# Covariance testing and update on $^{239}$Pu and $^{235}$U PFNS covariances

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Thanks to: Roberto Capote, Mark Chadwick, Nathan Gibson, Patrick Talou and Andrej Trkov.

# These covariances changed from VIII.0 -> VIII.1beta1:

- **Light elements: 003_Li_006,004_Be_009, 005_B_010,** *008_O_016*, **009_F_019**
- **Fe: 026_Fe_054, 026_Fe_056**
- **Rh: 045_Rh_103**
- **Ce: 058_Ce_140, 058_Ce_142**
- **Dy:  Dy_156, Dy_158, Dy_160, Dy_161, Dy_162, Dy_163, Dy_164**
- **Er: 068_Er_168**
- **U: U_234,** *U_235*, **U_236,** *U_238*
- **Pu:** *094_Pu_239*
- *Red isotopes will not be covered here.*

List from Nathan Gibson and Patrick Talou.

# How did we get and test the covariances?

- Nathan Gibson processed MF=31,32,33 with NJOY2016,
- They were processed onto a LANL-defined 51-energy grid, and put into json file.

- The were tested via Denise Neudecker's ``CovVal'' code for:
  - Maths properties: positive semi-definite, symmetry, |cor| <=1
  - Physics properties: checking if relative uncertainties are within
    - Expert judgment limits by Don Smith,
    - Template limits,
    - Standards limit,
    - PUBs (fission only).

CovVal testing is documented in Neudecker, "Definitions on Testing Whether Evaluated Nuclear Data Relative Uncertainties are Realistic in Size", LA-UR-21-32171 (2021).
**Comment: I also have that for all ENDF/B-VIII.0 covariances if there is interest.**

# Mathematical checks are performed.

| Isotope | Positive semi-definite | Symmetric | \|cor\| <= 1 |
|---------|------------------------|-----------|--------------|
| Li6 | Y | Y | Failed |
| Be9 | Y | Y | Failed |
| B10 | Y | Y | Failed |
| F19 | Y | Y | Failed |
| Fe54 | Y | Y | Y |
| Fe56 | Y | Y | Failed |
| Rh103 | Y | Y | Failed |
| Ce140 | Y | Y | Y |
| Ce142 | Y | Y | Y |
| Dy156 | Y | Y | Y |

| Isotope | Positive semi-definite | Symmetric | \|cor\| <= 1 |
|---------|------------------------|-----------|--------------|
| Dy158 | Y | Y | Failed |
| Dy160 | Y | Y | Failed |
| Dy161 | Y | Y | Failed |
| Dy162 | Y | Y | Failed |
| Dy163 | Y | Y | Y |
| Dy164 | Y | Y | Failed |
| Er168 | Y | Y | Y |
| U234 | Y | Y | Failed |
| U236 | Y | Y | Failed |
|  |  |  |  |

Comment: I wonder if processing onto 51-energy grid leads to small values >0 for |cor|-1.

