Decay of a $K^\pi = 21/2^-$, 17-ms isomer in ^{185}Ta

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High-spin states in the neutron-rich nucleus ^{185}Ta, populated in the decay of a long-lived, three-quasiparticle state, have been studied using deep-inelastic reactions with ^{136}Xe ions and a ^{186}W target. The lifetime of the isomer has been measured as 17(2) ms and the spin and parity determined to be $K^\pi = 21/2^-$, leading to a $\pi 7/2^+[404]\nu 3/2^-[512]11/2^+[615]$ configuration assignment. The isomer decays into the rotational band built upon the $\pi 9/2^-[514]$ intrinsic state via K-forbidden transitions with reduced hindrances of 52 and 71. The $\pi 9/2^-[514]$ state is itself an isomer with a lifetime of 17(3) ns. It decays via K-allowed $E1$ transitions to states in the $\pi 7/2^+[404]$ band with strengths that are similar to equivalent transitions in the lighter tantalum isotopes.

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I. INTRODUCTION

In well-deformed, axially symmetric nuclei, the projection, K, of the total angular momentum on the nuclear symmetry axis is nominally a good quantum number. For nuclei in the mass-180 region, the proximity to the Fermi surface of a number of high-K, single-particle states results in low-lying, high-K multiparticle states that can often only decay via transitions for which the change in K is larger than the transition multipolarity, λ. Such transitions are, in principle, forbidden, with the forbiddenness defined by $\nu = \Delta K - \lambda$. In practice, the transitions are strongly hindered rather than forbidden, with the result that some states are long-lived, so-called K isomers. For the classification of K isomers, it is useful to define a reduced hindrance, $f_\nu = F^{1/\nu}$, where F is the traditional hindrance relating the measured transition strength to the Weisskopf estimate. In axially symmetric nuclei with "good K," the reduced hindrances for K-forbidden transitions typically lie in the range of 30 to 200. Some anomalous cases where the reduced hindrances are substantially lower can be explained in terms of specific K mixing due to various sources, including local mixing with isolated states, or Coriolis mixing due to rotation (see, for example, Ref. [1] and references therein).

There has been considerable speculation concerning the persistence of high-K isomers in more neutron-rich nuclei and, in particular, the extent of the high-K isomer "island" in the $A = 180$ region. For example, the review by Walker and Dracoulis [2] discusses another "island" expected around the (predicted) favorable case of ^{188}Hf, but this nucleus is presently inaccessible, lying eight neutrons past the heaviest stable hafnium isotope. Although information on these neutron-rich nuclei is still comparatively sparse, recent experiments using incomplete-fusion [3,4], deep-inelastic [5–9], and relativistic fragmentation reactions [10,11] have started to make inroads into this region.

The nuclide ^{185}Ta lies four neutrons beyond the heaviest stable isotope of tantalum, and until recently there was very little known concerning its high-spin states. Wheldon and co-workers [5] observed the decay of a high-spin isomer populated in deep-inelastic reactions between ^{238}U ions and a ^{186}W target and assigned it to ^{185}Ta on the basis of yield and coincidences with characteristic tantalum x rays. They reported a lower lifetime limit of $T_{1/2} > 1$ ms and did not make a definitive spin and parity or configuration assignment for the isomer. Some ambiguity also remained in the order of the transitions in the level scheme. More recently, Shizuma and co-workers investigated neutron-rich ^{183}Ta [12] and ^{185}Ta [13] using transfer reactions. In particular, they used the proton transfer reaction, ^{186}W(^{18}O,^{19}F)^{185}Ta, to positively identify low-spin states in ^{185}Ta, firmly ordering the lowest-lying transitions and extending further the low-lying level scheme. Both of the above

