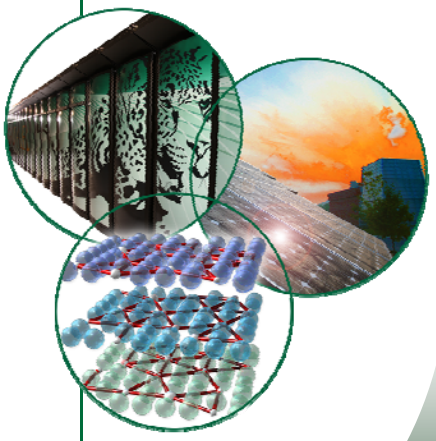
Resonance Evaluation Status for ^{239}Pu



L. C. Leal and M. E. Dunn
Nuclear Data and Criticality Safety Group
Oak Ridge National Laboratory

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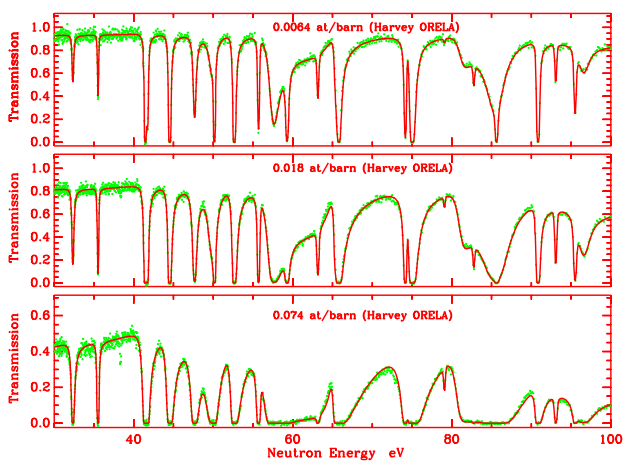
Motivation for a New ^{239}Pu Evaluation

- Improved ^{239}Pu resonance evaluation needed to solve long-standing problem for thermal critical benchmark calculations
- Need resonance parameter covariance data
- Existing resonance parameter (RP) representation has three disjoint resonance parameter regions:
  1.0×10^{-5} eV to 1 keV, 1 keV to 2 keV, 2 keV to 2.5 keV
  - Cross-section mismatch at the energy boundaries
  - Not easy to generate uncertainty for the whole energy region (zero correlation between disjoint resonance regions)
- Need new evaluation with single resonance parameter set covering energy range 1.0×10^{-5} eV to 2.5 keV

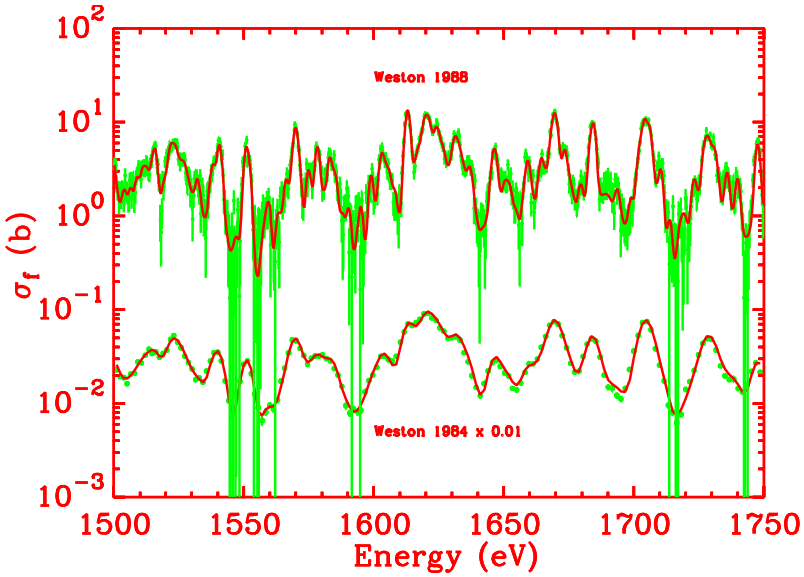
Experimental Data Sets Used in the RR Evaluation

