Kick-off Meeting of WPEC Subgroup 39 on
Methods and approaches to provide feedback from nuclear and covariance data adjustment for improvement of nuclear data files

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Recommendations from ADJ2010 Adjustment

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Introduction

ADJ2010 is a 70-group adjusted library based on JENDL-4.0, where 488 integral experimental data from 8 facilities (ZPPR, ZEBRA, JOYO, MONJU, BFS, MASURCA, SEFOR and Los Alamos) were used for the adjustment.

Here, the major alteration of nuclear data by the adjustment is summarized for 5 nuclides (Pu-239, U-238, U-235, Fe-56 and Na-23), and compared with ENDF/B-VII.1 and JEFF-3.1.2.

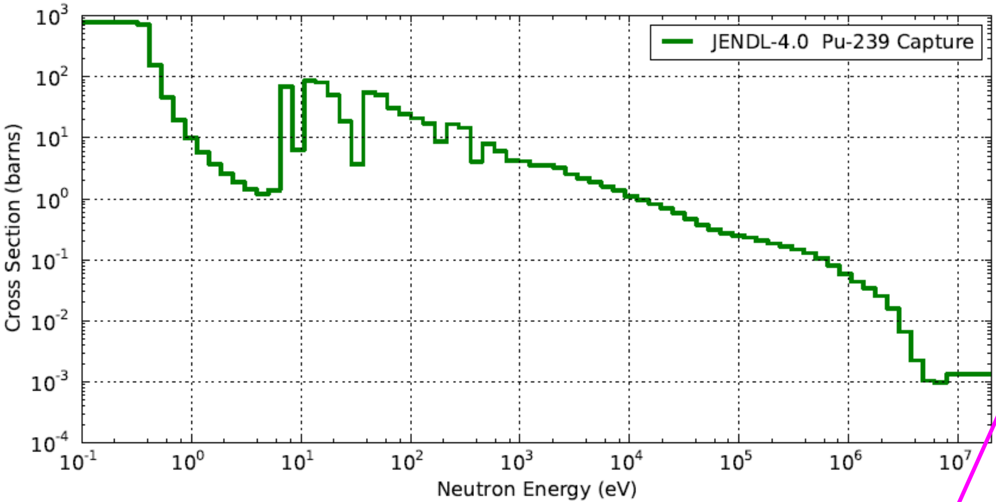
Finally, we try to make some recommendations to nuclear-data evaluators, though it is not mature.

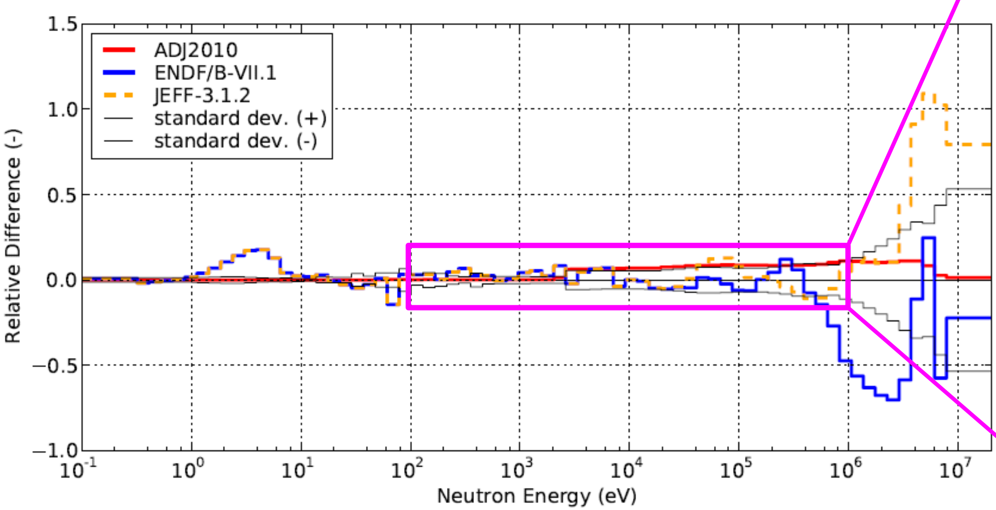
A thick report of ADJ2010 is available from the URL below with the huge numerical results in digital files.

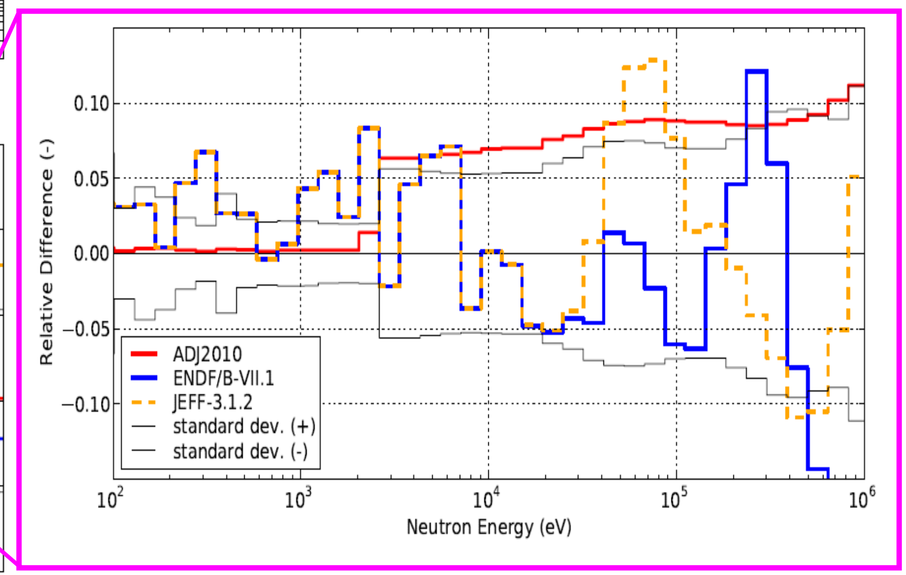
http://jolissrch-inter.tokai-sc.jaea.go.jp/search/servlet/search?5035118&language=1

Pu-239

Pu-239 Capture





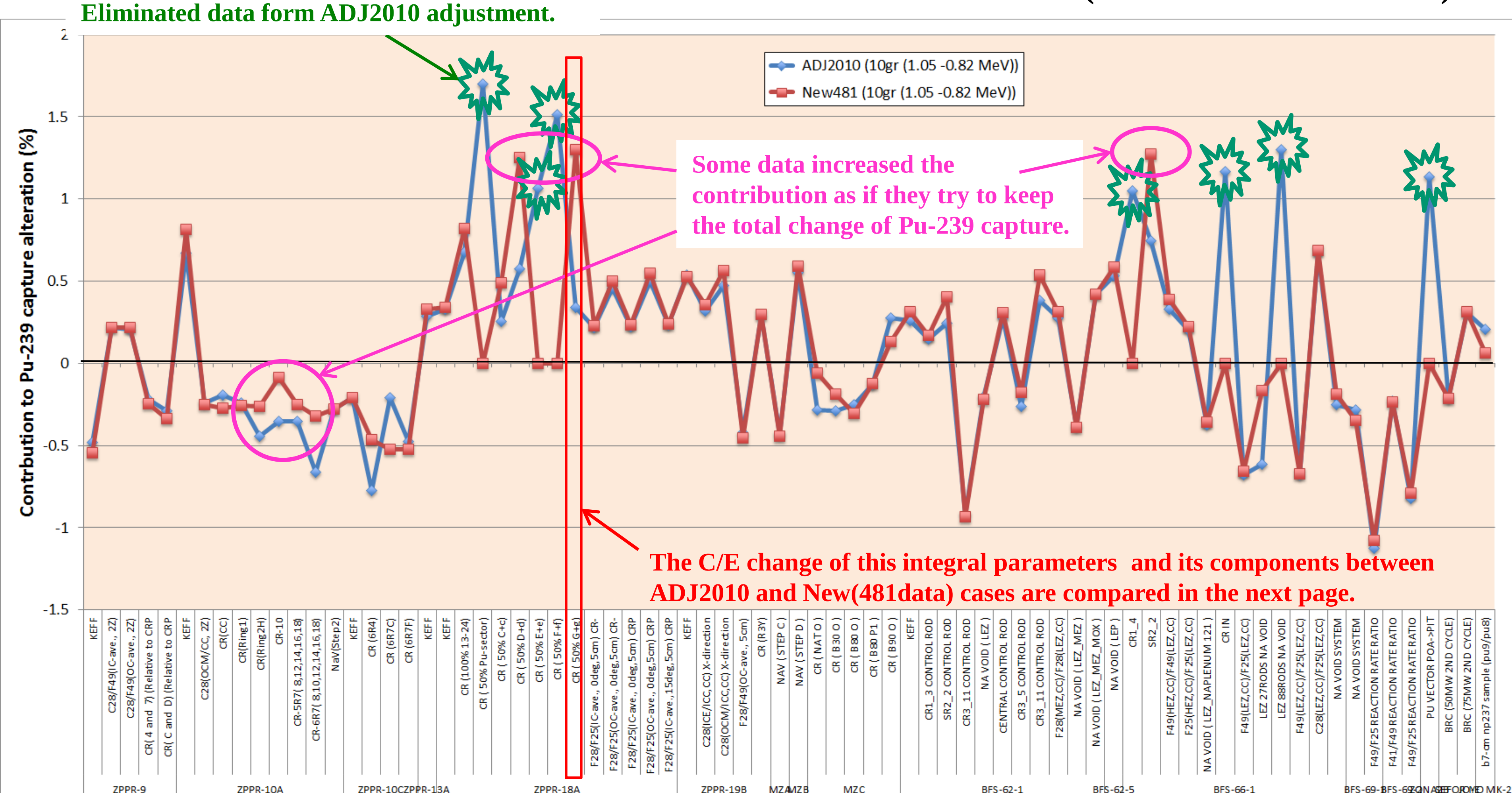


- ADJ2010 increases Pu-239 capture cross-section over 3keV by 7 to 9%. This large alteration is at the variance bound of JENDL-4, but agrees with NEITHER of the three major libraries. The mechanism of increase is NOT known. -> next slide.
- Present measured data are quite old before 1976. New DANCE data will be published soon.

