Confirmation of a prolate structure for ^{153}Ho

Dibyadyuti Pramanik[1], M. Saha Sarkar[2], S. Sarkar[1*]
[1]*Bengal Engineering and Science University, Howrah - 711103, INDIA,*
[2]*Saha Institute of Nuclear Physics, Kolkata - 700064, INDIA*
**email: ss@physics.becs.ac.in*

Introduction

The few valence particle nuclei around doubly magic ^{146}Gd nucleus have been found to be very soft against shape changes. Their structural features evolve from pure single particle excitations to strongly deformed collective modes with increase in spin as well as in the number of valence particles. These sharp structural changes within the excitation spectra of a single nucleus has been manifested through an island of high-spin isomers found in the region N ~ 82-86, Z ~ 64-68 [1,2].

We have been studying a few Ho isotopes spanning neutron numbers from 84 to 87, experimentally using data from INGA campaigns [3]. The evolution of structural features in these Ho isotopes with neutron numbers and spin has been studied theoretically using shell model as well as Total Routhian Surface (TRS) calculations. We have also studied a few high spin isomers in the mass 150 region using RF – gamma coincidence data .

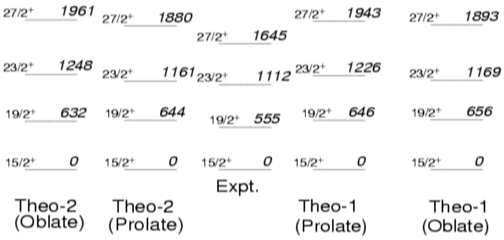

Fig. 1 The positive parity spectra below the isomer compared with theoretical results.

We have extensively analysed our experimental data on ^{153}Ho [3]. We have done Particle Rotor Model calculations to interpret our data. From the comparison of experimental and calculated excitation spectra we have found that there is a possibility of shape coexistence in this nucleus even at lower spins. The positive parity states are reproduced with prolate deformation only contradicting the earlier claim [2] of oblate deformation. So for a conclusive understanding of the shape of this nucleus, we concluded that comparison of experimental and calculated lifetimes of the states would be important. The previous workers [1,2] have reported four isomers in the excitation spectra of ^{153}Ho. We have already confirmed one of these isomers in our previous work [3].

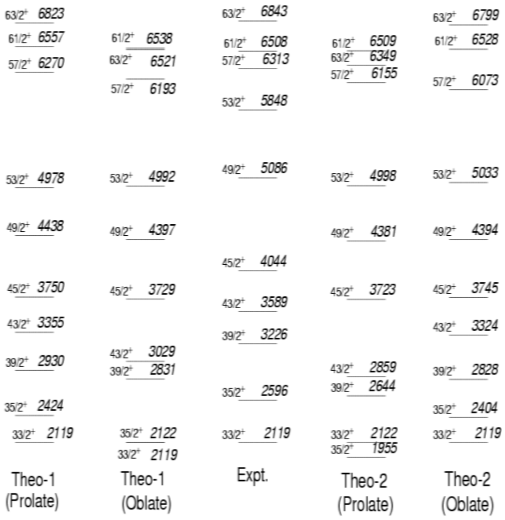

Fig. 2 The positive parity spectra below the isomer compared with theoretical results.

In the present work we have theoretically studied ^{153}Ho, especially the lifetimes of the three isomers in the positive parity states to verify our claim of prolate deformation for the these states [3].

The Model

Theoretical calculations have been done using a version of the Particle-Rotor Model (PRM), where experimental energies of the core can be directly given as inputs. The relevant details of the calculations are discussed in Ref. [4]. The ^{153}Ho nucleus is represented as an odd proton coupled to a ^{152}Dy core. The yrast spectra of ^{152}Dy [1] are used as core energies.

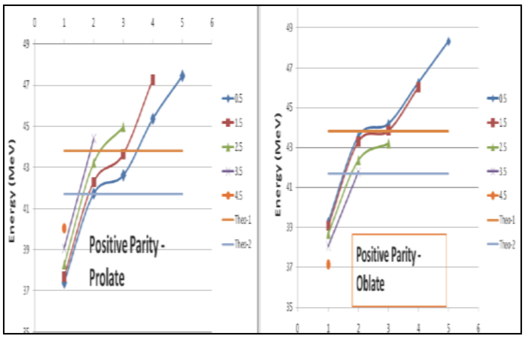

Fig.3 Location of the Fermi levels in Theo 1 and Theo 2.

The Nilsson parameters μ and κ are chosen as 0.592 and 0.065 , respectively. The pairing gap Δ=1.5 MeV has been obtained from experimental odd-even mass difference. The deformation parameter δ is ± 0.14 for prolate and oblate options. For transition probability calculations, standard parameters were used [4].

Table 1: The comparison of results for half-lives of the isomers with experiment.

$I_i^\pi \to I_f^\pi$	*Half-life*				
	Expt	**Theory**			
		Oblate		**Prolate**	
		Theo-1	**Theo-2**	**Theo-1**	**Theo-2**
$31/2^+ \to 27/2^+$	229 (2) ns	8851.5 ns	8789.10 ns	9719.31ns	8448 ns
$43/2^+ \to 39/2^+$	~500 ps	85.46 ps	113.67 ps	108.62 ps	81 ps
$61/2^+ \to 57/2^+$	2.95 (15) ns	1.81 ns	173.28 ns	2.09ns	1.87 ns

Results and Discussion

For negative parity levels, we have found [3] that for lower spins the nucleus is prolate, which changes to an oblate structure at higher spins. However, for positive parity, we can get reasonably good agreement only if the isomeric state $31/2^+$ (229 ns) is isolated from the set. So we have shown the results for states below and above the isomer separately. We have calculated the energy spectra with the same Fermi level (Theo-1) as in our earlier work. However, it has been shown that for oblate deformation, the high spin positive parity states are not reproduced well. So we varied the Fermi level to get better agreement for the oblate deformation at higher spins (Theo-2). Figs 1, 2 show the nature of agreement for levels below (Fig.1) and above the isomer. The location of the two choices of Fermi levels in Theo-1 and Theo-2 vis-à-vis the Nilsson single particle orbitals are shown in Fig. 3.

We find that the energy spectra for both higher and lower spins can be reproduced well with either Theo-1 or Theo-2. Now let us analyse the theoretical results for the lifetimes of the isomers (Table 1). The theoretical results also indicated that the $31/2^+$ state is a long-lived isomer. The large value of half-life compared to experiment can be justified as we have only considered the E2 branch ignoring the M2 branch of its decay. For the 500ps isomer, neither prolate nor oblate option gives preferentially better result.

However, the isomer (~3 ns) at spin $61/2^+$, is only crucial in distinguishing the shape of the nucleus. The Theo-1 result reproduces the isomer life for both prolate and oblate options. However, the energy agreement for Theo-1 is unacceptable for the oblate shape. For Theo-2, although the oblate shape reproduces the energy spectra similar to the prolate one, the isomer life is drastically different from the experimental data. So this result clearly shows that especially at higher spins, at least for the positive parity states, the prolate shape of the nucleus is favoured compared to oblate.

References

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