Experiencia de datos nucleares en simulaciones PWR

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Acknowledgments

1.1 Cuál es el TARGET u objetivo de los cálculos en LWRs ?

- Target Accuracy for PWRs

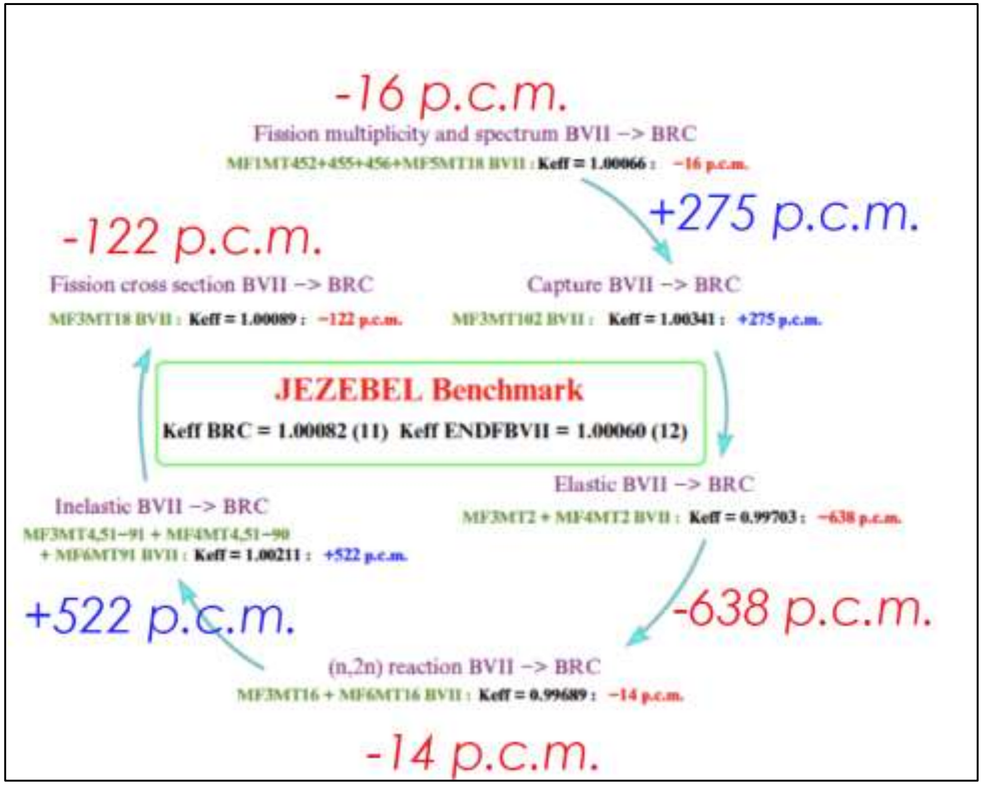
Table 22. PWR target accuracies (1σ)

k_{eff}	Doppler reactivity coefficient	Burn-up $\Delta\rho$	Transmutation
0.5%	10%	500 pcm	5%

Reference: International Evaluation Co-operation Volume 26.
“Uncertainty and Target Accuracy Assessment for Innovative Systems Using Recent Covariance Data Evaluations” (2008)

