



WIR SCHAFFEN WISSEN – HEUTE FÜR MORGEN

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# Impact of JEFF-3.3, ENDF/B-VIII.o and JENDL-4.0 uncertainties on PIE isotopic compositions and decay heat



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2021



# Summary

- Overview of the method
- Global results
- Uncertainties
- Conclusion

**EUropean Joint Programme on RADioactive Waste Management  
EURAD**

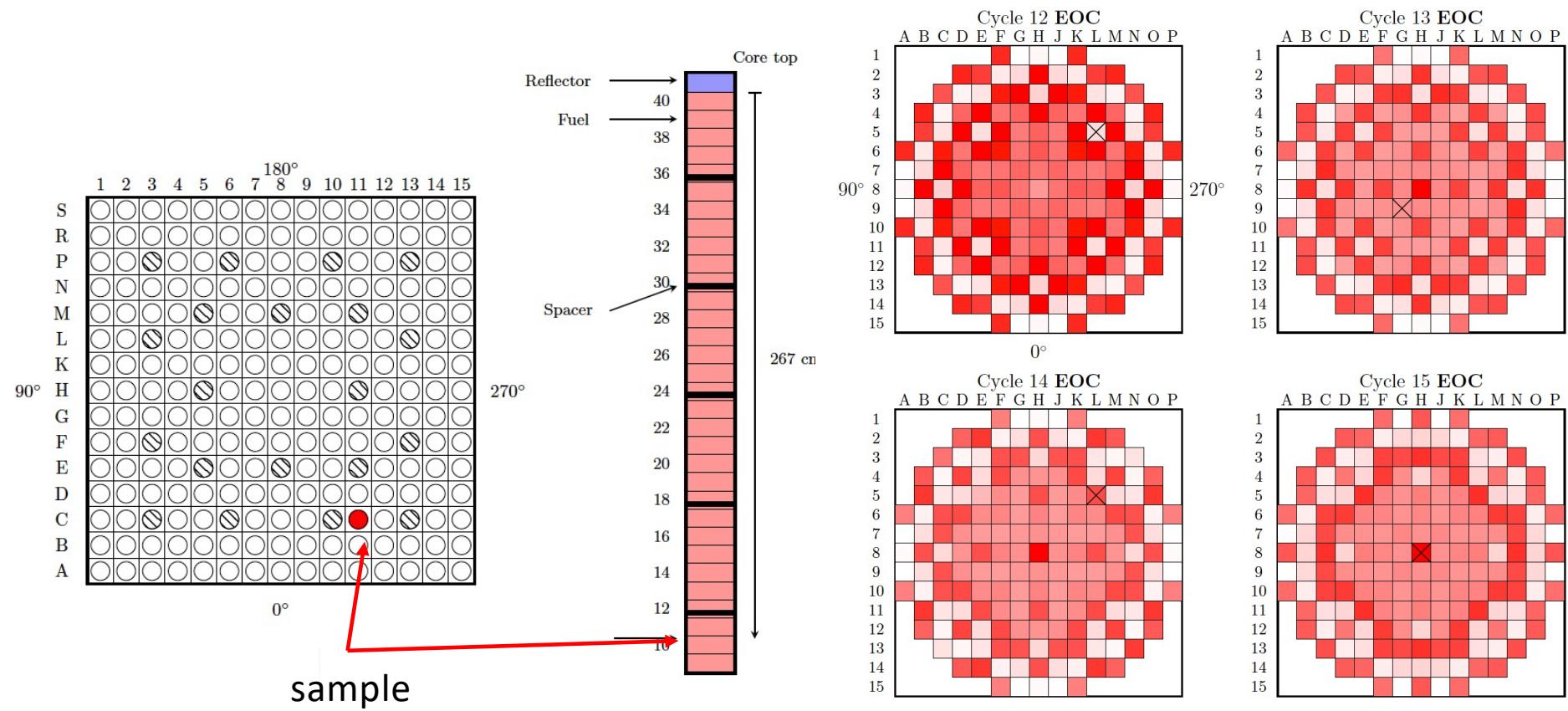
**5-year implementation phase 1 – EURAD-1**



