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Status of Pu-239 Evaluations

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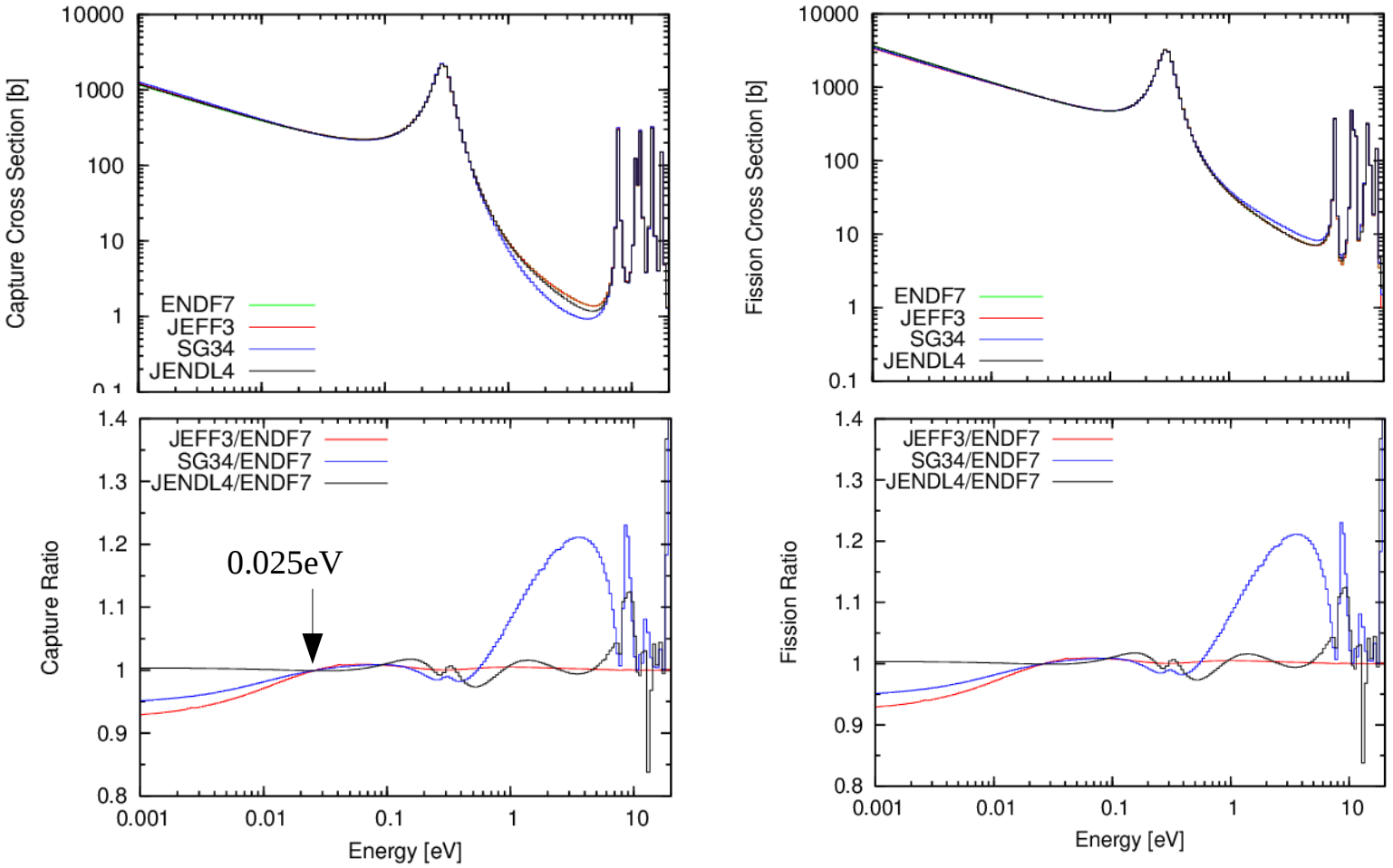
Quick View of Evaluated Pu-239 Data Files in Libraries

- **ENDF/B-VII.1**
  - basically the same as ENDF/B-VII.0 evaluated in 2006
  - above RRR, GNASH evaluations by Young, Chadwick, et al.
  - fission cross section from Standards evaluation at IAEA
- **JENDL-4.0**
  - new evaluation by Iwamoto et al. in 2007, with CCONE
  - fission cross section by Otsuka with SOK
- **JEFF-3.1**
  - new evaluation for JEFF-3.0, updated to 3.1, 3.1.1, and 3.1.2
  - CEA/DEN small modifications to resonance parameters made
  - CEA/DAM ECIS-GNASH evaluation
    - rotation-vibration model, including negative parity states
    - better class-I II coupling scheme
- **RU(O)SFOND-2010**
  - same as JEFF-3.1, with some modest modifications by IPPE
- **CENDL-3.1**
  - evaluation by Liang et al. in 1994 (?) for CENDL-2.1

