Report on Status of SG39

WPEC/SG39

May, 2015

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- **Title: “Methods and approaches to provide feedback from nuclear and covariance data adjustment for improvement of nuclear data files”**
- **Goals, Mandate, Working Method:**
  - **Mandate for this WPEC subgroup is to provide criteria and practical approaches to use effectively the results of sensitivity analyses and cross section adjustments for feedback to evaluators and differential measurement experimentalists in order to improve the knowledge of neutron cross sections, uncertainties, and correlations to be used in a wide range of applications.**
  - **Review issues and summarize findings on methodologies used to provide feedback to evaluated data files (e.g. reactor physics experiment accuracies, adjustment methodologies etc.).**
  - **Select and define test cases for application.**
  - **Based on obtained results, recommend a general methodology and practices for providing feedback to evaluators both on nuclear data and on associated covariance data, based on specific examples.**
  - **Actual feedback will be provided to evaluation projects (e.g. CIELO initiative) on the specific examples indicated in the previous point.**

Current Activities

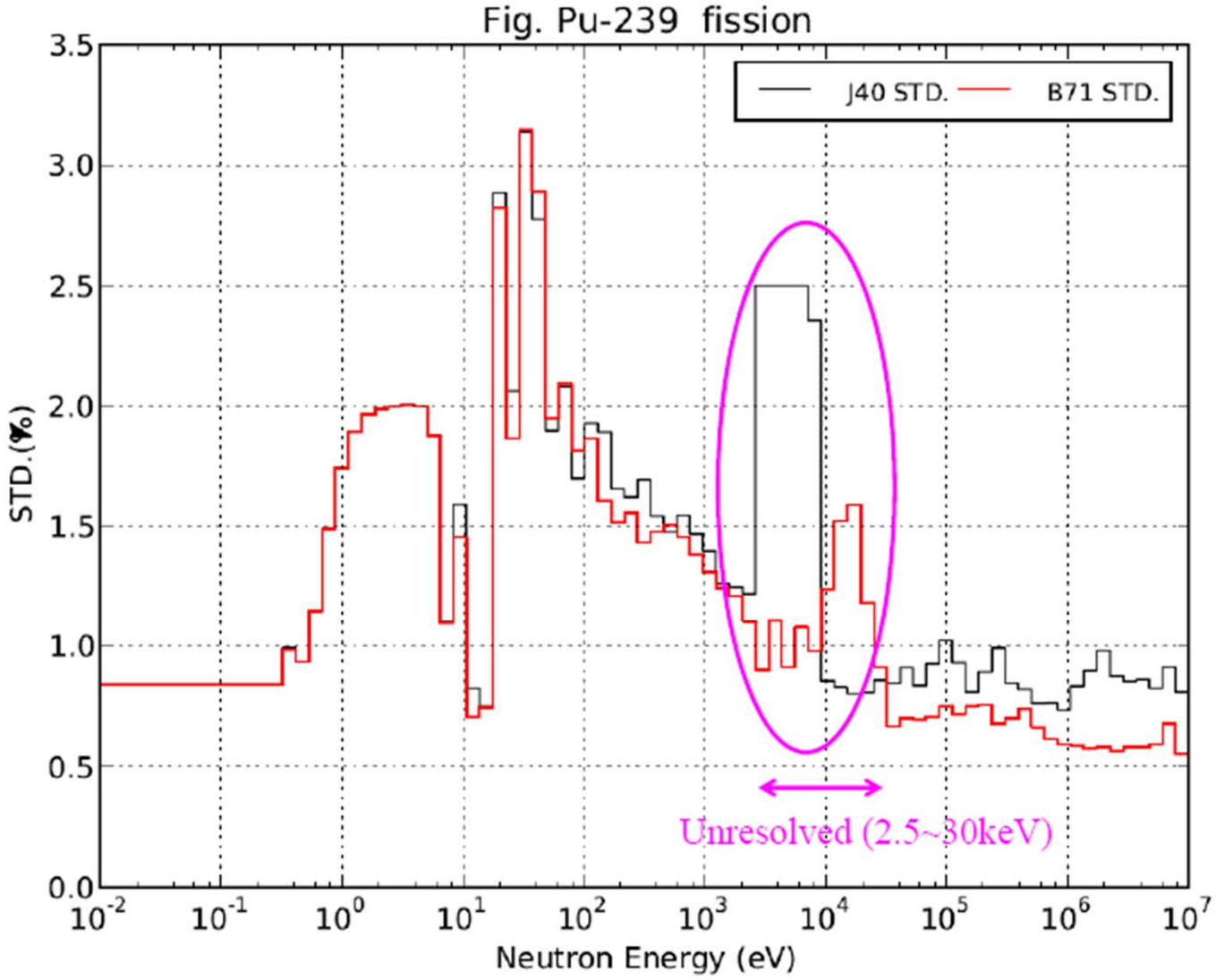
- **Finalize several deliverables**
- **Analyzing new experiments of elemental and separation of effects type.**
- **Developing new adjustment strategies and in particular for coping with the compensation issue.**
- **Account for new emerging needs: industry, criticality safety for space application.**

