Pu Evaluations

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Plutonium Isotopes

	xs (fast)	xs (RRR)	xs (URR)	PFNS	Nu-bar	Covariances
236	JENDL-4.0	JENDL-4.0	JENDL-4.0	JENDL-4.0	JENDL-4.0	31,32,33,34,35
237	JENDL-4.0	JENDL-4.0	JENDL-4.0	JENDL-4.0	JENDL-4.0	31,32,33,34,35
238	ENDF/B-VII.1	JENDL-4.0	JENDL-4.0	ENDF/B-VII.1	ENDF/B-VII.1	31,33,35
239	ENDF/B-VIII	ENDF/B-VIII	ENDF/B-VIII	ENDF/B-VIII	ENDF/B-VIII	31,32,33,35
240	ENDF/B-VII.1	ENDF/B-VIII	ENDF/B-VII.1	ENDF/B-VII.1	ENDF/B-VII.1	31,32,33,35
241	ENDF/B-VI	ENDF/B-VI	ENDF/B-VI	ENDF/B-VI	ENDF/B-VI	ENDF/B-VII
242	JENDL-4.0	ENDF/B-VII	ENDF/B-VII	JENDL-4.0	JENDL-4.0	31,33,34,35
243	ENDF/B-V-VI	ENDF/B-V-VI	ENDF/B-V-VI	ENDF/B-V-VI	ENDF/B-VIII	
244	JENDL-4.0	JENDL-4.0	JENDL-4.0	JENDL-4.0	ENDF/B-VIII	31,32,33,34,35
245	ENDF/B-VIII?	ENDF/B-VIII?	ENDF/B-VIII?	From Pu243	From Pu243	
246	JENDL-4.0	JENDL-4.0	JENDL-4.0	JENDL-4.0	ENDF/B-VIII	31,33,34,35

Legend:
- ENDF/B-VIII.0
- Older ENDF/B
- Recent, OK
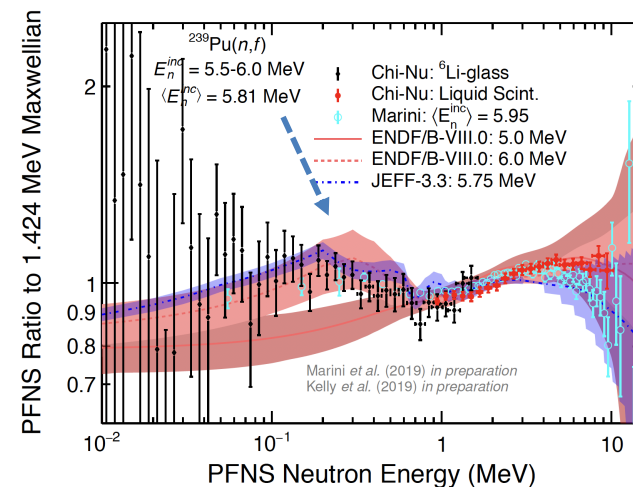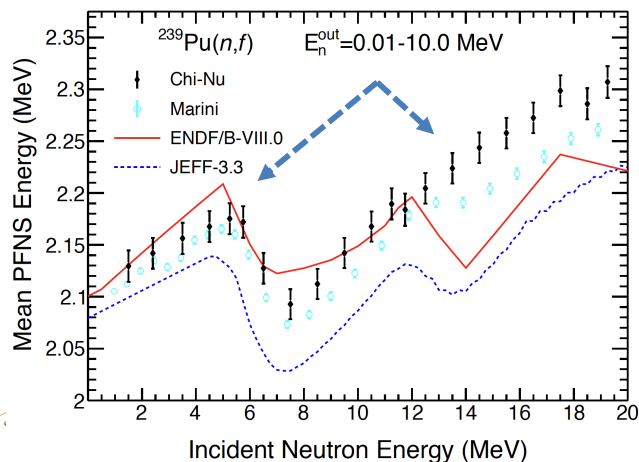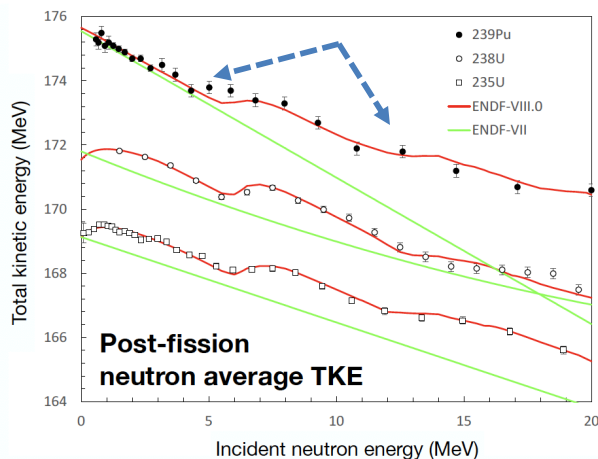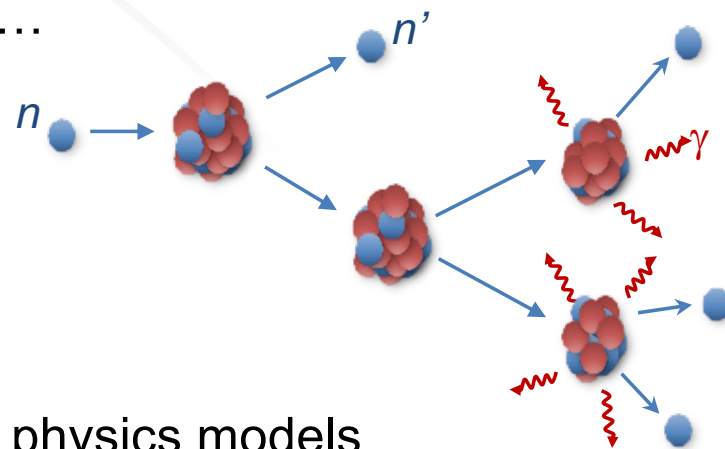- Needs work
- Bad
- Nothing
- Other evaluation

