α decay and recoil decay tagging studies of ^{183}Tl

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High-spin states in the nucleus ^{183}Tl have been studied using the recoil decay tagging and recoil tagging techniques. The data have enabled new structures to be identified which are believed to be based on prolate $f_{7/2}$, $h_{9/2}$, and oblate $h_{9/2}$ configurations. In addition, the prolate $i_{3/2}$ structure has also been extended. The systematics of the newly identified structures will be discussed. The α decay of ^{183}Tl has also been investigated. Examination of both delayed and prompt γ rays in coincidence with the prominent 6333-keV α decay, together with an investigation of the effects of the summing of L electrons, allow assignment of transitions and the construction of tentative low-spin decay schemes for ^{179}Au and ^{175}Ir.

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I. INTRODUCTION

Even-even nuclei in the light lead and mercury region around $A \leq 190$ are known to provide excellent examples of the shape coexistence phenomenon [1,2]. In these nuclei, examples of prolate, oblate, and spherical (see Refs. [1–11]) structures have been found at low excitation energy. Investigations of odd proton and neutron nuclei have proved invaluable in helping to understand which orbitals are responsible for the various nuclear shapes in these even-even nuclei. In this regard, spectroscopic studies of the neutron-deficient odd mass Tl isotopes have played an important role. For example, these have revealed the presence of oblate structures resulting from the occupancy of $\pi h_{9/2}$ and $\pi h_{11/2}$ orbitals as well as prolate configurations involving $\pi h_{9/2}$, $\pi i_{13/2}$, and $\pi f_{7/2}$ orbitals (e.g., see Refs. [2,3]).

Detailed studies of bands built on some of the above configurations have shown that the 1p-2h oblate $h_{9/2}$ intruder band minimizes its energy around $N=108$, while the prolate intruder band, which is based on the coupling of the $i_{13/2}$ orbital to the 4p-6h prolate Hg core, has been found to decrease in excitation energy down to the mid shell nucleus ^{183}Tl ($N=102$) [3]. This latter feature is in good agreement with recent results in the even-even Pb isotopes [4], which show that the prolate structure reaches a minimum energy at this neutron number. In the present work, the spectroscopy of the odd mass nucleus ^{183}Tl has been extended and new structures have been identified which are believed to be based on the prolate $f_{7/2}$, $h_{9/2}$, and the oblate [505]9/2$^-$ ($h_{9/2}$) orbitals. The systematics of these states will be discussed. The present results provide important data which will aid the interpretation of recent work on the structures of the even-even ^{184}Pb [12].

Previous α-decay studies of ^{183}Tl have been performed by Schrewe *et al.* [13] and Reviol *et al.* [5]. The present work examines the effects of prompt electron summing in the DSSD to ^{183}Tl α decays. Tentative, low spin levels are suggested for the ^{179}Au nucleus. In addition, a new α branch from ^{179}Au was identified, decaying to the previously reported first excited state in ^{175}Ir [14,15].

II. EXPERIMENTAL DETAILS

States in ^{183}Tl were populated at the Accelerator Laboratory of the University of Jyväskylä using the ^{144}Sm(^{42}Ca,$p2n$) fusion evaporation reaction. The ^{42}Ca beam was delivered by the JYFL cyclotron at energies of 195 and 200 MeV, and was incident on a target consisting of two (95% enriched) stacked, 500 μg cm^{-2} thick, self supporting ^{144}Sm foils. γ rays at the target position were detected using the JUROSPHERE II array which consisted of seven TESSA-type [16], five NORDBALL [17], and 15 EUROGAM Phase I [18] detectors. The total photopeak efficiency was ~1.5% for 1.3-MeV γ rays. The gas filled recoil ion transport unit (RITU) [19] was used to separate fusion-evaporation residues from unwanted beamlike and fission nuclei. The fusion evaporation residues were then implanted into an 80×35 mm silicon strip detector, which covered around 70% of the recoil distribution at the focal plane.

The silicon strip detector was also used to detect subsequent α decays of the implanted recoils. The α-decay spec-

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TABLE I. α-particle energies and relative intensities for α decays from the $9/2^-$ isomer in ^{183}Tl. The intensity for the 6333-keV α decay includes the peaks due to electron summing.

From Schrewe *et al.* [13]		Present work	
E_α (keV)	I_α	E_α (keV)	I_α (keV)
6343(10)	83(4)	6333(10)	78(9)
6378(15)	16(2)	6384(16)	16(4)
6449(15)	1.0(3)	6456(15)	4(2)

trum was calibrated using known α lines in ^{180}Hg, ^{179}Hg, and ^{176}Pt. Approximately 50% of the α particles emitted from the implanted recoils were detected with full energy, and purification of α-decay events was achieved by vetoing high-energy scattered particles through the use of a Multiwire Proportional Avalanche Counter (MWPAC) situated 110 mm upstream of the silicon strip detector. Surrounding the focal plane were three NORDBALL- [17] and two TESSA-type [16] Ge detectors giving a total efficiency of ~1% at 1.3 MeV.

At the focal plane recoil and α-particle positions, energies and detection times were recorded along with γ-ray energies. At the target position γ-ray energies, and timing information were recorded. These data were stored on magnetic tape and analyzed off line.

