Evaluated Data for Fissile Actinides in the Resolved and Unresolved Resonance Region and their Coupling to Neutron Multiplicities

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Nuclear Data Week Cross section Evaluation Working Group (CSEWG) Evaluation and Covariance session, November 2021, USA

OVERVIEW

- **^{233}U**
  - Motivation: underestimated reactivity for critical assemblies
  - Status: updates to PFNS, thermal constants, *R*-matrix improved subset of benchmarks[1]
  - RRR: extension up to 2 keV and inclusion of possible newly measured capture data
  - URR: relevant to assess impact on benchmark calculations in the energy range 2–40 keV
- **^{235}U**
  - Motivation: investigation on reactivity rates related to depletion calculations
  - Status: ^{238}U evaluation (see Capote/Trkov presentation) affecting the burn-up trend
  - URR: updated evaluation by including recently measured fission data
- **^{239}Pu**
  - Motivation: *R*-matrix analysis to include TNC values (STD 2017) and PFNS (IAEA+LANL)
  - Status: partial work to extend RRR up to 5 keV
  - Neutron multiplicities: updated evaluation with fluctuations and related covariances in progress

[1] Annals Nuclear Energy **163** (2021) 108595.

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U(nresolved) R(esonance) R(egion) ANALYSIS OF ^{235}U

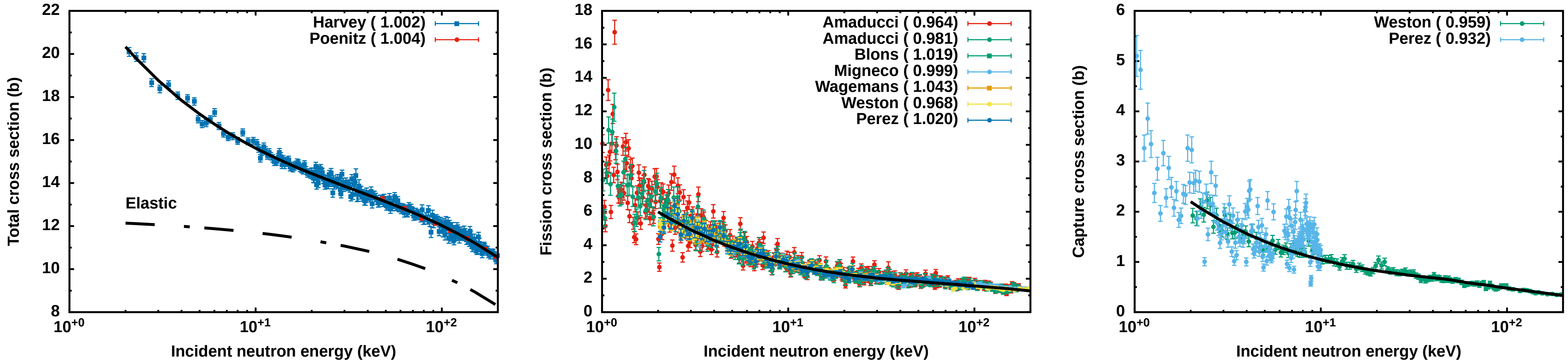

Figure 1: Preliminary SAMMY/FITACS fit of available total, fission, and capture data sets. Elastic channel computed by difference and inelastic channel parameterized by neutron strength functions and energy scaled penetrability factors.

- Except for the inelastic channel (11%), scaling factors ranging up to 6%
- Except for fluctuations, reasonable agreement with ENDF/B-VIII.0 (file 3)
- 20 keV is an acceptable upper energy limit for URR fit to account for self shielding effects

