

Preliminary Feedback on Using CIELO Covariance Matrices

G. Palmiotti, M. Salvatores

Idaho National Laboratory, Idaho Falls, USA

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- We looked first at what is the performance (i. e. impact on measurement/calculations discrepancy) of ENDF/B-VII.0 and CIELO (presented at last meeting)
- The 5 CIELO isotopes (^{16}O , ^{56}Fe , ^{235}U , ^{238}U , and ^{239}Pu) and their covariance matrices have been replaced on the initial files. Corresponding C/E have been derived using a perturbation formula.
- Here we check the consistency of the discrepancies between the C and E comparing them against uncertainties using COMMARA 2.0 for ENDF/B-VII.0 and the modified COMMARA 2.0 with CIELO covariance.
- The analysis look at two main consistencies:
 - the consistency between the individual (C-E)/E of the two evaluated files and the associated uncertainties calculated with the two covariance matrices
 - the consistency between the differences (impact on the C/E) between the two evaluated files and the corresponding uncertainties.
- For this latter case also we look at the differences between the uncertainties obtained with the two covariance matrices of individual isotopes and, among others, at the impact of correlations.

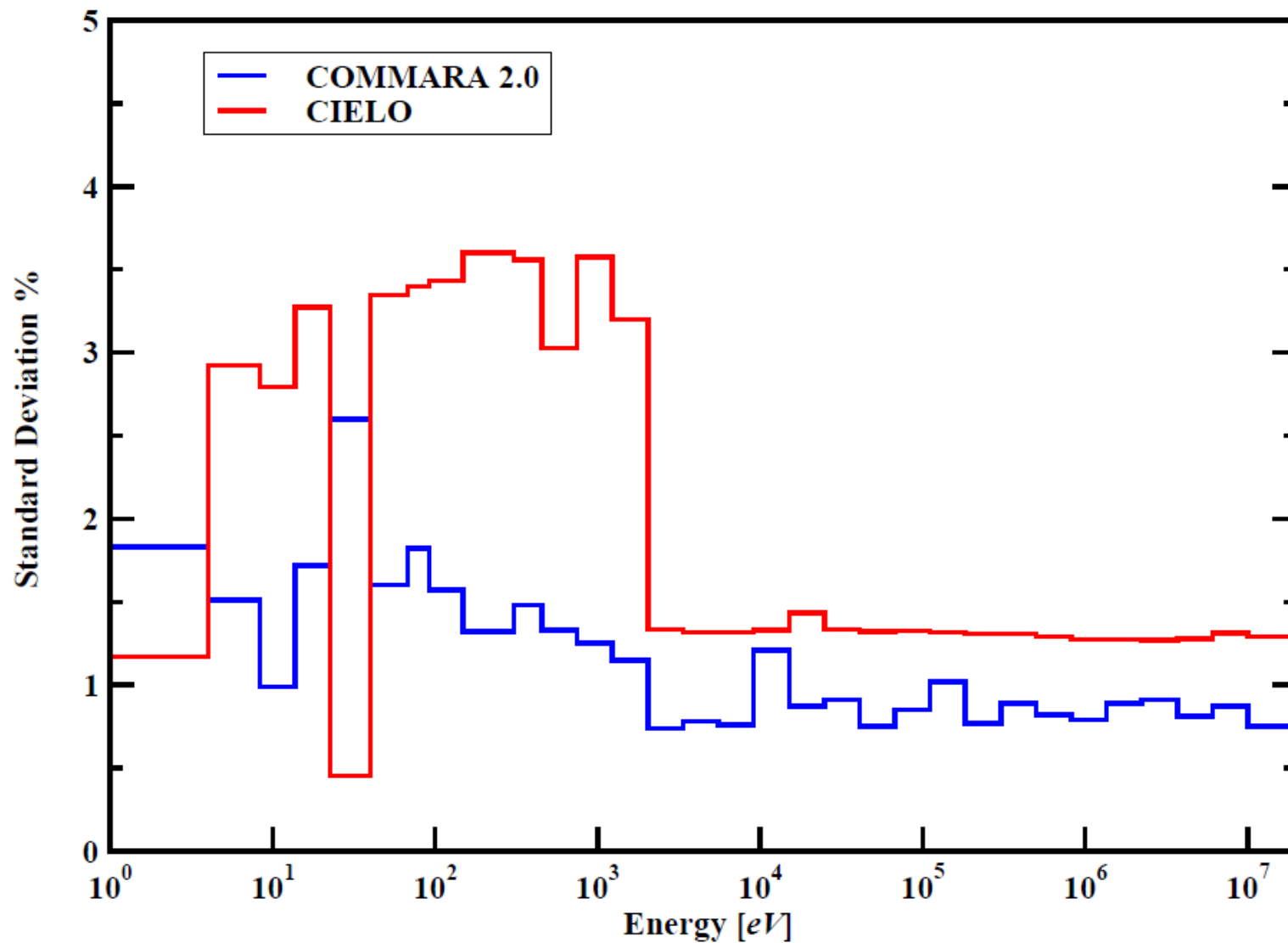
Background information

- **The linearity hypothesis was used and the calculated values related to the CIELO isotopes was derived by using sensitivity coefficients: $C' = C(1 + S \cdot \Delta\sigma/\sigma)$**
- **CIELO isotopes were downloaded from NNDC as ENDF/B-VIII.**
- **Reference C/E values were obtained using the corresponding isotopes of ENDF/B-VII.0. This file was the one used for calculating with the most accurate tool (i. e. Monte Carlo) the reference C.**
- **Both set of files were processed in exactly the same way generating infinite dilution cross sections using the latest version (34) of NJOY2016.**
- **At the same time covariance matrices were generated for MF31, Mf33, MF34, and MF35 for the CIELO isotopes**