< from e-mail sent to SG33 members (May 31, 2013) >

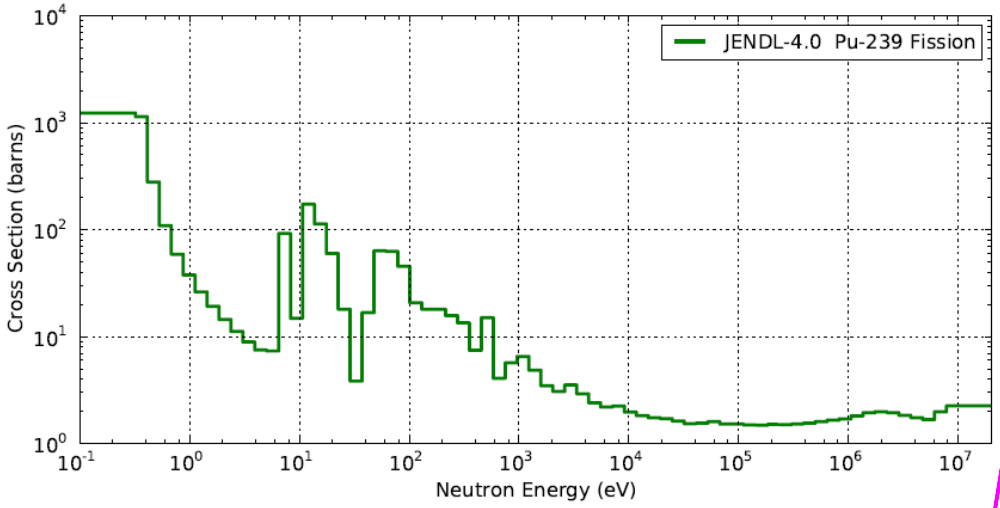
Integral Data contributing to Pu-239 Capture Change

(* Data more than 0.2 %)

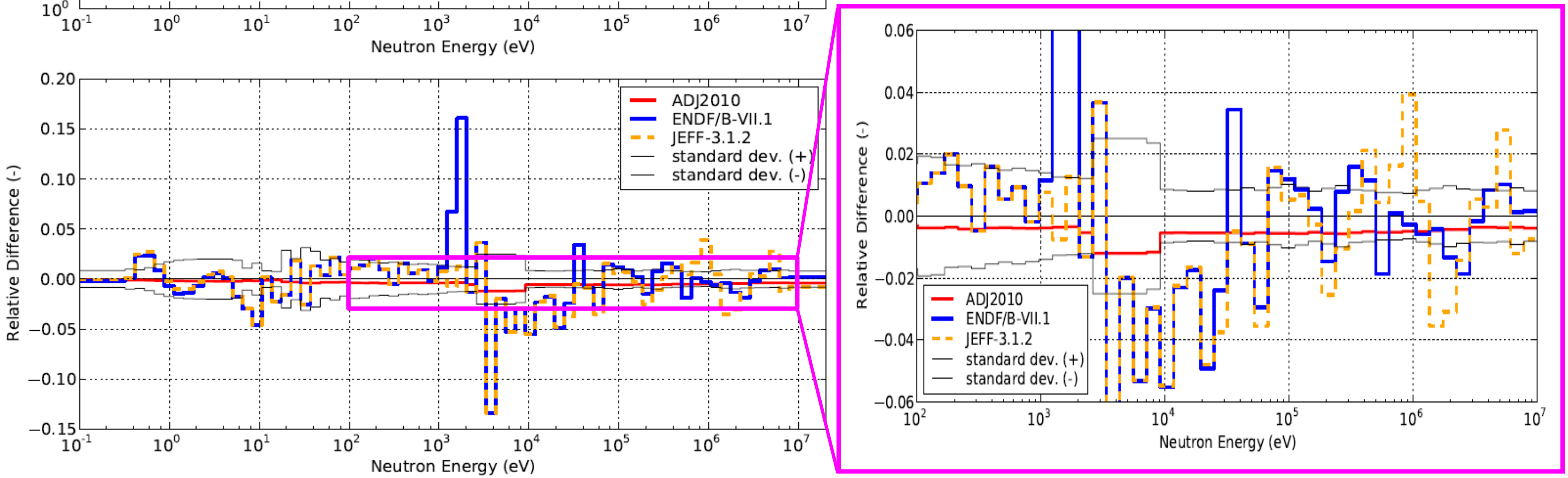


■ $T' - T_0 = MG^t[GMG^t+Ve+Vm]^{-1}[Re-Rc(T_0)]$.

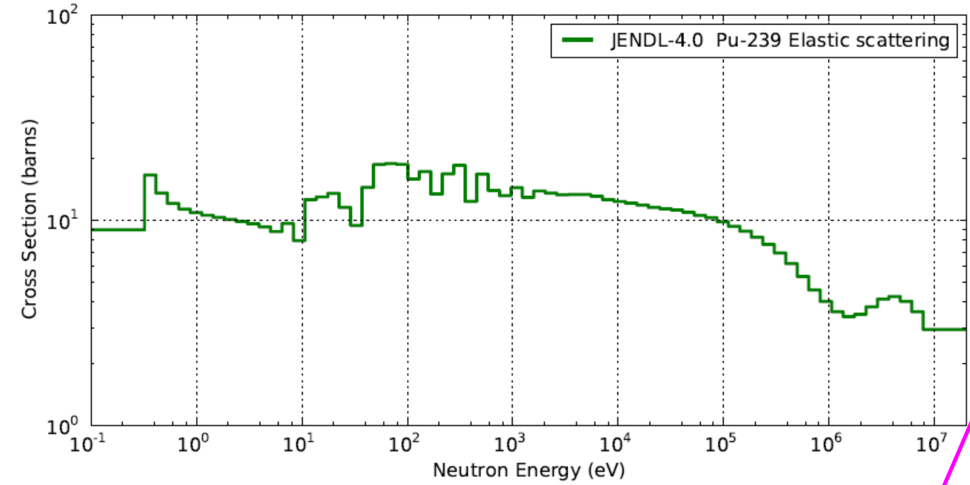
■ The physical interpretation is not yet revealed.



Pu-239 Fission

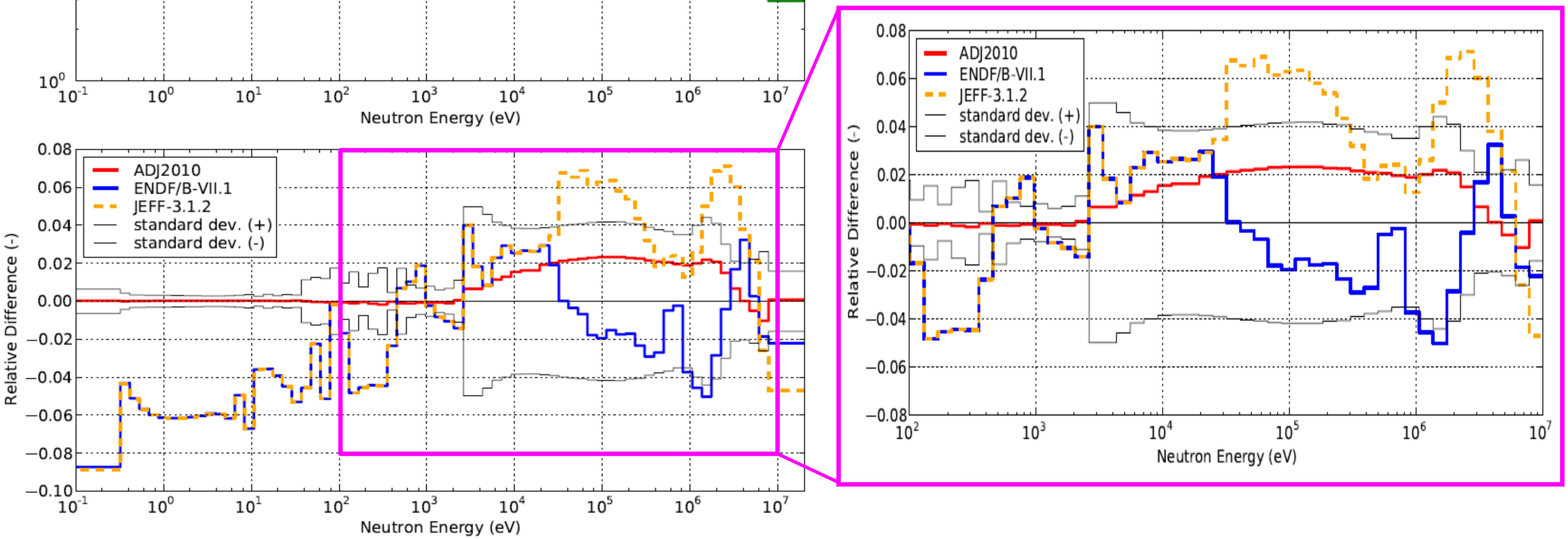


- ADJ2010 decreases Pu-239 fission cross-section by approximately 0.5%.
- ENDF and JEFF seem to be consistent with JENDL-4.0 or ADJ2010 in average, but there are large fluctuations exceeding the variance. It may be better to consult nuclear data people about the reason.



Pu-239

Elastic scattering

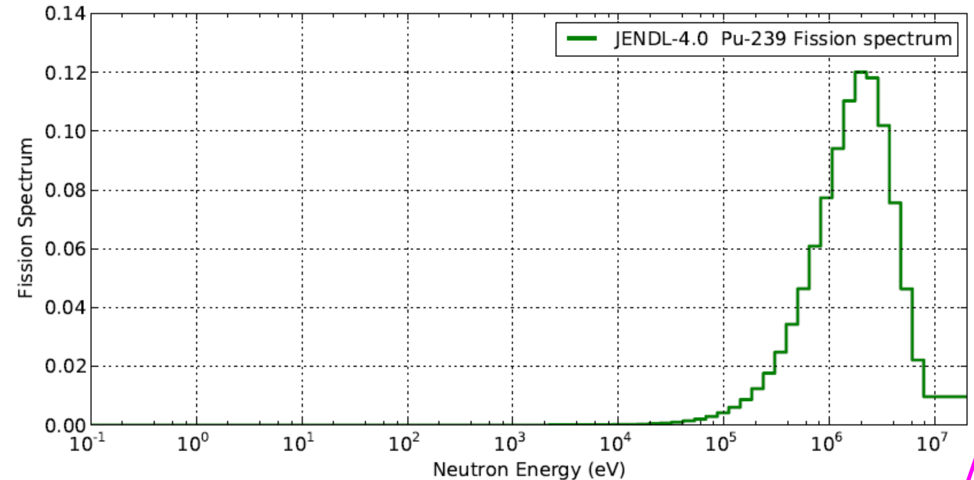


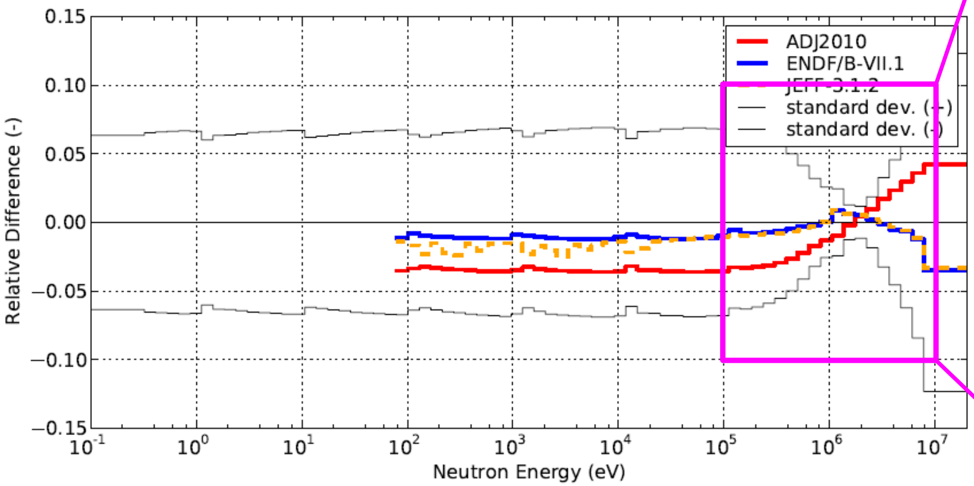
- ADJ2010 increases Pu-239 elastic-scattering cross-section by 2% at the maximum.

