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Short note

Quadrupole moment measurement of the highly deformed $\pi g_{9/2} \otimes \nu h_{11/2}$ band in ^{130}Pr

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Abstract. The quadrupole moment for the $\pi g_{9/2}\otimes\nu h_{11/2}$ band in the ^{130}Pr nucleus has been measured using the Doppler-shift attenuation method. A centroid shift analysis was carried out and a value of Q_0=6.1±0.4 *e*b, corresponding to an axial prolate deformation of β_2=0.35(3), has been determined. This is the first direct experimental confirmation of the deformation-driving character of the $\pi g_{9/2}$ orbital in an odd-odd nucleus in the A∼135 superdeformed region.

PACS. 21.10.Tg Lifetimes – 21.10.Re Collective levels – 23.20.Lv Gamma transitions and level energies – 27.60.+j $90 \le A \le 149$

The stabilization of nuclear shapes in the so-called "superdeformed" second minimum of the potential energy is generally associated with a delicate interplay between the large shell gaps in the nucleon single-particle spectrum of states for high quadrupole deformation values and the occupation of high-j, low-Ω intruder orbitals. For nuclei around A∼135, the occupation of one or more $i_{13/2}$ neutrons is thought to have a strong polarization effect on the nuclear shape [1,2]. However, it has been recently shown that certain strongly coupled bands, built upon the $9/2^+[404]$ ($g_{9/2}$) proton orbital, in the odd-Z ^{131}Pr [3] and ^{133}Pm [4] isotopes, exhibit high dynamical moment-of-inertia values, as well as quadrupole deformations, comparable to the values found for highly deformed structures in the A∼135 region which involve $i_{13/2}$ neutrons. Bands involving the same $\pi g_{9/2}$ orbital have also been recently reported in the odd-odd ^{130}Pr [5] and ^{132}Pr [6] isotopes, however, direct confirmation of their high deformation values from lifetime measurements have not previously been presented.

The current work reports on lifetime measurements for the $\pi g_{9/2}\otimes\nu h_{11/2}$ band in the ^{130}Pr nucleus [5], together with complementary results for the previously studied $\pi g_{9/2}$ band in ^{131}Pr [3]. The aim was to establish the relative quadrupole deformations associated with these structures and hence clarify the polarization effect towards higher deformation for bands involving the $\pi g_{9/2}$ orbital. Analysis of data for normally deformed yrast structures in these nuclei [3,7,8] is also included for comparison.

The experiment was performed at the 88-Inch Cyclotron at the Lawrence Berkeley National Laboratory, where the high efficiency and resolving power of the GAMMASPHERE γ-ray spectrometer array [9] were combined with the selectivity of the MICROBALL charged-particle detector system [10]. The ^{35}Cl+^{105}Pd fusion-evaporation reaction at a beam energy of 173 MeV was used. The target consisted of an enriched (up to 95%) ^{105}Pd foil of thickness 1 mg/cm^2 mounted on a 17 mg/cm^2 Au backing. The 2α particle channel (1.6% of the total data) contained 21×10^6 threefold or higher Compton-suppressed coinci-

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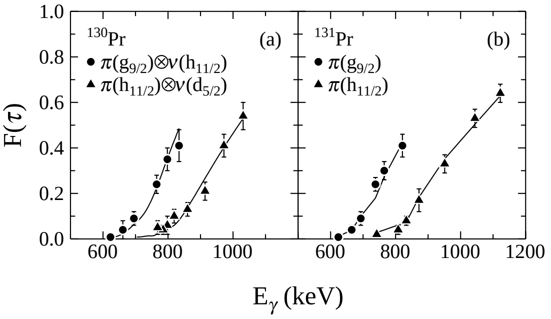

Fig. 1. The experimental and calculated F(τ) values as a function of γ-ray energy for selected bands in ^{130}Pr and ^{131}Pr. Calculated curves are shown as solid lines and correspond to the best fit to the data

Table 1. Quadrupole moments and deformations extracted for selected bands in ^{130}Pr and ^{131}Pr