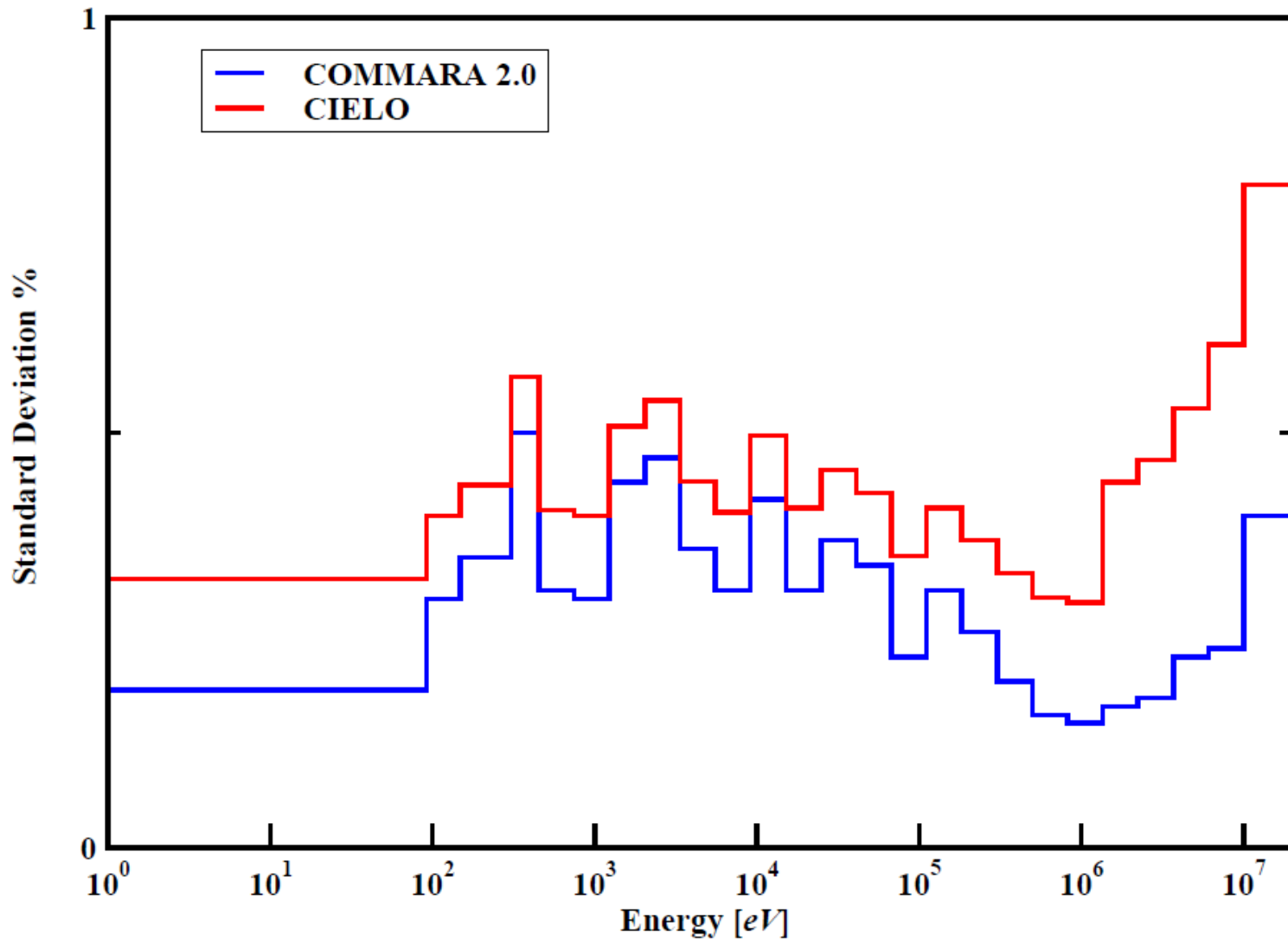
Feedback on CIELO Covariance Matrices Values

- **Missing covariance data for:**
 - **P_1 of ^{56}Fe , ^{235}U , ^{238}U (Used corresponding JENDL-4 data)**
 - **Cross correlations for ^{56}Fe reactions that were present in COMMARA 2.0**
- **Unacceptable values (correlation >1) for:**
 - **^{235}U cross correlations: inelastic/ (capture and fission), fission/capture**
 - **^{238}U cross correlations: elastic/inelastic, inelastic/ (capture and fission)**
 - **^{238}U fission spectrum (very low energy)**
- **Strange values (>>>>100%) for ^{16}O P_1 values at low energy**
- **Some difficulties in processing MF35 data (Oscar Cabellos helped)**

