PIA: Progressive Incremental Adjustment

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November 28, 2014

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INL

The problem of compensations

In many cases, the adjustment can produce untrustworthy results in terms of adjusted cross sections, when some forms of compensation exist.

Compensations can have different causes:

- It is possible that some reaction variations of the same isotope compensate each other (e. g. 239Pu χ and inelastic) or that different isotope cross section variations have opposite and compensating effects (e.g. U-238 capture increase associated to Pu-239 fission increase)
- Lack of reactions and cross correlations in the covariance matrix
- Inadequate values in the covariance matrix that in an adjustments lead to correct certain cross sections more than others.

Remedies for compensations

One of the main reasons for compensations is that there are very few experiments able to discriminate among parameters. There is a need for specific (preferably of elemental type) integral experiments:

- irradiation experiments (for capture, (n,2n))
- spectral indices (mainly capture and fission and, at a lesser extent, inelastic)
- "flat" or "steep" adjoint flux reactivity experiments (to separate inelastic from absorption cross section and, partly, from fission spectrum effects)
- neutron transmission or leakage experiments (mostly for inelastic and elastic cross sections)
- reaction rate spatial distribution slopes (elastic, and inelastic, including, partly, angular scattering effects)

Next Step: PIA (Progressive Incremental Adjustment)

- The proposed approach for avoiding compensations and give more reliable feedback to evaluator is to perform a progressive incremental adjustment.
- In PIA the starting point is giving priority to the utilization of experiments of elemental type (those sensitive to a specific cross section), following a definite hierarchy on which type of experiment to use (see next slide).
- Once the adjustment is performed, both the new adjusted data and the new covariance matrix are kept. This will limit the range of variability of the adjusted cross sections.
- In the final steps integral experiments that are sensitive to a large variety of cross sections (global type like critical mass) are added.

PIA Experiment Hierarchy

- **For actinides:**
  1. **Fission spectral indices: sensitive to fission cross sections (but also to inelastic and fission spectrum, in the case of threshold fission cross sections)**
  2. **Irradiation experiments: sensitive to capture cross sections (and second order to fission) and (n,2n)**
  3. **Sample oscillation experiments and other experiment sensitive to inelastic (e. g. transmission, flat/steep adjoint as in STEK and SEG)**
  4. **Critical masses**
  5. **Reactivity variations (both reactivity coefficients and associated to fissile isotope variations in the same core geometry)**
- **For structural materials:**
  1. **Propagation experiments (inelastic and elastic)**
  2. **Sample oscillations (add capture)**
  3. **Critical masses**
  4. **Reactivity variations (e.g. k-infinity type experiments, sodium void, control rods)**

PIA Exercise on ENDF/B-VII.0 Adjustment

- **Four steps applied:**
  1. **Fission step**. Fission spectral indices mostly oriented to fission cross section: 24 experiments.
  2. **Capture step**. Added capture spectral indices and irradiation experiments for capture and (n,2n): 42 experiments
  3. **K_{eff} step**. Added critical masses: 18 experiments
  4. **Reactivity step**. Added reactivity variations: 7 experiments
- **At each step:**
  - Cross sections variations are calculated and, in principle, used for next step, see below.
  - New C/E (relative to cross section variations) calculated and used for successive adjustment step
  - New covariance matrix calculated and used for successive adjustment step
  - Non linear effect not taken into account as sensitivity coefficients are kept the same and new C/E calculated using sensitivity coefficients folded with cross section variations.

Type of experiments used in adjustment

	keff	Reactivity Coefficients	Spectral index	Irradiation	total # cases
Jezebel	2		3		5
Flattop	1		2		3
ZPR-3,6,9	6		3		9
JOYO	1				1
Godiva	1		3		4
BigTen	1		3		4
Np Sphere	1				1
ZPPR-9,10,15	3	7	3		13
COSMO			9		9
PROFIL				25	25
TRAPU				15	15
CIRANO	2				2
Total	18	7	26	40	91

PIA steps influence on C/E of some K_{eff}

- **The table below shows the PIA steps C/E for the K_{eff} of some very well known experiments. The initial C/E with ENDF/B-VII.0 are all very close to 1, but in the two first PIA steps we can observe several hundreds of pcm swings proving that compensations exist if we trust the elemental experiments.**

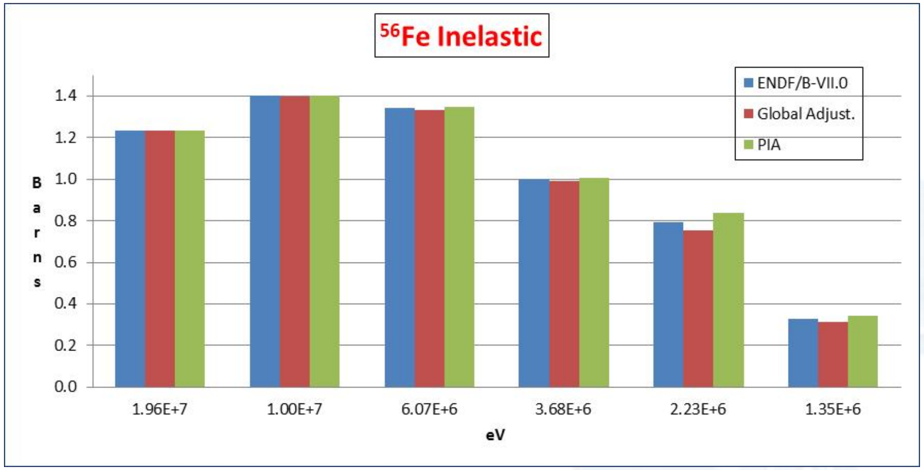
Experiment	ENDF/B-VII.0	Fission step	Capture Step	K_{eff} step	Reactivity step
JEZEBEL ^{239}Pu	0.99986	1.00294	1.00210	1.00061	1.00069
FLATTOP ^{239}Pu	1.00097	1.00376	1.00346	0.99959	0.99994
ZPR6 7	1.00043	1.00494	0.99859	0.99880	0.99927
GODIVA	0.99983	0.99382	1.00324	1.00084	1.00036
BIGTEN	1.00002	1.00336	1.00665	1.00075	1.00004

PIA against Global Adjustment

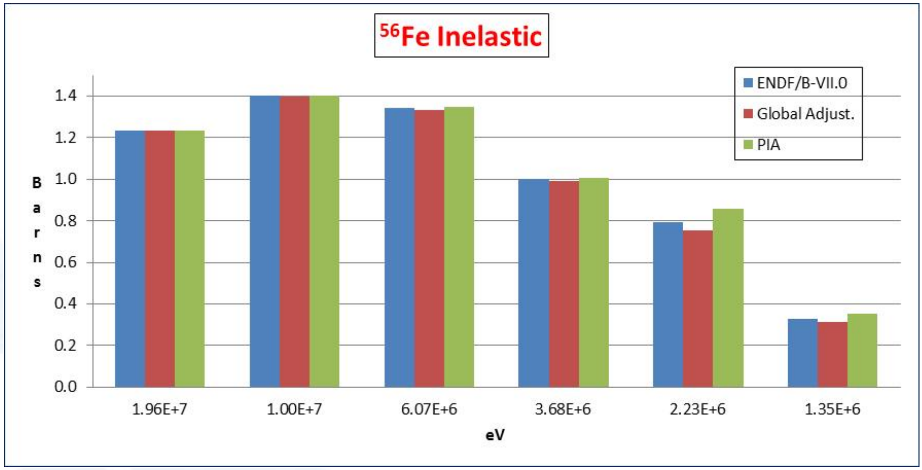
- **For cross section changes of the 5 isotopes of interest of SG39 :**
  - **Fission, nubar, and fission spectra do not change significantly for both the Global adjustment and PIA. This is due to the fact that the initial standard deviations in COMMARA 2.0 are very small.**
  - **Some significant changes (even different behavior) can be observed for inelastic cross sections (^{23}Na, ^{238}U, ^{239}Pu) and capture cross sections (^{235}U, ^{239}Pu).**
- **For standard deviation changes:**
  - **In general they follow the same behavior of cross sections and tends to be lower than the corresponding ones of the Global adjustments**
  - **In some cases they can be higher than those of the Global adjustment, but that occurs for cross sections that are less or not adjusted at all in PIA.**

