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European Joint Programme on Radioactive Waste Management

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Estimation of decay heat from Spent Nuclear Fuel: a PSI example

Technical Meeting on Nuclear Heating Theory and Data, Hybrid, IAEA, Vienna, April 19-22, 2022

Summary

- Situation in Switzerland
- SNF decay heat characteristics
- Integrated simulation approach
- Best estimate code validation, biases and uncertainties for decay heat
- Direct/indirect decay heat validation
- International projects

EUropean Joint Programme on RADioactive Waste Management

EURAD

5-year implementation phase 1 – EURAD-1

This project receives funding from the Euratom research and training programme under grant agreement No 847593.

Current status and plans in Switzerland

- 4 running reactors, 1 shutdown

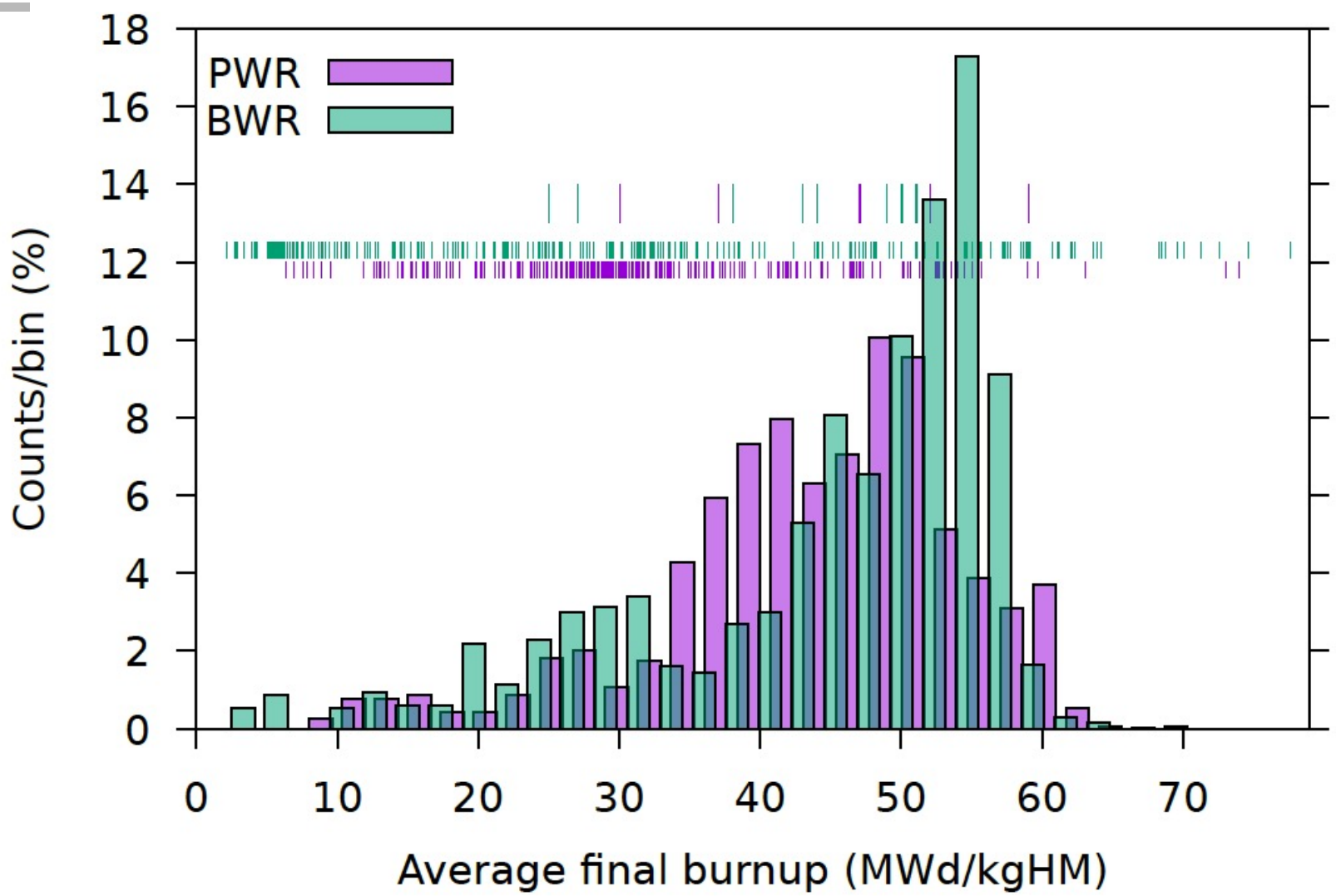
- Spent Fuel Assemblies (SFA) are currently stored wet onsite, before transferred to wet or dry storage at independent facilities (two dry, one wet)

- By 2050 (base scenario),
  - about 2200 tHM SFA projected (~12 000 SFA)
  - about 130 BWR casks and 100 PWR casks

- By 2065, the final repository facility (BEVA) starts operation,
  - transport of casks to BEVA,
  - Unloading/loading to canisters (4 PWR SFA and 9 BWR SFA per canisters),
  - Example for BWR : >900 canisters
  - Example for PWR: >900 canisters

Representative SNF characteristics (≠ countries)