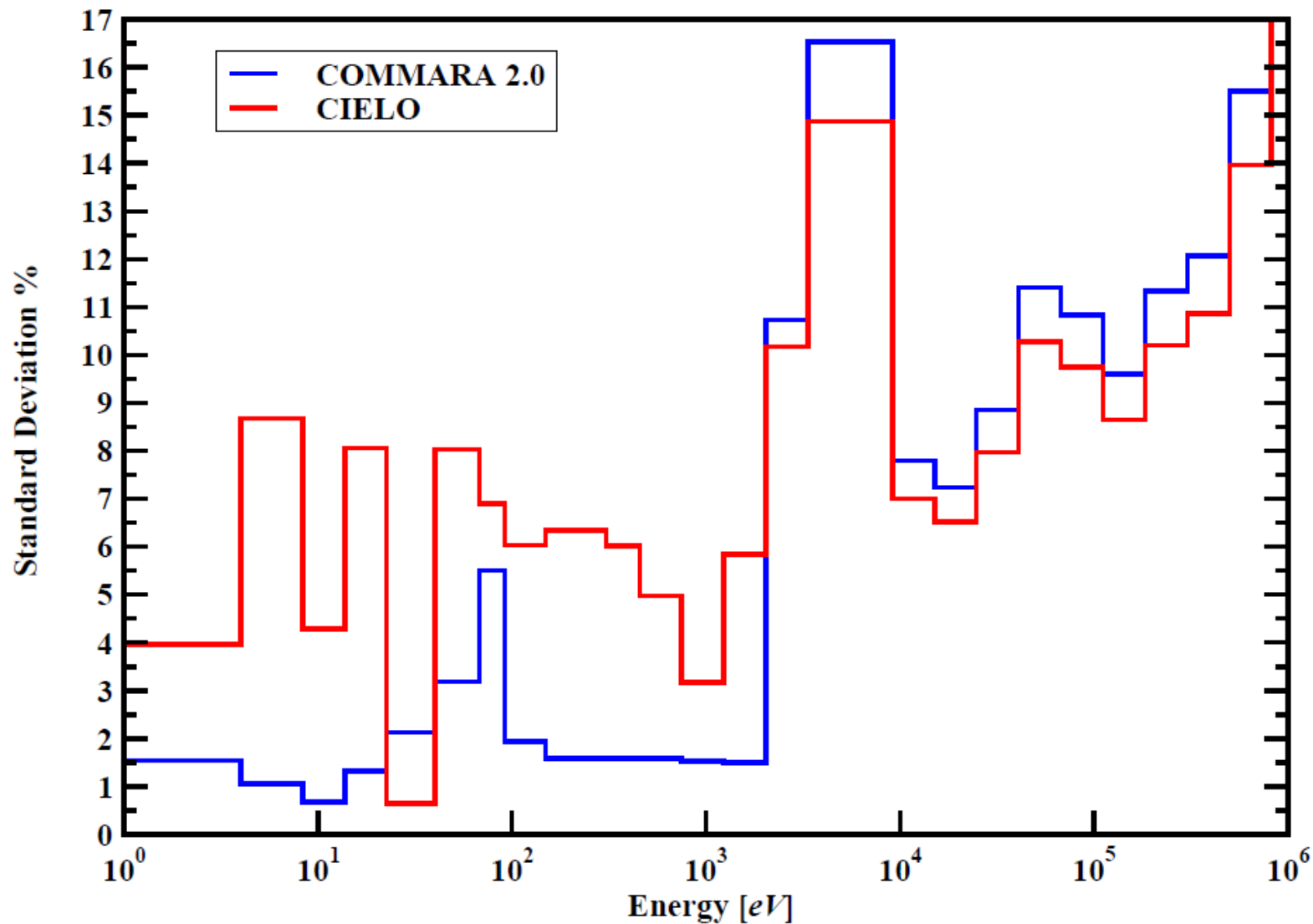
^{239}Pu σ Fission Standard Deviation %



^{239}Pu v Bar Standard Deviation %

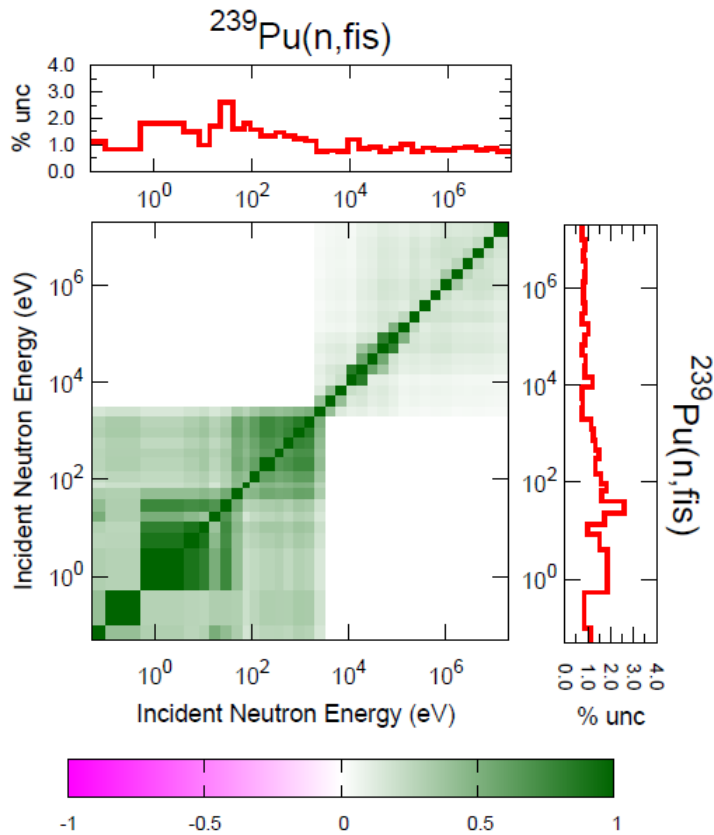


^{239}Pu σ Capture Standard Deviation %

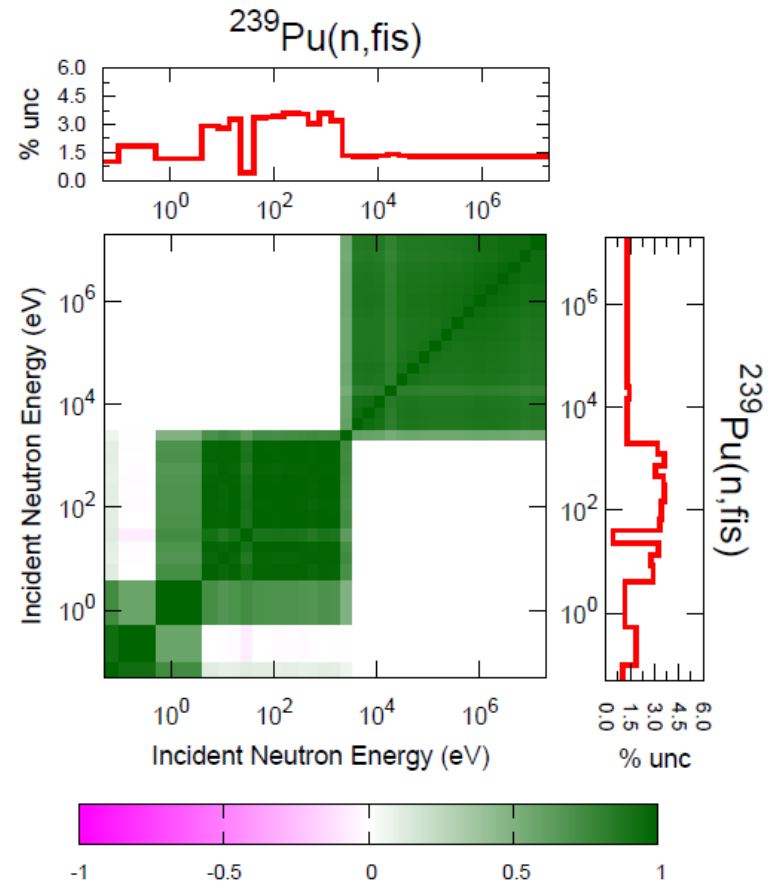