A plethora of inconsistent physics models…

Prompt Fission Neutron Spectra

- A=236, 237, 5/18, CCONE (JENDL-4.0)
- A=238, 5/18, LAM (ENDF/B-VII.1)
- **A=239**, 5/18, LAM+Chi-Nu (B-VIII.0) *to be finalized*
- A=240, 5/18, LAM (B-VII.1, 2010)
- A=241, 5/18, Maxwellian, (B-VI, 1990)
- A=242, 5/18, CCONE (JENDL-4.0)
- A=243, 5/18, Maxwellian (B-VI.1)
- A=244, 5/18, CCONE (JENDL-4.0)
- A=245, 5/18, adopted from Pu243
- A=246, 5/18, CCONE (JENDL-4.0)

The role of multi-chance fission

- Emission of neutron(s) prior to fission (of residual nucleus)
  - First-chance (n,n'f), second-chance (n,2nf), …
  - It ties together the suite of isotopes
    - But it's not a trivial connection!
- Fission observables
  - Cross Sections, PFNS,
    kinetic energy of fragments, FPY, etc
  - It places constraints on *sophisticated* fission physics models
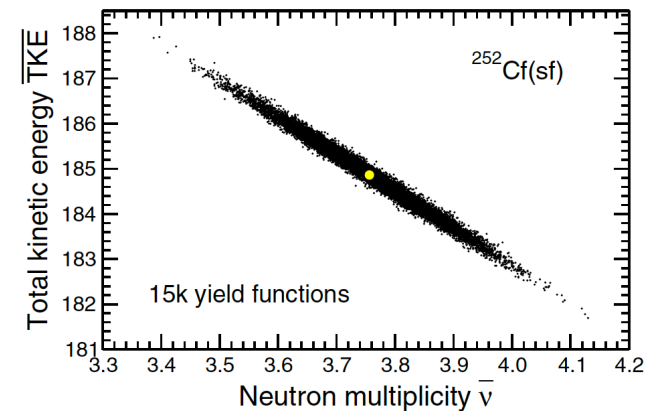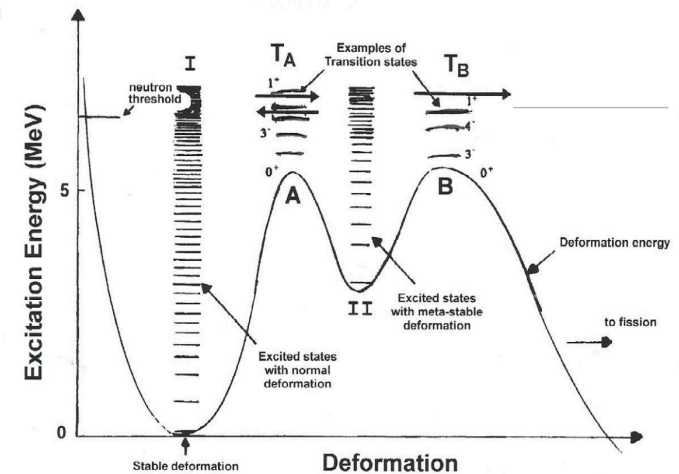
More sophisticated physics models are needed to make use of those correlations as constraints

- **Fission cross section modeling**
  - R-matrix, Bouland, Lynn, Talou, PRC 88, 054612 (2013)
  - Optical model, Sin, Capote, Herman, Trkov, PRC 93, 034605 (2016)
  - Multi-dimensional fission paths?
  - Fission fragment angular distributions
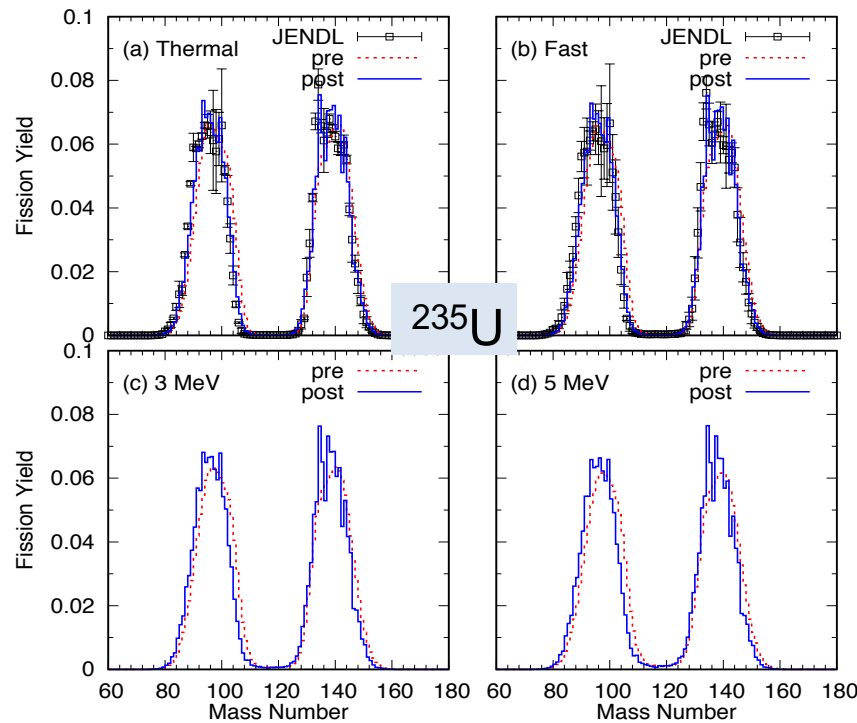 - (n,γf) process (also ties to <ν> fluctuations) Lynn, Talou, Bouland, PRC 97, 064601 (2018)
- **Prompt fission data (PFNS, PFγS, …)**
  - Statistical decay of fission fragments (CGMF, FREYA, BeOH)
  - Ties together Y(A,Z), TKE, PFNS, <ν>, PFG … *without the need for Jezebel!*
  - Randrup, Talou, Vogt, PRC 99, 054619 (2019)

