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Title: Report on the CSEWG covariance and measurement session initiative on establishing templates of expected measurement uncertainties

Author(s): Neudecker, Denise

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Report on the CSEWG covariance and measurement session initiative on establishing templates of expected measurement uncertainties

Denise Neudecker CSEWG, 11/5/2019

Thanks to: all mini-CSEWG 2019 participants and further contributors to this initiative.

Outline

- Mini-CSEWG 2019 summary
- What is a template of expected uncertainties and how can this template help us?
- Summary of templates we have so far.
- Impact of applying such a template for evaluations (example: updating ^{239}Pu(n,f) covariances in the Neutron Data Standards database)

Mini-CSEWG, spring 2019 summary

Mini-CSEWG spring 2019, between covariance and measurement session

- Organizers: D. Neudecker, Y. Danon, M.C. White, P. Talou
- Location: Los Alamos, NM, USA
- Date: April 28, 29 and May 1st
- Attendees: 35-40 scientists
  - Experimentalists (LANL, LLNL, BNL, TUNL, JRC Geel, ANL, NIST, LBNL, UC Berkeley, RPI, Duke University, USNA)
  - Evaluators (LANL, LLNL, BNL, JRC Geel, IAEA, NIST, LBNL, UC Berkeley, RPI)
  - EXFOR compilers (BNL)

- Aim: **Create template of expected uncertainty sources for specific measurement sources.**

Why: to set up foundation for better experimental UQ for community → more realistic evaluated uncertainties.

What is a template of expected measurement uncertainties?

What is a template?

Unc. Source	Absolute	Clean Ratio	Indirect Ratio
Sample Mass	> 1%	Both Samples	Both samples
Counting Statistics	Sample-dependent	Both, combined	Both samples
Attenuation	0.2-2%	0.02-0.2%	0.2-2%
Detector Efficiency	1-2%	0-0.3%	1-2%, 0.5-1%
FF Angular Distrib.	~0.1%	Less than for abs.	~0.1%
Background	0.2 - >10%	0.2 - >10%	0.2 - >10%
Energy Unc.	1%, 1-2 ns	Combined	Both detectors
Neutron Flux	>1%	Cancels or small	Cancels or small
Multiple Scattering	0.2-1%	Reduced for abs.	0.2-1%
Impurit. in Sample	Sample-dependent	Both samples	Both samples
Dead Time	>0.1%	Both, combined	Both detectors

(1) A template should list all the typical measurement types for a specific observable.

Unc. Source	Absolute	Clean Ratio	Indirect Ratio
Sample Mass	> 1%	Both Samples	Both samples
Counting Statistics	Sample-dependent	Both, combined	Both samples

<u>Established based on:</u>

- going through relevant databases (EXFOR,…)
- discussions with experimenters/ evaluators

(2) A template should list all typical unc. sources encountered in measuring this observable.

Unc. Source	Ab
Sample Mass	>
Counting Statistics	Sample-
Attenuation	0.
Detector Efficiency	1
FF Angular Distrib.	~(
Background	0.2 -
Energy Unc.	1%,
Neutron Flux	>
Multiple Scattering	0.
Impurit. in Sample	Sample-
Dead Time	>(

<u>Established based on:</u>

- going through relevant databases (EXFOR,…)
- discussions with experimenters/ evaluators

(3) A template gives reasonable unc. ranges for unc. sources that can be used if missing.

Unc. Source	Absolute	Clean Ratio	Indirect Ratio
Sample Mass	> 1%	Both Samples	Both samples
Counting Statistics	Sample-dependent	Both, combined	Both samples
Attenuation	0.2-2%	0.02-0.2%	0.2-2%
Detector Efficiency	1-2%	0-0.3%	1-2%, 0.5-1%
FF Angular Distrib.	~0.1%	Less than for abs.	~0.1%
Background	0.2 - >10%	0.2 - >10%	0.2 - >10%
Energy Unc.	1%, 1-2 ns	Combined	Both detectors
Neutron Flux	>1%	Cancels or small	Cancels or small
Multiple Scattering	0.2-1%	Reduced for abs.	0.2-1%
Impurit. in Sample	Sample-dependent	Both samples	Both samples
Dead Time	>0.1%	Both, combined	Both detectors

Established based on:

- going through relevant databases and literature
- discussions with experimenters/ evaluators

(4) A template gives estimates for correlation information if missing.

