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Title: Validating ENDF/B-VIII.1beta2 with LLNL pulsed-sphere and EUCLID experiments

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Validating ENDF/B-VIII.1beta2 with LLNL pulsed-sphere and EUCLID experiments

D. Neudecker

August, 2023

LA-UR-23-

Thanks to the XCP-5 nuclear data team for processing and V&V of nuclear data, and Stephanie Frankle for LPS input decks.
Thanks to the EUCLID team for all EUCLID-related results.

LPS and EUCLID experiments are not benchmarks (yet). However, they can provide valuable input.

LPS allow us to validate nuclear data up to 15 MeV. They test scattering and fission data. They have incomplete uncertainties from 2-8%. I take note when:

- I see C/E differences above the peak and before late times => 20%.
- Simulated results between libraries change by => 20% without a good explanation.

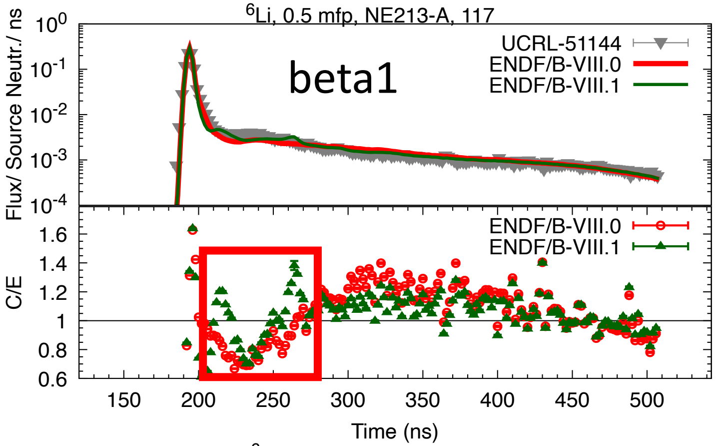
EUCLID experiments were optimized to explore compensating errors between ^{239}Pu scattering, fission, and capture data in the fast range via two configurations and several responses. Their uncertainties are preliminary and it is not an ICSBEP benchmark. We can explore:

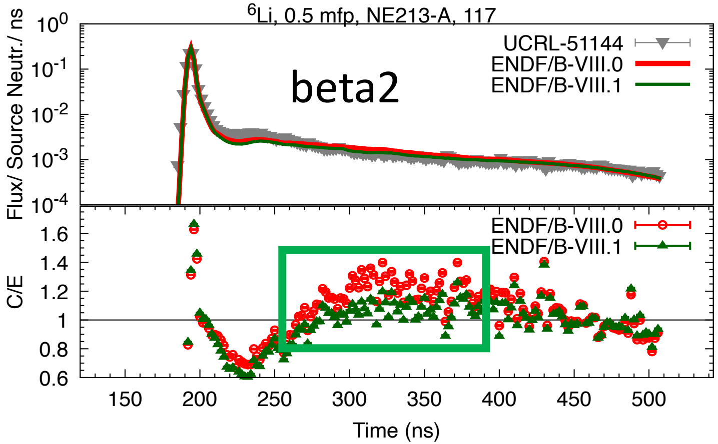
- Performance across two different configurations.
- Understand especially impact of inelastic and elastic nuclear data.

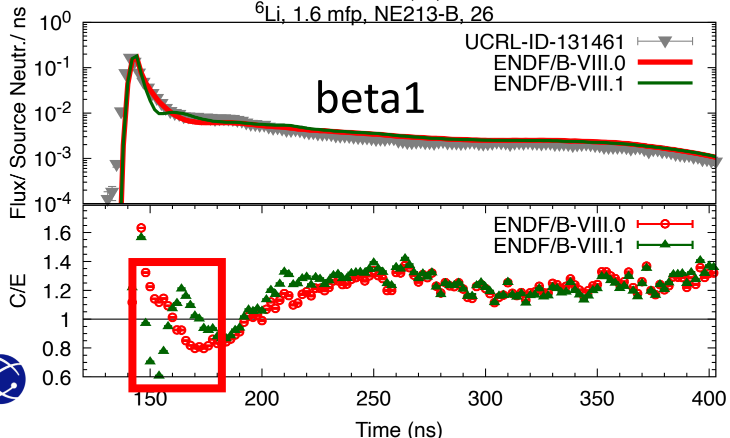
Noteworthy changes from VIII.1beta0/1 -> VIII.1beta2

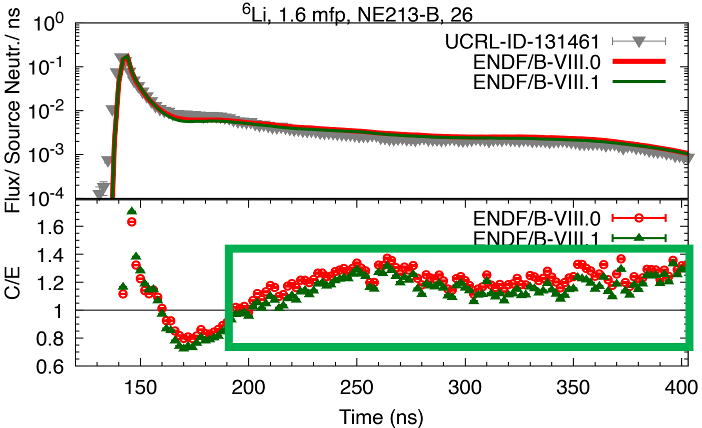
- ^{6}Li – fixed (also seen in ^{7}Li sphere)
- ^{9}Be: I would recommend studying what nuclear data led to an increase in C/E right after peak.
- Pb isotopes: I am concerned about new structures introduced after peak.
- ^{239}Pu: Is it worth improving right now?

