High spin states in ^{75}Kr: Approaching superdeformation in the $A=80$ region

D. F. Winchell, M. S. Kaplan, J. X. Saladin, and H. Takai
Department of Physics, University of Pittsburgh, Pittsburgh, Pennsylvania 15260

J. J. Kolata
Department of Physics, University of Notre Dame, Notre Dame, Indiana 46556

J. Dudek
Centre de Recherches Nucleaires, F-67037 Strasbourg CEDEX, France

(Received 7 July 1989)

Excited states in ^{75}Kr were populated via the reaction ^{46}Ti(^{32}S,2*pn*) at a beam energy of 97 MeV. Several new high-spin states were found. Evidence for band crossings was found in both the positive- and negative-parity bands. Calculations using a cranked Strutinsky-Bogolyubov model with a Woods-Saxon potential indicate noticeably different deformations for the opposite parity bands: $\beta_2=0.40$, $\gamma=-8°$ for the positive-parity band and $\beta_2=0.36$, $\gamma=3°$ for the negative-parity band. These deformations are comparable to superdeformations reported by other authors in the cerium region. Signature splitting in both positive- and negative-parity bands was well reproduced by the calculations. Indirect evidence suggests shape coexistence within the positive-parity band at low spin.

I. INTRODUCTION

In recent years there have been extensive experimental and theoretical studies[1–10] of the high-spin properties of nuclei in the mass $A=70-80$ region. The nuclear structure and modes of excitation of nuclei in this mass region have a strong dependence on N, Z, and angular momentum. Several studies[3–5] have found strong evidence for shape coexistence in various nuclei in this region. Piercey *et al.*[5] discovered evidence for shape coexistence in ^{74,76}Kr. It was found that these nuclei are well deformed in the ground state and have coexisting, excited 0^+ states, which are interpreted as being nearly spherical. Recent studies[8–10] of the odd-A nuclei ^{77}Rb, ^{73}Br, and ^{75}Br have shown that the addition of an odd particle in an even-even core can stabilize the nuclear shape, removing this shape coexistence.

The work presented here is a study of high-spin states in the $N=39$ nucleus ^{75}Kr. Previous investigations[11–13] of ^{75}Kr reported two well-defined rotational bands built on the $[422]\frac{5}{2}^+$ and $[301]\frac{3}{2}^-$ Nilsson orbitals. Herath-Banda *et al.*[11] discuss the observed signature splitting of these bands in terms of a particle plus rotor model. A deformation of $\beta_2=0.37$ and $\gamma=-15°$ gave the best fit to the data for the ground-state band.[14] The present work considerably extends both bands.

The experimental results are interpreted within the framework of the cranked shell model. As a first step, calculations without pairing were performed using the generalized Strutinsky method. These calculations show the global shape coexistence properties and the evolution of nuclear shape with spin. The degree of deformation indicated by these calculations is comparable to the superdeformation found in the cerium region.[15] Using the information about nuclear shape obtained in this way, we performed more detailed, pairing self-consistent calculations, the results of which can be directly compared with experiment.

II. EXPERIMENTAL METHOD

High-spin states in ^{75}Kr were populated via the ^{46}Ti(^{32}S,2*pn*) reaction using a 97 MeV ^{32}S beam from the Notre Dame three-stage tandem accelerator. The target material was enriched to 81% in ^{46}Ti. Two stacked, self-supporting targets of thickness 550 μg/cm^2 were used. Gamma rays from the reaction were detected with the Pitt multidetector array,[16] which at the time of the experiment consisted of five Compton-suppressed HPGe detectors and a sum-energy and multiplicity spectrometer (SMS) made up of 14 BGO scintillation detectors. The HPGe detectors were placed at angles of $-65.0°$, $90.0°$, $-108.3°$, $-150.9°$, and $151.4°$ with respect to the beam. An event trigger was defined by the simultaneous firing of at least two HPGe detectors and one SMS element. This multiple-coincidence requirement enhances the selection of high-spin events. Approximately 30 million events were collected in event-by-event mode on tape. The HPGe energy data were gain matched and corrected for Doppler shifts. All possible coincidence pairs were used to construct a symmetric 2500×2500 channel γ-γ correlation matrix. An additional 4.2 million events of singles data (no coincidence requirement) were collected and used to determine angular distributions.

III. RESULTS

Figures 1 and 2 show typical gamma-ray spectra, obtained by gating on the strongest transitions in the

