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Use of Recent Covariances in Fast Reactor Studies

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Introduction

Under the Fast Reactor Campaign of Global Nuclear Energy Partnership, work (in collaboration with INL, LANL and BNL) was initiated to improve the nuclear data by a combined use of the science-based covariance data and integral experiments.

- **The purpose of this activity is to precisely account for existing integral experiment data to reduce the uncertainty of reactor performance predictions.**

- **For the initial phase of study, the equilibrium cycle metal and oxide core configurations of a reference 1000 MWt Advanced Burner Reactor (ABR) were selected as the tentative target systems.**

Selected Experiments

Main Features of the Investigated Systems.

	Fuel Type	Coolant	Core Volume [liters]	% Pu in (U+Pu+MA)	% Pu239 in Pu	% MA[(a)] in (U+Pu+MA)	Blanket	Reflector
ZPR3 Assembly 53	Carbide		226	40	93	-	Yes	No
ZPR3 Assembly 54	Carbide		197	40	93	-	No	Yes
ZPPR-2	Oxide	Na	2407	15 - 22 [(b)]	87 - 87 [(b)]	0.04 - 0.06 [(b)]	Yes	Yes
ZPPR-9	Oxide	Na	4599	11 - 16 [(b)]	87 - 87 [(b)]	0.07 - 0.10 [(b)]	Yes	Yes
ZPPR-15A	Metal	Na	2505	12 - 18 [(b)]	87 - 87 [(b)]	0.12 - 0.18 [(b)]	Yes	Yes
ZPR6 Assembly 6A	Oxide	Na	3990	-	-	-	Yes	No
ZPR6 Assembly 7	Oxide	Na	3120	15 - 15 [(b)]	87 - 87 [(b)]	0.04 - 0.04 [(b)]	Yes	No
CIRANO/ZONA2A	Oxide	Na	477	27 - 25 [(b)]	79 - 92 [(b)]	0.73 - 0.07 [(b)]	Yes	No
CIRANO/ZONA2A3	Oxide	Na	425	27	79	0.73	Yes	Yes
CIRANO/ZONA2B	Oxide	Na	388	27	79	0.73	No	Yes
MUSE-4	Oxide	Na	477	27	79	0.85	No	Yes
COSMO	Oxide	Na	396	27	79	0.75	No	Yes
GODIVA	Metal		2.8	-	-	-	No	No
BIGTEN	Metal		64	-	-	-	No	Yes
Pu239 JEZEBEL	Metal		1.1	100	95	-	No	No
Pu240 JEZEBEL	Metal		1.2	100	76	-	No	No
U233 JEZEBEL	Metal		0.9	-	-	-	No	No
FLATTOP Pu	Metal		0.4	100	95	-	No	Yes
FLATTOP U235	Metal		1.0	-	-	-	No	Yes
FLATTOP U233	Metal		0.5	-	-	-	No	Yes
ABR Metal Core	Metal	Na	3532	17 - 22 [(b)]	54 - 52 [(b)]	1.5 - 2.2 [(b)]	No	Yes
ABR Oxide Core	Oxide	Na	4730	21 - 23 - 33 [(c)]	47 - 46 - 46 [(c)]	2.2 - 2.4 - 4.1 [(c)]	No	Yes

[(a)] MA: Minor Actinides (Np, Am, Cm isotopes); [(b)] Inner Core - Outer Core; [(c)] Inner Core - Middle Core - Outer Core

The approach and theoretical background

Integral experiments play an essential role in the reduction of design uncertainties related to reactor neutronics calculations. For this purpose, it is recommended that the proposed experiment shows neutronics features similar to those of the calculated reactor.

- **A quantitative and synthetic measure on which to judge the relevance of selected experiments to the ABR systems can be based on the "representativity" concept. The approach uses a sensitivity methodology associated with selected integral parameters and based on the Generalized Perturbation Theory (GPT).**

- **To carry out a representativity study, sensitivity coefficients have to be first calculated for the selected integral parameters:**

$$S = \frac{dP}{P} \Big/ \frac{d\sigma}{\sigma}$$

$\sigma = \sigma_x$ with x = isotope, energy group, cross-section type.

The approach and theoretical background

Sensitivity studies using Generalized Perturbation Theory (GPT).

- Uncertainty assessment;
- Representativity analysis.

