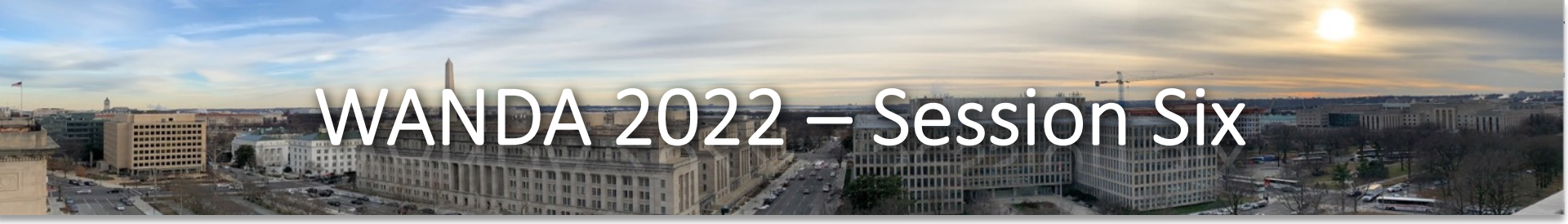

WANDA 2022 – Session Six

Nuclear Data Adjustment and Impact on Applications

Chairs: Denise Neudecker (LANL) Amanda Lewis (NNL) Robert Casperson (LLNL)

NDWG Advisor: Patrick Talou (LANL)

Rapporteurs: Katelyn Cook (RPI), Ali Dreyfuss (LLNL), Daniel Siefman (LLNL)

Introduction to Nuclear Data Adjustment

WANDA 2022
Session 6 – Nuclear Data Adjustment and Impact on Applications
March 3, 2022

Robert Casperson
Lawrence Livermore National Laboratory

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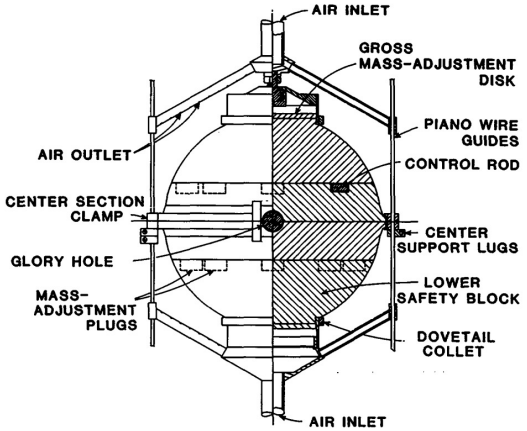
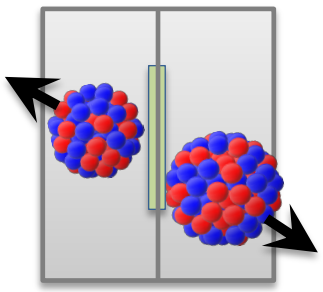
Lawrence Livermore National Laboratory

What is adjustment?

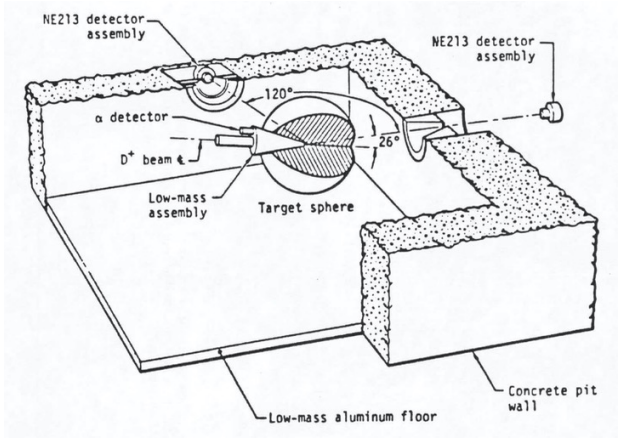
- Adjustment refers to the inclusion of integral data in a differential evaluation.
- Adjustment requires prior knowledge of the differential evaluation, and realistic nuclear data for all materials the integral system is sensitive to.
- Integral data often has smaller uncertainties than differential data, so adjustment can reduce uncertainties in an application specific way.



