Eur. Phys. J. A 2, 25–27 (1998)

THE EUROPEAN PHYSICAL JOURNAL A

Short note

Intruder states in even-even neutron-rich Pd isotopes

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Received:13 March 1998
Communicated by B. Povh

Abstract. The decays of ^{112}Rh^{g} and ^{112}Rh^{m} obtained as on-line mass separated fission products have been investigated by standard β and γ spectroscopic techniques and γ-γ angular correlations. Low-lying 0^+ and 2^+ states are identified in the daughter nucleus ^{112}Pd. Systematics suggests the existence of an intruder band which is the lowest in ^{110}Pd, i.e. two neutrons before the midshell.

PACS. 27.60.+j $90 \leq A \leq 149$ – 23.20.Lv Gamma transitions and level energies

Proton-pair excitations across the Z = 50 shell have been demonstrated to account for the presence of low-lying intruder structures in Z ≈ 50 nuclei [1]. They appear to minimize their energies close to the neutron midshell. Recently, we have carried out experiments on even-even $_{48}$Cd [2] and odd-proton $_{45}$Rh isotopes [3]. Neutron-rich Pd isotopes have been investigated up to ^{116}Pd. Using β-decay of Rh isotopes, Äystö et al. [4] reported several low and medium spin levels, including low-lying 0^+ states which could be candidates for the heads of intruder bands. Some of these levels have been reported also in $(t,p\gamma\gamma)$ reaction [5]. The ground state band and the γ bands have been extended to high spin using prompt-fission [6]. Coulomb excitation experiments by Svensson [7] have established bands built on 0^+ states in ^{108}Pd and ^{110}Pd.

We have used on-line mass separation with the ion-guide technique [8] to investigate in more detail the levels in the neutron midshell nucleus ^{112}Pd. A new measurement is meaningful since production yields have been increased by about two orders of magnitude since the former experiment [4]. The parent nucleus ^{112}Rh has 1^+ and I≥4 states which populate ^{112}Pd levels in the I = 0 - 6 range.

Rh isotopes are obtained as products of p-induced fission of natural uranium using a 25-MeV beam of typically 10 μA. The IGISOL facility [8] delivered beams of A = 112 isobars of which about 85% are ^{112}Rh. Two thin plastic scintillators and four 70% EUROGAM-Phase II Ge-detectors were placed on a plane at a distance of about 10 cm from the implantation spot. This set-up offered the possibility to record γ-γ angular correlations in addition to β-γ-t and γ-γ coincidences. A partial level scheme of ^{112}Pd inferred from our new data shows these levels and their de-excitation that are relevant for the present issue, see Fig. 1.

The new data do not support the existence of the 0^+ state at 890 keV. This level was based on a 541 keV transition tentatively reported in [4] and in (t,p) reaction [5] but not observed in our work, see Fig. 2. Meyer et al. [5] have also reported a 1140 keV γ-ray which was likely due to coincidence summing of the 791 and 349 keV lines. A definite spin cannot be assigned to the 1140 keV level. The angular correlation yields $A_{22}(791\text{-}349) = 0.34(9)$ in agreement with $A_{22}(0\text{–}2\text{–}0) = 0.357$ but I = 2 cannot be ruled out due to the large uncertainty of the A_{44} value. Moreover, there is interference from another 791 keV transition, see Fig. 1. Nevertheless, 0^+ is favoured since no transition to the ground state ($I_\gamma(1140)/I_\gamma(791) < 0.07$) nor feeding from levels with I> 2 could be detected in our experiment. Thus, the 890 keV (0^+) and 1140 keV (2^+) levels are replaced by the 1140 keV (0^+) and 1403 keV (2^+) levels. The fact that one of the 0^+ states has branches to both 2_1^+ and 2_2^+ levels but the other has a single branch to the 2_1^+ level is used to connect the bands in the way shown in Fig. 3. We have tentatively extrapolated the systematics to ^{106}Pd, for which there is some ambiguity for the choice of 4^+ states of both bands. In ^{112}Pd there are close-lying doublets of 0^+ and 2^+ states. We conclude that the 2^+ state at 1423 keV belongs to the same structure as the 1540 keV level in ^{108}Pd, since they both have their stronger branchings (in terms of relative B(E2) values) to the 3^+ of the K = 2 band and to one of the excited 0^+ states (in ^{112}Pd the 1126 keV level). Consequently, the other 0^+ (1140 keV) and 2^+ (1403 keV) levels belong to the other band, which is consistent with the decays of the 1140 keV level to both 2_1^+ and 2_2^+ levels. Like for ^{108}Pd

