Prompt Fission Neutrons

LANL Evaluation Plans

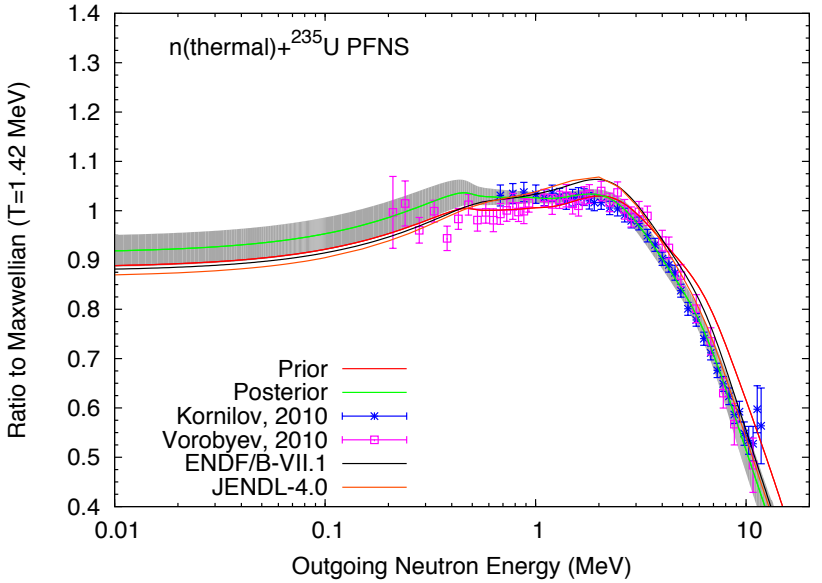
Patrick Talou

T-2, Nuclear Physics Group
Los Alamos National Laboratory

New PFNS evaluations for **uranium & plutonium isotopes**

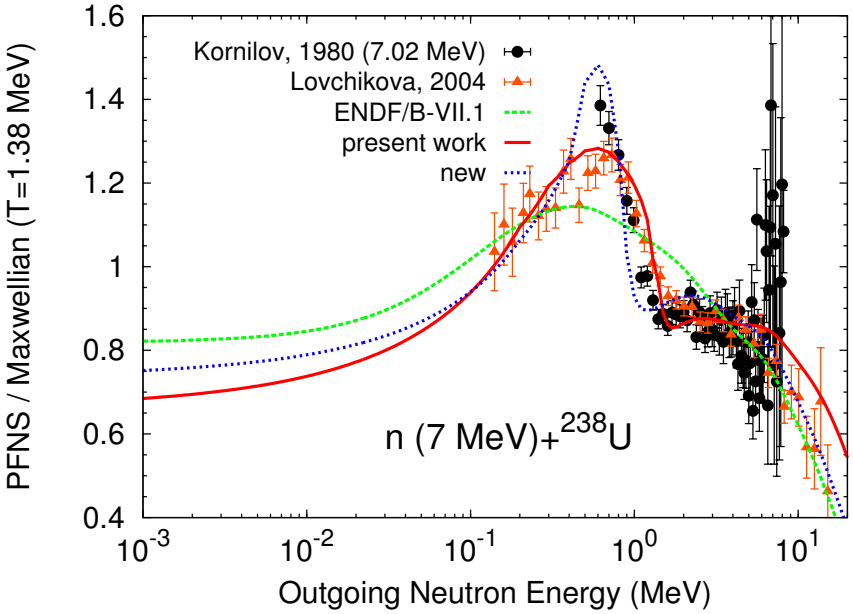
- **Evaluations & UQ**
  - Uranium isotopes, A=229-238
  - Plutonium isotopes, A=235-242
- "Evaluation and Uncertainty Quantification of Prompt Fission Neutron Spectra of Uranium and Plutonium Isotopes," M.E.Rising, P.Talou, T.Kawano, and A.K.Prinja, Nucl. Sci. Eng. **175**, 81 (2013)
- Correlations in energy and isotope
- Limited to first-chance fission

