Uncertainty propagation of nuclear data: how and what for?

*WONDER-2026 : 7th edition of the International **W**orkshop **O**n **N**uclear **D**ata **E**valuation for **R**eactor Applications*
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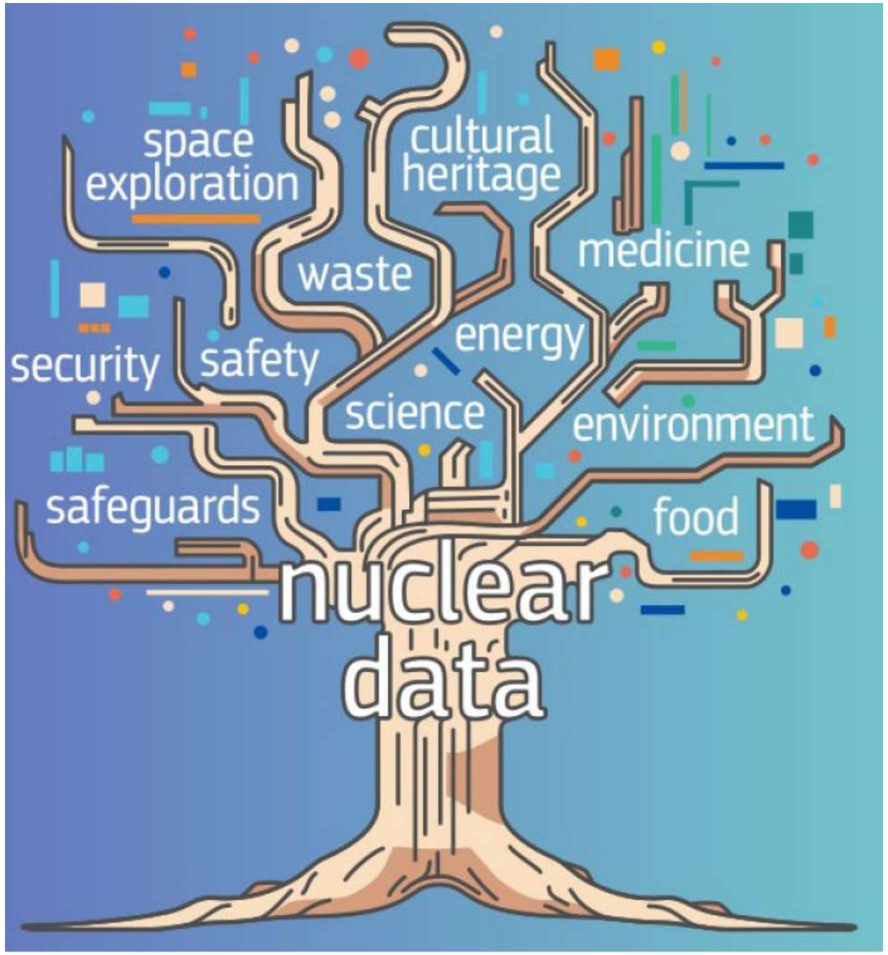

courtesy by A.Plompen (ND2025)

1.The Speaker

Oscar Cabellos
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- I am Oscar Cabellos, full professor in nuclear engineering at the Polytechnic University of Madrid (UPM)
- I am coordinator of UPM courses on “Introduction on Nuclear Technology”, “*Simulation of Nuclear Power Plants*” and “*Design and Simulation of PWRs*” which is one of the UPM coursed based on the CDIO (Conceive, Design, Implement and Operate) initiative
- My background is reactor physicist, specifically in PWR (Pressure Water Reactors) simulations where I did my PhD in 1998
- Since 2005 I have been involved in EU projects working on nuclear data activities: EUROTRANS (2005-2010), ANDES(2010-2013), CHANDA(2013-2018), SANDA (2019-2023), APRENDE (2024-2028)
- In 2014-2017, I moved to OECD/Nuclear Energy Agency (NEA)/Data Bank as Nuclear Data Scientist working in the development of EXFOR and JEFF databases, and JANIS and NDaST web-tools
- Currently, I am actively working in the JEFF (Joint Evaluation Fission and Fusion) project and WPEC (Working Party on International Nuclear Data Evaluation and Cooperation) activities of the OECD/NEA
- Member of the JEFF-Coordination Group, WPEC (co-coordinator WPEC/SG46 and monitor of WPEC/SG47) , WPNCS (Working Party on Nuclear Criticality and Safety) and IAEA/INDEN Network
- Member of the OECD/NEA/NSC – (Nuclear Science Committee) and OECD/NEA/MBDAV – (Management Board for the Development, Application and Validation of Nuclear Data and Codes)
- Member of the IAEA - International Nuclear Data Committee (INDC)

2. Introduction and Motivation

Motivation: The objective of this talk is not only to review methods for nuclear-data uncertainty propagation, but also to discuss **why** we do it, **what** information we need, and **how** the results can be used by evaluators, reactor physicists and end-users.

Focus on **the role of covariance data**, quality and consistency, and use in applications such as benchmark uncertainty quantification (UQ), nuclear-data adjustment (NDA) and target accuracy requirements (TAR).

Why do we propagate nuclear-data uncertainties?

Nuclear simulations support decisions in reactor design, safety analysis and fuel-cycle applications. However, a calculated value is not enough.

We need to know:

- How reliable is the prediction?
- Which nuclear data dominate the uncertainty?
- Are current covariances credible for the application?
- Can integral experiments reduce uncertainties consistently?
- What new measurements or evaluations are really needed?

Uncertainty propagation connects evaluated nuclear data with application needs

Evaluated nuclear data → Covariances → Processing → Application calculation → Uncertainty / priorities

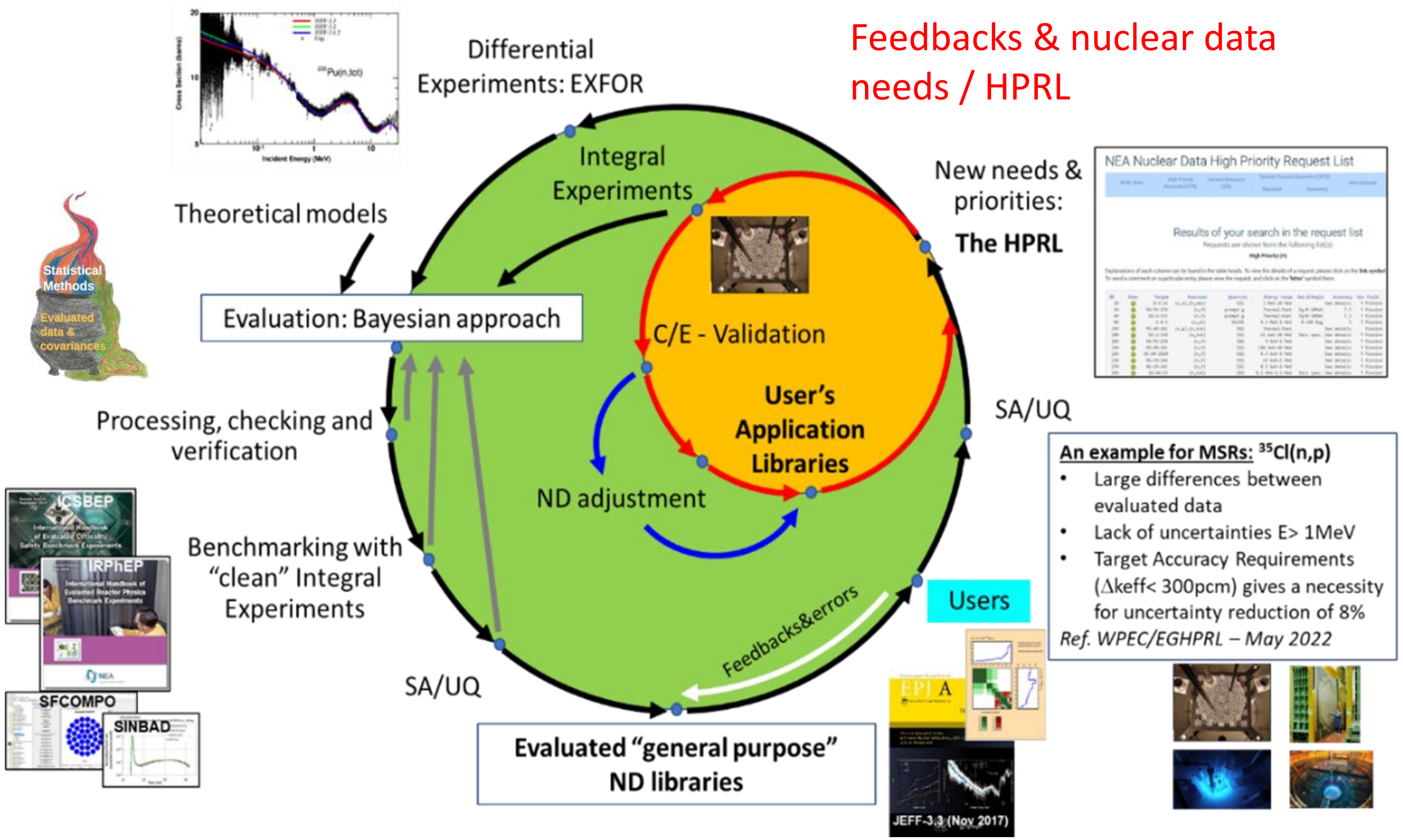
From data uncertainty to decision support

3. Nuclear Data Life Cycle

Figure 1. An example of *“nuclear data life cycle”*

Evaluated data
& covariances

Feedbacks & nuclear data
needs / HPRL



An example for MSRs: ^{35}**Cl(n,p)**

- Large differences between evaluated data
- Lack of uncertainties E> 1MeV
- Target Accuracy Requirements (Δkeff< 300pcm) gives a necessity for uncertainty reduction of 8%

Ref. WPEC/EGHPRL – May 2022

C/E validation + ND adjustment

Evaluated nuclear data and covariances are not the end of the process.

They are used in:

- processing and application libraries
- validation against integral experiments
- uncertainty propagation in user applications
- nuclear data adjustment and assimilation
- identification of new experimental and evaluation needs

ND-UQ is the quantitative link between evaluated data, applications and feedback

4. What is inside a covariance matrix?

A covariance matrix contains more than standard deviations. It provides variances and correlations between nuclear-data quantities across materials, reactions and energy groups.:

$$V^{(i,x)-(i\prime,x\prime)} = \begin{bmatrix} cov\left(\sigma_1^{i,x}, \sigma_1^{i\prime,x\prime}\right) & \cdots & cov\left(\sigma_1^{i,x}, \sigma_G^{i\prime,x\prime}\right) \\ \vdots & \ddots & \vdots \\ cov\left(\sigma_G^{i,x}, \sigma_1^{i\prime,x\prime}\right) & \cdots & cov\left(\sigma_G^{i,x}, \sigma_G^{i\prime,x\prime}\right) \end{bmatrix}$$

where:

i-material and i’- material
x-nuclear reaction and x’-nuclear reaction
g-energy group and g’ energy group

The covariance data included in ENDF-6 format is allocated under the following files:

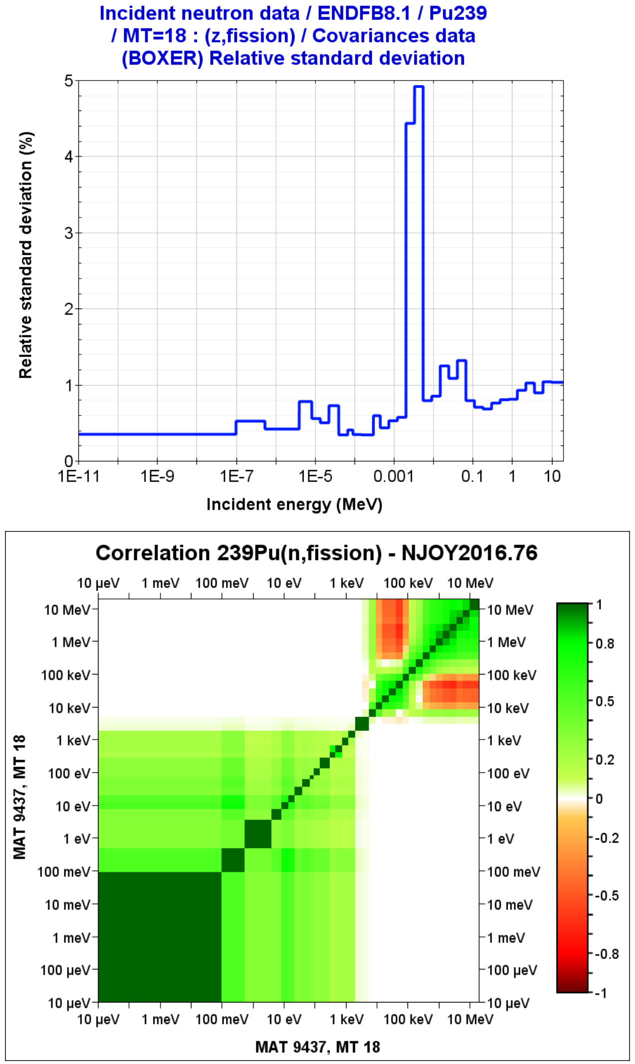
- MF31: covariance of **average number of neutrons per fission**
- MF32: covariance of **resonance parameters**
- MF33: covariance of **neutron cross sections**
- MF34: covariance of **angular distributions of secondary neutrons**
- MF35: covariance of **energy distributions of secondary neutrons**
- MF40: covariance of **radionuclide production**

- Thus, covariance matrices include information about:
  - **Energy co-variance** based on physics, systematic experimental uncertainties and/or random exp. uncertainties
  - **Channel reaction covariance** combining/subtracting two reactions to obtain other reaction
  - **Element/material covariance** when data is measured as ratio to different materials

- ENDF files provide mean values and covariance information; probability distributions are not explicitly provided

4. What is inside a covariance matrix?

Figure 2. Covariance matrix for the 239Pu(n,fission) - ENDF/B-VIII.1



Diagonal terms → individual uncertainties, e.g. standard deviations
Off-diagonal terms → correlations: how uncertainties move together

$$V^{(i,x)-(i\prime,x\prime)} = \begin{bmatrix} cov\left(\sigma_1^{i,x}, \sigma_1^{i\prime,x\prime}\right) & \cdots & cov\left(\sigma_1^{i,x}, \sigma_G^{i\prime,x\prime}\right) \\ \vdots & \ddots & \vdots \\ cov\left(\sigma_G^{i,x}, \sigma_1^{i\prime,x\prime}\right) & \cdots & cov\left(\sigma_G^{i,x}, \sigma_G^{i\prime,x\prime}\right) \end{bmatrix}$$

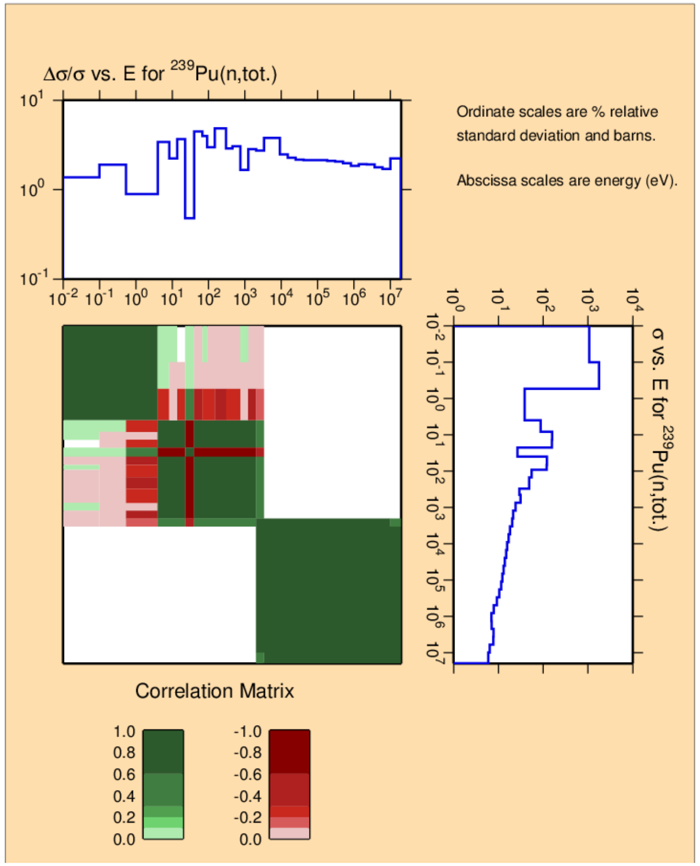
- **A covariance matrix is not simply a collection of error bars**

  The diagonal terms quantify the uncertainty of each nuclear-data quantity, but the off-diagonal terms are equally important because they describe the relationships between data.
- These relationships may come from experimental normalization, nuclear-reaction models, evaluation constraints, sum rules, conservation equations… or feedback from integral experiments
- Two covariance evaluations with similar standard deviations may lead to different propagated uncertainties if their correlations are different.

