LANL update to ^{239}Pu

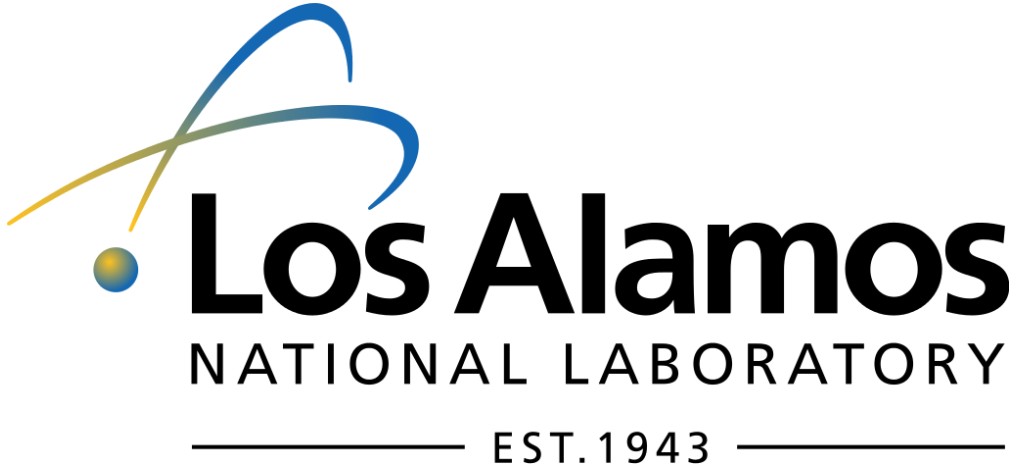
in the fast energy range

Los Alamos NATIONAL LABORATORY EST. 1943

MATTHEW MUMPOWER
DENISE NEUDECKER

NDT
Nuclear Data Team

LA-UR-21-31243



SUMMARY OF CURRENT STATUS: UPDATES SINCE ENDF/B-VIII.0

We are in the process of updating the ^{239}Pu cross sections in the fast energy range
(complementing the work of IAEA / INDEN / ORNL lower energy work in the resonance range)

LANL has been overhauling its evaluation tools (CoH, CGMF, DeCE, Kalman, NEXUS, PySOK, SOK)

Focus on consistency throughout evaluation (we are evaluating more isotopes)

Model update: new collective enhancement allows for simultaneous description of (n,f) and (n,2n) channels

Model update: new inelastic scattering model using the Engelbrecht-Weidenmuller transformation

New cross section evaluation goes up to 30 MeV (as well as nu-bar and PFNS)

New (n,γ) data from S. Mosby up to ~1 MeV

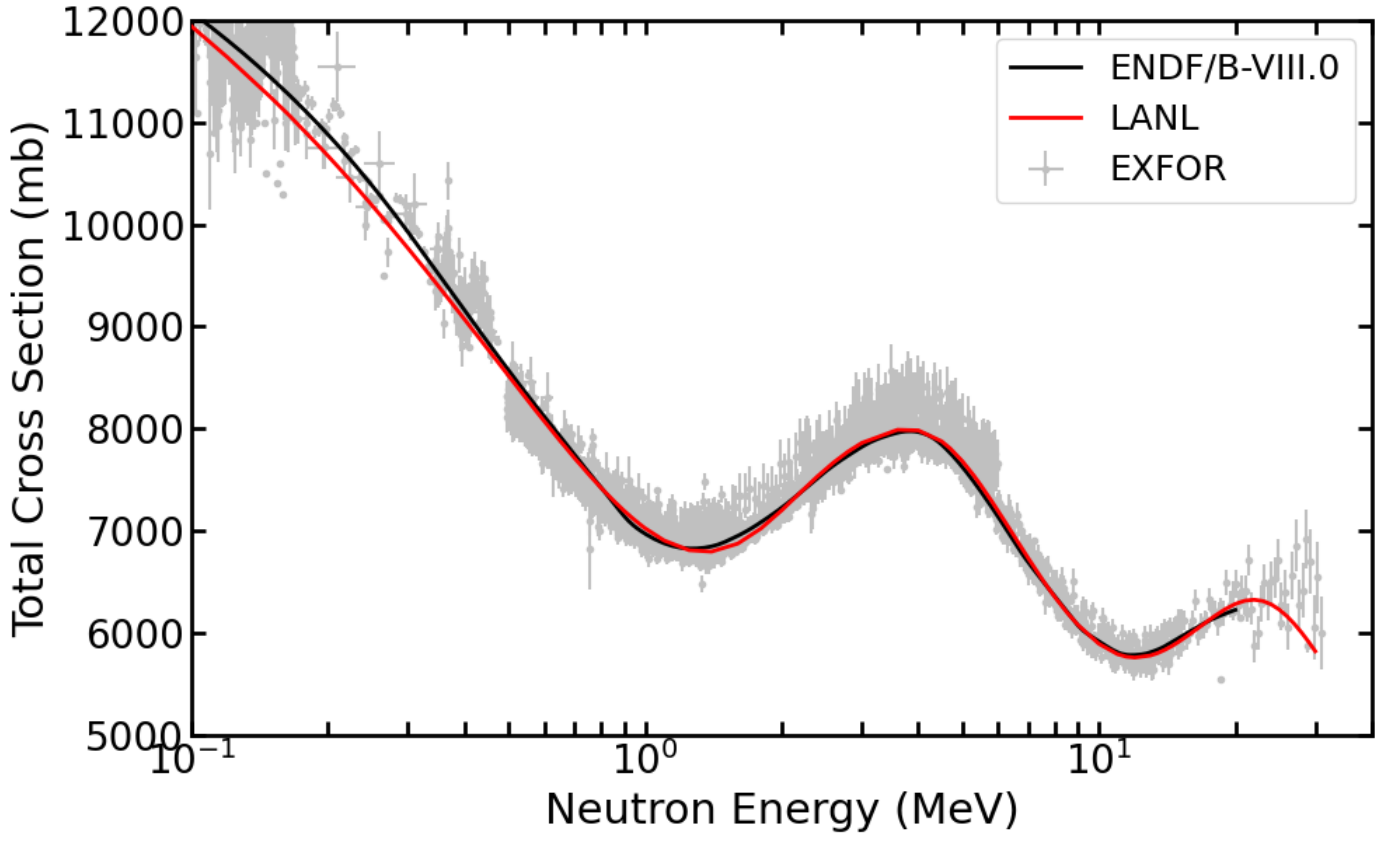
Neutron Data standards ^{239}Pu(n,f) cross section;
includes updates in covariances with templates and new (n,f) data from fissionTPC (Snyder)

New nu-bar including improved exp. UQ, Marini data and consistent CGMF modeling

New PFNS: INDEN non-model evaluation at thermal, Los Alamos model evaluation above including new Chi-Nu and CEA data

We are actively testing the file versus integral benchmarks; starting covariances

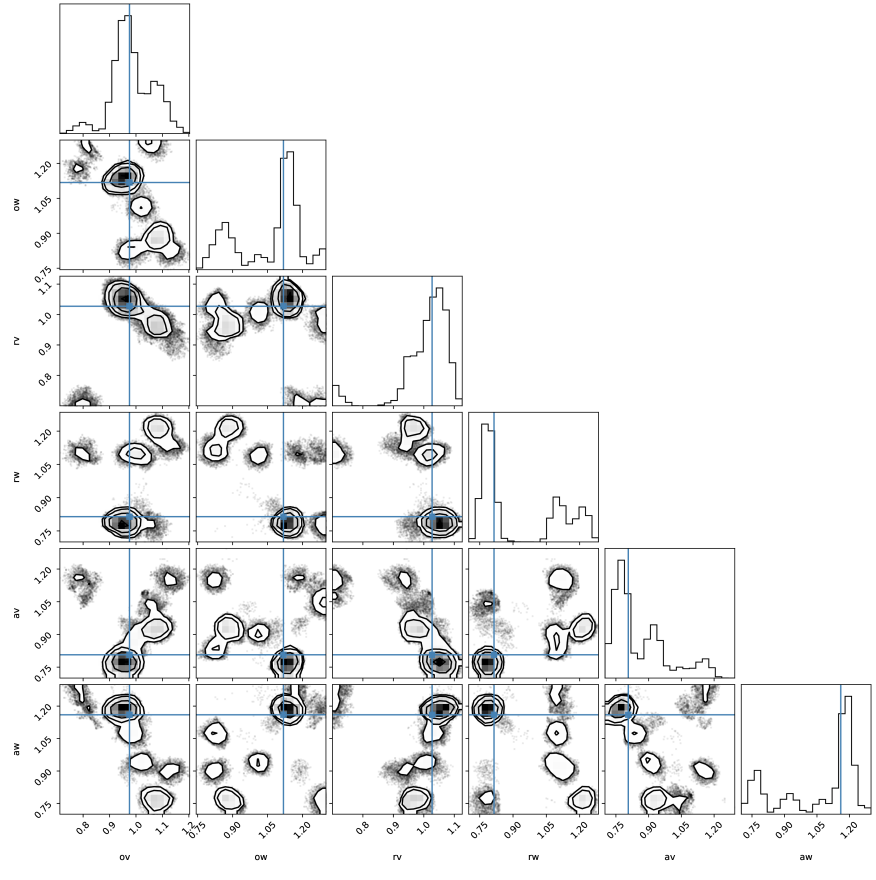
TOTAL CROSS SECTION



Model: Soukhovitskii (2005) optical model [deformation ~0.21]; coupled channels with 7 levels

Tuned parameters using Bayesian Hyperparameter Optimization to fit to ENDF/B-VIII.0 and parsed EXFOR compilation

BAYESIAN OPTIMIZATION OF PARAMETERS



We fit the Soukhovitskii (2005) optical model parameters

(potential depths, radii and diffuseness)