Unc. Source	Typical range	Correlations	Cor(Exp$_1$, Exp$_2$)
Sample Mass	> 1%	Full	Possible (same sample)
Counting Statistics	Sample-dependent	Diagonal	0
Attenuation	0.02-2%	Gaussian	Likely
Detector Efficiency	0-0.3%, 1-2%	Full < 10 MeV	Likely, 0.5-1.0
FF Angular Distrib.	~0.1%	Gaussian	Likely, 0.75-1.0
Background	0.2 - >10%	Gaussian	Possible
Energy Unc.	1%, 1-2 ns	Arises from conv.	Technique-dependent
Neutron Flux	0%, >1%	Full-0.5	Technique-dependent
Multiple Scattering	0.2-1%	Gaussian	0.5-0.75
Impurit. in Sample	Sample-dependent	1.0-0.9	0.5-0.75
Dead Time	>0.1%	Full	0

<u>Established based on:</u>

- Literature on physics sub-processes
- discussions with experimenters/ evaluators

Earlier work related to creating templates of expected uncertainties

- P. Schillebeeckx, B.Becker, Y. Danon et al., Nucl. Data Sheets 113, p. 3054 (2012).
- F. Gunsing, P. Schillebeeckx and V. Semkova, IAEA Report INDC(NDS)-0647 (2013)
  →created EXFOR templates of information that ought to be provided for transmission experiments including but not limited to uncertainties and gave uncertainty procedure to provide information.

- P. Helgesson, H. Sjöstrand and D. Rochman, Nuclear Data Sheets 145, p. 1 (2017).
  → created tables of uncertainties for specific measurement types based on experimental data of a specific observable.

How can this template help us?

A template ***can be used by experimental community*** as check-list if all unc. are provided.

Unc. Source	Ab
Sample Mass	>
Counting Statistics	Sample-
Attenuation	0.
Detector Efficiency	1
FF Angular Distrib.	~(
Background	0.2
Energy Unc.	1%,
Neutron Flux	>
Multiple Scattering	0.
Impurit. in Sample	Sample-
Dead Time	>(

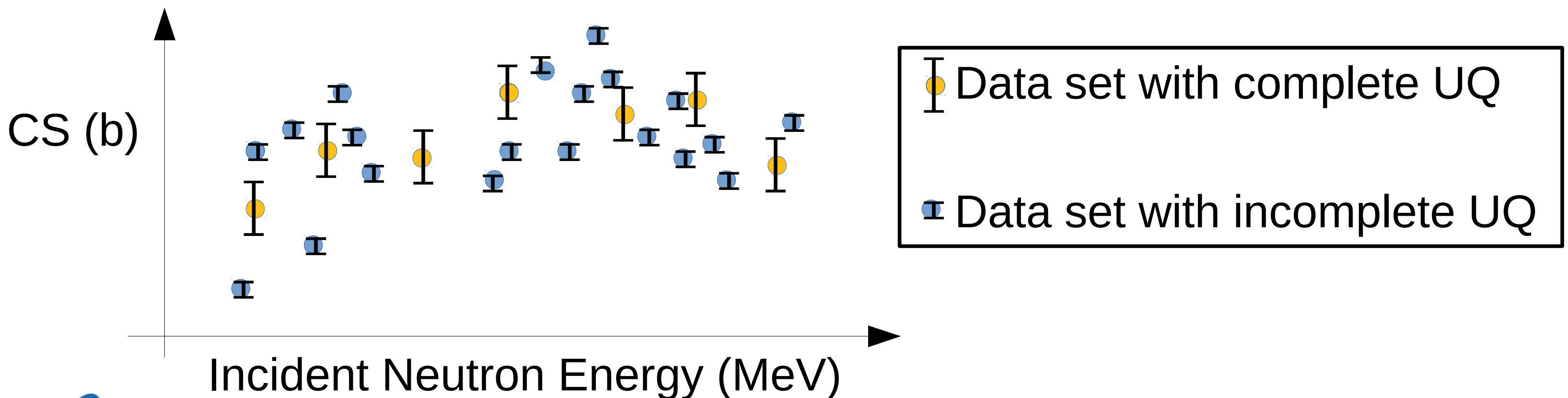
- ☑ Sample Mass
- ☑ Counting
- ☑ Background
- ❑ *OOPS!*

