Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Structural materials in the latest and next ENDF/B releases

G.P.A. Nobre[1], D.A. Brown[1] *et al.*

National Nuclear Data Center

[1]National Nuclear Data Center, Brookhaven National Laboratory

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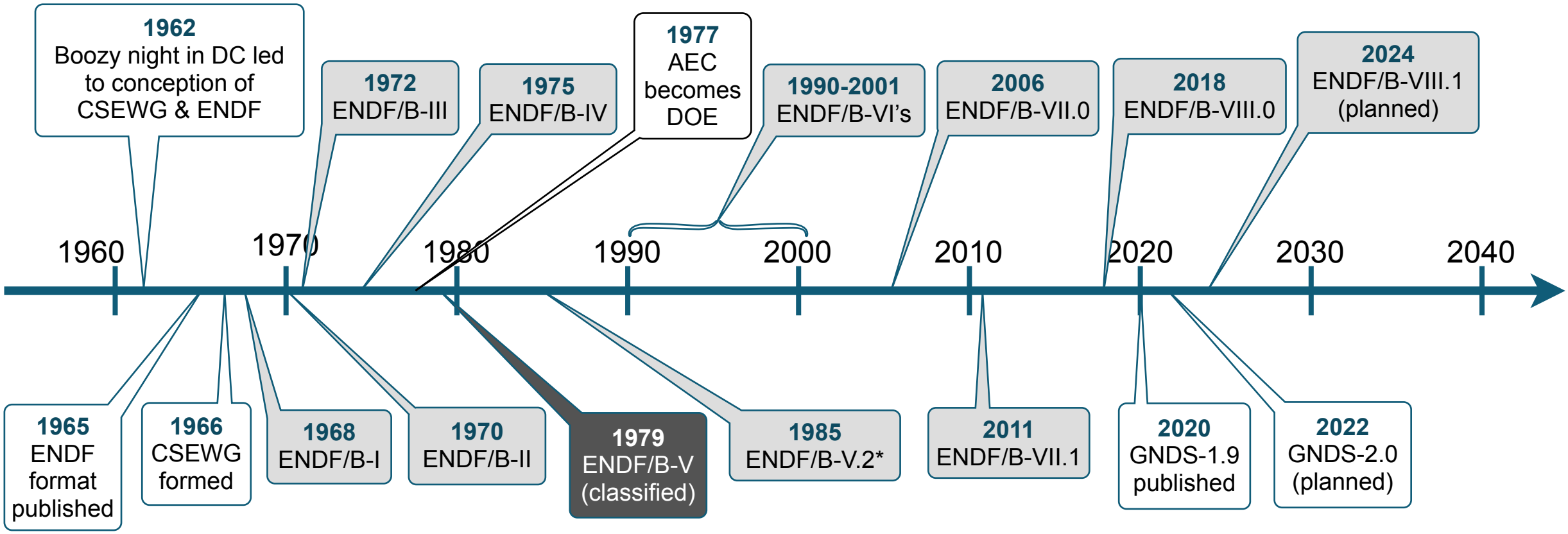
INDEN Consultants Meeting on Structural Materials
IAEA, Vienna, Austria
December 16-20, 2024

ENDF Timeline



* everybody's favorite release

Timeline courtesy of Dave Brown

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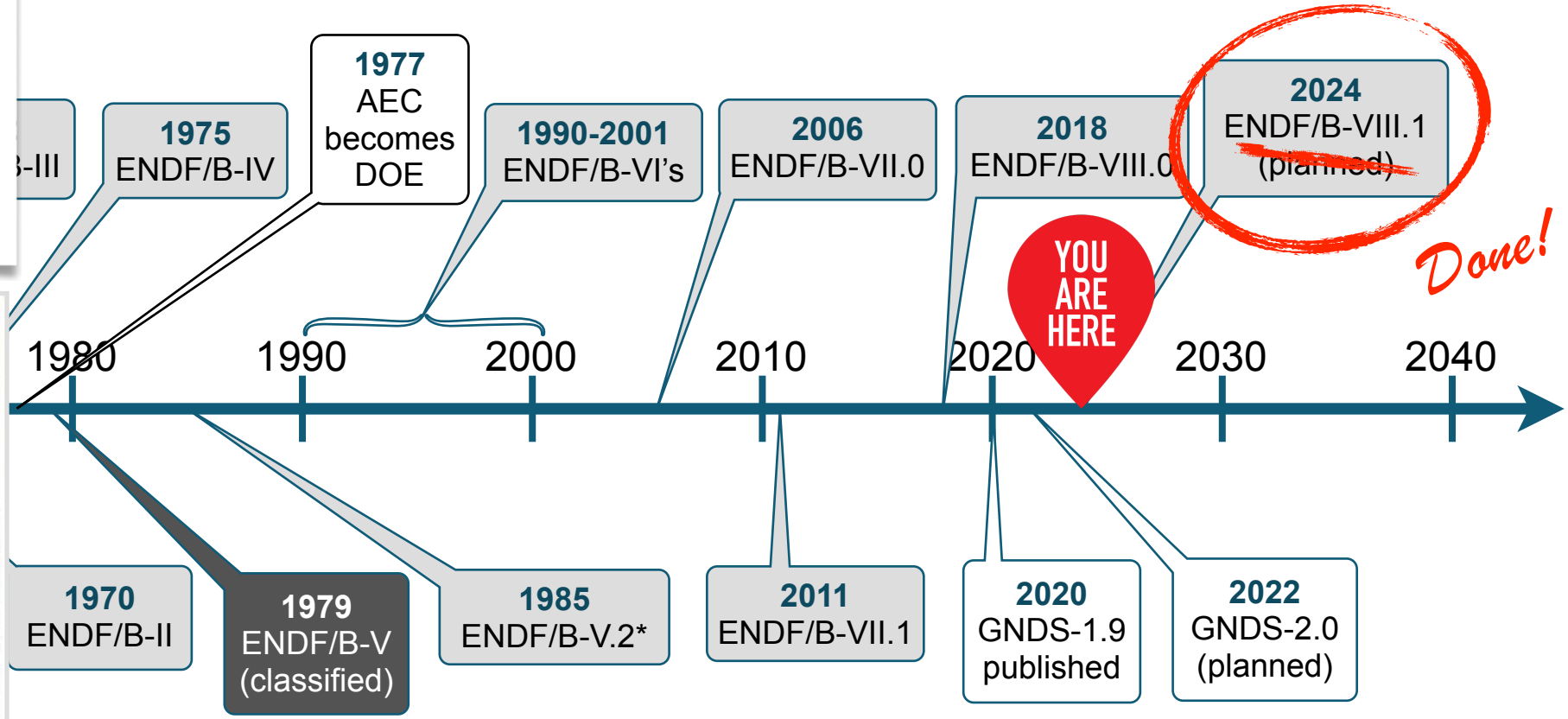

ENDF/B-VIII.1 was released on August 30th, 2024!

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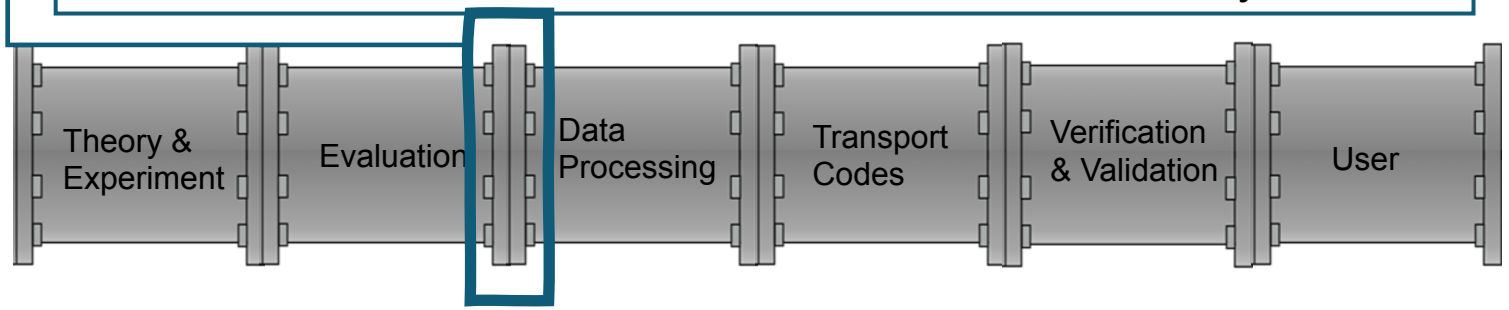
ENDF/B releases are a key interface in the improvement of the nuclear data that reaches the users' community!



