Prompt Fission Data in ^{235,238}U and ^{239}Pu

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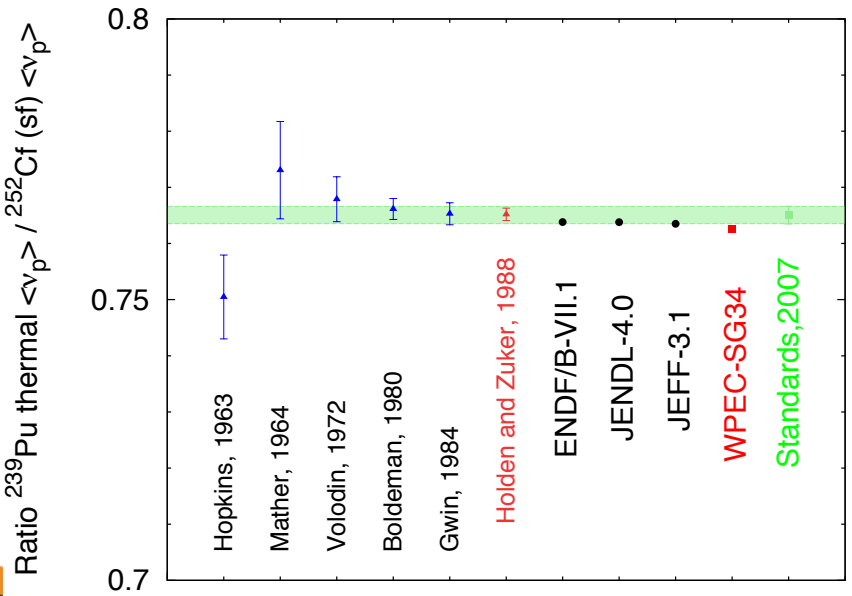
CSEWG, Brookhaven National Laboratory, Nov. 3-5, 2014

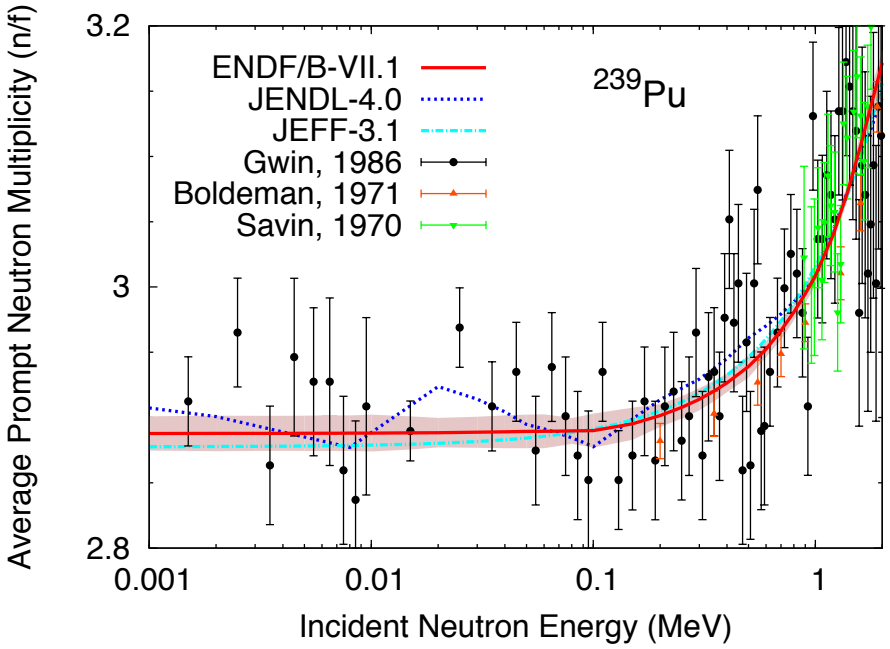
Prompt Fission Data

- Prompt fission neutrons
  - Average multiplicity, $\langle\nu\rangle(E_{inc})$
  - Multiplicity distribution, $P(\nu)$
  - Energy spectrum, PFNS, $\chi(E_{inc},E_{out})$
- Prompt fission gammas
  - Energy spectrum $N_{\gamma}(E_{inc},E_{out})$
- $\langle\nu\rangle$ and $\langle E_{\gamma}^{tot}\rangle$ fluctuations in the RRR
  - the $(n,\gamma f)$ process

