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Title: Validating Evaluated Uncertainties of the Neutron-induced Fission Cross-sections by the Neutron Standards Data Project in ENDF/B-VIII.0 and Summarizing the 239Pu PFNS Evaluation of ENDF/B-VIII.0

Author(s): Neudecker, Denise

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Validating Evaluated Uncertainties of the Neutron-induced Fission Cross-sections by the Neutron Standards Data Project in ENDF/B-VIII.0 and Summarizing the ^{239}Pu PFNS Evaluation of ENDF/B-VIII.0

Denise Neudecker

WPEC, SG44 May 14-16, 2018

Abstract

The ^{239}Pu, ^{238}U and ^{235}U neutron-induced fission cross-sections and associated uncertainties in ENDF/B-VIII.0 [1] were provided by the "Neutron Standards Data" [2] project coordinated by the IAEA. The evaluated uncertainties increased in some energy ranges by a factor of 2 or more leading to significantly increased uncertainties on the criticality of specific critical assemblies [3]. This talk will highlight reasons why this increase of uncertainty is justified. The talk will also introduce the "Physical Uncertainty Boundary" [4] method which has been used to validate the size of these fission cross-section uncertainties independently.

This talk will cover as a second topic the evaluation of the ^{239}Pu prompt fission neutron spectrum (PFNS) which is considered in ENDF/B-VIII.0.

[1] D.A. Brown et al., Nuclear Data Sheets Vol. 148, p. 1 (2018).
[2] A.D. Carlson et al., Nuclear Data Sheets Vol. 148, p. 143 (2018).
[3] M.B. Chadwick et al., Nuclear Data Sheets Vol. 148, p. 189 (2018).
[4] D.E. Vaughan et al., Los Alamos National Laboratory Report LA-UR-14-20441 (2014).

Part 1: Validating Evaluated Uncertainties of the ^{239}Pu(n,f) Cross-Sections by the Neutron Standards Data Project in ENDF/B-VIII.0

Denise Neudecker

Thanks to: B. Hejnal, F. Tovesson, D.L. Smith, M.C. White, D. Vaughan, R. Capote, TPC collaboration (K. Schmitt, N. Bowden, L. Snyder, R. Casperson, N. Walsh, S. Sangiorgio, W. Younes)

Validating increased evaluated uncertainties of the ^{239}Pu(n,f) cs in ENDF/B-VIII.0

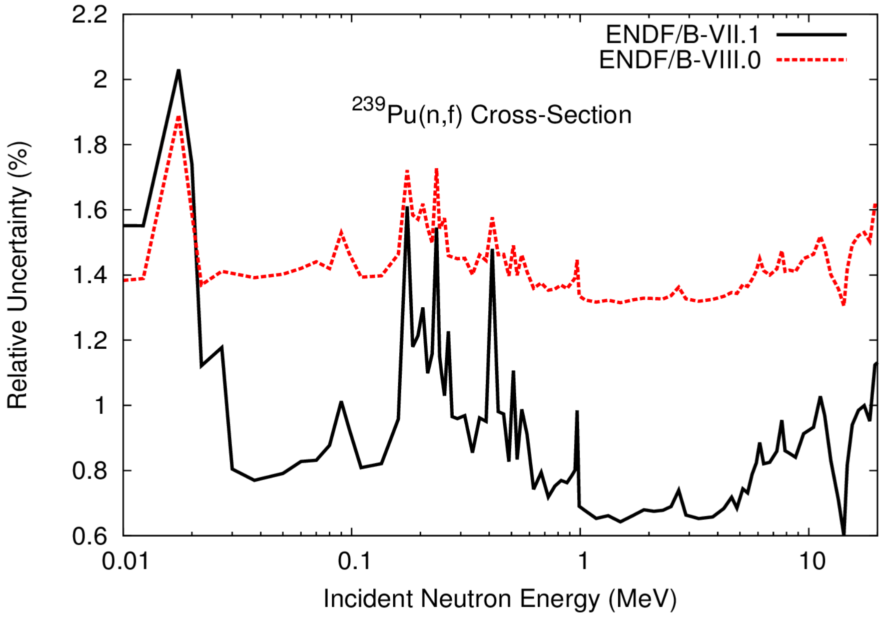
- Why should we validate increased ^{239}Pu(n,f) cs uncertainties?

- Are there good reasons to increase the ^{239}Pu(n,f) cs uncertainties from ENDF/B-VII.1 to ENDF/B-VIII.0?

- How can we validate evaluated ^{239}Pu(n,f) cs uncertainties in ENDF/B-VIII.0?

Why should we validate increased $^{239}Pu(n,f)$ cs uncertainties?

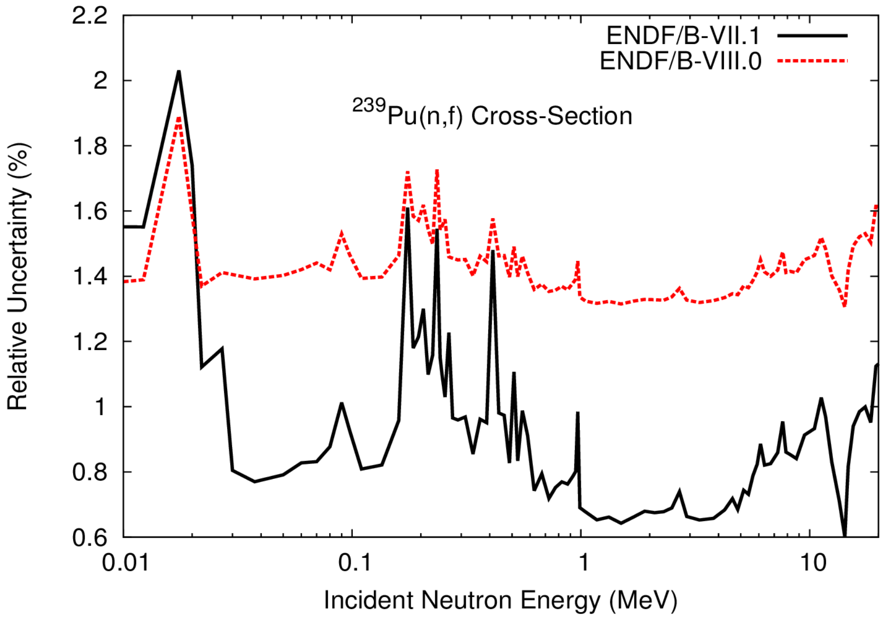
^{239}Pu(n,f) cross-section unc. were increased for ENDF/B-VIII.0 by expert judgment



^{239}Pu(n,f) VII.1 unc. were considered to be unrealistically small. Analysis of unknown systematic unc. by the standards evaluation committee (A. Carlson et al., NDS (2018)) led to increased unc.

^{239}Pu(n,f) cs strongly impacts k_{eff} of Pu-assemblies. Jezebel k_{eff} unc. due to (n,f) cs increased from 331 pcm to 903 pcm.

^{239}Pu(n,f) cross-section unc. were increased for ENDF/B-VIII.0 by expert judgment



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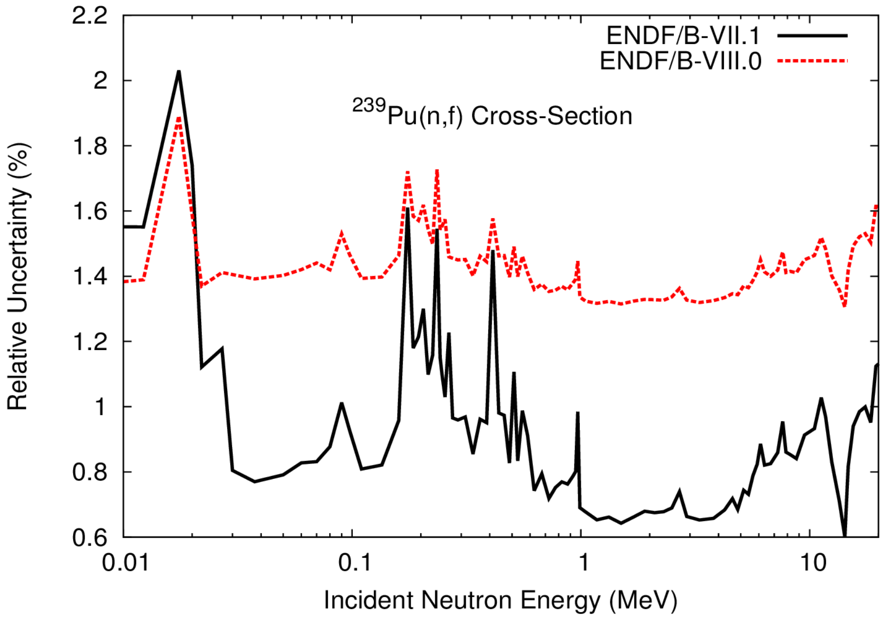
Unc. are underestimated because:

- Unrecognized unc. across many data sets due to using same methods.
- Missing cross-correlations between experimental data.
- Missing uncertainty sources for single experimental data sets.

Are there good reasons to increase the ^{239}Pu(n,f) cs uncertainties from ENDF/B-VII.1 to ENDF/B-VIII.0?

Example 2: ^{239}Pu(n,f) cross-section unc. were increased for ENDF/B-VIII.0 by expert judgment



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Unc. are underestimated because:

- Unrecognized unc. across many data sets due to using same methods.
- Missing cross-correlations between experimental data.
- Missing uncertainty sources for single experimental data sets.

We investigate those via a template.

A template of unc. typically encountered in fission cross-section measurements (LA-UR-17-29963):

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

The template distinguishes between different measurement types.

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

This template can help evaluators and experimentalists estimate experimental unc.