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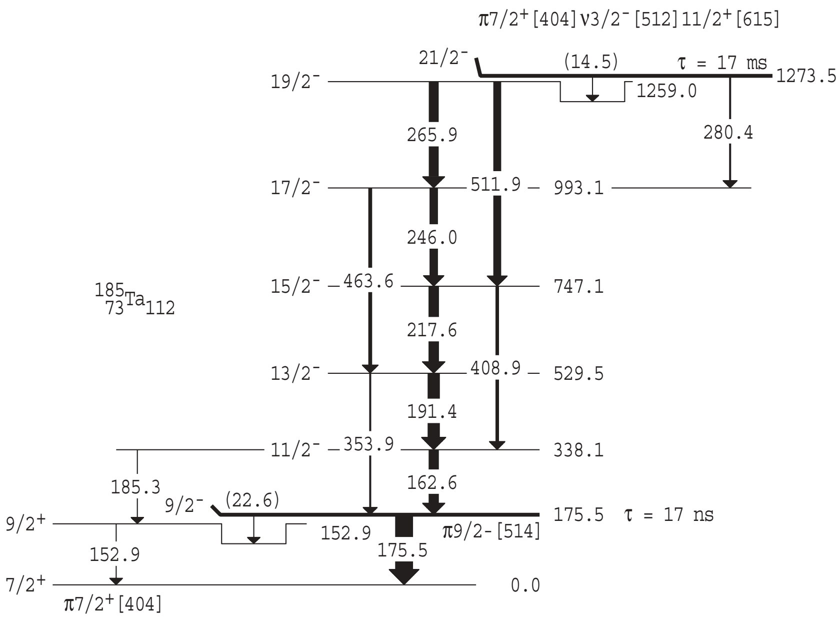

FIG. 1. Partial level scheme for ^{185}Ta deduced in the present work. Transition widths indicate out-of-beam γ-ray intensities observed in the decay of the 1273.5-keV isomer. Uncertainties in transition energies are $\pm$0.2 keV, except for the weak 185.3-keV transition which is $\pm$0.5 keV. The energies and intensities of the unobserved 14.5- and 22.6-keV transitions are inferred from coincidence relationships.

measurements for ^{185}Ta built upon information available from a prior experiment that employed the ^{186}W(t,α) reaction with a polarized triton beam [14].

In the present work, ^{185}Ta was strongly populated via one proton removal from ^{186}W, through a combination of the proton transfer and deep-inelastic processes that occur in reactions between a beam of ^{136}Xe ions and a thick ^{186}W target. The decay of the isomer observed by Wheldon *et al.* [5] has been characterized, including measurement of its lifetime, identification of the depopulating transitions, and measurement of its spin and parity. The quasiparticle structure of the isomeric state has been investigated through comparison with multi-quasiparticle calculations that include the effects of pairing and residual interactions. New information on the decay of the 9/2$^-$[514] intrinsic state is also presented.

II. EXPERIMENTAL METHODS

The results reported here were obtained at Argonne National Laboratory in two experiments performed with Gammasphere, which, for these measurements, consisted of 99 Compton-suppressed HPGe detectors. A beam of 840-MeV ^{136}Xe ions from the ATLAS accelerator was incident on a 6 mg/cm^2 metallic target of ^{186}W (enriched to 99.8%) with a 25 mg/cm^2 gold backing. In the first experiment, 1-ns beam pulses separated by 825 ns were used. Approximately 1.0 $\times$ 10^9 events were collected requiring at least three Compton-suppressed γ rays to be detected within a coincidence overlap of approximately $\pm$800 ns. The data were gain-matched offline in time and energy and the events sorted into a Blue database [15], from which time-correlated spectra and coincidence histograms were projected. The principal analysis was performed using a $\gamma\gamma\gamma$ coincidence cube selecting γ rays in the out-of-beam region 100–800 ns after the beam pulse.

The second experiment used a macroscopically chopped beam with different beam on/beam off periods to measure the decay of isomeric states with lifetimes greater than about 5 μs. Following an exploration of different time regions, the main measurements reported here were carried out with a 10-ms on/40-ms off chopping rate. The γ-ray data were collected only in the beam-off period, whenever two or more Compton-suppressed γ rays were detected. An ADC clock, reset with every beam burst, was used to record the time of the event within each beam-off period.

