Shape coexistence in the very neutron-rich odd-odd ^{96}Rb

J. A. Pinston,[1,*] J. Genevey,[1] R. Orlandi,[2,3] A. Scherillo,[2,4] G. S. Simpson,[2] I. Tsekhanovich,[2] W. Urban,[5] H. Faust,[2] and N. Warr[4]

[1]*Laboratoire de Physique Subatomique et de Cosmologie, IN2P3-Centre National de la Recherche Scientifique/Université Joseph Fourier, F-38026 Grenoble Cedex, France*

[2]*Institut Laue-Langevin, B.P. 156, F-38042 Grenoble Cedex 9, France*

[3]*Department of Physics and Astronomy, The University of Manchester, Brunswick Street, M13 9PL, United Kingdom*

[4]*Institut für Kernphysik, Universität zu Köln, Zülpicherstrasse 77, D-50937 Cologne, Germany*

[5]*Faculty of Physics, Warsaw University, ul. Hoża 69, PL-00-681 Warsaw, Poland*

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Microsecond isomers of neutron-rich nuclei in masses $A = 96$ and 98 were reinvestigated at the Institut Laue-Langevin reactor (Grenoble). These nuclei were produced by thermal-neutron induced fission of ^{241}Pu. The detection is based on the time correlation between fission fragments selected by the Lohengrin mass spectrometer and the γ rays and conversion electrons from the isomers. A new level scheme of ^{96}Rb is proposed. We have found that the ground state and low-lying levels of this nucleus are rather spherical, and a rotational band develops at 461-keV energy. This band has properties consistent with a $\pi[431\,3/2] \times \nu[541\,3/2]K = 3^-$ Nilsson assignment and a deformation $\beta_2 > 0.28$. It is fed by a $I^\pi = 10^-$ microsecond isomer consistent with a $\pi(g_{9/2})\nu(h_{11/2})$ spherical configuration. It is interesting to note that the same unique-parity states $\pi(g_{9/2})$ and $\nu(h_{11/2})$ are present in the same nucleus in a deformed and in a spherical configuration. The neighboring odd-odd nucleus ^{98}Y presents a strong analogy with ^{96}Rb and is also discussed.

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I. INTRODUCTION

The isotones with $N = 59$ neutrons are of special interest in the $A \sim 100$ mass region because they are just at the border between a rather spherical and a well-deformed region [1]. Recently, new experimental data were reported, concerning mainly the Zr, Sr [2–6], and Kr odd nuclei. In both ^{97}Sr and ^{99}Zr, the ground state (g.s.) and first two excited states are the neutron $s_{1/2}$, $d_{3/2}$, and $g_{7/2}$ shell-model levels, whereas two rotational bands built on the [411 3/2$^+$] and [541 3/2$^-$] orbitals are present at ~600 keV. Very recently, the excited states of these bands have been extended up to spin 31/2$^+$ (^{97}Sr) and 29/2$^+$ (^{99}Zr) for the positive-parity band and 39/2$^-$ (^{97}Sr,^{99}Zr) for the negative-parity band in [6]. In these two nuclei, the negative-parity bands are not regular, and the effective moments of inertia exceed the rigid-body value at low rotational frequency. This effect is very likely the consequence of the aligned angular momentum expected for the [541 3/2$^-$] orbital, originating from the spherical $h_{11/2}$ unique-parity state. This alignment is stronger for low-K orbitals. From picosecond-lifetime measurements, Urban *et al.* [2] have deduced a mean deformation $\beta_2 = 0.32(2)$ for the two bands in ^{97}Sr and ^{99}Zr. This value is smaller than the deformation measured for the g.s. band in ^{98}Sr [$\beta_2 = 0.41(2)$] [2,7], which is expected to be the maximum deformation of this mass region. Very recently, bands built on the [404 9/2$^+$] orbital were also observed [3–5] at ~1 MeV in the $N = 59$ ^{97}Sr and ^{99}Zr isotones, and their deformation was found to be comparable with the maximum value $\beta_2 \sim 0.4$. Wu *et al.* [6] have extended the level scheme of these bands up to spin 23/2$^+$ and 27/2$^+$ in ^{97}Sr and ^{99}Zr, respectively, and they have shown that the intraband transitions have very close energies in these two nuclei, suggesting analogous deformations. Below ^{97}Sr, the very neutron-rich ^{95}Kr, $N = 59$ isotone was recently studied [8], but only the spherical states at low energy were identified, and it was not possible to observe rotational levels. In conclusion, the study of these odd isotopes has unambiguously shown that three different shapes coexist in the $N = 59$ isotones but, to complete this work, one needs also to obtain nuclear-structure information on odd-odd nuclei. A long time ago, a rotational band was seen in ^{98}Y [9], coexisting with a g.s. and low-lying, rather spherical, levels, but the nature of the rotational band was unclear. This situation was the consequence of an incorrect spin and parity assignment for the bandhead at 496.2 keV. Very recently, Brant, Lhersonneau, and Sistemich [10] changed the spin assignment of the bandhead from 2$^-$ to 4$^-$ and proposed a more convincing $\pi[431\ 5/2] \times \nu[541\ 3/2]K = 4^-$ configuration. These authors have also compared the experimental levels of the band with an Interacting Boson Fermion Model (IBFFM) calculation, assuming that the g.s. band of ^{98}Sr is the deformed effective core of ^{98}Y. The theory reproduces roughly the experimental data, but a staggering that is too strong is observed for this band. This nucleus was also studied by Hwang *et al.* [11], who succeeded in finding two new levels of the band, but proposed a spin 2$^-$ assignment for the bandhead.

