Feedback on CIELO Isotopes from ENDF/B-VII.0 Adjustment

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Adjustment

- A comprehensive multigroup neutron cross section adjustment has been carried out using ENDF/B-VII.0 data files and COMMARA 2.0 covariance matrix.
- An initial set of 148 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 87 experimental values based on several considerations (duplications, some covariance data not available, etc.). Later on added 5 more experiments (more sensitivity to isotope of interest), reaction covariance, and isotopes (to avoid compensations).
- A 33 energy group structure was adopted and sensitivity coefficients were calculated. Generalized Perturbation Theory (by ERANOS system) was used for static integral parameters and Depletion Perturbation Theory for time dependent parameters (done at ANL).

Type of experiments used in adjustment

	keff	Reactivity Coefficients	Spectral index	Irradiation	total # cases
Jezebel	2		3		5
Flattop	1		2		3
ZPPR-6/7,9	3	2	6		11
JOYO	1				1
Godiva	1		3		4
BigTen	1		3		4
Np Sphere	1				1
ZPPR-10,15	3	5			8
COSMO			9		9
PROFIL				26	26
TRAPU				15	15

Additions

- **Experiments (5 more critical masses):**
  - **ZPR9-34 (^{235}U and ^{56}Fe)**
  - **ZPR3-53 (^{239}Pu and ^{238}U)**
  - **ZPR3-54 (^{239}Pu and ^{56}Fe)**
  - **CIRANO 2A (^{239}Pu and ^{238}U)**
  - **CIRANO 2B (^{239}Pu and SS)**
- **Reactions:**
  - **χ (^{235}U, ^{238}U)**
  - **P_1 elastic (^{235}U, ^{238}U, ^{239}Pu)**
- **9 more isotopes**

43 COMMARA-2.0 nuclei with covariances used in adjustment

- **Light Nuclei:**

  ^{10}B, ^{16}O, ^{12}C

- **Structural materials and fission fragments:**

  ^{23}Na, ^{52}Cr, ^{56}Fe, ^{58}Ni, ^{95}Mo, ^{97}Mo, ^{101}Ru, ^{105}Pd, ^{106}Pd, ^{133}Cs, ^{143}Nd, ^{145}Nd, ^{149}Sm, ^{151}Sm, ^{153}Eu,

  ^{54}Fe, ^{57}Fe, ^{50}Cr, ^{53}Cr, ^{50}Cr, ^{60}Ni, ^{62}Ni, ^{55}Mn

- **Major actinides:**

  ^{235}U, ^{238}U, ^{239}Pu

- **Minor actinides:**

  ^{234}U, ^{236}U, ^{237}Np, ^{238}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu

  ^{241}Am, ^{242m}Am, ^{243}Am, ^{242}Cm, ^{243}Cm, ^{244}Cm, ^{245}Cm

Eight types of parameters included in the adjustment

- (n,f):
  - cross section
  - nubar
  - PFNS (7 cases)
- (n,el):
  - cross section
  - P_1 (5 cases)
- (n,inel): cross section
- (n,γ): cross section
- (n,2n): cross section

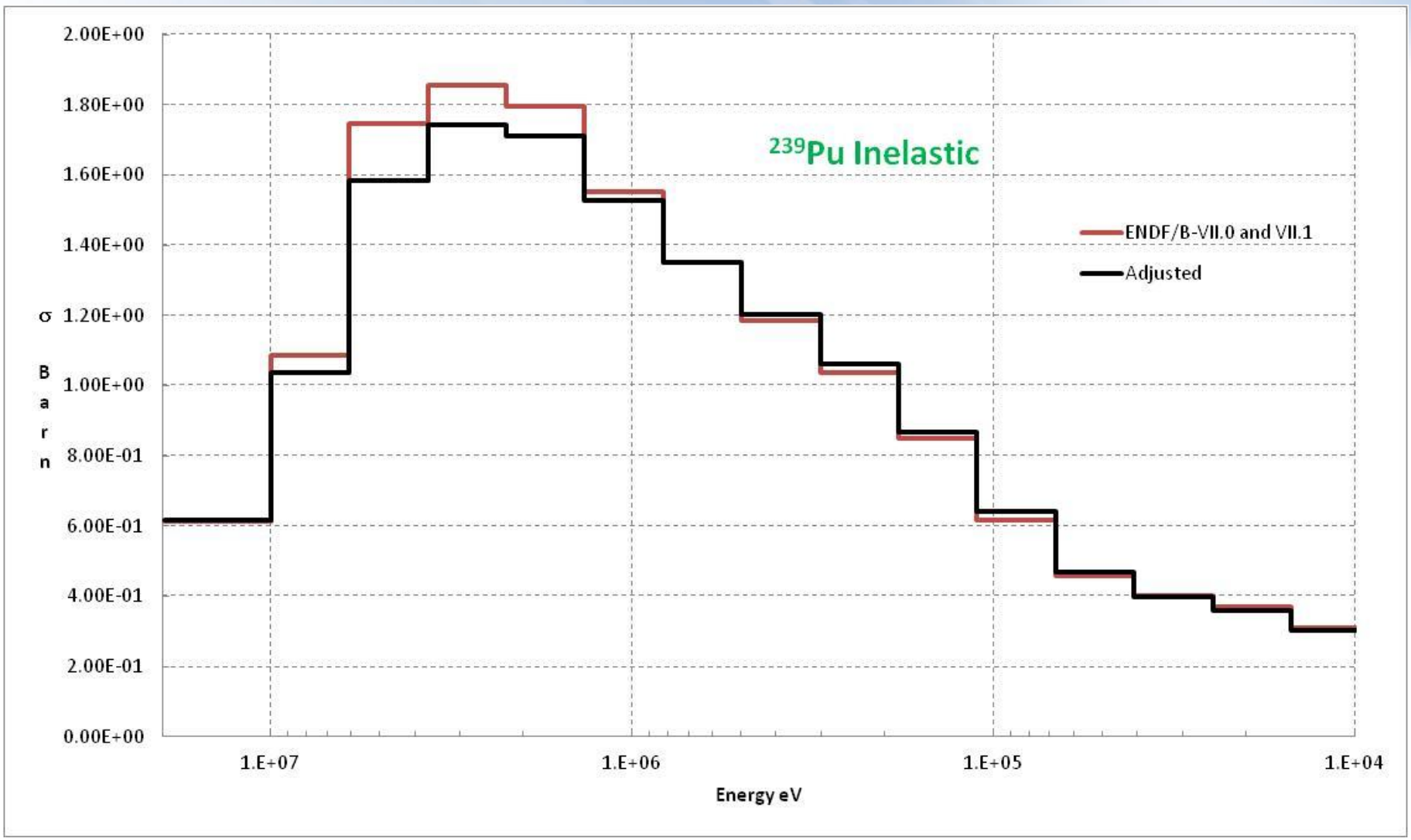
In all, 8976 points could have been adjusted, but only 1374 most important kept:

