Structure of $^{71-78}$Ga isotopes in $f_{5/2}p_{9/2}$ and $fp_{9/2}$ spaces

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Abstract.
We have performed comprehensive set of shell model calculations for Ga isotopes including high-spin states with three different effective interactions. This work will add more information in the earlier work by Cheal et al. for odd-even Ga isotopes [Phys. Rev. Lett. 104, 252502 (2010)] and Mané et al. for odd-odd Ga isotopes [Phys. Rev. C 84, 024303 (2011)], where only few excited states are studied in $f_{5/2}p_{9/2}$ space. For lighter isotopes $fp$ interaction is better and for heavier isotopes jj44b is quantitatively better than JUN45. These results show that limitation of existing interactions and calling for further improvements to predict nuclear structure properties of Ga isotopes.

1. Introduction
The structural changes between $N = 40$ and $N = 50$ of gallium isotopes recently attracted much experimental attention. At Argonne National Laboratory, Stefanescu et al. [1] have populated odd-A $^{71-77}$Ga isotopes in deep-inelastic reactions. More recently, in the Coulomb excitation experiment at REX-ISOLDE, the existence of a $1/2^-$, $3/2^-$ ground-state doublet has been proposed in $^{73}$Ga [2]. For odd-even Ga isotopes nuclear spins and moments has been reported in [3]. Recently ground-state spins and moments of $^{72,74,76,78}$Ga isotopes using laser spectroscopy has been reported in [4]. The evolution of the $1/2^-$ and $5/2^-$ levels in odd-A gallium isotopes are shown in Fig. 1. Except for $^{73}$Ga and $^{81}$Ga all have ground state (g.s.) $3/2^-$. The first $1/2^-$ reaches minimum in $^{73}$Ga where it becomes the ground state and the first $5/2^-$ start decreasing with $N = 40$ onwards and it becomes the ground state in $^{81}$Ga. This figure also demonstrate abrupt changes of structure from $N = 40$ to $N = 42$.

Following our recent shell-model (SM) studies for neutron-rich even isotopes of Fe [5], odd-odd Mn isotopes [6], and odd-mass $^{61,63,65}$Co isotopes [7], in this paper we report large scale shell model calculations for $^{71-78}$Ga isotopes. Earlier shell model calculation using pairing plus quadrupole-quadrupole interaction for $^{75,77,79}$Ga isotopes have been reported by Yoshinaga et al. [8]. They consider only low-lying negative-parity states in

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the analysis. The aim of present study is to analyze recently accumulated experimental data which includes both positive and negative high-spin states on neutron-rich Ga isotopes. Further, this work will add more information in the earlier work for odd-even Ga isotopes by Cheal et al. [3], where only few excited negative-parity states ($< 1$ MeV) are studied in $f_{5/2}g_{9/2}$ space. Present work also include further theoretical development which is proposed in [3], by including $f_{7/2}$ orbital in the model space.

![Figure 1. Experimental low-energy systematics of odd-A gallium isotopes [1] [2] [3].](image)

2. Details of Calculation

The present shell model calculations have been carried out in $f_{5/2}g_{9/2}$ and $f_{pg}g_{9/2}$ spaces. In the first set, calculations have been performed with two recently derived effective shell model interactions, JUN45 and jj44b, that have been proposed for $1p_{3/2}$, $0f_{5/2}$, $1p_{1/2}$ and $0g_{9/2}$ single-particle orbits. JUN45 which is recently develop by Honma et al. [9], this realistic interaction based on the Bonn-C potential with fitting 400 experimental binding and excitation energy data with mass numbers $A=63\sim 96$. Since the present model space is not sufficient to describe collectivity in these region thus data have been not used while fitting in the middle of the shell along $N = Z$ line. For JUN45, the data mostly fitted to develop this interaction closure to $N = 50$, thus this interaction is very suitable for shell-model study of neutron rich Ga isotopes as $N \sim 50$. Although this interaction is not successful to explain data for Ni and Cu isotopes possibly due to missing $0f_{7/2}$ orbit in the present model space. The jj44b interaction due to Brown et al. [10] was developed by fitting 600 binding energies and excitation energies with $Z = 28 – 30$ and $N = 48 – 50$. Instead of 45 as in JUN45, here 30 linear combinations of good $J – T$ two-body matrix elements varied, with the rms deviation of about 250 keV from experiment. For JUN45 interaction the single-particle energies are taken to be $-9.8280$, $-8.7087$, $-7.8388$, and $-6.2617$ MeV for the $p_{3/2}$, $f_{5/2}$, $p_{1/2}$ and $g_{9/2}$ orbit, respectively. Similarly for jj44b interaction the single-particle energies are taken to be $-9.6566$, $-9.2859$, $-8.2695$, and $-5.8944$ MeV for the $p_{3/2}$, $f_{5/2}$, $p_{1/2}$ and $g_{9/2}$ orbit, respectively.
In the second set of calculations for the $fpg_{9/2}$ space, with $^{48}$Ca core (a $^{40}$Ca core, with eight neutrons were frozen in the $\nu f_{7/2}$ orbital), an interaction reported by Sorlin et al. in [11] has been employed. This interaction, called $fpg$ interaction, was built using $fp$ two-body matrix elements (TBME) from [12] and $rg$ TBME from [13]. The remaining $f_{7/2}g_{9/2}$ TBME are taken from [14]. The single-particle energies are taken to be 0.0, 2.0, 4.0, 6.5 and 9.0 MeV for the $f_{7/2}$, $p_{3/2}$, $p_{1/2}$, $f_{5/2}$, and $g_{9/2}$ orbit, respectively. As here the dimensions of the matrices become very large, a truncation has been imposed. We used a truncation by allowing up to a total of three particle excitations from the $f_{7/2}$ orbital to the upper $fp$ orbitals for protons and from the upper $fp$ orbitals to the $g_{9/2}$ orbital for neutrons.

