OAK RIDGE National Laboratory

# FY22 NCSP accomplishments for U and Pu Evaluations

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Nuclear Criticality Safety Program (NCSP) Technical Program Review (TPR) Meeting
Sandia National Laboratory (SNL), February 2023, Albuquerque, NM

# OVERVIEW: uraniums

- **$^{233}$U**
  - Motivation: underestimated reactivity for critical assemblies
  - FY21–FY22: RRR extended up to 2.5 keV including fluctuating $\bar{\nu}_p$. Validation including suite of 180 benchmarks[1] showed increased reactivity trend
  - FY23 (current): inclusion of ratio capture-to-fission data recently measured at LANL and updates to URR in the energy range 2.5–40 keV are in progress
    - Preliminary $\nu$ and cross section covariance generation for the resolved resonance energy range up to 2.5 keV
- **$^{235}$U**
  - Motivation: investigation of reactivity rates related to depletion calculations
  - FY21–FY22: $^{238}$U evaluation[2] affecting the burn-up trend and updated URR evaluation by including recently measured fission data
  - FY23 (current): define strategy to improve the low reactivity at high burnup among the interplay of four nuclides ($^{16}$O, $^{235,238}$U, $^{239}$Pu). **Inclusion of sub-thermal measured ratio $^{235}$U/$^{238}$U data (Anton Wallner)**
    - Preliminary $\nu$ and cross section covariance generation for the resolved resonance energy range up to 2.25 keV

[1] Pigni, NCSP TPR 2022.
[2] Updated evaluation released within INDEN collaboration.