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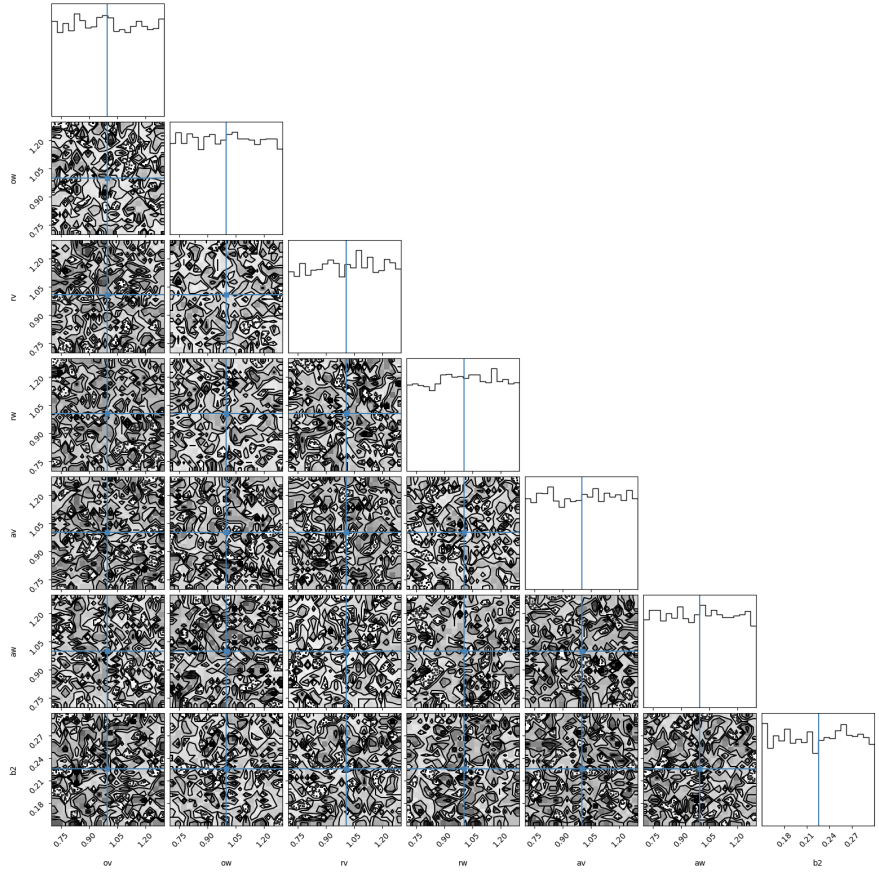
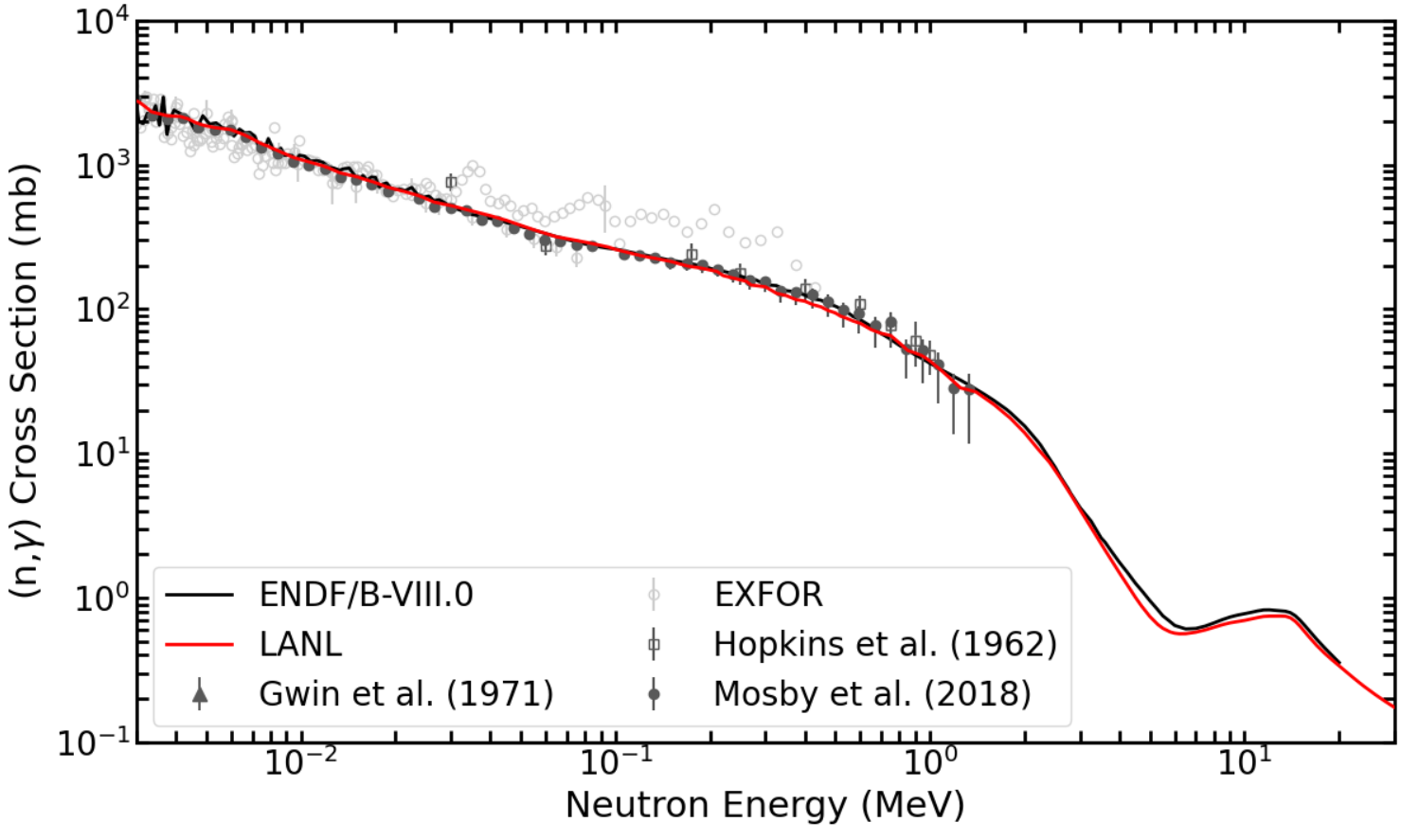


Soukhovitskii (2005) also depends on deformation, but it is not well constrained given cross section data

A cautionary tale; higher dimensional spaces are tricky; holding fixed some parameters is necessary

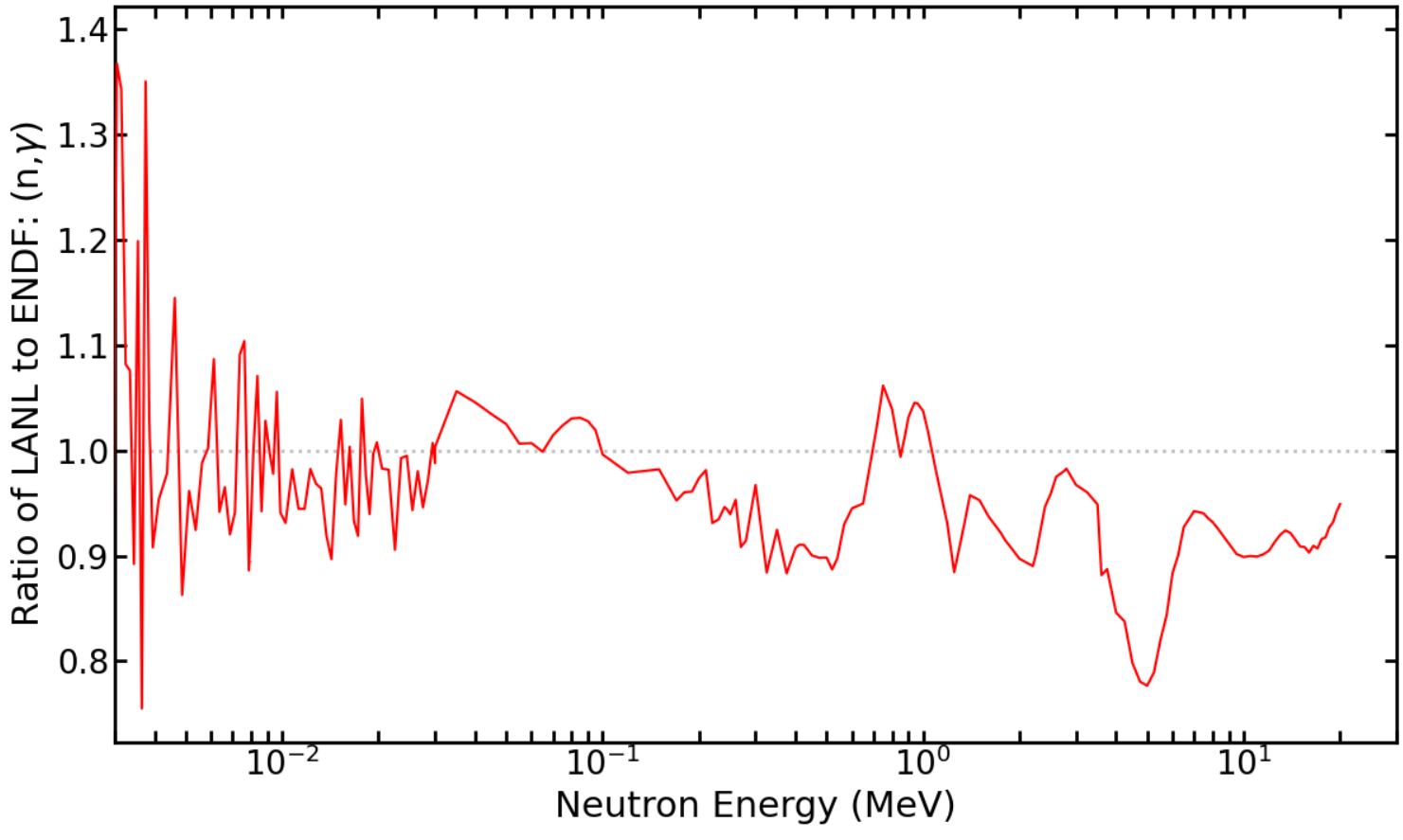
CAPTURE CROSS SECTION



Model: M1 enhancement employed from systematics of Mumpower *et al.* PRC 96 024612 (2017)