Los Alamos
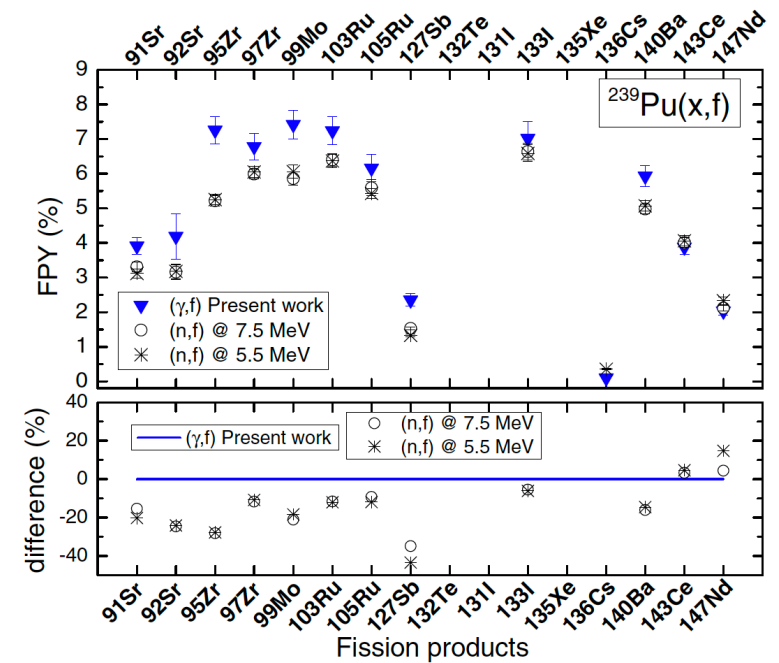NATIONAL LABORATORY
EST. 1943

Fission Product Yield Evaluation efforts will also help!

- See FPY Session

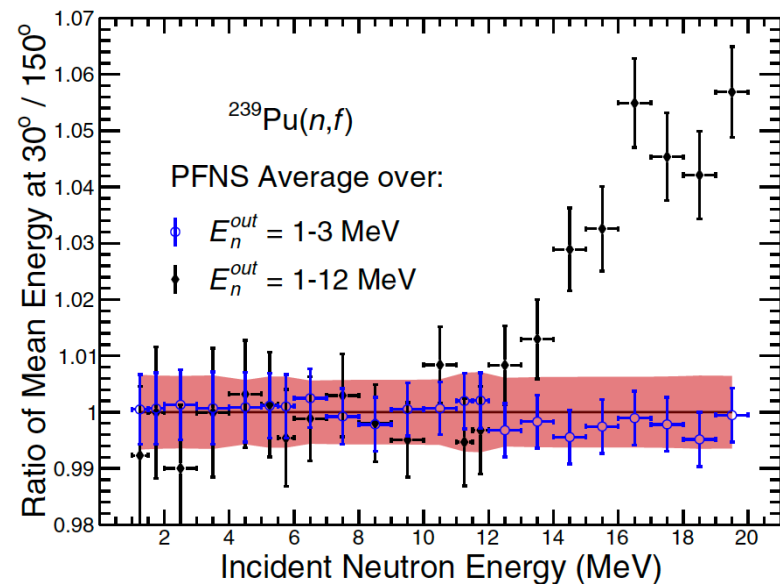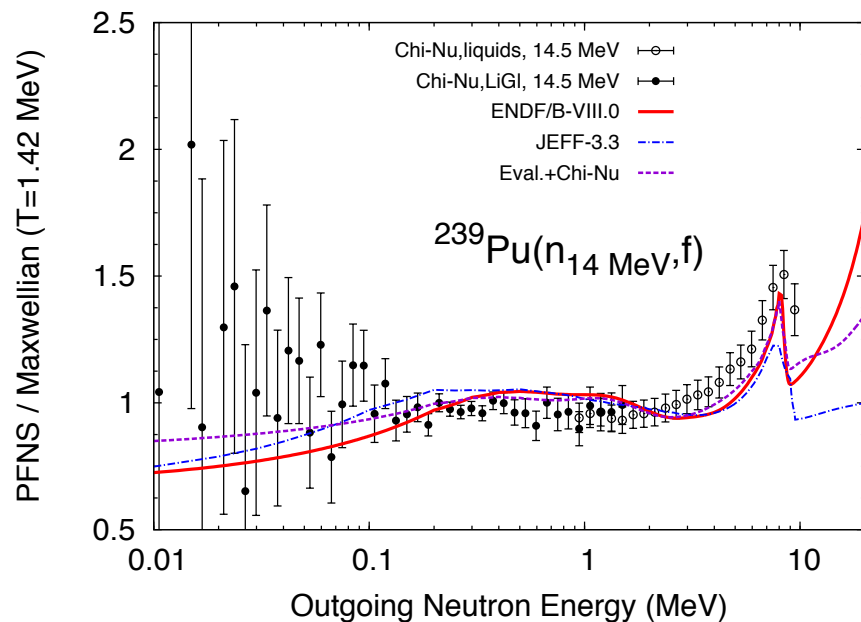- Ties prompt and β-delayed fission data to IFY and CFY

Okumura, Kawano et al, JNST (2018)

Krishichayan et al, PRC 100, 014608 (2019)

