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Short note

Rotational bands in ^{181}Ta

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Abstract. High-spin states in ^{181}Ta have been studied via the ^{176}Yb(^{11}B,α2n) reaction at 52 MeV using the PEX array and at 57 MeV using the NORDBALL array, with α-particle detection. The previously known, $K^\pi = \frac{7}{2}^+$ ground state band and $K^\pi = \frac{9}{2}^-$ band have been extended to spins $\frac{29}{2}^+$ and $\frac{31}{2}^-$, respectively. Two new one-quasiparticle bands, the $K^\pi = \frac{5}{2}^+$ band built on the known $\frac{5}{2}^+$ isomer and a $K^\pi = (\frac{1}{2}^-)$ band have been observed. Two other rotational bands with three-quasiparticle structure, $K^\pi = \frac{15}{2}^-$ and $(\frac{19}{2}^+)$ with $\pi\frac{7}{2}[404]\nu^2\frac{1}{2}[510]\frac{9}{2}[624]$ and $\pi\frac{9}{2}[514]\nu^2\frac{1}{2}[510]\frac{9}{2}[624]$ configurations, respectively, have been newly observed. The half-life of the $K^\pi = (\frac{19}{2}^+)$ bandhead which decays to the head of the $\frac{15}{2}^-$ band has been measured to be 140(36) ns. However, transitions from the $(\frac{19}{2}^+)$ state to the $\frac{15}{2}^-$ band have not been observed.

PACS. 21.10.Re Collective levels – 21.10.Tg Lifetimes – 23.20.En Angular distribution and correlation measurements – 23.20.Lv Gamma transitions and level energies – 27.70.+q $150 \leq A \leq 189$

Information on ^{181}Ta has been limited in part because this nucleus lies on the beta-stability line and few fusion-evaporation reactions can populate it to high-spin. The structure of ^{181}Ta has been studied by Coulomb excitation experiments [1], ^{181}Hf β^- decay experiments [2,3,4], and ^{180}Ta(n,γ) experiments [5]. In the present work, high-spin states of ^{181}Ta have been populated via the ^{176}Yb(^{11}B,α2n) reaction at 52 MeV using the PEX array and at 57 MeV using the NORDBALL array in the Niels Bohr Institute, Denmark. The PEX array consisted of four EUROBALL cluster detectors and one clover detector. The NORDBALL array consisted of 18 Ge-detectors and two planar Ge-detectors (LEP). Since the cross section of the α2n channel was calculated approximately to be 0.2 % of the total fusion-evaporation cross section, the Si-ball [6], which consisted of 25 Si-detectors for the PEX array and 30 elements for the NORDBALL array, was used to detect charged particles in coincidence with γ-rays. The coincidence window between γ-rays was set to 472 ns using the PEX array and 552 ns in the experiment with the NORDBALL array. Data corresponding to the detection of two γ-rays and one α-particle were sorted offline into two-dimensional $\gamma-\gamma$-matrices with different time conditions.

Figure 1 shows the proposed level scheme of ^{181}Ta constructed in the present work. The ground state band with a $\pi\frac{7}{2}[404]$ Nilsson configuration [1,2,3,4,5] and the $K^\pi = \frac{9}{2}^-$ band with a $\pi\frac{9}{2}[514]$ configuration [2,3,4,5] have been extended to $\frac{29}{2}^+$ and $\frac{31}{2}^-$, respectively. A new rotational band, assigned to the $\frac{5}{2}[402]$ configuration, has been observed on the known $\frac{5}{2}^+$ isomer at 482 keV [2,3,4,5], to a spin of $\frac{19}{2}^+$. The configuration assignment is supported by the good agreement between the experimental B(M1)/B(E2) ratios and the theoretical values for the $\frac{5}{2}[402]$ configuration, as shown in Fig. 2a. The half-life of

