5th Meeting of WPEC Subgroup 33 on
Methods and issues for the combined use of integral experiments and covariance data

May 11, 2011
NEA Headquarters, Issy-les-Moulineaux, France

Adjustment Results based on JENDL-4.0

Makoto ISHIKAWA

Japan Atomic Energy Agency (JAEA)

Outline of Adjustment by JAEA

- **Base library: JENDL-4.0 released in May 2011,**
- **Energy structure: 33 groups of SG33 standard,**
- **Isotopes to be adjusted: B-10, O-16, Na-23, Fe-56, Cr-52, Ni-58, U-235, -238, Pu-239, -240, -241 (Total 11),**
- **Reactions to be adjusted: Elastic, Total inelastic, Capture (n,alpha for B-10), Fission, Nu-total, Chi-p, Mu, Nu-d (Total 8),**
- **Nuclear data covariance: JENDL-4.0 processed with NJOY,**
- **Integral data for adjustment: JEZEBEL-Pu239 (keff, F28/F25, F49/F25, F37/F25), -Pu240 (keff), FLATTOP-Pu (keff, F28/F25, F37/F25), ZPR-6/7 (keff, F28/F25, F49/F25, C28/F25), -High Pu240 (keff), ZPPR-9 (keff, F28/F25, F49/F25, C28/F25, Na void reactivity (Step 3, 5)), JOYO Mk-I (keff) (Total 20).**

Analytical Method applied to obtain C/E values

<table>
<tr><th>No.</th><th>Core</th><th>Parameter</th><th>Case 0
(SG33 Standard MC method)</th><th>Case 1
(As-built MC for ZPPR-9)</th></tr>
<tr><td>1, 2, 3, 4</td><td>JEZEBEL-Pu</td><td>keff, F28/F25, F49/F25, F37/F25</td><td colspan="2" rowspan="3">ICSBEP benchmark model calculation with continuous energy Monte Carlo (MC) code, MVP</td></tr>
<tr><td>5</td><td>" -Pu240</td><td>keff</td></tr>
<tr><td>6, 7, 8</td><td>FLATTOP-Pu</td><td>keff, F28/F25, F37/F25</td></tr>
<tr><td>9, 10, 11, 12</td><td>ZPR-6/7</td><td>keff, F28/F25, F49/F25, C28/F25</td><td colspan="2" rowspan="2">2D MC of simple model + Corrective factor (C.F.) by INL</td></tr>
<tr><td>13</td><td>" -High Pu240</td><td>keff</td></tr>
<tr><td>14</td><td rowspan="3">ZPPR-9</td><td>keff</td><td>2D MC + C.F. by INL</td><td>As-Built MC by JAEA</td></tr>
<tr><td>15, 16, 17</td><td>F28/F25, F49/F25, C28/F25</td><td colspan="2">2D MC + C.F. by INL</td></tr>
<tr><td>18, 19</td><td>Na void reactivity (Step 3, 5)</td><td>2D MC + C.F. by INL</td><td>As-Built MC by JAEA</td></tr>
<tr><td>20</td><td>JOYO Mk-I</td><td>keff</td><td colspan="2">2D MC + C.F. by JAEA
(C.F. by INL=0.99666, by JAEA=0.99515)</td></tr>
</table>

Integral Data for Adjustment (Case 0)

(Case 0: SG33 Standard Monte Carlo method (2D MC + INL's Corrective factors))

No.	Core	Parameter	Parameter value		C/E value	Relative uncertainty (%)			2D Monte Carlo by JAEA	Corrective factor by INL
			Experiment	Calculation		Experiment	Analytical modeling	*Sum*		
1	JEZEBEL-Pu239	keff	1.00000	0.99865	0.9987	0.200	0.027	*0.202*		
2		F28/F25	0.2133	0.20660	0.9686	1.1	0.94	*1.450*		
3		F49/F25	1.4609	1.43701	0.9836	0.9	0.75	*1.174*		
4		F37/F25	0.9835	0.96322	0.9794	1.4	0.80	*1.614*		
5	JEZEBEL-Pu240	keff	1.00000	0.99839	0.9984	0.200	0.027	*0.202*		
6	FLATTOP-Pu	keff	1.00000	0.99859	0.9986	0.300	0.033	*0.302*		
7		F28/F25	0.1799	0.17582	0.9773	1.1	0.84	*1.382*		
8		F37/F25	0.8561	0.84968	0.9925	1.4	0.69	*1.562*		
9	ZPR-6/7	keff	1.00051	1.00579	1.0053	0.230	0.025	*0.231*	0.99158	1.01433
10		F28/F25	0.0223	0.0230	1.0336	3.0	2.24	*3.74*	0.02202	1.04673
11		F49/F25	0.9435	0.9237	0.9790	2.1	1.43	*2.54*	0.9359	0.9870
12		C28/F25	0.1323	0.1345	1.0167	2.4	1.22	*2.69*	0.1398	0.9625
13	ZPR-6/7 High-Pu240	keff	1.00080	1.00413	1.0033	0.220	0.030	*0.222*	0.98980	1.01448
14	ZPPR-9	keff	1.00080	1.00498	1.0042	0.154	0.011	*0.154*	0.99121	1.01389
15		F28/F25	0.0207	0.02034	0.9828	2.7	2.09	*3.41*	0.02004	1.0152
16		F49/F25	0.9225	0.9218	0.9992	2.0	1.21	*2.34*	0.9261	0.9953
17		C28/F25	0.1296	0.1320	1.0184	1.9	1.39	*2.36*	0.1395	0.9465
18		Na void (Step 3)*	29.18	35.33	1.2108	1.7	12.94	*13.06*	34.33	1.029
19		Na void (Step 5)*	31.30	34.37	1.0980	1.7	11.14	*11.27*	43.17	0.796
20	JOYO Mk-I	keff	1.00105	0.99923	0.9982	0.180	0.028	*0.182*	1.00410	0.99515

*Cent unit (beta value of ZPPR-9 by JENDL-4.0 = 0.003594) (by JAEA)

1) **Black bold** – same with June 2010 meeting.
2) **Blue bold** – Specification change by INL or JAEA.
3) **Red bold** – 2D RZ Monte Carlo result by JAEA.
4) **Green bold** – (INL's MC ^2+JAEA's MC^2)**1/2

***Note: Analytical modeling error is twice as the MC statistical error.**

Integral Data for Adjustment (Case 1)

(Case 1: As-built Monte Carlo results for ZPPR-9 by JAEA)

No.	Core	Parameter	Parameter value		C/E value	Relative uncertainty (%)				
			Experiment	Calculation		Experiment	Analytical modeling	*Sum*	2D Monte Carlo by JAEA	Corrective factor by INL
1	JEZEBEL-Pu239	keff	1.00000	0.99865	0.9987	0.200	0.027	*0.202*		
2		F28/F25	0.2133	0.20660	0.9686	1.1	0.94	*1.450*		
3		F49/F25	1.4609	1.43701	0.9836	0.9	0.75	*1.174*		
4		F37/F25	0.9835	0.96322	0.9794	1.4	0.80	*1.614*		
5	JEZEBEL-Pu240	keff	1.00000	0.99839	0.9984	0.200	0.027	*0.202*		
6	FLATTOP-Pu	keff	1.00000	0.99859	0.9986	0.300	0.033	*0.302*		
7		F28/F25	0.1799	0.17582	0.9773	1.1	0.84	*1.382*		
8		F37/F25	0.8561	0.84968	0.9925	1.4	0.69	*1.562*		
9	ZPR-6/7	keff	1.00051	1.00579	1.0053	0.230	0.025	*0.231*	0.99158	1.01433
10		F28/F25	0.0223	0.0230	1.0336	3.0	2.24	*3.74*	0.02202	1.04673
11		F49/F25	0.9435	0.9237	0.9790	2.1	1.43	*2.54*	0.9359	0.9870
12		C28/F25	0.1323	0.1345	1.0167	2.4	1.22	*2.69*	0.1398	0.9625
13	ZPR-6/7 High-Pu240	keff	1.00080	1.00413	1.0033	0.220	0.030	*0.222*	0.98980	1.01448
14	ZPPR-9	keff	1.00080	1.00295	1.0021	0.154	0.020	*0.155*		
15		F28/F25	0.0207	0.02034	0.9828	2.7	2.09	*3.41*	0.02004	1.0152
16		F49/F25	0.9225	0.9217	0.9992	2.0	1.21	*2.34*	0.9261	0.9953
17		C28/F25	0.1296	0.1320	1.0188	1.9	1.39	*2.36*	0.1395	0.9465
18		Na void (Step 3)*	29.18	31.39	1.0759	1.7	5.26	*5.54*		
19		Na void (Step 5)*	31.30	33.34	1.0651	1.7	4.95	*5.24*		
20	JOYO Mk-I	keff	1.00105	0.99923	0.9982	0.180	0.028	*0.182*		

*Cent unit (beta value of ZPPR-9 by JENDL-4.0 = 0.003594)

1) **Black bold** – same with June 2010 meeting.
2) **Blue bold** – Specification change by INL or JAEA.
3) **Red bold** – 2D RZ Monte Carlo result by JAEA.
4) **Green bold** – (INL's MC ^2+JAEA's MC^2)**1/2
5) **Pink bold** – As-built Monte Carlo result by JAEA.