New cross section data incorporated from S. Mosby *et al.* NDS 148 312 (2018)

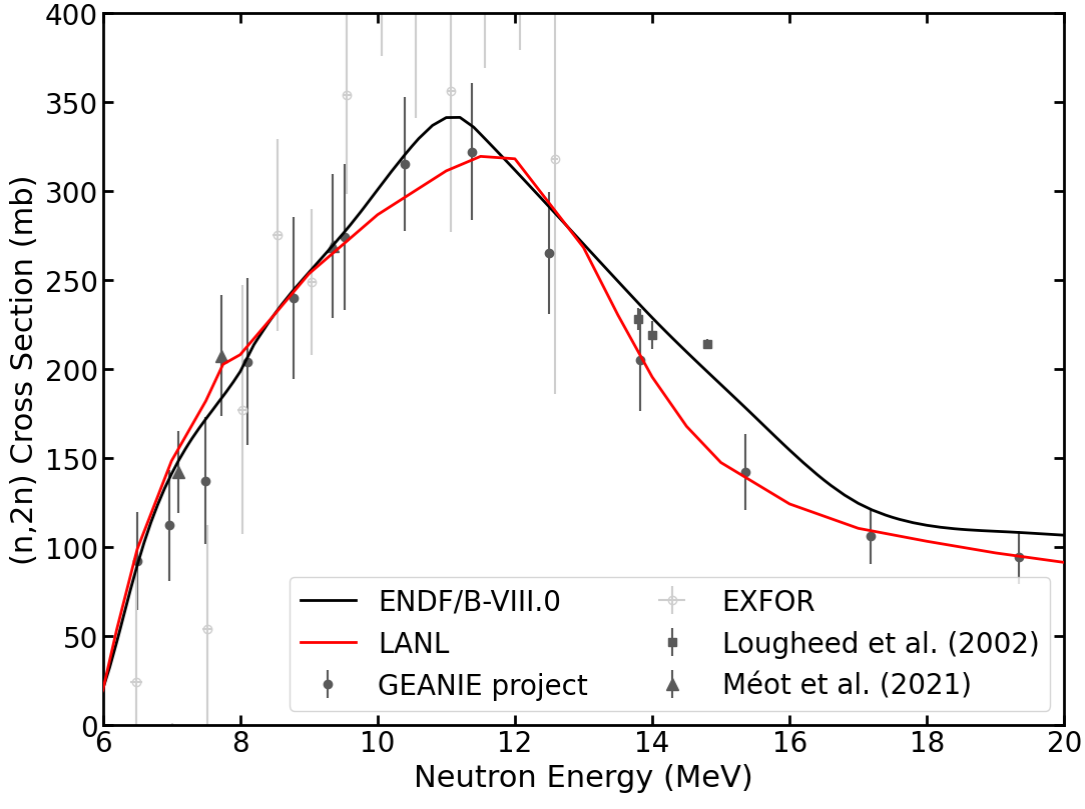
CAPTURE CROSS SECTION RATIO



ENDF/B-VIII.0 has some oscillatory behavior around 10 keV

The LANL CoH model in contrast is rather smooth; in agreement with Mosby data

(N,2N) CROSS SECTION



Model: new collective enhancement allows for simultaneous description of (n,f) and (n,2n) channels [difficult to describe in past versions of CoH]

Tight integration of model and experimental data leads to the updates relative to ENDF/B-VIII.0

we are actively testing this change

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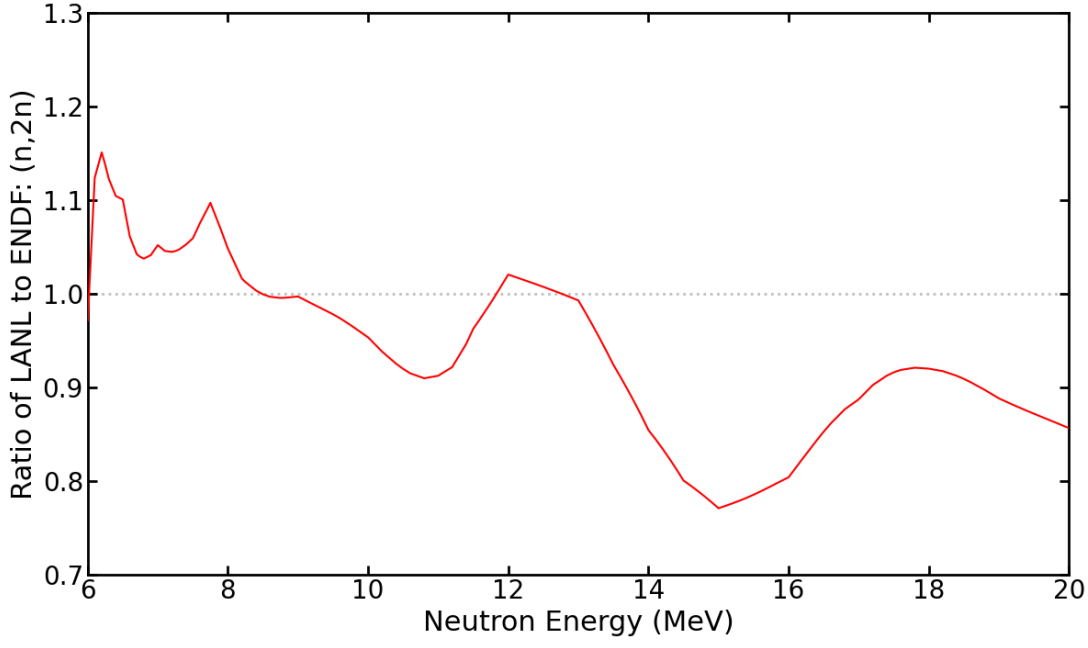

