Testing Calibration Effects with SG33 Benchmarks

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CNDC CHINA NUCLEAR DATA CENTER

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1. Background

- ✓ **Mark Chadwick's proposal**
  - **A toy calculation to understand how calibration affects the adjustment results.**

ENDF-1. (calibrated),
ENDF-2 (uncalibrated) + *Same covariance* → ***Adjusted-1***
Adjusted-2

- ✓ **Conclusion of stress test**

Different constraints can lead to different, even contrary adjusted results for both integral and differential data. ***-- Haicheng***

- ✓ **Pino's PIA exercise has shown**

"the succession of experiments to be used in the progressive adjustment will impact significantly the final results both in terms of central values and a posterior covariance." -- Pino

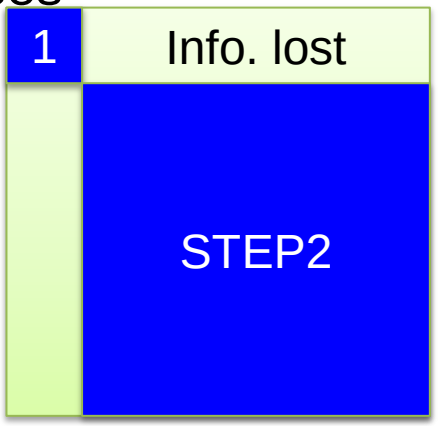
- ✓ **Qualitative analysis has never been done before.**
  - Play with the SG33 exercises can help to understand how the previous conclusions function in evaluation calibration.

2. Calibration exercises (PHASE I)

2.1 Description of exercises

- **CASE 0 (Sg33 benchmark exercise)**
  - 11 isotopes
    - ^{10}B, ^{16}O, ^{23}Na, ^{52}Cr, ^{56}Fe, ^{58}Ni, $^{235,238}U$, $^{239,240,241}Pu$
  - 8 Reactions
    - (n, el), (n, inl), (n, disappearance),(n, f), Nu-total, Chi-p, Mu, Nu-delay.
  - Covariance: JENDL-4.0
  - 20 Integral data
    - JEZEBEL-Pu239 (k_{eff}, F28/F25,F49/F25, F37/F25), -Pu240 (k_{eff}), FLATTOP-Pu (k_{eff}, F28/F25, F37/F25), ZPR-6/7 (k_{eff}, F28/F25, F49/F25, C28/F25), -High Pu240 (k_{eff}), ZPPR-9 (k_{eff}, F28/F25, F49/F25, C28/F25, Na void reactivity (Step 3, 5)), JOYO Mk-I (k_{eff}) .

- **CASE 1 (no doubling counting calibration with both nuclear data and covariances adjusted)**
  - STEP 1 (1 integral par.)
    - The same isotopes, reactions and covariances
    - Integral data
      - JEZEBEL-Pu239 k_{eff}
      - loss correlation.
  - STEP 2(19 integral par.)
    - The same isotopes, reactions, sensitivities
    - Nuclear data and covariances from STEP1
    - Integral data and correlation for 19 parameters.
      - JEZEBEL-Pu239 (~~k_{eff}~~, F28/F25,F49/F25, F37/F25), -Pu240 (k_{eff}), FLATTOP-Pu (k_{eff}, F28/F25, F37/F25), ZPR-6/7 (k_{eff}, F28/F25, F49/F25, C28/F25), -High Pu240 (k_{eff}), ZPPR-9 (k_{eff}, F28/F25, F49/F25, C28/F25, Na void reactivity (Step 3, 5)), JOYO Mk-I (k_{eff}) .



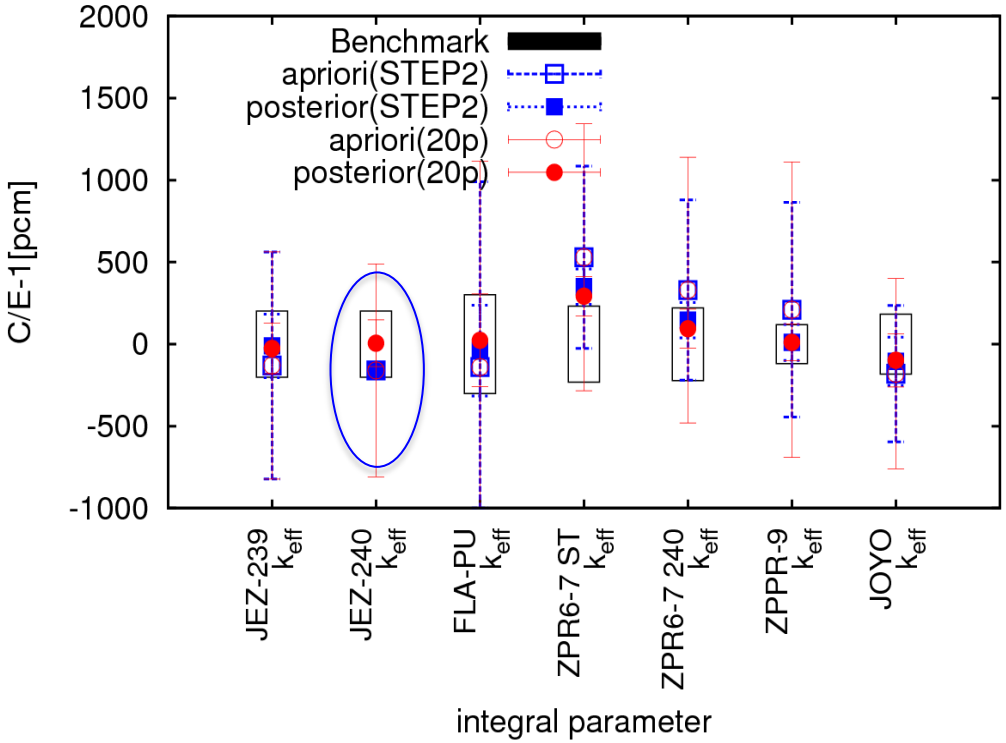
- **CASE 2 (doubling counting calibration with both nuclear data and covariances adjusted)**
  - STEP 1 (1 integral par.)
    - The same isotopes, reactions and covariances
    - Integral data
      - JEZEBEL-Pu239 k_{eff}
  - STEP 2a(20 integral par.)
    - The same isotopes, reactions, sensitivities
    - Nuclear data and covariances from STEP1
    - Integral data and correlation for 20 parameters
      - Update JEZEBEL-Pu239 k_{eff} and uncertainty with STEP1.

- **CASE 3 (calibration with only nuclear data)**
  - STEP 1 (1 integral par.)
    - The same isotopes, reactions and covariances
    - Integral data
      - JEZEBEL-Pu239 k_{eff}
  - STEP 2b(20 integral par.)
    - The same isotopes, reactions, sensitivities
    - Nuclear data from STEP1
    - ND covariances from STEP0
    - Integral data updated with STEP1
    - Integral correlation for 20 parameters from STEP0

