Correlations between LCT Integral Experiments and Their Impact on Adjustments

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SG39
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Overview

The main point is to attempt to estimate correlations between existing ICSBEP experiments and show what the impact of these estimated correlations would be on nuclear data adjustments.

Not a toy exercise; meant to be best estimate of real data

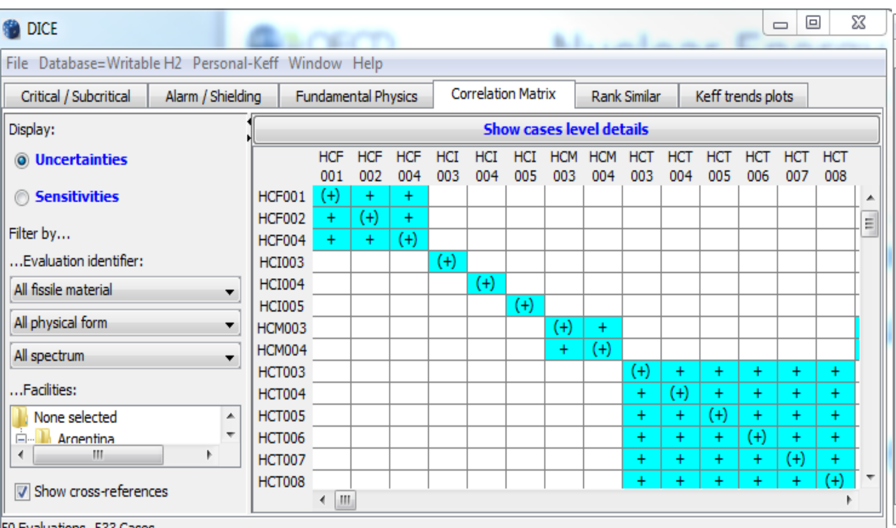
- Status of Existing Correlations
- Tools to Generate Correlations
- New Correlation Data, tests? [focus of this presentation]
- Impact of Integral Correlation Data on Adjustment [focus of this presentation]

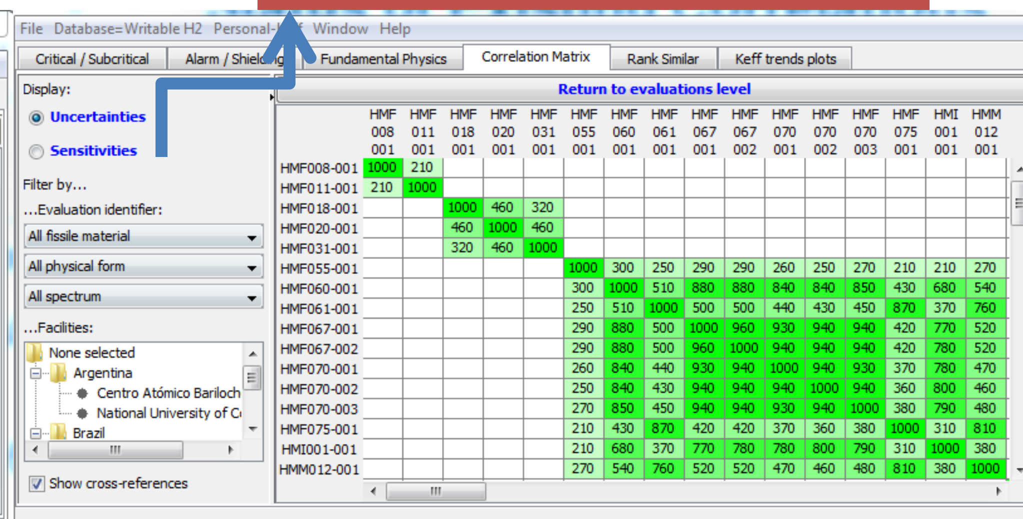
Status of Existing Correlations (DICE Uncertainties button)

- Correspond to the correlations of benchmark model uncertainties
  - Level 1 correlations show that evaluations are correlated
  - Level 2 correlations give the quantitative information about the correlations between cases
  - Currently 94 cases have correlation data [level2] in DICE

(or ~2%). Level 2 required for analysis.

Also Compute Cosine Similarity of Sensitivity Vectors!





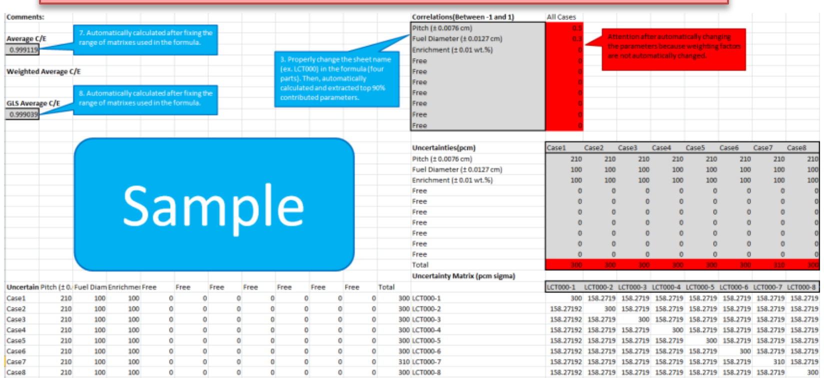
NEA: Tools to Simplify Covariance Generation

Current Situation

	LCT021-1	LCT021-2	LCT021-3	LCT021-4	LCT021-5	LCT021-6
LCT021-1	720	0	0	0	0	0
LCT021-2	0	720	0	0	0	0
LCT021-3	0	0	720	0	0	0
LCT021-4	0	0	0	500	0	0
LCT021-5	0	0	0	0	500	0
LCT021-6	0	0	0	0	0	500

Shared uncertainty in benchmark models ☹

Made Spreadsheet Tool



Used Tool to Generate Correlations for ~600 LCT Cases

Generate Correlation Matrix

Uncertainties(pcm)	Case1	Case2	Case3	Case4	Case5	Case6
Clad Thickness	400	400	400	72	72	72
Boron Concentration	384	384	384	130	130	130
Enrichment	338	338	338	363	363	363
Experimental Uncertalnty	300	300	300	300	300	300
Pitch	5	5	5	270	270	270

Sum shared components

$$\rho_{12} = \frac{\sum \sigma_1^X \rho \sigma_2^X}{\sigma_1^T \sigma_2^T}$$

	LCT021-1	LCT021-2	LCT021-3	LCT021-4	LCT021-5	LCT021-6
LCT021-1	1.000	0.784	0.784	0.408	0.408	0.408
LCT021-2	0.784	1.000	0.784	0.408	0.408	0.408
LCT021-3	0.784	0.784	1.000	0.408	0.408	0.408
LCT021-4	0.408	0.408	0.408	1.000	0.694	0.694
LCT021-5	0.408	0.408	0.408	0.694	1.000	0.694
LCT021-6	0.408	0.408	0.408	0.694	0.694	1.000

When rho is between 0 and 1?
Do we shamelessly make it up?

FYI: Similar Tools exists for Nuclear data

V.Zerkin, "Web Tool for Constructing a Covariance Matrix from EXFOR Uncertainties", EPJ Web of Conferences 27, 00009 (2012)

After Assignment: Impact of Integral Benchmark Correlations

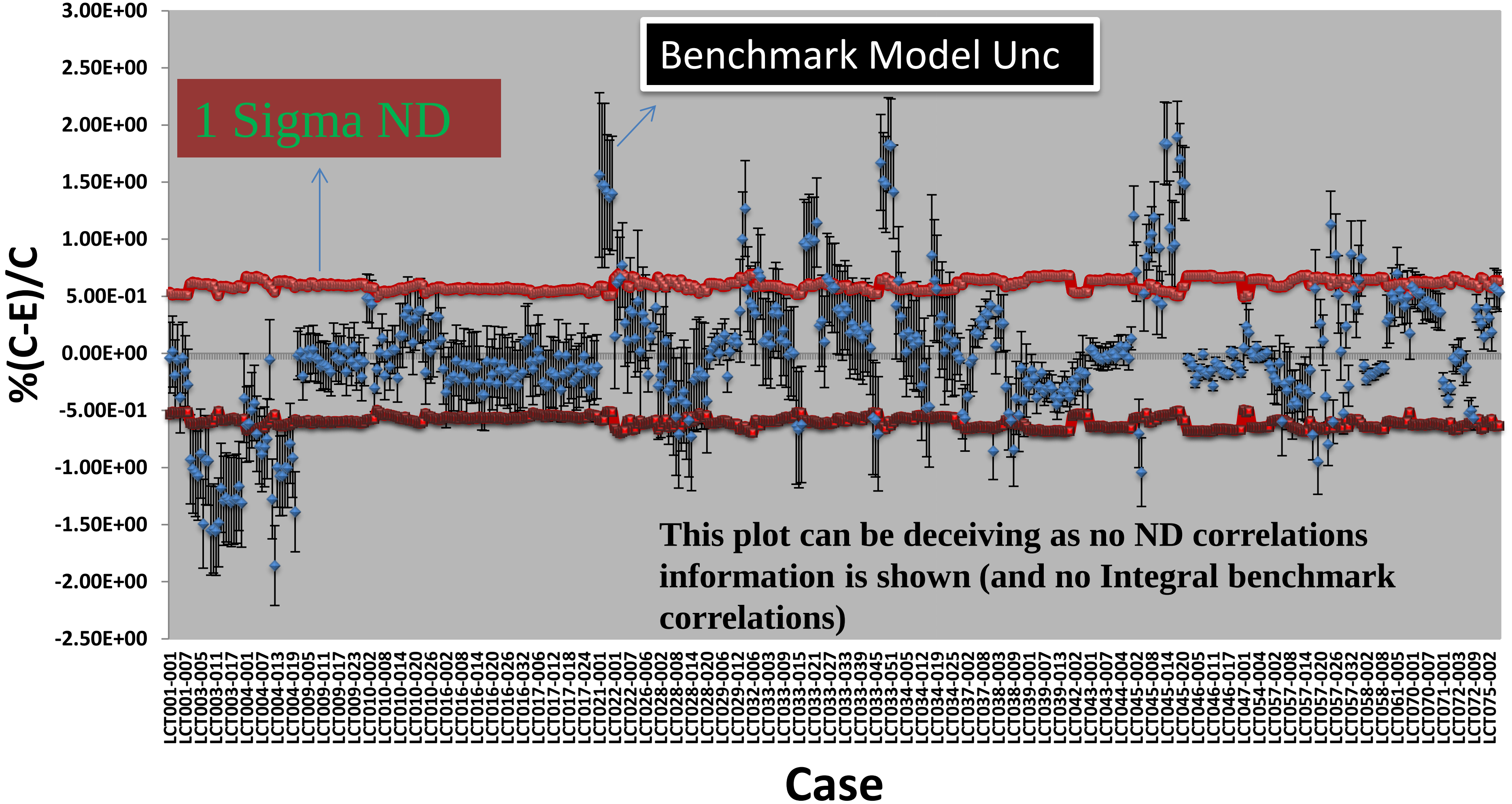
Some issues explored……

- How does the goodness of fit change?
- Limitations to chi squared + other tests
- How does the GLS fit change?
- Difficultly decoupling Nuclear data and Benchmark uncertainty
- What is the impact on data adjustment?
- Newly available data (4200 sensitivity coefficients)