***Note: Analytical modeling error is twice as the MC statistical error.**

Experimental Error Matrix *Ve* (from June 2010 meeting)

No.	Core		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Jezebel - Pu239	keff	0.20																			
2		F28/F25	0	1.1																		
3		F49/F25	0	+0.2	0.9																	
4		F37/F25	0	+0.2	+0.3	1.4																
5	Jezebel - Pu240	keff	0	0	0	0	0.20															
6	Flattop	keff	0	0	0	0	0	0.30														
7		F28/F25	0	0	0	0	0	0	1.1													
8		F37/F25	0	0	0	0	0	0	+0.2	1.4												
9	ZPR6-7	keff	0	0	0	0	0	0	0	0	0.23											
10		F28/F25	0	0	0	0	0	0	0	0	0	3.0										
11		F49/F25	0	0	0	0	0	0	0	0	0	+0.2	2.1									
12		C28/F25	0	0	0	0	0	0	0	0	0	+0.2	+0.3	2.4								
13	ZPR6-7 Pu240	keff	0	0	0	0	0	0	0	0	+0.9	0	0	0	0.22							
14	ZPPR-9	keff	0	0	0	0	0	0	0	0	+0.6	0	0	0	+0.6	0.15						
15		F28/F25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.7					
16		F49/F25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+0.2	2.0				
17		C28/F25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+0.2	+0.3	1.9			
18		Na void (Step 3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7		
19		Na void (Step 5)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+0.5	1.7	
20	Joyo	keff	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.18

Symmetric

* Diagonal term: Error value (1 sigma, %)

** Non-diagonal term : Correlation factor (between -1 and +1)

Analytical Modeling Error Matrix *Vm* (Case 0)

No.	Core		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Jezebel - Pu239	keff	0.03																			
2		F28/F25	0	0.9																		
3		F49/F25	0	+0.5	0.8																	
4		F37/F25	0	+0.5	+0.5	0.8																
5	Jezebel - Pu240	keff	0	0	0	0	0.03										Symmetric					
6	Flattop	keff	0	0	0	0	0	0.03														
7		F28/F25	0	0	0	0	0	0	0.8													
8		F37/F25	0	0	0	0	0	0	+0.5	0.7												
9	ZPR6-7	keff	0	0	0	0	0	0	0	0	0.03											
10		F28/F25	0	0	0	0	0	0	0	0	0	2.2										
11		F49/F25	0	0	0	0	0	0	0	0	0	+0.5	1.4									
12		C28/F25	0	0	0	0	0	0	0	0	0	+0.5	+0.5	1.2								
13	ZPR6-7 Pu240	keff	0	0	0	0	0	0	0	0	0	0	0	0	0.03							
14	ZPPR-9	keff	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01						
15		F28/F25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.1					
16		F49/F25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+0.5	1.2				
17		C28/F25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+0.5	+0.5	1.4			
18		Central Na void	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12.9		
19		Large Na void	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11.1	
20	Joyo	keff	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03

* Diagonal term: Error value (1 sigma, %)

** Non-diagonal term : Correlation factor (between -1 and +1)

Analytical Modeling Error Matrix *Vm* (Case 1)

No.	Core		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Jezebel - Pu239	keff	0.03																			
2		F28/F25	0	0.9																		
3		F49/F25	0	+0.5	0.8																	
4		F37/F25	0	+0.5	+0.5	0.8																
5	Jezebel - Pu240	keff	0	0	0	0	0.03															
6	Flattop	keff	0	0	0	0	0	0.03														
7		F28/F25	0	0	0	0	0	0	0.8													
8		F37/F25	0	0	0	0	0	0	+0.5	0.7												
9	ZPR6-7	keff	0	0	0	0	0	0	0	0	0.03											
10		F28/F25	0	0	0	0	0	0	0	0	0	2.2										
11		F49/F25	0	0	0	0	0	0	0	0	0	+0.5	1.4									
12		C28/F25	0	0	0	0	0	0	0	0	0	+0.5	+0.5	1.2								
13	ZPR6-7 Pu240	keff	0	0	0	0	0	0	0	0	0	0	0	0	0.03							
14	ZPPR-9	keff	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02						
15		F28/F25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.1					
16		F49/F25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+0.5	1.2				
17		C28/F25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+0.5	+0.5	1.4			
18		Central Na void	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.3		
19		Large Na void	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.0	
20	Joyo	keff	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03

Symmetric

* Diagonal term: Error value (1 sigma, %)

** Non-diagonal term : Correlation factor (between -1 and +1)

Results of Adjustment (Case 0)

(Case 0: SG33 Standard Monte Carlo method (2D MC + INL's Corrective factors))

No.	Core	Parameter	C/E value		Relative uncertainty (%)		Nuclea-data-induced error (%)		Ratio of C/E-1 to prior total-error*
			Before	After	Experiment (Ve)	Analytical modeling (Vm)	Before (GMG)	After (GM'G)	
1	JEZEBEL-Pu239	keff	0.9987	0.9996	0.20	0.03	0.69	0.15	0.18
2		F28/F25	0.969	0.990	1.1	0.94	3.20	1.02	0.89
3		F49/F25	0.984	0.987	0.9	0.75	0.63	0.47	1.23
4		F37/F25	0.979	0.989	1.4	0.80	1.50	0.66	0.94
5	JEZEBEL-Pu240	keff	0.9984	1.0000	0.20	0.03	0.65	0.14	0.24
6	FLATTOP-Pu	keff	0.9986	1.0007	0.3	0.03	1.26	0.28	0.11
7		F28/F25	0.977	0.998	1.1	0.84	2.94	0.97	0.70
8		F37/F25	0.993	1.002	1.4	0.69	1.44	0.72	0.35
9	ZPR-6/7	keff	1.0053	1.0023	0.23	0.03	1.07	0.16	0.48
10		F28/F25	1.034	1.028	3.0	2.24	4.95	1.92	0.54
11		F49/F25	0.979	0.976	2.1	1.43	1.21	0.84	0.75
12		C28/F25	1.017	1.015	2.4	1.22	3.61	1.24	0.37
13	ZPR-6/7 High-Pu240	keff	1.0033	1.0004	0.22	0.03	1.06	0.15	0.30
14	ZPPR-9	keff	1.0042	1.0010	0.15	0.01	1.20	0.15	0.35
15		F28/F25	0.983	0.974	2.7	2.09	5.45	2.11	0.27
16		F49/F25	0.999	0.996	2.0	1.21	1.24	0.85	0.03
17		C28/F25	1.018	1.016	1.9	1.39	3.72	1.27	0.42
18		Na void (Step 3)	1.211	1.172	1.7	12.9	6.29	4.54	1.46
19		Na void (Step 5)	1.098	1.052	1.7	11.1	7.78	5.62	0.72
20	JOYO Mk-I	keff	0.9982	0.9991	0.18	0.03	0.68	0.16	0.26

