4th Meeting of WPEC Subgroup 33 on
Methods and issues for the combined use of integral experiments and covariance data

November 29-30, 2010
NEA Headquarter, Issy-les-Moulineaux, France

Proposal to Evaluate Nuclear Data Covariances in SG33

Makoto ISHIKAWA

Japan Atomic Energy Agency (JAEA)

Discussion Points

- **Why we need to discuss about nuclear data covariances**
- **Comparison of major libraries with various covariance data**
- **Procedure to discuss about covariances in SG33**

Flow of Needs for Quantitative Uncertainty Evaluation

Step	Physical Property or Product by Using the Quantitative Error Values of B (= A)	Man or Organization who Needs the Qualitative Error Property and Quantitative Error Value of A (= B)
1	(Efficiency of Radiation Detector, Isotopic Composition of a Sample)*	Experimentalist of Nuclear Data
2	Measured Value and Document of Nuclear Data	Evaluator of Nuclear Data file
3	Evaluated Nuclear Data Library => "with Nuclear Data Covariances"	Analyst of Reactor Physics Experimentalist, Developer of Reactor Physics Analytical Modeling and Code
4	(Experimental Data of Reactor Physics)*	
5	C/E Value of Integral Experimental Analysis	Reactor Plant Design Manufacturer, Adjuster of Group-constant Set
6	Design Value of Nuclear Core Parameter of the Target Reactor	Owner of the Plant, Electricity Company
7	Accident Analysis Results of the Target Reactor Core	Licensing Authority, Public People

* means this item is not always on the flow of the error supplier and consumer.

-> Uncertainty of a property is always required by its user, NOT by its supplier.

(Ref.) Workshop on Covariances, BNL, Nuclear Data Sheets 109, pp.2778-2784 (2008)

Theory of Cross-section Adjustment

※ J.B.Dragt, et al.: "Methods of Adjustment and Error Evaluation of Neutron Capture Cross Sections; Application to Fission Product Nuclides," NSE 62, pp.117-129, 1977

- Based on the Bayes theorem, i.e., the conditional probability estimation method
  → To maximize the posterior probability that a cross-section set, ***T***, is true, under the condition that the information of integral experiment, ***Re***, is obtained.

$$J(T) = (T-T_0)^t M^{-1}(T-T_0) + [Re-Rc(T)]^t[Ve+Vm]^{-1}[Re-Rc(T)]$$

Minimize the function $J(T)$. → $dJ(T)/dT = 0$

- The adjusted cross-section set ***T'***, and its uncertainty (covariance), ***M'*** ***(Algebra)***

$$T' = T_0 + MG^t[GMG^t+Ve+Vm]^{-1}[Re-Rc(T_0)]$$

$$M' = M - MG^t[GMG^t+Ve+Vm]^{-1}GM$$

✓If $GMG^t \ll Ve+Vm$, $T' \fallingdotseq T_0$ and $GM'G^t \fallingdotseq GMG^t$
✓If $GMG^t \gg Ve+Vm$, $GM'G^t \fallingdotseq Ve+Vm$
✓If $GMG^t \fallingdotseq Ve+Vm$, $GM'G^t \fallingdotseq 1/2 \times GMG^t$

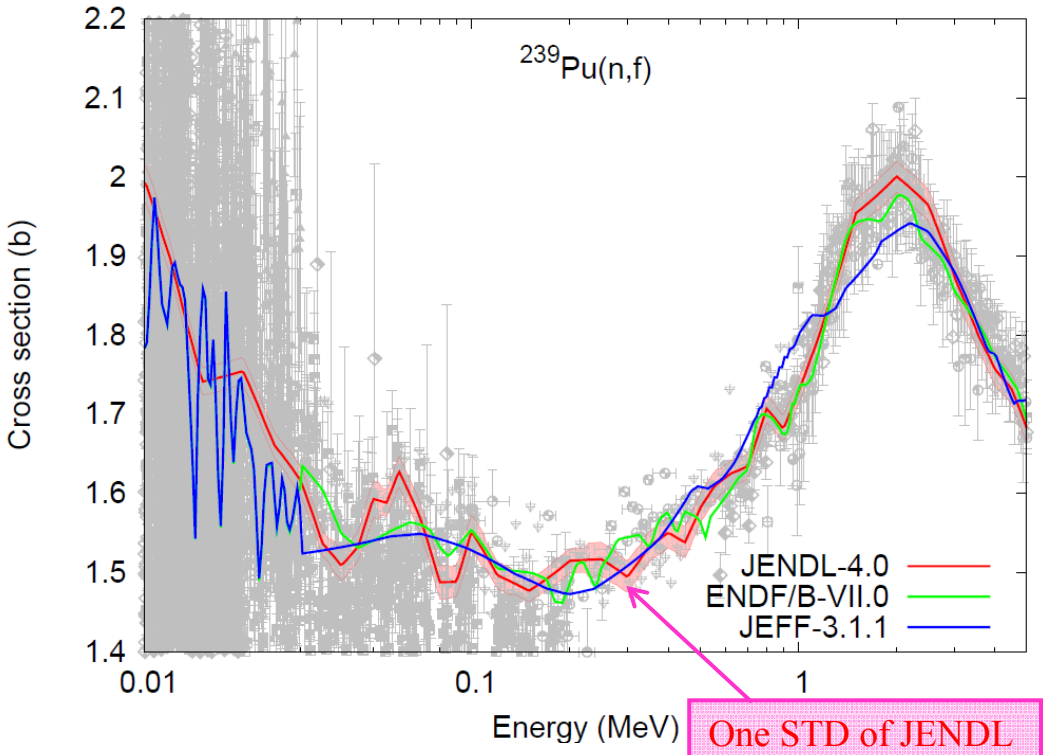
- Prediction error induced by the cross-section errors

