Core Power Distribution Sensitivity

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Sommaire

I. Introduction i. Context / Problem

My thesis subject : *"Uncertainties characterization methods on industrial core calculation chain"*

Current validated chain by:
- Benchmark
- Experiments
- Segments of accidents
- Industrial measurements

Possibility to use current chain to predict behavior of new reactors:
- But less experience, less available data.. → **Important to benchmark**

New reactors design tends to:
- More burnable poison
- Higher enrichment
- Different size scale
- Different reflector conception

Need: To access well uncertainty on Power Distribution → Safety margins

Tools:
- Uncertainty & Sensitivity
- Core calculation chain (Deterministic code)
- Monte Carlo codes → As for example: **SERPENT**

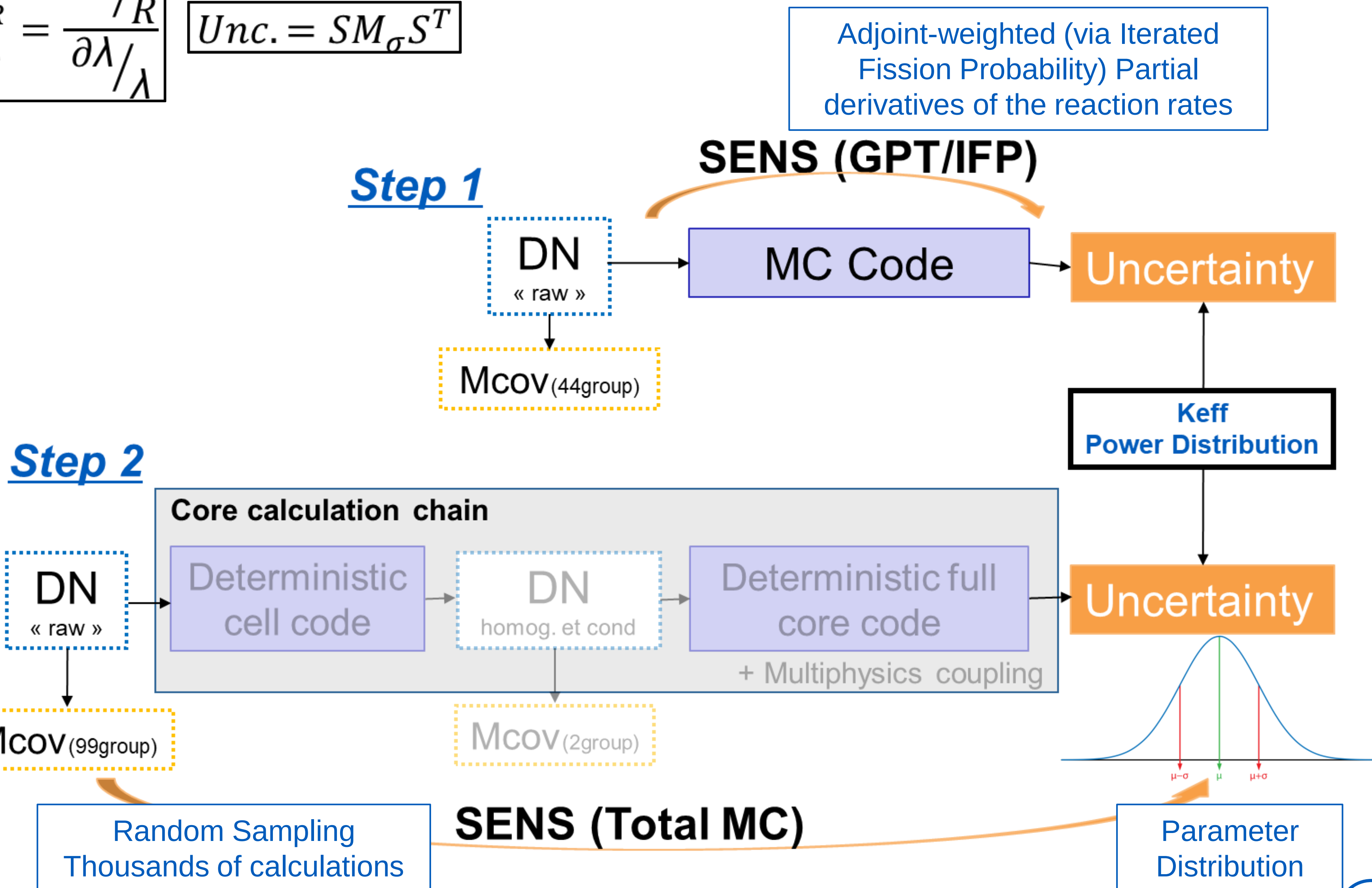
Sensitivity capability :
GPT/IFP *(Generalized Perturbation Theory/ Iterated Fission Probability)*

