Los Alamos
NATIONAL LABORATORY

Adjusting VIII.0 mean values and covariances with different integral responses

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LANL

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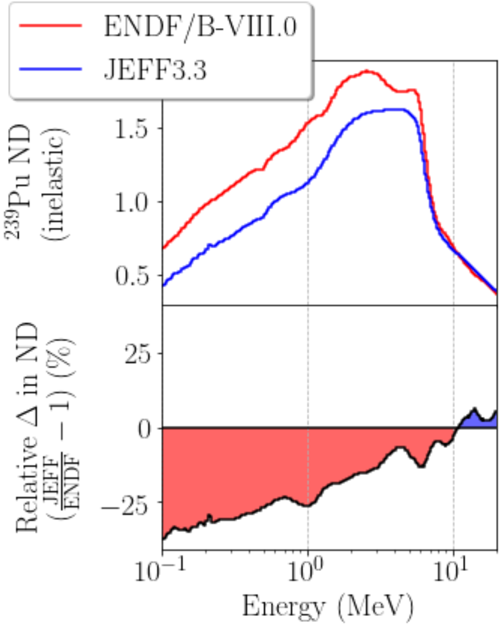
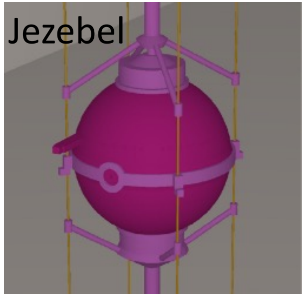
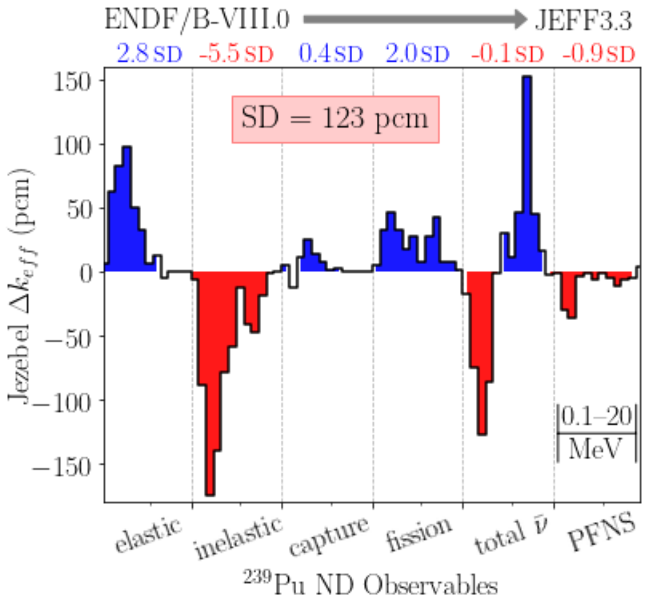
Why should we care about studying ND uncertainty spaces via various integral responses?

Compensating errors occur in libraries when we tweak uncertain ND to integral responses with many degrees of freedom.



Differences VIII.0 and JEFF3.3 ND within uncertainty of diff exp. **VIII.0 & JEFF3.3 give same Jezebel k_{eff}** but reaction contributions differ drastically.





Going towards IX.0, we should think of how to carefully select integral experiments to validate combinations of ND to reduce uncertainty space between them. Studying experiments with different sensitivities to ND is key.

Using adjustment to Jezebel and EUCLID integral responses to discuss strengths and weaknesses of each of them.

Comment:

- ***Adjustment* = tool to show impact of responses, NOT to guide tweaking ND***.
- Impact of adjusted ND on predicting PMF006 k_{eff} indicates issue in exp. response.

*Done via "EAT" by M. Grosskopf (GLS augmented with Gaussian processes).

