Brookhaven
National Laboratory
U.S. DEPARTMENT OF
ENERGY
The ENDF Project
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16 Jan 2024
@BrookhavenLab

Outline

CSEWG

ENDF/B-VIII.1

Big Paper

ENDF format

Brookhaven National Laboratory

Cross Section Evaluation Working Group

Brookhaven National Laboratory

Before ENDF

By 1960, there were many data efforts worldwide

- different formats
- often hard-coded libraries
- proprietary data
- Notable efforts: UKNDL (AWE, UK), NDA library (US), ENDL (LRL, US)

~1962 H. Honeck (BNL), A. Henry (Westinghouse), G. Joanou (GA) met at Colony Restaurant in DC decided on action

- requested Reactor Mathematics and Computation Division of ANS to sponsor 2 meetings to link databases

http://www.streetsofwashington.com/2013/10/fine-dining-in-washington-dc-in-1950s.html

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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**

We are always open to new users and collaborators

CSEWG collaboration meeting in November 2022: our first in-person meeting since the pandemic started!

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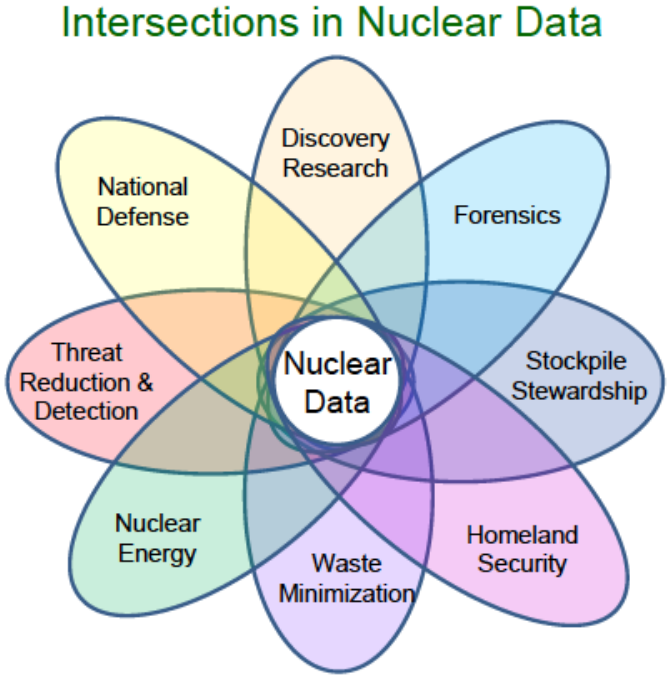
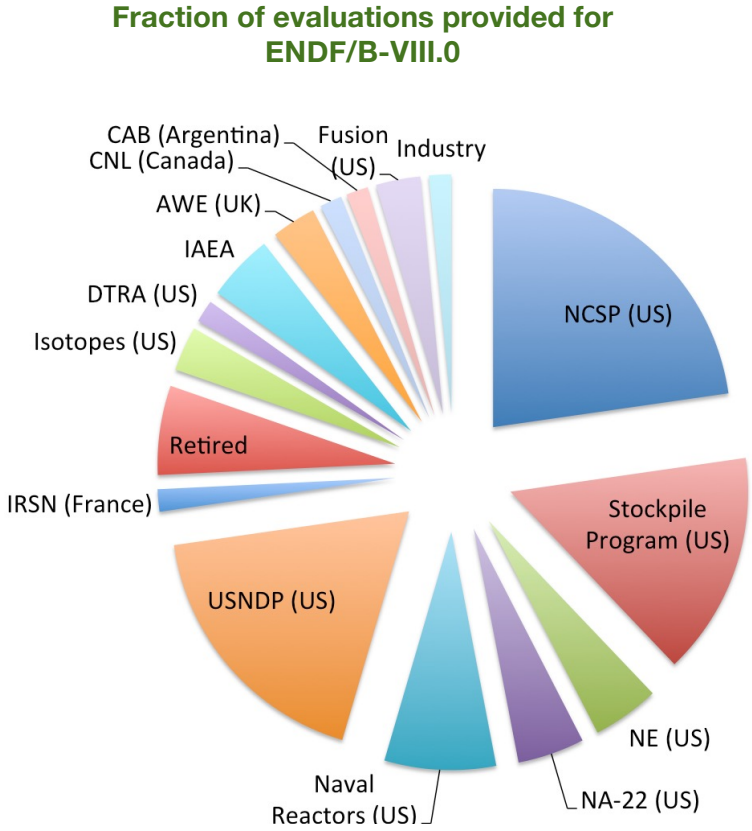
CSEWG is a long standing collaboration between the data users who are also the biggest content providers



Dr. Timothy Hallman, Associate Director of the Office of Science for Nuclear Physics
April 5, 2015



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By sharing through CSEWG many sponsors reap the benefit of collaboration

Program	Measurement	Theory	Compilation	Evaluation	QA (V&V, IE)	Infrastructure (gitlab, etc.)
DTRA	✓					
International (IAEA,NEA,…)	✓	✓	✓	✓	✓	✓
NA-22	✓	✓		✓		
Naval Reactors	✓			✓	✓	
NCSP	✓	✓		✓	✓	✓
Nuclear Energy					✓	
Other (IP, Fusion, …)	✓	✓				
Defense Programs	✓	✓		✓	✓	✓
USNDP	✓	✓	✓	✓	✓	✓

TRIUMF
Argonne
NATIONAL LABORATORY
Canadian Nuclear Laboratories
Laboratoires Nucléaires Canadiens
CSEWG
Cross Section Evaluation Working Group
Rensselaer
BERKELEY LAB
Lawrence Livermore National Laboratory
BROOKHAVEN
NATIONAL LABORATORY
Sandia National Laboratories
NAVAL NUCLEAR LABORATORY
Los Alamos
NATIONAL LABORATORY
EST.1943
NIST
NC STATE UNIVERSITY
OAK RIDGE
National Laboratory
CNEA

CSEWG is not limited to the Americas

All steps of nuclear data pipeline are coordinated through CSEWG

Chair:
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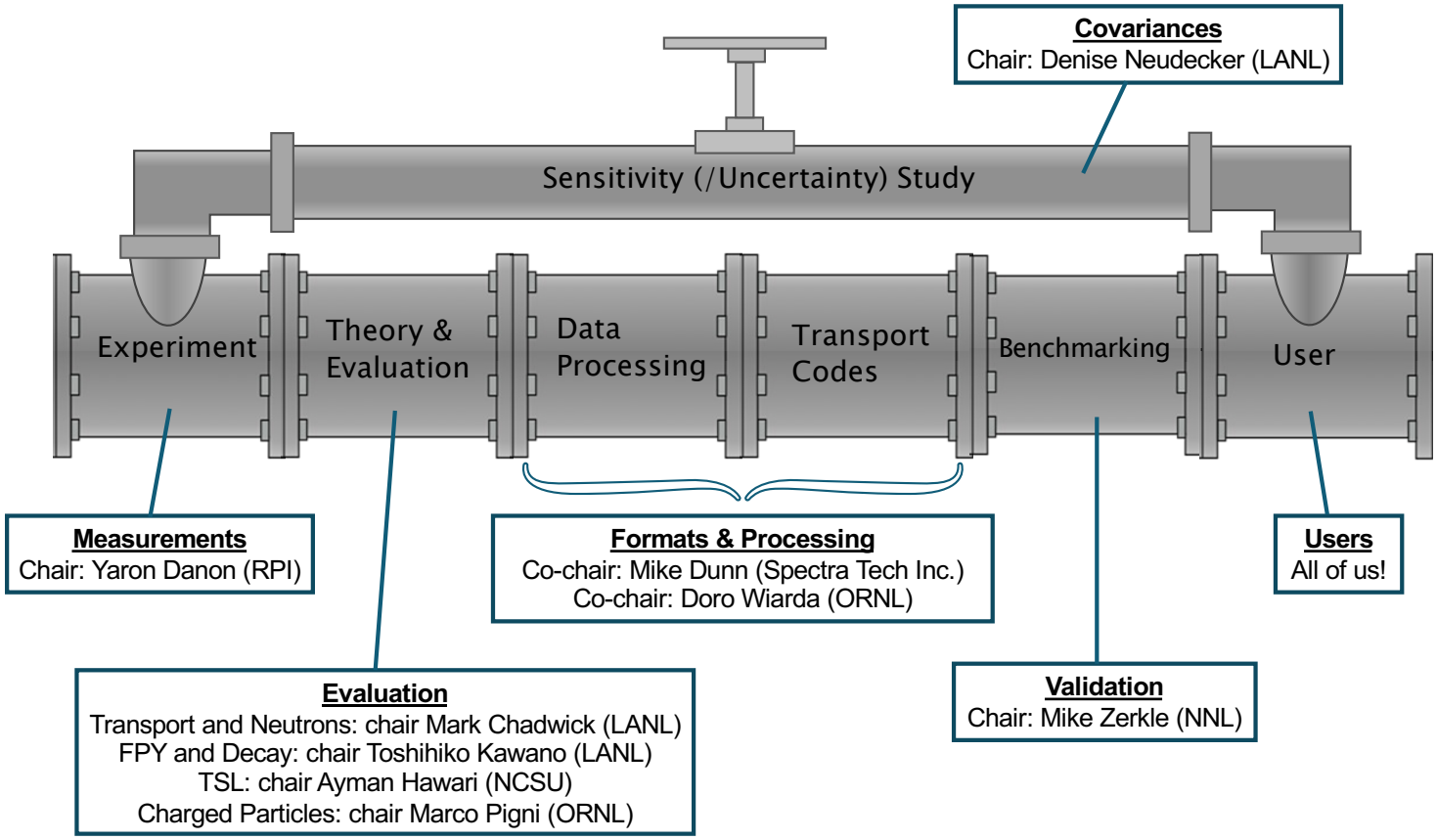
gnobre@bnl.gov



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The next ENDF/B release

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ENDF/B-VIII.1 release

The next release of the ENDF/B library is scheduled for **May 2024!**

Although technically “minor”, it will have **major** impact.

- Why **VIII.1** and not **IX**?
  - There are no planned updates of the standards library for this release
  - Standards are well-stablished cross sections, in specific energy ranges, used in ratios with other measurements
  - However, many, many important and impactful changes are on the way!!
- Next release will be in both legacy **ENDF-6** format and **GNDS-2.0**
- Will have an accompanying **“Big Paper”**
- Implemented review system: Multiple VIII.1 Beta versions have been released
- Preliminary validation indicate that this will be the best-performing library ever!