PIA: 4 steps σ changes

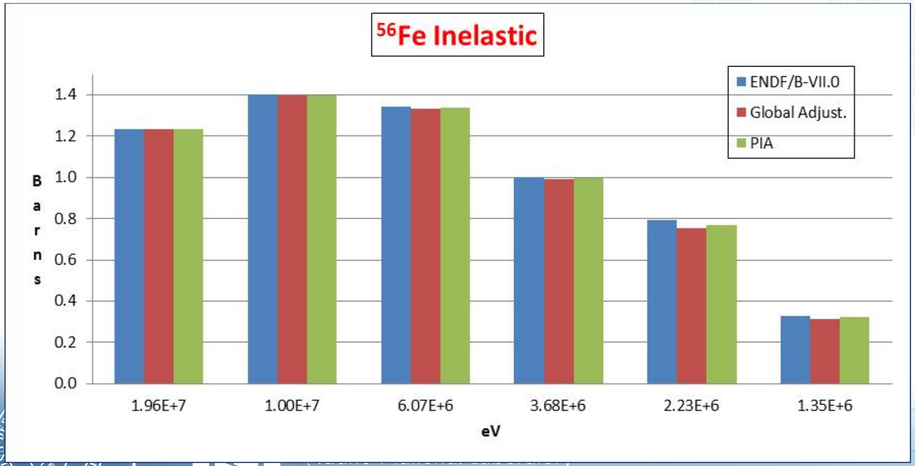
Fission Step



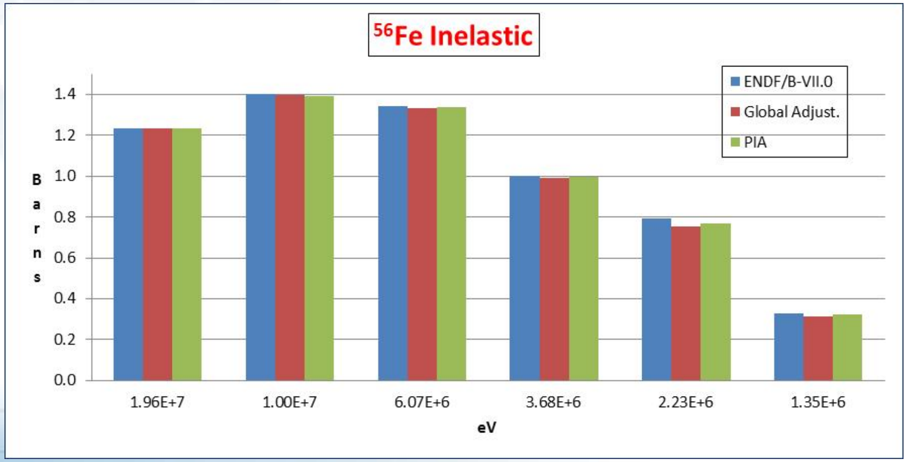
Capture Step



K_{eff} Step

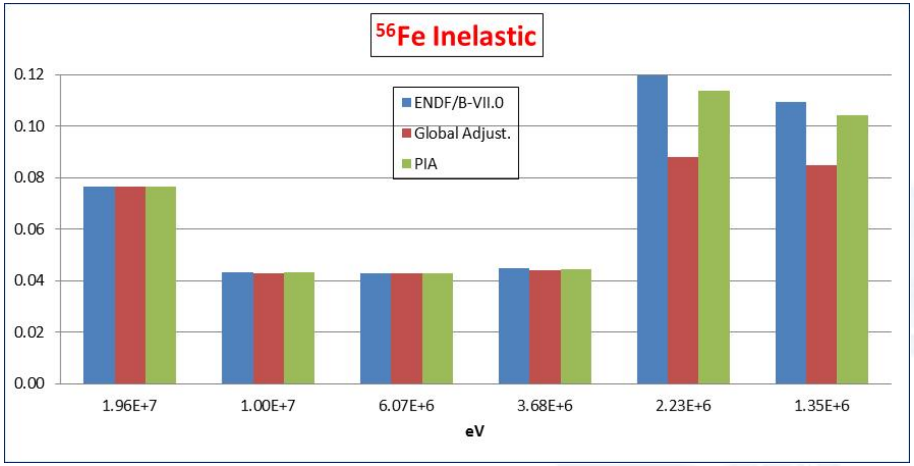


Reactivity Step

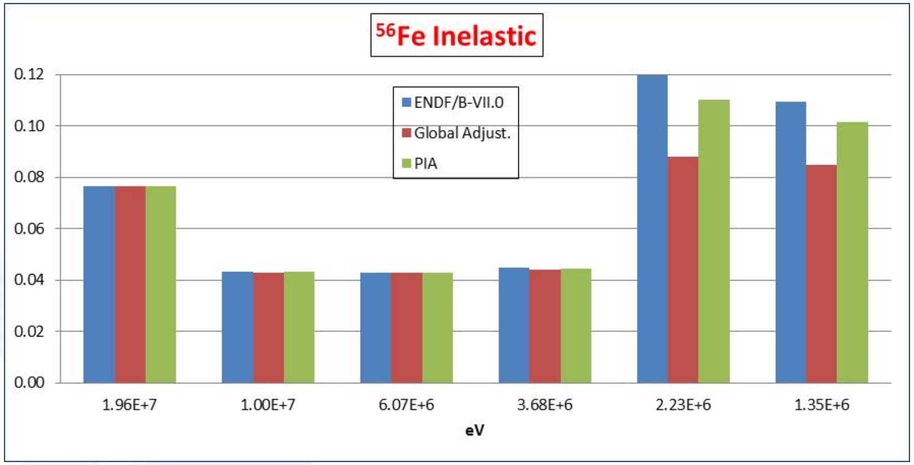


PIA: 4 steps standard deviation changes

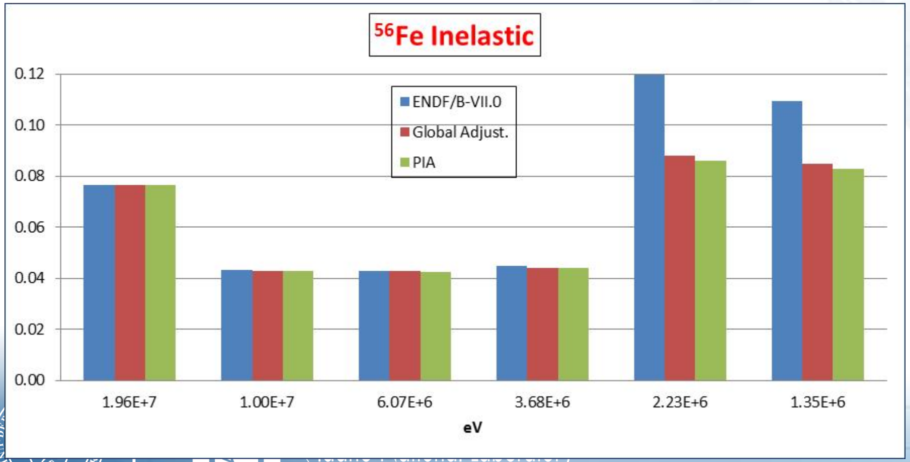
