JENDL Actinoid File 2008 and Plan of Covariance Evaluation

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Introduction

- JENDL Actinoid File 2008
  - Released in March 2008
  - Ac (Z=89) to Fm (Z=100)
  - 79 nuclides = 62 (JENDL-3.3) + 17 (new; $T_{1/2}$ > 1d)
  - En = 10^{-5} eV to 20 MeV
- Covariance
  - To be evaluated by March 2009
  - Fission & capture cross section
  - Number of neutron per fission
  - Methods of JENDL-3.3 covariance evaluation

Nuclides in JENDL/AC

Heigh ← priority → low

	A	B	C	D	E (new)
Ac				225, 226, 227	
Th	232		228, 229, 230	227, 233, 234	231
Pa			231, 232, 233		229, 230
U	233, 235, 238	232, 234, 236	237		230, 231
Np		237	236, 238, 239	235	234
Pu	239, 240, 241	242	238, 244	236, 237, 246	
Am	241, 243	242m	242	244, 244m	240
Cm		242, 244, 245	243, 246, 247,248, 250	240,241,249	
Bk			247	249, 250	245, 246, 248
Cf			249, 250	251, 252, 254	246, 248, 253
Es				254, 255	251, 252, 253,254m
Fm				255	

Covariance (FY2008)

Covariance data for JENDL-3.3

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						

At least MT's will be evaluated for JENDL/AC-2008

Covariance Data for JENDL-3.3

- Fission cross section
  Experimental data were analyzed with a least-squares fitting code GMA developed by Poenitz.
- Capture cross section
  Statistical model code CASTHY and covariance generation code KALMAN developed by Kawano were used.
  Covariance matrices were calculated from sensitivities and uncertainties of model parameters.
- Resonance parameters
  Standard deviations were given to a resonance energy, neutron, capture and fission widths of each resonance.
- Number of neutrons per fission
  Experimental data were fitted with a straight line.

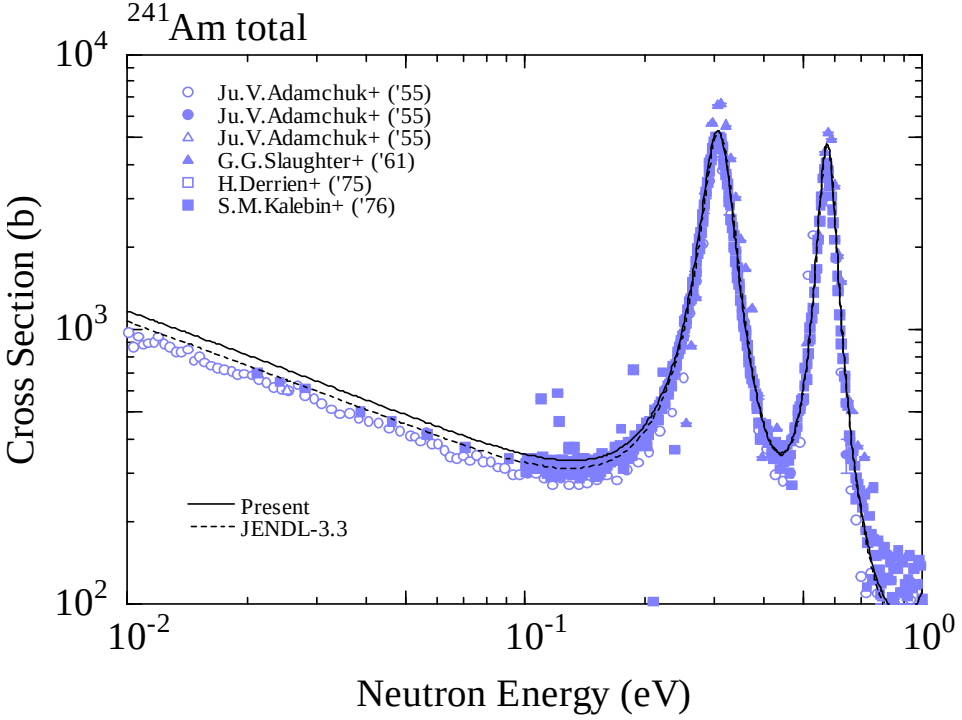
JENDL/AC Resonance region

- Thermal cross section
  - Fission and capture cross sections
  - Re-evaluated
- Resonance parameter
  - Major actinide
    - Th-232, U-233, U-238, Pu-241: ENDF/B-VII.0
    - U-235: JENDL-3.3, Upper boundary 2.25keV → 500 eV
    - Pu-239: Derrien (ND2007)
    - Pu-240: JENDL-3.3 slightly modified
  - Minor actinide
    - Np-236, 238: Furutaka (JAEA) SAMMY analysis
    - others: MLBW formula, adjusted based on experimental data.

^{241}Am thermal capture cross section

Thermal capture cross sections (b)	
Kalebin (1976)	624 ± 20
Shinohara+ (1997)	854 ± 58
Fioni+ (2001)	696 ± 48
Bringer+ (2006)	714 ± 23
Present	**697.1**
JENDL-3.3	**639.5**

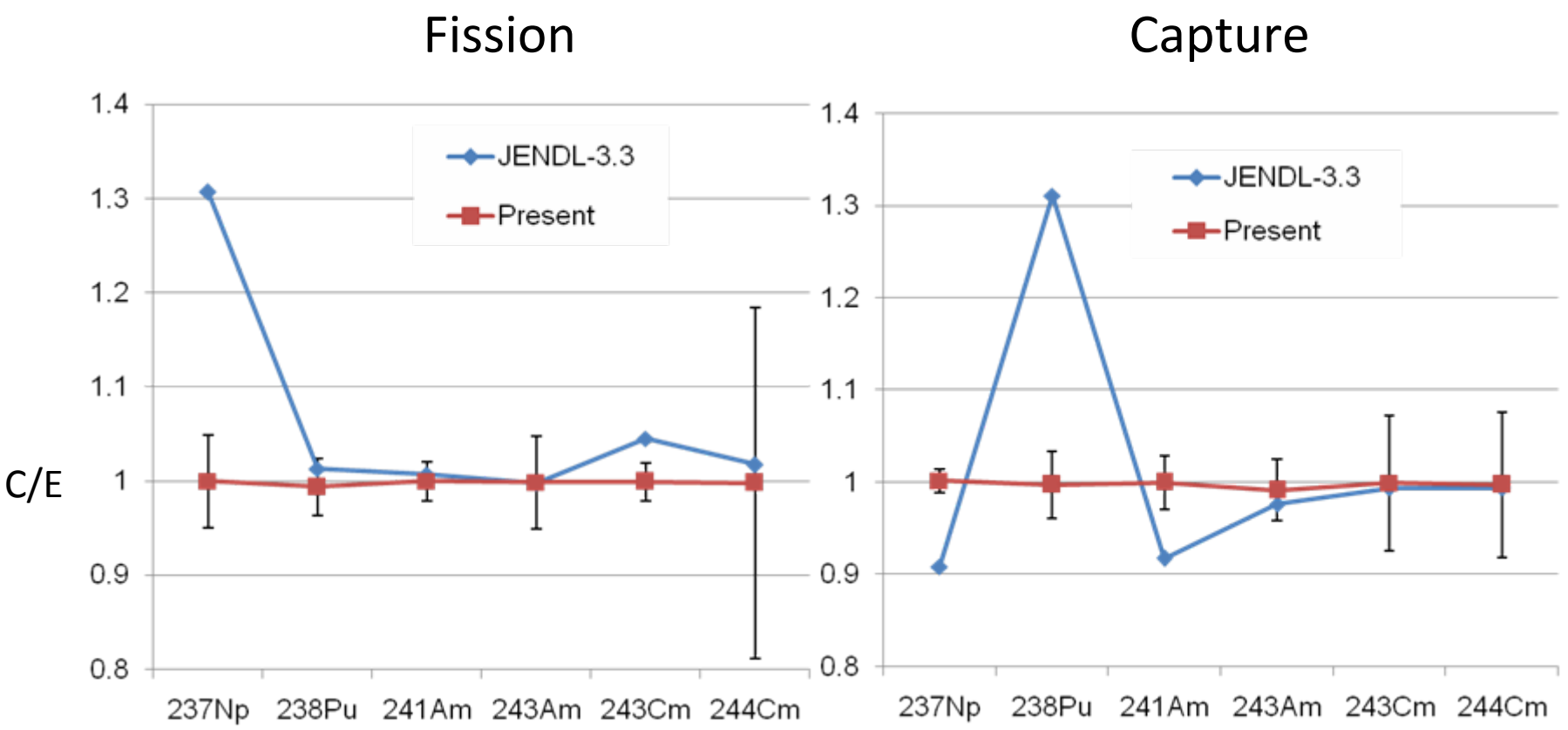
★ Inconsistent with experimental data of total cross section



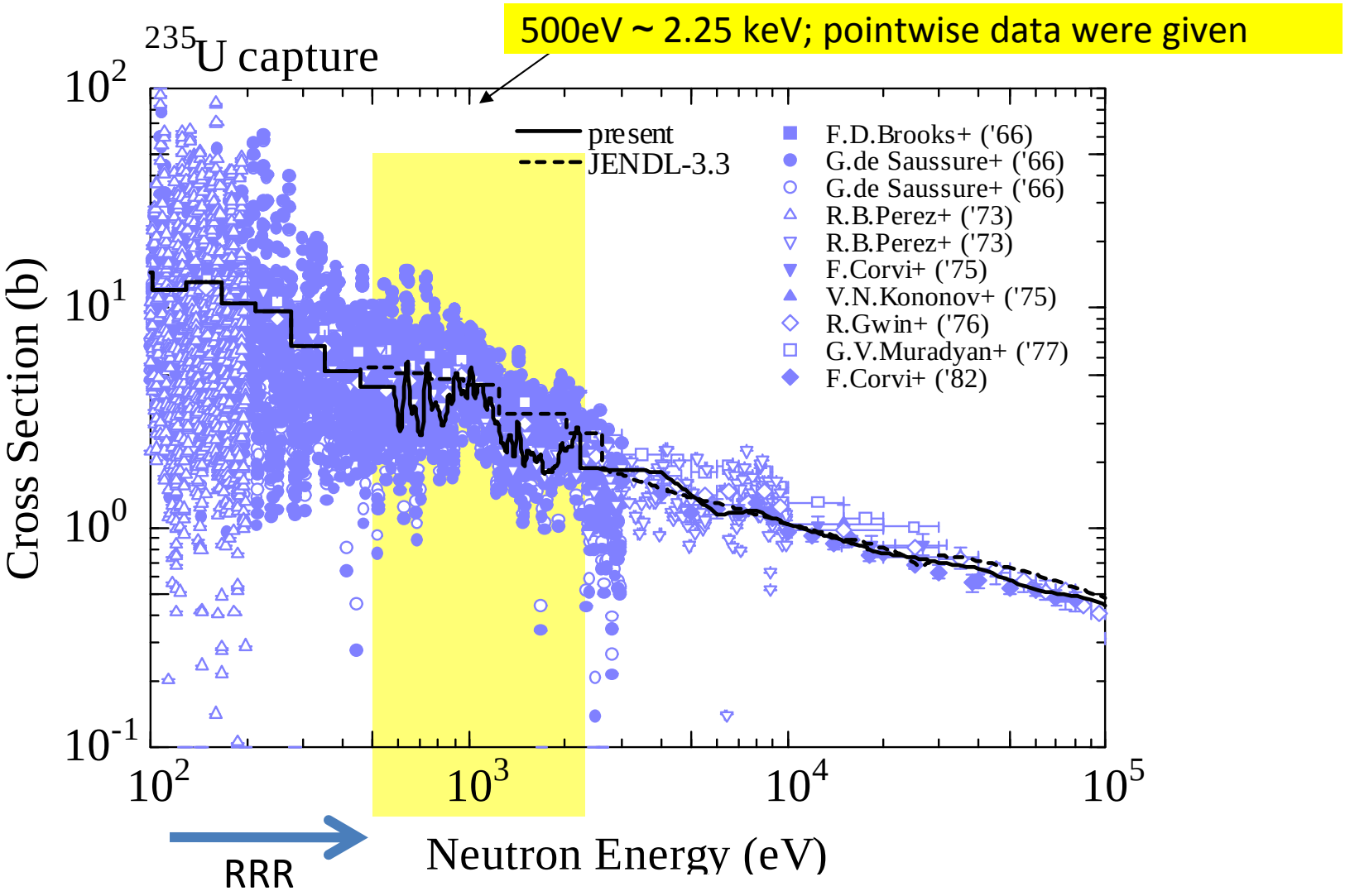
★ $\sigma_g = 620 \pm 25$ S. Nakamura+ (2007)

$\sigma_{g+m} = 692 \pm 28$ (IR=0.896)

