

FPY Data Evaluation for ENDF/B-VII.1

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New FPY Evaluation for Pu-239 at LANL

- Re-analysis of chain yields by Chadwick, Mac Innes, et al. (NDS **111**, 2923 (2010), **112**, 3135 (2011))
- Energy dependence in the fast range considered
 - FPY data given at the thermal (same as before), 0.5 MeV, 2 MeV, and 14 MeV
- Require both cumulative yields and independent yields that are consistent with the evaluated chain yield
- We employed an adjustment technique with the KALMAN code
 - calculate decay chain from IY to CY using the decay data in CINDER2008
 - calculate sensitivities of the individual FP to the chain yield
 - apply KALMAN to update the IY, including constraint;

$$\sum Y_i = 2, \quad \sum Y_i A_i = A_{cn} - \bar{\nu}, \quad \text{and} \quad \sum Y_i Z_i = Z_{cn}$$

- calculate decay chain again to obtain CY

Matrix Notation

The chain yield $Y(A)$ can be related to the independent yield $I(Z, A, M)$ as

$$\mathbf{Y} = F(\mathbf{I})$$

where the elements of vectors \mathbf{Y} and \mathbf{I} are $Y(A)$ and $I(Z, A, M)$.

Normalization

$$\mathbf{T}^t \mathbf{I} = \sum_i^N I_i = 2$$

Mass conservation

$$\mathbf{U}^t \mathbf{I} = \sum_i^N I_i A_i = A_{CN} - \bar{\nu}$$

Charge conservation

$$\mathbf{V}^t \mathbf{I} = \sum_i^N I_i Z_i = Z_{CN}$$

Bayesian Method

Let \mathbf{I}_0 be the vector of prior independent yields. When the evaluated \mathbf{Y} is provided as new information, an updated \mathbf{I}_1 is given by

$$\begin{aligned}\mathbf{I}_1 &= \mathbf{I}_0 + \mathbf{P}_1 \mathbf{S}^t \mathbf{Z}^{-1} \{\mathbf{Y} - F(\mathbf{I}_0)\} \\ \mathbf{P}_1 &= \mathbf{X} - \mathbf{X} \mathbf{S}^t (\mathbf{S} \mathbf{X} \mathbf{S}^t + \mathbf{Z})^{-1} \mathbf{S} \mathbf{X}\end{aligned}$$