III. RESULTS

A. α-decay studies of ^{183}Tl

Three α decays have been previously reported for ^{183}Tl with energies of 6343, 6378, and 6449 keV (see Table I), all of which were suggested to correspond to the decay of the $9/2^-$ isomer [13]. The α branch of ^{183}Tl is relatively low and has been estimated to be around 3% by Schrewe *et al.* [13] and 1.5% by Reviol *et al.* [5]. By comparing the total α yield to that of the delayed 346.6-keV γ ray which feeds the $9/2^-$ isomer, we estimate that the α branch is around 2%. From the present work, it is clear that the observed α spectrum for ^{183}Tl has a very complex shape, which we attribute to the effects of the prompt summing of conversion electrons in the silicon strip detector (see Fig. 1) which were not observed in previous studies [13].

In order to determine which α decays corresponded to the decay of ^{183}Tl, a correlation was performed with the subsequent daughter decay of ^{179}Au, within a search time of one second. Although the α-decay half life of ^{179}Au has been measured to be 3100 ms [20], this search time was chosen in order to suppress contaminants from random α decays. As well as the previously known α decay of ^{179}Au, a new, second α line, 5810(15) keV, was observed which we attribute to a fine structure decay from ^{179}Au. As far as can be ascertained, all the α activity associated with ^{183}Tl in the present work has the same half life, suggesting that it originates from the same state. This half life was determined to be 53.3(3) ms by fitting the time difference between 29 000 pairs of α decays and recoils, using an exponential fit to the

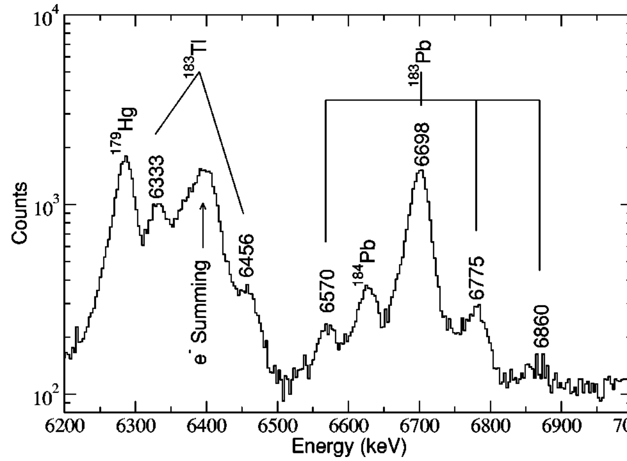

FIG. 1. Inset of the total α-decay spectrum obtained in the present work. The α decays of ^{183}Pb and ^{183}Tl are labeled with their energy. α decays associated with other nuclei are labeled according to their origin.

decay curve and assuming an exponential background. This compares with the previous half-life value of 60(15) ms obtained by Schrewe *et al.* [13].

An α decay with an energy of 6333 keV is observed which we believe corresponds to the strongest line previously observed for ^{183}Tl, see Table I. The 6456-keV α decay has no γ rays in coincidence with it and we assume this feeds an isomeric state in ^{179}Au which has a half life in excess of 100 μs. The large irregularly shaped bump above the 6333-keV line in the α spectrum is believed to be associated with electron summing as can be seen by plotting α decays in coincidence with focal plane γ rays (Fig. 2). The process of electron summing and the resultant shape of the spectrum make it hard to extract accurate α energies. Scaling the γ-ray coincidence spectrum and subtracting it from the total α spectrum tentatively shows evidence for a 6384-keV α decay

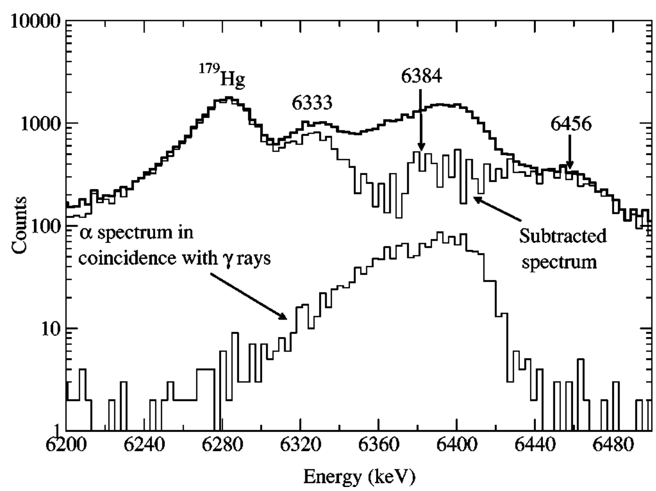

FIG. 2. Expanded region of the α particle energy spectrum for ^{183}Tl. The spectrum in bold is the total α spectrum. The spectra below are the α particle spectrum in coincidence with focal plane γ rays and the total spectrum with the normalized γ-ray coincidence spectrum subtracted.

TABLE II. Energies and intensities of γ rays observed in the focal plane germanium detectors following the α decay of ^{183}Tl. The assigned multipolarities are discussed in the text. Intensities corrected for internal conversion are deduced from the tables of Rosel *et al.* [22].