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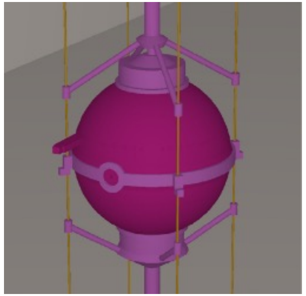
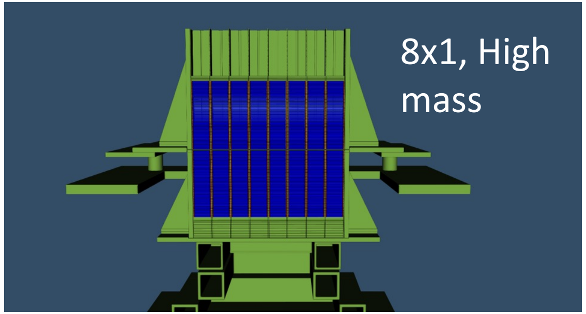
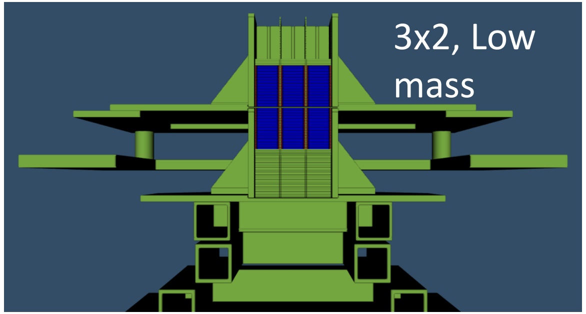
Jezebel – PMF001



- Well-studied k_{eff}.
- Many not so well-studied responses.
- Mostly ^{239}Pu.

EUCLID – not an ICSBEP benchmark



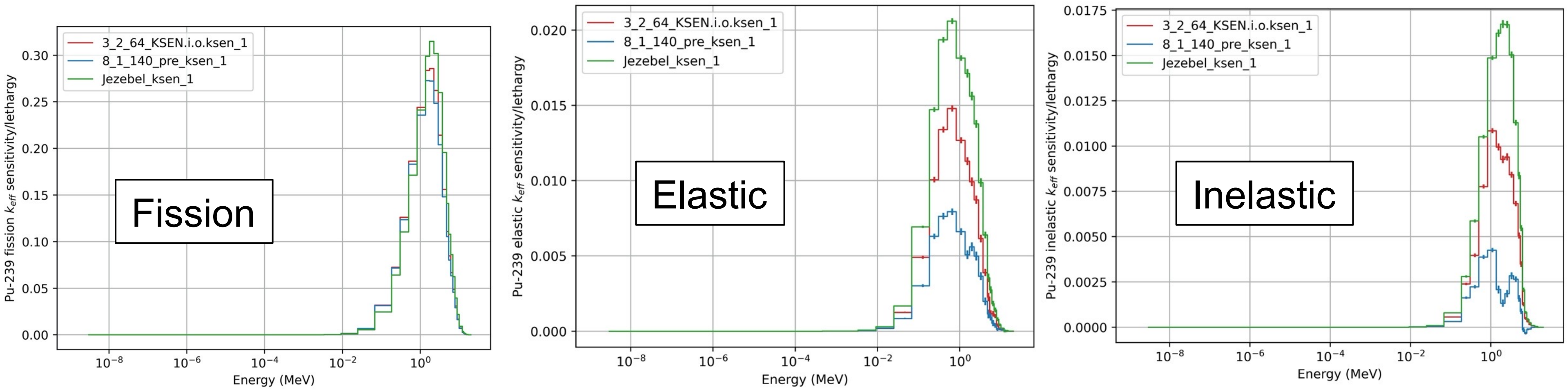


- k_{eff} designed to tease out compensating errors in ND.
- Many well-studied responses that were recently done.
- Mostly ^{239}Pu.

k_{eff} experiments designed to have dissimilar sensitivities can help us understand ND better.

Using ML to design integral experiments can help us find configurations with differing ND sensitivities.

