Working Party on International Nuclear Data Evaluation Co-operation (WPEC) Subgroup 33
Methods and issues for the combined use of integral experiments and covariance data
3rd meeting, NEA, Issy-les-Moulineaux, France, 2 June 2010

BENCHMARK RESULTS BY JAEA *(PRELIMINARY)*

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1. Calculation and Adjustment Conditions

- Nuclear data: **JENDL-4.0**
- Covariance data: **JENDL-4.0**
- Base calculation: With 33-group cross-section set
- Corrective factors: Given (practically ZPR6-7 only)
- Analytical modeling error (A.M.E.): **Standard method at JAEA**
  -> Results for 2 cases (**With A.M.E.** / No A.M.E.)
- Adjusted parameters (complements)
  -- Total fission spectrum (not prompt)
  -- Total Nu-bar (not prompt)
  -- Energy-averaged delayed neutron fraction (not delayed Nu-d)

1. Calculation and Adjustment Conditions
- Correlation Coefficients of Critical Mass -

For experimental error

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 error

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 error 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 unkown error component

1. Calculation and Adjustment Conditions
- Correlation Coefficients of Spectral Indices -

For experimental error

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 error

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 error 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 error

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

For analytical modeling error

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

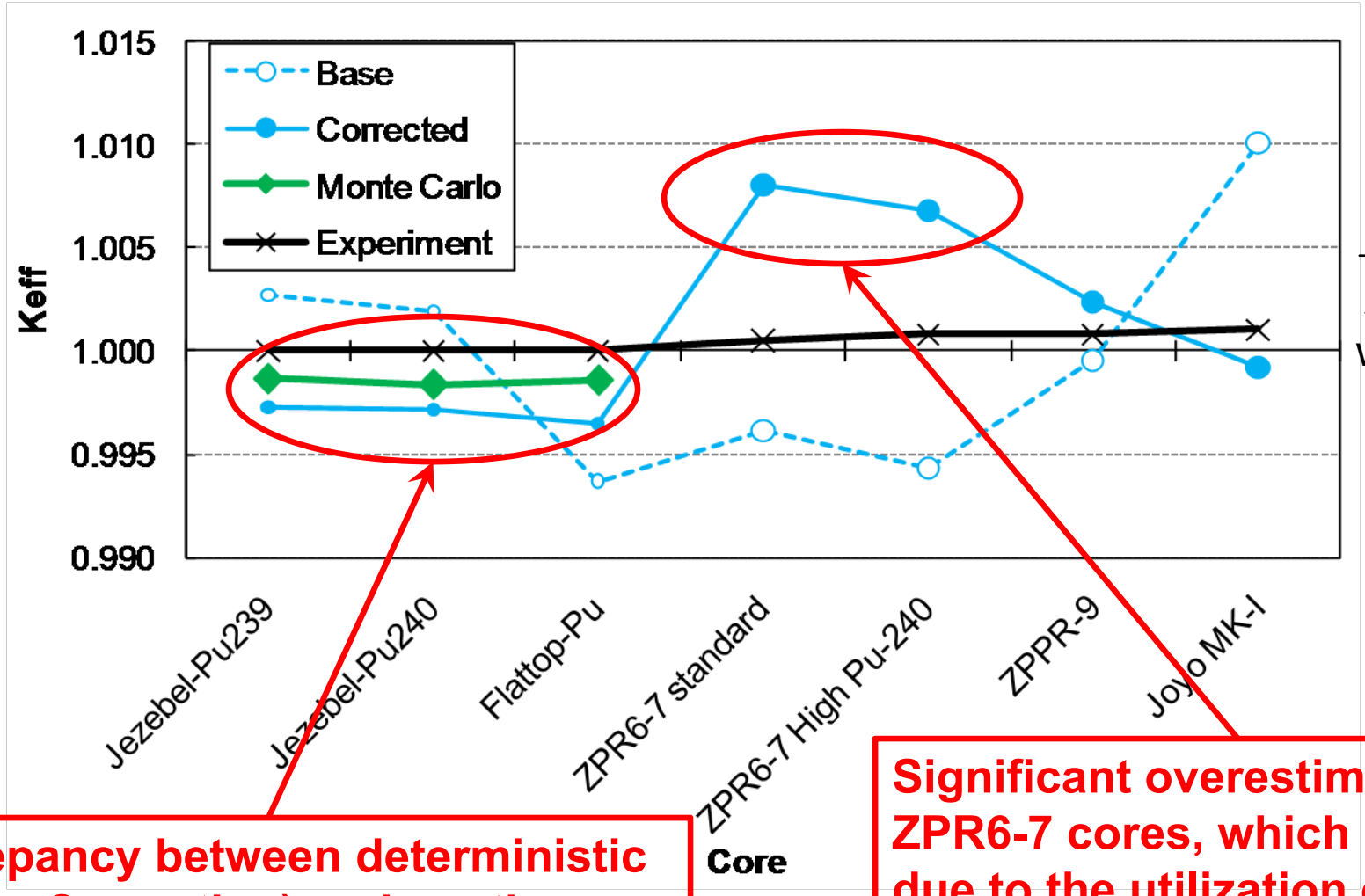
Detail on analytical modeling error

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			Remark
			Experiment	Calculation*1	Sum	
JEZEBEL-Pu239	Critical mass	0.9987	2.00E-03	1.33E-04	2.00E-03	Monte Calro
	S-Index (F28/F25)	0.9686	1.08E-02	4.72E-03	1.18E-02	Monte Calro
	S-Index (F49/F25)	0.9837	8.90E-03	3.77E-03	9.66E-03	Monte Calro
	S-Index (F37/F25)	0.9794	1.42E-02	4.02E-03	1.48E-02	Monte Calro
JEZEBEL-Pu240	Critical mass	0.9984	2.00E-03	1.33E-04	2.00E-03	Monte Calro
FLATTOP-Pu	Critical mass	0.9986	3.00E-03	1.63E-04	3.00E-03	Monte Calro
	S-Index (F28/F25)	0.9773	1.11E-02	4.18E-03	1.19E-02	Monte Calro
	S-Index (F37/F25)	0.9925	1.40E-02	3.46E-03	1.44E-02	Monte Calro
ZPR6-7 standard	Critical mass	1.0075	8.67E-04	5.96E-03	6.02E-03	Deterministic
	S-Index (F28/F25)	0.9709	3.00E-02	1.38E-02	3.30E-02	Deterministic
	S-Index (F49/F25)	0.9766	2.10E-02	7.55E-03	2.23E-02	Deterministic
	S-Index (C28/F25)	1.0163	2.40E-02	1.84E-02	3.02E-02	Deterministic
ZPR6-7 High Pu-240	Critical mass	1.0060	8.55E-04	6.26E-03	6.31E-03	Deterministic
ZPPR-9	Critical mass	1.0016	1.54E-03	1.40E-03	2.08E-03	Deterministic
	S-Index (F28/F25)	0.9575	2.65E-02	3.13E-02	4.10E-02	Deterministic
	S-Index (F49/F25)	0.9867	2.12E-02	5.62E-03	2.19E-02	Deterministic
	S-Index (C28/F25)	1.0233	1.73E-02	1.19E-02	2.10E-02	Deterministic
	Na void (Step 3)	1.1174	1.22E-02	3.57E-02	3.78E-02	Deterministic
	Na void (Step 5)	1.0480	1.14E-02	1.01E-01	1.02E-01	Deterministic
Joyo MK-I	Critical mass	0.9982	1.80E-03	5.37E-03	5.66E-03	Deterministic
*1: α=0.5 for deterministic method						

