

Nuclear Data at BNL: Toward ENDF/B-IX.0

G.P.A. Nobre

Third International Workshop on
Perspectives on Nuclear Data for the Next Decade
March 9-13, 2026 - Paris, France

Outline

- Contextualizing ND at BNL: NNDC
- ENDF/B-VIII.1
- ENDF Library activities towards ENDF/B-IX.0
 - Expectations
 - Developments
 - Status and plans



Brookhaven
National Laboratory

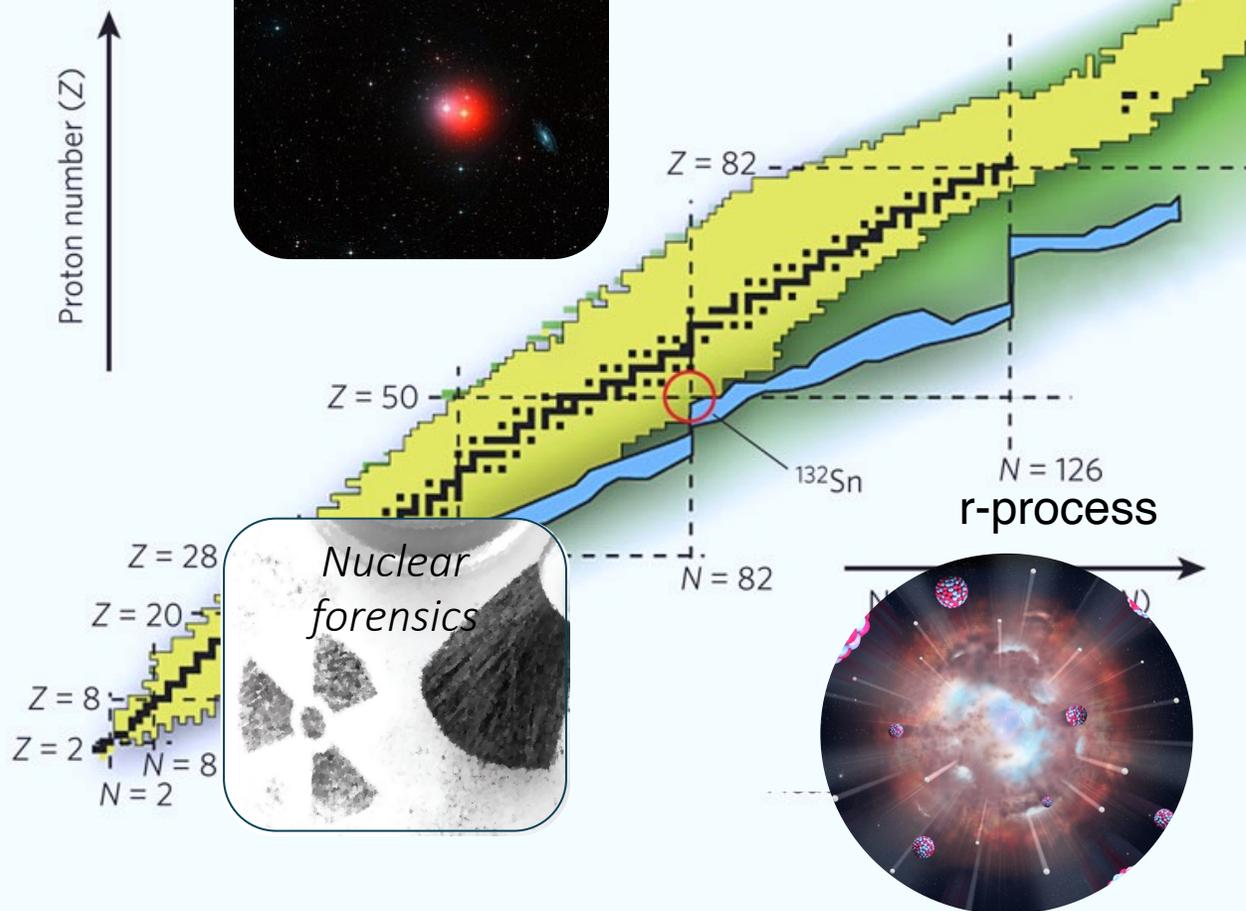
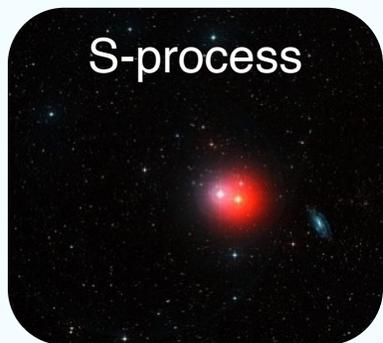
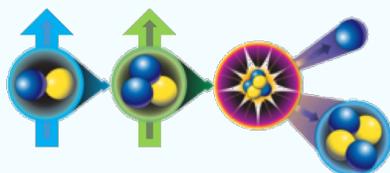


**National Nuclear
Data Center**
A DOE PuRe Data Resource Facility

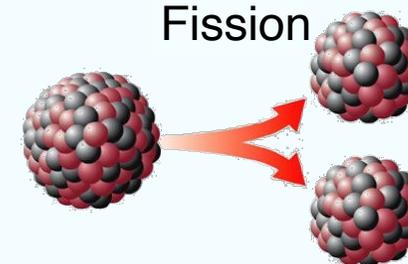
ENDF/B
VIII.1

Nuclear Data is the interface between nuclear physics and science, and technical nuclear applications on which they depend

Thermonuclear Fusion



Fission



What is the NNDC?

Mission

The [National Nuclear Data Center \(NNDC\)](https://www.nndc.bnl.gov/) collects, evaluates, and disseminates nuclear physics data for basic nuclear research and applied nuclear technologies. The NNDC is a worldwide resource for nuclear data. The information available to the users of NNDC services is the product of the combined efforts of the NNDC and cooperating data centers and other interested groups, both in the United States and worldwide.

**some people are missing in the picture!*



<https://www.nndc.bnl.gov/about/>
<https://www.nndc.bnl.gov/history/>

<https://www.nndc.bnl.gov/>



National Nuclear
Data Center



Outdated!

We've moved to 490D

The Cross Section Evaluation Working Group produces ENDF/B library



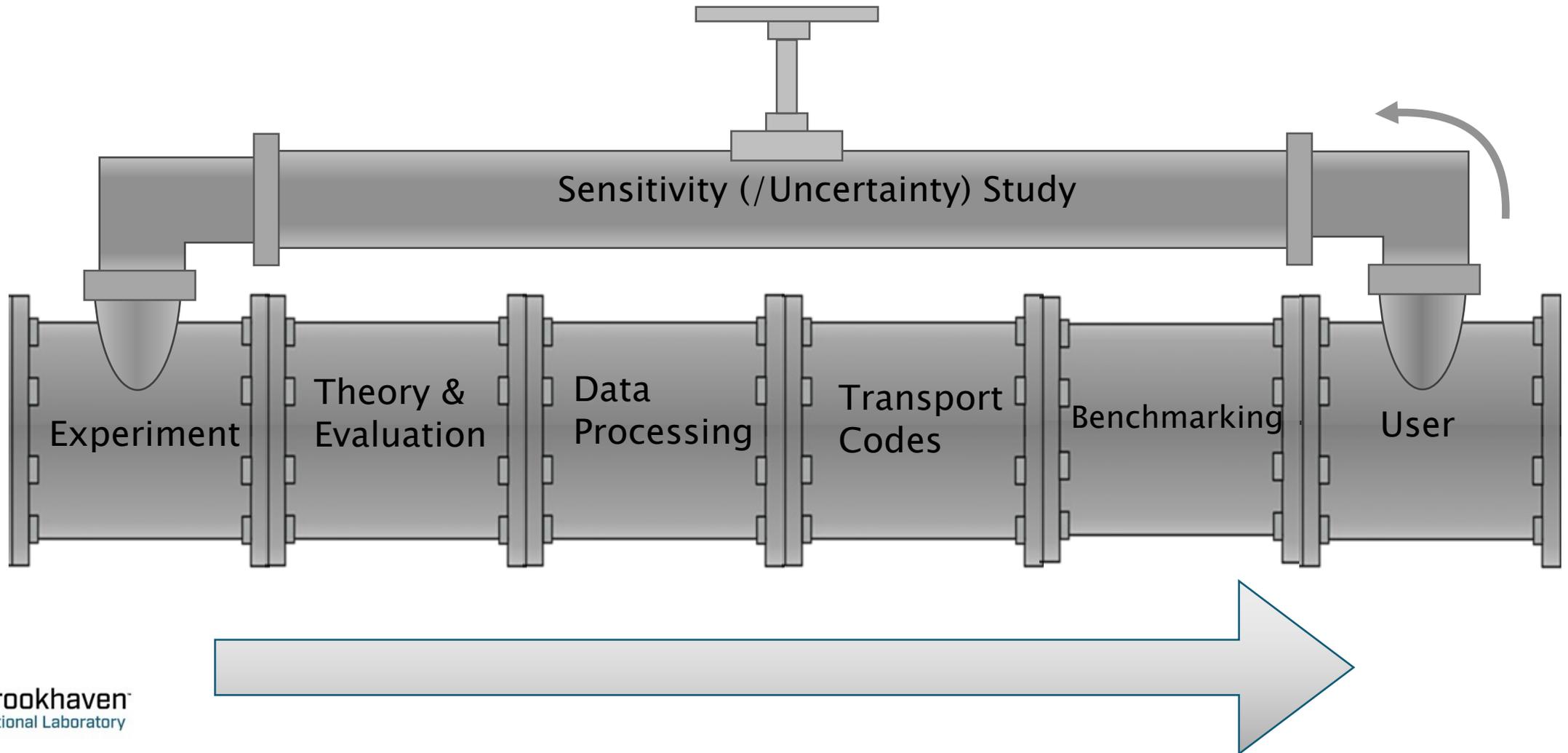
- **Formed 1966 & Chaired by BNL**
- **Currently ~200 members of the collaboration from 25 institutions**
 - US programs, industry and international partners
 - If you see something in the library, at some point a sponsor somewhere wanted it
- **All steps of nuclear data pipeline coordinated through CSEWG**
- **Depending on what needs done, getting required data in library can be major effort**



