Nuclear Data for Innovative Fast Reactors: Impact of Uncertainties and New Requirements

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Introduction and Objective (1/2)

- It is widely accepted that the current status of neutronics calculations for fast reactor design is such that present uncertainties on nuclear data should still be significantly reduced, in order to get full benefit from advances in modeling and simulation.

- Only a parallel effort in advanced simulation, in high accuracy validation experiments and in nuclear data improvement will provide designers with more general and well validated calculation tools to meet tight design target accuracies to further improve safety and economics.

- This paper presents very recent results related to nuclear data uncertainty impact assessment, as a new step in the frame of an international activity, sponsored by OECD-NEA.

Introduction and Objective (2/2)

The most significant recent initiative aiming to a systematic nuclear data uncertainty impact assessment, was taken by the Working Party on Evaluation Cooperation (WPEC) of the OECD Nuclear Energy Agency Nuclear Science Committee:

- **A Subgroup was set up to develop a systematic approach to define data needs for advanced reactor systems and to make a comprehensive study of such needs for Gen-IV reactors.**

- **The Subgroup was established at the end of 2005, and a final report has been published in 2008**

Very recently, a joint effort, lead by BNL, has produced an improved version (AFCI 1.2) of the initial covariance data library (BOLNA) with an energy group structure of 33 groups (instead of 15 in BOLNA).

Revised uncertainties have been calculated on a wide range of Fast Reactor systems and of integral parameters.

Features of the Fast Reactor Systems

System	Fuel	Coolant	TRU/ (U+TRU)	MA[a]/ (U+TRU)	Power (MWth)
ABR	Metal	Na	0.162	~0	250
ABR	MOX	Na	0.162	~0	250
SFR	Metal	Na	0.605	0.106	840
EFR	MOX	Na	0.237	0.012	3600
GFR	Carbide	He	0.217	0.050	2400
LFR	Metal	Pb	0.233	0.024	900
ADMAB[b]	Nitride	Pb-Bi	1.0	0.680	380

(a) Minor Actinides
(b) ADS

Selected results of the uncertainty analysis: the case of keff

SFR: keff Uncertainty (%)

ISOTOPE	CAPTURE	ELASTIC	NU	INELASTIC	FISSION	TOTAL
Pu-238	0.06	0.00	0.16	0.02	1.31	1.32
Pu-241	0.13	0.00	0.03	0.01	0.99	1.00
Pu-240	0.47	0.01	0.44	0.03	0.39	0.76
Am-242M	0.09	0.00	0.05	0.02	0.65	0.66
Pu-242	0.20	0.00	0.08	0.03	0.38	0.44
Cm-245	0.01	0.00	0.05	0.00	0.42	0.42
Fe-56	0.20	0.20	0.00	0.04	0.00	0.29
Cm-244	0.18	0.00	0.11	0.01	0.14	0.25
U-238	0.05	0.04	0.03	0.23	0.01	0.24
Pu-239	0.13	0.02	0.08	0.06	0.13	0.21
Am-241	0.10	0.00	0.04	0.01	0.09	0.14
TOTAL	0.64	0.21	0.51	0.27	1.91	2.11

Selected results of the uncertainty analysis: the case of k_{eff}

SFR: keff Uncertainty Difference (%) between AFCI1.2 and BOLNA (major contributions)

ISOTOPE	CAPTURE	ELASTIC	NU	INELASTIC	FISSION	TOTAL
Pu-238	0.00	0.00	-0.20	0.01	0.77	0.67
Fe-56	0.09	0.10	0.00	-0.41	0.00	-0.19
Na-23	-0.01	0.01	0.00	-0.15	0.00	-0.15
Cm-244	0.12	0.00	0.03	0.00	-0.24	-0.15
B-10	-0.14	-0.01	0.00	0.00	0.00	-0.14
Pu-240	0.16	0.00	0.01	0.02	0.03	0.11
TOTAL	0.18	0.10	-0.08	-0.29	0.37	0.30

Selected results of the uncertainty analysis: the case of k_{eff}

EFR: keff Uncertainty (%)