Average neutron multiplicity, ^{239}Pu

- Thermal $\langle\nu_p\rangle$, latest WPEC-SG34 vs. Standards'07
- Fluctuations in the RRR
- Re-evaluation needed in the fast energy range?
- Fixed the B-VII.1 covariance matrices for $\langle\nu_p\rangle$ for both ^{235}U and ^{239}Pu (submitted to NNDC in Aug. 2014)

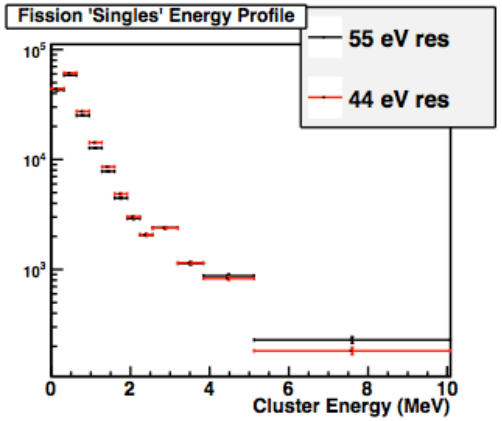


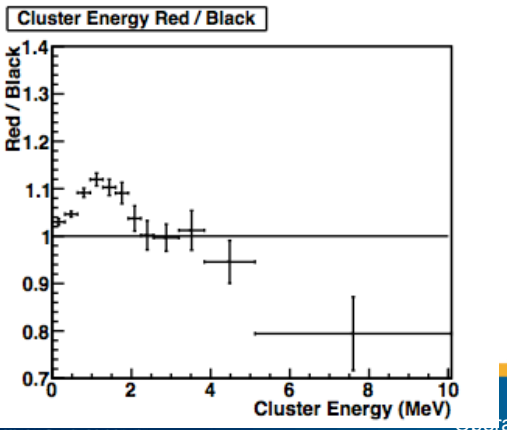


Average neutron multiplicity, ^{239}Pu

Fluctuations in the RRR

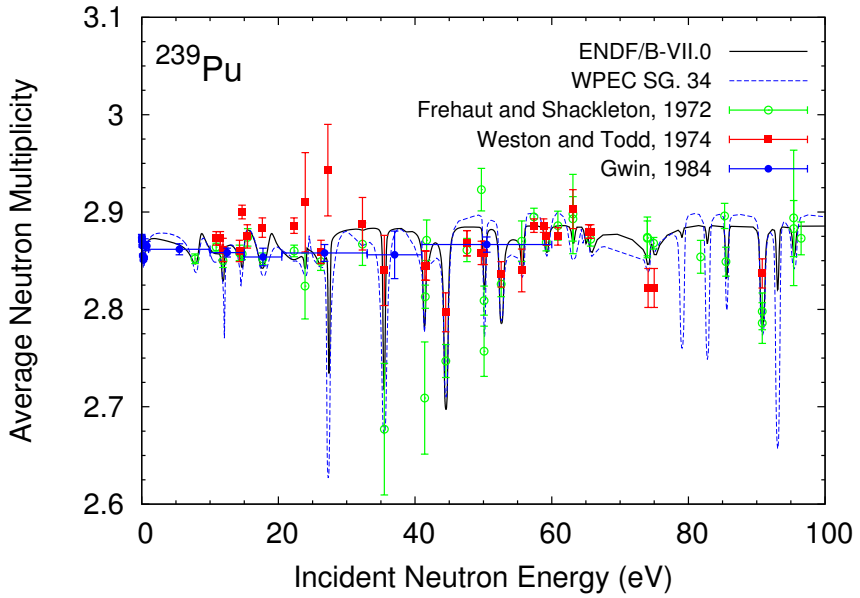
- Physics: (n,γf) or/and Y(A,Z,TKE)?
- Impact on applications?

