

Preliminary Cross Section Adjustment Using GMADJ

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Computational Methods and Data

- Generalized least square fitting code GMADJ of ANL has been resurrected and modified to be applicable on modern computer environments
- Preliminary adjustment was performed for the cross section adjustment exercise of the OECD/NEA WPEC Subgroup 33
 - Cross section data: ENDF/B-VII
 - Covariance data: 33-group COMMARA-2.0 (AFCI-2.0)
 - 20 experiments were used
 - 33-group sensitivity coefficients calculated with VARI3D (diffusion theory) or ERANOS (transport theory) based on ENDF/B-VII data
 - Calculated values provided by INL
 - 1021 group constants were considered
 - Isotopes: U-235, U-238, Pu-239, Pu-240, Pu-241, Fe-56, Cr-52, Ni-58, O-16, Na-23, B-10
 - Reactions: capture ((n,α) for B-10), fission, total nu, elastic scattering, inelastic scattering

Experiment Covariance Matrix (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	0.18

Symmetric

* Diagonal term: **Error value (1 sigma, %)**, ** Non-diagonal term : **Correlation factor (between -1 and +1)**



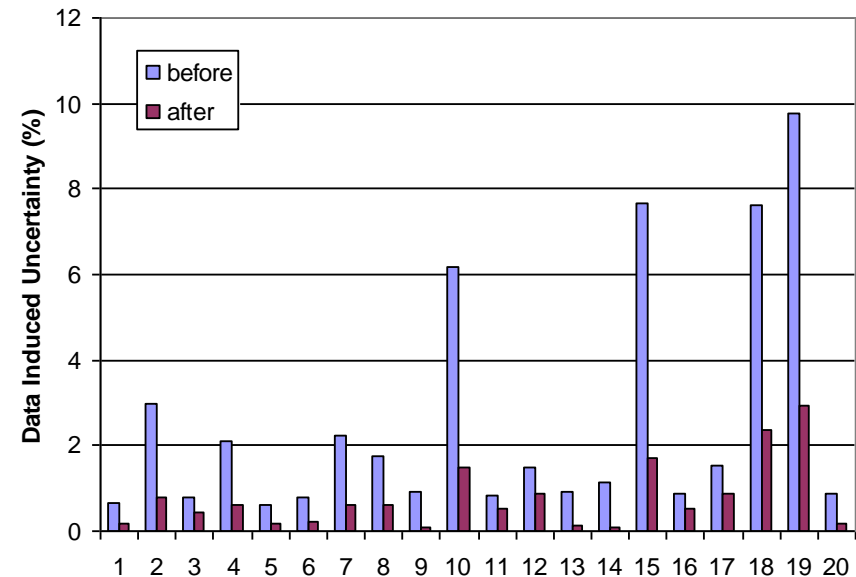
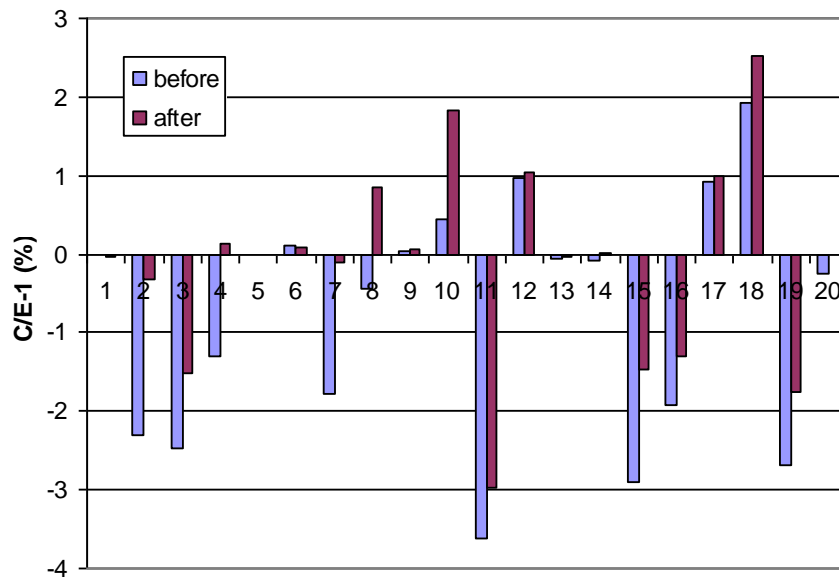
Adjustment without Experiment Correlations

