Los Alamos
NATIONAL LABORATORY

New ^{238}U PFNS evaluation including Chi-Nu experimental data and ENDF/B-VIII.1b4 validation with LLNL pulsed spheres

Denise Neudecker
Mini-CSEWG, 8/14/24

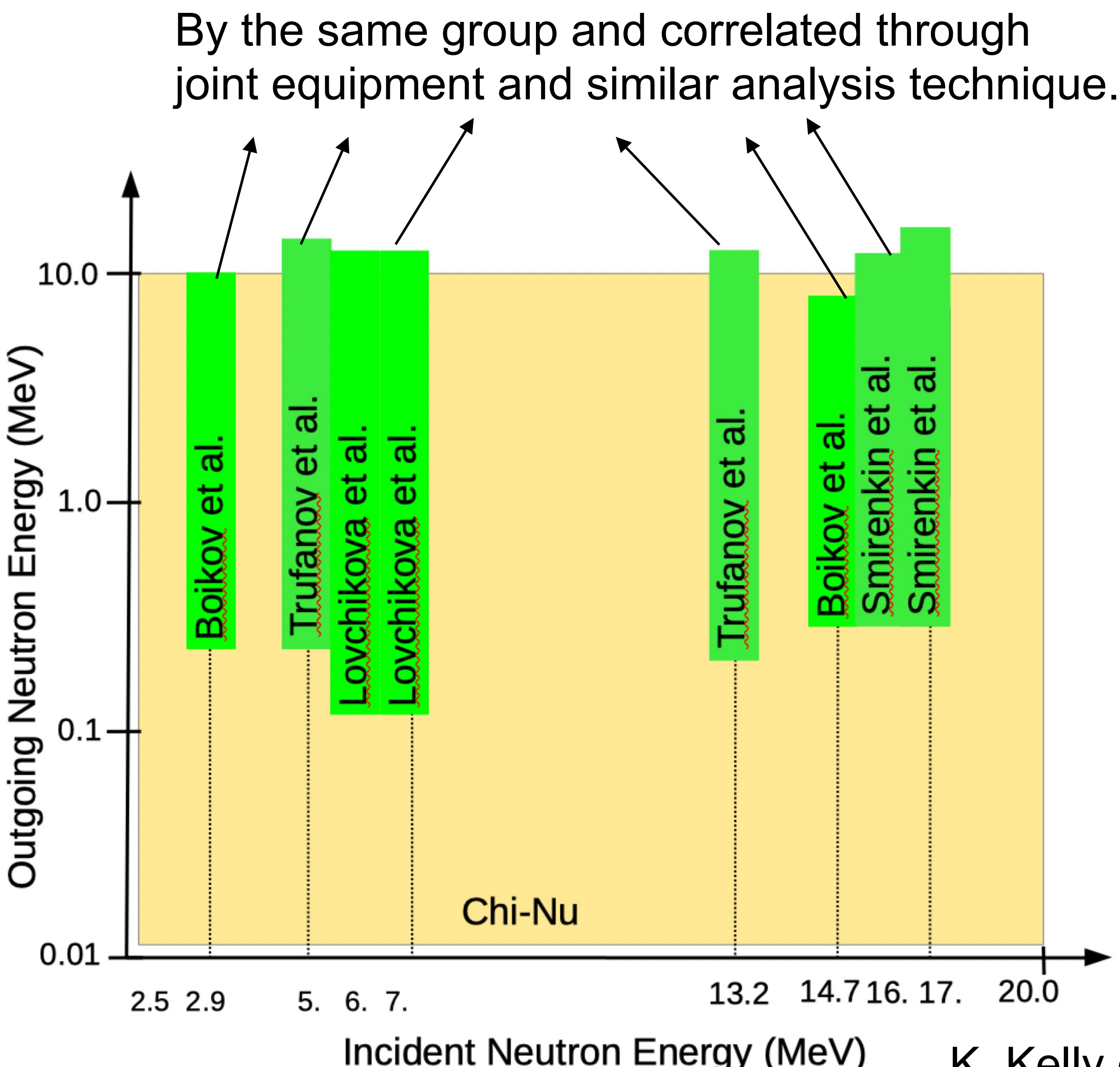
Thanks to: K.J. Kelly, T. Kawano, A.E. Lovell, R.C.Little, M. Devlin, P. Talou, and M.B. Chadwick.

LA-UR-24-28536

The evaluation is published in DN et al., LA-UR-24-25503.

Why a new ^{238}U PFNS evaluation?

New high-precision Chi-Nu ^{238}U PFNS cover a broad E_{inc} and E_{out} range allowing for a consistent evaluation.



LANL/ LLNL Chi-Nu data:

- Cover broader Einc and E_{out} ranges than previously available.
- Have carefully assessed uncertainties.

→ Chi-Nu data are key to map evaluated PFNS more completely out.

Also, VIII.1 is VIII.0 < 5 & > 8 MeV , and JENDL-5.0 otherwise. Here, we have one evaluation.