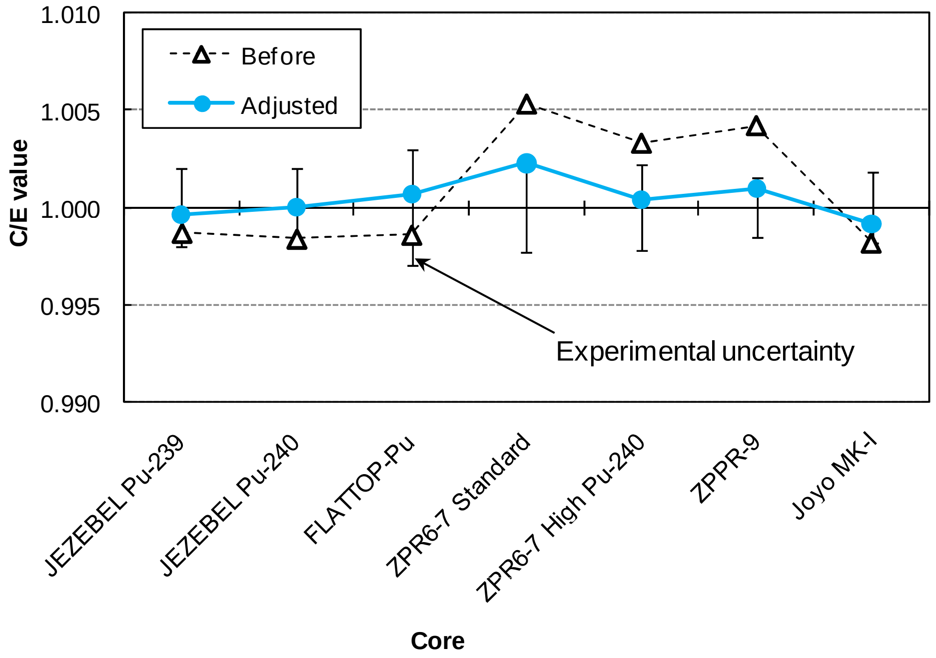
Results of Adjustment (Case 1)

(Case 1: As-built Monte Carlo results for ZPPR-9 by JAEA)

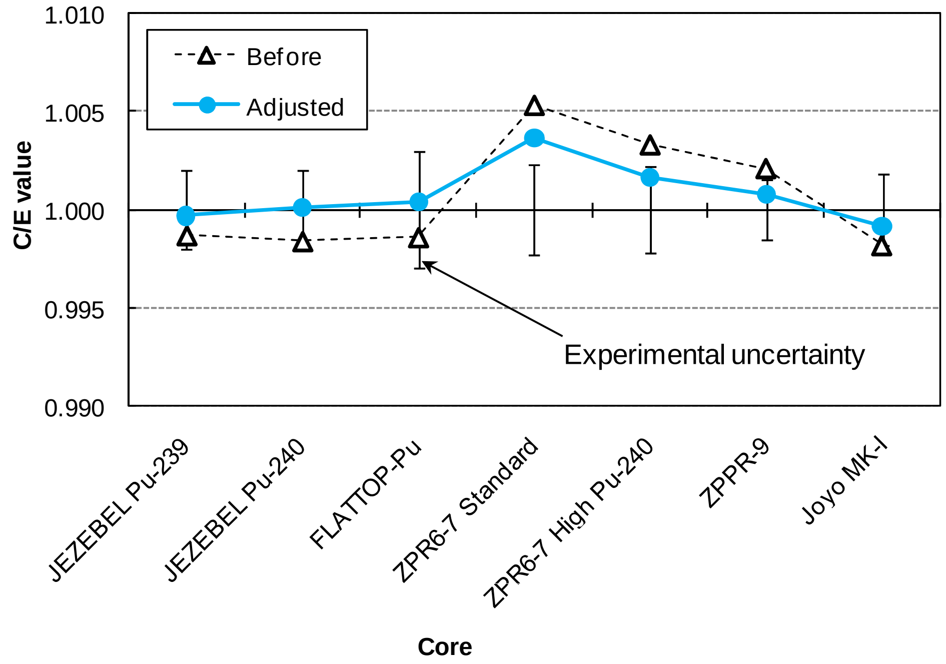
No.	Core	Parameter	C/E value		Relative uncertainty (%)		Nuclea-data-induced error (%)		Ratio of C/E-1 to prior total-error*
			Before	After	Experiment (Ve)	Analytical modeling (Vm)	Before (GMG)	After (GM'G)	
1	JEZEBEL-Pu239	keff	0.9987	0.9997	0.20	0.03	0.69	0.15	0.18
2		F28/F25	0.969	0.990	1.1	0.94	3.20	1.02	0.89
3		F49/F25	0.984	0.987	0.9	0.75	0.63	0.47	1.23
4		F37/F25	0.979	0.990	1.4	0.80	1.50	0.66	0.94
5	JEZEBEL-Pu240	keff	0.9984	1.0001	0.20	0.03	0.65	0.14	0.24
6	FLATTOP-Pu	keff	0.9986	1.0004	0.30	0.03	1.26	0.28	0.11
7		F28/F25	0.977	0.998	1.1	0.84	2.94	0.97	0.70
8		F37/F25	0.993	1.002	1.4	0.69	1.44	0.72	0.35
9	ZPR-6/7	keff	1.0053	1.0036	0.23	0.03	1.07	0.16	0.48
10		F28/F25	1.034	1.030	3.0	2.24	4.95	1.91	0.54
11		F49/F25	0.979	0.977	2.1	1.43	1.21	0.84	0.75
12		C28/F25	1.017	1.009	2.4	1.22	3.61	1.24	0.37
13	ZPR-6/7 High-Pu240	keff	1.0033	1.0017	0.22	0.03	1.06	0.15	0.30
14	ZPPR-9	keff	1.0021	1.0008	0.15	0.02	1.20	0.15	0.17
15		F28/F25	0.983	0.977	2.7	2.09	5.45	2.10	0.27
16		F49/F25	0.999	0.996	2.0	1.21	1.24	0.85	0.03
17		C28/F25	1.019	1.011	1.9	1.39	3.72	1.27	0.43
18		Na void (Step 3)	1.076	1.034	1.7	5.26	6.29	2.99	0.91
19		Na void (Step 5)	1.065	1.014	1.7	4.95	7.78	3.67	0.69
20	JOYO Mk-I	keff	0.9982	0.9991	0.18	0.03	0.68	0.16	0.26
Chi-square/Freedom = 0.63							* = (((C/E-1)**2)/(GMG+Ve+Vm))**1/2		

Change of C/E values (keff)

(Case 0: SG33 Standard Monte Carlo method (2D MC + INL's Corrective factors))



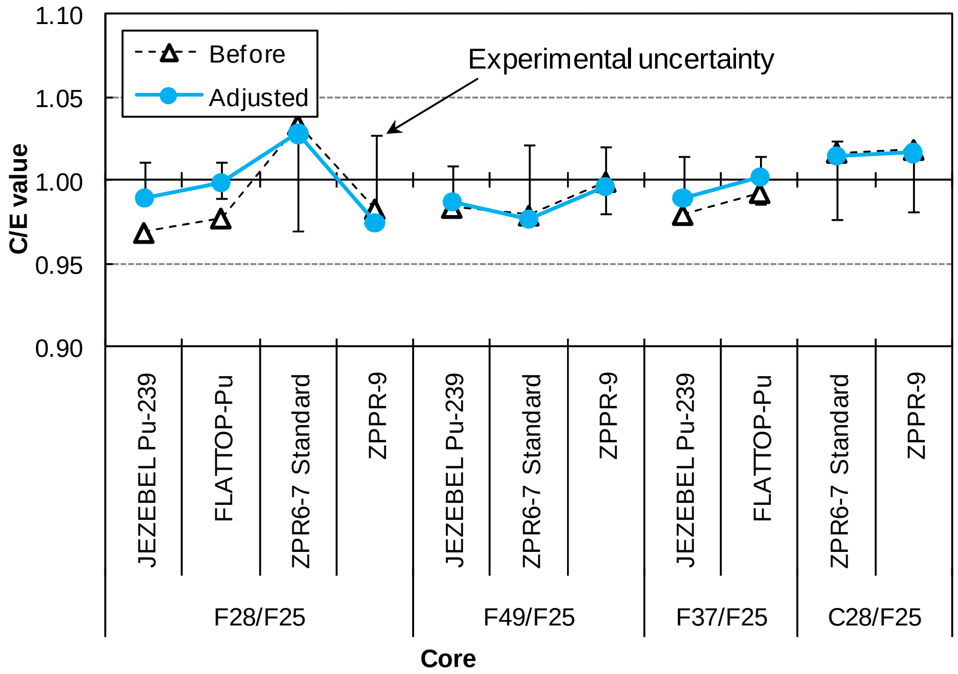
(Case 1: As-built Monte Carlo results for ZPPR-9 by JAEA)