# Possible "physics issues" in covariances.



**Li006 elasticcrossSection**

**Be009 elasticcrossSection**

**B010 elasticcrossSection**
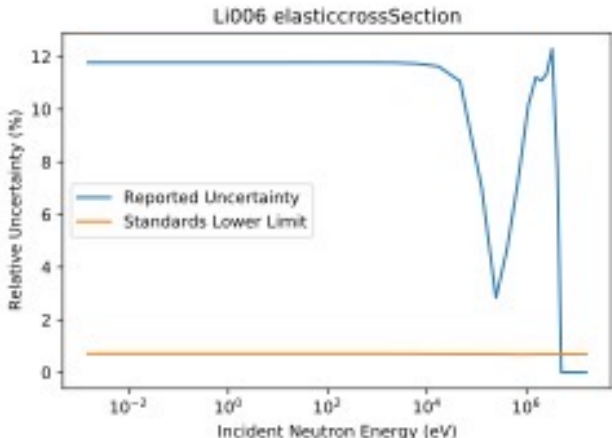
Could the bins of uncertainties end too low in energy for $^6$Li(n,el) cs covariances?
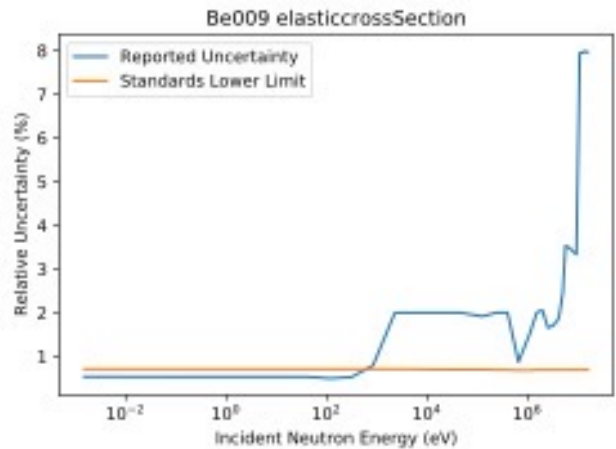
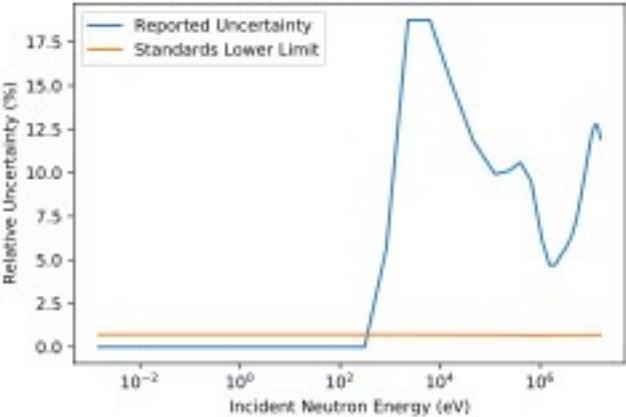Is the $^9$Be(n,el) cs uncertainty realistic in size? It is below the $^1$H(n,el) cs unc.
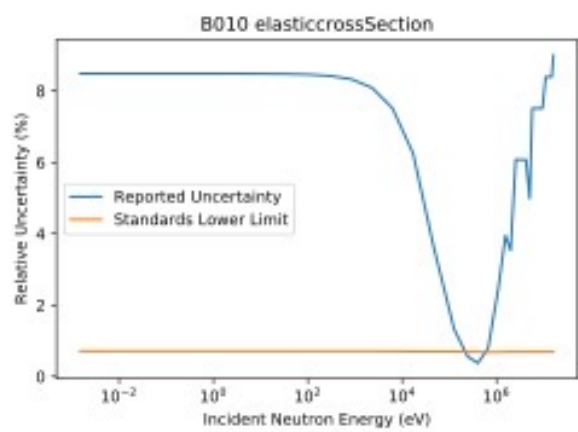
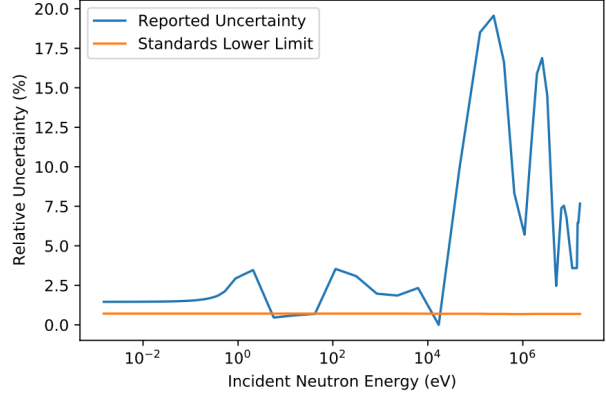Is the $^{10}$B(n,el) cs uncertainty realistic in size? Do we know it better than the C(n, n) cs?

# Possible "physics issues" in covariances.



Why is the $^{54}$Fe(n,el) uncertainty zero below 100 eV? Is there an issue in formatting, data, or processing?