Criticality: 0.3%

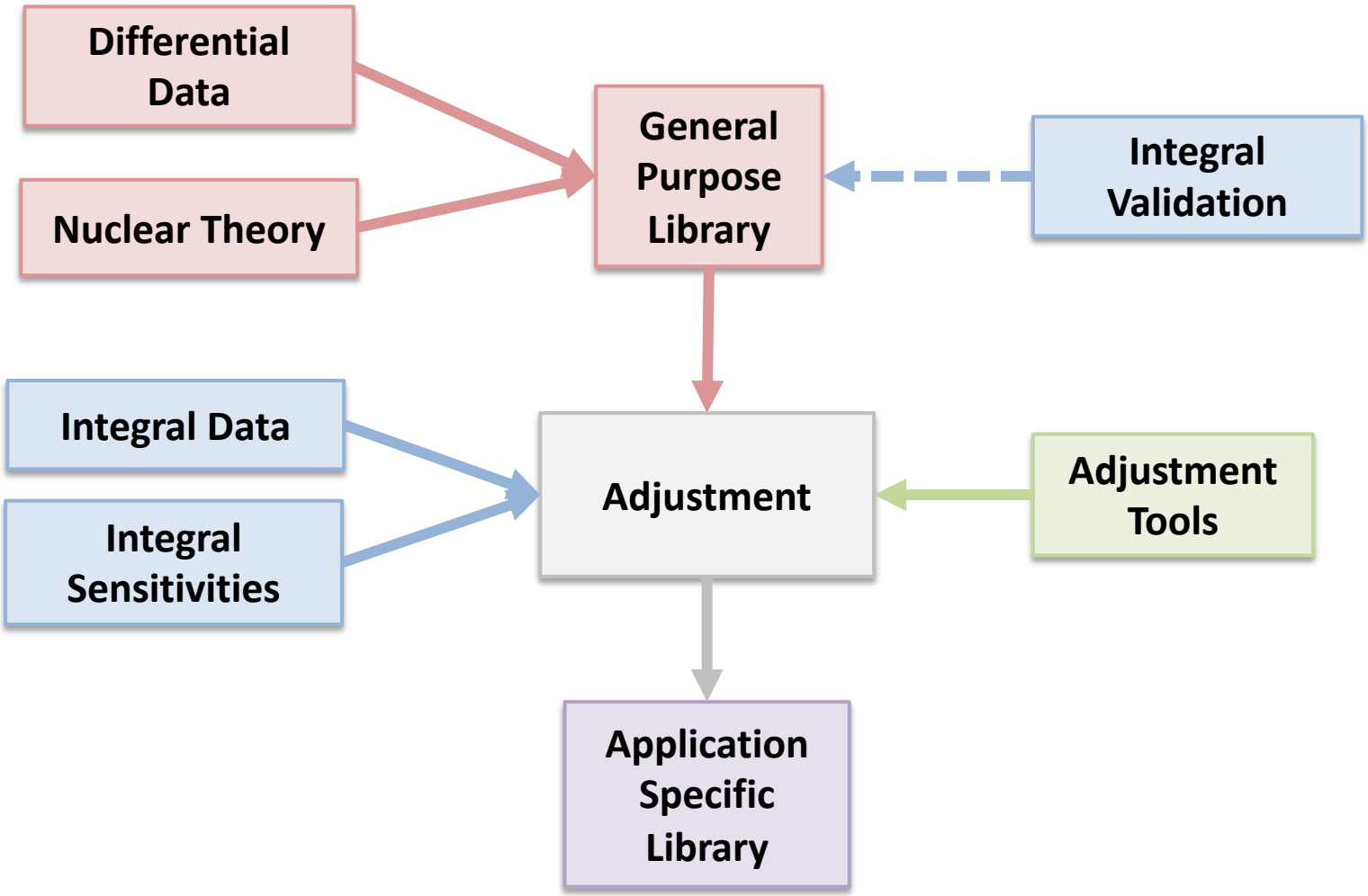


Fission Ratios: 1%



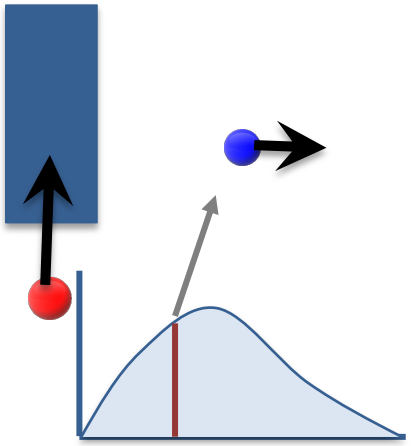
Pulsed Spheres: 4-7%

The adjustment process

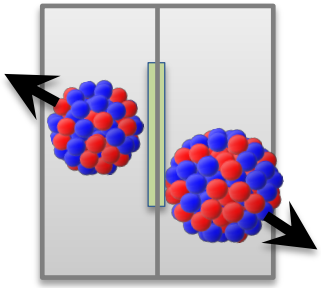


Simplest example of integral data

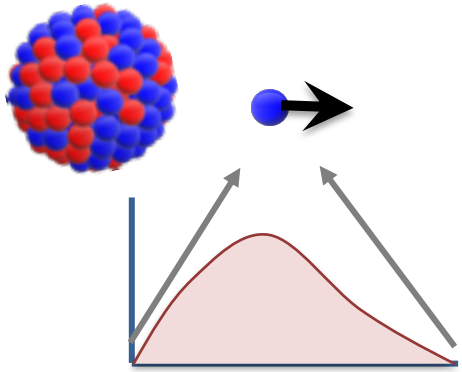
Spallation neutrons with nToF



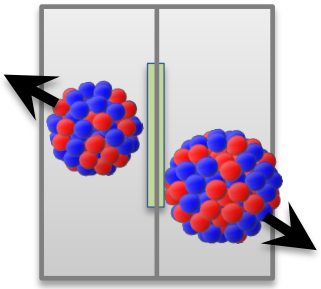
$^{239}Pu/^{235}U$ fission chamber



Neutrons from ^{252}Cf fission

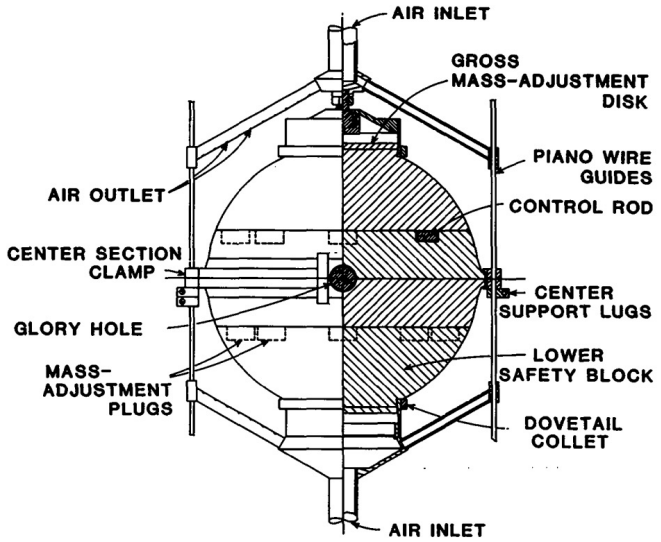