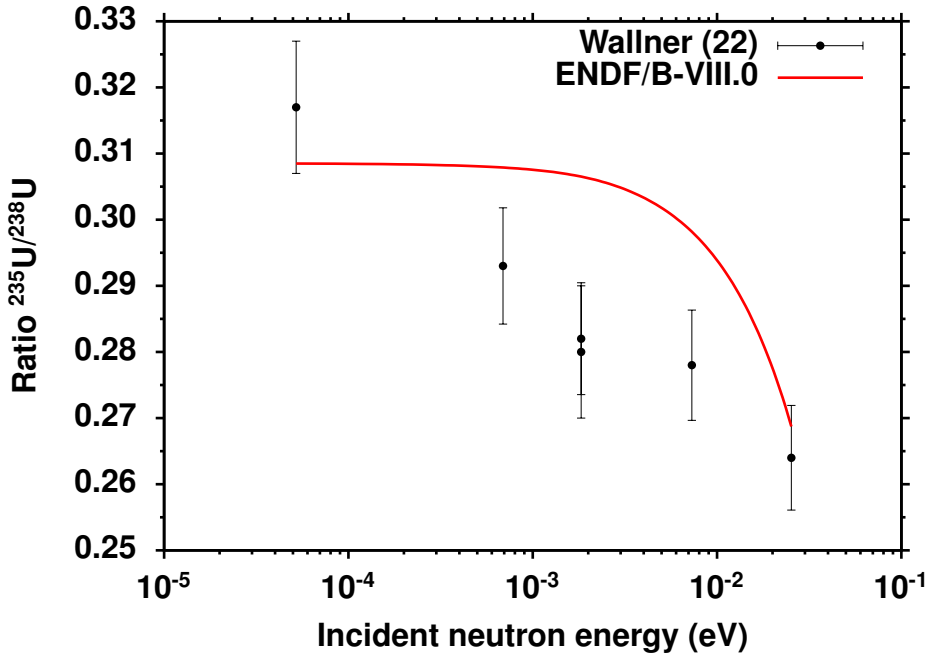
# OVERVIEW: plutonium

- Current status in ENDF/B-VIII.0 ($<$2018):
  - Evaluated resonance parameters and related covariance matrix were adopted from WPEC (SG34)
  - WPEC (SG34) work mainly consists on merging three independent sets of resonance parameters into a single set of parameters by keeping unchanged the performances of the evaluated data on PST benchmarks and MOX fuel calculations
  - No updates in the RRR (up to 2.5 keV) performed within the CIELO collaboration
- Motivation: $R$-matrix analysis to include TNC values (STD 2017) and PFNS (IAEA+LANL)
- $<$FY20: updates in TNC and PFNS[3] with partial work to extend RRR up to 5 keV
- FY21: continuing with the extension updates and the coupling RRR and neutron fission multiplicities.
- FY22: RRR extension up to 5 keV completed including fluctuating neutron fission multiplicities.
- FY23 (current): latest ENDF file (up to 5 keV) released and currently under testing, verification, and validation. **Inclusion of Mosby (2014) ratio capture-to-fission data**
  - Preliminary $\nu$ and cross section covariance generation for the resolved resonance energy range up to 2.25 keV

[3] INDEN evaluation (`https://www-nds.iaea.org/INDEN/`) including ORNL updates in the RRR as well as IAEA improvements in the fast region was recently adopted for ENDF/B-VIII.1 beta release.

# $^{235}$U: inclusion of sub-thermal data

- Ratio $^{235}$U/$^{238}$U data very recently measured at the Accelerator Mass Spectrometry & Isotope Research Helmholtz-Zentrum Dresden (HZDT)[4]




- ENDF/B-VIII.0 evaluations considerably deviates from the measured trend below the thermal neutron energy
- Preliminary work to reproduce the trend by varying bound energy levels and relative widths

[4]Preliminary data from Anton Wallner (TU Dresden) presented at the INDEN meeting 2022.

# $^{233}$U and $^{239}$Pu: inclusion of LANL ratio capture-to-fission data

- Simultaneous measurement of coincident fission and anti-coincident capture events performed by Mosby (2014) for $^{239}$Pu and by E. Leal (2022) for $^{233}$U
  - These data are usually reported as a ratio capture to fission normalized to a specific energy range where resonance levels are well known

$$\alpha(E) = \frac{\sigma_\gamma(E)}{\sigma_\mathrm{f}(E)} = A\,\frac{Y_\gamma(E)}{Y_\mathrm{f}(E)} \tag{1}$$

  - $A$ depends on ENDF capture and fission broadened cross section

$$A = \left(\int \sigma_\mathrm{f}^{\mathrm{ENDF}}\,dE \int Y_\mathrm{f}\,dE\right)\left(\int \sigma_\gamma^{\mathrm{ENDF}}\,dE \int Y_\gamma\,dE\right)^{-1} \tag{2}$$

- However, another option is to work in terms of detector efficiencies $\varepsilon_x$ as

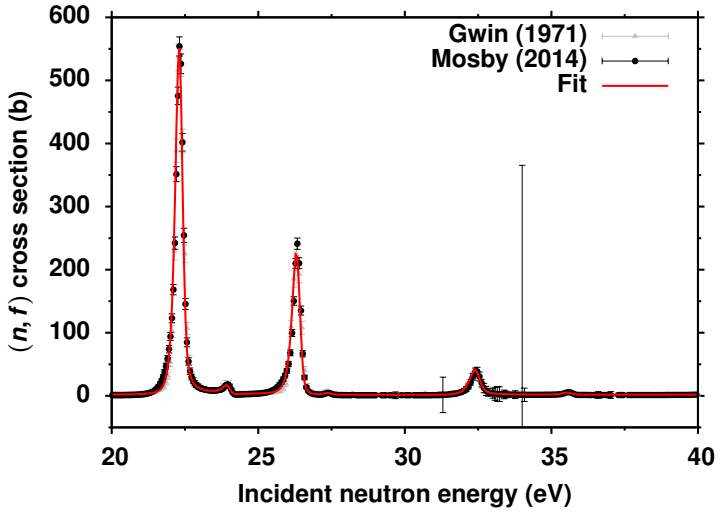
$$\alpha(E) = \frac{C_\gamma(E)}{C_\mathrm{f}(E)} = \frac{\varepsilon_\gamma\,Y_\gamma(E)}{\varepsilon_\mathrm{f}\,Y_\mathrm{f}(E)}, \tag{3}$$

