Prompt Fission Neutron Spectrum: Evaluation and Uncertainty Quantification for a Suite of Uranium Isotopes

[1,2]M.Rising, [1]P.Talou, [1]T.Kawano and [2]A.Prinja

[1]Theoretical Division, Los Alamos National Laboratory, USA

[2]Department of Nuclear Engineering, University of New Mexico, USA

LA-UR-11-11976

Uncertainty Quantification in Evaluations

- **OECD/WPEC Subgroup 24 Report:**
  "Covariance Data in the Fast Neutron Region", Eds. By M.Herman and D.Smith
- **Several covariance methodologies:**
  - **Deterministic**: Bayesian inference
    - Linear assumption around central values;
    - Gaussian distributions;
    - Difficulty in assessing UQ on discrete quantities.
  - **Stochastic**: Monte Carlo sampling, e.g., "Total Monte Carlo", "Forward-Backward Monte Carlo", …
    - Do not incorporate experimental uncertainties;
    - Computationally intensive;
    - No more covariance matrices.
  - **Hybrid:**
    - GANDR
    - Unified Monte Carlo

The Los Alamos Model

- **Average over fission fragments and over de-excitation cascades**
- **Provide *average* prompt fission neutron spectrum (PFNS) and multiplicity (PFNM)**

$$N(E) = \frac{1}{2\sqrt{E_f}T_m^2} \int_{\left(\sqrt{E}-\sqrt{E_f}\right)^2}^{\left(\sqrt{E}+\sqrt{E_f}\right)^2} \sigma_c(\epsilon)\sqrt{\epsilon}d\epsilon \times \int_0^{T_m} k(T)T exp(-\epsilon/T)dT$$