E_γ (keV)	I_γ (eff. corr.)	I (conv corr.)	Multipolarity	Nucleus
46.3(2)	51(7)			^{178}Au
52.4(2)	109(10)	1058(97)	($M1$)	^{179}Au
61.8(3)	1233(35)	1602(45)	($E1$)	^{179}Au
89.4(2)	124(11)	1204(107)	($E2$)	^{179}Au

underneath the bump due to summing. This line has a similar energy and intensity to the previously reported 6378-keV α decay in ^{183}Tl [13].

Four γ rays with energies of 46.3(2), 52.4(2), 61.8(3), and 89.4(2) keV are found to be in prompt coincidence with the broad region of the α spectrum from 6320 to 6430 keV. The transition intensities and nucleus of origin are given in Table II. None of these transitions appear to be delayed with respect to the α particle and this therefore limits their multipolarity to the possibilities $E1$, $M1$, or $E2$.

Examining γ-γ coincidences at the focal plane, tentatively suggests that the 52- and 62-keV transitions are in prompt coincidence (three coincident events) as well as the 52- and 89-keV transitions (1 coincident event). There is negligible background in the coincidence matrix. No coincidence is found between the 62- and 89-keV transitions. However, given the level of statistics for the other coincidences discussed above, we assume that these three transitions form a coincident cascade. Whilst the γ-ray evidence is rather weak, the behavior of the summed α spectrum strongly supports this suggestion (see Fig. 3 and discussion below).

For transitions with energy below the K binding energy, the principal conversion electrons are L electrons, in particular, $L1$ conversion electrons in the case of $M1$ transitions and $L2$ and $L3$ electrons for $E2$ transitions. We investigated the effects of summing of L electrons in the present case using the Monte Carlo simulation code GEANT [21]. When gating on the 52-keV transition, the summed α spectrum has the expected shape for the summing of L electrons from a highly converted coincident 89-keV transition. This implies that the 89-keV transition most likely has $E2$ multipolarity, since if it had $E1$ multipolarity the summing effects would be negligible and if it had $M1$ multipolarity then the sum spectrum would have a different shape as the dominant conversion electrons would be from the K shell. The low yield of K x rays allows the $M1$ assignment to be rigorously ruled out (see Fig. 4).

Gating on the 89-keV transition shows the effect of summing of L electrons from the 52-keV transition. This would imply either an $M1$ or $E2$ assignment for this transition. Compelling evidence for the three coincident transitions is found in the gate on the 62-keV γ ray at the focal plane, which shows the effects of summing L electrons from both the 52- and 89-keV transitions individually and sequentially, see Fig. 3. Accepting, therefore, that the transitions form a cascade, that the predominant feeding comes at the top of the

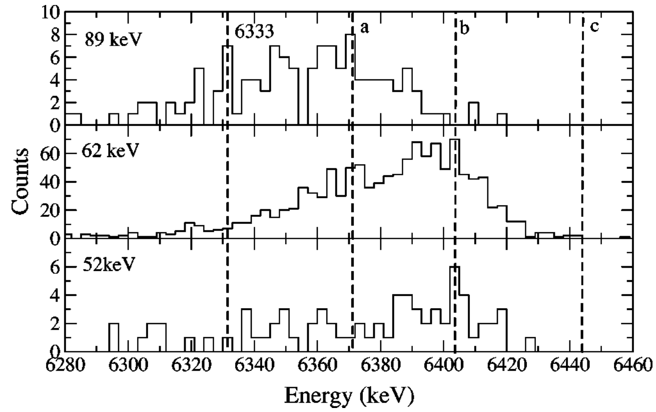

FIG. 3. α particle energy spectrum for α particles in coincidence with γ rays at the focal plane. The three panels are labelled according to the energy of the coincident γ ray. The position of the 6333-keV unsummed α decay is marked. The location of peaks corresponding to the summing of conversion electrons at the focal plane with the 6333-keV α decay are marked with dashed lines. Position "a" corresponds to the summing of an L electron from the 52-keV transition. Position "b" corresponds to the summing of an L electron from the 89-keV transition. Position "c" corresponds to the summing of L electrons from both the 52- and 89-keV transitions.

cascade via the 6333-keV α decay and that the 89-keV transition has $E2$ multipolarity, we can match the intensity of the 52- and 62-keV γ rays to that of the 89-keV γ ray corrected for internal conversion and, hence, estimate the total conversion coefficients and deduce their multipolarity. We therefore estimate a total conversion coefficient of around 10 for the 52-keV transition and assign it $M1$ multipolarity [calculations give $\alpha_{tot}(E1)=0.5$, $\alpha_{tot}(M1)=8.8$, $\alpha_{tot}(E2)=97$ [22]]. Similarly the 62-keV transition has a very small total conversion coefficient (<0.5) which allows it to be firmly assigned $E1$ multipolarity [calculations give $\alpha_{tot}(E1)=0.3$, $\alpha_{tot}(M1)=5.5$, $\alpha_{tot}(E2)=45$].