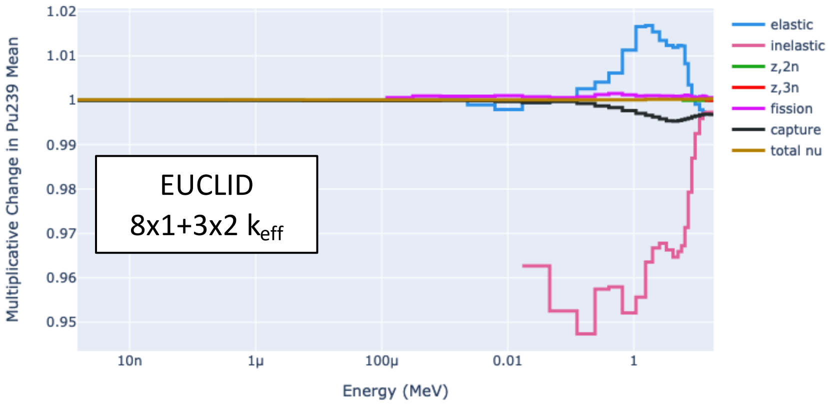
- k_{eff} is sensitive to elastic, inelastic, **fission**, capture cross sections, **nu-bar**, PFNS and angular distributions.
- Bayesian analysis and D-optimality used to design EUCLID to maximally reduce ^{239}Pu ND uncertainties while being dissimilar to past experiments.
- EUCLID k_{eff} sensitivities very dissimilar for elastic & inelastic cross sections.

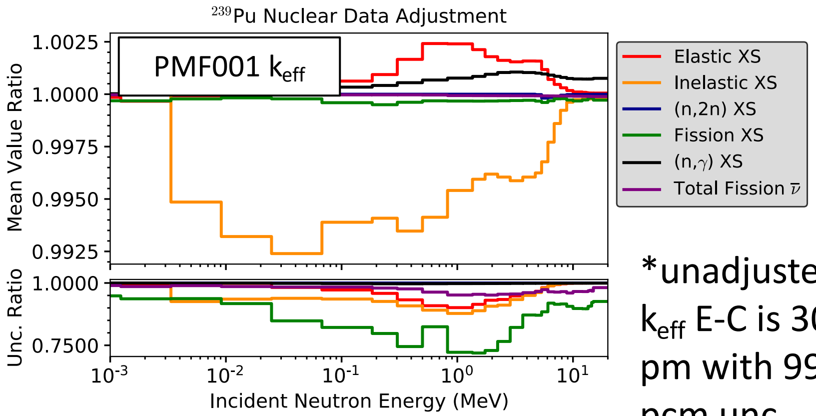


Adjustment in cs 10x smaller for PMF001 than for EUCLID pointing to tweaking to Jezebel.

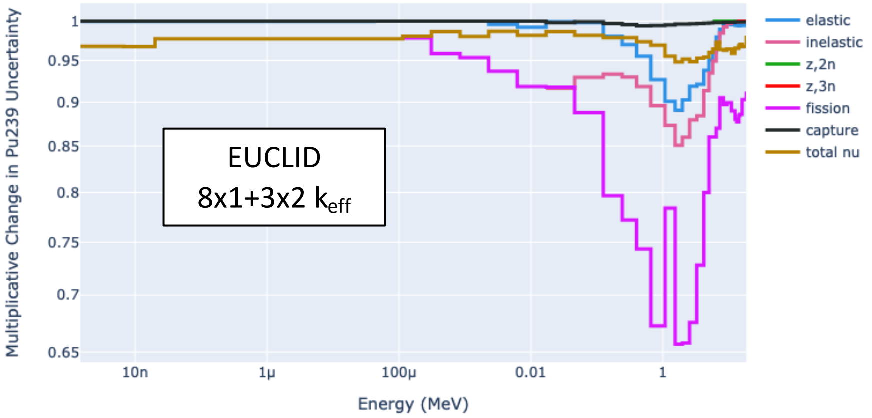
Adjustments go in similar directions and new designs point towards elastic and inelastic.

