LOW LYING 1^- STATES IN $^{116-124}$Sn ISOTOPES

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ABSTRACT:

Based on Pyatov-Salamov [14] method within Galileo invariant pair interaction the low-lying 1^- states in $^{116-124}$Sn isotopes are investigated. Calculations are made in both spherical and deformation base. This calculations shows that the energies of lowest-lying 1^- states are around (7.5-8.5) MeV (in spherical case) and around 3.5 MeV (in small deformation case) in the examined nuclei. The corresponding excitation probabilities B(E1) are $(1\text{-}5)10^{-3}e^2fm^2$ and $(10\text{-}15)10^{-3}e^2fm^2$ units respectively.

1. INTRODUCTION

In the multiple performed with (e, e$'$) and (γ,γ') reactions have been identified at low energy region strong electric dipole transitions [1-7]. In this experiments it was found that the absolute E1 strength from the ground state to the low-lying 1^- states is around (10-20) $10^{-3}e^2fm^2$ [8].

To explain fast E1 transitions between low-lying states in heavy deformed nuclei, Iachello proposed a cluster description of nuclei. In this case the centre of mass will not consider with the centre of charge thus generating a large dipole moment, which in turn induces the observed E1 transitions[9].

Low-lying 1^- states in heavy nuclei are often treated $\left[\left(2^+ \otimes 3^-\right)\right]$ two phonon excitations. One of possibility to explain strong E1 transitions detected in (e, e$'$) and (γ,γ') measurements is one-particle-one-hole (1p-1h) admixtures, at the low energy tail of the giant dipole resonance(GDR) into the low-lying two-phonon 1^- states[10]. The low-lying excitations of heavy nuclei have long been described in terms of phonons in collective[11], IBM[12], and microscopic models[13].

As known the mean field potential of the nucleus using in microscopic model does not invariant under the translation and moreover, under Galilean transformation if taken into account the pairing correlation's. The restoration of broken translation invariance of the mean field and its effect on the macroscopic characteristics of the electric dipole excitations were investigated by Pyatov-Salamov in detail [14]. The aim of this study is to restore of broken Galilean symmetry of pairing correlation based on Pyatov-Salamov method [14] and examine its effect on low-lying 1^- excitations. $^{116\text{-}124}$Sn isotopes which have been topic of many investigation [15-16] were studied.

2. TRANSLATION INVARIANCE HAMILTONIEN WITH GALILEAN INVARIANCE PAIRING

If the processes done by Pyatov-Salamov have been performed in the quasi-particle space by using the Pyatov-Salamov method then the Hamilton operator is:

$$H = H_{SQP} + h_0 + h_1 + h_\Delta \qquad (1)$$

Here H_{SQP} is the single quasi-particle Hamiltonien, h_0 is the kinematics correlation term, h_1 represents the isovector dipole forces which have the translational invariance forme, The last term h_Δ is a term which makes the pairing interaction potential a Galilean invariance[14]. The eigenfunctions and eigenvalues of the Hamilton operator in eq. (1) can be obtained from the following equation of motion:

$$\left[H, Q_i^+(\mu)\right]\left|0\right\rangle = \omega_i Q_i^+(\mu)\left|0\right\rangle \qquad (2)$$

The transition probability from the ground state (0^+) to the excited 1^- states for the even-even nuclei is given by:

$$B(E1, 0^+ \rightarrow 1_i^-) = \left|\left\langle 0\left|\left[Q_i^+, D_{1i}\right]\right|0\right\rangle\right|^2 \qquad (3)$$

Here $D_{1i} = e\sum_i r_i Y_{1i}(\vartheta_i, \varphi_i)$ is the electric dipole and Q_i^+ is RPA phonon operator.

Since the breaking of the Galilean invariance of pairing affects the transition probabilities, it is useful to calculate the cross sections which are the integral characteristics of the 1^- states. These cross sections are calculated as[14]:

$$ó_n = \int E^n ó(E)dE = \frac{16ð^3}{9\hbar c}\sum_i ù_i^{n+1} B(E1, 0^+ \rightarrow 1_i^-)$$

ω_i is energies of 1^- excitations, and n=-2,-1,0,2. Detailed calculations can be found in Ref[17].