ENDF/B
VIII.1-β2

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What to expect when expecting…
… the ENDF/B-VIII.1 release

Neutrons:

- Many INDEN contributions
- Actinides:
  - ^{239}**Pu**: multi-institution effort, with important updates to fission, nubar, PFNS, capture, URR, RRR, (n,2n)
  - ^{235}**U**: resonances, nubar, covariances,
  - ^{238}**U**: resonance update to improve performance on depletion benchmarks
  - ^{240,241}**Pu**: work in concert with changes in ^{239}Pu and ^{238}U to recover burnup performance
- Stainless steel & other structure materials:
  - ^{54,56,57}**Fe**: Corrects leakage deficiency from ENDF/B-VIII.0
  - ^{50,52,53,54}**Cr**: Thorough re-evaluation, impact in criticality and leakage benchmarks
  - ^{206,207,208}**Pb**: complete evaluations (RPI/LANL)
  - ^{63,65}**Cu**: improved performance
  - ^{55}**Mn**: Gamma spectra
  - ^{28,29,30}**Si**: resonance evaluations
- Others:
  - ^{6}**Li,** ^{9}**Be** (LANL)
  - ^{234,236}**U** (LANL)
  - ^{140,142}**Ce** (ORNL)
  - ^{103}**Rh** (RPI/IRSN)
  - ^{86}**Kr** (BNL)
  - ^{181}**Ta** (RPI/ORNL/LANL)
  - ^{95}**Mo** (IRSN/LANL)
  - Many, many, many more…

What to expect when expecting…
… the ENDF/B-VIII.1 release

TSL:

- 70+ new updated/files
- **Polystyrene**, **zirconium hydride**, **UC**, **UN**, **UO_2**, **sapphire**, **lucite**, **FLiBe**, **etc…**
- Fuel materials with different enrichments
- So many new evaluations that we had to re-think how to identify them.
- Low-temperature extrapolations to light water
- Community-wide review and validation

Fission Yields:

- Many fixes
- …but no changes to the actual yields

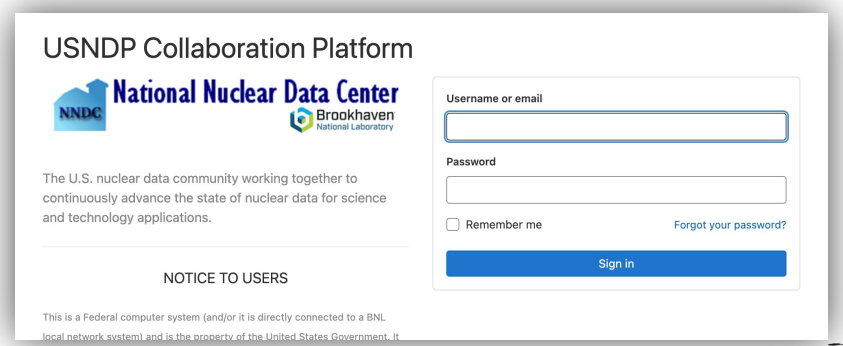
Photo-nuclear:

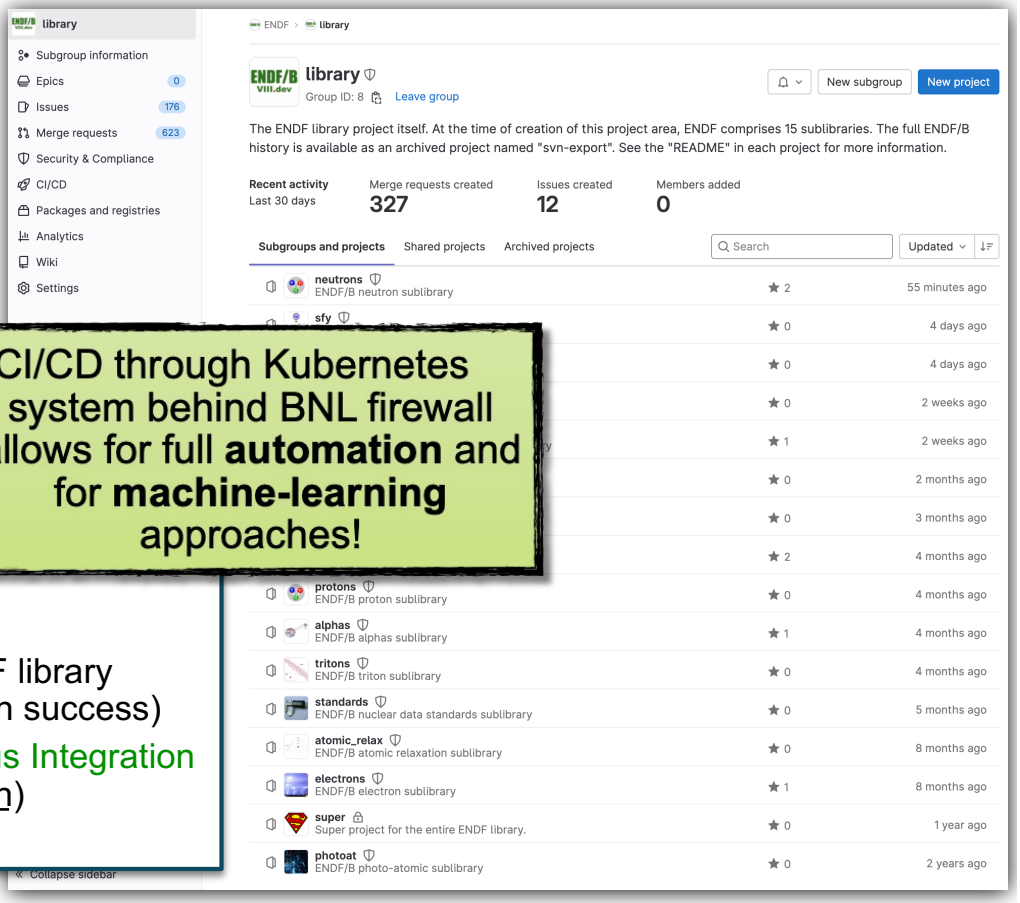
- **200+** updates coming from IAEA CRP

Charged particles:

- A few improvements and fixes

ENDF versioned repository: GitLab

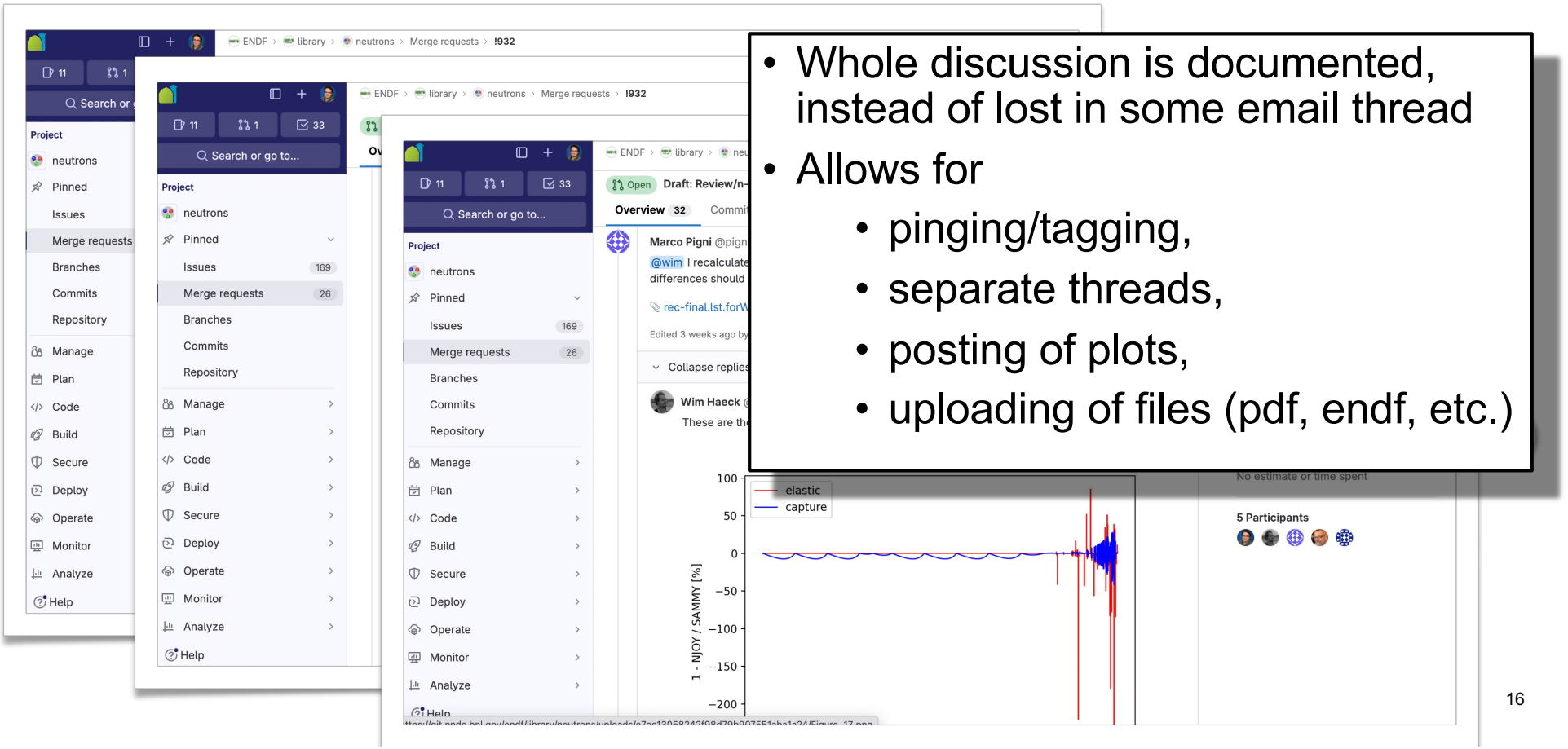




- Constantly updated and maintained
- Keeps track of
  - Any changes
  - Development, **review** and release branches
  - Issue trackers
  - etc…
- Usage is growing! Currently ~60 active members in ENDF library group (unfortunately there's a seat limit: victims of our own success)
- Integration of library repository in GitLab with a Continuous Integration system: **ADVANCE** (R. Arcilla, R. Coles, B. Shu, D. Brown)

CI/CD through Kubernetes system behind BNL firewall allows for full **automation** and for **machine-learning** approaches!