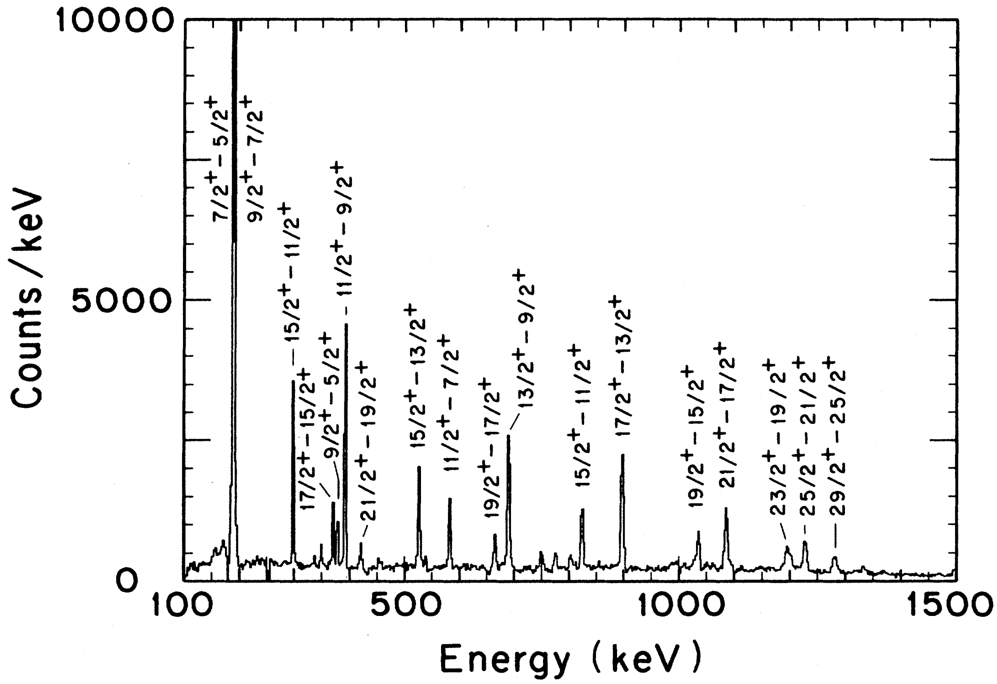

FIG. 1. Gamma-ray spectrum created by gating on positive-parity transitions. Gates were placed on the 187, 191, 297, 378, 392, 583, and 689 keV transitions.

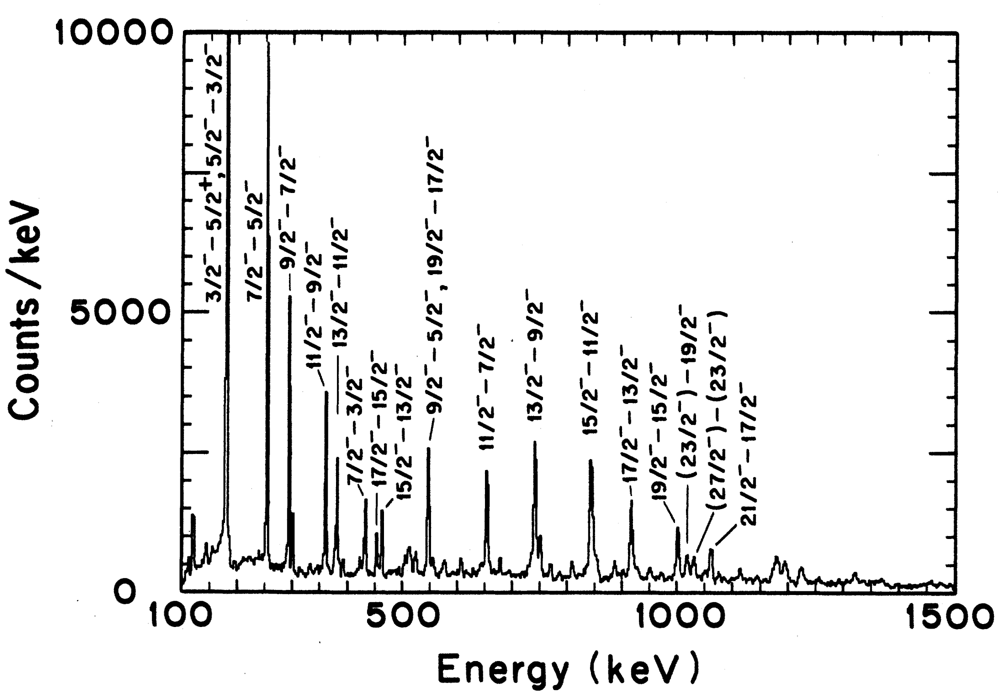

FIG. 2. Gamma-ray spectrum created by gating on negative-parity transitions. Gates were placed on the 179, 253, 293, 360, 432, 546, and 653 keV transitions.

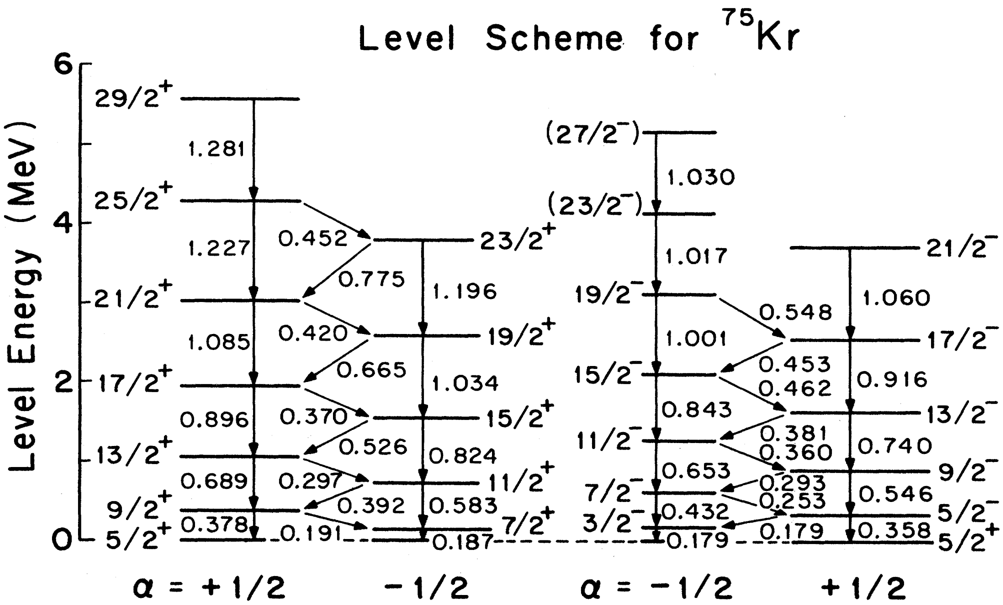

FIG. 3. Decay scheme of ^{75}Kr showing the bands extended by this work.

