

ELECTROMAGNETIC PROPERTIES OF CHIRAL BANDS IN $^{124}\text{Cs}^*$

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The spontaneous chiral symmetry breaking was experimentally studied at the Heavy Ion Laboratory of the University of Warsaw by use of the DSAM and DCO analysis. Obtained lifetimes, branching ratios and E2/M1 mixing ratios were used to determine $B(\text{M}1)$ and $B(\text{E}2)$ values. The preliminary results for ^{124}Cs confirm spontaneous chiral symmetry breaking hypothesis in the $15\hbar$ – $20\hbar$ spin range.

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1. Introduction

The nuclear chiral symmetry, postulated for the first time in 1997 by Frauendorf and Meng in [1], can appear in an odd–odd nucleus with triaxial deformation, where angular momenta of odd proton, odd neutron and even–even core are mutually orthogonal. In such a case, one can distinguish two possible equivalent configurations of angular momenta, which are called left-handed and right-handed. Spontaneous breaking of this symmetry leads

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to existence of a doublet of nearly degenerated bands with characteristic features of electromagnetic transitions [2]. Specific patterns of electromagnetic transitions as expected for chiral symmetry breaking were observed experimentally in ^{126}Cs and ^{128}Cs [2, 3]. Angular momentum operators are axial vectors hence transition from left- to right-handed configuration requires use of the time-reversal operator and, in consequence, the chiral symmetry offers an interesting opportunity to investigate spontaneous time-reversal symmetry breaking for non-relativistic energies. In the mass region $A \sim 130$, odd-odd nuclei can be described as an even-even core coupled with proton (particle) and neutron (hole) occupying the same $h_{11/2}$ orbital. If the core exhibits some additional property (*e.g.* $\gamma = 30^\circ$ in the rigid case), one can expect another symmetry — the so-called *s*-symmetry [4, 5], which leads to characteristic staggering of M1 transitions inside and between bands. Some properties of ^{124}Cs bands suggest that this nucleus is a good case for investigating existence of the critical frequency ω_c (or critical spin) below which the effects of the chiral symmetry breaking disappear, see [6] for the theoretical background. In this paper, we present new experimental results concerning several E2 and M1 transitions in the ^{124}Cs nucleus obtained using the DSA and DCO methods. Presented data will be very useful in further studies of the nuclear chiral symmetry.

2. The ^{124}Cs experiment

The experiment was performed at the Heavy Ion Laboratory, University of Warsaw with the EAGLE array [8] equipped with 15 germanium detectors obtained from European GAMMAPOOL. The ^{124}Cs nuclei were produced in the $^{114}\text{Cd}(^{14}\text{N}, 4n)^{124}\text{Cs}$ reaction at beam energy of ~ 73 MeV. The ^{114}Cd target 34 mg/cm² thick was used. This thickness was enough to stop all ^{124}Cs recoils. The ^{14}N beam was delivered by the U-200P cyclotron. γ - γ coincidences were used to determine lifetimes of excited states and angular correlations. Level energies, spins and parities of the ^{124}Cs nuclei were taken from [9]. Our data analysis confirmed the sequence of excited states in ^{124}Cs presented in Fig. 1.

2.1. The DSA lifetime analysis

The DSA analysis was performed with the COMPA, GAMMA and SHAPE codes described in details in [10]. The collected data allowed us to determine lifetimes and branching ratios for 8 levels (6 from the yrast band and 2 from the side band). Further analysis resulted in $B(\text{M1})$ and $B(\text{E2})$ in-band transition probabilities, which are shown in Fig. 2 and in Fig. 3. For the $\Delta I = 1$ transitions, we assume pure M1 multipolarities. The DCO experiment described in the next section supports this assumption.

