Nuclear structure investigations of the Ge isotopes by means of (p,t) reactions and microscopic studies of nuclear deformations and collective spectra

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(Received 7 March 1978; revised manuscript 15 June 1978)

Systematics are presented from our study of the Ge nuclei by means of the (p,t) reaction. From observed intensities and excitation energies, conclusions are drawn concerning structure and reaction mechanisms. They are discussed in the frame of microscopic calculations. These calculations predict a shape transition from a nearly spherical nucleus (^{70}Ge) to a slightly oblate one (^{74}Ge). The energies of the low-lying 0^+ levels are well fitted; dynamical effects induced by pairing fluctuations are shown to play a major role in this feature as well as in the striking evolution of their intensitie in the (p,t) reaction. A connection is presented with the possibility of 0^+ pairing isomer states. The outstanding splitting of the $L = 3$ strength at $N = 42$ appears as a characteristic feature of this region suggesting coupling effects in octupole modes.

NUCLEAR REACTIONS ^{70,72,74,76}Ge(p,t), deduced and presented systematics about nuclear structure and reaction mechanisms.

NUCLEAR STRUCTURE ^{70,72,74,78}Ge; calculated deformation energy curves and collective spectra. Used microscopic theory. Compared with experimental systematics.

I. INTRODUCTION

In previous papers,[1] we have presented our data for the ^{70,72,74,76}Ge$(p,t)^{68,70,72,74}$ Ge reactions. The analysis of the measured angular distributions has permitted us to propose many new spin and parity assignments up to 4.5–5 MeV excitation energy and to locate some new 0^+, 2^+, and 4^+ levels among the first excited levels of the Ge isotopes. The aim of the present paper is mainly to develop the systematics and to discuss our whole data in order to bring out the specific features of nuclear structure and reaction mechanism that are revealed by our results after comparison with neighboring data and with the usual interpretations of two-nucleon transfer reactions.

Few calculations are available on the even Ge nuclei, but the structure of their low-lying 0^+ (first) excited state has been much discussed together with the transitional type of such nuclei. In a recent paper,[2] we have presented Hartree-Fock calculations that led to the possibility of an oblate to prolate shape transition between $N = 36$ and 46. However, these calculations are restricted to axially symmetric nuclei and cannot account for pairing fluctuations induced by dynamical effects. These pairing fluctuations and competitions between collective and single-particle effects are characteristic of transitional nuclei and are highly suggested by our data. The recent dynamic deformation theory has been shown[3,4] to give good fits for a large range of transitional nuclei and for shape (or gap) transitions. The second aim of this paper is to use the available results of this theory to discuss our experimental data and the related data found in the literature.

II. DISCUSSION OF THE (p,t) DATA

A. Observed level energies and intensities

Using the summed cross sections of our (p,t) data, we have reported in Fig. 1 the observed

