Use of AFCI1.2 Covariance Matrix for Uncertainty Estimates on the Main Integral Parameters of Fast Neutron Systems

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AFCI covariance matrix

- A first release of the matrix (AFCI1.0) was made in November last year. The first applications of AFCI1.0 were presented at the data adjustment meeting held at INL in December 2008 and at the Nuclear Physics Working Group meeting held in San Diego (CA) in May 2009. The matrix was used to calculate the uncertainty of the multiplication factor of all fast systems investigated in the Sg26 activity (ABTR, SFR, EFR, GFR, LFR, ADMAB).

- An updated version of the matrix, called AFCI1.1, was released by BNL and LALN in May 2009: Pu239 (only ν), Fe56, Cr50, Ni58, C, O, Na23, B10, Zr90 and Mn55 have been reprocessed. Applications were presented at the NNDC meeting in Port Jefferson, June 2009 (see also ANS paper, Nov. 2009).

- The AFCI1.2 matrix was released in August 2009: 14 MAs were updated as guided by Maslov review and missing correlation matrices were recovered; U235 capture and Pu239 nu were updated; Structural materials (Cr, Fe, Ni, Pb, Bi) were reviewed and updated.

- The present work shows an extensive application of the recent AFCI1.2 matrix, with the determination of the uncertainty for the main integral parameters (multiplication factor, power peaking factor, Doppler reactivity coefficient, coolant void reactivity worth and burnup reactivity swing) of a series of fast reactors (ABR metal core, ABR oxide core, SFR, EFR, GFR, LFR, ADMAB).
  The obtained AFCI1.2 parameter uncertainties are also compared with the results presented in previous studies with the BOLNA correlation matrix.

AFCI1.2 Covariance Matrix at a Glance

- Processed/used isotopes:
  U234, U235, U236, U238, Np237, Pu238, Pu239, Pu240, Pu241, Pu242, Am241, Am242m, Am243, Cm242, Cm243, Cm244, Cm245, Cm246, Fe56, Fe57, Cr50, Cr52, Ni58, Ni60, Zr90, Zr91, Zr92, Zr94, Na23, O, He4, Si28, C, N15, B10, B11, P204, Pb206, Pb207, Pb208, Bi209, Mn55, Mo92, Mo94, Mo95, Mo96, Mo97, Mo98, Mo100.

- Processed/used reactions:
  ν, fission, capture, elastic, inelastic and n2n for fissile isotopes and **capture, elastic, inelastic and n2n** for structural isotopes.

- For most of the isotopes AFCI1.2 contains covariance data for the reaction itself, only for **U235, U238, Pu239, Cm246, Fe56, Cr52, Ni58, O, Zr90, C, B10, B11, Mn55, N15** some cross-correlations have been also provided.

- In the AFCI1.2 matrix there are no “cross-material” correlations.

Features of the Investigated Systems

System	Coolant	Fuel Type	%TRU in (U+TRU)	% MA[a] in (U+TRU)	Power $[MW_{th}]$
ABR Metal Core	Na	Metal	18.5 – 24.2 [b]	1.5 – 2.2 [b]	1000
ABR Oxide Core	Na	MOX	23.2 – 37.1[b]	2.2 – 4.1 [b]	1000
SFR	Na	Metal	60.5	10.6	840
EFR	Na	MOX	23.7	1.2	3600
GFR	He	Carbide	21.7	5.0	2400
LFR	Pb	Metal	23.3	2.4	900
ADMAB	LBE	Nitride	100	68.0	380

[a] MA: Minor Actinides;

[b] Inner Core – Outer Core.

Sodium Cooled Fast Neutron Systems: Nominal Values and Total Uncertainties (%)

Reactor		k_{eff}	Power Peaking Factor	Doppler Coefficient	Coolant Void Worth	Burnup Reactivity Swing [a]
ABR Metal	Nominal Value	0.972326			1402 pcm [1]	
	BOLNA	1.47			13.10	
	AFCI1.2	1.54			10.32	
ABR Oxide	Nominal Value	0.988232			2443 pcm [2]	
	BOLNA	1.44			7.82	
	AFCI1.2	1.49			5.60	
SFR	Nominal Value	1.05280	1.53 [3]	231 pcm [4]	1831 pcm [5]	-3981.1 pcm [6]
	BOLNA	1.86	0.45	5.57	17.11	3.55
	AFCI1.2	2.16	0.22	6.88	14.02	4.25
EFR	Nominal Value	1.10848	1.63 [7]	1289 pcm [8]	1934.5 pcm [9]	-9123.9 pcm [10]
	BOLNA	1.27	1.18	3.80	7.83	3.49
	AFCI1.2	1.29	1.01	4.03	5.40	3.43

[a] The uncertainties show the component due to cross section uncertainties (the component due to the isotope buildup is not taken into account)

ABR Metal	SFR	EFR
[1] Na loss at the core center	[3] (R , Z) =(66.59 , 143.03)$_{cm}$	[7] (R , Z) =(153.24 , 125)$_{cm}$
	[4] T_{fuel}=300K - T_{fuel}=850K	[8] T_{fuel}=300K - T_{fuel}=1520K
ABR Oxide	[5] Na loss in core	[9] Na loss in core and blanket
[2] Na loss at the core center	[6] 155 days	[10] 1700 days

Fast Neutron Systems: Nominal Values and Total Uncertainties (%)

