



ANS Winter Meeting & Expo

2018 Joining Forces to Advance Nuclear



ENDF/B-VIII.0: the 8th major release of the ENDF/B library

D.A. Brown

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ENDF/B-VIII.0 was released on
2 Feb. 2018 by the Cross Section
Evaluation Working Group (CSEWG)

Integrates contributions for many sources

- Neutron Data Standards IAEA, NIST
- CIELO Pilot Project BNL led Fe,
LANL led ^{16}O and ^{239}Pu , IAEA led $^{235,238}\text{U}$
- Many new and improved neutron evaluations
(DP, **Crit. Safety**, NE, USNDP)
- New thermal scattering libraries
(**Crit. Safety**, Naval Reactors)
- Decay data USNDP (BNL)
- Charged particles USNDP (LLNL)
- New atomic data (LLNL)
- Success rests on EXFOR & ENSDF libraries
*USNDP (BNL) compiles EXFOR reaction data for US & Canada
USNDP develops the ENSDF library*



Happy
50th
Anniversary!*

A lot changed



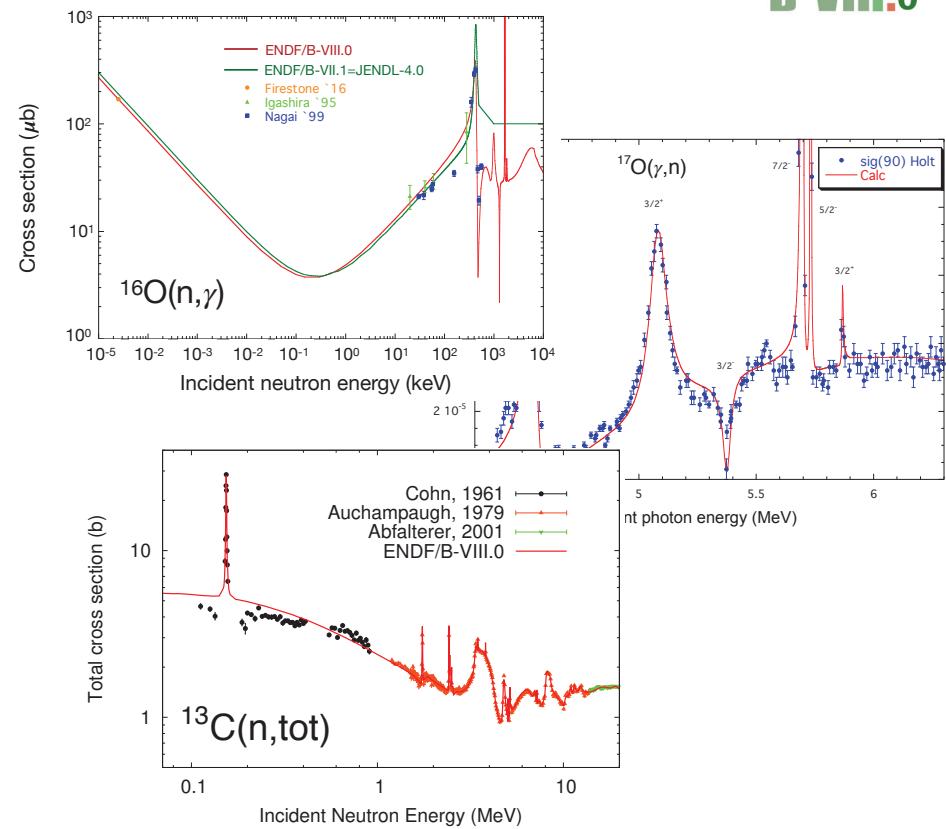
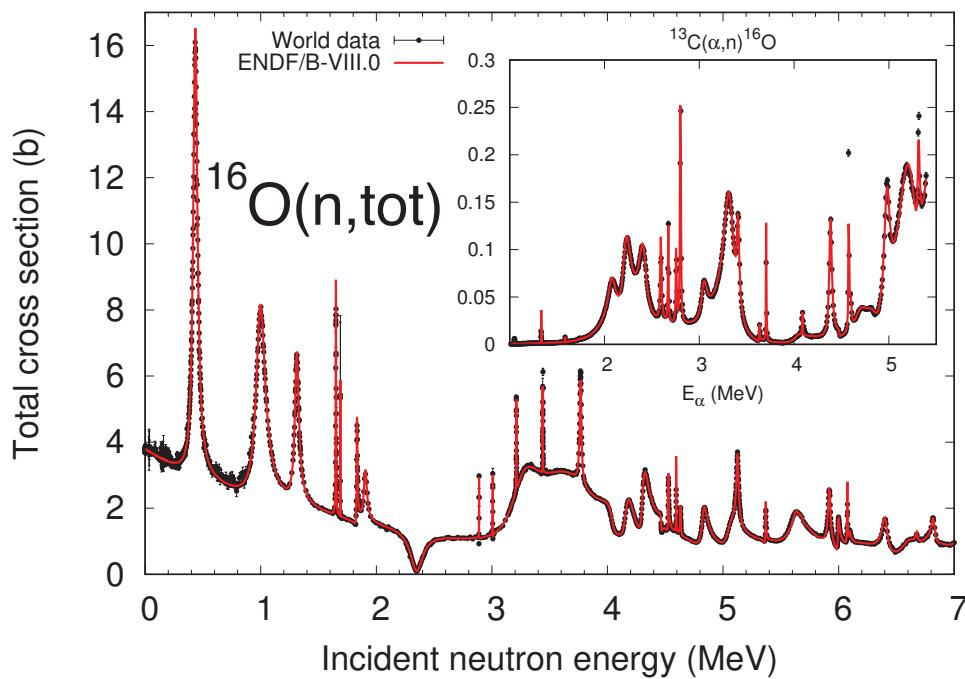
This is a giant release with many important changes

Sublibrary	VIII.0	VII.1	VII.0	VI.8
Neutron	557	423	393	328
Thermal n-scattering	33	21	20	15
Proton	49	48	48	35
Deuteron	5	5	5	2
Triton	5	3	3	1
Helium3	3	2	2	1
Alpha	1	n/a	n/a	n/a
Photonuclear	163	163	163	n/a
Atomic relaxation	100	100	100	100
Electron	100	100	100	100
Photoatomic	100	100	100	100
Decay data	3821	3817	3838	979
SFY	9	9	9	9
NFY	31	31	31	31
Standards	10	8	8	8

- **CIELO:** ^1H , ^{16}O , ^{56}Fe , ^{235}U , ^{238}U , ^{239}Pu
- **Neutron Data Standards:** ^1H , ^3He , ^6Li , ^{10}B , ^{12}C , ^{13}C , ^{197}Au , ^{235}U , ^{238}U
- **Essentially all new TSL sublibrary**
- Major revisions to **atomic relaxation, electro-atomic and photo-atomic data**
- **New neutron evaluations** for 49 stable and 125 unstable nuclei — there are no longer gaps in ENDF, so can do in-line activation
- **Fun change:** anti-neutrino spectra added to **decay sublibrary** (useful for non-proliferation and basic science)

