LA-UR-13-28051

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Title:	Analyzing the low evaluated uncertainties and strong model dependence of the 239Pu PFNS ENDF/B-VII.1 evaluation.
Author(s):	Neudecker, Denise Capote, Roberto Talou, Patrick
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Analyzing the low evaluated uncertainties and strong model dependence of the ^{239}Pu PFNS ENDF/B-VII.1 evaluation.

Ongoing collaboration of:
D. Neudecker[1], R. Capote[2], D.L. Smith[3], T. Burr[1] and P. Talou[1]

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PFNS-CRP Meeting, IAEA Vienna, Austria, 10/21-24/2013

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ENDF/B-VII.1
^{239}Pu PFNS evaluation

Impact of the normalization condition

Studying the evaluation: normalization and strong model cor.

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Analyzing the low evaluated uncertainties and strong model dependence of the ^{239}Pu PFNS ENDF/B-VII.1 evaluation.

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Evaluated covariance information was included for n(E_{inc}=0.5 MeV)+^{239}Pu PFNS in ENDF/B-VII.1.

ENDF/B-VII.1 ^{239}Pu PFNS evaluation

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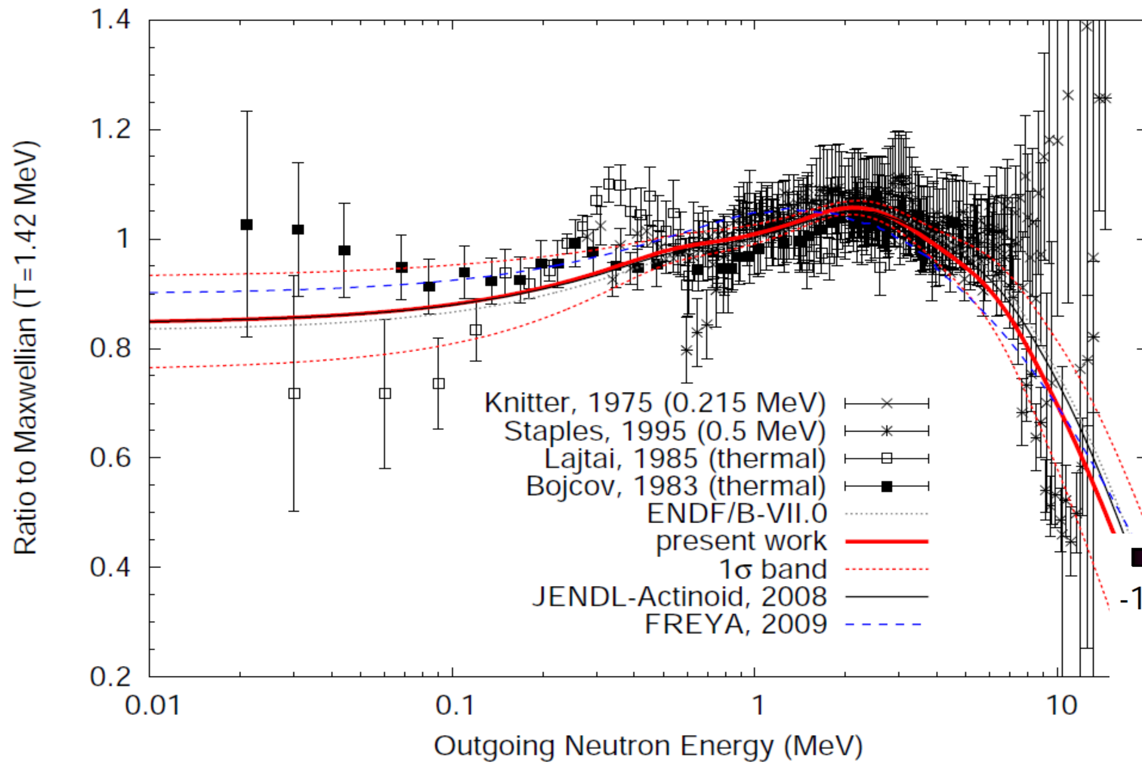
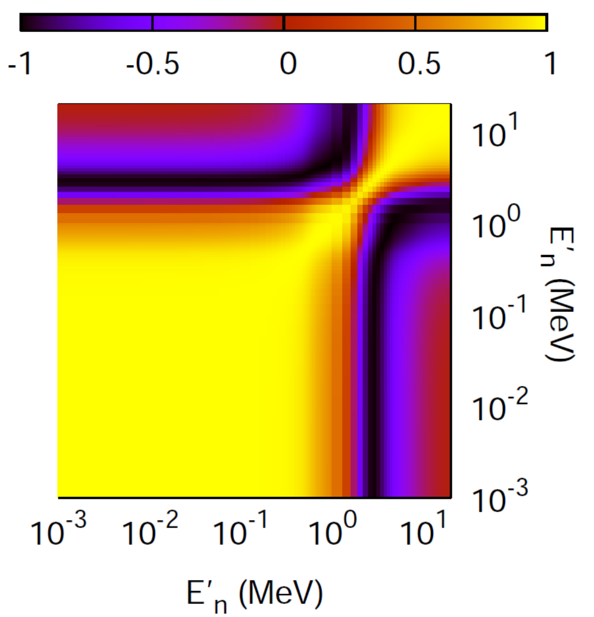


FIGURE 11. Final 1σ uncertainty band after including a "model error" component below 500 keV

Model: Los Alamos model, D.G. Madland, J.R. Nix, NSE 81, 213 (1982).

Experiment: Knitter, Staples, Bojcov, Lajtai



Figures taken from:
P. Talou et al., NSE 166, No. 3, 254 (2010).

Open questions: unexpected low evaluated uncertainties and strong model impact.

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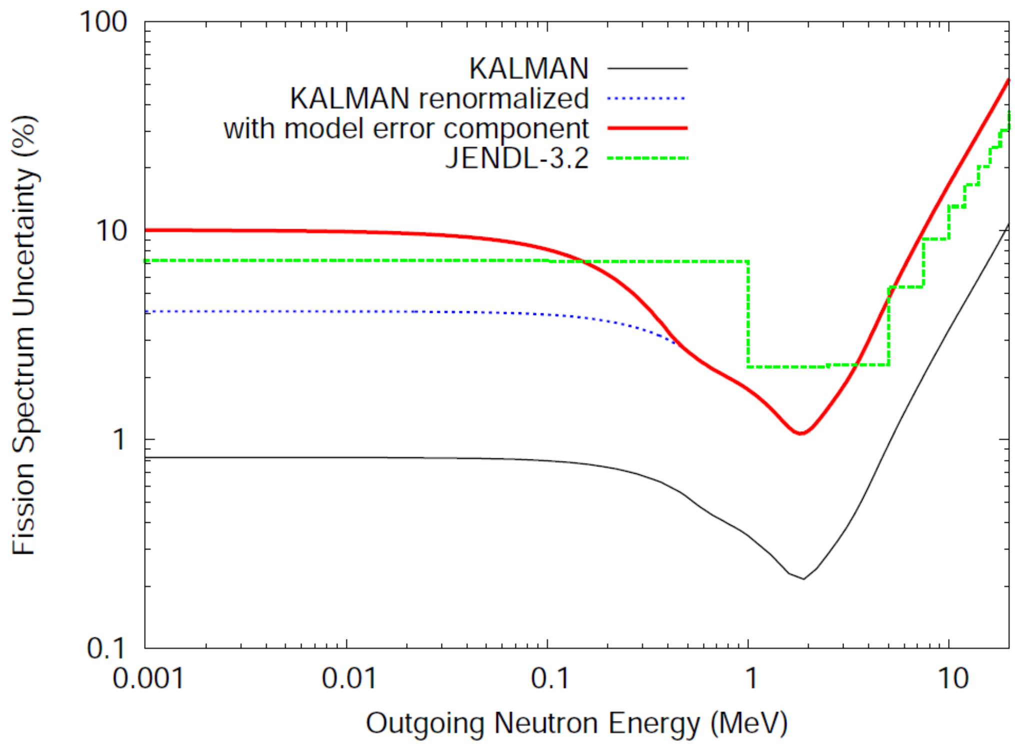
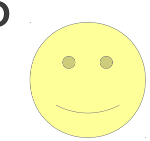


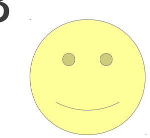
FIGURE 4. Calculated standard deviations for the evaluated PFNS of n(0.5 MeV)+^{239}Pu. See text for details.