Fission Step



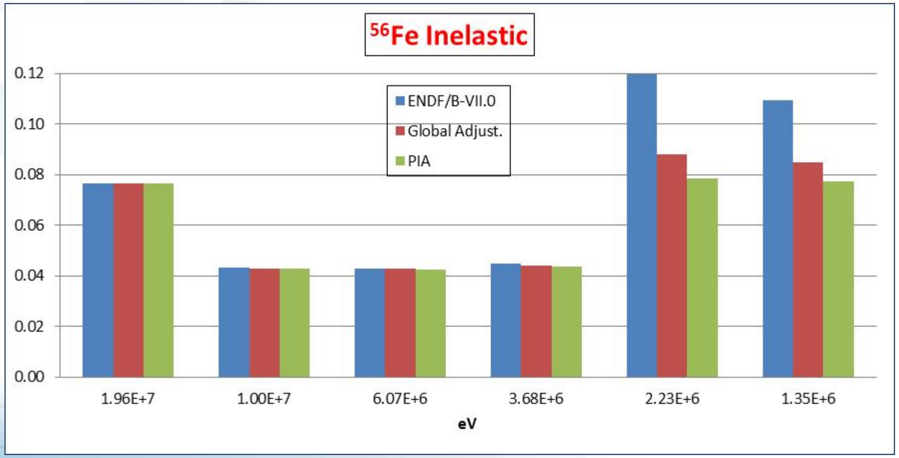
Capture Step



K_{eff} Step

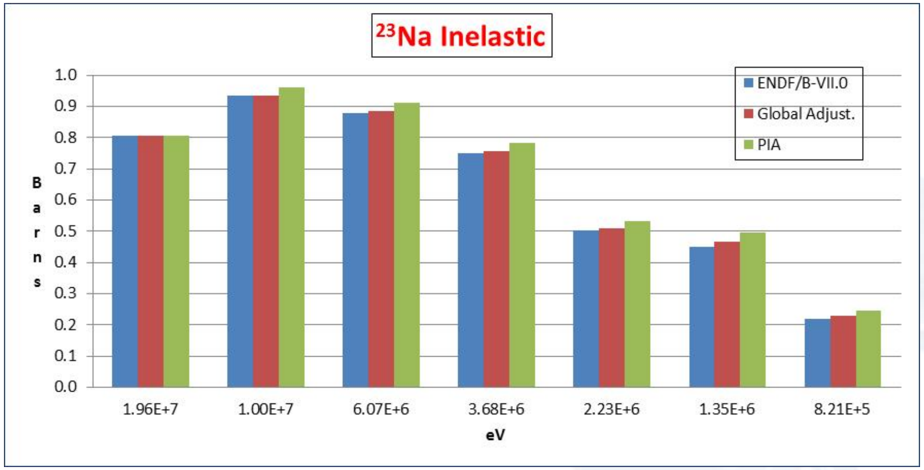


Reactivity Step

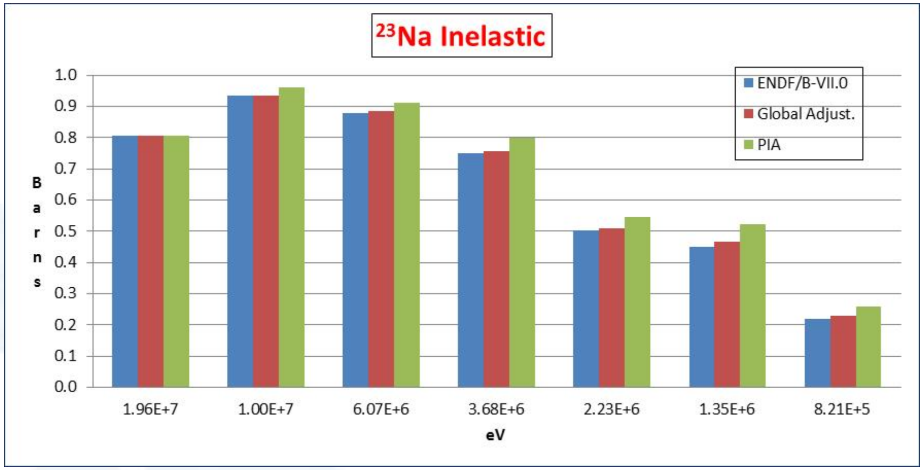


PIA: 4 steps σ changes

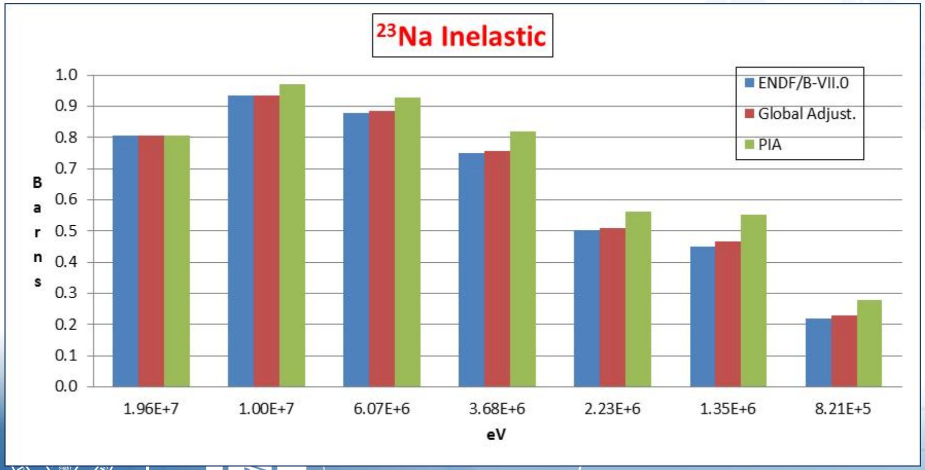
Fission Step



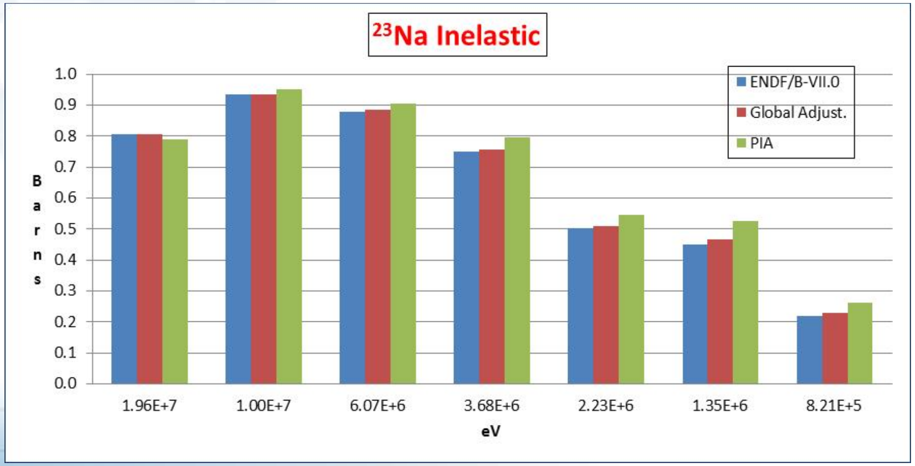