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

# PIE samples

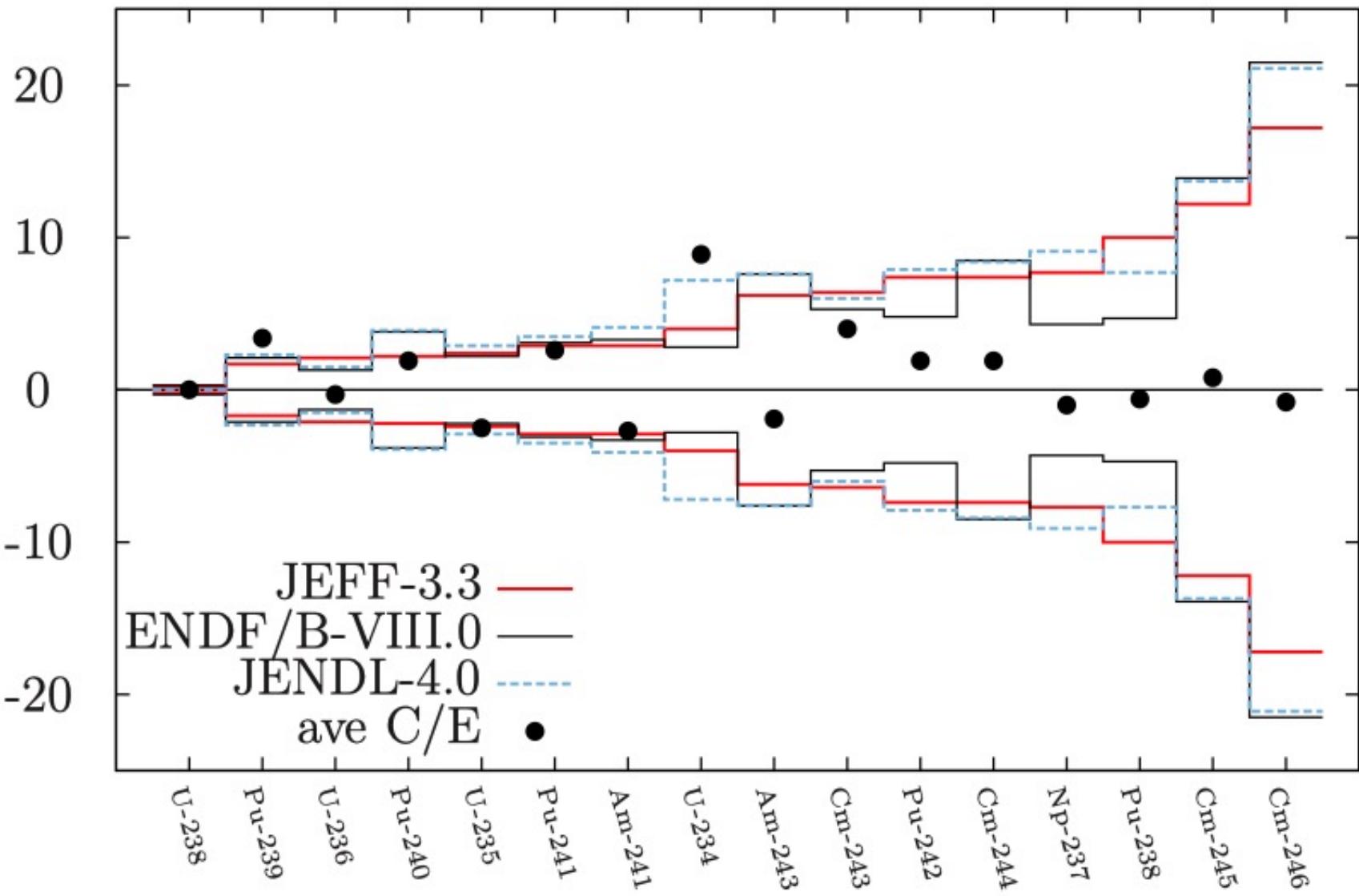
- PIE data: isotopic concentrations from irradiated samples in a specific reactor
- Measured actinides and fission products (e.g. in mg/gU)
- Used for transport and depletion code validation