Figures taken from:
P. Talou et al., NSE 166, No. 3, 254 (2010).

Only unc. of 4 model parameters → parameter space enlarged in M. Rising et al., LANL Report LA-UR-12-21035 (2012).



Exp. cor. roughly estimated → detailed unc. analysis in D.N. et al., LANL Report LA-UR-13-24743 (2013).



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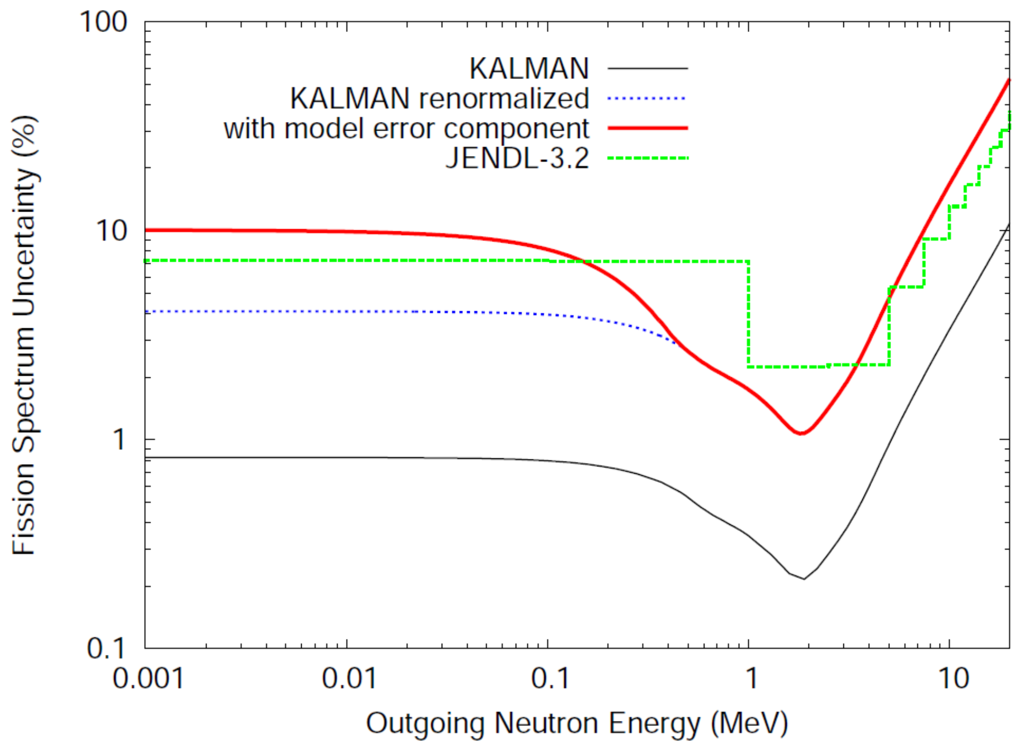

FIGURE 4. Calculated standard deviations for the evaluated PFNS of n(0.5 MeV)+^{239}Pu. See text for details.

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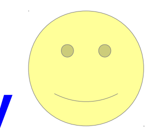
Only unc. of 4 model parameters



Exp. cor. roughly estimated

Low evaluated uncertainties?? (see also F.H. Froehner, NSE 106, No. 3, 345 (1990).)

Strong impact of model data on evaluation?? (issue raised by Kornilov)

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Low evaluated uncertainties: what do we know from cross section space.

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- **Missing correlations between the same and different experiments**. (see e.g. described in A. Carlson, “Internat. Eval. of Neutron Cross-Section Standards”, IAEA Report STI/PUB/1291 (2007), study of D.N. et al., NDS, ND2013 conference proceedings, accepted.)
- *Lower model uncertainties than those of* the majority of the *experiments* due to pathologically chosen parameter uncertainties to obtain model uncertainties or due to model deficiencies. (D.N., R.C. and H. Leeb, NIM A 723, 163 (2013)).
- Peelle's Pertinent Puzzle (described e.g. in A. Carlson, IAEA Report STI/PUB/1291 (2007).)

→ One additional condition: **normalization of spectrum**

The ENDF-6 format requires the PFNS to be normalized to unity and the rows of covariances to sum to zero.

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In the ENDF-6 format, the energy spectrum of outgoing fission neutrons is parted in 2 quantities: the neutron-multiplicity and the **PFNS which is a probability distribution**. → hence, **normalization conditions apply.**

$\Phi(E^i_{out})$ … Bin average values

$\varphi(E^i_{out})$ … Bin probability of PFNS

ΔE^i_{out} … Bin width

$$\sum_i \varphi(E^i_{out}) \Delta E^i_{out} = \sum_i \Phi(E^i_{out}) = 1$$

$$\frac{\sum_j Cov\left(\varphi(E^i_{out}), \varphi(E^j_{out})\right)}{\varphi(E^i_{out})} < 10^{-5}$$

ENDF-6 formats manual, edited by A. Trkov, M. Herman and D. Brown, BNL Report BNL-90365-2009 Rev. 2 (2012).

Normalization does not change shape of PFNS. How about covariances??

ENDF/B-VII.1 ^{239}Pu PFNS evaluation

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If the PFNS and covariances are not-normalized quantities, the normalization transformation using linear error propagation reads:

$$\Omega\left(E_{out}^{i}\right)=\frac{\Phi\left(E_{out}^{i}\right)}{G} \qquad G=\sum_{i}\Phi\left(E_{out}^{i}\right)$$

Shape of PFNS remains the same.

$$Cov_{\Omega}=T\,Cov_{\Phi}\,T^{+} \qquad T_{ij}=\frac{G\,\delta_{ij}-\Phi_{i}}{G^{2}}$$

COVARIANCES MIGHT BE CHANGED, BUT HOW???

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Statistical unc. are hardly changed by the normalization transformation.