1.2 Qué son los errores de compensación en los datos nucleares ?

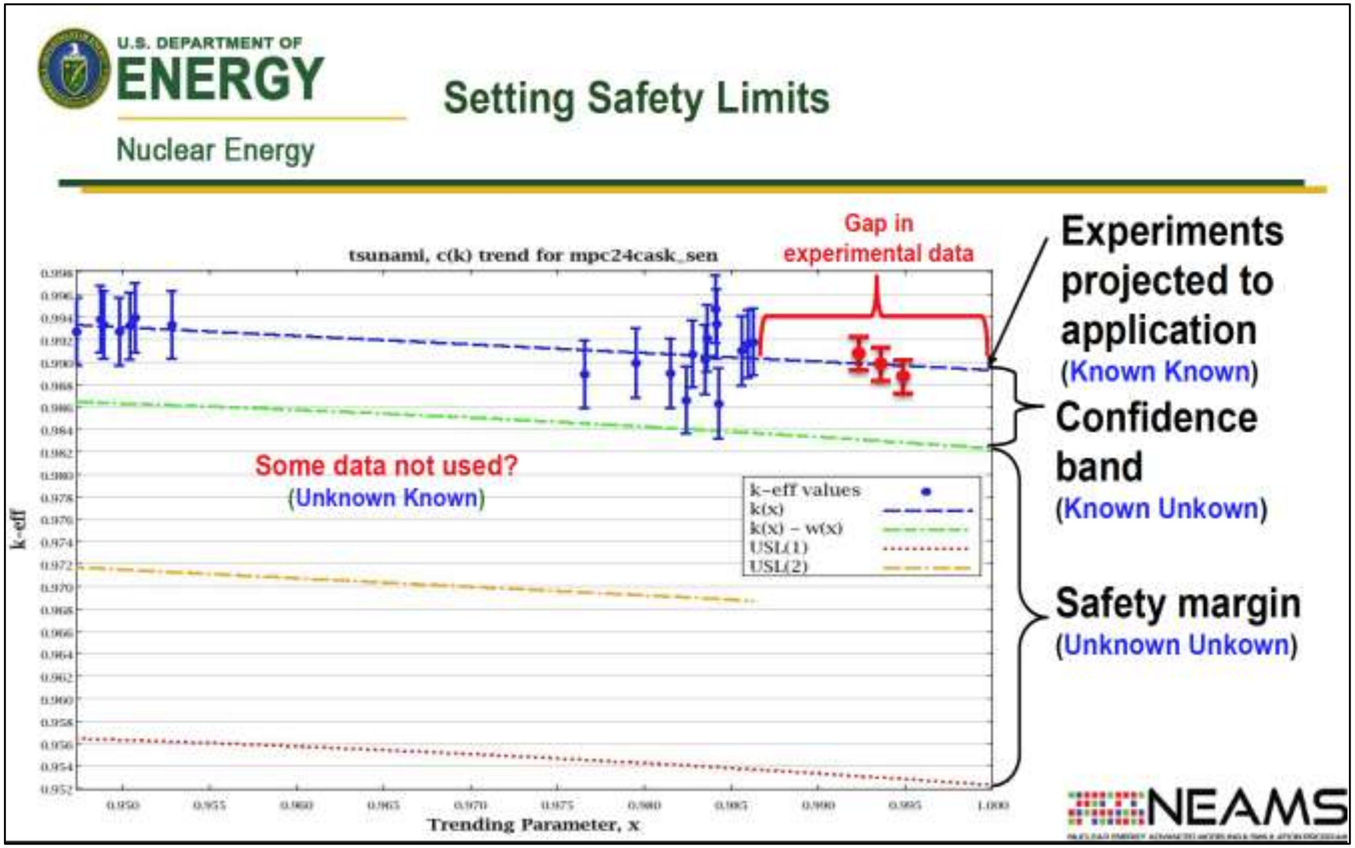
- Errores de compensación de los DNs en las Librerías Evaluadas



Reference: E. Bauge *et al.,* Eur. Phys. J. A (2012) 48: 113

1.3 Qué tipos de incertidumbres tienen los datos nucleares ?

- Impacto de las incertidumbres de los DNs en las Librerías Evaluadas



Reference: B.T. Rearden, Nuclear Energy Advanced Modeling and Simulation (NEAMS)Status and Perspectives, Workshop on Multi-physics Model Validation North Carolina State University. Department of Nuclear Engineering June 27-29, 2017

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1.4 Qué necesidades existen de DNs en LWRs?

