Validating Pu-isotope ENDF/B-VIII.0 Nuclear Data with Critical Assemblies and Pulsed Spheres using Machine Learning Algorithms

CSEWG, Validation Session 12/2/20

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How did we validate Pu-isotope ($^{238-242}$Pu) nuclear data?

Statistics tools used: Random forests and SHAP metric. Shown to be able to highlight issues in nuclear data in Neudecker et al., NDS 167, 36-60 (2020).

Nuclear data validated: $^{238-242}$Pu for ENDF/B-VII.1 and ENDF/B-VIII.0.

Validation experiments used:

- 875 criticality experiments
- 15 LLNL pulsed-sphere neutron-leakage spectra

Additional information used for validation:

- Systematic comparison of nuclear data with differential experimental data from EXFOR (only in rare cases detailed analysis)
- Nuclear-theory considerations

Validation of ^{241}Pu nuclear data: this is a challenge due to compensating errors!

Energy ranges and observables highlighted as problematic by ML.

Energy (MeV)	PFNS	Nu-bar	(n,f)	(n,g)	(n,el)	(n,inl)
Thermal						
7e-8-1e-5						
1-5.5e^{-4}						
5.5e^{-4}-2.5e^{-2}						
2.5e^{-2}-2.479						
2.479-4.8						
4.8-8.187						

No Diff. Exp.

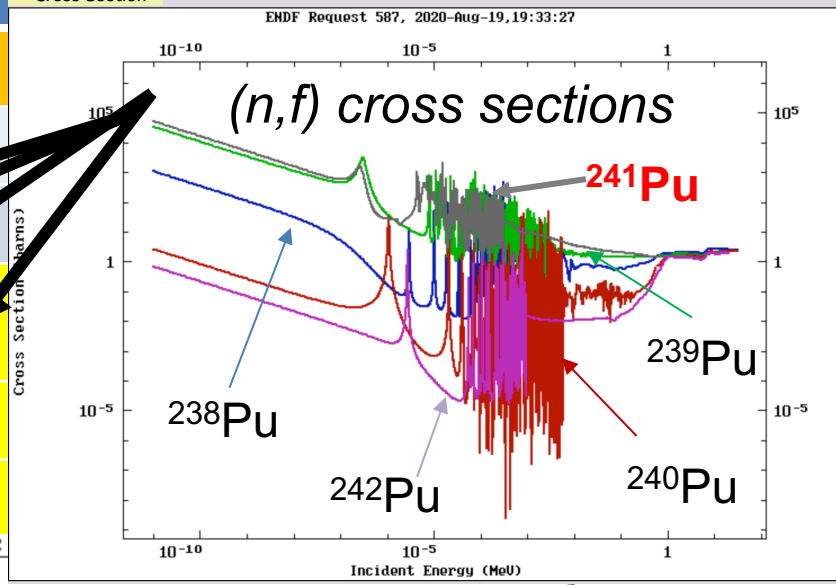
Exp. Agree with evaluation but freedom to move

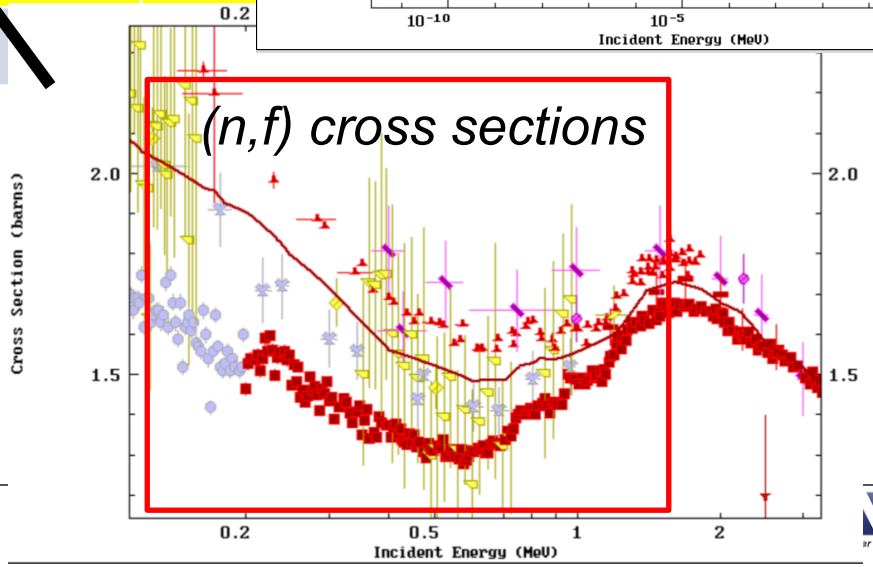
Diff. Exp. Disagree with evaluation

“Highlights” of issues in ^{241}Pu nuclear data:

Can we extend resonance range of (n,f), (n,el) and (n,g)?

