

INL Adjustment Results with Stress Test

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Calculation Data

- **Cross Section Used: ENDF/B-VII data**
- **Covariance Used: COMMARA 2.0**
- **21 experiments, including ZPR9-34, have been used with MCNP solutions for all of them.**
- **Sensitivity coefficients calculated in S_4P_1 with ERANOS and ENDF/B-VII data**
- **Isotopes considered: U235, U238, Pu239, Pu240, Pu241, Fe56, Cr52, Ni58, O16, Na23, B10**
- **Reaction considered: Capture, Fission, Nu, Elastic, Inelastic, χ , P_1^{elas} (only for Na23 and Fe56)**
- **493 variables were selected using the following criteria on uncertainty produced by a single cross section: 0.01% for K_{eff} , 0.1% for spectral indices, and 0.1% for sodium void.**

C/E with 20 or 21 experiments

20 exp. $\chi^2=0.50$ ----- 21 exp. $\chi^2=0.54$

Experiment	20 exp.C/E $\pm \sigma$	21 exp. C/E $\pm \sigma$	Experiment	20 exp.C/E $\pm \sigma$	21 exp. C/E $\pm \sigma$
JEZEBEL_Pu239 Keff	0.9999 \pm 0.002	0.9999 \pm 0.002	ZPR6-7 Pu239 F49/F25	0.9696 \pm 0.006	0.9694 \pm 0.006
JEZEBEL_Pu239 F28/F25	0.9929 \pm 0.011	0.9930 \pm 0.011	ZPR6-7 Pu239 C28/F25	1.0077 \pm 0.009	1.0066 \pm 0.009
JEZEBEL_Pu239 F37/F25	0.9987 \pm 0.008	0.9989 \pm 0.008	ZPR6-7 Pu240 Keff	0.9997 \pm 0.001	0.9998 \pm 0.001
JEZEBEL_Pu239 F49/F25	0.9837 \pm 0.005	0.9837 \pm 0.005	ZPPR9 Keff	1.0002 \pm 0.001	1.0003 \pm 0.001
JEZEBEL_Pu240 Keff	1.0000 \pm 0.002	1.0001 \pm 0.002	ZPPR9 F28/F25	0.9830 \pm 0.018	0.9816 \pm 0.018
FLATTOP Keff	1.0008 \pm 0.002	1.0011 \pm 0.002	ZPPR9 F49/F25	0.9865 \pm 0.006	0.9863 \pm 0.006
FLATTOP F28/F25	0.9964 \pm 0.009	0.9959 \pm 0.009	ZPPR9 C28/F25	1.0073 \pm 0.009	1.0062 \pm 0.009
FLATTOP F37/F25	1.0067 \pm 0.007	1.0063 \pm 0.007	ZPPR9 Na Void Step 3	1.0275 \pm 0.040	1.0359 \pm 0.039
ZPR6-7 Pu239 Keff	1.0008 \pm 0.001	1.0008 \pm 0.001	ZPPR9 Na Void Step 5	0.9842 \pm 0.049	0.9863 \pm 0.049
ZPR6-7 Pu239 F28/F25	1.0159 \pm 0.016	1.0151 \pm 0.016	JOYO Keff	0.9998 \pm 0.002	0.9991 \pm 0.002

Experiment	old C/E $\pm \sigma$	new C/E $\pm \sigma$
ZPR9-34 Keff	1.0088 \pm 0.001	1.0001 \pm 0.001