^{16}O is product of R-matrix evaluation from LANL for CIELO

**ENDF
B-VIII.0**



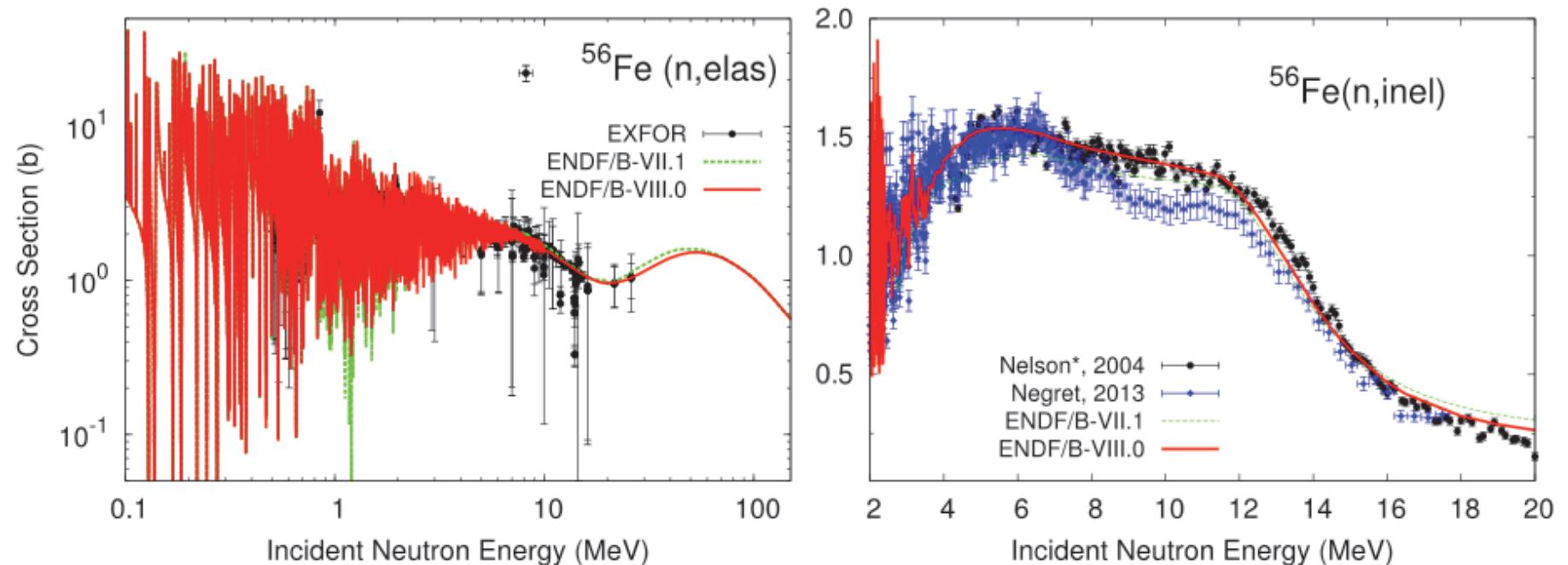
Must consider all channels that connect to ^{17}O compound nucleus

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D. Brown *et al.*, Nuclear Data Sheets 418, 1 (2018)

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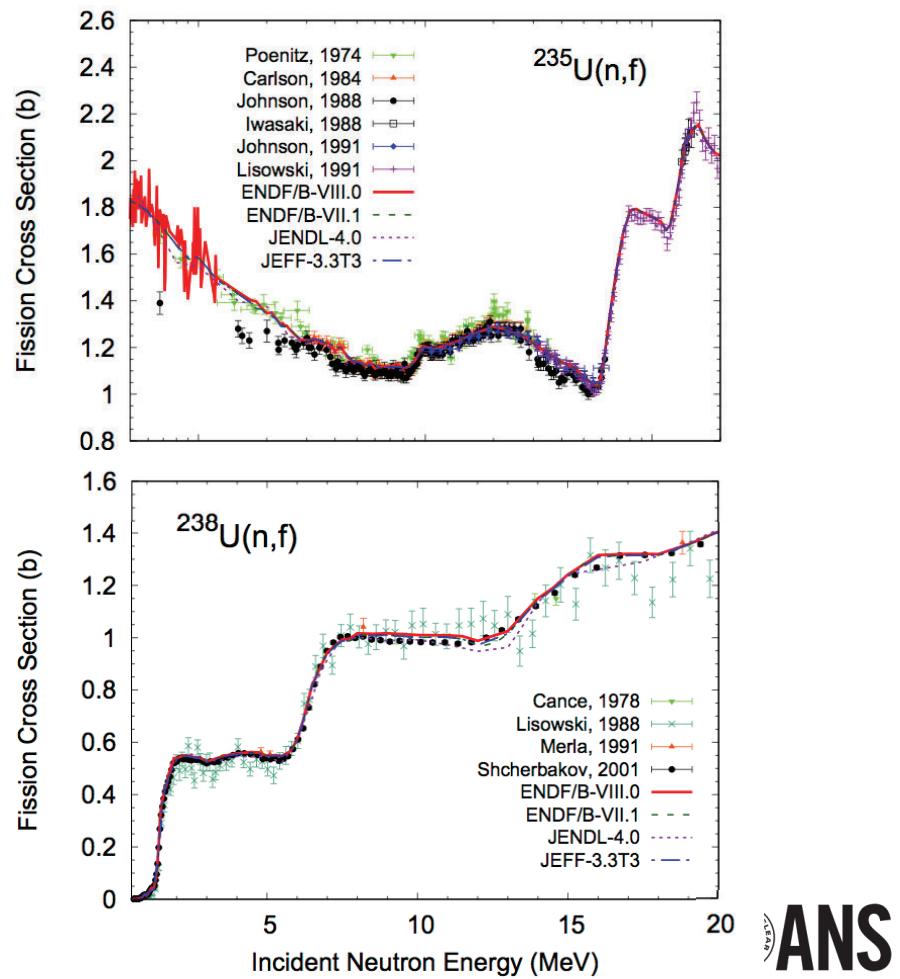
Most important changes to ^{56}Fe were to (in)elastic scattering



We tuned inelastic to match data from LANL (Nelson),
elastic adjusted downward to compensate

Large overlap in evaluations of Big 3

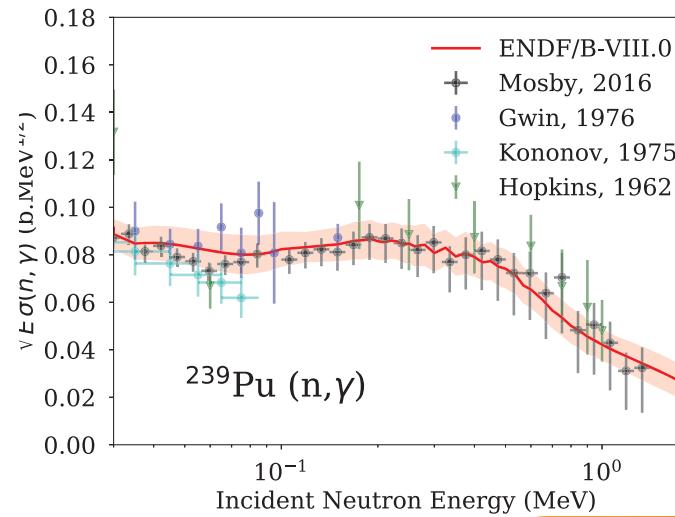
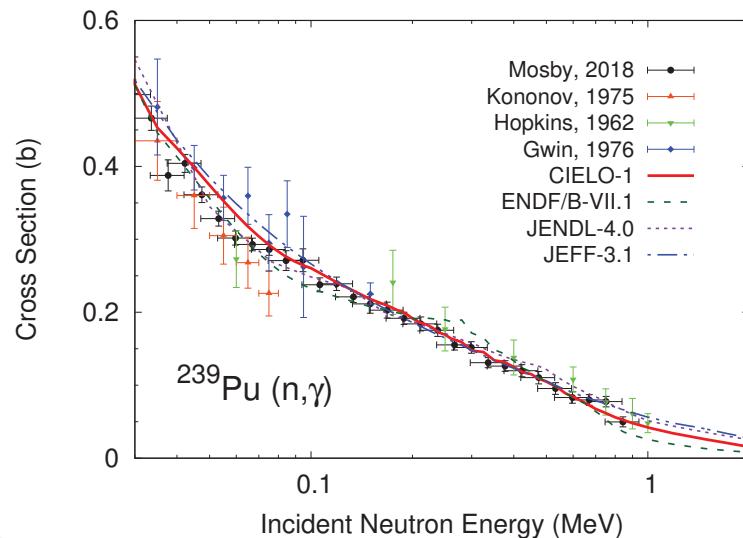
- **Neutron Data Standards:**
(n,f) cross section
- **P(nu)** for neutrons and gammas
(Talou)
- **Fission energy release** (Lestone)
- **PFNS & associated cov.** (Neudecker)
- **PGFS new**, resolves long standing problem with fission gammas (Stetcu)
- **Feedback from benchmarks**
- **Main differences:** treatments of RR & Fast parts of evaluation