positive- and negative-parity bands of ^{75}Kr. A decay scheme showing the bands observed in this work is given in Fig. 3. Energies and intensities of the observed transitions are given in Tables I and II for the positive- and negative-parity bands, respectively. Previous studies[11,12] established the two signature partners of the positive-parity band to spins $\frac{15}{2}$ and $\frac{17}{2}$, and those of the negative-parity band to spins $\frac{11}{2}$ and $\frac{13}{2}$. The present work extends the positive-parity sequences to spins $\frac{29}{2}$ and $\frac{23}{2}$, and the

TABLE I. Level energies, gamma-ray energies, and gamma-ray intensities for the positive-parity band. Intensities are normalized to the $\frac{7}{2}^+$ to $\frac{5}{2}^+$ transition.

I^π	E_I (keV)	E_γ (keV)	Intensity
$\frac{7}{2}^+$	187.1	187.1	100
$\frac{9}{2}^+$	377.7	190.7	68(6)
		377.7	22(3)
$\frac{11}{2}^+$	769.8	392.0	37(3)
		582.7	16(2)
$\frac{13}{2}^+$	1067.0	297.4	20(2)
		689.1	39(4)
$\frac{15}{2}^+$	1593.1	526.1	22(3)
		823.6	22[a]
$\frac{17}{2}^+$	1963.1	370.0	7(2)
		896.0	34(5)
$\frac{19}{2}^+$	2627.8	664.7	22(3)
		1034	17[a]
$\frac{21}{2}^+$	3047.7	419.9	5[a]
		1085	28[a]
$\frac{23}{2}^+$	3823	775	6[a]
		1196	19[a]
$\frac{25}{5}^+$	4275	452	3[a]
		1227	22(5)
$\frac{29}{2}^+$	5556	1281	13[a]

[a]Estimate of intensity based on coincidence data.

TABLE II. Level energies, gamma-ray energies and gamma-ray intensities for the negative-parity band. Intensities are normalized to the $\frac{7}{2}^+$ to $\frac{5}{2}^+$ transition.

I^π	E_I (keV)	E_γ (keV)	Intensity
$\frac{3}{2}^-$	178.8	178.8	
$\frac{5}{2}^-$	357.8	179.0	
		357.8	5[a]
$\frac{7}{2}^-$	611.0	253.1	65(5)
		432.2	26(3)
$\frac{9}{2}^-$	904.1	293.1	35(3)
		546.3	29(3)
$\frac{11}{2}^-$	1264.1	359.9	19(3)
		653.1	30[a]
$\frac{13}{2}^-$	1644.6	380.6	14(2)
		740.4	34[a]
$\frac{15}{2}^-$	2107.4	462.5	9(2)
		843.3	40[a]
$\frac{17}{2}^-$	2560.2	452.9	9(2)
		915.6	26[a]
$\frac{19}{2}^-$	3108	548	8[a]
		1001	14(3)
$\frac{21}{2}^-$	3620	1060	35(6)
$(\frac{23}{2}^-)$	4125	1017	11[a]
$(\frac{27}{2}^-)$	5155	1030	11[a]

[a]Estimate of intensity based on coincidence data.

negative-parity sequences to $\frac{27}{2}$ and $\frac{21}{2}$. Spins and parities for the new levels were assigned on the basis of intensities of transitions observed in gated spectra and on angular distribution data. The spin assignments of the two highest transitions in the negative-parity band are tentative.

Results reported in recent conference proceedings[17,18] also extend the decay scheme beyond what had been reported in Refs. 11 and 12. Our results agree with those of Ref. 18, except in the assignments of the $\frac{23}{2}^- - \frac{19}{2}^-$ and $\frac{27}{2}^- - \frac{23}{2}^-$ transitions.

IV. DISCUSSION

A cranked shell model analysis, as proposed by Bengtsson and Frauendorf,[19,20] was applied to the data. Experimental Routhians are plotted in Fig. 4. There is a nearly constant signature splitting of approximately 0.1 MeV within the positive-parity band. The negative-parity band does not show any significant signature splitting. The component of spin along the rotational axis I_x is plotted as a function of angular frequency in Fig. 5. The beginning of an upbend can be seen in the ground-state band at $\hbar\omega=0.6$ MeV. An analogous upbend is seen[6,21] in ^{76}Kr and ^{78}Kr, where it is interpreted as resulting from the alignment of two $g_{9/2}$ quasiprotons.[1,10,21] Gross *et al.*[7] report an upbend due to a quasiproton alignment at $\hbar\omega=0.5$ MeV in ^{77}Kr.

