

**$^{189}\text{Pb}$   $\epsilon$  decay (50 s) [2009Sa09](#)**

Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	T. D. Johnson, Balraj Singh		NDS 142, 1 (2017)	15-Apr-2017

Parent:  $^{189}\text{Pb}$ : E=40 4;  $J^\pi=(13/2^+)$ ;  $T_{1/2}=50$  s 3;  $Q(\epsilon)=6772$  16;  $\% \epsilon + \% \beta^+$  decay=100.0

$^{189}\text{Pb}$ - $J^\pi, T_{1/2}$ : From  $^{189}\text{Pb}$  Adopted Levels.

$^{189}\text{Pb}$ - $Q(\epsilon)$ : from [2017Wa10](#).

$^{189}\text{Pb}$ - $\% \epsilon + \% \beta^+$  decay:  $\% \alpha$  is expected to be small, probably <1%.

$^{189}\text{Pb}$  source was formed in U(p,X) reaction ( $\text{UC}_x$  target) with a beam energy of 1.4 GeV.  $^{189}\text{Pb}$  was also excited using a laser beam at resonant frequencies from RILIS at the ISOLDE facility at CERN.

Two experiments were performed:

1. Measured  $\beta\gamma$  coin using  $4\pi$   $\beta$  plastic scintillator and three Ge detectors (one planar HPGe and two Ge detectors). The  $\gamma$  rays in  $^{189}\text{Pb}$  were also identified in hyperfine laser spectroscopy from low-lying levels.
2. Measured  $E\gamma, I\gamma, \gamma\gamma$  coin using two HPGe detectors with Be window. The hyperfine laser spectroscopy was also carried out for some of the strong  $\gamma$  rays.

Comparison with rotor plus particle model calculations.

Decay of the high-spin isomer.

$^{189}\text{Tl}$  Levels

Expected configurations and bands are from [2009Sa09](#) based on axial-rotor coupled to one quasiparticle (Hartree-Fock+BCS) calculations for oblate and prolate deformations.

E(level) <sup>†</sup>	$J^\pi$ <sup>‡</sup>	$T_{1/2}$	Comments
281 <sup>@</sup> 7	(9/2 <sup>-</sup> )	1.4 min <i>I</i>	$\% \epsilon + \% \beta^+ \approx 100$ <a href="#">Additional information 1.</a> E(level): from Adopted Levels, see the comments therein. $T_{1/2}$ : From Adopted Levels.
599.79 <sup>b</sup> 16	(9/2 <sup>-</sup> )		
667.45 <sup>@</sup> 13	(11/2 <sup>-</sup> )		
744.71 <sup>&amp;</sup> 16	(7/2 <sup>-</sup> )		
981.59 <sup>@</sup> 15	(13/2 <sup>-</sup> )		
1028.12 <sup>b</sup> 16	(13/2 <sup>-</sup> )		
1062.51 <sup>&amp;</sup> 15	(9/2 <sup>-</sup> )		
1105.46 <sup>a</sup> 18	(11/2 <sup>-</sup> )		
1147.88 <sup>#</sup> 21	(13/2 <sup>+</sup> )		
1227.80 25	(11/2 <sup>-</sup> )		
1324.98 15	(13/2 <sup>-</sup> )		
1332.28 <sup>&amp;</sup> 20	(11/2 <sup>-</sup> )		
1388.79 23	(11/2 <sup>-</sup> )		
1408.82 <sup>@</sup> 19	(15/2 <sup>-</sup> )		
1420.94 22			
1461.1 <sup>a</sup> 5	(13/2 <sup>-</sup> )		
1464.29 22	(13/2 <sup>-</sup> )		
1492.52 25	(11/2 <sup>-</sup> )		
1533.0 3	(11/2,13/2,15/2 <sup>-</sup> )		$J^\pi$ : (11/2 <sup>-</sup> ) if 787 $\gamma$ to (7/2 <sup>-</sup> ) is proven correct.
1546.8 <sup>#</sup> 3	(15/2 <sup>+</sup> )		
1553.2 3	(11/2,13/2 <sup>-</sup> )		
1614.9 5	(11/2,13/2 <sup>-</sup> )		
1646.1 <sup>@</sup> 5	(17/2 <sup>-</sup> )		
1752.6 4	(11/2,13/2 <sup>-</sup> )		

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$^{189}\text{Pb}$   $\varepsilon$  decay (50 s) **2009Sa09** (continued)

$^{189}\text{Tl}$  Levels (continued)

E(level) <sup>†</sup>	J $\pi$ <sup>‡</sup>	Comments
1756.81 <sup>b</sup> 21	(17/2 <sup>-</sup> )	Band assignment is tentative.
1761.5 4	(11/2,13/2,15/2 <sup>-</sup> )	
1783.2 <sup>&amp;</sup> 5	(13/2 <sup>-</sup> )	
1812.6 3	(11/2,13/2,15/2)	
1830.1 <sup>#</sup> 4	(17/2 <sup>+</sup> )	
1844.6 10	(17/2 <sup>-</sup> )	
1861.5 3	(11/2,13/2,15/2)	
1865.2 5	(11/2,13/2,15/2 <sup>-</sup> )	
1878.2 3	(11/2,13/2,15/2 <sup>-</sup> )	
1894.0 11	(11/2,13/2,15/2)	
1959.8 5	(11/2,13/2,15/2)	
1962.2 5	(11/2,13/2,15/2)	
1995.8 5	(17/2 <sup>+</sup> )	
2006.3 4	(13/2 <sup>-</sup> ,15/2)	
2025.4 5	(11/2,13/2,15/2 <sup>-</sup> )	
2174.7 4	(11/2,13/2,15/2 <sup>-</sup> )	
2185.0 3	(13/2 <sup>-</sup> ,15/2)	
2213.5 5	(11/2,13/2,15/2 <sup>-</sup> )	
2420.3 5	(11/2,13/2,15/2)	

<sup>†</sup> From least-squares fit to  $\gamma$  data using 281-keV level as fixed. Uncertainty of 7 keV in this energy is not reflected in the uncertainties of other level energies.

<sup>‡</sup> From Adopted Levels.

<sup>#</sup> Band(A):  $\pi 13/2[606]$  (oblate).

<sup>@</sup> Band(B):  $\pi 9/2[505]$  (oblate).

<sup>&</sup> Band(C):  $\pi 7/2[514]$  (oblate).

<sup>a</sup> Band(D):  $\pi 11/2[505]$  (prolate).

<sup>b</sup> Band(E):  $\pi 1/2[541]$  (prolate).

$\varepsilon, \beta^+$  radiations

The beta feedings and associated  $\log ft$  values have been deduced by the evaluators. The feedings given by **2009Sa09** are given under comments.

Since this decay has a Q value of over 5 MeV and the only observed levels are below 2.5 MeV, the scheme is incomplete.

Therefore, the  $\varepsilon + \beta^+$  intensities are upper limits and  $\log ft$  values are lower limits.

