Intrinsic Structures in highly n-deficient odd-odd nucleus $^{158}$Ho

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The observed [1] level scheme for the highly neutron-deficient odd-odd nucleus $^{158}$Ho (which has 7 neutrons less than the stable isotope $^{165}$Ho) has several distinctive features. Firstly, it has 3 long-lived isomers with comparable half-lives, namely, an 11.3m $^{5+}$ ground state, a 28m $^{2-}$ isomer at 67.2 keV and a 21.3m $^{9+}$ isomer. As listed in the latest [1] Nuclear Data Sheets (NDS), Sood et al. [2] had earlier reported two-quasiparticle (2qp) configuration for these 3 isomers, placed the $^{9+}$ isomer at ~180keV, and also assigned 2qp configuration to the 29ns isomeric state at $E_x=156.9$ keV. However, the latest NDS evaluation of $^{158}$Er $\gamma$-decay [1], while incorporating the allowed-unhindered decay to a newly identified 1$^+$ level at 146.90 keV [3] superseding the earlier reported 139.2 keV 1$^+$ level, does not include any characterisation whatsoever of the other 9 levels of $^{158}$Ho populated in this decay. The present study reports the results of such an investigation, based on a critical examination of the available configuration space and the results of Quasi-Particle Rotor Model (QPRM) calculation of various 2qp bandhead energies.

Fig. 1: Experimental [4] excitation energies of N=91 ($^{157}$Dy) and Z=67 ($^{157}$Ho) n and p Nilsson orbitals in (A-1) isotope/isotope relevant to the level spectra of odd-odd $^{158}$Ho. Following convention of Jain et al. [5], the particle/hole states are placed above/below the respective Fermi level.

\[157_{\text{66}}^{} \text{Dy}_{91}\]

\begin{align*}
1/2^+[521\downarrow] & : 464 & \quad \text{n}_7 \\
5/2^+[523\downarrow] & : 341 & \quad \text{n}_4 \\
5/2^+\uparrow [642\uparrow] & : 188 & \quad \text{n}_1 \\
3/2^+\uparrow [521\uparrow] & : 0 & \quad \text{n}_0 \\
11/2^+[505\uparrow] & : 199 & \quad \text{n}_2 \\
3/2^+[651\uparrow] & : 235 & \quad \text{n}_3 \\
3/2^-[532\downarrow] & : 350 & \quad \text{n}_5 \\
1/2^-[400\uparrow] & : 388 & \quad \text{n}_6 \\
\Omega^+[\text{Nn}_3\Lambda\Sigma] & : \text{n}_i \\
p_5: & 482 & \quad 1/2^+[541\downarrow] \\
p_0: & 0 & \quad 7/2^+[523\uparrow] \\
p_1: & 53 & \quad 5/2^+[402\uparrow] \\
p_2: & 67 & \quad 7/2^+[404\downarrow] \\
p_3: & 175 & \quad 3/2^+[411\uparrow] \\
p_4: & 391 & \quad 5/2^+[532\uparrow] \\
p_5: & E_x(\text{keV}) & \quad \Omega^+[\text{Nn}_3\Lambda\Sigma]
\end{align*}

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Table 1: Two-quasiparticle (2qp) bands expected in $^{158}$Ho based on the observed[4] 1qp orbitals in respective (A-1) isotone/isotope as seen in Fig. 1. Entries in each box are $K^=\Omega_p\Omega_n$ values with the spins-parallel $K_T$ listed first and spins-antiparallel $K_S$ next for each GM doublet. $K^=\Omega_p\Omega_n$ of confirmed levels are shown in bold. Except $n_2$ (for 21m $9^+$ isomer), only orbitals relevant to $^{168}$Er EC decay are included herein. All $E_x$ are rounded off values in keV.

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<tr>
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The experimentally identified[4] single particle Nilsson orbitals $\Omega_pA\Omega_n\Lambda\Sigma$ and their observed excitation energies (input data for QPRM) in the respective (A-1) isotope and isotone, namely $^{157}$Ho and $^{157}$Dy are shown in Fig. 1. The 2qp band quantum numbers, $K^=\Omega_p\Omega_n$ for each ($\Omega_p\Omega_n$) coupling expected in the odd-odd nucleus $^{158}$Ho are listed in the Table 1. This table includes K-listings only for the 2qp bands with confirmed assignments (bold entries[1-3] or bands expected to be populated in $^{158}$Er decay.

Our analysis confirm (entries in bold in table 1) the earlier[1-3] 2qp assignments to the 3 isomers and the two isomeric states at 146.7 keV(1.85ns) and at 156.9 keV(29ns). All the other 9 levels populated in $^{158}$Ho from $^{158}$Er ($I^=0^-$) $\varepsilon$-decay are reported[1] to have $5.20 < \log ft < 6.25$, and hence have $J=0$ or 1. The observed multipolarities of respective decay restrict spin-parity still further.

The NDS adopted levels [1] list $J^=1^+, 2^+, 3^+$ for the 91.8 keV level based on M1 $\gamma$ to 2$^-$ level. If we further note that it has log $ft = 5.95$ from 0$^+$ Er, (1f: $\Delta I=0.1$, $\Delta\pi=\text{yes}$) the only choice left is $J^=1^+$. A look at our table 1 for appropriate energy uniquely yields the 2qp assignment,

91.8 keV: $1^+\{p:5/2[402] – n:3/2[521]\} --- (1)

This ($p_1n_0$) assignment is consistent with the observed M1 $\gamma$ from this level to the 67 keV 2$^-$ with ($p_2n_0$) configuration. Its GM triplet partner with $K^=4^-$ is expected to lie lower at (40±20)keV.

Preliminary analysis of the data of $\varepsilon$-fed levels in $^{158}$Ho yields the following tentative assignments:

- 241 keV [1+, $p_2n_1$]; 386 keV [1$^0$; $p_1n_0$];
- 433 & 462 keV 1$^+$ levels: ($p_3n_1$ and $p_1n_0$);
- 438 keV [1-, $p_2n_4$]; 663keV [1+, $p_3n_4$] --- (2)

Detailed investigations of these structures using QPRM are being pursued.

References