"If the diagonal of a covariance matrix is a measure of our ignorance, the off-diagonal elements are a measure of our wisdom." by M. Herman (2017)

What is inside a covariance matrix?

Figure 3. Covariance matrix for the 239Pu(n,total) - ENDF/B-VIII.0 evaluation processed with NJOY2016.69 in 33 energy groups of energy.



Where do covariances come from?

- experimental uncertainties and normalization factors
- correlations between measured data points
- nuclear-reaction model parameters
- Bayesian evaluation procedures
- conservation constraints and sum rules
- validation feedback from integral experiments

A covariance matrix should therefore preserve the statistical and physics memory of the evaluation process.

What makes covariance data useful? For uncertainty propagation, covariance data should be:

- **mathematically sound:** positive definite or positive semi-definite
- **complete:** not only cross sections, but also nu-bar, PFNS/χ, angular distributions, fission yields, decay data and TSLs
- **consistent:** mean values and covariances should reflect the same evaluation information
- **traceable:** the origin of uncertainties and correlations should be documented
- **application-aware:** covariance data should be tested in representative benchmarks

4.1 Covariances beyond cross sections?

In many UQ studies, **“nuclear-data covariances” are often understood as cross-section covariances**. However, application responses may also depend on:

- neutron multiplicities (nu-bar) - MF31
- prompt fission neutron spectra (PFNS) – MF35
- angular distributions – MF34
- TSLs
- fission yields
- decay data
- …

A complete uncertainty propagation requires covariance data for all nuclear-data quantities to which the application is sensitive

Examples: “The relevant covariance data are application-dependent”

Small Fast critical systems

- Angular distributions affect neutron leakage and spectrum

LWRs

- TSLs – H in $H2O$

Fission Pulse Decay Heat calculations

- Fission yields, decay data
- Fission Yield correlations can strongly reduce or reshape propagated uncertainties

5. How do we propagate nuclear-data uncertainties?

Two complementary approaches are commonly used:

Technique	S/U method	Monte Carlo sampling
Propagation	• Linearized • Fast, transparent and well suited for uncertainty decomposition	• Direct sampling • More flexible and able to capture non-linear effects, but computationally more expensive
Main expression	Sandwich Formula $\sigma^2(R) = S \cdot V \cdot S^T$	$x^{(1)}, x^{(2)}, \dots, x^{(\mathrm{N})} \rightarrow R^{(1)}, R^{(2)}, \dots, R^{(\mathrm{N})}$ Statistics of R(k)
CPU cost	Low	High
Decomposition	Excellent	Requires post-processing
Non-linear effects	Limited	Better suited
Typical use	UQ diagnosis, TAR	Depletion, multi-physics, non-linear responses
Tools	OECD/NEA - NDaST Tool	ND Sampling: SANDY, FRENDY, … TMC/TENDL, JEFF4/FYs random

Both methods rely on the quality and consistency of the input covariance information

5. How do we propagate nuclear-data uncertainties?

☐ Bias and nuclear data uncertainties in HEU-MET-FAST-001 Benchmark (Godiva)

	JEFF-3.3		ENDF/B-VIII.0
Exp. Uncertainty	±100		±100
|C-E|	16		6
	NDaST	SANDY	NDaST
Nubar	510	503	400
PFNS	364	216*	124
Fission	648	643	788
Elastic	109	-	276
Inelastic	698	-	244
Capture	375	-	281
Correlated Sum	1342	1262	1036

* Differences in PFNS covariance for UQ using SANDY and NDaST

Note: (values in pcm)
NDAST – sandwich formula
Monte Carlo sampling using SANDY with 300 random samples

Both methods rely on the quality and consistency of the input covariance information

5.1 Processing and Q&A of covariances

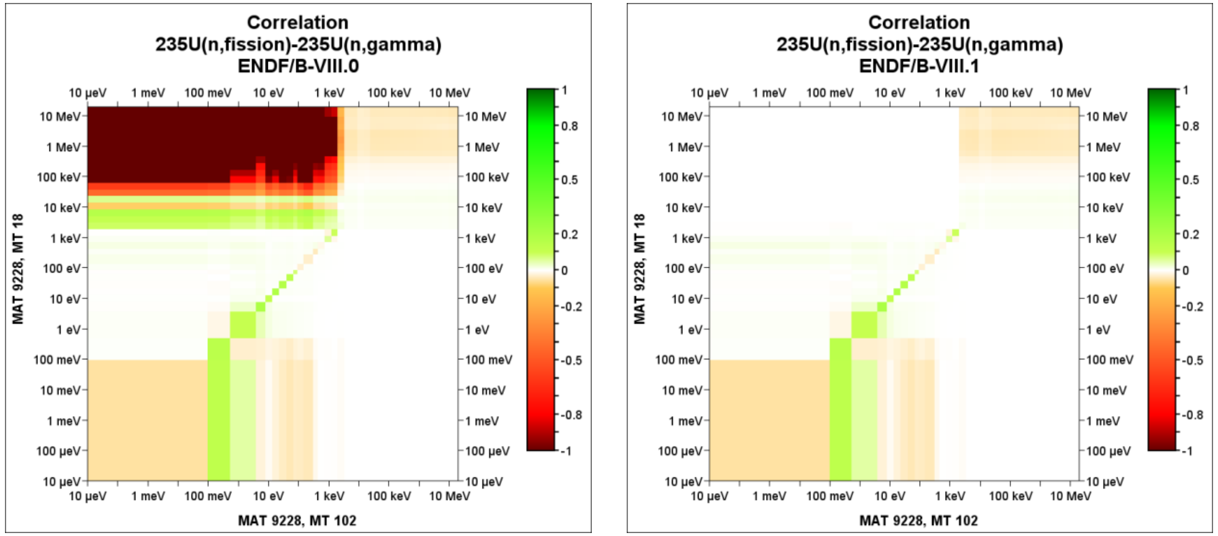
Typical workflow:

→ covariance processing
→ multigroup representation
→ consistency checks
→ uncertainty propagation

Key Q&A checks:

- covariance blocks are available and readable
- missing covariance blocks or incomplete reaction-channel
- energy-group collapse is consistent
- correlations remain within physical limits
- covariance matrices are positive semi-definite
- processed data are compatible with S/U or sampling tools
- uncertainty contributions are reasonable in benchmark applications

Figure 4. Processing 235U(n,f) - 235U(n,γ) ENDF/B-VIII.0 vs VIII.1



Correlation
235U(n,fission)-235U(n,gamma)
ENDF/B-VIII.0

Correlation
235U(n,fission)-235U(n,gamma)
ENDF/B-VIII.1

ENDF/B-VIII.0

ENDF/B-VIII.1

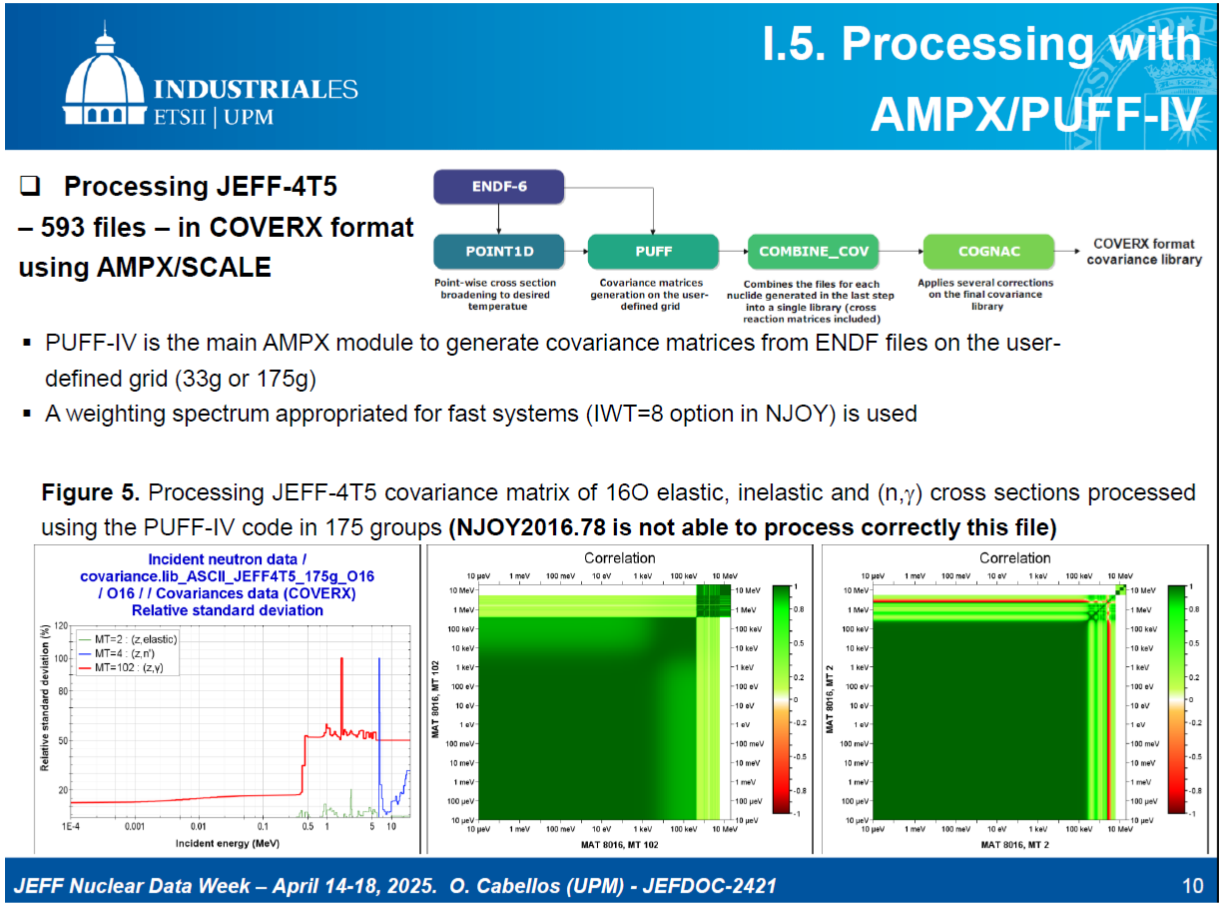
Covariance data must be usable, not only available.

Q&A is not only a numerical check: it is a physics check !

5.1 Processing and Q&A of covariances

❑ Q&A checks in JEFDOC-2421, April 2025

- Processing issues of 16O/ENDF/B-VIII.1 using NJOY2016



I.5. Processing with AMPX/PUFF-IV

❑ Processing JEFF-4T5 – 593 files – in COVERX format using AMPX/SCALE

- PUFF-IV is the main AMPX module to generate covariance matrices from ENDF files on the user-defined grid (33g or 175g)
- A weighting spectrum appropriated for fast systems (IWT=8 option in NJOY) is used

Figure 5. Processing JEFF-4T5 covariance matrix of 16O elastic, inelastic and (n,γ) cross sections processed using the PUFF-IV code in 175 groups **(NJOY2016.78 is not able to process correctly this file)**

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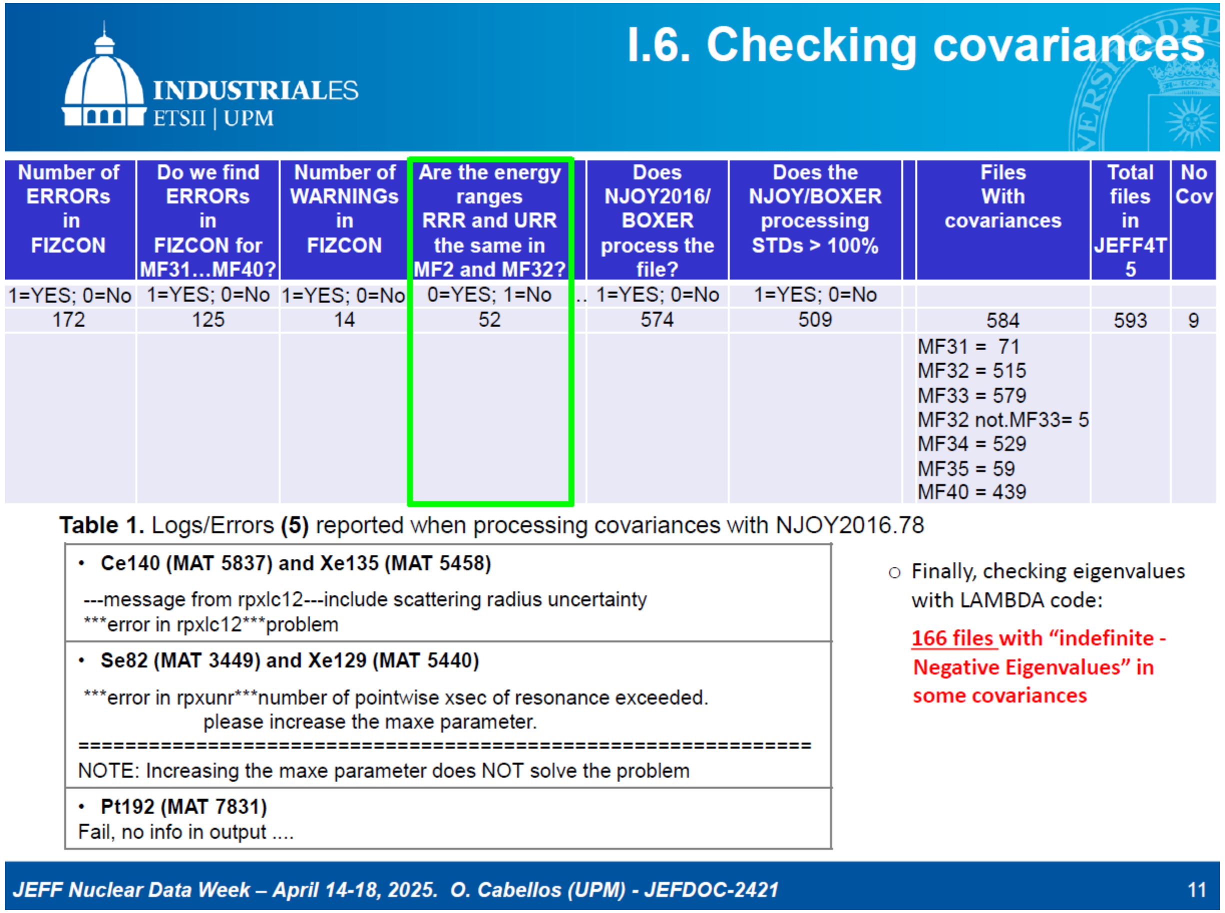
- Consistency ENDF format in JEFF-4.0: MF2 vs MF32 ?



I.6. Checking covariances

Number of ERRORs in FIZCON	Do we find ERRORs in FIZCON for MF31…MF40?	Number of WARNINGs in FIZCON	Are the energy ranges RRR and URR the same in MF2 and MF32?	Does NJOY2016/ BOXER process the file?	Does the NJOY/BOXER processing STDs > 100%		Files With covariances	Total files in JEFF4T5	No Cov
1=YES; 0=No	1=YES; 0=No	1=YES; 0=No	0=YES; 1=No	.. 1=YES; 0=No	1=YES; 0=No				
172	125	14	52	574	509		584	593	9
							MF31 = 71 MF32 = 515 MF33 = 579 MF32 not.MF33= 5 MF34 = 529 MF35 = 59 MF40 = 439		

Table 1. Logs/Errors **(5)** reported when processing covariances with NJOY2016.78

- **Ce140 (MAT 5837) and Xe135 (MAT 5458)**

---message from rpxlc12---include scattering radius uncertainty
error in rpxlc12problem

- **Se82 (MAT 3449) and Xe129 (MAT 5440)**

error in rpxunrnumber of pointwise xsec of resonance exceeded.
please increase the maxe parameter.
===
NOTE: Increasing the maxe parameter does NOT solve the problem

- **Pt192 (MAT 7831)**

Fail, no info in output ….

○ Finally, checking eigenvalues with LAMBDA code:

166 files with "indefinite - Negative Eigenvalues" in some covariances

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5.2 Ex: Testing covariances in Criticality

Recent covariance testing exercises include:

- processing covariance data (e.g. ENDF/B-VIII.1)
- checking covariance blocks such as MF31, MF32, MF33, MF34 and MF35
- propagating uncertainties in ICSBEP-type benchmarks
- decomposing contributions from cross sections, ν, PFNS and angular distributions
- comparing uncertainty estimates across evaluated libraries

These tests help identify:

- missing or problematic covariance files
- changes between library versions
- dominant uncertainty contributors
- application-dependent covariance needs

Benchmark propagation is a QA tool for covariance data !

