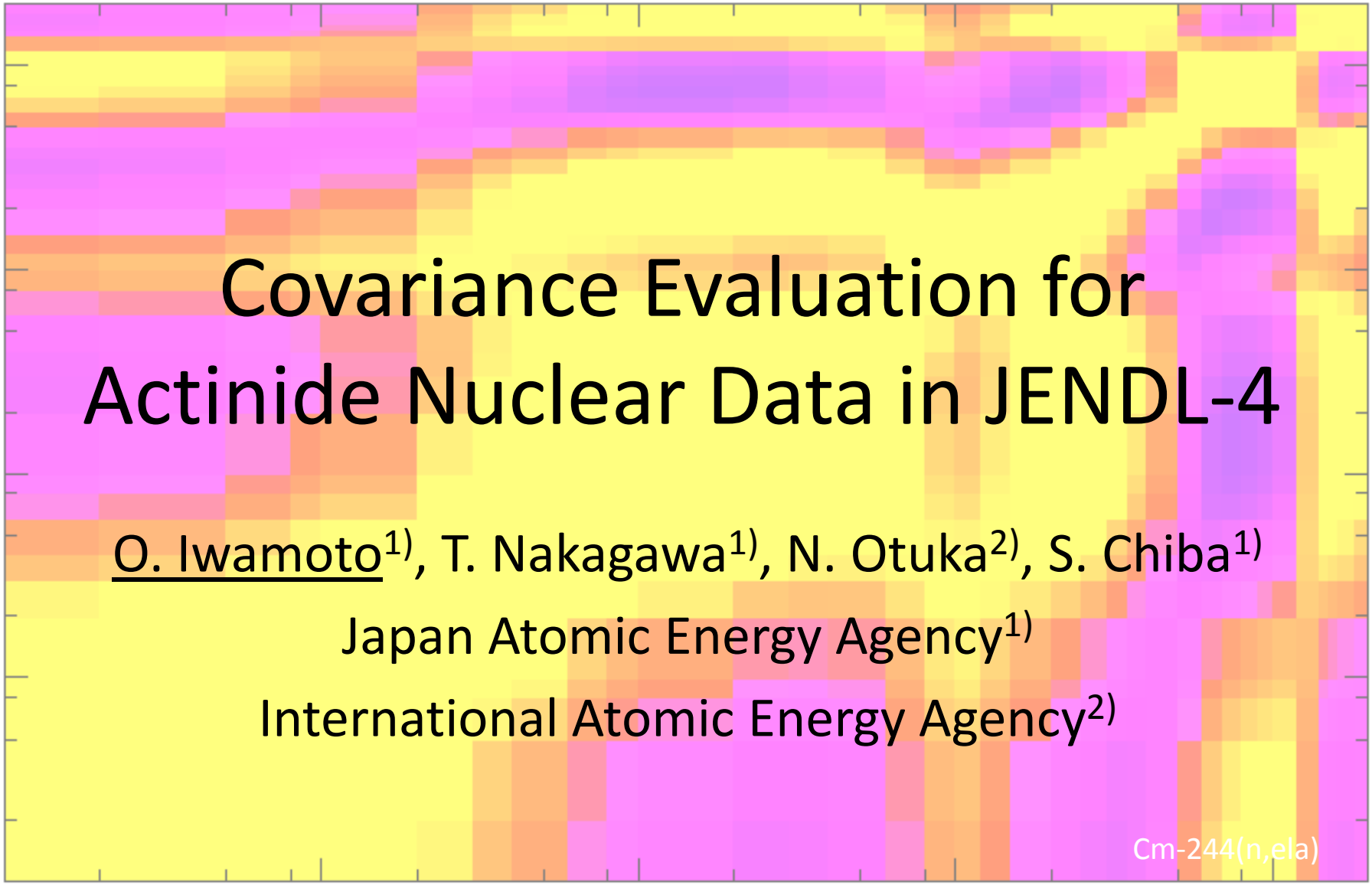
Covariance Evaluation for Actinide Nuclear Data in JENDL-4

O. Iwamoto[1)], T. Nakagawa[1)], N. Otuka[2)], S. Chiba[1)]

Japan Atomic Energy Agency[1)]

International Atomic Energy Agency[2)]



Covariance in JENDL-3.3

after JENDL-3.3 release

MF	MT	U233	U235	U238	Np237	Pu238	Pu239	Pu240	Pu241	Pu242	Am241	Am242m	Am243	Cm244
31	452	x	x	x	x		x		x		x		x	
	455	x	x	x	x		x		x		x		x	
	456	x	x	x	x		x	x	x		x		x	
32	151	x		x	x	x	x	x	x	x	x	x	x	x
33	1	x	x	x			x	x	x					
	2	x	x	x			x	x	x					
	4	x	x	x			x	x	x					
	16	x	x	x			x	x	x					
	17	x	x	x			x	x	x					
	18	x	x	x	x	x	x	x	x	x	x	x	x	x
	37		x	x			x	x	x					
	51-90		x	x			x	x	x					
	91		x	x			x	x	x					
	102	x	x	x	x	x	x	x	x	x	x	x	x	x
34	2	x	x	x			x	x	x					
35	18	x	x	x			x	x						

<u>JENDL-4.0 covariance</u>

number of fission neutron (MF31), resonance parameter (MF32), cross section (MF33), angular distribution of elastic scattering (MF34 1st order Legendre coefficient), fission spectrum (MF35)

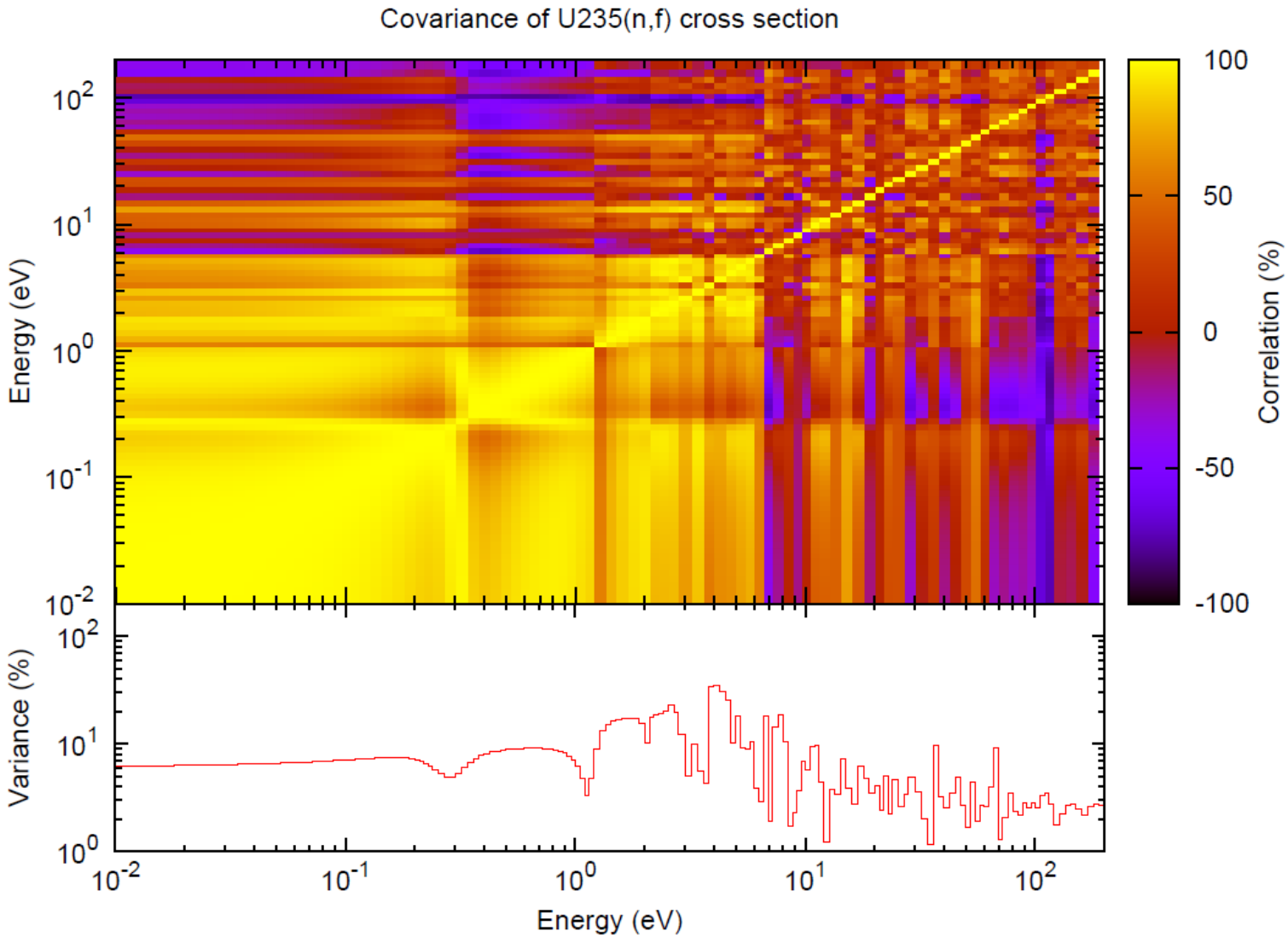
Methodology

- Resonance parameter
  - Major actinide： ORNL SAMMY (Larson)
  - Minor actinide: variance only
- Fission cross section
  - Major ： simultaneous evaluation by SOK (Kawano 2000)
  - Minor ： Least-squares fitting by GMA (Poenitz 1981, Chiba 1991)
- Other cross section, angular distribution (CCONE+KALMAN)
  - Nuclear reaction model calculation by CCONE (Iwamoto 2007)
    + Least squares fitting by KALMAN (Kawano 1997)
- Fission spectrum
  - Point wise covariance (JENDL-3.3)
    → group wise covariance (format transformation; ENDF-6 manual)
  - CCONE+KALMAN
- Number of fission neutron
  - prompt neutron： least square fitting using linear function
  - delayed neutron： estimation from experimental data