K. Kelly et al., PRC **108, 024603** (2023)

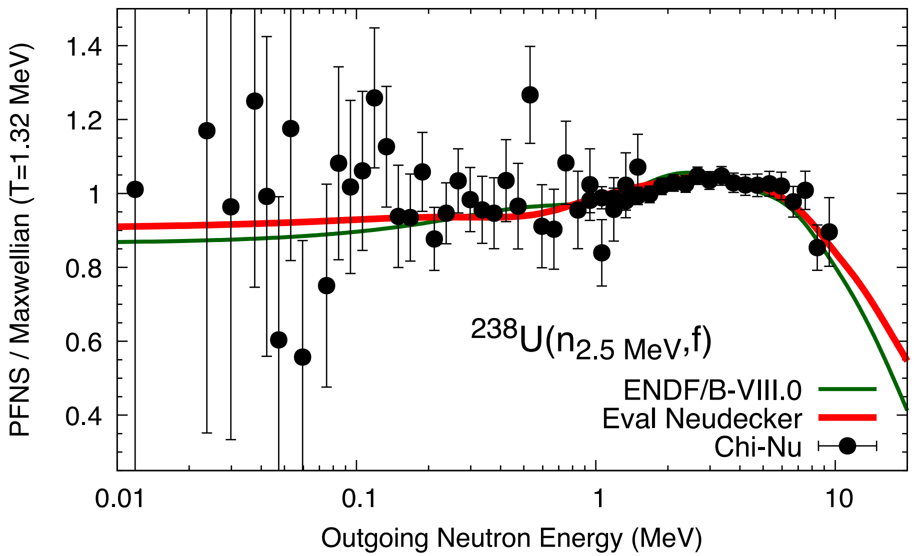
Evaluation algorithm and model input

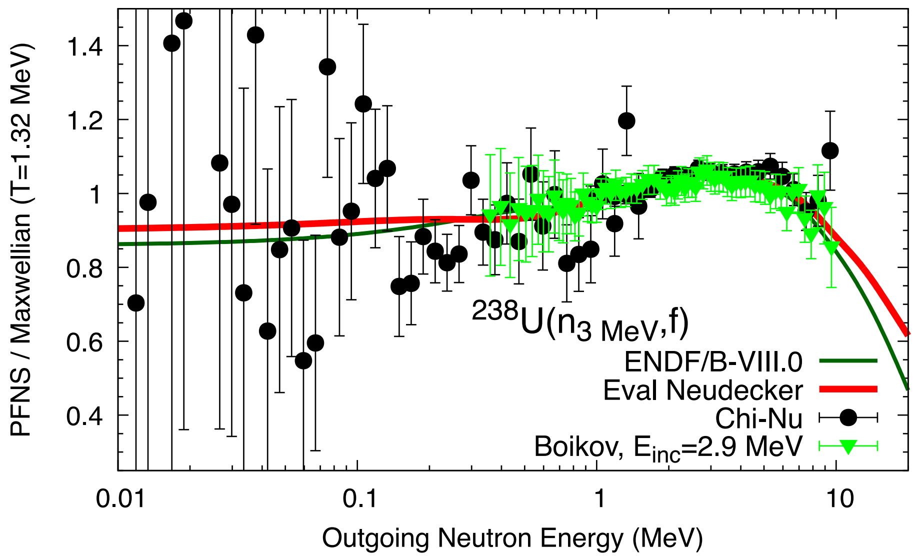
Model PFNS were obtained with an extended Los Alamos model in CoH. Evaluation done with GLS.

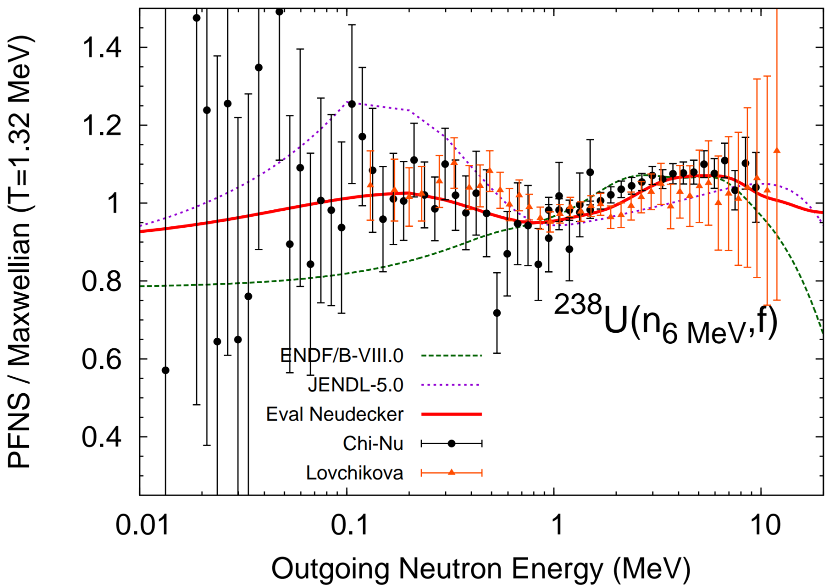
- Model PFNS provide prior for GLS evaluation. We have precise experimental data from E_{inc} = 2-20 MeV and E_{out}=0.8-10 MeV. The prior helps to extrapolate to high and low E_{out}, and below E_{inc} = 2 MeV (^{238}U fission threshold is between 1-2 MeV).
- Used CoH code and ^{238}U input deck by Toshihiko Kawano for level scheme, fission barriers, etc.
- Used extended Los Alamos model as described in D. Neudecker et al., Nucl. Data Sheets 148, 293 (2018); D. Neudecker et al., NIMA 791, 80 (2015).
- Parametrized TKE, energy release, etc., as a function of E_{inc}.
- Exciton model used to describe pre-equilibrium component.
- Evaluation undertaken with GLS in PFNS space.