Having established the behavior of the principal 6333-keV α decay and the focal plane transitions which follow this decay, the origin of the 46-keV γ ray and the 6384-

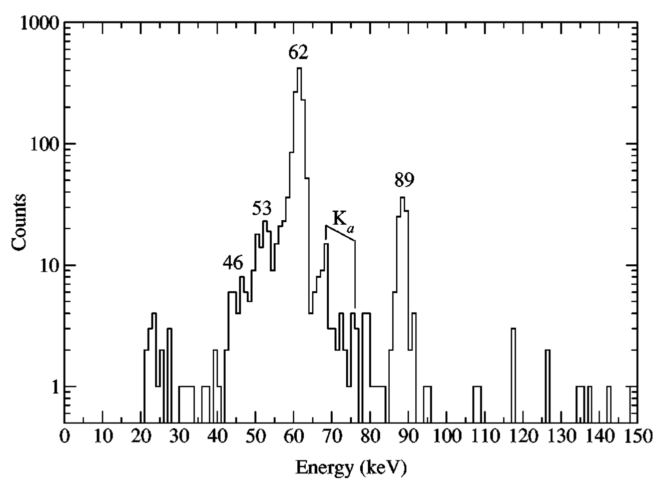

FIG. 4. Spectrum of γ rays detected in the focal plane germanium detectors in prompt coincidence with α decays from ^{183}Tl. The transitions are labeled with their energy in keV.

and 6456-keV α transitions remains to be discussed. First, by correlating the 46-keV γ ray in the focal plane with its preceding α decay, it is clear that this transition is only associated with an α peak with an energy of 6403(15) keV. We suggest this corresponds to the previously observed α decay of ^{182}Tl [24]. We do not have sufficient data to draw further conclusions about low-lying states in ^{178}Au.

Given the extensive summing of the 6333-keV α decay which serves to bury the 6384-keV α decay, we cannot convincingly determine whether the latter is followed by focal plane γ transitions. However, the energy difference between the two α decays is consistent within errors with 52 keV, hinting that the 52-keV transition immediately follows the 6333-keV α decay and that the 6384-keV α decay is associated with a decay to the state fed by the 52-keV transition. We assume that the strongest α decay observed, the 6333-keV transition, connects the $9/2^-$ isomer in ^{183}Tl with a structurally similar $9/2^-$ state in ^{179}Au via a favored α decay ($\Delta L=0$). Using the Rasmussen prescription [25], the hindrance factor of the other α decays may be expressed relative to that for the unhindered 6333-keV decay. The relative hindrance factor for the 6384-keV α decay is 7.5(1.9) which suggests a modest change in angular momentum for the α decay, without underlying structural change. This might correspond to an α decay to a $7/2^-$ state with similar structure to the $9/2^-$ state in ^{179}Au.

The 6456-keV α decay from ^{183}Tl is not in coincidence with γ rays at the focal plane, nor is there any evidence for prompt summing with conversion electrons from the focal plane Si detector. Since it decays from the same $9/2^-$ level in ^{183}Tl as the other α decays, it cannot be feeding the ground state in ^{179}Au but rather a relatively long-lived isomeric level. The relative hindrance factor for the 6456-keV decay is 58(16), based on an intensity of 4(2)% found in the present work (see Table I). The outcome of the various possibilities considered above leads to the tentative α-decay scheme for ^{183}Tl suggested in Fig. 5. Aside from the 52-keV transition, we are not able to unambiguously order the remaining transitions in the focal plane cascade. However, we have assigned tentative spin parities to excited states based on the arguments presented above.

We cannot establish whether the γ cascade following the α decay proceeds as far as the ^{179}Au ground state. Nevertheless, to accommodate the change in parity implied by the

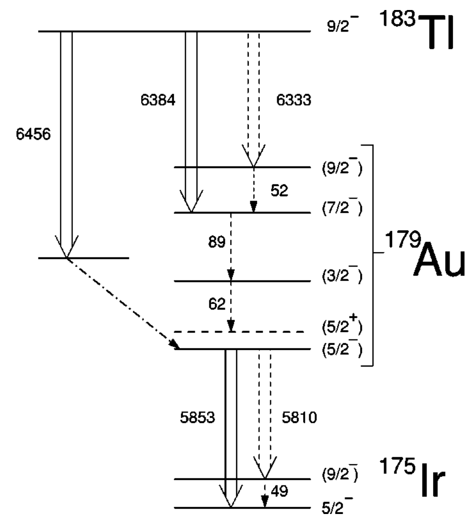

FIG. 5. Tentative decay scheme for the α decay of ^{183}Tl into ^{179}Au and subsequently into ^{175}Ir. α (double arrows) and γ (single arrows) decays are indicated with their energy in keV. Tentative α and γ transitions are shown by dashed arrows. A possible isomeric decay is shown as a dot-dash arrow. All tentative spin assignments are based on the assumption that the spin decreases as the excitation energy decreases within ^{179}Au. We note that this may not necessarily be the case. (Note, the order of the 89- and 62-keV γ transitions is not confirmed. Also the 6333- and the 5810-keV α decays are dashed as their termination states have tentative assignments.)

62-keV $E1$ transition, the lowest state we observe must have positive parity, perhaps $(5/2^+)$ which could arise from the $5/2[402]$ orbital at moderate prolate deformation. By comparison a $5/2^+$ state in ^{175}Ir has been seen by Dracoulis *et al.* [14] and lies 52 keV above the suggested $5/2^-$ ground state. However, given that the α decay from ^{179}Au is unhindered, i.e., $5/2^-$ to $5/2^-$, it is likely that we have not seen a low-energy γ ray connecting the $(5/2^+)$ to the $5/2^-$ ground state. Further work on establishing the masses and ground state spin parities of both ^{175}Ir and ^{179}Au is necessary to fully understand the present α-decay work.

