Investigation of nuclear structure below the ^{132}Sn core

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Introduction

The structure of the neutron- rich nuclei in ^{132}Sn region, particularly binding energy, low lying excited states and beta decay rates at finite temperature are important ingredients of nucleo-synthesis calculation [1]. They play an important role in the synthesis of heavy elements through rapid neutron capture process. However, experimental information on the spectroscopic properties of this region is restricted [2]. Therefore, it is important to have reliable theoretical predictions to understand stellar evolution in a better way. Developing a proper effective interaction and validating it over a large region form an essential corner stones of these theoretical endeavours.

It is well known that that long isotopic chain of tin isotopes between N=50 to N=82 provides a unique ground for testing nuclear models. One interesting feature for these Sn isotopes is the mismatch of experimental and theoretical B(E2) values for the most neutron-deficient ones. A series of Coulomb excitation experiments performed at CERN, GSI, and MSU laboratories have uncovered unexpectedly large values of B(E2) for light Sn isotopes [3]. These experimental values deviate from theoretical predictions based on realistic interaction with different cores.

The near degeneracy of the energies of $1g_{7/2}$ and $2d_{5/2}$ is another issue of concern in this mass region and their relative order is a subject of debate. In ^{103}Sn (ground spin=$5/2^+$) there is a ground spin inversion with respect to the ^{101}Sn (ground spin=$7/2^+$). Recently, C Qi proposed a new monopole optimized effective interaction named as *Bonnnew* [4] which can explain the swap of the spin. This interaction has also been applied for lighter Te and I isotopes with neutron number just above N=50.

However, for heavier isotopes of Sn, Te, I with N< 82 but close to it, *sn100pn* [5] has been used successfully. The new interactions generated to tackle the issues in lighter Sn isotopes have not been utilized fully to explain these heavier isotopes.

Recently ^{132}Te is studied within large basis shell model to interpret the experimental data obtained using INGA facility at TIFR, Mumbai [6]. Taking standard interaction *sn100pn*, the theoretical calculation was successful to a great extent. However, there were a few issues which needed additional effort.

Therefore, it is evident that all these prevailing issues in this mass region, over the range of neutron numbers from 50 to 82 have been dealt in a segregated way. So, we felt that a consolidated approach is needed to understand the region better.

In the present work, we have compared the results using different effective interactions successful in heavier and lighter isotopes for the same set of nuclei to understand them better and to suggest necessary additions and alternations in effective single particle energies as well as two body matrix elements.

Theoretical Calculation

Large Basis Shell Model (LBSM) calculations have been performed for a few neutron rich nuclei in A~132 region, using the code OXBASH [7]. The valence space consists of $1g_{7/2}$, $2d_{5/2}$, $2d_{3/2}$, $3s_{1/2}$, $1h_{11/2}$ orbitals for both neutron and protons above the ^{100}*Sn* inert core.

We have studied the energy spectra, transition probabilities and moments of these nuclei with three different interactions. The first one *sn100pn.int* [5] was obtained from a realistic interaction derived from CD Bonn nucleon-nucleon interaction. The second interaction *Bonnnew.int* [4] is in isospin formalism. So we converted this interaction into an equivalent proton-neutron form. The single particle energies for both protons and neutrons are the same in this interaction, as it was used to study nuclei close to ^{100}Sn. However, for working in regions with neutron number closer to N=82, neutron single particle energies may differ from those of protons. So in the last interaction (*Bonnsn*), we have replaced the single particle energies of proton and neutron in *Bonnnew* interaction by those used in *sn100pn.int*, which are derived from experiments.

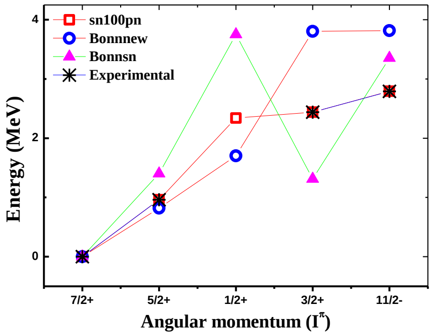

Fig 1 Comparison of experimental and theoretical excitation energies of ^{133}Sb.