Nucleus	Configuration[(1)]	Q_0, eb [β_2] present[(2)]	previous	ref.
^{130}Pr	$\pi g_{9/2}\otimes\nu h_{11/2}$	6.1(5) [0.35(3)]		
	$\pi h_{11/2}\otimes\nu d_{5/2}$	3.4(2) [0.20(1)]		
^{131}Pr	$\pi g_{9/2}$	5.3(4) [0.31(2)]	5.5(8) [0.32(5)]	[3]
	$\pi h_{11/2}$	3.3(2) [0.19(1)]	3.9(3) [0.23(2)]	[3]

(1) Configurations are taken from refs. [3,5,7,8]; $\pi g_{9/2}$: $9/2^+$[404], $\pi h_{11/2}$: $3/2^-$[541], $\nu h_{11/2}$: $7/2^-$[523], $\nu d_{5/2}$: $5/2^+$[402]
(2) The quoted absolute errors are subject to a 15−25% systematic error, as explained in the text.

dence events. The ^{130}Pr nucleus (2α2n channel) accounted for about 36% of the 2α data set and the $\pi g_{9/2}\otimes\nu h_{11/2}$ band was populated at a level of ∼4% of the total 2α2n cross section. The $\pi g_{9/2}$ band in ^{131}Pr received a substantial population (∼15%) in the 2α1n channel, which accounted for ∼37% of the 2α events.

The data were sorted off-line into a number of two-dimensional matrices in which one axis consisted of a group of detectors either at "forward" (31.7^o and 37.4^o) or "backward" (142.6^o and 148.3^o) angles, while the other axis contained coincident detectors at any angle. One-dimensional spectra were constructed by summing gates on the cleanest, fully stopped transitions at the bottom of the band of interest and projecting the events onto the "forward" and "backward" axes, respectively. The fractional Doppler shift, F(τ), was extracted for each γ-ray transition from these spectra using the centroid-shift technique [11]. Gating on transitions above the level of interest was also tried in order to eliminate the effect of side feeding, but the limited statistics of the resultant spectra were not sufficient to make this approach meaningful. The experimental F(τ) values for the highly deformed bands in ^{130}Pr and ^{131}Pr are shown in Fig. 1 (circles), as a function of γ-ray energy. In order to illustrate the deformation differences between the highly deformed and normally deformed structures, the F(τ) values for the $\pi h_{11/2}\otimes\nu d_{5/2}$ (^{130}Pr [7,8]) and $\pi h_{11/2}$ (^{131}Pr [3]) bands are also plotted (triangles) in Fig. 1.

The average quadrupole moments, Q_0, were extracted through a χ^2-minimization fit of the experimental F(τ) data points to the values computed using the code FITFTAU [12]. The lifetime of the in-band levels was related to Q_0 (assumed to be constant within the whole band) using rotational model formulae [13]. The stopping powers were calculated using the 1995 version of the code TRIM [14] and multiple scattering corrections were introduced using the prescription given by Blaugrund [15]. The side feeding into each state was modeled according to the experimental in-band intensity profile by assuming a rotational cascade of three transitions with the same Q_0 as the in-band states. For the strongly coupled bands, the effect of additional I→I−1 branches on the partial level lifetime has been taken into account using the experimentally determined branching ratios. Table 1 summarizes the extracted Q_0 values, as well as the quadrupole deformations, β_2, deduced by assuming an axially symmetric prolate shape with no hexadecapole deformation [16]. A value of β_2=0.35(3), deduced for the highly deformed $\pi g_{9/2}\otimes\nu h_{11/2}$ configuration in ^{130}Pr, is consistent with the prediction made using total Routhian surface (TRS) calculations [5]. The results obtained for the bands in ^{131}Pr are in agreement with those reported previously [3] (see Table 1). It should be emphasized, that although the uncertainties in the stopping powers and the modeling of the side feeding may contribute an additional systematic error of 15−25% in the absolute Q_0 values, the relative deformations can be considered to be accurate to 5−10%, since the bands were studied under the same conditions.

The present results show that the quadrupole deformation of the $\pi g_{9/2}\otimes\nu h_{11/2}$ band in ^{130}Pr is similar or perhaps slightly larger to that found for the highly deformed $\pi g_{9/2}$ band in ^{131}Pr, and that it is much greater than the value deduced for structures where the $\pi g_{9/2}$ orbital is not involved. Many more highly deformed bands, formed by the coupling of different neutron orbitals to the $\pi g_{9/2}$ proton, are expected in odd-odd nuclei in this mass region. The observation of these structures and the measurement of their detailed properties remain a challenge for further studies.

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