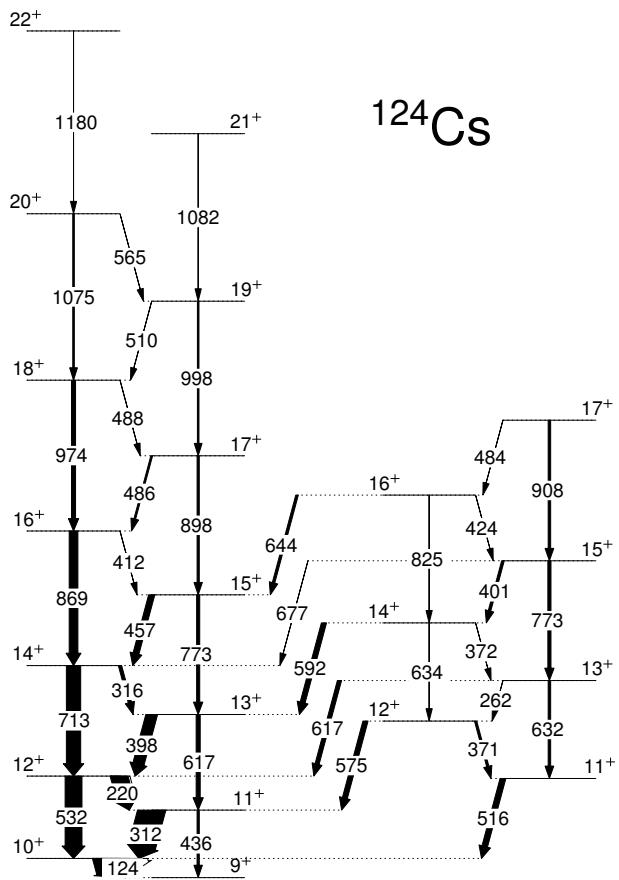


Fig. 1. ^{124}Cs level scheme from [9]. Sequence of levels and transitions confirmed in our experiment.

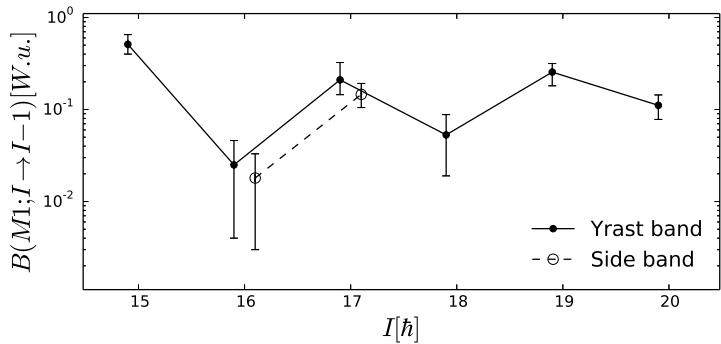


Fig. 2. In-band $B(M1)$ values in the partner bands of ^{124}Cs .

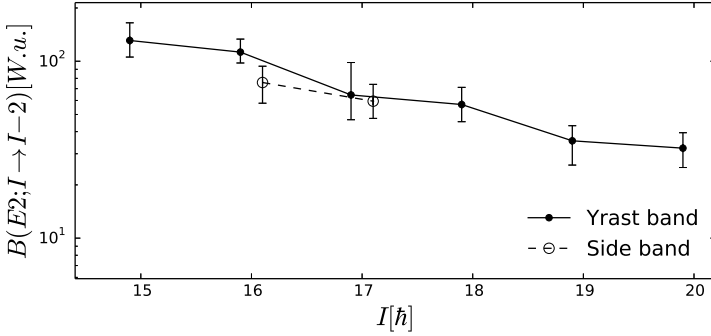


Fig. 3. In-band $B(E2)$ values in the partner bands of ^{124}Cs .

For the yrast in-band transitions, one can see in Fig. 2 a staggering pattern of $B(M1)$ transitions similar to those observed in $^{126,128}\text{Cs}$ [2, 3]. For the side band, experimental data are still scarce but for measured $B(M1)$ and $B(E2)$ probabilities we see close similarity to corresponding values in the yrast band.

