Uncertainty quantification of actinoid and fission product number densities after fuel depletion using the JENDL-5 covariance data

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Numerical tools and methods

- Nuclear data-induced uncertainties of nuclide number densities after nuclear fuel depletion were quantified using the multi-group sensitivities and covariances.

- These sensitivities were calculated using the depletion perturbation theory capability of the reactor physics code system CBZ.

- Multi-group covariance data were generated by NJOY2016/ERRORR.

Uncertainty in actinoid number density after fuel depletion

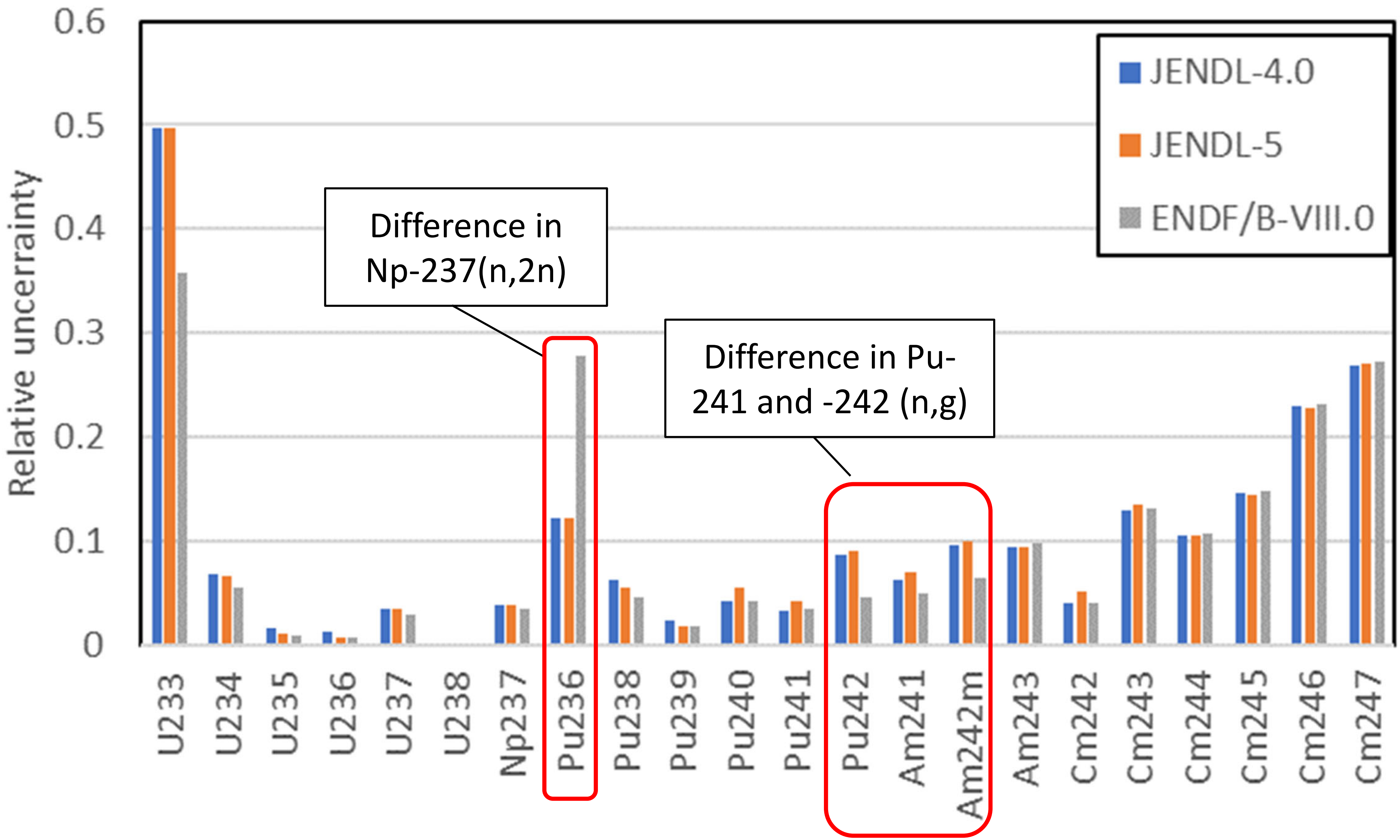
- A typical PWR UO2 fuel cell model with the U-235 enrichment of 4.1wt% was concerned.

- Sensitivities of actinoid number densities at 45 GWD/t without any cooling period with respect only to reaction cross sections were calculated.

- Using the covariance data of the reaction cross sections in JENDL-4.0, -5, and ENDF/B-VIII.0, nuclear data-induced uncertainties were quantified.

- Uncertainties of other important nuclear data such as decay and reaction branching ratios were not considered.

Uncertainty in actinoid number density after fuel depletion



Three results are similar with each other with several exceptions.

Uncertainty in FP number density after fuel depletion

- The same PWR UO2 fuel cell model with the U-235 enrichment of 4.1wt% was concerned.