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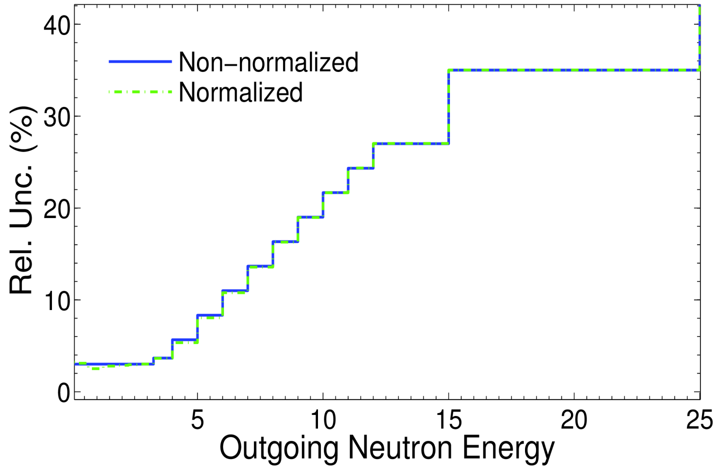

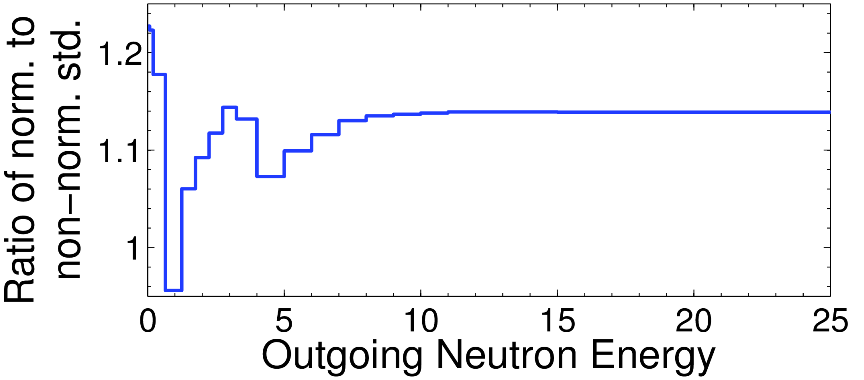

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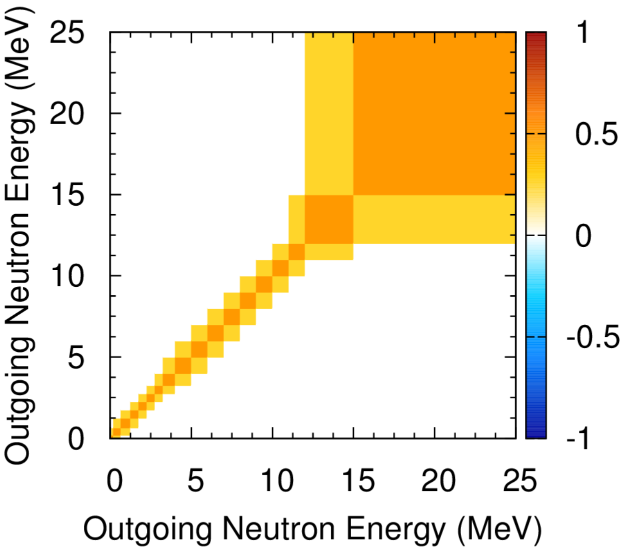

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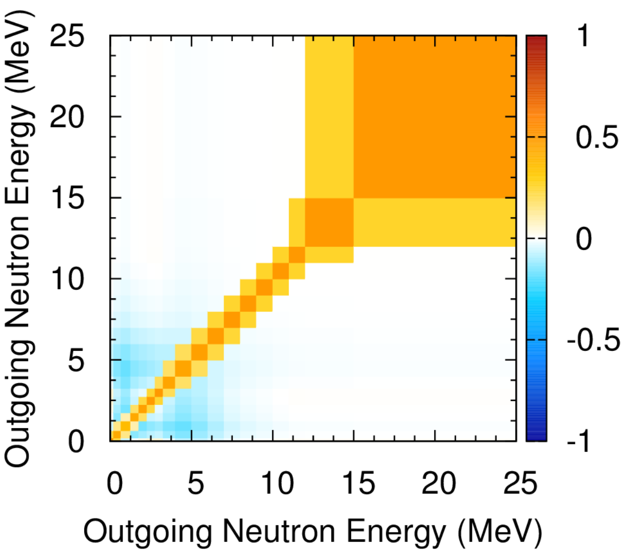

Scaling unc. reduce to zero in the normalization transformation.

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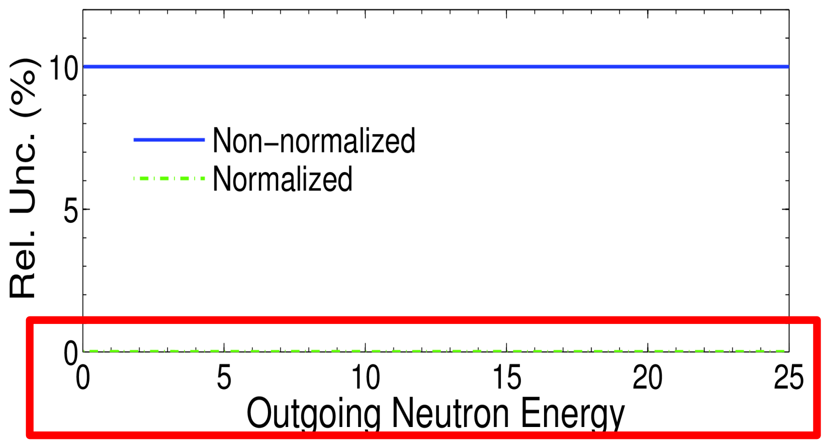

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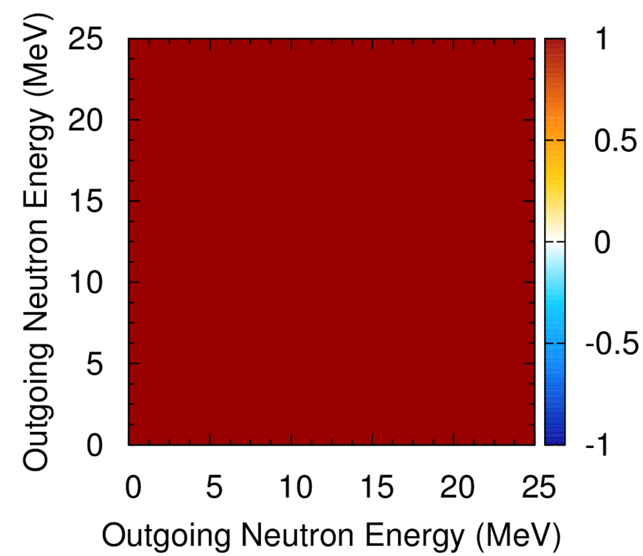

By the **normalization** of the PFNS, **we fix the scaling constant of the PFNS with 1/G.**
Hence, it is only natural that all uncertainties pertinent to the scaling factor drop out.

Can also be shown analytically.

Already 'normalized cor.' and rel. unc. are unchanged by normal. transfor.