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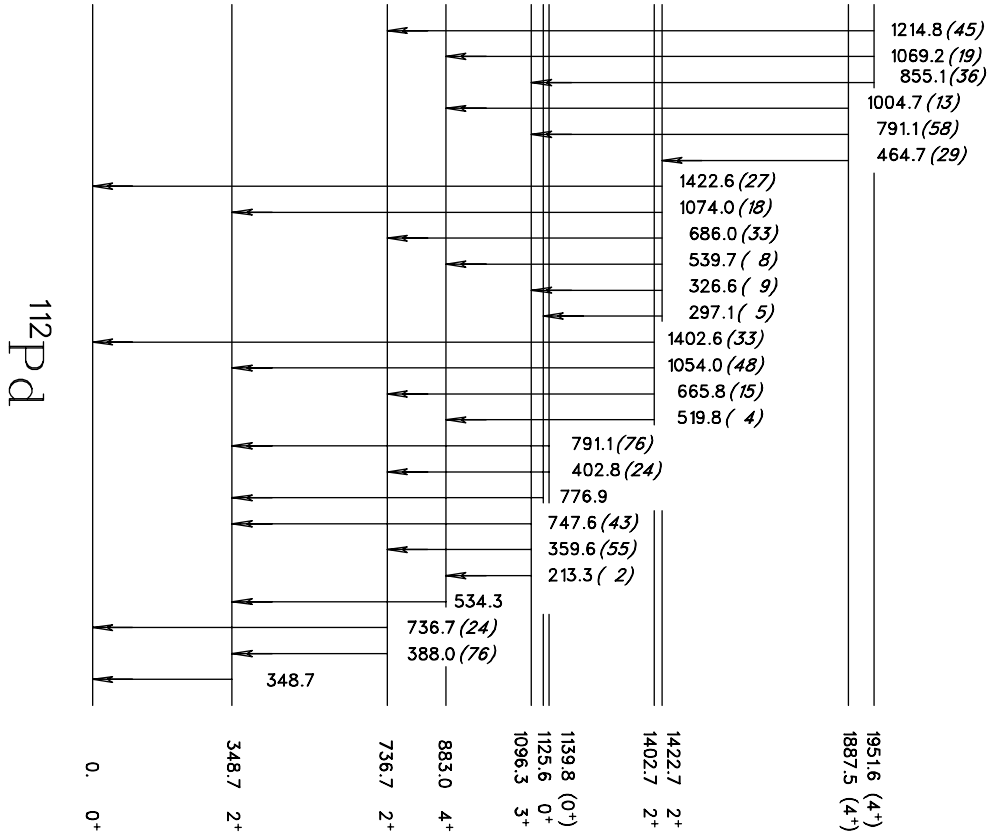

Fig. 1. Levels proposed to belong to the bands based on 0^+ states in ^{112}Pd and levels subsequently populated in their decay. Figures between brackets are γ-ray intensity branchings normalised to 100 per level

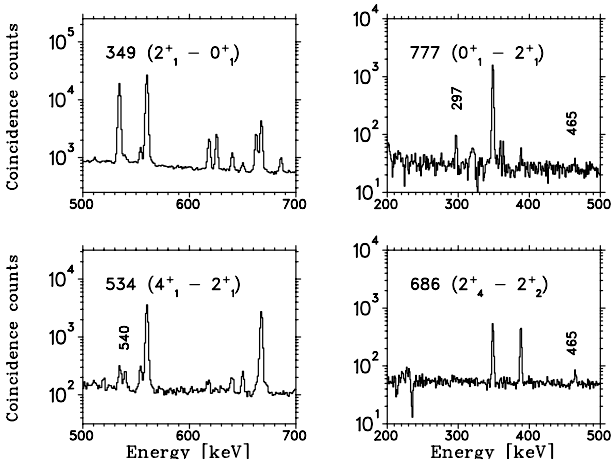

Fig. 2. Selected gated spectra. Left-hand side: there is no evidence for the formerly reported 541.6 keV line. The transition closest in energy is the 539.7 keV transition placed on top of the 883 keV level since it is seen in the 349 and 534 keV gates. Right-hand side: The gates on the 777 and 686 keV lines show the evidence for placing the 297.1 and 464.7 keV transitions as a $(4^+)\rightarrow 2^+ \rightarrow 0^+$ cascade built on the 0^+ state at 1126 keV

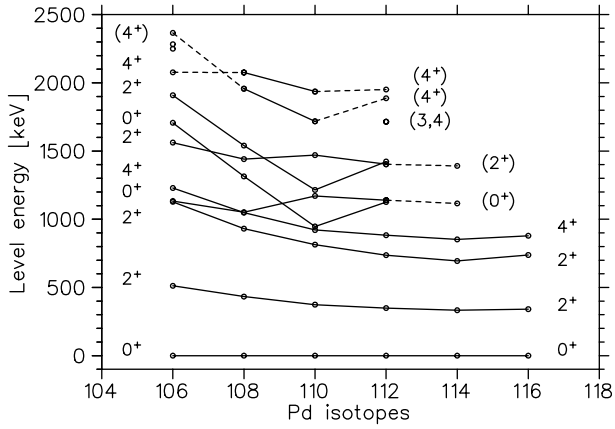

Fig. 3. Level systematics for $^{106-114}$Pd. The levels based on excited 0^+ states are shown. Assignments of 4^+ states in ^{106}Pd to a particular band are tentative. The proposed I=4^+ for levels in ^{112}Pd are not unique according to the presently available data. In this interpretation, the I = (3,4) level at 1715 keV is the only ^{112}Pd level observed in β-decay below 2 MeV not assigned to a band structure. For clarity only the 2^+, 4^+ levels of the g.s. band and the 2^+ head of the K=2 band are shown

and ^{110}Pd the strongest branching in terms of the B(E2) value is to the second 2^+ state. The 1887 and 1951 keV levels could be the 4^+ states of these bands.

Relative γ-ray branchings are in agreement with the existence of a $4^+(1887)$–$2^+(1423)$–$0^+(1126)$ band of highly collective character formed by the 297 and 465 keV transitions, see Fig. 2. The excitation energies versus N exhibit a V-shape that resembles the systematical trend of intruder states for the even-even Cd neighbours [2], and also for the odd-proton neighbours Rh and Ag [3,

9]. The minimum of energy is at N = 64, thus before the neutron midshell, like for $_{45}$Rh isotopes and not at N = 66 as in Ag and Cd nuclei. The mechanism responsible for this shift towards lower N values has to be investigated further. Detailed experimental data will be presented in a forthcoming paper.

This work was supported by the Human Capital and Mobility program of the European Union.

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