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OBSERVATION OF γ-BAND STRUCTURE IN ^{104}Pd

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Abstract

Excited states of the nucleus ^{104}Pd was investigated experimentally via the ^{96}Zr(^{13}C,5n) reaction at beam energies of 51 and 58 MeV, using the EUROBALL IV γ-ray spectrometer in conjunction with the DIAMANT charged particle array. On the basis of $\gamma\gamma\gamma$-coincidence data two non yrast low-lying positive-parity

bands were identified, which were assigned to soft γ-vibrational excitations.

I. Introduction

Low-lying cascades built on the second 2^+ state have been observed in several Pd and Ru isotopes in the $A \approx 100$ mass region. Recently, such a structure has been identified also in ^{102}Ru and it was interpreted as a quasi-γ band associated with γ-soft triaxial deformation, which might be confined in a region away from axial symmetry [1]. Since the nuclear structure of ^{104}Pd shows similar characteristics than that of ^{102}Ru having only 2 protons less, the existence of a quasi-γ band is expected also in the studied nucleus. In a recent experiment aimed at studying the candidate chiral structures in the rhodium isotopes around A$\sim$104 by in-beam γ-spectroscopy we collected a significant amount of data also on ^{104}Pd, making it possible to extend its band structure.

II. Experimental methods and results

Excited states in ^{104}Pd were populated using the ^{96}Zr(^{13}C,5n) fusion-evaporation reaction at beam energies of 51 and 58 MeV. The ^{13}C beam, provided by the Vivitron accelerator at IReS, Strasbourg, impinged on a stack of two targets, each of thickness 558 μg/cm^2 and enriched to 86% in ^{96}Zr. The emitted γ rays were detected by the EUROBALL IV detector array [2] equipped with 15 cluster [3] and 26 clover [4] composite Ge detectors. The cluster detectors were placed at backward angles, while the clover detectors were positioned in two rings at an average angle of 90° relative to the beam direction. The γ rays were measured in anti-coincidence with light charged particles in order to eliminate the contaminants from reaction channels produced by evaporation of protons and α-particles from the ^{109}Pd compound nuclei. The detection of charged particles was performed by means of the highly efficient DIAMANT array which was consisted of 88 CsI detector elements [5].

The data obtained from the Ge detectors were sorted off-line into a 3-dimensional histogram. The γ-ray energies and relative intensities, as well

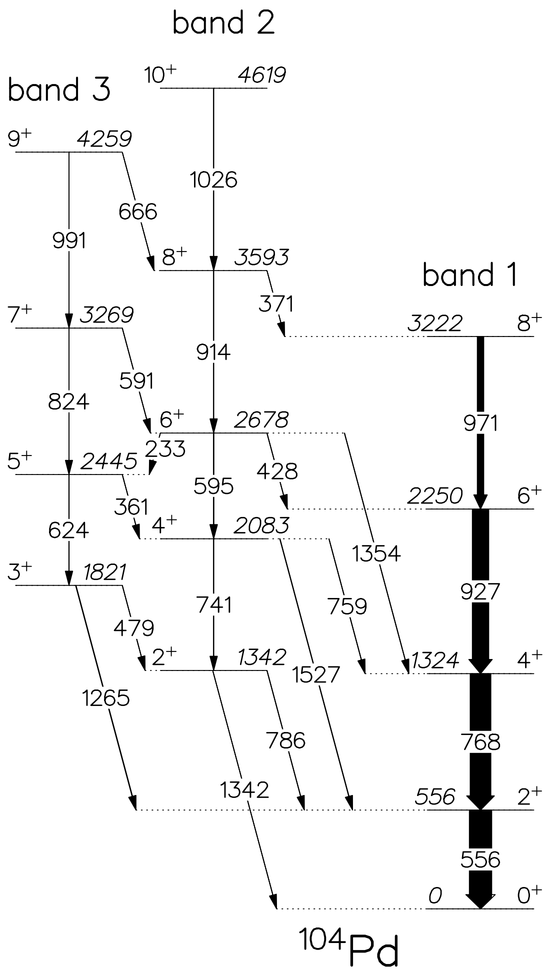

Figure 1: The partial level scheme of ^{104}Pd obtained in the present work. Width of the arrows are proportional to the intensity of the transitions. The energy of the excited states and the gamma transitions are in keV.

as their coincidence relations were derived from the $\gamma\gamma\gamma$-coincidence cube. Information on the multipolarities of transitions with sufficient intensity was extracted from an analysis of directional correlation of oriented nuclei (DCO) ratios [6]. The multipolarity assignments were further supported by deducing the electromagnetic character of the transitions by measuring the linear polarization of the γ rays. The level scheme shown in Fig. 1 was constructed using the $E_\gamma - E_\gamma - E_\gamma$ coincidence relations, as well as energy and intensity balances. The placement of the known transitions is consistent with the previous work [7].