(n,γ) Cross Section



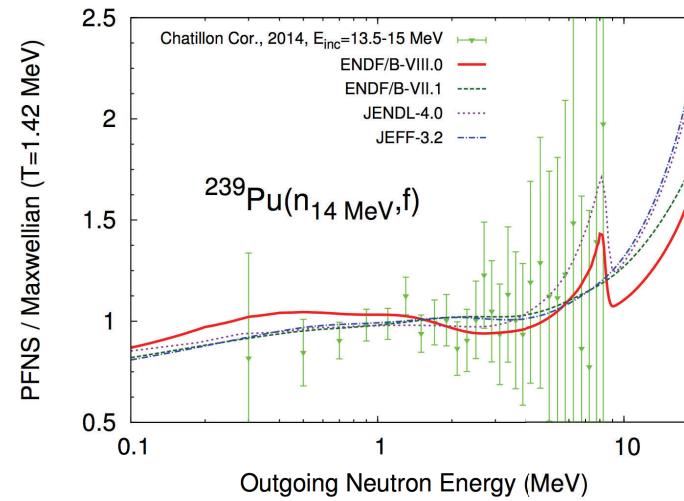
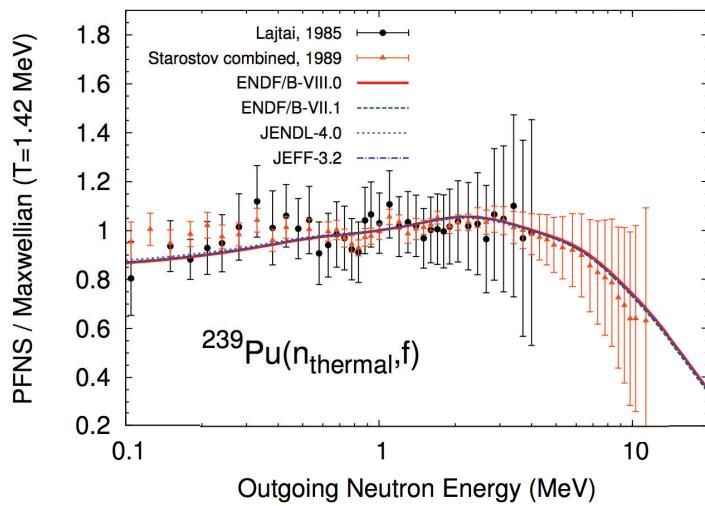
- New experimental results from DANCE measurement (**Mosby et al.**)
- New theoretical work (**Kawano**, CoH₃), including M1 “scissors” mode (also, **Ullmann et al.**)



Prompt Fission Neutron Spectrum



- Small tweak for thermal PFNS to improve modeling of Plutonium thermal solution benchmarks
- Unchanged from B-VII.1 from 0.5 to 5 MeV
- New evaluation (**Neudecker et al.**) above 5 MeV
- Preliminary chi-nu data (**Kelly et al.**)



ENDF/B-VIII TSL Evaluations

Material	ENDF Library Name	Evaluation Basis	Institution
Beryllium metal	tsl-Be-metal.endf	DFT/LD	NCSU
Beryllium oxide (beryllium)	tsl-BeinBeO.endf	DFT/LD	NCSU
Beryllium oxide (oxygen)	tsl-OinBeO.endf	DFT/LD	NCSU
Light water (hydrogen)	tsl-HinH2O.endf	MD	CAB
Light water ice (hydrogen)	tsl-HinIceIh.endf	DFT/LD	BAPL
Light water ice (oxygen)	tsl-OinIceIh.endf	DFT/LD	BAPL
Heavy water (deuterium)	tsl-DinD2O.endf	MD	CAB
Heavy water (oxygen)	tsl-OinD2O.endf	MD	CAB
Polymethyl Methacrylate (Lucite)	tsl-HinC5O2H8.endf	MD	NCSU
Polyethylene	tsl-HinCH2.endf	MD	NCSU
Crystalline graphite	tsl-graphite.endf	MD	NCSU
Reactor graphite (10% porosity)	tsl-reactor-graphite-10P.endf	MD	NCSU
Reactor graphite (30% porosity)	tsl-reactor-graphite-30P.endf	MD	NCSU
Silicon carbide (silicon)	tsl-CinSiC.endf	DFT/LD	NCSU
Silicon carbide (carbon)	tsl-SiinSiC.endf	DFT/LD	NCSU
Silicon dioxide (alpha phase)	tsl-SiO2-alpha.endf	DFT/LD	NCSU
Silicon dioxide (beta phase)	tsl-SiO2-beta.endf	DFT/LD	NCSU
Yttrium hydride (hydrogen)	tsl-HinYH2.endf	DFT/LD	BAPL
Yttrium hydride (yttrium)	tsl-YinYH2.endf	DFT/LD	BAPL
Uranium dioxide (oxygen)	tsl-OinUO2.endf	DFT/LD	NCSU
Uranium dioxide (uranium)	tsl-UinUO2.endf	DFT/LD	NCSU
Uranium nitride (nitrogen)	tsl-NinUN.endf	DFT/LD	NCSU
Uranium nitride (uranium)	tsl-UinUN.endf	DFT/LD	NCSU