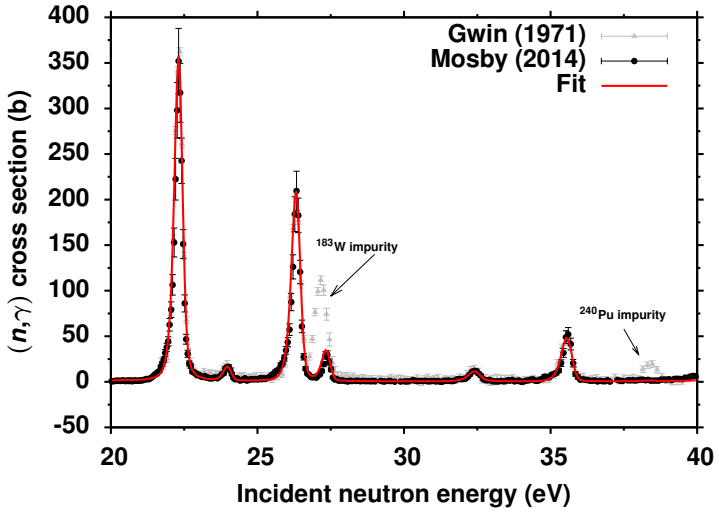
  where the detector efficiencies are SAMMY input parameters and the fission and capture yields can be computed including resolution broadening, self-shielding and multiple scattering corrections, ...

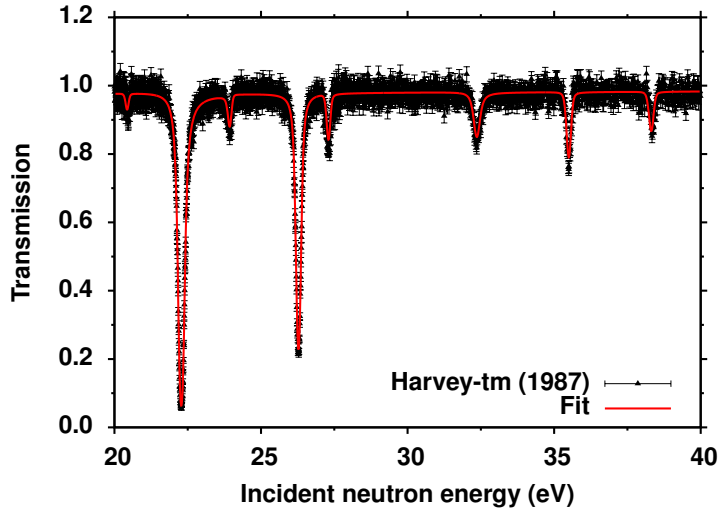
- With detector efficiencies, SAMMY perfectly compatible to include LANL data for both capture and fission yields

# $^{239}$Pu: preliminary fit of Mosby's data as reported

- Sequential fit of fission[5], capture, and transmission data reveals impurities in Gwin's data and a systematic enhancement in the resonance left wing tail that is typical of a resolution effect[6]



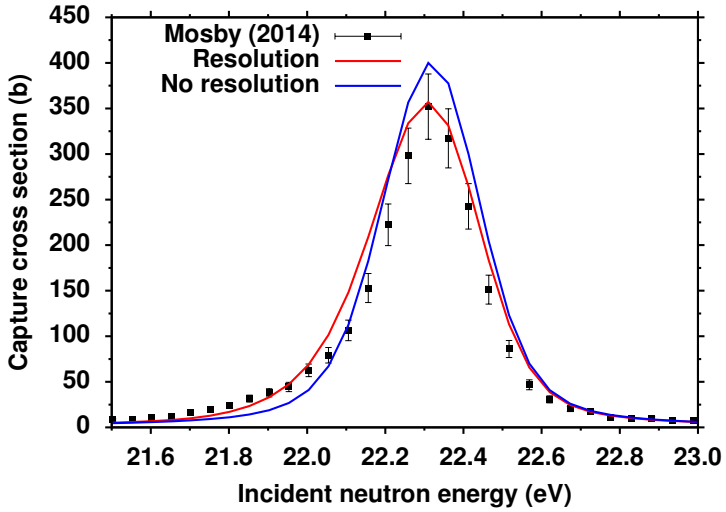

- Particularly for sharp resonances, resolution effects are important to fit peaks and tails of the capture data
- Possible improvements obtained by including optimization of detector efficiencies in the simultaneous fit: compatibility test with other measured data

