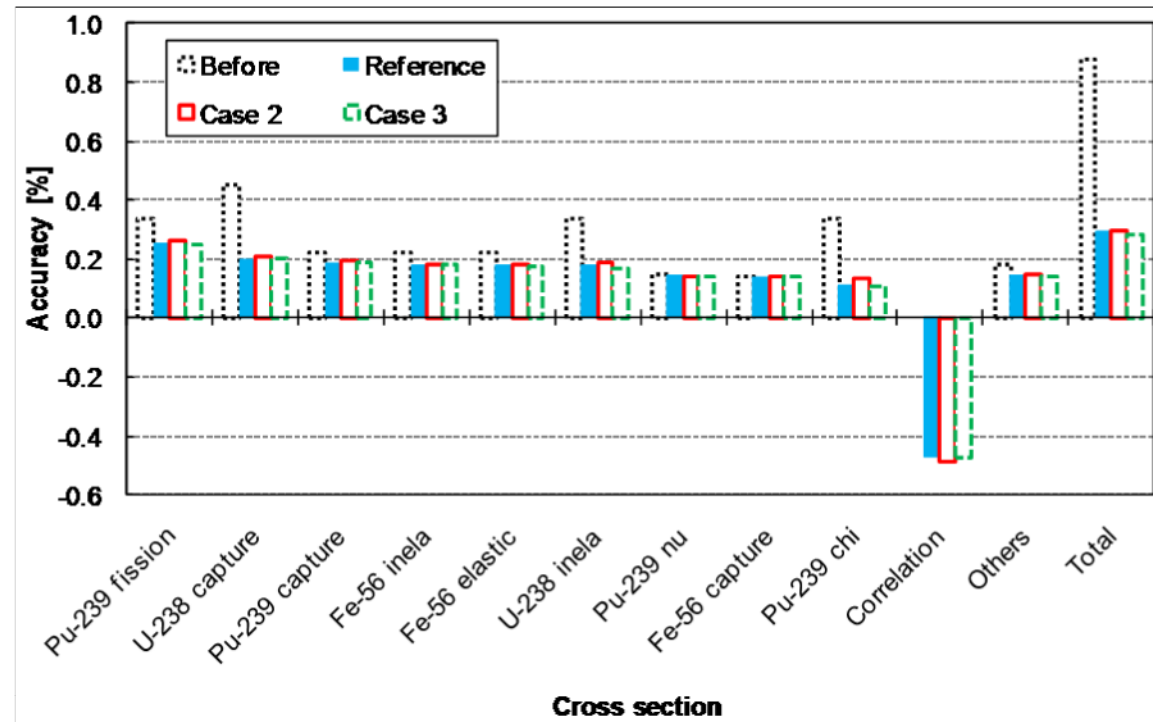


Fig. Components of prediction accuracy in critical mass for the ABR metal core

4. Adjustment Results in Cross-sections

- Prediction alterations for target cores -

Table Prediction alterations in critical mass for three target cores

	ABR Oxide	ABR Metal	JAEA FBR
Reference	-0.49	-0.35	-0.07
Case 2	-0.49	-0.31	-0.09
Case 3	-0.45	-0.19	-0.06