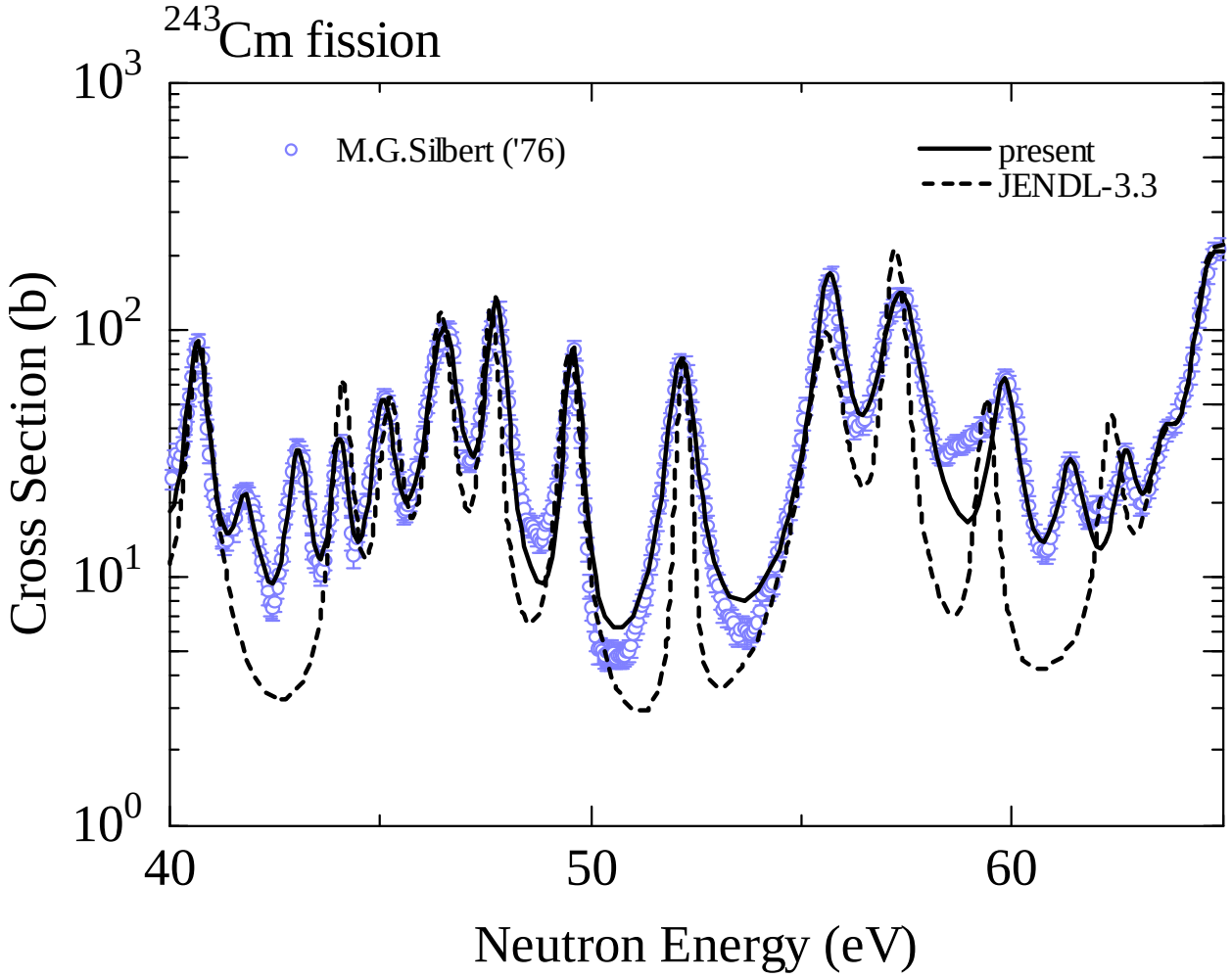
Thermal cross sections



^{235}U Capture Cross Section



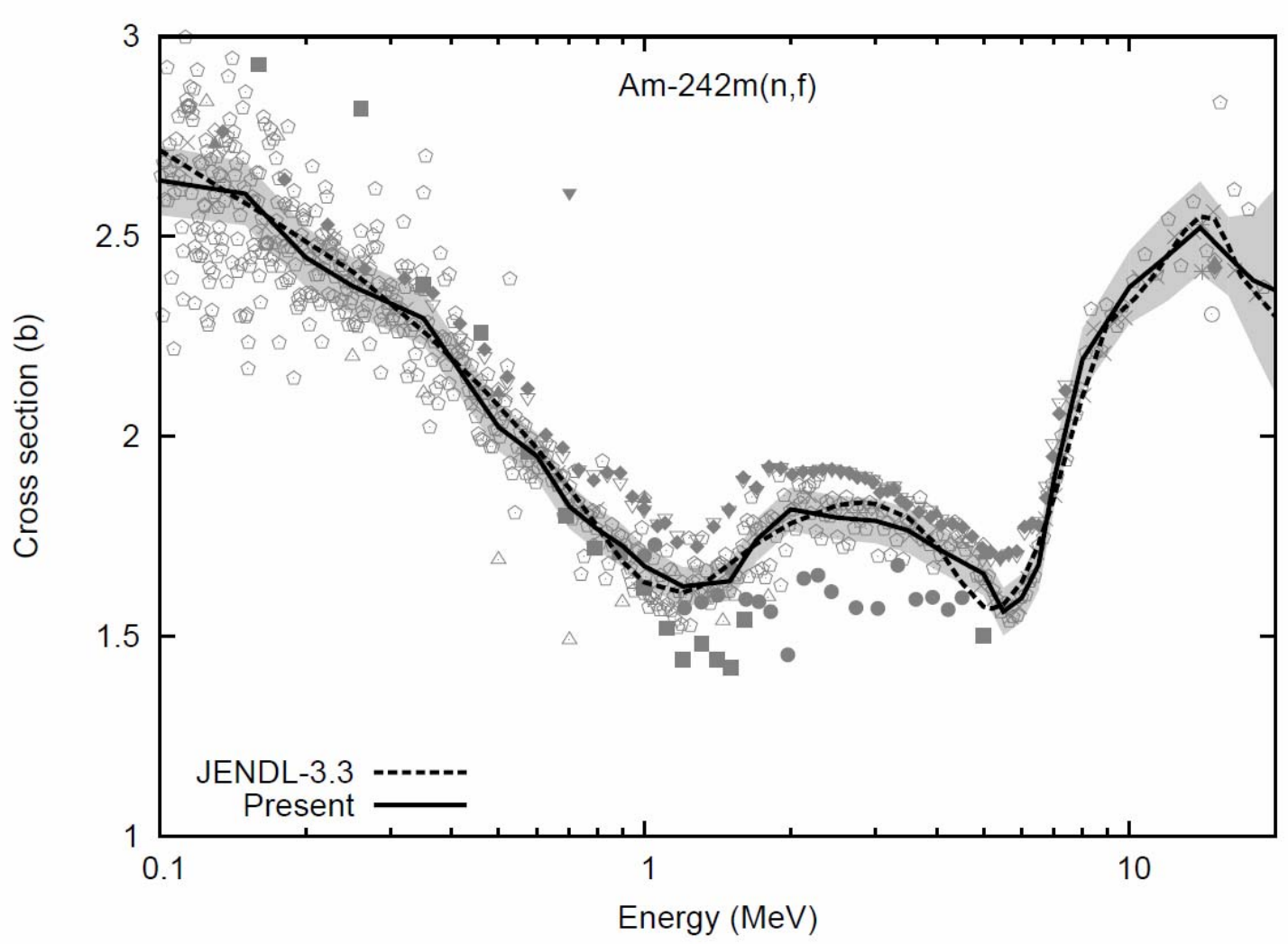
Revised resonance parameter



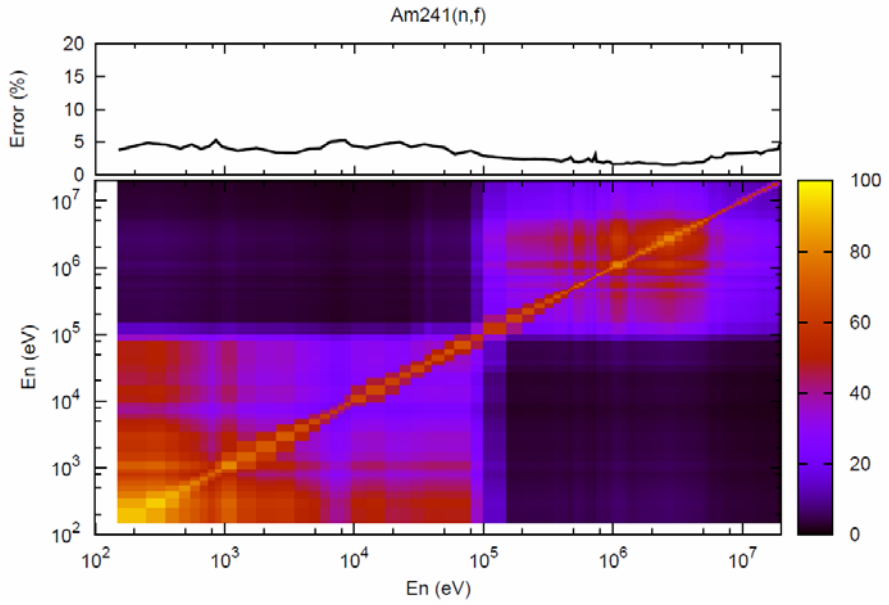
Cross sections in fast region

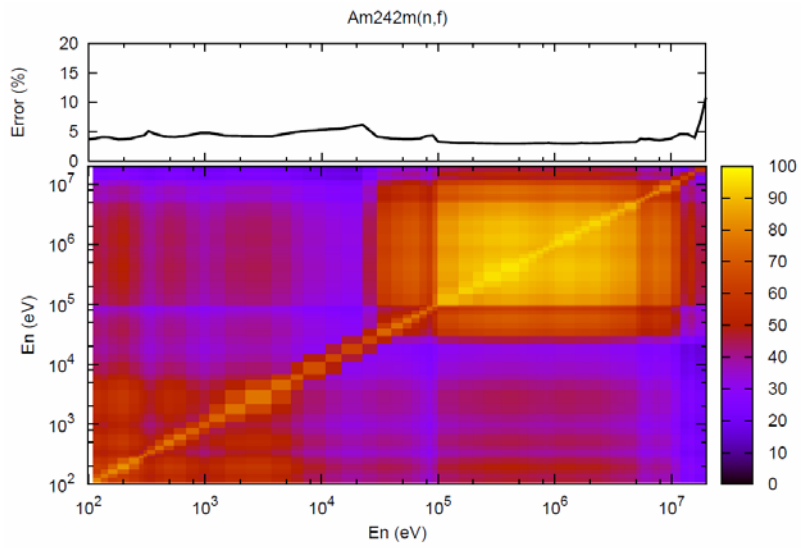
- CCONE code
  - Model
    - CC(rotational) + DWBA(vibrational) + Exciton (π+ν,γ)
      + Hauser-Feshbach(WFC, n+f+γ)
  - OMP(CC)
    - Total, shape elastic, direct inelastic cross sections
    - transmission coefficients
    - Soukhovitskii(2005), Kunieda(2007), adjusted
  - Level density
    - Fermi-gas + constant temperature, Shell energy correction (Ignatyuk),
      Collective enhancement
- Fissoin cross section
  - GMA code（ Poenitz, S. Chiba)
  - Simultaneous evaluation: SOK code (Kawano)
    - U-233, U-235, U-238, Pu-239, Pu-240, Pu-241
    - En=10 keV to 20 MeV

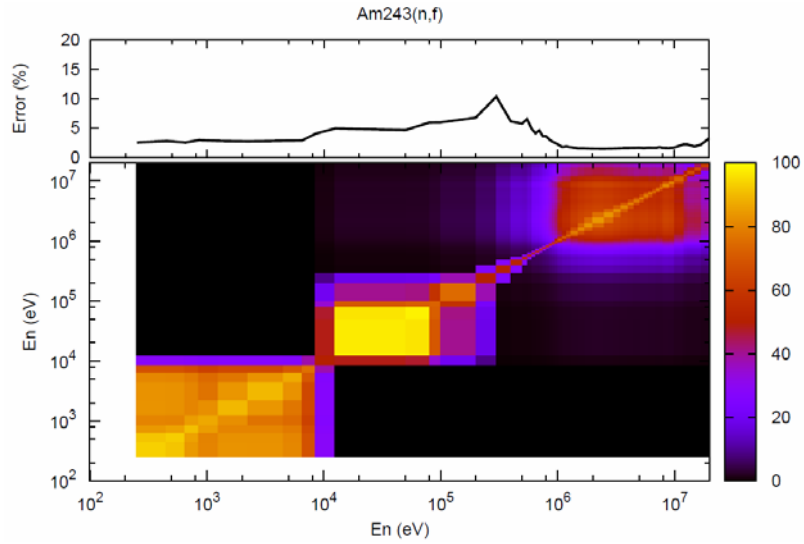
Am-242m fission cross section (G M A)