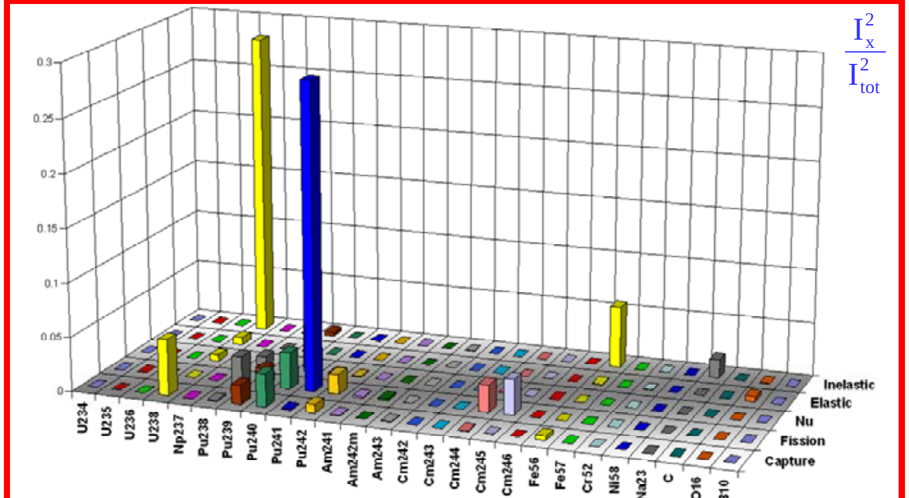
Reactor		k_{eff}	Power Peaking Factor	Doppler Coefficient	Coolant Void Worth	Burnup Reactivity Swing [a]
GFR	Nominal Value	1.01049	1.45 [1]	1549 pcm [2]	350.1 pcm [3]	1081.3 pcm [4]
	BOLNA	1.89	1.68	5.51	7.67	16.94
	AFCI1.2	1.95	1.71	5.44	6.75	27.47
LFR	Nominal Value	1.00023	1.29 [5]	228.1 pcm [6]	6575.5 pcm [7]	-1464 pcm [8]
	BOLNA	1.40	0.64	4.35	7.18	2.42
	AFCI1.2	1.67	0.58	6.20	9.81	3.39
ABMAB	Nominal Value	0.94816	2.67 [9]	28.3 pcm [10]	3138.4 pcm [11]	-1347.6 pcm [12]
	BOLNA	2.90	21.42	-	15.49	56.63
	AFCI1.2	2.46	17.99	-	13.89	105.11

[a] The uncertainties show the component due to cross section uncertainty (the component due to the isotope buildup is not taken into account)

GFR	LFR	ADMAB
[1] Center core radially and axially	[5] (R , Z) =(100.96 , 117.90)$_{cm}$	[9] (R , Z) =(20 , 102.5)$_{cm}$
[2] T_{fuel}=300K - T_{fuel}=1263K	[6] T_{fuel}=300K - T_{fuel}=900K	[10] T_{fuel}=1773K - T_{fuel}=980K
[3] He loss in core and reflector	[7] Pb loss in core	[11] Pb-Bi loss in core
[4] 415 days	[8] 310 days	[12] 366 days

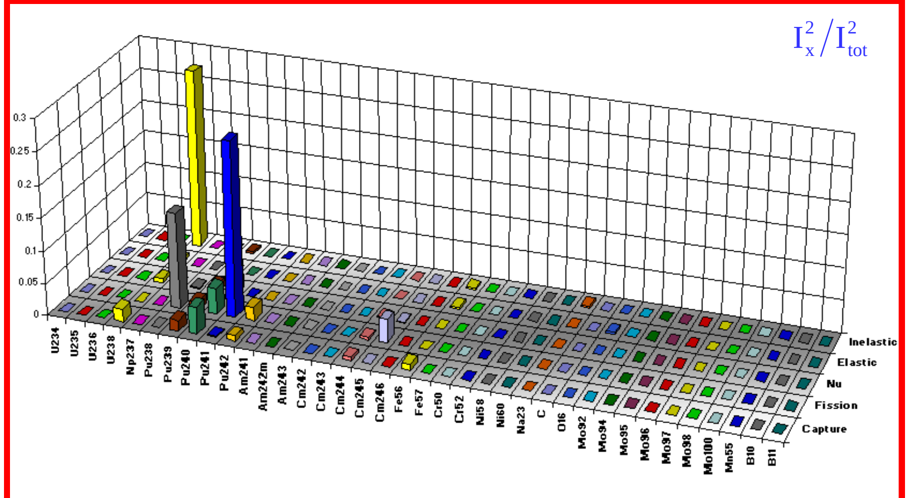
ABR Oxide Core k_{eff}: BOLNA Full Uncertainties (%) by Isotope