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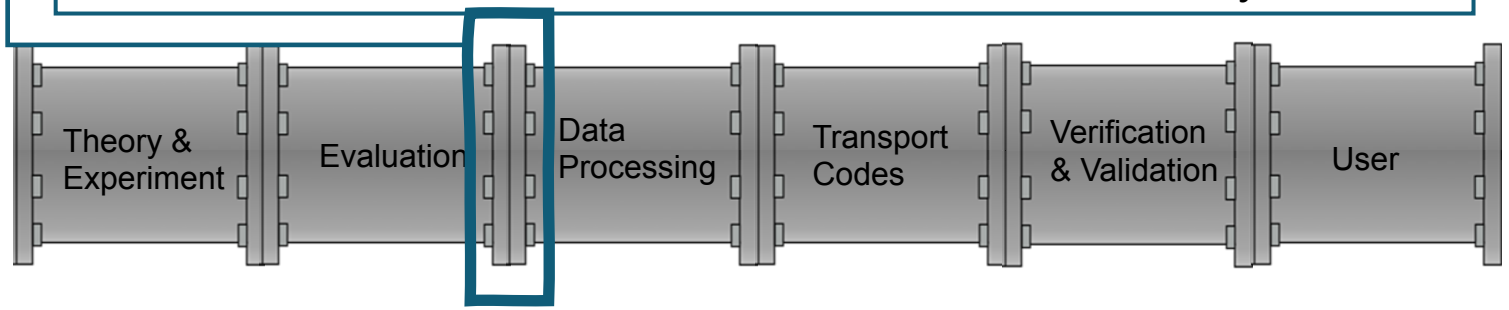

The previous release (VIII.0) was great, but…

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

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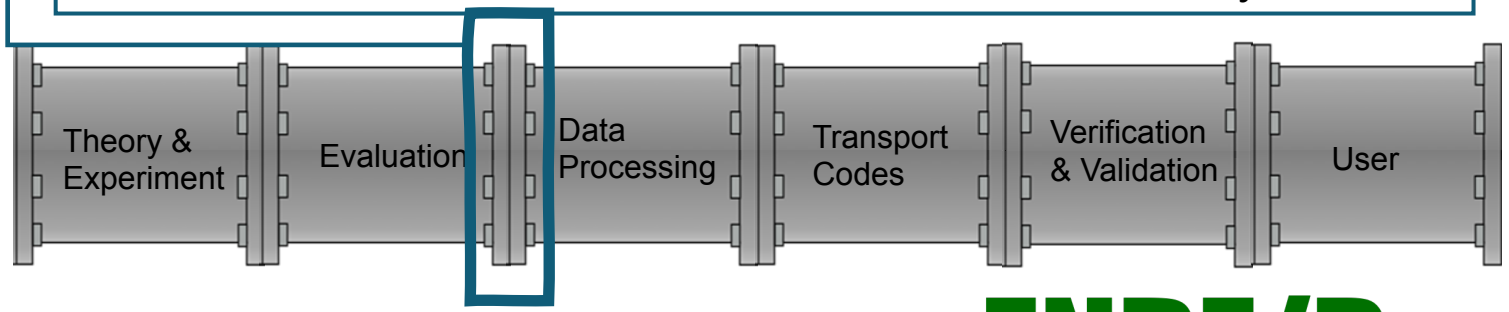

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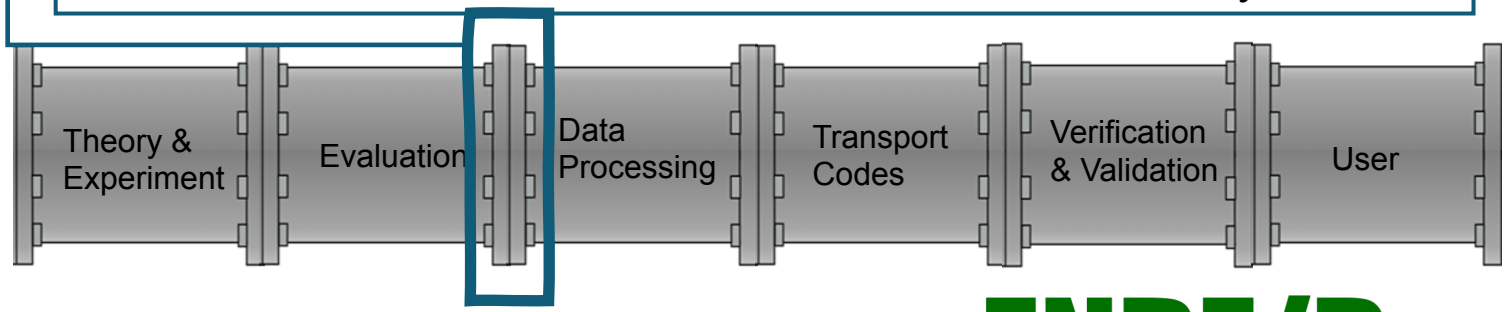

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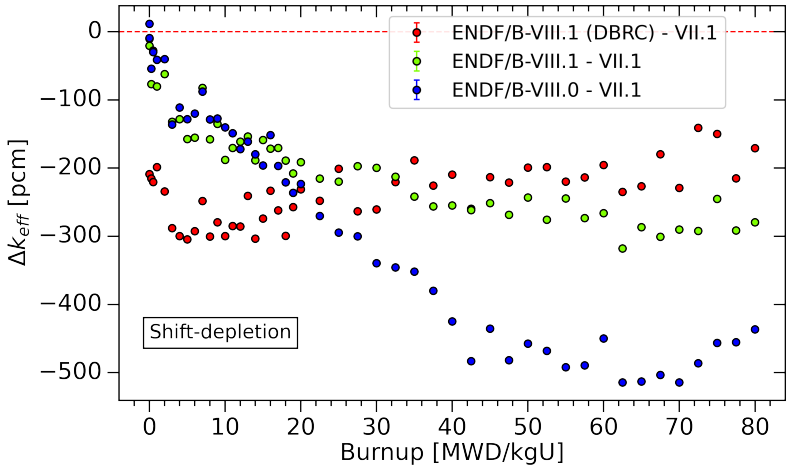

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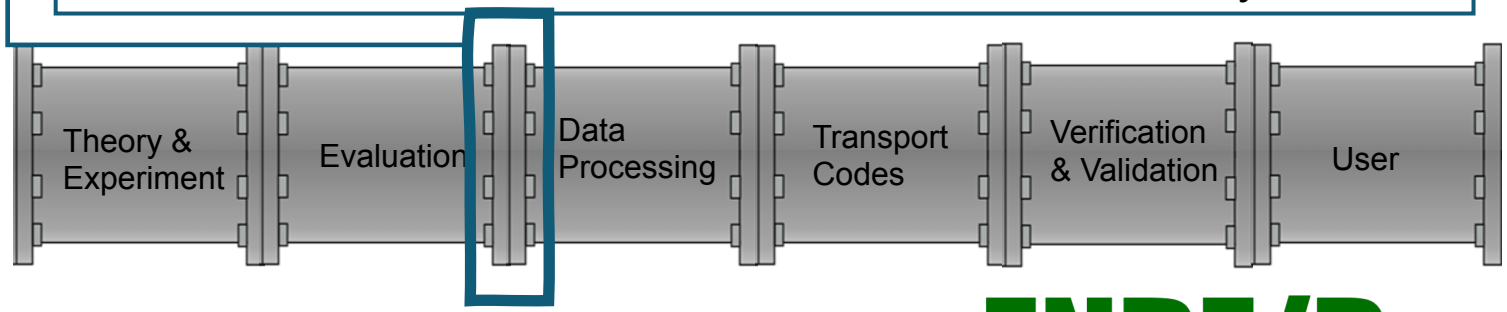