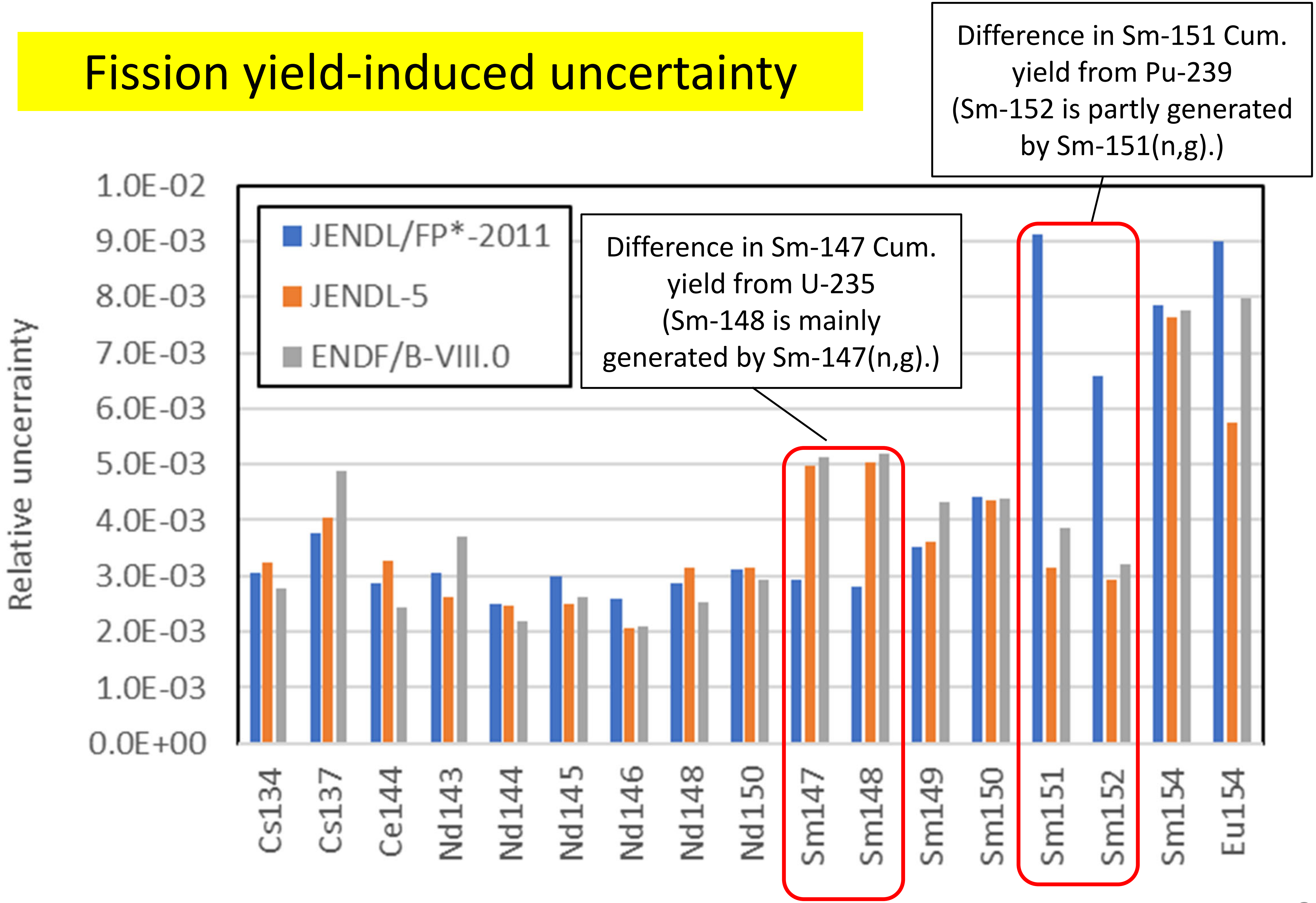
- Sensitivities of FP number densities at 45 GWD/t without any cooling period with respect to fission yields, decay half-life, and decay branching ratio were calculated.

- Using the covariance data of these quantities in JENDL/FPY-2011+JENDL/FPD-2011, JENDL-5, and ENDF/B-VIII.0, nuclear data-induced uncertainties were quantified.

- The covariance matrix of the fission yields was constructed assuming the correlation among the nuclides belonging to the same mass chain. This treatment gives similar results to those by more sophisticated methods such as GLLS with the physical constraints.