- Necesidades de DNs en LWRs

Nuclear Data for LWRs

- It does not seem that new measurements are needed for LWRs using UO_2 fuel
- New data needed for accident tolerant fuel (ATF) (e.g., U_3Si_2, UN, coated cladding, etc.)
- Westinghouse observed some discrepancies between the ENDF-VII.1 and ENDF-VIII.0. libraries:
  - A standard benchmark unit assembly (a typical 17x17 Westinghouse fuel assembly with IFBA) was modeled using ENDF-VII.1 and ENDF-VIII.0. Differences were observed between the two libraries.
  - 3 cycles of a 4-loop plant were calculated and results compared to plant measured data
    - Simulations performed with ENDF-VII.1 are in a good agreement with the plant data
    - Results of the simulations with ENDF-VIII.0 are significantly different and the difference increases with depletion. Power distributions and the critical boron concentrations were investigated.
- Information/feedback on the comparison of ENDF-VII.1 and ENDF-VIII.0 and experience of other users are of interest for us

Westinghouse

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Reference: Alex Levinsky, PhD. Westinghouse Electric Co. “Nuclear Data Needs for Current and Future Nuclear Energy Systems”. WANDA Nuclear Energy Roadmapping Session. January 2019

1.5 Qué librerías se han distribuido recientemente ?

- JEFF-3.3 (November 2017)
- ENDF/B-VIII.0 (February 2018)

Fig. Ratio MT18 (n,fission) JEFF-3.3/ENDF/B-VIII.0

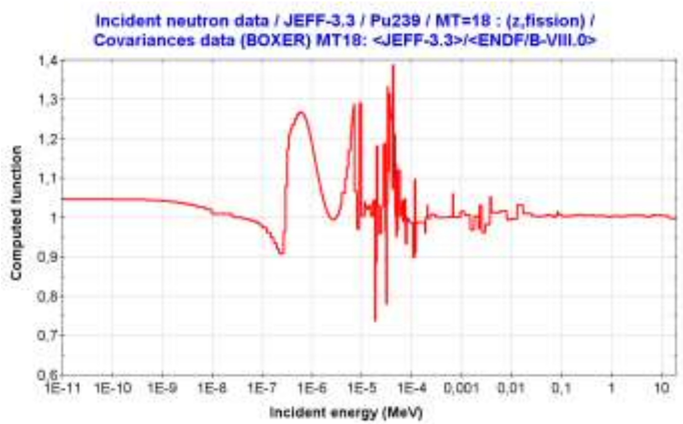
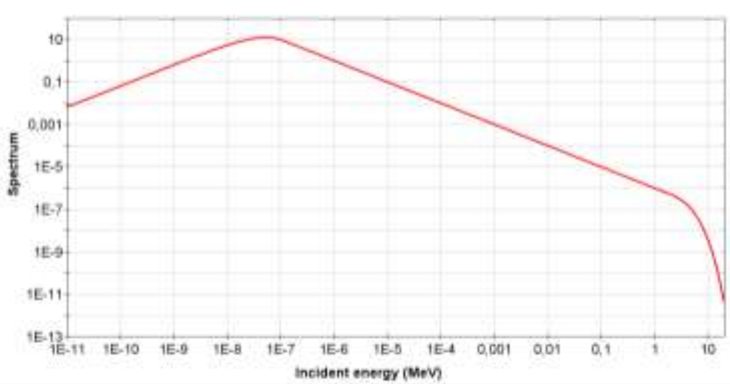


Fig. JANIS PWR Spectrum for weighting



- Table. PWR spectrum weighted “Average Cross-Section “ over [1.0E-5eV - 20MeV]

	Pu239		
MTs	**ENDF/B-VIII.0**	**JEFF-3.3**	**(J-E)/E*100(%)**
MT18	142.778465	144.884286	**1.5**
MT102	83.671134	85.492381	**2.1**
MT452	2.915869	2.899943	**-0.5**
MT1018	0.008248	0.008228	**-0.2**
	U235		
MTs	**ENDF/B-VIII.0**	**JEFF-3.3**	**(J-E)/E*100(%)**
MT18	54.340942	54.546999	**0.4**
MT102	14.816737	14.641728	**-1.2**
MT452	2.457456	2.457786	**0.0**
MT1018	0.008226	0.008208	**-0.2**
	U238		
MTs	**ENDF/B-VIII.0**	**JEFF-3.3**	**(J-E)/E*100(%)**
MT4	0.436791	0.419927	**-4.02**
MT18	0.037318	0.036846	**-1.3**
MT102	14.975353	14.973455	**0.0**
MT452	2.471642	2.42593	**-1.9**
MT1018	0.008214	0.008196	**-0.2**

