WPEC/SG46 TAR exercise:
Preliminary Results

O. Cabellos
Universidad Politécnica de Madrid (UPM), Madrid, Spain
E-mail: oscar.cabellos@upm.es

WPEC/SG46 Participants

Special thanks to JAEA, CIEMAT, UPM and SCK

Outline

- *Legacy Work WPEC/SG26 (2005-2008)*
- *WPEC/SG46 (2019-2021)*
- *Target Accuracy Requirements: Necessity of "Expert Judgment"*
- *Methodology: The inverse problem*
- *TAR Benchmark Specifications*

  https://oecd-nea.org/download/wpec/sg46/
- ***Processing Covariances (previous presentation)***
- *New reactor systems in WPEC/SG46: ASTRID, ESFR-SMART, JSFR750 and ALFRED*
- ***Preliminary Results**: Uncertainty Quantification*
- ***Preliminary TAR Results for ENDF/B-VIII.0***

❑ Legacy Work WPEC/SG26 (2005-2008)

https://oecd-nea.org/download/wpec/volume26/volume26.pdf

- ## Systems

ABTR: 250 MWth	Na cooled
SFR: (Burner: CR=0.25) 840 MWth	Na cooled
EFR: 3600 MWth	Na cooled
GFR: 2400 MWth	He cooled
LFR: 900 MWth	Pb cooled
ADMAB: 377 MWth	Pb-Bi cooled
VHTR	TRISO fuel
Extended BU PWR	8.5wo%

- ## Integral parameters

Criticality (keff)	(in pcm)
Local Power Peak	(in %)
Burnup reactivity swing	(in pcm)
Reactivity coefficients	(in %)
Nuclide inventories/transmutation at EOL	(in %)

- A first list of data priorities (i.e**. for uncertainty reduction**) for GEN-IV reactors was established and implemented in the HPRL at NEA

Table 26. SFR: uncertainty reduction requirements needed to meet integral parameter target accuracies

Isotope	Cross-Section	Energy range	Uncertainty (%)			
			Initial	Required		
				$\lambda=1$	$\lambda\neq1$ (a)	$\lambda\neq1$ (b)
U238	σ_{capt}	24.8 - 9.12 keV	9	4	3	3
	σ_{inel}	6.07 - 0.498 MeV	20	5	6	10
Pu238	σ_{capt}	183 - 24.8 keV	20	12	12	10
	σ_{fiss}	6.07 – 0.09 MeV	20	3	3	3
	ν	1.35 - 0.067 MeV	7	3	3	2
Pu239	σ_{capt}	498 – 2.03 keV	12	6	4	4
	σ_{inel}	6.07 – 0.498 MeV	25	12	15	22

TAR Exercise in WPEC/SG26:

- *Covariance data matrices: **BOLNA***
- *Energy structure: "**15 energy groups** (based on physical considerations)"*
- *No-correlations in energy, reactions and isotopes are considered **in TAR exercise***
- ***14** HPRL entries based on SG26 studies!*

❑ WPEC/SG46 (2019-2021)

https://oecd-nea.org/download/wpec/sg46/

- **WPEC/SG46** is again a new **bridge** between ND evaluators and end-users in the utilisation of integral experiments

- WPEC/SG46 to provide **updated target accuracies for nuclear data uncertainty reduction**
  - *"It is essential to* ***verify the status of design target accuracies*** *and their potential evolution (reactor operation and fuel cycle parameters)"*
  - *New reactors concepts are presently explored besides Gen-IV, MA burners, and ADS: MSR, SMR, micro reactors, and test reactors*

- **TAR WPEC/SG46 methodology** based on:
  - *New covariance data matrices: ENDF/B-VIII.0, JEFF-3.3 and JENDL-4.0u*
  - *Using correlations in energy, reactions and isotopes*
  - *Energy structure: "7 energy groups (based on physical considerations)"*

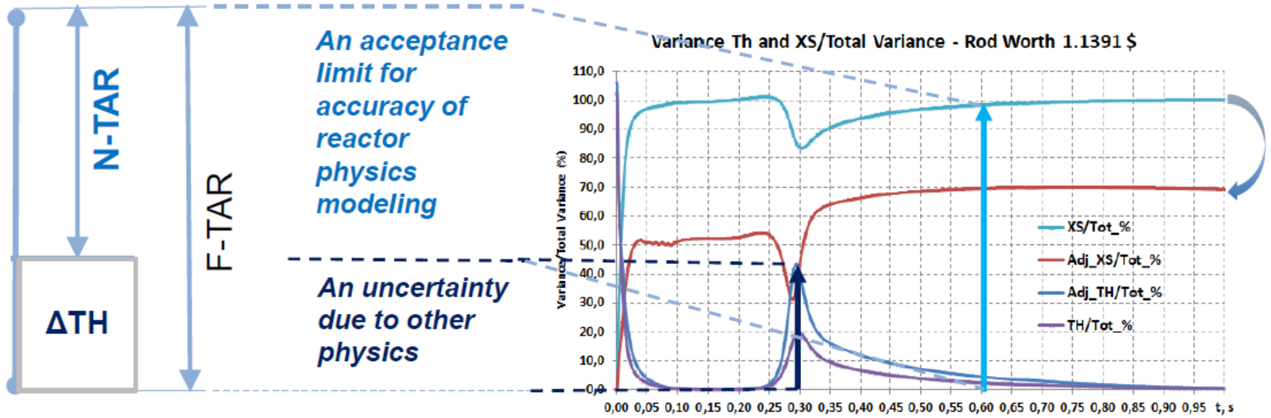
- *"The* ***HPRL*** *will certainly benefit from an update, to motivate and focus new experiments and to meet potential new requirements"*

❑ Target Accuracy Requirements:

Necessity of "Expert Judgment"

Target accuracy establishment for multi-physics processes

- Target Accuracy Requirements (TARs) represent wishes and acceptance limits established by designers and/or assessors
- Sg46 task => to establish TARs for Nuclear Data libraries
- One should separate (approximately) impacts due to reactor physics and due to other physics => combining sampling and linearized response (sensitivity) studies
- Sampling-based back-propagation with reduced (adjusted) ND uncertainties
- Note: practically used simulations (no exemptions) based on a hierarchic structure; we are following a kind of a gradient descent approach to quantify uncertainties of different nature



23 OECD-NEA/NSC/WPEC/SG46, NOVEMBER 11, 2020, WEBEX MEETING IRSN MEMBRE DE ETSON

Ref. Evgeny Ivanov (WPEC/S46, Nov.2020)

❑ Methodology: The inverse problem

https://oecd-nea.org/download/wpec/sg46/

❑ The "**inverse problem**":

- To define the TAR on design parameters: R_n^T
- To find out **the required reduction in the cross-section uncertainties:** Δx_i

$$\text{To minimize: } \left(\sum_i \frac{\lambda_i}{\Delta x_i^2}\right)$$
$$i = 1, \ldots, K$$

λ_i: cost parameter related with each cross−section

Δx_i: uncertainty cross−section (i.e. standard deviation)

K: total number of reactions-energy groups whose uncertainty is to be determined

- ISOTOPES: ^{10}B, ^{16}O, ^{52}Cr, ^{56}Fe, ^{58}Ni, $^{235,238}U$, $^{239,240,241}Pu$, $^{206,207,208}Pb$,^{23}Na + others (e.g. ^{35}Cl)?
- REACTIONS: σ_{cap}, σ_{fiss}, ν , σ_{el}, σ_{inel}, PFNS and elastic-P1 + others (e.g. (n,p), n(alpha))?
- ENERGY Groups: 7g

The **objective function** is constrained to:

correlation terms

1) $\Delta x_{i0} \geq \Delta x_i \geq 0; i = 1 \ldots K$
2) $\sum_i S_{ni}^2 \cdot \Delta x_i^2 + \boldsymbol{\sum_{ii'} S_{ni} \cdot \Delta x_i \cdot corr_{ii'} \cdot \Delta x_{i'} \, S_{ni}^+} \leq (R_n^T)^2; n = 1 \ldots N$

- S_{ni}: sensitivity coefficient for the integral parameter R_n
- $corr_{ii'}$: correlation between i and i′
- R_n^T : target accuracies on the N-integral parameters

❑ Methodology: The inverse problem

https://oecd-nea.org/download/wpec/sg46/

❑ Who is involved in TAR exercise?

$$\textit{To minimize}: \left(\sum_i \frac{\lambda_i}{\Delta x_i^2}\right)$$

$$i = 1, \ldots, K$$

The objective function is constrained to:

1) $\Delta x_{i0} \geq \Delta x_i \geq 0; i = 1 \ldots K$

2) $\sum_i S_{ni}^2 \cdot \Delta x_i^2 + \sum_{ii'} S_{ni} \cdot \Delta x_i \cdot corr_{ii'} \cdot \Delta x_{i'} S_{ni}^{+} \leq (R_n^T)^2; n = 1 \ldots N$

- ❑ **ND Differential measurement experts**
  - Cost parameters assigned to isotopes, reactions, and/or energy group
- ❑ **ND Processing**
  - AMPX/NJOY codes
  - Issues to be solved:
    - MF34/O16-P_1 for JENDL
    - MF34/235U and 238U in ENDF/B-VIII.0
  - Limitations in NJOY: unique Ein value for MF35/PFNS
  - Correlations between MATs-MTs-Energy to be processed and used
- ❑ **Lower uncertainty**
  - Standards?
- ❑ **ND Evaluators**
  - Uncertainties for all MATs/MTs
  - Credible uncertainties
  - Mathematically "positive definite" for full covariance data
- ❑ **Reactor Designers**
  - Safety margins
  - Licensing
- ❑ **Reactor Physicists**
  - Reactor Model
  - Sensitivity Profiles
- ❑ **TAR Solving**
  - Assumptions
  - Inverse method + others ML/AI?
  - **Note:** TAR calculations performed by UPM using the solver DONLP2 (Spelluci P., 1998)

Ref.: Spellucci, P. "*An SQP method for general nonlinear programs using only equality constrained subproblems*". Math. Program. 82, 413–448 (1998)

❑ Methodology: The inverse problem

https://oecd-nea.org/download/wpec/sg46/

❑ TAR Solver

- TAR calculations performed by UPM using the solver DONLP2 (Spelluci P., 1998) based on a SQP (sequential quadratic programming) method