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ENDF/B-VIII.1

Covariance Testing

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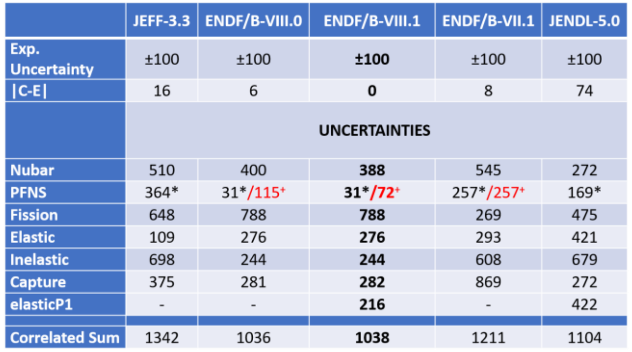
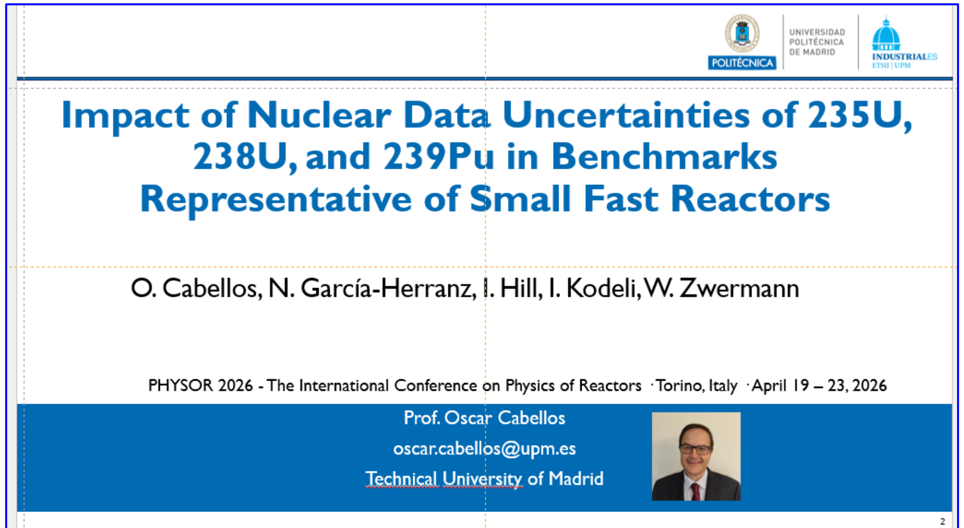
Table 1. *Bias and nuclear data uncertainties in* ***HEU-MET-FAST-001***



	JEFF-3.3	ENDF/B-VIII.0	ENDF/B-VIII.1	ENDF/B-VII.1	JENDL-5.0
Exp. Uncertainty	±100	±100	**±100**	±100	±100
|C-E|	16	6	**0**	8	74
			UNCERTAINTIES		
Nubar	510	400	**388**	545	272
PFNS	364*	31*/115⁺	**31*/72⁺**	257*/257⁺	169*
Fission	648	788	**788**	269	475
Elastic	109	276	**276**	293	421
Inelastic	698	244	**244**	608	679
Capture	375	281	**282**	869	272
elasticP1	-	-	**216**	-	422
Correlated Sum	1342	1036	**1038**	1211	1104

NOTE: (values in pcm)
NDAST – Uncertainty Quantification using 1st-order approximation *"Sandwich formula"*
Calculations (C) performed with MCNP6-1.0
NOTE: *PFNS covariance Eincident =100keV (default value); ⁺ PFNS covariance Eincident =1MeV

https://indico.bnl.gov/event/24320/contributions/97752/attachments/58237/100319/OCabellos_CSWEG-Nov2024-COVARIANCES-v6.pptx



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Impact of Nuclear Data Uncertainties of 235U, 238U, and 239Pu in Benchmarks Representative of Small Fast Reactors

O. Cabellos, N. García-Herranz, I. Hill, I. Kodeli, W. Zwermann

PHYSOR 2026 - The International Conference on Physics of Reactors · Torino, Italy · April 19 – 23, 2026

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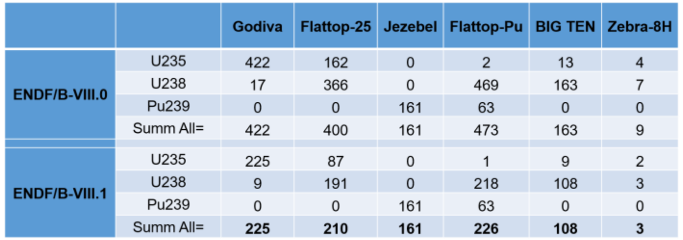
Table 2. *Summary of keff-uncertainties results using covariances of nuclear data in MF34*



		Godiva	Flattop-25	Jezebel	Flattop-Pu	BIG TEN	Zebra-8H
ENDF/B-VIII.0	U235	422	162	0	2	13	4
	U238	17	366	0	469	163	7
	Pu239	0	0	161	63	0	0
	Summ All=	422	400	161	473	163	9
ENDF/B-VIII.1	U235	225	87	0	1	9	2
	U238	9	191	0	218	108	3
	Pu239	0	0	161	63	0	0
	Summ All=	**225**	**210**	**161**	**226**	**108**	**3**

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5.3 Ex.: Individual perturbations vs UQ

- ❑ Uncertainty Quantification: Main individual contributions

Table 3. Main contributions (> 100 pcm) to the JEFF-3.3 ("J33") vs ENDF/B-VIII.0 ("E80") multiplication factor deviations of the set of Benchmarks in pcm, in comparison with the contributions to the uncertainties from the nuclear covariance data values in pcm).

Case	Main contributor	E80→J33* Substitution MCNP calc.	E80→J33 Perturbation S/A	JEF-3.3 =JEFF-4.0 uncertainty	ENDF/B-VIII.0 uncertainty	ENDF/B-VIII.1 uncertainty
Jezebel	**Pu239(n,n')**	**742**	**773**	**131**	**679**	**578**
	Pu239(n,n)	-339	-337	101	528	393
	Pu239(n,fission)	-258	-255	303	905	549
	Pu239(n,chi)	189	189	509	217	95
BigTen	**U238(n,gamma)**	**-970**	**-985**	**614**	**396**	**396**
	U238(n,n')	490	501	506	267	267
	U235(n,gamma)	317	297	466	316	316
	U238(n,n)	-236	-233	126	262	262
	U238(n,fission)	211	216	390	178	178
	U235(n,nubar)	151	150	410	311	248
	U238(n,nubar)	-142	-145	232	293	293
ZEBRA-8H	**U238(n,gamma)**	**-1463**	**-1456**	**860**	**583**	**582**
	U235(n,gamma)	327	320	446	299	299
	U238(n,fission)	207	229	394	182	182
	U238(n,nubar)	-159	-146	249	315	293
	U235(n,n')	**127**	**38**	136	43	43
	U235(n,nubar)	120	114	406	310	243
	U238(n,n')	**-39**	**-207**	1326	786	786

Noticeable that **in some cases, "the individual contributions to the library deviations" are significantly higher than the respective nuclear data uncertainty contributions**, see the case of:

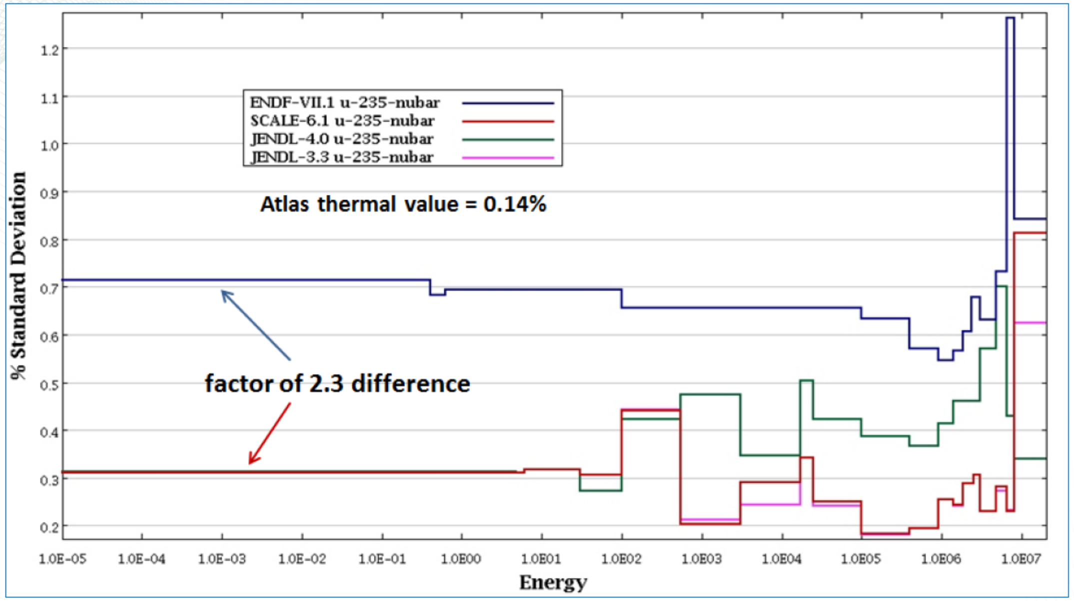
- 239Pu(n,n') in Jezebel
- 238U(n,gamma) in BigTen and ZEBRA-8H

5.4 Example… USER perspective

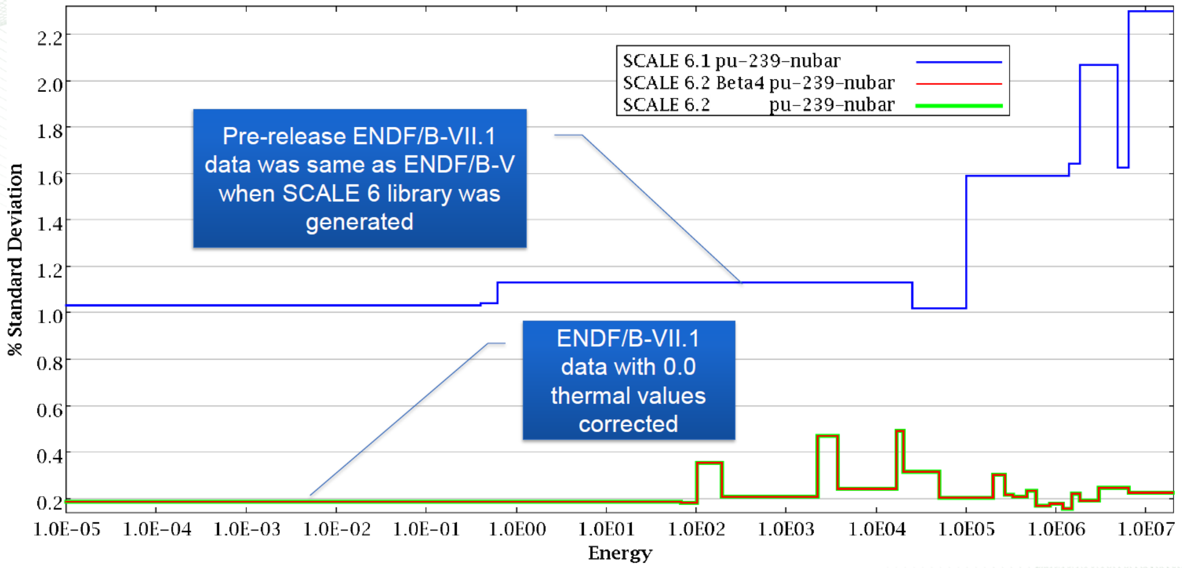
- ☐ ***"If the diagonal of a covariance matrix is a measure of our ignorance, the off-diagonal elements are a measure of our wisdom." by M. Herman (2017)***

In practice, the diagonal terms are not only a measure of ignorance…. from the application perspective (USERS), these uncertainties may be judged too large, too conservative, or not representative of the required predictive capability.

U-235 nubar uncertainty



Pu-239 nubar uncertainty

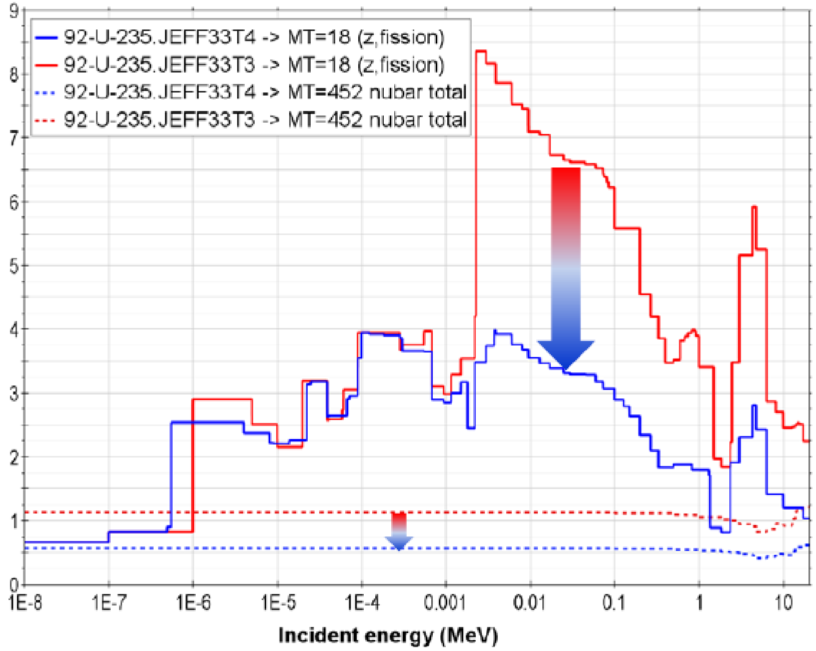


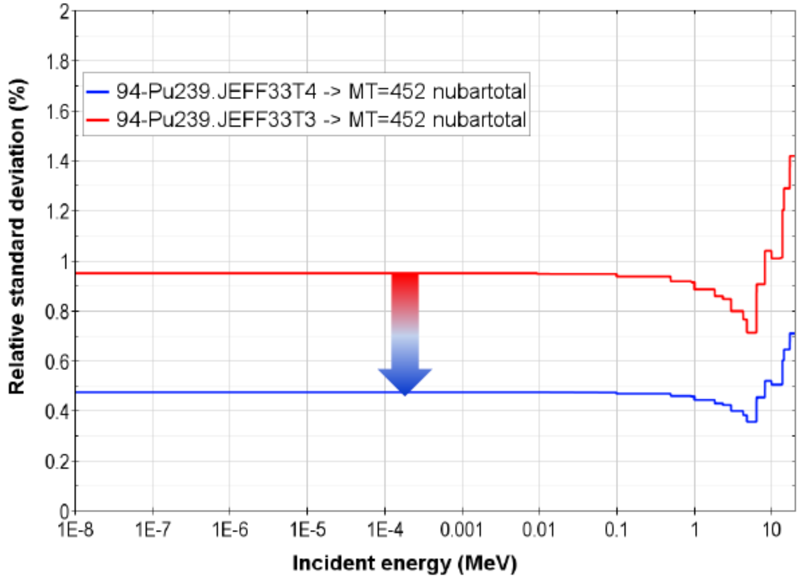
Ref. : B. T. Rearden, W. J. Marshall, D. Wiarda, "SCALE/AMPX Sensitivity and Uncertainty Analysis Capabilities and Data", WPEC/SG44, May 15-17, 2017

5.4 Example… USER perspective

❑ Differences between JEFF-3.3T4 and JEFF-3.3T3

- **JEFF-3.3T3:** uncertainty in the fast range was based on microscopic experiment only.
- **JEFF-3.3T4:** reduced uncertainties to reflect adjustment (e.g. fast range to JEZEBEL).