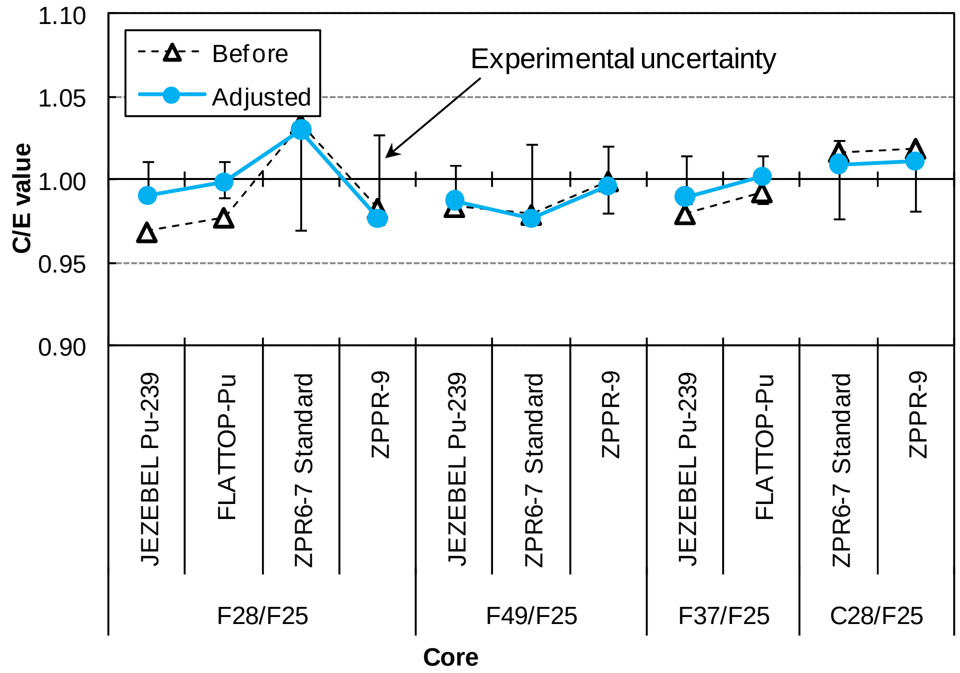
=> Both cases show enough accuracy of keff from small through large cores.

Change of C/E values(Reaction rate ratio)

(Case 0: SG33 Standard Monte Carlo method (2D MC + INL's Corrective factors))



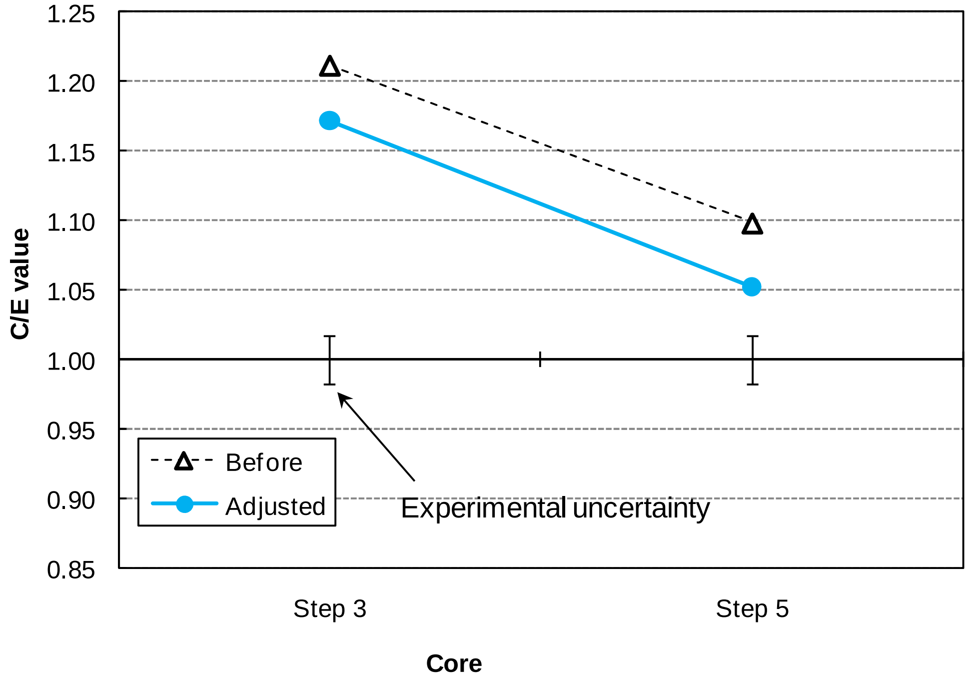
(Case 1: As-built Monte Carlo results for ZPPR-9 by JAEA)



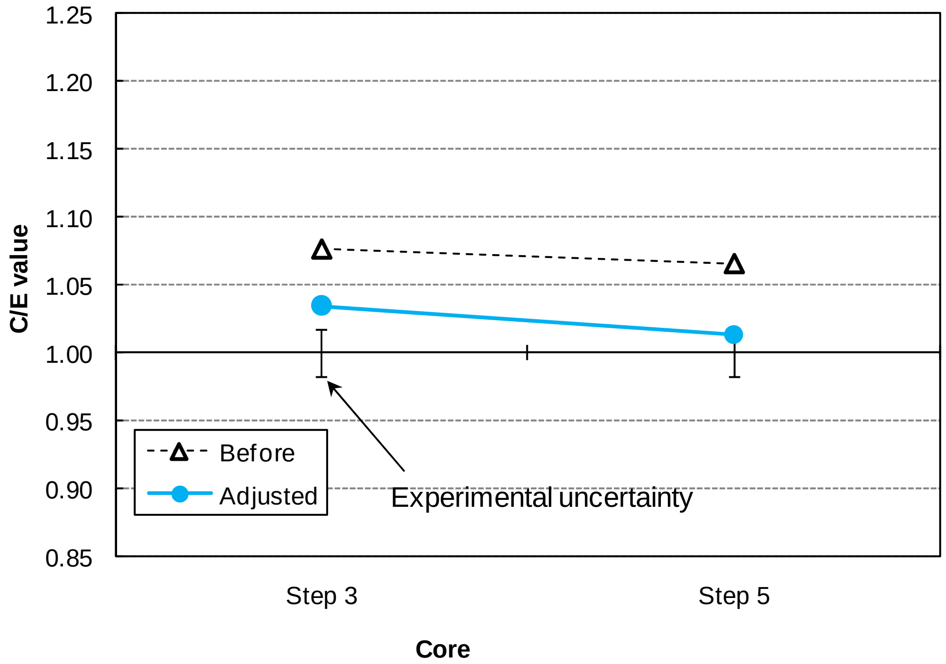
=> Both cases show satisfactory results from small through large cores for every R.R. ratio.

Change of C/E values (Na void reactivity)

(Case 0: SG33 Standard Monte Carlo method (2D MC + INL's Corrective factors))



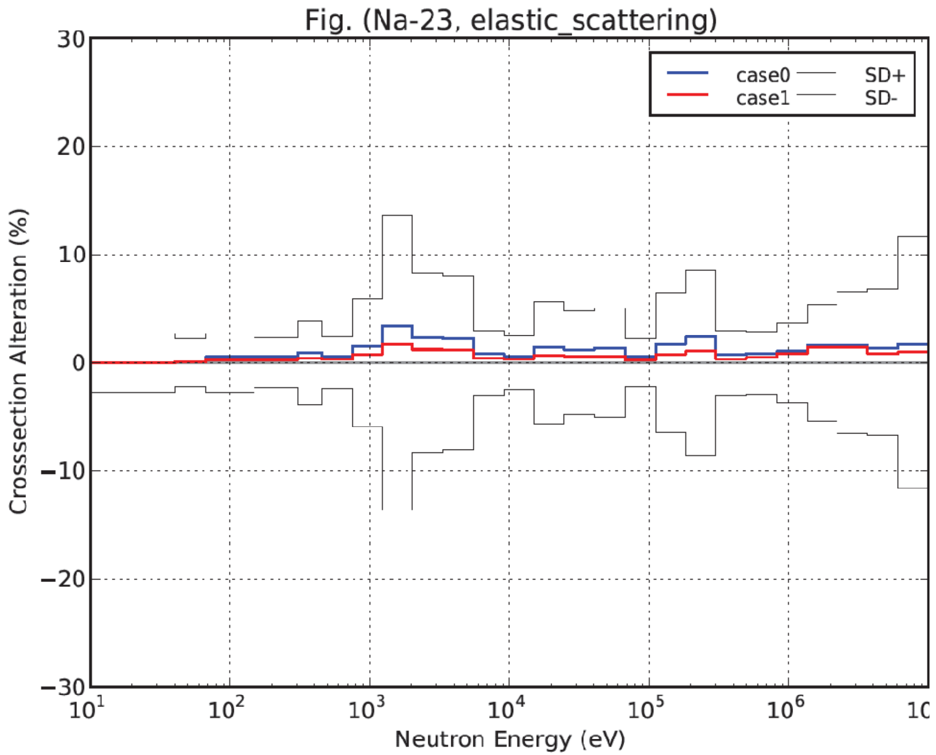
(Case 1: As-built Monte Carlo results for ZPPR-9 by JAEA)