Using the sensitivity coefficients, S_R, for each integral parameter P of the reactor R under study and the covariance matrix D, the uncertainty on the integral parameter P can be evaluated:

$$I_R^2 = S_R^+ D S_R$$

An integral experiment can be conceived in order to reduce the uncertainty I_R^2 . If S_E is the sensitivity matrix associated with this experiment, a "representativity factor" defined as:

$$r_{RE} = \frac{\left(S_R^+ D S_E\right)}{\left[\left(S_R^+ D S_R\right)\left(S_E^+ D S_E\right)\right]^{1/2}}$$

can be introduced to quantify the similarity between the reactor and the selected experiment.

It can be shown that the uncertainty on the reference parameter P is reduced by: $I_R'^{\,2} = I_R^2 \cdot \left(1 - r_{RE}^2\right)$

- From this expression it is clear that the experiment should be conceived in such a way that the sensitivity matrices S_E and S_R are as similar as possible, i.e. r_{RE}^2 should be as close to 1 as possible.

Representativity of Combined Experiments

In the case of two experiments, characterized by sensitivity matrices S_{E_1} and S_{E_2} the following expression can be derived:

$$\left(I_R^2\right)' = I_R^2 \cdot (1 - r_{RE_1E_2}^2) = I_R^2 \cdot \left[1 - \frac{\left(r_{RE_1} - r_{RE_2}\right)^2}{1 - r_{E_1E_2}^2} - \frac{2 r_{RE_1} r_{RE_2}}{1 + r_{E_1E_2}}\right]$$

where $r_{RE_1E_2}$ is the representativity factor with the two experiments combined, and:

$$r_{E_1E_2} = \frac{\left(S_{E_1}^+ DS_{E_2}\right)}{\left[\left(S_{E_1}^+ DS_{E_1}\right)\left(S_{E_2}^+ DS_{E_2}\right)\right]^{1/2}}$$

$$r_{RE_1} = \frac{\left(S_R^+ DS_{E_1}\right)}{\left[\left(S_R^+ DS_R\right)\left(S_{E_1}^+ DS_{E_1}\right)\right]^{1/2}}$$

$$r_{RE_2} = \frac{\left(S_R^+ DS_{E_2}\right)}{\left[\left(S_R^+ DS_R\right)\left(S_{E_2}^+ DS_{E_2}\right)\right]^{1/2}}$$

Computational tools

- Three response parameters are considered: the core multiplication factor, spectral index of U238 fission to Pu239 fission at the core center, and coolant void reactivity worth. For the spectral indices, only the indirect effect of the sensitivity coefficients has been considered, since the direct effect, which essentially dominates the sensitivity profiles with the U238 and Pu239 fission reaction, is of a minor interest.

- For the present analysis, cross-sections were generated using the MC^2-2 code and the ENDF/B-VII nuclear data in a 33 energy group structure. Sensitivity coefficient calculations were performed in diffusion theory using the VARI3D code. Flux, adjoint flux, and generalized adjoint flux were calculated with the finite difference diffusion theory option of the DIF3D code. Previous studies demonstrated that for the kind of systems under investigation, the transport and diffusion approaches show generally non-negligible differences in the parameter calculated values, but no significant difference is observed on the sensitivity coefficients.