- Templates were, e.g., developed for providing EXFOR data and uncertainties in the resonance region in F. Gunsing et al., INDC(NDS)-0647 (2013).
- Can provide guidelines for experimentalists **what uncertainties need to be provided for an evaluation**.
- Helps evaluators **pinpoint cross-correlations between other experiments** if the same template is used consistently.
- Helps evaluators **pinpoint missing experimental unc. of single experimental data sets.**

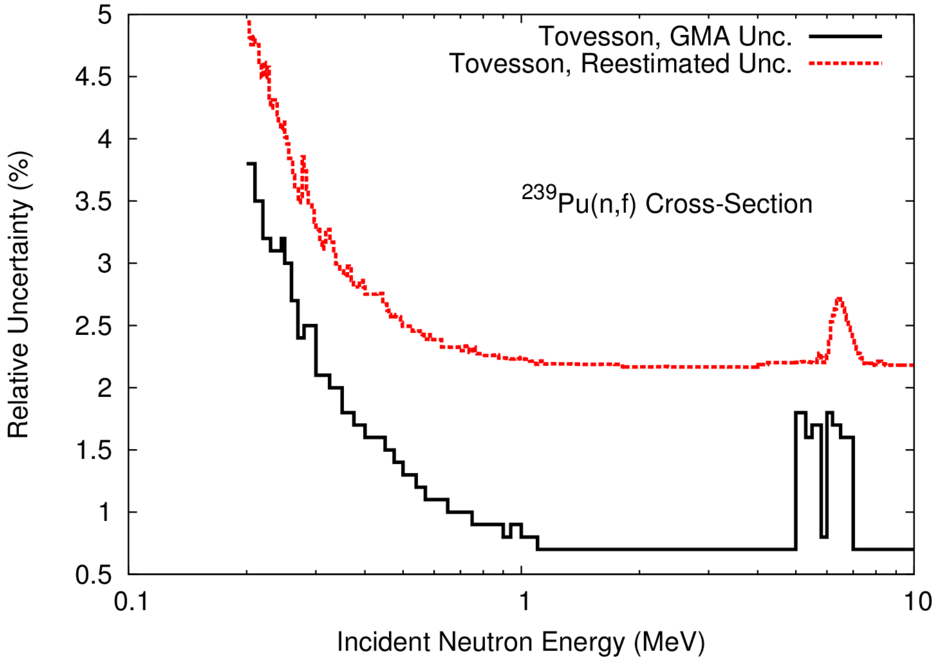
Applied that to data in the GMA database.

Case 1, the absolute ^{239}Pu(n,f)/^{235}U(n,f) exp. with lowest unc. in the GMA database

Data Set	Data Type	Min δ	Max δ	Min E	Max E	EXFOR #
611	absolute	1.0	1.0	1.45E+01	1.45E+01	
644	absolute	2.0	2.0	1.45E+01	1.45E+01	30634
615	absolute	2.1	2.1	5.00E+00	5.00E+00	
1038	absolute	2.3	7.7	1.00E+00	5.50E+00	30670
640	absolute	2.4	3.1	1.50E-01	9.60E-01	10314
620	absolute	2.8	6.6	3.00E-02	9.80E-01	20567
⋮						
8002	ratio absolute ^{235}U(n,f)	0.7	3.8	2.00E-01	1.30E+01	14271
602	ratio absolute ^{235}U(n,f)	0.8	6.8	2.53E-08	1.00E+01	
654	ratio absolute ^{235}U(n,f)	1.0	5.7	2.40E-02	7.50E+00	
685	ratio absolute ^{235}U(n,f)	1.1	1.1	1.45E+01	1.45E+01	
653	ratio absolute ^{235}U(n,f)	1.2	6.9	1.20E-01	7.00E+00	40824
1014	ratio absolute ^{235}U(n,f)	1.3	1.6	8.50E-01	6.00E+01	13801
600	ratio absolute ^{235}U(n,f)	1.7	27.4	8.50E-04	3.00E+01	10562
605	ratio absolute ^{235}U(n,f)	1.7	15.3	5.50E-03	1.00E+00	20363
608	ratio absolute ^{235}U(n,f)	2.0	12.6	4.50E-02	5.00E-01	21463
609	ratio absolute ^{235}U(n,f)	2.0	2.1	1.00E+00	1.40E+01	21195
631	ratio absolute ^{235}U(n,f)	2.1	2.1	2.53E-08	1.50E-01	
1012	ratio absolute ^{235}U(n,f)	2.1	5.8	5.70E-01	2.00E+02	41455
⋮						
630	ratio shape ^{10}B(n,α)	2.3	5.0	2.53E-08	1.50E-01	

Sample mass unc. should be ~1.5% questionably small!!!

E.g., a normalization uncertainty was overlooked for Tovesson et al. ^{239}Pu(n,f)/^{235}U(n,f)



This is the data set related to the ^{239}Pu(n,f) cross-section in GMA with the lowest uncertainty!!!

→ We would need a measurement to the 0.7% level to strongly impact the GMA evaluation UNLESS WE UPDATE THE DATABASE!!!!!!!!!!!

Case 2: the absolute measurement with lowest unc. in GMA is strongly correlated with 3 other GMA exp.

This measurement is part of a series and correlated with 615-617.

Also, sample mass unc. Should be 1%, questionably small.

Data Set	Data Type	Min δ	Max δ	Min E	Max E	EXFOR #
611	absolute	1.0	1.0	1.45E+01	1.45E+01	
644	absolute	2.0	2.0	1.45E+01	1.45E+01	30634
615	absolute	2.1	2.1	5.00E+00	5.00E+00	
1038	absolute	2.3	7.7	1.00E+00	5.50E+00	30670
640	absolute	2.4	3.1	1.50E-01	9.60E-01	10314
620	absolute	2.8	6.6	3.00E-02	9.80E-01	20567
⋮						
8002	ratio absolute $^{235}U(n,f)$	0.7	3.8	2.00E-01	1.30E+01	14271
602	ratio absolute $^{235}U(n,f)$	0.8	6.8	2.53E-08	1.00E+01	
654	ratio absolute $^{235}U(n,f)$	1.0	5.7	2.40E-02	7.50E+00	
685	ratio absolute $^{235}U(n,f)$	1.1	1.1	1.45E+01	1.45E+01	
653	ratio absolute $^{235}U(n,f)$	1.2	6.9	1.20E-01	7.00E+00	40824
1014	ratio absolute $^{235}U(n,f)$	1.3	1.6	8.50E-01	6.00E+01	13801
600	ratio absolute $^{235}U(n,f)$	1.7	27.4	8.50E-04	3.00E+01	10562
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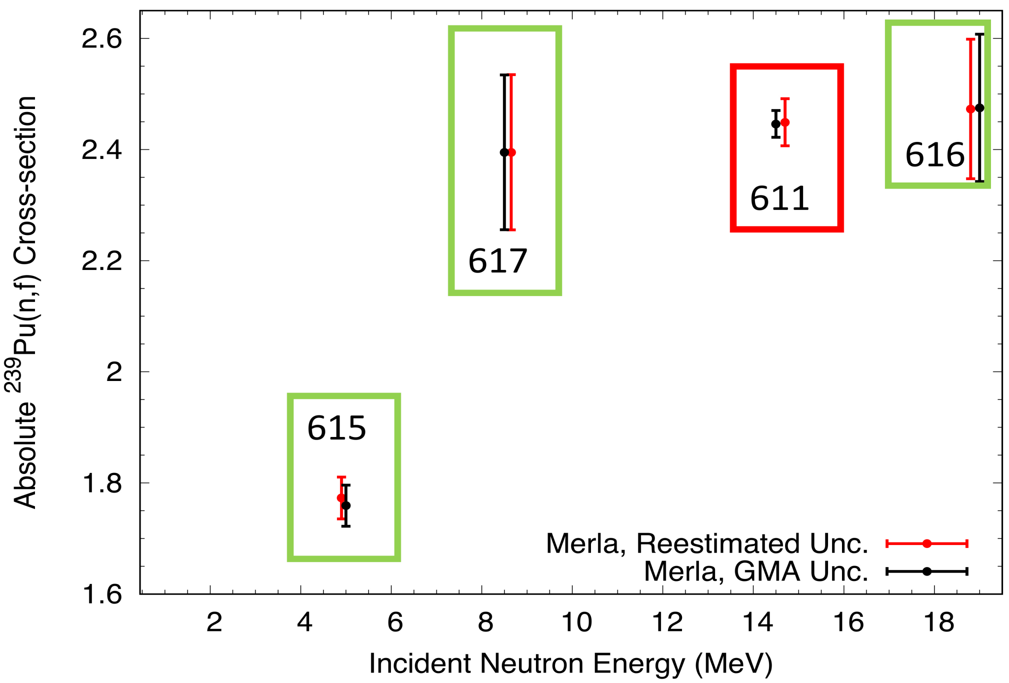
⋮						
630	ratio shape $^{10}B(n,\alpha)$	2.3	5.0	2.53E-08	1.50E-01	

Case 2: the absolute measurement with lowest unc. in GMA has too small unc. & is strongly correlated



