Los Alamos NATIONAL LABORATORY

Covariance testing and missing covariances

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CSEWG November 2022

LA-UR-22-31474

Thanks to EUCLID folks!

In January 2023, covariances should be provided for VIII.1.

Please, counter-check your covariances before release!

Mathematical constraints:

- Covariances must be positive-definite (no eigenvalues <0),
- Covariances for same observable must be symmetric (symmetry assumed by format),
- Diagonal(correlation matrix) must be 1,
- Check constraints on PFNS (rows/columns sum to 0), and angular distributions (no |unc| > 1), etc.
- $-1 \leq cor(x_1, x_2) \leq 1$

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Counter-checking if uncertainties are in reasonable range:

- Don Smith's expert judgment estimate,
- Reactions often measured relative to standard should not have smaller unc. than standard unc.,
- Bounds based on templates of expected measurement uncertainties,
- Physical Unc. Bounds test for fission observables,
- See D. Neudecker, LA-UR-21-32171.

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These are not strict bounds BUT reasoning should be given if your uncertainties are distinctly smaller/ larger.

Just a reminder: Don Smith's expert judgment lower bounds.

Table I: 1-σ lower limits for uncertainties of various neutron-induced nuclear-data observables are provided based on Ref. [8].

Observable	Lower Uncertainty Limit (%)
Total Cross Section	1.0
Elastic Cross Section	2.0
(n,γ) Cross Section	2.0
Inelastic Cross Section	3.0
Fission Cross Section	1.0
(n,p) Cross Section	3.0
(n,α) Cross Section	3.0
Other Cross Section	3.0
Average Prompt/ Delayed Neutron Multiplicity	1.0

BNL is recovering original document.

Table II: 1-σ lower limits for evaluated PFNS uncertainties are provided based on expert judgment.

Outgoing-neutron Energy (MeV)	Lower Uncertainty Limit (%)
0.01	10
1.0	1
5.0	3
10.0	20

Well, these are from me.

From D. Neudecker, LA-UR-21-32171.

Just a reminder: lower bounds from 2018 standards.

Table III: This table shows which standard observables are frequently used as monitors for measurements of various neutron-induced nuclear-data observables. "CS" is short for cross section, while the variable $\overline{\nu}_t$ and $\overline{\nu}_p$ denote the average total- or prompt-fission neutron multiplicity. PFNS stands for prompt-fission neutron spectrum.

Observable	Standards used for Limit
Total Cross Section	None
Elastic Cross Section	^{1}H(n,n) CS (left-hand side of Fig. 2), C(n,n) CS ($\sim$ 0.7%)
(n,γ) Cross Section	None
Inelastic Cross Section	^{1}H(n,n) CS (left-hand side of Fig. 2), C(n,n) CS ($\sim$ 0.7%)
Fission Cross Section	^{235}U(n,f) CS (left-hand side of Fig. 2)
(n,p) Cross Section	None
(n,α) Cross Section	None
Other Cross Section	None
$\overline{\nu}_t$ and $\overline{\nu}_p$	^{252}Cf(0,f) $\overline{\nu}_t$ (0.43%)
PFNS	^{252}Cf(0,f) PFNS (right-hand side of Fig. 2)

From D. Neudecker, LA-UR-21-32171.

