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IPNO-DRE 97-07

DEFORMATION CHANGE BETWEEN ISOMERIC AND GROUND STATES OF ISOTONES N=105

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Presented to the International Workshop on Hyperfine Structure and Nuclear Moments of Exotic Nuclei by Laser Spectroscopy, February 3-5, 1997, Poznan, Poland

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Abstract : The properties of the ^{182}Ir and ^{184}Au doubly-odd isotones are compared. Results on conversion-electron measurements performed with a high resolution spectrograph for the ^{182}Pt and ^{183m}Pt β^+/EC decays are also presented. They confirm the $\pi\otimes\nu$ configurations proposed for the ^{182}Ir ground state and the ^{184}Au isomeric and ground states. It is also shown that the anomaly observed in ^{184}Au cannot be explained by the influence of the V_{pn} residual interaction but would be rather due to a small deformation change either between the isomeric level and the ground state of ^{184}Au or between ^{184}Au and its neighbouring odd-A nuclei.

1. Introduction

In recent years, considerable work on doubly-odd nuclei situated between the prolate-deformed rare-earth and the semi-magic lead nuclei has been performed in order to study the proton-neutron coupling schemes and to obtain information on the influence of the V_{pn} proton-neutron residual interaction on nuclear properties. In this transitional region, a lot of experiments using two complementary methods, radioactive decay and in-beam reactions, have been undertaken providing many interesting results [1-19]. Thus, collective structures observed using in-beam experiments [6, 8, 13] exhibit properties depending on the proton-neutron ($\pi\otimes\nu$) configuration of states on which they are built. They have been classified according to the coupling schemes of a proton and a neutron to each other and to a deformed core [9, 14]. Therefore, by now the $\pi\otimes\nu$ configuration of a state can be deduced from the properties of the rotational band built on it. Besides, it has been shown that a good estimate of the relative energy location of the different $\pi\otimes\nu$ states located at low excitation energy in a doubly-odd nucleus is usually provided by the zero-order level scheme built by linear interpolation of the energies of the proton and neutron states observed in their neighbouring odd-A nuclei [3, 5, 8, 10, 13].

The comparison of the level schemes of the two N=105 isotones ^{184}Au and ^{182}Ir is of particular interest because these nuclides are situated on the prolate edge of the transitional region considered. The zero-order level scheme of the ^{182}Ir prolate-shaped nucleus is easily deduced from the neutron state energies known in ^{181}Os [20], ^{183}Pt [21-23] and the h9/2 proton state observed as the ground state of ^{181,183}Ir [24, 25]. Except for the I=3 ground state, the low-energy levels of ^{182}Ir have been clearly identified from the rotational bands observed in an in-beam experiment [8]. The ground state is believed to be the bandhead of a doubly-decoupled band which corresponds to the π h9/2 $\otimes$ ν 1/2$^-$[521] configuration according to the ^{182}Ir zero-order level scheme [8, 17] (see fig. 1). The ground state of the ^{184}Au odd-A neighbours have a prolate shape. Therefore, in spite of the presence of shape coexistence in Au and Hg isotopes, the zero-order level scheme shown in figure 1 has been built using the prolate neutron states of ^{183}Pt [23] and ^{185}Hg [4], and the prolate proton h9/2 ground state of $^{183,\ 185}$Au [22, 26]. Spin and parity values of the isomeric and ground states of ^{184}Au have been determined from a recent radioactive decay investigation [16]. In the new ^{184}Au level scheme, the ground state of spin and parity values 5$^+$ cannot have the expected configuration which likely corresponds to the 2$^+$ isomeric level located at 68.6 keV. Then, the state expected at 36 keV in the zero-order level scheme could correspond to the ^{184}Au ground state (fig. 1). Therefore, in both the ^{182}Ir and ^{184}Au doubly-odd nuclei, observed states would have the same $\pi\otimes\nu$ configurations but, whereas in ^{182}Ir their relative energy locations are in good agreement with the zero-order level scheme, in ^{184}Au they would be at variance with it (fig. 1).

