

Cluster effects in the structure of the ground state and superdeformed bands of ^{60}Zn G. G. Adamian,^{1,2} N. V. Antonenko,^{1,2} R. V. Jolos,^{1,2} Yu. V. Palchikov,^{1,2} and W. Scheid¹¹*Institut für Theoretische Physik der Justus-Liebig-Universität, D-35392 Giessen, Germany*²*Joint Institute for Nuclear Research, RU-141980 Dubna, Russia*

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The properties of the states of the superdeformed band in ^{60}Zn , including the moment of inertia and its angular momentum dependence, transition quadrupole moment, and the decay intensities into the ground state band, are analyzed in the framework of the dinuclear system model. The model Hamiltonian depends only on special degree of freedom, namely, on the mass asymmetry coordinate. The results of calculations agree well with the experimental data.

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I. INTRODUCTION

In many light nuclei clustering is a very prominent feature in a large number of states. Typical examples of clustering in light nuclei are known, for example, in ^{16}O and ^{20}Ne , where $^{12}\text{C} + \alpha$ and $^{16}\text{O} + \alpha$ structures are particularly stable [1–3]. It is interesting that the clustering in ^{20}Ne is realized in the ground state band, but in ^{16}O a cluster structure has the excited band built on the 6.06 MeV intruder state. In heavier nuclei the α -cluster structures have been predicted to be stable in ^{40}Ca and ^{44}Ti . In Refs. [3,4] the α clustering is discussed with respect to the excited deformed band in ^{40}Ca and the ground band in ^{44}Ti .

In the pairs of nuclei $^{16}\text{O} - ^{20}\text{Ne}$ and $^{40}\text{Ca} - ^{44}\text{Ti}$ one of the partners is a spherical double magic nucleus and the other is a double magic nucleus plus α particle. The next pair of this kind is $^{56}\text{Ni} - ^{60}\text{Zn}$. In ^{56}Ni the excited deformed rotational band is known [5] up to $I^\pi = 12^+$. In ^{60}Zn the threshold for the α decay is only 2.7 MeV higher than the ground state. Therefore, it is quite possible that the ground state band of ^{60}Zn contains an α -cluster component. In Ref. [6] this assumption has been used for the description of the ground state band of ^{60}Zn where an α -cluster configuration with fixed mass asymmetry has been applied. However, there is also observed a superdeformed band in ^{60}Zn [7]. At spins higher than 12 only $E2$ transitions between the states of the superdeformed band have been seen. In the spin region $I = 8 - 12$ the superdeformed band decays into the states of the ground band. The decay of superdeformed rotational bands into normally deformed or spherical states is one of the very interesting nuclear structure problems. It can be viewed as a shape coexistence phenomenon. By using the experimental information on the decay out of the superdeformed states, the mixing mechanism of states having very different internal structures can be studied as a function of spin and excitation energy. The properties of the superdeformed states in heavy nuclei have been analyzed in the framework of the dinuclear model in Ref. [8]. The properties of the superdeformed bands in the $A \cong 60$ region have also been theoretically explained within the cranked Hartree-Fock, cranked Nilsson-Strutinsky, and relativistic mean field approaches [9–13].

In the superdeformed band of ^{60}Zn the moment of inertia depending on spin takes the values $(692 - 795)m \text{ fm}^2$, where

m is the nucleon mass. These values are close to the sticking moment of inertia of the $^{52}\text{Fe} + ^8\text{Be}$ cluster configuration, which is $750m \text{ fm}^2$. We should mention also that the threshold energies for the decay of ^{60}Zn into $^{52}\text{Fe} + ^8\text{Be}$ (10.8 MeV) and $^{48}\text{Cr} + ^{12}\text{C}$ (11.2 MeV) are close to the extrapolated value of the superdeformed band head, which is approximately 7.5 MeV. Thus, it is quite possible for ^{60}Zn that we have two sets of states belonging to two cluster configurations. The first set includes states of the ground state band and contains the α -cluster configuration as an important component. The second set includes states of the superdeformed band and corresponds mainly to the Be-cluster configuration.

