Preliminary Adjustment Using CIELO Isotopes and Their Associated Covariance Matrices

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Adjustment Data

- The multigroup neutron cross section adjustment has been carried out using ENDF/B-VII.0 data files and COMMARA 2.0 covariance matrix.
- The 5 CIELO isotopes (^{16}O, ^{56}Fe, ^{235}U, ^{238}U, and ^{239}Pu) and their covariance matrices have been replaced on the initial files. Corresponding C/E have been derived using a perturbation formula.
- An initial set of more than 200 integral experimental quantities has been analyzed (using the best calculational tools available) in order to provide C/E and associated calculational and experimental uncertainties and correlations.
- The initial set was reduced to 110 experimental values based on several considerations (duplications, sensitivities, inconsistency after adjustment, experimental uncertainties, etc.)
- 45 isotopes including major and minor actinides, fission products, structural, coolant, and light isotopes were adjusted.
- A 33 energy group structure was adopted and sensitivity coefficients were calculated.

Background information

- The linearity hypothesis was used and the calculated values related to the CIELO isotopes was derived by using sensitivity coefficients: $C' = C(1 + S * \Delta\sigma/\sigma)$
- CIELO isotopes were downloaded from NNDC as ENDF/B-VIII.
- Reference C/E values were obtained using the corresponding isotopes of ENDF/B-VII.0. This file was the one used for calculating with the most accurate tool (i. e. Monte Carlo) the reference C.
- Both set of files were processed in exactly the same way generating infinite dilution cross sections using the latest version (34) of NJOY2016.
- At the same time covariance matrices were generated for MF31, Mf33, MF34, and MF35 for the CIELO isotopes

Feedback on CIELO Covariance Matrices

- **Missing covariance data for:**
  - **P_1 of ^{56}Fe, ^{235}U, ^{238}U (Used corresponding JENDL-4 data)**
  - **Cross correlations for ^{56}Fe reactions that were present in COMMARA 2.0**
- **Unacceptable values (correlation >1) for:**
  - **^{235}U cross correlations: inelastic/ (capture and fission), fission/capture**
  - **^{238}U cross correlations: elastic/inelastic, inelastic/ (capture and fission)**
  - **^{238}U fission spectrum (very low energy)**
- **Strange values (>>>>100%) for ^{16}O P_1 values at low energy**
- **Some difficulties in processing MF35 data (Oscar Cabellos helped)**

Experiments used in the Adjustment

Facility	Experiment	Type of experiment	Number of experim.
LANL Small criticals	GODIVA, JEZEBEL BIGTEN, Np SPHERE	K_{eff}, reaction rate ratios	17
ZPR/ZPPR	ZPR6/7 ; ZPR3/53 and 54 ZPR9-34 ZPPR-9 ZPPR-10 ZPPR-15	K_{eff}; void reactivity, central control rod Fission and capture rate ratios major actinides	22
MASURCA	CIRANO	K_{eff};	2
PHENIX	PROFIL1 ; PROFIL2 ; TRAPU	Separated isotope irradiations: major, minor actinides, fission products. Variable actinide content pins	36
PROTEUS	HCLWR phase II *	K_{∞}; reaction rate ratios	7
ASPIS	ASPIS 88 *	Foil detectors rates and slopes at several radial positions	7
JOYO		K_{eff}	1
FCA	FCA-IX*	Reaction rate ratios	18

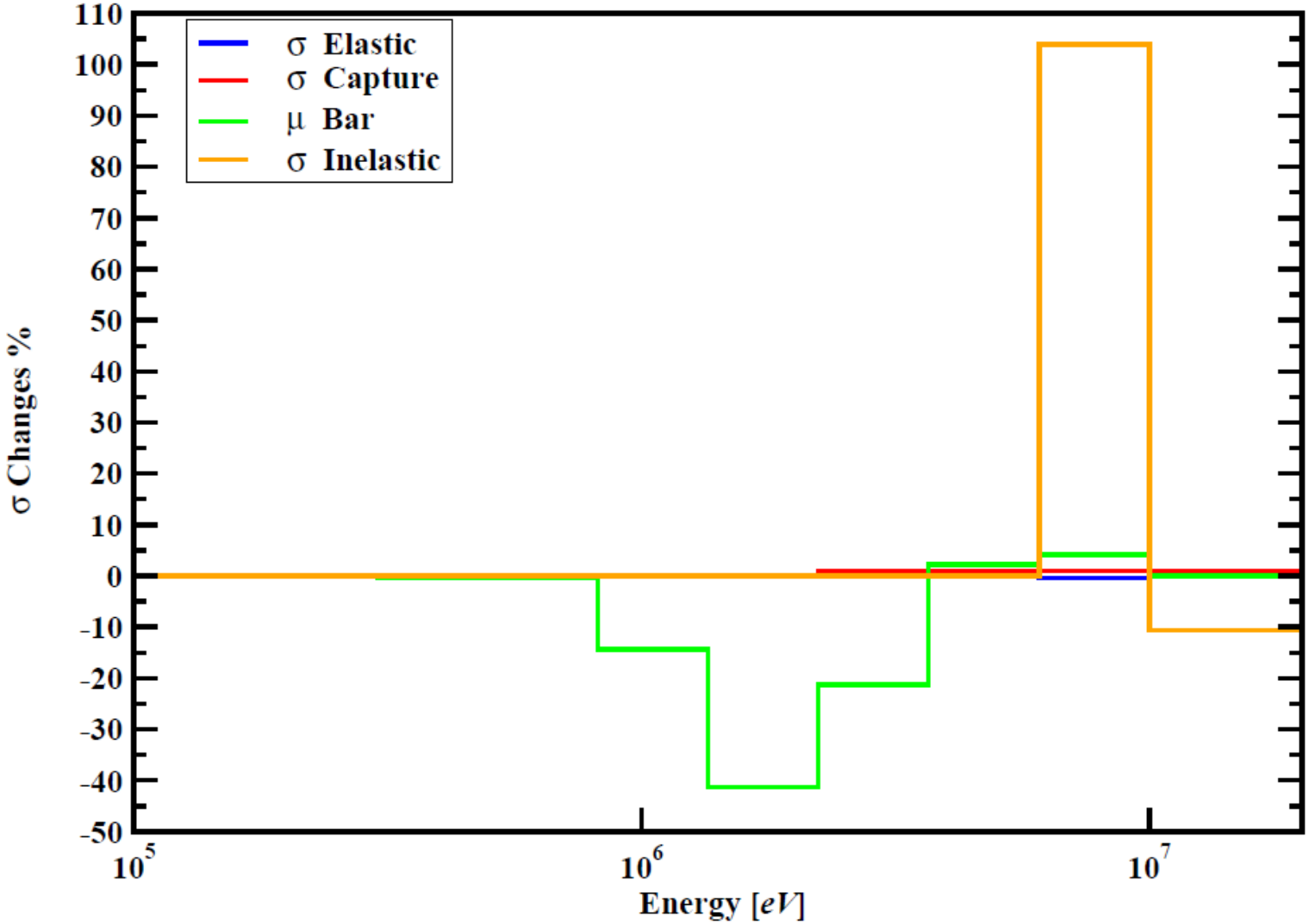
Some General Considerations

- Final χ^2 is satisfactory, 1.2 against starting one at 23. Major contribution after adjustment coming from ZPR9/34 K_{eff} with 0.143 against a starting 6.3, with a starting C/E of 1.03 and final of 1.0007.
- Some cross section adjustment is bigger than the standard deviation:
  - ^{56}Fe inelastic from 10 Mev to 800 Kev and capture from 800Kev to 60 Kev
  - ^{238}U inelastic from 1.3 Mev to 800 Kev
  - ^{239}Pu capture from 15 Kev to 2 Kev and (n,2n) from 10 to 6 MeV
- In general standard deviations are significantly reduced, but some small increase is observed for a few cases of elastic and capture. This could indicate some problem in the cross correlation among reactions.
- MA irradiation experiments have impact also on major actinides.
- FCA experiments impacted by ^{238}U inelastic (i.e. change in spectrum).
- ASPIS-88 and ZPR9/34 impact ^{56}Fe capture, elastic, and inelastic.

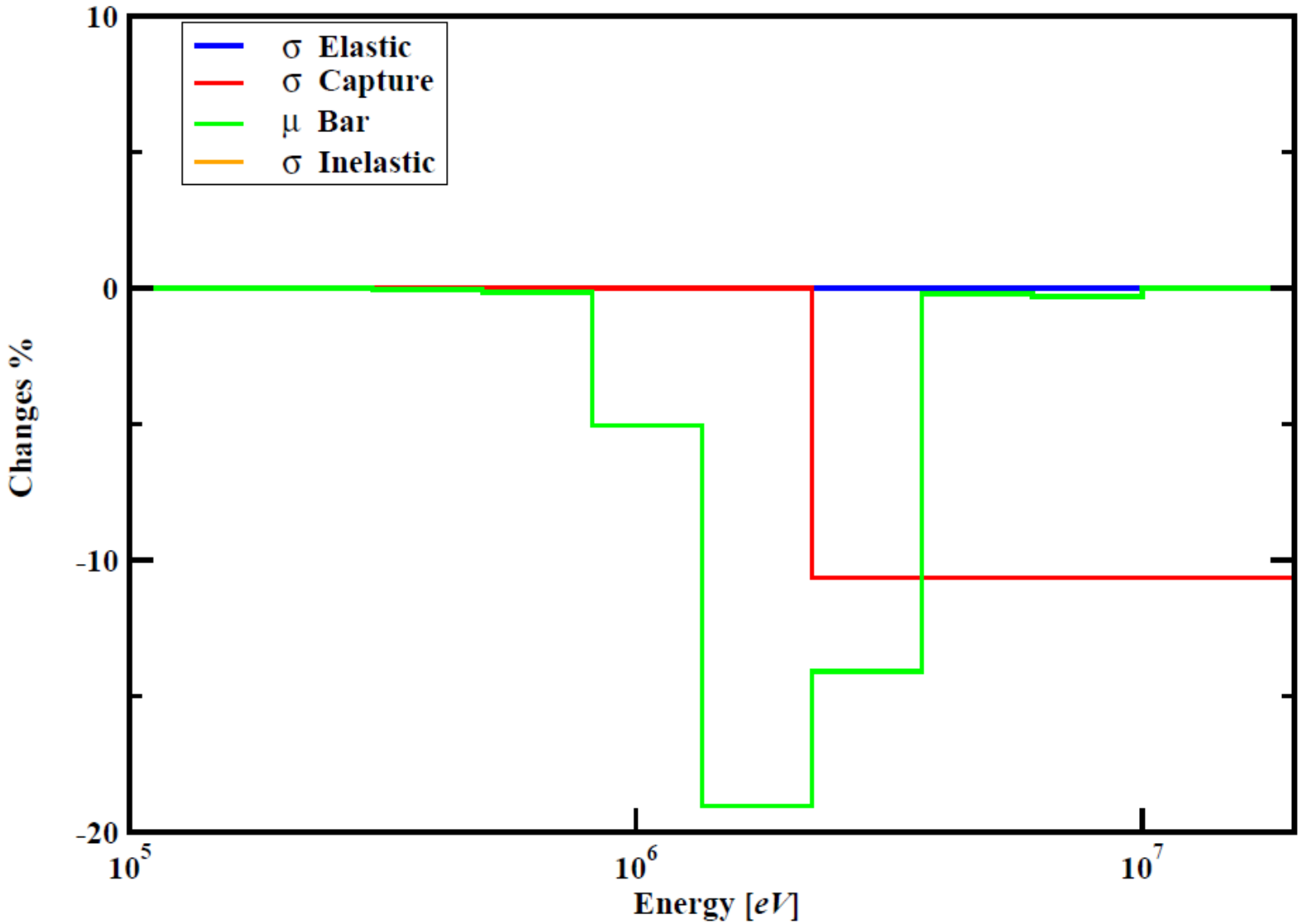
Major Findings for the 5 CIELO Isotopes

- ^{16}O: Significant inelastic cross section change and some impact on P_1 scattering. However, no major sensitivity to this isotope, and therefore changes should be ignored.
- ^{56}Fe: Significant increase of capture at very high energy (up to 50%). Decrease of inelastic (almost 20% at 1 MeV). Some change in P_1 (+10% from 100 KeV to 1MeV).
- ^{235}U: Increase (~5%) in capture from 5 KeV to 5 MeV. Decrease of χ below 1 MeV and increase above. P_1 elastic decreases between 800 and 100 KeV. Systematic decrease of inelastic of few %.
- ^{238}U: decrease in capture (~2% average from 25 KeV to 1 KeV). Decrease of inelastic ~5-10%. Change in shape of χ. Significant decrease of P_1 (300 KeV to 5 KeV).
- ^{239}Pu: Significant increase (~20%) of capture from 10 to 1 KeV; some also at thermal energies. Change in shape of inelastic (significant). Change in χ shape. Large change of n,2n (~+30% from 10 to 6 MeV).