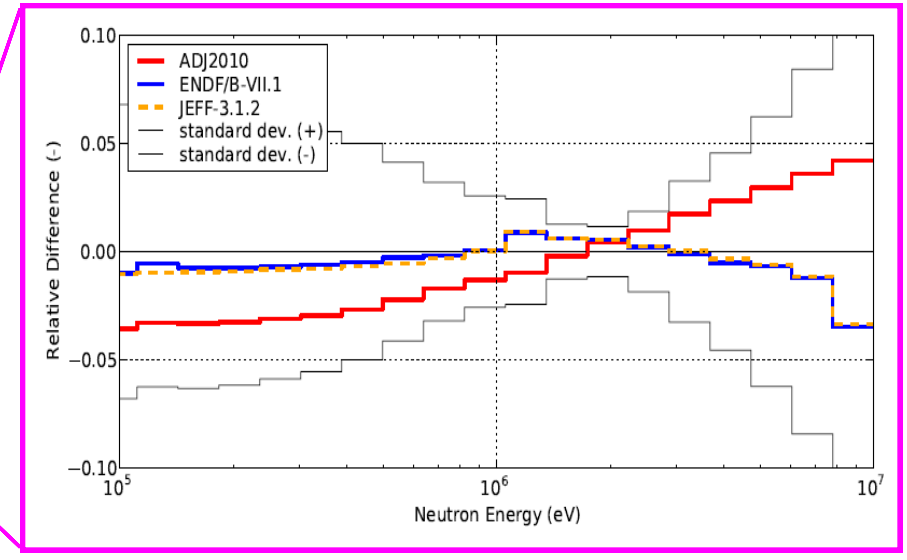
  This alteration is within the variance of JENDL-4.

Pu-239

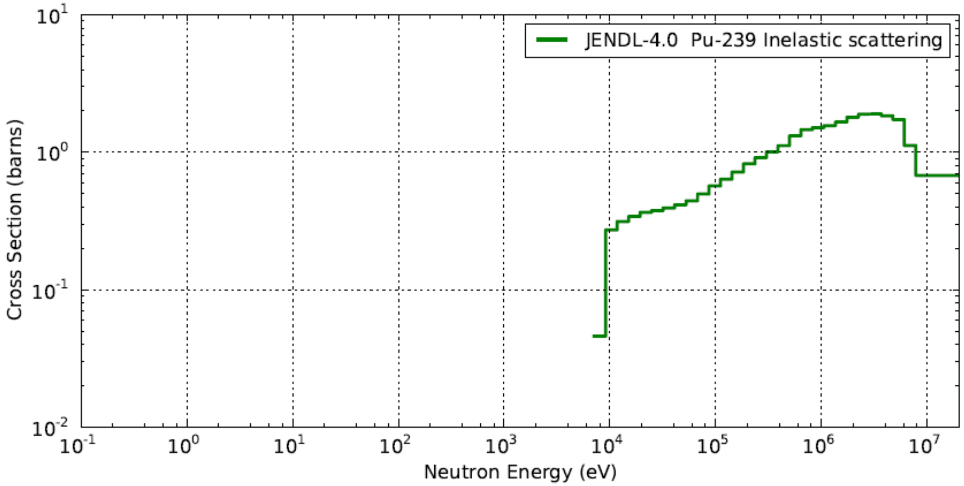
Fission spectrum





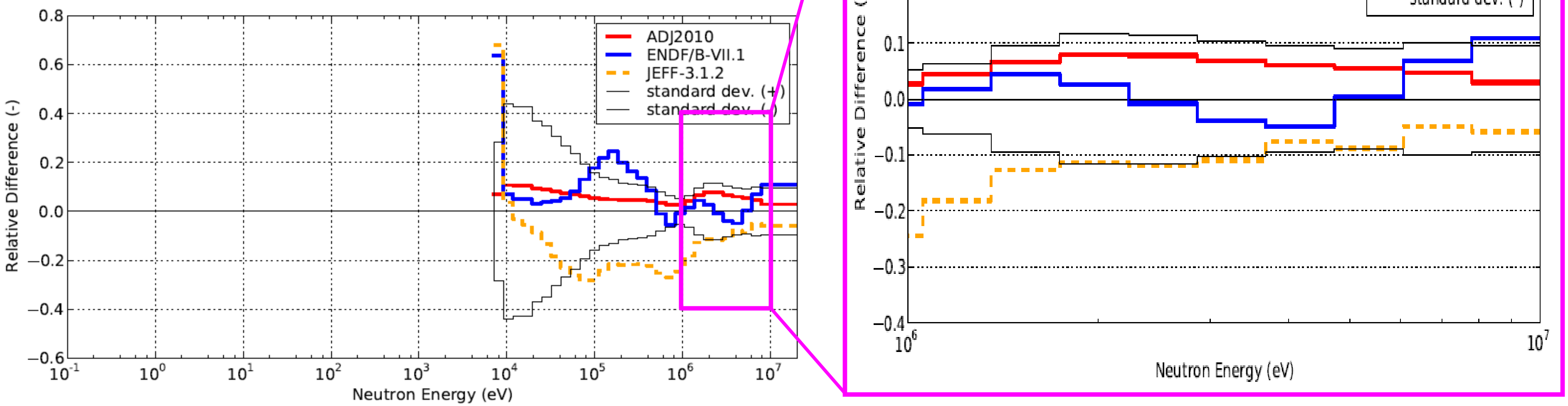


- ADJ2010 hardened Pu-239 fission spectrum by 4% at the maximum.
- This large alteration is within the variance of JENDL-4, but agrees with NEITHER of the three major libraries.
- Current covariance fixes the peak value of spectrum at 2MeV.

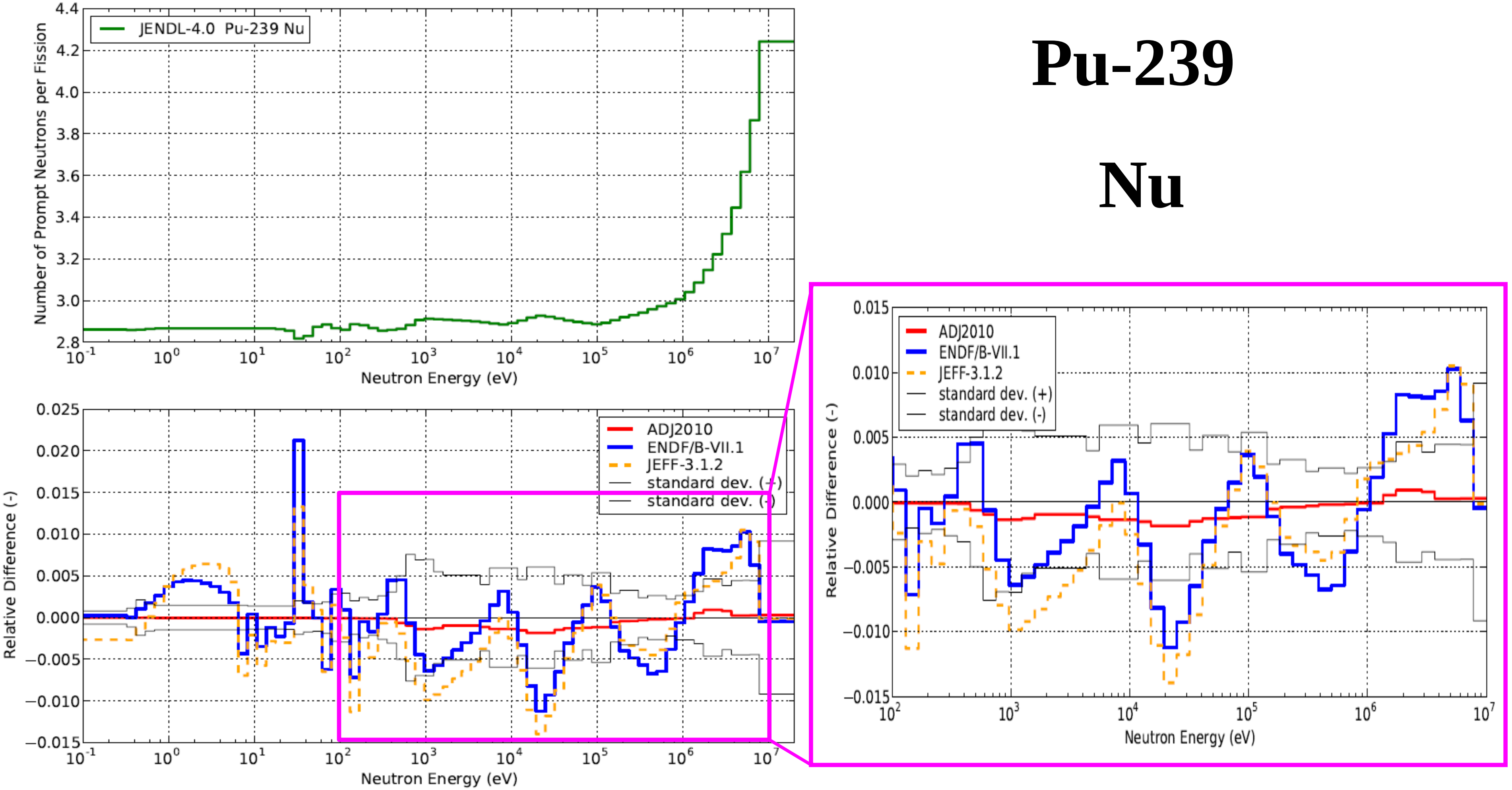


Pu-239

Inelastic scattering



- ADJ2010 increases Pu-239 inelastic scattering cross-section by 10% at the maximum. This alteration is within the variance of JENDL-4.
- Increase of inelastic scattering compensates the effect of the Pu-239 fission spectrum hardening on Na void reactivity, but the mechanism of increase is NOT known.