Ref.: Spellucci, P. "*An SQP method for general nonlinear programs using only equality constrained subproblems*". Math. Program. 82, 413–448 (1998)

Ref.: The IMSL function **"constrained_nlp"** provides an interface to a licensed version of subroutine DONLP2,

- The objective function is constrained to the following boundary conditions:

$$\Delta x_{i0} \geq \Delta x_i \geq 0; i = 1 \ldots K$$

- $\Delta x_i \geq$ **0% (positive relative standard deviation)**
- **Min (**Δx_i **)** $=$ **0%** which may gives very low experimental uncertainties
- **If** $\Delta x_{i0} \geq$ **100%** $\Rightarrow \Delta x_{i0}=$ **100%**
- **If** $\Delta x_{i0}=$ **0%** $\Rightarrow \Delta x_{i0}=$ **10%**
- **Full set of parameters:** 14 MATs/9MTs/7g with no-null sensitivities $\Rightarrow$ **370 variables /JSFR-Keff**
- **Reduced set of parameters:** ~98% uncertainty only diagonal $\Rightarrow$ **45 variables /JSFR-Keff**

❑ TAR Benchmark Specifications:

https://oecd-nea.org/download/wpec/sg46/

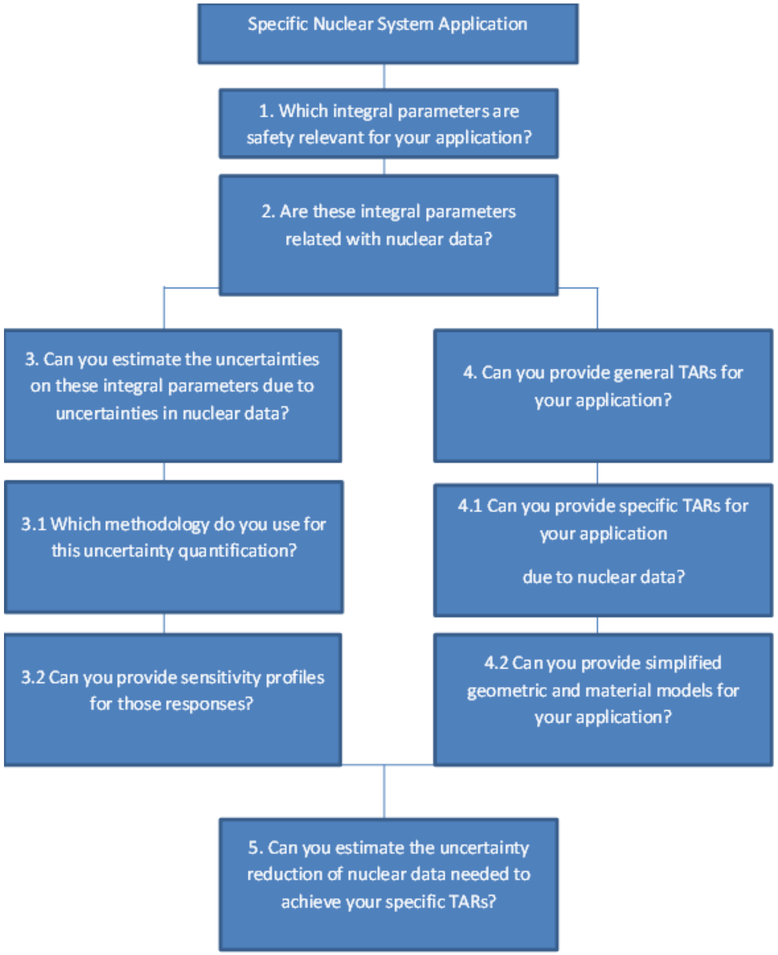
❑ Benchmark Specifications: WPEC/SG46 Exercise on Target Accuracy Requirement (TAR)

WPEC/SG46, May 2021

Table 1. Energy group structure

Group #	Lower Energy (eV)	Upper Energy (eV)	
1	$2.23130\ 10^{6}$	$1.96403\ 10^{7}$	Above Threshold fertile
2	$4.97871\ 10^{5}$	$2.23130\ 10^{6}$	Above Threshold inelastic
3	$6.73795\ 10^{4}$	$4.97871\ 10^{5}$	Continuum to URR
4	$2.03468\ 10^{3}$	$6.73795\ 10^{4}$	URR
5	$2.26033\ 10^{1}$	$2.03468\ 10^{3}$	RRR
6	$5.40000\ 10^{-1}$	$2.26033\ 10^{1}$	EPITHERMAL
7	$1.40000\ 10^{-5}$	$5.40000\ 10^{-1}$	THERMAL

Figure 1. Procedure for any specific application to participate in WPEC/SG46 exercise on TAR



https://oecd-nea.org/download/wpec/sg46/materials/documents/WPEC_SG46_TAR_Exercise-v2_HM41-OC_GP-OC-v1.pdf

❑ Processing Covariances

❑ Issues in evaluated files

ND Evaluation	Large procesed uncertainties (> 100%)	Lack of ND covariances	Processed null
JEFF-3.3	B10(n,n') – g=2 U238(n,elasticP1) – g=6,7	No MF31 • Pu240 No MF33 • Pb206(n,p), Pb206(n,alpha) • Pb207(n,p), Pb207(n,alpha) • Pb208(n,p), Pb208(n,alpha) No MF34 • B10 • O16 • Na23 • Cr52 • U235 • Pu239, Pu240 No MF35 • Pu240	Processed null values • B10(n,alpha) –g=1 • B10(n,n') - g=3-7 • Cr52(n,n') - g=3-7 • Ni58(n,alpha) – g=3-7 • Ni58(n,p) –g=3-7 • Fe56(n,alpha) –g=2-7 • U235(n,n') – g=5 • Ni58(n,elasticP1) –g=3-7 • Pu241(n, elasticP1) –g=6-7

Note: **See presentation in Processing Session**

INDUSTRIALES ETSII | UPM

❑ Values for Cost parameters (λ_i) related to each cross−section

Table 2. Different set of values for the cost parameters (λ_i)

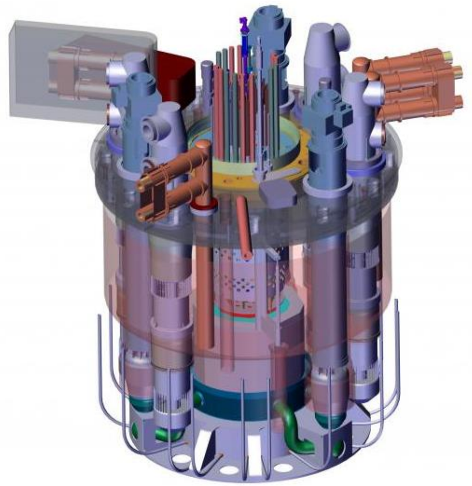
Isotopes and reactions	cost parameters (λ_i)		
	Set A	Set B	Set C
^{235}U, ^{238}U and ^{239}Pu – capture, fission, ν	1	1	1
Other fuel isotopes – capture, fission, ν	1	2	2
Non-fuel isotopes – capture	1	1	1
All isotopes – elastic scattering	1	1	1
All isotopes – inelastic scattering	1	3	10

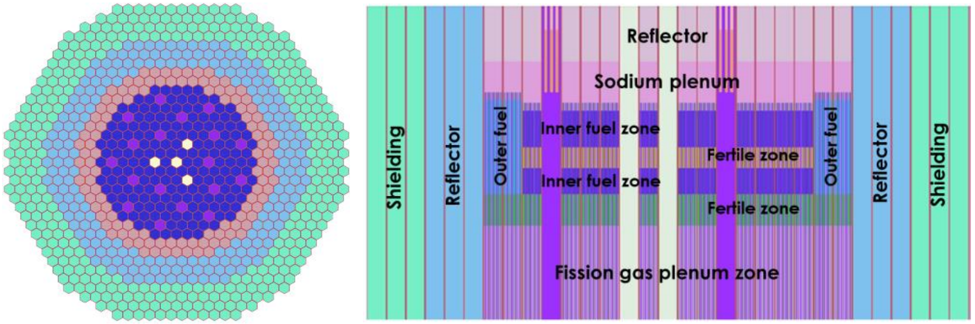
❑ Additional set of values:

– Add energy dependence?

Reference:
M. Salvatores et al., "OECD/NEA WPEC Subgroup 26 Final Report: Uncertainty and Target Accuracy Assessment for Innovative Systems Using Recent Covariance Data Evaluations", OECD/NEA/Nuclear Science, 2008.

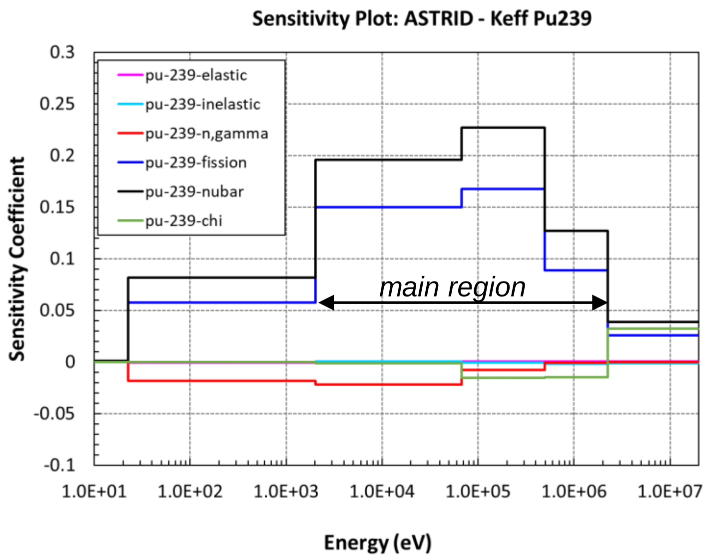
❑ New reactor systems in WPEC/SG46: ASTRID





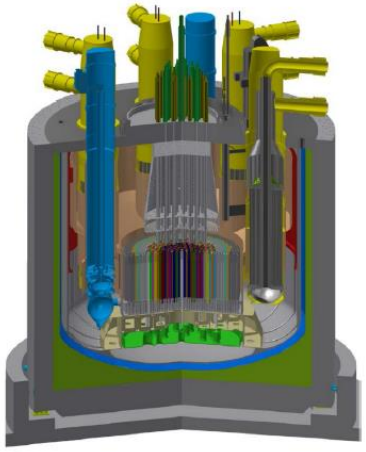
Reference: P. Sciora, ESNII+ deliverable D6.1.1-1

