OAK RIDGE National Laboratory

Covariance Testing Progress for ENDF/B-VIII.1β1 at ORNL

B.J. Marshall

Mini-CSEWG
Livermore, CA
April 25-27, 2023

ORNL is managed by UT-Battelle LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

Outline

- Data-induced uncertainty in VALID benchmarks
- Data-induced uncertainty for fission products in SNF
- C_k values for SNF validation

Data-induced uncertainty in VALID benchmarks

- Historically a check ORNL has used to compare predicted variability with observed variability from benchmarks
- TSUNAMI-IP propagates covariance data with sensitivities from benchmarks
- The uncertainty is determined by reaction-nuclide pair and summed to determine the total data-induced uncertainty in k_{eff}
- Examination of results highlights covariance data issues

Results

Category	Number of Cases	Avg C/E (CE_V8.1)	Avg Exp. Unc. (pcm)	St. Dev. Of C/Es (pcm)	Avg 1σ XS Unc (pcm)		% of Cases Within	
					E8+SCALE	E8.1+SCALE	Exp. Unc. Band	E8.1+SCALE XS Band
HMF	50	1.00002	193	467	979	950	34.0	96.0
HST	52	0.99900	494	615	652	792	75.0	96.2
IMF	13	1.00132	269	362	1027	1003	46.2	100
LCT	140	0.99874	195	162	603	737	56.4	100
LST	19	0.99920	318	283	824	944	57.9	100
MCT	49	0.99244	400	313	973	758	18.4	51.0
MST	10	0.99177	452	384	1323	1019	0	50.0
PMF	12	0.99902	207	133	1022	1038	66.7	100
PST	81	0.99927	497	429	1344	937	76.5	92.6