2. Calculation Results (Before Adjustment)
- Critical Mass -



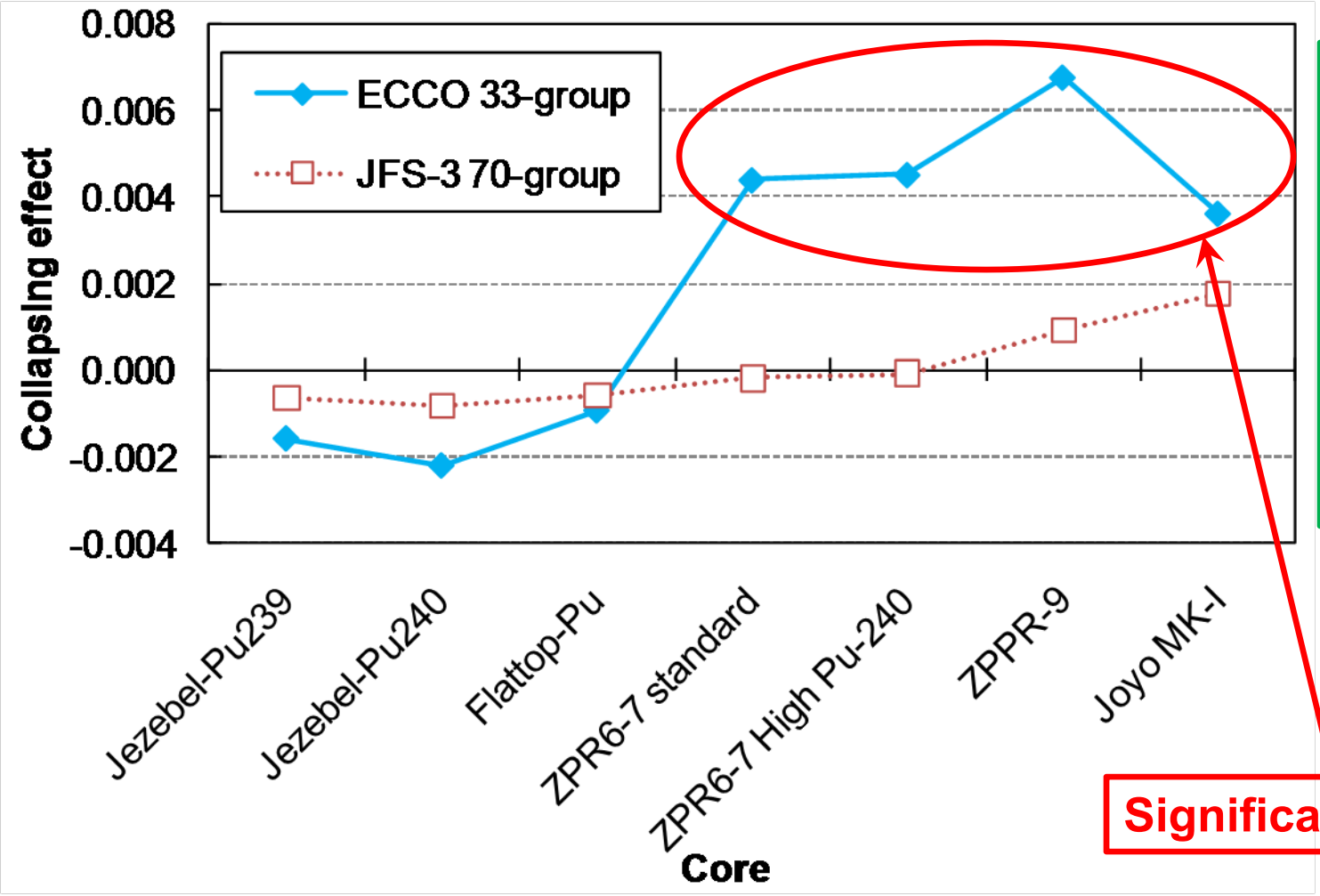
$$\frac{\chi^2}{20-1} = 3.3$$

without A.M.E.

Discrepancy between deterministic (Base + Correction) and continuous energy Monte Carlo methods

Significant overestimation in ZPR6-7 cores, which may be due to the utilization of corrective factors given by other organization.

