PAUL SCHERRER INSTITUT

Wir schaffen Wissen – heute für morgen

SG39 kick-off meeting on November 28-29 at NEA Paris

Paul Scherrer Institut

Sandro Pelloni

SG33 benchmark: Comparative adjustment results for JEFF-3.1/COMMARA-2.0 and ENDF/B-VI.8/BOLNA

PAUL SCHERRER INSTITUT

Methodology

The deterministic code system **ERANOS (Edition 2-2.N)** is thoroughly used.

In addition to the original SG33 benchmark specifications, the current simulations were chosen to make use of a well defined route for analyzing typical, **Superphénix-like sodium-cooled configurations:**
The one- and two-dimensional, finite difference, **discrete-ordinates transport-theory code BISTRO** has been used in conjunction with **P_1S_{16} approximations** for direct and adjoint calculations, and this on the basis of **33 neutron group** cross-sections and **mesh sizes of less than 1mm** .

Because ENDF/B-VII data is not part of the current ERANOS package, the reference case adjustment was performed in conjunction with JEFF-3.1 cross-sections (**JEFF-3.1/COMMARA-2.0**). The additional consideration of a 15 group subset of the 33 groups on the one hand allows comparing COMMARA-2.0 with BOLNA before and after adjustment. The use of ENDF/B-VI.8 instead of JEFF-3.1 cross-sections in the calculations with BOLNA (**ENDF/B-VI.8/BOLNA**) makes it also possible, on the other hand, to investigate on a consistent basis the effect of the adjustment on different prior data sets.

Why excluding k_{eff} for FLATTOP-Pu from the current adjustment

Deterministic transport-theory results obtained using 175 broad group cross-sections.

P_5S_{100}: consistent with stochastic *C/E* values from SERPENT-2 (continuous energy Monte Carlo).

Core	Parameter	Experiental error, *E* (%)	Prior *C/E* ($\mathbf{S_{16}}$) Anisotropic scattering P_5	P_3	$\mathbf{P_1}$	Prior *C/E* $\mathbf{P_5S_{100}}$
Flattop-Pu	k_{eff}	0.300	1.001	0.999	**0.982**	**0.999**
	F28/F25	1.100	0.990	0.987	0.968	0.989
	F37/F25	1.400	1.015	1.014	1.003	1.014
Jezebel-Pu239	k_{eff}	0.200	1.000	1.000	0.993	0.998
	F28/F25	1.100	0.984	0.984	0.974	0.984
	F49/F25	0.900	0.984	0.984	0.983	0.984
	F37/F25	1.400	1.004	1.004	1.000	1.004
Jezebel-Pu240	k_{eff}	0.200	1.004	1.004	0.997	1.002
Godiva	k_{eff}	0.100	0.997	0.997	0.992	0.995
	F28/F25	1.096	0.958	0.958	0.950	0.957
	F49/F25	0.989	0.981	0.981	0.980	0.981
	F37/F25	1.409	0.978	0.978	0.975	0.978

The analytical modeling error in the case of k_{eff} for FLATTOP-Pu would be too large. For this parameter, the difference between 33 and 175 group results is much smaller as compared to the effect of using higher order of anisotropy than P_1.

ZPPR9: A typical sodium-cooled core with blankets.

Approximation→	$\mathbf{P_1S_{16}}$	P_1S_8	P_3S_{16}	P_5S_{16}
Experiment↓	Prior *C/E*			
k_{eff}	1.000	1.000	1.000	1.000
F28/F25	0.964	0.963	0.963	0.963
Central Na-void	1.062	1.060	1.059	1.059
Large Na-void	0.989	0.987	0.986	0.986

C/Es

JEFF-3.1/COMMARA-2.0

Core	Experiment	(a)	Prior	Posterior	
			ERANOS	ERANOS	GLLS
Jezebel-Pu239	k_{eff}	0.200	**0.993**	**0.997**	**0.997**
	F28/F25	1.100	**0.956**	**0.991**	**0.991**
	F49/F25	0.900	0.983	0.998	0.998
	F37/F25	1.400	0.990	1.007	1.007
Jezebel-Pu240	k_{eff}	0.200	**0.997**	1.000	1.001
Flattop-Pu	*F28/F25*	1.100	**0.951**	**0.964**	**0.980**
	F37/F25	1.400	0.993	0.999	1.008
ZPR6-7	k_{eff}	0.251	1.003	1.004	1.002
	F28/F25	3.173	0.965	0.989	0.991
	F49/F25	2.342	1.020	1.027	1.028
	C28/F25	2.614	1.004	1.011	1.011
ZPR6-7 Pu240	k_{eff}	0.241	1.002	1.001	1.001
ZPPR9	k_{eff}	0.153	1.001	1.000	1.000
	F28/F25	2.875	0.962	0.988	0.988
	F49/F25	2.230	0.982	0.989	0.989
	C28/F25	2.141	0.996	1.003	1.003
	Central Na-void	4.188	1.059	1.045	1.045
	Large Na-void	4.113	**1.002**	0.990	**0.990**
JOYO	k_{eff}	0.206	0.997	1.001	1.000