Finalize deliverables

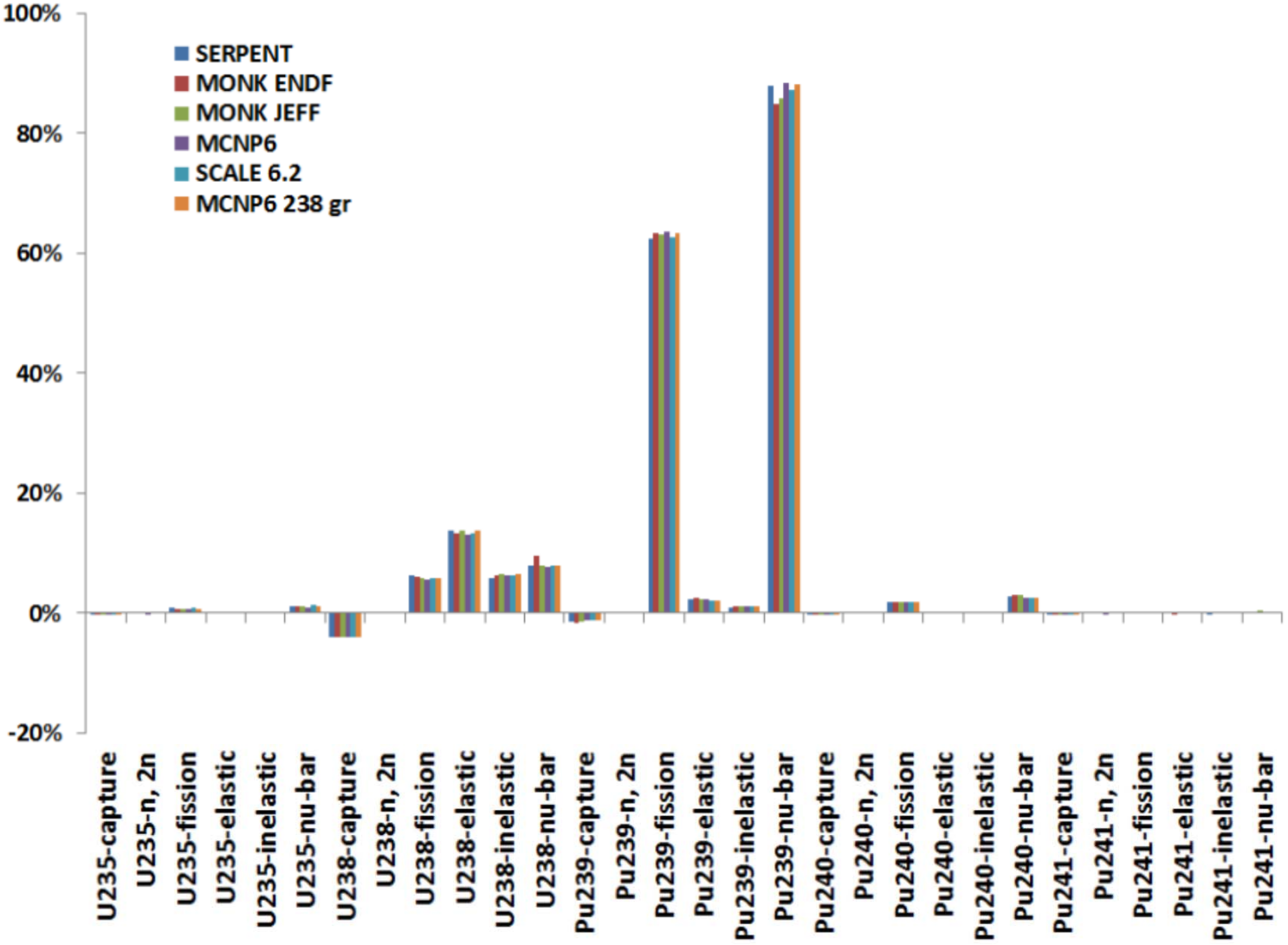
- **Deliverable on covariance data to be finalized in 1-2 months. Feedback on covariance analysis expected.**
- **Deliverable on methodology issues (how to avoid compensations, key topic). Next version of deliverable by November 2015.**
- **Sensitivity coefficients (MC vs deterministic, other issues).**
- **Produce report on the status of uncertainties of Am-241 (for critical sphere, criticality-safety issues).**

Comparison of Covariances

Pu-239 Fission (2/3)



Popsy: Integrated Sensitivities (2/3)