- SNF characteristics: burnup, enrichment, cooling



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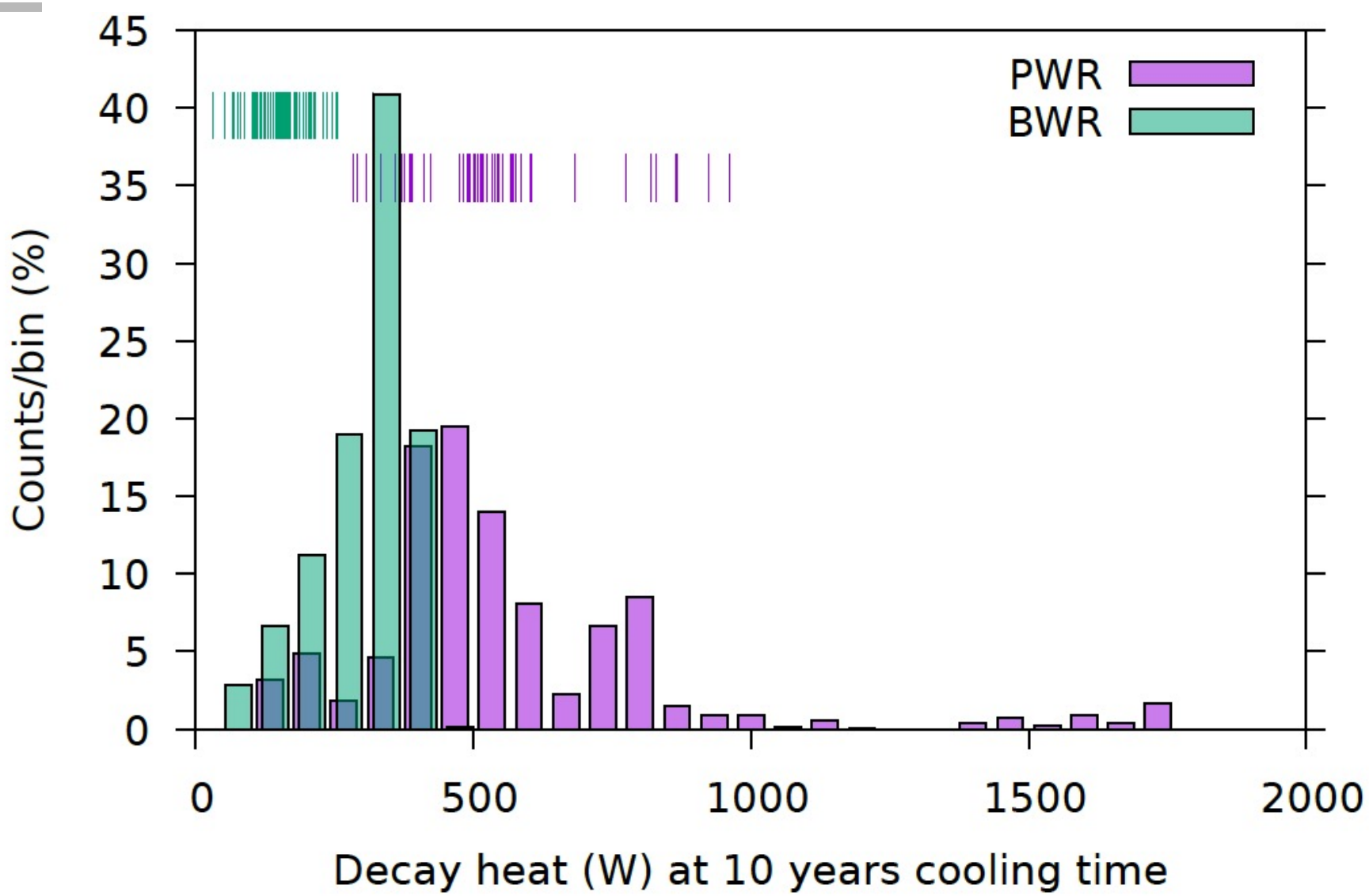
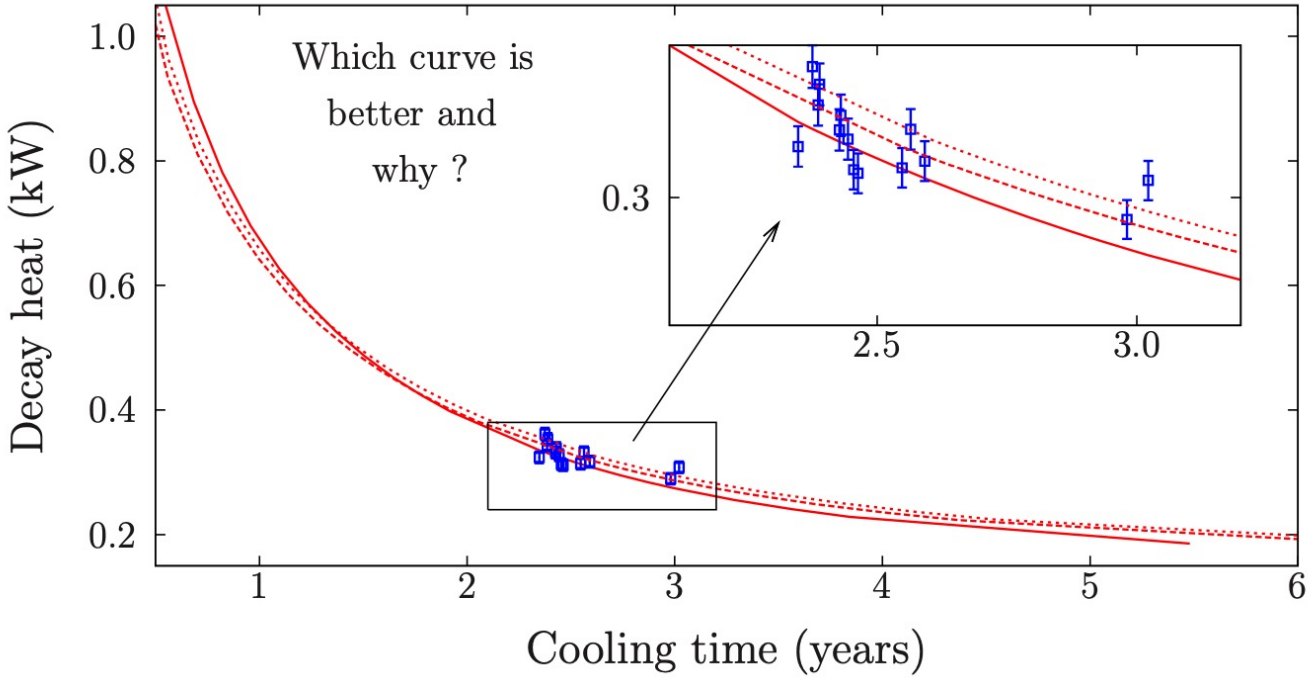
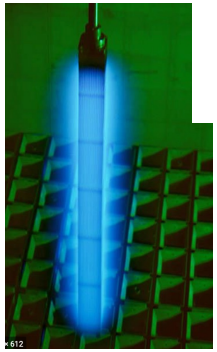
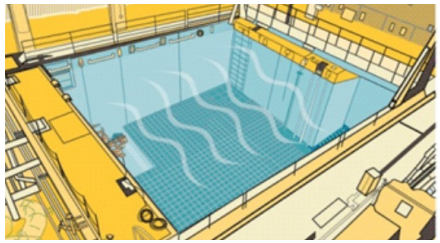


Which decay heat ?