The library is well tested



ENDF/B-VIII.0 is our best performing and highest quality library yet

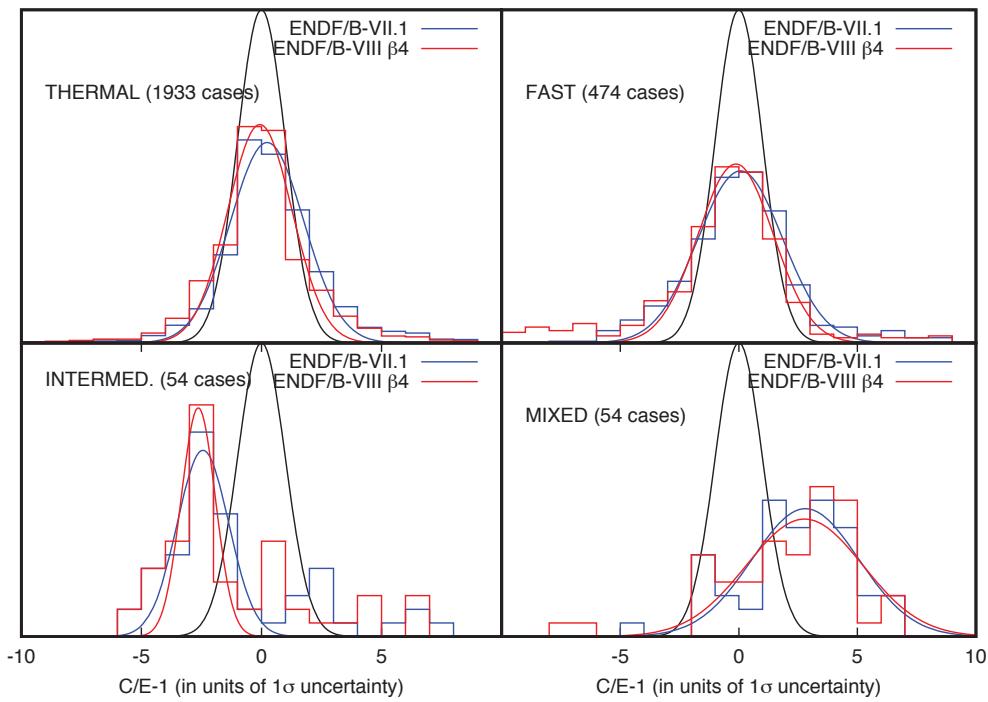
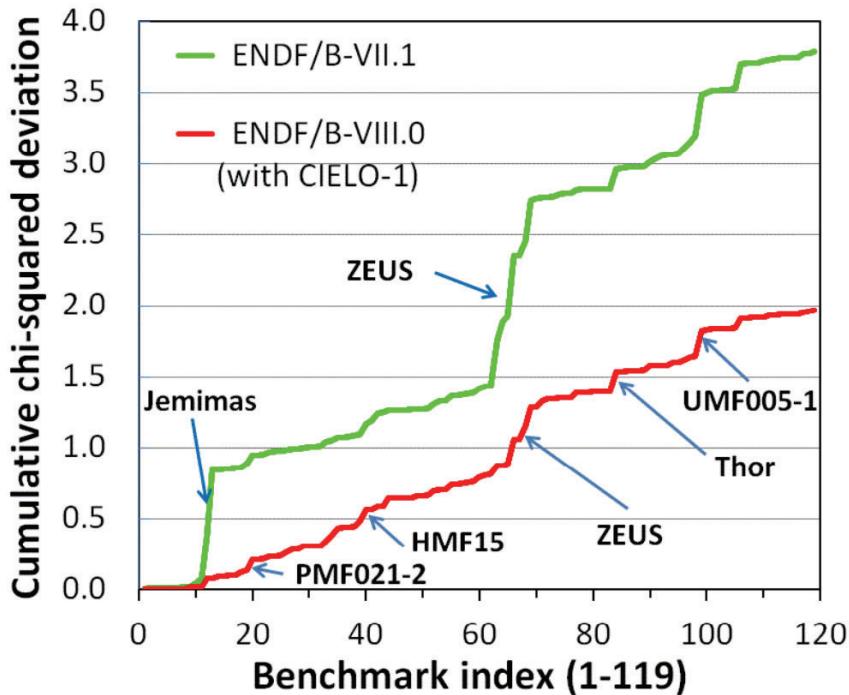
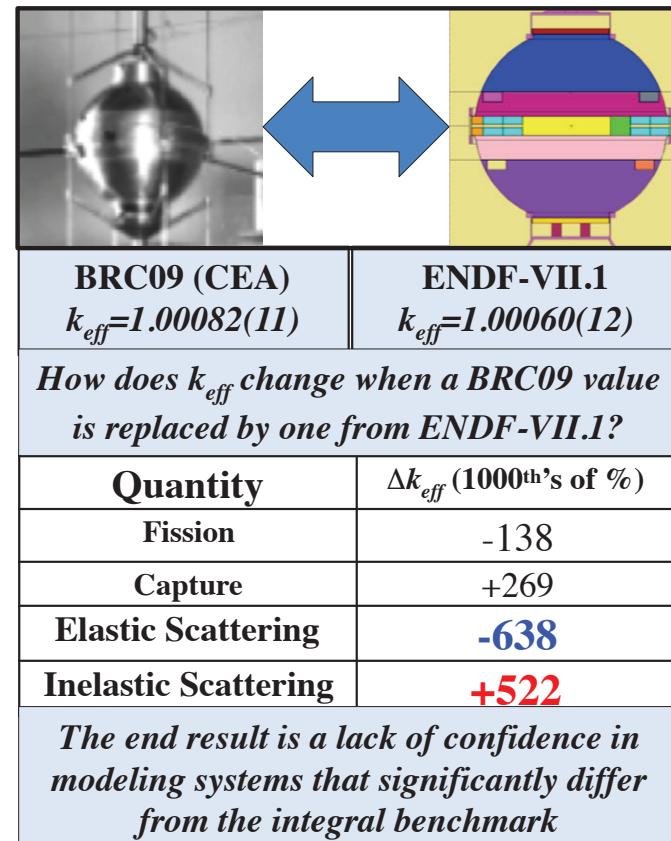


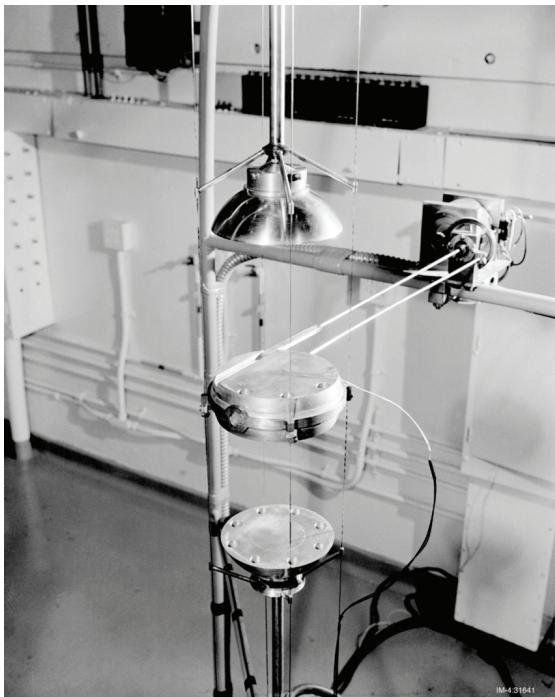
FIG. 29. (Color online) The distribution of C/E , in units of the combined benchmark and statistical uncertainty. The normal distribution (in black) would be the perfect situation.

There are many ways to “get the right answer”

- E. Bauge, et al. (CEA-DAM)
- Swap portions of one evaluation for other until completely swapped
- Elastic & inelastic scattering provided biggest swing



Situation “unchanged” in VIII.0



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Pu-239 CEA-CIELO to LANL-CIELO

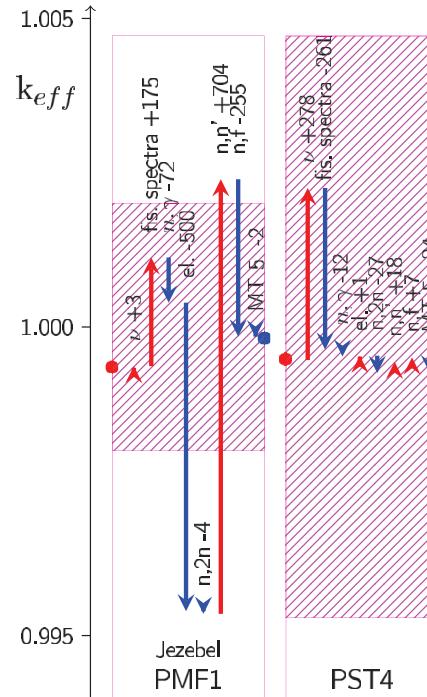


FIG. 28. (Color online) Simulations of criticality k_{eff} for ^{239}Pu for two critical assemblies: a fast assembly (Jezebel, PMF-1), and a thermal assembly (PST-4). This figure shows that both LANL CIELO-1 (ENDF/B-VIII.0) and CEA CIELO-2 (JEFF-3.3) predict similar k_{eff} values, but do so for very different reasons. The changes in criticality are evident when individual cross section channels are substituted between the two evaluations.

