Search for Chiral Doublet Structures in 79Kr with Hyperball2

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I. 1. Search for Chiral Doublet Structures in ^{79}Kr with Hyperball2

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Nearly degenerate pairs of ΔI = 1 rotational bands, which are interpreted as chiral twin bands candidate[1,2], are observed in several odd-odd and few odd-*A* nuclei in the *A*~130 [3-7] and the *A*~105 [8-13] regions. In these triaxial nuclei, left- and right-handed chiral geometries in the body-fixed frame can be formed from the mutually perpendicular angular momentum of the valence proton, valence neutron and the core rotation. In odd-*A* nuclei, one of the components of angular momentum is a broken pair of quasi-particles at higher spin states. Chirality can be identified via (1) nearly degenerate pair of ΔI=1 rotational bands with the same parity and (2) $B(E2; I \rightarrow I-2)_{in,out}$ and $B(M1; I \rightarrow I-2)_{in,out}$ having same or similar values between the pair bands.

Recently, life time for chiral candidate members in ^{134}Pr in the A~130 region was measured; however *B*(*E*2) values are largely different between the two bands[14]. This result suggests a difference in deformation between the two, challenging the origin of these doublets from formation of chirality [15]. While verification of nuclear chirality is being carried out in the mentioned mass region, observations of chiral candidates are expected in a new mass region, namely the mass *A*~80 region.

In this region, the best single particle configuration for chiral geometry is $\pi g_{9/2} \otimes \nu g_{9/2}{}^{-1}$ for odd-odd nucleus. Angular momentum of valence proton is aligned along the short axis, and that of valence neutron is aligned along the long axis where three axes are defined by triaxial mass distribution. This mechanism is opposite to that of $\pi g_{9/2}{}^{-1} \otimes \nu h_{11/2}$ in the *A*~105 region, and similar to $\pi h_{11/2} \otimes \nu h_{11/2}{}^{-1}$ in the A~130 region. In this study, we tried to search for chiral twin bands in ^{79}Kr in the mass 80 regions.

High spin states in ^{79}Kr were populated via the $^{70}\mathrm{Zn}\left(^{13}\mathrm{C},4\mathrm{n}\right)$ reaction at the beam energy of 65 MeV, obtained from the 930 cyclotron at Cyclotron and Radioisotope Center, Tohoku university, impinging upon a stack of two 500 μg/cm^2 thickness self-supporting ^{70}Zn (70% enriched) targets. The emitted gamma rays were detected by the Hyperball-2 array. This array houses 14 normal type detectors and 6 clover type detectors, each of which is shielded with BGO counters for Compton background suppression. A total of approximately 370 million triple gamma coincidence events was sorted into cubes and analyzed with the RADWARE programs[16)]. Example of triple gamma coincidence spectrum is shown in Fig. 1.

The partial level scheme for ^{79}Kr obtained from the present experiment is shown in Fig. 2. Bottom and upper part of band labeled as (a) in Fig. 2 was previously reported by Johns *et. al.*[17)] with the $\nu g_{9/2}{}^{-1}$ and $\pi g_{9/2}{}^{2} \otimes \nu g_{9/2}{}^{-1}$ configuration assigned, respectively. Band (b) in Fig. 2 is identified in the present experiment for the first time. Level (c) was observed previously. The level is assigned with 21/2+ and could be independent from band (b) because of no gamma ray transition observed between the 23/2+ states in band (b) and the 21/2+ states.

Linear polarization for links connecting (a) and (b) can be extracted with clover detectors to infer relative spin and parity for the side band (b). The experimental linear polarization is defined as $P = (1/Q)(N_{\perp}-N_{\parallel})/(N_{\perp}+N_{\parallel})$, where $N_{\perp}\,(N_{\parallel})$ is the number of added-back photo peak counts which are events scattered in to perpendicular (parallel) direction with respect to the reaction plane and *Q* is polarization sensitivity of the clover detectors. Polarization sensitivity *Q* has yet to be measured; however the sign of *P* can determined without knowing *Q*. Positive linear polarization values indicate electric character of transitions, while negative values indicate their magnetic character. In the analysis, two γ-γ matrices were sorted with one axis corresponding to a single-hit event including that of single crystal detector and the other axis corresponding to added-back double-hit events. One matrix is sorted from only parallel-scattered events, while the other matrix from perpendicular-scattered events. The results from these measurements for γ-ray transition in the positive parity band are shown in Fig. 3. The transitions assigned as $E2$ in Ref.[17] (Red and Sky-blue) are found to have positive polarization values, and the transitions assigned as $M1$ in Ref.[17] (Orange) have near zero or negative values.

The 472-keV transition shows electric character; if the parity were negative ($E1$), the 636-keV and 1616-keV transition would be of $M2$ and $M3$, respectively. For the same level, if the spin were 25/2, the 1616-keV transition would be of $E3$. Therefore, level (c) is assigned as 21/2+. The 811-keV transition shows electric character; if the spin were 27/2, 1676-keV transition would be of $E3$, and thus the band head for band (b) is assigned as 23/2+.

