Impact of Updated Isomeric Yield Ratios on Reactor Antineutrino High-Energy Spectra

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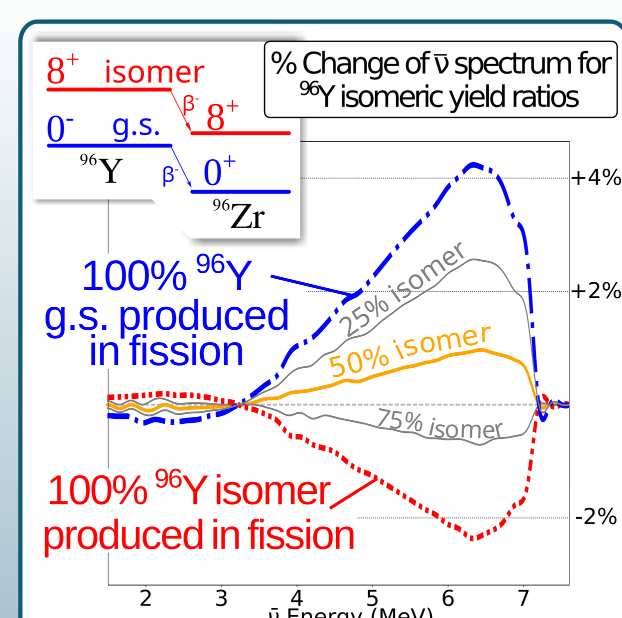
Isomeric Yield Ratios for Antineutrino Spectra

Nuclear fission can produce a nuclide in its ground state or in a metastable isomeric state. The two states can have different half-lives, beta-decay branches, and endpoint energies.
For reactor antineutrino summation calculations, the relevant quantity is the split between the two states, the isomeric yield ratio (IYR).

$$\text{IYR} = \frac{\text{Fission Yield of Isomeric State}}{\text{Total Fission Yield of Nuclide}}$$

Changing the IYR changes how much activity feeds each beta-decay scheme. The effect is small for most fission products, but can become very important in the high-energy antineutrino region where only a handful of beta branches contribute.

Why IYRs matter: fission yield is split between ground and metastable states, which can feed different beta-decay branches and produce different antineutrino spectra.

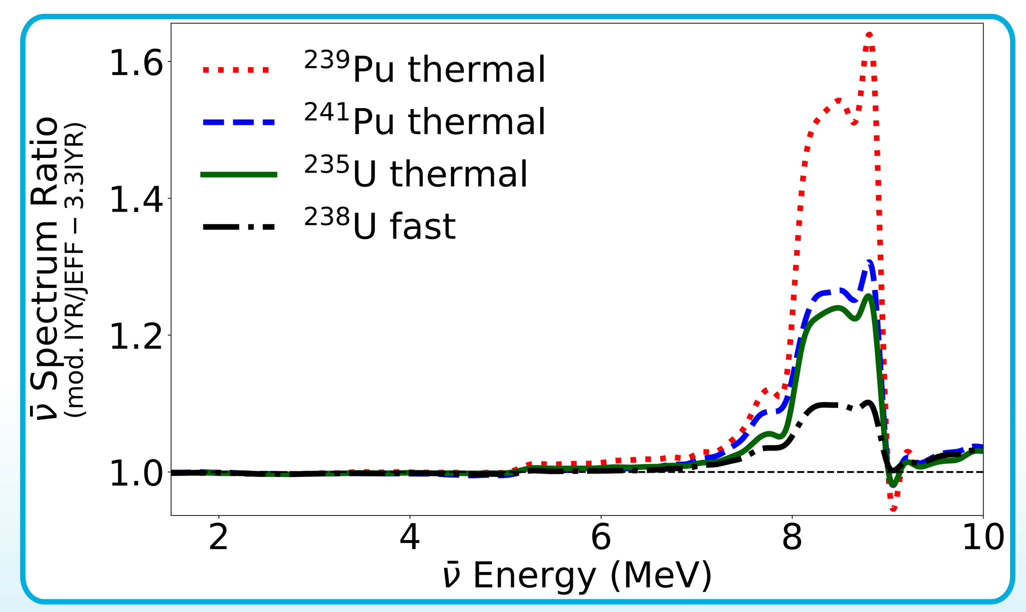


C. Sears et al.
10.1016/j.nds.2021.04.005

Current Status of IYR and Connection to High-Energy Antineutrino Spectra

Our previous compilation was assembled in 2019–2020 and published in 2021, where we provided a vetted set of experimental independent IYRs.

A recent sensitivity study showed that reactor-antineutrino spectra are not equally sensitive to all IYRs. The largest effects occur above about 5 MeV, especially in the 5–8 MeV region associated with the reactor-antineutrino "bump" and the high-energy tail.



Only a small set of fission products dominates this energy region. Several are light fission fragments where the old compilation had little or no direct experimental IYR information.

Since that work, the experimental situation has changed. There are new measurements, newly compiled legacy data, and new light-fragment information.

