New effective interaction for $fpg_{9/2}d_{5/2}$ space: collectivity around $N \sim 40$

Vikas Kumar* and P.C. Srivastava†
Department of Physics, Indian Institute of Technology, Roorkee - 247667, INDIA

Introduction

Recent experimental and theoretical evidence suggest a rapid shape change in the neutron-rich nuclei around $N = 40$ in the fp shell nuclei. To study the development of collectivity around $N = 40$ the model space must include the $0g_{9/2}$ orbital and its quasi SU3-counterpart the $1d_{5/2}$ have to be taken into account simultaneously [1]. Recently two attempts have been made to develop modern effective interactions by including $d_{5/2}$ orbital in the $fpg_{9/2}$ model space [2, 3]. In the ref. [3], although protons orbital $f_{7/2}$ and $p_{3/2}$ have been taken.

Motivated with the recent experimental data around $N = 40$ and INGA campaign, we developed effective interaction for $fpg_{9/2}d_{5/2}$ model space. The effective interaction is based on a G matrix obtained from a realistic nucleon-nucleon potential [4]. The interaction proposed in this work is denoted by PSVK. We performed calculations for Ca, Ti, Cr, Fe and Ni isotopes. Here we are reporting only the results of Ti isotopes for energy, $B(E2; J + 2 \to J)$ and quadrupole moments.

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 $1p_{3/2}$, $1p_{1/2}$, $0f_{5/2}$, $0g_{9/2}$, and $1d_{5/2}$ orbits, respectively. We allowed maximum two particle excitations in the $\nu 1d_{5/2}$ orbit. The diagonalization has been done using ANTOINE shell model code.

*Electronic address: vikasphysicsiitr@gmail.com
†Electronic address: pcsrifph@iitr.ac.in

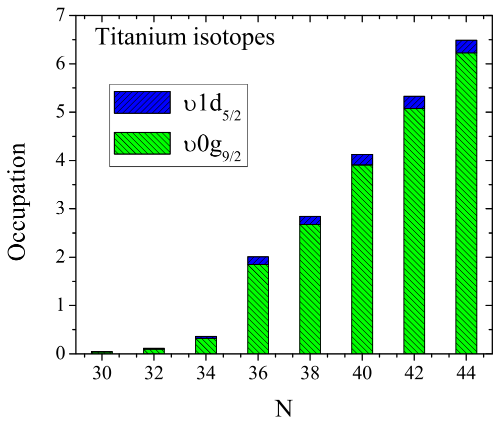

FIG. 1: The Neutron occupation number for the orbitals $0g_{9/2}$ and $1d_{5/2}$ for Ti isotopes using $fpg_{9/2}d_{5/2}$ model space.

Results and Discussions

For the Ti isotopes, the excitation energies for 2^+ states are compared to the available experimental data in Fig.2(a). Fig. 2(b), represents the ratio of excitation energies $E(4^+)/E(2^+)$ and $E(6^+)/E(4^+)$, this ratio make it possible to recognize whether the nuclear spectrum is close to that of the rigid rotor or not. The ratio $E(4^+)/E(2^+)$=3.33 and $E(6^+)/E(4^+)$=2.1 required for the perfect rotational limit. The theoretical and experimental $B(E2)$ transition probabilities along the yrast band is shown in Fig. 2(c). Fig. 2(d) represents the intrinsic quadrupole moments derived from the calculated spectroscopic ones.

In order to compare the calculated values of quadrupole moment with experimental data, we need intrinsic quadrupole moment Q_{int} as

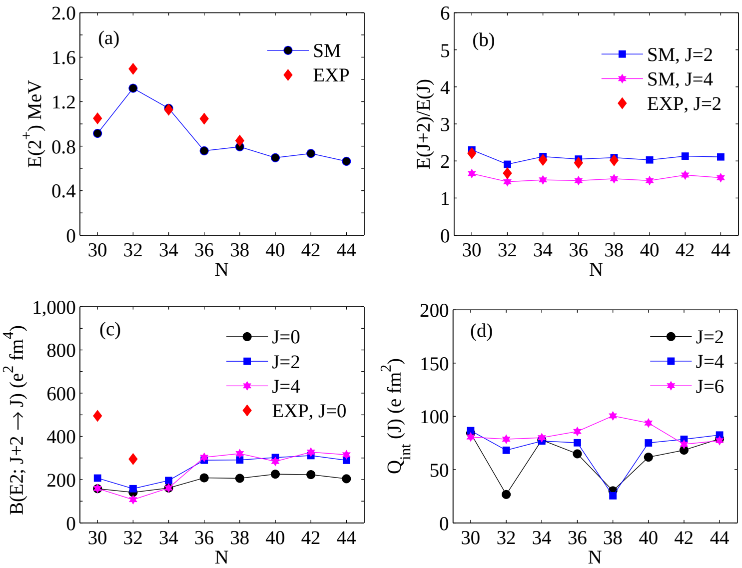

FIG. 2: Comparison between calculated and experimental results for Ti isotopes with PSVK interaction: the excitation energies of the 2^+ states are shown in panel (a), in panel (b) we present the ratio of energies of $E(J+2)/E(J)$, the B(E2) transition rates are plotted in panel (c), and the calculated intrinsic quadrupole moments in panel (d). The experimental data are taken from NNDC.

well as the value of K for the band.

$$Q_{int} = \frac{(J+1)(2J+3)}{3K^2 - J(J+1)} Q_{spec}(J), K \neq 1, \tag{1}$$

It is possible to extract deformation parameter β_2 for $^{52-66}$Ti isotopes from the energy of their 2^+ states by using the empirical formula of Raman *et al.* [5]:

$$\beta_2 = const \times \sqrt{A^{-0.69}/E(2^+)}. \tag{2}$$

For $^{52-66}$Ti isotopes the $\beta_2 \sim 0.23$, 0.19, 0.20, 0.25, 0.24, 0.25, 0.24, and 0.25, respectively, from this results prolate or oblate shapes can not be distinguished. 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 $N = 30$ to $N = 44$. It is demonstrating the significant role of $d_{5/2}$ orbital in the model space to explain collectivity in this region by exciting neutrons across $N = 50$ shell. Overall the calculated excitation energies and transition rates are in good agreement with the experimental data. During the meeting we will present results of rest fp shell nuclei.

PCS would like to thank Prof. M. Hjorth-Jensen and Prof. V.K.B. Kota for useful discussions during this work. V. Kumar acknowledges financial support from CSIR-INDIA for his PhD thesis work.

References

[1] E. Caurier *et al.*, Rev. Mod. Phys. **77**, 427 (2005).

[2] S.M. Lenzi *et al.*, Phys. Rev. C **82**, 054301 (2010).

[3] L. Coraggio *et al.*, Phys. Rev. C **89**, 024319 (2014).

[4] M. Hjorth-Jensen *et al.*, Phys. Rep. **261**, 125 (1995).

[5] S. Raman *et al.*, Phys. Rev. C **37**, 805 (1988).