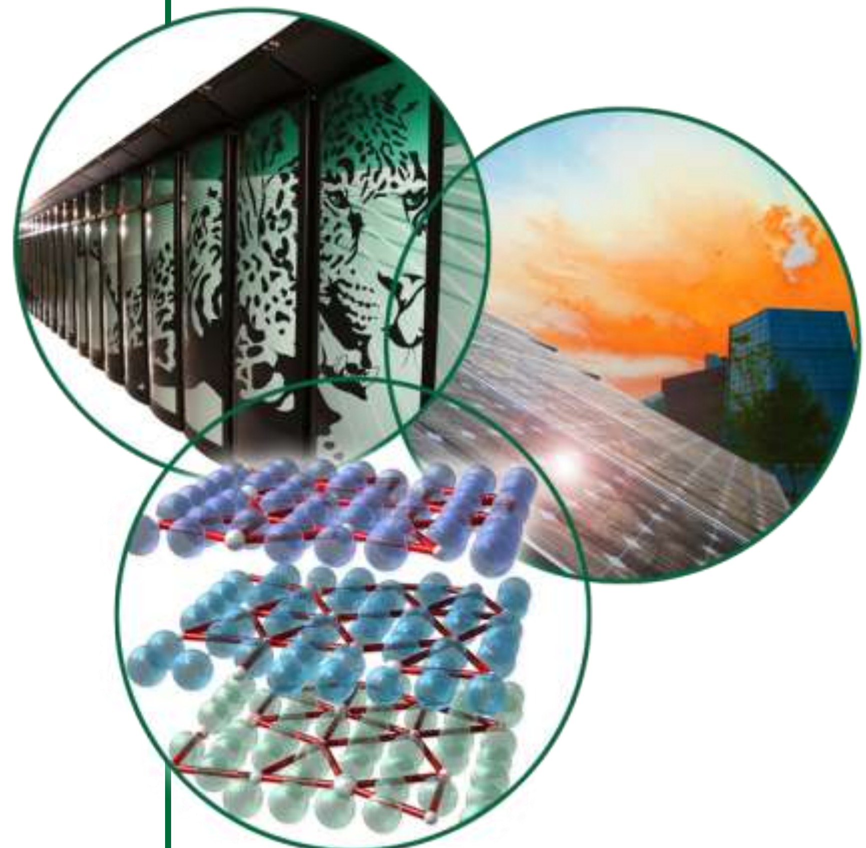
Data Adjustment Exercises for Fast Critical Benchmark Problems Using SCALE



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Introduction

- The Working Party on International Nuclear Data Evaluation Co-operation (WPEC) Subgroup 33 was established to study the use of integral experiments and covariance data for nuclear data adjustment and to recommend a set of best practices for improving evaluated nuclear data files.
- In the Phase II Benchmark of Subgroup 33, participants were asked to calculate integral responses for several fast critical benchmark experiments and nuclear data sensitivity coefficients for these quantities. These sensitivity coefficients are used to guide the adjustment of nuclear data to minimize the difference between the calculated and experimental responses.
- This work summarizes the results of the Oak Ridge National Laboratory's (ORNL) participation in this data adjustment exercise using the sensitivity and uncertainty analysis capabilities of the SCALE code system.

Methodology – Sensitivity Coefficients

- Sensitivity coefficients describe the change in a system response that occurs in response to uncertainty or perturbations in a nuclear data parameter.

$$S_{k,\Sigma_x} = \frac{\delta k / k}{\delta \Sigma_x / \Sigma_x}$$

- Sensitivity coefficients were calculated for the eigenvalue and several spectral index responses using the TSUNAMI-1D code.
- Because TSUNAMI-1D uses the one-dimensional XSDRNPM code to solve the forward, adjoint, and generalized-adjoint transport equations, the scope of this analysis was limited to the one-dimensional benchmark cases (JEZEBEL239, JEZEBEL240, and FLATTOP-PU).
- The development of a 2D (R–Z) or 3D generalized perturbation tool would allow TSUNAMI to analyze all cases in this benchmark study.

