Report on Status of SG39

WPEC/SG39

May, 2017

G. Palmiotti, M. Salvatores

www.inl.gov

Idaho National Laboratory

- **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

- Finalized several chapters of the final deliverable: Stress test, MC sensitivity calculation, Asymptotic PIA.
- Provide new experiments aimed at improving adjustments.
- Pursue development of continuous energy adjustment technique.
- Provide some feedback for CIELO isotopes (no covariance yet available).
- Formulated proposal for follow up activity: SG46.

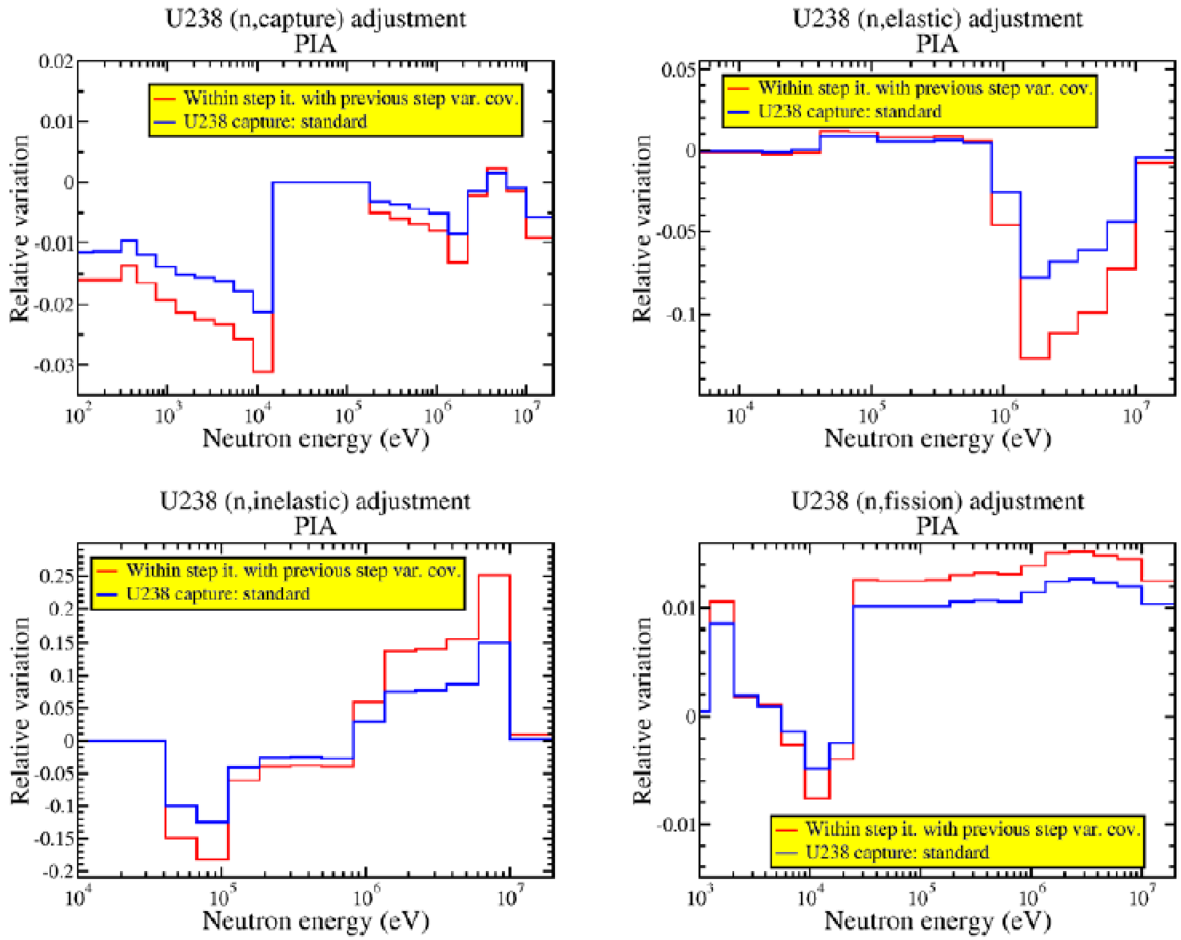
PAUL SCHERRER INSTITUT

Sandro Pelloni :: Senior Scientist :: Paul Scherrer Institut

Comparison of PIA sequences by using the UR ^{238}U capture cross-section as a standard

May 16-17, 2017: WPEC/SG-39

Adjustment of ^{238}U with respect to JEFF-3.1 (1ST, 1STm)



- Adjustment similar trends, however, as expected, stronger when using a priori variance/ covariance matrix at beginning of each incremental step.

Blue: $\boldsymbol{M_i}$ (Eq. (2.1))
Red: $\boldsymbol{M_0}$ (Eq. (2.2))

SG39 Meeting
May 16-17, 2017

Update on Continuous Energy Cross Section Adjustment.