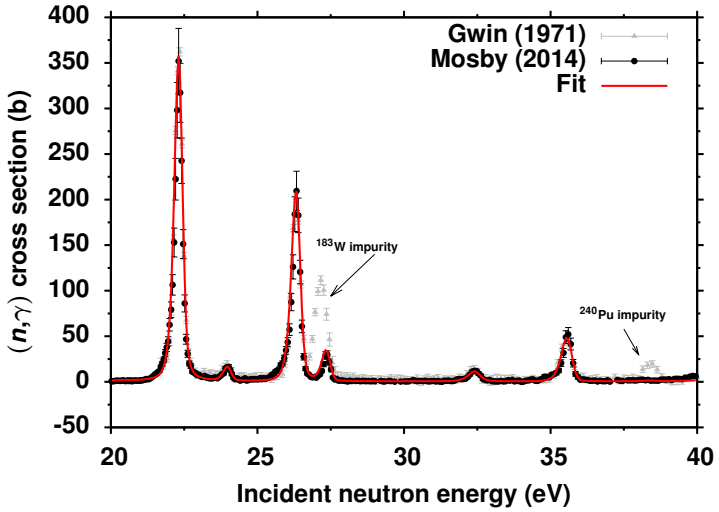
[5]For Mosby's data, fission data were derived by capture and $\alpha$ data as defined in Eq. (1)

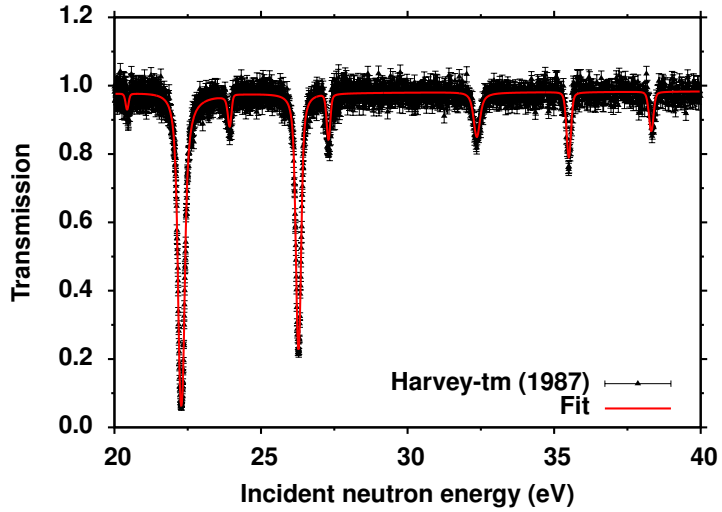
[6]Mosby's data were fitted by including an exponential form for the resolution broadening as implemented in SAMMY.

# $^{239}$Pu: preliminary fit of Mosby's data as reported

- Sequential fit of fission, capture, and transmission data reveals impurities in Gwin's data and a systematic enhancement in the resonance left wing tail that is typical of a resolution effect[7]



