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U.S. DEPARTMENT of ENERGY

# ENDF developments beyond ENDF/B-VIII.1

**G.P.A. Nobre[1], D. A. Brown, E.V. Chimanski, D. Mason, B. Shu, R. Coles and R. Arcilla**

*National Nuclear Data Center, Brookhaven National Laboratory*

7th International Workshop on Nuclear Data Evaluation for Reactor Applications (WONDER-2026), Aix-en-Provence, France
June 29 to July 3, 2026

BNL-8270931

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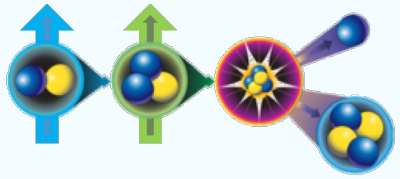
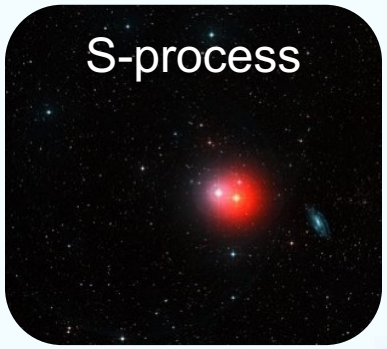
National Nuclear Data Center

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

Thermonuclear Fusion

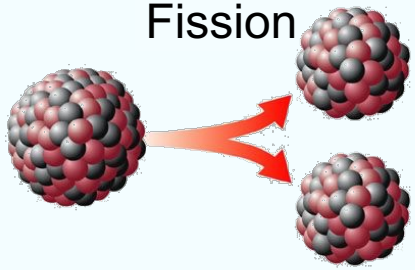


S-process






Fission







r-process



# Main news: The ENDF/B-VIII.1 “Big Paper” has been published!

## “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
- **April 7, 2026:** Accepted for publication
- **May 6, 2026:** Published online
- **May 18, 2026:** Printed journal shipped

Nuclear Data Sheets, 210 (2026) 1-224
https://doi.org/10.1016/j.nds.2026.04.001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OPEN ACCESS

# DOIs for ENDF/B-VIII.1 data


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


PuRe Data Resources

National Nuclear Data Center
A DOE PuRe Data Resource Facility

In addition to citing the library through the main publication, one can also cite and make reference to the actual data: individual sublibrary or whole release

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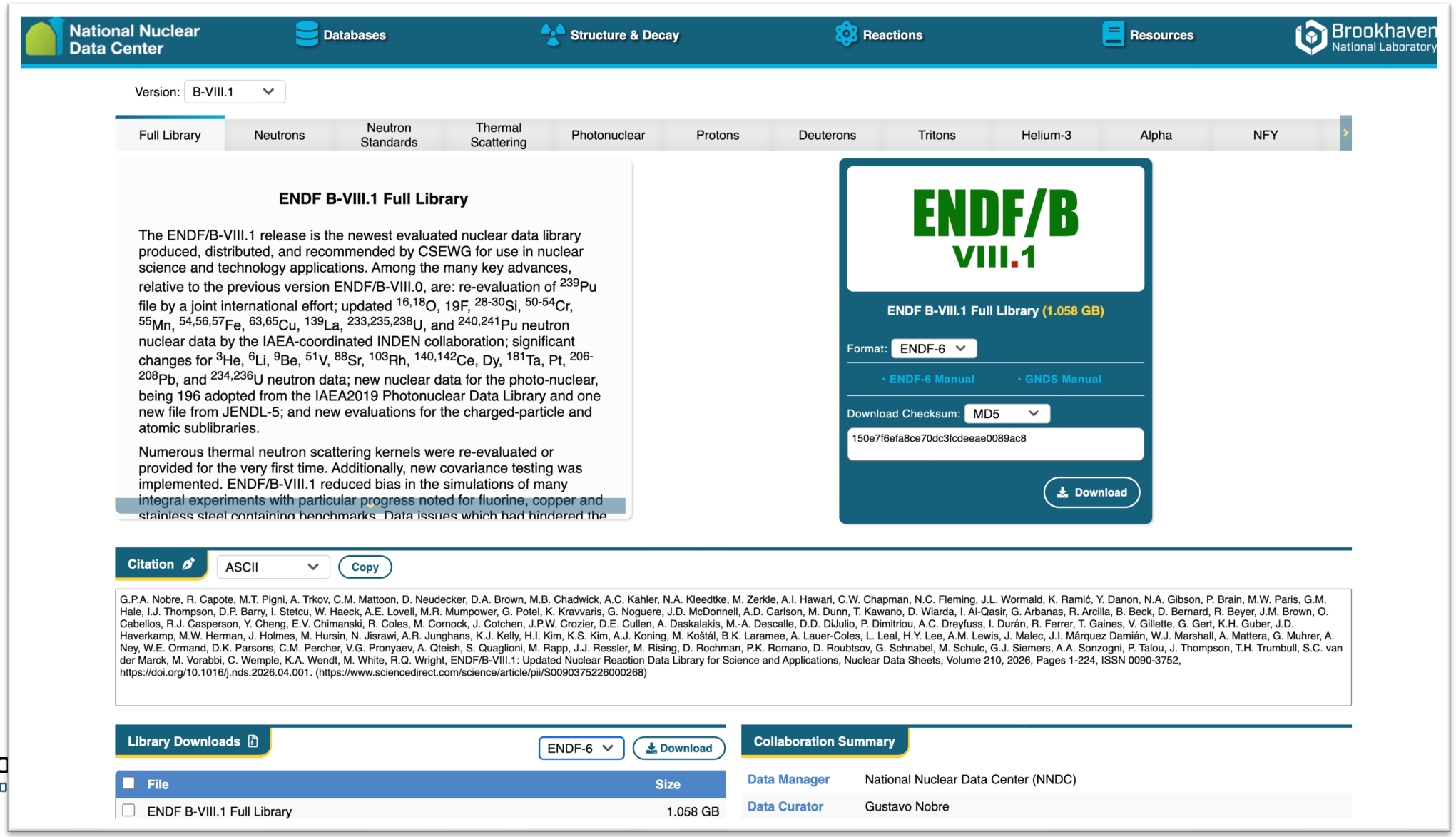
# New ENDF release webpage



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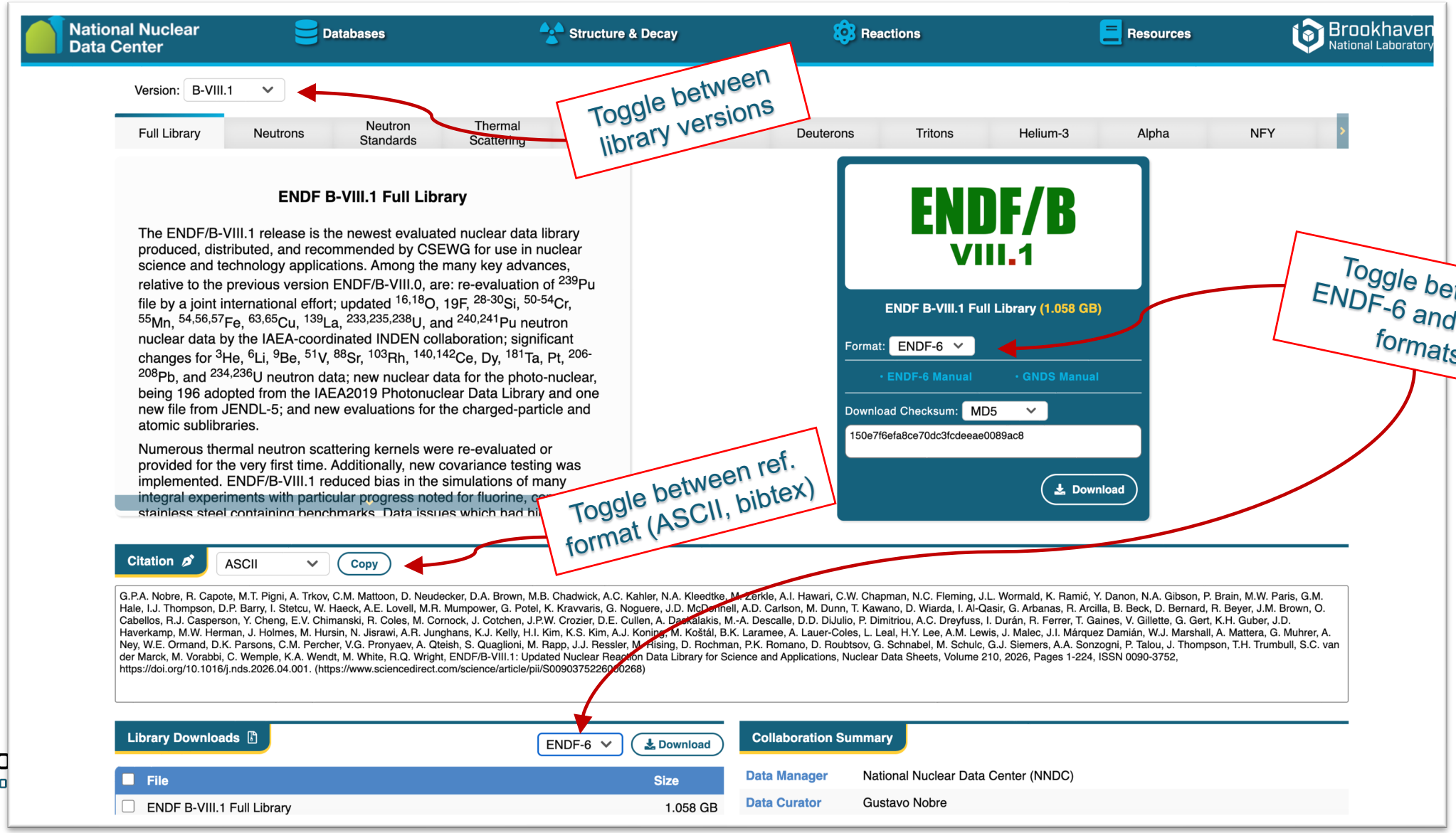