Energy (MeV)	PFNS	Nu-bar	(n,f)	(n,g)	(n,el)	(n,inl)
Thermal						
7e-8-1e-5						
1-5.5e^{-4}						
5.5e^{-4}-2.5e^{-2}						
2.5e^{-2}-2.479						
2.479-4.8						
4.8-8.187						





MAXWELLIAN USED FOR PFNS! Not a good approximation

High-level summary of issues in ^{241}Pu nuclear data:

Issues that are recommended to be investigated for a new release:	• **(n,f) cross section from 0.1-2 MeV.** • **Replace PFNS with an evaluation that captures the physics expected behavior better.** • **Investigate if it is possible to extend the resonance range to higher E_{inc}.**
Potential freedom in nuclear data that could be exploited to obtain better agreement with validation experiments:	• Get a finer grid for nu-bar. • Investigate if it is feasible and beneficial to get closer to some standards at thermal, especially (n,f) and nu-bar (the (n,f) thermal value differs by about 1 sigma from standard value).

Validation of ^{239}Pu nuclear data: also a challenge due to compensating errors!

Energy ranges and observables highlighted as problematic by ML.

Energy (MeV)	PFNS	Nu-bar	(n,f)	(n,g)	(n,el)	(n,inl)	(n,2n)
Thermal							
$5e^{-8}$-$4e^{-7}$							
$4e^{-7}$-$8.1e^{-6}$							
$8.1e^{-6}$-0.1							
0.1-2.354							
2.354-8.187							

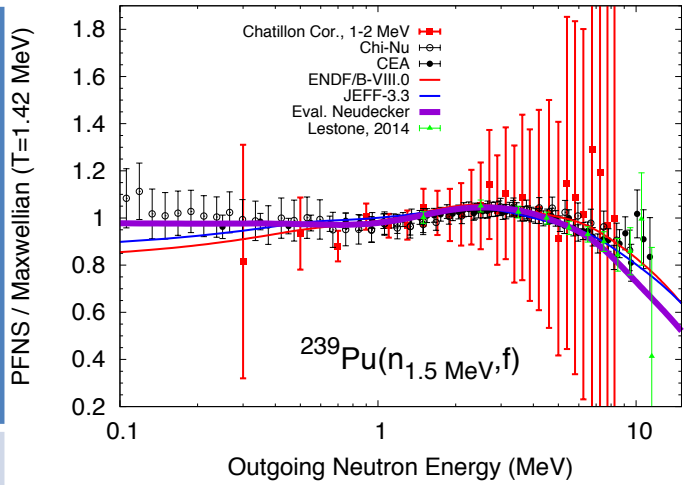
No Diff. Exp.

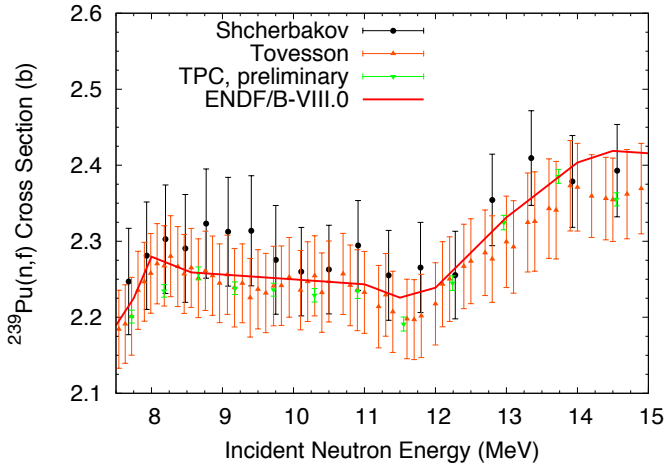
Exp. Agree with evaluation but freedom to move

Diff. Exp. Disagree with evaluation

High-level summary of issues in ^{239}Pu:

Issues that are recommended to be investigated for a new release:	• **Re-evaluate PFNS with recent Chi-Nu and CEA exp. data.** • **(n,f): Are there structures in the URR? (see Bertsch, PRC 98, 014611 (2018)); where should the eval. cs above 10 MeV go?**
Potential freedom in nuclear data that could be exploited to obtain better agreement with validation experiments:	• After PFNS is fixed, one might investigate thermal constants compared to standard values. • Incorporate newest (n,f) standard. • 0.3-17 keV for nu-bar (no exp. data) and tweaking nu-bar in the fast. • Balance (n,tot), (n,el) & (n,inl) cs from 0.1-2.4 MeV.