All analysis will use SCALE, with ENDF/B-VII.0 CE, and 44 Group Covariance Library, no filtering applied

Intent was to explore the reasonability and impact of the previously assigned integral benchmark correlations………

LCT Data Set


Benchmark Model Unc
1 Sigma ND
This plot can be deceiving as no ND correlations information is shown (and no Integral benchmark correlations)
%(C-E)/C
Case
3.00E+00
2.50E+00
2.00E+00
1.50E+00
1.00E+00
5.00E-01
0.00E+00
-5.00E-01
-1.00E+00
-1.50E+00
-2.00E+00
-2.50E+00

Initial Chi Squared Within An Evaluation – No Integral Experiment Correlations

$$\chi^2 = \sum_i \sum_j d_i V_{i,j}^{-1} d_j$$

d=c-e

ND+Int.BM

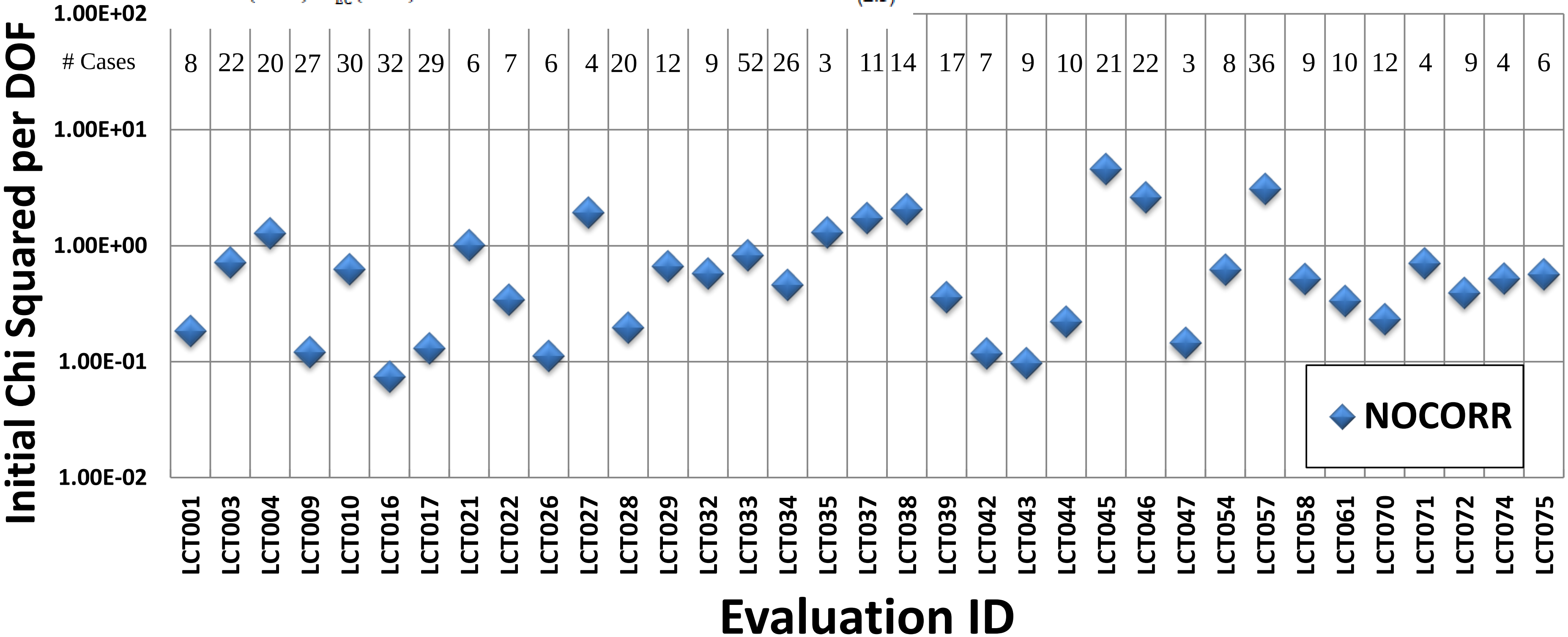
8 > chi/dof=1

26 < chi/dof=1

Total Uncertainty Over Estimated (Either ND, INT), Or the degree of correlation is mis-estimated (under?)

$$\chi^2_{\text{init}} = (\sigma - \tilde{\sigma})^T M_\sigma^{-1} (\sigma - \tilde{\sigma}) + (E - C(\tilde{\sigma}))^T M_{EC}^{-1} (E - C(\tilde{\sigma}))\Big|_{\tilde{\sigma}=\sigma} = (E - C)^T M_{EC}^{-1} (E - C). \quad (2.9)$$

χ^2 total = 2.4



Chi Squared Within An Evaluation – No Integral Experiment Correlations

$$\chi^2 = \sum_i \sum_j d_i V_{i,j}^{-1} d_j$$

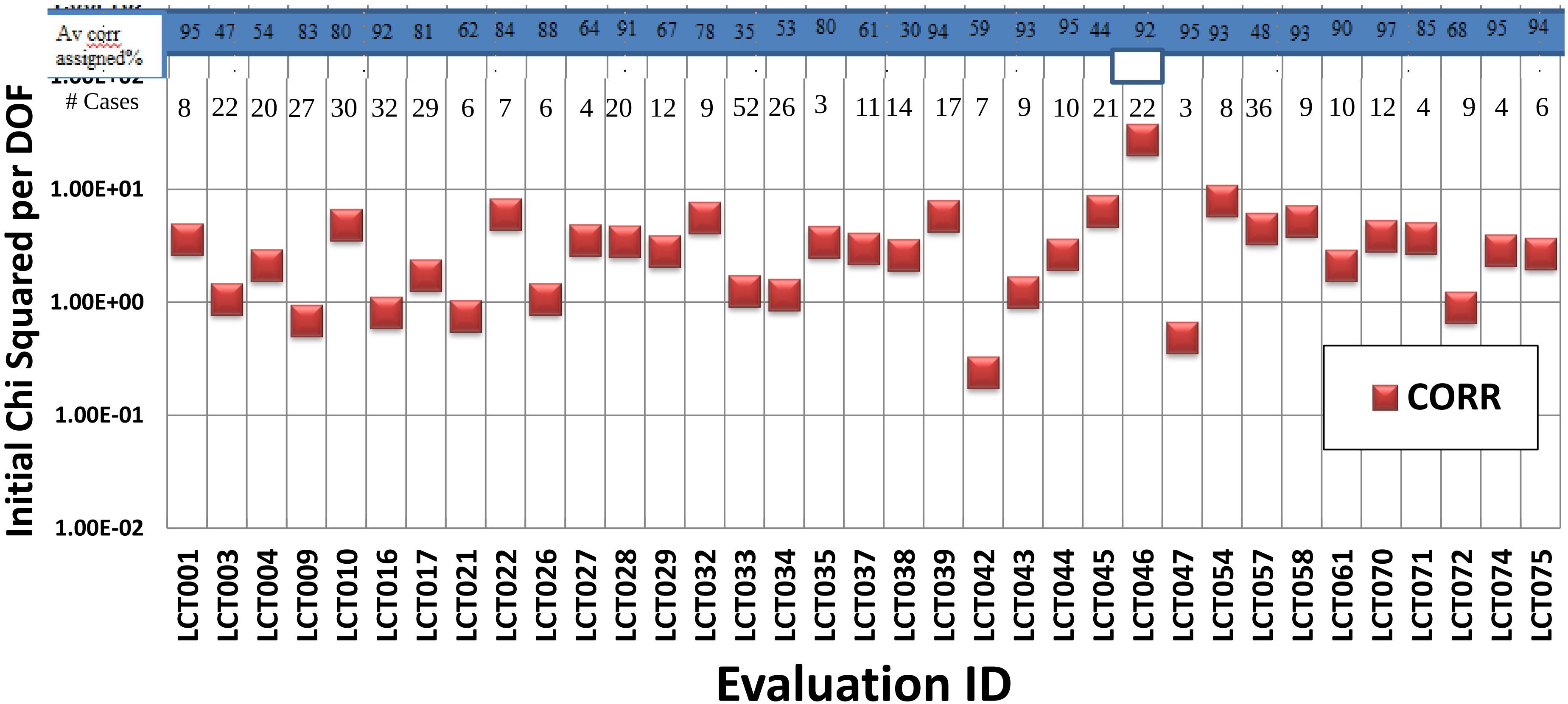
d=c-e

ND+Int.BM

Total Uncertainty Under Estimated (Either ND, INT or mis-estimated Covariance (over?))

28 > chi/dof=1 total = 4.7
6 < chi/dof=1

Since this isn't a real adjustment exercise next step of chi squared filtering wasn't done



Components of Chi squared

$$\chi^2 = \sum_i \sum_j d_i V_{i,j}^{-1} d_j$$

Contributing terms are:

1) Shared Errors in Nuclear Data
2) Unshared Errors in Nuclear Data
3) Shared Uncertainties in Benchmark Model
4) Unshared Errors In Benchmark Model