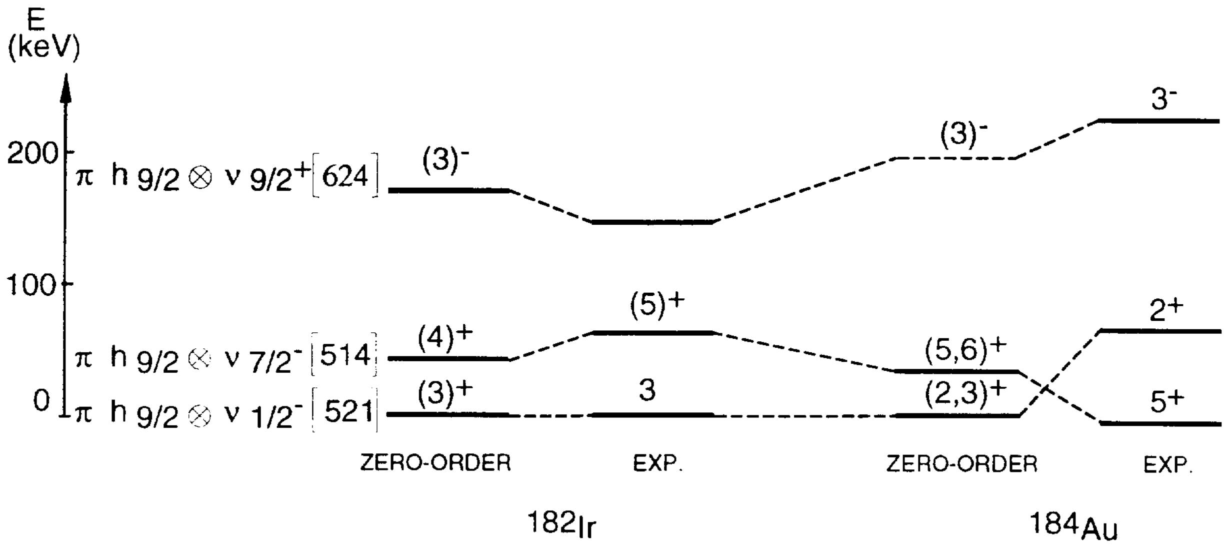

Fig. 1 - Comparison of the zero-order level schemes with the experimental results obtained for the ^{182}Ir and ^{184}Au doubly-odd nuclides [8, 16]. One level has been drawn with a dashed line because the ν9/2$^+$ [624] state energy is not known in ^{185}Hg. Spin and parity values reported for the zero-order level schemes are predicted by a rotor-plus-two-quasiparticle model.

This observation is difficult to understand and raises questions : Is shape coexistence present in ^{184}Au ? Are the above proposed $\pi\otimes\nu$ configurations for the ground state of ^{182}Ir and the isomeric and ground states of ^{184}Au, correct ?

2. Collective structures in ^{184}Au

An in-beam experiment performed to establish collective structures in ^{184}Au answers the first question. In this study, four rotational bands could be identified [18]. The two strongly populated are certainly built on the isomeric and ground states of ^{184}Au. One resembles the collective structure observed in ^{182}Ir, identified as having the prolate $\pi h9/2\otimes\nu 7/2^-$ [514] configuration [8] which was also proposed above for the ^{184}Au ground state. The other one is a doubly-decoupled band which is a signature of the prolate $\pi h9/2\otimes\nu 1/2^-$ [521] configuration. Furthermore, no collective structures similar to those known for the oblate states in $^{186, 188}$Au [12] were observed. So, the assumption that ^{184}Au in its isomeric or ground state could have another shape than a prolate one must be ruled out.

3. The $\pi\otimes\nu$ configuration of the ^{182}Ir ground state

The I=3 ground state of ^{182}Ir is believed to be the bandhead of the doubly-decoupled band only built on a 5^+ state. However, up to now, a link between this I=3 state and the 5^+ state of the collective structure was neither observed in the in-beam experiment [8] nor in the radioactive decay study [17]. Such $5^+ \rightarrow 3^+$ transitions between the states of the doubly-decoupled structure were not observed in $^{184, 186}$Ir [5, 10]. The very low-energy spacing between the 5^+ and 3^+ states expected in the Ir isotopes could explain this non observation. In ^{182}Ir, the energy spacing of the 5^+ state and the I=3 ground state has been indirectly determined to be 25.7 keV in the radioactive decay experiment [17]. An E2, 25.7 keV transition must exist if the ground state is the bandhead of the doubly-decoupled band. It can be observed only through its internal conversion electrons. To search for, a radioactive decay experiment was recently performed at ISOLDE (CERN) using the molten lead target [27] to produce a Hg mass-separated beam. The ^{182}Pt nuclei were produced by two successive β^+/EC decays from ^{182}Hg nuclei. To perform the electron measurement a magnetic spectrograph was coupled to a tape transport system [28]. The radioactive ions were slowed from 60 kV to 0.7 kV before collection to prevent an implantation into the tape. This preserved the high resolution for low-energy electrons. Furthermore, 13 kV were applied to the source inside the spectrograph to accelerate the emitted electrons so that the low-energy electrons can be detected by the photographic film. The low-energy part of the electron spectrum recorded in this experiment is shown in figure 2.