E(decay)	E(level)	I $\beta^+$ <sup>†</sup>	I $\varepsilon$ <sup>†</sup>	Log $ft$	I( $\varepsilon + \beta^+$ ) <sup>†</sup>	Comments
(4392 17)	2420.3	0.1	0.3 1	7.0 1	0.4 1	av E $\beta$ =1496 20; $\varepsilon K$ =0.553 7; $\varepsilon L$ =0.0981 13; $\varepsilon M$ + =0.0317 4
(4599 17)	2213.5	0.1	0.3 1	7.1 1	0.4 1	av E $\beta$ =1589 20; $\varepsilon K$ =0.522 7; $\varepsilon L$ =0.0924 12; $\varepsilon M$ + =0.0298 4
(4627 17)	2185.0	0.94 11	1.7 2	6.31 6	2.6 3	av E $\beta$ =1602 20; $\varepsilon K$ =0.517 7; $\varepsilon L$ =0.0916 12; $\varepsilon M$ + =0.0296 4 I( $\varepsilon + \beta^+$ ): 2.5 1 ( <b>2009Sa09</b> ).
(4637 17)	2174.7	0.40 7	0.70 13	6.7 1	1.1 2	av E $\beta$ =1607 20; $\varepsilon K$ =0.516 7; $\varepsilon L$ =0.0913 12; $\varepsilon M$ + =0.0295 4
(4787 17)	2025.4	0.22 4	0.35 6	7.0 1	0.57 10	av E $\beta$ =1675 20; $\varepsilon K$ =0.493 7; $\varepsilon L$ =0.0873 12; $\varepsilon M$ + =0.0282 4
(4806 17)	2006.3	0.27 5	0.42 7	6.9 1	0.69 12	av E $\beta$ =1683 20; $\varepsilon K$ =0.491 7; $\varepsilon L$ =0.0867 12; $\varepsilon M$ + =0.0280 4
(4816 17)	1995.8	0.25 2	0.38 3	6.98 5	0.63 5	av E $\beta$ =1688 20; $\varepsilon K$ =0.489 7; $\varepsilon L$ =0.0865 12; $\varepsilon M$ + =0.0279 4 Log $ft$ : too low for $\Delta J=2$ , $\Delta \pi$ =no $\beta$ transition. I( $\varepsilon + \beta^+$ ): 0.62 4 ( <b>2009Sa09</b> ).
(4850 17)	1962.2	0.25 4	0.36 6	7.0 1	0.61 10	av E $\beta$ =1703 20; $\varepsilon K$ =0.484 7; $\varepsilon L$ =0.0856 12; $\varepsilon M$ + =0.0276 4

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$^{189}\text{Pb}$   $\varepsilon$  decay (50 s) 2009Sa09 (continued) $\varepsilon, \beta^+$  radiations (continued)

E(decay)	E(level)	$I\beta^+$ †	$I\varepsilon$ †	Log $ft$	$I(\varepsilon + \beta^+)$ †	Comments
(4852 17)	1959.8	0.47 4	0.70 6	6.73 5	1.17 10	av $E\beta=1704$ 20; $\varepsilon K=0.484$ 7; $\varepsilon L=0.0855$ 12; $\varepsilon M+=0.0276$ 4
(4918 17)	1894.0	0.32 4	0.45 6	6.93 7	0.77 10	av $E\beta=1734$ 20; $\varepsilon K=0.474$ 7; $\varepsilon L=0.0838$ 12; $\varepsilon M+=0.0271$ 4
(4934 17)	1878.2	0.79 9	1.1 1	6.54 6	1.9 2	av $E\beta=1741$ 20; $\varepsilon K=0.472$ 7; $\varepsilon L=0.0833$ 12; $\varepsilon M+=0.0269$ 4
(4947 17)	1865.2	0.29 6	0.39 8	7.0 1	0.68 14	av $E\beta=1747$ 20; $\varepsilon K=0.470$ 7; $\varepsilon L=0.0830$ 12; $\varepsilon M+=0.0268$ 4
(4951 17)	1861.5	0.59 8	0.81 12	6.68 7	1.4 2	av $E\beta=1749$ 20; $\varepsilon K=0.469$ 7; $\varepsilon L=0.0829$ 12; $\varepsilon M+=0.0268$ 4
(4967 17)	1844.6	0.079 11	0.28 4	9.10 <sup>lu</sup> 7	0.36 5	av $E\beta=1709$ 20; $\varepsilon K=0.628$ 5; $\varepsilon L=0.1143$ 10; $\varepsilon M+=0.0371$ 4
(4982 17)	1830.1	0.47 4	0.63 6	6.79 5	1.1 1	$I(\varepsilon + \beta^+)$ : 0.35 (2009Sa09). av $E\beta=1763$ 20; $\varepsilon K=0.465$ 7; $\varepsilon L=0.0821$ 12; $\varepsilon M+=0.0265$ 4 Log $ft$ : too low for $\Delta J=2$ , $\Delta\pi$ =no transition.
(4999 17)	1812.6	0.82 13	1.1 2	6.6 1	1.9 3	$I(\varepsilon + \beta^+)$ : 0.99 6 (2009Sa09). av $E\beta=1771$ 20; $\varepsilon K=0.462$ 7; $\varepsilon L=0.0816$ 12; $\varepsilon M+=0.0264$ 4
(5029 17)	1783.2	0.32 3	0.41 4	6.99 6	0.73 7	av $E\beta=1785$ 20; $\varepsilon K=0.458$ 7; $\varepsilon L=0.0809$ 12; $\varepsilon M+=0.0261$ 4
(5051 17)	1761.5	0.66 9	0.84 11	6.68 7	1.5 2	av $E\beta=1795$ 20; $\varepsilon K=0.455$ 7; $\varepsilon L=0.0803$ 12; $\varepsilon M+=0.0259$ 4
(5055 17)	1756.81	0.35 9	1.2 3	8.5 <sup>lu</sup> 1	1.5 4	Log $ft$ : too low for $\Delta J=2$ , $\Delta\pi$ =no. av $E\beta=1747$ 20; $\varepsilon K=0.619$ 5; $\varepsilon L=0.1124$ 10; $\varepsilon M+=0.0365$ 4
(5059 17)	1752.6	0.48 9	0.62 11	6.8 1	1.1 2	av $E\beta=1799$ 20; $\varepsilon K=0.454$ 7; $\varepsilon L=0.0801$ 12; $\varepsilon M+=0.0259$ 4
(5166 17)	1646.1	0.19 4	0.58 11	8.9 <sup>lu</sup> 1	0.77 14	av $E\beta=1795$ 20; $\varepsilon K=0.606$ 5; $\varepsilon L=0.1100$ 10; $\varepsilon M+=0.0357$ 4
(5197 17)	1614.9	$\approx 0.84$	$\approx 0.96$	$\approx 6.6$	$\approx 1.8$	$I(\varepsilon + \beta^+)$ : 0.74 (2009Sa09). av $E\beta=1862$ 20; $\varepsilon K=0.434$ 7; $\varepsilon L=0.0766$ 11; $\varepsilon M+=0.0247$ 4
(5259 17)	1553.2	0.57 10	0.63 11	6.8 1	1.2 2	av $E\beta=1890$ 20; $\varepsilon K=0.426$ 6; $\varepsilon L=0.0751$ 11; $\varepsilon M+=0.0242$ 4
(5265 17)	1546.8	1.8 5	2.0 5	6.3 1	3.8 10	av $E\beta=1893$ 20; $\varepsilon K=0.425$ 6; $\varepsilon L=0.0749$ 11; $\varepsilon M+=0.0242$ 4
(5279 17)	1533.0	$\approx 1.2$	$\approx 1.3$	$\approx 6.5$	$\approx 2.5$	$I(\varepsilon + \beta^+)$ : 3.7 3 (2009Sa09). av $E\beta=1899$ 20; $\varepsilon K=0.423$ 6; $\varepsilon L=0.0746$ 11; $\varepsilon M+=0.0241$ 4
(5319 17)	1492.52	1.3 2	1.3 3	6.5 1	2.6 5	$I(\varepsilon + \beta^+)$ : 3.2 2 (2009Sa09). av $E\beta=1917$ 20; $\varepsilon K=0.417$ 6; $\varepsilon L=0.0736$ 11; $\varepsilon M+=0.0238$ 4
(5348 17)	1464.29	1.5 4	1.6 5	6.5 1	3.1 9	$I(\varepsilon + \beta^+)$ : 2.5 2 (2009Sa09). av $E\beta=1930$ 20; $\varepsilon K=0.414$ 6; $\varepsilon L=0.0729$ 11; $\varepsilon M+=0.0235$ 4
(5351 17)	1461.1	0.14 3	0.14 3	7.5 1	0.28 6	$I(\varepsilon + \beta^+)$ : 3.0 2 (2009Sa09). av $E\beta=1932$ 20; $\varepsilon K=0.413$ 6; $\varepsilon L=0.0728$ 11; $\varepsilon M+=0.0235$ 4
(5403 17)	1408.82	2.2 3	2.2 3	6.32 7	4.4 6	av $E\beta=1956$ 20; $\varepsilon K=0.406$ 6; $\varepsilon L=0.0716$ 11; $\varepsilon M+=0.0231$ 4
(5423 17)	1388.79	1.4 2	1.3 2	6.54 7	2.7 4	$I(\varepsilon + \beta^+)$ : 4.1 1 (2009Sa09). av $E\beta=1965$ 21; $\varepsilon K=0.404$ 6; $\varepsilon L=0.0711$ 11; $\varepsilon M+=0.0230$ 4
(5480 17)	1332.28	1.5 4	1.5 3	6.5 1	3.0 7	$I(\varepsilon + \beta^+)$ : 2.6 2 (2009Sa09). av $E\beta=1991$ 21; $\varepsilon K=0.396$ 6; $\varepsilon L=0.0698$ 11; $\varepsilon M+=0.0225$

