A Review of Chirality for Mass A~130 Region

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1. Introduction

Chirality is an interesting phenomenon that proposed symmetry in nuclear rotation, which was originally suggested by Frauendorf and Meng [1]. Spontaneous breaking of chiral symmetry can occur at low spin in odd-odd nuclei when the Fermi level is positioned in the lower part of the proton (or neutron) high-j subshell (which behaves like a particle) and in the upper part of the neutron (or proton) high-j subshell (which behaves like a hole), while the core remains triaxial. In this scenario, the angular momenta of the valence particles align along the short and long axes of the triaxial core, whereas the angular momentum of the rotational core aligns along the intermediate axis. These three perpendicular angular momenta create either a left-handed or a right-handed configuration (Fig. 1). As a result, the total angular momentum vector, I, becomes tilted relative to the planes defined by the principal axes of the nucleus, introducing chirality. The experimental signature of this chiral symmetry breaking is the presence of two nearly degenerate bands with the same parity and spin (I=1), known as chiral twin/doublet bands.

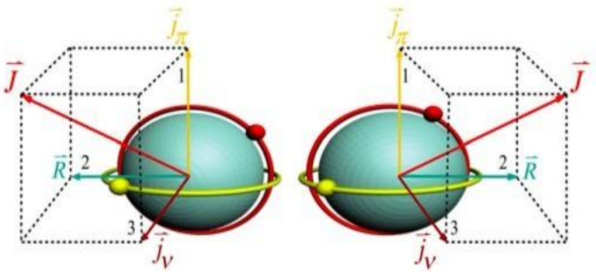

Figure.1: Chiral systems in a triaxial odd-odd nucleus both in left-handed and right-handed configurations [3].

Nuclear chirality, first proposed in Ref. [2] and extensively studied in recent years from both theoretical and experimental perspectives, remains a topic of lively debate. It has emerged as one of the prominent areas of interest in contemporary nuclear physics, as highlighted in several review articles Refs. [3-9]. The largest ensemble of chiral Nuclei (Fig.2) describes by B.W. Xiong and Y.Y. Wang [10].

2. Discussion

The first chiral bands were observed in odd-odd nuclei at low spins, where the shape is γ-soft and competition with other collective modes plays a significant role. At medium spins, the shape may alter due to the polarizing effect of unpaired nucleons resulting from pair breaking. In some instances, the triaxial shape becomes more stable, anchored by a deeper minimum in the potential energy surface.

Three-quasiparticle (3-qp) chiral bands have been observed at medium spins in nuclei within the A~130 mass region, including ^{133}La [11], ^{133}Ce [12], ^{135}Nd [13], and ^{137}Nd [14], as well as in the A ~100 mass region, such as ^{103}Rh [15], ^{105}Rh [16,17], ^{111,113}Rh [18], ^{105}Ag [19], and ^{107}Ag [20]. Additionally, four and six- qp chiral bands have been observed in even-even nuclei within the A~130 mass region, specifically in ^{131}Ba [21], ^{136}Nd [22] and ^{138}Nd [23]. While most nuclei exhibited only a single chiral doublet, a select few chiral nuclei displayed two or more chiral doublets. These include ^{78}Br [24], ^{103}Rh [15], ^{105}Rh [13], ^{131}Ba [21], ^{133}Ce [12], ^{135}Nd [13] ^{136}Nd [22], ^{195}Tl [25], and possibly ^{107}Ag [26], showcasing the rare phenomenon of multiple chiral doublet bands.

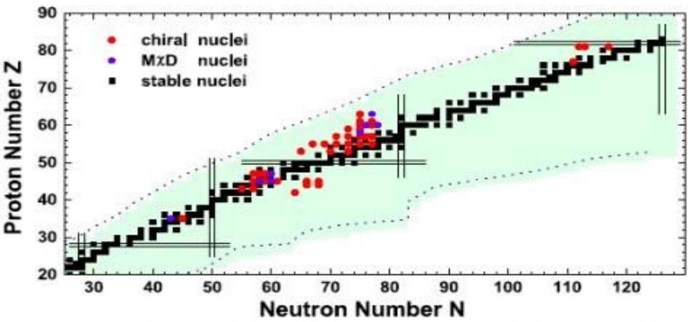

Figure.2: Chart for the territory of chirality [10].

In the even-even nucleus ^{136}Nd, a remarkable discovery of five nearly degenerate band pairs was found. These pairs exhibit properties consistent with a chiral interpretation within the framework of tilted axis cranking constrained density functional theory (TAC-CDFT) [22]. Additionally, they were thoroughly described as chiral doublets using the multi-j shell particle rotor model (PRM) [27].

A different formalism predicting a novel form of chirality, distinct from that found in odd-odd and odd-even nuclei, was also proposed based on the generalized coherent state model and applied to the even-even nucleus ^{138}Nd [28,29].

From systematic observation of experimental and theoretical data from the A~130 mass region, these nuclei have suggested that the chiral bands show the following characteristics:

(1) The existence of near-degenerate, doublet, ΔI=1 bands of the same parity.

(2) The energy staggering parameter S(I), defined as S(I)=[E(I)-E(I-1)]/2*I, should possess a smooth dependence with spin since the particle and hole an- gular momenta are both perpendicular to the core rotation.

(3) The staggering interband B(M1)/B(E2) ratios of partner bands with spin. In the A~100 mass region, the even spin members of the chiral bands should be staggered higher than the odd spin members, which is opposite to the chiral bands of the A~130 mass region. It is that which is built on the different configuration.

(4) In high spin states, there are weaker E2 linking transitions and larger interband M1 transitions.

(5) The probabilities of electromagnetic transitions are nearly similar for chiral bands.

3. Summery

Nuclear chirality is a concept that arises in triaxial nuclei where the angular momentum vectors of the protons, neutrons, and the core can form a chiral system. The conditions under which chirality occurs, focusing on the triaxial shapes of nuclei where the distribution of mass and charge does not align symmetrically along the principal axes. The study of multi-quasiparticle chiral symmetry associated doublet bands near the A~130 mass region provides a deeper understanding of the collective excitations in nuclei nuclear structure and the dynamics of angular momentum in deformed nuclei, which encourages us to continue the study of chirality in nuclei, both experimentally (measurement of lifetimes and search for chiral doublets in other nuclei) and theoretically.

4. Acknowledgments

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