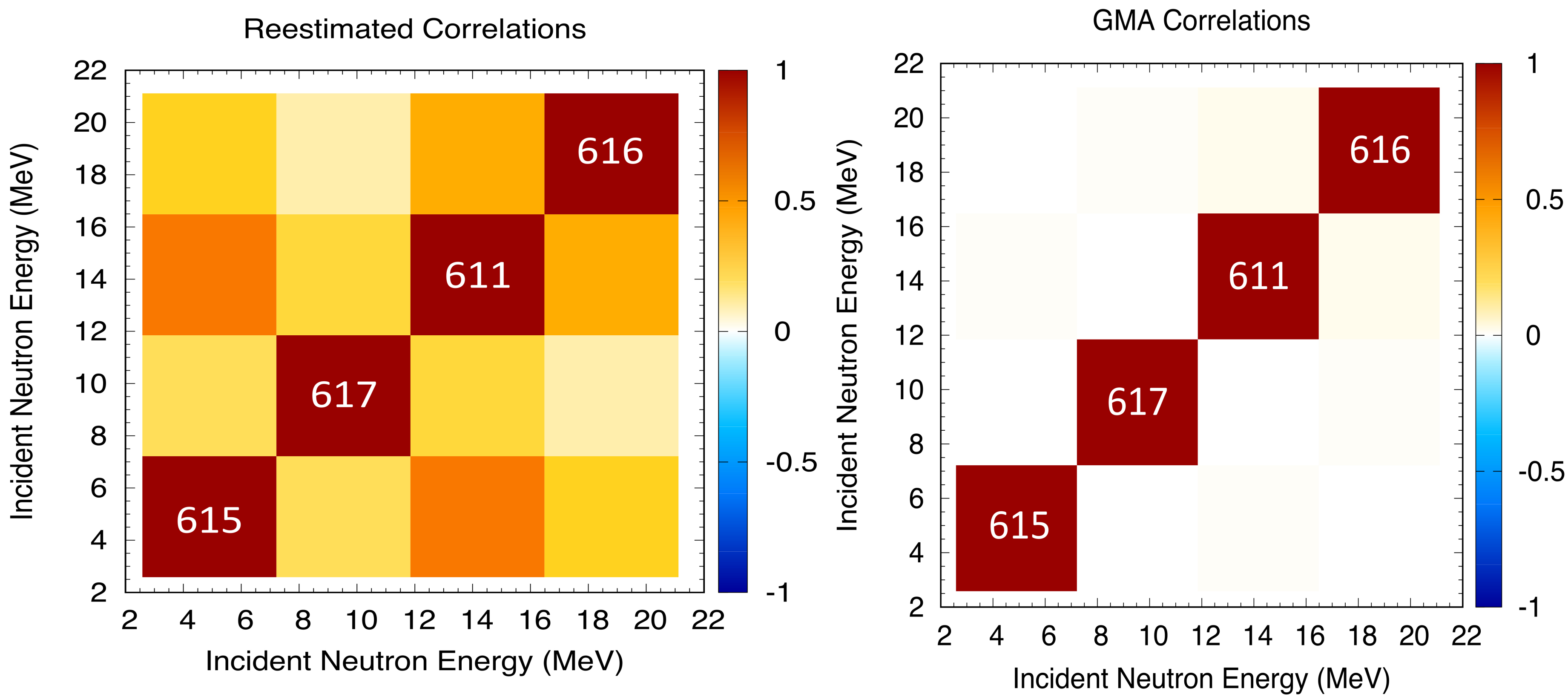
611 GMA unc.: 1%

611 Reestimated unc.: ***1.7%***

Sample mass unc. of 1% missing and background unc. of 0.5% missing.

Cross-correlations arise because same sample was used, same detector, same multiple scattering correction, etc.

Case 2: template helped to pin-point underestimated correlations in GMA



These two cases of underestimated unc. are typical cases rather than exceptions!

GMA #	GMA unc.	Reestimated unc.
611	1.0	**1.7**
644	2.0	**2.2**
615	2.1	**2.4**
1038	2.3-7.7	2.3-7.7
640	2.4-3.1	**3.3-4.3**
620	2.8-6.6	**3.5-6.7**
622	2.8-7.0	**3.6-7.3**
619	2.9	**4.7**
621	2.9-3.2	**3.6-11.0**
623	3.2-4.1	**3.4-3.9**
612	3.8-4.7	**4.0-5.8**
672	4.9-5.4	**5.4-5.5**
616	5.4	5.1

GMA #	GMA unc.	Reestimated Unc.
617	5.8	5.8
628	5.9	**6.4**
657	9.3	9.3
521	2.3-4.8	**3.4-5.6**
589	2.9-3.9	**3.7-14.0**
671	4.3-25.8	**5.5-26.0**
8002	0.7-3.8	**2.2-4.9**
602	0.8-6.8	**1.5-6.9**
654+653	1.0-6.9	**1.8-75.5**
685	1.1	**2.0**
1014	1.3-1.6	**1.7-2.6**
536	0.7-6.5	**1.0-7.3**
1029	1.0-2.5	**2.5-3.5**

ARIADNE input decks in LA-UR-18-20767

If you order ^{239}Pu(n,f) according to lowest unc. & type of data, the order of reestimated unc. changes

GMA absolute data	Reestimated
611	611
644	644
615	**1038**
1038	**615**
640	640
620	**623**
622	**620**
619	**622**
621	621
623	**612**
612	**619**
672	**616**

GMA ^{239}Pu/^{235}U	Reestimated
8002	**602**
602	**1014**
654+653	654+653
685	685
1014	**8002**

Work in progress!

Evaluated mean values and covariances are likely to change if new information is taken into account!!! An increased uncertainty compared to VII.1 is very likely!

How can we validate evaluated ^{239}Pu(n,f) cs uncertainties in ENDF/B-VIII.0?

Physical Uncertainty Boundaries (PUBs) methodology by D. Vaughan and D. Preston

PUBs methodology (D.E. Vaughan, D.L. Preston, LANL Report LA-UR-14-20441 (2014)) was developed to **estimate the upper bounds** of a physical quantity **based on physics considerations** rather than optimization with physics models and experimental data. It was applied to estimate bounds of quantity of interests (QoI) of other physics areas.

It is used here to validate the increased ^{239}Pu(n,f) cs uncertainties. This methodology cannot give us mean values!!!

Using PUB methodology step-by-step

1) **Part** the QoI (here: **^{239}Pu(n,f) cs**) **into** its constituting independent **sub-processes**.

2) **Establish the dominant sub-processes**, i.e., those that contribute the most to the variability of the ^{239}Pu(n,f) cs .

3) Answer: what are the **most extreme values** you could imagine **for the dominating sub-processes**? Or what is the most extreme variability on the ^{239}Pu(n,f) cs you could imagine coming from the variability of the sub-process?

4) What is the **functional form** of the variability on the ^{239}Pu(n,f) cs due to the dominant sub-processes?

(1) ^{239}Pu(n,f) cs in VIII.0 is evaluated based on exp. data only → part an experiment into sub-processes

$$cs(E)=\frac{N(C(E)-C_b(E))\beta(E)\alpha(E)m(E)}{\epsilon(E)\varphi(E)d(E)}-\sum_i \zeta_i(E) \quad with \quad \zeta_i - N_i cs_i(E)$$

N … number of atoms in the sample
C … total counts
N_i ... number of atoms from impurity
φ ... neutron flux

Measured separately

d … dead time correction
m … multiple scattering correction
β ... attenuation correction
α ... fission fragment angular distribution correction
cs_i ... cross section of contamination

Simulated or given by data

ϵ ... detector efficiency
C_b … background counts

Simulated and measured

(2) From the template we establish which sub-processes contribute the most to the variability.

$$cs(E)=\frac{N(C(E)-C_b(E))\beta(E)\alpha(E)m(E)}{\epsilon(E)\varphi(E)d(E)}-\sum_i \zeta_i(E) \qquad with \quad \zeta_i - N_i cs_i(E)$$

N … number of atoms in the sample

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α ... fission fragment angular distribution correction

cs_i ... cross section of contamination

Simulated or given by data

ϵ ... detector efficiency

C_b … background counts

Simulated and measured

(3) I use the template to obtain extreme variability of ^{239}Pu(n,f) cs due to variability in sub-processes

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

Well, actually these are not the most extreme uncertainties you can get on each sub-processes (you can always do something wrong in your experiments :-)) but a reasonable accuracy to which you can get each sub-processes with a standard measurement.

We believe that it is hard to describe the sub-processes with better accuracy.

(4) What is the functional form of the sub-processes? A few examples.

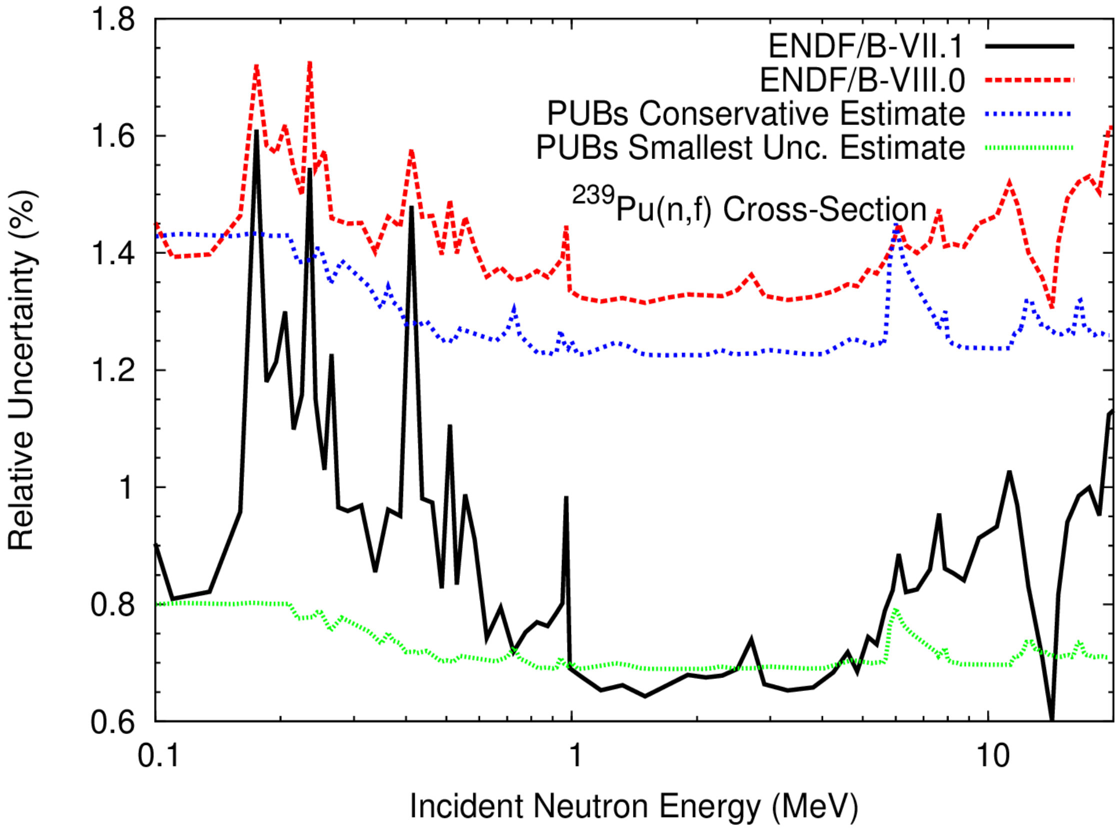
- N: this is the same for the whole cross-section measurement, i.e., a linear coefficient of the cross-section.
- є: for E < 10 MeV, this is a constant factor, i.e., a linear coefficient of the cross-section. Then another functional form sets in.
- C_b: defined by a functional form with few parameters + nuclear data used in a code. I assume a Gaussian kernel.