All the SM calculations are performed on the 20-node cluster computer at PRL using the code ANTOINE [15].

3. Results for odd-even Ga isotopes

3.1. $^{71}$Ga:

Stefanescu et al. [1] assigned positive parity states at 2082, 2941, and 4028 keV, for $13/2^+$, $17/2^+$, and $21/2^+$ respectively. In the same experiment the negative states $9/2^-$, $13/2^-$, $17/2^-$, and $(19/2^-, 21/2^-)$ are proposed at 1498, 2684, 3696, and 4165 keV, respectively. In this paper they argue that these sequence of levels arises due to coupling of $\pi f_{5/2}$ and $\nu g_{9/2}$. In Fig. 2 experimental data for $^{71}$Ga are compared with the calculated energy levels using JUN45, jj44b and $fpg$ interactions. The band built on $3/2^-$, is reproduced correctly by JUN45 interaction, while levels are compress with jj44b interaction. These results show that the yrast sequence of levels $3/2^-$, $5/2^-$, $7/2^-$, $11/2^-$ is connected with strong $E2$ transitions. The $B(E2)$ values for $5/2^-\rightarrow3/2^-$, $7/2^-\rightarrow5/2^-$, $11/2^-\rightarrow7/2^-$, are 6, 222 and 223 e$^2$fm$^4$ respectively with JUN45 and corresponding value for jj44b are 5, 209 and 383 e$^2$fm$^4$. Similarly, a band built on $5/2^-$, with JUN45 interaction is slightly higher, while jj44b interaction predicted compress states. The band built on $9/2^+$, with the JUN45 interaction, predicted $9/2^+$, $13/2^+$, $17/2^+$, $21/2^+$ are at 2478, 2893, 3526 and 4979 keV, while its corresponding experimental values are 1493, 2082, 2941 and 4028 keV respectively. The calculated positive parity states around 1 MeV higher than experimental data with JUN45. The predicted results show an inadequacy of this interaction to explain positive parity states. The jj44b interaction predicts $9/2^+$, $13/2^+$, $17/2^+$, $21/2^+$ at 1922, 2855, 3689 and 4866 keV respectively, which is better than JUN45 interaction. The calculated $B(E2)$ values are shown in Table 1. The JUN45 interaction predicts, leading configuration of $\pi(p_{3/2}^3)\otimes\nu(p_{3/2}^3f_{5/2}^6g_{9/2}^2)$ for the ground state with probability of 29.2%. The calculated occupancy of $g_{9/2}$ orbital is 0.53, 0.83 by JUN45 and jj44b interaction respectively. States with $I=5/2^-$, $7/2^-$, $9/2^-$, $11/2^-$, $13/2^-$ are dominated with $\pi(p_{3/2}^3f_{5/2}^1)\otimes\nu(p_{3/2}^3f_{5/2}^4p_{1/2}^2g_{9/2}^2)$ configurations by $fpg$ interaction. While for this interaction positive parity states with $I=9/2^+$, $13/2^+$, $17/2^+$, $21/2^+$ are dominated with $\pi(p_{3/2}^3f_{5/2}^3)\otimes$
Figure 2. Experimental data for $^{71}$Ga compared with shell-model results. The levels marked with an asterisk (*) have been also experimentally found, but not form a band.

$$\nu(p_{3/2}f_{5/2}^{5}p_{1/2}^{1}/2g_{9/2})$$ configurations. The $13/2^+$ predicted by fpg interaction is within 50 keV with experimental data. The fpg interaction predict better result for excitation energies in comparison to JUN45 and jj44b interactions.