The electron lines for the internal conversion of the 25.7 keV transition in the L_1, L_2, L_3, M_2, M_3 and N subshells are very clearly observed. Their relative intensities are in perfect agreement with those expected for an E2 multipolarity, which unambiguously determines a positive parity

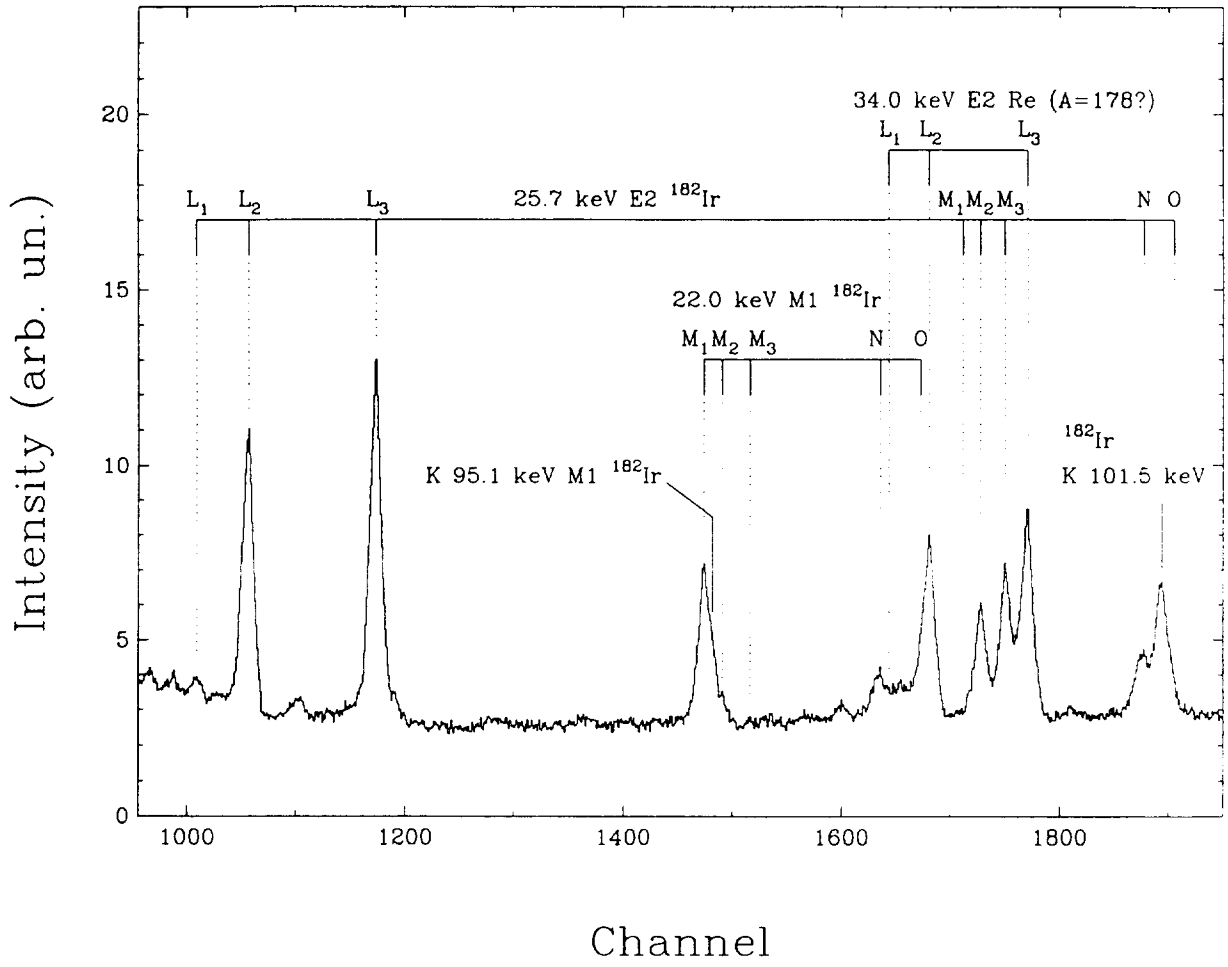

Fig. 2 - Low-energy part of the electron spectrum obtained from the ^{182}Pt β^+/EC decay.