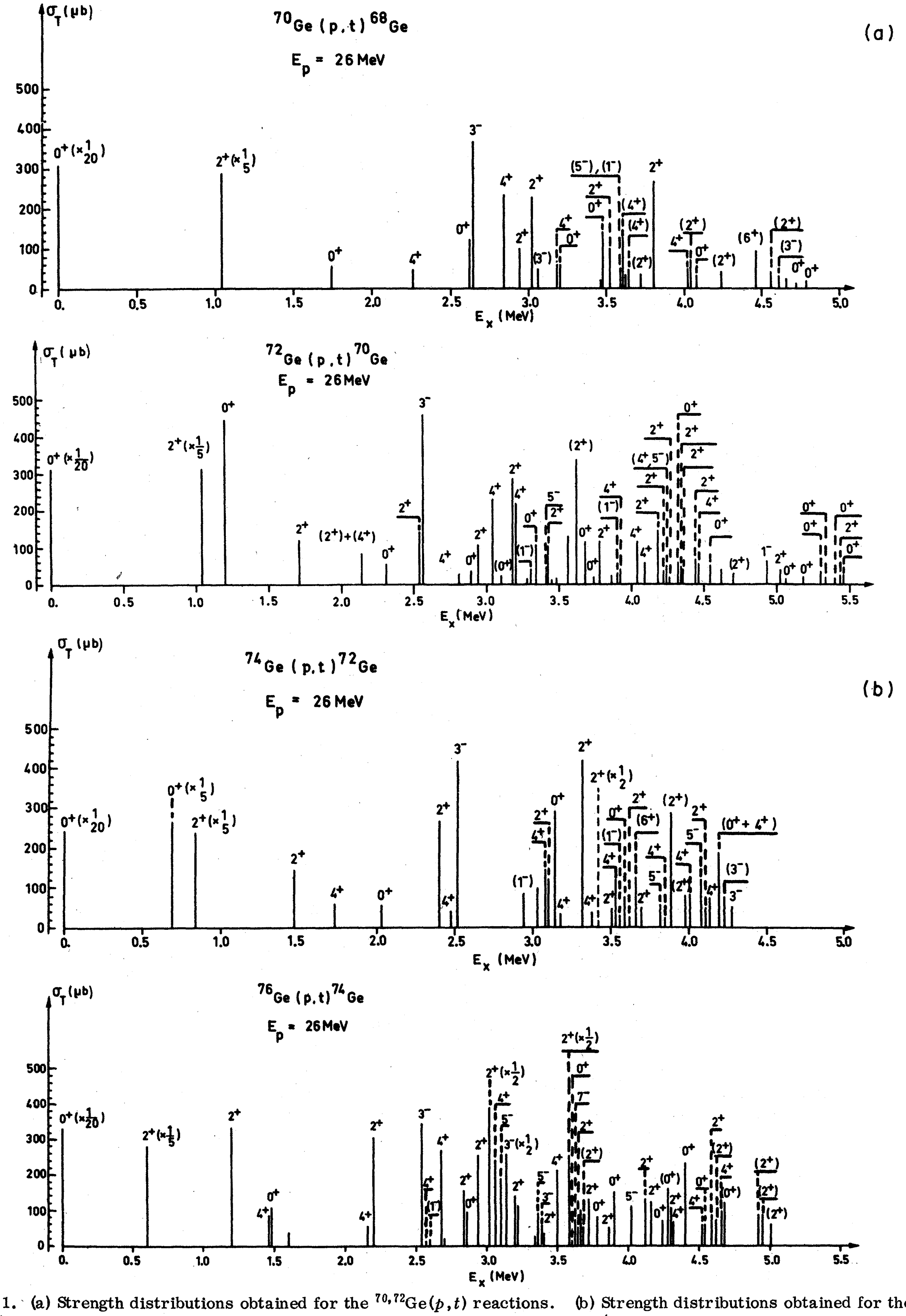

FIG. 1. (a) Strength distributions obtained for the ^{70,72}Ge(p,t) reactions. (b) Strength distributions obtained for the ^{74,76}Ge(p,t) reactions. Vertical bars refer to the summed cross sections in mb/sr.

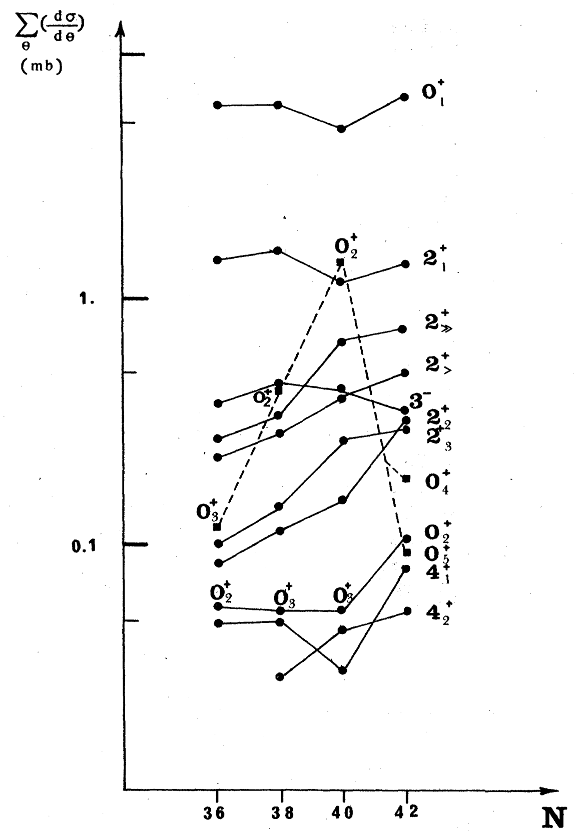

FIG. 2. Experimental summed cross sections versus the neutron number of the residual Ge isotope for some first excited levels (see text). The symbols > and ≫ refer to two strongly populated $J^\pi = 2^+$ levels near 3.2 MeV energy. The drawn correspondences between levels of the same spin and parity are based on similarities in intensities or angular distribution shapes (see Secs. II A and II B).

strength distributions for the ^{68}Ge, ^{70}Ge, ^{72}Ge, and ^{74}Ge isotopes. Their variations versus the neutron number N of the residual nuclei are also reported in Fig. 2 for some of the first excited levels. One observes the correlation between the ground state (0_1^+), the first excited 2^+ and 4^+ states (2_1^+ and 4_1^+) characterized by a relative regularity in the four isotopes except for a marked minimum occurring at $N = 40$ (^{72}Ge). (The presence[1] of a contaminant in the ^{72}Ge 4_1^+ state has only permitted a rough estimate of its summed cross section.) The excitation energies of the 2_1^+ and 4_1^+ states show a regular decrease (Fig. 3) up to $N \sim 42-44$. The same is true (Fig. 3) for the 2_2^+, 2_3^+, and 4_2^+ states which, moreover, exhibit a regular and similar increase of their intensities (Fig. 2). It can be also observed in Fig. 1 that the four ^{68,70,72,74}Ge isotopes exhibit two strongly populated $J^\pi = 2^+$ states in the energy range from 3 to 4 MeV; these levels, labeled 2^+≫ and 2^+>, are connected in Figs. 2 and 3 according to the criterion of comparable intensity.

The most striking feature shown in Fig. 1 appears for the first 0^+ state. The first excited 0^+ states (0_2^+) are strongly populated in the ^{72}Ge and ^{70}Ge nuclei while they are weakly populated in ^{68}Ge and ^{74}Ge. Even at higher excitation energy, one cannot find strongly populated 0^+ levels in ^{68}Ge and ^{74}Ge: The 2.617 MeV $J^\pi = 0^+$ level in ^{68}Ge carries only 2% of the ground state strength; the possible $J^\pi = (0^+)$ levels at 1.726 MeV (Ref. 5) and 2.229 MeV (Refs. 6 and 7) in ^{74}Ge do not seem noticeably populated in our reaction. However, we emphasize the existence of an important $L = 0$ transition at 3.139 MeV in ^{72}Ge. The strengths carried by this level and by the 0_2^+ at 0.690 MeV make up almost exactly for the missing strength in the ^{72}Ge ground state strength (Fig. 2).