Capture Step



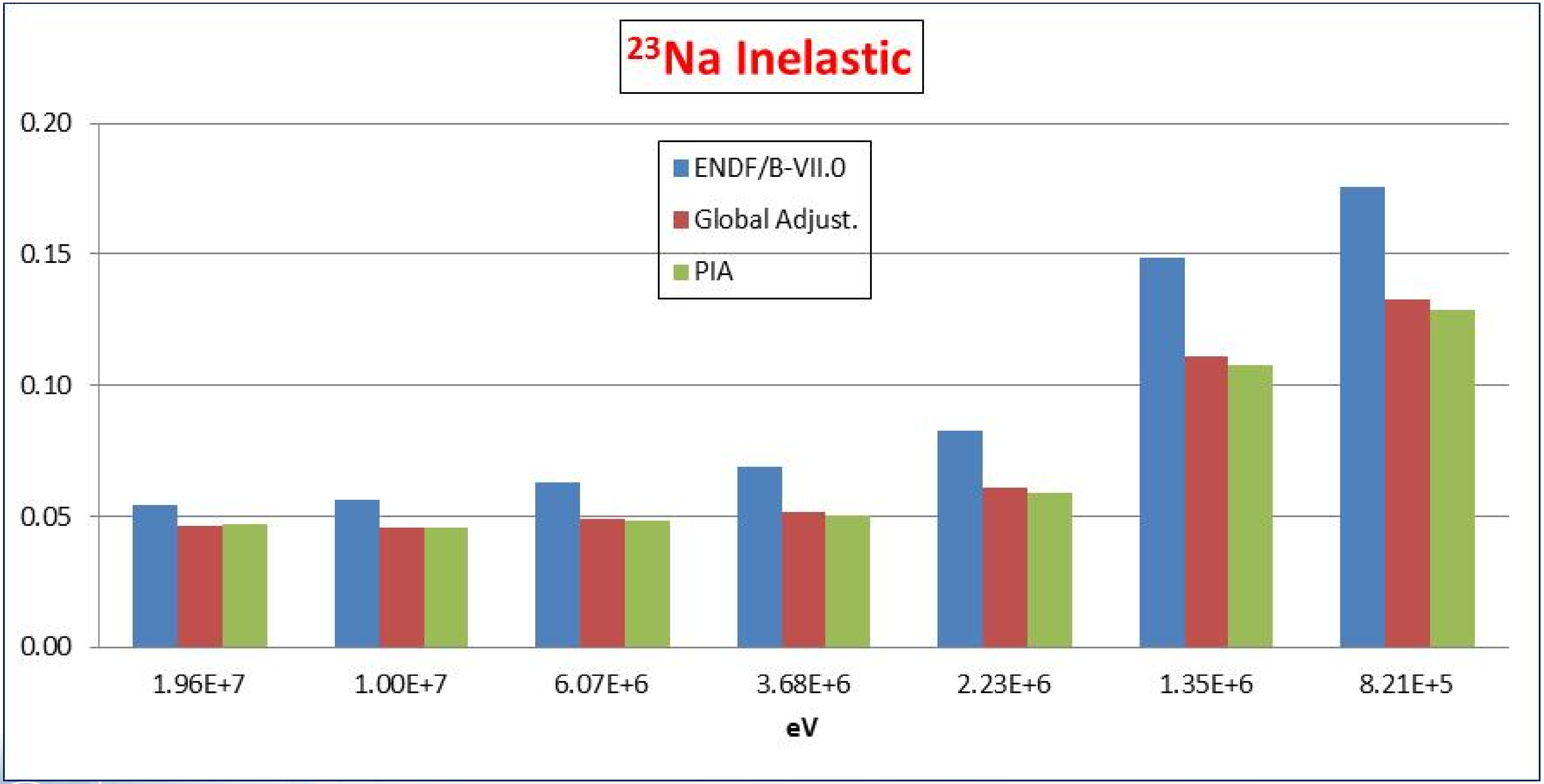
K_{eff} Step



Reactivity Step



Standard deviation change comparison PIA against Global



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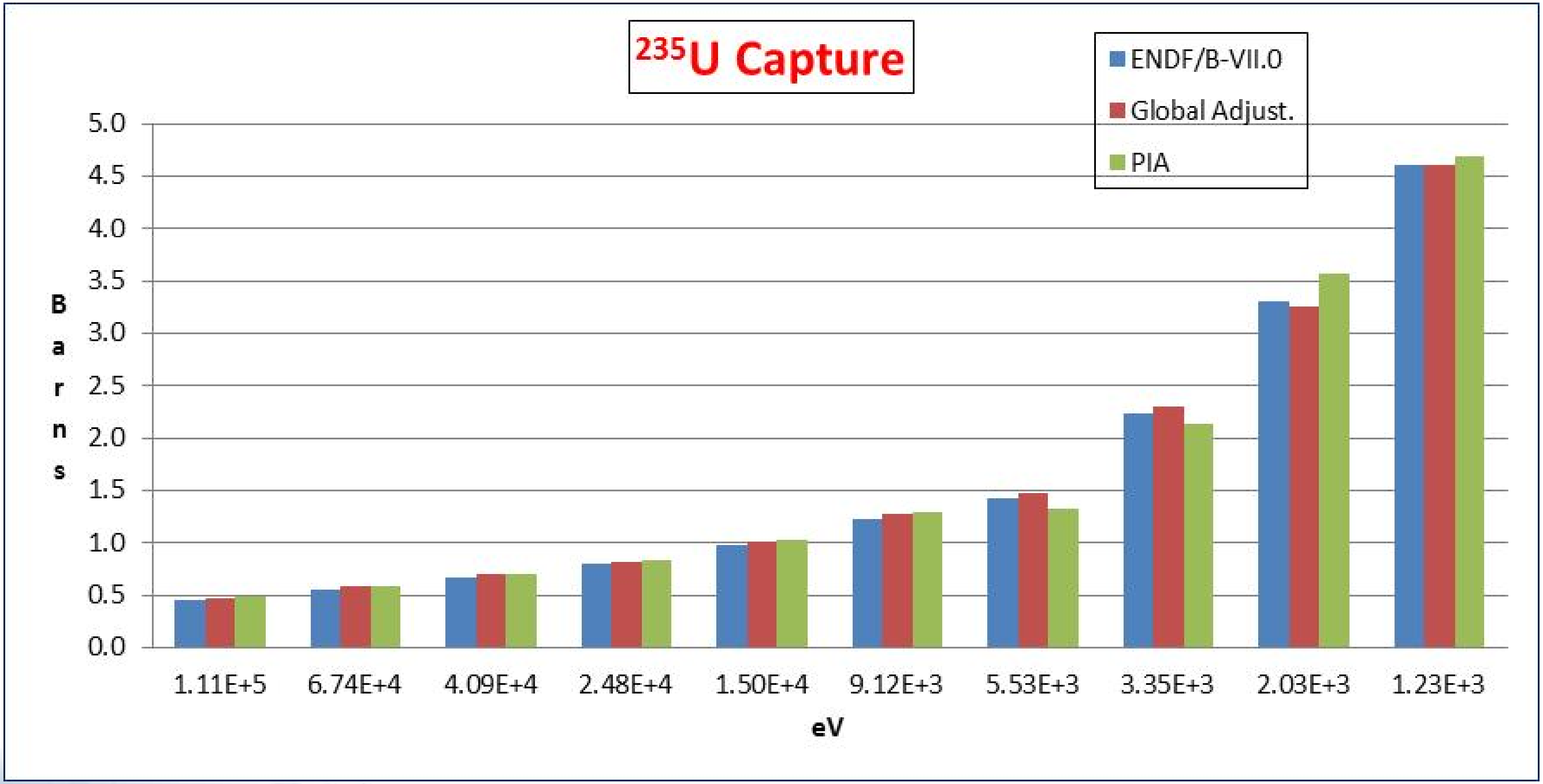
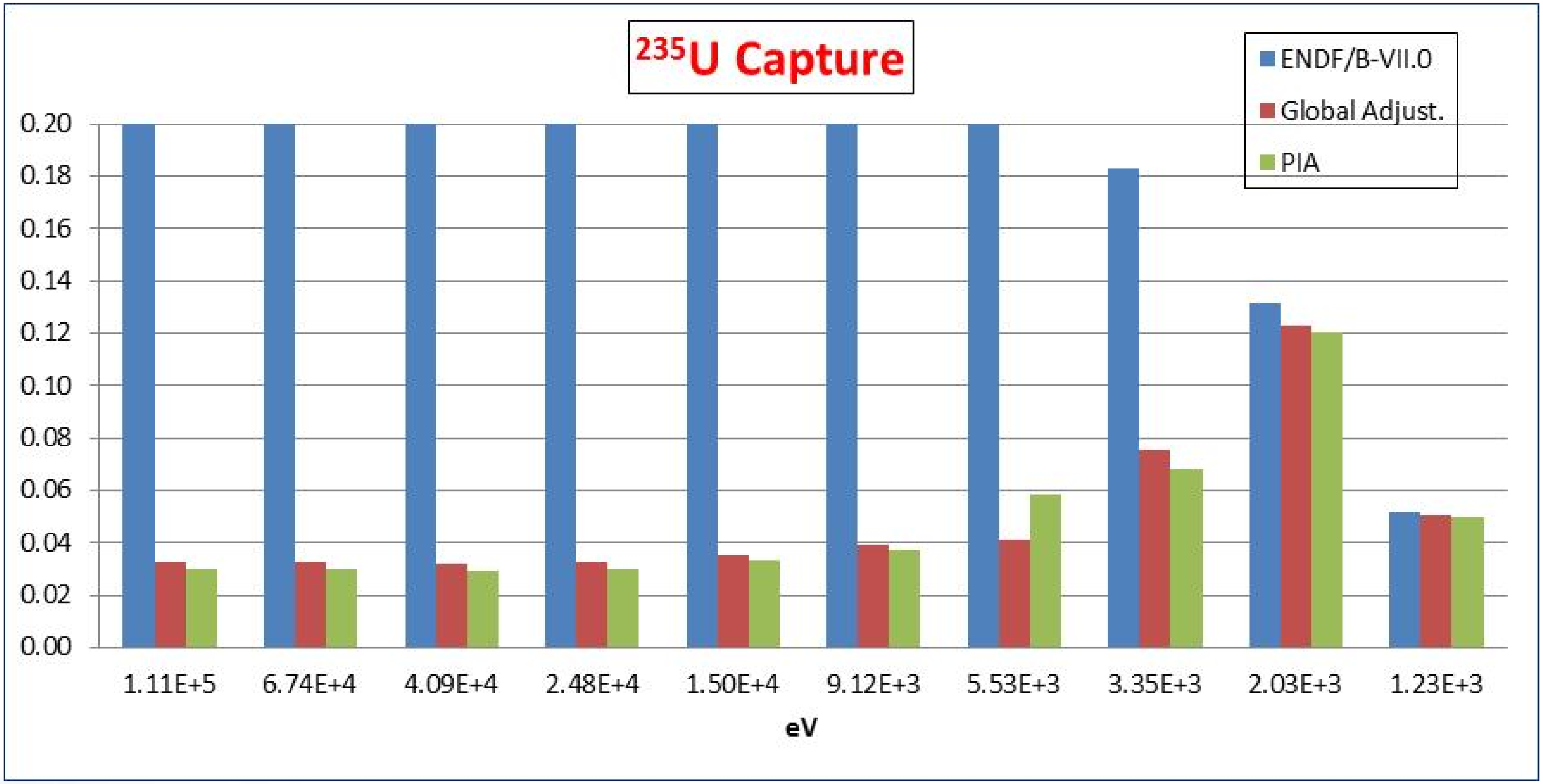
σ change comparison PIA against Global