^{6}Li: problem in beta1 nuclear data was fixed. beta2 better than VIII.0.

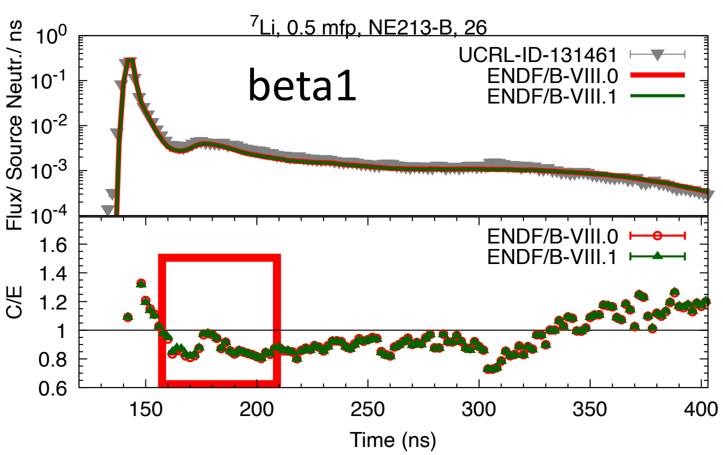


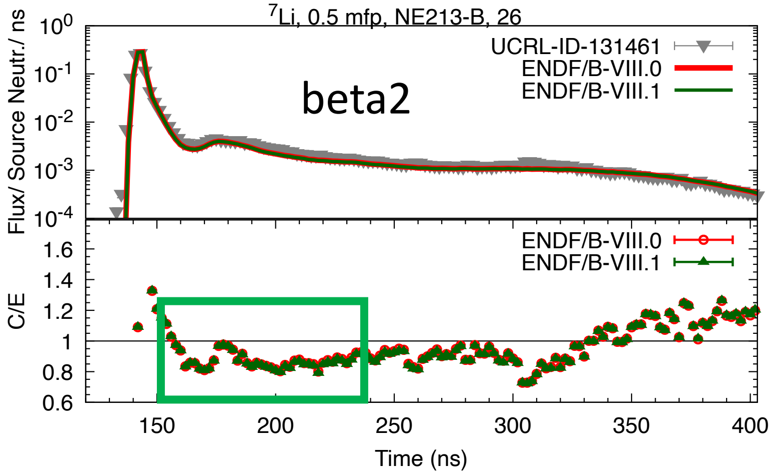






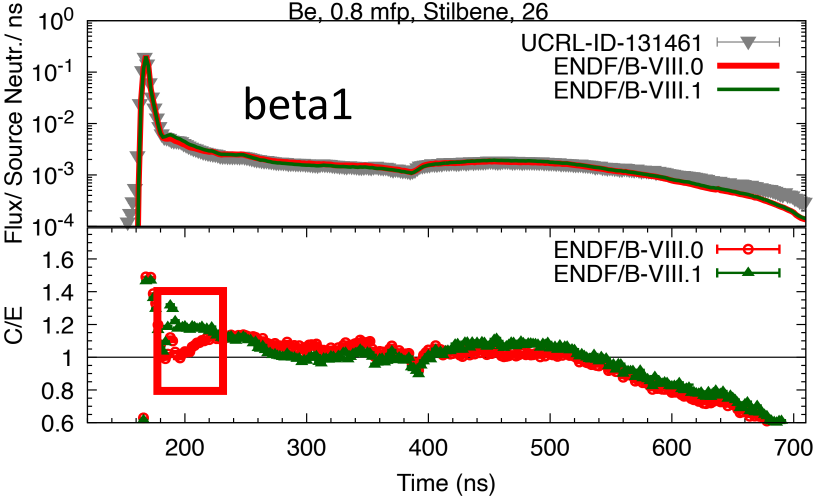
^{7}Li: problem in ^{6}Li beta1 nuclear data was fixed, can be also seen in ^{7}Li LPS (LPS has small ^{6}Li content)