for the ^{182}Ir ground state and confirms its I=3 spin value. Moreover the total intensity of the 25.7 keV transition is equal (within error bars) to the total intensity that populates the 5^+ state at 25.7 keV (fig. 3). So the 3^+ ground state and the 5^+ excited level which are linked by the strong intensity E2 25.7 keV transition, have the same configuration : $\pi h9/2 \otimes \nu 1/2^-$ [521].

4. Test of the neutron configurations in ^{184}Au

The $\pi h9/2 \otimes \nu 1/2^-$ [521] and $\pi h9/2 \otimes \nu 7/2^-$ [514] configurations were suggested above for the 2^+ isomeric state and 5^+ ground state of ^{184}Au, respectively. The two states are linked by an M3 transition [7, 15]. As the neutron states are coupled to the same $\pi h9/2$ proton state, a signature of the neutron configurations can be provided by the comparison of the reduced transition probabilities B(M3) in ^{184}Au and in the neighbouring odd-neutron nucleus, ^{183}Pt [15].

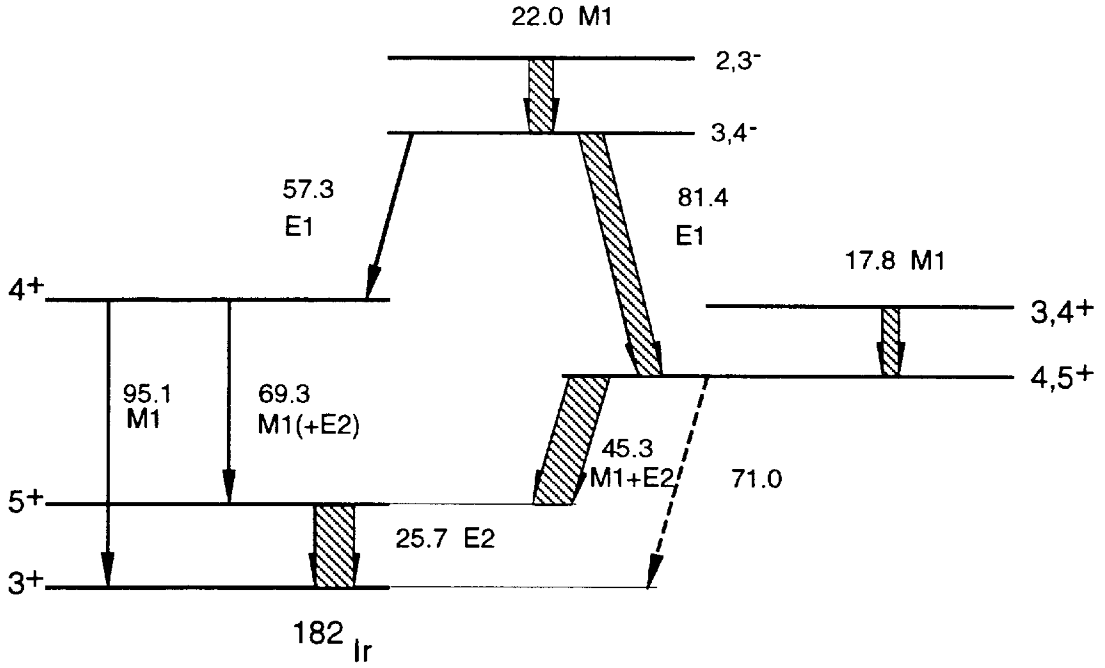

Fig. 3 - Partial level scheme of ^{182}Ir from the ^{182}Pt β/EC decay.