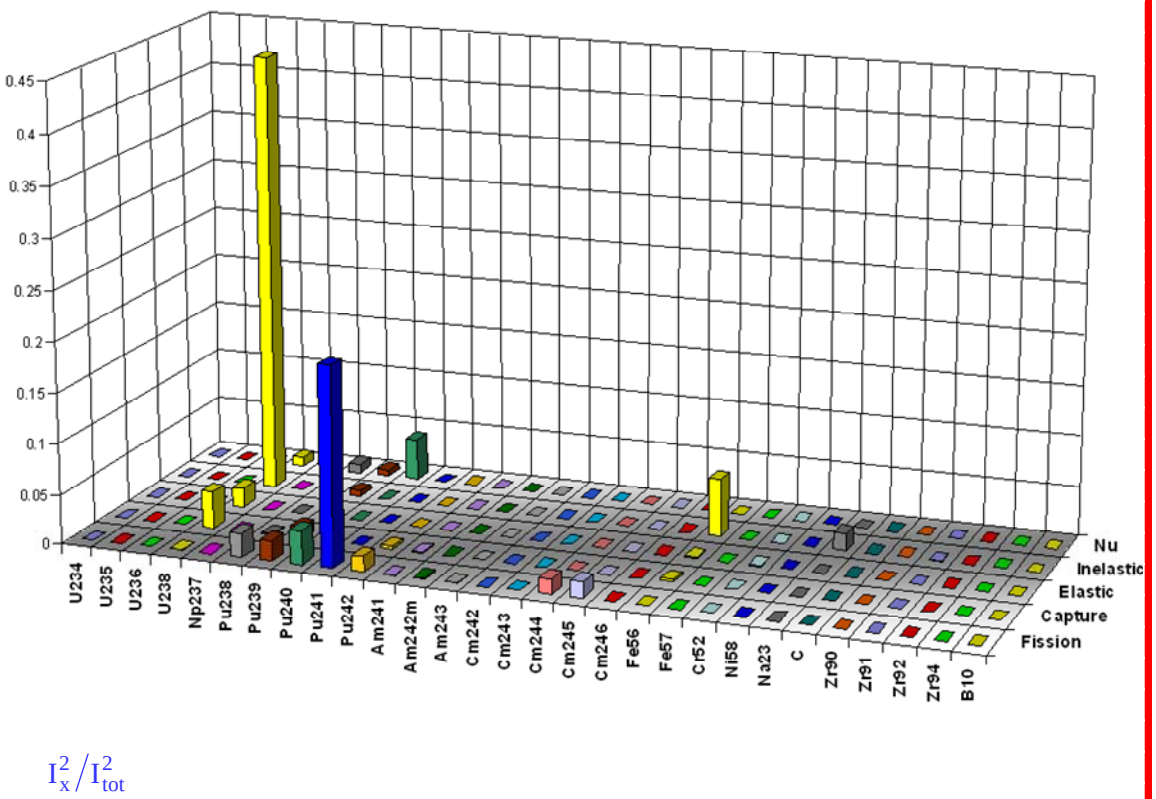
"Diagonal" and "Full BOLNA" Total Uncertainties. Values are in %.

	k_{eff}		$\frac{\langle \sigma_{fiss,U238} \Phi \rangle}{\langle \sigma_{fiss,Pu239} \Phi \rangle}$		Coolant Void Worth	
	Diagonal	Full	Diagonal	Full	Diagonal	Full
ZPR3-53	0.70	0.88	2.22	3.13	-	-
ZPR3-54	0.87	1.15	2.27	3.28	-	-
ZPPR2	0.70	0.92	4.71	5.90	172.34	212.55
ZPPR9	0.92	1.25	5.58	7.18	10.22	13.32
ZPPR15A	0.72	1.00	5.18	6.10	8.18	9.66
ZPR6-6A	1.23	2.39	-	-	9.58	10.46
ZPR6-7	0.78	1.04	4.65	5.81	79.92	104.50
ZONA2A	0.66	0.90	3.74	4.91	8.92	10.41
ZONA2A3	0.58	0.80	3.70	4.88	7.17	8.45
ZONA2B	0.53	0.74	3.66	4.83	5.99	7.13
MUSE-4	0.52	0.73	3.68	4.82	6.64	8.00
COSMO	0.53	0.74	3.68	4.87	6.33	7.53
GODIVA	0.64	1.23	-	-	-	-
BIGTEN	1.68	2.44	-	-	-	-
Pu239 JEZEBEL	0.41	0.44	-	-	-	-
Pu240 JEZEBEL	0.53	0.66	-	-	-	-
U233 JEZEBEL	2.36	4.49	-	-	-	-
FLATTOP Pu	0.49	0.54	-	-	-	-
FLATTOP U235	0.79	1.48	-	-	-	-
FLATTOP U233	2.72	5.30	-	-	-	-
ABR Metal Core	0.95	1.47	5.19	6.33	10.94	13.10
ABR Oxide Core	0.95	1.44	4.75	5.47	6.66	7.82

Uncertainty profiles

"Full BOLNA" Uncertainties (%) for k_{eff} of ABR Metal Fuel.