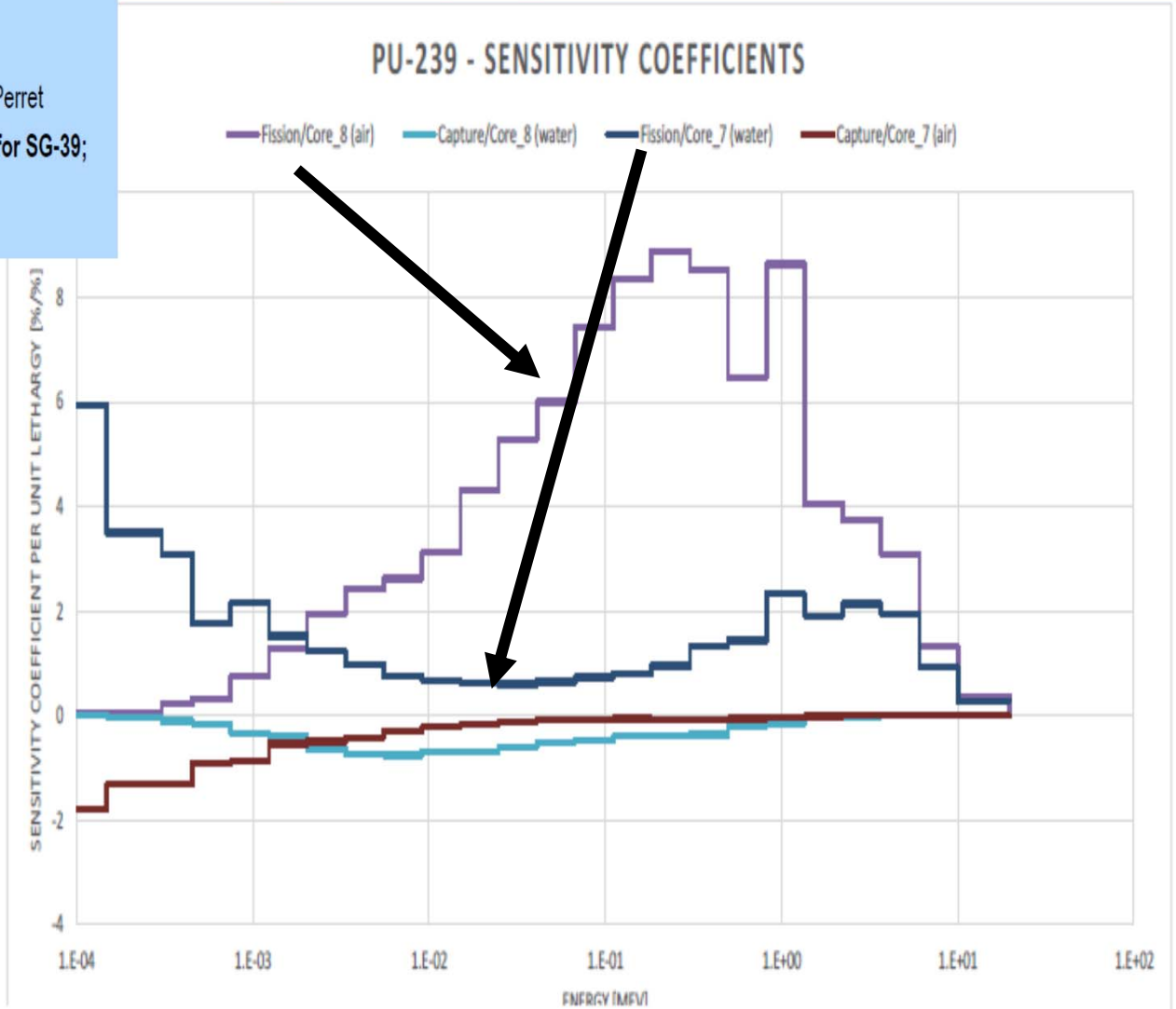
New experiments (elemental and separate effects) and their analysis

- **PROTEUS (link between epithermal and fast energy range: k- infinity, void coefficient, reaction rate ratios): U-238, Pu isotopes**
- **B_{eff} experiments (new inelastic information, but need delayed nubar uncertainty). U-238, Pu-239, U-235**
- **Variable adjoint experiments (e.g. SEG) to separate inelastic from absorption effects. Check experiment availability.**
- **Neutron leakage experiments (RPI, CALIBAN?) mostly for U-238 and Fe-56 inelastic**
- **Possibly, selected neutron propagation experiments (inelastic, elastic). Mostly Fe, also Na-23**
- **STEK experiments? For now, in standby**

Fission and capture SC of water- and air-moderated core configurations (7 & 8)

Paul Scherrer Institut
Efstathios Vlassopoulos[a], Mathieu Hursin, Gregory Perret

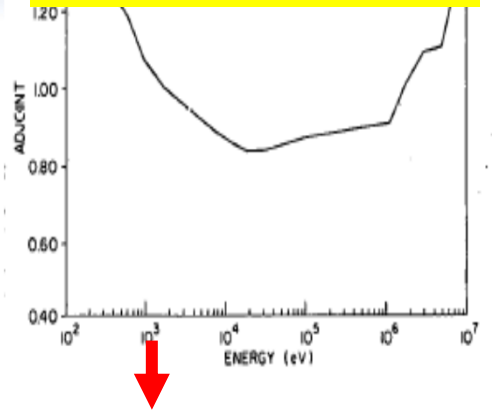
PROTEUS FDWR-II (HCLWR) program summary for SG-39; Status of Re-analysis for Core 7, 8 & 9



Sensitivity Coefficient x 100 with MCNP-6.1.1

The energy-dependence of the adjoint flux (or neutron importance) is characterized by a depression at about 10 keV and a more or less rapid increase at lower and higher energies, which is due to the greater number of fission neutrons produced per neutron absorbed.