3. RESULTS AND DISCUSSIONS

In this work calculations were done both spherical and deformation base. The Woods-Saxon potential has been chosen as the average potential. The eigenfunctions and the eigenvalues of Schrödinger equation solved by the parameters of Chepurnov have been used as a base states in the calculations(spherical case). For deformation base we take the Nilsson single-particle energies are calculated with a deformed Woods-Saxon potential developed by G.Leander[18]. The small ($\delta(n) = \delta(p) = 0.005$) deformation parameters were taken for investigation of $^{116\text{-}124}$Sn isotopes. The pairing interaction constants –correlation functions- for the proton and neutron systems has been accepted as $\Delta_n = \Delta_n = 12A^{-1/2}$.

The isovector forces strength parameter χ_1 was estimated from the condition that the 1^- excitations with the largest B(E1) values appear in the region of the experimental maximum energy of GDR. A good description was obtained with: $\chi_1 = (300\text{-}325)A^{-5/3}$MeV fm^{-2}[14].

Calculated excitation energy (E_x) of the lowest 1^- state, the electric dipole transition strength B(E1) from ground (0^+) to lowest 1^- state and integral cross-section σ_0 in a spherical base were shown in Table 1. The results without pairing interaction are also given in this table. NGI corresponds to Non Galilean Invariant and NG corresponds to Galilean Invariant case. As seen from the Table 1 considering pair interaction among the nucleons not significantly change the above mentioned quantities. Although the restoration of broken Galilean symmetry of pairing correlation has significant effect on the energy lowest 1^- excitation, it readably change the B(E1) transition strength and cross-section σ_0. The low-lying 1^- states with large electric dipole transition strength determined by the experiment can be explained in terms of accepting existence of small deformation in nuclei. Even a small(δ_2 = 0.005) deformation cause to open ($1h_{11/2} \rightarrow 2g_{9/2}$) and ($1h_{11/2} \rightarrow 2d_{5/2}$) transition channels which one forbidden in spherical case. As known deformation leads to the splitting $1h_{11/2}$ {505↑,514↑,523↑, 532↑, 541↑, 550↑} and $2g_{9/2}$ {404↑,413↑,422↑, 431↑, 440↑} levels. The electric dipole transitions between suitable states are allowed. The states splitted by small deformation are very close to each other and may be taken as one state. The transition strength B(E1) can be accepted as sum of their transition strengths. The calculated energies of the lowest $K^\pi = 1^-$ states for $^{116\text{-}124}$Sn isotopes was shown in Fig. 1. Note that these states are formed from (523↑404↑),(532↑413↑) and (521↑421↑) neutron states. As seen Fig.1 the restoration of Galilean invariance was not effected noticeable the energy of the lowest 1^- state. The fact that energies shift down a bit is due to h_Δ attraction obtained the results of restoration. Seen that there is good agreement between theoretical and experimental values[6,16]. In Fig. 2 the electric dipole transition strengths from ground state (0^+) to low-lying $K^\pi = 1^-$ states are shown. It was shown that the restoration of Galilean invariance pairing effects on the transition strengths more considerable. Increasing transition strengths are due to attractive character restoring force h_Δ too. The calculated values of transition strengths in studied nuclei are around (9-11) $10^{-3}e^2fm^2$ and exceed systematically the experimental values (6-7.5) $10^{-3}e^2fm^2$. The cross section σ_0 calculated for GI and NGI cases are shown in Table 2. As seen integral cross-section σ_0 has not been effected much from restoration Galilean symmetry.

4.CONCLUSIONS

Calculations based on Pyatov-Salamov method were shown that assumption considering small(δ_2=0.005) deformations satisfy determination of 1^- states which have fast electric dipole strengths in $^{116\text{-}124}$Sn isotopes. As a result restoration Galilean symmetry of pairing has no remarkable effect on the macroscopic quantities of 1^- states but has pronounce effect on the electric dipole strengths. Therefore it is necessary to restore broken Galilean symmetry if one take into account the pairing interaction between nucleons.