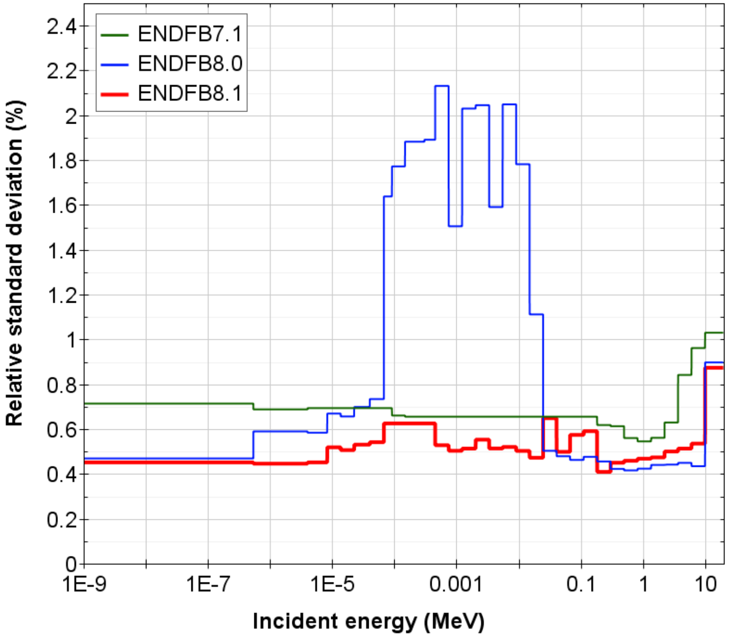

Incident neutron data / / MAT9228 / / Covariances data (BOXER) Relative standard deviation


Incident neutron data / / MAT9437 / MT=452 : nubar total / Covariances data (BOXER) Relative standard deviation

Ref.: O. Cabellos, J.Dyrda, N. Soppera , “Checking, processing and verification of nuclear data covariances” NEA Nuclear Data Week & JEFF Meeting , 20 –24 November 2017, JEFDOC-1887

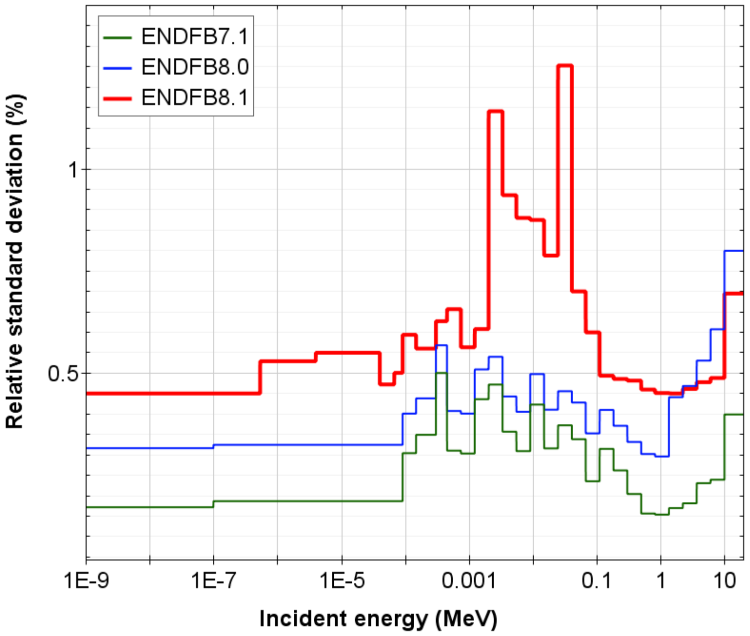
5.4 EVAL perspective in ENDF/B-VIII.1

U235(nubar)



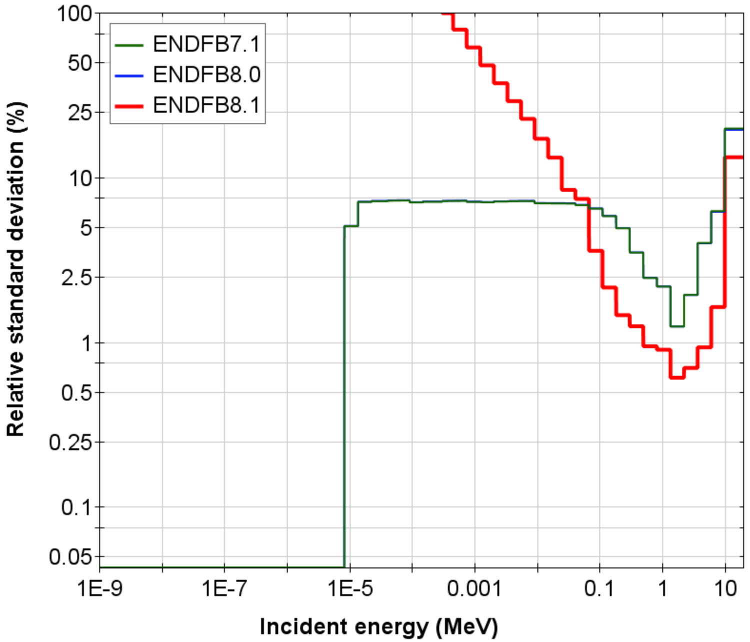
Incident neutron data / / U235 / MT=452 : nubar total / Covariances data (BOXER) Relative standard deviation

Pu239(nubar)



Incident neutron data / / Pu239 / MT=452 : nubar total / Covariances data (BOXER) Relative standard deviation

Pu239(PFNS)



Incident neutron data / / Pu239 / MT=1018 / Covariances data (BOXER) Relative standard deviation

“**Gwin nubar data** were directly used from 500 eV up to 80 keV, … **Uncertainties for all experimental data were reevaluated** in detail using the literature of data sets as well as templates of expected *ν* measurement uncertainties.”

“… **PFNS uncertainties for Pu** assemblies dropped due to the inclusion of **Chi-nu, CEA and Lestone experimental data**,
while ***ν* uncertainties increased** because of considering the new standard uncertainties (252Cf(sf)) in the evaluation process.”

Ref.: G. Nobre et al, ENDF/B-VIII.1: Updated Nuclear Reaction Data Library for Science and Application, Nuclear Data Sheets 210 (2026) 1–224

6. Examples of Personal Experience dealing with Application of Covariance Data

Some examples of my experience/work…

1. Activation calculations
2. Depletion calculations
3. Core calculations
4. **Fission Pulse Decay Heat**
    - **4.1 Importance of FY correlations**

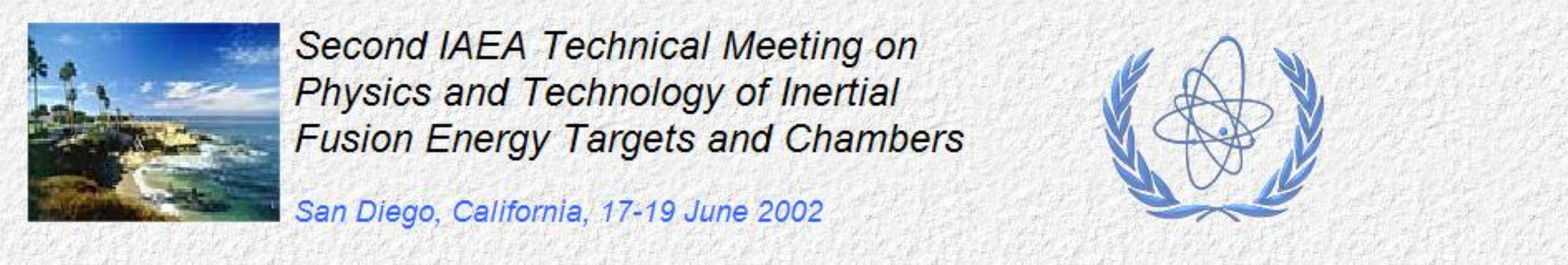
➡ ***… especially dedicated to Olivier Serot*** in recognition of his outstanding contributions to FY nuclear data covariance evaluation…☺

5. Hidden correlations / CIELO / SG44
6. Uncertainty Quantification (UQ) due to Nuclear Data Uncertainties
7. TAR Calculations and nuclear data needs

"Wisdom comes from experience. Experience is often a result of lack of wisdom"
by Sir Terry Pratchet (1948-2015)

[1] Uncertainty in Activation calculations

My first publication with ND Uncertainties using Monte Carlo sampling (2002)



Second IAEA Technical Meeting on
Physics and Technology of Inertial
Fusion Energy Targets and Chambers

San Diego, California, 17-19 June 2002

“Monte Carlo Uncertainty Analyses of Pulsed Activation in the NIF Gunite Shielding”

J. Sanz, R. Falquina, A. Rodriguez, O. Cabellos, S. Reyes, J. F. Latkowski
Fusion Science and Technology | Volume 43 | Number 3 | May 2003 | Pages 473-477
doi.org/10.13182/FST03-A293

Abstract.

*The need to estimate the effect of “**activation cross section uncertainties”** in the accuracy of isotopic inventory calculations is an issue that is drawing more and more attention. Concerning this problem, cross section uncertainty files have been made available, such as **FENDL UN/A-2.0**, and some calculational procedures have been proposed. We developed a method based on the **first order Taylor series**, which was found practical for providing the uncertainty indices associated to each of the reaction cross sections in a continuous irradiation scenario. One of the drawbacks of the method is that its application to pulsed scenarios is difficult, and the other and most important is that it is impractical to deal with the **synergetic/global effect of the uncertainties of the complete set of cross sections**. To overcome these limitations, we have developed a **Monte Carlo procedure** based on simultaneous random sampling of all the cross sections involved in a problem, and it has been implemented in the activation code ACAB. The main characteristics of the method are presented here.*

Experience often starts with unpublished work…

My second Monte Carlo study on ND uncertainties unpublished (2002)

“Activation Cross Sections Uncertainties Implications in the NIF Worker Doses”

TOFE2002 – 15th ANS Topical Meeting on the Technology of Fusion Energy
R. Falquina; J. Sanz; A. Rodíguez; O. Cabellos; J.F. Latkowski; S. Reyes.
No published.

… because conservative or inconsistent input uncertainties led to misleading conclusions

[2] Uncertainty in Depletion calculations

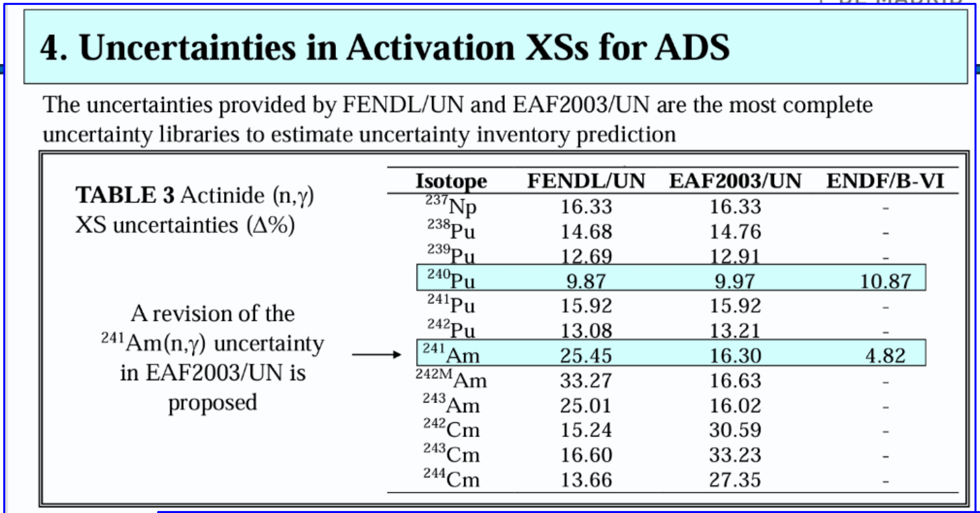
First publication on Transmutation UQ (2004)

Sensitivity and Uncertainty Analysis to Burn-up Estimates on ADS Using ACAB Code

O. Cabellos, J. Sanz et al.

Abstract.

*Within the scope of the **Accelerator Driven System (ADS)** concept for nuclear waste management applications, the burnup uncertainty estimates **due to uncertainty in the activation cross sections (XSs)** are important regarding both the safety and the efficiency of the waste burning process. We have applied both sensitivity analysis and Monte Carlo methodology to actinides burnup calculations in a lead-bismuth cooled subcritical ADS. The sensitivity analysis is used to identify the reaction XSs and the dominant chains that contribute most significantly to the uncertainty. The Monte Carlo methodology gives the burnup uncertainty estimates due to the synergetic/global effect of the complete set of XS uncertainties. These uncertainty estimates are valuable to assess the need of any experimental or systematic re-evaluation of some uncertainty XSs for ADS.*



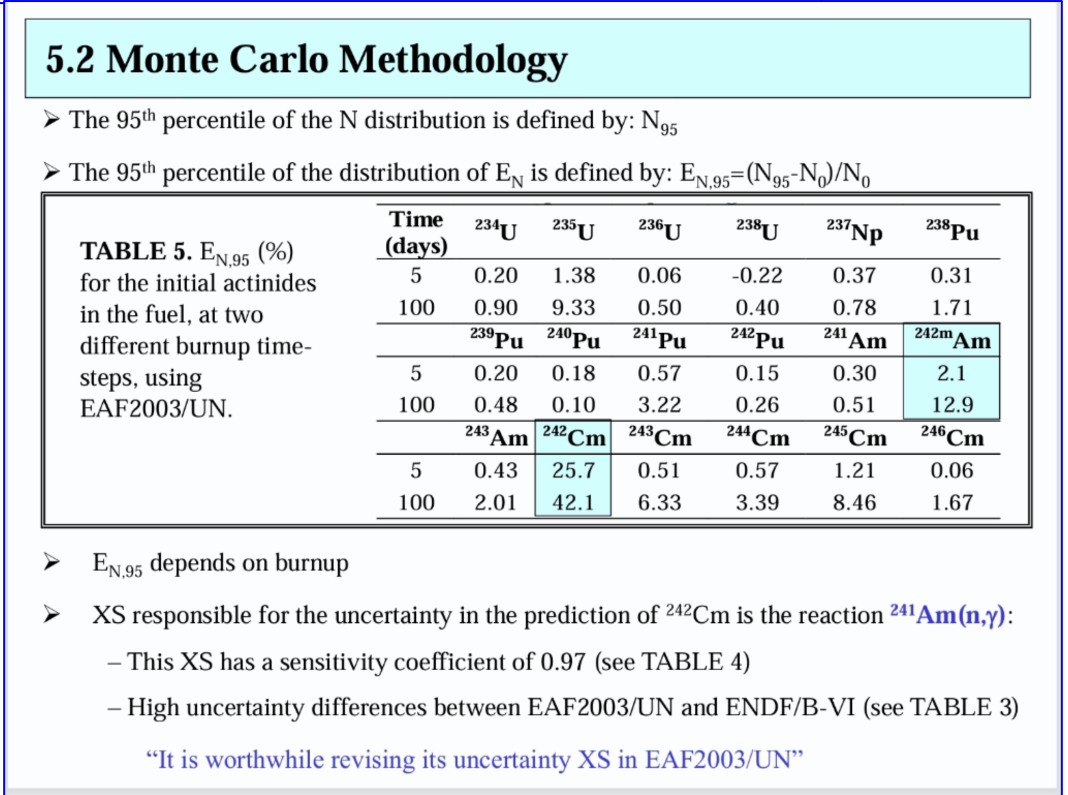
4. Uncertainties in Activation XSs for ADS

The uncertainties provided by FENDL/UN and EAF2003/UN are the most complete uncertainty libraries to estimate uncertainty inventory prediction

TABLE 3 Actinide (n,γ) XS uncertainties (Δ%)

Isotope	FENDL/UN	EAF2003/UN	ENDF/B-VI
^{237}Np	16.33	16.33	-
^{238}Pu	14.68	14.76	-
^{239}Pu	12.69	12.91	-
^{240}Pu	9.87	9.97	10.87
^{241}Pu	15.92	15.92	-
^{242}Pu	13.08	13.21	-
^{241}Am	25.45	16.30	4.82
^{242M}Am	33.27	16.63	-
^{243}Am	25.01	16.02	-
^{242}Cm	15.24	30.59	-
^{243}Cm	16.60	33.23	-
^{244}Cm	13.66	27.35	-

A revision of the ^{241}Am(n,γ) uncertainty in EAF2003/UN is proposed →



5.2 Monte Carlo Methodology

- The 95th percentile of the N distribution is defined by: N_{95}
- The 95th percentile of the distribution of E_N is defined by: $E_{N,95}=(N_{95}-N_0)/N_0$

TABLE 5. $E_{N,95}$ (%) for the initial actinides in the fuel, at two different burnup time-steps, using EAF2003/UN.