Is the $^{103}$Rh(n,el) cs uncertainty realistic in size? Do we know it better than the C(n, n) cs?
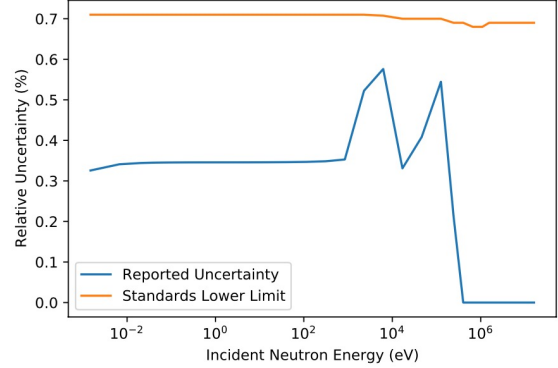
Is the $^{140}$Ce(n,el) cs uncertainty realistic in size? Do we really know it better than the $^{1}$H(n,n) or C(n, n) cs? Also, why is it zero above 100 keV?

# Dy covariances: zero uncertainties for some fast cross sections. Processing, missing data, or formatting issue?
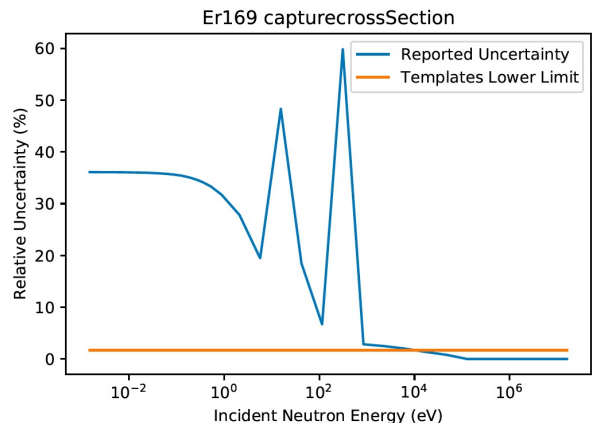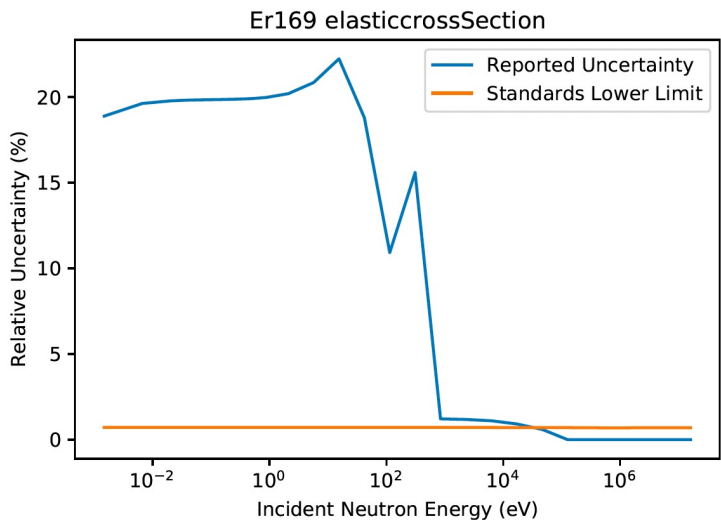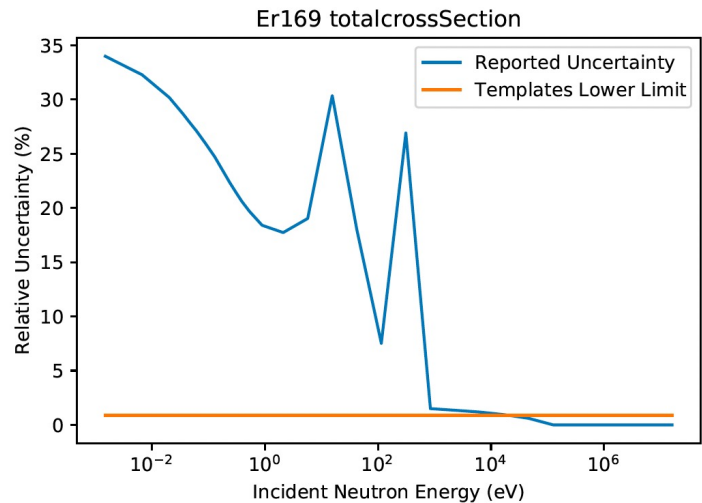