(5) Total bounds are obtained by considering correlations between experiments.

- Assess how unc. of each sub-process reduce if measured multiple times, i.e., are the uncertainties **correlated between experiments**? If "Yes", how high is the correlation? How many experiments are considered?
- **Combine the resulting average uncertainties of each sub-process**

- ***We cannot asses those uncertainties which were overlooked in all experiments because they use very similar methods. So while a reasonable bound it might not be the upper bound.***

(5) The conservative bound of PUBs is close to the ENDF/B-VIII.0 evaluated uncertainties.



Conclusions:

- **VIII.0 ^{239}Pu(n,f) cs unc**. were investigated and validated because they **increased by more than a factor of 2** in some energy range **impacting significantly k_{eff} unc.** of specific assemblies.

- **Are there good reasons** to increase the ^{239}Pu(n,f) cs uncertainties from ENDF/B-VII.1 to ENDF/B-VIII.0? **YES! Uncertainties of single experimental data sets and correlations between different experiments are missing** for many data sets underlying the standards evaluation. **If the standards database is updated with this information, mean values and unc. will change likely.**

- **^{239}Pu(n,f) cs uncertainties in ENDF/B-VIII.0** were **validated by PUBs** methodology. **VIII.0 unc. are are a bit higher than a conservative PUBs estimate.**

Part 2: Summarizing the ^{239}Pu PFNS Evaluation of ENDF/B-VIII.0

Denise Neudecker

Thanks to: P. Talou, T. Kawano, R. Capote, D.L. Smith, T. Taddeucci, R.C. Haight, M. Devlin, K. Kelly, J. Gomez, A.C. Kahler, M.C. White, M.E. Rising, J. O'Donnell, B. Kiedrowski, D.G. Madland

The ^{239}Pu PFNS Evaluation of ENDF/B-VIII.0:

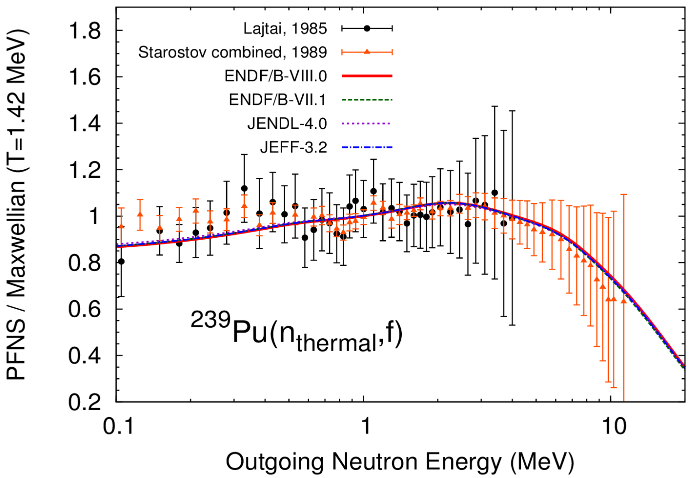
- Comparing ENDF/B-VII.1 and ENDF/B-VIII.0 ^{239}Pu(n,f) PFNS mean values and how they were evaluated.
- Comparing ENDF/B-VII.1 and ENDF/B-VIII.0 ^{239}Pu(n,f) PFNS covariances and how they were evaluated.
- What should we do better for the next evaluation?

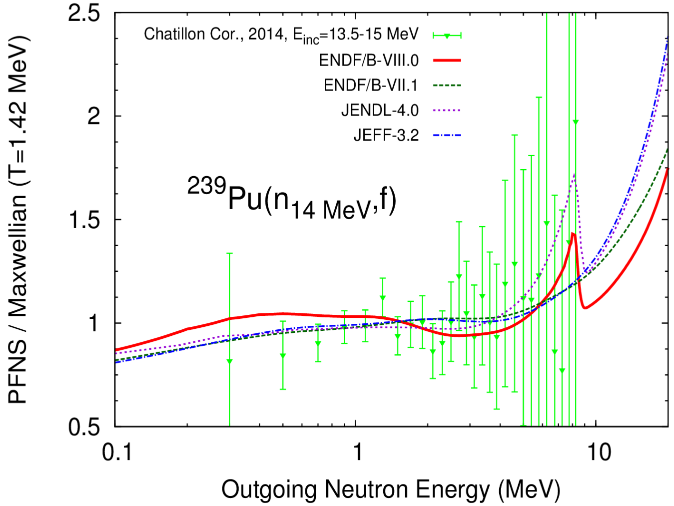
Comparing ^{239}Pu PFNS evaluated mean values

<u>ENDF/B-VII.1</u>

Evaluated by D.G. Madland for ENDF/B-VII.0

ENDF/B-VII.1 was carried over to maintain good agreement of benchmarks while waiting for new experimental data.





<u>ENDF/B-VIII.0</u>

Thermal: **VII.1** was slightly hardened to increase criticality benchmark performance

0.5-5 MeV: carried over from **VII.1**

> 5 MeV: **new evaluation** by D. Neudecker et al., NDS 148, 293 (2018).

Comparing ^{239}Pu PFNS evaluated mean values

	ENDF/B-VII.1	ENDF/B-VIII.0, E_{inc} > 5 MeV
Model	Original LAM as by D.G. Madland, NSE 81, 213 (1982), no pre-equilibrium component	Extended LAM (D. Neudecker et al., NIMA 791, 80 (2015).), exciton model for pre-equilibrium component (DN NDS 148.)
PFNS Exp.	Knitter, Staples et al.	Starostov, Boytsov, Nefedov et al., Knitter, Lestone et al., Lajtai et al., Chatillon et al.
Eval. Technique	LS for E_{inc} < 6 MeV, above grid-search minimization to fit model parameters	GLS

Comparing ^{239}Pu PFNS **evaluated covariances**

ENDF/B-VII.1	ENDF/B-VIII.0
Evaluated by P. Talou et al., NSE 166, 254 (2010). Given for E_{inc} up to 0.5 MeV. **The evaluated data and covariances were obtained independently but evaluated mean values agreed well.**	E_{inc} up to 0.5 MeV: carried over from **VII.1** and **applied up to 5 MeV** as physics and consequently covariances are very similar. **E_{inc} > 5 MeV: new evaluation** by D. Neudecker (NDS 148, NIMA). **Covariances were evaluated with mean values.**

Comparing ^{239}Pu PFNS evaluated covariances

	ENDF/B-VII.1	ENDF/B-VIII.0
Model	Original LAM, **unc. for 4 model parameters** by PT NSE.	Extended LAM + multiple-chance fission, **unc. for ~22 model parameters** (DN NDS 148. & NIMA)
PFNS Exp.	**Simplified unc. estimate** for Knitter, Staples et al., Boytsov et al., Lajtai et al.	Starostov, Boytsov, Nefedov et al., Knitter, Lestone et al., Lajtai et al., Chatillon et al. → **detailed unc. estimate** in D. Neudecker et al., NDS 131, 289 (2016).
Eval. Technique	Kalman filter	GLS

What should we do better for the next evaluation?

GLS was used for new VIII.0 and the Kalman filter was used for VII.1 covariances.

The **generalized least squares algorithm combines model ("M") and experimental mean values ("x")** and their associated covariances to evaluated mean values and covariances ("post").

$$\underline{\phi}^{post} = \underline{\phi}^{M} + \mathbf{Cov}^{post}\mathbf{S}^{+}(\mathbf{Cov}^{x})^{-1}\left(\underline{\phi}^{x} - \mathbf{S}\underline{\phi}^{M}\right),$$

$$\mathbf{Cov}^{post} = \mathbf{Cov}^{M} - \mathbf{Cov}^{M}\mathbf{S}^{+}\left(\mathbf{S}\mathbf{Cov}^{M}\mathbf{S}^{+} + \mathbf{Cov}^{x}\right)^{-1}\mathbf{S}\mathbf{Cov}^{M}$$

It **assumes that:**

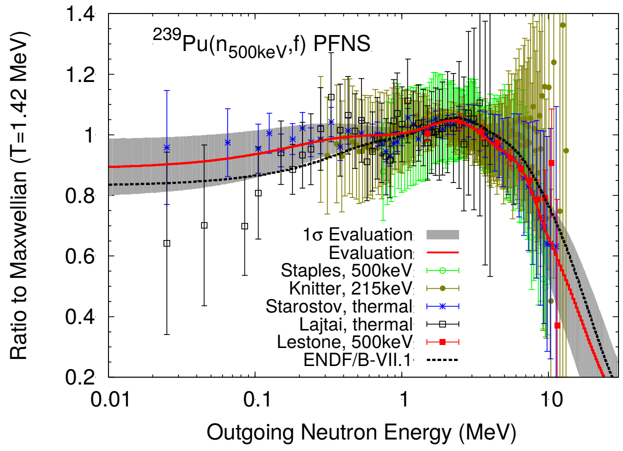
- ❑ Experimental data and model values to be normally distributed.
- ❑ Linear relationship between all observables.
- ❑ Non-discrepant data.
- ❑ Data that is less than ~30% uncertain.
- ❑ Data that should not cover many orders of magnitude.