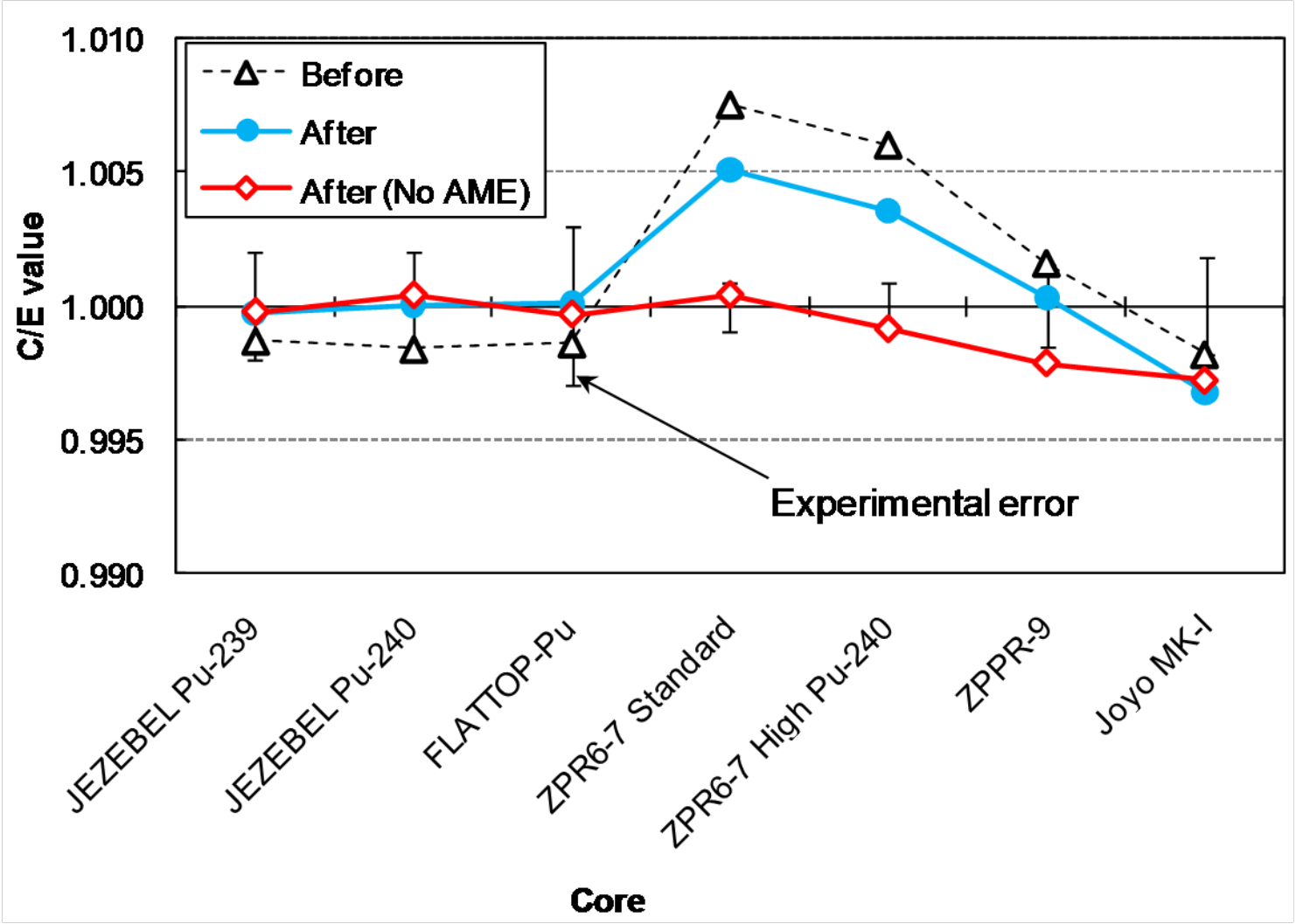
2. Calculation Results (Before Adjustment)
- Critical Mass -



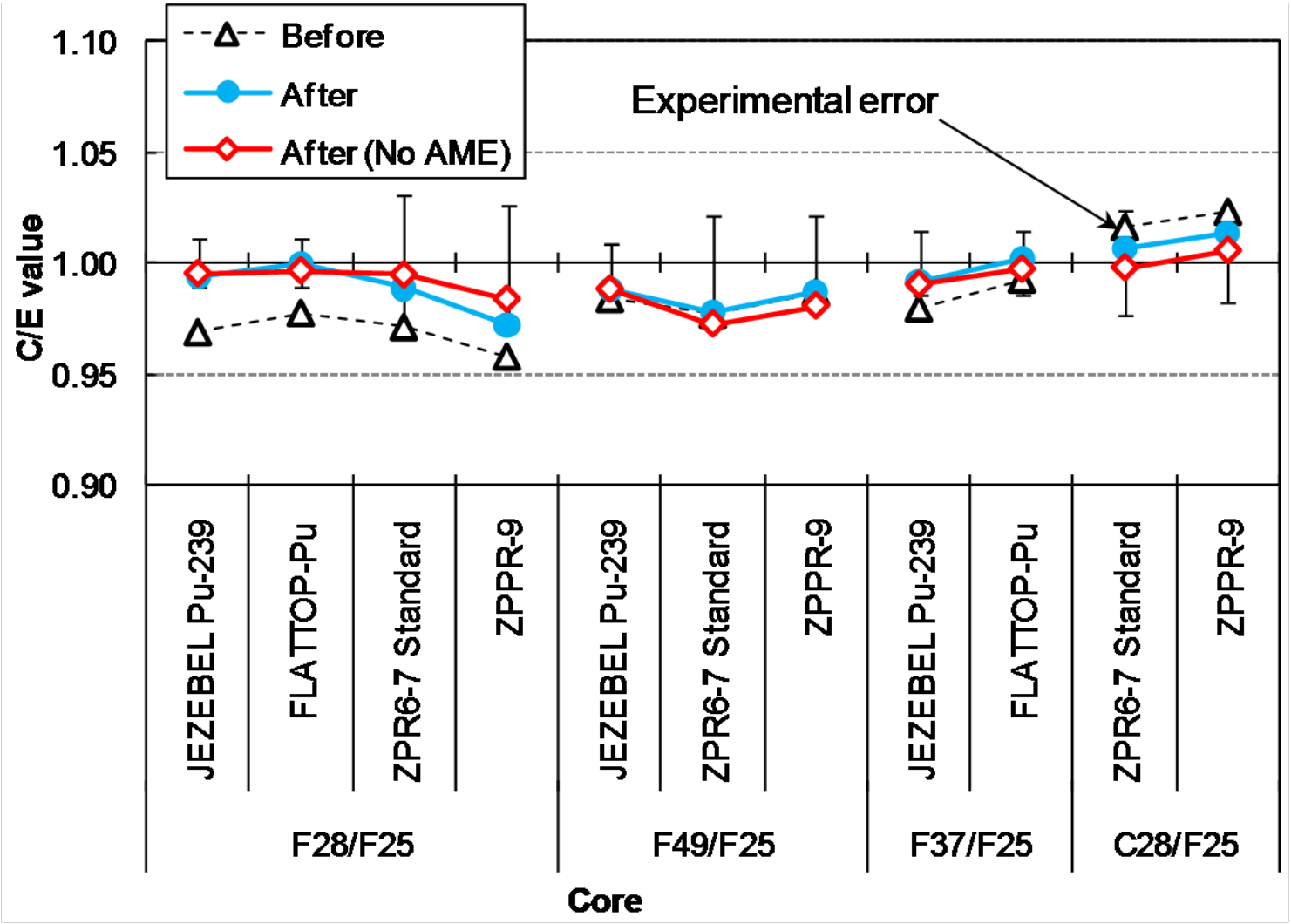
ECCO-type 33-group and JFS-3-type 70-group cross-section sets in JAEA were prepared with collision density of middle-size FBR core.