Presented results agree with a spontaneous chiral symmetry breaking scenario, analogous to that observed in $^{126,128}\text{Cs}$ [2, 3]. Moreover, the $B(M1)$ staggering in the yrast band suggests that the s -symmetry [5] is useful in description of the ^{124}Cs nucleus. A more detailed study at the level energies in the yrast and side bands shows that some properties of these bands change below spin around $15\hbar$. This can be most easily seen (see Fig. 4) from the plot of the so-called staggering parameter $S(I) = [E(I) - E(I-1)]/2I$. This lead to hypothesis of existence of the critical frequency ω_c , below which effects of the chiral symmetry disappear, see also [2]. Unfortunately, our

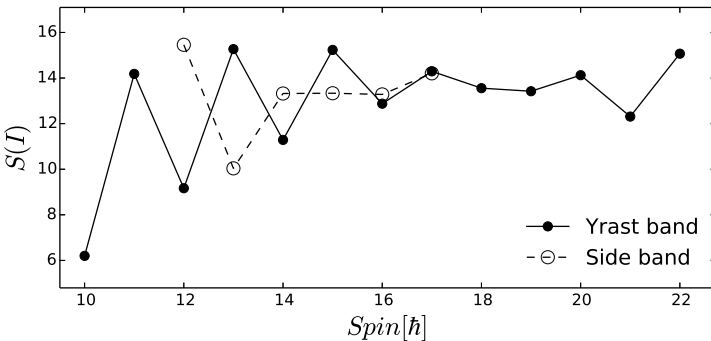


Fig. 4. Staggering of energy levels calculated for each of the partner bands. $S(I) = (E(I) - E(I-1))/2I$, where $E(I) - E(I-1)$ is level energy difference between adjacent levels belonging to the same band.

lifetime measurements are limited to spins greater than $14\hbar$ and, in consequence, they are insufficient to confirm this hypothesis in the case of the ^{124}Cs nucleus.

2.2. The DCO analysis

The better statistics for γ -transitions from levels with spins below $15\hbar$ allowed us to perform the DCO (Directional Correlations from Oriented nuclei [11]) analysis to investigate transition multipolarities. The preliminary results for six γ -transitions between states belonging to the partner bands are shown in Table I. It follows from the measured mixing ratios $\delta(\text{E2/M1})$ that studied $\Delta I = 1$ transitions have nearly pure M1 multipolarity. These experimental results ($\delta^2 \approx 0$) are in agreement with theoretical calculations within the Core-Particle-Hole Coupling model [12].

TABLE I

Mixing ratios $\delta(\text{E2/M1})$ measured in the present experiment using the DCO method. The spin alignment parameter σ/I was taken as 0.3.

I_i^π	E_i [keV]	I_f^π	E_f [keV]	E_γ [keV]	$\delta(\text{E2/M1})$	Multipolarity
12_1^+	1316	11_1^+	1096	220	-0.21 ± 0.03	4%E2 + 96%M1
13_1^+	1714	12_1^+	1316	398	-0.23 ± 0.03	5%E2 + 95%M1
13_2^+	1933	12_1^+	1316	617	-0.14 ± 0.06	2%E2 + 98%M1
14_1^+	2029	12_1^+	1316	713	∞	pure E2
14_1^+	2029	13_1^+	1714	316	-0.17 ± 0.05	3%E2 + 97%M1
15_1^+	2486	14_1^+	2029	457	-0.14 ± 0.04	2%E2 + 98%M1

3. Conclusions

The present experiment allowed us to confirm the level scheme of ^{124}Cs proposed in Ref. [9]. The DCO analysis showed that $\Delta I = 1$ transitions have nearly pure M1 multipolarity with small ($< 5\%$) E2 admixture. Lifetimes of 8 levels obtained from the DSA measurement and branching ratios allowed us to determine eight $B(\text{M1})$ and eight $B(\text{E2})$ reduced transition probabilities. The experimental results confirm the validity of the hypothesis of the chiral character of the ^{124}Cs nucleus in the $15\hbar$ – $20\hbar$ spin range. In order to answer the question of existence of the ω_c chiral critical frequency, which is suggested by the levels energy pattern needs more experimental data on electromagnetic properties.

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