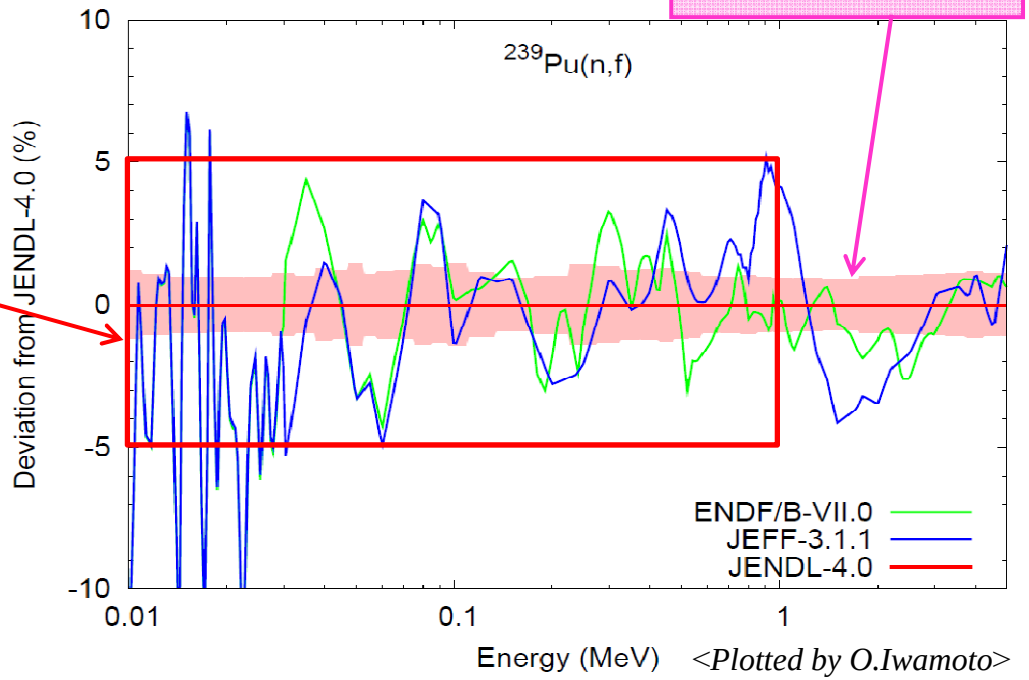
Before adjustment: GMG^t After adjustment: $GM'G^t$

Where, ***T_0*** : Cross-section set before adjustment
M : **Covariance before adjustment**
Re : Measured values of integral experiments
Rc : Analytical values of integral experiments
Ve : Experimental errors of integral experiments
Vm : Analytical modeling errors of integral experiments
G : Sensitivity coefficients, $(dR/R)/(d\sigma/\sigma)$

(Ex.1)
Pu-239 Fission (above 10keV*)

- **Note:** The fluctuation among three libraries seems quite large compared with the STD of JENDL. We had better consult the nuclear data people of each library.