Correlations

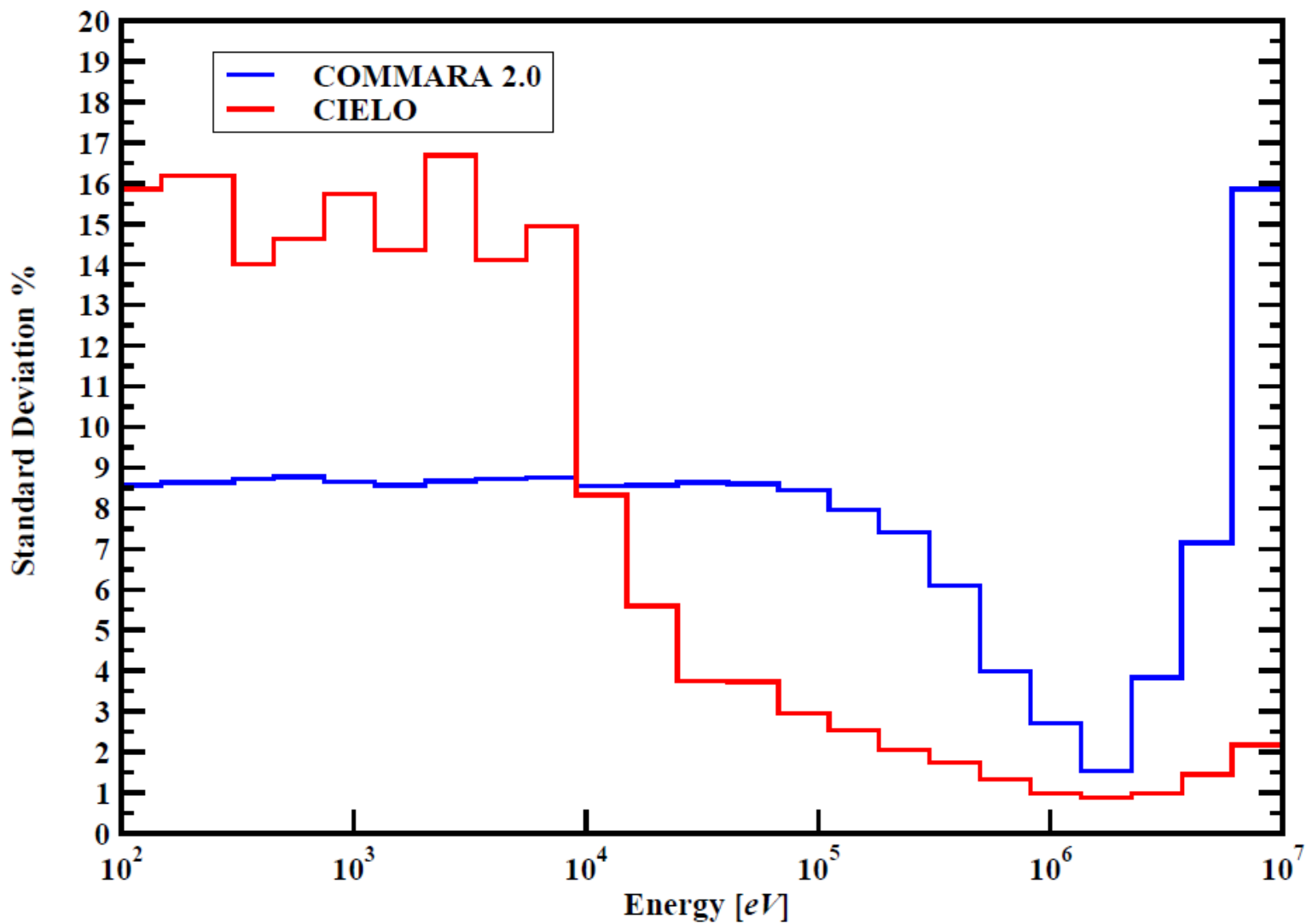
COMMARA-2.0



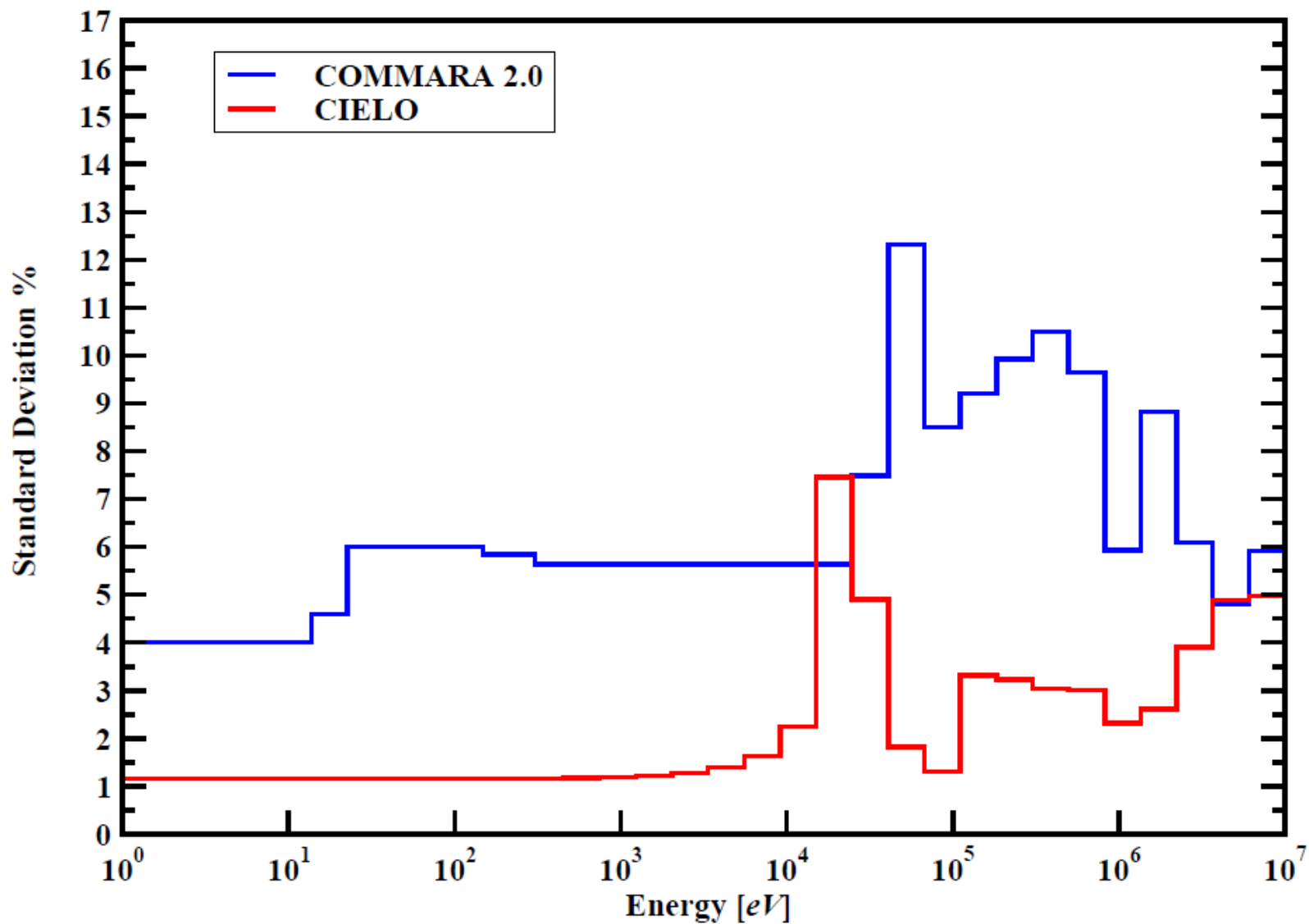
CIELO



^{235}U χ Standard Deviation %

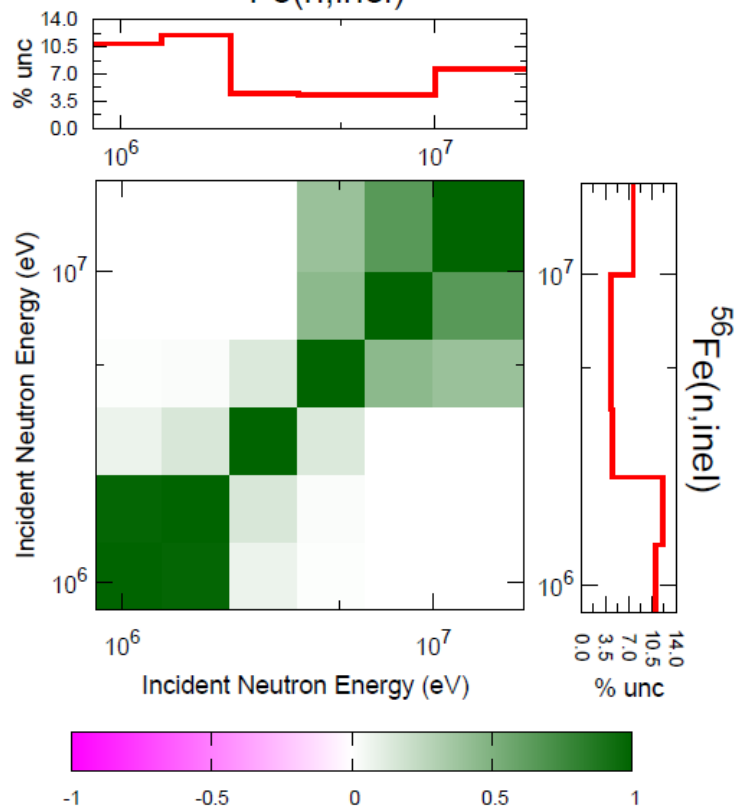


^{56}Fe σ Elastic Standard Deviation %