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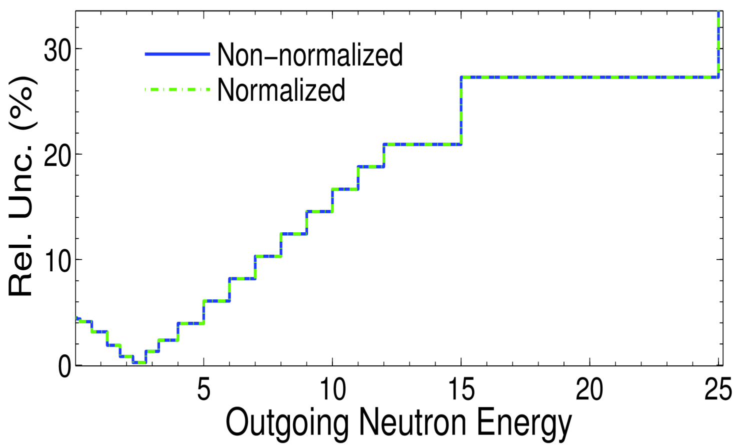

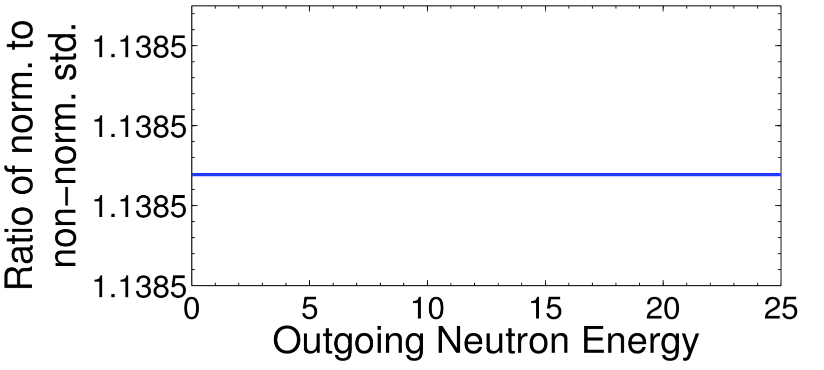

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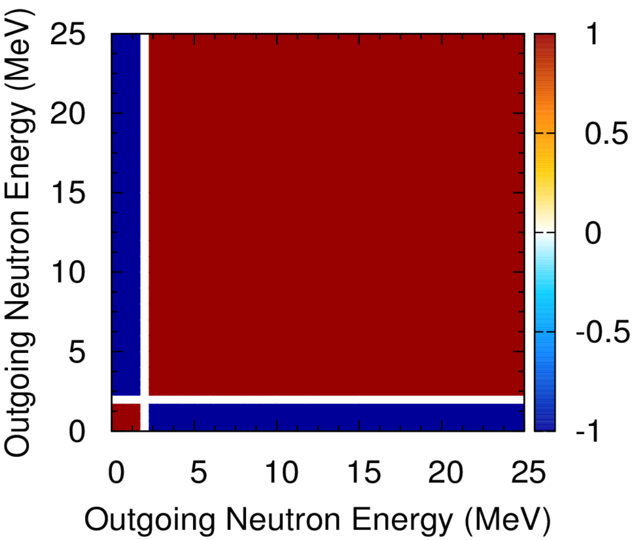

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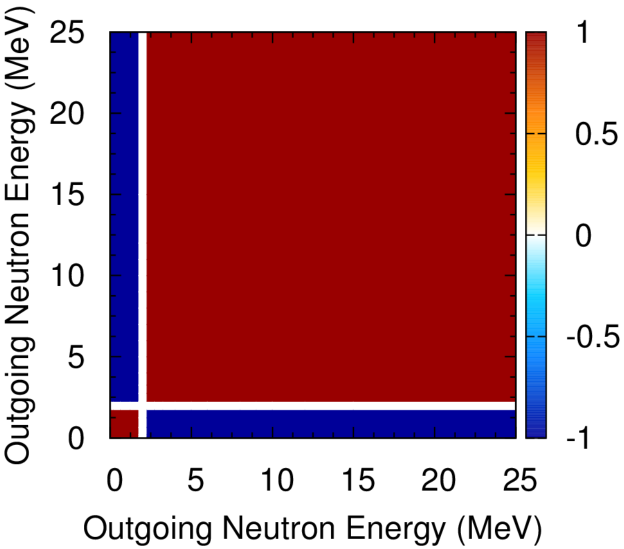

Can also be shown analytically.

Model and exp. data have intrinsically different uncertainty sources.

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	Model	Experiment
Statistical uncertainty source	NO	YES
Scaling uncertainty source	NO	POSSIBLE
Normalized uncertainty source	YES	POSSIBLE

Model uncertainty near mean energy is smaller than experimental uncertainties.

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Impact of the normalization condition

Studying the evaluation: normalization and strong model cor.

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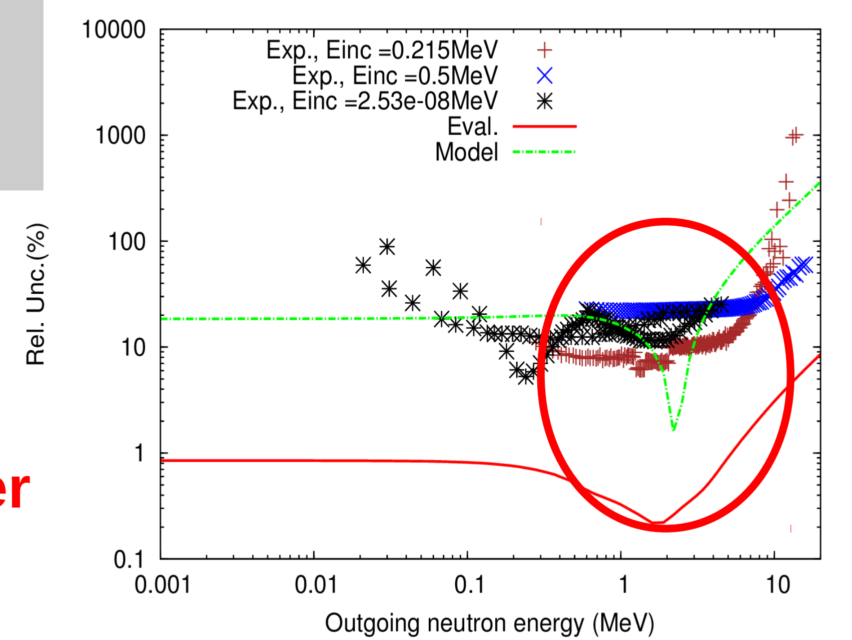
	Model	Experiment
Statistical uncertainty source	**NO**	**YES**
Scaling uncertainty source	**NO**	**POSSIBLE**
Normalized uncertainty source	**YES**	**POSSIBLE**

Model uncertainty of Los Alamos model is already normalized and has a **minimum near the mean energy which is distinctly smaller than experimental uncertainties.**



Using experimental data only yields eval. unc. of 1-20% for E_{out} = 0.1-10 MeV.