Methodology – Data Adjustment

- **The Sensitivity Data Files (SDFs) generated from these calculations were passed to the TSURFER code, which used them to guide the cross-section adjustment in this study.**
  - **TSURFER uses a Generalized Linear Least Squares (GLLS) approach to adjust cross-section data and minimize the difference between the experimental and application responses.**

$$\chi^2 = \underbrace{\sum_{\alpha}^{N}\left(\frac{\alpha'-\alpha}{\sigma_\alpha}\right)^2}_{\text{data adjustments in units of variance}} + \underbrace{\sum_{k}^{M}\left(\frac{k'-k}{\sigma_k}\right)^2}_{\text{measurement adjustments in units of variance}} \quad \text{(no correlations)}$$

  - **TSURFER filters the experimental and application cases and identifies outlier cases which are ignored during the data adjustment process. The Delta-Chi-Square filtering method was used in this study.**

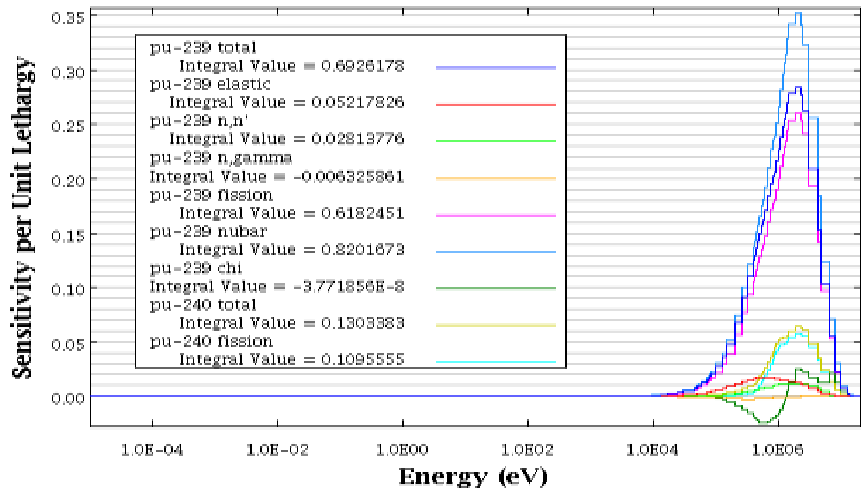
- **All calculations used ORNL ENDF/B-VII 238-group cross-section data and ENDF/B-V 44-group covariance data.**

Sensitivity Coefficient Results

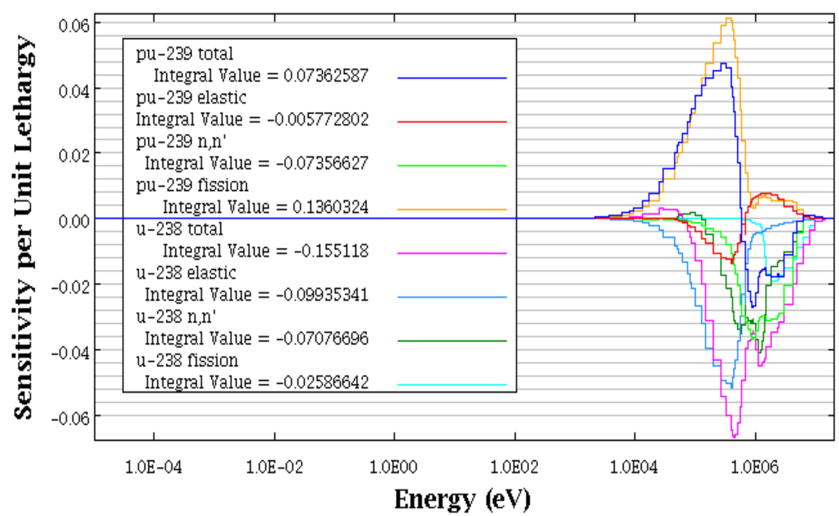
Experimental Responses of Interest

Experiment	Responses
Jezebel-Pu239	k_{eff}
	F28/F25
	F49/F25
	F37/F25
Jezebel-Pu240	k_{eff}
Flattop	k_{eff}
	F28/F25
	F37/F25

- k_{eff} = System Eigenvalue
- F25 = U-235 Fission Reaction Rate
- F28 = U-238 Fission Reaction Rate
- F37 = Np-237 Fission Reaction Rate
- F49 = Pu-239 Fission Reaction Rate



Sample Jezebel-Pu240 k_{eff} sensitivities



Sample Flattop F37/F25 sensitivities

TSURFER Data Adjustment Results

Initial, Experimental, and Adjusted Response Values

Experiment	Response	Calc. Value	Exp. Value	Adj. Value
Jezebel-Pu239	k_{eff}	1.0000	1.0000	0.9996
	F28/F25	0.2086	0.2133	0.2134
	F49/F25	1.4243	1.4609	1.4393
	F37/F25	0.9714	0.9835	0.9774
Jezebel-Pu240	k_{eff}	1.0008	1.0000	1.0003
Flattop	k_{eff}	1.0026	1.0000	1.0005
	F28/F25	0.1746	0.1799	0.1789
	F37/F25	0.8477	0.8561	0.8549

