Microscopic Shell Model Calculations for sd-Shell Nuclei

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Several techniques now exist for performing detailed and accurate calculations of the structure of light nuclei, *i.e.*, $A \leq 16$. Going to heavier nuclei requires new techniques or extensions of old ones. One of these is the so-called No Core Shell Model (NCSM) with a Core approach, which involves an Okubo-Lee-Suzuki (OLS) transformation of a converged NCSM result into a single major shell, such as the *sd*-shell. The obtained effective two-body matrix elements can be separated into core and single-particle (s.p.) energies plus residual two-body interactions, which can be used for performing standard shell-model (SSM) calculations. As an example, an application of this procedure will be given for nuclei at the beginning of the *sd*-shell.

KEYWORDS: NCSM, OLS transformation, *ab initio* input for the valence-space shell model

1. Introduction

Great progress has been made in the last 15 to 20 years in our understanding of the structure of atomic nuclei starting from the fundamental nucleon-nucleon (NN) and three-nucleon (3N) interactions among the protons and neutrons in light nuclei ($A \leq 16$). Such models as the NCSM [1], the Coupled Cluster theory [2], the Green's Function Monte Carlo approach [3], *etc.* have had considerable success in describing the physical properties of such nuclei and even predicting the properties of nuclei in this mass region that have not yet been measured experimentally. One of the major problems challenging these microscopical approaches to nuclear structure is how to extend them to describe medium- to heavy-mass nuclei.

In this contribution we describe such a formalism, which we call the NCSM with a Core (or the *ab initio* Shell Model) method. This name comes from the approach used in our model, namely, we use the basic NCSM method to calculate the core and s.p. energies plus the residual effective two-body matrix elements necessary for performing SSM calculations within a single major shell, thereby using the fundamental theory to install the core into the NCSM.

2. Formalism for the NCSM with a Core Approach

The formulation for this technique can be summarized as follows:

(1) Perform a standard NCSM calculation in a large basis space for a nucleus, such as ^{18}F, *i.e.*, an ^{16}O core plus two valence nucleons, so as to obtain converged results for the 18-nucleon energies