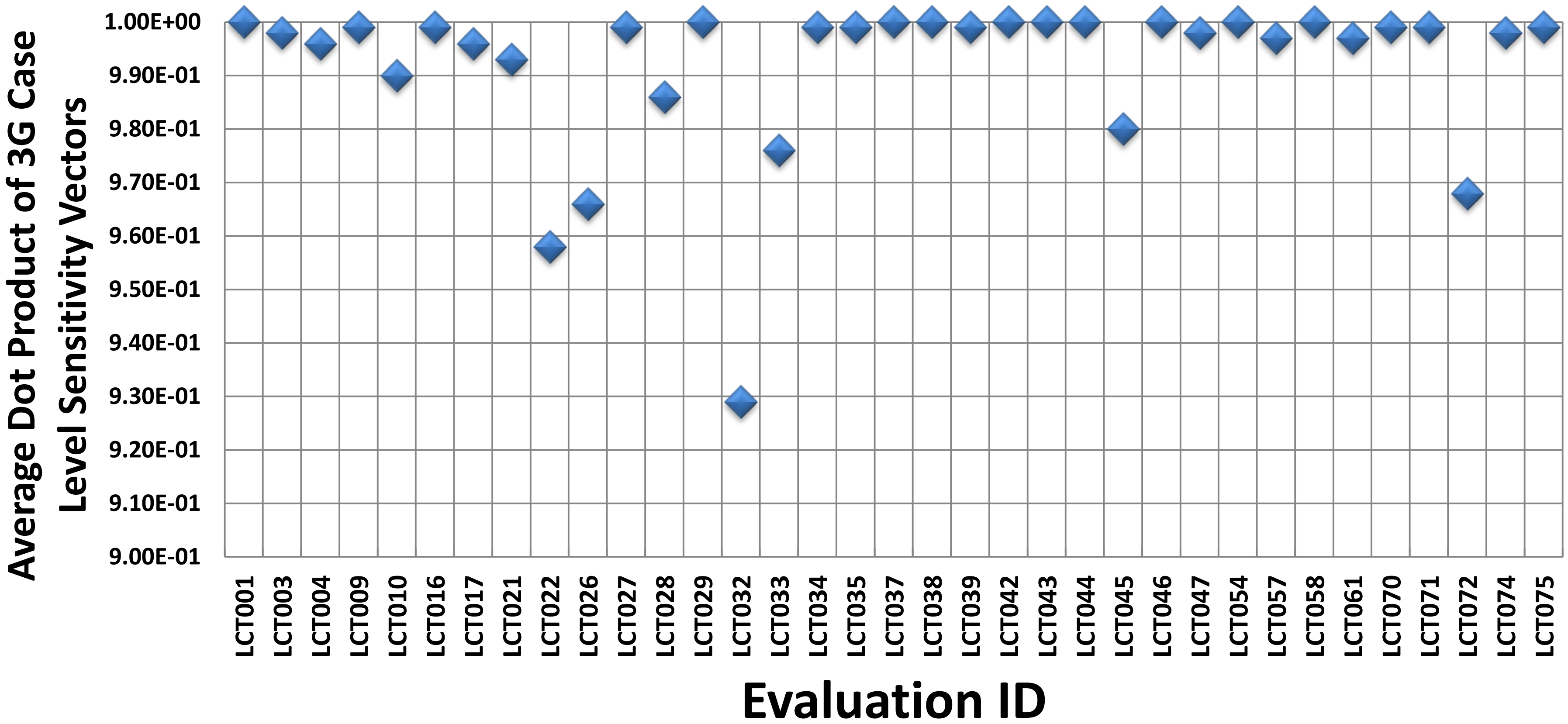
$$\chi^2_{\mathrm{init}} = (\sigma - \tilde{\sigma})^T M_{\sigma}^{-1}(\sigma - \tilde{\sigma}) + \left(E - C(\tilde{\sigma})\right)^T M_{EC}^{-1}\left(E - C(\tilde{\sigma})\right)\Big|_{\tilde{\sigma}=\sigma}$$
$$= (E - C)^T M_{EC}^{-1}(E - C).$$

Contributing terms are:

1) Shared Errors in Nuclear Data **[Often Similar Between CASES AND EVALUATIONS].**
~~2) Unshared Errors in Nuclear Data [SMALL]~~
3) Shared Uncertainties in Experimental Benchmark Model [**Similar between CASES, but not between EVALUATIONS (exp series)**].
4) Unshared Errors In Experimental Benchmark Model **'[All cases].**

How Similar is the Response to ND?

Many of these have a very similar nuclear data response
The uncertainty from ND isn't so much different



And Some ck's (same as before but covariance weighted)

$$C_{kk} = S_k C_{\alpha,\alpha} S_k^{\dagger}$$

LCT001

	1	2	3	4	5	6	7	8
1	1.0000E+00	9.9690E-01	9.9780E-01	9.9860E-01	9.9760E-01	9.9770E-01	9.9810E-01	9.9620E-01
2	9.9690E-01	1.0000E+00	9.9990E-01	9.9960E-01	9.9990E-01	9.9990E-01	9.9970E-01	9.9990E-01
3	9.9780E-01	9.9990E-01	1.0000E+00	9.9990E-01	9.9990E-01	9.9990E-01	9.9990E-01	9.9970E-01
4	9.9860E-01	9.9960E-01	9.9990E-01	1.0000E+00	9.9980E-01	9.9980E-01	9.9980E-01	9.9930E-01
5	9.9760E-01	9.9990E-01	9.9990E-01	9.9980E-01	1.0000E+00	1.0000E+00	9.9990E-01	9.9980E-01
6	9.9770E-01	9.9990E-01	9.9990E-01	9.9980E-01	1.0000E+00	1.0000E+00	9.9990E-01	9.9980E-01
7	9.9810E-01	9.9970E-01	9.9990E-01	9.9980E-01	9.9990E-01	9.9990E-01	1.0000E+00	9.9960E-01
8	9.9620E-01	9.9990E-01	9.9970E-01	9.9930E-01	9.9980E-01	9.9980E-01	9.9960E-01	1.0000E+00

LCT022

	1	2	3	4	5	6	7
1	1.000	0.984	0.936	0.901	0.880	0.843	0.841
2	0.984	1.000	0.982	0.961	0.945	0.907	0.904
3	0.936	0.982	1.000	0.995	0.987	0.953	0.949
4	0.901	0.961	0.995	1.000	0.998	0.973	0.970
5	0.880	0.945	0.987	0.998	1.000	0.984	0.981
6	0.843	0.907	0.953	0.973	0.984	1.000	1.000
7	0.841	0.904	0.949	0.970	0.981	1.000	1.000

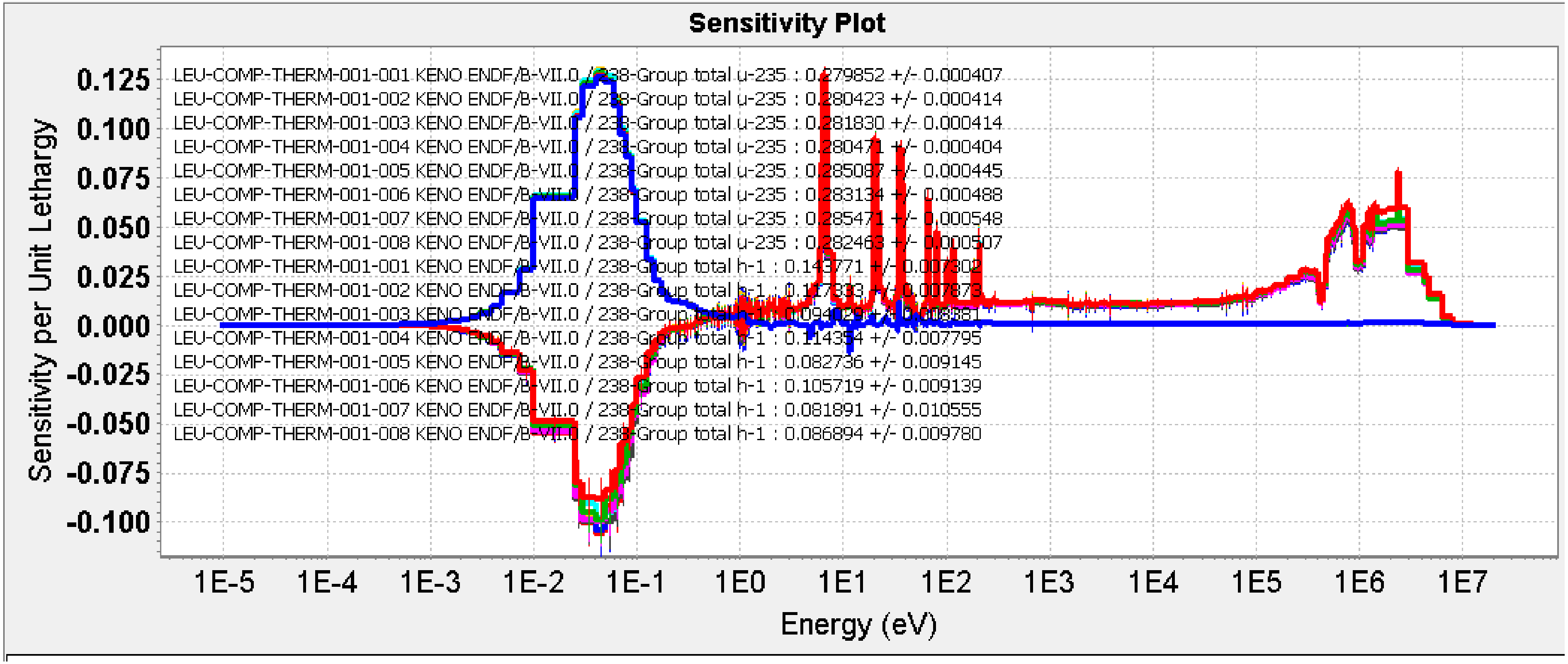
LCT054

	1	2	3	4	5	6	7	8
1	1.0000	1.0000	0.9999	0.9999	0.9999	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000
4	0.9999	1.0000	1.0000	1.0000	1.0000	0.9999	0.9999	0.9999
5	0.9999	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000
6	1.0000	1.0000	1.0000	0.9999	1.0000	1.0000	1.0000	1.0000
7	1.0000	1.0000	0.9999	0.9999	0.9999	1.0000	1.0000	1.0000
8	1.0000	1.0000	1.0000	0.9999	1.0000	1.0000	1.0000	1.0000