Kinematic boost from c.m. to lab

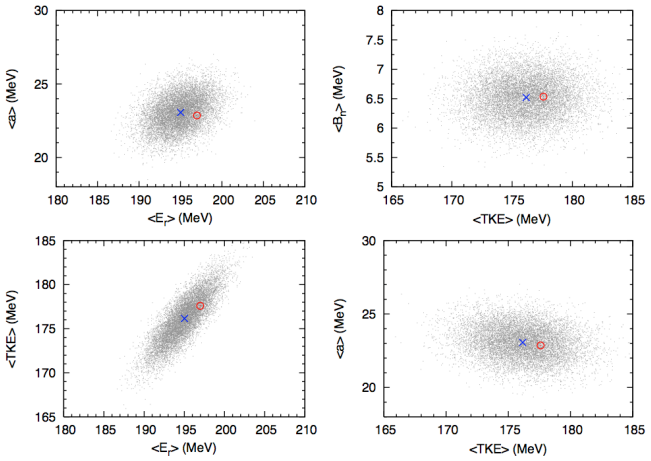
Weisskopf evaporation spectrum

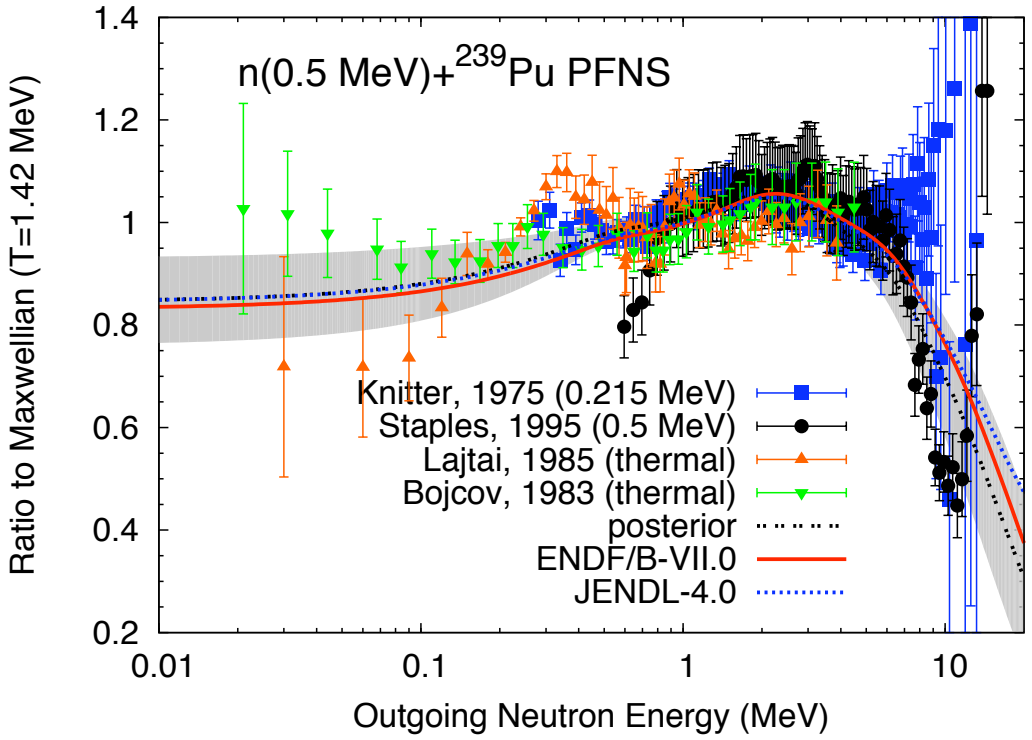
Triangular distribution of *effective* temperatures

Application: n(0.5 MeV)+^{239}Pu PFNS

- P.Talou, T.Kawano, D.G.Madland, A.C.Kahler, D.K.Parsons, M.C.White, R.C.Little, and M.B.Chadwick, Nucl. Sci. Eng. **166**, 254 (2010).

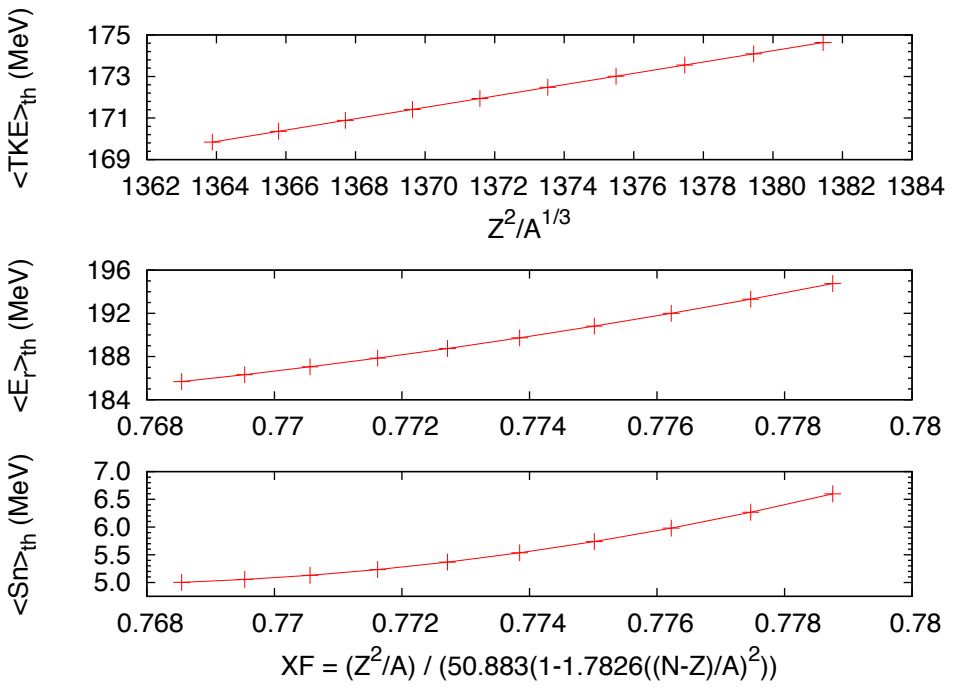
PDF of model parameters





Study across a suite of isotopes

- **Advantages**
  - Cross-isotope correlations
  - Consistent evaluation procedure
  - Reasonable evaluations and UQ where no data exist
- **LA model parameters**
  - Systematics used as prior: A.Tudora, Annals of Nuclear Energy **36**, 72 (2009).
- **Experimental database for entire suite**
  - Current limitations: partial database only, simple experimental correlation matrices, no use of $<\nu>(E_{inc})$ data.



