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STRUCTURE OF POSITIVE PARITY STATES IN $^{141\text{-}147}$LA ISOTOPES

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Abstract

The structure of positive parity states in $^{141\text{-}147}$La isotopes has been investigated using the interacting boson fermion model (IBFM-2). The $^{140\text{-}146}$Ba nuclei have been used as the cores. The seven protons beyond Z = 50 closed shell are allowed to occupy the $1g_{7/2}$, $2d_{5/2}$, $2d_{3/2}$, $3s_{1/2}$ and $1h_{11/2}$ single particle orbitals. The study of the influence of the boson-fermion interaction parameters on the energy states has been undertaken. The reduced transition probabilities and branch ratios of these nuclei have been calculated and compared with the available experimental data

Keywords: *Energy Levels, Electromagnetic Transitions, Nuclear Structure, Nuclear Models, La-Isotopes.*

1. INTRODUCTION

The description of the nuclear structure of the nuclei (Z > 50, N > 82) has grown during the past few years [1-6]. The nuclear properties of neutron-rich odd-A nuclei above the Z= 50 have been exhaustively investigated [7-11]. The Lanthanum isotopes have seven protons outside the Z=50 closed shell and neutron number crossing the N=82 closed shell. So the study of these isotopes provides a chance to identify transition shape. Scott et al. [12] have established transition from vibrational to rotational features in the mass number A=140-150. In the previous β-decay experiments [13-20], many low-spin levels have been identified in $^{141\text{-}147}$La isotopes.

The level scheme and transition multipolarities of ^{141}La isotope were investigated as belonging to the ^{141}Ba decay [21]. Wang et al. have investigated the high spin states and the B(E1)/B(E2) branching ratios in ^{143}La isotope [22]. A strong octupole correlations were found in the ^{145,147}La isotopes [23]. Zhu et al. [24] have found evidence for the coexistence of symmetric and asymmetric shapes of these isotopes.

Many attempts have been carried out to describe the structure properties of La (N <82) isotopes within the framework of different nuclear models. For instance, Alonso et al. [25] have compared the available experimental energy levels and electromagnetic transition rates with the predictions of IBFM-2 for odd-mass $^{119-135}$La isotopes. For ^{137}La isotope, the energy spectra and electromagnetic transitions were measured from ^{136}Ba (n,γ) nuclear reaction, and the obtained data were compered with IBFM results [26]. Wang and Guo [27], have performed calculations using the refection asymmetric relativistic mean field model. Their calculations included the ground state properties of $^{145-155}$La isotopes. A theoretical interpretation of the excitation energies in odd-La (N>82) chain was formerly missing. In the present work the IBFM-2 has been used to study the structure of odd Lanthanum isotopes (A=141-147), as a first application of the model for these isotopes.

2. THE MODEL

The three versions of IBM-i(i=1-3) are built on the same idea, where the nuclear collective states were described as composed of identical pairs (bosons), only boson with L=0 (s-boson) and L=2 (d-boson) are included [28]. The IBM-1deals with one kind of boson. In the proton-neutron interacting boson model (IBM-2) there are two kinds of boson p-p (π) and n-n (ν), and it is intimately related to shell-model microscopy [29]. To describe the nuclear structure of the lighter nuclei, the IBM has been extended to IBM with isospin (IBM-3). In this version has three kinds of boson including: p-p (π), n-n (ν)and p-n (δ), which forms the isospin T=1 multiplet [30-34].

The IBM was developed to describe odd-mass nuclei, where an odd nucleon is coupled with the bosons of core. There are IBFM-1, IBFM-2 and IBFM-3 versions [35]. The model has been successful in systematizing the low-lying states and electrometric transition in odd-A nuclei [36-40] The model contributes in the investigation of the nuclear β-decay rates. Good agreement has been found with the available experimental data [41-48]

The IBFM-2 Hamiltonian employed here is of the form [41]

$$H = H_B + H_F + V_{BF} , \qquad (1)$$

where the H_B denotes the IBM-2 Hamiltonian for even-even core nucleus which can be written as [28]

$$H_B = \varepsilon_d(\hat{n}_{d\pi} + \hat{n}_{d\upsilon}) + k_{\pi\upsilon}\hat{Q}_\pi.\hat{Q}_\upsilon + \hat{M}_{\pi\nu} \sum_{\rho=\pi,\upsilon} \hat{V}_{\rho\rho} + \sum_{L=0}^{4} G_{\pi\nu}^{(L)}\left(\left[d_\nu^+ d_\pi^+\right]^{(L)}.\left[d_\nu d_\pi\right]^{(L)}\right) \quad (2)$$

H_F contains the single-particle energies

$$H_F = \sum_i \varepsilon_i a_{\pi i}^+ \tilde{a}_{\pi i} , \qquad (3)$$

where ε_i is the energy of a quasiparticle in the i-th orbital, calculated in the standard BCS approximation [49]. $a^+_{\pi i}$ and $a_{\pi i}$ are the creation and annihilation proton particle operator. The summation runs over the single particles orbitals allowed to the odd particle.

$$\varepsilon_i = \sqrt{(E_i - \lambda)^2 + \Delta^2} \qquad (4)$$

where λ is the Fermi energy and Δ is the paring gap. The occupation probabilities are then given by

$$\upsilon_i = \left[\frac{1}{2}(1 - \frac{E_i - \lambda}{\varepsilon_i})\right]^{1/2} , \; u_i = (1 - \upsilon_i^2)^{1/2} \quad (5)$$

V_{BF} represents the two-body interaction between bosons and fermions and reads

$$V_{BF} = \sum_{i,j} \Gamma_{ij} \left(\left[a_i^+ \tilde{a}_j \right]^{(2)} \cdot Q_{\rho'}^B \right) + A \sum_i n_i n_{d\rho'} +$$
$$\sum_{i,j} \Lambda_{ki}^{j} \left\{ : \left[\left[d_\rho^+ \tilde{a}_j \right]^{(k)} a_i^+ s_\rho \right]^{(2)} : \cdot \left[s_{\rho'}^+ \tilde{d}_{\rho'} \right]^{(2)} + H.c. \right\}. \quad (6)$$