3.2. $^{73}$Ga:

Cheal et al. [3] assigned $1/2^-$ as a ground state, in another experiment recently Diriken et al. [2] shown an evidence for a $1/2^-$, $3/2^-$ doublet near the ground state, with an excitation energy of the $\sim 0.8$ keV for $3/2^-$. In Fig. 3, experimental data for $^{73}$Ga are compared with the calculated energy levels using JUN45, jj44b and fpg interactions. In contrast to ground state doublet predicted in recent experiment [2], the JUN45, jj44b and fpg interactions predict $1/2^-$ state at 219, 91 and 505 keV respectively. Indeed, JUN45 predict too high $1/2^-$ for $^{73}$Ga. Similar trend has been also observed with JUN45 interaction for Cu isotopes where $5/2^-$ is too high below $N = 40$ and $1/2^-$ is too high above $N = 40$.

The band built on $3/2^-$, reproduced correctly by JUN45 and jj44b interaction. The band built on $5/2^-$, is more correctly reproduced by jj44b interaction. The $B(E2)$ values for $9/2^-\rightarrow5/2^-$, $13/2^-\rightarrow9/2^-$, $17/2^-\rightarrow13/2^-$, are 42, 194 and 4 $e^2$fm$^4$ respectively with JUN45 and corresponding value for jj44b are 81, 270 and 161 $e^2$fm$^4$. The results of band built on $7/2^-$, is better for jj44b in comparison to JUN45. The band built on $9/2^+$, with
the JUN45 interaction, predicted \(9/2^+, 13/2^+, 17/2^+, 21/2^+\) are at 2230, 2749, 3267 and 4588 keV, while its corresponding experimental values are 1232, 1814, 2718 and 3974 keV respectively. The occupancy of \(g_9/2\) orbital is predicted by JUN45 and \(jj44b\) interaction as 0.92 and 0.83 respectively. With \(fpg\) interaction \(13/2^+\) become lower than \(9/2^+\). The calculated \(B(E2)\) values obtained with \(jj44b\) give reasonable agreement with experimental data. The experimental excitation energy of \(9/2^+\) decreases from \(71\text{Ga}\) to \(73\text{Ga}\) and again starts rising from \(75\text{Ga}\) onwards. Indeed, intruder \(\pi g_9/2\) leading to onset of deformation around neutron mid-shell at \(N = 42\). Only JUN45 interaction predict this trend from \(71\text{Ga}\) to \(73\text{Ga}\). States with \(I = 7/2^-, 9/2^-, 11/2^-, 13/2^-, 15/2^-, 17/2^-, 19/2^-, 21/2^-\) are dominated with \(\pi(p_{3/2}f_{5/2})^3 \otimes \nu(p_{3/2}f_{5/2}^2)^2\) configurations by \(jj44b\) interaction for \(73\text{Ga}\). The overall results of \(jj44b\) interaction are better than JUN45 and \(fpg\).

### 3.3. \(75\text{Ga}\):

In Fig. 3, experimental data for \(75\text{Ga}\) are compared with the calculated energy levels with JUN45, \(jj44b\) and \(fpg\) interactions. The band built on \(3/2^-\), reproduced correctly by JUN45 and \(jj44b\) interaction. The band built on \(5/2^-\), is more correctly reproduced by \(jj44b\) interaction. The results of band built on \(7/2^-\) is reasonable with \(jj44b\).
The results of $fpg$ having configuration $\pi$ experimental values are 1510, 2088, 2946 and 4148 keV respectively. The ground state $9/2$ by $JUN45$ interaction, while levels are slightly higher with $jj44b$ interaction. The occupancy of $g$ corresponding value for $jj44b$ is 38 and 310 e$^2$fm$^4$. The band built on $9/2^+$, 11/2$^+$, 13/2$^+$, 17/2$^+$, 21/2$^+$ are at 2206, 2726, 3277 and 4576 keV, while its corresponding $fpg$ are 2291, 2794, 3312 and 4576 keV respectively. The ground state having configuration $\pi(p_3/2f_5/2)$ with probability 14.9 and 22.4% for $JUN45$ and $jj44b$ interaction. The results of $fpg$ interaction are more compressed. States with $I= 7/2^−, 9/2^−, 11/2^−, 13/2^−, 15/2^−, 17/2^−, 19/2^−, 21/2^−$ are dominated with $\pi(p_3/2f_5/2)^3 \otimes \nu(p_3/2f_5/2p_1/2g_9/2)$ configurations by $jj44b$ interaction for $^{75}$Ga. The first $9/2^+$ has $\pi(f_5/2g_9/2) \otimes \nu(p_3/2f_5/2p_1/2g_9/2)$ configuration with $jj44b$ for $^{75}$Ga. With $jj44b$ the occupancy of $g_9/2$ orbital is 0.49. The results of $jj44b$ interaction are better than $JUN45$ and $fpg$.