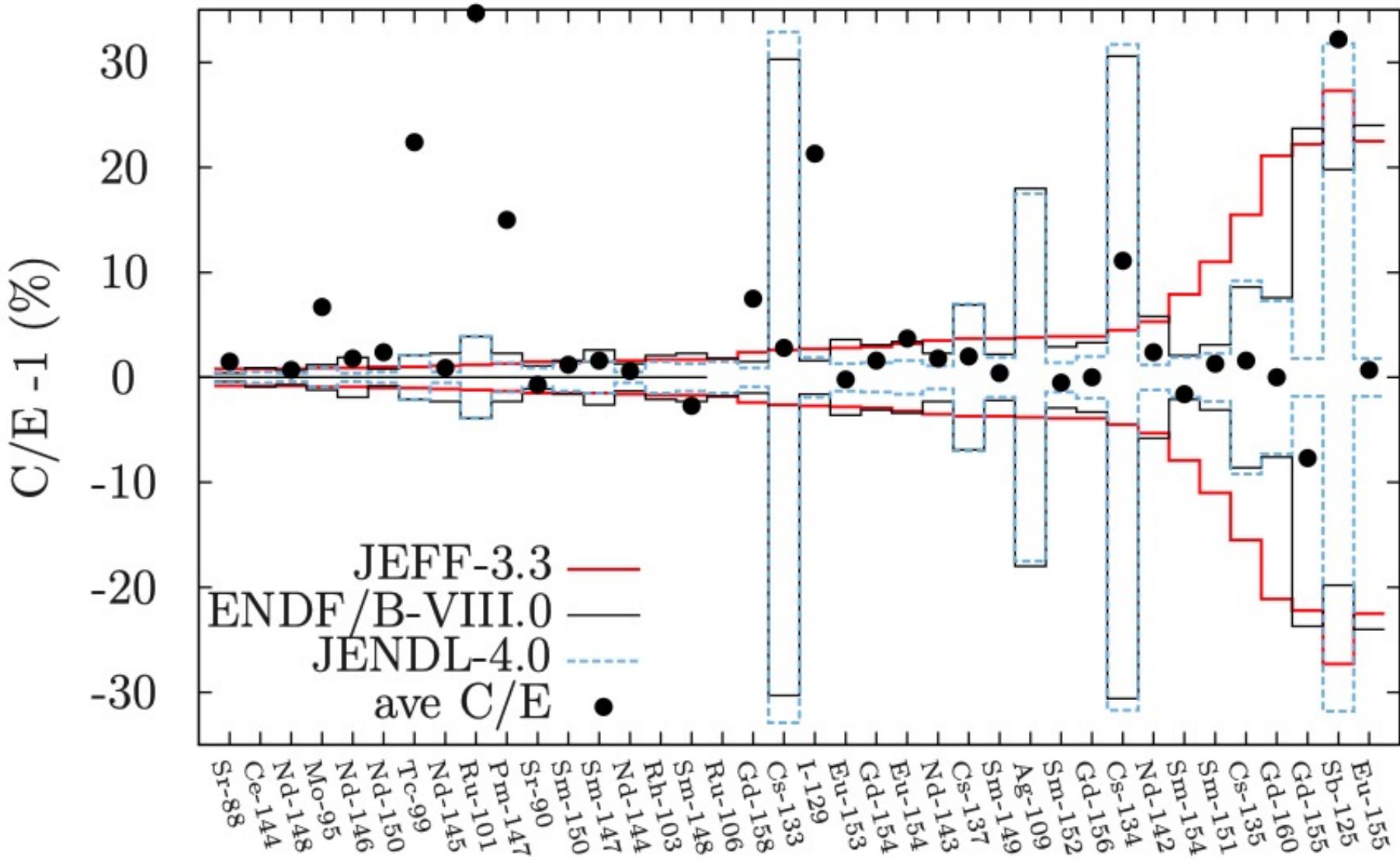
# PIE data

- PSI database: 27 samples irradiated in Swiss reactors
  - UO<sub>2</sub>, MOX, PWR, BWR, 30 to 120 MWd/kgU
- Uncertainty propagation:
  - Repeat 1000 times the same CASMO5 calculation (ENDF/B-VII.1 base library)
  - Each time changing perturbations on nuclear data
  - Performed with JEFF-3.3, JENDL-4.0 and ENDF/B-VIII.0, all covariances
  - Results presented are averaged over the 17 samples:
    - 6 PWR MOX
    - 9 PWR UO<sub>2</sub>
    - 2 BWR UO<sub>2</sub>

## PIE data: actinides (averaged over 17 samples)

 $C/E - 1$  (%)

## PIE data: fission products (averaged over 17 samples)



# Details for a PIE sample PWR UO<sub>2</sub>

**Table B.2.** Uncertainties  $\Delta C$  from nuclear data libraries for the GU3' sample (CASMO5 v2.03 calculations).

All values are in %.

	ENDF/B-VIII.0	JEFF-3.3	JENDL-4.0	ENDF/B-VIII.0	JEFF-3.3	JENDL-4.0
<sup>234</sup> U	2.3	2.2	7.9	<sup>90</sup> Sr	0.7	1.4
<sup>235</sup> U	1.2	1.6	1.8	<sup>95</sup> Mo	0.9	0.7
<sup>236</sup> U	0.8	1.7	1.2	<sup>99</sup> Tc	1.4	0.8
<sup>238</sup> U	0.0	0.0	0.0	<sup>101</sup> Ru	2.8	0.9
<sup>237</sup> Np	3.3	3.9	4.0	<sup>106</sup> Ru	1.5	1.7
<sup>238</sup> Pu	4.8	9.4	7.0	<sup>103</sup> Rh	1.7	1.7
<sup>239</sup> Pu	1.8	1.7	2.2	<sup>109</sup> Ag	21	4.4
<sup>240</sup> Pu	4.3	2.5	4.4	<sup>125</sup> Sb	18	27
<sup>241</sup> Pu	3.2	3.1	3.4	<sup>129</sup> I	3.0	6.1
<sup>242</sup> Pu	4.8	8.5	8.6	<sup>133</sup> Cs	28	2.3
<sup>244</sup> Pu	8.9	8.1	9.2	<sup>134</sup> Cs	29	4.6
<sup>241</sup> Am	3.4	3.1	3.9	<sup>135</sup> Cs	7.1	20
<sup>242m</sup> Am	3.8	3.2	4.5	<sup>137</sup> Cs	6.7	3.6
<sup>243</sup> Am	8.5	7.7	9.0	<sup>144</sup> Ce	0.4	0.6
<sup>242</sup> Cm	3.6	2.7	4.1	<sup>147</sup> Pm	2.5	1.2
<sup>243</sup> Cm	11	16	12	<sup>142</sup> Nd	5.1	5.0
<sup>244</sup> Cm	9.7	9.3	10	<sup>143</sup> Nd	2.0	3.6
<sup>245</sup> Cm	15	14	15	<sup>144</sup> Nd	1.2	2.2
<sup>246</sup> Cm	24	21	24	<sup>145</sup> Nd	2.0	0.9
				<sup>146</sup> Nd	1.7	0.7
				<sup>148</sup> Nd	0.4	0.6
				<sup>150</sup> Nd	0.4	0.9
				<sup>147</sup> Sm	2.2	1.2
				<sup>148</sup> Sm	1.8	1.9
				<sup>149</sup> Sm	1.7	3.5
				<sup>150</sup> Sm	1.2	1.3
				<sup>151</sup> Sm	2.7	12
				<sup>152</sup> Sm	2.6	3.8
				<sup>154</sup> Sm	1.6	7.3
				<sup>153</sup> Eu	3.3	2.1
				<sup>154</sup> Eu	2.8	2.3
				<sup>155</sup> Eu	24	24
				<sup>155</sup> Gd	23	1.1

# Details for a PIE sample BWR UO<sub>2</sub>

**Table 5.** Uncertainties  $\Delta C$  from nuclear data libraries for the ENUSA samples for the isotopic concentrations (CASMO5 v2.03 calculations). All values are in %.