2025 CSEWG meeting, BNL, Jan. 2026

We are always open to new users and collaborators

The Nuclear Data Pipeline



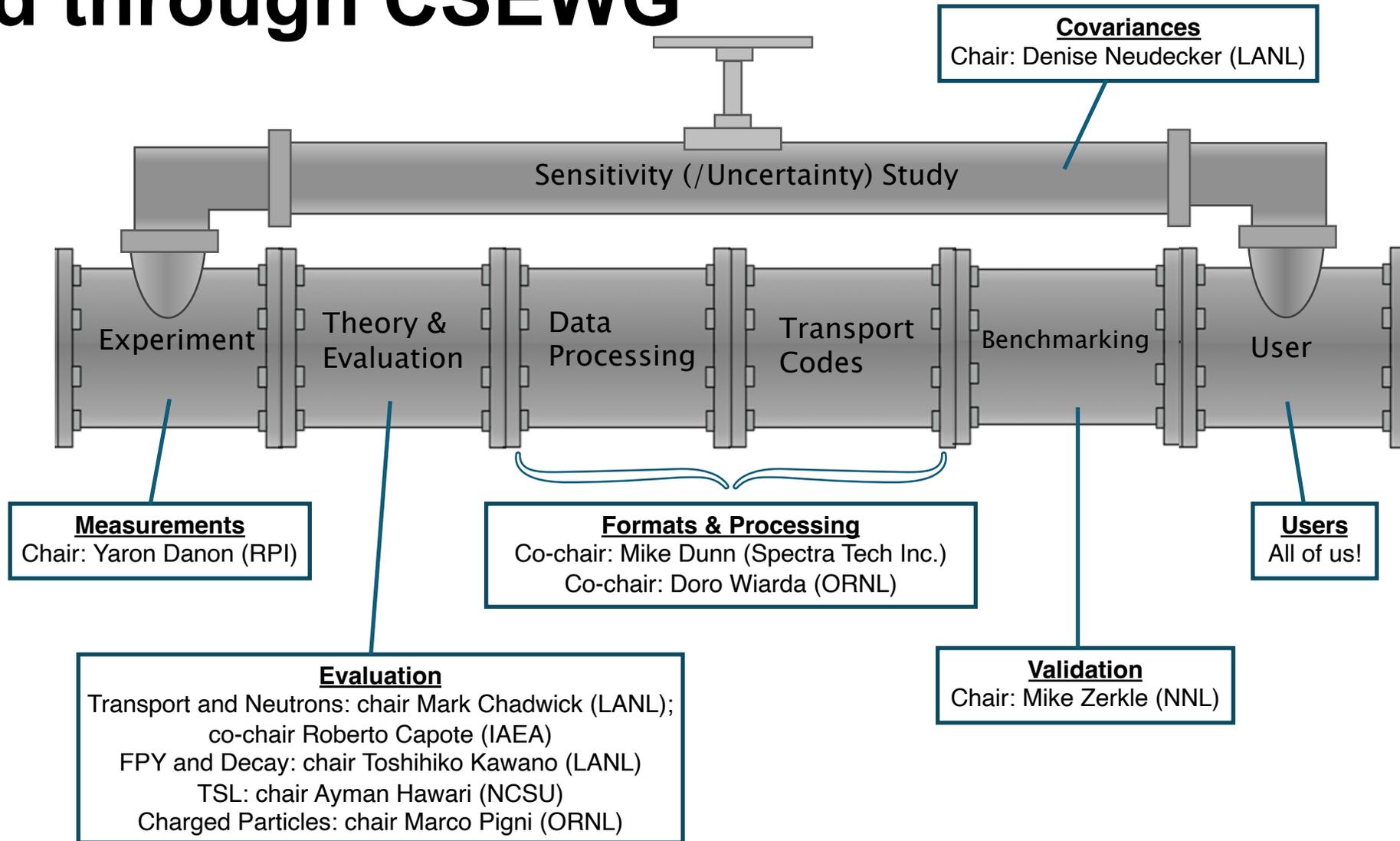
All steps of nuclear data pipeline are coordinated through CSEWG

Chair:

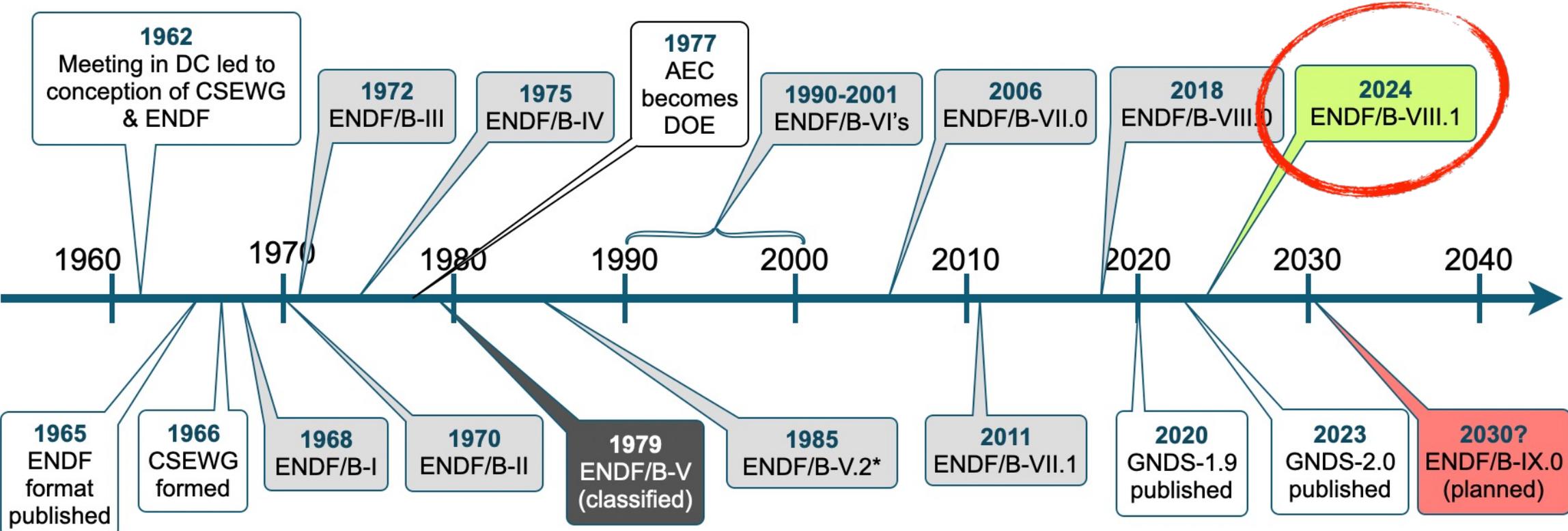
David Brown (BNL)
dbrown@bnl.gov

Library Manager:

Gustavo Nobre (BNL)
gnobre@bnl.gov



ENDF Timeline



Strong connection with user needs!

- Shortly after the ENDF/B-VIII.0 release, it was reported that a loss reactivity was found at high burnup, which discouraged its adoption by the nuclear reactor community
- This depletion issue was taken seriously in validation efforts during VIII.1 development

Article

Neutronic Characteristics of ENDF/B-VIII.0 Compared to ENDF/B-VII.1 for Light-Water Reactor Analysis

 OAK RIDGE
National Laboratory

Kang-Seog Kim * and William A. Wieselquist

Investigation on the Reactivity Underestimation of ENDF/B-VIII.0 Compared to ENDF/B-VII.1 for Thermal Reactor Analysis

2020 CSEWG Meeting
December 2, 2020

SCALE XSPROC Team

ORNL is managed by UT-Battelle, LLC
for the US Department of Energy

Discussion & Conclusion

- **ENDF/B-VII.1 vs. ENDF/B-VIII.0**
 - **Most influencing nuclides**
 - U-238, Pu-239, O-16 and U-235
 - U-238: +300 pcm at 0 burnup & getting decreased at high burnup
 - O-16: -150 pcm at all burnup steps
 - U-235: -150 pcm at all burnup steps
 - Pu-239: -200 pcm at high burnups
 - **Error cancellation**
 - U-238 (positive) vs. U-235 + O-16 (negative)
 - **Decay data & F.P. yield data**
 - No impact
 - **Thermal reactor analysis**
 - Generally accepted that even ENDF/B-VII.1 underestimates keff at high burnup
 - No epithermal upscattering
 - Considering epithermal upscattering would make it more negative
 - ENDF/B-VIII.0 may not be used for thermal reactor (PWR & BWR) analysis
 - **ENDF/B release**
 - May need to perform a sensitivity study for depletion effect

Strong connection with user needs!

- Shortly after the ENDF/B-VIII.0 release, it was reported that a loss reactivity was found at high burnup, which discouraged its adoption by the nuclear reactor community
- This depletion issue was taken seriously in validation efforts during VIII.1 development
- As shown by multiple independent sets of calculations, the depletion performance was **dramatically improved in ENDF/B-VIII.1**

Article

Neutronic Characteristics of ENDF/B-VIII.0 Compared to ENDF/B-VII.1 for Light-Water Reactor Analysis

Kang-Seog Kim * and William A. Wieselquist

Investigation on the Reactivity Underestimation of ENDF/B-VIII.0 Compared to ENDF/B-VII.1 for Thermal Reactor Analysis

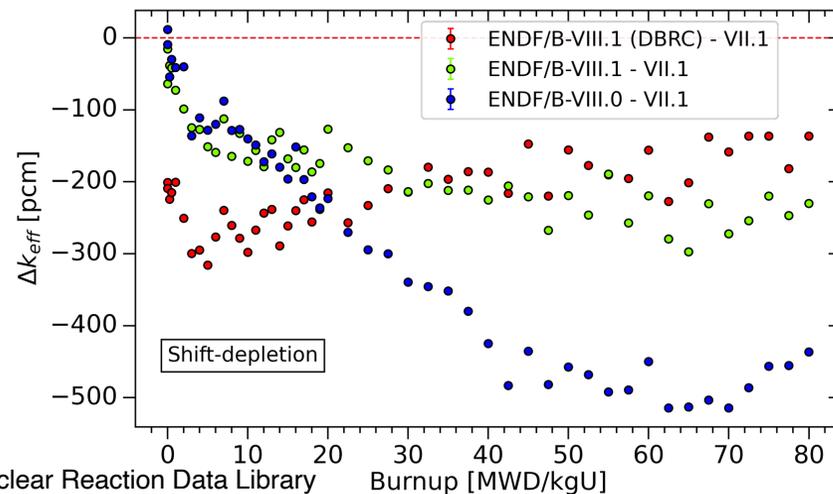
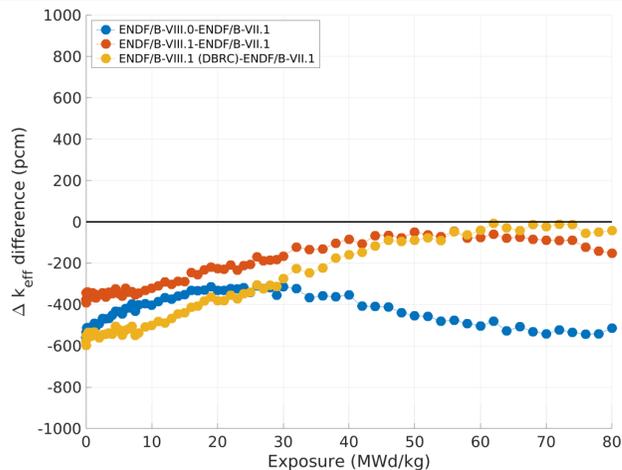
2020 CSEWG Meeting
December 2, 2020