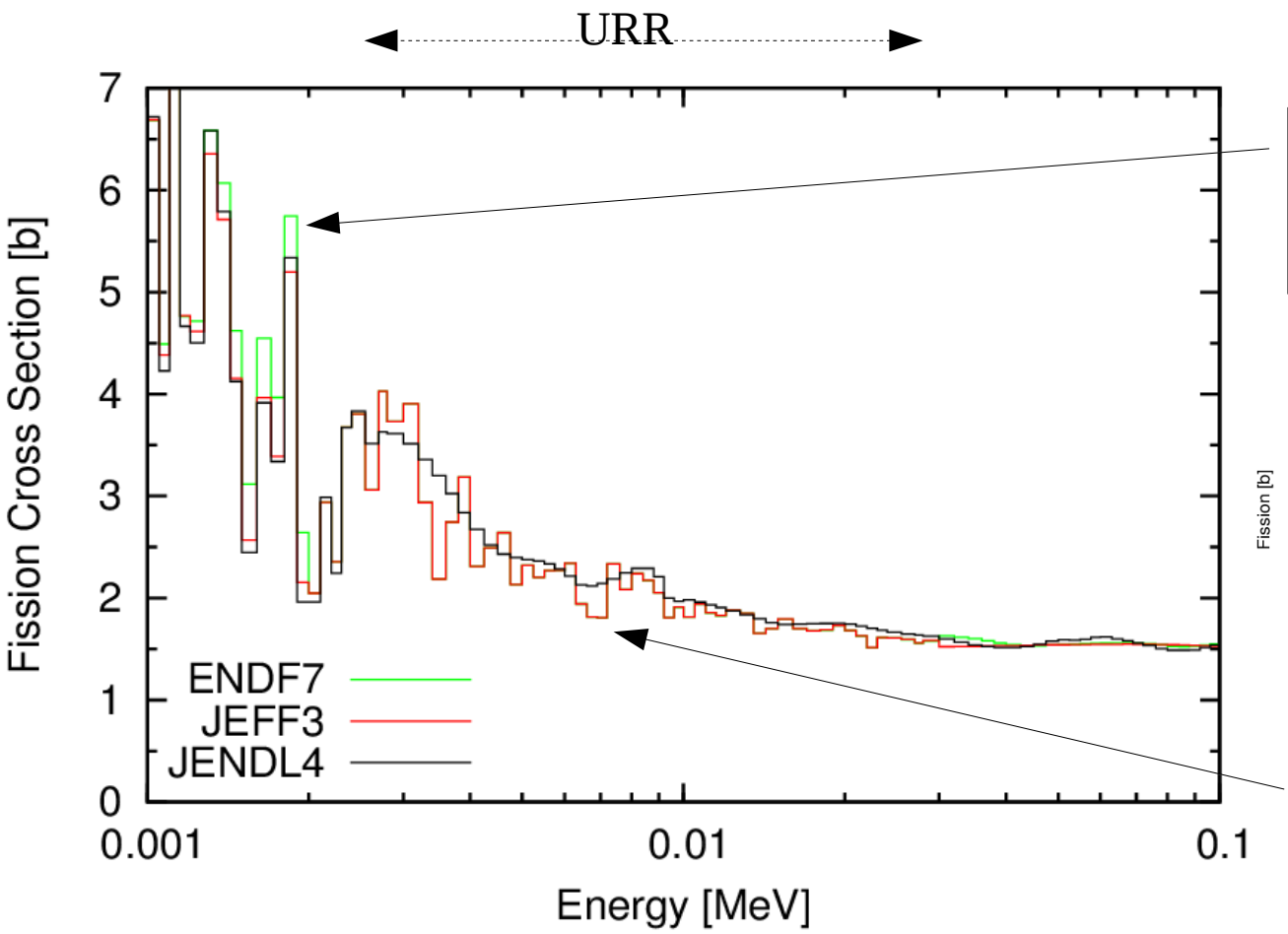
Resonance Parameter Status

- **JENDL-3 (3.2, 3.3)**
  - Derrien 1993 (JNST 30, 145 (1993))
  - Probably original SAMMY analysis by Derrien
  - RRR 0-1, 1-2, 2-2.5 keV, URR 2.5 - 30 keV
- **ENDF (VI, VII.0, VII.1)**
  - Derrien and Nakagawa 1993 (probably the same as Derrien 1993)
  - URR data are only different from JENDL-3
  - VII.1 comment section says new resonances, but not
- **JENDL-4**
  - Derrien (ND2007), RRR one energy group representation, 0 - 2.5 keV
- **JEFF-3.1**
  - Derrien 1993 with tweak: ad-hoc negative resonance at -0.02 eV
- **WPEC/SG34 resonance parameter**
  - Leal and CEA/DEN (ND2013)
- **CENDL-3**
  - It says data are taken from JENDL-3, but they are different (origin unknown)
  - RRR 0-1, URR 1-30 keV