To increase our information in the $N = 59$ odd-odd isotones, we reinvestigated the very neutron-rich ^{96}Rb nucleus. It was previously measured by Genevey *et al.* [12] with the Lohengrin spectrometer at the Institut Laue-Langevin (ILL) reactor in Grenoble. A new microsecond isomer was found, and the γ decay of this isomer was studied. However, the

*Email address: pinston@lpsc.in2p3.fr

efficiency of the γ detection was too weak to build a reliable level scheme. More recently, this efficiency was strongly improved and in this new experiment, the γ and conversion electrons deexciting the isomer were studied. In this work, we have also remeasured the γ intensity of the intraband transitions of ^{98}Y to get a better precision than in the paper of Brant *et al.* [10].

The paper is organized as follows. In Sec. II, we describe the experimental procedure; in Sec. III, the results of our new measurement of ^{96}Rb are presented. In Sec. IV, the properties of the rotational bands in ^{96}Rb and ^{98}Y, bandhead configurations, and deformations are discussed. In Sec. V, the structure of the 10^- isomer observed in these two nuclei is discussed. Section VI contains a summary of our conclusions.

II. EXPERIMENTAL PROCEDURE

Nuclei of masses $A = 96$ and 98 were produced by thermal-neutron induced fission of ^{241}Pu. Two different setups were installed at the focal plane of the spectrometer; in the first conversion electrons, x rays, and γ rays were measured, and in the second the nuclear charge Z and γ rays were measured.

The Lohengrin mass spectrometer was used to separate the fission fragments (FFs) recoiling from a thin target of $\sim$400 μg/cm^2, according to their mass-to-ionic-charge ratios (A/q). The FFs were detected in a gas detector of 13-cm length, and subsequently stopped in a 12-μm thin Mylar foil. Behind the foil, two cooled adjacent Si(Li) detectors covering an area 2×6 cm^2 were placed to detect the conversion electrons and x rays, and the γ rays were detected by two Ge of 60% placed perpendicular to the beam. This setup allows conversion electrons to be detected down to low energy (15 keV) and allows γ-electron coincidences to be obtained. Details on this experimental setup can be found in [13,14].

In the second setup, the FFs were detected in an ionization chamber filled with isobutane at a pressure of 47 mb. This ionization chamber has good nuclear charge (Z) identification. It consists of two regions of gas, $\Delta E1 = 9$ cm and $\Delta E2 = 6$ cm, separated by a grid. This system is able to identify the nuclear charge in the $Z \sim 40$ region, with a resolution (FWHM) of about two units. The γ rays deexciting the isomeric states were detected by a Clover Ge detector and three single Ge crystals of the Miniball array [15] assembled in the same cryostat. All these detectors were placed perpendicular to the ion beam. They were packed in a very close geometry, thanks to the small thickness (6 cm) of the ionization chamber. The total efficiency for the γ detection is 20% and 4% for photons of 100 keV and 1 MeV, respectively. More details on this experimental setup can be found in [8].

III. EXPERIMENTAL RESULTS

In the present work, we have observed the microsecond isomer in ^{96}Rb previously reported by Genevey *et al.* [12].

The nuclear charge identification ($Z = 37$) was confirmed from the measurement of the energy lost by the ions in the first stage of the ionization chamber and the x-ray energies

TABLE I. Absolute intensities of the γ transitions observed in the isomer decay of ^{96}Rb.

E_γ (keV)	I_γ	E_γ (keV)	I_γ
38.0(5)	7(2)	240.3(2)	42(3)
59.3(2)	17(2)	276.3(3)	5(1)
89.5.2)	8(1)	300.0(3)	68(5)
92.8(2)	37(2)	301.0(4)	17(3)
116.8(2)	36(3)	329.0(4)	7(1)
122.0(3)	32(3)	366.8(3)	10(1)
123.5(3)	36(3)	369.2(3)	13(2)
126.0(3)	7(2)	402.4(4)	3(1)
148.8(3)	7(1)	405.5(4)	4(1)
166.1(3)	7(1)	461.6(2)	48(3)
177.6(2)	12(1)	495.2(3)	5(2)
185.4(2)	12(2)	554.5(3)	5(1)
209.9(2)	16(2)		

measured with the Si detectors in coincidence with γ rays deexciting the isomer (see below). The γ-counting rates obtained in this new measurement are about ten times higher than in the previous one. Consequently, although in the previous paper only 9 γ rays having the strongest intensities were reported, in this new study, 25 γ rays were observed and are reported in Table I. Moreover, low-energy γ rays of 38 and 59.3 keV were observed for the first time. The half-life measured for the strong γ line of 300.0 keV, $T_{1/2} = 2.00(10)$ μs, is shown in Fig. 1. It is more precise and agrees in the limit of the error bars with the previous measurement [$T_{1/2}(240 + 300 + 461)$] = 1.65(15) μs [12]. Examples of $\gamma - \gamma$ coincidences are shown in Fig. 2.

