RESONANCE COVARIANCE FOR ACTINIDES AT ORNL

Nuclear Data Group
Nuclear Science and Technology Division
Oak Ridge National Laboratory

Luiz Leal

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OBJECTIVE

Generate resonance parameter covariance for major actinides:

^{233}U, ^{232}Th, ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu, ^{241}Pu, and others

Make the data available to the user community through the Evaluated Nuclear Data Files (ENDF)

TOOLS

- **EVALUATION TOOLS:**

SAMMY CODE

- **Evaluation code used for data and uncertainty evaluations in the resonance region**
- **Used also to check the results (average cross sections)**

- **To my knowledge SAMMY is the only available capability that generate R-matrix resonance parameter covariance**

- **PROCESSING TOOLS: NJOY/ERRORJ and AMPX/PUFF**
  - **ERRORJ (Japan)**
  - **PUFF (ORNL)**

COMPUTER CODE SAMMY

- **Used for analysis of neutron, charged-particle cross-section data.**
- **Uses Bayes' method (generalized least squares) to find parameter values.**
- **Uses R-matrix theory, Reich-Moore approximation (default) or multi- or single-level Breit-Wigner theory.**
- **Generates covariance and sensitivity parameters for resonance region (generalized least squares)**

Application
Average Group Cross Sections

$$\Phi_g \overline{\sigma}_{xg} = \int_{E_g}^{E_{g+1}} \sigma_x(E)\Phi(E)dE$$

with

$$\Phi_g = \int_{E_g}^{E_{g+1}} \Phi(E)dE$$

Covariance Matrix for Group Cross Sections

If $p_1, p_2, \ldots, p_n$ are evaluated resonance parameters such that

$$\sigma_x = \sigma_x(p_1, p_2, \ldots, p_n)$$

Then

$$\delta\bar{\sigma}_{xg} = \sum_j \frac{\partial \sigma_{xj}}{\partial p_j} \delta p_j$$

Group Covariance Matrix

$$< \delta\bar{\sigma}_{xg} \; \delta\bar{\sigma}_{xg'} > = \sum_{j\,k} \frac{\partial \sigma_{xj}}{\partial p_j} < \delta p_j \; \delta p_k > \frac{\partial \sigma_{xk}}{\partial p_k}$$

Covariance of the group cross sections depends on the covariance of the resonance parameters *p as*

$$< \delta p_j \; \delta p_k >$$

These quantities are calculated (evaluated) with SAMMY !!

Resolved Resonance Region

R-Matrix Resonance Parameters:

Formalism most used resonance formalism in ENDF/B is based in the Reich-Moore (RM) methodology

In general the RM formalism each resonance is represented by five parameters

$$E_r \quad \Gamma_\gamma \quad \Gamma_n \quad \Gamma_{f1} \quad \Gamma_{f2}$$

Covariance Evaluation

Memory Estimation for SAMMY

Dominant contribution to the SAMMY array (sensitivity matrix):

Number of resonances N_{res}

Number parameters per resonance N_{par} (E_r, Γ_γ, Γ_n, Γ_{f1}, Γ_{f2})

Number of experimental data points N_{dat} (auxiliary grid)

SAMMY requested memory size:

$$\text{Mem} = (N_{res} \times N_{par} \times N_{dat}) \times 8 \text{ bytes}$$

SAMMY computation of the Resonance Parameter Covariance Matrix (RPCM) requires a memory size of approximately

$$2 \times \text{Mem}$$

Covariance Evaluation for ^{239}Pu

Full covariance has been generated in the energy range from 10^{-5} eV to 2.5 keV (RR) at ORNL

