Lifetime measurements in chiral nucleus ^{130}Cs*

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Abstract The level lifetimes in partner bands of ^{130}Cs have been measured using the Doppler Shift Attenuation method. The high-spin states of ^{130}Cs were populated via fusion evaporation reaction ^{124}Sn(^{11}B, 5n)^{130}Cs at a beam energy of 65 MeV. The absolute M1 and E2 transition probabilities have been deduced. The results indicate that the partner bands of ^{130}Cs manifest the chiral properties.

Key words triaxial shape, chiral bands, DSAM, electromagnetic transition probabilities

PACS 25.40.Cm, 28.75.Gz, 21.60.-n

1 Introduction

Since the existence of chiral symmetry in triaxial nuclei has been predicted by Frauendorf and Meng[1], nuclear chiral structure has attracted significant interest to theoretical and experimental studies. Nuclear chirality takes place due to the angular momentum coupling mechanism between the valence particles, holes and the core of the nucleus[2]. The three angular momentum vectors are different in triaxial nuclei. The core collective angular momentum is aligned along the intermediate axis. The angular momenta of particles are aligned along the short axis of the triaxial core, whilst the holes angular momenta aligned along the long axis.The three angular momenta are mutually perpendicular and form the left- and right- handed axial vector systems. The two systems can be mutually transformed by the rotation and the time reversal operations. The spontaneous symmetry breaking in odd-odd triaxial nuclei is recently considered to explain the appearance of the chiral partner bands.

In the $A\sim$100 and $A\sim$130 mass regions, such chiral partner bands were observed in odd-odd nuclei ^{106}Ag[3], $^{102-106}$Rh[4—6] and ^{134}Pr[7], $^{124-132}$Cs[8—12]. These chiral bands in the two regions are built on the $(\pi g_{9/2})^{-1}\otimes\nu h_{11/2}$ negative parity and the $\pi h_{11/2}\otimes(\nu h_{11/2})^{-1}$ positive configurations[13], respectively. The experimental and theoretical studies on these nuclei have suggested that nuclear chiral bands show the following characteristics.

(1) The existence of near-degenerate, doublet, $\Delta I=1$ bands of the same parity.

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

(3) The staggering interband $B(\mathrm{M1})/B(\mathrm{E2})$ ratios of partner bands with spin. In the $A\sim$100 mass region, the even spin members of the chiral bands should be staggered higher than the odd spin members, which is opposite to chiral bands of $A\sim$130 mass region. It is that which are built on the different con-

Received 3 September 2008

* Supported by Major State Basic Research Development Program (2007CB815000) and National Natural Science Foundation of China (10775184, 10675171, 10575133, 10575092, 10375092)

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figurations.

(4) The stronger interband M1 transitions and the weak E2 linking transitions in high spin states.

(5) The electromagnetic transition probabilities should be similar in chiral bands.

Recently, chiral bands in odd-odd ^{130}Cs are reported[11]. For ^{130}Cs, the Fermi level lies in the lower proton $h_{11/2}$ sub-shell and the higher neutron $h_{11/2}$ sub-shell. Through Total Routhian Surface (TRS) calculation, the shape parameters of ^{130}Cs are $\beta_2 \sim$0.17 and $\gamma \sim 30°$. The γ- soft core of ^{130}Cs and particle-like proton, hole-like neutron can be suitable for chiral structure. From the energy spectra analysis, the partner bands of ^{130}Cs exhibit the properties which seem to be consistent with the ideal chiral geometry[11]. The further evidence of the electromagnetic transition probabilities will prove that whether the partner bands of ^{130}Cs show the chiral structure.

2 Experiment and results

The high spin states of the ^{130}Cs were populated by the reaction ^{124}Sn(^{11}B, 5n)^{130}Cs at a beam energy of 65 MeV. The ^{11}B beam was provided by the HI-13 tandem accelerator in the China Institute of Atomic Energy. The target consisted of a 7.06 mg/cm^2 thick ^{124}Sn backed on lead with 6.7 mg/cm^2 thickness. The γ-γ coincidences have been measured by an array of fourteen Anti-Compton Shielded Germanium spectrometers. More than 200×10^6 γ-γ coincidence events were collected. Level lifetimes of chiral bands in ^{130}Cs have been measured using Doppler Shift Attenuation method (DSAM). The line shapes of γ-transitions are fitted by means of the DSAMFT code of Gascon[14]. The lifetimes of seven states in yrast band and five states in side band have been deduced in this work. Representative examples of Doppler broaden line shape fits are shown in Fig. 1 and the preliminary lifetime results of chiral bands are presented in Fig. 2. The spin and parity assignment of excite states in Fig. 2 is based on Ref. [11]. For ^{130}Cs, it was estimated that the uncertainty of stopping power affects by 10% the measured lifetimes in the present experiment.

