Draft by JAEA: April 24, 2015

SG39 Deliverables

Comments on Covariance Data

1 Introduction

The covariance matrix [1] of a scattered data set, x_i (i=1,n), which must be symmetric and positive-definite, is defined as follows (Ref.1):

- ✓ Variance: $\mu_{ii} = \mathrm{var}(x_i) = <(x_i - m_{0i})^2> \quad for\ \ i = 1, n$ $\quad (m_{0i} = \langle x_i \rangle :\ \ mean\ value)$
  - ● Standard deviation: $\sigma_i = std(x_i) = \sqrt{\mathrm{var}(x_i)}$

- ✓ Covariance: $\mu_{ij} = \mathrm{cov}(x_i, x_j) = <(x_i - m_{0i})(x_j - m_{0j})> \quad for\ \ i, j = 1, n \ \ with\ i \neq j$
  - ● Correlation factor: $\rho_{ij} = \dfrac{\mu_{ij}}{\sqrt{\mu_{ii}\mu_{jj}}} = \dfrac{\mathrm{cov}(x_i, x_j)}{std(x_i) \times std(x_j)} \quad where,\ -1 \leq \rho_{ij} \leq 1$

As one of WPEC/SG39 contributions to the SG40/CIELO project, several comments or recommendations on the covariance data are described here from the viewpoint of nuclear-data users. To make the comments concrete and useful for nuclear-data evaluators, the covariance data of the latest evaluated nuclear data library, JENDL-4.0 (J-4.0 hereafter, Ref.2~5) and ENDF/B-VII.1 (E-7.1 hereafter, Ref.6~9) are treated here as the representative materials [2]. The surveyed nuclides are five isotopes that are most important for fast reactor application. The nuclides, reactions and energy regions dealt with are followings:

- Pu-239: fission (2.5~10keV) and capture (2.5~10keV),
- U-235: fission (500eV~10keV) and capture (500eV~30keV),
- U-238: fission (1~10MeV), capture (below 20keV, 20~150keV), inelastic (above 100keV) and elastic (above 20keV),
- Fe-56: elastic (below 850keV) and average scattering cosine (mu-bar hereafter) (above 10keV),

and, ·Na-23: capture (600eV~600keV), inelastic (above 1MeV) and elastic (around 2keV).

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[1] Covariance matrix is sometimes called "variance-covariance matrix".

[2] Note that the covariance data are not physical properties in the strict meaning. Even if a set of central cross-section values in two libraries are identical, the correcponding covariance data are not necessary to be the same with each other, since the covariance data evaluated by a library are completely dependent on the evaluation methodology and the experimental cross-section values adopted by the library. The work to compare the covariance data between two libraries, therefore, must be very careful.

2 Comments on Covariance Data of JENDL-4.0 and ENDF/B-VII.1

2.1 Pu-239 Fission

The neutron energy discussed here is in the range from 2.5keV to 10keV, which is the lower part of the unresolved resonance region, 2.5~30keV, in both J-4.0 and E-7.1. Figure 1 shows the covariance data of Pu-239 fission cross-section of both libraries, the comparison of the standard deviation (STD) values and the adjusted result based on J-4.0 (ADJ2010, Ref.10). In (a) and (b) of the figure, the upper part is the energy dependency of the STD values, the right part that of the cross-section values, and the central part the energy distribution of the correlation factors. Figure (c) shows the comparison of the STD values between two libraries, and (d) is the alteration of Pu-239 fission cross-section by the ADJ2010 adjustment, respectively.

The facts observed in Fig.1 is that the STD values of 2.5~10keV show an abrupt peak in J-4.0, on the contrary, no such discontinuity is seen in E-7.1.

As the results of survey, the following information was obtained. In the former JENDL-3.3 (J-3.3 hereafter, Ref.11), the covariance data of the whole unresolved resonance region were evaluated from the uncertainty of resonance parameters, consequently, the STD values were generally large. Above 10keV, J-4.0 changed to adopt the simultaneous evaluation for the center cross-section values of major fission isotopes, and the resonance parameters were only used to calculate the shielding factors. Since the simultaneous evaluation was found to evaluate the STD values too small [3], the variance of J-4.0 was multiplied by a factor of 2 to compensate this defect (Ref.3, p.1226), but still small compared with the STD values of J-3.3, which was carried over to J-4.0 in 2.5~10keV (Ref.12). Since the evaluation method of the covariance data is consistent with that of the central value of cross-section, the discontinuity at 2.5~10keV in J-4.0 is methodologically acceptable. However, this discontinuity was found to unnaturally affect the cross-section change by adjustment as seen in Fig.1 (d).

<*Recommendations*>

It is desirable for J-4.0 to improve the covariance evaluation of the 2.5~10keV region.

2.2 Pu-239 Capture

The energy range is 2.5~10keV as same as that of Pu-239 Fission. The covariance data of Pu-239 capture cross-section in J-4.0 and E-7.1, the STD comparison, and the adjusted result of ADJ2010 are depicted in Fig.2.

The facts from Fig.2 are that the STD values of E-7.1 are notably large in 2.5~10keV, on the other hand, those of J-4.0 are quite smooth above 2.5keV.

The following information was gathered. Above 2.5keV, J-4.0 adopted the results of the CCONE-KALMAN calculation (Ref.4), not the simultaneous evaluation unlike the fission case, therefore, the STD values tend to be smooth in the high energy region (Ref.12). On the other hand, there seems no explanation in the E-7.1 comment file (Ref.8) to correspond to its discontinuity. In the US, there seems an opinion that the Pu-239 capture cross-section above 2.5keV should be 10% larger than E-7.1 (Ref.13), but no information was obtained on the relation with this covariance trend. The adjusted result of ADJ2010 in Fig.2 (d) seems to be somewhat coincident with the expectation of Pu-239 capture increase, but it might have occurred by chance.

<*Recommendations*>

The ENDF evaluators may be asked if there is any physical reason for this discontinuity.

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[3] The underestimation of the fission variance is attributed to the fact of "so many experimental data points were considered without correlation among different data sets" (Ref.2, p.22).

2.3 U-235 Fission

The energy range treated here is 500eV~10keV, which is a part of unresolved resonance region in J-4.0 and a part of resolved and unresolved in E-7.1. Figure 3 exhibits the covariance data and the STD comparison of U-235 fission cross-section.

The observed facts in Fig.3 are that the STD values of E-7.1 in 500eV~2keV are extremely low, on the other hand, J-4.0 shows the large values around 5%. Further, E-7.1 has very sharp peak near 2keV.

The following information was found. J-4.0 adopted the resonance parameter values obtained from Oak Ridge National Laboratory (ORNL) below 500eV, and re-evaluated in the range of 500eV~2.25keV based on those of ENDF/B-VI.5 (= J-3.3) (Ref.2). In 2.25~9keV, the CCONE code was used, and above 10keV, the simultaneous evaluation was adopted. J-4.0 assumed the STD values of 5% in 500eV~9keV (Ref.4), but the reason is unknown. The covariance data of E-7.1 were evaluated with GNASH-KALMAN (Ref.9, p.20), but the strange STD peak appears around 2keV.

<*Recommendations*>

The JENDL evaluators could be asked about the physical basis of 5% in the range of 500eV~9keV, and the ENDF evaluators may explain the reason of the sharp peak around 2keV, which might be a problem of the processing code NJOY.

2.4 U-235 Capture

The focused energy range is 500eV~30keV, which is the unresolved resonance region of J-4.0, on the other hand, the resolved and the unresolved regions of E-7.1. The covariance data and the STD comparison of J-4.0 and E-7.1 are shown in Fig.4.

The observed facts in Fig.4 is that the STD values of J-4.0 in 500eV~2.25keV are 10% constant with perfect positive correlations, on the other hand, E-7.1 increases from a few % to 35%. In 2.25~30keV range, E-7.1 gives the STD values of 35% with almost perfect positive correlations, while J-4.0 shows several % with weak correlations. Further, the negative correlations with high energy region were found in E-7.1, on the contrary, no such trend in J-4.0.

The following information was found. The resonance parameters of J-4.0 has the same explanation with U-235 fission, but the correction was added to make the center cross-section values close to those of JENDL-3.2 in 500eV~2.25keV, according to the discussion made in WPEC/SG29 [4] (Ref.2, p.7), and the uncertainty was assumed as 10% (Ref.4). Above 2.25keV, the covariance data were obtained with the least-square calculation with the GMA code, based on the experimental results of the alpha values [5]. The resonance parameters of E-7.1 below 2.25keV adopted the ORNL results, but the constant STD values of 35% would reflect the recent LANL measurements. The reason of the slope from several % to 35% is unknown.

<*Recommendations*>

It is needed to confirm the reasons of the observed facts to both J-4.0 and E-7.1 evaluators.

2.5 U-238 Fission

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[4] The report of WPEC/SG29 concluded that "The possible overestimation of ^{235}U capture cross-section in the 0.1 to 2.5 keV range is consistent with the alpha measurement and the integral experiments of Na-void reactivity of BFS and FCA, and the criticality trends of FCA and ZEUS. The new FCA experiments were described better with JENDL-3.2 and JENDL-4.0, which have lower ^{235}U capture cross-sections around 1 keV than other libraries. The magnitude of the overestimation could be ~10% or more."

[5] Alpha value is defined as the ratio of capture to fission cross-section.

The energy range concerned is 1~10MeV above fission threshold energy. Figure 5 shows the covariance data and the STD comparison for J-4.0 and E-7.1.

From Fig.5, the cross-section and STD values in 1~10MeV seem very similar between J-4.0 and E-7.1. According to the documents, J-4.0 adopted the results of the simultaneous evaluation (Ref.2), on the other hand, the covariance data of E-7.1 applied the evaluation by GNASH-KALMAN (Ref.8). The similar results from the different evaluation methods might come from the ample experimental data of U-238 fission.

There are no comments for the covariance data of U-238 fission.

2.6 U-238 Capture

Two energy ranges are discussed here: 1) below 20keV (resolved resonance region), and 2) 20~150keV (unresolved resonance region). The covariance data and the STD comparison of J-4.0 and E-7.1 are depicted in Fig.6.

The observed facts are: a) The covariance data below 20keV are almost identical between J-4.0 and E-7.1, but the spikes of the STD values appear only in J-4.0, and b) In the unresolved region of 20~100keV, the STD values of J-4.0 are significantly larger than those of E-7.1, and vice versa in 100~150keV.

The gathered information is below: a) Both J-4.0 (Ref.4) and E-7.1 (Ref.9, p.20) adopted the same resonance parameters obtained from ORNL, and converted it to File 33. The process from File 32 to File 33 has some arbitrariness such as energy boundaries, therefore, some differences are possible even if the resonance parameters are identical (Ref.12). b) The U-238 capture in the energy range of 20~150keV greatly affects the breeding ratio and burnup reactivity loss in the fast reactor application, therefore, these differences are very important from the nuclear design viewpoint. The covariance data of J-4.0 resonance parameters were evaluated with ASREP-KALMAN in 1997 (Ref.5, p.13), but the details are not recorded.

<*Recommendations*>

It is very important for fast reactor people to ask the reason of item 2) to both J-4.0 and E-7.1 evaluators.

2.7 U-238 Inelastic

The energy range concerned here is above 100keV with meaningful inelastic cross-section values. Figure 7 shows the covariance data, the STD comparison and the adjusted result in ADJ2010.

In Fig.7, the total inelastic cross-section seems quite similar between J-4.0 and E-7.1, but the STD values and their energy shapes are completely different.

The authors had wondered about a possibility, that is, the excitation level-wise evaluation of both libraries were different, but the total inelastic cross-section was forced to be similar because of ample measurements etc. However, according to Ref.12, the total of inelastic cross-section is simply a summation of each level-wise value, unlike the relation between the total and the elastic cross-section case, therefore, this idea was found not to be the reason of the differences. The adjusted result of ADJ2010 in Fig.7 (d) suggests the reduction of U-238 inelastic [6].

<*Recommendations*>

It is recommended to consult both J-4.0 and E-7.1 evaluators about the reason of the STD differences.