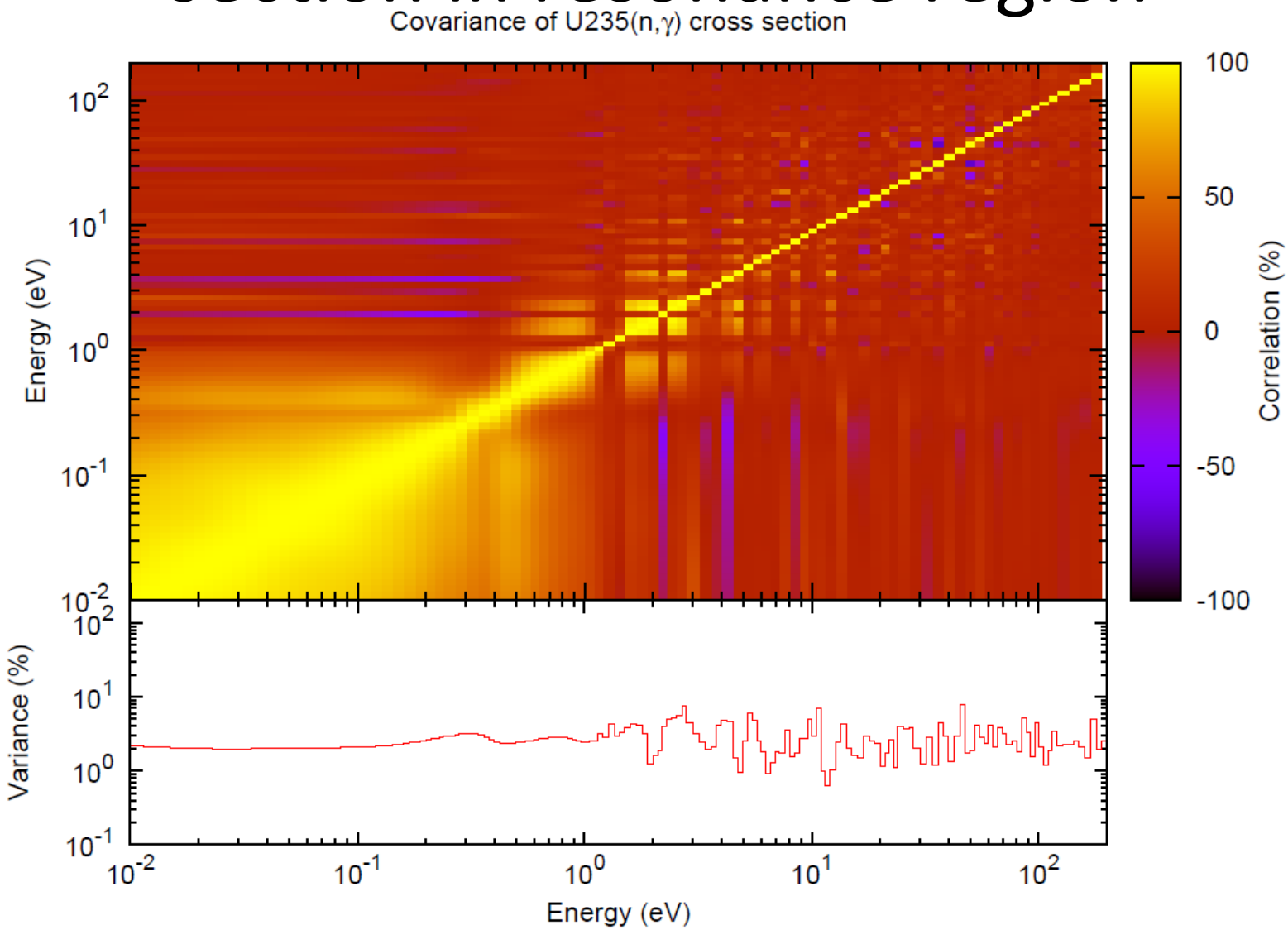
Resonance region for major actinide

Nuclide	JENDL-3.3	JENDL-4.0
U-233	Derrien ’91 (< 600 eV) MF32 (SAMMY)	Leal ’03 (< 600 eV) < 300 eV: MF32 (SAMMY) > 300 eV: MF33 (SAMMY)
U-235	Leal ‘99 (< 2.25 keV) MF33 (GMA Shibata JENDL3.3+α)	Leal ‘99 (< 500 eV) < 200 eV: MF32 (SAMMY) > 200 eV: MF33 (SAMMY)
U-238	Moxon ‘88 (< 10 keV) MF32 (KALMAN Kawano)	Derrien ‘09 (< 20 keV) < 2 keV: MF32 (SAMMY) > 2 keV: MF33 (Nakagawa)
Pu-239	Derrien ‘93 (< 2.5 keV) MF32 (KALMAN Kawano)	Derrien ‘07 (< 2.5 keV) MF33 (SAMMY)
Pu-240	Bouland ‘97 (< 2.7 keV) MF32 (SAMMY variance only)	=JENDL-3.3 (LCOMP=2)
Pu-241	Derrien ’90, ‘94 (< 300 eV) MF32 (SAMMY, 1 positive + 1 negative resonances)	Derrien ‘05 (< 300 eV) MF33 (Nakagawa)

Covariance of U-235 fission cross section in resonance region



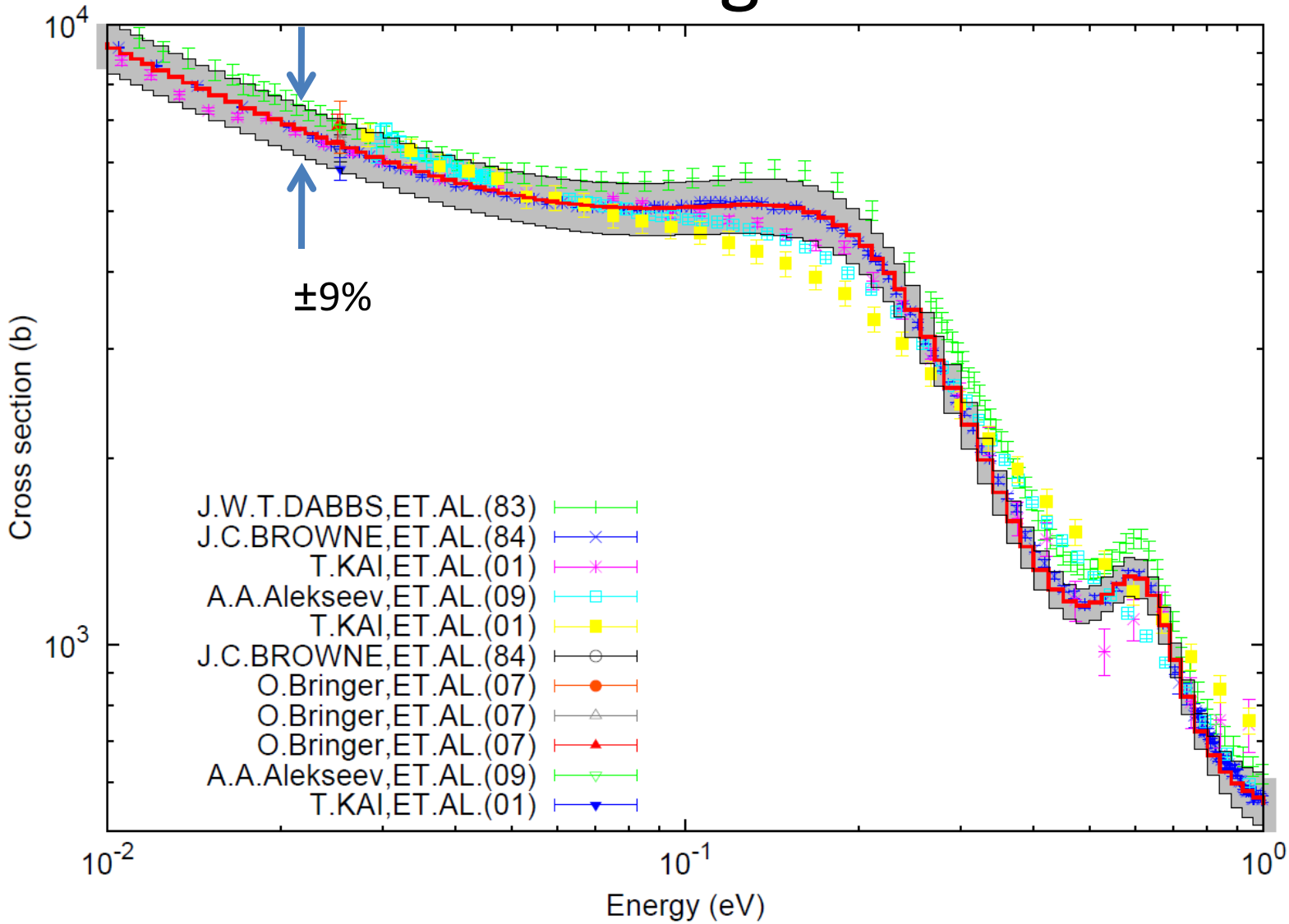
Covariance of U-235 capture cross section in resonance region