UC Berkeley / INL collaboration

Projection vs. discretization

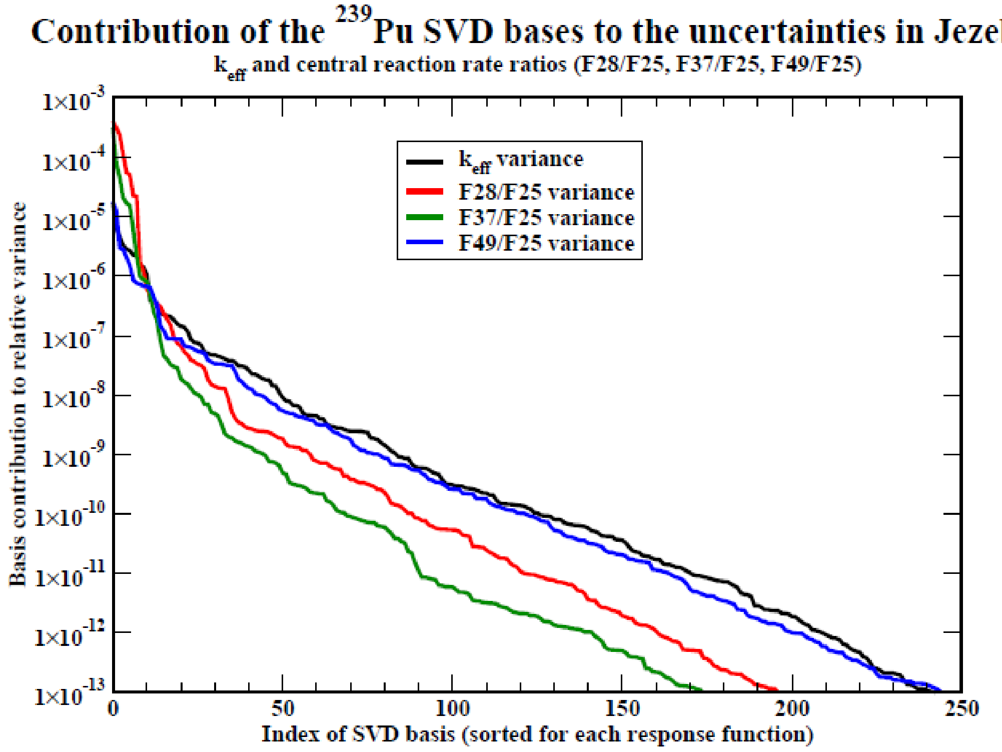
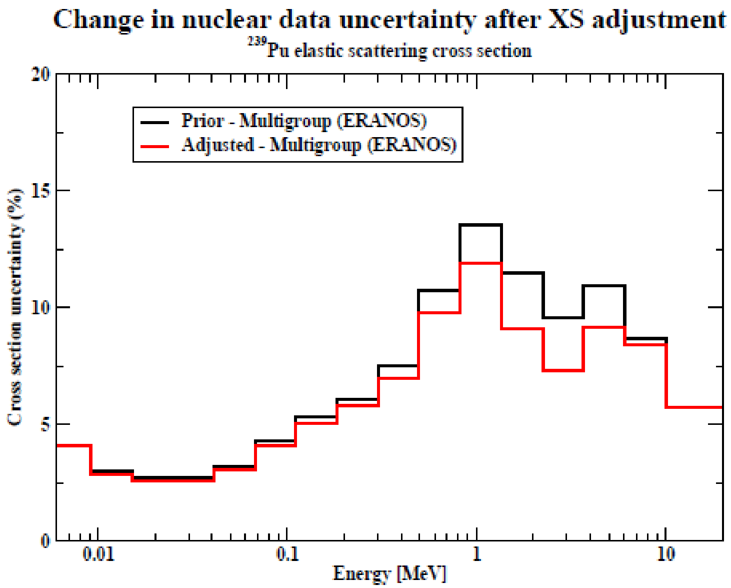


Figure: Eigenfunctions contribution to the total variances in Jezebel. Response functions: k_{eff} , F28/F25, F37/F25, F49/F25. (^{239}Pu ENDF/B-VII covariances).

Continuous vs. multi-group: uncertainty reduction



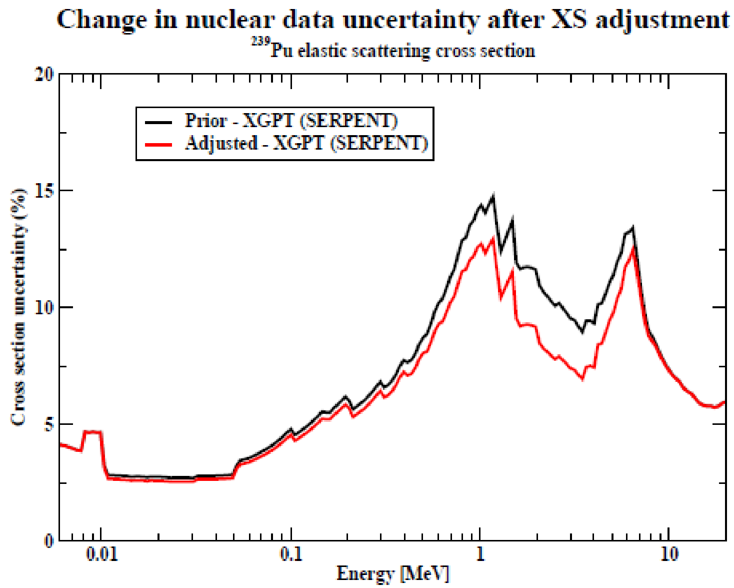


Figure: ^{239}Pu elastic scattering uncertainty before and after the adjustment process. Multi-group (left) and continuous energy (right) results.