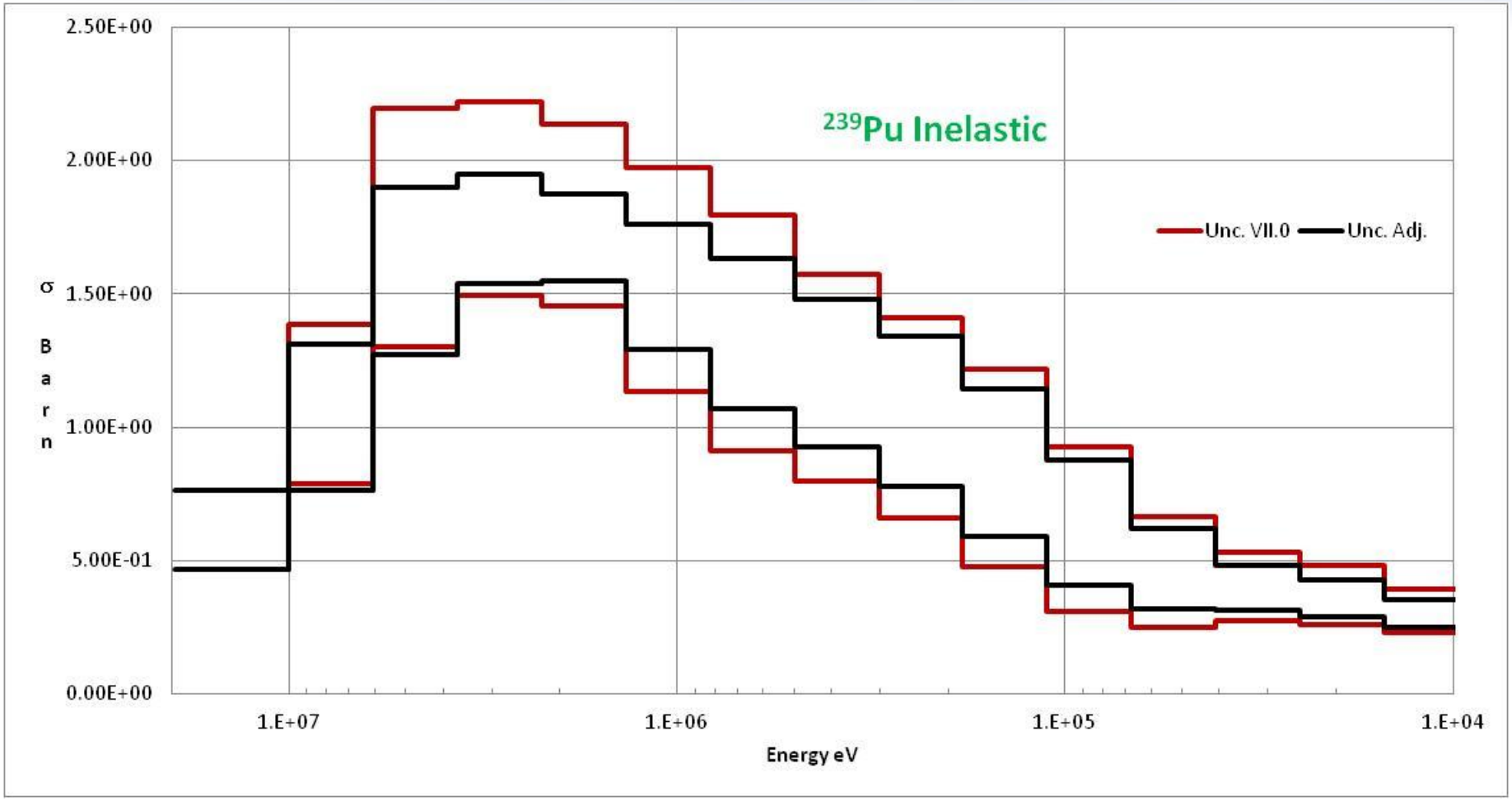
$$\left|\Delta R_{ip}^{1}\right| - \left|S_R^{+} DS_R\right| \geq \varepsilon^{1}$$

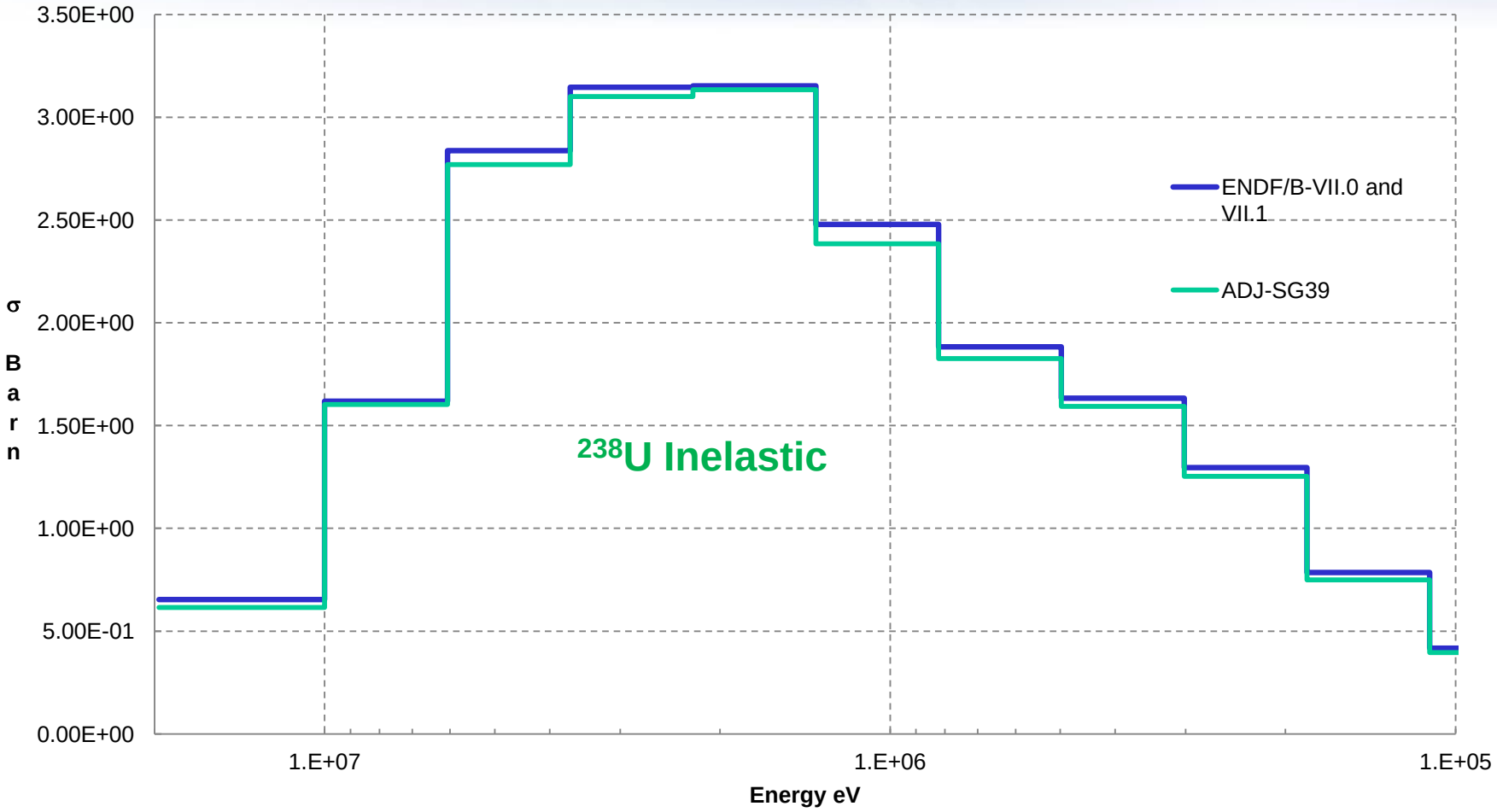
$$\mathbf{S}_{\mathbf{R}pj} = \frac{\Delta R_p}{\Delta \sigma_j}$$

