ENDF/B-VIII.0 Augmented Covariance Data, the first iteration*

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LARGE UNCERTAINTIES ON INTEGRAL DATA

Nuclear data are necessary for reliable modeling and simulation of the next generation of nuclear reactors. However, the variation in the ratio of the computed to experimental values (C/E) for certain types of nuclear systems is much less than predicted by evaluated nuclear data file (ENDF)/B covariances. Figure 1 provides an example of a set of metal-plutonium–fueled, fast-spectrum (PU-MET-FAST) integral experiments from the International Criticality Safety Benchmark Evaluation Project (ICSBEP) [1] in the Oak Ridge National Laboratory (ORNL) VALID [2] database. The variation in the C/E values, shown with one standard deviation error bars, is 100% covered by both the SCALE [3] and ENDB/VIII.0 [4] covariance data. This is due to the comparisons to integral data that are essential during the evaluation process. However, the ENDF evaluations represent uncertainties and correlations in differential data only; they do not reflect the impact of the comparison to integral data in the covariance evaluations.

APPROACH PHILOSOPHY

The discrepancy originates from a non-systematic treatment of the integral data in the evaluation process. Therefore, the solution is also likely to be non-systematic. The approach for the effort described in this paper is to test proposed solutions and iterate with the nuclear data community and users. The method used to augment the covariance data will be documented exactly, thereby ensuring that everything will be reproducible. The goal of the first iteration is not to solve the problem outright, but to show conservative progress in the right direction.

Much of the problem can be attributed to very few important nuclides and some of their specific observables. In the first iteration, the focus is on estimating the cross correlations between nu-bar and the fission cross section for ^{239}Pu. The ENDF/B-VIII.0 covariance matrix will be augmented with estimates of the bulk correlation coefficient (on a coarse 3-group structure). Only new cross correlations will be added, and variances or existing correlations will not be adjusted.

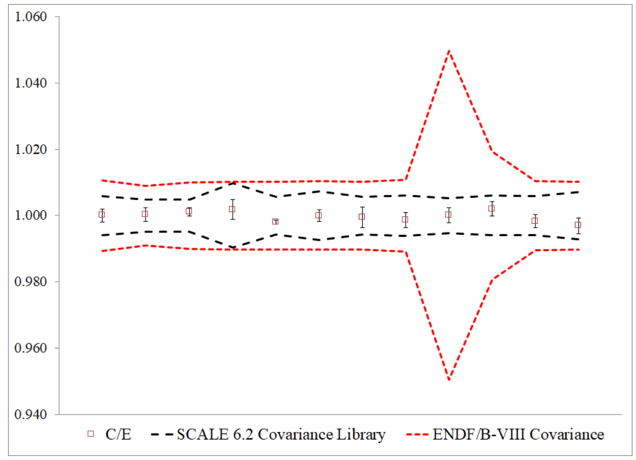

Figure 1. Results for PU-MET-FAST systems. The experiments are sorted by their ICBSEP-assigned number on the horizontal axis. C/E values are shown on the vertical axis.

RESULTS

The technical execution of this concept involved the use of the generalized-linear-least-squares (GLLS) code TSURFER [5] of the SCALE code package to perform global nuclear data adjustment to ICSBEP benchmarks in the VALID database. Only the posterior cross correlations were extracted, while the posterior (adjusted) variance was discarded. The estimated correlation coefficients are presented in Table 1.

Table 1 shows relative stability, in sign and order of magnitude, of the estimated correlation coefficients, regardless of which integral benchmarks were used in the GLLS TSURFER calculation. The bulk cross correlations are only weakly dependent on the choice of integral system. This result is intuitive; nu-bar and fission of ^{239}Pu are used in very similar ways between different integral experiments. This is an important argument for reliably estimating correlation coefficients after the ENDF/B-VIII.0 covariance library has been created.

The ENDF/B-VIII.0 covariance library augmented only by the estimated bulk cross correlations between nu-bar and fission for ^{239}Pu results in a reduction of uncertainty by 10–20% in the PU-MET-FAST systems the VALID

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library. The results of the propagation of uncertainty studies are presented in Figure 2, with the augmented library labeled as "Adj v0." The SCALE 6.2 Covariance Library is based on ENDF/B-VII.1 and therefore shows a lower propagated uncertainty than ENDF/B-VIII.0, due mainly to the difference between the uncertainty on the microscopic cross section of ^{239}Pu between the two libraries.