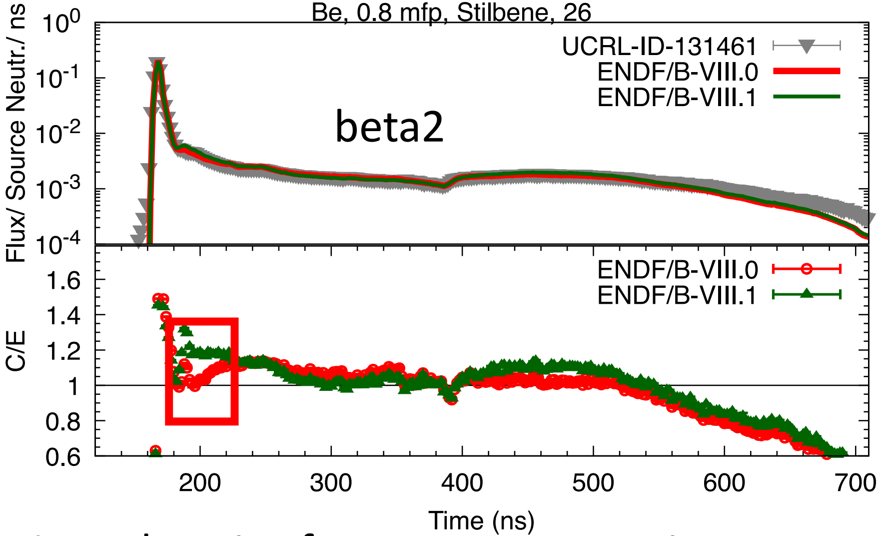


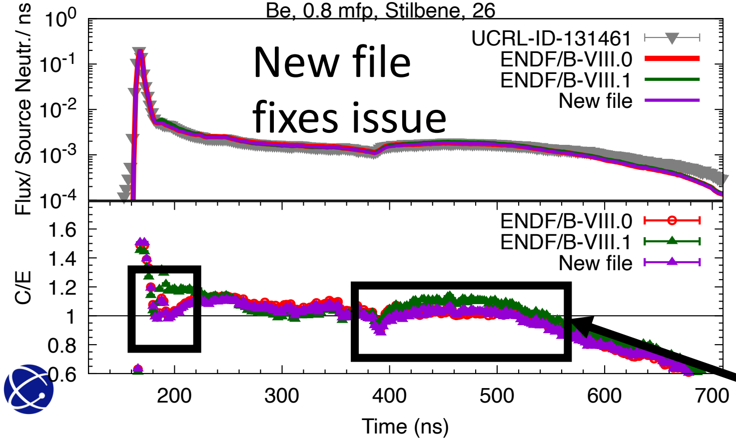


Bottom line: issue in ^{6}Li VIII.1beta1 fixed for beta2 from view-point of LPS.

^{9}Be: ENDF/B-VIII.0 better than beta1/2 right after elastic peak.







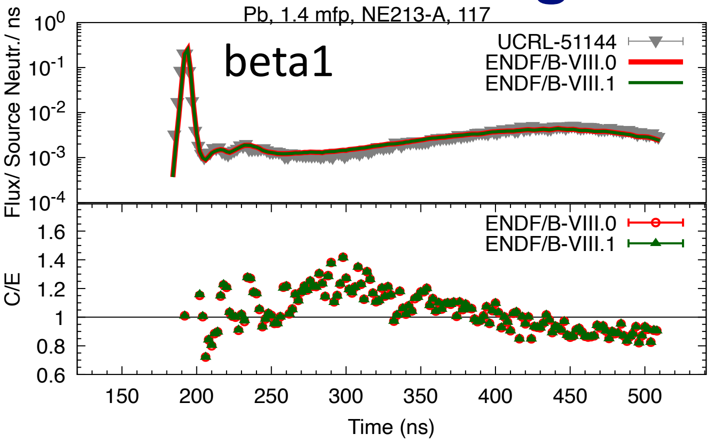
Less than 1 mfp -> on average < 1 scatter.

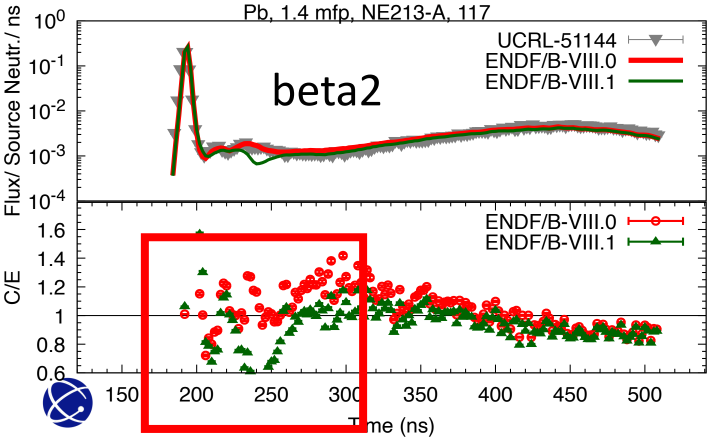
Changes could come from:

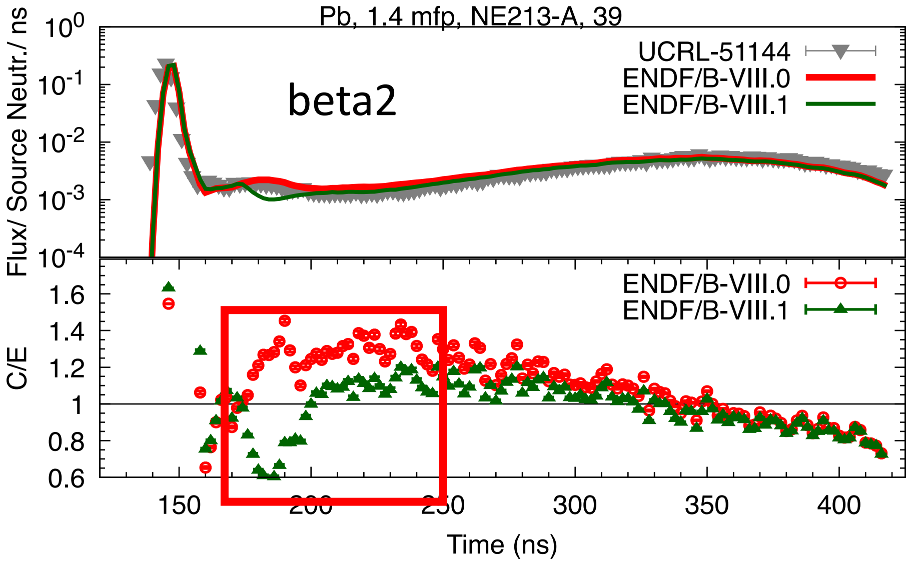
- (n,2n) cs/ angular distribution,
- elastic angular distribution, or
- new (n,inl) cs/ angular distribution (small).

Changes came from (n,2n) cs.

Significant structures introduced by beta2 in Pb LPS that need to be investigated.