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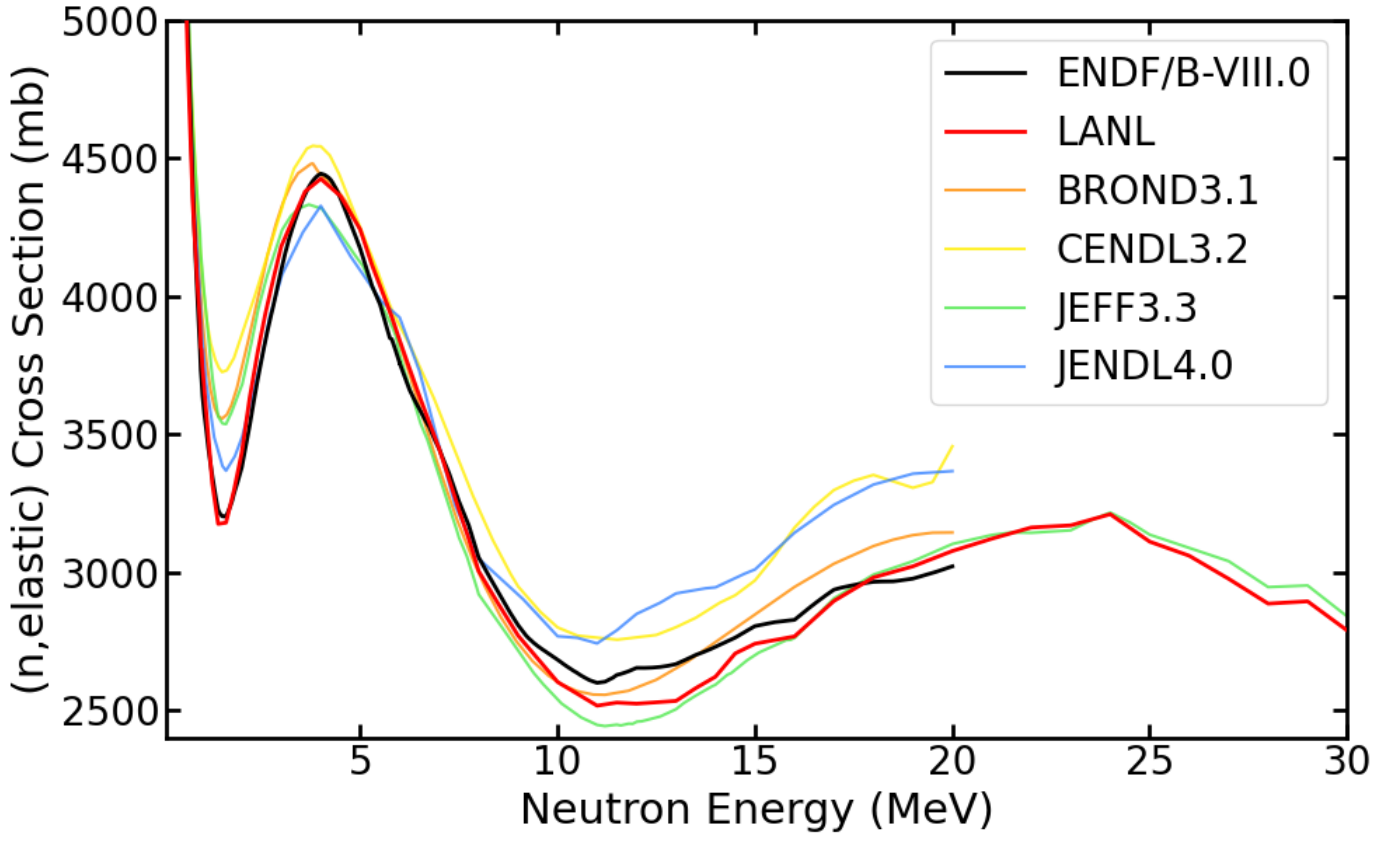
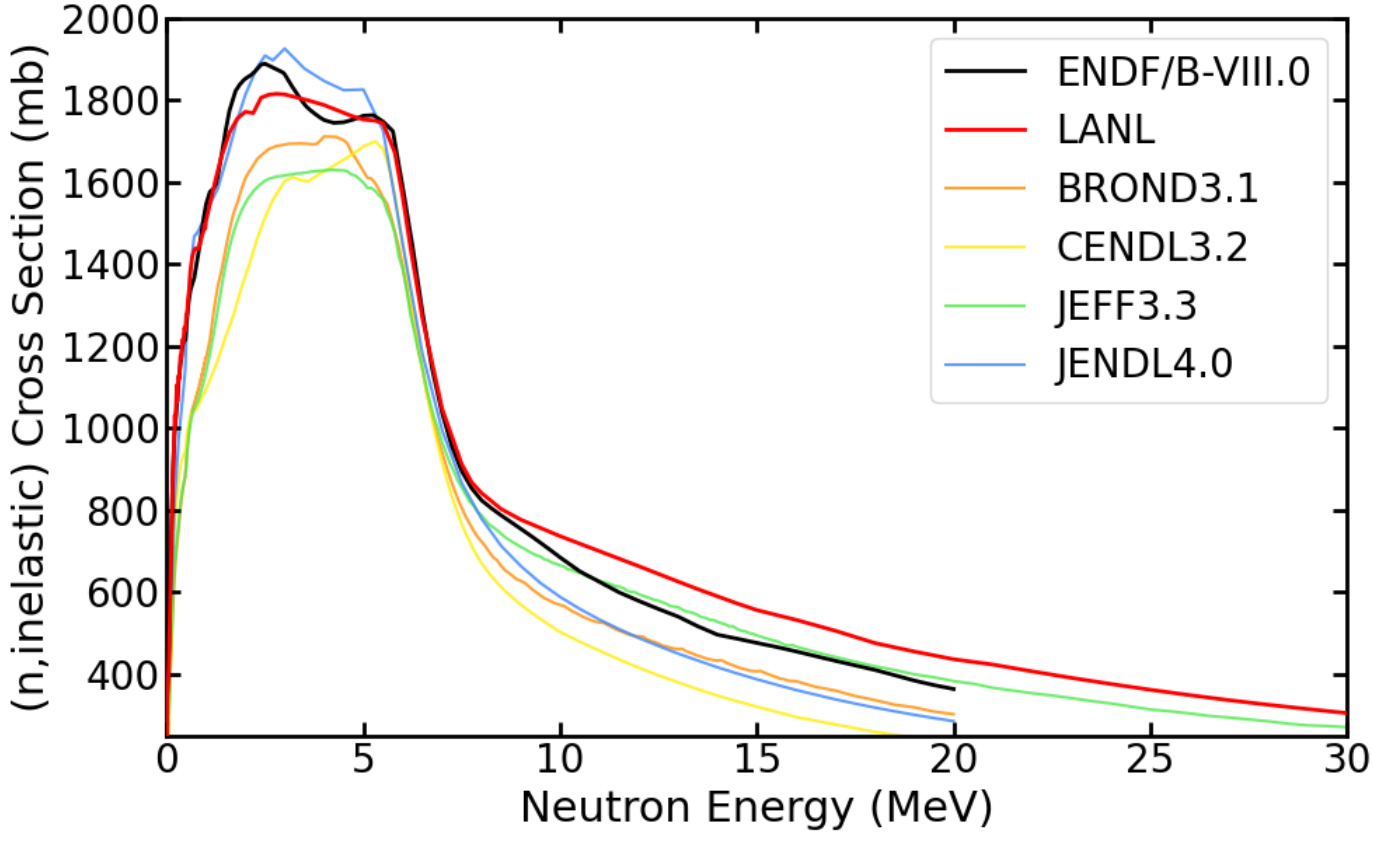
ELASTIC CROSS SECTION



Model: generally tracks ENDF/B-VIII.0 with more substantial differences above 10 MeV

Note that there is a large spread in evaluations as compared to other channels

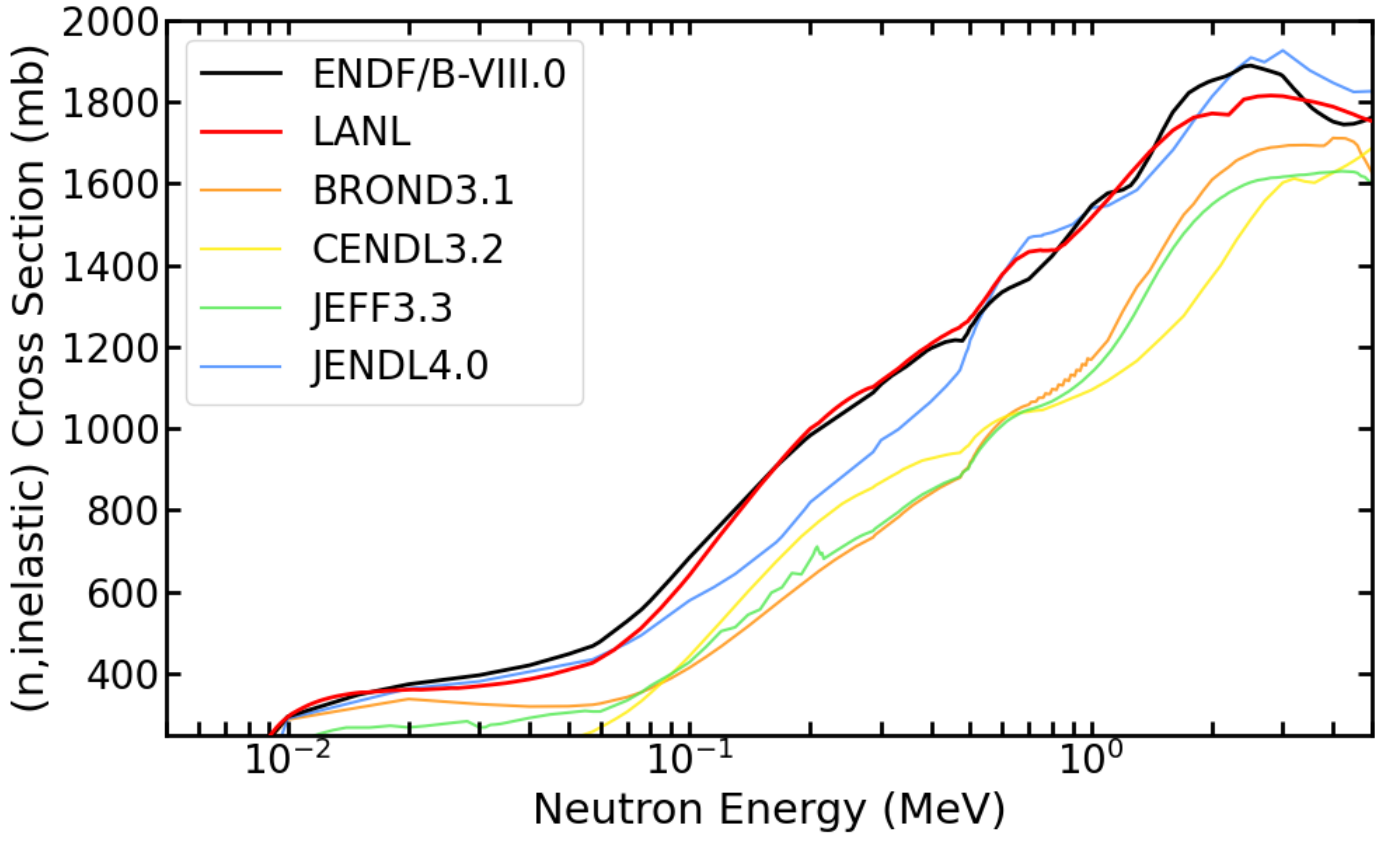
INELASTIC CROSS SECTION



Model: new inelastic scattering model using the Engelbrecht-Weidenmuller transformation (collective enhancement → removal of fictitious levels); similar to IAEA results