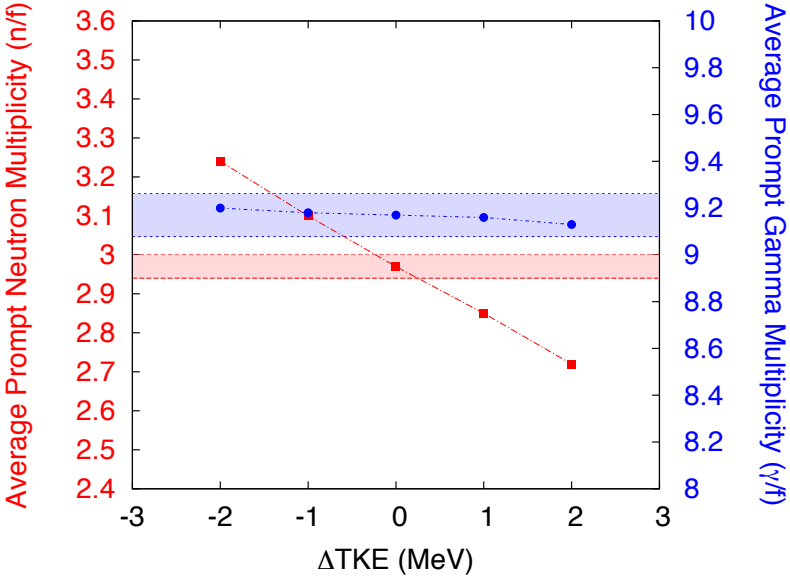




DANCE γ-ray data (Mosby, Couture)

Monte Carlo Hauser-Feshbach calculations with Y(A,Z,TKE+ΔTKE)





Average neutron multiplicity, ^{235,238}U

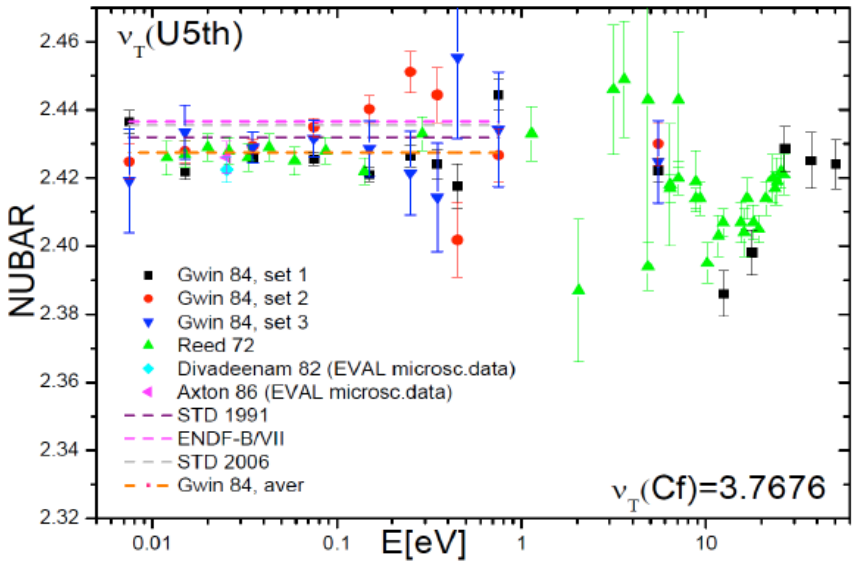
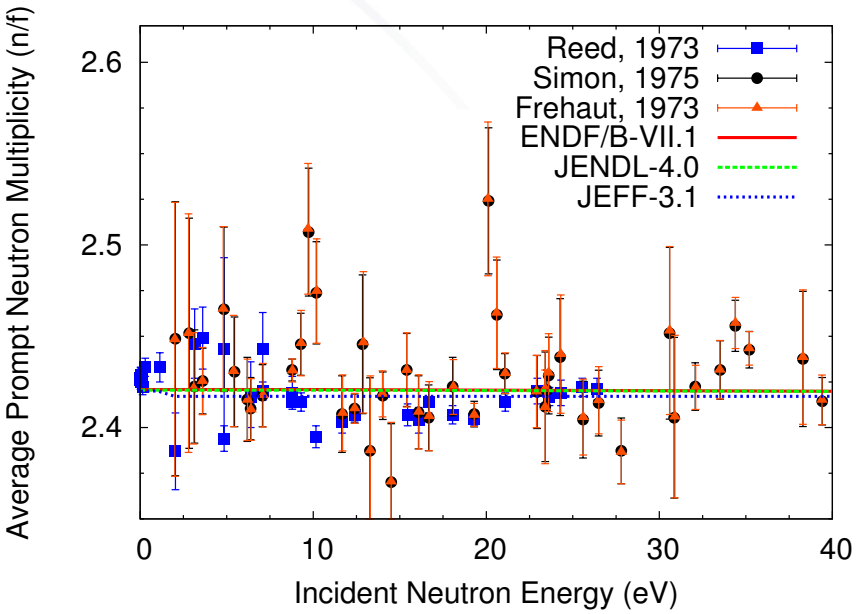