The Si(Li) spectrum in coincidence with the sum of four γ gates is shown in Fig. 3. The thinner lines at low energy are interpreted as K_α and K_β x rays of the Rb isotope, and the next two broad lines are the K- and L-conversion electrons of a 40(1) keV transition. For this transition, the measured electron intensity ratios are $I_K/I_L = 2.5(4)$ and 2.9(5) in the singles and in the coincidence spectrum, respectively. The comparison with theory, which predicts a ratio of 8.7 for $E1$ or $M1$ multipolarities and 2.9 for $E2$, allows a pure $E2$ multipolarity

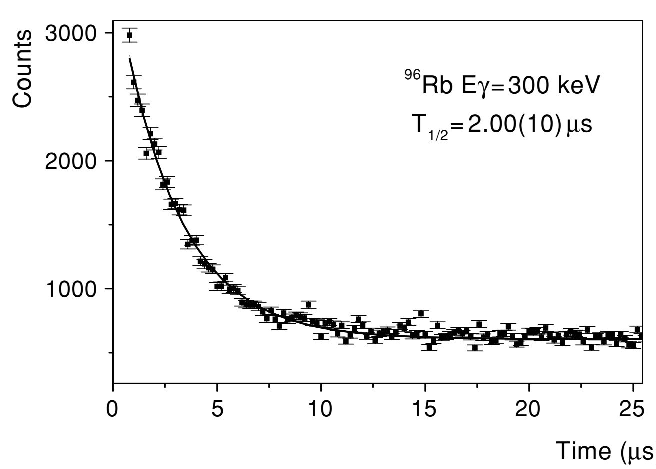

FIG. 1. Time spectrum of the 300.0-keV transition in ^{96}Rb.

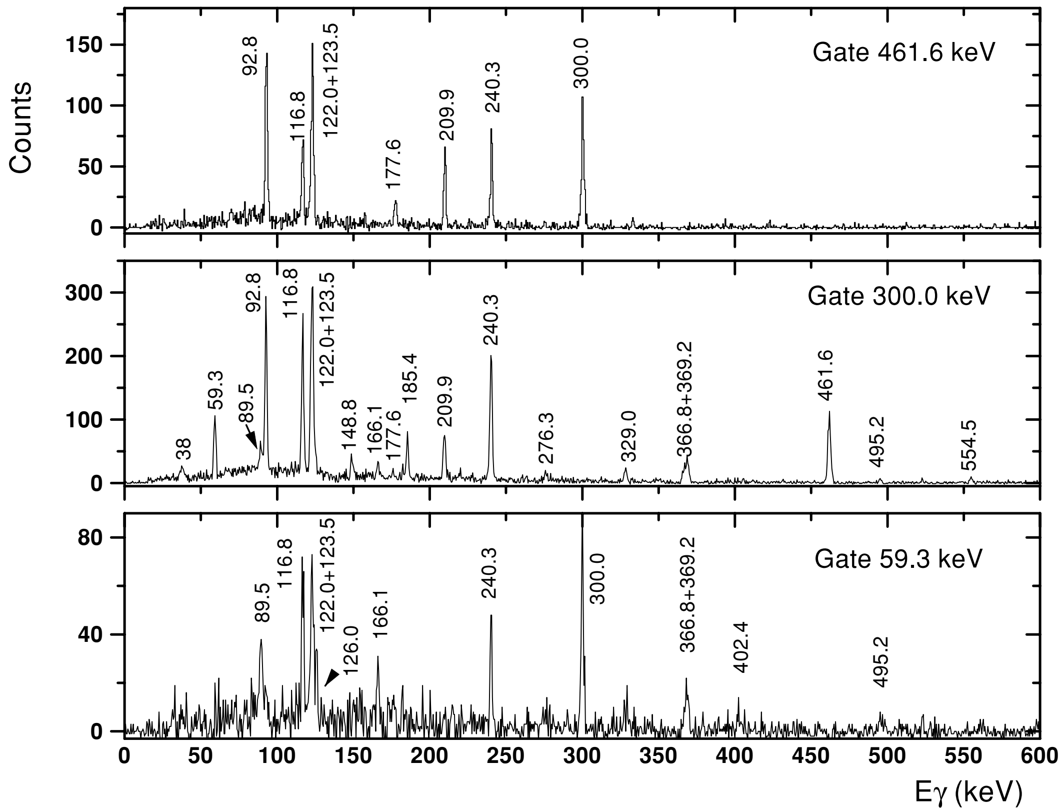

FIG. 2. Examples of $\gamma - \gamma$ coincidences in ^{96}Rb.

to be assigned for the 40-keV transition. The results of the conversion-electron measurements deduced from the singles Si(Li) spectrum are presented in Table II. The sum of the *K* and *L* electron intensities of the 40-keV transition represents $I_K + I_L = 95(9)\%$ of the total decay intensity of the isomer. The very weak *K* electron line of the 148.8-keV transition (7% of the isomer decay) is observed only in the $\gamma - e$ coincidence spectrum of Fig. 3. The evidence of this electron line suggests an *E*2 mutipolarity for the transition. However, this assignment is only tentative because this *K* electron transition is missing in the singles Si(Li) spectrum.

IV. LEVEL SCHEME ^{96}RB

The level scheme that is based on $\gamma - \gamma$ and $e - \gamma$ coincidences is shown in Fig. 4. An important change is observed between the group of low-lying levels below 230 keV

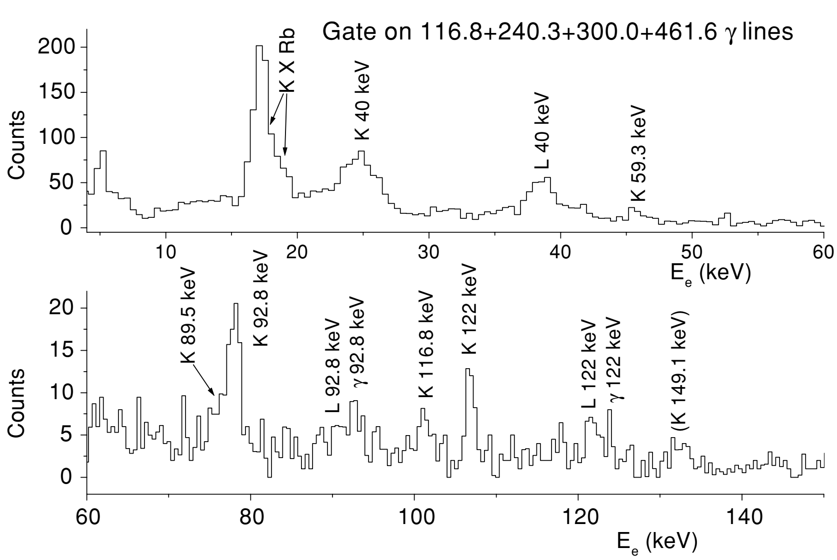

FIG. 3. Electrons and x rays in coincidence with the sum of four γ gates in ^{96}Rb.