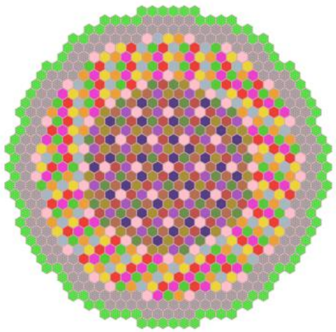
- Core Power – medium size: 1500MWth / **600 MWe**
- Sodium-cooled fast reactor
- Fuel type: MOX
  - 177 Inner FA, Pu content (%) 24.3wt%
  - 114 Outer FA, , Pu content (%) 20.7wt%
- Active fuel: 90 cm (fissile height) + 20 cm (axial blanket)

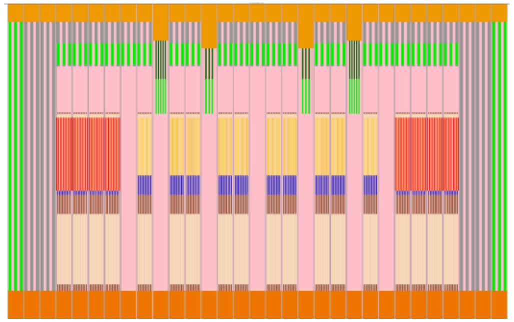


Reference:
P. Romojaro et al., Joint CIEMAT and UPM contribution: ASTRID, ESFR, ALFRED and MYRRHA , WPEC/SG46, June 2019.

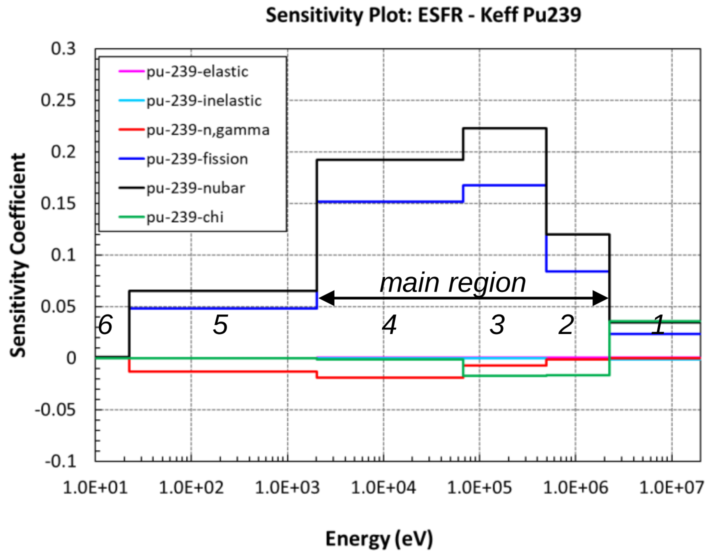
❑ New reactor systems in WPEC/SG46: ESFR-SMART







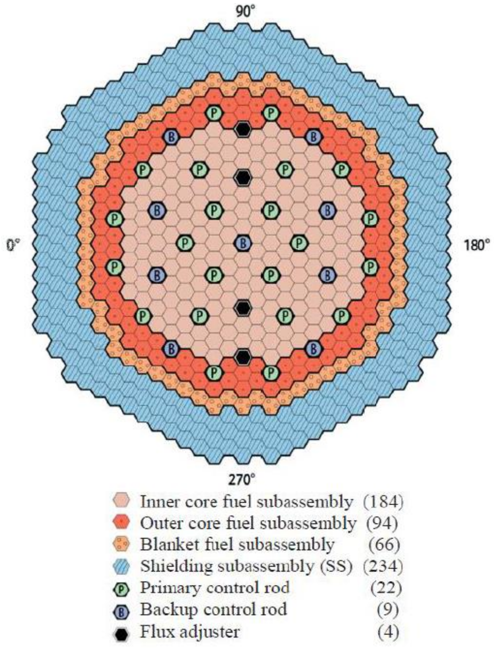
Reference: A. Rineiski et al., ESFR-SMART deliverable D1.1.2



- Core Power – commercial size: 3600MWth / **1500 MWe**
- Sodium-cooled fast reactor
- Fuel type: MOX
  - 216 Inner FA, Pu content (%) 17.99wt%
  - 288 Outer FA, , Pu content (%) 17.99wt%
- 24 control rods
- Active fuel region height (inner core): 75 cm

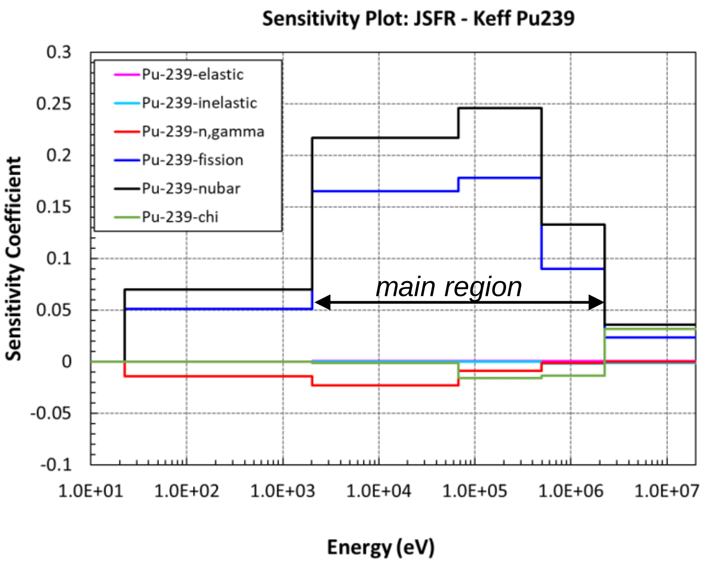
Reference:
A. Jiménez-Carrascosa et al., Joint UPM and CIEMAT contribution: Progress on European Sodium Fast Reactor (ESFR) , WPEC/SG46, November 2020.

❑ New reactor systems in WPEC/SG46: J-SFR750



- Core Power : **750 MWe**
- Sodium-cooled Fast Reactor
- 184 Inner FA (126 pins+1 dummy): 19.1 wt.% Pu/HM
- 94 Outer FA (126 pins+1 dummy): 25.3 wt.% Pu/HM
- 31 Control Rod
- Active fuel: 100 cm

Ref: T. Kan, et al, Proc. Int. Conf. of ICAPP2017, April 24-28, 2017, Fukui and Kyoto, Japan



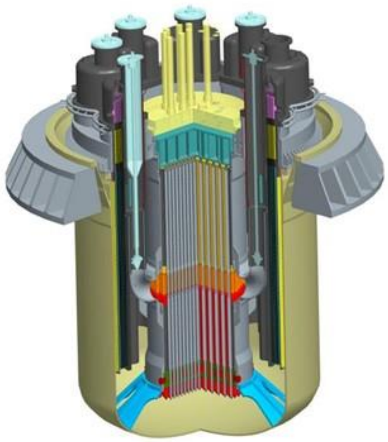
Reference:

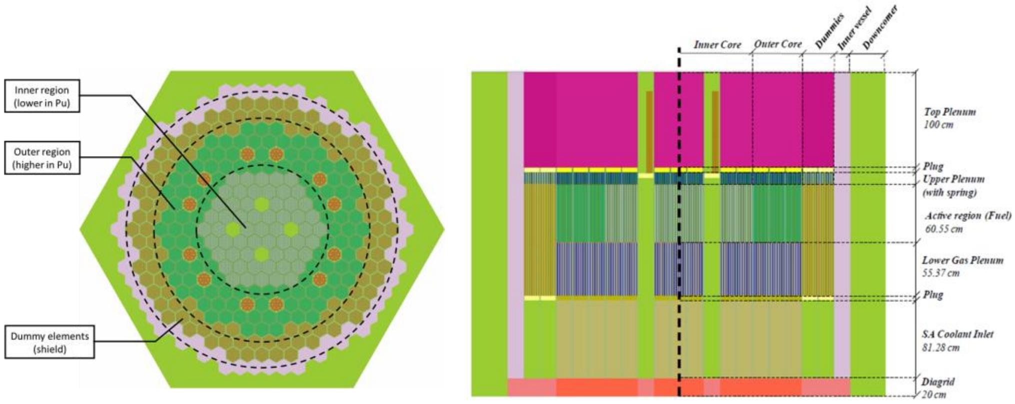
K. Sugino, et al., Models of the 750MWe JSFR core, WPEC/SG46, November 2018

K. Yokoyama, Reactivity and Sensitivity Calculation Results with Leakage and Non-leakage Components for Sodium Void Reactivity of the 750MWe JSFR Core, WPEC/SG46, November 2020

K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46, April 2021

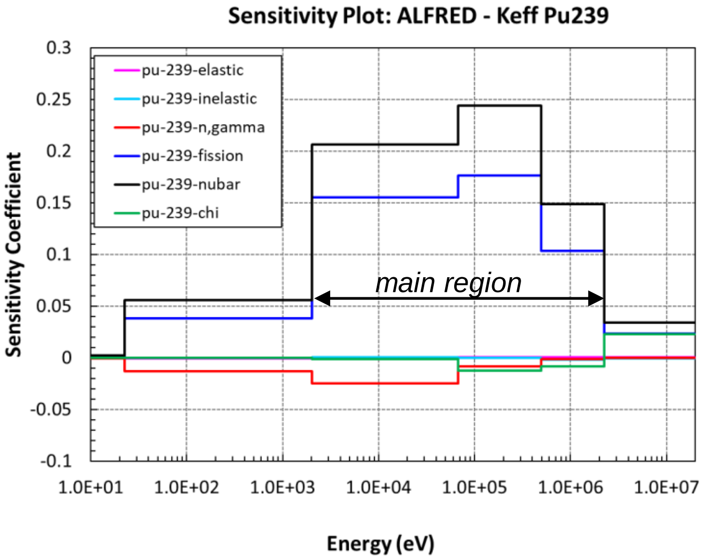
❑ New reactor systems in WPEC/SG46: ALFRED





Reference: G. Grasso et al., ESNII+ deliverable D6.1.1-3

- ❑ Core Power – demonstrator: 300 MWth / **125 MWe**
- ❑ Lead-cooled Fast Reactor
- ❑ Fuel type: MOX
  - 57 Inner FA, Pu content (%) 21.8wt%
  - 114 Outer FA, , Pu content (%) 27.9wt%
- ❑ 12 Control Rod
- ❑ Active fuel: 81 cm



Reference:
G. Grasso et al, The current ALFRED code design, WPEC/SG46, June 2019.
P. Romojaro et al., Joint CIEMAT and UPM contribution: ASTRID, ESFR, ALFR and MYRRHA , WPEC/SG46, June 2019.
G. Grasso, TAR update: Application to ALFRED, WPEC/SG46, April 2021.