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



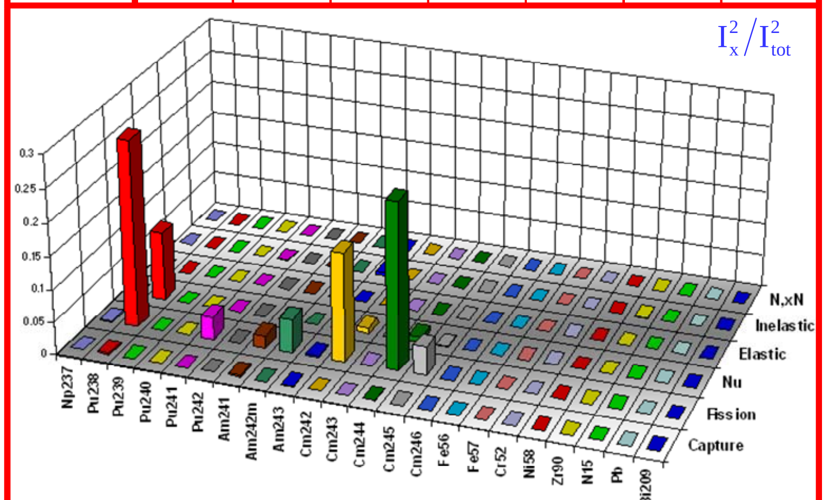
ABR Oxide Core k_{eff}: AFCI1.2 Full Uncertainties (%) by Isotope

Isotope	σ_{capt}	σ_{fiss}	ν	σ_{el}	σ_{inel}	Total
U235	0.01	-	-	-	-	**0.01**
U238	0.21	0.03	0.11	0.11	0.78	**0.83**
Np237	0.01	0.01	-	-	-	**0.02**
Pu238	0.04	0.57	0.06	-	0.01	**0.58**
Pu239	0.19	0.18	0.15	0.02	0.09	**0.32**
Pu240	0.30	0.30	0.31	-	0.02	**0.53**
Pu241	0.06	0.77	0.03	-	0.02	**0.78**
Pu242	0.13	0.21	0.04	-	0.02	**0.25**
Am241	0.06	0.05	0.02	-	0.01	**0.08**
Am242m	0.01	0.05	-	-	-	**0.05**
Am243	0.04	0.03	0.01	-	0.01	**0.05**
Cm242	-	0.02	-	-	-	**0.02**
Cm243	-	-	-	-	-	**-**
Cm244	0.10	0.08	0.06	-	-	**0.15**
Cm245	0.01	0.28	0.02	-	-	**0.28**
Cm246	0.01	0.01	0.02	-	-	**0.02**
Fe56	0.15	-	-	0.07	0.07	**0.18**
Fe57	0.01	-	-	0.01	0.02	**0.03**
Cr50	0.01	-	-	-	-	**0.01**
Cr52	0.01	-	-	0.01	0.02	**0.02**
Na23	-	-	-	0.02	0.08	**0.09**
O16	-	-	-	0.08	-	**0.08**
Mo95	0.01	-	-	-	-	**0.01**
Mo97	0.01	-	-	-	-	**0.01**
Mn55	-	-	-	-	0.01	**0.01**
Total	**0.48**	**1.09**	**0.38**	**0.16**	**0.80**	**1.49**



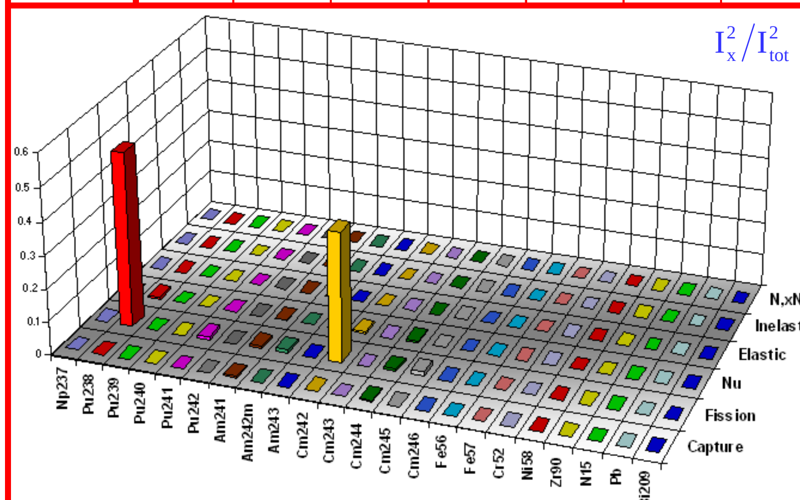
ADMAB Burnup: BOLNA Full Uncertainties (%) by Isotope

Isotope	σ_{capt}	σ_{fiss}	ν	σ_{el}	σ_{inel}	$\sigma_{n.2n}$	Total
Np237	0.78	2.30	0.49	-	1.17	-	**2.73**
Pu238	2.57	30.16	18.35	0.01	1.17	-	**35.42**
Pu239	0.66	1.01	0.45	0.08	1.32	-	**1.85**
Pu240	0.73	0.98	0.87	0.01	0.08	-	**1.50**
Pu241	0.87	10.57	0.31	-	0.26	-	**10.61**
Pu242	1.26	2.24	0.46	-	0.27	-	**2.62**
Am241	2.84	7.96	1.60	-	1.82	-	**8.79**
Am242m	0.57	12.80	0.97	-	0.38	0.01	**12.86**
Am243	1.38	2.65	0.73	-	3.98	-	**5.03**
Cm242	1.30	23.00	5.29	-	0.53	-	**23.64**
Cm243	0.01	0.89	0.06	-	-	-	**0.89**
Cm244	2.06	28.52	5.20	0.01	0.45	-	**29.06**
Cm245	0.10	11.91	1.80	-	0.10	-	**12.05**
Cm246	0.02	0.33	0.06	-	0.02	-	**0.34**
Fe56	0.25	-	-	0.05	1.15	-	**1.17**
Fe57	0.08	-	-	-	0.02	-	**0.08**
Cr52	0.02	-	-	0.02	0.02	-	**0.04**
Ni58	-	-	-	-	-	-	**-**
Zr90	0.06	-	-	0.03	0.19	-	**0.21**
N15	-	-	-	0.49	0.02	-	**0.49**
Pb	0.39	-	-	0.08	0.09	-	**0.41**
Bi209	0.06	-	-	0.04	0.55	0.01	**0.55**
Total	**5.20**	**52.47**	**20.01**	**0.51**	**5.11**	**0.01**	**56.63**