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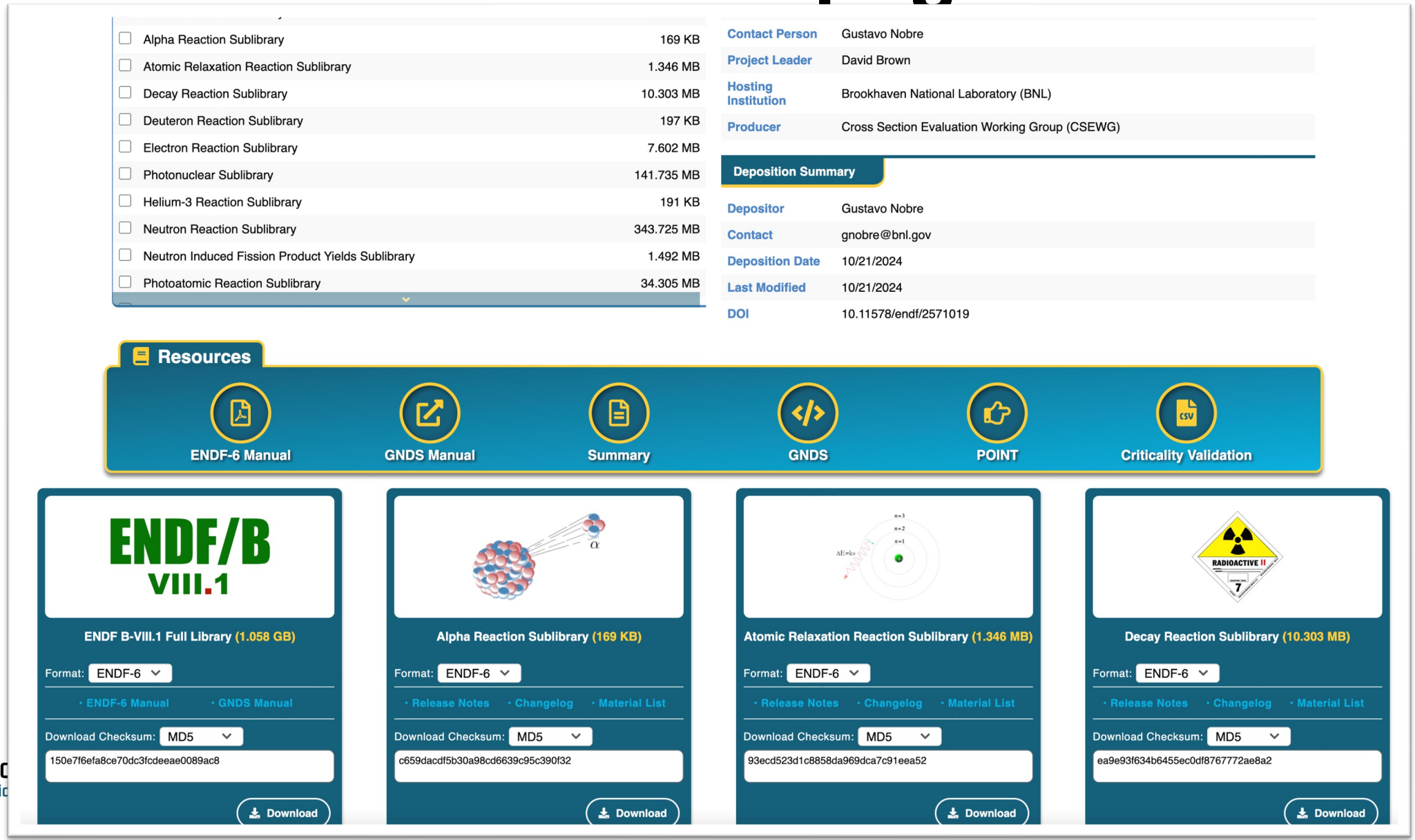
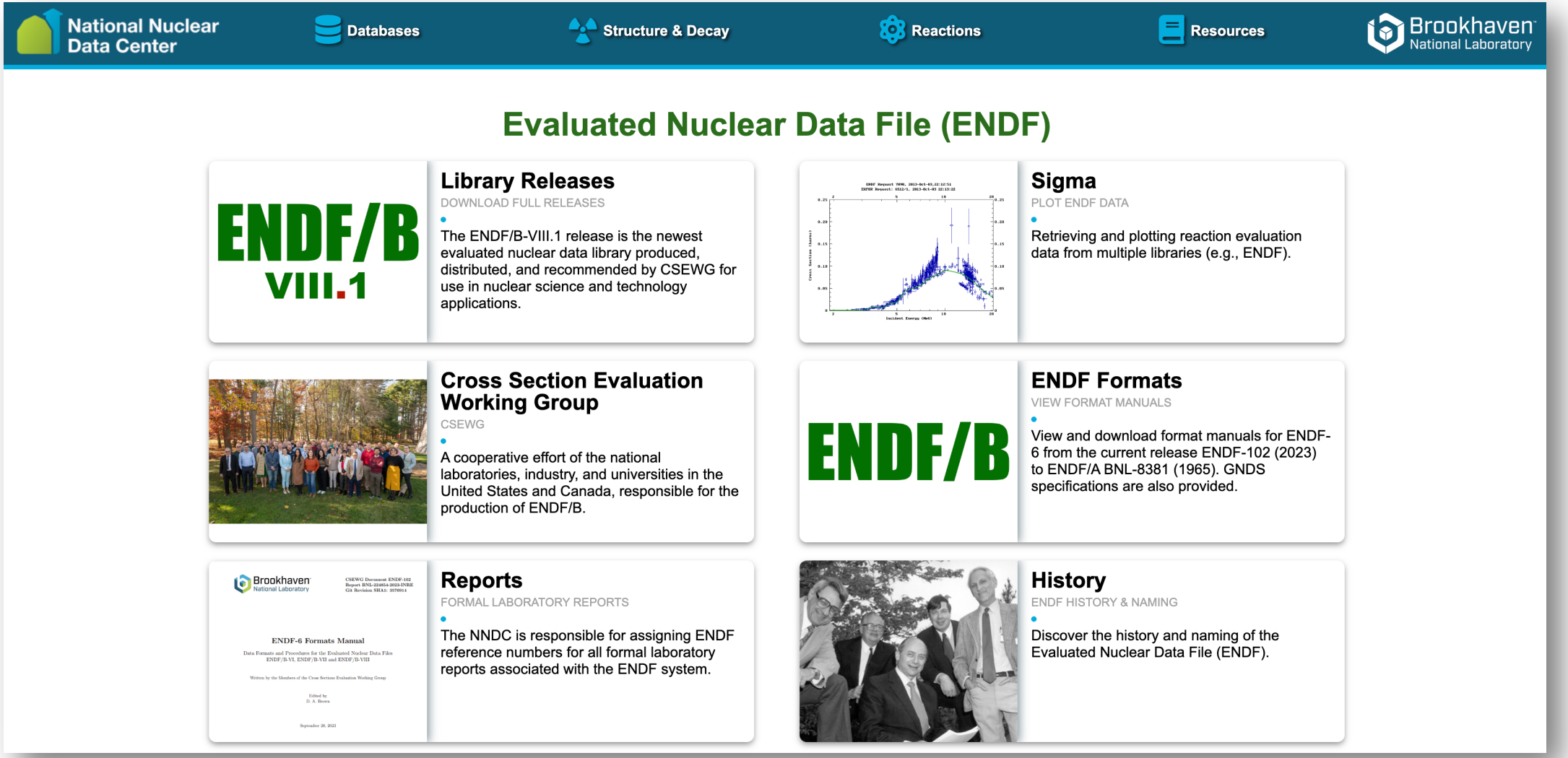
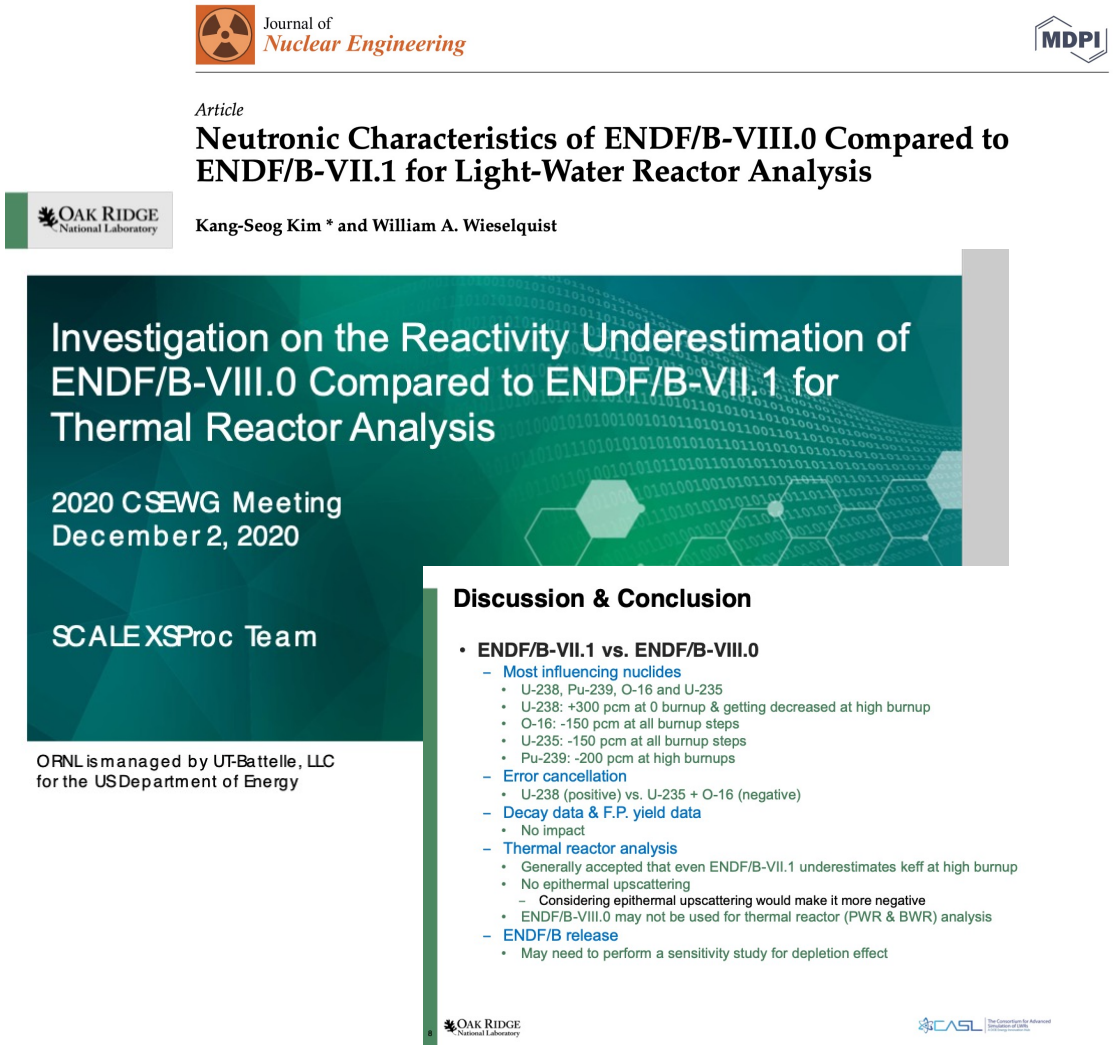