Reactor	Parameter	C/E-1 (%)		Data uncertainty (%)		Experiment uncertainty (%)
		before	after	before	after	
JEZEBEL_P239	keff	-0.01	-0.03	0.64	0.16	0.20
JEZEBEL_P239	F28/F25	-2.30	-0.32	2.96	0.81	1.17
JEZEBEL_P239	F49/F25	-2.47	-1.51	0.79	0.42	0.91
JEZEBEL_P239	F37/F25	-1.30	0.14	2.09	0.63	1.40
JEZEBEL_P240	keff	-0.02	0.00	0.63	0.18	0.20
FLATTOP_P239	keff	0.10	0.09	0.81	0.22	0.30
FLATTOP_P239	F28/F25	-1.78	-0.11	2.24	0.63	1.30
FLATTOP_P239	F37/F25	-0.44	0.86	1.74	0.60	1.41
ZPR6_7	keff	0.04	0.07	0.94	0.10	0.23
ZPR6_7	F28/F25	0.45	1.84	6.18	1.51	3.13
ZPR6_7	F49/F25	-3.62	-2.98	0.83	0.54	2.21
ZPR6_7	C28/F25	0.98	1.04	1.51	0.88	2.47
ZPR6_7_Pu240	keff	-0.06	-0.03	0.94	0.11	0.22
ZPPR9	keff	-0.08	0.01	1.16	0.10	0.12
ZPPR9	F28/F25	-2.90	-1.46	7.67	1.70	2.76
ZPPR9	F49/F25	-1.92	-1.29	0.87	0.53	2.03
ZPPR9	C28/F25	0.93	1.00	1.54	0.88	1.93
ZPPR9	VOID_STEP3	1.92	2.52	7.63	2.38	4.15
ZPPR9	VOID_STEP5	-2.68	-1.76	9.77	2.92	4.04
JOYO	keff	-0.25	-0.02	0.86	0.18	0.18

Adjustment without Experiment Correlations

- C/E values are improved for 13 cases among 20 experiments
 - Non-negligible deterioration for 3 cases
- Estimated parameter uncertainty due to data uncertainties is reduced significantly for all 20 cases

		before	after
C/E	RMS error (%)	2.73	1.54
	Outside of $1\sigma_e$	6	2
	Outside of $2\sigma_e$	1	0
RMS of data induced uncertainty (%)		14.20	1.18



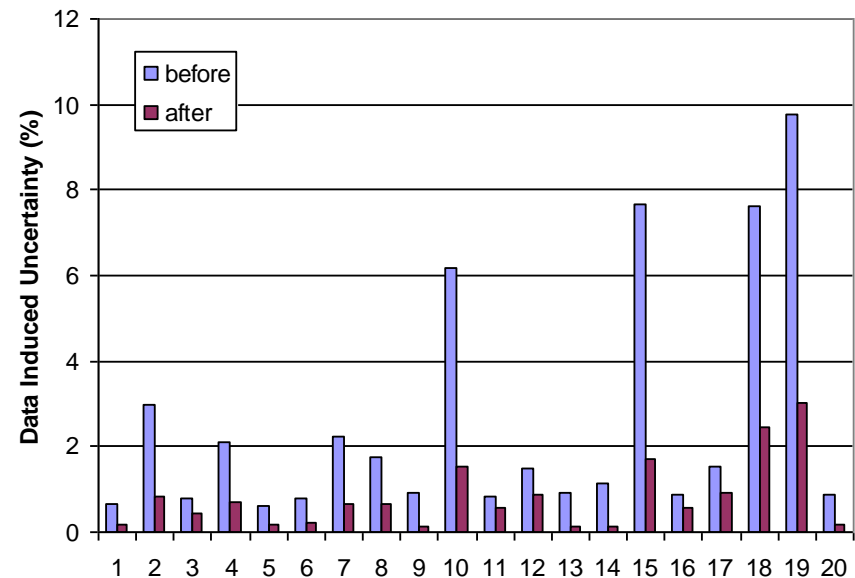
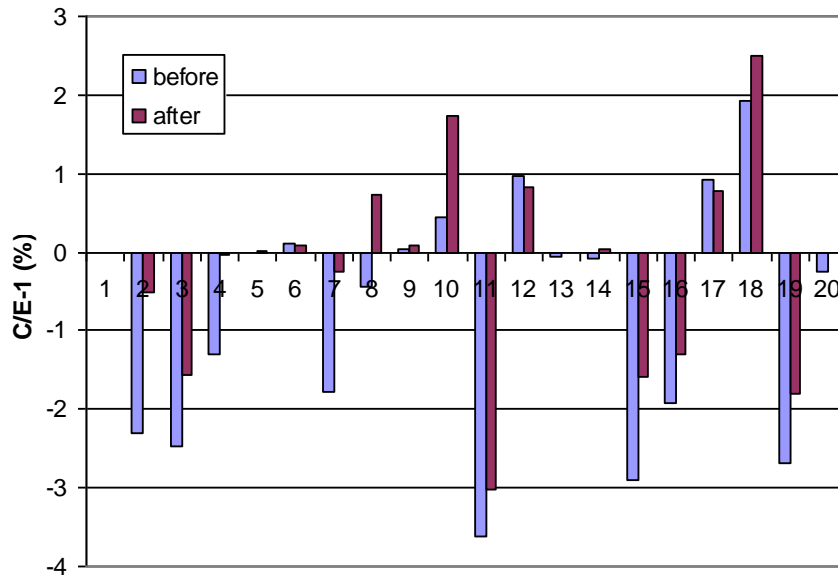
Adjustment with Experiment Correlations