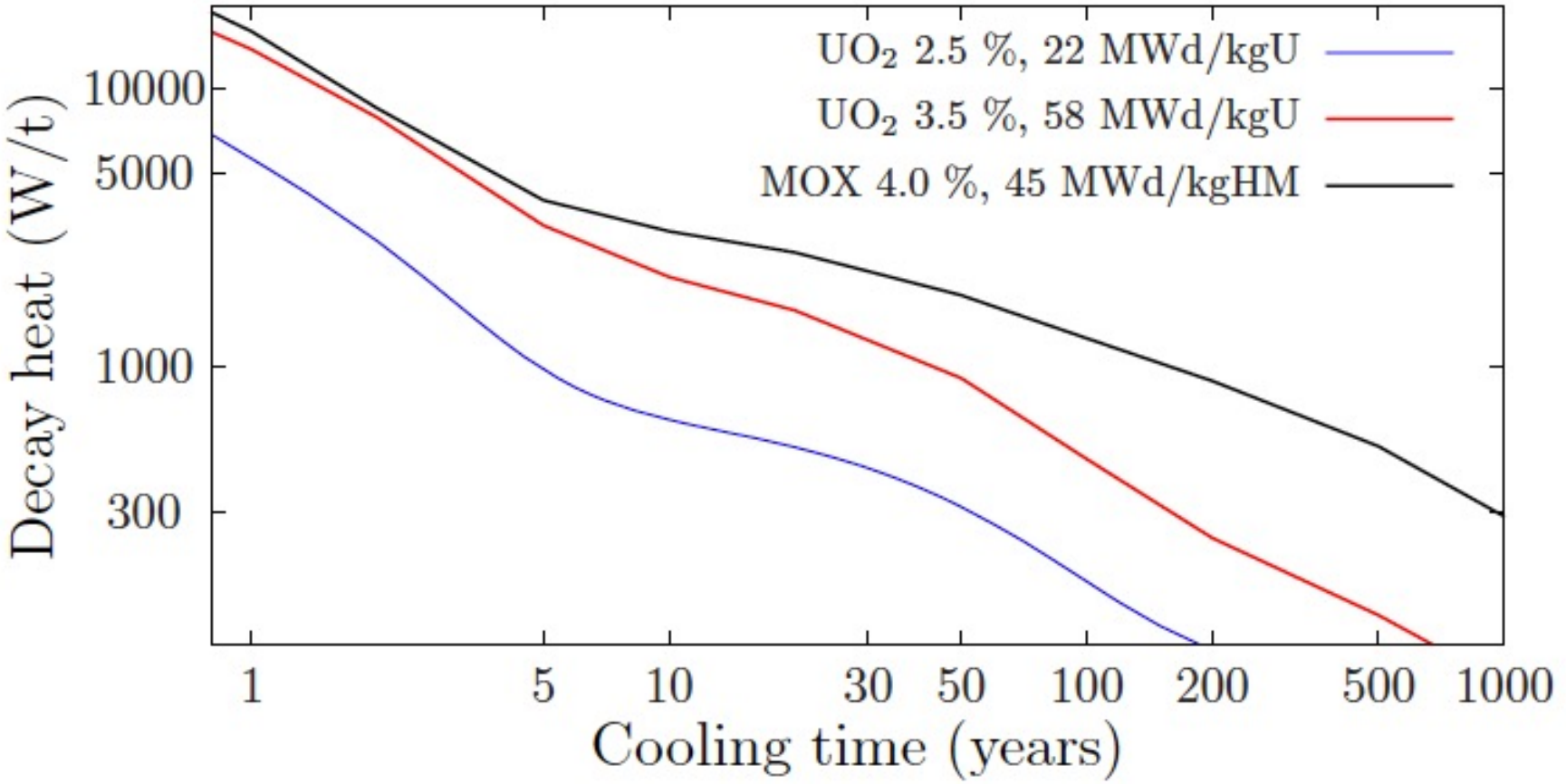




- Measured or calculated ?
- Best decay heat ?
- Bias & uncertainty ?