2.8 U-238 Elastic

[6] The reduction of U-238 inelastic cross-section results in the hardening of neutron spectrum. However, we have to be careful about the cross-section alteration, since the alteration of Pu-239 fisson spectrum always compensates the effect of U-238 inelastic cross-section in fast reactor cores.

The energy range is above 20keV that corresponds to the unresolved resonance and the continuous energy regions. The covariance data, the STD comparison and the adjusted result of ADJ2010 are in Fig.8, where the STD values and energy shapes of both libraries are rather similar, but the energy regions with strong negative correlations were found in J-4.0, but not in E-7.1.

It was reported that the covariance data of J-4.0 were evaluated by CCONE-KALMAN (Ref.4), and those of E-7.1 by GNASH-KALMAN (Ref.8), while both applied the relation of "Elastic=Total - Nonelastic" to evaluate the central elastic cross-section values (Ref.4, 8). Only for information, the adjusted result of ADJ2010 is shown in Fig.8 (d).

<*Recommendations*>

It is not critical for the users, but better to ask the possible reason of the correlation differences to both J-4.0 and E-7.1 evaluators in order to deepen the understanding on the mechanism of the nuclear data evaluation.

2.9 Fe-56 Elastic

The energy region treated here is below 850keV, that is, the resolved resonance region. Figure 9 shows the covariance data and the STD comparison.

The facts from Fig.9 is that the covariance data of E-7.1 in the energy region of 100~300eV and 300eV~30keV show the complete correlations respectively, but the the STD values of E-7.1 and J-4.0 are rather similar around 6~8%. Above 30keV, the STD values of both libraries are utterly different. Further, a sharp peak near 10keV appears in J-4.0, but not in E-7.1.

The information obtained was followings: the central cross-sections are almost identical, since they are evaluated with almost the same resonance parameters based on Pereys' evaluation in 1990 (Ref.14). The covariance data of E-7.1 were evaluated by Kernel approximation [7] (Ref.15) with the resonance parameter uncertainty of Mugahabghab (Ref.9, p.15), while those of J-4.0 adopted the least-square calculation of Fe-56 experimental data, and corrected the covariance data based on the difference of the least-square-based central values and J-4.0 (Ref.4).

<*Recommendations*>

It would be necessary to ask the plausibility of the Fe-56 elastic covariance data to both J-4.0 and E-7.1 evaluators.

2.10 Fe-56 Mu-bar

The concerned energy region is above 10keV that has meaningful mu-bar values. The covariance data and the STD comparison are shown in Fig.10.

Figure 10 reveals quite a different evaluation of both libraries. In J-4.0, the maximum value of STD is 10%, on the other hand, 35% in E-7.1. The strong negative correlations appear in J-4.0, but not in E-7.1. Further, the correlation factors are a value of +1.0 below 50keV in E-7.1, but not in J-4.0.

According to the documentations, the covariance data of J-4.0 were evaluated with ELIESE3-KALMAN in 1997 (Ref.5, p.8). Those of E-7.1 are supposed to be obtained with Kernel approximation as well as those of the elastic cross-section (Ref.9, p.15). The reason of these large differences between J-4.0 and E-7.1 are unknown.

<*Recommendations*>

[7] There is a description about the correlation evaluation with Kernel approximation in Ref.15, p.32: "Difficult part of establishing correlation coefficients in our procedure consists in the fact that they are not available in Atlas. Making their plausible estimate is therefore one of the most important issues that an evaluator must resolve."

It would be required to make the reason of the large differences clear by both J-4.0 and E-7.1 evaluators. Besides, E-7.1 has only the covariance data of mu-bar for Na-23, Fe-56 and minor actinides, but those of other isotopes such as U-238 are also necessary for the reactor application.

2.11 Na-23 Capture

The energy region pointed is 600eV~600keV that is the upper part of resolved resonance in both libraries, and a part of the continuous energy region only in J-4.0. Figure 11 shows the covariance data and the STD comparison.

In J-4.0, the STD values are around 10% in the energy, on the other hand, 100% in E-7.1, although the cross-section values are very small, the order of milli-barn.

It was reported that the covariance data of J-4.0 were evaluated from the experimental values with the least-square fitting with the GMA code (Ref.5, p.5), while E-7.1 adopted the results of EMPIRE-KALMAN (ref.9, p.14). The 100% STD value of E-7.1 might be a priori guess which was not changed due to the large experimental uncertainty.

<*Recommendations*>

Though this reaction is not important for the reactor application, there would be some concerns from sodium activation viewpoint related to plant maintenance work. It is better to ask the reason of the STD differences between 10% and 100% to both J-4.0 and E-7.1 evaluators.

2.12 Na-23 Inelastic

The treated energy region is above 1MeV where the inelastic cross-section has meaningful values. The covariance data, the STD comparison and the adjusted result of ADJ2010 are in Fig.12.

The facts found from Fig.12 are that the STD values of E-7.1 monotonously decrease from 17% at 1MeV to 5% at 6MeV, on the other hand, those of J-4.0 keep a constant value of 20% until 3MeV, and monotonously decrease to 5% at 6MeV. Consequently, the STD differences of two libraries are more than double in the important 2~3 MeV region.

The following information was obtained. The cross-sections of E-7.1 was evaluated with the EMPIRE code using the RIPL library (Ref.16, p.8), while those of J-4.0 adopted the results of the TNG code (1986), and the first excitation level was multiplied by a factor of 1.25 (Ref.4), according to an analytical result of an integral experimental related to neutron penetration in thick sodium layers at ORNL. The covariance data of both libraries were evaluated with KALMAN (Ref.4, 8), but there are no information related to the large STD differences between J-4.0 and E-7.1. The adjusted result of ADJ2010 shown in Fig.12 (d) designates the large decrease of Na-23 inelastic cross-section.

<*Recommendations*>

It is better to ask the physical reason of the large STD differences to both J-4.0 and E-7.1 evaluators.

2.13 Na-23 Elastic

The energy region discussed is around 2keV with a giant resonance peak. Figure 13 shows the covariance data, the STD comparison and the adjusted result in ADJ2010.

In J-4.0, the STD values at the resonance peak take the maximum value of 17%, on the other hand, those of E-7.1 the minimum value of 1%. Further, the correlations with other energy region at the peak energy are seen in J-4.0, but not in E-7.1.

The physical reason of the large covariance differences between two libraries was interpreted as follows (Ref.17, p.38): In this energy range, there appears a giant resonance peak which significantly affects the sodium-voiding reactivity in sodium-cooled fast reactor cores. As shown in Fig.13, the STD values are extremely different between two libraries, that is, the minimum STD value occurs at the cross-section peak energy in E-7.1, in contrast, the maximum appears there in J-4.0. It can be concluded that the trend of E-7.1 seems more natural, since the larger cross-sections would be more accurate due to the small statistical error in the measurement. The correlations are also quite different. In the E-7.1 covariance, the peak around 2keV has no correlations with other energy, while J-4.0 is partially positive everywhere above 100 eV. The covariance of E-7.1 was evaluated by the the EMPIRE/KALMAN combination, where the prior resonance model parameter uncertainties are derived from Mughabghab (Ref.9, p.14), on the other hand, J-4.0 applies the GMA code with some corrections to meet the measured cross-sections with the evaluated ones of J-4.0 which is based on the multi-level Breit-Wigner formula with rather old resonance parameter values recommended by BNL in 1981 (Ref.14). The central cross-section differences between E-7.1 and J-4.0 are -17~+4% around 2keV, therefore, the differences of the STD values could be reasonable taking into account the corrections given to the J-4.0 covariance data. Only for information, the adjusted result of ADJ2010 is shown in Fig.13 (d).

There are no comments for the covariance data of Na-23 elastic.

3 Concluding Remarks

The latest evaluated nuclear-data libraries such as JENDL-4.0, or ENDF/B-VII.1 supply excellent covariance data from the viewpoints of both quality and quantity. However, it is also true that the evaluation of the covariance data has not yet been matured or converged on the satisfactory level in their application, therefore, the close communication on the evaluation of the covariance data is indispensable between the nuclear-data evaluators and users. The recommendations made in the present section are the first trial of WPEC/SG39 to launch such conversations. We believe that the continuous efforts at this kind of activity could improve the reliability and accountability of the evaluated covariance data in near future.

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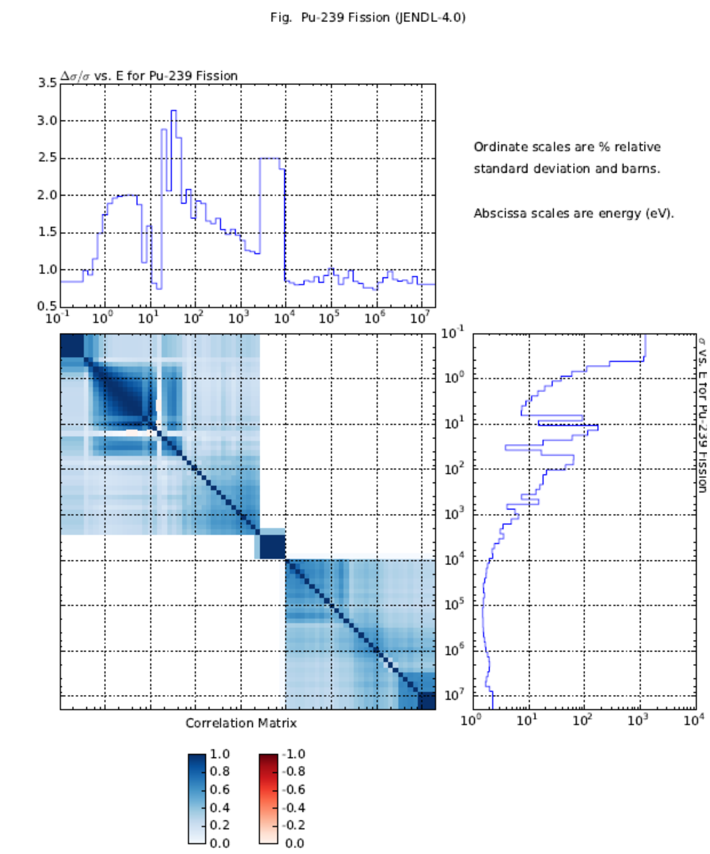
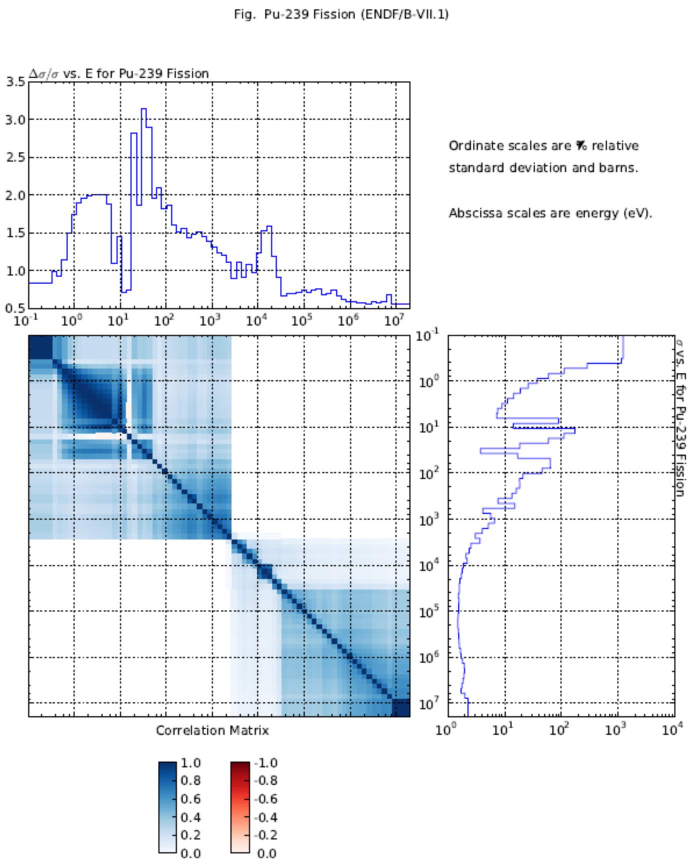
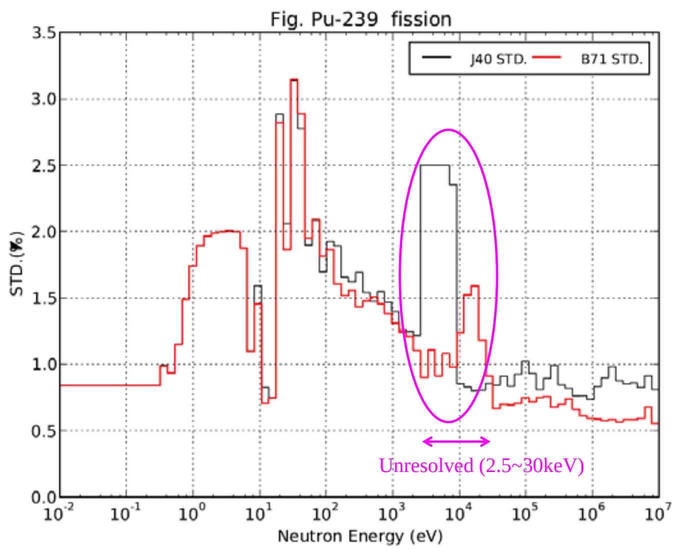