The constraints on \mathbf{I}_1 can be added

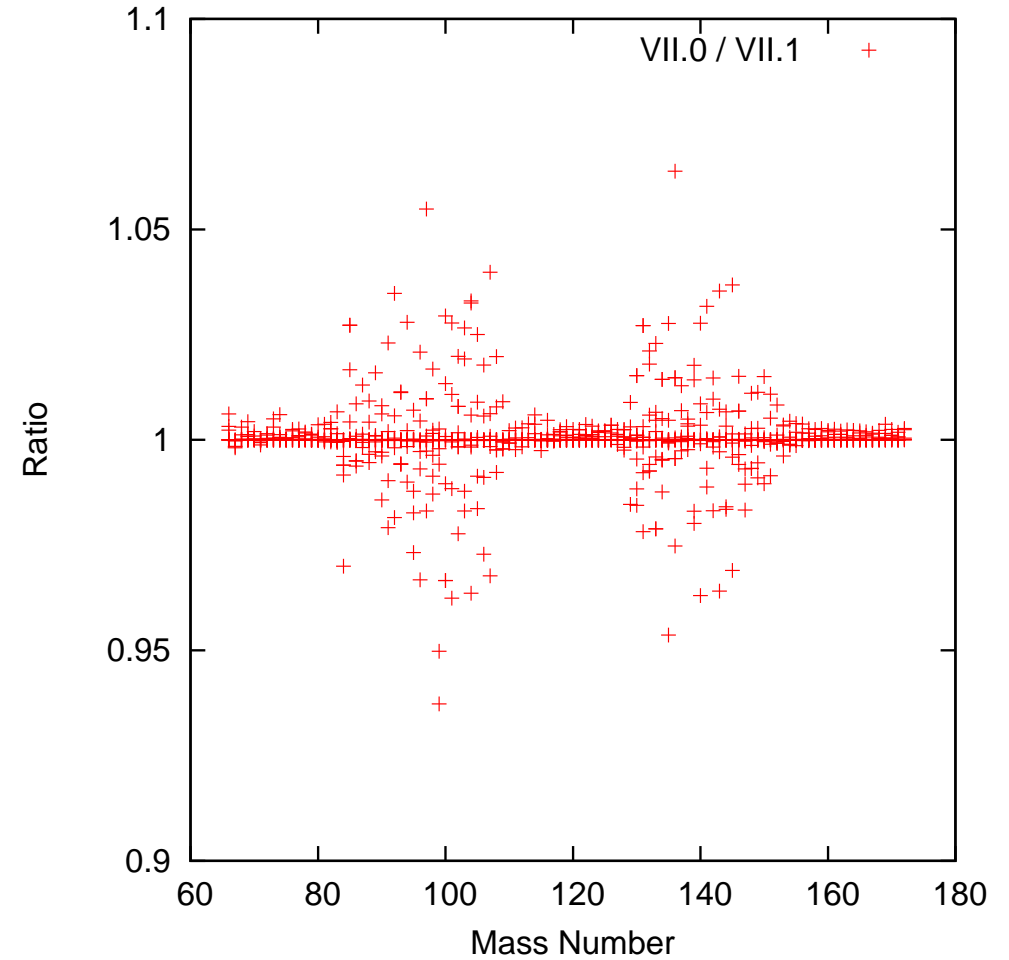
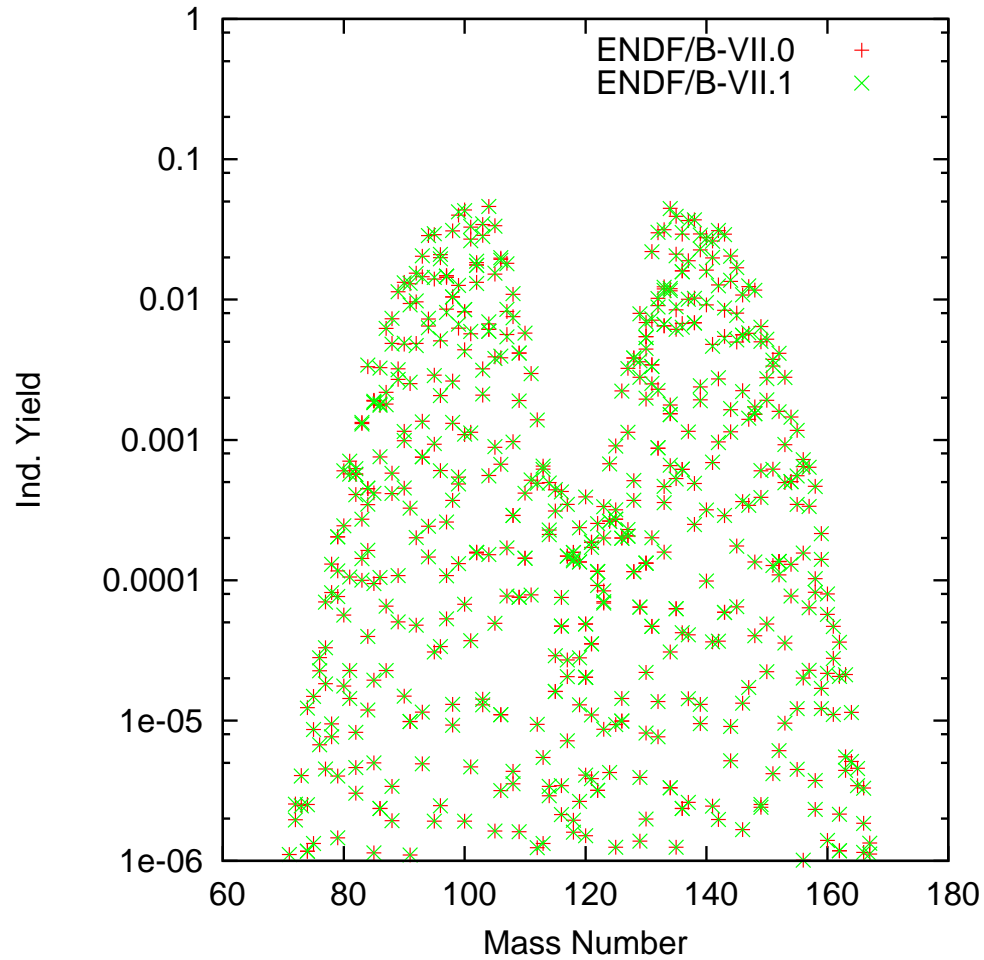
$$\mathbf{I}_2 = \mathbf{I}_1 + \frac{1}{\sigma_T^2} \mathbf{P}_2 \mathbf{T}^t (2 - \mathbf{T}^t \mathbf{I}_1), \quad \mathbf{P}_2 = \mathbf{P}_1 - \mathbf{P}_1 \mathbf{T}^t (\mathbf{T} \mathbf{P}_1 \mathbf{T}^t + \sigma_T^2)^{-1} \mathbf{T} \mathbf{P}_1$$