Uncertainties Before and After Adjustment

Experiment	Unc. before adj	Unc. after adj	Experiment	Unc. before adj	Unc. after adj
JEZEBEL_Pu239 Keff (pcm)	± 636	± 164	ZPR6-7 Pu239 F49/F25 (%)	± 0.8	± 0.6
JEZEBEL_Pu239 F28/F25 (%)	± 3.7	± 1.1	ZPR6-7 Pu239 C28/F25 (%)	± 1.5	± 0.9
JEZEBEL_Pu239 F37/F25 (%)	± 2.4	± 0.8	ZPR6-7 Pu240 Keff (pcm)	± 971	± 131
JEZEBEL_Pu239 F49/F25 (%)	± 0.8	± 0.5	ZPPR9 Keff (pcm)	± 1191	± 118
JEZEBEL_Pu240 Keff (pcm)	± 656	± 181	ZPPR9 F28/F25 (%)	± 7.9	± 1.8
FLATTOP Keff (pcm)	± 764	± 220	ZPPR9 F49/F25 (%)	± 0.9	± 0.6
FLATTOP F28/F25 (%)	± 3.1	± 0.9	ZPPR9 C28/F25 (%)	± 1.5	± 0.9
FLATTOP F37/F25 (%)	± 2.0	± 0.7	ZPPR9 Na Void Step 3 (%)	± 7.6	± 3.9
ZPR6-7 Pu239 Keff (pcm)	± 968	± 127	ZPPR9 Na Void Step 5 (%)	± 9.7	± 4.9
ZPR6-7 Pu239 F28/F25 (%)	± 6.4	± 1.6	JOYO Keff (pcm)	± 863	± 171

Experiment	Unc. before adj	Unc. after adj
ZPR9-34 Keff (pcm)	± 2416	± 121

Major Contributors to Improved C/E

ZPR9-34 K_{eff}

Cross Section	Contribution (pcm)
Fe56 σ^{elas} gr. 8	-241
Fe56 σ^{elas} gr. 9	-197
Fe56 σ^{elas} gr. 7	-171
Fe56 σ^{elas} gr. 10	-168
U235 σ^{cap} gr. 14	100
Fe56 σ^{elas} gr. 11	-84
Fe56 σ^{cap} gr. 7	-80
Fe56 σ^{cap} gr. 8	-76
U235 σ^{cap} gr. 10	73
Total	-864

Major Cross Section Adjustments

U235

Param.	20 exp. Adjus. %	21 exp. Adjus. %	Stand. Deviat. %		
			Initial	20 exp. Adj.	21 exp. Adj.
$\sigma^{\text{cap}}_{\text{gr. 9}}$	-9.6	-6.9	20.0	10.2	9.9
$\sigma^{\text{cap}}_{\text{gr. 10}}$	-9.7	-6.9	20.0	10.1	9.8
$\sigma^{\text{cap}}_{\text{gr. 11}}$	-9.7	-6.9	20.0	10.1	9.9
$\sigma^{\text{cap}}_{\text{gr. 12}}$	-9.7	-6.9	20.0	10.1	9.9
$\sigma^{\text{cap}}_{\text{gr. 13}}$	-9.7	-6.9	20.0	10.1	9.8
$\sigma^{\text{cap}}_{\text{gr. 14}}$	-9.7	-6.9	20.0	10.1	9.8

Major Cross Section Adjustments

Fe56

Param.	20 exp. Adjus. %	21 exp. Adjus. %	Stand. Deviat. %		
			Initial	20 exp. Adj.	21 exp. Adj.
$\sigma^{el} gr. 7$	-0.1	-5.4	9.6	9.3	8.1
$\sigma^{cap} gr. 8$	-0.5	-6.9	10.5	10.1	8.3
$\sigma^{cap} gr. 9$	-0.5	-6.7	9.9	9.5	7.7
$\sigma^{cap} gr. 10$	-0.5	-5.7	9.2	8.8	7.5
$\sigma^{cap} gr. 7$	2.4	11.9	25.2	24.9	23.5
$\sigma^{cap} gr. 8$	2.4	12.2	25.2	24.9	23.3

ABR Ox. Uncertainty on K_{eff} (pcm)

Original Covariance

Adjusted Covariance 20 Exp.