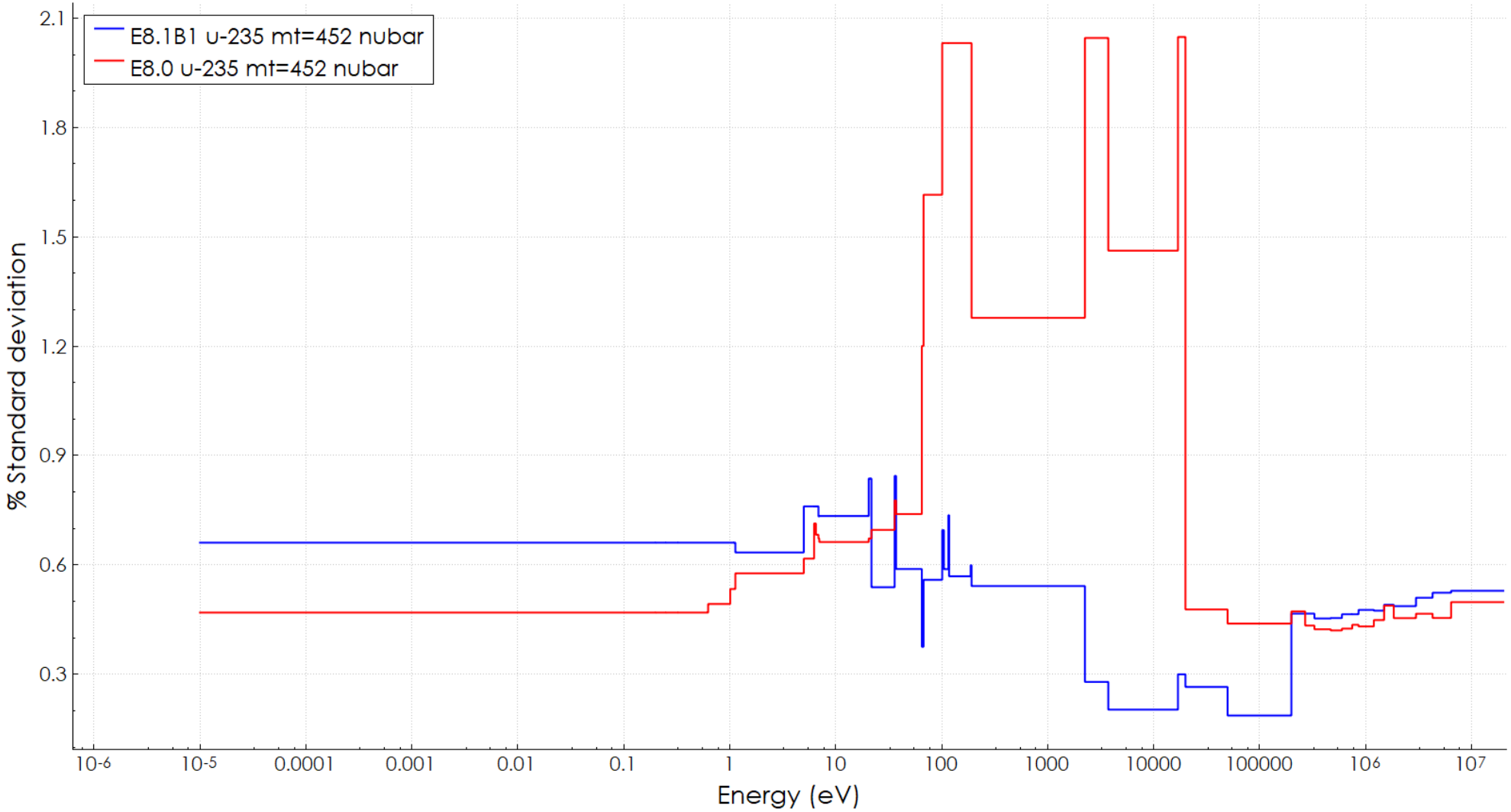
Small changes…

- HMF systems show small differences in general: ~3%
  - HMF systems reflected with DU appear to have significant reductions in ^{235}U nubar uncertainty (~400 pcm in E8.0 → ~225 pcm in E8.1)
- IMF system uncertainties ~2% lower with ENDF/B-VIII.1β1
  - ^{235}U nubar ~10% lower, 3rd highest contribution to uncertainty
- PMF systems a little less than 2% higher on average

Big changes (1): HST, LCT, and LST

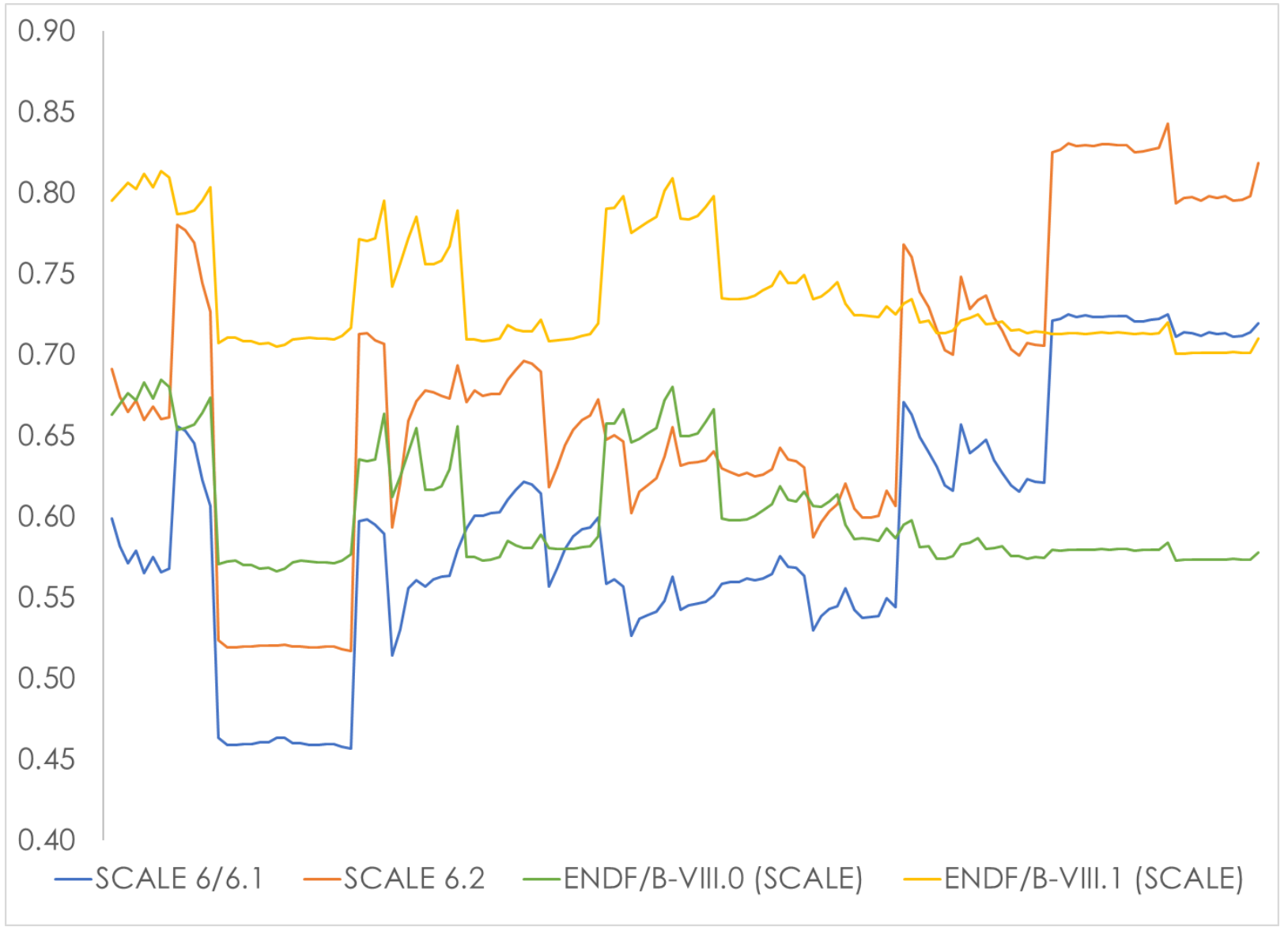
- HST, LCT and LST systems see large increases in uncertainty
  - Average uncertainty increased ~22% for HST and LCT systems and ~15% for LST systems
- Directly attributable to ~40% increase in nubar contribution to uncertainty in thermal uranium systems
  - ORNL still disagrees with the ^{1}H covariance introduced in ENDF/B-VIII.0 and *its* associated significant increase in data-induced uncertainty
- Plot on next slide shows comparison of ENDF/B-VIII.0 and ENDF/B-VIII.1β1 nubar