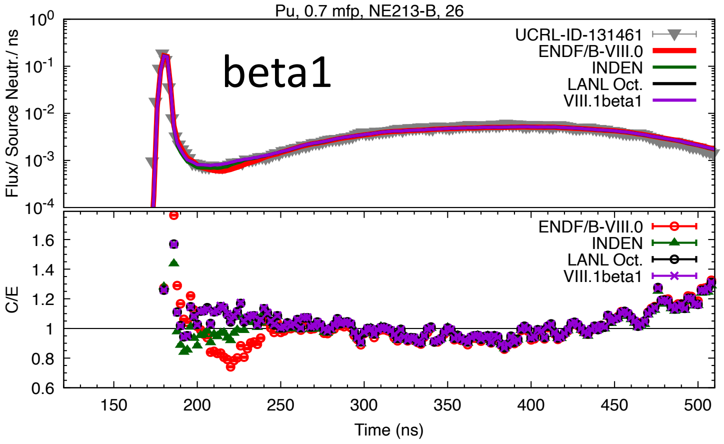


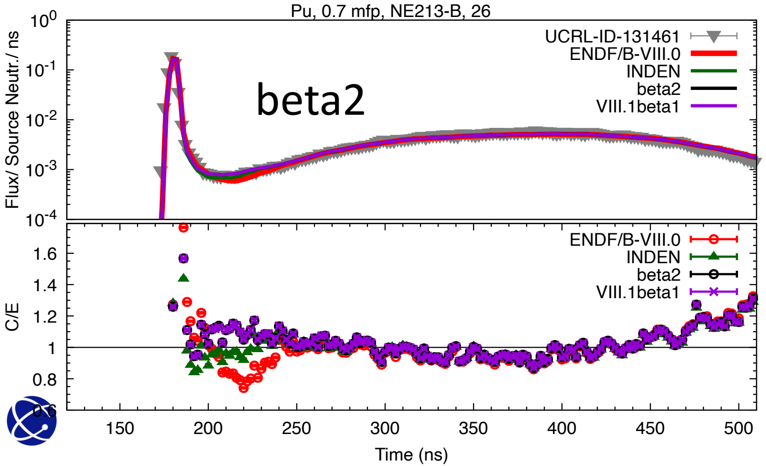


Changes could come from $^{206-208}$Pb :

- (n,2n) cs/ angular distribution,
- elastic angular distribution, or
- (n,inl) cs/ angular distribution (comparably small).

^{239}Pu: large changes coming from inelastic scattering.





INDEN … from ENDF/B-VIII.1beta0
LANL Oct … in-house LANL version that provided inelastic cross sections and angular distributions now in ENDF/B-VIII.1beta1

VIII.1 Beta1:

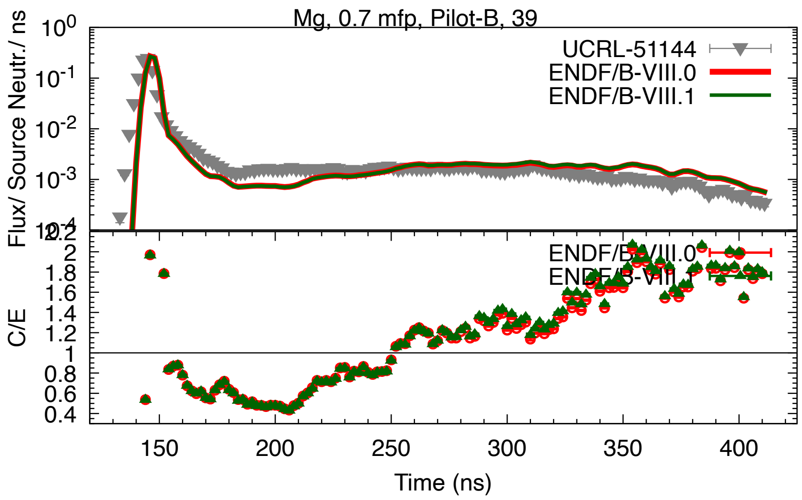
- (n,2n), (n,gamma) … INDEN
- (n,inl), (n,el) … LANL Oct.
- Fission source term … same as for ENDF/B-VIII.1beta0

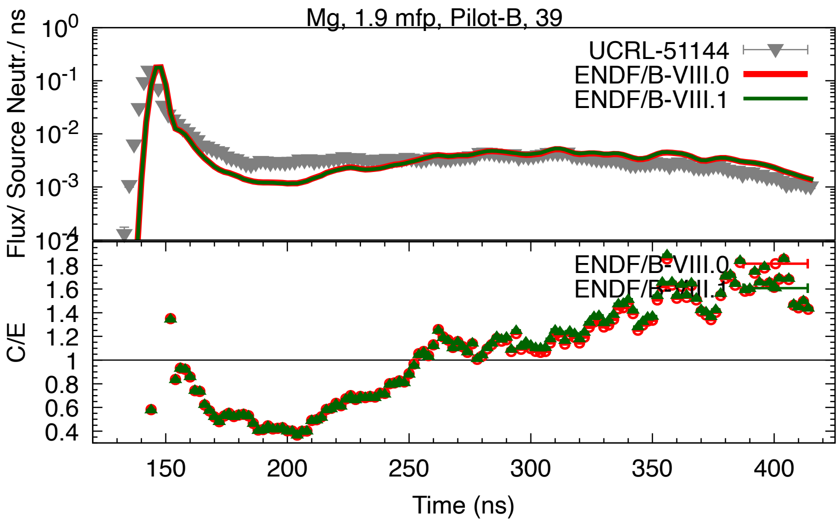
The changes we see are coming from inelastic cross sections and angular distributions (MF={3,4,6}). The continuum spectrum could play a large role.

Small to medium-sized changes

- Mg
- Concrete: changes in ^{16}O and Si lead to slight changes in LPS but all fine

Mg: The changes are affecting late times (inelastic cs/ ang. dist. changes?). The predictions of Mg LPS is bad.



