ISOMER SPECTROSCOPY OF $N \simeq Z$ NUCLEI CLOSE TO ^{100}Sn*

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Isomers in neutron deficient nuclei close to ^{100}Sn were studied with a recoil catcher setup following the reactions ^{58}Ni+^{40}Ca $\rightarrow$ ^{98}Cd* and ^{58}Ni+^{46}Ti $\rightarrow$ ^{104}Sn*. New spin gap isomers were found in ^{92}Ru, $I^\pi =$ (5^-), $t_{1/2} = 16(2)$ns; ^{95}Pd, $I^\pi = (31/2^-)$, $t_{1/2} = 12(3)$ ns; and ^{94}Pd,$I^\pi =$ (14^+),
$t_{1/2} = 0.8(2)$ μs. The $T_z = 1$ nucleus ^{94}Pd was identified for the first time in-beam. The decay of the $I^\pi = (8^+)$ isomer in ^{100}Cd was revised leading to the identification of the full set of pure neutron (ν) particle and proton (π) hole states below the isomer. The results are compared to large scale shell model calculations with emphasis on the $\pi\nu$ residual interaction.

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1. Introduction

The structure of neutron deficient nuclei close to $N \simeq Z$ and the proton dripline is expected to exhibit phenomena, that can not be studied close to the stability line. As protons (π) and neutrons (ν) occupy identical shell model orbits, their mutual interaction is exceptionally strong, which leads to a new kind of pairing based on the strongly bound $T = 0$, $I = 1$, $I_{\rm max}$ spin aligned two-body matrix elements (TBME) [1]. In nuclei with identical particle/hole character of protons and neutrons therefore spin gap isomers are expected. In contrast the $\pi\nu$ interaction is weak in ph configurations, so that the $T = 1$ interaction governs the structure of high spin nucleons giving rise to seniority isomers. The exclusive spectroscopy of high spin isomers therefore provides a crucial test of the $\pi\nu$ interaction.

2. Experiment and results

A dedicated experimental setup was designed [2], where the evaporation residues recoiling from the target were stopped 40 cm downstream on a catcher foil placed in the center of the OSIRIS γ–ray spectrometer. To avoid excessive background from radioactivity the catcher foils were exchanged in automatic cycles. Filter detectors for neutrons and charged particles surrounding the target served for identification of neutron deficient exit channels. Two experiments were performed with the reactions ^{58}Ni+^{40}Ca→^{98}Cd* and ^{58}Ni+ ^{46}Ti → ^{104}Sn* at 215 MeV and 230 MeV energy of the Ni beam from the tandem–cyclotron combination VICKSI at HMI. Further experimental details are given in Refs. [2–4].

In the first experiment two new isomers in ^{92}Ru with $I^{\pi} = (5^{-})$ and $t_{1/2} = 16(2)$ ns (Fig. 1c) and in ^{95}Pd with $I^{\pi} = (31/2^{-})$ and $t_{1/2} = 12(3)$ ns (Fig. 1d) were found besides the well known $I^{\pi} = 8^{+}$ seniority [5] and $I^{\pi} = (21/2^{+})$ spin gap [6] isomers.

Further a delayed γ-ray cascade of 6 transitions (Fig. 2a) was observed, which from its coincidence intensities with protons and neutrons could be assigned as the $(2p2n)$ exit channel from ^{98}Cd, *i.e.* to ^{94}Pd. Details of the evaporation particle multiplicity assignment are given elsewhere [3, 7]. The halflife of the high spin isomer was determined to $t_{1/2} = 0.8(2)$ μs (Fig. 2a). The transition strength is compatible only with the assumption of a highly converted low energy transition, when compared to typical E2 and E1 strengths in the $\pi\nu$ $(p_{1/2}, g_{9/2})$ model space. The tentative level scheme for this previously unobserved nucleus, which is populated with an estimated cross section of 0.2 mb, is shown in Fig. 2b.

In the second experiment the decay of the $I^{\pi} = 8^{+}$ proton isomer in ^{100}Cd [8] was studied. Due to the improvement of the detection sensitivity by an order of magnitude in the present setup 6 new weak γ–rays (see insert in Fig. 3a) were observed in the decay of the isomer, and two new levels were established, the proton 4_2^+ and 6_2^+ states (Fig. 3b).