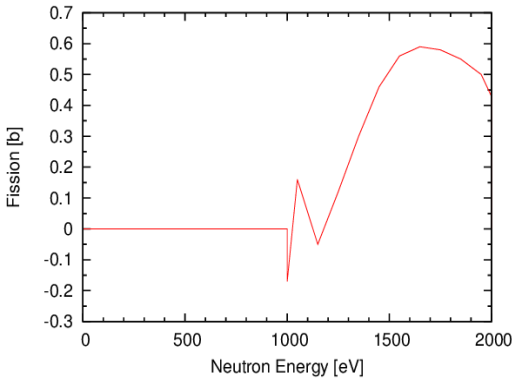
Capture and Fission in Thermal Region



Fission Cross Section in Fast Region

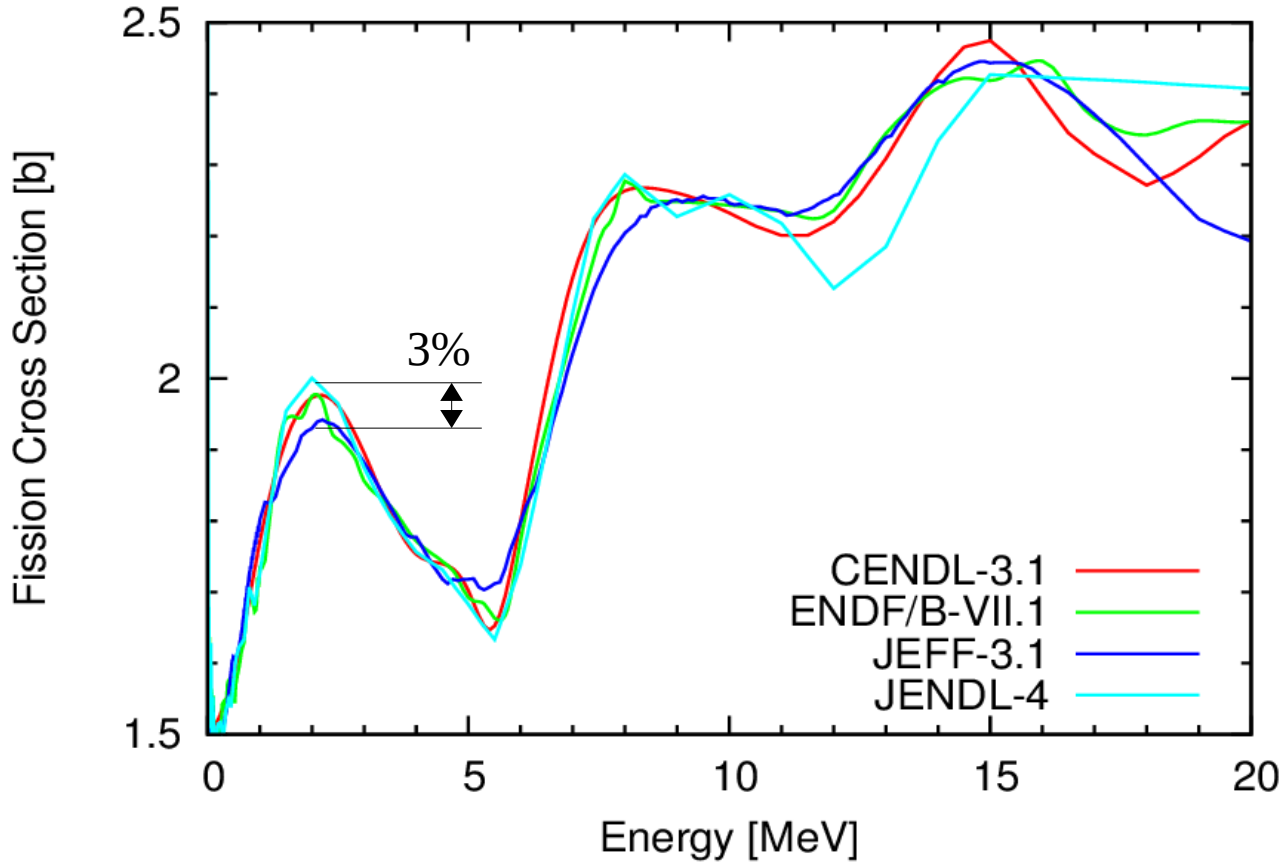


JEFF and ENDF have the same RR parameter, but ENDF has BG in 1-2 keV

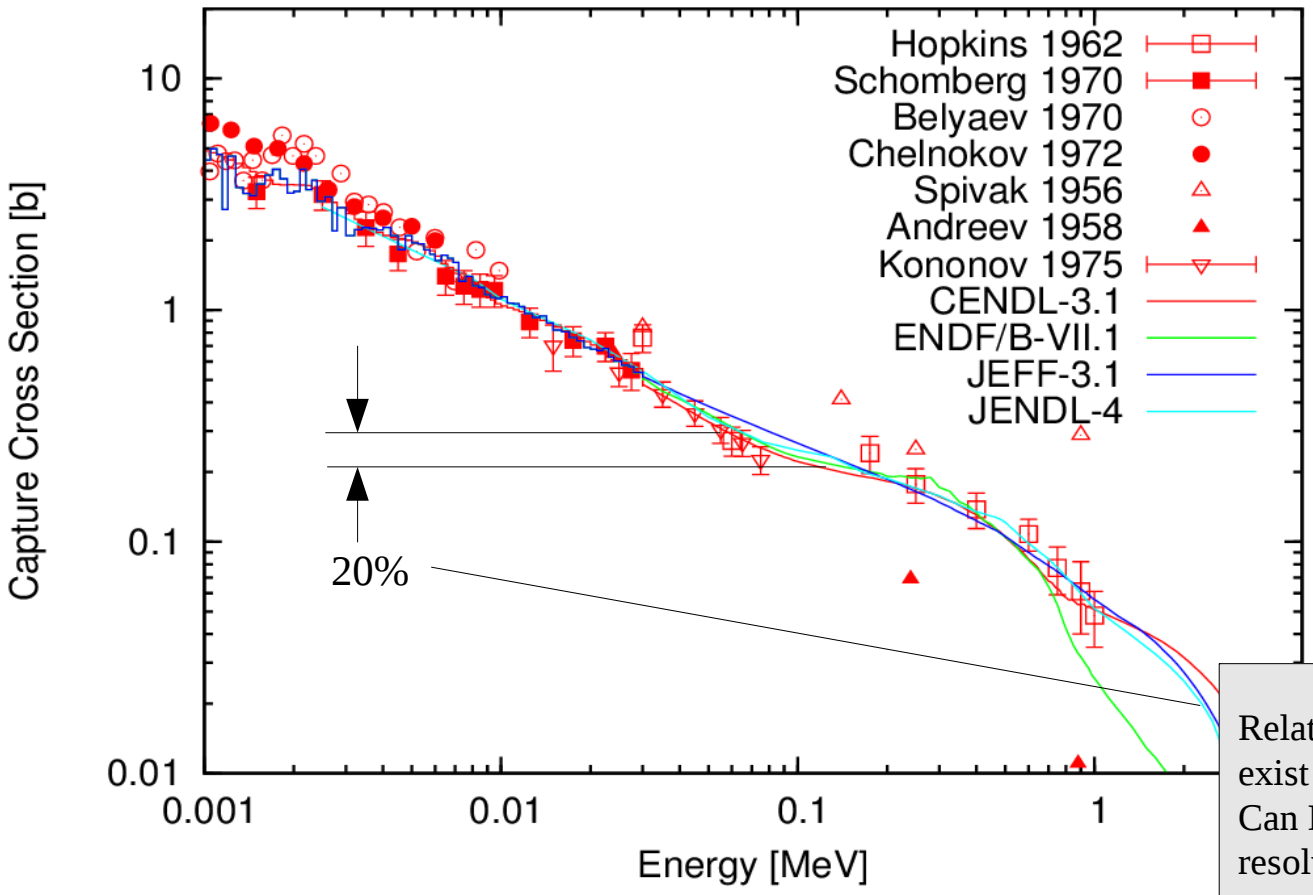


JEFF and ENDF identical. JENDL uses LSSF=1

Fission Cross Section up to 20 MeV



Capture Cross Section



Relatively large uncertainty exist in the fast energy range
Can DANCE new data resolve these discrepancies?

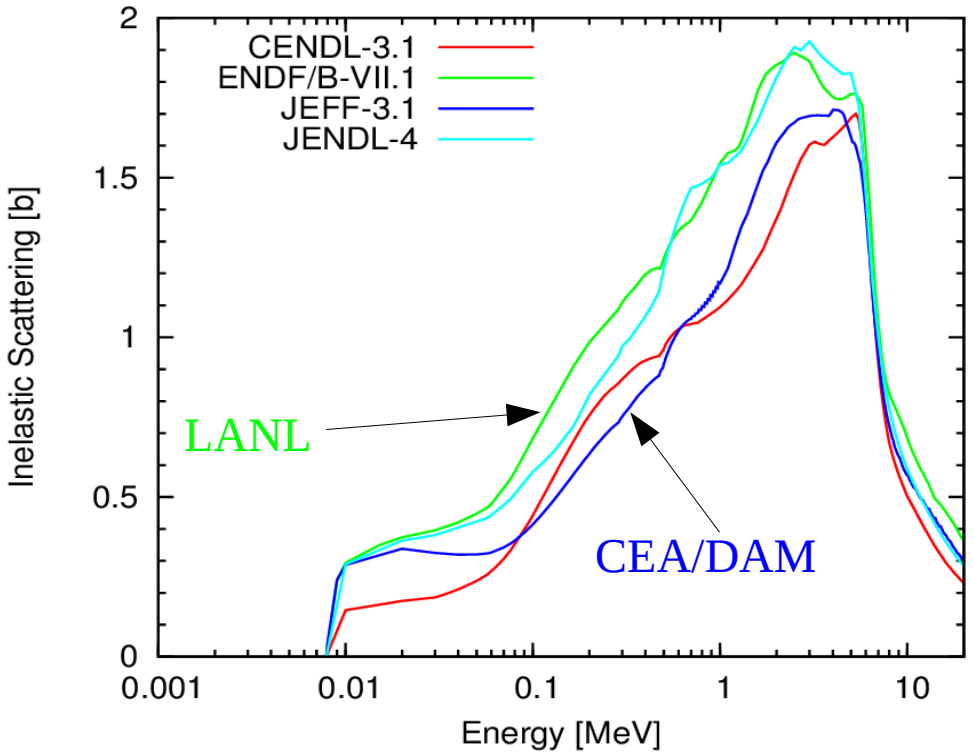
Famous Inelastic Scattering Discrepancy

- **IAEA Technical Meeting on Model Calculation for Major Actinides**
  - Summary report published: INDC(NDS)-0597, R. Capote, et al.

These two files equally work for Jezebel keff prediction.

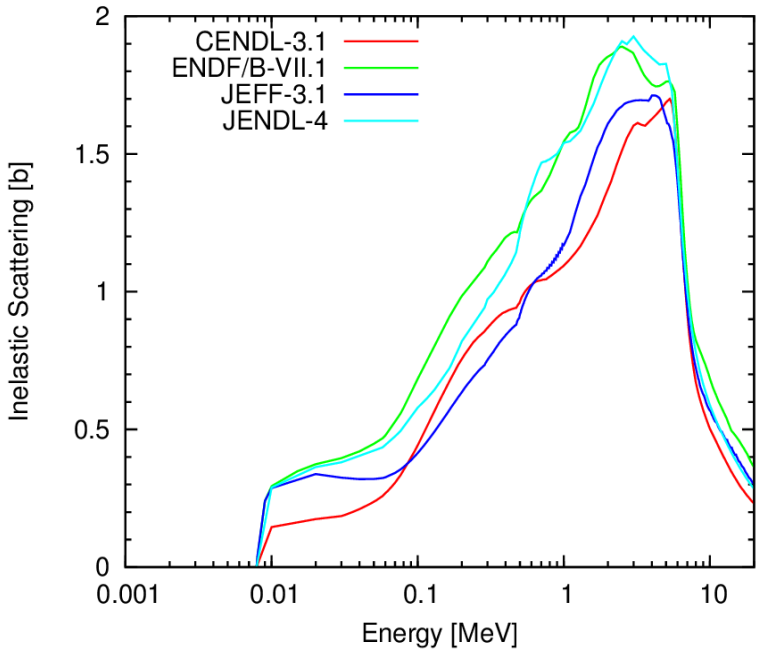
For inelastic scattering cross sections, model calculations are essential.