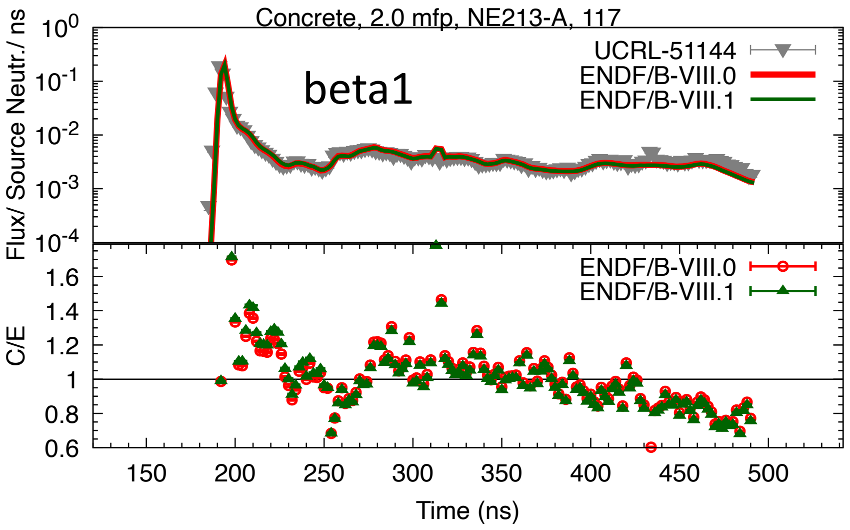


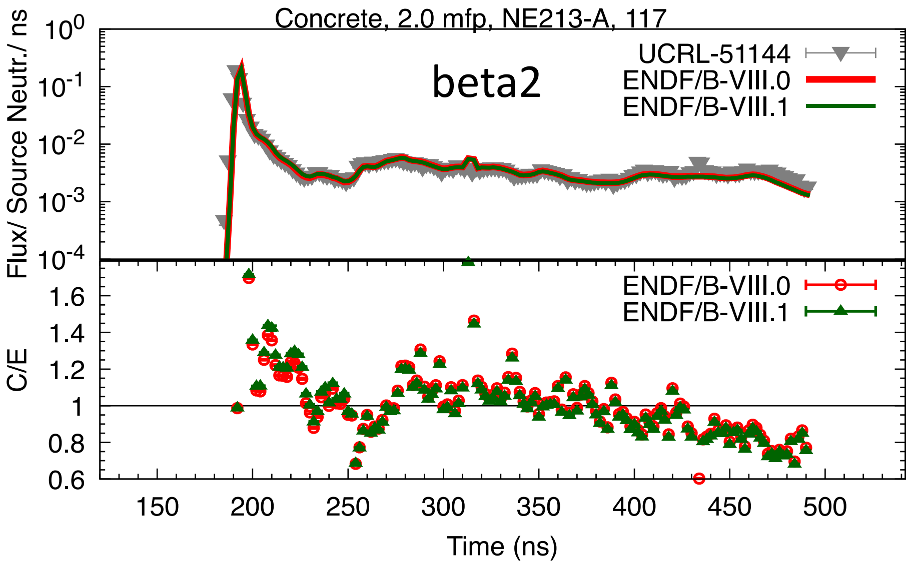
After ND that matter most for ^{24}Mg:

- MF=4, MT2,
- MF={3,4}, MT=51, continuum.

Can we fix that?

Concrete: changes in ^{16}O and Si lead to slight changes in LPS but well within exp. unc.





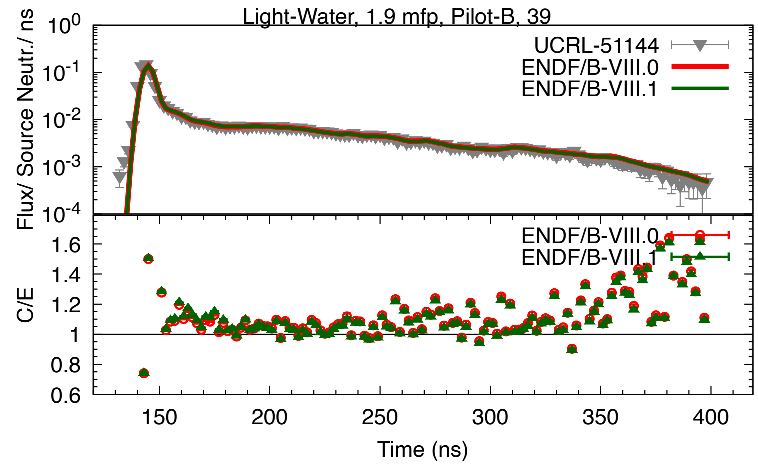
Beta1: 16O changes; beta2: Si changes.

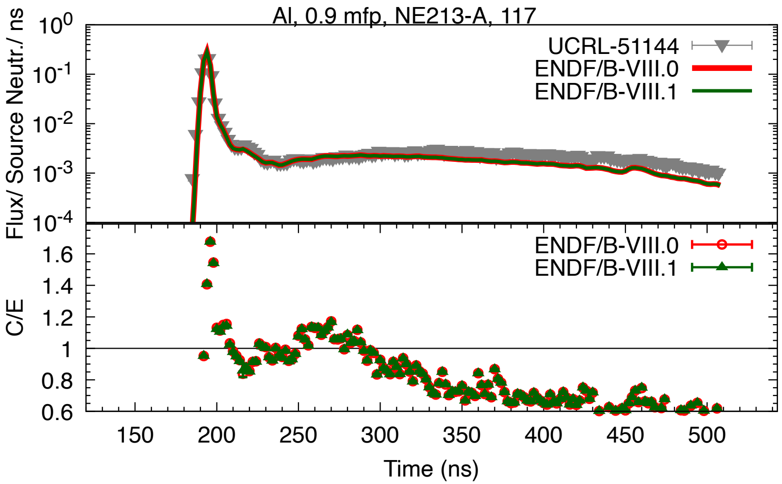
While C/E gets slightly worse for changes in both, 16O and Si. These changes are well within exp. unc. and, hence, no strong indication for a need to fix data.