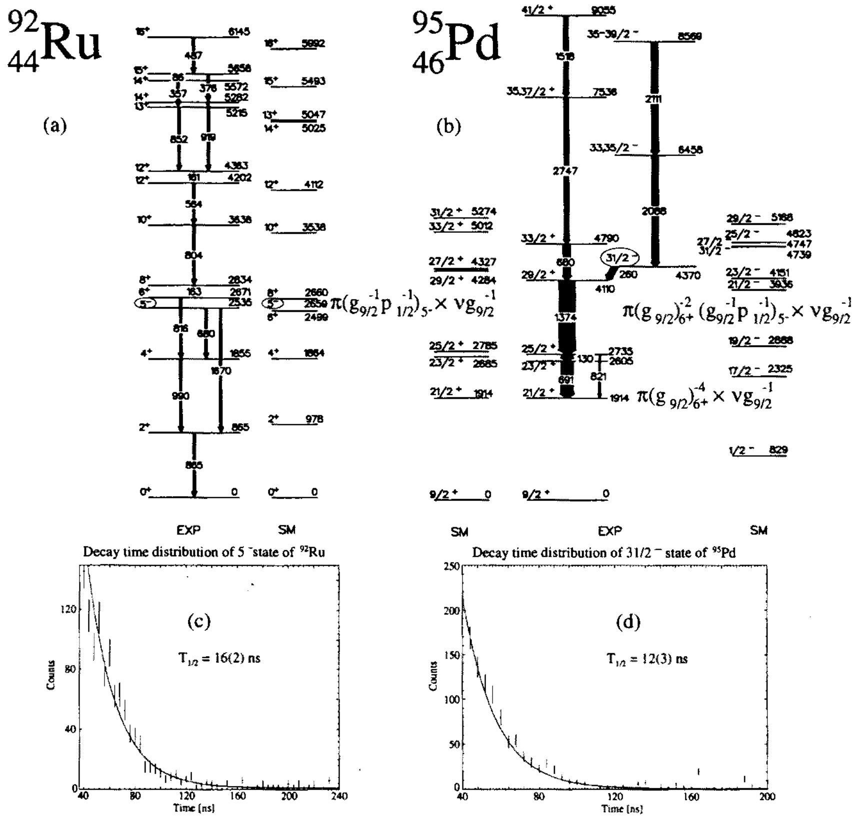

Fig. 1. Experimental [9, 10] and shell model level schemes (present work) for ^{92}Ru (a) and ^{95}Pd (b) and decay of the $I^\pi = (5^-)$ (c) and $I^\pi = (31/2^-)$ (d) spin gap isomers.

3. Discussion

3.1. Spin gap isomers in ^{92}Ru and ^{95}Pd

The $I^\pi = (5^-)$ state in ^{92}Ru and the $I^\pi = (31/2^-)$ level in ^{95}Pd can be regarded as spin gap isomers, as there are no lower lying states of the same parity that can be reached by M1 and E2 γ–decay (see shell model theory in Fig. 1a,b). This opens the possibility to observe retarded parity changing transitions of E1 and E3 multipolarity, which are not allowed in the $\pi\nu$ $(p_{1/2}, g_{9/2})$ shell model space. Thus the observed strength is a test for

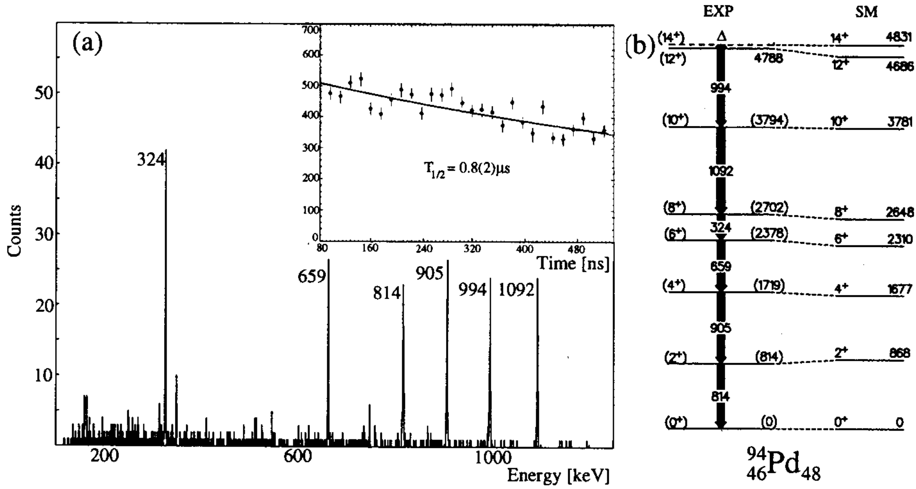

Fig. 2. Sum coincidence spectrum and decay of the $I^{\pi} = (14^{+})$ isomer in ^{94}Pd (a) and experimental and shell model level scheme (b).

the purity of the shell model wave functions. For ^{92}Ru $B(E1;5^{-} \rightarrow 4^{+}) = 3.8(7)*10^{-8}$ W.u. is deduced, implying high configurational purity for both states. On the other hand the E3 strength of $B(E3;5^{-} \rightarrow 2^{+}) = 1.8(4)$ W.u. as compared to the "normal" $B(E3;3^{-} \rightarrow 0^{+}) = 25(3)$ W.u. [12] yields an admixture of 7% of $2^{+} \otimes 3^{-}$ to the 5^{-} wave function, which, however, does not contribute to the $5^{-} \rightarrow 4^{+}$ E1 transition.