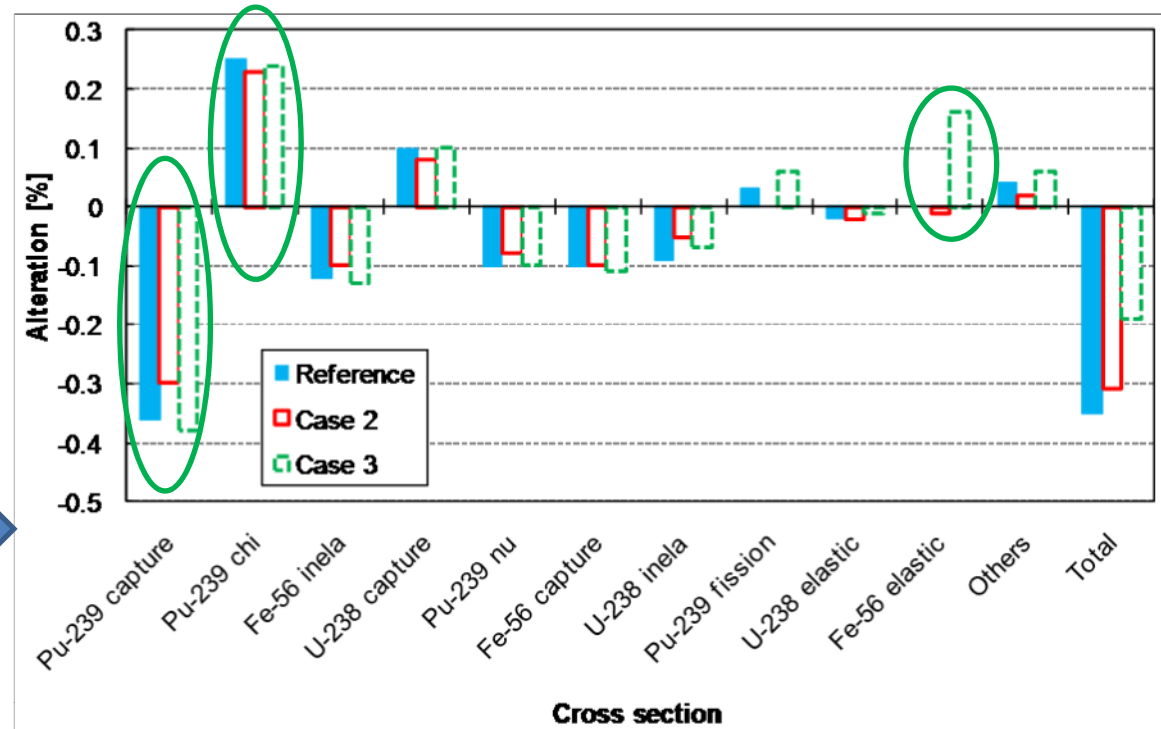
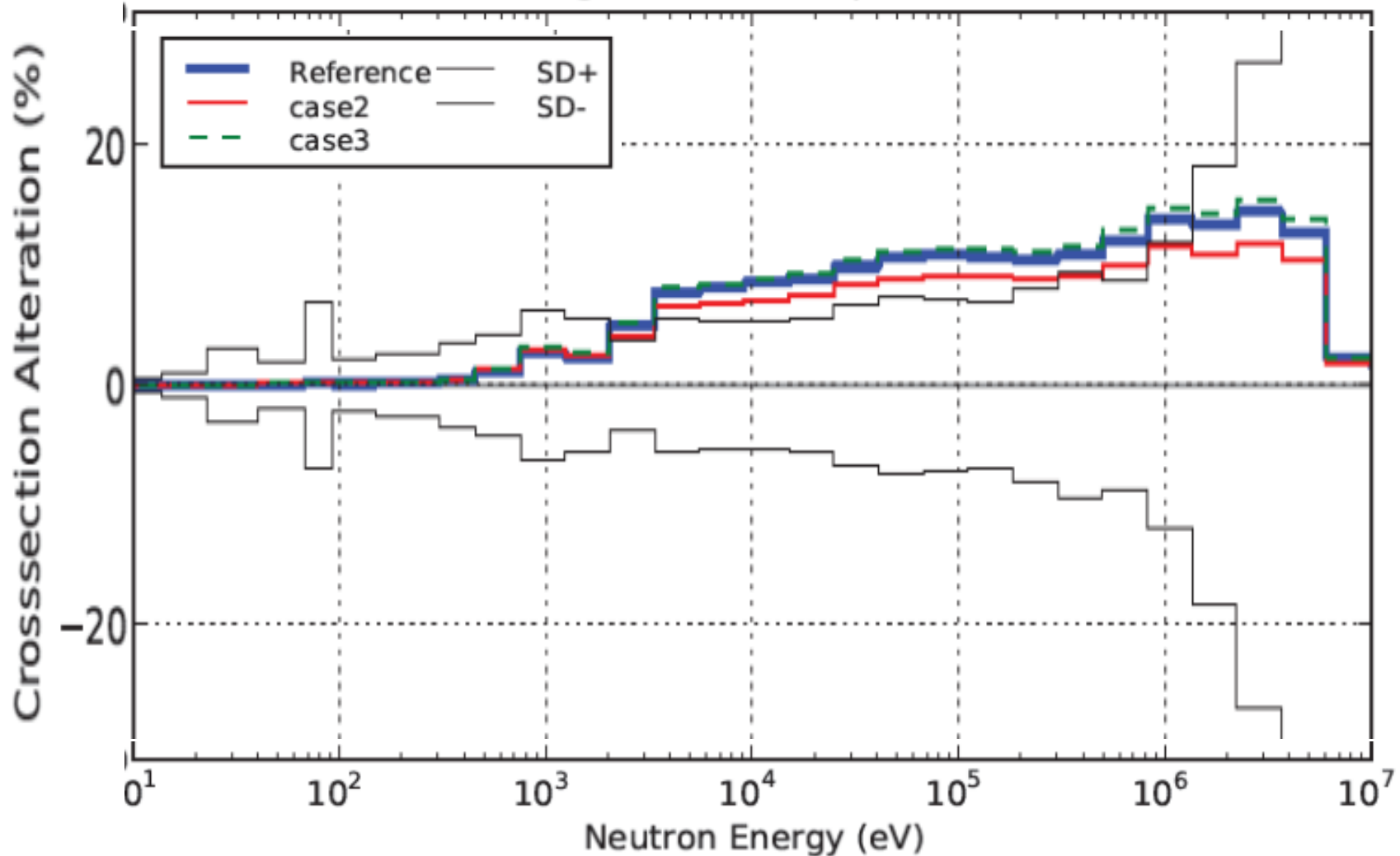