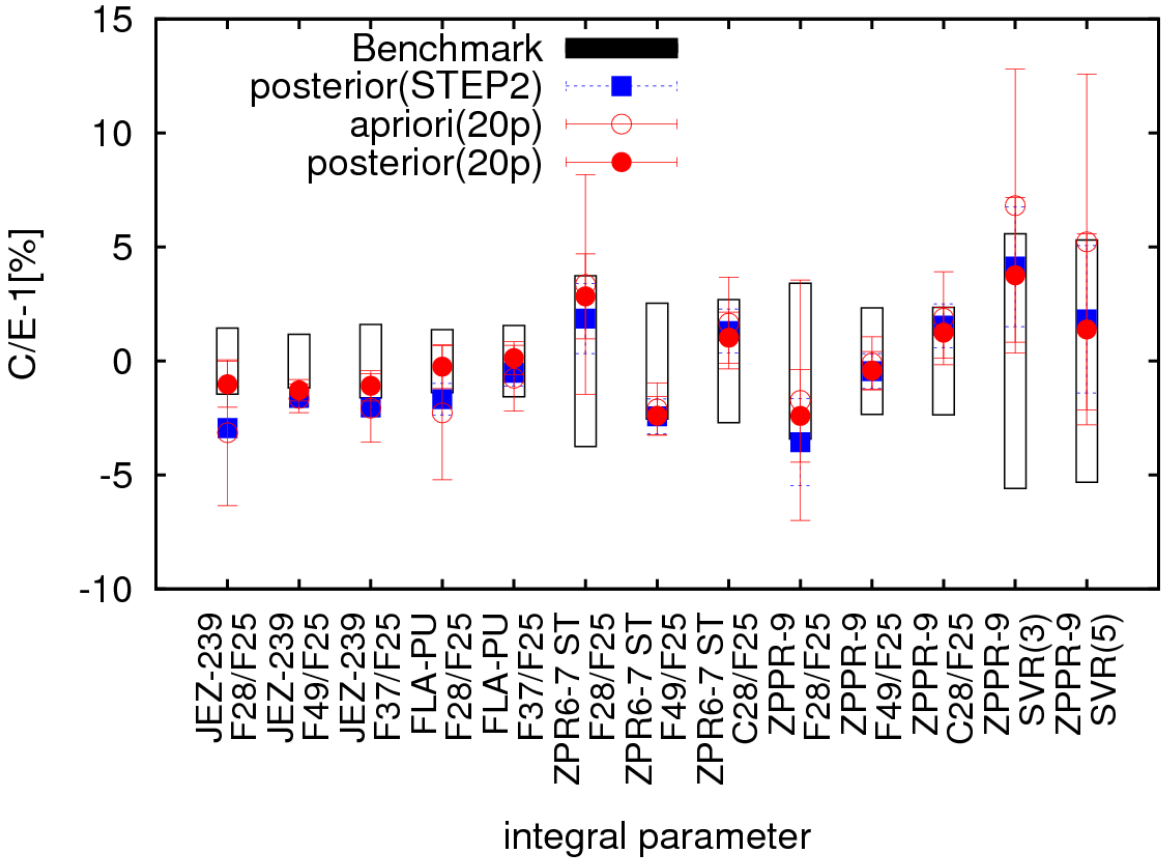
Patrick Talou said this "calibration" process should not have much of an impact on your post-evaluation adjustment process, *as long as* the evaluated covariance is not modified at the evaluation stage.

2.2 Results and discussion

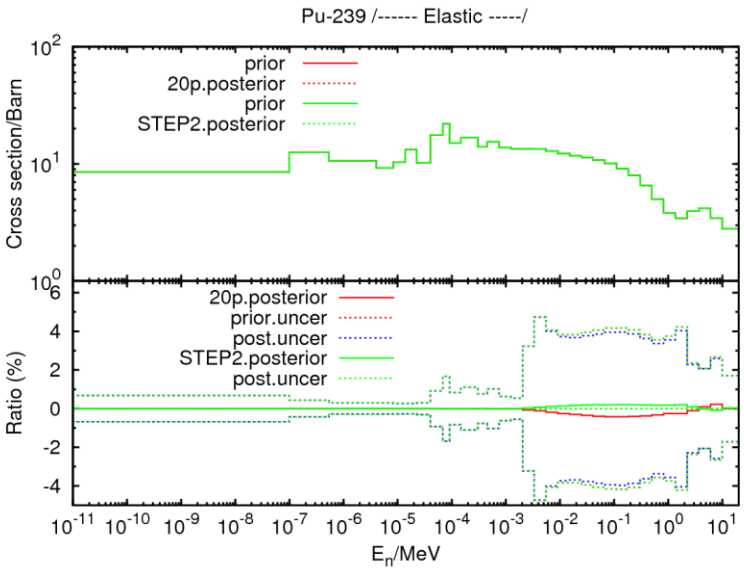
- **CASE0 vs. CASE1**
  - Just as the conclusion of PIA exercises, change sequence will change adjusted results.
    - The adjusted k_{eff} values of Jezebel-240 are not benefit from Jezebel .

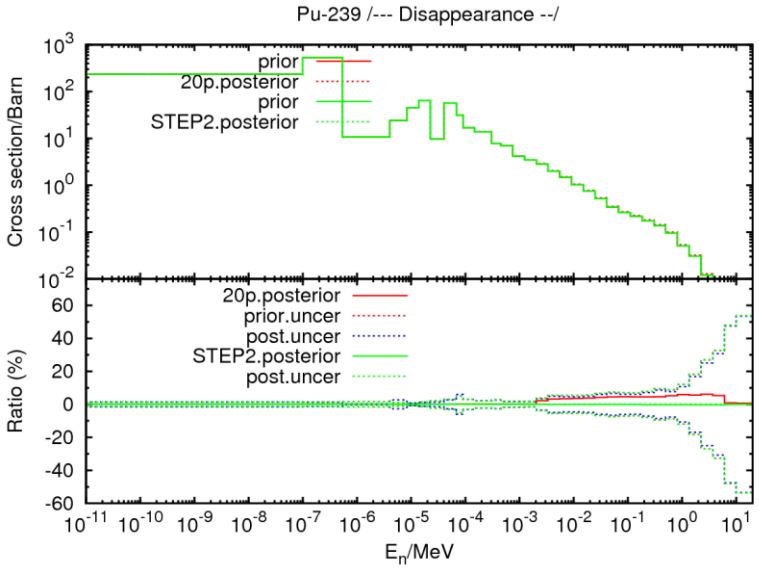


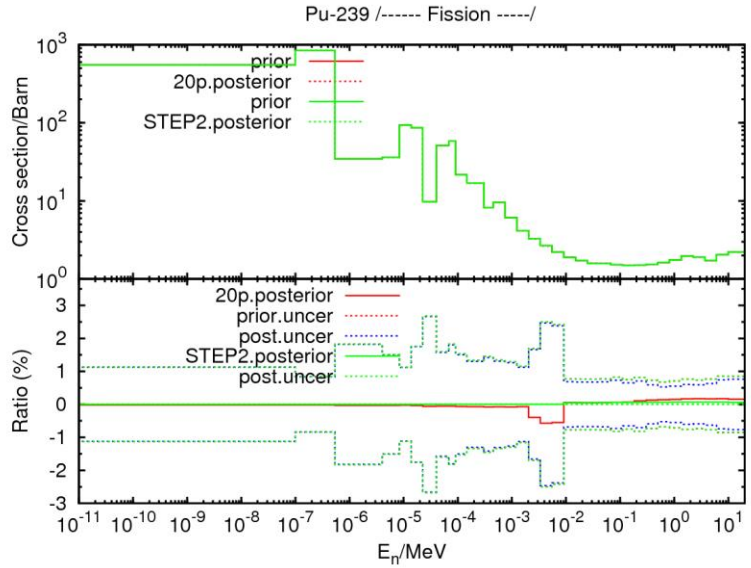
– Posteriors of many reaction rate ratios are also affected, some of them are not improved.



– The posteriors of nuclear data were different.
  - For STEP2, zero uncertainties of ^{239}Pu XS for reactions, such as (n,el), (n,disapp.) and (n,f).
  - XS of (n,el),(n,f) and (n,g) nearly unchanged, which cause the k_{eff} of Jezebel-240 was not improved.