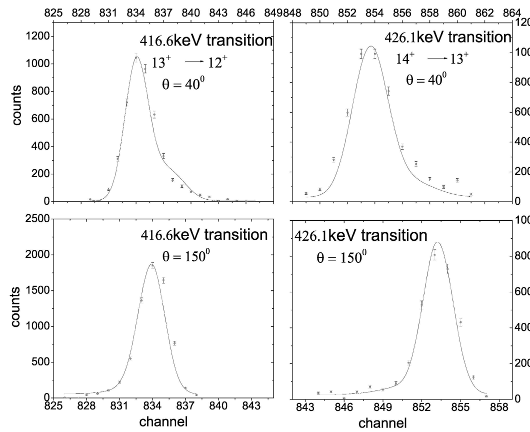

Fig. 1. Example of line shape fits for γ transitions at the angles of 40° and 150° with respect to the beam axis in the chiral bands of ^{130}Cs. Left part: 416.6 keV $13^+ \rightarrow 12^+$ transition. Right part: 426.1 keV $14^+ \rightarrow 13^+$ transition.

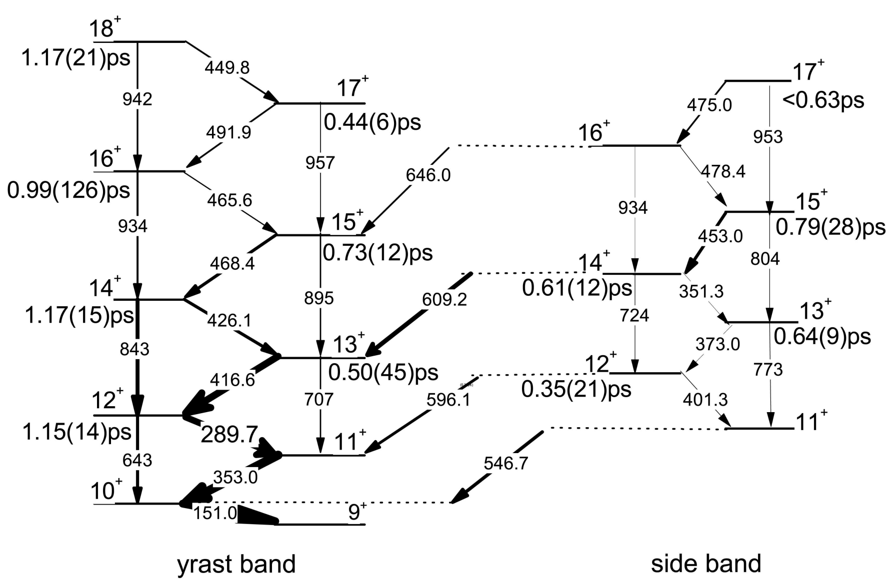

Fig. 2. The level lifetimes of Partner bands built on $\pi h_{11/2}\otimes(\nu h_{11/2})^{-1}$ configuration in ^{130}Cs.

3 Discussion

The reduced transition probabilities, B(E2) and B(M1), can be derived from the lifetimes of excited states. Comparison of the experimental B(E2) and B(M1) values for the chiral bands of ^{130}Cs is shown in Fig. 3. The theoretical study of the transition probabilities and selection rules for the idealized chiral symmetry breaking shows that the transition probabilities in the chiral bands should be same with the corresponding levels. One can see that the B(E2) and B(M1) values of the chiral bands are essentially same from the spin 14^+ to 17^+ within the experimental error limits. With the increasing spin in the chiral bands, the B(E2) values remain a constant value and the B(M1) values show characteristic staggering. The main features of the experimental data are consistent with the behaviors of chiral partner bands. In view of the Ref. [11] and the present study, the partner bands of ^{130}Cs show the chirality above the spin 14^+.

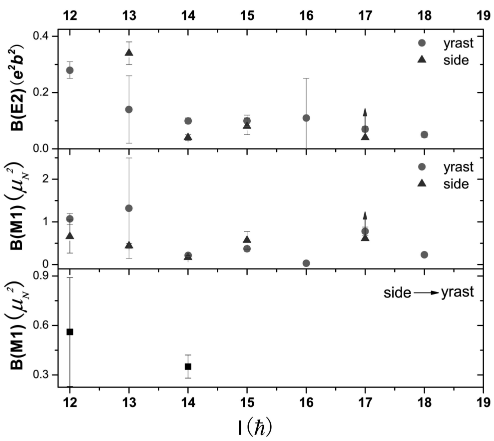

Fig. 3. The absolute reduced transition probabilities in the yrast and side bands versus spin. Top and middle: B(E2) and B(M1) values in the chiral bands. Bottom: B(M1) values for side → yrast linking transitions.

4 Summary

The high-spin states of ^{130}Cs have been populated via fusion evaporation reaction ^{124}Sn(^{11}B, 5n)^{130}Cs at a beam energy of 65 MeV. The electromagnetic transition probabilities in the partner bands of ^{130}Cs are deduced from the lifetime measurements using the Doppler Shift Attenuation method. Comparison of the B(E2) and B(M1) values suggests that the partner bands of ^{130}Cs show the better chiral characteristics.

We are grateful to the staff of the HI-13 tandem accelerator in the China Institute of Atomic Energy for providing the beam. We would also like to thank Fan Qi-Wen for preparing the target.

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