The aim of the present paper is to describe the properties of the superdeformed band of ^{60}Zn and especially the decay of the superdeformed band into the ground state band by using the dinuclear model, which is a variant of a cluster model. In this model the mass asymmetry variable $\eta = (A_1 - A_2)/(A_1 + A_2)$, which describes the partition of nucleons between the clusters, is used as a collective coordinate [14]. Since in this model η is a dynamical variable, the wave function of the nucleus contains the components of different cluster configurations including the mononucleus.

II. MODEL

Nuclear systems consisting of the heavy cluster A_1 plus a light cluster A_2 belong to the class of dinuclear-type shapes. They were first introduced to explain data on deep inelastic and fusion reactions with heavy ions. Instead of a parametrization of the nuclear shape in terms of quadrupole, octupole, and higher multipole deformations, the mass asymmetry coordinate η and the distance R between the centers of mass of the clusters are used as relevant collective variables. They form a minimal set of the collective variables, which can be used to describe both mirror symmetric and mirror asymmetric deformations of a dinuclear system. There is another collective variable, namely, the charge asymmetry coordinate $\eta_Z = (Z_1 - Z_2)/(Z_1 + Z_2)$, which also plays an important role. However, since ^{60}Zn is an $N = Z$ nucleus, we specify the trajectory of the motion of the system in the $\eta - \eta_Z$ plane taking $\eta_Z = \eta$ along this trajectory. In this case both clusters are nuclei with isospin $T = 0$ in the ground state and the symmetry energy is minimized.

Since for very asymmetric systems considered in the paper the frequency of the oscillation in R in the cluster-cluster interaction potential is much larger than the frequency of the oscillation in η , we can set $R=R_m(\eta)$, where $R_m(\eta)$ is a distance between the centers of mass of the clusters at the minimum of the cluster-cluster interaction potential, in the treatment of the motion in η . This approximation reduces the problem to the one-dimensional one. The used effective cluster-cluster interaction potential at $R=R_m(\eta)$ takes the zero-point energy in R into account [8,15].

As mentioned in the Introduction, the wave function in η can be thought of as a superposition of different cluster-type configurations including the mononucleus configuration with $|\eta|=1$. The relative contribution of each cluster component to the total wave function is determined by the collective Hamiltonian. Treating the dynamical variable η as a continuous variable, we take the collective Hamiltonian in the form

$$H = -\frac{\hbar^2}{2} \frac{d}{d\eta} \frac{1}{B(\eta)} \frac{d}{d\eta} + U(\eta, I), \quad (1)$$

where $B(\eta)$ is the inertia coefficient and $U(\eta, I)$ the potential energy. The eigenfunctions of this Hamiltonian have a well defined parity with respect to the reflection $\eta \rightarrow -\eta$, which is in fact a space reflection. Here, we take $R=R_m(\eta)$ and deal with the one-dimensional problem.

The potential $U(\eta, I)$ in Eq. (1) is taken as the dinuclear system potential energy for $|\eta| < 1$ [8,15],

$$U(\eta, I) = B_1(\eta) + B_2(\eta) - B + V(R=R_m, \eta, I). \quad (2)$$

Here, the quantities $B_1(\eta)$ and $B_2(\eta)$ (which are negative) are the experimental binding energies of the clusters forming the dinuclear system at a given η , and B is the binding energy of the mononucleus. The quantity $V(R, \eta, I)$ in the Eq. (2) is the effective nucleus-nucleus interaction potential. It is given as

$$V(R, \eta, I) = V_{Coul}(R, \eta) + V_N(R, \eta) + V_{rot}(R, \eta, I) \quad (3)$$

with the Coulomb potential V_{Coul} , the centrifugal potential $V_{rot} = \hbar^2 I(I+1) / [2\mathcal{J}(\eta, R)]$, and the nuclear interaction V_N , which is obtained with a double-folding procedure using the ground state nuclear densities of the clusters [15]. Antisymmetrization between the nucleons belonging to different clusters is regarded by a density dependence of the nucleon-nucleon forces used in a double-folding procedure. This density dependence of the nucleon-nucleon forces produces a repulsive core in the cluster-cluster interaction potential and, thus, the minimum at $R=R_m$. The details of calculation of V_N are presented in Ref. [8].