XSProc Team

Managed by UT-Battelle, LLC
Department of Energy

Discussion & Conclusion

- **ENDF/B-VII.1 vs. ENDF/B-VIII.0**
 - **Most influencing nuclides**
 - U-238, Pu-239, O-16 and U-235
 - U-238: +300 pcm at 0 burnup & getting decreased at high burnup
 - O-16: -150 pcm at all burnup steps
 - U-235: -150 pcm at all burnup steps
 - Pu-239: -200 pcm at high burnups
 - **Error cancellation**
 - U-238 (positive) vs. U-235 + O-16 (negative)
 - **Decay data & F.P. yield data**
 - No impact
 - **Thermal reactor analysis**
 - Generally accepted that even ENDF/B-VII.1 underestimates keff at high burnup
 - No epithermal upscattering
 - Considering epithermal upscattering would make it more negative
 - ENDF/B-VIII.0 may not be used for thermal reactor (PWR & BWR) analysis
 - **ENDF/B release**
 - May need to perform a sensitivity study for depletion effect

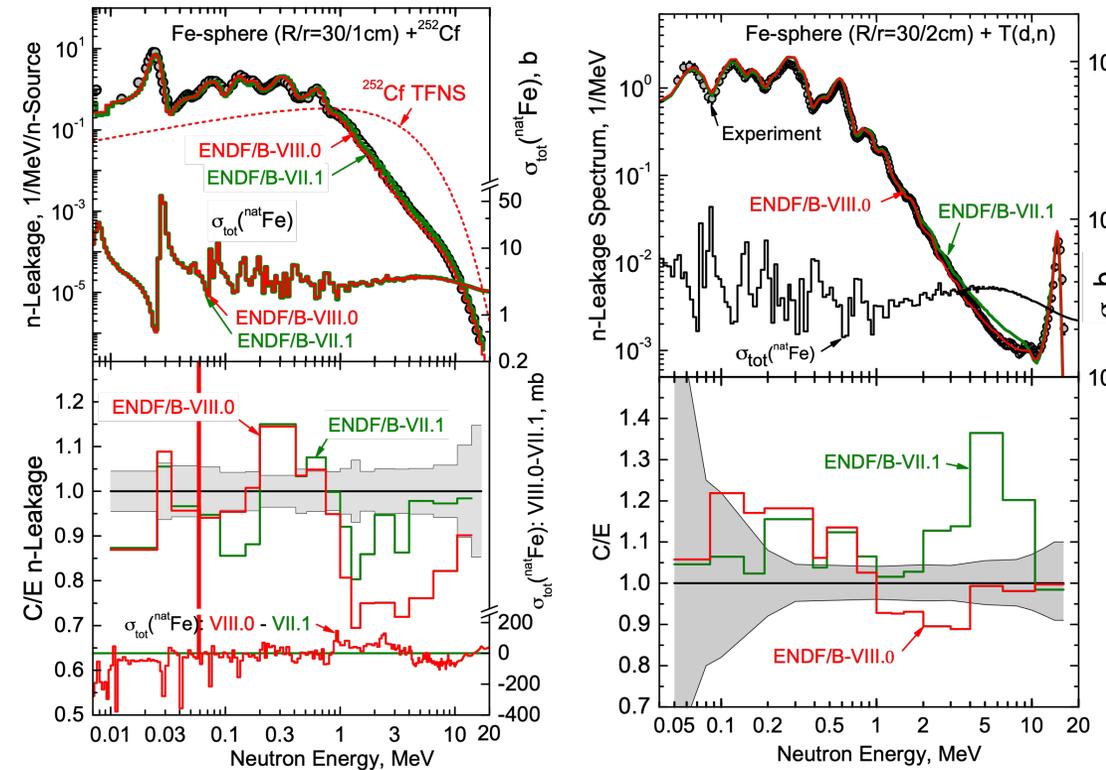


G. P. A. NOBRE et al., "ENDF/B-VIII.1: Updated Nuclear Reaction Data Library for Science and Applications," Nucl. Data Sheets (2024) (submitted for publication).

Strong connection with user needs!

- Just before the ENDF/B-VIII.0 release, it was found that there was a 30% underestimation of neutron leakage in iron spheres.
- This prevented VIII.0 Fe to be used in reactor shielding simulations

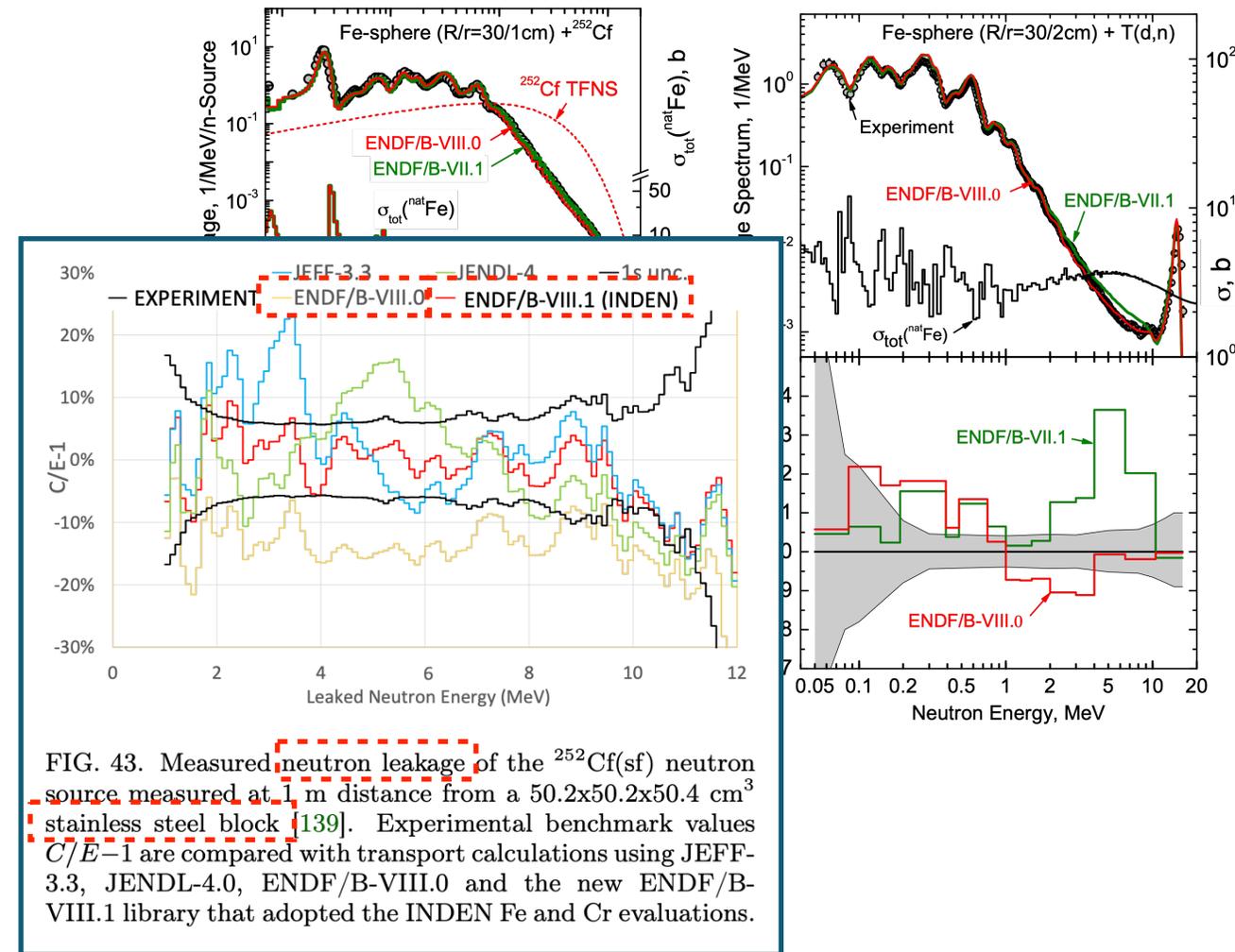
Figs. 32, 35, Nuclear Data Sheets, 148 (2018) 214-253



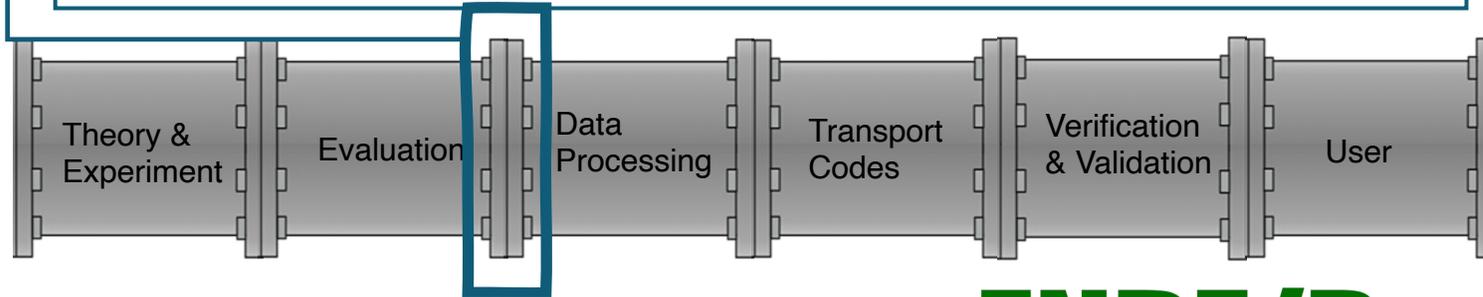
Strong connection with user needs!

- Just before the ENDF/B-VIII.0 release, it was found that there was a 30% underestimation of neutron leakage in iron spheres.
- This prevented VIII.0 Fe to be used in reactor shielding simulations
- This was fixed in ENDF/B-VIII.1
- Feedback from reactor community that this finally allowed them to move to a more recent release
- **Bonus:** Leakage validation was considered more carefully in the evaluation of other structural materials: Cr, Cu, Pb, etc...

Figs. 32, 35, Nuclear Data Sheets, 148 (2018) 214-253



ENDF/B releases are a key interface in the improvement of the nuclear data that reaches the users' community!