# Redesigning the ENDF section of the NNDC website



# 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



Journal of Nuclear Engineering

MDPI

*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

OAK RIDGE National Laboratory

CASL

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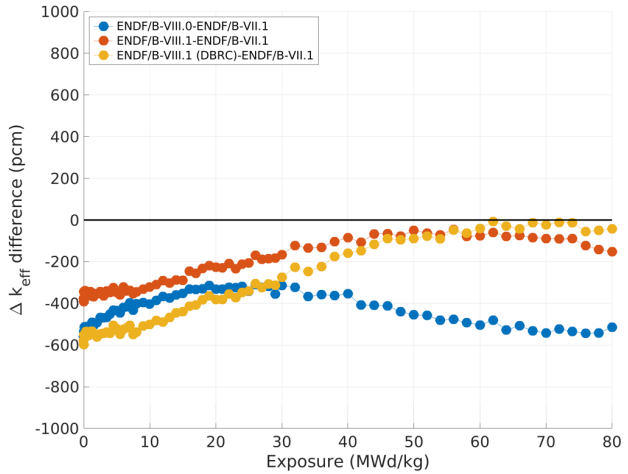
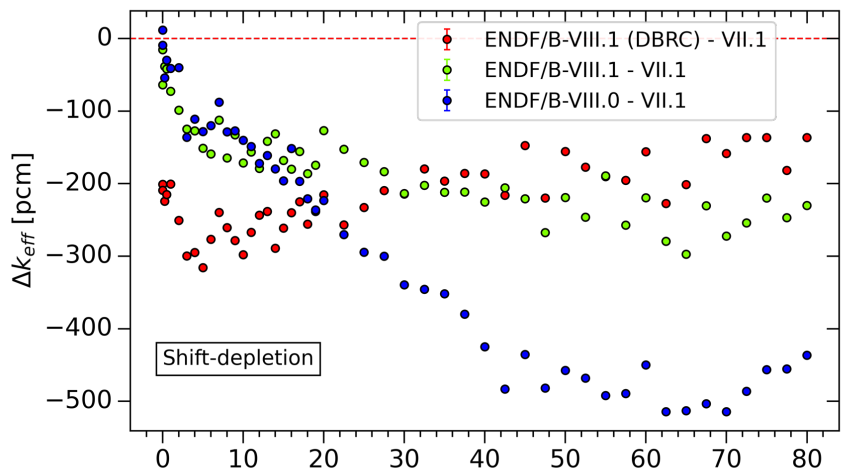
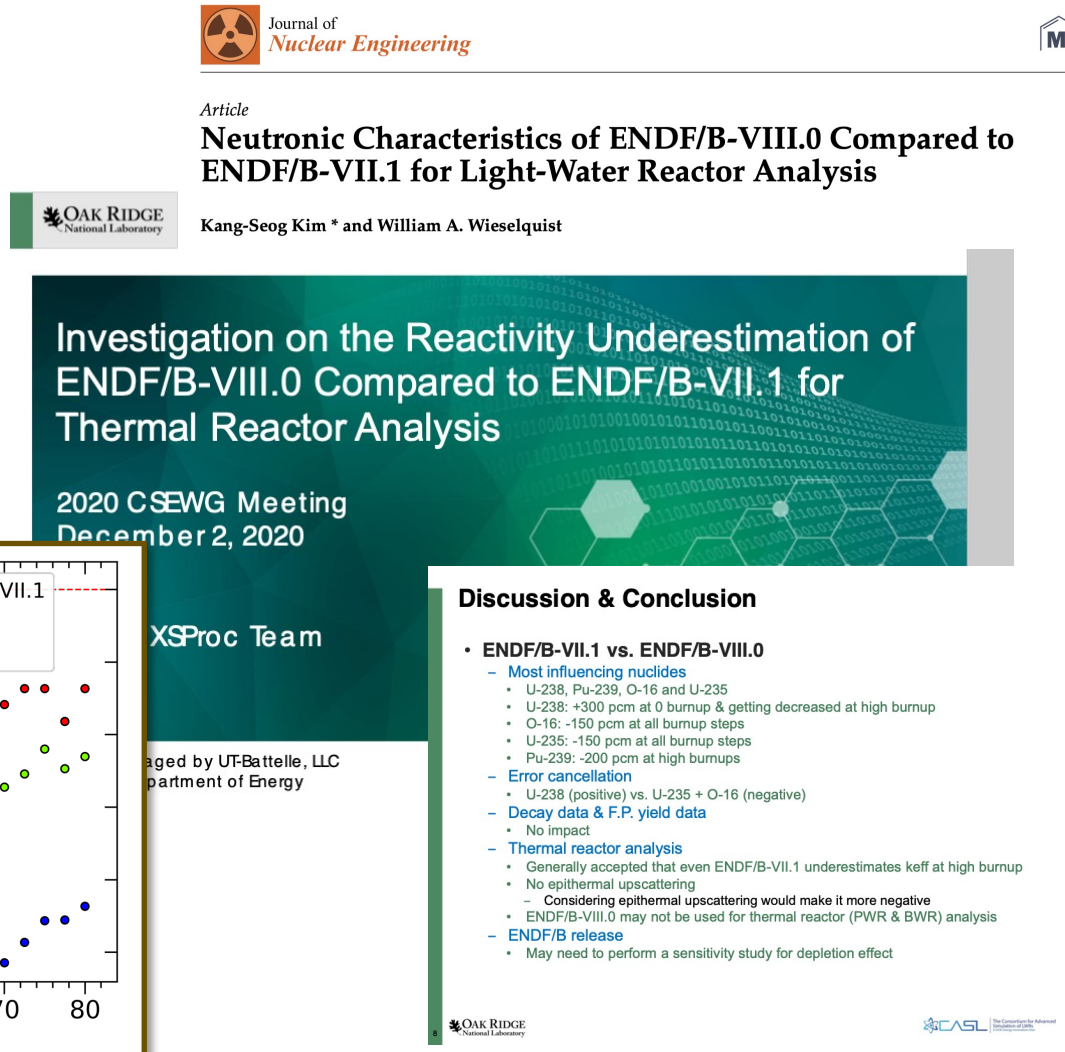
# Strong connection with user needs!