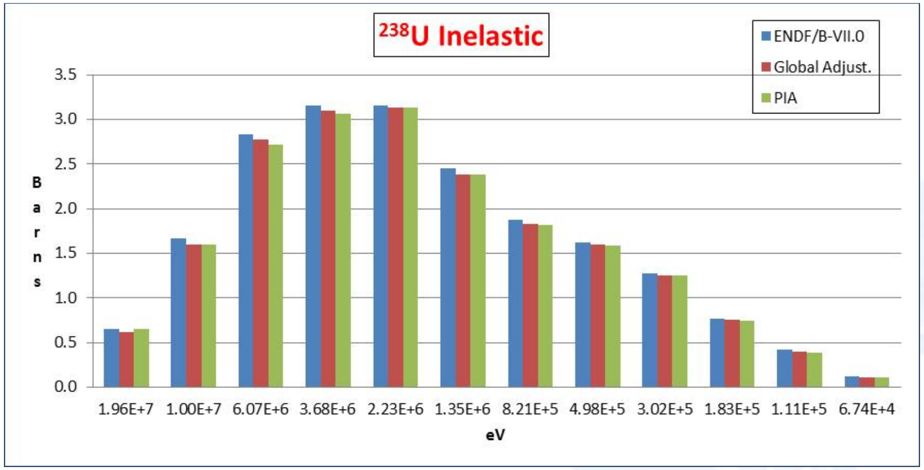


Standard deviation change comparison PIA against Global

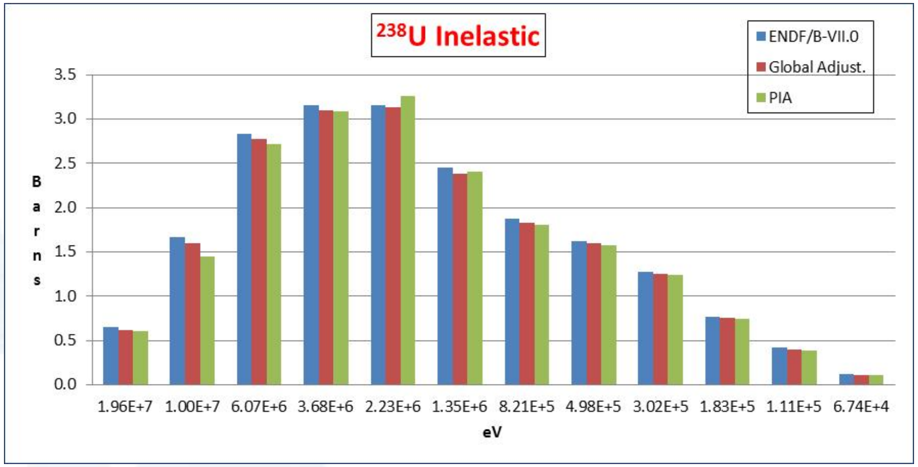


PIA: 4 steps σ changes

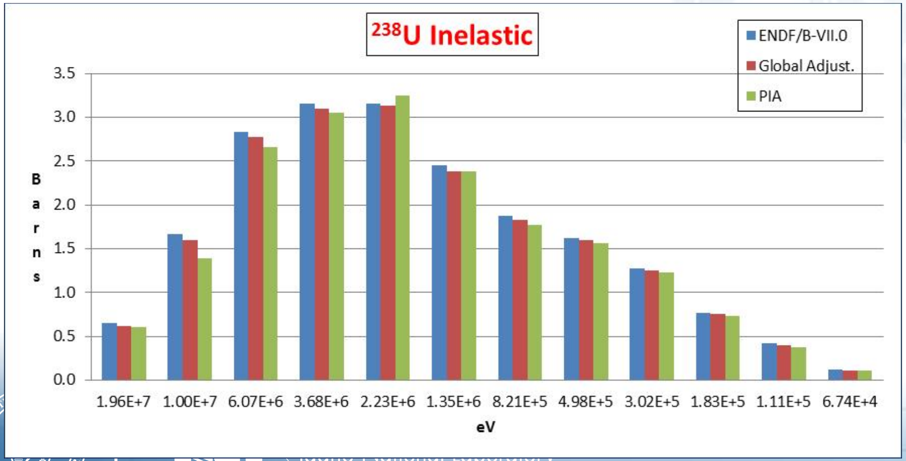
Fission Step