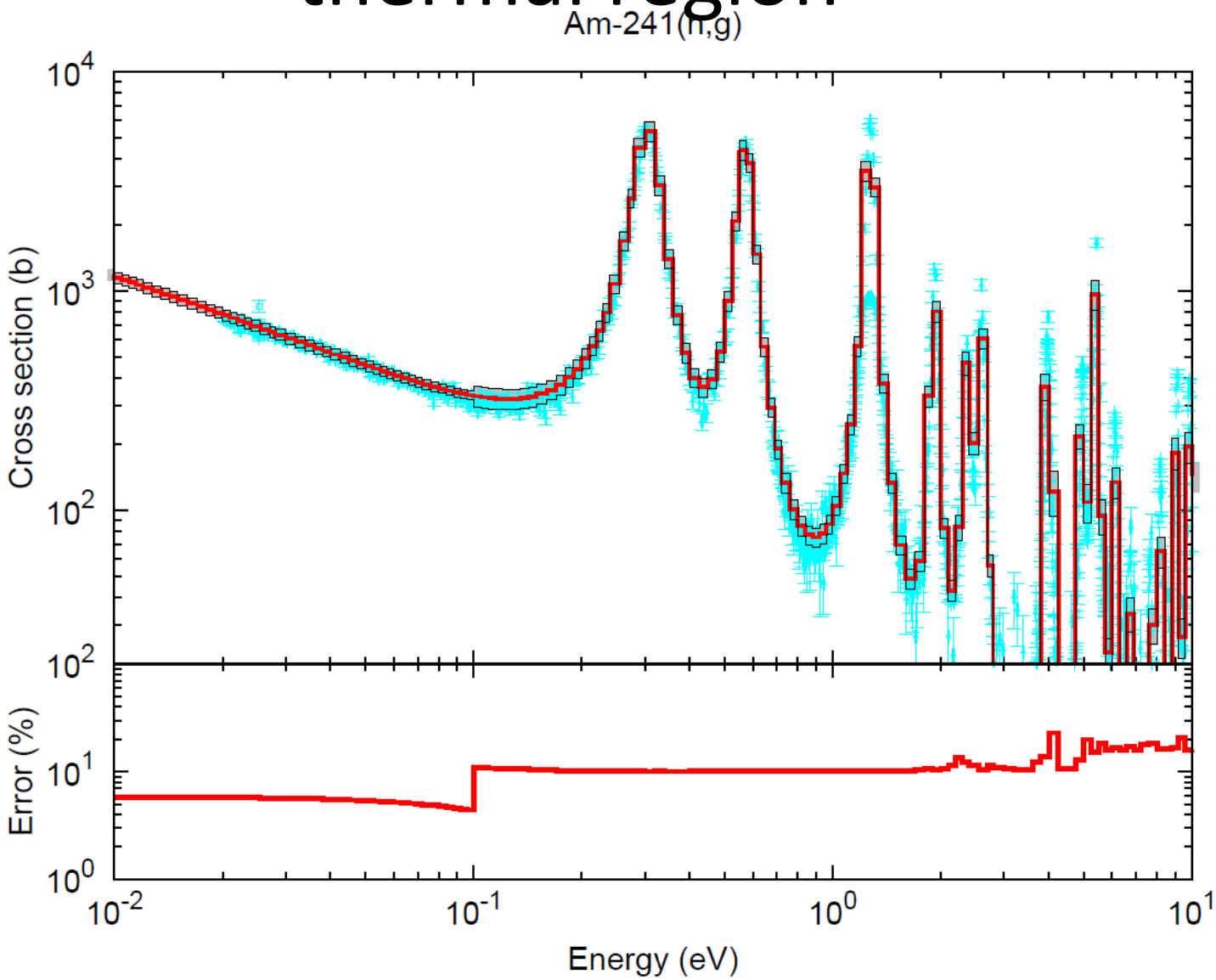
Minor actinide in resonance region

- Resonance parameter uncertainty (variance only)
  - Resonance analysis
  - Mughabghab, "Atlas of neutron resonances" (2006)
- Unknown case
  - resonance energy： 0.1% assumed
  - neutron, fission, gamma widths：10-50% assumed
- Comparison with experimental data and evaluated thermal cross section uncertainty
  - Modify negative resonance parameter uncertainty （ thermal cross section ）
  - Add cross section uncertainty (MF33)

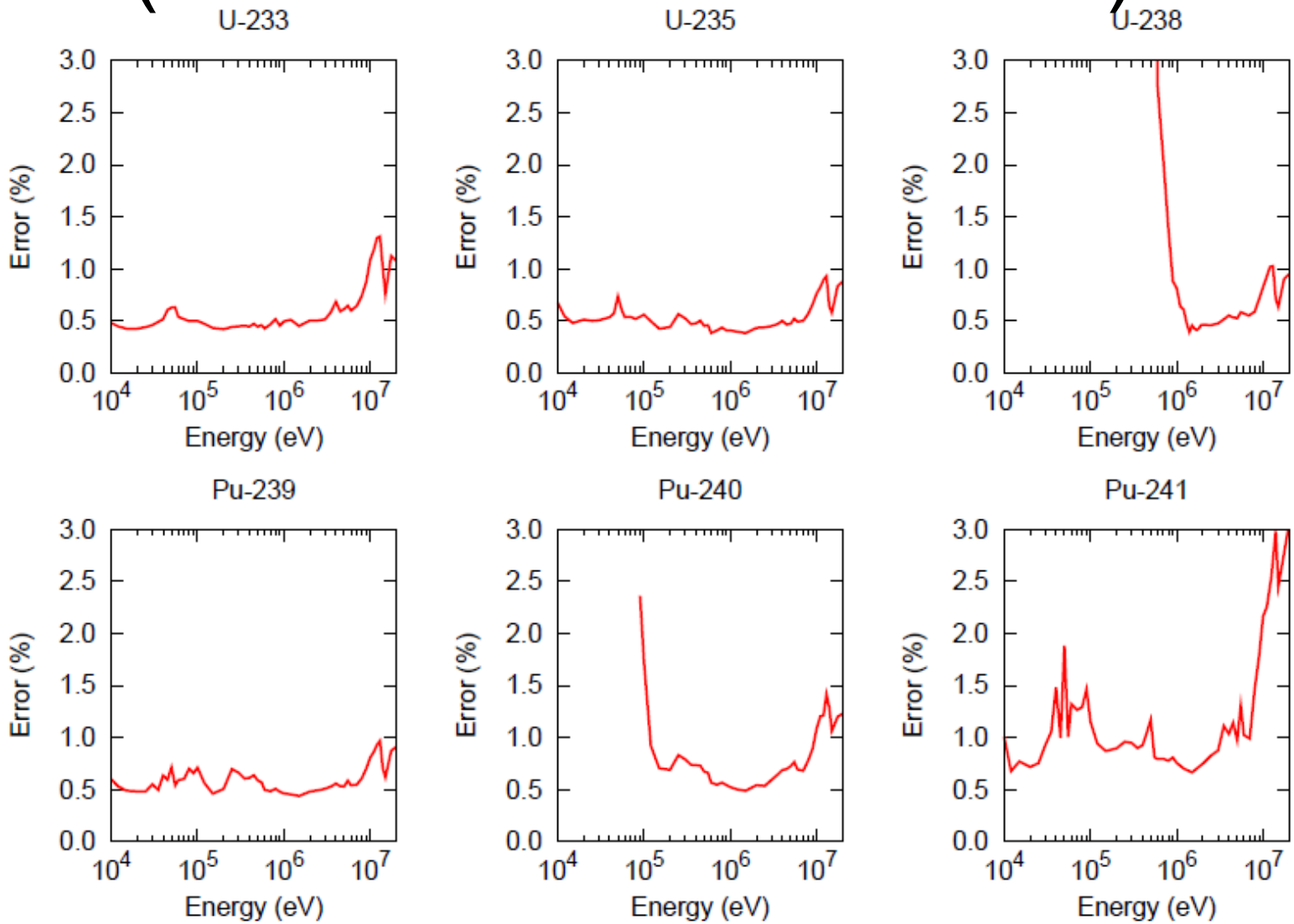
Am-242m fission cross section at thermal region



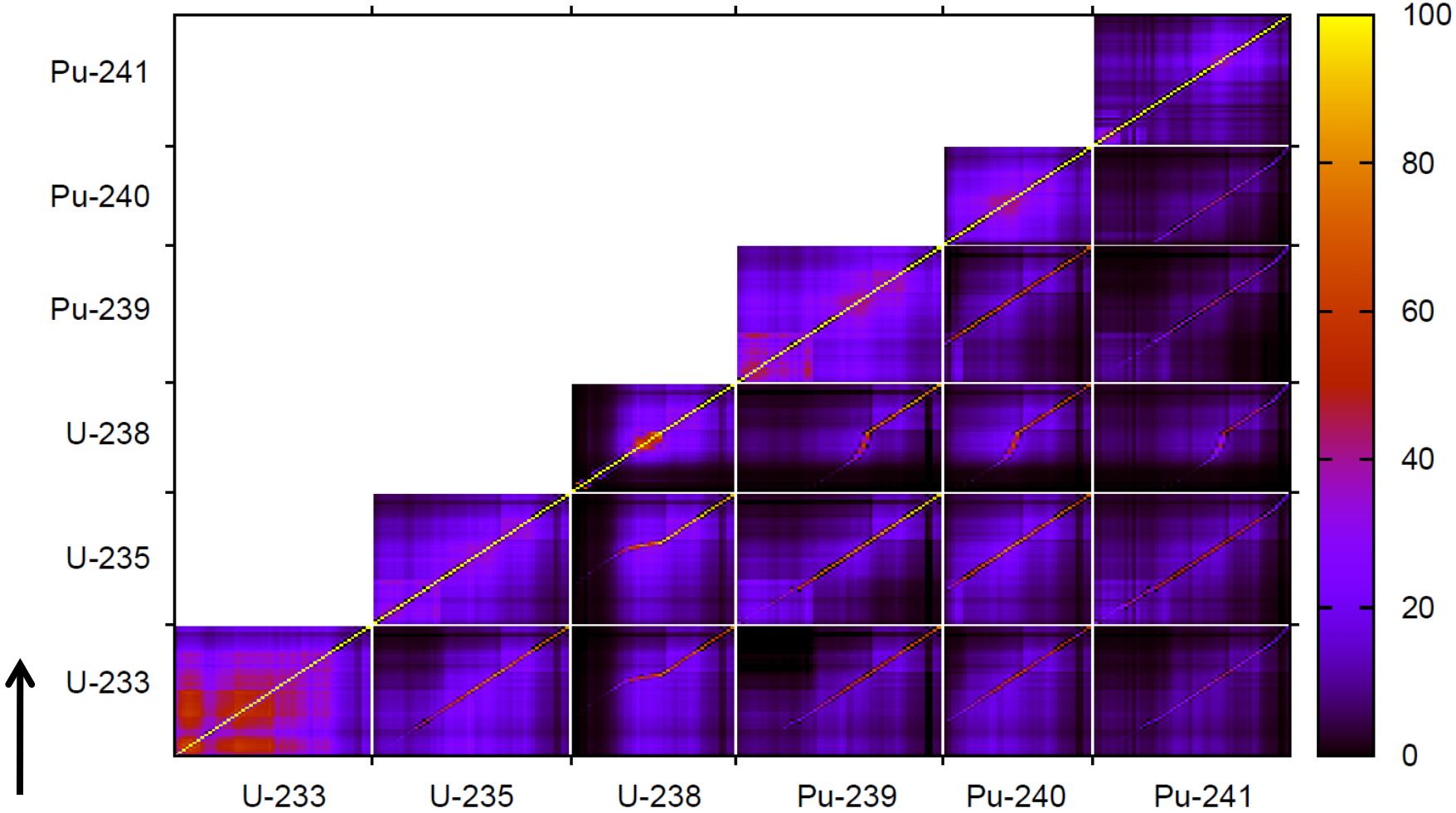
Am-241 capture cross section at thermal region



Fission cross section uncertainty (simultaneous evaluation)