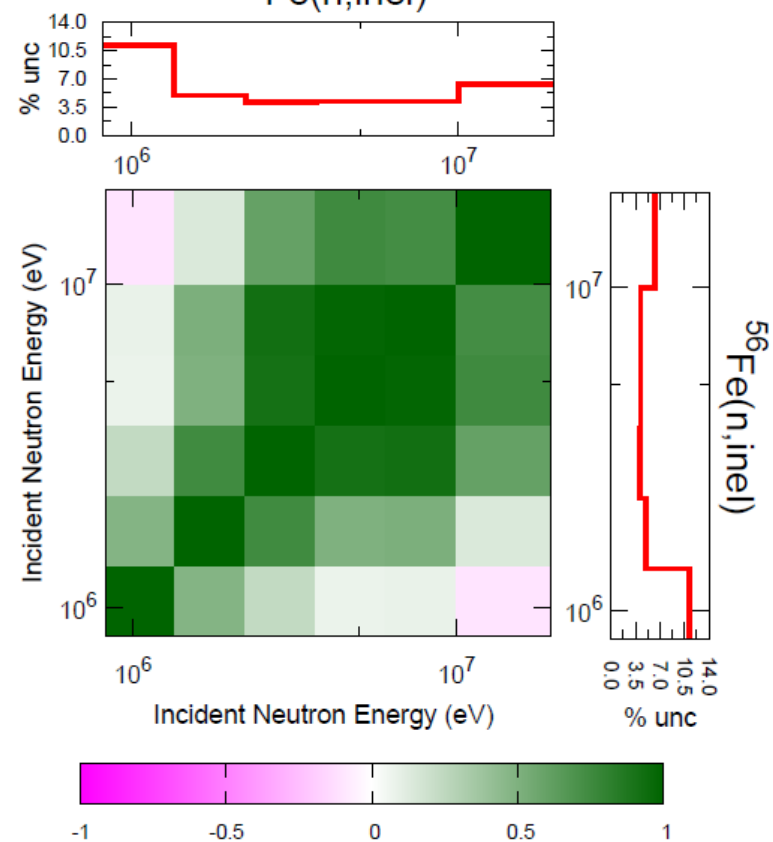


Correlations

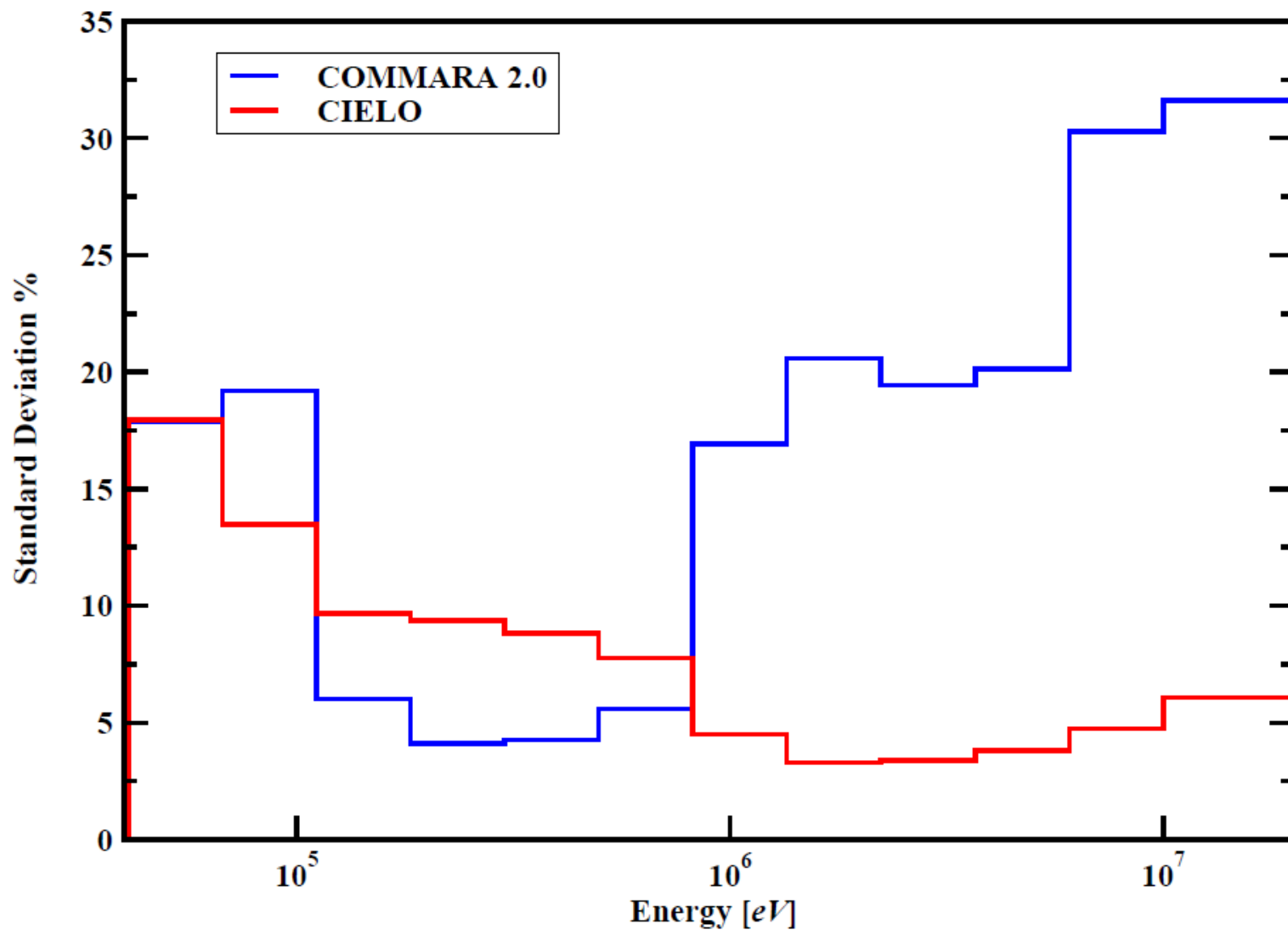
COMMARA-2.0

 $^{56}\text{Fe}(n,inel)$


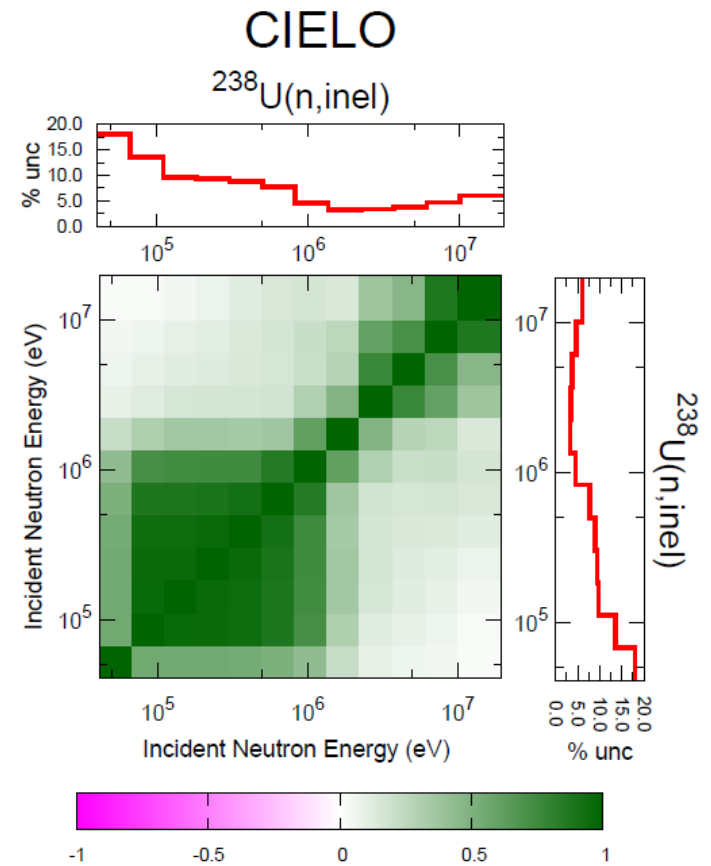
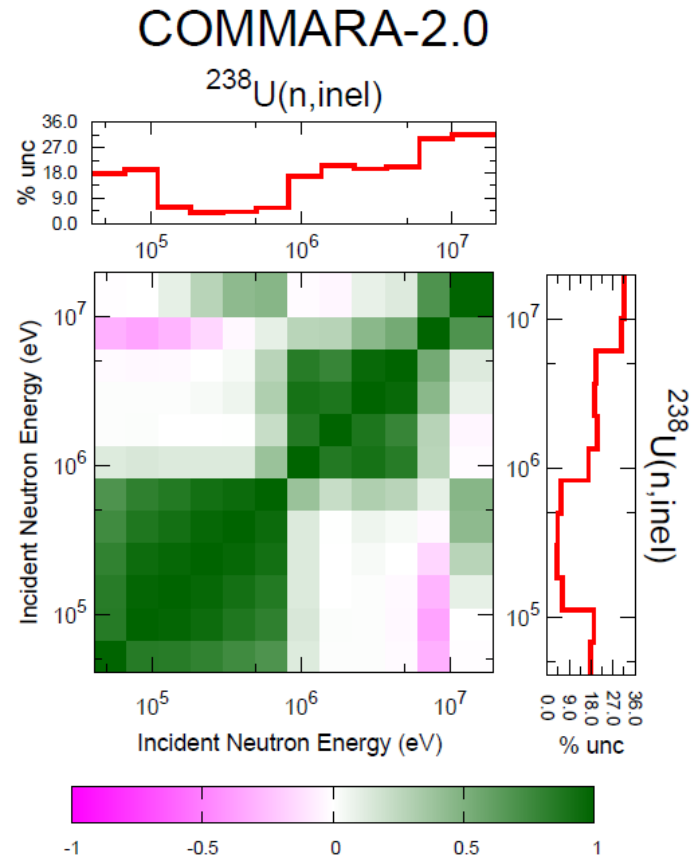