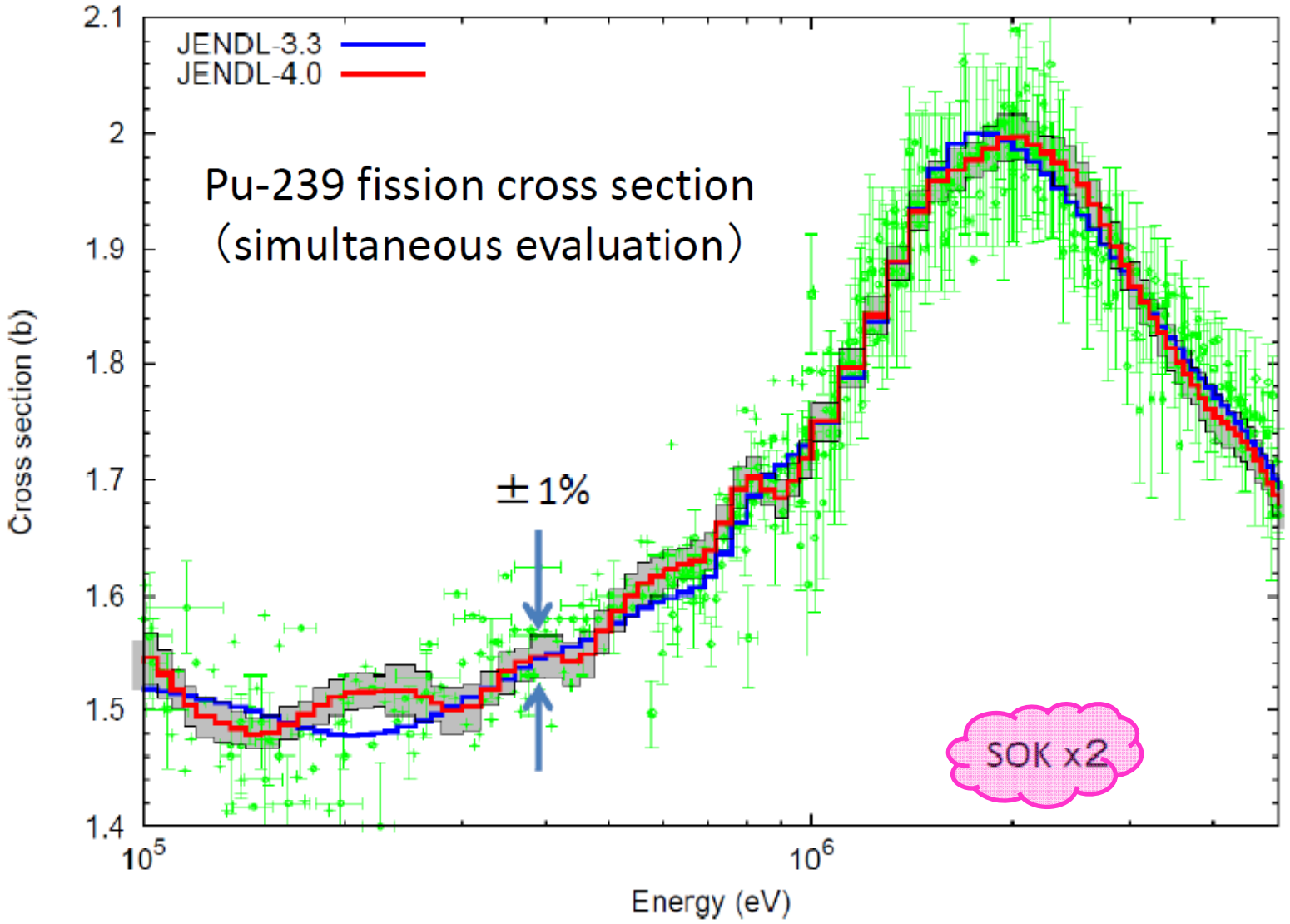




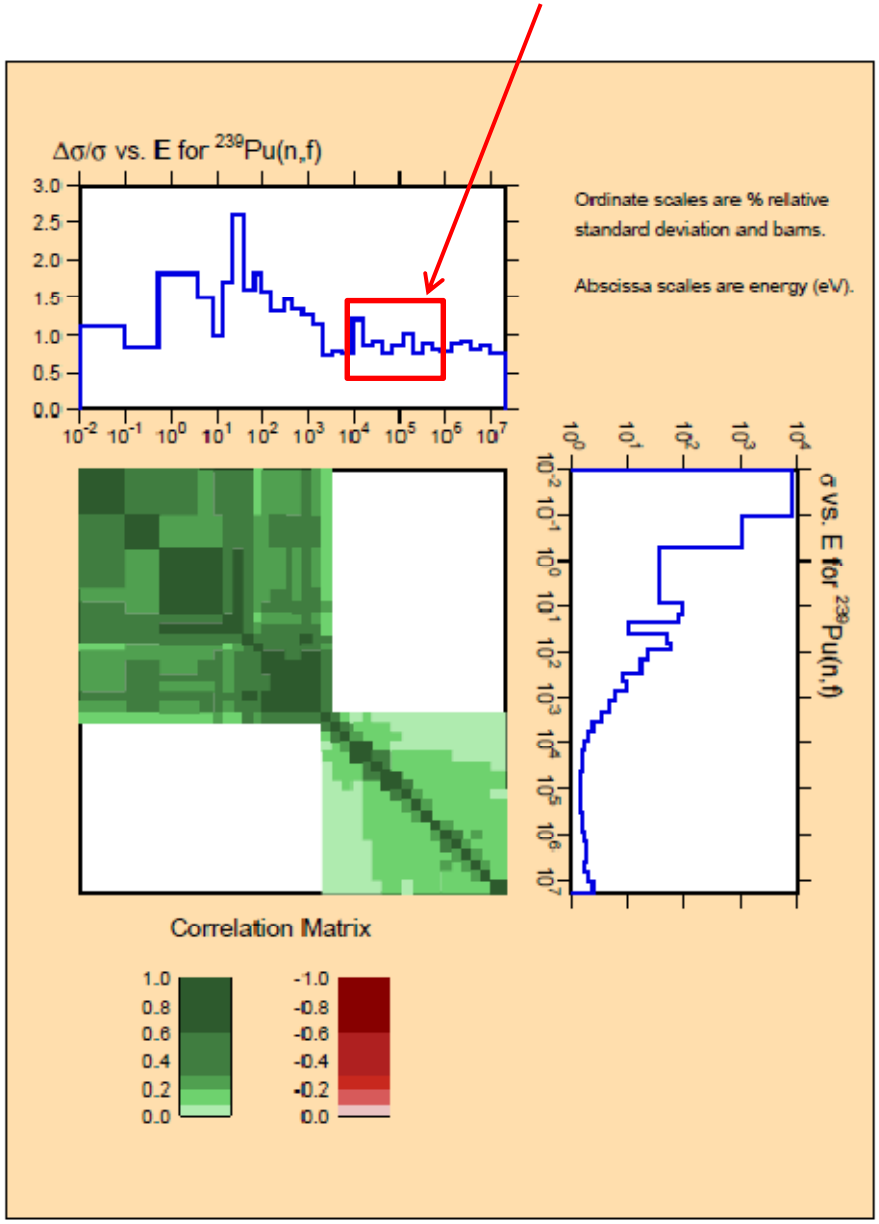
<Plotted by O.Iwamoto>

---

* Above 10 keV, experimental data measured after 1960 analyzed in JENDL-4.0 by simultaneous fitting of U-233, U-235, U-238, Pu-239, Pu-240 and Pu-241 fission cross sections and their ratios by the SOK code.



<Plotted by O.Iwamoto>



<*AFCI 1.2 Report, Sep.2009*>

		^{239}Pu					
Gr	**E [MeV]**	**ν**	**σ_f**	**σ_{inel}**	**σ_{el}**	**σ_{capt}**	**$\sigma_{n,2n}$**
1	**19.6**	0.5	0.63	23.06	6.94	37.08	8.53
2	**6.07**	0.17	0.69	22.18	9.36	37.8	4.34
3	**2.23**	0.17	0.89	19	10.3	26.56	0
4	**1.35**	0.12	0.64	29.01	10.29	18.18	0
5	**4.98e-1**	0.19	0.68	34.01	5.66	11.55	0
6	**1.83e-1**	0.54	0.85	46.06	3.98	9.04	0
7	**6.74e-2**	0.58	0.72	40.04	2.37	10.12	0
8	**2.48e-2**	0.58	0.96	28.52	2.16	7.39	0
9	**9.12e-3**	0.65	0.62	8.64	4.04	15.46	0
10	**2.03e-3**	0.2	1.2	0	0.74	1.39	0
11	**4.54e-4**	0.2	1.24	0	1.2	1.25	0
12	**2.26e-5**	0.2	0.47	0	0.24	0.61	0
13	**4.00e-6**	0.2	1.43	0	0.3	1.22	0
14	**5.40e-7**	0.2	0.88	0	0.44	1.36	0
15	**1.00e-7**	0.2	1.11	0	0.68	1.6	0