Adjusted to	E-C k_{eff} PMF006*	k_{eff} unc. PMF006
PMF001 k_{eff}	61 pcm ✓	746 pcm
EUCLID k_{eff}	-30 pcm ✓	745 pcm





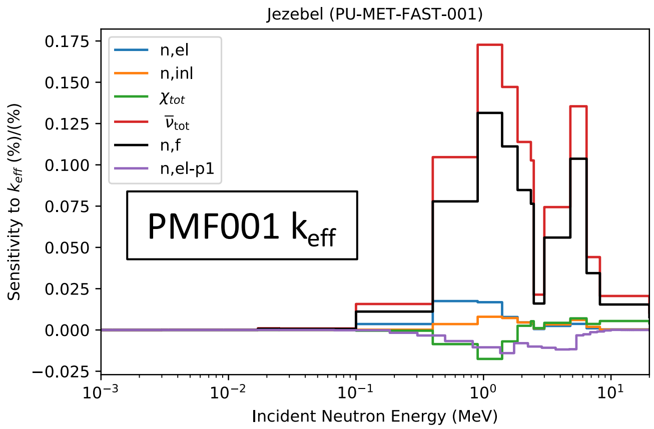
*unadjusted k_{eff} E-C is 30 pm with 992 pcm unc.

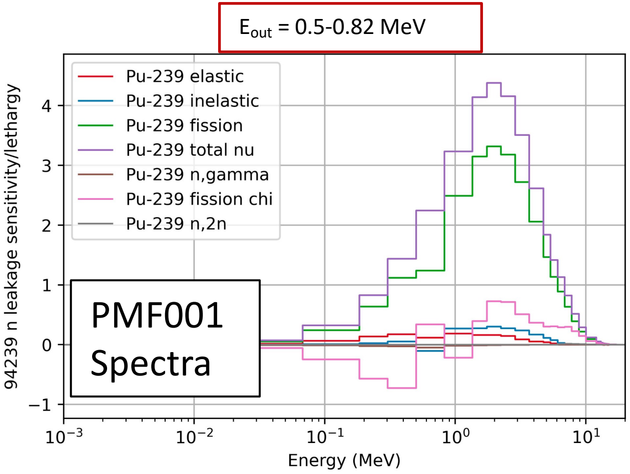


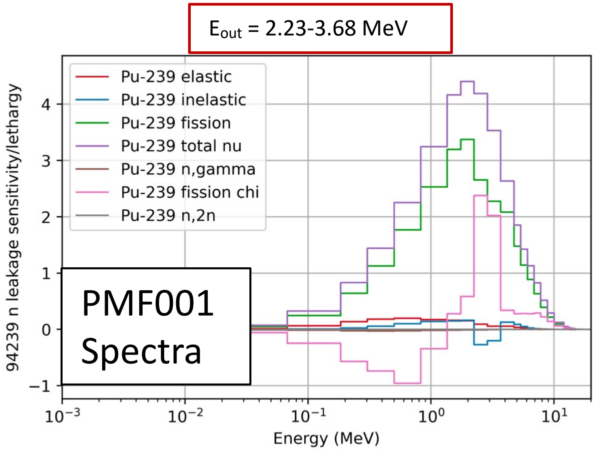
Neutron-leakage spectra as function of E_{out} emitted from assemblies can help us dive deeper on PFNS, elastic and inelastic.

Jezebel spectra sensitivities to elastic, inelastic and PFNS change distinctly as a function of E_{out}!

- Neutron leakage spectra usually measured by neutron detector on outside of assembly.
- FSEN MCNP6.3 capability was used to calculate sensitivities for various E_{out} bins.
- Sensitivities of nu-bar and (n,f) cs similar to k_{eff}, but very different behavior of inelastic, elastic and PFNS.