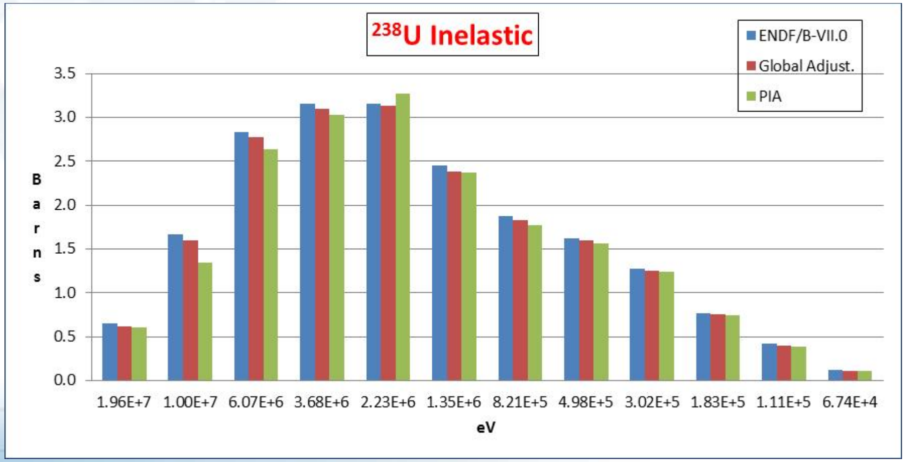
Capture Step



K_{eff} Step



Reactivity Step



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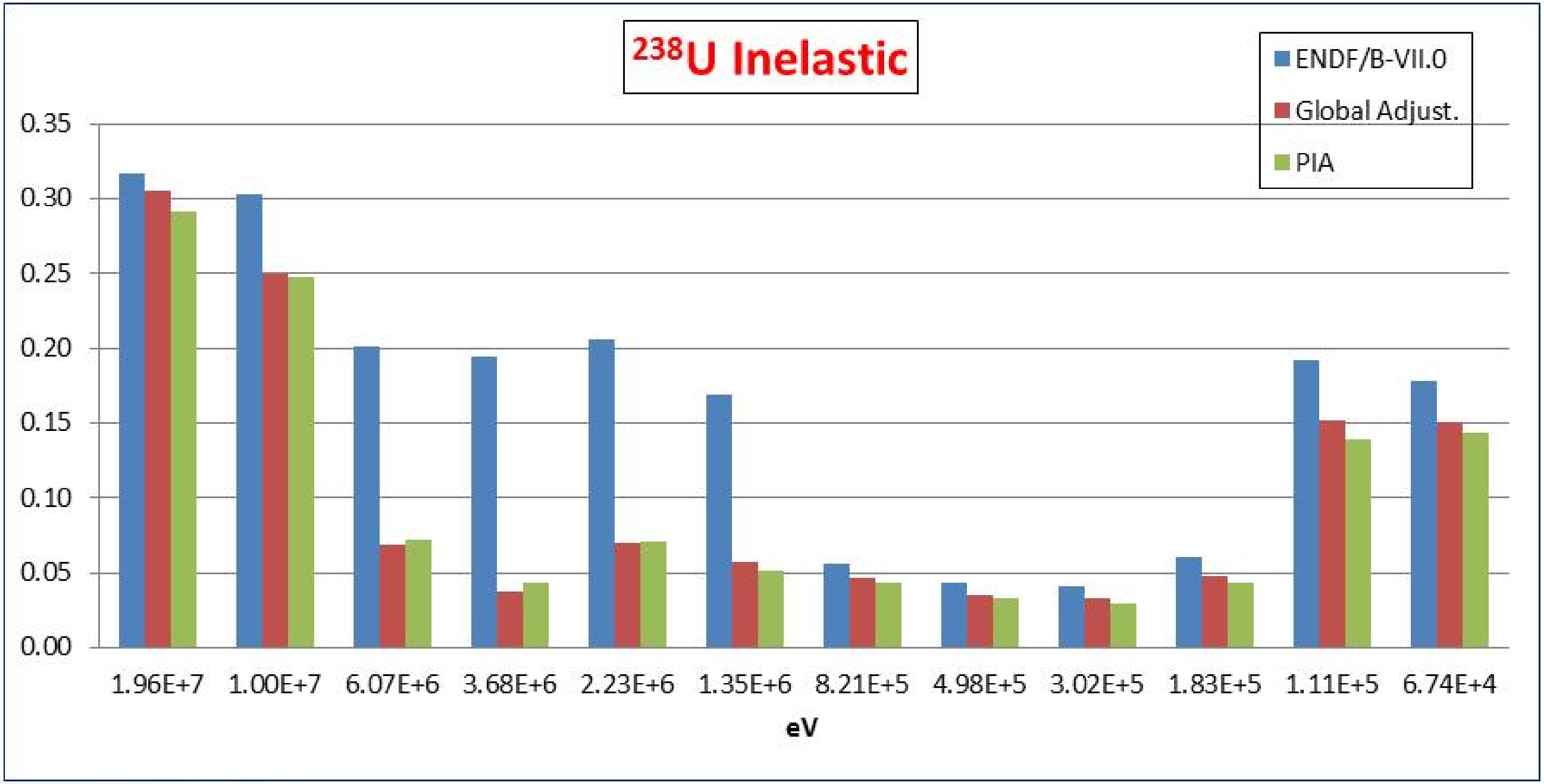
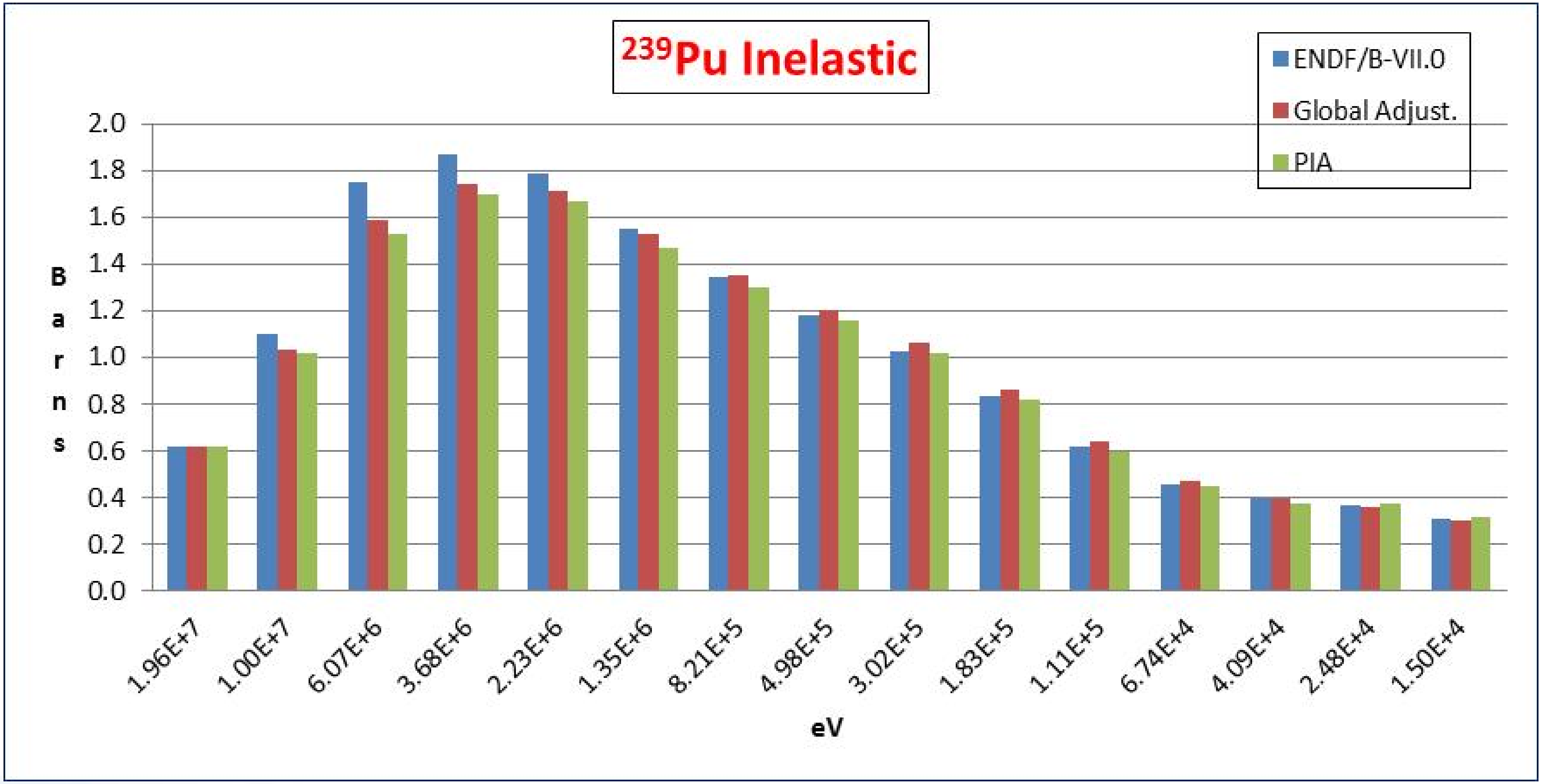