TPC data normalized to VIII.0 at 13.75 MeV

Validation of ^{240}Pu nuclear data:

Energy ranges and observables highlighted as problematic by ML.

Energy (MeV)	PFNS	Nu-bar	(n,f)	(n,g)	(n,el)	(n,inl)
Thermal						
3.25e-7-5.5e-4						
5.5e^{-4}-2.5e-2						
2.5e^{-2}-1.85						
1.85-3						
3-12.84						
12.84-15.68						

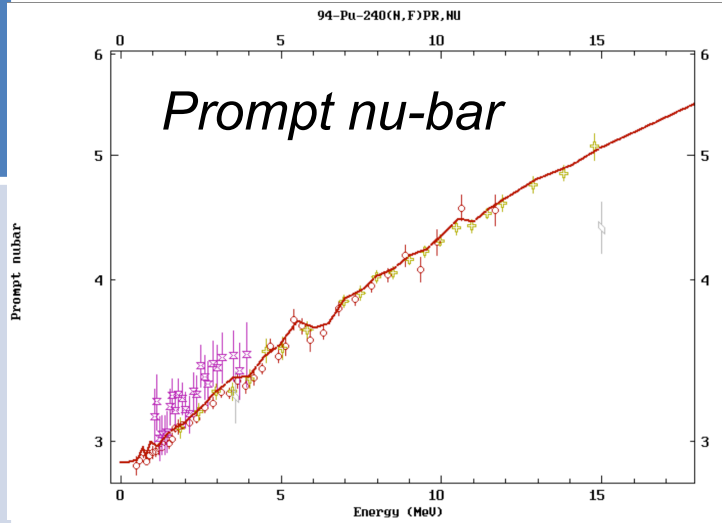
No Diff. Exp.

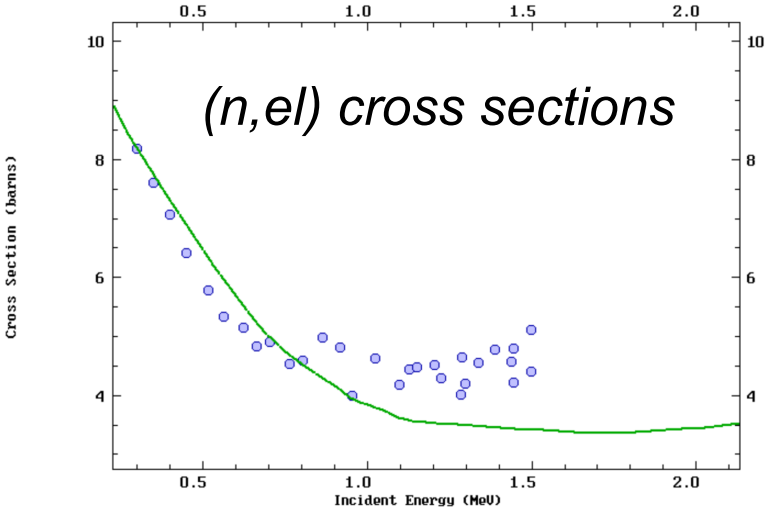
Exp. Agree with evaluation but freedom to move

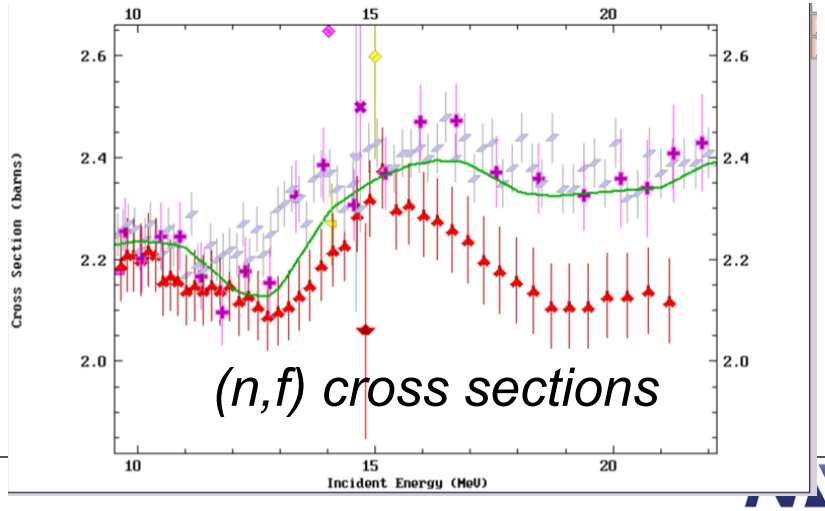
Diff. Exp. Disagree with evaluation

High-level summary of issues in ^{240}Pu:

Issues that could be investigated:	• Is the shape of nu-bar physical? (0.5-0.9, 4-6, 13-15 MeV) • Study (n,f) cs in the fast range
Potential freedom in nuclear data:	• Re-evaluate PFNS with Chi-Nu exp. if different (avoid compensating effects) • Is there an issue in the (n,el) cs from 0.9-1.2 MeV? Exp. Data might be misleading.







National Nuclear Security Administration

Validation of ^{238}Pu nuclear data:

Energy ranges and observables highlighted as problematic by ML.

Energy (MeV)	PFNS	Nu-bar	(n,f)	(n,g)	(n,el)	(n,inl)
Thermal						
$1e^{-7}$-$3.25e^{-7}$						
$3.25e^{-7}$-$8.1e^{-6}$						
$8.1e^{-6}$-$1.7e^{-2}$						
$1.7e^{-2}$-0.9						
0.9-2.479						
2.479-3						

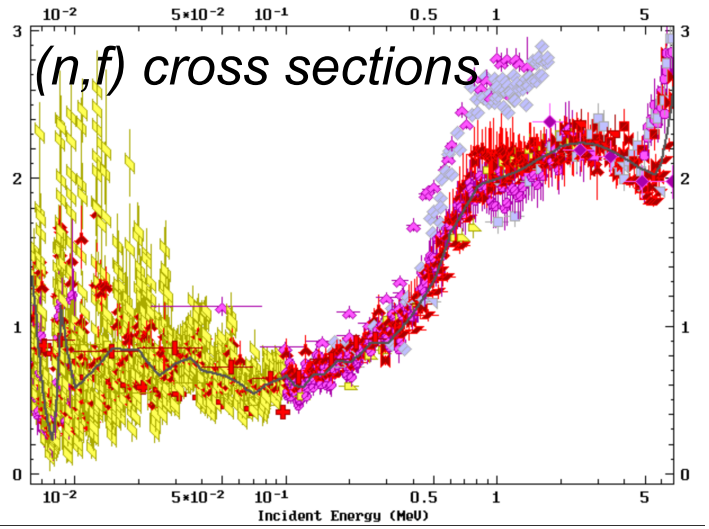
No Diff. Exp.

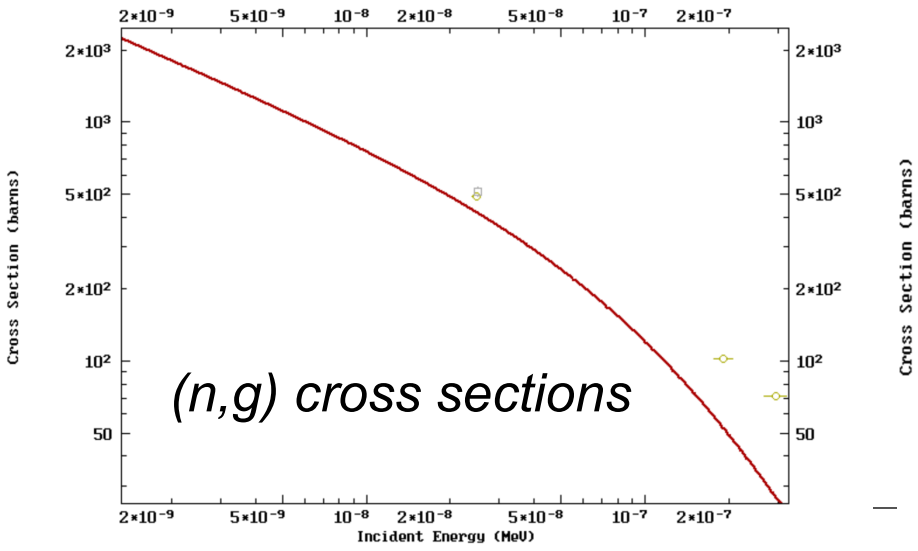
Exp. Agree with evaluation but freedom to move