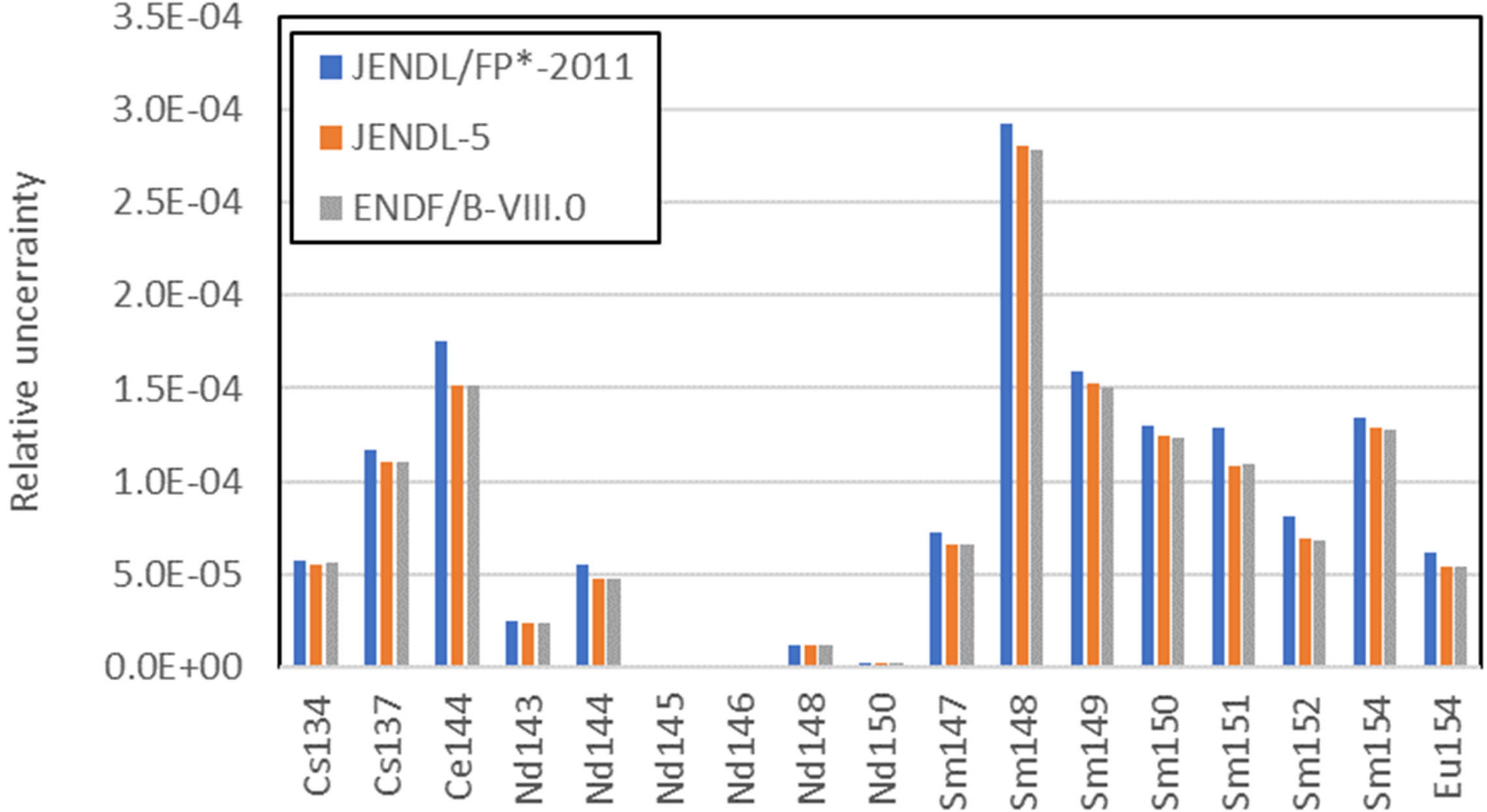
Uncertainty in FP number density after fuel depletion

Fission yield-induced uncertainty



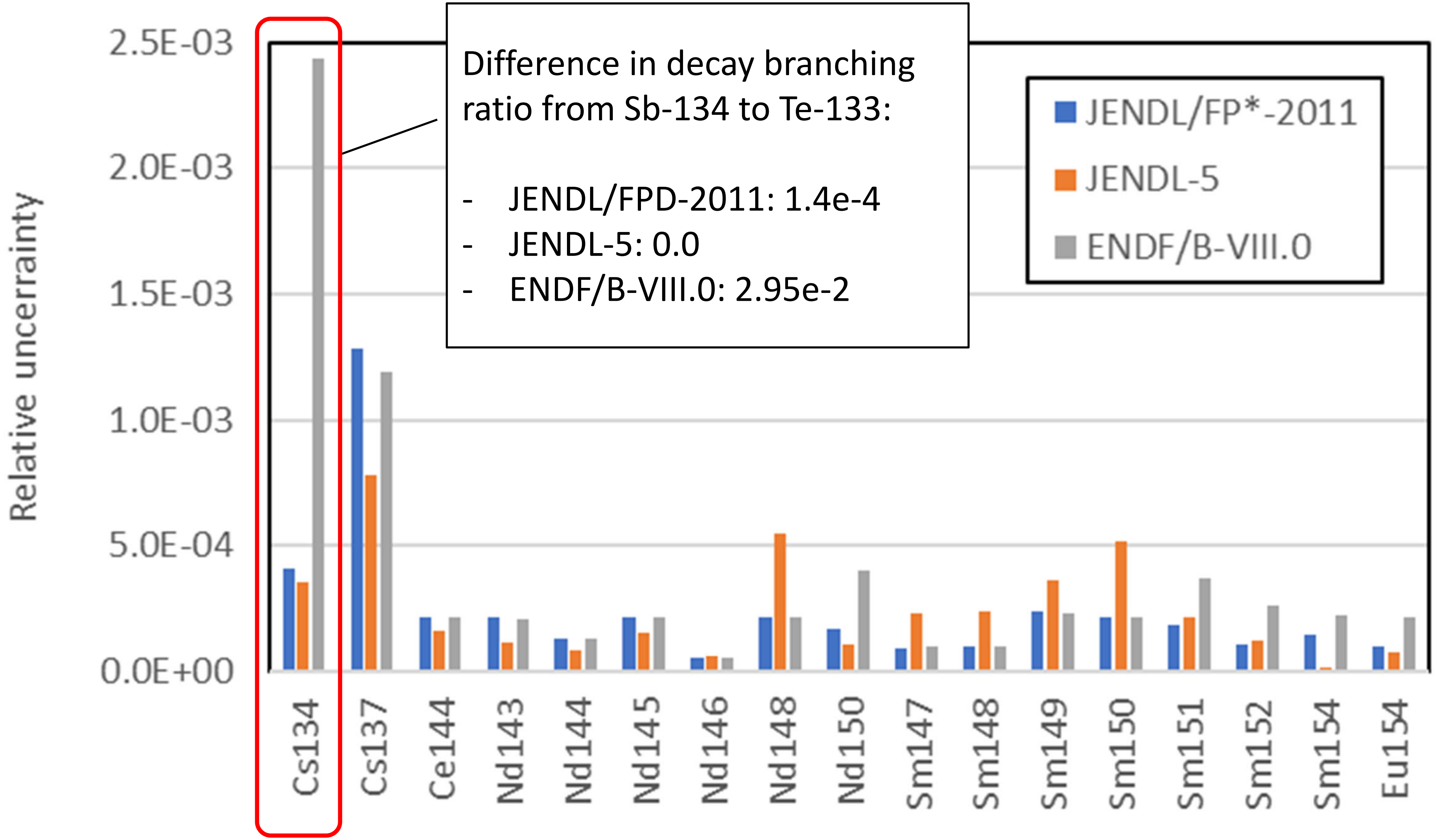
Uncertainty in nuclide number density after fuel depletion