2. Scheme of the PWR Core Analysis SEANAP System

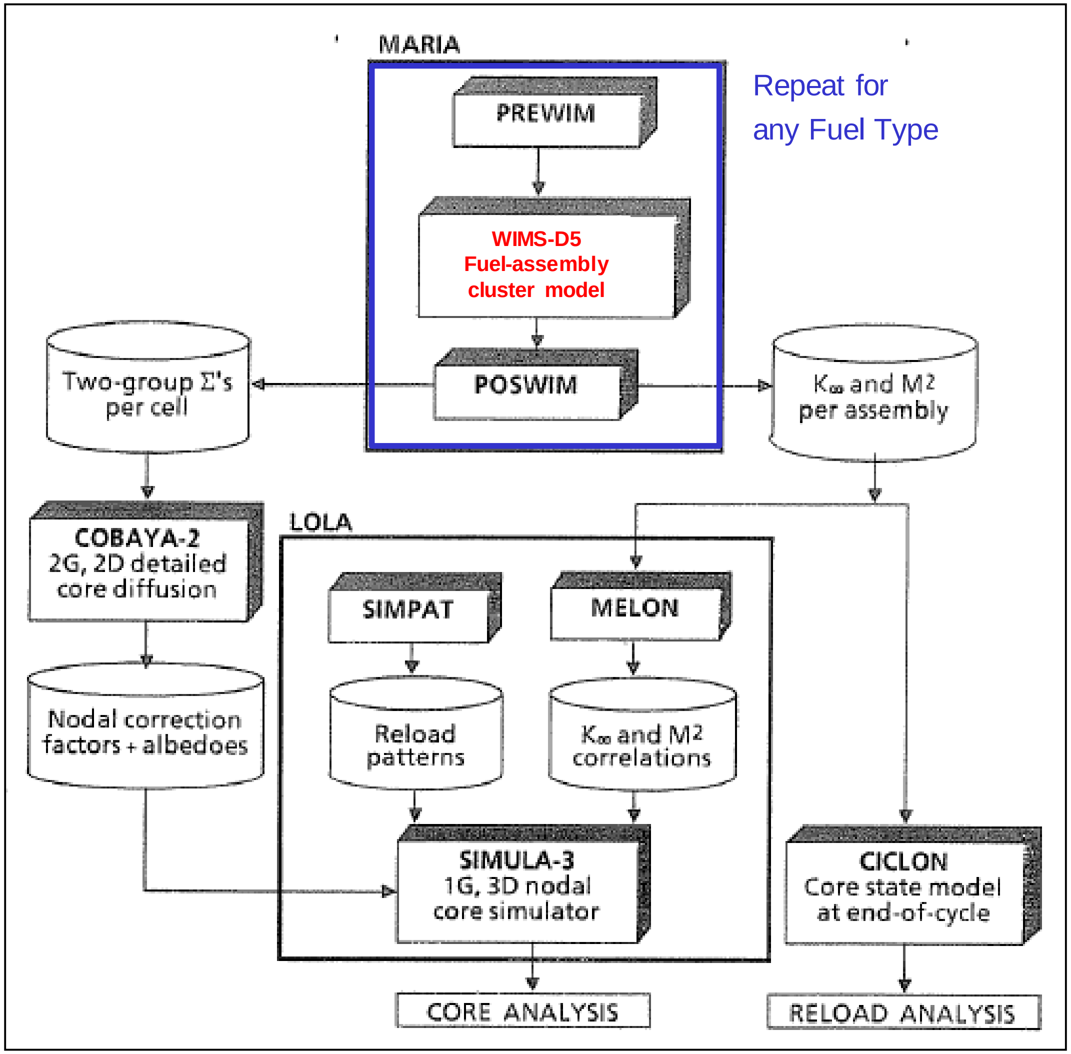
Fig. Scheme of the PWR Core Analysis System **SEANAP-86**

Ref.: *"Validation of PWR Core Analysis system SEANAP-86 with measurements in test and operation", C. Ahnert et al., M&C87*