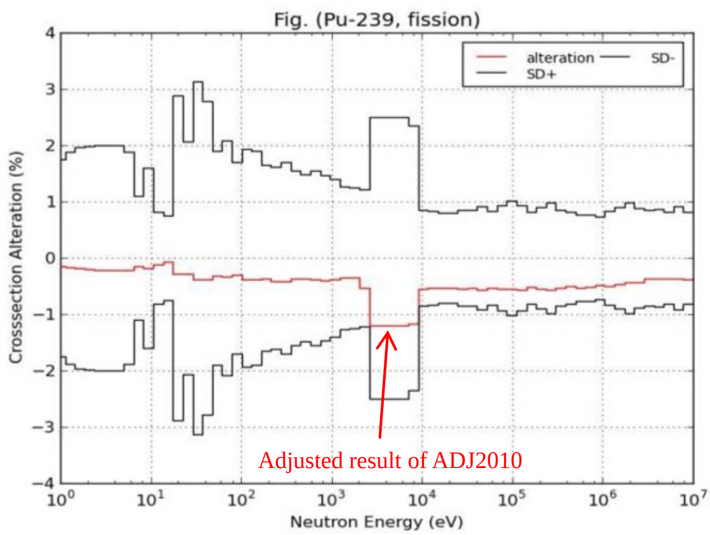
(a) JENDL-4.0



(b) ENDF/B-VII.1

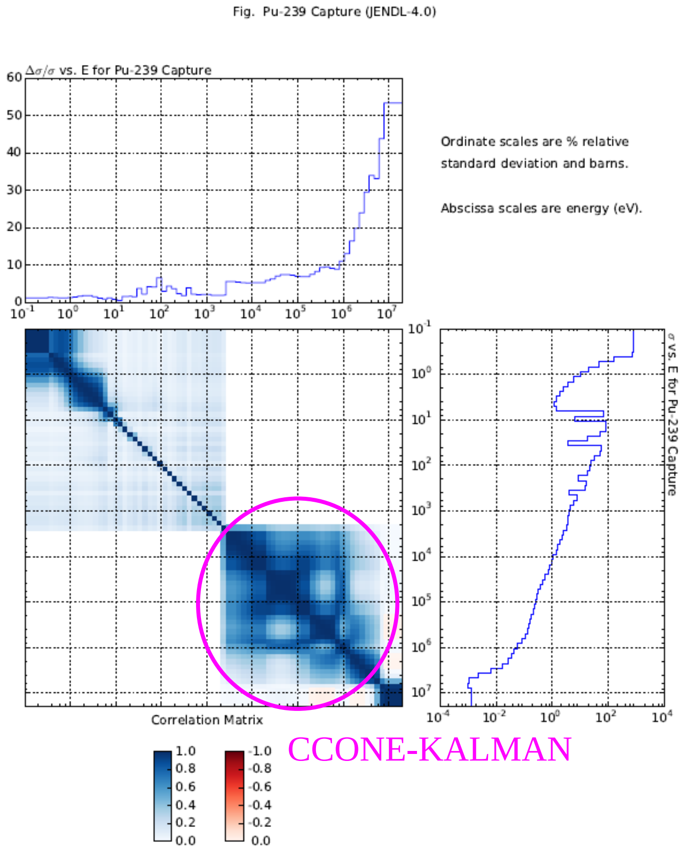


(c) Comparison of Standard Deviation

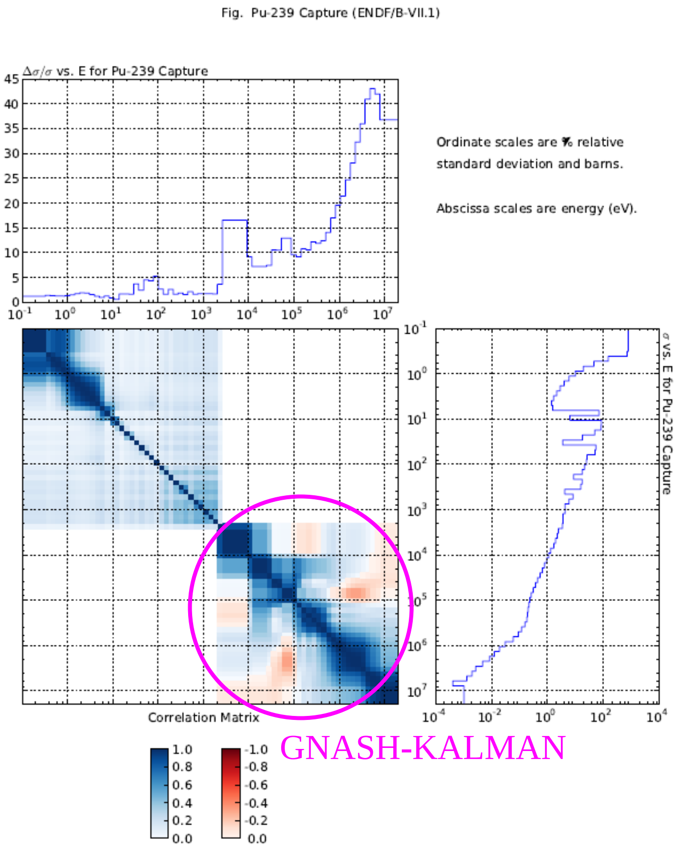


(d) Alteration of Pu-239 fission cross-section by the adjustment based on JENDL-4.0

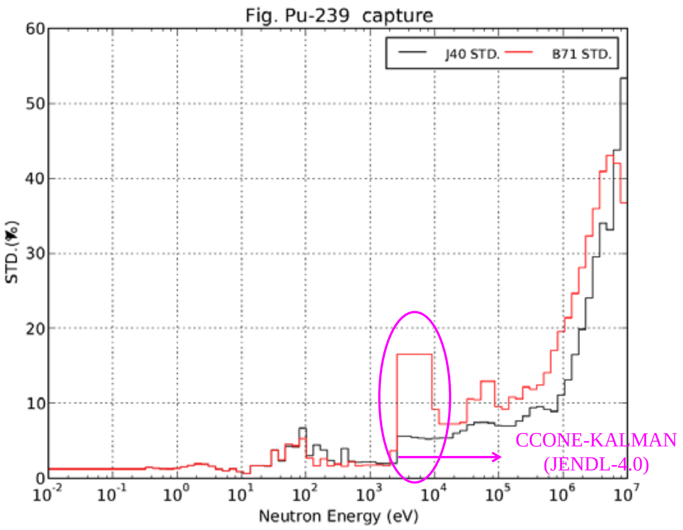
Figure 1 JENDL-4.0 and ENDF/B-VII.1 Covariance - Pu-239 Fission -



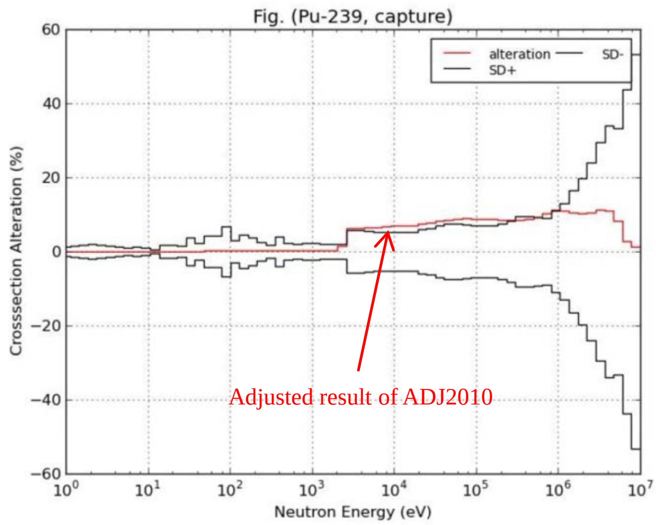
(a) JENDL-4.0



(b) ENDF/B-VII.1

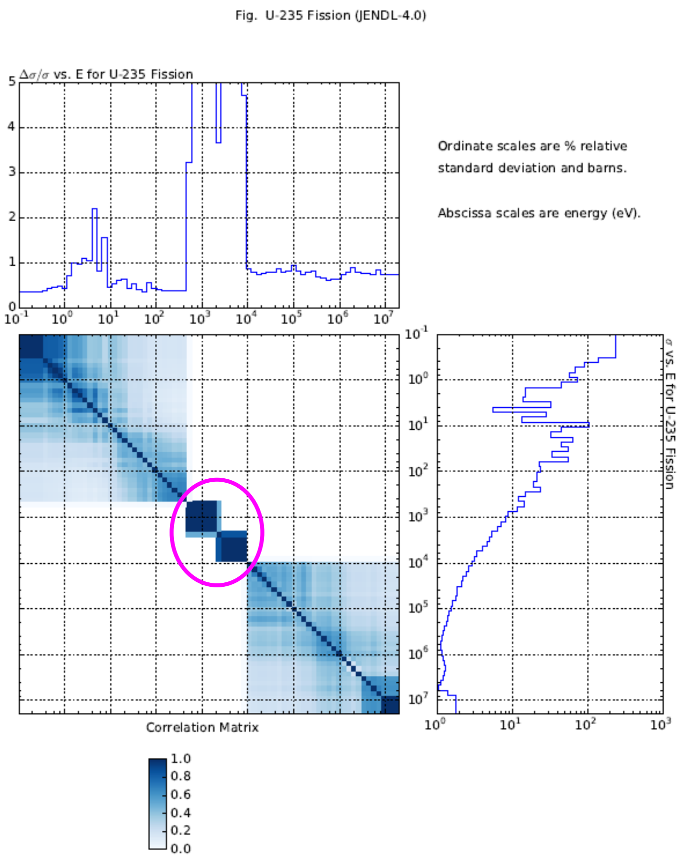


(c) Comparison of Standard Deviation

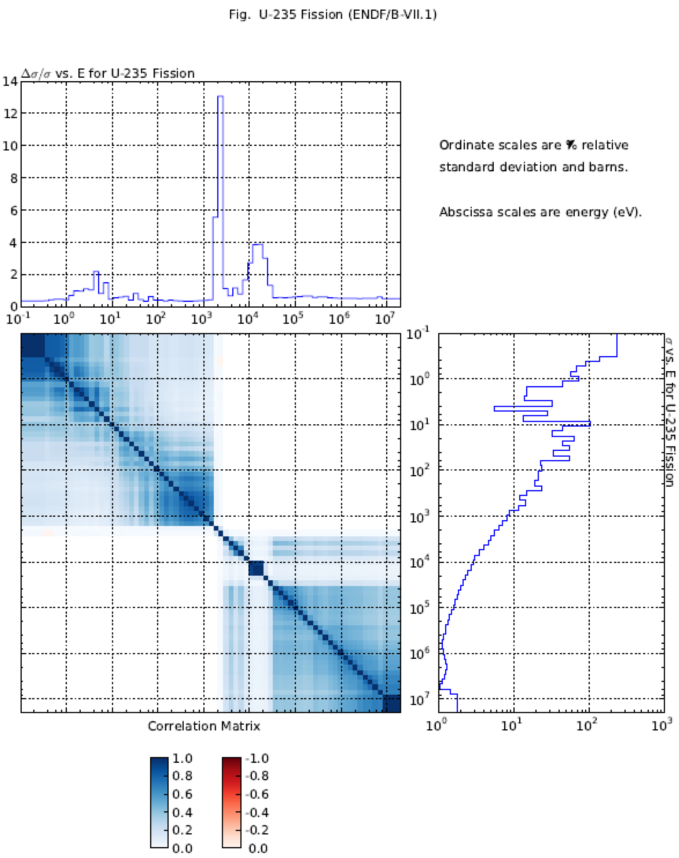


(d) Alteration of Pu-239 capture cross-section by the adjustment based on JENDL-4.0

