Nuclear state densities of heavy nuclei in the static-path plus random-phase approximation

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Nuclear level densities are important inputs to the Hauser-Feshbach theory of compound-nucleus reactions, which have numerous applications in basic nuclear science and nuclear astrophysics. Because experimental data for level densities are scarce and common phenomenological models cannot be reliably extrapolated to new regions of the nuclear chart, it is important to develop microscopic models of level densities that are based on the underlying nucleon-nucleon interaction and are computationally efficient for heavy nuclei. I will present the recent application of the static-path plus random-phase approximation (SPA+RPA) to nuclear state densities in a chain of heavy samarium isotopes $^{148\text{-}155}$Sm that describes the transition from vibrational to rotational collectivity [P. Fanto and Y. Alhassid, in preparation]. Formulated in the configuration-interaction shell model framework, the SPA+RPA includes large-amplitude static fluctuations beyond the mean field and small-amplitude time-dependent quantal fluctuations around each static fluctuation. We benchmark the method using a pairing plus quadrupole effective interaction and find that the SPA+RPA state density is in excellent agreement with the exact (up to a controllable statistical error) state density obtained with the shell model Monte Carlo (SMMC) method for each of the isotopes considered. For the even-mass samarium isotopes, we also compare our SPA+RPA results with mean-field state densities and find that the SPA+RPA overcomes the deficiencies of the mean-field approximation associated with the broken rotational symmetry in deformed nuclei and the broken particle-number conservation in nuclei with a strong pairing condensate. In particular, the SPA+RPA reproduces the rotational enhancement of the state density in the deformed even-mass samarium isotopes, avoiding the need to use an empirical collective enhancement factor as is done in mean-field-based methods. I will conclude by discussing the advantages and limitations of the SPA+RPA, as well as current efforts to extend the method to heavier nuclei and more general effective nuclear interactions.

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