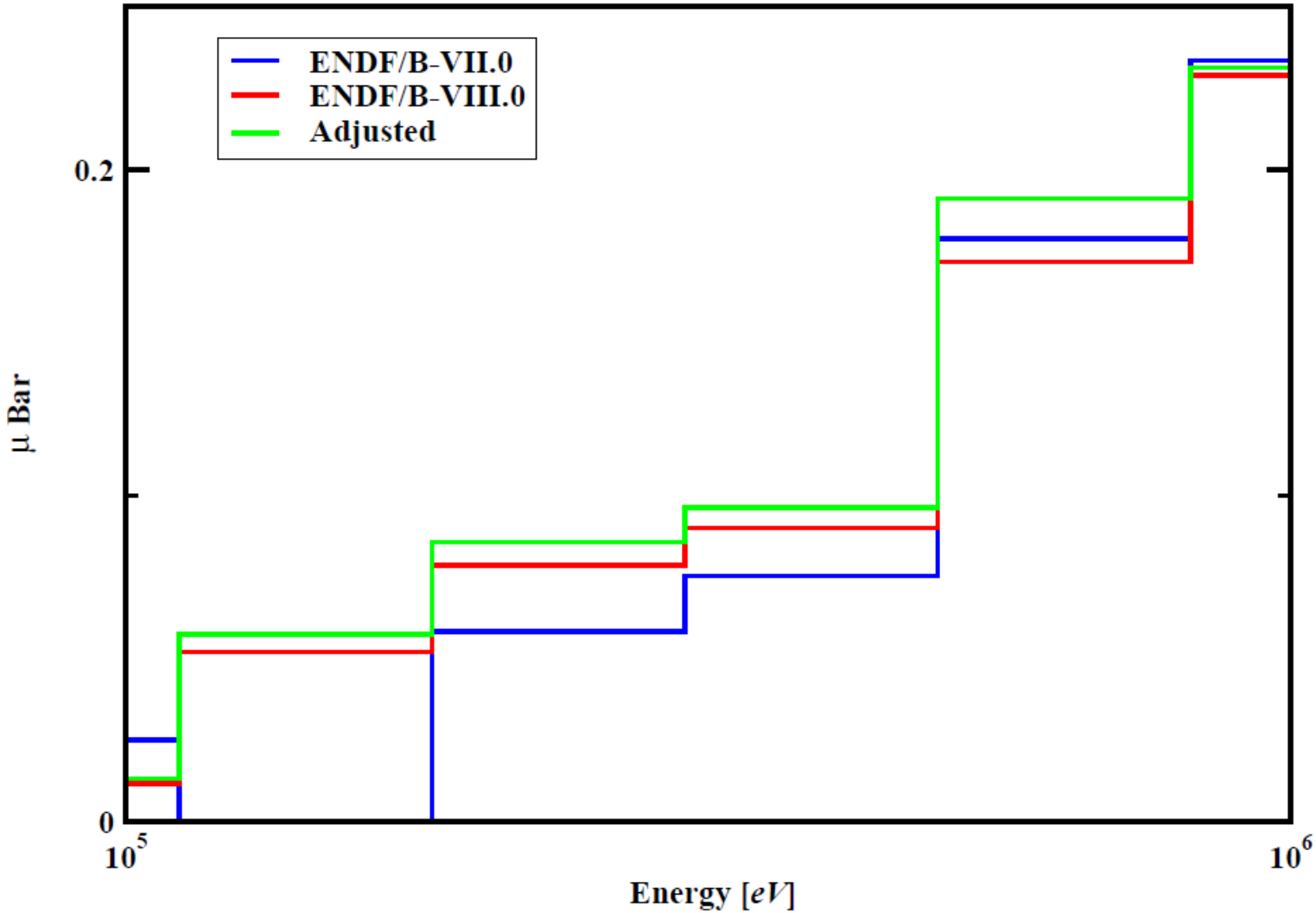
^{16}O σ Changes

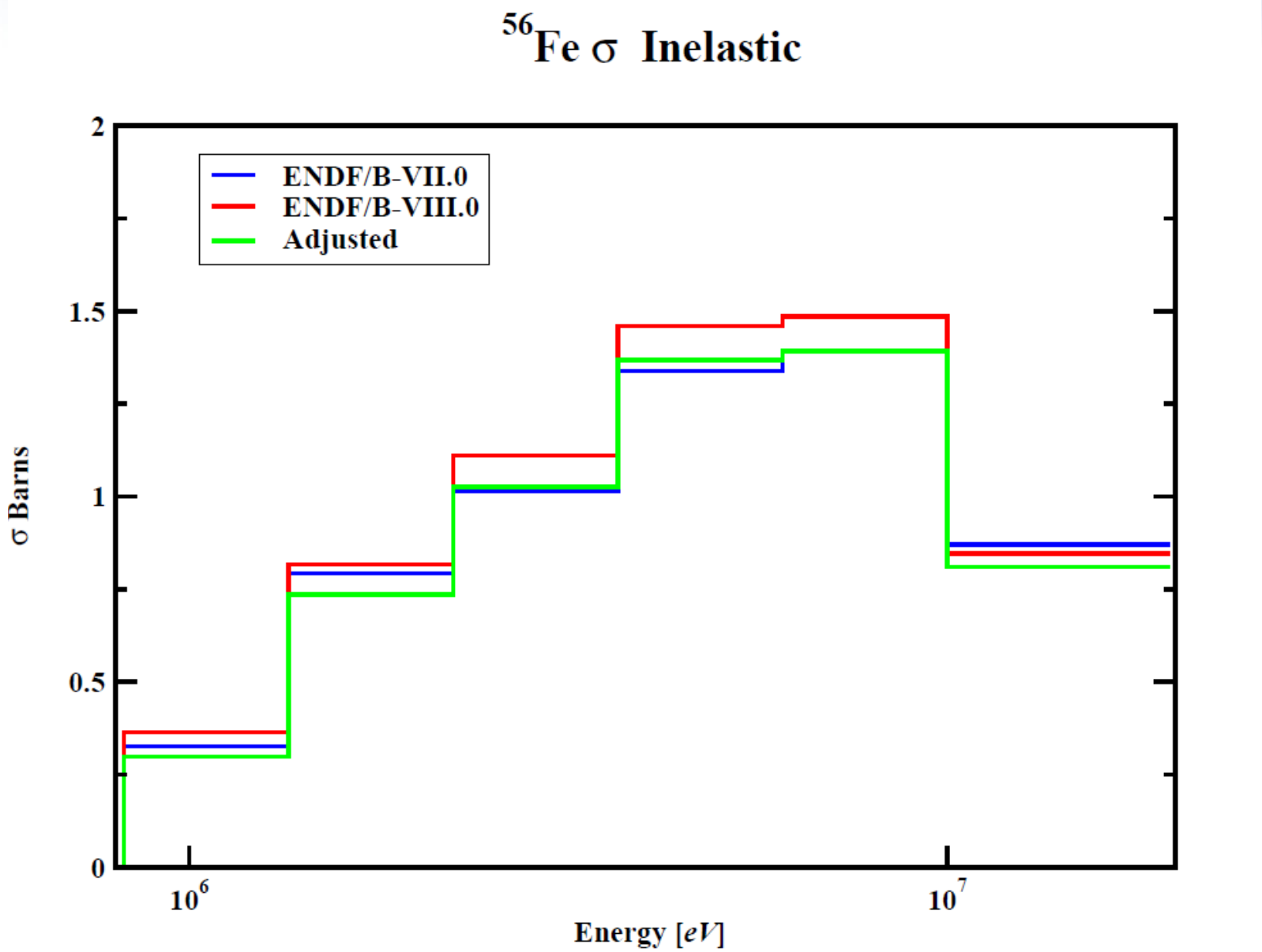


^{16}O Standard Deviation Absolute Changes in %

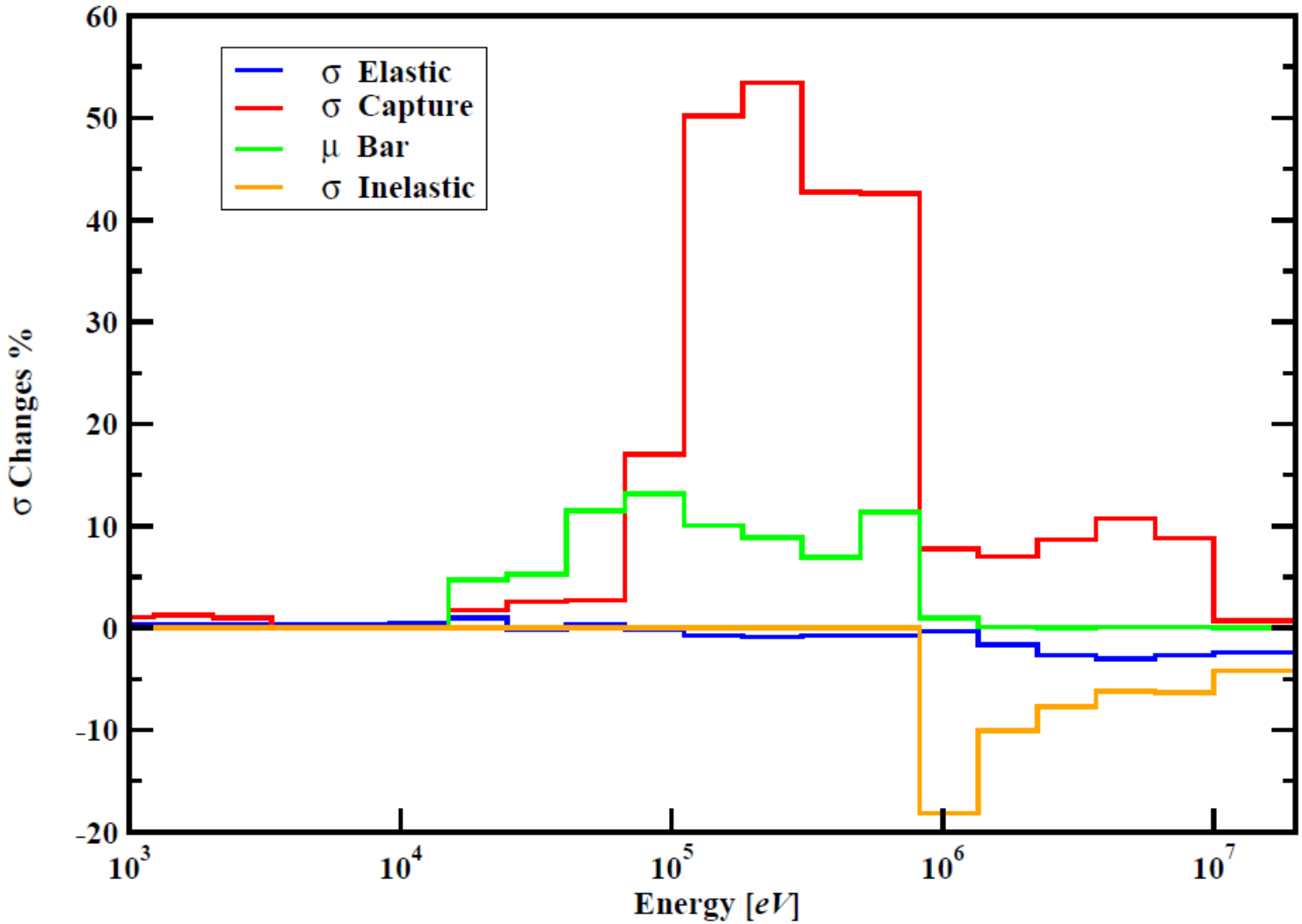


^{56}Fe μ Bar

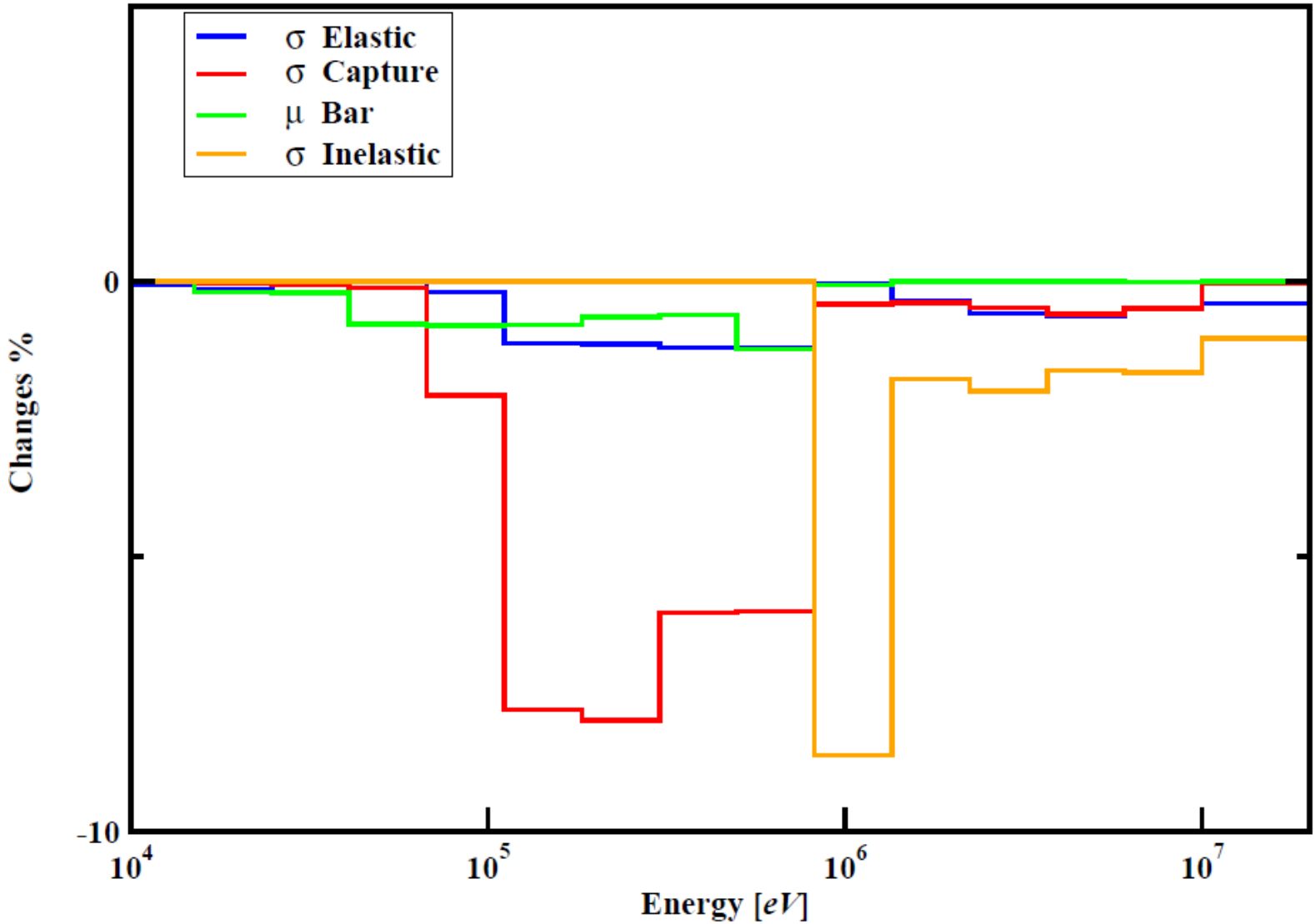