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$^{189}\text{Pb}$   $\varepsilon$  decay (50 s) 2009Sa09 (continued) $\varepsilon, \beta^+$  radiations (continued)

<u>E(decay)</u>	<u>E(level)</u>	<u><math>I\beta^+</math></u> †	<u><math>I\varepsilon</math></u> †	<u>Log <math>ft</math></u>	<u><math>I(\varepsilon + \beta^+)</math></u> †	<u>Comments</u>
(5487 17)	1324.98	2.4 5	2.2 5	6.3 1	4.6 10	<sup>4</sup> I( $\varepsilon + \beta^+$ ): 2.9 5 (2009Sa09). av E $\beta$ =1994 21; $\varepsilon$ K=0.395 6; $\varepsilon$ L=0.0696 11; $\varepsilon$ M+=0.0225 4 I( $\varepsilon + \beta^+$ ): 4.4 1 (2009Sa09).
(5584 17)	1227.80	1.9 3	1.7 3	6.5 1	3.6 6	av E $\beta$ =2039 21; $\varepsilon$ K=0.383 6; $\varepsilon$ L=0.0674 10; $\varepsilon$ M+=0.0218 4 I( $\varepsilon + \beta^+$ ): 3.5 5 (2009Sa09).
(5664 17)	1147.88	5 2	4 1	6.1 2	9 3	av E $\beta$ =2076 21; $\varepsilon$ K=0.373 6; $\varepsilon$ L=0.0656 10; $\varepsilon$ M+=0.0212 4 I( $\varepsilon + \beta^+$ ): 8.4 3 (2009Sa09).
(5707 17)	1105.46	5.3 12	4.3 10	6.1 1	9.6 22	av E $\beta$ =2095 21; $\varepsilon$ K=0.368 6; $\varepsilon$ L=0.0647 10; $\varepsilon$ M+=0.0209 4 I( $\varepsilon + \beta^+$ ): 9.4 5 (2009Sa09).
(5749 17)	1062.51	0.8 5	1.5 9	8.6 <sup>1u</sup> 3	2.3 14	av E $\beta$ =2051 20; $\varepsilon$ K=0.538 6; $\varepsilon$ L=0.0971 10; $\varepsilon$ M+=0.0315 4 I( $\varepsilon + \beta^+$ ): 2.3 15 (2009Sa09).
(5784 17)	1028.12	2.1 4	1.6 3	6.5 1	3.7 7	av E $\beta$ =2131 21; $\varepsilon$ K=0.358 6; $\varepsilon$ L=0.0630 10; $\varepsilon$ M+=0.0203 3 I( $\varepsilon + \beta^+$ ): 4.0 1 (2009Sa09).
(5830 17)	981.59	5.9 11	4.6 8	6.1 1	10.5 19	av E $\beta$ =2152 21; $\varepsilon$ K=0.353 6; $\varepsilon$ L=0.0620 10; $\varepsilon$ M+=0.0200 3 I( $\varepsilon + \beta^+$ ): 9.5 7 (2009Sa09).
(6145 17)	667.45	7 3	4.3 20	6.2 2	11 5	av E $\beta$ =2297 21; $\varepsilon$ K=0.317 5; $\varepsilon$ L=0.0557 9; $\varepsilon$ M+=0.0180 3 I( $\varepsilon + \beta^+$ ): 11 4 (2009Sa09).

† Absolute intensity per 100 decays.

γ(<sup>189</sup>Tl)

I<sub>γ</sub> normalization: Deduced from Σ(I(γ+ce)) of γ rays to 281 level)=100. Same value is obtained from analysis in 2009Sa09.  
All the unplaced γ rays are arbitrarily assigned to the decay of the high-spin isomer.

