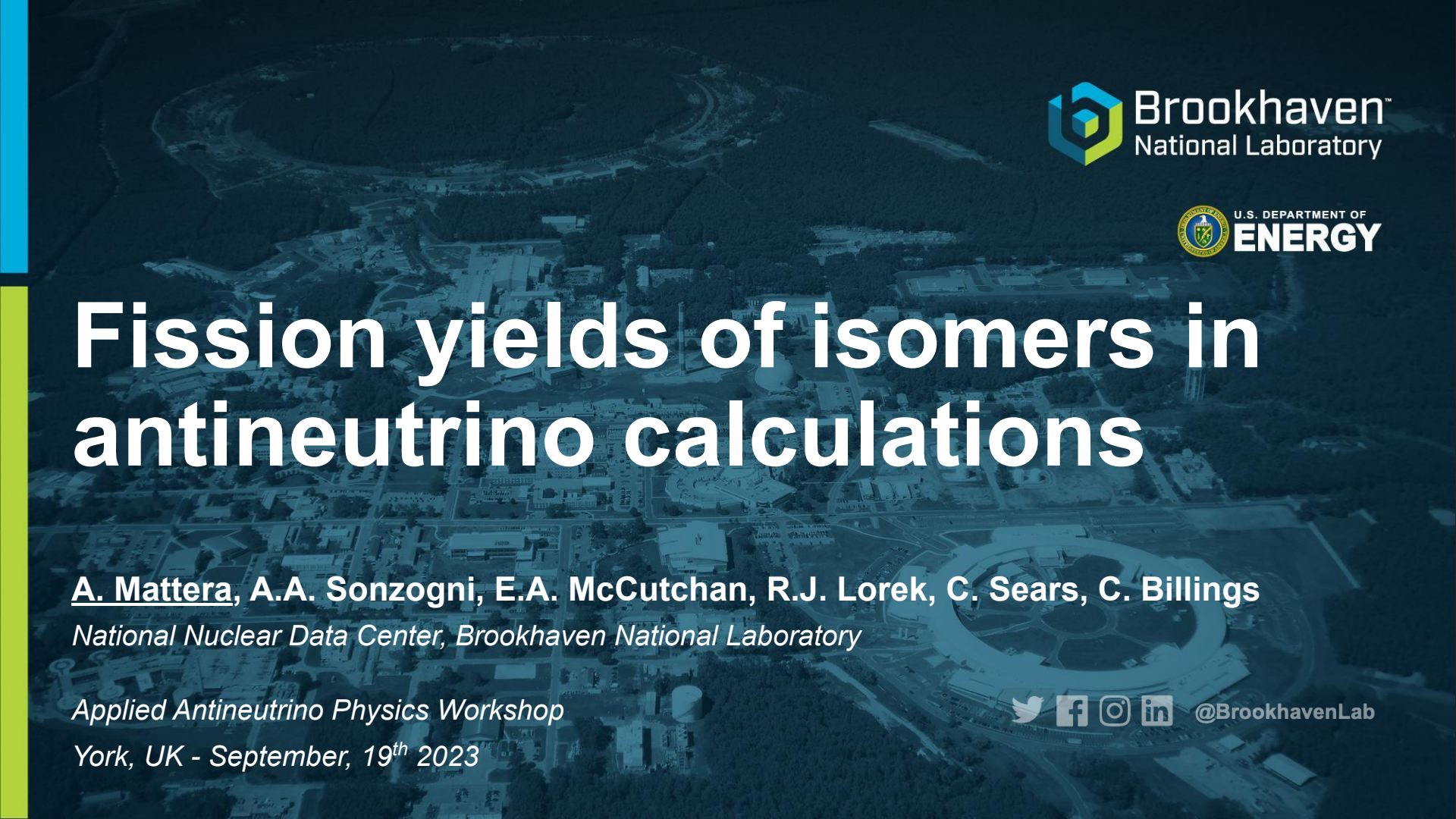

Fission yields of isomers in antineutrino calculations

A. Mattera, A.A. Sonzogni, E.A. McCutchan, R.J. Lorek, C. Sears, C. Billings

National Nuclear Data Center, Brookhaven National Laboratory

Applied Antineutrino Physics Workshop

York, UK - September, 19th 2023

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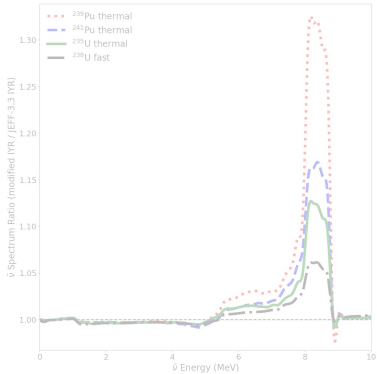
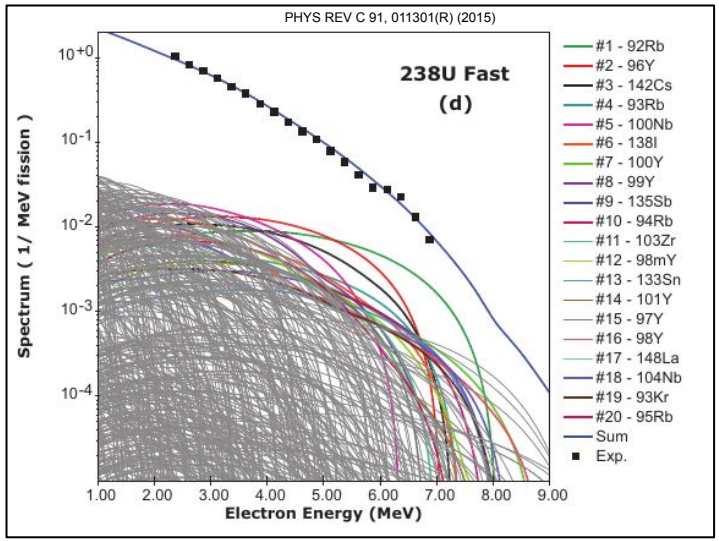
Outline

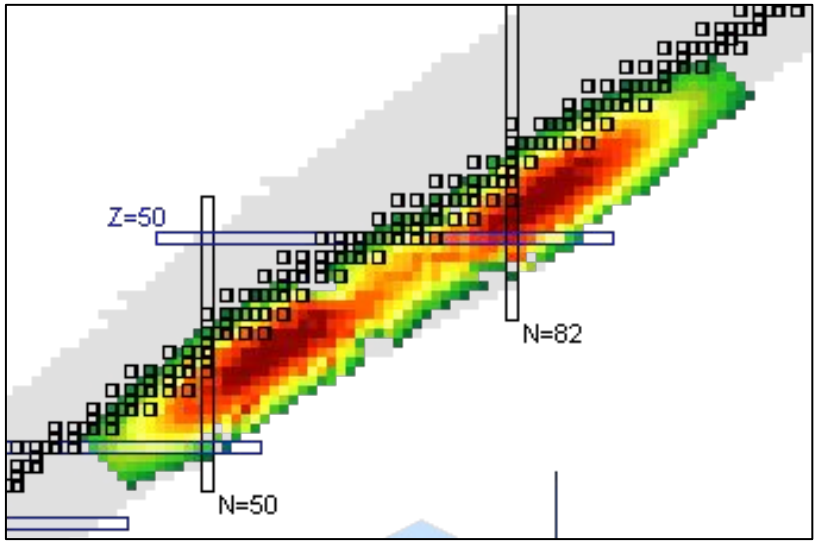
- Fission yields and isomers in antineutrino summation calculations
- Recommended experimental isomeric yield ratios
- Impact of recommended experimental isomeric yields
- Outlook