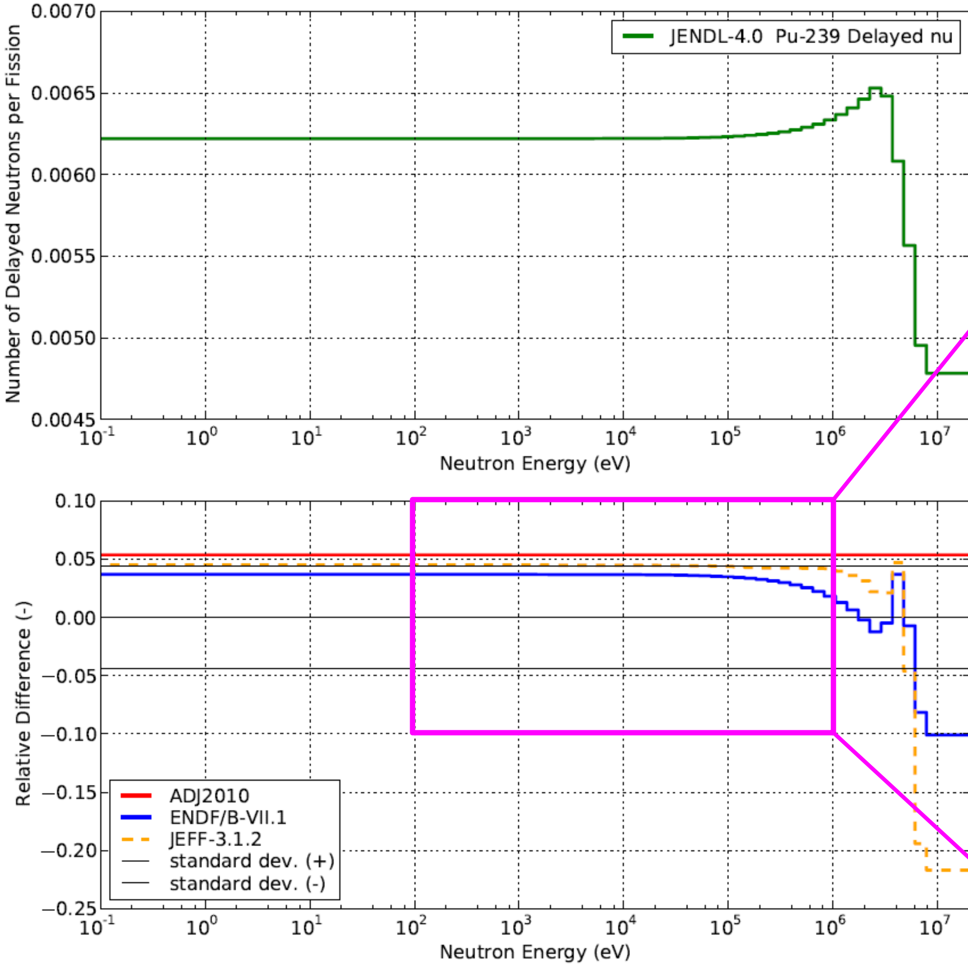
Pu-239

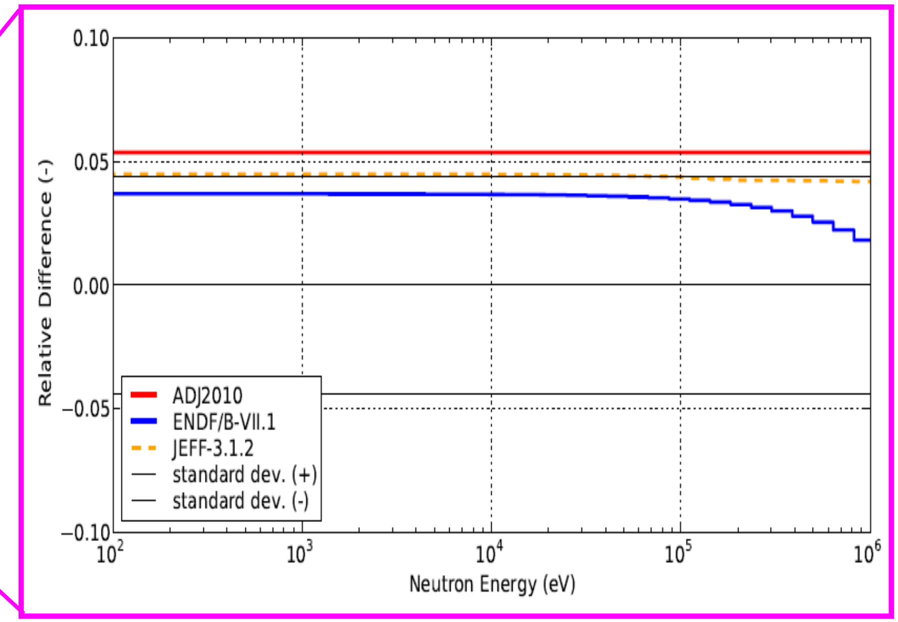
Nu

- ADJ2010 decreases prompt neutron number from Pu-239 fission by 0.2%. This small decrease is consistent with the 0.2%dk overestimation of JENDL-4 for large Pu-fueled cores.
- The difference between JENDL-4.0 and ENDF/JEFF shows strange wave-shape.

Pu-239

Delayed neutron

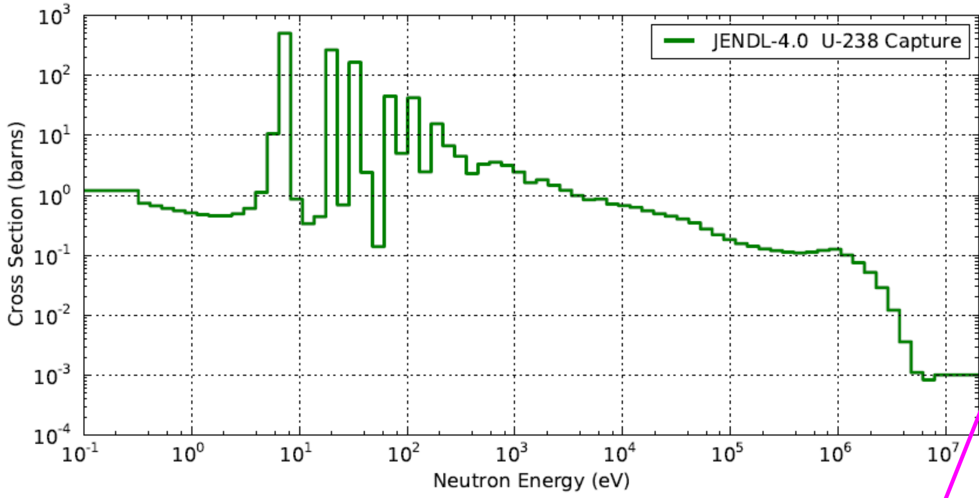


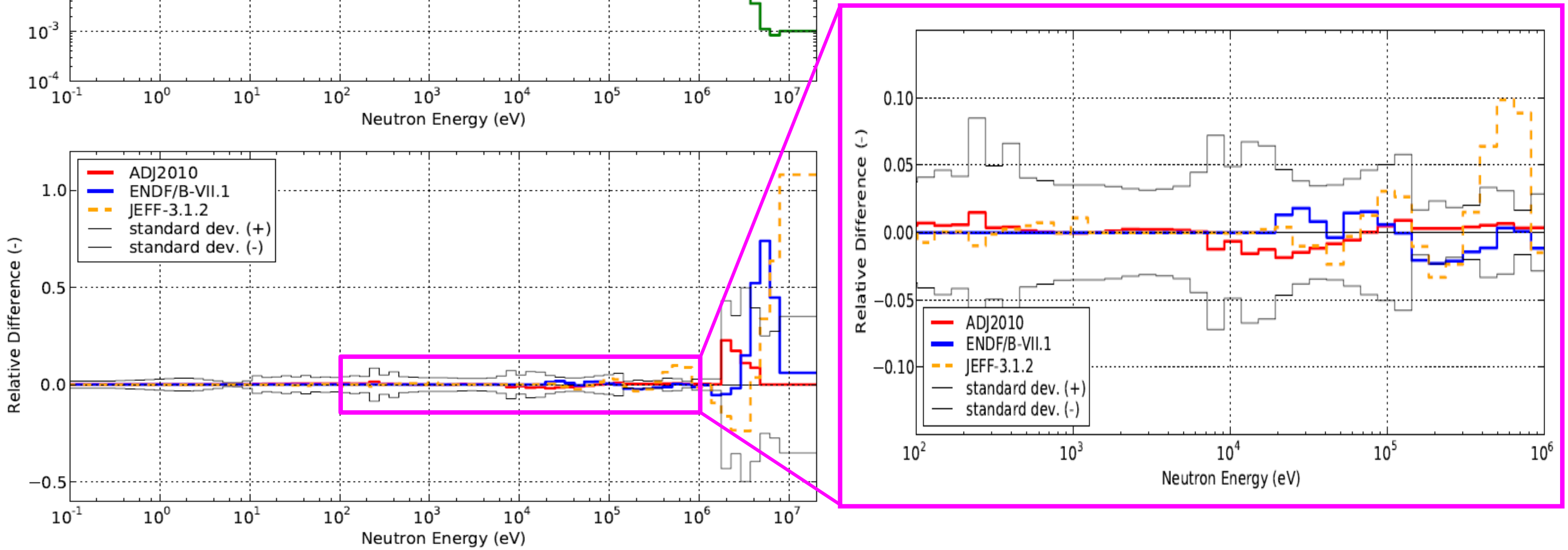


- ADJ2010 increases Pu-239 delayed neutron fraction by 5% due to the overestimation of reactivity parameters with JENDL-4.0. This large alteration is the variance bound of JENDL-4, and exactly agrees with ENDF and JEFF.