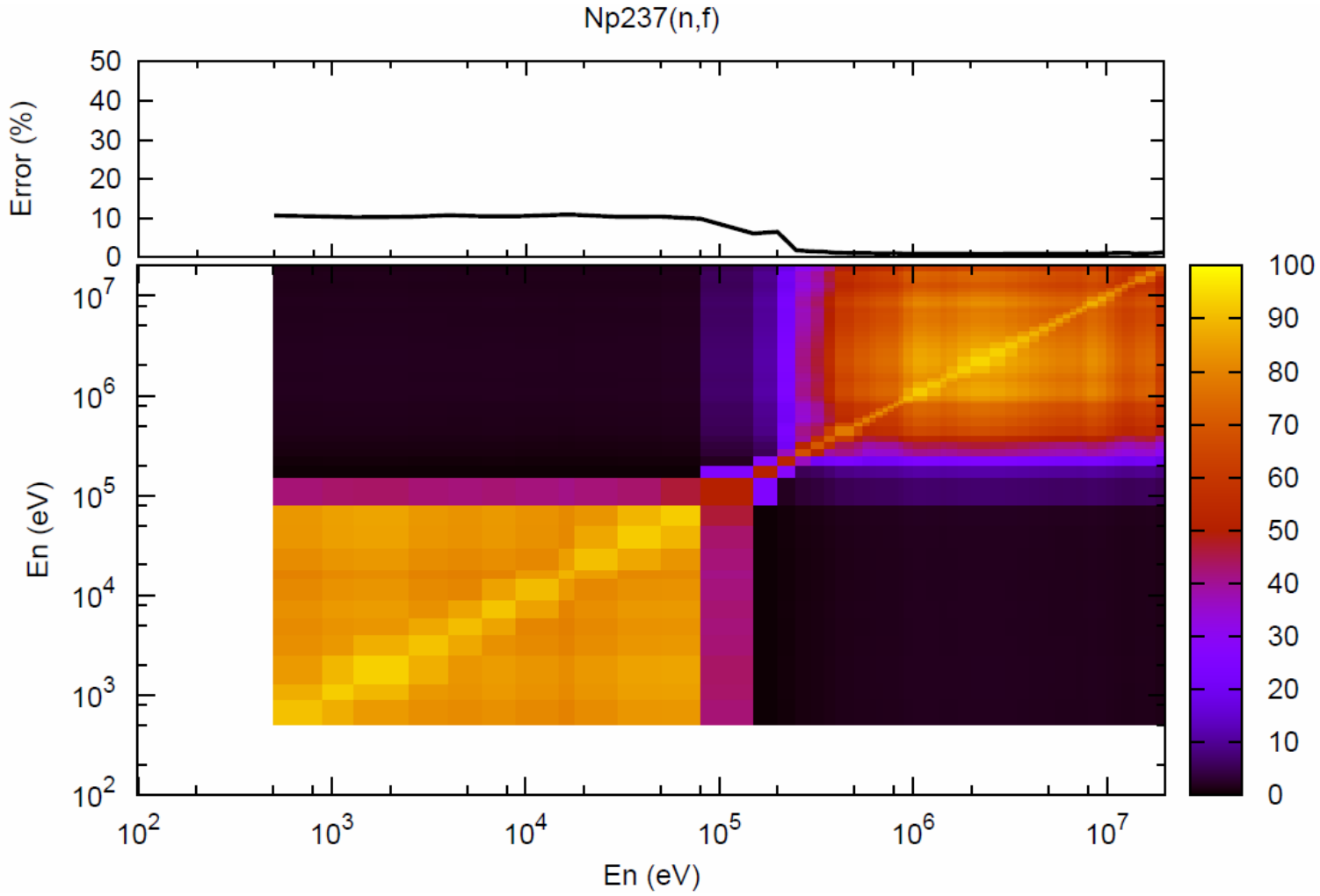
Covariance for Am fission cross section



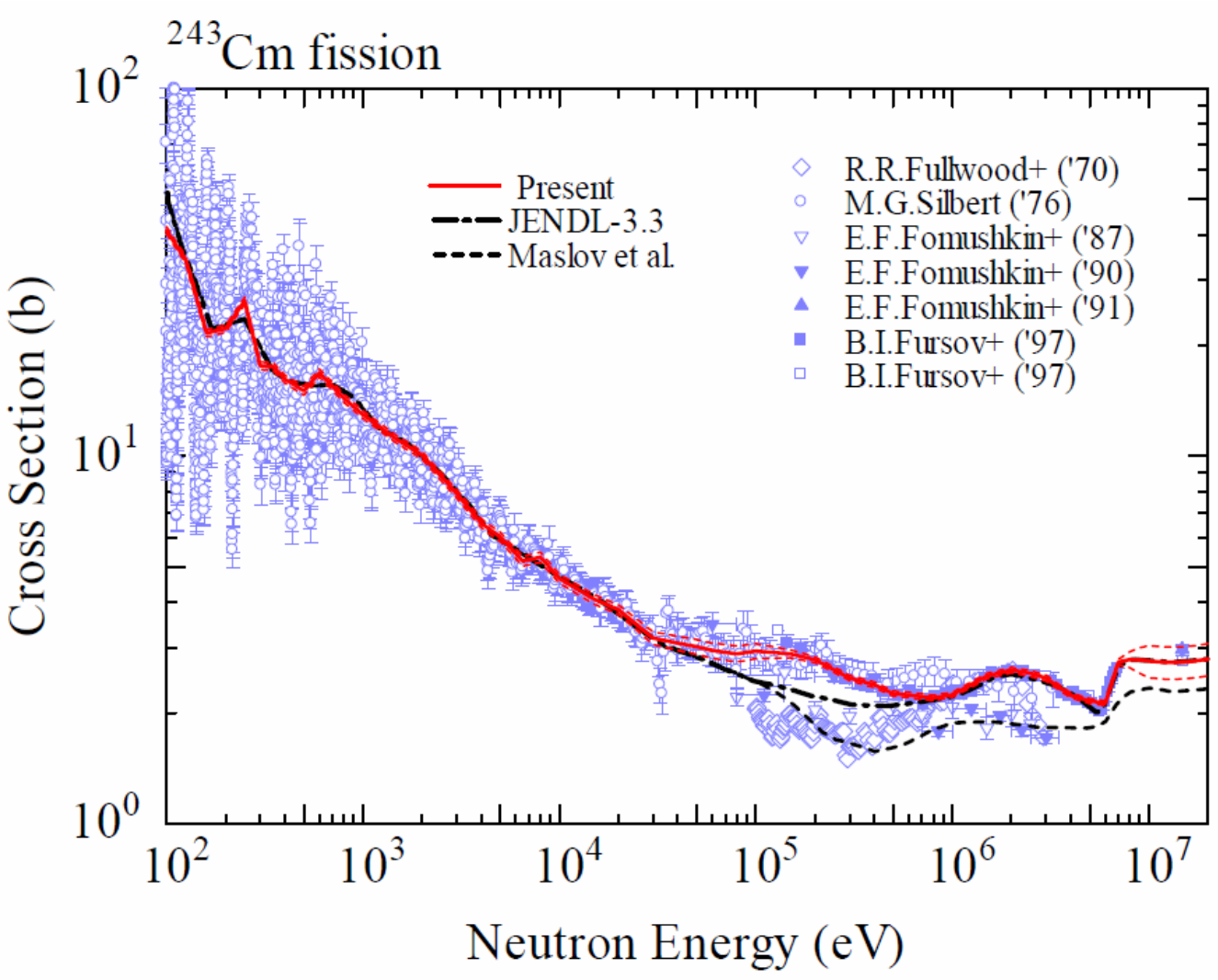




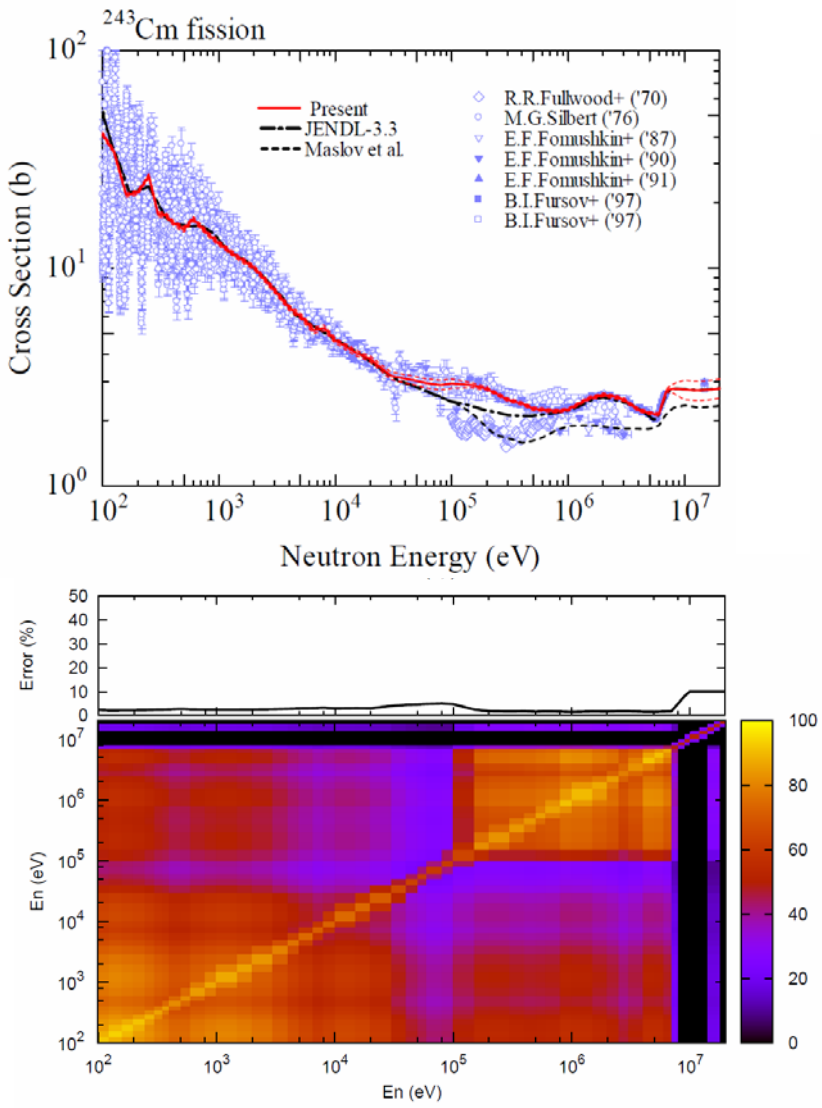
Covariance for Np-237 fission cross section

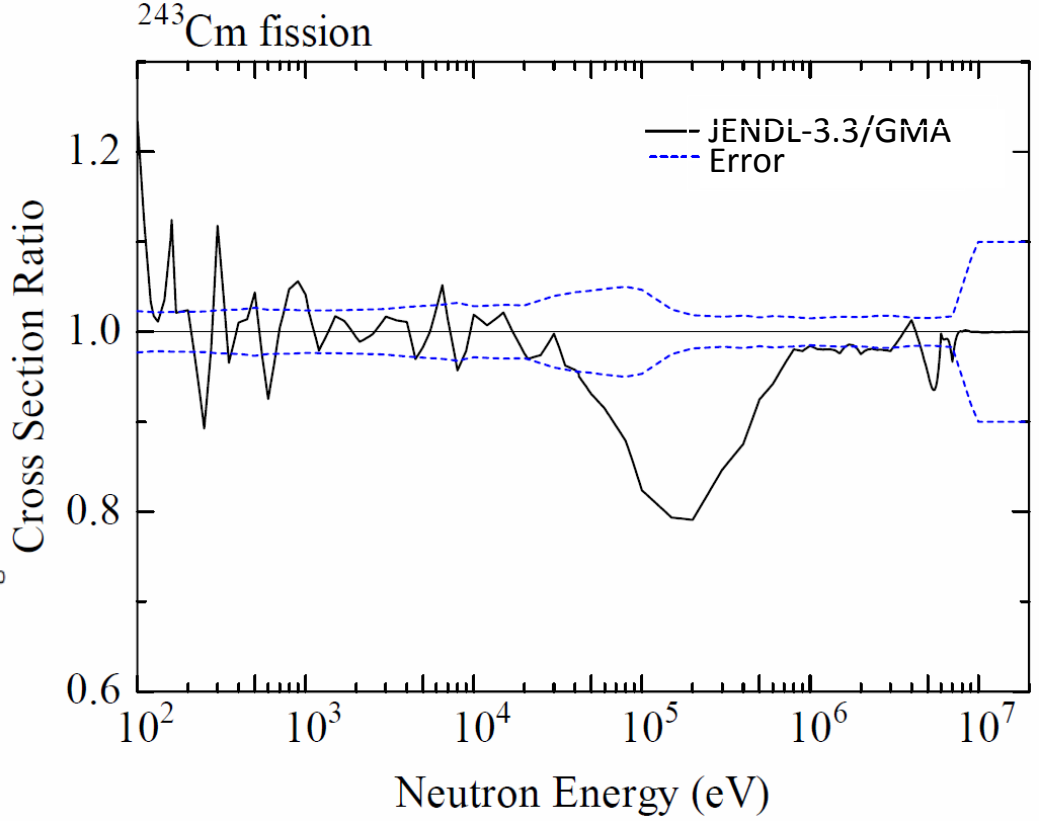


Cm-243 fission cross section



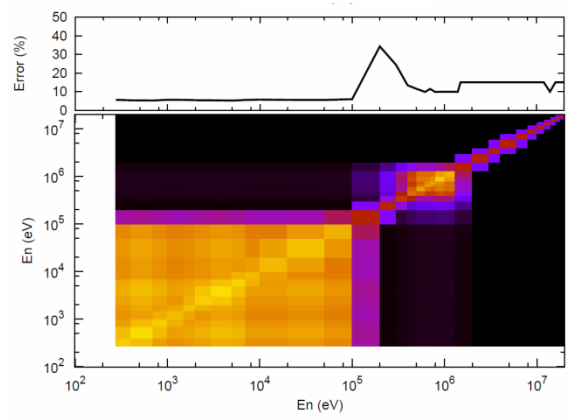
Covariance for Cm-243 fission cross section



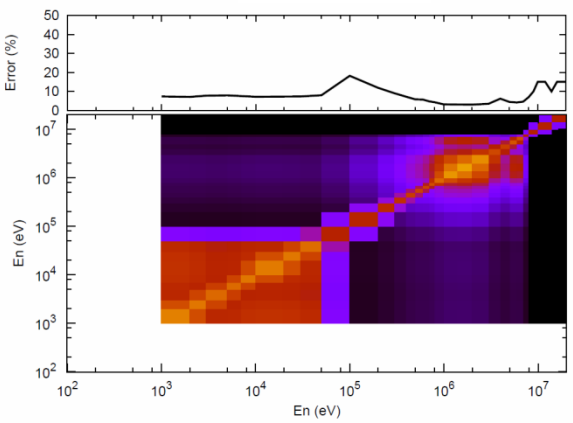


Covariance for Cm(n,f)