Evaluated results

New eval. PFNS gets reasonably close to Chi-Nu PFNS at E_{inc} < 7 MeV and differs in the wings from VIII.0.



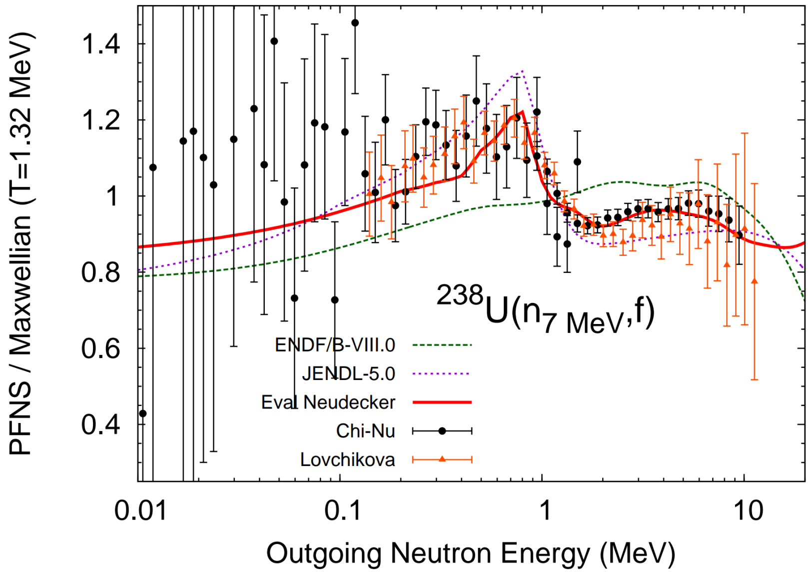


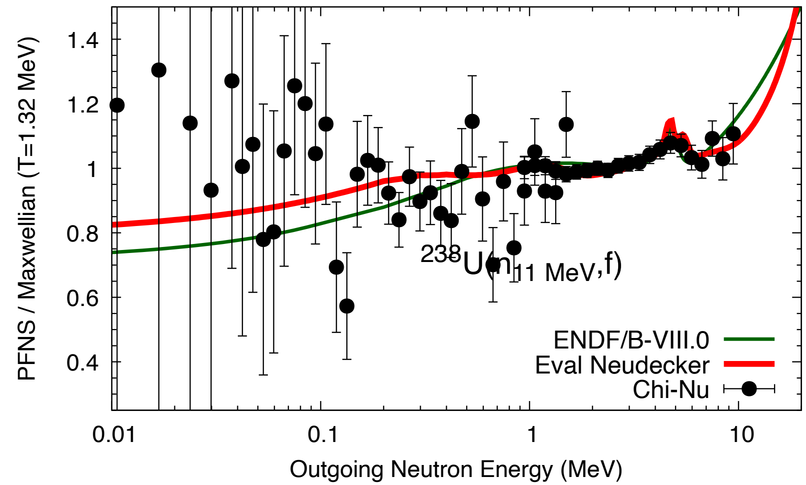


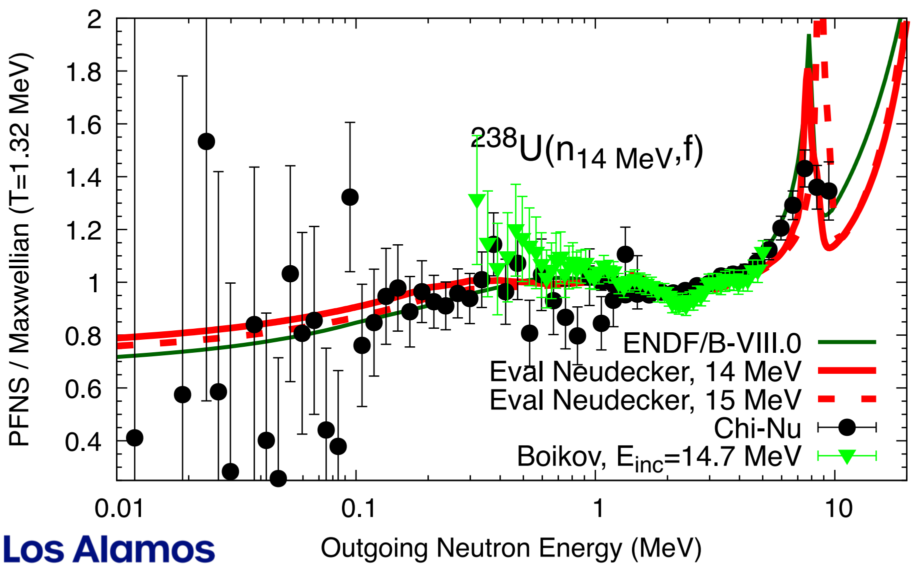
- The evaluated PFNS is close to ENDF/B-VIII.0 for E_{inc} <= 5 MeV.
- No larger change in crit k_{eff} expected.
- Increase at low E_{out} for E_{inc} = 6 MeV shows second chance fission clearly.