3.4. $^{77}$Ga :

In Fig. 6 experimental data for $^{77}$Ga are compared with the calculated energy levels with $JUN45$, $jj44b$ and $fpg$ interactions. The band built on $3/2^−$, is reproduced correctly by $JUN45$ interaction, while levels are slightly higher with $jj44b$ interaction. The $B(E2)$ values for $7/2^−\rightarrow 3/2^−, 11/2^−\rightarrow 7/2^−$, are 45 and 265 e$^2$fm$^4$ with $JUN45$ and corresponding value for $jj44b$ is 38 and 310 e$^2$fm$^4$. The $B(E2)$ values for $9/2^−\rightarrow 5/2^−$, 15/2$^−\rightarrow 11/2^−$, 19/2$^−\rightarrow 15/2^−$, are 278, 109 and 92 e$^2$fm$^4$ respectively with $JUN45$ and corresponding values for $jj44b$ are 388, 368 and 281 e$^2$fm$^4$. The band built on $9/2^+$, 13/2$^+$, 17/2$^+$, 21/2$^+$ are at 2206, 2726, 3277 and 4576 keV, while its corresponding experimental values are 1510, 2088, 2946 and 4148 keV respectively. The ground state having configuration $\pi(p_3/2f_5/2)$ with probability 14.9 and 22.4% for $JUN45$ and $jj44b$ interaction. The results of $fpg$ interaction are more compressed. States with $I= 7/2^−, 9/2^−, 11/2^−, 13/2^−, 15/2^−, 17/2^−, 19/2^−, 21/2^−$ are dominated with $\pi(p_3/2f_5/2)^3 \otimes \nu(p_3/2f_5/2p_1/2g_9/2)$ configurations by $jj44b$ interaction for $^{75}$Ga. The first $9/2^+$ has $\pi(f_5/2g_9/2) \otimes \nu(p_3/2f_5/2p_1/2g_9/2)$ configuration with $jj44b$ for $^{75}$Ga. With $jj44b$ the occupancy of $g_9/2$ orbital is 0.49. The results of $jj44b$ interaction are better than $JUN45$ and $fpg$. 

![Figure 4. Experimental data for $^{75}$Ga compared with shell-model results. The levels marked with an asterisk (*) have been also experimentally found, but not form a band.](image-url)
13/2^− → 9/2^−, 17/2^− → 13/2^−, are 135, 33 and 105 e^2fm^4 respectively with JUN45 and corresponding value for jj44b are 167, 78 and 101 e^2fm^4. The band built on 9/2^+ is correctly reproduce by JUN45 interaction. The 13/2^+ is predicted at 2724 keV by JUN45, while at 2345 keV by jj44b, which is slightly compressed. The ground state as 3/2^- having configuration $\pi(p_3/2f_{5/2})$ with probability 35.7 and 24.5% for JUN45 and jj44b interaction respectively. With jj44b interaction the 1/2^- is high for $^{77}$Ga. Similar trend has been also found for Cu isotopes, where 1/2^- bit too high in $^{73,75}$Cu. States with $I= 7/2^−, 9/2^−, 11/2^−, 13/2^−, 15/2^−, 17/2^−, 19/2^−, 21/2^−$ are dominated with $\pi(p_3/2f_{5/2})^3 \otimes \nu(p_3/2f_{5/2}p_{1/2}g_{9/2})$ configurations by JUN45 interaction for $^{77}$Ga. The occupancy of g_{9/2} orbital for first 9/2^+ state is 0.96 for JUN45, while it is only 0.053 for jj44b interaction. The results of JUN45 and jj44b are reasonable. The positive parity states predicted by fpg are more compressed.