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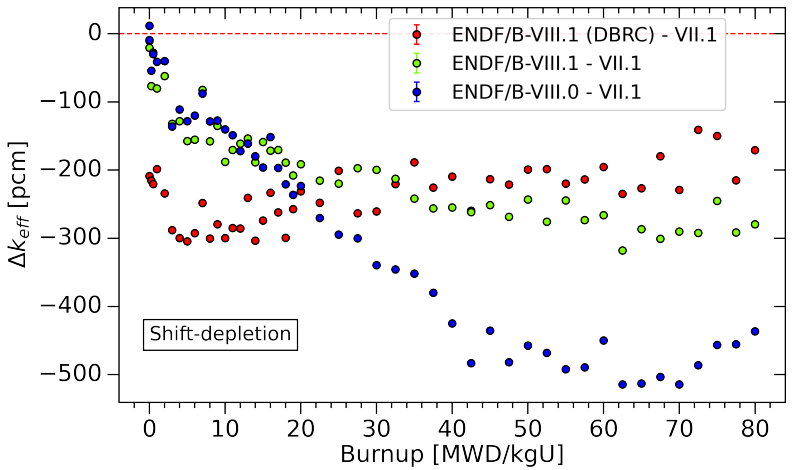

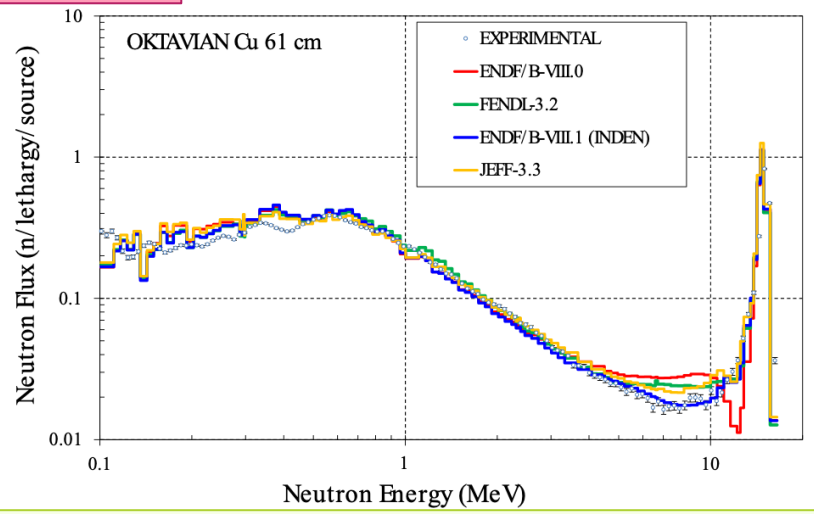

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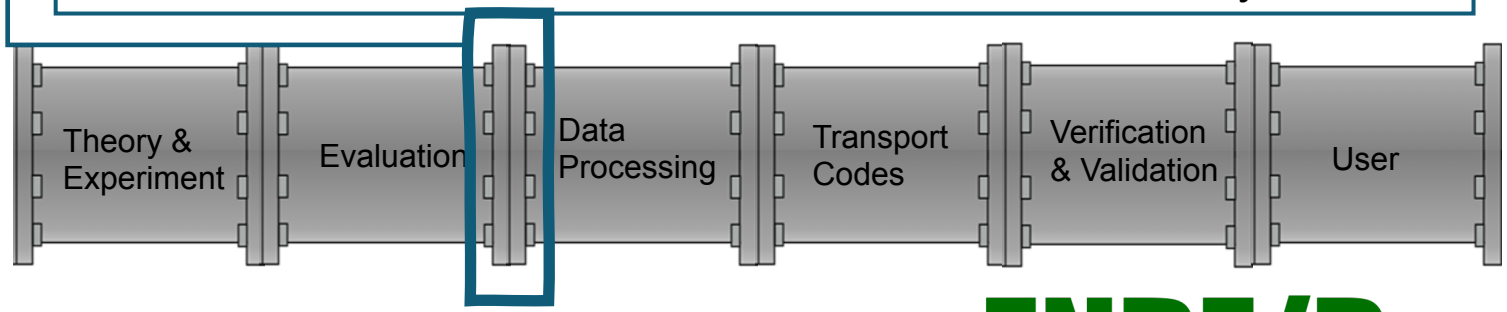

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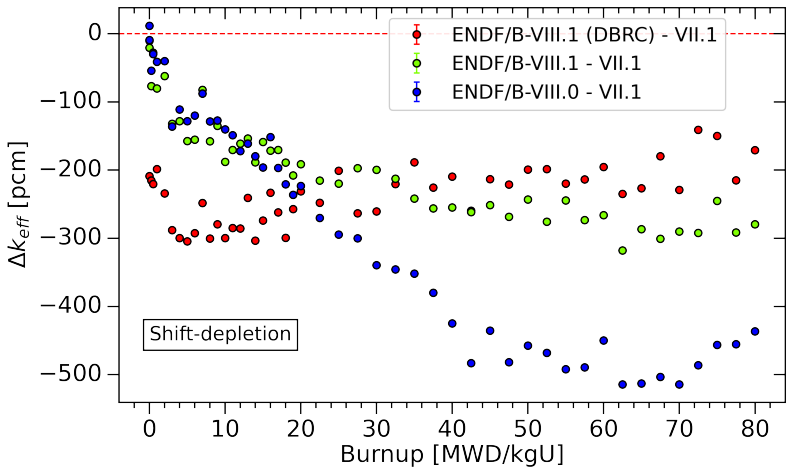
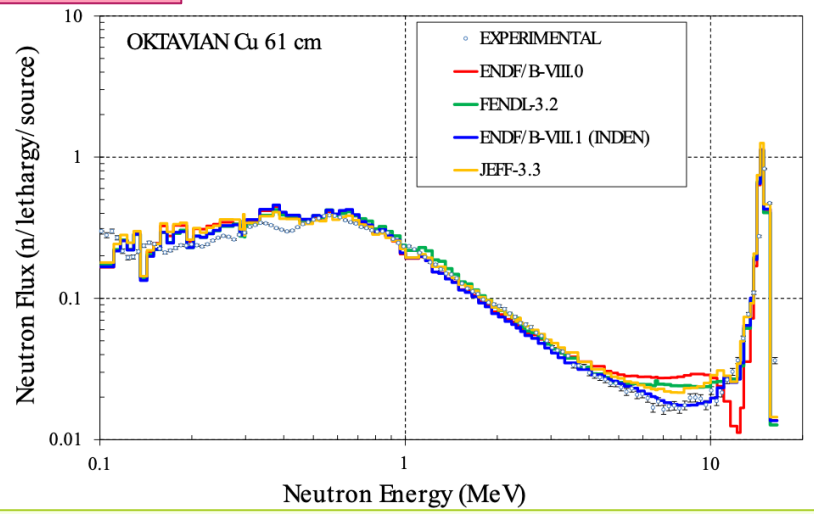
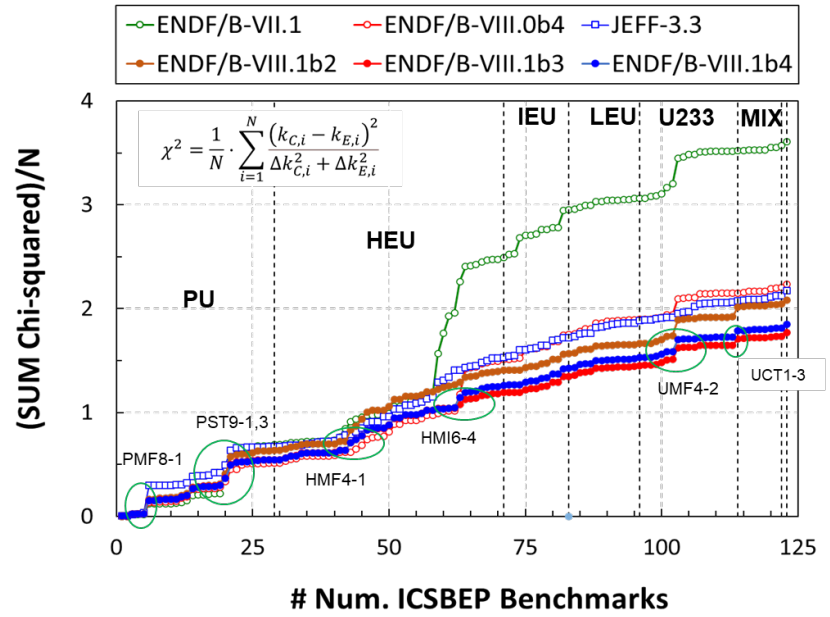