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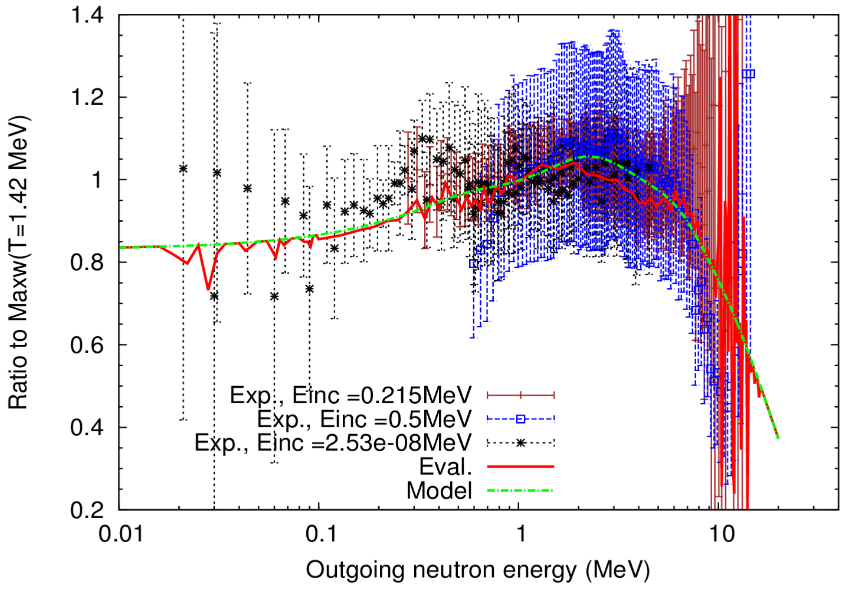
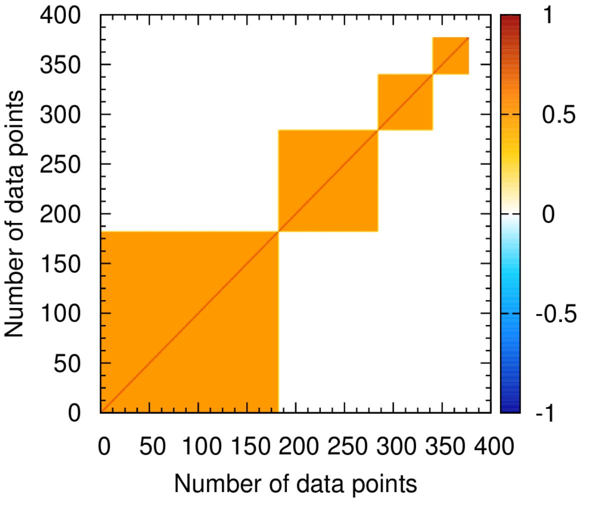
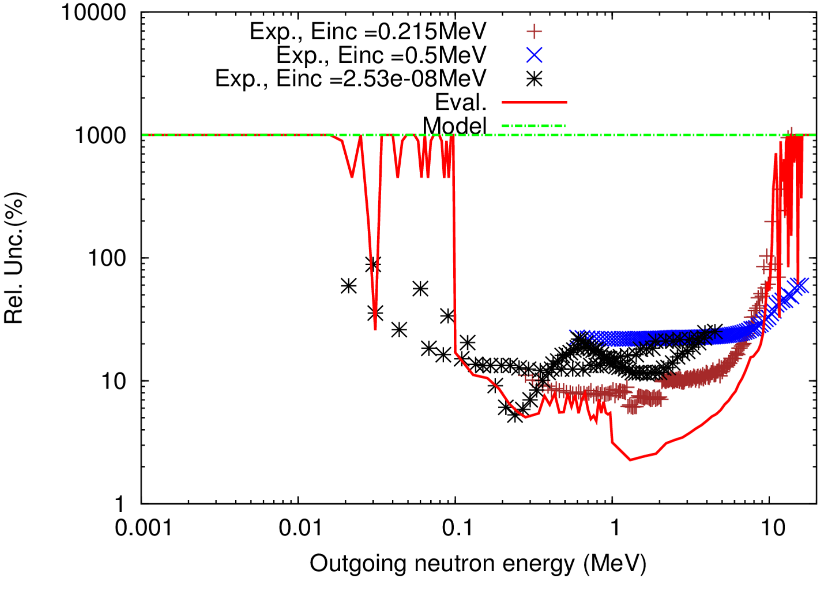




<u>Input data:</u>

Experiment: the same as used for the 2010 evaluation

Model: model mean values & diagonal cov with 1000% unc. to minimize impact on evaluation.



An evaluation including model data leads to eval. unc. of a magnitude smaller.

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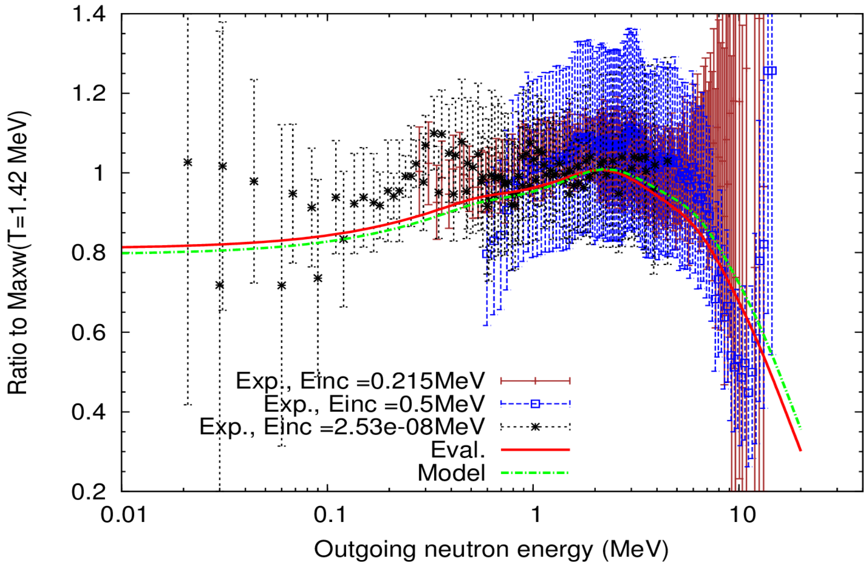
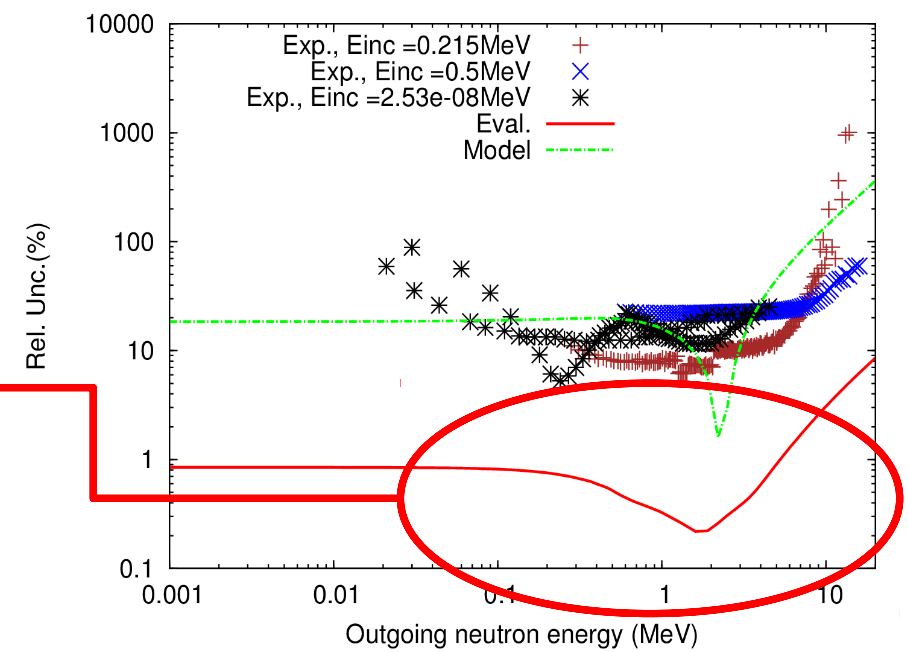


<u>Input data:</u>
Experiment: the same as used for the 2010 evaluation

Model: model parameters and uncertainties as from the 2010 paper.



Evaluated uncertainties distinctly smaller over whole energy range than what we expect from experiment only.

Increasing model uncertainties with a multiplicative factor doesn't help.