σ change comparison PIA against Global



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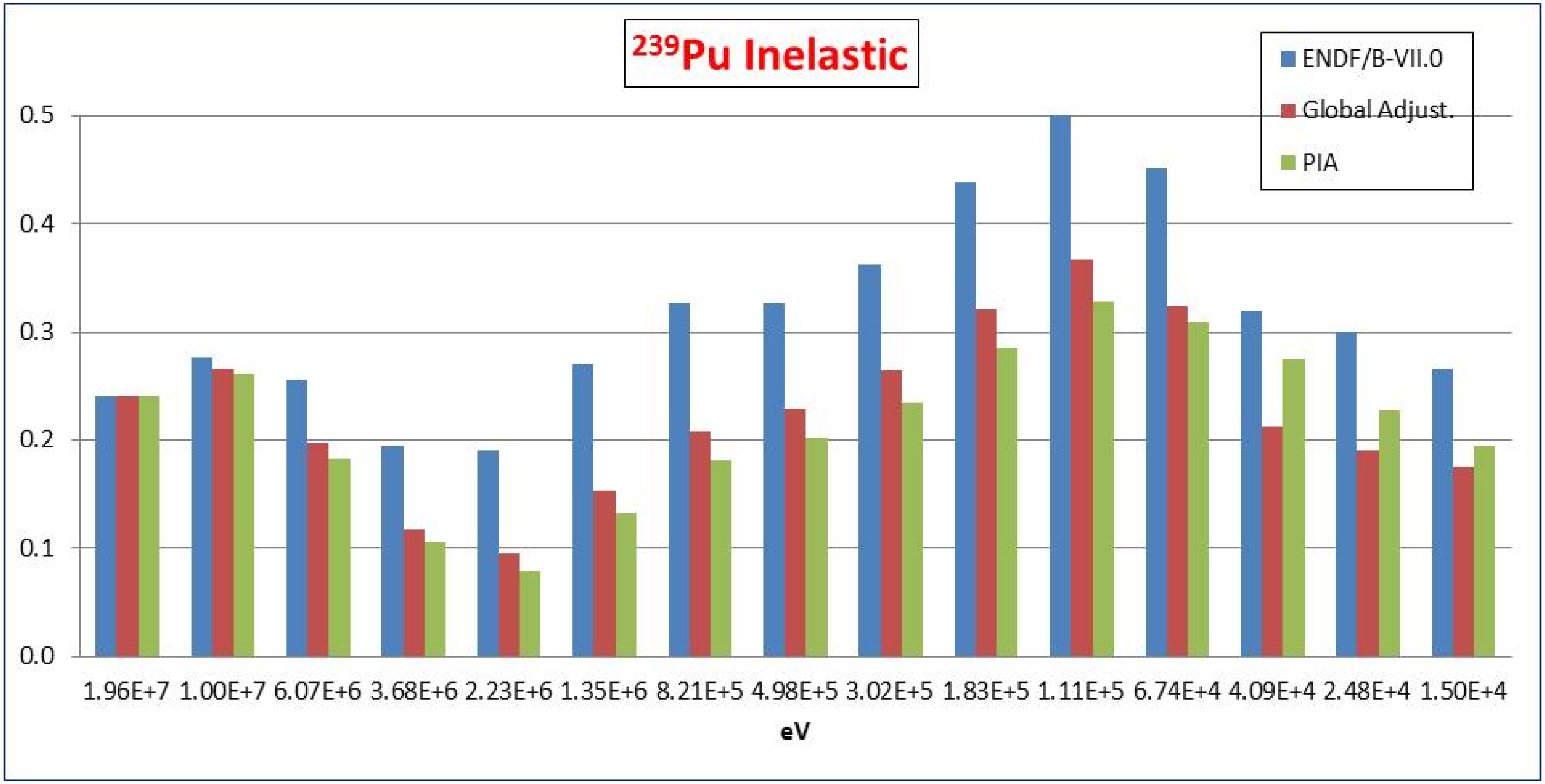
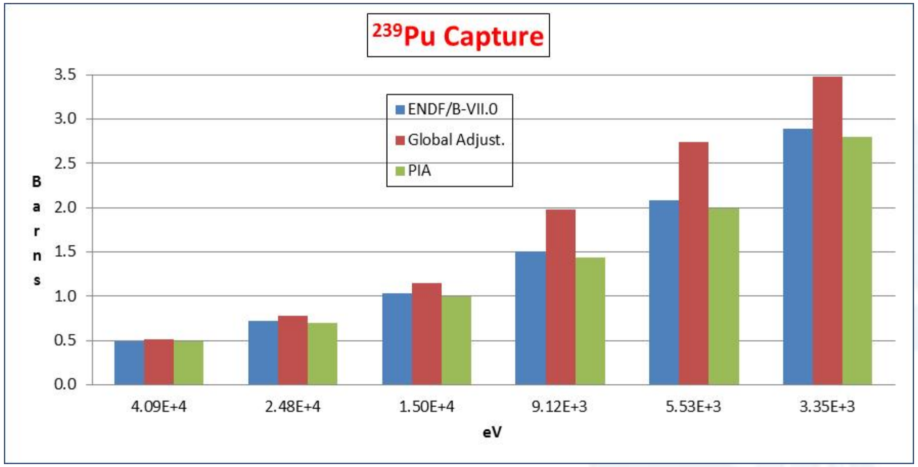
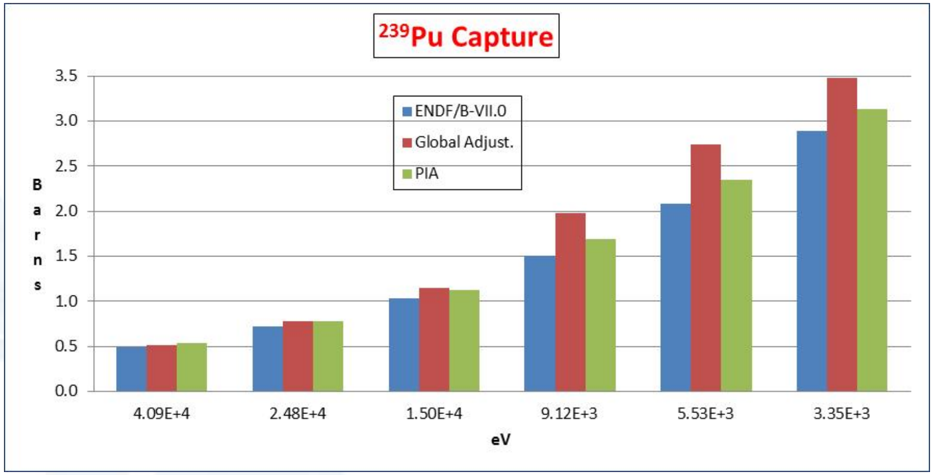


PIA: 4 steps σ changes

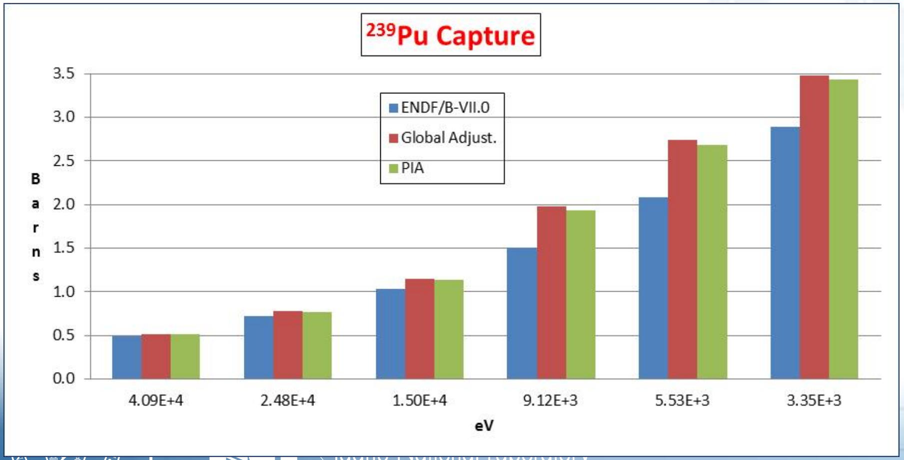
Fission Step



Capture Step



K_{eff} Step



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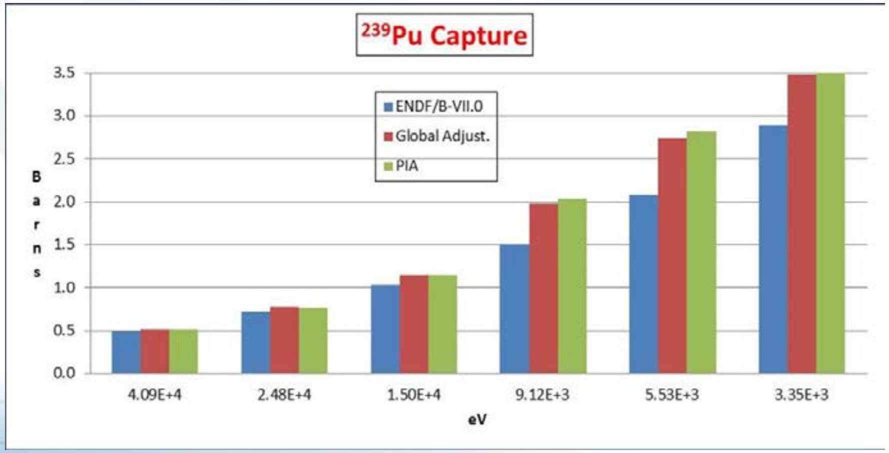