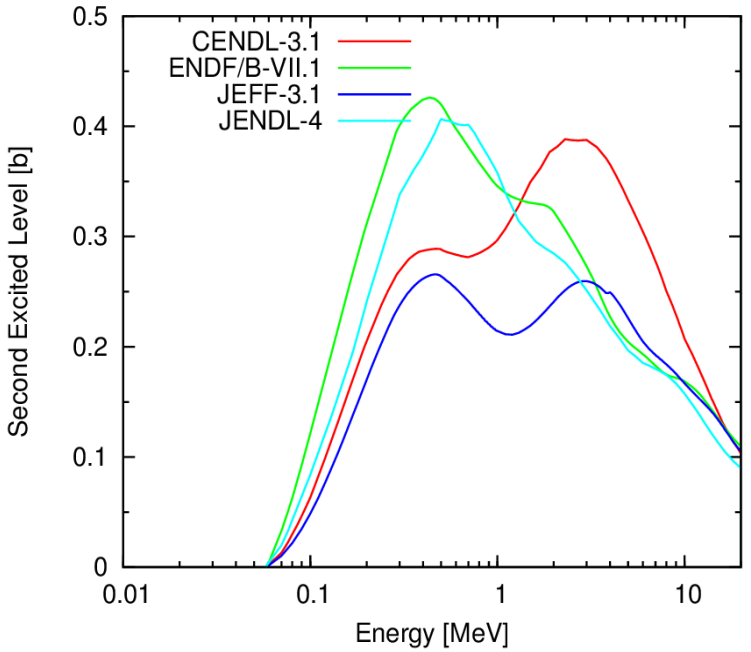
Understanding of these significant difference on going
- transmission coefficient
- optical potential
- coupling scheme
- fission competition
- width fluctuation model



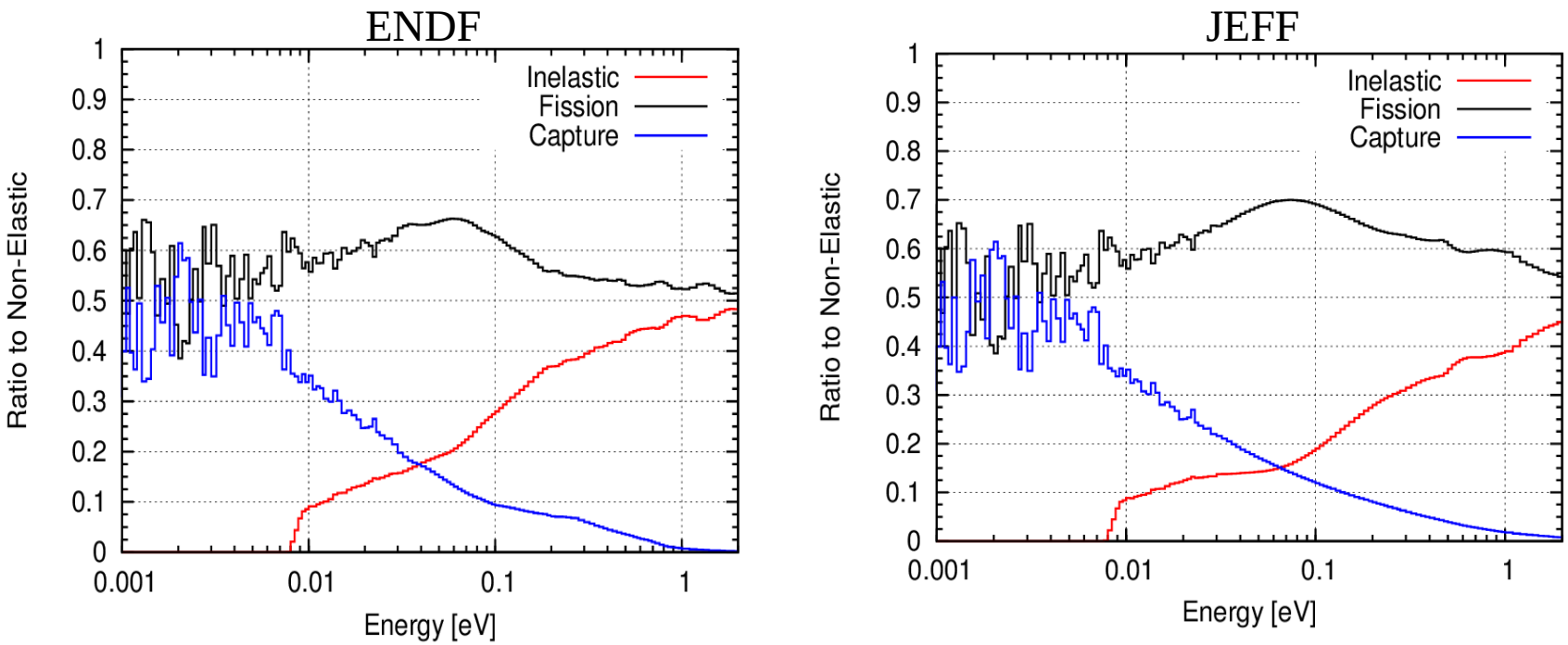
Inelastic Scattering: First and Second Excited Levels

- **Individual level comparison between the libraries**



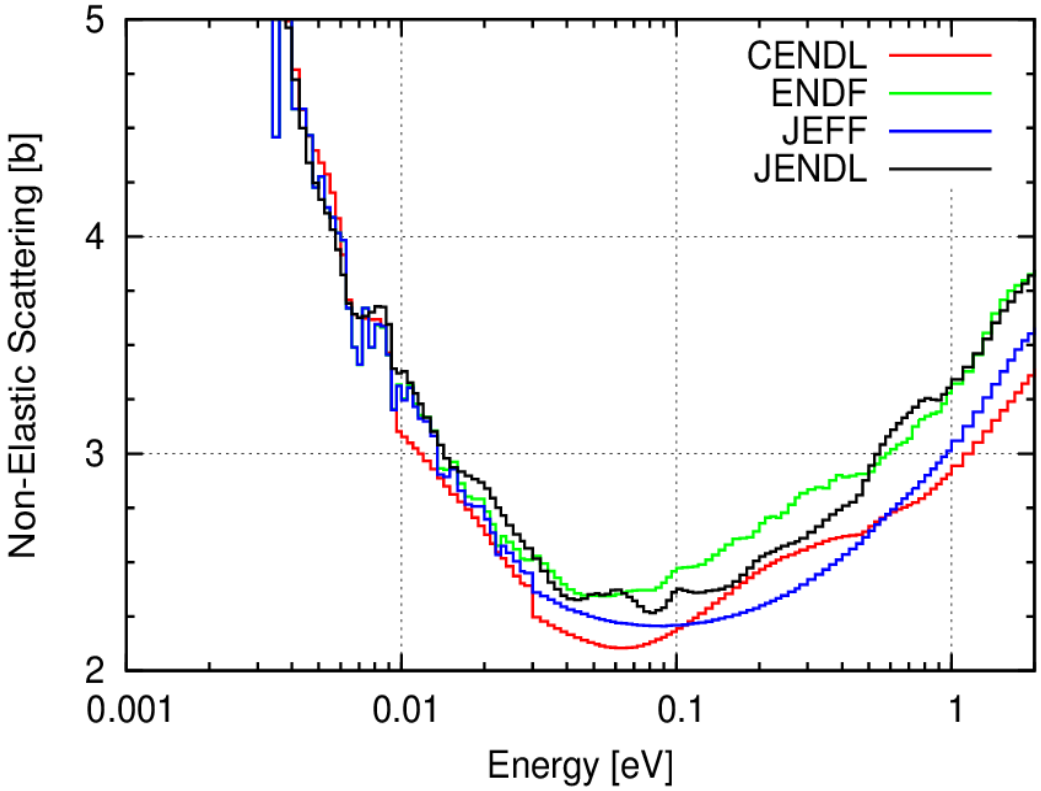


Ratio to Non-Elastic Scattering (Total - Elastic)