TABLE II. Absolute conversion-electron intensities and multipolarities of ^{96}Rb transitions.

Transition (keV)	I_e	I_γ	α_K Exp.	α_K $E1$	α_K $M1$	α_K $E2$	Multipolarity
K 40	68(7)						
L 40	27(5)						
K 59.3	10.5(15)	17(2)	0.62(9)	0.40	0.56	5.32	$M1$
K 89.5(15)	4.7(10)	8(1)	0.59(15)	0.12	0.18	1.26	$M1+E2$
K 92.8	8.5(20)	37(2)	0.23(5)	0.11	0.16	1.06	$M1$
K 116.8	3.0(9)	36(3)	0.09(2)	0.05	0.095	0.47	$M1$
K 122.0 + 123.5	3.5(10)	68(6)	0.05(2)	0.045	0.072	0.38	$E1$, $M1$
K 240.3	1.7(5)	42(3)	0.040(12)	0.007	0.013	0.035	$E2$
K300.0 + 301.0	1.2(5)	85(8)	0.018(8)	0.004	0.007	0.02	($E2$)

and the higher-energy structure, which is characterized by a cascade of γ rays linked by strong crossovers. Moreover, the conversion-electron measurements reported in Table II show that the more intense transitions in this group of levels have $M1$ mutipolarities, whereas the crossovers are $E2$ in nature. This observation strongly suggests that the levels above 460 keV behave like a rotational band. An analogous rotational band was reported in the odd-odd, $N = 59$ isotone ^{98}Y [10,11]. In this nucleus, the band is built on a bandhead at 496.2-keV excitation energy. Apart from this rotational band, the authors of Ref. [10] have also shown that the low-lying levels below the rotational band are rather spherical as well as the 10^- isomeric state at 1181.5 keV. This isomer in ^{98}Y decays by an $E2$ transition of 110.8-keV energy and 0.83-μs half-life. The $E2$ multipolarity found for the 40-keV transition in ^{96}Rb and its total intensity suggest that it could be the isomeric transition. The $B(E2)$ values found for these two isomers, 3.7(2) and 1.4 W.u. for ^{96}Rb and ^{98}Y, respectively, are roughly comparable and are weakly accelerated together.

The observed analogies between ^{98}Y and ^{96}Rb allow the level scheme of the latter nucleus to be built, and spins and parities to be assigned to several levels. The g.s. spin $I = 2$ was already measured for ^{96}Rb by laser spectroscopy, and the magnetic and quadrupole moments were also investigated [16]. The measured value of the intrinsic quadrupole $Q_0 = 0.86(16)$ b corresponds to a weak deformation $\beta_2 = 0.10(2)$, which means that this state is rather spherical, as is the case for the g.s. of ^{98}Y. From these considerations, Genevey *et al.* [12] have proposed the spherical configuration $\pi(f_{5/2})\nu(s_{1/2})$ for the 2^- g.s. This configuration gives a good agreement between the experimental magnetic moment and its computed value. For this calculation, the unique ingredients were the experimental magnetic moment of the $I = 1/2^+$ g.s. of the odd-neutron ^{97}Sr [16] and the $I = 5/2^-$ g.s. of the odd-proton ^{95}Rb [17]. Consequently the dominant configurations of the low-lying states in ^{96}Rb are expected to result from the coupling of the proton $\pi(f_{5/2})$ orbital with the three neutron states $\nu(s_{1/2})$, $\nu(d_{3/2})$, and $\nu(g_{7/2})$. We have to note that these neutron states are also the g.s. and the first two excited states in the neighboring $N = 59$ isotones of ^{97}Sr and ^{95}Kr. The neutron orbitals are the same in ^{96}Rb and ^{98}Y, but the proton $\pi(p_{1/2})$ in ^{98}Y is replaced with the $\pi(f_{5/2})$ in ^{96}Rb. In this assumption, the first excited state at 59.3 keV in ^{96}Rb that decays to the g.s. by an $M1$ transition is very likely the second member of the $\pi(f_{5/2})\nu(s_{1/2})$ multiplet and has a spin and parity $I^\pi = 3^-$ (see Fig. 5).

The next 148.8-keV level, which decays by an $M1 + E2$ and an ($E2$) transition, has then a spin and parity $I^\pi = 4^-$ and is a member of the multiplet of dominant configuration $[\pi(f_{5/2})\nu(d_{3/2})]_{4^-}$. The decay pattern of this level is analogous to the one of the 170.8 keV in ^{98}Y, and in these two configurations, the neutron and proton are fully aligned.

It is difficult to fix unambiguously the spin of the bandhead of the rotational band in ^{96}Rb. However, these two bands are fed by microsecond isomers close in excitation energy, 1181.5 keV in ^{98}Y and 1135 keV in ^{96}Rb, and the isomeric transitions have comparable $B(E2)$ values. All these features, strongly suggest that the two isomers have the same $[\pi(g_{9/2})\nu(h_{11/2})]_{10^-}$ configuration. In this hypothesis, it is possible to assign spins to the levels above 460 keV, and the bandhead of ^{96}Rb has a spin and parity $I^\pi = 3^-$. The decay patterns of the bandhead and first excited states of the band to the low-lying levels are compatible with this assignment.