A. Mattera, et al.
10.1103/xrgf-6f3h

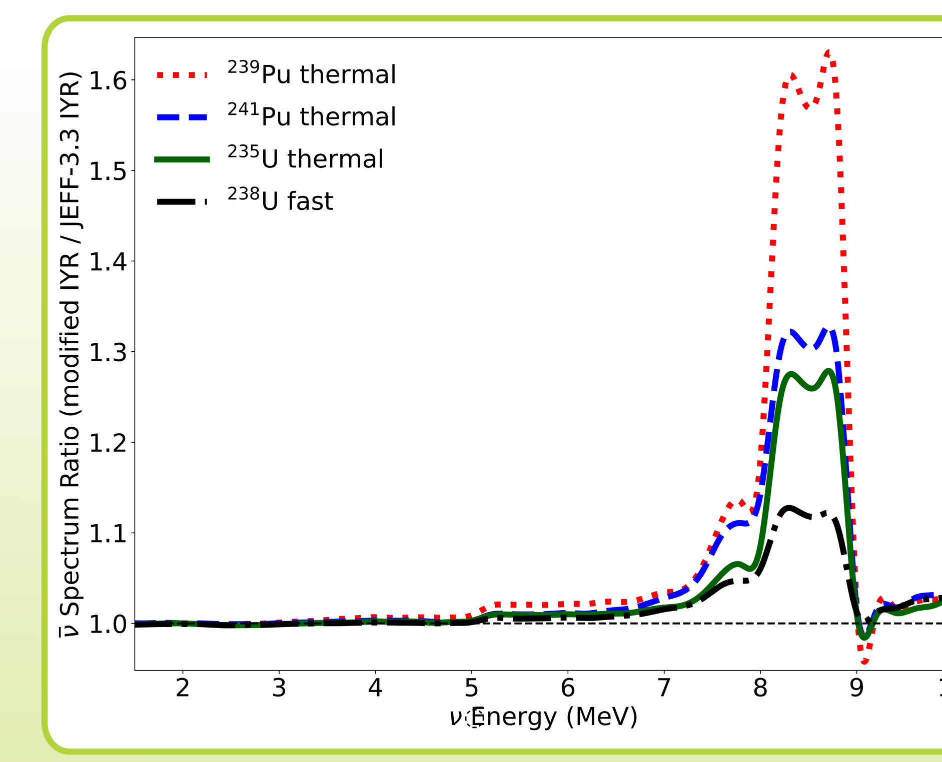
New Experimental Data for the Fission Products that Matter

Among the newly available IYR measurements, Cannarozzo's ^{232}Th(α,f) data are especially useful because they add first-time constraints for three high-impact light fission products: ^{100}**Y**, ^{100}**Nb**, and ^{102}**Nb**.

These nuclides were absent from the previous experimental IYR table, but they appear among the fission products driving the reactor antineutrino high-energy sensitivity. The measurement reports state-resolved high-spin versus low-spin yield ratios for ^{232}Th(α,f).

After conversion to approximate neutron-induced equivalent IYRs, these new constraints can be propagated through summation calculations to estimate their impact on the reactor antineutrino spectrum.

Reactor antineutrino spectral response to updated IYR assumptions for key fission products. The plotted ratio compares modified-IYR spectra to the reference calculation. The effect is concentrated above ~7 MeV, where changes in ground-state and isomeric beta-decay feeding noticeably alter the predicted antineutrino yield.

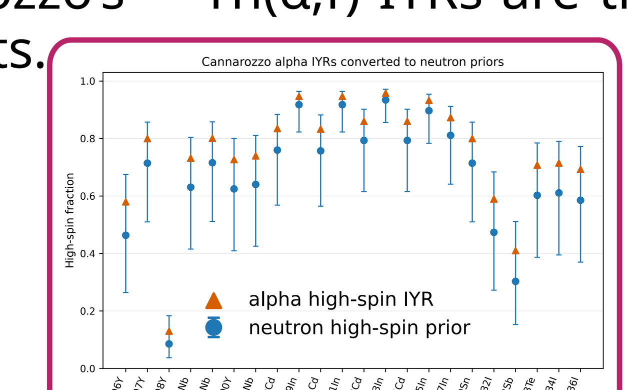


A Systematic Study to Convert (α,F) IYR to (n,F)

Alpha-induced fission carries more angular momentum than neutron-induced fission. As a result, the population of ground and isomeric states can be different even for the same fission product.

We use fission products measured in both reactions to estimate the projectile-dependent shift in state population. Cannarozzo's ^{232}Th(α,f) IYRs are then converted into approximate neutron-induced equivalents.

These converted IYRs provide a practical estimate of the antineutrino impact of newly measured products for which direct neutron-induced data are still missing.



S. Cannarozzo
diva2:1952832

Conclusion

The IYR problem matters because ground and isomeric states can feed different beta-decay branches, changing the predicted reactor antineutrino spectrum.

The 2021 evaluated compilation remains the baseline, but new measurements now reach light fission products identified as important for the high-energy antineutrino region.

Cannarozzo's ^{232}Th(α,f) data provide first-time constraints for ^{100}Y, ^{100}Nb, and ^{102}Nb. After conversion to approximate neutron-induced equivalents, these data allow the antineutrino impact of previously missing IYRs to be estimated. Direct neutron-induced measurements are still needed for the high-impact light fragments that dominate the high-energy antineutrino sensitivity.

Acknowledgements

The work at Brookhaven National Laboratory was sponsored by the Office of Nuclear Physics, Office of Science of the U.S. Department of Energy under Contract No. DE-SC0012704 with Brookhaven Science Associates, LLC. This project was supported in part by the U.S. Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists (WDTS) under the Science Undergraduate Laboratory Internships Program (SULI).