Analysis of CIELO specific cross section adjustments

- **Inelastic cross section adjustments for the "Big Three" actinides:**
  - **^{238}U and ^{239}Pu cross sections are all reduced in the range ~1-5 MeV. Their adjustments can be coupled to significant uncertainty reduction. ^{235}U inelastic does not change too much.**

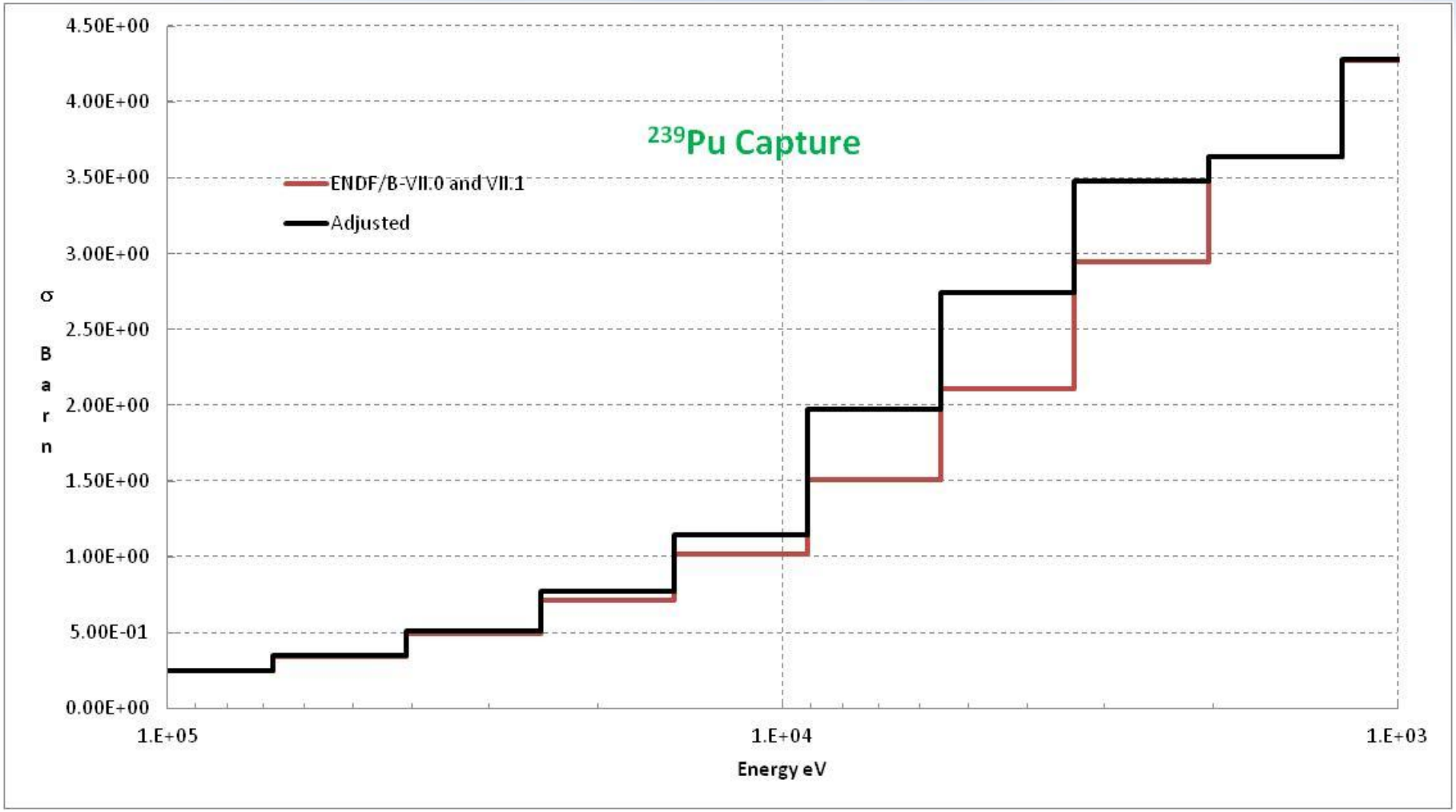

239Pu Inelastic
ENDF/B-VII.0 and VII.1
Adjusted
σ Barn
2.00E+00
1.80E+00
1.60E+00
1.40E+00
1.20E+00
1.00E+00
8.00E-01
6.00E-01
4.00E-01
2.00E-01
0.00E+00
1.E+07
1.E+06
1.E+05
1.E+04
Energy eV