The behavior of the first excited 0^+ state appears markedly different from the behavior observed in the case of Se and Kr isotopes according to the available (p,t) data on these nuclei. Recent experiments[8,9] on the ^{78,76}Se$(p,t)^{76,74}$Se reactions have shown that the relative strength of the 0_2^+ level is much weaker at $N = 40$ than in ^{72}Ge (only 4% of the ground state strength). The relative (p,t) cross section for the 0_2^+ state in ^{76}Kr ($N = 40$) is only 1% and much smaller than the value measured in ^{78,84}Kr isotopes[10] (greater than 10% of the ground state transition). These results suggest a strong influence of the proton number on the neutron pairing correlations around $N = 40$. This feature also appears in the experimental proton transfer data with (^{3}He,d) or (d,^{3}He) reactions where the neutron number strongly affects the measured strengths.[2,7,11]

The predominance of the $L = 0$ ground-state transition in this region might suggest a superfluid structure. Indeed the comparison of the experimental ground state energies of the Ge nuclei with the pairing rotational model[12] (Fig. 4) shows a smooth variation with the neutron number (between 32 and 48) well reproduced by a linear plus a quadratic term as predicted by this model. However, when one looks at the relative (p,t) transition strengths between the ground states, the pairing rotational scheme fails near $N = 40$. Clearly a phase transition is taking place here, indicating pairing fluctuations or coupling of pairing mode to other modes of excitation (such as proton-neutron coupling as suggested above) not taken into consideration in a pure pairing description.

Another striking feature of our data is the first excited 3^- state. This state has a noticeable constant excitation energy (~2.5 MeV) in the ^{68,70,72,74}Ge isotopes and represents the near totality of the $L = 3$ strength. In ^{74}Ge this strength is divided into two levels at 2.542 and 3.147 MeV (Fig. 1). Their strengths make up for the strength observed for

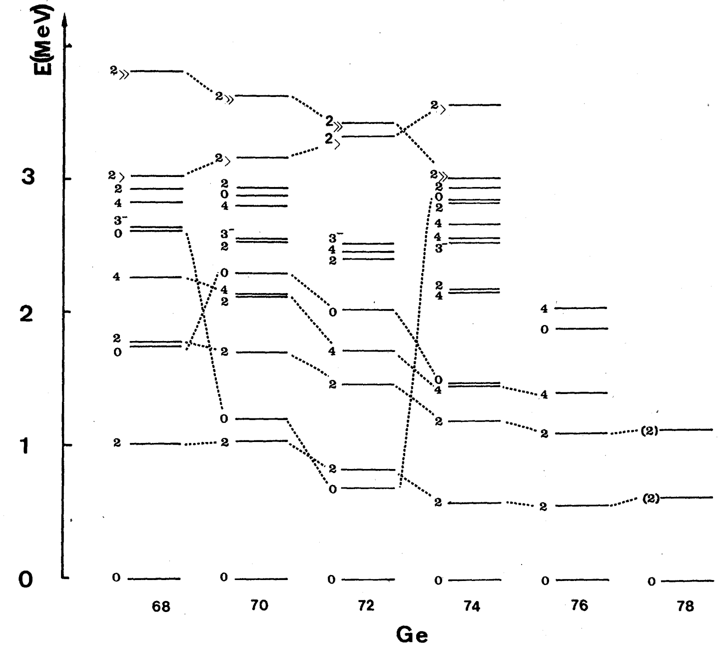

FIG. 3. Correspondences drawn between some of the levels of ^{68,70,72,74}Ge populated by the Ge(p,t) reaction (see text). All the levels observed below 3 MeV are quoted here plus two strong populated 2^+ levels (labeled $2^+>, 2^+\gg$) above 3 MeV. Additional levels of ^{76,78}Ge taken from Ref. 25 are shown in order to picture the tendencies discussed in Sec. IV. The parity of all the levels is positive except when indicated.

the 3_1^- state in the other isotopes. The found constancy of the total $L=3$ strength is in disagreement with an interpretation of the 3^- states as simple configurations including the positive parity orbitals (i.e., $1g_{9/2}$). In this frame, one expects an increasing $L=3$ strength between $N=36$ and 42. A survey of the (p,t) data for a large range of nuclei shows that splitting of the $L=3$ strength (as in ^{74}Ge) may occur for deformed nuclei. The same observations and conclusions have been drawn[14] from (d,d'), (α,α'), or (p,p') inelastic scattering data. A splitting of the octupole strength has been observed for the ^{74,76}Ge(p,p') reactions by Curtis *et al.*[5] correlated with a strong decrease of the $B(E3)$ strength for the lowest 3^- state. Similar observations have recently been quoted in the Kr (p,p') data of Matsuki *et al.*[15] for ^{78,80}Kr, isotones of ^{74}Ge and ^{76}Ge ($N=42$ and 44, respectively). The possibility of a larger deformation for $N\geqslant 42$ then could be supported by our data.