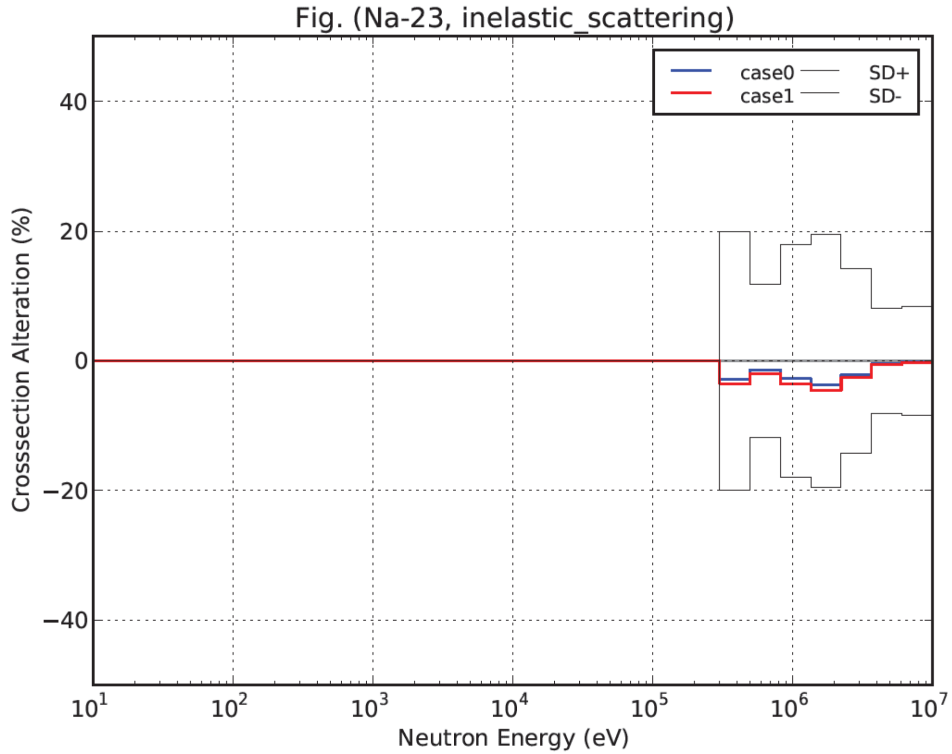
=> Case 0 keeps large discrepancy for Step 3 due to the large MC statistics error, on the other hand, Case 1 is very satisfactory.

Change of Nuclear data (1)

Na: Elastic scattering



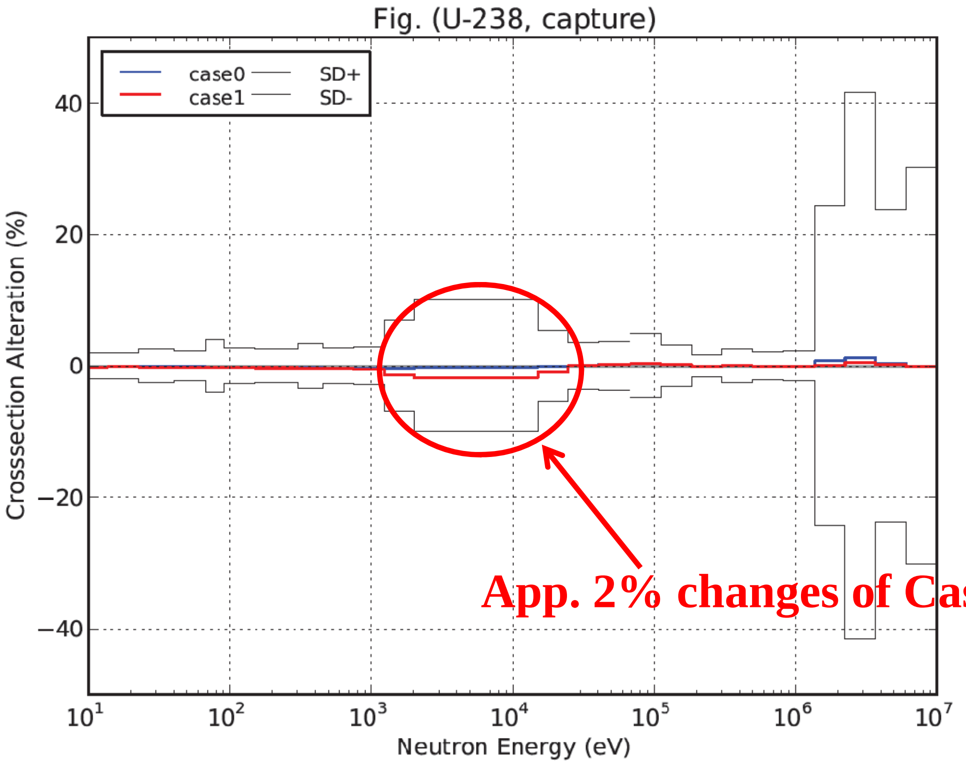
Na: Total inelastic scattering



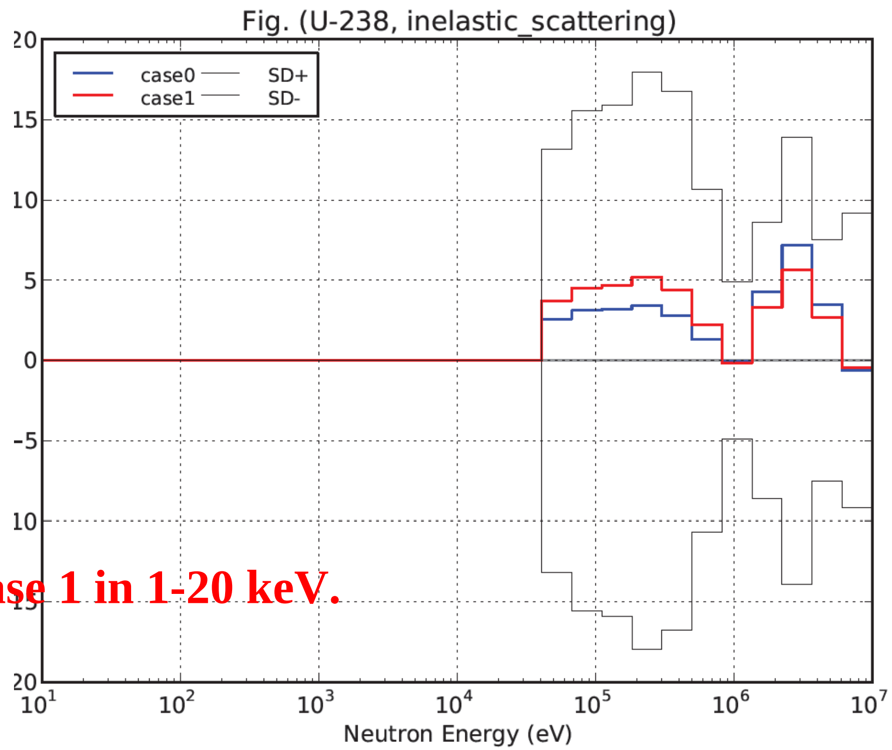
=> Within the STD deviation.