$$\mathbf{I}_3 = \mathbf{I}_2 + \frac{1}{\sigma_U^2} \mathbf{P}_3 \mathbf{U}^t (A_{CN} - \bar{\nu} - \mathbf{U}^t \mathbf{I}_2), \quad \mathbf{P}_3 = \mathbf{P}_2 - \mathbf{P}_2 \mathbf{U}^t (\mathbf{U} \mathbf{P}_2 \mathbf{U}^t + \sigma_U^2)^{-1} \mathbf{U} \mathbf{P}_2$$

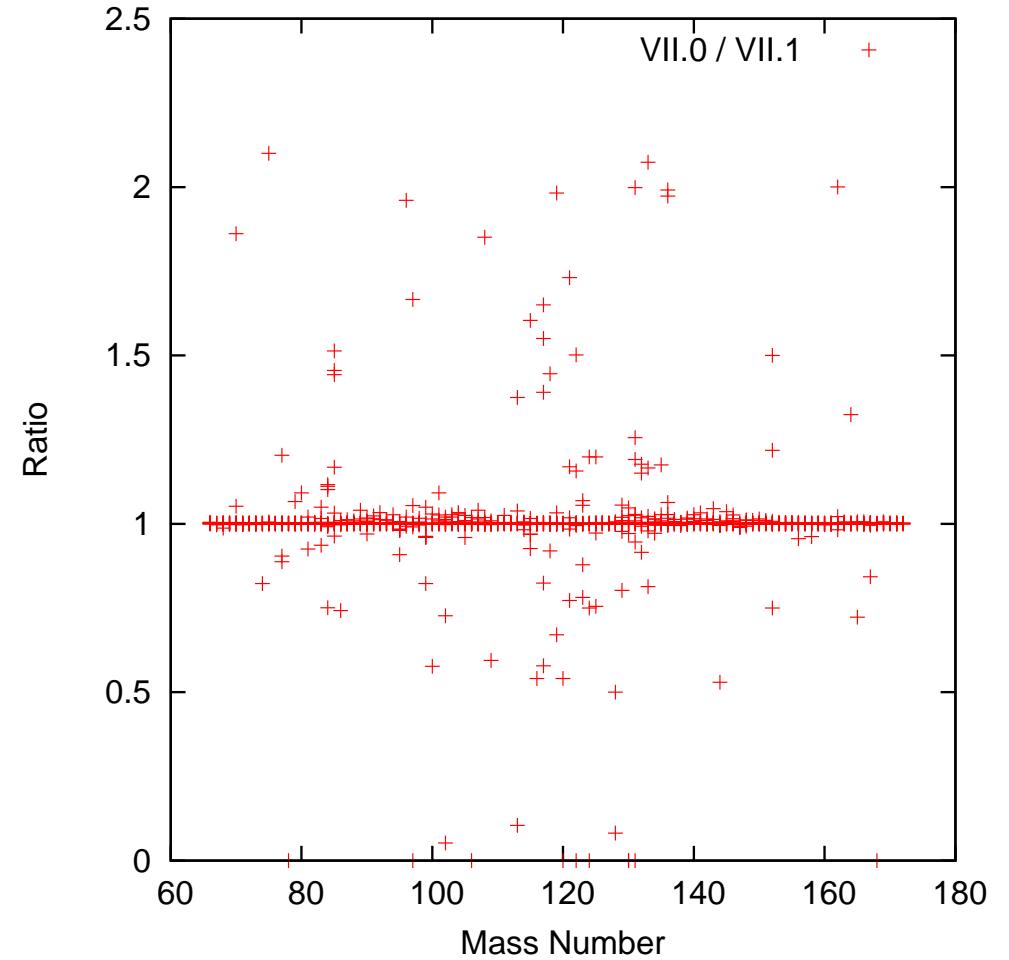
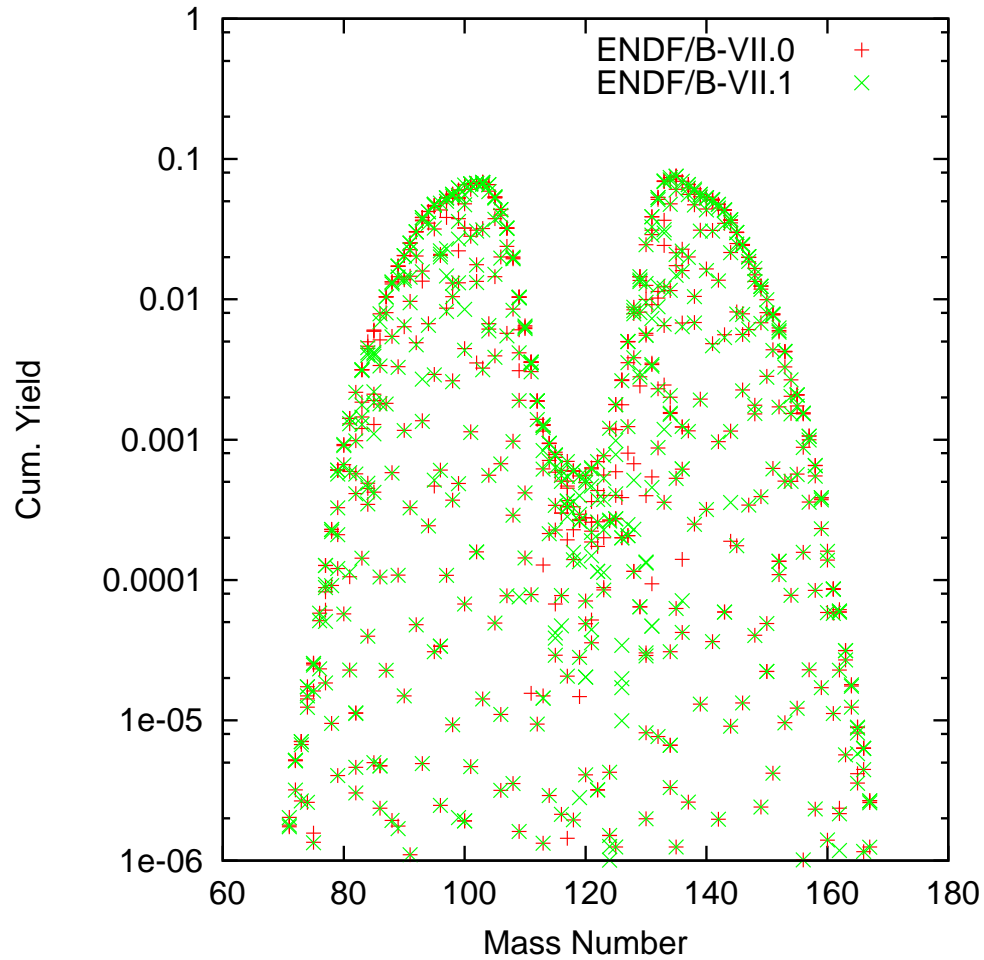
$$\mathbf{I}_4 = \mathbf{I}_3 + \frac{1}{\sigma_V^2} \mathbf{P}_4 \mathbf{V}^t (Z_{CN} - \mathbf{V}^t \mathbf{I}_3), \quad \mathbf{P}_4 = \mathbf{P}_3 - \mathbf{P}_3 \mathbf{V}^t (\mathbf{V} \mathbf{P}_3 \mathbf{V}^t + \sigma_V^2)^{-1} \mathbf{V} \mathbf{P}_3$$

where σ 's are criteria to satisfy these constraints.