Decay constant-induced uncertainty



Uncertainty in nuclide number density after fuel depletion

Decay branching radio-induced uncertainty



Post-Irradiation Examination (PIE) analyses

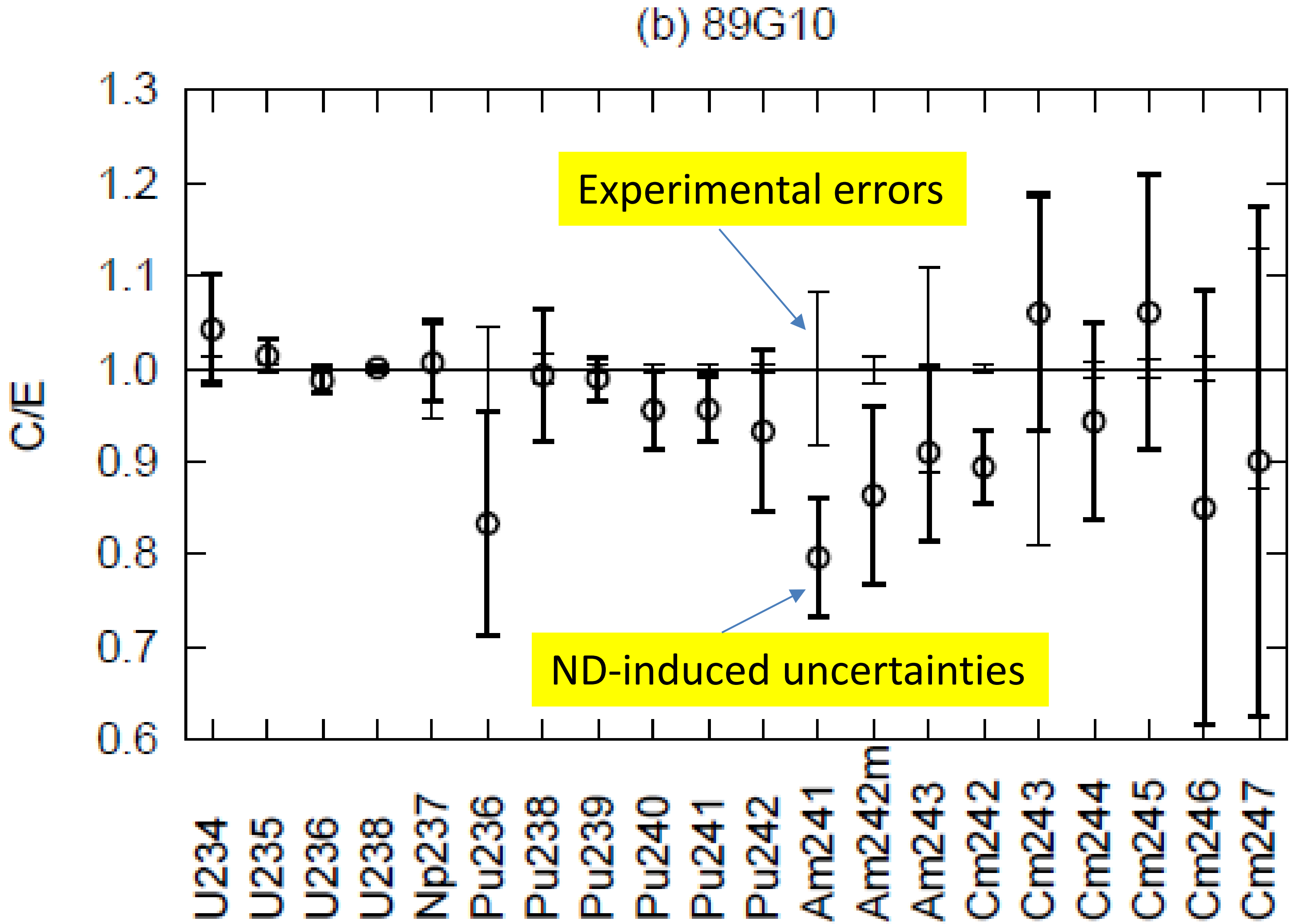
- The experimental data of PIE are very useful to validate the nuclear data, and those have been utilized.