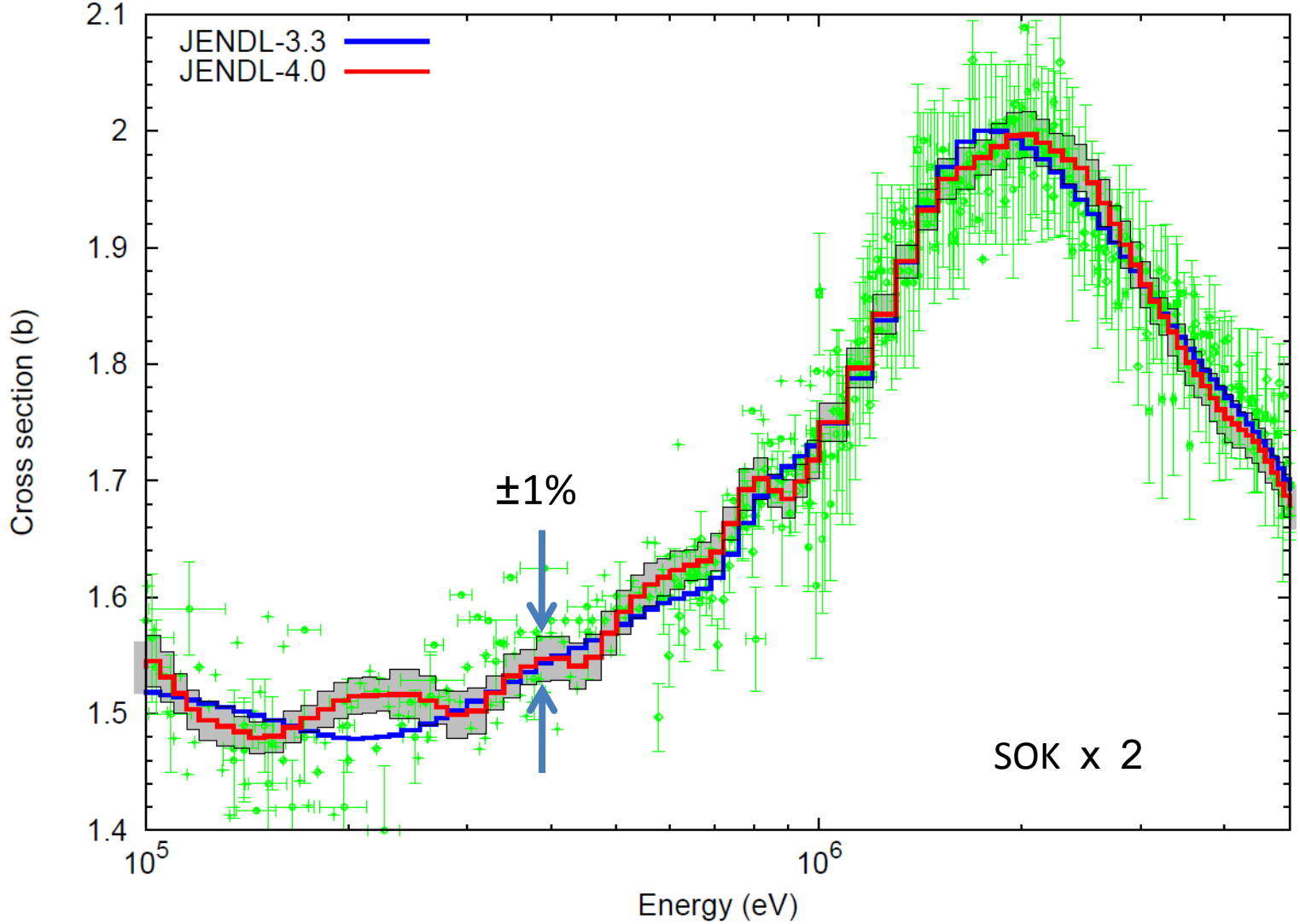


Correlation matrix
(simultaneous evaluation)

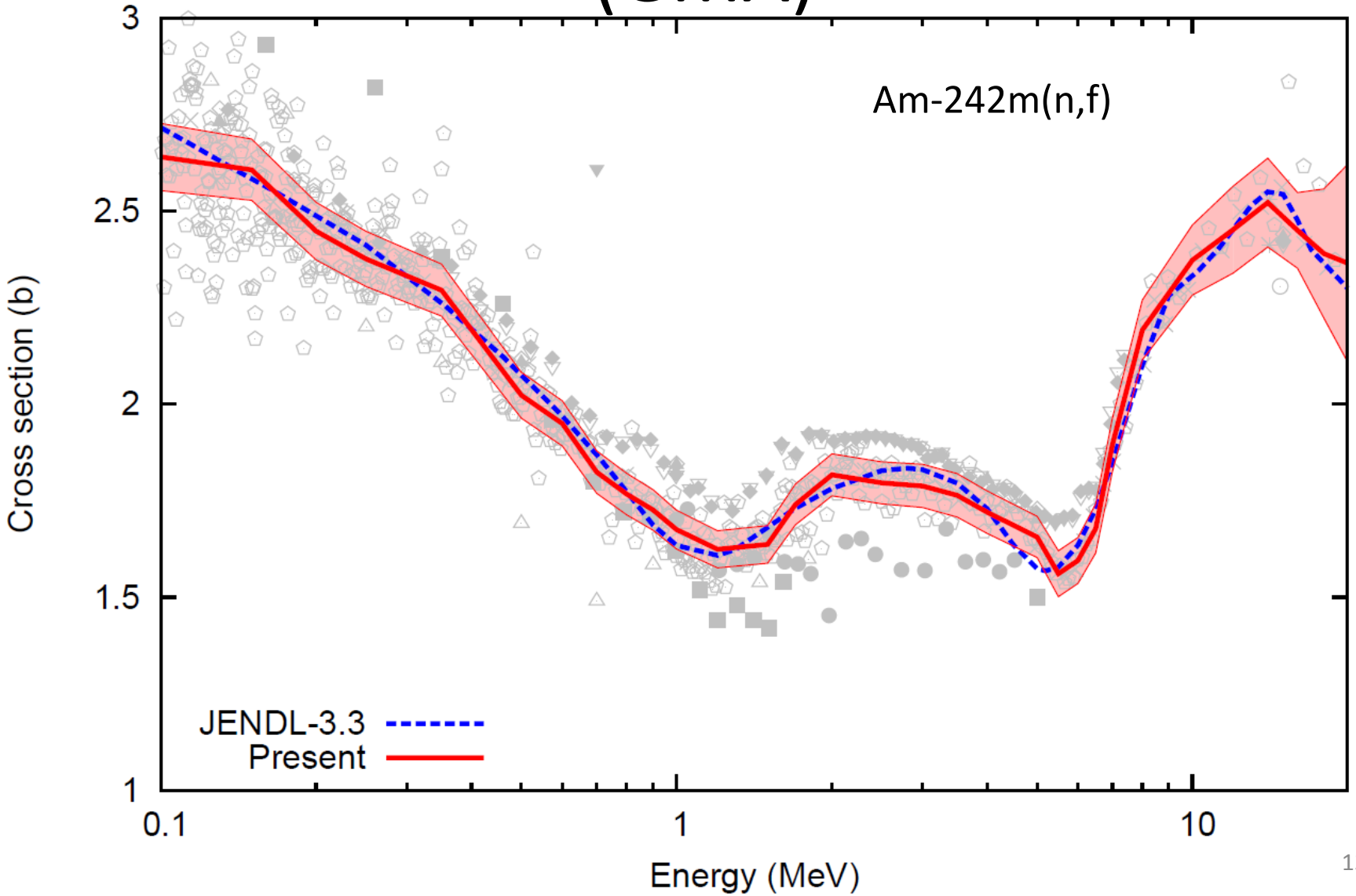


Grid No.

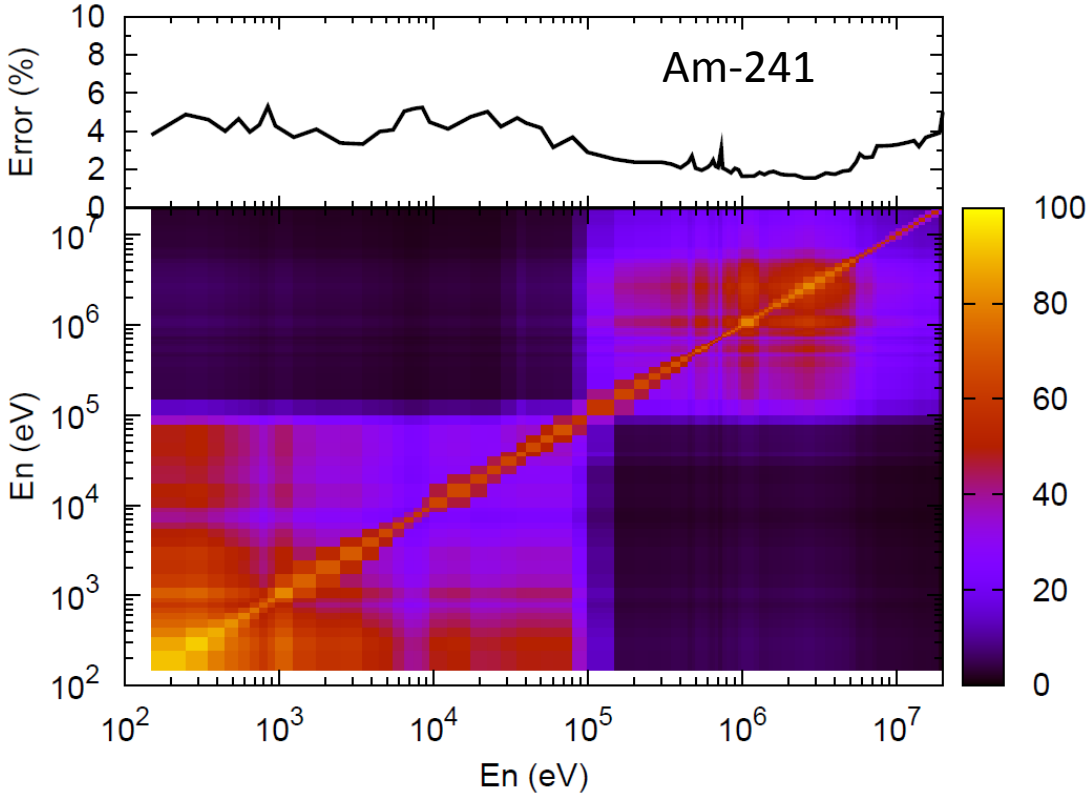
Pu-239 fission cross section
(simultaneous evaluation)