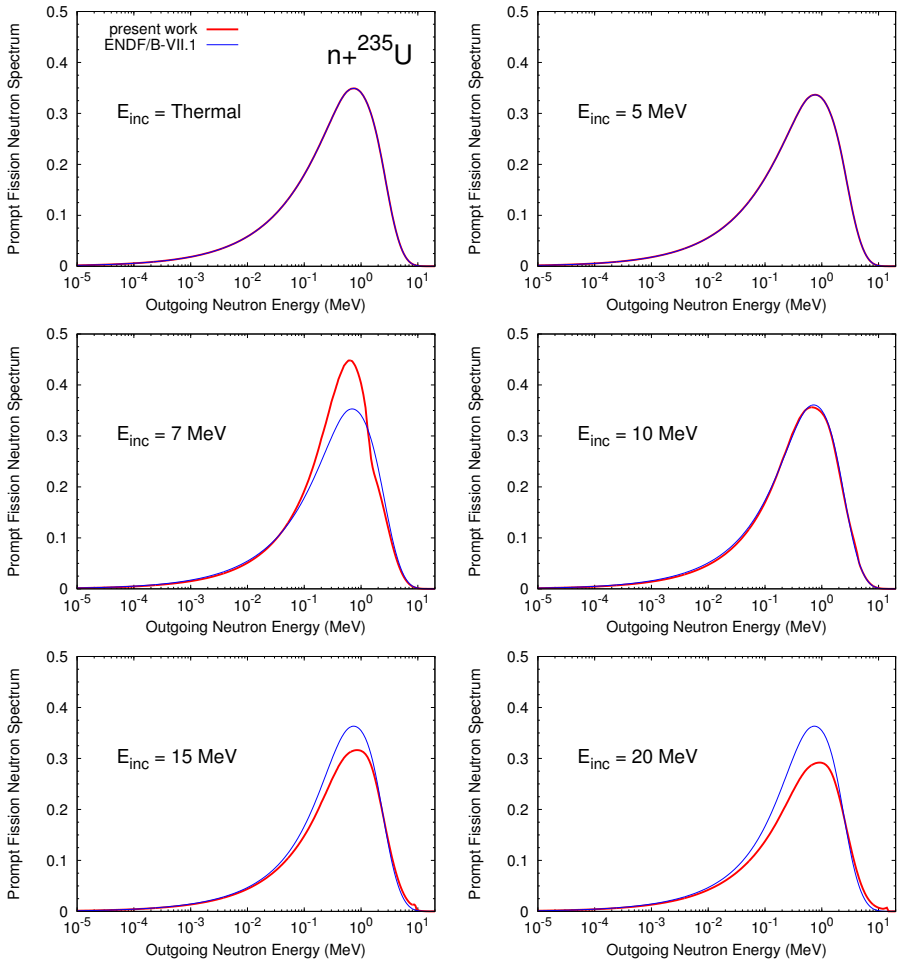
$$\langle TKE \rangle_{th} = \alpha_1 + \alpha_2 Z^2/A^{1/3},$$
$$\langle E_r \rangle_{th} = \alpha_3 + \alpha_4 x + \alpha_5 x^2,$$
$$\langle S_n \rangle_{th} = \alpha_6 + \alpha_7 x + \alpha_8 x^2,$$
$$\langle a \rangle = A/\alpha_9$$