Our calculations have shown for ^{60}Zn that the dinuclear configuration with an α cluster as the light cluster has a potential energy smaller than the energy of the mononucleus at $|\eta|=1$. With respect to the ground state energy the potential at the α minimum is equal to -4.5 MeV. Next important minima correspond to ^8Be and ^{12}C cluster configurations with the following values of the potential at the minima: 5.1 MeV and 9.0 MeV, respectively, with respect to the energy of the mononucleus. At the values of η corre-

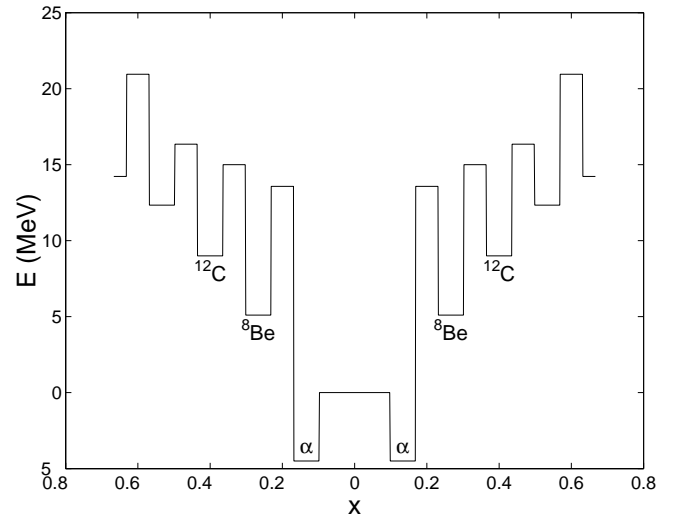


FIG. 1. Potential energy of ^{60}Zn as a function of x used in the calculations. The variable x is defined as $x = \eta + 1$ if $\eta \leq 0$, $x = \eta - 1$ if $\eta > 0$.

sponding to the Li- and B-cluster configurations, potential energy has maxima. Using the calculated values of the potential at $\eta = \eta_\alpha, \eta_{\text{Li}}, \eta_{\text{Be}}, \eta_{\text{B}}, \eta_{\text{C}}$ and so on we have approximated the potential U by the stepwise potential shown in Fig. 1. The widths of the minima and the barriers of the potential U are not known from our calculations, since these calculations give us only the values of the potential at discrete points. To minimize the number of the free parameters, we have taken the widths of all the potential minima to be equal to each other. The same is done for the barrier's widths. The widths of the potential minima are taken to be slightly wider than the widths of the barriers in order to describe correctly the energy of the experimentally known 3^- state, which is very sensitive to the width of the α minimum.

To calculate the potential energy at $I \neq 0$, we need the moments of inertia. For different cluster configurations, they are set equal to the dinuclear moment of inertia calculated under the sticking condition

$$\mathcal{J} = \mathcal{J}_{A_1}^r + \mathcal{J}_{A_2}^r + \frac{A_1 A_2}{A} m R_m^2(\eta), \quad (4)$$

where $\mathcal{J}_{A_i}^r (i=1,2)$ is the rigid body moment of inertia of the i th cluster. To reach the correct description of the γ -transition energies in the ground state band, we describe this band as a soft rotor with the moment of inertia linearly depending on spin I for $I \leq 8$. Thus, the known energies of the states of the ground band are fitted, in fact. It is seen from the experimental data that the ground state band of ^{60}Zn changes abruptly above $I=8$. The experimental energy of the $I=10$ state is much higher than the value that can be obtained by extrapolating smoothly the data for the lower spins. The physical reason is clear. In the configurations with $I \leq 8$ the four valence nucleons, two protons and two neutrons, occupy single particle states of the pf shell: $p_{3/2}, f_{5/2}$, and $p_{1/2}$. In this case $I=8$ is the maximum angular momen-