❑ Preliminary Results:
Uncertainty Quantification

Table 3. Uncertainties quantification due to nuclear data and preliminary SG46 TAR values

	ENDF/B-VII.1	ENDF/B-VIII.0	JEFF-3.3	JENDL-4.0u	Target
ALFRED-00-keff (in pcm)	701	**865**	827	675	**435 pcm**
ALFRED-01-coolant-density (in %)	57.0	**35.0**	62.3	64.7	-
ALFRED-02-doppler (in %)	9.4	**5.7**	6.1	4.9	-
ASTRID-00-keff (in pcm)	988	**919**	894	728	**300 pcm**
ASTRID-01-fullvoid (in %)	20.0	**21.6**	16.5	18.8	-
ESFR-00-keff (in pcm)	1199	**928**	961	774	**300 pcm**
ESFR-01-fullvoid (in %)	10.8	**13.2**	9.3	10.9	-
ESFR-02-temp-coef (in %)	4.6	**3.7**	3.4	3.3	5%
ESFR-03-control (in %)	2.1	**1.5**	1.7	1.4	5%
JSFR_KEFF (in pcm)	951	**969**	903	750	**200/300 pcm**
JSFR_BRS (in %)	5.0	**5.6**	5.8	6.1	18%
JSFR_CRW (in %)	2.8	**2.8**	3.0	2.3	2%
JSFR_DOP (in %)	4.1	**3.9**	3.5	3.0	2%
JSFR_Power distribution (F49) (in %)	1.6	**1.7**	1.7	1.3	1%
JSFR_SVR (in %)	4.6	**5.9**	3.9	4.8	3%

- UQ performed with sandwich formula and using the full ND covariance matrix (see **Appendix I**)

❑ JSFR: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 10. Uncertainties (in pcm) for the keff due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
U238(n,n')	721	Pu239(n,fission)	615	Pu240(n,fission)	515	U238(n,gamma)	396.5
Pu239(n,gamma)	253	Fe56(n,n')	299	Pu240(n,fission)-(n,gamma)	-460	Pu239(n,fission)	267.4
U238(n,gamma)	216	U238(n,gamma)	264	U238(n,gamma)	333	U238(n,n')	247.1
U238(n,n')-(n,elastic)	211	Pu239(n,gamma)	255	Pu239(nubar)	316	Pu239(CHI)	238.1
Pu239(n,fission)	210	U238(n,n')	213	Pu239(n,fission)	306	Fe56(n,n')	224.2
All correlations =	**951**		**969**		**903**		**750.0**
Except MAT =	950		913		903		736.8
Except MAT&MT =	926		920		955		733.6
Only STDs =	800		699		688		623.5
Uncertainty drops due to no correlations (%)	15.8		27.9		23.7		16.9

TAR value : 200/300 pcm

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

1) Preliminary TAR Results:

Methodology: No correlations .vs. correlations

❑ J-SFR: TAR preliminary results for ENDF/B-VIII.0, "set A" cost parameters

Table 4. Target accuracy requirement on top-10 most important reactions. **No-correlations** in TAR exercise.

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	0.3	18.4
2	pu-239(n,fission)	4	1.3	0.4	17.0
3	fe-56(n,inelastic)	2	18.9	1.2	9.6
4	pu-239(n,fission)	2	1.3	0.5	8.2
5	pu-239(n,fission)	5	4.6	0.6	5.9
6	u-238(n,gamma)	4	1.5	0.4	5.1
7	pu-239(n,gamma)	4	7.5	0.9	4.5
8	u-238(n,gamma)	3	1.8	0.7	3.4
9	u-238(n,inelastic)	1	5.7	1.0	2.1
10	pu-239(n,gamma)	3	9.3	1.5	2.0

Total keff unc. due to ND with ENDF/B-VIII.0: 969 pcm

Table 5. Target accuracy requirement on top-10 most important reactions. **Correlations*** in TAR exercise.

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	0.2	18.4
2	pu-239(n,fission)	4	1.3	0.2	17.2
3	pu-239(n,fission)	2	1.3	0.2	9.3
4	fe-56(n,inelastic)	2	18.9	0.9	8.4
5	pu-239(n,fission)	5	4.6	0.4	5.2
6	u-238(n,gamma)	4	1.5	0.3	5.0
7	pu-239(n,gamma)	4	7.5	0.7	4.0
8	u-238(n,gamma)	3	1.8	0.4	3.7
9	pu-239(n,fission)	1	1.3	0.4	2.1
10	u-238(n,inelastic)	1	5.7	0.8	1.9

*** Ref:** G. Palmiotti et al., "Nuclear Data Target Accuracies for GenIV Systems Based on the Use of New Covariance Data", ND2010

"The impact of correlation terms is very significant in TAR assessments evaluation and produces very stringent requirements in ND", Ref. : ND2010

TAR JSFR/keff value : 200 pcm

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

2) Preliminary TAR Results

Cost parameters: set A .vs. set C

- J-SFR: TAR preliminary results for ENDF/B-VIII.0, “set A – set C” cost param.

Table 6. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise - **set A**.

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	0.2	18.4
2	pu-239(n,fission)	4	1.3	0.2	17.2
3	pu-239(n,fission)	2	1.3	0.2	9.3
4	fe-56(n,inelastic)	2	18.9	0.9	8.4
5	pu-239(n,fission)	5	4.6	0.4	5.2
6	u-238(n,gamma)	4	1.5	0.3	5.0
7	pu-239(n,gamma)	4	7.5	0.7	4.0
8	u-238(n,gamma)	3	1.8	0.4	3.7
9	pu-239(n,fission)	1	1.3	0.4	2.1
10	u-238(n,inelastic)	1	5.7	0.8	1.9

Table7 . Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise – **set C**.

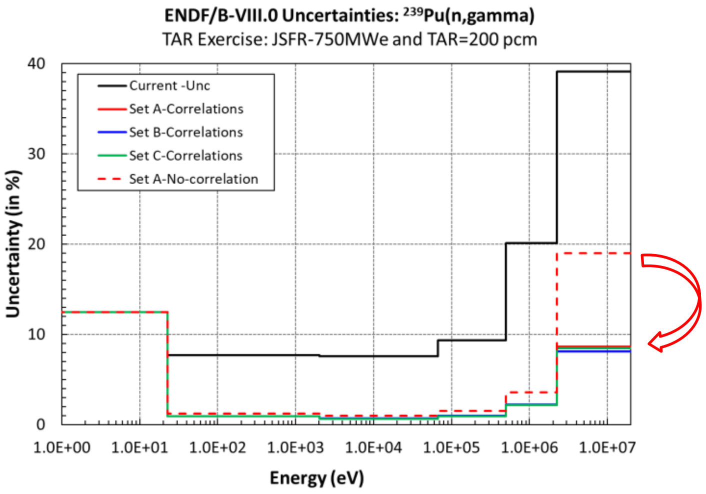
Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	0.2	18.5
2	pu-239(n,fission)	4	1.3	0.2	17.3
3	pu-239(n,fission)	2	1.3	0.2	9.4
4	fe-56(n,inelastic)	2	18.9	1.5	8.4
5	pu-239(n,fission)	5	4.6	0.4	5.2
6	u-238(n,gamma)	4	1.5	0.3	5.1
7	pu-239(n,gamma)	4	7.5	0.6	4.0
8	u-238(n,gamma)	3	1.8	0.3	3.8
9	pu-239(n,fission)	1	1.3	0.4	2.2
10	pu-239(n,gamma)	3	9.3	0.9	1.9
11	u-238(n,inelastic)	1	5.7	1.3	1.8

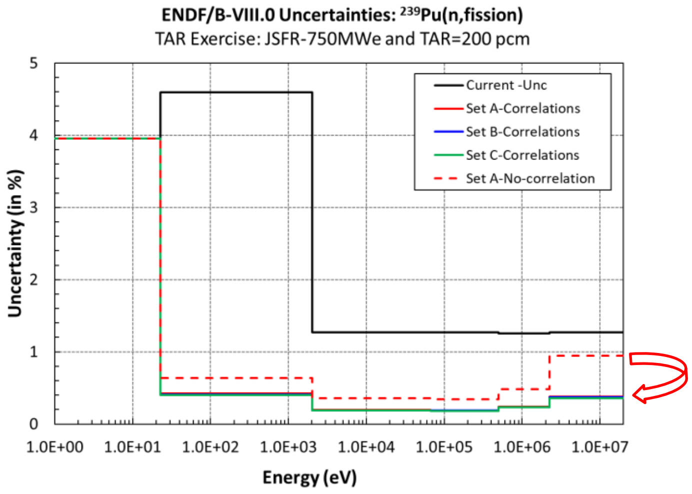
Total keff unc. due to ND with ENDF/B-VIII.0: 969 pcm