SAMMY memory size estimation

No. of resonances = 1045

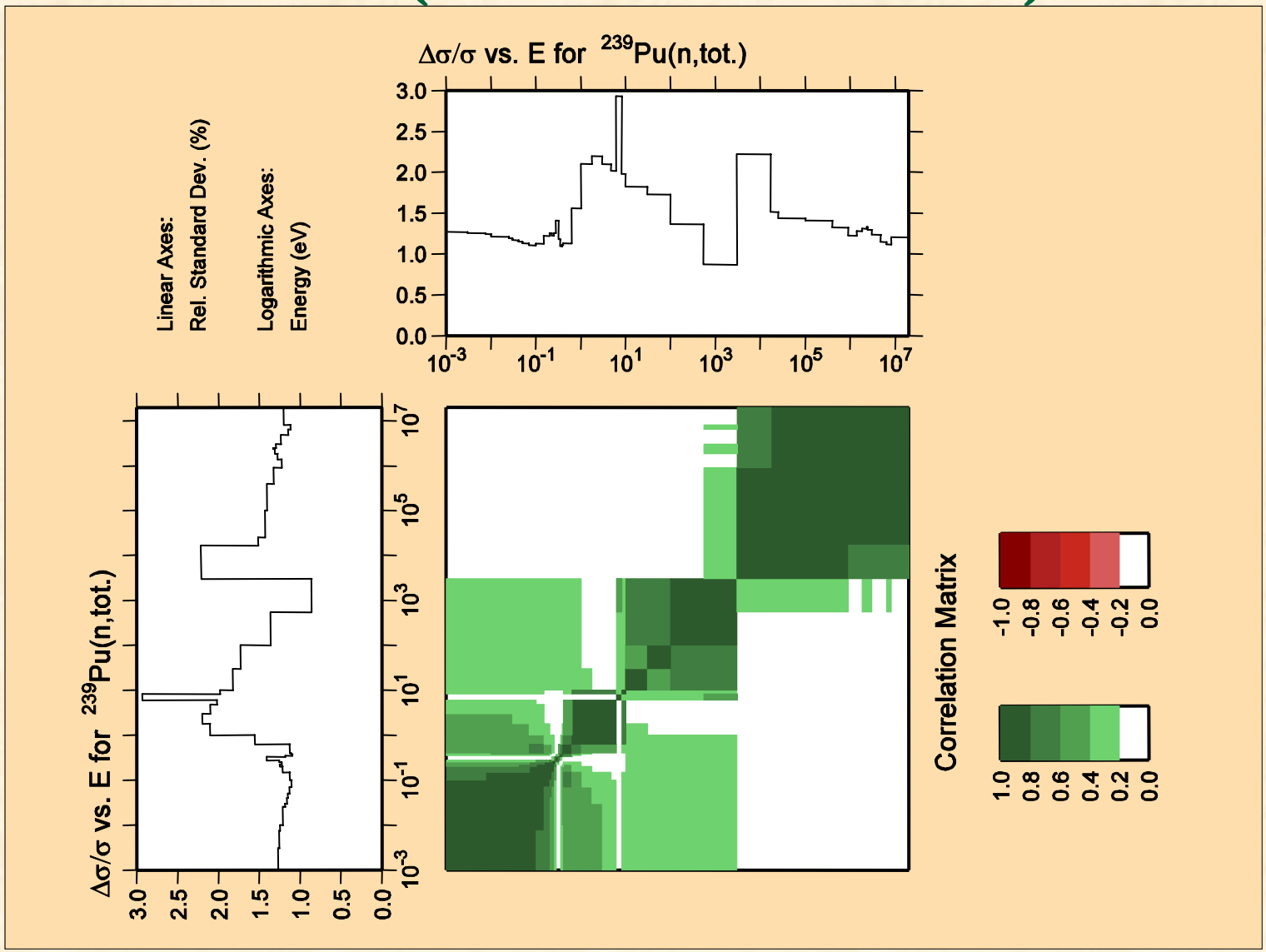
No. of varied parameters per resonance = 5