Figure 3: Comparison of energy-dependent measured values of nu-bar and some "Standards" and their evolution with time.



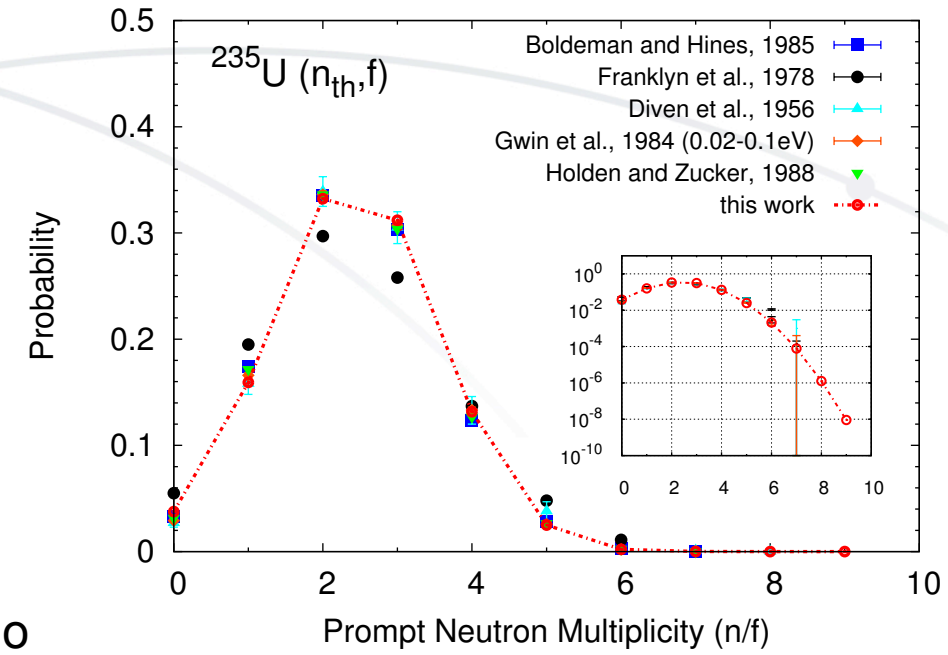
From Trkov, Capote (2014)