- Comparing unc. sources of a measurement to the template, makes it less likely that some unc. sources are forgotten.
- **Giving evaluators information needed makes the data easier to use with fewer assumptions made (i.e., more citations).**

Experimenters contributing to template help evaluators make better unc. assumptions.

- **Experimenters can give via this template guidelines to evaluators what are realistic estimates of missing uncertainties** (i.e., protect yourself from the assumptions we make otherwise :-))

- **By adding in missing uncertainties of all data set, a more realistic weight to all data is given compared with each other** (i.e., experimenters who do a good UQ are no longer punished compared to data with incomplete UQ.)



EXFOR compilers and editors have guidelines they can point to for information needed.

- Templates could become a guideline sanctioned by the community on what (uncertainty) information is needed from measurement to be maximally helpful for evaluations. **EXFOR compilers/ editors can point to this document to ask for information.**

- May lead to **more complete uncertainties in new EXFOR entries**.

- **More usable information for evaluators in journal publications** (editors might not always know what evaluators need)

Templates help evaluators to perform more complete UQ → more realistic eval. unc.

- Evaluators can make **more informed choices to fill in missing uncertainty** and correlation information.
- Leads to a **more balanced uncertainty quantification across different data sets.**
- **More complete uncertainties of future experiments**

LEADING TO more realistic evaluated uncertainties for nuclear data libraries.

Summary of templates we have so far

A first version of the (n,f) template is finished:

Unc. Source	Typical range	Correlations	Cor(Exp_1,Exp_2)
Sample Mass	> 1%	Full	Possible (same sample)
Counting Statistics	Sample-dependent	Diagonal	0
Attenuation	0.02-2%	Gaussian	Likely
Detector Efficiency	0-0.3%, 1-2%	Full < 10 MeV	Likely, 0.5-1.0
FF Angular Distrib.	~0.1%	Gaussian	Likely, 0.75-1.0
Background	0.2 - >10%	Gaussian	Possible
Energy Unc.	1%, 1-2 ns	Arises from conv.	Technique-dependent
Neutron Flux	0%, >1%	Full-0.5	Technique-dependent
Multiple Scattering	0.2-1%	Gaussian	0.5-0.75
Impurit. in Sample	Sample-dependent	1.0-0.9	0.5-0.75
Dead Time	>0.1%	Full	0

D. Neudecker, Nuclear Data Sheets, January 2020.

Session lead: D. Neudecker

The prompt, delayed and isomer gamma measurements template is close to be finished:

Unc. source	Range (%)	Correlations	Cor(Exp_1,Exp_2)
Mass	0.3	full	High
Isot. abundance	0.2	full	high
Self-absorption	0.7	full	high
Det. Eff.	2 (HPGe, Ge(Li)), 3 (NaI)	full	High if same facility, low
Nuclear Data	Take from library	Take from library	Take from library
Neutron source	1 (ASSOP), 2 (TOF), 2.6-3 (Gas/ solid target generator)		
Prompt gamma intensity	Modeling uncertainty	Method developed by A. Lewis	Code-dependent