tum, which can be realized. To obtain a larger value of I , the nucleons have to occupy higher lying single particle states. First of all, $g_{9/2}$. In this case the energies of the states with $I \geq 10$ obtain an additional shift related to the shell gap. In the group theoretical realization of the cluster model [16], which takes into account the Pauli principle exactly, this abrupt change is described by a change of the irreducible representation of the dynamical symmetry group describing the cluster configuration. In our rather macroscopical model we describe it by an increase of the value of $U(|\eta|=1, I=10)$ needed to reproduce the experimental energy of the $I^\pi=10^+$ state. For higher values of I , we assume the same angular momentum dependence of the moment of inertia of the ground state band on I as for $I \leq 8$. We did not change the I dependence of the moment of inertia because of the following reasons: in the shell model the wave functions of the states of the ground state band with $I \leq 8$ are characterized mainly by four valence nucleons. States with $I \geq 10$ have more valence nucleons. However, nuclei from the same part of the nuclide chart as ^{60}Zn , but having more than four valence nucleons, such as ^{60}Fe , ^{62}Ni , $^{62,64}\text{Zn}$, and ^{64}Ge have approximately the same energies of the first 2^+ and 4^+ states as ^{60}Zn .

The inertia coefficient B is considered as a function of η . In Ref. [15], where the alternating parity bands in actinides have been analyzed, the inertia coefficient was treated as a constant. However, in the present paper a lighter nucleus is considered and because of this the scale of variation of η is larger, since this scale is proportional to A^{-1} . Moreover, in the present investigation at least two minima of the potential U play an important role. Our previous investigation of the cluster effects in the structure of the actinides [15] has shown that for mass asymmetries corresponding to the α or Be cluster, theoretical models can give only a qualitative estimate of the value of $B(\eta)$, since in this case a smaller number of single particle states is involved in the nucleon transfer and fluctuations of the matrix elements become important. The average value of the inertia coefficient B can be estimated in the following way. Rewriting the Schrödinger equation with Hamiltonian (1) and a constant B in a discrete form

$$-\frac{\hbar^2}{2B(\Delta\eta)^2}[\psi(\eta+\Delta\eta)+\psi(\eta-\Delta\eta)-2\psi(\eta)]+U(\eta)\psi(\eta)=E\psi(\eta), \quad (5)$$

we obtain the following expression for the nondiagonal matrix element of H in a discrete basis:

$$\langle\eta+\Delta\eta|H|\eta\rangle=-\frac{\hbar^2}{2B(\Delta\eta)^2}. \quad (6)$$

As it follows from the definition of η , for two-nucleon transfer $\Delta\eta=4/A$. The quantity $\langle\eta+\Delta\eta|H|\eta\rangle$ can be estimated in the case of two-nucleon transfer as a matrix element of the pairing interaction. Then $|\langle\eta+\Delta\eta|H|\eta\rangle|$ takes the values between the pairing interaction constant G , which is estimated as $G=25/A$ MeV, and the pairing gap Δ if there are

pairing correlations. Substituting G instead of $\langle\eta+\Delta\eta|H|\eta\rangle$, we obtain the upper boundary for B ,

$$B \leq \frac{\hbar^2 A^3}{2 \times 16 \times 25 \text{ MeV}} = \frac{\hbar^2 A^3}{800 \text{ MeV}}. \quad (7)$$

For ^{60}Zn , it gives $B=11165m \text{ fm}^2$. This estimate can be used for orientation only in the case of massive clusters where pairing concept is better justified. The case of the α cluster should be considered separately. The best description of the experimental data we obtain taking $B(\eta=\eta_{\text{Be}})=7580m \text{ fm}^2$ is not far from estimate (7). The value of the inertia coefficient at the α -minimum, where it determines the value of the zero point energy, is fixed by the experimental value of the ground state energy. We obtained $B(\eta=\eta_\alpha)=790m \text{ fm}^2$, which is used in our calculations.