U-238

U-238 Capture

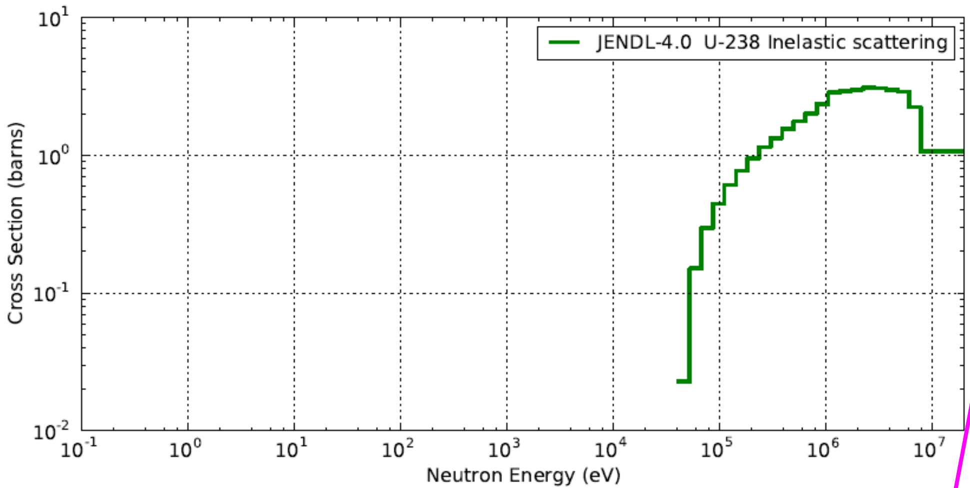


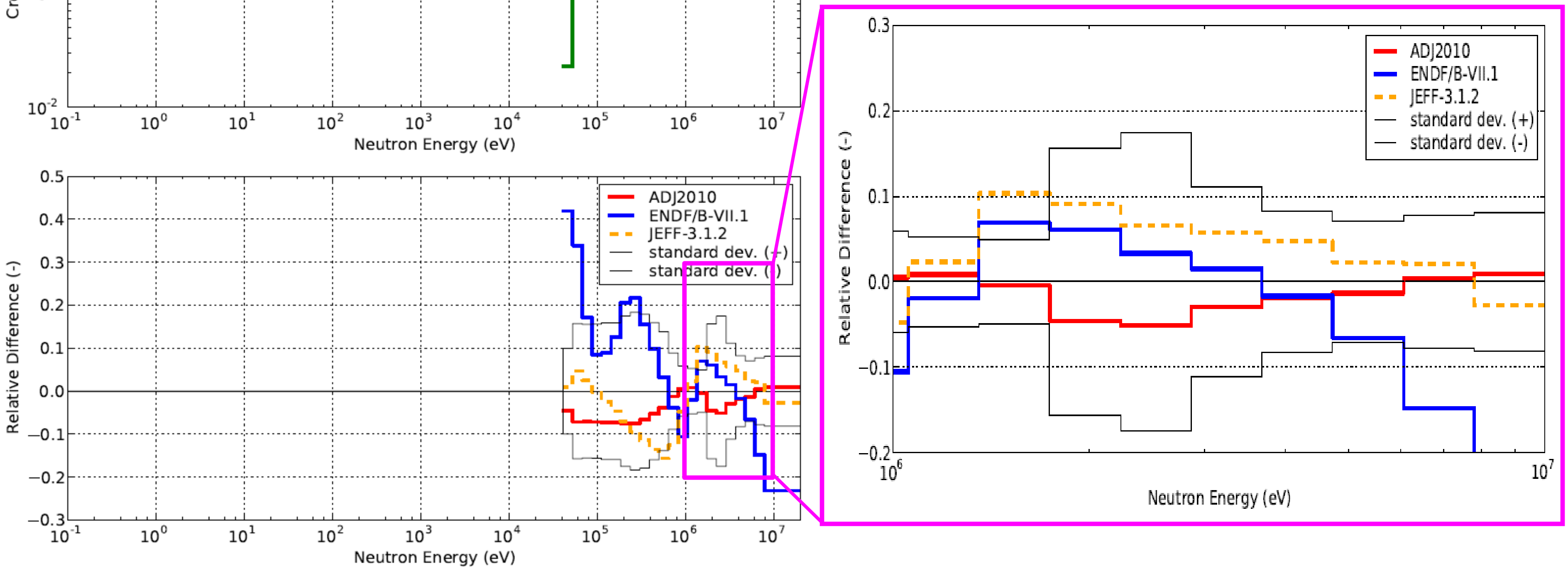


- ADJ2010 changes U-238 capture cross-section between +2 and -2%. This small alteration is within the variance of JENDL-4, and agrees with the three major libraries.

U-238

Inelastic scattering

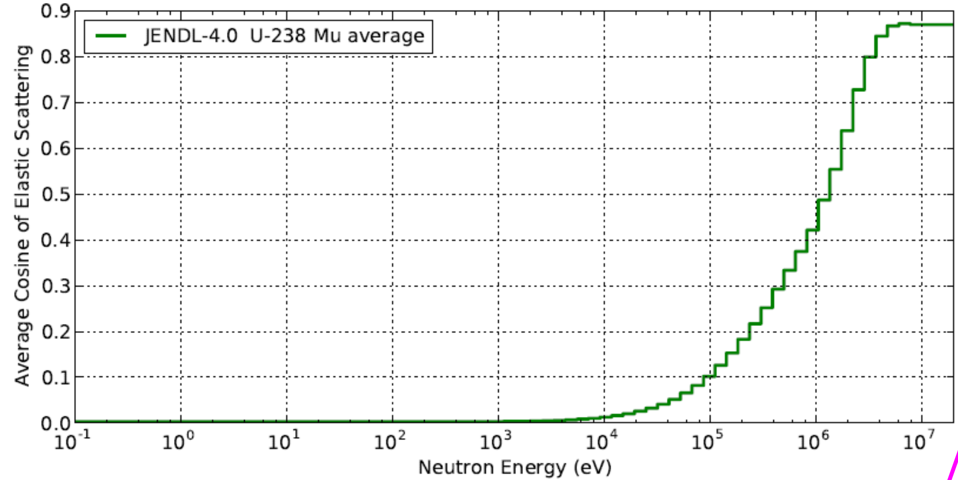


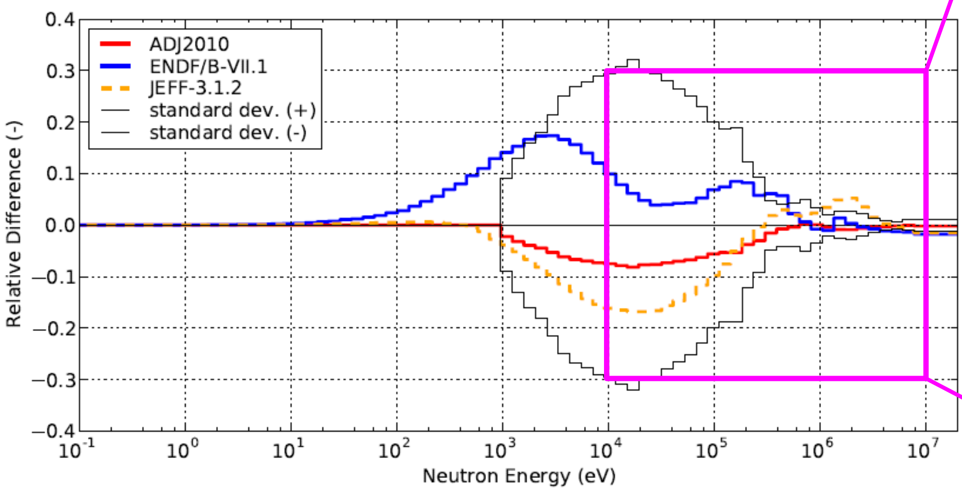


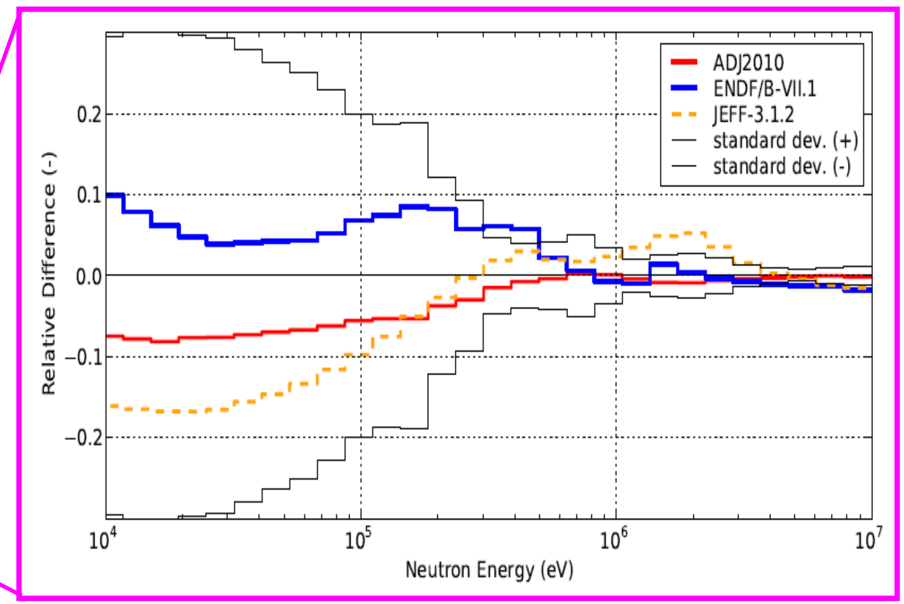
- ADJ2010 slightly decreases Pu-239 inelastic-scattering cross-section between 0 and 5% over 1MeV. This alteration is within the variance of JENDL-4.
- This decrease of inelastic-scattering is the opposite direction to correct the overestimation of Na void reactivity for Pu-fueled cores with JENDL-4.0.

U-238

Mu-ave.



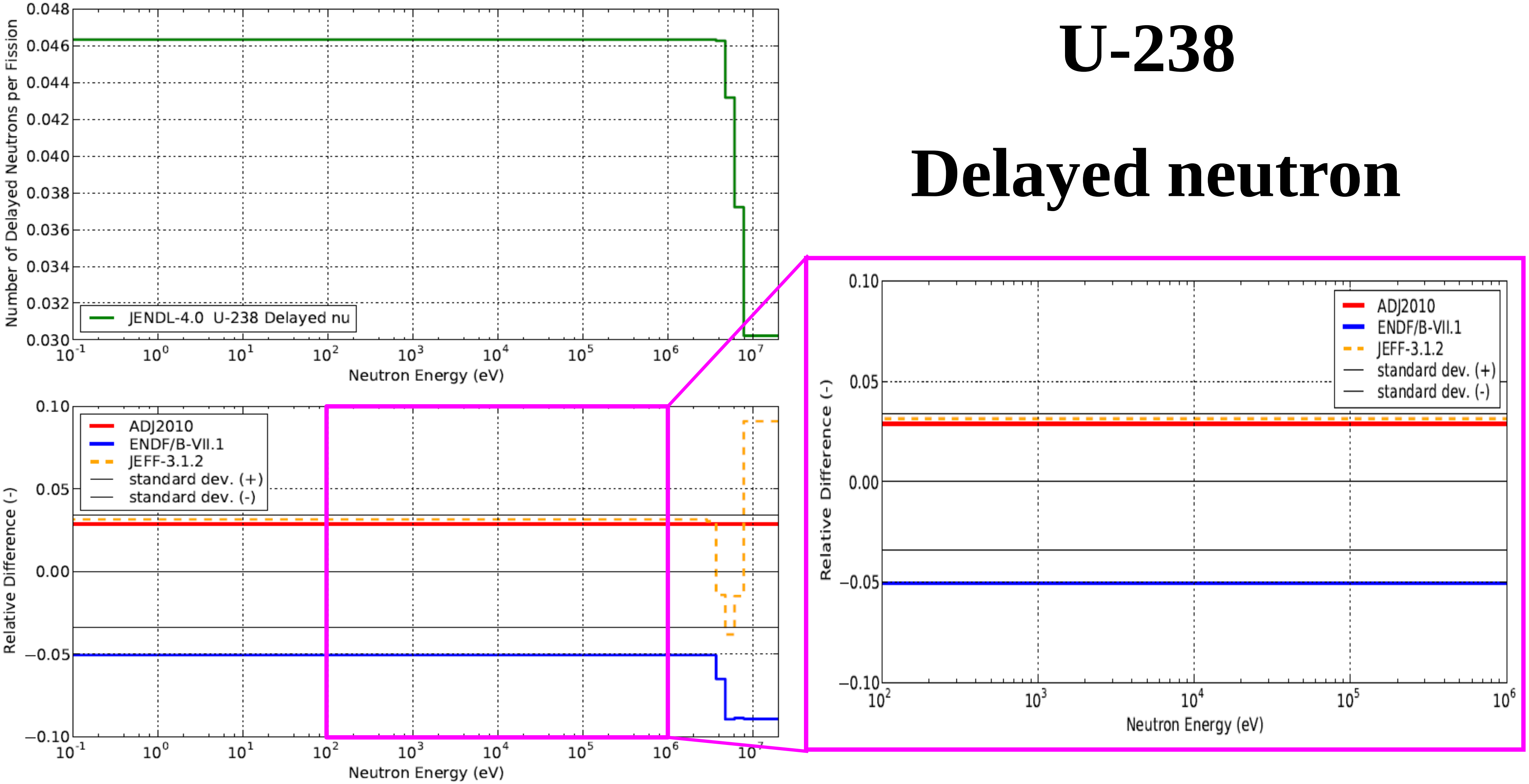




- ADJ2010 decreases U-238 mu-ave. by 8% at maximum. The effect of this alteration to adjusted C/Es are NOT clear.
- The evaluation of mu-ave. does NOT seem converged at all. Expect to be improved by SG35.