Mosteller's Suite - 123

Case HMF4.1: Δkeff EXP=30 pcm



VIII.1 dramatically improves depletion performance,…

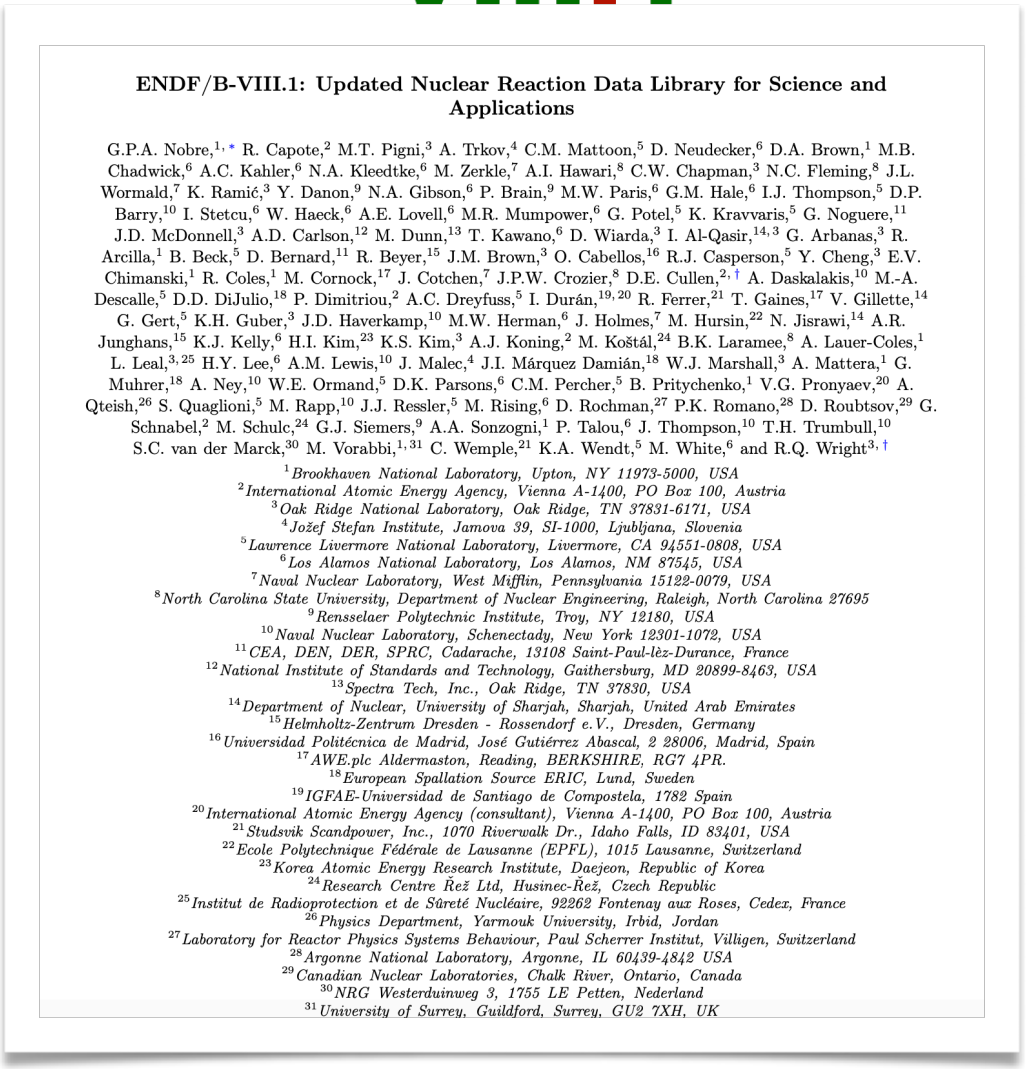
…performs much better in leakage and shielding experiments due to updates in Cu, Fe, Cr, Pb,…

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

ENDF/B-VIII.1 “Big Paper”

ENDF/B VIII.1

- Paper was reviewed by national labs for export control / public utterance: Green light!
- Secured OPEN ACCESS, supported by NCSP
- 220+ pages!
- We are only waiting for the final complete validation tables to add the appendix and then submit to Nuclear Data Sheets! We’re getting there!



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

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INDEN was an important component in ENDF/B-VIII.1

CONTENTS

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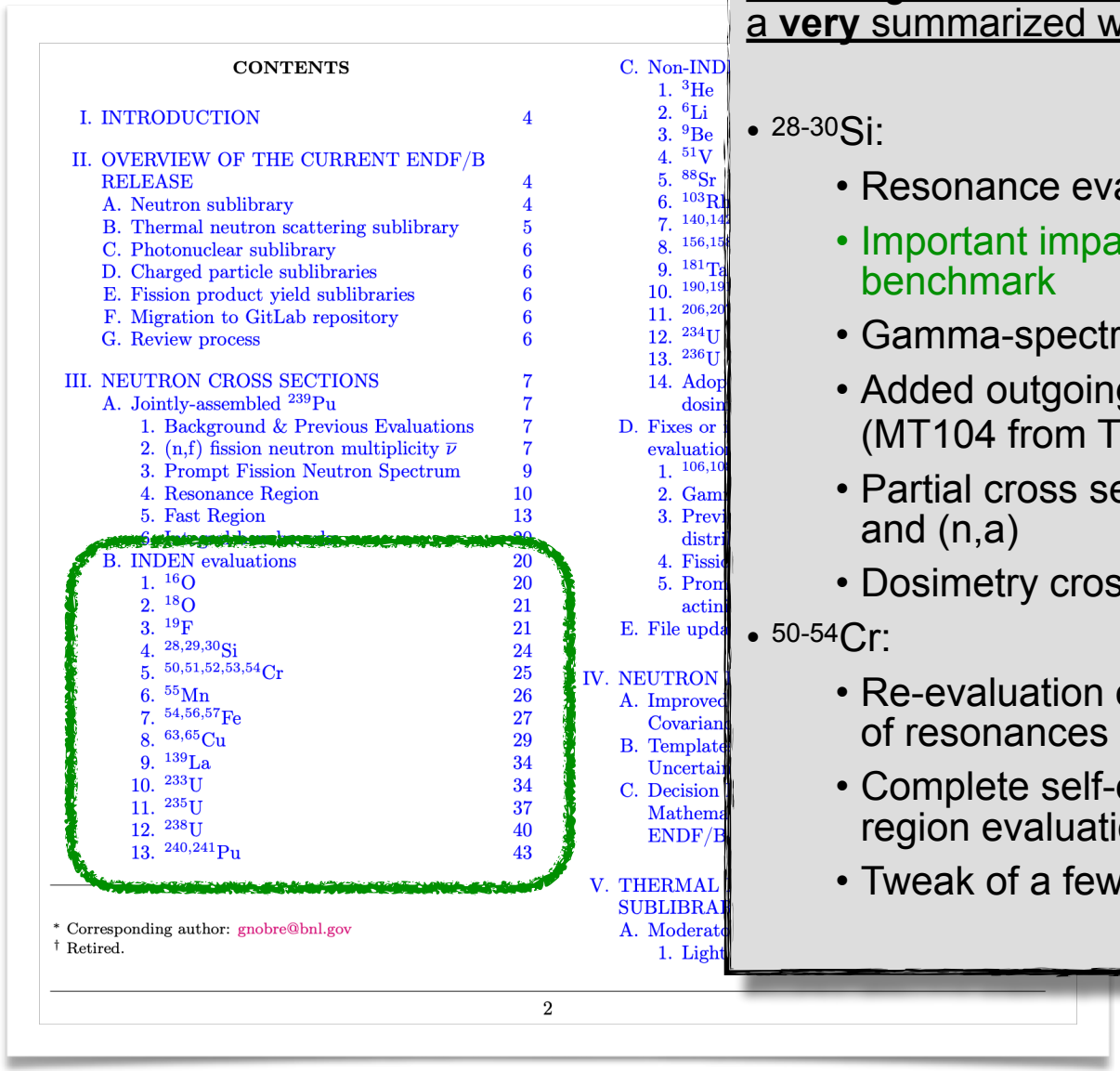