^{56}Fe σ Inelastic
ENDF/B-VII.0
ENDF/B-VIII.0
Adjusted
σ Barns
2
1.5
1
0.5
0
10^6
10^7
Energy [eV]

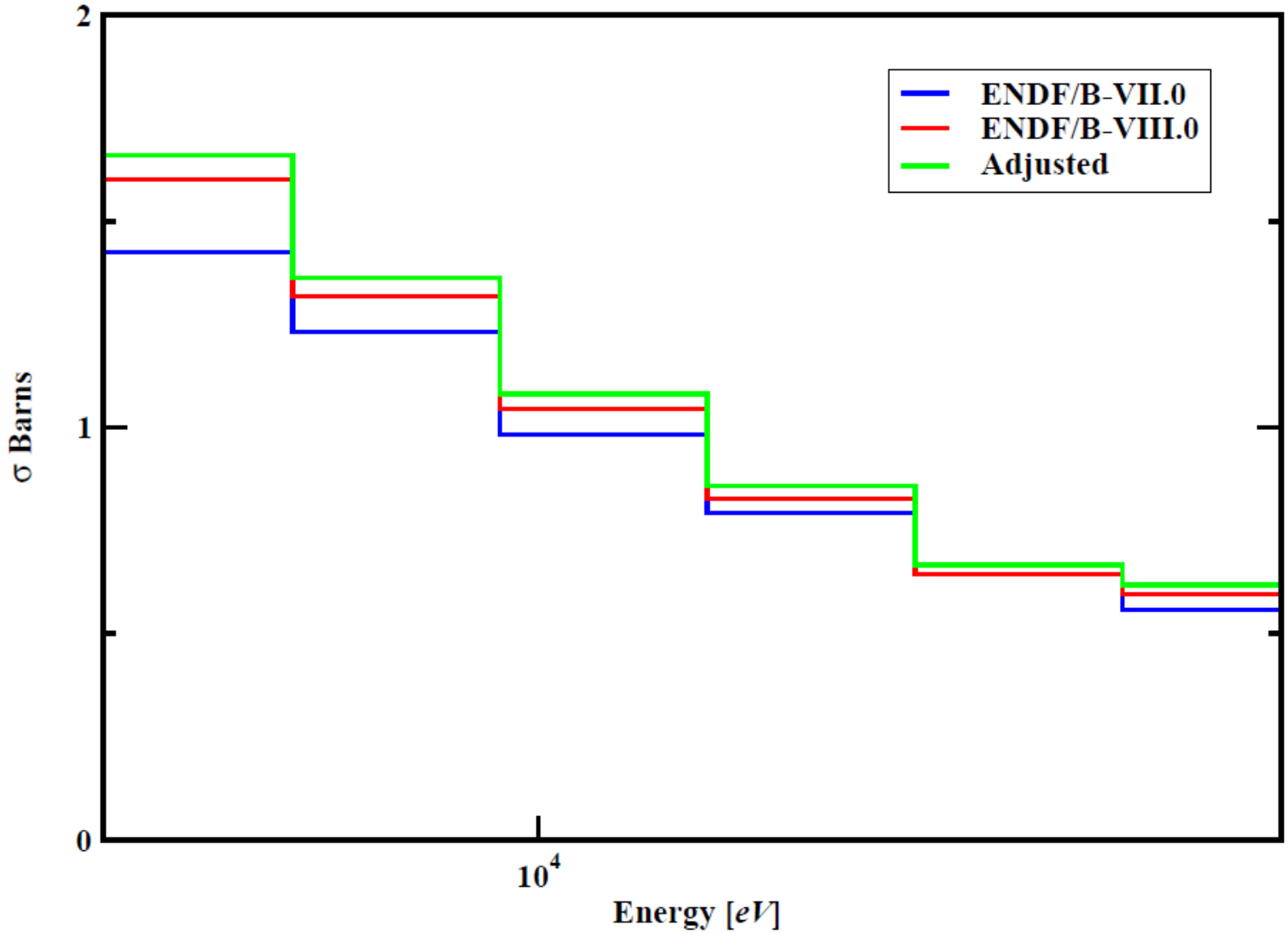
^{56}Fe σ Changes



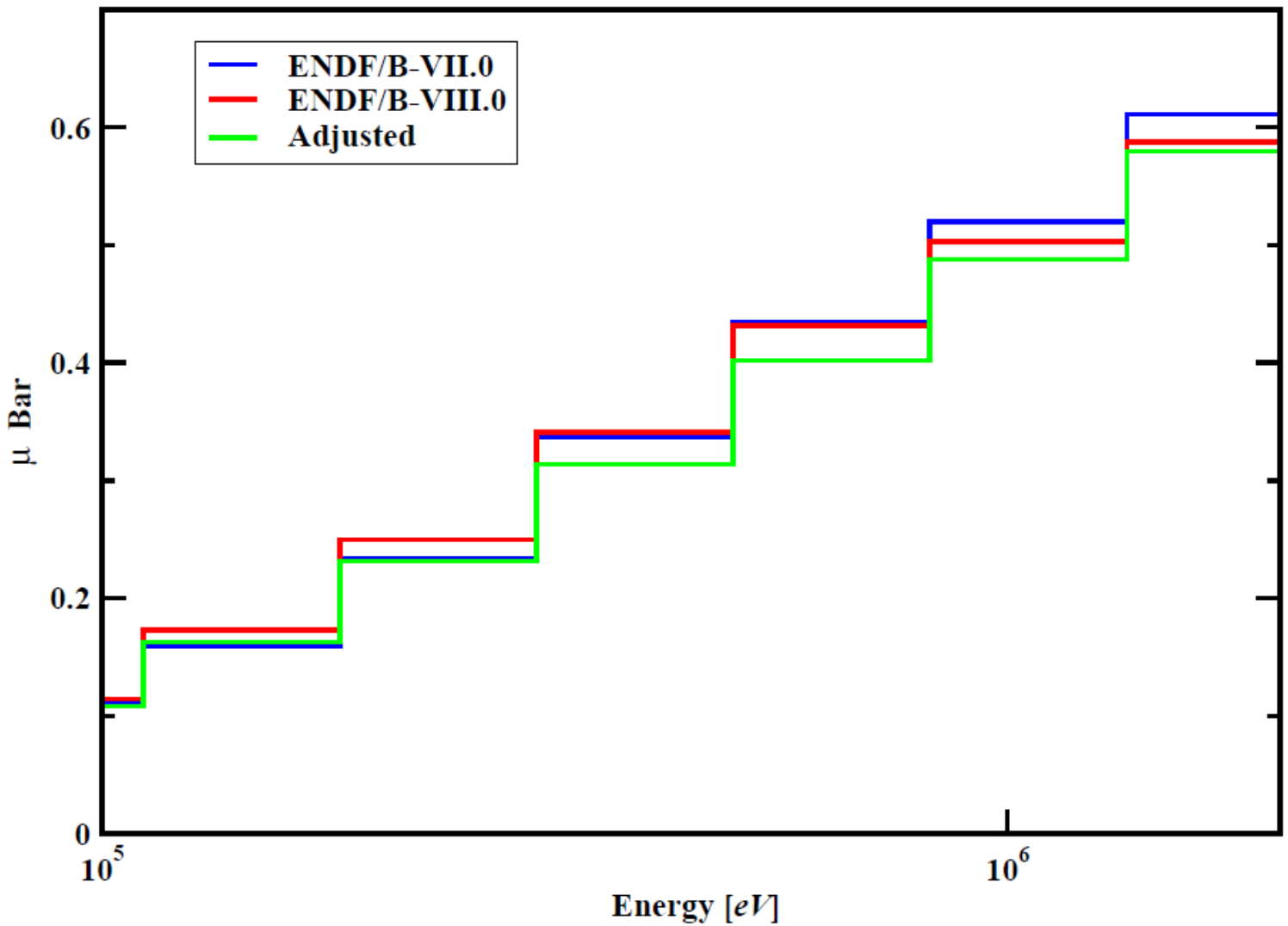
^{56}Fe Standard Deviation Absolute Changes in %