The actual fission cross sections at 100keV are almost the same (1.5b).
ENDF non-elastic cross section is larger than JEFF.
Similar comparison performed by P. Roman, see IAEA report

Non-Elastic Scattering Cross Section



CoH3 calculation (100keV)

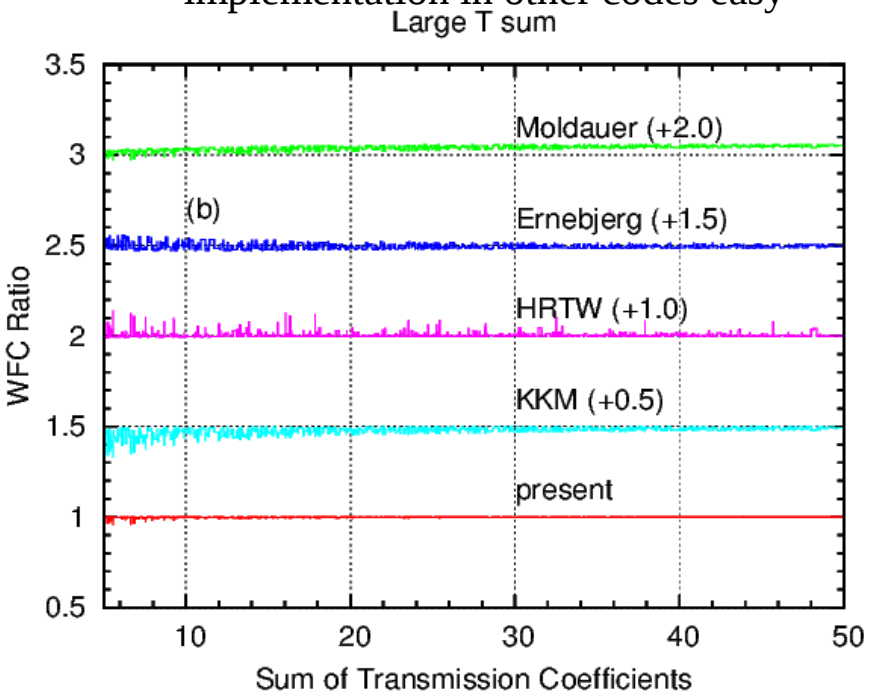
Non-Elastic
= Total - SE - CE
= Reaction - CE
= 4.7 - 2.1 = 2.6 b

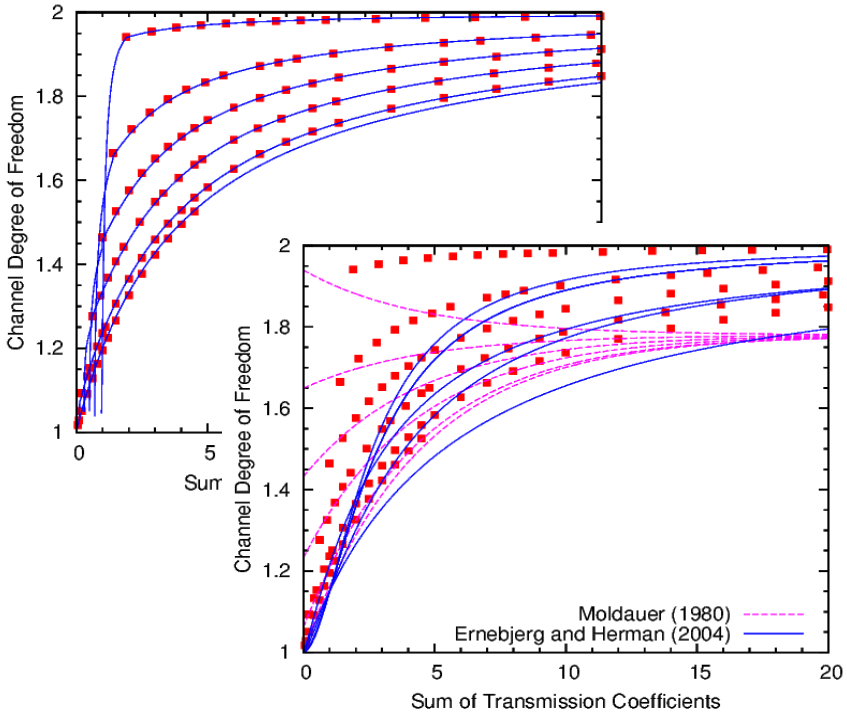
CE ≈ non-elastic

Large CE may bring relatively large uncertainty in non-elastic

Improved Width Fluctuation Correction to Hauser-Feshbach

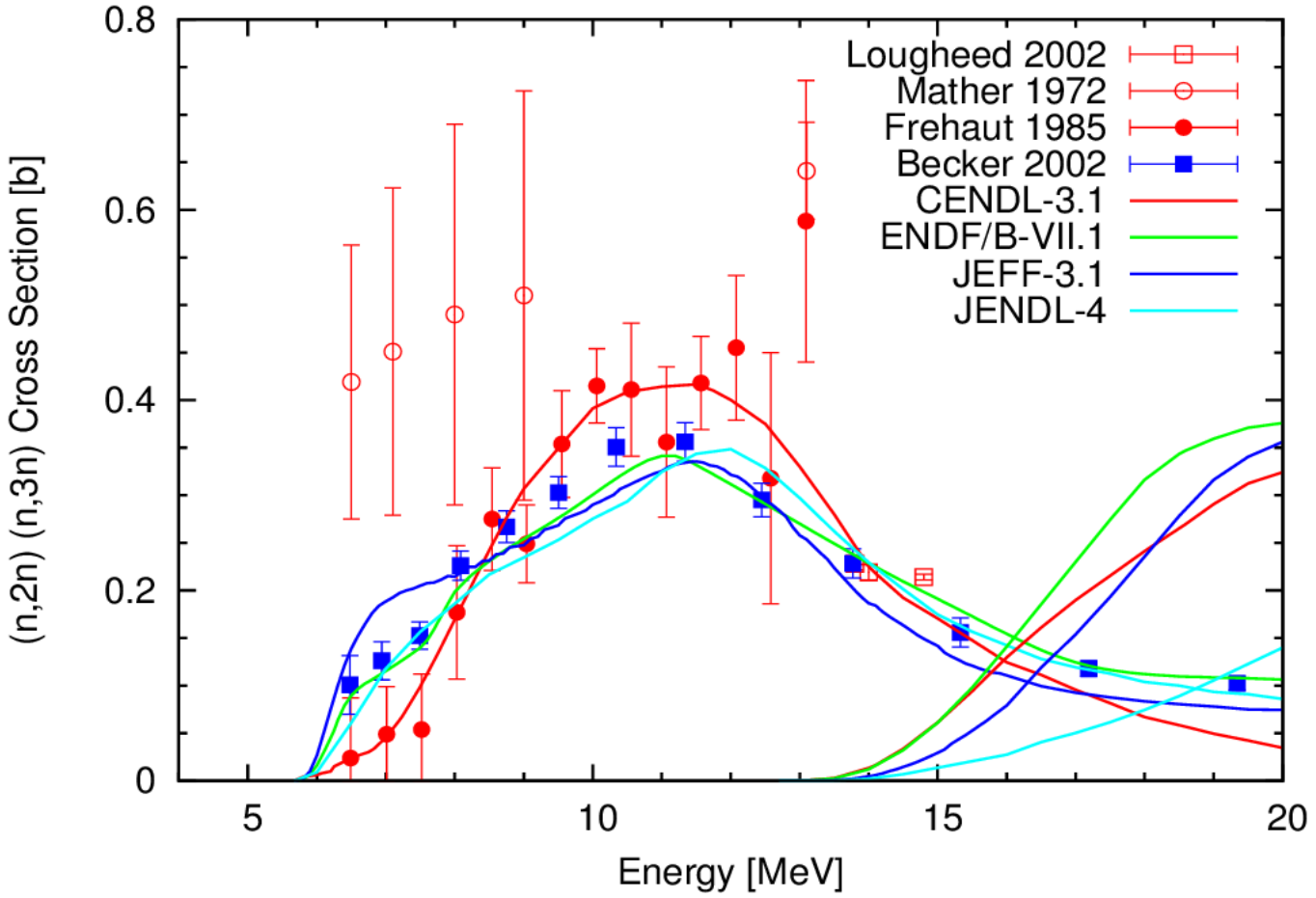
- **New Moldauer parameterization**
  - ND2013, T. Kawano, P. Talou
  - Better agreement with GOE
  - implementation in other codes easy





