Study of collectivity in Ti isotopes and new realistic interaction for the $fpg_{9/2}d_{5/2}$ model space

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Introduction

The neutron-rich Ca, Ti, and Cr isotopes have been the focus of many studies during recent years. This effort was prompted primarily by the observation of an $N = 32$ subshell closure in ^{52}Ca [1, 2], ^{54}Ti [3], and ^{56}Cr [4]. The high-lying 2^+ state observed in ^{68}Ni and its low $B(E2; 2^+ \rightarrow 0^+)$ value are the result of the relatively large energy gap separating the fp and $0g_{9/2}$ orbitals [5]. This gap gets reduced when few protons are removed from ^{68}Ni, showing a sudden change in nuclear structure with a rapid increase in collectivity [6]. Due to enormous computational advancements in the recent years and the development of new interactions suggest a rapid shape change in the neutron-rich nuclei around $N = 40$ in the fp shell. To study the development of collectivity caused by quadrupole correlations which energetically favor the deformed intruder states around $N = 40$ the model space must involve the neutron $\nu 0g_{9/2}$ and $\nu 1d_{5/2}$ orbitals [7]. This can be explained in terms of the quasi-SU(3) approximate symmetry.

Motivated with the recent experimental data around $N = 40$, we developed effective interaction based on a G-matrix obtained from a realistic nucleon-nucleon potential [8] for $fpg_{9/2}d_{5/2}$ model space. We have performed calculations for Ti isotopes using this interaction.

The proton single particle energies are taken to be -9.627, -6.542, -5.555, and -5.134 MeV for $0f_{7/2}, 1p_{3/2}, 0f_{5/2}$, and $1p_{1/2}$ orbits, respectively, while for neutron the single particle energies are -5.157, -3.157, -1.157, -1.357, and 2.843 MeV for $1p_{3/2}, 0f_{5/2}, 1p_{1/2}, 0g_{9/2}$, and $1d_{5/2}$ orbits, respectively. We allowed maximum two particle excitations in the $\nu 1d_{5/2}$ orbital. The diagonalization has been done using ANTOINE shell model code.

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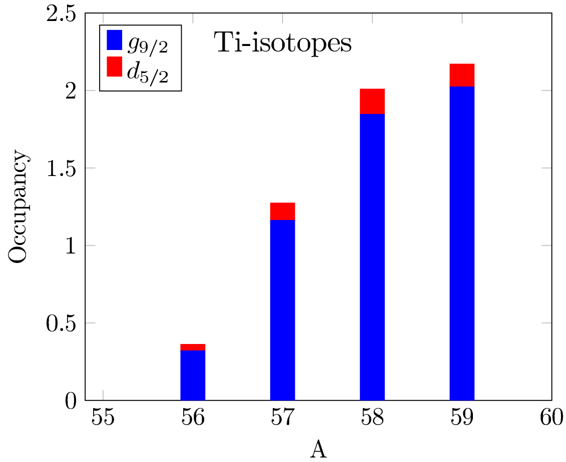

FIG. 1: The neutron occupation number for the orbitals $0g_{9/2}$ and $1d_{5/2}$ for Ti isotopes using $fpg_{9/2}d_{5/2}$ model space.

Results and Discussions

The energy spectra from the new effective interaction for $fpg_{9/2}d_{5/2}$ model space along with the LNPS effective interaction for odd isotopes [10] in comparison with the experimental data are shown in Fig. 2.

The calculations for ^{56}Ti with our interaction precisely reproduce the data. The first excited state is produced as 2^+, with a second and third excited as 4^+ and 6^+ respectively, although our interaction predicting 6^+ state at 600 keV higher than the experimental data.

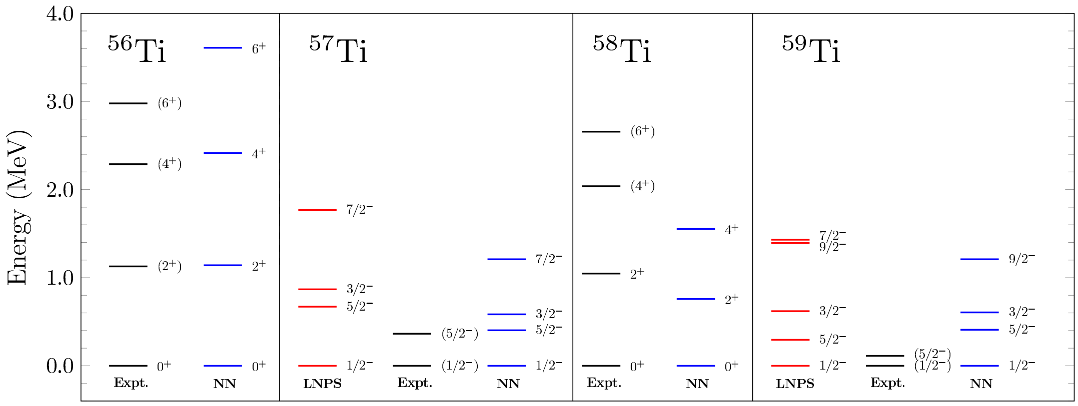

FIG. 2: Level schemes of $^{56-59}$Ti with large scale shell model calculations using the new effective interaction and in comparison with the experimental data [9] and the LNPS effective interaction for odd isotopes [10].

In ^{57}Ti, only two states with suggested negative parity are known experimentally. As shown in Fig. 2, the calculations with the LNPS interaction and our interaction predict a ground state with $1/2^-$ and a first excited $5/2^-$ state. The configuration of the wave function of the ground state is observed with one neutron in the *gd* orbitals, and dominated by fp configuration in our calculations. This indicates that ^{57}Ti (N=35) is outside Island of Inversion around N=40, but from N= 35 onwards, we can see a significant increase in the role of *gd* orbitals.

The calculations for ^{58}Ti in our interaction giving slightly compressed spectra. The first excited state is produced as 2^+, with a second excited as 4^+. Thus it reflects importance of the excitation of more neutrons to the *gd* orbitals.

For ^{59}Ti, with our interaction the spin of the ground state is predicted to be $1/2^-$ (as for ^{57}Ti), with a first $5/2^-$ excited state at 409 keV (300 keV larger than the experimental value). The configuration of the wave function of the ground state is dominated by two neutrons in the *gd* orbitals, which indicates that ^{59}Ti also belongs to the Island of Inversion around N=40.

In the Fig.1, we have plotted the neutron occupancy of $g_{9/2}$ and $d_{5/2}$ orbitals, the occupancy of $d_{5/2}$ orbital increasing from $A = 56$ to $A = 59$. It is demonstrating the significant role of the *gd* orbitals in the model space to explain collectivity in this region by exciting neutrons across $N = 50$ shell. We have also calculated $B(E2)$ and quadrupole moments which we will report during the symposium.

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