In Fig. 4(a), the excitation energy of the yrast and the partner band is plotted as a function of spin. Energy difference of about 1 MeV, which are not degenerate, is observed. In Fig. 4(b), the excitation energy is plotted relative to a rigid rotor, which reveals single particle alignment. If the two bands were chiral partners, it would show a similar trend. In Fig. 4(c), $S(I)=\left[E(I)-E(I-1)\right]/2I$ is plotted as a function of spin. Smooth variation of $S(I)$ with I suggests perpendicular coupling of a single particle angular momentum to the core rotation, as a strongly coupled band built on a single particle angular momentum aligned perpendicular to the rotational axis for an axial symmetric rotor has no signature splitting. The present result indicates that one of the single particle angular momenta has sizable component along the core rotation. Overall, the two bands do not show chiral characters from this work.

In summary, the side band structure to the $\pi g_{9/2}{}^{2}\otimes \nu g_{9/2}{}^{-1}$ yrast has been identified in ^{79}Kr. Tentative spin and parity assignments are made based on the linear polarization measurement. The current result shows that the side band structures are of non chiral nature.

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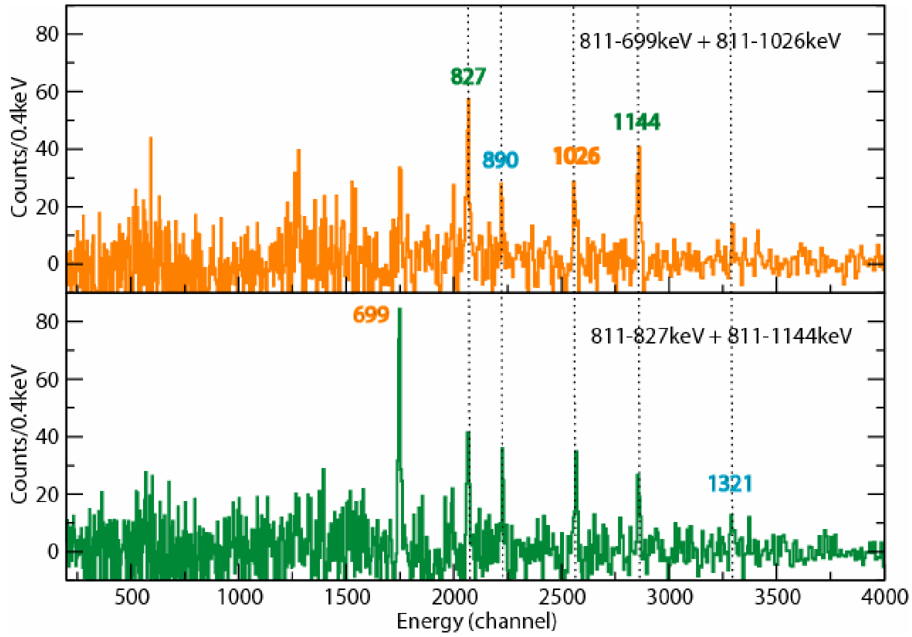

Figure 1. Example of double gated gamma-ray coincidence spectra. Peaks labeled with their energy in keV are assigned to ^{79}Kr.