ADMAB Burnup: AFCI1.2 Full Uncertainties (%) by Isotope

Isotope	σ_{capt}	σ_{fiss}	ν	σ_{el}	σ_{inel}	$\sigma_{n.2n}$	Total
Np237	1.70	2.72	0.51	-	1.48	-	**3.57**
Pu238	2.34	76.13	8.07	0.01	2.42	-	**76.63**
Pu239	0.64	1.00	0.48	0.09	1.32	-	**1.84**
Pu240	0.87	1.04	0.84	0.01	0.20	-	**1.60**
Pu241	1.72	10.55	0.30	-	0.16	-	**10.69**
Pu242	1.18	2.30	0.49	-	0.21	-	**2.64**
Am241	6.22	9.03	3.26	-	1.38	-	**11.52**
Am242m	1.14	11.19	0.84	-	0.46	0.01	**11.29**
Am243	1.51	3.37	0.76	0.01	2.75	-	**4.67**
Cm242	5.71	65.50	8.13	-	2.52	-	**66.30**
Cm243	0.01	0.35	0.11	-	-	-	**0.37**
Cm244	7.32	9.65	7.49	0.01	0.60	-	**14.25**
Cm245	0.08	12.18	1.50	-	0.05	-	**12.27**
Cm246	0.02	0.09	0.23	-	0.01	-	**0.24**
Fe56	0.51	-	-	0.19	0.12	-	**0.55**
Fe57	0.06	-	-	0.03	0.05	-	**0.09**
Cr52	0.03	-	-	0.03	0.03	-	**0.05**
Ni58	-	-	-	-	-	-	**-**
Zr90	0.13	-	-	0.06	0.12	-	**0.19**
N15	0.01	-	-	0.72	0.02	-	**0.72**
Pb	0.78	-	-	0.19	0.18	-	**0.83**
Bi209	1.05	-	-	0.21	0.62	-	**1.24**
Total	**12.01**	**103.31**	**14.25**	**0.81**	**5.17**	**0.01**	**105.11**



Isotope/Reaction Contributing to 90% of Multiplication Factor Uncertainty with AFCI1.2

		ABR Metal	ABR Oxide	SFR	EFR	GFR	LFR	ADMAB
U238	inelastic	1.00	0.78		0.90	1.49	0.74	
U238	capture				0.25			
Pu238	fission	0.56	0.57	1.36	0.34	0.53	0.94	0.53
Pu239	capture				0.25			
Pu240	nu	0.31	0.31	0.42	0.27		0.34	
Pu240	fission	0.28	0.30					
Pu240	capture		0.30	0.46	0.34		0.39	
Pu241	fission	0.67	0.77	1.02	0.39	0.79	0.64	1.05
Am241	fission							0.94
Am241	capture							0.79
Am242m	fission			0.69				
Am243	fission							0.44
Cm244	nu							0.50
Cm244	fission							0.65
Cm245	fission			0.43				1.09
Pb206	inelastic						0.41	
Total [(a)]		**1.39**	**1.35**	**1.98**	**1.18**	**1.77**	**1.51**	**2.22**
Overall [(b)]		**1.54**	**1.49**	**2.16**	**1.29**	**1.95**	**1.67**	**2.46**

[(a)] Total uncertainty yield by the cross sections listed in the Table;

[(b)] Overall uncertainty yield by all cross sections.

Isotope/Reaction Contributing to 90% of Multiplication Factor Uncertainty with BOLNA

		ABR Metal	ABR Oxide	SFR	EFR	GFR	LFR	ADMAB
U238	**inelastic**	0.97	0.76		0.87	1.42	0.73	
U238	**capture**	0.28	0.33		0.37	0.41	0.25	
Pu238	**nu**			0.36			0.23	
Pu238	**fission**	0.22		0.56			0.34	
Pu239	**capture**				0.25			
Pu240	**nu**	0.30	0.31	0.41	0.27		0.33	
Pu240	**fission**	0.27	0.26				0.29	
Pu240	**capture**		0.25		0.26		0.27	
Pu241	**fission**	0.65	0.77	1.01	0.39	0.82	0.61	1.04
Pu242	**fission**			0.38				
Am241	**fission**							0.82
Am242m	**fission**			0.77				
Cm244	**fission**			0.41				1.90
Cm245	**fission**		0.26	0.41			0.22	1.04
Fe56	**inelastic**	0.35	0.35	0.46				0.83
C	**elastic**					0.31		
O16	**capture**				0.29			
B10	**capture**						0.44	
Total		**1.33**	**1.30**	**1.71**	**1.16**	**1.72**	**1.28**	**2.67**
Overall		**1.47**	**1.44**	**1.86**	**1.27**	**1.89**	**1.40**	**2.90**