Dy156 elasticcrossSection



Dy164 capturecrossSection



Dy164 totalcrossSection
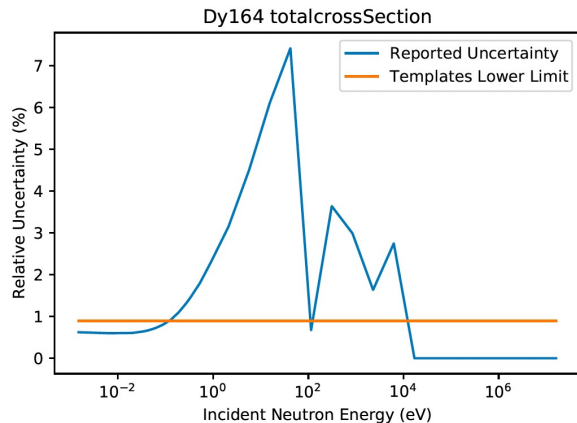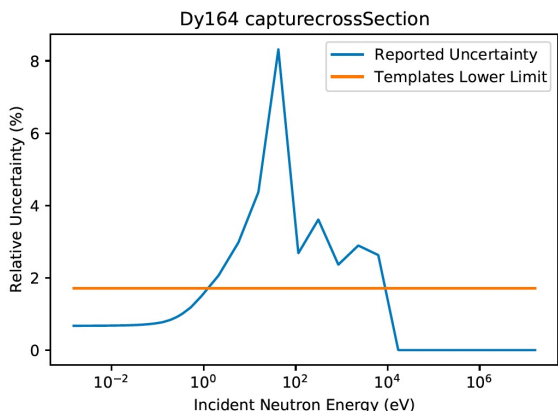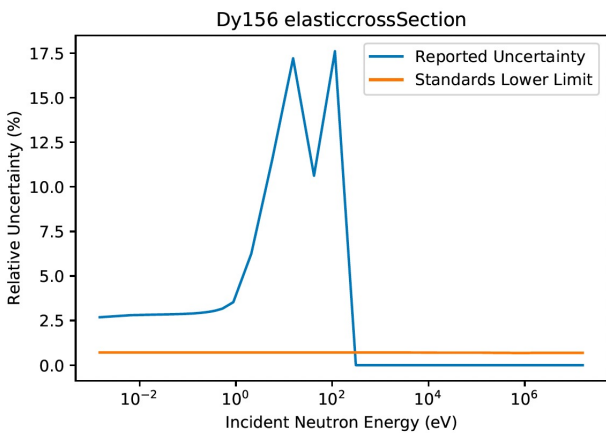
Why is the $^{156,158}$Dy(n,el) uncertainty zero above 100 eV? Is there an issue in formatting, data, or processing?