III. EXPERIMENTAL RESULTS

A. Level scheme

The partial level scheme for ^{185}Ta established from the present work is shown in Fig. 1. While the overall band structure is similar to that presented in Refs. [5,13,14], the current results include new transitions, the determination of two lifetimes, and the firm establishment of all the spins and parities. The figure does not include states not observed in the present work, including levels at 418 and 885 keV that were tentatively assigned as 5/2$^+$[402] and 7/2$^-$[523] intrinsic states, respectively, in Refs. [13,14]. Also not shown are the 1/2$^+$[411] intrinsic state at 406 keV and the associated rotational band states first observed by Løvhøiden *et al.* [14]. Subsequent measurements by Shizuma *et al.* [13] established the 1/2$^+$[411] state as a 900-ns isomer and extended its rotational band to higher spin. The new information obtained for ^{185}Ta from the present work is detailed below.

Double-gated spectra for ^{185}Ta, projected from the out-of-beam coincidence cube and collected with 1 ns/825 ns pulsing, can be found in Fig. 2. Figure 2(a) shows a double-gate on the first $\Delta I = 1$ transition (162.6 keV) in the 9/2$^-$[514] rotational band and the 175.5-keV transition from the bandhead to the ground state. A new transition is observed at 280.4 keV, with other coincidence information clearly placing it in parallel with the 265.9-keV transition. For example, the 280.4-keV transition is absent from the spectrum double-gated on the

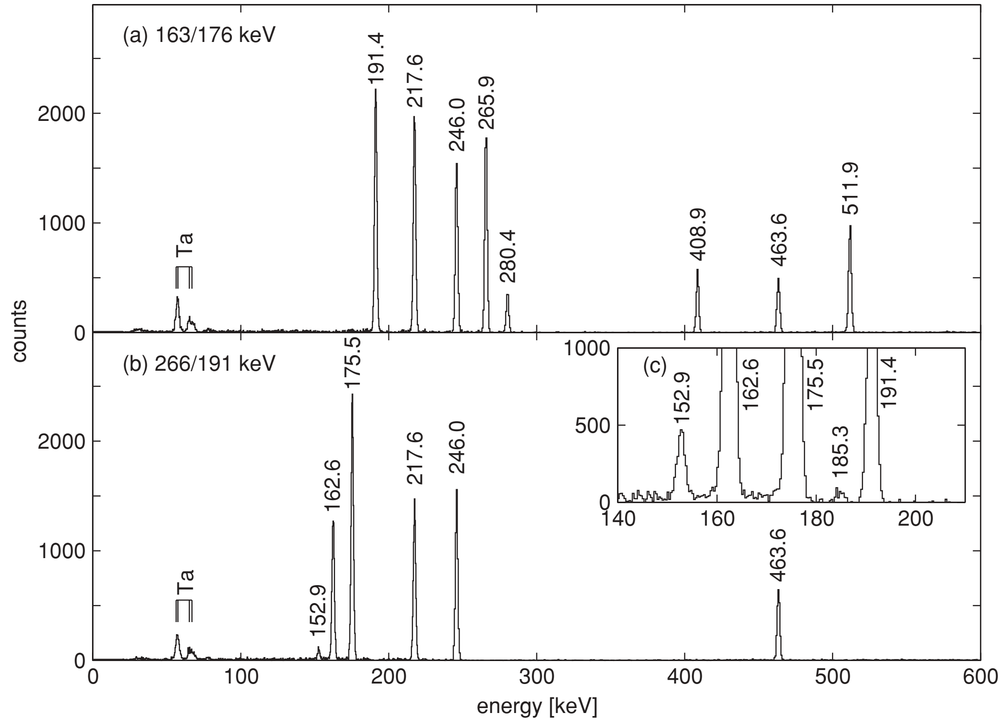

FIG. 2. Double-gated coincidence spectra projected from the out-of-beam $\gamma\gamma\gamma$ coincidence cube. Panels (a) and (b) were produced with double gates on the 163/176 keV and 266/191 keV pairs of transitions, respectively, while panel (c) is the sum of eight spectra double-gated on the 191/218, 191/266, 191/464, 191/512, 246/218, 246/409, 266/464, and 409/512 keV pairs of transitions.

265.9- and 191.4-keV γ rays [Fig. 2(b)]. This suggests that the 280.4-keV transition decays from the isomer at 1273.5 keV to the 993.1-keV state, while population of the 1259-keV level implies that it is fed by an unobserved 14.5-keV transition from the same isomer.