CIELO

 $^{56}\text{Fe}(n,inel)$


^{238}U σ Inelastic Standard Deviation %



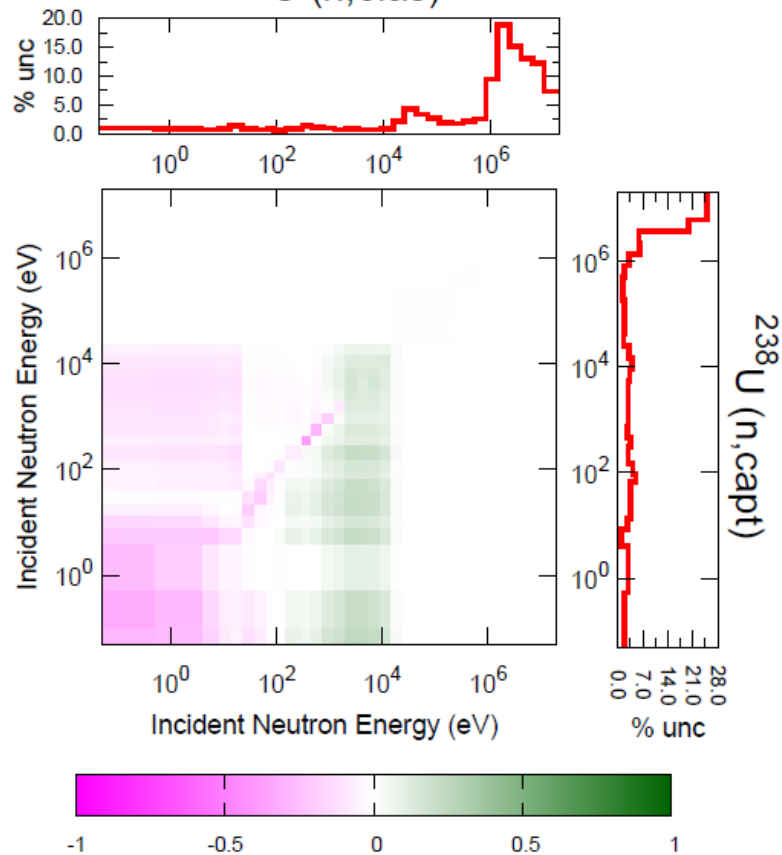
Correlations



Correlations

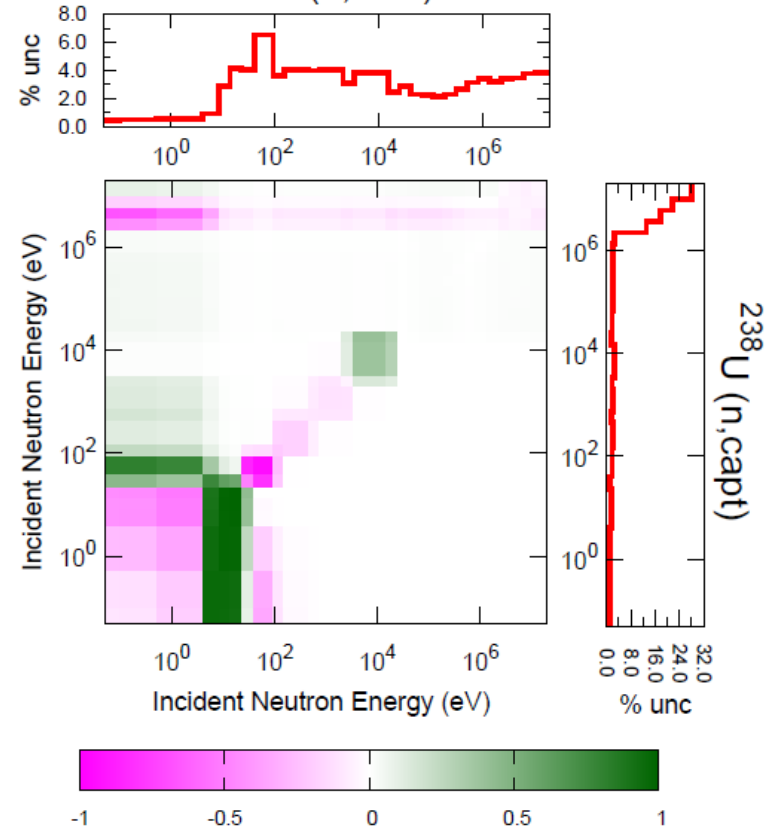
COMMARA-2.0

^{238}U (n,elas)