Showcase example: ^{88}Sr review



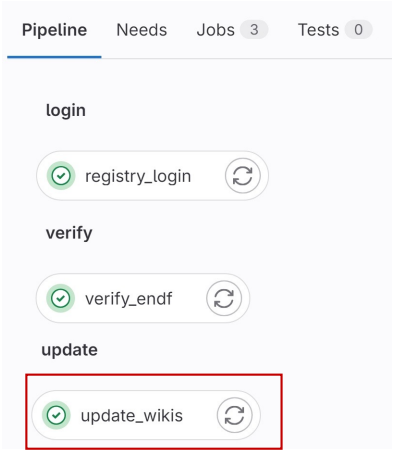
- Whole discussion is documented, instead of lost in some email thread
- Allows for
  - pinging/tagging,
  - separate threads,
  - posting of plots,
  - uploading of files (pdf, endf, etc.)

ENDF Repo Auto-updating Wikis

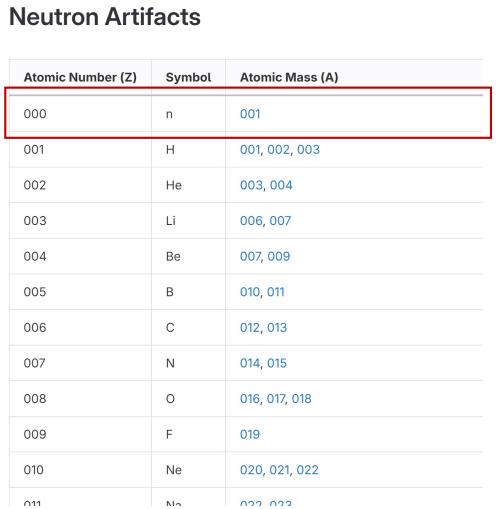
A new job is being added to GitLab ENDF repositories to auto-update the repo's wiki with useful information about job and artifact status.

Example: https://git.nndc.bnl.gov/endf/library/neutrons/-/wikis/Neutron-Artifacts

1) update_wikis job runs after verify_endf



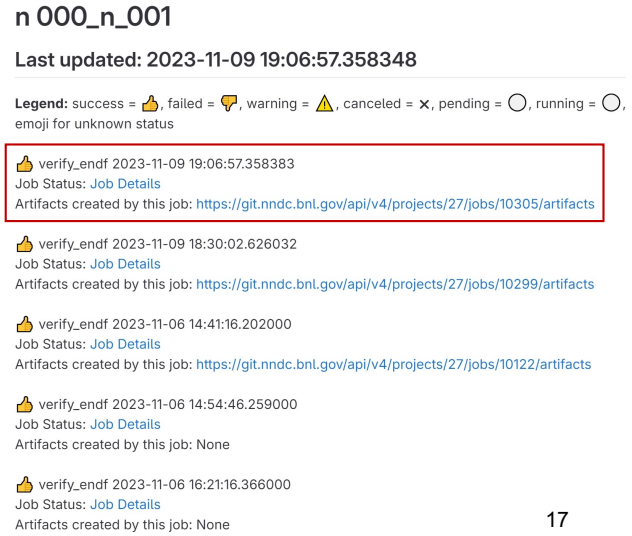
2) Use Wiki table of contents to find your data



Neutron Artifacts

Atomic Number (Z)	Symbol	Atomic Mass (A)
000	n	001
001	H	001, 002, 003
002	He	003, 004
003	Li	006, 007
004	Be	007, 009
005	B	010, 011
006	C	012, 013
007	N	014, 015
008	O	016, 017, 018
009	F	019
010	Ne	020, 021, 022

3) Enjoy a record of job and artifact data all in one place



n 000_n_001

Last updated: 2023-11-09 19:06:57.358348

Legend: success = 👍, failed = 👎, warning = ⚠, canceled = ×, pending = ◯, running = ◯, emoji for unknown status

verify_endf 2023-11-09 19:06:57.358383
Job Status: Job Details
Artifacts created by this job: https://git.nndc.bnl.gov/api/v4/projects/27/jobs/10305/artifacts

verify_endf 2023-11-09 18:30:02.626032
Job Status: Job Details
Artifacts created by this job: https://git.nndc.bnl.gov/api/v4/projects/27/jobs/10299/artifacts

verify_endf 2023-11-06 14:41:16.202000
Job Status: Job Details
Artifacts created by this job: https://git.nndc.bnl.gov/api/v4/projects/27/jobs/10122/artifacts

verify_endf 2023-11-06 14:54:46.259000
Job Status: Job Details
Artifacts created by this job: None

verify_endf 2023-11-06 16:21:16.366000
Job Status: Job Details
Artifacts created by this job: None

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Status of “Big Paper”

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Past ENDF release published accompanying paper in Nuclear Data Sheets

Volume 148, February 2018 ISSN 0090-3752

ELSEVIER

Nuclear Data Sheets

A Journal Devoted to Compilations and Evaluations of Experimental and Theoretical Results in Nuclear Physics

E. A. McCutchan, Editor
National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY 11973-5000, USA
www.nndc.bnl.gov

Special Issue on Nuclear Reaction Data

Special Issue Editor: Pavel Obložinský
Special Issue Assistant Editor: Boris Pritychenko

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ENDF B-VIII.0

Nuclear Data Sheets 148, 1-142 (2018)

Nuclear Data Sheets
Volume 148, February 2018, Pages 1-142

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

D.A. Brown [a], M.B. Chadwick [b], R. Capote [c], A.C. Kahler [b], A. Trkov [c], M.W. Herman [a], A.A. Sonzogni [a], Y. Danon [d], A.D. Carlson [e], M. Dunn [f], D.L. Smith [g], G.M. Hale [b], G. Arbanas [h], R. Arcilla [a], C.R. Bates [b], B. Beck [i], B. Becker [j], F. Brown [b], R.J. Casperson [i], J. Conlin [b], D.E. Cullen [i], M.-A. Descalle [i], R. Firestone [k], T. Gaines [i], K.H. Guber [h], A.I. Hawari [m], J. Holmes [n], T.D. Johnson [a], T. Kawano [b], B.C. Kiedrowski [o], A.J. Koning [c], S. Kopecky [p], L. Leal [q], J.P. Lestone [b], C. Lubitz [r], J.I. Márquez Damián [s], C.M. Mattoon [i], E.A. McCutchan [a], S. Mughabghab [a], P. Navratil [t], D. Neudecker [b], G.P.A. Nobre [a], G. Noguere [u], M. Paris [b], M.T. Pigni [h], A.J. Plompen [p], B. Pritychenko [a], V.G. Pronyaev [v], D. Roubtsov [w], D. Rochman [x], P. Romano [g], P. Schillebeeckx [p], S. Simakov [y], M. Sin [z], I. Sirakov [aa], B. Sleaford [i], V. Sobes [h], E.S. Soukhovitskii [ab], I. Stetcu [b], P. Talou [b], I. Thompson [i], S. van der Marck [ac], L. Welser-Sherrill [b], D. Wiarda [h], M. White [b], J.L. Wormald [m], R.Q. Wright [h], M. Zerkle [h], G. Žerovnik [p], Y. Zhu [m]

Cited 1,658 times!

Nuclear Data Sheets 112, 2887-2996 (2011)

Nuclear Data Sheets
Volume 112, Issue 12, December 2011, Pages 2887-2996

ENDF B-VII.1

ENDF/B-VII.1 Nuclear Data for Science and Technology: Cross Sections, Covariances, Fission Product Yields and Decay Data

M.B. Chadwick [a], M. Herman [b], P. Obložinský [b], M.E. Dunn [c], Y. Danon [d], A.C. Kahler [a], D.L. Smith [e], B. Pritychenko [b], G. Arbanas [c], R. Arcilla [b], R. Brewer [a], D.A. Brown [b,f], R. Capote [g], A.D. Carlson [h], Y.S. Cho [m], H. Derrien [c], K. Guber [c], G.M. Hale [a], S. Hoblit [b], S. Holloway [a], T.D. Johnson [b], T. Kawano [a], B.C. Kiedrowski [a], H. Kim [m], S. Kunieda [a,o], N.M. Larson [c], L. Leal [c], J.P. Lestone [a], R.C. Little [a], E.A. McCutchan [b], R.E. MacFarlane [a], M. MacInnes [a], C.M. Mattoon [f], R.D. McKnight [c], S.F. Mughabghab [b], G.P.A. Nobre [b], G. Palmiotti [n], A. Palumbo [b], M.T. Pigni [c], V.G. Pronyaev [i], R.O. Sayer [c], A.A. Sonzogni [b], N.C. Summers [f], P. Talou [a], I.J. Thompson [f], A. Trkov [j], R.L. Vogt [f], S.C. van der Marck [k], A. Wallner [l], M.C. White [a], D. Wiarda [c], P.G. Young [a]

Cited 3,138 times!

Nuclear Data Sheets, 107 (2006), p. 2931

ENDF B-VII.0 Evaluated Nuclear Data File

Nuclear Data Sheets
Volume 107, Issue 12, December 2006, Pages 2931-3060

ENDF/B-VII.0: Next Generation Evaluated Nuclear Data Library for Nuclear Science and Technology

Cited 2,753 times!

This is really, *really* impactful!