Results and Discussion

To start with, we have tested the single particle energies of the first two interactions by comparing our results with the experimental data for single neutron-hole nucleus ^{131}Sn (1νh-0πp, with Z=50, N=81) and ^{133}Sb, which has a single proton particle with totally filled up neutron orbits (0νh-1πp, Z=51, N=82). For testing the two body matrix elements (TBME), results for ^{132}Sb (1νh-1πp), ^{130}Sn (2νh-0πp), ^{134}Te (0νh-2πp) have been compared with experimental data. We have also calculated spectroscopic properties of ^{132}Te (2νh-2πp), ^{134}I (1νh-3πp) nuclei.

The results show that for ^{131}Sn, *sn100pn* and *Bonnnew* match well with the experimental one. However, for ^{133}Sb (Fig. 1), only *sn100pn* matches well with the experimental one because the single particle energy is taken from experimental data. Large deviation is observed for *Bonnnew*. The reason of deviation for *Bonnnew* may be analyzed further. For both the nuclei, *Bonnsn* is totally unsuccessful. This is expected as we know that single particle energies (*spe*) and TBMEs are integrally coupled in a Hamiltonian. So mere coupling *spe*'s from one interaction cannot be used right away in another one. We need to tune them to be best suited with TBMEs of *Bonnnew*.

In order to test the (νh-πp) TBMEs, the results for ^{132}Sb have been shown in Fig 2. Large deviations are observed for *Bonnsn* results, as expected. It is also interesting that although *Bonnnew* fails for ^{133}Sb (Fig. 1), good agreement for ^{132}Sb with both *Bonnnew* and *sn100pn* is noted. This indicates that in *Bonnnew*, (ν-π) TBMEs are better tuned to work near N=82 also.

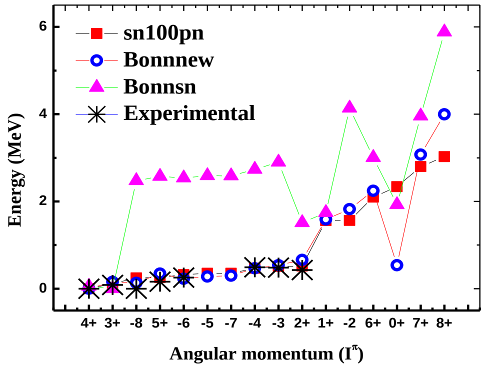

Fig 2 Comparison of experimental and theoretical excitation energies of ^{132}Sb.

We have also checked the results for ^{132}Te and ^{134}I. We have calculated the transition probabilities and moments for these nuclei and compared them with experiments to suggest the best fitted Hamiltonian to work throughout this mass region.

References

[1] M. Saha. Sarkar et al., *http://arxiv.org/abs/1411.2353v1;* M. Saha. Sarkar et al., POS (NIC X) 147 and references therein.
[2] http://www.nndc.bnl.gov
[3] A. Ekstrom et al., Phys. Rev Lett. **101**, 012502 (2008); J. Cederkall et al., Phy Rev Lett. 98, 172501 (2007); A. Banu et al., Phys. Rev C. 72, 061305(R)(2007); C. Vaman et al., Phys. Rev Lett. 99,162501 (2008) and references therein.
[4] Chong Qi et al., Phys. Rev C86, 044323 (2012) and references therein.
[5] B. A. Brown et al., Phy Rev C71, 044317 (2005).
[6] Abhijit Bisoi et al., Proc. DAE-BRNS symp. Nucl. Phys. (India) B59 (2014) 94
[7] B.A. Brown, A. Etchegoyen, W.D.M. Rae, N.S. Godwin, MSU-NSCL Report No. 524, 1985, unpublished.