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B-VIII.0

M. Chadwick et al., Nuclear
Data Sheets 418, 189 (2018)

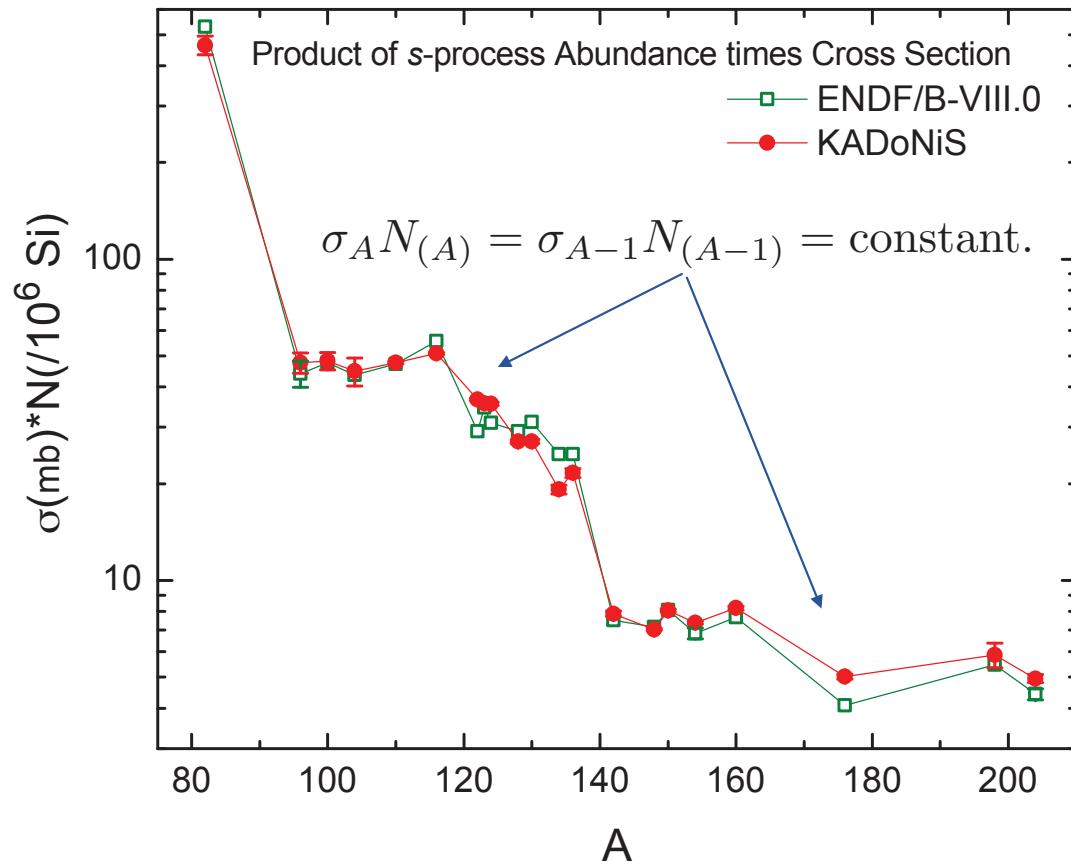
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We focused on thermal & fast applications,
but had some fun too

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B-VIII.0



<http://www.eso.org/public/images/potw1447a/>
ESO/S. Ramstedt (Uppsala University, Sweden) &
W. Vlemmings (Chalmers University of Technology, Sweden)



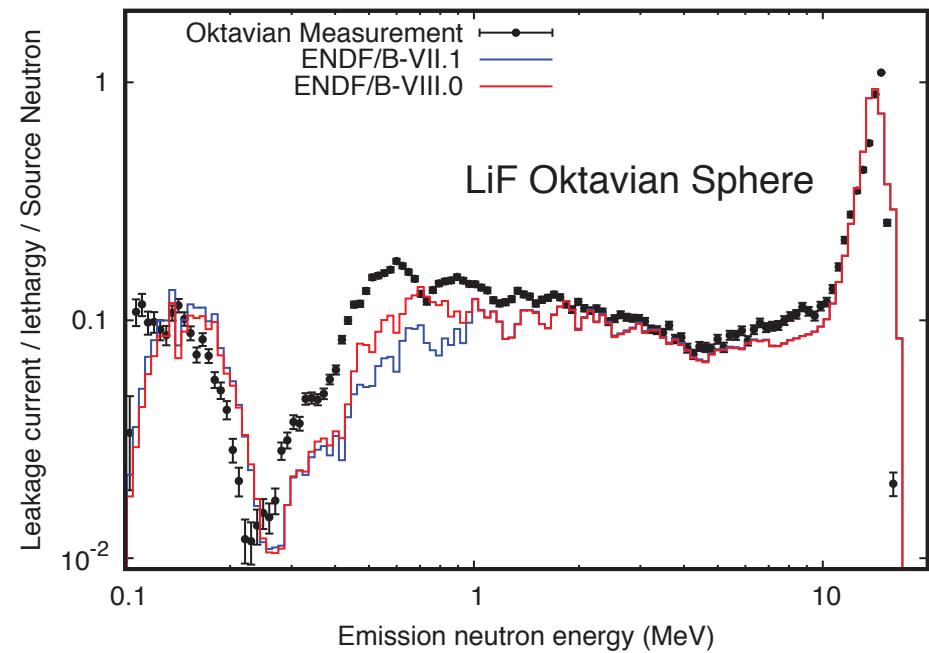
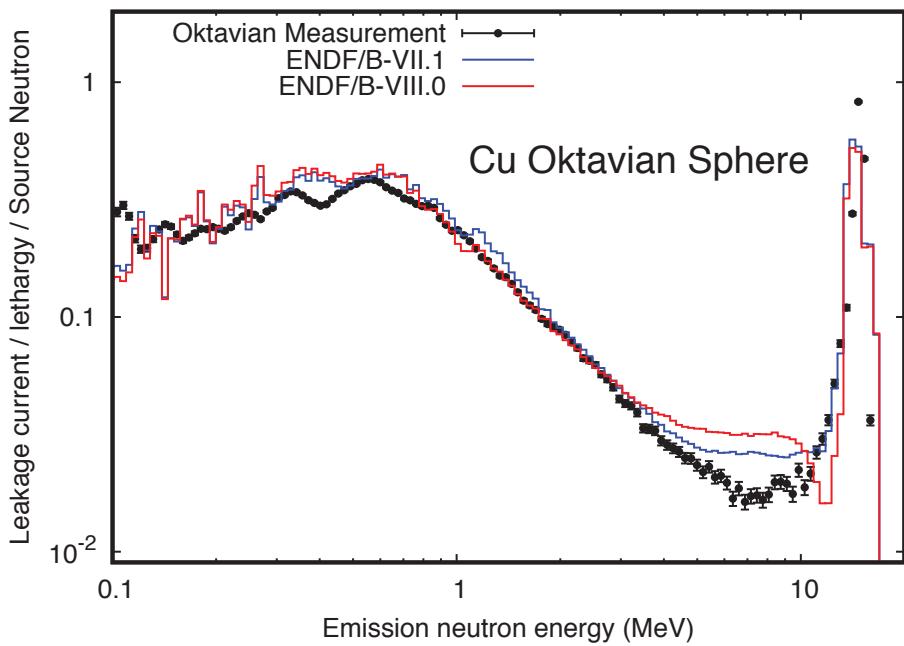
D. Brown *et al.*, Nuclear Data Sheets 418, 1 (2018)



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ENDF/B-VIII.0 is our best performing and highest quality library yet, but there are warts



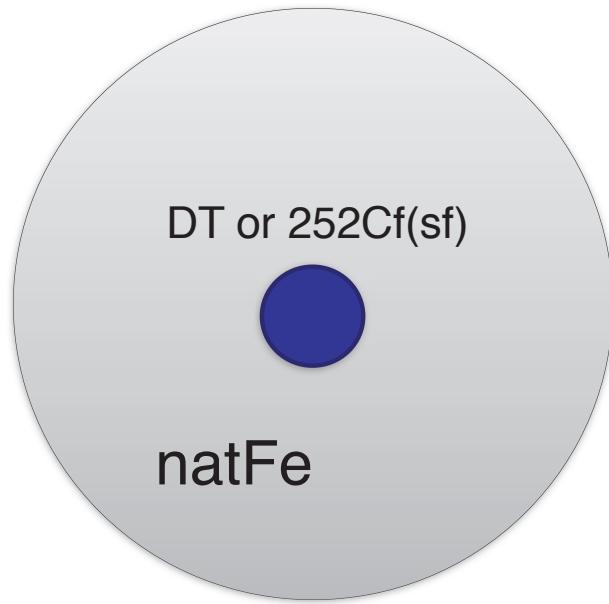
Transmission experiments proved to be very informative