Big Paper updates

- Many contributions have been sent but there are still gaps that will be addressed after CSEWG Meeting
- Defined preliminary full author list and ordering
- Big Paper is shaping up: huge “stitching” effort
- Aiming to have a complete manuscript soon

FIXME: Full title of ENDF/B-VIII.1 paper

G.P.A. Nobre,[1,*] R. Capote,[2] M.T. Pigni,[3] A. Trkov,[4] C.M. Mattoon,[5] D. Neudecker,[6] D.A. Brown,[1] M.B. Chadwick,[6] A.C. Kahler,[6] N.A. Kleedtke,[6] M. Zerkle,[7] A.I. Hawari,[8] C.W. Chapman,[3] N.C. Fleming,[8] J.L. Wormald,[7] K. Ramić,[3] Y. Danon,[9] N.A. Gibson,[6] P. Brain,[9] M.W. Paris,[6] G.M. Hale,[6] I.J. Thompson,[5] D.P. Barry,[7] I. Stetcu,[6] W. Haeck,[6] A.E. Lovell,[6] M.R. Mumpower,[6] G. Potel Aguilar,[5] K. Kravvaris,[5] G. Noguere,[10] A.D. Carlson,[11] M. Dunn,[12] T. Kawano,[6] D. Wiarda,[3] G. Arbanas,[3] R. Arcilla,[1] B. Beck,[5] D. Bernard,[10] R. Beyer,[13] J.M. Brown,[3] O. Cabellos,[14] R.J. Casperson,[5] E.V. Chimanski,[1] R. Coles,[1] M. Cornock,[15] J. Cotchen,[7] J.P.W. Crozier,[8] D.E. Cullen,[2] A. Daskalakis,[7] M.-A. Descalle,[5] D.D. DiJulio,[16] P. Dimitriou,[2] A.C. Dreyfuss,[5] FIXME: Ignacio Duran,[17] R. Ferrer,[18] T. Gaines,[15] G. Gert,[5] K.H. Guber,[3] J.D. Haverkamp,[7] M.W. Herman,[6] J. Holmes,[7] A.R. Junghans,[13] K. Kelly,[6] H.I. Kim,[19] P.E. Koehler,[6] M. Koštál,[20] B.K. Laramee,[8] A. Lauer-Coles,[1] L. Leal,[3,21] H.Y. Lee,[6] A.M. Lewis,[7] J. Malec,[4] J.I. Márquez Damián,[16] W.J. Marshall,[3] A. Mattera,[1] J.D. McDonnell,[3] G. Muhrer,[16] A. Ney,[7] W.E. Ormand,[5] D.K. Parsons,[6] C.M. Percher,[5] B. Pritychenko,[1] V.G. Pronyaev,[22] S. Quaglioni,[5] M. Rapp,[7] J.J. Ressler,[5] P.K. Romano,[23] D. Roubtsov,[24] G. Schnabel,[2] M. Schulc,[20] A.A. Sonzogni,[1] P. Talou,[6] J. Thompson,[7] T.H. Trumbull,[7] M. Vorabbi,[1] C. Wemple,[18] K.A. Wendt,[5] M. White,[6] and R.Q. Wright[25]

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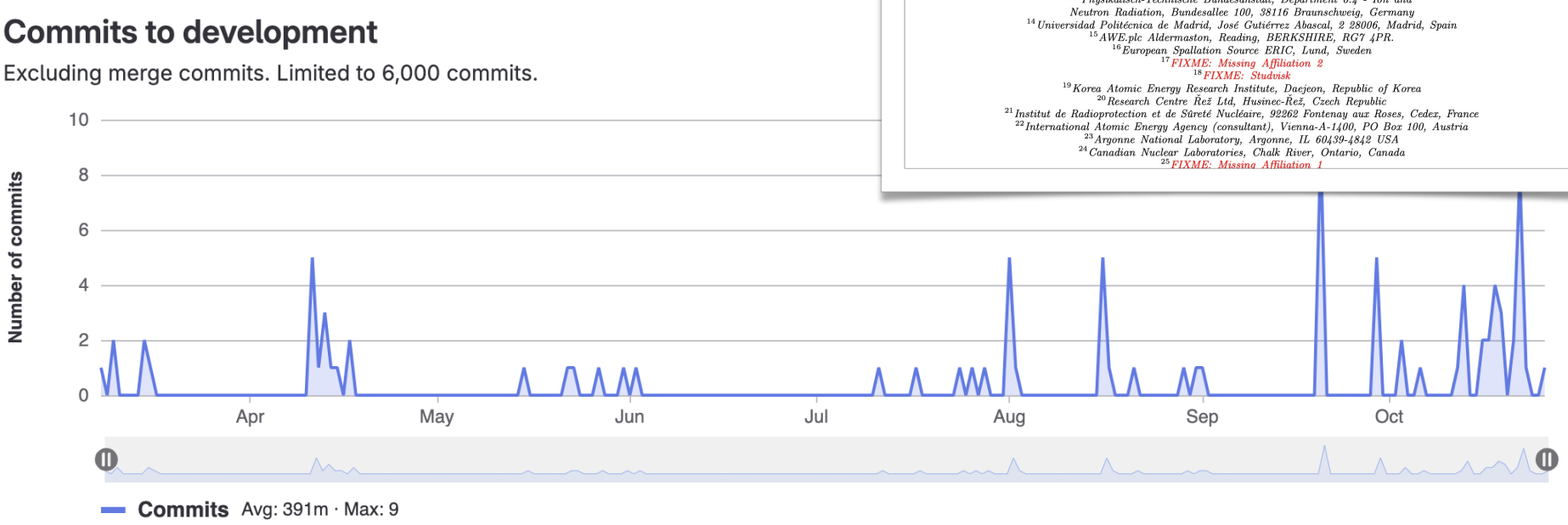
[25] *FIXME: Missing Affiliation 1*



Final comments

- **CSEWG and ENDF:**
  - Welcomes collaboration in and out of US (but inside is easier)
  - Long tradition of quality/continuous improvement
  - Conservative, driven by experiment when possible
  - Golden Rule (whoever has the gold makes the rules)
- **USNDP and NNDC are a resource for many other data products**
- **When complete, data is OPEN**
  - (admittedly we are still learning what the evolving BNL process is for opening the data)

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National Laboratory
U.S. DEPARTMENT OF
ENERGY
Old Sigma
(and what to replace it with)
David Brown
National Nuclear Data Center, Brookhaven National Laboratory
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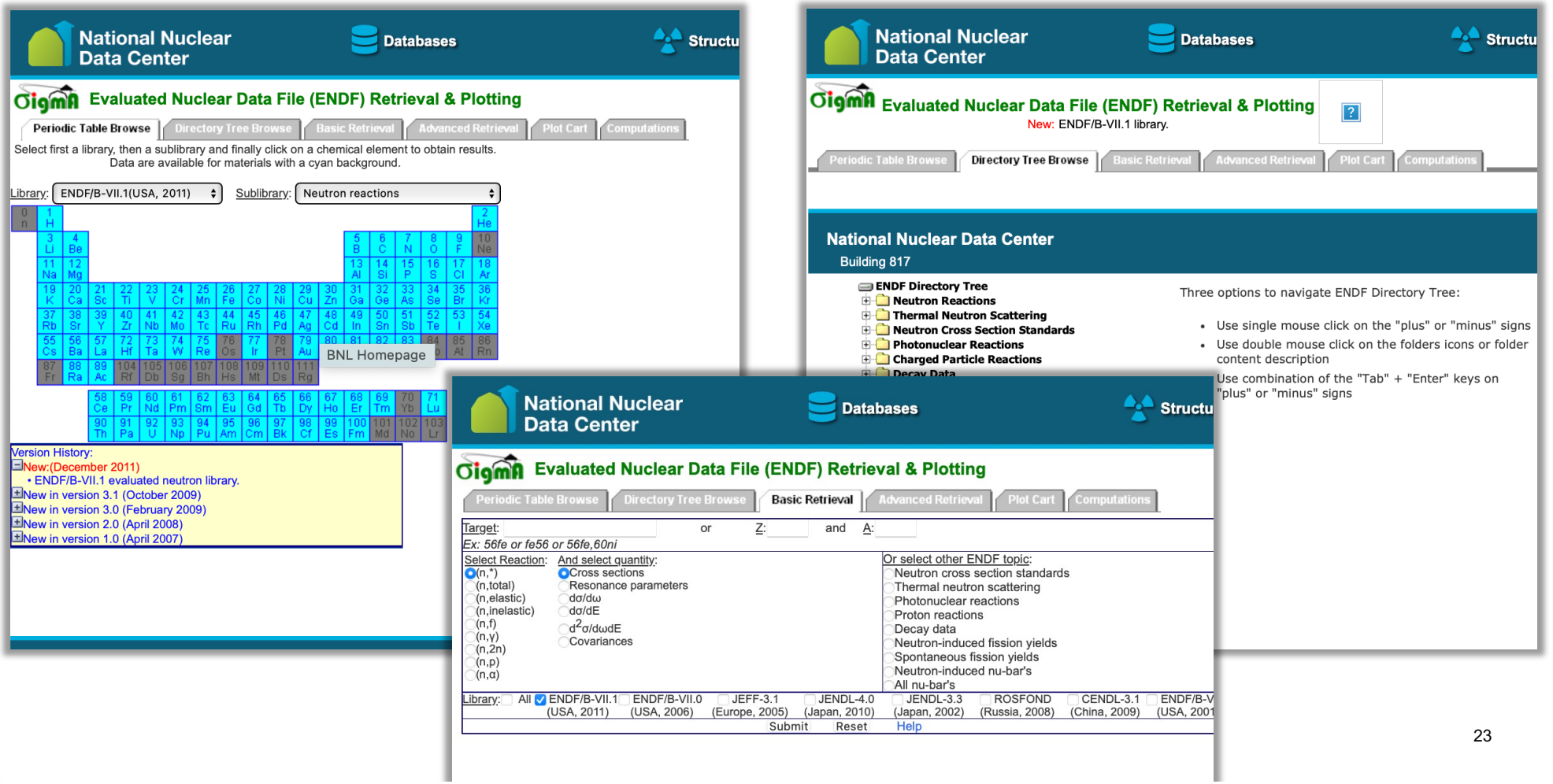
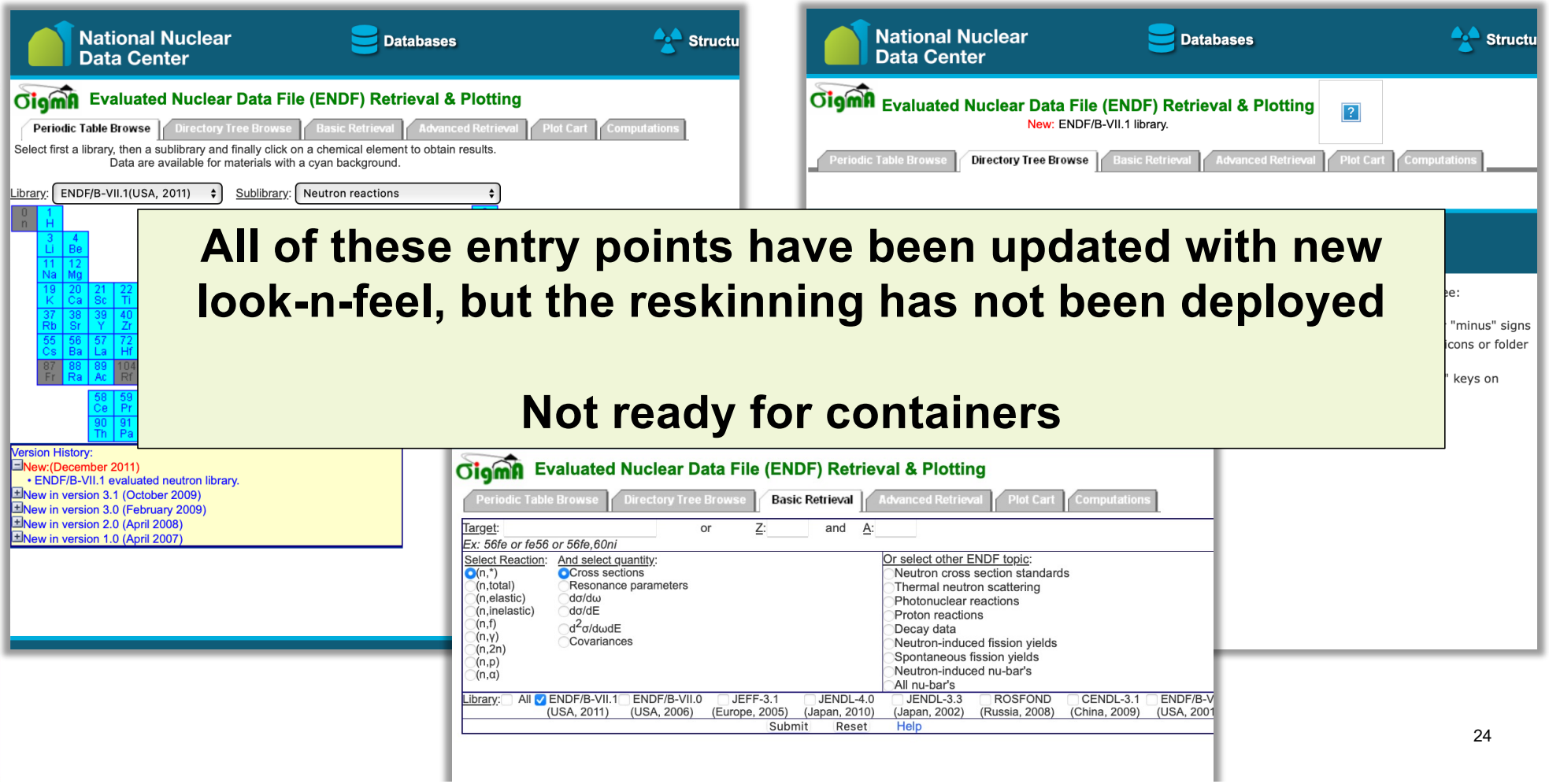
16 Jan 2024
@BrookhavenLab

