# Anatomy of USDB Shell Model interaction

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## Introduction

Shell model (SM) is one of the most successful approaches to study the nuclear many body problems.It was first proposed by M. G. Mayer in 1949 to give the mathematical description of the experimentally observed shell structure (magic number) properties of atomic nuclei [1]. Since then, nuclear structure studies have been carried out in shell structure based model space. The popularity of the SM can be assessed from its regular application in low, medium and heavy mass region [2]. Its success, however, entirely depends on the two body matrix elements (TBMEs) employed in it. In the SM calculations, the realistic TBMEs, which are obtained from elementary quark-level interactions, are usually transfigured into effective values for a given model space to achieve better validation of underlying knowledge of the behavior of nucleons inside a nucleus [3]. In the course of transition, the tensor structure of two nucleon interaction is enfolded and their summed effect on nuclear binding energy, energy of excited states, level density and other physical observables are studied.

To study the contribution of individual components on the nuclear structure properties, a method was suggested by the Elliott [4] and Krison [5] to decompose the effective interaction into its spin-tensor structure. This method is also very useful to examine the role of each component in building the semi-magic neutron and proton number in the exotic nuclei [6]. In the present work, the spin-tensor decomposition method and its application to the *sd*-model space are discussed.

## Theoretical framework and results

Since the TBMEs represent the measurement of two body force, therefore, in LS representation, the rotational invariant interaction between two spin 1/2 particles can be written as

$$V_{LS}(1,2) = \sum_{k=0}^{2} V_{LS}^{k} = \sum_{k=0}^{2} C^{k}.S^{k} \qquad (1)$$

where, $C^k$ and $S^k$ are irreducible tensor operators of rank $k$ for configuration-space and spin-space, respectively. The k = 0, 1, and 2 correspond to the central, spin-orbit and tensor component of $V_{LS}(1,2)$ interaction, respectively. In the SM, the interaction between two nucleon are defined in $jj$ basis, therefore, we cannot directly employ Eq.(1) in the calculations. Using the transformation of $jj$ to $LS$ basis, 6j-symbol properties and method given by Eillott [4] along with Eq.(1), the most general expression of shell model two body interaction is written as

$$V_{jj}(1,2) = \sum_{k=0}^{2} V_{jj}^{k} \qquad (2)$$

For the calcualtions, universal *sd*-B (USDB) effective interaction [3] of *sd*-model space has been considered which is characterized by 66 parametric values *viz.*, 3 bare single particle energies, 33 and 30 TBMEs of T = 0 and 1, respectively.

Using Eq. (2), the USDB TBMEs are decomposed into the central, spin-orbit and tensor matrix elements. Their numerical values relative to total USDB matrix elements are illustrated in Figure 1. As can be seen from this figure, the T = 0 matrix elements are

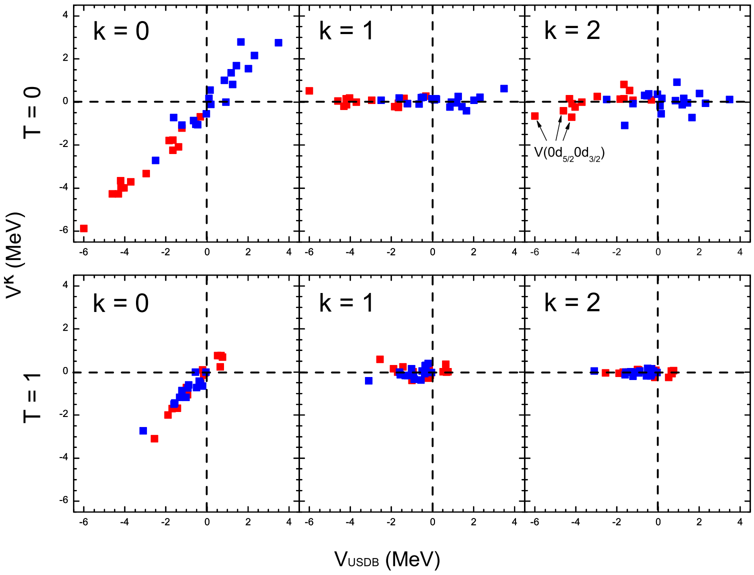


FIG. 1: Comparison of central, spin-orbit and tensor TBMEs with USDB TBMEs. The diagonal and non-diagonal matrix elements are shown by solid red and blue symbols, respectively.

widely spread between -5 to 3 MeV, whereas the T = 1 matrix elements are confined in narrow range from -2 to 0 MeV. The central matrix elements of both isospin states lie very close to the diagonal line. Thus, it can be inferred that the central component carries maximum part of total matrix elements. Further, among the central components of T = 0 and 1, the T = 0 diagonal matrix elements have large and attractive two body character. The spin-orbit components of both isospin states are close to zero. Similar behavior is also observed for T = 1 tensor matrix elements. For T = 0, tensor matrix elements are scattered between -1 to 1 MeV where among the diagonal matrix elements, the $(0d)^2$ matrix elements have relatively large values, in particular, for $V_{0d_{5/2}0d_{3/2}}$, see Fig.1. This leads to a considerable averaged attractive tensor force between $\pi 0d_{5/2} - \nu 0d_{3/2}$ and $\pi 0d_{3/2} - \nu 0d_{5/2}$ orbitals. As a result, the relative gap between $\nu 0d_{5/2}$ and $\nu 0d_{3/2}$ is reduced when $\pi 0d_{5/2}$ is being filled.

To summarize, the spin-tensor decomposition method was used for the USDB interaction of the *sd*-model space. It was found that the central components of USDB interaction has significant contribution to total matrix elements relative to non-central components. The non-central components were found to be very close to vanishing value except T = 0 tensor component. The effects of $V^{T=0}_{0d_{5/2}0d_{3/2}}$ tensor TBMEs were also highlighted in the calculations. Details of this work will be presented during the symposium.

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