The spectrum in Fig. 2(b) also shows a transition at 152.9 keV, presumably the first transition in the $\pi 7/2^{+}[404]$ band observed by Shizuma *et al.* [13], who also observed a 185-keV transition between the 338.1- and 152.9-keV states. This transition is very weak in the present data. It can be seen in the inset spectrum [Fig. 2(c)], produced by a sum of eight double-gated spectra chosen to select decay paths that feed into the 338.1-keV state. Our measured energy of 185.3(5) keV satisfies the required energy sum, while the coincidence information supports its placement parallel to the 162.6-keV transition. Note that the intensity of the 185.3-keV transition is far too weak to balance the intensity out of the 152.9-keV state that it feeds, implying the presence of an unobserved 22.6-keV branch from the $9/2^{-}[514]$ bandhead to the first excited state in the $7/2^{+}[404]$ band.

B. Lifetimes

The $\pi 9/2^{-}[514]$ states in ^{179}Ta, ^{181}Ta, and ^{183}Ta have lifetimes and excitation energies of 2.05 μs at 31 keV, 8.73 μs at 6 keV, and 107 ns at 73 keV, respectively [16–18]. Because the $9/2^{-}[514]$ state energy is considerably higher in ^{185}Ta, a shorter lifetime is expected. It was measured from a time difference spectrum obtained from the out-of-beam coincidence data (from the 825-ns pulsed beam measurement) that were sorted into a γ-γ-time difference cube. Figure 3 shows the time spectrum obtained by starting on the 162.6-keV γ rays and stopping on the 175.5-keV γ rays. The solid line is the fitted time spectrum including an exponential decay and the effect of the detector time response, as determined from the prompt time difference spectrum observed between the 162.6- and 191.4-keV transtions. A lifetime of 17(3) ns is adopted for the 175.5-keV, $\pi 9/2^{-}[514]$ bandhead.

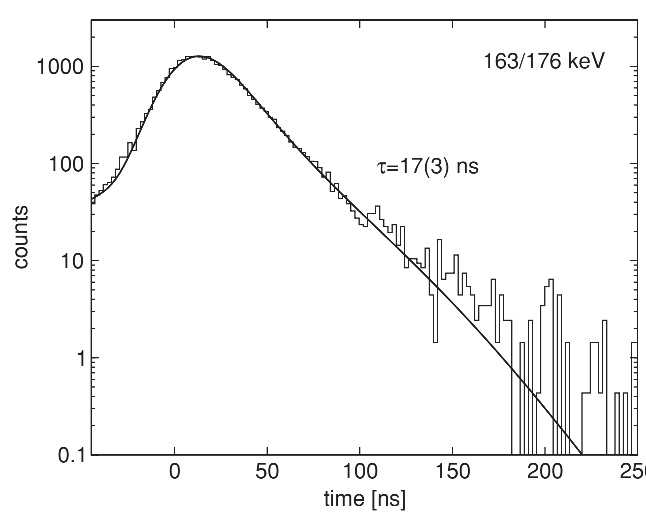

FIG. 3. Time difference measured between the 163- and 176-keV transitions in ^{185}Ta.

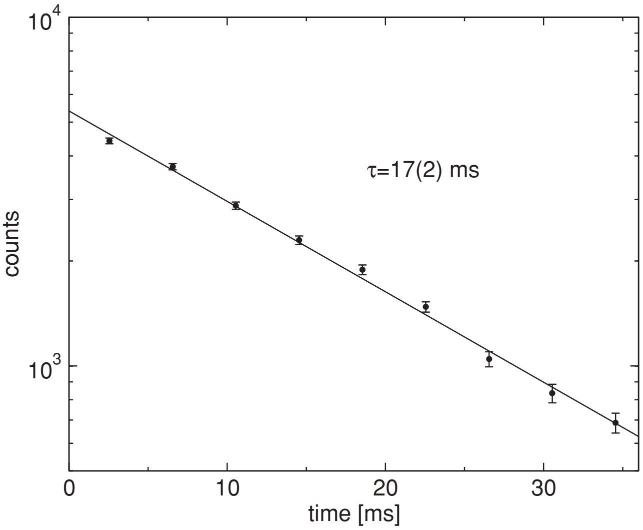

FIG. 4. Time dependence of the intensities of γ rays that are fed by the isomer at 1273.5 keV, measured in the beam-off period with 10 ms/40 ms beam chopping.

