Two-particle structure in odd-odd nucleus $^{178}_{73}Ta_{105}$

R. Gowrishankar* and P C Sood

Department of Physics, Sri Sathya Sai Institute of Higher Learning, Prasanthinilayam, A.P., 515134 INDIA

*· * email: rgowrishankar@sssihl.edu.in*

As a part of our ongoing investigations of level structures in odd-odd deformed nuclei, we present here a discussion of $^{178}_{73}Ta_{105}$ levels [1,2]. This report is a follow up of our recent studies of its odd-odd isotopic neighbours ^{184,186}Ta [3,4] and isotonic neighbour ^{176}Lu [5]. Our investigations employ the well-tested 3-step Two Quasiparticle Rotor Model {TQRM} which has been extensively and effectively used to elucidate the level structures of odd-odd deformed nuclei of both the rare-earth and actinide regions. Historically [6], two independent β-decaying ^{178}Ta low-lying isomers, namely an $I^{\pi}=7^-$, 2.2 h and another an $I^{\pi}=1^+$, 9.3 min isomer, have been known for well over six decades. Since then, a few reaction studies [7-9] have been reported aimed at primarily exploring the high-spin (2qp and also 4qp) spectra in the nucleus. However, as explicitly stated by the latest NDS evaluator [2], "there is no experimental evidence to establish either the energy difference, or even the order, of the low lying 1^+ and 7^- states for this nuclide". Further the presently available data hardly includes any information on low-lying low-spin levels in this nucleus.

First step in the evaluation of 2qp bandhead energies using the 3-step TQRM involves mapping of the relevant 1qp configuration space using the observed [1] single particle excitation energies (E_x) in the neighbouring odd-mas isotopes/isotones. All the neighbouring odd mass isotopes of Ta have their I^{π}(gs) = 7/2[404]. However, as shown in Fig. 1, E_x for $9/2^-$[514] orbital decreases sharply from 132 keV to 6 keV

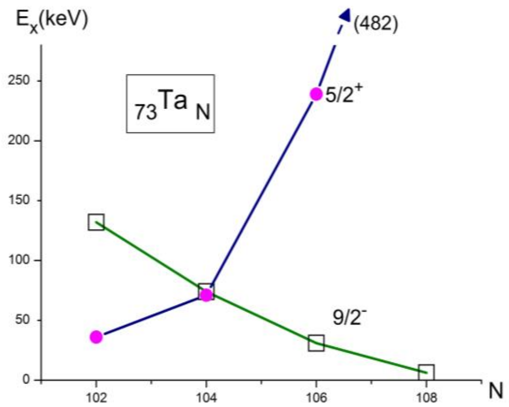

Fig. 1: A plot of Experimental [1] excitation energies of $9/2^-$[514] and $5/2^+$[402] levels of odd-A=175(2)181 Ta isotopes

in going from N=102 to 108, whereas, E_x for $5/2^+$[402] rises sharply from 36 keV to 482 keV over this region. Accordingly, E_x for these two orbitals relevant to $^{178}Ta_{105}$ are taken as interpolated values from (A±1) Ta neighbours.

In the second step, we enumerate in Table 1, the physically admissible low-lying 2qp doublet bands, in accordance with the GM rule which places the spins-parallel triplet band K_T lower in energy than its spins-antiparallel counterpart singlet band K_S. In this table, we have included the 3 lowest proton orbitals and only the first excited neutron orbital, thus corresponding to the summed (E_p+E_n) < 500 keV range. Entries in round brackets are the experimental $\Delta E(K_S-K_T)$ for each ($p_i n_0$) doublet from ^{176}Lu and ($p_i n_1$) doublet from ^{180}Ta [1].

Table 1: 2qp bands in ^{178}Ta arising from the coupling of the single particle proton and neutron states.

p_i $E_p \rightarrow$ n_j $E_n \downarrow$	p_0 0 $7/2^+$[404]	p_1 52 $9/2^-$[514]	p_2 155 $5/2^+$[402]
n_0 0 $7/2^-$[514]	7^- 0^- (237)	1^+ 8^+ (294)	1^- 6^- (177)
n_1 310 $9/2^+$[624]	1^+ 8^+ (178)	9^- 0^- (31)	7^+ 2^+ (203)