Initial and Adjusted C/E Values

Experiment	Response	Initial C/E	Adjusted C/E
Jezebel-Pu239	k_{eff}	1.0000	0.9996
	F28/F25	0.9782	1.0006
	F49/F25	0.9749	0.9852
	F37/F25	0.9877	0.9938
Jezebel-Pu240	k_{eff}	1.0008	1.0003
Flattop	k_{eff}	1.0026	1.0005
	F28/F25	0.9705	0.9946
	F37/F25	0.9902	0.9986
Average C/E		**0.9881**	**0.9966**

- **The TSURFER data adjustment process produced an adjusted set of nuclear data that improved the accuracy of nearly all of the response parameters.**

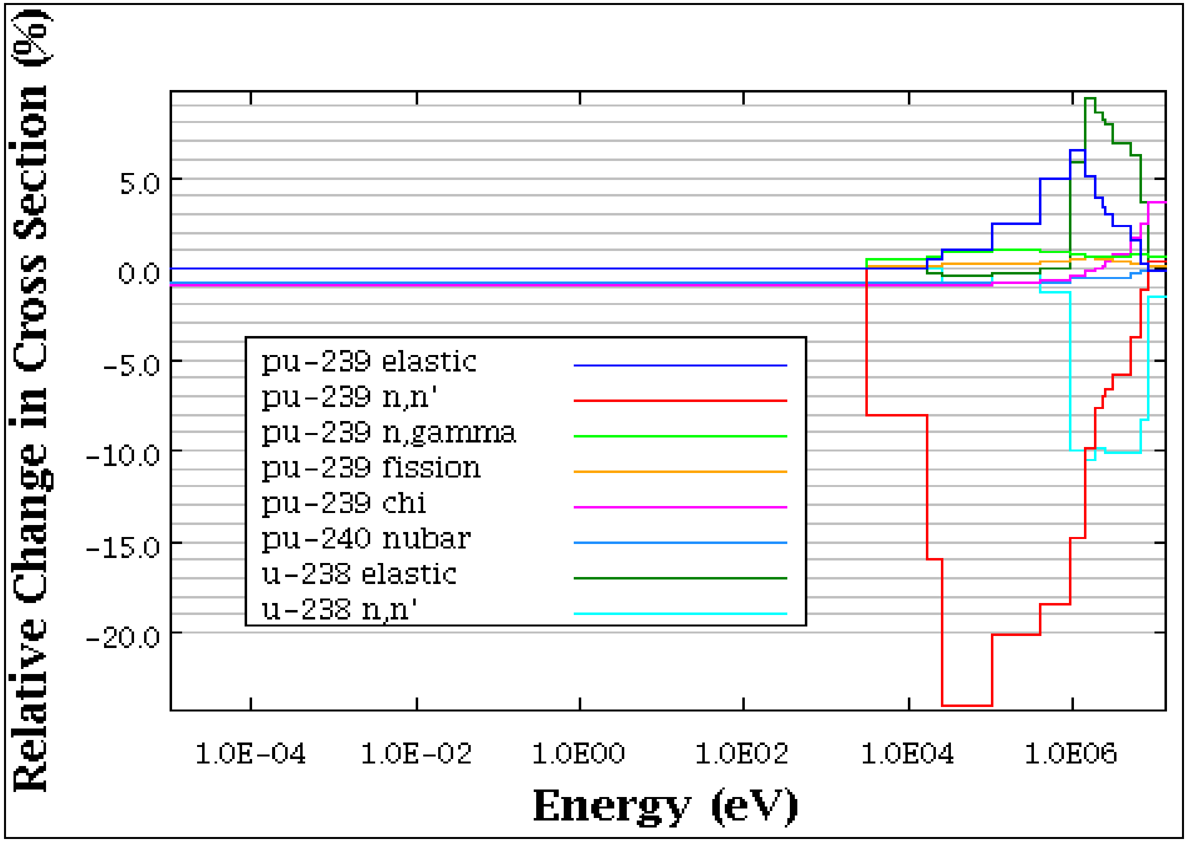
Effect of the Nuclear Data Adjustment on the Response Uncertainties

- **The GLLS data adjustment process significantly reduced the amount of uncertainty in the calculated responses.**