Continuous vs. multi-group: XS adjustment

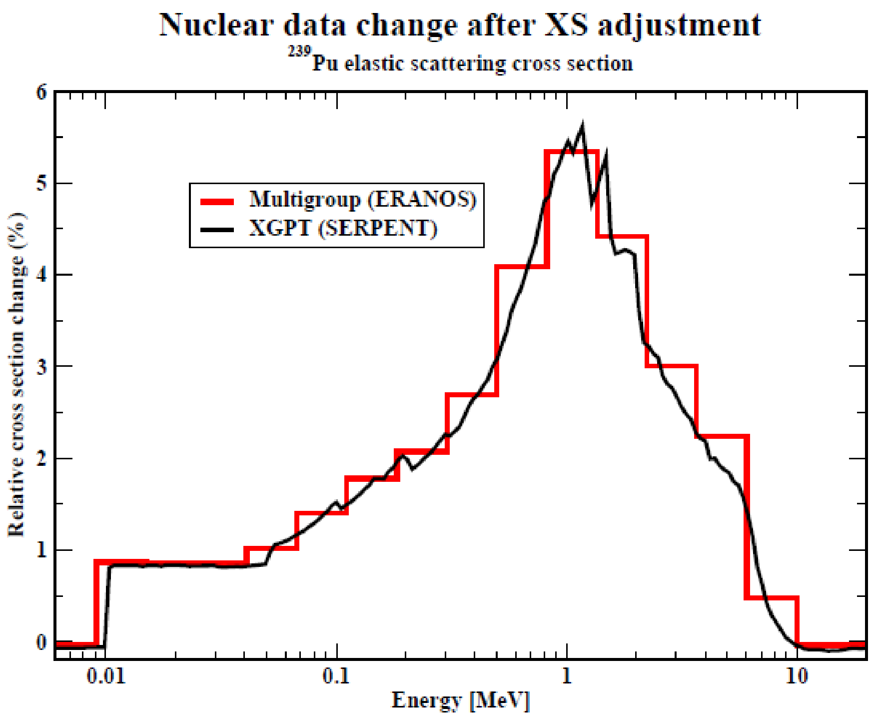


Figure: ^{239}Pu elastic scattering cross section before and after the adjustment process. Multi-group (red) and continuous energy (black) results.

Continuous vs. multi-group: XS adjustment

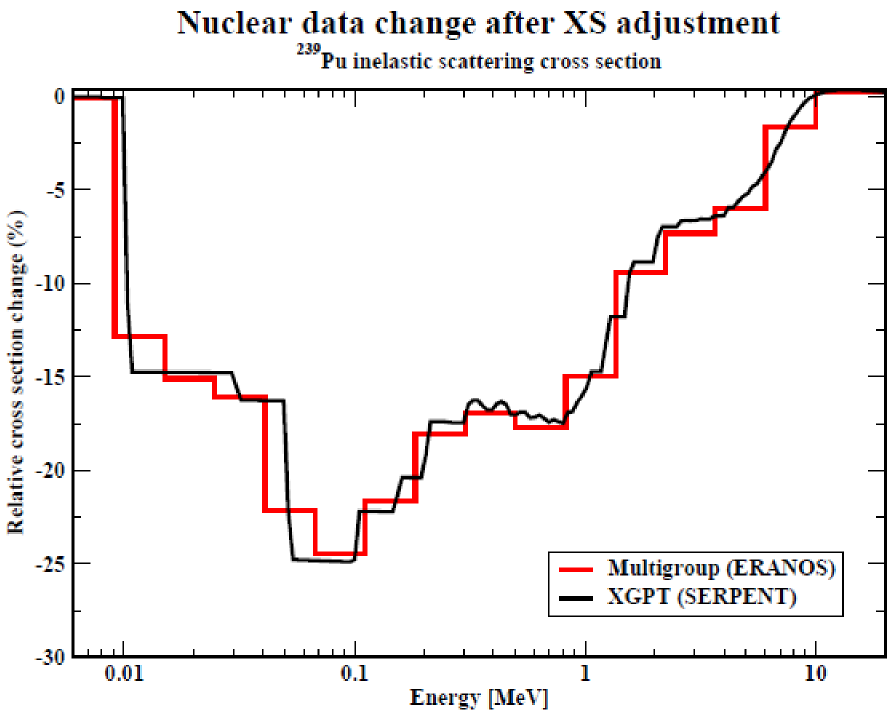


Figure: ^{239}Pu inelastic scattering cross section before and after the adjustment process. Multi-group (red) and continuous energy (black) results.

DE LA RECHERCHE À L'INDUSTRIE

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Application of EGPT in the analysis of small-sample reactivity worth experiments

DEN/CAD/DER/SPRC/LEPh | **Pierre Leconte**.
DEN/CAD/DER/SPRC | Alain Santamarina
DEN/CAD/DER/SPEx | Patrick Blaise, Paul Ros

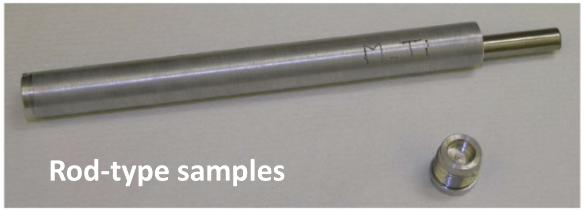
16/05/2017, OECD/NEA, WPEC/SG39.

SELECTED EXPERIMENTS
The MAESTRO experiment (2012-2016)

Validation of nuclear on a large range of materials used in GEN-II/GEN-III reactor cores

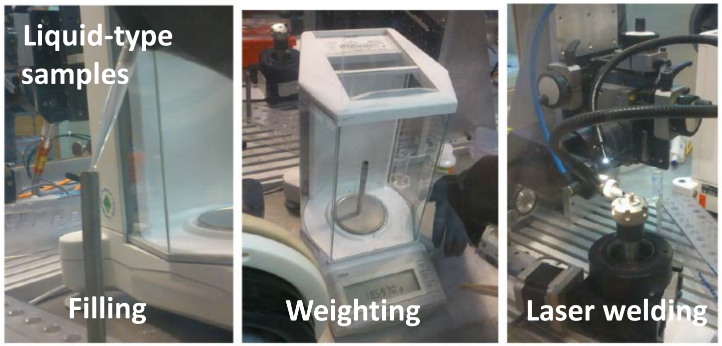
More than 60 samples :

