



Application of Marginal Likelihood Optimization to Haicheng's Stress Test

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Haicheng's Stress Test

- In SG33 benchmark exercise, adjusted results for ZPR6-7 F49/F25, ZPPR9 F28/F25 and F49/F25 reaction ratios are getting worse (decreased) due to missing essential constraints on ^{235}U (n,f) in the energy region between 1 to 10keV.
- A stress test on ^{235}U (n,f) to identify compensation errors was suggested with critical benchmarks sensitive to ^{235}U (n,f) between 1 to 10keV.
 - HEU-COMP-INTER-004-001 (HCI-004) k_{eff} (infinity HEU moderated with graphite)
 - HEU-MET-INTER-006-002 (HMI-006) k_{eff} (intermediate-spectrum critical assembly with a graphite-HEU core surrounded by a copper reflector)
- Lead to different, even contrary adjustments for both integral and differential data

Marginalized Likelihood Optimization (MLO)

- **Idea:** Account for biases or underestimated uncertainties with an extra uncertainty term, $\mathbf{M}_{\text{extra}}$
- Minimize the negative of the log-likelihood to estimate $\mathbf{M}_{\text{extra}}$

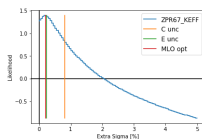
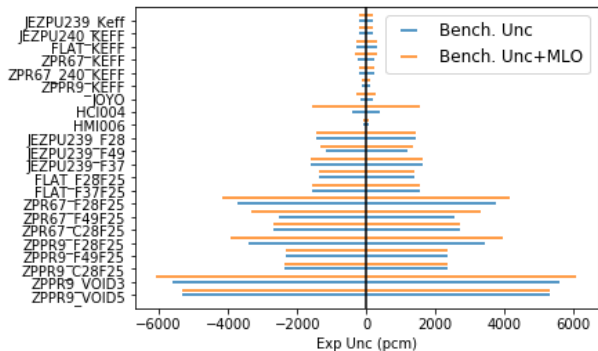
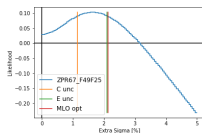
$$\chi^2 = (\mathbf{E} - \mathbf{C})^T (\mathbf{M}_{\mathbf{E}} + \mathbf{M}_{\mathbf{C}} + \mathbf{M}_{\text{extra}})^{-1} (\mathbf{E} - \mathbf{C}) \quad (1)$$

$$L = \frac{e^{-\chi^2/2}}{\sqrt{(2\pi)^N \det(\mathbf{M}_{\mathbf{E}} + \mathbf{M}_{\mathbf{C}} + \mathbf{M}_{\text{extra}})}} \quad (2)$$

$$\min \left[\frac{1}{2} (N * \log(2\pi) + \log(\det(\mathbf{M}_{\mathbf{E}} + \mathbf{M}_{\mathbf{C}} + \mathbf{M}_{\text{extra}})) + \chi^2) \right] \quad (3)$$

- Objective of the present study is to analyze the effect of MLO on Haicheng's stress test

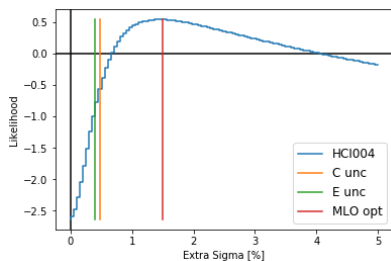
Extra Uncertainty produced by MLO

ZPR6-7, k_{eff} 

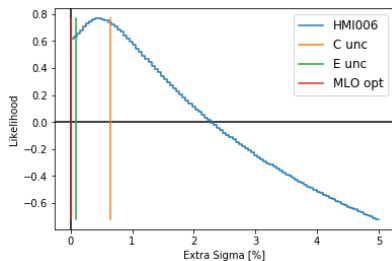
ZPR6-7, F49/F25

- M_{extra} is small for SG33 benchmarks
- No surprise as they have been chosen to be consistent

Zoom on the extra benchmarks



HCI-004

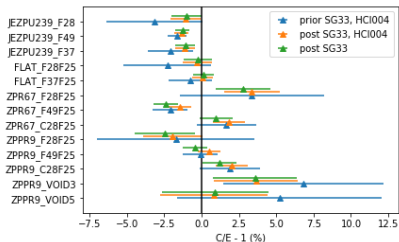


HMI-006

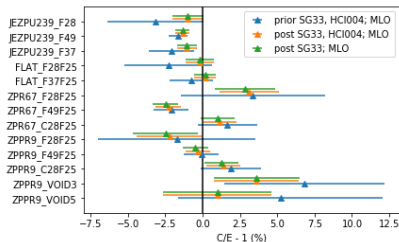
- MLO produces large extra uncertainty for HCI-004
- Most likely due to inconsistencies between C & E

