Isomers configurations in the odd-odd nucleus ^{154}Pm

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Even after over 40 years of identification of two isomers ($t_{1/2}$ = 2.68m and 1.73m) in ^{154}Pm, no definitive conclusion is available so far on their spin-parity (I^{π}) assignments, or even their relative ordering. Only tentative assignments of I = (3,4) and I = (0,1) respectively have been quoted [1] from log ft values of β^- branches to ^{154}Sm levels of known I^{π} in the latest Nuclear Data Sheets (NDS2009). Further the NDS2009 evaluator had pointed out 'conflicts concerning the I^{π} assignments between the experimental data [2] and the detailed model-dependant arguments of Sood and Sheline [3]'. We herein report briefly the conclusions of a critical 'model-independent' analysis of all, including the more recent [4-7], experimental data related to I^{π} assignments to ^{154}Pm isomers. The inputs for this analysis include mapping of the available configuration space, vide Fig.1, the universally adopted GM coupling rules, and application of NDS adopted rules for I^{π} assignments based on log ft values from β^- decay and γ multipolarities.

Table 1 Low lying 2qp bands comprising GM doublets K_T^{π} and K_S^{π} expected in ^{154}Pm from summed ($E_P + E_n$) < 400 keV. The entries below $\Omega(Nn_3\Lambda)$ are experimental E_x (keV) in respective A=153/155 isotope/isotone.

$\Omega^{\pi}[Nn_3\Lambda\Sigma]$ $p_i\downarrow$ E_x $n_{i:}\rightarrow$	n_0: $3/2^-[521\uparrow]$ 0 / 0	n_1: $5/2^+[642\uparrow]$ 192 / 17
p_0: $5/2^-[532\uparrow]$ 0 / 0	4^+ 1^+	5^- 0^-
p_1: $5/2^+[413\downarrow]$ 32 / 181	1^- 4^-	0^+ 5^+

Firstly, we examine the 1.73m ^{154}Pm β^- decay which populates 27 levels in ^{154}Sm[1]; 69% β^- intensity from this decay goes into these 3 branches:

i) 33 % β log ft =5.2 E_x=2140 keV $I^{\pi} = (1,2^+)$
ii) 21.7% =5.5 =2069 keV $I^{\pi} = (2^+)$
iii) 14.4% =6.1 =1476 keV $I^{\pi} = 1^-$ ...(1)

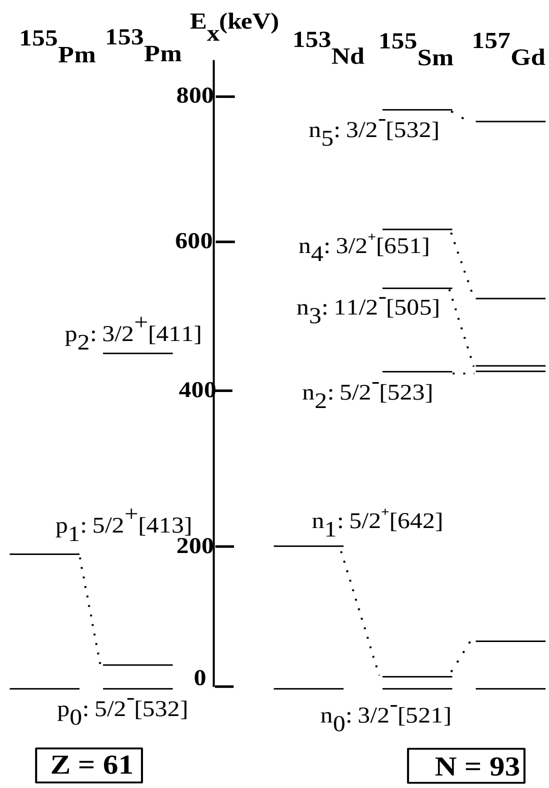

Fig.1: Experimental [8] excitation energies of single particle Nilsson orbitals in the Z=61 isotopes and N=93 isotones defining the available configuration space for ^{154}Pm.

Rest of the 31% intensity is distributed among 24 other branches, all with log ft>6.0. The NDS adopted strong rule (all β^- transitions with log ft<5.9 are allowed with ΔI = 0,1 and Δπ = no) uniquely suggests $I^{\pi} = 1^+$ for the parent in view of the data listed in eq.(1) above. Even if we relax the π-selection rule, the I = 0 assignment for the 1.73m ^{154}Pm parent is clearly ruled out, in view of transition (ii) of eq.(1) since log ft=5.5 does not admit ΔI = 2.