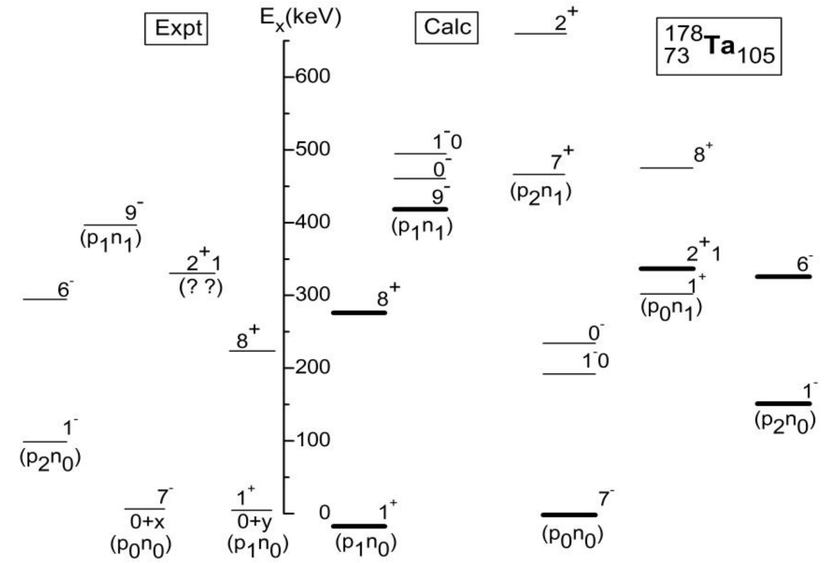

Fig. 2. Plot of experimental (left) and calculated (right) low-lying 2qp levels expected in ^{178}Ta. The calculated levels that match the presently available experimental data [1,2] are shown in bold lines. Rotational levels for the $K_<$ band of the p_0n_0, p_0n_1 and p_1n_1 configurations are labelled by $I^\pi K$.

Finally, the bandhead energies of 2qp bands of Table 1 are evaluated using the following expressions [3,4 and references therein]:

$$E^K(\Omega_p, \Omega_n) = E_0 + E_p + E_n + E_{rot} + < V_{np} >;$$

$$< V_{np} > = -\left[\frac{1}{2} - \delta_{\Sigma,0}\right] E_{GM} + (-)^I E_N \delta_{K,0}. \quad (1)$$

$$E_{GM} = \Delta E + E_{rot} \text{ for } K^- = K_S$$

$$= \Delta E - E_{rot} \text{ for } K^- = K_T. \quad (2)$$

Wherein, E_p, E_n and ΔE are as specified in Table 1. Our TQRM evaluated ^{178}Ta level energies for respective bands listed in Table 1 are shown in Fig. 2 in comparison with the corresponding presently known experimental data. A careful examination of data in Fig. 2 leads to the following observations.

Taking note of the fact that TQRM evaluation does not include any available information on ^{178}Ta levels, the agreement between the experimental and calculated values can be rated as very satisfactory. Further we note that TQRM does not aim for any quantitative fit to the existing data but is used to provide location guides for as yet unobserved/unassigned energy levels. Accordingly, we assign, as shown in Fig. 2, (p_0n_1) configuration to the 329.5 keV (2^+1) level of Kondev *et al* [8]. Our evaluation places the 1^+ (p_1n_0) band lower in energy (~20 keV) than the 7^- (p_0n_0) level, in agreement with their tentative placement by Burke *et al.* [9] based on the experimental data of Kondev *et al.* [8]. However, taking note of the reservations expressed by Burke *et al.*[9] and the experimentally established very strong mixing of the two (1^+ 8^+) doublets in ^{176}Lu[5], we presently refrain from concluding 1^+ as the ^{178}Ta gs.

Our calculated energies of as yet unobserved levels, as shown in Fig.2, can serve as useful guide for further experimentation to identify both the low and high spin structures.

References

[1] ENSDF and XUNDL continuously updated data files at NNDC (July 2017 Version).

[2] E. Achterberg, O.A. Capurro and G.V. Marti, Nucl. Data Sheets 110, (2009) 1473.

[3] R. Gowrishankar and P. C. Sood., Eur. Phys. J. **A52**, 31 (2016).

[4] P. C. Sood and R. Gowrishankar, Phys. Rev. **C90**, (2014) 067303.

[5] P. C Sood *et al.*, Proc. DAE-BRNS Symp. Nucl. Phys. 60 (2015) 120.

[6] G. Wilkinson, Phys. Rev. 80, (1950) 495.

[7] F. Dubbers *et al.*, Nucl. Phys. **A315**, (1979) 317.

[8] F. G. Kondev *et al.*, Nucl. Phys. **A632**, (1998) 473.

[9] D. G. Burke *et al.*, Nucl. Phys. **A778**, (2006) 125.