

# Systematics of collectivity studied for even-even stable Zn-isotopes

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## 1. Introduction

The collectivity of stable even-even Zn-isotopes was investigated through Shell model calculations using the BIGSTICK code written in Fortran-90 for the many-fermion problem [1]. It is an open source and flexible configuration-interaction code. The Hamiltonian is solved for its low-lying eigen values by producing basis states of the Slater Determinants (Occupational representation). This is assumed in the code that the Hamiltonian is rotationally invariant and it conserves parity and also constrained by 2-body forces and in some cases by 3-body forces.

The calculations were performed using the FUJITSU workstation @IUAC having Intel Xeon processor with a RAM of 64GB and clock speed 2.40 GHz. This machine has 20 cores (10x2) along with a general storage of 1TB.

## 2. Excitation energy spectrum

Even-even <sup>62-70</sup>Zn-isotopes have 30 protons (Z) and 32,34,36,38,40 number of neutrons (N) respectively and based on the shell structure of these nuclei a single particle space is defined as:  $0f_{5/2}, 1p_{3/2}, 1p_{1/2}$  and  $0g_{9/2}$  (fpg model space). The protons and neutrons were activated in all the orbits of Zn-isotopes. After defining the model space the interaction matrix element were needed by the BIGSTICK code which can be defined in one, two or in some cases, three body space. The interaction matrix element for this calculation were taken from JUN45 effective interaction [2] having 133 two-body matrix element (TBME) , 4

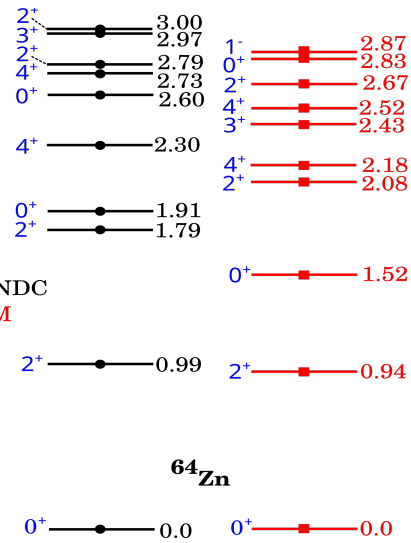


FIG. 1: Low-lying energy level scheme of <sup>64</sup>Zn.

single particle energies and with <sup>56</sup>Ni (Z=28, N=28) as core.

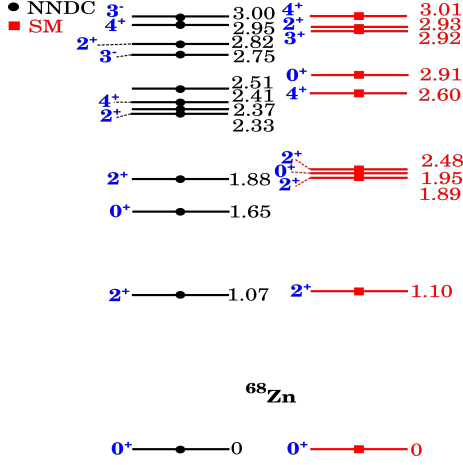
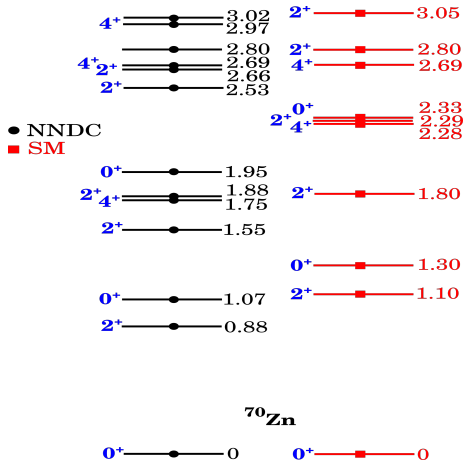
The TBME are defined as:

$$V_{JT}(ab, cd) = \langle ab; JT | V | cd; JT \rangle$$

where a,b,c,d label orbits as ordered in the single particle space (fpg.sps) file, J and T are the total angular momentum and total isospin of the two-body states  $|ab; JT\rangle$ . In addition, the code provides the option to scale with respect to some known nuclei or to use auto-scaling option can be chosen, to generate the excitation energy spectrum. The standard procedure of diagonalization called Lanczos with default convergence (ld) was chosen for all the five nuclei. The criterion for energy convergence was such that energy should be minimised to less than 0.0010 MeV.

The code uses the Lanczos algorithm [1] to reduce the Hamiltonian matrix to a truncated

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 FIG. 2: Low-lying energy level scheme of  $^{68}\text{Zn}$ .

 FIG. 3: Low-lying energy level scheme of  $^{70}\text{Zn}$ .

tridiagonal matrix whose eigen values approximate the extremal eigen values of the full matrix. The figures 1, 2 and 3 shows our calculated theoretical results for three isotopes and how they compare with the experimental results [3]. There is a reasonable agreement among the experimental and this work's results of excitation energy for even-even stable Zn-isotopes (only three isotopes are shown).

### 3. Reduced transition strength

For the computation of transition probabilities the given sample input for the 'dens' pro-

Zn-isotopes	$(B(E2; 2_1^+ \rightarrow 0_1^+))$	
	BIGSTICK ( $e^2b^2$ )	NNDC ( $e^2b^2$ )
$^{62}\text{Zn}$	0.0211	0.025
$^{64}\text{Zn}$	0.0366	0.0296
$^{66}\text{Zn}$	0.0472	0.0270
$^{68}\text{Zn}$	0.0487	0.0242
$^{70}\text{Zn}$	0.0396	0.0289

 TABLE I: The reduced transition strength;  $B(E2; 2_1^+ \rightarrow 0_1^+)$  for stable even-even Zn-isotopes calculated with BIGSTICK, compared with the experimental results from NNDC.

gram was used. 'dens' is a nuclear density and electromagnetic form factor program which is a part of the OXBASH package developed by B.A. Brown [4].

The  $^{56}\text{Ni}$  was used as a core with valence space up to  $0g_{9/2}$  orbital corresponding to shell-closure at 50. One-body transition densities calculated from BIGSTICK code was used as an input to the dens. BIGSTICK has a few choices to generate density matrices. We used the option to compute one-body densities from the previous run, which is given as 'dx' in the menu. For the good isospin in the interaction file, the one-body density matrices will be coupled to good isospin. But if the interaction file breaks the isospin, the density matrices will be in proton-neutron format. The effective charges are initially set at (0.5, 0.5) and were varied to a maximum value of (1.5, 1.5). The obtained results are shown in the table and are consistent with the experimental transition probabilities [3]. The inclusion of  $g_{9/2}$  in the model space and its effect on the N=40 subshell closure has also been studied and the interpretation arising thereof will be presented.

### References

- [1] Johnson et al., Computer Physics Communications **184**, 2761-2774 (2013)
- [2] M. Honma et al, Phys. Rev. C **80**, 064323 (2009)
- [3] <https://www.nndc.bnl.gov/>
- [4] <https://people.nslc.msu.edu/~brown/>