NATIONAL LABORATORY

Eval. PFNS gets reasonably close to Chi-Nu PFNS for 2nd and 3rd-chance fission and pre-equilibrium component.

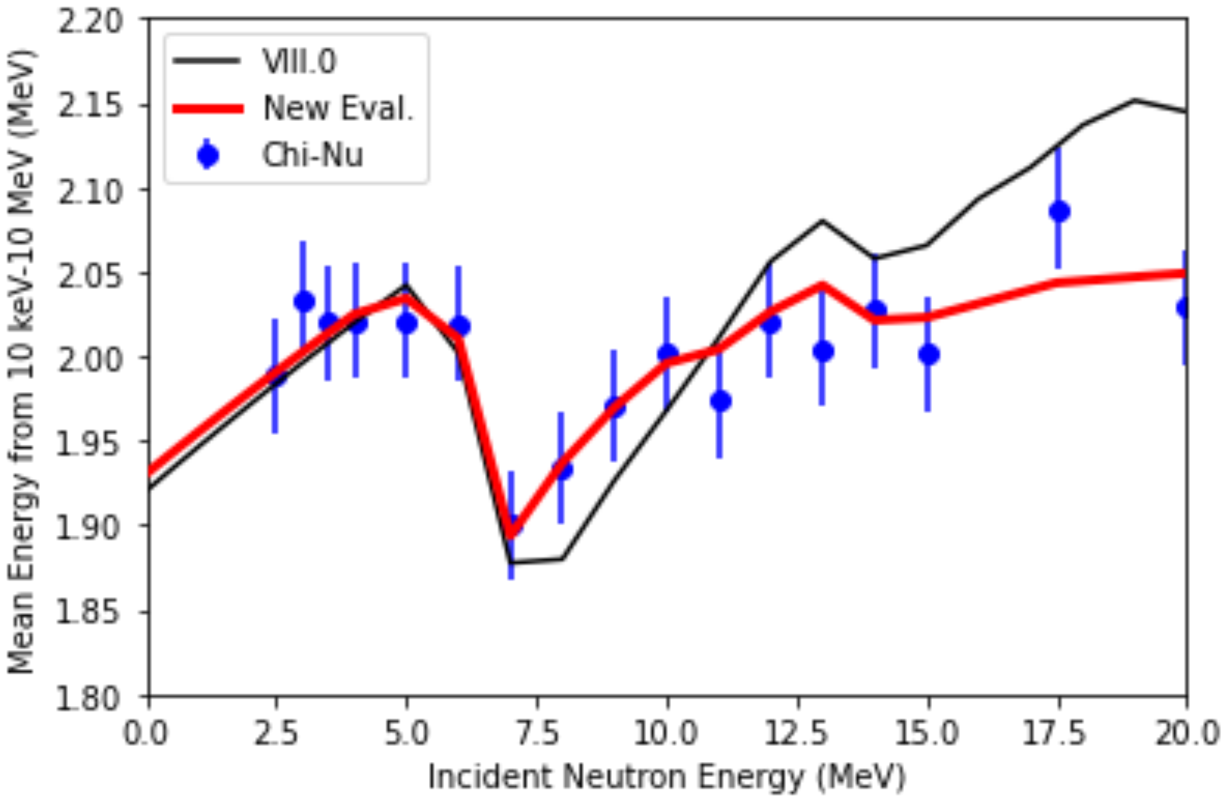






- More pronounced shape at E_{inc} = 7 MeV due to large angular anisotropy of FF emission compared to $^{235}U/^{239}Pu$.
- Third-chance fission component to the PFNS more subtle but pre-equilibrium process is visible.
- Larger changes at high E_{inc} will impact LPS.

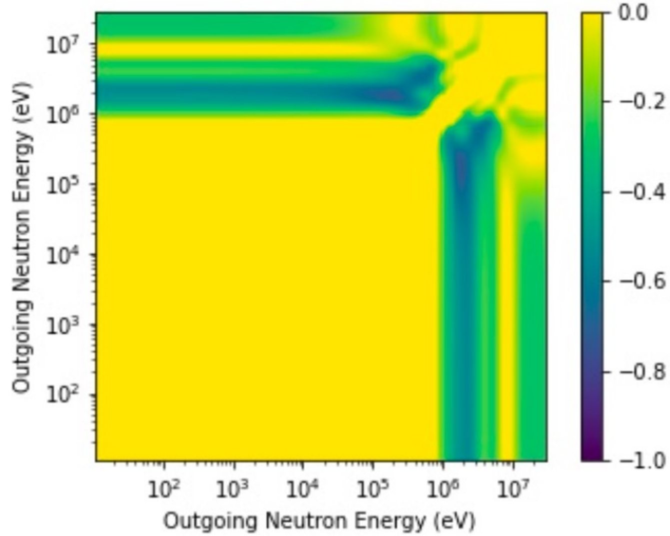
Mean energy of the PFNS shows that new eval. and Chi-Nu are close to ENDF/B-VIII.0 for E_{inc} < 6 MeV.