SEANAP is integrated by 4 subsystems:

1. **MARIA** system for assembly calculations
2. **COBAYA** system for a detailed (pin-by-pin) core calculations at reference conditions
3. **SIMULA** system for 3D 1 group corrected-nodal core simulation
4. **CICLON** system for fuel management analysis of reload cycles

CPU Time/cycle ~ 5 min / i7 870@2.93GHz



Extended Validation in PWRs

- More and different PWRs (V, C, …)
- More Cycles: V1 to V5, C13
- Operational Maneuvers

PWR (Westinghouse), 3 loops. 157 Fuel Assemblies. Power 2775 MWth

¼ CORE

1	13	4	21	6	21	16	14
13	11	15	2	16	6	20	7
4	15	3	21	8	22	19	
21	2	21	9	18	20	5	
6	16	8	18	12	17		
21	6	22	20	17			
16	20	19	10				
14	7						

¼ CORE

		C				D	
	SB				SA		
C		D		B		A	
			SB				
		B		C			
	SA						
D		A					

Location of control rod banks

3.1 Core Measurements: Measured Boron Concentrations (ppm) and calculated values versus cycle operation

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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	Meas.	WIMS-D4 ND-1981		WIMSD5 ND-JEFF-3.3		WIMSD5 ND-ENDF/B-VIII.0	
Power (%)	(GWd/tHM)	(ppm)	C	C-M	C	C-M	C	C-M
50	0.015	1200	1150	-50	1172	-28	1200	0
75	0.031	1113	1071	-42	1092	-21	1119	6
100	0.134	985	1000	15	1017	32	1045	60
100	1.340	870	897	27	900	30	935	65
100	2.487	779	806	27	802	23	843	64
100	2.842	755	778	23	773	18	815	60
100	3.591	688	714	26	705	17	752	64
100	4.441	604	645	41	634	30	685	81
100	5.549	504	544	40	531	27	588	84
100	6.692	412	439	27	425	13	487	75
100	7.716	319	340	21	325	6	393	74
100	8.823	227	239	12	223	-4	296	69
100	10.284	101	100	-1	83	-18	162	61
100	11.351	4	-7	-7	-24	-28	60	56

- Calculations with ND libraries processed in **69 energy groups**
- **Calculations**
  - **V1->V5**
- **Results at:**
  - **PWR-V, cycle 5**

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

3.2 Example of Operational Maneuver: "to recover HFP after a reactor trip with 12 hours at HZP"

Fig. Power Level and Xe Level as a function of time (in hours)

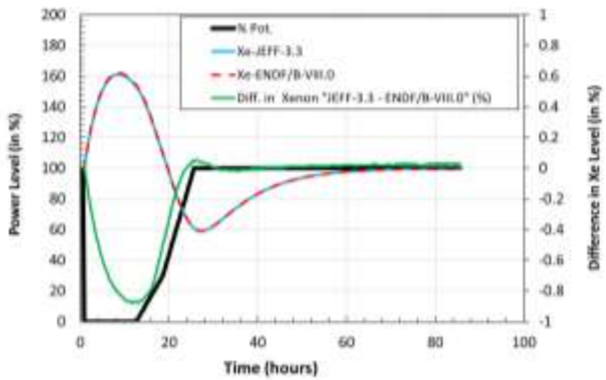


Fig. Critical Boron (ppm) as a function of time

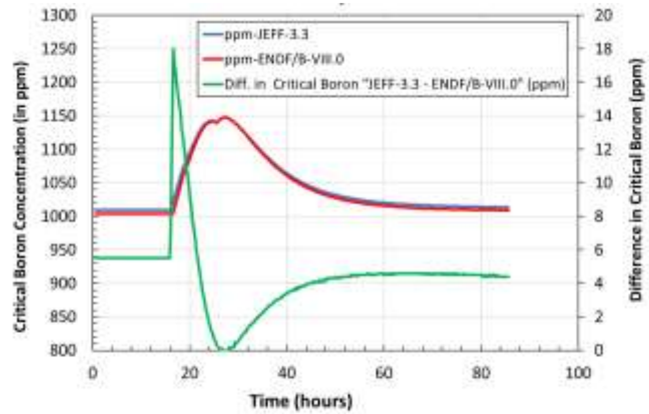


Fig. Surveillance of the axial power difference (delta-I incore) during operation procedure