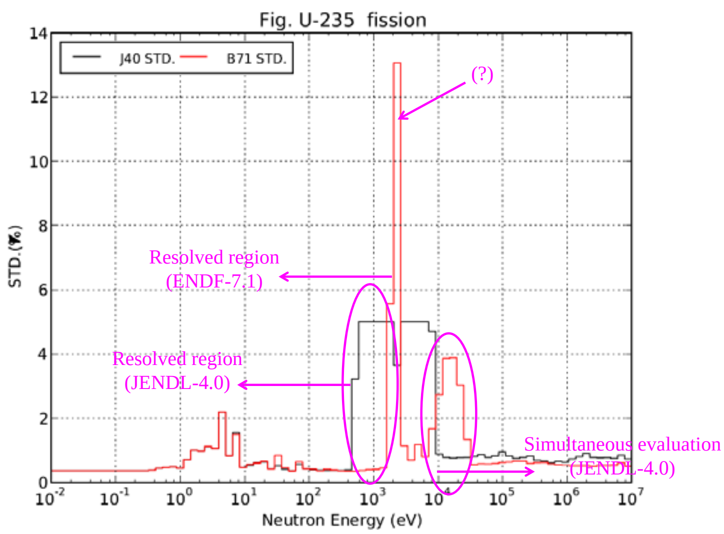
Figure 2 JENDL-4.0 and ENDF/B-VII.1 Covariance - Pu-239 Capture -



(a) JENDL-4.0

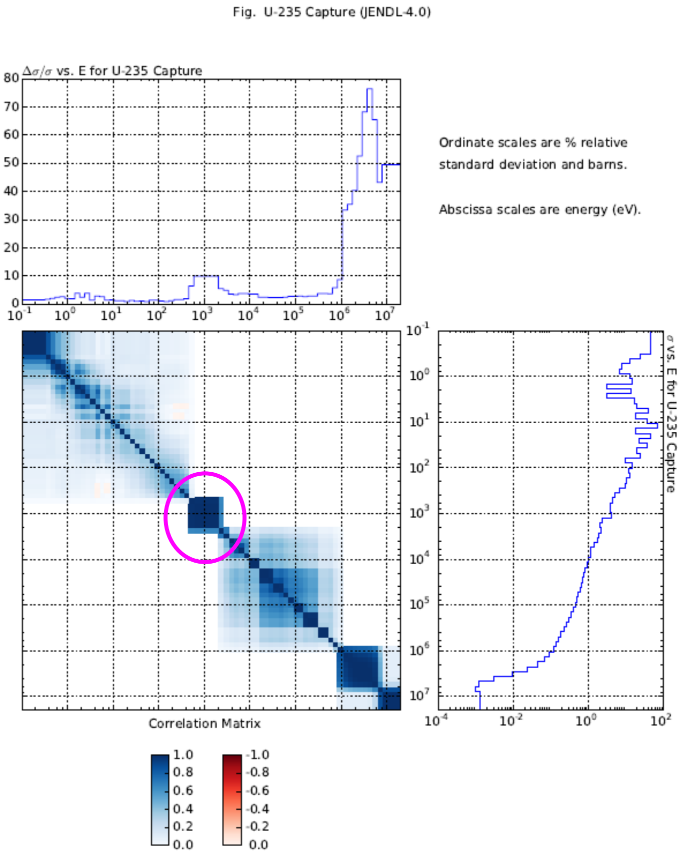


(b) ENDF/B-VII.1

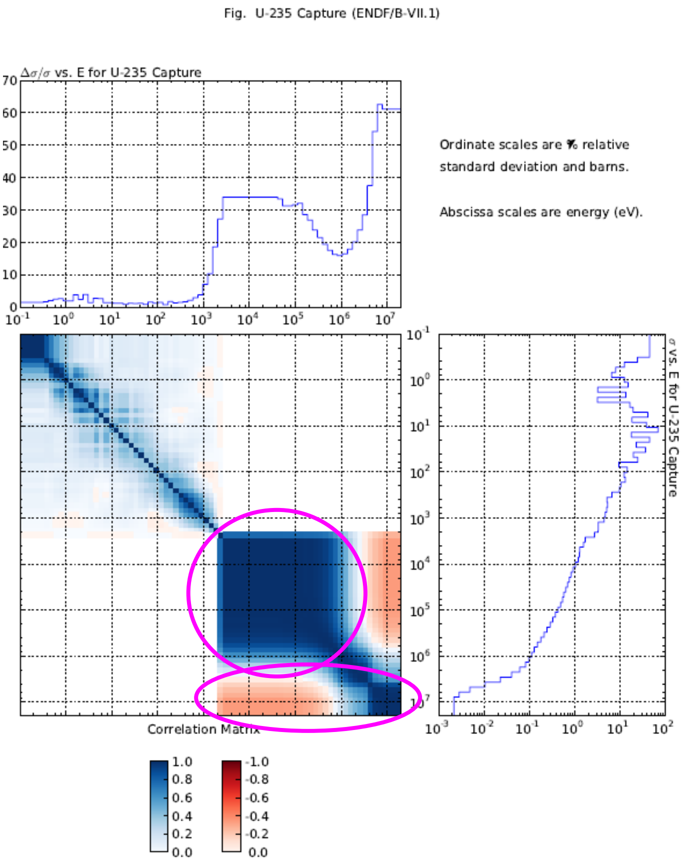


(c) Comparison of Standard Deviation

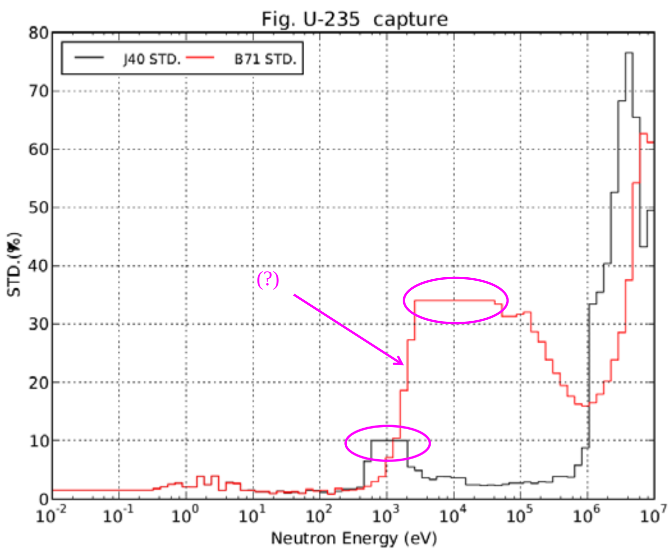
Figure 3 JENDL-4.0 and ENDF/B-VII.1 Covariance - U-235 Fission -



(a) JENDL-4.0

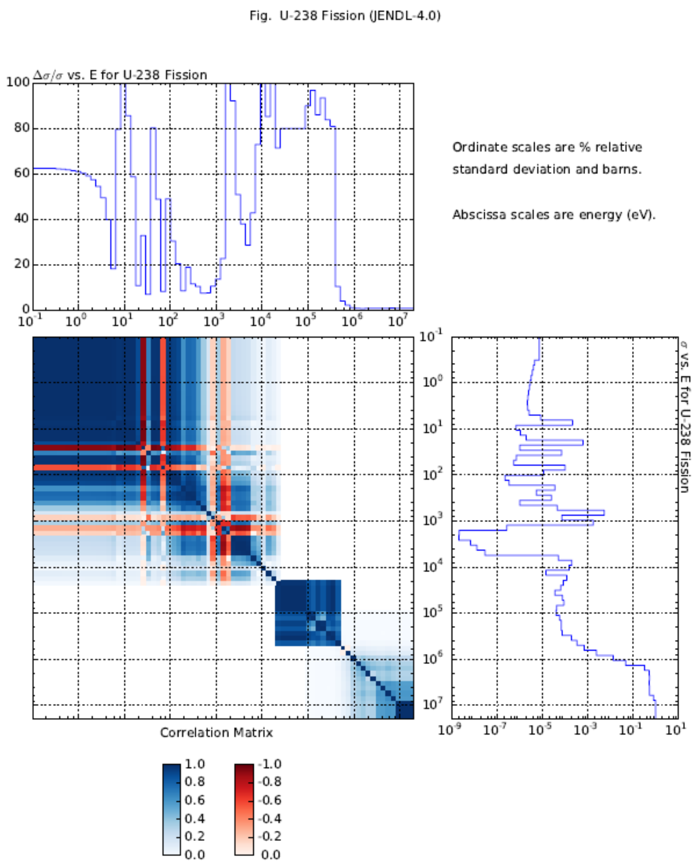


(b) ENDF/B-VII.1

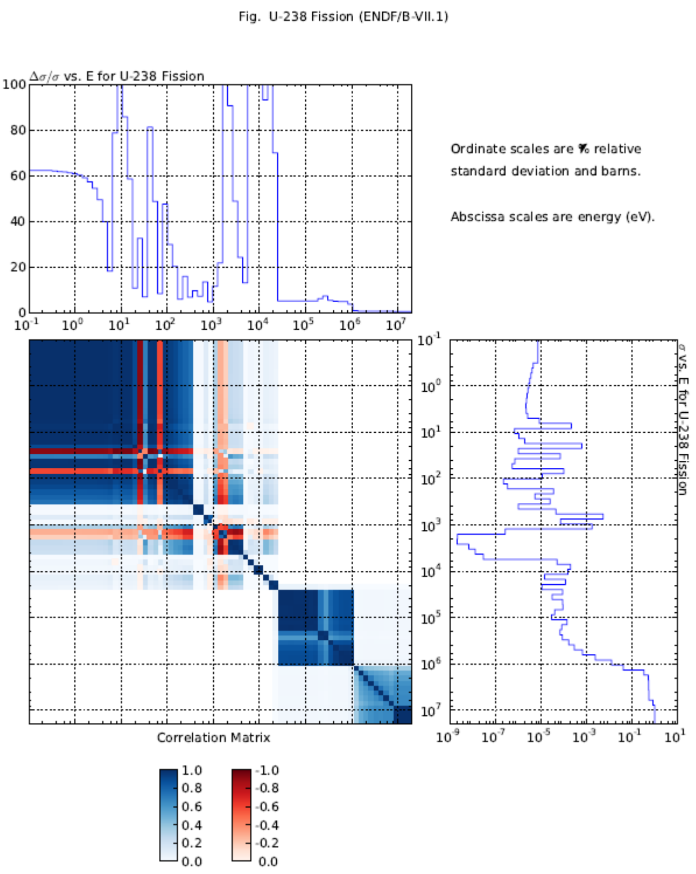


(c) Comparison of Standard Deviation

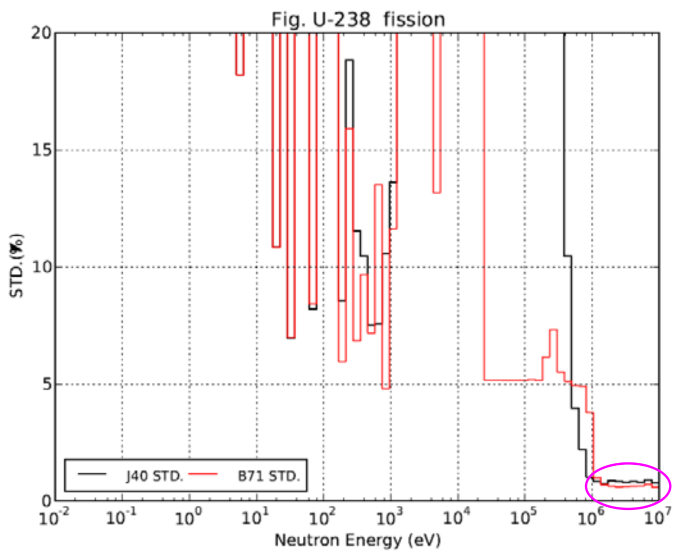
Figure 4 JENDL-4.0 and ENDF/B-VII.1 Covariance - U-235 Capture -