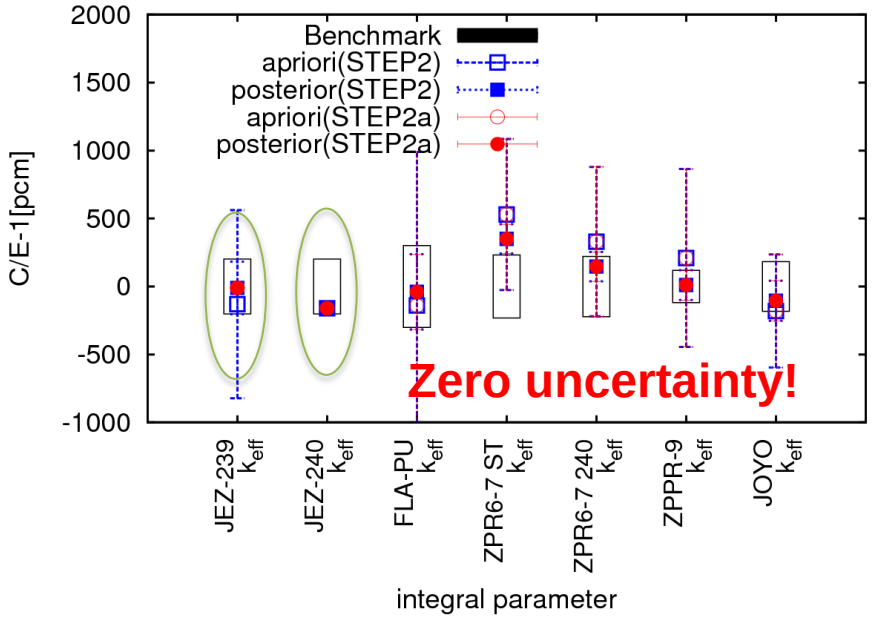


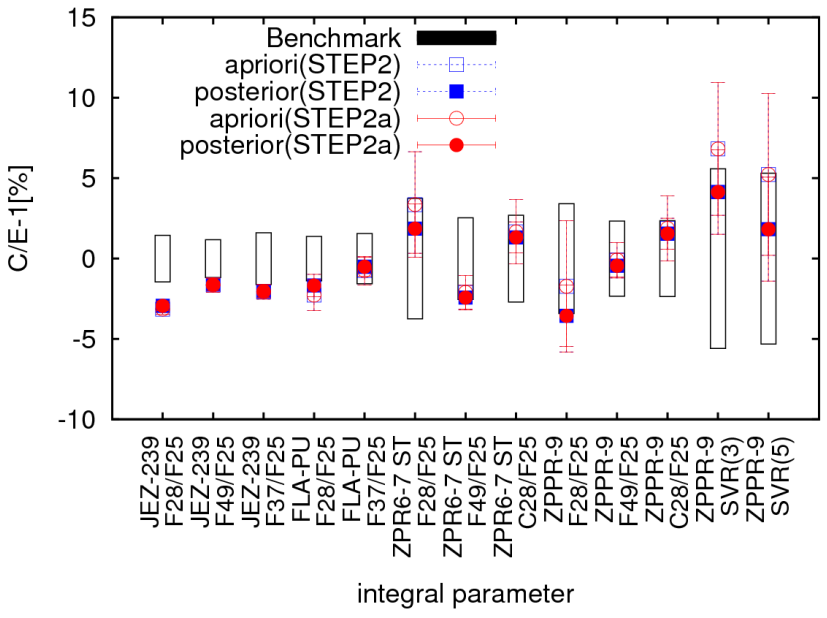


- **CASE1(no double counting) vs. CASE2(double counting)**
  - The posteriors of calculated IPs are exactly the same, but uncertainty of Jezebel k_{eff} completely changed.

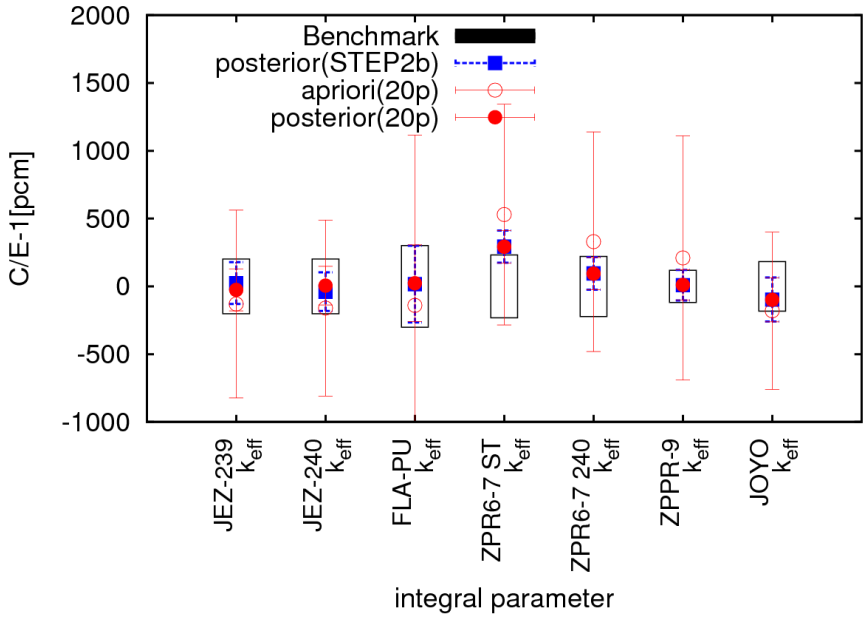
posteriors	STEP1/STEP2	Δk=194 pcm
	STEP2a	$\Delta k \approx 0$ pcm

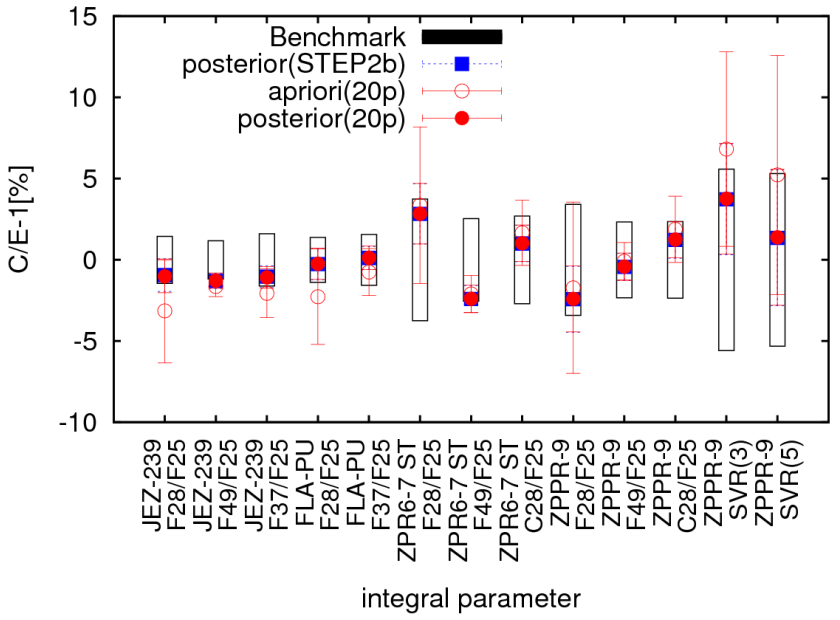
Reusing the same integral parameters will cause underestimating posterior uncertainties of both integral parameters and nuclear data?