I.ii. Objective

Sensitivity & Uncertainty equations

$$S_{\lambda}^{R} = \frac{\partial R / R}{\partial \lambda / \lambda}$$

$$Unc. = S M_{\sigma} S^{T}$$



I.ii. Objective

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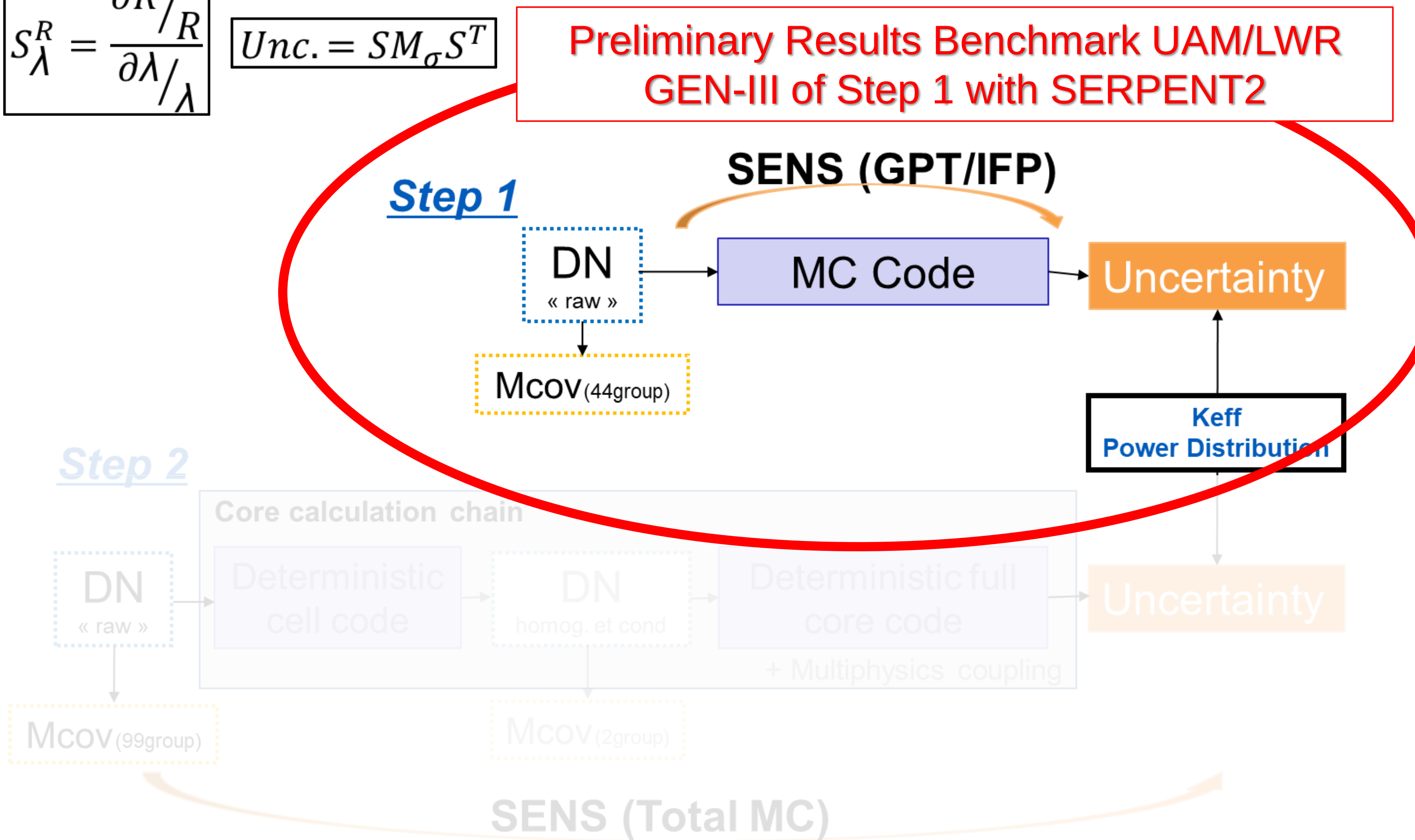
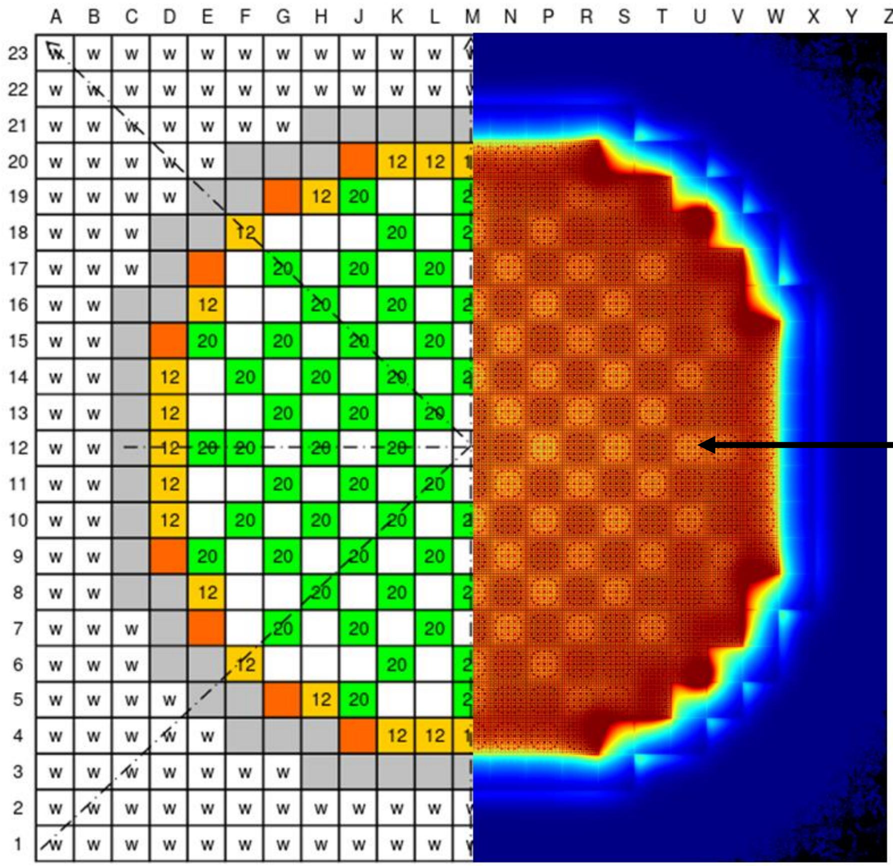
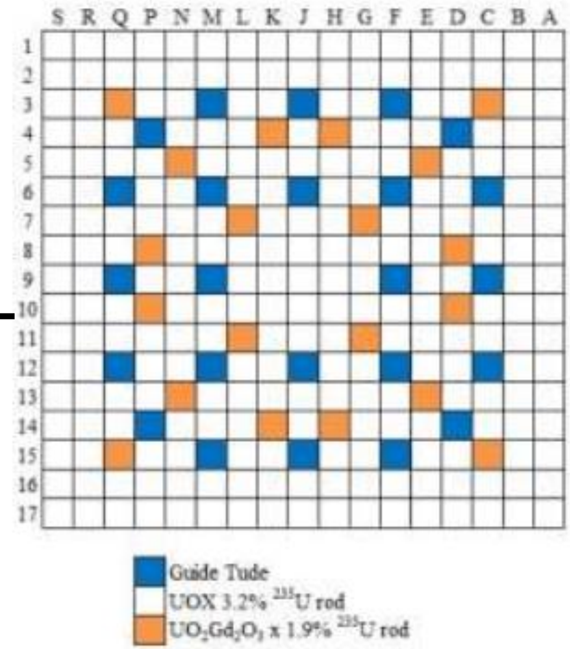