Figure 5 also shows the new α branch attributed to ^{179}Au which is assigned on the basis of it being correlated with ^{183}Tl α decays. The energy of this new decay [5810(15) keV] is consistent with it feeding the first excited state $(9/2^-)$ in ^{175}Ir, see Refs. [14,15]. However, no evidence

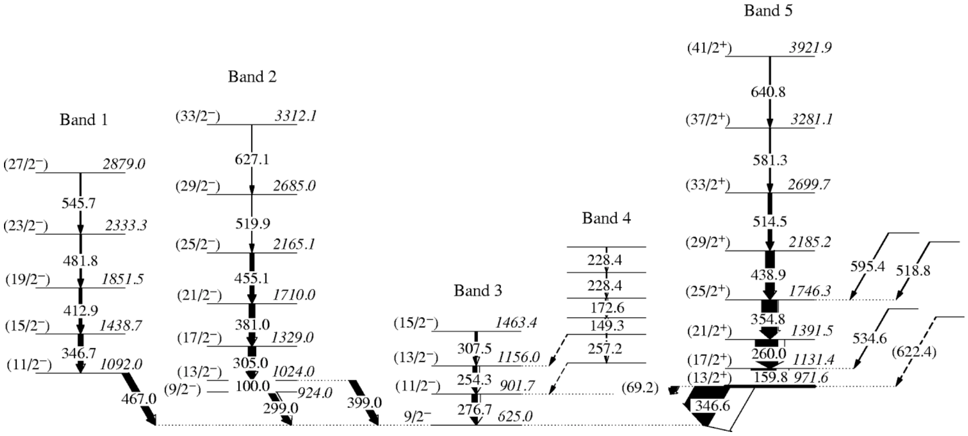

FIG. 6. The level scheme for ^{183}Tl, above the α-decaying $9/2^-$ state, deduced from the current work.

TABLE III. Table of γ-ray energies and intensities. The intensities are normalized to the strongest (260.0 keV) γ-ray transition in the prolate $i_{13/2}$ band. Errors for γ rays are 0.3 keV for low energies up to 0.5 keV for high energies.

Band	E_i	J_i^π	J_f^π	E_γ	I_γ	Mult.
1	1092	$(11/2^-)$	$9/2^-$	467.0	8.4(8)	$(M1)$
1	1439	$(15/2^-)$	$(11/2^-)$	346.7	6.9(20)	$(E2)$
1	1852	$(19/2^-)$	$(15/2^-)$	412.9	3.7(13)	$(E2)$
1	2333	$(23/2^-)$	$(19/2^-)$	481.8	2.2(10)	$(E2)$
1	2879	$(27/2^-)$	$(23/2^-)$	545.7	1.6(9)	$(E2)$
2	924	$(9/2^-)$	$9/2^-$	299.0	8.4(8)	$(E2/M1)$
2	1024	$(13/2^-)$	$(9/2^-)$	100.0	0.4(2)	$(E2)$
2	1024	$(13/2^-)$	$9/2^-$	399.0	4.0(20)	$(E2)$
2	1329	$(17/2^-)$	$(13/2^-)$	305.0	9.8(23)	$(E2)$
2	1710	$(21/2^-)$	$(17/2^-)$	381.0	8.0(14)	$(E2)$
2	2165	$(25/2^-)$	$(21/2^-)$	455.1	5.3(12)	$(E2)$
2	2685	$(29/2^+)$	$(25/2^-)$	519.9	<0.2	$(E2)$
2	3312	$(33/2^-)$	$(29/2^+)$	627.1	<0.2	$(E2)$
3	901	$(11/2^-)$	$9/2^-$	276.7	8.4(8)	$(M1)$
3	1155	$(13/2^-)$	$(11/2^-)$	254.3	5.7(18)	$(M1)$
3	1463	$(15/2^-)$	$(13/2^-)$	307.5	1.9(12)	$(M1)$
4				257.2	<1	
4				149.3	<1	
4				172.6	<1	
4				228.4	<0.2	
4				228.4	<0.2	
5	1132	$(17/2^+)$	$(13/2^+)$	159.8	8.4(8)	$(E2)$
5	1391	$(21/2^+)$	$(17/2^+)$	260.0	100	$(E2)$
5	1746	$(25/2^+)$	$(21/2^+)$	354.8	78(4)	$(E2)$
5	2185	$(29/2^+)$	$(25/2^+)$	438.9	21.4(20)	$(E2)$
5	2700	$(33/2^+)$	$(29/2^+)$	514.5	7.0(12)	$(E2)$
5	3281	$(37/2^+)$	$(33/2^+)$	581.3	<1	$(E2)$
5	3922	$(41/2^+)$	$(37/2^+)$	640.8	<1	$(E2)$
Feeds 5	1666		$(17/2^+)$	534.5	5(3)	
Feeds 5	2342		$(25/2^+)$	595.0	<0.2	
Feeds 5	1594		$(13/2^+)$	622.0	<1	
Feeds 5	2265		$(25/2^+)$	518.4	<0.2	
Delayed from band 5	972	$(13/2^+)$	$(9/2^-)$	346.6		$(M2)$
Delayed from band 5	902	$(11/2^-)$	$(9/2^-)$	277.0		$(M1)$
Delayed from band 5	972	$(13/2^+)$	$(11/2^-)$	69.2		$(E1)$

for the low energy 49-keV γ ray of ^{175}Ir was seen in this work. It would, nevertheless, be expected to be highly converted.