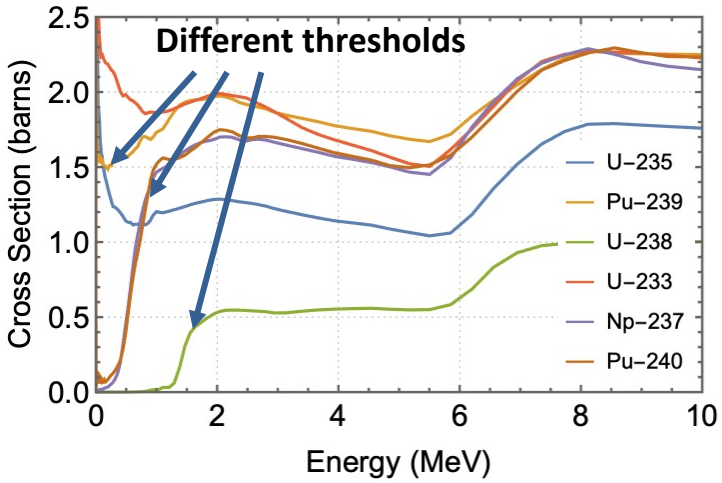
$^{239}Pu/^{235}U$ fission chamber



- There are many differential fission measurements with systematic uncertainty of 1-2%.
- Integral measurements with $^{252}Cf(sf)$ neutrons require shape information, but also have uncertainties of 1%.
- **There is a 2.4% discrepancy between ENDF and these $^{252}Cf(sf)$ neutron measurements,** so adjustment may have a large impact on actinide nuclear data.