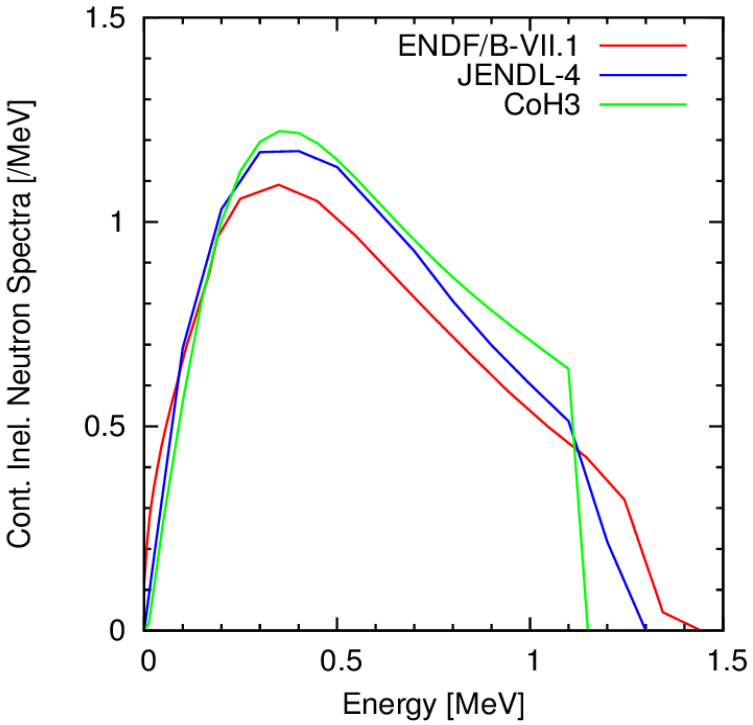
However, difference in CE was invisible for the Pu239 case

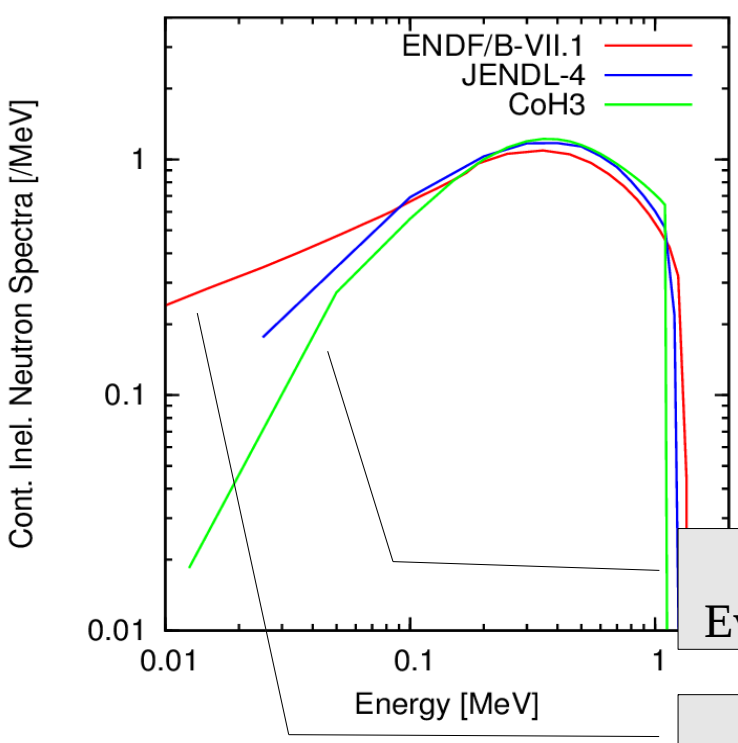
(n,2n) and (n,3n) Reaction Cross Sections