A sharp upbend occurs in the negative-parity band at $\hbar\omega=0.5$ MeV. This may again be due to a quasiproton alignment, although we would expect this to occur at about the same frequency as in the ground-state band. Another possibility is that this is due to the alignment of two $g_{9/2}$ quasineutrons, which is blocked in the ground-state band. Studies[22,23] of the $N=38$ nuclei ^{74}Kr and ^{73}Br show similar upbends in the yrast band at $\hbar\omega=0.55-0.6$ MeV, although it has not been determined whether the upbend in ^{74}Kr is due to a quasiproton or quasineutron alignment. Because pairing correlations are reduced in odd-A nuclei, a reduction in the crossing frequency compared with the even-even neighbors might be expected. In addition, there is a systematic decrease in the neutron crossing frequency of the even-even Kr isotopes with decreasing neutron number. In ^{78}Kr this crossing occurs at $\hbar\omega=0.87$ MeV, while in ^{76}Kr it is seen at $\hbar\omega=0.65$ MeV.

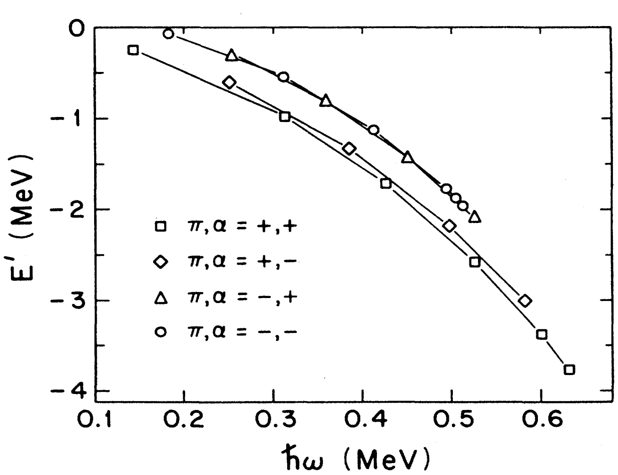

FIG. 4. Experimental Routhians as a function of angular frequency.

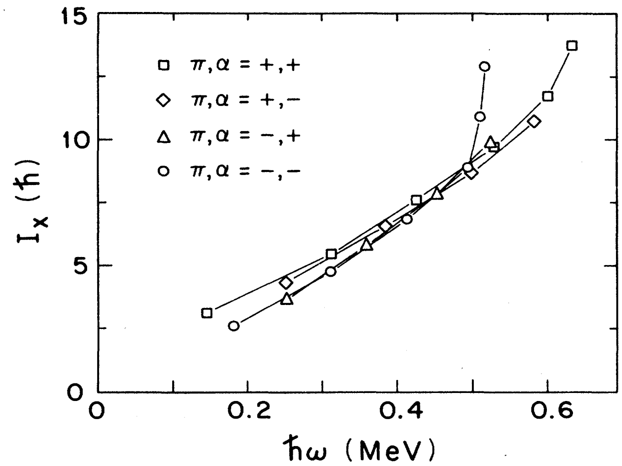

FIG. 5. I_x vs angular frequency.

In order to better understand the microscopic structure of nuclei in this region, we have performed calculations using a deformed Woods-Saxon potential and Strutinsky shell correction. The parameters used to characterize the Woods-Saxon potential are the "universal" parameters (see, e.g., Cwiok *et al.*[24]). Eigenstates ψ^ω of the cranking Hamiltonian

$$H^\omega = H_{WS} - \hbar\omega j_x$$

were calculated by expanding the ψ^ω wave functions into the static eigenfunctions of the Woods-Saxon Hamiltonian, H_{WS}. The total nuclear energy in the lab frame was then found using a shell-correction approach:

$$E_{tot} = E_{LD} + \delta E_{shell} ,$$

where E_{LD} is the liquid drop energy calculated using the Moller-Nix formula[25] and δE_{shell} is the Strutinsky[26] shell correction generalized to use the eigenstates of the cranking Hamiltonian.[27] These calculations are carried out for a mesh of 255 points on the (β_2,γ) plane, with β_4 chosen at each point to minimize the liquid drop energy at an intermediate spin. The calculations were performed for 21 values of $\hbar\omega$ in the range 0.0–2.0 MeV. The method is described in some detail by Dudek *et al.*[2] and references quoted therein (for original presentation in terms of the Nilsson model see, e.g., Bengtsson and Ragnarsson[28]). At this stage of the calculations pairing interactions were neglected. Total energy surfaces corresponding to four different spin values are shown in Fig. 6. The total energy surfaces shown in this figure were calculated requiring positive parity and signature $\alpha=+\frac{1}{2}$. As is the case for other nuclei in this mass region, the surfaces display a significant degree of gamma softness. At $I=\frac{5}{2}$ the deepest minimum is at the prolate shape $\beta_2=0.40$, $\gamma=-8°$. This is in fairly good agreement with the results of Ref. 11 when one takes into account the gamma softness. This minimum remains yrast to a spin of $\frac{25}{2}$, with the value of β_2 changing only slightly to 0.39. Four surfaces with negative parity and $\alpha=-\frac{1}{2}$ are shown in Fig. 7. Here the nucleus is predicted to be almost axially symmetric. The deepest minimum at $I=\frac{7}{2}$ occurs at $\beta_2=0.37$, $\gamma=3°$.

The large elongations suggested by the theoretical calculations for ^{75}Kr are in direct correspondence with the general abundance of the superdeformed configurations as proposed in Ref. 29. There it is argued that the approximate pseudo-SU(3) symmetry, manifested by the realistic average field potentials, should give rise to characteristic "chains" of superdeformed shell closures.