(a) JENDL-4.0

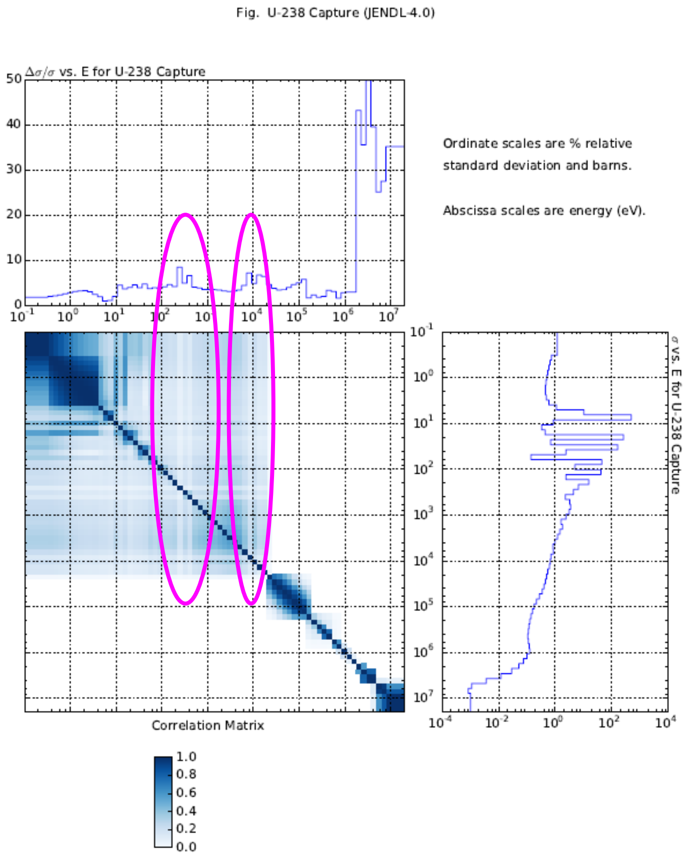


(b) ENDF/B-VII.1

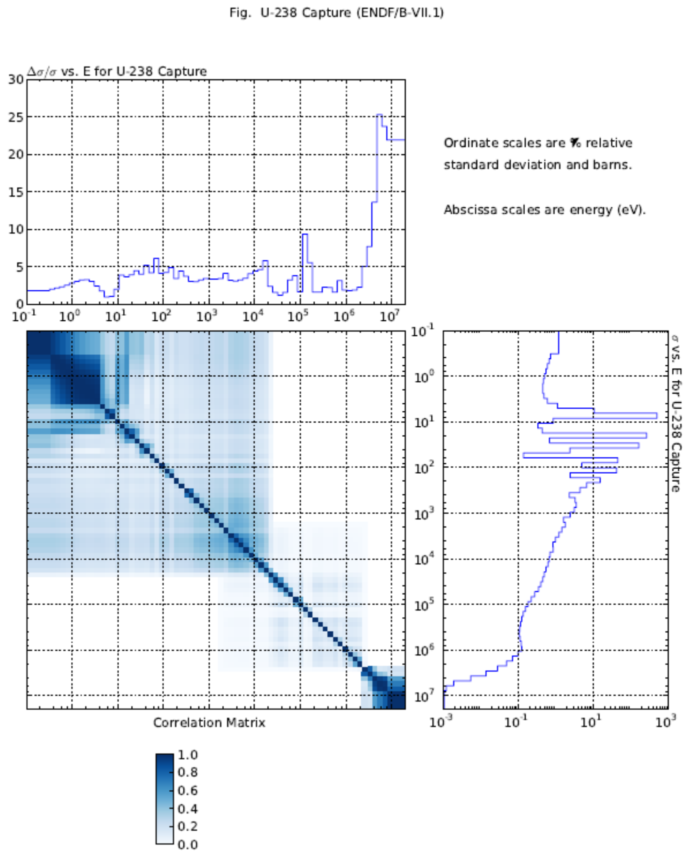


(c) Comparison of Standard Deviation

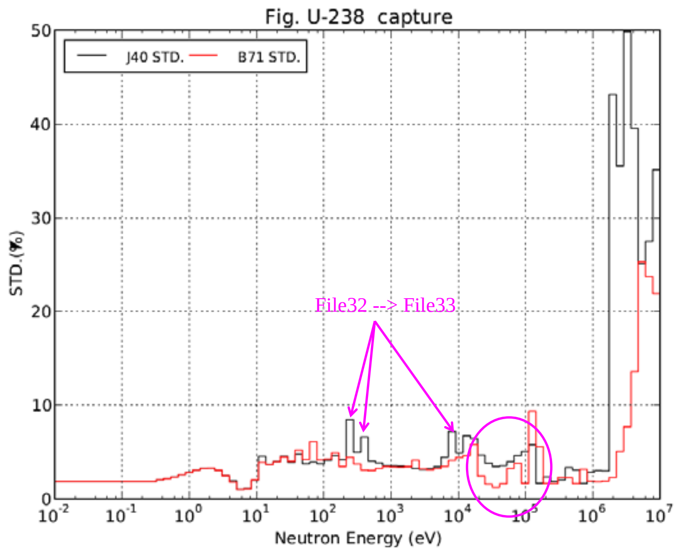
Figure 5 JENDL-4.0 and ENDF/B-VII.1 Covariance - U-238 Fission -



(a) JENDL-4.0

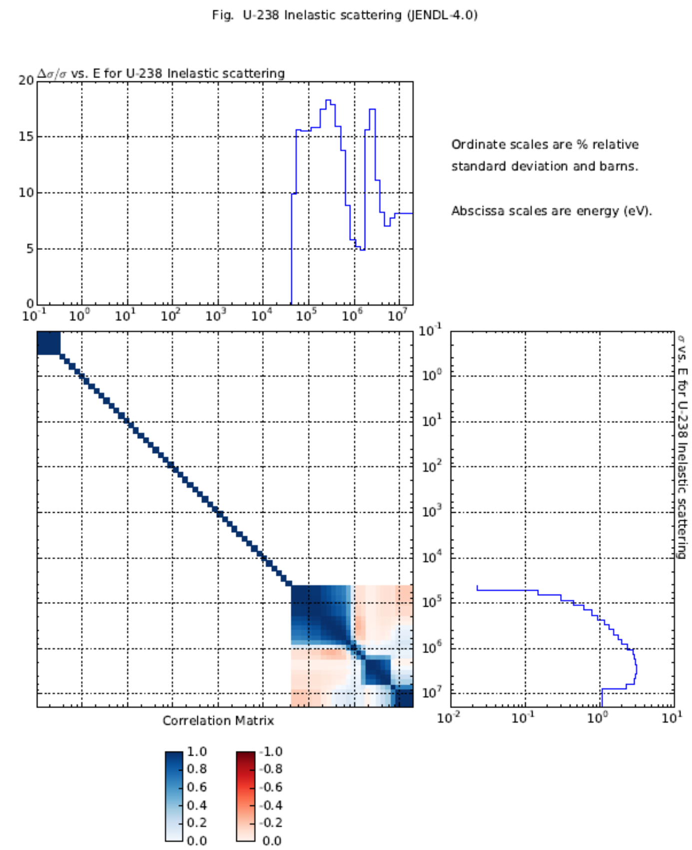


(b) ENDF/B-VII.1

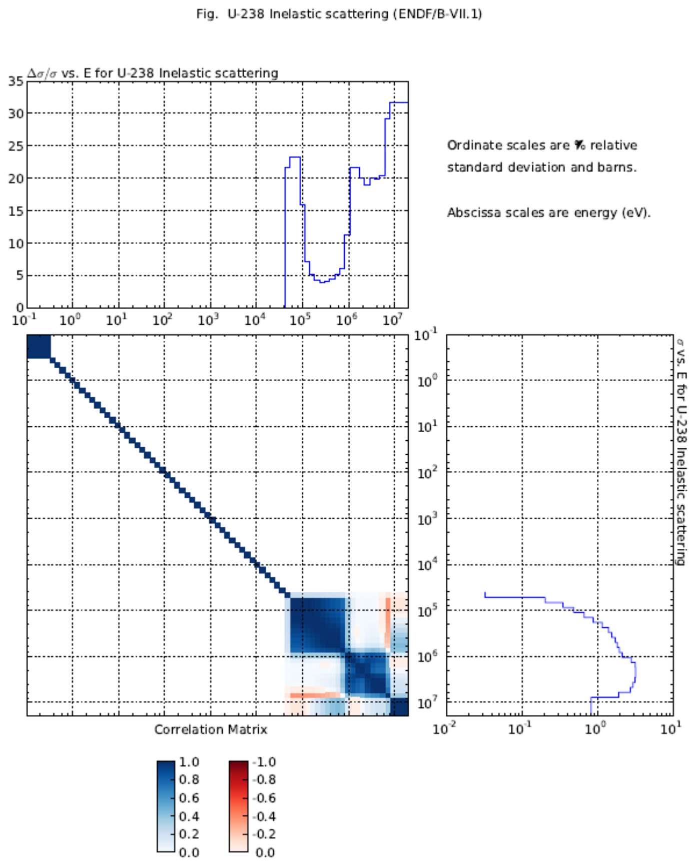


(c) Comparison of Standard Deviation

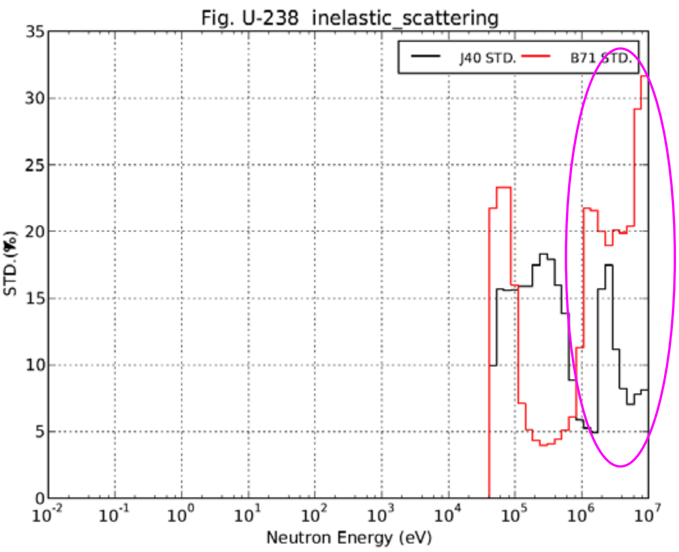
Figure 6 JENDL-4.0 and ENDF/B-VII.1 Covariance - U-238 Capture -