	C/E	σ_E	σ_C
HCI-004	1.015	0.4%	0.5%
HMI-006	0.998	0.1%	0.6%

C/E adjustments



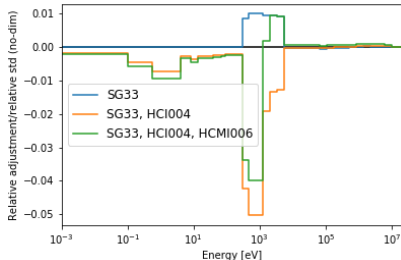
w/o MLO



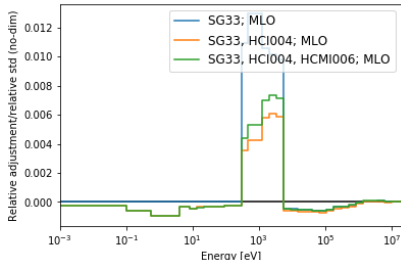
w/ MLO

- Without MLO, adding HMI-004 constraint leads to different direction for the posterior with respect to prior
 - ZPR6/7 F49/F25 and C28/F25
 - ZPPR9 F49/F25 and C28/F25
- With MLO, all adjustments are going in one direction! Even though not always towards C/E=1

^{235}U (n,f) adjustments

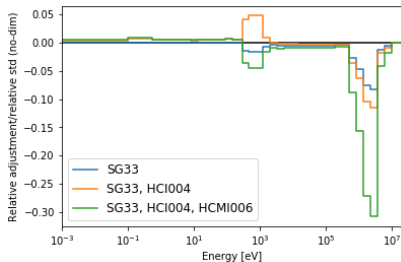


w/o MLO

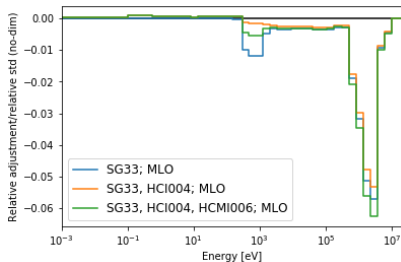


w/ MLO

- All adjustments go in the same direction with MLO although their magnitude changes as constraints are added.
- Without MLO, adjustment does not recover from HCI-004. . . .

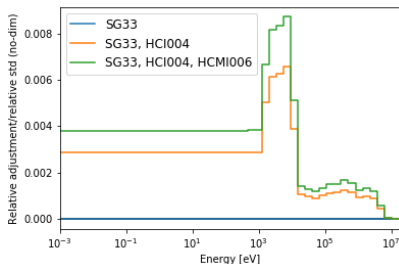
^{235}U (n,c) adjustments

w/o MLO

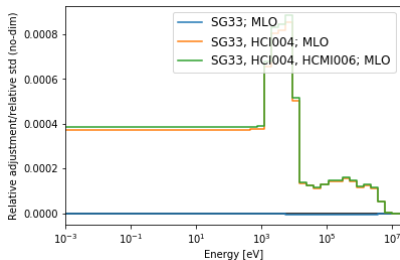


w/ MLO

- All adjustments go in the same direction with MLO although their magnitude changes as constraints are added.

^{10}B (n,c) adjustments

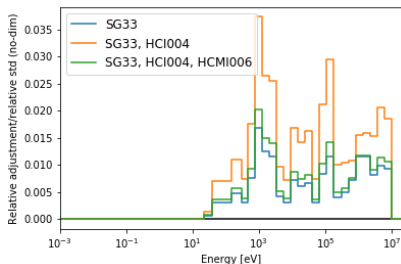
w/o MLO



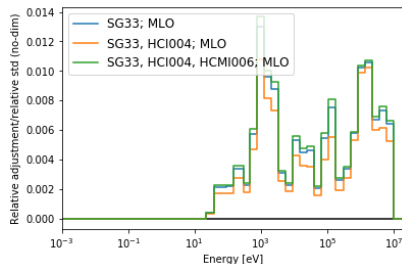
w/ MLO

- All adjustments go in the same direction with MLO
- magnitude of adjustment is reduced.

^{23}Na (n,el) adjustments



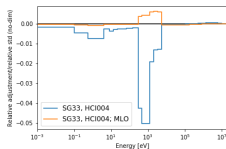
w/o MLO



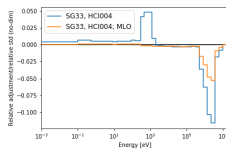
w/ MLO

- All adjustments go in the same direction with MLO
- magnitude of adjustment is reduced.

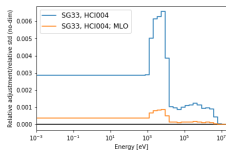
MLO effect on adjustment magnitude



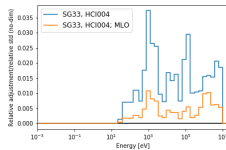
^{235}U (n,f)



^{235}U (n,c)



^{10}B (n,c)



^{23}Na (n,el)

- Magnitude of adjustments is damped with MLO

Conclusions

- Outcomes of stress test (H. Wu presentation SG39 / Nov. 2015)
 - Different constraints can lead to different, even contrary adjustments for both integral and differential data.
 - To avoid compensation error and make adjusted nuclear data for general purpose, we need complete constraints.
- MLO helps resolving those issues
 - Contrary adjustments are avoided
 - Reduce the weight of discrepant benchmarks on adjustments
- Future work
 - Consider a larger experimental data set (towards complete constraints)
 - Maximizing the likelihood function becomes difficult