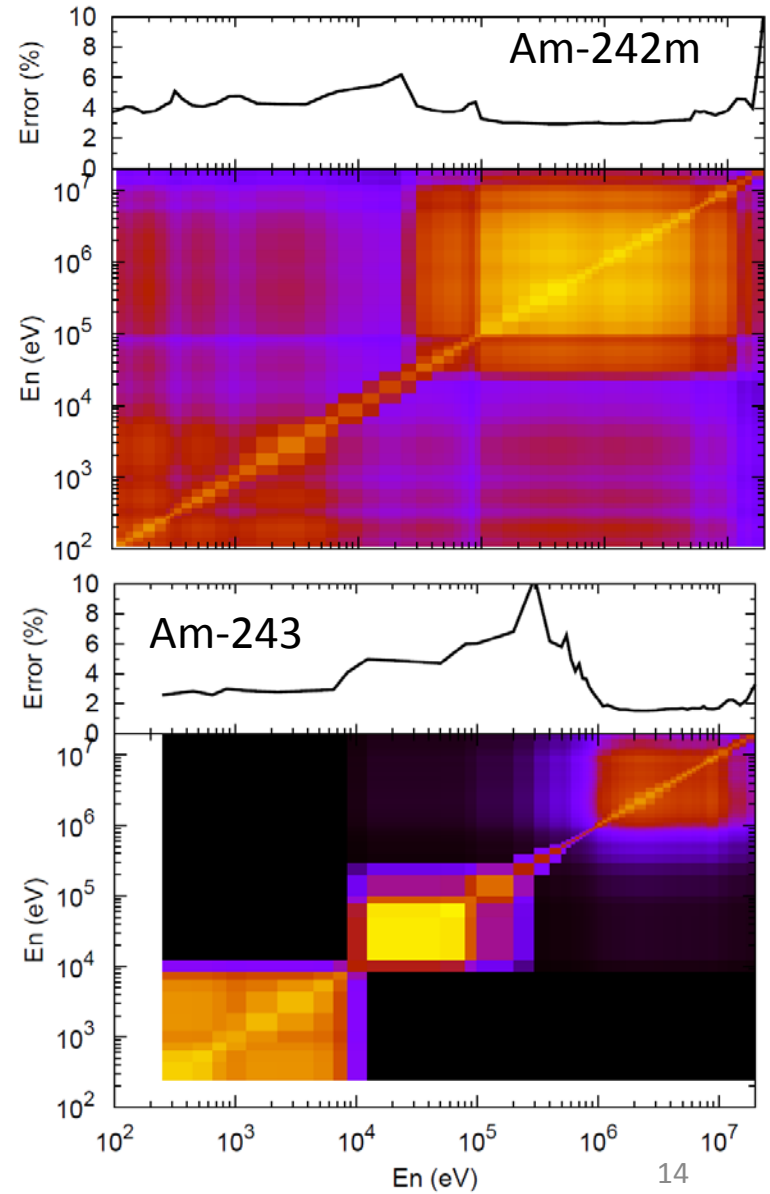


Am-242m fission cross section (GMA)



Covariance of Am(n,f)

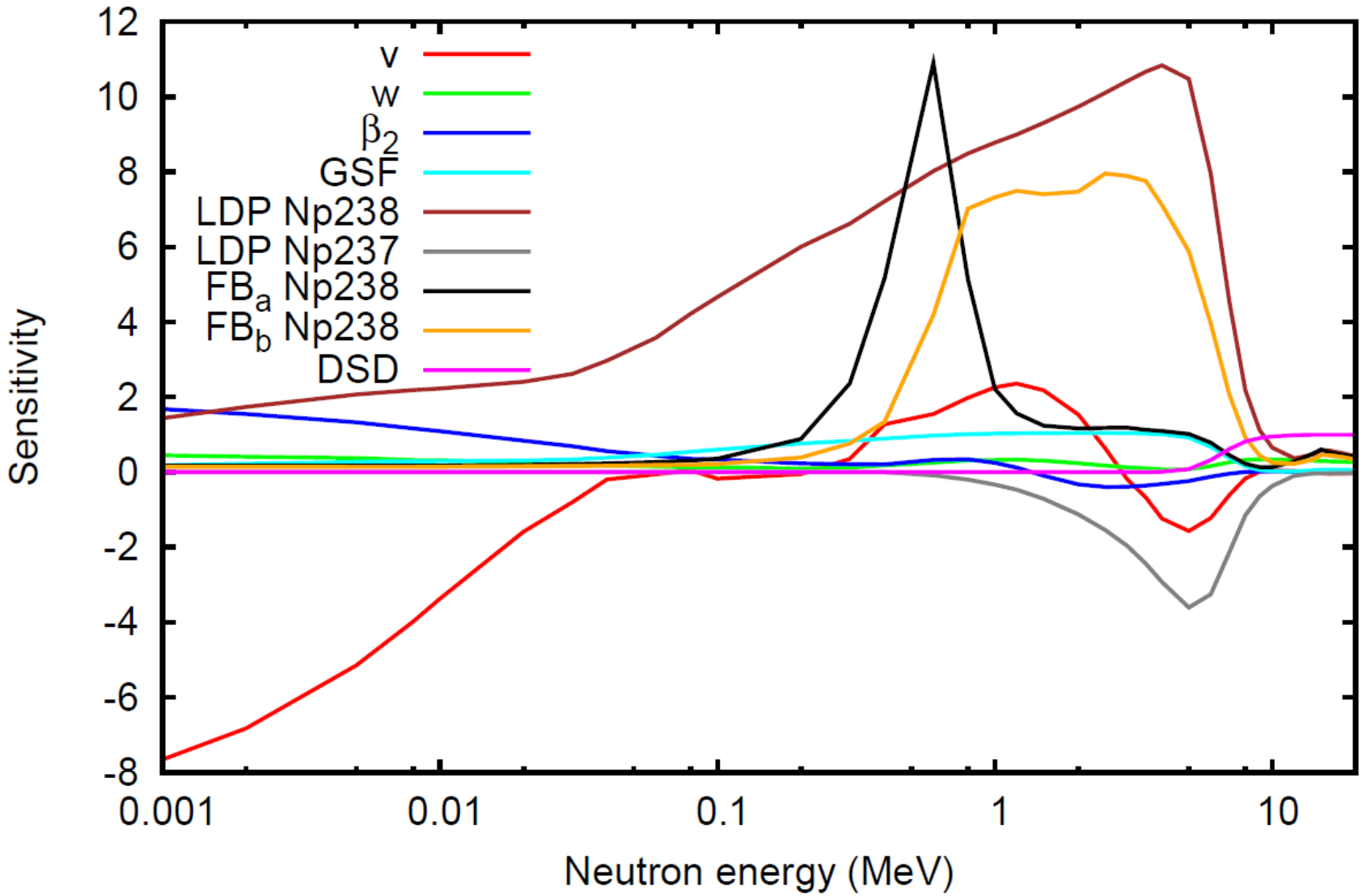




CCONE+KALMAN method

- Capture cross section (“High fidelity”)
  - JENDL/AC-2008
  - experimental data → CCONE+KALMAN
- Other cross section for which experimental data exist (“Middle fidelity”)
  - estimate cross section uncertainty from experimental data
  - estimated uncertainty→ CCONE+KALMAN
- no experimental data (“Low fidelity”)
  - estimate parameter uncertainty to cover experimental data
  - twice uncertainty
- sensitivity to parameters（ ~ 50 parameters ）
  - OMP: depth, radius of real and imaginary potential, deformation
  - level density：target, compound, produced nucleus
  - gamma strength function
  - fission barrier parameter
  - direct and simi-direct captrure

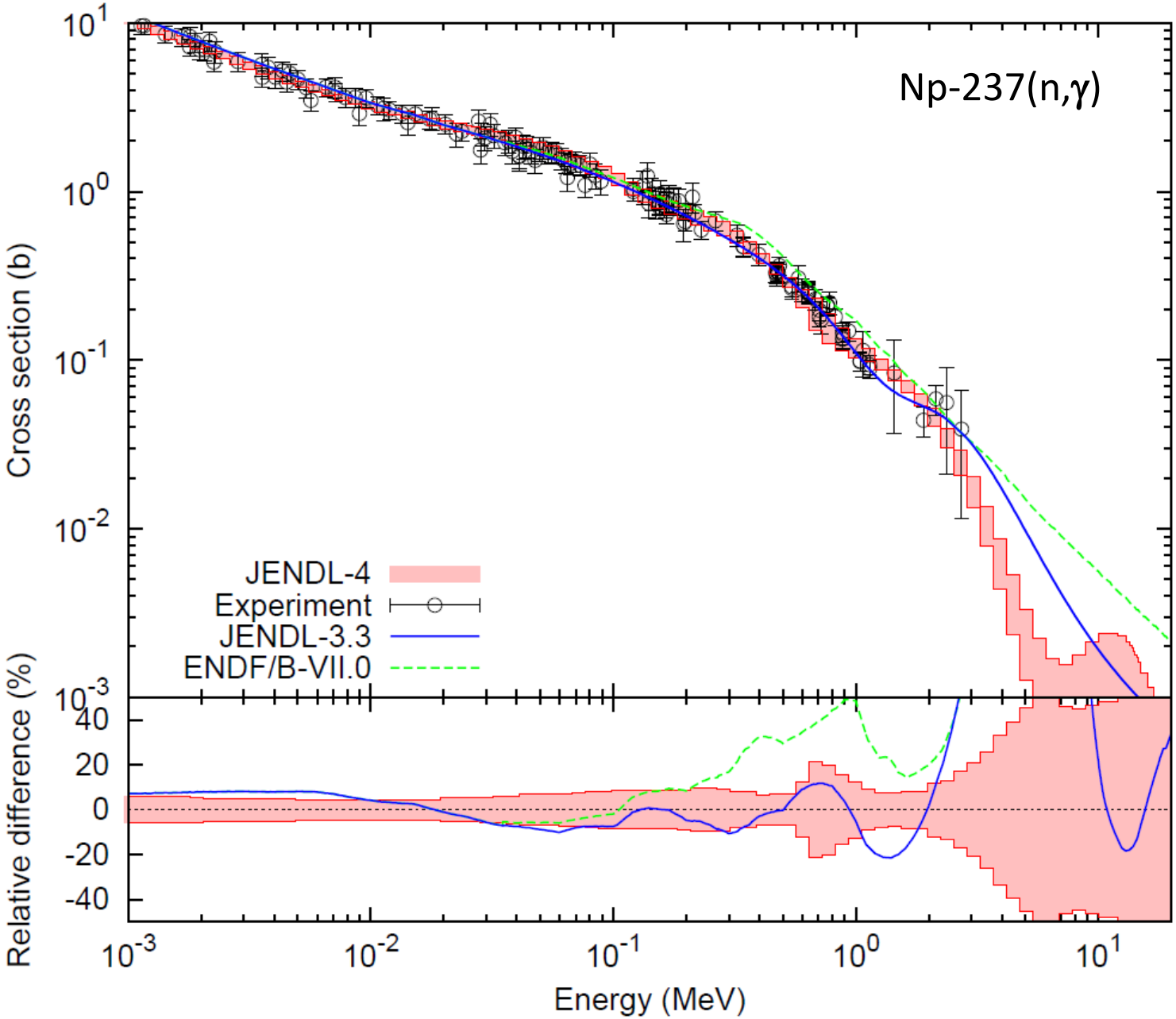
Np-237(n,g) sensitivity to model parameter (dσ/dt)/(σ/t)