In order to compare our experimental results with the model calculations in a more quantitative fashion, it is necessary to include pairing correlations. Calculations were performed with monopole pairing interactions included, using the deformation values corresponding to the energy minima in the nonpairing calculations described earlier. Previous studies[1,10] have found that this approach gives satisfactory results except, perhaps, at the lowest spins. The pairing gaps and the corresponding quasiparticle energies were calculated self-consistently as a function of ω. The moment of inertia calculated in this way is compared with experiment in Fig. 8. The agreement between calculation and experiment, especially in the position of the proton upbend, is quite good. Calculated quasiparticle Routhians for ^{75}Kr as a function of angular frequency are shown in Fig. 9 for the deformation $\beta_2=0.40$, $\gamma=-8°$. Plots of the pair gap are shown below the Routhian plots. The positive-parity proton Routhians [Fig. 9(a)] exhibit a crossing at $\hbar\omega=0.6$ MeV, in good agreement with the experimentally observed upbend in the ground-state band. There is qualitative agreement between the observed signature splitting in the positive-parity band (Fig. 4) and the energy difference between the lowest two neutron Routhians in Fig. 9(b). On the other hand, for this choice of deformation parameters the calculations predict a very large signature splitting for the negative-parity band, a result which does not agree with the experiment. As was seen above (Fig. 7), the nuclear shape is predicted to be nearly axially sym-

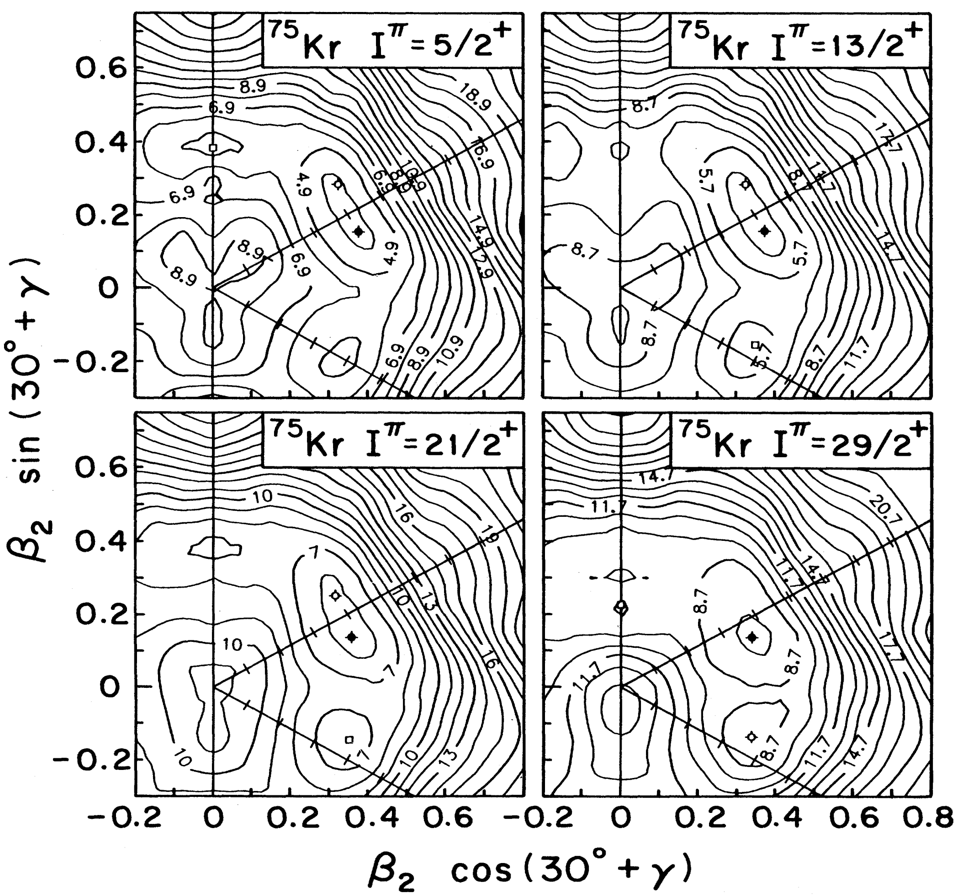

FIG. 6. Calculated total energy surfaces for four spins in the $\pi=+$, $\alpha=+\frac{1}{2}$ sequence. Filled circles mark the position of the deepest energy minimum, empty circles the second deepest, and empty squares the third deepest minimum.