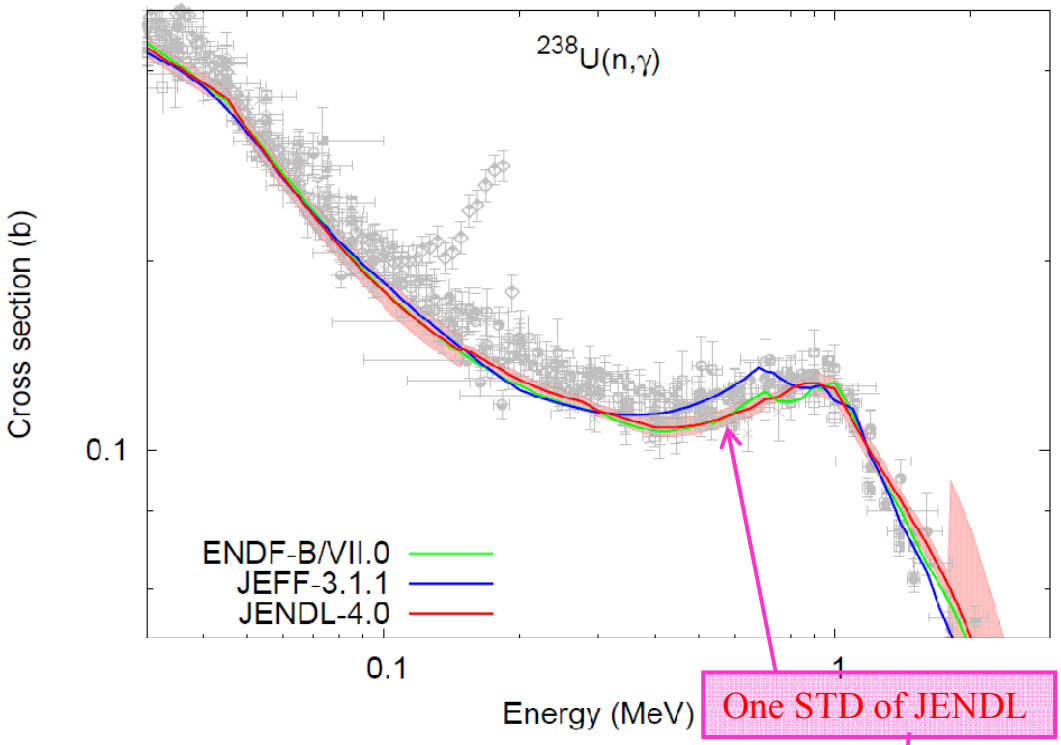
<BOLNA Covariance, *SG26Report, 2008*>

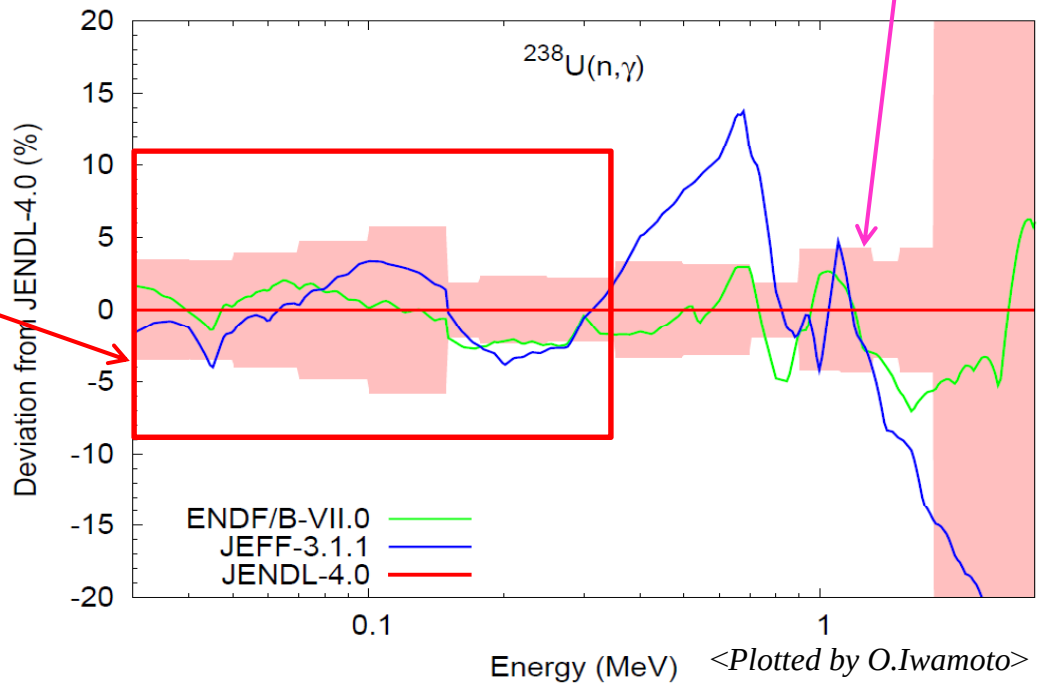
		^{239}Pu					
Gr	**E [MeV]**	**ν**	**σ_f**	**σ_{inel}**	**σ_{el}**	**σ_{capt}**	**$\sigma_{n,2n}$**
1	**19.6**	1	5	10	5	15	50
2	**6.07**	1	5	10	5	15	50
3	**2.23**	1	5	10	5	15	0
4	**1.35**	1	5	15	5	15	0
5	**4.98e-1**	1	5	15	5	15	0
6	**1.83e-1**	1	5	15	5	15	0