Fig. Collapsing effects in critical mass relative to the cross-section set with 112-group (above 50keV) and 100,000-group (below 50keV)

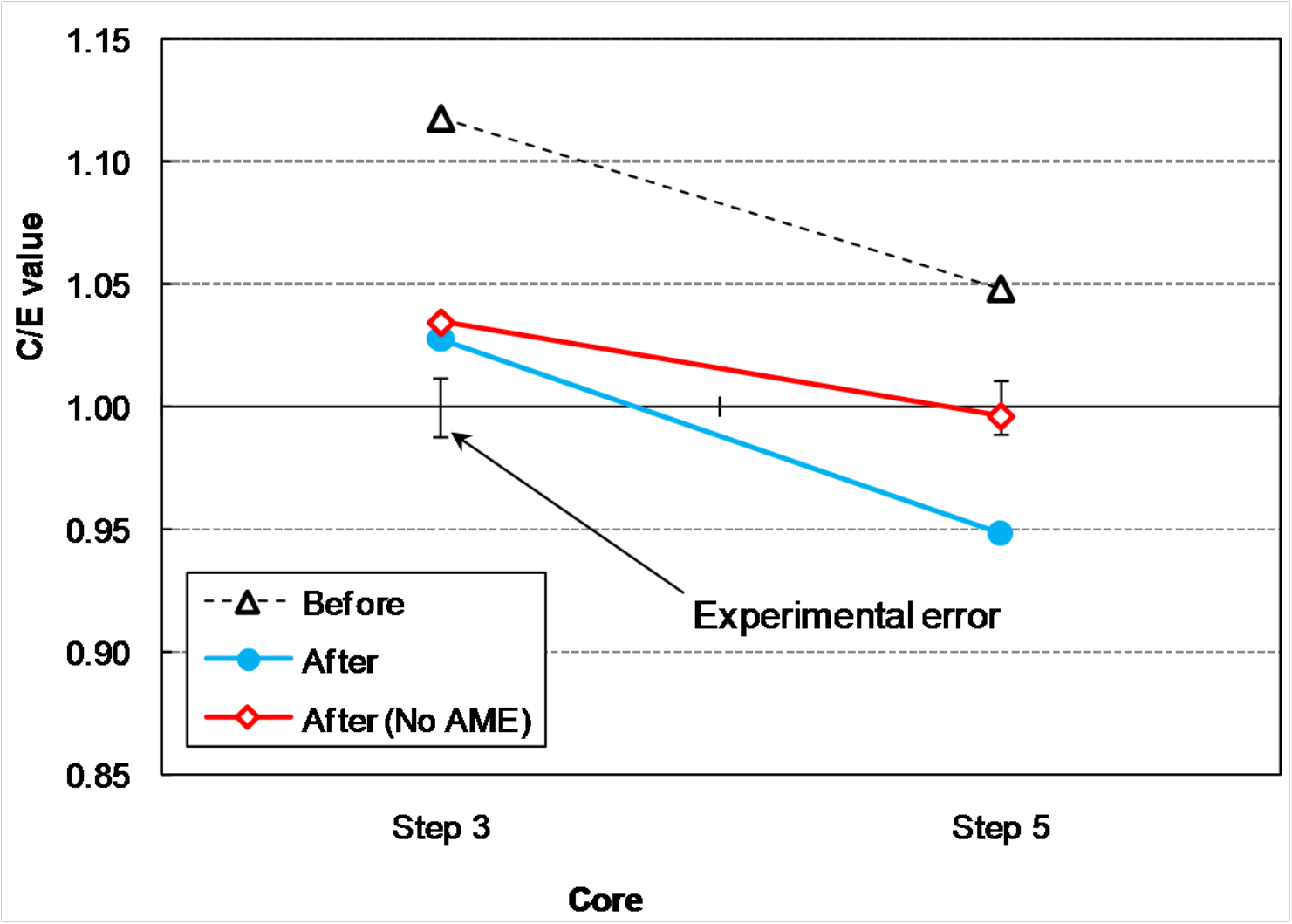
3. Adjustment Results in C/E Values
- Critical Mass -



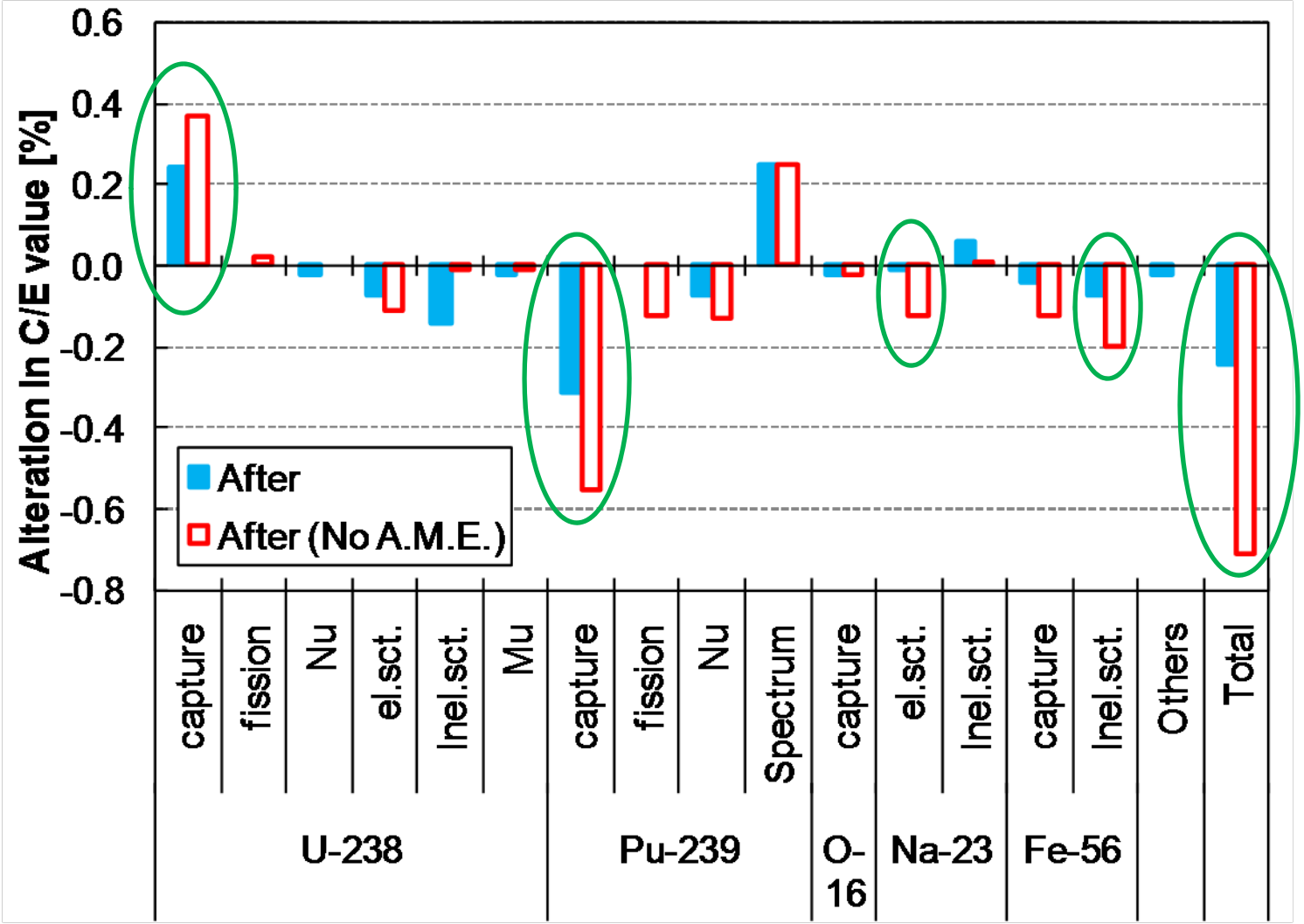
3. Adjustment Results in C/E Values
- Spectral Indices -