CIELO

^{238}U (n,elas)



LANL Criticals C/E

EXPERIMENT	ENDF7 (C-E)/E	CIELO (C-E)/E	COMM. Uncert.	CIELO Uncert.
JEZEBEL K_{eff}	-0.014	-0.082	0.646	1.080
JEZEBEL F28/F25	-2.300	-1.082	3.677	4.009
GODIVA K_{eff}	-0.017	0.050	1.003	1.077
GODIVA F28/F25	-4.500	-3.506	4.376	2.052
FLATTOP K_{eff}	0.002	-0.230	0.861	1.084
FLATTOP F28/F25	-1.780	-0.584	3.078	3.359
BIGTEN K_{eff}	0.351	0.028	2.582	0.972
BIGTEN F28/F25	-5.300	-5.555	13.058	0.907
BIGTEN F37/F25	-3.300	-6.518	6.975	2.579

JEZEBEL K_{eff} CIELO – ENDF7 Difference (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁹ Pu	0.009	-	-0.063	-	0.071	-0.040	0.070	-0.080

JEZEBEL K_{eff} COMMARA Unc. No Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁹ Pu	0.188	0.396	0.036	0.068	0.237	0.065	0.878	1.0145

JEZEBEL K_{eff} COMMARA Unc. with Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁹ Pu	-0.415	0.640	0.079	0.149	0.343	0.082	0.162	0.646

JEZEBEL K_{eff} CIELO Unc. No Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁹ Pu	0.196	0.396	0.033	0.068	0.351	0.152	0.877	1.056

JEZEBEL K_{eff} CIELO Unc. with Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁹ Pu	-0.421	0.640	0.073	0.149	0.884	0.313	0.159	1.080

GODIVA K_{eff} CIELO – ENDF7 Difference (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁵ U	0.384	-0.379	-0.015	0.052	0.107	-0.093	-0.018	0.075

GODIVA K_{eff} COMMARA Unc. No Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁵ U	0.118	0.255	0.259	0.213	0.114	0.058	1.510	1.577

GODIVA K_{eff} COMMARA Unc. with Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁵ U	-0.172	0.464	0.719	0.406	0.262	0.078	0.247	1.002

GODIVA K_{eff} CIELO Unc. No Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁵ U	0.107	0.136	0.127	0.213	0.282	0.147	0.422	0.608

GODIVA K_{eff} CIELO Unc. with Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁵ U	0.273	0.265	0.295	0.406	0.774	0.400	0.370	1.077

BIGTEN F28/F25

BIGTEN F28/F25 CIELO – ENDF7 Difference (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁸ U	0.051	-0.169	--0.003	0.073	1.401	0.002	-0.031	1.004

BIGTEN F28/F25 _f COMMARA Unc. No Correlation (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁸ U	0.175	7.693	0.183	0.153	0.302	0.002	1.073	7.779

BIGTEN F28/F25 COMMARA Unc. with Correlation (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁸ U	-1.241	13.057	0.404	0.221	0.492	0.004	2.472	13.248

BIGTEN F28/F25 _f CIELO Unc. No Correlation (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁸ U	0.157	1.322	0.207	0.153	0.629	0.003	0.368	1.610

BIGTEN F28/F25 CIELO Unc. with Correlation (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁸ U	0.353	0.808	0.534	0.221	-1.471	0.005	0.836	0.907

ZPPRs C/E

EXPERIMENT	ENDF7 (C-E)/E	CIELO (C-E)/E	COMM. Uncert.	CIELO Uncert.
ZPPR-9 K_{eff}	-0.078	-0.158	1.220	0.922
ZPPR-9 F28/F25	-2.900	-3.097	8.017	1.979
ZPPR-9 C28/F25	0.930	-0.731	1.546	1.602
ZPPR-9 STEP 3	1.920	4.584	7.638	6.613
ZPPR-9 STEP 5	-2.680	1.141	9.881	8.478
ZPPR-10 K_{eff}	0.015	-0.085	1.135	0.922
ZPPR-10 STEP 2	15.898	19.472	7.006	6.661
ZPPR-10 STEP 3	5.639	9.035	7.070	6.818
ZPPR-10 STEP 6	3.665	7.632	7.952	7.568
ZPPR-10 STEP 9	0.826	5.402	9.058	8.562
ZPPR-10 Central Control Rod	6.700	6.236	1.611	1.456
ZPPR-15 K_{eff}	-0.127	0.039	0.985	0.924

ZPPR-10 STEP9

ZPPR-10 STEP9 CIELO – ENDF7 Difference (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁸ U	-0.072	-0.267	-1.674	-0.310	0.252	-0.188	-0.007	-2.266

ZPPR-10 STEP9 COMMARA Unc. No Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁸ U	0.203	3.479	1.738	0.191	0.070	0.319	2.396	4.588

ZPPR-10 STEP9 COMMARA Unc. with Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁸ U	1.370	6.363	2.953	0.247	0.116	0.493	1.740	7.378

ZPPR-10 STEP9 CIELO Unc. No Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁸ U	0.199	0.822	1.240	0.191	0.147	0.333	0.843	1.770

ZPPR-10 STEP9 CIELO Unc. with Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁸ U	-0.478	1.609	1.945	0.247	-0.627	0.520	0.568	2.538

ZPPR-10 STEP9

ZPPR-10 STEP9 CIELO – ENDF7 Difference (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁹ Pu	0.004	-	0.465	-	5.229	0.377	-0.036	6.111

ZPPR-10 STEP9 COMMARA Unc. No Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁹ Pu	0.034	0.324	0.941	0.009	1.176	0.489	1.412	2.147

ZPPR-10 STEP9 COMMARA Unc. with Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁹ Pu	0.205	0.785	0.642	0.016	0.210	0.606	0.336	2.444

ZPPR-10 STEP9 CIELO Unc. No Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁹ Pu	0.036	0.324	1.662	0.009	2.976	0.623	1.411	3.712

ZPPR-10 STEP9 CIELO Unc. No Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
²³⁹ Pu	0.154	0.785	2.826	0.016	6.110	0.892	0.345	6.826

ZPRs C/E

EXPERIMENT	CIELO-2 (C-E)/E	CIELO (C-E)/E	COMM. Uncert.	CIELO Uncert.
ZPR6/7 K_{eff}	0.043	-0.098	0.994	0.911
ZPR6/7 F49/F25	-3.620	-4.456	6.474	1.621
ZPR6/7 C28/F25	0.980	-0.687	1.512	1.582
ZPR6/6A K_{eff}	-0.124	0.112	1.605	0.946
ZPR9-34 K_{eff}	0.882	2.993	2.404	1.164
ZPR3-53 K_{eff}	0.923	0.781	1.734	0.983
ZPR3-54 K_{eff}	1.202	2.740	1.069	1.101