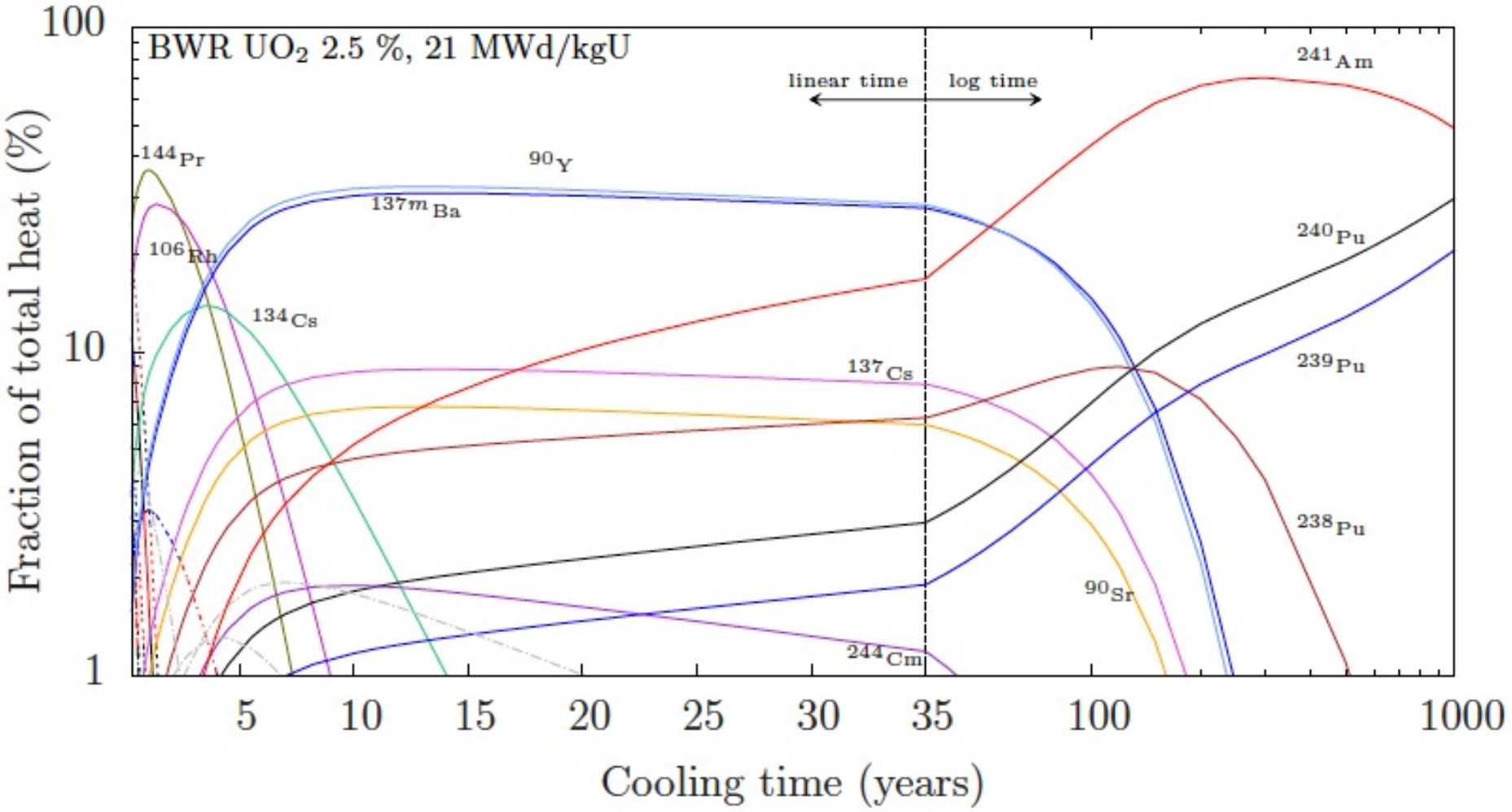
Representative SNF characteristics

- SNF characteristics: decay heat



Representative SNF characteristics

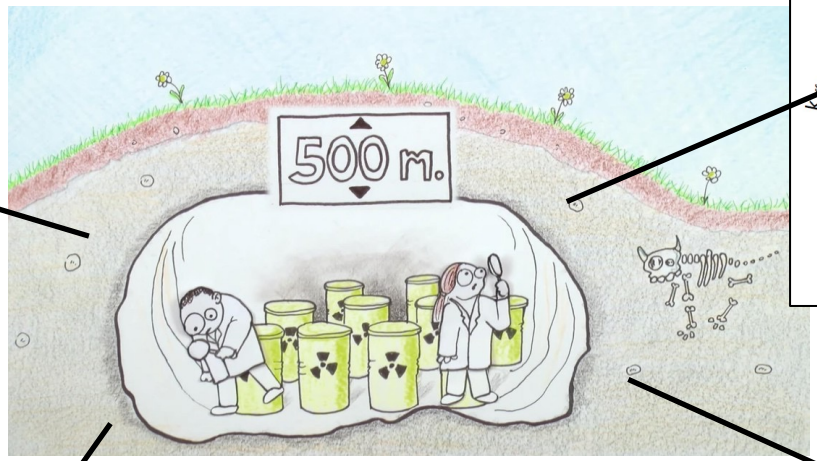
- SNF characteristics: decay heat fraction (same isotopes for ≠ SNF !)

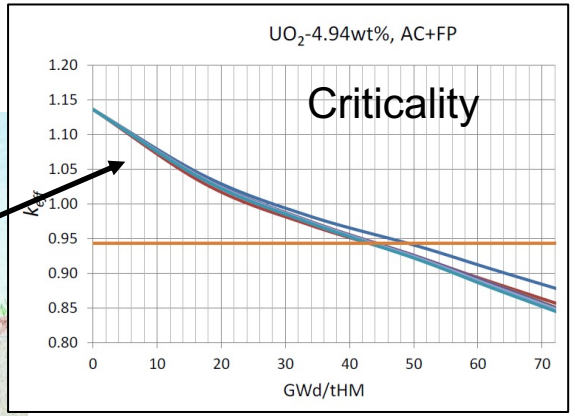


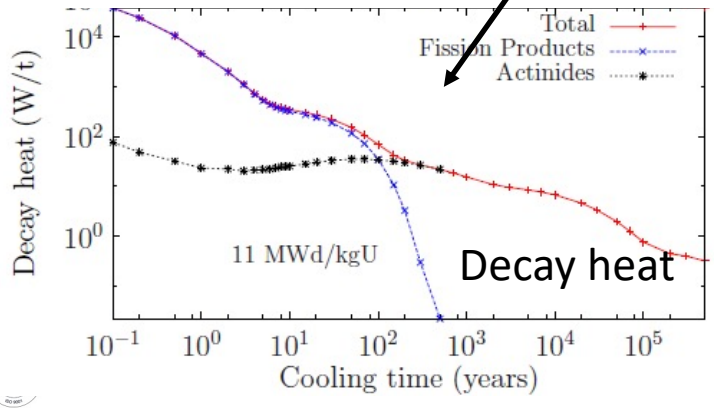
Acceptance Criteria for loading optimization

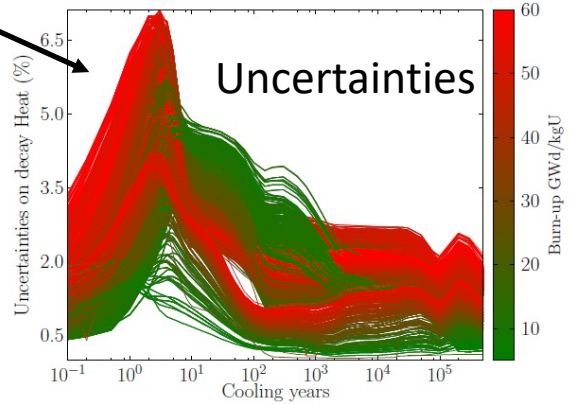
- Decay heat: limit per canister
- Criticality: k_{eff} for each canister must be below a limit
- Dose rate: for cask/canister transport, handling and monitoring

Dose









Why optimizing ?

- Considering current and future cask loading,
  - it helps to minimize SFA in pool
  - It helps to minimize plant operation costs after final shutdown

- In total, about 1800-1900 canisters needed at minimum (more realistically 2200). Given a price of 1 M$/canister, minimization is important.

- It helps to design the BEVA capabilities (stations, storage, volume) and adjust ist cost.