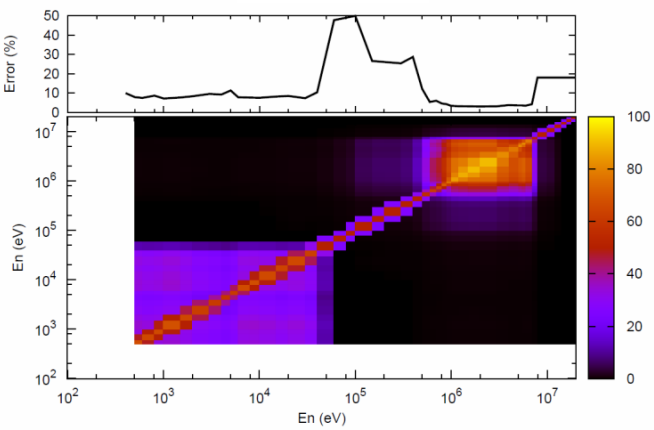
Cm-242



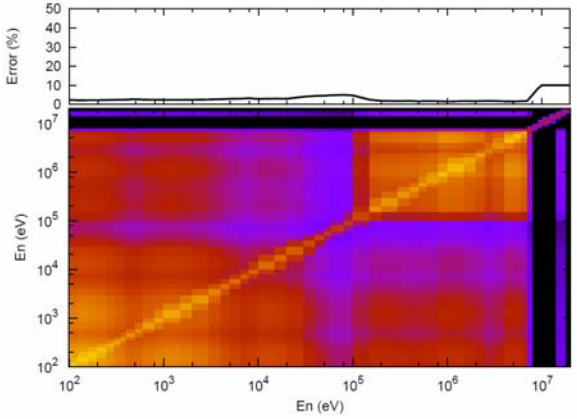
Cm-244



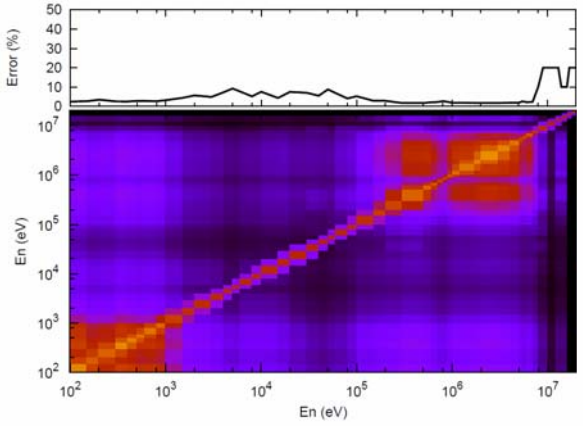
Cm-246



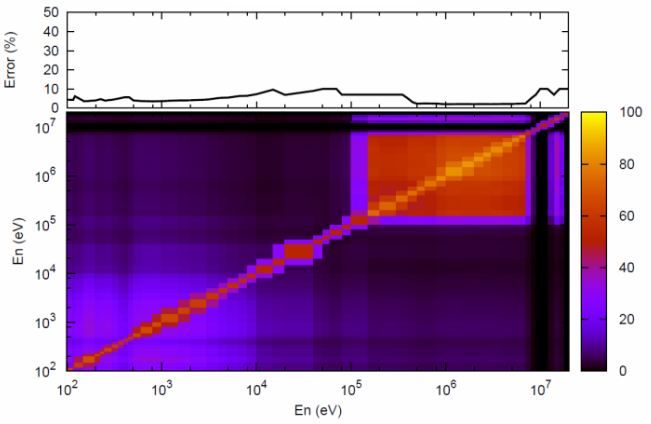
Cm-243



Cm-245



Cm-247

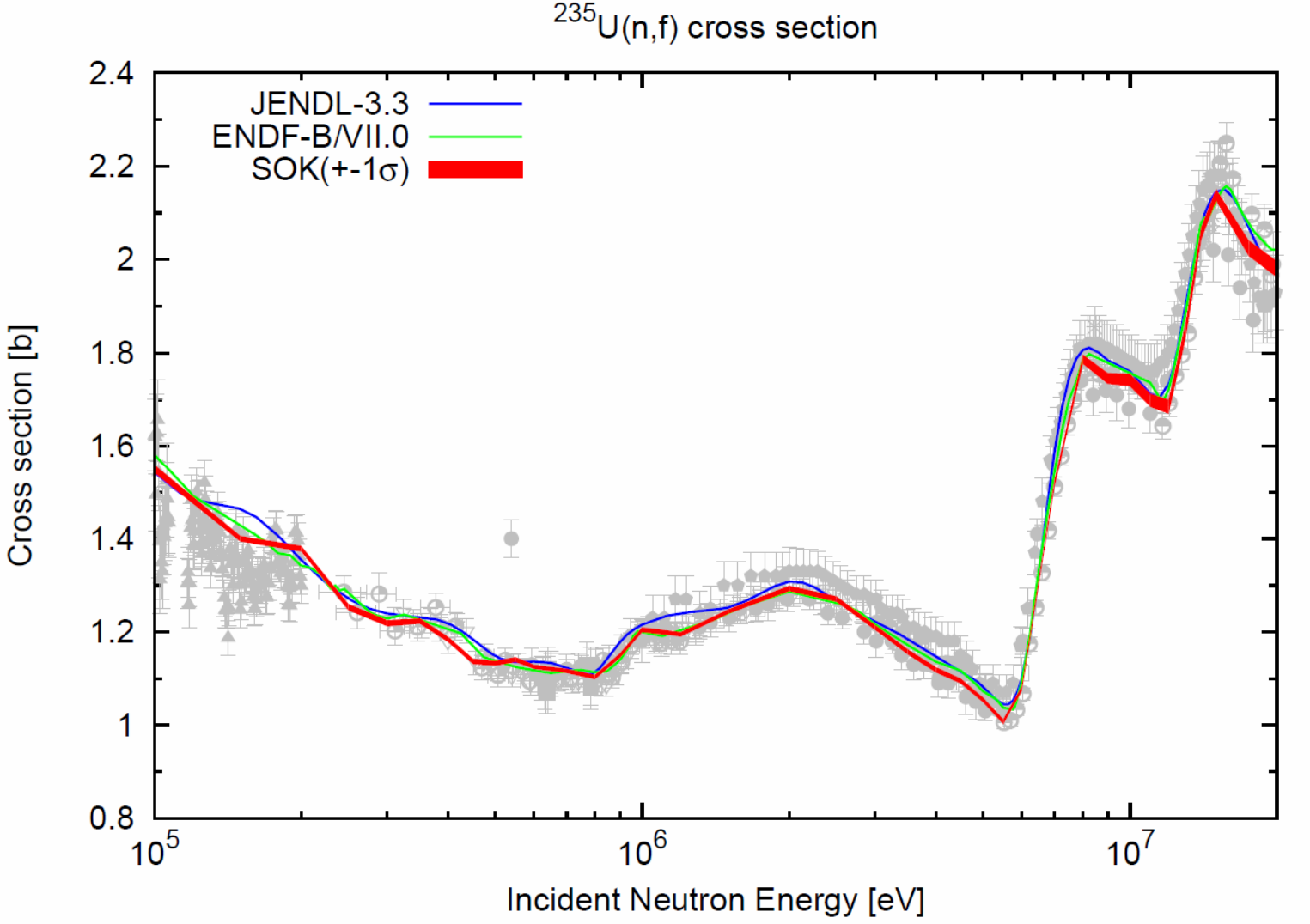


Simultaneous evaluation of fission cross section

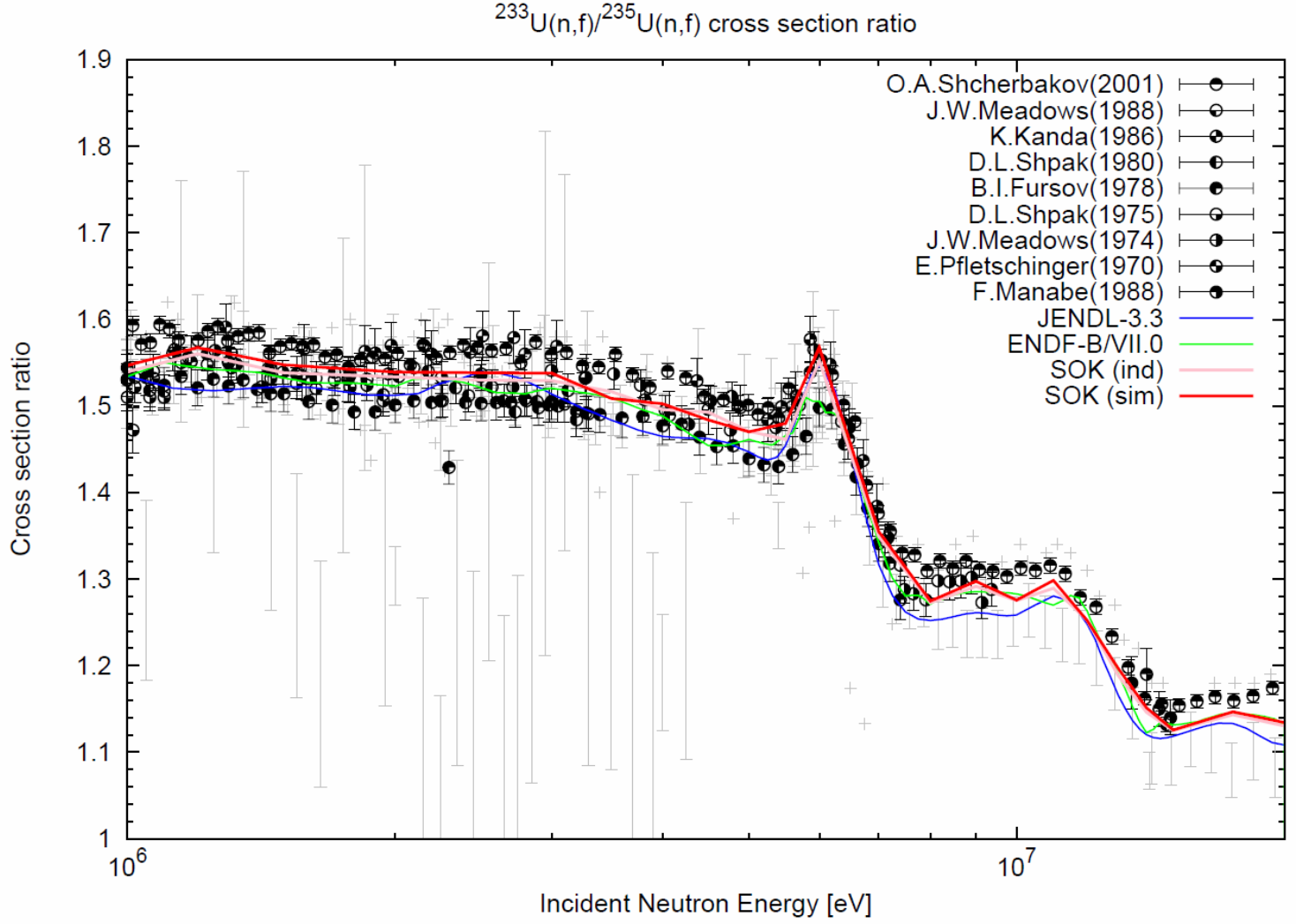
- Least-squares fitting
  - SOK code (Kawano)
  - First order spline
- Experimental data

Reaction	sets	Reaction	sets
^{233}U	13	^{233}U/^{235}U	9
^{235}U	17	^{238}U/^{233}U	1
^{238}U	9	^{238}U/^{235}U	18
^{239}Pu	16	^{239}Pu/^{235}U	14
^{240}Pu	4	^{240}Pu/^{235}U	12
^{241}Pu	6	^{240}Pu/^{239}Pu	1
		^{241}Pu/^{235}U	4