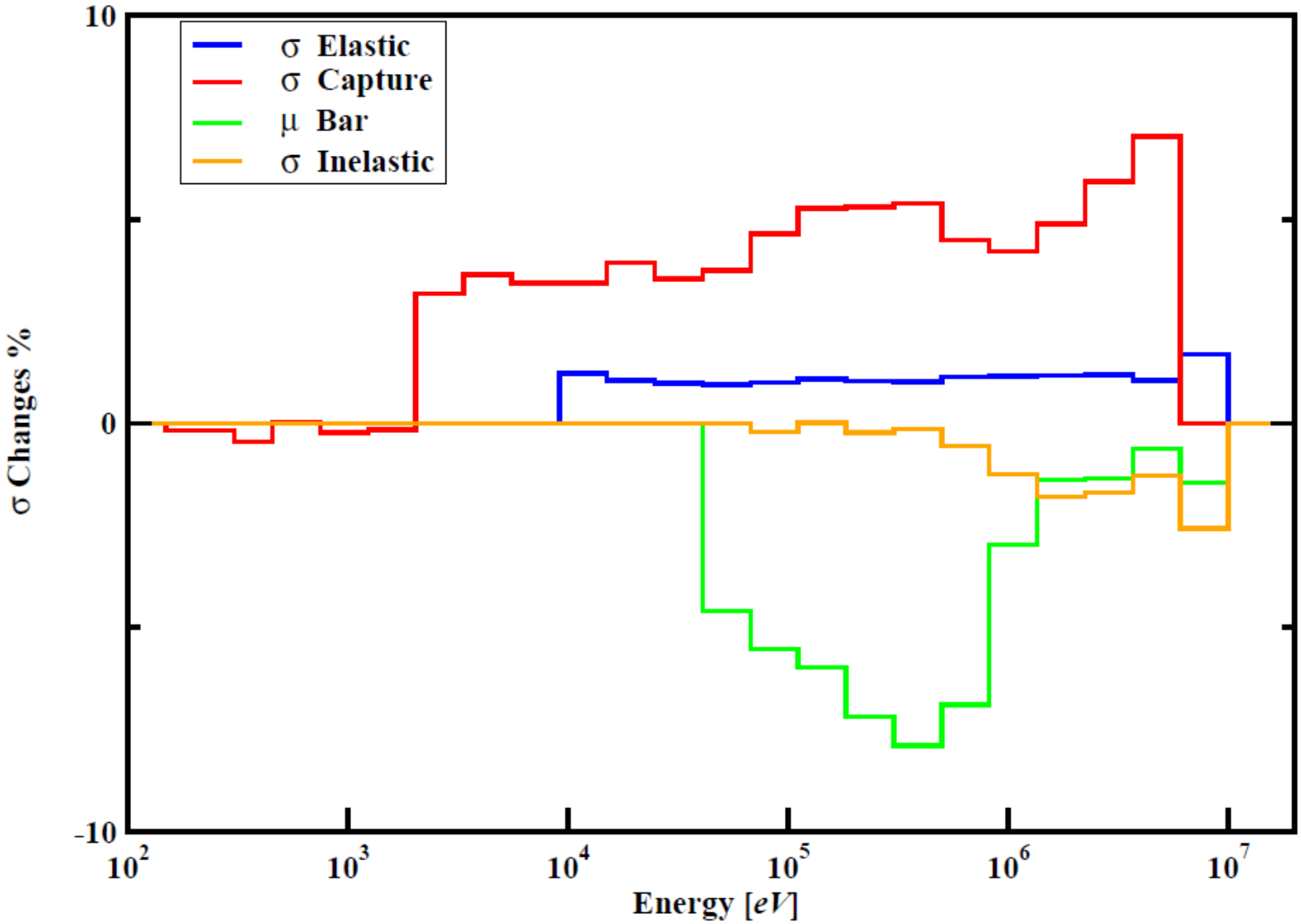
^{235}U σ Capture



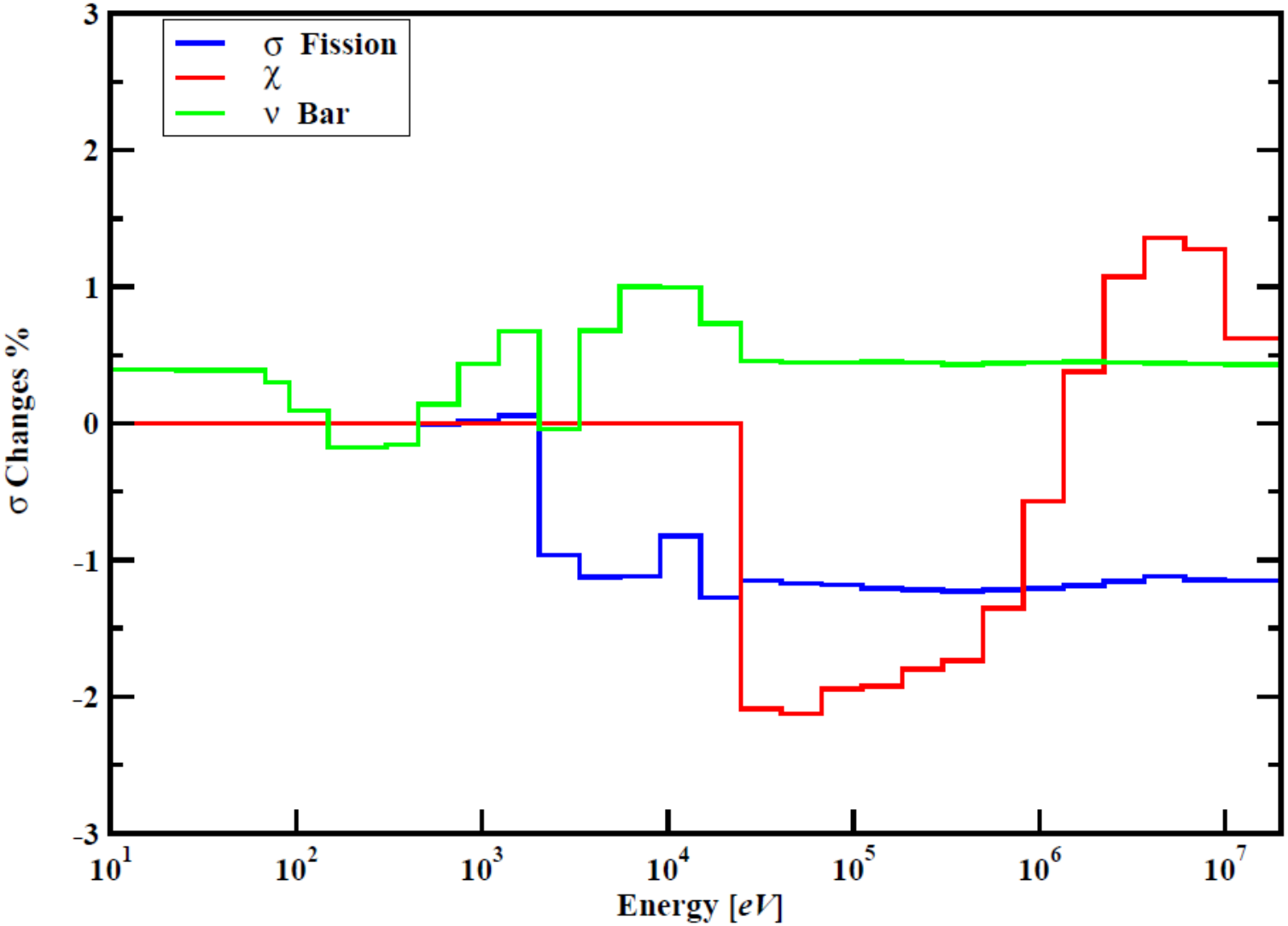
^{235}U μ Bar


ENDF/B-VII.0
ENDF/B-VIII.0
Adjusted
0.6
0.4
0.2
0
μ Bar
10^5
10^6
Energy [eV]