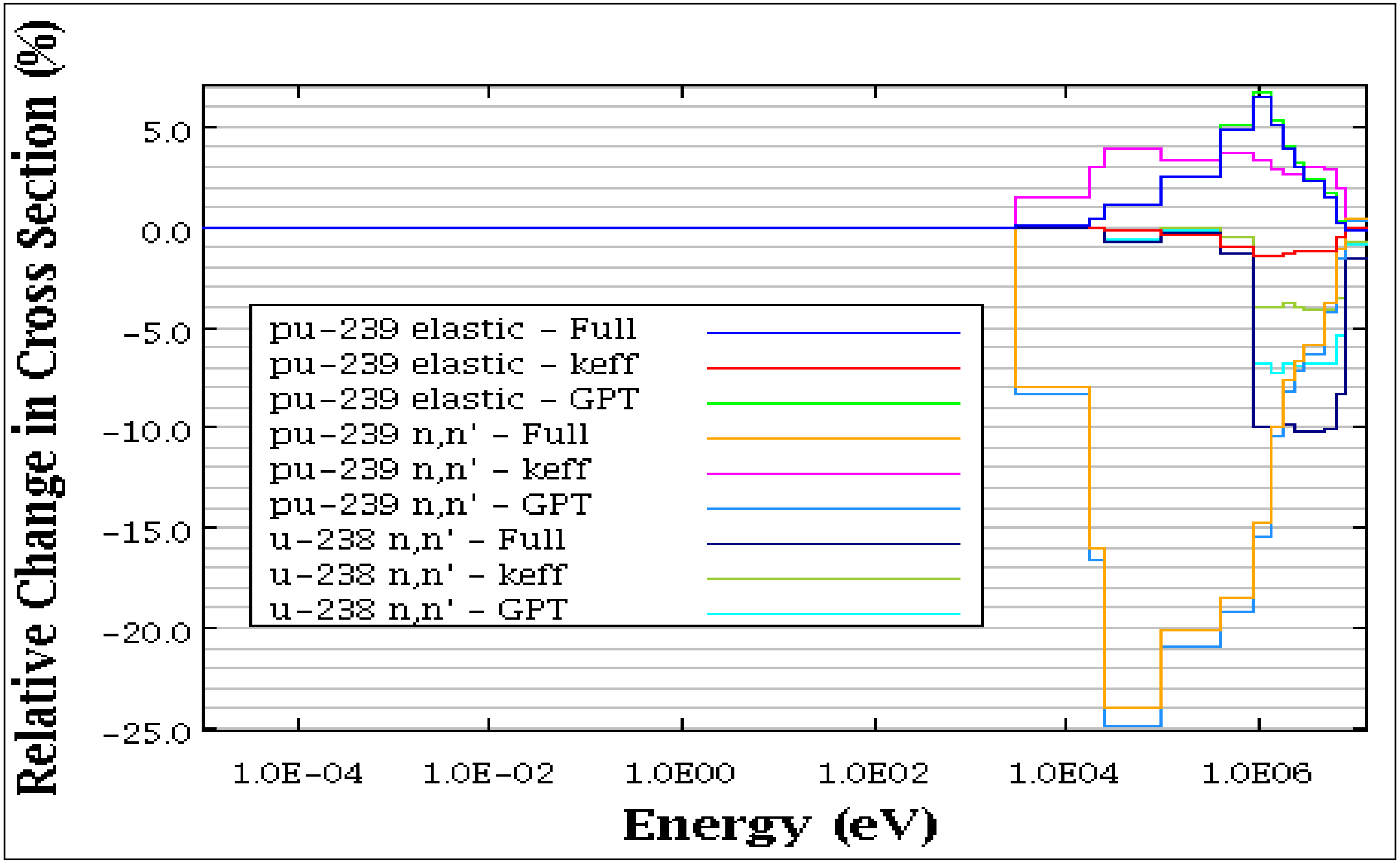
Exp.	Resp.	Exp. Unc.	Calc. Unc.	Adj. Unc.	Unc. Reduct.
Jezebel-Pu239	k_{eff}	0.20%	1.39%	0.17%	87.5%
	F28/F25	1.10%	4.11%	0.85%	79.3%
	F49/F25	0.90%	0.81%	0.54%	32.6%
	F37/F25	1.40%	7.49%	1.01%	86.6%
Jezebel-Pu240	k_{eff}	0.20%	1.21%	0.17%	85.9%
Flattop	k_{eff}	0.30%	1.25%	0.25%	79.7%
	F28/F25	1.10%	3.67%	0.81%	78.0%
	F37/F25	1.40%	7.40%	1.00%	86.4%

TSURFER Data Adjustment Results

- **The largest cross-section adjustments were observed for the elastic and *(n, n')* reactions.**
- **The predicted adjustments for the fission reactions were relatively small compared to other adjustments.**



The Importance of the GPT Analysis



Conclusions and Future Work

- The TSUNAMI methodology for nuclear data adjustment has been applied to several test problems within the scope of the WPEC Subgroup 33 mission. The TSUNAMI-1D code calculated sensitivity coefficients for the test problems, and these sensitivity coefficients were used by the TSURFER code to adjust the nuclear data to minimize the difference between the calculated and experimental responses of interest.
- The ^{239}Pu, ^{240}Pu, and ^{238}U elastic and inelastic cross sections were affected the most by this adjustment.
- Future work includes developing a generalized perturbation capability in TSUNAMI-3D and expanding the scope of this study to span many other systems, including several challenge problems with C/E values that are not close to unity.

References

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