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Focusing on the structural materials, in a **very** summarized way:

- 28-30Si:
  - Resonance evaluations
  - Important impact on HMM-005 benchmark
  - Gamma-spectra fixes to ^{28}Si
  - Added outgoing distributions (MT104 from TENDL) for ^{28}Si
  - Partial cross sections for (n,p) and (n,a)
  - Dosimetry cross sections
- 50-54Cr:
  - Re-evaluation of 5-10 keV cluster of resonances in ^{50,53}Cr
  - Complete self-consistent fast-region evaluations
  - Tweak of a few ^{52}Cr resonances
  - Important impact in PMI-002 and other SS benchmarks
- ^{55}Mn:
  - Dosimetry cross sections
  - Thermal capture prompt gammas
  - Good performance on the Mn bath transmission
- ^{54,56,57}Fe:
  - Important targeted fixes to VIII.0
  - Fixed leakage performance
  - Dosimetry cross sections
- ^{63,65}Cu:
  - Resonance evaluation in select region
  - Angular distributions impacting integral benchmarks
  - Dosimetry cross sections
  - Impact on benchmarks with Cu reflectors

See Roberto's talk tomorrow

What's next?
Or… Why talk about ENDF/B-IX.0?

ENDF release

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BTW, there will be updates to standards, so

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

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- Tools are in place for a relatively quick turnaround for a IX-Beta1
- We, as a collaboration, should take the time to plan out what we want to develop for IX.0
- INDEN had a huge impact in VIII.1: Now what INDEN should focus on to also have a big impact in IX.0?

ENDF release

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BTW, there will be updates to standards, so

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

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Aiming to start discussion on which structural materials INDEN could/should focus for IX.0

<u>From VIII.1, it seems:</u>

- Cu and Pb need some post-VIII.1 care
- Cr will likely be updated following new resonance measurements
  - I hope to take the opportunity to finally do consistent fast-region covariances
- Fe will always need to be tweaked
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From 2024 CSEWG meeting:

- Many talks began to lay out plans
- Roberto gave a great talk on planned work for Fe, Cr, Ni (hope to hear more about it this week!)
- Multiple talks about Zr (evaluation and measurements)

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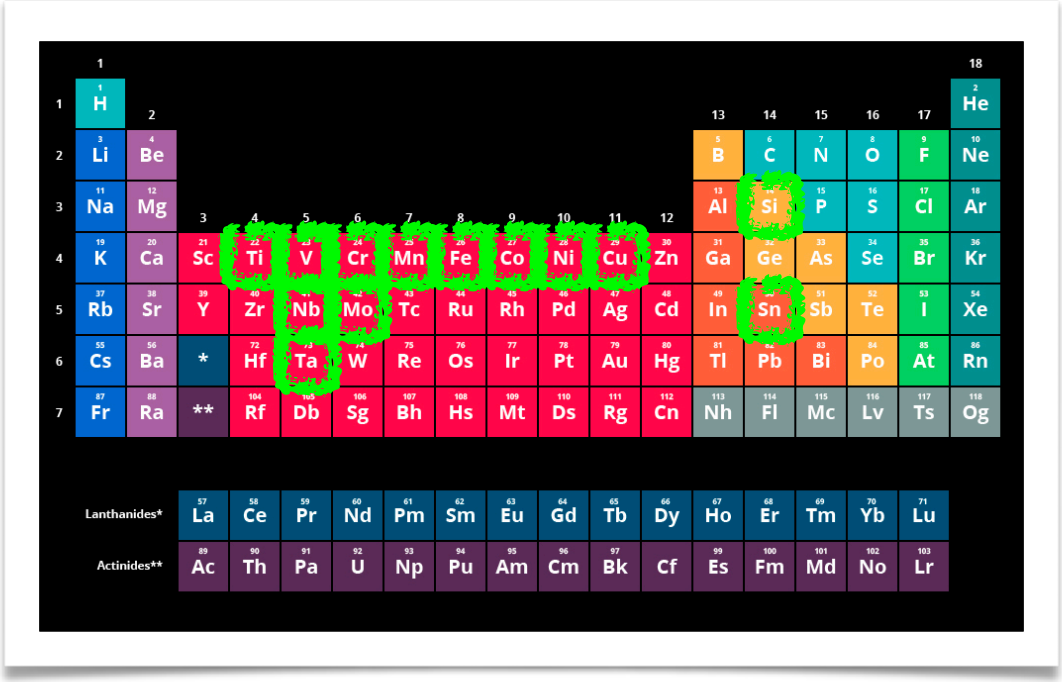
Talking about Zr… WPEC SG-53

- During the WPEC meeting in May 2024, we proposed a sub group to converge efforts and to collaborate on Zr evaluations
- Plan is to:
  - Focus on ^{90,91}Zr, for which there are recent resonance data and perform new resonance evaluations
  - Evaluate fast region with EMPIRE, which could be somewhat easily extended to minor isotopes
  - PhD thesis of Greg Siemers (RPI)
  - Leveraging previous fruitful collaboration among BNL/IAEA/JSI/ORNL/RPI…
- Was formally approved in August: “SG53: Stable Zirconium Evaluations and Validation”
- Trying to organize a kickoff meeting
  - Some challenges due to secretariat change in NEA
  - Hope to have a half-day meeting in the end of January

Other potential candidates

- Lot of attention is turning towards fusion:
  - Finalizing a summary paper on 2024 talk at WANDA
  - NDIAWG FOA call
  - Magnet components: Nb, Sn, …?
  - Vessel/blanket: Ti, V, …?



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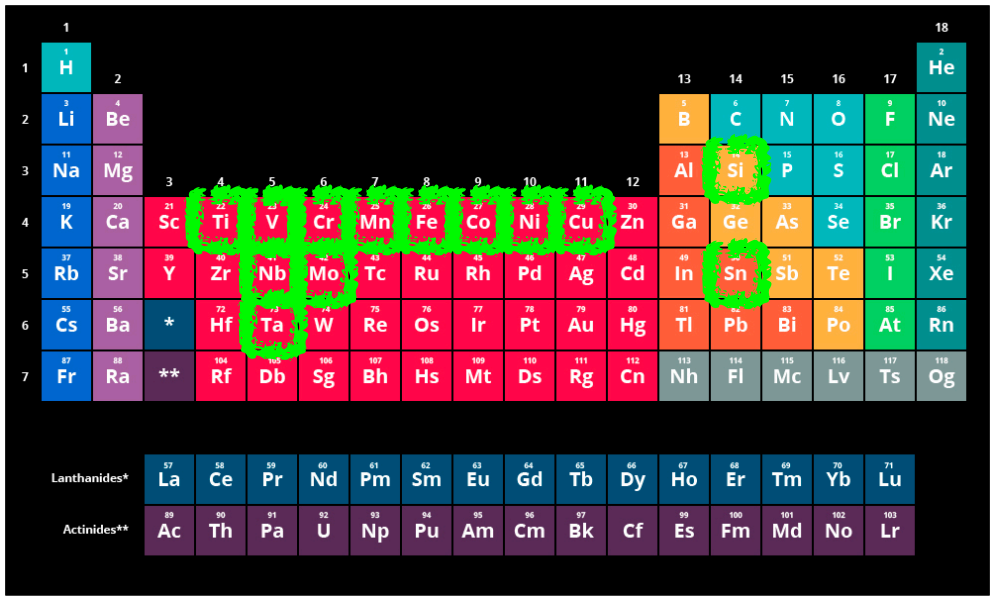
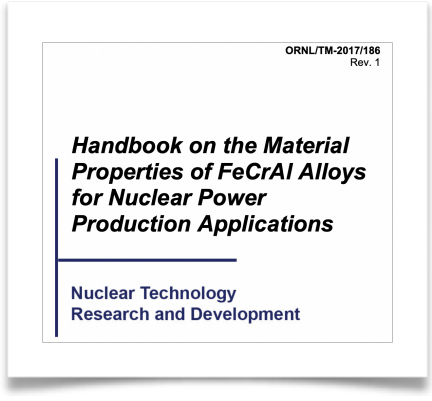


- ^{27}Al
  - Many known issues
  - Lastly really updated in 1998
  - Has low-fidelity ang. dist.
  - Many relevant new data since then for (n,2n), (n,a), (n,2p), partial cross sections, angular distributions, …
  - FeCrAl alloys for nuclear power applications
- Ni
  - Next-order component in SS
  - Many exp. data newer that last complete evaluation
- What else???