B. 0^+ states angular distributions

Our analysis of the (p,t) data has shown[1] anomalies in the shape of some angular distributions. Particularly, the angular distributions of the 0_2^+ state at 1.481 MeV in ^{74}Ge, the 0_3^+ state at 2.029

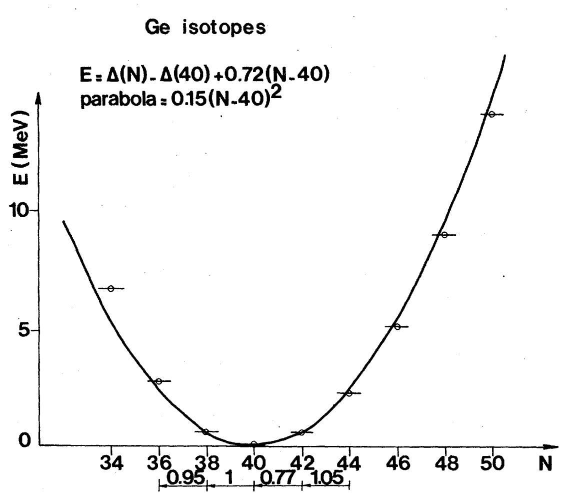

FIG. 4. The Ge pairing rotational band. The energies plotted versus neutron number N are the mass excess of each isotope minus the ^{72}Ge one plus a linear term in $(N-40)$. The coefficient was chosen so that $E(^{70}\mathrm{Ge}) = E(^{74}\mathrm{Ge})$. The equation of the parabola is found by forcing it through the three values $E(^{70}\mathrm{Ge})$, $E(^{72}\mathrm{Ge})$, $E(^{74}\mathrm{Ge})$. The numbers below the N axis are our observed Ge(p,t) cross sections normalized to the ^{72}Ge $\rightarrow$ ^{70}Ge transition. The mass excesses are from Ref. 1 for ^{68}Ge and Ref. 13.

MeV in ^{72}Ge and to a less extent the 1.753 MeV in ^{68}Ge differ drastically from the other $L=0$ transitions. As was already mentioned,[1] they exhibit two maxima at 25° and 55° which are completely out of phase with the usual $L=0$ shapes. Our set of optical parameters which otherwise well reproduces our whole data and $L=0$ transitions in the same range of energy cannot account for such features. Several attempts were made with other optical model parameters but appeared unsuccessful due to shapes very different from the usual $L=0$ direct patterns.

The above discrepancy is to our knowledge mentioned for the first time in this mass region for a two-neutron transfer reaction. We would like to point out that exactly the same anomalies are observed in our recent Ge(t,p) data[16] for the 0_3^+ state in ^{74}Ge and the 0_2^+ state in ^{72}Ge. Their occurrence for specific states in the two inverse reactions correlated with a decrease of the transfer intensity in both cases denotes a strong structure effect correlated with different transfer mechanisms.

Recent coupled-channel-Born-approximation (CCBA) studies have been made by Udagawa[17] and Izumoto[18] for (p,t) reactions leading to two-phonon states of vibrational nuclei. Indeed, the Cd(p,t) data show shape and magnitude variations in the angular distributions of the 0_2^+ states, rather similar to ours. They were explained[17] by the introduction of a small amount of direct process from the ground to a two-phonon state. This transition, forbidden in the description of a two-phonon state by a four quasiparticle state could be accounted for by a mixing of two phonon and two quasiparticle states indicating a wave-function change with mass number. From all the above calculations, a destructive interference between direct and indirect processes was found for target nuclei in the beginning of major shells and a constructive one when the shells are almost full. The above systematics and occupation number dependence have been found[18,19] appropriate for a wide mass region. It would be very interesting to see if our data could be explained by such calculations. This would require a competition between quasiparticle and collective states in the description of the first excited states.

III. STRUCTURE CALCULATIONS

In order to account for the above observations, any structure calculations for the Ge nuclei should be microscopic so as to allow for coupling between collective and single-particle motions. The experimental data suggest also a great influence of the pairing fluctuations as well as strong correlations between proton and neutron numbers. Furthermore, the difficulty in distinguishing valence from core nucleons in these nuclei (far from closed shells) implies that all the nucleon states must be included. In order to distinguish between the mechanisms responsible for the transitions and the fluctuations quoted above, the model predictions have to depend on as few parameters as possible and to cover a large range of nuclei.

A. Presentation of our microscopic calculations

We have investigated the Ge nuclei structure with the dynamic deformation theory of Kumar *et al.* which has been shown[3] to take most of the above features into consideration with rather good success for many even-even nuclei. Partial results of these calculations for the Ge isotopes have already been published.[4,20,21]

This theory is an improvement of the pairing-plus-quadrupole model[22] with the aim of including all the nucleons in the calculations and by the way, reducing the number of adjustable parameters. The potential energy of deformation is the shape-dependent part of the binding energy. Self-consistent methods have also been used[2] but due to the complexity of the calculations, they have usually been restricted to axially symmetric shapes which are not enough for the full dynamical studies. The dynamic deformation theory uses a modified Nilsson model to define the deformed-single-particle basis; the $\vec{l}\cdot\vec{s}$ and $\vec{l}^2$ potentials are taken to be shell dependent, without any isospin dependence. The deformed single particle basis is thus computed once for all. The pairing correlations are introduced via the BCS theory with an isospin- and A-dependent strength. A first estimate for the binding energy is obtained by summing all the single particle energies at each deformation. Due to the lack of self-consistency of such a method, only the levels near the Fermi surface are well determined and only the short range behavior of the binding energy is reproduced. The Strutinsky method is used to extract this shell-dependent part. To compute the uniform part of the binding energy, two models have been used: (i) the liquid drop model with the parameters given by Seeger and Howard,[23] (ii) the droplet model with the surface diffuseness correction of Myers and Swiatecki.[24] The two parametrizations are comparable at small deformations, but become significantly different for larger values of β, the first one giving nuclei too soft against deformation.[20] The droplet model has been employed in the calculations reported in the present paper.