	ENUSA-1		
	ENDF/B-VIII.0	JEFF-3.3	JENDL-4.0
<sup>234</sup> U	1.9	2.0	7.3
<sup>235</sup> U	1.6	2.1	2.5
<sup>236</sup> U	0.7	1.7	1.2
<sup>238</sup> U	0.0	0.0	0.0
<sup>237</sup> Np	3.3	4.0	4.0
<sup>238</sup> Pu	4.8	11	7.9
<sup>239</sup> Pu	2.0	1.9	2.3
<sup>240</sup> Pu	4.0	2.3	4.1
<sup>241</sup> Pu	3.3	3.2	3.7
<sup>242</sup> Pu	4.4	8.4	8.5
<sup>241</sup> Am	3.5	3.3	4.1
<sup>243</sup> Am	8.8	7.9	9.3
<sup>244</sup> Cm	9.8	9.6	10
<sup>246</sup> Cm	25	22	25

	ENUSA-1		
	ENDF/B-VIII.0	JEFF-3.3	JENDL-4.0
<sup>94</sup> Mo	4.7	17	13
<sup>109</sup> Ag	22	4.2	25
<sup>110</sup> Pd	15	7.3	11
<sup>111</sup> Cd	20	8.6	17
<sup>125</sup> Sb	18	28	16
<sup>133</sup> Cs	29	2.3	28
<sup>134</sup> Cs	29	4.1	28
<sup>135</sup> Cs	7.8	17	7.7
<sup>151</sup> Sm	2.5	13	1.9
<sup>154</sup> Sm	1.7	7.4	1.7
<sup>157</sup> Gd	4.6	10	4.5
<sup>160</sup> Gd	9.0	29	9.1

# Details for a PIE sample PWR MOX

**Table B.7.** Comparison in % between the impact of the nuclear data libraries for the BM1-P sample with the assembly model, based on the CASMO5 v2.03 calculations. Value are at the time of measurement.

	ENDF/B-VIII.0	JEFF-3.3	JENDL-4.0		ENDF/B-VIII.0	JEFF-3.3	JENDL-4.0
<sup>234</sup> U	2.0	4.0	4.5	<sup>235</sup> U	0.8	1.1	1.0
<sup>236</sup> U	0.9	1.7	1.1	<sup>238</sup> U	0.0	0.0	0.0
<sup>237</sup> Np	5.9	18	18	<sup>238</sup> Pu	3.2	8.0	5.3
<sup>239</sup> Pu	1.8	1.7	2.0	<sup>240</sup> Pu	2.2	1.5	2.8
<sup>241</sup> Pu	1.7	2.6	3.2	<sup>242</sup> Pu	3.8	6.2	6.1
<sup>241</sup> Am	1.9	2.4	3.6	<sup>242m</sup> Am	1.9	2.1	3.5
<sup>243</sup> Am	6.2	3.8	4.9	<sup>244</sup> Cm	6.8	4.2	5.4
<sup>245</sup> Cm	12	9.6	11	<sup>246</sup> Cm	23	15	21
<sup>90</sup> Sr	1.1	1.5	1.1	<sup>95</sup> Mo	1.1	0.9	1.1
<sup>99</sup> Tc	2.6	1.1	2.4	<sup>101</sup> Ru	5.0	1.3	4.7
<sup>106</sup> Ru	1.4	1.8	1.4	<sup>103</sup> Rh	1.8	1.5	1.6
<sup>109</sup> Ag	24	4.3	22	<sup>125</sup> Sb	22	35	35
<sup>133</sup> Cs	33	2.9	37	<sup>134</sup> Cs	33	5.0	35
<sup>135</sup> Cs	12	13	13	<sup>137</sup> Cs	6.8	4.4	6.8
<sup>144</sup> Ce	0.5	0.9	0.5	<sup>142</sup> Nd	7.1	7.0	0.9
<sup>143</sup> Nd	1.4	1.6	0.6	<sup>144</sup> Nd	1.0	1.3	0.4
<sup>145</sup> Nd	1.5	1.1	0.6	<sup>146</sup> Nd	1.4	0.8	0.5
<sup>148</sup> Nd	0.5	0.8	0.5	<sup>150</sup> Nd	0.6	1.1	0.6
<sup>147</sup> Sm	2.6	1.5	1.7	<sup>148</sup> Sm	2.4	1.6	1.8
<sup>149</sup> Sm	2.2	4.1	1.8	<sup>150</sup> Sm	1.5	1.7	1.5
<sup>151</sup> Sm	3.2	12	2.5	<sup>152</sup> Sm	2.8	4.2	1.6
<sup>154</sup> Sm	2.0	11	1.8	<sup>153</sup> Eu	3.3	3.5	1.3
<sup>154</sup> Eu	4.2	3.9	1.6	<sup>155</sup> Eu	27	33	1.5
<sup>154</sup> Gd	4.4	4.2	1.6	<sup>155</sup> Gd	27	33	1.5
<sup>156</sup> Gd	4.8	6.5	2.7	<sup>158</sup> Gd	1.2	3.3	0.9
<sup>160</sup> Gd	9.2	27	8.6				