- Moderating materials: H_2O, ^{nat}Be, ^{nat}C, CH_2
- Structural materials: ^{nat}Mg, ^{nat}Al, ^{nat}Cl, ^{nat}Ca, ^{nat}Ti, ^{nat}Cr, ^{nat}Fe, ^{nat}Ni, ^{nat}Cu, ^{nat}Zn, ^{nat}Zr, ^{nat}Mo, ^{nat}Sn
- Detection materials: ^{nat}V, ^{nat}Mn, ^{nat}Co, ^{nat}Nb, **^{nat}Rh**
- Absorbing materials: ^{nat}Ag, ^{nat}In, ^{nat}Cd ^{nat}Eu, ^{nat}Gd, ^{nat}Dy, ^{nat}Er, ^{nat}Hf ^{153}Eu, ^{107}Ag, ^{nat}Cs
- Industrial alloys: Zy4, M5, SS304, SS316, Inconel-800
- Calibration materials ^{nat}Au, ^{6}Li, ^{10}B



- **Both pile oscillation and neutron activation experiments**

- **10-30cm long tubes filled with materials of different physical forms**
  - Pure rods
  - Liquid solutions
  - Powder mixed with Al_2O_3 diluant



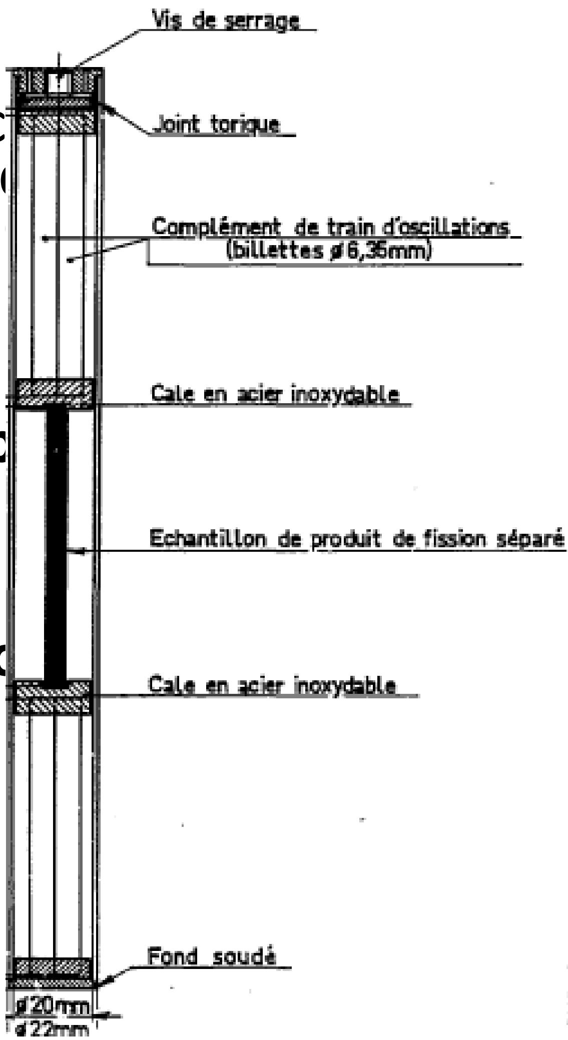
SELECTED EXPERIMENTS
The ERMINE-V experiment (1974-1979)

Validation of the integral capture of fission products in SCFR in support to SUPER-PHENIX

- **Various kinds of samples in 3-10cm long tubes:**
  - Individual fission products: ^{141}Pr, ^{133}Cs, ^{99}Tc ^{100}Mo, ^{104}Ru, ^{108}Pd, ^{142}Ce, ^{146}Nd, ^{148}Nd, ^{150}N
  - Irradiated fuel pins from PHENIX and RAPS

- **Both pile oscillation and neutron activation exp**

- **In parallel of the PROFIL and PROFIL-2 irradiatic in PHENIX**

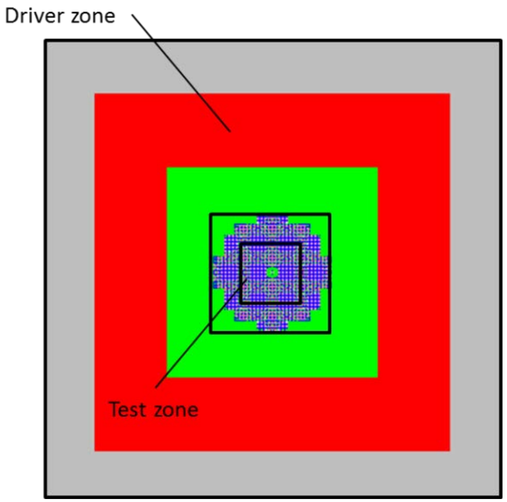


CONCLUSIONS AND PERSPECTIVES

Open question to investigate

- **In the case of experimental results reported as infinite diluted reactivity worth (e.g. RRR/SEG), which mass to consider to apply the EGPT? Is the balance between indirect and direct contributions sensitive to the magnitude of the RW? Limit range for linear assumption?**
  - Large masses: + no convergence issues
    - increase of self-shielding effects
  - Small masses: + closer to the real experiment
    - convergence issues

  ⇨ Test of increasing concentrations for the sample mass



- **In fast spectrum experiments, are the EGPT profiles influenced by the size of the geometrical model?**

  ⇨ Test of various model sizes

- **Can Monte-Carlo methods replace deterministic ones for SSRW sensitivities? Minimum acceptable RW value?**