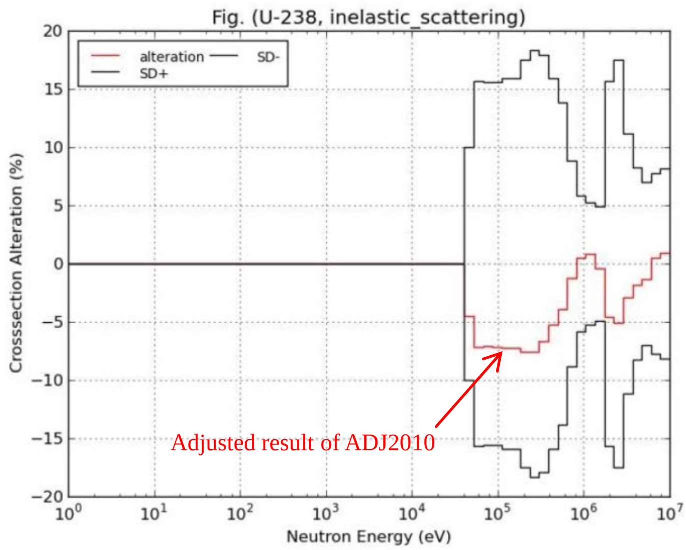
(a) JENDL-4.0



(b) ENDF/B-VII.1

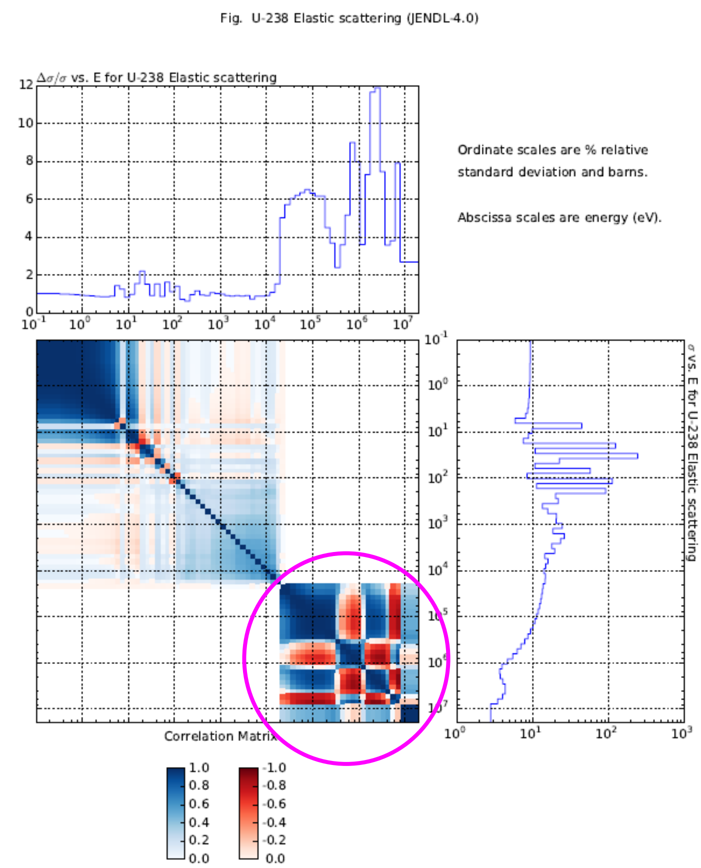


(c) Comparison of Standard Deviation

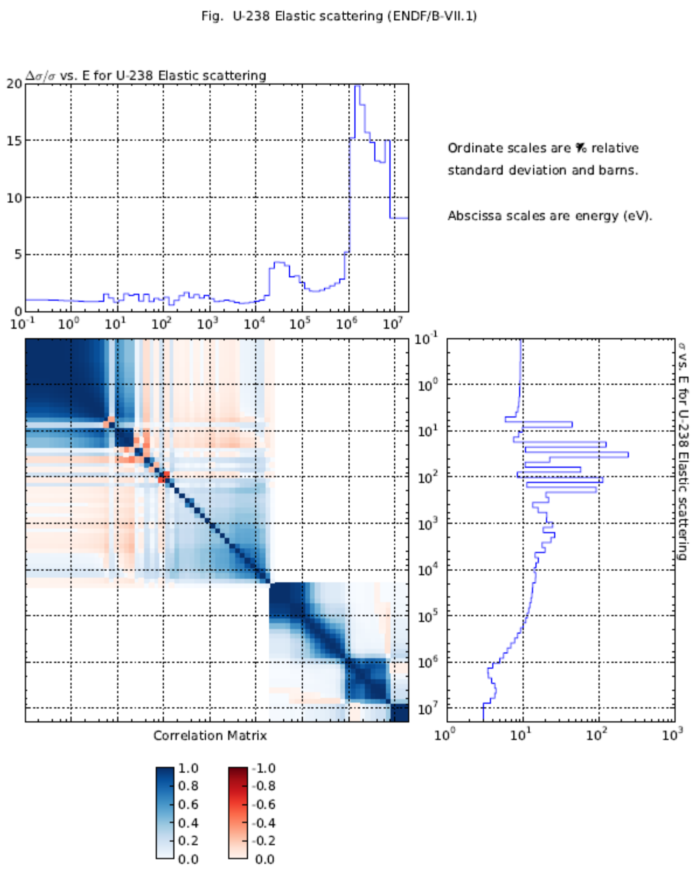


(d) Alteration of U-238 inelastic cross-section by the adjustment based on JENDL-4.0

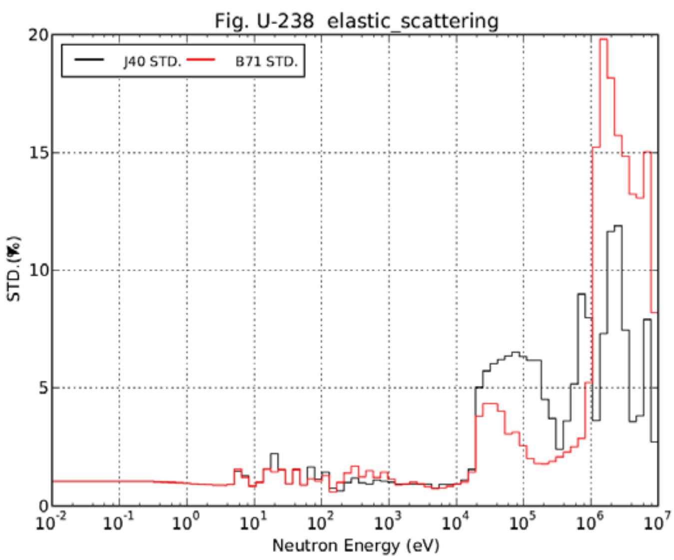
Figure 7 JENDL-4.0 and ENDF/B-VII.1 Covariance - U-238 Inelastic -



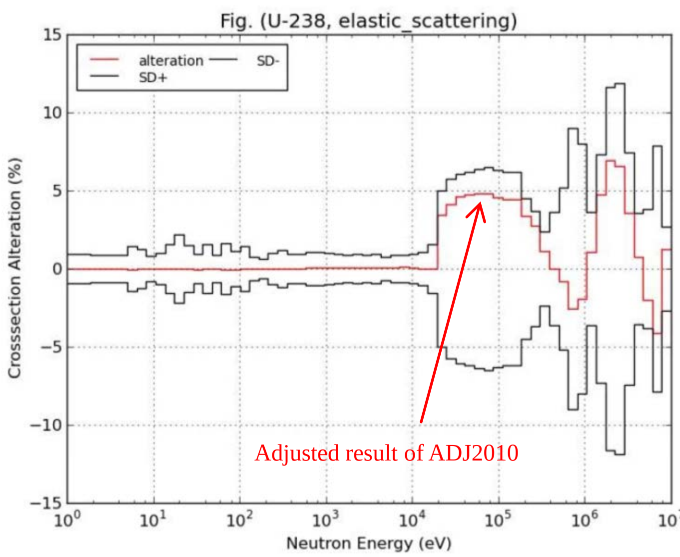
(a) JENDL-4.0



(b) ENDF/B-VII.1

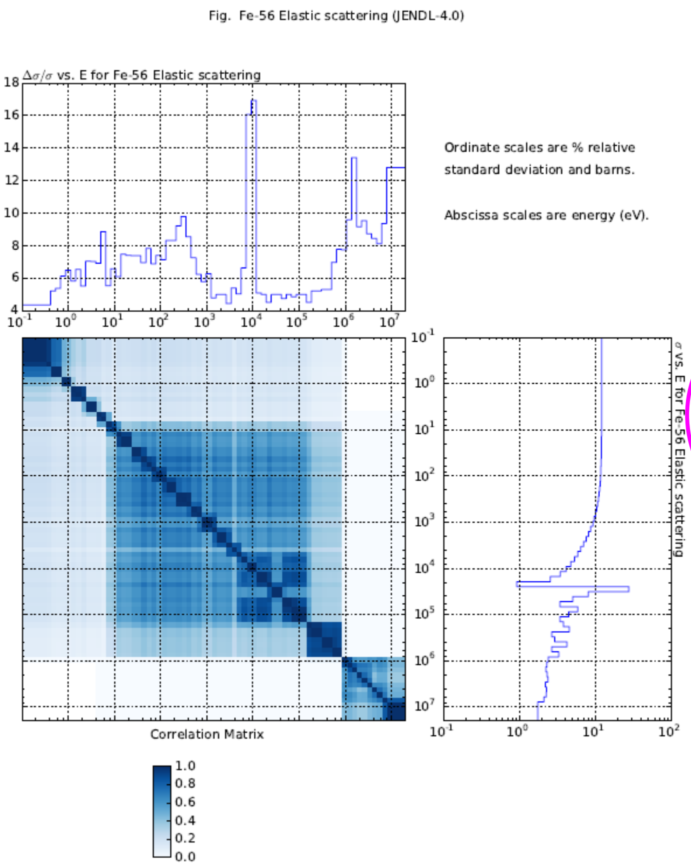


(c) Comparison of Standard Deviation

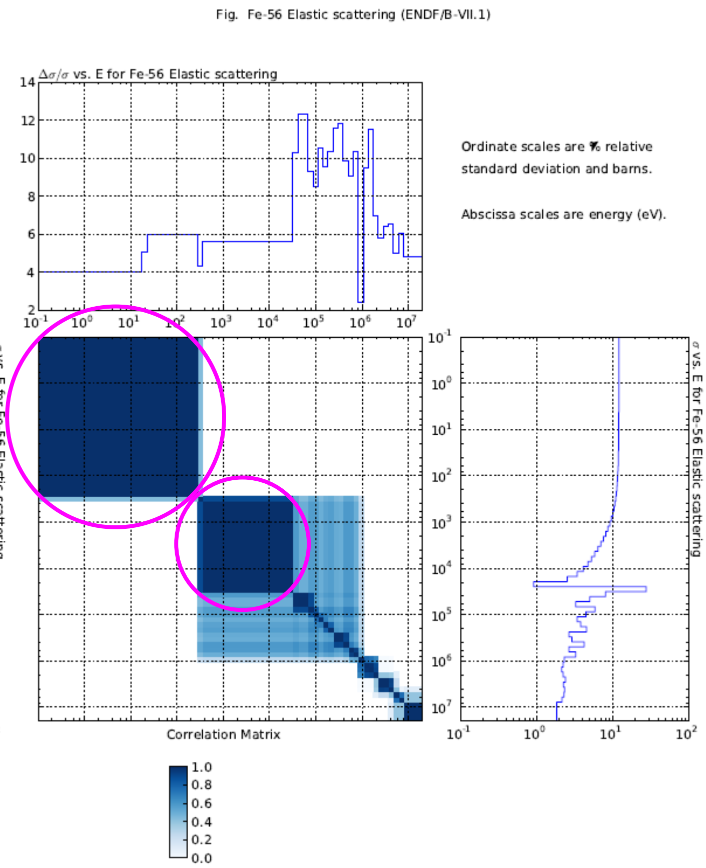


(d) Alteration of U-238 elastic cross-section by the adjustment based on JENDL-4.0

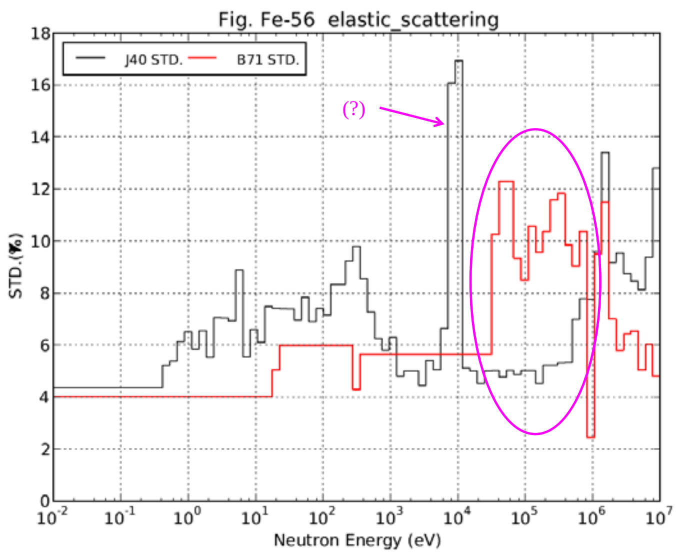
Figure 8 JENDL-4.0 and ENDF/B-VII.1 Covariance - U-238 Elastic -