Session lead: A. Lewis

The transmission template is in good shape:

Unc. source	Range (%)	Correlations	Cor(Exp_1,Exp_2)
Background	~ 3%	Full	Facility dependent
Normalization	0.25%	Full	Facility dependent
Statistical	If not given, do not use data	Diagonal	0
Resolution function	2.5 meV	Given with resolution function	Possible
Transmission geometry	?	Full	Possible
Sample thickness	0.2%	Full	Possible

Session lead: P. Schillebeeckx

The (n,g) template needs more work:

Unc. source	Range (%)	Correlations	Cor(Exp_1,Exp_2)
Normalization	0.3-2%	full	Possible
Background	3%	full	0
Attenuation	2-5%	?	?
Reaction and Fluence counts	Should be given, otherwise reject	diagonal	0
Nuclear Data	Take from library	Take from library	Take from library
Detector efficiency	Part of normalization	full	possible

Session lead: P. Schillebeeckx

The (n,xn) template is in good shape:

Uncertainty source	Magnitude (typ.)	Correlation
Counting	Similar exp.	diagonal
Background	0.2-3%	Gaussian
Mult. Scatt. & Att.	0-20%/ 0-2%	??
Detector Efficiency	2-7%	Gaussian
Angle center/spread	0.5/2.0 degrees	Gaussian?
Deadtime	0%	Full?
Nuclear Data	0.1-5%	ND libraries
trsl	2.5 ns	From Eq.
TOF length	1 mm	From Eq.

Session lead: R.C. Haight

The structure template needs some work, maybe published separately:

Unc. source	Range (%)	Correlations	Cor(Exp_1,Exp_2)
Energy resolution	1-5 keV (LaBr), 0.1-0.5 keV (Ge), 1 keV (Si), 5% (scinti))	See Lewis	See Lewis
Efficiency	See Lewis	See Lewis	See Lewis
Background	Could be high	measured	possible
trigger	Nuclear data used	Nuclear data used	Nuclear data used
Counting	Should be given	diagonal	0

Session lead: A. Sonzogni

The (n,cp) template is in good shape:

RANDOM ERRORS

Symbol	Magnitude (%)	Description
R_1	0.2	Exposure, waiting and counting times.
R_2	0.3 - 47.8	0.320-MeV gamma-ray yield.
R_3	0.7 - 1.5	Fission yield.
R_4	1 - 2	Extrapolation correction.
R_5	N - 3[a]	Background fission correction.
R_6	0.2 - 1.2	Background activation.
R_7	1.5	Geometric corrections.

SYSTEMATIC ERRORS

Symbol	Magnitude (%)	Description
S_1	0.1	^{51}Ti decay half life.
S_2	2	^{238}U content of monitor deposit.
S_3	0.2	^{51}V content of samples.
S_4	0.8	Uranium deposit thickness correction.
S_5	2.4	Gamma-ray counting efficiency.
S_6	1	^{51}Ti gamma-ray decay branch factor.
S_7	N[a]	Orientation of sample for counting.
S_8	2	Neutron source properties.
S_9	N[a]	Room-return fission events.
S_{10}	1.4 - 2.1	Neutron scattering corrections.
S_{11}	1.5	Geometric corrections.
S_{12}	0.5 - 19.5	Average neutron energy.

[a] N = Negligible

From D.L. Smith et al., ANL Report, ANL/NDM-85 (1984).