  ⇨ EGPT benchmark to be done between various deterministic (APOLLO2, ERANOS) and Monte-Carlo (SERPENT, TRIPOLI, MCNP) codes

Correlations between LCT Integral Experiments and Their Impact on Adjustments

Ian Hill
Nuclear Science Division

SG39
May 2017

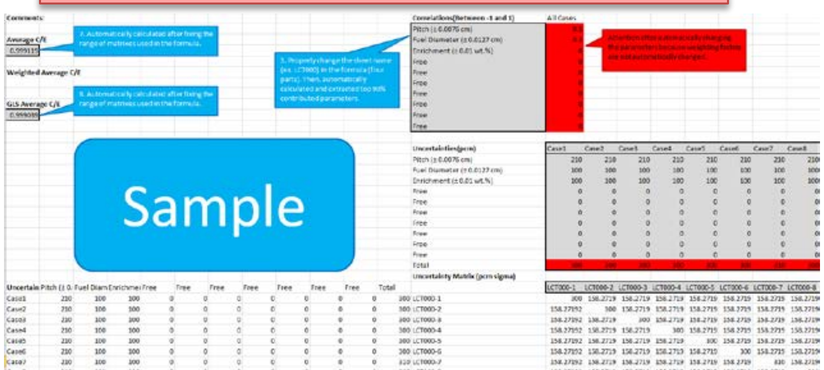
NEA: Tools to Simplify Covariance Generation

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

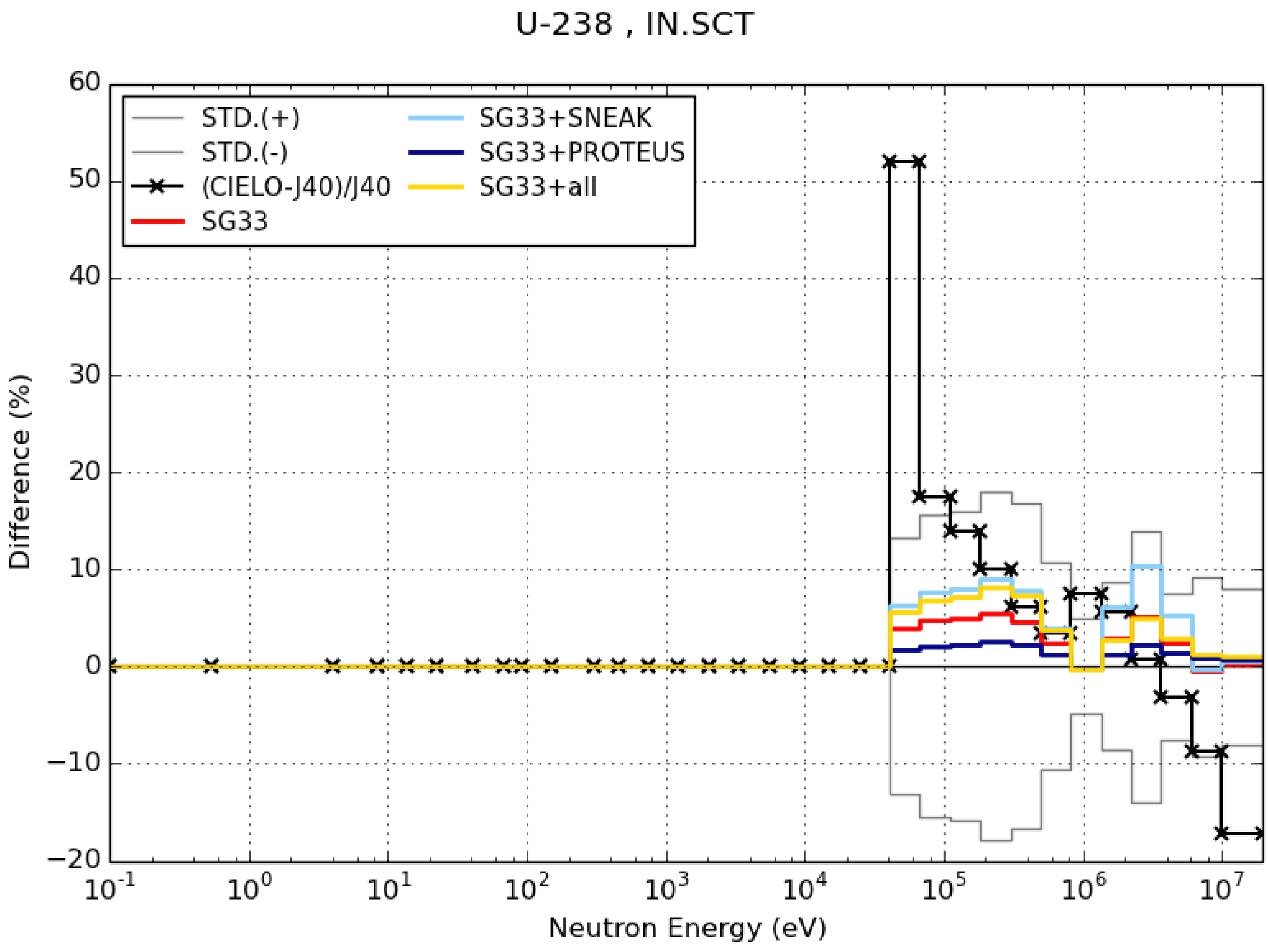
V.Zerkin, "Web Tool for Constructing a Covariance Matrix from EXFOR Uncertainties", EPJ Web of Conferences 27, 00009 (2012)

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.

