FOUR-QUASIPARTICLE ALIGNMENTS IN ^{66}Ge*

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Above angular momentum 10^+, we found two positive-parity sequences, connected by energetically staggered $\Delta I = 1$ M1 transitions. The total Routhian surface calculations predict a strong triaxial deformation for them. To our knowledge, this is the first observation of staggered M1 transitions in a deformed four-quasiparticle $\pi(g^2_{9/2})\nu(g^2_{9/2})$ regime.

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Up to now, no positive-parity band structures have been investigated above the first band crossing in ^{66}Ge. The aim of the present work was to investigate the 4-*qp* $(\pi g^2_{9/2})\nu(g^2_{9/2})$ alignment in ^{66}Ge.

The neutron-deficient nucleus ^{66}Ge was populated at high spin in two experiments using the reaction ^{40}Ca(^{32}S,$\alpha 2p$) at beam energies of 105 and 95 MeV. In the first experiment, a self-supporting ^{40}Ca target (860 μg/cm^2) was used, while a target of similar thickness deposited on a 15 mg/cm^2 gold backing was used in the second experiment. Gamma rays were detected with the EUROBALL array, combined with the charged-particle detector system EUCLIDES and the Neutron Wall. We sorted matrices and cubes for the

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different reaction channels. In addition to the latest study [1], we extended the level scheme (see Fig. 1) by two new level sequences on top of the 6581 and 9404 keV states, respectively. The previously known part of the level scheme was complemented with newly observed transitions. On the basis of DCO analyses, spin assignments for most of the new levels were possible and previous assignments could be confirmed or rejected.

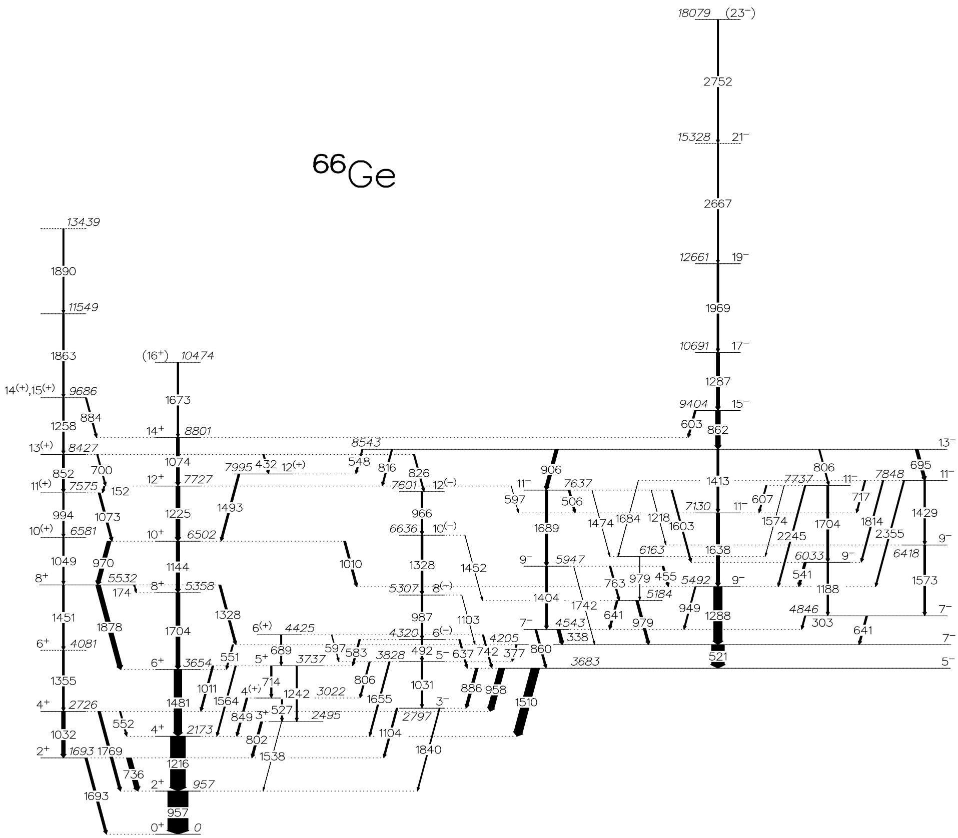

Fig. 1. Level scheme of ^{66}Ge deduced from the present experiment.