Exclusive Neutron Energy Spectra

Energy spectra for continuum inelastic scattering, at 2 MeV



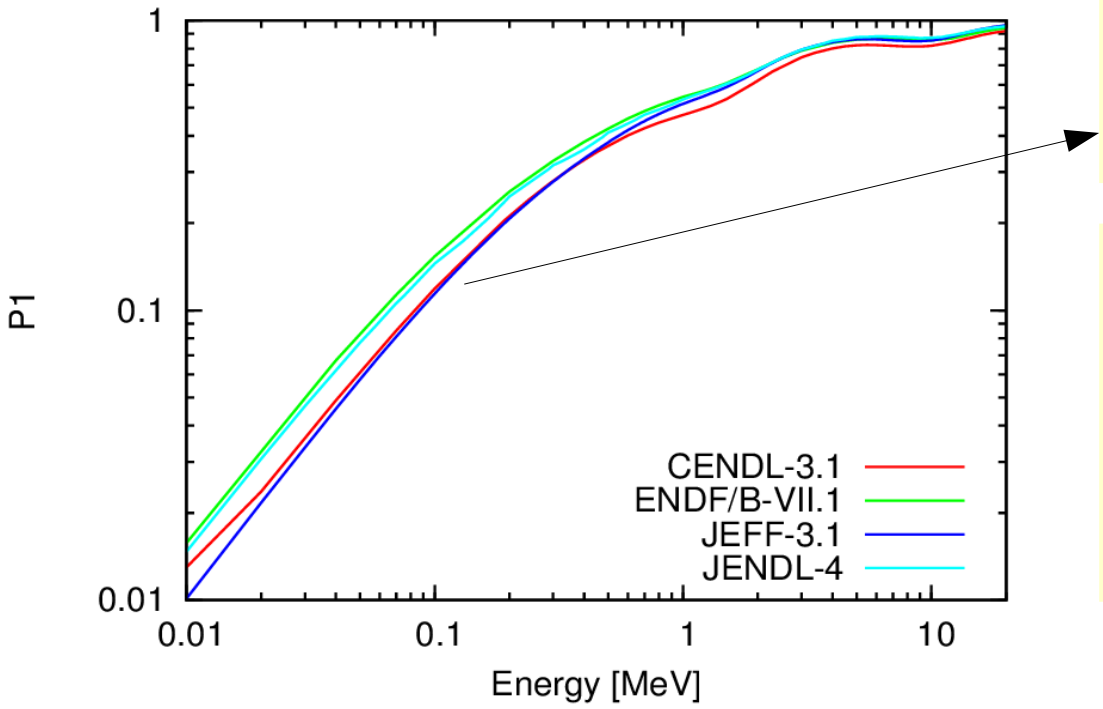


1/E
Evaporation

1/sqrt(E)
Maxwellian

Anisotropy of Elastic Scattering

- **P1 component of elastic scattering**
  - known to have high sensitivity to k-eff calculation for small systems
  - scattering angular distribution changes neuron leakage



at 100 keV
ENDF and JENDL 0.15
CENDL and JEFF 0.11

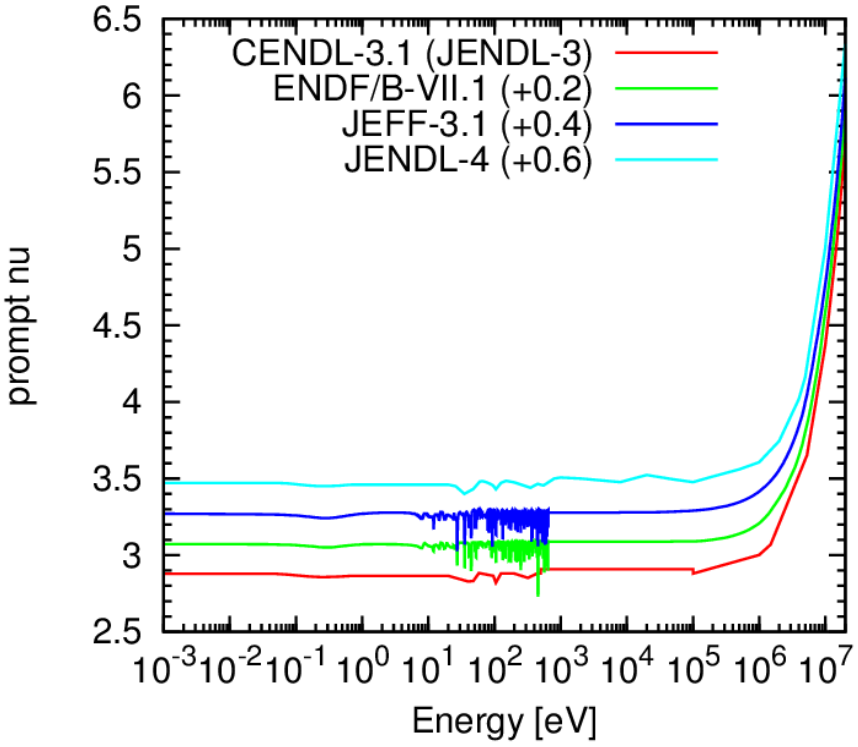
CoH3 calculation

3 levels 0.16
4 levels 0.18
5 levels 0.12
6 levels 0.15
7 levels 0.17

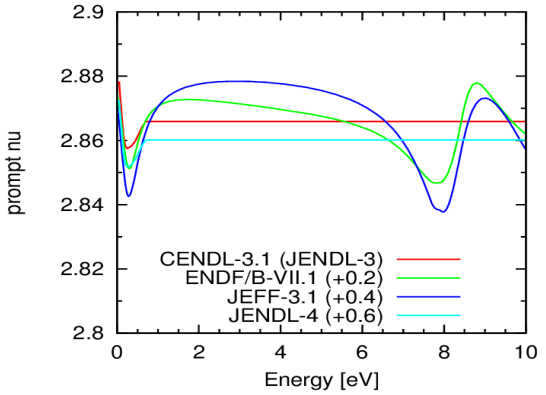
F.Dietrich. I. Thompson, T. Kawano,
PRC 85 044611 (2011)

Average Number of Prompt Fission Neutrons

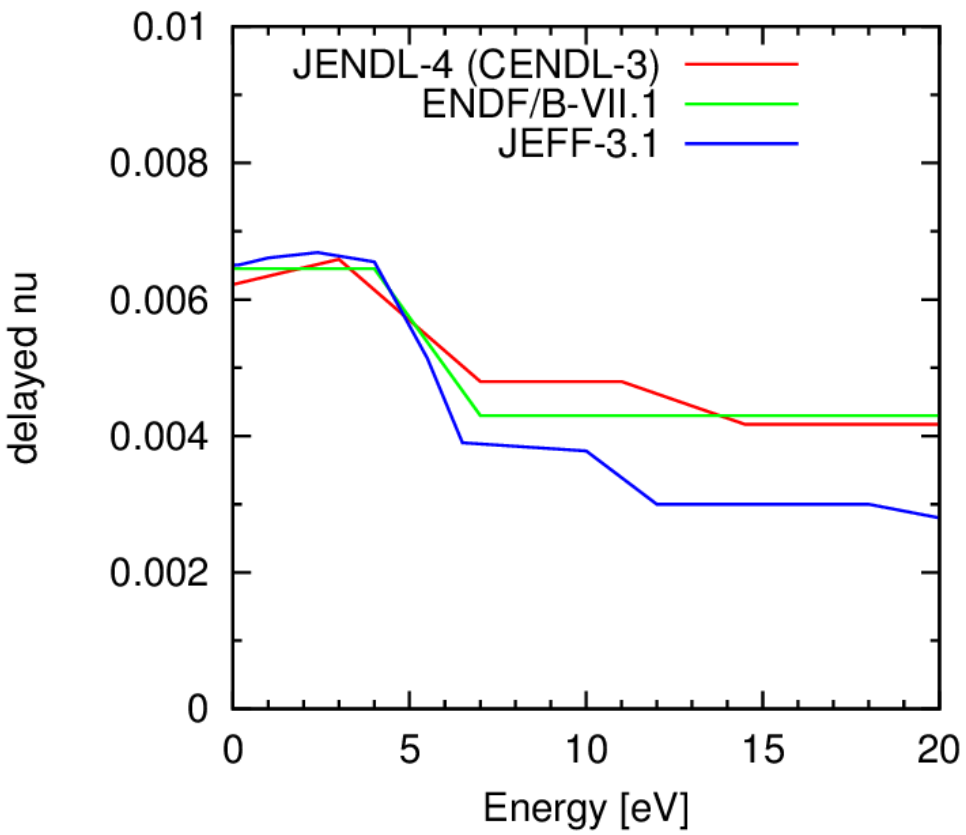
- **All libraries agree in the high energy region**
- **ENDF and JEFF have Structure in the resonance region**



Library	Thermal nu-p
CENDL (JENDL-3)	2.878
ENDF/B-VII.1	2.873
JEFF-3.1	2.868
JENDL-4	2.872



Average Number of Delayed Fission Neutrons



Library	Thermal nu-p
JENDL-3,4 (CENDL)	0.00622
ENDF/B-VII.1	0.00645
JEFF-3.1	0.00650