In addition to the already known excited states, there appeared two new rotational-like structures, *bands 2* and *3*. The 1265 keV γ ray linking the lowest-lying state in *band 3* to the yrast band has been observed by Grau *et al.* and a stretched M1 multipolarity has been assigned to it [7]. On the basis of our experimental data we confirmed the position of this transition and the I^π=3^+ spin-parity of its initial state at 1821 keV. Using the observed coincidence relations a new band was built on this state up to an excitation energy of E_x≈4.3 MeV. Based on the quadrupole character of the 624, 824 and 991 keV γ rays, we propose 5^+, 7^+ and 9^+ spin-parity values for the levels at 2445, 3269 and 4259 keV. The yrare 2^+ and 4^+ states have been identified by Grau *et al.* [7]. Our coincidence data confirm the previous placements of the 1342, 786, 741, 1527 and 759 keV transitions, and make it possible to extend the cascade by three levels and to connect to *band 1* and *2* by several transitions. The obtained stretched E2 and quadrupole multipolarities of the 1342, 1527 and 741 keV γ rays are in accordance with the 2^+ and 4^+ spin-parities of the states at 1342 and 2083 keV, thus, we adopt those values to them.

On the basis of the DCO and linear polarization analysis, stretched E2 and quadrupole characters are deduced also to the 1354, 914 and 1026 keV transitions, respectively, suggesting unambiguous I^π=6^+, 8^+ and 10^+ values for the states at 2678, 3593 and 4619 keV. The spin-parity assignments in *band 2* and *3* are further corroborated by the ΔI=1 (233, 361, 666 keV γ rays) and the ΔI=0 (371, 428, 759 keV γ rays) dipole natures of the linking transitions.

Further details of the experimental analysis can be found in Ref. [8].

III. Discussion

The levels of the non yrast low-lying positive-parity structure were grouped into a γ-band which is built on the second 2^+ state of ^{104}Pd. The band assignment is based on the observed decay pattern and on the similarities with the structure of ^{102}Ru. A distinction between excitations in a γ-soft and a γ-rigid potential can be deduced from the energy sequence in the γ-band and can be expressed in the odd-even spin energy staggering function

$$S(I, I-1, I-2) = \\ = \frac{E(I) + E(I-2) - 2E(I-1)}{E(2_1^+)}.$$

In the case of a triaxial rigid rotor this staggering gives positive values for even spins and negative ones for odd spins. For a γ-soft rotor it has an opposite phase, the values fall below 0 for even spins and above 0 for odd spins.

The experimental odd-even spin energy staggerings deduced for these bands are displayed in Fig. 2 together with the values extracted for ^{102}Ru [1] and other Palladium isotopes with available data [9, 10]. The resulted phase of the staggering is the same in all displayed nuclei. In the case of ^{104}Pd the $S(I, I-1, I-2)$ values vary between the negative values of -0.23 and -0.53 for even spins and they fall between the positive values of 0.17 and 0.62 for the odd spins. Accordingly to the obtained odd-even spin energy staggerings in ^{104}Pd, we can rule out the rigid triaxial rotor scenario and assign a γ-soft character to this nucleus. It is worth to note that although the values obtained for ^{104}Pd are in the same order of magnitude as in ^{102}Ru, ^{108}Pd and ^{110}Pd, there seem to be some differences. For lower spins the staggerings are larger for the heavier Palladiums than for ^{104}Pd, while they increase at higher spins of ^{104}Pd unlike ^{102}Ru. These behaviours might indicate an increased γ-soft character in ^{108,110}Pd at lower spins compared to ^{104}Pd, while the latter might have a more γ-soft shape at higher spins than ^{102}Ru.

IV. Summary

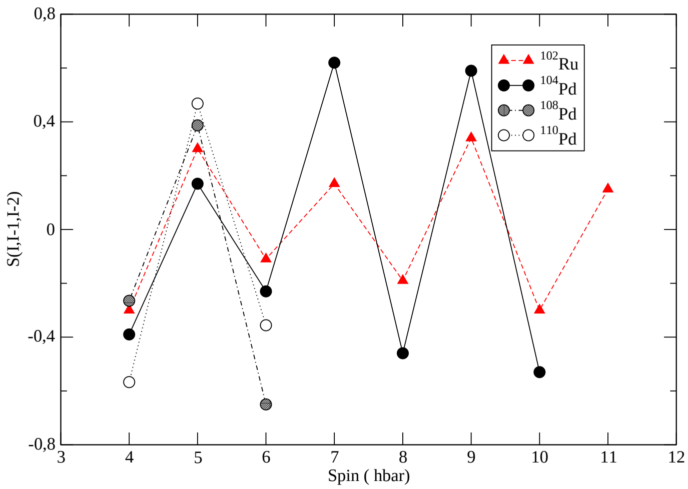

Figure 2: Experimentally observed odd-even spin energy staggerings in the non yrast low-lying positive-parity band in ^{104}Pd compared to the values of the quasi-γ band in ^{102}Ru, ^{108}Pd and ^{110}Pd. The lines between the symbols are drawn to guide the eye.

Medium-spin states of ^{104}Pd were studied via the ^{96}Zr(^{13}C,5n) reaction using the Euroball IV γ-ray spectrometer coupled with the Diamant array for the detection of charged particles. The non yrast low-lying positive-parity bands were interpreted as excitations associated with γ-soft deformation on the basis of their energy staggering as a function of spin.

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