- In addition to comparisons between calculation values and experimental values, nuclear data-induced uncertainties in the calculation values have been quantified in recent years*.

- Similar works were carried out using the covariances in JENDL-4.0, JENDL/FPD-2011, and JENDL/FPY-2011 and sensitivities calculated by the depletion perturbation theory.

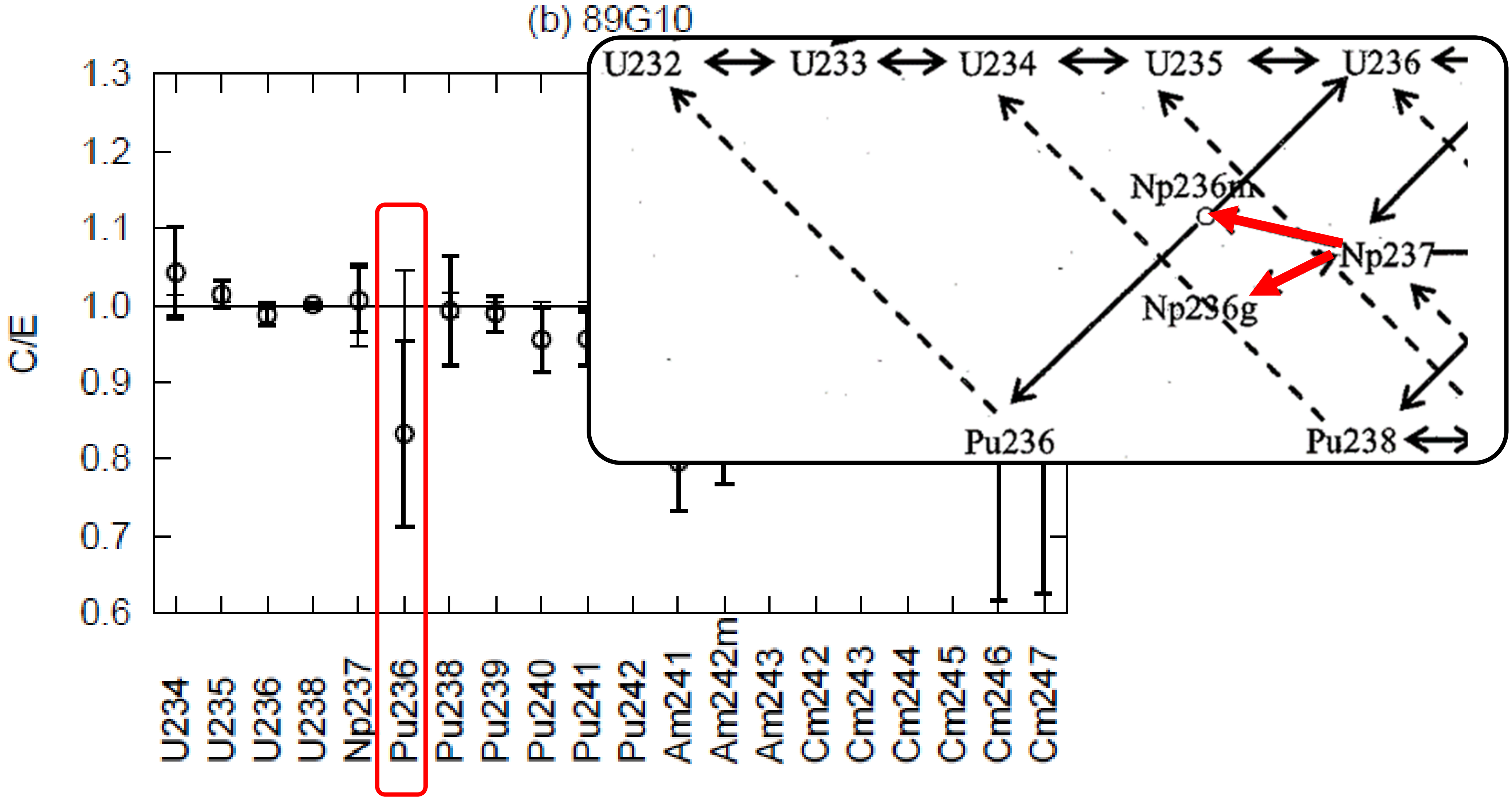
* Luca Fiorito, et al., "Inventory calculation and nuclear data uncertainty propagation on light water reactor fuel using ALEPH-2 and SCALE 6.2," Ann. Nucl. Energy, 83, p.137 (2015).