Pu238 Fission, Pu240 Capture, Cm242 fission, Pb206 Inelastic are much larger with AFCI1.2

Pu241 Fission, Cm244 Fission, Na Inelastic, Fe56 Inelastic, B10 Capture are much larger with BOLNA

Isotope/Reaction Contributing to 90% of Power Peaking Factor Uncertainty with AFCI1.2

		SFR	EFR	GFR	LFR	ADMAB
U238	inelastic	0.07	0.90	1.60		
Pu238	fission	0.05				3.83
Pu241	fission					7.67
Am241	fission					6.61
Am241	capture					6.12
Am243	fission					3.08
Cm244	nu					3.64
Cm244	fission					4.59
Cm244	capture					2.85
Cm245	fission					7.91
Fe56	elastic	0.10				
Fe56	capture	0.06				
Na23	elastic	0.13	0.29			
Zr90	elastic	0.05				
Pb207	elastic				0.14	
Pb208	elastic				0.52	
Total		**0.20**	**0.94**	**1.60**	**0.53**	**16.40**
Overall		**0.22**	**1.01**	**1.71**	**0.58**	**17.99**

Isotope/Reaction Contributing to 90% of Doppler Uncertainty with AFCI1.2

		SFR	EFR	GFR	LFR
U238	inelastic		2.80	4.24	2.65
Pu238	fission	3.44	0.89		2.19
Pu239	capture		0.79		
Pu240	fission	1.46			
Pu241	fission	2.59	1.03	1.91	1.50
Am241	capture			1.56	
Am242m	fission	1.71			
Fe56	elastic	2.17			
Fe56	capture	2.08			
Na23	elastic	2.77	1.31		
O16	elastic		1.12		
Pb206	inelastic				1.29
Pb207	elastic				1.64
Pb208	elastic				3.62
Total		**6.35**	**3.65**	**4.90**	**5.62**
Overall		**6.88**	**4.03**	**5.44**	**6.20**

Isotope/Reaction Contributing to 90% of Coolant Void Reactivity Worth Uncertainty with AFCI1.2

		ABR Metal	ABR Oxide	SFR	EFR	GFR	LFR	ADMAB
U238	inelastic	3.76	2.16		2.45	6.03	4.76	
U238	elastic	2.26						
U238	capture	2.62	1.56		1.36			
Pu238	fission	3.37	1.33	8.87				
Pu239	nu		1.08		1.17			
Pu239	fission		1.19		1.16			
Pu240	nu			2.56				
Pu240	fission	1.74	1.40	2.60	1.00			
Pu241	fission	2.90	1.92	3.99		1.56		3.34
Am241	capture							2.89
Am242m	fission			2.60				
Cm245	fission							2.58
Fe56	elastic	4.12		3.01				
Na23	inelastic	4.40	2.72	5.66	2.89			
Na23	elastic	1.71	1.40	2.52	2.16			
Pb206	inelastic						6.30	
Pb207	inelastic						2.37	
Pb208	elastic						3.72	
Pb	capture							4.55
Bi209	inelastic							9.83
Bi209	capture							3.82
Total		**9.38**	**5.14**	**12.73**	**4.96**	**6.23**	**9.05**	**12.58**
Overall		**10.32**	**5.60**	**14.02**	**5.40**	**6.75**	**9.81**	**13.89**

Isotope/Reaction Contributing to 90% of Burnup Reactivity Uncertainty with AFCI1.2

		SFR	EFR	GFR	LFR	ADMAB
Pu238	**fission**	3.15	0.73	11.97	2.10	76.13
Pu241	**fission**	1.87	3.03	10.08	1.80	
Pu242	**fission**	0.82				
Cm242	**fission**	0.86		20.12	1.53	65.50
Total		**3.86**	**3.12**	**25.49**	**3.16**	**100.43**
Overall		**4.25**	**3.43**	**27.47**	**3.39**	**105.11**

Target Accuracy

To establish priorities and target accuracies on data uncertainty reduction, a formal approach can be adopted by defining target accuracies on design parameters and finding out the required accuracy on cross-section data.

The unknown uncertainty data requirements d_i can be obtained by solving the following minimization problem:

$$\sum_i \lambda_i / d_i^2 = \min \quad i = 1 \ldots I$$

(I is the total number of parameters) with the following constraints:

$$\sum_i S_{ni}^2 d_i^2 < \left(R_n^T\right)^2 \qquad n = 1 \ldots N$$

(N is the total number of integral design parameters) where S_{ni} are the sensitivity coefficients for the integral parameter R_n, and R_n^T are the target accuracies on the N integral parameters.

λ_i are "cost" parameters related to each σ_i and should give a relative figure of merit of the difficulty of improving that parameter (e.g., reducing uncertainties with an appropriate experiment).

NT. A Target Accuracy study was performed within the Subgroup26 activities with the use of the BOLNA covariance matrix.