4. Results for odd-odd Ga isotopes

In Fig. 6 the calculated energy levels for even Ga isotopes with JUN45, jj44b and fpg interactions are compared with experimentally known data. Recently ground-state spins and moments for even Ga isotopes with A=72,74,76,78 has been reported in [4]. For $^{72}$Ga all the three interactions predict different g.s. The first 3^- is predicted at 200, 131 and 321 keV by JUN45, jj44b and fpg interaction respectively. In $^{74}$Ga the JUN45 interaction predict 3^- as a g.s. which is in agreement with tentative assignment.
While with jj44b and \( f_{pg} \) it is more than 200 keV higher. The jj44b interaction predict gradual drop in 2\(^{-}\) energy from \( ^{74}\text{Ga} \) to \( ^{78}\text{Ga} \). This is reasonable trend because for \( ^{78}\text{Ga} \) it is a g.s. which is in agreement with experimental data. As we move from \( ^{72}\text{Ga} \) onwards, the contribution in g.s. wavefunction for \( \pi(f_{5/2}) \) configuration is start increasing. There is also similarity between spectra of gallium and copper isotopes such as 2\(^{-}\) is a g.s. in case of \( ^{72,74}\text{Cu} \) and \( ^{76,78}\text{Ga} \). The leading proton configuration in \( ^{72,74}\text{Cu} \) is \( \pi(f_{5/2}) \) which show an agreement with experimental moments.

### 5. Electromagnetic properties

As proposed in [3] possibility of proton excitations across \( Z=28 \) may play important role, by including the proton \( f_{7/2} \) orbital in the model space. We have calculated static quadrupole moments with effective charges \( e_{p}^{\text{eff}} = 1.5e, e_{n}^{\text{eff}} = 1.1e \) and magnetic moments with \( g_{s}^{\text{eff}} = 0.7g_{s}^{\text{free}} \) in \( f_{pg9/2} \) model space as shown in Table 2. The \( f_{pg} \) interaction predict correct sign of quadrupole moments for \( ^{71,73,75,77}\text{Ga} \) and results are better than if we use only \( f_{5/2}p_{9/2} \) space [3]. The change in sign of quadrupole moments from \( ^{71}\text{Ga} \), i.e. \( N = 40 \) onwards, demonstrate a changing of shell structure. This is due to ground state of \( ^{71}\text{Ga} \) have \( \pi(p_{3/2}^{1}) \) configuration (\( \sim \) 28\%) and \( ^{75,77}\text{Ga} \) have \( \pi p_{3/2}^{1}(f_{5/2}p_{1/2})^{2} \) configuration. These configurations reveal change of sign of
quadrupole moments because filling of higher orbital started. Thus below $N = 42$, a hole configuration ($\pi(p_3^3/2)$) has a positive quadrupole moment and above $N = 42$, a particle configuration ($\pi p_{3/2}^1(f_5/2p_1/2)^2$) has a negative quadrupole moment. The fpg interaction predict correct sign of magnetic moment for $^{73}$Ga while JUN45 and jj44b gives negative sign. This support ground state as $1/2^-$ for $^{73}$Ga. We have also reported quadrupole moments for $^{72,74,76,78,80}$Ga isotopes with fpg interaction. For $^{74}$Ga the fpg give reasonable value of quadrupole moment in comparison to jj44b [4] while it predict too low value for $^{72}$Ga.

### 6. Summary

In the present work large scale shell model calculations have been performed for $^{71-78}$Ga isotopes in $f_5/2p_9/2$ and fpg$\nu_9/2$ model spaces with $^{56}$Ni and $^{48}$Ca core respectively. For

### Table 1. Calculated $B(E2)$ values for some transition for $^{71-77}$Ga isotopes with standard effective charges: $e'_{\text{eff}}=1.5e$, $e''_{\text{eff}}=0.5e$ (the experimental $\gamma$-ray energies corresponding to these transitions are also shown).