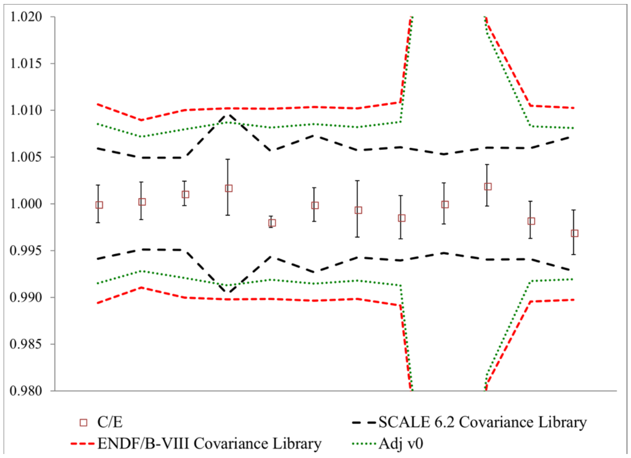

Figure 2. Results for PU-MET-FAST systems. The experiments are sorted by their ICBSEP-assigned number on the horizontal axis. C/E values are shown on the vertical axis.

FUTURE DEVELOPMENT

The future development of this work will only estimate the most impactful cross correlations. The objective is not to have a full covariance matrix for the entire ENDF/B-VIII.0 library. Furthermore, in the spirit of the first iteration, only cross correlations will be estimated, as there is currently no plan to the adjust variances which are believed to be bound by the evaluated differential nuclear data.

Collaboration with the community will be key. Testing whether propagated uncertainty on unstudied integral systems is not significantly reduced is very important for this approach to be conservative. The goal is to reduce uncertainty as far as is justified by realistic estimation of generic cross correlations independent of integral system. Benchmarks beyond the ICSBEP (e.g., reaction rate, shielding, and transmission) will be included and tested frequently with the nuclear data user community.

The goal is not to reduce propagated nuclear data uncertainty exactly down to the level of C/E discrepancy in integral data. However, through careful examination of nuclear data correlations (energy, reaction, isotope), propagated uncertainties on well-known systems can be small and large for systems without vast validation data

ACKNOWLEDGEMENTS

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TABLE 1: Coarse group cross correlation estimates for ^{239}Pu based on including different VALID benchmarks in the TSURFER GLLS adjustment (in percent).

PU-MET-FAST (PMF)

	fission fast	fission intermediate	fission thermal
nu-bar fast	-53	-33	
nu-bar intermediate	-2	-1	-1
nu-bar thermal	N/A	N/A	N/A

PU-SOL-THERM (PST) (single experiment from each benchmark series)

	fission fast	fission intermediate	fission thermal
nu-bar fast	N/A	N/A	N/A
nu-bar intermediate	-1	-2	-2
nu-bar thermal	-7	-10	-10

PU-SOL-THERM (PST) (all experiments)

	fission fast	fission intermediate	fission thermal
nu-bar fast	N/A	N/A	N/A
nu-bar intermediate	-2	-3	-3
nu-bar thermal	-9	-15	-16

MIX-COMP-FAST (MCF)

	fission fast	fission intermediate	fission thermal
nu-bar fast	-18	-19	
nu-bar intermediate	-4	-5	-5
nu-bar thermal	N/A	N/A	N/A

MIX-SOL-THERM (MST) (single experiment from each benchmark series)

	fission fast	fission intermediate	fission thermal
nu-bar fast	N/A	N/A	N/A
nu-bar intermediate	-2	-3	-3
nu-bar thermal	-8	-13	-14

MIX-SOL-THERM (MST) (all experiments)

	fission fast	fission intermediate	fission thermal
nu-bar fast	N/A	N/A	N/A

nu-bar intermediate	-3	-4	-4
nu-bar thermal	-11	-17	-18

MIX-COMP-THERM (MCT) (single experiment from each benchmark series)

	fission fast	fission intermediate	fission thermal
nu-bar fast	N/A	N/A	N/A
nu-bar intermediate	-3	-5	-5
nu-bar thermal	-4	-7	-7

MIX-COMP-THERM (MCT) (all experiments)

	fission fast	fission intermediate	fission thermal
nu-bar fast	N/A	N/A	N/A
nu-bar intermediate	-4	-5	-5
nu-bar thermal	-6	-10	-11

All cases in VALID containing plutonium

	fission fast	fission intermediate	fission thermal
nu-bar fast	-54	-34	
nu-bar intermediate	-3	-3	-3
nu-bar thermal	-7	-10	-10