E <sub>γ</sub> <sup>†</sup>	I <sub>γ</sub> <sup>‡b</sup>	E <sub>i</sub> (level)	J <sub>i</sub> <sup>π</sup>	E <sub>f</sub>	J <sub>f</sub> <sup>π</sup>	Mult.	α <sup>a</sup>	Comments
165.4 1	≈0.9&	1227.80	(11/2 <sup>-</sup> )	1062.51	(9/2 <sup>-</sup> )	[D,E2]	1.1 10	α(K)=0.0973 15; α(L)=0.0174 3; α(M)=0.00407 7; α(N+..)=0.001218 19 α(N)=0.001015 16; α(O)=0.000189 3; α(P)=1.416×10 <sup>-5</sup> 22
166.4 4	≈2	1147.88	(13/2 <sup>+</sup> )	981.59	(13/2 <sup>-</sup> )	[E1]	0.1200 19	
194.0 4	≈1.7	1614.9	(11/2,13/2 <sup>-</sup> )	1420.94		[D,E2]	0.7 7	α(K)=0.26 18; α(L)=0.063 10; α(M)=0.0153 17; α(N+..)=0.0046 6 α(N)=0.0038 5; α(O)=0.00072 12; α(P)=5.4×10 <sup>-5</sup> 25
249.7 4	0.6 1	2006.3	(13/2 <sup>-</sup> ,15/2)	1756.81	(17/2 <sup>-</sup> )	[D,E2]	0.3 3	
269.7 2	3.4 5	1332.28	(11/2 <sup>-</sup> )	1062.51	(9/2 <sup>-</sup> )	[M1+E2]	0.34 19	
283.4 <sup>c&amp;d</sup> 4	≈0.4 <sup>c&amp;</sup>	1388.79	(11/2 <sup>-</sup> )	1105.46	(11/2 <sup>-</sup> )	[D,E2]	0.25 22	α(K)=0.284 4; α(L)=0.0478 7; α(M)=0.01116 16; α(N+..)=0.00342 5 α(N)=0.00282 4; α(O)=0.000547 8; α(P)=5.18×10 <sup>-5</sup> 8
283.4 <sup>c&amp;</sup> 4	≈0.9 <sup>c&amp;</sup>	1830.1	(17/2 <sup>+</sup> )	1546.8	(15/2 <sup>+</sup> )	(M1)	0.459	
292.6 4	0.9 1	1756.81	(17/2 <sup>-</sup> )	1464.29	(13/2 <sup>-</sup> )	[E2]	0.119	
314.1 2	13 2	981.59	(13/2 <sup>-</sup> )	667.45	(11/2 <sup>-</sup> )	M1	0.346	
317.7 <sup>#</sup> 2	11 2	1062.51	(9/2 <sup>-</sup> )	744.71	(7/2 <sup>-</sup> )	[M1+E2]	0.21 12	
318.8 2	20 <sup>@</sup> 10	599.79	(9/2 <sup>-</sup> )	281	(9/2 <sup>-</sup> )	[M1]	0.332	α(K)=0.272 4; α(L)=0.0459 7; α(M)=0.01071 16; α(N+..)=0.00328 5 α(N)=0.00270 4; α(O)=0.000525 8; α(P)=4.97×10 <sup>-5</sup> 7
326.2 4	0.9 1	1388.79	(11/2 <sup>-</sup> )	1062.51	(9/2 <sup>-</sup> )	[D,E2]	0.17 15	α(K)=0.12 8; α(L)=0.026 8; α(M)=0.0064 16; α(N+..)=0.0019 5 α(N)=0.0016 4; α(O)=0.00030 9; α(P)=2.5×10 <sup>-5</sup> 13
336.3 4	1.0 2	1756.81	(17/2 <sup>-</sup> )	1420.94		[D,E2]	0.15 14	
348.5 <sup>#</sup> 4	≈0.8	1812.6	(11/2,13/2,15/2)	1464.29	(13/2 <sup>-</sup> )	[M1+E2]	0.16 9	
355.6 4	0.6 1	1461.1	(13/2 <sup>-</sup> )	1105.46	(11/2 <sup>-</sup> )			
361 <sup>c&amp;</sup> 1	≈1.7 <sup>c&amp;</sup>	1105.46	(11/2 <sup>-</sup> )	744.71	(7/2 <sup>-</sup> )			
361 <sup>c</sup> 1	≈1.7 <sup>c</sup>	1894.0	(11/2,13/2,15/2)	1533.0	(11/2,13/2,15/2 <sup>-</sup> )	[D,E2]	0.13 11	α(K)=0.0415 7; α(L)=0.0178 3; α(M)=0.00450 8; α(N+..)=0.001346 24 α(N)=0.001130 20; α(O)=0.000203 4; α(P)=1.166×10 <sup>-5</sup> 19
372.5 4	0.5 1	2185.0	(13/2 <sup>-</sup> ,15/2)	1812.6	(11/2,13/2,15/2)	[D,E2]	0.12 10	

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<sup>189</sup>Pb ε decay (50 s) 2009Sa09 (continued)

γ(<sup>189</sup>Tl) (continued)

$E_\gamma$ †	$I_\gamma$ ‡b	$E_i$ (level)	$J_i^\pi$	$E_f$	$J_f^\pi$	Mult.	$\alpha^a$	Comments
386.2 2	100	667.45	(11/2 <sup>-</sup> )	281	(9/2 <sup>-</sup> )	M1+E2	0.13 8	$\alpha(K)=0.160$ 4; $\alpha(L)=0.0270$ 5; $\alpha(M)=0.00630$ 12; $\alpha(N+..)=0.00193$ 4 $\alpha(N)=0.00159$ 3; $\alpha(O)=0.000309$ 6; $\alpha(P)=2.92\times 10^{-5}$ 7
391.4 4	2.5 4	1812.6	(11/2,13/2,15/2)	1420.94				
398.9 2	11 2	1546.8	(15/2 <sup>+</sup> )	1147.88	(13/2 <sup>+</sup> )	M1+E2	0.12 7	
420.2 4	1.3 2	1752.6	(11/2,13/2 <sup>-</sup> )	1332.28	(11/2 <sup>-</sup> )	[D,E2]	0.09 8	
427.1 2	≈3.5	1408.82	(15/2 <sup>-</sup> )	981.59	(13/2 <sup>-</sup> )	M1	0.1503	
427.5 & 2	≈7 &	1533.0	(11/2,13/2,15/2 <sup>-</sup> )	1105.46	(11/2 <sup>-</sup> )	[D,E2]	0.08 7	
428.1 & 4	≈3 &	2185.0	(13/2 <sup>-</sup> ,15/2)	1756.81	(17/2 <sup>-</sup> )	[D,E2]	0.08 7	
428.3 2	≈9	1028.12	(13/2 <sup>-</sup> )	599.79	(9/2 <sup>-</sup> )	[E2]	0.0413	$\alpha(K)=0.0282$ 4; $\alpha(L)=0.00993$ 14; $\alpha(M)=0.00248$ 4; $\alpha(N+..)=0.000743$ 11 $\alpha(N)=0.000623$ 9; $\alpha(O)=0.0001133$ 16; $\alpha(P)=7.11\times 10^{-6}$ 10
429 & d 1	≈1 &	1761.5	(11/2,13/2,15/2 <sup>-</sup> )	1332.28	(11/2 <sup>-</sup> )	[D,E2]	0.08 7	
430.0 2	5.4 8	1492.52	(11/2 <sup>-</sup> )	1062.51	(9/2 <sup>-</sup> )	[D,E2]	0.08 7	
437.8 4	2.6 4	1105.46	(11/2 <sup>-</sup> )	667.45	(11/2 <sup>-</sup> )	[M1+E2]	0.09 6	$\alpha(K)=0.07$ 5; $\alpha(L)=0.014$ 5; $\alpha(M)=0.0034$ 12; $\alpha(N+..)=0.0010$ 4 $\alpha(N)=0.0009$ 3; $\alpha(O)=0.00016$ 6; $\alpha(P)=1.4\times 10^{-5}$ 8
<sup>x</sup> 439.9 # 4	≈0.9							
449.0 4	≈1.4	1995.8	(17/2 <sup>+</sup> )	1546.8	(15/2 <sup>+</sup> )	(M1)	0.1323	$\alpha(K)=0.1087$ ; $\alpha(L)=0.0181$ ; $\alpha(M)=0.00423$ ; $\alpha(N+..)=0.00111$ $\alpha(N)=0.00107$ ; $\alpha(O)=0.000207$ ; $\alpha(P)=1.97\times 10^{-5}$
450.9 # 4	≈1.7	1783.2	(13/2 <sup>-</sup> )	1332.28	(11/2 <sup>-</sup> )	[M1+E2]	0.08 5	$\alpha(K)=0.07$ 5; $\alpha(L)=0.013$ 5; $\alpha(M)=0.0031$ 11; $\alpha(N+..)=0.0010$ 4 $\alpha(N)=0.0008$ 3; $\alpha(O)=0.00015$ 6; $\alpha(P)=1.3\times 10^{-5}$ 7
463.7 2	33 @ 3	744.71	(7/2 <sup>-</sup> )	281	(9/2 <sup>-</sup> )	[M1+E2]	0.08 5	$\alpha(K)=0.06$ 4; $\alpha(L)=0.012$ 5; $\alpha(M)=0.0029$ 10; $\alpha(N+..)=0.0009$ 3 $\alpha(N)=0.0007$ 3; $\alpha(O)=0.00014$ 6; $\alpha(P)=1.2\times 10^{-5}$ 7
480.3 2	37 6	1147.88	(13/2 <sup>+</sup> )	667.45	(11/2 <sup>-</sup> )	E1	0.01004	$\alpha(K)=0.00831$ 12; $\alpha(L)=0.001327$ 19; $\alpha(M)=0.000307$ 5; $\alpha(N+..)=9.31\times 10^{-5}$ 13 $\alpha(N)=7.71\times 10^{-5}$ 11; $\alpha(O)=1.473\times 10^{-5}$ 21; $\alpha(P)=1.274\times 10^{-6}$ 18
483.1 2	4.8 7	1227.80	(11/2 <sup>-</sup> )	744.71	(7/2 <sup>-</sup> )	[E2]	0.0306	
491.0 4	0.6 1	1553.2	(11/2,13/2 <sup>-</sup> )	1062.51	(9/2 <sup>-</sup> )	[D,E2]	0.06 5	
498 & d 1	≈0.4 &	1962.2	(11/2,13/2,15/2)	1464.29	(13/2 <sup>-</sup> )	[D,E2]	0.05 5	
536.4 4	2.0 3	1861.5	(11/2,13/2,15/2)	1324.98	(13/2 <sup>-</sup> )	[D,E2]	0.05 4	
541.8 4	0.9 1	2006.3	(13/2 <sup>-</sup> ,15/2)	1464.29	(13/2 <sup>-</sup> )	[D,E2]	0.04 4	
560.3 d 4	2.0 3	1227.80	(11/2 <sup>-</sup> )	667.45	(11/2 <sup>-</sup> )	[D,E2]	0.04 4	
<sup>x</sup> 562.7 4	1.3 2							
587.6 2	7.2 11	1332.28	(11/2 <sup>-</sup> )	744.71	(7/2 <sup>-</sup> )	[E2]	0.0193	Possible coincidence with 317.7γ. $\alpha(K)=0.01433$ 20; $\alpha(L)=0.00375$ 6; $\alpha(M)=0.000916$ 13; $\alpha(N+..)=0.000276$ 4 $\alpha(N)=0.000230$ 4; $\alpha(O)=4.27\times 10^{-5}$ 6; $\alpha(P)=3.09\times 10^{-6}$ 5 Coincidence with 317.7γ.
<sup>x</sup> 611.2 & 4	≈0.9 &							
613.2 # 4	≈1.7	1761.5	(11/2,13/2,15/2 <sup>-</sup> )	1147.88	(13/2 <sup>+</sup> )	[D,E2]	0.032 26	
644.1 2	5.1 8	1388.79	(11/2 <sup>-</sup> )	744.71	(7/2 <sup>-</sup> )	[E2]	0.0157	
657.2 2	10 2	1324.98	(13/2 <sup>-</sup> )	667.45	(11/2 <sup>-</sup> )	M1	0.0485	