The V_{BF} included a monopole-monopole, quadrupole-quadrupole and the exchange terms, respectively. The last one takes into account the effect of the Pauli principle. To reduce the number of parameter, a simplified form has been introduced on the basis of microscopic considerations in the framework of generalized seniority treatment of quasiparticles in the valence shell [35], where

$$\Gamma_{i,j} = (u_i u_j - \upsilon_i \upsilon_j) Q_{i,j} \Gamma,$$
$$\Lambda_{k,i}^{j} = -\beta_{k,i} \beta_{j,k} \left(\frac{10}{N_\rho (2 j_k + 1)} \right)^{1/2} \Lambda, \quad (7)$$
$$\beta_{i,j} = (u_i \upsilon_j + \upsilon_i u_j) Q_{i,j},$$
$$Q_{i,j} = \left\langle l_i, \frac{1}{2}, j_i \left\| Y^{(2)} \right\| l_j, \frac{1}{2}, j_j \right\rangle.$$

In the IBFM-2, the E2 transition operator is [41]

$$T^{E2} = e^B T_B^{E2} + e^F T_F^{E2} \quad (8)$$

where the first term operates on the boson part and the second term on the fermion part of the wave function can be written as

$$T^{E2} = e_\pi^B Q_\pi^B + e_\upsilon^B Q_\upsilon^B + \sum_{i,j} e_{i,j}^F \left[a_i^+ \tilde{a}_j \right]^{(2)}, \quad (9)$$

where e^B and e^F are the boson and fermion effective charges. Q_ρ is the boson quadruple operator, for $\rho = \nu$ or π

$$\hat{Q} = (d_\rho^+ s_\rho + s_\rho^+ \tilde{d})^{(2)} + \chi_\rho [d_\rho^+ \tilde{d}_\rho]^{(2)} \quad (10)$$

For the single-particle operator

$$e_{i,j}^F = -\frac{1}{\sqrt{5}} (u_i u_j - \upsilon_i \upsilon_j)$$
$$\left\langle l_i, \frac{1}{2}, j_i \left\| r^2 Y^{(2)} \right\| l_j, \frac{1}{2}, j_j \right\rangle. \quad (11)$$

The M1 transition operator in IBFM-2 is [41]

$$T^{M1} = \sqrt{\frac{3}{4\pi}} \left(g_\pi^B L_\pi^B + g_\upsilon^B L_\upsilon^B + \sum_{i,j} g_{i,j}^F \left[a_i^+ \tilde{a}_j \right]^{(1)} \right),$$

where g_ρ and L_ρ are defined as in IBM-2, and $g_{i,j}^F$ is the single-particle contribution, which depends on g_l and g_s for the odd nucleon. $\tilde{L}$ is the angular momentum operator given as $\tilde{L}_\rho = \sqrt{10}[d^\dagger . d]^{(1)}$, and

$$g_{ij}^F = -\frac{1}{\sqrt{3}} (u_i u_j + \upsilon_i \upsilon_j) \left\langle l_i, \frac{1}{2}, j_i \left\| g_l l + g_s s \right\| l_j, \frac{1}{2}, j_j \right\rangle.$$

3 RESULTS AND DISCUSSION

3.1 Energy Levels

In the calculations, the values of the H_B parameters have been taken from Ref. [50] . In order to calculate the quasiparticle energies and occupation probabilities, the single-particle energies are extracted from Ref. [51]. The calculations are preformed by using BCS equation with all the above five single-particle orbitals, where Δ=12A-1/2 [41-43]. The quasiparticle energies (in MeV unit) and occupation probabilities of the $^{141-147}$La are summarized in Table 1. The behavior of the calculated energy states as a function of boson-fermion interaction parameters has been investigated. It is found that A=0.0 MeV is suitable for all isotopes and different values of Λ and Γ. The following values were deduced: (Λ and Γ) = (0.54, 0.05), (0.44, 0.05), (0.34, 0.15) and (0.34, 0.44) MeV for the $^{141-147}$La isotopes, respectively. The total angular momentum of the first excited states and the ground states are well reproduced, except for the first excited state for ^{143}La where $J^{\pi}= 3^{+}/2$ (0.029 MeV) while the calculated one is $5^{+}/2$ (0.031 MeV). Figs. 1 and 2 show the comparison between the theoretical and available experimental energy states. For $J^{+} \leq 9/2$, only six lowest calculated levels are shown in the figures for each angular momentum.

Table 1: The quasiparticle energies (in MeV unit) and occupation probabilities for $^{141\text{-}147}$La isotopes.

A		$g_{7/2}$	$d_{5/2}$	$d_{3/2}$	$s_{1/2}$	$h_{11/2}$
141	ε_i	1.019	1.143	3.011	3.229	2.192
	υ_i^2	0.564	0.274	0.029	0.025	0.056
143	ε_i	1.013	1.138	2.991	3.214	2.187
	υ_i^2	0.566	0.271	0.029	0.025	0.056
145	ε_i	1.006	1.133	2.971	3.199	2.181
	υ_i^2	0.569	0.269	0.029	0.025	0.055
147	ε_i	1.000	1.123	2.952	3.185	2.177
	υ_i^2	0.571	0.267	0.029	0.025	0.055

