Characterization of Low-lying Isomer Triplet in ^{162}Lu

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Introduction

As part of our ongoing investigations on the level structures of doubly-odd deformed nuclei in both the rare-earth and actinide regions, we present here the analysis and results of our studies on the low-lying level structures of ^{162}Lu. Despite being identified more than five decades ago, there have been very few dedicated experimental studies to understand the low-lying level structure of this isotope. The latest data sheet (2024) for ^{162}Lu [1] still lists levels as high as 600 keV without any spin-parity assignments. Most importantly, ^{162}Lu is one among the few candidates in the rare-earth region that exhibits an isomer triplet. The half-lives of the three isomeric states have been determined from decay studies, but their spin, parity and energies remain ambiguous or unknown [1].

In this work, we attempt to characterize some of the low-lying levels in ^{162}Lu using the well-tested three step Two Quasiparticle Rotor Model formulation (TQRM) [2,3]. As a first step, we mapped the relevant 1qp configuration space from the experimentally observed [1] energies of proton and neutron orbitals in the neighboring (A±1) isotope/isotone. A survey of the experimental data of 1qp proton states in odd-mass Lu isotopes ($161 \le A \le 171$) reveals that the 1/2[411] p-orbital remains as g.s. in ^{161,163,165}Lu with the first excited state being 5/2[402]. The low energy p-orbital trends are depicted in Fig. 1. For the odd neutron, two of the lowest lying 1qp neutron states from ^{161}Yb were chosen. As the second step in the formulation, we constructed the physically admissible 2qp GM doublet bands in ^{162}Lu, arising from the coupling of the 1qp proton and neutron states. These GM doublets for each ($p_i n_j$) for a summed energy of $E_p + E_n \le 400$ keV are enumerated in Table 1. The third step in this formulation is to evaluate the bandhead energies using the following equations [3]:

$E(p_i,n_j) = E_0 + E_p + E_n + E_{rot} + < V_{np} >$ where,

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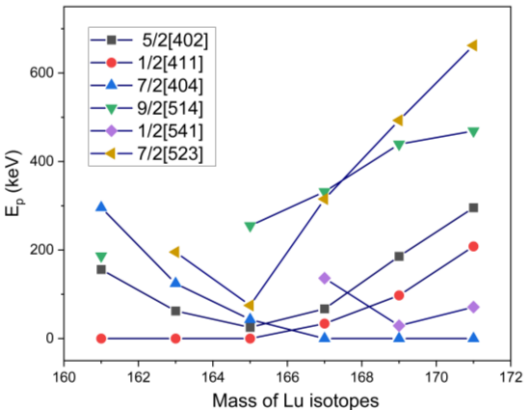

Fig. 1: *Energies of 1qp proton orbitals in 161 ≤A ≤171 Lu isotopes*

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

$$E_{rot} = \frac{\hbar^2}{2I}\left[K - \left(\Omega_p + \Omega_n\right)\right] = \frac{\hbar^2}{2I}(\Omega_<)\delta_{K,K^-}$$

Here, E_p and E_n are experimental single particle excitation energies for proton and neutron orbitals respectively.

Results and Discussion

The model-evaluated energies for 2qp bandheads, using the notation of Table 1, are shown in Fig. 2.

Table 1: *Physically admissible 2qp GM doublet bands (K_T & K_S) in ^{162}Lu.*

$\mathbf{n_j}$ E_n (keV) $\mathbf{p_i}$ E_p (keV)	$\mathbf{n_0}$ 0 $3/2^-[521\uparrow]$		$\mathbf{n_1}$ 200 $3/2^+[651\downarrow]$	
	$\mathbf{K_T}$	$\mathbf{K_S}$	$\mathbf{K_T}$	$\mathbf{K_S}$
$\mathbf{p_0}$ 0 $1/2+[411\downarrow]$	1^-	2^-	1^+	2^+
$\mathbf{p_1}$ 62 $5/2^+[402\uparrow]$	4^-	1^-	4^+	1^+
$\mathbf{p_2}$ 167 $9/2^+[514\uparrow]$	2^-	5^-	2^+	5^+
$\mathbf{p_3}$ 167 $9/2^+[514\uparrow]$	6^+	3^+	3^-	6^-