Again, a large spread in evaluations as compared to other channels

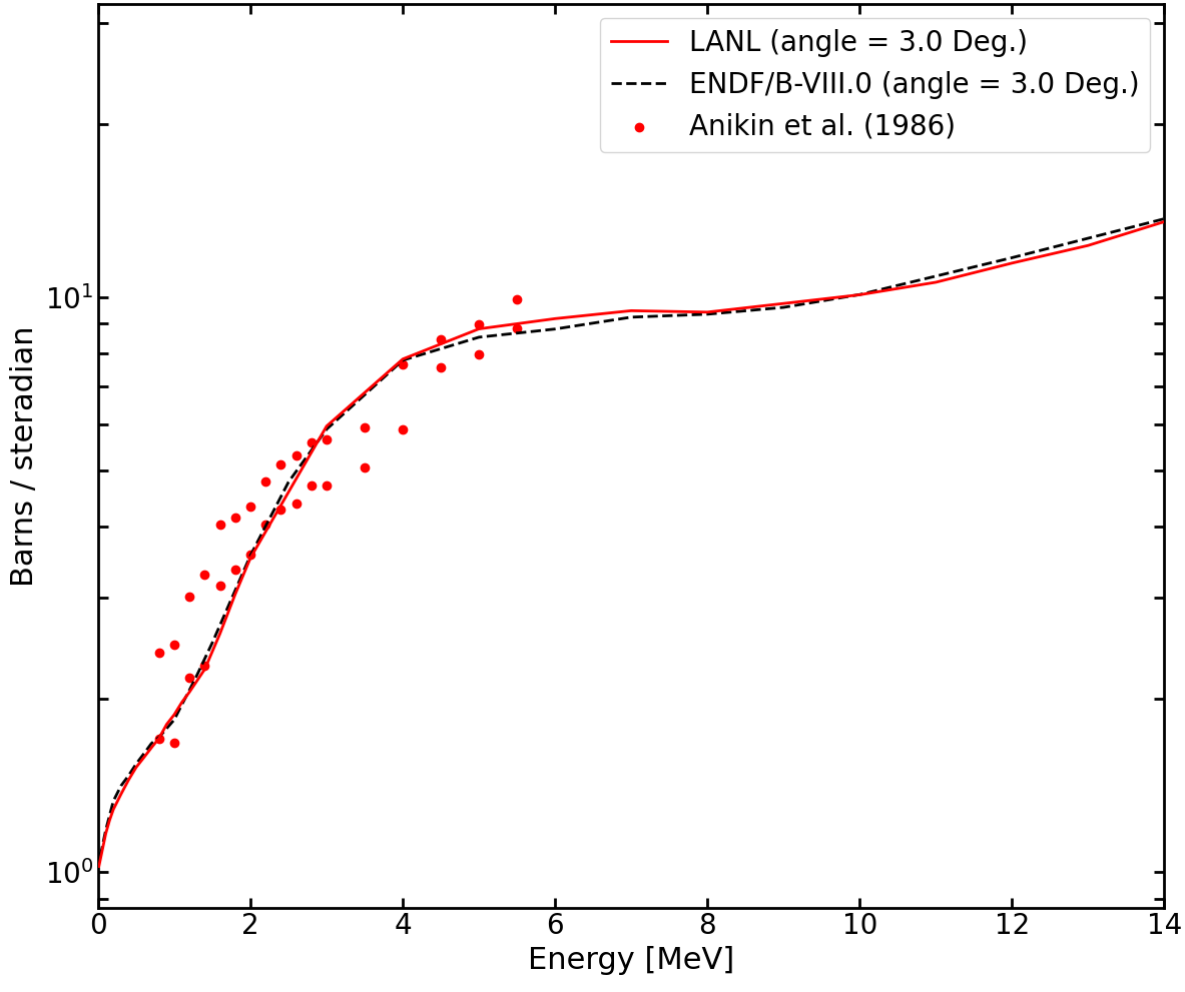
INELASTIC CROSS SECTION LOGSCALE



Model: new inelastic scattering model using the Engelbrecht-Weidenmuller transformation (collective enhancement → removal of fictitious levels); similar to IAEA results

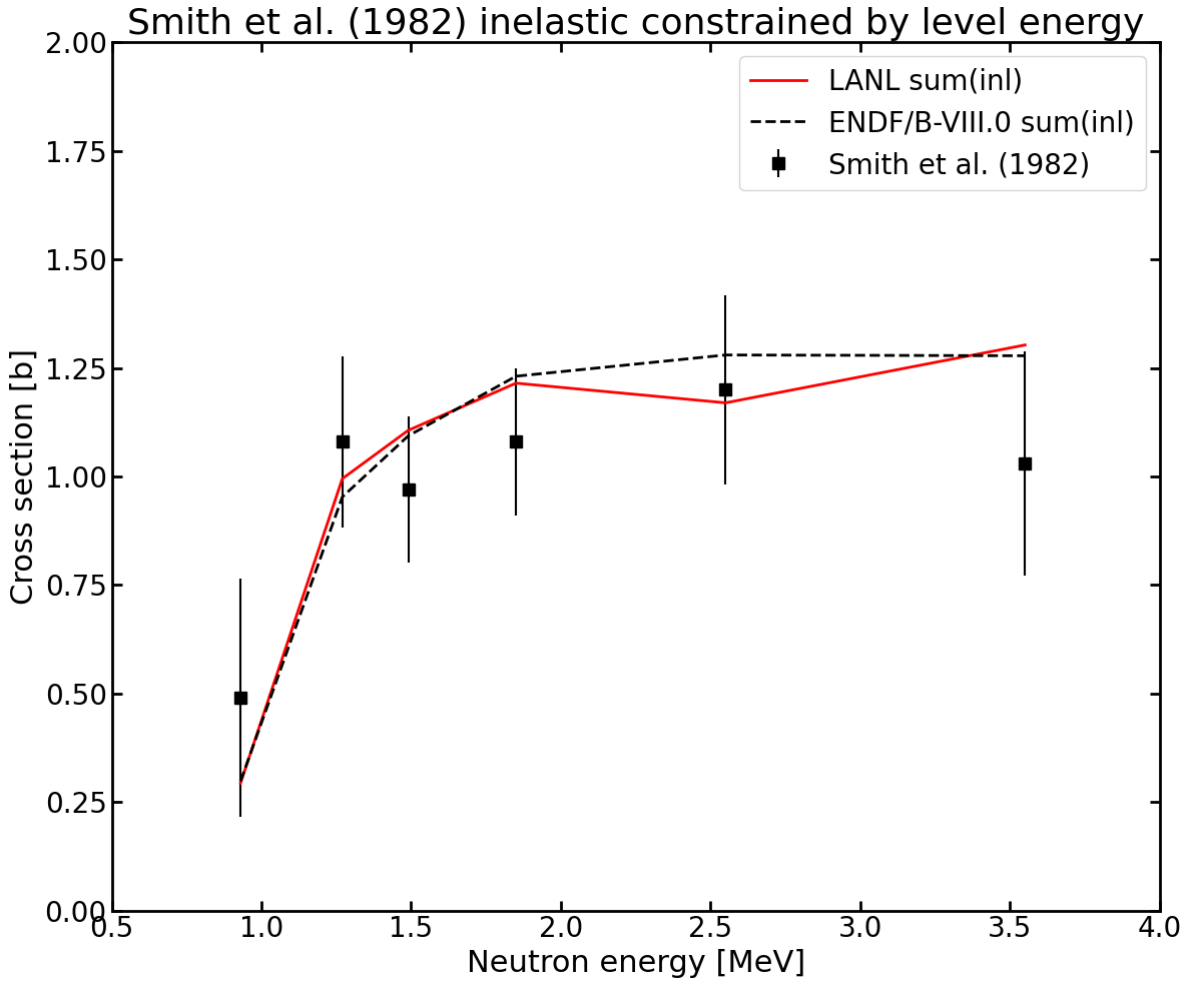
Threshold behavior is similar to ENDF/B-VIII.0 [logscale between 5 keV and 5 MeV]

ELASTIC CROSS SECTION



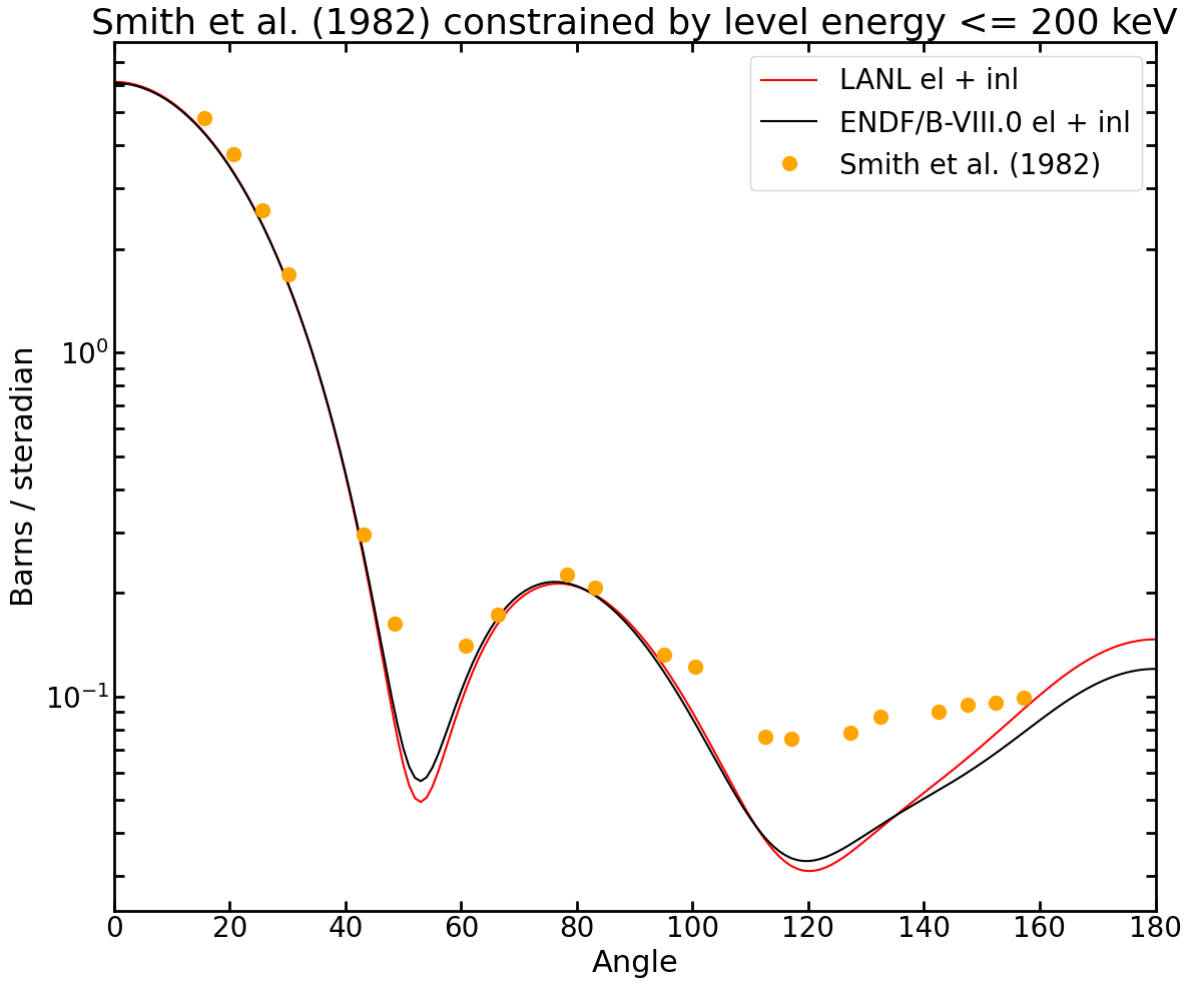
Performs similar to ENDF/B-VIII.0 @ 3 degree