For ^{141}La isotope, besides the ground-state only six excited states have been assigned experimentally with uncertainly spin and parity. Many states without spin assignments below 3 MeV have been observed as shown in Fig. 1. The model reproduces all spin assignments states within a good sequence. All energy levels up to 2 MeV are mainly of proton $g_{7/2}$ and $d_{5/2}$ single-quasiparticle nature. The ground state is assigned a $\pi g_{7/2}$ configuration coupled to the ^{140}Ba isotope. The first and second excited states have $J = 5^{+}/2$ at 0.190 and 0.304 MeV, and they are close to first and second calculated states with $J = 5^{+}/2$ at 0.121 and 0.302 MeV, respectively. The position of the $J = 3^{+}/2_1$ state depends strongly on the differences in energy for the $g_{7/2}$ and $d_{5/2}$ single particles orbitals. The calculated state appeared at 0.424 MeV is close to the experimental one at 0.467 MeV, where the calculated wave functions is 33% $g_{7/2}$ + 66 % $d_{5/2}$ + 1 % $d_{3/2}$. On the other hand, the calculated $3^{+}/2_2$ state at 0.697 MeV is close to the experimental one $3^{+}/2$ at 0.647 MeV have $\pi g_{7/2}$ as dominating configuration. It is worth noting that theoretically a first $9^{+}/2_1$ and second $7^{+}/2_2$ states are predicted at 0.603 and 0.704 MeV excitation, respectively. Both of them belong to the $g_{7/2}$ family and have not been established experimentally. The first present of $J^{+}= 11^{+}/2$ up to $21^{+}/2$ are rather pure and belong to $\pi g_{7/2}$ configuration.

The positive-parity states of ^{143}La isotope are shown in Fig. 1. Up to 1.3 MeV, all the states having $g_{7/2}$ and $d_{5/2}$ configurations, where the $d_{3/2}$ and $s_{1/2}$ components never surpassing 5% together. The observed low-lying states are J= $(7/2)^+$ ground state, $(3/2)^+$ at 0.029 MeV, $3/2^+$, $5/2^+$ at 0.208 MeV, $(5/2)^+$ at 0.211 MeV, $(5/2)^+$ at 0.291 MeV, two states at 0.424 and 0.461 MeV without spin and parity assignment and $(5/2)^+$ at 0.465 MeV. The existence of such levels up to 0.5 MeV imposes strict

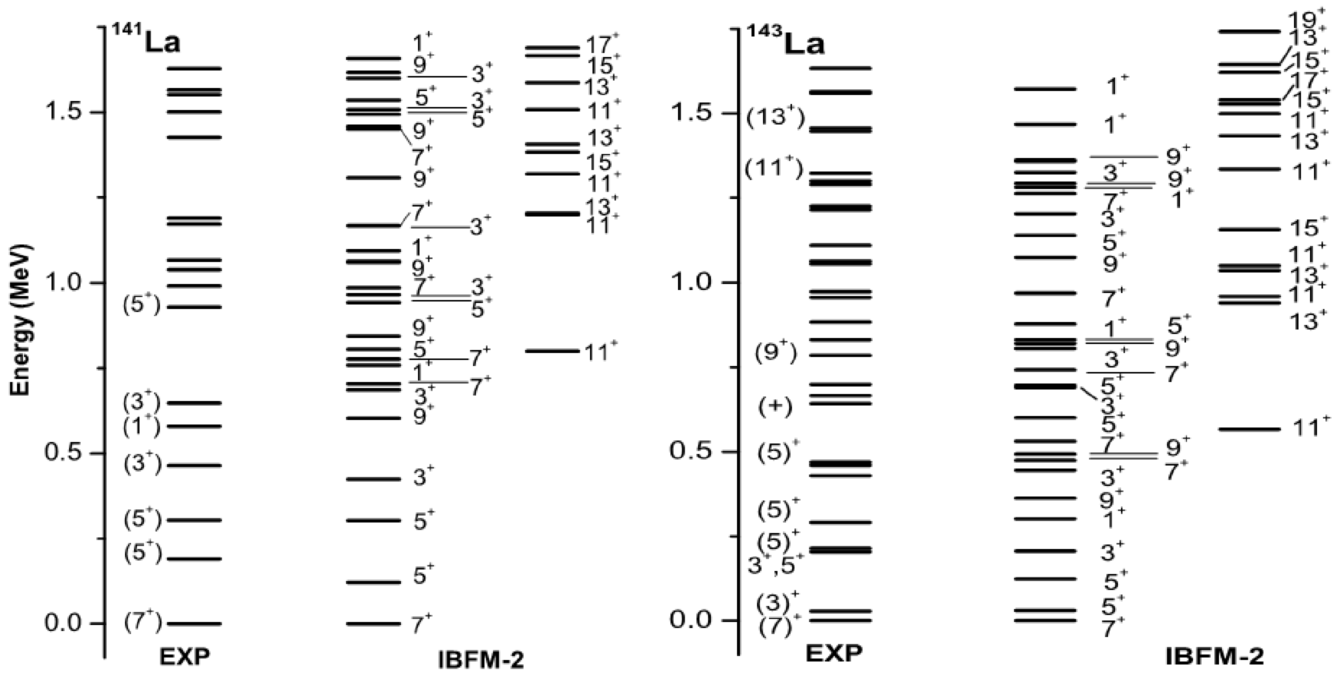

Figure 1: Experimental [52] and theoretical level scheme of ^{141,143}La isotopes. The numbers represent twice the angular momentum