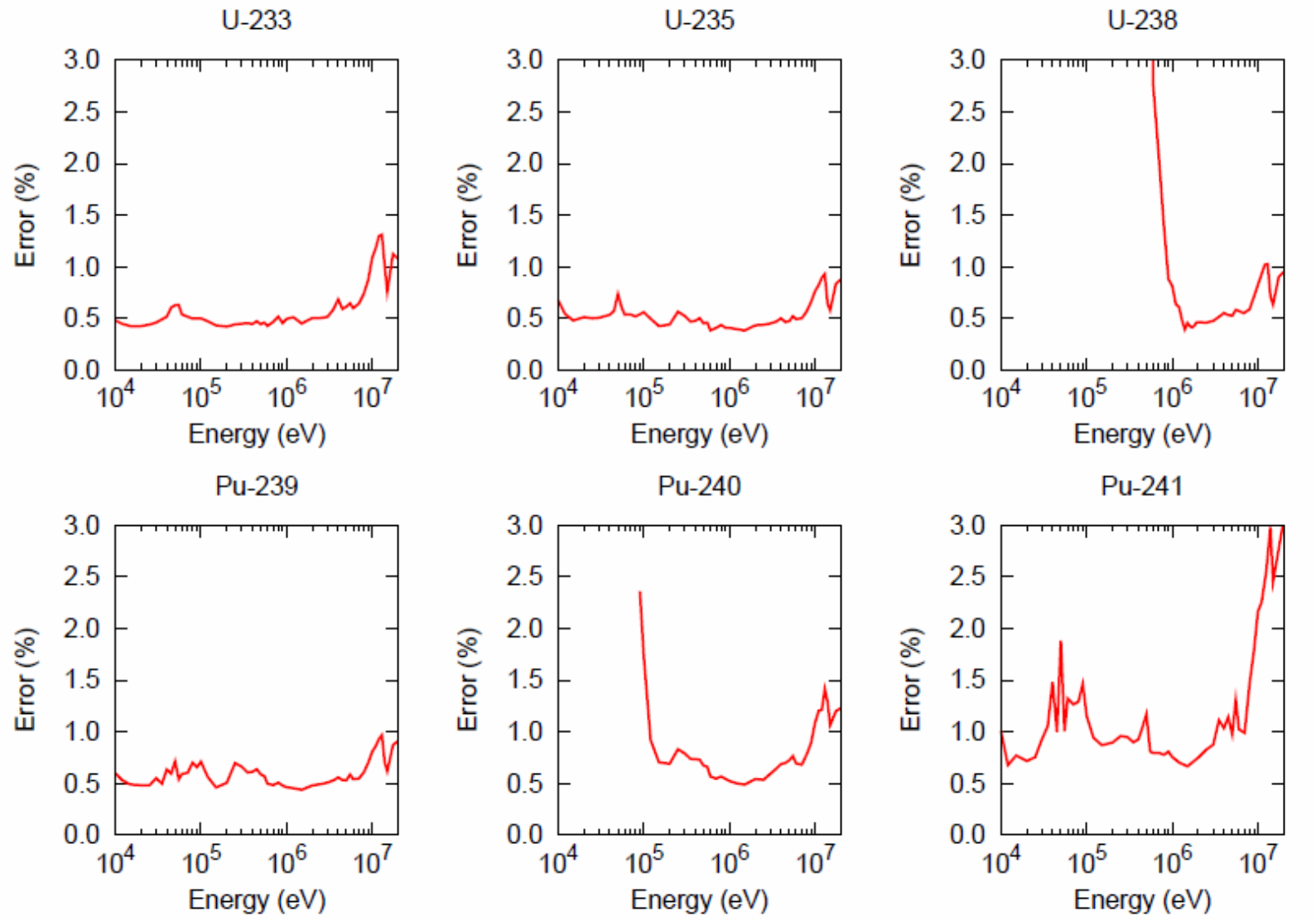
^{235}U fission cross section (SOK)



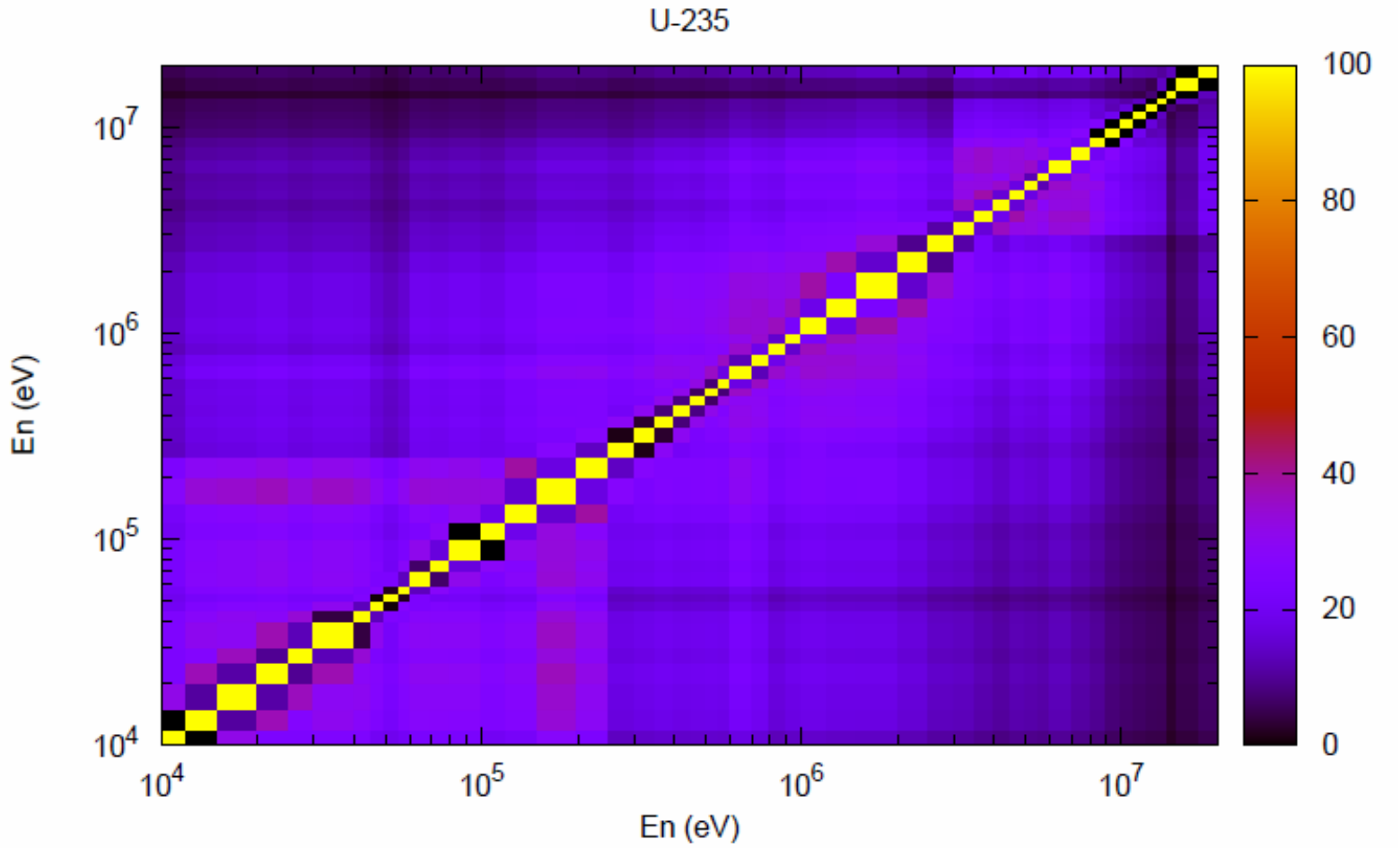
U-233(n,f)/U-235(n,f) (SOK)