Reactor	Parameter	C/E-1 (%)		Data uncertainty (%)		Experiment uncertainty (%)
		before	after	before	after	
JEZEBEL_P239	keff	-0.01	-0.02	0.64	0.16	0.20
JEZEBEL_P239	F28/F25	-2.30	-0.52	2.96	0.85	1.17
JEZEBEL_P239	F49/F25	-2.47	-1.57	0.79	0.45	0.91
JEZEBEL_P239	F37/F25	-1.30	-0.04	2.09	0.69	1.40
JEZEBEL_P240	keff	-0.02	0.02	0.63	0.18	0.20
FLATTOP_P239	keff	0.10	0.09	0.81	0.22	0.30
FLATTOP_P239	F28/F25	-1.78	-0.25	2.24	0.67	1.30
FLATTOP_P239	F37/F25	-0.44	0.72	1.74	0.64	1.41
ZPR6_7	keff	0.04	0.09	0.94	0.14	0.23
ZPR6_7	F28/F25	0.45	1.74	6.18	1.52	3.13
ZPR6_7	F49/F25	-3.62	-3.01	0.83	0.55	2.21
ZPR6_7	C28/F25	0.98	0.82	1.51	0.89	2.47
ZPR6_7_Pu240	keff	-0.06	0.00	0.94	0.14	0.22
ZPPR9	keff	-0.08	0.03	1.16	0.12	0.12
ZPPR9	F28/F25	-2.90	-1.58	7.67	1.70	2.76
ZPPR9	F49/F25	-1.92	-1.31	0.87	0.55	2.03
ZPPR9	C28/F25	0.93	0.79	1.54	0.90	1.93
ZPPR9	VOID_STEP3	1.92	2.50	7.63	2.46	4.15
ZPPR9	VOID_STEP5	-2.68	-1.81	9.77	3.02	4.04
JOYO	keff	-0.25	-0.02	0.86	0.18	0.18

Adjustment with Experiment Correlations

- No noticeable difference from adjustment without experiment correlations
- C/E values are improved for 13 cases among 20 experiments
- Estimated parameter uncertainty due to data uncertainties is reduced significantly for all 20 cases

		before	after
C/E	RMS error (%)	2.73	1.52
	Outside of $1\sigma_e$	6	2
	Outside of $2\sigma_e$	1	0
RMS of data induced uncertainty (%)		14.20	1.25



Comparison of New C/E-1 Values with INL Results

Reactor	Parameter	w/o Exp. Correlation (%)		w/ Exp. Correlation (%)	
		ANL	INL	ANL	INL
JEZEBEL_P239	keff	-0.03	-0.09	-0.02	-0.08
JEZEBEL_P239	F28/F25	-0.32	-0.31	-0.52	-0.18
JEZEBEL_P239	F49/F25	-1.51	-1.06	-1.57	-0.98
JEZEBEL_P239	F37/F25	0.14	-0.60	-0.04	-0.52
JEZEBEL_P240	keff	0.00	0.01	0.02	0.01
FLATTOP_P239	keff	0.09	-0.01	0.09	0.00
FLATTOP_P239	F28/F25	-0.11	-0.04	-0.25	0.05
FLATTOP_P239	F37/F25	0.86	0.87	0.72	0.93
ZPR6_7	keff	0.07	0.07	0.09	0.06
ZPR6_7	F28/F25	1.84	0.90	1.74	0.02
ZPR6_7	F49/F25	-2.98	-1.34	-3.01	-1.43
ZPR6_7	C28/F25	1.04	1.01	0.82	1.09
ZPR6_7_Pu240	keff	-0.03	-0.02	0.00	-0.03
ZPPR9	keff	0.01	0.02	0.03	0.02
ZPPR9	F28/F25	-1.46	-0.39	-1.58	-0.50
ZPPR9	F49/F25	-1.29	-1.49	-1.31	-1.47
ZPPR9	C28/F25	1.00	0.99	0.79	1.06
ZPPR9	VOID_STEP3	2.52	3.37	2.50	3.09
ZPPR9	VOID_STEP5	-1.76	-0.75	-1.81	-1.11
JOYO	keff	-0.02	-0.02	-0.02	-0.02