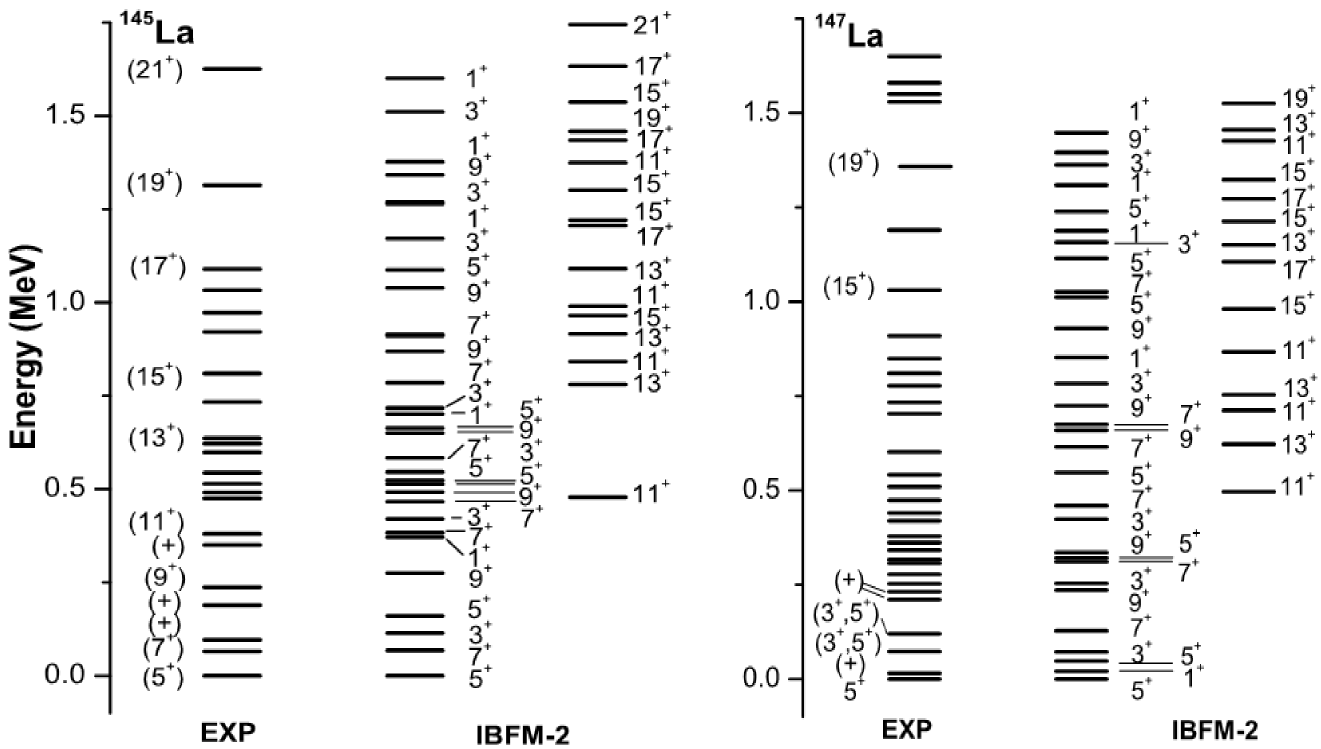

Figure 2: Same as Fig. 1, but for the ^{145,147}La isotopes.

conditions on the theoretical description of this isotope. The transitions are characterized by the following experimental features [52]:

$$I_\gamma\left[(\frac{3}{2}^+,\frac{5}{2}^+)_{0.208}\rightarrow(\frac{7}{2})^+_{g.s}/(\frac{3}{2})^+_{0.029}\right]=0.36$$

$$I_\gamma\left[(\frac{5}{2})^+_{0.211}\rightarrow(\frac{7}{2})^+_{g.s}/(\frac{3}{2})^+_{0.029}\right]=32$$

$$I_\gamma\left[(\frac{5}{2})^+_{0.291}\rightarrow(\frac{7}{2})^+_{g.s}/(\frac{3}{2})^+_{0.029}\right]=5$$

$$I_\gamma\left[(\frac{5}{2})^+_{0.465}\rightarrow(\frac{7}{2})^+_{g.s}/(\frac{3}{2})^+_{0.029}\right]=0.78.$$

The $(5/2)^+_{0.211} \rightarrow (3/2)^+_{0.029}$ is M1transition with B(M1)= 0.0002 μ_N^2 while $(5/2)^+_{0.211} \rightarrow (7/2)^+_{g.s}$ is M1 + E2 transition with mixing ratio equal to +0.07(3). Such experimental features exclude the possibility to interpret the $(5/2)^+_{0.211} \rightarrow (3/2)^+_1$ and $(1/2)^+_1$ states as J= j-2 and j-3 are associated with a $g_{7/2}$ configuration. Indeed, these states have $d_{5/2}$ as dominating configuration accompanying with $(5/2)^+_2$ state. The calculated $(5/2)^+_3$ state is close to the experimental one at 0.465 MeV.

By including all the levels observed, the comparison with the calculated positive-parity states in ^{145}La isotopes exhibits a good sequence in the low energy region as shown in Fig. 2. The IBFM-2 results agree with the experimently data about the $5^+/2$ and $7^+/2$ spin and parity assignment to the ground and first excited states. The wave functions are dominated by the $g_{7/2}$ orbital with a 91% and 96% component, respectively. The second and third observed excited states are located at 0.096 and 0.189 MeV with parity (+) and without spin assignment. On the other, hand these states have emerged from IBM-2 with energy 0.115 and 0.161 MeV with $J^{\pi} = 3^{+}/2$ and $J = 5^{+}/2$ respectively. Their wave functions are dominated by the $\pi d_{5/2}$ component with an amplitude of 71% and 87%, respectively. The calculated $J = 9^{+}/2_{1}$ state at 0.275 MeV is close to experimental one at 0.237 MeV, its wave function has $\pi g_{7/2}$ (94%) and $\pi d_{5/2}$(6%) components. The $1^{+}/2_{1}$ and $7^{+}/2_{2}$ have been produced at 0.379 MeV and 0.384 MeV, respectively. These states do not appear experimentally. There is an observed state at 0.351 MeV with parity(+) and without spin assignment, it decay by the strongest M1 transition Eγ= 0.162 MeV) to 0.189 MeV state. According to above model predictions, the $J^{+}= 7^{+}/2$ is more probable for the 0.351 MeV state. The IBFM-2 calculations are successful in reproducing the energy of the $J^{+}= 11^{+}/2$ to $21^{+}/2$ states as shown in the figure.