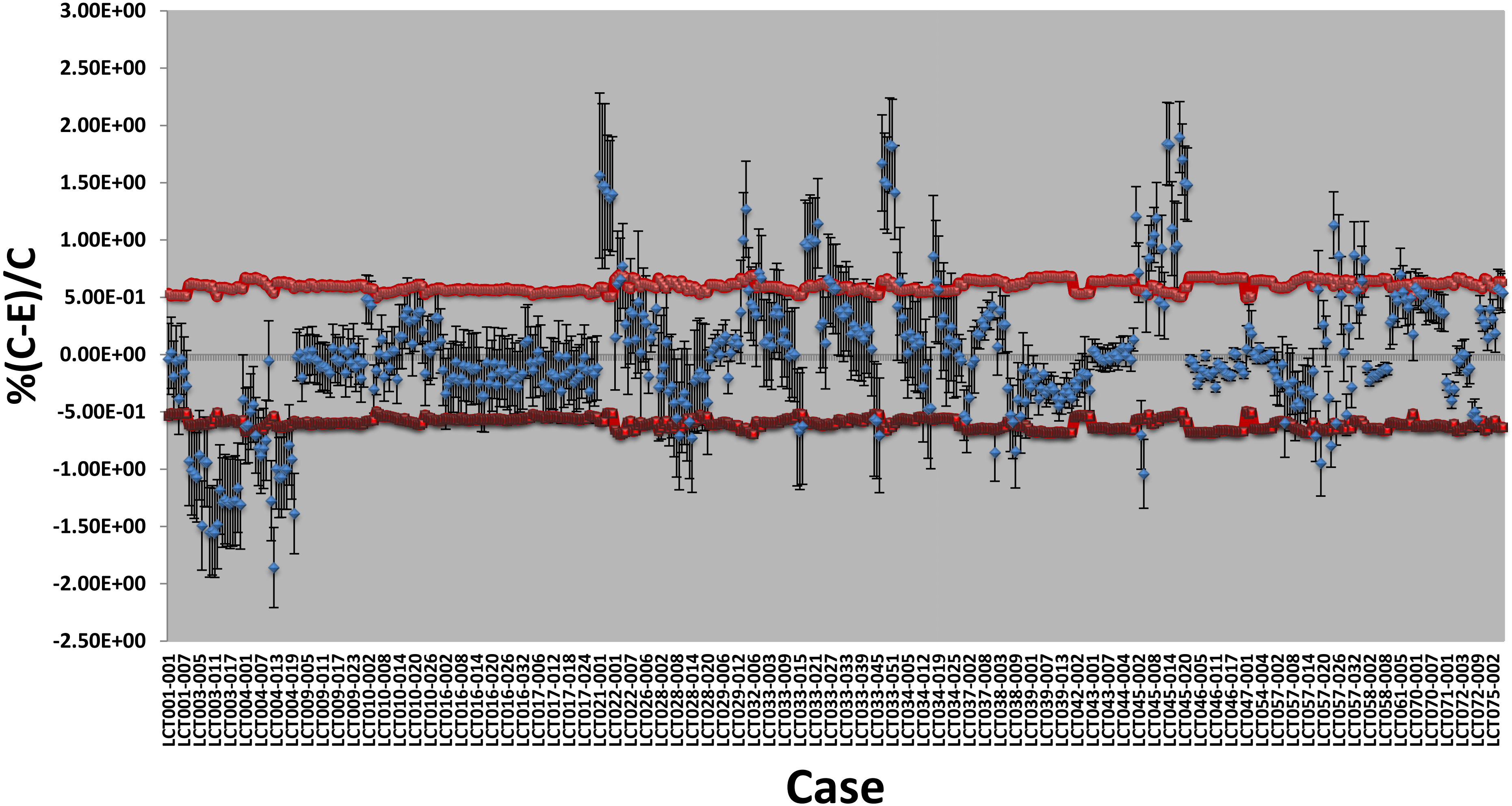
And Some Sensitivity Profiles: LCT001, 8 Cases

U235 Total, and H1 Total. You are looking a all 8 cases ☺

Moral is: the metrics aren't perfect…but cases have very similar uncertainty to nuclear data and response to changes in nuclear data.

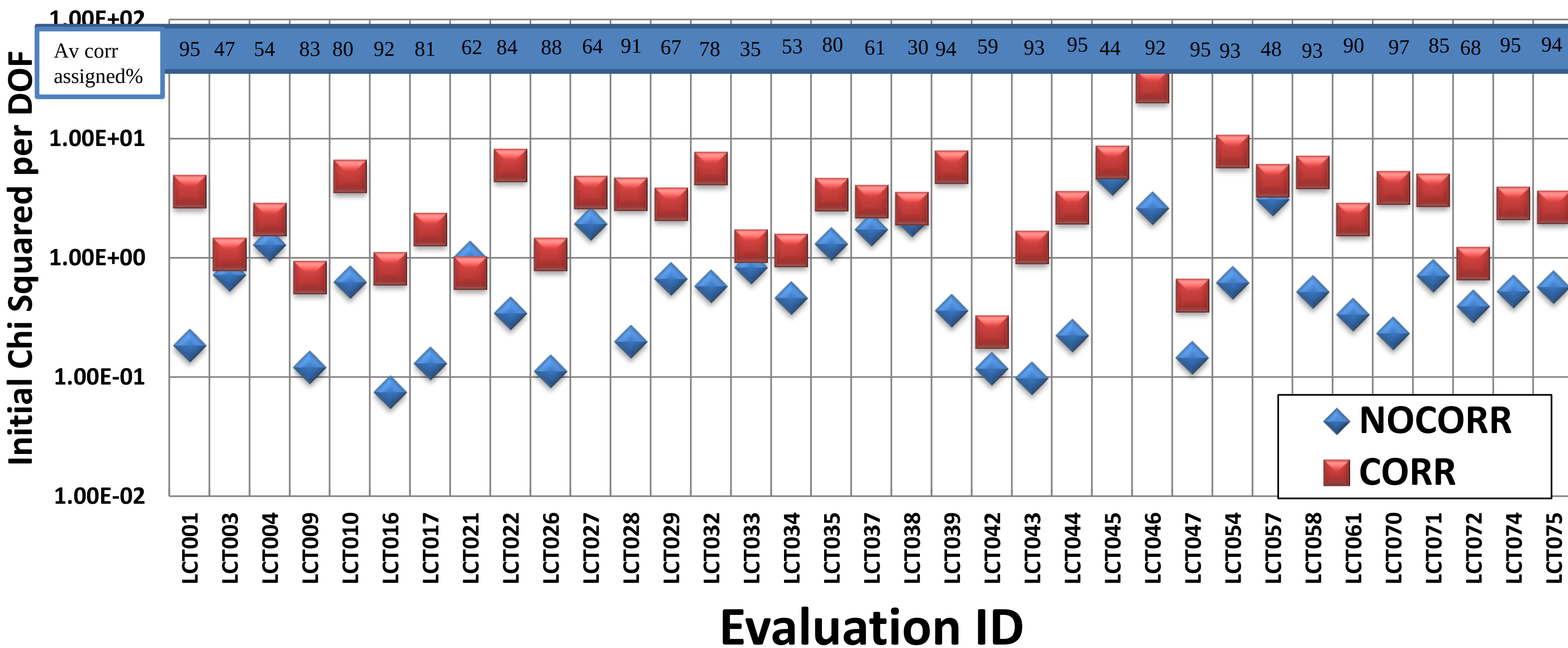


LCT Data Set


3.00E+00
2.50E+00
2.00E+00
1.50E+00
1.00E+00
5.00E-01
0.00E+00
-5.00E-01
-1.00E+00
-1.50E+00
-2.00E+00
-2.50E+00
%(C-E)/C
LCT001-001
LCT001-007
LCT003-005
LCT003-011
LCT003-017
LCT004-001
LCT004-007
LCT004-013
LCT004-019
LCT009-005
LCT009-011
LCT009-017
LCT009-023
LCT010-002
LCT010-008
LCT010-014
LCT010-020
LCT010-026
LCT016-002
LCT016-008
LCT016-014
LCT016-020
LCT016-026
LCT016-032
LCT017-006
LCT017-012
LCT017-018
LCT017-024
LCT021-001
LCT022-001
LCT022-007
LCT026-006
LCT028-002
LCT028-008
LCT028-014
LCT028-020
LCT029-006
LCT029-012
LCT032-006
LCT033-003
LCT033-009
LCT033-015
LCT033-021
LCT033-027
LCT033-033
LCT033-039
LCT033-045
LCT033-051
LCT034-005
LCT034-012
LCT034-019
LCT034-025
LCT037-002
LCT037-008
LCT038-003
LCT038-009
LCT039-001
LCT039-007
LCT039-013
LCT042-002
LCT043-001
LCT043-007
LCT044-004
LCT045-002
LCT045-008
LCT045-014
LCT045-020
LCT046-005
LCT046-011
LCT046-017
LCT047-001
LCT054-004
LCT057-002
LCT057-008
LCT057-014
LCT057-020
LCT057-026
LCT057-032
LCT058-002
LCT058-008
LCT061-005
LCT070-001
LCT070-007
LCT071-001
LCT072-003
LCT072-009
LCT075-002
Case

Properties: ND vs INT Correlations

- Some series are impacted by integral benchmark correlations, some aren't.
- At an assigned average correlation of 50% chi doesn't move, above 80% it moves a lot…..caution advised above 90%! [possible limits? Check MVB? PPP Limits?]
- Looking at chi squared, we can lose some appreciation of spread vs. bias
- **ND should be mostly bias.**



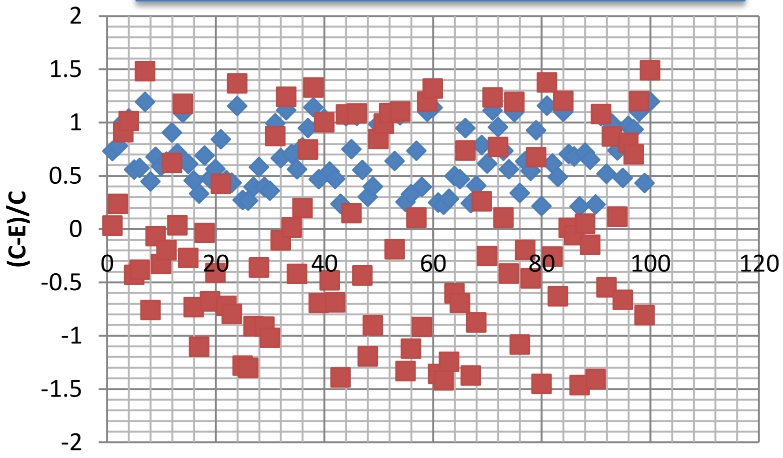
More Tests…..