^{235}U nubar comparison



OAK RIDGE National Laboratory

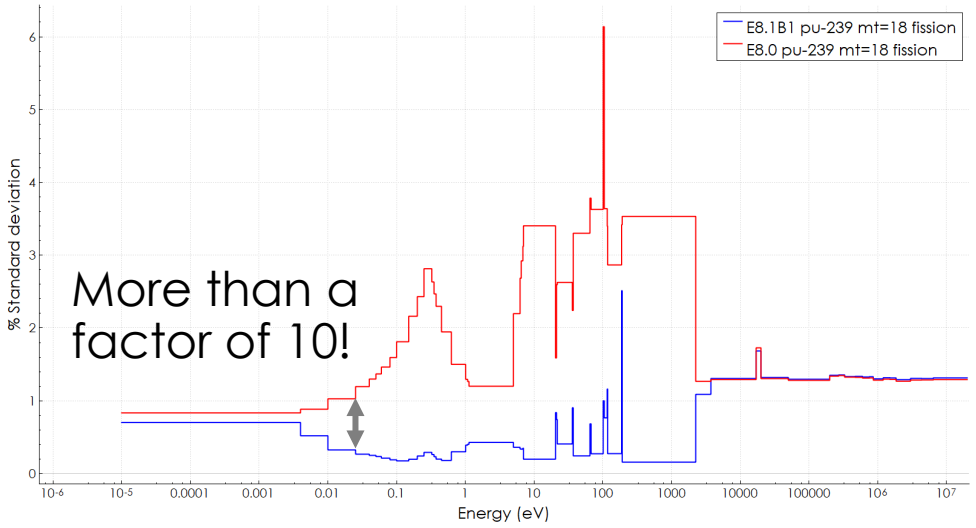
Historical perspective on LCTs

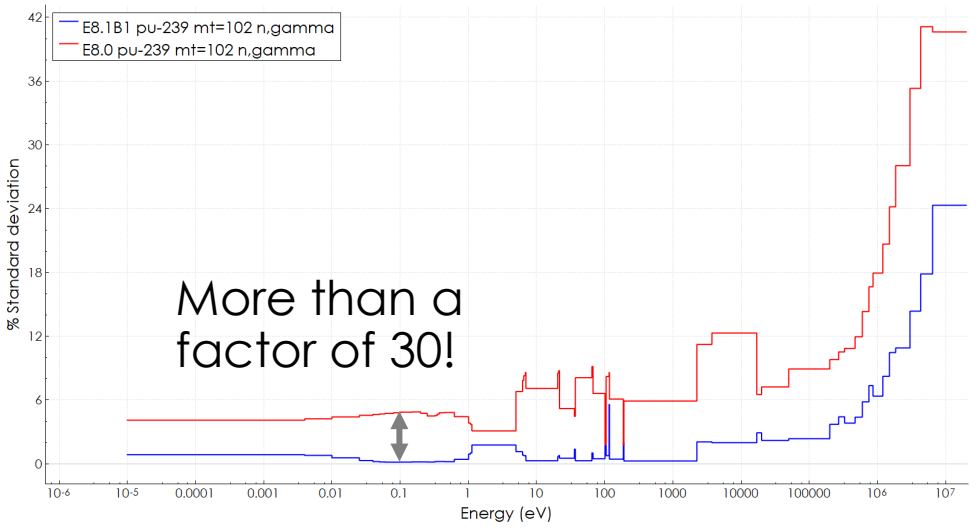


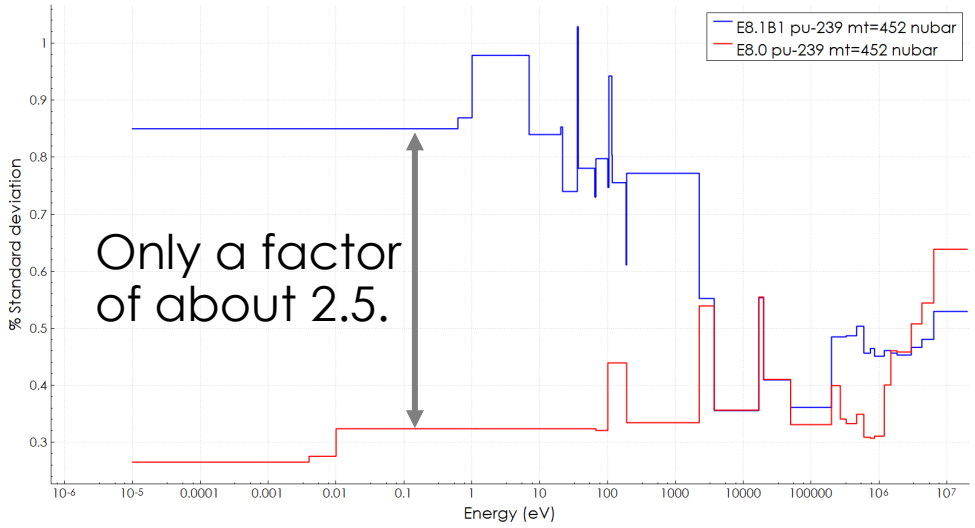
Big changes (2): MCT, MST, and PST

- MST, MCT, and PST systems see large decreases in uncertainty
  - Average uncertainty decreased ~22% for MST and MCT systems and ~30% for PST systems
- Basically all the ^{239}Pu covariance data is totally different
  - Nubar uncertainty up by 167%
  - Chi down by 80%
  - Fission down by >85%
  - n,gamma (leading contributor in E8.0) down by 95%
    - 1130 pcm → 50 pcm

^{239}Pu fission, nubar, and n,gamma uncertainties







OAK RIDGE National Laboratory

Questions on VALID results?