Time (days)	^{234}U	^{235}U	^{236}U	^{238}U	^{237}Np	^{238}Pu
5	0.20	1.38	0.06	-0.22	0.37	0.31
100	0.90	9.33	0.50	0.40	0.78	1.71
	^{239}Pu	**^{240}Pu**	**^{241}Pu**	**^{242}Pu**	**^{241}Am**	**^{242m}Am**
5	0.20	0.18	0.57	0.15	0.30	2.1
100	0.48	0.10	3.22	0.26	0.51	12.9
	^{243}Am	**^{242}Cm**	**^{243}Cm**	**^{244}Cm**	**^{245}Cm**	**^{246}Cm**
5	0.43	25.7	0.51	0.57	1.21	0.06
100	2.01	42.1	6.33	3.39	8.46	1.67

- $E_{N,95}$ depends on burnup
- XS responsible for the uncertainty in the prediction of ^{242}Cm is the reaction ^{241}Am(n,γ):
  - – This XS has a sensitivity coefficient of 0.97 (see TABLE 4)
  - – High uncertainty differences between EAF2003/UN and ENDF/B-VI (see TABLE 3)

"It is worthwhile revising its uncertainty XS in EAF2003/UN"

[2] Uncertainty in Depletion calculations

UQ using XSs, DD, and FYs (2010)…

International Conference on Nuclear Data for Science and Technology

April 26-30, 2010
Jeju Island, Korea

organized by the Korean Nuclear Society
and Korea Atomic Energy Research Institute
under the auspices of the OECD Nuclear Energy Agency

Propagation of Nuclear Data Uncertainties in Transmutation Calculations Using ACAB Code

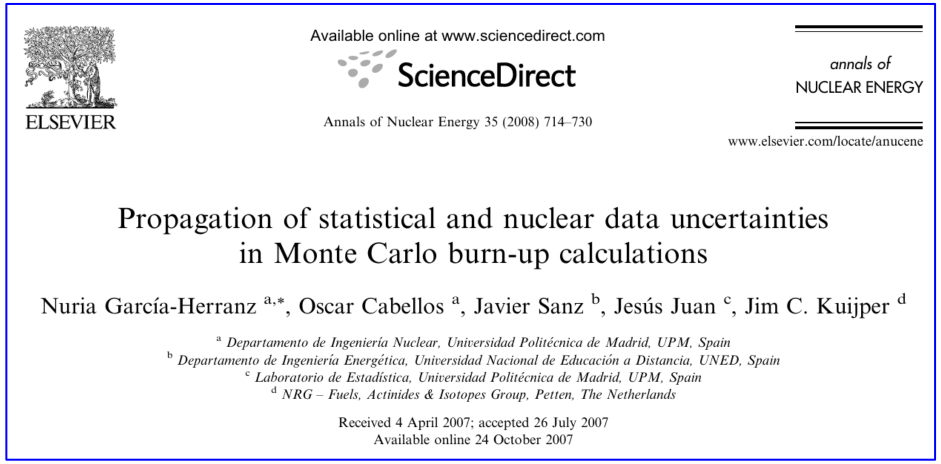
O. Cabellos, O. Garcia-Herranz, Carlos J. Diez de la Obra, R. Alvarez-Cascos, H, Sanz, F. Ogando, P. Sauvan

J. Korean Phys. Soc. 59(2(3)), 1268 - 1271 (2011)

Abstract

The assessment of the accuracy of parameters related to the reactor core performance (e.g. keff) and fuel cycle (e.g. isotopic evolution/transmutation) due to the uncertainties in the basic nuclear data (ND) is a critical issue. Different error propagation techniques (adjoint/forward sensitivity analysis procedures and/or Monte Carlo technique) can be used to address by computational simulation the systematic propagation of uncertainties on the final parameters. To perform this uncertainty assessment, the ENDF covariance files (variance/correlation in energy and cross-reactions-isotopes correlations) are required. In this paper, we assess the impact of ND uncertainties on the isotopic prediction for a conceptual design of a modular European Facility for Industrial Transmutation (EFIT) for a discharge burnup of 150 GWd/tHM. **The complete set of uncertainty data for cross sections (EAF2007/UN, SCALE6.0/COVA-44G), radioactive decay and fission yield data (JEFF-3.1.1) are processed and used in ACAB code.**

Development of "Hybrid Monte Carlo method" (2008)…



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Annals of Nuclear Energy 35 (2008) 714–730
annals of
NUCLEAR ENERGY
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Propagation of statistical and nuclear data uncertainties in Monte Carlo burn-up calculations

Nuria García-Herranz [a],*, Oscar Cabellos [a], Javier Sanz [b], Jesús Juan [c], Jim C. Kuijper [d]

[a] *Departamento de Ingeniería Nuclear, Universidad Politécnica de Madrid, UPM, Spain*
[b] *Departamento de Ingeniería Energética, Universidad Nacional de Educación a Distancia, UNED, Spain*
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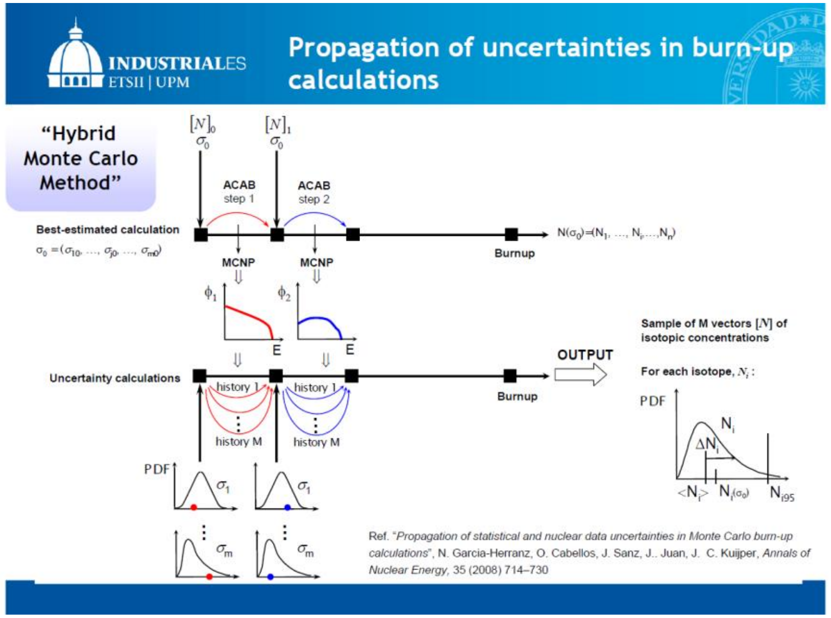
Received 4 April 2007; accepted 26 July 2007
Available online 24 October 2007

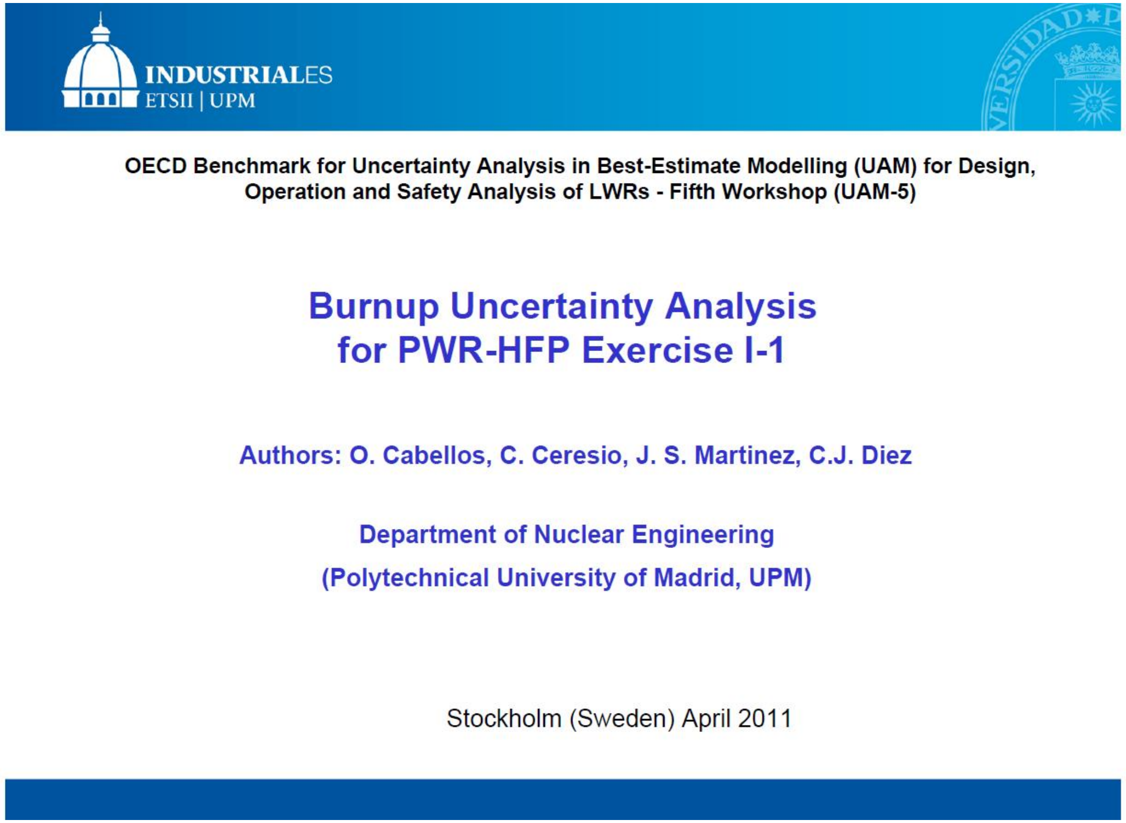


Propagation of uncertainties in burn-up calculations

Ref. "*Propagation of statistical and nuclear data uncertainties in Monte Carlo burn-up calculations*", N. Garcia-Herranz, O. Cabellos, J. Sanz, J.. Juan, J. C. Kuijper, *Annals of Nuclear Energy*, 35 (2008) 714–730

[2] Uncertainty in Depletion calculations

First UQ in Burnup calculation – OECD/UAM (2011) …



OECD Benchmark for Uncertainty Analysis in Best-Estimate Modelling (UAM) for Design, Operation and Safety Analysis of LWRs - Fifth Workshop (UAM-5)

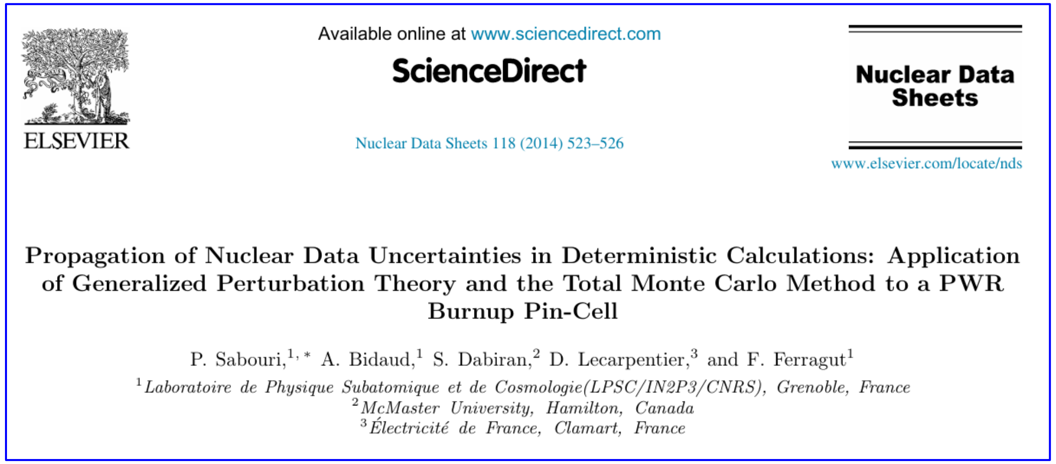
Burnup Uncertainty Analysis
for PWR-HFP Exercise I-1

Authors: O. Cabellos, C. Ceresio, J. S. Martinez, C.J. Diez

Department of Nuclear Engineering
(Polytechnical University of Madrid, UPM)

Stockholm (Sweden) April 2011

Hybrid Monte Carlo and full Monte Carlo approaches were explored for burnup uncertainty propagation.



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ScienceDirect

Nuclear Data Sheets 118 (2014) 523–526

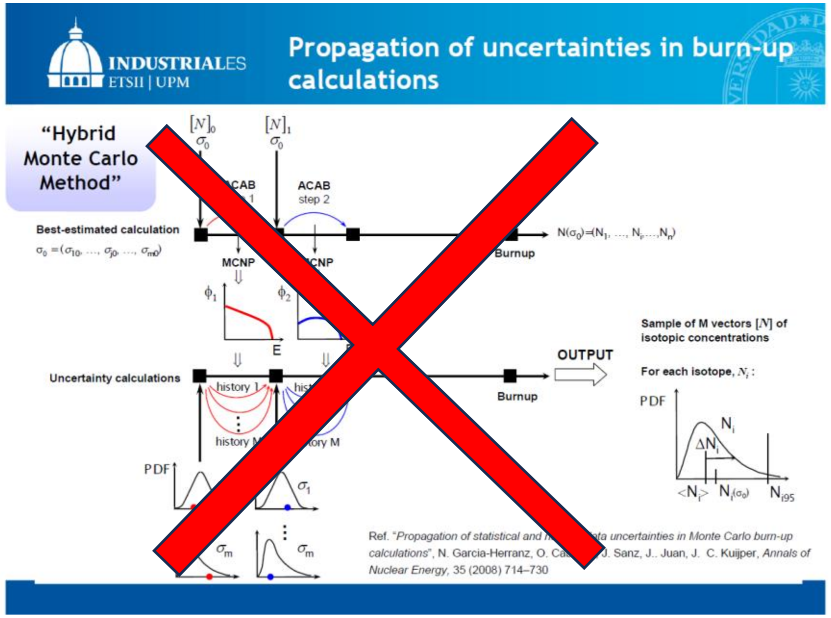
Nuclear Data Sheets

www.elsevier.com/locate/nds

Propagation of Nuclear Data Uncertainties in Deterministic Calculations: Application of Generalized Perturbation Theory and the Total Monte Carlo Method to a PWR Burnup Pin-Cell

P. Sabouri,[1,*] A. Bidaud,[1] S. Dabiran,[2] D. Lecarpentier,[3] and F. Ferragut[1]

[1] *Laboratoire de Physique Subatomique et de Cosmologie(LPSC/IN2P3/CNRS), Grenoble, France*
[2] *McMaster University, Hamilton, Canada*
[3] *Électricité de France, Clamart, France*



Propagation of uncertainties in burn-up calculations

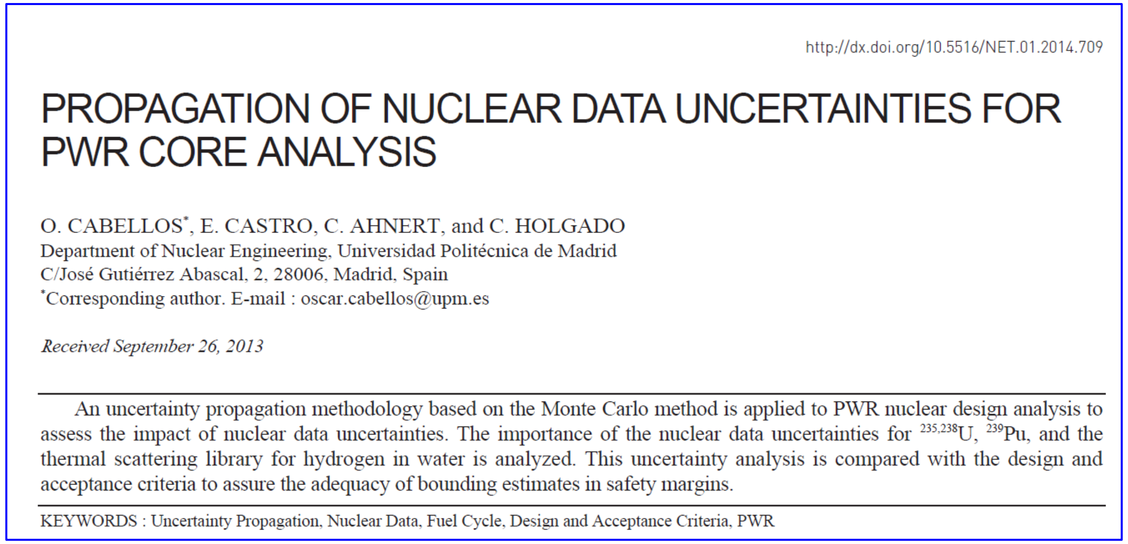
"Hybrid Monte Carlo Method"

Ref. "*Propagation of statistical and n… ata uncertainties in Monte Carlo burn-up calculations*", N. Garcia-Herranz, O. Ca… J. Sanz, J.. Juan, J. C. Kuijper, *Annals of Nuclear Energy*, 35 (2008) 714–730

"Hybrid Monte Carlo" method fails in Burnup calculations… full Monte Carlo approach …
Thanks to Adrian Bidau (2014)!