B. RDT analysis of ^{183}Tl

Previous work on the structure of excited states in ^{183}Tl can be found in Refs. [3,5]. The extended ^{183}Tl level scheme, deduced from the present work, is shown in Fig. 6. The energies and spins of the $1/2^+$ (ground state), $3/2^+$ (250 keV), and $9/2^-$ (625 keV) levels have been assumed from the α-decay studies of Batchelder *et al.* [26]. The $9/2^-$ and $13/2^+$ levels are isomeric with lifetimes of 53.3 ms and 1.48 μs [3], respectively. Data were collected over a period of seven days, and a total of 1.34 million events were sorted into a two-dimensional recoil-γ-γ matrix. The RADWARE analysis package [27] was used for the construction of the level scheme, shown in Fig. 6. Table III provides details of the intensities and multipolarities of the γ rays.

Figure 7 shows the γ-ray spectrum in coincidence with all three α branches from the decay of ^{183}Tl. This spectrum was produced using a correlation time of approximately three times the half life of the α decay (150 ms). In addition, a

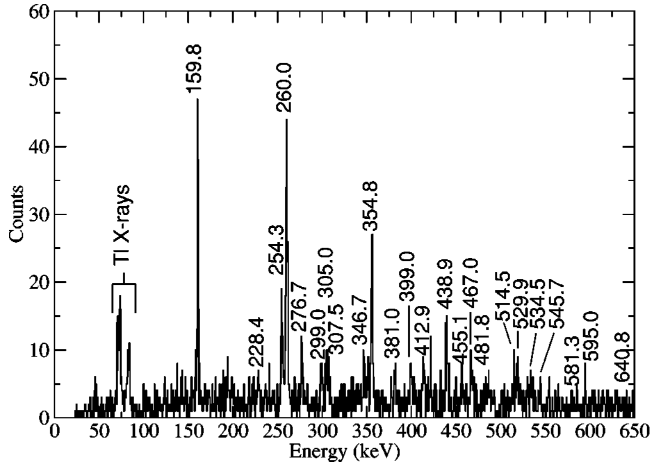

FIG. 7. Spectra showing all transitions correlated with the α decay of ^{183}Tl using a search time of 450 ms, which is equivalent to three half lives ($\tau_{1/2}=150$ ms).

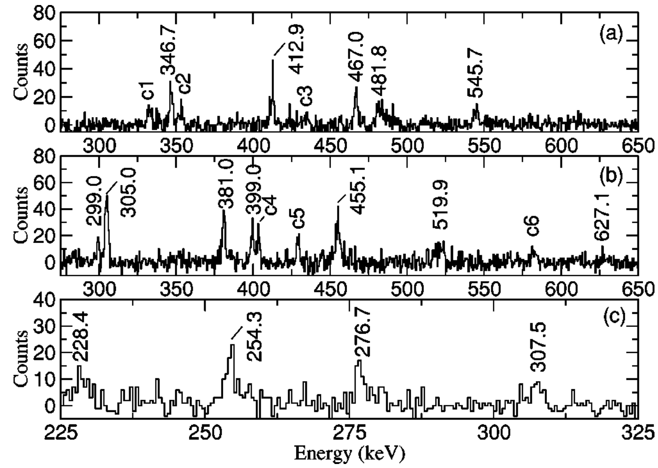

FIG. 9. (a) Spectrum showing sum of gates for (a) band 1, (b) band 2, and (c) band 3. Contaminants are marked with a "c" and are discussed in the text.

reverse RDT measurement was performed producing an α spectrum in coincidence with the strongest prompt γ ray (160 keV) from ^{183}Tl. This spectrum showed evidence for three α decays as reported in Sec. III A.

The delayed transition from the yrast $i_{13/2}$ band (band 5) has been measured to be 346.6 keV. This is consistent, within errors, to the previously reported energy of 346.8 keV [3]. This band has been extended up to a tentative spin of 41/2. The majority of transitions within this band can be observed when gating on the isomeric 346.6-keV transition, see Fig. 8(a). The remaining transitions are clearly seen when viewing a spectrum containing the sum of several gates in the band, see Fig. 8(b). Four new transitions (622.0, 534.5, 518.4, and 595.0 keV, see Fig. 6) have been identified which decay into the lower part of the $i_{13/2}$ band. These can most easily be observed in the 346.6-keV delayed gate spectrum shown in Fig. 8(a). Their location in the decay scheme is