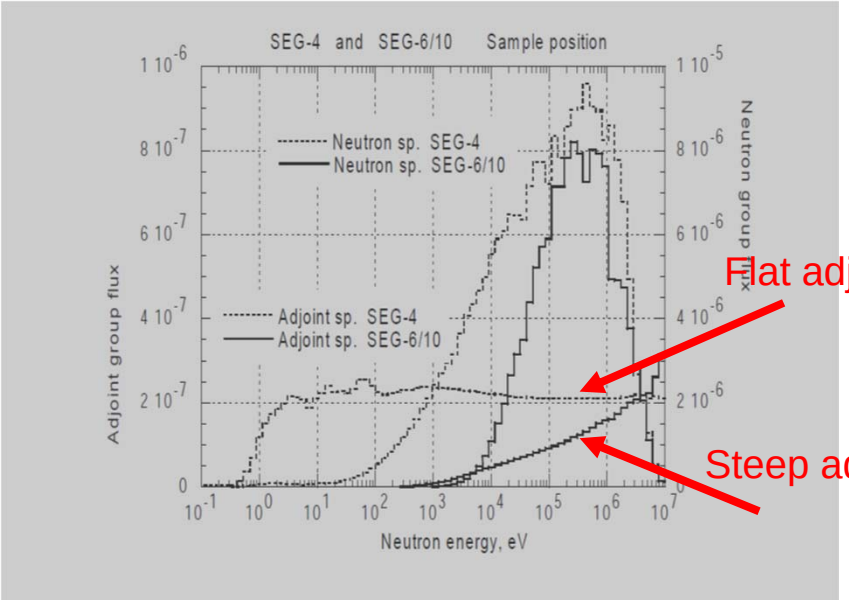
Typical adjoint flux energy shape



To "lower" the adjoint in the fast energy range, the content of 238U in the system should be as low as possible.

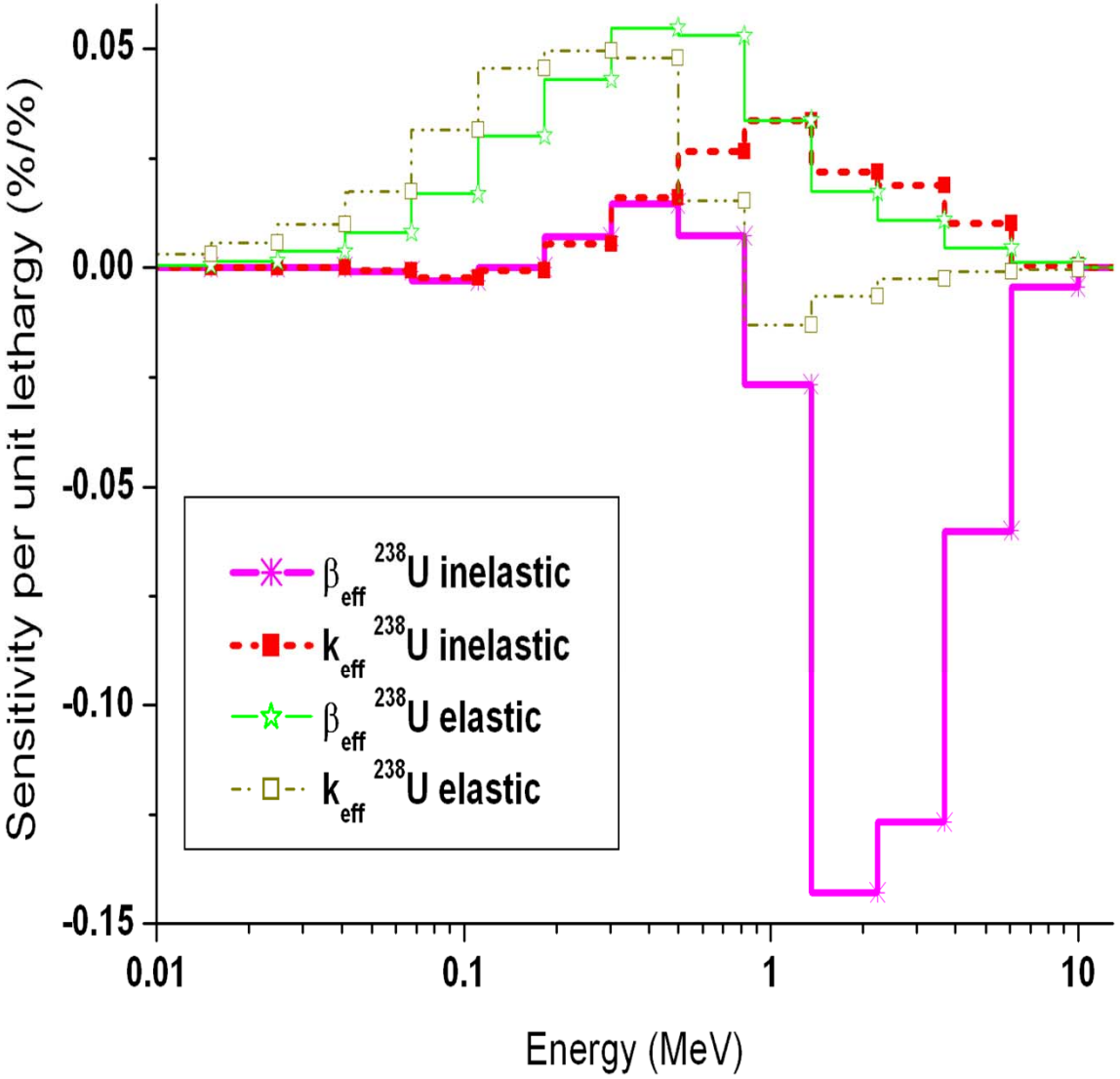
Moreover, the neutron spectrum, Can be shifted to lower energies by a *scattering material introduced into the system* (in SEG: essentially graphite).