U-238

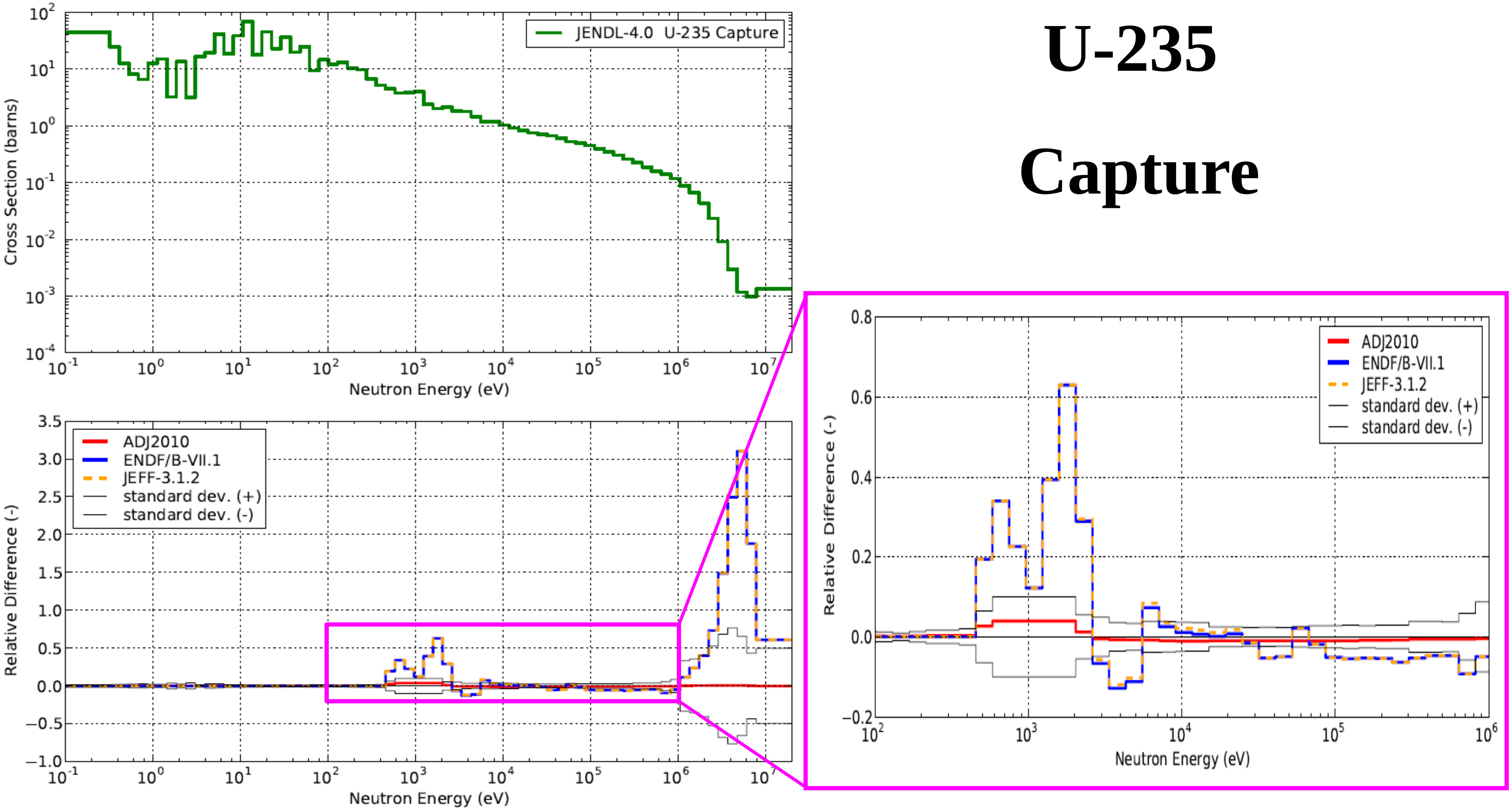
Delayed neutron



- ADJ2010 increases U-238 delayed neutron fraction by 3% due to the overestimation of reactivity parameters with JENDL-4.0. This large alteration is the bound of the variance of JENDL-4, and exactly agrees with JEFF, but NOT ENDF.

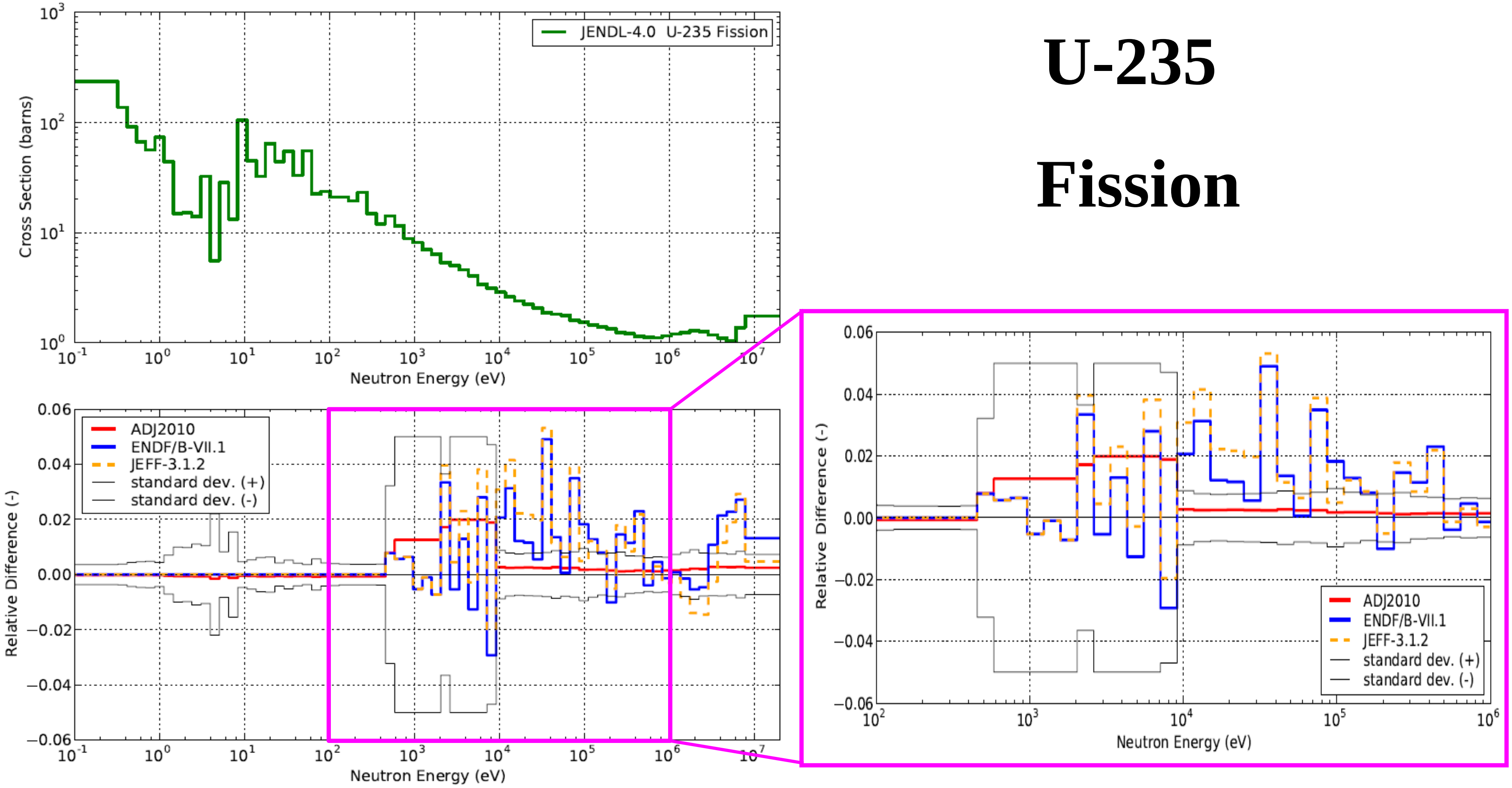
U-235

U-235 Capture



- ADJ2010 slightly changed U-235 capture cross-section only around 1 keV. This little alteration is consistent with CIELO evaluation, which is similar with JENDL-4.0.

U-235 Fission

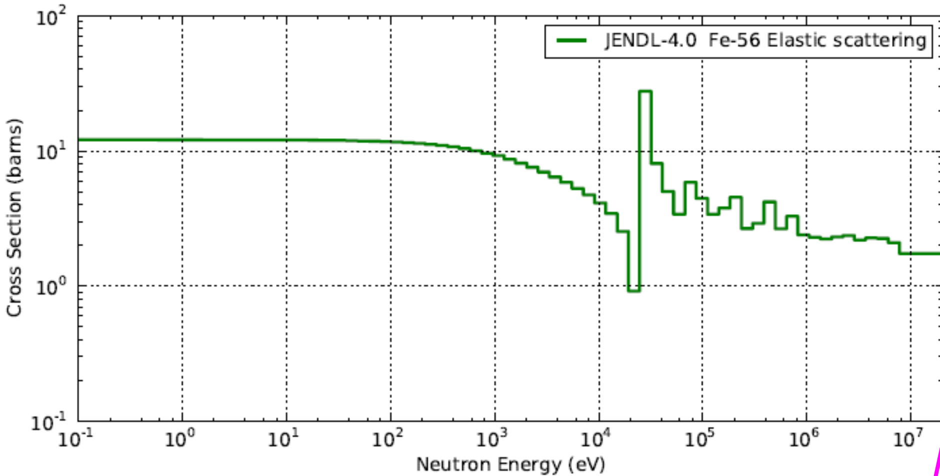


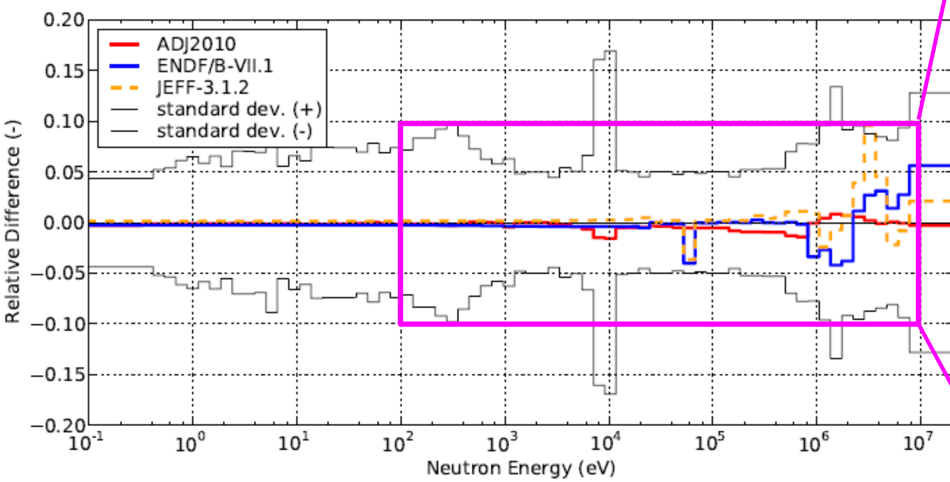
- No comments for ADJ2010.
- Even this major cross-section has quite large difference among libraries in high energy region, since it is not related to thermal reactors, maybe.