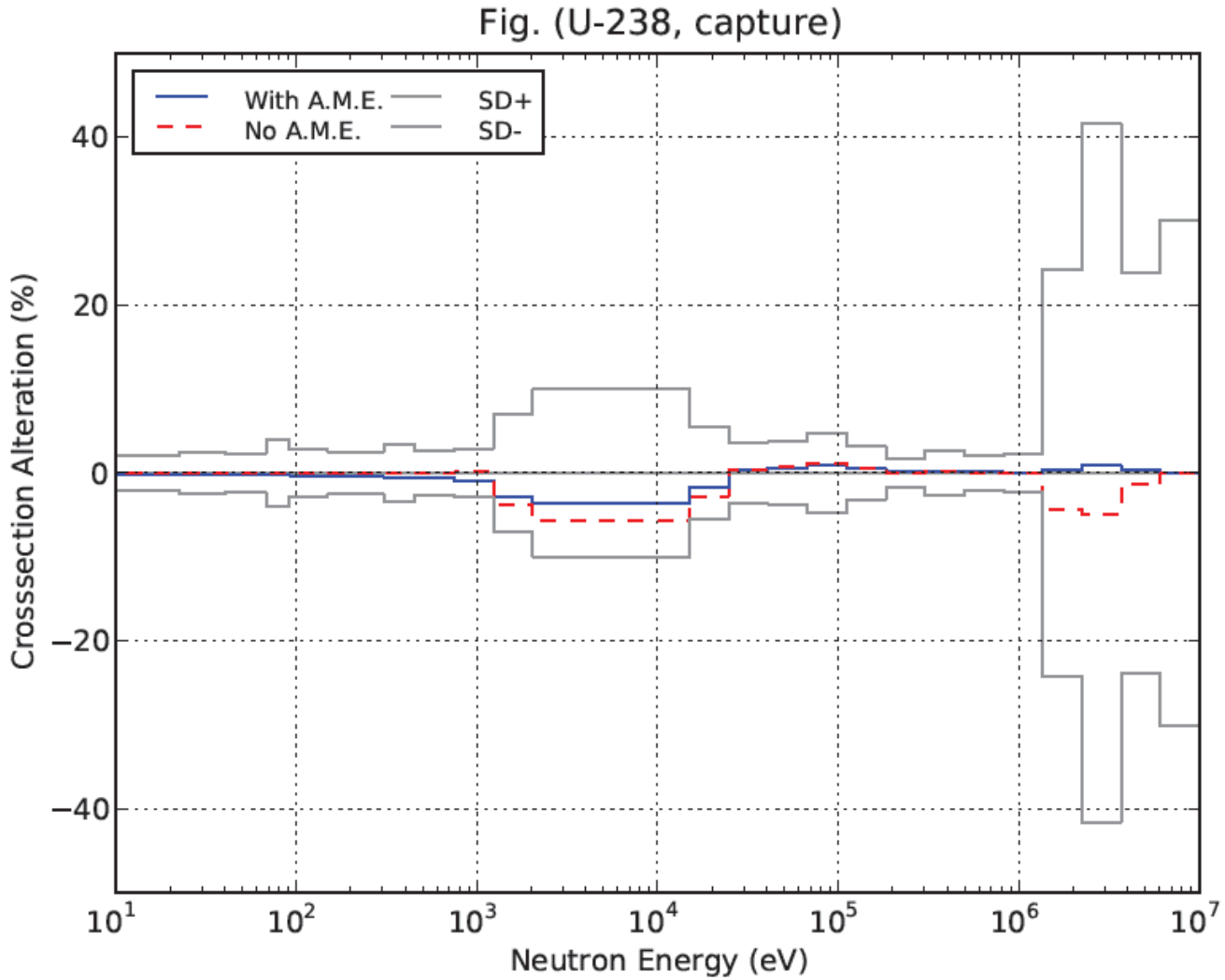
3. Adjustment Results in C/E Values
- Na Void Reactivity -