I.iii.BENCHMARK UAM/GEN III UOx

Core layout

- Large core
- Heavy reflector
- High poison concentration
- Intercalated Gd pattern (chessboard-like)
- 4 types of assemblies
- Power peak at the boundaries





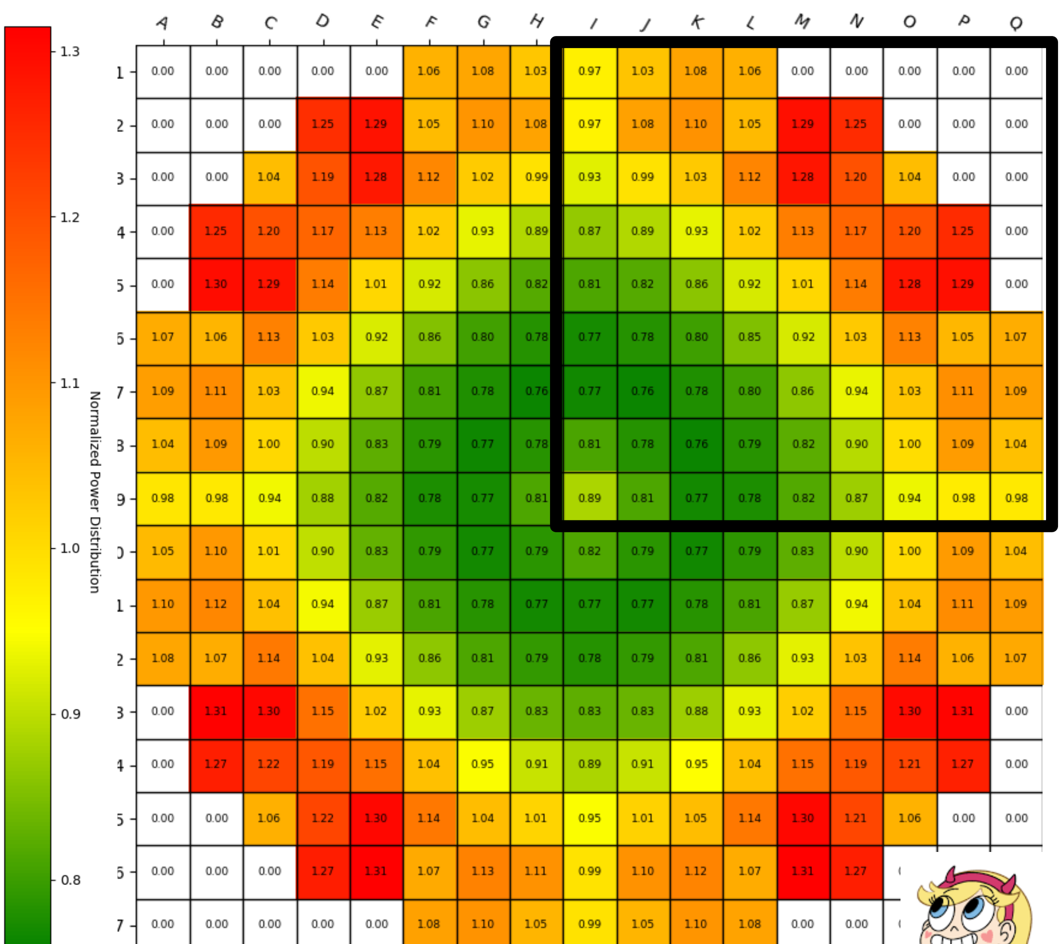
Type 3: UOX 3.2% ^{235}U assembly with 20 UO_2-Gd_2O_3 (1.9% ^{235}U) rods

- UOX 2.1% ^{235}U assembly
- UOX 4.2% ^{235}U assembly
- 20 — UOX 3.2% ^{235}U assembly with 20 UO2-Gd_2O_3 rods
- 12 — UOX 4.2% ^{235}U assembly with 12 UO2-Gd_2O_3 rods
- Stainless steel reflector assembly
- W — Borated water reflector assembly

II. Preliminary Results i. Normalized Power Distribution

Comparison with others participants results

- Same shape
- Similar values



- **SERPENT2 MC code**

(Our results)

(Participant 1)

- **Deterministic code**

Maximum difference in central assembly 6,7%

1.03	1.08	1.13	1.10					
1.01	1.09	1.11	1.11	1.34	1.29			
0.95	0.98	1.05	1.12	1.29	1.22	1.11		
0.84	0.90	0.91	1.04	1.13	1.22	1.22	1.29	
0.81	0.78	0.86	0.89	1.03	1.13	1.29	1.34	
0.73	0.78	0.77	0.85	0.89	1.04	1.12	1.11	1.10
0.75	0.72	0.76	0.77	0.86	0.91	1.05	1.11	1.13
0.76	0.76	0.72	0.78	0.78	0.90	0.98	1.09	1.08
0.83	0.76	0.75	0.73	0.81	0.84	0.95	1.01	1.03