INELASTIC CROSS SECTION



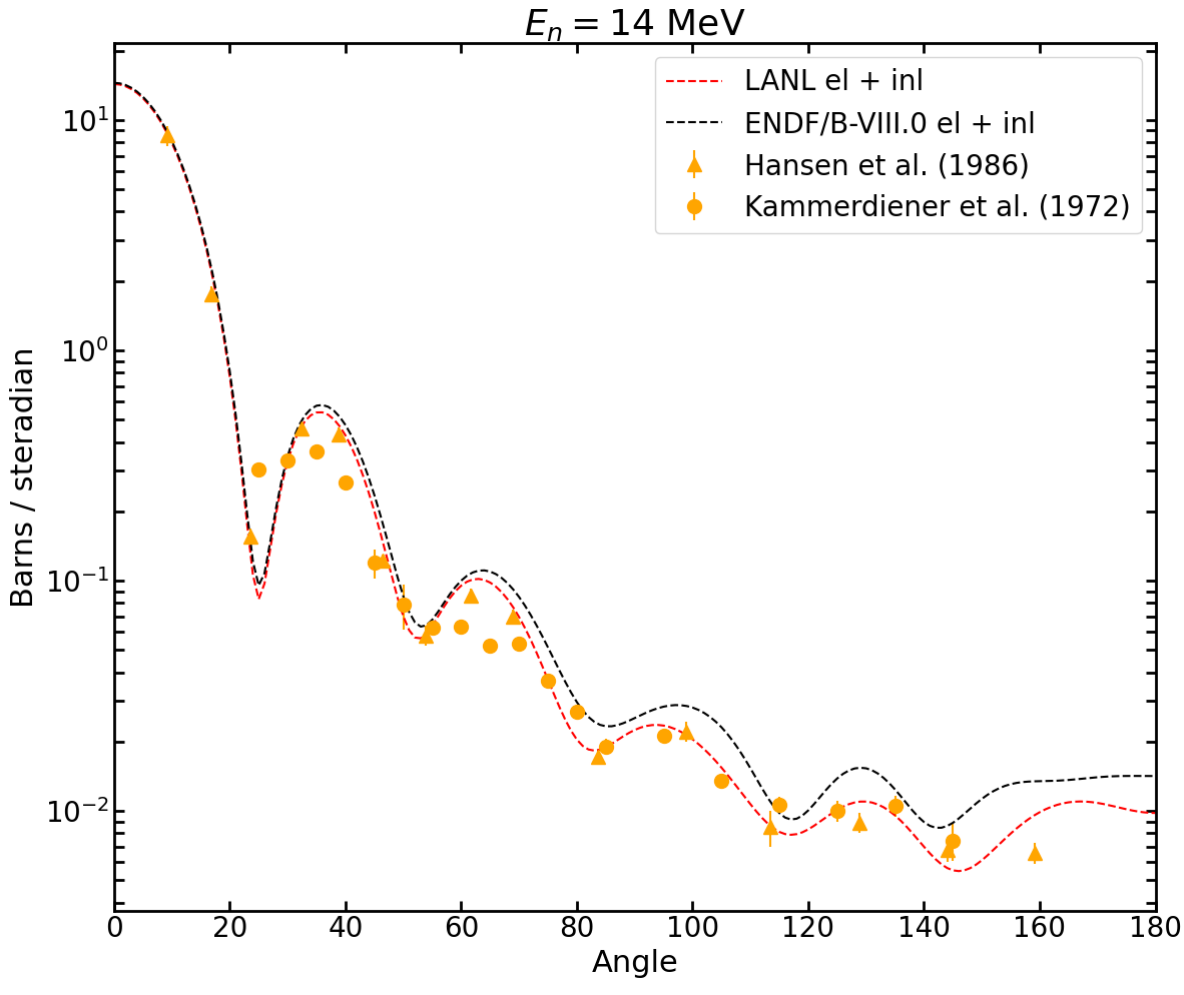
Performs similar to ENDF/B-VIII.0; Excitation energy between 0.08 and 0.3 MeV; energy resolution not quoted

ELASTIC PLUS INELASTIC ANGULAR DISTRIBUTION



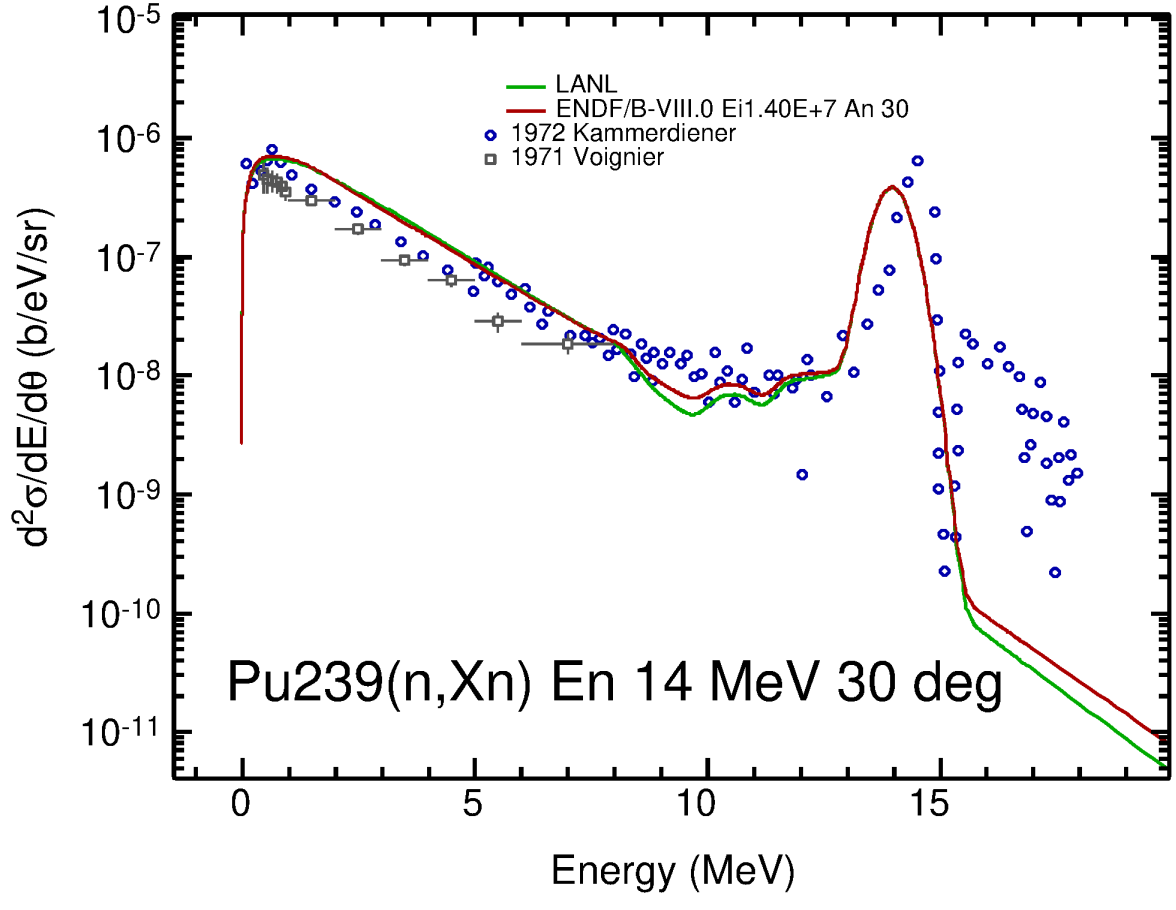
Performs similar to ENDF/B-VIII.0; Incident neutron energy 2.5 MeV; 7 levels under 200 keV quoted 3% exp. uncertainty

ELASTIC PLUS INELASTIC ANGULAR DISTRIBUTION



We seem to perform slightly better than ENDF/B-VIII.0 @ 14 MeV; Kammerdiener energy resolution ~1 MeV

