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Beyond the Shell Model: Computing Nuclei with Coupled-Cluster Theory

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Investigations of rare isotopes in the laboratory are opening the way to understand and clarify the properties of all nuclei and bulk nuclear matter. In this talk I will assess where we stand today in solving the nuclear problem and how future rare isotope facilities will impact our understanding of nuclei. The first part of the nuclear problem concerns our ability to describe complex nuclei using as input the basic interactions among protons and neutrons. Indeed, our community is on the verge of discovering how light nuclear systems are built from nuclear interactions that have their roots in QCD. I will describe this exciting frontier of research through illustrating recent progress in the nuclear implementation of coupled-cluster methods, a quantum many-body technique that enjoys great success in quantum chemistry. Nuclei offer some interesting challenges to coupled-cluster theory and quantum many-body theory generally: first, effective field theory implementations of the nuclear forces indicate the presence of a three-body force. Second, very weakly bound nuclei can best be described utilizing a single-particle basis consisting of bound and continuum states. In both cases, we have developed methods to solve for nuclear properties in these systems. I will also describe the computational requirements for the solution of the nuclear coupled-cluster problem. This research is supported by the U.S. Department of Energy under Contract Number DE-AC05-00OR22725 with UT-Battelle, LLC (Oak Ridge National Laboratory).