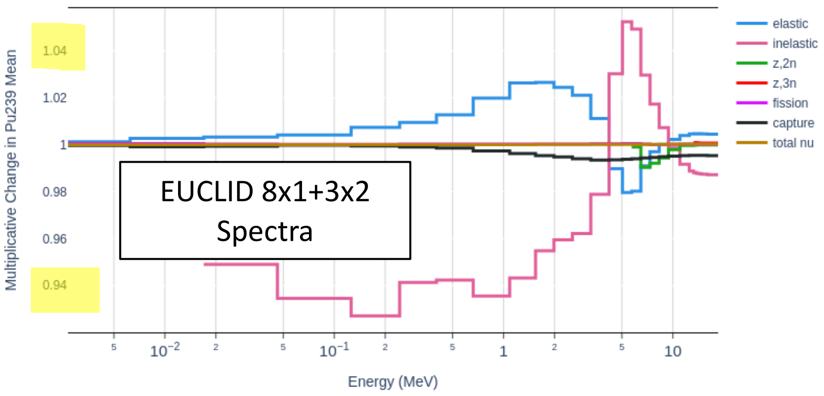


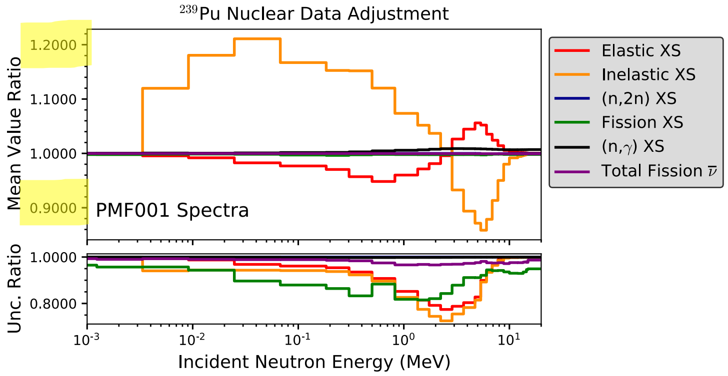
Plots from: N. Thompson et al., 2022 ANS Winter Meeting and Technology Expo.

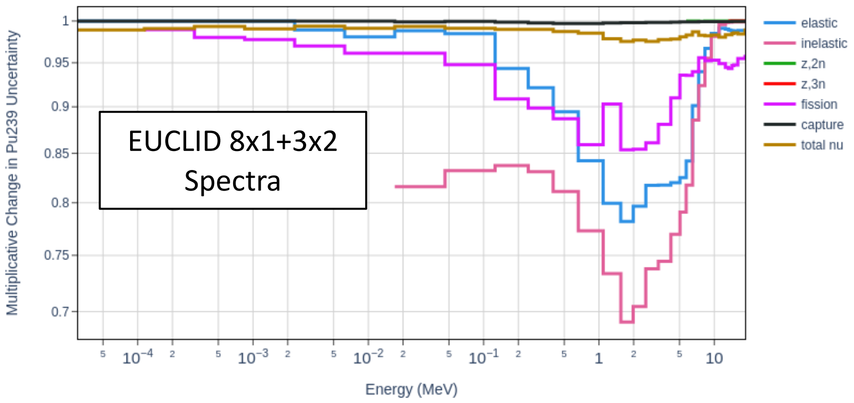
Spectra is an impactful response type but we need to investigate Jezebel spectra more.

Jezebel spectra adjustment has opposite trend to its k_{eff} & EUCLID spectra. Check PMF001 spectra!