The growing increase of the neutron importance at lower energies is best compensated by poisoning the system with *1/v-absorber material* (in SEG: Cd or B4C).



Comparison of βeff and keff sensitivities with respect to inelastic and elastic cross-sections of ^{238}U

(Popsy - FLATTOP-Pu)



Development of new adjustment strategies

- **In order to cope with the key issue of compensation of effects new adjustment strategies are under development:**
  - **Adjustment Potential and Motive Force (JAEA)**
  - **PIA (Progressive Incremental Adjustment) and REWIND (Ranking Experiments by Weighting for Improved Nuclear Data) (INL)**
- **China Nuclear Data Center has developed its own adjustment capability**
- **AREVA is developing a new Monte Carlo adjustment methodology that eventually will adjust the continuous energy files.**

Adjustment Potential

Potential is calculated as well as *motive force* by using

$$(\Delta T/T)'_{i,j} = M_j G^{\mathrm{T}}_{i,j}[G_{i,j} M_j G^{\mathrm{T}}_{i,j} + V_i]^{-1}[J - \overline{R_{c,I}}/\overline{R_{e,I}}]$$

in place of

$$(\Delta T/T)_{i,j} = M_j G^{\mathrm{T}}_{i,j}[G_{i,j} M_j G^{\mathrm{T}}_{i,j} + V_i]^{-1}[J - R_{c,i}/R_{e,i}]$$