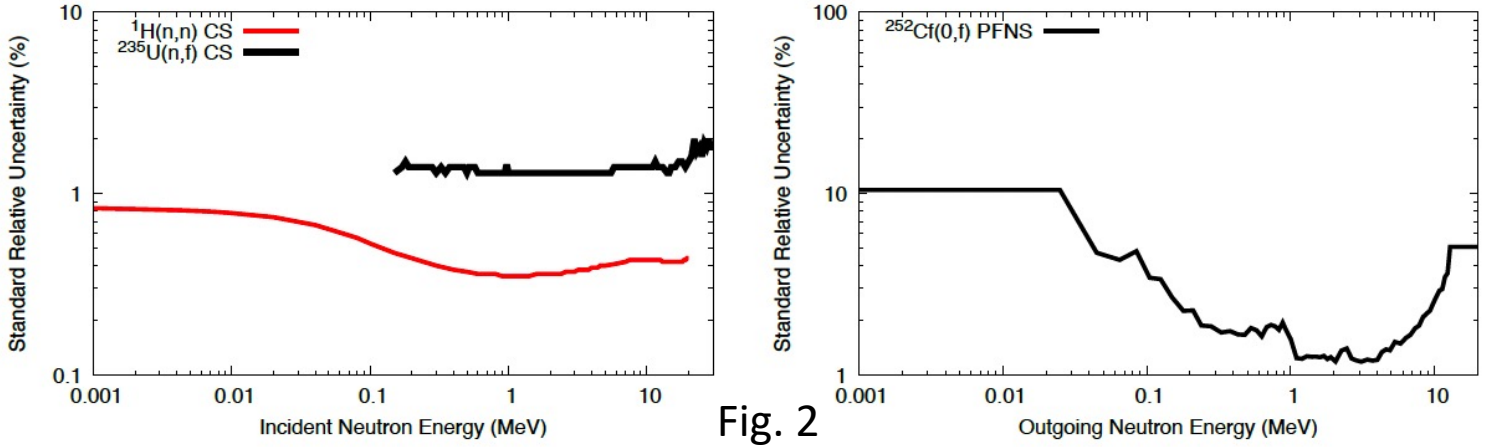
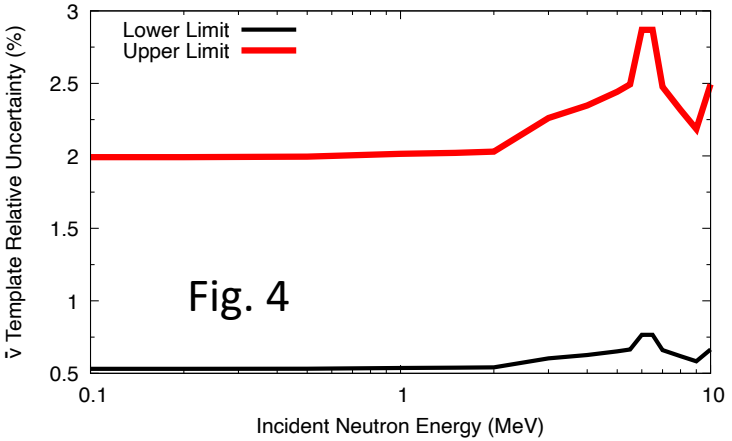


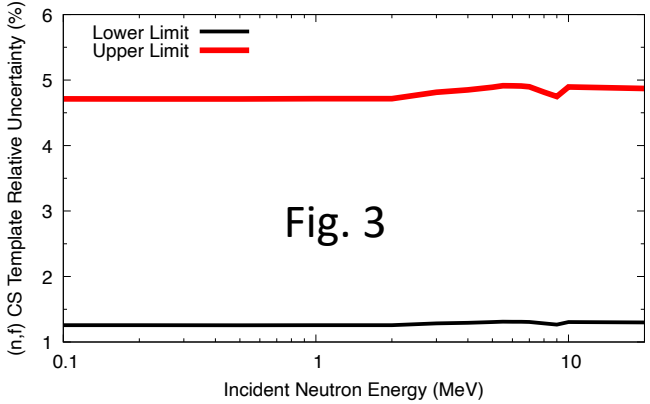
Fig. 2

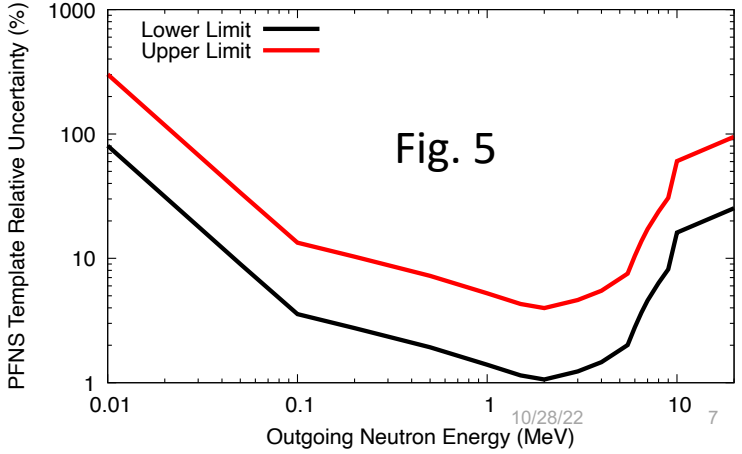
Lower and upper bounds from templates.

Table V: Upper and lower limits (1-σ) for uncertainties of various neutron-induced nuclear-data observables are listed. These limits were estimated based on templates of expected measurement uncertainties [9,12].