Sigma access points



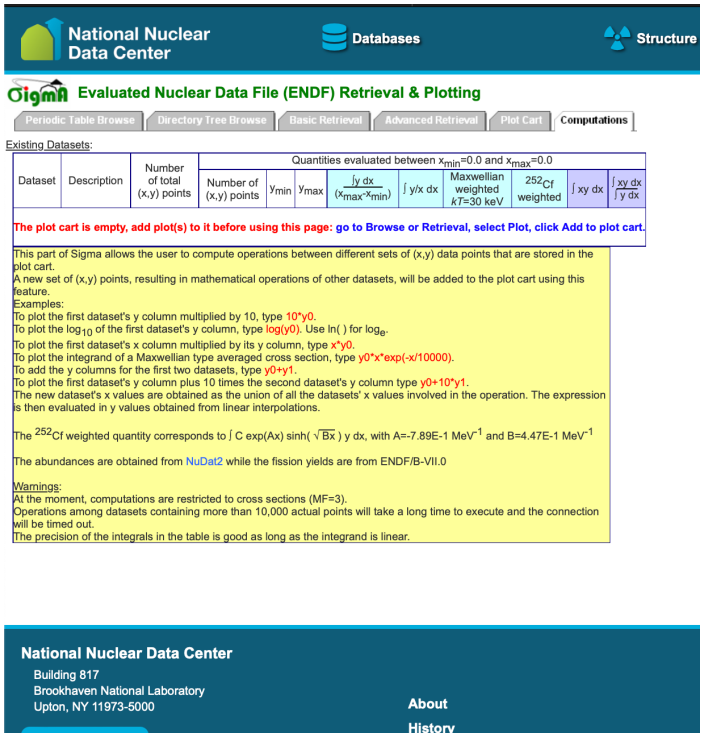
Sigma access points

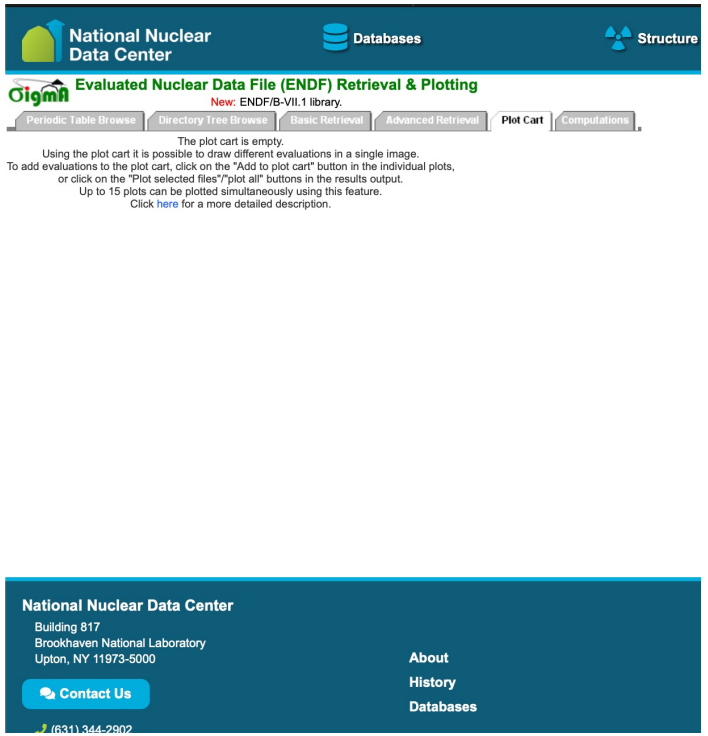


All of these entry points have been updated with new look-n-feel, but the reskinning has not been deployed

Not ready for containers

Two other features: computations, shared plot cart with exfor-endf





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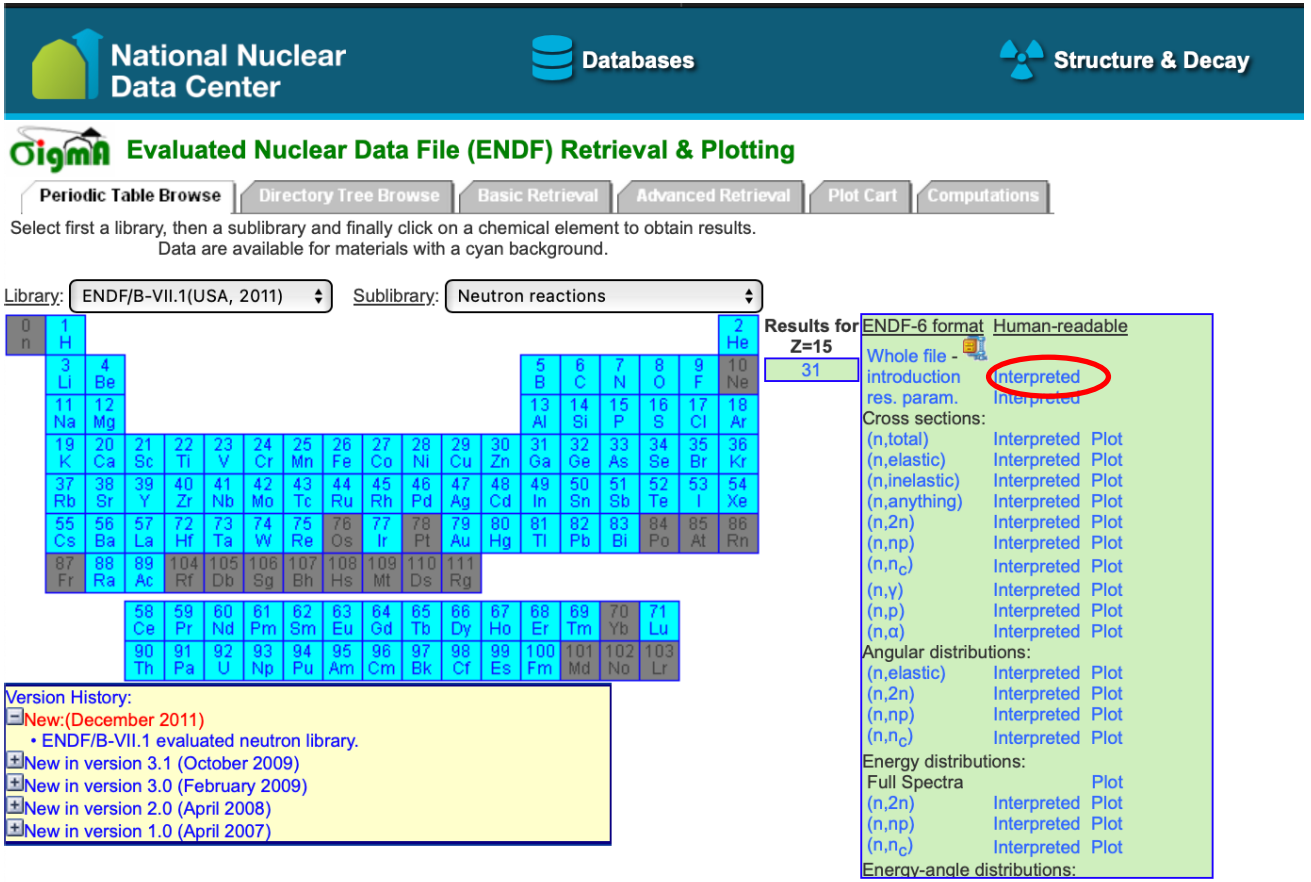
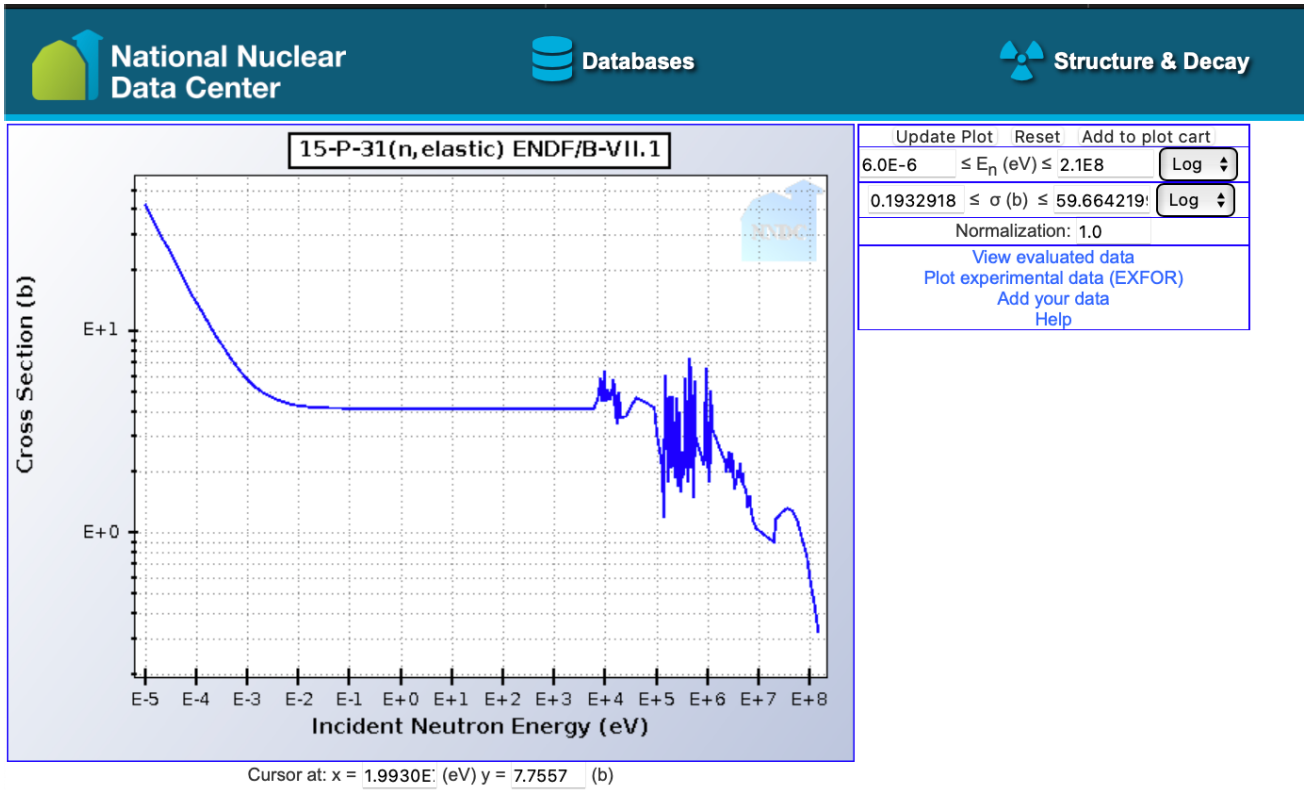
Outline & interpreted versions provided by Bob MacFarlane's endf2htm