1.01	1.06	1.11	1.11					
0.98	1.09	1.11	1.07	1.31	1.29			
0.94	1.00	1.03	1.12	1.27	1.20	1.08		
0.87	0.90	0.93	1.02	1.12	1.16	1.20	1.29	
0.82	0.83	0.87	0.92	1.00	1.12	1.27	1.31	
0.77	0.79	0.80	0.86	0.92	1.02	1.12	1.07	1.11
0.77	0.76	0.78	0.80	0.87	0.93	1.03	1.11	1.11
0.80	0.78	0.76	0.79	0.83	0.90	1.00	1.09	1.06
0.87	0.80	0.77	0.77	0.82	0.87	0.94	0.98	1.01

- **MC code multigroup**

Maximum difference in central assembly 4,7%

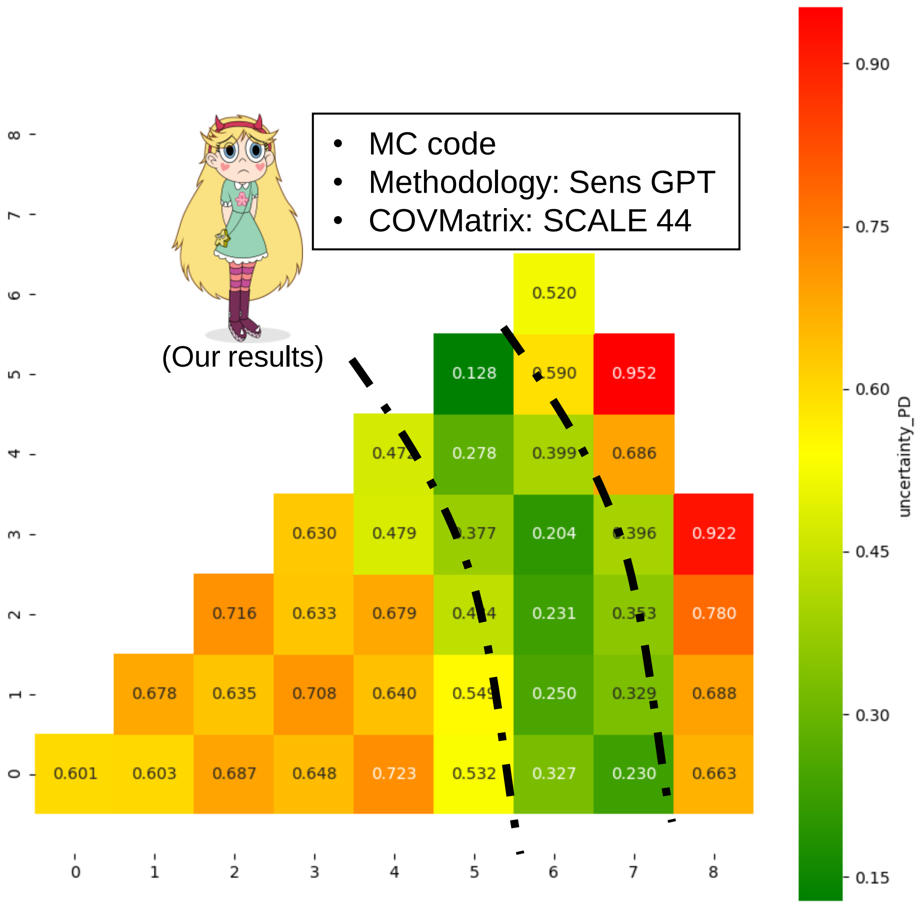
(Participant 2)

II.ii. Uncertainty of Power Distribution

Comparison with others participants results

- Same shape
- but…. Values difference **X10**..
  - Convergence?
  - Multigroup calculations?
  - Anisotropy treatment?

$$Unc. = S M_{\sigma} S^{T}$$



- MC code
- Methodology: Sens GPT
- COVMatrix: SCALE 44

(Our results)

Minimum Uncertainty where the power is normalized to 1

- Deterministic code
- Methodology: Sens GPT
- COVMatrix: COMAC

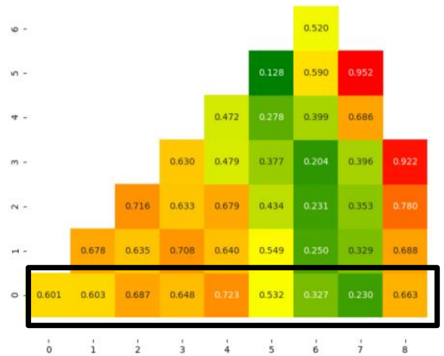
(Participant 1)

- MC Code multigroup
- Methodology: Total MC
- COVMatrix: SCALE 56

(Participant 2)