Average of 1 – C/E over a set of core parameters related to *i*

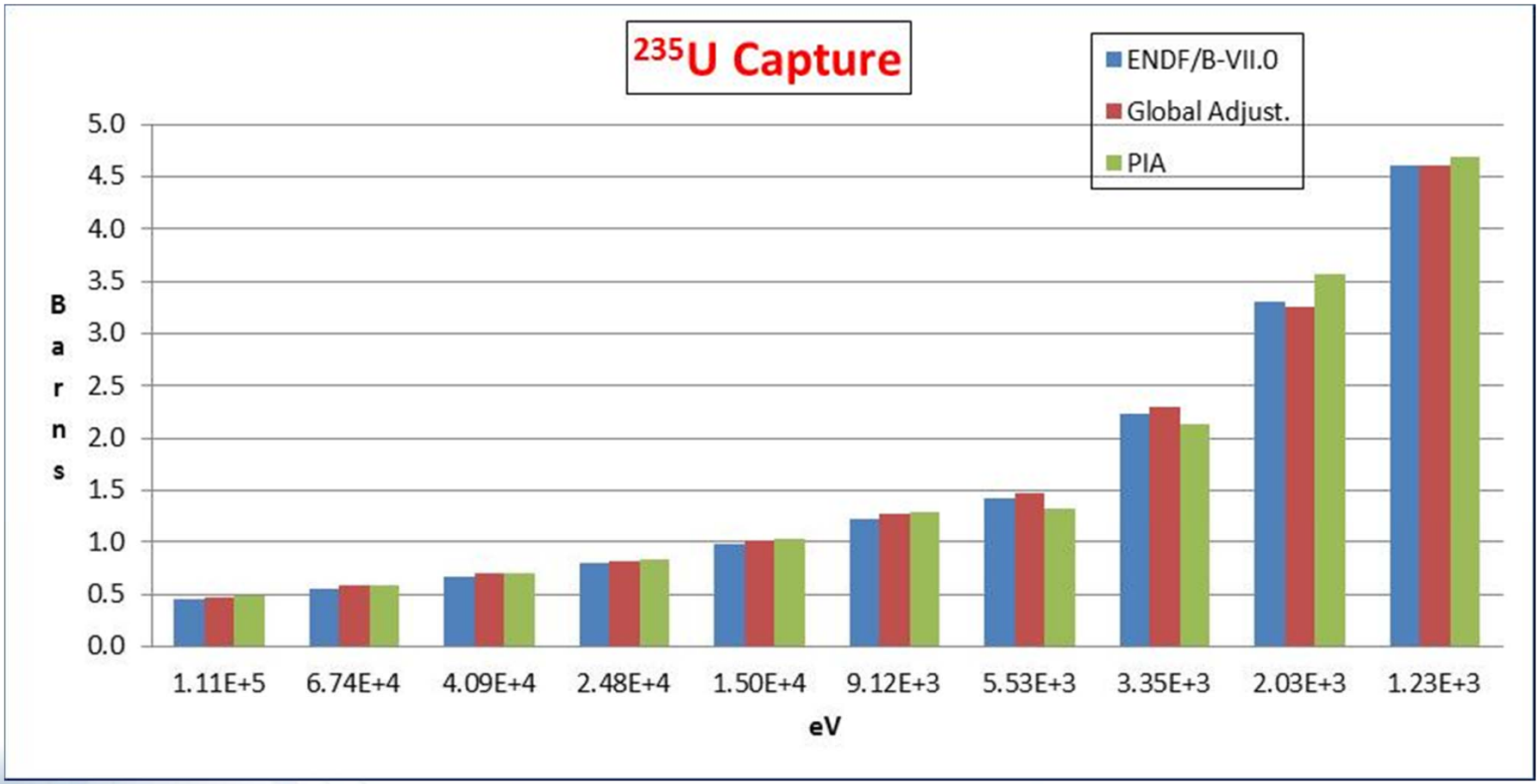
1 – C/E of the core parameter *i*

- *Motive force* becomes null in two cases:
  - Not sensitive to the integral experiment: G ~ 0.0

    → There is no *motive force*
  - Sensitive but not necessary to adjust the cross sections: G >> 0.0 and C/E ~ 1.0

    → There is force that keeps the present values, or *frictional force*
- Therefore, *Potential* is needed to distinguish the two cases.
- The amplitude of *Potential* is comparable with that of a different kind of integral experiments, such as criticality and Na void reactivity

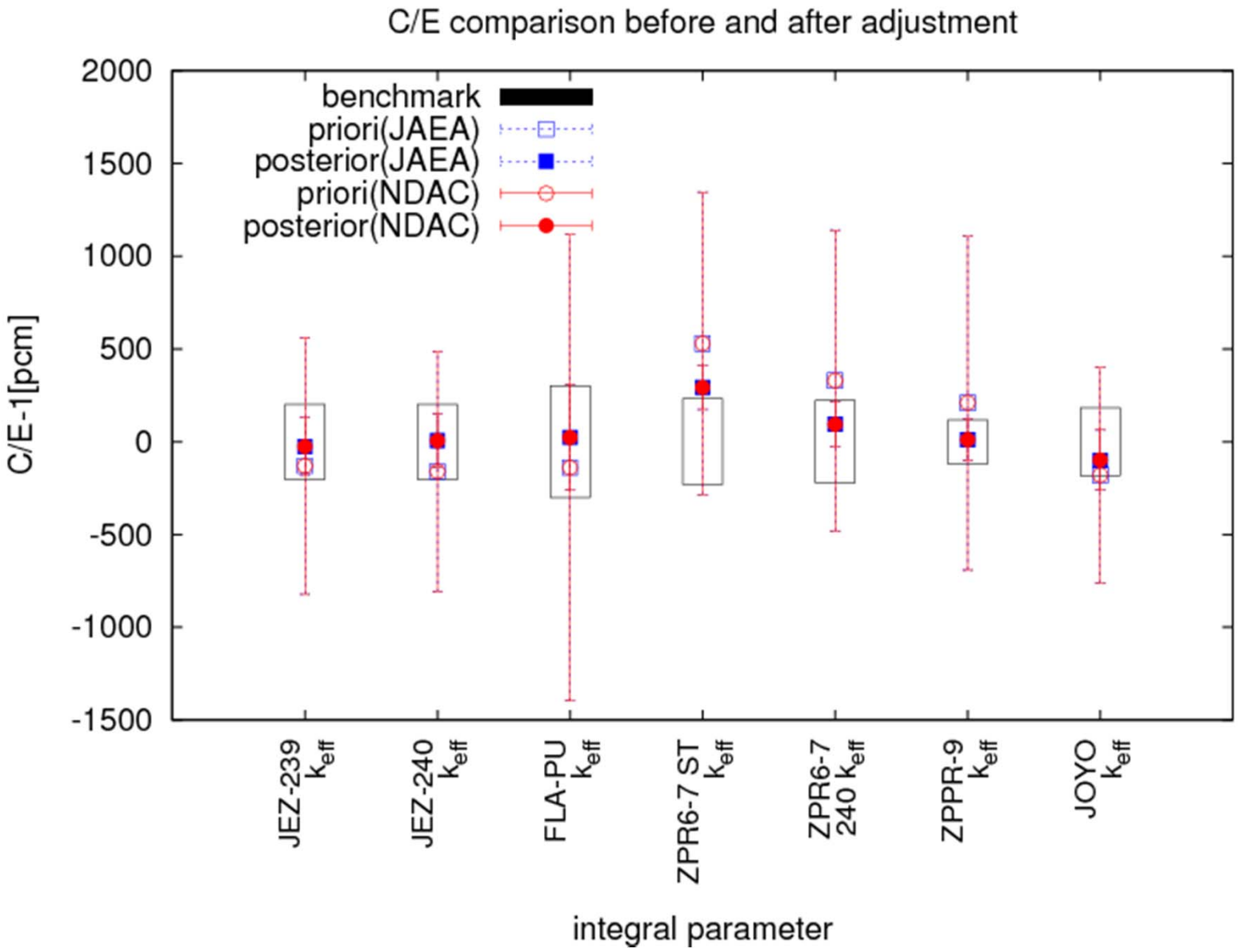
σ change comparison PIA against Global



REWIND applied to SG33 set of experiments and 5 Isotopes: ^{23}Na, ^{56}Fe, ^{235}U, ^{238}U, ^{239}Pu