Session lead: D.L. Smith

The PFNS template is in good shape:

Unc. Source	Shape	Clean Ratio	Ratio Calibration
Counting	Similar exp.	Similar exp. both	Similar exp. both
Background	0.2-3%	0.2-2%	0.2-2% both
Mult. Scatt. & Att.	0-20%/ 0-2%	0-2%/ 0-0.2%	0-2%/ 0-0.2% both
Detector Efficiency	2-7%	drops out	$PFNS_R$ unc.
Angular distribution	0.1%	0.1% both	0.1% both
Deadtime	0%	0%	0%
Nuclear Data	0.1-5%	ND libraries	ND libraries
trsl	2.5 ns	2.5 ns both	2.5 ns both
TOF length	1 mm	1 mm both	1 mm both

Session lead: D. Neudecker

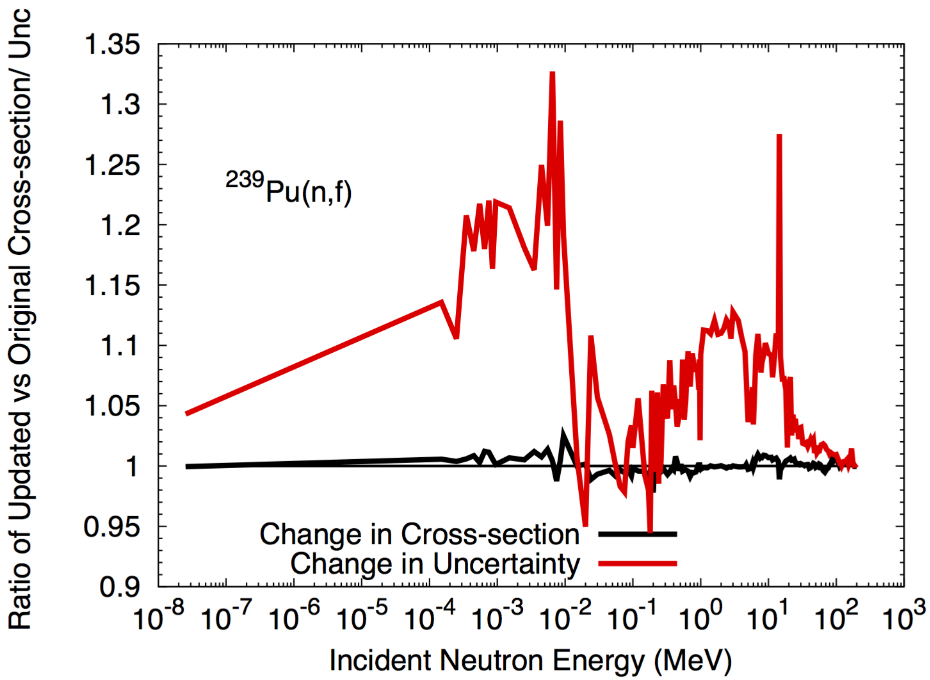
The FY template was just begun:

- Here, we just started a discussion on what evaluators need and experimentalists can provide.
- Different measurement techniques were listed.
- This is a work in progress as new FY measurements and evaluations are underway.
- However, additional information could be provided at recent fission yield conference.

Session lead: A. Sonzogni

Impact of applying such a template

^{239}Pu(n,f) cov. in the Neutron Data Standards database were updated with the template:



Benchmark	C/E k_{eff} VIII.0	C/E k_{eff} upd. ^{239}Pu(n,f) cs	Δ k_{eff} (pcm)
PMF001	0.99981 (8)	0.99892 (8)	-89
PMF002	1.00147 (8)	1.00075 (8)	-72
PMF006	0.99978 (10)	0.99869 (10)	-109
PMI002	1.00393 (7)	1.00316 (7)	-77
PST034.10	0.99652 (16)	0.99653(22)	1

Updating these covariances with the template impacted:

- **evaluated mean values,**
- **covariances and**
- **benchmark calculations!**

D. Neudecker, niffteTPC et al., Nuclear Data Sheets forthcoming.

Outlook:

- Short-term goal: **publish finalized templates** of several observables as journal article(s) and on the homepage of the NNDC **as a resource for evaluators, experimentalists, EXFOR compilers and editors for better uncertainty quantification of experimental data**.

- Long-term goal: **Engage international community** either through a WPEC subgroup or IAEA working group if there is enough interest.

Thank you for your attention!