Comparison of New Uncertainties with INL Results

Reactor	Parameter	w/o Exp. Correlation (%)		w/ Exp. Correlation (%)	
		ANL	INL	ANL	INL
JEZEBEL_P239	keff	0.16	0.2	0.16	0.2
JEZEBEL_P239	F28/F25	0.81	0.9	0.85	0.9
JEZEBEL_P239	F49/F25	0.42	0.6	0.45	0.6
JEZEBEL_P239	F37/F25	0.63	0.5	0.69	0.5
JEZEBEL_P240	keff	0.18	0.2	0.18	0.2
FLATTOP_P239	keff	0.22	0.3	0.22	0.3
FLATTOP_P239	F28/F25	0.63	0.8	0.67	0.7
FLATTOP_P239	F37/F25	0.60	0.6	0.64	0.6
ZPR6_7	keff	0.10	0.1	0.14	0.1
ZPR6_7	F28/F25	1.51	1.5	1.52	1.5
ZPR6_7	F49/F25	0.54	0.6	0.55	0.6
ZPR6_7	C28/F25	0.88	0.9	0.89	0.9
ZPR6_7_Pu240	keff	0.11	0.1	0.14	0.1
ZPPR9	keff	0.10	0.1	0.12	0.1
ZPPR9	F28/F25	1.70	1.7	1.70	1.7
ZPPR9	F49/F25	0.53	0.6	0.55	0.6
ZPPR9	C28/F25	0.88	0.9	0.90	0.9
ZPPR9	VOID_STEP3	2.38	3.9	2.46	3.6
ZPPR9	VOID_STEP5	2.92	4.8	3.02	4.4
JOYO	keff	0.18	0.2	0.18	0.2

Uncertainty Evaluation for Other Experiments

- Uncertainty was evaluated with adjusted cross sections for 14 additional experiments that were not included in the adjustment
- Estimated parameter uncertainty due to data uncertainties is reduced significantly for all 14 cases, but C/E values became slightly worse for 5 cases

Reactor	Parameter	C/E-1 (%)		Data uncertainty (%)		Experiment uncertainty (%)
		before	after	before	after	
GODIVA	keff	-0.02	0.14	0.89	0.54	0.20
GODIVA	F28/F25	-4.48	-4.52	2.16	1.97	1.24
GODIVA	F37/F25	-0.87	-0.89	1.59	1.44	1.61
GODIVA	F49/F25	-1.41	-0.81	0.71	0.52	1.81
NP_SPHERE	keff	-0.56	-0.47	0.57	0.32	0.36
BIGTEN	keff	0.00	0.44	2.33	0.66	0.07
BIGTEN	F49/F25	-2.56	-2.01	1.02	0.59	0.91
BIGTEN	F37/F25	-3.32	-2.91	6.81	1.88	1.03
BIGTEN	F28/F25	-5.32	-4.41	13.06	2.94	0.76
ZPPR10A	keff	-0.13	-0.01	0.94	0.24	0.01
ZPPR15A	keff	-0.01	0.09	1.10	0.12	0.04
ZPR6_6A	keff	-0.12	0.43	1.56	0.56	0.09
ZPR3_53	keff	0.92	0.78	0.71	0.36	0.09
ZPR3_54	keff	1.20	0.98	1.25	1.00	0.17

Summary

- **Preliminary** adjustment has been performed for the cross section adjustment exercise of the OECD/NEA WPEC Subgroup 33
 - Generalized least square fitting code GMADJ of ANL has been resurrected and modified to be applicable on modern computer environments
 - The uncertainties of predicted reactor performance parameters have been evaluated for 20 experiments with full application of integral experiment values
- Adjustment will be repeated using final integral data provided to SG33 and final results submitted – Final results should be similar to present preliminary values