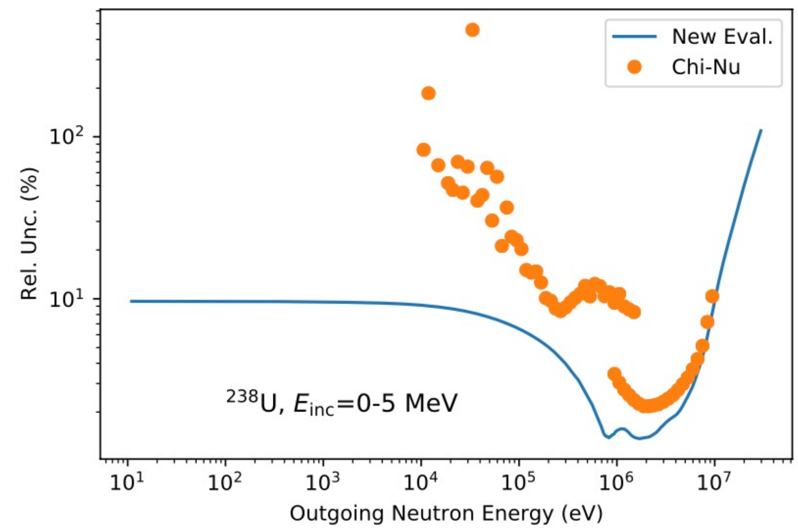


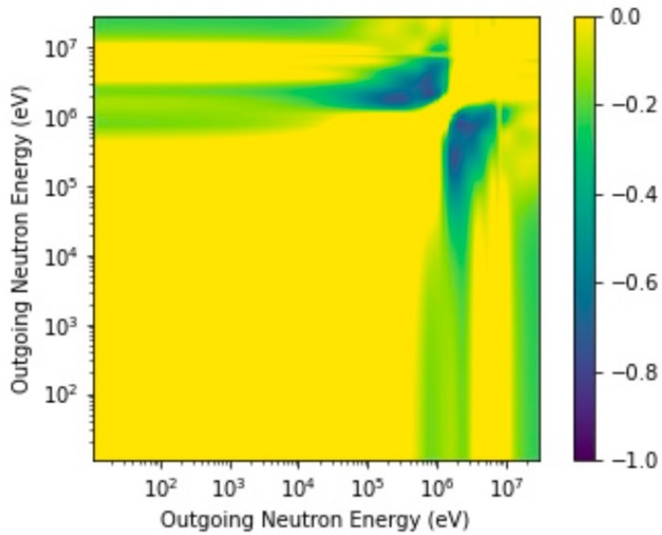
- Given how close the new eval. is to VIII.0 for E_{inc} < 6 MeV, little impact on k_{eff} of ICSBEP benchmarks expected.
- Larger change for E_{inc} ~ 14 MeV could impact LLNL pulsed spheres simulations.

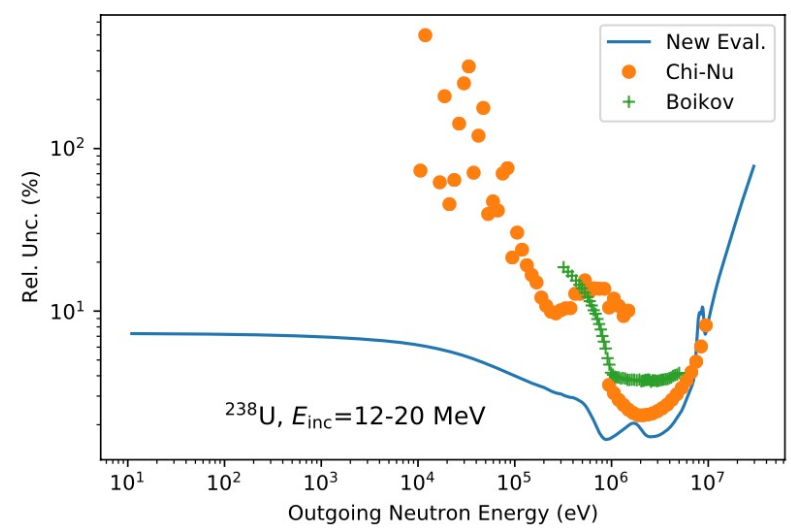
E_{inc}-group	Mean Energy Uncertainty (keV)
0–5	19.3
5–9	23.5
9–12	20
12–20	21.5

Evaluated uncertainties are driven by Chi-Nu experimental uncertainties and model correlations.









Los Alamos NATIONAL LABORATORY

Validation results

- Uses DECE by T. Kawano to produce ENDF-6 formatted data.
- NJOY for processing.
- MCNP-6.2 for neutron-transport simulations.
- Thanks to S. Frankle and S. Kahler for input decks.