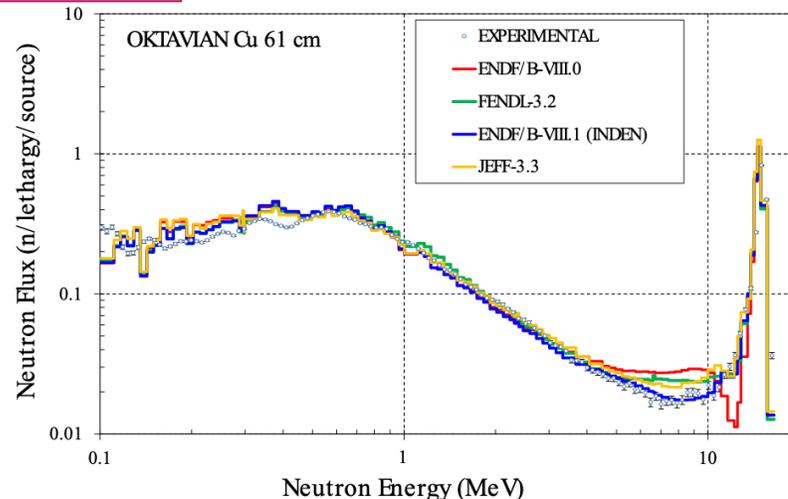
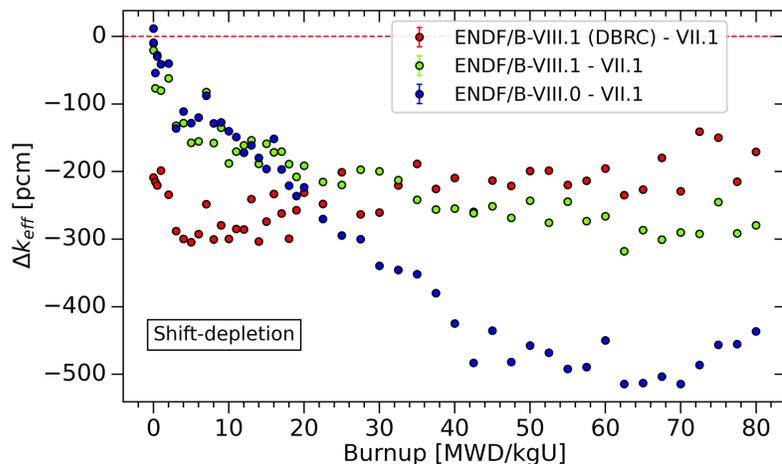


The previous release (VIII.0) was great, but...

- Underpredicted depletion at high burnup
- Had deficiencies in leakage benchmarks
- Many other contributions since then

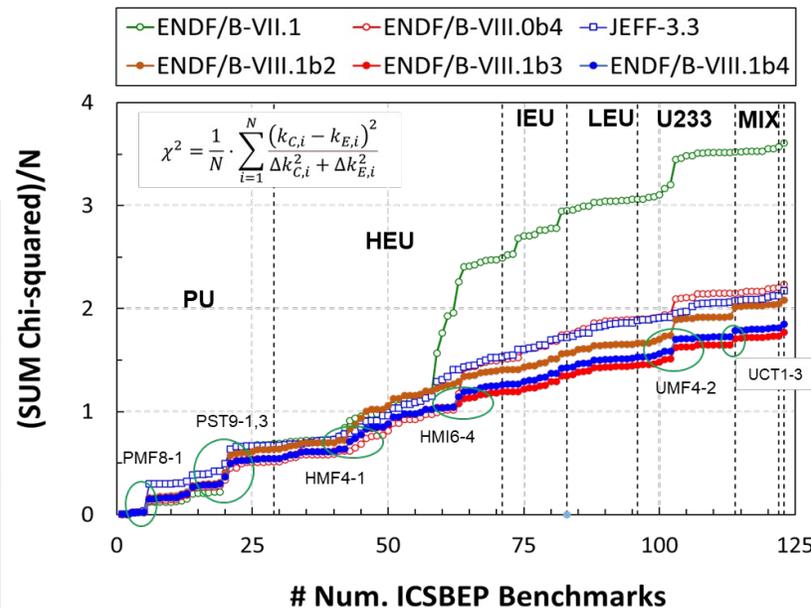
ENDF/B VIII.1

was released Aug 30, 2024!



Mosteller's Suite - 123

Case HMF4.1: Δk_{eff} EXP=30 pcm



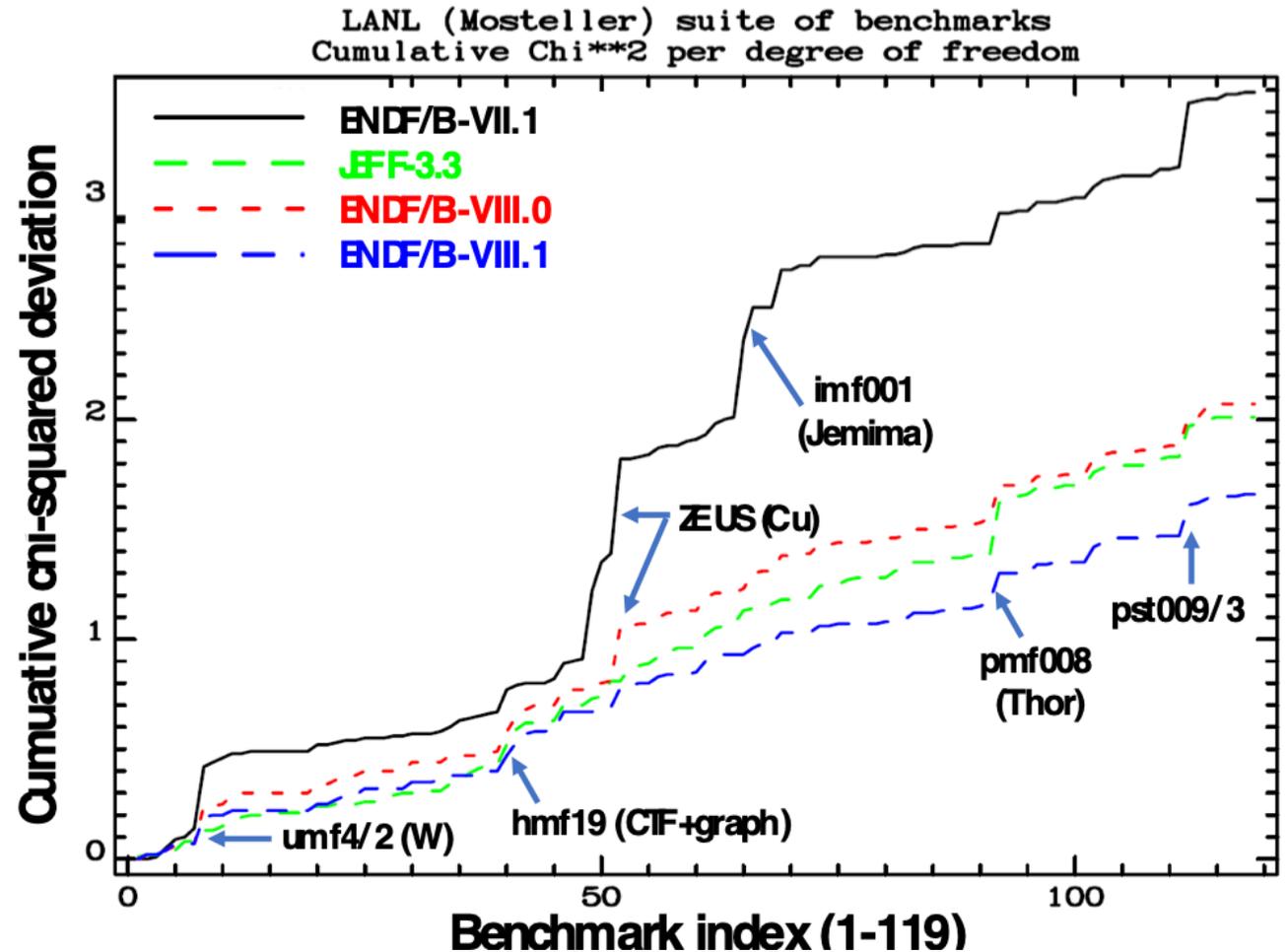
VIII.1 dramatically improves depletion performance,...

...performs much better in leakage and shielding experiments due to updates in Cu, Fe, Cr, Pb,...

...all while further improving the performance in criticality benchmarks, with updates to ²³⁹Pu, ^{235,238}U, et al.!!

Further improvement in criticality performance

- Performance of the library assessed thoroughly and consistently throughout the development against complete suite of benchmarks
- Final set further improves agreement with integral data!!
- Not perfect, still room for improvements



G. P. A. NOBRE et al., "ENDF/B-VIII.1: Updated Nuclear Reaction Data Library for Science and Applications," Nucl. Data Sheets (2024) (submitted for publication).



gnobre@bnl.gov

Bottom line:

If you find an **issue** with the ENDF/B library, **PLEASE**
report to us!

DOIs for ENDF/B-VIII.1 data

ENDF B-VIII.1 Full Library

The ENDF/B-VIII.1 release is the newest evaluated nuclear data library produced, distributed, and recommended by CSEWG for use in nuclear science and technology applications. Among the many key advances, relative to the previous version ENDF/B-VIII.0, are: re-evaluation of ^{239}Pu file by a joint international effort; updated 16,18O, 19F, $^{28-30}\text{Si}$, $^{50-54}\text{Cr}$, ^{55}Mn , $^{54,56,57}\text{Fe}$, $^{63,65}\text{Cu}$, ^{139}La , $^{233,235,238}\text{U}$, and $^{240,241}\text{Pu}$ neutron nuclear data by the IAEA-coordinated INDEN collaboration; significant changes for ^3He , ^6Li , ^9Be , ^{51}V , ^{88}Sr , ^{103}Rh , $^{140,142}\text{Ce}$, Dy, ^{181}Ta , Pt, $^{206-208}\text{Pb}$, and $^{234,236}\text{U}$ neutron data; new nuclear data for the photo-nuclear, being 196 adopted from the IAEA2019 Photonuclear Data Library and one new file from JENDL-5; and new evaluations for the charged-particle and atomic sublibraries.

Numerous thermal neutron scattering kernels were re-evaluated or provided for the very first time. Additionally, new covariance testing was implemented. ENDF/B-VIII.1 reduced bias in the simulations of many integral experiments with particular progress noted for fluorine, copper and stainless steel containing benchmarks. Data issues which had hindered the

ENDF/B VIII.1

ENDF B-VIII.1 Full Library (907.934 MB)

Format: ENDF-6

Download Checksum: MD5

9696a44db1aeb833502a3f128e1e957e

Download

Citation: TBD

Awaiting Publication...