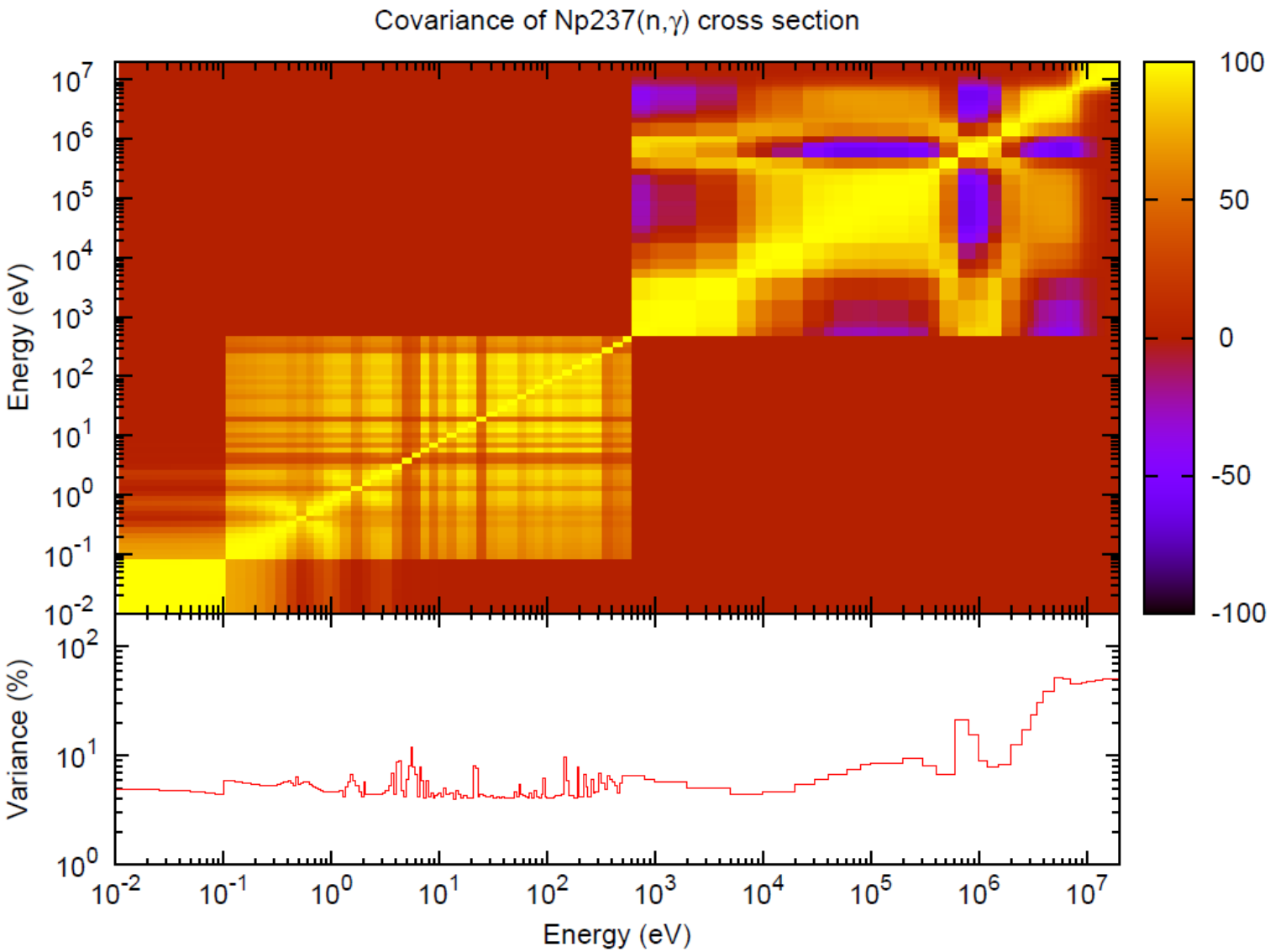
Capture cross section covariance (High fidelity)

- Experimental data
  - statistical error：no correlation (diagonal matrix)
  - systematic error：strong correlation (all matrix element=1)
  - correlation between data sets by
    - the same author: 0.8
    - different authors：0.4
  - modify experimental uncertainty: chi-square ~ 1
- Final covariance
  - “KALMAN covariance”
    + “difference between posterior and prior”