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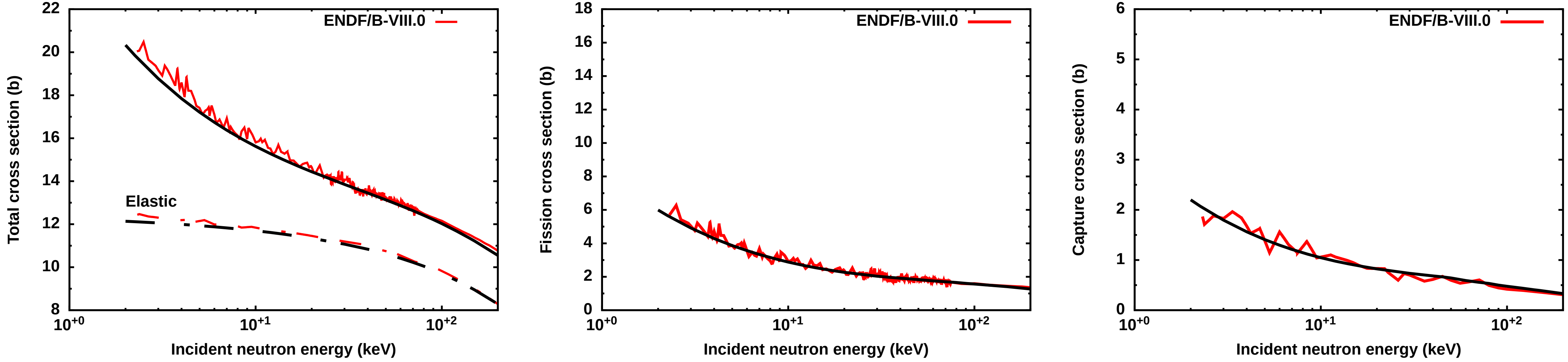

Figure 2: Preliminary SAMMY/FITACS fit compared to ENDF/B-VIII.0 evaluated data (file 3).

- ENDF/B-VIII.0 evaluated data show fluctuating behavior (to be checked if there is formal consistency between file 2 and file 3)

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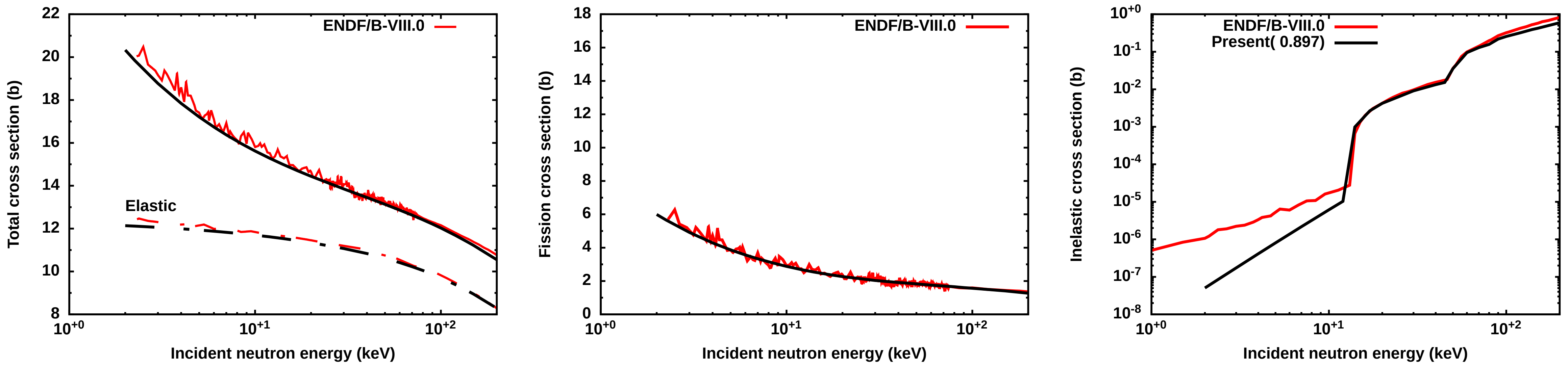

Figure 3: Preliminary SAMMY/FITACS fit compared to ENDF/B-VIII.0 evaluated data (file 3).