Change of Nuclear data (2)

U-238: Capture



U-238: Total inelastic scattering

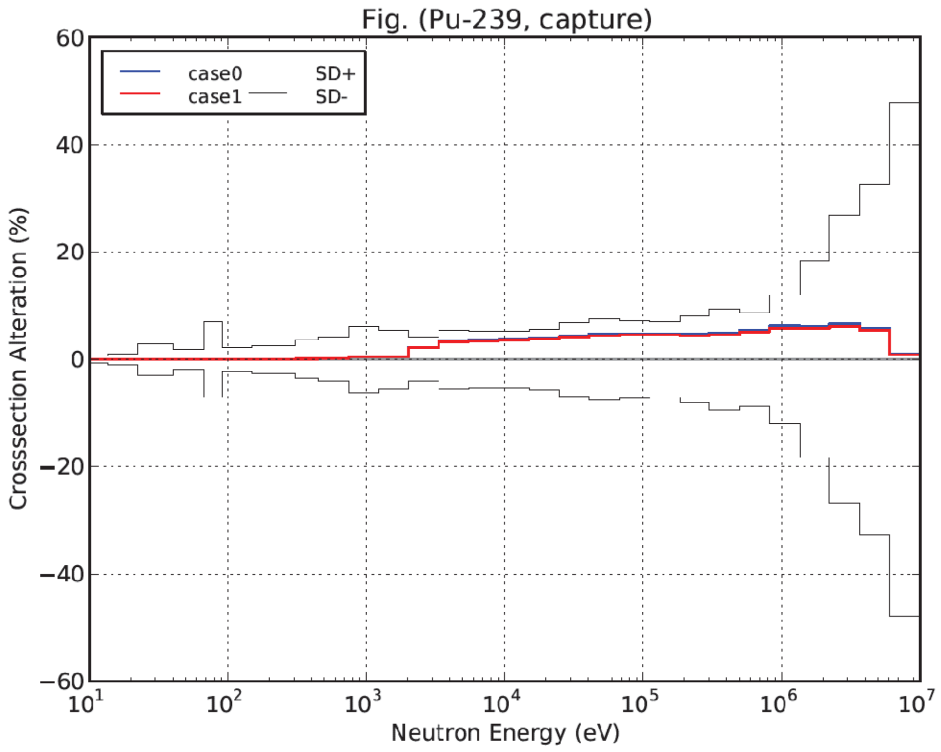


App. 2% changes of Case 1 in 1-20 keV.

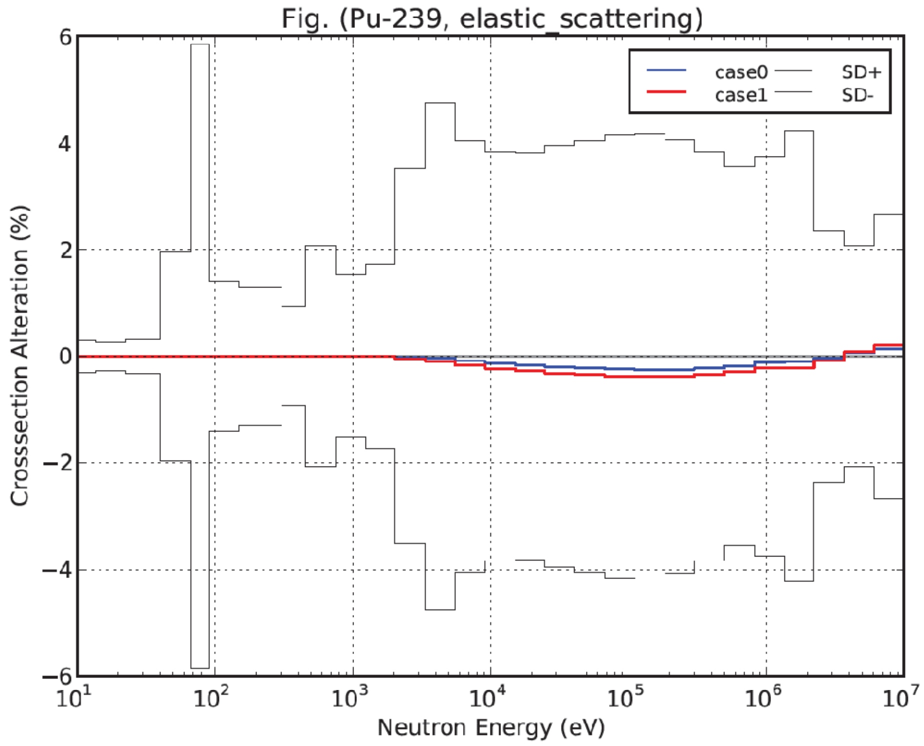
=> Capture changed in resolved resonance region <u>in only Case 1, by the difference of Na void reactivity evaluation</u>.
Fission spectrum became softer by inelastic.

Change of nuclear data (3)

Pu-239: Capture



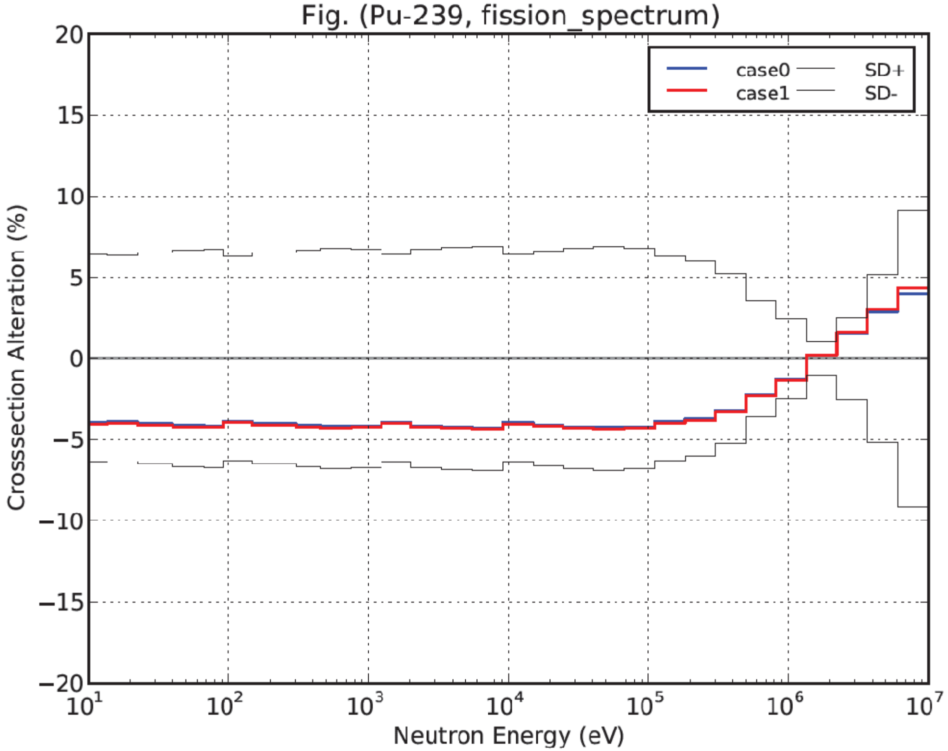
Pu-239: Elastic scattering



=> Capture change might come from the overestimation of large FBR's keff. Elastic change might be caused by negative correlation to keep Total.

Change of nuclear data (4)