Suite of Uranium Isotopes

- **Experimental Database, low incident neutron energies only**

Table 1: Experimental database on prompt fission neutron spectra for the suite of uranium isotopes studied

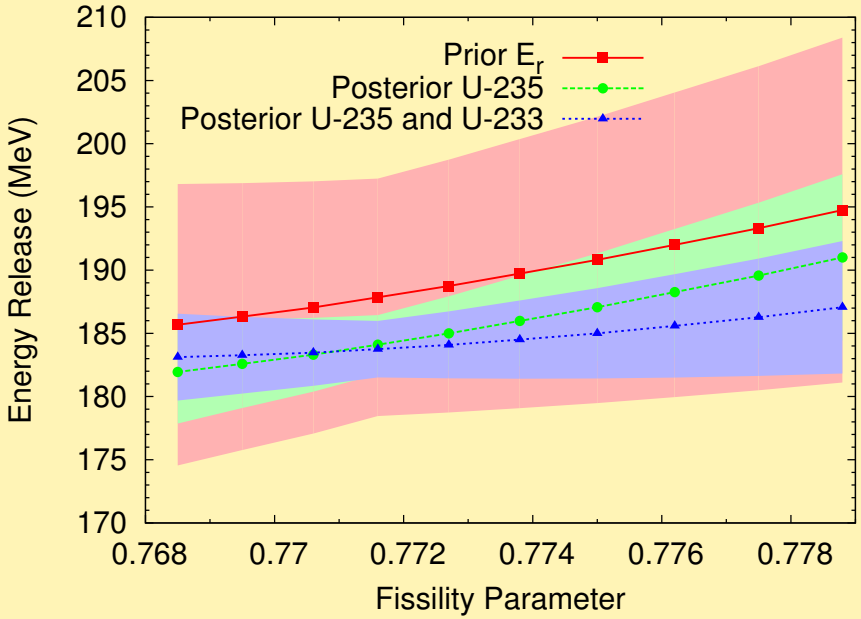
Isotope	EXFOR	First Author	Year	E_{inc}
U-233	22688-002	T. Miura	2002	0.55 MeV
	30704-002	A. Lajtai	1985	thermal
	40872-005	B.I. Starostov	1983	thermal
U-235	-	F.-J. Hambsch	2010	thermal
	30704-003	A. Lajtai	1985	thermal
	40872-004	B.I. Starostov	1983	thermal
	40873-001	A.A. Bojcov	1983	thermal
	20175-001	P.I. Johansson	1977	0.53 MeV
	20996-003	J.M. Adams	1975	0.52 MeV
U-238	41110-010	G.S.Boykov	1991	2.9 MeV