V. PROPERTIES OF THE ROTATIONAL BAND

A. Configurations of the ^{98}Y and ^{96}Rb Bandheads

The two odd-odd nuclei have effective moments of inertia $J = 44$ and 47 MeV$^{-1}\hbar^2$ for ^{98}Y and ^{96}Rb, respectively, values that are well beyond the rigid-body value $J \sim 30$ MeV$^{-1}\hbar^2$ for this mass region. This result suggests that these nuclei have some aligned angular momentum along the rotational axis. To find an approximate value of the alignment, the total aligned angular momentum $I_X = \sqrt{(I+1/2)^2 - K^2}$ for the experimental bands in ^{98}Y and ^{96}Rb is displayed in Fig. 6 as a function of the rotational frequency $\hbar\omega$.

In this transitional region, it is difficult to find a reference configuration that presents rotational characteristics comparable with these two nuclei; the collective band in ^{96}Sr has a vibrational structure [6] and only the g.s. band of ^{98}Sr is therefore available. This nucleus is known to have the maximum deformation observed in this region, and this value is expected to be equal or greater than the value for the two odd-odd nuclei. In the latter nuclei, $I_X = i + R = i + J\omega$, where i is the alignment, R is the rotational angular momentum, and J is the moment of inertia. In contrast, $i = 0$ in ^{98}Sr, and

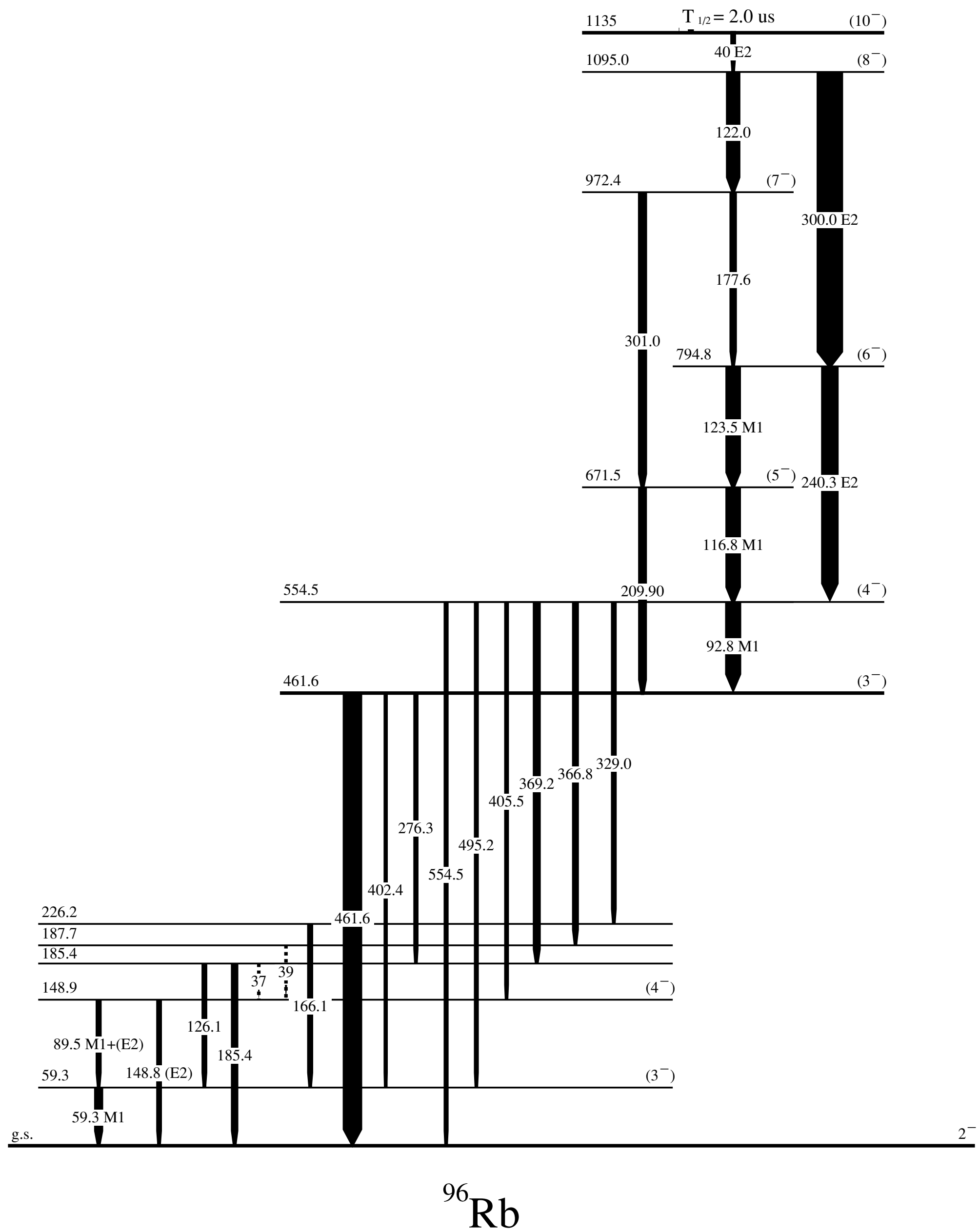

FIG. 4. Decay scheme of the 2.0-μs isomer in ^{96}Rb obtained in the present work. The low-lying levels and the isomer at 1135 keV have rather spherical configurations, and a rotational band develops above 460 keV.