Reference	Energy Range (eV)	Facility	Measurement
Bollinger et al. (1956)	0.01–1.0		Total cross section
Gwin et al. (1971)	0.01–0.5	ORELA	Fission and absorption at 25.6 m
Gwin et al. (1976)	1.0–100.0	ORELA	Fission and absorption at 40.0 m
Gwin et al. (1984)	0.01–20.0	ORELA	Fission at 8 m
Weston et al. (1984)	9.0–2500.0	ORELA	Fission at 18.9 m
Weston et al. (1988)	100.0–2500.0	ORELA	Fission at 86 m
Weston et al. (1993)	0.02–40.0	ORELA	Fission at 18.9 m
Wagemans et al. (1988)	0.002–20.0	GELINA	Fission at 8 m
Wagemans et al. (1993)	0.01–1000.0	GELINA	Fission at 8 m
Harvey et al. (1985)	0.7–30.0	ORELA	Transmission at 18 m
Harvey et al. (1985)	30.0–2500.0	ORELA	Transmission at 80 m

^{239}Pu Resonance Evaluation



^{239}Pu Resonance Evaluation



Effective System Multiplication Factor k_{eff}

$$\frac{\textit{Production}}{\textit{Absorption} + \textit{Leakage}}$$

k_{eff} → > 1 (supercritical)

k_{eff} → = 1 (critical)

k_{eff} → < 1 (subcritical)

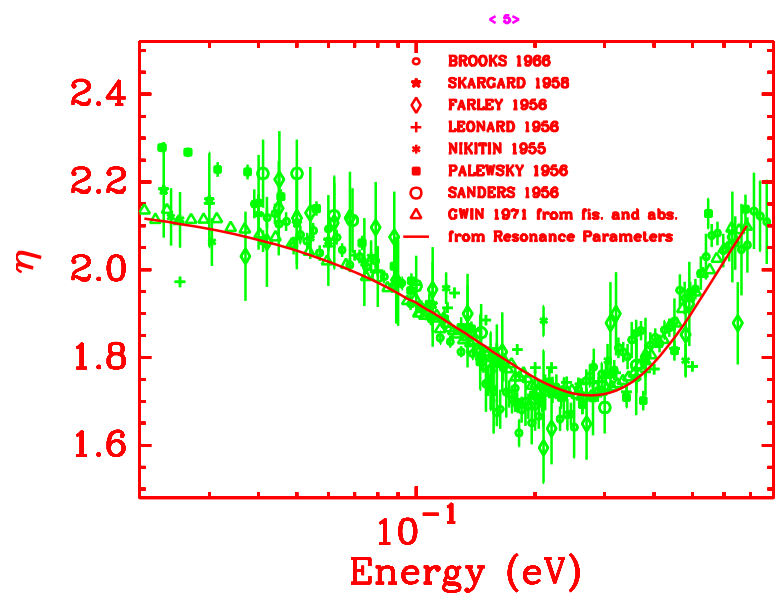
Multiplication Factor: k_∞

Leakage $\longrightarrow$ *0*

$$\frac{\textit{Production}}{\textit{Absorption}}$$

$$k_\infty \propto \eta = \frac{\nu\sigma_f}{\sigma_a}$$

^{239}Pu Resonance Evaluation



Issues with Current ^{239}Pu Evaluation

- Results of plutonium solution calculations indicate little to no improvement with latest evaluation—long-standing thermal benchmark problem persists
- Review and evaluation update for ^{239}Pu is in progress
- Multi-organization and international effort coordinated through OECD/NEA Working Party for Evaluation Co-operation (WPEC) Subgroup 34: ORNL, LANL, CEA and others

International Effort

- OECD/NEA WPEC Subgroup 34:
  - Objective: address ^{239}Pu evaluation issues resulting in discrepancies for Pu-SOL-THERMAL assemblies and Pu-INTER assemblies calculations
  - Strategy
    - Use new Leal/Derrien ENDF resonance evaluation with covariance data
    - Use sensitivity/uncertainty analysis tools to identify parameters important for both differential and integral data adjustment
  - Goal: obtain a ^{239}Pu resonance evaluation that:
    - represents the differential data well
    - leads to improvements in calculations of integral data

General Work Plan

- Benchmark selection:
  - Define set of benchmarks sensitive to ^{239}Pu from ICSBEP and IRPhEP

    Common Benchmarks: ICSBEP ^{239}Pu benchmark systems water-reflected and bare spheres of plutonium nitrate solutions

    Include intermediate and fast benchmarks
- ORNL, CEA, and LANL
  - Perform benchmark calculations with various evaluations (ENDF, JEFF, JENDL) using Monte-Carlo and Deterministic codes