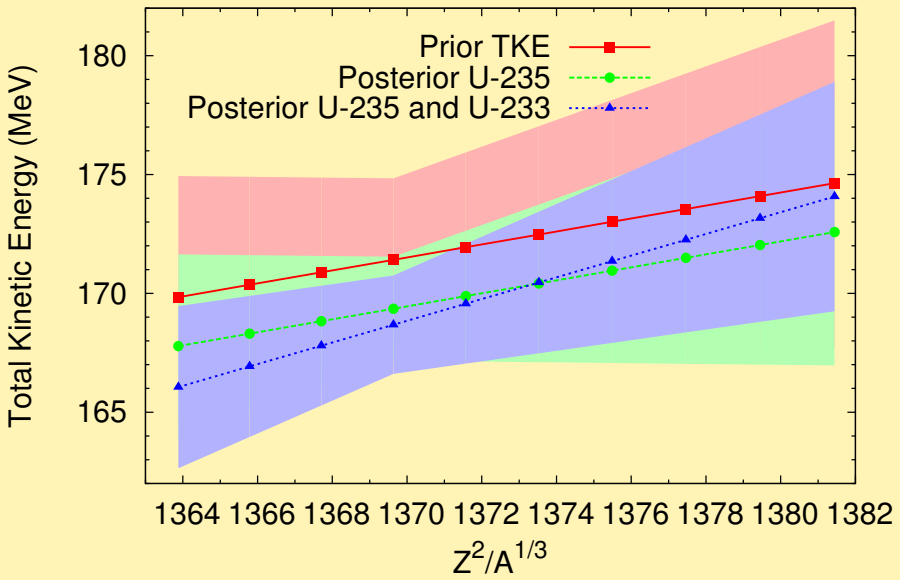
Model Input Parameters

- ***Prior parameters***:
  A.Tudora, Annals of Nuclear Energy **36**, 72 (2009).

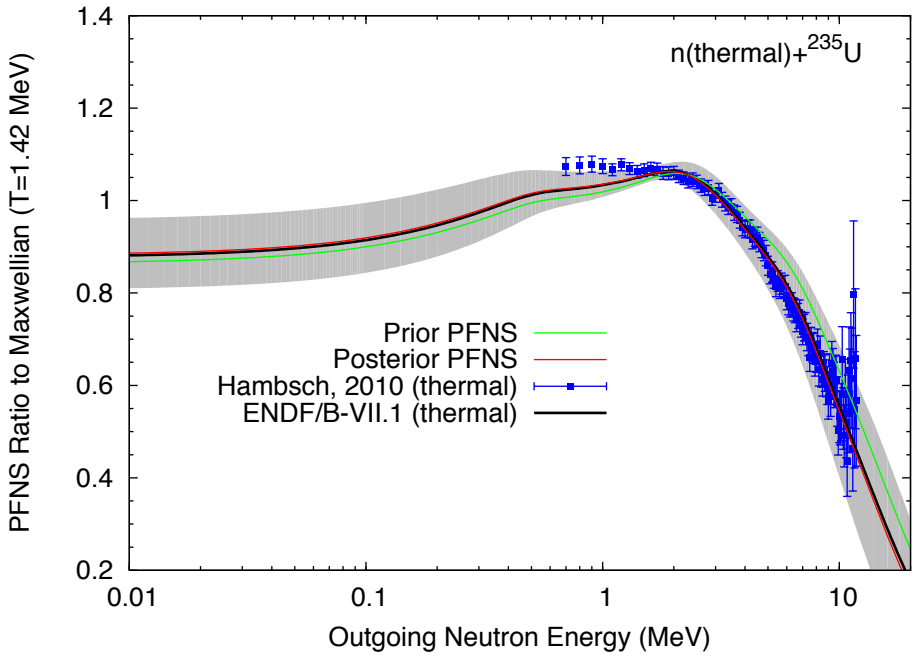
$$\langle TKE\rangle_{th} = \alpha_1 + \alpha_2 Z^2/A^{1/3},$$
$$\langle E_r\rangle_{th} = \alpha_3 + \alpha_4 x + \alpha_5 x^2,$$
$$\langle S_n\rangle_{th} = \alpha_6 + \alpha_7 x + \alpha_8 x^2,$$
$$\langle a\rangle = A/\alpha_9$$