only the second term, corresponding to the collective rotation, is present. Consequently one may compute the aligned angular momentum i from difference between the I_X values in the odd-odd nuclei and the reference configuration. The value found $i \sim 2 - 3\hbar$ is almost identical for the two nuclei. In an odd-odd nucleus, the total aligned angular momentum is the sum of the individual neutron and proton contributions. It is therefore interesting to compare the alignment in the odd-odd nuclei with odd-neutron and odd-proton nuclei having the same orbitals. For this purpose, we also showed in Fig. 6 the I_X experimental values for the $\pi[422\ 5/2]$ orbital in ^{99}Y [18] and $\nu[541\ 3/2]$ orbital in ^{97}Sr [2]. These two orbitals are the two components previously proposed for the bandhead of the rotational band in ^{98}Y [10]. One may note in Fig. 6 that the alignment $i_n \sim 2\hbar$ for the neutron is much larger than the value $i_p \sim 0.5\hbar$ for the proton and that the sum $i_n + i_p \sim 2.5\hbar$ is close to the value found for the two odd-odd nuclei. This result gives *a posteriori* some support to the configurations proposed for the rotational bands in ^{98}Y. Moreover, the comparable alignment observed for the bands in ^{98}Y and ^{96}Rb suggests also analogous configurations for these two nuclei. However, ^{97}Sr has two protons less than ^{98}Y and its proton orbital is very likely the $\pi[431\ 3/2]$ Nilsson state. This produces the configuration $\pi[431\ 3/2] \times \nu[541\ 3/2]K = 3^-$

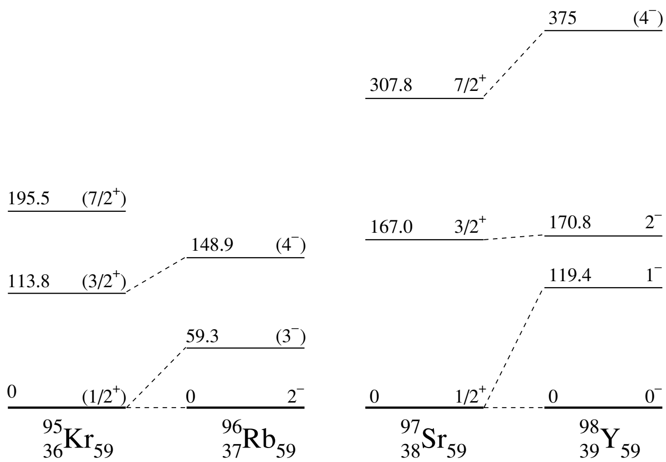

FIG. 5. Comparison of the low-lying levels in odd and odd-odd $N = 59$ isotones. The configurations of these states originate from the coupling of the $s_{1/2}$, $d_{3/2}$, and $g_{7/2}$ neutrons with the $p_{1/2}$ or $f_{5/2}$ protons in ^{98}Y or ^{96}Rb, respectively.

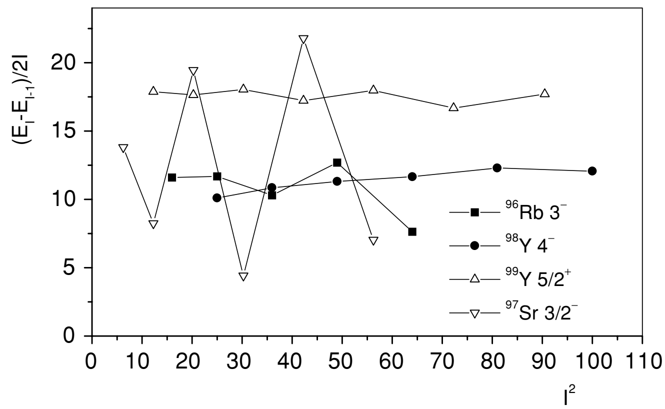

FIG. 7. Experimental staggerings in odd-neutron, odd-proton, and odd-odd nuclei close to ^{96}Rb. The staggering of the $K = 3/2^-$ odd neutron is much stronger than in the $K = 5/2^+$ odd proton. The staggering observed in the two odd-odd nuclei is closer to that of the odd proton.

and explains the K value difference between the two nuclei. Although possible bands based on the $\pi[431\ 3/2]$ orbital are still unknown in this mass region, one may conclude from the comparison of the I_X values for ^{98}Y and ^{96}Rb in Fig. 6 that the alignments do not change substantially between the $\pi[431\ 3/2]$ and the $\pi[422\ 5/2]$ Nilsson orbitals.

We have seen that the alignment is much higher for the $h_{11/2}$ than for the $g_{9/2}$ orbital and consequently, for the favored odd-odd band, the neutron is always placed in the $[h_{11/2}, \alpha = -1/2]$ whereas the proton may be placed either in the $[g_{9/2}, \alpha = -1/2]$, giving a total signature $\alpha = -1$ (odd spins), or in $[g_{9/2}, \alpha = +1/2]$, giving $\alpha = 0$ (even spins). Consequently, in these two nuclei, the staggering is expected to be caused by the odd proton and the favored signature corresponds to the maximum alignment that is for $\alpha = 0$ (even spin). The staggering is also expected to increase when K decreases, which explains the increase observed in ^{96}Rb.