- Existing tools:
  - CASKLOAD (Studsvik)
  - SIMAN (NAGRA)
  - PSI developments

Spent Nuclear Fuel: Integrated approach

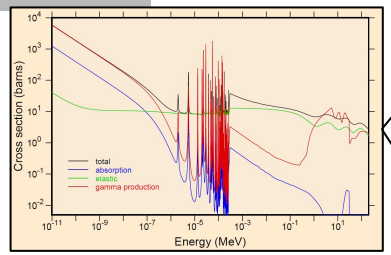
Nuclear data

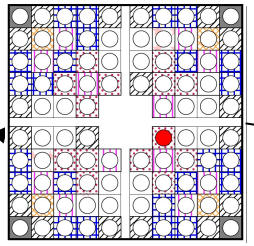
fuel characteristics

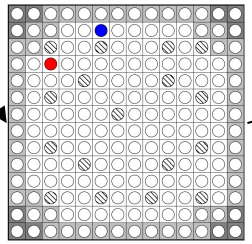
core simulation

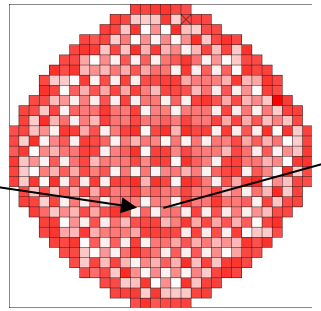
spent fuel

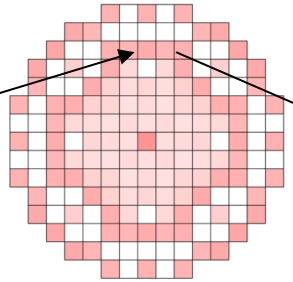
repository

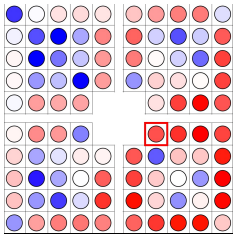