NEUTRON SPECTRUM

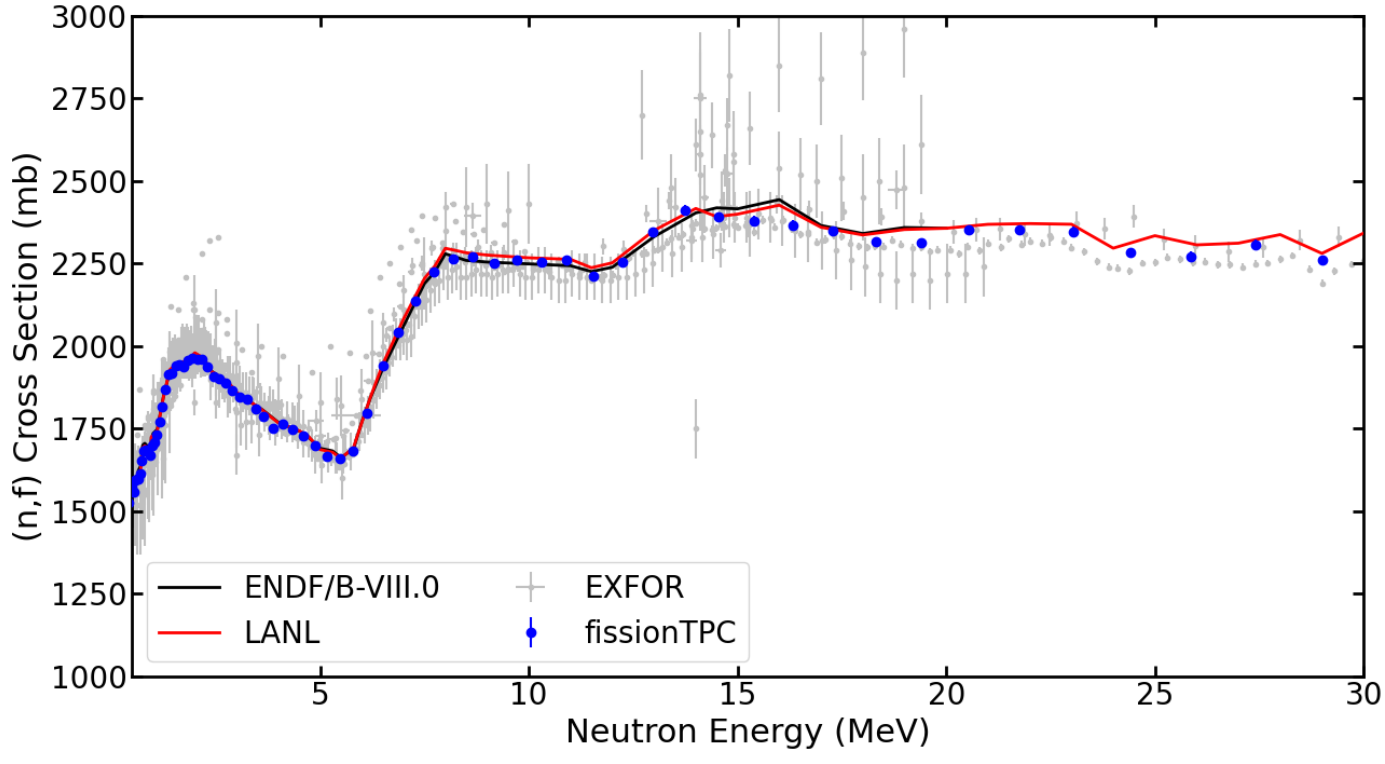


Use of Madland-Nix model; performs similar to ENDF/B-VIII.0

Collective enhancement will be an upgrade (increase green curve); not shown here

Figure by M. Herman

FISSION CROSS SECTION

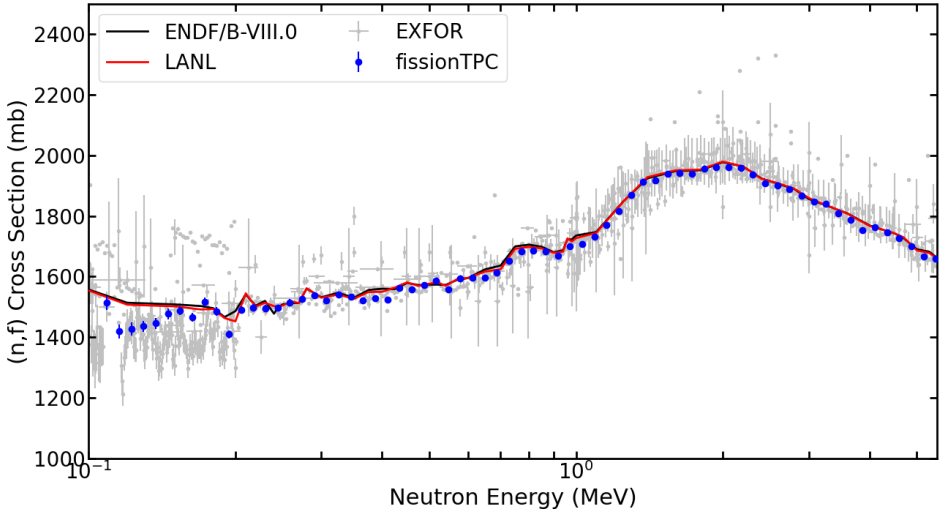


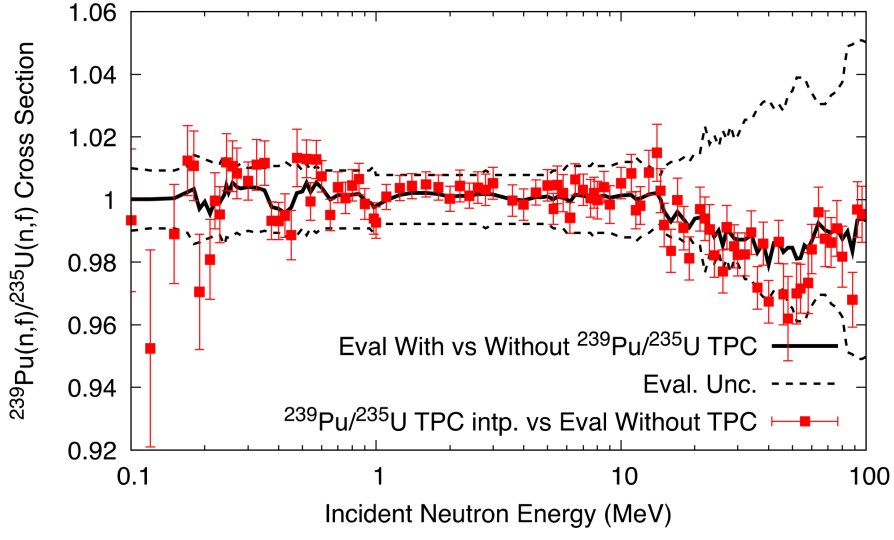
This evaluation differs from the VIII.0 (n,f) cross section; it comes out of standards analysis including updated covariances using the template approach and fissionTPC data; it is a reference cross section.

Our evaluation goes up to 30 MeV (part of the IAEA standards effort)

Neudecker *et al.* NDS 163 (2020) • Neudecker *et al.* LA-UR-21-24093 (2021)

FISSION CROSS SECTION





Cross sections in the fast range are similar to ENDF/B-VIII.0

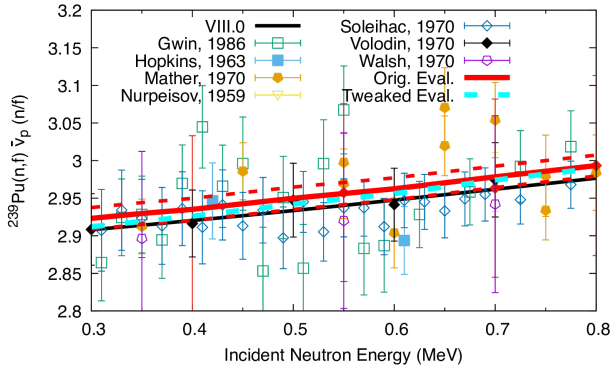
High-precision data by fissionTPC (used as shape) confirms overall trend of fission-chamber measurements

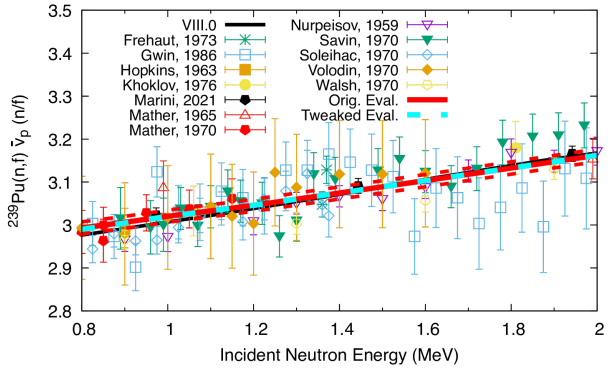
Standards are discussing the normalization factor published by fissionTPC data and how it relates to spectral indices in LANL fast critical assemblies

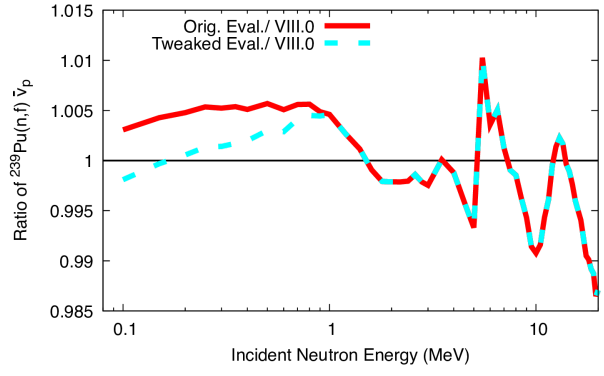
Right figure shows the impact of fissionTPC data only

Neudecker *et al.* NDS 163 (2020) • Neudecker *et al.* LA-UR-21-24093 (2021)