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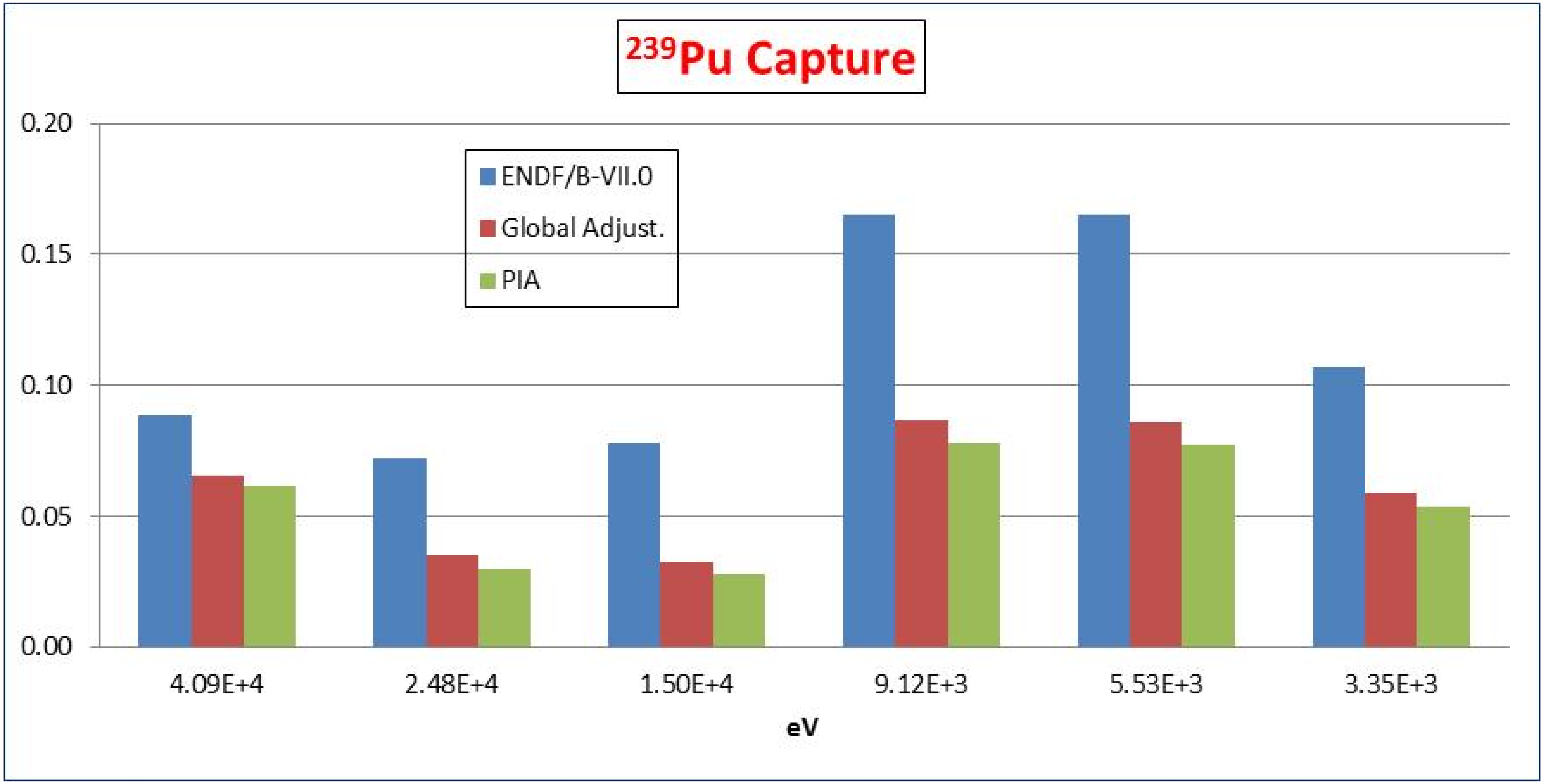

ABR Ox. K_{eff} Uncertainty (pcm)

COMMARA 2.0

Isotope	σ_{cap}	σ_{fiss}	ν	σ_{el}	σ_{inel}	χ	P_1^{el}	Total
U238	278	29	112	105	547	145	24	650
PU239	308	223	71	30	79	161	2	428
FE56	170	0	0	172	147	0	44	287
PU240	61	45	82	5	17	24	0	116
NA23	4	0	0	20	80	0	69	107
CR52	21	0	0	38	18	0	0	47
O16	5	0	0	45	2	0	0	46
PU241	10	7	3	0	2	0	0	13
Total	453	229	156	213	578	218	85	846

Global Adjustment

Isotope	σ_{cap}	σ_{fiss}	ν	σ_{el}	σ_{inel}	χ	P_1^{el}	Total
U238	-20	-12	-11	-17	-47	8	-14	-58
PU239	38	45	17	6	16	-37	2	52
FE56	80	0	0	-8	61	0	9	101
PU240	14	10	29	2	9	1	0	35
NA23	6	0	0	-12	-11	0	13	-9
CR52	6	0	0	-10	-11	0	0	-14
O16	5	0	0	37	2	0	0	37
PU241	2	6	4	0	2	0	0	8
Total	88	45	32	27	41	-36	6	109

PIA

Isotope	σ_{cap}	σ_{fiss}	ν	σ_{el}	σ_{inel}	χ	P_1^{el}	Total
U238	-36	-12	-21	-17	-40	-14	-9	-63
PU239	10	8	20	5	16	-45	2	-35
FE56	72	0	0	-24	48	0	8	84
PU240	9	10	30	3	11	-10	0	34
NA23	5	0	0	-12	-16	0	5	-19
CR52	7	0	0	-13	-6	0	0	-13
O16	5	0	0	33	2	0	0	33
PU241	-1	6	4	0	2	0	0	7
Total	65	8	30	-10	29	-49	5	60

Conclusions

- A new adjustment strategy has been proposed, PIA (Progressive Incremental Adjustment), where priority is given to elemental type experiments in order to cope with the problem of compensations.
- An exercise applied to the previously presented ENDF/B-VII.0 (Global) adjustment has shown that, if we trust the elemental experiments, compensations occur in integral type of experiments (e. g. critical masses).
- Moreover, PIA indicates some significant impact on both central values and standard deviations.
- The new covariance matrix obtained by PIA produces significantly reduced uncertainty on target reactors.

Conclusions

- Following the previous investigations the following recommendations are made in order to produce trustworthy feedback to the CIELO evaluators:
  - Have better "a priori" evaluations. Adjustments results tend to stick to initial values. In general a better "a priori" values produces a better "a posteriori" values. We welcome from the CIELO subgroup better data files for the isotopes of interest.
  - Have a better, reliable, and complete covariance matrix. Again, we welcome an action on this subject by the CIELO subgroup.
  - In view of the PIA results it is paramount to add reliable experiments of the elemental type in order to avoid, whenever possible, compensations. The SG39 should develop an action to select, analyze, and compute sensitivity coefficients of such experiments. The participants should use the existing databases (e. g. IRPhEP, SINBAD) to identify such kind of experiments and "volunteer" for their analysis. Moreover, it should also pinpointed, if recognized, the need of new elemental experiments.