A more complex example of integral data





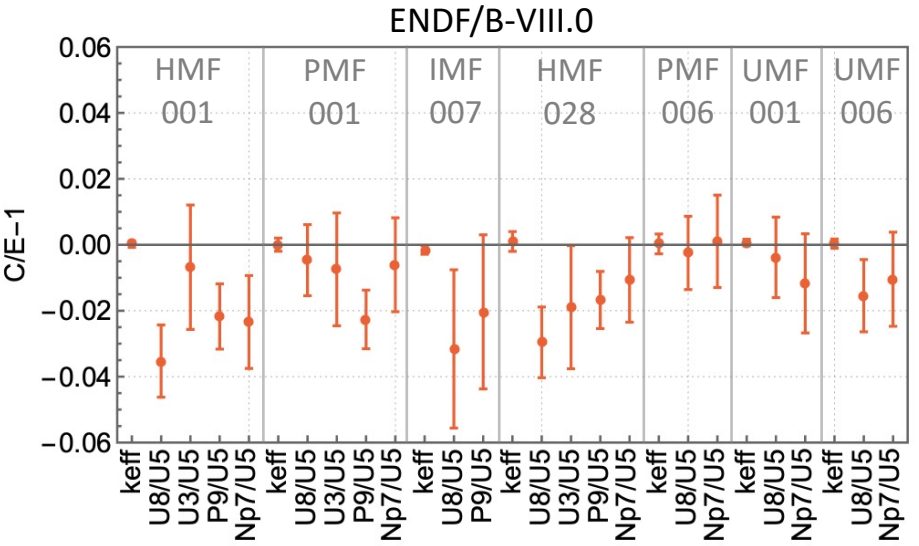
- Critical assembly fission ratio measurements are sensitive to fission cross sections and the assembly neutron spectrum.
- Criticality data is considered here along with fission ratios to ensure PFNS and scattering properties that are consistent with the critical assembly.
- The variety of fission cross section thresholds available also constrain the neutron spectrum.
  - One concern about these measurements is the need for modeling corrections due to the presence of the fission chamber.
  - Otherwise, the measurements were quick, which allowed for multiple fission chambers and foil thicknesses.

The ENDF/B-VIII.0 Spectral Indices Validation Data

D. A. Brown et al., Nuclear Data Sheets **148**, 1 (2018).

Assembly	Quantity	U238f/U235f	Np237f/U235f	U233f/U235f	Pu239f/U235f
Godiva	Calc	0.1583	0.8318	1.5793	1.3846
(HMF001)	Exp-B	0.1643 ±0.0018	0.8516±0.012		1.4152 ± 0.014
	Exp-A	0.1642 ±0.0018	0.837 ±0.013	1.59±0.03	1.402±0.025
	Calc/Exp	C/E=0.9636	C/E=0.9767	C/E=0.9933	C/E=0.9784
Jezebel	Calc	0.2121	0.9770	1.5560	1.4273
(PMF001)	Exp-B	0.2133 ±0.0023	0.9835 ±0.014		1.4609 ± 0.013
	Exp-A	0.2137 ±0.0023	0.962 ±0.016	1.578 ±0.027	1.448 ±0.029
	Calc/Exp	C/E=0.9943	C/E=0.9934	C/E=0.9924	C/E=0.9770
Big-10	Calc	0.0358			1.170
(IMF007)	Exp	0.0375 ±0.0009			1.198 ± 0.028
	Calc/Exp	C/E=0.954			C/E=0.977
Jezebel-23	Calc	0.2121	0.9851		
(UMF001)	Exp-B	0.2131 ±0.0026	0.9970 ±0.015		
	Exp-A	0.2131 ±0.0023	0.977 ±0.016		
	Calc/Exp	C/E=0.9951	C/E=0.988		
Flattop-25	Calc	0.1451	0.7735	1.5664	1.3622
(HMF028)	Exp-B	0.1492 ±0.0016	0.7804 ±0.01	1.608 ±0.003	1.3847 ±0.012
	Exp-A	0.149 ±0.002	0.76 ±0.01	1.60 ±0.003	1.37 ±0.02
	Calc/Exp	C/E=0.9722	C/E=0.9911	C/E=0.9741	C/E=0.9837
Flattop-Pu	Calc	0.1801	0.8593		
(PMF006)	Exp-B	0.1799 ±0.002	0.8561 ±0.012		
	Exp-A	0.180 ±0.003	0.84 ±0.01		
	Calc/Exp	C/E=1.0011	C/E=1.0037		
Flattop-23	Calc	0.1892	0.9030		
(UMF006)	Exp-B	0.1916 ±0.0021	0.9103 ±0.013		
	Exp-A	0.191 ±0.003	0.89 ±0.01		
	Calc/Exp	C/E=0.9876	C/E=0.9920		