To establish if an M3 isomeric transition exists in ^{183}Pt and to determine its intensity, a high-resolution electron measurement has been performed at ISOLDE using the apparatus described above. The low-energy part of the electron spectrum obtained for the decay of the ^{183}Pt isomer is displayed in figure 4. The L_1 and L_3 conversion electron lines of a 35.0 keV transition in Pt are observed whereas the L_2 line of this transition is not visible. The relative intensities of these L_1, L_2 and L_3 electron lines are in very good agreement with those expected for a 35.0 keV transition with an M3 multipolarity. From the intensity of the L_3 line the B(M3) value for the 1/2 → 7/2 transition has been calculated as 27 μ_N^2 fm^4, which corresponds to a Weisskopf hindrance factor F_W(M3)=64. This value is quite similar to that known for ^{184}Au (F_W(M3) ~ 45) [19]. This agreement supports the $\pi h9/2 \otimes \nu 1/2^-$ [521] and $\pi h9/2 \otimes \nu 7/2^-$ [514] configurations previously suggested for the 2$^+$ isomeric and 5$^+$ ground states of ^{184}Au, respectively [16].

All of these results confirm the $\pi \otimes \nu$ configurations proposed for the low-energy states of the ^{182}Ir and ^{184}Au doubly-odd nuclei. It remains to understand why the states of ^{184}Au are inverted relative to the order observed in all the N=105 neighbouring nuclei. At this stage, one wonders whether the residual interaction V_{pn} or a small deformation change can be responsible of this state inversion.