Fission Yields in anti-ν spectra summation calculations

DECAY DATA + **FISSION YIELDS**





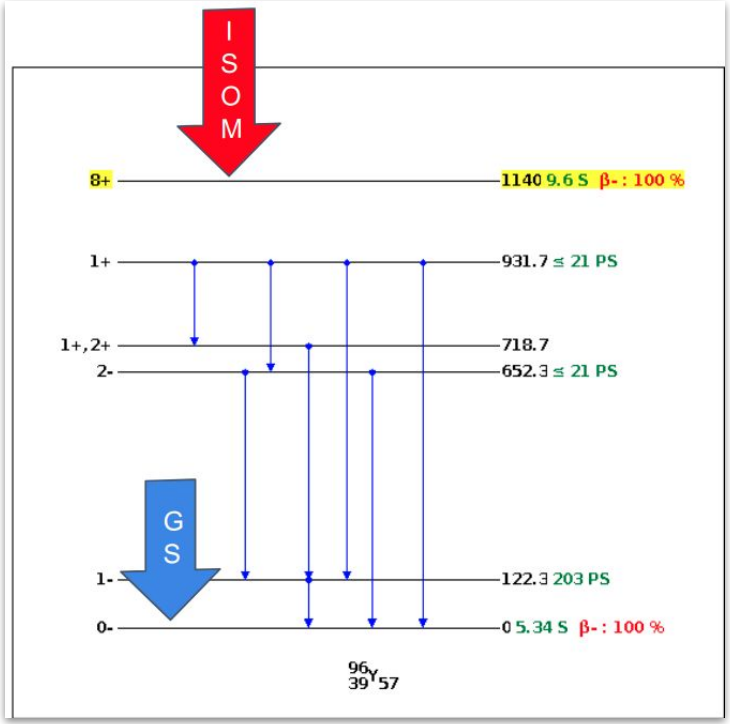
Fission Yields key component of the summation method - weigh the contribution from the β-decay of each fission product

Isomeric Yield Ratios

150+ fission products have a known long-lived excited state (isomer)

Isomeric Yield Ratios represent another key component of FY evaluations - fraction of the yield populating the isomer.

$$IYR = \frac{Y_{isom}}{(Y_{isom} + Y_{gs})}$$



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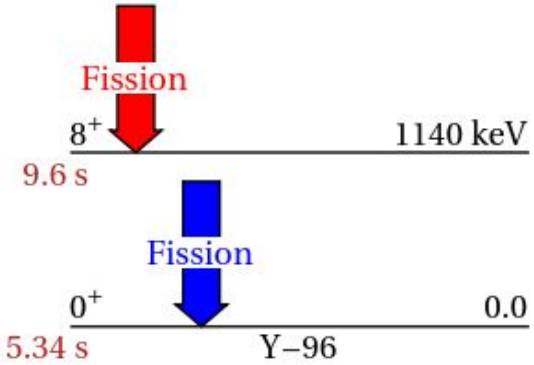
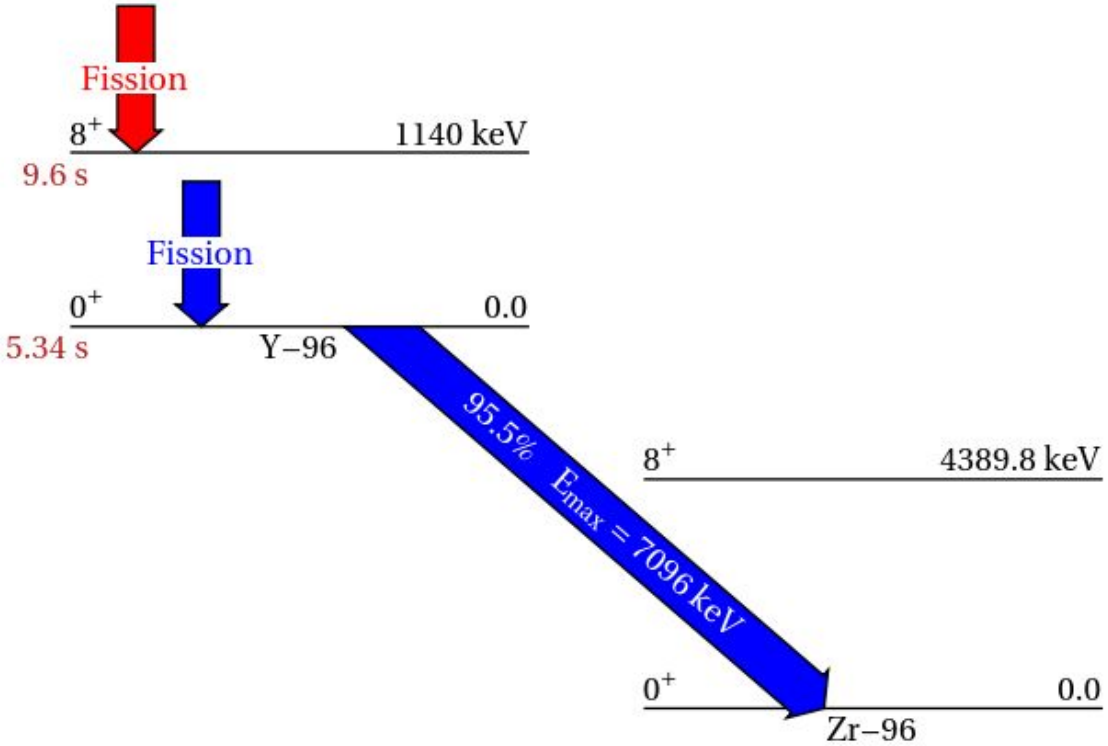
Isomers and antineutrino spectra