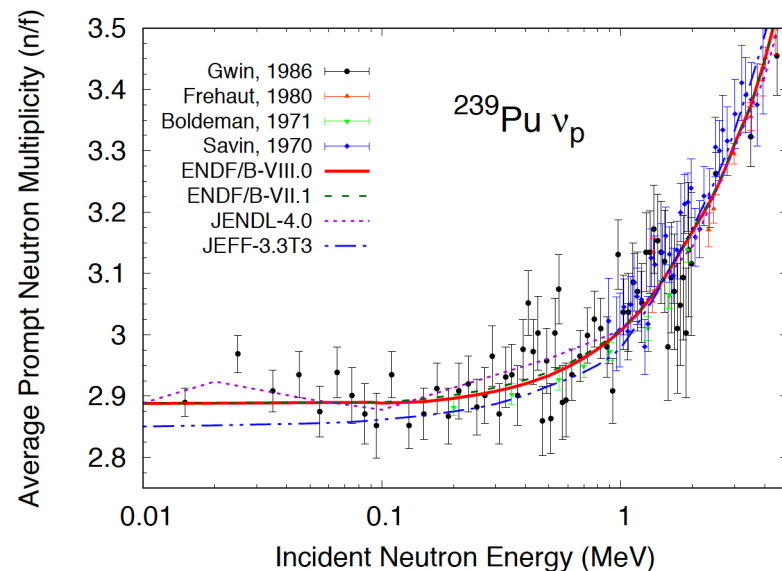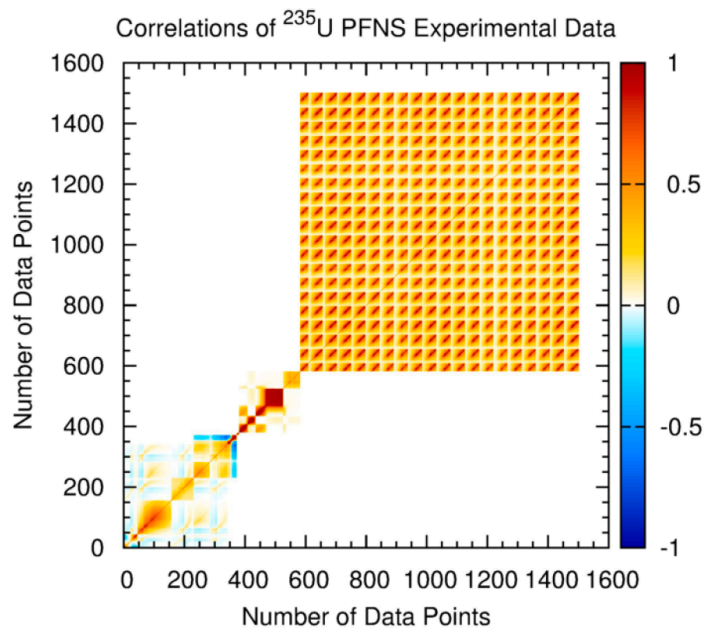# Prompt Fission Neutron Spectrum (PFNS)

- Latest ^{239}Pu ChiNu data (see Lee's talk) + new evaluation

- Other isotopes? New data?

- Modeling with CGMF/FREYA? PFNS too soft?

- RPI quasi-integral (n,xn) experiments (see Danon's talk)

Kelly et al, PRL 122, 072503 (2019)

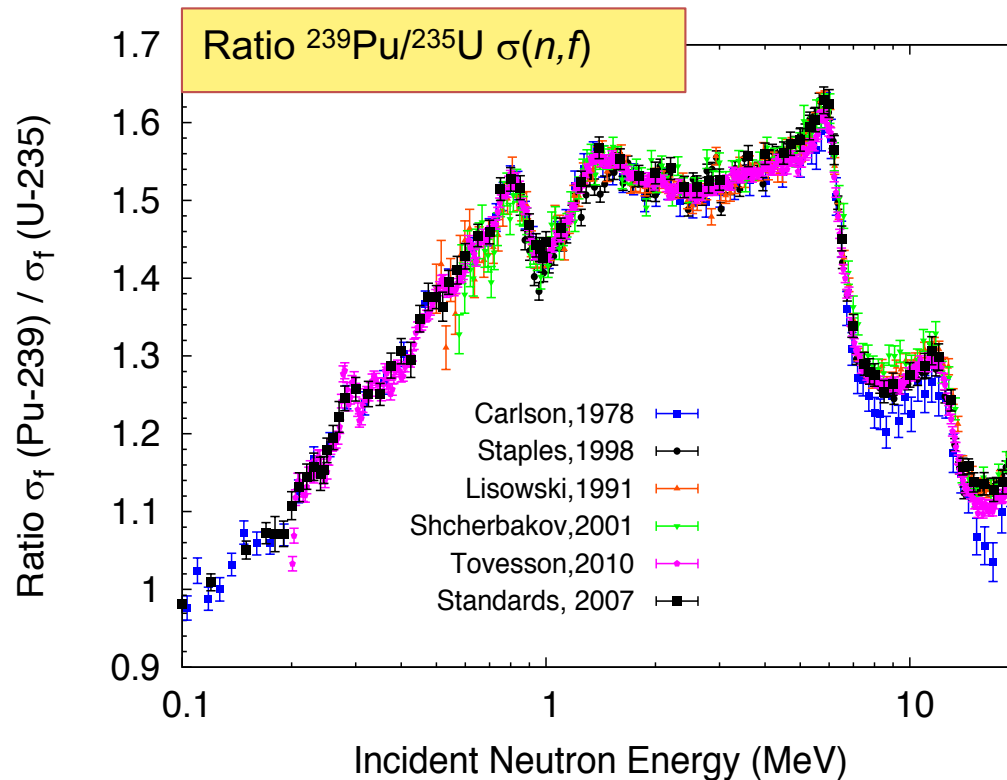# Status of uncertainties & correlations

- Not too bad: covariances available for many isotopes and reactions

- Consistent across suite of isotopes: no

- Realistic: probably not – needs validation

- Lots of UQ work on PFNS, σ_f, $<\nu>$ for ^{239}Pu only (Neudecker et al)