Extension to Higher Incident Energies

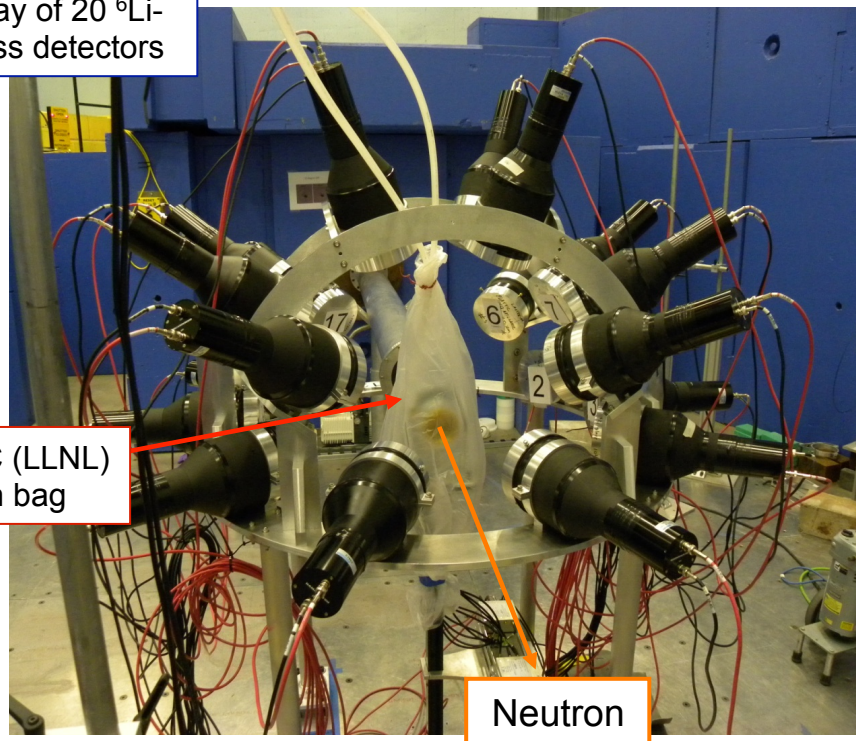
$n+^{235}U$





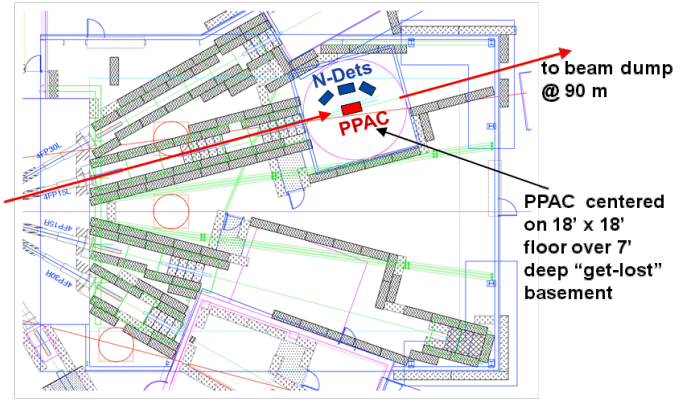
Chi-Nu data to be included
when available