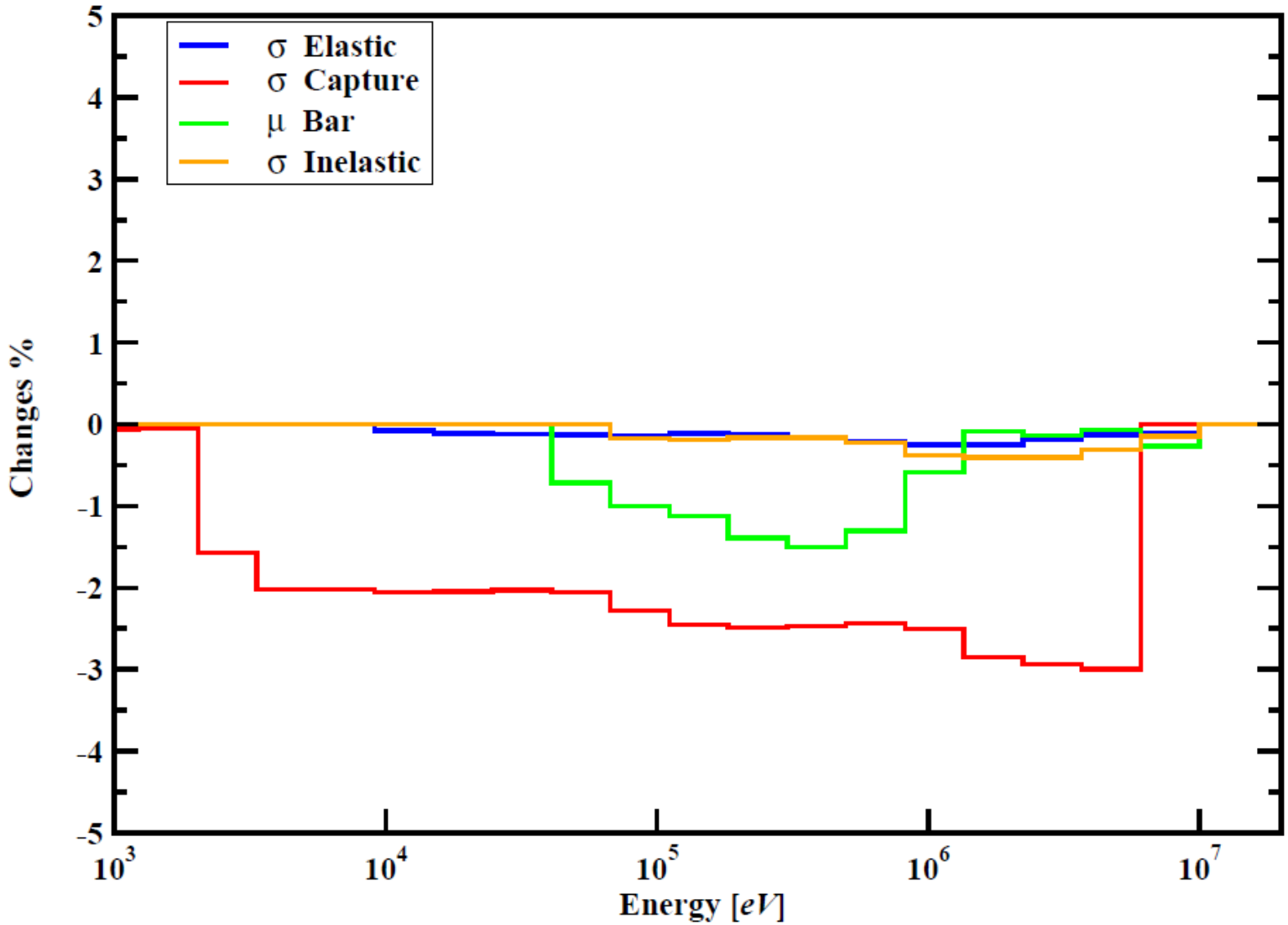
^{235}U σ Changes



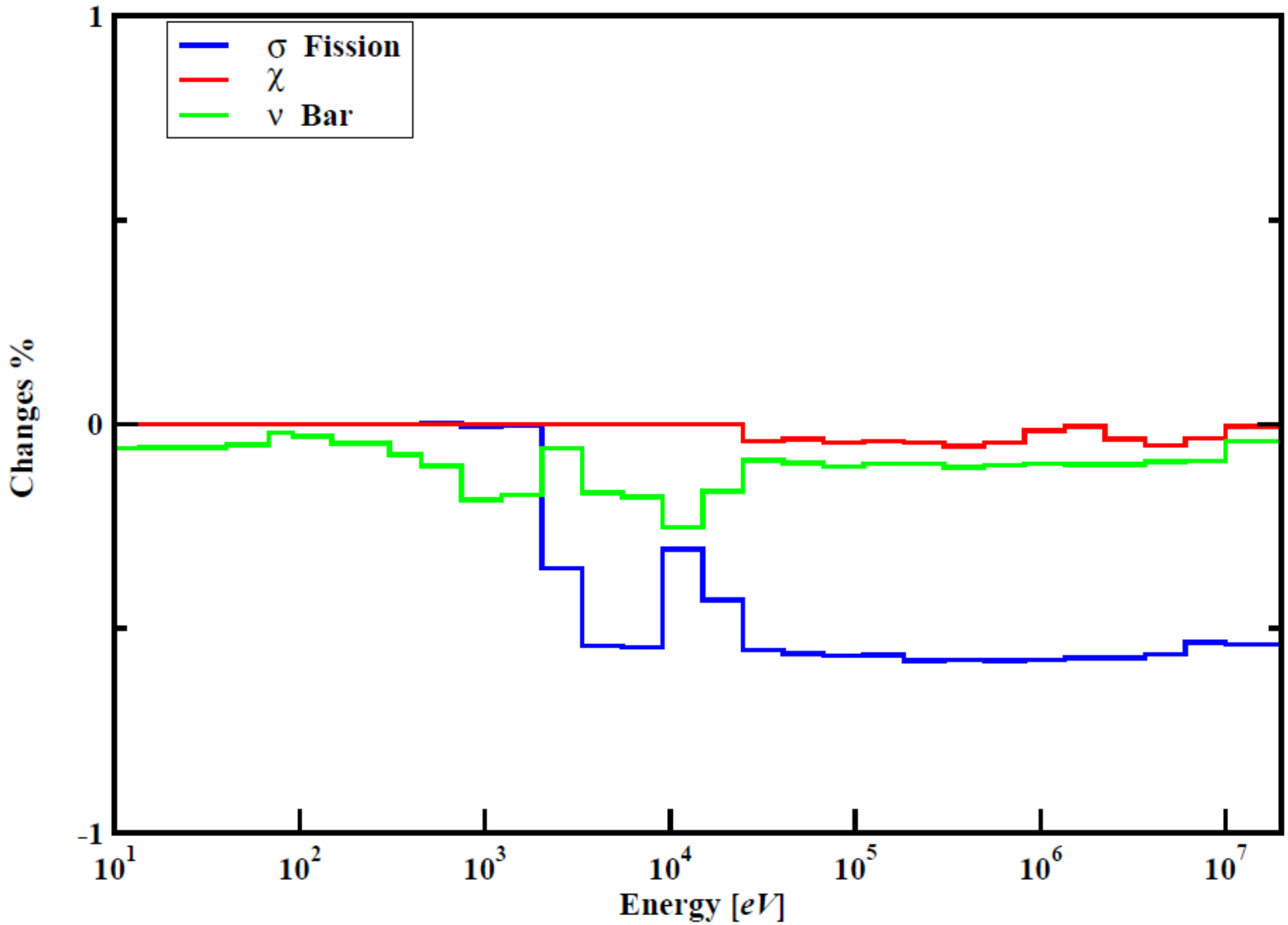
^{235}U σ Changes



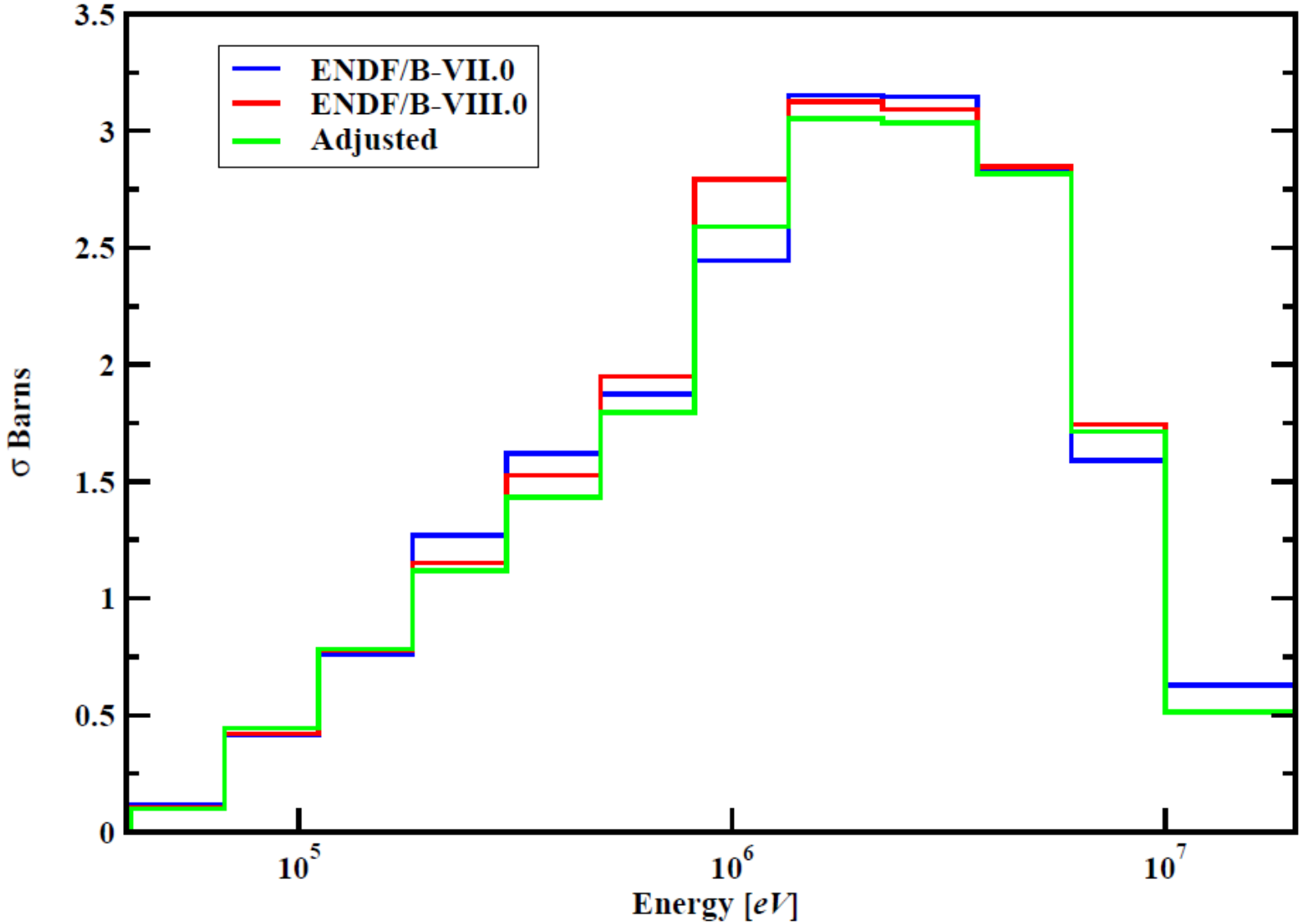
^{235}U Standard Deviation Absolute Changes in %



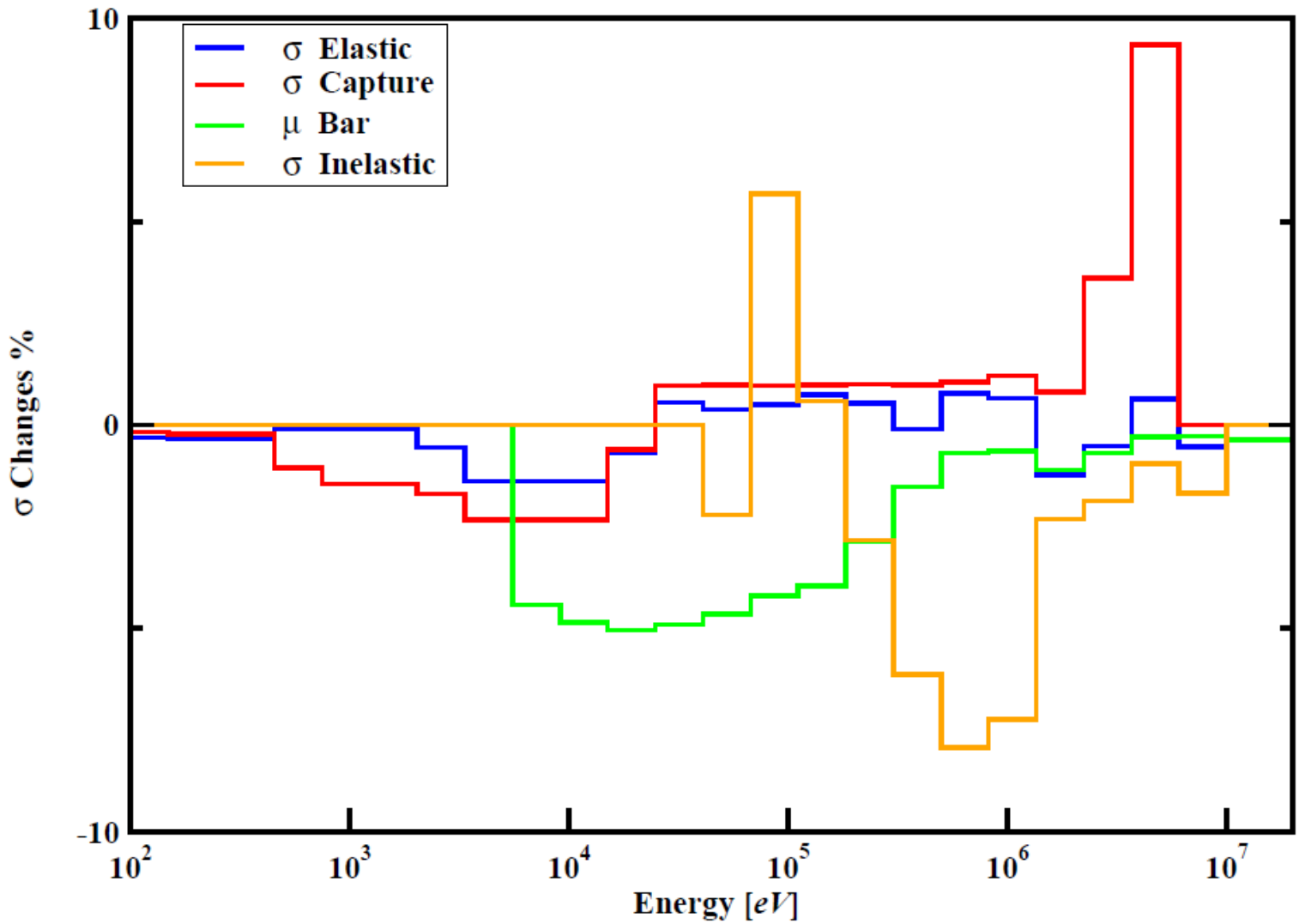
^{235}U Standard Deviation Absolute Changes in %