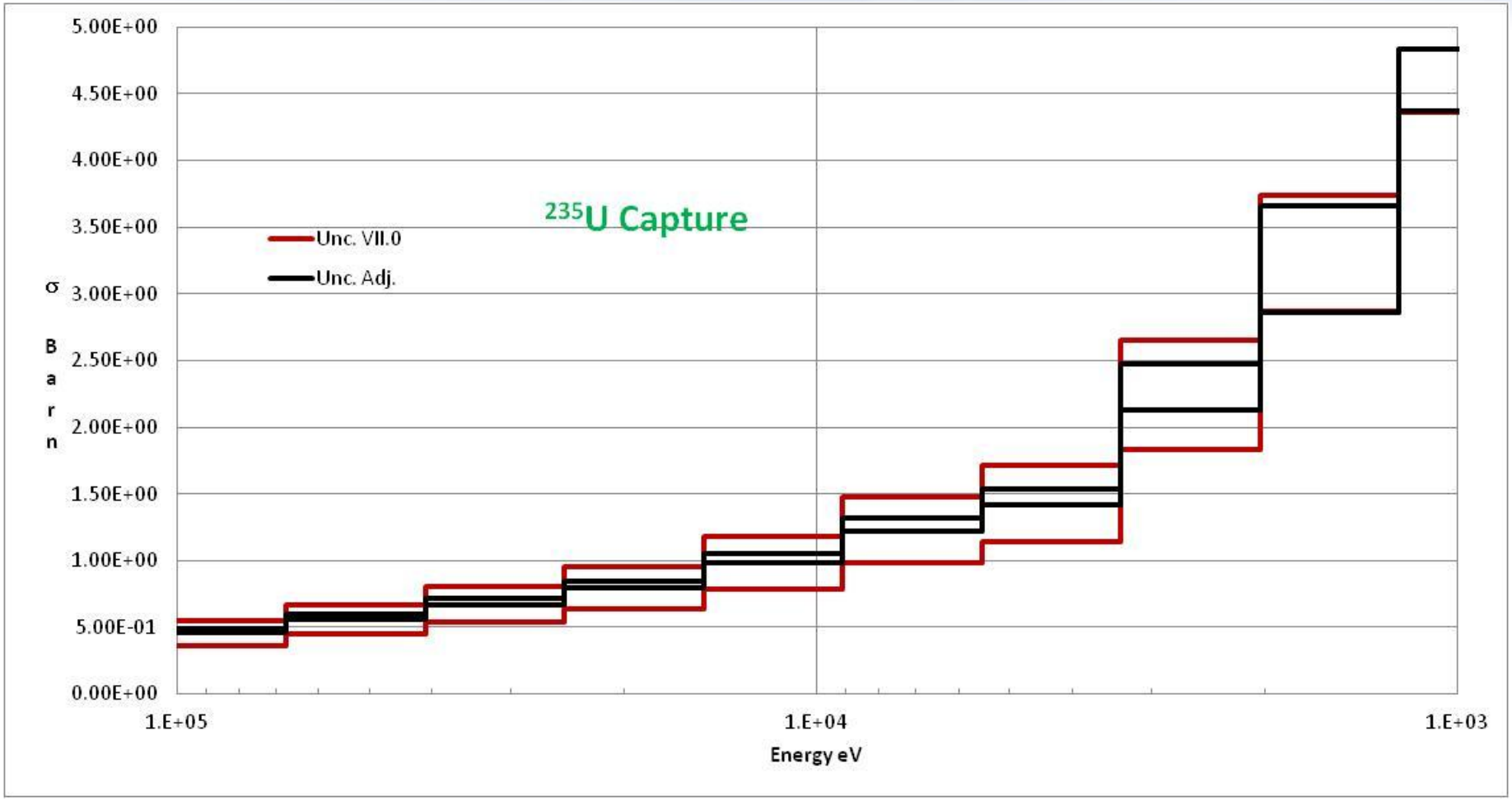

239Pu Inelastic
Unc. VII.0
Unc. Adj.
2.50E+00
2.00E+00
1.50E+00
1.00E+00
5.00E-01
0.00E+00
σ
B
a
r
n
1.E+07
1.E+06
1.E+05
1.E+04
Energy eV


3.50E+00
3.00E+00
2.50E+00
2.00E+00
1.50E+00
1.00E+00
5.00E-01
0.00E+00
σ
B
a
r
n
1.E+07
1.E+06
1.E+05
Energy eV
ENDF/B-VII.0 and VII.1
ADJ-SG39
238U Inelastic

Analysis of CIELO specific cross section adjustments

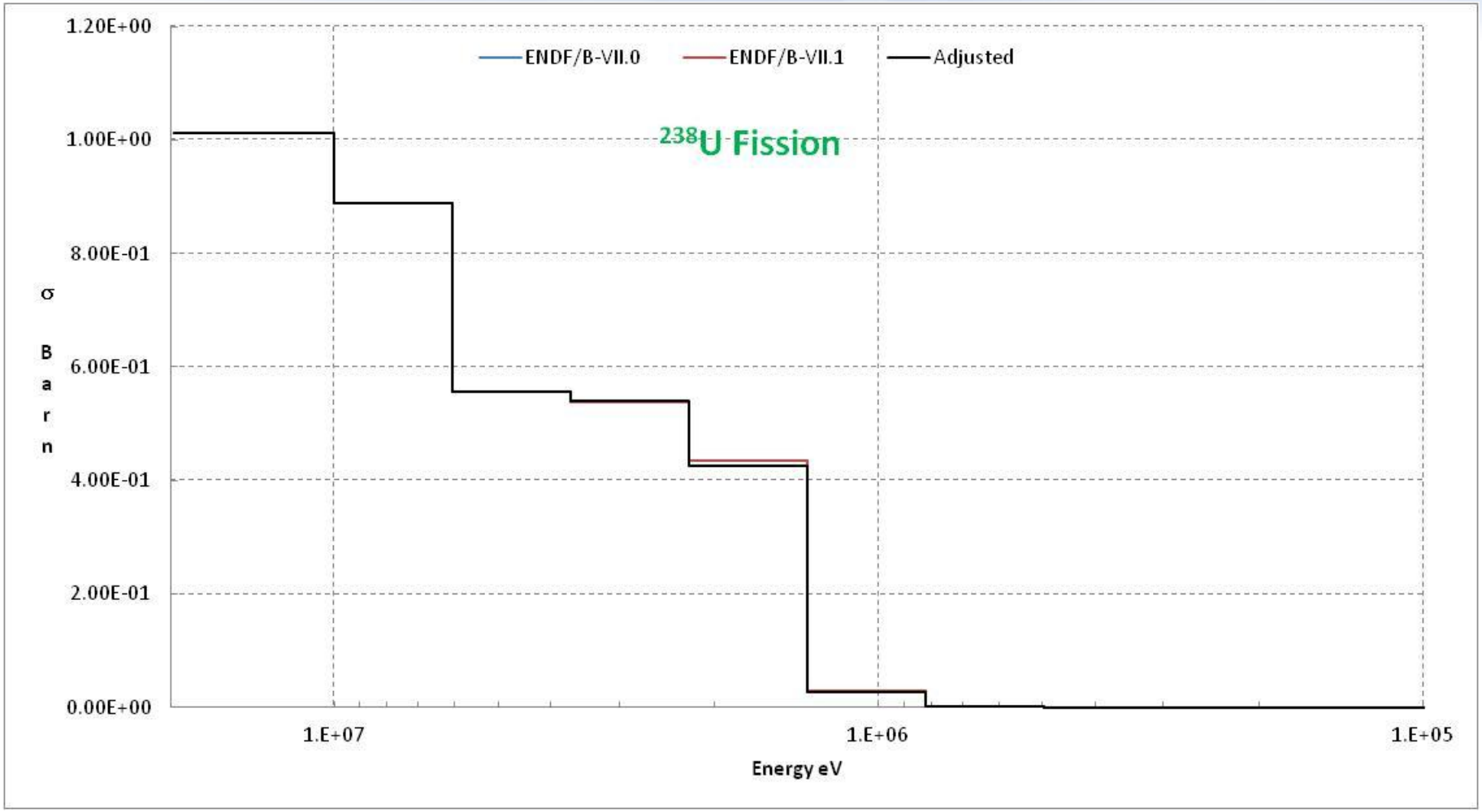
- **Capture cross section adjustments for the "Big Three" actinides:**
  - **The ^{239}Pu capture cross section is significantly increased (5 to 10%) in the 1 Kev to 10 Kev range.**
  - **The ^{235}U and ^{238}U capture cross sections do not change too much but the ^{235}U adjustment is coupled to a very significant uncertainty reduction.**