II.ii. Main contributions to the uncertainty of Power Distribution

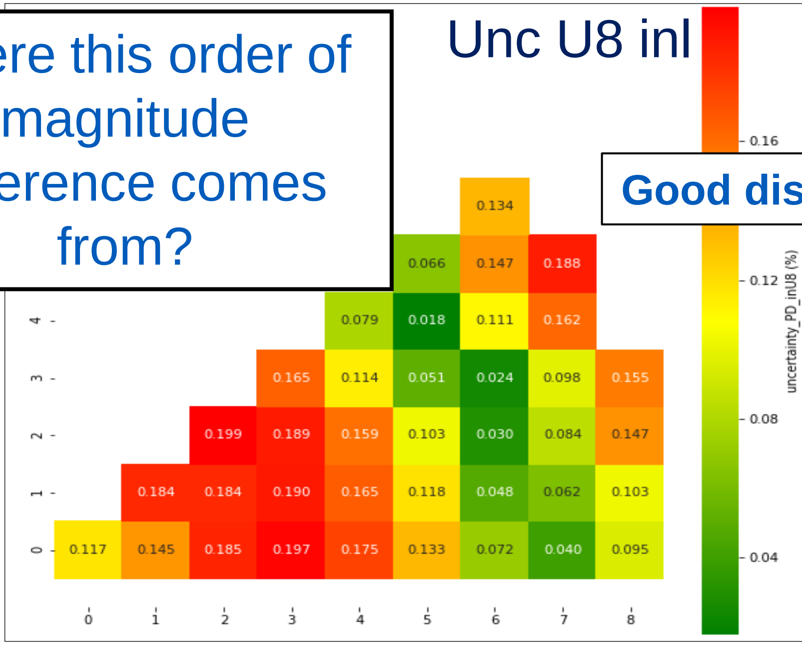
- **Importance of Diffusion reactions**
- The Ela O16 et Inl U8 are the **dominant uncertainties** according to the Participant_1



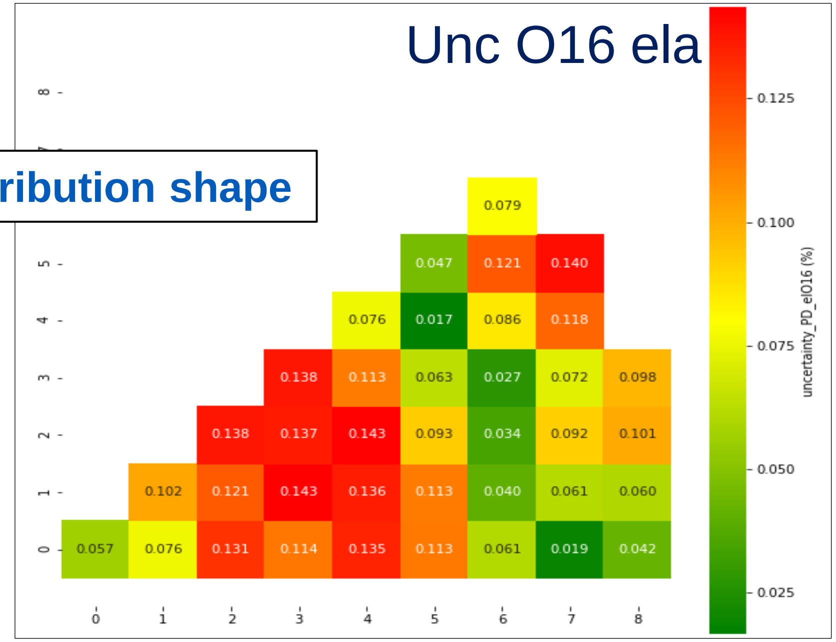
1	2	3	4	5	6	7	8	9	Max Power	Keff
Capt U8	Ela H1	Ela H1	Ela H1	Ela H1	Ela H1	Ela H1	Fis U8	Fis U8	Ela H1	Capt U8
Ela H1	Capt U8	Fis U8	Fis U8	Capt U8	Capt U8	Inl U8	Capt U8	Capt U8	Capt U8	Ela H1
Fis U8	Capt U5	Capt U5	Capt U8	Inl U8	Capt U5	Ela O16	Fis U5	Capt U5	Capt U5	Fis U5
Capt U5	Fis U5	Inl U8	Capt U5	Ela O16	Inl U8	Capt U5	Capt U5	Fis U8	Inl U8	Capt U5