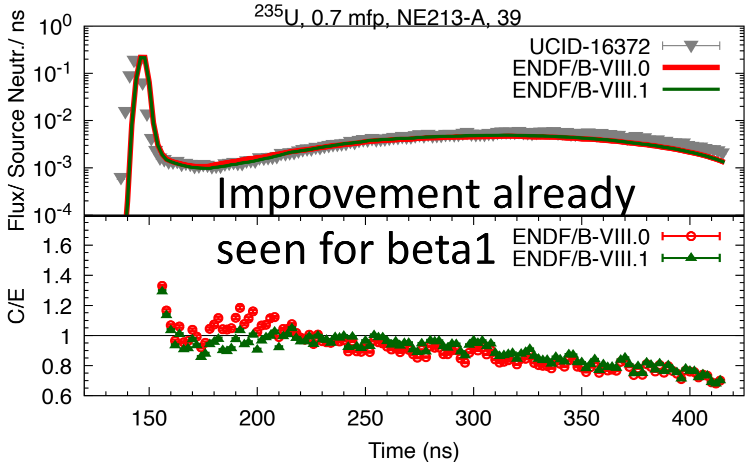
Negligible changes

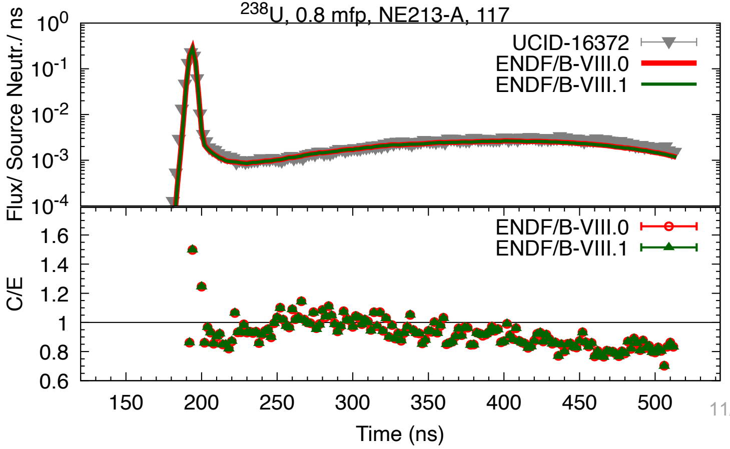
- Light water sphere
- ^{27}Al
- $^{235,238}U$: changes were already seen in beta0, nothing new with beta2, all fine.

Examples of negligible changes for the sake of completeness.







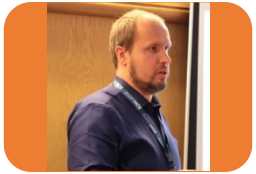


EUCLID Team

Experiments
Underpinned by
Computational
Learning for
Improvements in nuclear
Data

Nuclear Data


Noah Kleedtke


Wim Haeck


Michal Herman

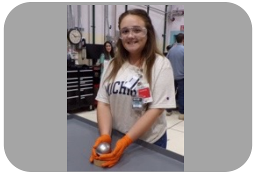

Robert Little


Denise Neudecker

Simulations


Jennifer Alwin


Alexander Clark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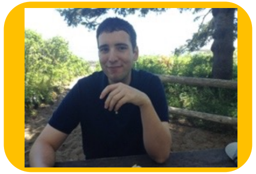
Michael Rising