C/E with ND-induced uncertainty in the PIE analyses for Ohi Unit 2



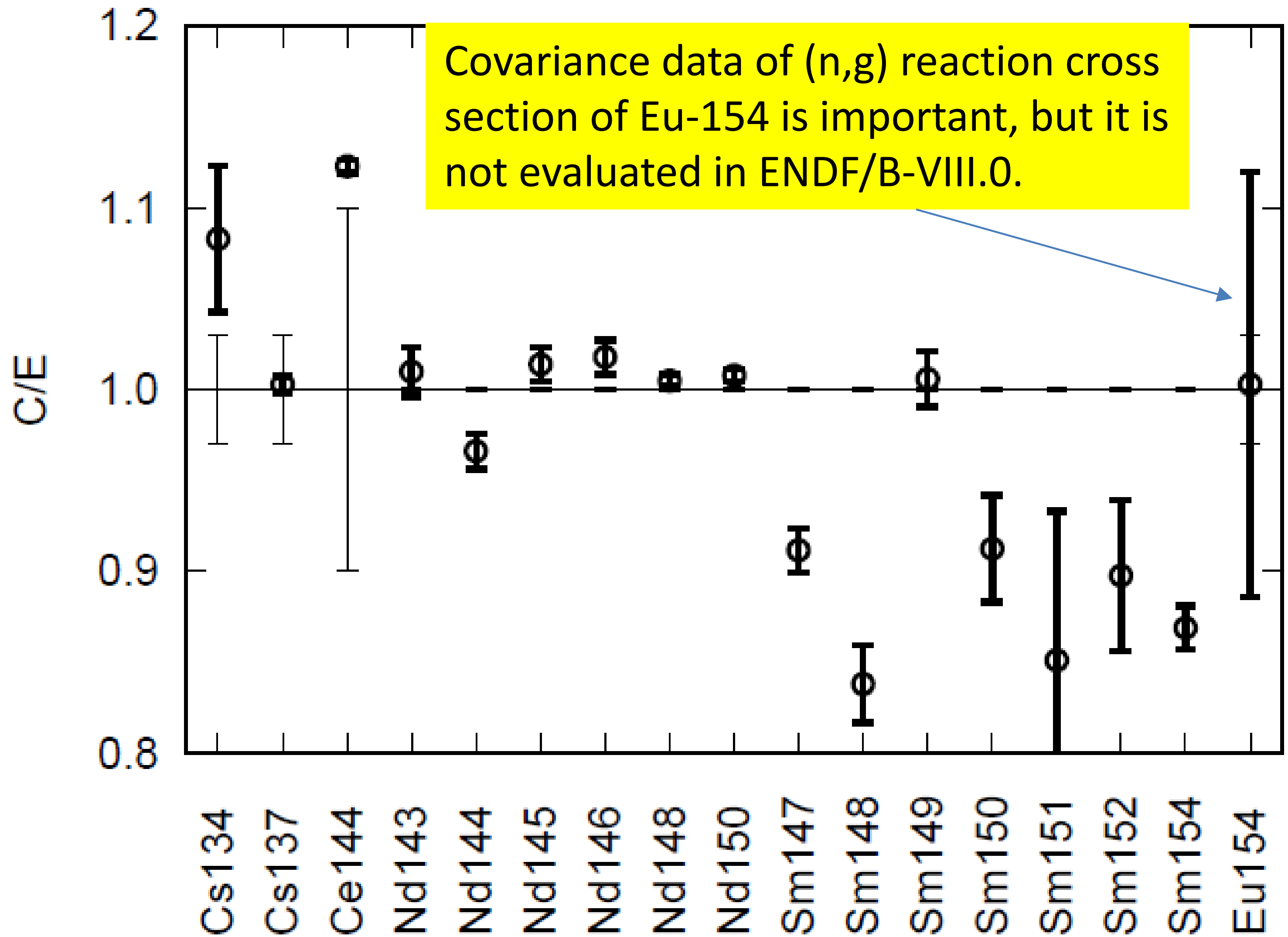
- C/E, the experimental uncertainties, and the ND-induced uncertainties seem consistent with each other from the statistical point of view.
- It is well known that the Am-241 (n,g) branching ratio affects the production of Am-242m, -243, and Cm isotopes, but no covariance data are given.