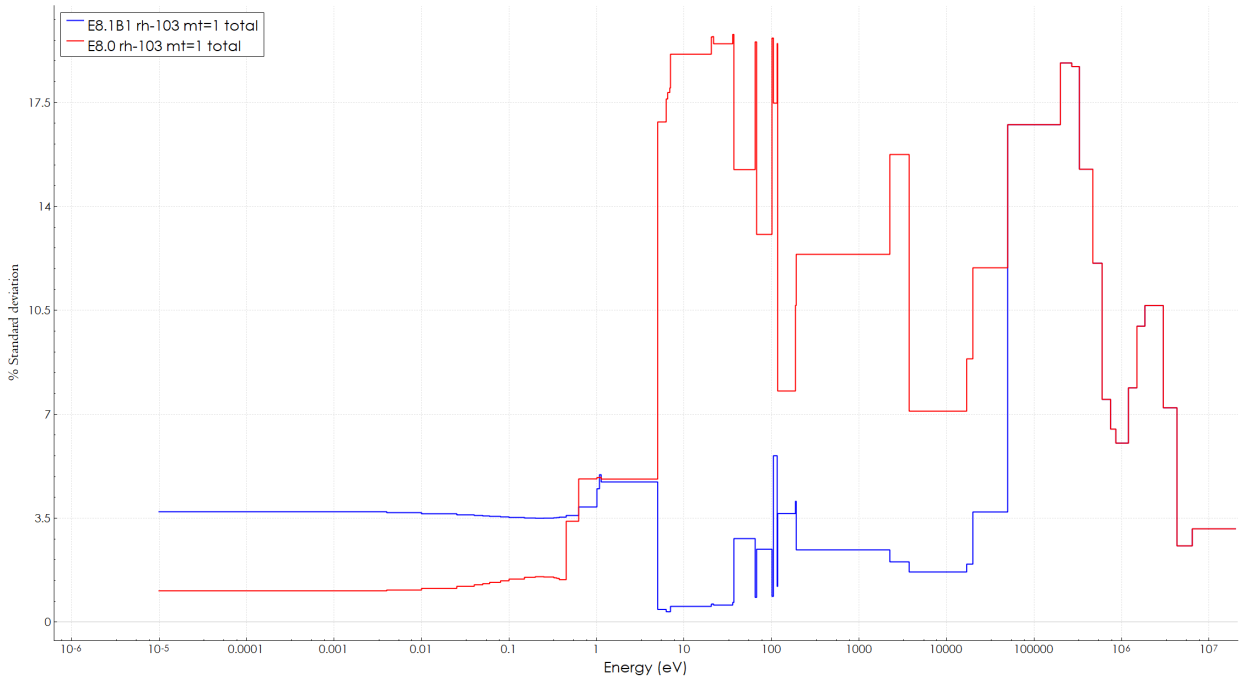
Data-induced uncertainty in SNF k_{eff}

- Data-induced uncertainty in minor actinides and fission products used to determine a potential validation penalty in NUREG/CR-7109
- Currently incorporated in NUREG-2215, Appendix 7A, and NUREG-2216, Appendix 6A
- Penalty based on uncertainty as a fraction of fission product worth
  - Work on-going to re-evaluate entirely in ENDF/B-VII.1 and ENDF/B-VIII.0
- Covariance testing looks only at how much the uncertainty has changed

Results

Nuclide	E8.0 Unc. (% Δk)	E8.1 Unc. (% Δk)	Difference (%)
mo-95	0.00499	0.00499	0.06%
tc-99	0.00990	0.00990	0.00%
ru-101	0.00788	0.00788	0.00%
rh-103	0.02118	0.02735	29.11%
ag-109	0.00232	0.00232	0.00%
cs-133	0.01693	0.01693	0.00%
sm-147	0.00549	0.00549	0.00%
sm-149	0.02050	0.02050	0.00%
sm-150	0.00521	0.00521	0.00%
sm-151	0.01234	0.01234	0.00%
sm-152	0.00617	0.00617	0.00%
nd-143	0.03510	0.03510	0.00%
nd-145	0.01818	0.01818	0.00%
eu-151	0.00024	0.00024	0.00%
eu-153	0.00805	0.00805	0.00%
gd-155	0.01236	0.01236	0.00%
total	0.05808	0.06060	4.34%

Red: Big change Orange: SCALE data not in ENDF



OAK RIDGE National Laboratory

OAK RIDGE National Laboratory

Questions on fission product uncertainty data?