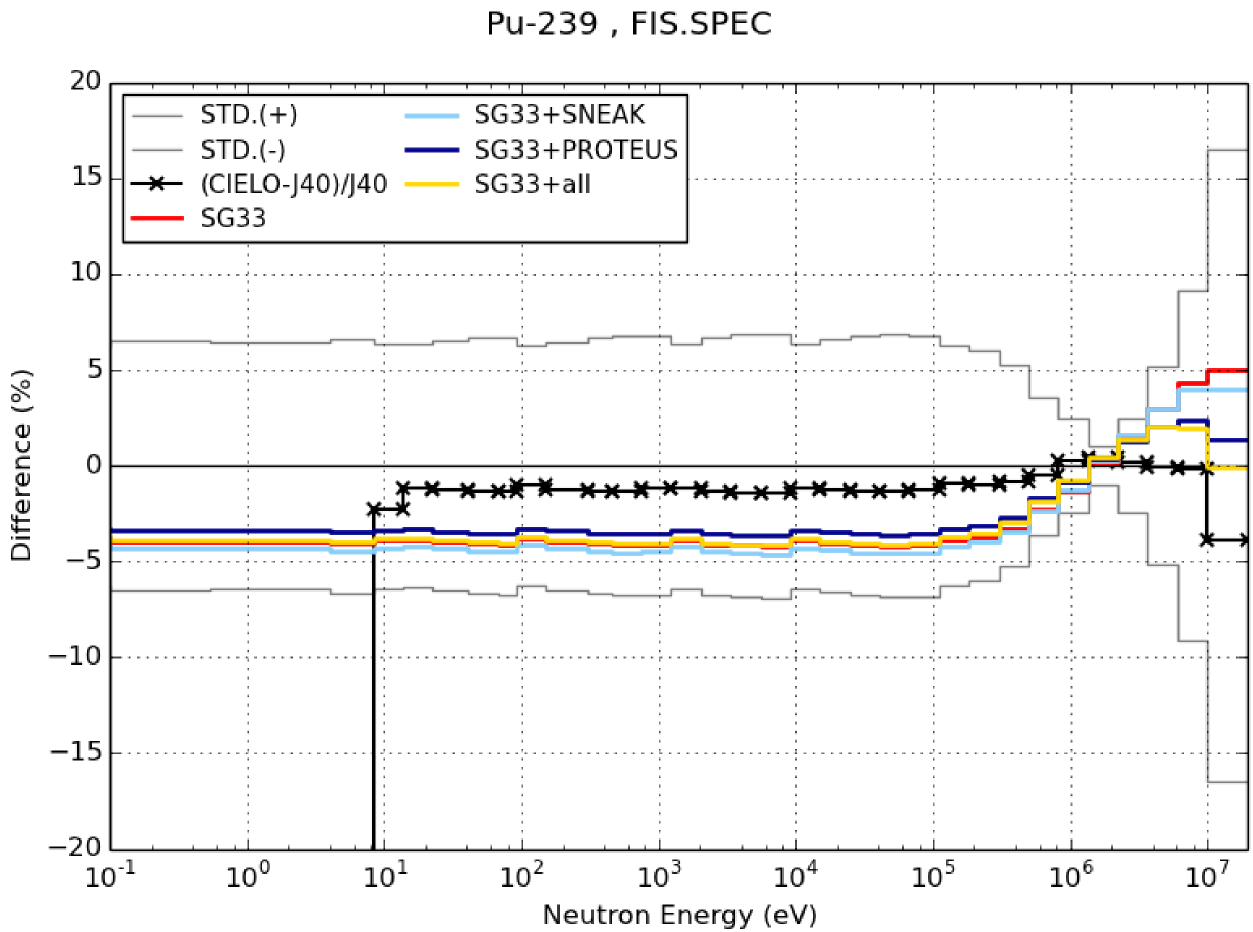
JENDL-4.0 Based Cross-section Adjustment by Adding New Experiments on the Basis of the SG33 Benchmark (Revised)