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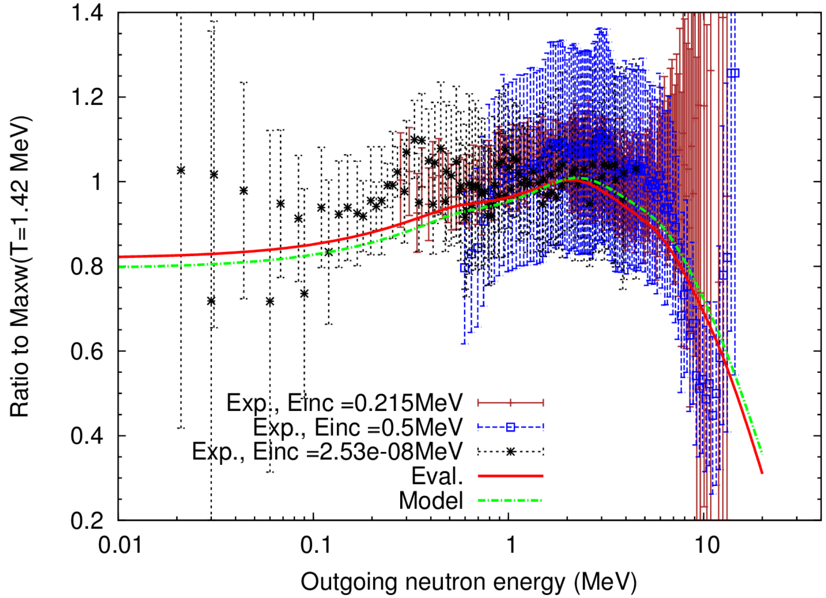
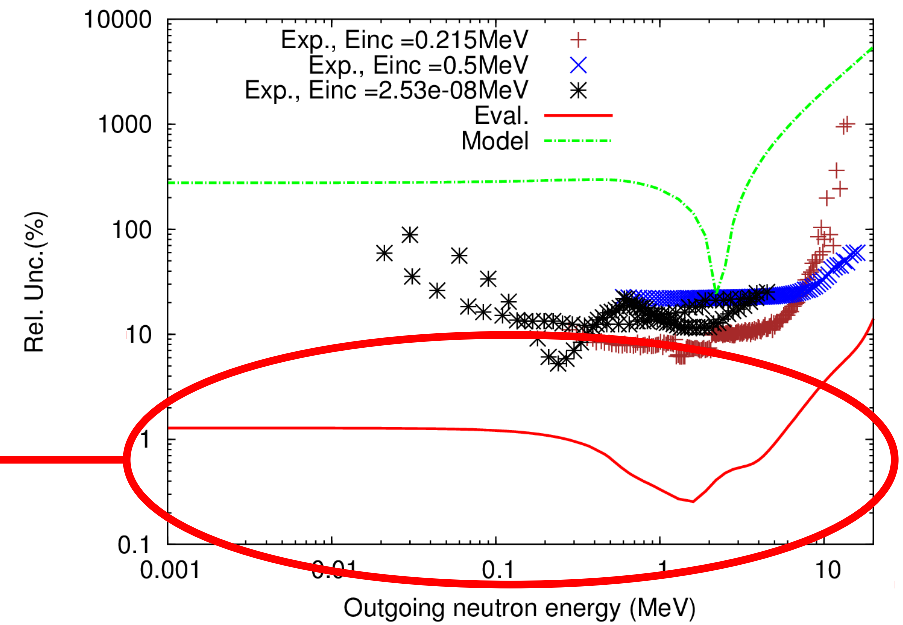


Input data:

Experiment: the same as used for the 2010 evaluation

Model: model unc. multiplied with constant to be larger than exp. unc., **model correlations and normalization kept.**

Eval. unc. near pivot point still small but larger in the tails.



Adding scaling unc. and thus breaking the cov. normalization condition, leads to more realistic unc. near mean energy.

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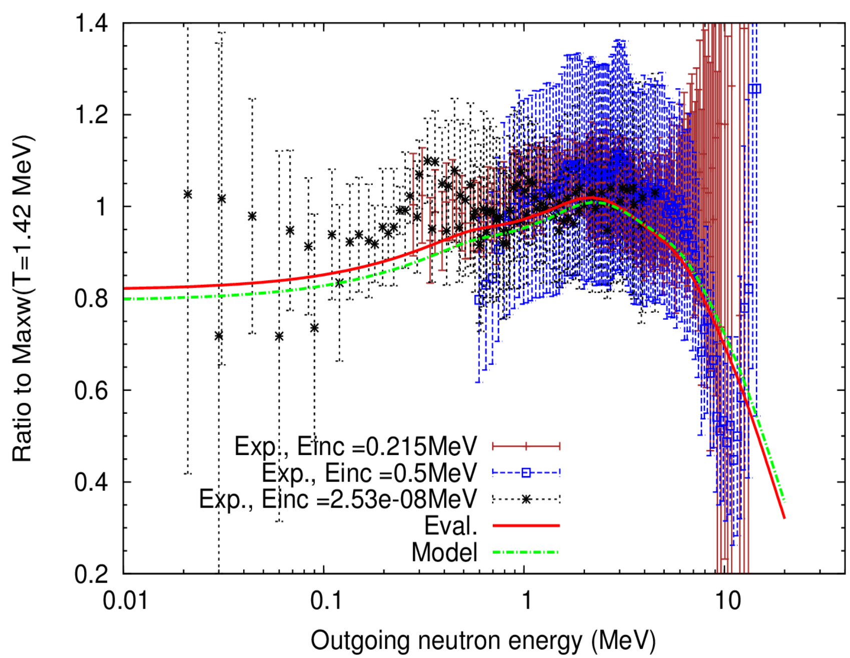
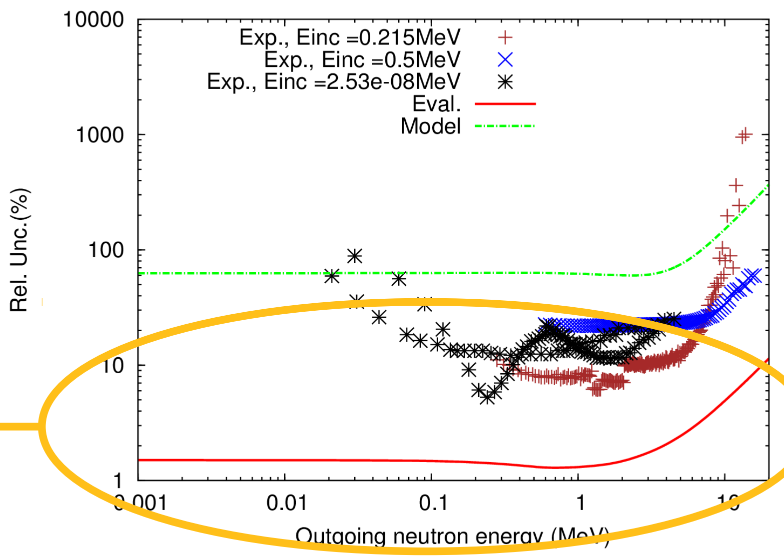


<u>Input data:</u>

Experiment: the same as used for the 2010 evaluation

Model: scaling unc. added to model unc. such that larger than exp. unc., **normalization condition of cov. broken.**

Eval. unc. near pivot point in better correspondence to evaluation with exp. data only but **low unc. near tail because of strong model cor.**



… however enforcing the normalization condition after the evaluation leads again to low uncertainties.