Machine Learning


Brian Bell


Michael Grosskopf


Isaac Michaud

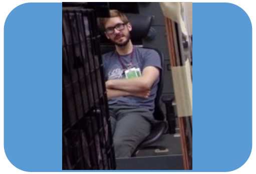

Scott Vander Wiel

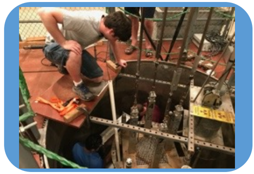
Experiments


Nick Wynne


Theresa Cutler

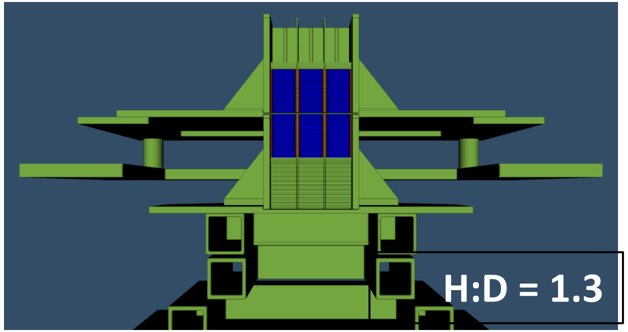

Jesson Hutchinson


Travis Smith

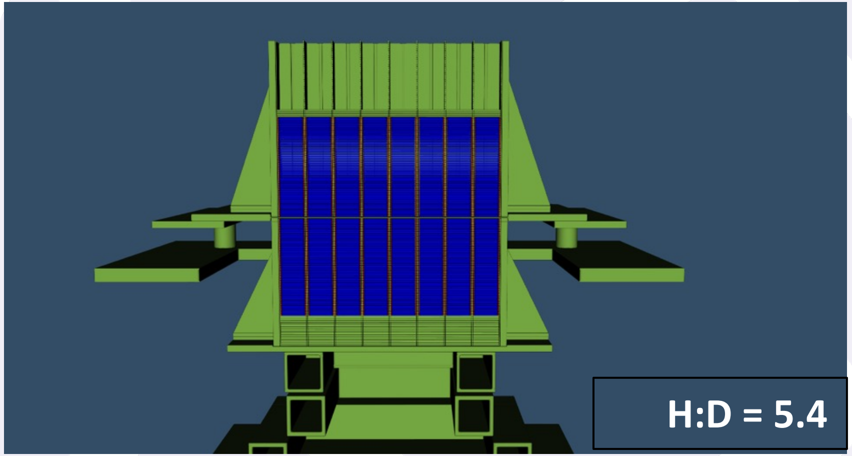

Nicholas Thompson

2 exp. configurations were designed by ML and executed at NCERC to explore compensating errors in fast ^{239}Pu ND.

3 X 2 (Low Mass/Cube)
Critical with 384 ZPPR plates (41 kg Pu)



8 X 1 (High Mass/Slab reactor)
Critical with 1033 ZPPR plates (109 kg Pu)

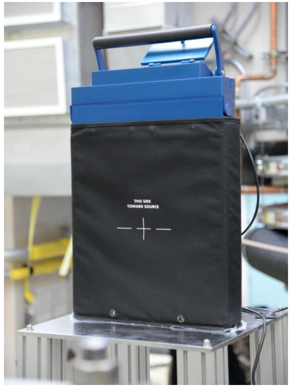


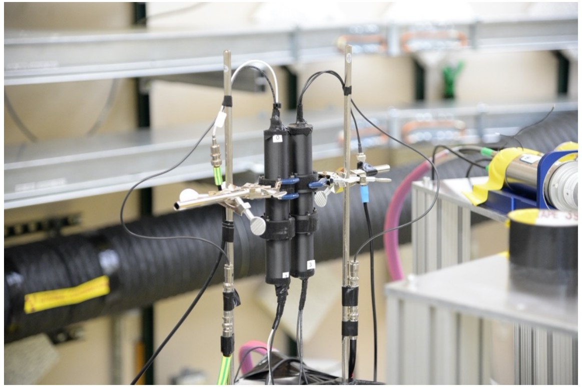
Both utilize WG PANN ZPPR plates as fuel

WG: Weapon Grade
PANN: Plutonium-Aluminum No-Nickel
ZPPR: Zero Power Physics Reactor

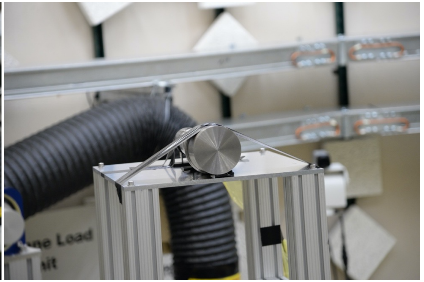
Six measurement responses were studied with the experiments.

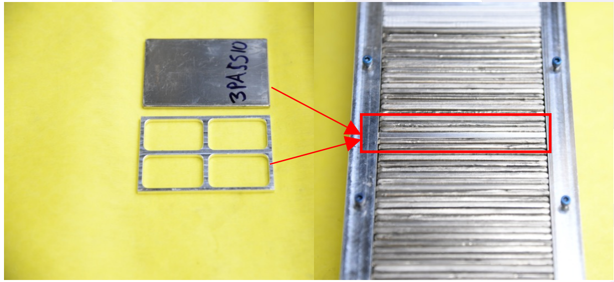
In the interest of time, I will only cover k_{eff}. More experimental results are available for other responses. Contact us if interested.

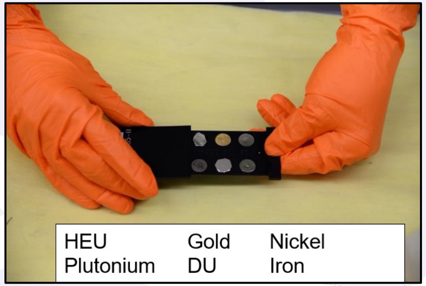




	8x1		3x2	
	Goal	Measured configurations	Goal	Measured configurations
Subcritical and leakage spectra measurements	3	8	3	5
Measurements at critical	1	2	1	2
Reactivity coefficients	2	11	2	7
Rossi-alpha measurements	3	8	3	5
Reaction rate irradiation	1	1	1	1