7	**6.74e-2**	1	5	20	5	10	0
8	**2.48e-2**	1	5	25	5	10	0
9	**9.12e-3**	1	5	30	5	5	0
10	**2.03e-3**	0.5	3	0	5	5	0
11	**4.54e-4**	0.5	3	0	5	5	0
12	**2.26e-5**	0.5	3	0	5	5	0
13	**4.00e-6**	0.5	3	0	5	4	0
14	**5.40e-7**	0.5	2	0	5	3	0
15	**1.00e-7**	0.3	1	0	5	2	0

<ANL Covariance, *SG26Report, 2008*>

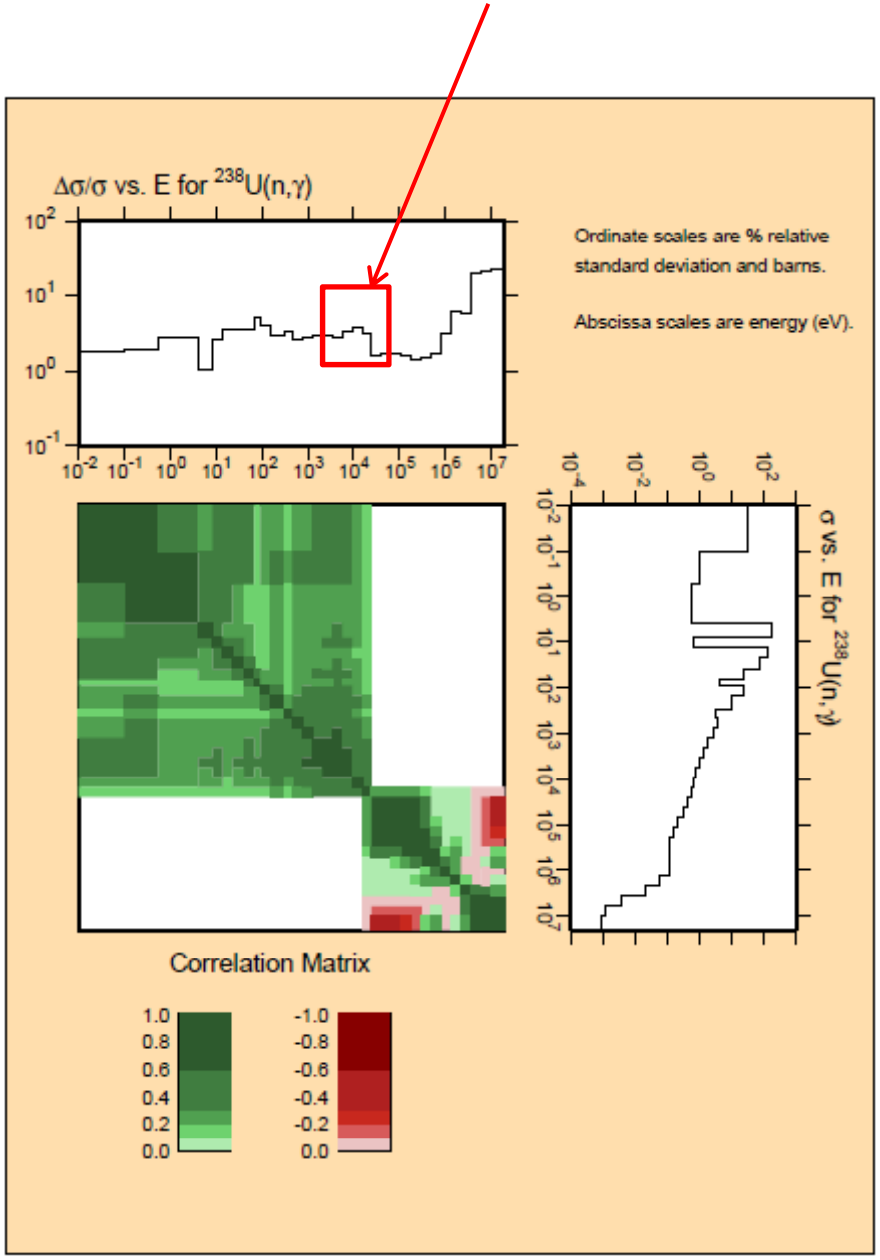
(Ex.2)
U-238 Capture
(above R.R region)