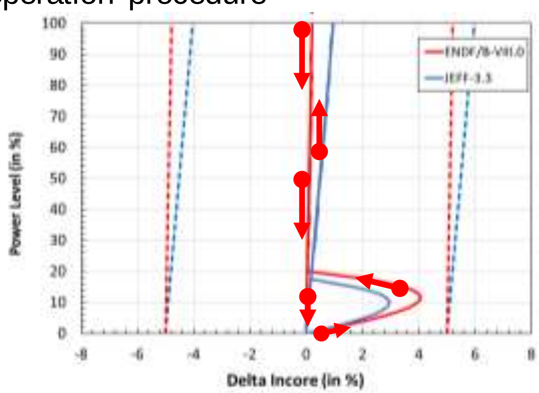
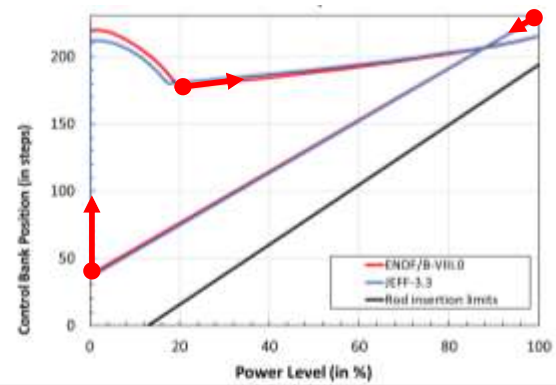


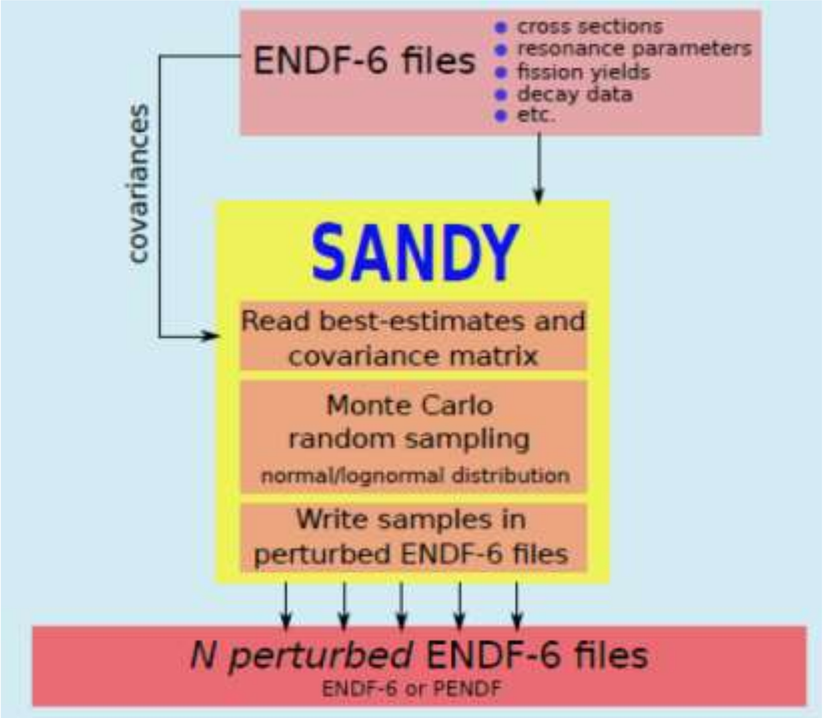
Fig. Position control Bank-D as a function of Power Level (in %) and as a function of time



- Calculations with ND libraries processed in **69 energy groups**

4. Propagación de incertidumbres de DNs: SANDY methodology - "Random files"

- **SANDY** (https://github.com/luca-fiorito-11/sandy)
  - SANDY: Numerical tool for nuclear data uncertainty quantification
  - Based on Monte Carlo sampling