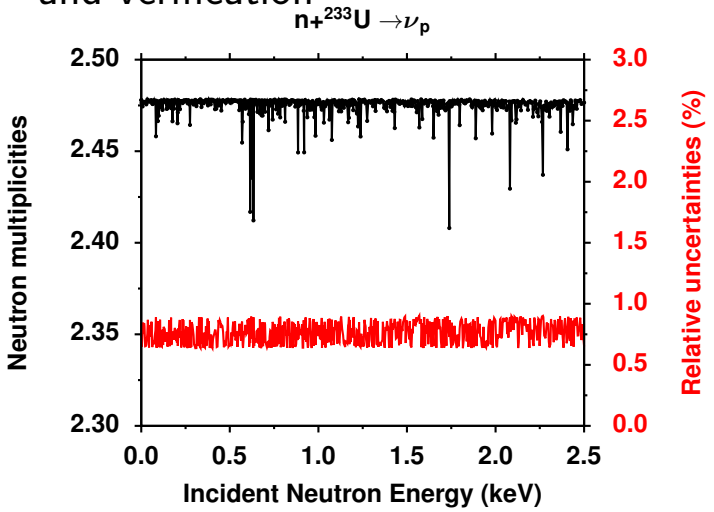



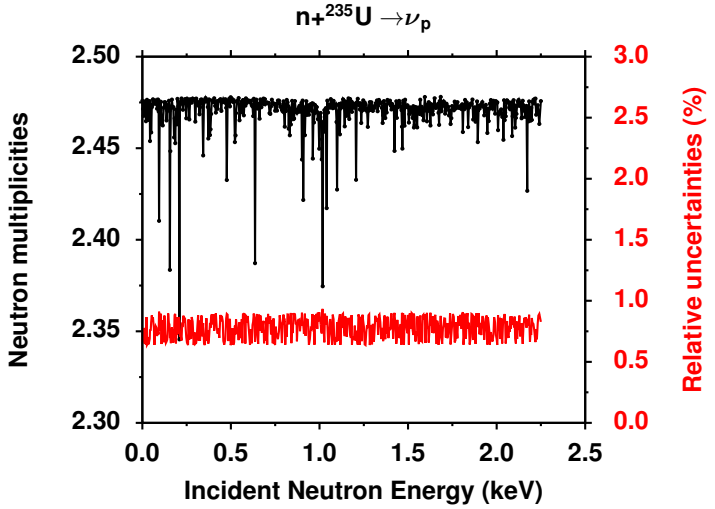

- Particularly for sharp resonances, resolution effects are important to fit peaks and tails of the capture data[8]
- Possible improvements obtained by including optimization of detector efficiencies in the simultaneous fit: compatibility test with other measured data

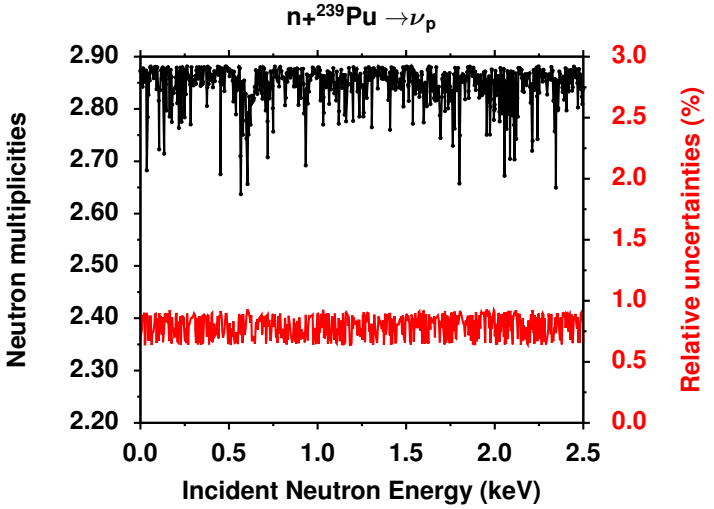
[7] Mosby's data were fitted by including an exponential form for the resolution broadening as implemented in SAMMY.
[8] In the figure 30% $\chi^2$ reduction between 21-24 eV due to resolution function.