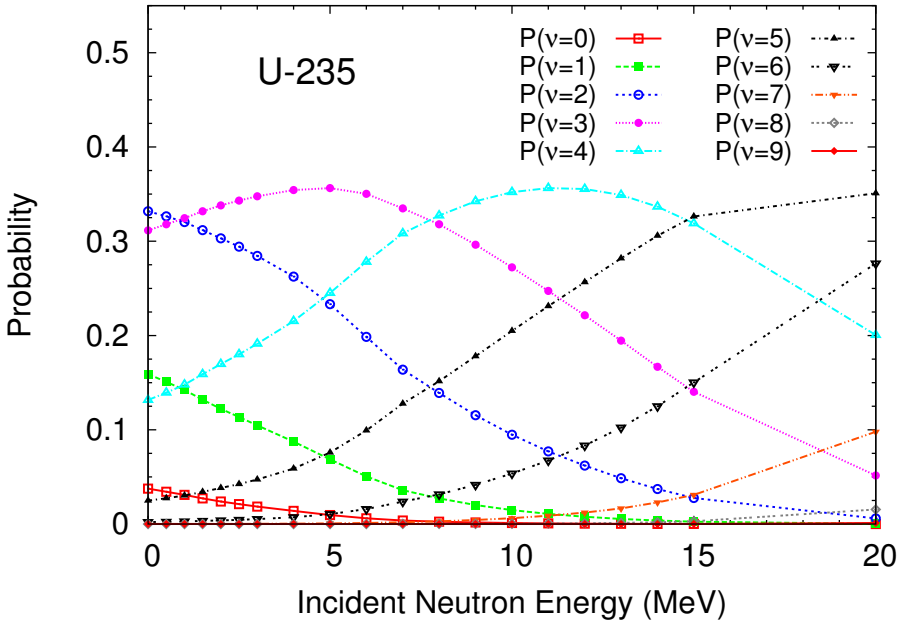
Lack of accurate experimental data

Neutron Multiplicity Distribution P(ν)

- Experiment:
  - very little data, esp. at higher energies
- Modeling:
  - new capabilities with Monte Carlo codes: CGMF, FREYA, FIFRELIN GEF, …
  - Systematics based on Terrell's formula, and compared to limited data by Frehaut

$$\sum_{n=0}^{\nu} P_n = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{(\nu-\overline{\nu}+1/2+b)/\sigma} exp(-t^2/2)dt$$