ENDF/BVI.8/BOLNA

Core	Experiment	(a)	Prior	Posterior	
			ERANOS	ERANOS	GLLS
Jezebel-Pu239	k_{eff}	0.200	0.990	**0.995**	**0.996**
	F28/F25	1.100	**0.935**	**0.989**	**0.987**
	F49/F25	0.900	0.972	0.997	0.997
	F37/F25	1.400	0.951	0.981	0.980
Jezebel-Pu240	k_{eff}	0.200	**0.990**	1.000	1.000
Flattop-Pu	*F28/F25*	1.100	**0.940**	**0.967**	**0.981**
	F37/F25	1.400	0.971	0.987	0.993
ZPR6-7	k_{eff}	0.250	1.006	1.001	1.001
	F28/F25	3.173	0.999	0.988	0.987
	F49/F25	2.342	1.029	1.039	1.039
	C28/F25	2.614	1.007	1.019	1.019
ZPR6-7 Pu240	k_{eff}	0.241	1.005	1.001	1.000
ZPPR9	k_{eff}	0.153	1.007	1.001	1.001
	F28/F25	2.875	1.013	0.988	0.987
	F49/F25	2.230	0.992	1.000	1.000
	C28/F25	2.141	0.999	1.012	1.012
	Central Na-void	3.843	1.152	1.050	1.048
	Large Na-void	3.679	**1.134**	1.014	**1.011**
JOYO	k_{eff}	0.206	0.992	1.001	1.000

(a) Combination of experimental and calculation uncertainties of the prior *C/E*s (%).

Posterior GLLS: Adjustment made on the basis of the JAEA methodology.
Posterior ERANOS: Explicit ERANOS recalculations on the basis of GLLS adjusted microscopic cross-sections and variance/covariance data.

Nuclear data uncertainties (%)

Core	Experiment	Prior	Posterior	
		ERANOS	GLLS	ERANOS
Jezebel-Pu239	k_{eff}	0.526	0.159	0.174
	F28/F25	2.345	0.770	0.622
	F49/F25	0.715	0.429	0.433
	F37/F25	1.656	0.629	0.512
Jezebel-Pu240	k_{eff}	0.587	0.178	0.189
Flattop-Pu	*F28/F25*	1.842	0.610	0.544
	F37/F25	1.372	0.598	0.540
ZPR6-7	k_{eff}	0.972	0.136	0.195
	F28/F25	6.484	1.609	1.637
	F49/F25	0.845	0.566	0.580
	C28/F25	1.496	0.941	0.933
ZPR6-7 Pu240	k_{eff}	0.973	0.137	0.187
ZPPR9	k_{eff}	1.203	0.136	0.179
	F28/F25	8.064	1.901	1.884
	F49/F25	0.881	0.560	0.571
	C28/F25	1.530	0.949	0.942
	Central Na-void	7.219	2.445	2.475
	Large Na-void	9.145	2.942	3.010
JOYO	k_{eff}	0.878	0.198	0.203

JEFF-3.1/COMMARA-2.0

Core	Experiment	Prior	Posterior	
		ERANOS	GLLS	ERANOS
Jezebel-Pu239	k_{eff}	0.645	0.165	0.178
	F28/F25	2.814	0.791	0.704
	F49/F25	0.771	0.451	0.432
	F37/F25	1.925	0.641	0.511
Jezebel-Pu240	k_{eff}	0.739	0.185	0.188
Flattop-Pu	*F28/F25*	2.137	0.624	0.593
	F37/F25	1.629	0.614	0.516
ZPR6-7	k_{eff}	1.008	0.137	0.151
	F28/F25	5.925	1.737	1.805
	F49/F25	0.826	0.573	0.586
	C28/F25	2.191	1.095	1.141
ZPR6-7 Pu240	k_{eff}	1.018	0.148	0.158
ZPPR9	k_{eff}	1.180	0.137	0.136
	F28/F25	7.317	1.982	1.977
	F49/F25	0.877	0.583	0.597
	C28/F25	2.254	1.118	1.172
	Central Na-void	7.396	2.436	2.453
	Large Na-void	9.283	2.994	3.008
JOYO	k_{eff}	1.301	0.203	0.212

ENDF/BVI.8/BOLNA

Posterior GLLS: Adjustment made on the basis of the JAEA methodology.
Posterior ERANOS: Explicit ERANOS recalculations on the basis of GLLS adjusted microscopic cross-sections and variance/covariance data.