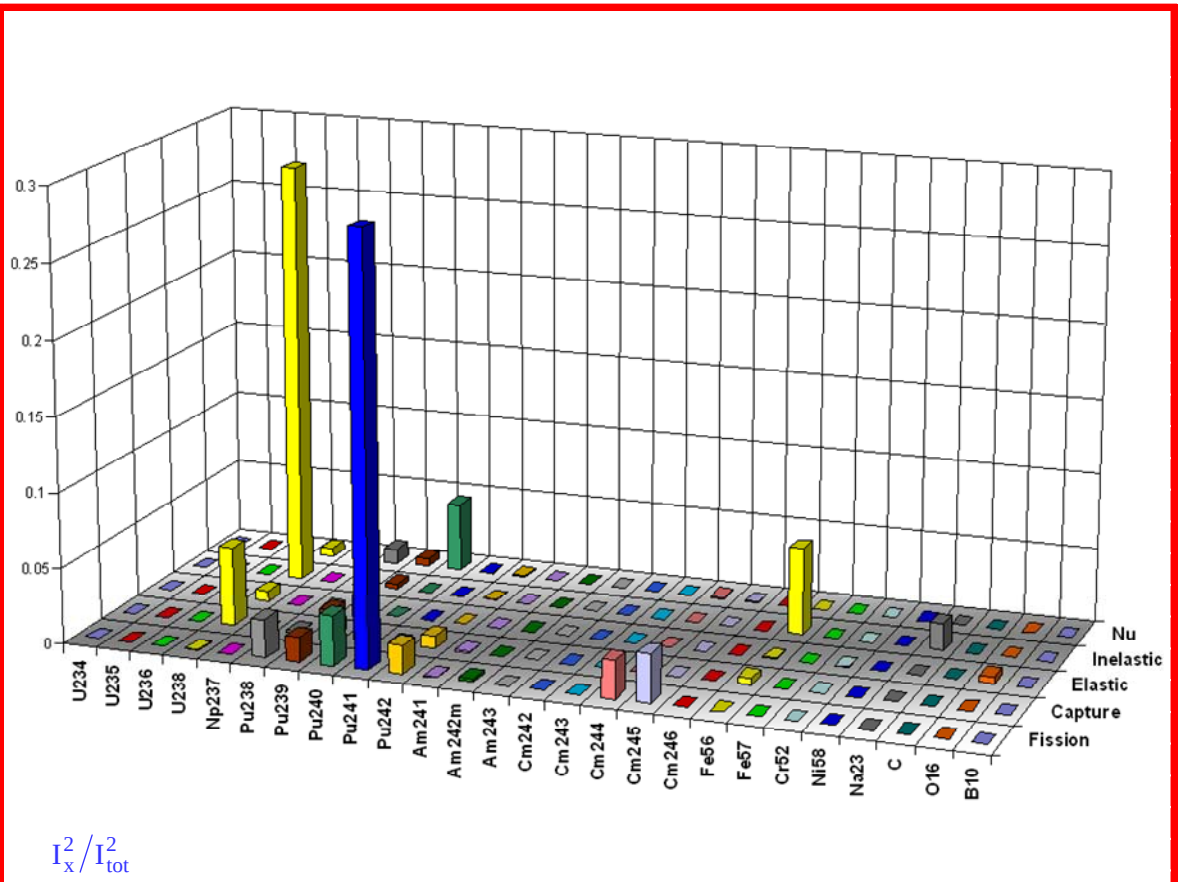
Isotope	σ_{fiss}	σ_{capt}	σ_{el}	σ_{inel}	ν	Total
U234	-	-	-	-	-	-
U235	-	0.01	-	-	-	0.01
U236	-	-	-	-	-	-
U238	0.04	0.28	0.21	0.97	0.14	1.04
Np237	0.02	0.01	-	0.01	-	0.02
Pu238	0.22	0.03	-	-	0.13	0.26
Pu239	0.21	0.16	0.03	0.11	0.11	0.31
Pu240	0.27	0.20	0.01	0.01	0.30	0.45
Pu241	0.65	0.03	-	0.01	0.02	0.65
Pu242	0.18	0.07	-	0.02	0.04	0.20
Am241	0.04	0.03	-	0.01	0.01	0.05
Am242m	0.05	-	-	-	-	0.05
Am243	0.02	0.02	-	0.02	0.01	0.03
Cm242	0.01	-	-	-	-	0.01
Cm243	0.01	-	-	-	-	0.01
Cm244	0.18	0.02	-	-	0.03	0.18
Cm245	0.18	0.01	-	-	0.02	0.19
Cm246	0.02	-	-	-	-	0.02
Fe56	-	0.07	0.05	0.35	-	0.36
Fe57	-	-	-	0.01	-	0.01
Cr52	-	0.01	0.04	0.01	-	0.04
Ni58	-	-	-	-	-	-
Na23	-	-	0.01	0.19	-	0.19
C	-	-	-	-	-	-
Zr90	-	0.01	0.01	0.04	-	0.04
Zr91	-	0.01	-	0.01	-	0.01
Zr92	-	0.01	-	0.02	-	0.02
Zr94	-	0.01	-	0.03	-	0.03
B10	-	-	0.01	-	-	0.01
Total	0.83	0.40	0.22	1.06	0.38	1.47



Uncertainty profiles

"Full BOLNA" Uncertainties (%) for k_{eff} of ABR Oxide Fuel.