- 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



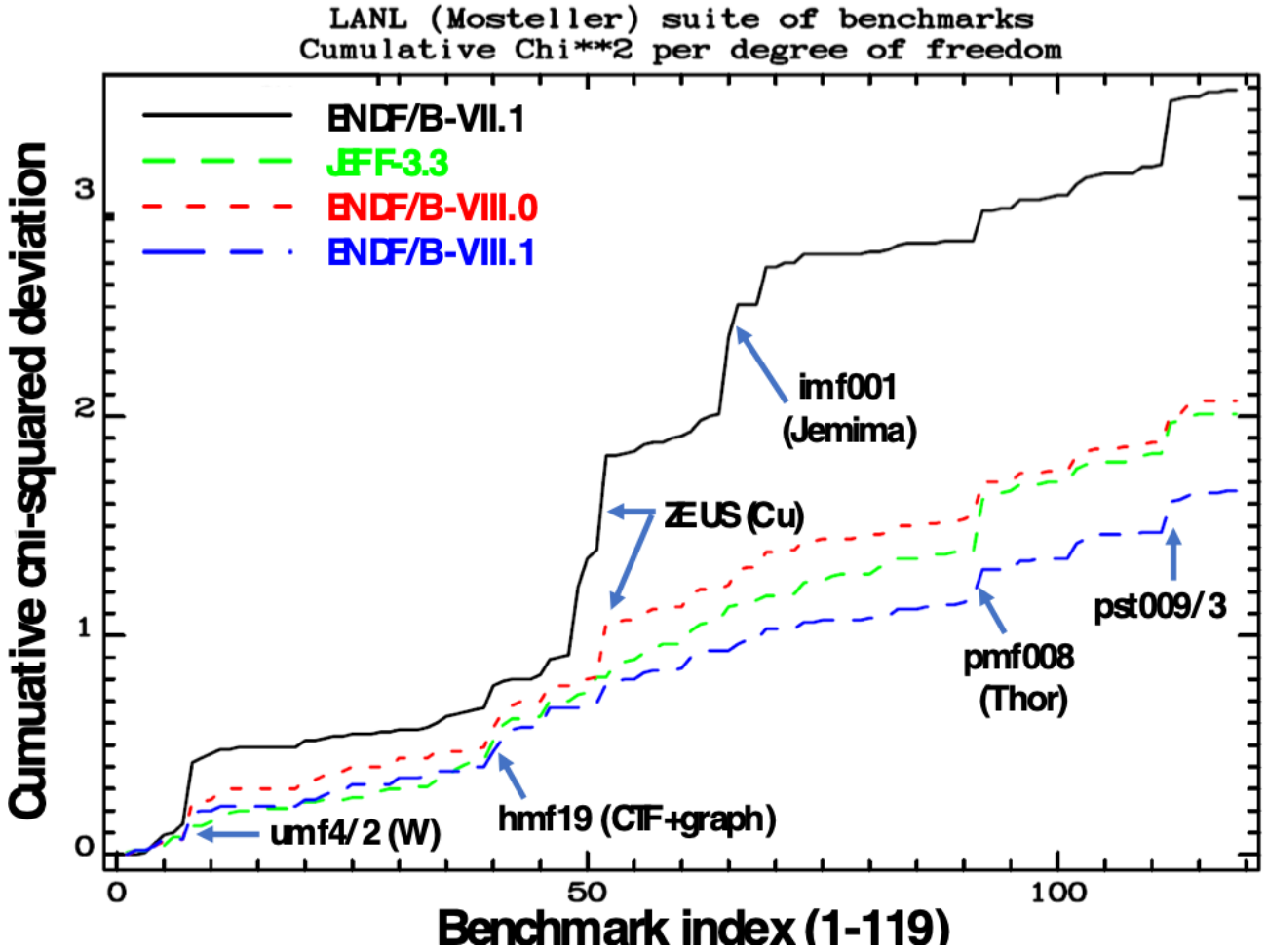




G. P. A. NOBRE et al., "ENDF/B-VIII.1: Updated Nuclear Reaction Data Library for Science and Applications," Nucl. Data Sheets (2024) (submitted for publication).



# 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

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

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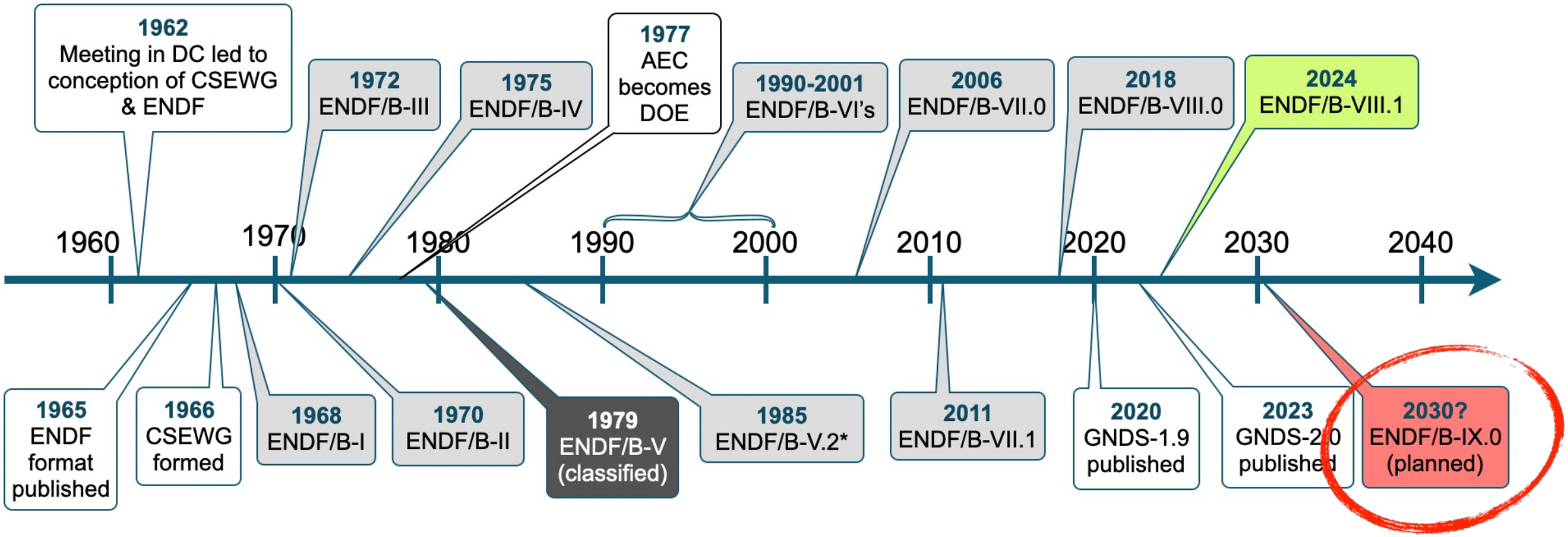
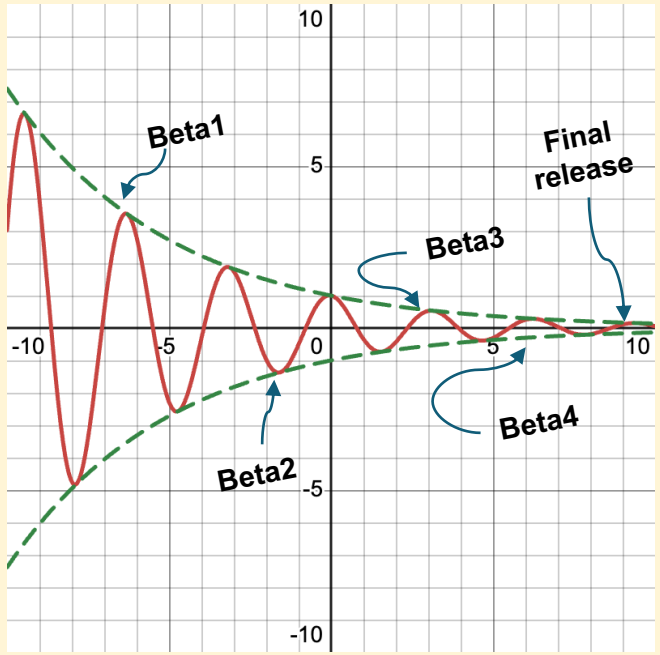
# ENDF Timeline