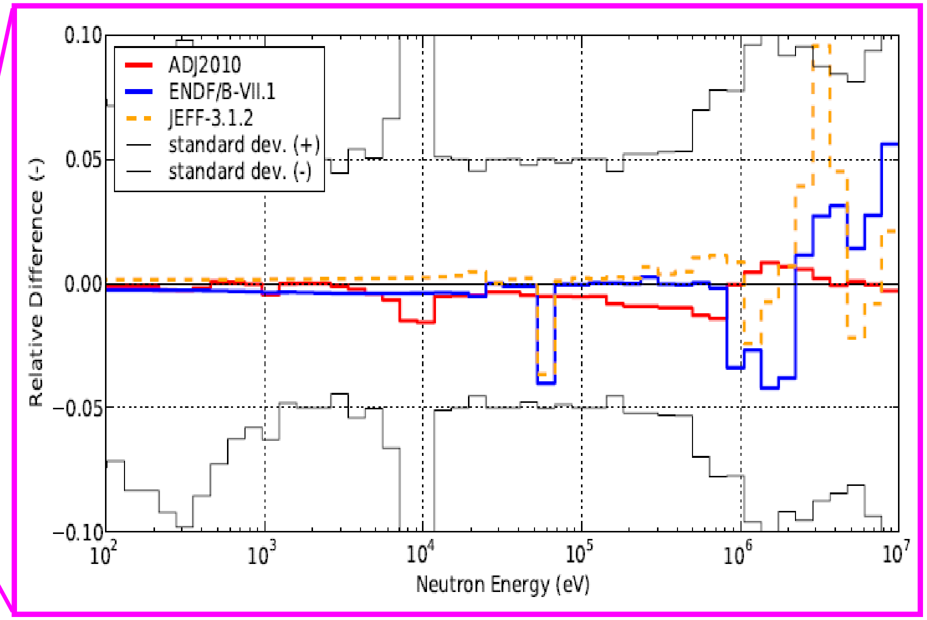
Fe-56

Fe-56

Elastic scattering





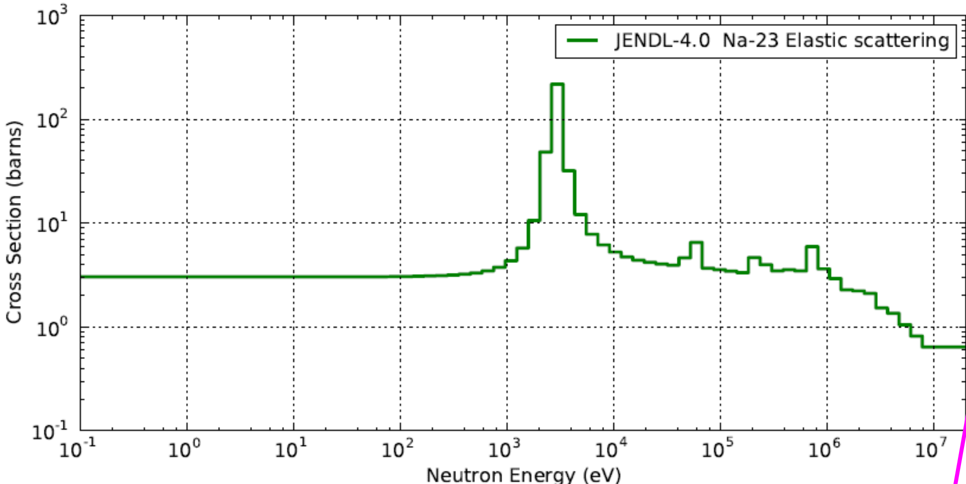


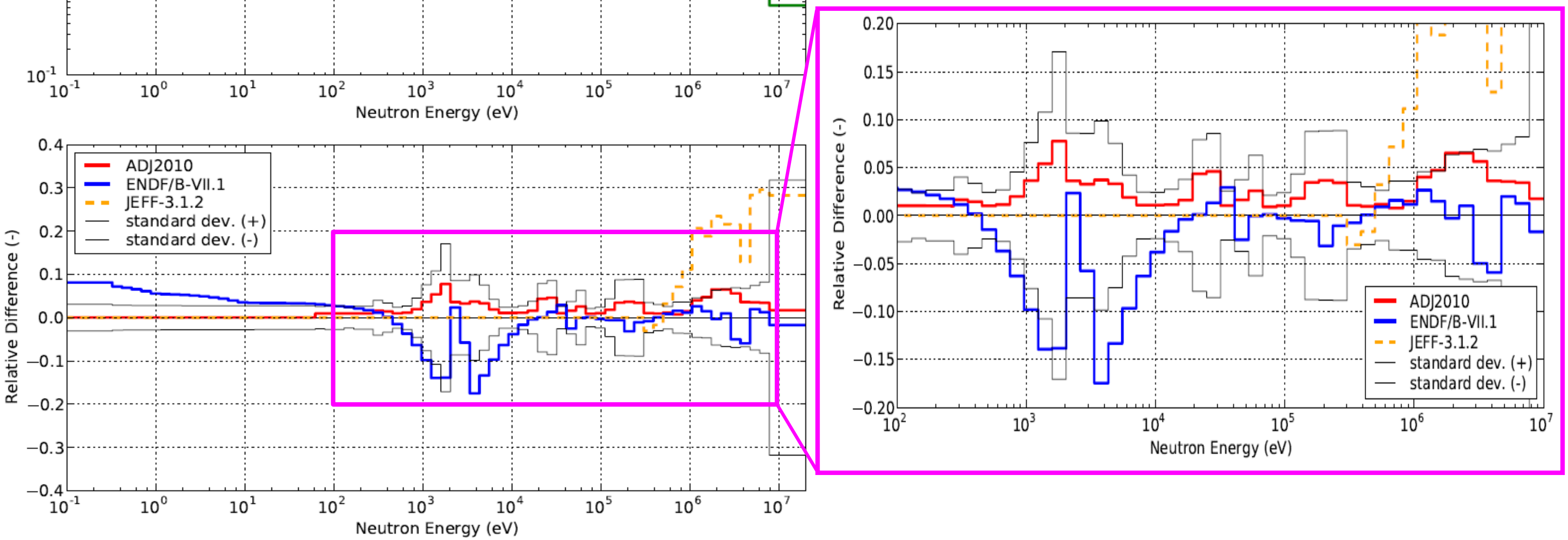
- No comments for ADJ2010.
- Three libraries are rather similar, but re-evaluation is underway in CIELO, using new measured data.

Na-23

Na-23

Elastic scattering





- ADJ2010 increases Na-23 elastic-scattering cross-section between 2 and 8%. This alteration is within the variance of JENDL-4.
- ENDF largely differs from JENDL and JEFF, since it is newer evaluation. The covariance of JENDL and COMMARA is consistent with this fact. -> next slide.

SG33 Final Report

Chap.3 Covariance

(Feb.20, 2013)

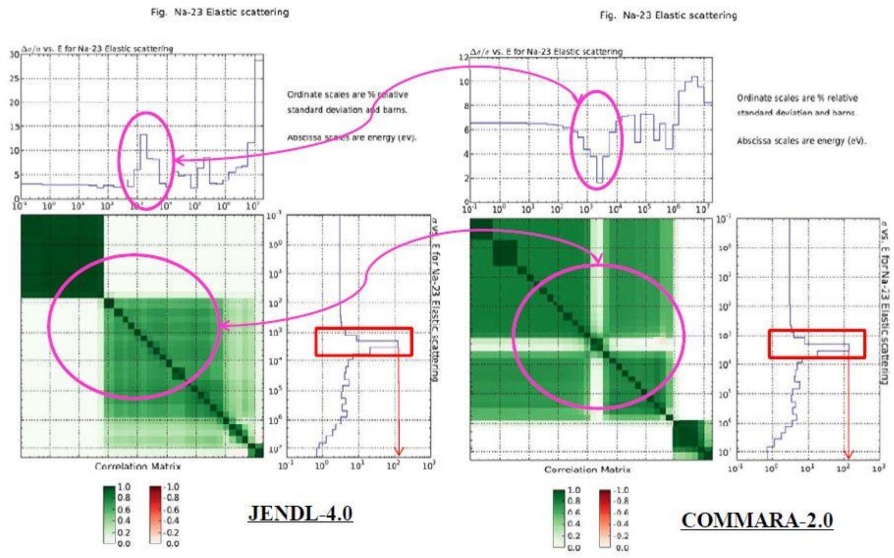


Figure 3.2 Comparison of JENDL-4.0 and COMMARA-2.0 Covariance (2/3) - Na-23 Elastic -