- In this work: **300 histories/variable**

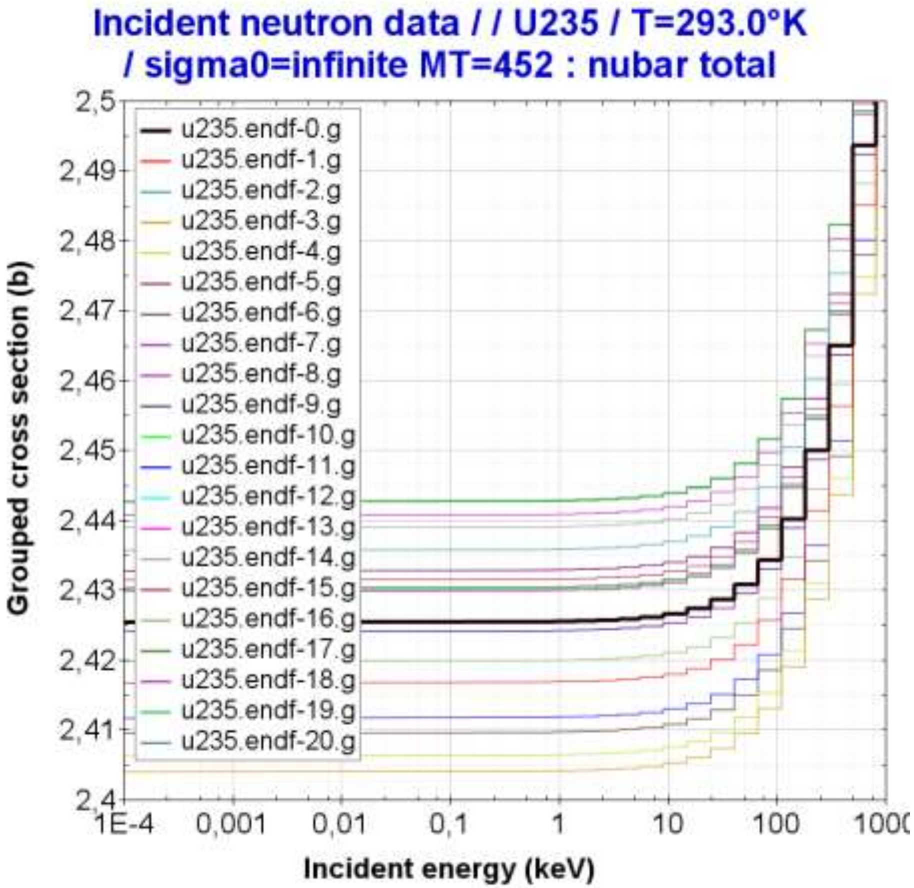


Fig.: First 20 **JEFF-3.3** random files processed with NJOY/GROUPR in 69 energy groups at 293K with infinite dilution

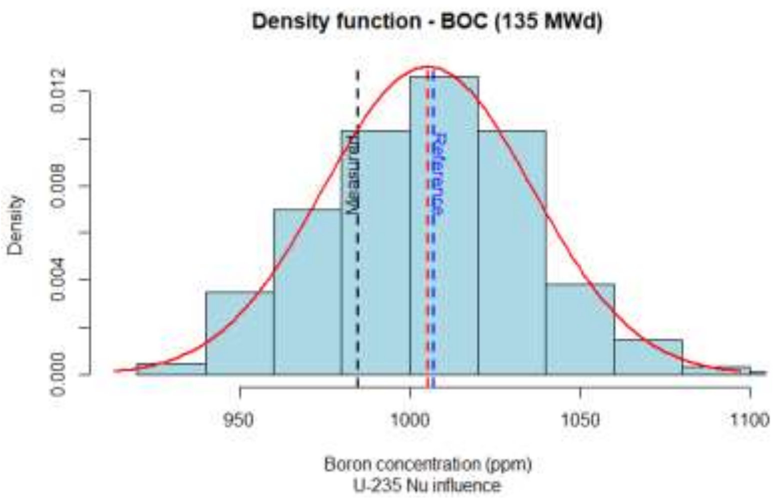
4.1 U&Q for Core Measurements: Measured Boron Concentrations (ppm) and calculated values versus cycle operation