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<sup>189</sup>Pb ε decay (50 s) 2009Sa09 (continued)

γ(<sup>189</sup>Tl) (continued)

$E_\gamma$ †	$I_\gamma$ ‡b	$E_i$ (level)	$J_i^\pi$	$E_f$	$J_f^\pi$	Mult.	$\alpha^a$	Comments
664.5 4	1.9 3	1646.1	(17/2 <sup>-</sup> )	981.59	(13/2 <sup>-</sup> )	E2	0.01467	$\alpha(K)=0.01117$ 16; $\alpha(L)=0.00266$ 4; $\alpha(M)=0.000646$ 10; $\alpha(N+..)=0.000195$ 3
682.1 4	1.4 2	1830.1	(17/2 <sup>+</sup> )	1147.88	(13/2 <sup>+</sup> )	E2	0.01386	$\alpha(N)=0.0001624$ 23; $\alpha(O)=3.03\times 10^{-5}$ 5; $\alpha(P)=2.30\times 10^{-6}$ 4 $\alpha(K)=0.01060$ 15; $\alpha(L)=0.00248$ 4; $\alpha(M)=0.000601$ 9; $\alpha(N+..)=0.000182$ 3
690.2 4	1.2 2	1752.6	(11/2,13/2 <sup>-</sup> )	1062.51	(9/2 <sup>-</sup> )	[D,E2]	0.024 19	$\alpha(N)=0.0001511$ 22; $\alpha(O)=2.83\times 10^{-5}$ 4; $\alpha(P)=2.16\times 10^{-6}$ 3
700.4 2	23 3	981.59	(13/2 <sup>-</sup> )	281	(9/2 <sup>-</sup> )	E2	0.01310	$\alpha(K)=0.01006$ 14; $\alpha(L)=0.00231$ 4; $\alpha(M)=0.000559$ 8; $\alpha(N+..)=0.0001690$ 24
720& 1	≈0.9&	2185.0	(13/2 <sup>-</sup> ,15/2)	1464.29	(13/2 <sup>-</sup> )	[D,E2]	0.021 17	$\alpha(N)=0.0001407$ 20; $\alpha(O)=2.63\times 10^{-5}$ 4; $\alpha(P)=2.03\times 10^{-6}$ 3
728.6 2	5.4 8	1756.81	(17/2 <sup>-</sup> )	1028.12	(13/2 <sup>-</sup> )	[E2]	0.01205	$\alpha(K)=0.00930$ 13; $\alpha(L)=0.00209$ 3; $\alpha(M)=0.000503$ 7; $\alpha(N+..)=0.0001522$ 22
730& 1	≈0.9&	1878.2	(11/2,13/2,15/2 <sup>-</sup> )	1147.88	(13/2 <sup>+</sup> )	[D,E2]	0.021 17	$\alpha(N)=0.0001266$ 18; $\alpha(O)=2.37\times 10^{-5}$ 4; $\alpha(P)=1.86\times 10^{-6}$ 3
741.5 2	6.8 10	1408.82	(15/2 <sup>-</sup> )	667.45	(11/2 <sup>-</sup> )	(E2)	0.01161	$\alpha(K)=0.00899$ 13; $\alpha(L)=0.00199$ 3; $\alpha(M)=0.000480$ 7; $\alpha(N+..)=0.0001453$ 21
747.1 2	8.0 12	1028.12	(13/2 <sup>-</sup> )	281	(9/2 <sup>-</sup> )	[E2]	0.01143	$\alpha(N)=0.0001208$ 17; $\alpha(O)=2.27\times 10^{-5}$ 4; $\alpha(P)=1.78\times 10^{-6}$ 3 $\alpha(K)=0.00886$ 13; $\alpha(L)=0.00196$ 3; $\alpha(M)=0.000471$ 7; $\alpha(N+..)=0.0001425$ 20
748& 1	≈0.7&	1492.52	(11/2 <sup>-</sup> )	744.71	(7/2 <sup>-</sup> )	[E2]	0.0114	$\alpha(N)=0.0001185$ 17; $\alpha(O)=2.23\times 10^{-5}$ 4; $\alpha(P)=1.754\times 10^{-6}$ 25
<sup>x</sup> 751.5 4	1.0 2							Coincidence with 386.2γ.
<sup>x</sup> 775.3 4	0.6 1							Possible coincidence with 463.7γ.
781.6 2	7.6 11	1062.51	(9/2 <sup>-</sup> )	281	(9/2 <sup>-</sup> )	[M1+E2]	0.021 11	$\alpha(K)=0.017$ 9; $\alpha(L)=0.0030$ 13; $\alpha(M)=0.0007$ 3; $\alpha(N+..)=0.00021$ 9 $\alpha(N)=0.00018$ 7; $\alpha(O)=3.4\times 10^{-5}$ 14; $\alpha(P)=3.1\times 10^{-6}$ 15
784.6& 4	≈1.7&	1812.6	(11/2,13/2,15/2)	1028.12	(13/2 <sup>-</sup> )			Coincidences with 318.8γ, 428.3γ, 747.1γ and possibly 372.5γ.
<sup>x</sup> 785.3 4	≈1.7							
787&d 1	≈0.7&	1533.0	(11/2,13/2,15/2 <sup>-</sup> )	744.71	(7/2 <sup>-</sup> )			
811.9 <sup>d</sup> 4	0.6 1	1959.8	(11/2,13/2,15/2)	1147.88	(13/2 <sup>+</sup> )	[D,E2]	0.016 13	
821.2 2	7.3 10	1420.94		599.79	(9/2 <sup>-</sup> )	[D,E2]	0.015 12	
824.5 2	30 5	1105.46	(11/2 <sup>-</sup> )	281	(9/2 <sup>-</sup> )	[M1+E2]	0.018 9	$\alpha(K)=0.015$ 8; $\alpha(L)=0.0026$ 11; $\alpha(M)=0.00061$ 25; $\alpha(N+..)=0.00019$ 8
<sup>x</sup> 848.4 4	0.6 1							$\alpha(N)=0.00015$ 7; $\alpha(O)=3.0\times 10^{-5}$ 13; $\alpha(P)=2.7\times 10^{-6}$ 13
860.0 4	1.8 3	2185.0	(13/2 <sup>-</sup> ,15/2)	1324.98	(13/2 <sup>-</sup> )	[D,E2]	0.014 11	
863& 1	0.9& 1	1844.6	(17/2 <sup>-</sup> )	981.59	(13/2 <sup>-</sup> )	[E2]	0.0085	
864.5 2	13 2	1464.29	(13/2 <sup>-</sup> )	599.79	(9/2 <sup>-</sup> )	[E2]	0.0085	
880.0 4	1.3 2	1861.5	(11/2,13/2,15/2)	981.59	(13/2 <sup>-</sup> )	[D,E2]	0.013 10	
885.5 4	2.3 3	1553.2	(11/2,13/2 <sup>-</sup> )	667.45	(11/2 <sup>-</sup> )	[D,E2]	0.013 10	