For ^{147}La isotope, the systematic positive values boson-fermion interaction parameters have been kept, i.e the J^{+} for ground state has not been taken into account in the fitting. However, the calculated $J^{+}_{g.s} = 5^{+}/2$ agrees with the experimental value [24]. In order to reduce $J^{+}_{g.s} = 3^{+}/2$ [52], one must use negative value of the quadrupole-quadrupole interaction parameter (Γ= -0.78 MeV). The calculated and experimental energy levels are plotted in Fig. 2. The first excited state proposed to be situated at an excitation energy of 0.015 MeV with (+) parity. In the theoretical spectrum, the first excited state is $J\pi = 1^{+}/2$ at 0.021 MeV. In its wave function, large contributions (3%, 86% and 9%) arise from the $g_{7/2}$, $d_{5/2}$ and $s_{1/2}$ single particle orbitals, respectively.

The characteristics of the observed states at 0.074 and 0.120 MeV with possible ($3^{+}/2$, $5^{+}/2$) angular momentum are close to the calculated $5^{+}/2_{2}$ and $3^{+}/2_{1}$ states. The experimental states with π= + at 0.211 and 0.278 MeV could correspond to the calculated $3^{+}/2_{2}$ at 0.254 MeV and $5^{+}/2_{3}$ at 0.321 MeV. The wave functions have a structure of 5% $g_{7/2}$ + 86% $d_{5/2}$+2% $d_{3/2}$ + 8\% $s_{1/2}$ and 3% $g_{7/2}$ + 93% $d_{5/2}$+1% $d_{3/2}$ + 3\% $s_{1/2}$, respectively. The calculated state $7^{+}/2_{1}$ at 0.121 MeV contains the $d_{5/2}$ component but not could be found experimentally. Systematically, the $7^{+}/2_{1}$ state has been measured at 0.059 MeV in the ^{145}La isotope. The position of the J^{π} = ($15^{+}/2$) and ($19^{+}/2$) at 1.031 and 1.352 MeV states are reproduced correctly by the calculations as illustrated in the figure.

3.2 Electromagnetic Transitions

In the calculation of electromagnetic transition probabilities, the boson effective charges were taken to be equal as in IBM-2 calculation for core nuclei [50]. The proton effective charge was taken $e^{F} = 1.5\,e$. The spin *g*-factor g^{F}_{s} value has been quenched by a factor of 0.7 [25,41-43, 53,54] while the g^{F}_{l} =1 μ_N, Then, no free parameters are left to calculate electromagnetic *E2* and *M1* transitions. The predicted values for B(E2) and B(M1) in odd-mass $^{141-147}$La isotopes are presented in Table 2. The table contains the electric quadrupole and magnetic dipole moments of ground state and some low-lying states. These quantities have not been measured yet. By studying the behavior of the experimental electric quadrupole transition probabilities [52] in the even-even Ba cores, an increase B(E2) values can be seen. For instance, the $B(E2;2^{+}_{1} \rightarrow 0^{+}_{1})$ equal to 0.073(34), 0.145(5), 0.221(6) and 0.280(60) e^2b^2 in $^{140-146}$Ba isotopes, respectively. For present nuclei only a few transition probabilities have been observed, where B(E2)=0.0006(5) e^2b^2 and

B(M1)=0.0.0036(5) μ_N^2 for $5^+/2_2 \rightarrow 7^+/2_1$ transition in ^{143}La isotope. Other values for ^{147}La isotope, where B(E2)=0.3316 e^2b^2 and B(M1)= 0.0061 μ_N^2 for $3^+/2_2 \rightarrow 1^+/2_1$ transition, and B(E2; $3^+/2_1 \rightarrow 5^+/2_1$) = 1.2208 e^2b^2. The changing of neutron number will lead to a change of collectivity in odd-nucleus relative to a change of even-even core nucleus. This effect is evident as shown in the calculated B(E2) in the $^{141-147}$La isotopes. Also the main difference between ^{141}La and ^{147}La isotopes can be explained as the first have a U(5) boson core, while the second have a SU(3) boson core [50].

In the E2 transition the contribution of boson part is larger than that from single particle part [55]. Hence, for E2 transition tend to final state with single particle angular momentum is not changed. According to this fact, one can see that the B(E2; $5^+/2_2 \rightarrow 3^+/2_1$) = 0.2148 e^2b^2 while B(E2; $5^+/2_2 \rightarrow 7^+/2_1$) = 0.0008 e^2b^2 in the ^{145}La isotope. The $5^+/2_2$, $3^+/2_1$ and $7^+/2_1$ are dominated by $\pi d_{5/2}$ and $\pi g_{7/2}$ single particle state, respectively. For B(M1) transition, since the model M1 operator does not change the number of d-bosons. From Table, it can be seen that the calculation gives zero M1 matrix elements, where the model adopted the state is purely symmetric in the boson space. This fact was found clearly in the ^{141}La isotope, where has a U(5) core. The branching ratios for M1 and E2 linking some low-lying states to lower states have been calculated. The behavior of the ratios almost agree with experimental ratios as shown in Table 3.

3 CONCLUSION

The present work has attempted IBFM-2 calculation for the energy of the positive-parity states in the heavy odd-mass La isotopes 141 to 147. The calculations describe reasonably well the available energy states. For $^{141-145}$La isotopes, the low-lying states are dominated by $g_{7/2}$ and $d_{5/2}$ single particle orbitals, while a strong mixing between the them and $d_{3/2}$ orbital is found to dominate the structure of many states above 1.2 MeV in the ^{147}La isotope. Also, there is an influential contribution of $s_{1/2}$ orbital in the structure of some states at low excitation energies. Future calculations will be possible if additional electromagnetic transition probabilities become available.