II.Ii Sensitivity of Power Distribution

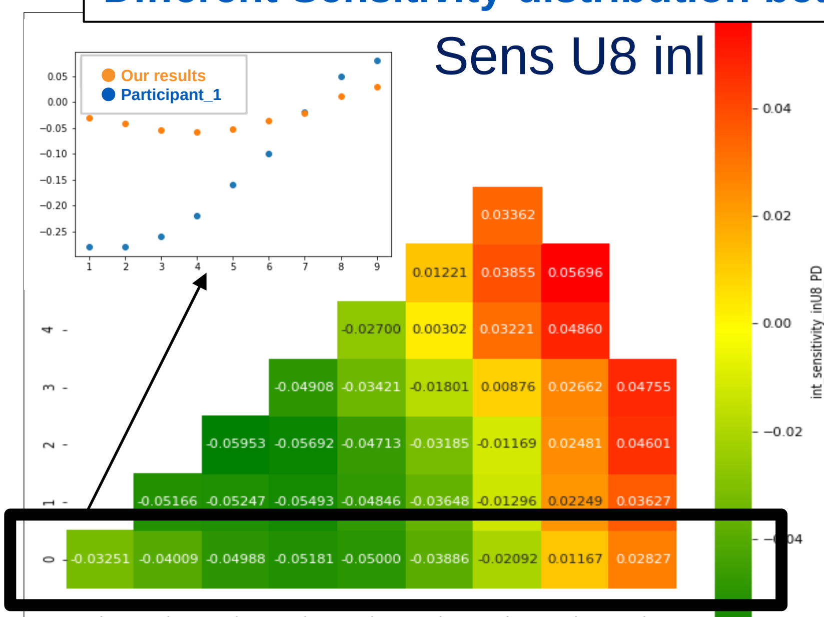
Where this order of magnitude difference comes from?