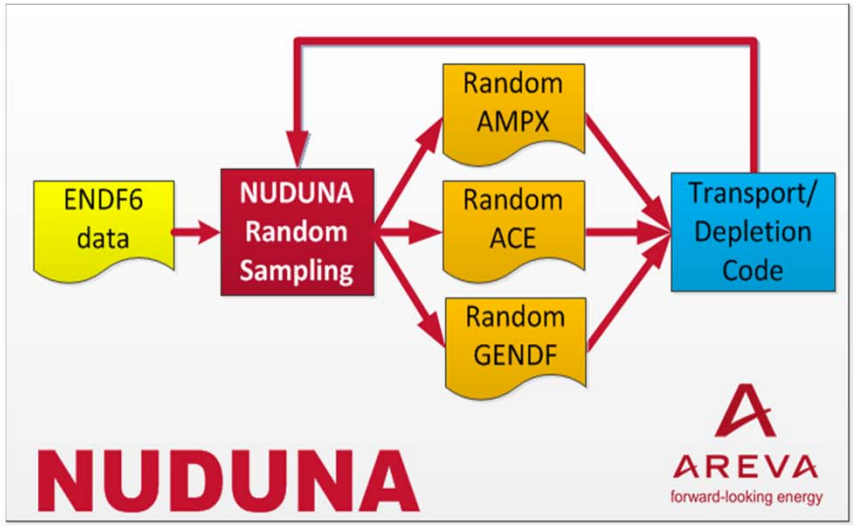
Experiment	Optimal weight %	Rank	Exp. Return %	Sharpe Ratio	Ishikawa Factor	Uncert. before adjust. %	Uncert. after adjust. %
JEZ_Pu239 KEFF	27.8	2	0.45	0.69	1.50	0.30	0.15
JEZ_Pu239 F28/F25	3.4	6	2.26	0.61	1.18	1.68	0.90
JEZ_Pu239 F37/F25	5.0	5	0.91	0.39	0.71	1.02	0.64
JEZ_Pu239 F49/F25	0.0	8	-0.13	-0.15	0.85	0.80	0.53
JEZ_Pu240 KEFF	0.0	8	0.29	0.59	2.44	0.49	0.18
FLATTOP KEFF	38.1	1	0.56	0.65	0.92	0.28	0.16
FLATTOP F28/F25	0.0	8	1.22	0.40	0.84	1.56	0.84
FLATTOP F37/F25	0.0	8	0.60	0.30	0.69	0.98	0.63
ZPR6/7 KEFF	0.0	8	0.76	0.77	1.84	0.42	0.12
ZPR6/7 F28/F25	0.0	8	2.97	0.46	0.63	2.19	1.41
ZPR6/7 F49/F25	0.0	8	-1.70	-2.07	0.29	0.72	0.57
ZPR6/7 C28/F25	0.0	8	-1.17	-0.78	0.47	1.26	0.90
ZPR6/7 PU40 KEFF	0.0	8	0.77	0.78	1.92	0.42	0.12
ZPPR9 KEFF	7.5	4	1.10	0.90	3.83	0.45	0.11
ZPPR9 F28/F25	3.3	7	5.10	0.64	0.81	2.37	1.53
ZPPR9 F49/F25	0.0	8	-1.26	-1.47	0.34	0.72	0.56
ZPPR9 C28/F25	0.0	8	-0.45	-0.29	0.64	1.27	0.90
ZPPR9 STEP3	0.0	8	-0.18	-0.02	0.70	5.44	3.93
ZPPR9 STEP5	0.0	8	2.26	0.23	0.91	6.87	4.88
JOYO KEFF	15.0	3	0.70	0.79	1.67	0.30	0.14

Experiment Portfolio Internal Correlation: -0.02


C/E comparison before and after adjustment
benchmark
priori(JAEA)
posterior(JAEA)
priori(NDAC)
posterior(NDAC)
C/E-1[pcm]
2000
1500
1000
500
0
-500
-1000
-1500
JEZ-239 keff
JEZ-240 keff
FLA-PU keff
ZPR6-7 ST keff
ZPR6-7 240 keff
ZPPR-9 keff
JOYO keff
integral parameter