Isomers and antineutrino spectra



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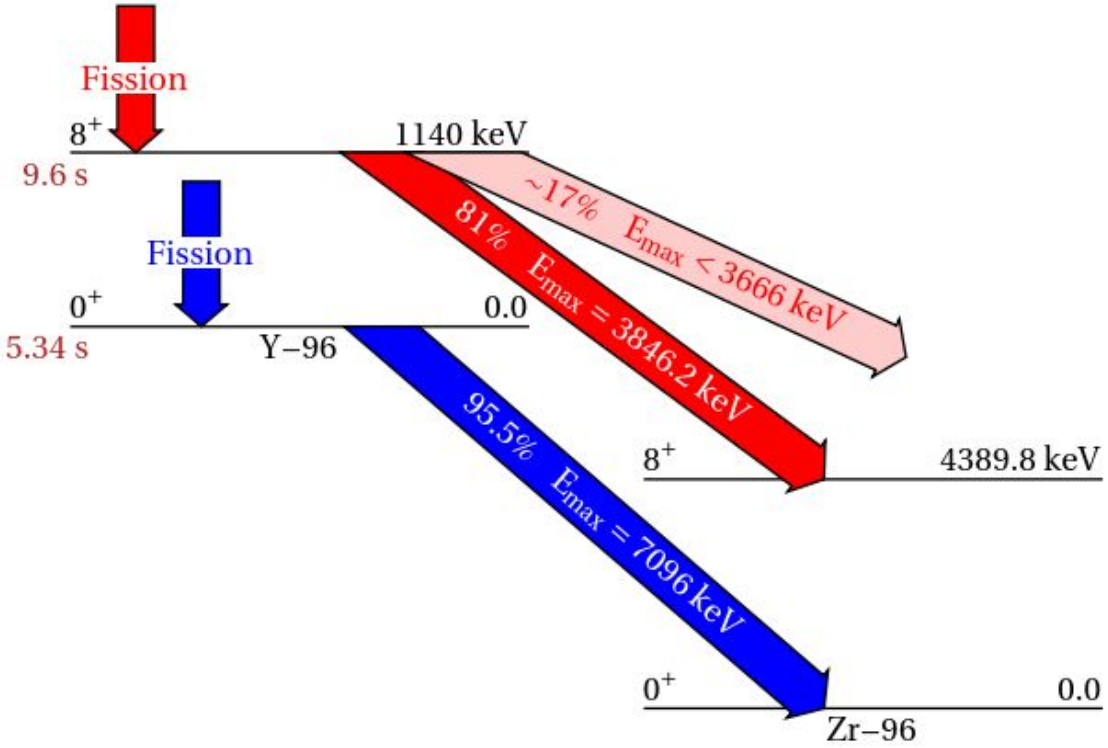
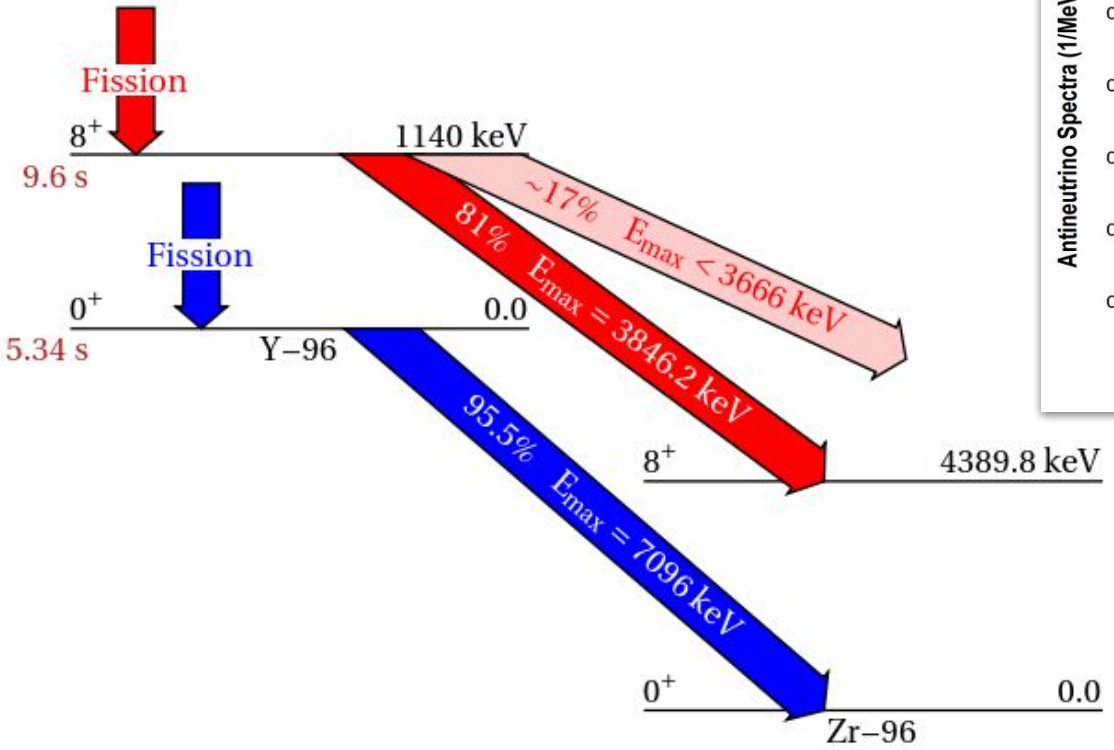
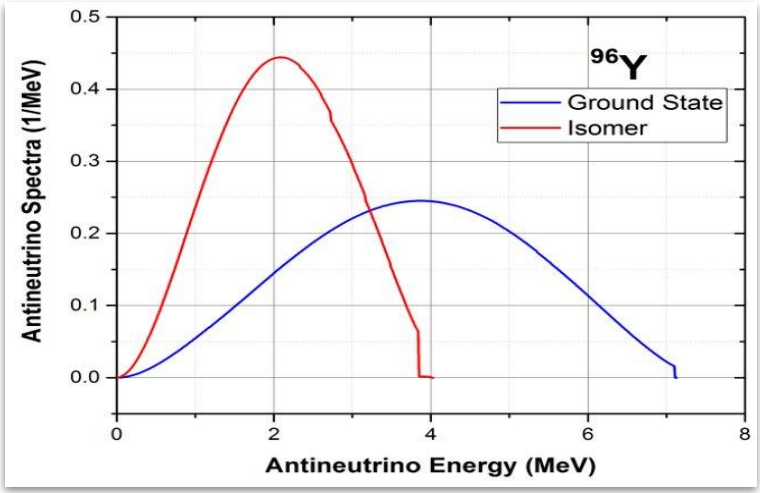


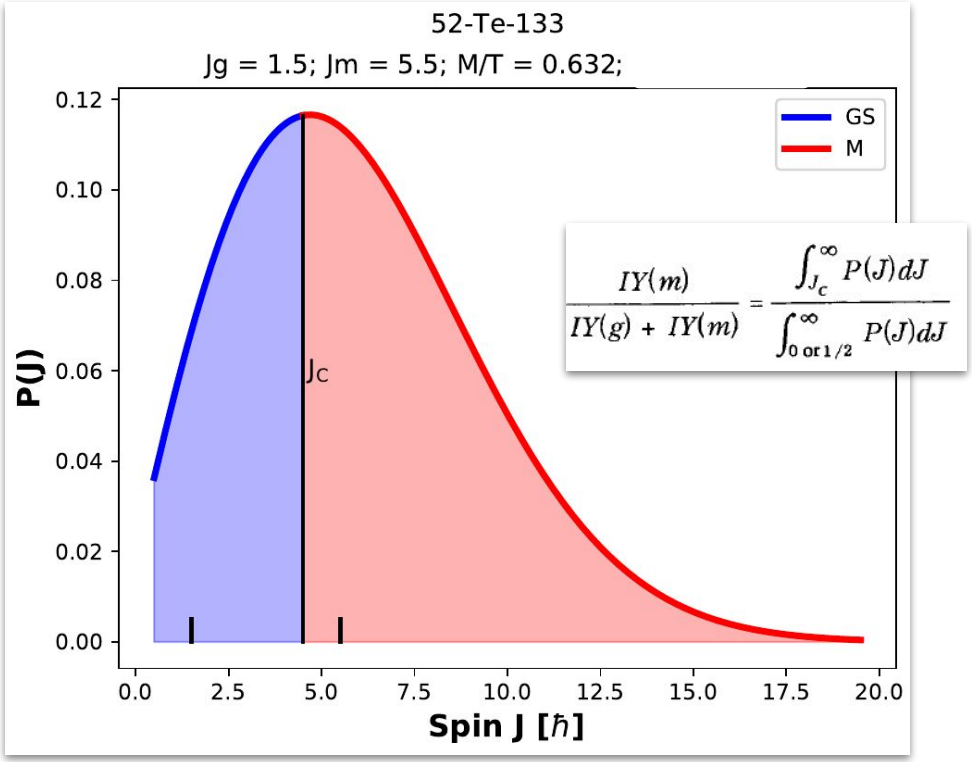
Isomers and antineutrino spectra





The importance of each curve is weighted by the yield that populates the G.S. or the isomer

IYRs in current FY evaluation



NUCLEAR SCIENCE AND ENGINEERING: 64, 859-865 (1977)

The Influence of Isomeric States on Independent Fission Product Yields

David G. Madland and Talmadge R. England

University of California, Los Alamos Scientific Laboratory, Theoretical Division
P. O. Box 1663, Los Alamos, New Mexico 87545

It predicts IYR with minimal information on the fission products:

- Isomeric ratio is split based on the J_g / J_m assuming a statistical P(J):

$$P(J) = P_0(2J + 1)\exp[-(J + \tfrac{1}{2})^2/\langle J^2\rangle]$$

- 1-parameter (J_{rms}) that fixes the P(J) distribution for **all** FFs

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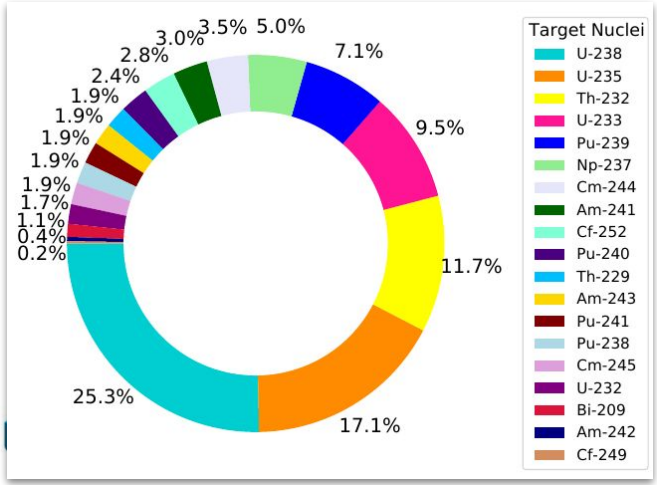
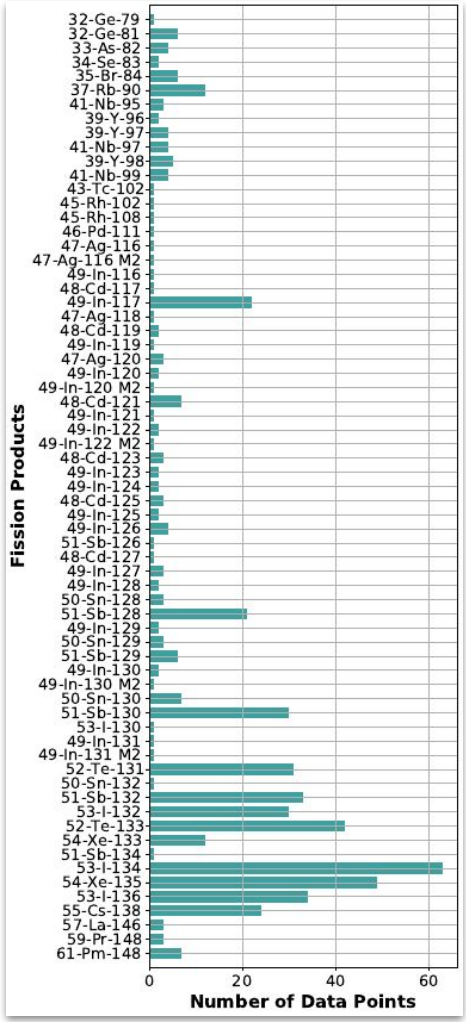
Recommended experimental IYRs

- compiled 538 independent isomeric yield ratios, from 39 compound nuclei, and 62 unique fission products
- 5x the amount of data available to Madland & England when they developed the model



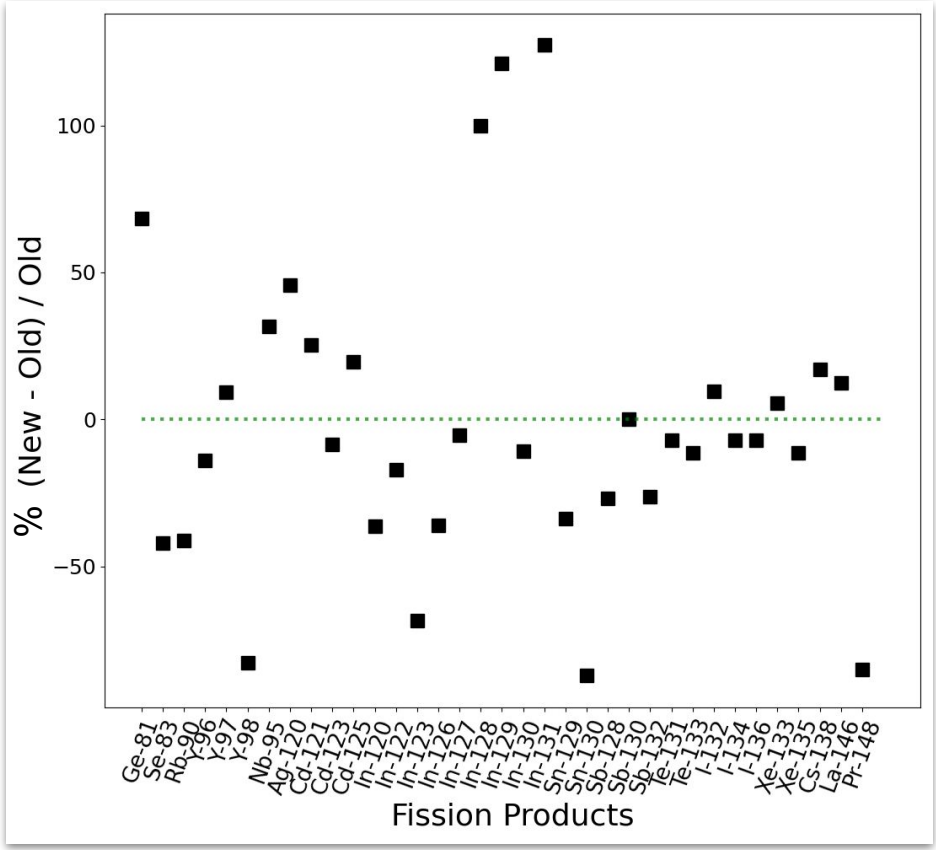
- Wealth of new data can be used to benchmark new models for the prediction of IYRs



Experimental IYRs evaluation

of all isomeric yields included in the ND libraries, only **42** have **exp. data at “low energy”**.

In about half the cases where data is available, the **libraries** contain a **value** that **doesn’t agree with the measurements** within the quoted uncertainties



Sears, C.J., et al. "Compilation and Evaluation of Isomeric Fission Yield Ratios." Nuclear Data Sheets 173 (2021): 118-143.

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Impact of experimental values on anti-ν spectra

Substitute all 42 recommended values into the libraroes

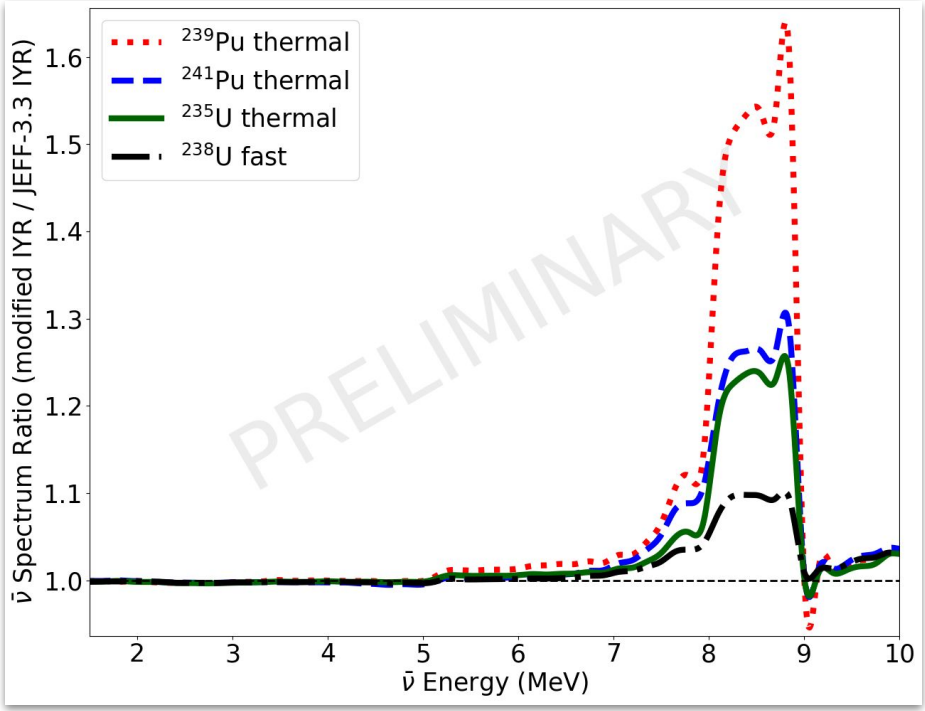
Spectrum shown as a ratio to the benchmark (JEFF-3.3)