The potential energy is not sufficient to describe the full dynamics of the nuclear deformations. In addition to the potential, the collective Schrödinger equation is determined by six inertial functions. Previous calculations have shown those to be very sensitive to the variations of the level density near the Fermi surface. The three moments of inertia and the three mass parameters are calculated in the complete β-γ plane with a modified version of the Kumar and Baranger method.[4] The collective Schrödinger equation is solved numerically with the method of Kumar.[22]

B. Single-particle level structure around N=40

In Fig. 5, one can see the single-particle level structure as calculated in the dynamic deformation theory.[20] The subshell closure at $N=40$ disappears quickly when the β deformation parameter increases. Two important gaps appear on the oblate side ($\beta \simeq -0.3$ and $\beta = -0.6$) at $N=36$ and $N=40$ due to the bunching of the $g_{9/2}$ levels. One can also notice that two $f_{5/2}$ levels stay very close for all negative values of β; the coexistence of important and small gaps around $N=40$ induces strong variations of the level density near the Fermi surface when the nuclear shape changes at constant N value. The level density is somewhat smoother on the prolate side. Some positive parity $g_{9/2}$ levels go deep inside the negative $p_{1/2}$ and $f_{5/2}$ levels as soon as the spherical shape is lost; it is expected that the occupation probability of the $g_{9/2}$ states must strongly depend on the intrinsic shape of the nucleus. Apart from a Z-A-dependent scaling factor for the level energies, our single particle basis is the same for proton and neutron states; both are pictured in Fig. 5, and any evolution in the proton-single-particle states for the different germanium isotopes ($Z=32$) can only be described in our model by shape fluctuations.

IV. DISCUSSION OF EXPERIMENTAL AND THEORETICAL RESULTS

As outlined above (Sec. II), the experimental data show two main features: (i) intensities and energies of corresponding 0^+, 2^+ and 4^+ states vary smoothly with N, (ii) a drastic change occurs close to $N=40$ especially for 0^+ states.

A. General evolutions of the Ge isotopes structure

In all the Ge isotopes studied, the energy centroid of the "triplet" 0^+, 2^+, 4^+ is located at about two times the energy of the 2_1^+ state. This feature indicates a vibrational rather than a well deformed character confirmed by our calculations for ^{70,72,74}Ge, for which the deformation energy $|V(\beta=0)-V_{min}|$ is less than 1.5 MeV which is not sufficient to make them well deformed. However, the potential energy surfaces (Fig. 6) show an increasing trend towards oblate deformation as N goes from 38 to 42. This trend is responsible for the regular lowering of the sequence 2_1^+, 4_1^+ already quoted in Sec. II. The available experimental data[25] on ^{76}Ge and ^{78}Ge (Fig. 3) show a rising of these levels indicating an evolution towards sphericity due to the proximity of the $N=50$ shell closure. This feature is well supported by our calculations[25] for ^{78}Ge where the magnitude of the deformation energy is found quite similar to the ^{74}Ge one.

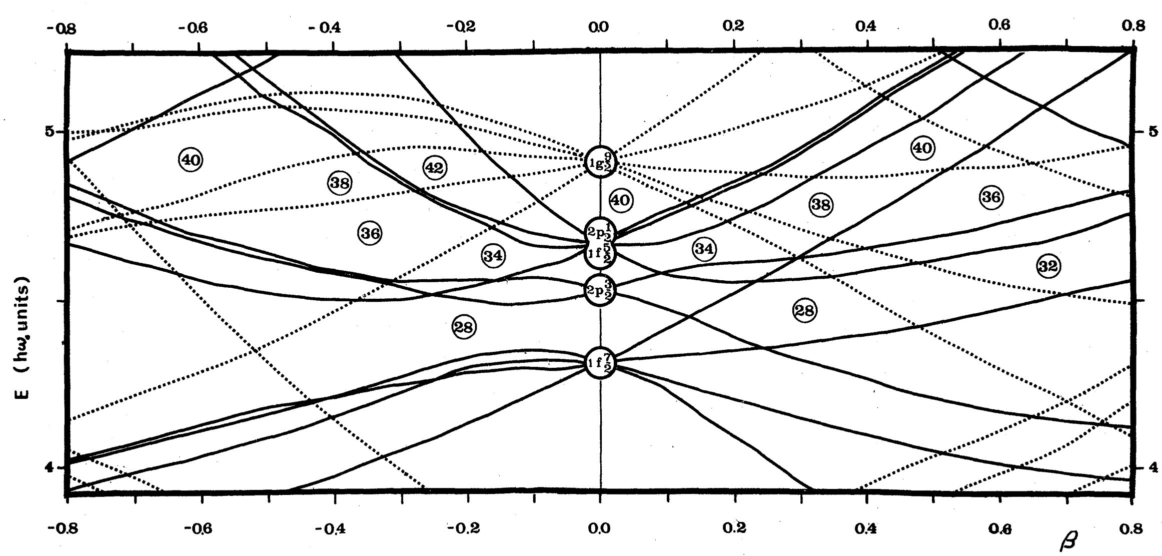

FIG. 5. Single particle levels for nuclei in the region $20 < N$ (or Z) < 50. Each line gives the single particle energy (in $\hbar\omega_0$ units) for axial symmetries of the nucleus ($\beta < 0$ for oblate symmetry and $\beta > 0$ for prolate). Full and dotted lines are, respectively, for negative and positive parity levels.