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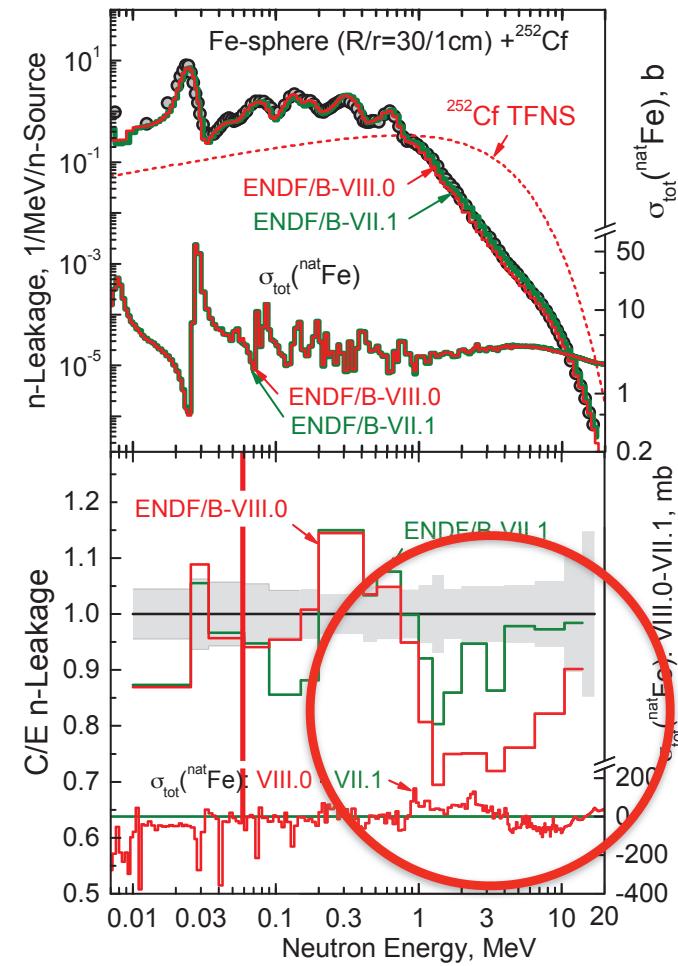
D. Brown *et al.*, Nuclear Data Sheets 418, 1 (2018)

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Validation in transmission experiments



Experiments at IPPE, Obninsk in 1980's

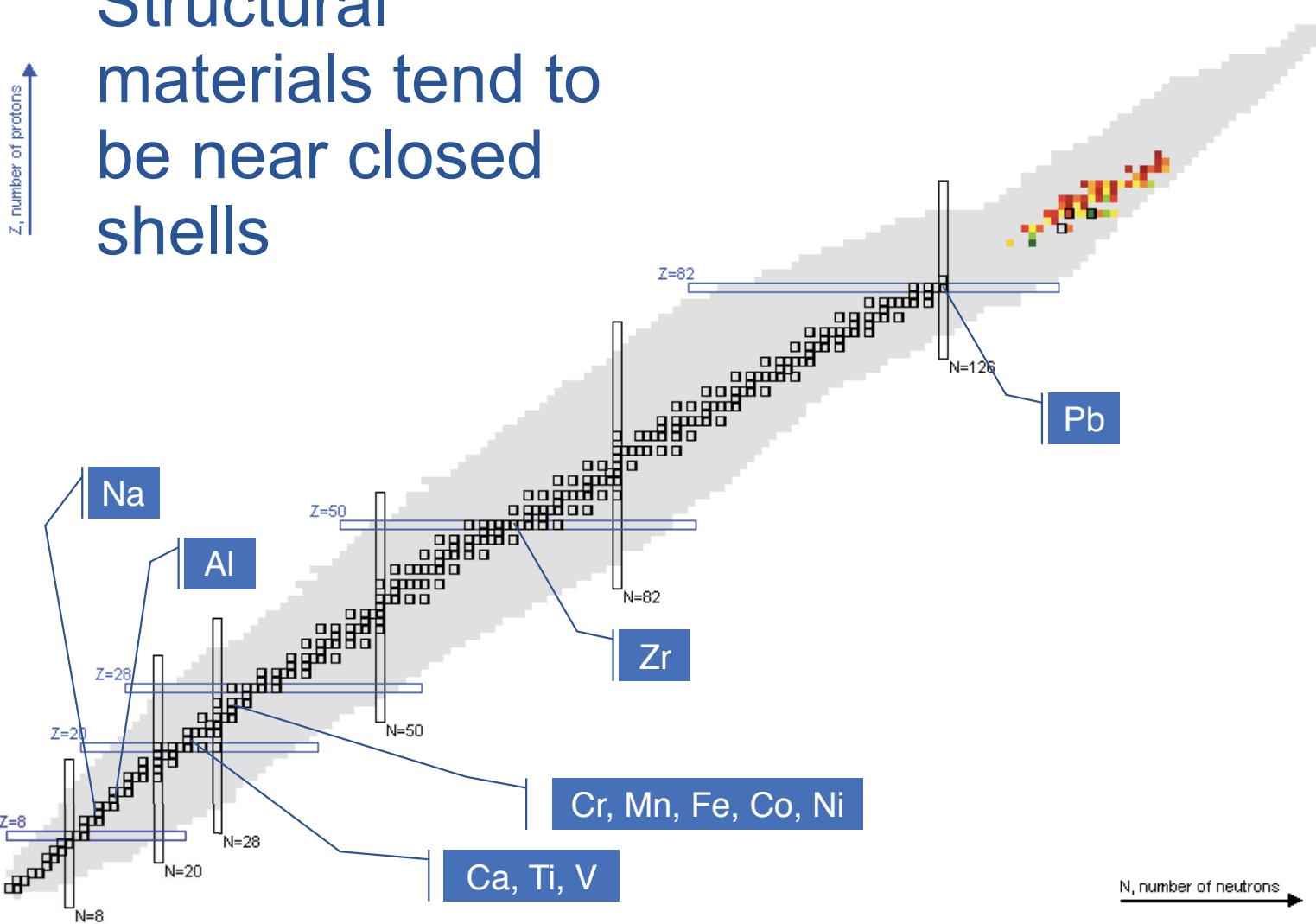


M. Herman et al., Nuclear Data Sheets 148, 214 (2018)

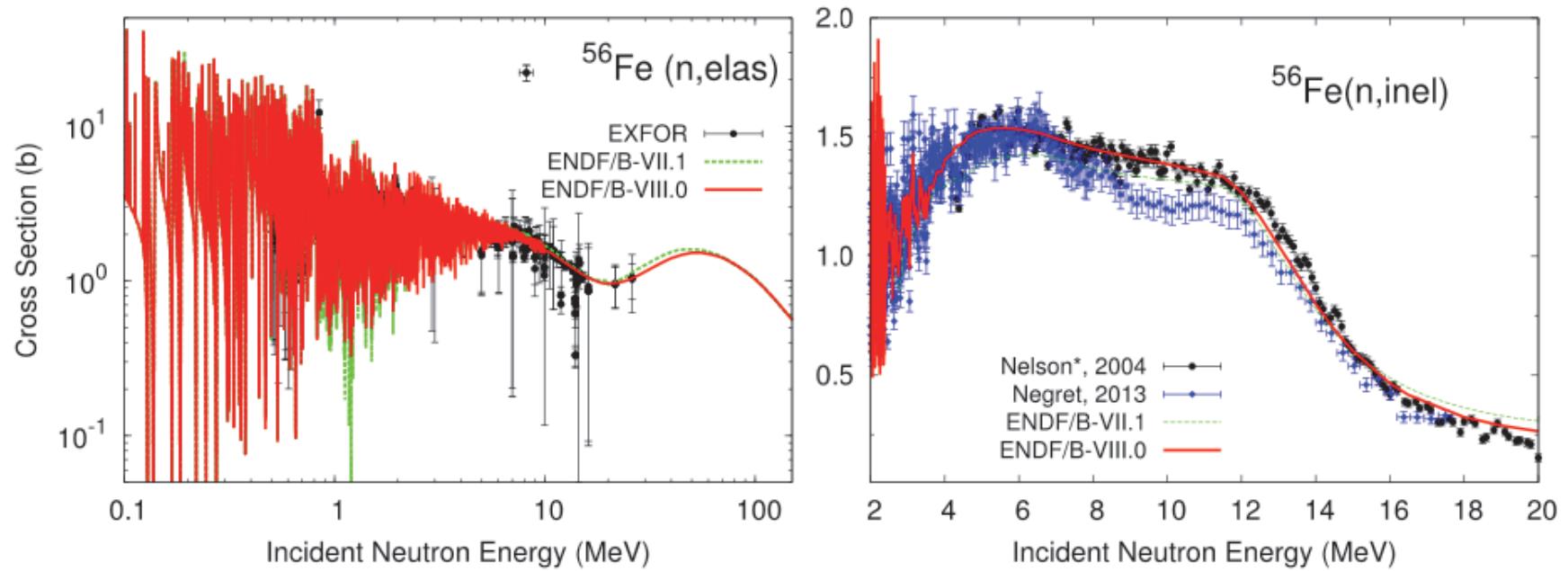
There is still work to do



Structural
materials tend to
be near closed
shells



Nuclei near closed shells have large cross section fluctuations that extend to high energies — These fluctuations dramatically impact neutron leakage and scattering