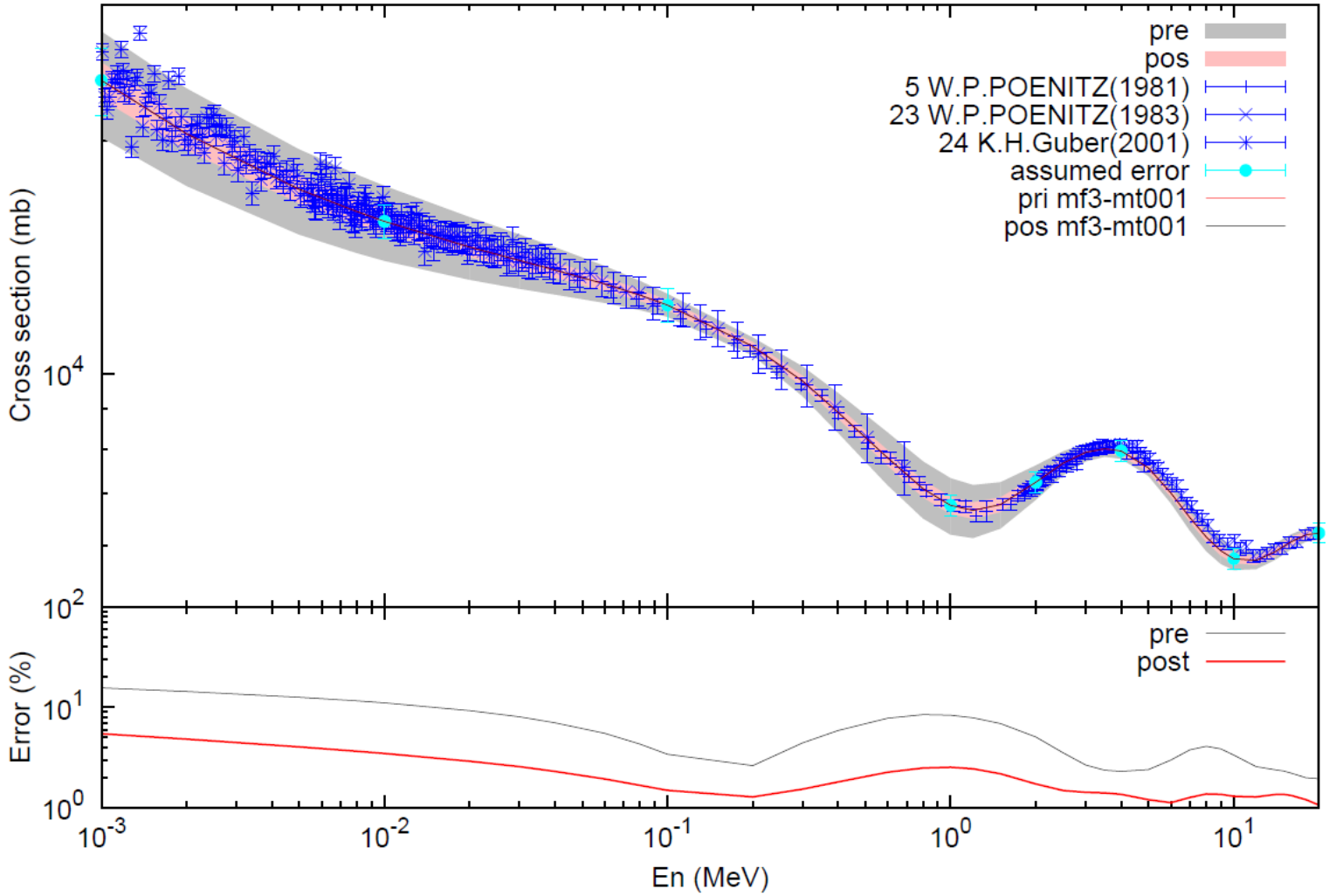
Np-237(n,g) cross sectin



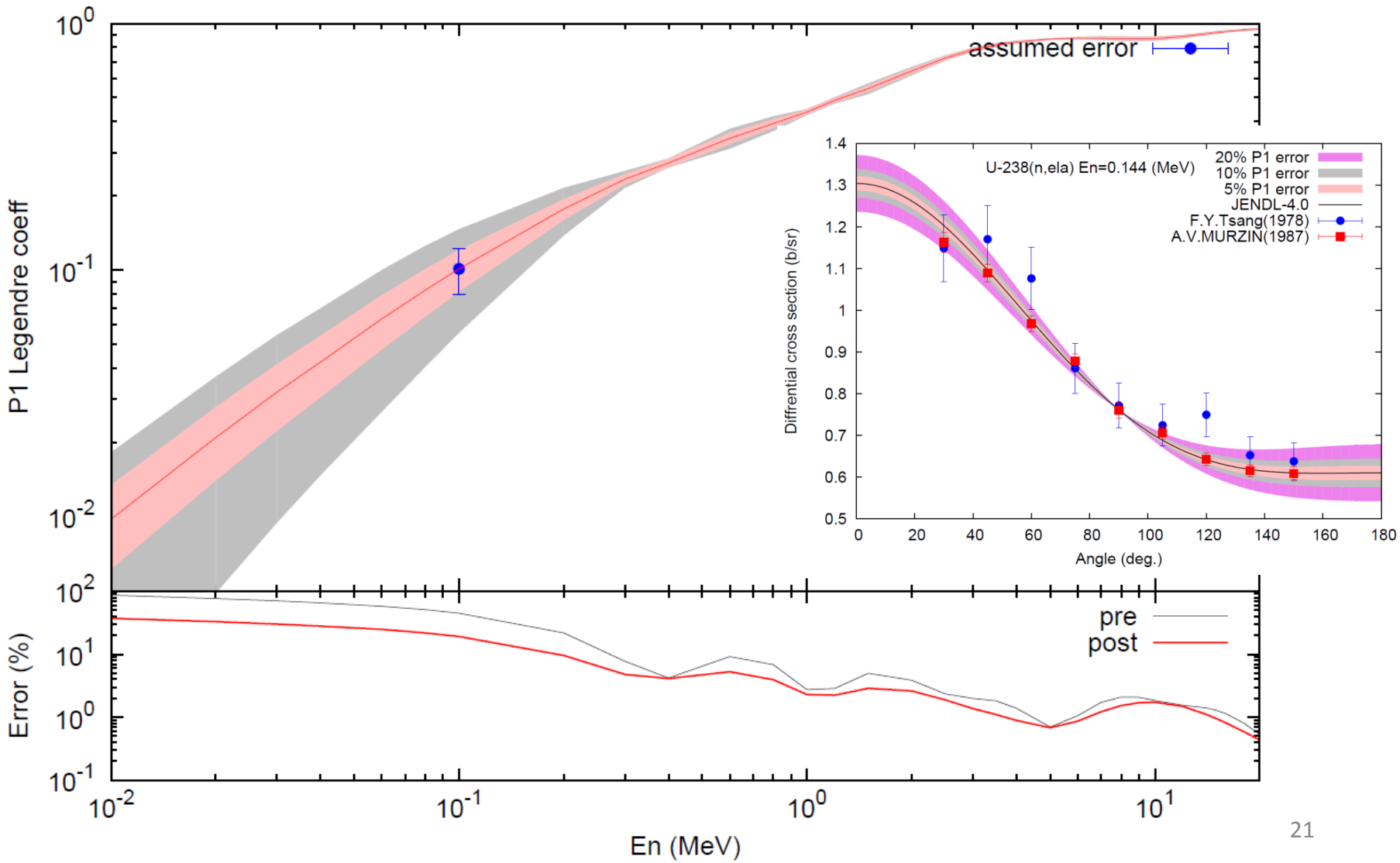
Covariance of Np-237(n,g)



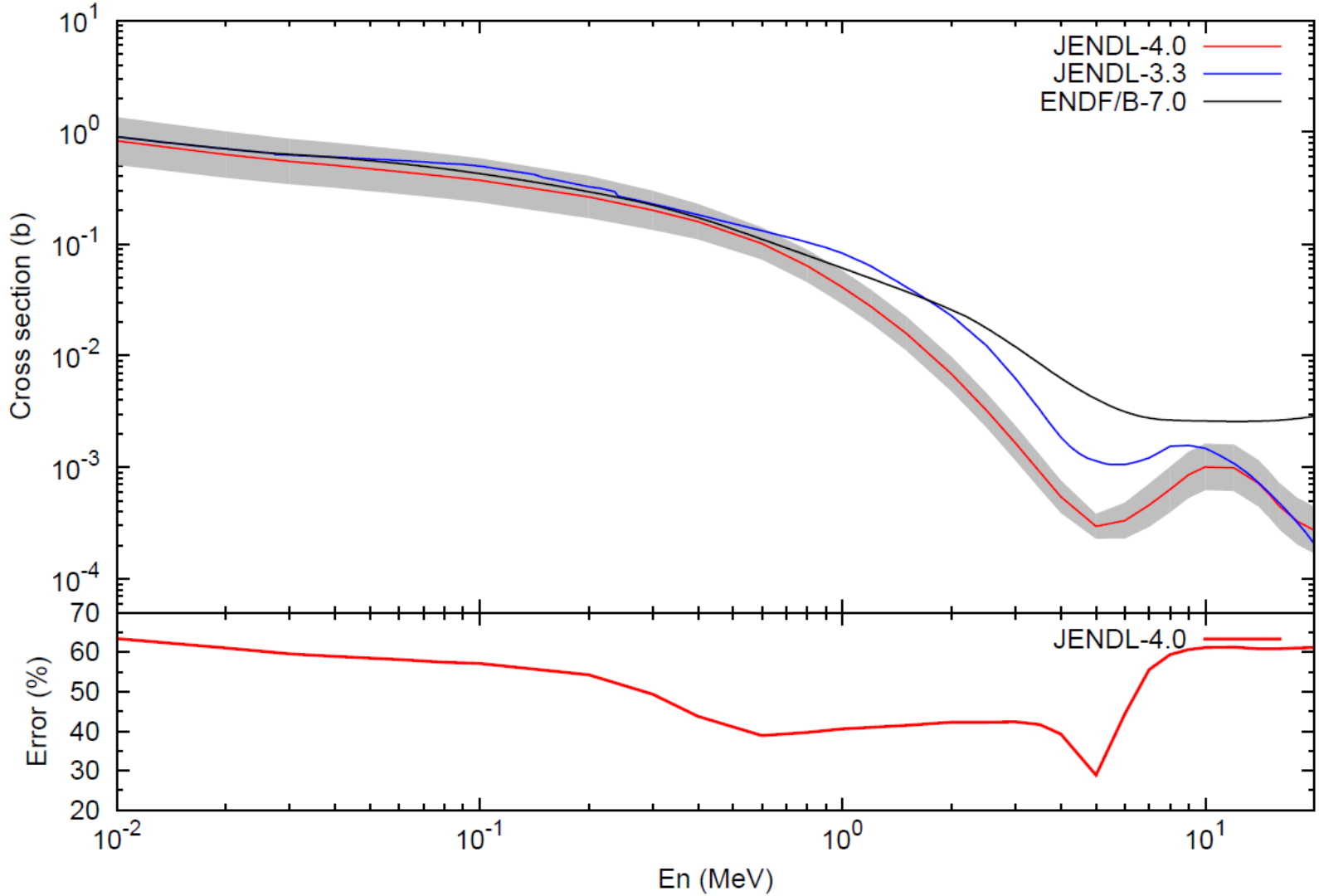
U-233 total cross section
(Middle fidelity)