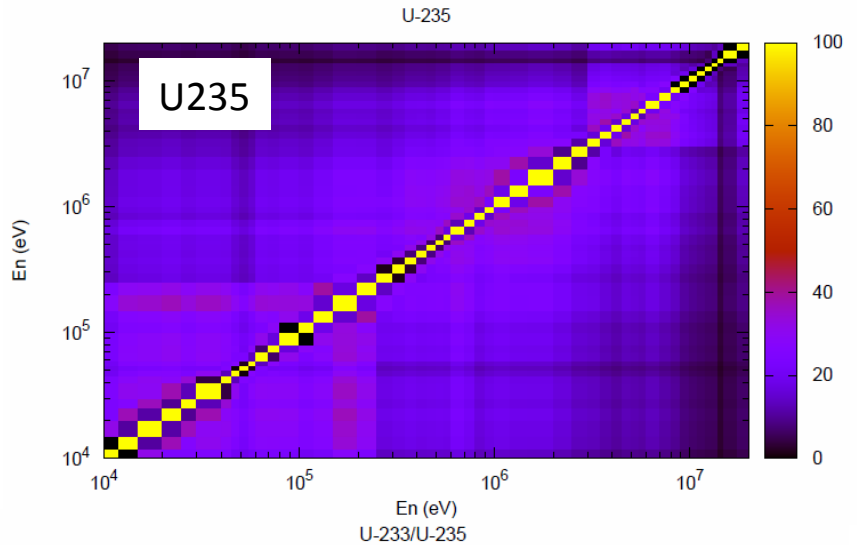
Error of fission cross section by SOK

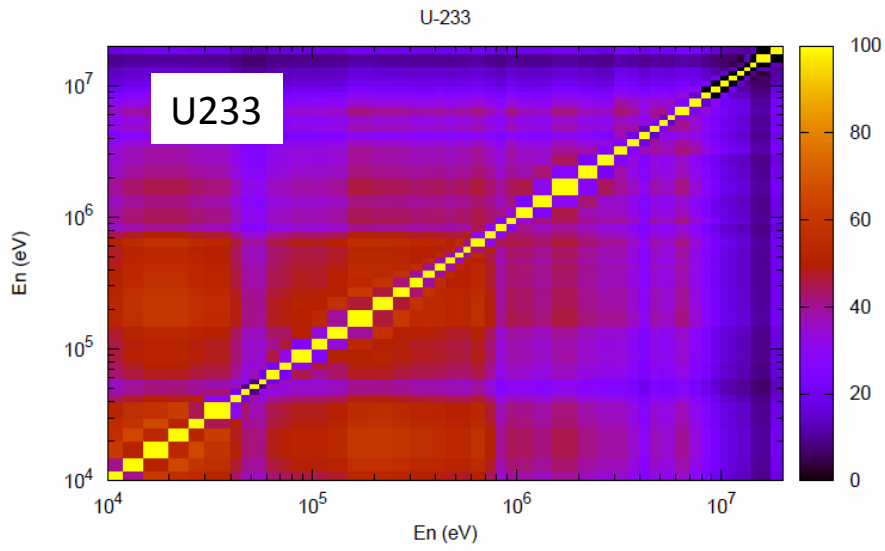


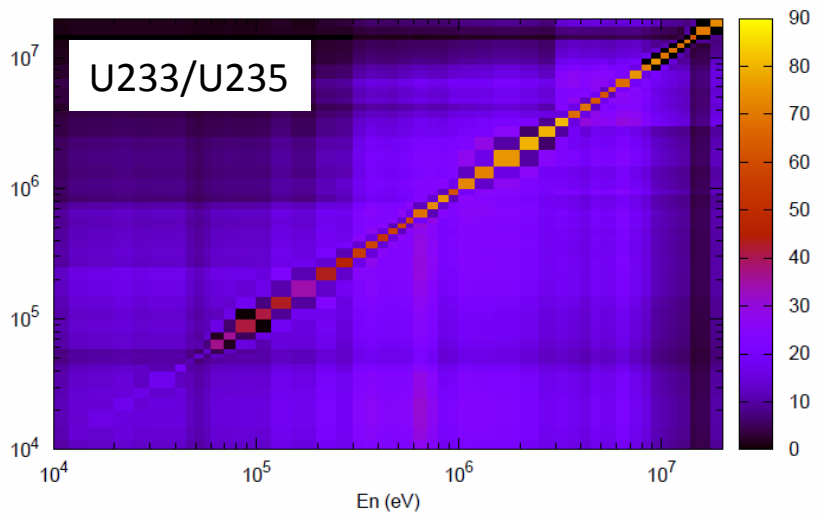
Correlation of U-235(n,f) SOK



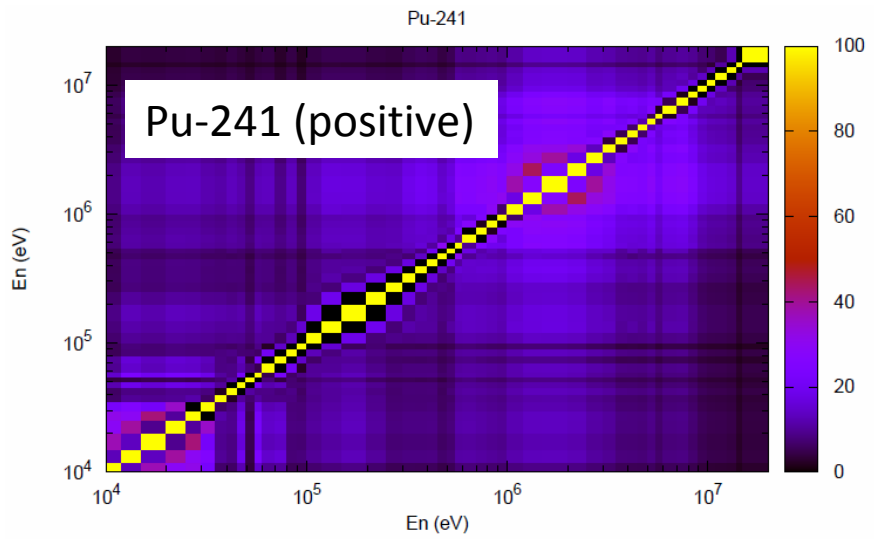
Correlation of U-233 & U-235

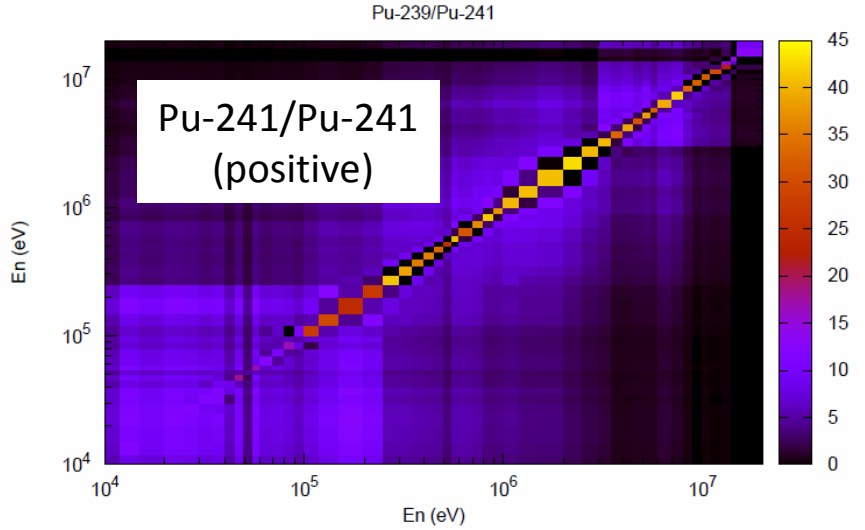


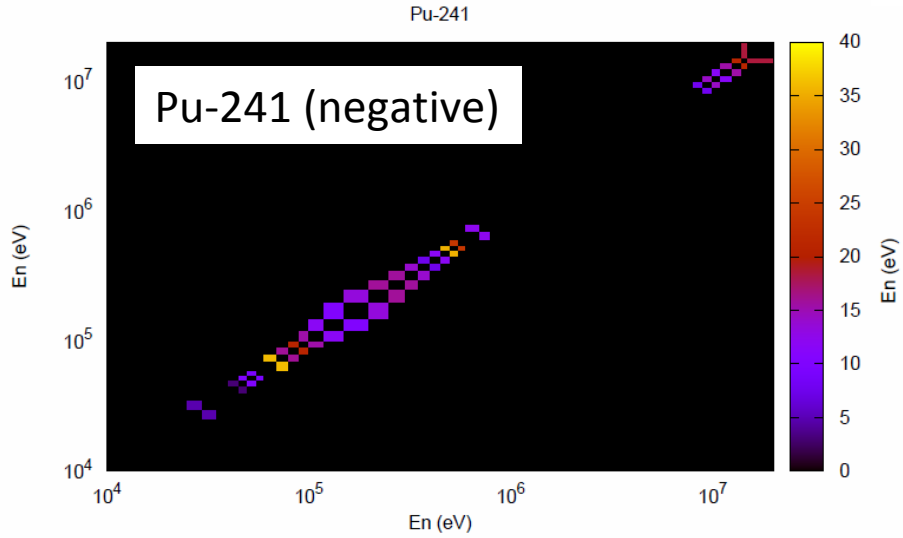


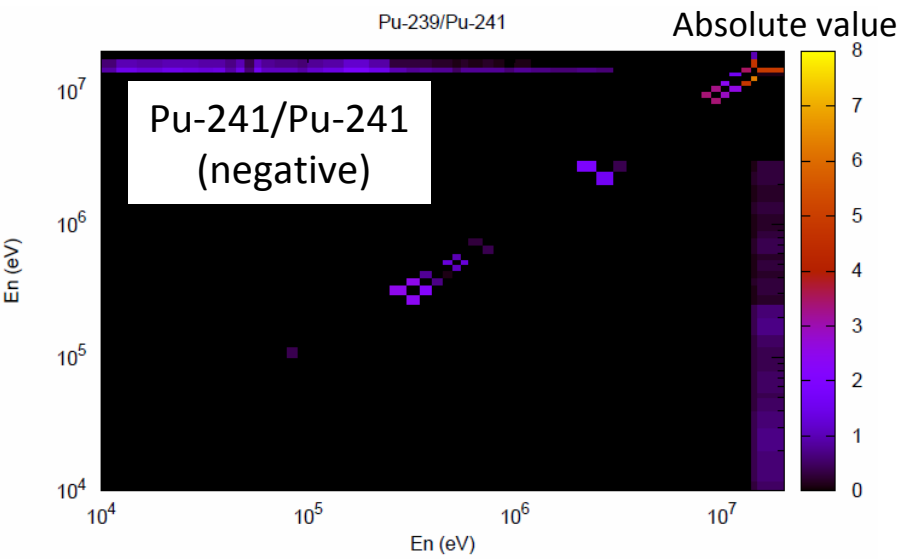


Correlation of Pu-241(n,f)

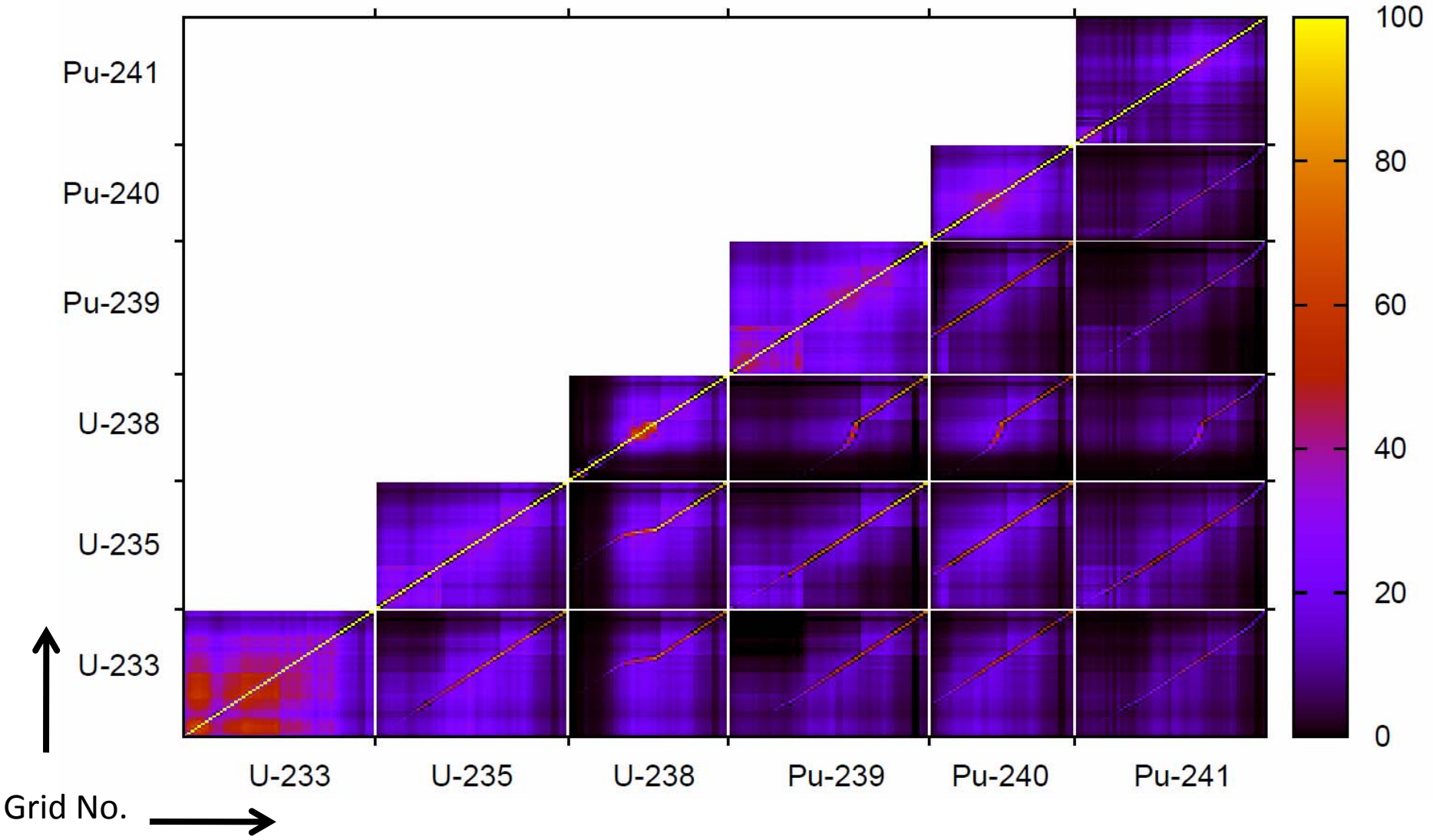




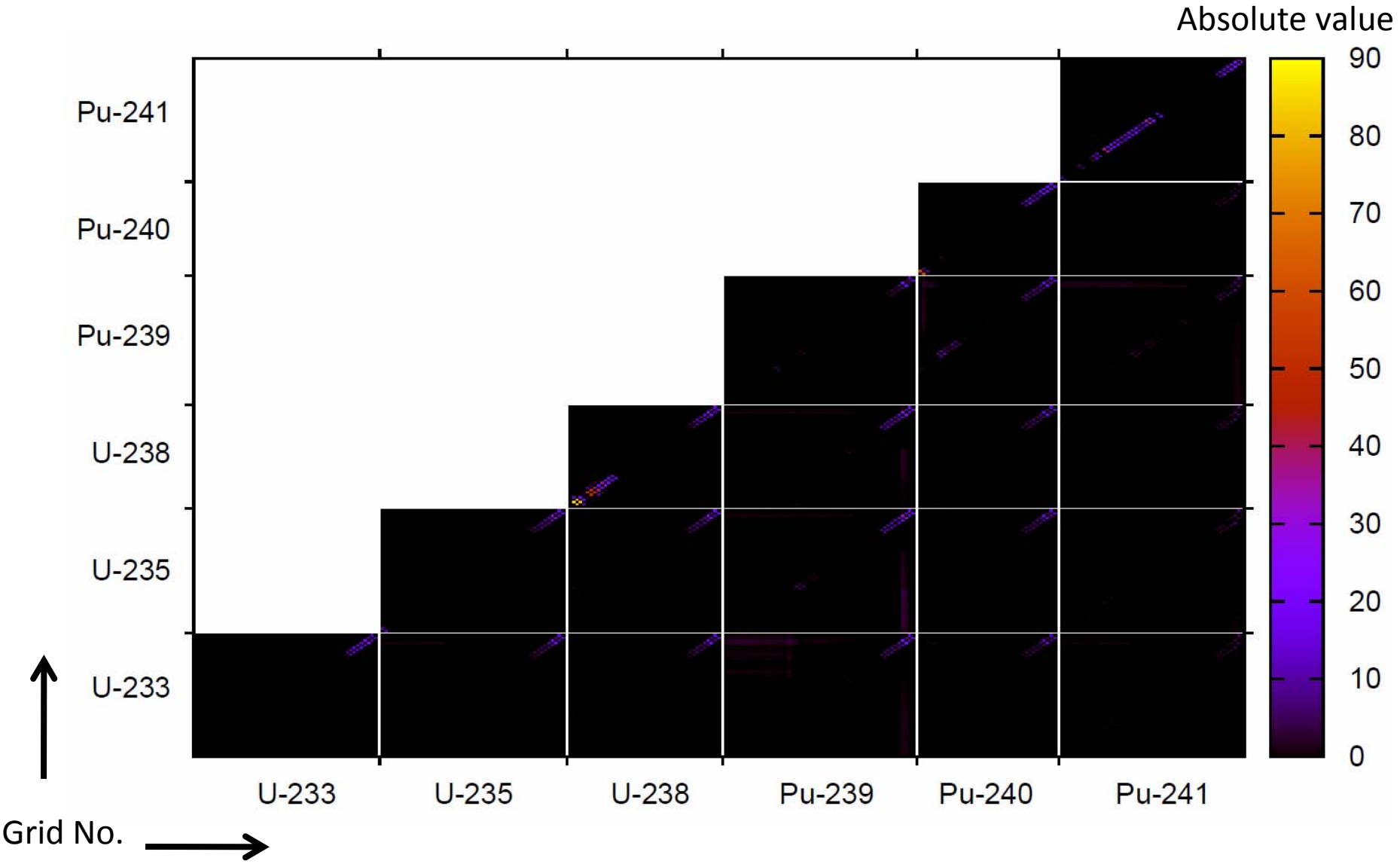




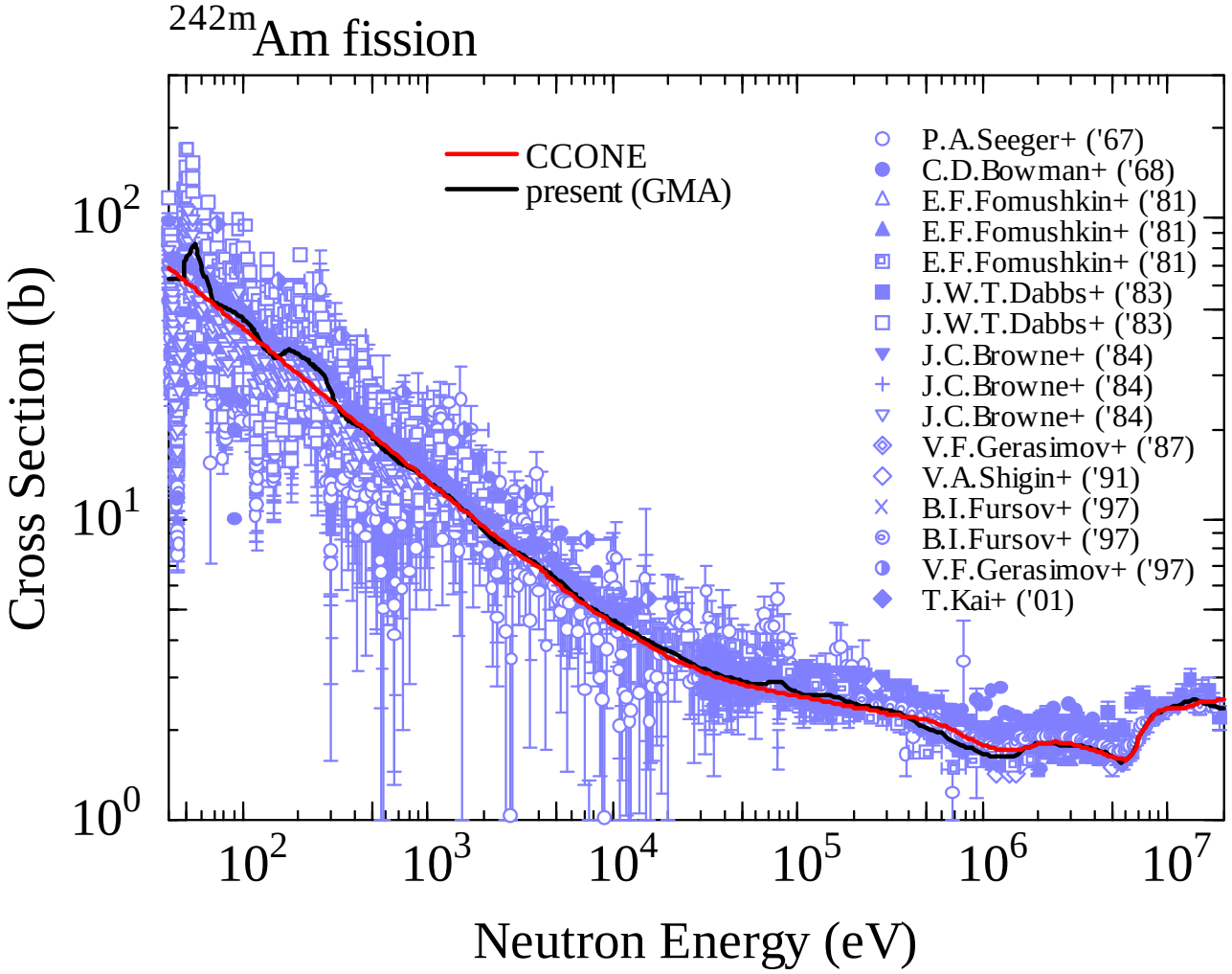
Correlation matrix by SOK (positive)