Data below ~same chi squared…

$$\chi^2 = \sum_i \sum_j d_i V_{i,j}^{-1} d_j$$

d=(c-e)/c

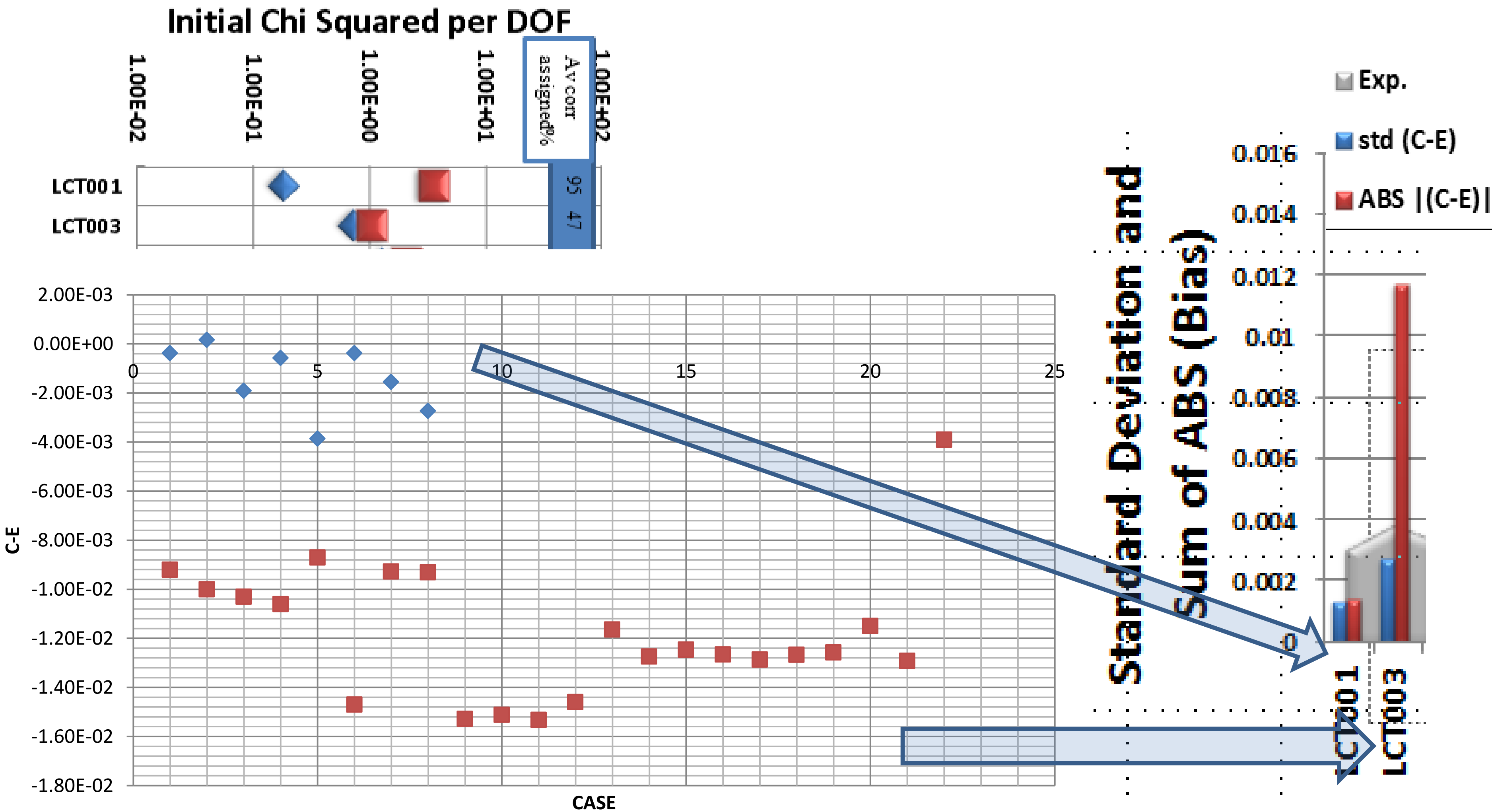
Con: Very sensitivity to bias
Pro: Good for identifying odd series



What is the spread of results compared to the anticipated spread? (Attempt to Check Random Component)

- Benchmark uncertainty is currently treated as uncorrelated
- Nuclear data uncertainty within a case is HIGHLY correlated
- Random spread of C-E/C results, would be close to the benchmark uncertainty if results are uncorrelated.

Mapping Data Sets…..

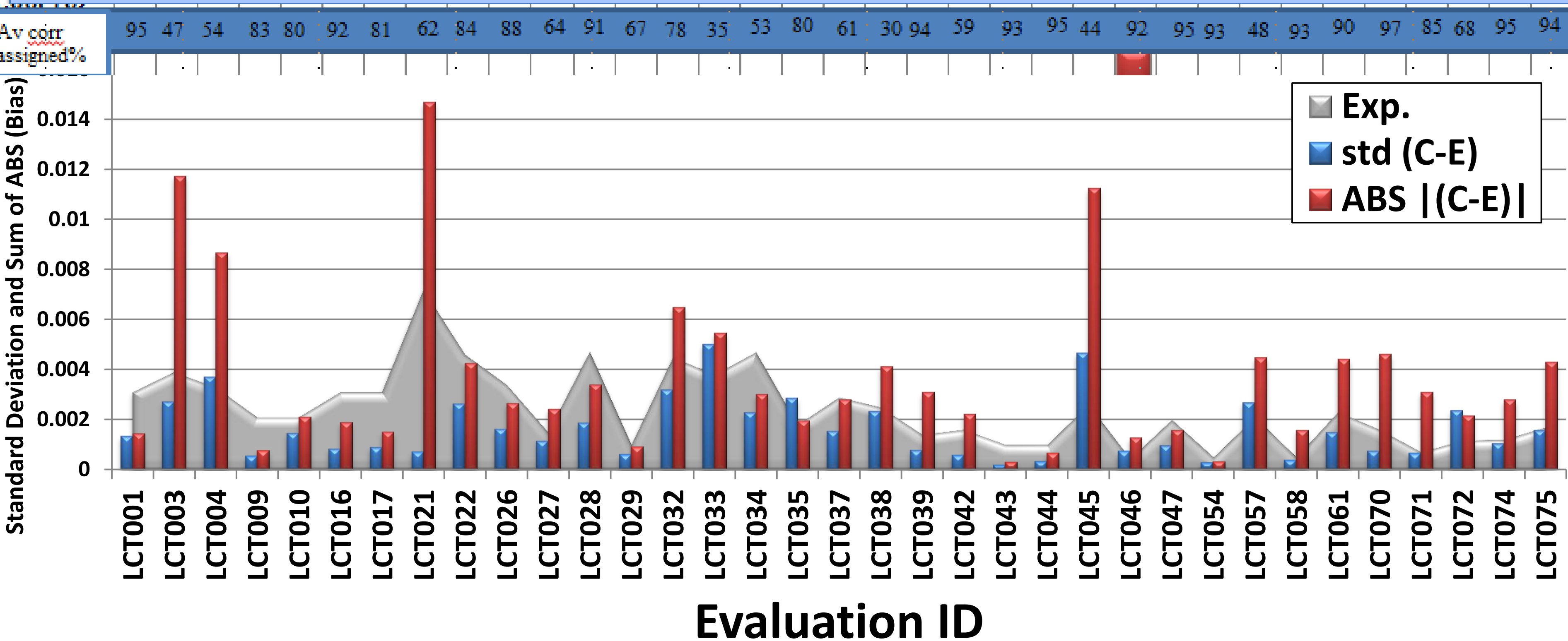


Standard Deviation of (C-E)/C Values Before GLS Fit

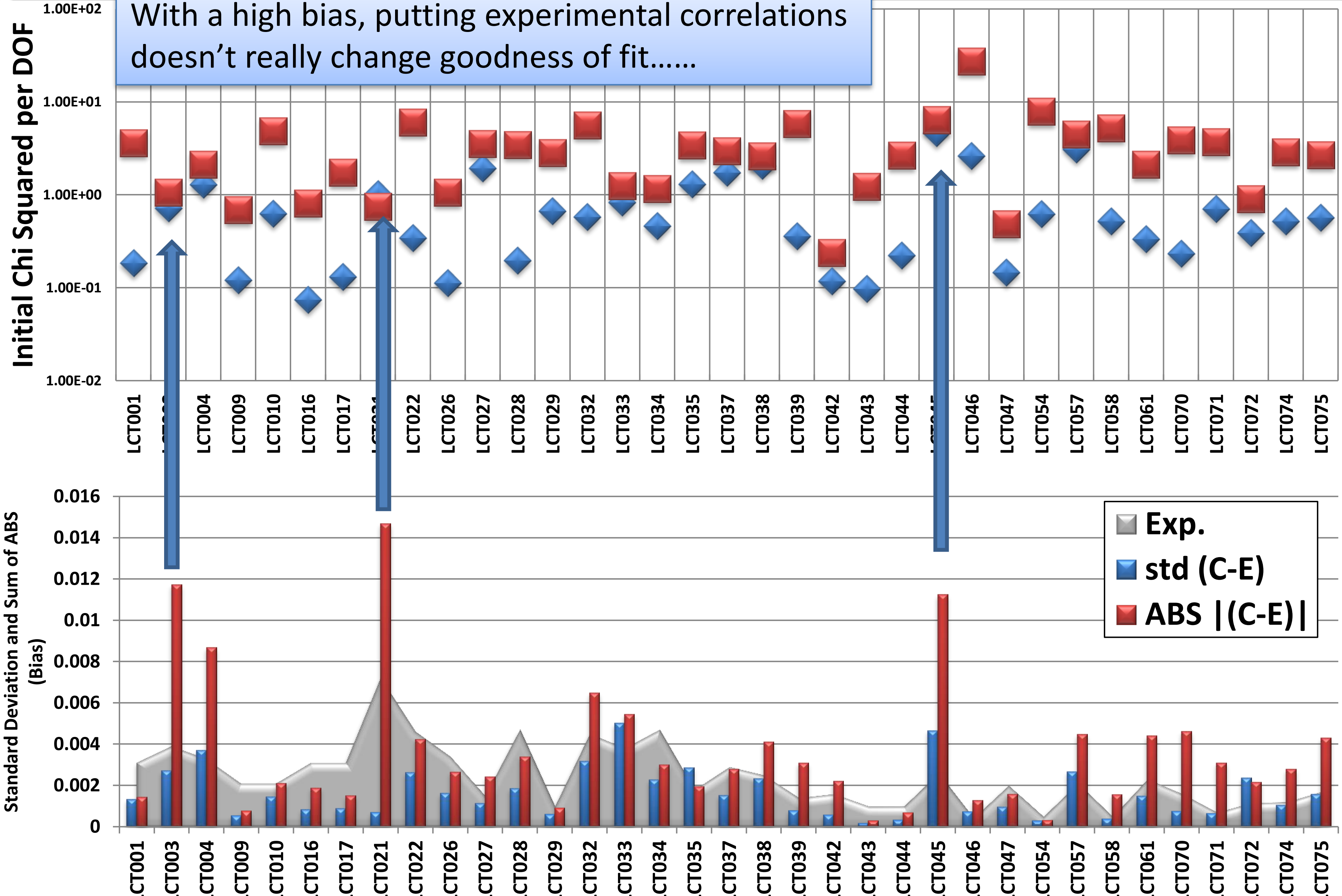
a) STD→Spread is less than Experimental Benchmark Uncertainty. Good!

b) Often, spread should mostly come from the random component of Integral Benchmark Uncertainty. Thankfully the quoted component (systematic+random) is less than the actual spread (random) mostly. **You would expect that where the spread is low vs EXP, there may be high Integral Correlations!**

c) The red bar is mostly bias and is ND+Integral. Since the total is fixed from the evaluation, later when I add correlations, I increase shared uncertainty/bias, and decrease expected std (blue).