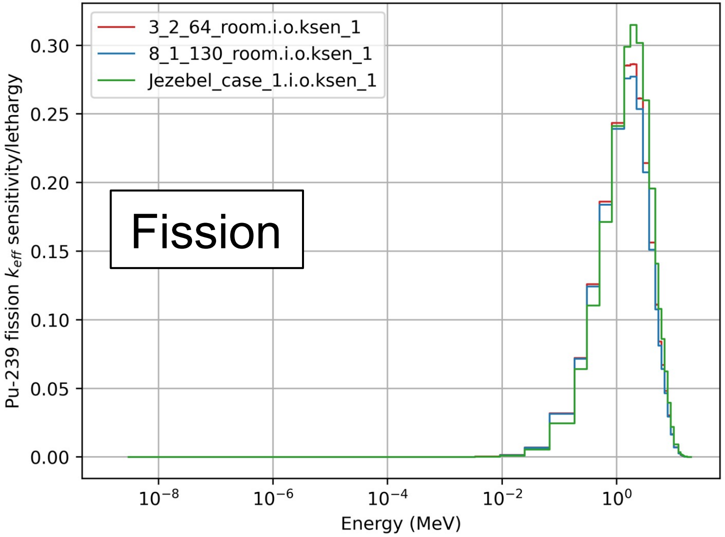




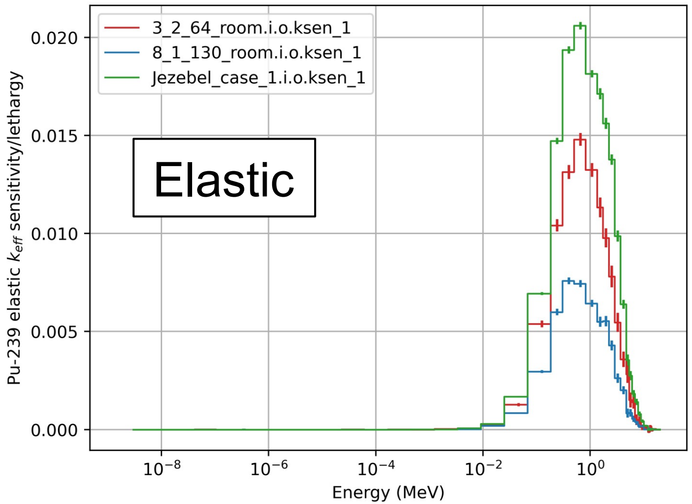


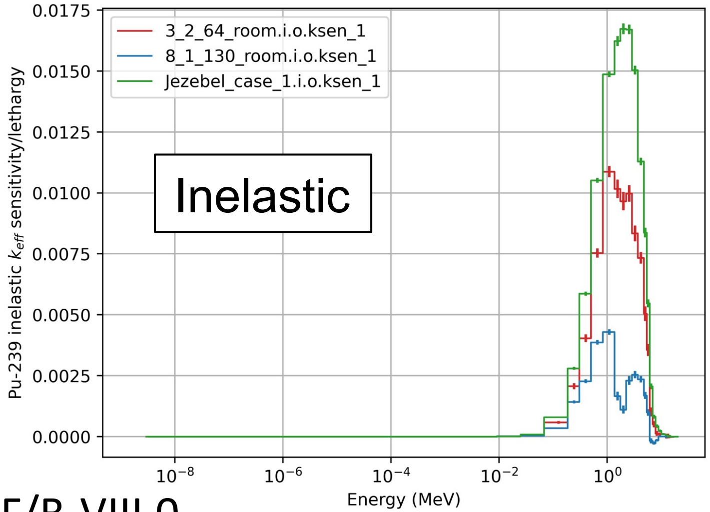
k_{eff} sensitivities are similar to Jezebel for fission but different for scattering

- Jezebel – detailed benchmark, case 1
- 3 X 2 X 64
- 8 X 1 X 130



Scattering sensitivities differ in magnitude and shape for **8x1** vs. **3x2**





MCNP calculations using ENDF/B-VIII.0

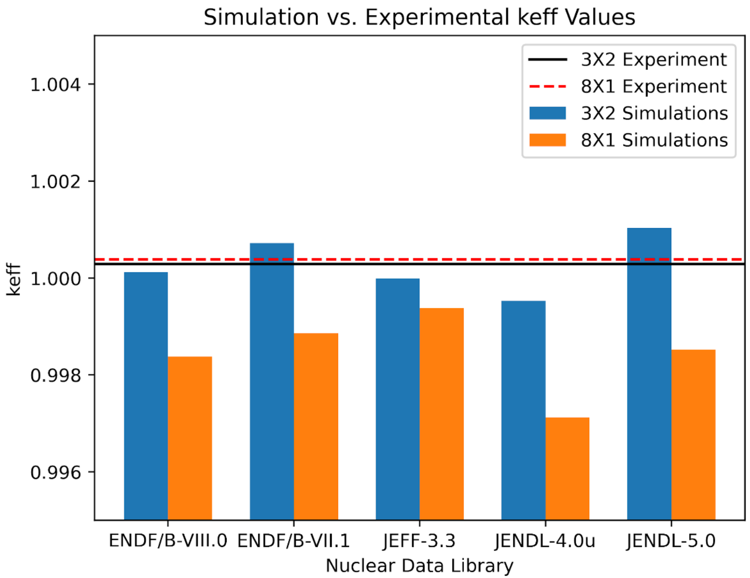
Calculated k_{eff} is mostly below experiment and varies with ^{239}Pu library by 10s to 100s of pcm. They point towards inl/ el.

3x2 exp: 1.00029 +/- 0.00200

Library	keff	keff unc	C-E (pcm)
ENDF/B-VIII.0	1.00012	0.00003	-17
ENDF/B-VII.1	1.00072	0.00003	43
JEFF-3.3	0.99999	0.00003	-30
JENDL-4.0u	0.99953	0.00003	-76
JENDL-5.0	1.00103	0.00003	74
Pu9VIII1beta1-11c	0.9991	0.00003	-119
Pu9LANL10172022-10c	1.00011	0.00003	-18
e81b2	0.99992	0.00003	-37

8x1 exp: 1.00038 +/- 0.00300

Library	keff	keff unc	C-E (pcm)
ENDF/B-VIII.0	0.99838	0.00003	-200
ENDF/B-VII.1	0.99886	0.00003	-152
JEFF-3.3	0.99938	0.00003	-100
JENDL-4.0u	0.99712	0.00003	-326
JENDL-5.0	0.99852	0.00003	-186
Pu9VIII1beta1-11c	0.99757	0.00003	-281
Pu9LANL10172022-10c	0.99802	0.00003	-236
e81b2	0.99815	0.00003	-223



Results when switching ^{239}Pu nuclear data (all other nuclides are ENDF/B-VIII.0)

Acknowledgements

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