Adjusted to	E-C k_{eff} PMF006*	k_{eff} unc. PMF006
PMF001 Spectra	130 pcm ?	795 pcm
EUCLID Spectra	-43 pcm ✓	822 pcm



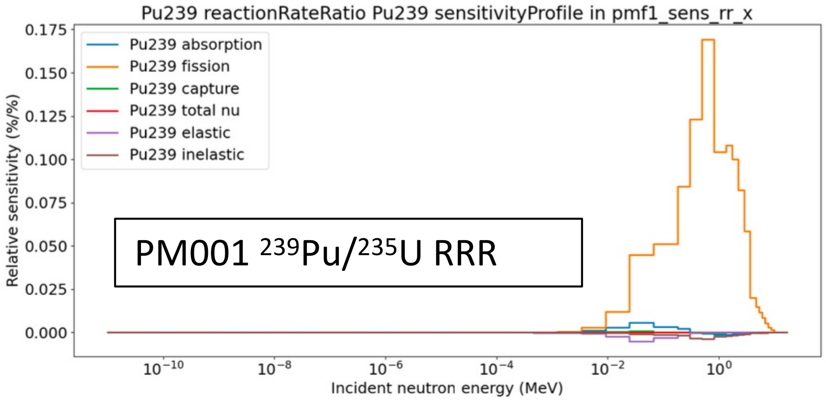


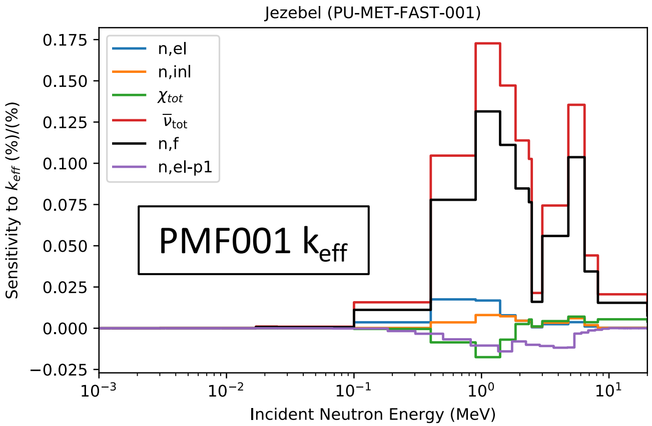


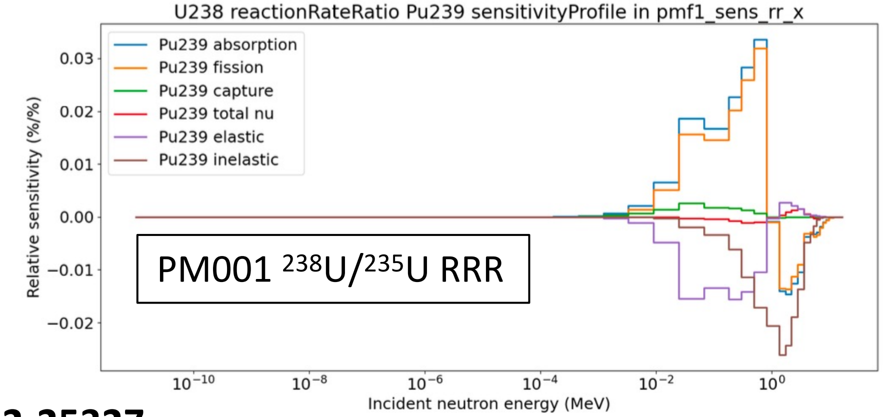
RRR help understanding the reaction at hand but also have much smaller sensitivity to nu-bar and capture.

Reaction rate ratios (RRR) have very different sensitivities compared to k_{eff} sensitivities but exp. more uncertain.

- RRR integral $$\frac{\langle\sigma^x\rangle}{\langle\sigma^y\rangle} = \frac{\int \sigma^x(E)\,\psi(E)dE}{\int \sigma^y(E)\,\psi(E)dE}$$
- Foils irradiated in assembly, then measured separately, or fission counters are in the assembly.
- Sensitivities were calculated with SENSMG.