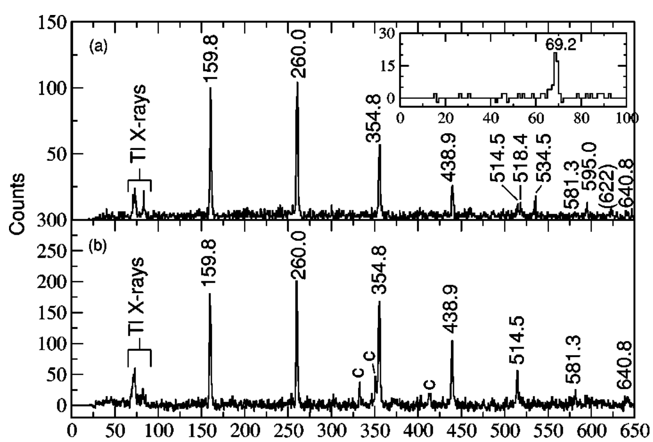

FIG. 8. (a) Spectrum of γ rays in coincidence with the delayed 346.6-keV decay from the $i_{13/2}$ band. The inset shows γ rays observed at the focal plane in coincidence with the 277.0 keV transition. (b) Represents a sum of 159.8-, 260.0-, 354.8-, 438.9-, 514.5-, and 581.3-keV transitions in the $i_{13/2}$ band. Contaminants from ^{182}Hg are marked with a "c."

confirmed by the recoil-γ-γ coincidence data. It is interesting to note that similar feeding of the $i_{13/2}$ structure was found in ^{187}Tl [2].

Figure 9(a) contains a spectrum showing the sum of gates of all transitions in band 1. The 467-keV transition was tentatively seen by Muikku *et al.* [3], and is confirmed in this work. Furthermore, a cascade of four more transitions is seen above this. Tentative spins and parities of states in this band have been assigned from systematics (see below). The ordering of these transitions is based on intensity arguments. Figure 9(a) also shows three peaks with energies 333.1, 351.8, and 435.3 keV, that are marked $c1$, $c2$, and $c3$, respectively. These are a result of contamination from ^{182}Hg and have been included when gating on the 412.9-keV transition in ^{183}Tl, which is close to the $8^+ \rightarrow 6^+$ transition of 414.0 keV in ^{182}Hg.

Figure 9(b) shows a sum of gates from transitions in band 2. Again there are contaminants, marked $c4$, $c5$, and $c6$, which are most likely to be from ^{183}Hg and have energies of 403.3, 429.0, and 521.0 keV, respectively. They are included in the spectrum when gating on the 399.0- and 519.9-keV transitions in ^{183}Tl.

Band 3 shows three new transitions which are believed to be built upon the oblate $9/2^-$ state and can be seen in Fig. 9(c). These γ rays are tentatively assigned as $M1$ transitions belonging to the oblate $h_{9/2}$ band. The $11/2^-$ state of band 3 is also fed through the delayed emissions from the $13/2^+$ state of band 5. The $11/2^-$ to $9/2^-$ transition was measured, from a delayed γ spectrum, to be 277.0(3) keV which is consistent, within error, to 276.7 keV as seen in the prompt γ data, and with the previous measurement by Muikku *et al.* of 277.4 keV [3]. The 69.3-keV tranisiton, reported by Muikku *et al.*, was seen when gating on the delayed 277.4-keV transition and has an energy of 69.2(2) keV, as seen in the insert of Fig. 8(a).

Next to band 3 there is a cascade of transitions which are currently unplaced in the level scheme. Moreover, the ordering of the γ rays within this cascade is uncertain. The transitions have been added into the decay scheme based solely on coincidence data. There is tentative evidence that they are in coincidence with the 276.7- and 254.3-keV γ rays. However, if one looks at Fig. 7 it is not clear if these particular transitions belong to ^{183}Tl, since they are not readily seen in the α tagged γ-ray spectrum. The location of the 228.4-keV doublet is shown on this spectrum. It is clear that these transitions are extremely weak. In addition, the 257.2-keV transition, if present, would be hidden under the 254.3-keV transtion of band 3.

Angular correlation and x-ray yield measurements to determine the multipolarity of transitions were attempted in this work. However, due to limited statistics unambiguous assignments could not be made. For bands 1 and 2 tentative spin and parity assignments have been made from a comparison with the heavier odd-mass Tl nuclei as published in Ref. [2] (see discussion below).

IV. DISCUSSION

The sequence of transitions in bands 1,2 3, and 5 in ^{183}Tl show a pattern which is very similar to that seen in ^{185,187}Tl [2]. The prolate $i_{13/2}$ band (band 5) is common in the neutron deficient odd-mass thallium isotopes and is generally observed to be the strongest cascade in the lighter nuclei. Furthermore, it has been noted that the band head of the $i_{13/2}$ configuration reduces in excitation energy down to the $N=102$ nucleus ^{183}Tl, see Fig. 4 from Ref. [3]. It would clearly be interesting to investigate ^{181}Tl, particularly since different calculations [2,28] are in conflict over where the minimum should arise. The calculations presented in Ref. [2] indicate that the $i_{13/2}$ band head should continue to decrease beyond the midshell, while Reviol *et al.* [28] suggest there should be a rise in excitation energy at $N=104$. Clearly, both the current and previous data on ^{183}Tl would appear to support the calculations of Lane *et al.* [2]. However, it will be interesting to investigate ^{181}Tl in order to confirm this conclusion, since it is possible that the up-turn in excitation energy may be slightly delayed. The situation in the odd Tl isotopes is very similar to that seen in the odd Au isotopes [23,29]. In the latter nuclei the data indicate that the position of the $i_{13/2}$ band head relative to the oblate $h_{9/2}$ band head continues to decrease down to $N=98$, while calculations suggest that the minimum energy diference between the two bands should occur at $N=100$ [30].