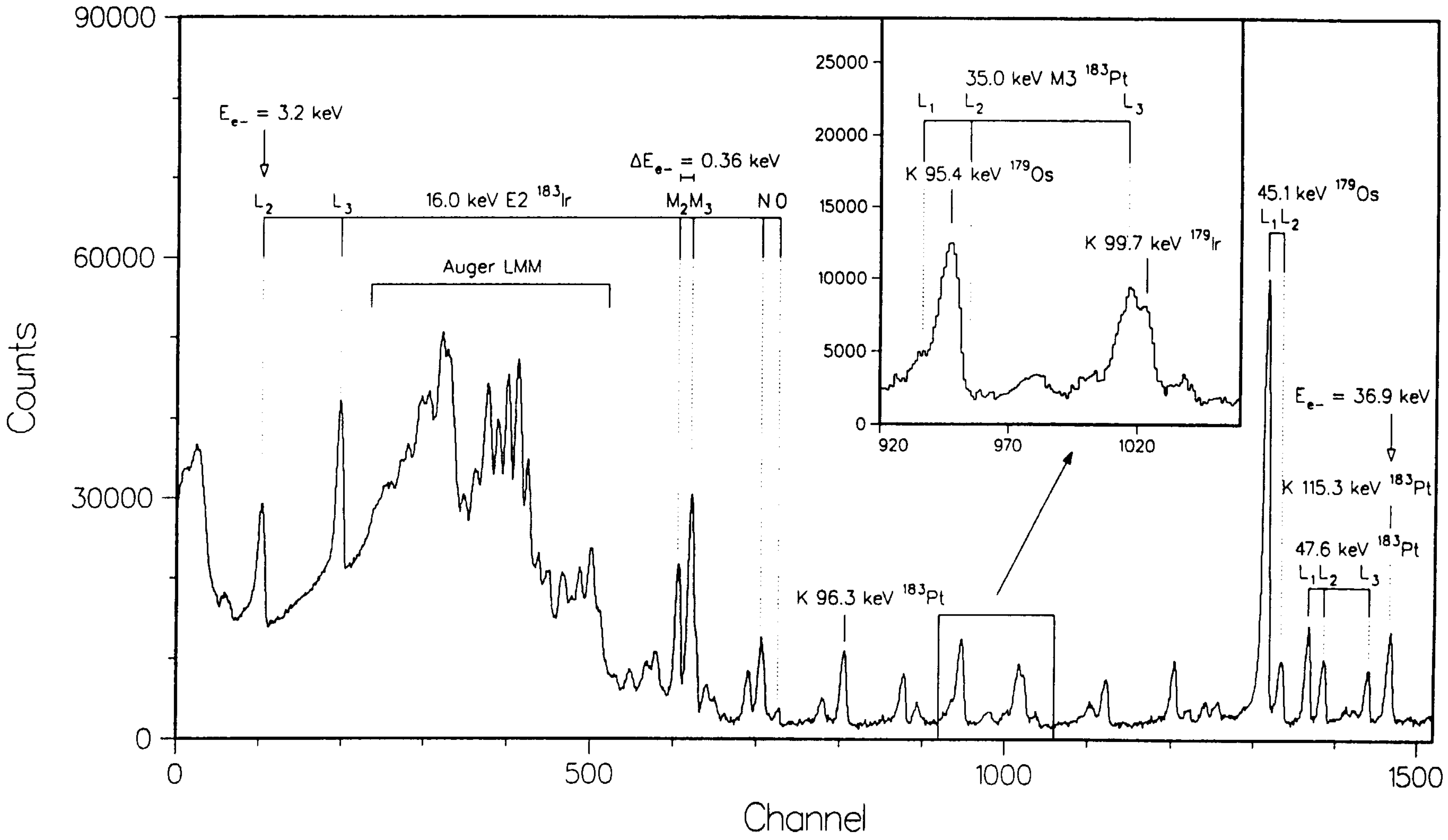

Fig. 4 - Low-energy part of the electron spectrum obtained from the ^{183m}Pt decay.

5. Influence of the V_{pn} interaction or of a small deformation change on the relative energy location of two-quasiparticle states

To accomplish this study, theoretical calculations assuming a nuclear axial symmetry have been performed for ^{184}Au. They are similar to those done for ^{182}Ir [17] and proceed in three steps :

i) to determine the static equilibrium deformation of the core and the associated quasiparticle wave functions, we perform Hartree-Fock-plus-BCS calculations using the Skyrme III force and usual pairing interaction with constant matrix elements G_{op} and G_{on} ;

ii) to calculate the energy location of the neutron state of the odd-A nuclei, we use the rotor-plus-one-quasiparticle model [29] in which all the self-consistent quasiparticle states lying less than 5 MeV from the Fermi level are taken into account ;

iii) to predict the energy position of the two-quasiparticle states of the doubly-odd nuclei, we use the rotor-plus-two-quasiparticle coupling model developed by L. Bennour et al. [30] in which the geometrical coupling of the proton with the neutron as well as that of each quasiparticle with the core are taken into account. This model consistently treats the residual V_{pn} term using the same Skyrme III force as that used in the HF+BCS calculations.

To evaluate the effect of a small deformation change we have also performed HF+BCS calculations in which the even-even core is constrained in order to take different deformations around the equilibrium solution. To describe the ^{184}Au nucleus, calculations have been performed using the ^{186}Hg core since the considered neutron states are located below the Fermi level. In figure 5a, the theoretical predictions for ^{185}Hg and ^{184}Au, at two different core deformations, are compared with the experimental results. The deformation parameter value β_2=0.28 corresponds to the equilibrium solution found for the ^{186}Hg core. In figure 5b a similar comparison for ^{183}Pt and ^{182}Ir, extracted from ref. [17], is shown for β_2=0.23. We have to note that the V_{pn} interaction only slightly modifies the relative energy position of the two-quasiparticle states. On the other hand, a change of deformation from β_2=0.24 to β_2=0.28 provides an inversion of the predicted states for both the odd-A and doubly-odd nuclei, which strongly suggests that the state inversion observed in ^{184}Au is due to a deformation change either between the isomeric level and the ground state of ^{184}Au or between ^{184}Au and its neighbouring odd-A nuclei.

Laser spectroscopy measurements constitute an excellent way to determine the deformation change between the ^{184}Au isomeric and ground states. The COMPLIS experimental setup has been used to measure isomer and isotope shifts, and hyperfine spectra providing charge radius changes and nuclear moments, respectively. In addition getting information about the deformation, the magnetic moment values further test the $\pi \otimes \nu$ configurations assigned to the ^{184}Au states. In the results obtained for ^{186}Hg-plus-two-quasiparticles with a deformation parameter β_2=0.28 (see fig. 5a), the 5^+ and 2^+ states have almost pure K=5 and K=2 wave functions respectively and the $\pi h9/2$ subshell may be