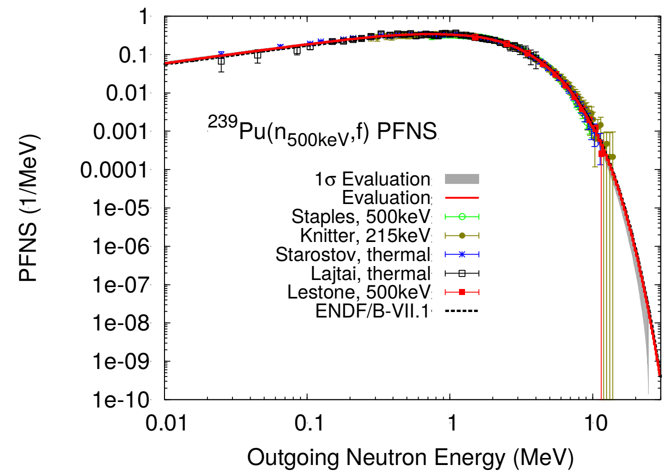
Generalized least squares is not ideal for evaluating PFNS

It requires:

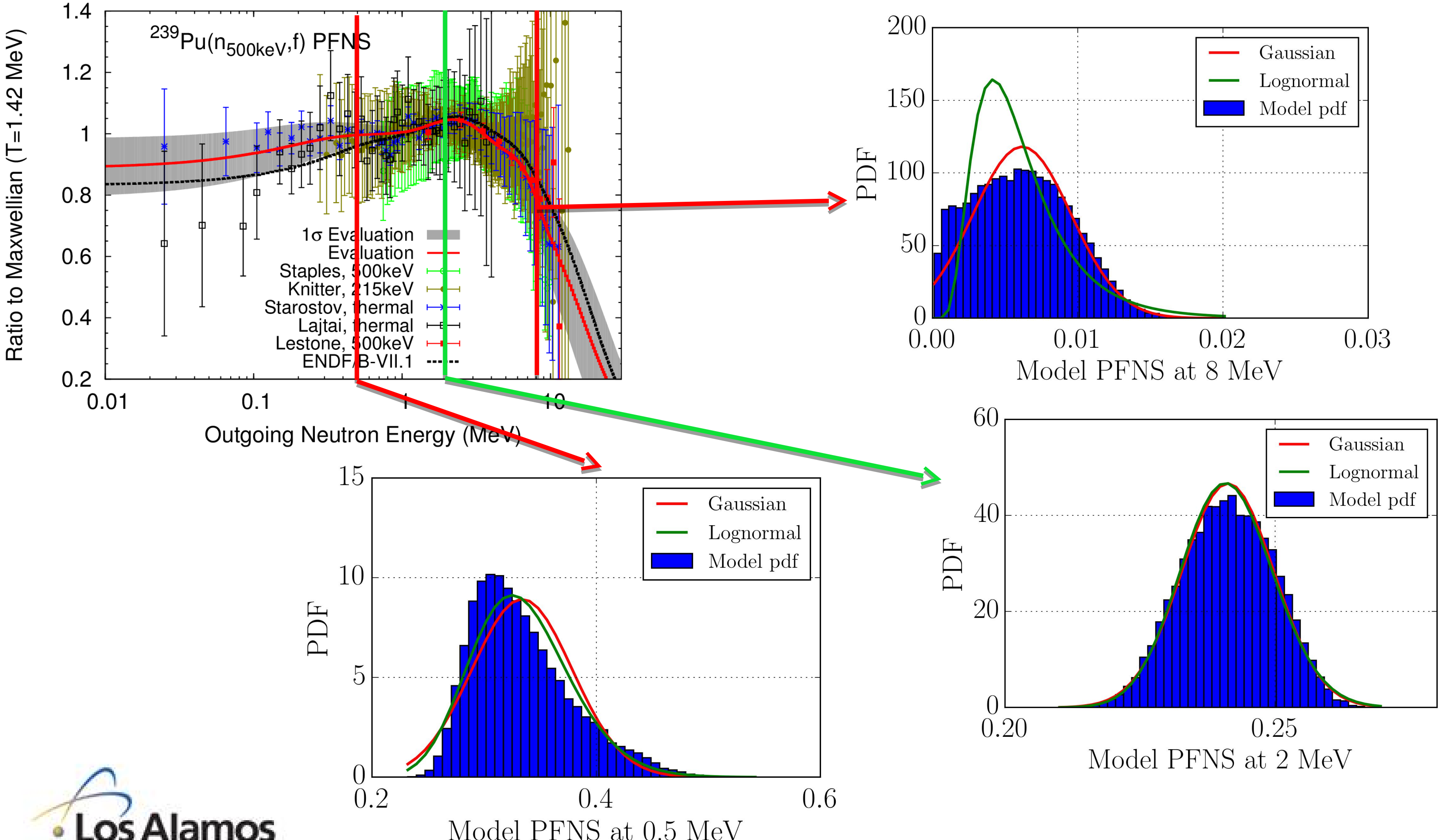
- Linear relationship between all observables.
- Non-discrepant data.
- Data that is less than ~30% uncertain.
- Data that should not cover many orders of magnitude.
- Experimental data and model values to be normally distributed.

VIII.0 yes, VII.1 no

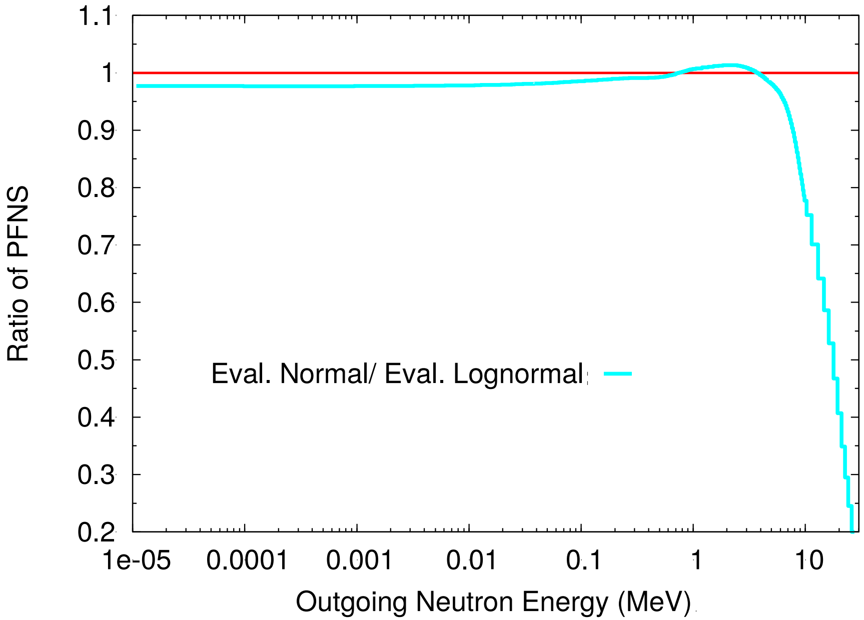


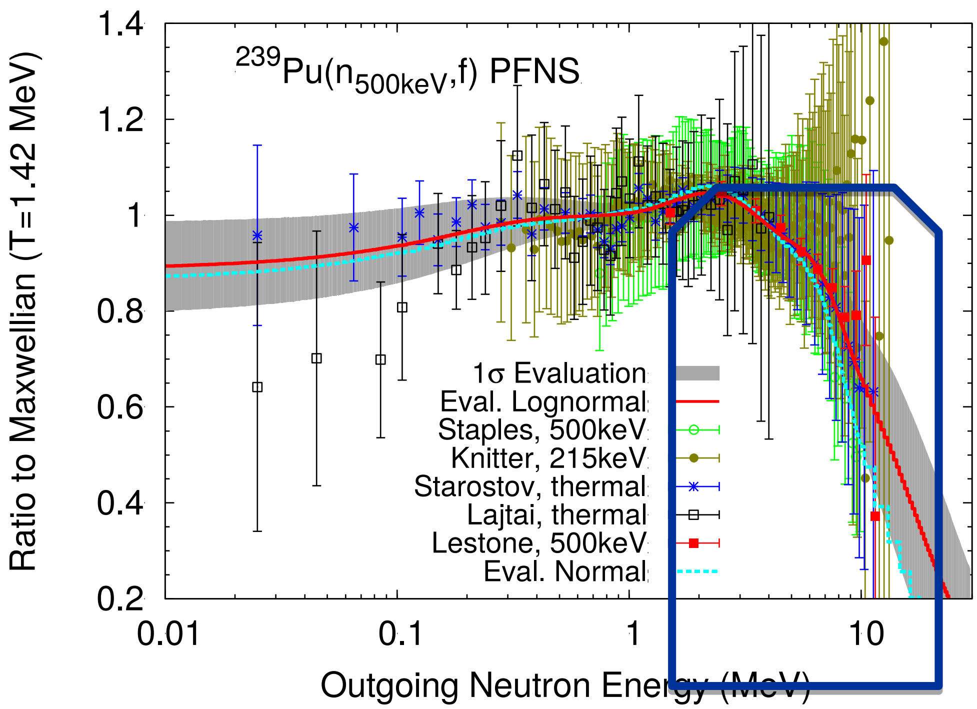


Model predicted values are neither normally nor lognormally distributed …

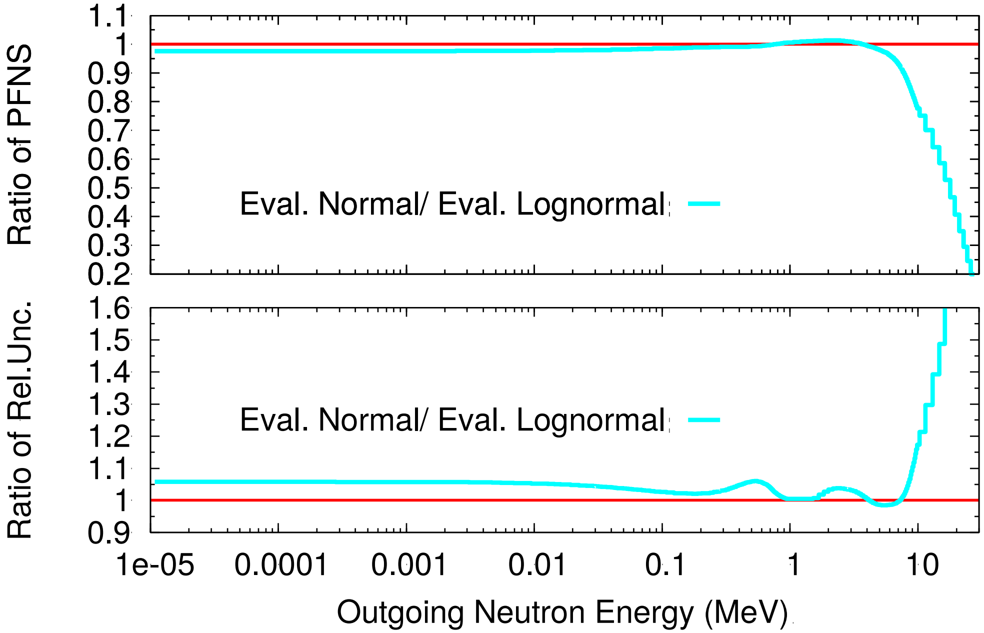


… and evaluating with GLS in PFNS or log space gives different evaluated results …