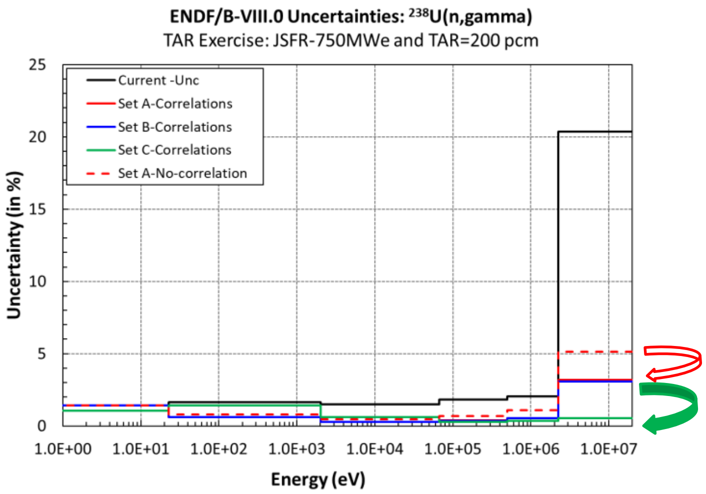
TAR JSFR/keff value : 200 pcm

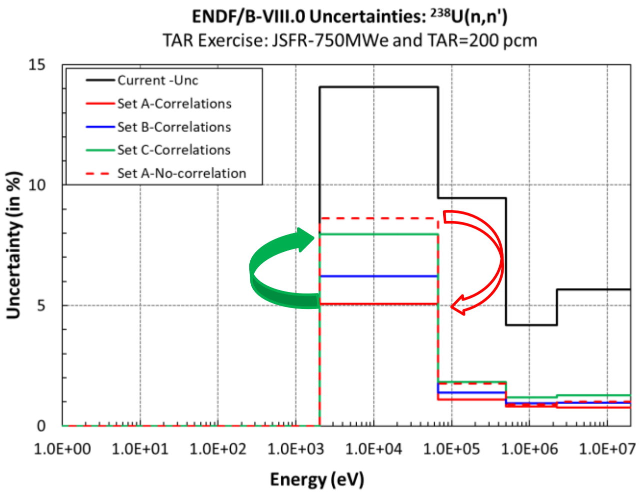
Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

❑TAR preliminary results
System JSFR - ENDF/B-VIII.0









3) Preliminary TAR Results

Different ND evaluations: ENDF/B-VIII.0 .vs. Others

❑ J-SFR: TAR preliminary results for ENDF/B-VIII.0 and other evaluations

Table 8. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise - **set C, ENDF/B-VIII.0**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	0.2	18.5
2	pu-239(n,fission)	4	1.3	0.2	17.3
3	pu-239(n,fission)	2	1.3	0.2	9.4
4	fe-56(n,inelastic)	2	18.9	1.5	8.4
5	pu-239(n,fission)	5	4.6	0.4	5.2
6	u-238(n,gamma)	4	1.5	0.3	5.1
7	pu-239(n,gamma)	4	7.5	0.6	4.0
8	u-238(n,gamma)	3	1.8	0.3	3.8
9	pu-239(n,fission)	1	1.3	0.4	2.2
10	pu-239(n,gamma)	3	9.3	0.9	1.9
11	u-238(n,inelastic)	1	5.7	1.3	1.8

Total keff unc. due to ND with ENDF/B-VIII.0: 969 pcm

Table 9. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise – **set C. ENDF/B-VII.1**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	u-238(n,inelastic)	1	24.3	1.4	38.4
2	u-238(n,inelastic)	2	15.5	1.3	27.1
3	pu-239(n,gamma)	4	8.4	0.8	4.6
4	u-238(n,gamma)	4	1.5	0.4	2.9
5	u-238(n,elastic)	2	7.8	1.1	2.5
6	pu-239(n,gamma)	3	10.4	1.2	2.2
7	fe-56(n,inelastic)	2	9.5	1.8	2.0
8	pu-240(n,gamma)	2	59.3	2.5	1.5
9	pu-239(n,chi)	1	2.7	0.6	1.4
10	o-16(n,gamma)	1	50	2.6	1.3
11	u-238(n,elastic)	1	16.7	2.1	1.1

Total keff unc. due to ND with ENDF/B-VII.1: 951 pcm

TAR JSFR/keff value : 200 pcm

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

4) Preliminary TAR Results

Impact of CC btw MATs

- J-SFR: TAR preliminary results for ENDF/B-VIII.0 – Impact of CC btw MATs

Table 8. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise - **set C, ENDF/B-VIII.0**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	0.2	18.5
2	pu-239(n,fission)	4	1.3	0.2	17.3
3	pu-239(n,fission)	2	1.3	0.2	9.4
4	fe-56(n,inelastic)	2	18.9	1.5	8.4
5	pu-239(n,fission)	5	4.6	0.4	5.2
6	u-238(n,gamma)	4	1.5	0.3	5.1
7	pu-239(n,gamma)	4	7.5	0.6	4.0
8	u-238(n,gamma)	3	1.8	0.3	3.8
9	pu-239(n,fission)	1	1.3	0.4	2.2
10	pu-239(n,gamma)	3	9.3	0.9	1.9
11	u-238(n,inelastic)	1	5.7	1.3	1.8

Total keff unc. due to ND with ENDF/B-VIII.0: 969 pcm

Table 9. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise – **set C. ENDF/B-VIII.0 – noCC in MATs**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	0.2	18.4
2	pu-239(n,fission)	4	1.3	0.2	17.2
3	pu-239(n,fission)	2	1.3	0.3	9.3
4	fe-56(n,inelastic)	2	18.9	1.5	8.4
5	pu-239(n,fission)	5	4.6	0.5	5.3
6	u-238(n,gamma)	4	1.5	0.3	5.1
7	pu-239(n,gamma)	4	7.5	0.7	4.0
8	u-238(n,gamma)	3	1.8	0.4	3.8
9	pu-239(n,fission)	1	1.3	0.4	2.1
10	pu-239(n,gamma)	3	9.3	1.0	1.9
11	u-238(n,inelastic)	1	5.7	1.4	1.8

Total keff unc. due to ND with ENDF/B-VIII.0: 969 pcm

TAR JSFR/keff value : 200 pcm

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

5) Preliminary TAR Results

Methodology … selection of important variables

J-SFR: TAR preliminary results for ENDF/B-VIII.0 – TAR Methodology

Table 8. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise - **set C, ENDF/B-VIII.0**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	0.2	18.5
2	pu-239(n,fission)	4	1.3	0.2	17.3
3	pu-239(n,fission)	2	1.3	0.2	9.4
4	fe-56(n,inelastic)	2	18.9	1.5	8.4
5	pu-239(n,fission)	5	4.6	0.4	5.2
6	u-238(n,gamma)	4	1.5	0.3	5.1
7	pu-239(n,gamma)	4	7.5	0.6	4.0
8	u-238(n,gamma)	3	1.8	0.3	3.8
9	pu-239(n,fission)	1	1.3	0.4	2.2
10	pu-239(n,gamma)	3	9.3	0.9	1.9
11	u-238(n,inelastic)	1	5.7	1.3	1.8

Total keff unc. due to ND with ENDF/B-VIII.0: 969 pcm

Table 9. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise – **set C. ENDF/B-VIII.0**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	0.1	18.8
2	pu-239(n,fission)	4	1.3	0.1	17.6
3	fe-56(n,inelastic)	2	18.9	0.7	8.3
4	pu-239(n,fission)	2	1.3	0.4	8.1
5	pu-239(n,fission)	5	4.6	0.3	5.1
6	u-238(n,gamma)	4	1.5	0.2	5.1
7	pu-239(n,gamma)	4	7.5	0.5	4.0
8	u-238(n,gamma)	3	1.8	0.3	3.9
9	pu-239(n,fission)	1	1.3	0.3	2.3
10	u-238(n,inelastic)	1	5.7	0.6	1.9
11	pu-239(n,gamma)	3	9.3	0.7	1.9

Total keff unc. due to ND with ENDF/B-VIII.0: 969 pcm
TAR selection of 45 "variables" ~ 98% uncertainty diag.

- Residual unc (Rj) = 95.6 pcm
- Unselected (Uj) = 88.3 pcm
- Selected (Cj) = 151.4 pcm
- (Cj) +(Uj) = 175.3 pcm

TAR JSFR/keff value : 200 pcm

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

5) Preliminary TAR Results

Methodology … selection of important variables

J-SFR: TAR preliminary results for ENDF/B-VIII.0 – TAR Methodology

Table 9bis. Target accuracy assessment for JSFR (pcm) : **45 parameters selected**
TAR exercise – **set C. ENDF/B-VIII.0**

		G+C	G+C+F	P	Total
No correlation	Initial	602	605	72	609
	Final	**174**	186	72	200
With Correlation	Initial	873	884	96	889
	Final	**151**	175	96	200

- G+C: uncertainty for selected parameters
  - G: Standard deviations
  - C: Correlations
- G+C+F: uncertainty among selected and unselected variables
- P: uncertainty residual term

TAR JSFR/keff value : 200 pcm

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

Table 9. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise – **set C. ENDF/B-VIII.0**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	0.1	18.8
2	pu-239(n,fission)	4	1.3	0.1	17.6
3	fe-56(n,inelastic)	2	18.9	0.7	8.3
4	pu-239(n,fission)	2	1.3	0.4	8.1
5	pu-239(n,fission)	5	4.6	0.3	5.1
6	u-238(n,gamma)	4	1.5	0.2	5.1
7	pu-239(n,gamma)	4	7.5	0.5	4.0
8	u-238(n,gamma)	3	1.8	0.3	3.9
9	pu-239(n,fission)	1	1.3	0.3	2.3
10	u-238(n,inelastic)	1	5.7	0.6	1.9
11	pu-239(n,gamma)	3	9.3	0.7	1.9

Total keff unc. due to ND with ENDF/B-VIII.0: 969 pcm
TAR selection of 45 "variables" ~ 98% uncertainty diag.