The value of $B(\eta_\alpha)$ can be estimated also in a different way. Let $\Psi_I^{(\pm)}$ be the eigenfunctions of the positive and negative parity states with angular momentum I . Their linear combinations $\Psi_I^{(R,L)}=1/\sqrt{2}(\Psi_I^{(+)} \pm \Psi_I^{(-)})$ are the wave functions located at the right or left α minima [17]. By analogy with Eq. (6) the transition matrix element $\langle\Psi_I^{(R)}|H|\Psi_I^{(L)}\rangle$ can be estimated as

$$\langle\Psi_I^{(R)}|H|\Psi_I^{(L)}\rangle \equiv \langle-\eta_\alpha^I|H|\eta_\alpha^I\rangle = \frac{\hbar^2}{2B(\eta_\alpha^I)[2(1-\eta_\alpha^I)]^2}. \quad (8)$$

At the same time, substituting in this matrix element the expressions for $\Psi_I^{(R,L)}$ in terms of the eigenfunctions $\Psi_I^{(\pm)}$ of the Hamiltonian H , we obtain

$$\langle\Psi_I^{(R)}|H|\Psi_I^{(L)}\rangle = \frac{1}{2}(E_I^{(-)} - E_I^{(+)}). \quad (9)$$

Thus,

$$(E_I^{(-)} - E_I^{(+)}) = \frac{\hbar^2}{B(\eta_\alpha^I)[2(1-\eta_\alpha^I)]^2}. \quad (10)$$

For $I=3$, parity splitting $(E_I^{(-)} - E_I^{(+)})$ can be calculated using the experimental energies of the lowest 3^- , 2^+ , and 4^+ states. Substituting this value and $\eta_\alpha^{I=3}=0.9$ into Eq. (10), we obtain $B(\eta_\alpha)=660m \text{ fm}^2$, which is consistent with the value used in the calculations.

The experimental mean quadrupole moment Q_I is determined by the transitions in the spin range $I=12-22$. The best fit to data is obtained with $Q_I=2.75 \pm 0.45 \text{ eb}$ [7]. In the cluster model the transition quadrupole moment is determined by the following expression [8]:

$$Q_I = 2e \frac{A_1 A_2}{A^2} \left(A_2 \frac{Z_1}{A_1} + A_1 \frac{Z_2}{A_2} \right) R_m^2(\eta) \\ = \frac{1}{4} e A R_m^2(\eta) (1-\eta^2) \left((1-\eta) \frac{Z_1}{A_1} + (1+\eta) \frac{Z_2}{A_2} \right), \quad (11)$$

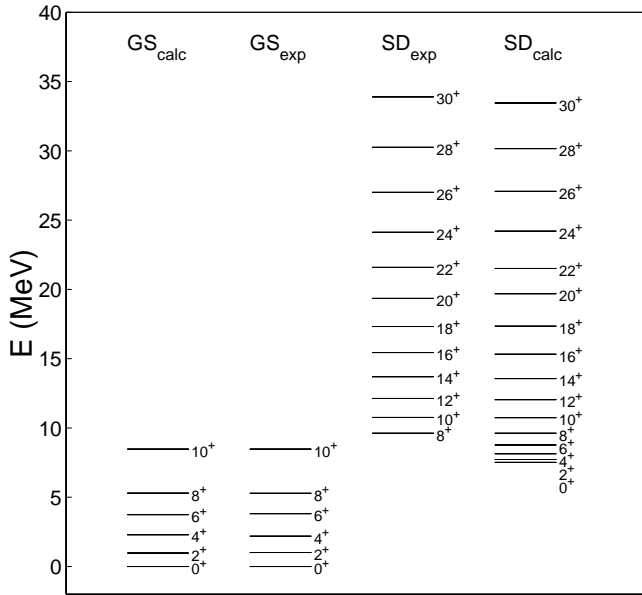


FIG. 2. Experimental and calculated energies of the states of the ground state (GS) and superdeformed (SD) bands in ^{60}Zn . Experimental data are taken from Ref. [7].