Isotope	σ_{cap}	σ_{fiss}	ν	σ_{el}	σ_{inel}	χ	P_1^{el}	Total	Isotope	σ_{cap}	σ_{fiss}	ν	σ_{el}	σ_{inel}	χ	P_1^{el}	Total
U238	278	29	112	105	547	0	0	633	U238	-67	-9	-58	-30	-92	0	0	-132
PU239	308	223	71	30	79	161	0	428	PU239	107	58	26	11	26	-25	0	125
FE56	170	0	0	172	147	0	44	287	FE56	122	0	0	124	99	0	39	204
PU240	61	45	82	5	17	24	0	116	PU240	27	23	25	3	11	4	0	45
NA23	4	0	0	20	80	0	69	107	NA23	6	0	0	12	27	0	26	40
CR52	21	0	0	38	18	0	0	47	CR52	21	0	0	30	9	0	0	38
O16	5	0	0	45	2	0	0	46	O16	5	0	0	44	2	0	0	45
PU241	10	7	3	0	2	0	0	13	PU241	10	7	4	0	2	0	0	13
Total	453	229	156	213	578	163	82	834	Total	153	62	-46	133	54	-25	46	217

Adjusted Covariance 21 Exp.

Isotope	σ_{cap}	σ_{fiss}	ν	σ_{el}	σ_{inel}	χ	P_1^{el}	Total
U238	-55	3	-52	-29	-96	0	0	-125
PU239	119	61	27	12	28	-35	0	135
FE56	87	0	0	84	105	0	30	164
PU240	31	25	31	4	12	-2	0	51
NA23	6	0	0	-8	21	0	50	54
CR52	13	0	0	24	10	0	0	29
O16	5	0	0	30	2	0	0	31
PU241	10	7	4	0	2	0	0	13
Total	141	66	-31	89	59	-35	59	192

FBR Uncertainty on K_{eff} (pcm)

Original Covariance

Isotope	σ_{cap}	σ_{fiss}	ν	σ_{el}	σ_{inel}	χ	P_1^{el}	Total
U238	310	39	145	182	796	0	0	886
PU239	230	179	56	25	66	153	0	341
PU240	126	108	194	13	43	69	0	268
FE56	87	0	0	64	107	0	17	153
PU241	94	61	37	1	19	0	0	119
PU242	88	37	31	2	5	0	0	101
NA23	3	0	0	16	85	0	68	110
O16	7	0	0	36	3	0	0	37
Total	434	225	253	199	812	168	71	1017

Adjusted Covariance 20 Exp.

Isotope	σ_{cap}	σ_{fiss}	ν	σ_{el}	σ_{inel}	χ	P_1^{el}	Total
U238	46	15	38	17	57	0	0	85
PU239	-52	-49	-8	4	15	-62	0	-93
PU240	95	72	111	14	48	40	0	175
FE56	34	0	0	18	34	0	11	52
PU241	93	61	37	1	22	0	0	120
PU242	88	37	31	2	5	0	0	101
NA23	5	0	0	-9	36	0	36	50
O16	7	0	0	25	3	0	0	26
Total	162	90	126	37	93	-47	37	244

Adjusted Covariance 21 Exp.

Isotope	σ_{cap}	σ_{fiss}	ν	σ_{el}	σ_{inel}	χ	P_1^{el}	Total
U238	43	15	35	17	58	0	0	84
PU239	-54	-49	-8	4	14	-61	0	-94
PU240	95	72	110	14	48	40	0	174
FE56	38	0	0	28	32	0	8	57
PU241	93	61	37	1	22	0	0	120
PU242	88	37	31	2	5	0	0	101
NA23	5	0	0	-10	37	0	32	48
O16	7	0	0	27	3	0	0	28
Total	161	90	125	44	94	-46	33	243

Conclusions

- The stress test using ZPR9-34 experiment was successfully carried out.
- Even though the initial discrepancy on the C/E was quite significant (~900 pcm) the adjustment was able to obtain a very good agreement with almost no impact on the χ^2 test obtained using 20 experiments.
- The cross sections that were more affected were those of Fe56 and U235.
- The impact on the uncertainty reduction of the targeted reactor design was negligible; however, the reduction on the ZPR9-34 experiment uncertainty due to cross sections was quite remarkable (almost a factor 20).