[3] Uncertainty in Core Calculations

PWR core UQ using TENDL2012 random files (2013)



http://dx.doi.org/10.5516/NET.01.2014.709

PROPAGATION OF NUCLEAR DATA UNCERTAINTIES FOR PWR CORE ANALYSIS

O. CABELLOS*, E. CASTRO, C. AHNERT, and C. HOLGADO
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Received September 26, 2013

An uncertainty propagation methodology based on the Monte Carlo method is applied to PWR nuclear design analysis to assess the impact of nuclear data uncertainties. The importance of the nuclear data uncertainties for ^{235,238}U, ^{239}Pu, and the thermal scattering library for hydrogen in water is analyzed. This uncertainty analysis is compared with the design and acceptance criteria to assure the adequacy of bounding estimates in safety margins.

KEYWORDS : Uncertainty Propagation, Nuclear Data, Fuel Cycle, Design and Acceptance Criteria, PWR

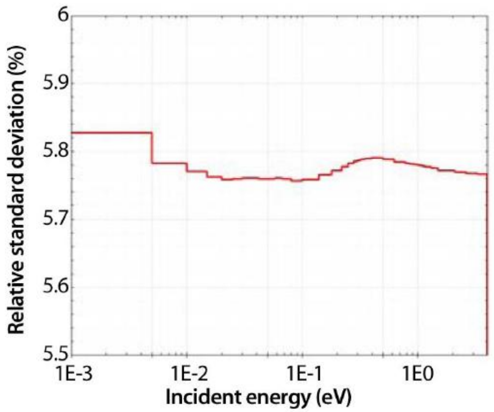
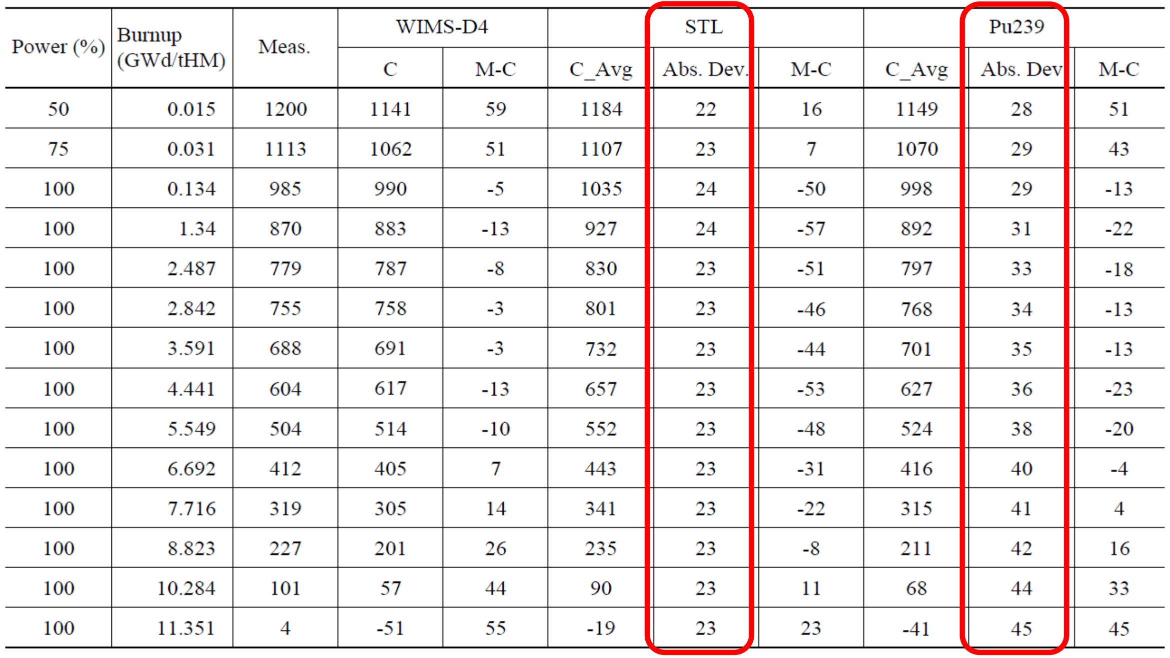


Figure 6. Uncertainties in the Incoherent Inelastic Scattering Cross Section Calculated from 800 Random TENDL2012 for STL-H in H2O.

Table 4. Measured Boron Concentrations (ppm) and Calculated Values Versus Cycle Operation. Calculated Values with Different Nuclear Data libraries: WIMS-D4 Reference Library, and Updated WIMS-D4 Library with Random TENDL2012 Files of STL-H in H2O or ^{239}Pu. Average and Absolute Deviation in ppm for Random Calculations.



Power (%)	Burnup (GWd/tHM)	Meas.	WIMS-D4		STL			Pu239		
			C	M-C	C_Avg	Abs. Dev.	M-C	C_Avg	Abs. Dev	M-C
50	0.015	1200	1141	59	1184	22	16	1149	28	51
75	0.031	1113	1062	51	1107	23	7	1070	29	43
100	0.134	985	990	-5	1035	24	-50	998	29	-13
100	1.34	870	883	-13	927	24	-57	892	31	-22
100	2.487	779	787	-8	830	23	-51	797	33	-18
100	2.842	755	758	-3	801	23	-46	768	34	-13
100	3.591	688	691	-3	732	23	-44	701	35	-13
100	4.441	604	617	-13	657	23	-53	627	36	-23
100	5.549	504	514	-10	552	23	-48	524	38	-20
100	6.692	412	405	7	443	23	-31	416	40	-4
100	7.716	319	305	14	341	23	-22	315	41	4
100	8.823	227	201	26	235	23	-8	211	42	16
100	10.284	101	57	44	90	23	11	68	44	33
100	11.351	4	-51	55	-19	23	23	-41	45	45

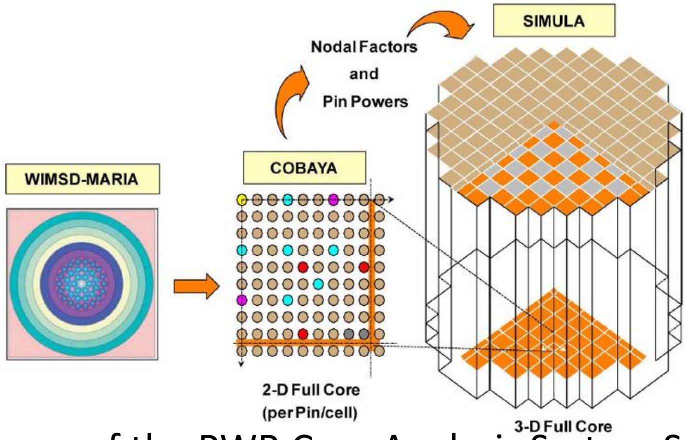
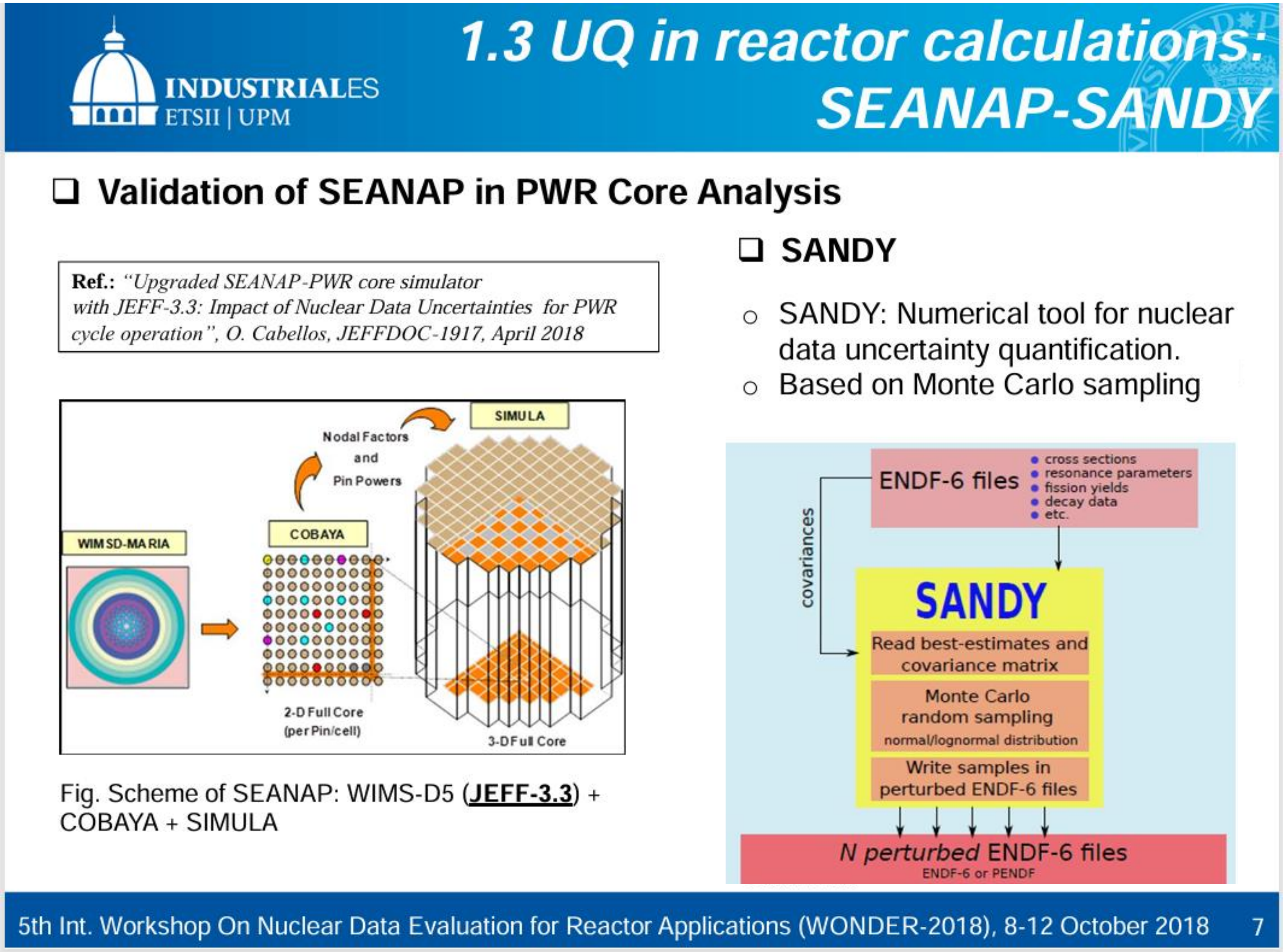


Figure 5. Scheme of the PWR Core Analysis System SEANAP: WIMS-D4, COBAYA, and SIMULA

[3] Uncertainty in Core Calculations

PWR core UQ using SANDY code for ND uncertainties in JEFF-3.3 (2018)



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1.3 UQ in reactor calculations: SEANAP-SANDY

☐ **Validation of SEANAP in PWR Core Analysis**

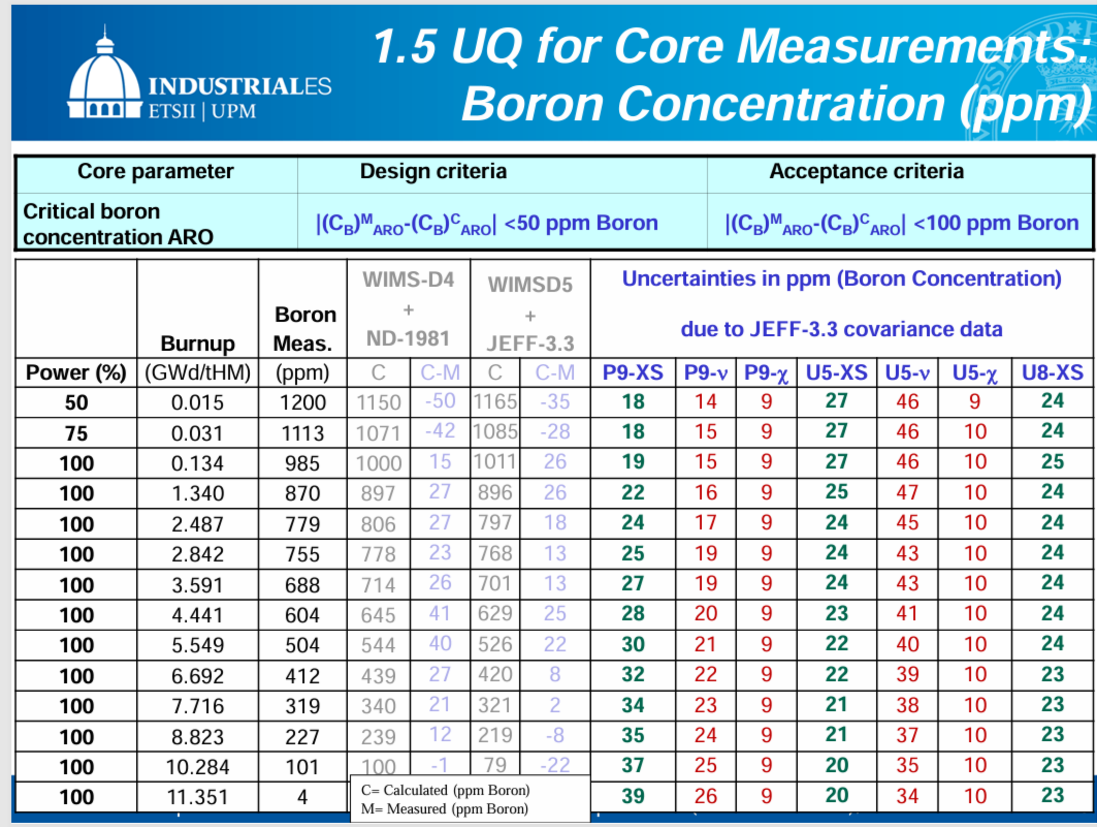
Ref.: *"Upgraded SEANAP-PWR core simulator with JEFF-3.3: Impact of Nuclear Data Uncertainties for PWR cycle operation", O. Cabellos, JEFFDOC-1917, April 2018*

Fig. Scheme of SEANAP: WIMS-D5 (**JEFF-3.3**) + COBAYA + SIMULA

☐ **SANDY**

- ○ SANDY: Numerical tool for nuclear data uncertainty quantification.
- ○ Based on Monte Carlo sampling

5th Int. Workshop On Nuclear Data Evaluation for Reactor Applications (WONDER-2018), 8-12 October 2018 7



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1.5 UQ for Core Measurements: Boron Concentration (ppm)

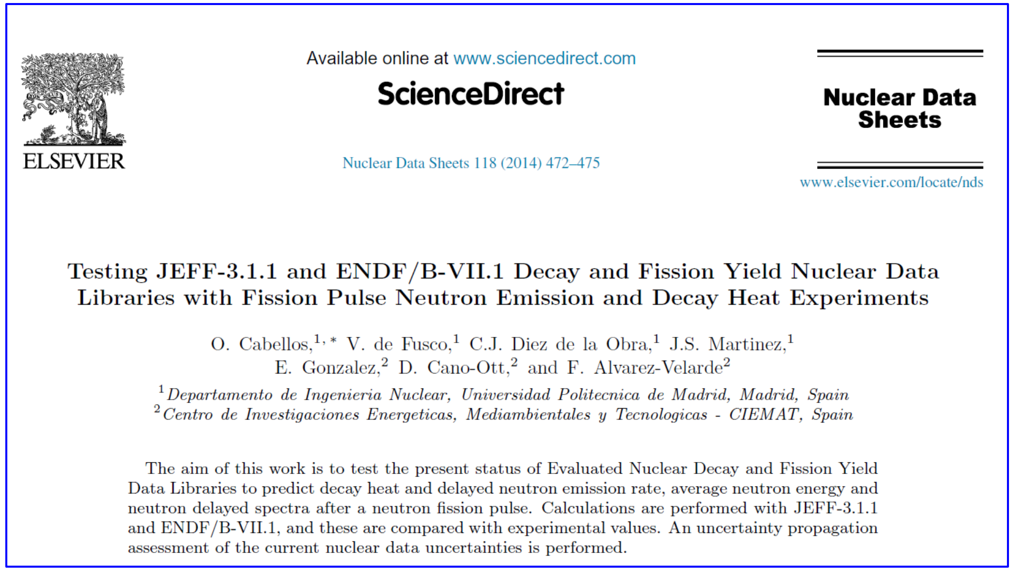
Core parameter	Design criteria	Acceptance criteria
Critical boron concentration ARO	$\lvert(C_B)^M_{ARO}-(C_B)^C_{ARO}\rvert$ <50 ppm Boron	$\lvert(C_B)^M_{ARO}-(C_B)^C_{ARO}\rvert$ <100 ppm Boron