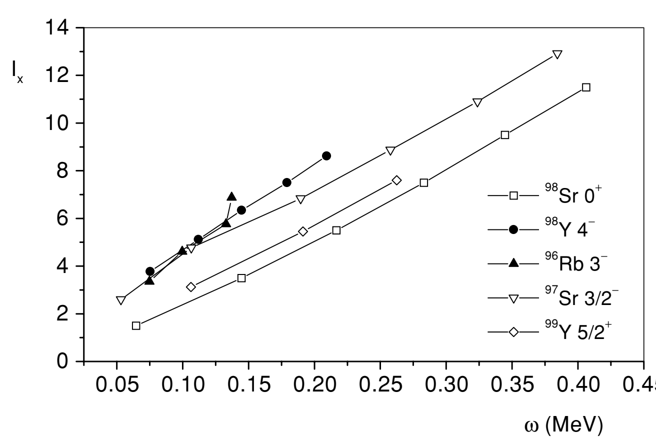

FIG. 6. Experimental alignments for the $\pi(g_{9/2})$, $\nu(h_{11/2})$ and $\pi(g_{9/2})\nu(h_{11/2})$ configurations in odd-neutron, odd-proton, and odd-odd nuclei close to ^{96}Rb. For an odd-odd nucleus the alignment is expected to be the sum of the neutron and proton contribution. The even ^{98}Sr is used as a reference configuration.

All these predicted features are correctly reproduced, as shown in Fig. 7, where the experimental staggering observed for the two odd-odd bands is reported and also for the neighbor proton and neutron bands. This plot shows also that the staggering curve is much higher for the odd-proton band than for the three other bands. This effect reflects the fact that the effective moment of inertia is smaller in the odd-proton band because the alignment is smaller for the proton than for the neutron, as discussed above.

B. Deformations in ^{98}Y and ^{96}Rb

The deformation of these two rotational bands is experimentally unknown. In their *IBFFM* calculations of ^{98}Y, Brant *et al.* [10] took the strongly deformed nucleus ^{98}Sr as the effective core of the odd-odd nucleus. However, the poor agreement with theory obtained cannot justify this hypothesis.

In the absence of a direct measurement of the quadrupole moment Q_0, it is possible to tentatively extract this value from the experimental γ branching ratios of $\Delta I = 1$ to $\Delta I = 2$ intraband transitions. In these two nuclei, the Nilsson orbitals of the configuration $\pi[422\ 5/2] \times \nu[541\ 3/2]K = 4^-$ in ^{98}Y and $\pi[431\ 3/2] \times \nu[541\ 3/2]K = 3^-$ originate from the shell-model unique-parity states $\pi(g_{9/2})$ and $\nu(h_{11/2})$. These intruder states cannot mix strongly with the other levels of the shell, which allows reliable estimates of the intrinsic gyromagnetic factor g_K to be made. These values are obtained from the formula

$$g_K = \frac{g_l + (g_s - g_l)}{2K} GMS(K \to K),$$

where $g_s = 0.6 g_s(\text{free})$ and $GMS(K \to K)$ is a quantity dependent of deformation and is tabulated in [19]. Assuming a collective gyromagnetic factor $g_R = Z/A = 0.39$, it is possible to compute the quantity $(g_K - g_R)/Q_0$ as a function of Q_0. For the two considered nuclei, it is also possible to deduce the experimental quantity $|g_K - g_R|/Q_0$ for all the

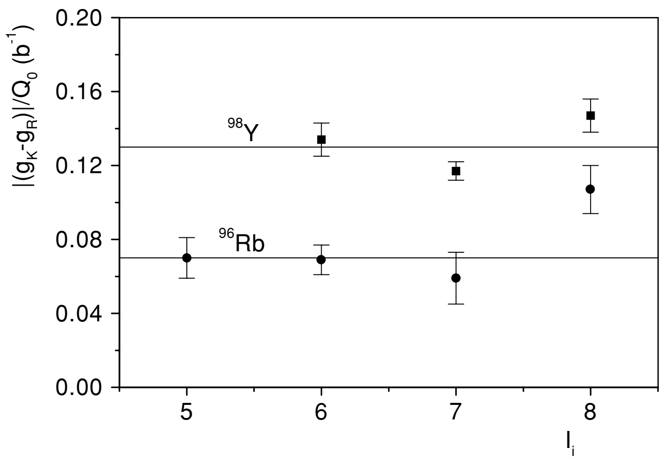

FIG. 8. Experimental values of $(g_K - g_R)/Q_0$ versus I deduced from the branching ratios of intraband transitions in ^{98}Y and ^{96}Rb.

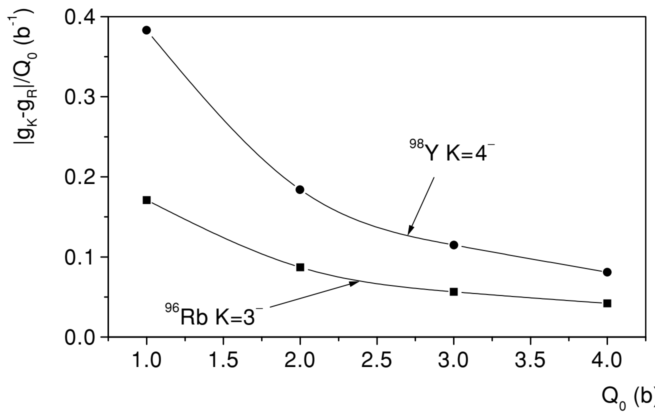

FIG. 9. Computed values of $(g_K - g_R)/Q_0$ for ^{98}Y and ^{96}Rb assuming $g_R = Z/A$ and pure K bands (see text). The comparison with experimental values allows estimations of the quadrupole moment values Q_0 to be extracted.

states of the band with spins $I \geqslant K + 2$. These values are shown in Fig. 8 as functions of I.

For ^{98}Y, we have used the branching ratios deduced from Table III, where our remeasured intensities of the γ decay of the ^{98}Y isomer are reported.