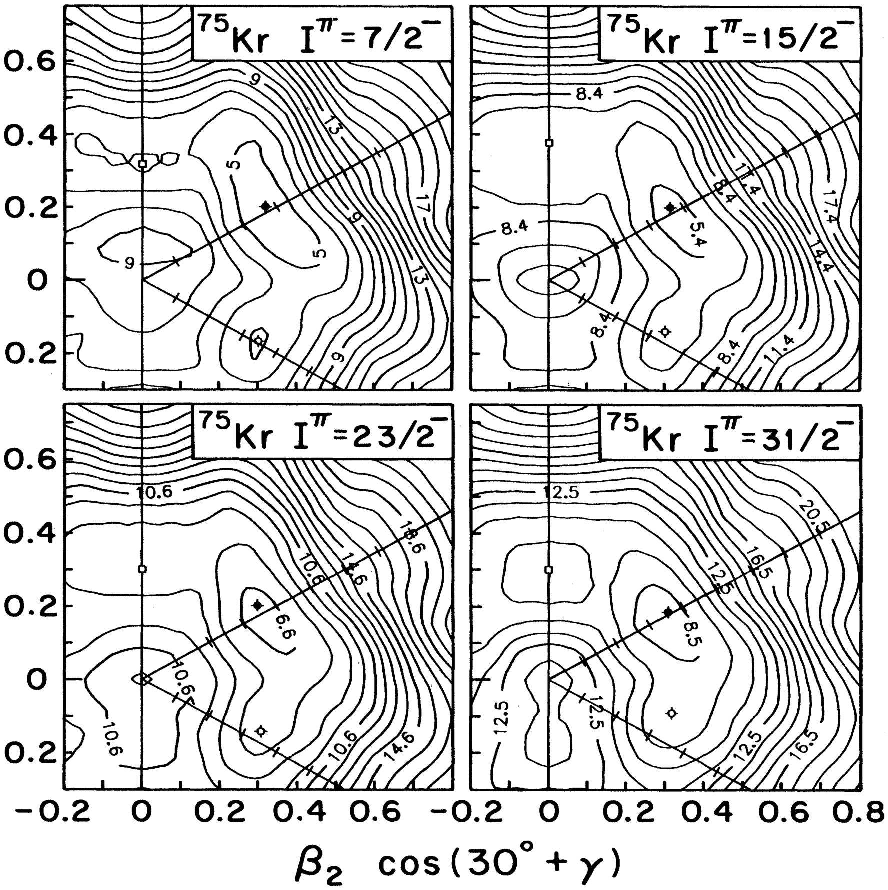

FIG. 7. Calculated total energy surfaces for four spins in the $\pi=-$, $\alpha=-\frac{1}{2}$ sequence.

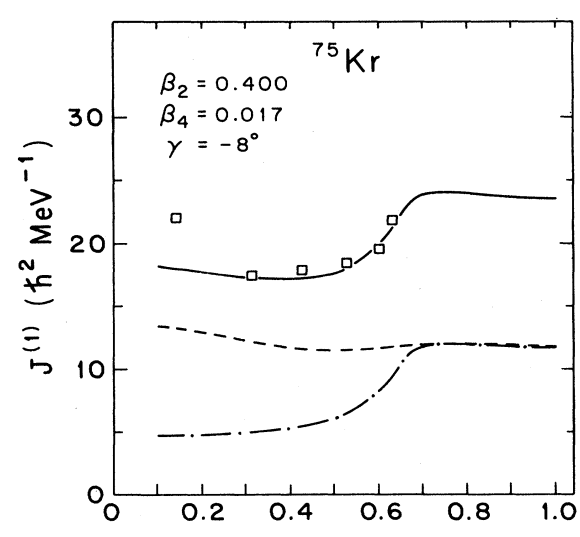

FIG. 8. Calculated versus experimental moments of inertia. Dashed lines indicates neutron contribution, dashed-dotted line proton contribution, and solid line the sum of the two. Squares indicate the experimentally derived points.

metric for negative-parity states. Routhian plots are shown in Fig. 10 for the deformation $\beta_2=0.36$, $\gamma=3°$, typical for the negative-parity band. Here the near-zero signature splitting of the negative-parity band is well reproduced. At this deformation the first two-quasiparticle alignments are predicted at $\hbar\omega=0.55$ MeV (protons) and $\hbar\omega=0.65$ (MeV) (neutrons), values too large to explain the observed upbend in the negative-parity band.

The experimentally derived moments of inertia, $J^{(1)}$, are plotted in Fig. 11 as a function of angular frequency for the yrast sequences of the four nuclei $^{74-77}$Kr. The strongly reduced value of $J^{(1)}$ for the lowest ω values in ^{74,76}Kr have been attributed to the interaction of the ground state with an excited, shape coexistent (spherical or slightly oblate) 0^+ state which lowers the ground-state energy and increases the 2^+-0^+ energy of the ground-state band.[5] In the neighboring odd nuclei ^{75,77}Kr, the value of $J^{(1)}$ *increases* for the lowest value of ω. This behavior may result from the depression of the $\frac{9}{2}^+$ member of the band due to the presence of an as yet unobserved shape coexistent $\frac{9}{2}^+$ state. The presence of such states have been established in the $N=39$ isotones ^{69}Zn, ^{71}Ge, ^{73}Se, and associated with the $[404]\frac{9}{2}^+$ Nilsson orbital cor-

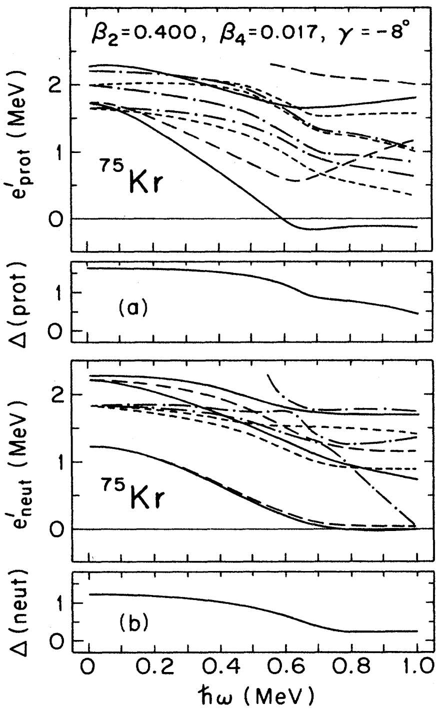

FIG. 9. Calculated quasiparticle Routhians for protons (a) and neutrons (b) at deformation $\beta_2=0.400$, $\gamma=-8°$, typical for the positive-parity band. Routhians are labeled by parity and signature quantum numbers: solid line ($\pi=+$, $\alpha=+\frac{1}{2}$), long-dashed line ($+$, $-\frac{1}{2}$), short-dashed line ($-$, $+\frac{1}{2}$), and dashed-dotted line ($-$, $-\frac{1}{2}$). The calculated pairing gap Δ, is shown beneath the Routhian plots.

