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Impact of the modelling (pin, assembly, core) for nuclide inventory: example of the MOX BM1 sample

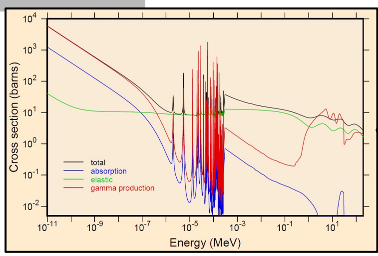
Consultant meeting, IAEA CRP "Spent Fuel Characterization", Virtual, June 29, 2021

Summary

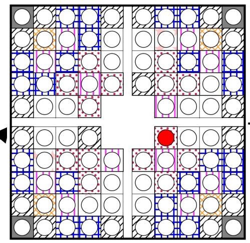
- Nuclide inventory, decay heat: why are biases and uncertainties important ?
- Our tools
- Examples of C/E for nuclide inventory
- Example with the ARIANE MOX BM1 sample

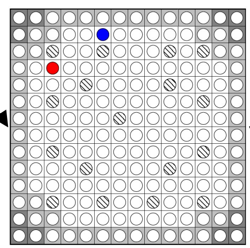
Spent Nuclear Fuel: Integrated approach

Nuclear data

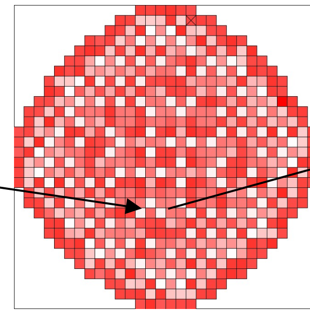


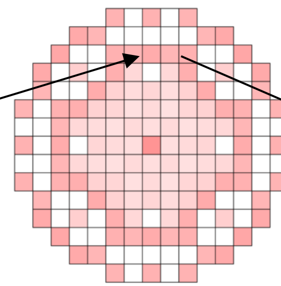
fuel characteristics



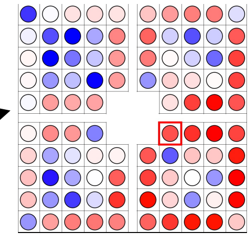


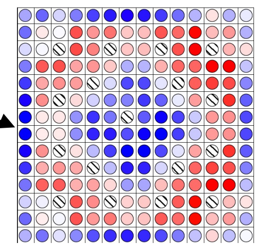
core simulation



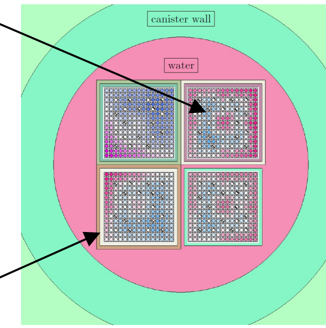


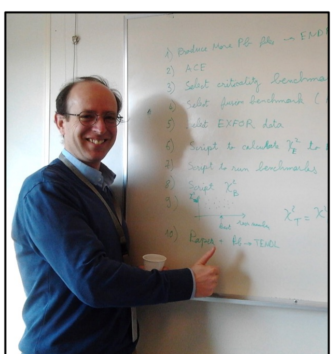
spent fuel

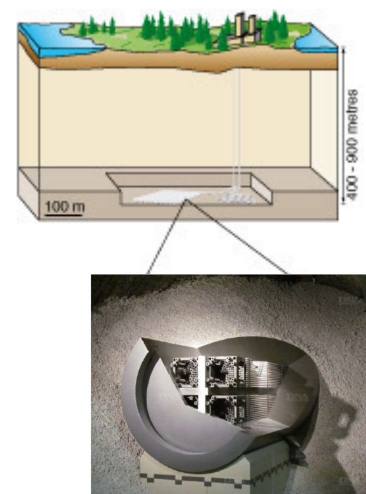




repository







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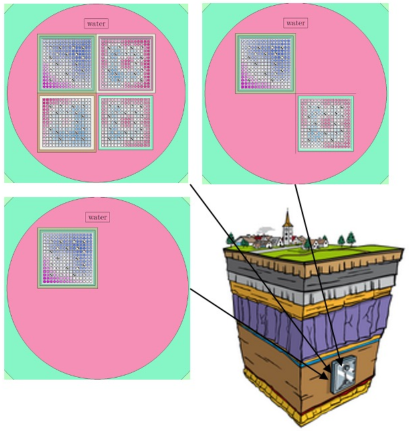
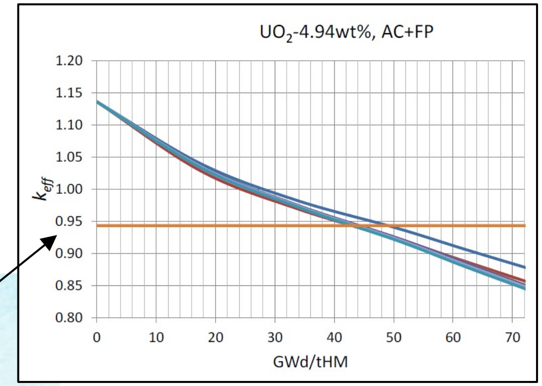
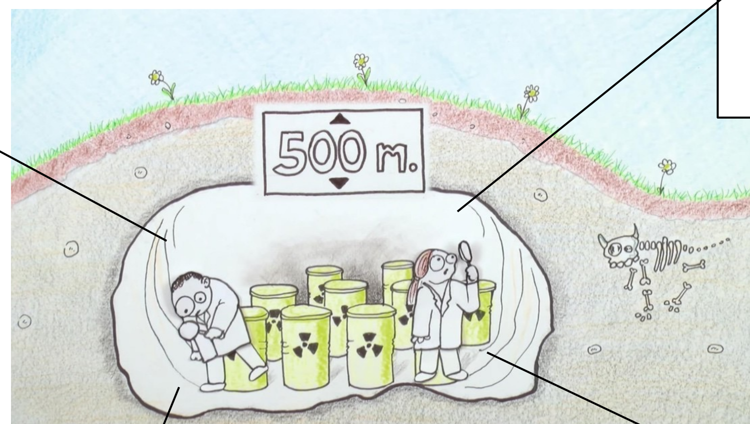
Better understanding for Spent Nuclear Fuel:

Optimization

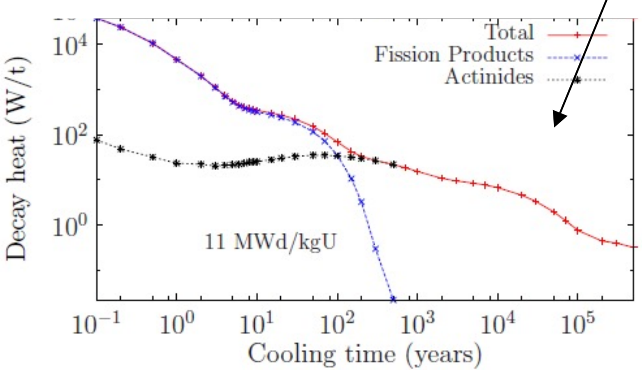


Criticality

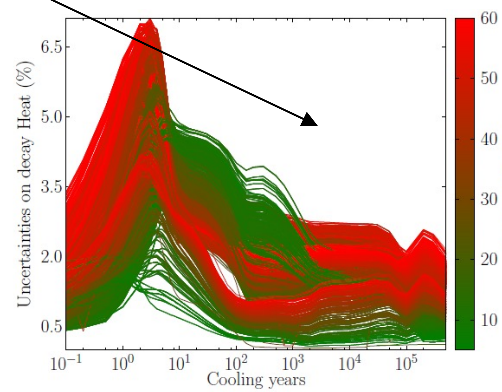




Decay heat

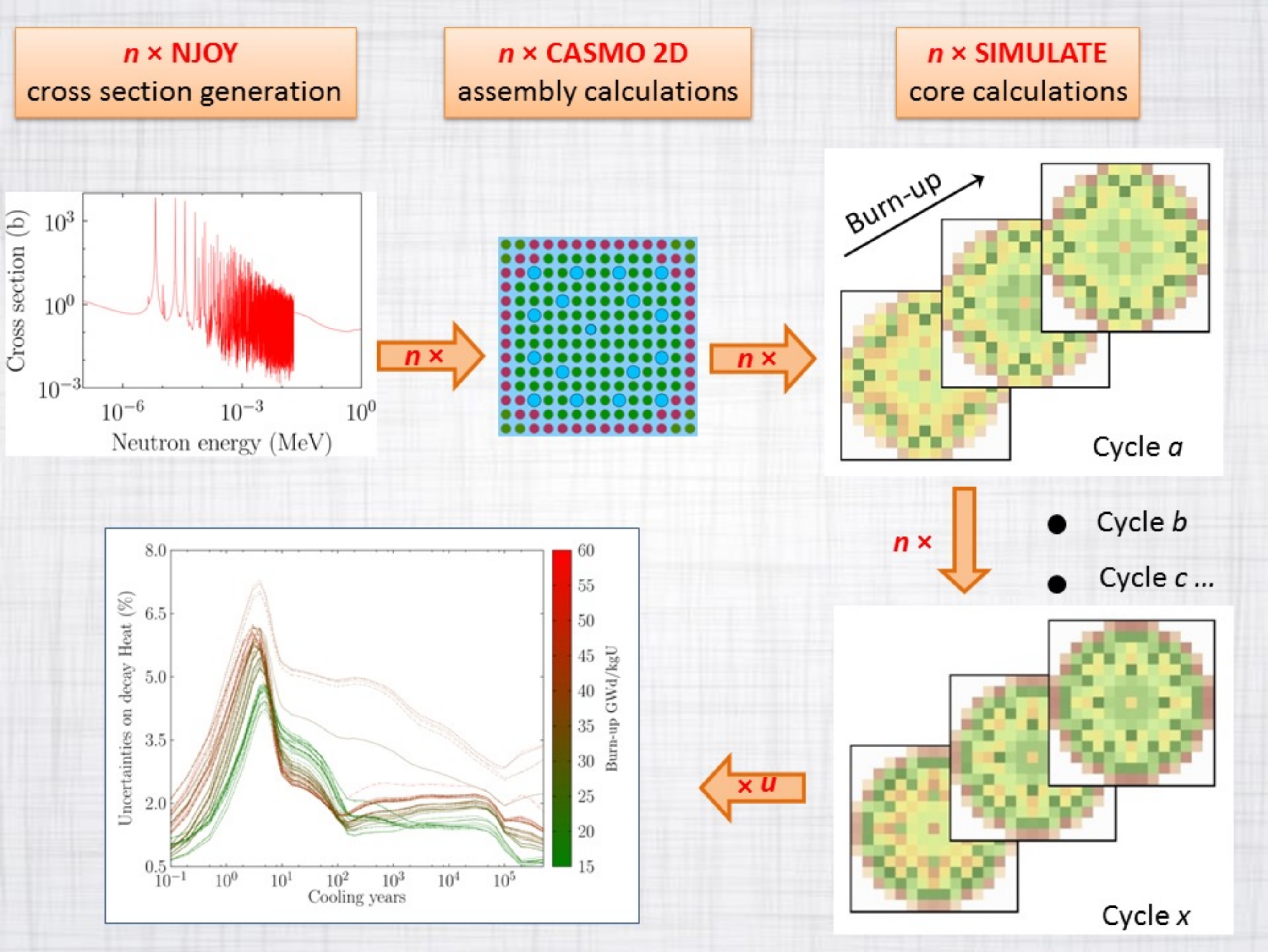


Uncertainties



Our tools: CASMO/SIMULATE/SNF + CMSYS

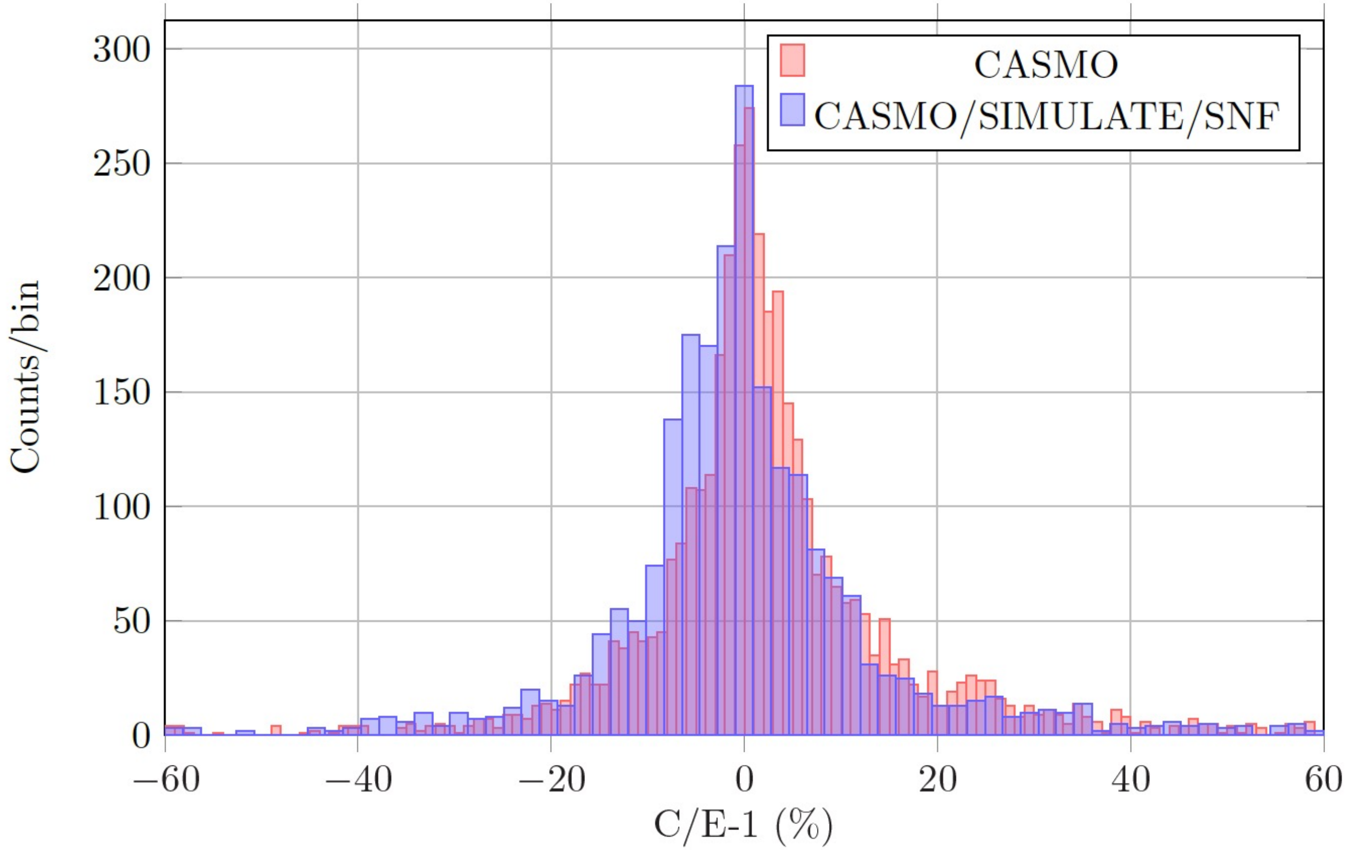