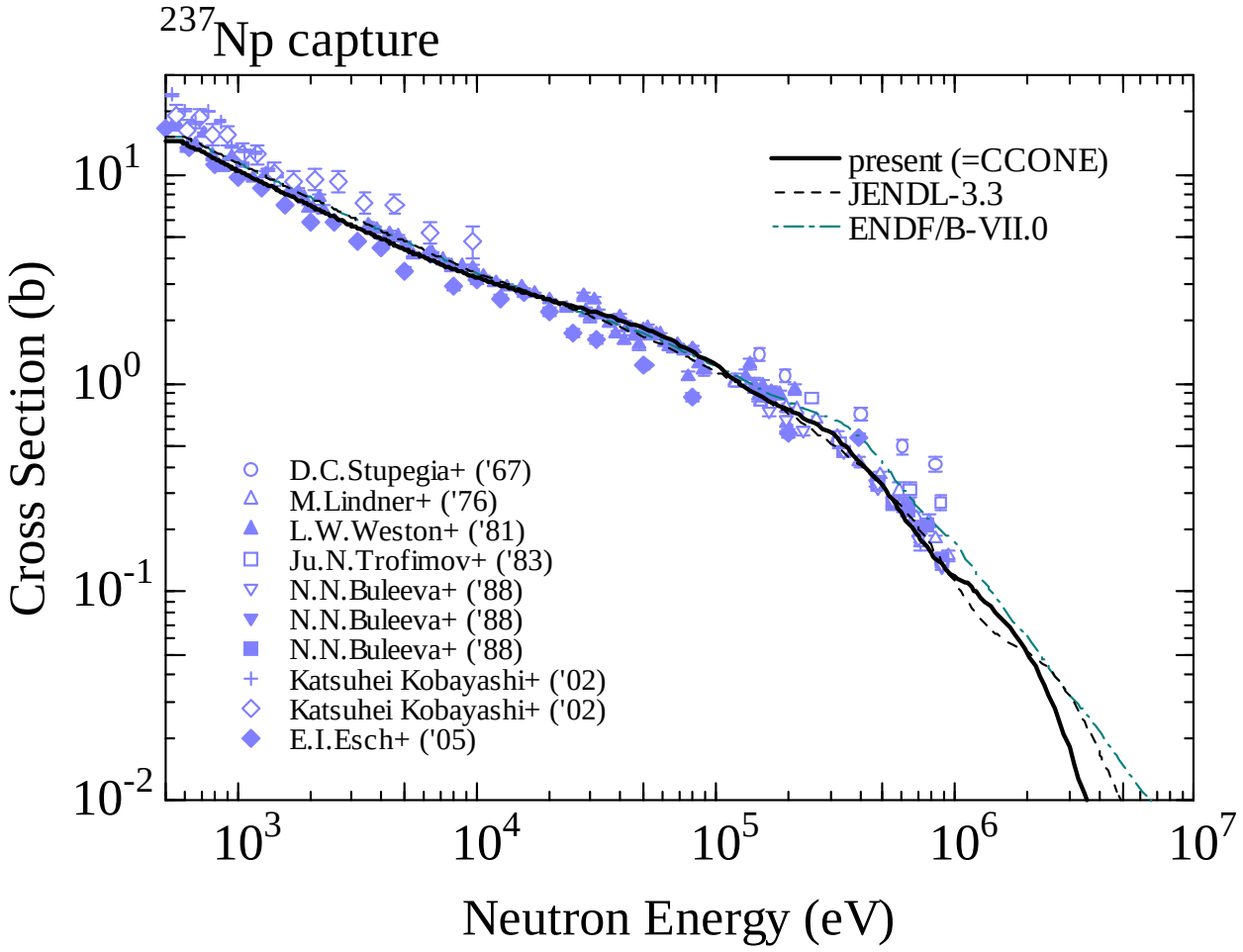
Correlation matrix by SOK (negative)



Fission cross section (CCONE vs. GMA)

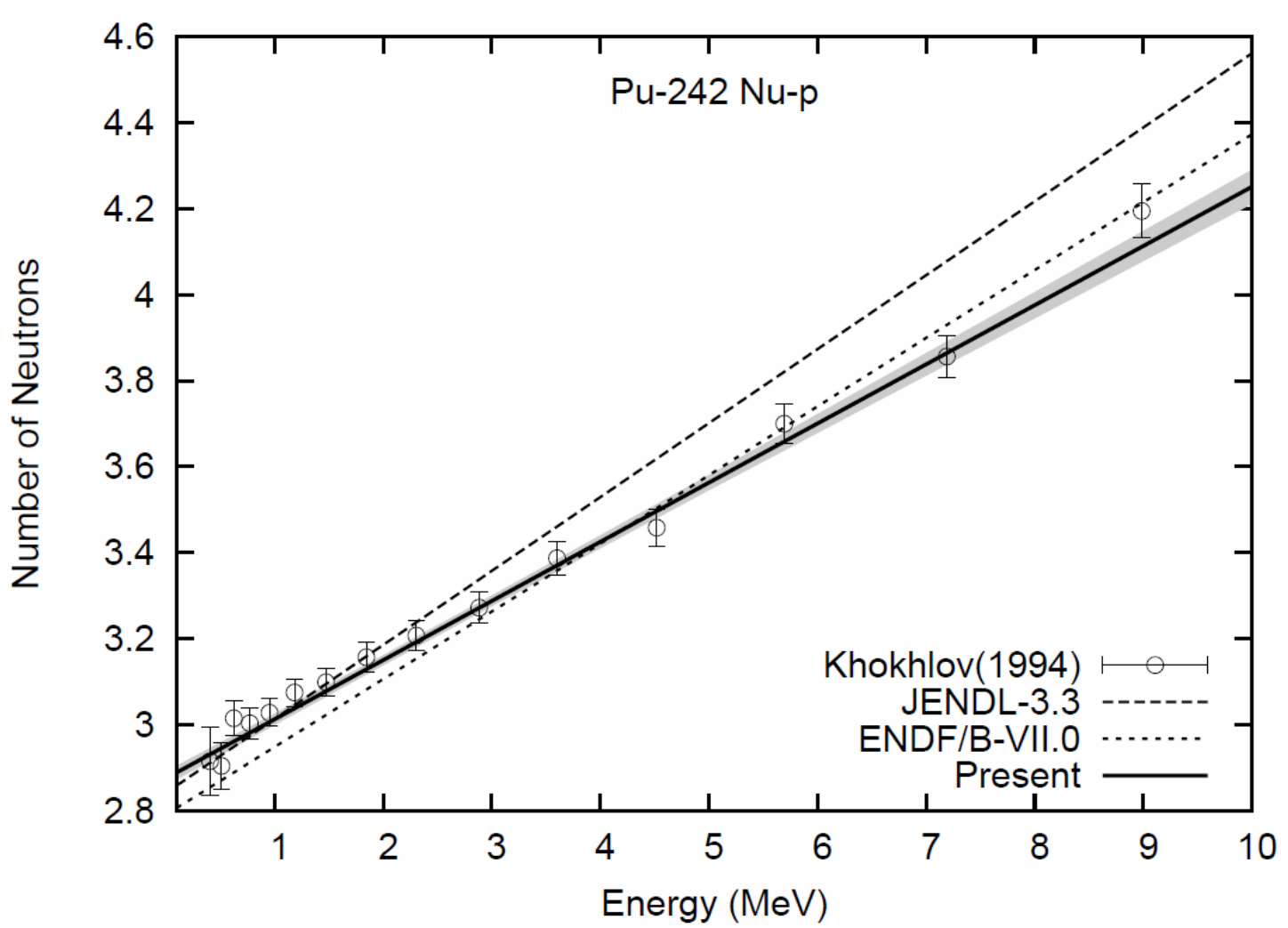


^{237}Np capture cross section (CCONE)



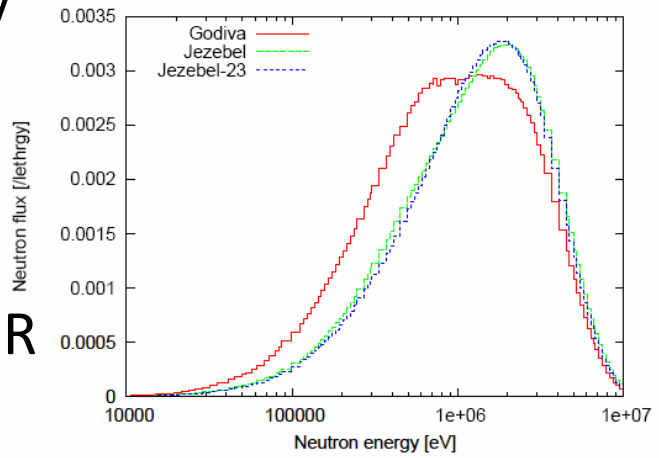
Covariance will be evaluated by KALMAN + CCONE.

Number of prompt neutrons per fission (ν_p)



Data correction by integral data

- Integral data
  - Small reactor k_{eff} (Jezebel, Jezebel-240, Godiva, Flattop-Pu …)
  - Small reactor central reaction rate（ ratio to U-235 fission ）
  - Others
- Maximal correction of parameter： ~ 0.5%
  - smaller than nuclear data uncertainty
- Nuclear data
  - $^{233, 235, 238}U$, $^{239, 240, 241}Pu$, ^{237}Np
- Parameters used for correction
  - Model paramters: OMP, LDP, FBP, GDR
  - Normalization parameter: σ_f , σ_c , ν_p



Parameter estimation

Calculated value of integral data

$$P = P_0 + \left(G^{+}V^{-1}G + M^{-1}\right)^{-1} G^{+}V^{-1}\left(1 - \frac{C(P)}{E}\right)$$