Fig. Components of prediction alteration in critical mass for the ABR metal core

4. Adjustment Results in Cross-sections

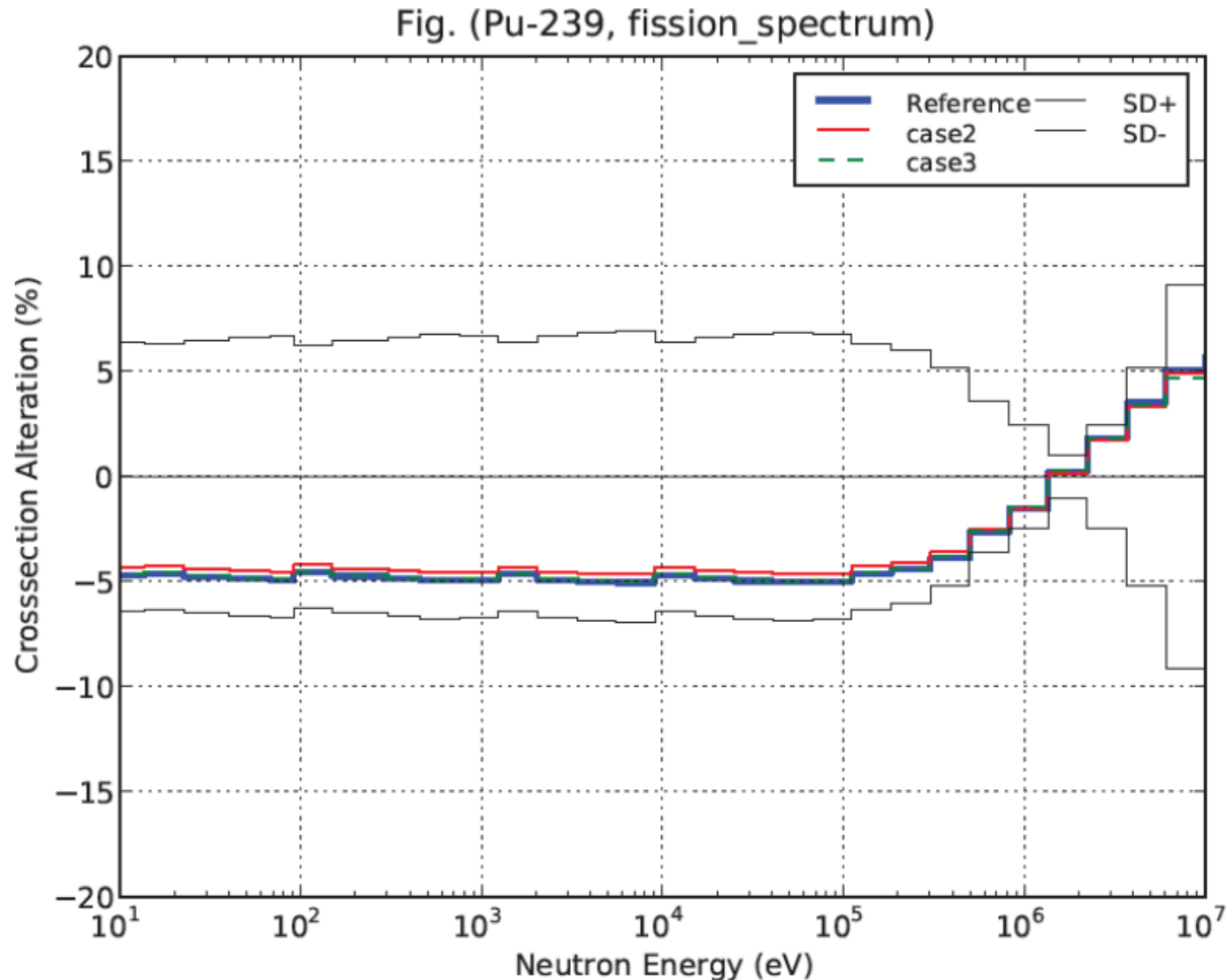
- Pu-239 capture cross-section data -

Fig. (Pu-239, capture)