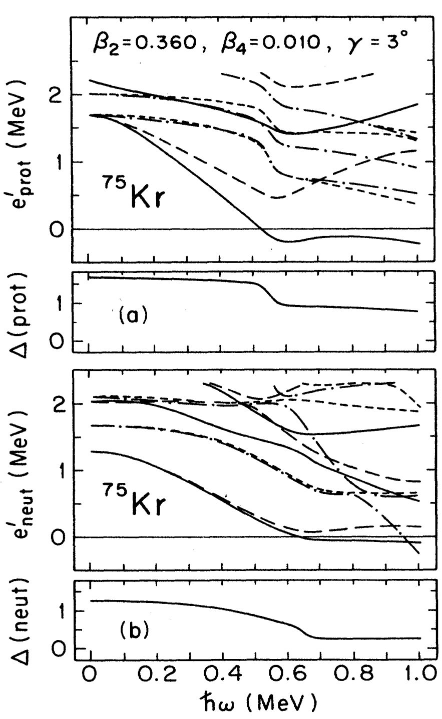

FIG. 10. The same as Fig. 9 at deformation $\beta_2=0.360$, $\gamma=3°$, typical for the negative-parity band.

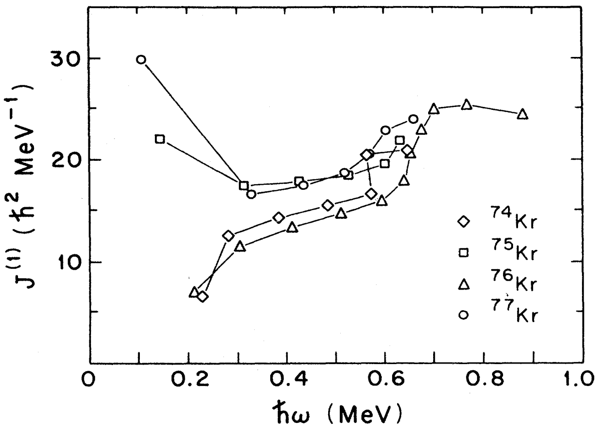

FIG. 11. Moments of inertia for the yrast sequences of the nuclei $^{74-77}$Kr. Data for ^{74}Kr is from Roth *et al.* (Ref. 22), for ^{76}Kr from Kaplan *et al.* (Ref. 6), and for ^{77}Kr from Gross *et al.* (Ref. 7).

responding to a spherical or slightly oblate shape ($\beta_2\approx 0.0--0.1$).[30]

V. CONCLUSION

The high-spin part of the ^{75}Kr level scheme has been extended. Upbends were found in both the positive- and negative-parity bands. Calculations using the generalized Woods-Saxon-Strutinsky method with pairing were performed. These calculations suggest that the observed bands are superdeformed. The data are consistent with deformations of $\beta_2=0.40$, $\gamma=-8°$ for the positive-parity band and $\beta_2=0.36$, $\gamma=3°$ for the negative-parity band. The quasiparticle Routhians calculated using these shape parameters correctly reproduce the signature splitting in both bands. In addition, the moment of inertia of the ground-state band as a function of angular frequency is well reproduced by the calculations. The positions of the experimentally observed and the theoretically predicted upbend in the negative parity-band differ by about 0.1 MeV.

There exists indirect evidence for a nearly spherical or slightly oblate state which coexists with the prolate-triaxial ground-state band. Further investigations of lifetimes and of spins above the band crossings will be important to test the superdeformed configuration hypothesis which, although reasonably well founded on theoretical grounds, has not yet been experimentally confirmed.

ACKNOWLEDGMENTS

We wish to thank U. Garg, C. Browne, E. Berners, and the University of Notre Dame for their help and hospitality. In addition, we are indebted to R. A. Sorensen, C. M. Vincent, and T. Werner for many illuminating discussions. This work was funded by the National Science Foundation.

