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Effective valence-space interactions for the nuclear shell model from many-body perturbation theory

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The nuclear shell model [1] is a well developed theory for the calculation of finite nuclei properties. Its main idea is simple: a non-relativistic A-nucleon Hamiltonian, containing nucleonic kinetic energies and inter-nucleon interactions, is diagonalized in a spherically-symmetric harmonic-oscillator basis. For light nuclei, the model treats all A nucleons as active particles occupying a large-dimensional model space comprised from many oscillator shells, representing thus a fully ab-initio many-body approach referred to as no-core shell model [2]. However, a rapid growth of the basis dimension with the number of nucleons prohibits such calculations for heavier nuclei. A common practice to limit the number of basis configurations is proposed by the interacting shell model which assumes an inert core (usually being a doubly-closed shell nuclei) and treats only valence nucleons as active particles moving in a model space comprised from one or two oscillator shells. Such severe truncation of the Hilbert space requires a consistent derivation of the so-called effective interaction for valence nucleons. Phenomenological effective interactions, obtained from a fit to experimental data [1,3], usually demonstrate a high descriptive and predictive power of the shell model. Construction of microscopic effective interactions from realistic nucleon-nucleon potentials has been a long-standing problem of nuclear theory which stays challenging up to present [4,5]. In this talk I will present novel developments within many-body perturbation theory which allows derivation of effective valence-space shell-model interactions from a nucleon-nucleon potential for the first time beyond the conventional 3rd order. Both harmonic-oscillator basis and self-consistent Hartree-Fock basis were implemented to investigate convergence properties of the theory with respect to the model-space parameters. As an example of application, we will consider in detail effective interactions for the p-shell obtained from the Daejeon16 nucleon-nucleon potential [6]. Calculated ground state energies and spectra of A=6 systems will be compared with those obtained from the phenomenological p-shell interaction [3] and with the results from the no-core shell model [6]. Finally, I will show ground-state energies and spectra of selected p-shell nuclei obtained from the derived effective interactions.

[References]

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