K. Yokoyama, T. Jin, and M. Ishikawa
Japan Atomic Energy Agency



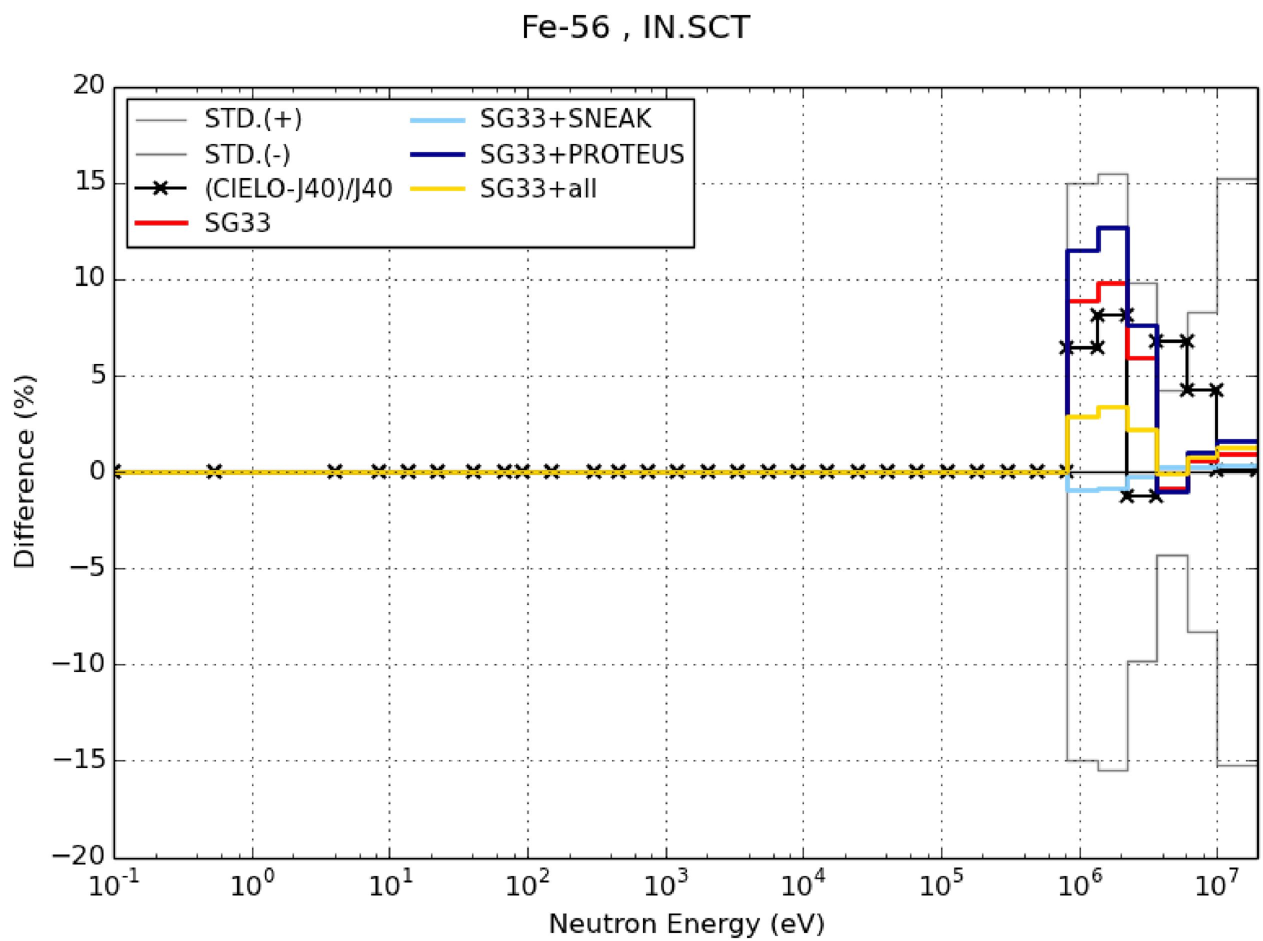
- SNEAK and PROTEUS increase U-238 inelastic scattering cross section.
- Even though U-238 inelastic scattering cross section may have a typical compensation effect with fission spectrums, could we say that these results support the evaluation of CIELO?

Pu-239 fission spectrum



- Both PROTEUS and SNEAK have a tendency to make the neutron spectrum harder.
- According to the adjustment result of U-238 inelastic cross section, they require softer neutron spectrum. (Is it a compensation effect?)

ns



- Again, could we say that these adjustment results in MeV range support Fe-56 inelastic scattering cross section of CIELO?
- We should carefully use these results when giving feedbacks to the evaluation of CIELO.

Concluding Remarks

- The result presented here is a model case of the methodology of CIELO verification by using cross-section adjustment technique, and the methodology itself seems to be very promising.

- However, we should be cautious about reflecting this cross-section adjustment results directly on the CIELO evaluation, since the integral experimental data applied here are quite limited.

- If we apply this methodology to much more comprehensive integral experimental data set and carefully determine the compensation effect, we would be able to provide useful information to CIELO in the future.

Impact of CIELO Evaluation on C/E of a Large Integral Experiments Data Base

G. Palmiotti, M. Salvatores

Idaho National Laboratory, Idaho Falls, USA

WPEC SG39 Meeting

May 16-17, 2017

Paris

ZPPRs Breakdown

ZPPR-9 STEP3 Difference (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{16}O	-0.841	-	0.323	-0.007	-	-	-	-0.526
^{56}Fe	0.033	0.716	-0.453	0.030	-	-	-	0.327
^{238}U	-0.008	0.402	1.255	0.005	-0.119	0.111	-0.026	1.672
^{239}Pu	-0.003	-	-0.340	-	-3.996	-0.300	-0.022	-4.662
Total	-0.819	1.114	0.866	0.027	-4.074	--0.190	0.003	-3.072

ZPPR-10 STEP9 Difference (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{16}O	-0.723	-	0.373	-0.007	-	-	-	-0.526
^{56}Fe	0.057	0.824	-0.701	-0.098	-	-	-	0.082
^{238}U	0.078	0.353	1.737	0.225	-0.248	0.186	0.028	2.360
^{239}Pu	-0.004	-	-0.477	-0.001	-5.786	-0.381	-0.035	-6.685
Total	-0.593	1.173	1.040	0.086	-5.984	--0.195	0.008	-4.481

ZPPR-10 Step9 Major Contributions:

^{239}Pu fission: 2.03 kev to 1.23 kev (-5.239%) ^{238}U capture: 1.23 kev to 0.749 kev (1.288%)

ZPPRs Breakdown

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ZPPR-10 STEP9 Difference (%)								
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FCA-IX Breakdown

FCA-IX-1 F53/F49 Difference (%)								
Isotope/Reaction	**Elast.**	**Inel.**	**Capt.**	**P_1 Elas**	**Fiss.**	**Nubar**	**χ**	**Sum**
^{56}Fe	0.014	0.312	-0.029	-0.025	-	-	-	0.272
^{235}U	0.006	-0.588	0.617	0.022	-0.451	0.005	1.692	1.304
^{239}Pu	-	-	-	-	-0.268	-	--	-0.268
Total	-0.008	-0.240	0.641	-0.037	-0.696	-0.009	1.693	1.345