<sup>189</sup>Pb ε decay (50 s) 2009Sa09 (continued)

γ(<sup>189</sup>Tl) (continued)

<u>E<sub>γ</sub><sup>†</sup></u>	<u>I<sub>γ</sub><sup>‡b</sup></u>	<u>E<sub>i</sub>(level)</u>	<u>J<sub>i</sub><sup>π</sup></u>	<u>E<sub>f</sub></u>	<u>J<sub>f</sub><sup>π</sup></u>	<u>Mult.</u>	<u>α<sup>a</sup></u>	<u>Comments</u>
896.0 4	1.7 3	1878.2	(11/2,13/2,15/2 <sup>-</sup> )	981.59	(13/2 <sup>-</sup> )	[D,E2]	0.012 10	
919.9 4	1.4 2	2025.4	(11/2,13/2,15/2 <sup>-</sup> )	1105.46	(11/2 <sup>-</sup> )	[D,E2]	0.012 9	
934.1 4	1.1 2	1962.2	(11/2,13/2,15/2)	1028.12	(13/2 <sup>-</sup> )	[D,E2]	0.011 9	
<sup>x</sup> 947.2 4	1.7 3							
956.0 4	1.1 2	2420.3	(11/2,13/2,15/2)	1464.29	(13/2 <sup>-</sup> )	[D,E2]	0.011 8	
978.2 <sup>&amp;</sup> 4	≈2.3 <sup>&amp;</sup>	1959.8	(11/2,13/2,15/2)	981.59	(13/2 <sup>-</sup> )	[D,E2]	0.010 8	
<sup>x</sup> 981.4 4	2.2 3							
<sup>x</sup> 1005.5 4	1.6 2							
<sup>x</sup> 1012.8 2	3.7 6							
1015 <sup>&amp;</sup> 1	≈1.7 <sup>&amp;</sup>	1614.9	(11/2,13/2 <sup>-</sup> )	599.79	(9/2 <sup>-</sup> )	[D,E2]	0.009 7	
1027 <sup>&amp;</sup> 1	≈0.9 <sup>&amp;</sup>	2174.7	(11/2,13/2,15/2 <sup>-</sup> )	1147.88	(13/2 <sup>+</sup> )	[D,E2]	0.009 7	
<sup>x</sup> 1041.3 4	1.2 2							
1044.3 2	5.0 8	1324.98	(13/2 <sup>-</sup> )	281	(9/2 <sup>-</sup> )	[E2]	0.00583 9	α=0.00583 9; α(K)=0.00468 7; α(L)=0.000877 13; α(M)=0.000207 3; α(N+..)=6.30×10 <sup>-5</sup> 9 α(N)=5.22×10 <sup>-5</sup> 8; α(O)=9.95×10 <sup>-6</sup> 14; α(P)=8.52×10 <sup>-7</sup> 12
1094.4 4	1.0 2	1761.5	(11/2,13/2,15/2 <sup>-</sup> )	667.45	(11/2 <sup>-</sup> )			
1108.0 4	1.0 2	2213.5	(11/2,13/2,15/2 <sup>-</sup> )	1105.46	(11/2 <sup>-</sup> )	[D,E2]	0.007 6	
<sup>x</sup> 1117.2 4	1.6 2							
<sup>x</sup> 1138.0 2	4.1 6							Coincidence with 386.2γ.
<sup>x</sup> 1179.3 4	2.5 4							
1197.7 4	1.7 3	1865.2	(11/2,13/2,15/2 <sup>-</sup> )	667.45	(11/2 <sup>-</sup> )	[D,E2]	0.006 5	
1211.4 4	2.0 3	1878.2	(11/2,13/2,15/2 <sup>-</sup> )	667.45	(11/2 <sup>-</sup> )	[D,E2]	0.006 5	
<sup>x</sup> 1250.4 4	1.3 2							
<sup>x</sup> 1253.9 4	1.9 3							
<sup>x</sup> 1272.8 2	4.4 7							
<sup>x</sup> 1314.4 4	1.7 3							
<sup>x</sup> 1369.8 4	1.2 2							Possible coincidence with 386.2γ and 480.3γ.
<sup>x</sup> 1491.9 4	0.7 1							
1507.2 4	1.8 3	2174.7	(11/2,13/2,15/2 <sup>-</sup> )	667.45	(11/2 <sup>-</sup> )	[D,E2]	0.0036 23	
<sup>x</sup> 1523.7 4	1.9 3							
<sup>x</sup> 1555.3 4	1.8 3							
<sup>x</sup> 1579.5 4	1.7 3							

<sup>†</sup> General uncertainty is quoted by 2009Sa09 as 0.2 keV for I<sub>γ</sub>>3 and 0.4 keV for weaker lines. Uncertainty of 1 keV is assigned by the evaluators when E<sub>γ</sub> quoted to nearest keV.