Timeline courtesy of Dave Brown

# Importance of review process

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



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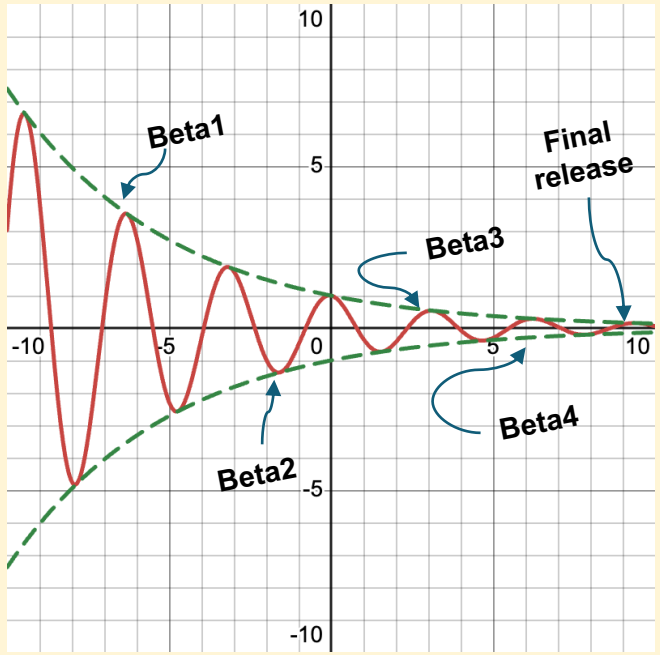


- We learned many lessons from the VIII.1 review process:
  - Identified several issues:
    - Current **review form** is not very useful
    - Wiki page and **report tarballs** are not very helpful either
    - Issues with integration with **processing codes**
  - On the positive side:
    - GitLab's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

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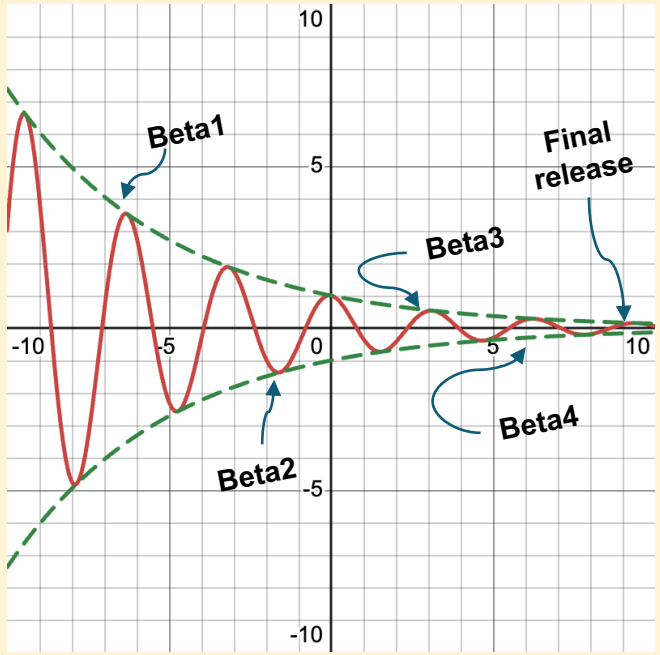


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For the ENDF/B-IX.0 cycle, we are planning a **complete re-work** of the review process through a working group, aiming to make it more user-friendly

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

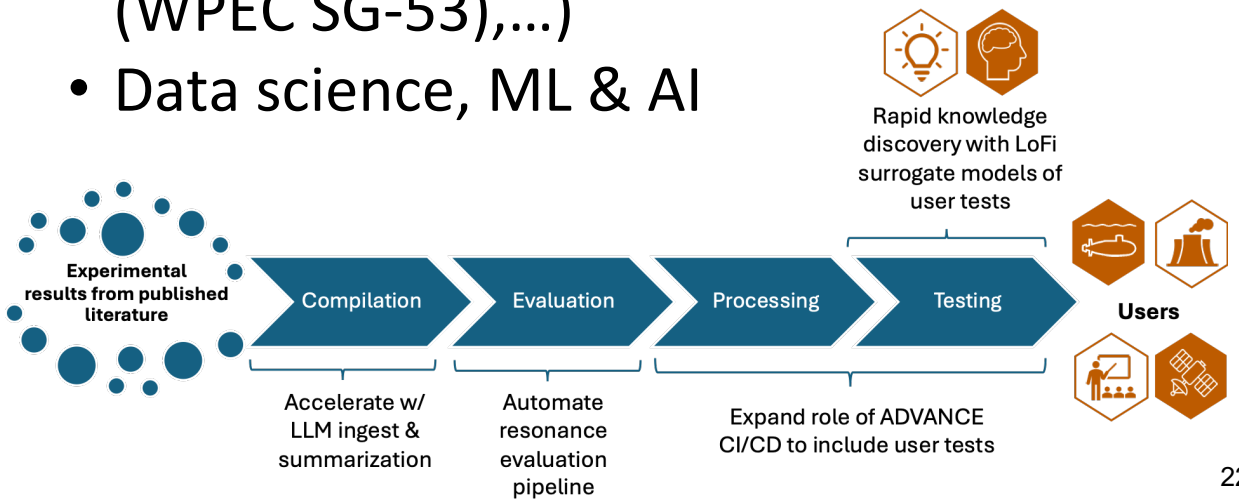
# It’s hard to know what exactly will be in the release, but we can guess…

## Known programmatic drivers

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

## Anticipated foci

- **Standards**
- **Actinides:** $^{239}$Pu, $^{233,235,238}$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)
- Nubar: $^{238,241,242}$Pu

**TSL:**

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

**Photonuclear:**

- $^{9}$Be (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-know 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,$\alpha$) | 0.0253 eV to 1 MeV |
| $^{10}$B(n,$\alpha_1\gamma$) | 0.0253 eV to 1 MeV |
| C(n,n) | 10 eV to 1.8 MeV[a] |
| Au(n,$\gamma$) | 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) | $\approx$ 34 MeV up to 1 GeV |
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| **Prompt $\gamma$-ray production reference cross sections** | |
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| $^{10}$B(n,$\alpha_1\gamma$) | 0.0253 eV to 1 MeV |
| $^{7}$Li(n,n'$\gamma$) | 0.9 MeV to 8 MeV |
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| **Thermal neutron constants at E=0.0253 eV (2200 m/s)** | |
| **Prompt fission neutron spectra (PFNS)** | |
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| $^{235}$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

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

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There will be updates to standards, so…

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

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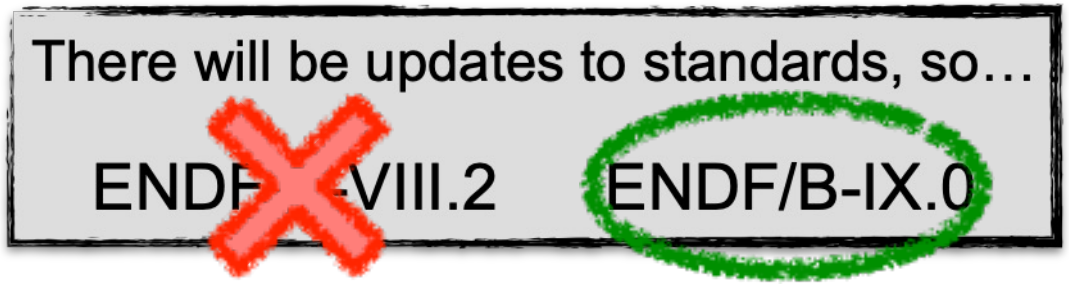


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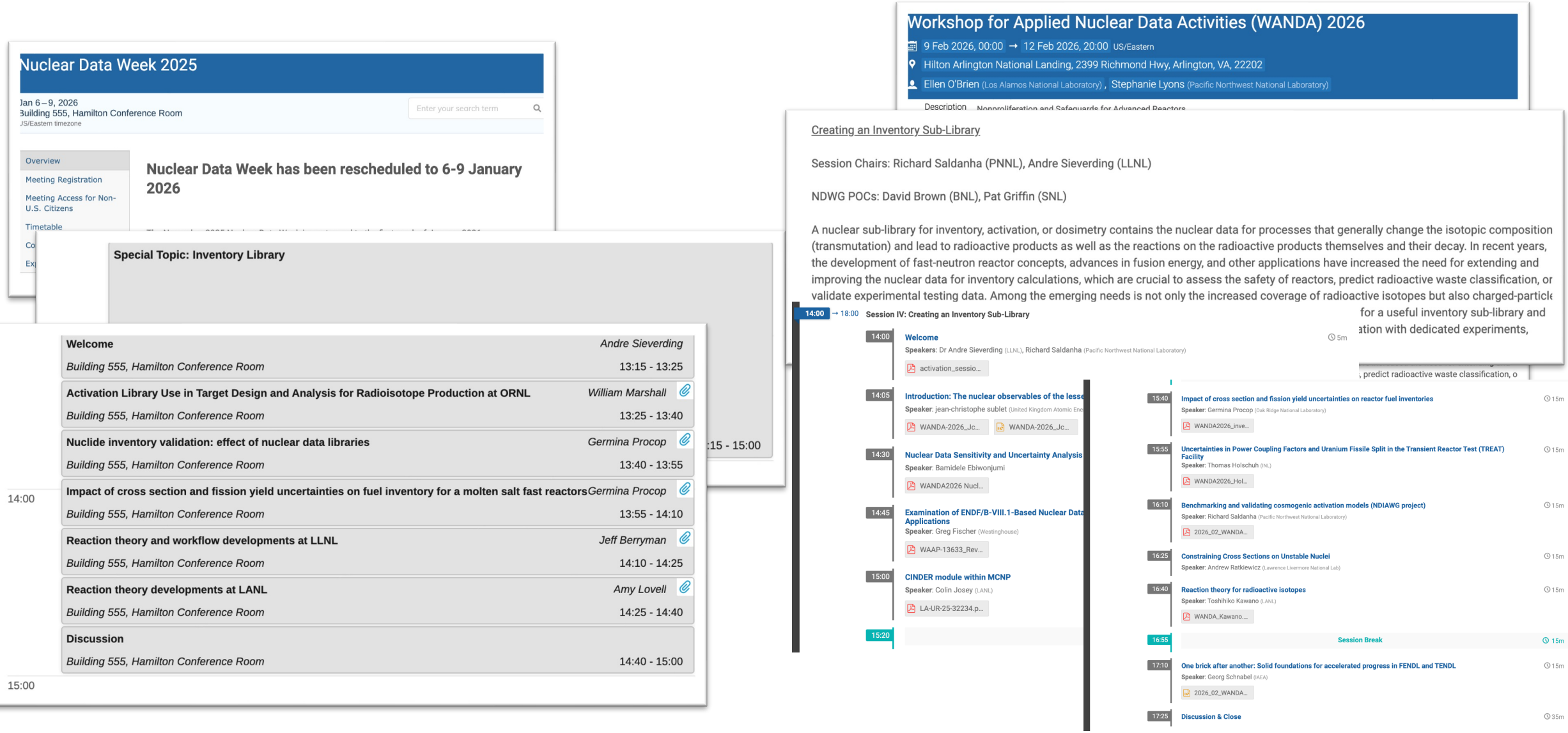