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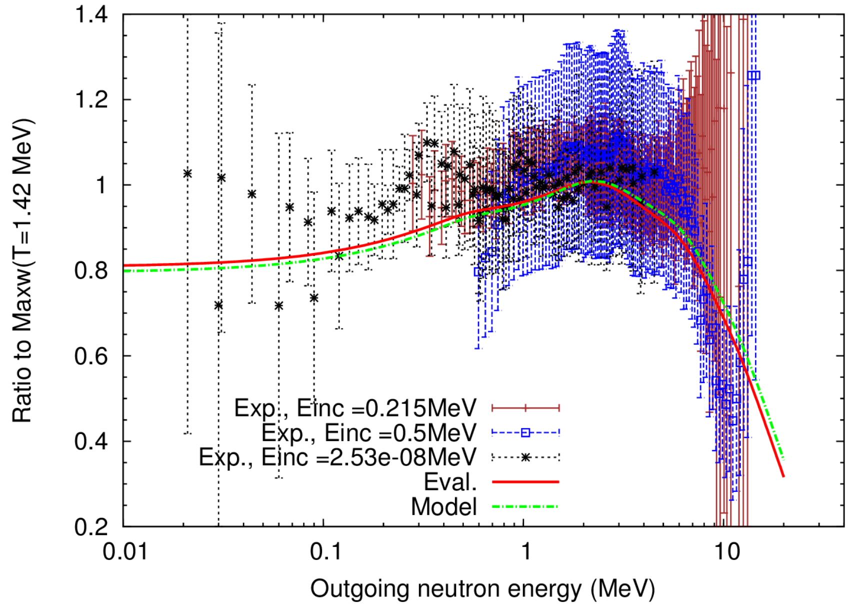
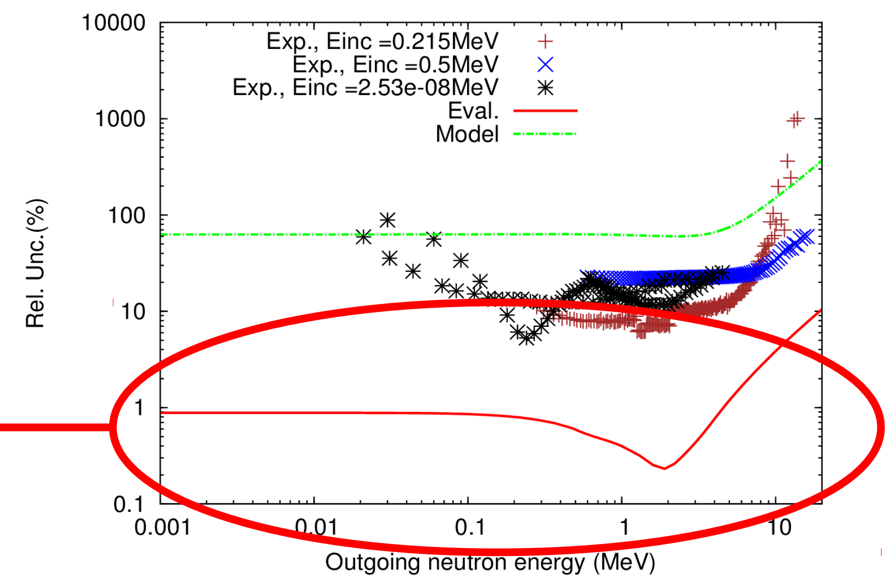


<u>Input data:</u>
Experiment: the same as used for the 2010 evaluation

Model: scaling unc. added to model unc. such that larger than exp. unc., **normalization condition of cov. broken → restored after evaluation.**

If we normalize evaluated results → we end up with low eval. unc. again!



If we add a statistical unc. source to model unc., we obtain reasonable unc. despite the normalization condition.

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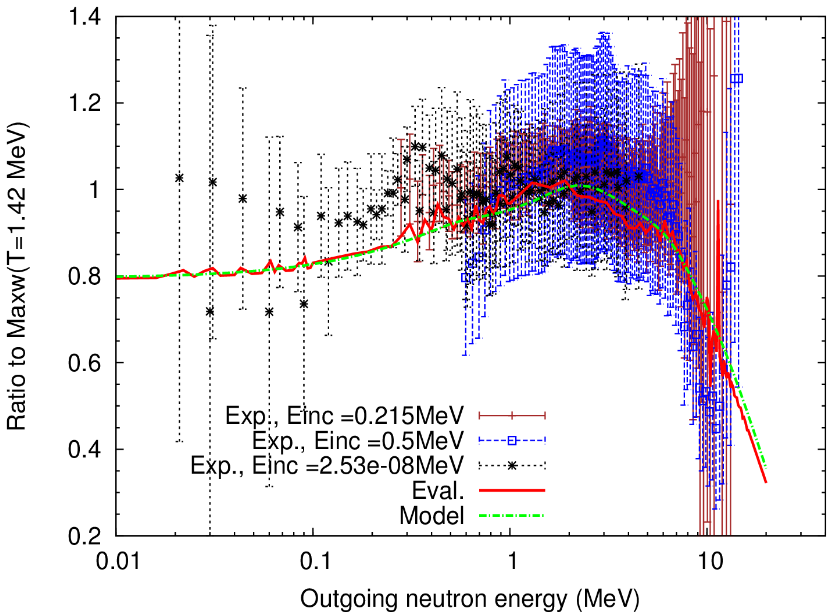
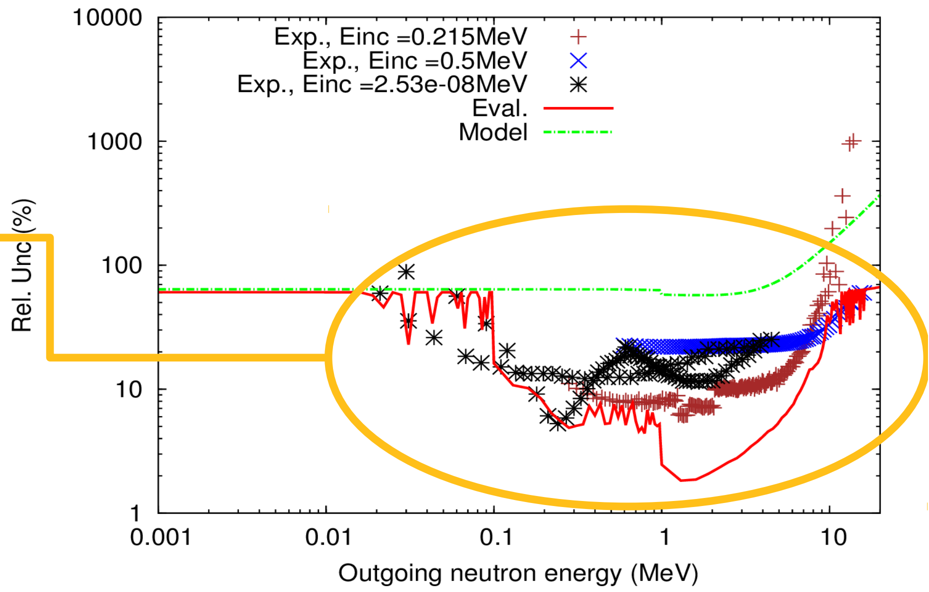


<u>Input data:</u>

Experiment: the same as used for the 2010 evaluation

Model: statistical unc. added to model unc. such that larger than exp. unc., **normalization condition on model cov. enforced.**

If we add statistical uncertainties to the model cov., we obtain reasonable eval. unc.



The strong model correlations in combination with the normalization condition lead to low eval. unc.