Virtually no difference below 5 MeV

Overall increase elsewhere:

up to + 5% at 6 MeV

up to +60% at 8 MeV



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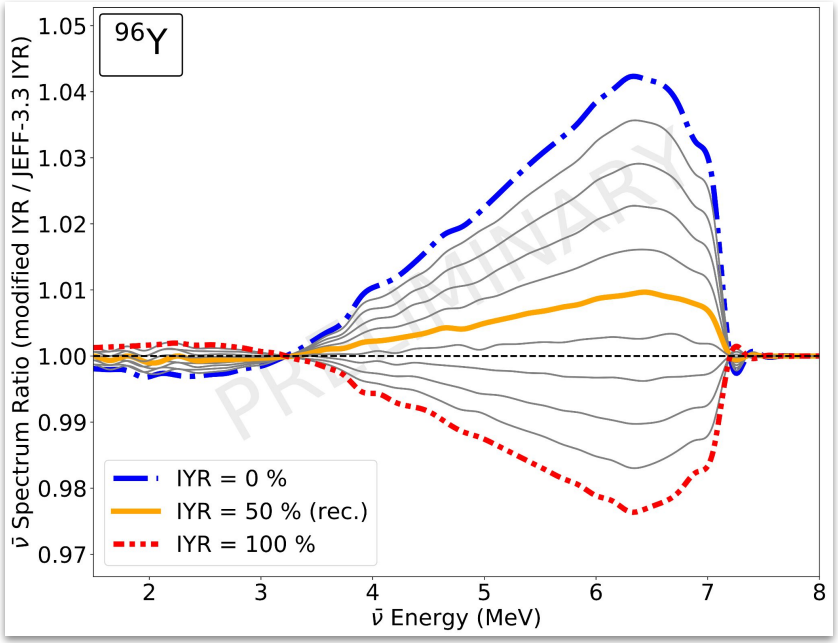
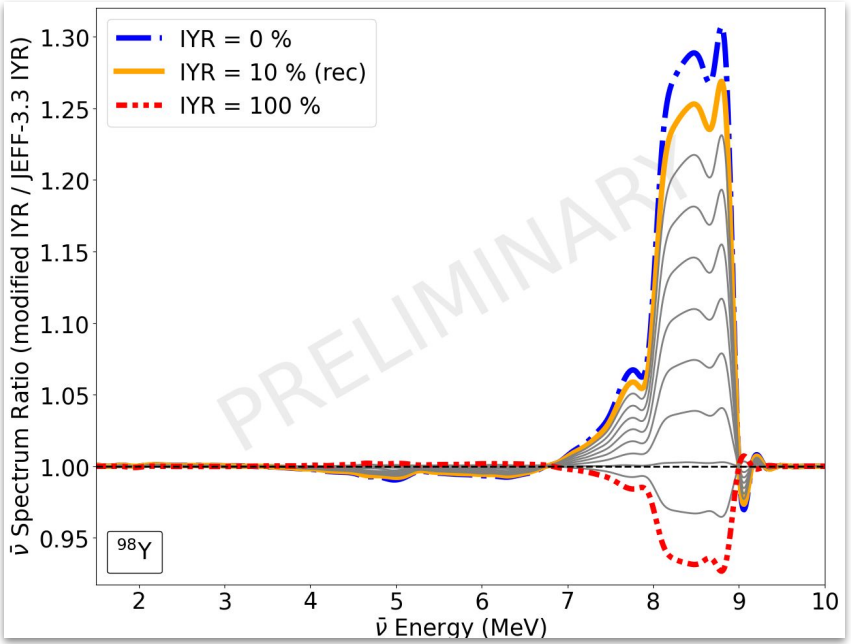
Wildly uneven contribution of different FPs





IYR_{th} = 65% → IYR_{exp} = 50 %
CFY ≈ 5 %

IYR_{th} = 81% → IYR_{exp} = 14 %
CFY ≈ 3 %

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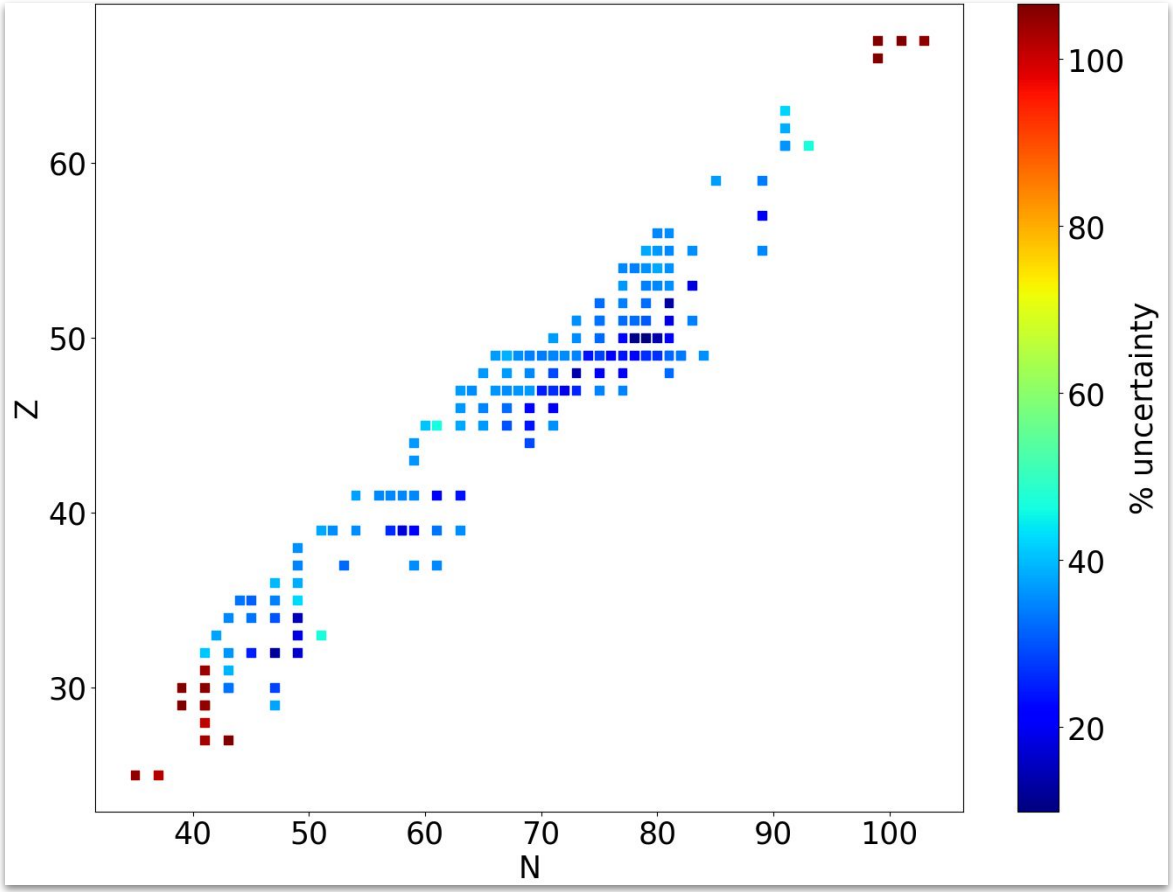
A broader sensitivity study: uncertainties

Are uncertainties in the libraries capturing the uncertainty on IYR?

