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Quantum entanglement patterns in the structure of atomic nuclei within the nuclear shell model

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Quantum entanglement offers a unique perspective into the underlying structure of strongly-correlated systems such as atomic nuclei. Using different entanglement metrics on equipartitions of the valence space, we analyze the structure of light and medium-mass berillyum, oxygen, neon and calcium isotopes within the nuclear shell model, and we identify mode-entanglement patterns related to the energy, angular momentum and isospin of the nuclear single-particle orbitals. We observe that the single-orbital entanglement is directly related to the number of valence nucleons and the energy structure of the shell, while the mutual information highlights signatures of proton–proton and neutron–neutron pairing, as well as nuclear deformation. Proton and neutron orbitals are weakly entangled by all measures, which provides a guide for designing more efficient quantum algorithms for the noisy intermediate-scale quantum (NISQ) era. For some of the studied examples, we show how to exploit this advantage by simulating an Adapt-VQE with circuits of fewer qubits than would be needed conventionally. This technique, known as entanglement forging, can make it possible for NISQ devices to simulate large nuclei in this regime.

session

I. Nuclear Structure and Reactions

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