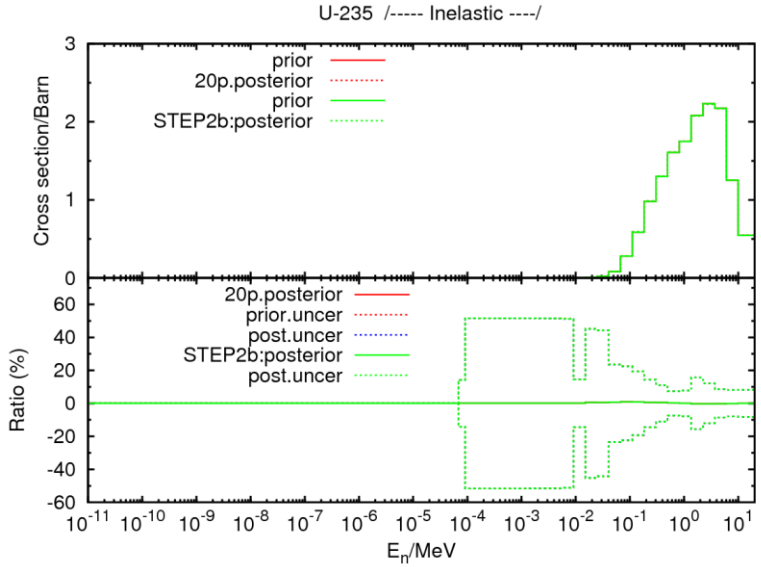


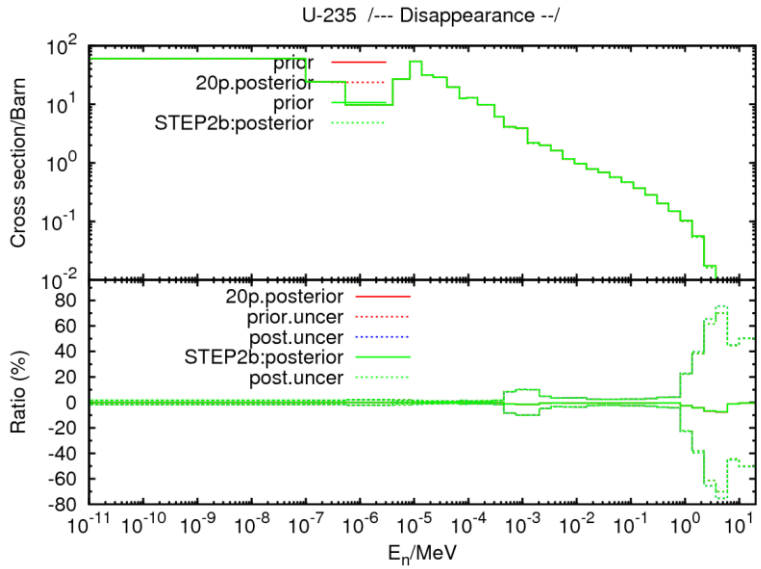


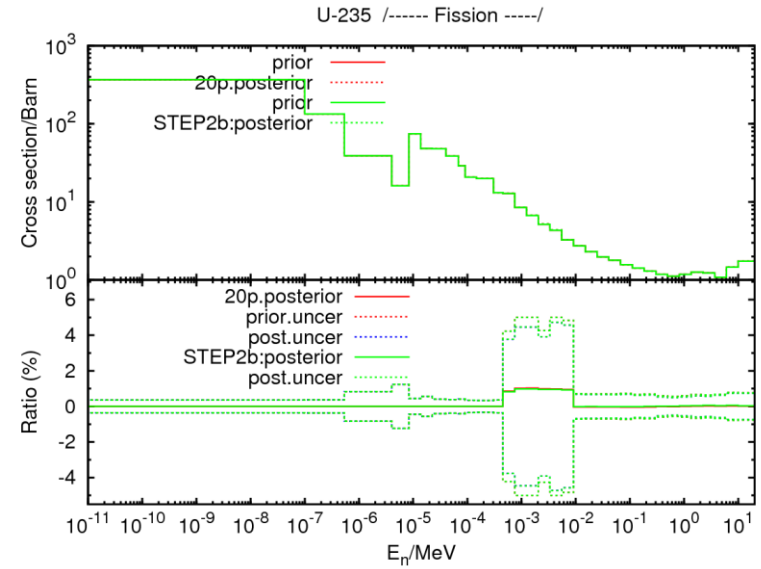
- **CASE0 vs. CASE3**
  - Comparing CASE0 and CASE3, both adjusted integral parameters and nuclear data of are close to each other.
    - Different ND, the same apriori of ND covariance.

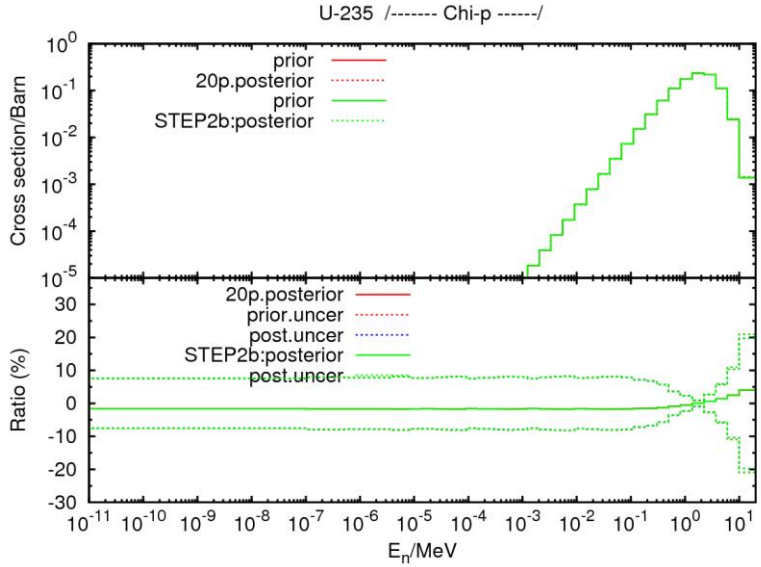


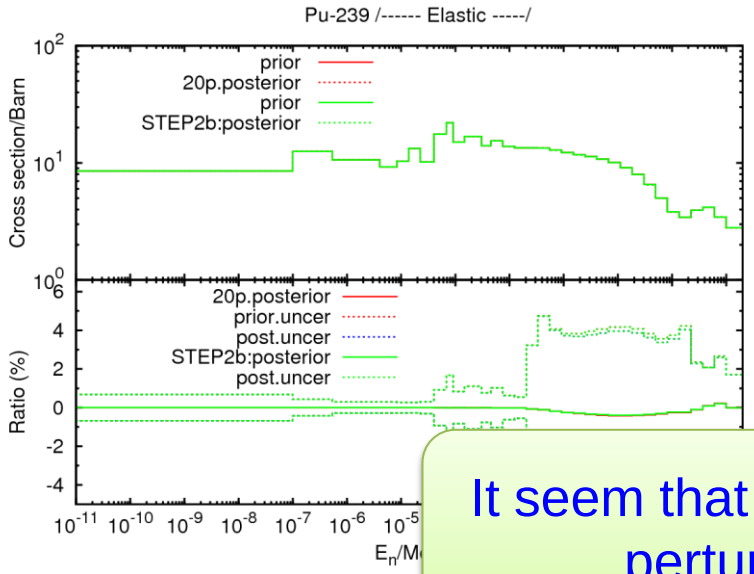


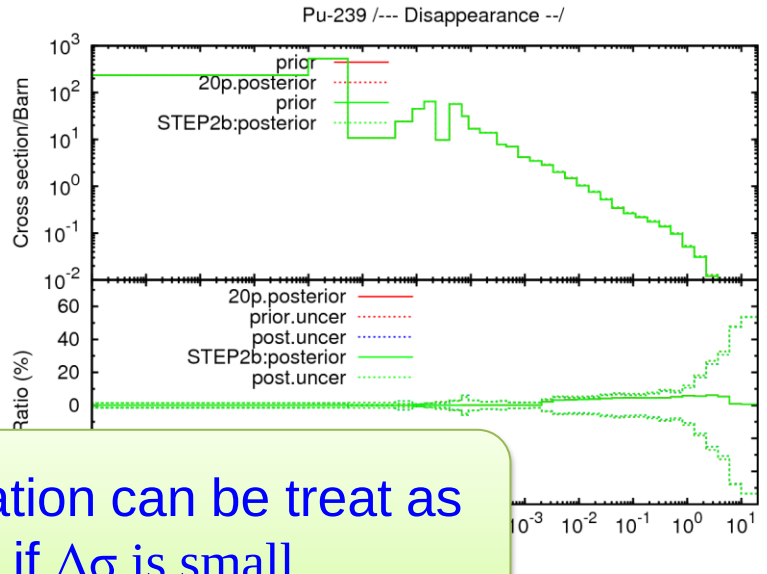

U-235 /----- Inelastic ----/
Cross section/Barn
prior
20p.posterior
prior
STEP2b:posterior
Ratio (%)
20p.posterior
prior.uncer
post.uncer
STEP2b:posterior
post.uncer
E_n/MeV