- Residual unc (Rj) = 96 pcm
- Selected: (Gj+Cj) = 151 pcm
- (Gj+Cj) +(Fj) = 175 pcm
- Unselected (Fj) = 88 pcm

6) Preliminary TAR Results

Methodology … Constraint for lower uncertainties

❑ J-SFR: TAR preliminary results for ENDF/B-VIII.0 – Impact of Standards

Table 8. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise - **set C, ENDF/B-VIII.0**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	0.2	18.5
2	pu-239(n,fission)	4	1.3	0.2	17.3
3	pu-239(n,fission)	2	1.3	0.2	9.4
4	fe-56(n,inelastic)	2	18.9	1.5	8.4
5	pu-239(n,fission)	5	4.6	0.4	5.2
6	u-238(n,gamma)	4	1.5	0.3	5.1
7	pu-239(n,gamma)	4	7.5	0.6	4.0
8	u-238(n,gamma)	3	1.8	0.3	3.8
9	pu-239(n,fission)	1	1.3	0.4	2.2
10	pu-239(n,gamma)	3	9.3	0.9	1.9
11	u-238(n,inelastic)	1	5.7	1.3	1.8

Total keff unc. due to ND with ENDF/B-VIII.0: 969 pcm

Table 9. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise – **set C. ENDF/B-VIII.0 + unc_standards**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	**0.5**	15
2	pu-239(n,fission)	4	1.3	**0.5**	13.8
3	fe-56(n,inelastic)	2	18.9	0.2	9.3
4	pu-239(n,fission)	2	1.3	**0.5**	7.9
5	u-238(n,gamma)	4	1.5	0.2	5.8
6	pu-239(n,fission)	5	4.6	**0.6**	5.7
7	u-238(n,gamma)	3	1.8	0.2	4.5
8	pu-239(n,gamma)	4	7.5	0.2	4.5
9	pu-239(n,gamma)	3	9.3	0.2	2.2
10	u-238(n,inelastic)	1	5.7	0.2	2.2
11	pu-239(n,fission)	1	1.3	**0.5**	2

Total keff unc. due to ND with ENDF/B-VIII.0: 969 pcm

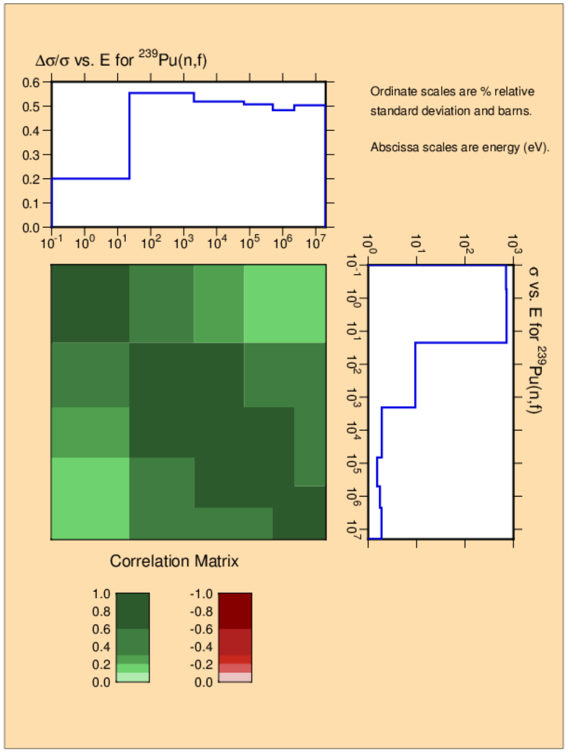
- $\Delta x_i \geq$ **unc. standards% . For the rest:** $\Delta x_i \geq$ **0.2%**

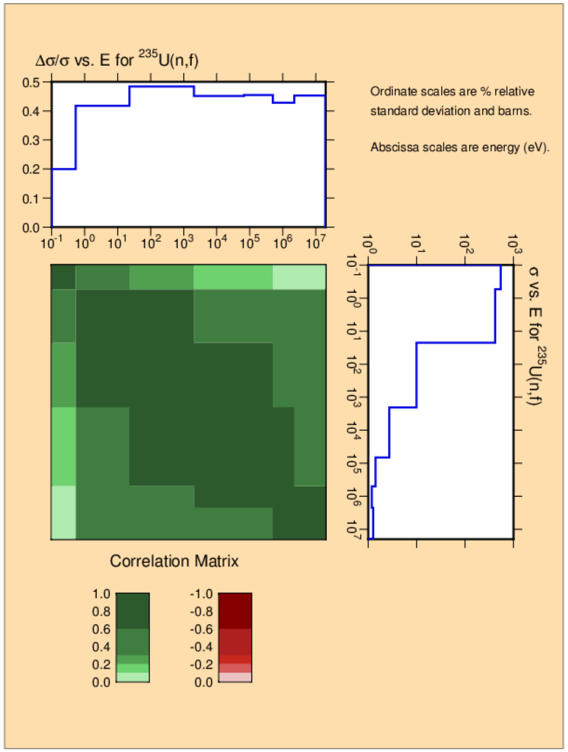
❑ **Low uncertainties- Standards:**
- **239Pu(n,fission)**
- **235U(n,fission)**
- **238U(n,fission)**

TAR JSFR/keff value : 200 pcm

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

❑ Uncertainty – Impact of Standards





IAEA NEUTRON DATA STANDARDS (2017)

https://www-nds.iaea.org/standards/

7) Preliminary TAR Results

Methodology … TAR 200pcm → 300pcm

❑ J-SFR: TAR preliminary results for ENDF/B-VIII.0 – more reliable TAR values

Table 9bis. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise - **set C. ENDF/B-VIII.0 + unc_standards**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	**0.5**	18
2	pu-239(n,fission)	4	1.3	**0.5**	16.6
3	fe-56(n,inelastic)	2	18.9	2.1	11
4	pu-239(n,fission)	5	4.6	0.8	6.8
5	u-238(n,gamma)	4	1.5	0.5	5.5
6	pu-239(n,gamma)	4	7.5	1.3	5.1
7	u-238(n,gamma)	3	1.8	0.6	4.1
8	u-238(n,inelastic)	1	5.7	1.1	2.4
9	pu-239(n,gamma)	3	9.3	1.5	2.4
10	pu-239(n,fission)	1	1.3	0.6	2.1
11	pu-240(n,gamma)	2	59.3	4.8	2.1

Total keff unc. due to ND with ENDF/B-VIII.0: 969 pcm

Table 9. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise – **set C. ENDF/B-VIII.0 + unc_standards**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	**0.5**	15
2	pu-239(n,fission)	4	1.3	**0.5**	13.8
3	fe-56(n,inelastic)	2	18.9	0.2	9.3
4	pu-239(n,fission)	2	1.3	**0.5**	7.9
5	u-238(n,gamma)	4	1.5	0.2	5.8
6	pu-239(n,fission)	5	4.6	**0.6**	5.7
7	u-238(n,gamma)	3	1.8	0.2	4.5
8	pu-239(n,gamma)	4	7.5	0.2	4.5
9	pu-239(n,gamma)	3	9.3	0.2	2.2
10	u-238(n,inelastic)	1	5.7	0.2	2.2
11	pu-239(n,fission)	1	1.3	**0.5**	2

Total keff unc. due to ND with ENDF/B-VIII.0: 969 pcm

○ $\Delta x_i \geq$ **unc. standards% . For the rest:** $\Delta x_i \geq$ **0.2%**

TAR JSFR/keff value : 300 pcm

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 Nov. 2019

TAR JSFR/keff value : 200 pcm

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 Nov.2019

8) Preliminary TAR Results

Different ND evaluations: keff .vs. Others

❑ J-SFR: TAR preliminary results for ENDF/B-VIII.0: Other integral parameters

Table 10. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise - set C, ENDF/B-VIII.0: **keff**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	0.2	18.5
2	pu-239(n,fission)	4	1.3	0.2	17.3
3	pu-239(n,fission)	2	1.3	0.2	9.4
4	fe-56(n,inelastic)	2	18.9	1.5	8.4
5	pu-239(n,fission)	5	4.6	0.4	5.2
6	u-238(n,gamma)	4	1.5	0.3	5.1
7	pu-239(n,gamma)	4	7.5	0.6	4.0
8	u-238(n,gamma)	3	1.8	0.3	3.8
9	pu-239(n,fission)	1	1.3	0.4	2.2
10	pu-239(n,gamma)	3	9.3	0.9	1.9
11	u-238(n,inelastic)	1	5.7	1.3	1.8

Total keff unc. due to ND with ENDF/B-VIII.0: 969 pcm

Table 11. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise - set C, ENDF/B-VIII.0: **SVR**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	5	4.6	1.7	50.2
2	na-23(n,elastic)	3	7.3	2.8	18.2
3	na-23(n,inelastic)	2	11.8	6.1	17.8
4	pu-239(n,gamma)	5	7.7	3.8	4.8
5	na-23(n,elastic)	2	6.8	3.9	3.6
6	o-16(n,elastic-P1)	2	58.5	13.7	2.9
7	na-23(n,gamma)	1	56.9	16.5	1.3
8	o-16(n,inelastic)	1	265.2	55.1	0.3
9	pu-240(n,fission)	5	18.9	12.6	0.3
10	na-23(n,gamma)	2	67.5	25.8	0.3
11	u-238(n,elastic-P1)	2	0	10	-0.2

Total SVR unc. due to ND with ENDF/B-VIII.0: 5.9%

TAR JSFR/keff value : 200 pcm

TAR JSFR/SVR value: 3%

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

9) Preliminary TAR Results

Different systems: JSFR .vs. Others

❑ TAR preliminary results for ENDF/B-VIII.0: Other systems

Table 12. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise - set C, ENDF/B-VIII.0: **J-SFR**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	0.2	18.5
2	pu-239(n,fission)	4	1.3	0.2	17.3
3	pu-239(n,fission)	2	1.3	0.2	9.4
4	fe-56(n,inelastic)	2	18.9	1.5	8.4
5	pu-239(n,fission)	5	4.6	0.4	5.2
6	u-238(n,gamma)	4	1.5	0.3	5.1
7	pu-239(n,gamma)	4	7.5	0.6	4.0
8	u-238(n,gamma)	3	1.8	0.3	3.8
9	pu-239(n,fission)	1	1.3	0.4	2.2
10	pu-239(n,gamma)	3	9.3	0.9	1.9
11	u-238(n,inelastic)	1	5.7	1.3	1.8

Total keff unc. due to ND with ENDF/B-VIII.0: 969 pcm

Table 13. Target accuracy requirement on top-10 most important reactions. **Correlations** in TAR exercise - set C, ENDF/B-VIII.0: **ESFR**

Rank #	Reaction	Energy Group	Current (%)	Target (%)	Rel. Unc. Reduction (%)
1	pu-239(n,fission)	3	1.3	0.3	18.1
2	pu-239(n,fission)	4	1.3	0.3	16.4
3	pu-239(n,fission)	2	1.3	0.4	8.8
4	u-238(n,gamma)	4	1.5	0.4	5.9
5	pu-239(n,fission)	5	4.6	0.6	5.5
6	u-238(n,inelastic)	1	5.7	1.5	5.0
7	fe-56(n,inelastic)	2	18.9	2.7	4.8
8	u-238(n,gamma)	3	1.8	0.5	4.5
9	pu-239(n,gamma)	4	7.5	1.4	3.2
10	u-238(n,inelastic)	2	4.2	1.5	3.0
11	o-16(n,inelastic)	1	265.2	7	2.4