PAUL SCHERRER INSTITUT

Comparison with the original SG33 adjustment results of PSI

Core	Experiment	Prior		Posterior	
		Original	Current	Original	Current
Jezebel-Pu239	k_{eff}	0.999	0.993	0.999	0.997
	F28/F25	0.982	0.956	0.993	0.991
	F49/F25	0.985	0.983	0.989	0.998
	F37/F25	1.000	0.990	1.004	1.007
Jezebel-Pu240	k_{eff}	1.004	0.997	1.001	1.000
Flattop-Pu	*F28/F25*	0.986	0.951	0.996	0.964
	F37/F25	1.007	0.993	1.010	0.999
ZPR6-7	k_{eff}	1.001	1.003	1.001	1.004
	F28/F25	1.004	0.965	1.022	0.989
	F49/F25	0.959	1.020	0.965	1.027
	C28/F25	1.005	1.004	1.006	1.011
ZPR6-7 Pu240	k_{eff}	1.001	1.002	1.001	1.001
ZPPR9	k_{eff}	1.000	1.001	1.000	1.000
	F28/F25	0.961	0.962	0.978	0.988
	F49/F25	0.976	0.982	0.981	0.989
	C28/F25	1.004	0.996	1.006	1.003
	Central Na-void	1.029	1.059	1.037	1.045
	Large Na-void	0.973	1.002	0.994	0.990
JOYO	k_{eff}	0.999	0.997	0.999	1.001

C/Es

Core	Experiment	Prior		Posterior	
		Original	Current	Original	Current
Jezebel-Pu239	k_{eff}	0.511	0.526	0.182	0.159
	F28/F25	2.426	2.345	1.148	0.770
	F49/F25	0.719	0.715	0.512	0.429
	F37/F25	1.421	1.656	0.784	0.629
Jezebel-Pu240	k_{eff}	0.579	0.587	0.198	0.178
Flattop-Pu	*F28/F25*	1.948	1.842	0.918	0.610
	F37/F25	1.421	1.372	0.784	0.598
ZPR6-7	k_{eff}	0.972	0.972	0.139	0.136
	F28/F25	6.399	6.484	1.600	1.609
	F49/F25	0.833	0.845	0.586	0.566
	C28/F25	1.493	1.496	0.950	0.941
ZPR6-7 Pu240	k_{eff}	0.973	0.973	0.140	0.137
ZPPR9	k_{eff}	1.203	1.203	0.144	0.136
	F28/F25	7.741	8.064	1.792	1.901
	F49/F25	0.846	0.881	0.579	0.560
	C28/F25	1.521	1.530	0.959	0.949
	Central Na-void	7.228	7.219	2.867	2.445
	Large Na-void	9.157	9.145	3.369	2.942
JOYO	k_{eff}	0.878	0.878	0.199	0.198

Nuclear data uncertainties (%)

JEFF-3.1/COMMARA-2.0

The difference between adjusted *C/Es* in most cases is smaller than the difference between prior values, whereas the prior and posterior uncertainties are rather similar.

Discussion

When using JEFF-3.1 cross-sections,
the current prior analytical values indicate an underestimate by over three standard deviations for k_{eff} in the case of Jezebel (^{239}Pu configuration);
F28/F25 is under predicted with an error of four standard deviations in the cases of Jezebel (^{239}Pu configuration) and Flattop (Pu configuration).

In comparison, ENDF/B-VI.8 leads to less accurate predictions especially for the effective multiplication of Jezebel (^{240}Pu configuration) and for the reactivity effect resulting from the large sodium void in ZPPR9.

Despite these different prior values, the posterior analytical values obtained by means of ENDF/B-VI.8/BOLNA are close to the corresponding JEFF-3.1/COMMARA-2.0 values in the sense that their discrepancy is smaller than or in the worst case close to be equal to the combination of experimental and calculation uncertainty.
The posterior cross-sections, however, might be quite different, indicating compensating effects.

By analyzing nuclear data uncertainties, we notice a clear decrease due to the adjustment, consistent with the overall SG33 results in which the larger fraction of this reduction could be attributed to the cross correlation terms originating from the adjustment.

The posterior ENDF/B-VI.8/BOLNA uncertainties are rather consistent with the corresponding JEFF-3.1/COMMARA-2.0 values, whereas the prior values might deviate more strongly.