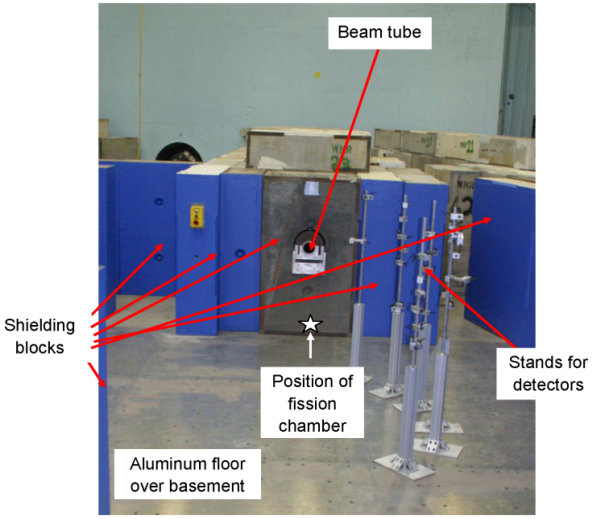
Array of 20 ^{6}Li-glass detectors



PPAC (LLNL) – in bag

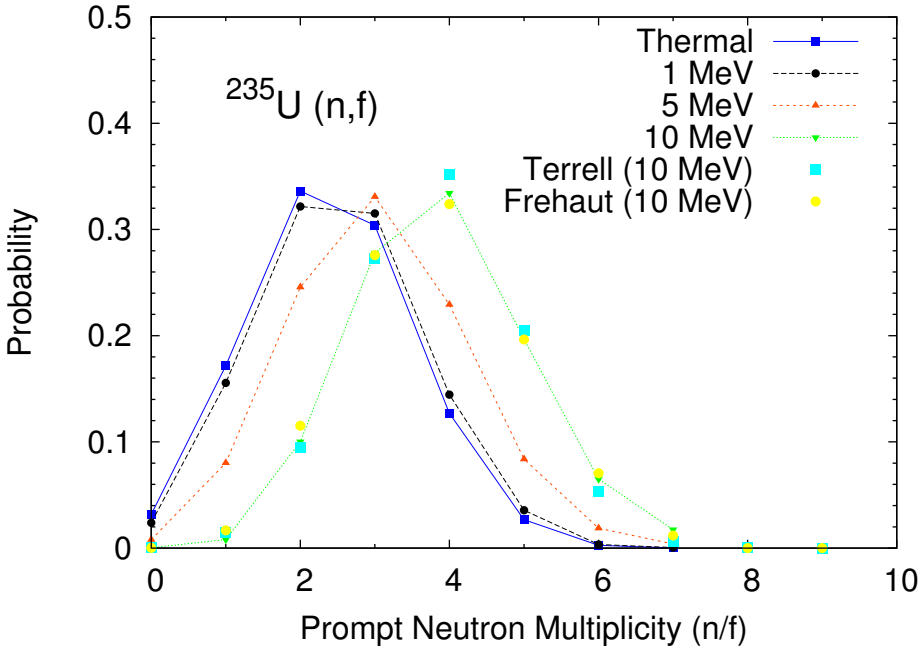
Neutron beam

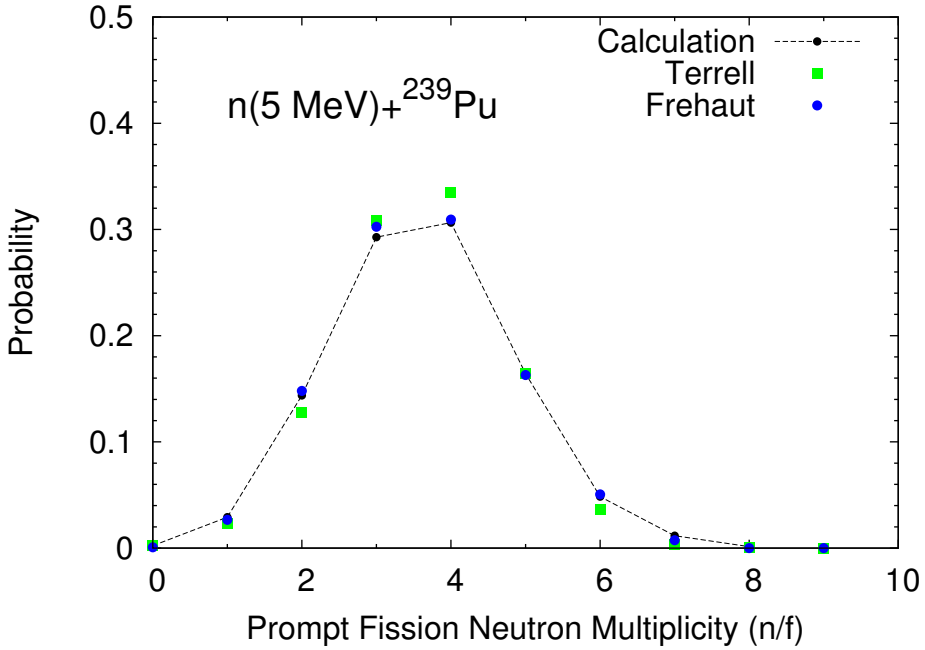




Prompt Fission Neutron Multiplicity Distribution P(ν)

- **Very little data on P(ν) beyond thermal values**
  - Frehaut, IAEA INDC(NDS)-220, 81 (1989)
  - Terrell, Phys. Rev. **108**, 783 (1957)
- **ENDF Formatting:** ^{235}U, ^{239}Pu from thermal up to 20 MeV
  - Move PFNS from MF5,MT18 to MF6,MT18; each subsection correspond to a multiplicity probability → cumbersome… new format?