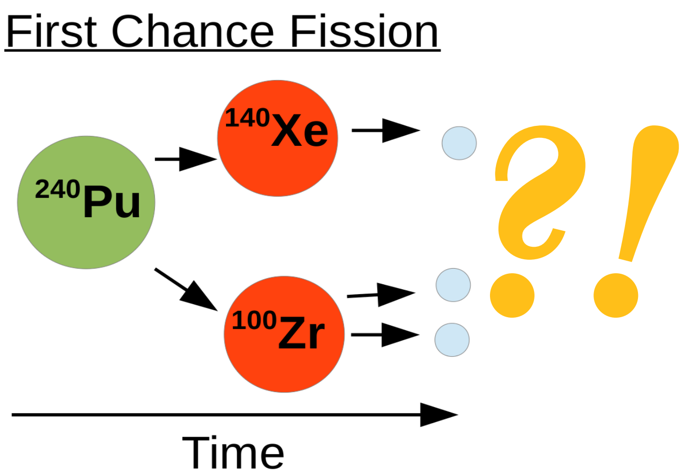
Evaluating with GLS in PFNS or log space impacts k_{eff} results distinctly, k_{eff} unc. only little.

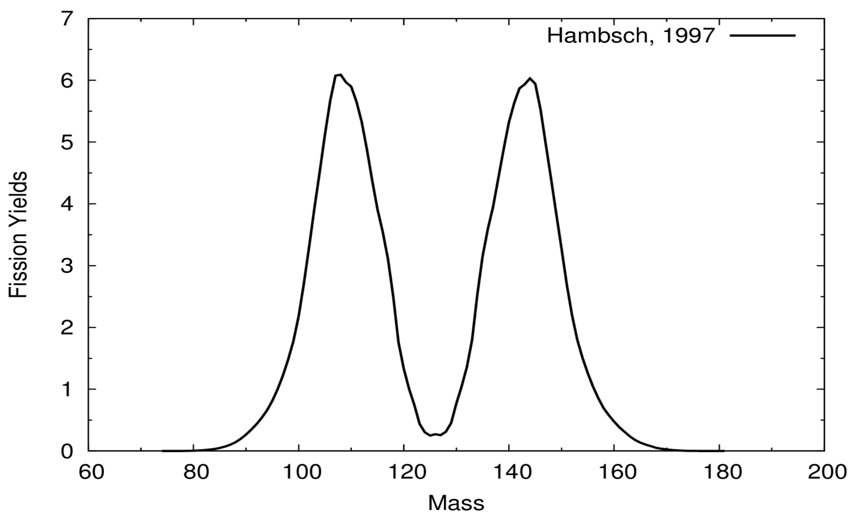


Change in Jezebel k_{eff}: -89 pcm

Increased Jezebel k_{eff} unc. due to PFNS uncertainty: +3.8%

Model development: switching to models which describes the fission process in more detail.



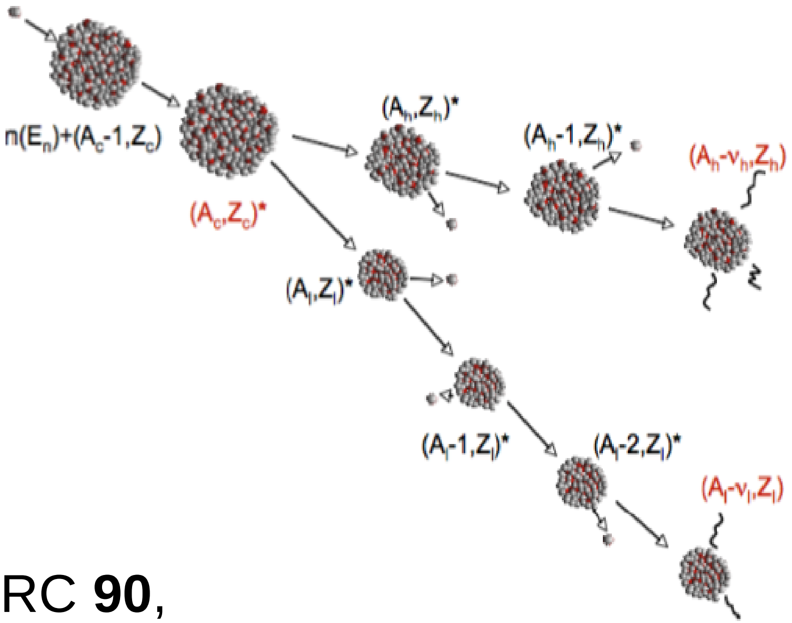


Original **LAM** assumes that neutrons are emitted from one average fission fragment pair and does not take into account the real distribution of fission fragments. This is just one of **many approximations.**

Model development: predicting correlated fission observables based on more physics input.

GGMF code (Talou, I. Stetcu, T. Kawano) samples from initial distribution of fission fragments and follows each decay step via Hauser-Feshbach model.

Provide **predictions of several fission quantities** (PFNS, p(ν), PFGS, etc.) and several isotopes → **MORE (measurable) INPUT QUANTITIES NEEDED.**



e.g.: I. Stetcu et al., PRC **90**, 024617 (2014).

Summary

- ENDF/B-VIII.0 ^{239}Pu(n,f) PFNS mean values are mostly carried over from VII.1 up to E_{inc} = 5 MeV. Above a new evaluation was adopted including more experimental data sets and extended modeling.

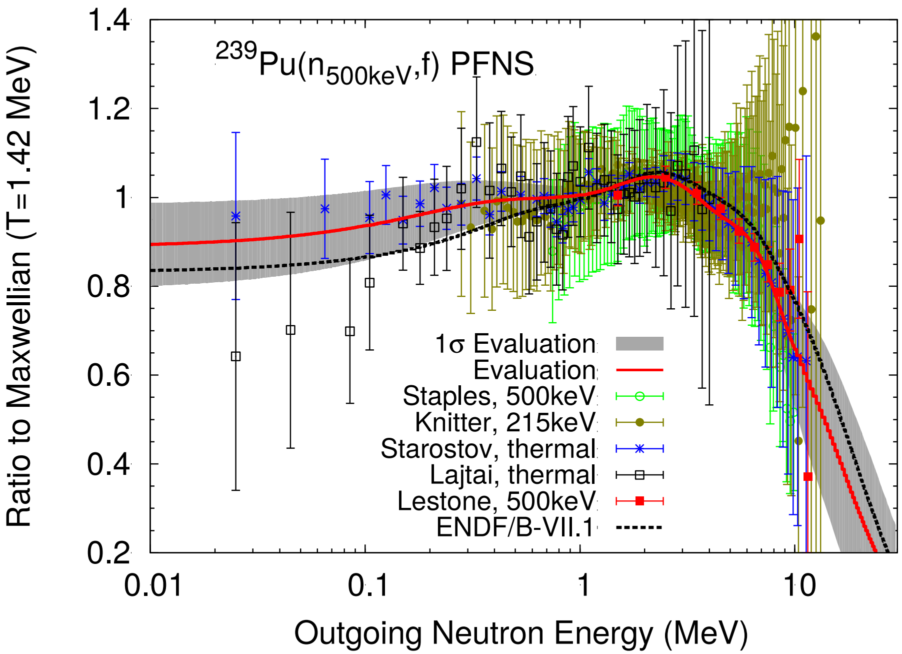
- ENDF/B-VIII.0 ^{239}Pu(n,f) PFNS covariances were carried over from VII.1 up to E_{inc} = 5 MeV. New files are given above. This covariances are based on a detailed analysis of experimental and mode uncertainties.

- The next evaluation will be likely based on a new physics model. Novel evaluation techniques should be studied.