| Nucleus | $I^e_i$ $\rightarrow$ $I^e_f$ | $E_x$ (keV) | $B(E2)$ (W.u.) |
|---------|-------------------------------|-------------|----------------|
|         |                               | Expt.       | JUN45 | jj44b | fpg |
| $^{71}$Ga | $5/2^+_1$ $\rightarrow$ $3/2^+_1$ | 965 | 4.43 | 16.82 | 4.93 |
|          | $7/2^+_1$ $\rightarrow$ $3/2^+_1$ | 1107 | 0.81 | 4.34 | 0.59 |
|          | $7/2^+_2$ $\rightarrow$ $3/2^+_1$ | 1395 | 2.84 | 8.38 | 1.55 |
| $^{73}$Ga | $5/2^+_1$ $\rightarrow$ $2/2^+_1$ | 199 | 11.02 | 7.58 | 7.36 | 0.17 |
|          | $3/2^+_2$ $\rightarrow$ $1/2^+_1$ | 218 | 7.51 | 11.62 | 7.92 | 5.50 |
|          | $5/2^+_1$ $\rightarrow$ $2/2^+_1$ | 496 | 6.51 | 3.65 | 6.38 | 9.65 |
|          | $5/2^+_2$ $\rightarrow$ $1/2^+_1$ | 1395 | 3.07 | 0.265 | 2.60 | 8.49 |
| $^{75}$Ga | $3/2^+_1$ $\rightarrow$ $3/2^+_1$ | 178 | - | 4.44 | 4.47 | 2.24 |
|          | $5/2^+_2$ $\rightarrow$ $3/2^+_1$ | 229 | - | 0.09 | 0.28 | 2.38 |
|          | $7/2^+_2$ $\rightarrow$ $3/2^+_1$ | 606 | - | 0.34 | 5.09 | 4.13 |
| $^{77}$Ga | $5/2^+_1$ $\rightarrow$ $3/2^+_1$ | 189 | - | 0.75 | 7.62 | 14.96 |
|          | $3/2^+_2$ $\rightarrow$ $3/2^+_1$ | 473 | - | 7.40 | 6.74 | 3.53 |
|          | $7/2^+_2$ $\rightarrow$ $3/2^+_1$ | 626 | - | 2.30 | 1.94 | 3.03 |

### Table 2. Calculated and experimental [3, 4, 16] quadrupole moments and magnetic moments of Ga isotopes. For even Ga isotopes these state may not be predicted as ground state by shell-model.

| Nucleus | $I$ | $Q_{s,expt}(eb)$ | $Q_{s,fpg}(eb)$ | $\mu_{s,expt}(\mu_N)$ | $\mu_{s,fpg}(\mu_N)$ | $\pi_{SM}$ | $Q_{s,expt}(eb)$ | $Q_{s,fpg}(eb)$ |
|---------|-----|-----------------|-----------------|------------------------|------------------------|----------|-----------------|-----------------|
| $^{71}$Ga | $3/2^+_1$ | +0.106(3) | +0.166 | +2.56227(2) | +2.198 | - | +0.536(29) | +0.017 |
| $^{71}$Ga | $1/2^+_1$ | 0 | 0 | +0.209(2) | +0.039 | - | +0.549(40) | +0.425 |
| $^{71}$Ga | $3/2^+_1$ | -0.285(17) | -0.338 | +1.836(4) | +1.715 | - | +0.329(19) | +0.268 |
| $^{71}$Ga | $3/2^+_1$ | -0.208(13) | -0.289 | +2.020(3) | +1.831 | - | +0.327(18) | +0.381 |
| $^{71}$Ga | $3/2^+_1$ | +0.158(10) | -0.074 | +1.047(3) | +1.489 | - | +0.478(27) | +0.568 |
| $^{81}$Ga | $5/2^+_1$ | -0.048(8) | +0.042 | +1.747(5) | +1.644 | - | +0.375(21) | +0.394 |
Shell model for $^{71−78}$Ga

the $f_{5/2}pg_{9/2}$ space, calculations have been performed with JUN45 and jj44b interactions and for $fpg_{9/2}$ model space with $fpg$ interaction. In $fpg_{9/2}$ space, we use a truncation by allowing maximum three particle excitations.

Our calculated results predict high-spin sequences built on top of the $3/2^-$, $5/2^-$ and $9/2^+$ levels in odd $^{71−77}$Ga. The results of $fpg$ interaction are better than JUN45 and jj44b in lighter isotopes. While for heavier isotopes, the results of jj44b interaction are quantitatively better than JUN45. The results of level energies for heavier Ga isotopes with $fpg$ interaction are more compressed. The calculated $B(E2)$ values for $^{73}$Ga with jj44b interaction give reasonable agreement with experimental data. We have also pointed out that the energy level systematics of Ga isotopes are quite similar to that in Cu isotopes. There is a clear need for suitable interaction for neutron-rich nuclei in this region for better understanding of nuclear structure.

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