Pu239: Fission spectrum

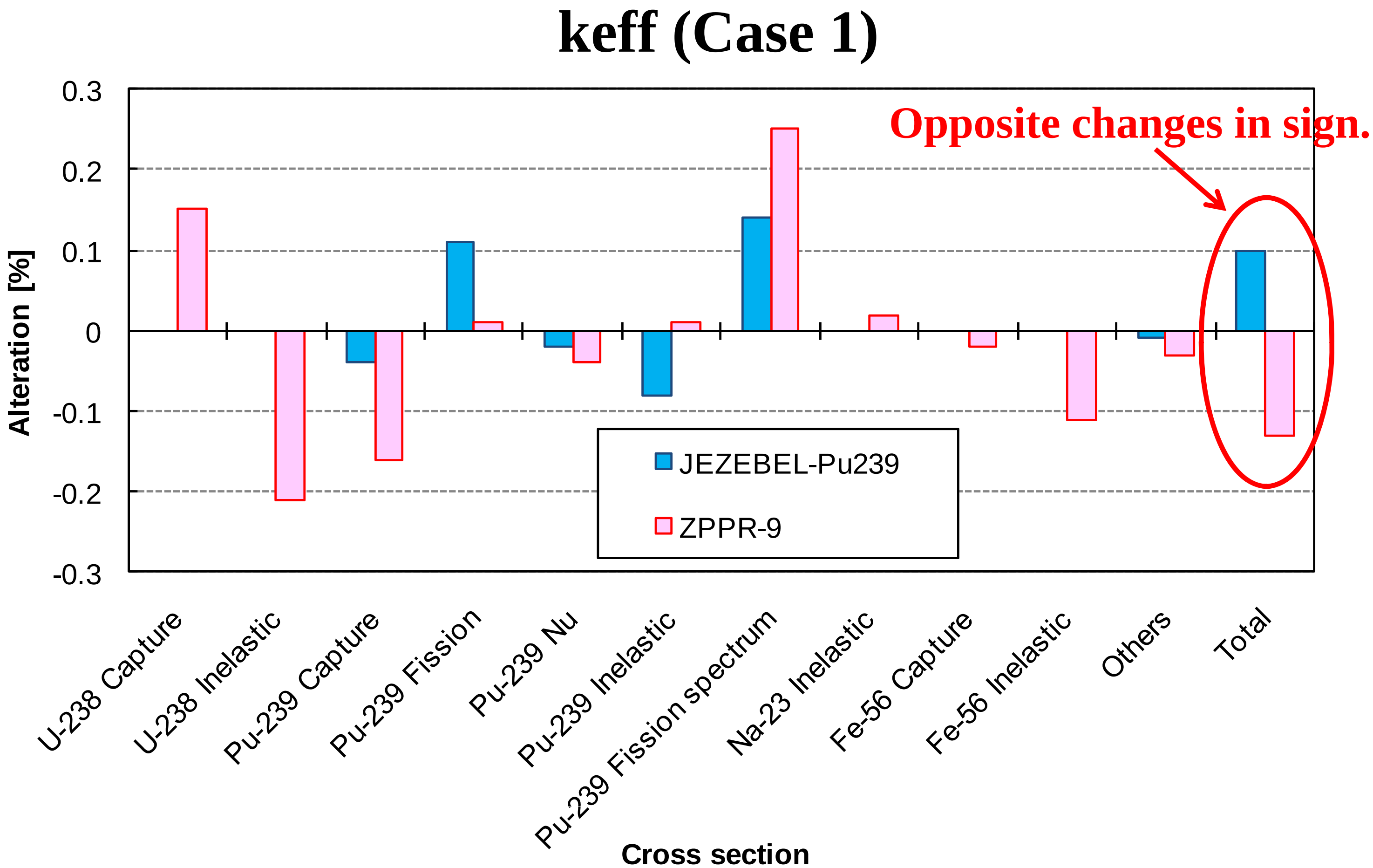


Delayed neutron fraction

Fission isotope	Case 0	Case 1
U-235	+0.02 %	+0.02 %
U-238	+0.76 %	+0.92 %
Pu-239	+0.90%	+1.08 %
Pu-240	+0.04 %	+0.05 %
Pu-241	+0.05%	+0.06 %

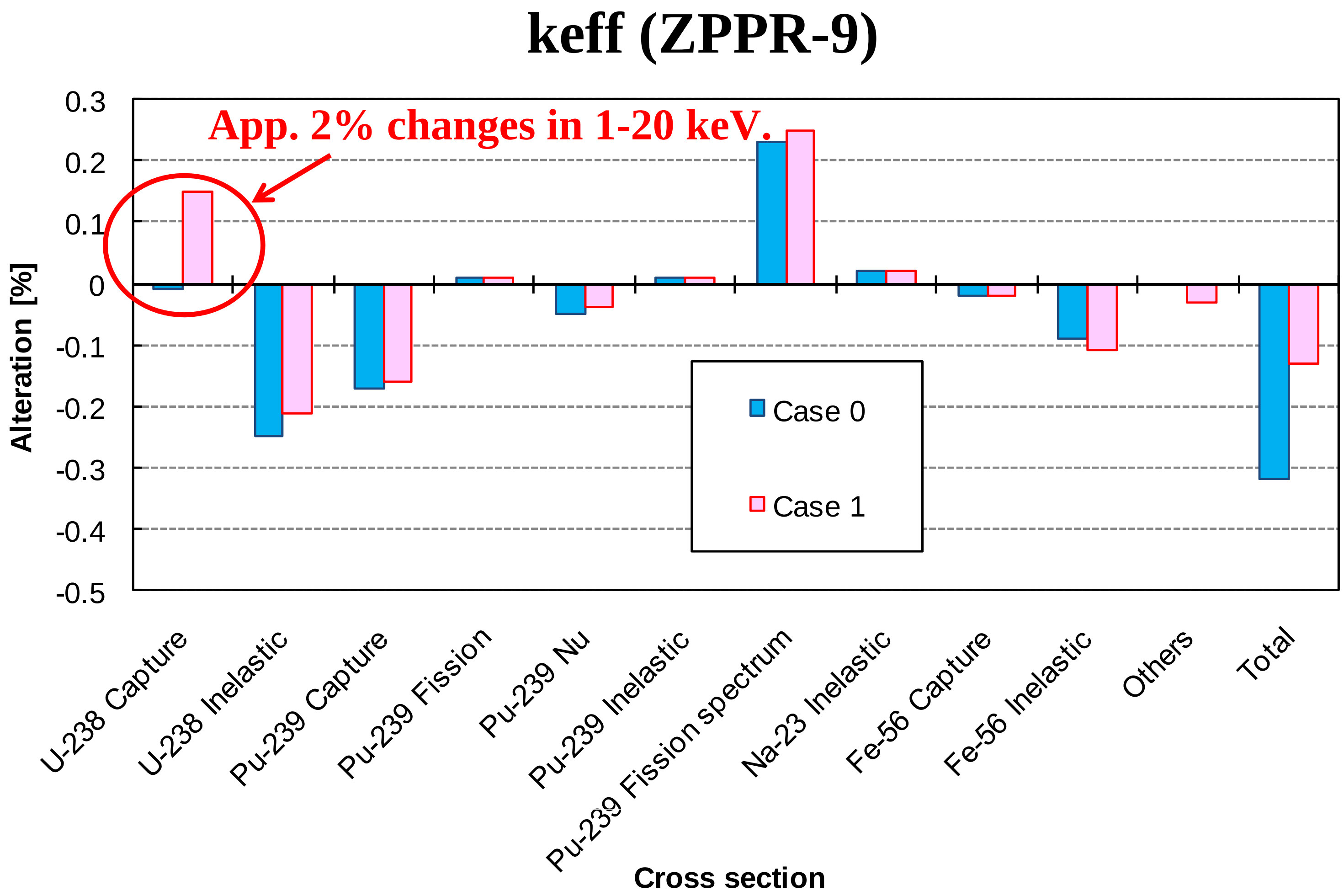
=> Fission spectrum became harder, maybe, to increase F28/F25, F37/F25 and keff of small cores. Obviously, Nu-d increased due to the overestimation of Na void reactivity.

Contribution to C/E change (1)



=> The opposite C/E changes of JEZEBEL and ZPPR-9 resulted from quite complicated cancellation of many isotopes and reactions, due to different energy-range contributions.

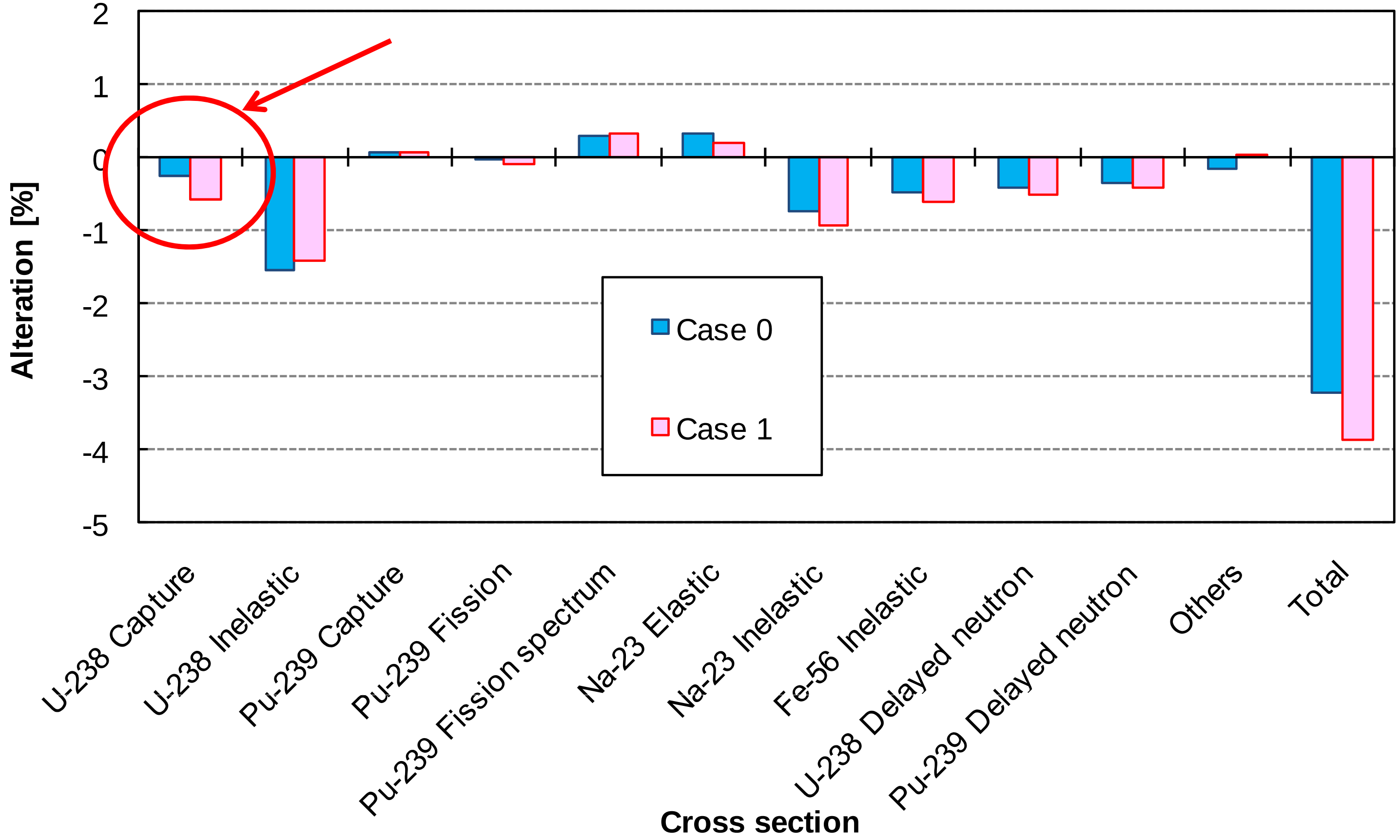
Contribution to C/E change (2)