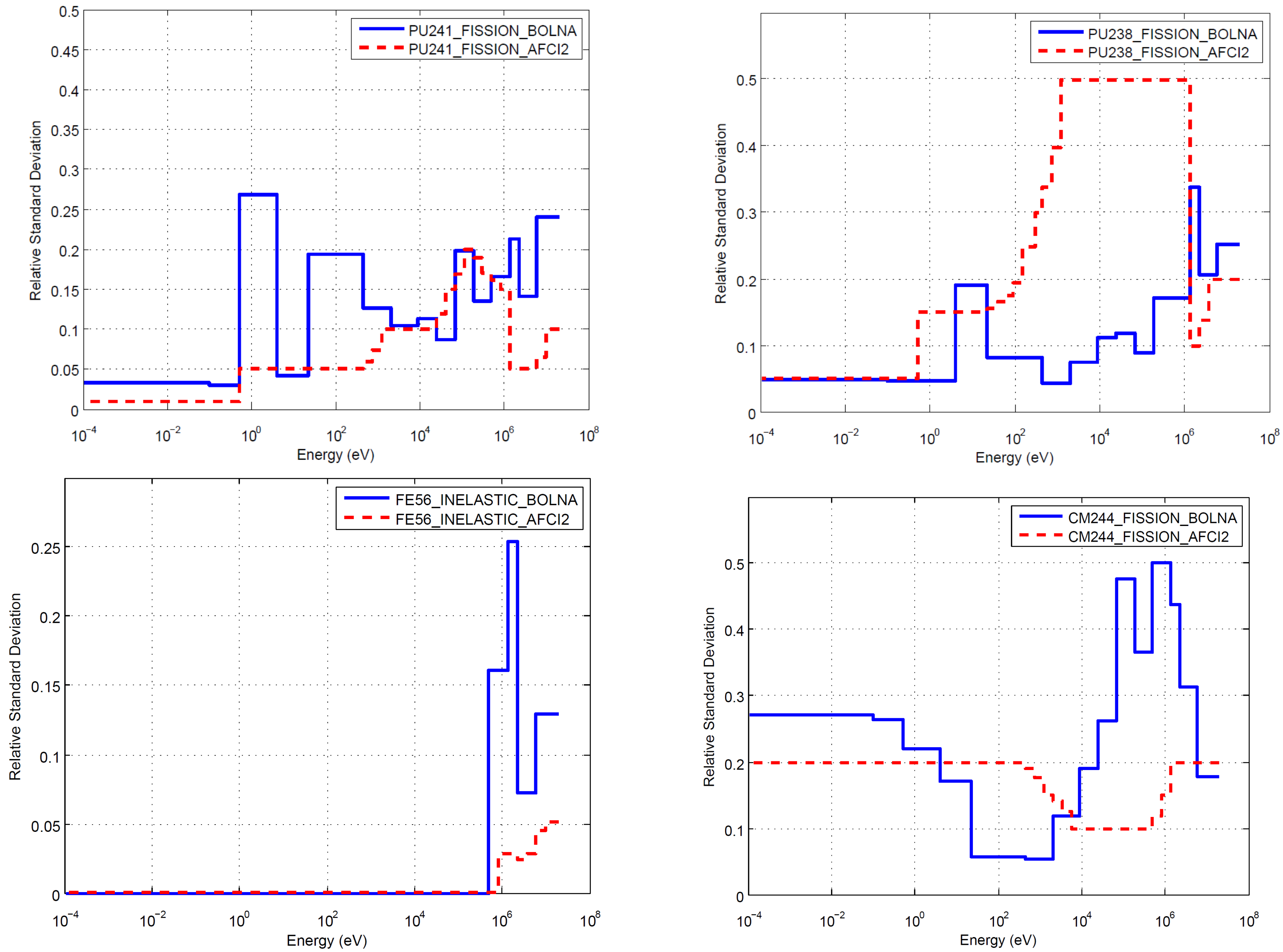
ISOTOPE	CAPTURE	ELASTIC	NU	INELASTIC	FISSION	SUM
U-238	0.25	0.16	0.13	0.89	0.03	0.95
Pu-240	0.33	0.00	0.28	0.02	0.26	0.51
Pu-241	0.05	0.00	0.01	0.00	0.40	0.40
Pu-239	0.25	0.02	0.15	0.08	0.20	0.37
Pu-238	0.02	0.00	0.04	0.01	0.34	0.34
SUM	0.52	0.20	0.35	0.90	0.63	1.28