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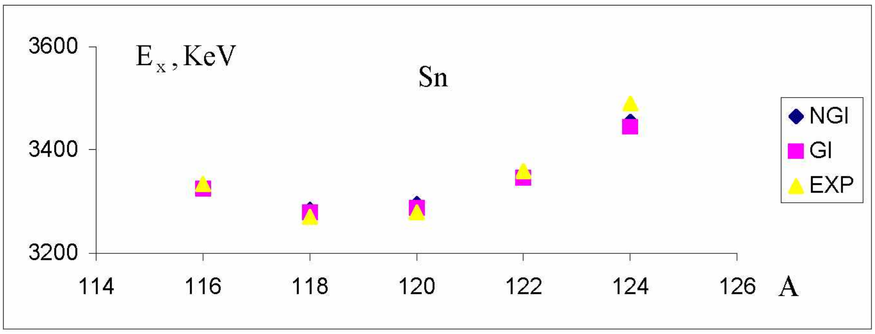

Figure 1.

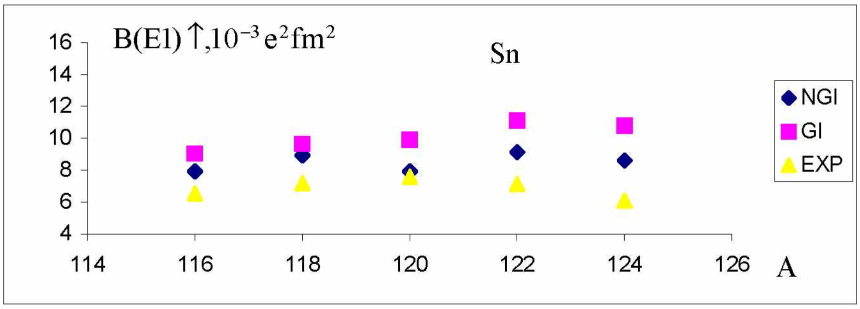

Figure 2.

Table 1. Properties of the low-lying 1^- levels in Sn isotopes(spherical case)

		^{116}Sn	^{118}Sn	^{120}Sn	^{122}Sn	^{124}Sn
E_x,MeV	a	7.335	6.803	6.746	6.691	6.639
	b	8.001	7.853	7.739	7.602	7.414
	c	8.001	7.853	7.739	7.602	7.414
B(E1)↑$10^{-3}e^2fm^2$	a	6.40	0.53	0.97	0.87	0.77
	b	0.17	0.17	0.10	0.23	0.57
	c	0.13	0.03	0.13	0.33	0.60
σ_0;MeV b	a	1.57	1.52	1.33	1.52	1.47
	b	2.35	2.41	2.26	2.21	2.33
	c	3.17	3.20	3.65	3.76	3.02

a-In model[14]

b-present work Non Galilean Invariant(NGI)

c-present work Galilean Invariant(GI)

Table 2. Properties of the low-lying 1^- levels in Sn isotopes(with deformation)

		^{116}Sn	^{118}Sn	^{120}Sn	^{122}Sn	^{124}Sn
E_x,KeV	a	3329	3284	3296	3354	3455
	b	3325	3279	3288	3347	3445
	c	3350	3290	3320	3420	3570
	d	3334	3271	3279	3359	3490
$B(E1,0^+\rightarrow1^-1)$ $10^{-3}e^2fm^2$	a	7.93	8.93	7.94	9.13	8.61
	b	9.06	9.66	9.92	11.13	10.80
	c	8.20	8.60	7.20	4.90	3.50
	d	6.55	7.20	7.60	7.16	6.08
σ_0;MeV b	a	1.15	1.14	1.12	1.06	1.08
	b	1.12	1.14	1.12	1.07	1.08

a-present work Non Galilean Invariant(NGI)

b-present work Galilean Invariant(GI)

c-Ref. [6,15] Theory.

d-Ref. [6,15] Exp.