ZPR9-34 K_{eff} CIELO – ENDF7 Difference (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{56}Fe	0.003	0.201	-0.999	2.504	-	-	-	1.709

ZPR9-34 K_{eff} COMMARA Unc. No Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{56}Fe	0.652	0.161	0.319	0.131	-	-	-	0.755

ZPR9-34 K_{eff} COMMARA Unc. with Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{56}Fe	1.318	0.146	0.669	0.199	-	-	-	1.498

ZPR9-34 K_{eff} CIELO Unc. No Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{56}Fe	0.220	0.164	0.287	0.131	-	-	-	0.418

ZPR9-34 K_{eff} CIELO Unc. with Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{56}Fe	0.400	0.165	0.589	0.199	-	-	-	0.757

Irradiation Experiments C/E

EXPERIMENT	CIELO-2 (C-E)/E	CIELO (C-E)/E	COMM. Uncert.	CIELO Uncert.
PROFIL-1 ²³⁵ U Sample	-5.100	-6.389	14.820	4.346
PROFIL-1 ²³⁸ U Sample	-2.800	-4.241	2.178	1.623
PROFIL-1 ²³⁹ Pu Sample	-9.400	-8.710	4.646	4.187
TRAPU-2 ²³⁵ U Sample	-0.500	0.880	1.783	4.027
TRAPU-2 ²³⁸ U Sample	1.200	0.864	0.550	0.594
TRAPU-2 ²³⁹ Pu Sample	-1.600	-1.231	1.367	1.196
MANTRA Cd Filter ²³⁵ U Sample	-3.000	-1.489	1.050	0.517
MANTRA Cd Filter ²³⁸ U Sample	3.000	2.732	1.547	1.130
MANTRA Cd Filter ²³⁹ Pu Sample	4.000	4.093	0.879	2.146

FCA-IX C/E

EXPERIMENT	CIELO-2 (C-E)/E	CIELO (C-E)/E	COMM. Uncert.	CIELO Uncert.
FCA-IX-1 F42/F49	4.700	3.734	2.794	1.513
FCA-IX-1 F51/F49	-5.200	-6.189	3.099	1.530
FCA-IX-1 F53/F49	-8.000	-9.019	1.384	1.542
FCA-IX-6 F42/F49	3.069	2.552	1.888	1.438
FCA-IX-6 F51/F49	-7.100	-8.165	2.286	1.488
FCA-IX-6 F53/F49	-9.300	-10.346	2.488	1.514
FCA-IX-7 F42/F49	4.700	1.872	5.812	1.888
FCA-IX-7 F51/F49	-6.600	-9.034	7.287	1.946
FCA-IX-7 F53/F49	-6.300	-8.817	7.906	1.984

PROTEUS C/E

EXPERIMENT	CIELO-2 (C-E)/E	CIELO (C-E)/E	COMM. Uncert.	CIELO Uncert.
C7 K_{eff}	0.973	0.848	0.858	0.940
C7 F25/F49	1.480	3.088	0.684	1.454
C8 K_{eff}	-0.548	-0.657	2.126	0.906
C8 C28/F49	2.257	1.355	1.927	1.813
C8 F28/F49	-0.461	0.179	9.621	1.501
PROTEUS Void	-42.304	-41.568	113.293	80.850

ASPIS C/E

EXPERIMENT	CIELO-2 (C-E)/E	CIELO (C-E)/E	COMM. Uncert.	CIELO Uncert.
ASPIS FE-88 Al (n, α) A7	35.100	14.199	31.655	14.846
ASPIS FE-88 S (n,p) A12/A7	-4.100	-19.153	10.587	11.260
ASPIS FE-88 S (n,p) A14/A7	-6.400	-26.586	15.455	15.485
ASPIS FE-88 In (n,inel) A11/A7	-0.600	-1.563	1.838	3.085
ASPIS FE-88 Rh (n,inel) A14/A7	4.300	5.020	14.627	5.016
ASPIS FE-88 Au (n, γ) A11/A7	1.400	-0.246	2.556	0.591
ASPIS FE-88 Au (n, γ) A14/A7	4.800	2.201	6.108	1.390

ASPIS FE-88 S (n,p) A14/A7 Idaho National Laboratory

ASPIS FE-88 S (n,p) A14/A7 CIELO – ENDF7 Difference (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
⁵⁶ Fe	2.585	-19.441	0.169	-4.812	-	-	-	-21.499

ASPIS FE-88 S (n,p) A14/A7 COMMARA Unc. No Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
⁵⁶ Fe	9.950	15.162	0.141	1.009	-	-	-	18.164

ASPIS FE-88 S (n,p) A14/A7 COMMARA Unc. with Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
⁵⁶ Fe	7.042	13.698	-0.043	1.113	-	-	-	15.442

ASPIS FE-88 S (n,p) A14/A7 CIELO Unc. No Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
⁵⁶ Fe	4.702	8.441	0.568	1.009	-	-	-	9.731

ASPIS FE-88 S (n,p) A14/A7 CIELO Unc. with Correlation (%)

Isotope/Reaction	Elast.	Inel.	Capt.	P ₁ Elas	Fiss.	Nubar	χ	Sum
⁵⁶ Fe	7.419	13.521	0.803	1.113	-	-	-	15.484

Summary of consistency between covariance

- Concerning differences observed on the C/E, CIELO does a good job on critical masses that are mostly used in validation, but perform poorly on others not so often used ones (e. g. ZPR/9-34, ZPR3-54) or reactivity variations (e. g. coolant void, rod worth). For quantities of the elementary type there very little improvement and many times worsening. **This indicates compensations.**
- There are severe differences between the two covariance matrix data, and in many instances the calculated uncertainties would not cover the C/E spread of the experiments, at least at the one sigma level.
- Of specific interest is the effect of the correlation. In many cases the differences leads to a different sign in the contribution.
- Regarding specific differences between the two covariance matrices related to the 5 isotopes, the major impacts are associated to:
 - ^{56}Fe : elastic, inelastic, capture.
 - ^{235}U : fission and fission spectrum
 - ^{238}U : elastic, inelastic, capture, fission, nubar, fission spectrum
 - ^{239}Pu : capture, fission.

Some Feedback from CIELO Adjustment

- **Some cross section adjustment is bigger than the standard deviation:**
 - **^{56}Fe inelastic from 10 Mev to 800 Kev and capture from 800Kev to 60 Kev**
 - **^{238}U inelastic from 1.3 Mev to 800 Kev**
 - **^{239}Pu capture from 15 Kev to 2 Kev and (n,2n) from 10 to 6 MeV**
- **In general standard deviations are significantly reduced, but some small increase is observed for a few cases of elastic and capture. This could indicate some problem in the cross correlation among reactions.**