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Shell-model study of ^{58}Ni using quantum computing algorithm

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This study presents a simulated quantum computing approach for the investigation into the shell-model energy levels of ^{58}Ni through the application of the variational eigensolver (VQE) method in combination with a problem-specific ansatz. The primary objective is to achieve a fully accurate low-lying energy spectrum of ^{58}Ni. In this study, we utilized two distinct shell model spaces: fp and fpg. The fp model space comprises the orbitals $1p_{3/2}$, $0f_{5/2}$, and $1p_{1/2}$ beyond the ^{56}Ni core, represented using 12 qubits (one per orbital). Extending our analysis, we delved into the broader model space fpg, which includes the orbitals mentioned earlier along with the $0g_{9/2}$ orbital above the ^{56}Ni core, utilizing 22 qubits for its representation. The chosen isotope, ^{58}Ni is particularly interesting in nuclear physics through its role in astrophysical reactions while also being a simple but not-trivial nucleus for shell-model study, it being two particles outside a closed shell. The Hamiltonian is based on shell-model interaction (JUN45). Our ansatz, along with the VQE method are able to reproduce exact energy values for the ground state and first and second excited states for 12 qubits. With 22 qubits, the ansatz accurately reproduces the ground state and second excited state energy values. However, there are disparities between the obtained results and the shell-model result for the first excited state with the prepared ansatz. For the first excited state, using 22 qubits, efforts are underway to improve and fine-tune the ansatz. We compare a classical shell model code, the values obtained by diagonalization of the Hamiltonian after qubit mapping, and a noiseless simulated ansatz+VQE simulation. The exact agreement between classical and qubit-mapped diagonalization shows the correctness of our method, and the high accuracy of the simulation means that the ansatz is suitable to allow a full reconstruction of the full nuclear wave function.

session

I. Nuclear Structure and Reactions

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