- **Note:** All three libraries run the bottom of experimental data because of some integral information. The deviation of three libraries are within the STD of JENDL in the range of 30keV to 400keV.





<Plotted by O.Iwamoto>



<AFCI 1.2 Report, Sep.2009>

		^{238}U					
Gr	E [MeV]	ν	σ_f	σ_{inel}	σ_{el}	σ_{capt}	$\sigma_{n,2n}$
1	19.6	1.26	0.57	29.28	13.34	21.41	5.32
2	6.07	1.17	0.55	19.75	14.57	13.5	0
3	2.23	1.34	0.6	20.58	18.78	6.05	0
4	1.35	1.3	2.91	11.56	5.35	2.27	0
5	4.98e-1	2	5.26	4.19	1.92	1.41	0
6	1.83e-1	2	5.14	10.96	2.12	1.67	0
7	6.74e-2	2	5.14	11.12	3.76	1.64	0
8	2.48e-2	2	50.31	0	1.52	9.43	0
9	9.12e-3	2	214.62	0	0.67	3.11	0
10	2.03e-3	2	9.69	0	0.72	2.1	0
11	4.54e-4	2	2.38	0	2.39	1.71	0
12	2.26e-5	2	5.82	0	5.97	1.03	0
13	4.00e-6	2	51.89	0	0.82	2.45	0
14	5.40e-7	2	55.19	0	0.92	1.66	0
15	1.00e-7	2	55.42	0	0.94	1.64	0