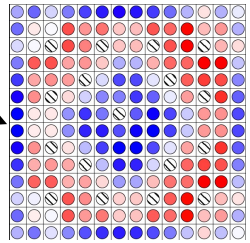


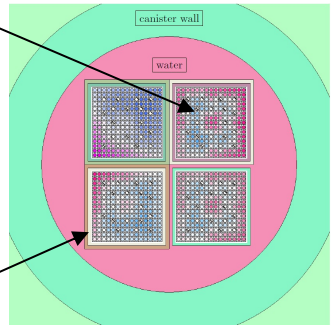


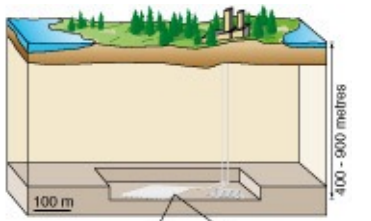






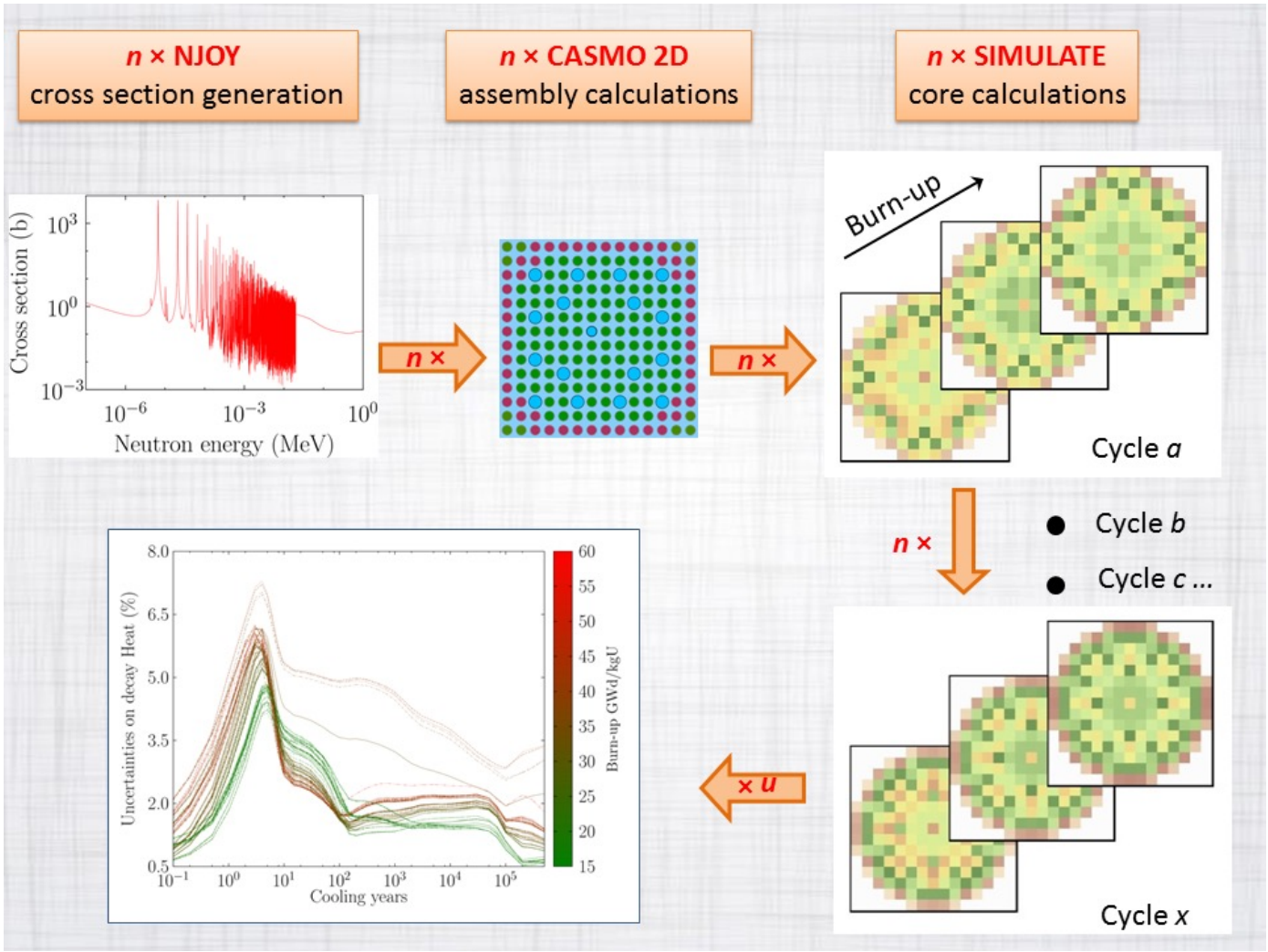




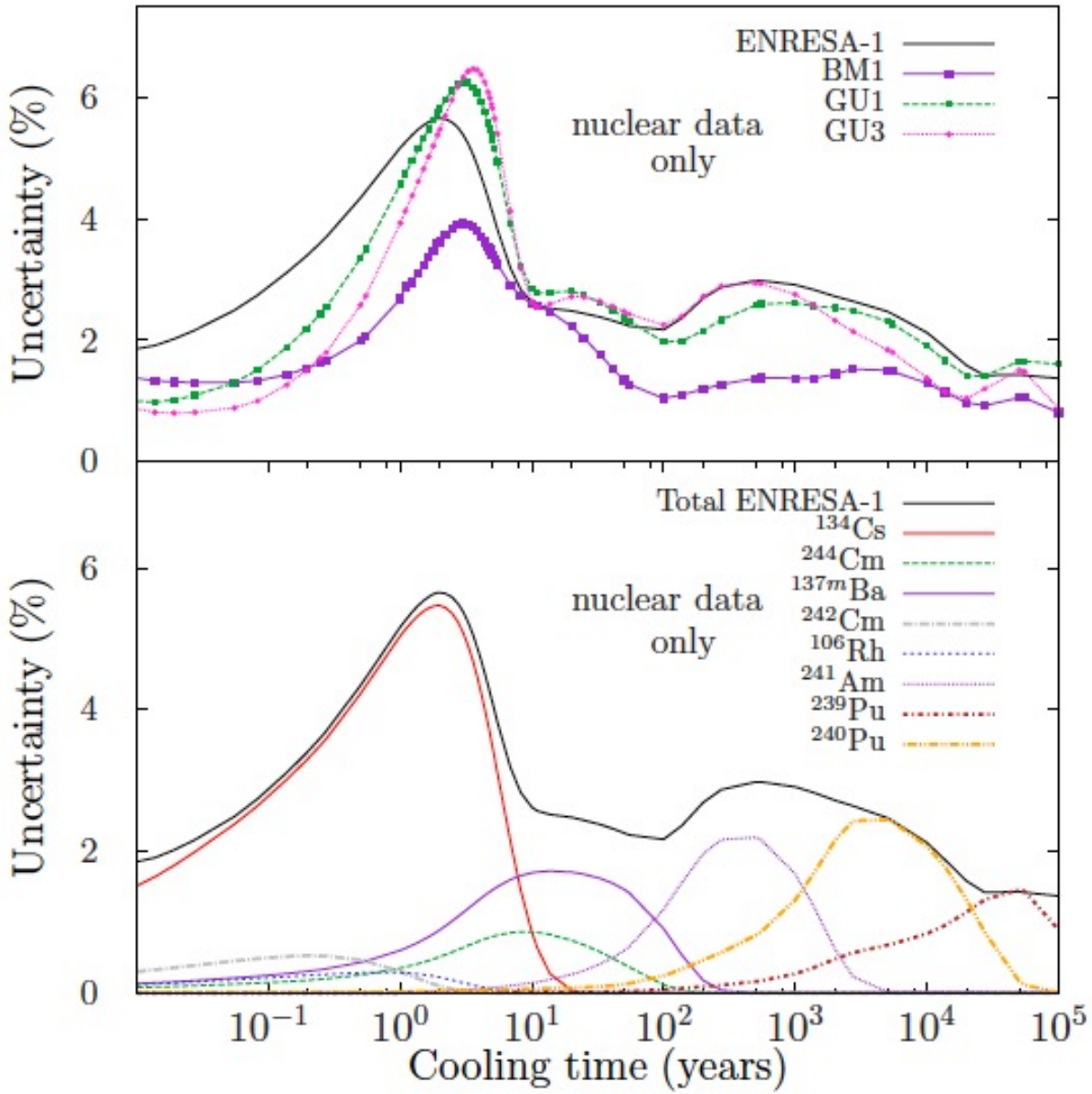


Our tools: CASMO/SIMULATE/SNF + CMSYS

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

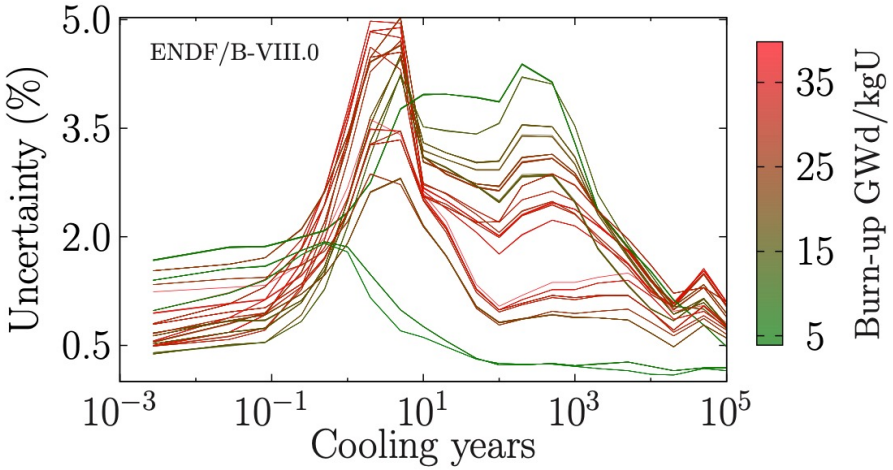


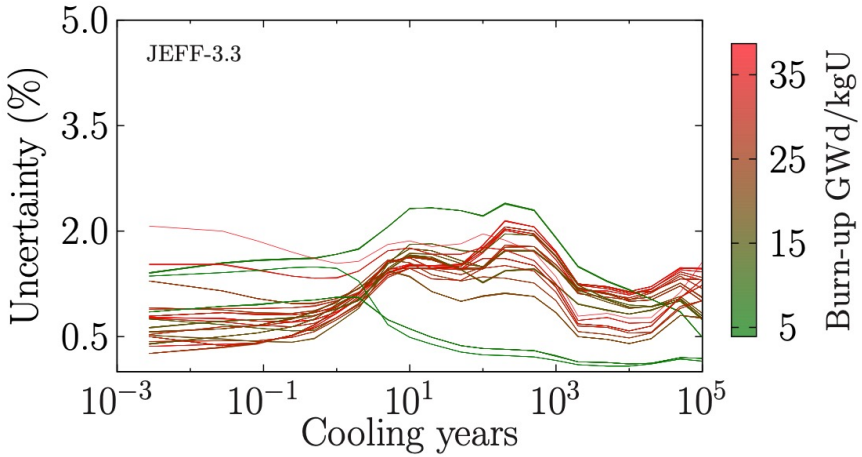
Example for uncertainty: assembly decay heat