where the intercluster distance R_m is equal to

$$R_m(\eta) = [1.14(A_1^{1/3} + A_2^{1/3}) + s] \text{ fm} \quad (12)$$

and s takes values between 0 and 0.5. For the cluster configuration with ^8Be $A_1=52$, $A_2=8$, $Z_1/A_1=Z_2/A_2=Z/A=1/2$, and $Q_i=3.43 \text{ eb}$ for $s=0.5$ and $Q_i=2.96 \text{ eb}$ for $s=0$. Thus, the results of the cluster model are in agreement with the experimental data for the transition quadrupole moment. Concerning the moment of inertia, we already mentioned in the Introduction that the experimental moment of inertia of the superdeformed band is in correspondence with the moment of inertia of the cluster configuration $^8\text{Be} + ^{52}\text{Fe}$ calculated under the sticking condition.

Thus, our estimates show that the cluster interpretation of the properties of the superdeformed band in ^{60}Zn is quite realistic. In the following section we present the results of calculations of the energies and decay properties of the superdeformed band with Hamiltonian (1).

III. RESULTS OF CALCULATIONS AND DISCUSSION

The calculated spectra of the ground state and superdeformed bands are shown in Fig. 2. As is described in Sec. II, the energies of the states of the ground state band with spins from $I=0$ to $I=10$ have been used to fix the angular momentum dependence of the moment of inertia and the additional shift of the $U(|\eta|=1, I=10)$. The energies of the states of the superdeformed band are described quite well including a variation of the moment of inertia with spin. In our calculations this variation is reproduced because at spin values around $I=20$ the superdeformed band is crossed by the ground state band, located mainly in the α -cluster minimum, and becomes the yrast band above $I=20$. In Fig. 3 the experimental upbending plot for the superdeformed band is

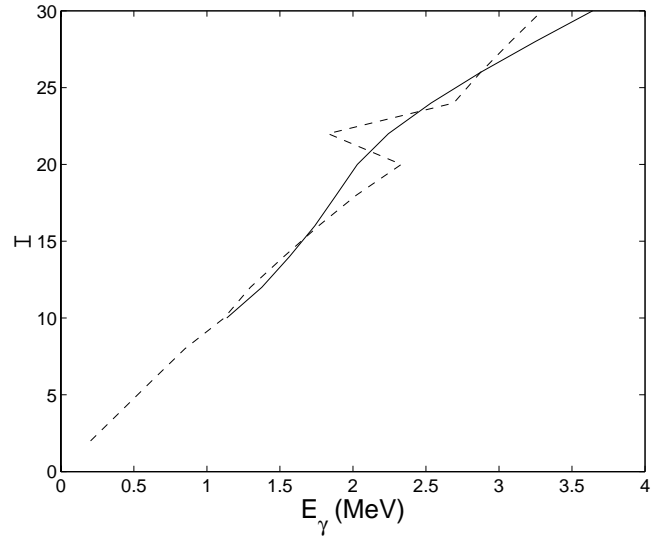


FIG. 3. Spin as a function of E_γ in the superdeformed band of ^{60}Zn . The results of calculations are shown by the dashed curve. The experimental data (solid curve) are taken from Ref. [7].

compared with the results of calculations. The calculations qualitatively reproduce a deviation from the smooth dependence of the angular momentum on the γ -transition energy. However, the effect is overestimated.

Figure 4 shows the squares of the wave functions of the states of the ground state and superdeformed bands taken at $I=8$ as functions of the variable x defined as

$$\begin{aligned} x &= \eta + 1 \text{ if } \eta \leq 0, \\ x &= \eta - 1 \text{ if } \eta > 0. \end{aligned} \quad (13)$$