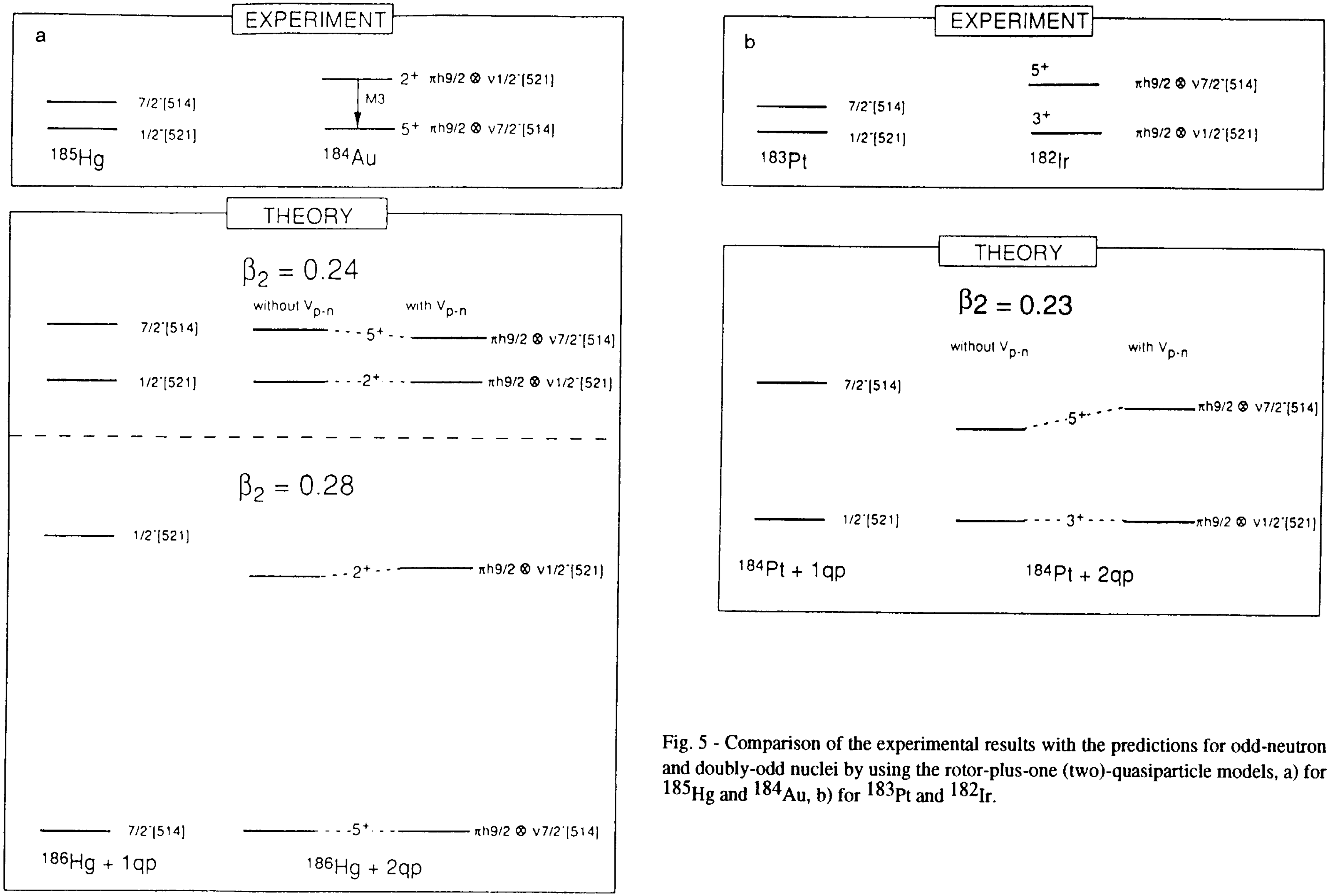

Fig. 5 - Comparison of the experimental results with the predictions for odd-neutron and doubly-odd nuclei by using the rotor-plus-one (two)-quasiparticle models, a) for ^{185}Hg and ^{184}Au, b) for ^{183}Pt and ^{182}Ir.

considered as the $\pi 3/2^-[532]$ orbital. Using the μ values for the ν $1/2^-$ [521], ν $7/2^-$ [514] and π $3/2^-[532]$ states in the neighbouring odd-A nuclei calculated as described in ref. [31] we have extracted the g_{Kn} and g_{Kp} values. Thus, the μ values could be estimated to be $\mu=2.36$ μ_N for the I=K=5 state and $\mu=1.27$ μ_N for the I=K=2 state of ^{184}Au, using the method described in reference [32] with g_{sfree} and $g_R=Z/A$. The laser spectroscopy experiment is described and the results discussed in the contribution by J. Pinard presented at this workshop [33].

We would like to thank Dr. M.G. Porquet for her work on the calculations and fruitful discussions.

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