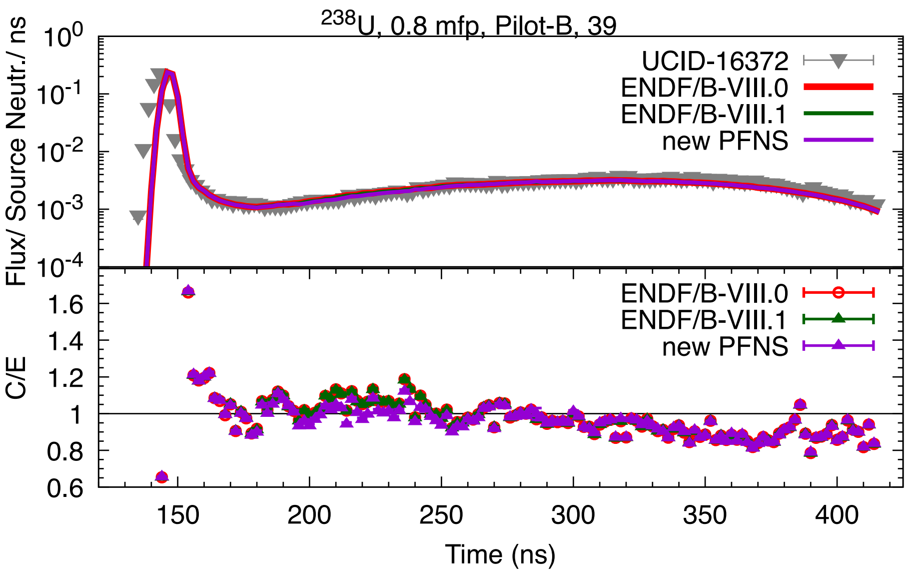
Crit testing: Changes are within 1-2 sigma of MC statistics.

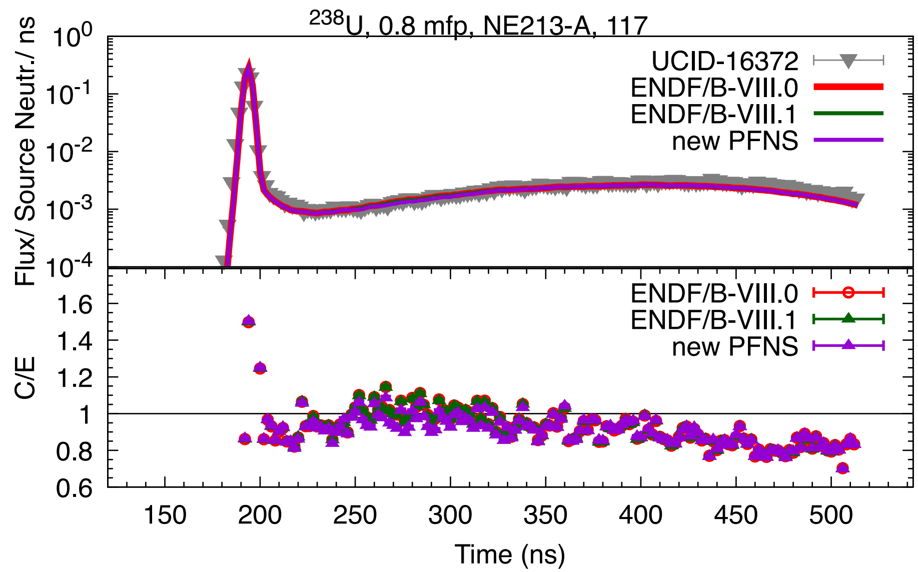
Assembly	VIII.0	VIII.1beta3	VIII.1beta3+PF NS	Experiment
Flattop-Pu (PMF006)	0.99970(10)	0.99989(10)	1.00009(10)	1.00000(300)
Flattop-U (HMF028)	1.00093(9)	1.00065(9)	1.00073(9)	1.00000(300)
BigTen (IMF007d)	1.00414(8)	1.00471(8)	1.00494(8)	1.00460(200)

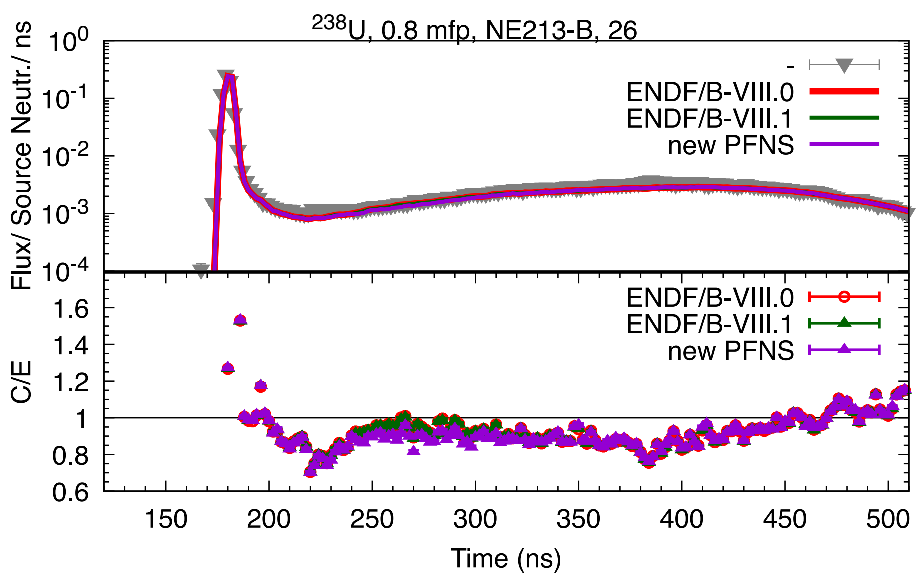
Assembly	C/E VIII.0	C/E VIII.1beta3	C/E VIII.1beta3+PF NS
Flattop-Pu (PMF006)	0.99970	0.99989	1.00009 Within 2s unc.
Flattop-U (HMF028)	1.00093	1.00065	1.00073 Within 1s unc.
BigTen (IMF007d)	0.99954	1.00011	1.00034 Within 2s unc.