REFRENCES:

[1] N. Blasi, L. Atanasova, D. Balabanski, S. Das Gupta, K. Gladinski, L. Guerro, S. Nardelli, and A. Saltarelli, Phys. Rev. C (2014)044317. .

[2] J. B. Gupta, Eur. Phys. J. A 50 (2014) 176.

[3] S. R. Lesher et al., Phys. Rev. C 91 (2015)054317.

[4] Y. Zhang et al., Chin. Phys. C 39 10 (2015)104103.

[5] J. M. Yao and J. Engel, Phys. Rev. C 94 (2016) 014306.

[6] G. L. Zimba et al., Phys. Rev. C 94 (2016)054303.

[7] H. L. Ma, B. Gillis Carlsson, I. Ragnarsson, and H. Ryde, Phys. Rev. C 90 (2014) 014316

[8] M. J. Taylor et al., Phys. Rev. C 91 (2015) 044322 .

[9] J. M. Rees et al., Phys. Rev. C 91 (2015) 054301.

[10] J. Zhong et al., Phys. Rev. C 92 (2015) 024308.

[11] E. H. Wang et al., Phys. Rev. C 92 (2015)034317.

[12] S. M. Scott et al., J. Phys. G: Nucl. Phys. 6 (1980) 1291.

[13] R. C. Greenwood et al., Nucl. Instr. and Meth. A 390 (1997) 95.

[14] S. H. Faller et al., Phys. Rev. C 38 (1988) 307.

[15] C. Greenwood, M. H. Putnam, K. D. Watts, Nucl. Instr. and Meth. A 378 (1996) 212.

[16] B. Pfeiffer et al., Z. Phys. A, 287 (1978) 191.
[17] S. H. Faller et al., Phys. Rev. C 38 (1988) 307.
[18] S. H. Faller et al., Phys. Rev. C 34 (1986) 654.
[19] J. C. Pacer et al. Jr., Phys. Rev. C 17 (1978) 710.
[20] F. Schussler et al., Z . Phys. A 290 (1979) 359.
[21] A. N. Proto, D. Otero, and E. Achterberg, J. Phys. G: Nucl. Phys. 5 (1979) 121.
[22] J. G. Wang et al., Phys. Rev. C 75 (2007) 064301.
[23] W. Urban et al., Phys. Rev. C 54 (1996) 945.
[24] S. Zhu et al., Phys. Rev. C, 59 (1999) 1316.
[25] C. E. Alonso, J. M. Arias and M. Lozano, J. Phys. G: Nucl. Phys. 13 (1987) 1269.
[26] V. A. Bondarenko et al., Nucl. Phys. A A582 (1996) 1.
[27] N. Wang and L. Guo, Sci China Ser G 52 (10) (2009) 1574.
[28] F. Iachello and A. Arima, *The Interacting Boson Mode*l, Cambridge University Press, NewYork (1987).
[29] T. Otsuka, *Algebraic Appraches to Nuclear Structure*, edited by R. F.Casten, Brookhaven National Laboratory, Upton, NY, Chap 4 (1993).
[30] J. P. Elliott, J. A. Evans, and S . V. Lac, Nucl. Phys. A, 597 (1996) 341.
[31] Long L G , Chin. J. Nucl. Phys. 16 (1994) 331.
[32] E. J. Garcia-Ramos and P. Van Isacker, Ann. Phys. 274 (1999) 45.
[33] J. A. Evans et al., Nucl. Phys. A 593 (1995) 85.
[34] F. H. Al-Khudair, Y. S. Li, and G. L.Long, Phys. Rev. C 75 (2007) 054316.
[35] O. Scholten and A. E. L. Dieperink *In Interacting Boson-Fermi Systems in Nuclei* , edited by F. Iachello, Plenum, New York (1991).
[36] D. Bazzacco et al., Phys. Rev. C 58 (1998) 2002.
[37] K. Nomura, T. Niksic, and D. Vretenar, Phys. Rev. C 94 (2016) 064310.
[38] F. H. Al-Khudair, Phys. Rev. C 91 (2015) 054304
[39] J.P. Elliott, J.A. Evans and P. Van Isacker, Nucl. Phys. A 481 (1988) 245.
[40] V.K.B. Kota and U. Datta Pramanik, Eur. Phys. J. A 3 (1998)243.
[41] N. Yoshida, L. Zuffi, and S. Brant, Phys. Rev. C 66 (2002) 014306.
[42] L. Zuffi, S. Brant, and N. Yoshida, Phys. Rev. C 68 (2003) 034308.
[43] S. Brant, N. Yoshida, and L. Zuffi, Phys. Rev. C 70 (2004) 054301.
[44] F. H. Al-Khudair, G. L. Long, and Y. Sun, Phys. Rev. C 77 (2008) 034303.
[45] J. Barea J and F. Iachello, Phys. Rev. C 79 (2009) 044301.
[46] F. H. Al-Khudair, Phys. Rev. C 80 (2009) 014306.
[47] N. Yoshida and F. Iachello, Prog. Theor. Exp. Phys. 2013 (2013) 043D01.
[48] E. Mardones et al., Phys. Rev. C 93 (2016)034332.
[49] J. Bardeen, N. L. Cooper, and J. R. Schrieffer, Phys. Rev. 108 (1957) 1175.
[50] A. R. H. Subber and F. H. Al-Khudair, Phys. Scr. 84 (2011) 035201.
[51] B. S. Reehal and R. Sorensen, Phys. Rev. C 2 (1970) 819.
[52] ENSDF, Nuclear data Sheet (2016) http:// www.nndc.bnl.gov/ensdf.
[53] J. M. Arias, C. E. Alonso, and R. Bijker, Nucl. Phys. A 445 (1985) 333.
[54] A. Gizon et al., Nucl. Phys. A 605 (1996) 301.
[55] A. Yoshida, A. Arima, and T. Otsuka, Phys. Lett. B 114 (1980) 86.