	Burnup	Boron Meas.	WIMS-D4 + ND-1981		WIMSD5 + JEFF-3.3		Uncertainties in ppm (Boron Concentration) due to JEFF-3.3 covariance data						
Power (%)	(GWd/tHM)	(ppm)	C	C-M	C	C-M	P9-XS	P9-ν	P9-χ	U5-XS	U5-ν	U5-χ	U8-XS
50	0.015	1200	1150	-50	1165	-35	18	14	9	27	46	9	24
75	0.031	1113	1071	-42	1085	-28	18	15	9	27	46	10	24
100	0.134	985	1000	15	1011	26	19	15	9	27	46	10	25
100	1.340	870	897	27	896	26	22	16	9	25	47	10	24
100	2.487	779	806	27	797	18	24	17	9	24	45	10	24
100	2.842	755	778	23	768	13	25	19	9	24	43	10	24
100	3.591	688	714	26	701	13	27	19	9	24	43	10	24
100	4.441	604	645	41	629	25	28	20	9	23	41	10	24
100	5.549	504	544	40	526	22	30	21	9	22	40	10	24
100	6.692	412	439	27	420	8	32	22	9	22	39	10	23
100	7.716	319	340	21	321	2	34	23	9	21	38	10	23
100	8.823	227	239	12	219	-8	35	24	9	21	37	10	23
100	10.284	101	100	-1	79	-22	37	25	9	20	35	10	23
100	11.351	4					39	26	9	20	34	10	23

C= Calculated (ppm Boron)
M= Measured (ppm Boron)

[4] Uncertainty in Fission Pulse Decay Heat

First FPDH UQ studies JEFF-3.1.1(ND 2014)



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Nuclear Data Sheets 118 (2014) 472–475
Nuclear Data Sheets
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Testing JEFF-3.1.1 and ENDF/B-VII.1 Decay and Fission Yield Nuclear Data Libraries with Fission Pulse Neutron Emission and Decay Heat Experiments

O. Cabellos,[1,*] V. de Fusco,[1] C.J. Diez de la Obra,[1] J.S. Martinez,[1]
E. Gonzalez,[2] D. Cano-Ott,[2] and F. Alvarez-Velarde[2]
[1] *Departamento de Ingenieria Nuclear, Universidad Politecnica de Madrid, Madrid, Spain*
[2] *Centro de Investigaciones Energeticas, Mediambientales y Tecnologicas - CIEMAT, Spain*

The aim of this work is to test the present status of Evaluated Nuclear Decay and Fission Yield Data Libraries to predict decay heat and delayed neutron emission rate, average neutron energy and neutron delayed spectra after a neutron fission pulse. Calculations are performed with JEFF-3.1.1 and ENDF/B-VII.1, and these are compared with experimental values. An uncertainty propagation assessment of the current nuclear data uncertainties is performed.

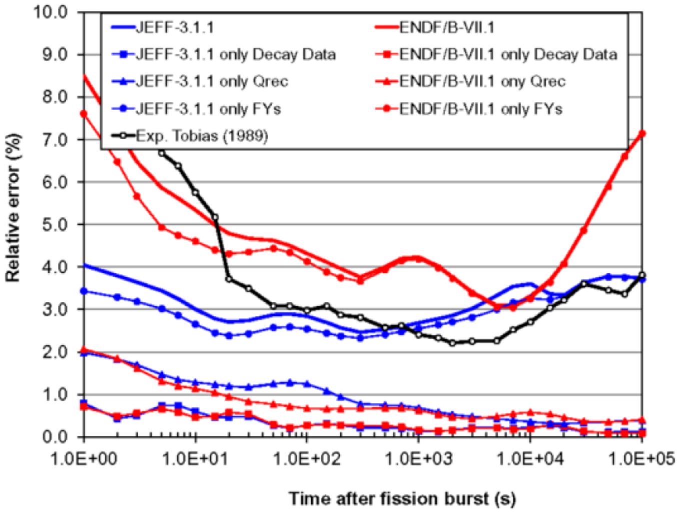
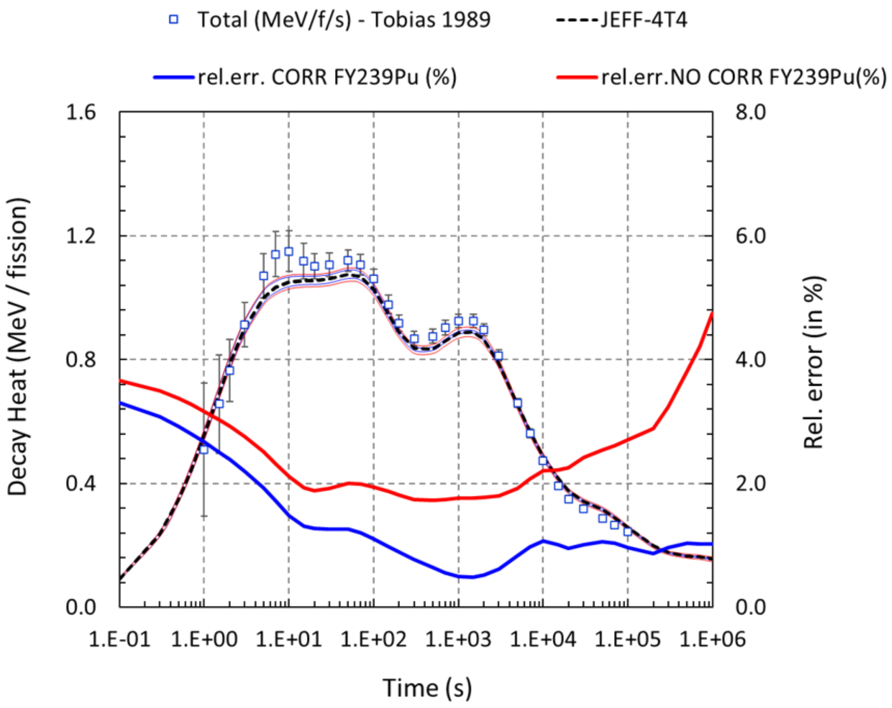


Figure 7. Predicted relative errors (in %) due to all nuclear data uncertainties propagated together and individually, compared to experimental uncertainty of total decay heat (β+γ) for thermal neutron fission burst of 239Pu.

Last FPDH studies: 3rd Research Coordination Meeting on Updated FY Data for Applications … UQ using JEFF-4.0 (2024)

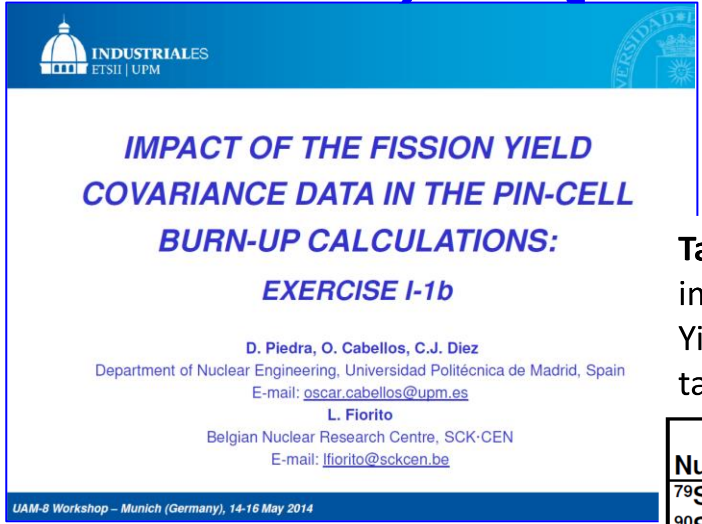
Figure 8. Total decay heat from thermal pulse on 239Pu.



- ❑ **Strong uncertainty reduction when JEFF-4 thermal fission-yield correlations are included**

[4.1] Importance of FY correlations …

FY uncertainty in burnup calculations (UAM 2014, PHYSOR 2014) … UQ using ENDF/B-VII.1



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IMPACT OF THE FISSION YIELD COVARIANCE DATA IN THE PIN-CELL BURN-UP CALCULATIONS:

EXERCISE I-1b

D. Piedra, O. Cabellos, C.J. Diez
Department of Nuclear Engineering, Universidad Politécnica de Madrid, Spain
E-mail: oscar.cabellos@upm.es
L. Fiorito
Belgian Nuclear Research Centre, SCK·CEN
E-mail: lfiorito@sckcen.be

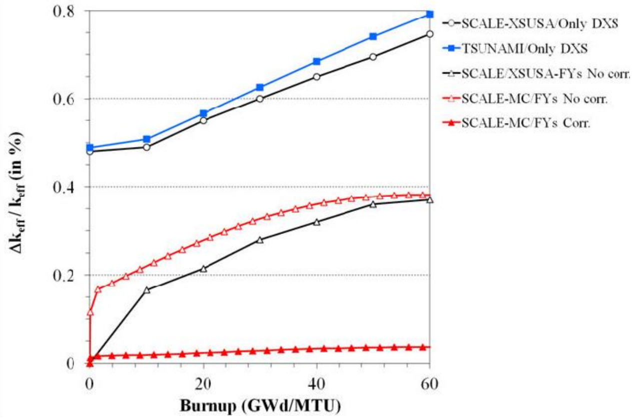
UAM-8 Workshop – Munich (Germany), 14-16 May 2014

- ❑ Assessing FY correlation matrix using Katakura/Diviliers Bayesian approach

Table 5. Uncertainty in number density for some important fission products at 60 GWd/MTU. Fission Yield source of uncertainty (standard deviation) is taken from ENDF/B-VII.1

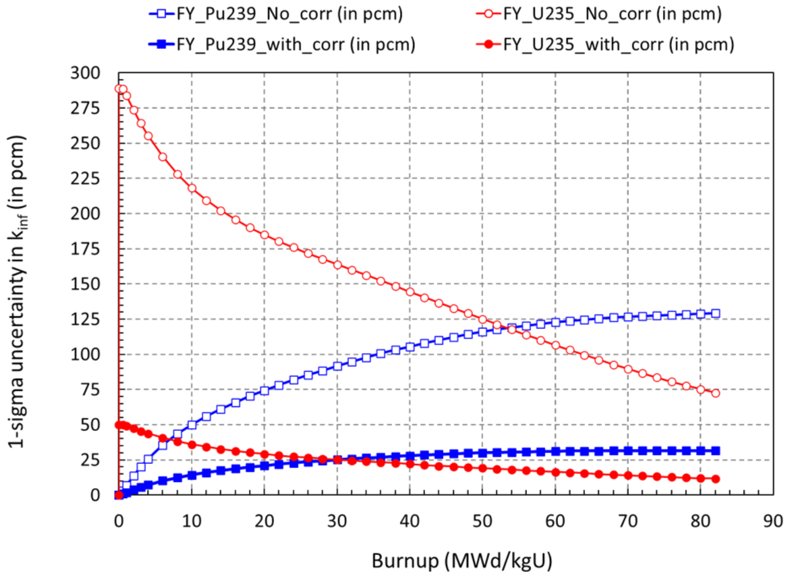
Nuclide	Corr.	No corr.	GRS XSUSA	Nuclide	Corr.	No corr.	GRS XSUSA
^{79}Se	3.5	16.0	-	^{142}Nd	0.8	3.5	3.5
^{90}Sr	0.8	6.2	-	^{143}Nd	0.4	6.5	5.9
^{95}Mo	0.5	8.4	7.9	^{144}Nd	0.2	3.9	-
^{99}Tc	0.8	10.0	9.5	^{145}Nd	0.4	7.1	6.7
^{101}Ru	0.7	4.6	5.0	^{146}Nd	0.7	10.8	9.5
^{106}Ru	1.2	13.7	14.1	^{148}Nd	0.8	13.7	13.0
^{103}Rh	1.1	12.1	11.9	^{147}Pm	0.6	10.3	-
^{109}Ag	10.9	17.8	14.8	^{147}Sm	0.5	9.4	8.4
^{125}Sb	4.2	19.1	-	^{149}Sm	0.6	12.2	10.6
^{129}I	2.7	20.7	-	^{150}Sm	0.6	10.3	9.3
^{135}I	2.8	4.3	-	^{151}Sm	0.7	11.7	10.5
^{131}Xe	0.4	6.9	-	^{152}Sm	0.6	11.3	8.8
^{135}Xe	0.4	5.1	-	^{151}Eu	0.7	12.1	10.9
^{133}Cs	0.3	3.4	3.3	^{153}Eu	0.8	9.9	8.3
^{134}Cs	0.3	3.0	2.9	^{154}Eu	0.8	10.4	8.7
^{135}Cs	0.3	3.4	3.4	^{155}Eu	1.0	9.5	8.1
^{137}Cs	0.5	1.5	1.7	^{155}Gd	1.0	10.5	8.8
^{139}La	0.9	3.2	3.2	^{156}Gd	1.2	9.0	7.8
^{144}Ce	0.2	8.0	8.4	^{157}Gd	1.3	9.5	-
				^{158}Gd	2.3	11.3	9.9

Figure 9. Relative standard deviation in keff (in %):



3rd Research Coordination Meeting on Updated FY Data for Applications … UQ using JEFF-4.0 (2024)

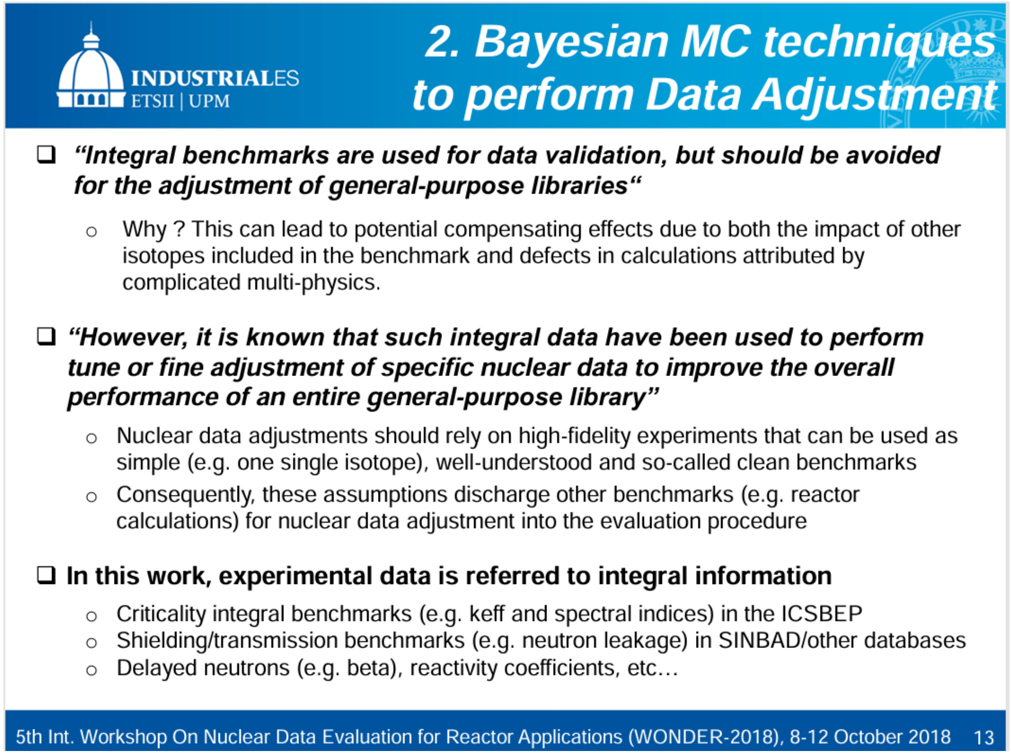
Figure 10. Uncertainty in the **kinf** (in pcm) along burnup for a typical **17x17-PWR Westinghouse fuel assembly with 4.8wt%.** Calculations performed with WIMSD5 code with 300 random JEFF4/FY files.



- ❑ **FY correlations strongly reduce and reshape the propagated uncertainty**

[5] Hidden correlations / CIELO / SG44

WONDER 2018...