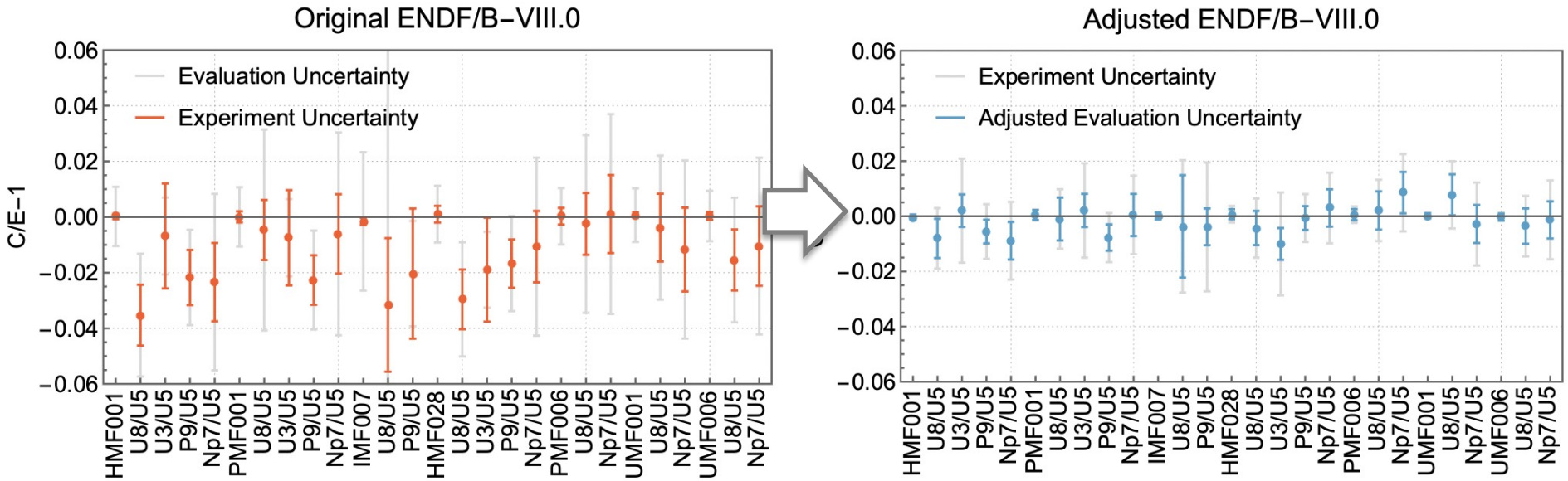
A decades-spanning typo



- Assembly letters indicate main actinide.
- For many assemblies, reaction rates systematically low by ~2%; all are ratios to ^{235}U(n,f).
- Some relevant fission ratios claim 1% uncertainty.

What can you do when validation data fails to validate? Adjust!