File	Size
ENDF B-VIII.1 Full Library	907.934 MB

Collaboration Summary

Data Manager: National Nuclear Data Center (NNDC)

Data Curator: Gustavo Nobre

- “ENDF/B-VIII.1 release.” <https://doi.org/10.11578/endl/2571019> (2024).
- “ENDF/B-VIII.1 release – alphas sublibrary.” <https://doi.org/10.11578/endl/2571012> (2024).
- “ENDF/B-VIII.1 release – atomic relaxation sublibrary.” <https://doi.org/10.11578/endl/2571013> (2024).
- “ENDF/B-VIII.1 release – decay sublibrary.” <https://doi.org/10.11578/endl/2571014> (2024).
- “ENDF/B-VIII.1 release – deuterons sublibrary.” <https://doi.org/10.11578/endl/2571015> (2024).
- “ENDF/B-VIII.1 release – electrons sublibrary.” <https://doi.org/10.11578/endl/2571016> (2024).
- “ENDF/B-VIII.1 release – photonuclear sublibrary.” <https://doi.org/10.11578/endl/2571020> (2024).
- “ENDF/B-VIII.1 release – helions sublibrary.” <https://doi.org/10.11578/endl/2571021> (2024).
- “ENDF/B-VIII.1 release – neutrons sublibrary.” <https://doi.org/10.11578/endl/2571022> (2024).
- “ENDF/B-VIII.1 release – neutron-induced fission product yields sublibrary.” <https://doi.org/10.11578/endl/2571023> (2024).
- “ENDF/B-VIII.1 release – photo-atomic sublibrary.” <https://doi.org/10.11578/endl/2571024> (2024).
- “ENDF/B-VIII.1 release – protons sublibrary.” <https://doi.org/10.11578/endl/2571025> (2024).
- “ENDF/B-VIII.1 release – spontaneous fission product yields sublibrary.” <https://doi.org/10.11578/endl/2571026> (2024).
- “ENDF/B-VIII.1 release – standards sublibrary.” <https://doi.org/10.11578/endl/2571027> (2024).
- “ENDF/B-VIII.1 release – thermal scattering law sublibrary.” <https://doi.org/10.11578/endl/2571028> (2024).
- “ENDF/B-VIII.1 release – tritons sublibrary.” <https://doi.org/10.11578/endl/2584305> (2024).

DOIs for ENDF/B-VIII.1 data

Library Downloads

ENDF-6
 Download

Collaboration Summary

File	Size
<input type="checkbox"/> ENDF B-VIII.1 Full Library	907.934 MB
<input type="checkbox"/> Alpha Reaction Sublibrary	181 KB
<input type="checkbox"/> Atomic Relaxation Reaction Sublibrary	1.397 MB
<input type="checkbox"/> Decay Reaction Sublibrary	10.358 MB
<input type="checkbox"/> Deuteron Reaction Sublibrary	208 KB
<input type="checkbox"/> Electron Reaction Sublibrary	7.544 MB
<input type="checkbox"/> Photonuclear Sublibrary	141.016 MB
<input type="checkbox"/> Helium-3 Reaction Sublibrary	203 KB
<input type="checkbox"/> Neutron Reaction Sublibrary	343.487 MB
<input type="checkbox"/> Neutron Induced Fission Product Yields Sublibrary	1.502 MB
<input type="checkbox"/> Photoatomic Reaction Sublibrary	33.635 MB

Data Manager	National Nuclear Data Center (NNDC)
Data Curator	Gustavo Nobre
Contact Person	Gustavo Nobre
Project Leader	David Brown
Hosting Institution	Brookhaven National Laboratory (BNL)
Producer	Cross Section Evaluation Working Group (CSEWG)

Depositor	Gustavo Nobre
Contact	gnobre@bnl.gov
Deposition Date	10/21/2024
Last Modified	10/21/2024
DOI	10.11578/endl/2571019

ENDF-6 Manual

GNDS Manual

Summary

GNDS

POINT

Criticality Validation

ENDF/B
VIII.1

ENDF B-VIII.1 Full Library (907.934 MB)

Format: ENDF-6

• ENDF-6 Manual
• GNDS Manual

Alpha Reaction Sublibrary (181 KB)

Format: ENDF-6

• Release Notes
• Changelog
• Material List

Atomic Relaxation Reaction Sublibrary (1.397 MB)

Format: ENDF-6

• Release Notes
• Changelog
• Material List

“ENDF/B-VIII.1 release.” <https://doi.org/10.11578/endl/2571019> (2024).

“ENDF/B-VIII.1 release – alphas sublibrary.” <https://doi.org/10.11578/endl/2571012> (2024).

“ENDF/B-VIII.1 release – atomic relaxation sublibrary.” <https://doi.org/10.11578/endl/2571013> (2024).

“ENDF/B-VIII.1 release – decay sublibrary.” <https://doi.org/10.11578/endl/2571014> (2024).

“ENDF/B-VIII.1 release – deuterons sublibrary.” <https://doi.org/10.11578/endl/2571015> (2024).

“ENDF/B-VIII.1 release – electrons sublibrary.” <https://doi.org/10.11578/endl/2571016> (2024).

“ENDF/B-VIII.1 release – photonuclear sublibrary.” <https://doi.org/10.11578/endl/2571020> (2024).

“ENDF/B-VIII.1 release – helions sublibrary.” <https://doi.org/10.11578/endl/2571021> (2024).

“ENDF/B-VIII.1 release – neutrons sublibrary.” <https://doi.org/10.11578/endl/2571022> (2024).

“ENDF/B-VIII.1 release – neutron-induced fission product yields sublibrary.” <https://doi.org/10.11578/endl/2571023> (2024).

“ENDF/B-VIII.1 release – photo-atomic sublibrary.” <https://doi.org/10.11578/endl/2571024> (2024).

“ENDF/B-VIII.1 release – protons sublibrary.” <https://doi.org/10.11578/endl/2571025> (2024).

“ENDF/B-VIII.1 release – spontaneous fission product yields sublibrary.” <https://doi.org/10.11578/endl/2571026> (2024).

“ENDF/B-VIII.1 release – standards sublibrary.” <https://doi.org/10.11578/endl/2571027> (2024).

“ENDF/B-VIII.1 release – thermal scattering law sublibrary.” <https://doi.org/10.11578/endl/2571028> (2024).

“ENDF/B-VIII.1 release – tritons sublibrary.” <https://doi.org/10.11578/endl/2584305> (2024).

“Big Paper” Timeline

- **October 23, 2024:** Text finalized, only tables and plots needed to be updated from last beta version to final VIII.1
- **December 23, 2024:** Final manuscript submitted to Nuclear Data Sheets
- **August 11, 2025:** Referee reports received
- **October 21, 2025:** Revised manuscript resubmitted
- **November 5, 2025:** Posted in arXiv

<https://doi.org/10.48550/arXiv.2511.03564>

ENDF/B-VIII.1: Updated Nuclear Reaction Data Library for Science and Applications

G.P.A. Nobre, R. Capote, M.T. Pigni, A. Trkov, C.M. Mattoon, D. Neudecker, D.A. Brown, M.B. Chadwick, A.C. Kahler, N.A. Kleedtke, M. Zerkle, A.I. Hawari, C.W. Chapman, N.C. Fleming, J.L. Wormald, K. Ramic, Y. Danon, N.A. Gibson, P. Brain, M.W. Paris, G.M. Hale, I.J. Thompson, D.P. Barry, I. Stetcu, W. Haeck, A.E. Lovell, M.R. Mumpower, G. Potel, K. Kravvaris, G. Noguere, J.D. McDonnell, A.D. Carlson, M. Dunn, T. Kawano, D. Wiarda, I. Al-Qasir, G. Arbanas, R. Arcilla, B. Beck, D. Bernard, R. Beyer, J.M. Brown, O. Cabellios, R.J. Casperson, Y. Cheng, E.V. Chimaniski, R. Coles, M. Cornock, J. Cotchen, J.P.W. Crozier, D.E. Cullen, A. Daskalakis, M.-A. Descalle, D.D. Djuliu, P. Dimitriou, A.C. Dreyfuss, I. Durán, R. Ferrer, T. Gaines, V. Gillette, G. Gert, K.H. Guber, J.D. Haverkamp, M.W. Herman, J. Holmes, M. Hursin, N. Jisrawi, A.R. Jungthans, K.J. Kelly, H.I. Kim, K.S. Kim, A.J. Koning, M. Košťál, B.K. Laramée, A. Lauer-Coles, L. Leal, H.Y. Lee, A.M. Lewis, J. Malec, J.J. Márquez Damián, W.J. Marshall, A. Mattera, G. Muhrer, A. Ney, W.E. Ormand, D.K. Parsons, C.M. Percher, V.G. Pronyaev, A. Qteish, S. Quagliioni, M. Rapp, J.J. Ressler, M. Rising, D. Rochman, P.K. Romano, D. Roubtsov, G. Schnabel, M. Schulc, G.J. Siemers, A.A. Sonzogni et al. (9 additional authors not shown)

The ENDF/B-VIII.1 library is the newest recommended evaluated nuclear data file by the Cross Section Evaluation Working Group (CSEWG) for use in nuclear science and technology applications, and incorporates advances made in the six years since the release of ENDF/B-VIII.0. Among key advances made are that the ^{239}Pu file was reevaluated by a joint international effort and that updated ^{16}O , ^{19}F , $^{28-30}\text{Si}$, $^{50-54}\text{Cr}$, ^{55}Mn , $^{54,56,57}\text{Fe}$, $^{63,65}\text{Cu}$, ^{139}La , $^{233,235,238}\text{U}$, and $^{240,241}\text{Pu}$ neutron nuclear data from the IAEA coordinated INDEN collaboration were adopted. Over 60 neutron dosimetry cross sections were adopted from the IAEA's IRDFF-II library. In addition, the new library includes significant changes for ^{16}O , ^{19}F , $^{28-30}\text{Si}$, $^{50-54}\text{Cr}$, ^{55}Mn , $^{54,56,57}\text{Fe}$, $^{63,65}\text{Cu}$, ^{139}La , $^{233,235,238}\text{U}$, and $^{240,241}\text{Pu}$ neutron data, and new nuclear data for the photonuclear, charged-particle and atomic sublibraries. Numerous neutron scattering kernels were reevaluated or provided for the very first time. On the covariance side, work was undertaken to introduce better uncertainty quantification standards and testing for nuclear data covariances. The significant effort to reevaluate important nuclides has reduced bias in the simulations of many integral experiments with particular progress noted for fluorine, copper, and stainless steel containing benchmarks. Data issues hindered the successful deployment of the previous ENDF/B-VIII.0 for commercial nuclear power applications in high burnup situations. These issues were addressed by improving the ^{239}Pu and $^{240,241}\text{Pu}$ evaluated data in the resonance region. The new library performance as a function of burnup is similar to the reference ENDF/B-VII.1 library. The ENDF/B-VIII.1 data are available in ENDF-6 and GND5 format at [this https URL](https://www.oecd-nea.org/db-series/2025/01/2025-01-01-ndf8-viii1).

arXiv:2511.03564v1 [physics.app-ph] 5 Nov 2025

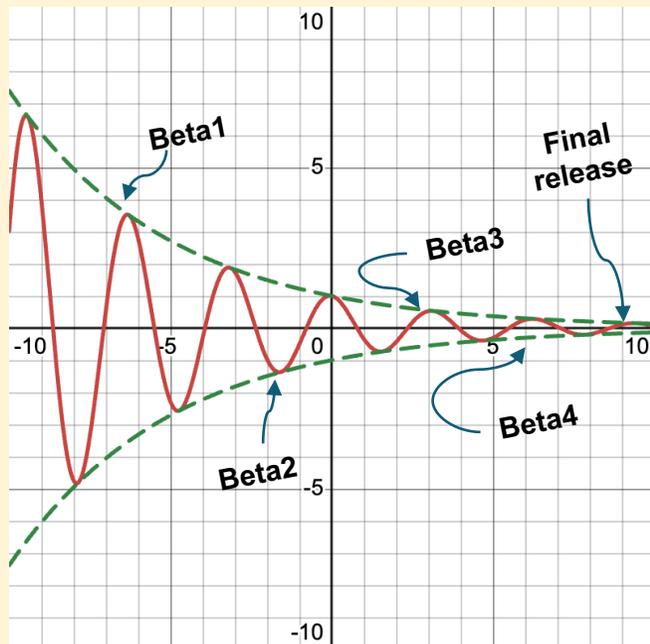
Hopefully, it will get published early 2026!