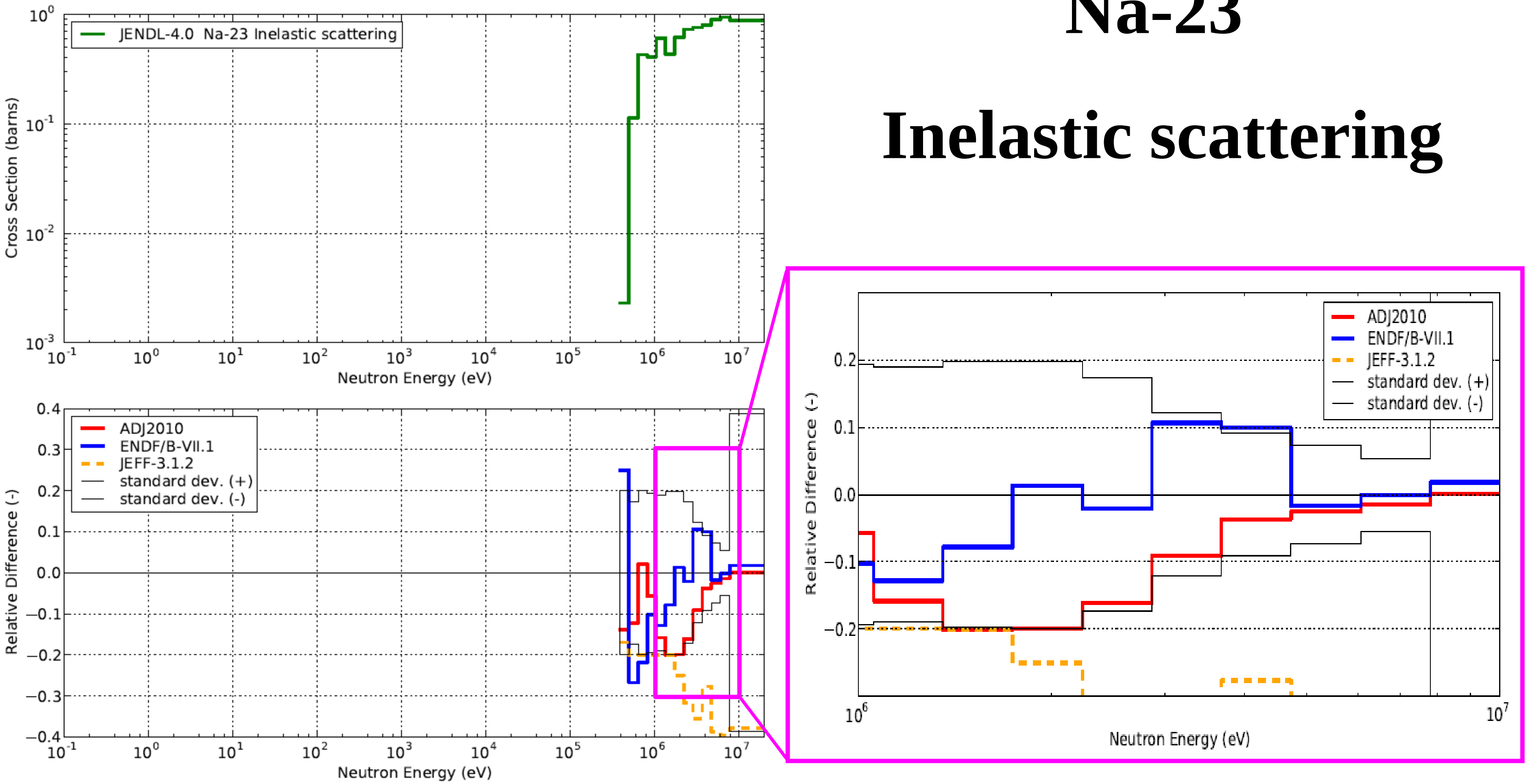
2) Na-23 elastic scattering data around 2 keV

At this energy, there appears a giant resonance peak which affects significantly the sodium-voiding reactivity in sodium-cooled fast reactor cores. As found in Fig.3.2, the shape of Standard deviation (STD) is extremely different between two libraries, that is, the minimum STD value occurs at the cross-section peak energy in C-2.0, on the contrary, the maximum appears there in J-4.0. With a simple consideration, the trend of C-2.0 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 C-2.0 covariance, the 2 keV peak has no correlations with other energy[3], while J-4.0 is partially positive everywhere above 100 eV. The covariance of C-2.0 is evaluated by the EMPIRE/KALMAN combination, where the prior resonance model parameter uncertainties are derived from Mughabghab (Ref.15), 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. The cross-section difference between ENDF/B-VII.0 and J-4.0 is -17~+4% around 2keV, therefore, the difference of STDs might be reasonable if we take into account the corrections given to J-4.0 covariance.

[3] This energy independency of 2 keV peak in the C-2.0 covariance is not well imagined from the general least-square analysis. There might have been some special treatments for the covariance evaluation in this resonance peak.

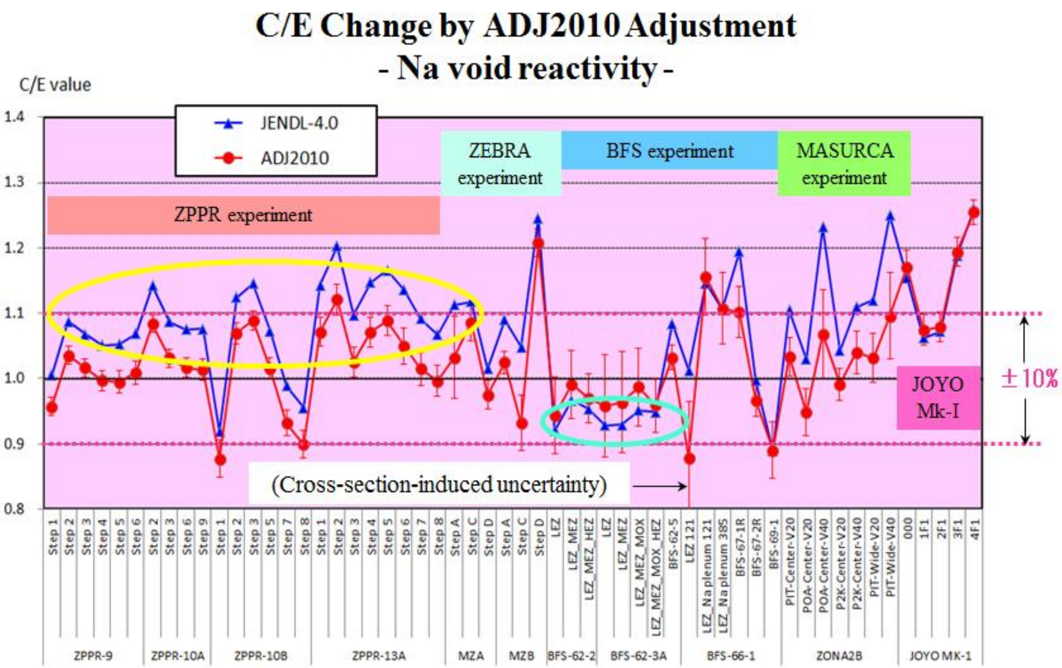
Na-23

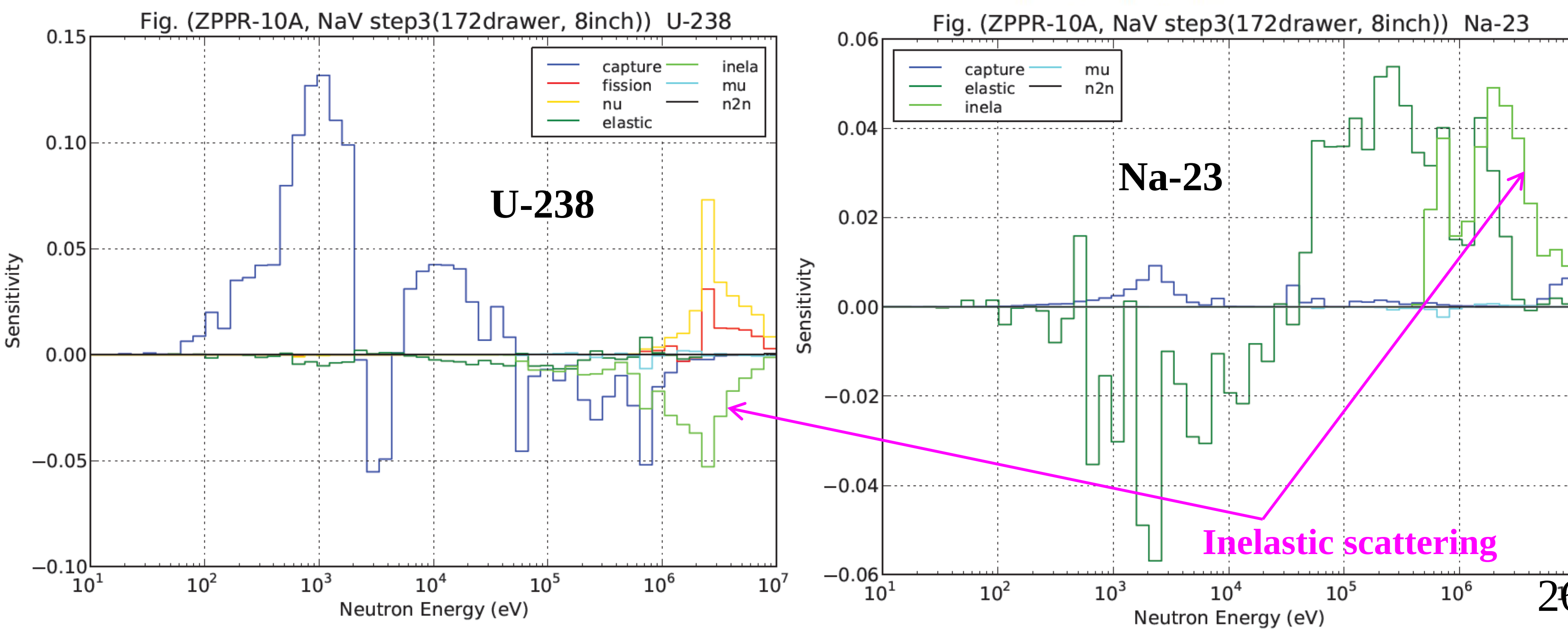
Inelastic scattering



- ADJ2010 largely decreases Na-23 inelastic-scattering cross-section between 5 and 20% over 1MeV. This alteration is at the variance bound of JENDL-4.
- This decrease of inelastic-scattering is consistent with the overestimation of Na void reactivity for ZPPR, and underestimation for BFS (negative reactivity). -> next slide.

Sensitivity for ZPPR-10A Na Void Reactivity





Concluding Remarks

1. **From ADJ2010 adjustment, we may recommend the followings to nuclear data evaluators: <*These have high sensitivity to good integral data.*>**
   - **Pu-239 fission --> Keep current data within 0.5% in average.**
   - **Pu-239 nu --> Keep current data within 0.2% in average.**
   - **Pu-239 delayed neutron --> Increase 5% from JENDL-4.0, that is, to be same with ENDF-VII.1 and JEFF-3.1.2.**
   - **U-238 capture --> Keep current data within 2%.**
   - **U-235 capture --> Follow JENDL-4.0 within its variance.**

2. **Although large alteration is observed, we cannot make comments:**
   - **Pu-239 capture --> Need to investigate the physical mechanism.**
   - **Pu-239 fission spectrum and Na-23 inelastic --> should study more as one combined set including U-238 inelastic and Pu-239 inelastic.**
     <*compensation problem exists.*>
   - **U-238 mu-ave. and U-238 delayed neutron --> Need to be converged among the major libraries.**
   - **U-235 fission --> Current fast-region integral database is not sufficient.**
   - **Fe-56 elastic scattering and Na-23 elastic --> Should be improved in CIELO project.**

Appendix: 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<< Ve+Vm, T'≒T_0 and GM'G^t≒GMG^t
✓If GMG^t>>Ve+Vm, GM'G^t≒Ve+Vm
✓If GMG^t≒Ve+Vm, GM'G^t≒1/2×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, $(dR/R)/(d\sigma/\sigma)$