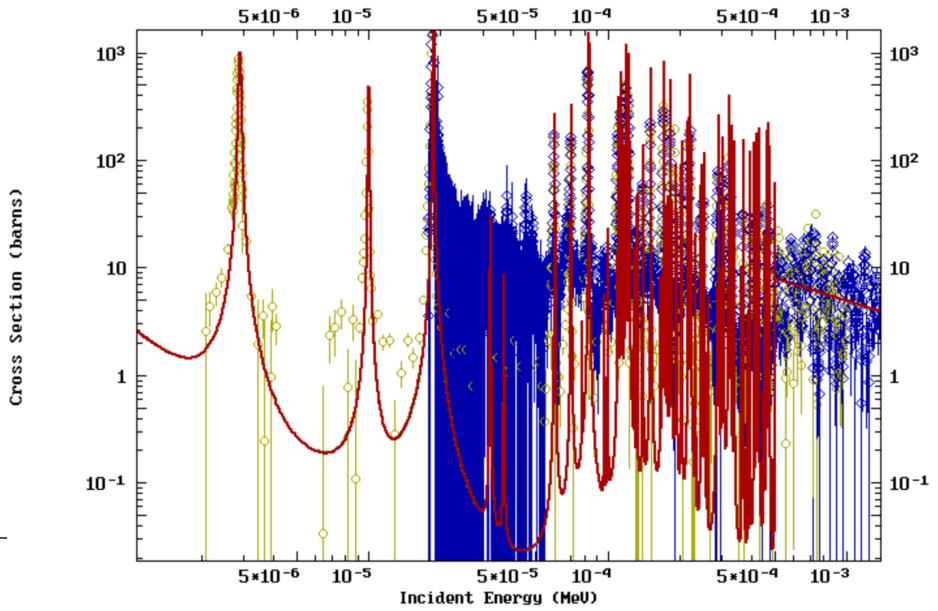
Diff. Exp. Disagree with evaluation

High-level summary of issues in ^{238}Pu:

Issues that could be investigated:	• Re-evaluate thermal nu-bar using exp. data • (n,g): study exp. Data close to ~1e^{-7} and for 1e^{-5}-1e^{-3} MeV
Potential freedom in nuclear data:	• (n,f): check at thermal, one can tweak from 0.1–3 MeV.







Validation of ^{242}Pu nuclear data:

Energy ranges and observables highlighted as problematic by ML.

Energy (MeV)	PFNS	Nu-bar	(n,f)	(n,g)	(n,el)	(n,inl)
Thermal						
$1.5e^{-7}$-$2e^{-7}$						
$2e^{-7}$-$3e^{-6}$						
$3e^{-6}$-$3e^{-3}$						
$3e^{-3}$-$1.72e^{-2}$						
$1.72e^{-2}$-0.9						
0.9-6.434						

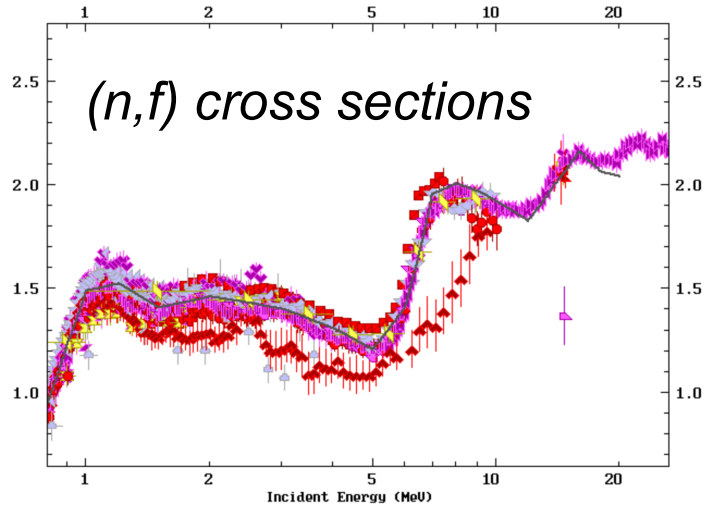
No Diff. Exp.