Beyond ENDF/B-VIII.1, towards ENDF/B-IX.0

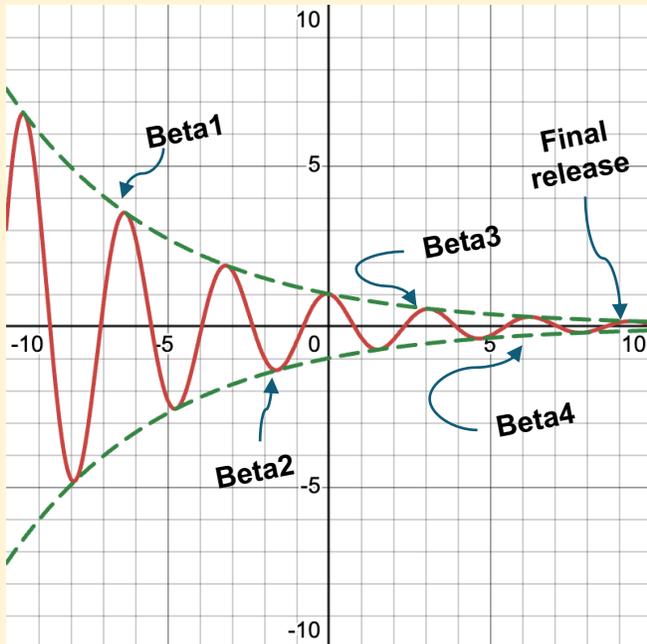
Importance of review process

Allied with consistent validation, **review system** allows for a **predictable, progressively-convergent** path towards a **final ENDF release!**



Importance of review process

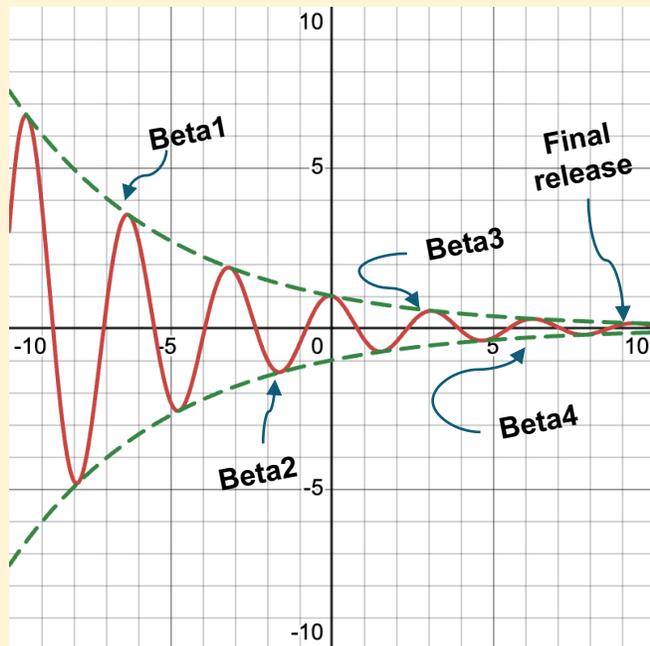
Allied with consistent validation, **review system** allows for a **predictable, progressively-convergent** path towards a **final ENDF release!**



- We learned many lessons from the VIII.1 review process:
 - Identified several issues:
 - Current **review form** is **not very useful**
 - Wiki page and **report tarballs** are **not very helpful** either
 - **Issues** with integration with **processing codes**
 - On the **positive side**:
 - GitLab's **merge request GUI environment** for review was **great** for discussions, documentation, tracking of updates, etc., **all integrated with commits and issue trackers**

Importance of review process

Allied with consistent validation, **review system** allows for a **predictable, progressively-convergent** path towards a **final ENDF release!**



- We learned many lessons from the VIII.1 review process:
 - Identified several issues:
 - Current **review form** is **not very useful**
 - Wiki page and **report tarballs** are **not very helpful** either
 - **Issues** with integration with **processing codes**
 - On the **positive side**:
 - GitLab's **merge request GUI environment** for review was **great** for discussions, documentation, tracking of updates, etc., **all integrated with commits and issue trackers**

For the ENDF/B-IX.0 cycle, we are planning a **complete re-work** of the review process through a **working group**, aiming to make it more user-friendly

- In the meantime, we will keep working as we have been doing...

Expectations for the next library release

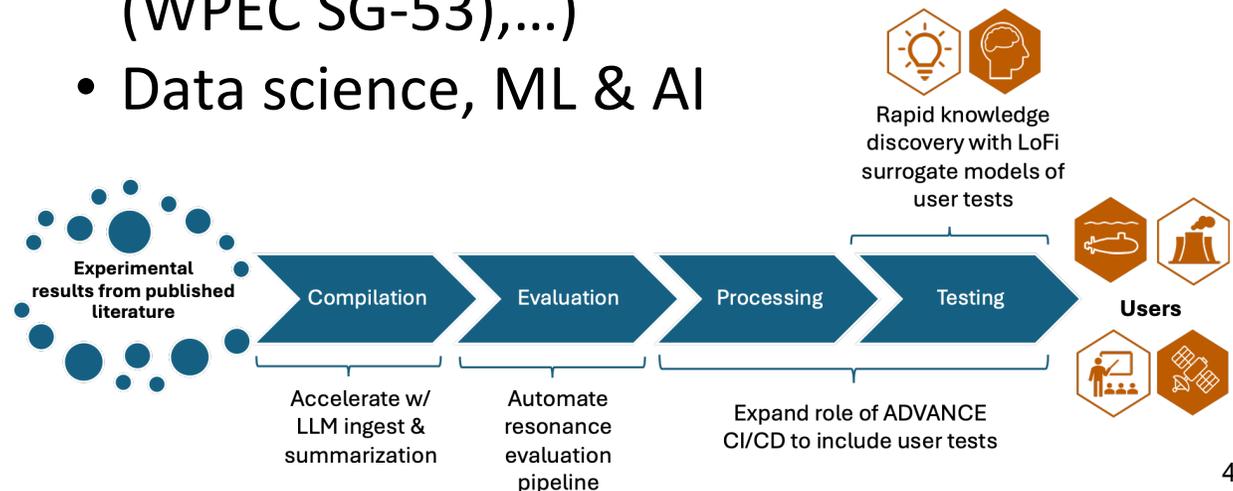
It's hard to know what exactly will be in the release, but we can guess...

Known programmatic drivers

- Fusion
- HALEU & next gen. reactors
- Non-proliferation needs
- Data science
- New Standards
- **Activation library**

Anticipated foci

- **Standards**
- **Actinides:** ^{239}Pu , $^{233,235,238}\text{U}$, etc.
- Reactions on unstable fission products
- Materials for next gen. reactors (Cl, Zr (WPEC SG-53),...)
- Data science, ML & AI



Evaluations already submitted

Neutrons:

- ^{35}Cl (LANL/Terrapower/ORNL)
- ^{238}U (PFNS from Chi-Nu data)

TSL:

- Polyethylene extended temperatures (NCSU/TAMU)
- W, V, Pb, Ni, Mo, Cu (ORNL)

Photonuclear:

- ^9Be (NNL)

Expected/planned submissions

Neutrons:

- ^{239}Pu (INDEN; updated inelastic, elastic, total)
- ^{95}Mo , Gd (ORNL)
- Zr (RPI/ORNL/BNL...)
- Gamma spectra fixes
- ...

Deuterons:

- D+T (LANL/LLNL)

Standards:

- ^{252}Cf sf
- Etc...

TSL

- Reactor graphite discussion

FPY

Decay

Evaluations already submitted

Neutrons:

- ^{35}Cl (LANL/Terrapower/ORNL)
- ^{238}U (PFNS from Chi-Nu data)

TSL:

- Polye temp
- W, V, Pb, Ni, Mo, Cu (ORNL)

Initial tests* in Fast MSR ($^{\text{Nat}}\text{Cl}$, Pu, MgO reflected) indicate that new Cl file has impact of the order of **~1500pcm**; equivalent to “savings” of about **75kg of ^{239}Pu !**

Photonuclear:

- ^9Be (NNL)

Expected/planned submissions

Neutrons:

- ^{239}Pu (INDEN; updated inelastic, elastic, total)
- ^{95}Mo , Gd (ORNL)
- Zr (RPI/ORNL/BNL...)
- Gamma spectra fixes
- ...

Deuterons:

- D+T (LANL/LLNL)

Standards:

- ^{252}Cf sf
- Etc...

TSL

- Reactor graphite discussion

FPY

Decay

Neutron Data Standards

- Standards are cross sections for specific reactions, in specific energy ranges, that are so well-known that they are often used as reference in other measurements
- New experimental data has prompted the need of reevaluation of the Standards
- For details see A. Carlson's talks in 2025 CSEWG: <https://indico.bnl.gov/event/29405/>
- IAEA project: <https://nds.iaea.org/standards/>

TABLE XLV. Neutron Data Standards.