Plans for 2025

- Planning for a Hackathon late Summer at ORNL
  - There are many remaining bugs in the library
  - With the push for the final release, Hackathon was low-priority
  - This is a good time to do it:
    - After VIII.1 and before IX-Beta1
- Release a Beta1 in late August

ENDF/B
IX.0-β1

Conclusion

- INDEN was incredibly successful and highly impactful for the ENDF/B-VIII.1 cycle
  - That was true for actinides, but very much as well for structural materials
  - The same argument applies to JEFF, JENDL, etc.
  - This happened because we tackled the right relevant problems
- How do we keep INDEN structural materials impactful for ENDF/B-IX.0?

ENDF/B VIII.1

ENDF/B IX.0-β1

Acknowledgements

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WPEC SG-53

Slides from SG-53 proposal

HPRL

Request ID	110		Type of the request	Special Purpose Quantity	
Target	**Reaction and process**	**Incident Energy**	**Secondary energy or angle**	**Target uncertainty**	**Covariance**
40-ZR-90	(n,2n) SIG/SPA	239Pu(n,f)		3	Y
Field	**Subfield**	**Created date**	**Accepted date**	**Ongoing action**	**Archived Date**
Fission	Dosimetry	26-MAR-18	06-JUN-18		

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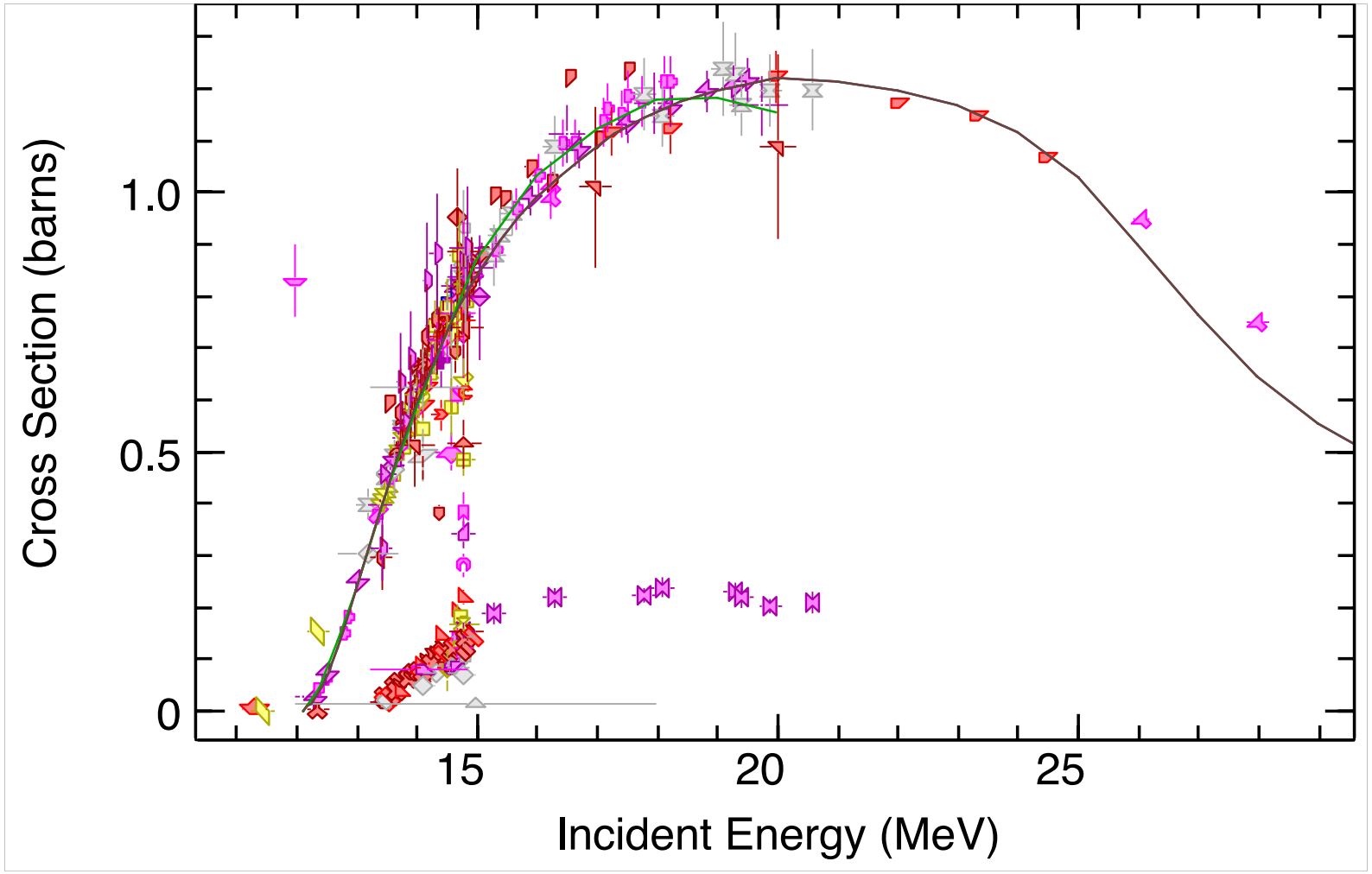

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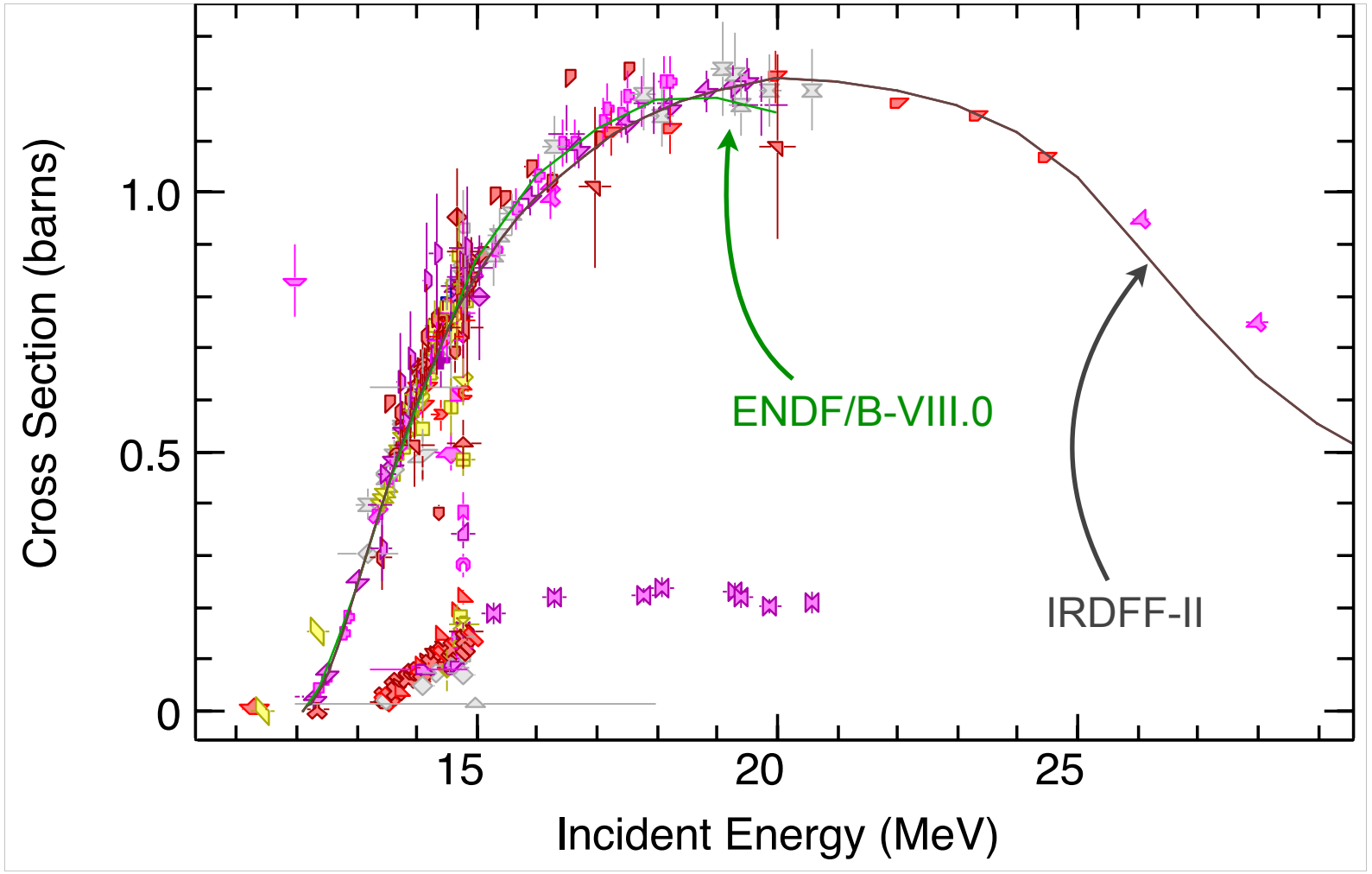
Field	**Subfield**	**Created date**	**Accepted date**	**Ongoing action**	**Archived Date**
Fission	Dosimetry	26-MAR-18	06-JUN-18		