(a) JENDL-4.0

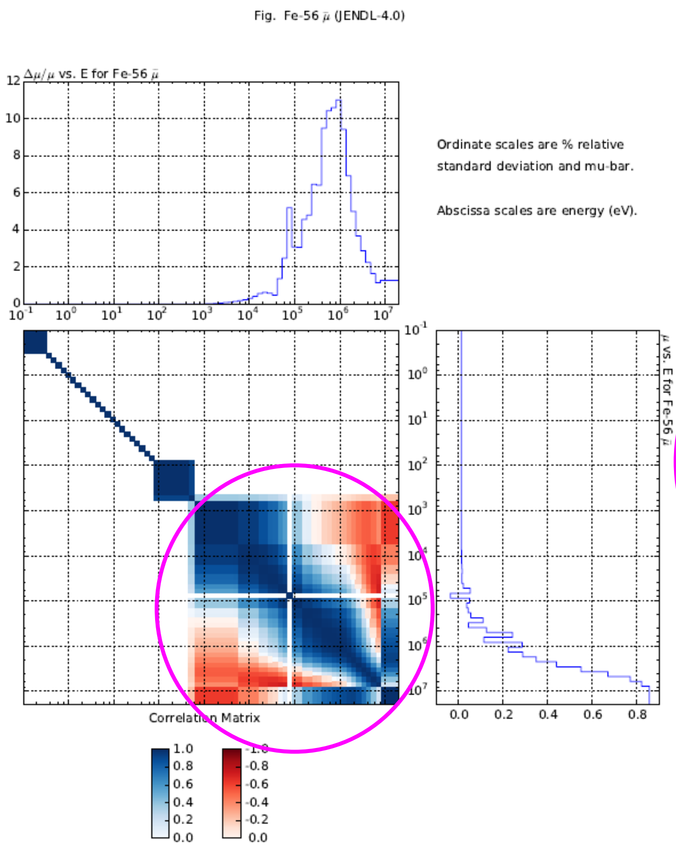


(b) ENDF/B-VII.1

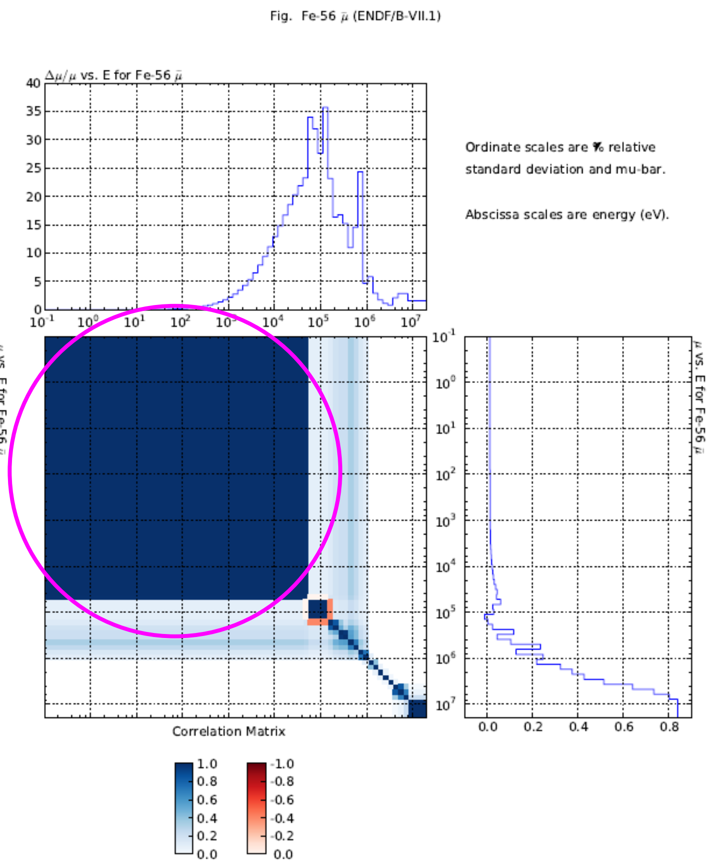


(c) Comparison of Standard Deviation

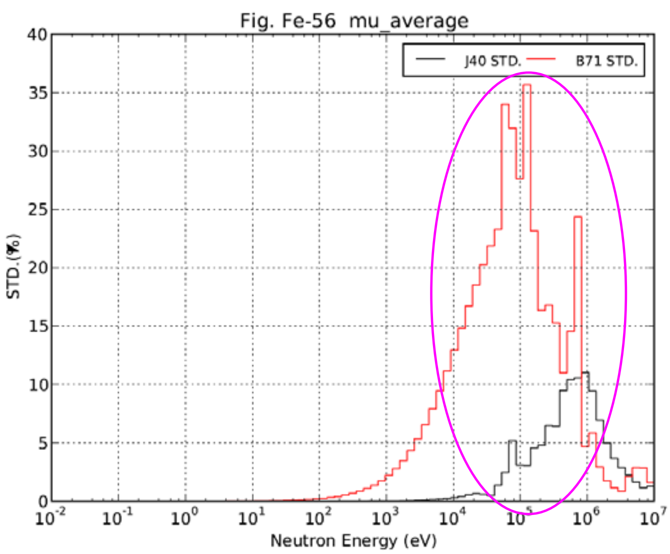
Figure 9 JENDL-4.0 and ENDF/B-VII.1 Covariance - Fe-56 Elastic -



(a) JENDL-4.0

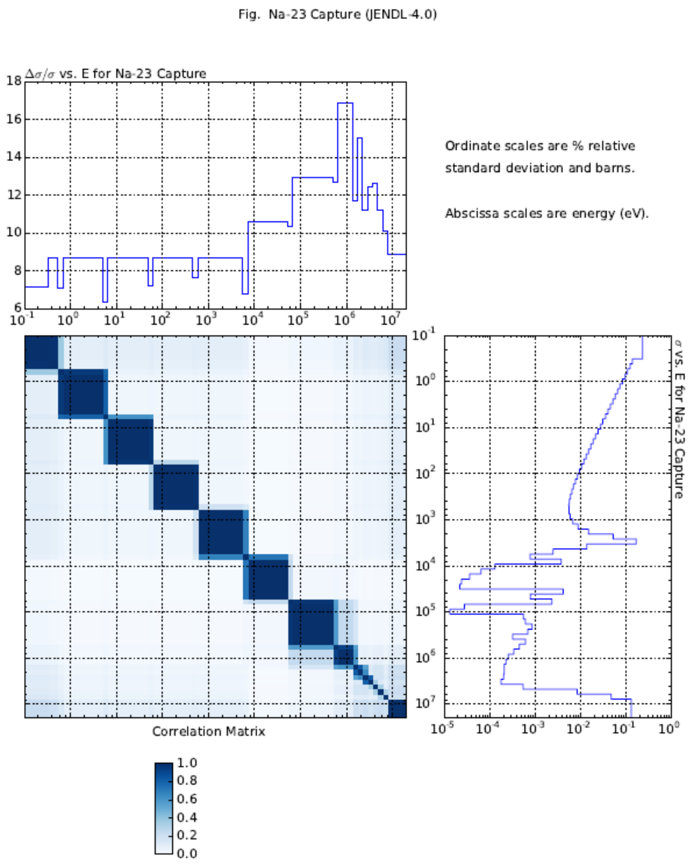


(b) ENDF/B-VII.1

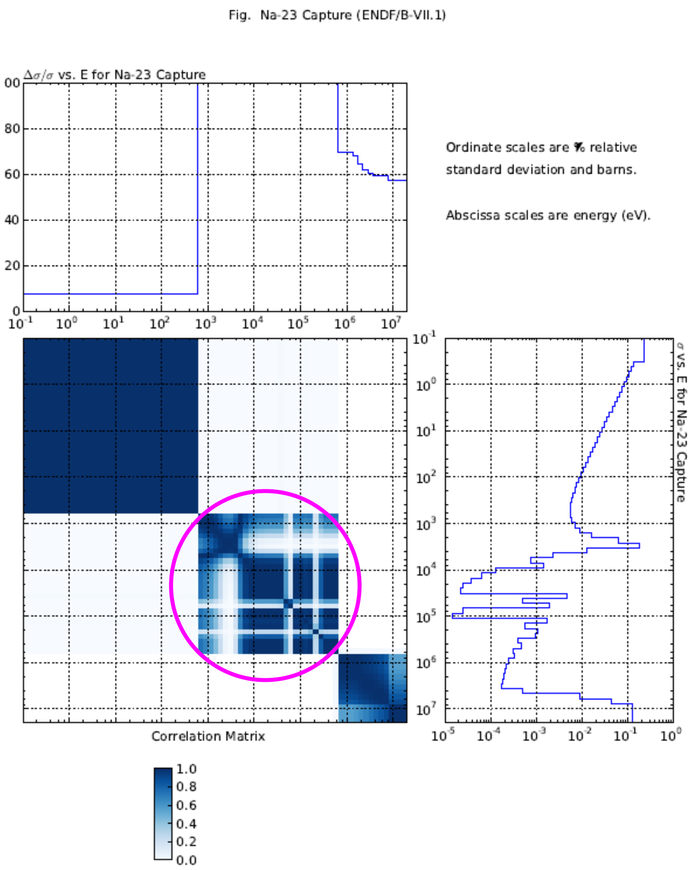


(c) Comparison of Standard Deviation

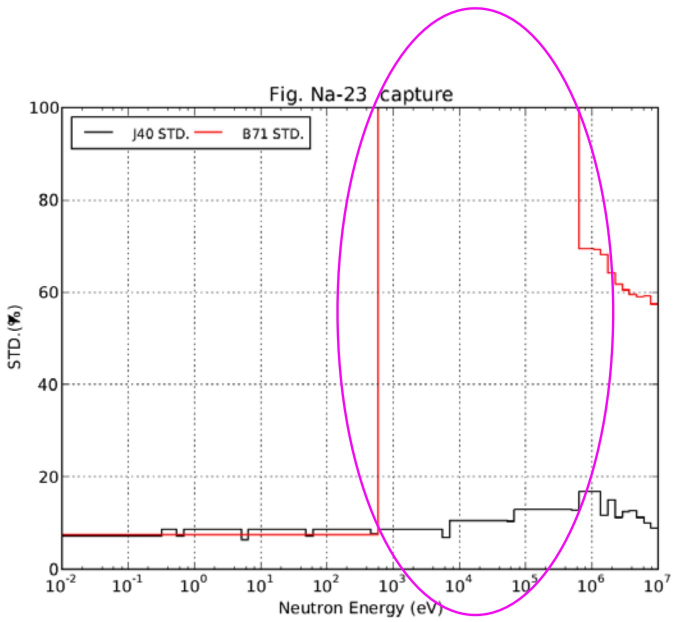
Figure 10 JENDL-4.0 and ENDF/B-VII.1 Covariance - Fe-56 Mu-bar -