No. of data points = 20,000

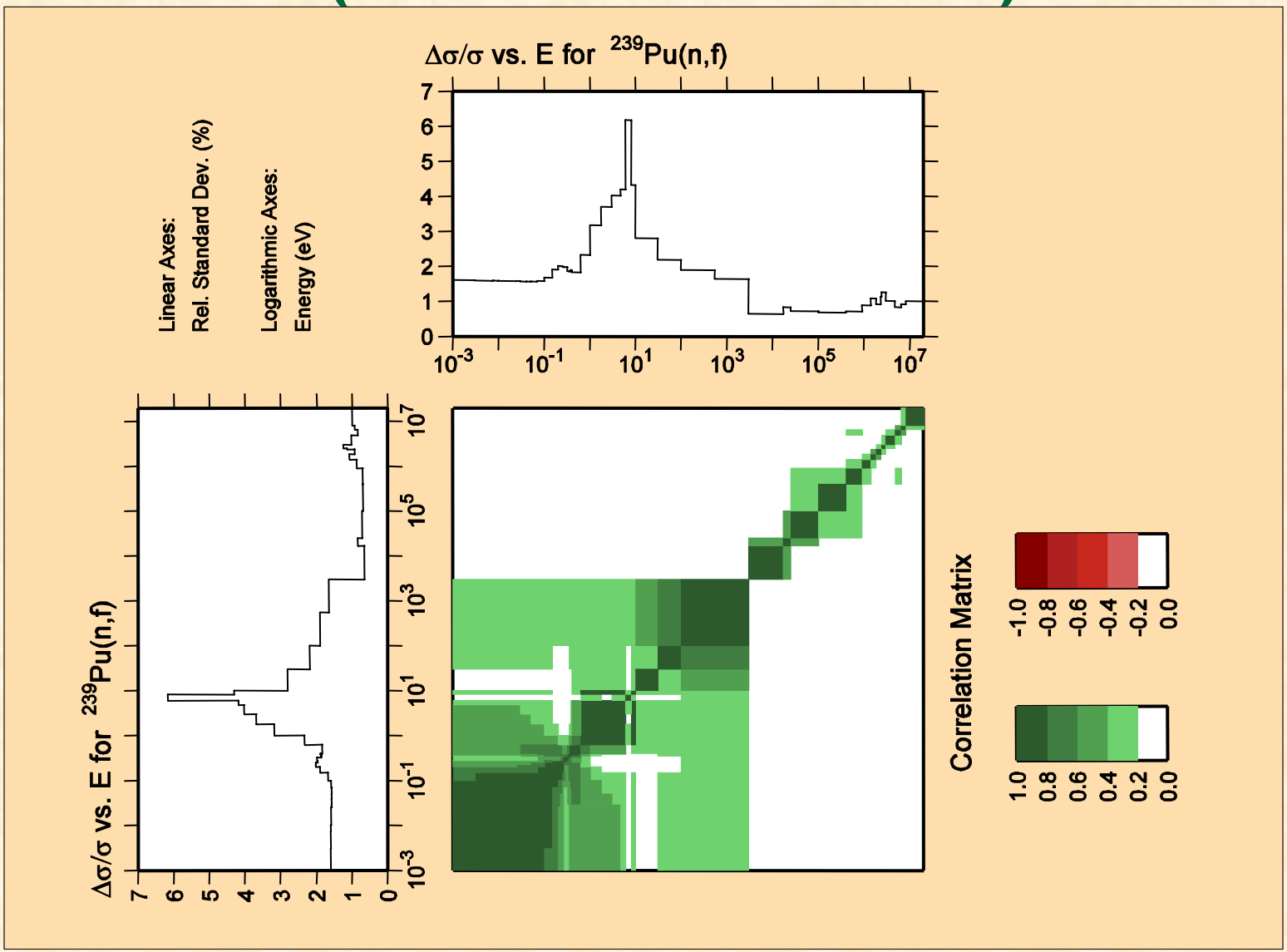
Mem= (1045 × 5 × 20,000) × 8

Memory needed = 2 × Mem ~ 1.7 Gbytes

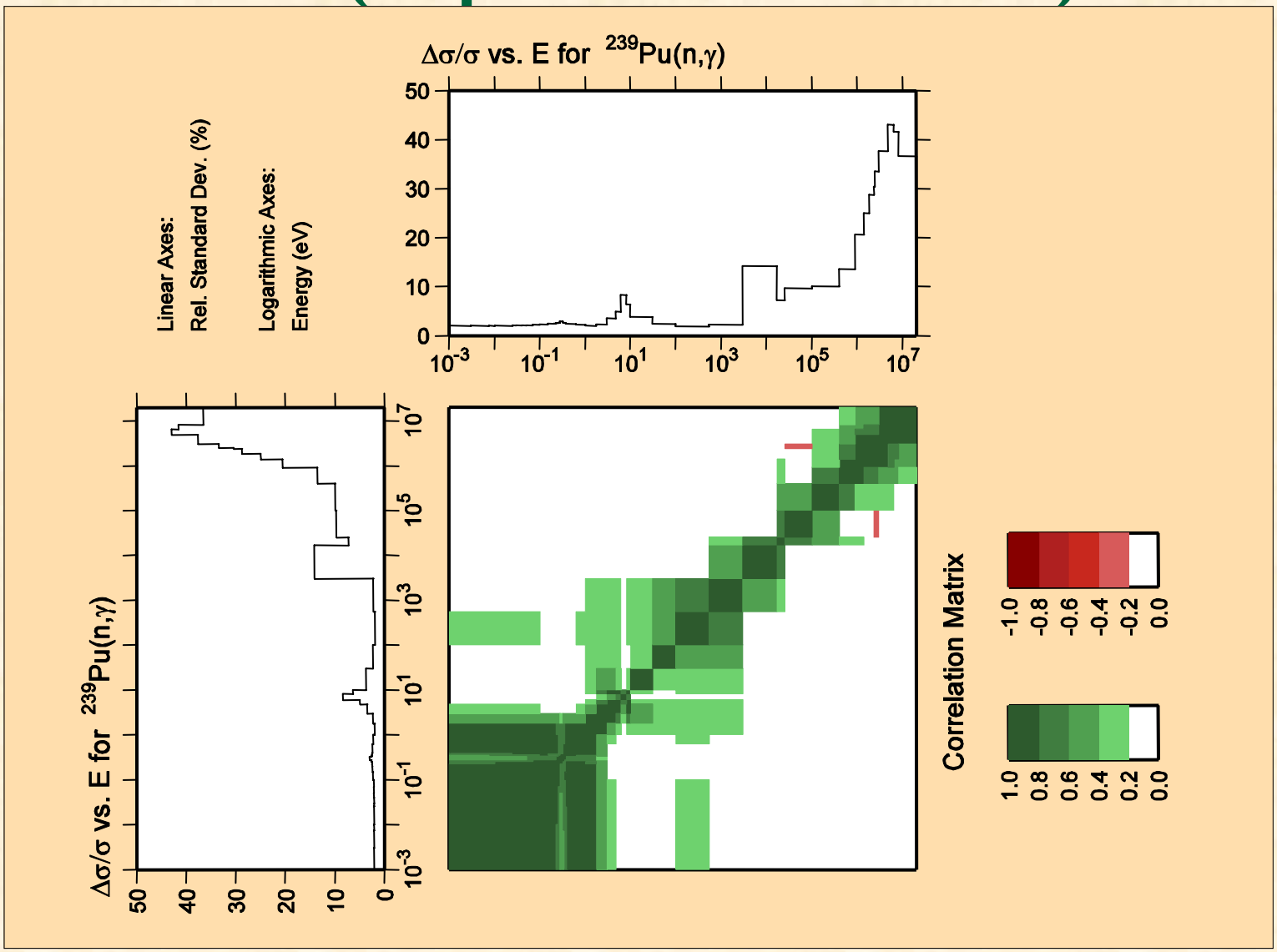
ERRORJ Processed Covariance (Total Cross Section)



ERRORJ Processed Covariance (Fission Cross Section)



ERRORJ Processed Covariance (Capture Cross Section)



Concluding Remarks

- **Resonance covariance data are generated at ORNL using SAMMY code**
- **Data have been converted into ENDF format and processed with PUFF and ERRORJ**
- **Data have been used in sensitivity calculation at ORNL using the sensitivity analysis code TSUNAMI**