Next we look at the ^{154}Nd(0^+) β^- decay [1,2], which directly populates 19 levels in ^{154}Pm, said to be based on its 1.73m isomer (g.s.). Partial decay scheme relevant to I^π assignments is shown in our Fig. 2. A critical examination of these data leads us to make the following observations:

a) Only one I^π assignment, namely 1^+ for the 850 keV level, is accepted as confirmed, and thus included in the NDS2009 'Adopted Levels', since it is populated with log ft=4.8 and hence is 'allowed unhindered'(au) transition. This 'au' characterization yields its 2qp configuration to be 1^+\{p:5/2[532]⊗ n:3/2[532]\}; p_0n_5 in our notation of Fig.1.

b) The 1.73m isomer g.s. is said to have negative parity (NP). Looking at the available configuration space, as sketched in Fig.1 and Table 1, the lowest NP state has the 2qp configuration 1^-\{p:5/2[413]⊗ n:3/2[521]\}; p_1n_0 in our notation. A γ transition from 850 keV $1^+(p_0n_5)$ to $1^-(p_1n_0)$ g.s. is forbidden, since it involves change of both n & p orbitals. Experimentally [1,2], this is the second most intense γ in 850 keV decay and hence admits of only one (n or p) orbital change. This configuration rules out $1^-(p_1n_0)$, while supporting $1^+(p_0n_0)$, g.s. configuration.

c) The 50 keV γ in Fig.2 is said to have E2 multipolarity. With $I^\pi=1^-$ for g.s., this yields $I^\pi=3^-$ for 50 keV level. A γ transition from 1^+ (850 keV) level to 3^- would be highly hindered. Experimentally, this is the most intense γ, which makes the indicated assignment unacceptable.

d) The proposed decay scheme lists both the γ's from 180 keV level to the 50 keV and to g.s. to have E1 multipolarity indicating parity change, whereas all these 3 levels are shown to have same parity.

e) NDS2009 finds all I^π assignments (except 1^+ for 850 keV) not supported enough to be included in their 'Adopted Levels' set. All these I^π's are 'based on suggested $I^\pi=1^+$ for 151 keV level (from log ft = 5.2 and hence Δπ = no). However in ^{154}Pm β^- decay to ^{154}Sm, the same authors [2] conclude a log ft = 5.2 β, vide our eq.(1), to correspond to Δπ = yes.

f) The NDS adopted strong rule mandates that 'all β-transitions with log ft<5.9 are allowed with ΔI = 0,1 and Δπ = no'. However here both in ^{154}Nd and ^{154}Pm decays, this strong rule is repeatedly violated by Greenwood *et al.* [2] who specify Δπ = yes in numerous cases having log ft <5.9.

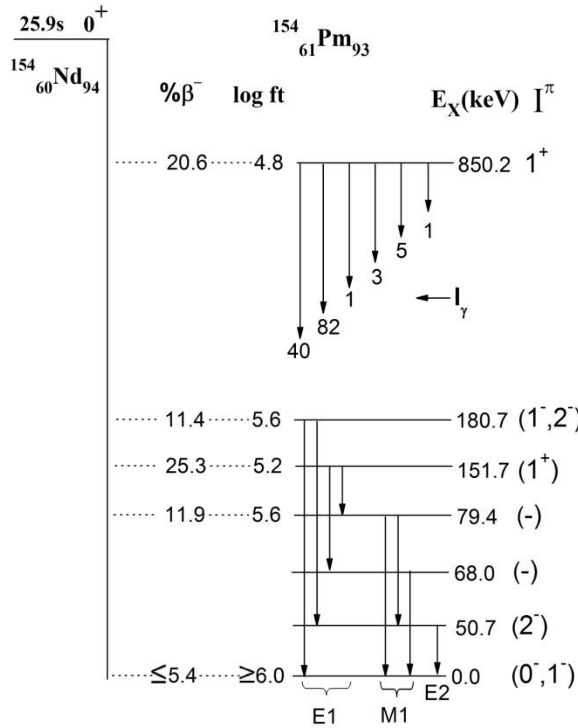

Fig.2: Partial ^{154}Nd β^- decay data [1,2] including specified ^{154}Pm levels which are relevant to the characterization of its 1.73m isomer g.s.

In consideration of the above (and many other) internally inconsistent/contradictory instances, it is evident that these data do not provide reliable input for I^π assignments. Specifically thier analyses do not establish a negative parity for the 1.73m ^{154}Pm isomer. In fact the decay of $1^+(p_0n_5)$ 850keV level to g.s., and also the decay of the latter to ^{154}Sm levels, support $1^+(p_0n_0)$ assignment for this isomer.

References:

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