QUASI-PARTICLE STATES IN EVEN-EVEN Pd AND LOW-LYING LOW-SPIN EXCITED STATES IN EVEN–EVEN Ru*

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(Received October 26, 1999)

$A = 110$ isobars separated by IGISOL on-line mass separator from fission products has been investigated by using Beta–gamma and gamma–gamma coincidence techniques. A new quasi-particle level at 2261 keV in ^{110}Pd was observed. Systematics of logft-values and excitation energies of the quasi-particle levels in even–even Pd isotopes is remarkably smooth. An excited 0^+ state at 1137 keV in ^{110}Ru was identified and the 2_3^+ state at 1396 keV was confirmed. Systematics of these low-spin excited states in even–even Ru isotopes gives a hint for intruder character of these states.

PACS numbers: 23.20.Lv

1. Introduction

The neutron-rich Pd, Ru isotopes are known to form a shape transitional region between axially deformed and spherical nuclei. Even–even Pd nuclei were studied by Äystö *et al.* from beta-decay of Rh [1] and Aryaeinejad et al. in spontaneous fission [2]. Äystö *et al.* found one or two quasi-particle states in nuclei from ^{108}Pd to ^{116}Pd, but there exist some singularities for these quasi-particle states. Recently, Lhersonneau *et al.* identified intruder states in even–even Pd isotopes from beta-decay of ^{112}Rh [3,4]. Ground state band and gamma band of even–even Ru isotopes were investigated by Äystö *et al.* and Lu *et al.* by proton induced fission of ^{238}U [5] and spontaneous fission [6]. Low-lying low-spin excited states of ^{104}Ru, ^{106,108}Ru were studied by Stachel *et al.* [7,8] in which they suggested the first 0^+ excited states based on an

* Presented at the XXVI Mazurian Lakes School of Physics, Krzyże, Poland September 1–11, 1999.

intruder configuration instead of a collective excitation (two-photon triplet or beta-band). Goal of our experiment was to clear up these singularities in the systematics of the quasi-particle states in even–even Pd isotopes and observe the low-spin excited states in ^{110}Ru.

2. Experiments

The experiment was performed by using 25 MeV proton induced fission of ^{238}U. The fission fragments were on-line mass separated at the IGISOL facility in Jyväskylä [9]. The selected mass 110 isobars were implanted onto a tape in front of the detector system. Two plastic scintillators and three Ge detectors were used for beta–gamma and gamma–gamma coincidence measurements. In some cases, a LeGe detector was used for low energy gamma-ray spectra due to its good resolution in this region. A gamma–gamma matrix was created off-line in the process of data analysis using events from all Ge detectors.

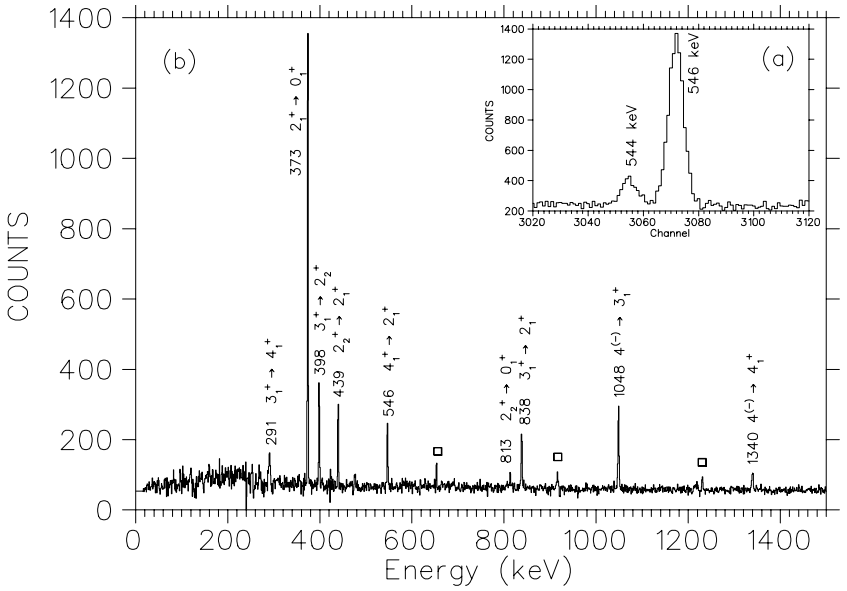

Fig. 1. A new transition of 544 keV in ^{110}Pd. The inset (a) shows the transitions of 544.4 keV and 546.9 keV resolved by the planar detector. The projection of γ–γ coincidences recorded with coaxial detectors (b) shows the coincident transitions leading to the placement of the 544 keV transition from the 2805 keV level to a new level at 2281 keV. Open squares mark transitions due to contamination by the 547 keV transition in the gate.