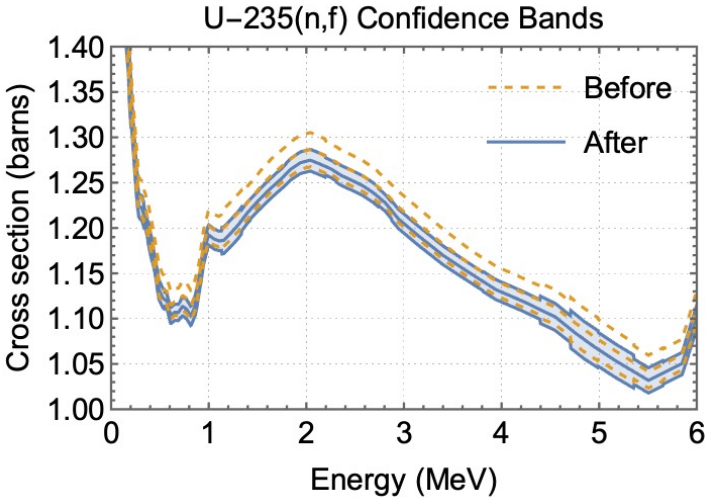
Adjustment with many integral data

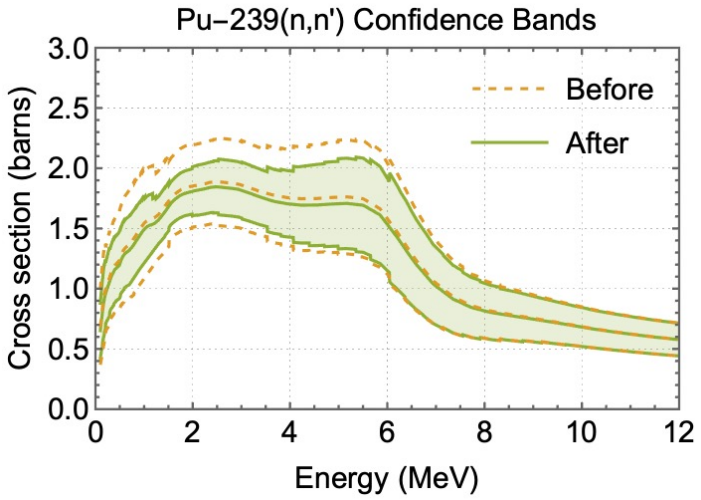


- Adjustment includes keff and reaction rates, so resulting evaluation consistent with both.
- This set of integral data from the ENDF spectral indices table has enough statistical significance to cause substantial changes in differential evaluation.

Impact on major actinide nuclear data

- Adjustment indicates a change in the $^{235}U(n,f)$ cross section.
- Adjusted fission and inelastic scattering uncertainties are reduced, resulting from combination of fission data, spectral sensitivity, and criticality data.
- Impact not sensitive to keff uncertainty; just as significant when all are set to 0.3%.