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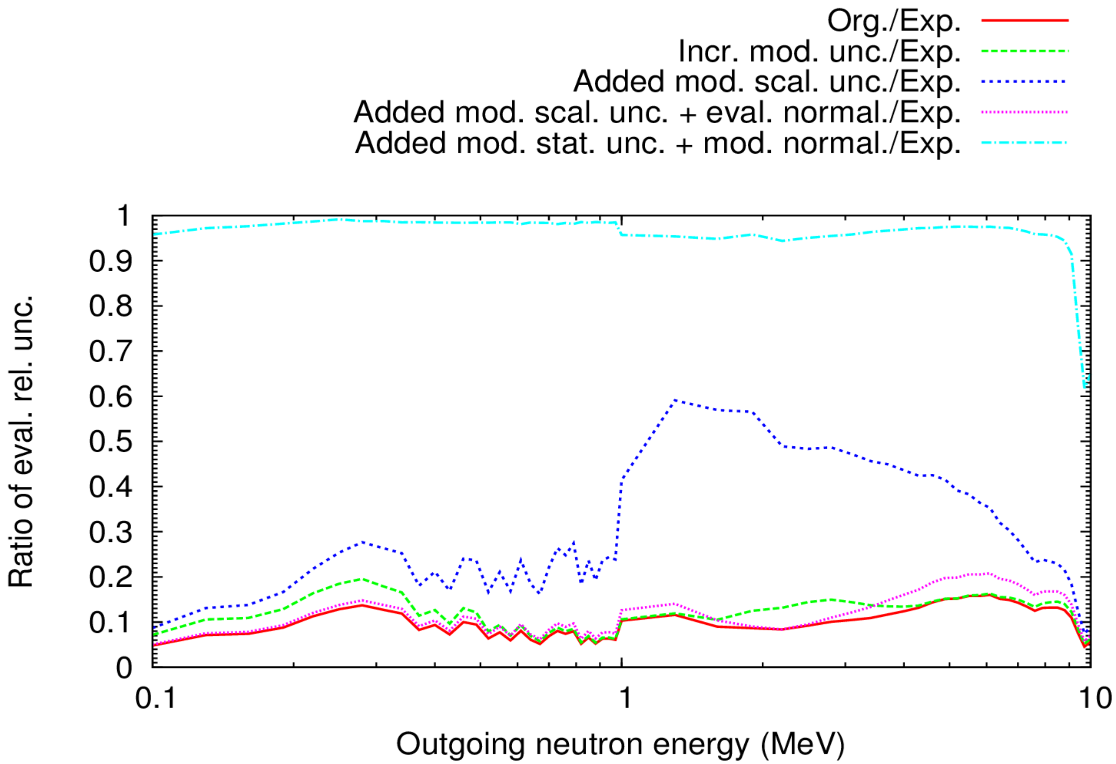

The strong model correlations in combination with the normalization condition on the model cov. lead to low evaluated uncertainties.

Part of this problem is that the **Los Alamos model** describes PFNS with only **4 contributing model parameters**. Is that **physical?** → If not, the low evaluated uncertainties might be an artifact. → tests with MCHF planned (e.g. B. Becker et al., Phys. Rev. C 87, 014617 (2013).)

The eval. shape depends mostly on the model correlations and less if model data are a normalized quantity.

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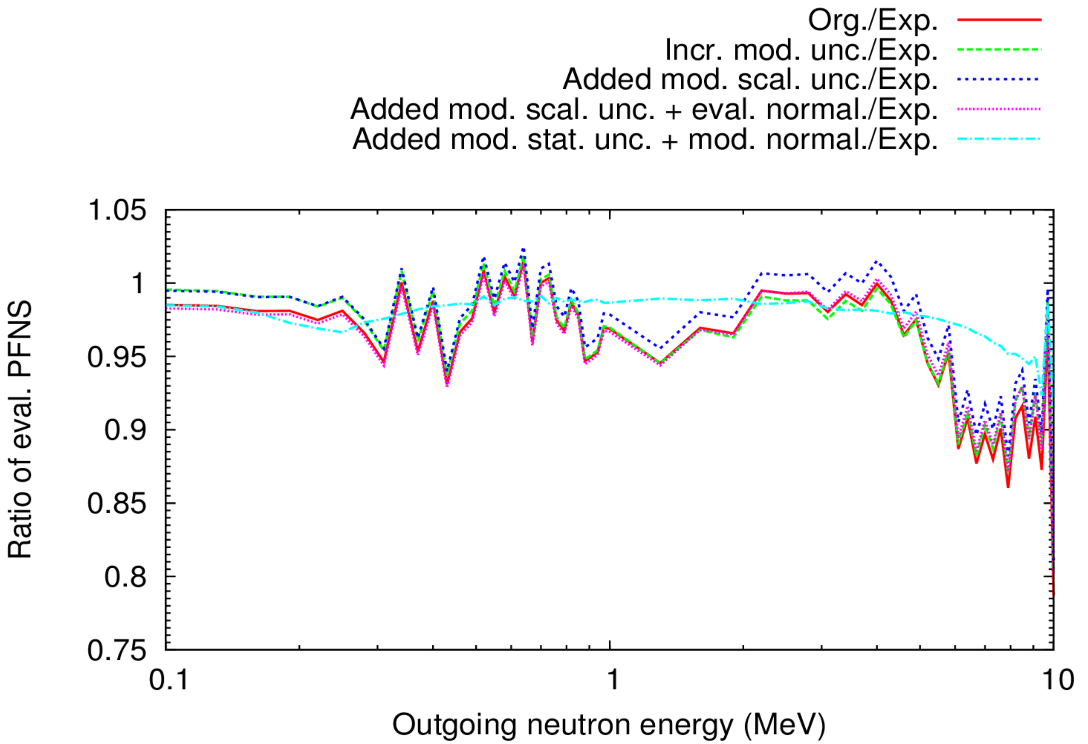

The strong model correlations have a clear impact on the model shape.

Eval. with exp. only and model disagree to 5-10% around 1 MeV and above 5 MeV.

Again, we ***might*** question if it is physical that the **Los Alamos model** describes PFNS with only **4 contributing model parameters**. → tests with MCHF planned (e.g. B. Becker et al., Phys. Rev. C 87, 014617 (2013).)

Summary and conclusion

- Under the **constraint of normalization**, uncertainties are smaller than what we expect from e.g. integral cross section evaluations as **scaling uncertainties drop out**.

- The **low evaluated uncertainties** in the NSE (2010) evaluation are caused by the **strong** Los Alamos **model correlations** in combination with the **normalization condition.**

- The **evaluated shape** is strongly influenced by the **rigid model correlations.** If we evaluate with experimental data only 5-10% differences to an evaluation including model data is observed around 1 MeV and above 4 MeV.

Summary and conclusion

ENDF/B-VII.1 ^{239}Pu PFNS evaluation

Impact of the normalization condition

Studying the evaluation: normalization and strong model cor.

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- Under the **constraint of normalization**, uncertainties are smaller than what we expect from e.g. integral cross section evaluations as **scaling uncertainties drop out**.

- The **low evaluated uncertainties** in the NSE (2010) evaluation are caused by the **strong** Los Alamos **model correlations** in combination with the **normalization condition.**

- The **evaluated shape** is strongly influenced by the]**rigid model correlations.** If we evaluate with experimental data only 5-10% differences to an evaluation including model data is observed around 1 MeV and above 4 MeV.

- Remaining question: ***do the model parameters of the Los Alamos model describe all the physics? → tests with MCHF planned.***