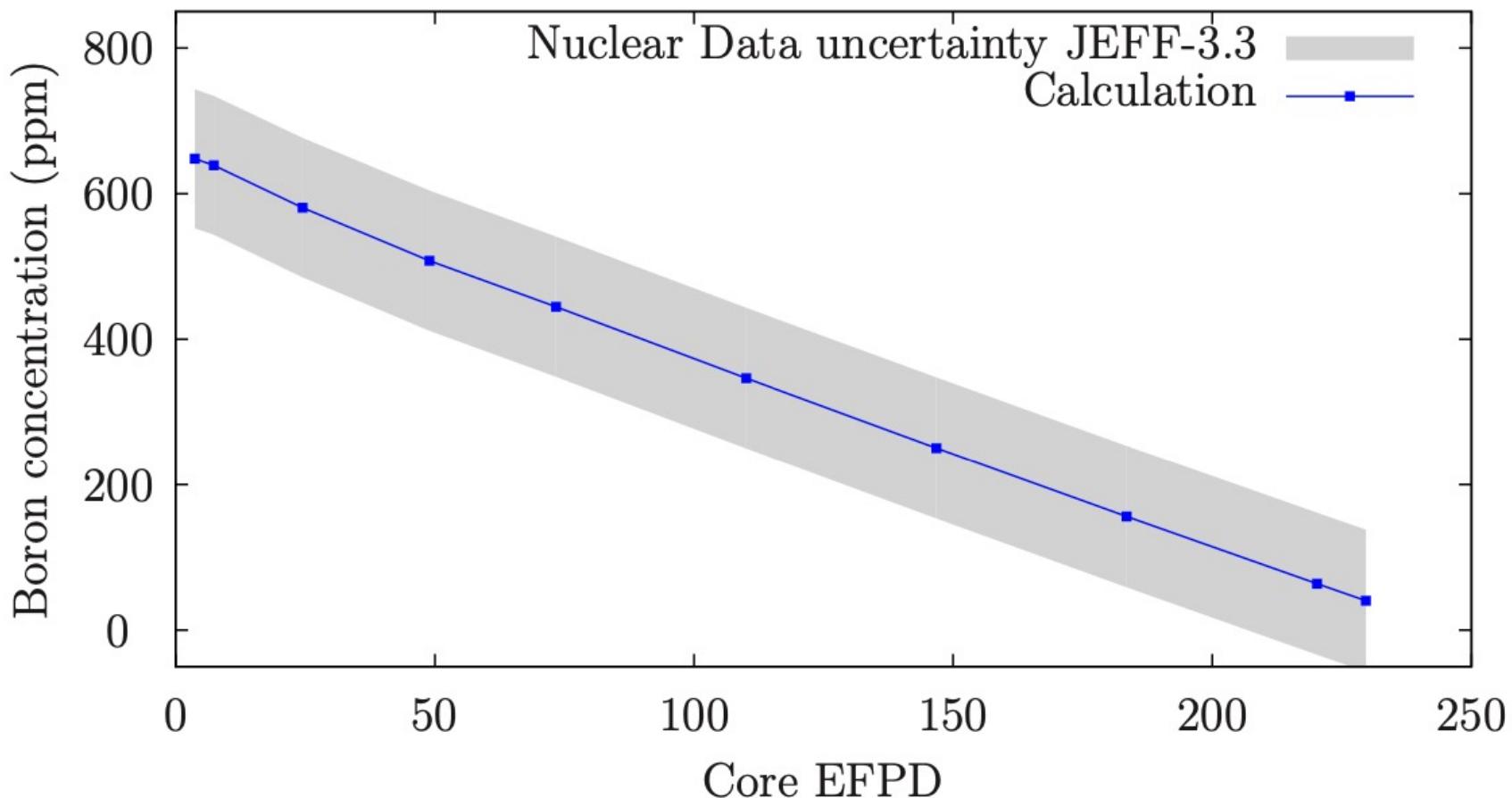
<https://www.epj-n.org/articles/epjn/abs/2021/01/epjn210030/epjn210030.html>

# Reactor and SNF Quantities

- System: PWR
- Propagation through 7 cycles
- Results are shown only for the 7<sup>th</sup> cycle, including MOX
  
- Uncertainty propagation:
  - Repeat 100 times the same CMSYS (CASMO5/SIMULATE/SNF) calculation
  - Each time changing perturbations on nuclear data
  - Performed with JEFF-3.3, JENDL-4.0 and ENDF/B-VIII.0, all covariances
  