Table 2: Theoretical B(E2) (in $e^2 b^2$ unit) and B(M1) (in μ_N^2 unit) for $^{141-147}$La isotopes. The last lines are include the electric quadrupole and magnetic dipole moments.

A	$J^+_i \rightarrow J^+_f$	B(E2)	B(M1)	A	$J^+i \rightarrow J^+_f$	B(E2)	B(M1)
141	$3^+/2_1 \rightarrow 5^+/2_1$	0.0540	0.0001	145	$7^+/2_1 \rightarrow 5^+/2_1$	0.2840	0.0027
	$3^+/2_1 \rightarrow 7^+/2_1$	0.0235			$3^+/2_1 \rightarrow 7^+/2_1$	0.0507	
	$5^+/2_2 \rightarrow 5^+/2_1$	0.0074	0.0001		$3^+/2_1 \rightarrow 5^+/2_1$	0.0562	0.0135
	$5^+/2_2 \rightarrow 7^+/2_1$	0.0733	0.0000		$5^+/2_2 \rightarrow 5^+/2_1$	0.0522	0.0015
	$3^+/2_2 \rightarrow 5^+/2_1$	0.0215	0.0002		$5^+/2_2 \rightarrow 3^+/2_1$	0.2148	0.0348
	$9^+/2_2 \rightarrow 7^+/2_1$	0.0685	0.0000		$9^+/2_1 \rightarrow 7^+/2_1$	0.2536	0.0077
	$7^+/2_2 \rightarrow 7^+/2_1$	0.0135	0.0000		$7^+/2_2 \rightarrow 5^+/2_1$	0.0052	0.0002
	$7^+/2_2 \rightarrow 5^+/2_1$	0.0488	0.0000		$7^+/2_2 \rightarrow 5^+/2_2$	0.1589	0.0012
	$7^+/2_3 \rightarrow 7^+/2_1$	0.0091	0.0000		$3^+/2_2 \rightarrow 1^+/2_1$	0.0070	0.1524
	$5^+/2_3 \rightarrow 5^+/2_1$	0.0544	0.0000		$3^+/2_2 \rightarrow 5^+/2_2$	0.0219	0.0103
	$5^+/2_3 \rightarrow 7^+/2_1$	0.0045	0.0000		$3^+/2_2 \rightarrow 7^+/2_1$	0.0507	
	$3^+/2_1$	0.0393	1.6581		$3^+/2_1$	0.4654	0.2452
	$5^+/2_1$	-0.1250	3.9489		$5^+/2_1$	0.7840	0.6627
	$7^+/2_1$	0.0427	2.3786		$7^+/2_1$	-0.0378	1.1886
	$9^+/2_1$	0.0089	3.1788		$9^+/2_1$	-0.4315	1.7999
143	$3^+/2_1 \rightarrow 7^+/2_1$	0.0117		147	$3^+/2_1 \rightarrow 5^+/2_1$	0.0911	0.1145
	$3^+/2_1 \rightarrow 5^+/2_1$	0.0280	0.0187		$3^+/2_1 \rightarrow 5^+/2_2$	0.0001	0.0010
	$5^+/2_1 \rightarrow 7^+/2_1$	0.1833	0.0004		$3^+/2_2 \rightarrow 1^+/2_1$	0.2590	0.0165
	$5^+/2_2 \rightarrow 7^+/2_1$	0.0007	0.0001		$3^+/2_2 \rightarrow 3^+/2_1$	0.2768	0.0719
	$9^+/2_1 \rightarrow 7^+/2_1$	0.1470	0.0012		$7^+/2_1 \rightarrow 3^+/2_1$	0.0163	
	$9^+/2_1 \rightarrow 5^+/2_2$	0.0051			$7^+/2_1 \rightarrow 5^+/2_1$	0.3841	0.0016
	$7^+/2_2 \rightarrow 3^+/2_1$	0.0352			$5^+/2_2 \rightarrow 7^+/2_1$	0.1530	0.0015
	$7^+/2_2 \rightarrow 5^+/2_1$	0.0055	0.0011		$5^+/2_2 \rightarrow 5^+/2_1$	0.3652	0.2309
	$3^+/2_2 \rightarrow 3^+/2_1$	0.0149	0.0339		$5^+/2_2 \rightarrow 3^+/2_1$	0.1191	0.1231
	$3^+/2_2 \rightarrow 5^+/2_2$	0.0299	0.0000		$5^+/2_3 \rightarrow 5^+/2_1$	0.0048	0.0009
	$3^+/2_2 \rightarrow 7^+/2_1$	0.0543			$5^+/2_3 \rightarrow 3^+/2_1$	0.2497	0.0602
	$3^+/2_1$	0.2116	-0.2500		$3^+/2_1$	0.3737	1.9740
	$5^+/2_1$	-0.3688	0.5968		$5^+/2_1$	0.5654	2.2437
	$7^+/2_1$	-0.1742	1.1048		$7^+/2_1$	0.2957	2.2913
	$9^+/2_1$	-0.2987	1.8069		$9^+/2_1$	-1.2369	4.3227

Table 3: Theoretical and experimental branching ratios in $^{141-147}La$ isotopes. E_i represents the experimental energy of initial state in MeV unit, the order of states corresponding to IBFM-2.