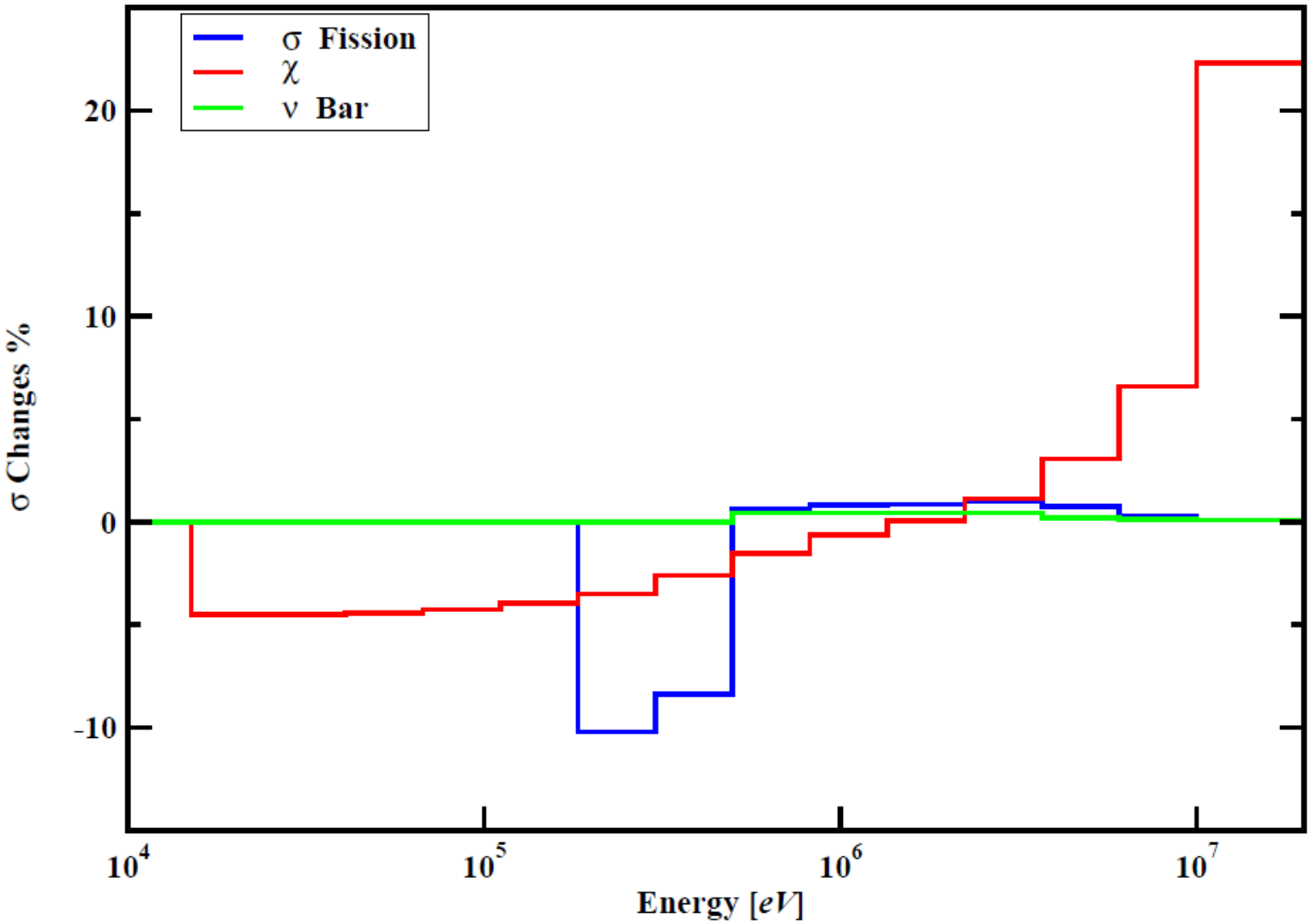
^{238}U σ Inelastic



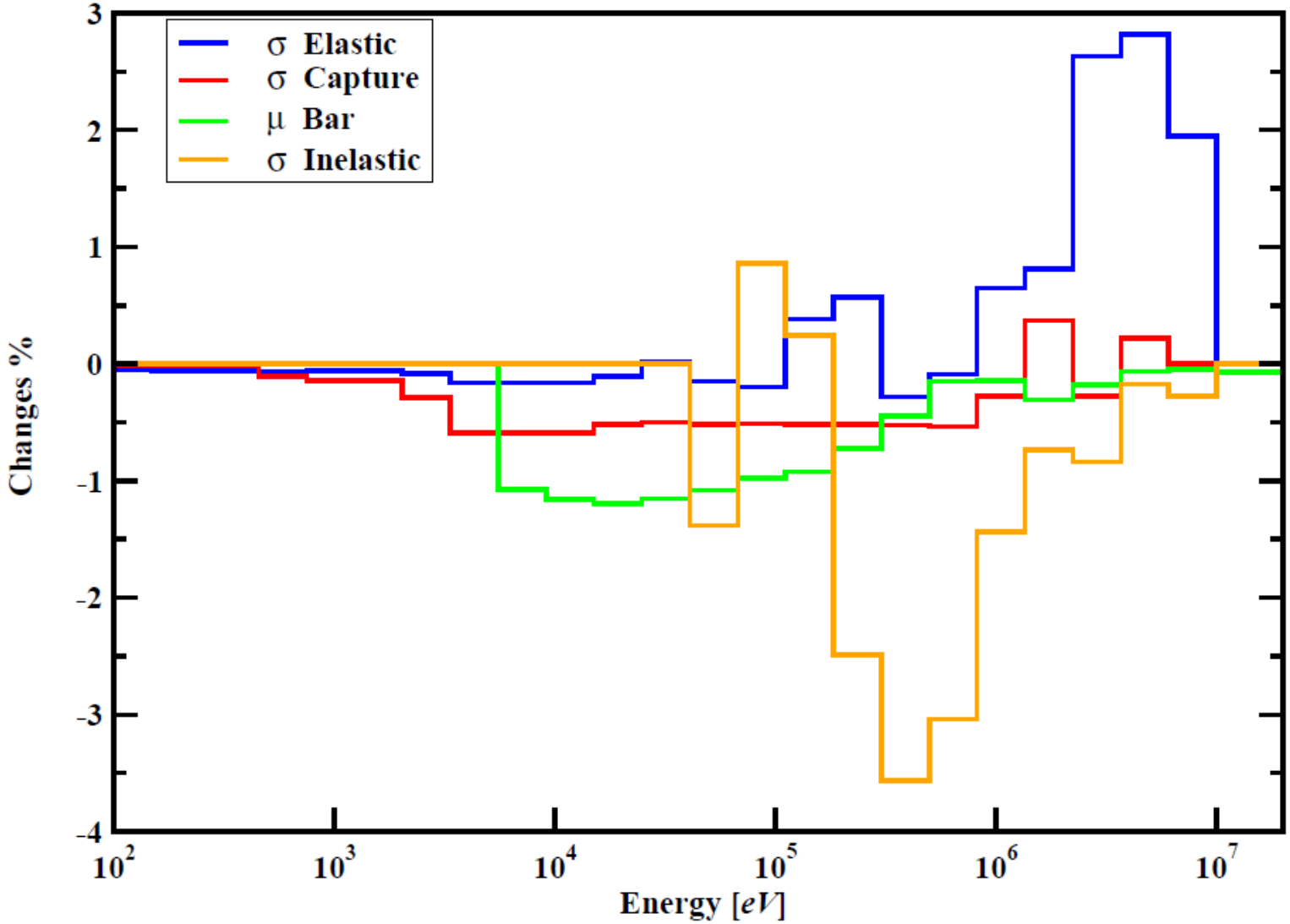
^{238}U σ Changes



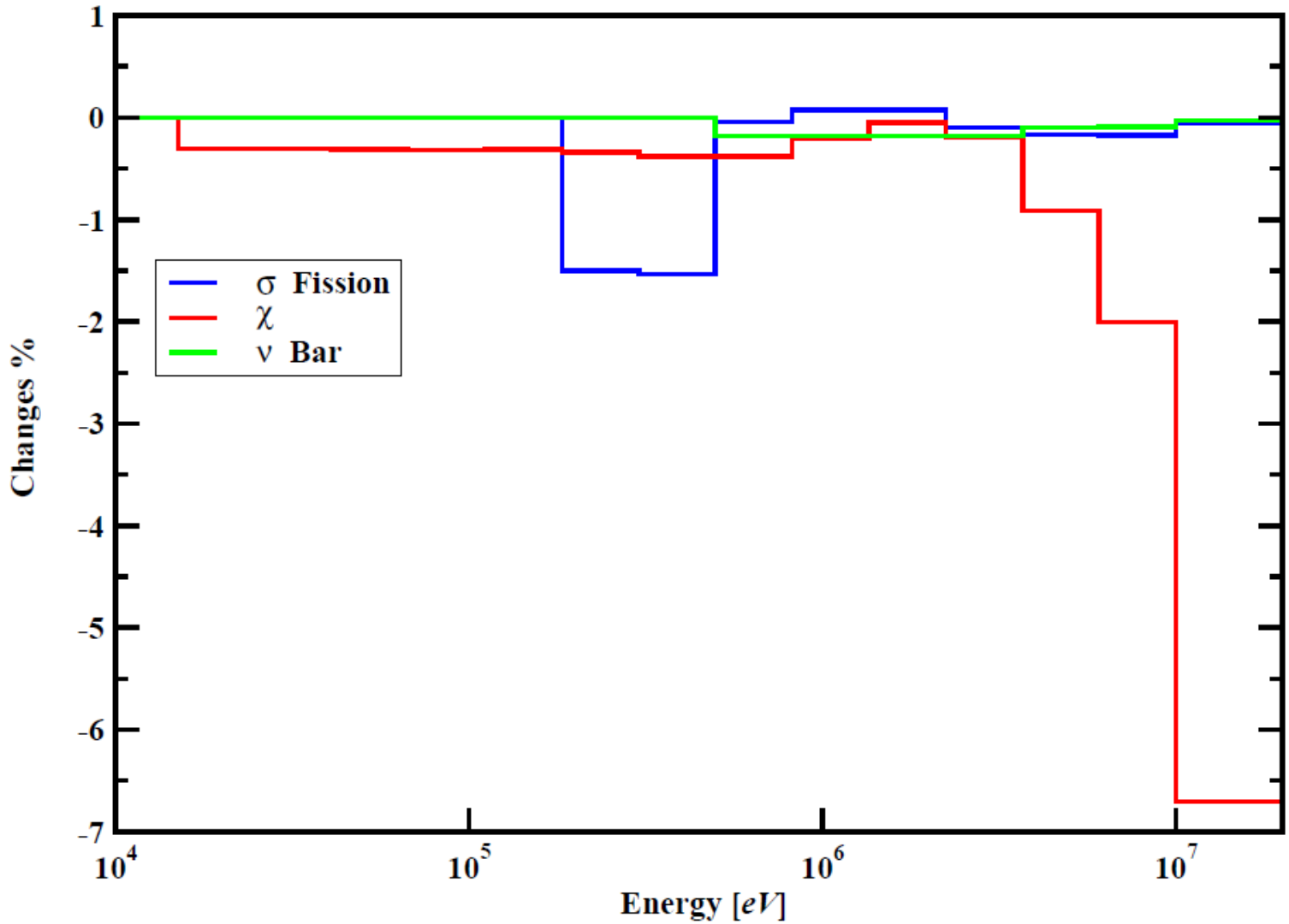
^{238}U σ Changes

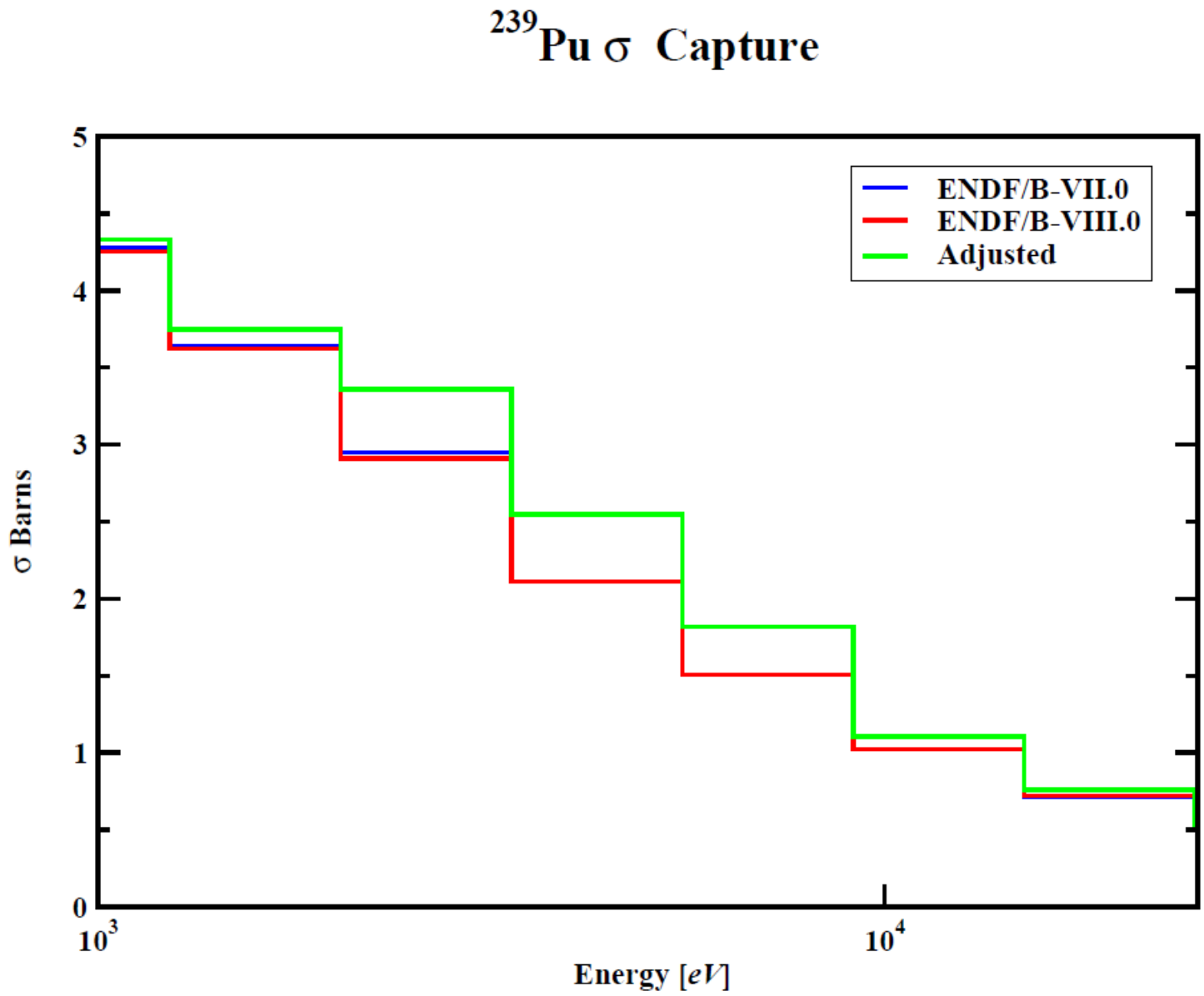


^{238}U Standard Deviation Absolute Changes in %