Backup

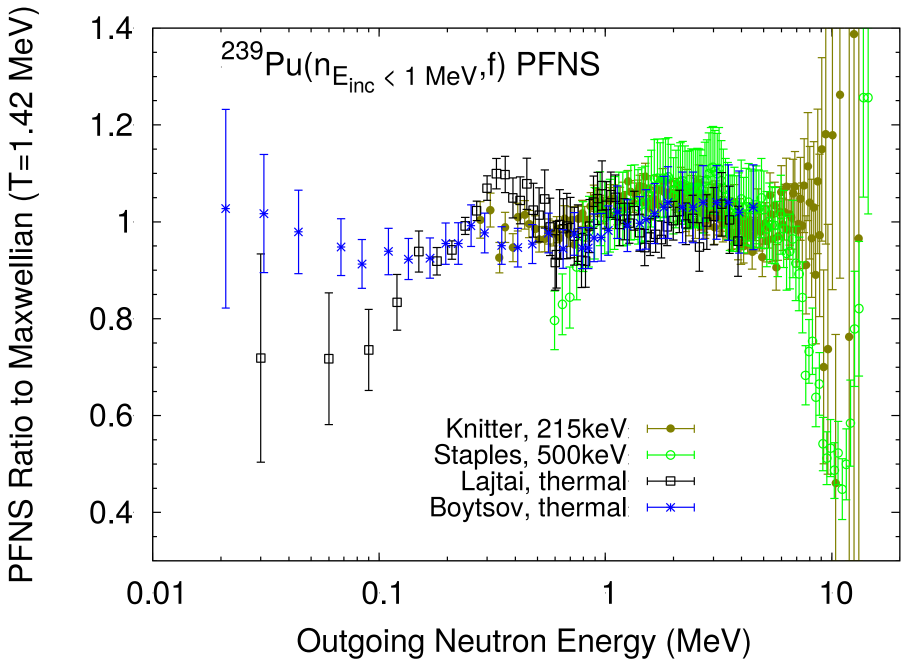
Taking data blindly from our databases (which people do!) is not a good idea …

Detailed uncertainty estimate



Detailed analysis of data and uncertainties.

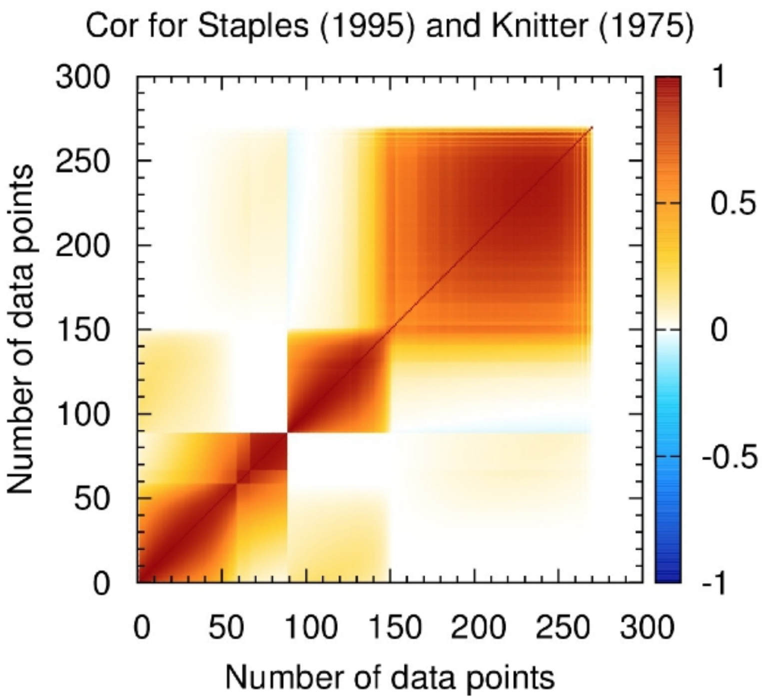
Simplified uncertainty estimate



Data and uncertainties taken as is from our databases discrepant!

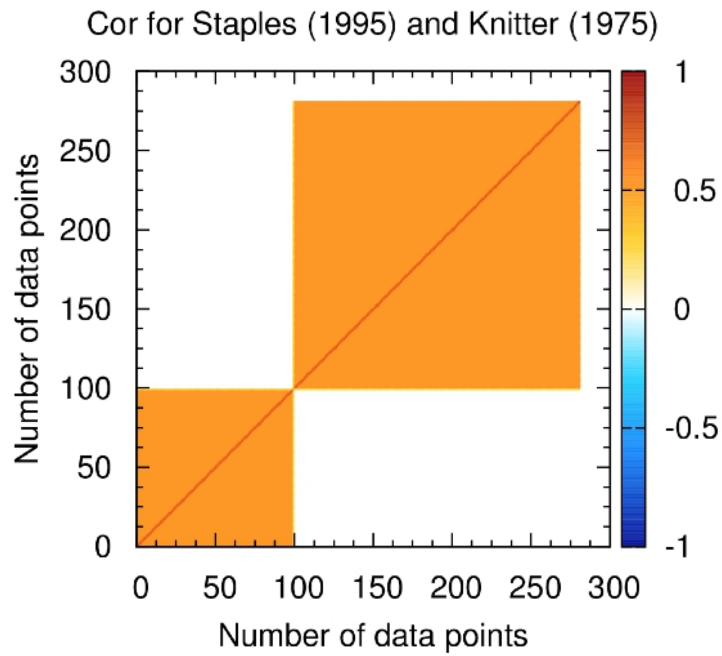
Estimating detailed experimental uncertainties is time-intensive because …

<u>Detailed uncertainty estimate</u>



Recommended approach to estimate unc. was taken.

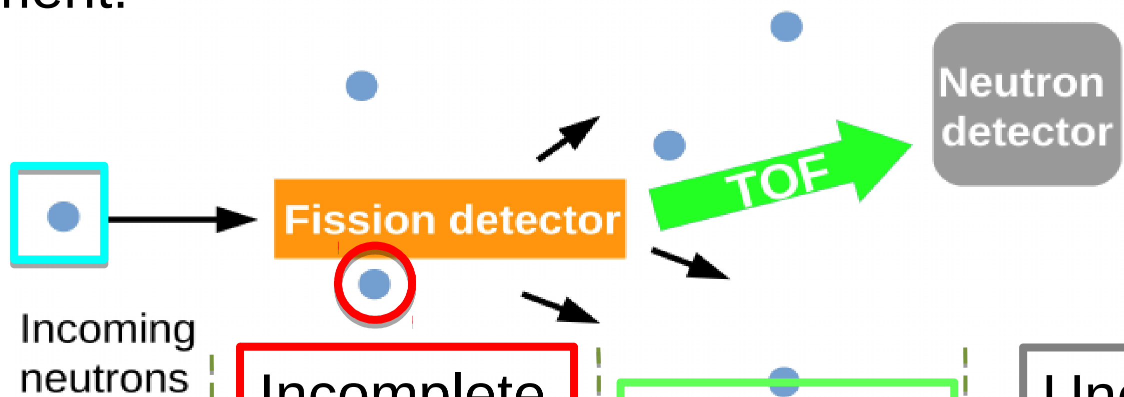
<u>Simplified uncertainty estimate</u>



Total uncertainties extracted from EXFOR and correlations of same exp. are 0.5, otherwise 0.

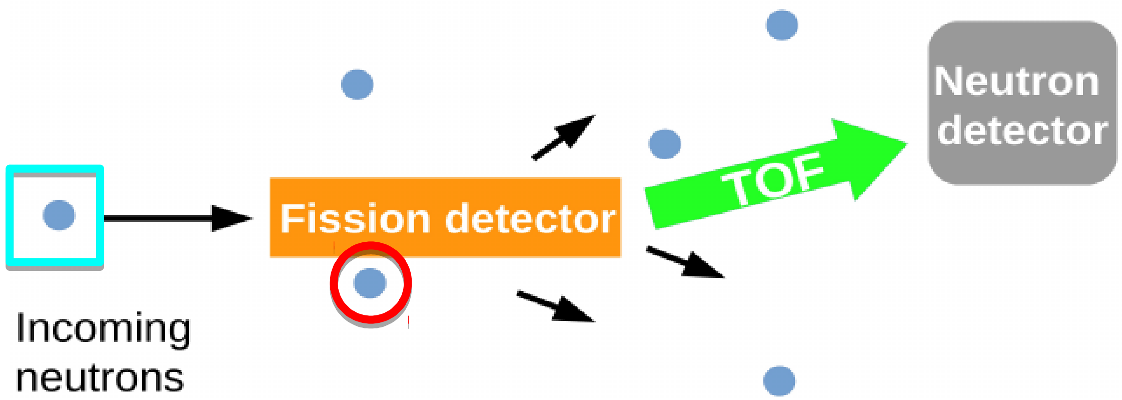
Detailed uncertainty estimate: First estimate covariances of partial uncertainties ...

Possible uncertainty sources of a PFNS experiment:



Incomplete correction of background particles	Incomplete correction of multiple scattered neutrons	Finite time resolution, TOF length unc, …	Uncertainty in determining neutron detector efficiency

… then add up partial covariances.