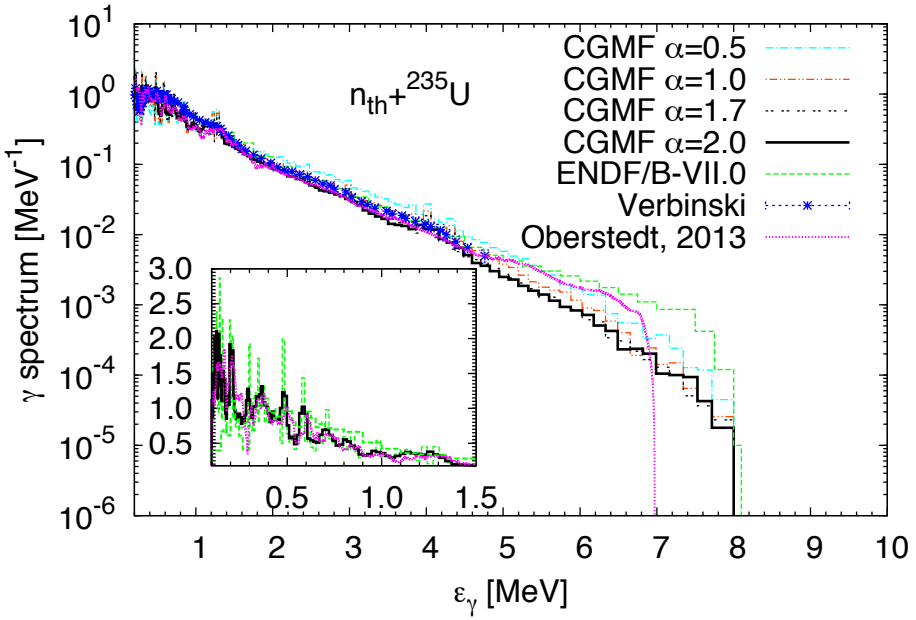




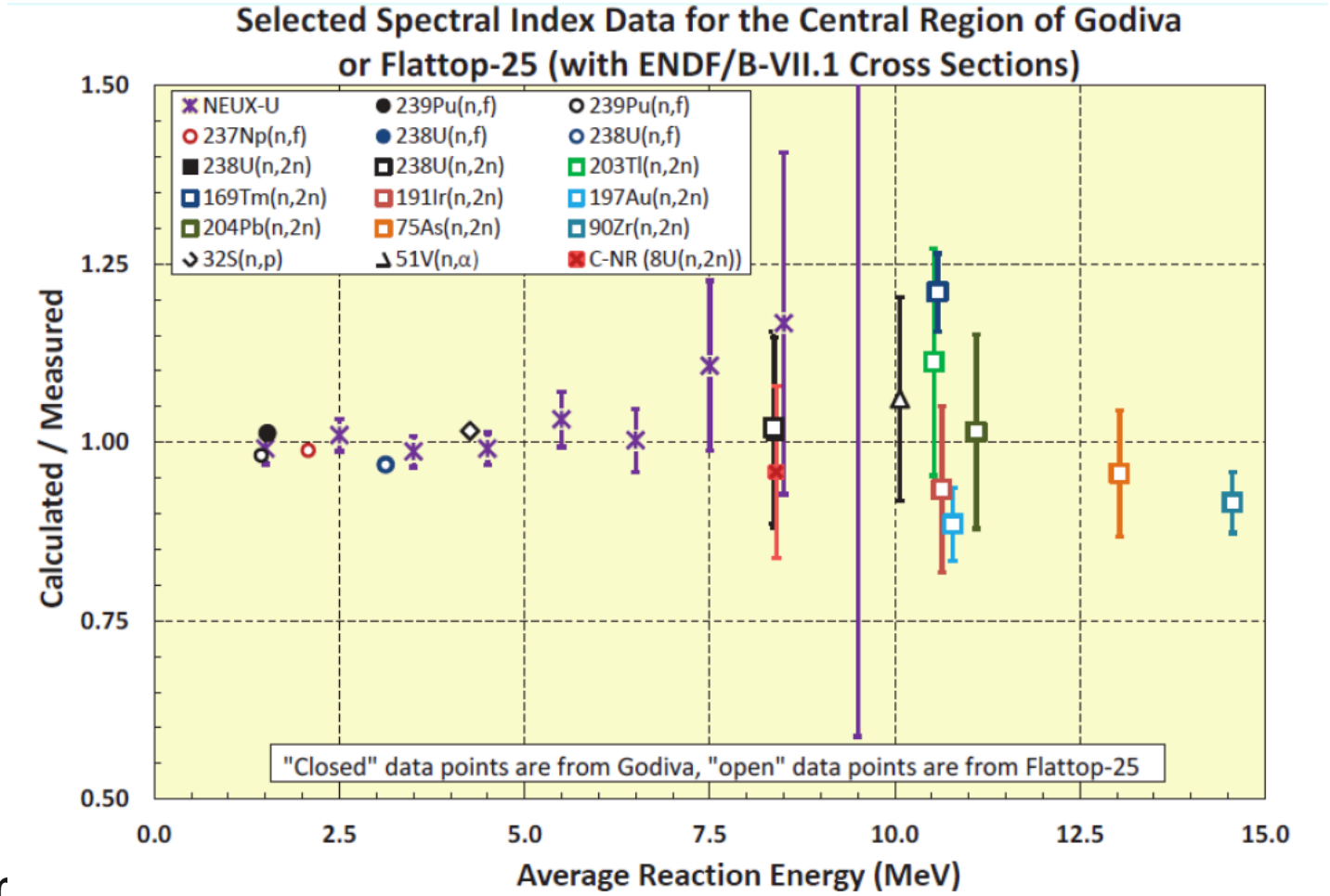
Prompt Fission Gamma Data

- New ENDF files ready for n+^{235}U, n+^{239}Pu, ^{252}Cf (sf)
- Calculated prompt fission gamma spectra

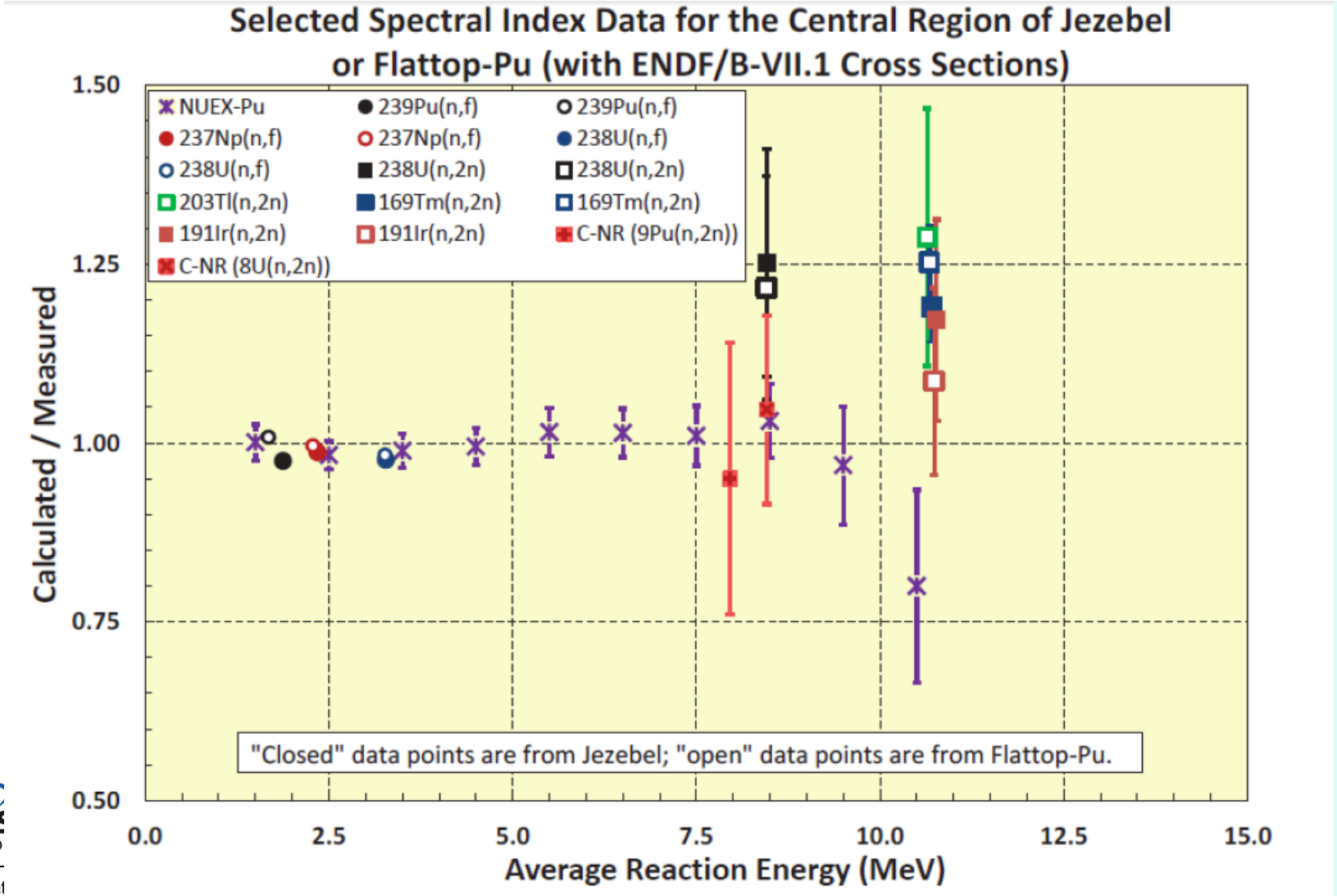
Reaction	Calc./Exp.	$\langle N_\gamma \rangle$	$\langle \varepsilon_\gamma \rangle$ (MeV)
^{252}Cf (sf)	Calc. (CGMF; α=1.7)	8.33	0.82
	Exp. (Billnert, 2013)	8.30(8)	0.80(1)
	ENDF/B-VII.1	7.48	0.94
n_{th}+^{235}U	Calc. (CGMF; α=2.0)	8.29	0.83
	Exp. (Oberstedt, 2013)	8.25(17)	0.84(17)
	ENDF/B-VII.1	7.78	0.87
n_{th}+^{239}Pu	Calc. (CGMF; α=1.5)	7.91	0.83
	ENDF/B-VII.1	7.05	0.87