Independent Yields at 500 keV

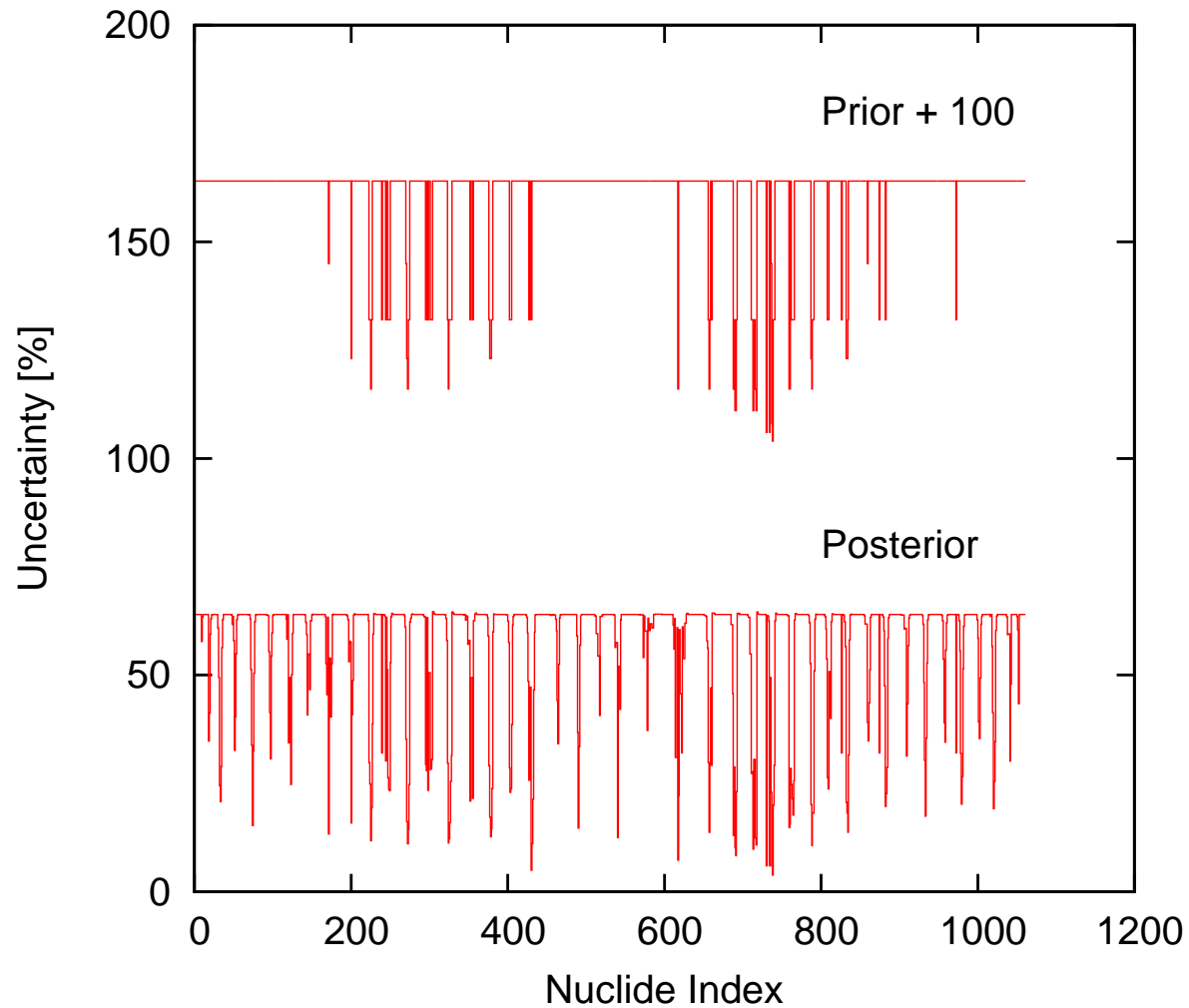


Cumulative Yields at 500 keV



Evaluated Independent Yields Uncertainties

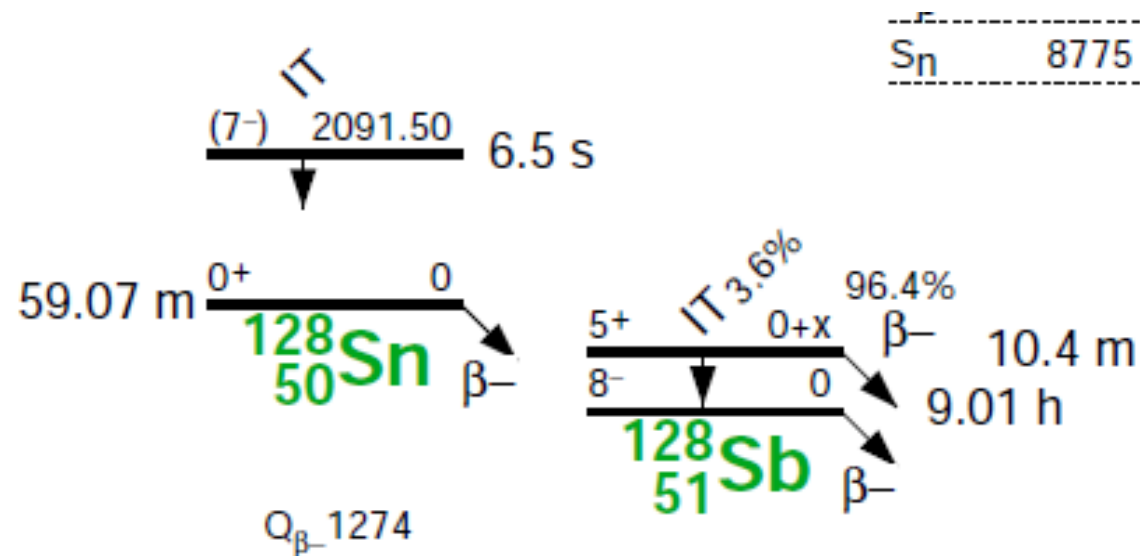
Comparison of Prior/Posterior Uncertainties



Correlation Matrix

Very sparse correlation matrix for $I(Z, A, M)$ obtained. Occasionally strong anti-correlations seen, mainly due to the competition of meta and ground states.

$$\text{Cov} \begin{pmatrix} {}^{127}\text{Sn} \\ {}^{127m}\text{Sn} \\ {}^{128}\text{Sn} \\ {}^{128m}\text{Sn} \\ {}^{129}\text{Sn} \\ {}^{129m}\text{Sn} \end{pmatrix} = \begin{pmatrix} 20 \\ 59 \\ 44 \\ 44 \\ 33 \\ 61 \end{pmatrix} \% \begin{pmatrix} 100 & & & & & \\ -94 & 100 & & & & \\ 0 & 0 & 100 & & & \\ 0 & 0 & -97 & 100 & & \\ 0 & 0 & 0 & 0 & 100 & \\ 0 & 0 & 0 & 0 & -56 & 100 \end{pmatrix} \%$$



Conclusion

- We presented a new calculational method to estimate the independent and cumulative fission yields when chain yield data are provided.
- With the Bayesian technique, required constraints such as the normalization can be simply included.
- We have applied this technique to the ^{239}Pu FPY data, and obtained the independent and cumulative yields at the neutron incident energies, 0.5, 2.0, and 14 MeV.
- Our evaluated FPY data are available as a part of ENDF FPY data library. However correlation matrices are not — the current data format does not allow to store these matrices.