Selected results of the uncertainty analysis: the case of k_{eff}

EFR: keff Uncertainty Difference (%) between AFCI1.2 and BOLNA (major contributions)

ISOTOPE	CAPTURE	ELASTIC	NU	INELASTIC	FISSION	SUM
Pu-238	0.00	0.00	-0.06	0.00	0.21	0.18
O-16	-0.25	0.04	0.00	-0.03	0.00	-0.17
Fe-56	0.04	0.00	0.00	-0.16	0.00	-0.09
Pu-240	0.08	0.00	0.00	0.01	0.04	0.07
SUM	-0.06	0.01	0.01	0.00	0.10	0.02

Examples of data from the covariance libraries



Selected results of the uncertainty analysis: the case of Na void reactivity

SFR: Coolant-voided Reactivity Uncertainty (%) by Isotope (Full AFCI 1.2 Correlation Data)

ISOTOPE	CAPTURE	ELASTIC	NU	INELASTIC	FISSION	SUM
Pu-238	0.7	0.0	0.4	0.2	8.8	8.8
Na-23	0.4	1.0	0.0	4.8	0.00	4.9
Fe-56	1.4	4.5	0.00	0.4	0.00	4.7
Pu-241	0.6	0.0	0.1	0.2	4.0	4.0
Pu-240	1.3	0.1	2.5	0.5	2.5	3.7
Pu-242	2.4	0.0	0.6	0.2	2.2	3.3
Am-242M	0.7	0.0	0.3	0.2	2.4	2.6
Cm-244	2.0	0.0	0.8	0.1	0.8	2.3
Pu-239	1.1	0.3	1.1	0.6	0.9	1.9
U-238	0.8	0.6	0.1	1.6	0.0	1.9
SUM	4.3	4.8	2.9	5.2	10.6	13.8

Analysis of the results (1/2)

- The impact of present evaluated uncertainties on nuclear data largely overshadow expected simulation improvement benefits.

- Required accuracies on nuclear data in order to meet core and fuel cycle design target accuracies are very tight, and often extremely difficult to meet even with smart and sophisticated experimental techniques.

- The potential presence of relatively large amounts of MA in the core and in the fuel cycle is a source of significant uncertainties.

Analysis of the results (2/2)

- **Pu isotopes** **other than Pu-239 need special consideration (fission data are crucial).**

- **U-238 and Fe inelastic cross section uncertainties are still an important issue.**

- **Covariance data libraries are continuously improved. However further efforts are needed to:**
  - **consolidate current neutron cross section values,**
  - **introduce systematically cross correlations and**
  - **expand them to items such as prompt neutron fission and angular distribution data.**

Conclusions (1/2)

- **The results of the present investigation indicate that a careful analysis is still needed in order to define the most appropriate and effective strategy for data uncertainty reduction.**

- **Besides a further consolidation of the present covariance data libraries, a strategy of combined use of integral and differential measurements should be further pursued in order to meet future requirements.**

- **A new Subgroup has been established by the WPEC of the NEA-NSC in order to evaluate and compare different approaches in the field of the so-called "statistical data adjustment" or "data assimilation" methods**

Conclusions (2/2)

- **The program of this new Subgroup is to inter-compare the statistical data adjustments performed simultaneously in different laboratories, starting from the same set of integral data and different cross section data sets**

- **The objective of the exercise is to verify at what extent a convergence of the adjusted data sets will be obtained.**

- **This type of outcome will greatly improve the perception of reliability of the adjusted data sets, in particular with respect to their domain of applicability.**

- **Moreover, the impact of different covariance data libraries will be evaluated and the significance of having a set of data consistent with the original cross section libraries will be assessed.**