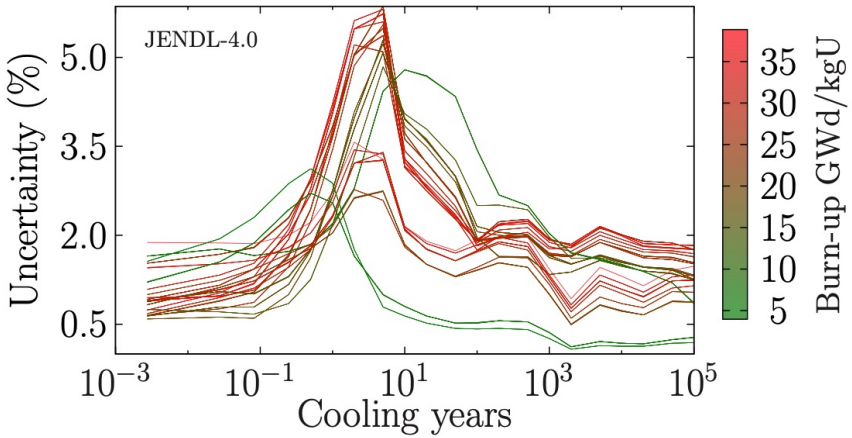


Decay heat uncertainties from different libraries

- 121 SNF at end of the 7th cycle







Indirect decay heat validation: nuclide concentrations

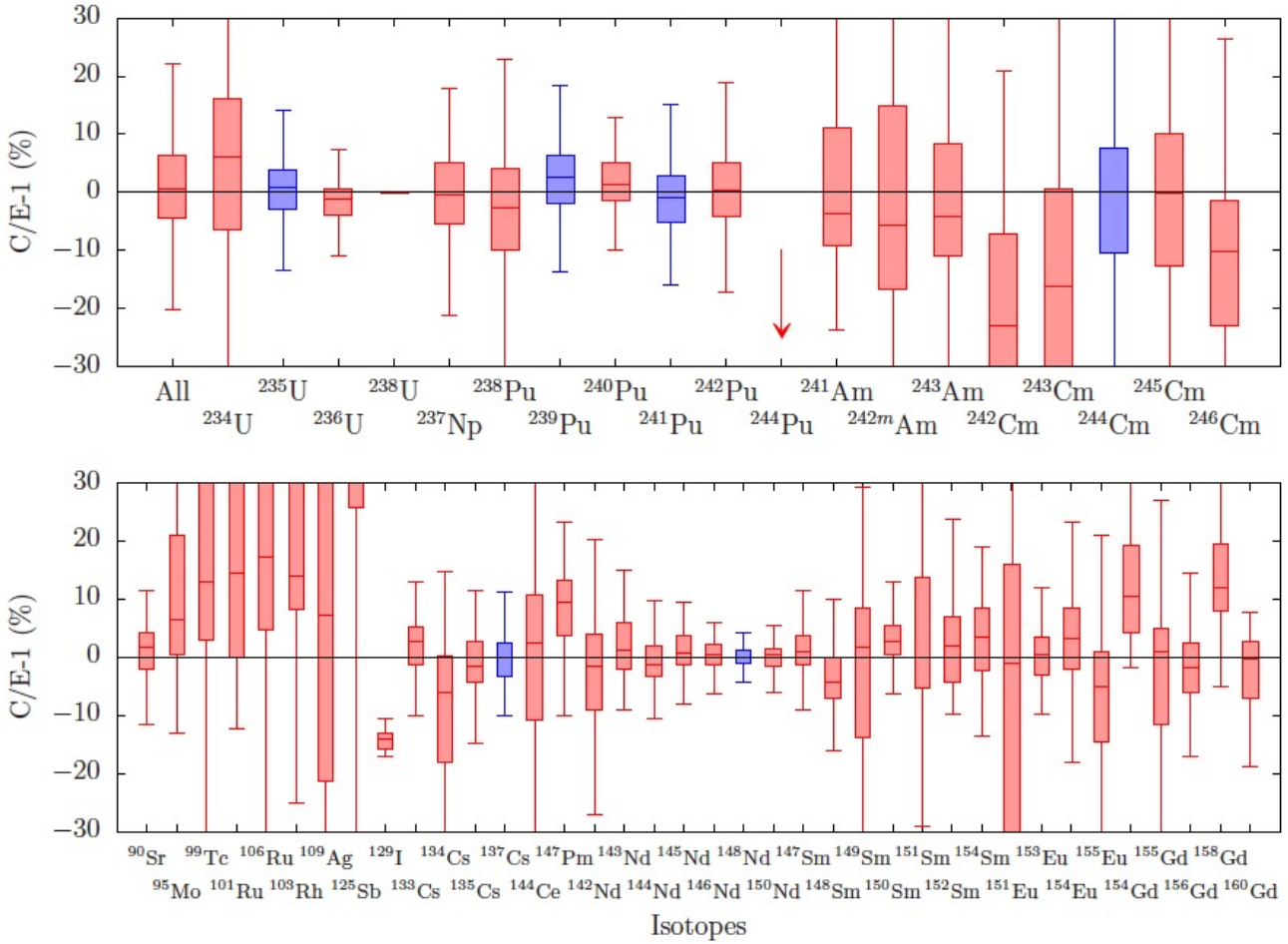


Fig. 4. Interquartile ranges for the $C/E-1$ isotopic concentrations, considering a total of more than 12 000 measured concentrations. The blue color is given to important isotopes. See Tables 3 and 4 for numerical values.