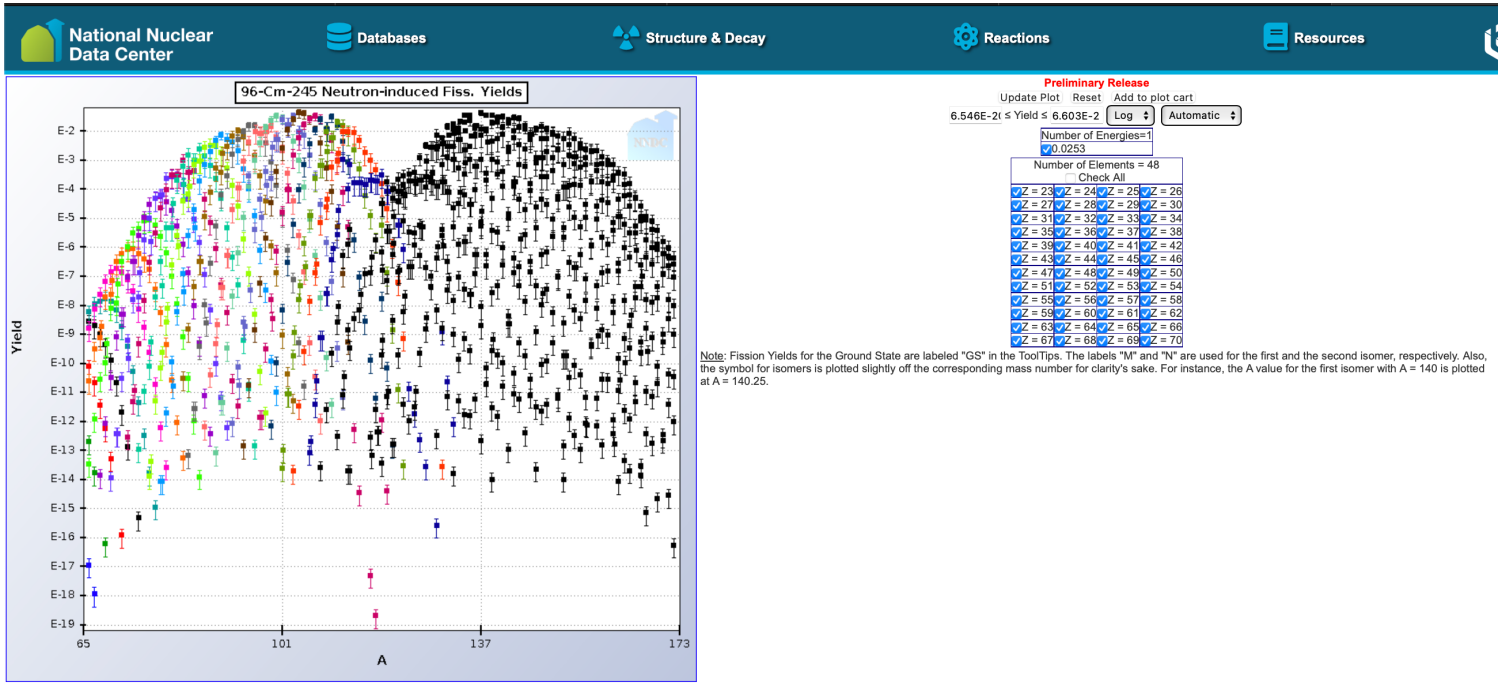


The plot link resolves to homebrew plotter with access to plot cart



To Zoom, left click on one of the limits and release the button on the other limit.
Zooming will work with the latest versions of FireFox and Internet Explorer.
Cross sections plots are reconstructed using the code PREPRO at T=300 K.

Most 2D data types can be plotted, as well as FPY



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System not designed for heavy loads and is not flexible

Webserver:

- Provides the view
- Performs all needed computations <- don't do this!
- A lot of arcane glue <- very dark magic

MYSQL database:

- Contains precomputed items, including resonance reconstructed cross sections and Doppler broadened cross sections

All ENDF data must be preprocessed before loading to database

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Codes in the backend & preprocessing steps (also significant amounts of java glue)

- endf2htm
- prepro (sigma1/recent)
- x4toc4
- lstab
- pltlst
- zvvddx <- only non-F77 code here!
- plotlst

It is getting harder to maintain these codes:

- New staff not trained on fortran
- gfortran *usually* works on them
- ENDF is cryptic & difficult
- EXFOR less cryptic & difficult
- Mapping between ENDF and EXFOR non-trivial

Proposal for a rewrite

- ENDF file preparation: use FUDGE and JSON!
  - ENDF -> GNDS (FUDGE does automatic resonance reconstruction)
  - Heating to RT
  - XML -> JSON is trivial
  - Need endf2htm analog
- EXFOR preparation
  - EXFOR -> JSON (four separate solutions!)
  - Need to replace EXFOR processing code (x4toc4)
- Replace MariaDB/MySQL with Couchdb or Mongodb
- Many off-the shelf client-side plotters available

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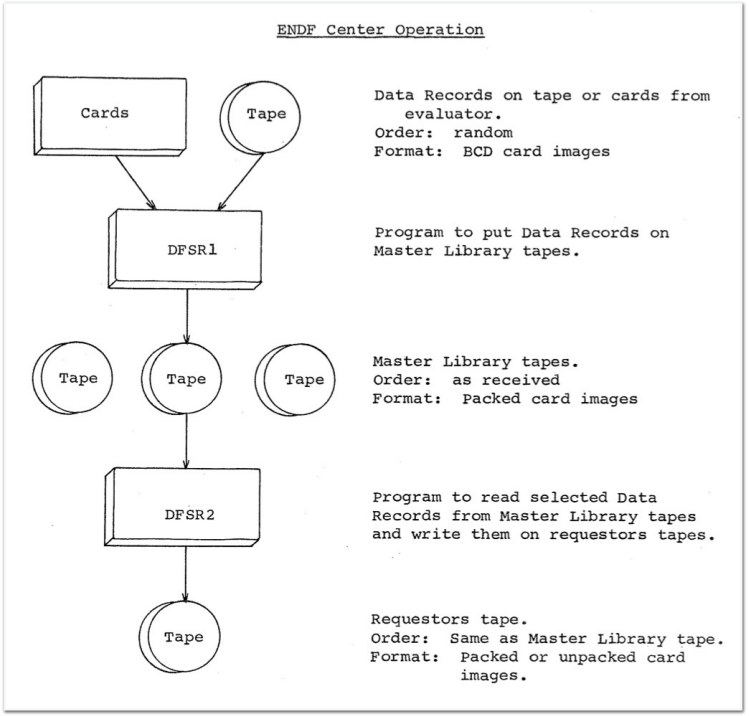
National Laboratory
U.S. DEPARTMENT OF
ENERGY
GNDS
David Brown
National Nuclear Data Center, Brookhaven National Laboratory
Upton, NY 11973, USA
16 Jan 2024
@BrookhavenLab