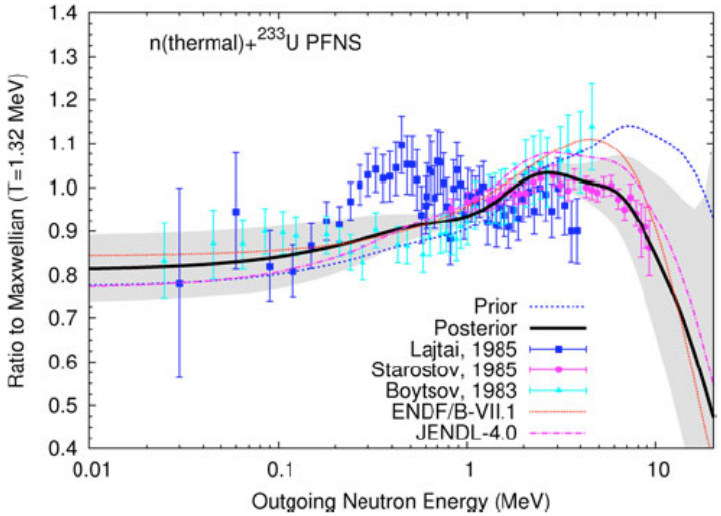


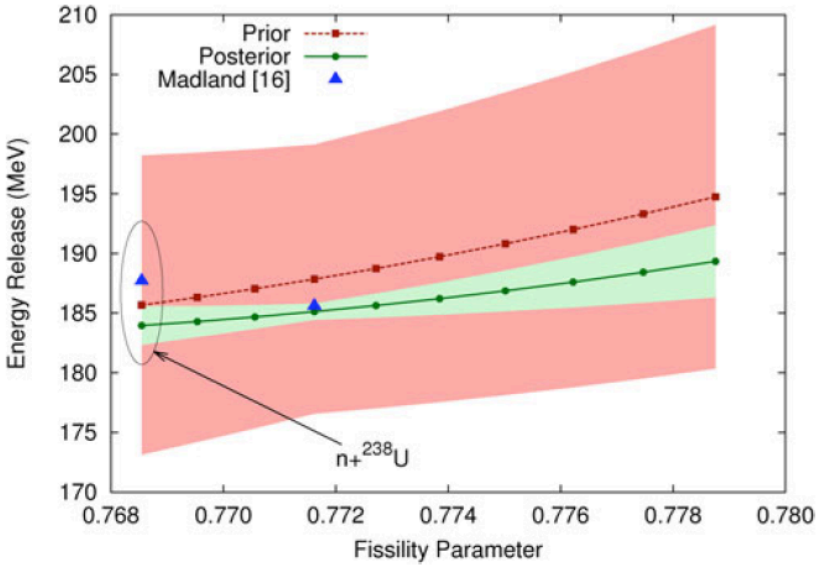
Prompt Fission Neutron Spectrum

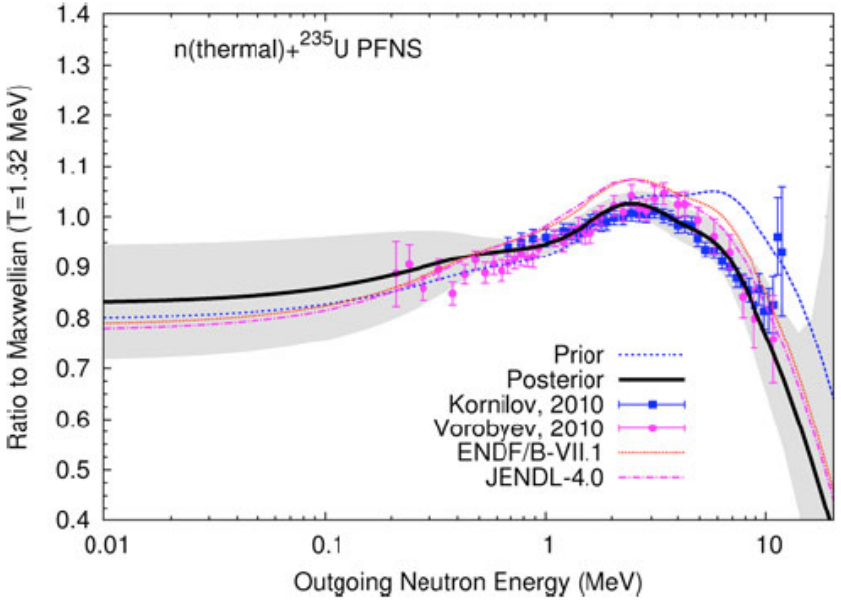
- Some general comments…
  - All evaluations rely on the ^{252}Cf(sf) PFNS, Mannhart, 1987; new ongoing work at RPI
  - All experimental data are considered as “shape” measurements
  - Difficulties in assessing PFNS at the lowest and highest outgoing energies
- ^{239}Pu: work at LANL (Neudecker)
- ^{235}U: work at IAEA (Trkov)
- ^{238}U: work at BRC (Morillon) & LANL eval.
- Experimental work at LANL (Haight)

“Global” evaluation for U and Pu isotopes

- Rising, Talou, Kawano, Prinja, NSE 175, 81 (2013)
- Systematics as function of (A,Z) and E_{inc} (up to 5 MeV only)
- Include covariance matrices