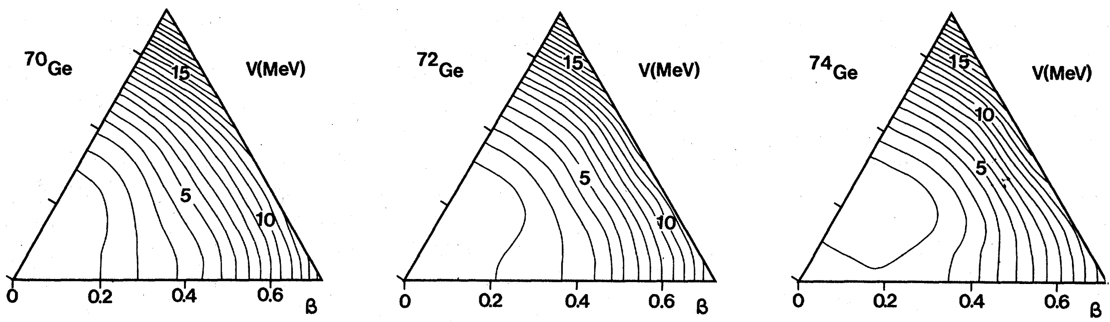

FIG. 6. Contour plots of the potential energy of ^{70,72,74}Ge. The deformation varies radially from 0.0 to 0.8, the asymmetry parameter γ varies from 0° (on the lower side) to 60° (on the left side). The equipotential curves are plotted for each integer value (in MeV units) of the potential energy. The potential energy is normalized to 0.0 for its minimum.

The calculated spectra shown in Fig. 7 present a remarkable agreement with the experiment. It should be emphasized that only one free parameter[4] (the Strutinsky width parameter Γ was used for these calculations). The energies of the first excited 2^+ and 4^+ states are well reproduced (Fig. 7) leading to a coherent description of these low-energy states in terms of zero-quasiparticle collective states. Moreover, the $B(E2)$ values of the 2_1^+ states are correctly fitted.[4] The splitting of the triplet 0^+, 2^+, 4^+ between 1.5 and 2 MeV is also well reproduced. Thus our discovery of the 2.029 MeV 0^+ level in ^{72}Ge and confirmation of the 2.307 MeV 0^+ level in ^{70}Ge put an end to the open question of the belonging of the low-lying and first excited 0^+ state to this triplet. The correct sequence of the upper levels ($2_3^+, 3_1^+, 4_2^+, \ldots$) is also found as well as the decrease of their excitation energies