=> The difference of keff alteration between Case 0 and 1 might come from the effect of Na void reactivity evaluation through U-238 capture.

Contribution to C/E change (3)

ZPPR-9, Na void reactivity (Step 3)



=> The contributions in Case 0 and Case 1 seem similar, but U-238 capture is a little different.

Effect to Target Core Parameter (keff) (1)

(Case 0: SG33 Standard Monte Carlo method (2D MC + INL's Corrective factors))

Target core	keff change	
	Before (GMG)	After (GM'G)
ABR Oxide	-0.30 %dk	
	(±0.98 %)	(±0.24 %)
ABR Metal	-0.26 %dk	
	(±0.88 %)	(±0.32 %)
JAEA FBR	-0.22%dk	
	(±1.06 %)	(±0.24 %)

(Case 1: As-built Monte Carlo results for ZPPR-9 by JAEA)

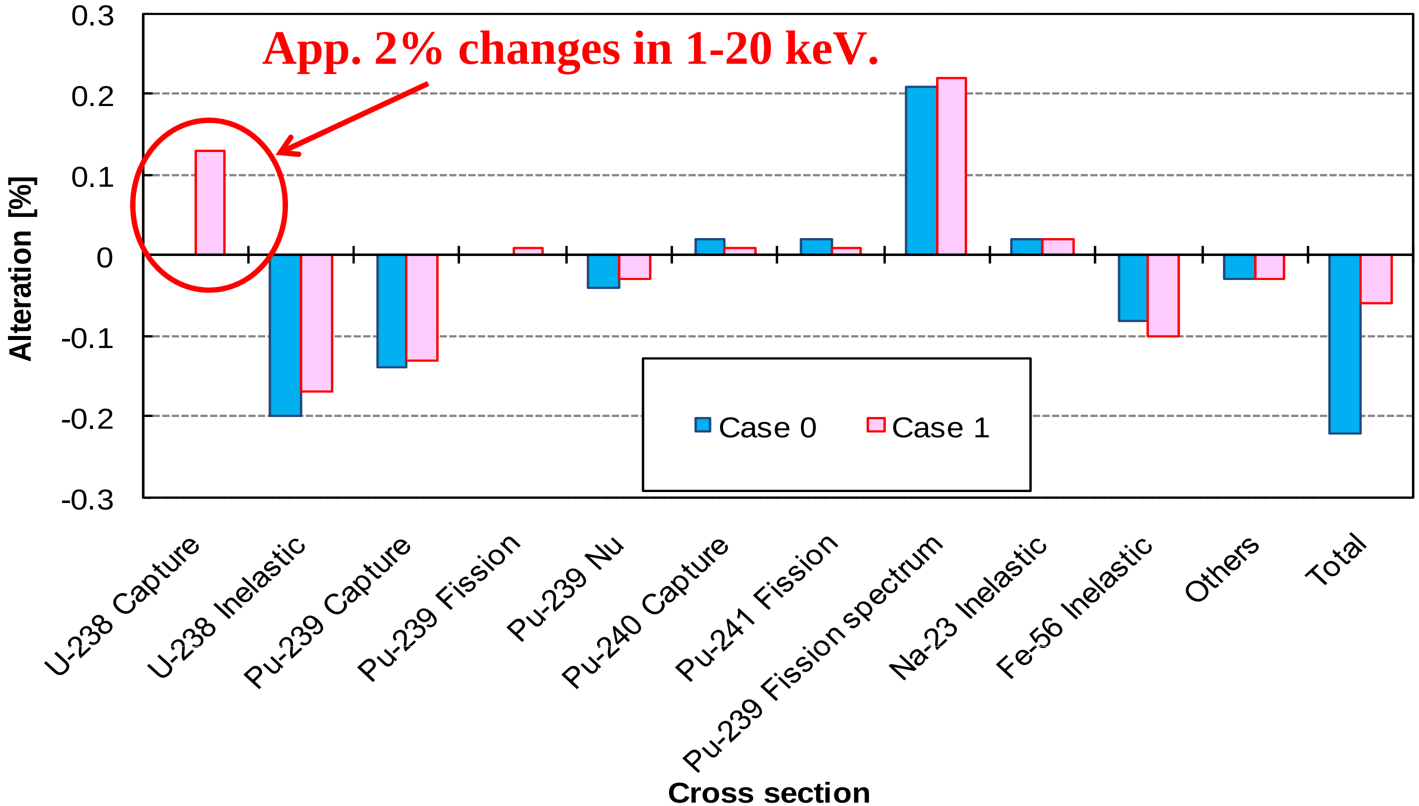
Target core	keff change	
	Before (GMG)	After (GM'G)
ABR Oxide	-0.18%dk	
	(±0.98 %)	(±0.24 %)
ABR Metal	-0.19%dk	
	(±0.88 %)	(±0.32 %)
JAEA FBR	-0.06%dk	
	(±1.06 %)	(±0.24 %)

=> Accuracy is identical between Case 0 and 1, but keff alteration is quite different, though the degree is within the uncertainty.

Effect to Target Core Parameter (keff) (2)

(Case 0: SG33 Standard Monte Carlo method (2D MC + INL's Corrective factors))

(Case 1: As-built Monte Carlo results for ZPPR-9 by JAEA)



=> Similar trend with ZPPR-9 keff.

Concluding Remarks

- **The results of SG33 adjustment exercise by JENDL-4.0 and Monte Carlo analysis demonstrated the promising feature with reasonable changes of C/E values and nuclear data.**

  - **The C/E-1 values of integral parameters after adjustment are within the target value, that is, for keff, less than 0.3%dk, for F28/F25, ~3%, for F49/F25 and C28/F49, ~2%. However, it depends on the applied analytical method for Na void reactivity, in the range of 1-17%.**

  - **The nuclear-data-induced errors of integral parameters after adjustment (GM'G, 1 sigma) are well below the target value, that is, for keff, 0.14 - 0.28%dk, for F28/F25, 1.0-2.1%, for F49/F25 and C28/F49, 0.5-1.3%, for Na void reactivity, 3-6%.**

- **The most essential point of the adjustment procedure would be to keep the quantitative consistency among: 1) C/E values, 2) uncertainty of integral parameters and 3) nuclear-data covariance.**

Appendix: Effect of MC statistical error

- **Case 0**: Vm = Twice as MC statistical error
- **Case 0B**: Vm = MC statistical error

No.	Core	Parameter	C/E value			Relative uncertainty		
			Before	After		Ve	Vm	
				Case 0	Case 0B		Case 0	Case 0B
18	ZPPR-9	Na void reactivity (Step 3)	1.211	1.172	1.123	1.7 %	12.9 %	6.5 %
19		" (Step 5)	1.098	1.052	1.005	1.7 %	11.1 %	5.6 %
Ratio of C/E-1 to prior total-error (= (((C/E-1)**2) / (GMG+Ve+Vm))**1/2)						Step 3	1.46	2.30
						Step 5	0.72	1.01

Chi-square/Freedom = 0.89