Neutron cross section standards	
Reaction	Standards incident neutron energy range
H(n,n)	1 keV to 20 MeV
³ He(n,p)	0.0253 eV to 50 keV
⁶ Li(n,t)	0.0253 eV to 1.0 MeV
¹⁰ B(n,α)	0.0253 eV to 1 MeV
¹⁰ B(n,α ₁ γ)	0.0253 eV to 1 MeV
C(n,n)	10 eV to 1.8 MeV ^a
Au(n,γ)	0.0253 eV, 0.2 to 2.5 MeV, 30 keV MACS
²³⁵ U(n,f)	8–11eV (integral) 0.15 to 200 MeV
²³⁸ U(n,f)	2 MeV to 200 MeV
High energy reference fission cross sections	
Reaction	Reference incident neutron energy range
^{Nat} Pb(n,f)	≈ 34 MeV up to 1 GeV
²⁰⁹ Bi(n,f)	≈ 34 MeV up to 1 GeV
²³⁵ U(n,f)	200 MeV to 1 GeV
²³⁸ U(n,f)	200 MeV to 1 GeV
²³⁹ Pu(n,f)	200 MeV to 1 GeV
Prompt γ-ray production reference cross sections	
Reaction	Reference incident neutron energy range
¹⁰ B(n,α ₁ γ)	0.0253 eV to 1 MeV
⁷ Li(n,n'γ)	0.9 MeV to 8 MeV
⁴⁸ Ti(n,n'γ)	2.8 MeV to 16 MeV
Thermal neutron constants at E=0.0253 eV (2200 m/s)	
Prompt fission neutron spectra (PFNS)	
Reaction	Reference outgoing neutron energy range
²³⁵ U(n _{th} ,f)	0.00001 eV to 30 MeV
²⁵² Cf(sf)	0.00001 eV to 30 MeV

^a The angular distributions at these incident energies are declared standard

Neutron Data Standards

- Standards are cross sections for specific reactions, in specific energy ranges, that are so well-known that they are often used as reference in other measurements
- New experimental data has prompted the need of reevaluation of the Standards
- For details see A. Carlson's talks in 2025 CSEWG: <https://indico.bnl.gov/event/29405/>
- IAEA project: <https://nds.iaea.org/standards/>

There will be updates to standards, so...

ENDF/B-VIII.2 ENDF/B-IX.0

TABLE XLV. Neutron Data Standards.

Neutron cross section standards	
Reaction	Standards incident neutron energy range
H(n,n)	1 keV to 20 MeV
³ He(n,p)	0.0253 eV to 50 keV
⁶ Li(n,t)	0.0253 eV to 1.0 MeV
¹⁰ B(n,α)	0.0253 eV to 1 MeV
¹⁰ B(n,α ₁ γ)	0.0253 eV to 1 MeV
C(n,n)	10 eV to 1.8 MeV ^a
Au(n,γ)	0.0253 eV, 0.2 to 2.5 MeV, 30 keV MACS
²³⁵ U(n,f)	8–11eV (integral) 0.15 to 200 MeV
²³⁸ U(n,f)	2 MeV to 200 MeV
High energy reference fission cross sections	
Reaction	Reference incident neutron energy range
^{Nat} Pb(n,f)	≈ 34 MeV up to 1 GeV
²⁰⁹ Bi(n,f)	≈ 34 MeV up to 1 GeV
²³⁵ U(n,f)	200 MeV to 1 GeV
²³⁸ U(n,f)	200 MeV to 1 GeV
²³⁹ Pu(n,f)	200 MeV to 1 GeV
Prompt γ-ray production reference cross sections	
Reaction	Reference incident neutron energy range
¹⁰ B(n,α ₁ γ)	0.0253 eV to 1 MeV
⁷ Li(n,n'γ)	0.9 MeV to 8 MeV
⁴⁸ Ti(n,n'γ)	2.8 MeV to 16 MeV
Thermal neutron constants at E=0.0253 eV (2200 m/s)	
Prompt fission neutron spectra (PFNS)	
Reaction	Reference outgoing neutron energy range
²³⁵ U(n _{th} ,f)	0.00001 eV to 30 MeV
²⁵² Cf(sf)	0.00001 eV to 30 MeV

^a The angular distributions at these incident energies are declared standard

Neutron Data Standards

- Standards are cross sections for specific reactions, in specific energy ranges, that are so well-known that they are often used as reference in other measurements
- New experimental data has prompted the need of reevaluation of the Standards
- For details see A. Carlson's talks in 2025 CSEWG: <https://indico.bnl.gov/event/29405/>
- IAEA project: <https://nds.iaea.org/standards/>

There will be updates to standards, so...

~~ENDF/B-VIII.2~~

ENDF/B-IX.0

TABLE XLV. Neutron Data Standards.

Neutron cross section standards	
Reaction	Standards incident neutron energy range
H(n,n)	1 keV to 20 MeV
³ He(n,p)	0.0253 eV to 50 keV
⁶ Li(n,t)	0.0253 eV to 1.0 MeV
¹⁰ B(n,α)	0.0253 eV to 1 MeV
¹⁰ B(n,α ₁ γ)	0.0253 eV to 1 MeV
C(n,n)	10 eV to 1.8 MeV ^a
Au(n,γ)	0.0253 eV, 0.2 to 2.5 MeV, 30 keV MACS
²³⁵ U(n,f)	8–11eV (integral) 0.15 to 200 MeV
²³⁸ U(n,f)	2 MeV to 200 MeV
High energy reference fission cross sections	
Reaction	Reference incident neutron energy range
^{Nat} Pb(n,f)	≈ 34 MeV up to 1 GeV
²⁰⁹ Bi(n,f)	≈ 34 MeV up to 1 GeV
²³⁵ U(n,f)	200 MeV to 1 GeV
²³⁸ U(n,f)	200 MeV to 1 GeV
²³⁹ Pu(n,f)	200 MeV to 1 GeV
Prompt γ-ray production reference cross sections	
Reaction	Reference incident neutron energy range
¹⁰ B(n,α ₁ γ)	0.0253 eV to 1 MeV
⁷ Li(n,n'γ)	0.9 MeV to 8 MeV
⁴⁸ Ti(n,n'γ)	2.8 MeV to 16 MeV
Thermal neutron constants at E=0.0253 eV (2200 m/s)	
Prompt fission neutron spectra (PFNS)	
Reaction	Reference outgoing neutron energy range
²³⁵ U(n _{th} ,f)	0.00001 eV to 30 MeV
²⁵² Cf(sf)	0.00001 eV to 30 MeV

^a The angular distributions at these incident energies are declared standard

There are many efforts in the community regarding measuring, modeling, evaluating unstable nuclei: **Activation library?**

There are many efforts in the community regarding measuring, modeling, evaluating unstable nuclei: **Activation library?**

Realistic Reaction Evaluations for Fission Products Off Stability

16TH NUCLEAR DATA FOR SCIENCE AND TECHNOLOGY CONFERENCE
JUNE 22ND – 27TH | MADRID (SPAIN) | 2025

Nuclear Reaction Data for Fission Products Off Stability

G.P.A. Nobre¹, K. Wendt¹, D.A. Brown¹, A.V. Voinov¹, E.V. Chimanski¹, S. Liu², A. Sharma²
¹Brookhaven National Laboratory, ²Lawrence Livermore National Laboratory, ³Ohio University

Nuclear applications such as nonproliferation, post-detonation forensics, spent-fuel assay, reactor burnup and design, as well as astrophysics, rely on the accurate description of the neutron interaction with unstable fission products. However, current cross-section descriptions of these nuclei are either non-existent or based on simplified assumptions, leading to unquantified impacts on predicted cross-sections. In this work we will discuss a newly funded project aiming to address these issues through predictive modeling, leveraging machine-learning methods, with an experimental component to help constrain model parameters. We will show details of the approach as well as preliminary results, focusing on the most produced nuclei off stability in the fission process of ²³⁵U. When completed, when the methods are well-established, the project should be able to provide realistic evaluated files for the whole isotopic chain of all off-stability fission products of ²³⁵U, ²³⁹Pu, and ²⁴¹Pu. The evaluated files will be submitted to ENDF/B for consideration in the future ENDF/B-X release.

Project Goals:

- To develop a robust, reproducible method to produce realistic neutron evaluations for fission-product nuclei off-stability
- To provide evaluated files for the main off-stability fission products of ²³⁵U and submit them to the ENDF/B nuclear data library
- Stretch goal: develop evaluated files for all off-stability fission products from ²³⁵U, ²³⁹Pu, ²⁴¹Pu
- NSA-NA-22 funded for FY25 - FY27

Anticipated Impact:

- Applications such as nonproliferation, post-detonation forensics, spent-fuel assay, reactor burnup and design, as well as astrophysics, rely on the accurate description of the neutron interaction with unstable fission products.
- Current cross-section descriptions of these nuclei are either non-existent or based on simplified assumptions, leading to unquantified impacts on predicted cross-sections.
- By project completion, more predictive/realistic new nuclear data will be produced, improving the reliability of applications involving fission products off stability!

Methods:

- Capture cross-section fluctuations:** There are too many resonances. It is not possible to predict their position or width. We focus on "strong" cross-section values and associated probability distributions that capture the size of fluctuations.
- Machine Learning:** Machine-learning approach can be trained with evaluated data of stable and (n,2n) cross sections to predict behavior of stability, serving as priors for model parameter tuning.
- Experimental level density constraints at Edwards lab, Ohio University:** Newly implemented campaign will improve estimates of the level density model parameters in the heavy region of fission products, providing a valuable experimental constraint for model validation.

Summary and Outlook: We will develop realistic neutron evaluations for fission products off stability through the combination of complementary approaches including experimental measurements of level densities, positive reaction modeling, and machine-learning methods. Currently, the first experiment has been successfully completed, and its data is being analyzed. Also, first preliminary iteration of fast-neutron files have been generated and should be combined with stochastically-generated resonances based on cross-section probability distributions.

References:
[1] G.P.A. Nobre, BNL-229070-2025-INRE
[2] K.Wendt et al., Phys. Rev. C, 101, 054601 (2020)

Acknowledgments: This work was supported by the Office of Defense Nuclear Nonproliferation Research and Development within the U.S. Department of Energy National Nuclear Security Administration. We are grateful to the following organizations for their support: Brookhaven National Laboratory, Lawrence Livermore National Laboratory, U.S. DEPARTMENT OF ENERGY, OHIO UNIVERSITY, and NNSA.

Brookhaven National Laboratory
Report # BNL-229070-2025-INRE

Summary of FY25 activities on the project Realistic Reaction Evaluations for Fission Products Off Stability (RREFPOS)

September 30, 2025

Managed by Brookhaven Science Associates on behalf of the U.S. Department of Energy

- Funded project to develop reaction evaluations for fission products off stability
- Leveraging **machine-learning** and **microscopic models**
- Expected to impact depletion, waste management, etc.
- Looking for ways to validate this effort

For details, see:

- ND2025 poster
- BNL-229070-2025-INRE report
- 2026 WANDA talk

Realistic Reaction Evaluations for Fission Products Off Stability

Gustavo Nobre¹, Aman Sharma², Emanuel Chimanski¹, Alexander Voinov³, Dave Brown¹, Kyle Wendt², Shusen Liu²

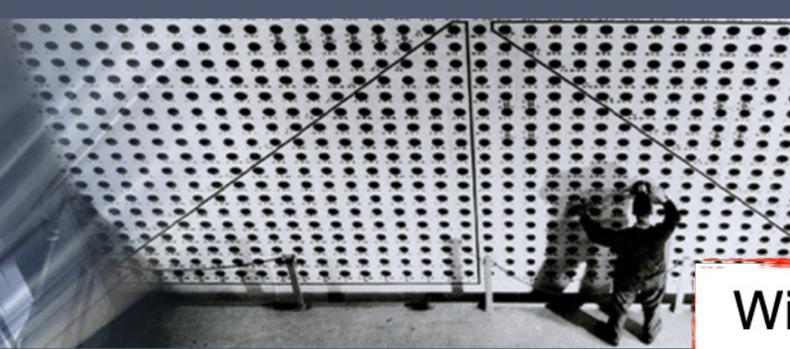
¹National Nuclear Data Center, Brookhaven National Laboratory
²Lawrence Livermore National Laboratory
³Ohio University

@BrookhavenLab
2026 Workshop for Applied Nuclear Data Activities (WANDA)
9-12 February 2026
BNL-7724184

1st Reactor Graphite (ReGra) Workshop

Bringing together experts in the nuclear data community

Hosted by Brookhaven National Laboratory
July 8–9, 2025



Within the community, there were **different perspectives** on what should the thermal-neutron scattering law libraries associated with reactor graphite.