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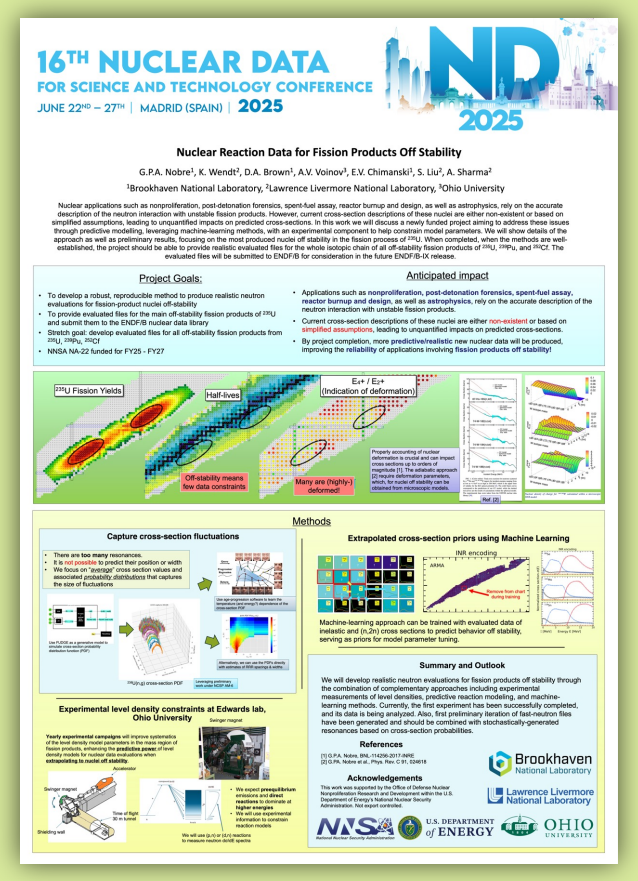
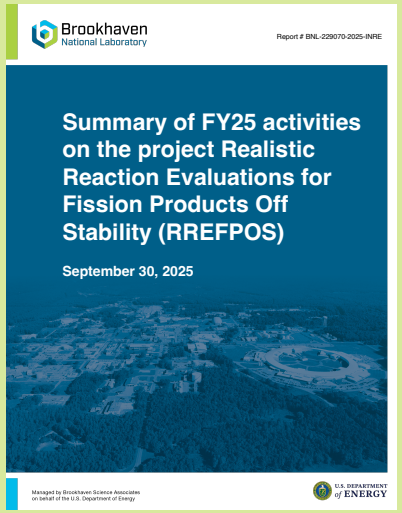
## Realistic Reaction Evaluations for Fission Products Off Stability




- 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


Reactor Graphite Workshop

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

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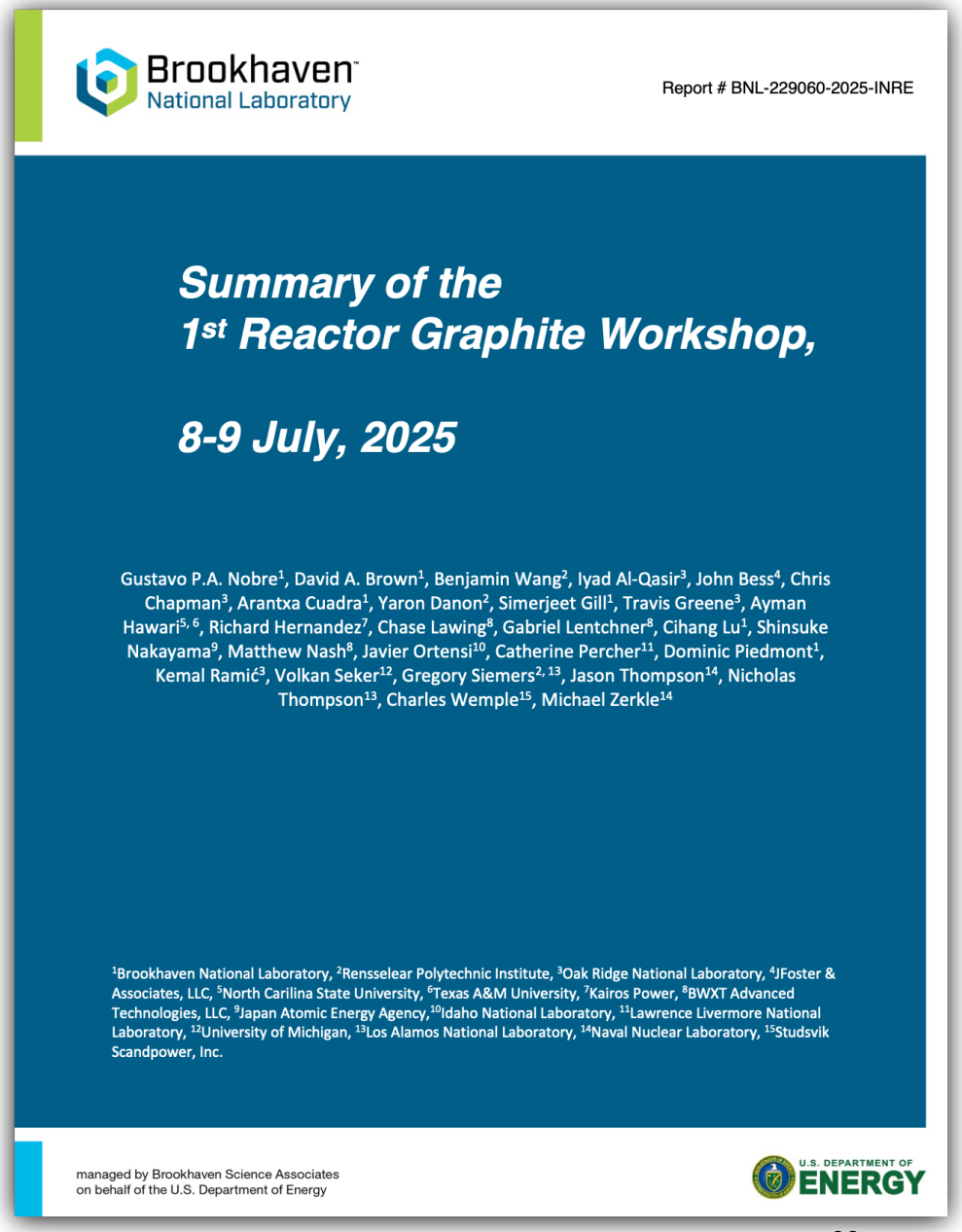
gnobre@bnl.gov

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

- 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?)


Brookhaven National Laboratory

Report # BNL-229060-2025-INRE

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

Gustavo P.A. Nobre[1], David A. Brown[1], Benjamin Wang[2], Iyad Al-Qasir[3], John Bess[4], Chris Chapman[3], Arantxa Cuadra[1], Yaron Danon[2], Simerjeet Gill[1], Travis Greene[3], Ayman Hawari[5, 6], Richard Hernandez[7], Chase Lawing[8], Gabriel Lentchner[8], Cihang Lu[1], Shinsuke Nakayama[9], Matthew Nash[8], Javier Ortensi[10], Catherine Percher[11], Dominic Piedmont[1], Kemal Ramić[3], Volkan Seker[12], Gregory Siemers[2, 13], Jason Thompson[14], Nicholas Thompson[13], Charles Wemple[15], Michael Zerkle[14]

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

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U.S. DEPARTMENT OF ENERGY

# Additionally…

- There are many fixes from the 2025 Hackathon (ORNL)
  - They are gradually being incorporated with other updates
- In process of identifying reviewers to speed up the acceptance of the already-submitted files
- Planning Beta1 release for the Summer, hopefully in sync with the Standards

**ENDF/B IX.0-β1**

vs.