Isotope	σ_{fiss}	σ_{capt}	σ_{el}	σ_{inel}	ν	Total
U234	-	-	-	-	-	-
U235	-	0.01	-	-	-	0.01
U236	-	-	-	-	-	-
U238	0.03	0.33	0.12	0.76	0.11	0.85
Np237	0.01	0.01	-	-	-	0.02
Pu238	0.23	0.05	-	0.01	0.14	0.27
Pu239	0.18	0.19	0.02	0.09	0.11	0.30
Pu240	0.26	0.25	0.01	0.01	0.31	0.48
Pu241	0.77	0.04	-	-	0.03	0.77
Pu242	0.20	0.13	-	0.02	0.04	0.24
Am241	0.05	0.05	-	0.01	0.01	0.07
Am242m	0.06	-	-	-	-	0.06
Am243	0.02	0.03	-	0.02	0.01	0.04
Cm242	0.01	-	-	-	-	0.01
Cm243	0.01	-	-	-	-	0.01
Cm244	0.23	0.03	-	-	0.05	0.24
Cm245	0.26	0.02	-	-	0.02	0.26
Cm246	0.03	0.01	-	-	-	0.03
Fe56	-	0.09	0.04	0.35	-	0.36
Fe57	-	0.01	-	0.01	-	0.01
Cr52	-	0.01	0.02	0.01	-	0.02
Ni58	-	-	-	-	-	-
Na23	-	-	0.02	0.19	-	0.19
C	-	-	-	-	-	-
O16	-	-	0.10	0.03	-	0.10
B10	-	-	-	-	-	-
Total	0.96	0.49	0.16	0.86	0.38	1.44



Uncertainty Analysis

Main Cross-Section Contributors to k_{eff} "Full BOLNA" Uncertainty. Values are in %.

	ZPR3-53	ZPR3-54	ZPPR-2	ZPPR-9	ZPPR-15A	ZPR6-6A	ZPR6-7	CIRANO ZONA2A	CIRANO ZONA2A3	CIRANO ZONA2B	MUSE-4	COSMO	ABR Metal Core	ABR Oxide Core
Total [a]	**0.88**	**1.15**	**0.92**	**1.25**	**1.00**	**2.39**	**1.04**	**0.90**	**0.80**	**0.74**	**0.73**	**0.74**	**1.47**	**1.44**
U235 σ_{capt}	- [b]	-	-	-	-	2.18	-	-	-	-	-	-	-	-
U235 ν	-	-	-	-	-	0.55	-	-	-	-	-	-	-	-
U238 σ_{capt}	0.29	0.17	0.46	0.56	0.43	0.59	0.51	0.30	0.26	0.21	0.22	0.21	0.28	0.33
U238 σ_{el}	0.30	-	0.23	0.25	0.28	-	0.26	0.27	0.21	0.16	0.15	0.16	0.21	0.12
U238 σ_{inel}	0.13	0.12	0.55	0.96	0.68	0.37	0.69	0.33	0.32	0.31	0.33	0.32	0.97	0.76
U238 ν	0.13	-	0.14	0.17	0.15	-	0.15	0.13	0.12	0.11	0.11	0.11	0.14	0.11
Pu238 σ_{fiss}	-	-	-	-	-	-	-	-	-	-	-	-	0.22	0.23
Pu239 σ_{fiss}	0.22	0.25	0.24	0.23	0.25	-	0.23	0.22	0.23	0.23	0.23	0.23	0.21	0.18
Pu239 σ_{capt}	0.54	0.61	0.31	0.29	0.25	-	0.31	0.27	0.27	0.27	0.28	0.27	0.16	0.19
Pu239 ν	0.12	0.13	0.14	0.14	0.14	-	0.14	0.13	0.12	0.12	0.13	0.13	0.11	0.11
Pu240 σ_{fiss}	-	-	0.06	-	0.07	-	-	0.12	0.13	0.13	0.14	0.13	0.27	0.26
Pu240 σ_{capt}	-	-	0.07	-	-	-	-	0.11	0.12	0.12	0.12	0.12	0.20	0.25
Pu240 ν	-	-	0.07	-	0.08	-	-	0.15	0.15	0.16	0.16	0.16	0.30	0.31
Pu241 σ_{fiss}	-	-	0.14	0.10	0.08	-	0.12	0.16	0.17	0.17	0.11	0.10	0.65	0.77
Pu242 σ_{fiss}	-	-	-	-	-	-	-	-	-	-	-	-	0.18	0.20
Cm244 σ_{fiss}	-	-	-	-	-	-	-	-	-	-	-	-	0.18	0.23
Cm245 σ_{fiss}	-	-	-	-	-	-	-	-	-	-	-	-	0.18	0.26
Fe56 σ_{el}	-	0.28	-	-	-	-	-	0.06	0.10	0.13	0.13	0.13	-	-
Fe56 σ_{inel}	-	0.09	0.15	0.16	0.26	-	0.16	0.07	0.07	0.07	0.07	0.07	0.35	0.35
Na23 σ_{inel}	-	-	0.08	0.11	0.09	-	0.10	-	-	-	0.03	-	0.19	0.19
C σ_{el}	0.45	0.84	-	-	-	-	-	-	-	-	-	-	-	
O16 σ_{el}	-	-	0.13	-	-	-	-	0.52	0.39	0.29	0.25	0.29	-	0.10