C/E with ND-induced uncertainty in the PIE analyses for Ohi Unit 2



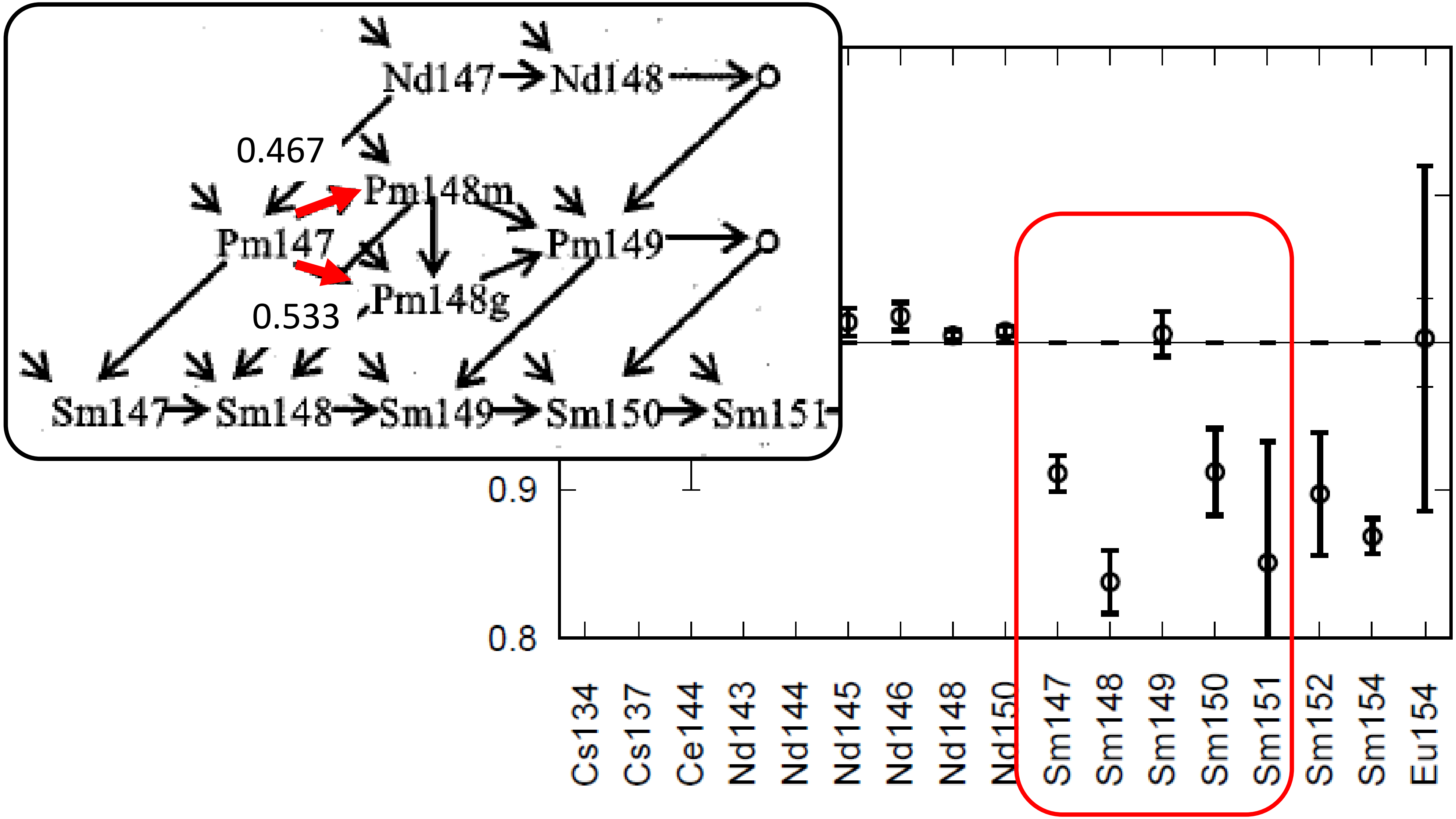
The uncertainty in the reaction branching ratio of Np-237 (n,2n) is not given in the evaluated nuclear data files, but it perhaps makes the ND-induced error large.

C/E with ND-induced uncertainty in the PIE analyses for Fukushima-Daini Unit 2



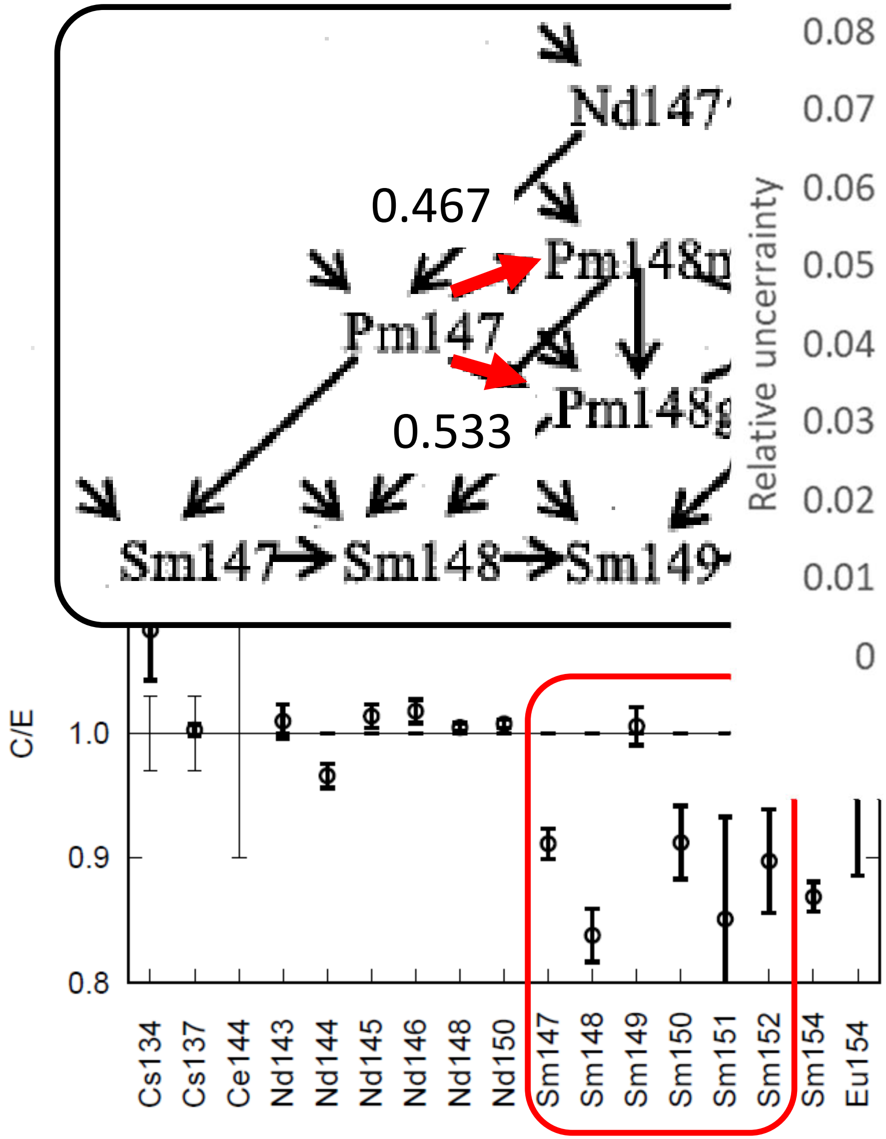
- Uncertainties in the reaction cross sections of FP are dominant.
- The JENDL libraries do not contain any covariance data for FP. ENDF/B-VIII.0 contains the data only for several FPs.

