Spectroscopic study of Double Beta Decay Nuclei within Deformed Hartree-Fock Model

S. K. Ghorui[1],* P. K. Raina[1,2], A. K. Singh[1], P. K. Rath[3], and C. R. Praharaj[4]
[1]*Department of Physics & Meteorology, IIT Kharagpur, Kharagpur-721302, INDIA*
[2]*Department of Physics, IIT Ropar, Rupnagar-140001, INDIA*
[3]*Department of Physics, University of Lucknow, Lucknow-226007, INDIA and*
[4]*Institute of Physics, Bhubaneswar-751005, INDIA*

Introduction

One of the most rare processes of nature, the double beta decay has unambiguous importance in explicitly linking nuclear structure aspects with neutrino physics [1]. Nuclear double beta decay (DBD) is a second order process which involved electroweak decay of two nucleons simultaneously. The two neutrino mode of DBD which is allowed in standard model and has been detected for nearly a dozen of nuclei [2]. The correct theoretical description of these observations serves as a test of various nuclear models and also a necessary step to understand the neutrinoless mode.

We have used the above model based on deformed Hartree-Fock and angular momentum projection technique for a reliable description of the nuclear structure of nuclei participating in double beta decay processes in the mass range $A = 116$ to 130.

The Model

Our model consists of self-consistent deformed Hartree-Fock mean field obtained with a Surface Delta residual interaction and subsequent Angular momentum projection to obtain states with good angular momentum. More details can be found in Refs. [3].

Results and Discussion

The deformed HF orbits are calculated with a spherical core of ^{56}Ni, the model space spans the $1p_{3/2}$, $0f_{5/2}$, $1p_{1/2}$, $0g_{9/2}$, $0d_{5/2}$, $0g_{7/2}$, $0d_{3/2}$, $2s_{1/2}$ and $0h_{11/2}$ orbits both for protons neutrons with single particle energies 0.0, 0.78, 1.88, 4.44, 8.88, 11.47, 10.73, 12.21 and 13.69 MeV respectively. We use a surface delta interaction (with interaction strength ∼0.36 for $p-p$, $p-n$ and $n-n$ interactions) as the residual interaction among the active nucleons in these orbits.

Deformed Hartree-Fock and Angular Momentum Projection calculations are performed for some medium-heavy nuclei with mass number $A = 116$ to $A = 130$. In our model we can calculate the energy spectra and other electromagnetic moments for even-even parents and grand-daughter as well as odd-odd intermediate nuclei.

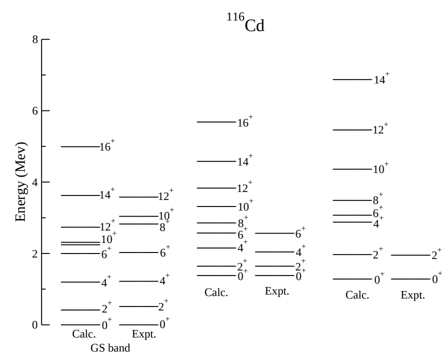

FIG. 1: Energy spectra for ^{110}Cd. The experimental values are taken from Refs. [4]

Our self-consistent calculations reproduce the band structure quit well for the nuclei studied here. As an example, the energy spectra of ^{116}Cd is shown in Figure . The compression in the ground band near $J = 8\hbar$ is occurring due to the crossing of 2-proton excitation bands across $Z = 50$ shell. The interplay be-

*Electronic address: `surja@phy.iitkgp.ernet.in`

TABLE I: Comparison of calculated and experimentally observed $B(E2; 0^+ \rightarrow 2^+)$, static quadrupole moments $Q(J^\pi)$, and magnetic dipole moments $\mu(J^\pi)$. Here $B(E2)$ and $Q(J^\pi)$ are calculated for effective charge $e_p = 1.6$ and $e_n = 0.6$. The g-factors of $g_l = 1.0\mu_N$ and $g_s = 5.586 \times 0.75\mu_N$ for protons and $g_l = 0\mu_N$ and $g_s = -3.826 \times 0.75\mu_N$ for neutrons are used for the calculations.In the column 4 the values marked by * are average $B(E2)$ values from Ref. [5]

Nucleus	J^π	$B(E2{:}0^+ \rightarrow 2^+)$ (e^2b^2)		$Q(J^\pi)$ (eb)		$\mu(J^\pi)$ (nm)	
		Theory	Experiment[5]	Theory	Experiment[6]	Theory	Experiment[6]
^{116}Cd	2^+	0.281	0.560±0.020*	-0.396	-0.42±0.04	+1.416	+0.60±0.14
			0.501±0.047		-0.42±0.08		
			0.608±0.030		-0.64±0.12		
^{116}In	1^+		- -	0.370	0.11±0.01	2.7645	2.7876±0.0006
^{116}Sn	2^+	0.106	0.209±0.006*	-0.258	-0.17±0.04	0.358	-0.3±0.2
			0.183±0.037				
			0.165±0.030				
^{124}Sn	2^+	0.125	0.1160±0.0040*	-0.305	0.0±0.2	-0.246	-0.3±0.2
			0.140±0.030				
			0.188±0.013				
^{124}Sb	3^-		- -	0.725	1.20±0.02	1.624	+1.9±0.4
^{124}Te	2^+	0.160	0.568±0.006*	-0.350	-0.45±0.05	0.649	+0.56±0.06
			0.39±0.08				+0.66±0.06
			0.539±0.028				+0.62±0.08
^{130}Te	2^+	0.229	0.295±0.007*	-0.428	-0.15±0.10	0.420	+0.58±0.10
			0.290±0.011				+0.66±0.16
			0.260±0.050				
^{130}I	5^+		- -	1.202	- -	3.708	3.349±0.007
^{130}Xe	2^+	0.465	0.65±0.05*	-0.614	- -	0.611	+0.67±0.02
			0.631±0.048				+0.76±0.14
			0.640±0.160				+0.62±0.08

tween prolate and oblate shapes are observed in our calculations for ^{130}Xe isotope. Our calculation for ^{130}Xe shows that low spin states of this isotope are of prolate shape but for the states above $J = 6\hbar$ are oblate dominance.

We have calculated the reduced transition moments, quadrupole moments and magnetic dipole moments. These values are presented in Tables I.

Conclusion

A reasonable agreement between calculated and experimentally observed quantities make us confident about the reliability of the deformed few body wave functions obtained in our microscopic self-consistent calculations. These wave functions will further be employed for nuclear transition matrix elements calculations of double beta transitions.

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