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Impact of Isomeric yield ratios on reactor antineutrino spectra

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Isomeric states have been observed in about 150 of the hundreds of isotopes that can be produced in the fission of major actinides. These isomers can be populated directly through fission, and the isomeric yield ratio (IYR) represents the relative population of the excited state(s) and the ground state (GS) independent yield.

Due to the underlying nuclear structure, the isomeric state often undergoes β decay and populates very different states in the daughter nucleus compared to the GS decay. This has important implications for the determination of the reactor antineutrino flux. The yields of certain fission products have been shown to play a particularly important role in the calculation of reactor antineutrino spectra with the summation method [1,2]. However, an exhaustive study of the impact of IYRs was never reported.

An evaluation of experimental isomeric yields was recently published [4], that provided recommended IYRs for 42 nuclides produced in low-energy neutron-induced fission. In this work, we present a comprehensive study of the extent to which IYRs affect the antineutrino flux predictions with the summation method using two different approaches. First, we estimated how the newly published recommended IYRs change the antineutrino spectra of all major actinides of interest for reactor antineutrino spectra (235,238U,239,241Pu). Then we individually looked at the contribution of each fission product with a known isomer, and studied how a different IYR value would affect the calculated antineutrino spectra.

A result from the first study, the antineutrino spectrum obtained with the newly evaluated IYRs was calculated as the ratio to the one obtained with the unmodified JEFF-3.3 yields [5,6]. While essentially no effect on the antineutrino spectrum is observed below 5 MeV, changes on the order of 1%-2% for each fuel type become evident between 5 and 7 MeV. These grow to as much as 30% above 7 MeV. The changes show consistently an increase in the antineutrino yield when the newly evaluated isomeric yields are used, compared to the original JEFF-3.3 values.

In the second phase of this work, we performed a sensitivity analysis to identify which IYRs the antineutrino spectrum is most dependent on. This looked beyond the experimentally determined values from Ref. [4], and allowed us to identify a number of fission products whose IYR might considerably affect the antineutrino spectrum in proximity to the bump region, and for which no direct yield measurement has been reported to date.

References

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