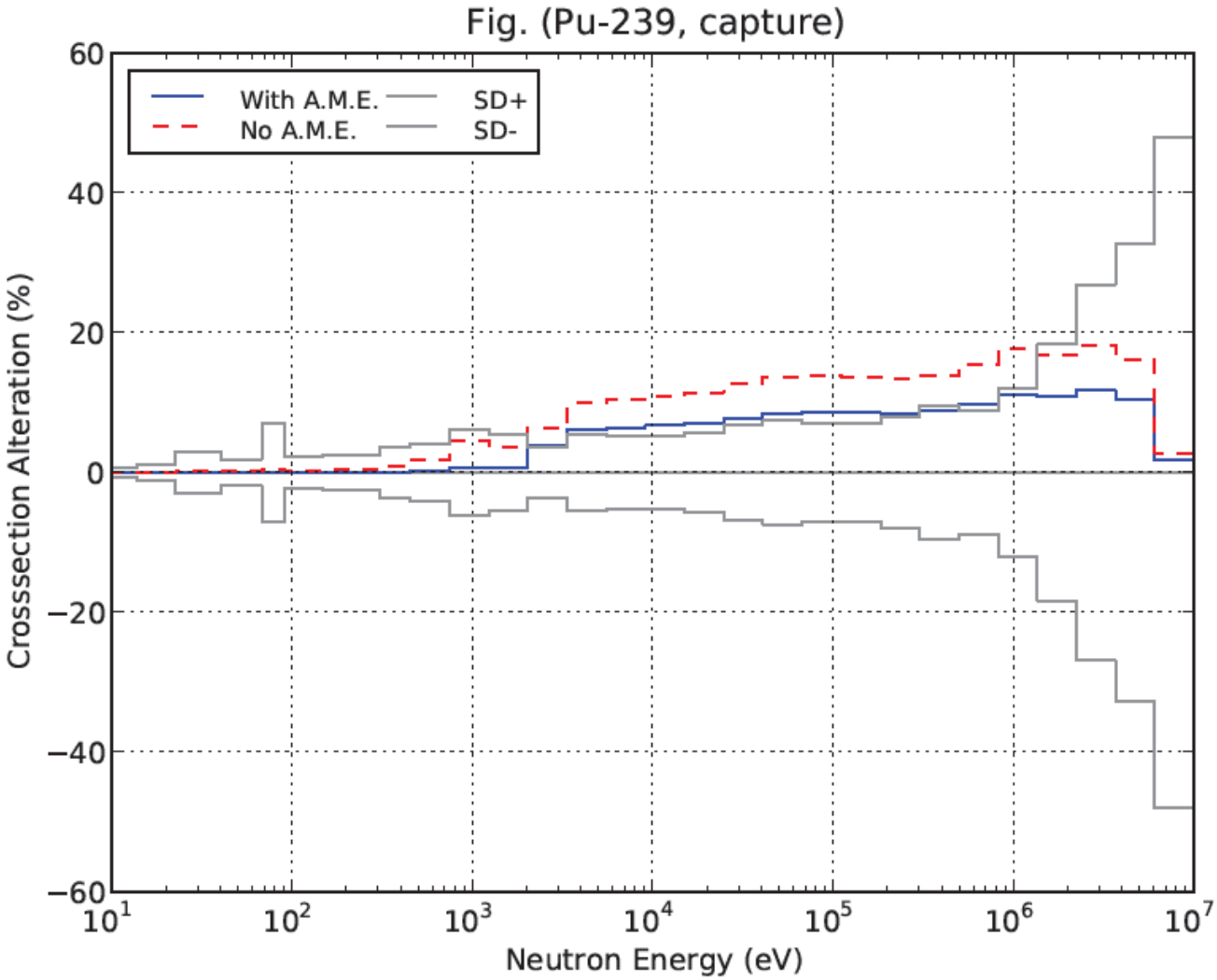
3. Adjustment Results in C/E Values
- Components of ZPR6-7 Critical Mass -



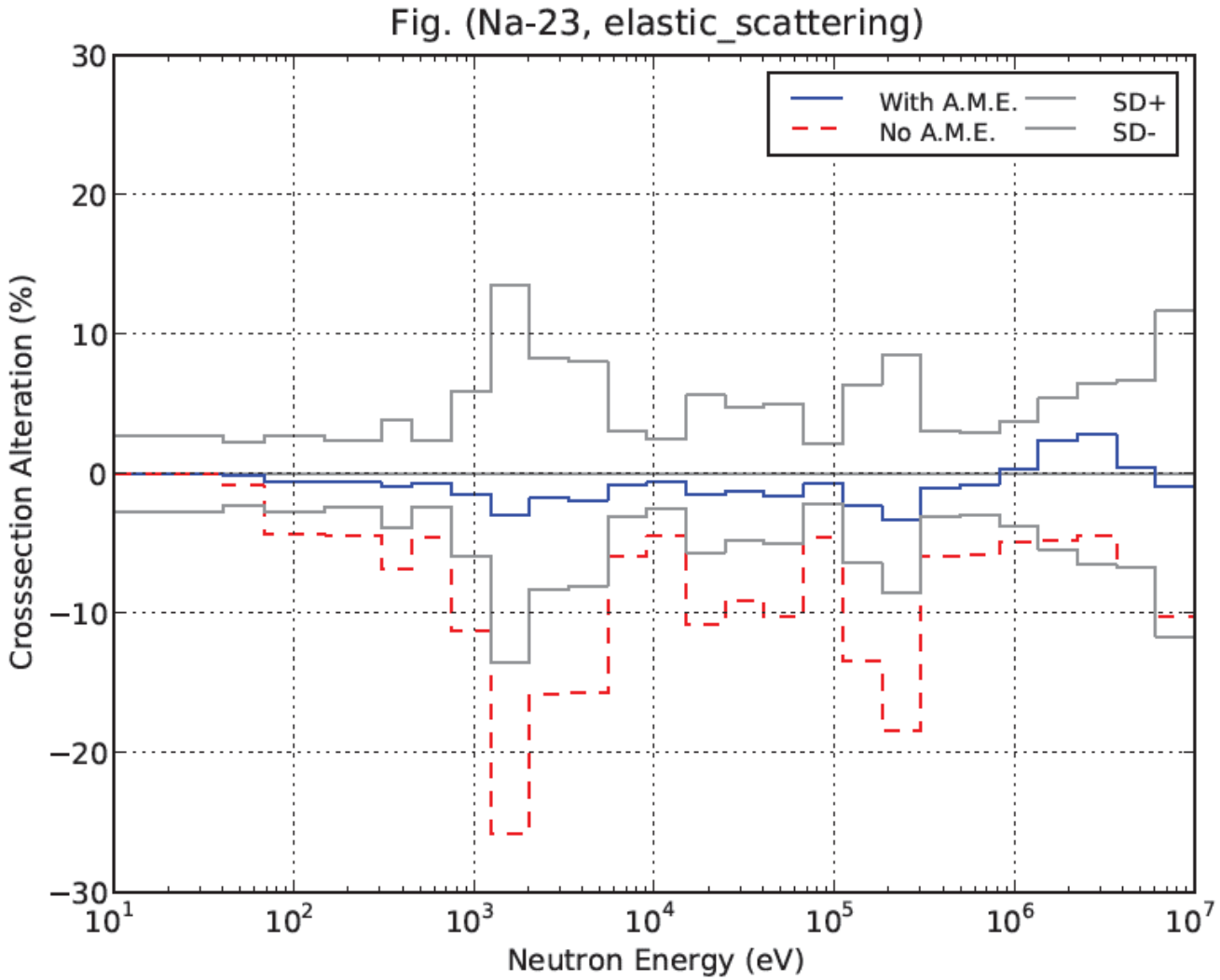
4. Adjustment Results in Cross-sections
- U-238 capture cross-section data -