- CMSYS: Validated database for irradiation history of the 5 Swiss reactors (cycles, assemblies,…)



Validation for isotopic concentrations

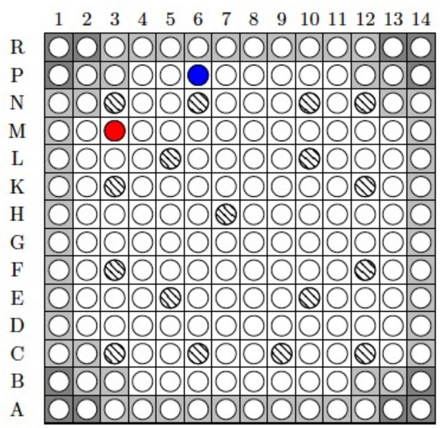
- Validating our tools is a mandatory step (C/E, biases, uncertainties)
- PIE nuclide inventory is a unique way to validate our CASMO

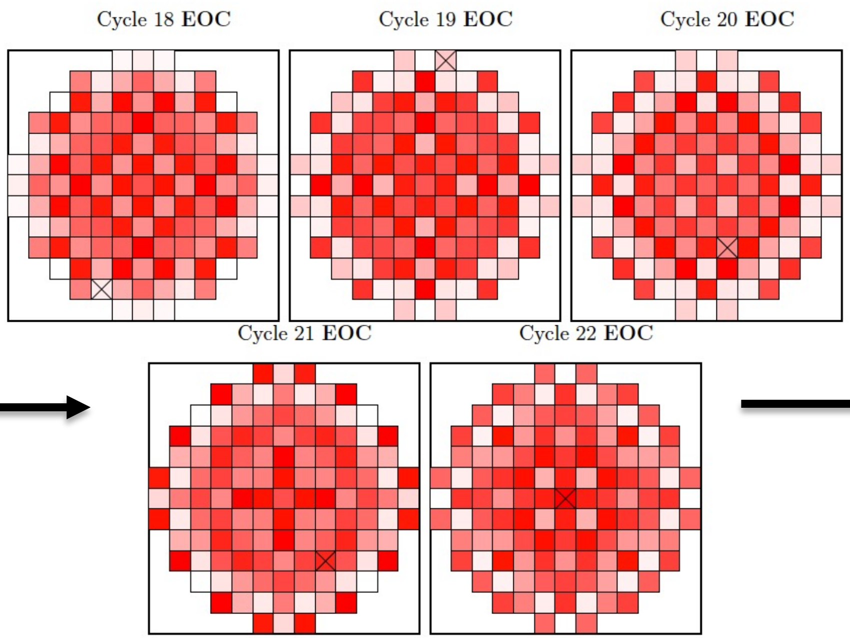
- Example with 27 samples based on CASMO/SIMULATE/SNF and CMSYS (ARIANE, PROTEUS. MALIBU): more than 2000 C/E values