These fluctuations impact neutron flux and leakage

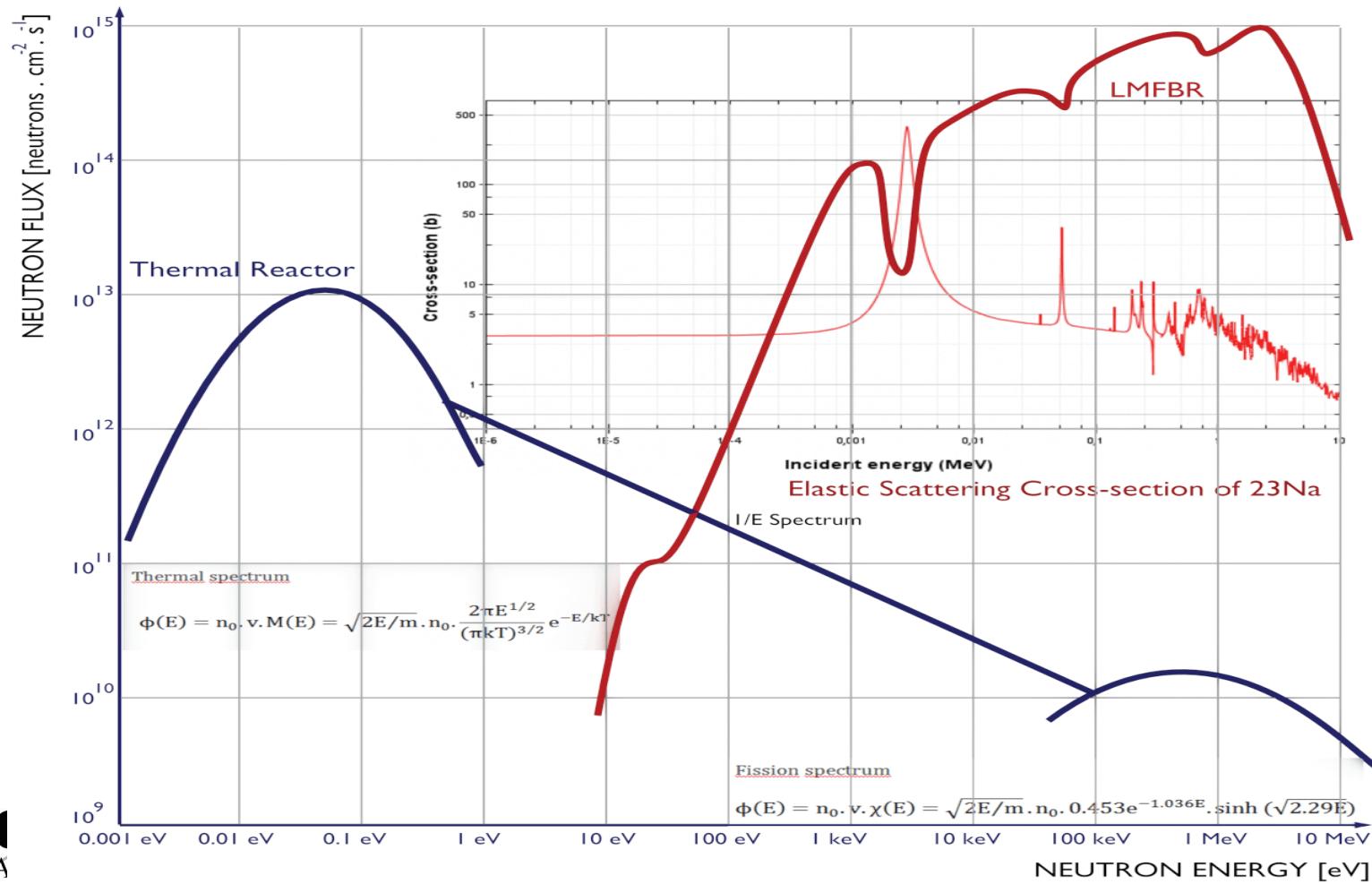
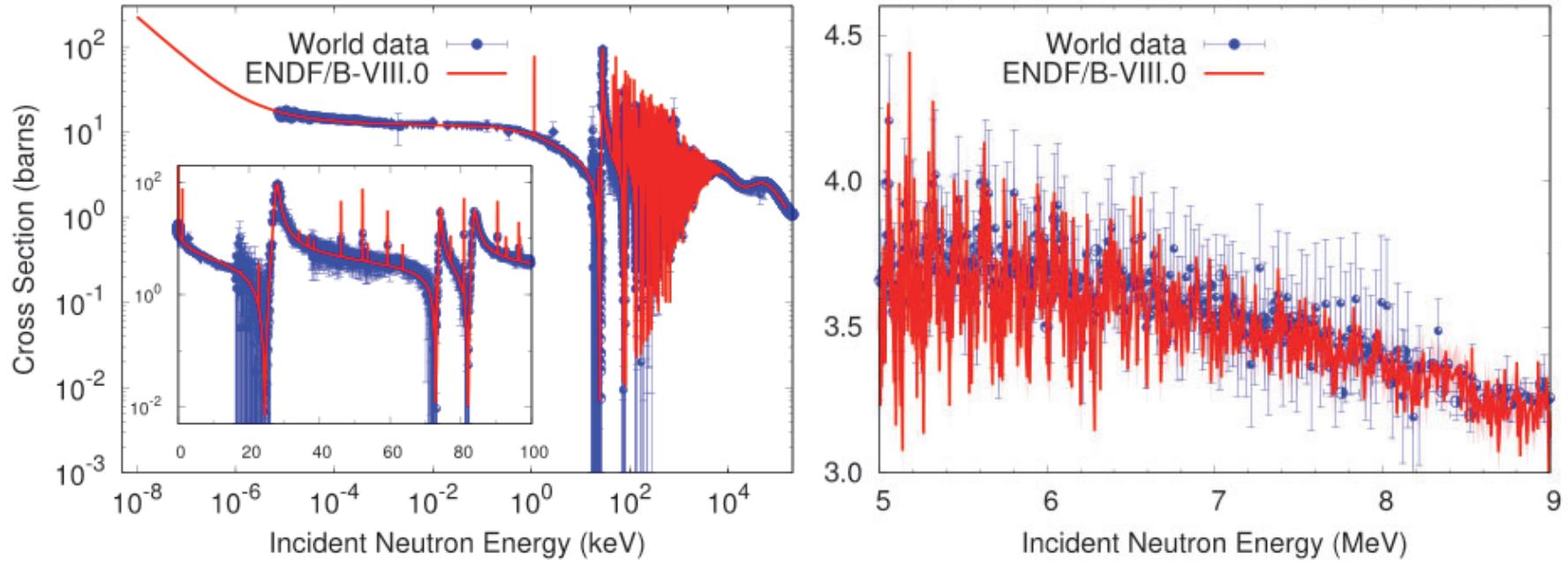


Figure from <https://www.nuclear-power.net/nuclear-power/reactor-physics/nuclear-engineering-fundamentals/neutron-nuclear-reactions/neutron-flux-spectra/>