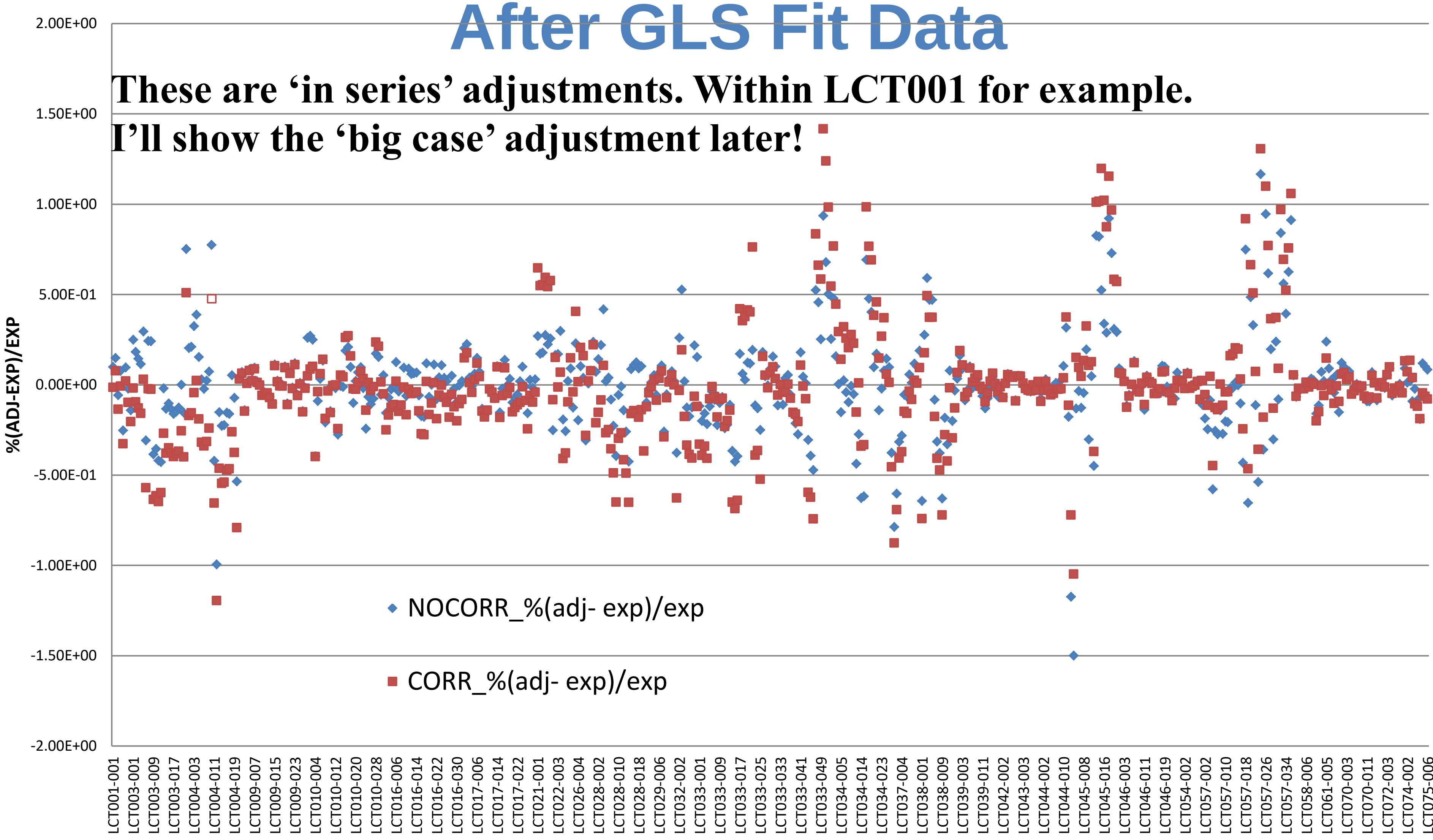


With a high bias, putting experimental correlations doesn't really change goodness of fit……



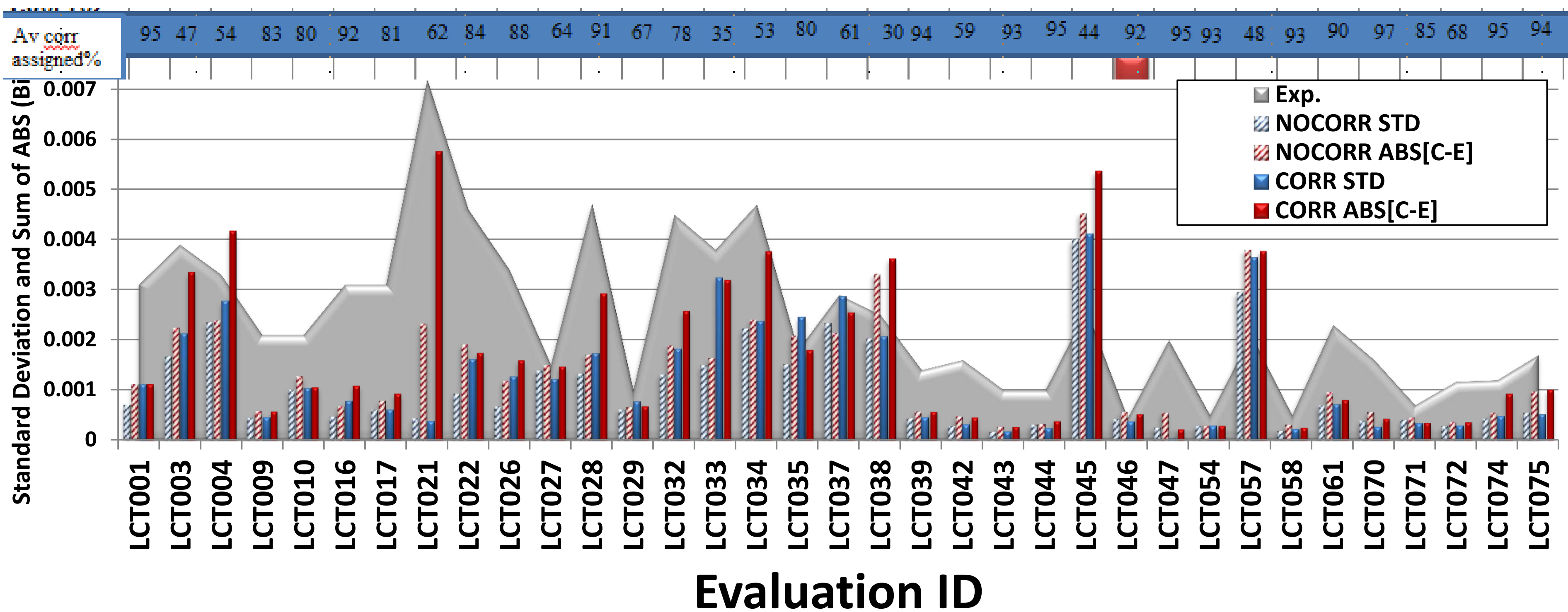
After GLS Fit Data

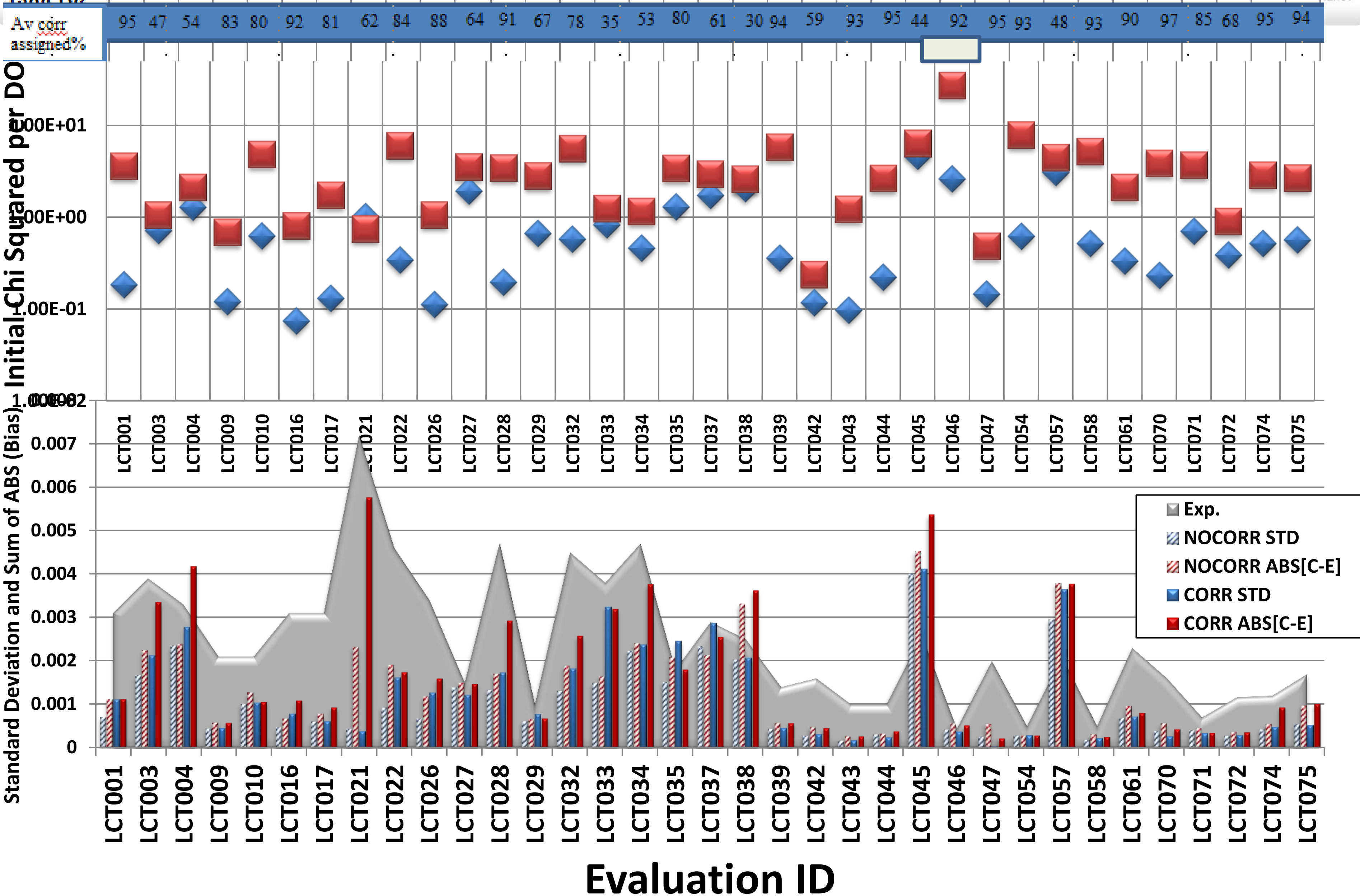
These are 'in series' adjustments. Within LCT001 for example.
I'll show the 'big case' adjustment later!