- Quantities of interest:
  - Boron curve
  - SNF Decay heat

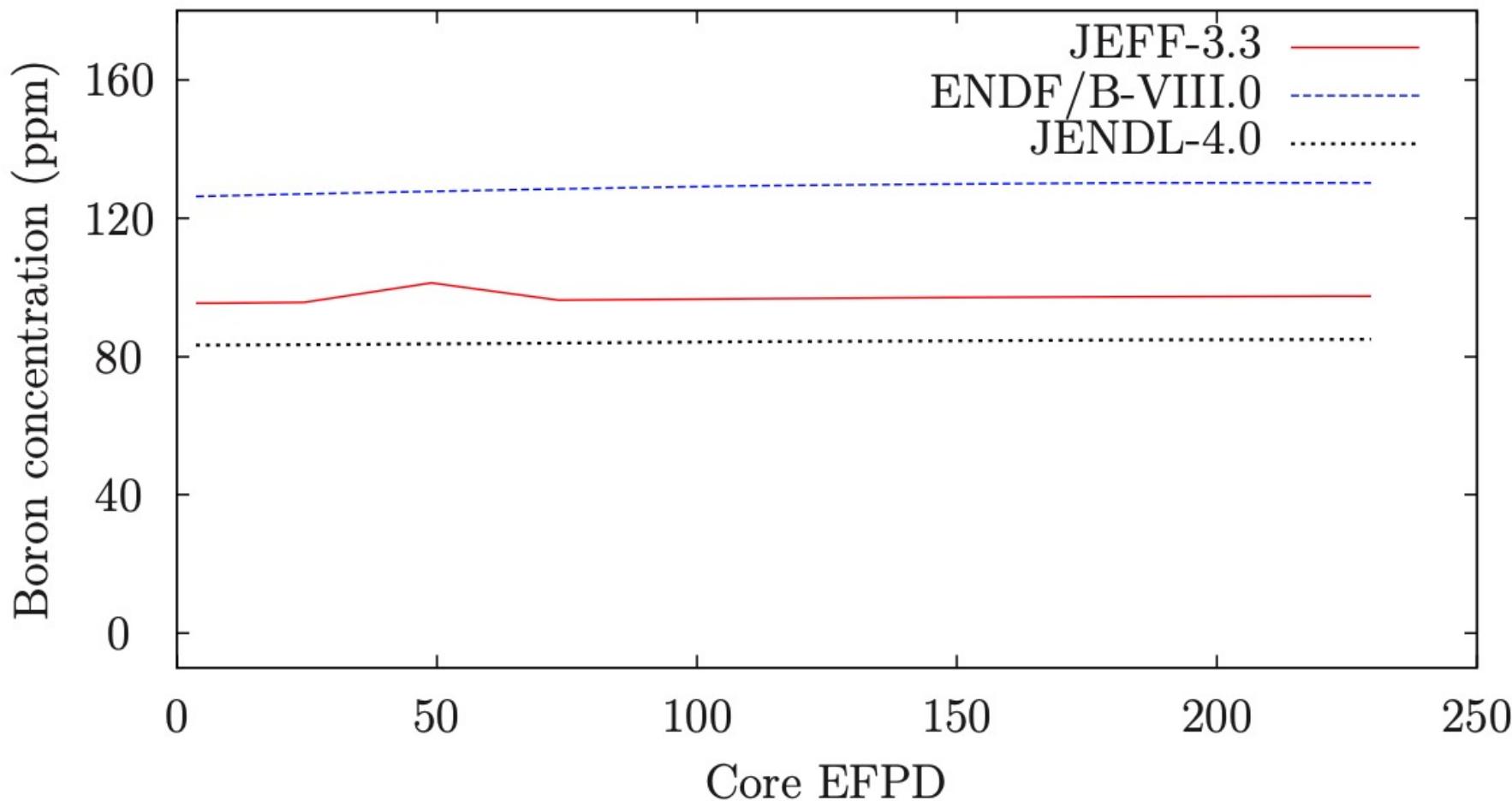
# Reactor Quantities: Boron curve

7<sup>th</sup> cycle



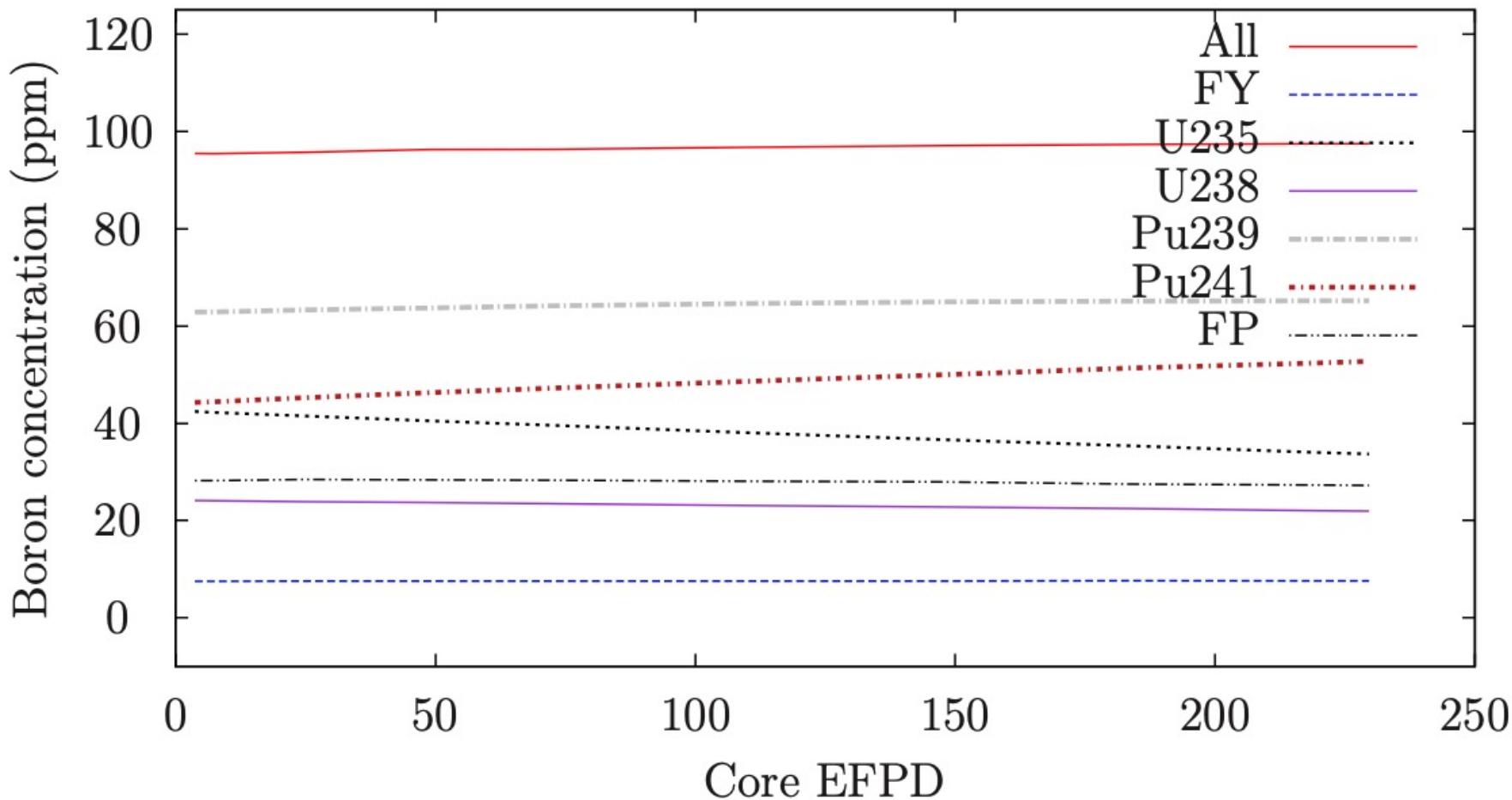