    Skip Kahler (LANL) identified subset of 7 Pu-Sol-Therm ICSBEP benchmarks to investigate evaluation performance

^{239}Pu Data Sensitivity and Adjustment at ORNL

- Use ^{239}Pu resonance evaluation with covariance data that has been evaluated at ORNL
- Process the evaluation with the AMPX/PUFF code system to generate group cross sections and covariance data
- 44-neutron group structure of the SCALE system used for covariance data
- 7 ICSBEP ^{239}Pu benchmark calculations
  - Thermal water reflected benchmark experiments used
- Sensitivity calculations with SCALE/TSUNAMI
- Data adjustment analysis with SCALE/TSURFER

SCALE S/U Analysis for Cross-Section Evaluations

- SCALE S/U capability invaluable tool for cross-section evaluation
  - Provides improved understanding of nuclear data physics for specific applications
  - Identify parameters and energy regions of importance

$$S = \frac{\sigma_X}{k}\frac{\partial k}{\partial \sigma_X} \quad \text{and} \quad V = S\,C\,S^T$$

- SCALE S/U tools used in support of the NCSP nuclear data evaluation effort
  - Nuclear data evaluator performs sensitivity analysis of critical experiment to understand the physics of the problem and identify energy regions that are "exercised" by the criticals

Consolidation of Computed and Measured Responses Using Generalized Linear Least-Squares (GLLS)—SCALE/TSURFER Module

- GLLS consolidates calculations with measured responses
- Computes "best" data adjustments to eliminate differences
- Results in more consistent results with lower uncertainties
- Propagation of data adjustments to integral application
- System provides computational bias and uncertainty

Application of GLLS to Data Adjustment

M-dimensional discrepancy vector:

$$d(\alpha, K_m) = K_c(\alpha) - K_m$$

computed measured

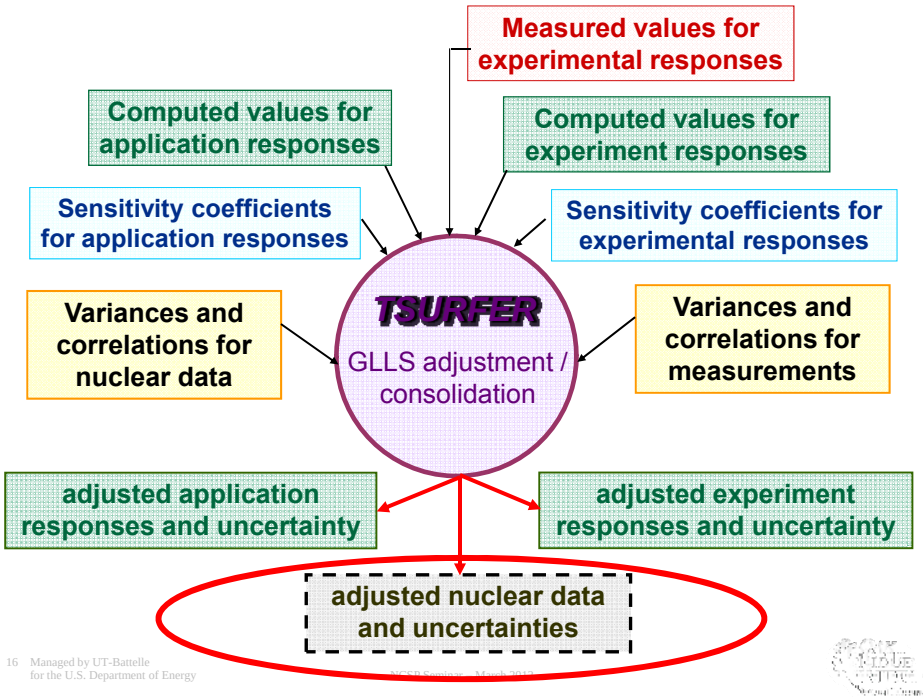
GLLS determines modified nuclear data α' and measured responses K'_m such that . . .