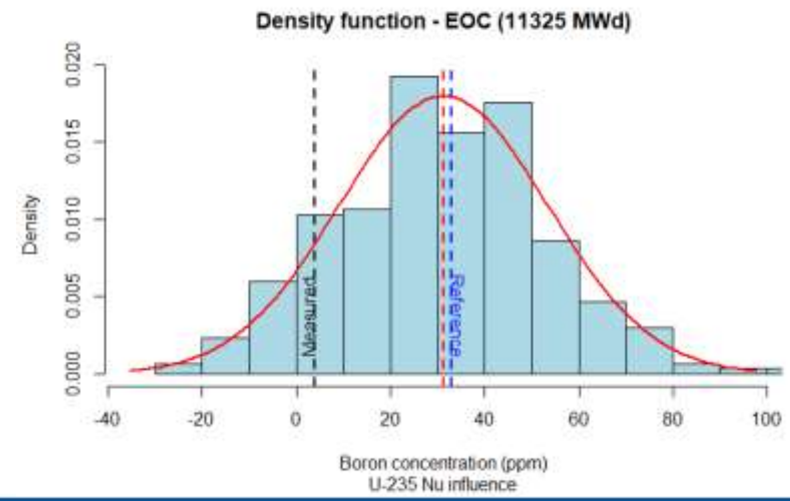
Core parameter	Design criteria	Acceptance criteria
Critical boron concentration ARO	$|(C_B)^M_{ARO}-(C_B)^C_{ARO}| < 50$ ppm	$|(C_B)^M_{ARO}-(C_B)^C_{ARO}| < 100$ ppm

Figure. Impact of nu-bar U235 uncertaitnies in ENDF/B-VIII.0

PDF of Critical Boron Concentration (in ppm) with 300 histories.

Calculations with SEANAP system in a PWR-V in cycle-5.





4.2 U&Q for Core Measurements: Measured Boron Concentrations (ppm) and calculated values versus cycle operation

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

Table. Uncertainties in Critical Boron Concentration (in ppm). PWR-V in cycle-5.

		JEFF-3.3 covariance data							ENDF/B-VIII.0 covariance data											
		Pu239			U235			U238	Pu239				U235				U238			
Power (%)	Burnup (GWd/tHM)	XS	ν	c	XS	ν	c	XS	XS	ν	c	Ang	XS	ν	c	Ang	XS	ν	c	Ang
50	0.015	18	14	9	27	46	9	24	34	9	15	0	-	31	-	0	23	11	0	1
75	0.031	18	15	9	27	46	10	24	35	9	15	0	-	31	-	0	24	11	0	1
100	0.134	19	15	9	27	46	10	25	37	10	16	0	-	31	-	0	25	11	0	1
100	1.340	22	16	9	25	47	10	24	43	11	15	0	-	29	-	0	24	11	0	1
100	2.487	24	17	9	24	45	10	24	47	12	15	0	-	28	-	0	23	11	0	1
100	2.842	25	19	9	24	43	10	24	49	12	15	0	-	28	-	0	23	11	0	1
100	3.591	27	19	9	24	43	10	24	52	12	15	0	-	27	-	0	23	11	0	1
100	4.441	28	20	9	23	41	10	24	55	13	15	0	-	27	-	0	23	11	0	1
100	5.549	30	21	9	22	40	10	24	59	14	15	0	-	26	-	0	22	11	0	1
100	6.692	32	22	9	22	39	10	23	63	14	15	0	-	25	-	0	22	11	0	1
100	7.716	34	23	9	21	38	10	23	66	15	15	0	-	24	-	0	22	11	0	1
100	8.823	35	24	9	21	37	10	23	69	15	15	0	-	24	-	0	22	11	0	1
100	10.284	37	25	9	20	35	10	23	73	16	15	0	-	23	-	0	21	11	0	1

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17	SERRA LOPEZ	,	LUIS
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