# Reactor Quantities: Boron curve

7<sup>th</sup> cycle Nuclear Data uncertainty



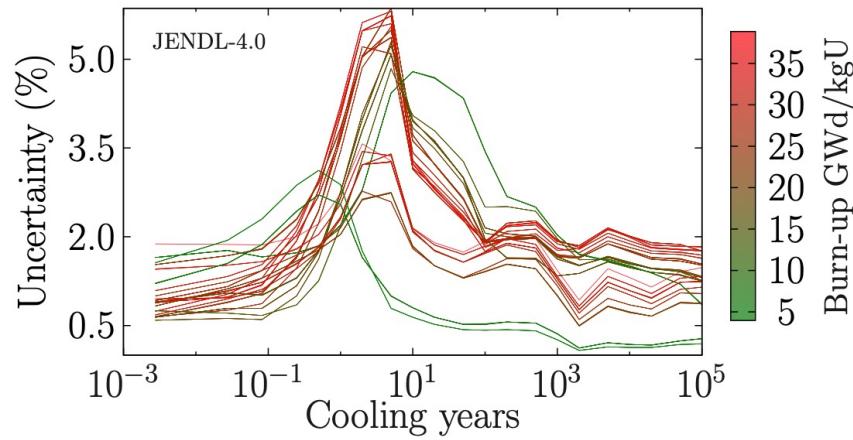
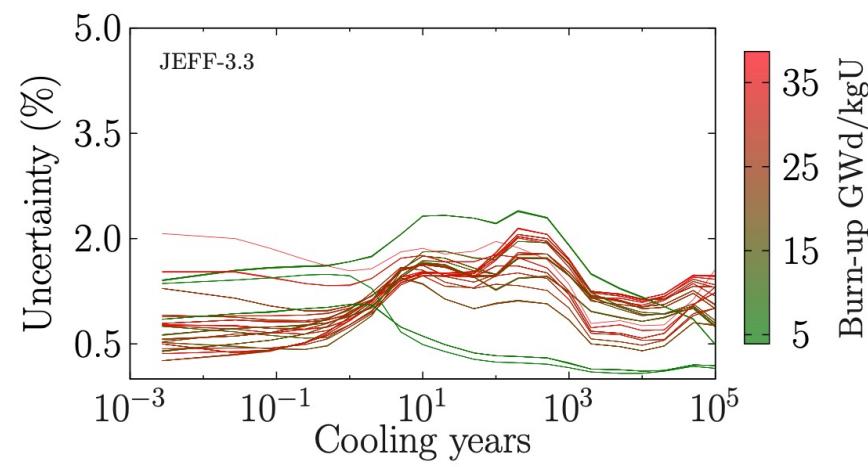
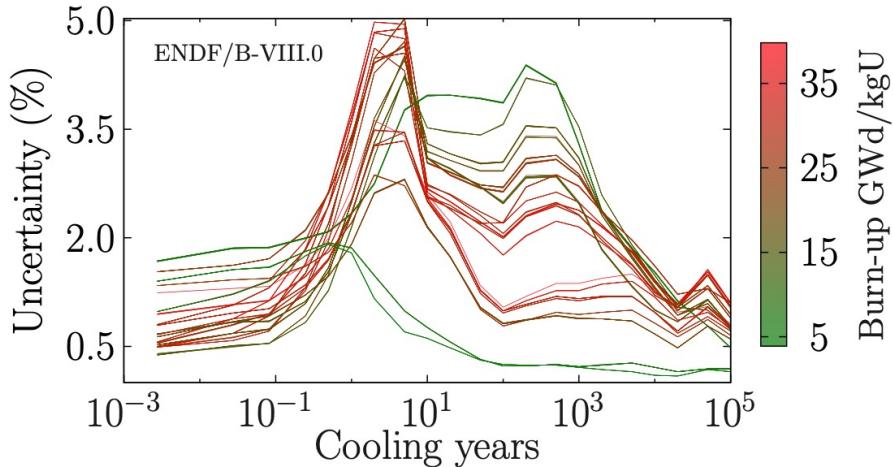
# Reactor Quantities: Boron curve