Isotope Cross-Correlations

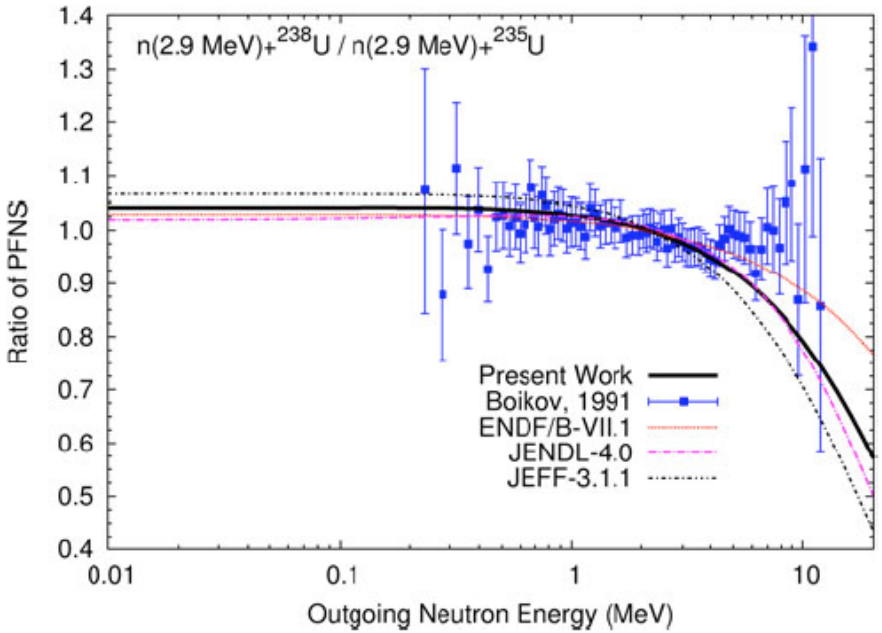


TABLE I

Experimental Measurements of the n + $^{229-238}$U PFNS Used in

Mass Number, A	First Author	Date of EXFOR Entry	E_{inc} (MeV)	E_{out} (MeV)		
233	Miura	2002	0.55	0.7 to 12.1		
233	Lajtai	1985	Thermal	0.03 to 3.855		
233	Starostov	1985	Thermal	0.83 to 9.3		
233	Boytsov	1983	Thermal	0.025 to 4.6		
235	Kornilov	2010	Thermal	0.68 to 11.8		
235	Vorobyev	2010	Thermal	0.21 to 10.8	41516-017	24, 14
235	Staples	1995	0.5 to 3.5	0.596 to 16.772	13982-002	29
235	Boikov	1991	2.9	0.232 to 11.885	41110-009	30
235	Wang	1989	Thermal	0.58 to 12.3	32587-002	31, 14
235	Lajtai	1985	Thermal	0.025 to 4.0	30704-003	26, 14
235	Starostov	1985	Thermal	0.085 to 12.3	40930-006	27, 14
235	Boytsov	1983	Thermal	0.025 to 4.6	40873-004	28, 14
235	Johansson	1977	0.53	0.625 to 14.45	20175-003	32
235	Adams	1975	0.52	0.625 to 15.629	20996-003	33
238	Trufanov	2001	5.0	0.28 to 12.27	41450-003	34
238	Boikov	1991	2.9	0.232 to 11.885	41110-010	30
238	Baba	1989	2.0	2.5 to 12.87	22112-002	35

*Including both work from the EXFOR database[13] and modified data from the IAEA PFNS experimental data.[14] Even though the IAEA modified data are preferred in this work, the original EXFOR entry is included for reference.

Average Prompt Fission Gamma Multiplicity $\langle \nu_\gamma \rangle$ and Total Energy $\langle E_\gamma^{tot} \rangle$

Isotope	Quantity	ENDF/B-VII	Oberstedt	DANCE (Jandel)	DANCE (Chyzh)	CGMF (LANL)
Pu239T	$\langle E_\gamma^{tot} \rangle$ (MeV)	6.741	-	8.07	7.94	6.66
	$\langle \nu_\gamma \rangle$ (γ/f)	7.78	-	7.08	7.93	7.48
U235T	$\langle E_\gamma^{tot} \rangle$ (MeV)	6.600	6.96	6.42	8.35	6.45
	$\langle \nu_\gamma \rangle$ (γ/f)	7.04	8.19	6.23	7.35	7.41
Cf252 (sf)	$\langle E_\gamma^{tot} \rangle$ (MeV)		6.64	7.22	8.52	6.85
	$\langle \nu_\gamma \rangle$ (γ/f)		8.30	8.02	8.75	8.15

Caution when comparing data and models…

Threshold gamma energies (E_{th}=100 keV) and time-coincidence window (6ns)