The TRS calculations for ^{66}Ge give five degenerate minima at $\hbar\omega = 0$ MeV, having β_2 values in the range 0.20–0.23 and different γ-values, forming in this way long valleys on the TR surfaces (see Fig. 2 on the left). Thus, ^{66}Ge turns out to be extremely soft with respect to triaxial degrees of freedom. An indication of γ-softness also comes from the γ-band, forming a (3^+,4^+) and (5^+,6^+) clustering. Above spin 10^+, the newly observed yrast sequence in ^{66}Ge differs from that in ^{68}Ge as well as in the heavier Ge isotopes, where rotational aligned $\Delta I = 2$ bands develop. The discussed

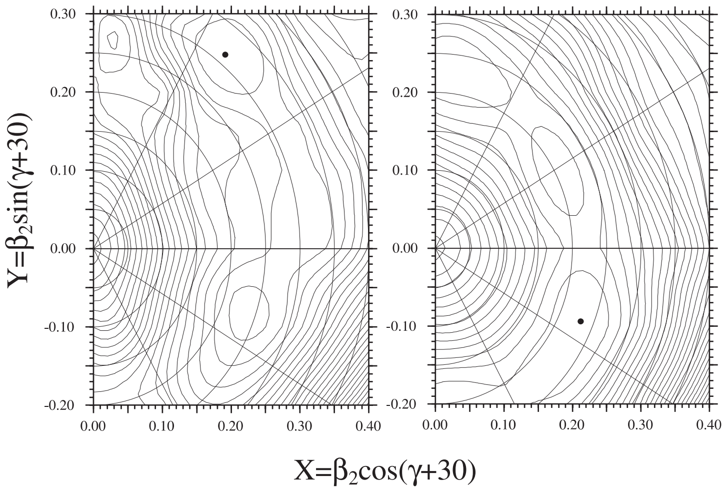

Fig. 2. TR surfaces for positive-parity states in ^{66}Ge at a frequency of 0 (on the left) and 0.693 (on the right) MeV.

sequence resembles a band with two signature partners, connected by staggered $\Delta I = 1$ M1 transitions. Actually, this structure is similar to the level structures above the 12_1^+ states in the spherical at their ground state $N = 46$ isotones ^{84}Sr, ^{86}Zr, and ^{88}Mo [2] and in the deformed at their ground state $N = 44$ isotones ^{84}Zr [3] and ^{86}Mo [4]. A strong influence of the spherical shell-model $\pi(g_{9/2}^2)\nu(g_{9/2}^2)$ 4-*qp* configuration was obtained for them. The recoupling of spins in this configuration is proposed to explain [2] the observed M1 energy and strength staggering. The resemblance of the level sequence above the 10^+ states in ^{66}Ge with that 4-*qp* structures suggests a decrease of deformation and even a near spherical shape. However, at $I \approx 9$–10, *e.g.* immediately after the first band crossing in ^{66}Ge, two minima very close in energy at $\hbar\omega = 0.59$ MeV, ($\beta_2 \approx 0.30$, $\gamma \approx 27°$) and $\hbar\omega = 0.69$ MeV, ($\beta_2 = 0.31$ and $\gamma \approx -23°$), result in the TRS calculations (see Fig. 2 on the right) corresponding to 4-*qp* configurations with different degrees of aligned protons and neutrons. Experimental B(E2) values reveal considerable deformation in similar structures with staggered M1 transitions involved and based on a $\pi g_{9/2}\nu g_{9/2}$ configuration in a number of odd-odd nuclei with $A \approx 80$. The $B(\mathrm{M1})/B(\mathrm{E2})$ ratios for the discussed new sequence in ^{66}Ge estimated directly from the energies of the M1 and E2 transitions and the branching ratios λ (mixing ratios δ were neglected) are similar to those in ^{72}As, where considerable deformation was found [5] and are by a factor of 4 smaller than those in ^{86}Zr, where near spherical shape was predicted [6]. This supports the rather strong deformation predicted by the TRS calculations.

To our knowledge, this is the first observation of staggered M1 transitions within a well deformed 4-*qp* $\pi(g^2_{9/2})\nu(g^2_{9/2})$ structure. The TRS calculations describe this structure as due to triaxial softness in the $g_{9/2}$ 4-*qp* regime. The predicted competing and mixed high-j $(g_{9/2})$ 4-*qp* band configurations with different alignment, changing in this way the γ-deformation along the discussed deformed structure may describe the observed M1 staggered transitions. They can occur between states with aligned quasiparticles having angular momentum j and $j-1$. Systematic theoretical studies are needed to reveal the intrinsic conditions that cause structures with staggered M1 transitions, *i.e.* why they appear in some nuclei and not in their neighbours.

An aligned $\nu(g^2_{9/2})\pi(p_{3/2}f_{5/2},g_{9/2})^2$ configuration was calculated for the newly observed band on top of the 15^- state. It is predicted to terminate at spin 20–21 at $\beta_2 \approx 0.28$ and $\gamma = 60°$. The TRS calculations also predict a negative-parity superdeformed band in ^{66}Ge with $\beta_2 \approx 0.42$ and $\gamma = -2.5°$.

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REFERENCES

[1] U. Hermekens *et al.*, *Z. Phys.* **A343**, 371 (1992).
[2] C.J. Lister *et al.*, *Nucl. Phys.* **A557**, 361 (1993).
[3] H.-Q. Jin *et al.*, *Phys. Rev. Lett.* **75**, 1471 (1995).
[4] D. Rudolph *et al.*, *Phys. Rev.* **C54**, 117 (1996).
[5] J. Döring *et al.*, *Phys. Rev.* **C49**, 2419 (1994).
[6] P. Chowdhury *et al.*, *Phys. Rev. Lett.* **67**, 2950 (1991).