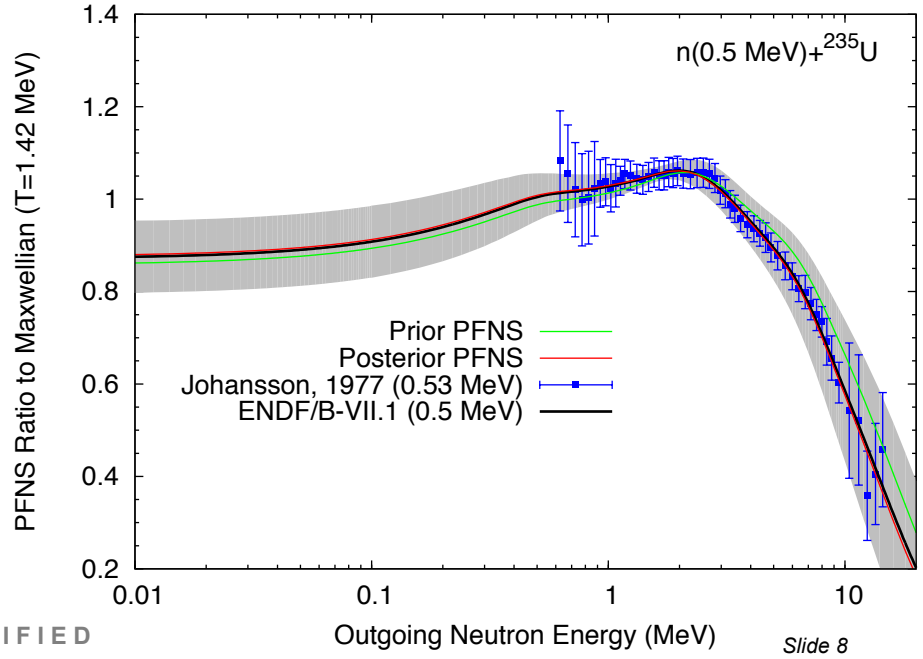
- ***Posterior parameters*** and uncertainties obtained with Kalman filter, experimental database and LAM calculations
- Presented at 2nd Workshop on Neutron Cross Section Covariances, Vienna, Sep. 2011