JEFF has 8 group constants

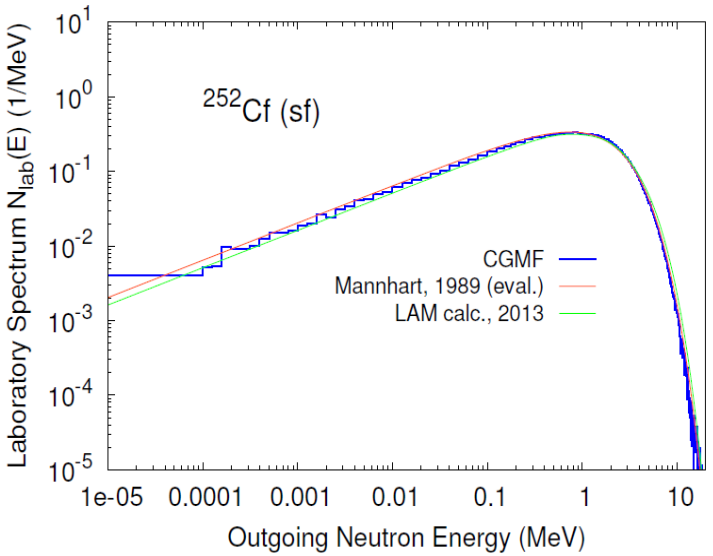
	ENDF/B-VII.0	ENDF/B-VII.1
1	0.01248	0.01327
2	0.02995	0.03088
3	0.1072	0.1134
4	0.3176	0.2925
5	1.352	0.8575
6	10.69	2.730

Toward New Actinide Data Evaluations

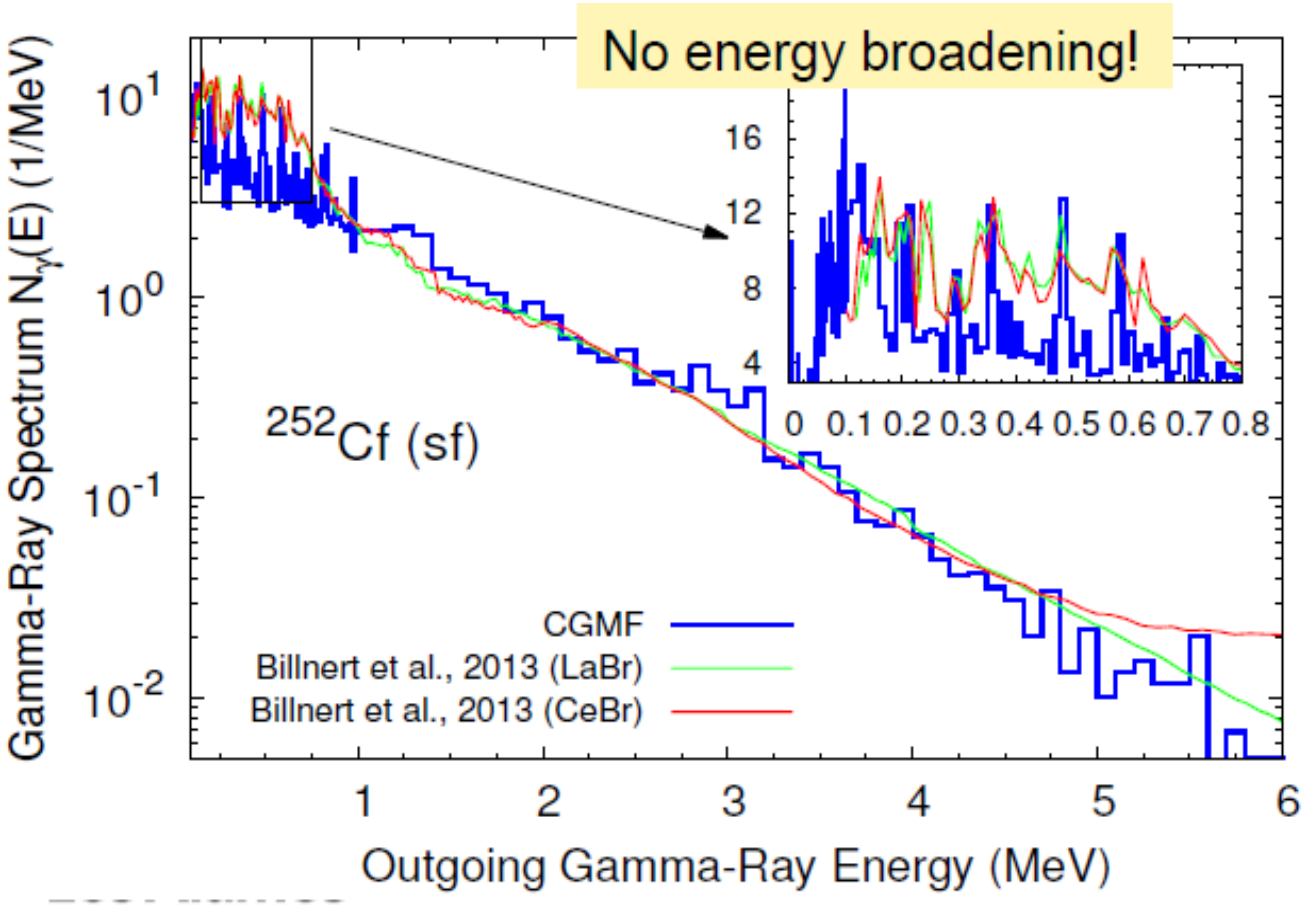
- **Nuclear reaction modeling still crucial**
  - Experimental data do not cover all the channels / energies
    - elastic/inelastic scattering cross section
    - particle energy / angular distributions
    - local fluctuation - real physics or just statistical
  - Need to pin down well-determined channels by experimental data / standards
- **Code development**
  - Hauser-Feshbach codes for nuclear data evaluation
    - CoH3, CGMF (T. Kawano, P. Talou LANL)
    - CCONE (O. Iawamo, JAEA)
    - EMPIRE (M. Herman, et al. BNL)
    - TALYS (A. Koning, et al. NRG)
    - and more …
- **Coupled-Channels Optical Potential**
  - Strong impact on the total CN formation cross section and scattering angular distribution

Monte Carlo Modeling of Fragment Decays

- **ENDF/B-VII.0 evaluation based on Madland-Nix model**
  - model calculations adopted by other libraries - JEFF, JENDL
  - average spectrum and multiplicity only
- **Advanced modeling using Monte Carlo simulations of fission fragment decay**
  - moving to Hauser-Feshbach decayes, not just Weisskopf-Ewing
  - New physical quantities can be evaluated
- **CGMF code developed at LANL**



Cf-252 SF: Prompt Gamma-Rays



Concluding Remarks

- **Comparison of Pu-239 files in libraries**
  - ENDF tends to agree with JENDL
  - 20% difference in capture in the fast energy region
    - DANCE data will be published soon
  - Significant difference seen in the inelastic scattering channel
    - JEFF and CENDL < ENDF and JENDL
  - JEFF and CENDL have slightly less forward-peaked angular distributions than ENDF and JENDL

- **Nuclear reaction modeling for actinides**
  - Improved nuclear reaction modeling for cross sections and fission spectrum crucial
  - Better prediction of experimentally unknown but important nuclear reactions, such as elastic/inelastic scattering
    - fixing well determined channel, such as fission