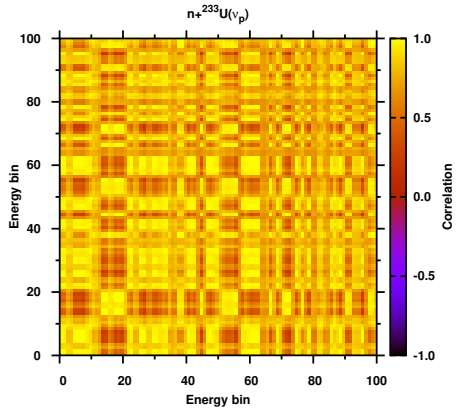
# Uncertainty quantification

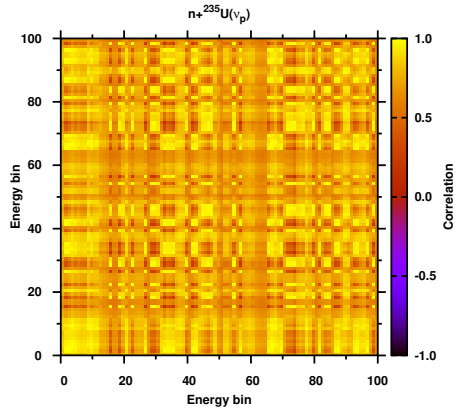
- For U and Pu evaluations preliminary covariance information for the RRR was generated for the ENDF beta library for testing and verification

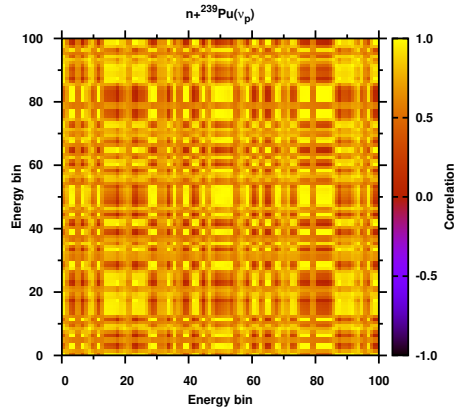


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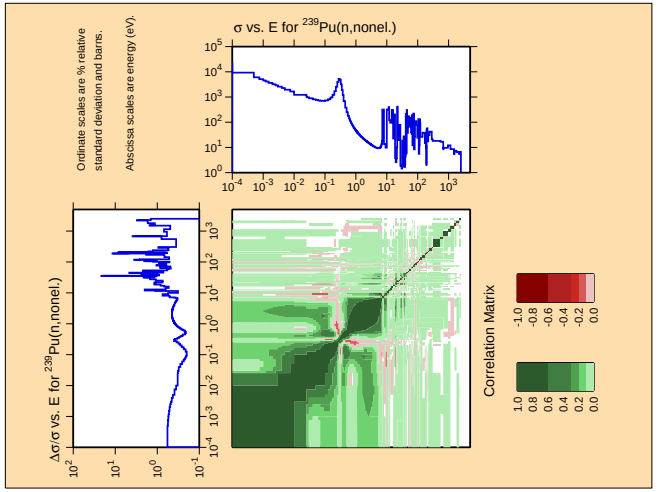