Assigned uncertainties may not reflect the uncertainty on the model used to derive IYRs



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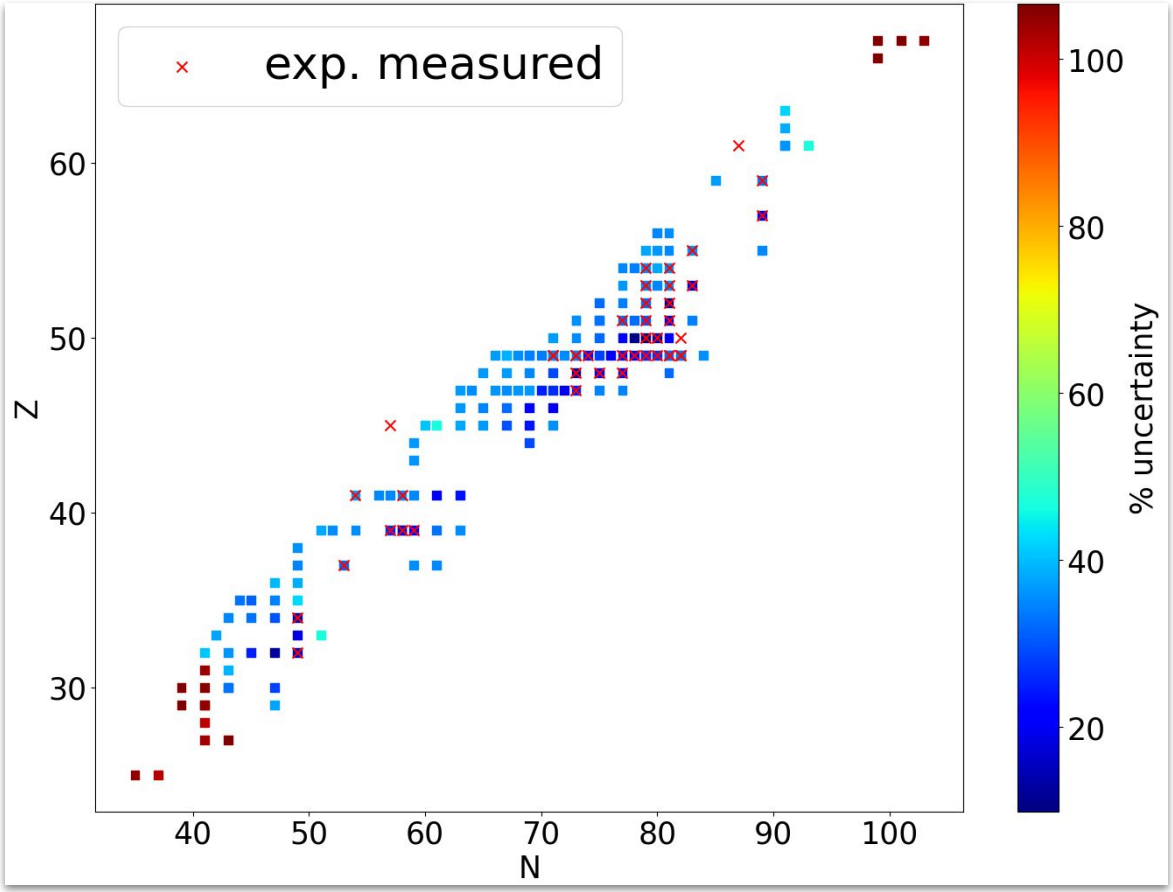

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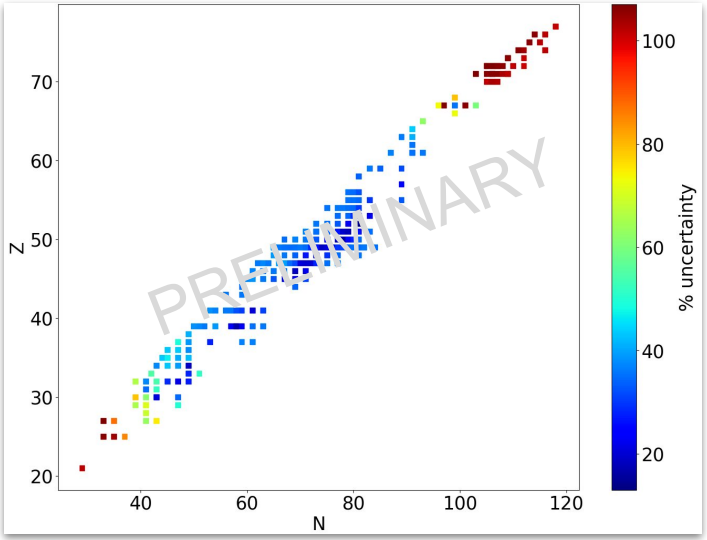