NUDUNA: nuclear data random sampling

- **Nuclear Data random sampling tool, developed at AREVA GmbH.**
- **Direct sampling of ENDF-6 data based on its covariance information**
  - Neutron multiplicities (File 1)
  - Resonance parameters (File 2)
  - Cross sections (File 3)
  - Angular distributions (File 4)
  - Decay data (File 8, Section 457)



- **Automatic creation of transport code libraries out of random ENDF6 data**
  - Based on NJOY 99, PUFF IV
  - Support for MCNP, SCALE & **WIMSD-4** (ALEPH, SERPENT, APOLLO2 in development)
  - Arbitrary temperatures and broad group structures

- **Limitations**
  - No sampling of fission spectra (χ, File 5) and no isotope-isotope correlations (in development)

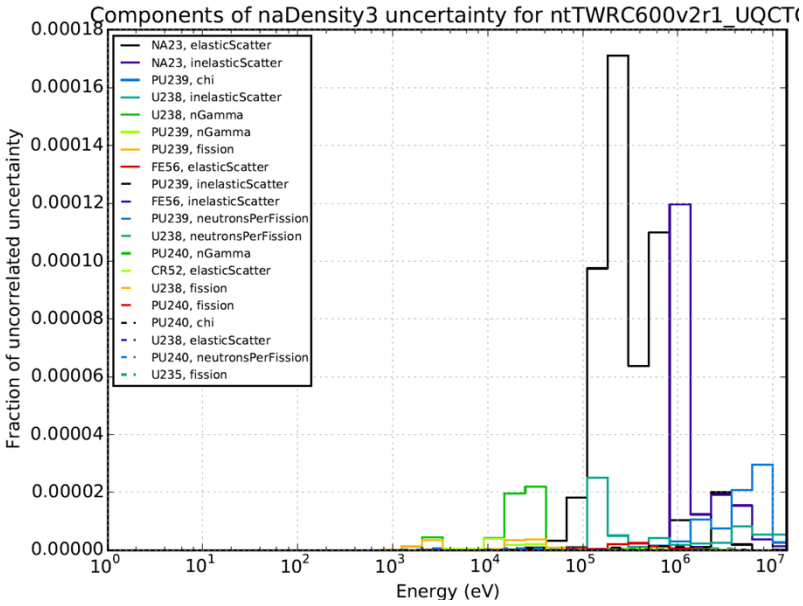
Account for new emerging needs

- **Industry driven (see TerraPower). How to help specific initiatives for data uncertainty reduction.**
- **New target uncertainties: input from industry? If yes, how to cope with them?**
- **Provide feedback to be used in the frame of ND activities towards MA improvement requirements (NSC Expert group).**
- **Request by British criticality safety community on uncertainty assessment of Am-241 for space battery applications.**

Relative Uncertainty Results in TWR

Integral Parameter	TWR-P BOL	TWR-P EOL	TWR-C EOL
k_{eff}	1.54E-02	1.19E-02	1.76E-02
CTC	1.24E+00*	1.07E-01	5.67E-02
Doppler coefficient	8.61E-02	4.80E-02	6.78E-02
Void worth	1.74E+00*	1.08E-01	5.45E-02

*CTC/void worth is very close to 0 at BOL, hence large relative uncertainty



Am-sphere: Uncertainty

Covariance data source	Uncertainty (%)	
	Transport XS used	
	JENDL-4.0m	ENDF/B-VII.0
JENDL-4.0m	1.7%* (mt4:1%) **2 % (using mt51-91)**** **5.1% (PFNS)***** **5.5% (total) ********	1.5 (mt4:0.9%, mt18:0.5%, ν:0.9%) **2.2 %**** **5.8% PFNS** **6.2% (total)**
COMMARA2	2.6%	**3%** (mt4:2.3%, mt18:0.9%)
SCALE6	6.1% (mt4: 5.4%)	**7.5%** (mt4: 6.8%)

* using JENDL4 total inelastic covariances (MT=4)
** using JENDL4 partial inelastic covariances (MT=51 to 91)
*** uncertainty due to prompt neutron fission spectrum (PFNS)
**** total uncertainty (due to transport XS + PFNS)

Future Action

Starting from CIELO new files (with uncertainties) attempt new adjustment:

- **Selection of specific integral experiments (old and new ones)**
- **Improved criteria for reliability (from methodology studies)**
- **A-posteriori covariance data: how to use them in evaluation**
- **Need more complete covariance information, possibly cross correlations, angular distributions etc.**

- **Schedule? Interest from CIELO?**
- **At present, most benchmarking or integral experiment (if any) selection seems (from what we understand) to be done with little « detailed » sensitivity analysis (?).**
- **We should avoid as much as possible the risk of using integral experiment information « twice » !**

Summary

- **The subgroup is very active and many, very useful, contributions have been produced by the participants.**
- **Four different intermediate deliverables on different subjects are being finalized and should be available soon.**
- **The main focus is concentrated on dealing with compensations and a dual approach has been adopted:**
  - **Adding more experiment of elemental type and/or of separation effect type.**
  - **Developing new adjustment strategy (ranking experiments)**
- **New emerging needs, customer driven, are considered.**
- **Expecting feedback from CIELO in terms of more complete and reliable covariance data in the next future.**