U-235 /--- Disappearance --/
Cross section/Barn
prior
20p.posterior
prior
STEP2b:posterior
Ratio (%)
20p.posterior
prior.uncer
post.uncer
STEP2b:posterior
post.uncer
E_n/MeV

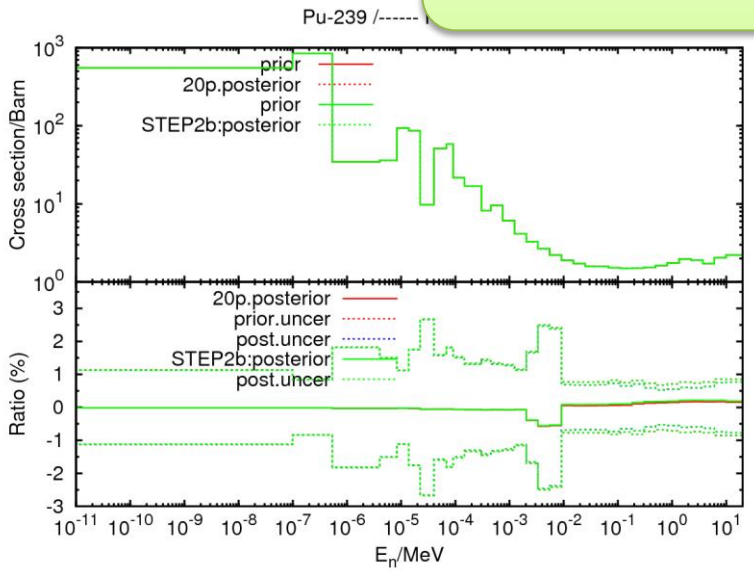

U-235 /------ Fission -----/
Cross section/Barn
prior
20p.posterior
prior
STEP2b:posterior
Ratio (%)
20p.posterior
prior.uncer
post.uncer
STEP2b:posterior
post.uncer
E_n/MeV

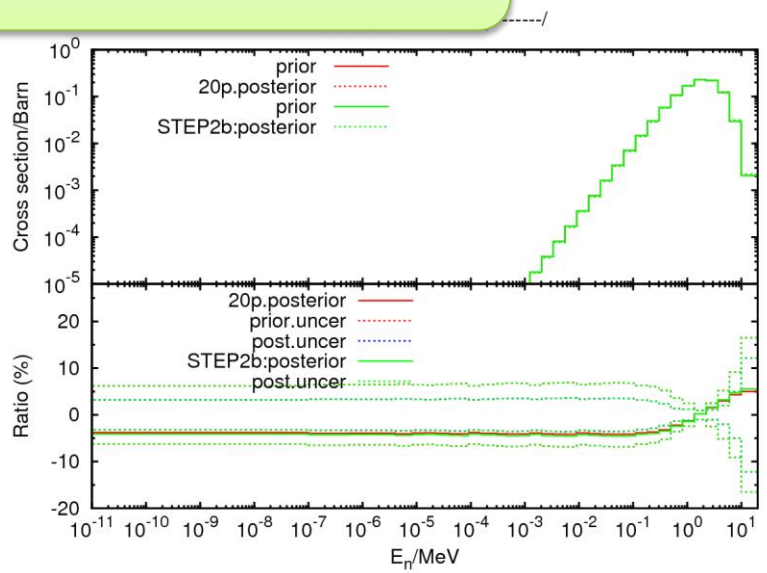

U-235 /------- Chi-p ------/
Cross section/Barn
prior
20p.posterior
prior
STEP2b:posterior
Ratio (%)
20p.posterior
prior.uncer
post.uncer
STEP2b:posterior
post.uncer
E_n/MeV





It seem that calibration can be treat as perturbation if $\Delta\sigma$ is small.





3.3 Summary of phase I

- **Case0 and 1 confirms**
  - Change PIA sequence will affect adjusted results significantly.
    - The priority and correlations of “IPs” were changed when using PIA method.
  - Zero posterior uncertainties were found.

- **Case 1 and 2 show "Calibration” with and without double counting**
  - The adjusted IPs were not affected significantly, if post-evaluation correlations are passed to the following adjustment.
  - However, this kind of calibration cause underestimation of the posterior covariances of nuclear data.

- **Case 0 and 3 show "Calibration" without the evaluated covariance modified.**
  - Adjustment results will not be affect so significant
    - Similar posteriors of integral parameters and nuclear data are obtained.
  - *Keep covariances untouched when you do calibration?*
    - *It looks like double counting will not so harmful if $\Delta\sigma$ is small.*

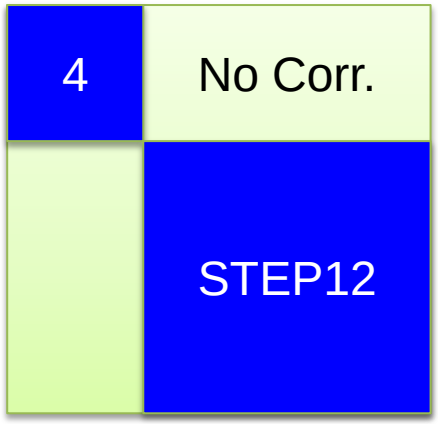
- **Remind**
  - Different constraints can lead to different, even contrary adjustment results for both integral and differential data.
    - Sequence of adjustment is also a kind of constrain.

3. Calibration exercises (PHASE II)

3.1 Description of exercises

- **CASE 0 (Sg33 benchmark exercise)**
  - 11 isotope
    - ^{10}B, ^{16}O, ^{23}Na, ^{52}Cr, ^{56}Fe, ^{58}Ni, $^{235,238}U$, $^{239,240,241}Pu$
  - 8 Reactions
    - (n, el), (n, inl), (n, disappearance),(n, f), Nu-total, Chi-p, Mu, Nu-delay.
  - Covariance: JENDL-4.0
  - 20 Integral data
    - JEZEBEL-Pu239 (k_{eff}, F28/F25,F49/F25, F37/F25), -Pu240 (k_{eff}), FLATTOP-Pu (k_{eff}, F28/F25, F37/F25), ZPR-6/7 (k_{eff}, F28/F25, F49/F25, C28/F25), -High Pu240 (k_{eff}), ZPPR-9 (k_{eff}, F28/F25, F49/F25, C28/F25, Na void reactivity (Step 3, 5)), JOYO Mk-I (k_{eff}) .

- **CASE 11 (calibration without reuse of the same integral parameters)**
  - STEP 11 (4 integral par.)
    - The same isotopes, reactions and covariances
    - Integral data
      - JEZEBEL-Pu239 (k_{eff}, F28/F25,F49/F25, F37/F25),
      - loss correlation.
  - STEP 12(16 integral par.)
    - The same isotopes, reactions, sensitivities
    - Nuclear data and covariances from STEP11
    - Integral data and correlation for 16 parameters.
      - JEZEBEL-Pu240 (k_{eff}), FLATTOP-Pu (k_{eff}, F28/F25, F37/F25), ZPR-6/7 (k_{eff}, F28/F25, F49/F25, C28/F25), -High Pu240 (k_{eff}), ZPPR-9 (k_{eff}, F28/F25, F49/F25, C28/F25, Na void reactivity (Step 3, 5)), JOYO Mk-I (k_{eff}) .