Total keff unc. due to ND with ENDF/B-VIII.0: 928 pcm

TAR JSFR/keff value : 200 pcm

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

TAR ESFR/keff value: 300 pcm

❑ Conclusion

- ***1st Phase: Definition of TAR***
  - *So far, ALFRED, ASTRID, ESFR-SMART and JSFR*
  - ***More reactors + sensitivity profiles: SMR, MSR, …Other systems ?***
- ***2nd Phase: Uncertainty Quantifications***
  - *Different libraries and associate covariance data (e.g. ENDF/B-VIII.0)*
  - *Assessment of 7-energy groups*
- ***3rd Phase: Performing TAR with inverse approach***
  - *7-energy groups*
  - *Correlation and no-correlation*
  - *Different set of cost parameters*
  - *Impact of different assumptions*
  - *One system and all parameters: e.g. JSFR*

Acknowledgments

This work is part of the SANDA project (Supplying Accurate Nuclear Data for energy and non-energy Applications) that has received funding from the European Union's H2020/Euratom under grant agreement No. 847552

❑ Appendix I:
Uncertainty Quantification

- *ALFRED*
- *ESFR-SMART*
- *ASTRID*
- *JSFR*

❑ ALFRED: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 1. Uncertainties (in pcm) for the keff due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
U238(n,n')	454	Pu239(n,fission)	599	Pu240(n,fission)	522	U238(n,gamma)	320.9
Pu239(n,gamma)	263	Pu239(n,gamma)	262	Pu240(n,fission)-(n,gamma)	-434	Pu239(n,fission)	265.4
Pu239(n,fission)	207	U238(n,gamma)	208	Pu239(nubar)	312	Pu239(n,gamma)	221.9
U238(n,gamma)	163	Pu239(nubar)	190	Pu239(n,fission)	281	Pb206(n,n')	186.8
Pu240(n,gamma)	136	Fe56(n,n')	174	U238(n,gamma)	265	Pu239(CHI)	176.0
All correlations =	**701**		**865**		**827**		**674.6**
Except MAT =	700		814		827		658.2
Except MAT&MT =	688		817		888		653.1
Only STDs =	579		579		645		551.3
Uncertainty drops due to no correlations (%)	17.4		33.1		22.0		18.3

TAR value : 435 pcm

Ref.: D. M. Castelluccio et al., Nuclear Data Target Accuracy Requirements for Advanced Reactors: The ALFRED Case, Annals of Nuclear Energy 162 (2021) 108533

INDUSTRIALES
ETSII | UPM

❑ ALFRED: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 2. Uncertainties (in %) for the coolant density coefficient due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
U238(n,n')	45.1	Pb206(n,n')	14.0	Pb206(n,n')	43.0	Pb206(n,n')	43.5
Pb206(n,n')	14.0	Fe56(n,n')	14.0	Pb207(n,n')	30.1	Pb207(n,n')	30.4
U238(n,n')-(n,elastic)	13.7	Pb207(n,n')	13.1	Pb208(n,n')	20.7	Pb208(n,n')	20.5
Pb207(n,n')	13.1	U238(n,n')	10.3	U238(n,n')	14.1	U238(n,n')	14.3
Fe56(n,elastic)	8.2	O16(n,n')	9.6	Pu239(CHI)	10.9	Fe56(n,n')	10.5
All correlations =	**57.0**		**35.0**		**62.3**		**64.7**
Except MAT =	57.0		35.6		62.3		64.7
Except MAT&MT =	55.1		36.1		62.6		63.2
Only STDs =	49.8		33.4		61.3		61.7
Uncertainty drops due to no correlations (%)	12.6		4.4		1.7		4.6

TAR value : none (> 14.7%)

Ref.: D. M. Castelluccio et al., Nuclear Data Target Accuracy Requirements for Advanced Reactors: The ALFRED Case, Annals of Nuclear Energy 162 (2021) 108533

❑ ALFRED: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 3. Uncertainties (in %) for the Doppler coefficient due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
U238(n,n')	8.5	Fe56(n,n')	3.3	U238(n,n')	3.8	U238(n,n')	2.7
Fe56(n,elastic)	2.3	U238(n,n')	2.2	U238(n,n')-(n,elastic)	2.2	Fe56(n,n')	2.2
Fe56(n,n')	1.7	Pu239(n,fission)	2.2	U238(n,gamma)-(n,n')	1.8	Pb206(n,n')	1.6
U238(n,n')-(n,elastic)	-1.6	Pu239(n,gamma)	1.5	Pb206(n,n')	1.6	Fe56(n,elastic)	1.3
Pu239(n,n')	1.4	Pu239(n,n')	1.4	Pu240(n,fission)	1.5	Pu239(CHI)	1.3
All correlations =	**9.4**		**5.7**		**6.1**		**4.9**
Except MAT =	9.4		5.7		6.1		4.9
Except MAT&MT =	9.5		5.7		5.4		5.0
Only STDs =	8.9		5.4		5.2		4.8
Uncertainty drops due to no correlations (%)	5.1		4.9		14.0		2.9

TAR value : none (> 2.94%)

Ref.: D. M. Castelluccio et al., Nuclear Data Target Accuracy Requirements for Advanced Reactors: The ALFRED Case, Annals of Nuclear Energy 162 (2021) 108533

❑ ASTRID: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 4. Uncertainties (in pcm) for the keff due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
U238(n,n')	807	Pu239(n,fission)	601	Pu240(n,fission)	462	U238(n,gamma)	396.1
Pu239(n,gamma)	231	U238(n,gamma)	261	Pu240(n,fission)-(n,gamma)	-383	U238(n,n')	274.2
U238(n,gamma)	220	Pu239(n,gamma)	254	U238(n,gamma)	327	Pu239(n,fission)	255.4
Pu239(n,fission)	202	U238(n,n')	234	U238(n,gamma)-(n,n')	320	Pu239(CHI)	236.9
U238(n,n')-(n,elastic)	194	Fe56(n,n')	204	Pu239(n,fission)	306	Pu239(n,gamma)	195.0
All correlations =	**988**		**919**		**894**		**728.2**
Except MAT =	987		859		894		713.5
Except MAT&MT =	968		867		911		710.3
Only STDs =	841		649		668		600.3
Uncertainty drops due to no correlations (%)	14.8		29.4		25.3		17.6

TAR value : 300 pcm

Ref.: L. Buiron, WPEC/SG47 Target Accuracy Requirements for Sodium Fast Reactor, WPEC/SG46, April 2021.

❑ ASTRID: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 5. Uncertainties (in %) for the full void coefficient due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
U238(n,n')	13.6	Pu239(n,fission)	16.0	Pu239(n,fission)	11.4	Na23(n,n')	13.2
Na23(n,n')	8.3	Pu239(n,gamma)	8.8	Pu239(n,gamma)	6.2	U238(n,gamma)	6.0
Fe56(n,elastic)	5.9	Na23(n,n')	8.3	Pu239(n,fission)-(n,gamma)	-4.6	Na23(n,n')-(n,elastic)	5.2
U238(n,n')-(n,elastic)	5.8	Pu239(n,fission)-(n,gamma)	-4.5	U238(n,n')	4.5	U238(n,n')	4.5
U238(n,gamma)	4.3	U238(n,n')	3.7	U238(n,gamma)	4.1	Pu239(n,fission)	4.3
All correlations =	**20.0**		**21.6**		**16.5**		**18.8**
Except MAT =	20.0		21.5		16.5		18.7
Except MAT&MT =	19.2		22.1		16.9		18.0
Only STDs =	17.2		21.0		16.2		17.5
Uncertainty drops due to no correlations (%)	14.0		2.7		1.7		7.1

TAR value : ???

Ref.: …

❑ ESFR: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 6. Uncertainties (in pcm) for the keff due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
U238(n,n')	1052	Pu239(n,fission)	576	Pu240(n,fission)	536	U238(n,gamma)	401.8
U238(n,gamma)	212	U238(n,n')	291	Pu240(n,fission)-(n,gamma)	-425	U238(n,n')	346.0
Pu239(n,gamma)	209	U238(n,gamma)	265	U238(n,gamma)-(n,n')	368	Pu239(CHI)	259.8
Pu239(n,fission)	197	Pu239(n,gamma)	216	U238(n,n')	368	Pu239(n,fission)	250.1
Pu239(CHI)	172	Fe56(n,n')	211	U238(n,gamma)	337	Pu239(n,gamma)	178.6
All correlations =	**1199**		**928**		**961**		**773.9**
Except MAT =	1199		866		961		758.3
Except MAT&MT =	1188		873		985		756.5
Only STDs =	1046		654		714		644.4
Uncertainty drops due to no correlations (%)	12.8		29.5		25.8		16.7

TAR value : 300 pcm

Ref.: L. Buiron, WPEC/SG47 Target Accuracy Requirements for Sodium Fast Reactor, WPEC/SG46, April 2021.

❑ ESFR: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 7. Uncertainties (in %) for the full void coefficient due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
Na23(n,n')	5.8	Pu239(n,fission)	9.5	Pu239(n,fission)	6.9	Na23(n,n')	8.5
U238(n,n')	5.1	Na23(n,n')	5.8	Pu239(n,gamma)	3.1	U238(n,gamma)	3.7
Na23(n,elastic)	4.6	Na23(n,elastic)	4.5	Pu239(n,fission)-(n,gamma)	-2.6	Na23(n,elastic)	2.9
U238(n,n')-(n,elastic)	3.0	Pu239(n,gamma)	4.4	U238(n,gamma)	2.3	Pu239(n,fission)	2.4
U238(n,gamma)	2.7	Pu239(n,fission)-(n,gamma)	-2.5	Na23(n,elastic)	2.2	Pu241(n,fission)	2.0
All correlations =	**10.8**		**13.2**		**9.3**		**10.9**
Except MAT =	10.8		13.2		9.3		10.9
Except MAT&MT =	10.3		13.4		9.5		10.9
Only STDs =	9.5		13.0		9.3		10.8
Uncertainty drops due to no correlations (%)	11.2		1.1		-0.5		1.1

TAR value : ???