Fast Reactor Target Accuracies (1 sigma)

Multiplication factor (BOL)	300 pcm
Power peaking factor (BOL)	2%
Burn-up reactivity swing	300 pcm
Coolant void reactivity worth (BOL)	7%
Doppler reactivity coefficient (BOL)	7%
Major nuclide[a] density at end of irradiation cycle	2%
Other nuclide density at end of irradiation cycle	10%

[a] U-235, U-238, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242

Priority Data Needs with BOLNA Data and Comparison with AFCI1.2 Data

Isotope Cross-Section	Energy Range	BOLNA STD (%)	
		Initial	Target
U238 σ_{inel}	19.6 - 6.07 MeV	29.3	9.0
	6.07 - 2.23 MeV	19.8	2.0
	2.23 - 1.35 MeV	20.6	2.1
	1.35 - 0.498 MeV	11.6	2.3
	498 - 183 keV	4.2	3.8
	183 - 67.4 keV	11.0	4.2
Pu241 σ_{fiss}	6.07 - 2.23 MeV	14.2	5.0
	2.23 - 1.35 MeV	21.3	3.9
	1.35 - 0.498 MeV	16.6	2.1
	498 - 183 keV	13.5	1.7
	183 - 67.4 keV	19.9	1.7
	67.4 - 24.8 keV	8.7	1.9
	24.8 - 9.12 keV	11.3	2.0
	9.12 - 2.03 keV	10.4	2.1
	2.03 - 0.454 keV	12.7	2.7
	454 - 22.6 eV	19.4	5.4
Cm244 σ_{fiss}	6.07 - 2.23 MeV	31.3	3.0
	2.23 - 1.35 MeV	43.8	2.6
	1.35 - 0.498 MeV	50.0	1.5
	498 - 183 keV	36.5	4.0
	183 - 67.4 keV	47.6	7.3

AFCI1.2 STD (%)

Gr.	[MeV]	U238 σ_{inel}	Pu241 σ_{fiss}	Cm244 σ_{fiss}
1	1.964E+1	31.6	10.0	20.0
2	1.000E+1	30.3	6.5	20.0
3	6.065E+0	20.1	5.0	20.0
4	3.679E+0	19.4	5.0	20.0
5	2.231E+0	20.6	5.0	20.0
6	1.353E+0	16.9	15.0	15.0
7	8.209E-1	5.6	16.2	11.9
8	4.979E-1	4.3	17.0	10.0
9	3.020E-1	4.1	18.9	10.0
10	1.832E-1	6.0	20.0	10.0
11	1.111E-1	19.2	16.9	10.0
12	6.738E-2	17.9	15.0	10.0
13	4.087E-2	-	11.9	10.0
14	2.479E-2	-	10.0	10.0
15	1.503E-2	-	10.0	10.0
16	9.119E-3	-	10.0	10.0
17	5.531E-3	-	10.0	12.5
18	3.355E-3	-	10.0	14.1
19	2.035E-3	-	10.0	15.0
20	1.234E-3	-	7.4	17.6
21	7.485E-4	-	5.9	19.1
22	4.540E-4	-	5.0	20.0
23	3.043E-4	-	5.0	20.0
24	1.486E-4	-	5.0	20.0
25	9.166E-5	-	5.0	20.0
26	6.790E-5	-	5.0	20.0
27	4.017E-5	-	5.0	20.0
28	2.260E-5	-	5.0	20.0
29	1.371E-5	-	5.0	20.0
30	8.315E-6	-	5.0	20.0
31	4.000E-6	-	5.0	20.0
32	5.400E-7	-	1.0	20.0
33	1.000E-7	-	1.0	20.0

- Pu241 fission and especially U238 inelastic are confirmed as priority needs with AFCI1.2 data. Cm244 fission becomes less urgent with respect to other MA data.

Priority Data Needs with BOLNA Data and Comparison with AFCI1.2 Data

Isotope Cross-Section	Energy Range	BOLNA STD (%) Initial	BOLNA STD (%) Target
U238 σ_{capt}	24.8 - 9.12 keV	9.4	1.8
	9.12 - 2.03 keV	3.1	1.8
Fe56 σ_{inel}	6.07 - 2.23 MeV	7.2	2.6
	2.23 - 1.35 MeV	25.4	1.7
	1.35 - 0.498 MeV	16.1	1.5
B10 σ_{capt}	498 - 183 keV	15.0	2.9
	183 - 67.4 keV	10.0	2.7
	67.4 - 24.8 keV	10.0	3.3
	24.8 - 9.12 keV	8.0	3.9
	9.12 - 2.03 keV	8.0	6.0
Pu239 σ_{capt}	1.35 - 0.498 MeV	18.2	6.6
	498 - 183 keV	11.6	4.4
	183 - 67.4 keV	9.0	4.0
	67.4 - 24.8 keV	10.1	4.2
	24.8 - 9.12 keV	7.4	3.8
	9.12 - 2.03 keV	15.5	3.2

AFCI1.2 STD (%)