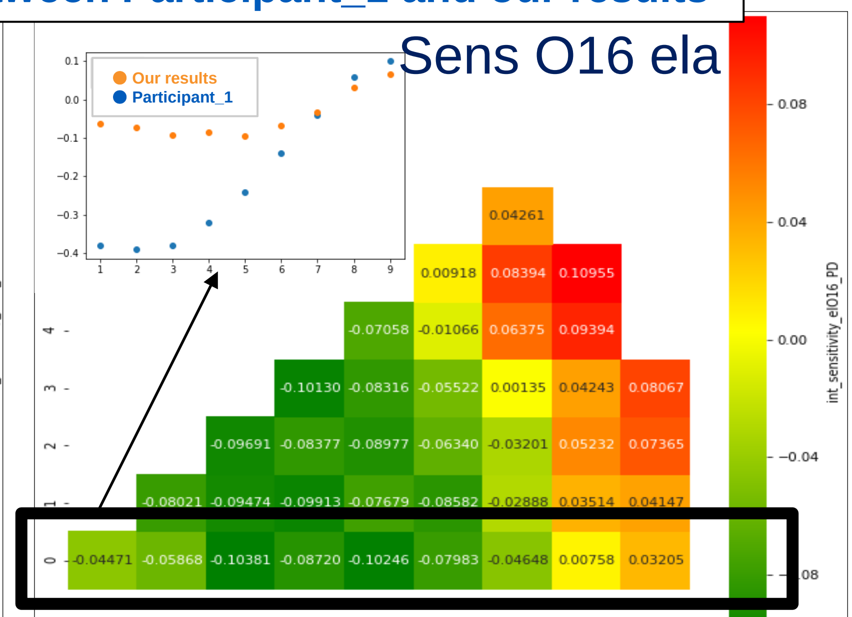


Good distribution shape

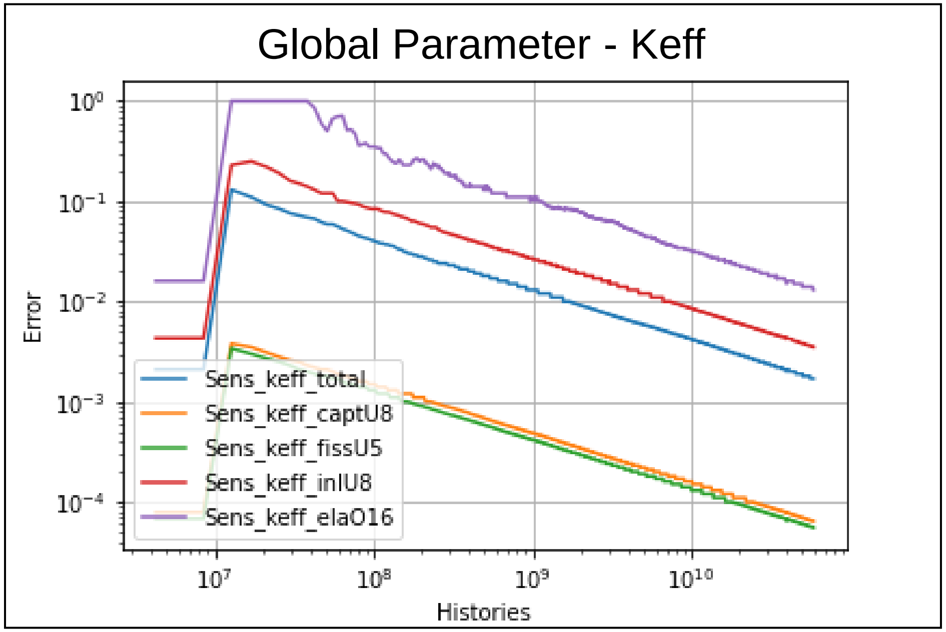


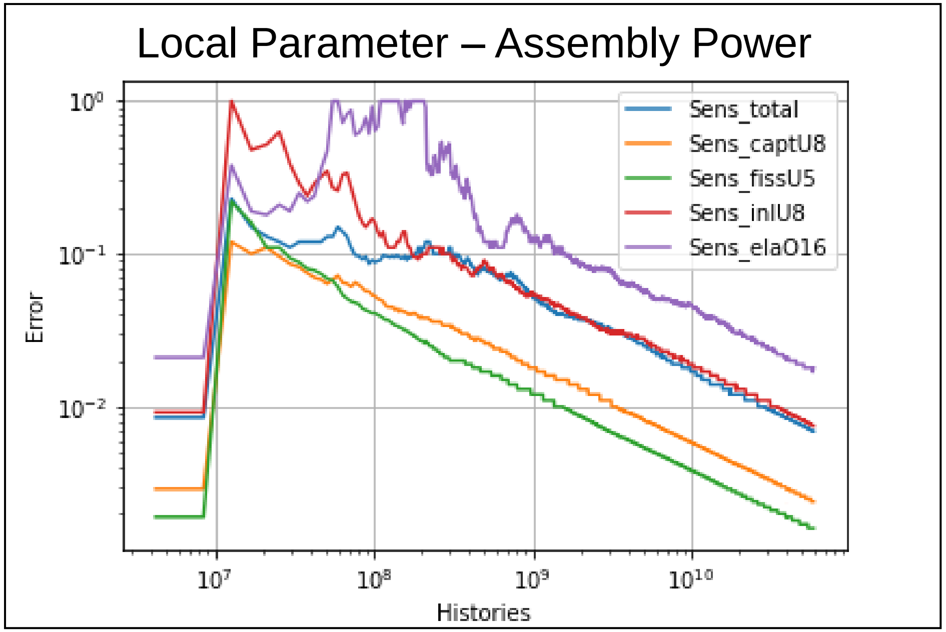
Different Sensitivity distribution between Participant_1 and our results





II.ii. Sensitivity Convergence - Keff and Power Distribution





→ Sensitivity convergence of diffusion reactions difficult for MC et Deterministic codes

- MC : Calculations 1 month → 15 - 20 days → 5 days → ? (OMP 48)
  - Already "analyzed/optimized" :
    - **set opti** <mode>
    - **set memfrac** FRAC
    - **BTCH :** batching interval
    - **sens opt latgen** NGEN
    - **set ifp** GEN
    - **set usym** UNI AX BC X0 Y0 θ0 θw [OPT]
  - Have to improve : MPI, save converged fission source, power modes convergence..
- Deterministic : Multigroup calculation (self-shielding), anisotropy treatment

III. Perspectives

- Understand the order of magnitude difference between our results and others participants
  - Suggestions?
- Improve Convergence
  - MPI
  - save converged fission source
  - Power modes convergence (Iterated Fission Matrix)
- Miltigroup XS → not implemented in SERPENT
  - Test MCNP multigroup XS for a pin 40000 pcm of difference for Keff
- Perform this calculations with EDF reference codes → Power Distribution Sensitivity capabilities not yet implemented
- Power Distribution Sensitivity due to Reflector “Composition” (% cooling water, H1 scattering..etc)

Thank you for your attention.
Questions? / Suggestions?