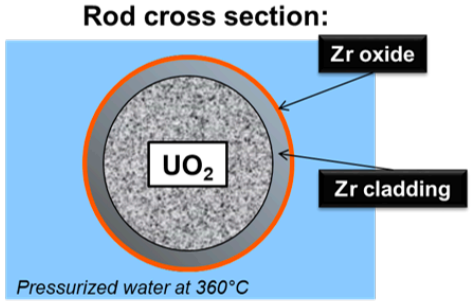
- ^{90}Zr(n,2n) from IRDFF-II is yet to be incorporated into ENDF/B
- When doing so, consistency among all reaction channels needs to be ensured

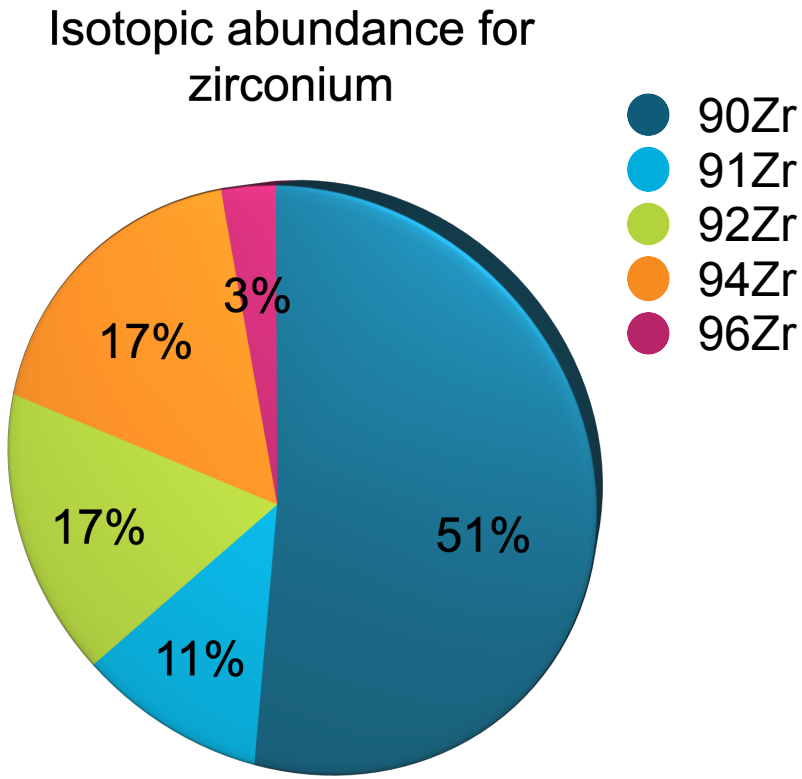
Next evaluations planned at BNL

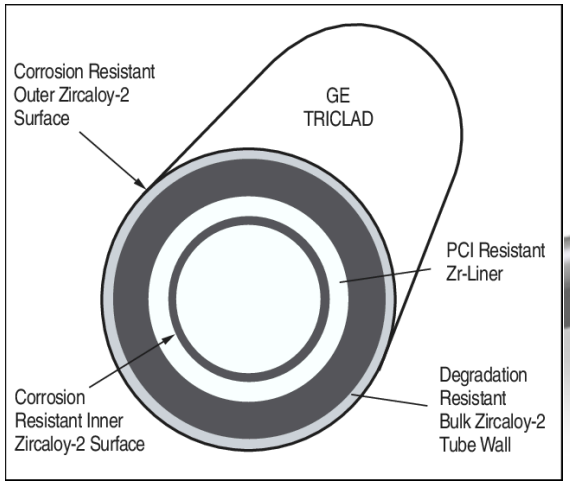
- After CIELO Fe evaluation, we did a study of which isotopes had measured data that were more recent than the last evaluation (at that time)
- Focusing on structural materials, we came up with a list of potential priorities for re-evaluations: Cr, Al, Zr, Ni, Ti, V, Co…
- Those conclusions remain more or less valid
- After finishing Cr, the natural next one would be Zr:
    - Improvement in benchmarks
    - Leveraging collaboration and experience gained with Fe, Cr
        - Resonances from ORNL
        - Fast and file assembly from BNL
        - Strong collaborations with IAEA; validation by JSI

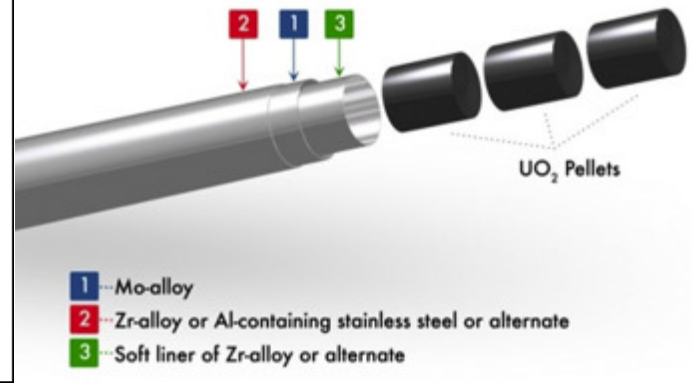
Why Zr?

- Other structural materials have been recently re-evaluated:
  - Fe (IAEA, JSI, BNL)
  - Cr (BNL, ORNL, IAEA, JSI)
  - Cu (LANL,ORNL)
- Applications:
  - Cladding
  - Zircaloy
  - Zirconium-Niobium alloy
  - Zirconium is used in fuel rods cladding due to its corrosion-resistance and low thermal neutron absorption cross-section. It is also considered in advanced reactor design studies as a moderator (in the form of zirconium hydride) and as inert matrix fuel material. The ENDF/B-VI.8 files evaluated in the 1970's relied heavily on experimental data and lacked quantities such as double-differential cross sections and gamma production.









Brookhaven National Laboratory

Critical benchmarks sensitive to Zr

From DICE search, critical/subcritical benchmarks sensitive to Zircalloy and Zirconium-Niobium Alloy

- LCT-015-001 — LCT-015-165
- LCT-020-001 — LCT-020-007
- LCT-021-001 — LCT-021-006
- LCT-026-001 — LCT-026-006
- LCT-030-001 — LCT-030-012
- LCT-031-001 — LCT-031-006
- LCT-036-001 — LCT-036-069
- LCT-053-001 — LCT-053-014
- LCT-060-001 — LCT-060-026
- LCT-061-001 — LCT-061-010
- LCT-064-001 — LCT-061-007
- LCT-070-001 — LCT-070-012
- LCT-071-001 — LCT-071-004
- LCT-072-001 — LCT-072-009
- LCT-073-001 — LCT-073-014
- LCT-075-001 — LCT-075-006
- LCT-079-001 — LCT-079-010
- LCT-081-001
- LCT-085-001 — LCT-085-013
- LCT-087-001 — LCT-087-025
- LCT-094-001 — LCT-094-011
- LMT-001-001 — LMT-001-005
- LMT-002-001 — LMT-002-006
- LMT-003-001 — LMT-003-015
- LMT-005-001 — LMT-005-012
- LMT-006-001 — LMT-006-010
- LMT-007-001 — LMT-007-012
- UCT-001-002 — UCT-001-004
- UCT-004-001
- MCT-002-001 — MCT-002-006
- MCT-004-001 — MCT-004-011
- MCT-006-001 — MCT-006-050
- MCT-007-001 — MCT-007-027
- MCT-008-001 — MCT-008-028