<sup>‡</sup> General uncertainty is quoted by 2009Sa09 as 15%.

# The γ ray mixed with a line from daughter activity.

@ From hyperfine spectrum in laser spectroscopy. Doublet, one component from the decay of the high-spin isomer and the other from the decay of the low-spin isomer of <sup>189</sup>Pb.



$\gamma(^{189}\text{Tl})$  (continued)

& From  $\gamma\gamma$  coin data.

<sup>a</sup> From BrIcc code (2008Ki07) with “Frozen Orbitals” approximation.

<sup>b</sup> For absolute intensity per 100 decays, multiply by 0.40 3.

<sup>c</sup> Multiply placed with intensity suitably divided.

<sup>d</sup> Placement of transition in the level scheme is uncertain.

<sup>x</sup>  $\gamma$  ray not placed in level scheme.

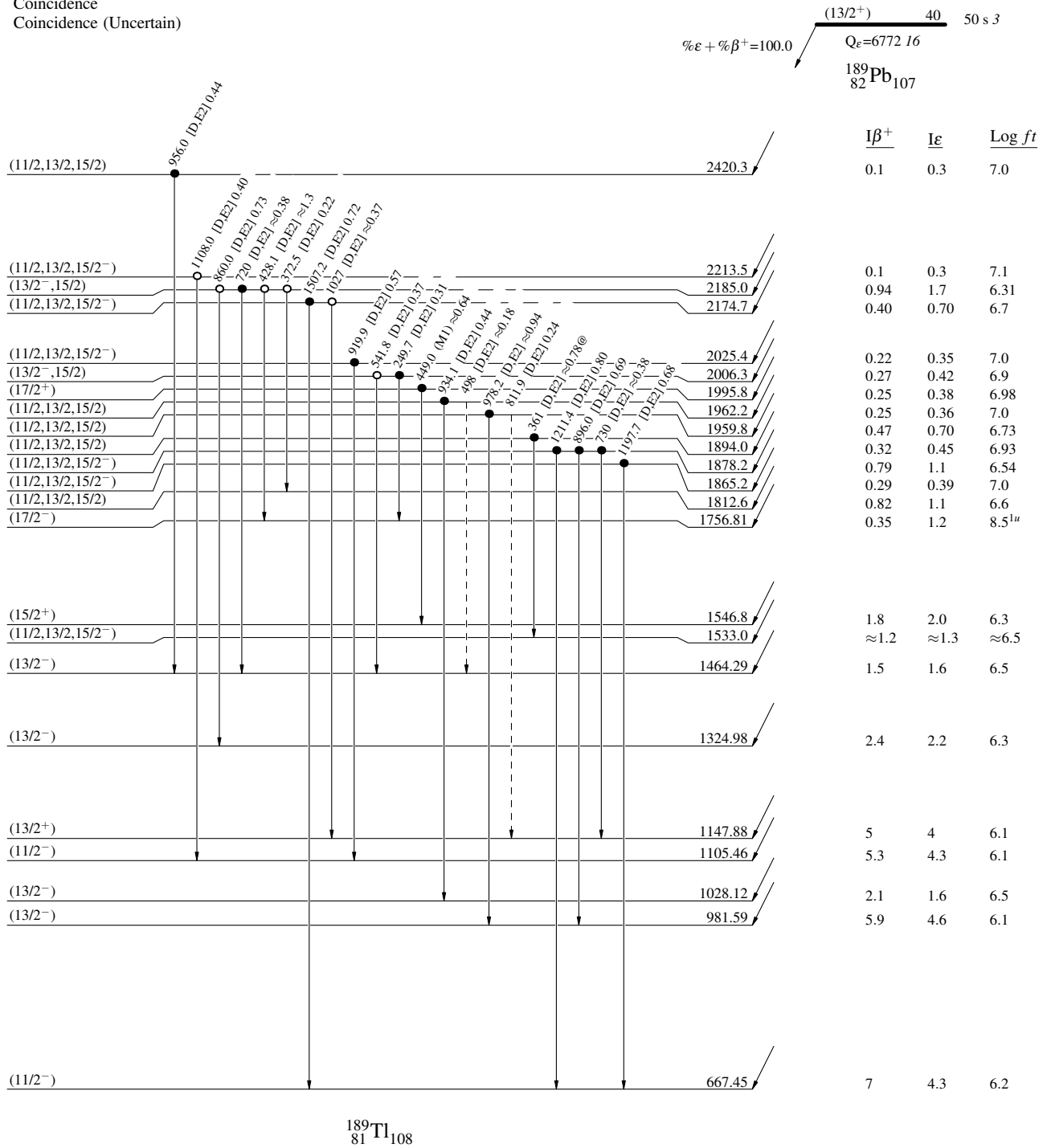
$^{189}\text{Pb}$   $\epsilon$  decay (50 s) 2009Sa09

Legend

- $I_\gamma < 2\% \times I_\gamma^{max}$
- $I_\gamma < 10\% \times I_\gamma^{max}$
- $I_\gamma > 10\% \times I_\gamma^{max}$
- - - -  $\gamma$  Decay (Uncertain)
- Coincidence
- Coincidence (Uncertain)

Decay Scheme

Intensities:  $I_{(\gamma+ce)}$  per 100 parent decays  
 @ Multiply placed: intensity suitably divided