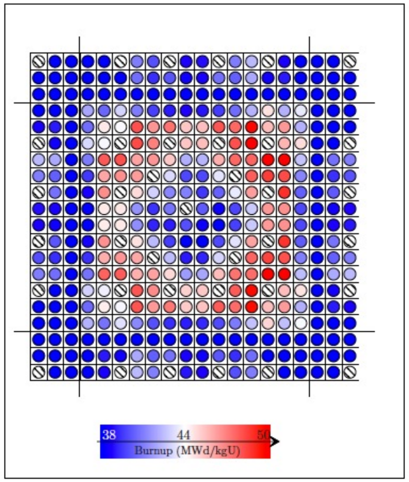


Example for BM1

- BM1 is a MOX sample from the ARIANE program
- Irradiated in Beznau, 47 MWd/kgU, 2.4% Pu



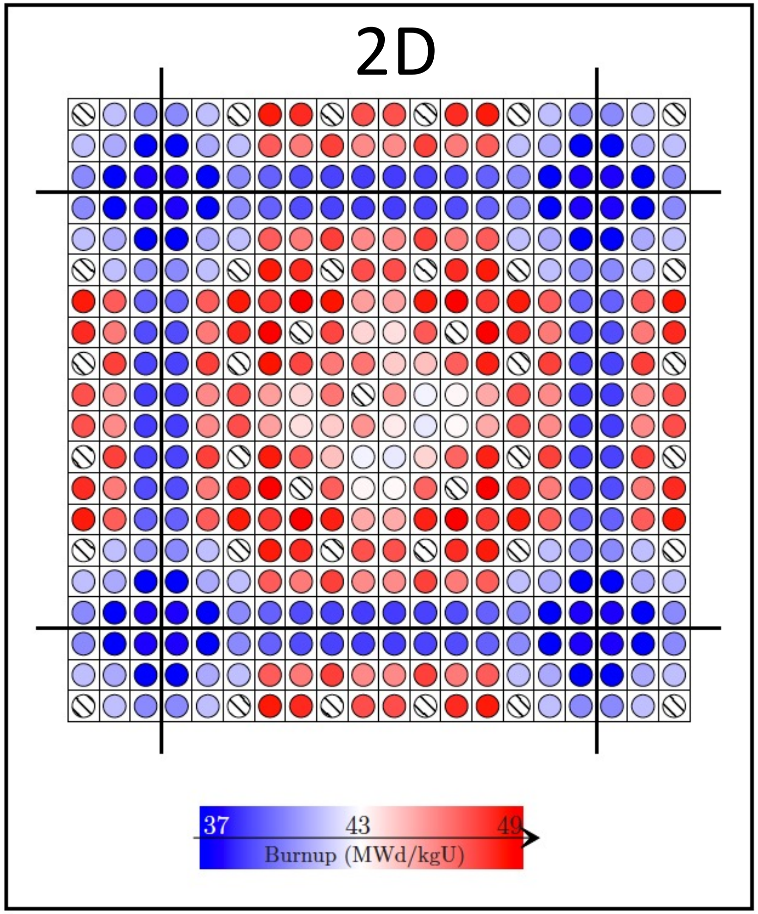


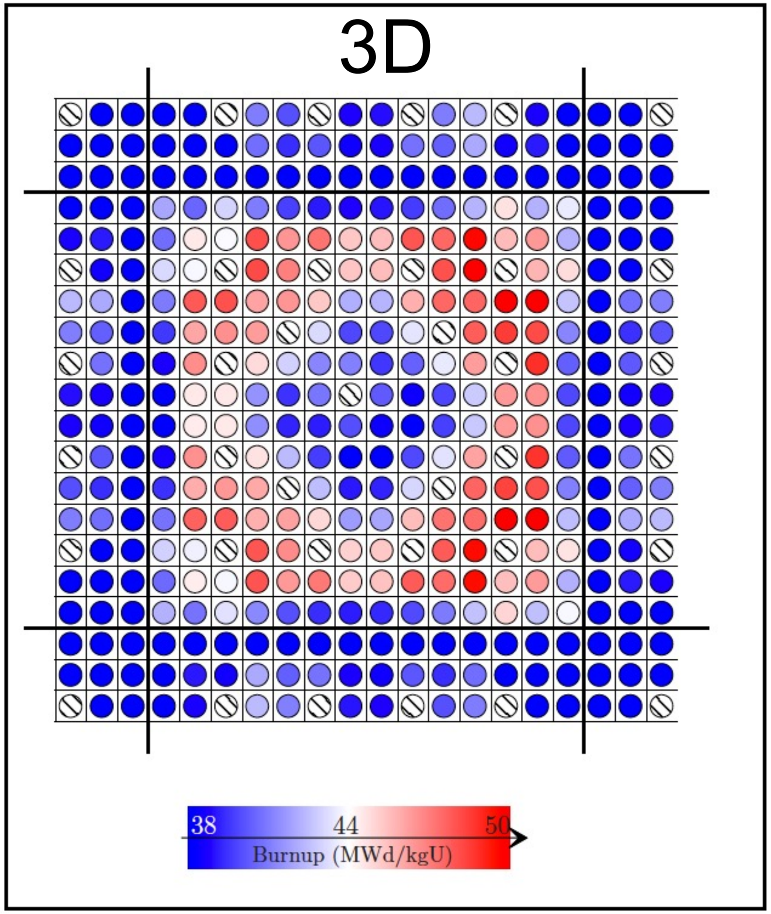


- Nuclide measured in PSI and SCK (BM1-P and BM1-S)
- 3 types of simulations: single pincell, 2D assembly, 3D full core

Example for BM1: burnup distribution

- 2D: reflective boundaries
- 3D: heterogeneous environment





Example for BM1: burnup distribution

- 2D: reflective boundaries
- 3D: heterogeneous environment

Comparison of calculated sample burnup values, following different methods. Values are provided in MWd/kgHM.

	BM1-P	BM1-S
2D pin	46.8	45.1
2D assembly, no adjustment	47.9	47.9
2D assembly, adjustment to BM1-P/-S	46.7	45.6
2D assembly, adjustment to BM3	48.0	48.0
3D core version (3D-1)	47.6	47.6
3D core version (3D-2)	47.7	47.7
3D core version (3D-3)	47.4	47.4
Average $\pm 1\sigma$	47.4 $\pm$ 1 %	47.0 $\pm$ 2.5 %
E(^{148}Nd) (mg/gU)	0.562 $\pm$ 5.0 %	0.548 $\pm$ 0.3 %