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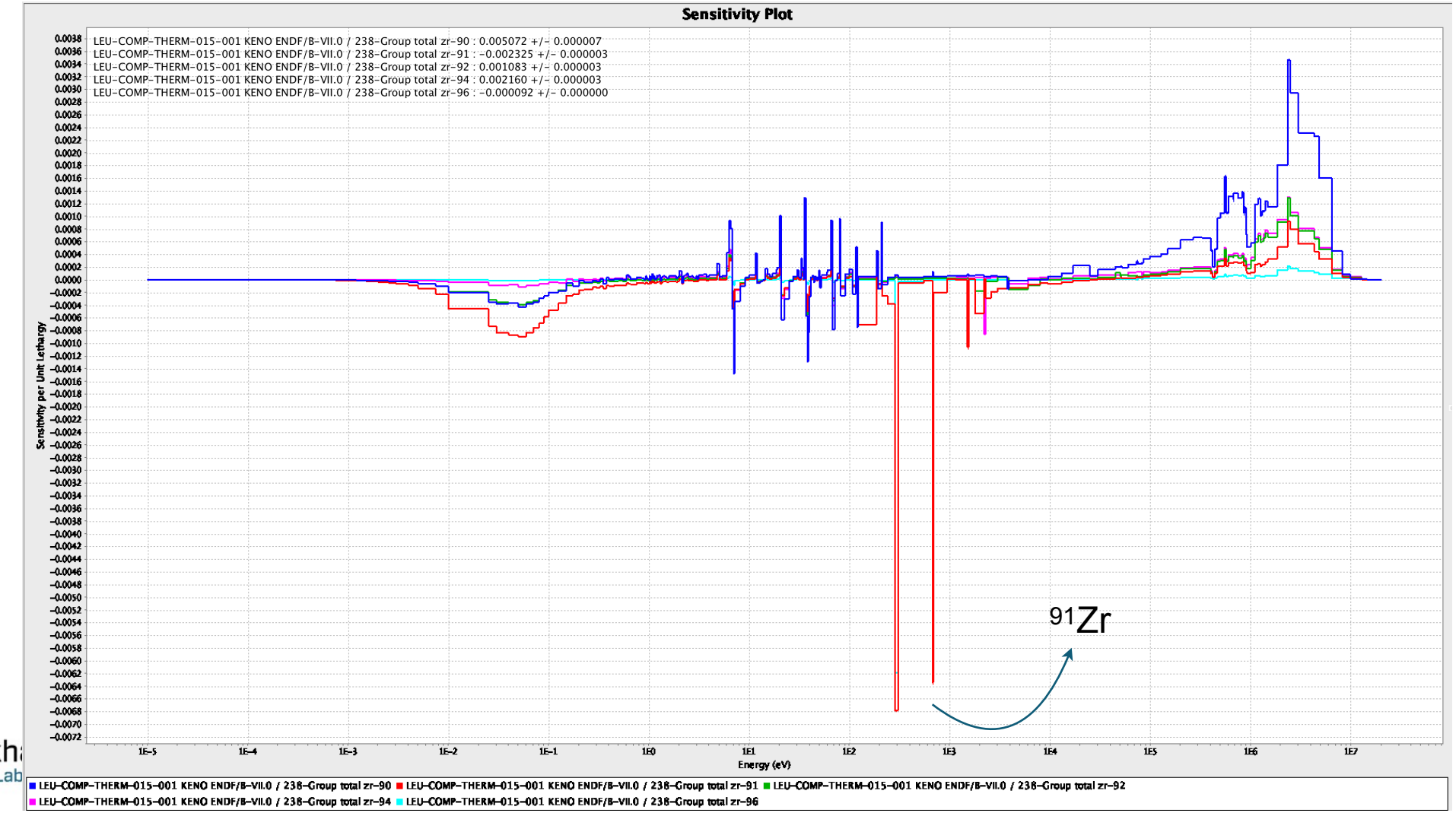

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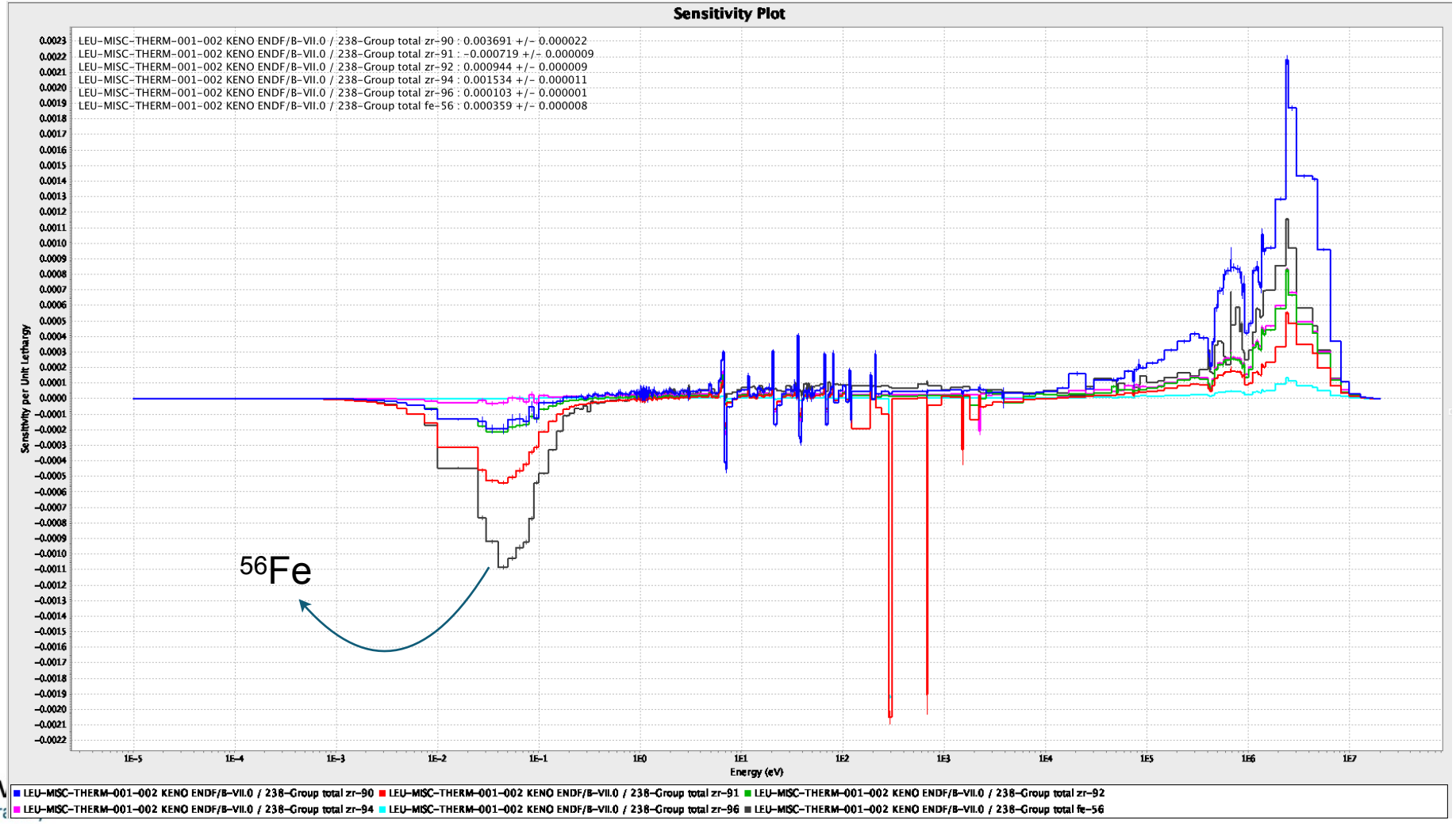

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    - New release of EMPIRE coming soon: which should make the life of a beginner a bit easier…