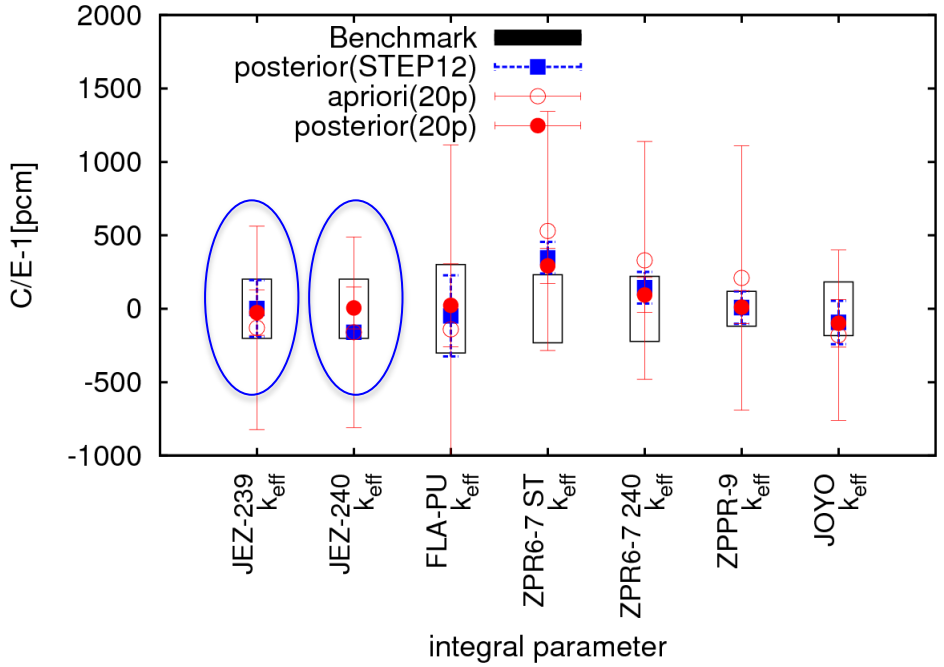


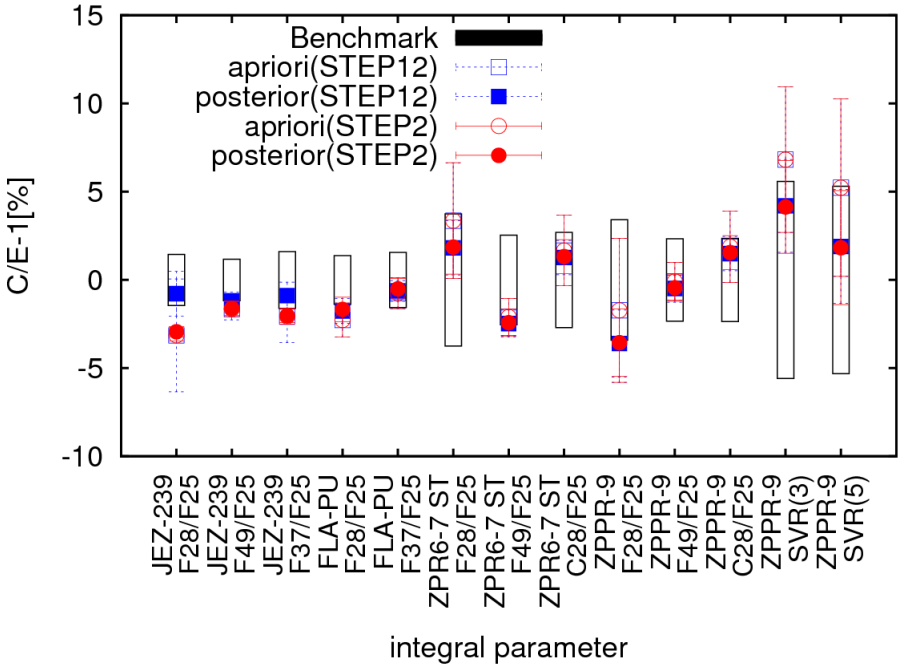
- **CASE 12 (calibration with and without double counting)**
  - STEP 11 (4 integral par.)
    - The same isotopes, reactions and covariances
    - Integral data
      - JEZEBEL-Pu239 (k_{eff}, F28/F25,F49/F25, F37/F25),
      - loss correlations.
  - STEP 12a(20 integral par.)
    - The same isotopes, reactions, sensitivities
    - Nuclear data and covariances from STEP11
    - Integral data and correlation for 20 parameters
      - Update prior of 4 parameters with the posterior of STEP11.

- **CASE 13 (calibration with only nuclear data)**
  - STEP 11 (4 integral par.)
    - The same isotopes, reactions and covariances
    - Integral data
      - JEZEBEL-Pu239 (k_{eff}, F28/F25,F49/F25, F37/F25),
  - STEP 12b(20 integral par.)
    - The same isotopes, reactions, sensitivities
    - Nuclear data from STEP11
    - ND covariances from STEP0
    - The prior of integral data updated with the posterior of STEP11
    - Integral correlation for 20 parameters from STEP0

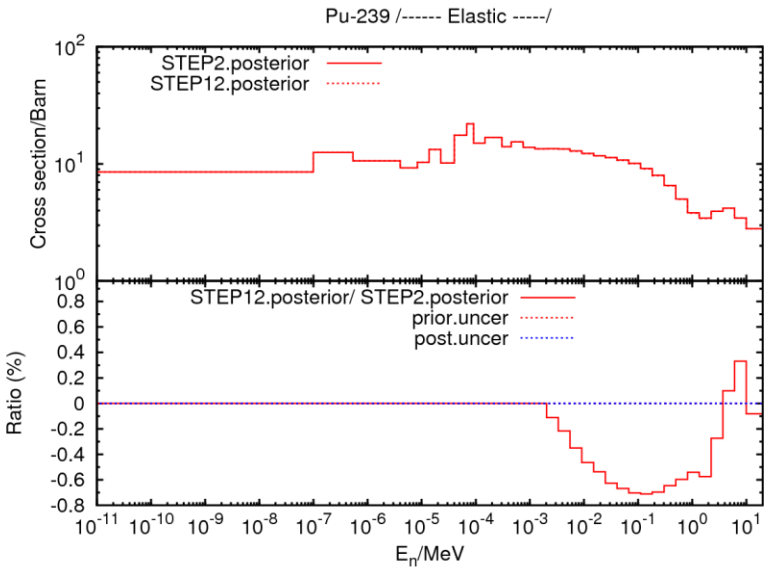
3.2 Results and discussion

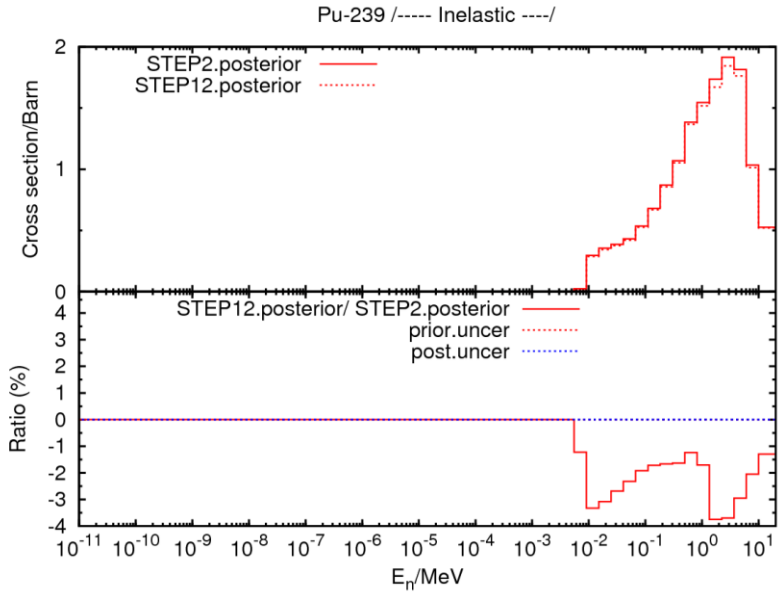
- **CASE0 vs. CASE11**
  - For CASE11, the posterior of reactivity ratios of Jezebel improved as expected, but k_{eff} values of Jezebel-240 is still not improved, which is similar with CASE1.
    - Posterior uncertainties of k_{eff} of Jezebel -239 and 240 go to zero again.