$^{189}_{81}\text{Tl}_{108}$

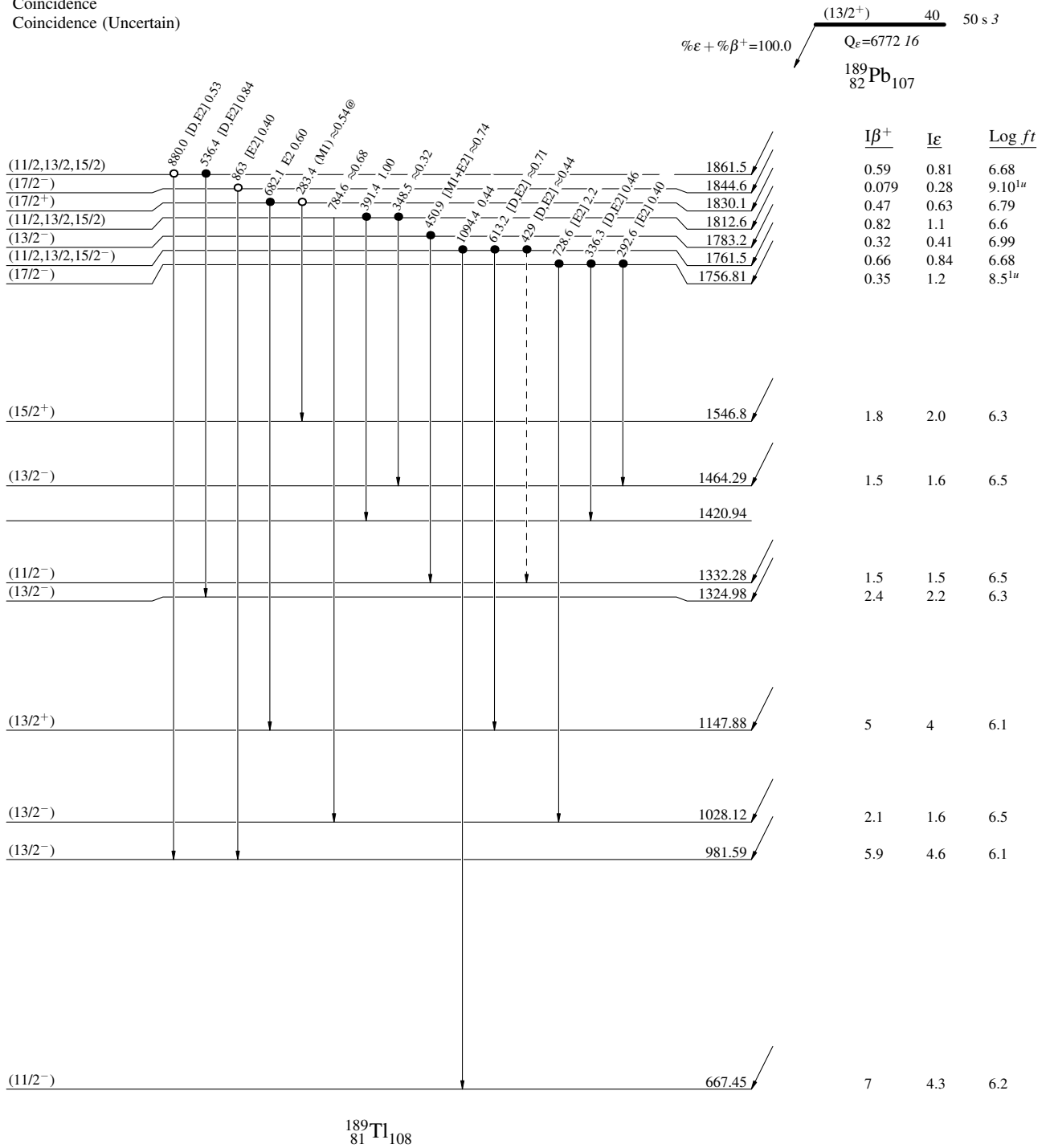
$^{189}\text{Pb}$   $\epsilon$  decay (50 s) 2009Sa09

Legend

- $I_\gamma < 2\% \times I_\gamma^{max}$
- $I_\gamma < 10\% \times I_\gamma^{max}$
- $I_\gamma > 10\% \times I_\gamma^{max}$
- - - - -  $\gamma$  Decay (Uncertain)
- Coincidence
- Coincidence (Uncertain)

Decay Scheme (continued)

Intensities:  $I_{(\gamma+ce)}$  per 100 parent decays  
 @ Multiplied: intensity suitably divided



$^{189}\text{Pb}$   $\epsilon$  decay (50 s) 2009Sa09

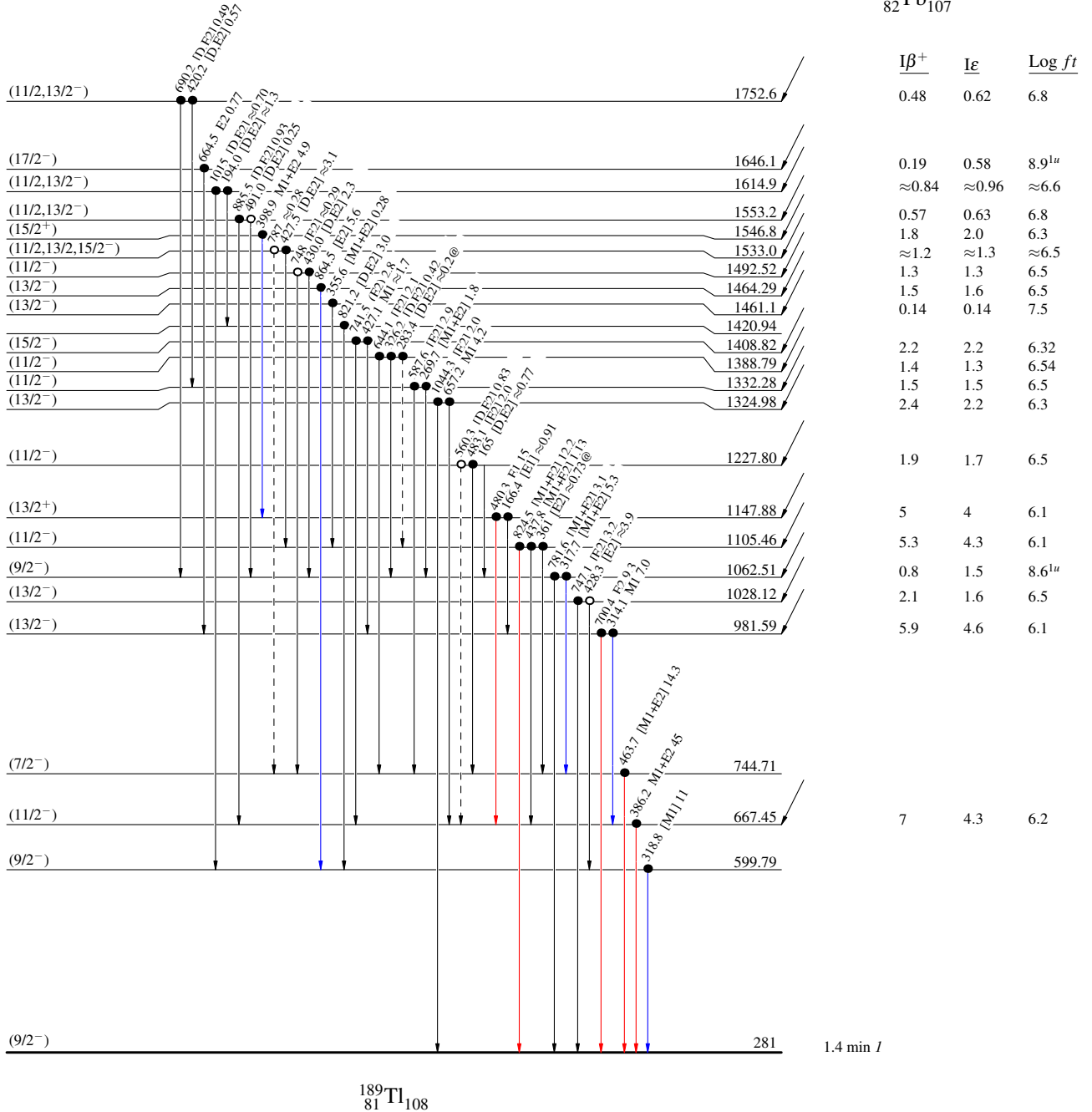
Legend

- $I_\gamma < 2\% \times I_\gamma^{\text{max}}$
- $I_\gamma < 10\% \times I_\gamma^{\text{max}}$
- $I_\gamma > 10\% \times I_\gamma^{\text{max}}$
- - - - -  $\gamma$  Decay (Uncertain)
- Coincidence
- Coincidence (Uncertain)

Decay Scheme (continued)

Intensities:  $I_{(\gamma+ce)}$  per 100 parent decays  
 @ Multiply placed: intensity suitably divided

$^{189}\text{Pb}_{107}$  (13/2<sup>+</sup>) 40 50 s 3  
 $Q_\epsilon = 6772.16$   
 $\% \epsilon + \% \beta^+ = 100.0$



$^{189}\text{Tl}_{108}$

1.4 min *t*