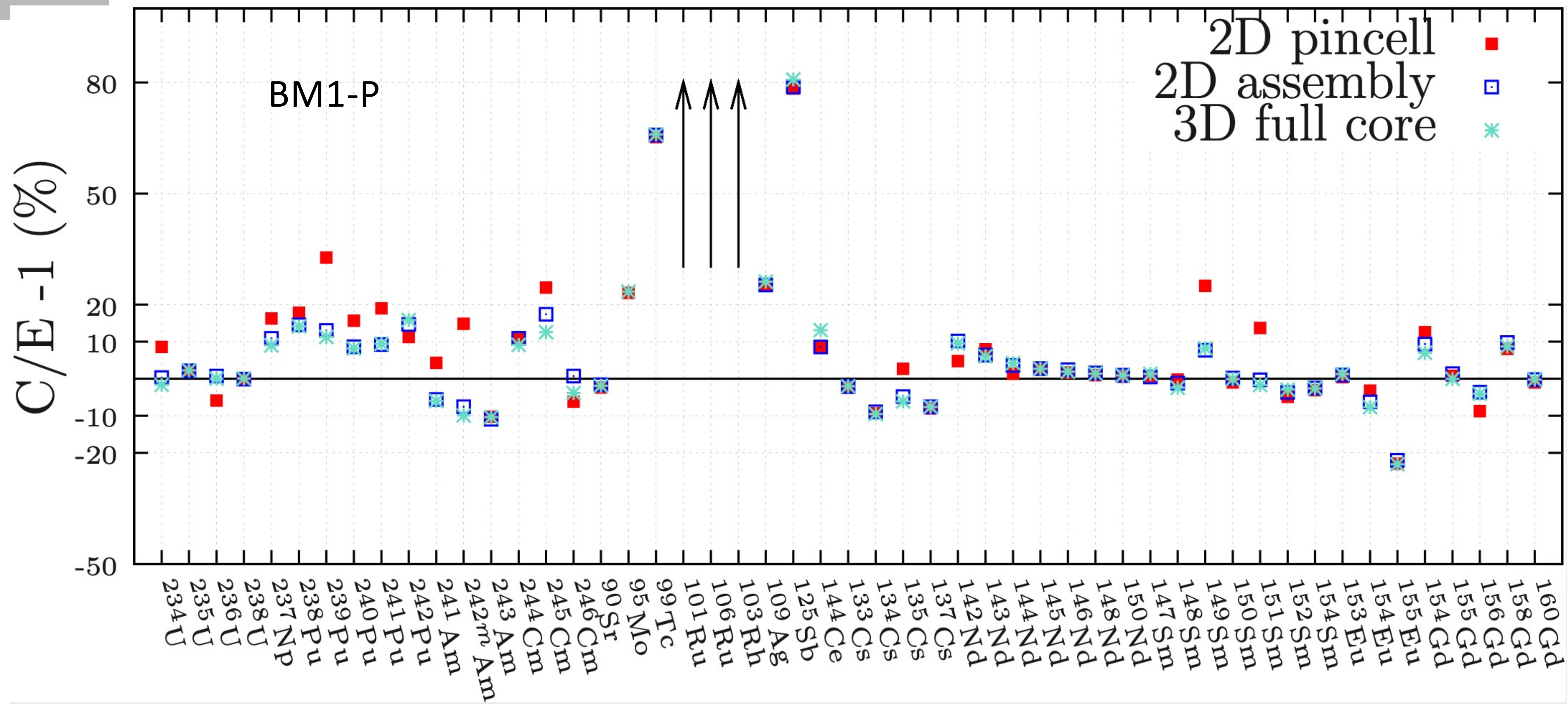
Example for BM1: Measurements

Measured concentrations for the BM1-P (from PSI) and BM1-S (from SCK-CEN) samples, with their experimental uncertainties for actinides in % (1σ). Differences are expressed relatively to the PSI values.

	BM1-P		BM1-S		Diff.
	mg/gU	± (%)	mg/gU	± (%)	(%)
^{239}Pu	13.7	1.3	14.7	0.3	-7.3
^{241}Pu	5.38	1.2	6.17	0.3	-15
^{244}Cm	0.570	1.3	0.662	0.9	-16
^{137}Cs	1.76	2.0	1.68	1.0	+4.5
^{148}Nd	0.562	5.0	0.548	0.3	+2.5

Example for BM1: C/E for nuclide inventory

- 2D: normalized to Nd-148
- 3D: no normalization



Example for BM1: Uncertainties from nuclear data

Uncertainties due to the ENDF/B-VIII.0 library with the three models (pin, assembly and core) for the BM1-P sample, based on the CASMO5 v2.03 calculations.

	Pin	Assembly	core
^{234}U	5.4	2.0	2.6
^{241}Pu	2.7	1.7	1.3
^{241}Am	3.2	1.9	1.9
^{148}Nd	0.5	0.5	1.1

Comparison between the impact of the nuclear data libraries for the BM1-P sample with the assembly model, based on the CASMO5 v2.03 calculations.