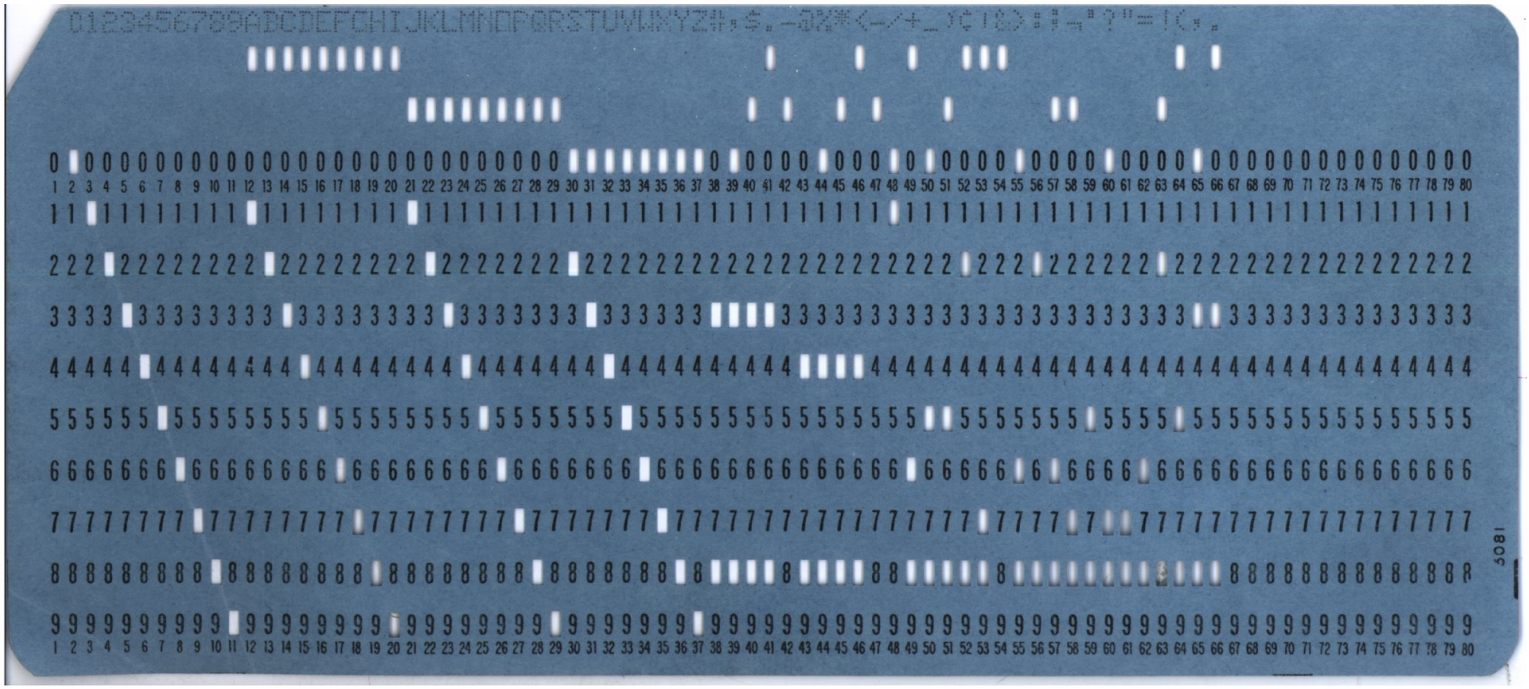
ENDF format & ontology was (and still is) tied to original infrastructure

- **Original format designed to fit on IBM 80 column punchcards**
  - Evaluations actually were occasionally submitted on punchcards
- **Original data stored on magnetic tapes**
- **It was possible to request ENDF data on tapes and/or punchcards**
  - Punchcard format was discouraged, BNL was trying to phase them out



From BNL-8381 (1966)

This is an IBM 80 column punchcard



https://en.wikipedia.org/wiki/Punched_card#/media/File:Blue-punch-card-front-horiz.png

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This is a chunk of the n+59Co evaluation: it's punchcard-ready

```
                                 14          83           1          02725 1451  286
                                 14          84           1          02725 1451  287
                                 14          85           1          02725 1451  288
                                 14          86           1          02725 1451  289
                                 14          87           1          02725 1451  290
                                 14          88           1          02725 1451  291
                                                                      2725 1  099999
                                                                      2725 0  0     0
 2.705900+4 5.842690+1           0           0           1          02725 2151    1
 2.705900+4 1.000000+0           0           0           1          02725 2151
 1.000000-5 1.000000+5           1           3           0          12725 2151    3
 3.500000+0 6.672000-1           0           0           2          32725
 5.842690+1 6.672000-1           0           0         600        1002725
-5.000000+3 3.000000+0 5.576800+2 9.215100+0 0.000000+0 0.000000+02725
-5.000000+3 4.000000+0 1.898100+2 1.868200-1 0.000000+0 0.000000+02725
-4.767000+2 4.000000+0 1.949000-2 2.148900+0 0.000000+0 0.000000+02725
-2.258800+2 3.000000+0 9.164400+0 5.214100-2 0.000000+0 0.000000+02725
 1.320000+2 4.000000+0 5.270100+0 4.700000-1 0.000000+0 0.000000+02725
 4.323100+3 4.000000+0 1.041400+2 4.173700-1 0.000000+0 0.000000+02725
 5.016000+3 3.000000+0 6.789601+2 1.332200+0 0.000000+0 0.000000+02725
 6.389700+3 4.000000+0 1.681100+0 3.155600-1 0.000000+0 0.000000+02725 2151   13
```

Line number, so you can put your punchcards back in order if you drop them

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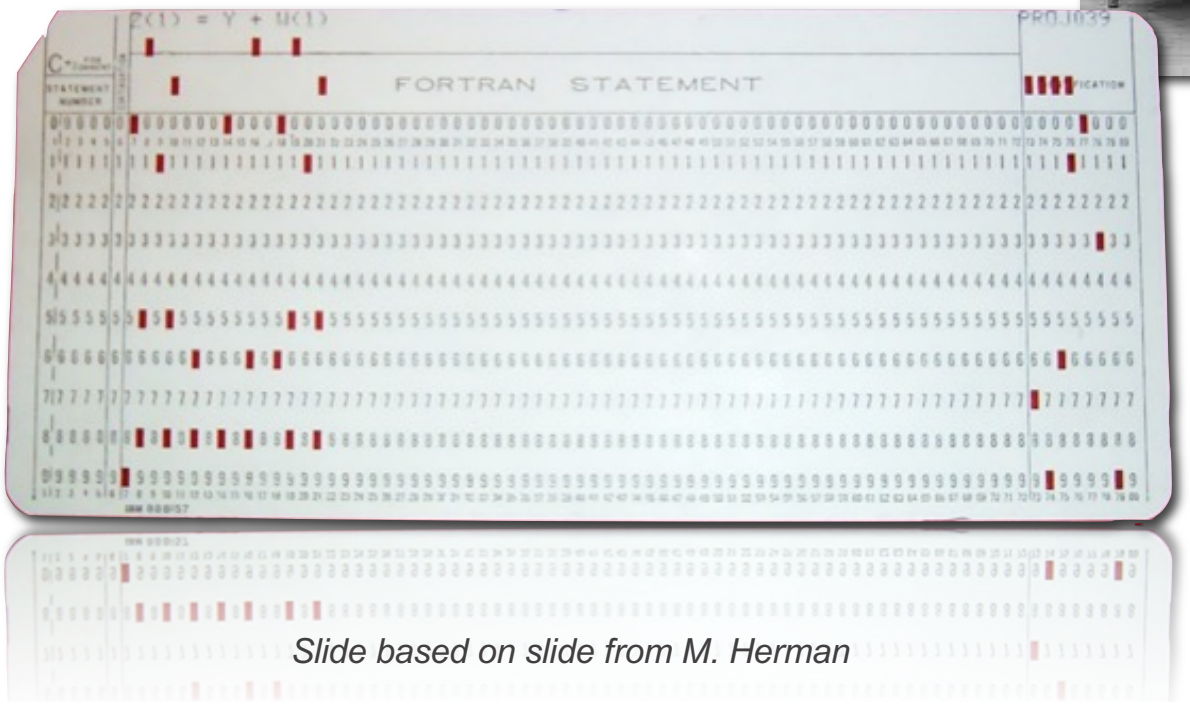
Legacy formats

…but will we continue to be enslaved by this "modern technology"?



Slide based on slide from M. Herman

No, seriously

A good format can determine the data structures used to interact with it

These data structures are the components we use to create new things

We are trying to create a development environment (tools + components) that we enjoy working with

We will be working with these tools for a long time

Good tools == Happy developers

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ENDF is resilient

Colony Restaurant closed 1963

AEC created CSEWG and ENDF; AEC ended in 1974, replaced with DOE in 1977

ENDF/B-V made “classified”, then unclassified

Management of CSEWG by DOE “faded away” in the 1990’s, but we kept going

Internet revolution(s)

11 US Gov’t administrations, so far

55th (-ish) anniversary this year

“It’s a fantastic design, but I’m worried that after the games it’ll just end up as a useless load of stone with no legacy potential.”

The most important part of ENDF is the ecosystem built on the format

PREPRO

NJOY

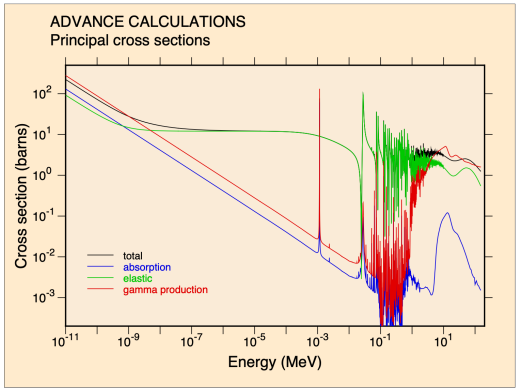
NNDC checking codes

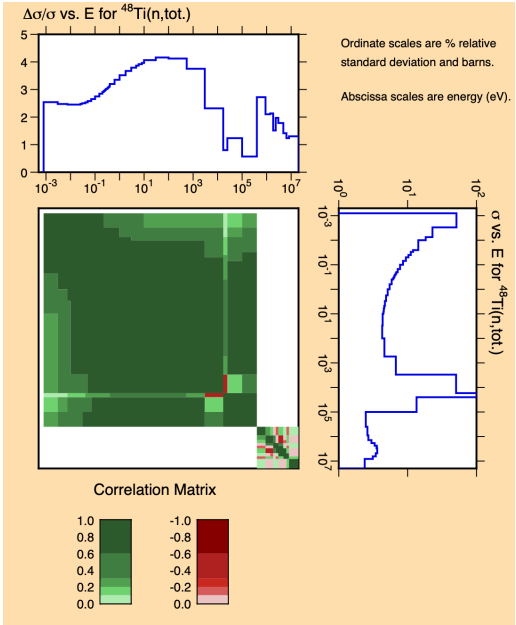
AMPX

CALENDF

…

These are the tools that get the data into user's hands





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ENDF is resilient, but…

Obsolete (and therefore confusing) constructs

- FEND, MEND, SEND and TEND “cards”
- line numbers (for the punchcards)