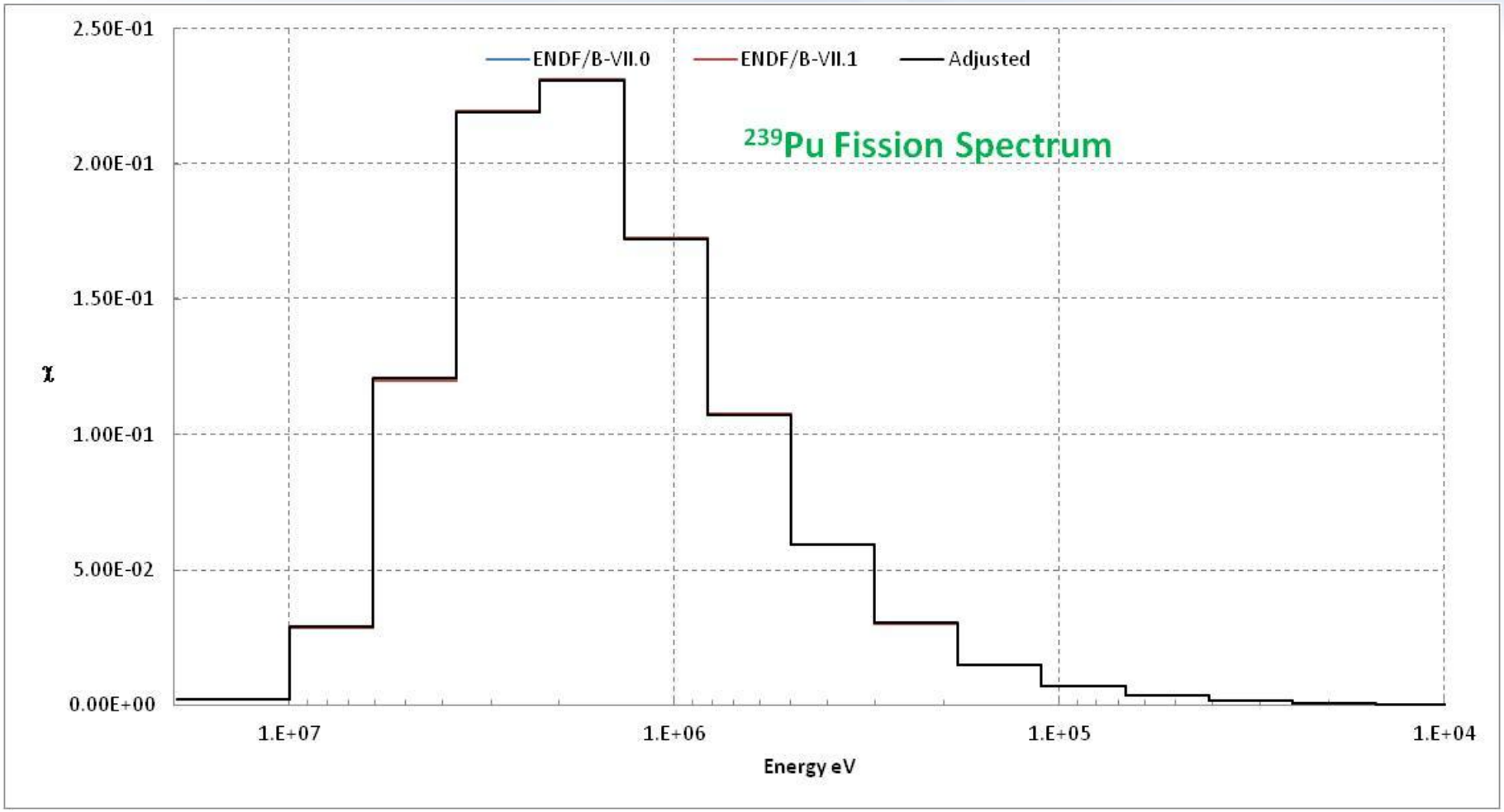

239Pu Capture
ENDF/B-VII.0 and VII.1
Adjusted
σ
Barn
4.50E+00
4.00E+00
3.50E+00
3.00E+00
2.50E+00
2.00E+00
1.50E+00
1.00E+00
5.00E-01
0.00E+00
1.E+05
1.E+04
1.E+03
Energy eV


5.00E+00
4.50E+00
4.00E+00
3.50E+00
3.00E+00
2.50E+00
2.00E+00
1.50E+00
1.00E+00
5.00E-01
0.00E+00
σ
B
a
r
n
235U Capture
Unc. VII.0
Unc. Adj.
1.E+05
1.E+04
1.E+03
Energy eV

Analysis of CIELO specific cross section adjustments

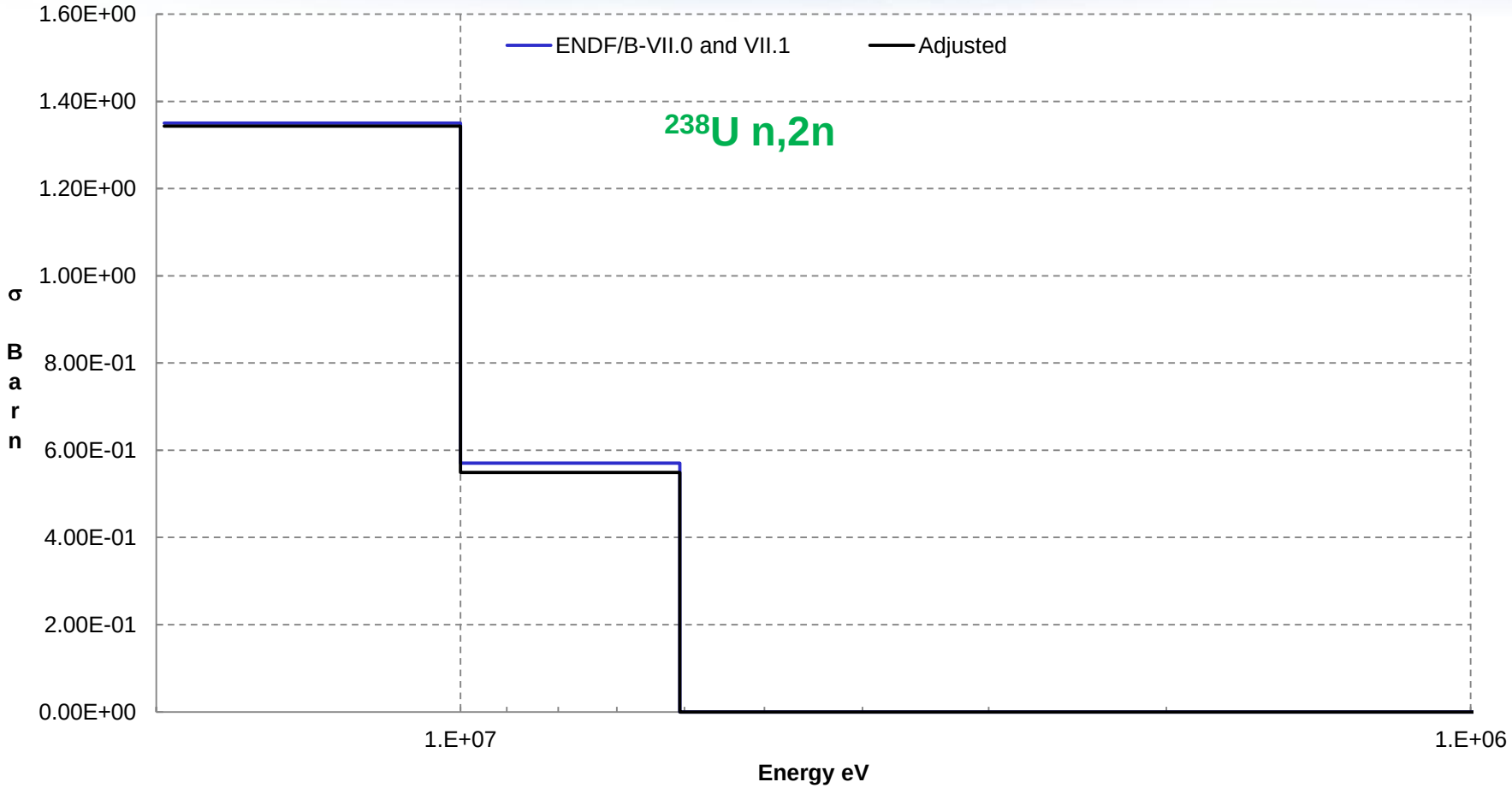
- **Fission cross sections and fission spectrum adjustments for the "Big Three" actinides:**
  - **No major adjustment because initial standard deviation is very low**
  - **Very low modification for ^{239}Pu fission spectrum**