All three benchmarks have thick reflectors with a high percentage of ^{238}U.

Thin ^{238}U LLNL Pulsed Spheres: two better, one worse after the inelastic valley, but within exp. uncertainty.

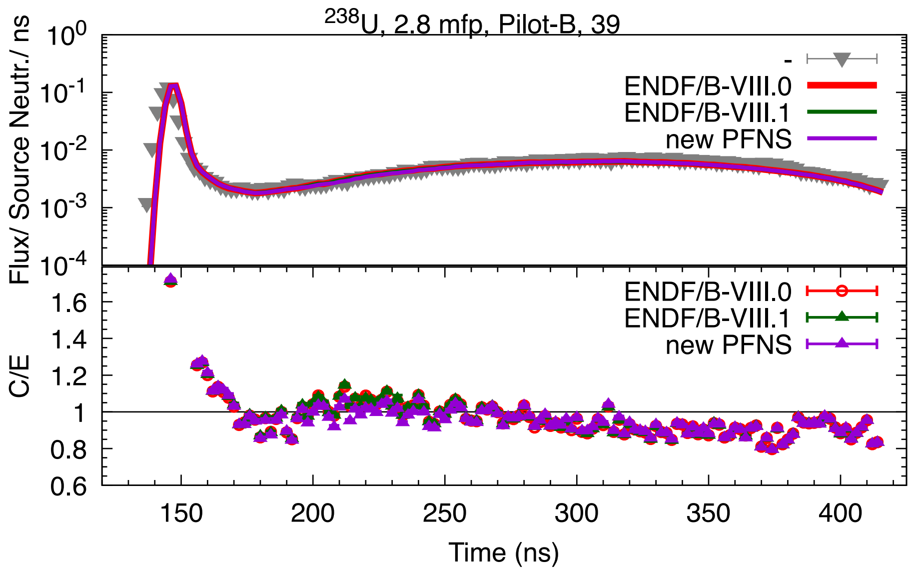


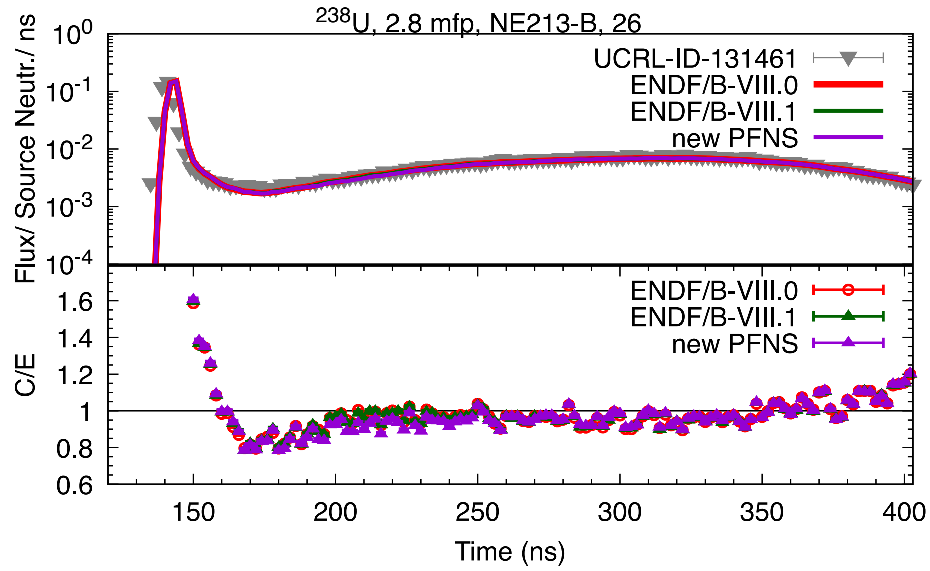




Los Alamos
NATIONAL LABORATORY

Thick ^{238}U LLNL Pulsed spheres: one better, one slightly worse after the inelastic valley but within exp. uncertainty,





- Over all five pulsed spheres, we are getting slightly better results after the inelastic valley.
- The spheres with 26 degree perform slightly worse, while the 39- and 117-degree spheres perform better but well with exp. unc.
- 26 degree queries slightly higher E_{inc} (more of E_{inc} = 15 MeV) compared to 39 and 117 degree.