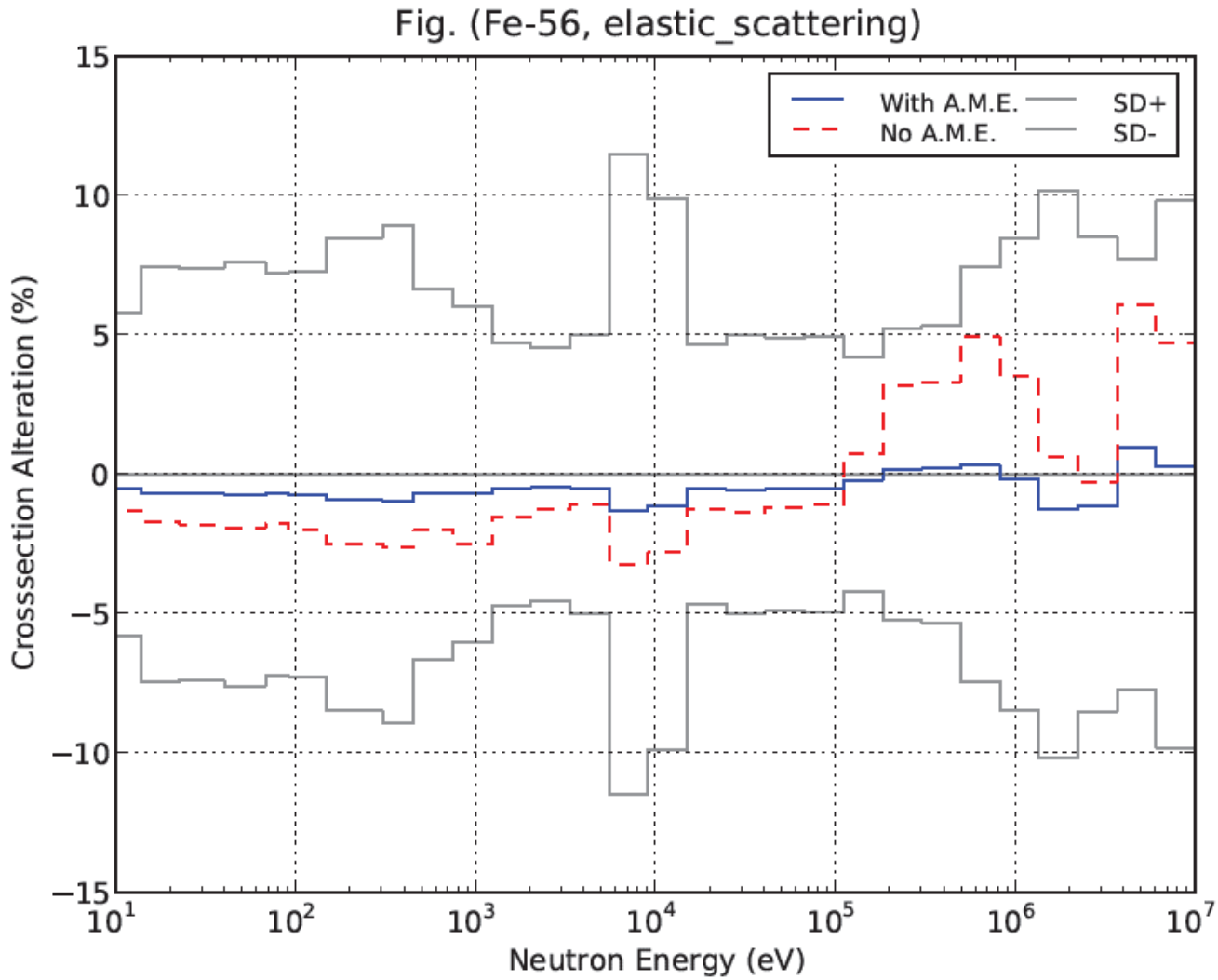
4. Adjustment Results in Cross-sections
- Pu-239 capture cross-section data -



4. Adjustment Results in Cross-sections
- Na-23 elastic scattering cross-section data -



4. Adjustment Results in Cross-sections
- Fe-56 elastic scattering cross-section data -



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
With A.M.E.	**-0.26**	**-0.31**	**-0.12**
No A.M.E.	-0.77	-0.46	-0.28

Significant alteration without consideration of analytical modeling error

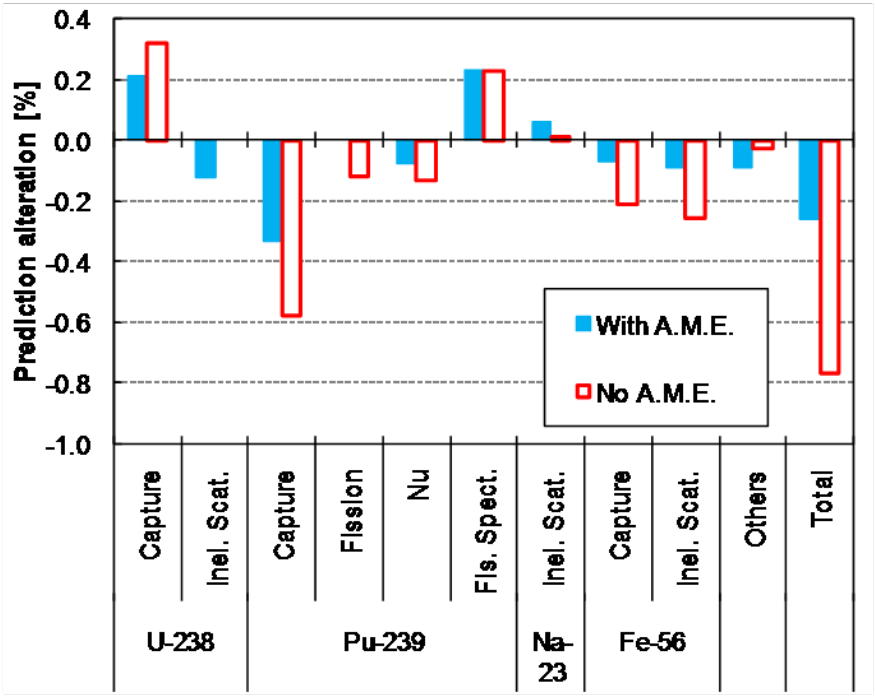


Fig. Components of prediction alteration in critical mass for the ABR oxide core

$$\mathbf{T}' = \mathbf{T}_0 + \mathbf{M}\mathbf{G}^t\left[\mathbf{G}\mathbf{M}\mathbf{G}^t + \mathbf{V}_e + \mathbf{V}_m\right]^{-1}\left(\mathbf{R}_e - \mathbf{R}_c(\mathbf{T}_0)\right)$$

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
After	With A.M.E.	**0.24**	**0.32**	**0.25**
	No A.M.E.	0.19	0.28	0.22