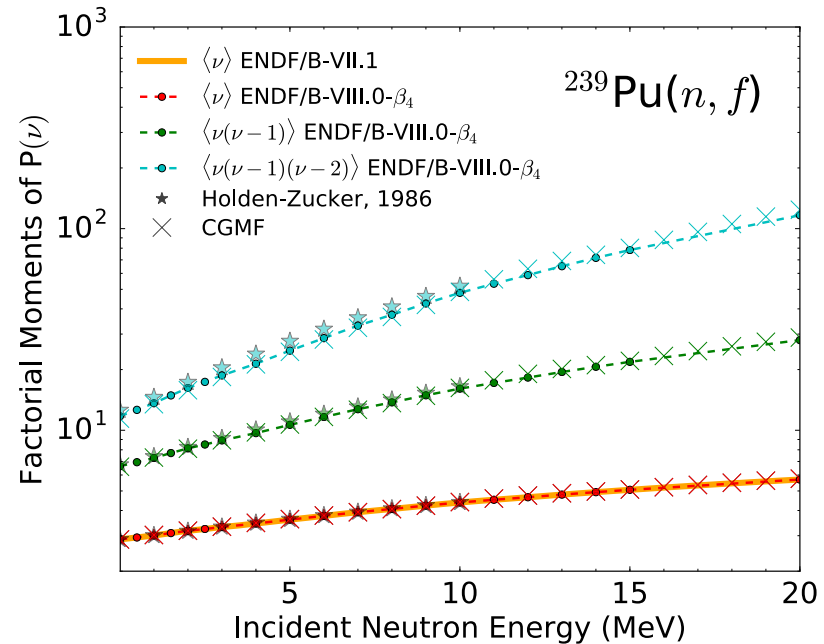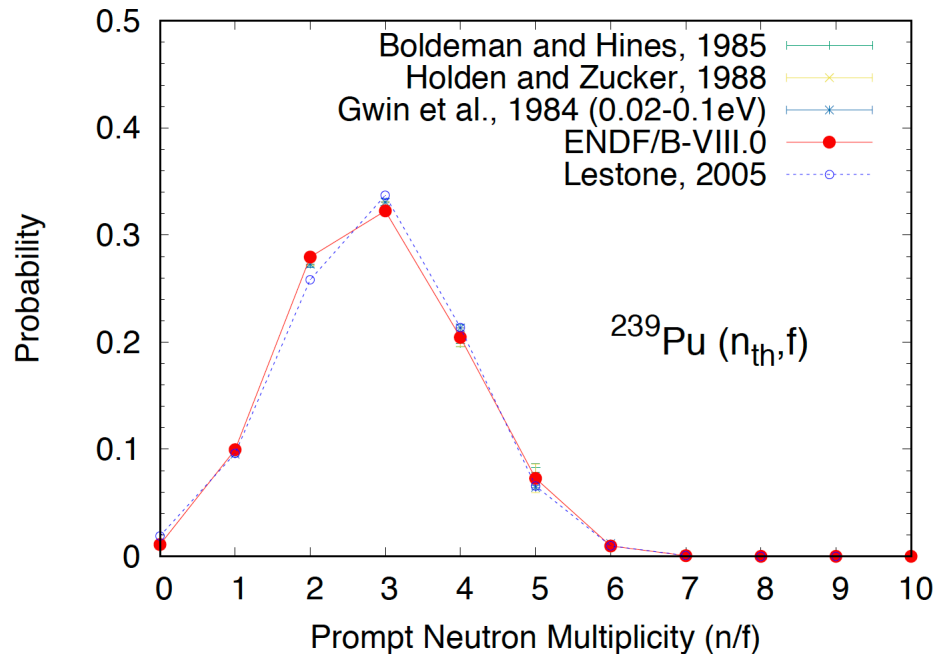- Model limitations w/o data?

Neudecker et al, NDS 148, 293 (2018)

Fission Cross Section

- NIFFTE fissionTPC data to be finalized, but new measurements in ratio to ^{6}Li(,nt) in progress

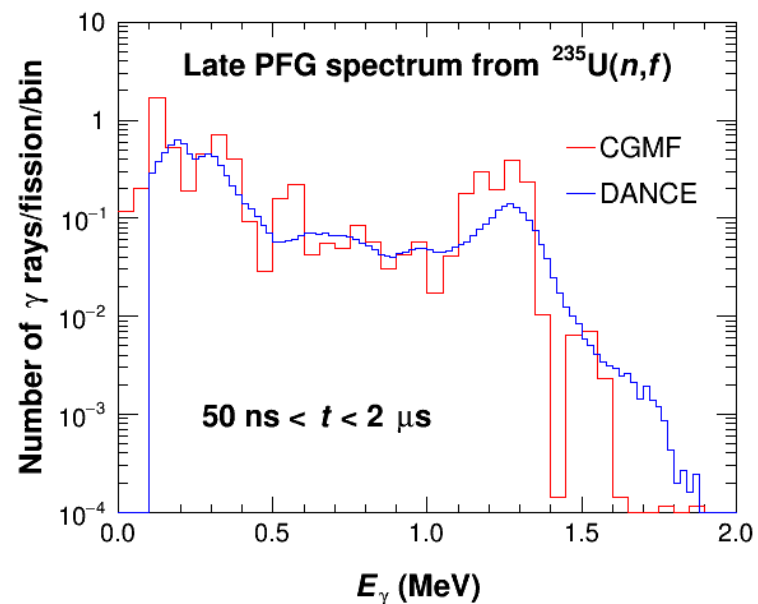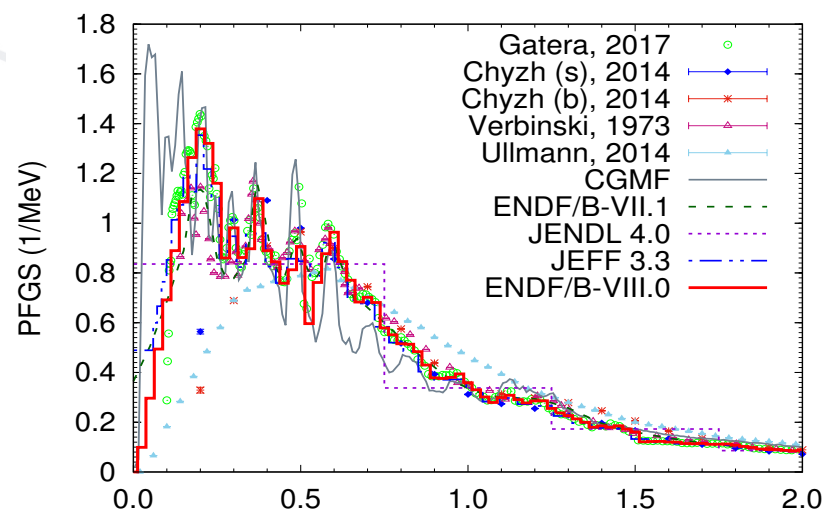- New modeling should tie measured angular distributions to cross sections