Standard Deviation of (C-E)/C Values after GLS Fit

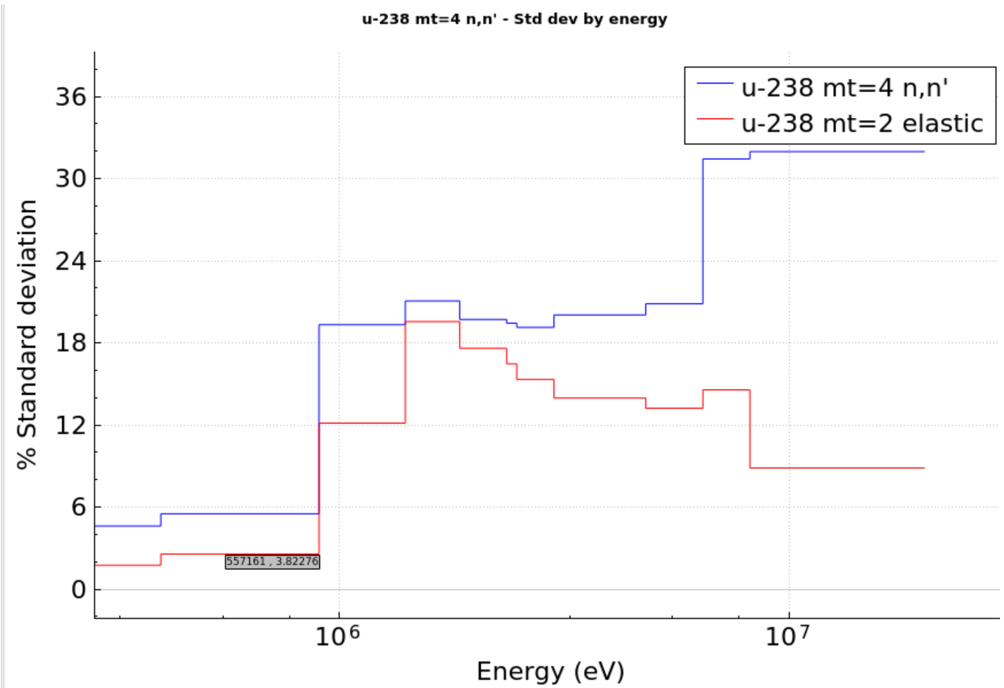
- Correlated have a higher spread
- Spread is less than the experimental benchmark uncertainty (uncorrelated spread)
- Nuclear data is highly correlated, often higher than 0.95, so most of the spread should be from experimental uncertainty
- Experimental uncertainty either too high or correlation is underestimated

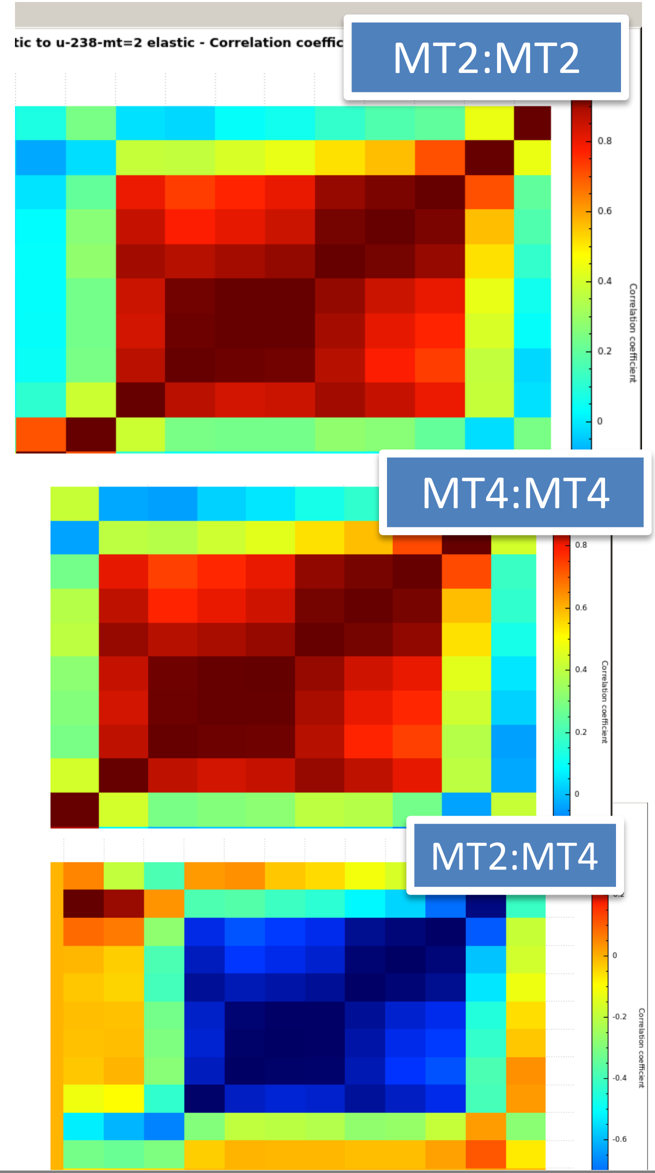



Av corr assigned%
95 47 54 83 80 92 81 62 84 88 64 91 67 78 35 53 80 61 30 94 59 93 95 44 92 95 93 48 93 90 97 85 68 95 94
Initial Chi Squared per DO
1.00E+01
1.00E+00
1.00E-01
LCT001 LCT003 LCT004 LCT009 LCT010 LCT016 LCT017 LCT021 LCT022 LCT026 LCT027 LCT028 LCT029 LCT032 LCT033 LCT034 LCT035 LCT037 LCT038 LCT039 LCT042 LCT043 LCT044 LCT045 LCT046 LCT047 LCT054 LCT057 LCT058 LCT061 LCT070 LCT071 LCT072 LCT074 LCT075
Standard Deviation and Sum of ABS (Bias)
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Exp.
NOCORR STD
NOCORR ABS[C-E]
CORR STD
CORR ABS[C-E]
LCT001 LCT003 LCT004 LCT009 LCT010 LCT016 LCT017 LCT021 LCT022 LCT026 LCT027 LCT028 LCT029 LCT032 LCT033 LCT034 LCT035 LCT037 LCT038 LCT039 LCT042 LCT043 LCT044 LCT045 LCT046 LCT047 LCT054 LCT057 LCT058 LCT061 LCT070 LCT071 LCT072 LCT074 LCT075
Evaluation ID

Impact on Adjustment

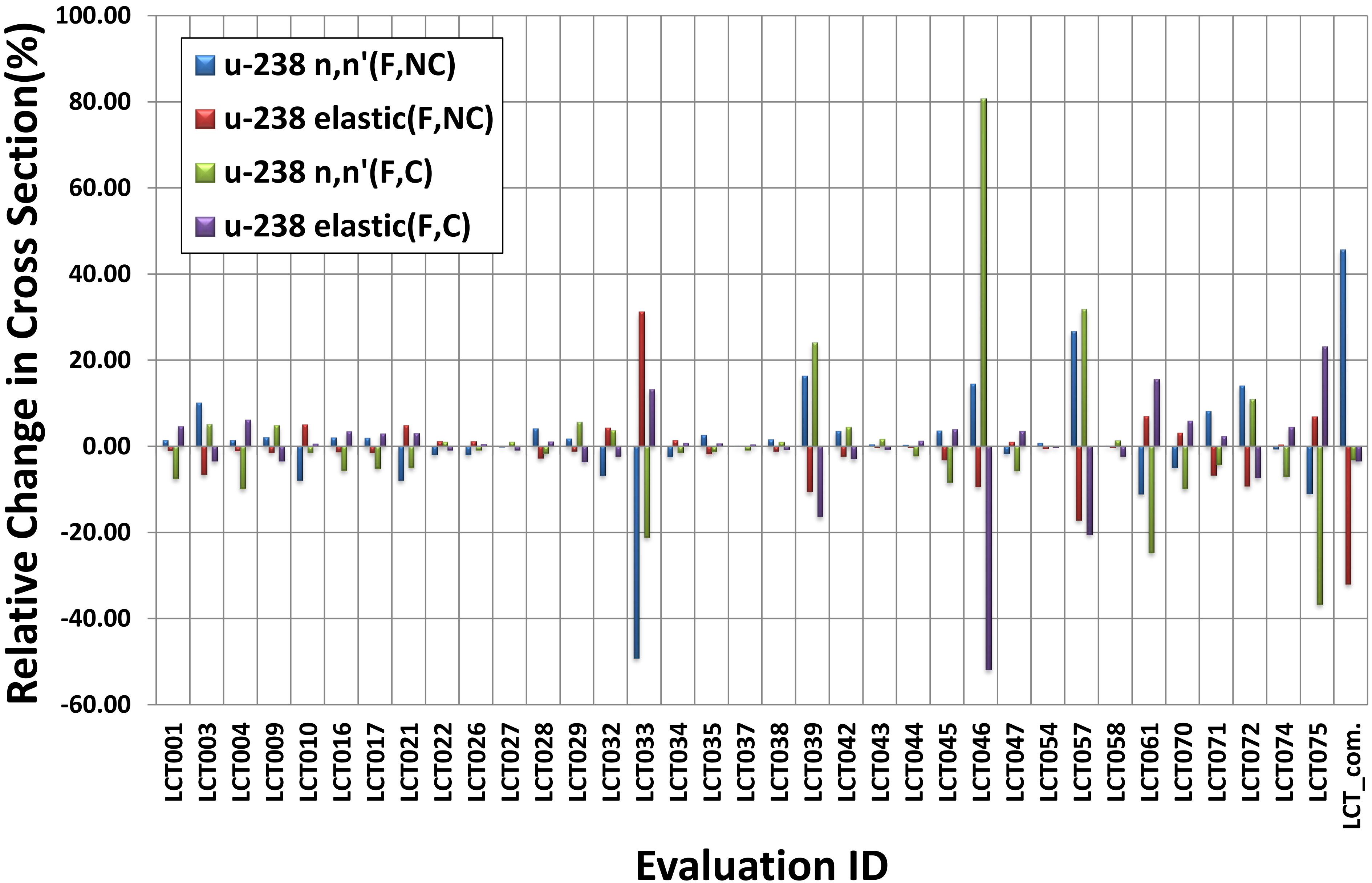
Many XS adjusted. Chose to look at U^{238} inelastic and elastic in the fast energy range