Gr.	[MeV]	U238 σ_{capt}	Fe56 σ_{inel}	B10 σ_{capt}	Pu239 σ_{capt}
1	1.964E+1	22.3	5.1	0.9	36.3
2	1.000E+1	21.2	4.5	1.2	39.9
3	6.065E+0	19.9	2.9	0.8	42.0
4	3.679E+0	5.9	2.4	1.2	34.2
5	2.231E+0	6.0	2.8	0.9	26.6
6	1.353E+0	3.1	2.8	0.7	20.5
7	8.209E-1	1.7	-	0.9	15.5
8	4.979E-1	1.5	-	0.9	12.1
9	3.020E-1	1.5	-	1.0	11.3
10	1.832E-1	1.7	-	1.0	9.6
11	1.111E-1	1.7	-	0.8	10.8
12	6.738E-2	1.7	-	0.8	11.4
13	4.087E-2	1.6	-	0.7	8.9
14	2.479E-2	3.2	-	0.7	7.2
15	1.503E-2	3.9	-	0.7	7.8
16	9.119E-3	3.3	-	0.7	16.5
17	5.531E-3	2.8	-	0.7	16.5
18	3.355E-3	2.9	-	0.7	10.7
19	2.035E-3	2.9	-	0.7	1.5
20	1.234E-3	2.8	-	0.7	1.5
21	7.485E-4	2.7	-	0.7	1.6
22	4.540E-4	3.4	-	0.7	1.6
23	3.043E-4	2.9	-	0.7	1.6
24	1.486E-4	4.1	-	0.7	1.9
25	9.166E-5	5.1	-	0.7	5.5
26	6.790E-5	3.6	-	0.7	3.2
27	4.017E-5	3.6	-	0.7	2.1
28	2.260E-5	3.6	-	0.7	1.3
29	1.371E-5	2.7	-	0.7	0.7
30	8.315E-6	1.0	-	0.7	1.0
31	4.000E-6	2.8	-	0.7	1.5
32	5.400E-7	2.0	-	0.7	1.3
33	1.000E-7	1.8	-	0.7	1.5

- Pu239 capture is confirmed as priority need with AFCI1.2 data. Less urgent U238 capture. Fe56 inelastic and especially B10 capture appear no longer priority data needs.

Priority Data Needs with BOLNA Data and Comparison with AFCI1.2 Data

Isotope Cross-Section	Energy Range	BOLNA STD (%)	
		Initial	Target
O16 σ_{capt}	19.6 - 6.07 MeV	100.0	37.9
	6.07 - 2.23 MeV	100.0	37.9
Am243 σ_{inel}	6.07 - 2.23 MeV	17.9	4.9
	2.23 - 1.35 MeV	35.3	3.9
	1.35 - 0.498 MeV	42.2	2.3
	498 - 183 keV	41.0	3.7
	183 - 67.4 keV	79.5	3.7
	67.4 - 24.8 keV	80.8	12.4
Am242m σ_{fiss}	1.35 - 0.498 MeV	23.4	21.4
	498 - 183 keV	16.5	6.3
	183 - 67.4 keV	16.6	4.7
	67.4 - 24.8 keV	16.6	4.8
	24.8 - 9.12 keV	14.4	5.6
	2.04 - 0.454 keV	11.8	5.9
Na23 σ_{inel}	1.35 - 0.498 MeV	28.0	10.5

AFCI1.2 STD (%)

Gr.	[MeV]	O16 σ_{capt}	Am243 σ_{inel}	Am242m σ_{fiss}	Na23 σ_{inel}
1	1.964E+1	50.0	25.0	40.0	10.8
2	1.000E+1	50.0	21.5	29.4	4.9
3	6.065E+0	50.0	20.0	25.0	5.1
4	3.679E+0	50.0	20.0	21.9	5.3
5	2.231E+0	50.0	20.0	20.0	8.1
6	1.353E+0	50.0	20.0	15.0	11.1
7	8.209E-1	50.0	26.2	15.0	11.6
8	4.979E-1	18.5	30.0	15.0	38.3
9	3.020E-1	10.0	30.0	15.0	-
10	1.832E-1	10.0	30.0	15.0	-
11	1.111E-1	10.0	30.0	15.0	-
12	6.738E-2	10.0	-	15.0	-
13	4.087E-2	10.0	-	13.1	-
14	2.479E-2	10.0	-	12.0	-
15	1.503E-2	10.0	-	12.0	-
16	9.119E-3	10.0	-	12.0	-
17	5.531E-3	10.0	-	11.0	-
18	3.355E-3	10.0	-	10.4	-
19	2.035E-3	10.0	-	10.0	-
20	1.234E-3	10.0	-	8.0	-
21	7.485E-4	10.0	-	6.7	-
22	4.540E-4	10.0	-	6.0	-
23	3.043E-4	10.0	-	6.0	-
24	1.486E-4	10.0	-	6.0	-
25	9.166E-5	10.0	-	6.0	-
26	6.790E-5	10.0	-	6.0	-
27	4.017E-5	10.0	-	6.0	-
28	2.260E-5	10.0	-	6.0	-
29	1.371E-5	10.0	-	6.0	-
30	8.315E-6	10.0	-	6.0	-
31	4.000E-6	10.0	-	6.0	-
32	5.400E-7	10.0	-	5.0	-
33	1.000E-7	10.0	-	5.0	-

- Am242 fission, Am243 inelastic and especially O16 capture become with AFCI1.2 less urgent data needs. Na23 inelastic appears no longer priority data need.