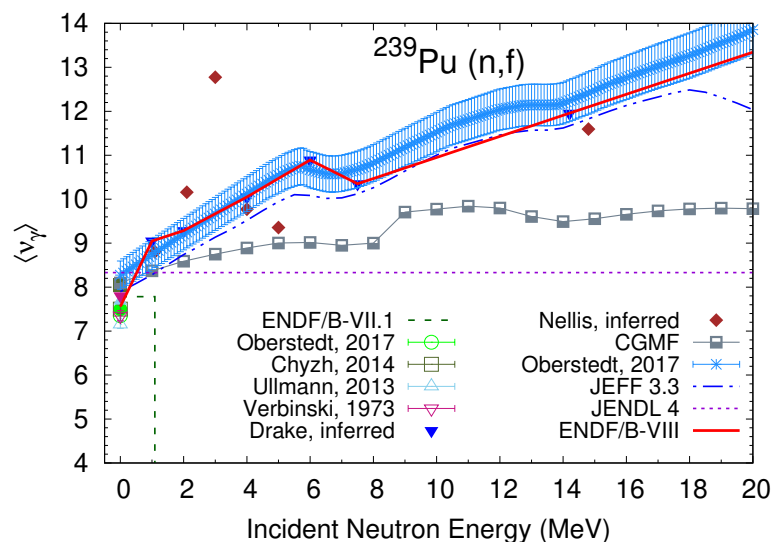Ratio ^{239}Pu/^{235}U $\sigma(n,f)$

Legend:
- Carlson, 1978
- Staples, 1998
- Lisowski, 1991
- Shcherbakov, 2001
- Tovesson, 2010
- Standards, 2007

Y-axis: Ratio σ_f (Pu-239) / σ_f (U-235)
X-axis: Incident Neutron Energy (MeV)

Prompt Fission Neutron Multiplicity ($\langle \nu \rangle$) and P(ν)

- P(ν;E_{inc}) now available for ^{239}Pu; can be calculated for all other Pu isotopes, given *reasonable* Y(A,Z,TKE;E_{inc})

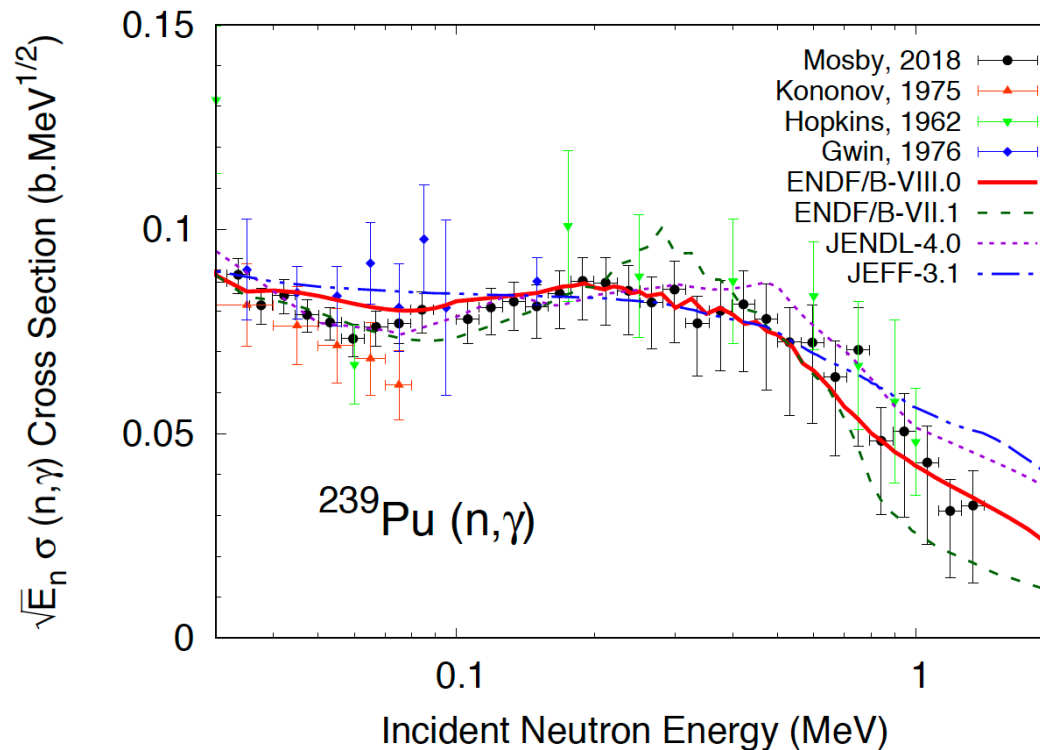- Still too large uncertainties for $\langle \nu \rangle$(E_{inc}) → new measurements?