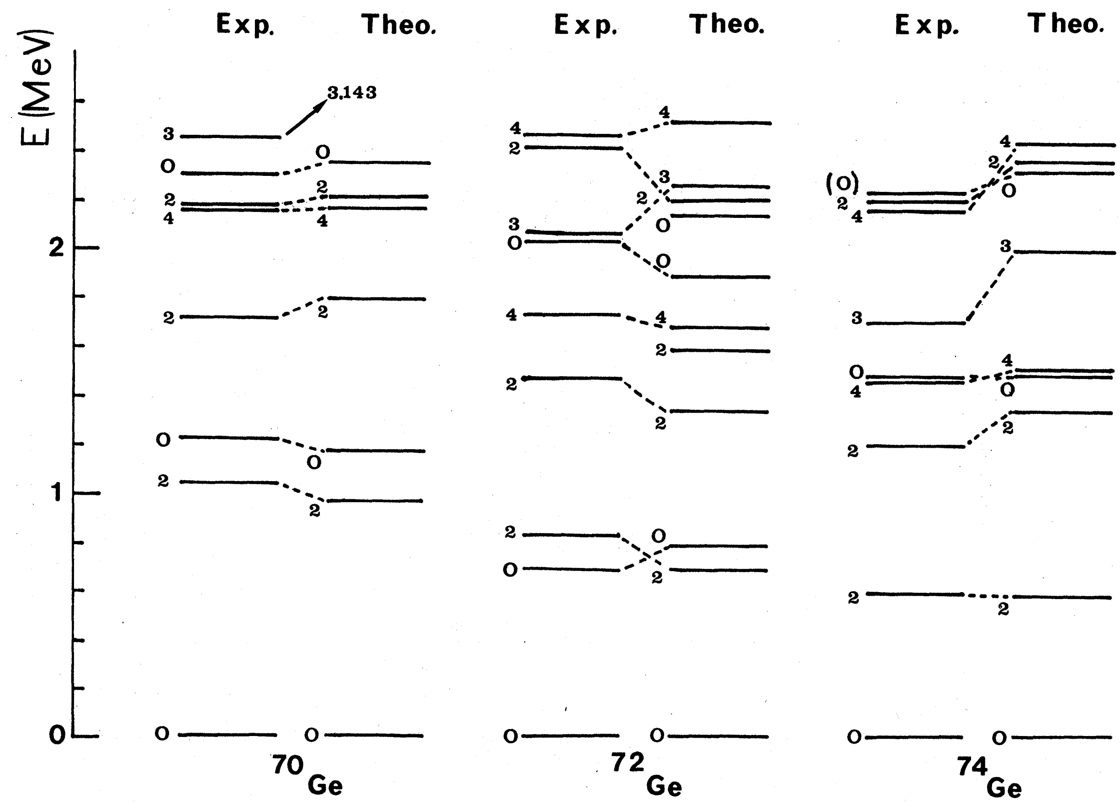

FIG. 7. Comparison of experimental and theoretical spectra for positive-parity levels of ^{70,72,74}Ge. The experimental levels are those observed in our (p,t) study except for the 3^+ states in the three isotopes and the $J^\pi = (0^+)$, 2.229 MeV ^{74}Ge level taken from the literature (see text).

(with increasing N): This last feature seems to be connected with the general increase of the moments of inertia associated with all the excited states. As these levels are thought to be rather sensitive to the asymmetry parameter γ, we can say that the Ge nuclei are rather soft as suggested by the feature of the potential energy surfaces.

B. Evolution of the low-lying 0^+ states around N=40

We have discussed the similarities for intensities and transfer mechanisms of some low-lying 0^+ states (Sec. II A): They have led us to propose correspondences between the 0^+ states at 1.753, 2.311, 2.029, and 1.481 MeV in ^{68,70,72,74}Ge, respectively (see Fig. 3). The two remaining lower 0^+ states at 0.690 MeV in ^{72}Ge could then correspond to higher excited and weaker populated 0^+ states in ^{68,74}Ge (Figs. 2 and 3); or at least, their structure has no similarity with other 0^+ states in $N=36$ or 42. Two questions arise about these 0^+ states: (i) their very low and much debated excitation energy which can be interpreted by structure calculations, (ii) their strong population in (p,t) or (^{3}He,d) (Ref. 2) reactions which can be described by reaction-mechanism calculations based on the above ones.

The present calculated spectra show a nice agreement with the experimental first excited 0^+ states in ^{70}Ge and ^{72}Ge (Fig. 7). Although two quasiparticle states are not included explicitly in the dynamic deformation theory, they are included via the dynamics. In particular, the dynamics of pairing fluctuations has important effects on the 0^+ states. As discussed in Ref. 4, these fluctuations induce strong variations in the values of the mass parameters versus deformation. Except for regions of large deformation ($\beta > 0.5$), the mass parameter B_{00} displays two peaks, one at $\beta \simeq -0.4$ and one at $\beta \simeq 0.25$. [See Fig. 8(c) for ^{72}Ge. Note that similar peaks occur in the B_{00} of ^{70,74}Ge.] The three 0_2^+ wave functions are pictured in Fig. 8(a). Although, the three potential energy surfaces (Fig. 6) are significantly different, one can see that the