New Priority Data Needs with AFCI1.2 Data

Comparison of BOLNA and AFCI1.2 Uncertainty Components (%)

SFR Multiplication Factor	BOLNA	AFCI1.2
Pu238 σ_{fiss}	0.56	1.36
Overall Uncertainty [a]	1.86	2.16

SFR Multiplication Factor	BOLNA	AFCI1.2
Pu240 σ_{capt}	0.33	0.46
Overall Uncertainty [a]	1.86	2.16

[a] Total of all isotopes

Comparison of BOLNA and AFCI1.2 Uncertainty Components (%)

GFR Burnup Reactivity	BOLNA	AFCI1.2
Cm242 σ_{fiss}	6.87	20.12
Overall Uncertainty [a]	16.94	27.47

LFR Coolant Void Worth	BOLNA	AFCI1.2
Pb206 σ_{inel}	2.77	6.30
Overall Uncertainty [a]	7.18	9.81

[a] Total of all isotopes

New Priority Data Needs with AFCI1.2 Data

STD (%)

Gr.	[MeV]	Pu238 σ_{fiss} BOLNA	Pu238 σ_{fiss} AFCI1.2	Pu240 σ_{capt} BOLNA	Pu240 σ_{capt} AFCI1.2	Cm242 σ_{fiss} BOLNA	Cm242 σ_{fiss} AFCI1.2	Pb206 σ_{inel} BOLNA	Pb206 σ_{inel} AFCI1.2
1	1.964E+1	25.2	20.0	52.2	55.0	31.5	100.0	19.8	42.0
2	1.000E+1		20.0		40.8		100.0		3.6
3	6.065E+0	20.5	20.0	32.5	35.0	52.6	100.0	5.5	4.6
4	3.679E+0		13.8		35.0		100.0		23.1
5	2.231E+0	33.8	10.0	19.7	35.0	19.0	100.0	14.2	29.9
6	1.353E+0	17.1	50.0	16.3	100.0	23.4	100.0	9.2	18.4
7	8.209E-1		50.0		56.5		100.0		2.2
8	4.979E-1	17.1	50.0	14.3	29.9	66.0	100.0	-	-
9	3.020E-1		50.0		17.5		100.0		-
10	1.832E-1	8.8	50.0	13.8	10.0	62.7	100.0	-	-
11	1.111E-1		50.0		10.0		100.0		-
12	6.738E-2	11.9	50.0	11.3	10.0	28.2	100.0	-	-
13	4.087E-2		50.0		10.0		100.0		-
14	2.479E-2	11.2	50.0	10.2	10.0	16.2	100.0	-	-
15	1.503E-2		50.0		6.9		100.0		-
16	9.119E-3	7.5	50.0	4.4	5.0	21.0	100.0	-	-
17	5.531E-3		50.0		5.0		100.0		-
18	3.355E-3		50.0		5.0		100.0		-
19	2.035E-3	4.3	49.9	1.5	5.0	11.7	99.9	-	-
20	1.234E-3		39.8		5.0		94.9		-
21	7.485E-4		33.7		5.0		91.9		-
22	4.540E-4	8.1	30.0	1.6	5.0	9.3	90.0	-	-
23	3.043E-4		24.8		4.7		90.0		-
24	1.486E-4		19.4		4.3		90.0		-
25	9.166E-5		17.4		4.2		90.0		-
26	6.790E-5		16.6		4.1		90.0		-
27	4.017E-5		15.6		4.0		90.0		-
28	2.260E-5	19.0	15.0	5.5	4.0	24.0	90.0	-	-
29	1.371E-5		15.0		4.0		90.0		-
30	8.315E-6		15.0		4.0		90.0		-
31	4.000E-6	4.6	15.0	0.4	4.0	35.6	90.0	-	-
32	5.400E-7	4.6	5.0	3.2	1.0	41.2	50.0	-	-
33	1.000E-7	4.9	5.0	4.8	1.0	42.6	50.0	-	-

Conclusions

The present work shows the first application of the recent AFCI1.2 matrix, with the determination of the uncertainty for the main integral parameters (multiplication factor, power peaking factor, Doppler reactivity coefficient, coolant void reactivity worth and burnup reactivity swing) of a series of fast reactors (ABR metal core, ABR oxide core, SFR, EFR, GFR, LFR, ADMAB). The obtained AFCI1.2 parameter uncertainties are also compared with the results presented in previous studies with the BOLNA correlation matrix.

The overall parameter uncertainties estimated with AFCI1.2 data generally are quite comparable with the BOLNA results (except for parameters like GFR or ADMAB burnup reactivity).

U238 inelastic is a large source of uncertainty for all investigated parameters except the burnup reactivity and for all reactors under study (except SFR and ADMAB). Pu238 fission and Pu241 fission are important contributors to the obtained uncertainties of most of the investigated integral parameters. Among minor actinides cross-sections, Am241 fission, Am241 capture, Cm245 fission are relevant for ADMAB, Am242 fission is relevant for SFR and Cm242 fission brings relevant uncertainties on burnup reactivities. Concerning structural isotopes, their contributions are non negligible in the case of power peaking factor (Fe56 elastic and Na elastic for SFR, Na elastic for EFR, Pb elastic for LFR), Doppler coefficient (Na elastic for SFR, Na elastic and O elastic for EFR, Pb elastic for LFR), and coolant void worth (Na inelastic for ABRs, SFR and EFR, Fe56 elastic for SFR, Na elastic for EFR, Pb inelastic and Pb elastic for LFR, Bi inelastic, Pb capture and Bi capture for ADMAB).

Compared to the BOLNA results the use of AFCI1.2 data yields much larger components of uncertainty from Pu238 fission, Cm242 fission, Pu240 capture and Pb206 inelastic, while smaller uncertainties are obtained from Pu241 fission, Cm244 fission, Na inelastic, Fe56 inelastic, B10 capture.

Based on the results of a Target Accuracy study performed with BOLNA data for the Sg26, U238 inelastic, Pu238 fission, Pu241 fission, Cm242 fission, Pu240 capture, Pb206 inelastic, Pu239 capture have been identified as priority needs for the AFCI1.2 data.