Dosimetry Reactions: ^{235}U PFNS



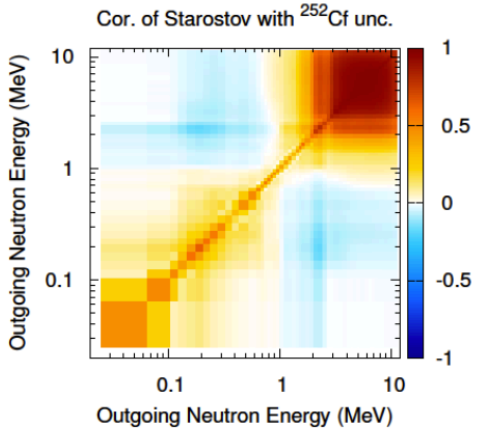
Dosimetry Reactions: ^{239}Pu PFNS



^{239}Pu PFNS Uncertainty Quantification

- Experimental uncertainty estimated described in detail in:
  D.Neudecker, T.Taddeucci, R.C.Haight, H.-Y.Lee, J.P.Lestone, J.M.O'Donnell, B.A.Perdue, M.E.Rising, P.Talou, M.White, LANL Report LA-UR-13-24743, (2013).

Authors	EXFOR-No.	Information available	selected
Abramson et al.	20997.001	Insufficient unc. information	NO
Conde et al.	20575.001	Insufficient unc. information	NO
Werle et al.	20616.001	Prompt AND delayed neutrons	NO
Batenkov et al.	41502.001	Insufficient unc. information	NO
Belov et al.	40137.001	Insufficient unc. information	NO
Starostov et al.	40930.001	Some information missing	**YES**
Lajtai et al.	30704.001	Unc. info. from other isotopes	**YES**
Staples et al.	13982.001	Well documented	**YES**
Knitter	20576.001	Some information missing	**YES**
Noda et al.	142900.003	Large E_{inc} uncertainty	NO(T YET)



New PFNS Evaluations from IAEA CRP

- **IAEA Coordinated Research Project on "Prompt Fission Neutron Spectra of Actinides", R.Capote et al., to be concluded in CY14.**
- **To be finalized:**
  - Complete list of PFNS experiments for ^{235,238}U, ^{239}Pu, ^{252}Cf (sf), ^{232}Th, ^{233}U, ^{237}Np
  - Detailed reports on uncertainties and correlations whenever possible
  - Complete list of new evaluations from LANL, LLNL, BRC, Bucharest, IAEA, CIAE
  - Clean-up and updating of EXFOR entries
  - Data testing using criticality and β-eff benchmarks, dosimetry reaction rates, NUEX
  - Final report and/or paper by end of CY14
- **Participants:**
  - Capote, Chen, Kodeli, Kornilov, Manturov, Morillon, Neudecker, Oberstedt, Otsuka, Saxena, Schmidt, Serot, Shu, Simakov, Talou, Tudora, Vogt

n+^{235}U Open Problem: Thermal + <E_{out}> vs. E_{inc}

^{235}U: AVERAGE ENERGY OF FISSION NEUTRONS