Level densities: extending the shell model theory to higher temperatures

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Quantum Monte Carlo methods for the interacting nuclear shell model have been successful in calculating the partition functions and level densities of nuclei at finite temperature and/or excitation energies. The Monte Carlo method enables realistic calculations in much larger configuration spaces than are possible by conventional methods.

The model spaces used in the fully correlated Monte Carlo calculations are very large but finite, and (for a single major shell) the results are no longer reliable at temperatures above $\sim 1.5 - 2$ MeV. We have combined [1] the correlated calculations in the truncated space with independent-particle calculations in the full space including all bound states and the continuum. The theory is valid under the assumption that the effects on the partition function are factorizable and leads to realistic calculations of level densities up to $T \sim 4$ MeV. We have applied the theory to nuclei in the iron region. In particular, we have found that the backshifted Bethe formula for level density is valid up to higher excitation energies than previously thought. This is consistent with experiments that find weak dependence of the single-particle level density parameter on temperature. The present theory showed more clearly the signature of pairing transition in the heat capacity of nuclei.

The extended theory is also applied to spin-projected observables. We find that the signature of pairing correlations in the spin-projected heat capacity decreases rapidly with angular momentum.

[1] Y. Alhassid, G.F. Bertsch, and L. Fang, Phys. Rev. C **68**, 044322 (2003).