[a] Overall uncertainty (this is not the total of the components listed in the table);
[b] Uncertainty component null or not important;

Main Cross-Section Contributors to k_{eff} "Full BOLNA" Uncertainties. Values are in %. (Con't)

	GODIVA	BIGTEN	Pu239 JEZEBEL	Pu240 JEZEBEL	U233 JEZEBEL	FLATTOP Pu	FLATTOP U235	FLATTOP U233
Total	**1.23**	**2.44**	**0.44**	**0.66**	**4.49**	**0.54**	**1.48**	**5.30**
U233 σ_{fiss}	-	-	-	-	4.44	-	-	5.22
U233 σ_{inel}	-	-	-	-	0.60	-	-	0.81
U234 σ_{fiss}	0.14	-	-	-	-	-	0.13	-
U235 σ_{fiss}	0.26	0.21	-	-	-	-	0.27	-
U235 σ_{capt}	0.99	1.23	-	-	-	-	1.29	-
U235 σ_{el}	0.11	-	-	-	-	-	-	-
U235 σ_{inel}	0.32	-	-	-	-	-	0.27	-
U235 ν	0.56	0.44	-	-	-	-	0.59	-
U238 σ_{capt}	-	0.33	-	-	-	-	-	-
U238 σ_{el}	-	0.73	-	-	-	0.19i	0.13i	-
U238 σ_{inel}	-	1.87	-	-	-	0.29	0.20	-
U238 ν	-	0.30	-	-	-	-	-	-
Pu239 σ_{fiss}	-	-	0.35	0.29	-	0.37	-	-
Pu239 σ_{capt}	-	-	0.09	0.08	-	0.15	-	-
Pu239 σ_{el}	-	-	0.20i	0.11i	-	0.18i	-	-
Pu239 σ_{inel}	-	-	0.30	0.15	-	0.30	-	-
Pu239 ν	-	-	0.09	0.08	-	0.11	-	-
Pu240 σ_{fiss}	-	-	0.07	0.32	-	0.07	-	-
Pu240 σ_{capt}	-	-	-	0.05	-	-	-	-
Pu240 σ_{el}	-	-	-	0.04	-	-	-	-
Pu240 ν	-	-	0.08	0.36	-	0.08	-	-
Pu241 σ_{fiss}	-	-	-	0.31	-	-	-	-

Main Cross-Section Contributors to the Coolant Void Reactivity Worth "Full BOLNA" Uncertainty. Values are in %.