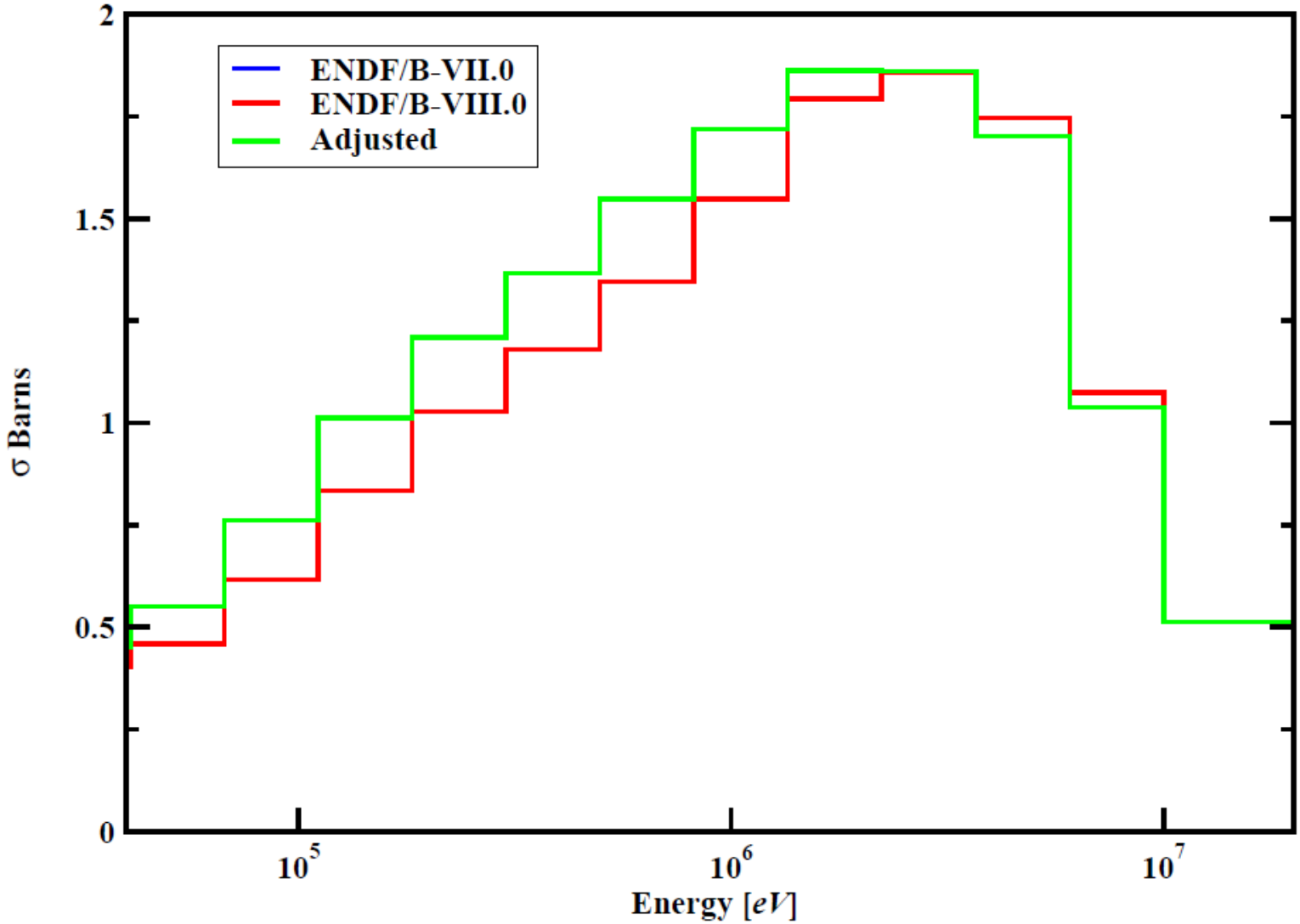


^{238}U Standard Deviation Absolute Changes in %

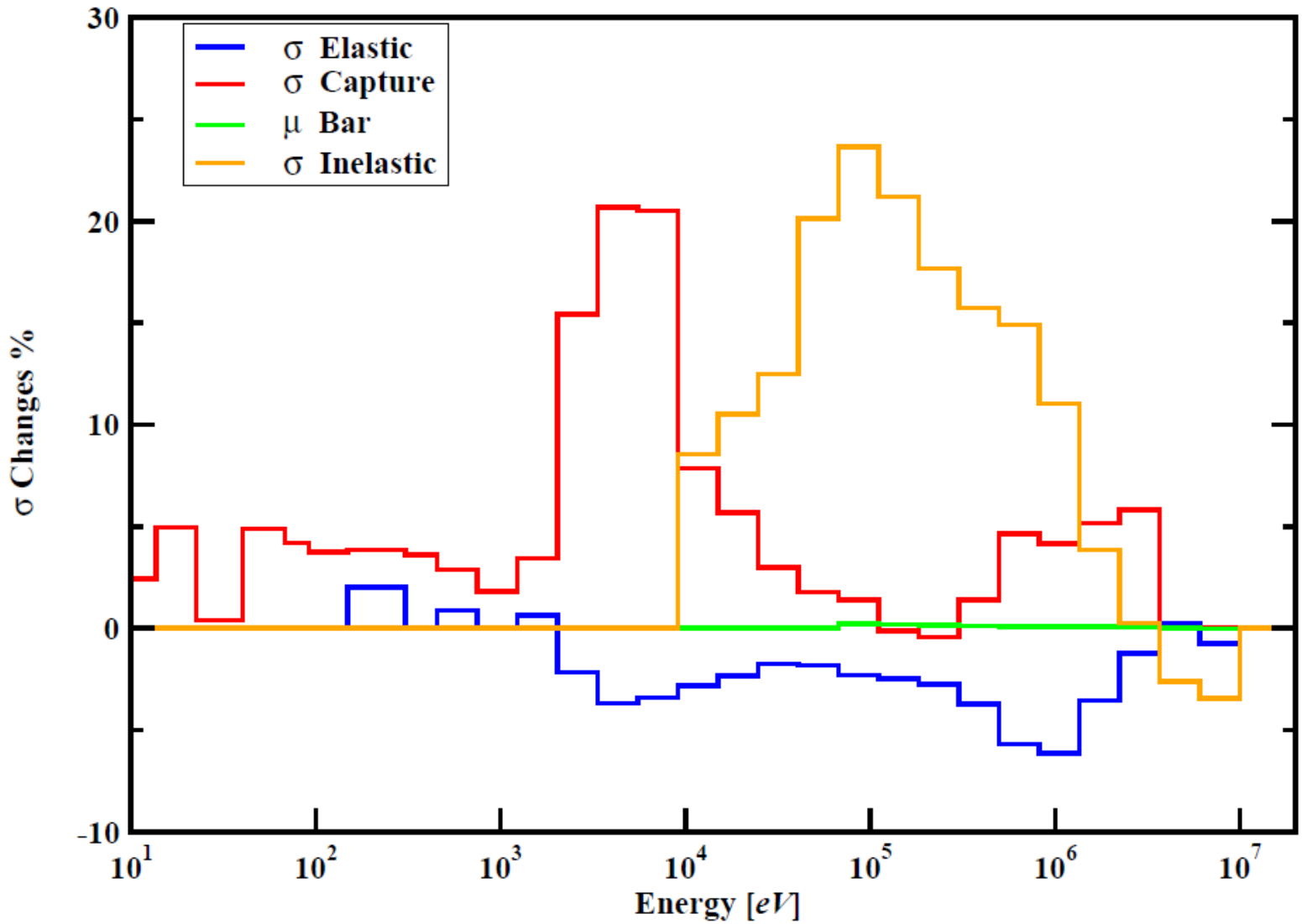



239Pu σ Capture
ENDF/B-VII.0
ENDF/B-VIII.0
Adjusted
σ Barns
Energy [eV]
0
1
2
3
4
5
10^3
10^4