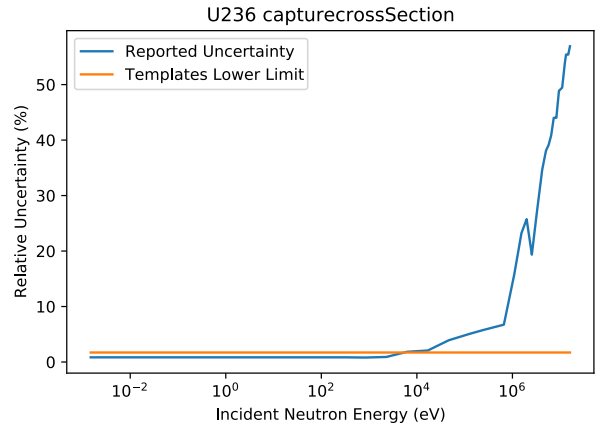For $^{160-164}$Dy(n,el) zero uncertainties for E >1-10 keV for:
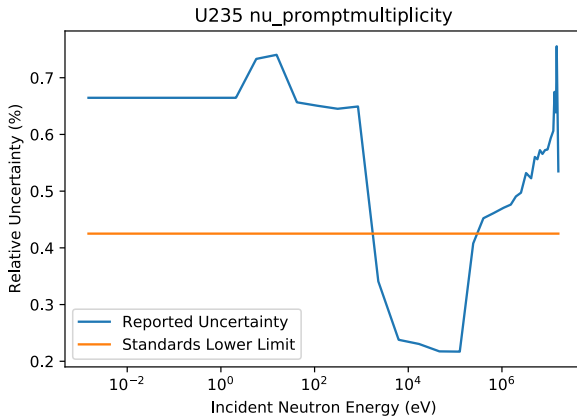
- (n,tot),
- (n,el),
- Capture.

# <sup>169</sup>Er: zero uncertainties for total, elastic and capture cross sections. Processing, missing data, or formatting issue?
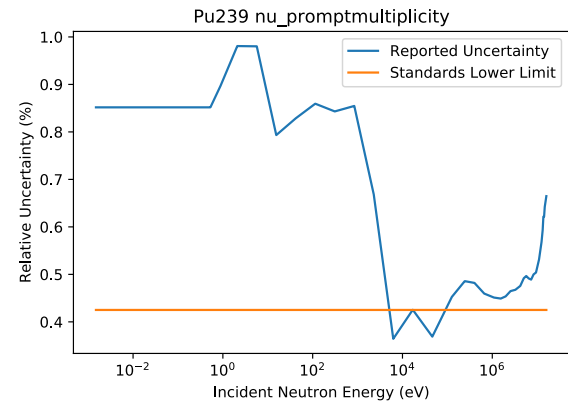
# Possible "physics issues" in covariances.



U236 capturecrossSection



U235 nu_promptmultiplicity



Pu239 nu_promptmultiplicity

Why is the $^{236}$U(n,g) cs uncertainty zero below 1 keV? Is there an issue in formatting, data, or processing?

The URR $^{235}$U(n,f) nu-bar uncertainty is below the $^{252}$Cf(sf) standard.

The URR $^{239}$Pu(n,f) nu-bar uncertainty is below the $^{252}$Cf(sf) standard.

# Short update on $^{235}$U and $^{239}$Pu PFNS covariances.

- After correcting a formatting and normalization issue in PFNS covariances, the mean energy uncertainties changed significantly.

- Thanks to Andrej, Nathan, Patrick, and Roberto in helping me figuring out my issue.

- The corrected PFNS covariances are in ENDF/B-VIII.1beta1.