3. Results and discussion

The new data confirm the previous observed quasi-particle state at energy 2805 keV in ^{110}Pd [1] which is strongly fed in beta-decay with logft=4.8. The uncertain branches from the 2805 keV level to the 4^+ state of ground state band and the 3^+ state of gamma band are confirmed by the clear gamma transitions of 1885 keV and 1594 keV. New 544 keV gamma peak was resolved from the very strong gamma peak 546 keV of the ground state band, see Fig. 1(a). The 544 keV transition decays from the 2805 keV level to a new level at 2261 keV which decays to 3^+ level of gamma band and 4^+ level of ground state band by transitions of 1048 keV and 1340 keV, see Fig. 1(b). The levels at 2864 keV (^{108}Pd), 2805 keV(^{110}Pd) and 2755 keV(^{112}Pd) show very smooth systematics. Even parity and I=5 has been suggested for the ^{108}Pd level and ^{112}Pd level [4, 10]. Therefore, I^π=5^+ could be tentatively assigned to the 2805 keV level in ^{110}Pd. The levels at 2282 keV(^{108}Pd), 2261 keV(^{110}Pd) and 2195 keV(^{112}Pd) form another smooth trend. These levels are strongly populated via a gamma transition from the above discussed levels. The similar gamma-ray relative branchings of these levels to 3^+ and 4^+ states suggest them to be all $I = 4$ states of the same parity, since $I = 4$ was assigned for the level in ^{112}Pd [4]. The systematics of these levels are shown in Fig. 2.

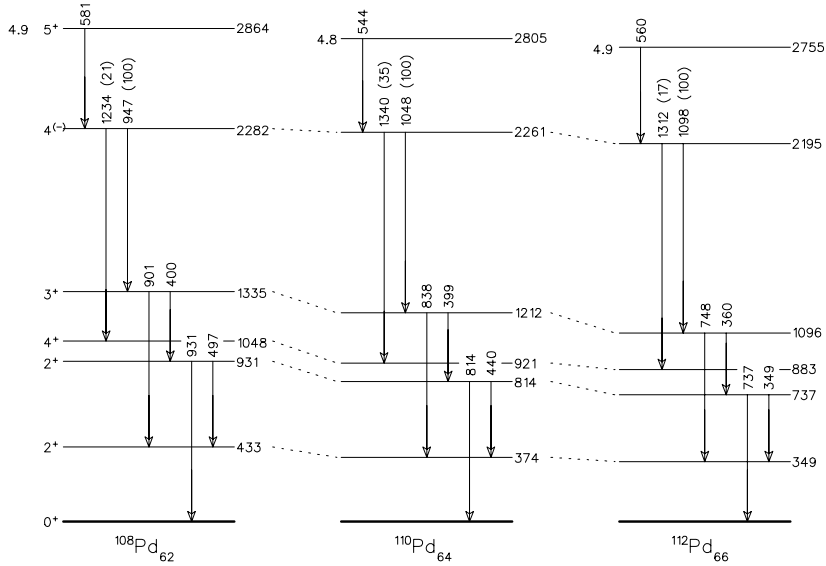

Fig. 2. Systematics of the quasi-particle levels in even–even Pd isotopes strongly fed in β-decay of the high-spin state of Rh. Only the selected transitions are shown for clarity.

In ^{110}Ru, a tentative level at 1137 keV shown in [10] is confirmed in our measurement by observing 897 keV gamma transition strongly in coincidence with 241 keV transition of 2^+ to 0^+ of ground state band. This level should be a 0^+ excited state since no transition to the ground state($I_\gamma(1137)/I_\gamma(890) < 0.06$) nor feeding to levels with $I > 2$ could be detected in our measurement. The $I^\pi = 2_3^+$ for the level at 1396 keV is confirmed by new transitions to 0^+ and 4^+ states. A weak gamma transition with energy 259 keV was observed to connect the 1396 keV level of 2_3^+ and the 1137 keV level. By measuring the excitation energies, the B(E2) values, the mixing ratios and quadrupole moments of low-lying excited states in ^{104,106,108}Ru, Stachel *et al.* outlined that 0_2^+, $2_3^+, \ldots$ sequence is not the collective excited states predicted by the nuclear models, but it is very likely based on an intruder configuration [7,8]. However, the systematics of these energies shown in Fig. 3 does resemble the systematical trend of intruder states for odd-proton Rh, Ag [11,12] and even–even Pd, Cd [3,13]. It gives a hint for intruder character of these states. The property of these low-lying low-spin states in even Ru isotopes is still an open question. Thus further detailed studies is needed.

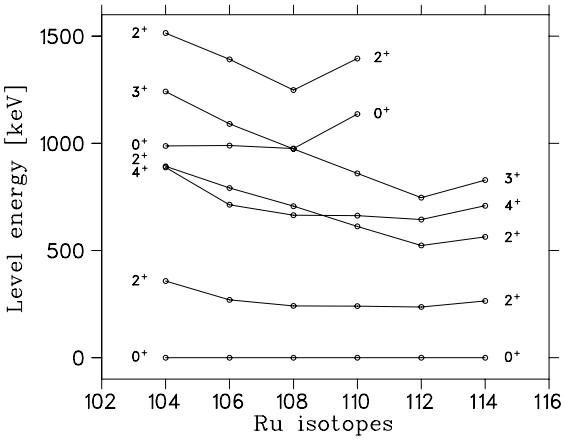

Fig. 3. Systematics of low-lying low-spin states of the even–even Ru isotopes.

In conclusion, the quasi-particle structure in even–even Pd isotopes is remarkably smooth. There is no discontinuity in the feedings from the high-spin Rh isomer to the 5^+ levels. This should make a theoretical interpretation feasible. In ^{110}Ru, an excited 0^+ state has been identified. Thus, there is evidence for a band with $E(2)$–$E(0) = 259$ keV but its nature as collective or due to p–h excitation has to be elucidated from more detailed measurement, such as lifetime measurements.

This work was financially supported by the Academy of Finland and the Access to Large Scale Facility program under the Training and Mobility of Researchers program of the European Union.

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