(a) JENDL-4.0

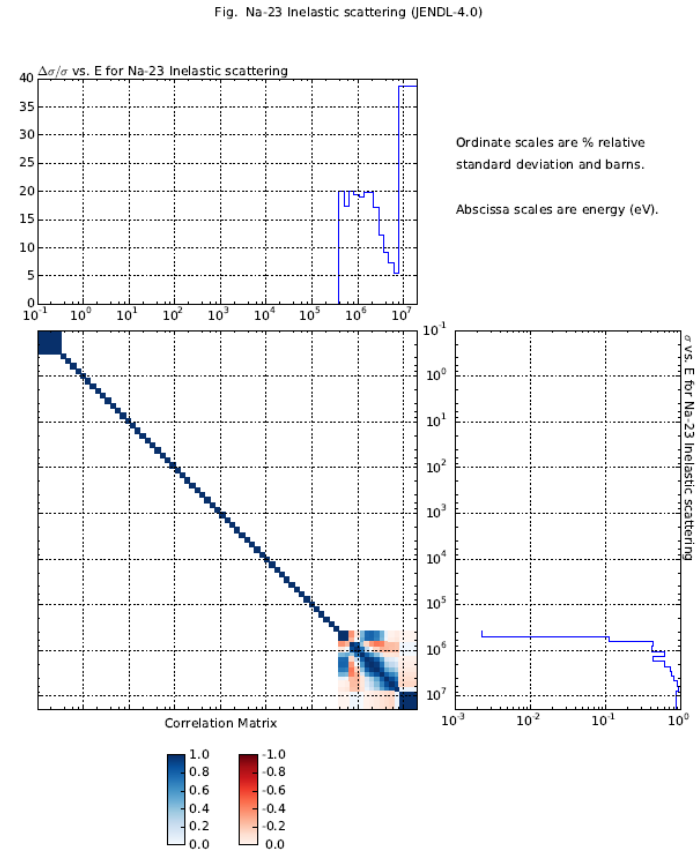


(b) ENDF/B-VII.1

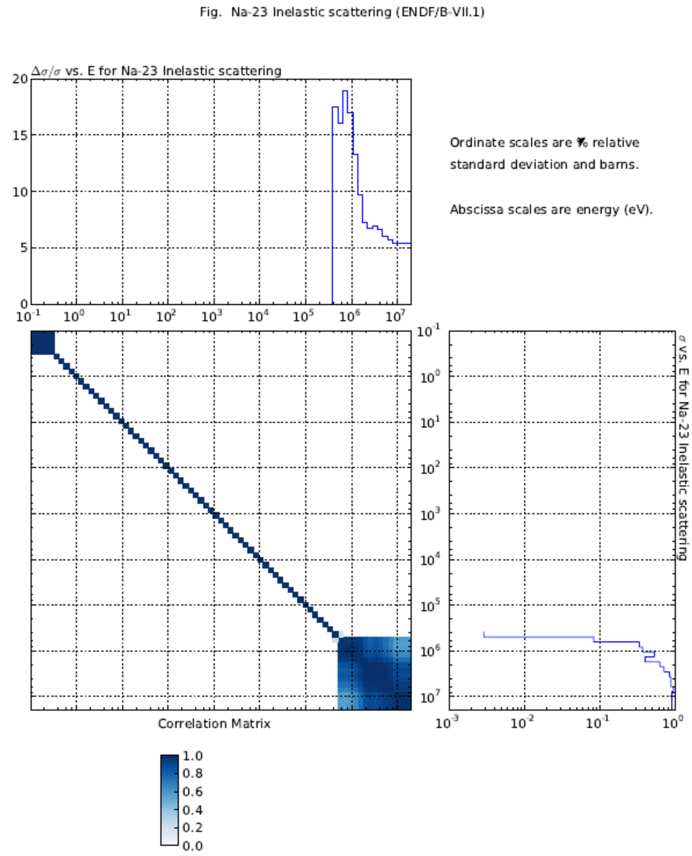


(c) Comparison of Standard Deviation

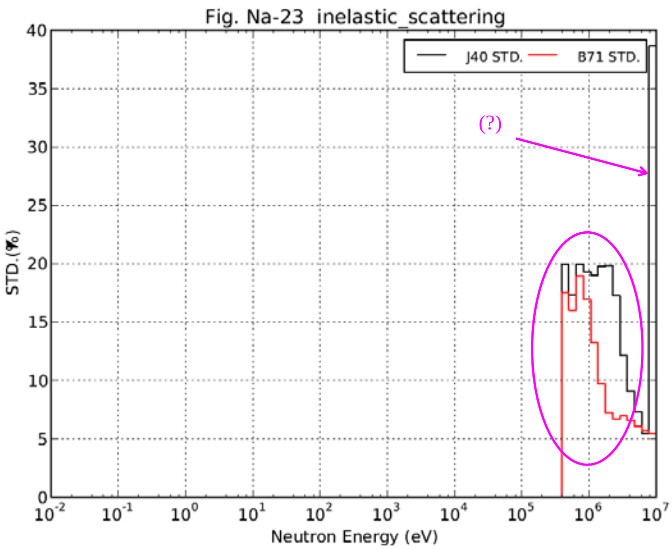
Figure 11 JENDL-4.0 and ENDF/B-VII.1 Covariance - Na-23 Capture -



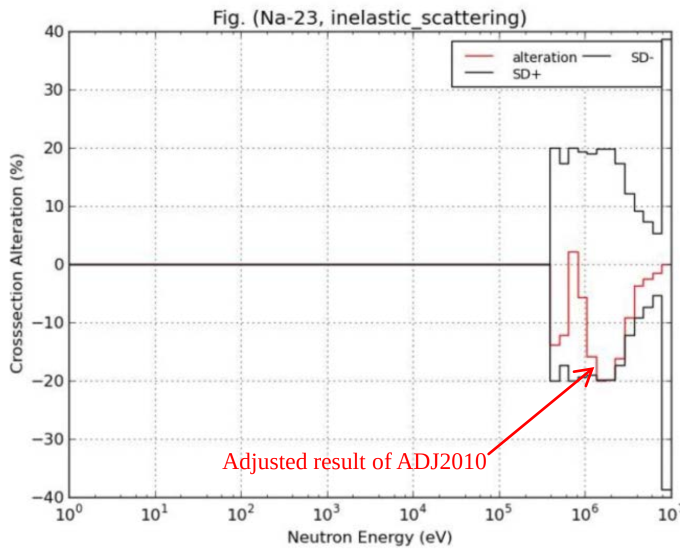
(a) JENDL-4.0



(b) ENDF/B-VII.1

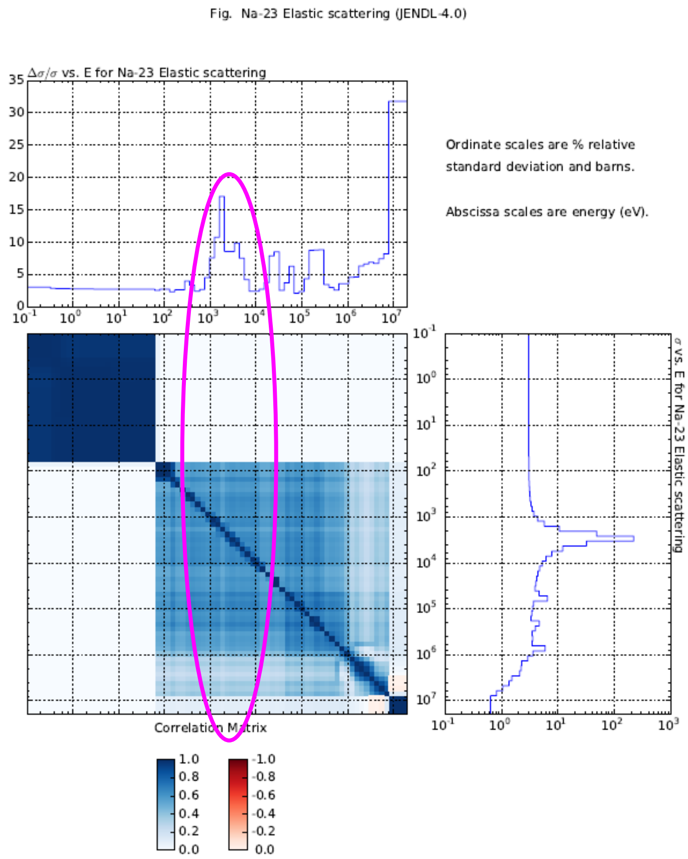


(c) Comparison of Standard Deviation

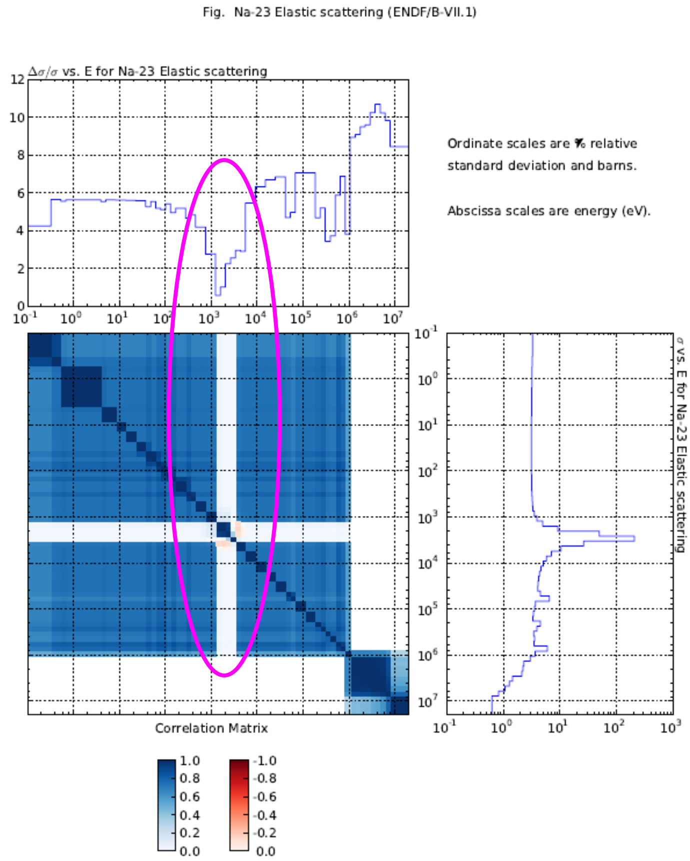


(d) Alteration of Na-23 inelastic cross-section by the adjustment based on JENDL-4.0

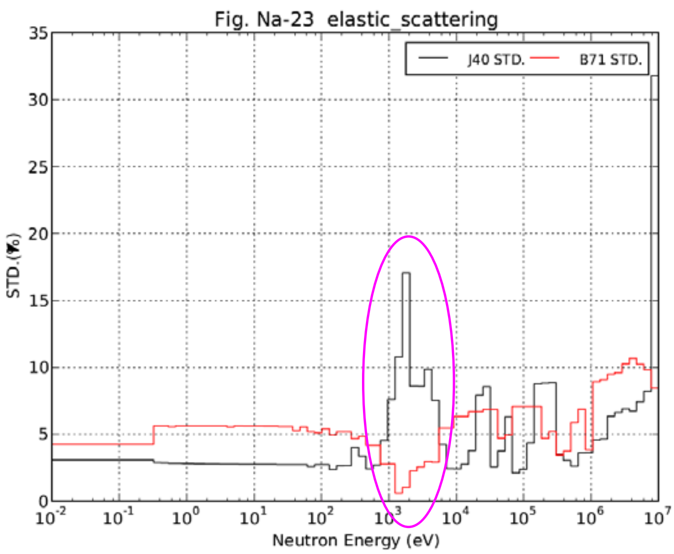
Figure 12 JENDL-4.0 and ENDF/B-VII.1 Covariance - Na-23 Inelastic -



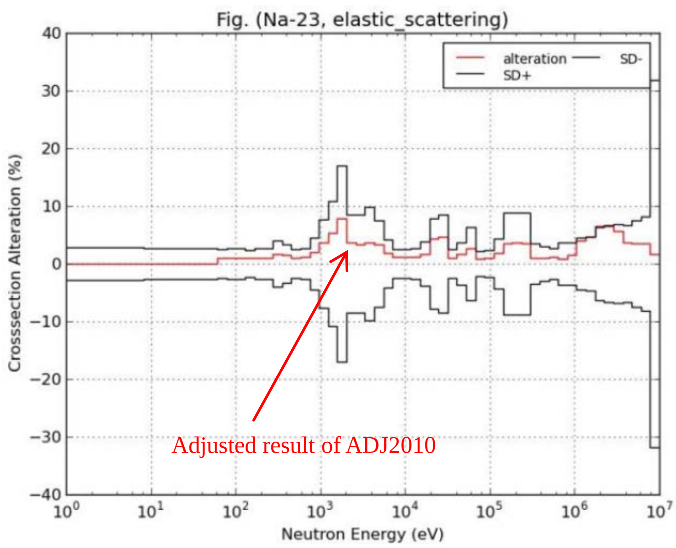
(a) JENDL-4.0



(b) ENDF/B-VII.1



(c) Comparison of Standard Deviation



(d) Alteration of Na-23 elastic cross-section by the adjustment based on JENDL-4.0

Figure 13 JENDL-4.0 and ENDF/B-VII.1 Covariance - Na-23 Elastic -