3.2. $\pi\nu$ interaction in stretched configurations in ^{94}Pd

In Fig. 2b the experimental level scheme is compared to shell model calculations in the $\pi\nu$ $(p_{1/2}, g_{9/2})$ model space using an empirical interaction [7, 11]. It should be noted that the level order, that cannot be determined in isomer spectroscopy, has been inferred uniquely from the systematics of $N = 48$ isotones [3]. In view of the excellent agreement from the theoretical $B(E2;14^{+} \rightarrow 12^{+}) = 4.9$ W.u. and the experimental halflife the energy of the primary isomeric transition is deduced as $\Delta \leq 90$ keV as compared to the shell model value of 145 keV. This allows to infer an improved value for the $\pi\nu$ $g^{2}_{9/2}$ $I^{\pi} = 9^{+}$ TBME of -2.0 MeV as compared to -1.75(7) MeV in Ref. [11], whereas no influence from the pairing counterpart TBME with $I^{\pi} = 1^{+}$ was found.

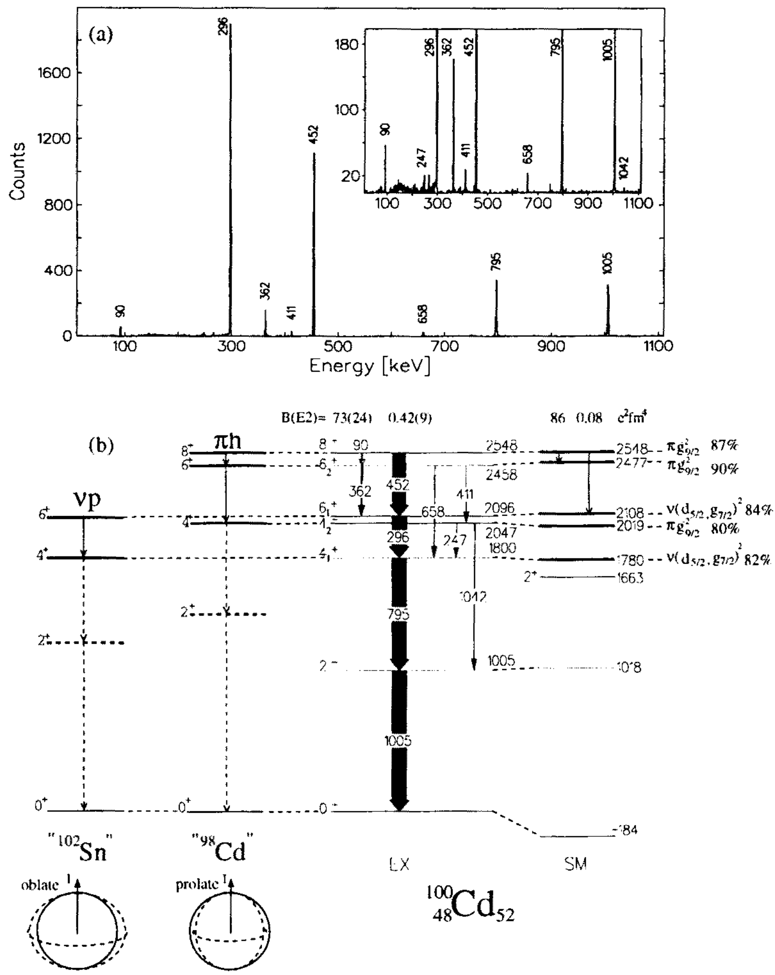

Fig. 3. Sum coincidence spectrum (a) and experimental and shell model level schemes (b) for ^{100}Cd.

3.3. $\pi\nu$ interaction in ph–configurations in ^{100}Cd

The nucleus $^{100}_{48}\mathrm{Cd}_{52}$ with two neutron particles (p) and two proton holes (h) outside the ^{100}Sn shell model core is well suited to test the $\pi\nu$ interaction in ph configurations. Due to the reduced spatial overlap it is expected to be weak in medium and high spin configurations. This is nicely borne out by the decay scheme shown in Fig. 3b. The weak branches between 6^+ and 4^+ yrast and yrare states and the $8^+ \to 6^+_{1,2}$ B(E2) values establish the predominant neutron and proton character of the 4^+_1, 6^+_1 and the 4_2^+, 6_2^+, 8_1^+ states, respectively. The shell model supports this conclusion with more than 80% configurational purity for these states and good agreement with the present and previous [8] spectroscopic data. Neglecting an appreciable influence by the minority components in the wave functions, we extrapolate predictions for the level schemes shown on the left side of Fig. 3b for the pure neutron particle (νp) and proton hole (πh) nuclei ^{102}Sn and ^{98}Cd, respectively.

In conclusion the highly sensitive test of residual interaction in large scale shell model calculations provided by the spectroscopy of isomeric states with simple structure in general confirms the concept of the adopted $\pi\nu$ interaction. Future corrections will not affect the basically high predictive power of these calculations.

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