[1]W. Nazarewicz, J. Dudek, R. Bengtsson, T. Bengtsson, and I. Ragnarsson, Nucl. Phys. **A435**, 397 (1985).
[2]J. Dudek, W. Nazarewicz, and N. Rowley, Phys. Rev. C **35**, 1489 (1987).
[3]J. H. Hamilton, A. V. Ramayya, W. T. Pinkston, R. M. Ronningen, G. Garcia-Bermudez, H. K. Carter, R. L. Robinson, H. J. Kim, and R. O. Sayer, Phys. Rev. Lett. **32**, 239 (1974).
[4]R. M. Ronningen, A. V. Ramayya, J. H. Hamilton, W. Lourens, J. Lange, H. K. Carter, and R. O. Sayer, Nucl. Phys. **A261**, 439 (1976).
[5]R. B. Piercey, J. H. Hamilton, R Soundranayagam, A. V. Ramayya, C. F. Maquire, X.-J. Sun, Z. Z. Zhao, R. L. Robinson, H. J. Kim, S. Frauendorf, J. Doring, L. Funke, G. Winter, J. Roth, L. Cleeman, J. Eberth, W. Neumann, J. C. Wells, J. Lin, A. C. Rester, and H. K. Carter, Phys. Rev. Lett. **47**, 1514 (1981).
[6]M. S. Kaplan, J. X. Saladin, L. Faro, D. F. Winchell, H. Takai, and C. N. Knott, Phys. Lett. B **215**, 251 (1988).
[7]C. J. Gross, P. D. Cottle, D. M. Headly, U. J. Huttmeier, E. F. Moore, S. L. Tabor, and W. Nazarewicz, Phys. Rev. C **36**, 2601 (1987).
[8]L. Luhmann, K. P. Lieb, C. J. Lister, B. J. Varley, J. W. Olness, and H. G. Price, Europhys. Lett. **1**, 623 (1986).
[9]B. Wormann, J. Heese, K. P. Lieb, L. Luhmann, F. Raether, D. Alber, H. Grawe, and B. Spellmeyer, Z. Phys. A **322**, 171 (1985).
[10]L. Luhmann, M. Debray, K. P. Lieb, W. Nazarewicz, B. Wormann, J. Eberth, and T. Heck, Phys. Rev. C **31**, 828 (1985).
[11]M. A. Herath-Banda, A. V. Ramayya, L. Cleeman, J. Eberth, J. Roth, T. Heck, N. Schmal, T. Mylaeus, W. Koenig, B. Martin, K. Bethge, and G. A. Leander, J. Phys. G **13**, 43 (1987).
[12]G. Garcia-Bermudez, C. Baktash, and C. J. Lister, Phys. Rev. C **30**, 1208 (1984).
[13]A. V. Ramayya and J. Eberth, in *Heavy-Ion Collisions,* Vol. 168 of *Lecture Notes in Physics,* edited by G. Madurga and M. Lozano (Springer-Verlag, Berlin, 1982), p. 317.
[14]Note that here and throughout this paper we use the Lund convention for γ. In Ref. 11 the convention for γ is based on the Bohr Hamiltonian and uses the opposite sign.
[15]A. J. Kirwan, G. C. Ball, P. J. Bishop, M. J. Godfrey, P. J. Nolan, D. J. Thornley, D. J. G. Love, and A. H. Nelson, Phys. Rev. Lett. **58**, 467 (1987).
[16]J. X. Saladin, IEEE Trans. Nucl. Sci. **NS-30**, 420 (1983).
[17]S. Skoda, J. Busch, J. Eberth, M. Liebchen, T. Mylaus, N. Schmal, R. Sefzig, W. Teichert, and M. Wiosna, in *Proceedings of the International Workshop on Nuclear Structure of the Zr Region, Bad Honnef, 1988,* edited by J. Eberth, R. A. Meyer, and K. Sistemich (Springer-Verlag, Berlin, 1988), p. 315.
[18]A. A. Chisti, M. Campbell, W. Gelletly, L. Goettig, A. N. James, C. J. Lister, D. J. G. Love, J. H. McNeill, R. Moscrop, O. Skeppstedt, and B. J. Varley, in *Proceedings of the International Workshop on Nuclear Structure of the Zr Region, Bad Honnef, 1988,* edited by J. Eberth, R. A. Meyer, and K. Sistemich (Springer-Verlag, Berlin, 1988), p. 320.
[19]R. Bengtsson and S. Frauendorf, Nucl. Phys. **A314**, 27 (1979).
[20]R. Bengtsson and S. Frauendorf, Nucl. Phys. **A327**, 139 (1979).
[21]R. B. Piercey, A. V. Ramayya, J. H. Hamilton, X. J. Sun, Z. Z. Zhao, R. L. Robinson, H. J. Kim, and John C. Wells, Phys. Rev. C **25**, 1941 (1982).
[22]J. Roth, L. Cleeman, J. Eberth, T. Heck, W. Neumann, M. Nolte, R. B. Piercey, A. V. Ramayya, and J. H. Hamilton, J. Phys. G **10**, L25 (1984).
[23]S. Wen, A. V. Ramayya, S. J. Robinson, C. F. Maguire, W. C. Ma, X. Zhao, T. M. Cormier, P. M. Stwertka, J. D. Coles, E. F. Zganjar, R. B. Piercy, M. A. Herath-Banda, J. Ebert, and M. Wiosna, J. Phys. G **11**, L173 (1985).
[24]S. Cwiok, J. Dudek, W. Nazarewicz, J. Skalski, and T. Werner, Comp. Phys. Comm. **46**, 379 (1987).
[25]P. Moller and J. R. Nix, Nucl. Phys. **A361**, 117 (1981).
[26]V. M. Strutinsky, Nucl. Phys. **A95**, 420 (1967).
[27]J. Dudek, in *Proceedings of the International Winter Meeting in Nuclear Physics, Bormio, Italy, 1987,* edited by I. Iori (Ricera Scientifica et Educazione Permanente, Milano, 1987).
[28]T. Bengtsson and I. Ragnarsson, Nucl. Phys. **A436**, 14 (1985).
[29]J. Dudek, W. Nazarewicz, Z. Szymanski, and G. A. Leander, Phys. Rev. Lett. **59**, 1405 (1987).
[30]K. Heiguchi, S. Mitarai, B. J. Min, and T. Kuroyanagi, Nucl. Phys. **A474**, 484 (1987).