prior parameter

covariance of prior parameter

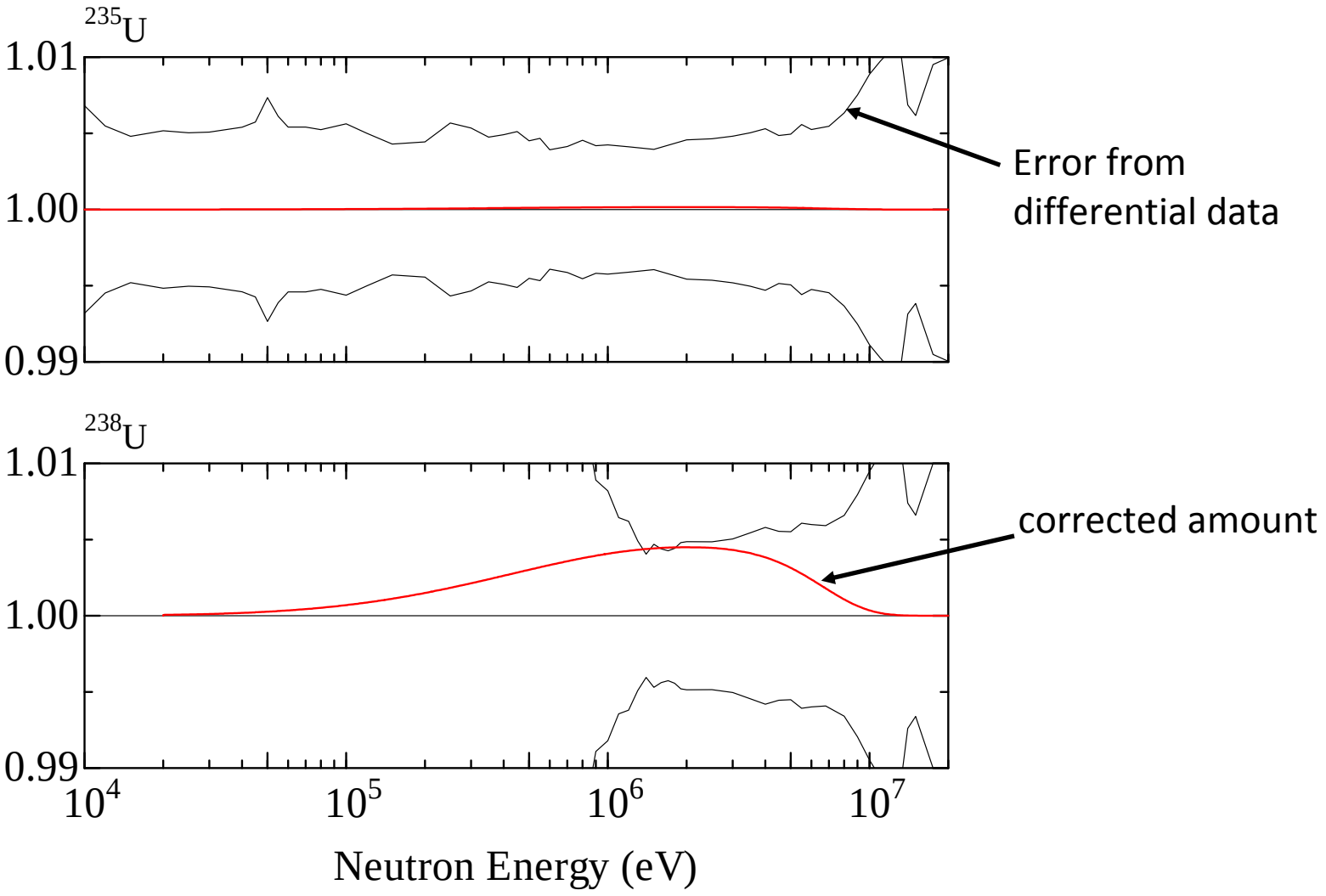
Covariance of integral data

Experimental data

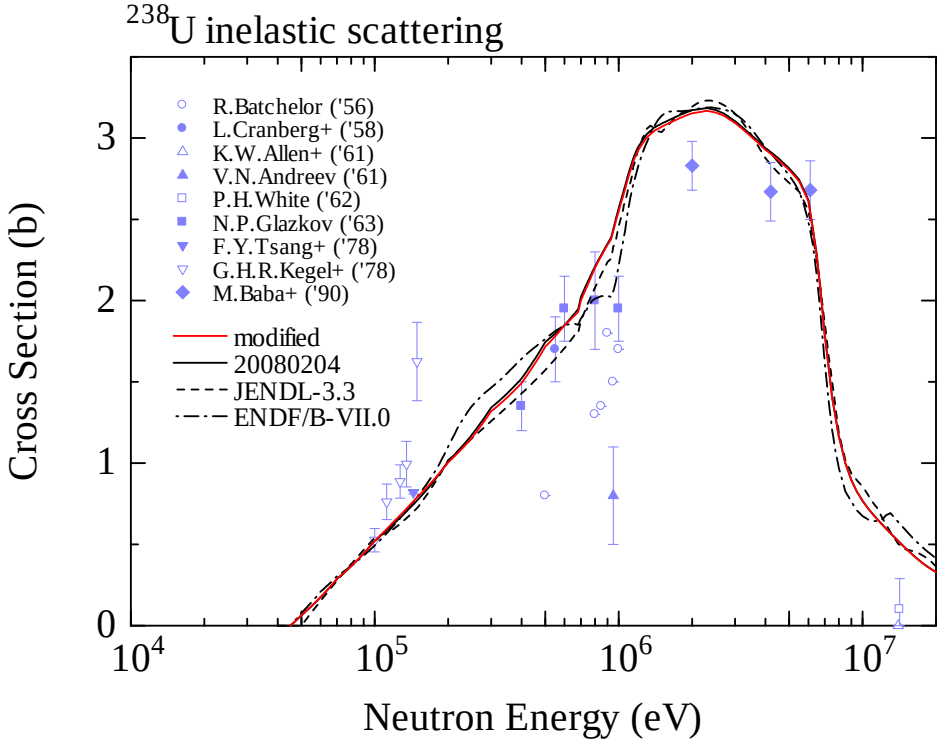
Sensitivity matrix

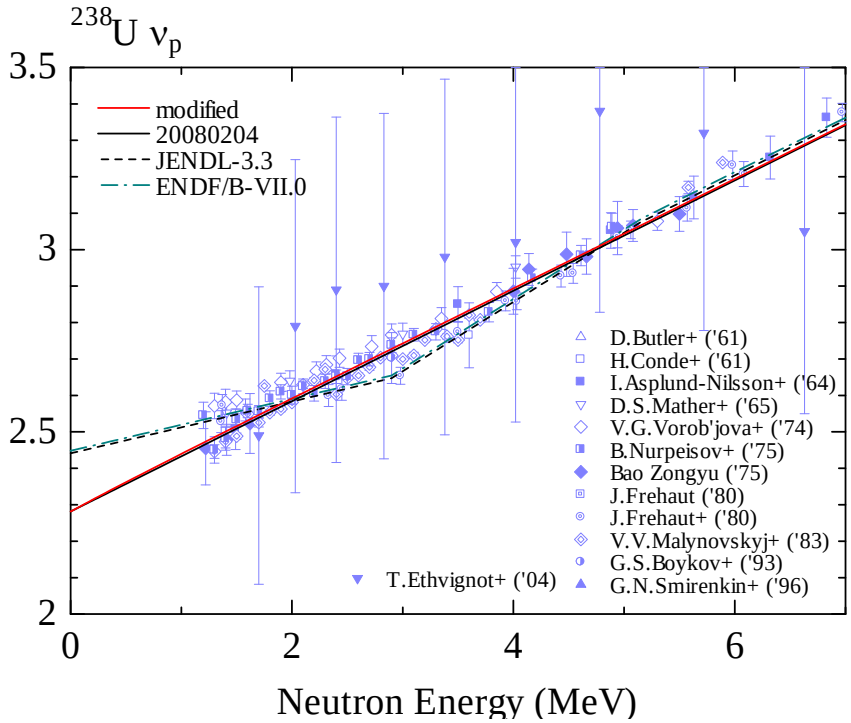
$$G_{ij} = \frac{\partial C_i / E}{\partial P_j} = \frac{C_i(P_j = P_j + \delta P_j)/E - C_i(P_0)/E}{\delta P_j}$$

Corrected amount of fission cross section

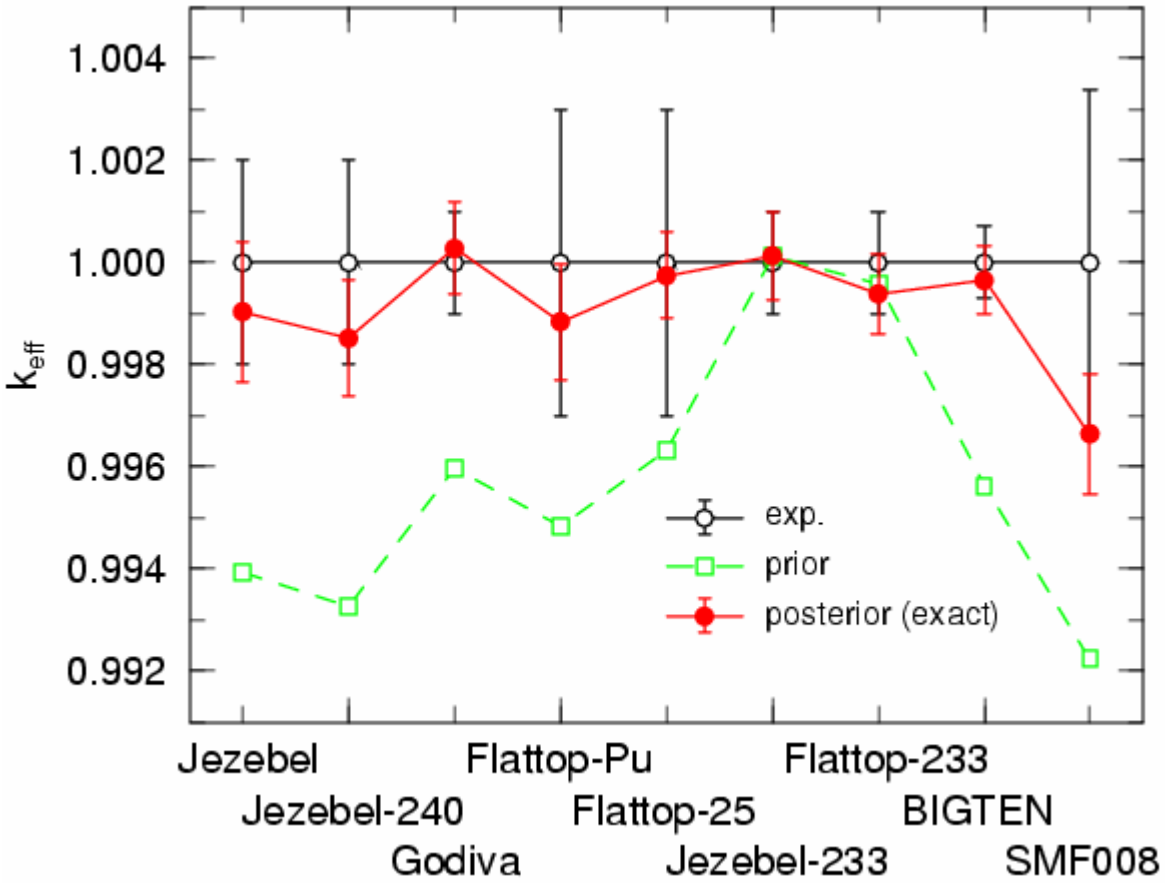


Corrected data

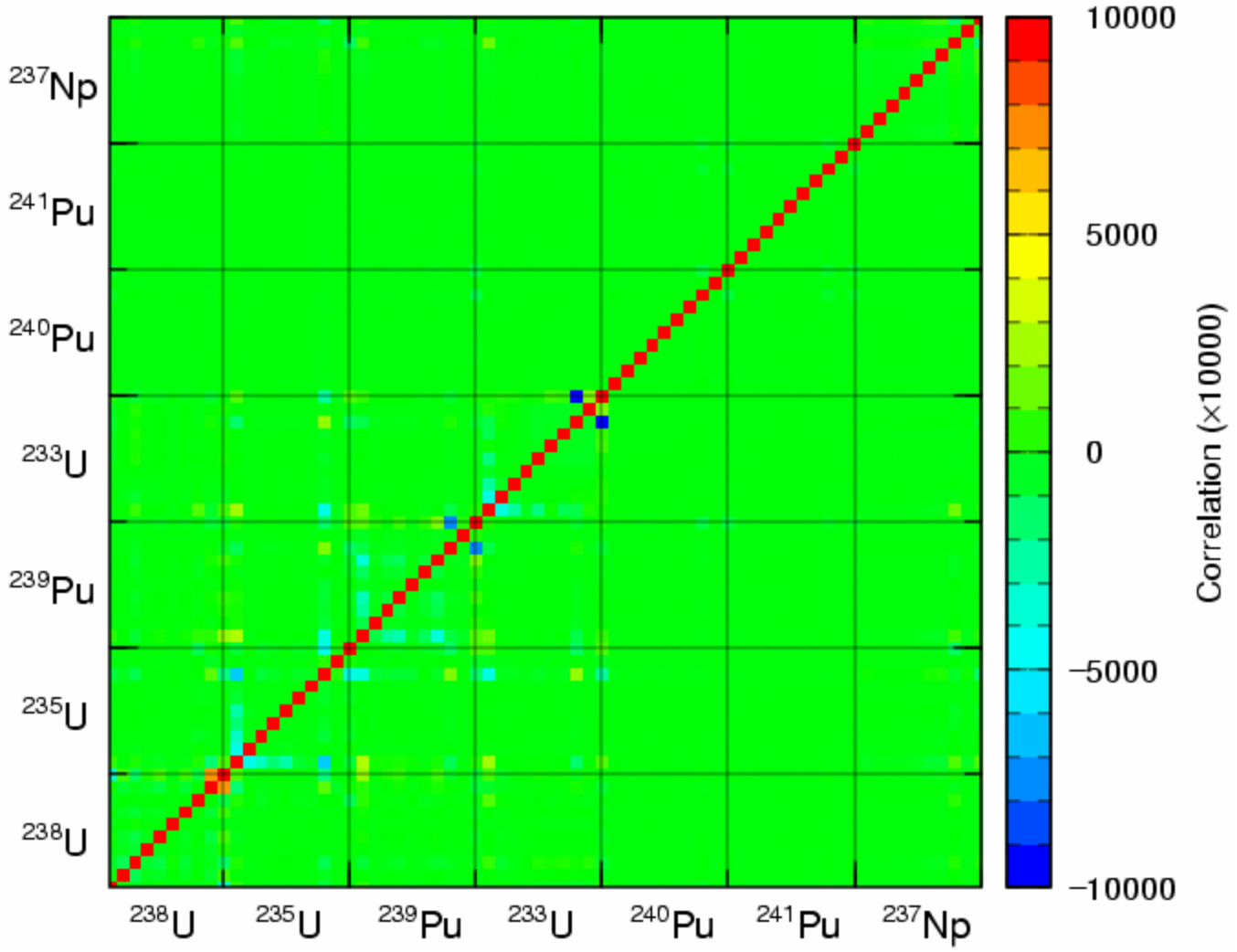




Small reactor k_{eff}



Correlation of parameters



Parameters

Vr_0

W_{d_disp}

β_2

Bfc_1

Bfc_2

σ_0

$a_{\_fac}$

σ_f

σ_c

v_p

Covariance of corrected data

Covariance of corrected parameters

$$V_P = \left(G^{+} V^{-1} G + M^{-1} \right)^{-1}$$

Total covariance of nuclear data

Covariance of nuclear data estimated from differential data

$$V_x = G_x V_P G_x^{\,t} + V_0$$

Sensitivity of nuclear data to corrected parameters

Conclusions

- JENDL Actinod File 2008 was released in March 2008.
- Evaluation method and results were shown.
- Preliminary covariance data for JENDL/AC-2008 were shown.
- Covariance files for JENDL/AC-2008 are planed to be evaluated by March 2009.