Summary:

- New evaluated ^{238}U PFNS make use of LANL/LLNL Chi-Nu high-precision experimental data paid for by NCSP.
- Extended Los Alamos and exciton models (CoH) used.
- New evaluated PFNS differ noticeably from VIII.0, but mean energy close for $E_{inc} < 6$ MeV.
- k_{eff} of crits with thick ^{238}U-containing reflectors are within 1-2 sigma of MC statistics.
- Changes in LLNL pulsed spheres are noticeable after inelastic peak and are within exp. unc.

We are happy to share evaluated data at this point.

Thank you for your attention!

This work was supported by the DOE Nuclear Criticality Safety Program, funded and managed by the NNSA for the Department of Energy.

We gratefully acknowledge the support of the Advanced Simulation and Computing (ASC) program at Los Alamos National Laboratory.

LLNL Pulsed Sphere Results with ENDF/B-VIII.1b4: no surprises

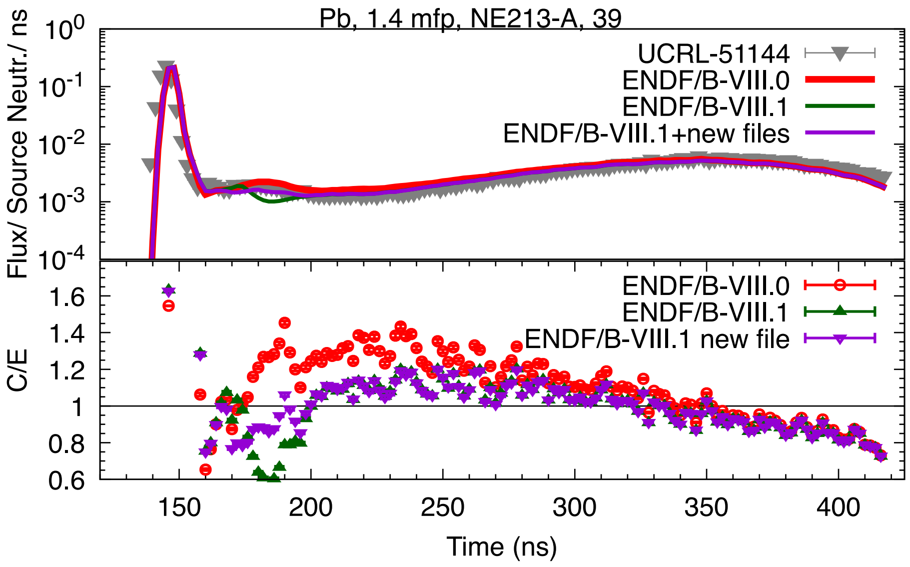
For beta4, these materials changed and the following LPS were tested:

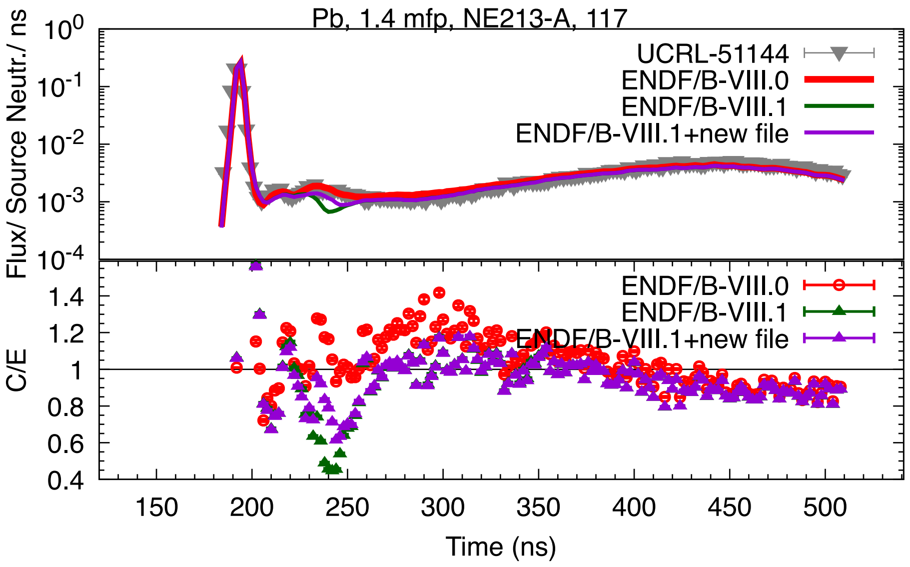
- n-003_Li_006.endf: Li6 and Li7 spheres.
- n-006_C_013.endf: C spheres, poly, Teflon,
- n-008_O_016.endf: O16 sphere, light and heavy water, concrete,
- n-026_Fe_056.endf: Fe spheres
- n-026_Fe_057.endf Fe spheres
- n-092_U_235.endf 235U spheres
- n-094_Pu_239.endf 239Pu spheres

All the changes from beta3 to beta4 were either zero or negligible for these LPS.

Thanks to Wim for processing!

Peter Brain provided new $^{206-208}$Pb files for beta4 (ENDF/B-VIII.1 + new files) improving beta3 (ENDF/B-VIII.1).





Less pronounced structures after the elastic peak than beta3.
Visible improvements compared to VIII.0 also in some TOF ranges.