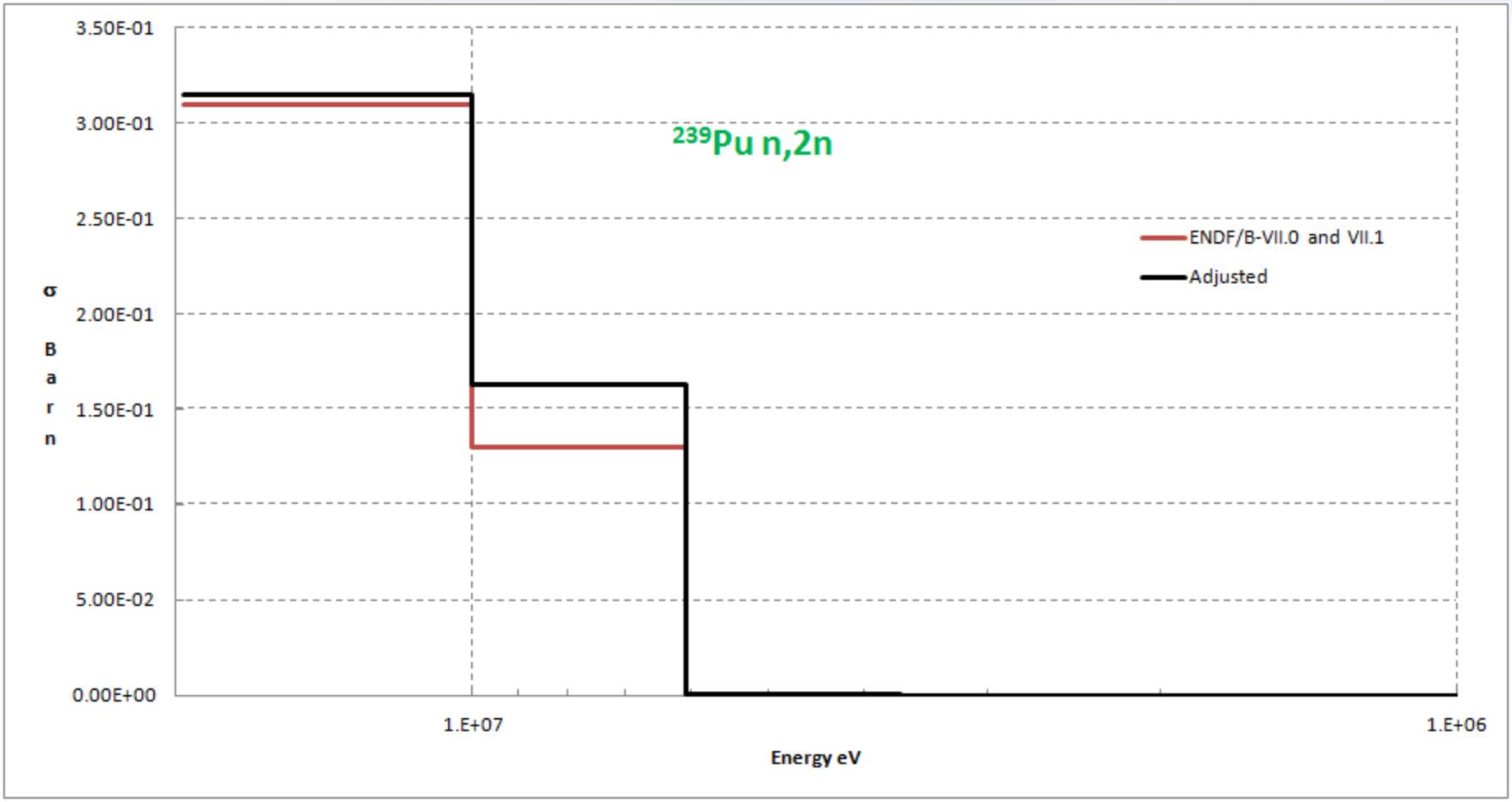

ENDF/B-VII.0
ENDF/B-VII.1
Adjusted
238U Fission
1.20E+00
1.00E+00
8.00E-01
6.00E-01
4.00E-01
2.00E-01
0.00E+00
σ
B
a
r
n
1.E+07
1.E+06
1.E+05
Energy eV


ENDF/B-VII.0
ENDF/B-VII.1
Adjusted
239Pu Fission Spectrum
2.50E-01
2.00E-01
1.50E-01
1.00E-01
5.00E-02
0.00E+00
χ
1.E+07
1.E+06
1.E+05
1.E+04
Energy eV