Angular distribution of U-238 elastic scattering （ Middle fidelity ）

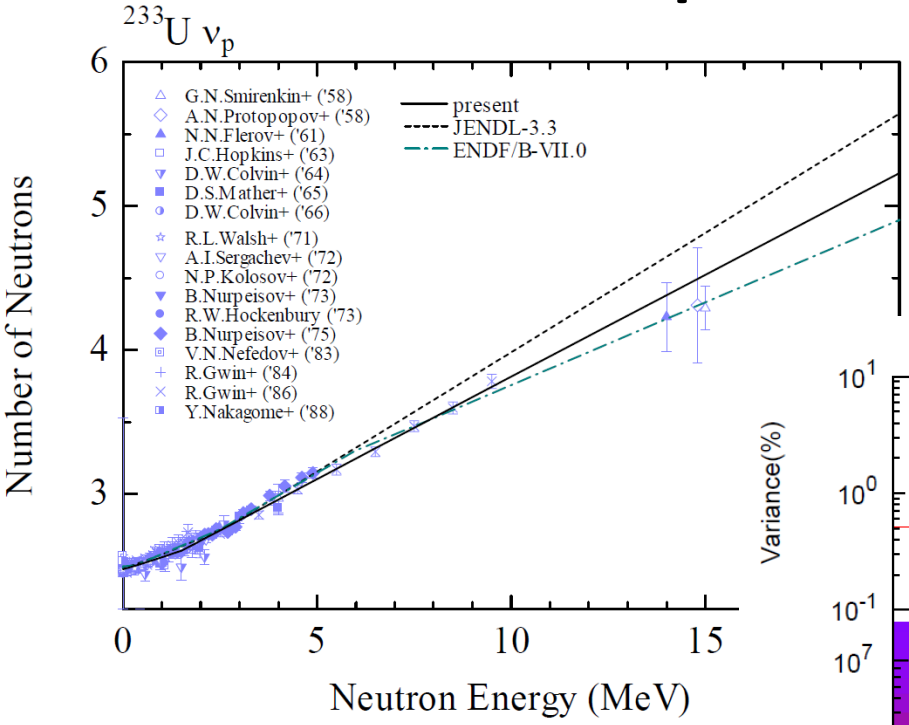


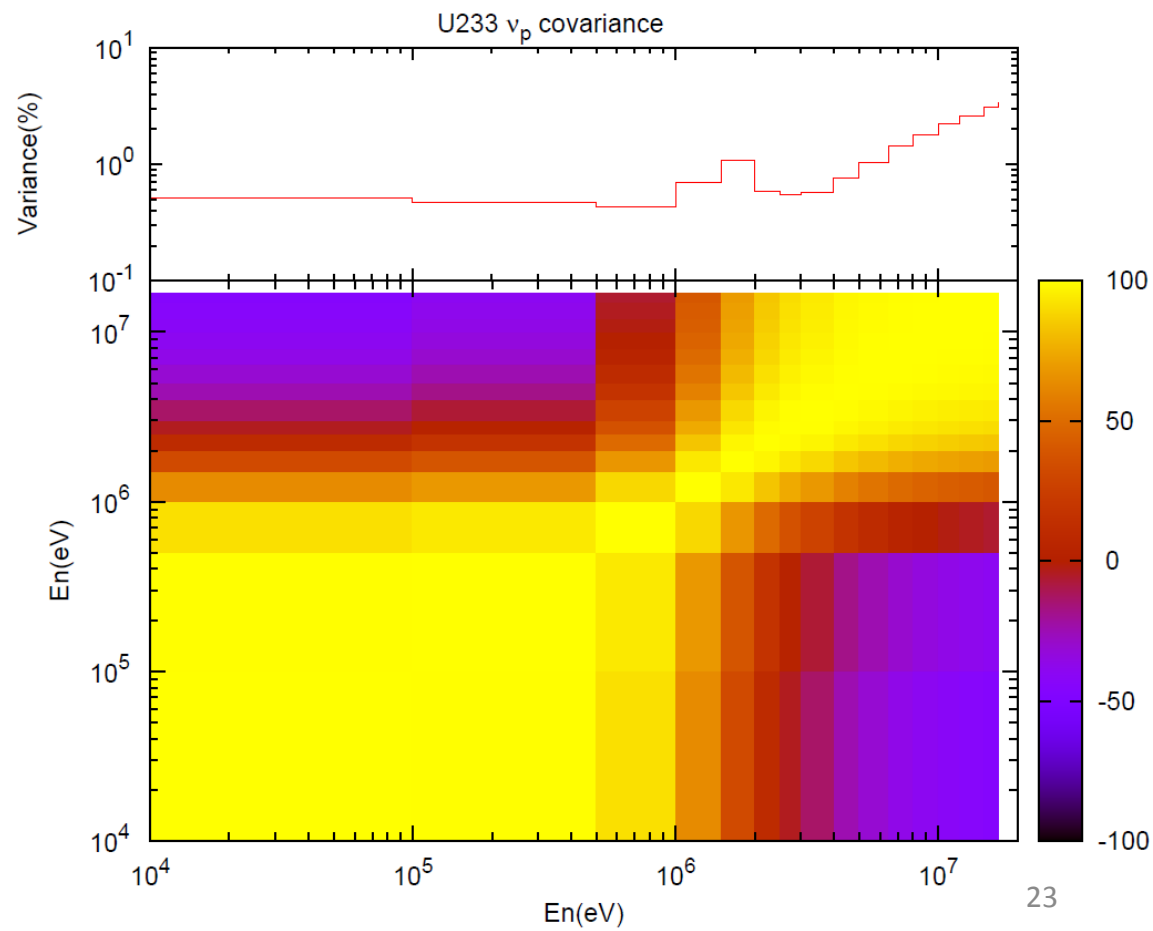
Am-242m capture cross ection (Low fidelity)



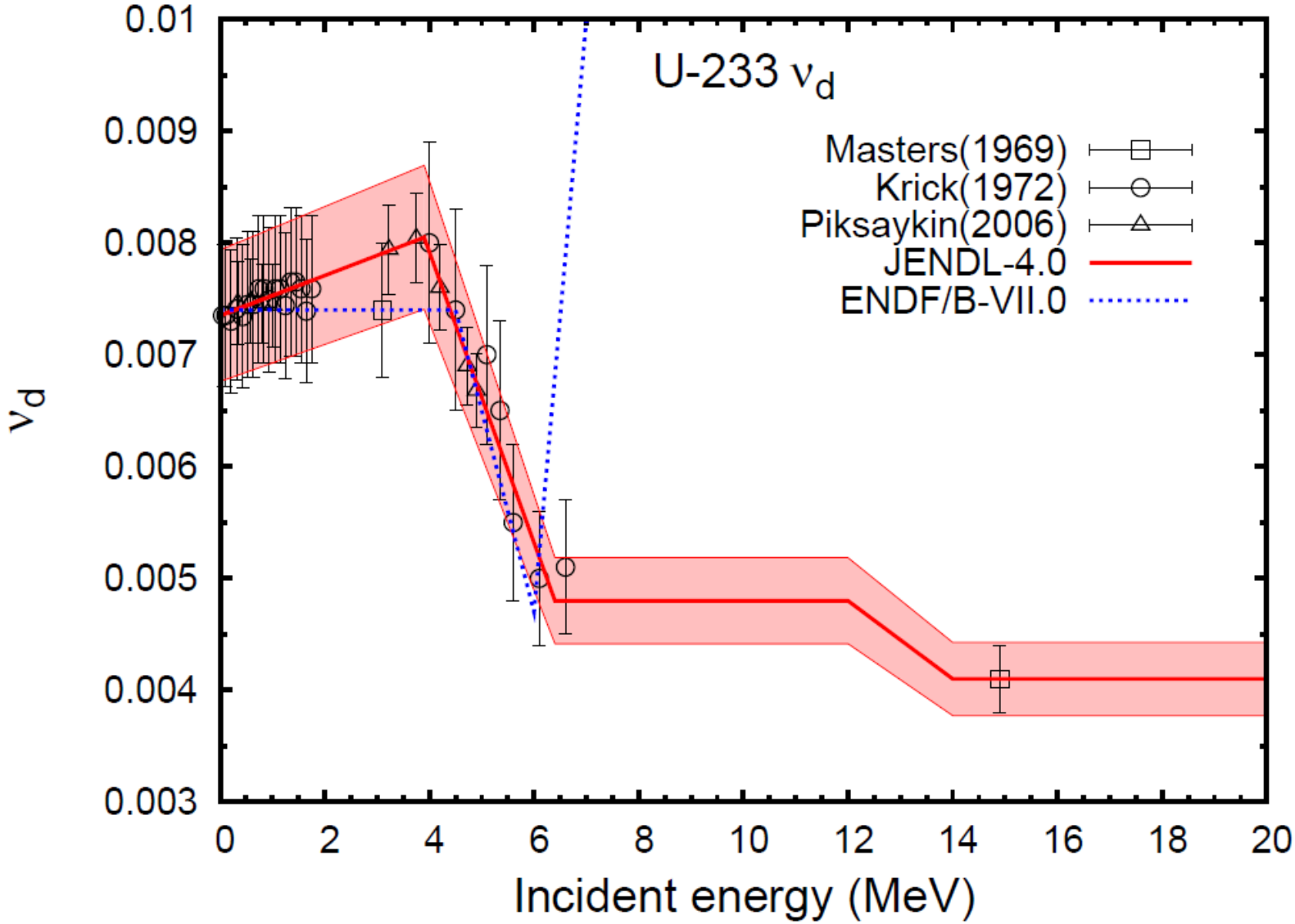
Number of prompt fission neutron

U-233

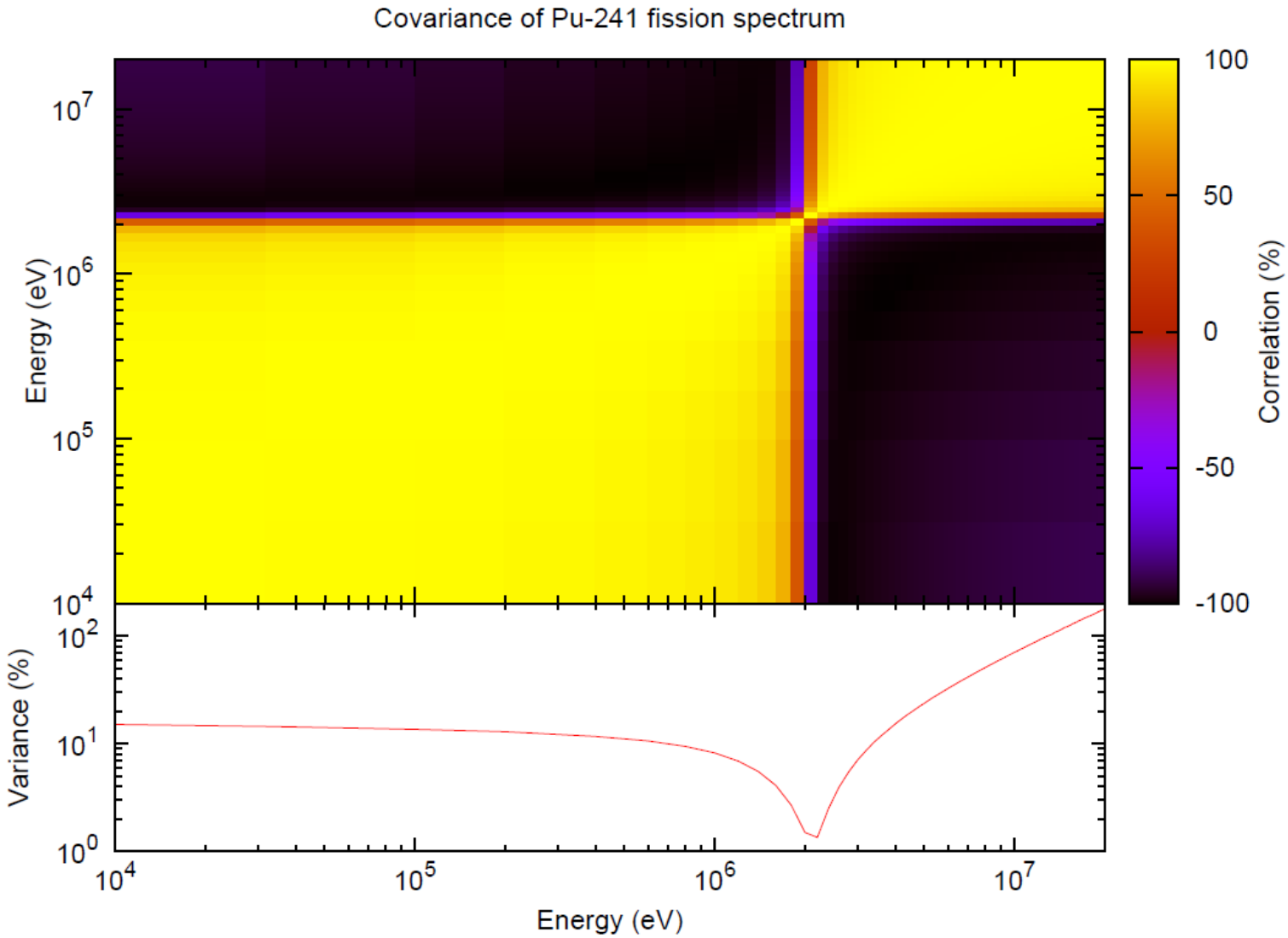




Number of delayed neutron



covariance of prompt fission spectrum for Pu-241



Conclusion

- Evaluated based on experimental data
  - least-squares method
  - experimental scatter
- Low-fidelity covariance
  - assumed model parameter uncertainty
- Covariance for all 79 actinides in JENDL-4.0
  - number of prompt and delayed neutrons (MF31)
  - resonance parameter (MF32)
  - reaction cross section (MF33)
  - angular distribution P1 (MF34)
  - fission spectrum (MF35)