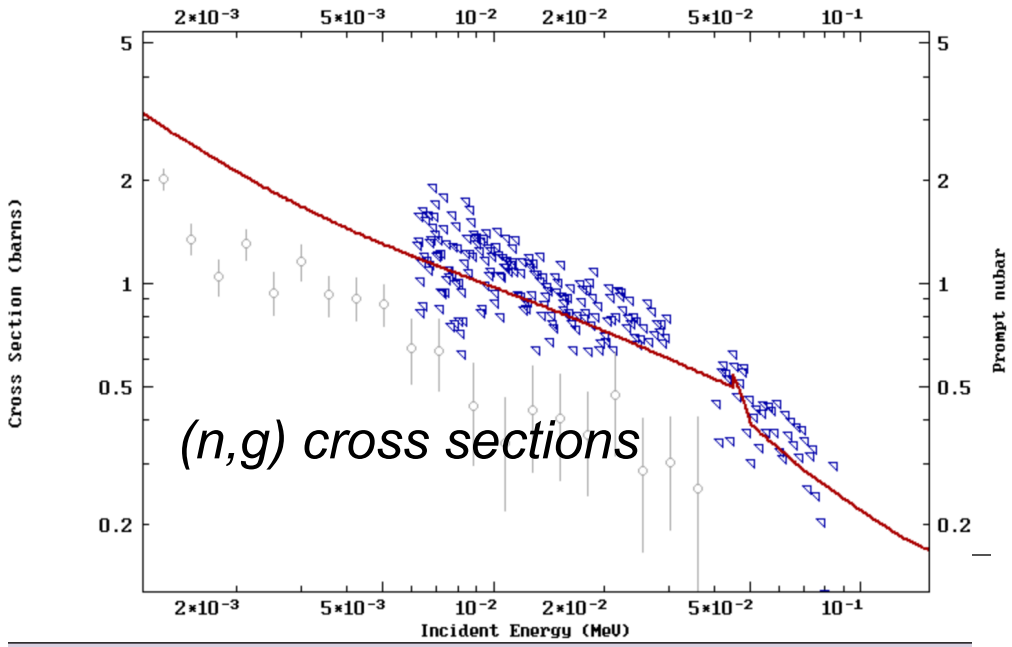
Exp. Agree with evaluation but freedom to move

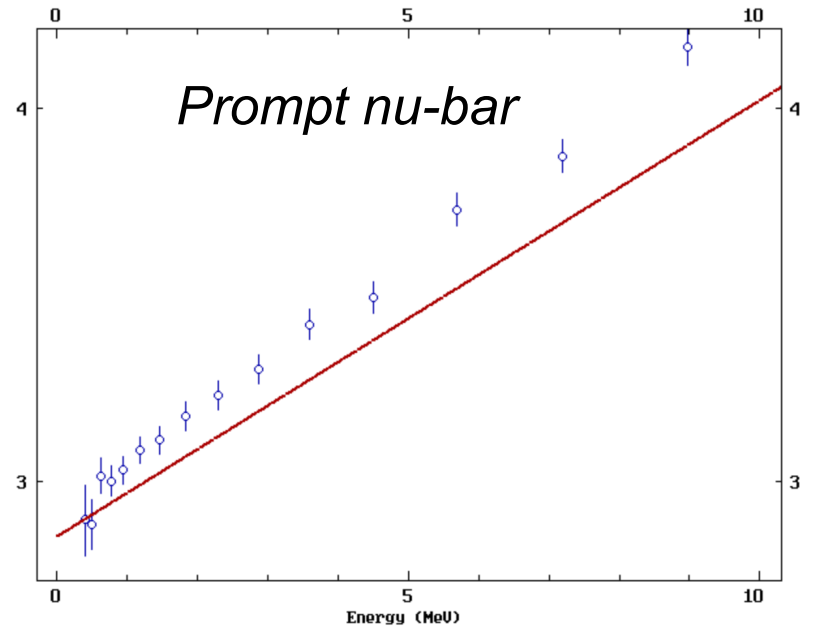
Diff. Exp. Disagree with evaluation

High-level summary of issues in ^{242}Pu:

Issues that could be investigated:	• **Analyze nu-bar using exp. data** • **(n,g): try to understand discrepancies in exp. And resonance range**
Potential freedom in nuclear data:	• (n,f): study experiments and tweak from 0.9–20 MeV.







Summary

- We validated $^{238\text{-}242}$Pu ENDF/B-VIII.0 nuclear data with respect to 875 critical assemblies and 15 pulsed spheres. We also compared evaluated data to differential data from EXFOR and took into account basic theoretical considerations.
- CAVEAT: experimental data were not analyzed in detail and a comparison to EXFOR as is might be misleading. SG-50 might help for such undertakings.
- A (down-selected) listing of potential issues in nuclear data that could be investigated for a new release was shown.
- Some hints potential freedom to move nuclear data is given.
- ***Is someone interested in helping us investigate resonance-range issues?***

Thank you for your attention!

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