Limitations imposed by original physical format

- Fixed precision
- Limited MT’s
- Limited MAT’s

“Design by committee”

- MF6
- Fission data in MT1 not MT18
- Resonances
- …

“Not fun to work with”, is often is barrier for newcomers

The biggest danger are the legacy tools becoming “black boxes”

Original developers are deceased, retired or soon to retire

- NJOY (LANL)
  - McFarlane retired
  - Kahler retired
- PREPRO (IAEA)
  - Cullen retired
- ndfgen/mcfgen (LLNL)
  - Perkins deceased
- AMPX (ORNL)
  - Greene retired
- CALENDF (CEA)
  - Ribon retired
- NNDC codes (BNL)
  - Dunford deceased

“if it ain’t broke, don’t fix it”, but…

A chance at a do-over

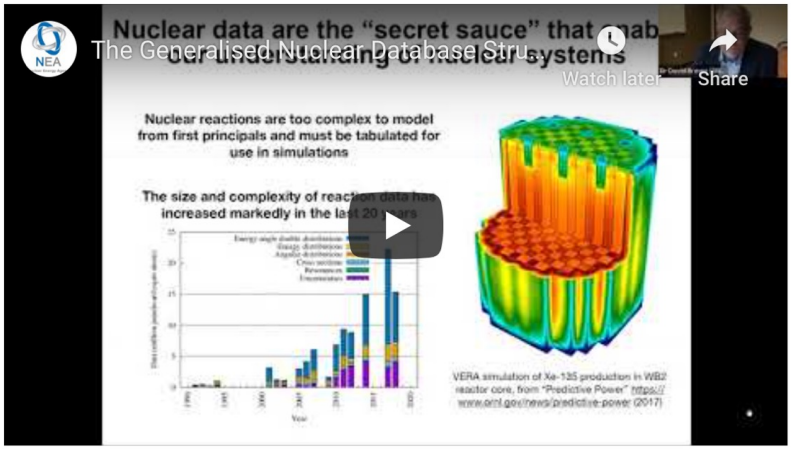
Want to preserve the evaluators' intent; but bad format meant evaluators put things in places they don't belong

- pseudo levels in 6,7Li (ab)used in MF4, before MF6 developed
- fission in W
- "battle over MT's" for high energy reactions
- gammas in MT3 or 4 rather than with the reaction that produced them
- …

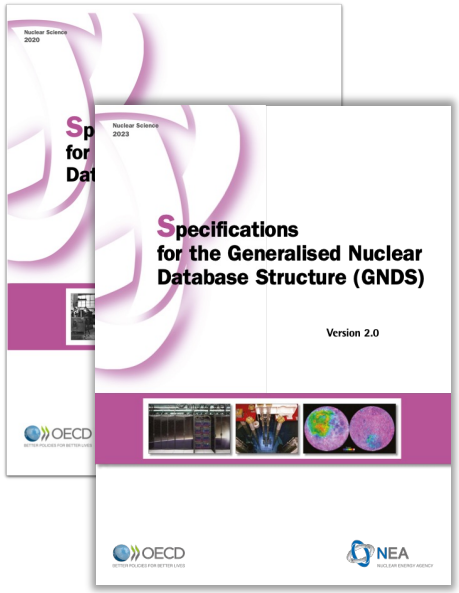
Bad design leads to mistakes, want to engineer them away

- Backgrounds in resonance region
- Multiple ways to store the same thing (gammas in MF12,13,14 vs. gammas in MF6), possible double counting
- Synchronization issues (masses, levels, …)
- …

ENDF & GNDS Formats



- **New NCSP relevant formats**
  - Mixed elastic scattering TSL data for nuclides with both coherent and incoherent components (M. Zerkle NNL)
  - Background R-matrix format (J. Brown ORNL)
- **GNDS & ENDF have similar format approval process**
  - Harness power of gitlab
  - Contact D. Brown (EG-GNDS chair) or D. Wiarda (ENDF Formats chair) for information
- **GNDS-1.9 published**
  - Specifications: https://oecd-nea.org/download/wpec/documents/7519-GNDS.pdf
  - XML Schema for GNDS-1.9: https://www.oecd-nea.org/download/wpec/gnds/gnds.xsd
  - GNDS Webinar: https://www.youtube.com/watch?v=h9Byrkxr8LE&feature=youtu.be
- **GNDS-2.0 published**
  - **Specifications:** https://oecd-nea.org/upload/docs/application/pdf/2023-09/7647_gnds-2.0.pdf



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GNDS Data Model

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GNDS types of files (“top level nodes”)

reactionSuite – reaction data for transport/inventory calculations

covarianceSuite – uncertainty data for the reactionSuite

PoPs – properties of particles, subsuming RIPL-like functions and the decay sublibrary. Planned for major revisions in next GNDS, now that there is an ENSDF-JSON.

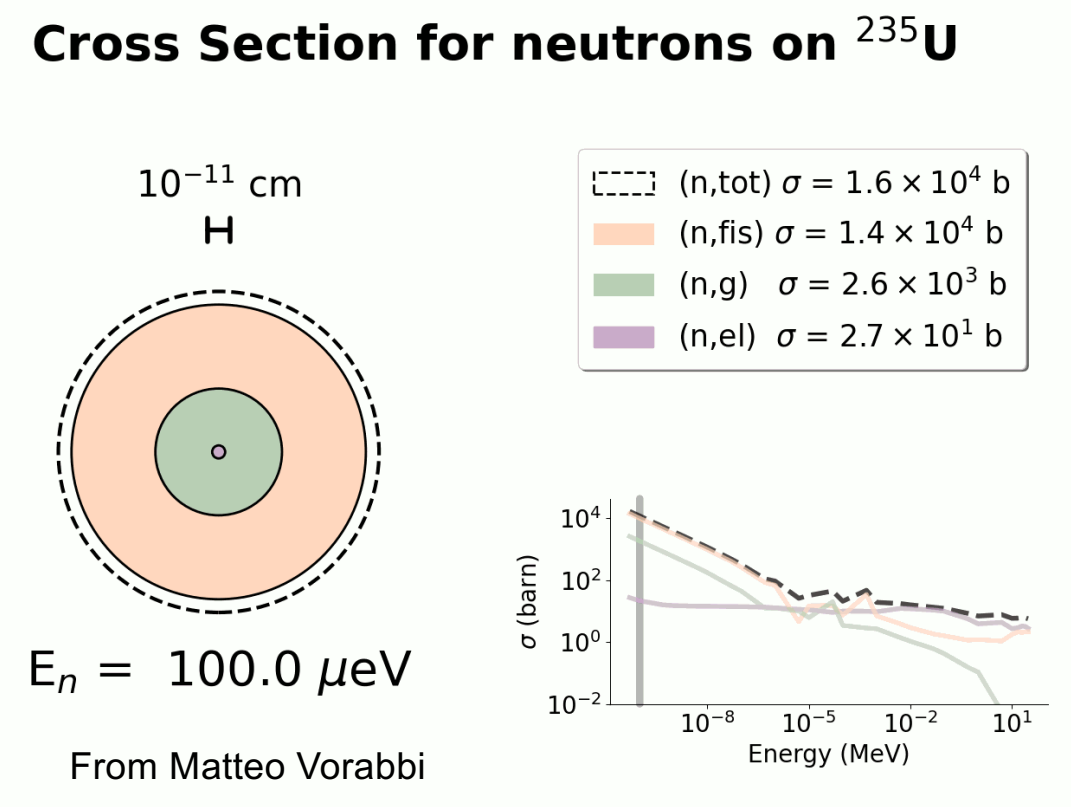
fissionFragmentData – fission product yield data is separate since it is bigg-ish and not needed for every application. Planned for major revisions in next GNDS.

map – like NJOY’s xsdir file, but with some added functionality. Great for organizing a library.

The reactionSuite data model is modeled after particle transport

Transport algorithm in a nutshell:

- In a zone, use atom density and total cross sections to decide what to hit
- In a nucleus, use partial cross sections to determine what reaction to sample
- In a reaction, sample outgoing distributions for each emitted particle



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All ENDF data has a home in GNDS, but the arrangement is much more rational

reactionSuite

- **styles – different styles of data live in same structure (evaluated, various kinds of processed data, etc.)**
- PoPs – the internal particle database
- resonances – resonance data (gets processed into pointwise cross sections)
- **reactions – main collection of data**
- sums – ENDF's many sumrules, rationalized
- productions – production cross sections
- applicationData – optional institution specific information

Dive into the reactions

```
<reactions>
  <reaction label="n + Al27" ENDF_MT="2">
    <crossSection>
      <resonancesWithBackground label="eval"> ... </resonancesWithBackground>
      <XYs1d label="recon"> ... </XYs1d></crossSection>
    <outputChannel genre="twoBody">
      <Q> ... </Q>
      <products>
        <product pid="n" label="n">
          <multiplicity> ... </multiplicity>
          <distribution>
            <angularTwoBody label="eval" productFrame="centerOfMass"> ... </angularTwoBody></distribution></product>
        <product pid="Al27" label="Al27">
          <multiplicity> ... </multiplicity>
          <distribution>
            <angularTwoBody label="eval" productFrame="centerOfMass"> ... </angularTwoBody></distribution></product></
            products></outputChannel></reaction>
```

Styles contain the documentation for each style of data in evaluation

```
<styles>
  <evaluated label="eval" date="2001-02-01" library="ENDF/B" version="8.0.1">
    <documentation>
      <authors>
        <author name="M.B.Chadwick+,Derrien+"></author></authors>
      <dates>
        <date value="2001-02-01" dateType="created"/></dates>
      <title><![CDATA[ENDF-6 file form ENDF/B version 8.0.1 translated to GNDS by FUDGE.]]></title>
      <body><![CDATA[See the endfCompatible section.]]></body>
      <endfCompatible><![CDATA[ ... ]]></endfCompatible></documentation>
    <temperature value="0" unit="K"/>
    <projectileEnergyDomain min="1e-5" max="1.5e8" unit="eV"/></evaluated>
  <crossSectionReconstructed label="recon" derivedFrom="eval" date="2016-11-06"></crossSectionReconstructed></styles>
```

The evaluated style is the one created by the evaluator, so it has the ENDF documentation. We have a much more expressive documentation markup, based on DataCite schema, but can't really use it for legacy data.

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Example files