Bands 1 and 2 do not appear to be connected in any way and hence are most likely decoupled structures. The state at 1092.0 keV in band 1 has been tentatively reported by Muikku *et al.* [3], as the $11/2^-$ member of the $h_{9/2}$ oblate band. The present work suggests that this transition most likely decays from a prolate band, since the states built above it have an energy spacing consistent with a cascade of $E2$ transitions. The observation of decoupled bands is consistent with prolate configurations resulting from the occupancy of low-Ω orbitals. From a comparison of the present decay scheme with those of ^{185,187}Tl [2] we tentatively assign bands 1 and 2 to have prolate $f_{7/2}$ and $h_{9/2}$ configurations, respectively. We note, however, that the assignment of a specific configuration to the aligned bands is not strictly correct, since both bands will involve a mixture of orbitals. We keep this notation for ease of identification and to be consistent with previous work.

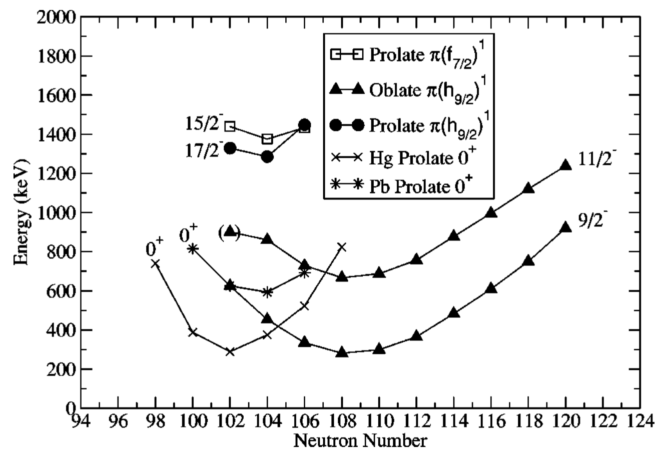

FIG. 10. Comparison of the systematic behavior of states in neutron-deficient Tl nuclei. The brackets around the $11/2^-$ state indicate that there is uncertainty as to the identification of this level.

Assuming that the above configuration assignments are correct the new data have been used to study the systematic behavior of the observed states in the odd mass Tl nuclei. The results are shown in Fig. 10. Additional data for this figure were taken from Refs. [2,3,5,31–33]. With the above assumptions regarding the assignments of bands 1 and 2 the new results suggest that both of the $f_{7/2}$ and $h_{9/2}$ bands reach a minimum in excitation energy at $N=104$. It should be noted that in the production of Fig. 10 we have also assumed that the 1375-keV state in ^{185}Tl [2] is the $15/2^-$ member of the $f_{7/2}$ band. Figure 10 also shows the unperturbed energies of the excited 0^+ states in Hg and Pb nuclei. These were obtained by fitting the formula $E(I)=A[I(I+1)+BI^2(I+1)^2+E_u(0)]$ to the known 4^+, 6^+, and 8^+ states of energies $E(I)$, which are assumed to be unmixed members of the prolate band. It is clear that these prolate bands also have a minimum excitation energy at around $N\sim 103,104$. These observations are consistent with the $f_{7/2}$ and $h_{9/2}$ configurations being important components of the deformed multiparticle-multihole configurations in the neighboring Hg/Pb nuclei. This is further supported by calculations [34,35], which indicate that the prolate states in the even Hg/Pb nuclei are based on complex $4p$-$4h$ and $4p$-$6h$ configurations, that involve excitations into the low-Ω orbitals from the $f_{7/2}$, $h_{9/2}$, and $i_{13/2}$ shells.

Finally, in the present work a tentative $11/2^-$ state is observed decaying to the oblate $h_{9/2}$ band-head state via a prompt 276.7-keV transition. There is, however, some doubt as to whether this is the oblate $11/2^-$ state, since as can be seen from Fig. 10 this state does not follow the expected trend. Clearly, further work with a more powerful γ-ray array will be required in order to clearly identify the states belonging to the oblate band as well as providing confirmation of the tentative assignments made above for the $f_{7/2}$ and $h_{9/2}$ prolate bands.

V. SUMMARY

In the present work the three known α-particle decays from ^{183}Tl, and the α branching ratio have been measured and found to be consistent with previous studies. An examination of prompt focal plane γ rays in coincidence with the favored 6333-keV α emission, and the summing of L electrons has allowed us to tentatively determine the low spin structures of ^{179}Au and ^{175}Ir. In addition, a new α decay of energy 5810 keV has been seen and attributed to the fine structure decay from ^{179}Au.

The high spin decay scheme of ^{183}Tl has been extended. The $\pi i_{13/2}$ band has been extended up to a spin of $41/2\hbar$. In addition, evidence for two new decoupled rotational bands has been observed. These have tentatively been assigned as the $f_{7/2}$ and $h_{9/2}$ prolate configurations based on systematics. Comparisons of excitation energies of states in these bands with equivalent states in ^{185,187}Tl suggests that these structures reach a minimum in excitation energy at $N=104$. This agrees well with the minimum excitation energy of the prolate intruder bands in both the even mass Hg and Pb isotopes, which, according to extrapolations, are found to occur at $N=104$ and 102, respectively.

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