# $^{235}$U PFNS uncertainties as given ENDF/B-VIII.1beta1



$E_{inc}$ = 1.5 MeV
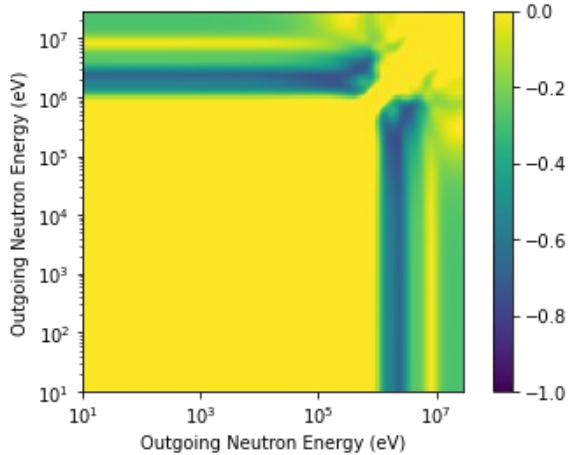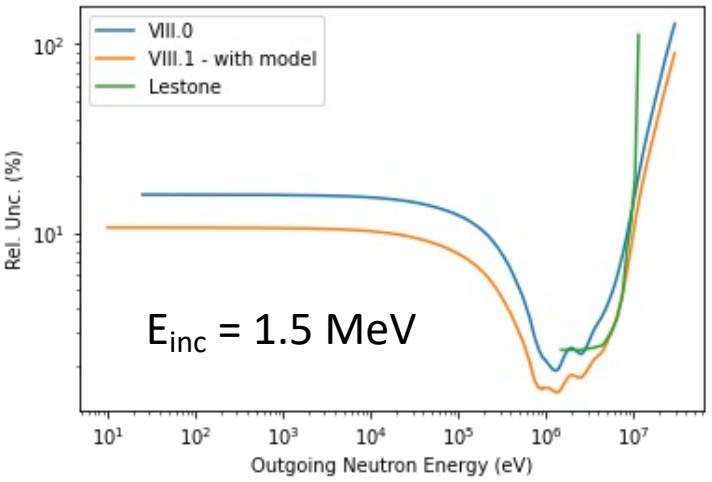


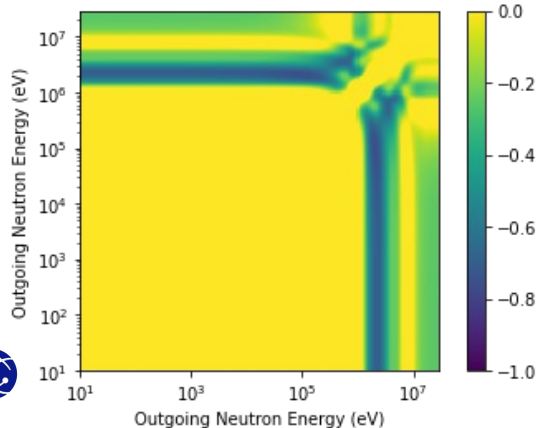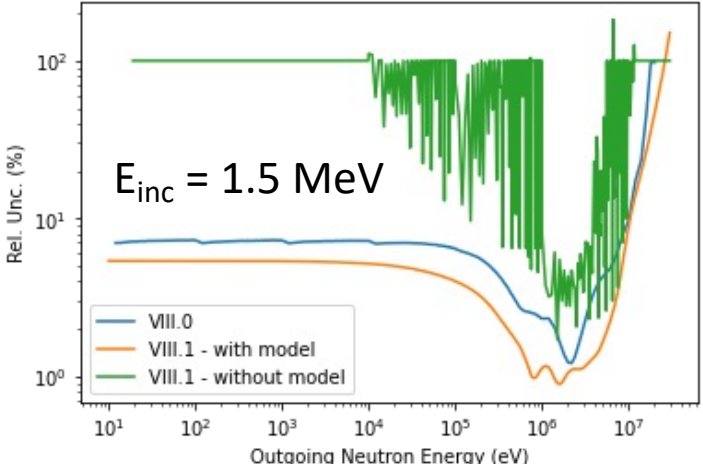| $E_{inc}$ (MeV) | <PFNS> unc. (keV) |
|---|---|
| 0.5-5 | 24 |
| 5-7 | 57 |
| 7-12 | 39 |
| 12-30 | 43 |

Chi-Nu and Lestone data inform PFNS.

Chi-Nu data inform PFNS.

CEA PFNS data coming soon reducing uncertainties further.

# $^{239}$Pu PFNS uncertainties as given ENDF/B-VIII.1beta1



$E_{inc}$ = 1.5 MeV

CEA and Knitter data inform PFNS.

Chi-Nu, CEA and Lestone data inform PFNS.

| $E_{inc}$ (MeV) | <PFNS> unc. (keV) |
|---|---|
| 0.25-0.75 | 37 |
| 0.75-3 | 15 |
| 3-5 | 33 |
| 5-6.5 | 33 |
| 6.5-13 | 34 |
| 13-30 | 40 |

Chi-Nu and CEA data inform PFNS.

# Acknowledgements