	ZPPR-2	ZPPR-9	ZPPR-15A	ZPR6-6A	ZPR6-7	CIRANO ZONA2A	CIRANO ZONA2A3	CIRANO ZONA2B	MUSE-4	COSMO	ABR Metal Core	ABR Oxide Core
Total	**212.55**	**13.32**	**9.66**	**10.46**	**104.50**	**10.41**	**8.45**	**7.13**	**8.00**	**7.53**	**13.10**	**7.82**
U235 σ_{fiss}	-	-	-	2.59	-	-	-	-	-	-	-	-
U235 σ_{capt}	-	-	-	5.89	-	-	-	-	-	-	-	-
U238 σ_{capt}	70.16	4.62	5.20	2.89	34.65	1.34	1.71	1.85	2.21	1.92	4.57	1.67
U238 σ_{el}	70.73	3.40	3.02	3.70	39.44	3.30	2.44	1.70	1.95	1.79	2.62	0.93
U238 σ_{inel}	103.92	7.82	2.82	5.29	60.85	2.15	2.30	1.93	2.41	1.99	3.84	2.24
U238 ν	18.67	-	-	1.24	8.67	1.06	0.83	0.62	0.69	0.64	-	-
Pu239 σ_{fiss}	60.48	3.11	2.16	-	27.70	1.44	1.43	1.39	1.71	1.43	1.41	1.23
Pu239 σ_{capt}	28.86	1.45	1.82	-	11.80	1.02	0.97	0.91	1.05	0.97	1.55	-
Pu239 σ_{inel}	13.03	1.00	0.71	-	6.62	-	-	-	-	-	-	-
Pu239 ν	16.26	0.83	0.92	-	7.23	-	-	0.48	0.57	-	-	-
Pu240 σ_{fiss}	-	-	-	-	-	-	0.86	0.89	1.03	0.90	1.58	0.83
Pu240 ν	-	-	-	-	-	-	0.80	0.83	0.97	0.85	1.39	-
Pu241 σ_{fiss}	22.02	0.80	-	-	9.43	-	0.68	0.67	0.54	-	2.82	2.84
Cm244 σ_{fiss}	-	-	-	-	-	-	-	-	-	-	1.22	0.65
Fe56 σ_{capt}	36.85	1.72	1.60	1.76	17.20	-	-	-	-	-	-	1.08
Fe56 σ_{el}	14.92	-	0.60	-	-	-	1.38	1.70	1.86	1.74	1.14	-
Fe56 σ_{inel}	20.53	-	1.11	1.11	8.18	-	0.80	0.92	1.04	0.97	1.46	-
Na23 σ_{el}	34.52	2.17	1.99	2.65	17.28	2.15	2.24	2.25	2.35	2.25	1.13	0.99
Na23 σ_{inel}	108.20	7.66	5.50	1.59	49.67	2.13	2.05	1.84	2.57	2.06	9.88	6.07
O16 σ_{el}	57.32	0.83	-	0.87	7.52	8.61	6.19	4.65	4.81	5.04	-	0.70

Uncertainty Analysis

Uncertainty Breakdown by Energy Group (Use of "Full BOLNA"). Values are in %.

	k_{eff}								Coolant Void Worth
	ZPR3 Assembly 54		ZPPR-2		ZPR6 Assembly 6A	CIRANO ZONA2A	ABR Oxide Core		ABR Metal Core
E [MeV]	C σ_{el}	Pu239 σ_{capt}	U238 σ_{inel}	U238 σ_{capt}	U235 σ_{capt}	O16 σ_{el}	Pu241 σ_{fiss}	Fe56 σ_{inel}	Na23 σ_{inel}
19.6	0.06	-	0.05	-	0.01i	0.09	0.02i	0.06i	1.47
6.07	0.27	0.01	0.40	-	0.05i	0.47	0.07	0.13i	2.67
2.23	0.25	0.02	0.35	0.02	0.08	0.14	0.18	0.31	3.62
1.35	0.43	0.06	0.11	0.05	0.29	0.10	0.28	0.20	8.66
4.98E-01	0.46	0.08	0.02	0.06	0.63	0.08	0.33	-	0.42
1.83E-01	0.28	0.08	0.04	0.09	1.01	0.04	0.45	-	-
6.74E-02	0.18	0.12	0.01	0.10	1.05	0.04	0.27	-	-
2.48E-02	0.18	0.21	-	0.41	1.09	0.06	0.20	-	-
9.12E-03	0.17	0.54	-	0.12	0.98	0.04	0.16	-	-
2.03E-03	0.06	0.06	-	0.10	0.11	0.03	0.13	-	-
4.54E-04	0.03	0.05	-	0.03	0.01	0.02i	0.05	-	-
2.26E-05	0.01i	-	-	-	-	0.01i	-	-	-
4.00E-06	-	-	-	-	-	-	-	-	-
5.40E-07	-	-	-	-	-	-	-	-	-
1.00E-07	-	-	-	-	-	-	-	-	-
Total	0.84	0.61	0.55	0.46	2.18	0.52	0.77	0.35	9.88

Experiments (E) and ABR Metal (R) Representativity with respect to the Parameter P. Use of "Full BOLNA". Uncertainty Values are in %.