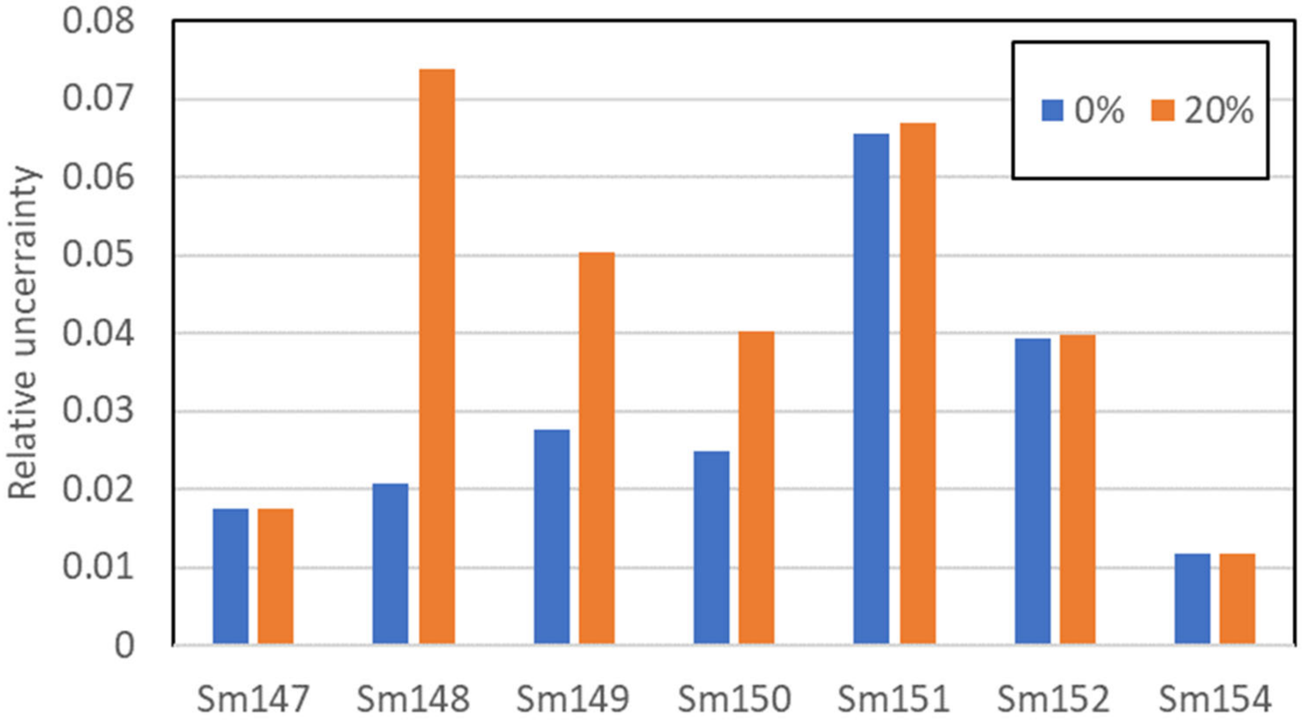
C/E with ND-induced uncertainty in the PIE analyses for Fukushima-Daini Unit 2



The uncertainty in the reaction branching ratio of Pm-147 (n,g) is not given in the evaluated nuclear data files, but it perhaps makes the ND-induced error large.

C/E with ND-induced uncertainty in the PIE analyses for Fukushima-Daini Unit 2





If 20% uncertainty is assumed to the reaction branching ratio of Pm-147 (n,g), the ND-induced uncertainties in the Sm isotopes inventory become large, especially for Sm-148.