Observable	Lower Uncertainty Limit (%)	Upper Uncertainty Limit (%)
Total Cross Section	0.9	3.4
Elastic Cross Section	3.0	18.2
(n,γ) Cross Section	1.7	6.4
Inelastic Cross Section	3.9 (discrete), 8.1 (continuum)	23.2 (discrete), 48.3 (continuum)
Fission Cross Section	Fig. 3	Fig. 3
(n,p) Cross Section	3.0	11.2
(n,α) Cross Section	3.0	11.2
Other Cross Section	None	None
$\overline{\nu}_p$ and $\overline{\nu}_t$	Fig. 4	Fig. 4
PFNS	Fig. 5	Fig. 5

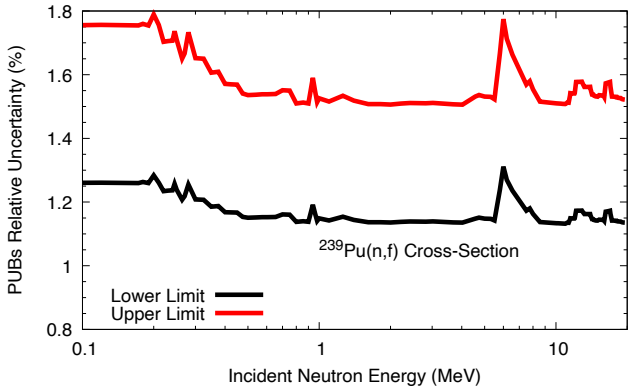


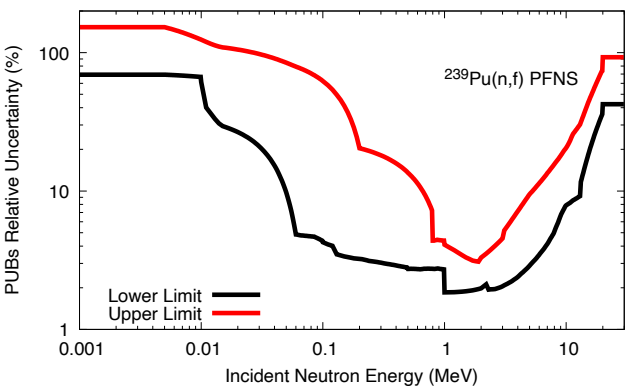


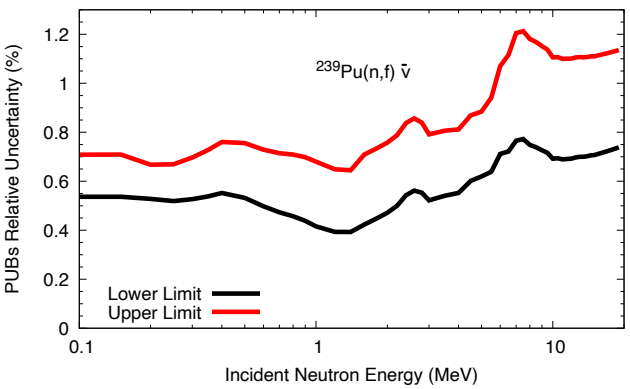


From D. Neudecker, LA-UR-21-32171.

Lower and upper PUBs bounds from templates.







PUBS (Physical Uncertainty Bounds) by Vaughan and Preston estimates bounds in a composite physics system by assigning uncertainties on each physics sub-process.
I estimated here unc. on physics sub-processes appearing in ^{239}Pu PFNS, (n,f), and nu-bar exp. Estimates always depend on the current state of the experimental database.

Bounds on unc. will evolve as we gain a better physics understanding of the observables.

From D. Neudecker, LA-UR-21-32171, D. Neudecker et al. EPJ-N **6**, 19 (2020)

Covariances that are missing for entire isotopes in VIII.0 were identified by means of sensitivities to integral responses.

Z number, Element	A
7, N	14
8, O	17, 18
16, S	32, 33, 34
20, Ca	42, 43, 44, 48
23, V	50, 51
26, Fe	**54**, 57, 58
27, Co	59
28, Ni	61, 62, 64
31, Ga	69, 71
40, Zn	64, 66, 67, 68, 70
41, Nb	93
47, Ag	107
48, Cd	106, 108, 110, 111, 112, 113, 114, 116
50, Sn	112, 114, 115, 116, 117, 118, 119, 120, 122, 124
51, Sb	121, 123
56, Ba	130, 132, 134, 135, 136, 137, 138
72, Hf	174, 176, 177, 178, 179, 180
73, Ta	181
74, W	**182**, **186**
75, Re	185, 187

I looked for covariances for isotopes that appear non-negligibly in:

- ICSBEP k_{eff} values,
- LLNL pulsed spheres,
- Subcrit assemblies,
- Reaction rates in crits,
- Reactivity coefficients in crits,
- Spectra in crits,
- Rossi-alpha in crits,
- beta-eff in crits.

EUCLID sensitivities were used for that aim (Alwin et al., LA-UR-22-21534)

Summary

- ***Preliminary covariances are due January 2023 to allow enough time for testing!***
- Please counter-check your covariances for maths constraints and if uncertainties are reasonable in size.
- Some covariances are missing for entire isotopes in VIII.0 that appear in our day-to-day validation experiments!!

Thank you for your attention.

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