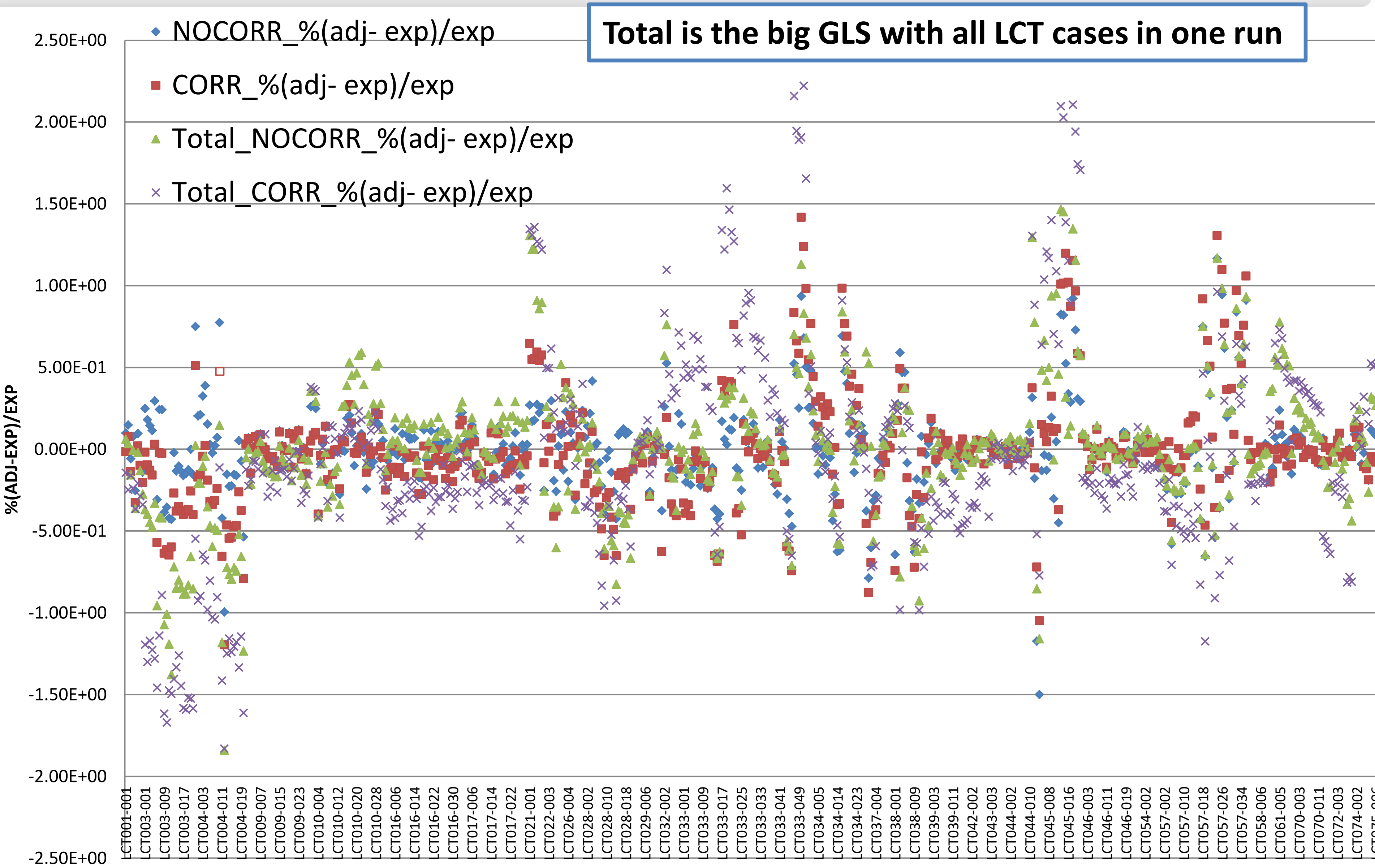


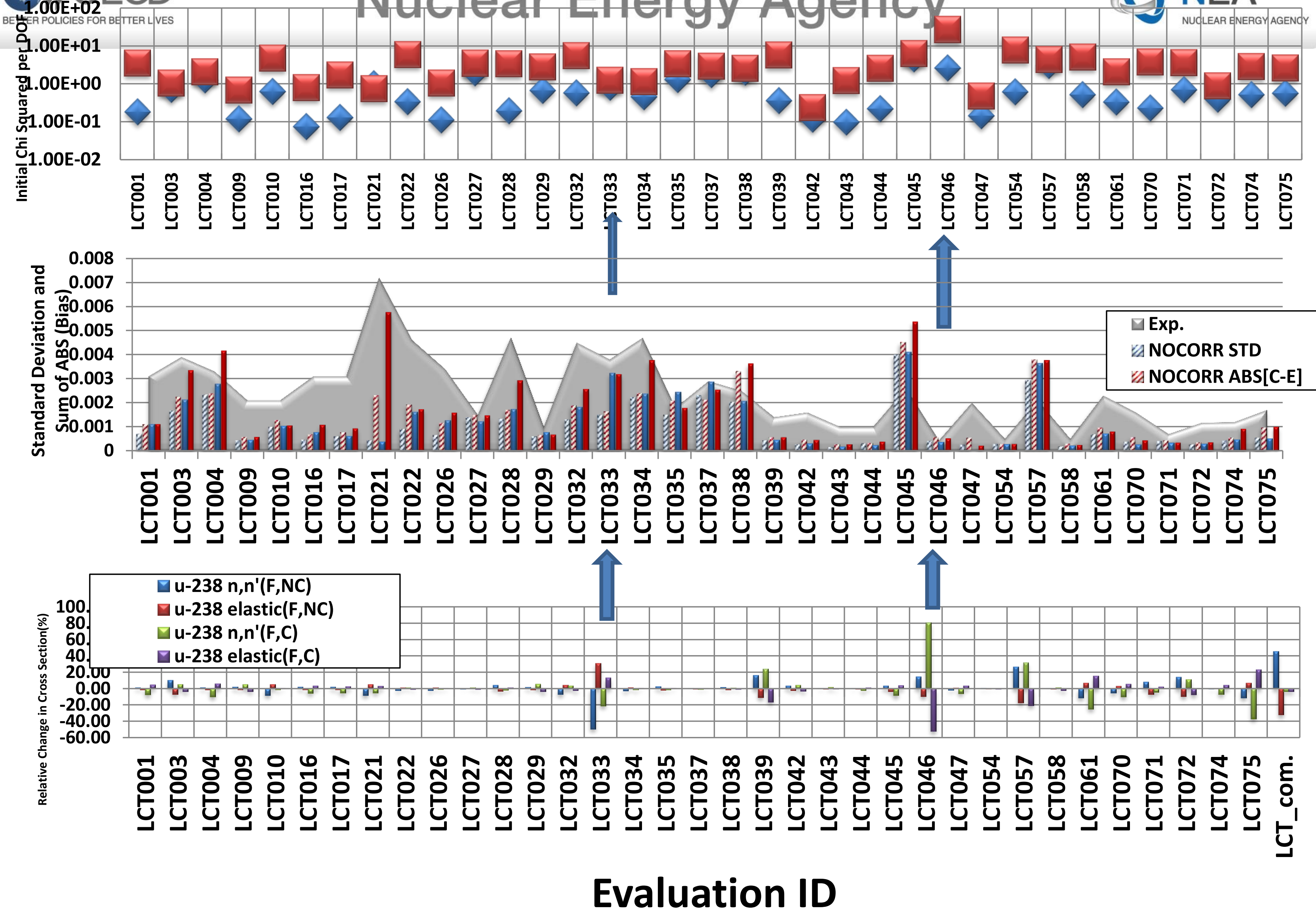
U238, Fast, Inelastic Sensitivity ~ 25 pcm/%XS

U238, Fast, elastic Sensitivity ~ 7 pcm/%XS


Relative Change in Cross Section(%)
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
-60.00
u-238 n,n'(F,NC)
u-238 elastic(F,NC)
u-238 n,n'(F,C)
u-238 elastic(F,C)
LCT001
LCT003
LCT004
LCT009
LCT010
LCT016
LCT017
LCT021
LCT022
LCT026
LCT027
LCT028
LCT029
LCT032
LCT033
LCT034
LCT035
LCT037
LCT038
LCT039
LCT042
LCT043
LCT044
LCT045
LCT046
LCT047
LCT054
LCT057
LCT058
LCT061
LCT070
LCT071
LCT072
LCT074
LCT075
LCT_com.
Evaluation ID

Total is the big GLS with all LCT cases in one run




Initial Chi Squared per DOF
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
LCT001 LCT003 LCT004 LCT009 LCT010 LCT016 LCT017 LCT021 LCT022 LCT026 LCT027 LCT028 LCT029 LCT032 LCT033 LCT034 LCT035 LCT037 LCT038 LCT039 LCT042 LCT043 LCT044 LCT045 LCT046 LCT047 LCT054 LCT057 LCT058 LCT061 LCT070 LCT071 LCT072 LCT074 LCT075
Standard Deviation and Sum of ABS (Bias)
0.008
0.007
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0.004
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0.002
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0
Exp.
NOCORR STD
NOCORR ABS[C-E]
LCT001 LCT003 LCT004 LCT009 LCT010 LCT016 LCT017 LCT021 LCT022 LCT026 LCT027 LCT028 LCT029 LCT032 LCT033 LCT034 LCT035 LCT037 LCT038 LCT039 LCT042 LCT043 LCT044 LCT045 LCT046 LCT047 LCT054 LCT057 LCT058 LCT061 LCT070 LCT071 LCT072 LCT074 LCT075
Relative Change in Cross Section(%)
u-238 n,n'(F,NC)
u-238 elastic(F,NC)
u-238 n,n'(F,C)
u-238 elastic(F,C)
100.
80.
60.
40.
20.00
0.00
-20.00
-40.00
-60.00
LCT001 LCT003 LCT004 LCT009 LCT010 LCT016 LCT017 LCT021 LCT022 LCT026 LCT027 LCT028 LCT029 LCT032 LCT033 LCT034 LCT035 LCT037 LCT038 LCT039 LCT042 LCT043 LCT044 LCT045 LCT046 LCT047 LCT054 LCT057 LCT058 LCT061 LCT070 LCT071 LCT072 LCT074 LCT075 LCT_com.
Evaluation ID

Summary

- Little correlation data available for integral experiments
- When doing integral testing, it's tough to judge the nuclear data covariance without integral covariance
- Generated integral benchmark correlations for LCT
- Took a look at their effect on various adjustment quantities
- Chi squared is good for finding outliers with odd systematic error….but its not great for checking constancy of random errors
- Deviations are good for random errors, nice to compare against integral benchmark correlation matrix
- Suggestions on checking benchmark correlations are appreciated!
- Adjustment is a statistical process….need lots of data
- Integral correlations have a strong impact on adjustments and it's a difficult task to generate them in aggregate
- Would be interesting to expand scale…….test PIA for series etc.