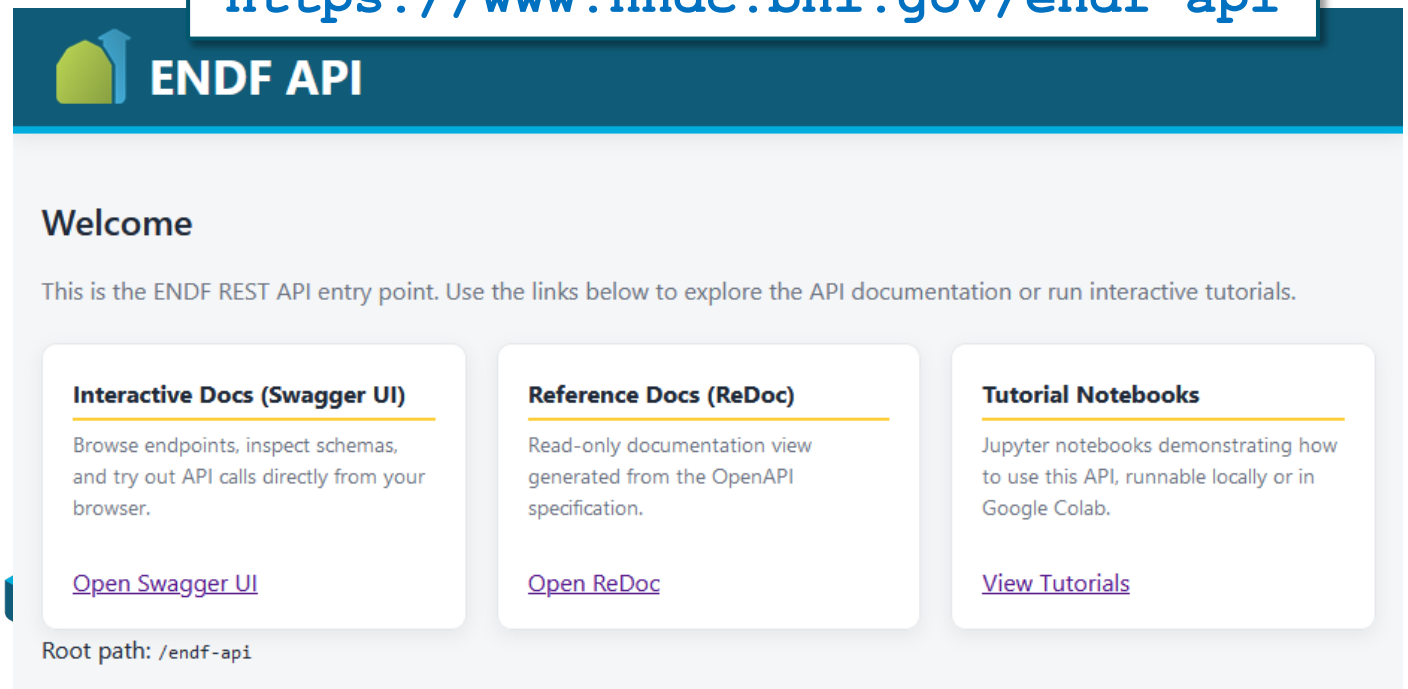
**ENDF/B VIII.2-β1**

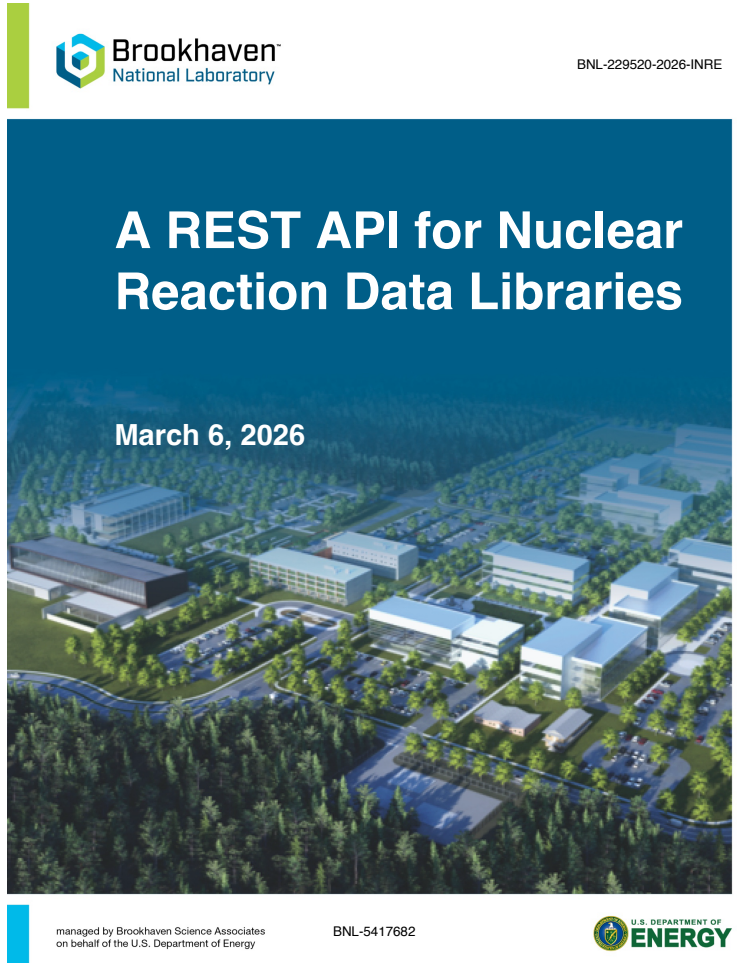
will depend whether standards will be updated in time