A	E_i	$J^+_i \rightarrow J^+_f$	I_γ		A	E_i	$J^+i \rightarrow J^+_f$	I_γ	
			IBFM-2	EXP				IBFM-2	EXP
141	0.190	$5^+/2_1 \rightarrow 7^+/2_1$	100	100	145	0.065	$7^+/2_1 \rightarrow 5^+/2_1$	100	
	0.467	$3^+/2_1 \rightarrow 5^+/2_1$	17.6	100(3)		0.096	$3^+/2_1 \rightarrow 7^+/2_1$	0.0	
		$5^+/2_2 \rightarrow 7^+/2_1$	100	24.4(8)			$3^+/2_1 \rightarrow 5^+/2_1$	100	100
	0.580	$1^+/2_1 \rightarrow 3^+/2_1$	100	76(7)		0.189	$5^+/2_2 \rightarrow 3^+/2_1$	100	100
		$1^+/2_1 \rightarrow 5^+/2_2$	0.10				$5^+/2_2 \rightarrow 7^+/2_1$	0.3	16.3
		$1^+/2_1 \rightarrow 5^+/2_1$	46.0	100(3)			$5^+/2_2 \rightarrow 5^+/2_1$	64.2	25.6
	0.647	$3^+/2_2 \rightarrow 1^+/2_1$	1.8	< 0.02		0.237	$9^+/2_1 \rightarrow 5^+/2_2$	0.0	
		$3^+/2_2 \rightarrow 3^+/2_1$	29.2	3.6(11)			$9^+/2_1 \rightarrow 7^+/2_1$	100	100
		$3^+/2_2 \rightarrow 5^+/2_2$	13.5	100(3)			$9^+/2_1 \rightarrow 5^+/2_1$	78.6	89
		$3^+/2_2 \rightarrow 5^+/2_1$	10.9	35(1)		0.351	$7^+/2_2 \rightarrow 9^+/2_1$	0.2	
		$3^+/2_2 \rightarrow 7^+/2_1$	100	44(1)			$7^+/2_2 \rightarrow 5^+/2_2$	21.2	100
	0.929	$5^+/2_3 \rightarrow 3^+/2_2$	8.5	2.1(3)			$7^+/2_2 \rightarrow 3^+/2_1$	100	27.3
		$5^+/2_3 \rightarrow 3^+/2_1$	100	100(3)			$7^+/2_2 \rightarrow 5^+/2_1$	36.5	45.5
		$5^+/2_3 \rightarrow 5^+/2_1$	62.2	74(2)		0.514	$3^+/2_2 \rightarrow 5^+/2_2$	45.0	48
		$5^+/2_3 \rightarrow 5^+/2_2$	30.0	99(3)			$3^+/2_2 \rightarrow 3^+/2_1$	100	100
		$5^+/2_3 \rightarrow 7^+/2_1$	7.9	15.4(9)			$3^+/2_2 \rightarrow 5^+/2_1$	8.8	
143	0.208	$3^+/2_1 \rightarrow 5^+/2_1$	100	100(1)	147	0.015	$1^+/2_1 \rightarrow 5^+/2_1$	100	
		$3^+/2_1 \rightarrow 7^+/2_1$	9.9	36(1)		0.074	$5^+/2_2 \rightarrow 1^+/2_1$	0.1	
	0.211	$5^+/2_2 \rightarrow 5^+/2_1$	100	3.1			$5^+/2_2 \rightarrow 5^+/2_1$	100	100
		$5^+/2_2 \rightarrow 7^+/2_1$	7.1	100		0.120	$3^+/2_1 \rightarrow 5^+/2_2$	4.7	2.27
		$5^+/2_2 \rightarrow 3^+/2_1$	0.0				$3^+/2_1 \rightarrow 1^+/2_1$	100	100
	0.424	$9^+/2_1 \rightarrow 5^+/2_2$	0.5				$3^+/2_1 \rightarrow 5^+/2_1$	69.6	7.73
		$9^+/2_1 \rightarrow 7^+/2_1$	100	100(5)		0.211	$3^+/2_2 \rightarrow 3^+/2_1$	31.4	4.6
	0.461	$7^+/2_2 \rightarrow 7^+/2_1$	100	100(5)			$3^+/2_2 \rightarrow 1^+/2_1$	100	100
		$7^+/2_2 \rightarrow 5^+/2_2$	8.4	21.8(16)			$3^+/2_2 \rightarrow 5^+/2_1$	5.2	16.1
		$7^+/2_2 \rightarrow 5^+/2_1$	19.5	30.7(16)		0.278	$5^+/2_3 \rightarrow 3^+/2_2$	70.6	
	0.465	$5^+/2_3 \rightarrow 5^+/2_2$	2.8	5.7(2)			$5^+/2_3 \rightarrow 3^+/2_1$	100	100
		$5^+/2_3 \rightarrow 3^+/2_1$	100	100(1)			$5^+/2_3 \rightarrow 3^+/2_1$	28.0	95.2
		$5^+/2_3 \rightarrow 7^+/2_1$	4.8	58(1)			$5^+/2_3 \rightarrow 5^+/2_1$	9.5	39.7

تركيب المستويات الموجبة لنظائراللانثانوم الفردية La (A=141-147)

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المخلص

تم حساب طاقة المستويات ذات التماثل الموجب وقيم احتمالية الانحلالات الكهرومغناطيسية لنظائر اللانثانوم الفردية $^{141-147}$La باستخدام انموذج بوزون–فيرميون بنسخته الثانية. استخدمت انوية الباريوم الزوجية $^{140-146}$Ba كقلب مغلق. بروتونات التكافؤ السبعة خارج القشرة المغلقة Z=50 سمح لها بالتواجد في مدارات الجسيم المنفرد التالية $1g_{7/2}$ و $2d_{5/2}$ و $2d_{3/2}$ و $3s_{1/2}$ و $1h_{11/2}$. تم دراسة تأثير تفاعلات بوزون–فيرميون على مستويات الطاقة . تم تدقيق الدوال الموجبة لجميع المستويات. تم تحليل قيم احتمالية الانحلالات الكهرومغناطيسية التي تعطي وصفا لطبيعة مستويات الطاقة. وجد تطابقا جيدا بين النتائج المستحصلة والقيم العملية المتوفرة

الكلمات المفتاحية:

Energy Levels, Electromagnetic Transitions, Nuclear Structure, Nuclear Models, La–Isotopes