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Recent advances in ab initio calculations of heavy nuclei

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One of the fundamental problems in nuclear physics is to predict the properties of nuclei based on underlying nuclear interactions. The applicability of nuclear ab initio calculation has been expanding in the past few decades, and systematic calculations can be performed up to mass number ~ 100. However, the applications for heavier systems are limited primarily due to the memory-expensive three-nucleon (3N) interaction matrix elements. Modern nuclear ab initio calculations begin with the nucleon-nucleon (NN) and 3N interactions, benefitting from chiral effective field theory. For medium- and heavy-mass nuclei, one can apply basis expansion methods such as the coupled-cluster method, self-consistent Green's function method, many-body perturbation theory, and in-medium similarity renormalization group, starting from the NN and 3N matrix elements expressed with the spherical harmonic-oscillator (HO) basis set, where a typical calculation is performed within 13 or 15 major-shell space. The memory requirement of the 3N matrix elements in such space will exceed 10 TB, and one needs another truncation for 3N matrix elements, known as $E_{3\mathrm{max}}$ defined by the sum of 3N HO quanta. It turned out that the current $E_{3\mathrm{max}}$ limit does not allow us to obtain converged results for nuclei heavier than $A \sim 100$. To overcome the limitation, we proposed a new storage scheme for the 3N matrix elements, where we exploit the feature of the normal-ordered two-body approximation widely used in the basis expansion methods. This new scheme enables us to compute the known heaviest doubly magic nucleus ^{208}Pb. In this presentation, I will show recent ab initio results for some heavy mass nuclei, including a prediction for the neutron-skin thickness of ^{208}Pb.

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