How can a diverse set of integral and semi-integral measurements inform identification of discrepant nuclear data?

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Nuclear data are widely used by the international community for a variety of applications, including criticality safety, reactor performance, and material safeguards. Despite the breadth of use-cases, critical benchmarks are primarily used for nuclear data validation, which are sensitive to specific energy regions and nuclides and are unable to uniquely constrain, for instance, neutron fission parameters (i.e., the average fission multiplicity, fission cross section, and fission spectrum). As a consequence, general-purpose nuclear data libraries, such as ENDF/B-VIII~\cite{Brown2018}, may have deficiencies that, while not apparent in criticality applications, negatively impact other applications, such as non-destructive analysis of special nuclear material~\cite{Miller2014, Evans2014}.

Recent work by the Experiments Underpinned by Computational Learning for Improvements in Nuclear Data (EUCLID) project demonstrated~\cite{Neudecker2020} that machine learning (ML) can effectively augment expert judgment in identifying discrepant nuclear data. The ML algorithm used random forests and the SHAP metric to determine which nuclear data contribute most to bias between measured and simulated $\kappa_{eff}$ values. Specifically, the authors were able to identify issues, both known (e.g., $^{239}$Pu thermal and resonance parameters in ENDF/B-VII) and unknown (e.g., $^{19}$F neutron inelastic scatter cross section from 0.4–0.9 MeV). EUCLID further applied~\cite{Neudecker2021} the ML algorithm to studying the impact of combining critical benchmarks with the LLNL pulsed sphere measurements~\cite{Wong1972}. Because the pulsed sphere time-of-flight neutron leakage spectra were sensitive to nuclear data in a different energy regime than compared to critical benchmarks, nuclear data for several nuclides could be identified as reliable ($^{1.5}$Li, $^{7}$Li, $^{9}$Be, $^{14}$N, $^{235,238}$U, and $^{239}$Pu) or having potential shortcomings ($^{6}$Li, $^{12}$C, $^{24–26}$Mg, $^{27}$Al, $^{48}$Ti, $^{56}$Fe, and $^{208}$Pb).

This work explores how the diverse set of integral and semi-integral responses,

- Critical benchmarks,
- Pulsed spheres measurements,
- Beta-effective measurements,
- Reactivity coefficient measurements,
- Reaction rate ratio measurements, and
- Neutron multiplicity counting benchmarks,

are differently (or similarly) sensitive to the same nuclear data and discusses how that adds to understanding shortcomings in nuclear data libraries. The focus will be on how changes between the response
sensitivities can potentially inform the ML-based identification of discrepancies in plutonium fission parameters. Future work will extend this analysis to a larger nuclear data set and discuss the impact on nuclear data validation.

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