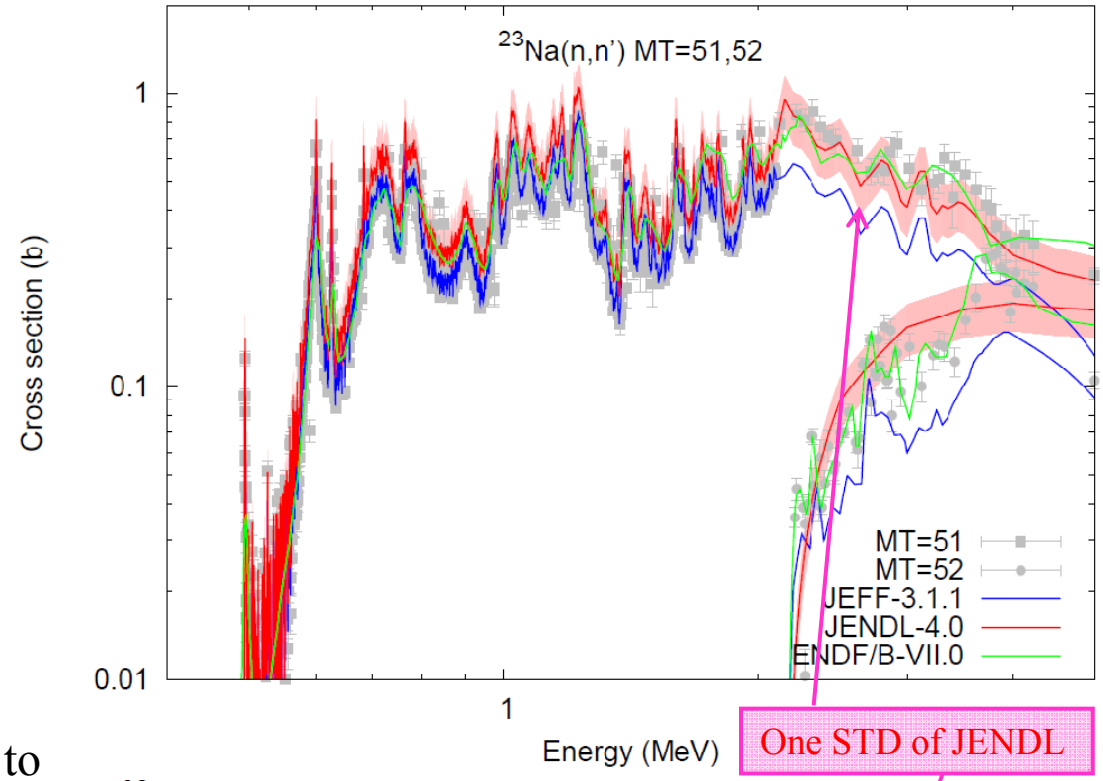
<BOLNA Covariance, *SG26Report, 2008*>

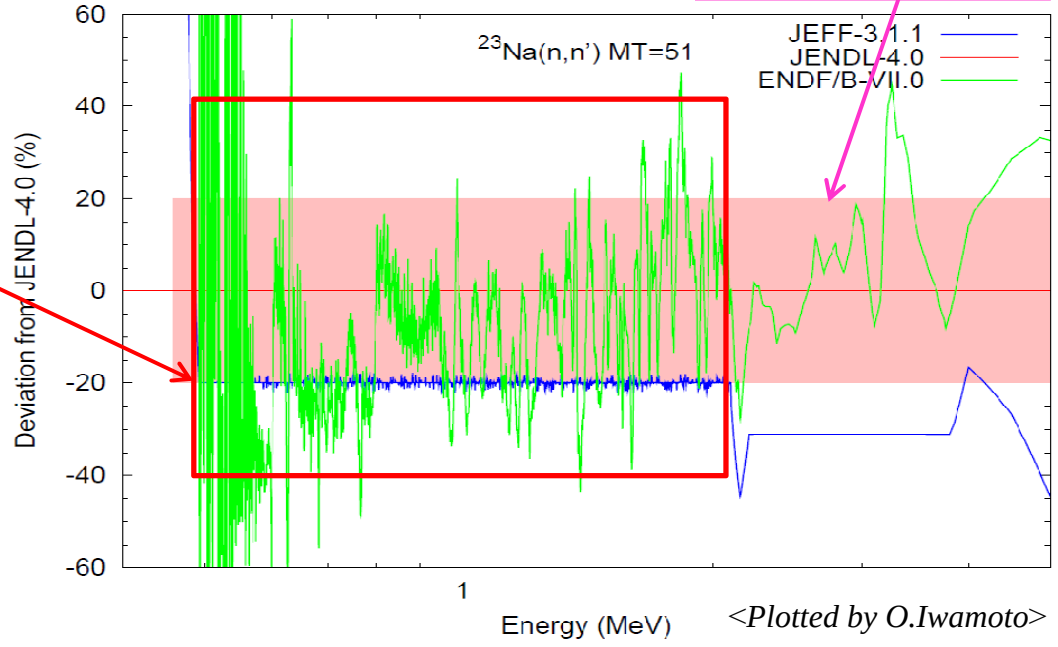
		^{238}U					
Gr	E [MeV]	ν	σ_f	σ_{inel}	σ_{el}	σ_{capt}	$\sigma_{n,2n}$
1	19.6	3	5	20	5	30	30
2	6.07	2	5	15	5	10	0
3	2.23	2	5	10	5	5	0
4	1.35	2	5	10	5	5	0
5	4.98e-1	2	5	10	5	5	0
6	1.83e-1	2	20	10	5	5	0
7	6.74e-2	2	20	15	5	5	0
8	2.48e-2	2	20	0	5	5	0
9	9.12e-3	2	20	0	5	3	0
10	2.03e-3	2	20	0	5	3	0
11	4.54e-4	2	20	0	5	3	0
12	2.26e-5	2	20	0	5	3	0
13	4.00e-6	2	20	0	5	3	0
14	5.40e-7	2	20	0	1	1	0
15	1.00e-7	2	20	0	1	1	0

<ANL Covariance, *SG26Report, 2008*>

(Ex.3)
Na-23 Inelastic (above 460keV*)

- **Note:** JEFF and JENDL fitted the same experimental data until 2Mev, but 20% bias was given from some integral information. ENDF seems to have evaluated independently.