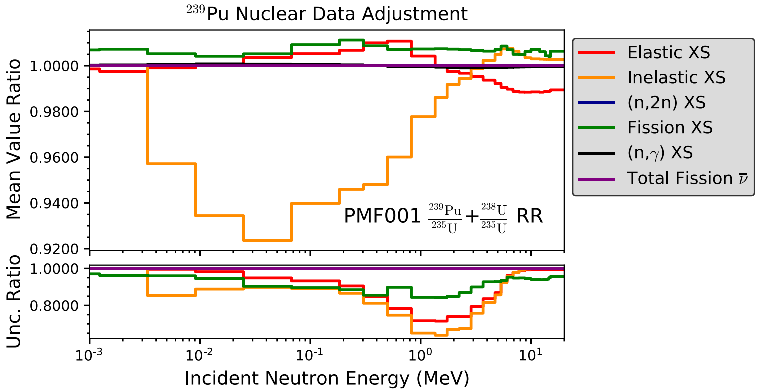




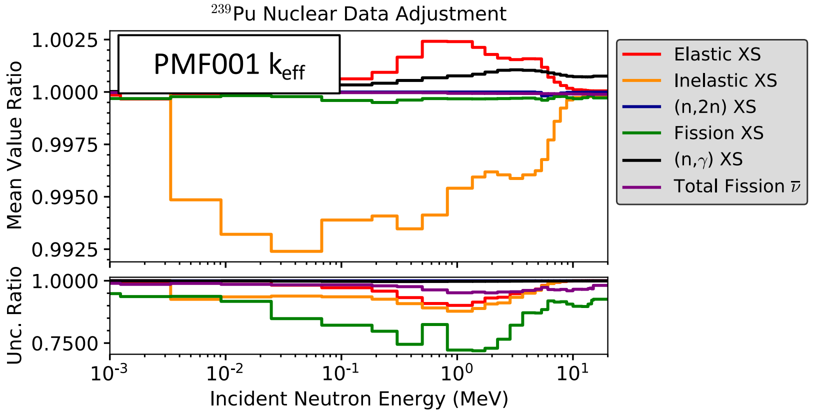
Right-hand side plots from J. Alwin et al., **LA-UR-22-25327**

Jezebel ^{239}Pu/^{235}U RRR leads to adjusted ND that predict k_{eff} of PMF006 outside of exp. unc. Need to investigate.

- Jezebel RRR adjustment has same trend (but factor 10 larger) for elastic and inelastic cross sections but different for fission cross section!
- Uncertainty reduction is distinctly smaller than k_{eff} and spectra!
- Still, exp. unc. are somewhat optimistic …



Adjusted to	E-C k_{eff} PMF006*	k_{eff} unc. PMF006
^{239}Pu/^{235}U PMF001 RRR	-354 pcm ✘	953 pcm
^{238}U/^{235}U PMF001 RRR	12pcm ✔	990 pcm
Both	-370 pcm ✘	951 pcm



EUCLID RRR with more conservative (realistic?) unc. reduce ND unc. distinctly less but similar trends to k_{eff}, spectra.

Adjusted to	E-C k_{eff} PMF006	k_{eff} unc.
Both PMF001 RRR	-370 pcm ✘	951 pcm
EUCLID 6 RRR	8 pcm ✔	982 pcm

