Search for transverse wobbling and chiral bands in ^{131}Ba

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The existence of triaxially deformed nuclei is a long standing debate. It appears questionable how well the non-axial shape is stabilized. The intimate mechanism which induces such a behavior needs detailed and accurate investigations, both from the experimental and theoretical points of view. Of particular interest is the wobbling motion at relatively low spins, which according to recent studies [1] can be transverse or longitudinal depending on how the angular momentum vector of the odd nucleon is oriented relative to that of the triaxial core, perpendicular or parallel, respectively. An unique opportunity for investigating the wobbling motion at normal deformation and low spins is offered by the A=130-140 lanthanide nuclei. Microscopic-macroscopic calculations indicate that these nuclei have triaxial shapes which develop over wide spin ranges. Strong experimental evidence in favor of chiral [2] and wobbling motions [3] in the ^{133}Ce and ^{135}Pr nuclei, respectively, has been obtained from recent Gammasphere experiments. However, to get confidence on the proposed novel interpretation of the observed bands, the existence of such structures in nuclei with similar properties from the same mass region has to be confirmed experimentally. We therefore decided to study the ^{130,131}Ba nuclei whose level schemes strongly suggest the presence of the triaxial shape, which would induce chiral and/or wobbling bands.

We performed a fusion-evaporation experiment to investigate the ^{131}Ba nuclei using the complex setup composed of GALILEO, EUCLIDES and the Neutron Wall. The first aim of the experiment was to investigate **the chiral bands in ^{131}Ba**. The existing experimental data on ^{131}Ba obtained in experiments performed at Stony Brook using 5 low-volume Ge detectors [4] and at Mumbai using the INGA array of 15 Compton-suppressed clover detectors [5], led to a level scheme developed up to spin 43/2, which includes three dipole bands of positive and negative parity which are similar to those observed in the isotone ^{133}Ce [2, 6, 7]. The bands 3 and 4 of ^{131}Ba are similar to two bands of ^{133}Ce first observed by Ma et al. [4] and recently demonstrated to be chiral partners of the band similar to the band 2 of ^{131}Ba [2]. It is therefore very probable that bands 3 and 4 of ^{131}Ba are in fact the chiral partners of band 2. The negative-parity dipole band built on the 4046 keV level of ^{131}Ba is also similar to a 3-quasiparticle band of ^{133}Ce, for which two chiral partners were identified [2]. Such chiral partners can therefore exist in ^{131}Ba. To prove these conjectures, we need a detailed characterization of the bands, which will be achieved with the high-statistics data set obtained in the present experiment. For bands 3 and 4 we need to establish all connecting transitions to low-lying states and to band 2, and to determine the spins-parity of band 4 through precise angular distribution measurements. We will also search for the possible chiral partners of the negative-parity dipole band built on the 4046 keV level.

The second aim of the present experiment is focused to **the transverse wobbling mode in ^{131}Ba**. This new wobbling mode was first observed in ^{135}Pr [3], an odd-proton nucleus in which the $h_{11/2}$ proton is particle-like and therefore has angular momentum aligned along the short axis, while the collective angular momentum of the triaxial core is aligned along the axis with maximum moment of inertia which is the intermediate axis. However, as stated in the theoretical paper on the transverse wobbling [1], the transverse geometry is also realized when coupling a triaxial core to a hole-like nucleon which has the angular momentum aligned to the long axis. One can then expect the existence of wobbling bands in odd-even nuclei with a $h_{11/2}$ neutron hole, as is the case for ^{131}Ba. In fact, in the level schemes of Refs. [4, 5] there are several negative-parity states with spins between $13/2^-$ and $25/2^-$ that decay to the yrast band based on a neutron orbital from the higher part of the $h_{11/2}$ sub-shell, having therefore a hole-like character. It could be that these states belong to such a predicted transverse wobbling band. To support this interpretation, one has to identify all transitions connecting the states to the yrast band and to extract precise mixing ratios from their angular distribution. If the mixing ratios of the connecting transitions show a predominant $E2$ character, the transverse wobbling interpretation of these states will be supported.

EXPERIMENTAL DETAILS AND RESULTS

We used the $^{13}C+^{122}Sn$ reaction at a beam energy of 65 MeV. A stack of two self-supporting ^{122}Sn targets of 0.5 mg/cm^2 were used. We measured for 7 days with beam intensities between 5 and 10 pnA. The use of the GALILEO+EUCLIDES +Neutron Wall setup will help in solving uncertainties in case of contaminating γ-rays or assignment of new γ-rays to specific channels. The most intense reaction channels were 4*n* and 5*n* leading to ^{131}Ba and ^{130}Ba, respectively, with cross sections of the order of 450 mb calculated with PACE4, for a total of 1110 mb. Other reaction channels involving the evaporation of charged particles (*pxn* and αxn) populated with relatively high cross sections will also be analyzed. The most intense ones lead to ^{130}Cs (38 mb), ^{131}Cs (75 mb), ^{132}Cs (4 mb), and to ^{127}Xe (15 mb), ^{128}Xe (66 mb), ^{129}Xe (4 mb). Most of these nuclei were not previously studied with high-efficiency arrays for γ-ray detection and newly observed transitions can reveal unexpected interesting nuclear structure phenomena.

A particular feature of the employed reaction $^{13}C+^{122}Sn$, observed already present in the online spectra, is that also the $2\alpha xn$ channels were relatively strongly populated, even if the calculated cross sections were negligible. This can be explained by the incomplete fusion of the ^{13}C beam with the ^{122}Sn target which populates ^{126}Te through the fusion of one α particle with ^{122}Sn, or the fusion of ^{3}He and ^{6}He produced through the breakup of the ^{9}Be nucleus resulting from the incomplete fusion, leading to ^{125}Te and ^{128}Te, respectively. An example $\gamma\gamma$-coincidence spectrum obtained by gating on 2α particles detected in the EUCLIDES array is shown in Fig. 1. The spectrum is very clean, showing only transitions populating excited states in ^{126}Te.

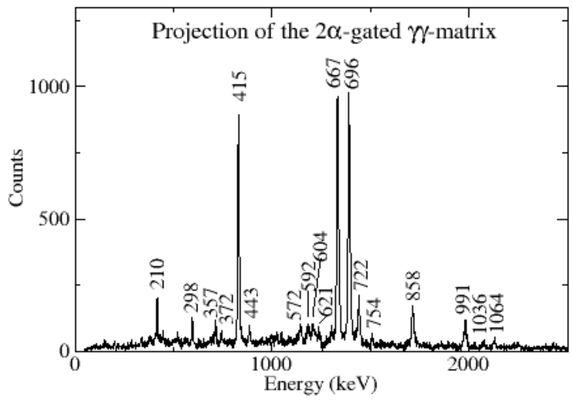

Fig. 1. Total projection of the $\gamma\gamma$-coincidence matrix gated on 2α particles detected in the EUCLIDES array.

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