The lifetime of the isomer at 1273.5 keV was determined from the second experiment by splitting the 40-ms, beam-off period into nine contiguous regions and creating a prompt $\gamma\gamma$ coincidence matrix for each, from which the time-dependent intensities of the γ rays in the $9/2^-[514]$ band fed by the isomer could be determined. This was done by setting gates on the clean transitions at 162.6 and 265.9 keV and measuring the intensities of the other major transitions from the band in each spectrum. The sums of these fitted intensities are presented in Fig. 4 as a function of time. The lifetime deduced is 17(2) ms.

C. In-band branching ratios and decay properties

Table I lists the observed in-band branching ratios for the $9/2^-[514]$ rotational band together with the inferred values of $|g_K - g_R|$ and the $M1/E2$ mixing ratios for the $\Delta I = 1$ transitions, assuming a value for the quadrupole moment of $Q_0 = 6.5$ eb (see, for example, Ref. [5]). Because the single-particle g factor is likely to be positive, assumption of a positive sign for $g_K - g_R$, and assuming $g_R = 0.35(5)$, results in a value for g_K of 1.21(5). This is close to the Nilsson model prediction of $g_K = 1.29$ for the $9/2^-[514]$ configuration.

The mixing ratio for the 152.9-keV transition from the $7/2^+[404]$ band is required for the intensity balance discussed in Sec. III E below and was calculated to be $\delta = 0.75$ from the rotational model expression

$$\frac{g_K - g_R}{Q_0} = \frac{0.93 E_\gamma (I \rightarrow I-1)}{\delta \sqrt{I^2 - 1}}, \quad (1)$$

using a calculated value from the Nilsson model of $g_K = 0.63$ for the $7/2^+[404]$ proton and the same values of g_R and Q_0 that were used above.

D. Transition multipolarities and level spin assignments

Restrictions on the multipolarities of interband transitions have been made by considering total conversion coefficients. For example, the spectrum in Fig. 2(b) can be used to balance the intensity of the 162.6-keV transition against the 175.5-keV transition. Small corrections for the branch through the 152.9-keV state are required, and the mixing ratio for the 162.6-keV transition is assumed to be $\delta = 0.2$ based on the results in Table I. The inferred conversion coefficient for the 175.5-keV transition is $\alpha_T = 0.17(12)$. This can be compared with theoretical values [19] of 0.085 for $E1$, 0.88 for $M1$, and 0.464 for $E2$, implying an $E1$ multipolarity and confirming the $9/2^-$ assignment for the 176-keV state.

In the decay of the higher-lying isomer, the spectrum in Fig. 2(a) can be used to measure the intensity balance across the 993.1-keV state and infer the conversion coefficient for the 280.4-keV transition, assuming multipolarities for the 265.9-, 246.0- and 463.6-keV transitions according to the band structure and the mixing ratio results in Table I. The limit of $\alpha_T \leqslant 0.53$ that is obtained rules out magnetic multipolarities larger than $M1$ (because for $M2, \alpha_T$ =1.013), but only eliminates electric multipolarities greater than $E3$, with $E3$ at the very limit of possibility (because for $E3, \alpha_T = 0.493$ and for $E4, \alpha_T = 2.73$). The observed intensities of the 265.9- and 511.9-keV transitions and the intensity balance through the 1259.0-keV state imply that the total transition intensity for the 14.5-keV transition is much greater than that for the 280.4-keV transition, indicating that the lower energy 14.5-keV transition out of the 1273.5-keV state is heavily favored compared to the 280.4-keV transition. Thus the 14.5-keV transition must have a multipolarity lower than that of the 280.4-keV transition, so the latter must be, therefore, either $E2$ or $E3$. An $E3$ multipolarity

TABLE I. Measured in-band, $\Delta I = 2/\Delta I = 1$ branching ratios for the $9/2^-[514]$ band in ^{185}Ta, together with inferred gyromagnetic ratios and $M1/E2$ mixing ratios.