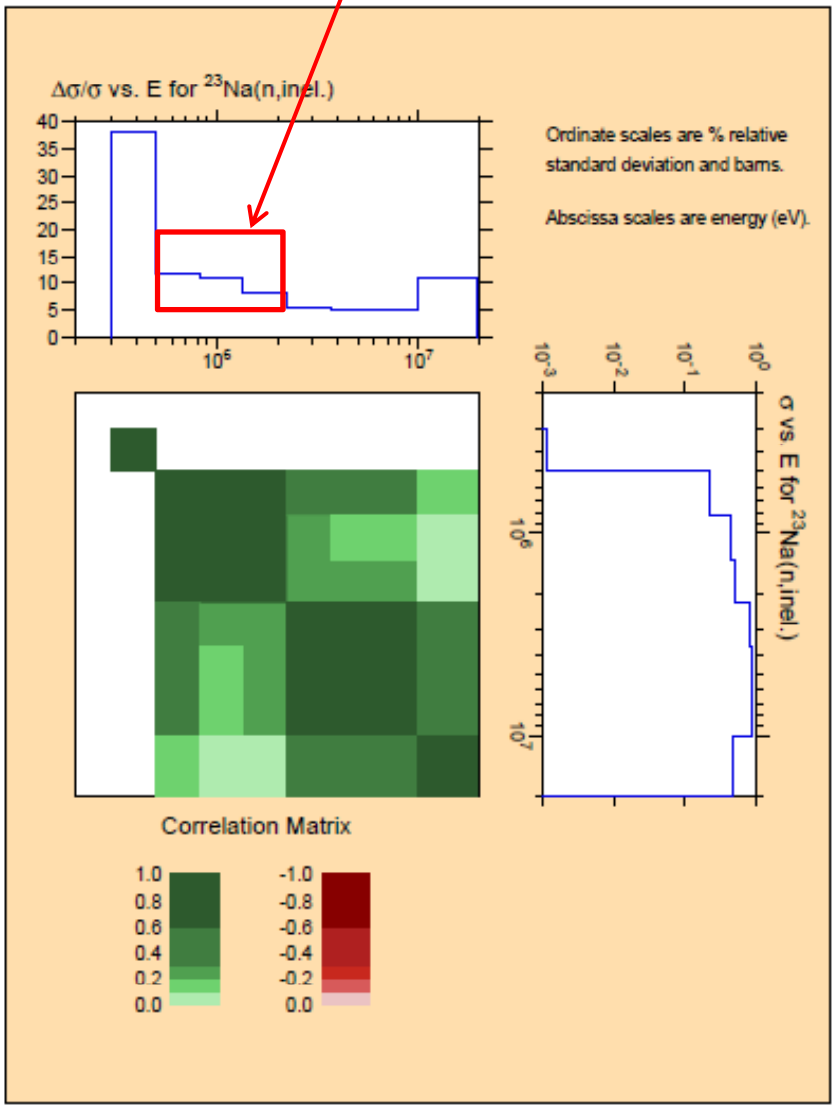


<*Plotted by O.Iwamoto*>

---

* For MT=51, the TNG calculations were replaced with the following data:

Threshold - 2.15 MeV: Maerten et al. multiplied by 1.25. The factor of 1.25 was derived from a benchmark test made by N. Yamano.



<AFCI 1.2 Report, Sep.2009>

		Na			
Gr	E [MeV]	σ_{inel}	σ_{el}	σ_{capt}	$\sigma_{n,2n}$
1	19.6	18.79	1.8	46.44	11.07
2	6.07	8.87	4.62	24.33	0
3	2.23	12.56	3.72	1.7	0
4	1.35	28	3.01	7.44	0
5	4.98e-1	50	3.31	6.81	0
6	1.83e-1	0	3.25	23.59	0
7	6.74e-2	0	2.38	6.79	0
8	2.48e-2	0	2.87	6.63	0
9	9.12e-3	0	3.23	1.18	0
10	2.03e-3	0	4.93	2.28	0
11	4.54e-4	0	4.76	2.3	0
12	2.26e-5	0	4.73	2.29	0
13	4.00e-6	0	4.71	2.29	0
14	5.40e-7	0	4.7	2.29	0
15	1.00e-7	0	4.59	2.07	0

<BOLNA Covariance, *SG26Report, 2008*>

		Na			
Gr	E [MeV]	σ_{inel}	σ_{el}	σ_{capt}	$\sigma_{n,2n}$
1	19.6	30	5	10	100
2	6.07	30	5	10	0
3	2.23	30	5	10	0
4	1.35	30	5	10	0
5	4.98e-1	35	5	10	0
6	1.83e-1	0	5	8	0
7	6.74e-2	0	5	8	0
8	2.48e-2	0	5	8	0
9	9.12e-3	0	5	8	0
10	2.03e-3	0	5	7	0
11	4.54e-4	0	5	7	0
12	2.26e-5	0	3	7	0
13	4.00e-6	0	3	7	0
14	5.40e-7	0	2	5	0
15	1.00e-7	0	2	5	0

<ANL Covariance, *SG26Report, 2008*>

Procedure to Discuss about Nuclear Data Covariances in SG33

(Step 1) All participants submit the (infinite-diluted) nuclear data and their covariance used in the adjustment benchmark based on the format proposed by Dupont on Feb.27, 2010. (Hereafter, we only concentrate on the major isotopes and reactions, i.e., "high-fidelity covariances".)

(Step 2) Plot the nuclear data and STD of each library in one figure, with the experimental data which are considered as valid in the present data evaluation.

(Step 3) Pickup some problematic data and STD of a certain library for specific isotopes, reactions, and energy ranges.

(Step 4) For above data, consult the nuclear-data people of each library at home country, i.e., starting the conversation between two parties.

(Step 5) Finally, we summarize the comments for the current covariance data from the integral user's viewpoint, and make some recommendations for future measurements and/or evaluations of nuclear data.