PROMPT NU-BAR





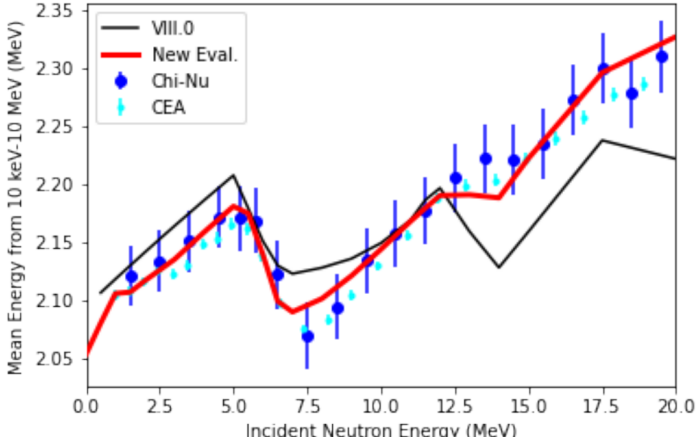


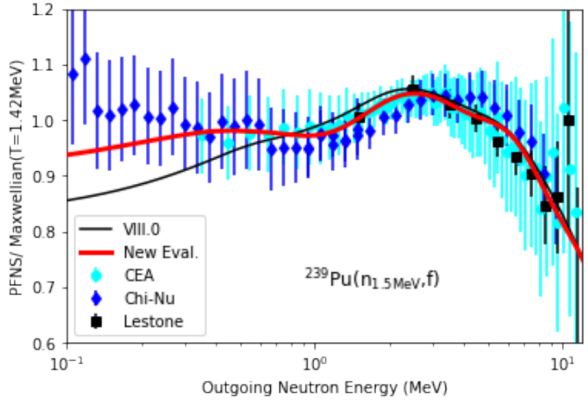
Requires small additional tweak since presentation at mini-CSEWG (2021) improving k_{eff} performance

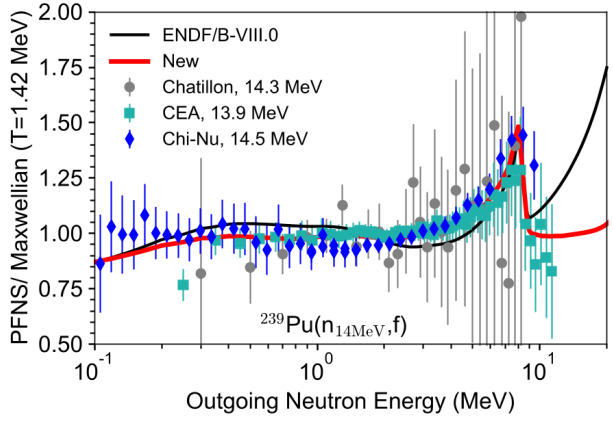
Nu-bar includes CGMF modeling, Marini data (measured with Chi-Nu array) and better experimental UQ

Special thanks to: Chadwick, Devlin, Kelly, Lovell, Marini, Neudecker, Taieb, Talou

PFNS







PFNS no change since mini-CSEWG (2021)

PFNS includes high precision Chi-Nu and CEA data both measured with Chi-Nu array

Special thanks to: Chadwick, Devlin, Kelly, Lovell, Marini, Neudecker, Taieb, Talou

VALIDATION OF OUR NEW ^{239}PU FILE IS ONGOING

Jezebel	keff	Pu9(n,2n)/(n,f)	Pu9(n,g)/(n,f)	U8/U5(n,f)	Np/U5(n,f)	U3/U5(n,f)	Pu9/U5(n,f)
VIII.0	1.00069(1)	0.00230(5)	0.0345(2)	0.212(1)	0.9768(5)	1.566(7)	1.427(6)
p35 INDEN	1.00031(1)	0.00235(8)	0.0355(3)	0.209(2)	0.9654(8)	1.567(11)	1.423(10)
p38 INDEN	1.00029(1)	0.00222(8)	0.0354(3)	0.209(2)	0.9653(8)	1.567(11)	1.423(10)
LANL, 11/1	1.00065(8)	0.00229(8)	0.0342(3)	0.208(2)	0.9640(8)	1.567(11)	1.422(10)

We are testing LANL and INDEN (p35, p38) files

PU-MET-FAST, PU-MET-INT critical assembly k_{eff}

Reaction rates in Jezebel and 3 Pu LLNL pulsed spheres

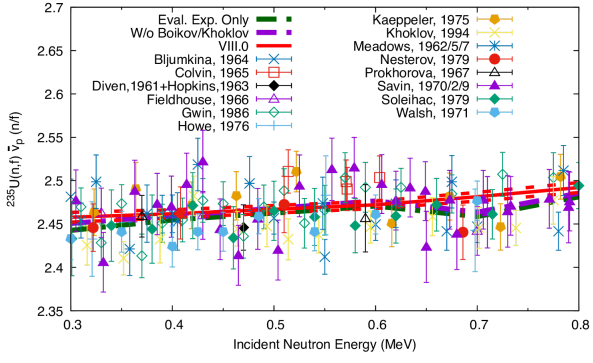
^{235,238}U PFNS AND (N,F) CROSS SECTION

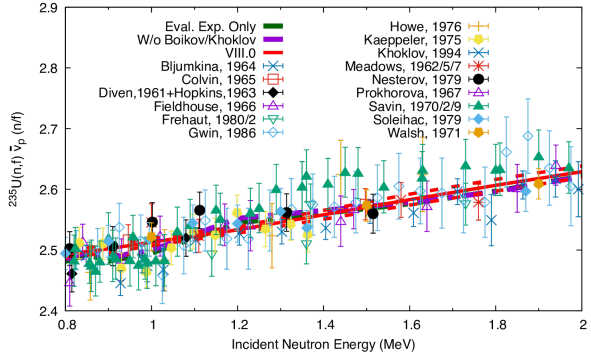
Work is ongoing as part of the Neutron Data Standards effort to update covariances of past experimental data related to ^{235,238}U(n,f) cross sections in GMA; ^{238}U(n,f) cross sections could be included in ENDF/B-VIII.1

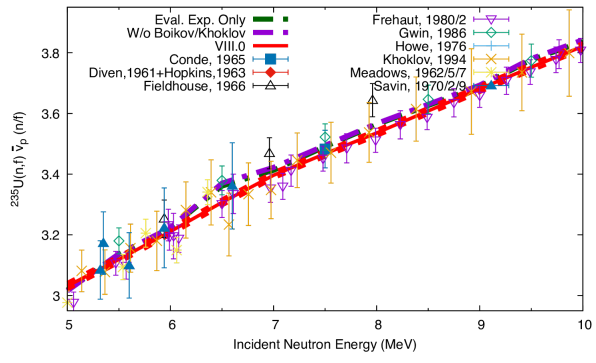
^{235}U PFNS: work is currently ongoing to include new Chi-Nu data, work by A. Lovell, D. Neudecker & P. Talou also underway to model via CGMF (challenging)

^{238}U PFNS: Chi-Nu data scheduled to be coming shortly before the release of ENDF/B-VIII.1

WORKING TOWARDS UPDATE OF ^{235}U(N,F) $\bar{\nu}_p$ (EXPERIMENTAL DATA ONLY)







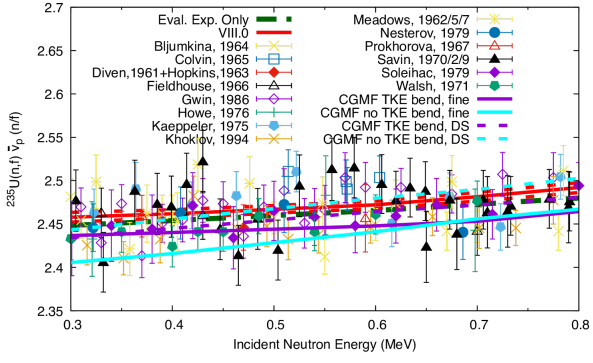
Started evaluation from scratch (no input files from Phil Young found), uncertainties of experimental data were re-estimated using templates of expected uncertainties

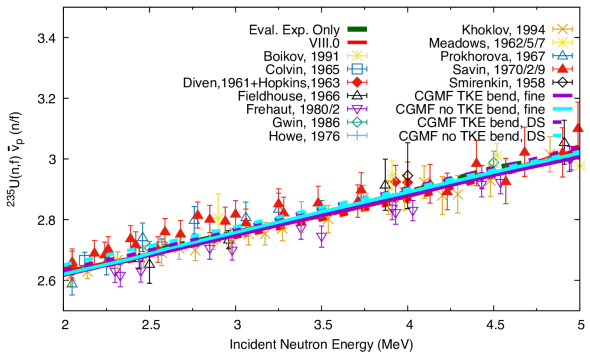
New data since last ENDF/B evaluation: Boikov and Khoklov, Khoklov data pull evaluation down below 1 MeV

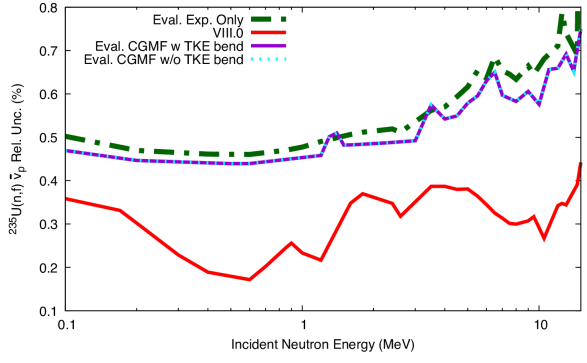
2nd chance fission threshold more clearly obsered

Evaluated uncertainties were increased compared to VIII.0 to account for newest standard uncertainties

WORKING TOWARDS UPDATE OF ^{235}U(N,F) $\bar{\nu}_p$ (INCLUDING CGMF MODEL)







Including CGMF modeling (A. Lovell is doing the modeling)

Below 1 MeV: We are just exploring if there should be a bend in $\langle TKE \rangle$

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SPECIAL THANKS TO OUR COLLEAGUES

Roberto Capote, Mark Chadwick, Matt Devlin, Mike Herman, Toshihiko Kawano, Keegan Kelly, Amy Lovell, Paola Marini, Vladimir Pronyaev, Luke Snyder, Ionel Stetcu, Julien Taieb, Patrick Talou, Andrej Trkov

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