J_i	$E_\gamma(I \rightarrow I-1)$ (keV)	$E_\gamma(I \rightarrow I-2)$ (keV)	$\lambda = \frac{I_\gamma(I\rightarrow I-2)}{I_\gamma(I\rightarrow I-1)}$	$\lvert g_K - g_R\rvert$[a]	$\lvert\delta\rvert$
$13/2^-$	191.4	353.9	0.130(12)	0.89(4)	0.20(1)
$15/2^-$	217.6	408.9	0.333(21)	0.83(3)	0.21(1)
$17/2^-$	246.0	463.6	0.479(30)	0.89(3)	0.20(1)
$19/2^-$	265.9	511.9	0.777(47)	0.84(3)	0.20(1)
			Weighted average:	0.857(12)	

[a]With $Q_0 = 6.5$ eb.

TABLE II. Measured transition strengths for isomeric transitions in ^{185}Ta, together with $E1$ decays from the $9/2^-[514]$ intrinsic state in lighter tantalum isotopes.

K^π_{initial}	τ	E_γ (keV)	I_γ	$\sigma\lambda$	α_T	$B(\sigma\lambda)$ (W.u.)	ν	f_ν
$21/2^-$	17(2) ms	280.4	100(6)	$E2$	0.101	$3.9(5) \times 10^{-8}$	4	71.0(24)
		(14.5)[a]	4.64(16)[a]	$M1$	217	$2.5(3) \times 10^{-9}$	5	52.4(13)
$9/2^-$	17(3) ns	175.5	100(7)	$E1$	0.085	$2.8(6) \times 10^{-6}$	0	–
		(22.6)[a]	1.52(12)[a]	$E1$	4.00	$2.0(4) \times 10^{-5}$	0	–
^{183}Ta,[b] $9/2^-$	154(16) ns	73.2	100	$E1$	0.815	$2.76(28) \times 10^{-6}$	0	–
^{181}Ta,[b] $9/2^-$	8.73(17) μs	6.24	100	$E1$	30.1	$4.63(9) \times 10^{-6}$	0	–
^{179}Ta,[b] $9/2^-$	2.05(12) μs	30.7	100	$E1$	1.731	$1.90(11) \times 10^{-6}$	0	–

[a]Unobserved transition. Energy and intensity inferred from coincidence data.
[b]Isomer decay data taken from Refs. [16–18].

implies an $M2$ multipolarity for the 14.5-keV transition and results in reduced hindrance values of 2.4 and 3.7, respectively. These are unrealistically low in the absence of an obvious mechanism for K mixing, ruling out the $E3$ possibility. As shown in Sec. III E immediately below, the alternative assignment of $E2$ multipolarity for the 280.4-keV transition, and, hence, $M1$ character for the 14.5-keV transition, results in reasonable transition strengths for both transitions and establishes $K^\pi = 21/2^-$ for the 1273.5-keV isomeric state.

E. Transition strengths

Both of the isomeric states observed in ^{185}Ta have decay branches that proceed via unobserved transitions, whose intensities can only be deduced using intensity balances and calculated conversion coefficients. The mixing ratios for the 152.9- and 265.9-keV transitions that are required for these intensity balances are given in Sec. III C. The resultant γ-ray intensities and the deduced transition strengths for the isomeric transitions are collated in Table II.

IV. DISCUSSION

A. K-allowed $E1$ transitions

The strength of the $E1$ decay between the $9/2^-[514]$ and $7/2^+[404]$ intrinsic states in ^{185}Ta is given in Table II. It lies in the typical range for this region and compares well with equivalent transitions in the lighter tantalum isotopes, which are also found in Table II. Note also that the higher excitation energy of the $9/2^-[514]$ state in ^{185}Ta compared with the lighter isotopes means that a $9/2^- \rightarrow 9/2^+$ transition is energetically possible in ^{185}Ta. This transition is seven times stronger than the $J \rightarrow J-1$ transition. Similar behavior has been observed elsewhere. For example, in the (odd-neutron) case of ^{177}Hf, a series of K-allowed (stronger) $J \rightarrow J$ and (weaker) $J \rightarrow J-1$ $E1$ transitions are observed over the spin range from $J = 9/2$ to $J = 21/2$ between states in the $\nu 9/2^+[624]$ and $\nu 7/2^-[514]$ rotational bands. Bernthal and Rasmussen [20] successfully explained these $E1$ transition strengths with a model that included octupole-vibration coupling.