The comparison between the experimental values shown in Fig. 9 and the theoretical estimations allow a Q_0 value to be deduced. The drawing shows that the two nuclei have intrinsic quadrupole values $Q_0 \sim 2.3$ and 2.6 b for ^{96}Rb and ^{98}Y, respectively, which corresponds to a mean deformation $\beta_2 \sim 0.28$. However, the effective quantity g_R is experimentally unknown in this region, and the quantity $g_R = Z/A$ is very likely a maximum value. In their analysis of the 1^+g.s. band of the odd-odd neighbor ^{100}Y, Mach *et al.* [20] used a value $g_R = 0.75Z/A$. Assuming this value, the theoretical quadrupole moments in ^{96}Rb and ^{98}Y increases by ~1 b and the nuclei reach a very high deformation $\beta_2 = 0.39$. One can conclude that the true value is between these two estimations.

The experimental and theoretical estimations of the quantity $(g_K - g_R)/Q_0$ are made under the assumption of pure K bands (i.e., Alaga rules). This hypothesis seems inconsistent with the observed alignments in these two bands and suggests some possible K mixing. However, the experimental values reported in Fig. 8 are rather constant as functions of spin, with the possible exception of the 8^- state in ^{96}Rb, which justifies *a posteriori* our hypothesis. From this analysis, one may conclude that the deformation of the rotational bands in ^{96}Rb and ^{98}Y is $\beta_2 > 0.28$. This value has to be compared with the deformation $\beta_2 = 0.32(2)$ deduced for the $\nu[541\,3/2]$ band in the $N = 59$ isotones by Urban *et al.* [2] from picosecond half-life measurements.

TABLE III. Absolute intensities of the γ transitions observed in the isomer decay of ^{98}Y.

Transition	E_γ(keV)	I_γ
$5^- \rightarrow 4^-$	100.7	100.0(2.5)
$10^- \rightarrow 8^-$	110.9	69.0(14)
$6^- \rightarrow 5^-$	129.8	95.8(17)
$7^- \rightarrow 6^-$	158.0	80.6(6)
$8^- \rightarrow 7^-$	186.4	94.4(12)
$6^- \rightarrow 4^-$	230.6	6.9(4)
$7^- \rightarrow 5^-$	287.8	19.8(8)
$8^- \rightarrow 6^-$	344.4	27.2(5)

It is also possible to find an experimentally based prediction for the value of the quantity $GQ_{\text{o-o}} = (g_K - g_R)/Q_0$ in ^{98}Y from the GQ_p and GQ_n values in the neighbor nuclei ^{99}Y and ^{97}Sr. In this case one has

$$GQ_{\text{o-o}} = \frac{K_p \times GQ_p - K_n \times GQ_n}{K}.$$

The negative sign in this expression comes from theory, which predicts a negative value for GQ_n, whereas only the modulus of this quantity may be deduced from experiment. A value $GQ_p = 0.291(30)$ b^{-1} was previously measured for the $K = 5/2^+$ band in ^{99}Y [18] and we have found a value $GQ_n = 0.122(13)$ b^{-1} for the $K = 3/2^-$ band in ^{97}Sr. The last value was deduced from the branching ratio of the $9/2^-$ state measured by Wu *et al.* [6]. The predicted value $GQ_{\text{o-o}} = 0.136(20)$ b^{-1} for ^{98}Y is in good agreement with the observed value $GQ_{\text{o-o}} = 0.130(15)$ b^{-1}.

VI. THE SPHERICAL ISOMER

In the two nuclei, the fully aligned 10^- isomers of configuration $\pi(g_{9/2})\nu(h_{11/2})$ have comparable excitation energies of about ~1100 keV. A strongly attractive $n - p$ interaction explains the presence of these isomers at a relatively low energy. Consequently, the strong n-p interaction may induce a competition between high-spin fully aligned spherical configurations and the levels of rotational bands in this transitional region. Moreover, it is interesting to note that the neutron and proton orbitals present in the configuration of the spherical isomer and in the deformed band of these odd-odd nuclei originate together from the same spherical unique-parity states $\pi(g_{9/2})$ and $\nu(h_{11/2})$. To our knowledge, it seems that this situation is unique in the whole nuclear chart. For the future, it would be interesting to know if the competition between spherical and deformed states is still present at higher spins.

VII. CONCLUSIONS

The present γ ray and conversion-electron measurements have allowed a reliable level scheme to be built for the ^{96}Rb doubly odd nucleus. This very neutron-rich nucleus has a structure comparable with the previously known ^{98}Y isotone. Both show rather spherical levels at low energy, whereas deformed states appear at $\sim$500 keV. Minor differences observed in the configurations of the low-lying spherical levels and in the bandhead of the deformed band are due to a different occupation of the proton orbitals in these two nuclei. The comparable behaviors observed for the decay of the isomer in both nuclei suggest that they have the same $\pi(g_{9/2})\nu(h_{11/2})$ configuration. These two unique-parity states and the $\nu(g_{9/2})$ neutron level play a considerable role in all these nuclei. The relative occupation of these orbitals is able to change drastically the shape of the nucleus. However, the same spherical $\pi(g_{9/2})$ and $\nu(h_{11/2})$ unique-parity states may also produce microsecond isomers in competition with deformed states because of a very strong attractive n-p interaction. Then, in the same nucleus, these unique-parity orbitals are present in spherical and deformed configurations.

In conclusion, a great wealth of information was recently gained in the odd-mass and odd-odd $N = 59$ isotones. These new data stress the importance of the unique-parity states in shape coexistence phenomenon. We hope that the new results obtained in odd-mass and odd-odd nuclei of the $N = 59$ isotones will trigger new theoretical calculations in this mass region.

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