Analysis of CIELO specific cross section adjustments

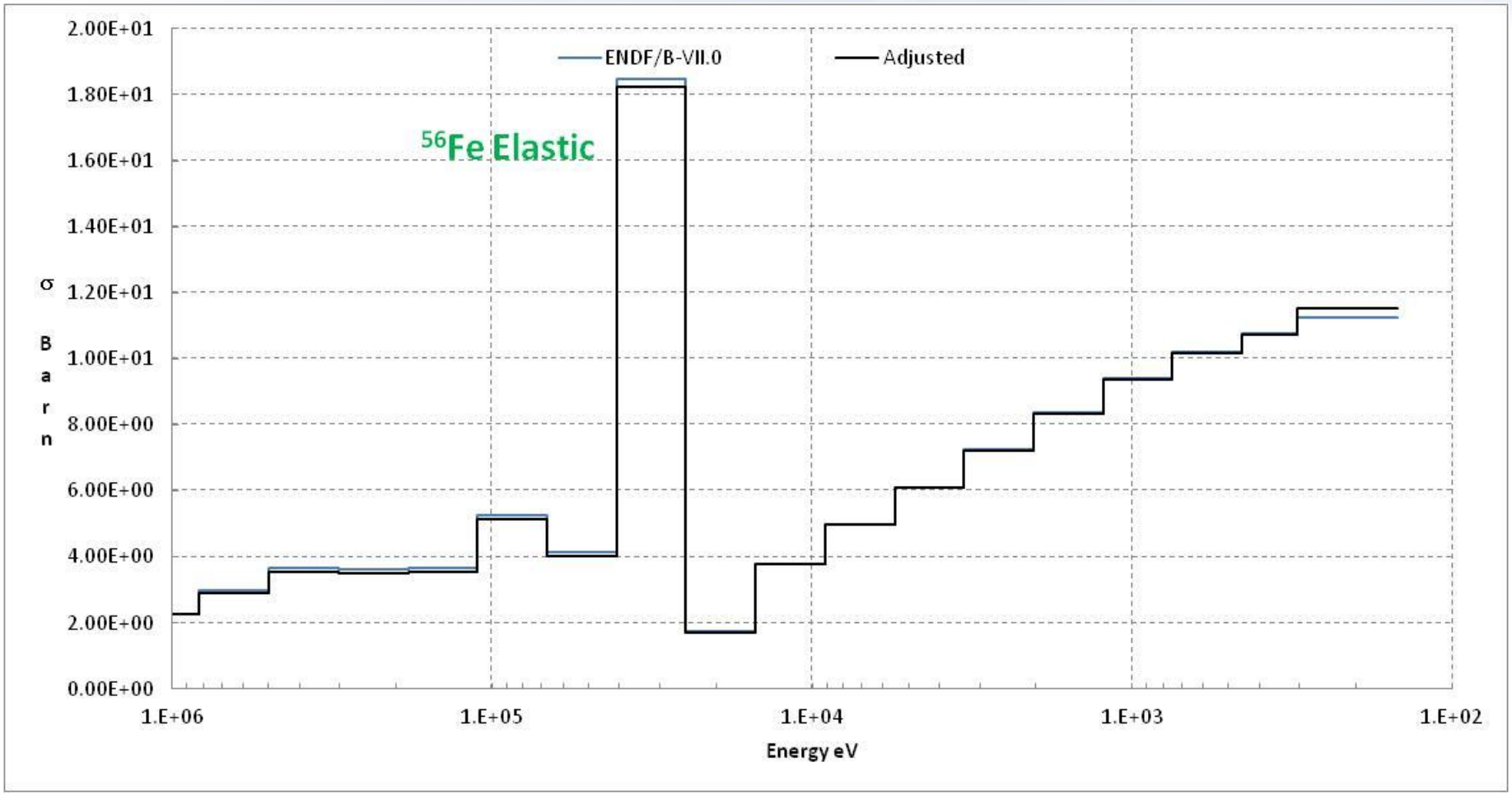
- **(n,2n) cross section adjustments for the "Big Three" actinides:**
  - **The ^{238}U (n,2n) is reduced.**
  - **The ^{239}Pu (n,2n)) is significantly increased**
  - **For the ^{235}U (n,2n) there is no sensitivity in the experiments.**

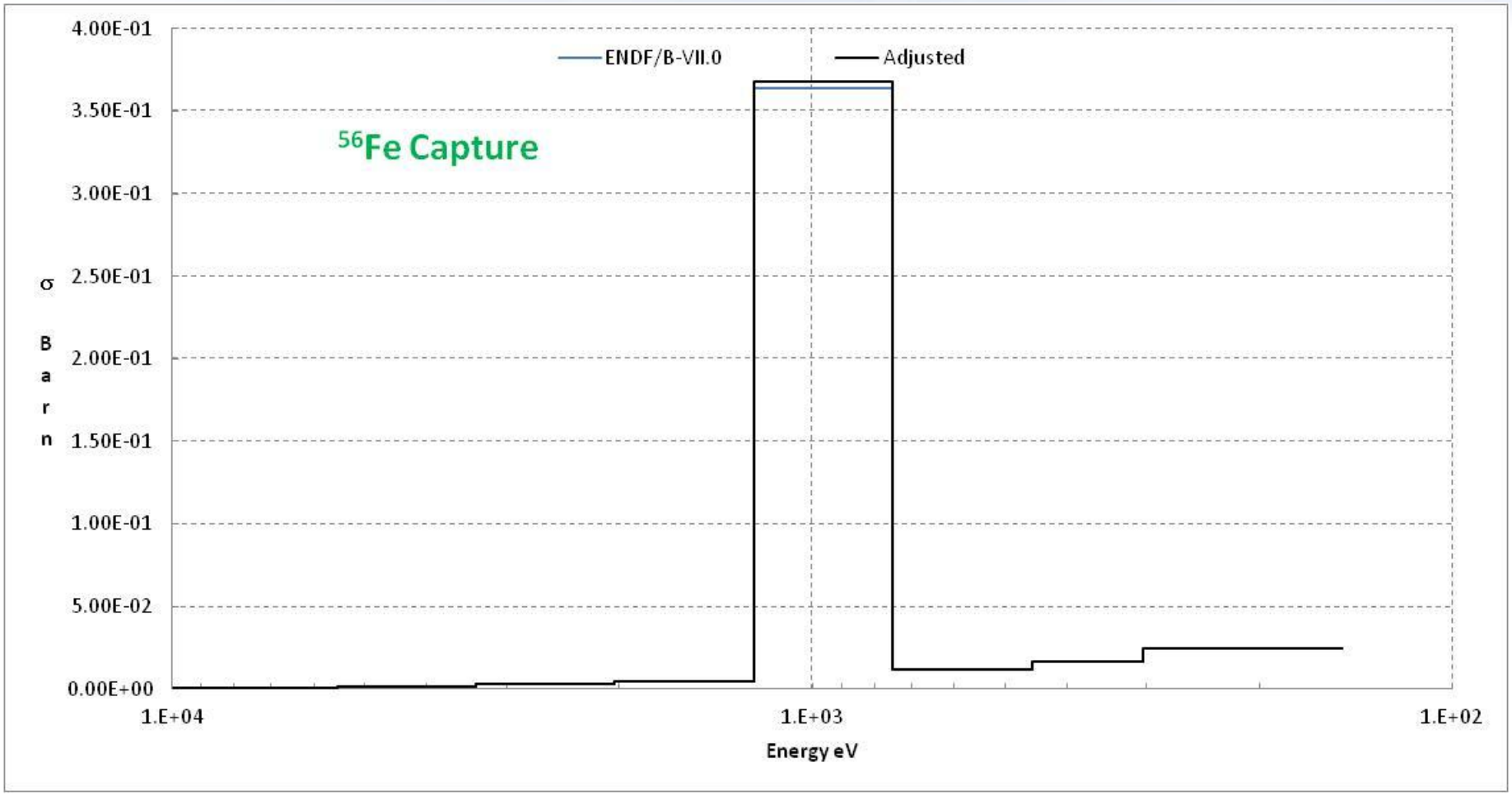

ENDF/B-VII.0 and VII.1
Adjusted
238U n,2n
1.60E+00
1.40E+00
1.20E+00
1.00E+00
8.00E-01
6.00E-01
4.00E-01
2.00E-01
0.00E+00
σ
Barn
1.E+07
1.E+06
Energy eV