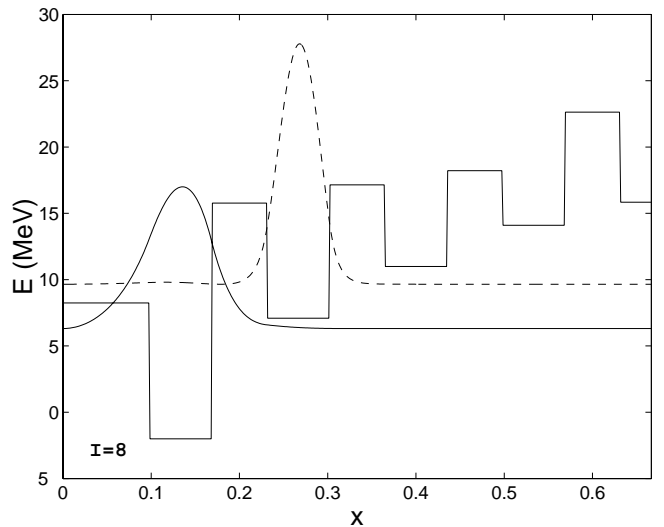


FIG. 4. Squares of the wave functions of the states of the ground state (solid curve) and superdeformed (dashed curve) bands with $I=8$ as functions of x . Definition of the variable x is given in the caption of Fig. 1. The scale for the squares of the wave functions is fixed so that at $x=0.4$ both wave functions are equal to zero.

It is seen that these wave functions are well separated. Let us consider the decay of the superdeformed states into the ground state band. We have calculated the branching ratios of the $E2 \Delta I=2$ intensities of the γ transitions. In the experiment for the 18_{sd}^+ , 16_{sd}^+ , and 14_{sd}^+ states only decay into the superdeformed states has been observed. In our calculations we obtain the branching ratios for these transitions

$$\frac{I(18_{sd}^+ \rightarrow 16_{g.s.}^+)}{I(18_{sd}^+ \rightarrow 16_{sd}^+)} = 0.02, \quad \frac{I(16_{sd}^+ \rightarrow 14_{g.s.}^+)}{I(16_{sd}^+ \rightarrow 14_{sd}^+)} = 0.07,$$

$$\frac{I(14_{sd}^+ \rightarrow 12_{g.s.}^+)}{I(14_{sd}^+ \rightarrow 12_{sd}^+)} = 0.18. \quad (14)$$

For the ratio $I(12_{sd}^+ \rightarrow 10_{g.s.}^+)/I(12_{sd}^+ \rightarrow 10_{sd}^+)$, where the lowest experimental 10^+ state is treated as the $10_{g.s.}^+$ state, the experimental value is 0.54 [18] and the calculated one is 0.42. For the ratio $I(10_{sd}^+ \rightarrow 8_{g.s.}^+)/I(10_{sd}^+ \rightarrow 8_{sd}^+)$ the experimental value is 0.60 [18] and the calculated one 0.63. If an upper limit of $\sim 4\%$ of the superdeformed band intensity is assumed for the unobserved $8_{sd}^+ \rightarrow 6_{sd}^+$ transition, a lower limit of 0.01 W.u. (Weisskopf unit) was obtained in [7] for the $B(E2; 8_{sd}^+ \rightarrow 6_{g.s.}^+)$. The calculated value of the $B(E2; 8_{sd}^+ \rightarrow 6_{g.s.}^+)$ is 0.19 W.u., which is large enough to explain an absence of the $8_{sd}^+ \rightarrow 6_{sd}^+$ transition. The last two ratios in Eq. (14) are, probably, not small enough to explain the absence of the corresponding transitions between the states of the superdeformed and the ground state bands. However, it is quite possible that the strength of the corresponding transitions is fragmented over several states that are not presented in our model, but can be reproduced by shell model calculations.

The crucial point for the asymmetric cluster structures is the existence of the alternating parity bands. Unfortunately, there is no experimental information about collective negative parity states in ^{60}Zn . There is known only the 3^- state at the excitation energy 3.504 MeV. With Hamiltonian (1) we have calculated the energies of the negative parity states. The results of calculations are shown in Fig. 5, together with the calculated positive parity states. It is seen from Fig. 5 that in the ground state band there is an appreciable shift of the negative parity states with respect to the positive parity ones, which is the parity splitting. In the superdeformed band the parity splitting practically disappears.