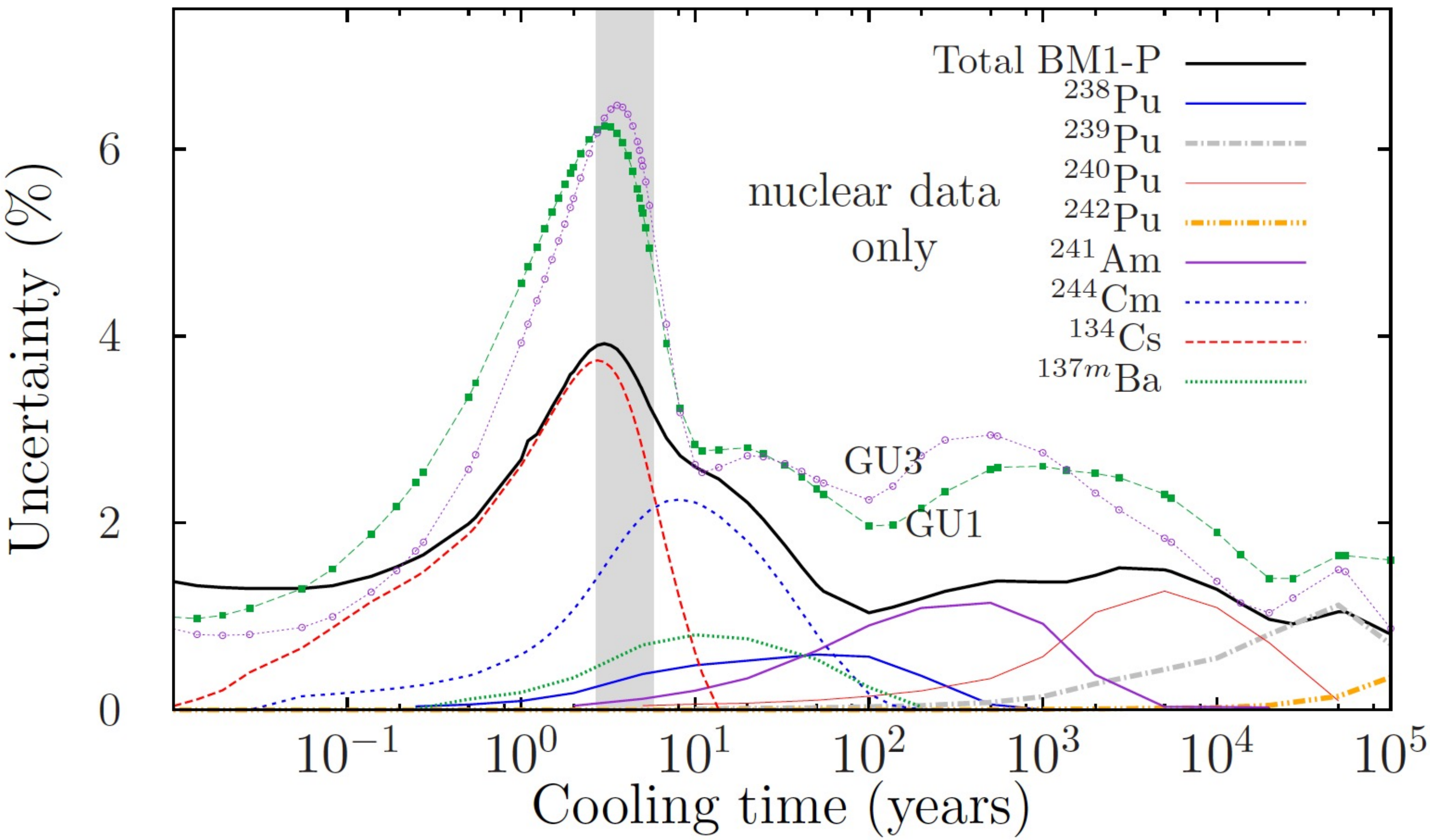
	ENDF/B-VIII.0	JEFF-3.3	JENDL-4.0
^{234}U	2.0	4.0	4.5
^{241}Pu	1.7	2.6	3.2
^{241}Am	1.9	2.4	3.6
^{148}Nd	0.5	0.8	0.5

Example for BM1: other uncertainties

Comparison of uncertainties from operating conditions and manufacturing tolerances between the assembly (2D) and full core (3D) models. Uncertainties are given in % (1σ).

	RADIUS		(X-Y)		PITCH	
	Assembly	core	Assembly	core	Assembly	core
^{239}Pu	0.5	0.5	1.3	0.5	1.3	2.0
^{242m}Am	0.6	0.4	1.3	0.5	1.9	2.2
^{244}Cm	0.4	1.2	0.8	0.5	1.5	1.5
^{134}Cs	0.4	1.0	1.0	0.4	1.1	1.6
^{137}Cs	0.3	0.6	0.7	0.3	0.5	1.1
^{148}Nd	0.3	0.7	0.7	0.3	0.6	1.1

Example for BM1: uncertainty for assembly decay heat



Additional uncertainties from operating conditions and manufacturing tolerances, as well as additional biases from nuclide inventory

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Conclusion

- 2D pincell modelling should be avoided
- 3D full core modelling has the advantage to avoid Nd148 normalization
- Nuclear data is still the major sources of uncertainties (nuclide and decay heat)

- Nuclide inventory varies for different modelling assumptions
- Uncertainties on nuclide inventory vary for different modelling assumptions
- Therefore biases for nuclide inventory depend on modelling assumptions
- Derived quantities (decay heat, criticality) follow similar variations

Wir schaffen Wissen – heute für morgen