# 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/endf-api`



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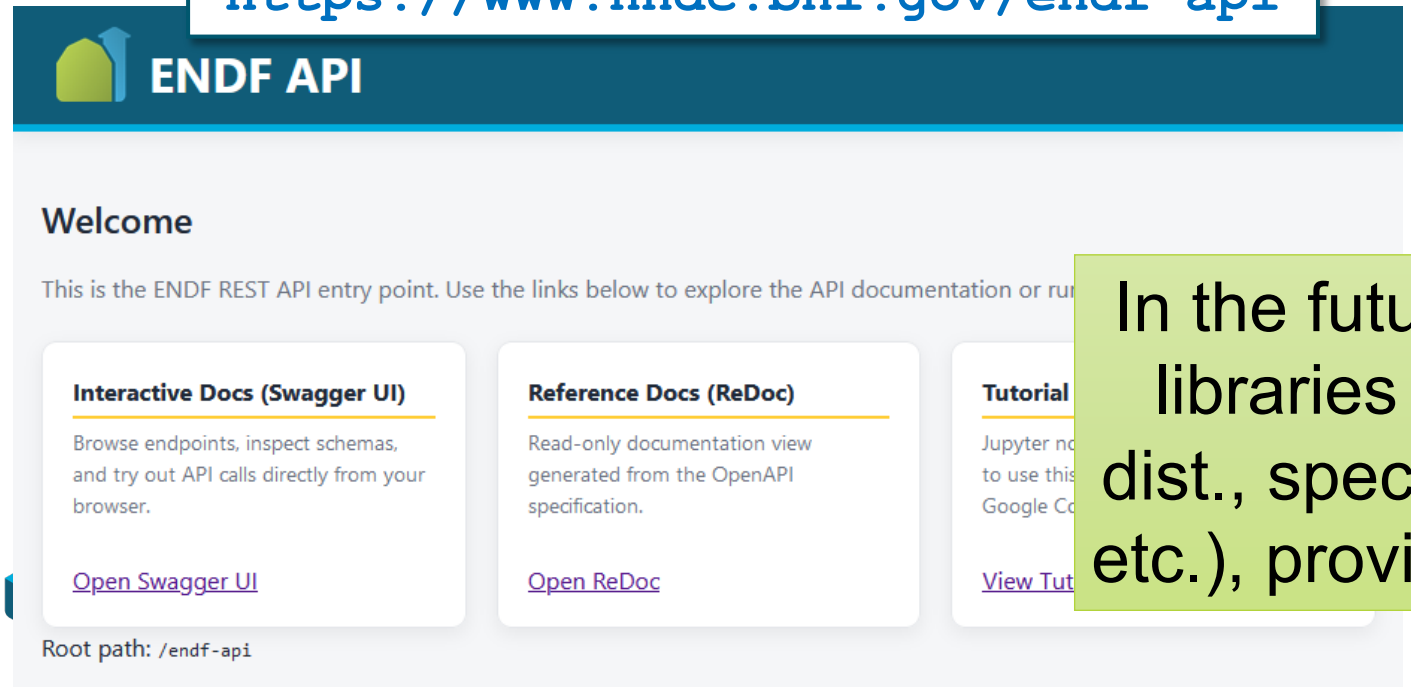
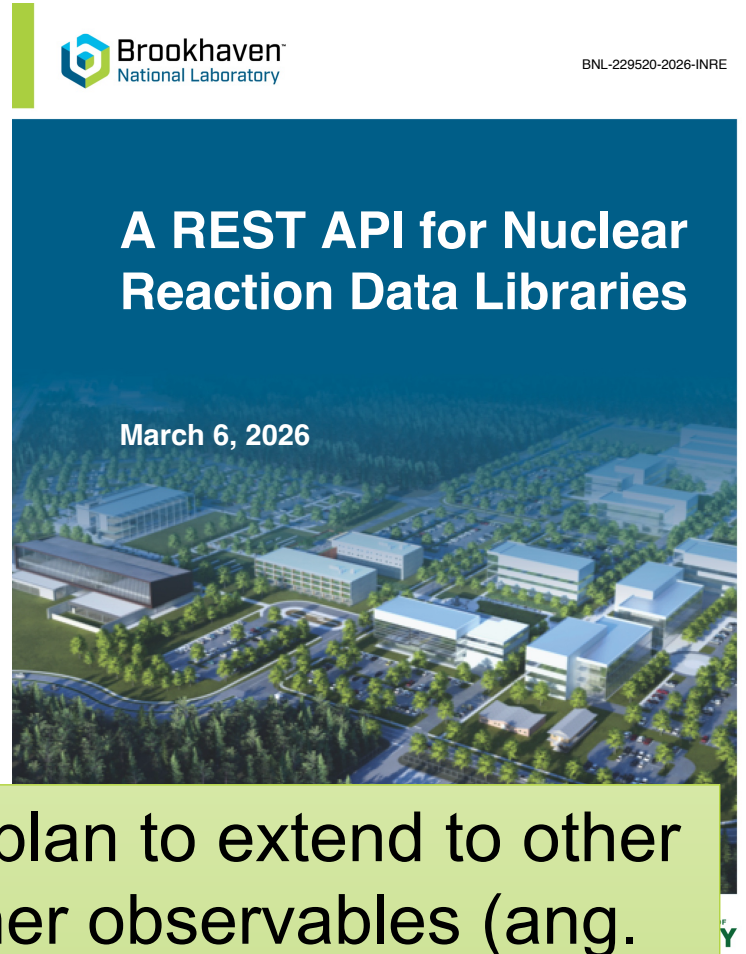
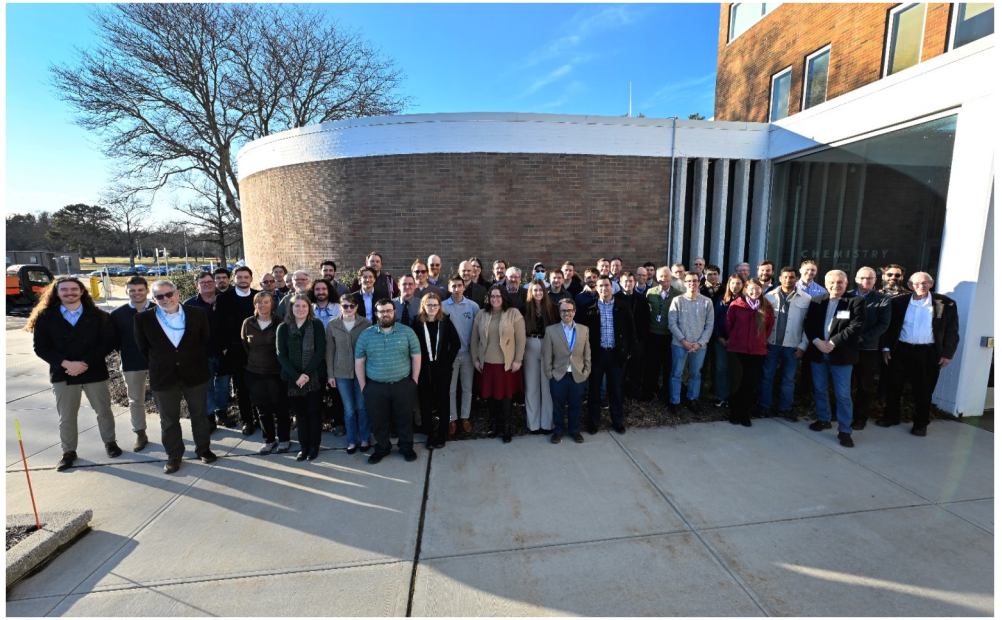



In the future, we plan to extend to other libraries and other observables (ang. dist., spectra, uncertainties/covariances, etc.), provided there is additional support

# 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**



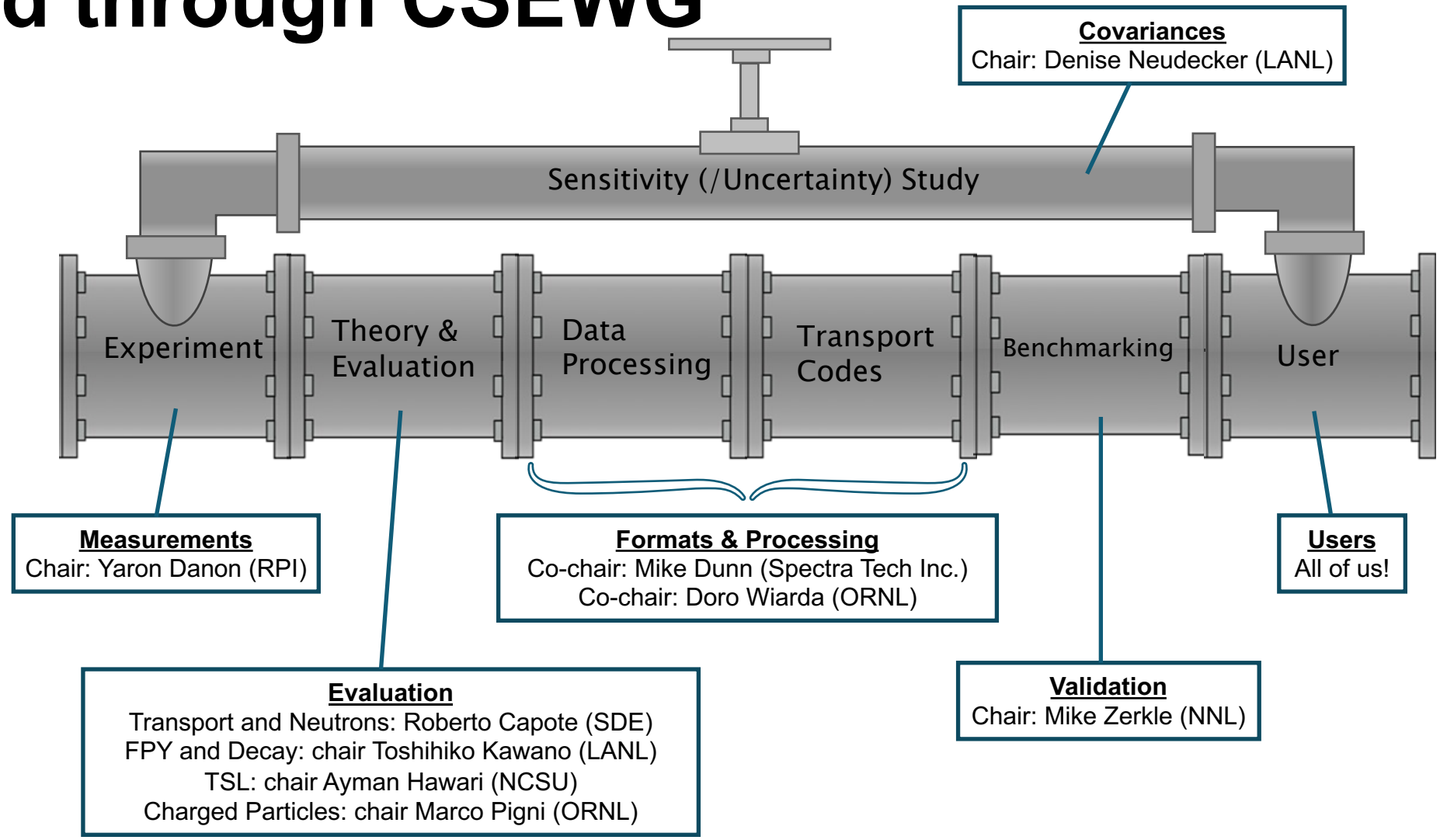
2025 CSEWG meeting, BNL, Jan. 2026

**We are always open to new users and collaborators**

# 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



# 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” is finally published through OpenAccess
  - Nuclear Data Sheets, 210 (2026) 1-224
  - https://doi.org/10.1016/j.nds.2026.04.001
- DOIs and landing page for data are available now
- **REST API** developed for automated access to **ENDF** data

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

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

# Acknowledgements

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NCSP NUCLEAR CRITICALITY SAFETY PROGRAM

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NNSA National Nuclear Security Administration