FCA-IX-6 F53/F49 Difference (%)								
Isotope/Reaction	**Elast.**	**Inel.**	**Capt.**	**P_1 Elas**	**Fiss.**	**Nubar**	**χ**	**Sum**
^{56}Fe	0.028	0.485	0.006	-0.158	-	-	-	0.361
^{235}U	-0.065	-1.165	-0.035	0.114	-0.051	0.005	1.323	0.127
^{238}U	-0.023	0.231	0.055	-0.034	0.039	-0.023	0.009	0.255
^{239}Pu	-	-	-	-	0.219	-	--	0.219
Total	-0.061	-0.450	0.027	0.207	-0.696	-0.018	1.332	0.960

FCA-IX-7 F53/F49 Difference (%)								
Isotope/Reaction	**Elast.**	**Inel.**	**Capt.**	**P_1 Elas**	**Fiss.**	**Nubar**	**χ**	**Sum**
^{56}Fe	0.004	0.109	0.002	-0.014	-	-	-	0.100
^{235}U	0.017	-0.689	-0.049	0.014	-0.054	0.001	1.121	0.361
^{238}U	-0.007	1.357	0.136	-0.028	0.024	-0.005	0.009	1.563
^{239}Pu	-	-	-	-	0.262	-	--	0.262
Total	0.013	0.777	0.090	-0.029	0.232	-0.004	1.206	2.285

PROTEUS Breakdown

PROTEUS C7 K_{eff} (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{16}O	-0.037	-	0.135	0.001	-	-	-	0.099
^{238}U	-0.005	0.009	-0.191	0.009	-0.069	0.057	-0.004	-0.195
^{239}Pu	0.001	-	0.070	-	-0.094	0.122	-0.017	0.083
Total	-0.040	0.041	0.029	0.012	-0.203	0.205	-0.005	0.039

PROTEUS C8 F28/F49 (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{16}O	-0.003	-	0.142	0.042	-	-	-	0.180
^{238}U	-0.025	-0.381	0.286	-0.003	-1.243	-0.005	-0.001	-1.374
^{239}Pu	0.001	-	-0.047	-	0.240	0.001	-0.146	-0.049
Total	-0.022	-0.018	0.356	0.081	-0.101	-0.005	-0.040	-0.658

PROTEUS Water Void Difference (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{16}O	-10.267	-	0.819	-2.010	-	-	-	-11.459
^{56}Fe	0.057	4.045	0.073	-0.104	-	-	-	4.934
^{235}U	0.077	-0.272	-0.485	0.035	2.569	-1.718	0.936	1.137
^{238}U	0.180	8.834	-4.883	-0.775	-3.626	2.726	0.087	3.327
^{239}Pu	-0.034	-	-1.535	-0.013	-2.573	-6.022	-0.581	-10.732
Total	-9.993	12.606	-5.356	-2.634	-3.630	-5.014	1.227	-12.793

ASPIS Breakdown

Idaho National Laboratory

ASPIS FE-88 Al (n,α) A7 (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{56}Fe	-3.485	15.825	-5.264	9.948	-	-	-	17.025
^{235}U	-	-	--	-	-	-	3.532	3.532
Total	-3.485	15.825	-5.264	9.948	-	-	3.532	20.548

ASPIS FE-88 S (n,p) A14 (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{56}Fe	-5.671	37.620	-0.740	14.801	-	-	-	46.073
^{235}U	-	-	--	-	-	-	2.236	2.236
Total	-5.671	37.620	-0.740	14.801	-	-	2.236	48.204

ASPIS FE-88 In (n,inel) A11 (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{56}Fe	-0.081	10.019	-0.414	-	-	-	-	9.523
^{235}U	-	-	--	-	-	-	1.148	1.148
Total	-0.081	10.019	-0.414	-	-	-	1.148	10.651

ASPIS FE-88 Rh (n,inel) A7 (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{56}Fe	-0.030	4.119	-0.263	-	-	-	-	3.887
^{235}U	-	-	--	-	-	-	0.887	0.887
Total	-0.030	4.119	-0.263	-	-	-	0.887	4.761

ASPIS FE-88 Au (n,γ) A14 (%)								
Isotope/Reaction	Elast.	Inel.	Capt.	P_1 Elas	Fiss.	Nubar	χ	Sum
^{56}Fe	-	-	4.659	-	-	-	-	4.659
Total	-	-	4.659	-	-	-	-	4.659

Summary

- **Regarding experiments, this exercise has shown that the experiments other than critical masses (e. g. spectral indices, irradiation experiments, reactivity coefficients, and neutron propagation) provide extremely useful information.**
- **Many compensations have been observed among reactions and also energy range (not shown in viewgraphs).**
- **Regarding the 5 isotopes, the major impacts are related to:**
  - **^{16}O: elastic, (n,α), P_1 elastic. Only few experiments are sensitive.**
  - **^{56}Fe: elastic, inelastic, capture, P_1 elastic. Propagation experiments are the most sensitive.**
  - **^{235}U: inelastic, capture, fission, fission spectrum**
  - **^{238}U: inelastic, capture, P_1 elastic, fission, nubar**
  - **^{239}Pu: capture, fission, nubar, fission spectrum (in general lesser impact than the other isotopes)**
- **When covariances will be available for CIELO isotopes, more relevant feedback could be provided through data assimilation using PIA strategy (avoiding compensations) and careful choice among available experiments.**

Future Actions and Conclusions

- **The subgroup is very active and many, very useful, contributions have been produced by the participants.**
- **INL and JAEA will perform adjustment for providing feedback to CIELO when covariances will be available: CIELO-1, CIELO-2?**
- **Results of adjustments will be discussed at next meeting in November.**
- **Write final report (deliverable) by May 2018 (last meeting of SG39).**
- **SG46 preparatory meeting in November and first official meeting in May 2018.**