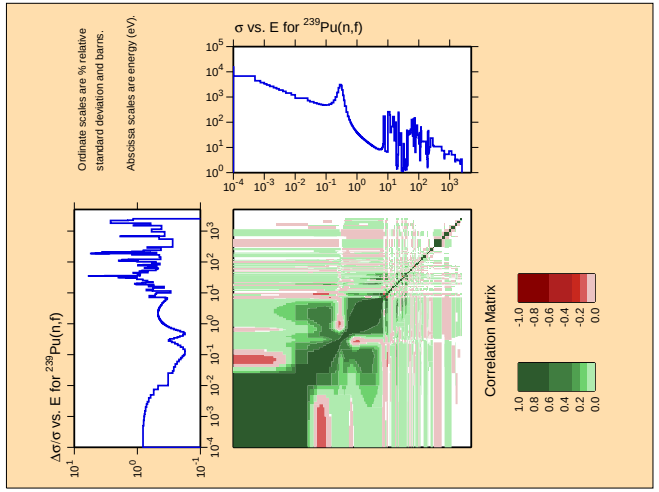


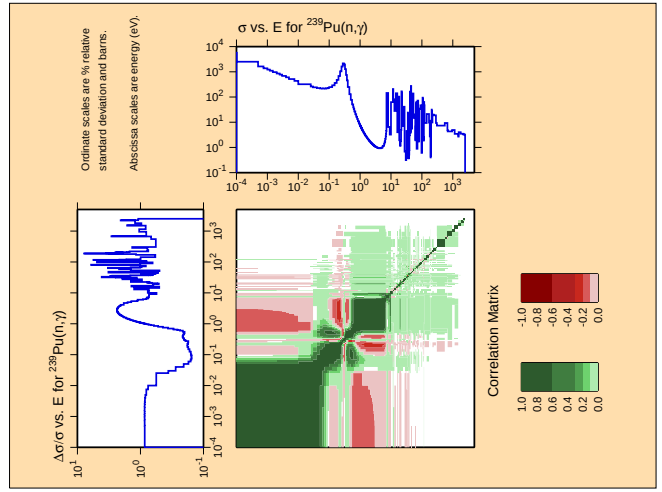


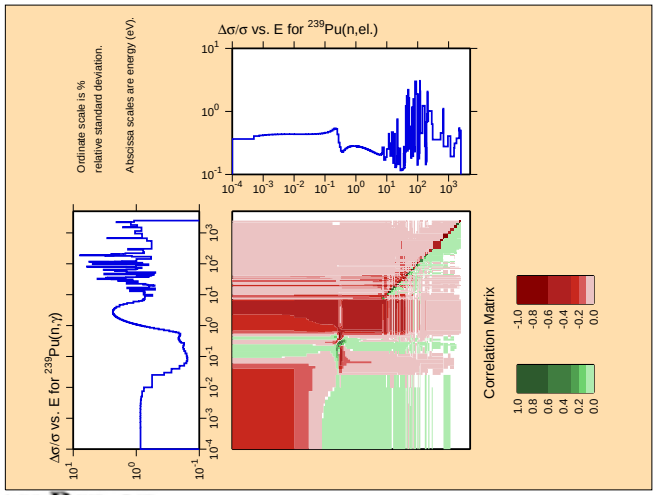


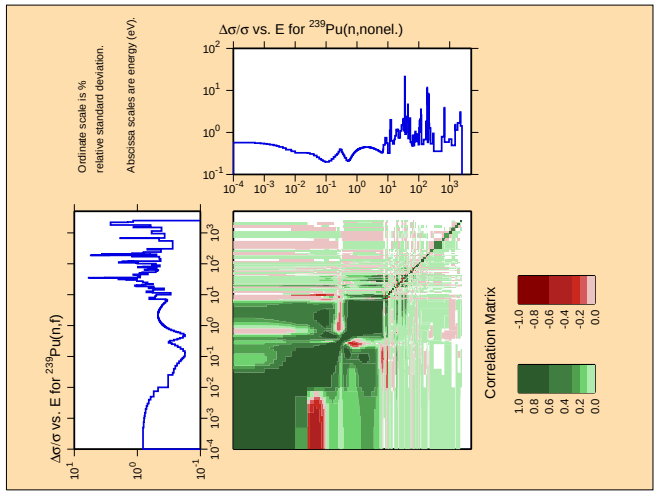


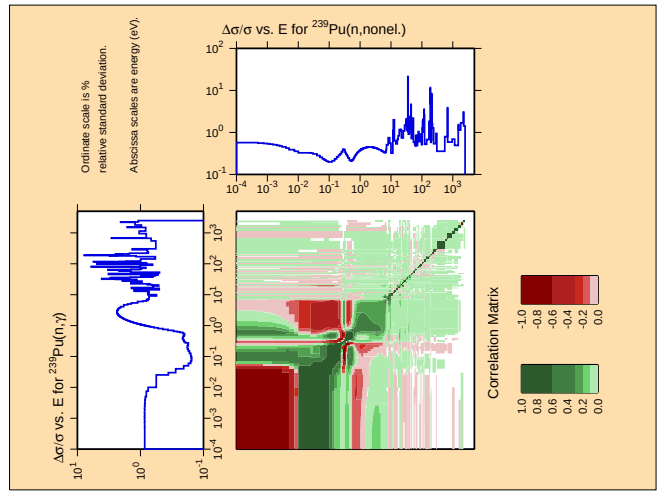

# ACKNOWLEDGMENTS

This work was supported by the Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the Department of Energy



**ORNL TEAM:** D. Wiarda, J. McDonnell, K. Ramic, K. Guber, T. Green, C. Chapman, J. Brown, G. Arbanas

Thank you!