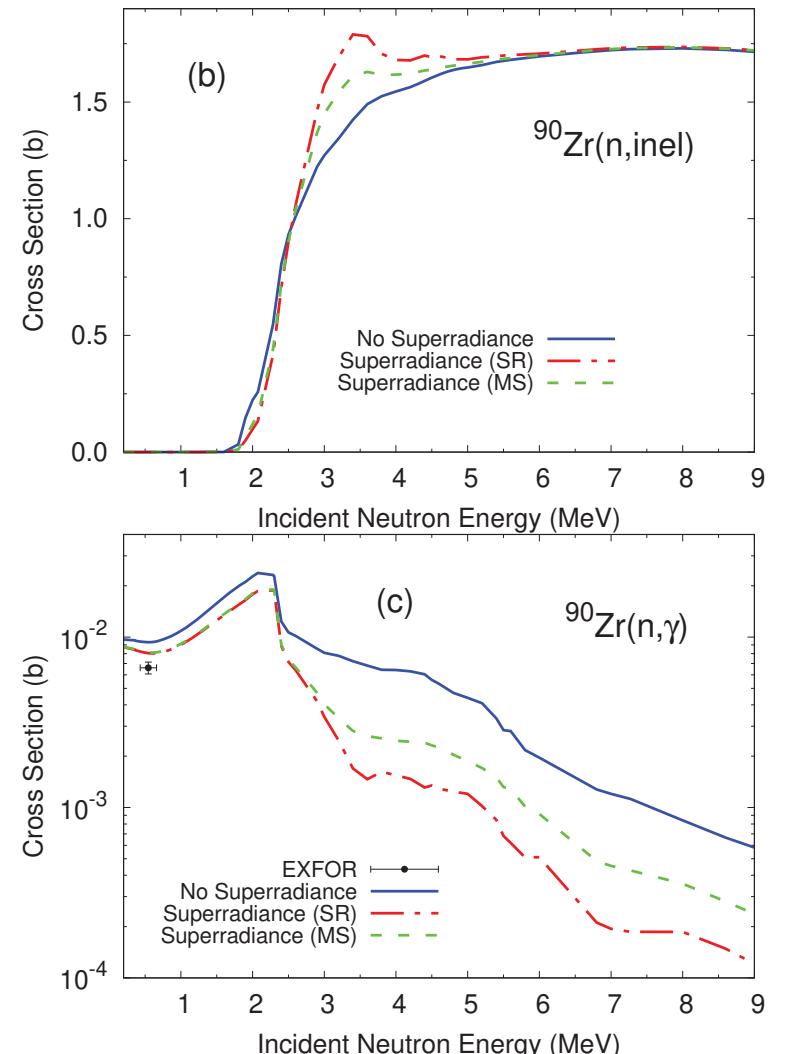
Fluctuations are individual neutron resonances



At low energies, can resolve them, at high energy they are run together and we can no longer resolve them

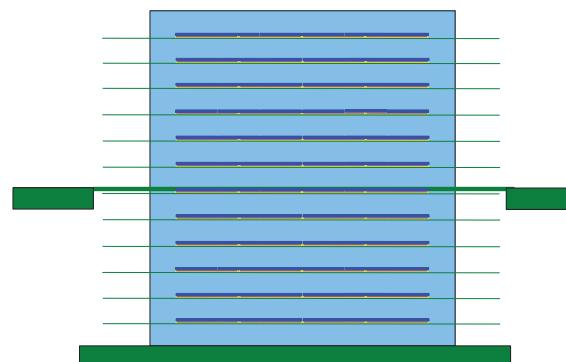
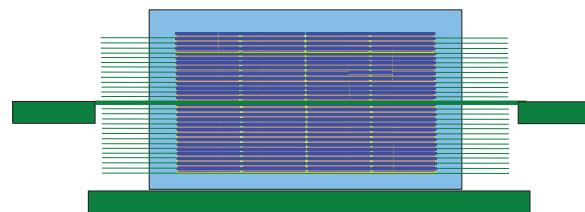
A multi-pronged effort is needed

- Improved RRR QA
- Improved treatments of Width Fluctuation Correction and URR probability tables
- Improved connections between RRR, URR and fast, which may imply **superradiance!**
- (n,n'g) measurements to remove evaluator knob
- More shielding benchmarks in testing regime
- TEX and CURIE!



Tantalum Experiment Characteristics

Experiment Number	Thickness of PE Plates (cm)	Thermal Fission Fraction (<0.625 eV)	Intermediate Fission Fraction (0.625 eV-100 KeV)	Fast Fission Fraction (>100 KeV)
6	0 (no PE)	0.07	0.14	0.79
7	0.159	0.8	0.36	0.56
8	0.476	0.19	0.45	0.36
9	1.111	0.43	0.36	0.21
10	2.540	0.64	0.22	0.14



C. Percher,
ANS Winter
Meeting
2018

Main messages

- **ENDF/B-VII.1 was very good**
 - $k_{\text{eff}}=1$ is “baked in”, which surprisingly is a problem for many customers
 - $k_{\text{eff}}=1$ but with really big uncertainty does mean we biased the mean somehow, but were conservative with our uncertainty estimates
- **But... ENDF/B-VIII.0 is much better**
- **There is still a lot of room for improvement**
- **Files available at <http://www.nndc.bnl.gov/endf/b8.0/download.html>**



Library and evaluations detailed in Nuclear Data Sheets vol. 148 (2018)

- **ENDF/B-VIII.0:** D. Brown *et al.*, Nuclear Data Sheets 148, 1 (2018)
- **Neutron Data Standards:** A. Carlson *et al.*, Nuclear Data Sheets 148, 143 (2018)
- **CIELO Overview:** M.B. Chadwick, *et al.*, Nuclear Data Sheets 148, 189 (2018)
- **CIELO Iron:** M. Herman, *et al.*, Nuclear Data Sheets 148, 214 (2018)
- **CIELO Uranium:** R. Capote, *et al.*, Nuclear Data Sheets 148, 254 (2018)
- **PFNS evaluation:** D. Neudecker, *et al.*, Nuclear Data Sheets 148, 293 (2018)
- **$^{239}\text{Pu}(n,g)$ measurement:** S. Mosby, *et al.*, Nuclear Data Sheets 148, 312 (2018)
- **^{235}U PFNS measurement:** M. Devlin, *et al.*, Nuclear Data Sheets 148, 322 (2018)

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Contents

ENDF/B-VIII.0: The 8th Major Release of the Nuclear Reaction Data Library with CIELO-project Cross Sections, New Standards and Thermal Scattering Data 143
D.A. Brown, M.B. Chadwick, R. Capote, A.C. Kahler, A. Trkov, M.W. Herman, A.A. Sonzogni, Y. Danon, A.D. Carlson, M. Dunn, D.L. Smith, G.M. Hale, G. Arbanas, R. Arcilla, C.R. Bates, B. Beck, B. Becker, F. Brown, J. Canlin, D.E. Cullen, M.-A. Descalle, R. Firestone, K.H. Guher, A.I. Hawari, J. Holmes, T.D. Johnson, T. Kawano, B.C. Kiedrowski, A.J. Konig, S. Kopecky, I. Leal, J. Lestone, C. Lubitz, J.I. Márquez Domínguez, C. Mattoon, E.A. McCutchan, S. Mughabghab, P. Navratil, D. Neudecker, G.P.A. Nobre, G. Noguere, M. Paris, M.T. Pigni, A. Plompen, B. Pritychenko, V.G. Pronyaev, D. Roubtsov, D. Rochman, P. Romano, P. Schillebeeckx, S. Simakov, M. Sin, I. Sirakov, B. Sleaford, V. Sober, E.S. Soukhoivitskii, I. Stetcu, P. Talou, I. Thompson, S.C. van der Marck, D. Wiarda, M. White, J.L. Wormald, R.Q. Wright, M. Zerkle, G. Zerovnik, Y. Zhu

Evaluation of the Neutron Data Standards 143
A.D. Carlson, V.G. Pronyaev, R. Capote, G.M. Hale, Z.-P. Chen, I. Duran, F.-J. Hambach, S. Kunieda, W. Mannhart, B. Marcinkievicius, R.O. Nelson, D. Neudecker, G. Noguere, M. Paris, S. Simakov, P. Schillebeeckx, D.L. Smith, X. Tao, A. Trkov, A. Wallner, W. Wang

Contents continued on the back cover page



Happy 50 ± 1 Anniversary!*

* CSEWG formed in 1966
ENDF/B-I released in 1968