	$P = k_{eff}$		$P = \frac{\langle \sigma_{fiss,U238} \Phi \rangle}{\langle \sigma_{fiss,Pu239} \Phi \rangle}$		P = Coolant Void Worth	
	$I_R = 1.47$		$I_R = 6.33$		$I_R = 13.10$	
	r_{RE}	$(I_R)'$	r_{RE}	$(I_R)'$	r_{RE}	$(I_R)'$
ZPR3-53	0.437	1.32	0.653	4.80	-	-
ZPR3-54	0.070	1.47	0.662	4.75	-	-
ZPPR-2	0.785	0.91	0.964	1.68	0.754	8.60
ZPPR-9	0.799	0.88	0.960	1.78	0.810	7.69
ZPPR-15A	0.819	0.84	0.991	0.84	0.874	6.36
ZPR6-6A	0.187	1.44	-	-	-0.335 [(a)]	12.34
ZPR6-7	0.796	0.89	0.966	1.65	0.747	8.70
ZONA2A	0.662	1.10	0.967	1.62	-0.384	12.09
ZONA2A3	0.710	1.03	0.970	1.55	-0.470	11.56
ZONA2B	0.727	1.01	0.972	1.49	-0.508	11.28
MUSE-4	0.728	1.01	0.952	1.94	-0.577	10.69
COSMO	0.710	1.04	0.970	1.55	-0.514	11.23
GODIVA	-0.008	1.47				
BIGTEN	0.584	1.19				
Pu239 JEZEBEL	0.155	1.45				
Pu240 JEZEBEL	0.425	1.33				
U233 JEZEBEL	-0.001	1.47				
FLATTOP Pu	-0.090	1.46				
FLATTOP U235	-0.055	1.47				
FLATTOP U233	-0.001	1.47				

Representativity Among ABR Metal Core (R) and Experiments E_1=ZPPR-15A and E_2 Combined with respect to k_{eff} ($r_{RE_1} = 0.819$).

E_2	r_{RE_2}	$r_{E_1E_2}$	$r_{RE_1E_2}$
ZPR3-53	0.437	0.623	0.825
ZPR3-54	0.070	0.162	0.822
ZPPR-2	0.785	0.956	0.819
ZPPR-9	0.799	0.972	0.819
ZPPR-15A	0.819	-	-
ZPR6-6A	0.187	0.275	0.820
ZPR6-7	0.796	0.975	0.819
ZONA2A	0.662	0.742	0.823
ZONA2A3	0.710	0.774	0.828
ZONA2B	0.727	0.773	0.832
MUSE-4	0.728	0.803	0.828
COSMO	0.710	0.787	0.826
GODIVA	-0.008	0.007	0.819
BIGTEN	0.584	0.664	0.821
Pu239 JEZEBEL	0.155	0.181	0.819
Pu240 JEZEBEL	0.425	0.204	0.861
U233 JEZEBEL	-0.001	-0.001	0.819
FLATTOP Pu	-0.090	-0.062	0.820
FLATTOP U235	-0.055	-0.041	0.819
FLATTOP U233	-0.001	-0.001	0.819

Conclusions

- Work was initiated to improve the nuclear data by a combined use of the science-based covariance data and integral experiments. The metal and oxide core configurations of a reference ABR were selected as the tentative target systems.

- To identify the most relevant experiments to the selected target systems, a representativity study was performed. In this approach, the similarity between the target system and a selected experiment in connection with the response parameter of interest is quantitatively evaluated by comparing the sensitivity profiles of the response parameter with respect to nuclear data in the two systems, filtered by the estimated covariance data. The estimated covariance data play a critical role, since the representativity factors employed in the comparison are dominated by the sensitivity components that correspond to the cross-sections of significant uncertainties.

- It has been found that the ZPPR-2, ZPPR-9, ZPPR-15A, ZPR6-7, CIRANO, MUSE-4 and COSMO experiments show a quite good similarity with both the metal and oxide core ABRs; only the coolant void reactivity worth shows significant discrepancies for some experiments because of different fuel to coolant loading ratios. However, with respect to k_{eff}, even the experiment providing the strongest representativity is not enough to bring the initial k_{eff} uncertainty below the desired accuracy of 0.3% for both ABRs. Degradation in the representativity factors is then observed when the ZPR3 and ZPR6-6A experiments are compared with the ABR cores. Similar conclusions can be made for the GODIVA, BIGTEN, JEZEBEL and FLATTOP experiments.

- By the combined use of two experiments at the same time it has been demonstrated that with respect to the multiplication factor, the strongest representativity provided by the single experiment (ZPPR-15A for the ABR metal core and ZPR6-7 for the ABR oxide core) is further improved if in addition it is considered an experiment bringing an information totally complementary (low representativity factors between the two experiments), like Pu240 JEZEBEL for both the target systems.