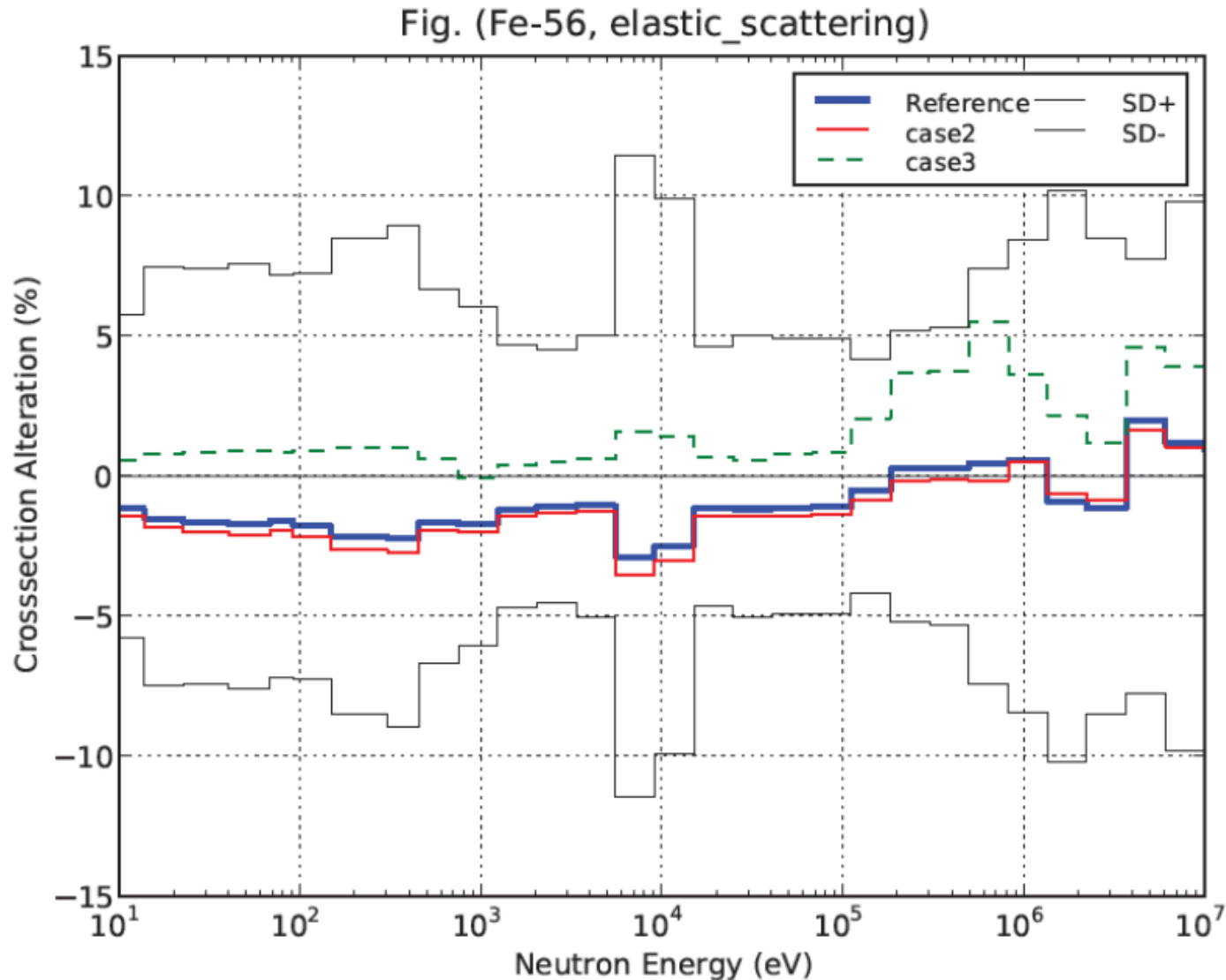
4. Adjustment Results in Cross-sections

- Pu-239 fission spectrum data -



4. Adjustment Results in Cross-sections

- Fe-56 elastic scattering cross-section data -



5. Concluding Remarks

- **Analytical modeling uncertainty should be adequately considered in cross-section adjustment.**

If not, unfavorable matters may occur.

- Exceeding adjustment of cross-sections beyond their uncertainties (standard deviations)
- Systematic errors in design parameters and underestimation of prediction accuracy.