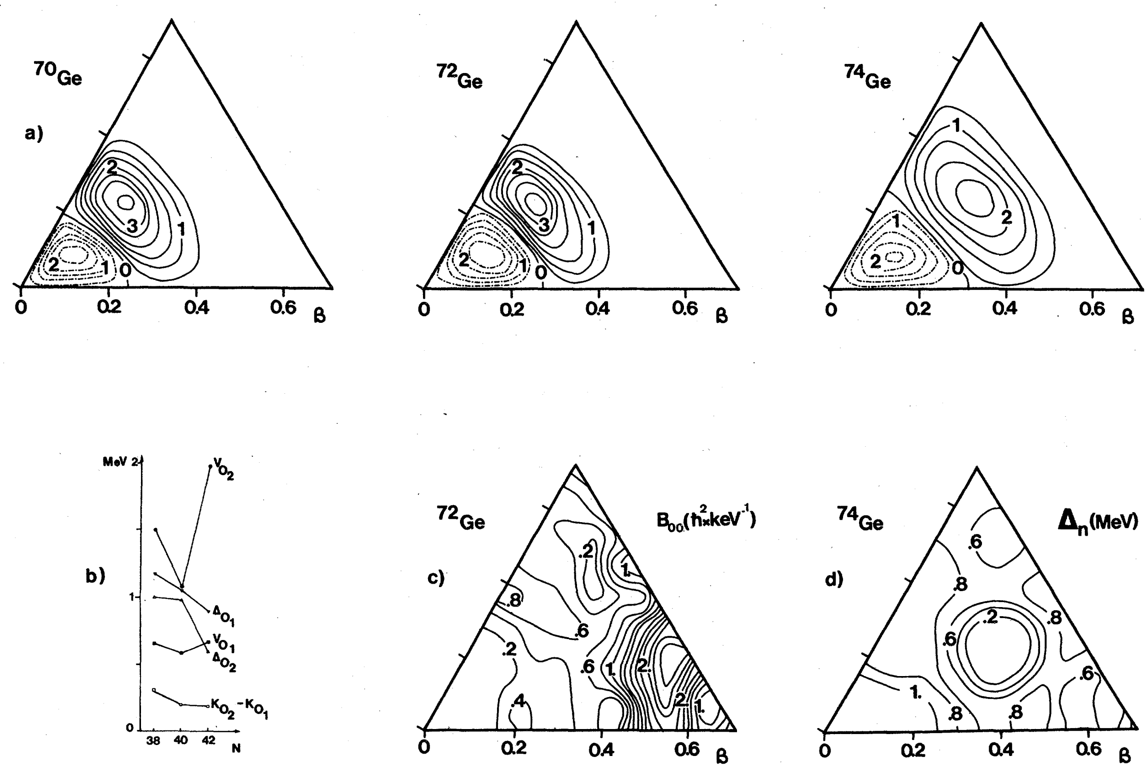

FIG. 8. Dynamic calculations for ^{70,72,74}Ge. (a) Contours plots of the wave functions of the first excited 0^+ state in arbitrary units. Full curves are for the positive part of the wave functions, the dashed and dotted curves are for the negative part. (See Fig. 6 for the parametrization of deformations). (b) Evolution with increasing neutron number N of some mean values. V_{01}, Δ_{01}, and K_{01} are, respectively, the potential energy, the neutron pairing gap, and the kinetic energy of the ground state. V_{02}, Δ_{02}, and K_{02} are the same for the first excited 0^+ state. Lines are for eye guiding. (c) Contour plot of the vibrational mass parameter B_{00} for ^{72}Ge. (d) Contour plot for the neutron pairing gap. Curves connect the points of equal pairing gap. The gap collapses in a broad area centered around $\beta \simeq 0.45$ and $\gamma \simeq 30°$.

three wave functions are very similar. The mass parameter peak at $\beta \approx -0.4$ pushes the wave function towards larger deformation in the first excited 0^+ state of all three nuclei. Also, the kinetic energy contribution to the excitation energy is very low in all three isotopes [see Fig. 8(b)]. The 0^+ excitation energy is lowest in ^{72}Ge because of the lowest change in potential energy [see Fig. 8(b)], which occurs because ^{72}Ge is softest against change in nuclear shape. However, the pair fluctuations (causing the mass parameter peak) play an essential role in lowering the 0^+ states.

Due to the small average deformation of these nuclei, only a few particle configurations are needed in the description of the low-lying levels. A collective interpretation of them is then not in contradiction with the two particle-two hole description that we have previously given[26,27] for the 0^+ levels in ^{72}Ge. The intensity of the 0_2^+ ^{72}Ge level in the ^{74}Ge$(p,t)^{72}$Ge reaction was calculated by this model to be 30% of the ground state one in very good agreement with the experimental ratio (27%).

The rapid evolutions of the transfer intensities can be connected to either a shape transition [28]or to pairing fluctuations.[29] The dynamic calculations discussed above do not seem to favor the first interpretation as only a soft shape transition has been found. As is well known,[23] the intensities of two nucleon-transfer reactions are very sensitive to the occupation probabilities of single-particle states near the Fermi surface and, hence, to the pairing correlations. We have already discussed in Sec. III B, that bunching and gap appear alternately in the single-particle energies around $N=40$. The calculated neutron pairing gaps, collapse for ^{70,72}Ge at too large deformations to affect the first excited levels.[20] For ^{74}Ge, the collapse occurs at $\beta \simeq 0.4$ [Fig. 8(d)] near the maximum of the 0_2^+ wave function [Fig. 8(a)]. The mean value of the pairing gap is thus lowered and reaches $\frac{2}{3}$ of the ground-state pairing gap [Fig. 8(b)]. Such situations seem to favor the appearance of low-lying 0^+ pairing isomers as defined in Ref. 29. A definitive answer to this possibility can only be given by mechanism reaction calculations including nonphenomenological form factors and which must also account for the anomalies observed in some angular distributions shapes (see Sec. II B). Such calculations are now in progress.[30] Among the remaining questions raised by the experimental data (Sec. II A), we have to deal with the splitting of the $L=3$ strength at $N=42$. The interpretation of this splitting may arise from the coupling of octupole modes to quadrupole deformations or to single-particle excitations.[31,14] The latter could be favored by the lowering of some positive parity $g_{9/2}$ levels (Fig. 5). Moreover, their strong shape-dependent occupation probabilities (Sec. III B) could account for the experimental constancy of the $L=3$ strength between $N=36$ and 42. The above microscopic model, which deals at present only with the positive parity states, cannot account for such mechanisms.

V. CONCLUSION

The structure of the even Ge nuclei has been investigated by means of (p,t) experiments and microscopic calculations. The theoretical study has permitted us to describe the low-lying excitation spectra of ^{70,72,74,78}Ge as arising from a shape transition from a spherical ^{70}Ge to weakly deformed ^{74,78}Ge. Our systematics of the (p,t) data has outlined connections between several excited levels up to 3 MeV excitation. We emphasize the experimental identification of some new 2^+, 4^+, and especially 0^+ states around 2 MeV which clarifies the interpretation of the spectra. A nice agreement has been obtained between experimental and theoretical spectra. The striking evolution of some low-lying 0^+ states, which has been discussed for years, has been connected to dynamical effects induced by pairing fluctuations; these are also responsible for the strong variation of the 0_2^+ cross section observed in our data. A connection has been also presented with the possibility of 0^+ pairing isomers states.

Another noticeable feature of our experimental systematics is the occurrence of several 3^- states strongly populated in ^{74}Ge, the interpretation of which implies the necessity of octupole mode calculations in this region. Finally, the wave functions calculated by the dynamic deformation theory will be a useful tool for the calculation of two-neutron amplitude transitions and for an interpretation of some multistep mechanisms clearly revealed by our data.

We are indebted to Dr. J. S. Vaagen for helpful discussion about our results.

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