The last result contradicts the experimental observations in Ref. [7], which show that the absence of a population of the negative parity superdeformed states can be understood only if these negative parity states are shifted up by 0.5–2.0 MeV [18,19] with respect to the positive parity superdeformed states. The reason of the absence of this shift in our calculations can be the following. In our approach the antisymmetrization effect is taken into account by a density dependence of the effective nucleon-nucleon interaction used in the calculations of the cluster-cluster interaction potential and therefore in the calculations of $U(\eta, I)$ [8,15]. This procedure produces parity independent potential $U(\eta, I)$. In a pure microscopical treatment the antisymmetrization effect is taken into account in a different way: a total wave function

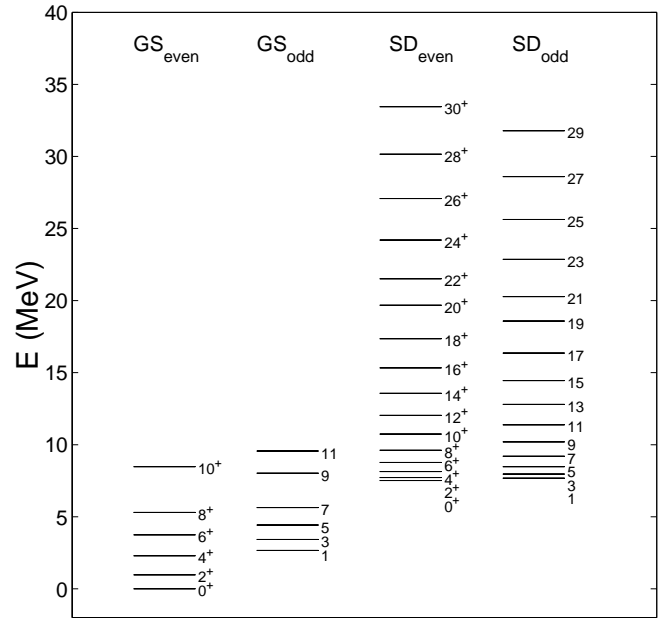


FIG. 5. Calculated energies of the positive and negative parity states in ^{60}Zn .

of the nucleus is taken as an antisymmetrized product of the cluster's wave functions. The antisymmetrization procedure excludes from this product components forbidden by the Pauli principle. The excluded components seem to be different for different parities. In light nuclei such as ^{60}Zn , open shells include only single particle states of the same parity. Therefore, in order to obtain states of negative parity in ^{60}Zn , at least one additional nucleon should be transferred from the p, f shell to the $g_{9/2}$ subshell. To obtain a notion of an additional energy needed to realize such a configuration, we can consider $p_{3/2}^{-1}g_{9/2} ph$ configuration as characterized by the largest octupole transition matrix element. The excitation energy of this configuration is 3–4 MeV [20] which is comparable to the 0.5–2.0 MeV parity splitting mentioned above. The shift of the potential for the negative parity states will not change our results for the positive parity states.

Thus, it is a crucial test of the model described above to look in more detail in the experiment whether the negative parity superdeformed states exist or not. If they exist but are shifted up in energy with respect to the positive parity superdeformed states it will support a treatment of the superdeformed band in ^{60}Zn as the asymmetric cluster configuration, although it will mean that approach should be more microscopic with respect to the account of antisymmetrization effects. If negative parity states do not exist it will exclude the asymmetric cluster treatment of the superdeformed band in ^{60}Zn . We mention, however, that our preliminary consideration indicates the possibility to consider the superdeformed band in ^{60}Zn as a mirror symmetric cluster configuration with two ^4He on the opposite sides of ^{52}Fe . This is possible because ^8Be is a system of two weakly bound α particles. This cluster configuration has approximately the same moment of inertia as $^8\text{Be} + ^{52}\text{Fe}$ configuration and leads to similar spectrum for the positive parity superdeformed states but excludes the negative parity superdeformed states.

IV. SUMMARY

In conclusion, we described the properties of the superdeformed band in ^{60}Zn including the branching ratios of the decay intensities of the $E2$ $\Delta I=2$ transitions with the dinuclear model, which is a variant of a cluster model. The Hamiltonian of the model contains the degree of freedom of mass asymmetry motion. Our analysis has shown that the states of the ground state band have a significant contribution of an α -cluster component. The states of the superdeformed

band are described mainly as Be-cluster configurations.

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