Indirect decay heat validation: nuclide concentrations

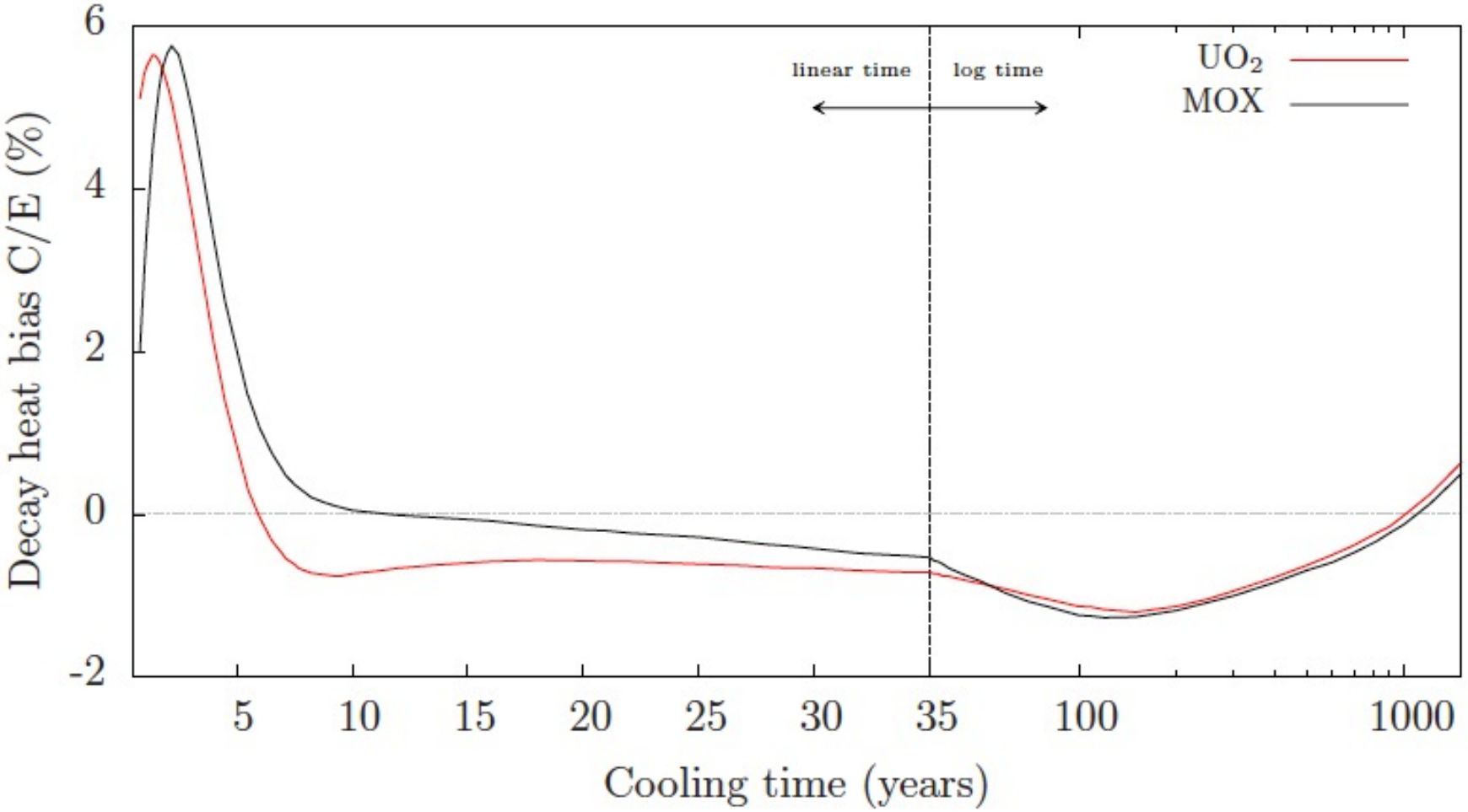
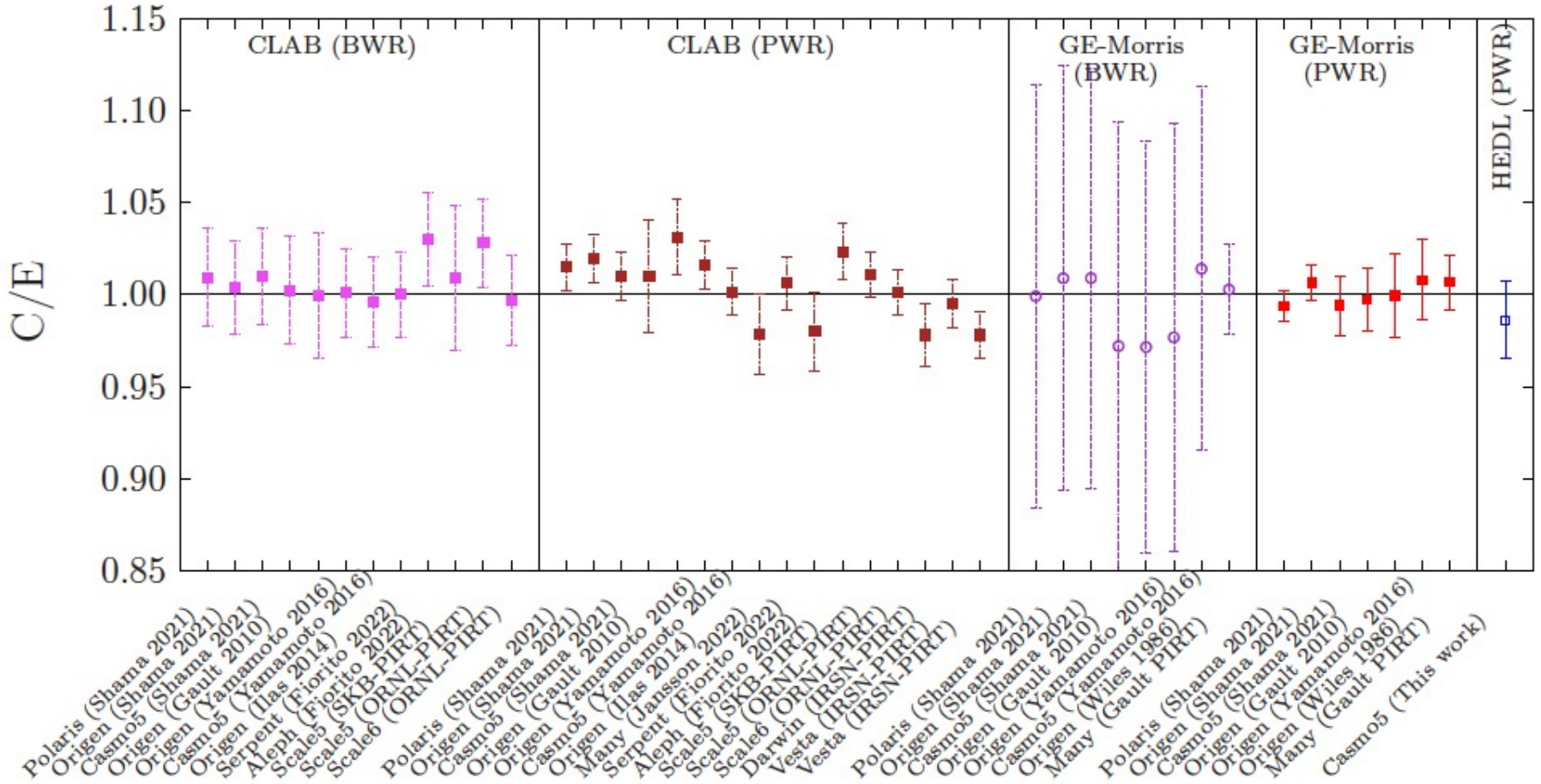


Fig. 9. Decay heat biases obtained from the mean biases on nuclide inventory.

Direct decay heat validation



International projects

- European Joint Programme on Radioactive Waste Management (EURAD) WP8 on “Spent Fuel Characterization”
- Coordinated Research Project (CRP) on SFC was established by the International Atomic Energy Agency (IAEA)
- Electric Power Research Institute (EPRI): dedicated study on the state of the art regarding the estimation of SNF decay heat
- Working Party on Nuclear Criticality Safety (WPNCS) of isotopic compositions from SNF within the SFCOMPO database and its technical review group of the Nuclear Energy Agency (NEA)
- WPNCS Subgroup 10 (SG10), on “Nuclear Data Uncertainties Quantification on Spent Fuel Inventory”
- WPNCS Subgroup 12 (SG12), dedicated to “Spent nuclear fuel decay heat: assessing the confidence level in experimental and computational estimations (SNF-DH)”

Conclusion

- Decay heat is one of the most important quantities for SNF
- Code validation is a requirement (best estimate, bias and uncertainty)
- Canister filling optimization is natural

- Direct measurements are scarce (and correlated): need for new (independent) measurements
- Existing open-source database do not cover all realistic SNF characteristics, such as decay heat
- Calculated decay heat is rarely known better than a few %

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