- Discrepancy vector $d(\alpha', K'_m) \rightarrow 0$
- Uncertainties/correlations in α and K_m (i.e., $C_{\alpha\alpha}$ and C_{mm} respectively) are taken account
- Overall consistency maximized by minimizing chi-squared:

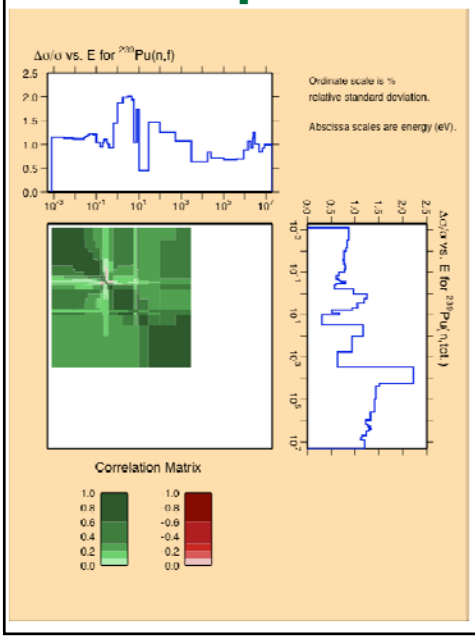
$$\chi^2 = [\alpha' - \alpha]^T [C_{\alpha\alpha}]^{-1} [\alpha' - \alpha] + [K'_m - K_m]^T [C_{mm}]^{-1} [K'_m - K_m]$$

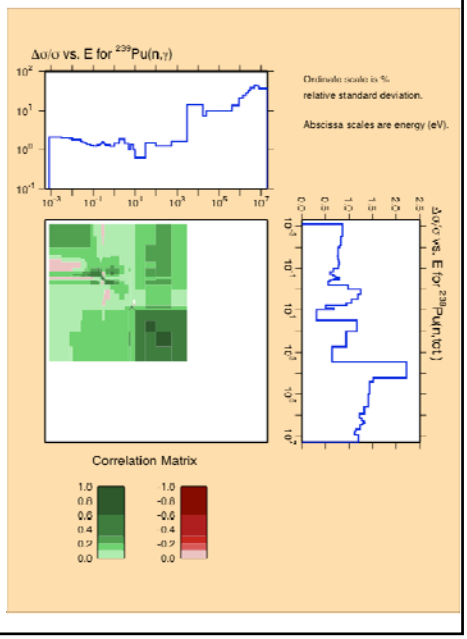
overall adjustments to data, in units of variance