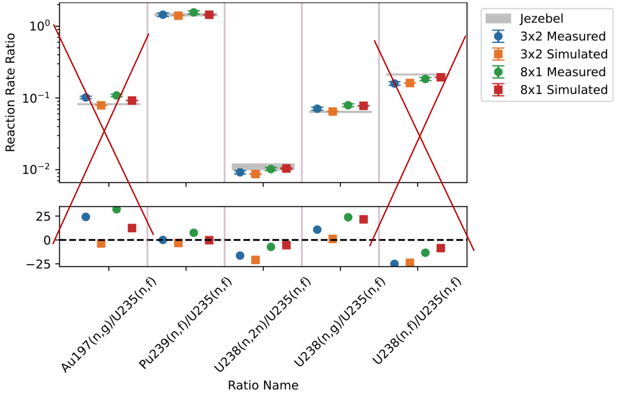
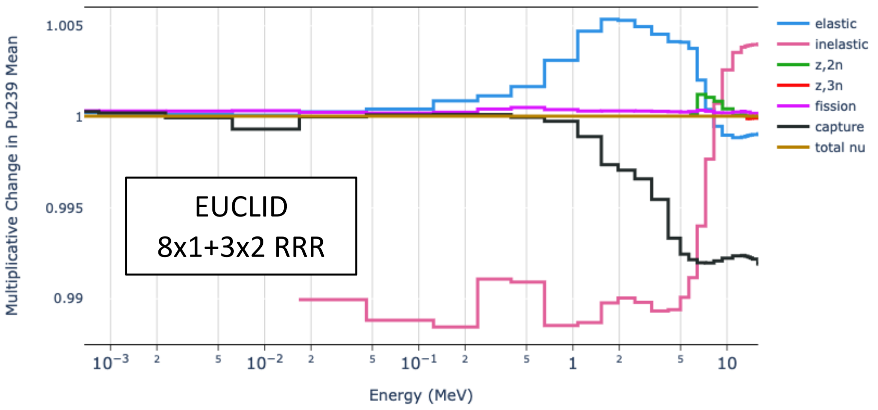
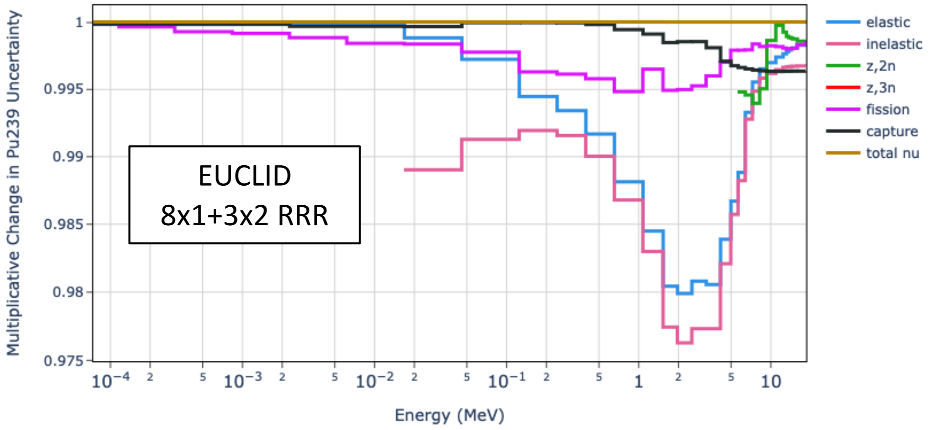


Fig. 23. Comparison between the EUCLID and Jezebel experiments. Jezebel is shown in the gray shaded region. The RRRs are shown in the top plot and the difference (in percent) between EUCLID and Jezebel is shown in the bottom plot.





Plot from J. Hutchinson et al., NSE, 2024, 1-19.

Integral experiments with very different sensitivities can help us better constrain ND and uncertainties. That can be:

- k_{eff} exp. designed to reduce compensating errors.
- Integral responses beyond k_{eff}:
  - RRR less sensitive to nu-bar and capture.
  - Spectra enhance our understanding of PFNS, elastic and inelastic cross section.

Stumbling blocks:

- Getting sensitivities beyond k_{eff} difficult.
- Lower quality and higher uncertainties on responses other than k_{eff} (e.g., Jezebel spectra and some RRR).

Acknowledgements

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Issues to tackle for IX.0 for the covariance session

- Developing covariance types for observables such as FY, TSL, etc.
- Continuing to develop and apply testing capabilities.
- Explore if MF=32 represents our complete covariance information.
- Work towards medium-fidelity covariances.
- Using adjustment results as part of covariance testing, guiding ND developments, studying response types, etc.
- Incorporating new standard covariances throughout library and learn from their best practices.
- Develop UQ recommendations.