$E1$ transitions have also been observed between the same pair of proton orbitals involved in the present case of ^{185}Ta, for example, in ^{169}Lu [21]. The $9/2^-[514]$ state in ^{169}Lu lies 439 keV above the $7/2^+[404]$ state (cf. 176 keV in ^{185}Ta), so that $E1$ decays are energetically possible (and are observed) over a much larger range of spins. The (relatively) large $E1$ transition strengths in ^{169}Lu can only be explained by the inclusion of octupole-vibration coupling [21]. Note that the $9/2^-[514]$ orbital originates from the $h_{11/2}$ spherical parent, while the $7/2^+[404]$ orbital has a mixed $d_{5/2}/g_{7/2}$ spherical parentage. It is known that transitions between $\Delta l = \Delta j = 3$ orbitals, such as $h_{11/2}$ and $d_{5/2}$, can have an octupole component.

The transition strength for the 185.3-keV transition in ^{185}Ta can be estimated by assuming that the in-band 162.6-keV γ ray has the expected rotational model strength. Assuming a quadrupole moment of $Q_0 = 6.5$ eb and taking $|g_K - g_R| = 0.857$ (from the average of the values in Table I), a value of $B(E1) = 7(3) \times 10^{-6}$ W.u. is obtained. This is consistent with the value for the $9/2^- \rightarrow 7/2^+$ transition; however, further $E1$ transitions would need to be observed before a more systematic analysis of the spin dependence of the $E1$ strengths would be possible.

B. K-forbidden transitions

The 14.5-keV $M1$ and 280.4-keV $E2$ transitions from the $K^\pi = 21/2^-$ isomer have reduced hindrances of 52.4(13) and 71.0(24), respectively, which fall within the range expected for axially symmetric nuclei with good K, albeit at the lower margin.

Kondev *et al.* [22] discuss the systematic behavior of the reduced hindrance for the $E2$ decays from $21/2^-$ isomers observed in odd-mass tantalum isotopes from $A = 173$ (for which $f_\nu = 11.5$) to $A = 181$ (for which $f_\nu = 39$). In all of these lighter cases, the isomer is assigned a three-proton configuration. Kondev *et al.* also discuss the expected trends in excitation energy for various configurations that will give $21/2^-$ states (see Fig. 15 in Ref. [22]). The larger hindrance of $f_\nu = 71$ observed in ^{185}Ta may be an indication of a configuration change different from that which occurs in the lighter isotopes. The configuration assignment is discussed further in the next section.

C. Configuration assignment for the 21/2$^-$ isomer

Wheldon *et al.* [5] suggested a three-proton, $\pi 7/2^+[404]9/2^-[514]5/2^+[402]$ configuration for the 21/2$^-$ isomer, based on a multi-quasiparticle calculation. In their study of the isotone ^{186}W [6], they assigned the 7$^-$, 26-μs isomer at 1517 keV to the two-proton, $\pi 9/2^-[514]5/2^+[402]$ configuration. Coupling of the $7/2^+[404]$ ground-state proton in ^{185}Ta to this 7$^-$ core state, would result in a 21/2$^-$ state in ^{185}Ta. However, the authors of Ref. [6] also noted that the 7$^-$ state in ^{186}W could be associated with an alternative two-neutron, $\nu 3/2^-[512]11/2^+[615]$ configuration. This could also couple to the $7/2^+[404]$ proton in ^{185}Ta to produce a 21/2$^-$ state, although this possibility is not mentioned in Ref. [5].

To investigate the possible configurations, a multi-quasiparticle calculation was performed with single-particle energies taken from the Nilsson model and using the Lipkin-Nogami formalism for nuclear pairing. The methodology is similar to that applied in previous calculations for lighter tantalum nuclei (see, for example, Ref. [22]) with the same pairing strengths, $G_\nu = 18.0$ MeV/A and $G_\pi = 20.8$ MeV/A. Deformations of $\epsilon_2 = 0.225$ and $\epsilon_4 = 0.113$, as calculated by Möller *et al.* [23] for ^{185}Ta, were assumed. The final multi-quasiparticle energies given below include a correction for the empirical residual interactions [24,25], denoted here by $V_{\rm res}$.