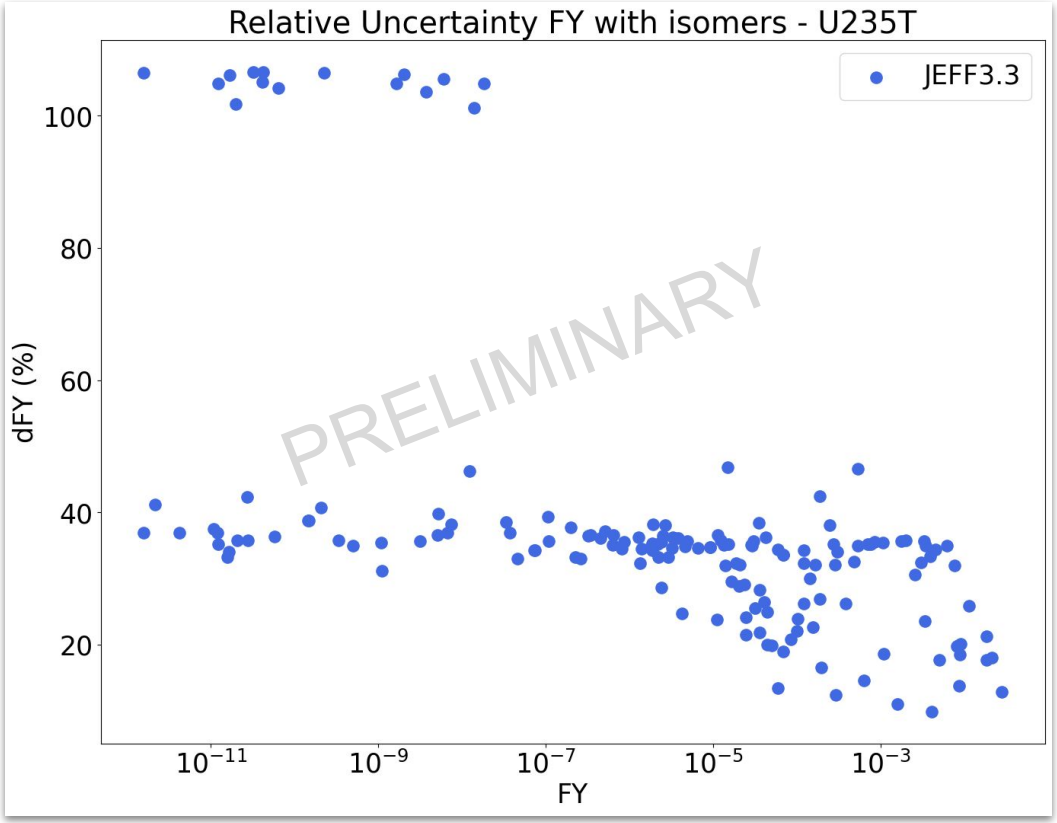

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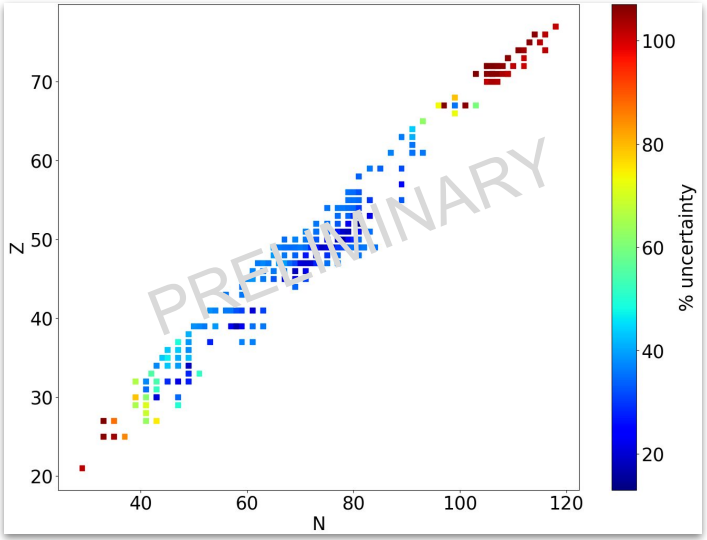

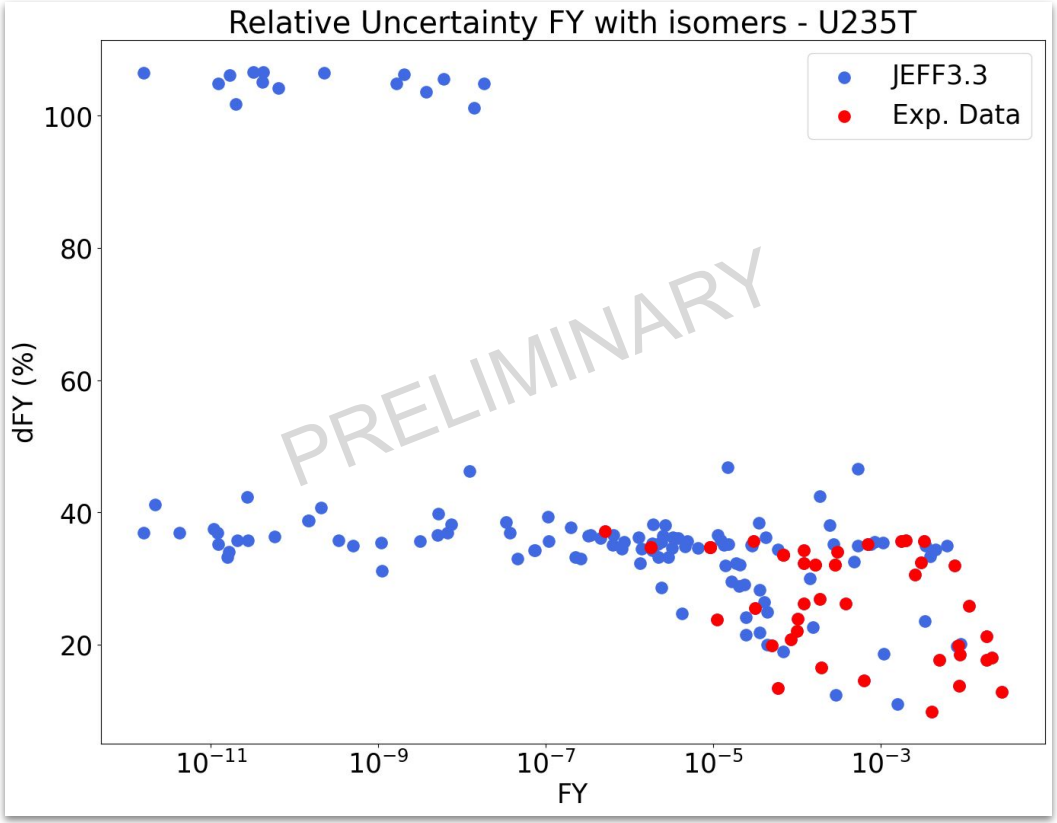

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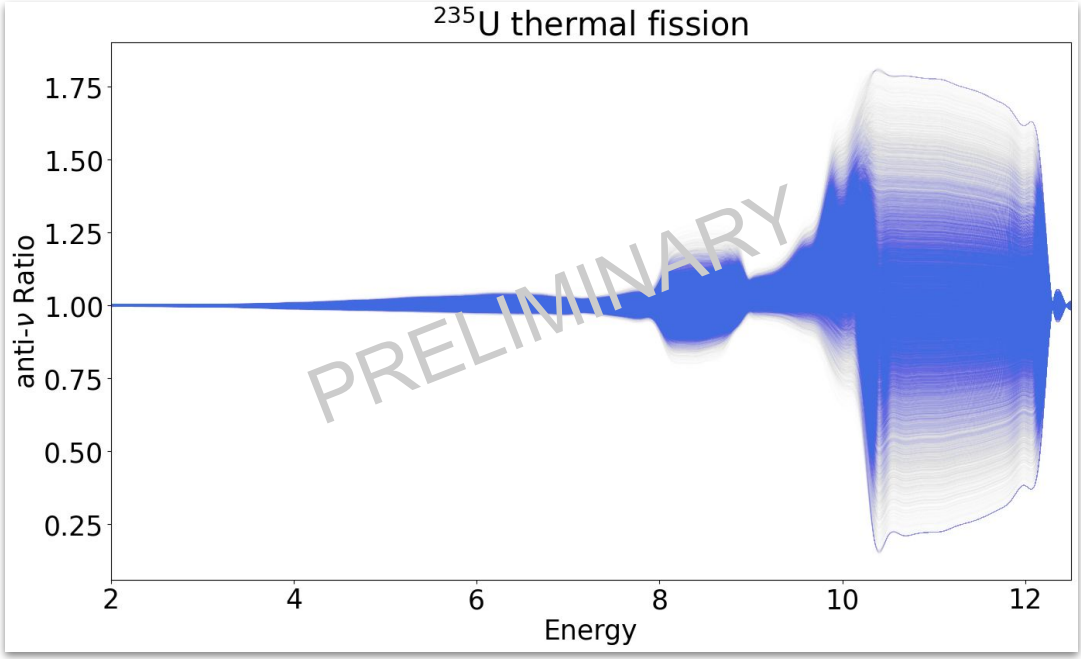
A broader sensitivity study: uncertainties

Brute-force sensitivity study: how do uncertainties of IYRs as a whole affect the spectrum?