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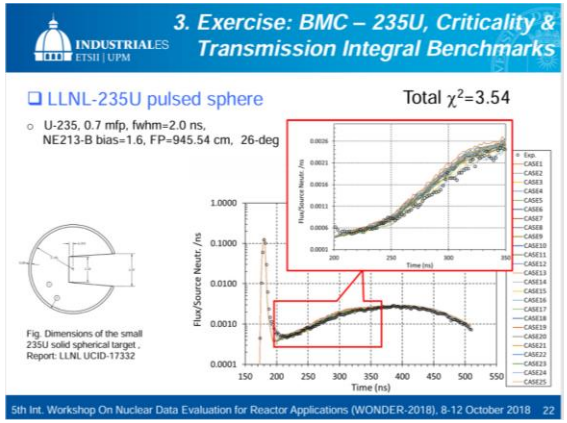
2. Bayesian MC techniques to perform Data Adjustment

- ☐ *"Integral benchmarks are used for data validation, but should be avoided for the adjustment of general-purpose libraries"*
  - Why ? This can lead to potential compensating effects due to both the impact of other isotopes included in the benchmark and defects in calculations attributed by complicated multi-physics.
- ☐ *"However, it is known that such integral data have been used to perform tune or fine adjustment of specific nuclear data to improve the overall performance of an entire general-purpose library"*
  - Nuclear data adjustments should rely on high-fidelity experiments that can be used as simple (e.g. one single isotope), well-understood and so-called clean benchmarks
  - Consequently, these assumptions discharge other benchmarks (e.g. reactor calculations) for nuclear data adjustment into the evaluation procedure
- ☐ **In this work, experimental data is referred to integral information**
  - Criticality integral benchmarks (e.g. keff and spectral indices) in the ICSBEP
  - Shielding/transmission benchmarks (e.g. neutron leakage) in SINBAD/other databases
  - Delayed neutrons (e.g. beta), reactivity coefficients, etc…

5th Int. Workshop On Nuclear Data Evaluation for Reactor Applications (WONDER-2018), 8-12 October 2018 13



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3. Exercise: BMC – 235U, Criticality & Transmission Integral Benchmarks

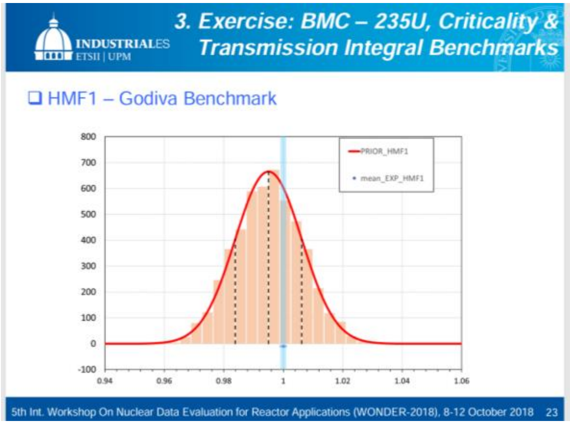
☐ LLNL-235U pulsed sphere

Total χ^2=3.54

- U-235, 0.7 mfp, fwhm=2.0 ns, NE213-B bias=1.6, FP=945.54 cm, 26-deg

Fig. Dimensions of the small 235U solid spherical target , Report: LLNL UCID-17332

5th Int. Workshop On Nuclear Data Evaluation for Reactor Applications (WONDER-2018), 8-12 October 2018 22



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3. Exercise: BMC – 235U, Criticality & Transmission Integral Benchmarks

☐ HMF1 – Godiva Benchmark

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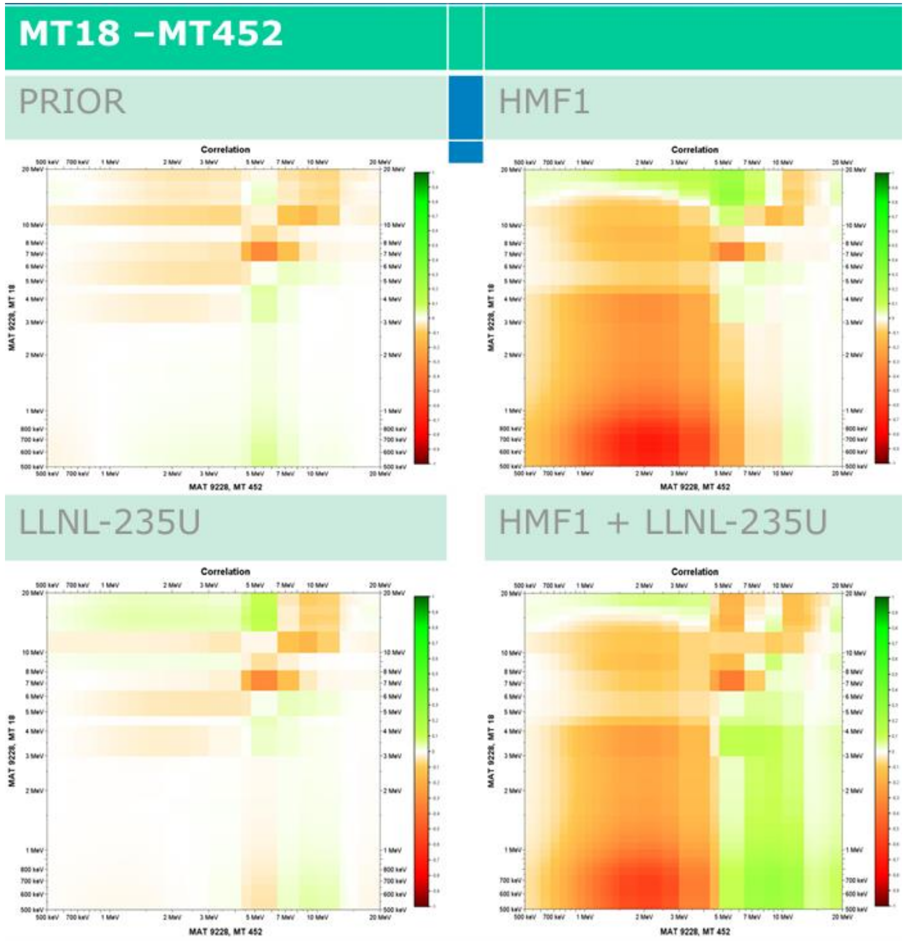

MT18 –MT452

PRIOR

HMF1

LLNL-235U

HMF1 + LLNL-235U

5000 random files 235U/TENDL2014

WPEC/SG44 (2019) … 1D-1group keff

$$k_{eff} = \frac{\bar{\nu} \cdot \sigma_f}{\sigma_f + \sigma_\gamma + L}$$

		ENDF/B-VIII.0 inputs	Evaluated (posterior)		
		Unc.[%]	$\bar{\nu}$[%]	$\sigma_{f[\%]}$	$\sigma_{\gamma[\%]}$
U-235	$\bar{\nu}$	0.55	1.00	−23.9	53.3
	σ_f	1.04	−23.9	1.00	68.4
	σ_γ	**13.2**	53.3	68.4	1.00
Δk_{eff}		Unconstrained: 1473 pcm			

[6] Uncertainty Quantification (UQ) due to Nuclear Data Uncertainties

SG46 (2017-2023) - WONDER 2023…

Table 6. Uncertainty quantification due to nuclear data uncertainties and SG46/TAR values

System	Parameter	ENDF/B-VII.1	ENDF/B-VIII.0	JEFF-3.3	JENDL-5.0	Target
ALFRED	keff (in pcm)	**717**	**826**	**831**	**736**	**300/435 pcm**
	Coolant-density (in %)	57.0	30.3	42.9	38.9	10%
	Coppler (in %)	9.0	4.6	6.5	5.5	3%
ASTRID	keff (in pcm)	**999**	**855**	**908**	**851**	**300 pcm**
	Fully voided (in %)	20.2	17.2	16.1	20.2	10%
ESFR	keff (in pcm)	**1147**	**865**	**967**	**899**	**300 pcm**
	Fully voided (in %)	37.1	31.2	26.7	33.8	10%
	Doppler (in %)	5.6	3.3	4.1	4.0	3%
	Rod worth (in %)	2.4	1.3	1.8	1.7	3%
JSFR-750	keff (in pcm)	**971**	**900**	**920**	**866**	**200 / 300 pcm**
	BRS (in %)	5.5	5.4	5.2	5.1	18% / 27%
	CRW (in %)	2.7	2.7	3.2	2.6	2% /-
	DOP (in %)	3.9	3.1	3.6	4.0	2% / 7%
	Power distribution (in %)	1.7	1.6	1.8	1.5	1% / 2%
	SVR (in %)	4.8	5.3	3.8	4.9	3% / 7%
MYRRHA	keff (in pcm)	**771**	**676**	**588**	**-**	300 pcm
MACRE	keff (in pcm)	**2435**	**-**	**-**	**-**	300 pcm
MOLTEX	keff (in pcm)	**584/836***	**922**	**1090**	**-**	300 pcm
NUSCALE	keff (in pcm)	**748**	**522**	**669**	**397**	300 pcm

ND uncertainty reduction is needed, especially for keff in many advanced systems.

❑ UQ performed with sandwich formula $(S\cdot V_{\alpha}\cdot S^{T})$ and using the full ND covariance matrix (V_{α})

❑ Calculations with OECD/NEA NDaST

* using covariances for ^{35}Cl above 1 MeV from TENDL2021

[7] TAR Calculations & nuclear data needs

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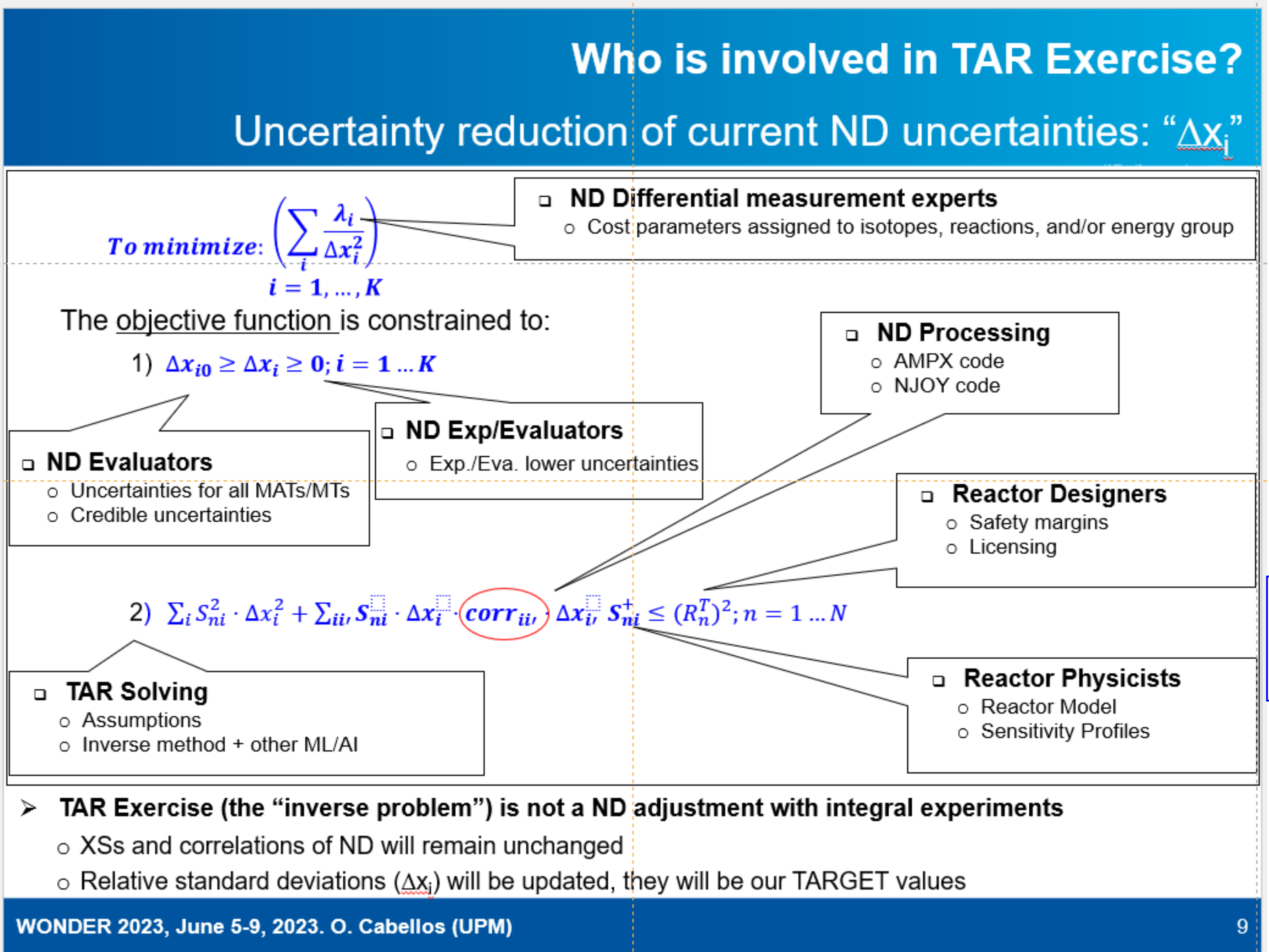
Target Accuracy Requirements (TAR) Exercise within WPEC/SG46 and Feedback on Nuclear Data Needs, ND2022 and WONDER 2023



Who is involved in TAR Exercise?

Uncertainty reduction of current ND uncertainties: “Δx_i”

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

$i = 1, \ldots, K$

- ❑ **ND Differential measurement experts**
  - ○ Cost parameters assigned to isotopes, reactions, and/or energy group

The objective function is constrained to:

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

- ❑ **ND Processing**
  - ○ AMPX code
  - ○ NJOY code
- ❑ **ND Exp/Evaluators**
  - ○ Exp./Eva. lower uncertainties
- ❑ **ND Evaluators**
  - ○ Uncertainties for all MATs/MTs
  - ○ Credible uncertainties
- ❑ **Reactor Designers**
  - ○ Safety margins
  - ○ Licensing

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

- ❑ **TAR Solving**
  - ○ Assumptions
  - ○ Inverse method + other ML/AI
- ❑ **Reactor Physicists**
  - ○ Reactor Model
  - ○ Sensitivity Profiles

➢ **TAR Exercise (the “inverse problem”) is not a ND adjustment with integral experiments**

- ○ XSs and correlations of ND will remain unchanged
- ○ Relative standard deviations (Δx_i) will be updated, they will be our TARGET values

WONDER 2023, June 5-9, 2023. O. Cabellos (UPM) 9

17-Cl-35(n,p)

ID	119
Type	H - High priority request
Target	17-Cl-35
Reaction	(n,p)
Quantity	SIG - Cross section
Incident energy	100 keV - 5 MeV
Accuracy	5-8 %
Field(s)	Fission
Subfield	Gen-IV
Accepted date	17-Apr-2022
Status	Work in progress
Latest review date	25-Sep-2025

Requester: Tom Taylor (Moltex Energy) and Tommy Cisneros (TerraPower)

https://www.oecd-nea.org/jcms/pl_68905/17-cl-35-n-p

Correlation terms in SG46 TAR assessments can produce stringent ND uncertainty requirements.

See also: EU/SANDA Project - “Report on assessment of nuclear data needs”
http://www.sanda-nd.eu/wp-content/uploads/2024/11/SANDA-D5.5.pdf

7. Conclusion & Lessons Learned

"If the diagonal of a covariance matrix is a measure of our ignorance, the off-diagonal elements are a measure of our wisdom." by M. Herman (2017)

Lessons learned

- ND-UQ is only as credible as the covariance data being propagated
- Covariances must preserve the statistical and physics memory of the evaluation
- Complete UQ requires more than cross sections: ν, PFNS, angular distributions, FYs, decay data and TSLs may be essential
- Benchmark propagation is a powerful QA tool for covariance data
- Integral experiments can reduce uncertainties only if the induced correlations are treated consistently

"Wisdom comes from experience. Experience is often a result of lack of wisdom"
by Sir Terry Pratchet (1948-2015)

Final messages

- S/U methods are essential for diagnosis, decomposition and TAR
- Monte Carlo sampling is valuable for complex, non-linear and depletion applications
- Differences between evaluated libraries may reveal limitations in current covariance data
- TAR translates application requirements into nuclear-data priorities
- The future need is not simply more covariance data, but more complete, consistent and traceable
- **USERS also need clear guidance on the domain of applicability, limitations and recommended use of evaluated covariance data**

Thanks for your attention !

E&T in ND

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Upcoming GRE@T-PIONEeR course on "Nuclear data for energy and non-energy applications" October 26-30, 2026 (https://great-pioneer.eu/)

Application period will **open on August 10, 2026, and will close on August 30, 2026**

- ❑ **E&T on nuclear data within the Great-Pioneer Project**
  - Experimental Data/Theory and Evaluation
  - Processing/Verification
  - Benchmarking/Validation
  - Sensitivity Analysis and Uncertainty Quantification

Figure. Course on ND: Chalmers September 2025

- ❑ **On-site participation :**
  - **Online self-paced learning phase taking place between September 25th, 2026, and October 23rd, 2026**
  - **Synchronous activities offered between October 26th, 2026, and October 30th, 2026 (those activities can be attended online or onsite at Chalmers University of Technology, Gothenburg, Sweden).**
- ❑ **To follow-up GRE@T-PIONEeR activities at:**

Web www.great-pioneer.eu

@GREATPIONEeR_EU

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Acknowledgments

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European Commission

APRENDE

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