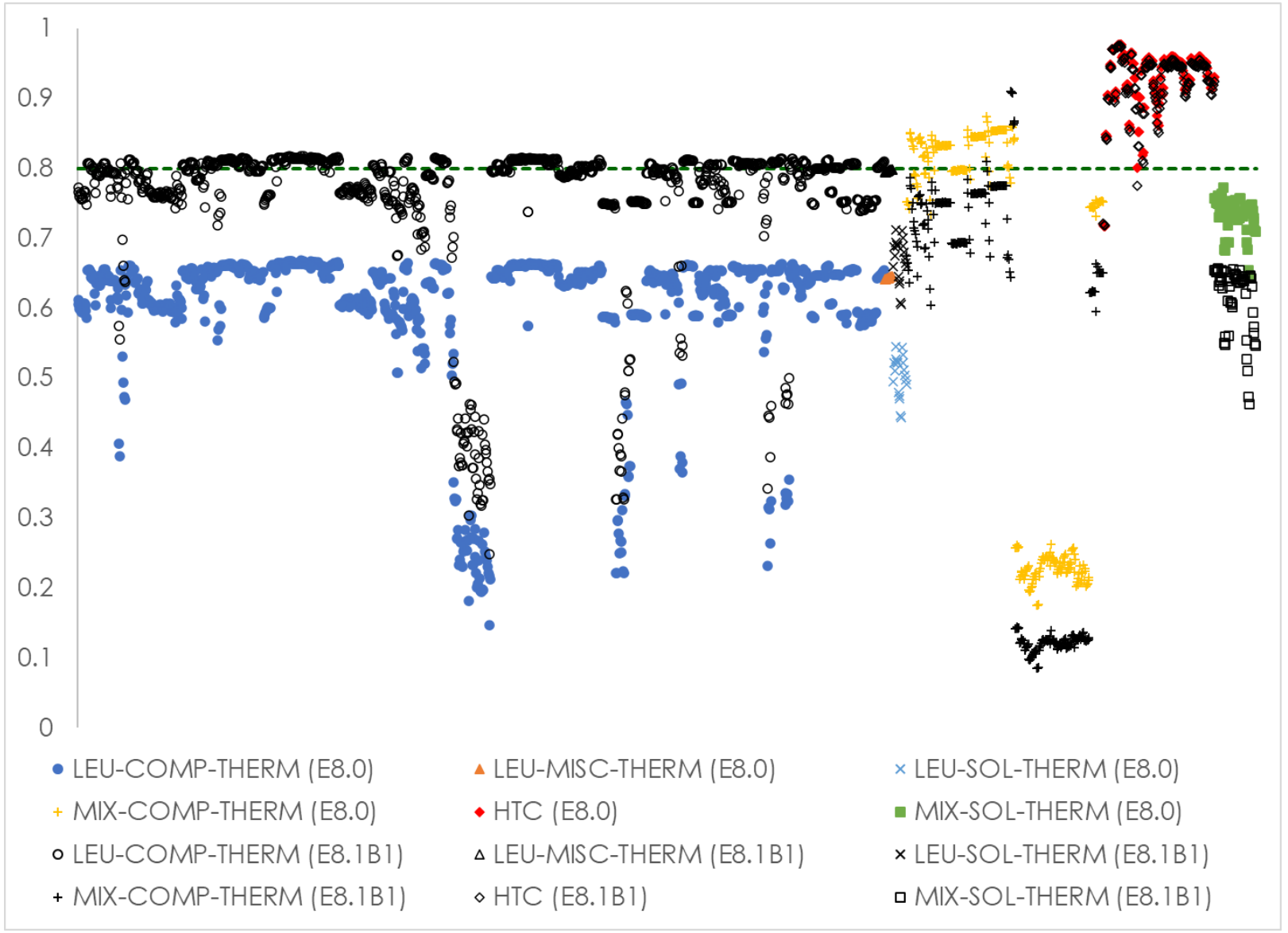
SNF cask c_k calculations

- The integral index c_k is used to assess similarity between an application system and potentially applicable benchmarks
- Calculated as the Pearson correlation coefficient of nuclear data induced uncertainty in k_{eff}

$$S_{R_1,\Sigma_x} \cdot Cov_{\Sigma_x,\Sigma_y} \cdot S^T_{R_2,\Sigma_y} = \sigma^2_{R_1,R_2} \Longrightarrow c_k = \frac{\sigma^2_{R_1,R_2}}{\sigma_{R_1}\sigma_{R_2}}$$

- Covariance data changes the relative contribution of different sensitivities to the overall similarity assessment
- Impacts are typically assessed on PWR SNF at 40 GWd/MTU
  - Included in the regulatory basis documents discussed earlier

Results: ENDF/B-VIII.1β1 vs. ENDF/B-VIII.0



Conclusions

- Data-induced uncertainty significantly increased for thermal ^{235}U-fueled systems
- ^{239}Pu covariance changes are worrying
- ^{103}Rh only significant important fission product change
- Impact of ENDF/B-VIII.1β1 on burnup credit similarity assessments similar to ENDF/B-VII.1 data

Acknowledgment

This presentation was supported by the Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the Department of Energy.

OAK RIDGE National Laboratory

Questions?