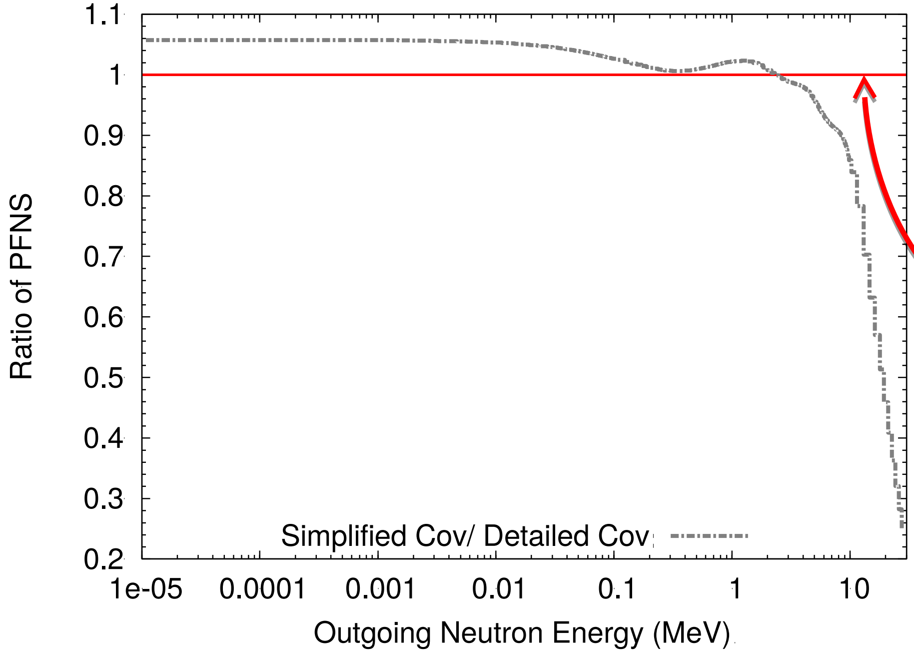


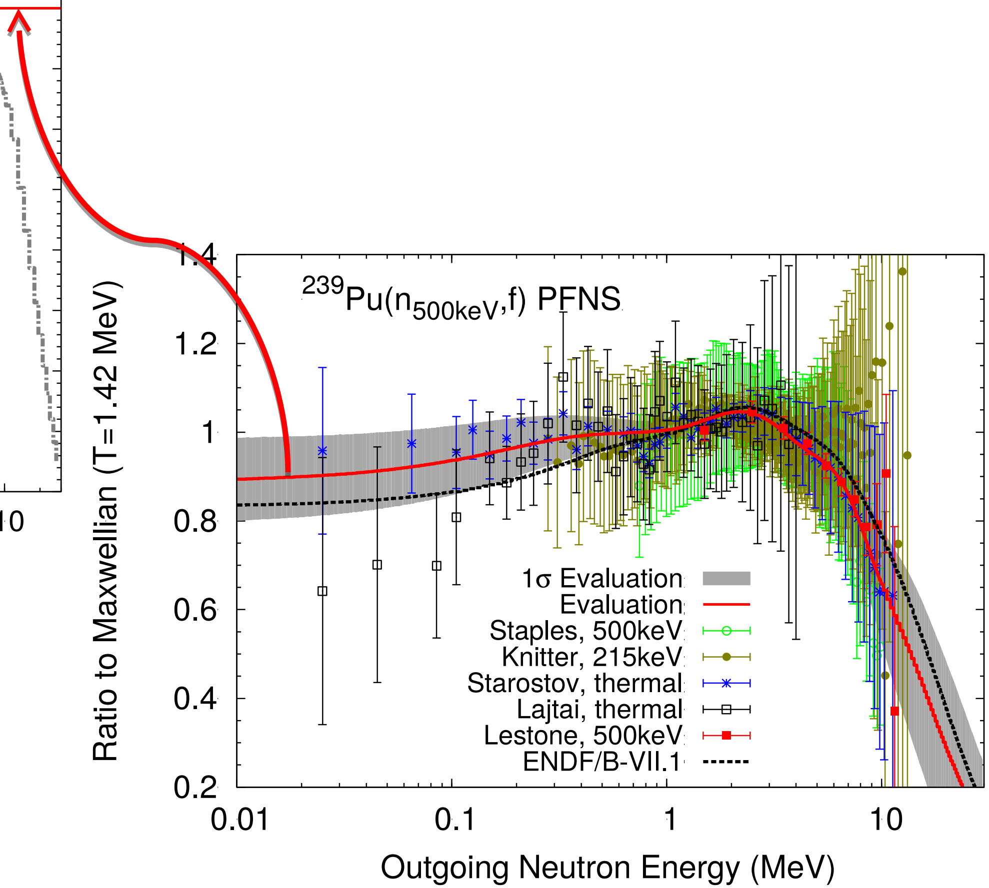
$$Cov^{exp} = Cov^{Count.\ Stat.} + Cov^{Backgd.} + Cov^{Mult.\ Scatt.} + Cov^{TOF} + Cov^{Det.\ Eff.} + \ldots$$

Advantages:

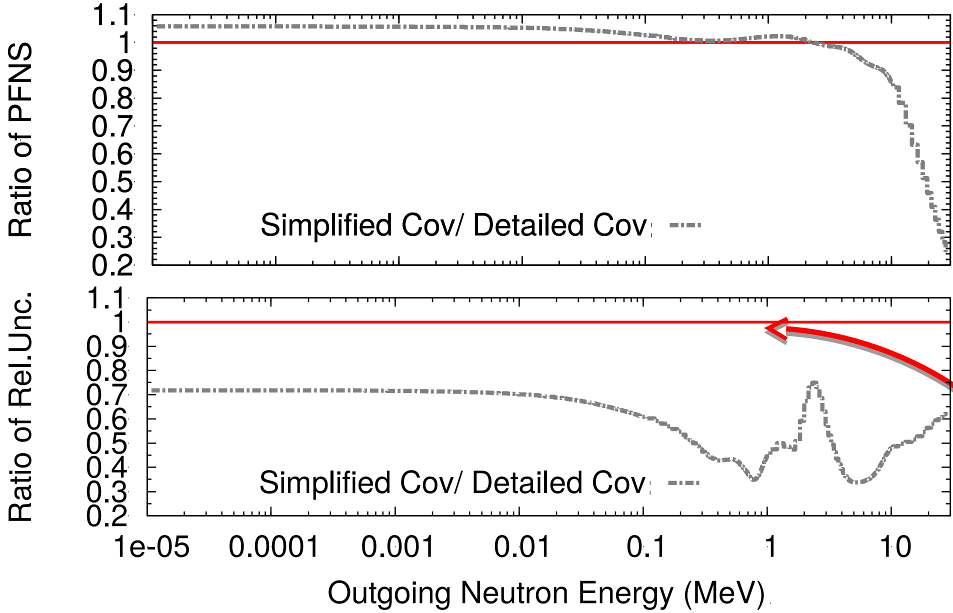
- Same technique can be used to **estimate covariances between experiments** more transparently.
- Additional **uncertainties can be easily added.**

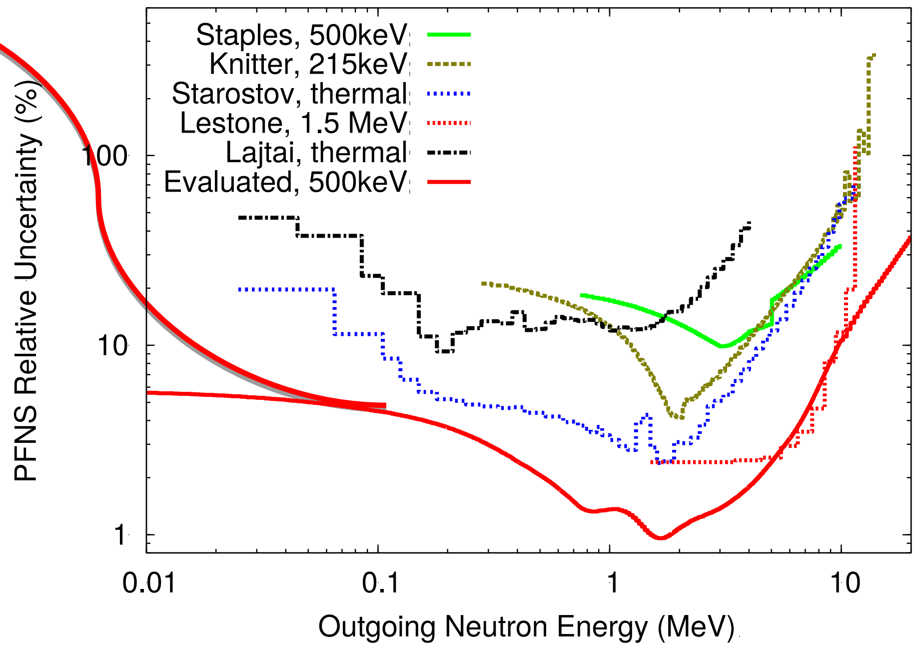
Simplified vs detailed uncertainty estimate leads to distinct change of evaluated PFNS.



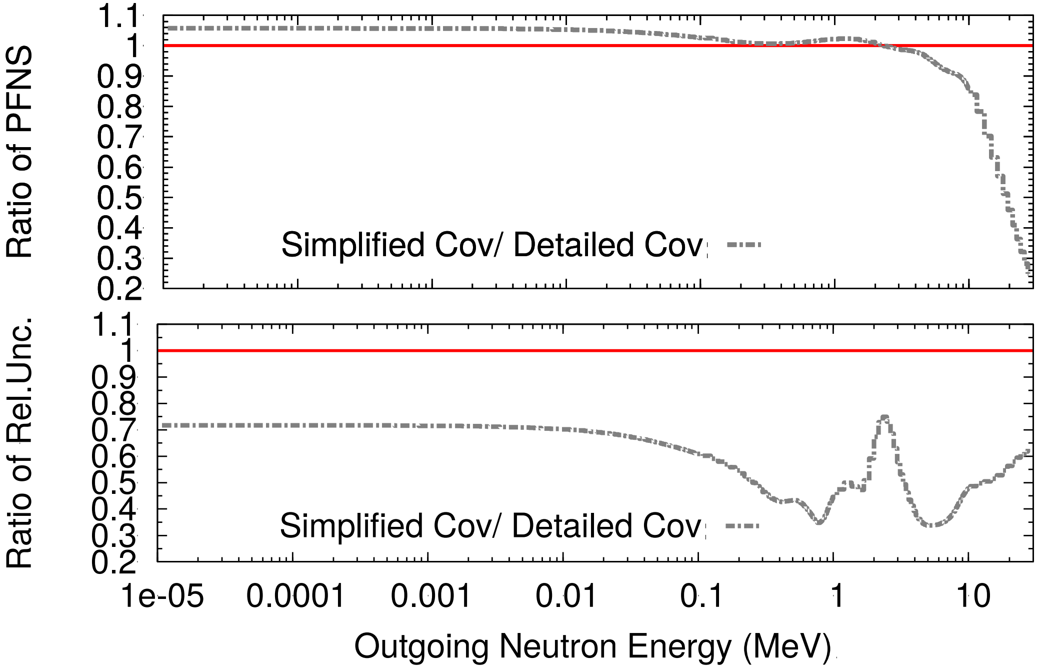


Simplified versus detailed uncertainty leads to significantly underestimated evaluated unc.





Simplified versus detailed uncertainty estimate significantly impacts benchmark results.



Change in Jezebel k_{eff}:

195 pcm !!!

Drop in Jezebel k_{eff} unc. due to PFNS uncertainty:

-69% !!!