7<sup>th</sup> cycle Nuclear Data uncertainty JEFF-3.3



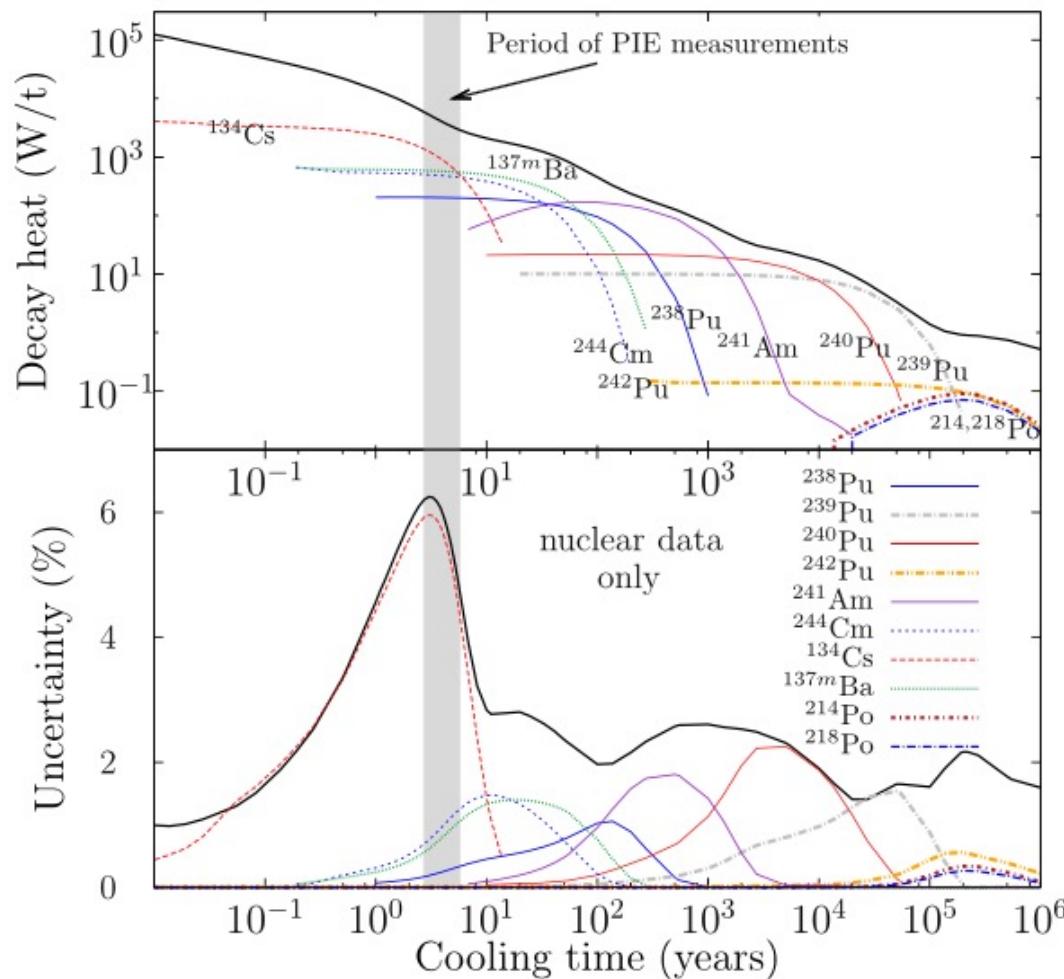
# SNF Quantities: Decay heat

- 121 SNF at end of the 7<sup>th</sup> cycle



# SNF Quantities: Decay heat

- Effect of Cs134 different in JEFF-3.3



**Fig. 10.** Calculated decay heat for the assembly containing the GU1 sample (top) and uncertainties due to nuclear data (bottom, with the ENDF/B-VIII.0 library). The ten most important contributors for the uncertainties are also presented.

# Conclusions

- Uncertainties propagated for PIE data, boron curves and SNF decay heat
- Some differences between JEFF-3.3 and JENDL-4.0, ENDF/B-VIII.0 for decay heat and PIE data, to be explored.
- Main differences between libraries for uncertainties (XS and FY):  
 $^{238}\text{Pu}$ ,  $^{237}\text{Np}$ ,  $^{94}\text{Mo}$ ,  $^{110}\text{Pd}$ ,  $^{111}\text{Cd}$ ,  $^{109}\text{Ag}$ ,  $^{125}\text{Sb}$ ,  $^{133,134,135}\text{Cs}$ ,  $^{151,154}\text{Sm}$ ,  $^{157,160}\text{Gd}$
- Missing covariances in JEFF-3.3:
  - U236, Am242m, Pu242,
  - $^{153,154}\text{Eu}$ ,  $^{155,156,158,160}\text{Gd}$ ,  $^{135}\text{Cs}$ ,  $^{109}\text{Ag}$ ,  $^{129}\text{I}$ ,  $^{148}\text{Sm}$ ,  $^{144}\text{Nd}$ ,  $^{147}\text{Pm}$ ,  $^{144}\text{Ce}$ ,  $^{99}\text{Tc}$ ,  $^{148}\text{Nd}$
- No fast range covariances: Am241

# Wir schaffen Wissen – heute für morgen