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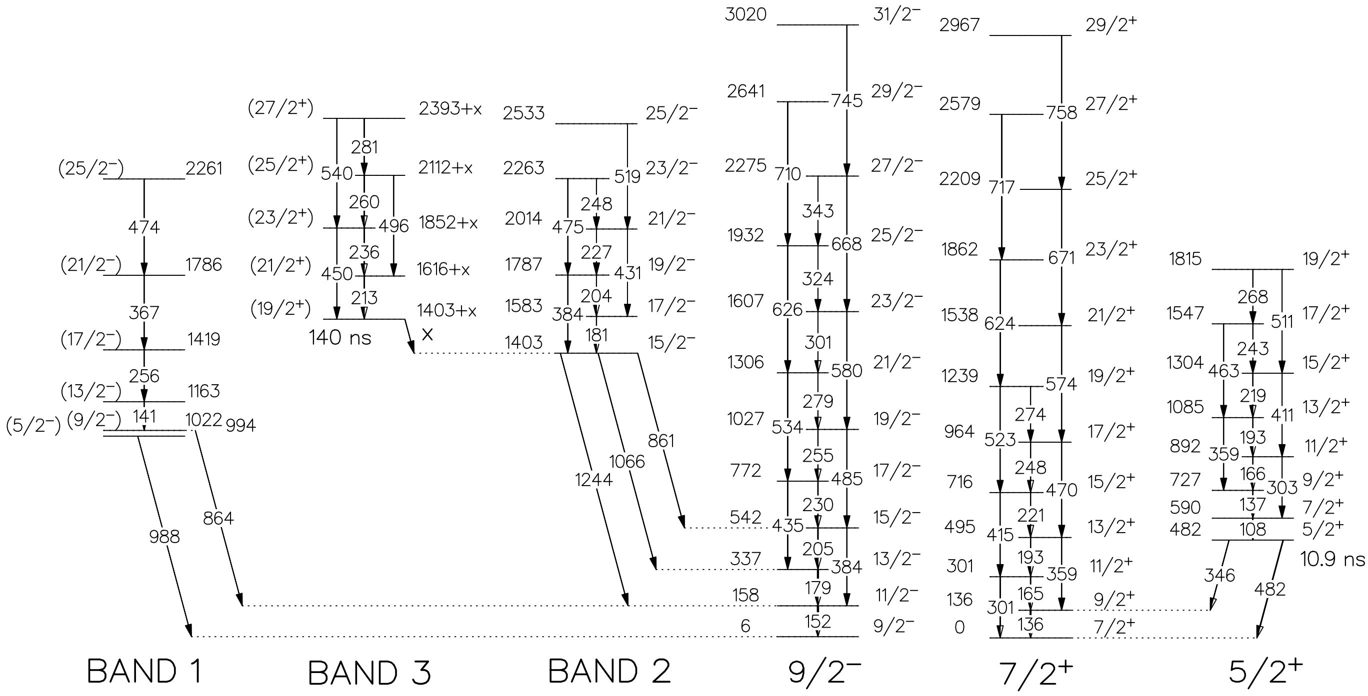

Fig. 1. Proposed level scheme of ^{181}Ta

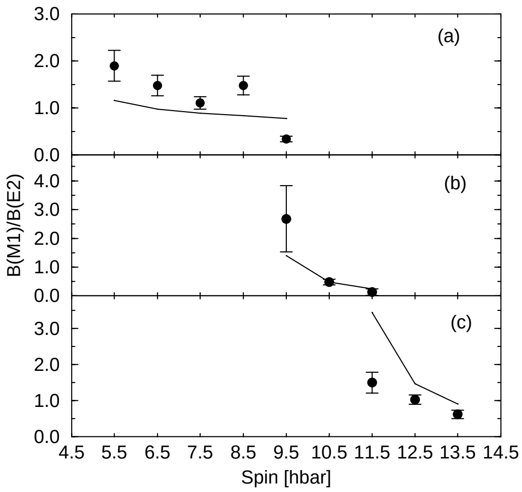

Fig. 2. B(M1)/B(E2) ratios in units of $\mu_{\rm N}^2/{\rm e}^2{\rm b}^2$. Experimental values (filled circles) and theoretical calculations of the proposed configuration (solid lines) for **a** the $K^\pi = \frac{5}{2}^+$ band, **b** the $\frac{15}{2}^-$ band (BAND 2), **c** the $(\frac{19}{2}^+)$ band (BAND 3). $Q_0 = 7.0$ eb and $g_R = 0.3$ are assumed

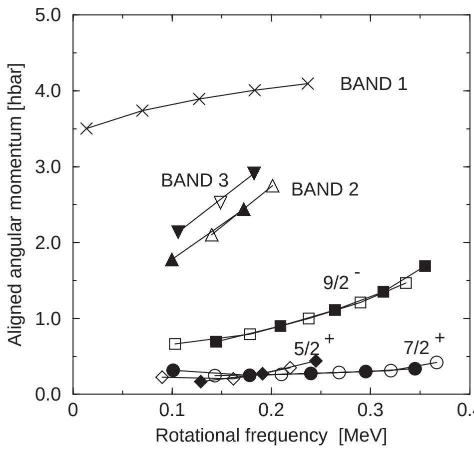

Fig. 3. Aligned angular momenta as a function of rotational frequency, with reference parameters $\Im_0 = 31.5$ MeV$^{-1}\hbar^2$ and $\Im_1 = 32.0$ MeV$^{-3}\hbar^4$

the $\frac{5}{2}^+$ state is measured to be 10.9(6) ns, which is in good agreement with the previous value of 10.8 ns [2,3,4]. Remarkably, the band structure is nearly identical to that of the ground state band.