- Inelastic channel deviates from ENDF/B-VIII.0 below ≈10 keV
- μbarn should have no impact on criticality!
- Next step is the inclusion of fluctuations! (Resonance parameters ⇒ fit ⇒ effective/theoretical cross sections)

NEUTRON MULTIPLICITIES: On the $(n,\gamma f)$ reaction

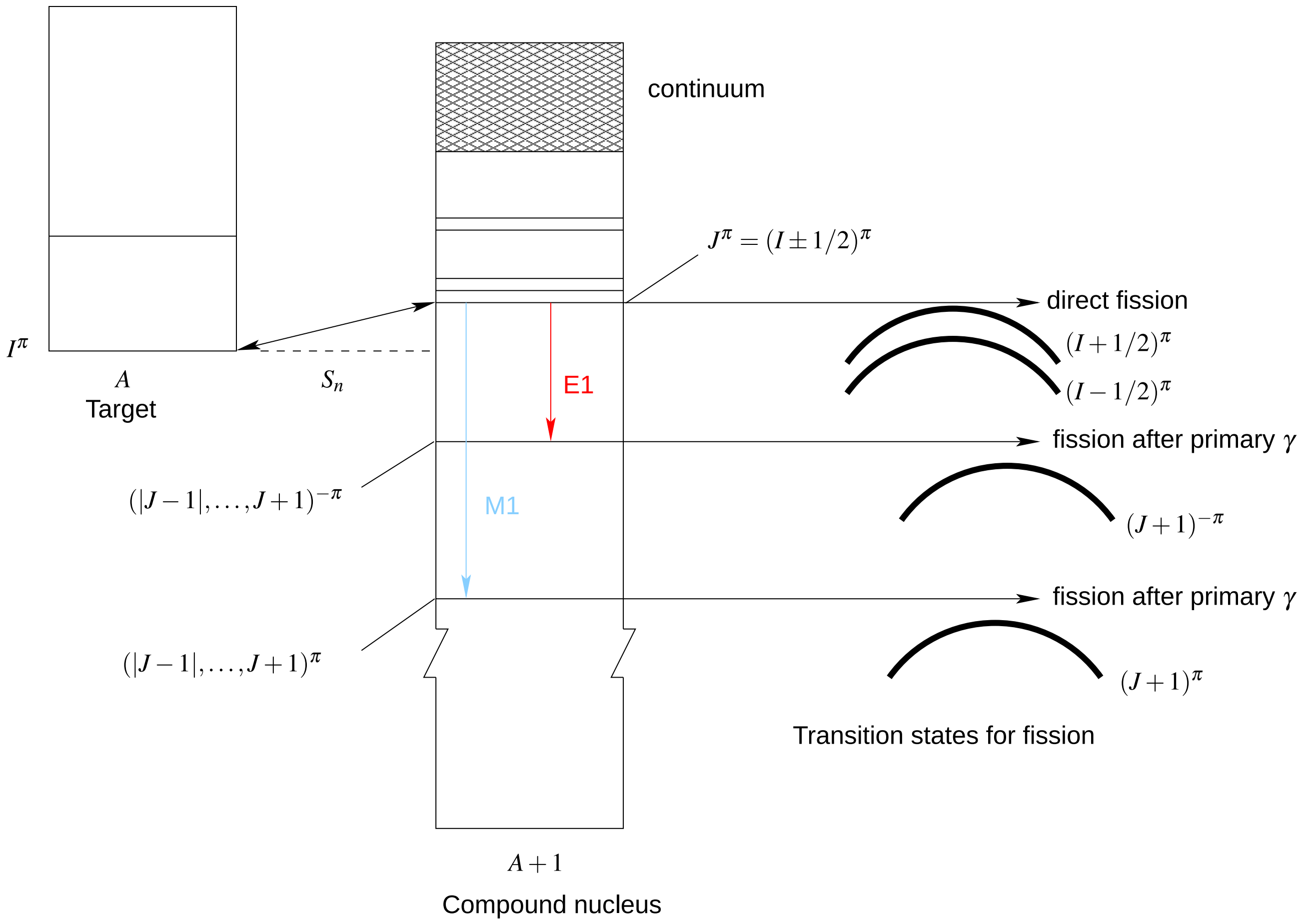

Figure 4: Schematic diagram of the $(n,\gamma f)$ reaction (Lynn 1965). After the emission of a primary γ-ray (e.g. E1, M1,..), the compound nucleus may still be in a highly excited state that may decay by fission as an alternative to secondary γ-ray emission. In the two-stage decay, the compound nucleus can be in an intermediate state that differs from the initial state depending on the multi-polarity of the transition.