Reactor Graphite Workshop

Jul 8–9, 2025
Berkner Hall (Bldg. 488)
US/Eastern timezone

- Homepage
- Overview
- Timetable
- Contribution List
- My Conference
- My Contributions
- Registration
- Contact
- gnobre@bnl.gov



- This motivated the organization of an **in-person, highly-focused workshop**.
- Participants from BNL, RPI, ORNL, NCSU, TAMU, Kairos Power, BWXT Advanced Technologies, Foster & Associates, JAEA, INL, LLNL, U. Michigan, LANL, NNL, Studsvik Scandpower

Meeting minutes published

- Published meeting minutes as a BNL lab report:
 - <https://doi.org/10.2172/2998877>
 - Report is **NOT** a scientific paper
 - Report is a description of **what happened** at the meeting:
 - What was presented
 - What was discussed: Comments, objections, replies, agreements and disagreements; past, present, future on the topic
 - Key takeaways: discussed, edited in real time, and agreed upon by ALL participants in the last session, before meeting ended
- Feedback was **positive**:
 - There will likely be a follow-up edition (2027?)

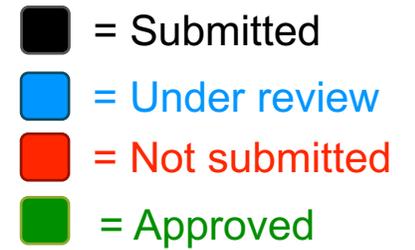
Summary of the 1st Reactor Graphite Workshop, 8-9 July, 2025

Gustavo P.A. Nobre¹, David A. Brown¹, Benjamin Wang², Iyad Al-Qasir³, John Bess⁴, Chris Chapman³, Arantxa Cuadra¹, Yaron Danon², Simerjeet Gill¹, Travis Greene³, Ayman Hawari^{5,6}, Richard Hernandez⁷, Chase Lawing⁸, Gabriel Lentchner³, Cihang Lu¹, Shinsuke Nakayama⁹, Matthew Nash⁸, Javier Ortensi¹⁰, Catherine Percher¹¹, Dominic Piedmont⁴, Kemal Ramić³, Volkan Seker¹², Gregory Siemers^{2,13}, Jason Thompson¹⁴, Nicholas Thompson¹³, Charles Wemple¹⁵, Michael Zerkle¹⁴

¹Brookhaven National Laboratory, ²Rensselaer Polytechnic Institute, ³Oak Ridge National Laboratory, ⁴Foster & Associates, LLC, ⁵North Carolina State University, ⁶Texas A&M University, ⁷Kairos Power, ⁸BWXT Advanced Technologies, LLC, ⁹Japan Atomic Energy Agency, ¹⁰Idaho National Laboratory, ¹¹Lawrence Livermore National Laboratory, ¹²University of Michigan, ¹³Los Alamos National Laboratory, ¹⁴Naval Nuclear Laboratory, ¹⁵Studs vik Scandpower, Inc.

Current status of the library

Neutrons sublibrary



n-004_Be_009.endf: GRIN capture gammas update
n-006_C_012.endf: GRIN updates to inelastic and capture gammas
n-007_N_014.endf: GRIN inelastic gamma updates
n-007_N_015.endf: GRIN inelastic gamma updates
n-008_O_016.endf: Fixes to elastic covariance issues introduced in Dec. 2022
n-008_O_017.endf: GRIN inelastic gamma updates
n-011_Na_022.endf: GRIN inelastic gamma updates
n-011_Na_023.endf: GRIN inelastic gamma updates
n-012_Mg_024.endf: GRIN updates to inelastic and capture gammas
n-012_Mg_025.endf: GRIN updates to inelastic and capture gammas
n-013_Al_027.endf: GRIN inclusion of branching ratios (needs to address a double-counting issue)
n-014_Si_028.endf: GRIN inclusion of branching ratios
n-014_Si_029.endf: GRIN inclusion of branching ratios (needs to fix an unintended change)
n-014_Si_030.endf: GRIN inclusion of branching ratios (needs to fix an unintended change)

n-014_Si_031.endf: GRIN inclusion of branching ratios
n-014_Si_032.endf: GRIN inclusion of branching ratios (There's a small change in MF/MT=6/800, was that intentional?)
n-016_S_032.endf: GRIN capture gammas update and interpolation flag fix in MT102 – Additional flag fix needs to be reviewed
n-017_Ci_035.endf:

- LANL/Terrapower
- ORNL

n-017_Ci_037.endf:

- LANL/Terrapower
- ORNL

n-025_Mn_055.endf: GRIN inclusion of branching ratios
n-026_Fe_054.endf: Patch to fix negative elastic cross sections
n-057_La_139.endf: ORNL/LANL evaluation
n-073-Ta_181.endf: Fix of URR covariances
n-092_U_234.endf: ORNL update to the two resonances & parameter transformation from MLBW to Reich-Moore
n-092_U_238.endf: LANL new PFNS eval. including Chi-Nu data

TSL sublibrary

[tsl-Cu.endf](#) - NJOY+NCrystal

[tsl-HinCH2.endf](#) - NCSU extension of VIII.0 evaluation (updated temperature grid and masses/free atom cross sections)

[tsl-Mo.endf](#) - NJOY+NCrystal

[tsl-Ni.endf](#) - NJOY+NCrystal

[tsl-Pb.endf](#) - NJOY+NCrystal

[tsl-V-metal.endf](#) - NJOY+NCrystal

[tsl-W-metal.endf](#) - NJOY+NCrystal

Photonuclear sublibrary

[g-004_Be_009.endf](#): Updated NNL evaluation

Additionally...



- There are many fixes from the 2025 Hackathon (ORNL) sitting on separate branches.
 - I'm slowly going through them, and they should be gradually incorporated into **phase1/phase2** branches.
- In process of identifying **reviewers** to speed up the acceptance of the already-submitted files
- Planning Beta1 release for the Spring, hopefully in sync with the Standards

ENDF/B
IX.0-β1

vs.

ENDF/B
VIII.2-β1

will depend whether standards will be updated in time

Automation of ENDF data retrieval

- ENDF data is now retrievable through a REST API
 - Allows automation through **scripts** using **unique URLs**
 - Usage examples provided using **Jupyter Notebook**
 - Integrated with **plotting** capability
 - So far implemented for **ENDF/B-VIII.1, VIII.0, VII.1** – whole files or individual cross sections
- Website is live; “README” report: **BNL-229520-2026-INRE**

<https://www.nndc.bnl.gov/endl-api>



Welcome

This is the ENDF REST API entry point. Use the links below to explore the API documentation or run interactive tutorials.

Interactive Docs (Swagger UI)

Browse endpoints, inspect schemas, and try out API calls directly from your browser.

[Open Swagger UI](#)

Reference Docs (ReDoc)

Read-only documentation view generated from the OpenAPI specification.

[Open ReDoc](#)

Tutorial Notebooks

Jupyter notebooks demonstrating how to use this API, runnable locally or in Google Colab.

[View Tutorials](#)

Root path: /endl-api

A REST API for Nuclear Reaction Data Libraries

March 6, 2026



Automation of ENDF data retrieval

- ENDF data is now retrievable through a REST API
 - Allows automation through **scripts** using **unique URLs**
 - Usage examples provided using **Jupyter Notebook**
 - Integrated with **plotting** capability
 - So far implemented for **ENDF/B-VIII.1, VIII.0, VII.1** – whole files or individual cross sections
- Website is live; “README” report: **BNL-229520-2026-INRE**

<https://www.nndc.bnl.gov/endl-api>

A REST API for Nuclear Reaction Data Libraries

March 6, 2026



In the future, we plan to extend to other libraries and other observables (ang. dist., spectra, uncertainties/covariances, etc.), provided there is **additional support**



ENDF API

Welcome

This is the ENDF REST API entry point. Use the links below to explore the API documentation or run

Interactive Docs (Swagger UI)

Browse endpoints, inspect schemas, and try out API calls directly from your browser.

[Open Swagger UI](#)

Reference Docs (ReDoc)

Read-only documentation view generated from the OpenAPI specification.

[Open ReDoc](#)

Tutorial

Jupyter notebook to use this API with Google Colab.

[View Tutorial](#)

Conclusion

ENDF/B-VIII.1 released on *August 30, 2024* :

- Many, many important updates
- Substantial improvement in performance
 - Reactor depletion
 - Criticality systems
 - Leakage/shielding
- Accompanying “Big Paper”
 - Revised version submitted in October, 2025, should be published this year
 - Preprint available: <https://doi.org/10.48550/arXiv.2511.03564>
- DOIs and landing page for data are available now

Beginning of next ENDF cycle, ENDF/B-IX.0:

- Bug fixes: Hackathon in early August at ORNL
- We expect: Standards, ^{239}Pu , $^{233,234,238}\text{U}$, chlorine, TSL graphite (1st ReGra workshop), etc.
- Improving infrastructure and evaluation & UQ methods
- Working on next Beta release: aiming for late Spring, hopefully in-sync with Standards

Acknowledgements

Work at Brookhaven National Laboratory was sponsored by the Office of Nuclear Physics, Office of Science of the U.S. Department of Energy under Contract No. DE-AC02-98CH10886 with Brookhaven Science Associates, LLC. Work at Lawrence Livermore National Laboratory was performed under Contract DE-AC52-07NA27344. Work at Los Alamos National Laboratory, operated by Triad National Security, LLC, was carried out under the auspices of the National Nuclear Security Administration of the US Department of Energy under Contract No. 89233218CNA000001. Work at Oak Ridge National Laboratory was authored by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725 with the U.S. Department of Energy. Work at Naval Nuclear Laboratory, operated by Fluor Marine Propulsion, LLC, was performed under contract No. 89233018CNR000004 with the U.S. Department of Energy. This work was supported by the Naval Nuclear Propulsion Program and Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the U.S. Department of Energy. This work received funding support from the NNSA Office of Defense Nuclear Nonproliferation R&D.



U.S. DEPARTMENT
of **ENERGY** | Office of
Science