- **Confirmation of relationship between prediction alteration and cross-section adjustment is important.**

(Example in the present adjustment)

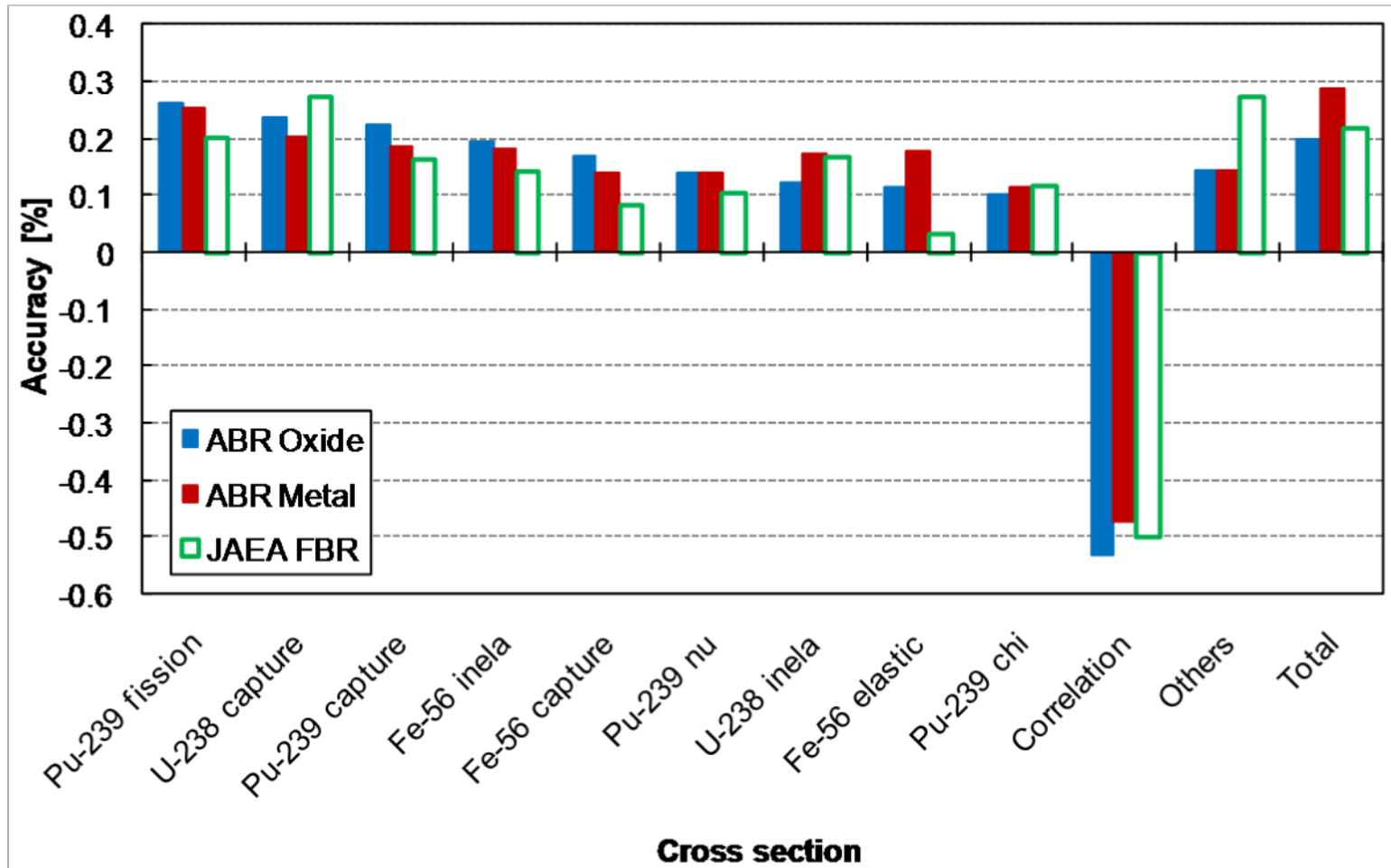
- Pu-239 capture cross-section due to large uncertainty

1. Calculation and Adjustment Conditions (Complement)

- Reason for the selection of the continuous energy Monte Carlo method for base calculations
- Difficulty in specification of the analytical modeling uncertainties based on the deterministic method; Simple (Separated) P_1 - S_4 calculations (For finer spatial mesh, higher order P_N and S_N effects)
 - Difficulty in calculations with the ERANOS reference scheme

4. Adjustment Results in Cross-sections (Complement)

- Prediction accuracies for target cores –



4. Adjustment Results in Cross-sections (Complement)

- Prediction alterations for target cores -