The two 21/2$^-$ states with the configurations discussed above are indeed both predicted to lie low in excitation energy. The three-proton configuration $\pi 7/2^+[404]9/2^-[514]5/2^+[402]$ ($V_{\rm res} = -76$ keV) is calculated to lie at 1330 keV, while the one-proton, two-neutron configuration $\pi 7/2^+[404]\nu 3/2^-[512]11/2^+[615]$ ($V_{\rm res} = -138$ keV) is calculated to lie slightly lower in energy at 1167 keV. Both are reasonably close to the observed 21/2$^-$ state at 1274 keV.

To obtain more precise predictions, it is usually necessary to adjust the single-particle energies to reproduce the low-lying single-quasiparticle states in nearby odd-mass isotopes. Because these states are comparatively poorly known in these neutron-rich nuclei, this was not attempted. Nevertheless, the calculation does (correctly) predict the $\pi 7/2^+[404]$ configuration to be the ground state, with the $\pi 9/2^-[514]$ state at 192 keV, close to its observed energy of 176 keV. However, the $5/2^+[402]$ proton orbital was calculated to lie at 169 keV, substantially lower than the state at 418 keV that has been associated (tentatively) with this configuration [13,14]. The calculated value for the three-proton configuration, which contains this orbital, may then be too low. We have also recently measured the γ-ray branching ratios within the rotational band built upon the 7$^-$ isomer in ^{186}W [26] and these clearly indicate that the 7$^-$ state arises from the two-neutron configuration. Both observations favor a $\pi 7/2^+[404]\nu 3/2^-[512]11/2^+[615]$ assignment for the 21/2$^-$ isomer in ^{185}Ta. Confirmation would require observation of the rotational band built upon the isomer, a task made difficult by the long lifetime and consequent difficulty in correlating any observed band structure with the known low-lying states. It should be noted, however, that because the isomer is strongly populated using the present reaction, it is likely that the associated rotational band is populated as well. Indeed, many new γ-ray sequences are observed to be in coincidence with tantalum x rays, but at this stage they have not all been assigned to specific isotopes.

D. Possibility of decays to the 7/2$^+$[404] band

Given that the 21/2$^-$ state is suggested to have a configuration related to the $7/2^+[404]$ band, decays from the isomer to the band built upon the $7/2^+[404]$ state might be expected. If the band is extrapolated to higher spin, assuming a constant moment-of-inertia, an $M2$ decay with an energy of $\sim$170 keV to the 17/2$^+$ state, together with a $\sim$460 keV $E3$ decay to the 15/2$^+$ state, would be possible. However, if these transitions were to have $f_\nu > 50$, their γ-ray intensities would still be more than 5000 times weaker than that of the 280.4-keV transition from the isomer and, therefore, would not compete.

V. CONCLUSIONS

The neutron-rich isotope ^{185}Ta, lying four neutrons past stability, has been studied using reactions between a beam of ^{136}Xe ions and an enriched ^{186}W target. The lifetime of the $9/2^-[514]$ intrinsic state has now been measured as 17(3) ns. The strengths of the $E1$ transitions observed between states in the $9/2^-[514]$ and $7/2^+[404]$ rotational bands are consistent with the equivalent decays in both the lighter tantalum isotopes and in other neighboring odd-proton isotopes. The observed spin dependence of the $E1$ strengths may be caused by the effects of octupole-vibration coupling.

The decay of the long-lived isomer first observed by Wheldon *et al.* [5] has now been fully characterized, including measurement of its lifetime [$\tau = 17(2)$ ms], determination of the spin and parity of the state ($K^\pi = 21/2^-$), and identification of the transitions by which it decays. The isomeric state has been assigned to the $\pi 7/2^+[404]\nu 3/2^-[512]11/2^+[615]$ configuration. The reduced hindrances for the 14.5 keV $M1$ and 280.4 keV $E2$ transitions are $f_\nu = 52$ and $f_\nu = 71$, respectively. These are reasonable values for a nucleus in which K is a good quantum number, implying a predominantly axially symmetric shape, at least for this specific configuration.

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