Prompt Fission γ-Ray Data

- Model calculations of PFGS reproduce well recent exp. data

- Role of isomers in time-dependent PFGS

- Multiplicity-dependent spectra
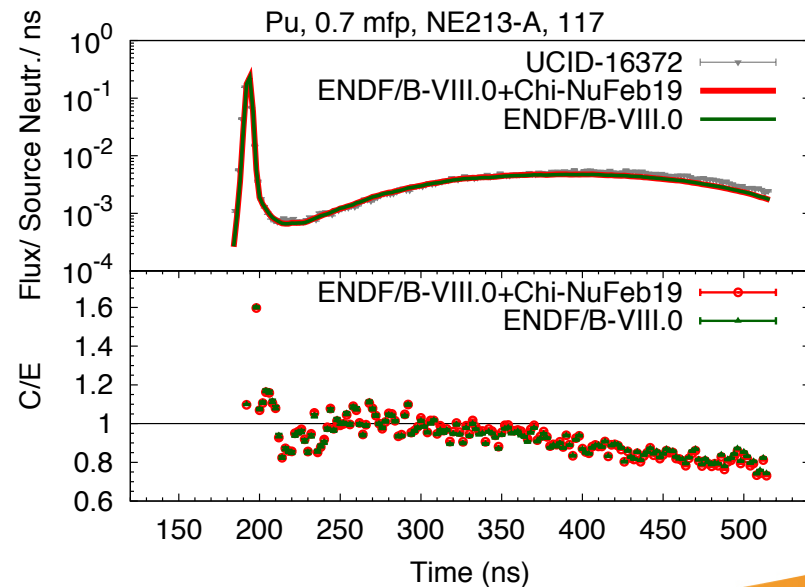
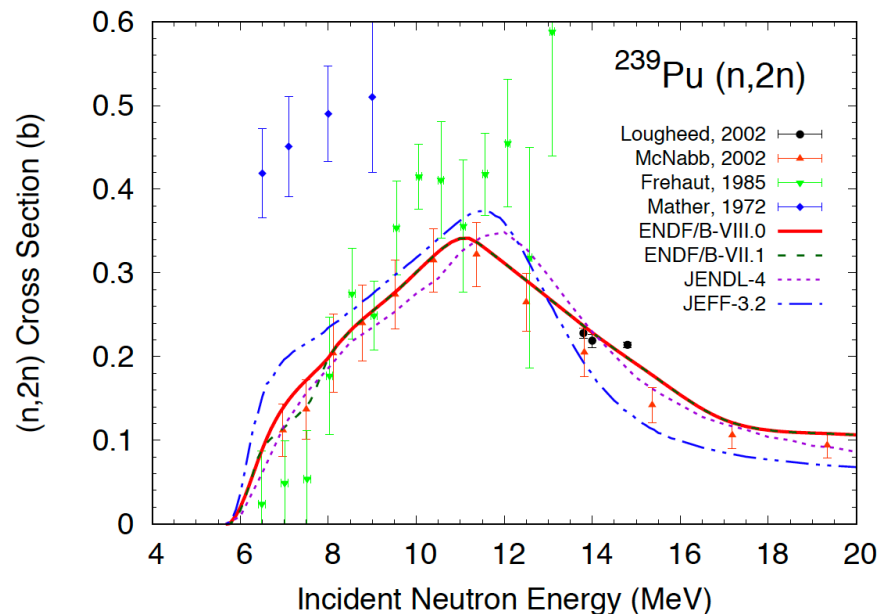- Problem with total γ-ray energy and/or multiplicity

Capture Cross Section

- ^{239}Pu (n,γ) cross section measurement [Mosby et al, NDS 148, 312 (2018)] → ENDF/B-VIII.0

- Impact of M1 "scissors" mode on other Pu capture cross sections

(n,xn) Cross Sections

- Small change to ^{239}Pu(n,2n) cross section near threshold, motivated by PROFIL studies and internal LANL data testing

- No other changes to elastic/inelastic

- Quasi-integral RPI scattering experiments (see Danon's talk)

- LLNL Pulsed-spheres

- New scattering experiments (Bernstein) → n,γ correlated exp/sim

^{239}Pu (n,2n)

Lougheed, 2002
McNabb, 2002
Frehaut, 1985
Mather, 1972
ENDF/B-VIII.0
ENDF/B-VII.1
JENDL-4
JEFF-3.2

Pu, 0.7 mfp, NE213-A, 117

UCID-16372
ENDF/B-VIII.0+Chi-NuFeb19
ENDF/B-VIII.0

ENDF/B-VIII.0+Chi-NuFeb19
ENDF/B-VIII.0
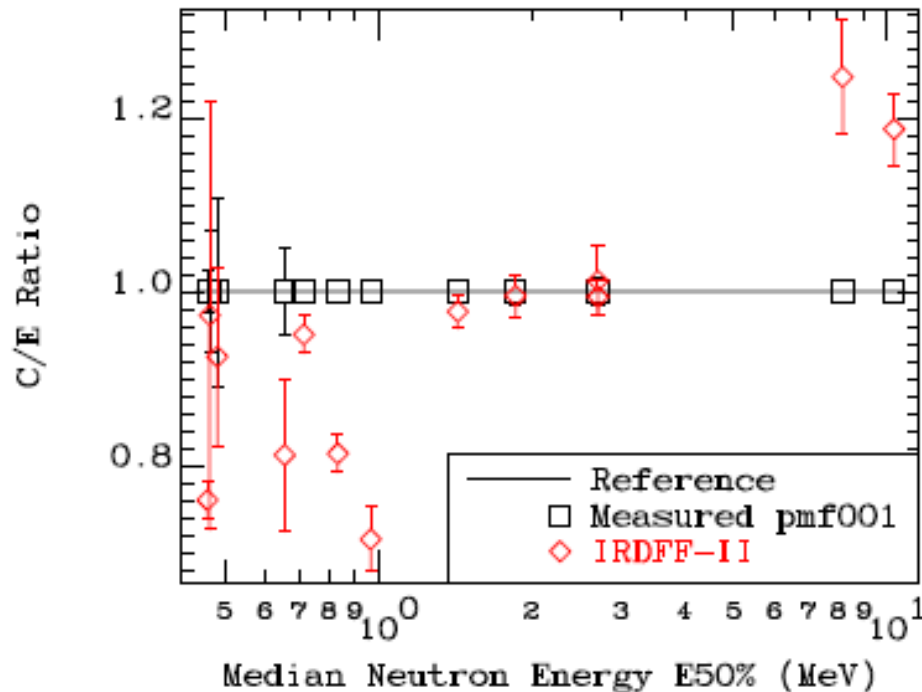
Jezebel and Flaptop-Pu Spectral indices