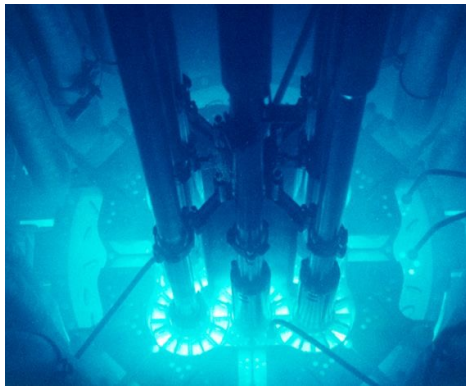




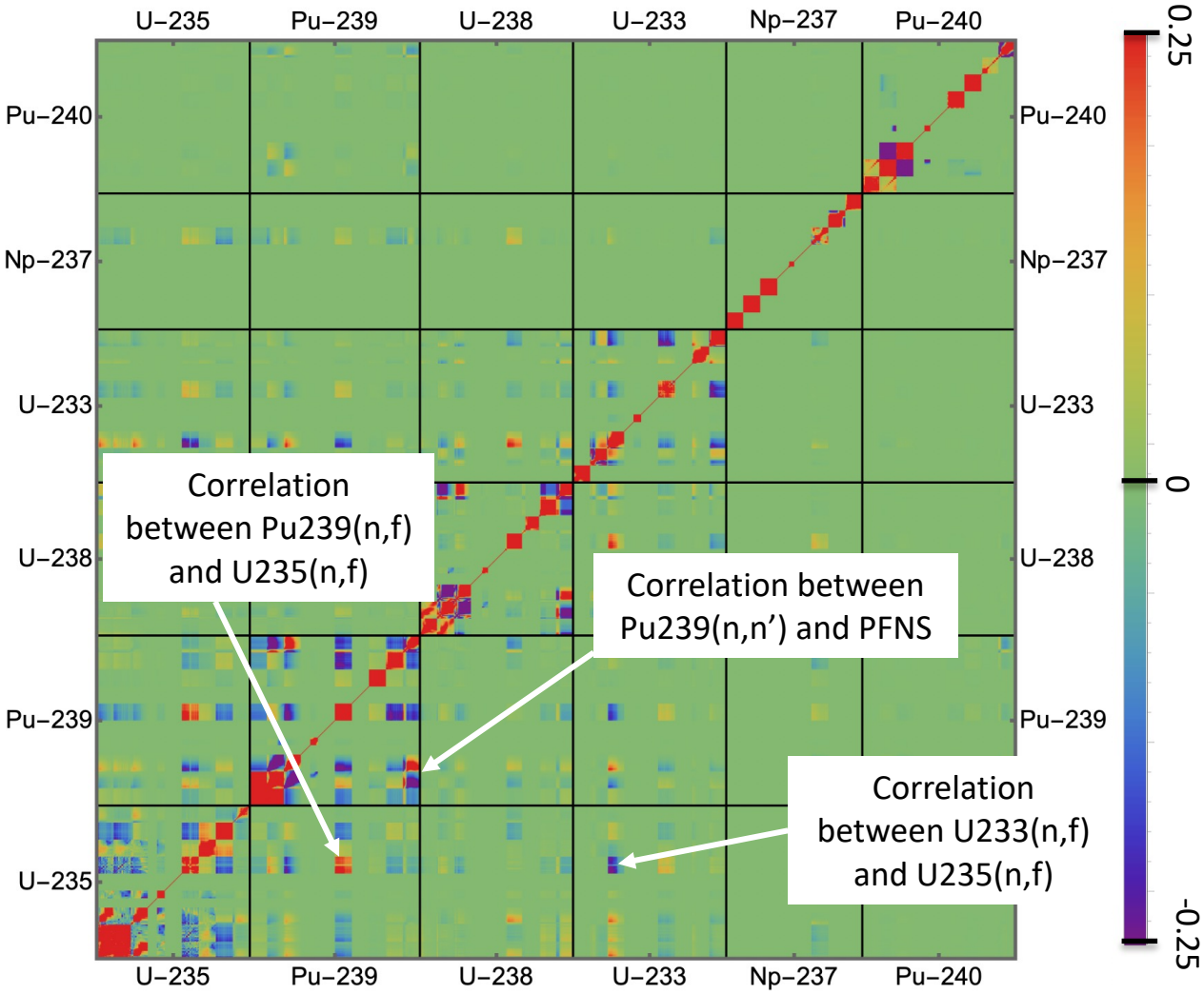
Who would be impacted by adjustment?

Several programs rely on actinide and other nuclear data:

- Nuclear Energy
- Criticality Safety
- Stockpile Stewardship
- Nuclear Forensics
- Incident Response
- Nuclear Threat Reduction



Correlations between isotopes



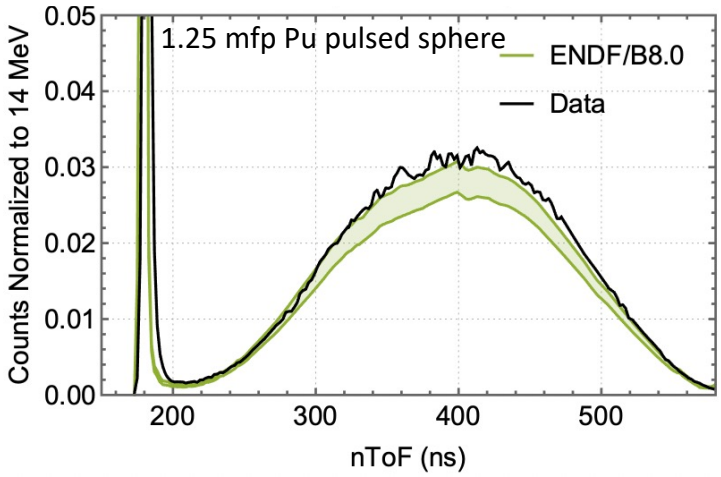
Reaction order from lower left to upper right:

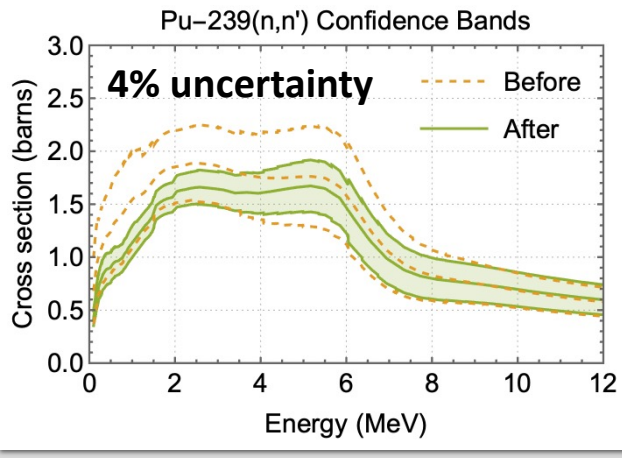
- (n,tot)
- (n,el)
- (n,n')
- (n,2n)
- (n,3n)
- (n,f)
- (n,g)
- nubar
- pfns

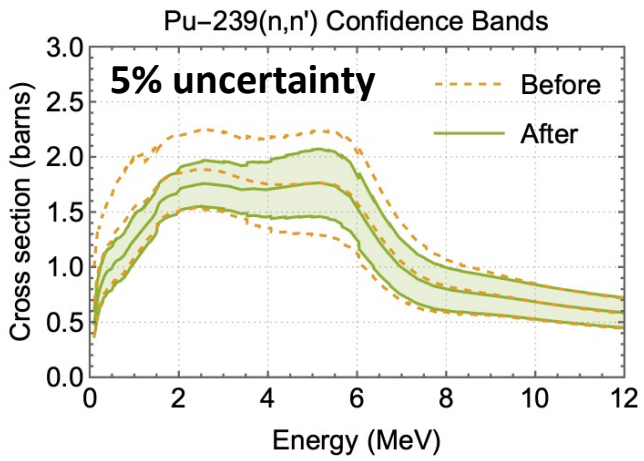
Adjusting with several integral data requires tracking correlations between all materials.

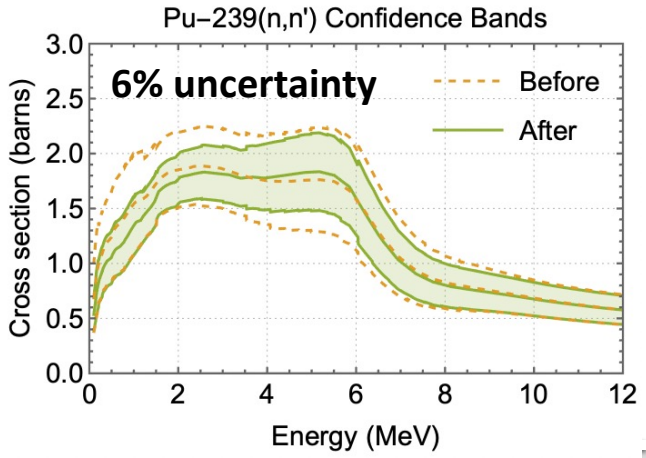
Adjustment with pulsed spheres

- Pulsed sphere nToF spectra are very sensitive to inelastic and prompt fission neutron spectra.
- Due to 14 MeV source, fission-relevant nuclear data only impacted if critical assembly constraint included.
- As shown below, result is very sensitive to efficiency and uncertainty assumptions.









Takeaways About Adjustment

- Adjustment is a useful tool for adding integral data to a differential evaluation.
- The small uncertainties of many integral experiments make it extremely impactful when it can be used.
- Adjustment relies on realistic uncertainties for all relevant materials.
- It provides a method for dealing with problems found in validation data.
- There is a diverse set of historical integral data that could impact many programs but would require a careful understanding of uncertainties.

Adjustment method

- There are several methods for adjustment, but we have used a hybrid of Monte Carlo sampling and sensitivity analysis for the regression (GLS).
  - Covariance matrices generated from ENDF/B-VIII.0 using NJOY.
  - Monte Carlo sample phases are decorrelated, which requires covariance rank + 1 samples.
  - Sensitivity vectors appear in joint evaluation/integral model covariance matrix.
  - Variations include PFNS covariance, but not elastic angular or inelastic spectral covariances.
- Assembly and foil nuclear data varied together, to account for uncertainty in assembly neutron spectrum.