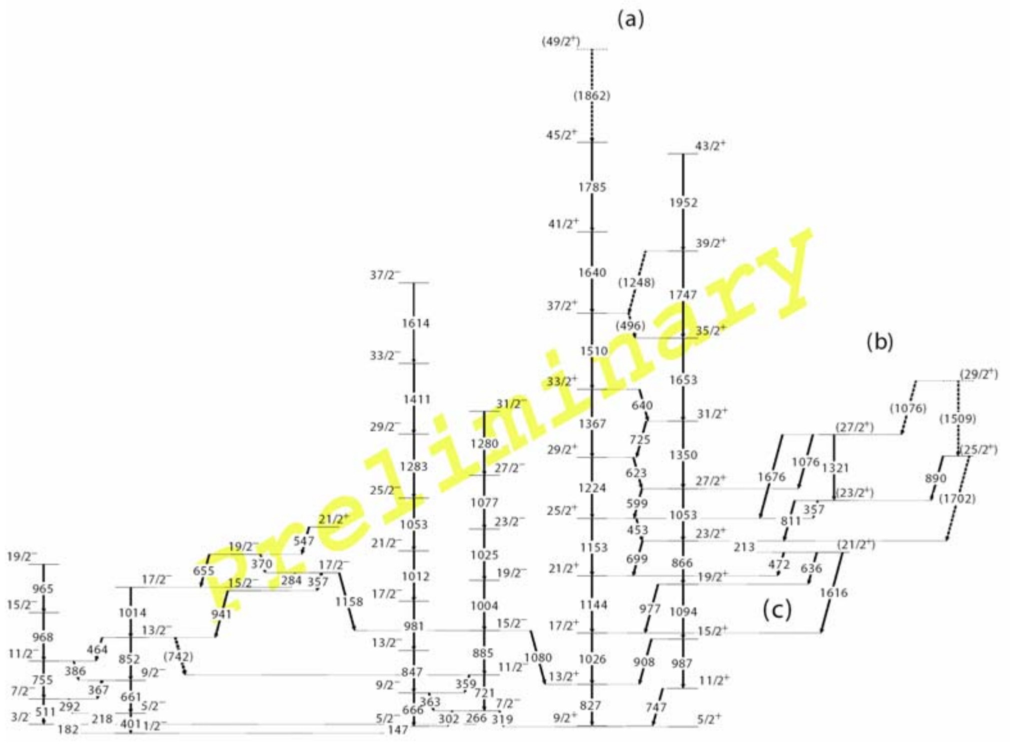

Figure 2. Partial level scheme of ^{79}Kr deduced from the resent study. The energy of the gamma transition is in keV.

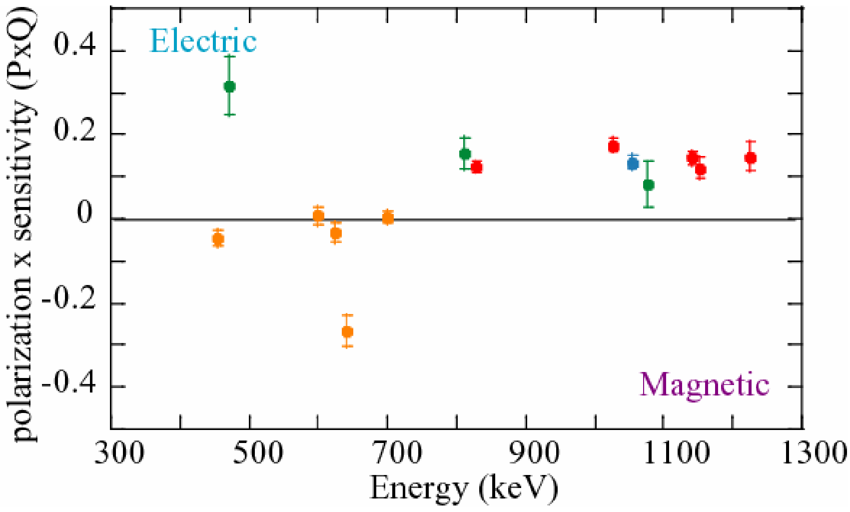

Figure 3. Linear polarization times the clover polarimeter sensitivity. Red and sky-blue points are consistent with electric character of these transitions. Orange colored points are consistent with *M*1 assignment for these transitions made in Ref. [17]. Green points are for transitions identified from the current study. The error bars show only statistical error.

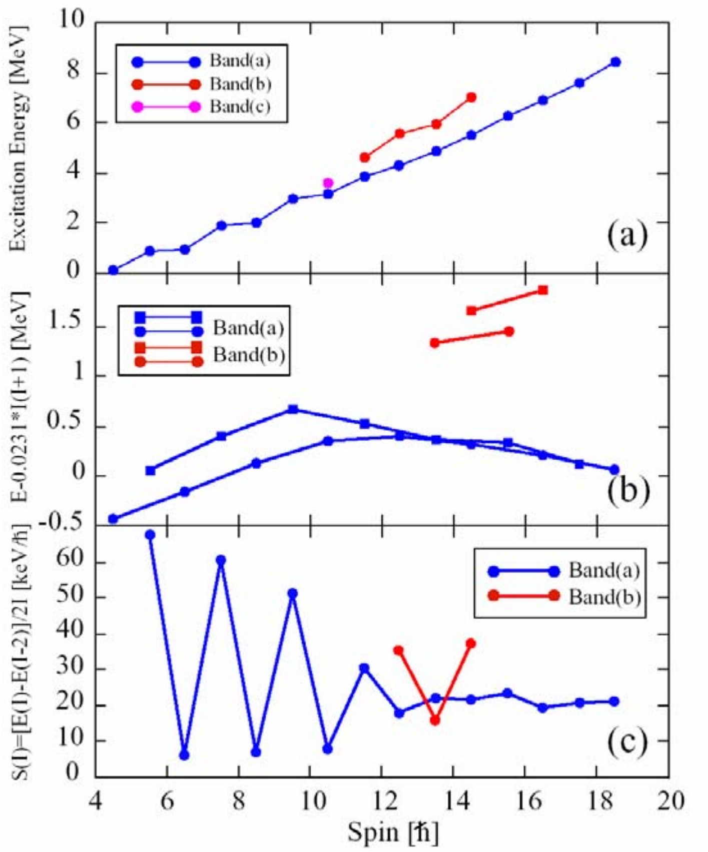

Figure 4 (a): excitation energy, (b): excitation energy minus the rigid-rotor reference, and (c): $S(I)$-$[E(I)$-$E(I$-$1)]/2I$.