A weakly populated band labeled by BAND 1 in Fig. 1 has been observed for the first time. The large energies of the in-band γ-rays suggest that they are likely to have E2 multipolarity, and the band is interpreted as a part of the favoured signature of the $K^\pi = \frac{1}{2}^-$ rotational band associated with a $\pi\frac{1}{2}[541]$ configuration. Since the levels at 994 keV and 1022 keV decay to the $\frac{9}{2}^-$ and $\frac{11}{2}^-$ states in the $K^\pi = \frac{9}{2}^-$ band, respectively, it is proposed that the level at 994 keV has $I^\pi = (\frac{5}{2}^-)$ and the state at 1022 keV has $I^\pi = (\frac{9}{2}^-)$. The $\frac{1}{2}^-$ level is not observed in the present work. The excitation energy of the bandhead, near 1 MeV, is in line with systematics from lighter Ta nuclei [7,8,9], where the excitation energy of the $\frac{5}{2}^-$, $\pi\frac{1}{2}[541]$, level increases systematically with increasing neutron number. Figure 3 shows the aligned angular momentum of this band, which ranges from 3.5 to 4.0 $\hbar$, consistent with the systematics of the $\pi\frac{1}{2}[541]$ bands [7,8,9].

A state at 1403 keV and γ-rays from this state to levels in the $\frac{9}{2}^-$ band had been previously reported in the ^{180}Ta(n,γ) experiment [5]. In the present work, a rotational band built on this state, BAND 2, has been observed. The spin assignment for the state at 1403 keV has been made using the DCO ratio for the 152 keV $\Delta I = 1$ transition in the $\frac{9}{2}^-$ band in coincidence with the 1244 keV γ-ray. The 152 keV is a mixed E2/M1 transition - the mixing ratio was taken to be 0.17(2), being the average mixing ratio of the $\Delta I = 1$ transitions in the $\frac{9}{2}^-$ band, deduced from in-band branching ratios using rotational model formulae. The experimental DCO ratio, 1.23(30), is in good agreement with the calculated DCO ratio for a stretched E2 transition (1.35(4)). Therefore, the spin of the state at 1403 keV is proposed to be $\frac{15}{2}$.

The excitation energies of all possible intrinsic states in ^{181}Ta have been calculated by the BCS theory with blocking, BBCS, with residual interactions described in [10]. The calculation indicates that the lowest $K = \frac{15}{2}$ bandhead lies at 1537 keV and is a $\pi\frac{7}{2}[404]\nu^2\frac{1}{2}[510]\frac{9}{2}[624]$ configuration. This assignment is supported by the good agreement between the experimental $B(\mathrm{M1})/B(\mathrm{E2})$ ratios of BAND 2 and the theoretical values for this configuration, shown in Fig. 2b.

A new rotational band, BAND 3, has been observed for the first time. The γ-rays in this band and the γ-rays below the $\frac{15}{2}^-$ state at 1403 keV are in coincidence within the time acceptance window between γ-rays for both Ge-detector arrays (approximately 500 ns, see above). However, the γ-ray linking the heads of BAND 3 and BAND 2, which is labeled by 'x' in Fig. 1, has not been observed. Its energy is likely to be lower than 50 keV, although it may be of higher energy if it were obscured by contaminating X-rays, or it is a highly converted transition. The half-life of the bandhead has been deduced to be 140(36) ns by fitting the time-difference spectra between the 213 keV and the 1244 keV γ-rays and between the 213 keV and the 1066 keV γ-rays. BAND 3 is populated with a higher intensity than BAND 2, which indicates that BAND 3 lies closer to the yrast line. Therefore, the K value of this band is likely to be either $\frac{17}{2}$ or $\frac{19}{2}$. The BBCS calculation indicates bandheads of $\frac{17}{2}^+$, $\frac{19}{2}^-$ and $\frac{19}{2}^+$ in this energy region. From g_K factors and $B(\mathrm{M1})/B(\mathrm{E2})$ ratios of BAND 3 deduced from in-band transition branching ratios, the first and the second possibilities were excluded. Fig. 2c shows the good agreement between the experimental $B(\mathrm{M1})/B(\mathrm{E2})$ ratios and the theoretical calculations for the $K^\pi = \frac{19}{2}^+$ $\pi\frac{9}{2}[514]\nu^2\frac{1}{2}[510]\frac{9}{2}[624]$ configuration. Therefore, it is proposed that BAND 3, the $K^\pi = (\frac{19}{2}^+)$ band, consists of this configuration.

Figure 3 shows that the aligned angular momenta of BAND 2 and BAND 3 are consistent with their proposed configurations. The difference between the bands is understood by the existence of a $\frac{9}{2}[514]$ proton in the configuration of BAND 3 instead of the $\frac{7}{2}[404]$ proton of the configuration of BAND 2.

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