Ref.: …

❑ ESFR: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 8. Uncertainties (in %) for the temperature coefficient due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
U238(n,elastic)	2.7	Na23(n,elastic)	1.8	Fe56(n,elastic)	1.8	Fe56(n,elastic)	2.3
Fe56(n,elastic)	1.9	Pu239(n,fission)	1.3	Pu240(n,fission)	1.7	U238(n,elastic)	1.1
Na23(n,elastic)	1.8	CR52(n,elastic)	1.3	Pu240(n,fission)-(n,gamma)	0.9	Na23(n,elastic)	1.0
U238(n,n')	1.5	Pu239(n,gamma)	1.3	Pu239(n,gamma)	0.9	U238(n,n')	0.7
Cr52(n,elastic)	1.3	Pu239(n,n')	1.2	Pu239(n,fission)	0.8	Pu239(CHI)	0.6
All correlations =	**4.6**		**3.7**		**3.4**		**3.3**
Except MAT =	4.6		3.6		3.4		3.3
Except MAT&MT =	4.7		3.6		3.1		3.3
Only STDs =	5.1		4.1		3.0		3.7
Uncertainty drops due to no correlations (%)	-10.8		-10.2		10.4		-12.0

TAR value : 5%

Ref.: L. Buiron, WPEC/SG47 Target Accuracy Requirements for Sodium Fast Reactor, WPEC/SG46, April 2021.

INDUSTRIALES
ETSII | UPM

❑ ESFR: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 9. Uncertainties (in %) for control rod worth the due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
U238(n,n')	1.3	Pu239(n,fission)	0.8	Pu240(n,fission)	1.0	Fe56(n,elastic)	0.6
Fe56(n,elastic)	1.0	Na23(n,elastic)	0.7	Pu239(CHI)	0.5	U238(n,n')	0.5
Na23(n,elastic)	0.7	Pu240(CHI)	0.3	O16(n,elastic)	0.5	Na23(n,elastic)	0.5
U238(n,n')-(n,elastic)	0.6	U238(n,n')	0.3	U238(n,fission)	0.5	U238(n,elastic)	0.4
O16(n,elastic)	0.5	U238(n,n')-(n,elastic)	-0.3	Fe56(n,elastic)	0.5	U238(n,gamma)	0.4
All correlations =	**2.1**		**1.5**		**1.7**		**1.4**
Except MAT =	2.1		1.4		1.7		1.4
Except MAT&MT =	2.0		1.4		1.7		1.4
Only STDs =	1.7		1.2		1.3		1.1
Uncertainty drops due to no correlations (%)	18.8		20.1		21.4		21.5

TAR value : 5%

Ref.: L. Buiron, WPEC/SG47 Target Accuracy Requirements for Sodium Fast Reactor, WPEC/SG46, April 2021.

❑ JSFR: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 10. Uncertainties (in pcm) for the keff due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
U238(n,n')	721	Pu239(n,fission)	615	Pu240(n,fission)	515	U238(n,gamma)	396.5
Pu239(n,gamma)	253	Fe56(n,n')	299	Pu240(n,fission)-(n,gamma)	-460	Pu239(n,fission)	267.4
U238(n,gamma)	216	U238(n,gamma)	264	U238(n,gamma)	333	U238(n,n')	247.1
U238(n,n')-(n,elastic)	211	Pu239(n,gamma)	255	Pu239(nubar)	316	Pu239(CHI)	238.1
Pu239(n,fission)	210	U238(n,n')	213	Pu239(n,fission)	306	Fe56(n,n')	224.2
All correlations =	**951**		**969**		**903**		**750.0**
Except MAT =	950		913		903		736.8
Except MAT&MT =	926		920		955		733.6
Only STDs =	800		699		688		623.5
Uncertainty drops due to no correlations (%)	15.8		27.9		23.7		16.9

TAR value : 200 pcm

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

❑ JSFR: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 11. Uncertainties (in %) for the Doppler coefficient due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
U238(n,n')	2.4	Pu239(n,gamma)	2.0	O16(n,elastic)	1.4	Na23(n,elastic)	1.7
Na23(n,elastic)	1.9	Pu239(n,fission)	2.0	Pu240(n,fission)	1.4	U238(n,n')	1.1
Fe56(n,elastic)	1.7	Na23(n,elastic)	1.9	Pu239(n,gamma)	1.4	Fe56(n,elastic)	1.1
O16(n,elastic)	1.4	Fe56(n,n')	1.1	U238(n,n')	1.2	Pu239(n,fission)	0.8
Pu239(n,gamma)	0.8	U238(n,n')	1.0	Pu239(n,fission)	1.1	Fe56(n,n')	0.8
All correlations =	**4.1**		**3.9**		**3.5**		**3.0**
Except MAT =	4.1		3.8		3.5		3.0
Except MAT&MT =	4.1		3.9		3.5		3.0
Only STDs =	3.3		3.3		2.8		2.4
Uncertainty drops due to no correlations (%)	19.7		13.8		18.4		19.3

TAR value : 3%

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

❑ JSFR: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 12. Uncertainties (in %) for the <u>burnup reactivity swing (BRS)</u> due to nuclear data (top-5 major

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
Pu239(n,gamma)	3.1	U238(n,gamma)	3.5	U238(n,gamma)	4.4	U238(n,gamma)	5.2
U238(n,gamma)	2.9	Pu239(n,gamma)	3.0	Pu240(n,gamma)	2.7	Pu239(n,gamma)	2.5
Pu240(n,gamma)	1.5	Pu239(n,fission)	2.4	Pu239(n,gamma)	1.7	Pu240(n,gamma)	1.4
U238(n,n')	1.3	Pu240(n,gamma)	1.5	U238(n,gamma)-(n,n')	1.4	Pu239(n,fission)	1.1
Pu241(n,gamma)	1.2	Pu241(n,gamma)	1.2	Pu239(n,fission)-(n,gamma)	-1.3	U238(n,n')	0.7
All correlations =	**5.0**		**5.6**		**5.8**		**6.1**
Except MAT =	5.0		5.7		5.8		6.1
Except MAT&MT =	4.9		5.6		5.7		6.1
Only STDs =	4.2		4.3		4.5		5.4
Uncertainty drops due to no correlations (%)	16.1		23.9		21.5		11.5

TAR value : 200 pcm = 18% (=1.1%dk/kk')

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

❑ JSFR: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 13. Uncertainties (in %) for the control rod worth (CRW) due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
Fe56(n,elastic)	2.0	O16(n,elastic-P1)	1.6	U238(n,elastic-P1)	1.5	Fe56(n,elastic)	1.2
U238(n,n')	1.2	Pu239(n,fission)	1.1	Pu240(n,fission)	1.2	U238(n,elastic)	0.9
U238(n,n')-(n,elastic)	-1.1	Na23(n,elastic)	1.0	O16(n,elastic)	0.9	Na23(n,elastic)	0.9
Na23(n,elastic)	1.0	B10(n,n')	0.8	Fe56(n,elastic)	0.9	U238(n,gamma)	0.8
O16(n,elastic)	0.9	U238(n,n')-(n,elastic)	0.6	B10(n,n')	0.8	U238(n,n')	0.7
All correlations =	**2.8**		**2.8**		**3.0**		**2.3**
Except MAT =	2.8		2.8		3.0		2.3
Except MAT&MT =	3.0		2.7		2.8		2.3
Only STDs =	2.4		2.4		2.3		1.8
Uncertainty drops due to no correlations (%)	13.2		15.0		23.3		23.5

TAR value : 2%

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

❑ JSFR: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 14. Uncertainties (in %) for the power distribution (F49) due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
U238(n,n')	1.7	O16(n,elastic-P1)	1.1	U238(n,elastic-P1)	0.9	U238(n,gamma)	0.7
U238(n,n')-(n,elastic)	-1.1	Pu239(n,fission)	0.8	U238(n,n')	0.7	U238(n,n')	0.6
Fe56(n,elastic)	0.5	U238(n,n')	0.5	U238(n,gamma)-(n,n')	0.6	Fe56(n,elastic)	0.4
U238(n,gamma)	0.4	U238(n,n')-(n,elastic)	0.5	Pu239(n,fission)	0.6	U238(n,elastic)	0.4
U238(n,elastic)	0.4	Fe56(n,n')	0.4	U238(n,gamma)	0.5	Fe56(n,n')	0.4
All correlations =	**1.6**		**1.7**		**1.7**		**1.3**
Except MAT =	1.6		1.7		1.7		1.3
Except MAT&MT =	2.0		1.6		1.5		1.3
Only STDs =	1.8		1.6		1.3		1.2
Uncertainty drops due to no correlations (%)=	-7.9		9.2		20.1		6.3

TAR value : 1%

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019

INDUSTRIALES
ETSII | UPM

❑ JSFR: Sensitivity Analysis (SA) / Uncertainty Quantification (UQ)

Table 15. Uncertainties (in %) for the sodium void reactivity (SVR) due to nuclear data (top-5 major contributors)

ENDF/B-VII.1		ENDF/B-VIII.0		JEFF-3.3		JENDL-4.0u	
Na23(n,elastic)	2.8	Pu239(n,fission)	3.9	Pu239(n,fission)	2.9	Na23(n,n')	4.1
Na23(n,n')	2.7	Na23(n,elastic)	2.7	Na23(n,elastic)	1.3	Na23(n,elastic)	1.8
U238(n,n')	1.3	Na23(n,n')	2.7	Pu239(n,gamma)	1.1	Na23(n,n')-(n,elastic)	-1.3
U238(n,gamma)	1.0	Pu239(n,gamma)	1.5	Pu239(n,fission)-(n,gamma)	-1.0	U238(n,gamma)	1.3
Pu239(n,fission)	1.0	Pu239(n,fission)-(n,gamma)	-1.0	Na23(n,n')	0.9	Pu239(n,fission)	1.0
All correlations =	**4.6**		**5.9**		**3.9**		**4.8**
Except MAT =	4.6		5.9		3.9		4.8
Except MAT&MT =	4.5		6.0		4.0		5.0
Only STDs =	4.0		5.7		3.8		4.9
Uncertainty drops due to no correlations (%)=	12.2		4.5		3.9		-1.5

TAR value : 3%

Ref.: K. Yokoyama, Input Information for SG46 Target Accuracy Requirements (TAR) Exercise using Models of 750MWe JSFR Core, WPEC/SG46 November 2019