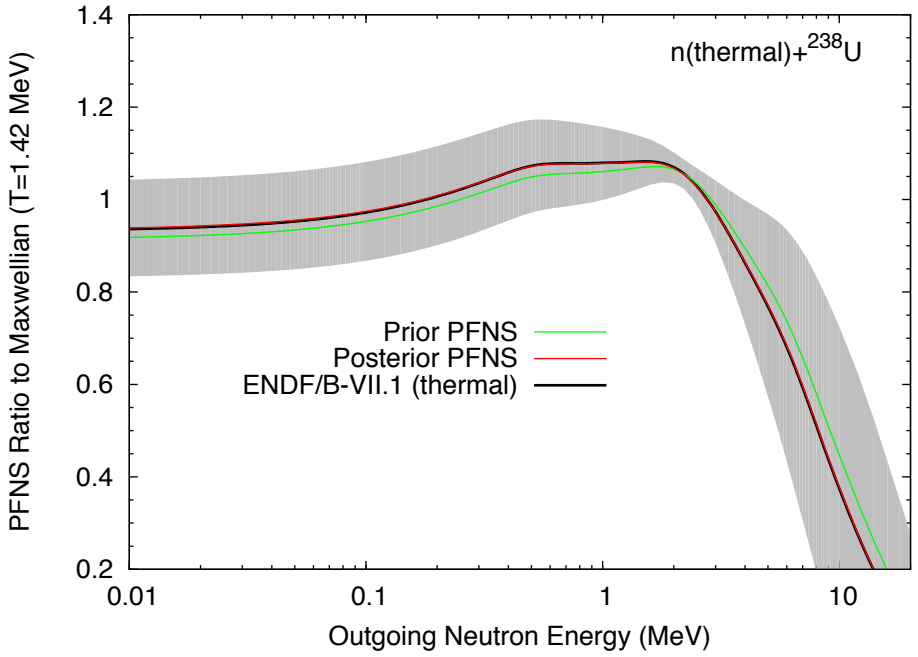


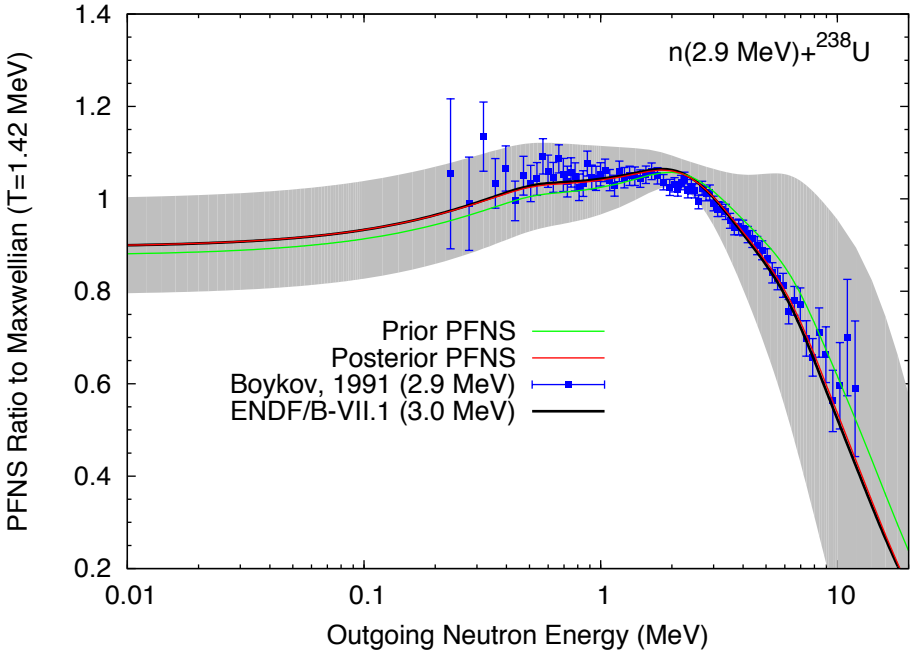
Posterior n+^{235}U PFNS

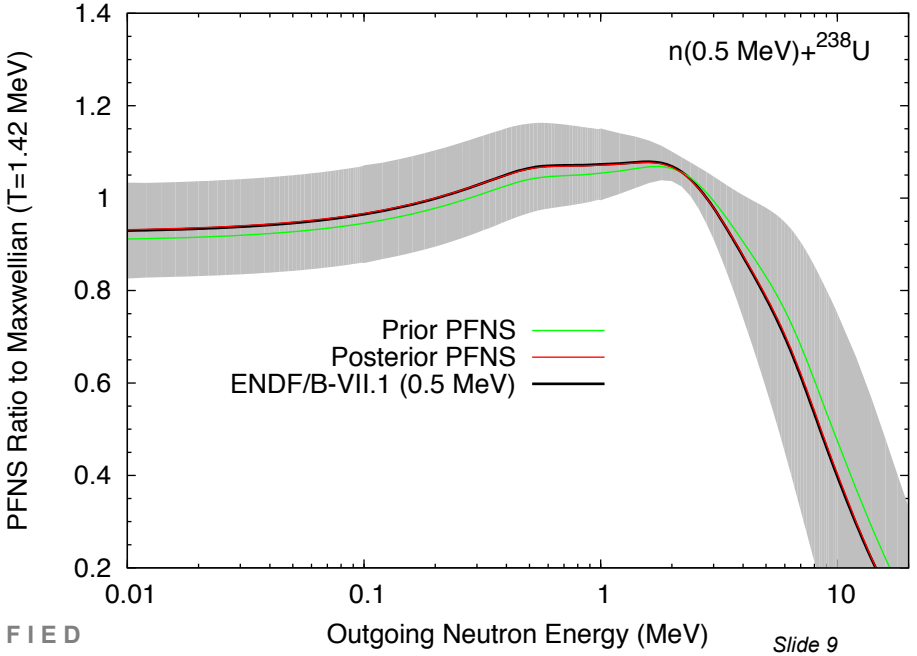




Posterior n+^{238}U PFNS

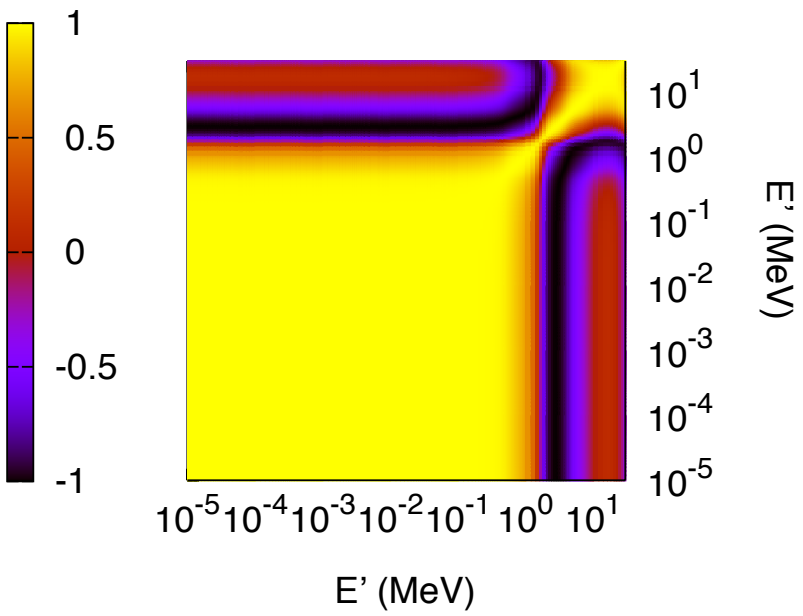




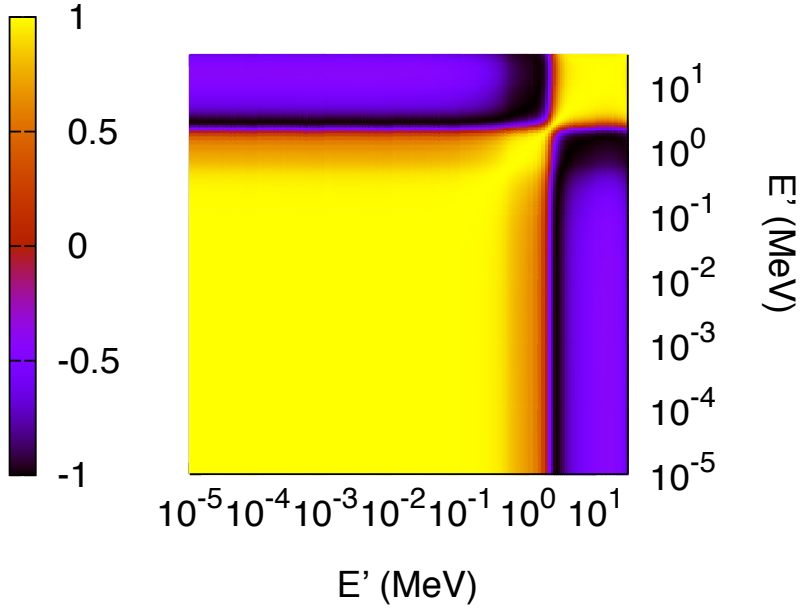


Posterior n(0.5 MeV)+^{235}U & n(0.5 MeV)+^{238}U Covariance

n(0.5 MeV)+^{235}U



n(0.5 MeV)+^{238}U



Final Thoughts

- **Covariance matrices for n(0.5 MeV)+^{235}U & n(0.5 MeV)+^{238}U included in ENDF/B-VII.1 library**
- **Upcoming paper:**
  P.Talou, P.G.Young, T.Kawano, M.Rising and M.B.Chadwick, *"Quantification of Uncertainties for Evaluated Neutron-Induced Reactions on Actinides in the Fast Energy Range,"* to appear in **Nuclear Data Sheets (Dec. 2011).**
- **Continued work on evaluation of actinide suites**
- **Use additional experimental data to constrain model parameters: $\langle\nu\rangle(E_{inc})$, $\langle\chi\rangle(E_{inc})$, etc.**