overall adjustments to measurements, in units of variance

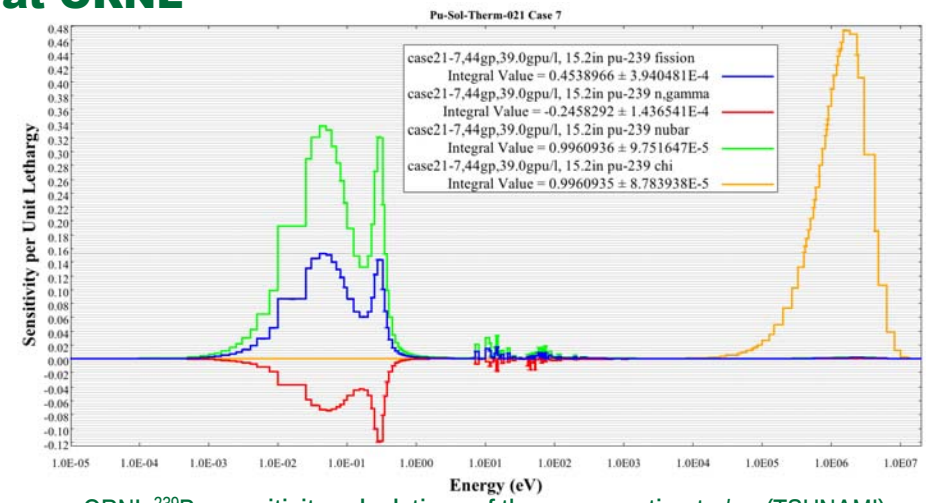


Covariance Work ^{239}Pu ORNL Fission/Capture Estimation



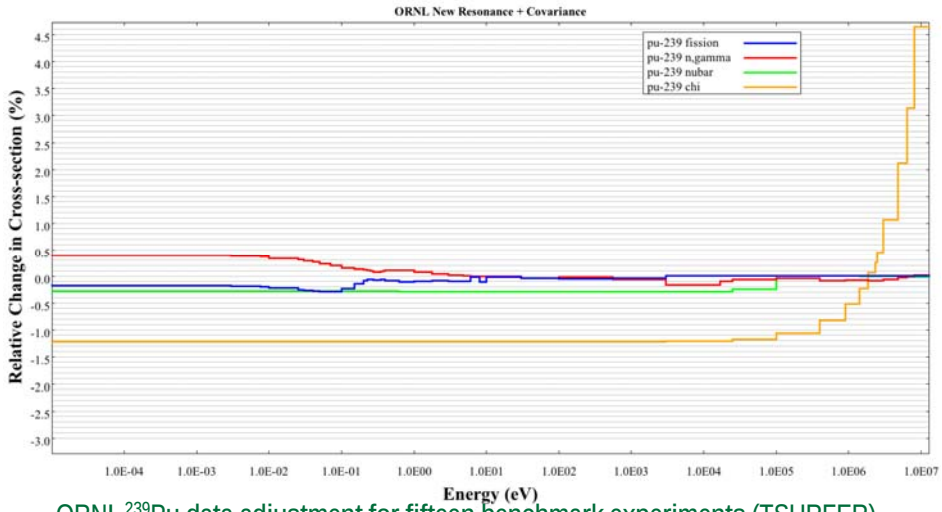


Benchmarking/Integral Data Feedback ^{239}Pu Data Sensitivity and Adjustment at ORNL



ORNL ^{239}Pu sensitivity calculations of the cross section to k_{eff} (TSUNAMI)

Benchmarking/Integral Data Feedback ^{239}Pu Data Sensitivity and Adjustment at ORNL



ORNL ^{239}Pu data adjustment for fifteen benchmark experiments (TSURFER)

ORNL and CEA/Cadarache Work

- ORNL/CEA
  - Use of S/U analysis (combine microscopic and integral experiments) to help improve the nuclear data evaluation
    - SCALE: KENO/TSUNAMI/TSURFER Codes at ORNL
    - ERANOS/SNATCH/CONRAD Codes at CEA
- ORNL/CEA
  - Calculate effects of new evaluated prompt neutron fission spectra (PNFS) from three different sources:
    - LANL
    - IAEA
    - LLNL

MCNP (LANL) and TRIPOLI (CEA) Calculations

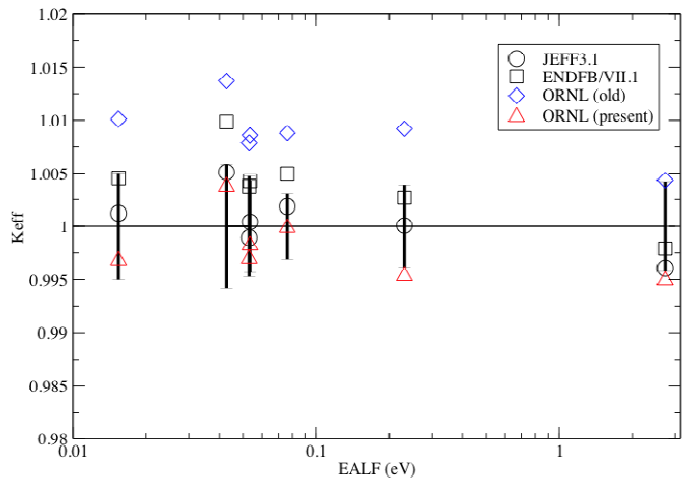
- Use NJOY to generate MCNP/ACE library
- Perform benchmark calculations including 7 thermal benchmarks and others identified by CEA
- Perform fast benchmark calculations (i.e., Pu-MET-FAST) to make sure there's no unintentional changes to fast systems
  - Cross-check TRIPOLI – MCNP k_{eff} calculations

Preliminary Results (Thermal)

- MCNP analysis
  - Calculations using JEFF 3.1
  - Calculations using ENDF/B-VII.1
  - Calculations using ORNL evaluation (preliminary)
  - Plots are k_{eff} vs energy of average neutron lethargy causing fission (EALF)

Note:
- All 7 benchmarks are critical systems (k_{eff} = 1.0)
- Error bars indicate experimental uncertainty

Preliminary Results



Concluding Remarks

- Benchmark experiments sensitive to the fission, capture cross sections, nu-bar and PNFS
- "Right" combination of capture-to-fission ratio (alpha) may lead to an improvement in k_{eff} calculations for thermal Pu systems
- Further studies are needed using new PNFS evaluations

Remaining Tasks

- Finalize document related to benchmark list and calculations
- New PNFS evaluations to be tested (JEFF/ENDF)
- Few weeks of intensive work between CEA/ORNL in 2012 to finalize the ^{239}Pu and the evaluate benchmark performance
- Complete ^{239}Pu resonance evaluation in FY2012