Possibility of underestimation of prediction accuracy

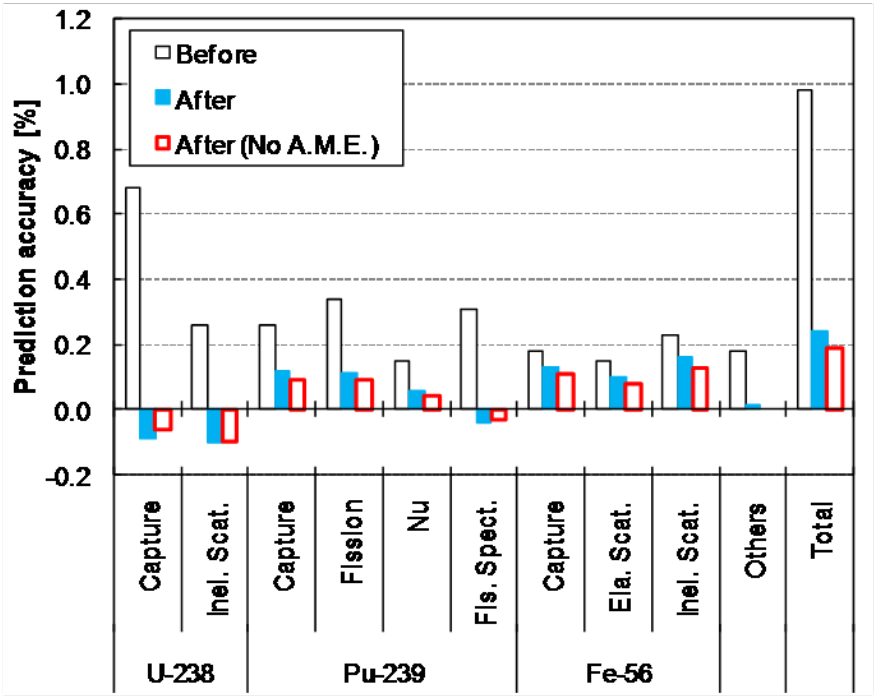


Fig. Components of prediction accuracy in critical mass for the ABR oxide core

$$\mathbf{M}' = \mathbf{M} - \mathbf{M}\mathbf{G}^t\left[\mathbf{G}\mathbf{M}\mathbf{G}^t + \mathbf{V}_e + \mathbf{V}_m\right]^{-1}\mathbf{G}\mathbf{M}$$

5. Concluding Remarks

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

  If not, unfavorable matters may occur.

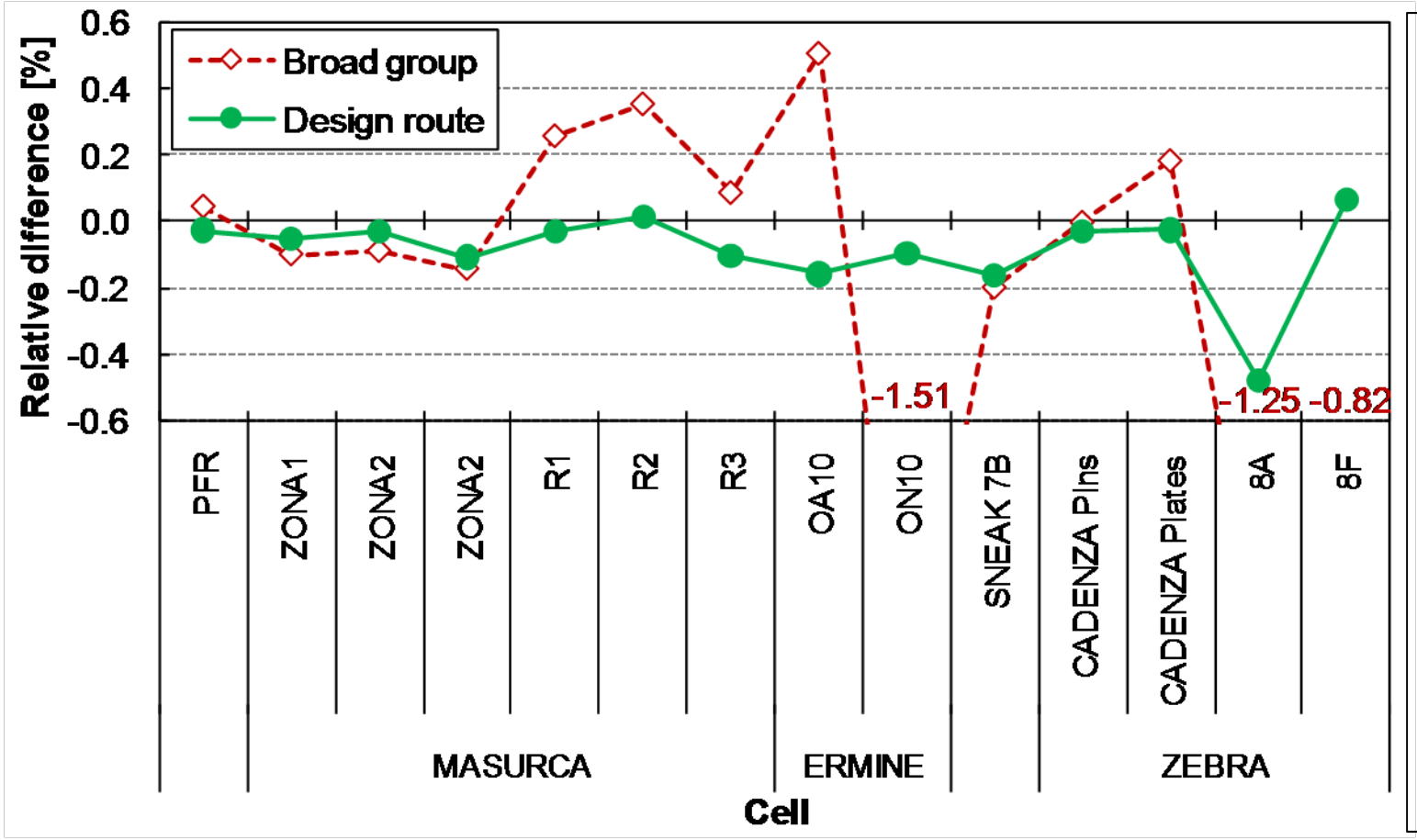
  -- Exceeding adjustment of cross-sections beyond their errors (standard deviations)

  -- Systematic errors in design parameters and underestimation of prediction accuracy.

- **Neutron energy collapsing effect should be calculated by each user.**

  -- Corrective factors for the use of coarse group (33-group) cross-section set include the effect of neutron energy collapsing, which depends on the procedure of cross-section set preparation (e.g. applied weighting function).

5. Concluding Remarks (Cont'd)
- Neutron energy collapsing effect -



Broad group: Collapsed by PFR spectrum into about 30 groups (Similar to the JAEA's way)

Design route: Collapsed by prior 2,000 group calculation into about 30 groups

Fine group reference route: 2,000 groups calculation

Fig. Reactivity differences between ECCO calculations using broad groups, the design route, and the fine group reference route (M.J.Grimstone, J.D.Tullett and G.Rimpault, PHYSOR'90, p.IX-24)