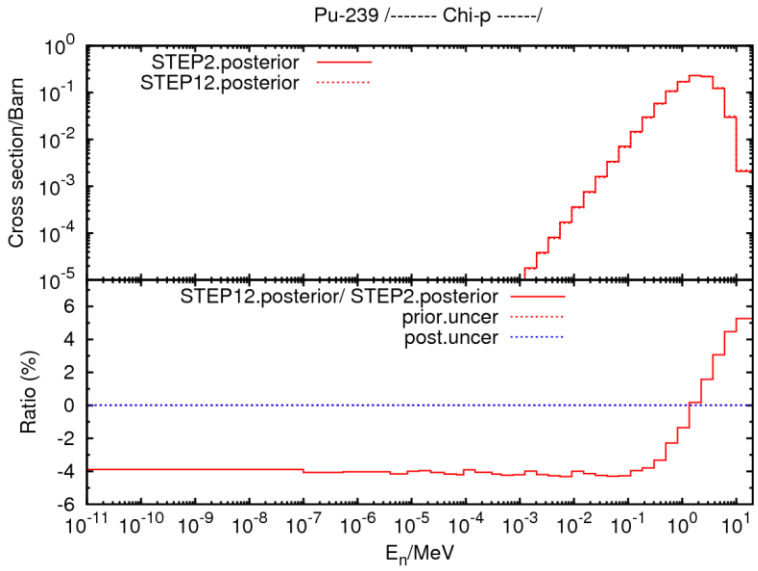




- **Compared with CASE1**
  - XS of ^{239}Pu(n,el), (n,inl) and chi are different obviously.
  - Again, zero uncertainties of ^{239}Pu XS for reactions were gotten.

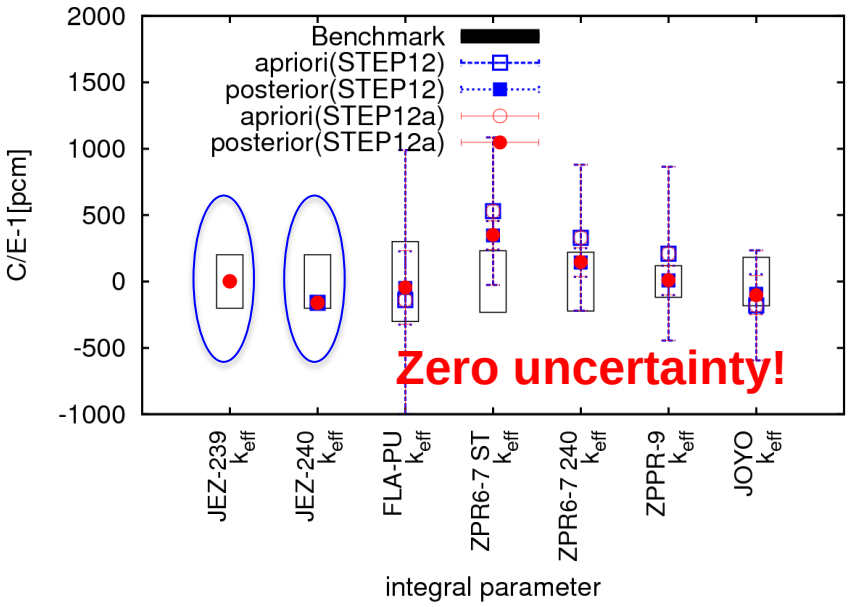


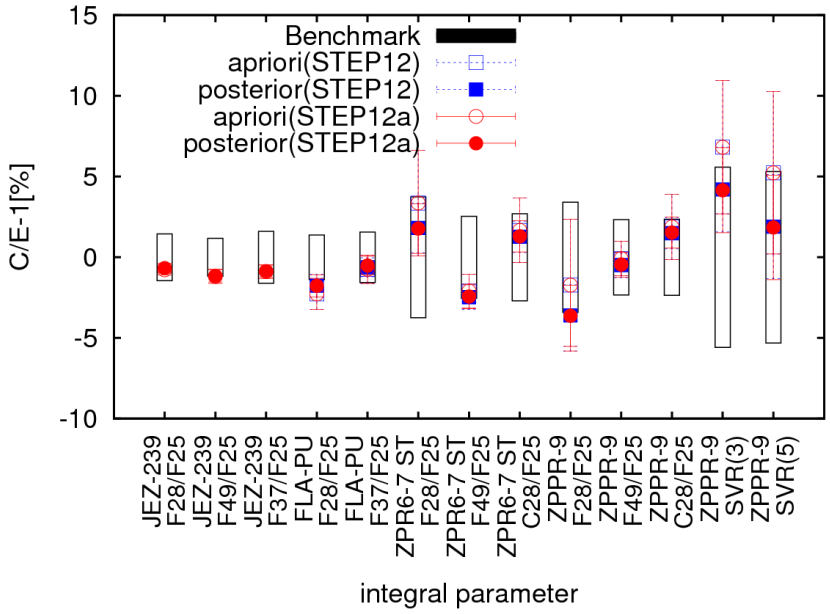




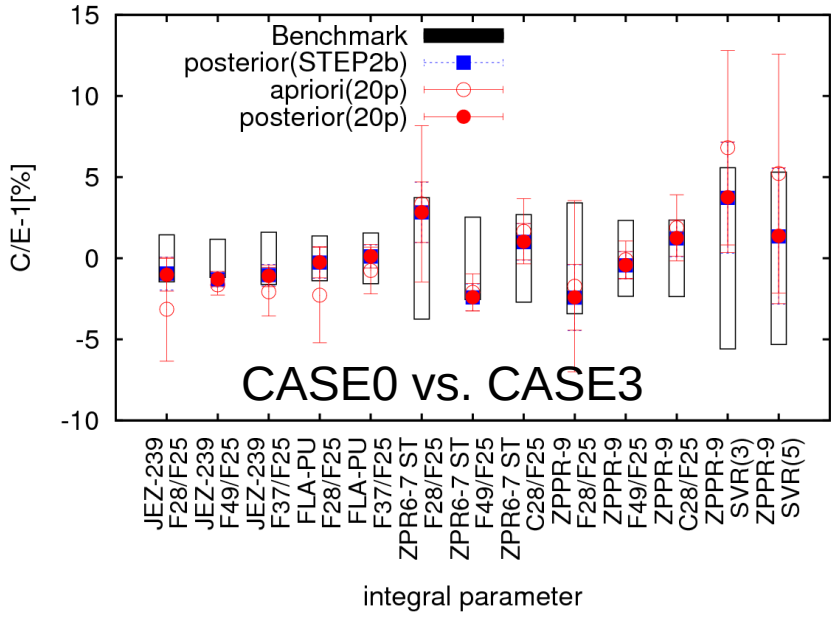
- **CASE11(no double counting) vs. CASE12(double counting)**
  - Similar with the comparison between CASE1 and 2, the posteriors of calculated IPs are nearly the same, and small uncertainties of IPs, which are double counted, were gotten.

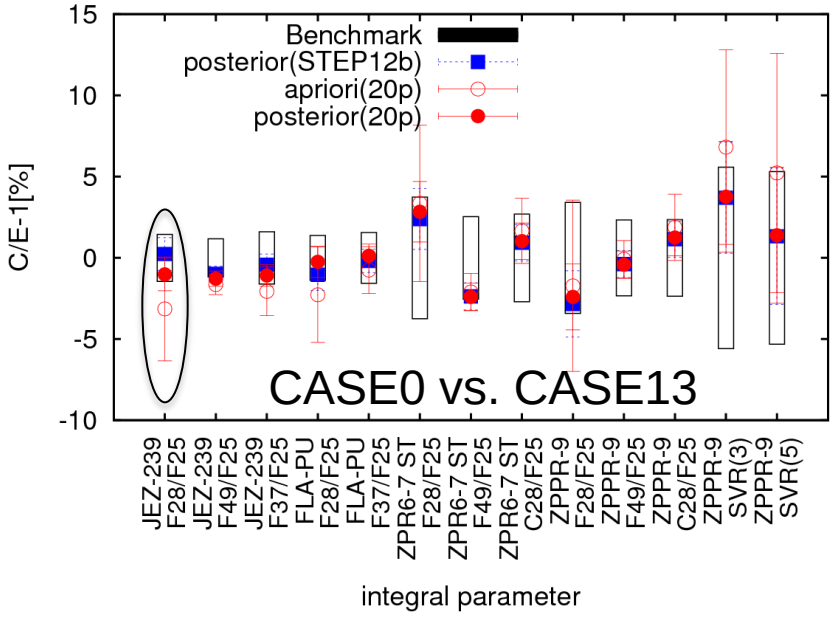
Reusing the same integral parameters will cause underestimating posterior uncertainties for both integral parameters and nuclear data.