Uncertainties increase dramatically at high energies, where only a few isotopes make up a large fraction of the anti-ν spectrum



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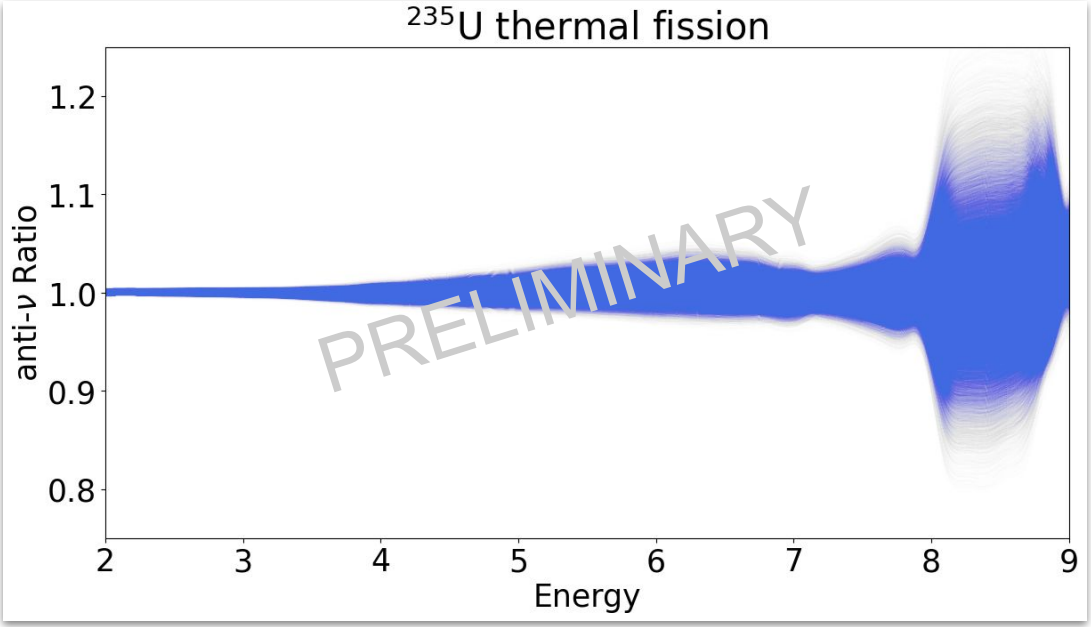

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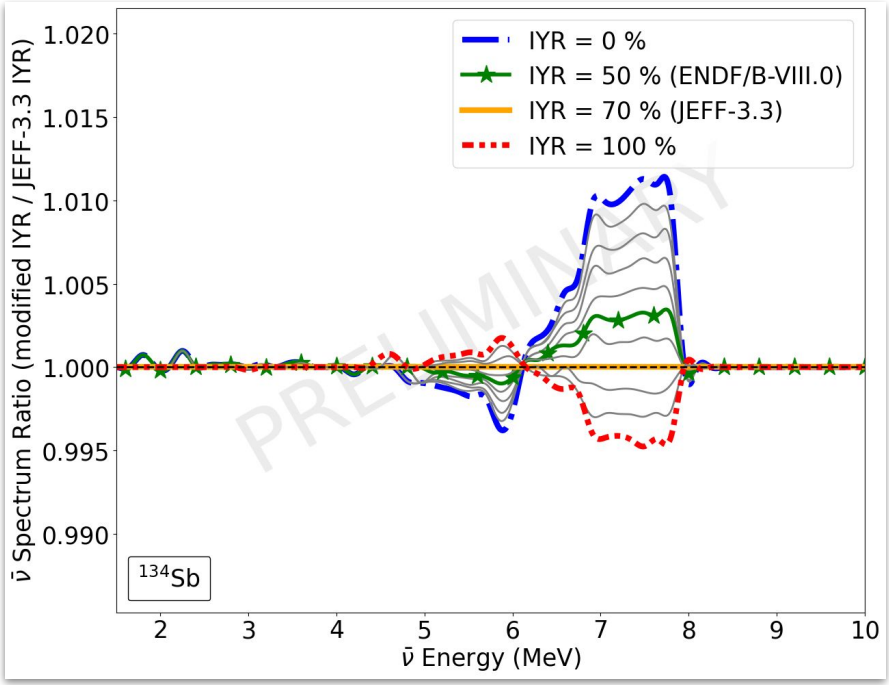
A broader sensitivity study

- Analysis of all fission products with a known isomer included in ENDF
- Varied the value within physical boundaries
- Identified a list of fission products, whose yield could affect the antineutrino spectra (e.g., Sb-134, Nb-100, La-146, Rb-90)



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Summary

- New evaluated isomeric ratios result in an **increased antineutrino flux** compared to the current FY libraries **up to 60%** for specific energies and fissile targets.
- Experimental data on IYRs exist only for a fraction of the fission products, and uncertainty on the FYs may not always capture the uncertainty on the IYR
- A sensitivity study shows that **a number of other isomers** considerably **affect the antineutrino spectrum** at high energies
- Provide a **high-priority list of IYRs** to be measured for reactor antineutrino calculations

16th Applied Antineutrino Workshop
September, 19th 2023

Fission yields of isomers in antineutrino calculations

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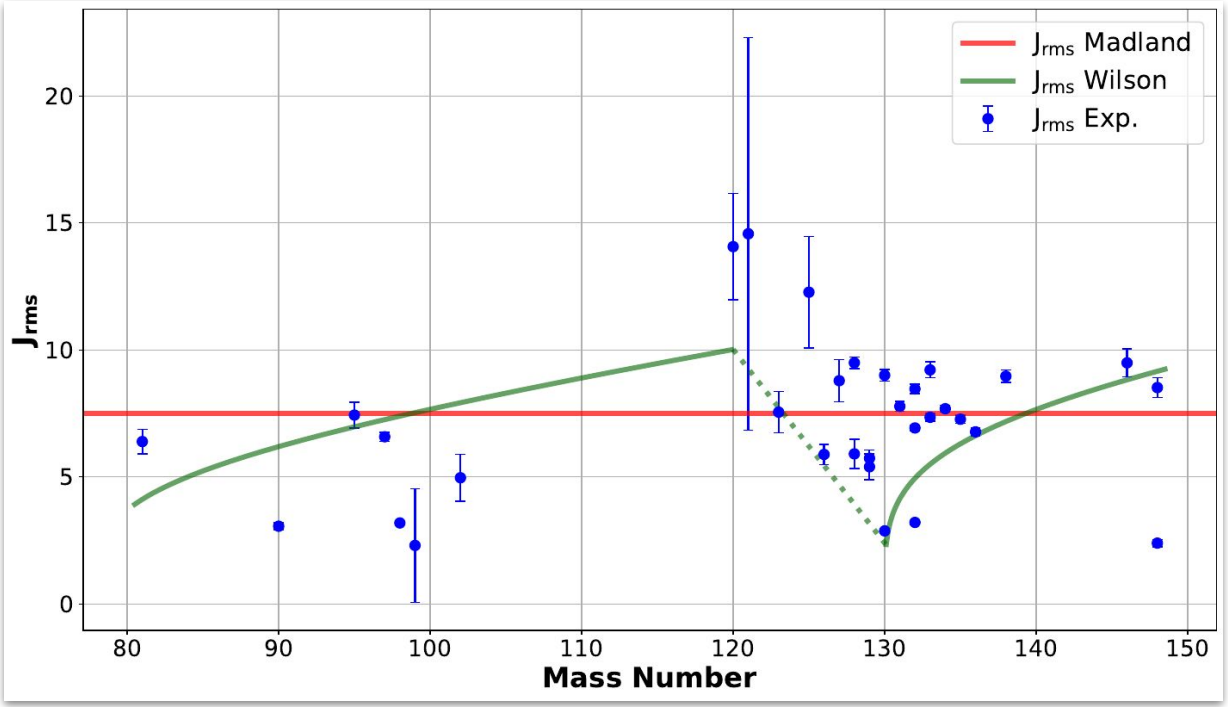
Madland & England *vs* Wilson

A new parametrization of J_{rms} following Wilson's[1] prescription does not lead to better IYR predictions

it is not easy to predict IYRs where no data are available!



[1] Wilson, J. N., et al. "Angular momentum generation in nuclear fission." Nature 590.7847 (2021): 566-570.

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