NEUTRON MULTIPLICITIES: Calculating spin effect and $(n,\gamma f)$

- Fluctuating behavior of prompt neutrons based on the competition of $(n,\gamma f)$ and direct fission (n,f) processes[3]
- Neutron multiplicity $\bar{\nu}_p(E) = \nu^{\text{spin}}(E) - \Delta\nu^{(n,\gamma f)}(E)$ defined by

$$\nu^{\text{spin}}(E) = \left[\sum_J \nu_{c,J} \sum_{k_J} \sigma_{f,k_J}(E)\right] / \sigma_f(E) \quad (1)$$

$$\Delta\nu^{(n,\gamma f)}(E) = \left[\sum_J C_J \sum_{k_J} \sigma_{f,k_J}(E)/\Gamma_{f,k_J}\right] / \sigma_f(E)\,, \quad (2)$$

  where the quantities $\nu_{c,J}$ and C_J are deduced by a least-squares of the measured data.
- The resonance fission widths Γ_{f,k_J} for each level E_λ are used to calculate the partial energy-dependent fission cross section $\sigma_{f,k_J}(E)$:

  - The coefficients $C_J = (\partial \nu_J/\partial E)\,\Gamma_{\gamma,f} \cdot E_{\gamma,f}$ are deduced from the linear dependence of $\bar{\nu}_p$ for the direct process, assuming that $\Gamma_{\gamma,f}$, $E_{\gamma,f}$ are constant due to the large number of independent channels involved.
  - For ^{239}Pu (having spins $J = 0^+, 1^+$), the parameters used in the calculations are four $\nu_{c,0^+}$, C_{0^+} and $\nu_{c,1^+}$, C_{1^+}

[3] Fort et al., NSE 99,375 (1988).

NEUTRON MULTIPLICITIES OF ^{239}Pu

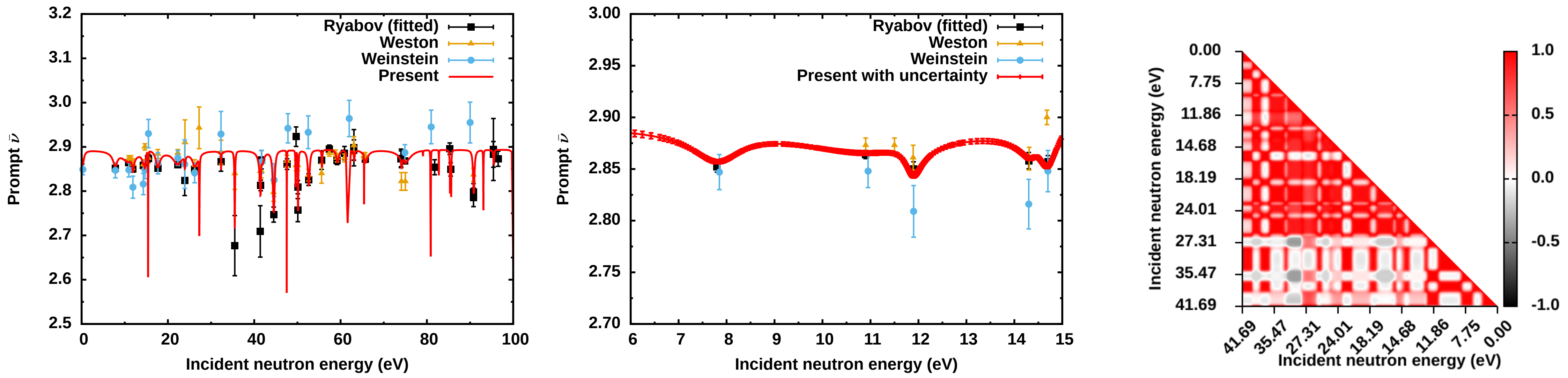

Figure 5: Preliminary fit of neutron multiplicities with available measured data and related covariance matrix.