FIG. 109. (Color online) Ratio of Calculated and Measured SI in the central region of PMF001 (Jezebel) assembly.
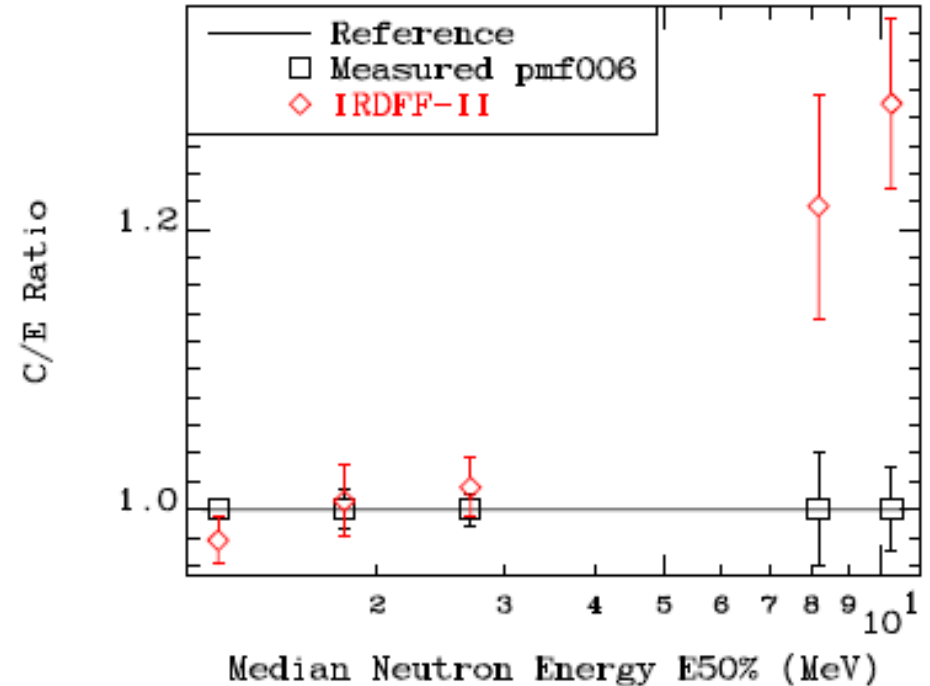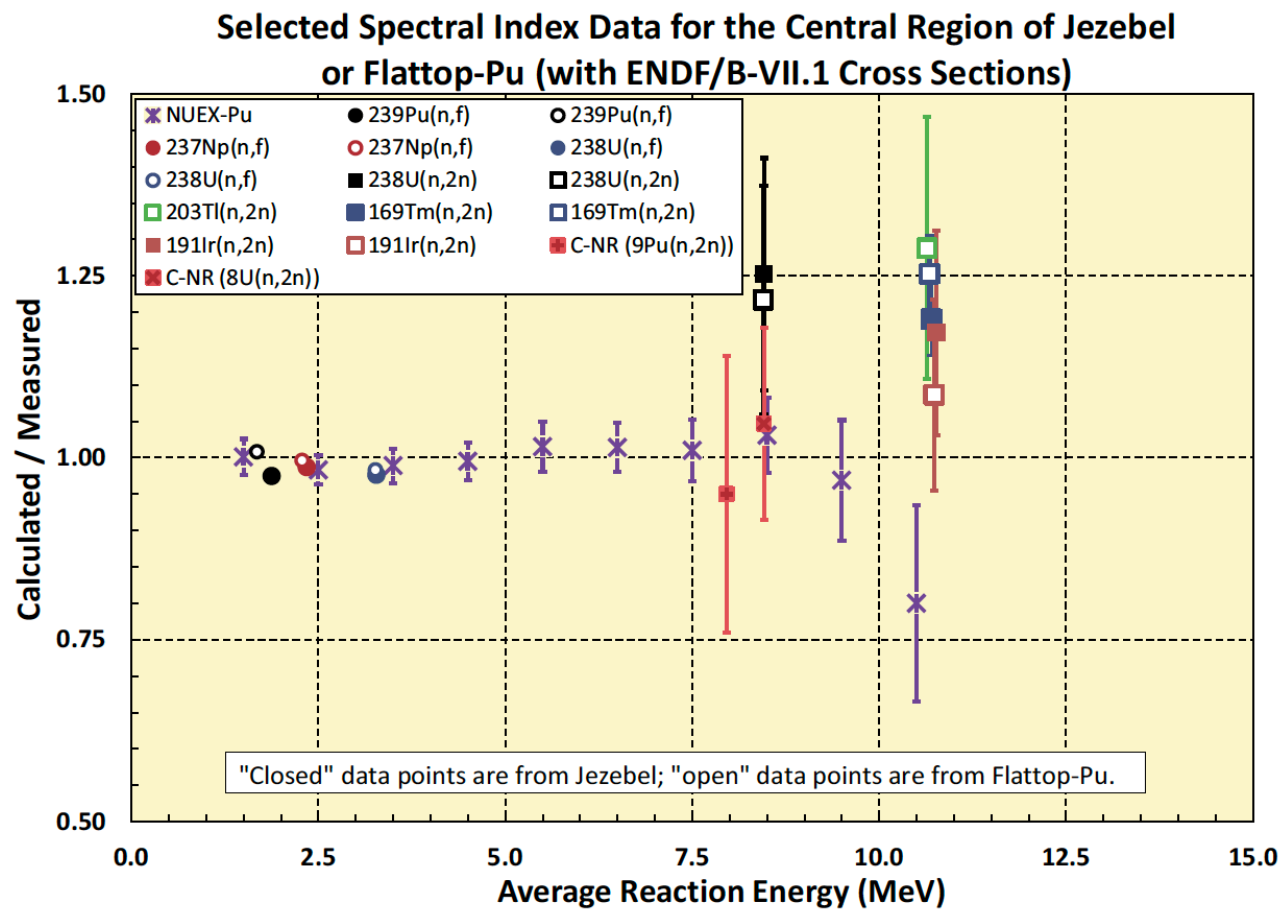
FIG. 110. (Color online) Ratio of Calculated and Measured SI in the central region of PMF006 (Flattop-Pu) assembly.

PMF assemblies, poor situation; more work needed for Pu data !!

Dosimetry reactions in plutonium fast critical assemblies

Chadwick et al., CIELO Collaboration, NDS118, 1-25 (2014)

Final remarks

- Advanced physics models provide tighter and correlated constraints on evaluated data

- Experimental data on suite of isotopes promise correlated information

- Realistic UQ would benefit from consistency across suite of isotopes

- Some advances made on major isotopes should benefit more minor ones

Thanks to:

Conlin, Haeck, Herman, Kawano, Mumpower, Neudecker, Parsons, Stetcu