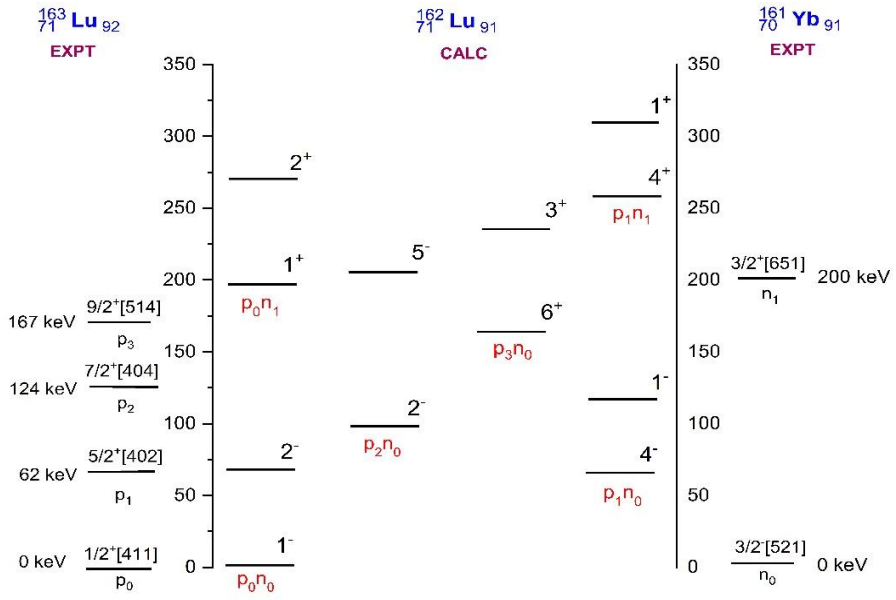

Fig 2*: TQRM model calculated bandhead energies of low-lying 2qp GM doublets in* ^{162}*Lu*

1.4 min ^{162}Lu g.s: The g.s of ^{162}Lu is listed as 1^- with the expected configuration {π1/2[411] ⊗ ν3/2[521]}. Our analysis is in complete agreement with the above, as seen in Fig. 2.

1.5 min isomer: The current data sheet lists the first isomeric state with a tentative $J^\pi = (4^-)$, but no energy value. The possible configuration of this state is suggested based on the observation of similar isomeric states in ^{164}Lu [1]. As seen in Fig. 2, the (p_1n_0) $J^\pi=4^-$ level has only the g.s. below it, to which its γ-decay will be K-hindered (ΔK=3). Hence, we confirm the configuration of the isomer as $J^\pi = 4^-\{\pi5/2[402] \otimes \nu3/2[521]\}$. Our calculations place this level at an energy $E_x \sim 62$ keV, slightly below the $J^\pi=2^-$ singlet partner of the g.s. GM pair.

1.9 min isomer: The current NDS do not specify any J^π or energy values for this level. From Fig. 2, the (p_3n_0) $J^\pi=6^+$: {π9/2[514]⊗ν3/2[521]} bandhead appears to be the only possible isomeric state owing to the γ-decay selection and K-hindrance factor, as proposed in our previous review study [4]. Our calculations place this level around $E_x \sim 160$ keV. An isomeric M2 transition, from this level to the 4^- isomeric state cannot be ruled out.

Our calculations also confirm the existence of a level $J^\pi=1^+$ (p_0n_1) at E_x~196 keV with configuration {π1/2[411]⊗ν3/2[651]} as proposed in the previous decay studies [5]. The J^π is in agreement with the log ft value assigned by Hild *et al*. [5] for the decay of ^{162}Hf gs (0^+).

Previous experimental studies carried out on the decay of ^{162}Lu to its daughter states do not list the individual decay of the isomeric states. Our model-based assignments of J^π and energies to the isomeric triplet in ^{162}Lu can be used to study their β-decays to the daughter levels of ^{162}Yb. Extension of our study to the neighbouring odd-odd Lu isotopes to uncover the underlying cause for the formation of low-lying long-lived isomer triplets in these isotopes is underway.

References

[1] ENSDF data files (August 2024 version) from NNDC, Brookhaven, USA.

[2] A. K. Jain *et al.*, Rev. Mod. Phys. **70** (1998) 843.

[3] D. M Headly *et al.*, At. Data Nucl. Data Tables, **69** (1998) 239.

[4] K. Vijay Sai *et al*., Proceedings of the DAE-BRNS Symp. on Nucl. Phys. **60** (2015).

[5] T.Hild, *et al.*, Phys Rev. **C52** 4 (1995) 2238.