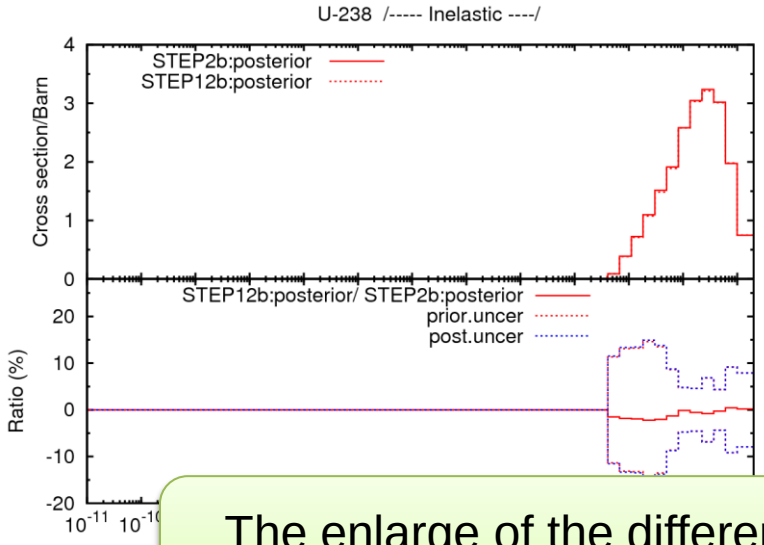


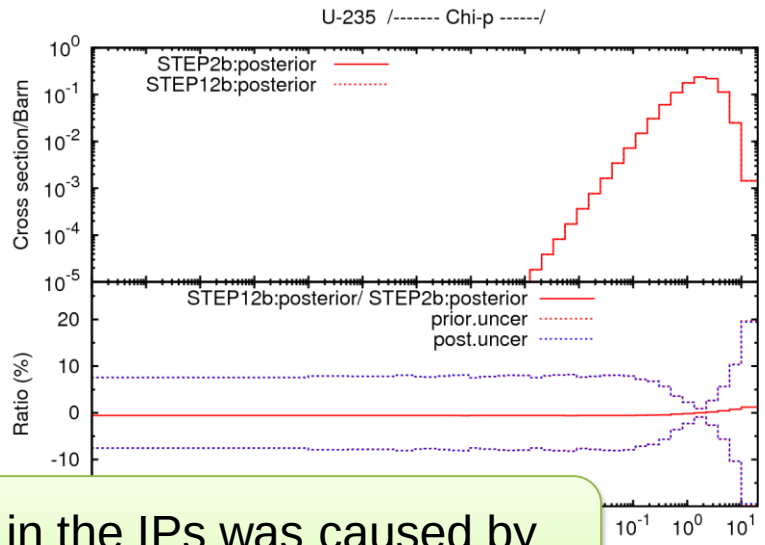
- **CASE0 vs. CASE13**
  - Unlike CASE0 vs. CASE3, difference between posterior and apriori of reactivity ratios gets larger after introduce reactivity ratios to first step.
    - Even keep the covariances of nuclear data unchanged, difference of posteriors comparable with uncertainty of IPs was observed.



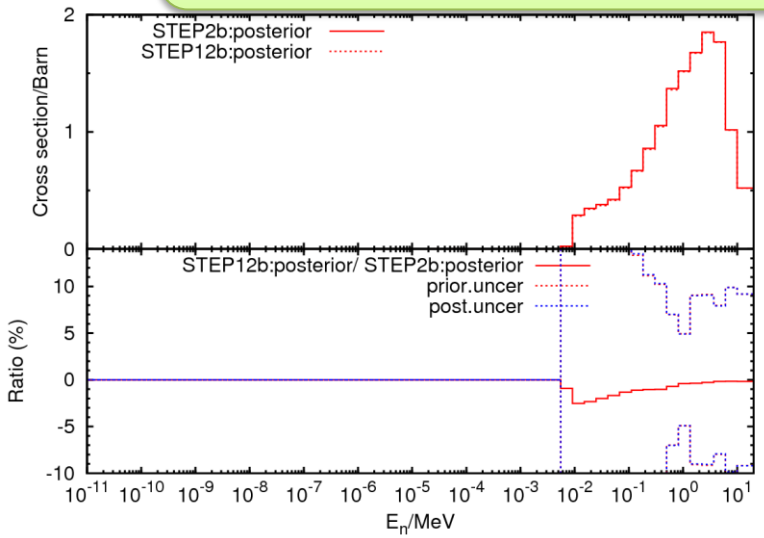


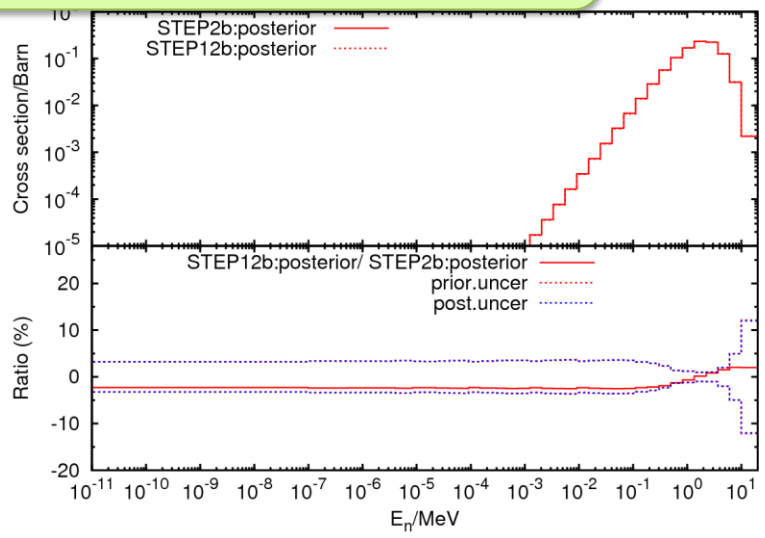
"Calibration" can have none neglectable impacts on the post-evaluation adjustment process, even if the evaluated covariance is not modified.





The enlarge of the difference in the IPs was caused by the different posteriors of nuclear data.





3.2 Summary of phase II

- **Case0 and 11 confirms**
  - Even if increasing the number of IPs used in “calibration”, change the PIA sequence will affect adjusted results significantly.
    - Zero posterior uncertainties were found again.
- **Case 11 and 12 show “calibration” with and without double coutning**
  - Reusing the same integral parameters will cause underestimating posterior uncertainties of both integral parameters and nuclear data.
- **Case 0 and 13 show the “calibration” without change evaluated covariance**
  - can have none neglectable impact on post-evaluation adjustment process.

4. Conclusions

- **About calibration**
  - Carry calibrated covariances with evaluation files will cause underestimation of the posterior covariances of nuclear data in adjustment.
  - Even if the evaluated covariance is not modified , none neglectable impact on post-evaluation adjustment process may still occur.
    - The effect is depending on what was used in the calibration process.
- **About PIA method**
  - Since losing correlation information will cause underestimation uncertainties of both integral and differential, correlated data have to be used in one step.

Thank you for your attention !