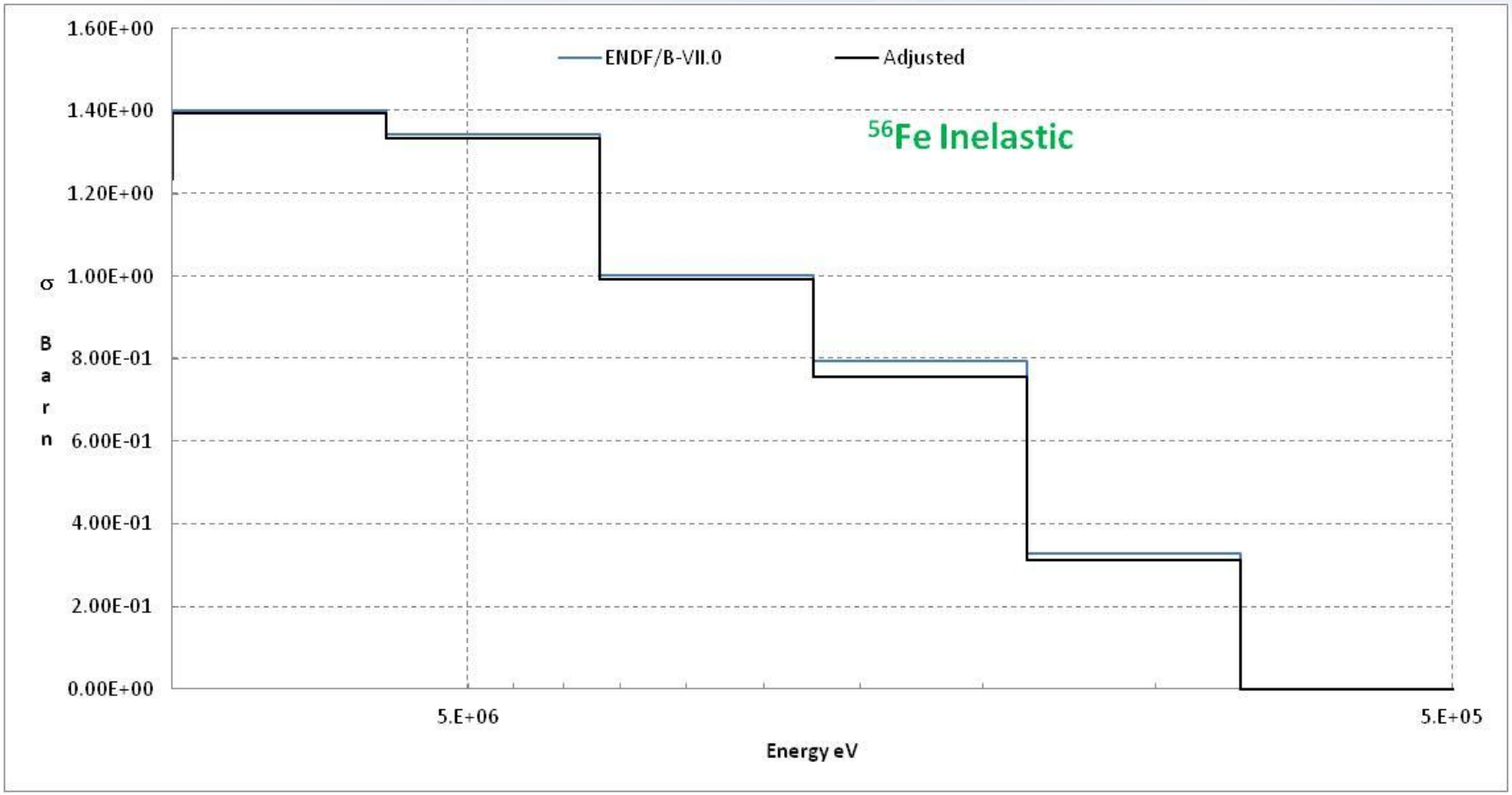

239Pu n,2n
ENDF/B-VII.0 and VII.1
Adjusted
σ
B
a
r
n
3.50E-01
3.00E-01
2.50E-01
2.00E-01
1.50E-01
1.00E-01
5.00E-02
0.00E+00
1.E+07
1.E+06
Energy eV

Analysis of CIELO specific cross section adjustments

- **^{56}Fe cross sections**
  - **Slight changes for elastic and capture in the big resonances**
  - **The inelastic is lowered (but not too much).**


ENDF/B-VII.0
Adjusted
56Fe Elastic
2.00E+01
1.80E+01
1.60E+01
1.40E+01
1.20E+01
1.00E+01
8.00E+00
6.00E+00
4.00E+00
2.00E+00
0.00E+00
σ
B
a
r
n
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
Energy eV


ENDF/B-VII.0
Adjusted
56Fe Capture
4.00E-01
3.50E-01
3.00E-01
2.50E-01
2.00E-01
1.50E-01
1.00E-01
5.00E-02
0.00E+00
σ
B
a
r
n
1.E+04
1.E+03
1.E+02
Energy eV


ENDF/B-VII.0
Adjusted
56Fe Inelastic
1.60E+00
1.40E+00
1.20E+00
1.00E+00
8.00E-01
6.00E-01
4.00E-01
2.00E-01
0.00E+00
σ
Barn
5.E+06
5.E+05
Energy eV

Conclusions

- **A comprehensive adjustment (92 experimental integral parameters) has been carried out and trends have been identified for 4 isotopes of interest for CIELO using as starting point ENDF/B-VII.0 cross sections and COMMARA 2.0 covariance data.**
- **However, caution has to be exerted as there is danger of compensations. Source of compensations include:**
  - Missing experiments able to discriminate among reactions, including: “flat” adjoint flux reactivity experiments (to separate inelastic from absorption cross section), neutron transmission or leakage experiments (mostly for elastic and inelastic cross sections), reaction rate spatial distribution slopes (elastic, and inelastic)
  - Missing data in covariance matrix: fission spectra, P_1 elastic, secondary energy distribution for inelastic cross sections (multigroup transfer matrix), cross correlations
  - Underestimation or overestimation of well known reaction standard deviations (e. g. ^{239}Pu fission)