Low-lying nuclear structure of stable even-A Zn-isotopes

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Introduction

From last few decades, significant efforts were made to study the evolution of nuclear shell structure, ranging from stable nuclei to the exotic nuclei. Experiments performed at the newly developed radioactive ion beam facilities have indicated that some of the traditional magic numbers should be replaced with new magic numbers. Zn-isotopes are of particular interest, being two protons away from the Z = 28 magic number and near neutron midshell (N=28-50) along with a harmonic subshell clousre for ^{70}Zn at N = 40. Generally, the collective vibrational motion is attributed to the structure of even-A Zn-isotopes on the basis of typical energy pattern of first few excited states viz. the two-phonon triplet states (0_2^+, 2_2^+, 4_1^+) at about twice the energy of first excited 2_1^+ state. However such a general picture fails while considering other electromagnetic properties of Zn-isotopes [1]. Moreover the excitation energy of 0_2^+ in these isotopes is also surprising as it follows altogether a different behaviour as compared with the other low-lying excited states. A myriad of nuclear phenomenon like shape coexistence, shape transition, etc. have been obeserved and predicted in the neighbouring nuclei of Zn-isotopic chain. While no clear evidences of such phenomenon are experimentally oberved in Zn-isotopes, a number of predictions are made theoretically and few hints available from some of the previous experiments.

Shell model calculations

Shell model calculations have been performed in order to understand the low-lying electromagnetic nuclear structure of Zn-isotopes. The calculations were taken up using KSHELL code of Shimizu et al.[2], and the available high performance computing facility at IUAC New Delhi.

The single particle space was provided by the f_5pg_9 model space viz. $1p_{3/2}$, $0f_{5/2}$, $1p_{1/2}$, $0g_{9/2}$ and the matrix elements of the interaction, by using two different interaction hamiltonian viz. JUN45 and jj44b, in pn format. An inert ^{56}Ni core was considered. In JUN45, the initial Hamiltonian is based on an effective interaction derived from the realistic Bonn-C potential in a microscopic way. It was modified iteratively using a set of 400 experimental binding and excitation energy data from 69 nuclei in the mass region A=63-96 on 45 well-determined linear-combinations of the 133 TBME and four SPE. Single-particle energies (SPE) are taken to be -9.8280, -8.7087, -7.8388, and -6.2617 MeV for the $p_{3/2}$, $f_{5/2}$, $p_{1/2}$ and $g_{9/2}$ orbits, respectively. Similarly the jj44b interaction was also derived from a realistic interaction based on the Bonn-C potential which has been developed by fitting 600 binding energies and excitation energies of nuclei with Z = 28-30 and N = 48-50. The single particle energies are taken to be -9.6566, -9.2859, -8.2695 and -5.8944 MeV for the $p_{3/2}$, $f_{5/2}$, $p_{1/2}$ and $g_{9/2}$ orbits, respectively.

Results and discussions

1. Excitation energy

The excitation energy spectrum is shown in Fig.1.

2. Reduced transition strength

The reduced transition strengths for even-even ^{62}Zn - ^{70}Zn are calculated using both the JUN45 and jj44b effective interactions and employing an effective charge of $e_\pi = 1.8e, e_\nu = 0.8e$ [3]. Fig. 2 shows the reduced electric quadrupole transition

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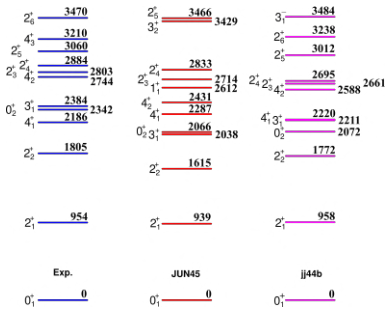

FIG. 1: The calculated level scheme with JUN45 and jj44b, compared with the experimental data, for ^{62}Zn.

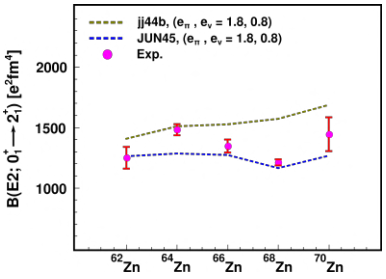

FIG. 2: Reduced transition probability calculated from the shell model, compared with experimental values for ^{62,64,66,68,70}Zn isotopes.

strength from g.s. to first excited state calculated from the shell model and compared with the experimental results [4] for Zn-isotopes. The Table I shows calculated B(E2) values for few low-lying transitions of ^{62}Zn. In the present plot it can be observed that the calculated results with JUN45 hamiltonian shows a better agreement with the experimental data than jj44b hamiltonian.

3. Electric quadrupole (E2) map

The E2 maps are shown in the Fig.3 obtained using JUN45 effective interaction for low-lying positive and negative parity states of ^{62}Zn. The width of the connected lines is proportional to the reduced electric quadrupole transition strength.

The calculations were performed in a similar fashion as described for ^{62}Zn for all the other even-A Zn-isotopes. A detail of the obtained results will be presented during the Conference.

TABLE I: Calculated reduced transition probabilities for a few low-lying states of ^{62}Zn using JUN45 and jj44b interaction hamiltonians.

Transition	BE2 [e^{2}fm^4]	
	JUN45	jj44b
$2_1^+ \rightarrow 0_1^+$	252.5	281.6
$2_2^+ \rightarrow 0_1^+$	3.8	0.1
$2_2^+ \rightarrow 2_1^+$	31.8	67.8
$0_2^+ \rightarrow 2_1^+$	70.8	22.3
$0_2^+ \rightarrow 2_2^+$	3.8	0.3
$4_1^+ \rightarrow 2_1^+$	232.0	360.6
$4_1^+ \rightarrow 2_2^+$	45.4	0.5

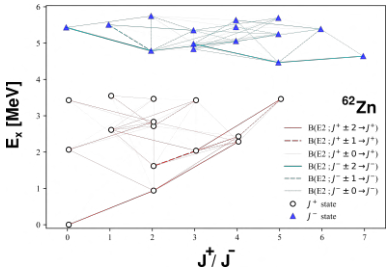

FIG. 3: E2 map for ^{62}Zn obtained with JUN45 hamiltonian.

Acknowledgments

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