- Measured data with different resolutions. Ryabov seems the most consistent
- As expected the correlation matrix reflects the $\bar{\nu}$ fluctuating behavior
- To reduce size of covariance matrix, energy grid properly defined around each energy level
- Calculated uncertainty is about $\leq$0.3%

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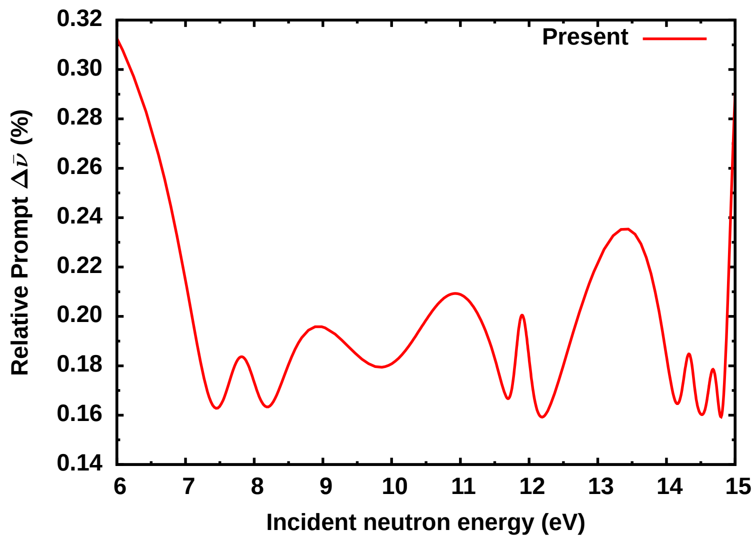

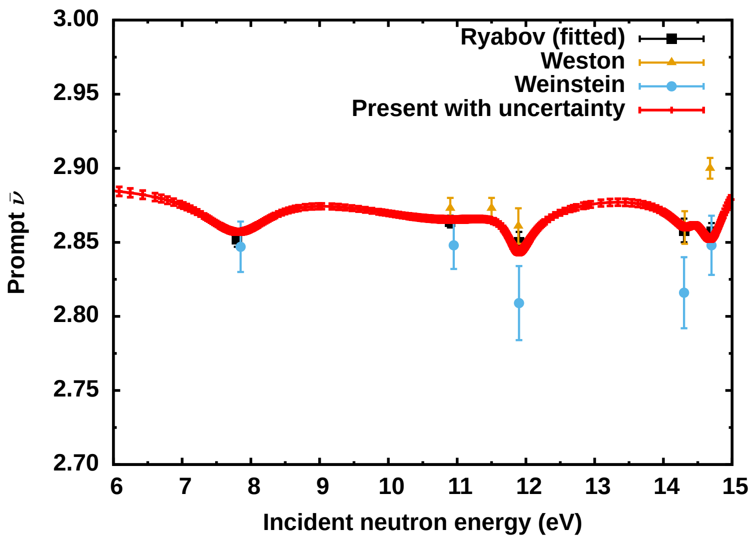

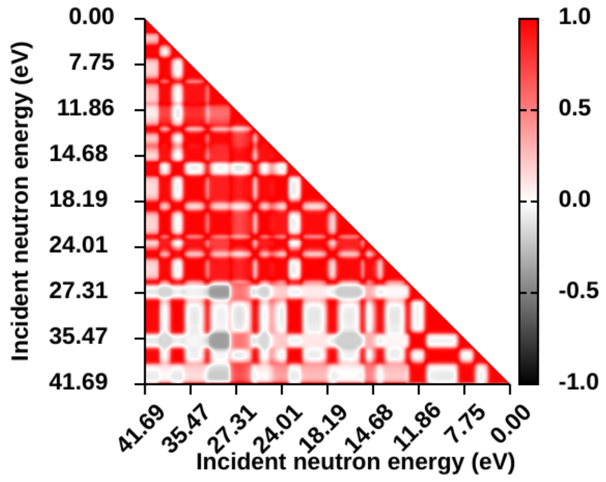

Figure 6: Preliminary fit of neutron multiplicities with available measured data and related covariance matrix.

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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

Collaborators: D. Wiarda, J. McDonnell, C. Chapman, J. Brown, A. Holcomb, G. Arbanas, K. Guber, K. S. Kim.

Questions?