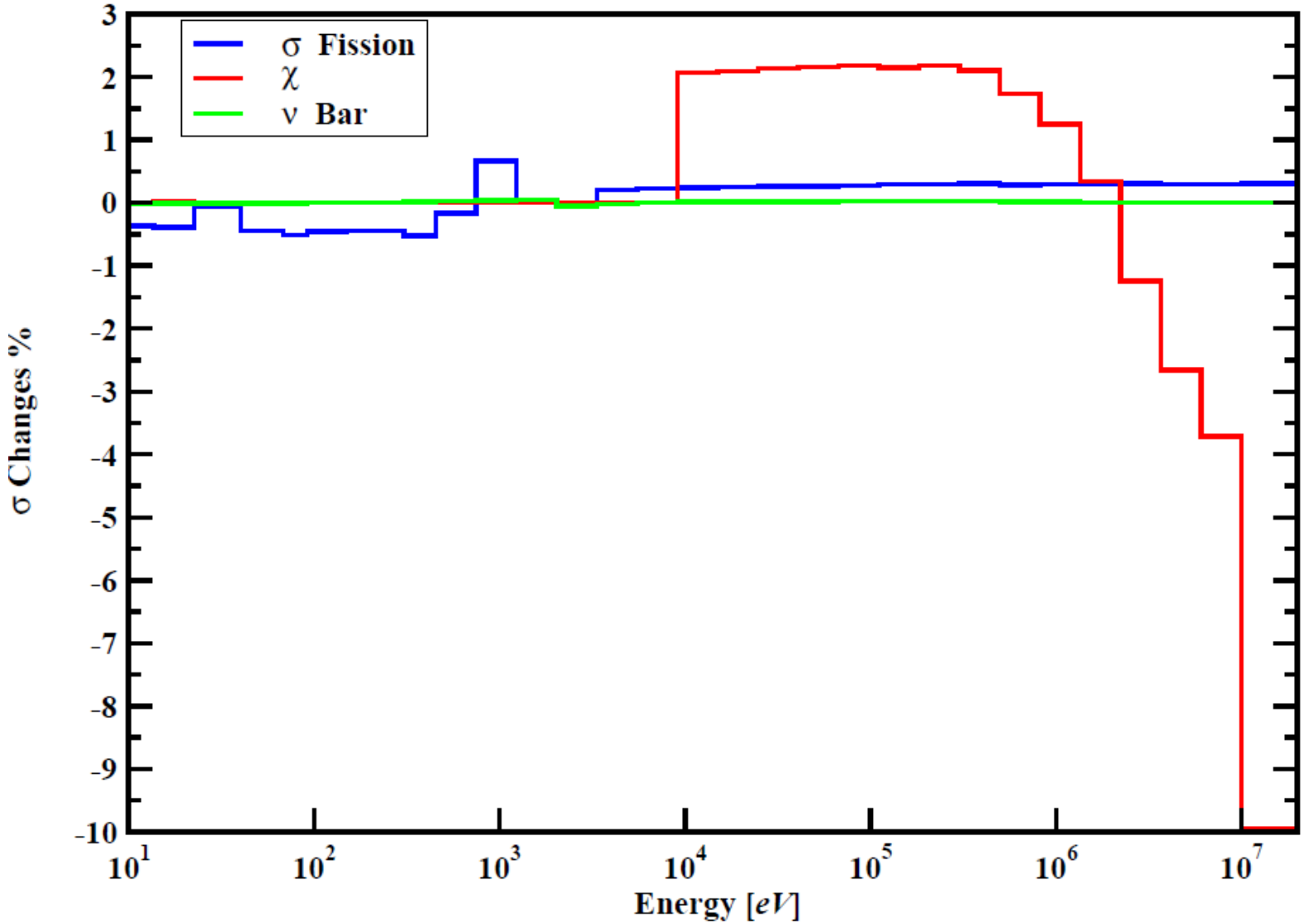
^{239}Pu σ Inelastic



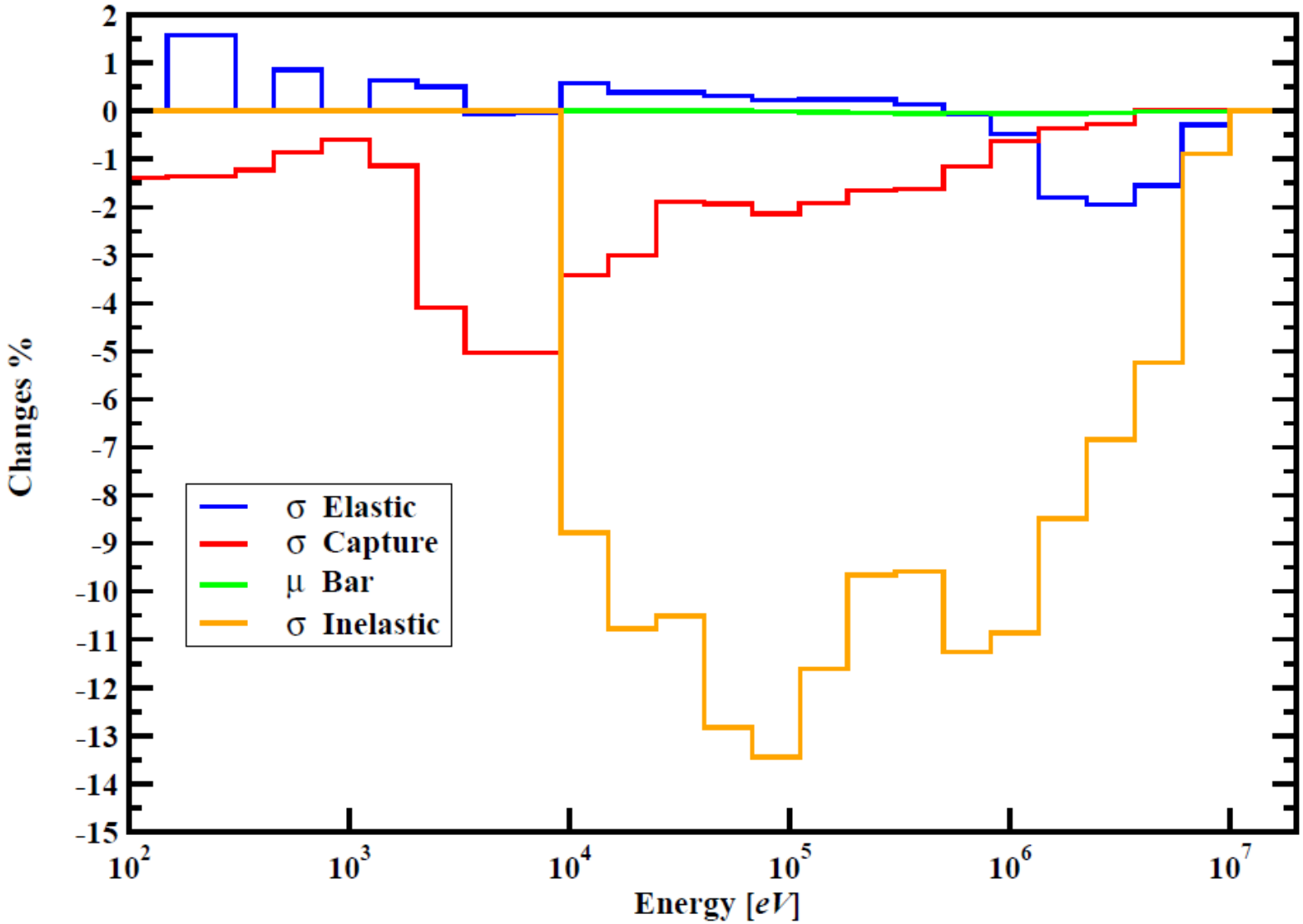
^{239}Pu σ Changes



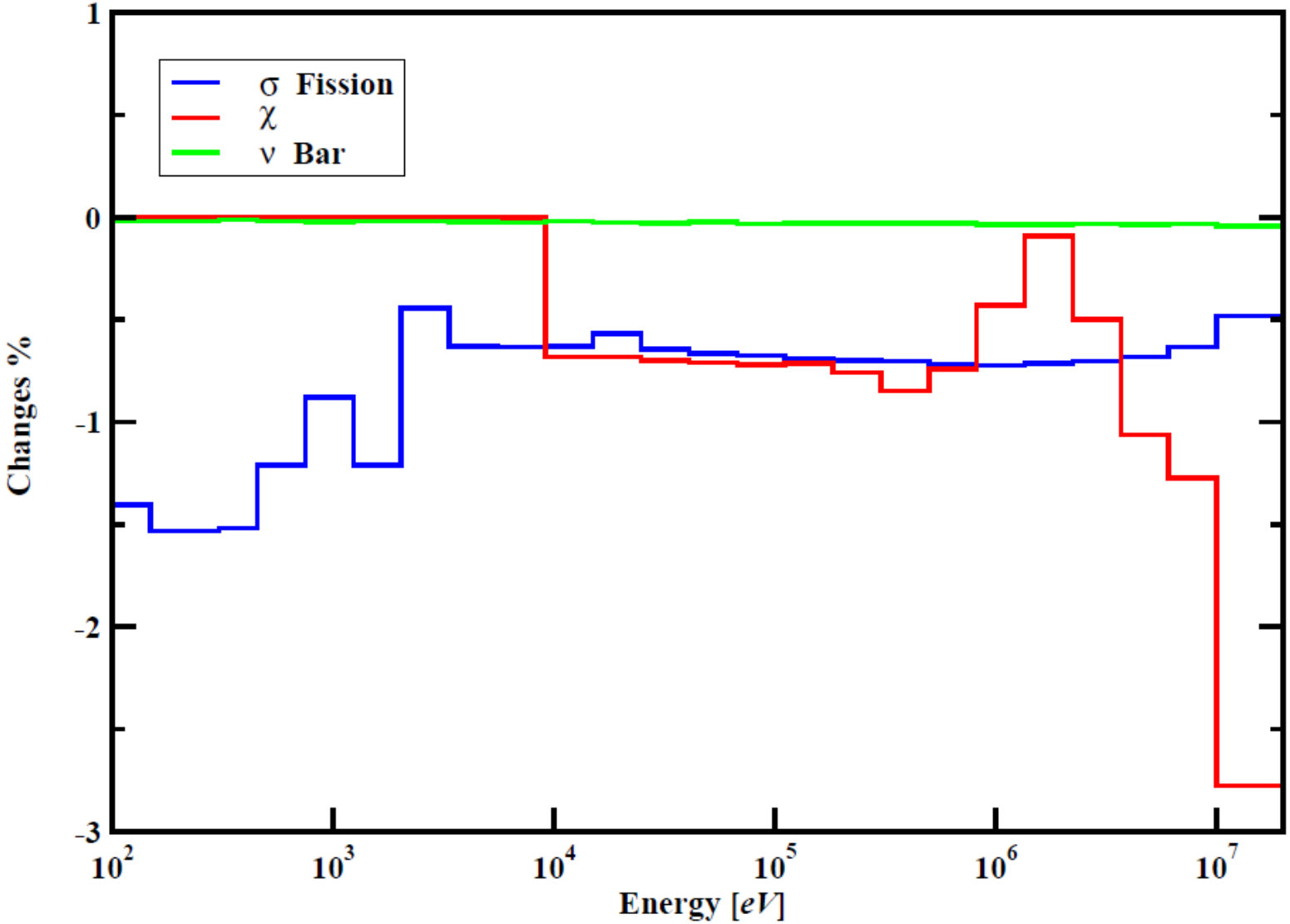
^{239}Pu σ Changes



^{239}Pu Standard Deviation Absolute Changes in %



^{2389}Pu Standard Deviation Absolute Changes in %



Conclusions

- An extended adjustment has been carried out including the cIELO isotopes and their associated covariance matrices. In particular "elementary type" of experiments often intended for specific reactions and energy range of the 5 isotopes of interest of the CIELO Subgroup have been added.
- Feedback have been provided for the 5 CIELO isotope cross sections and some incongruences have been observed for the covariance.
- In future an adjustment using the PIA approach will be attempted in order to avoid, if possible, compensations.
- However, we still need the missing data in the covariance matrices: P_1 elastic, secondary energy distribution for inelastic cross sections (multigroup transfer matrix), cross correlations (reactions and isotopes), delayed data (nubar and fission spectra).
- In the future would be nice to have a finer energy grid and eigenvalue decomposition of the covariance matrix, in order to perform a "continuous" energy adjustment.