^{159}Tb(^{48}Ca,4nγ) 2018Au01,2017Au05

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	F. G. Kondev	NDS 177, 509, 2021	4-Jul-2021

2018Au01,2017Au05: E(^{48}Ca)=198 MeV ^{48}Ca beam was produced from the K-130 cyclotron of the Accelerator Laboratory at the University of Jyvaskyla. Target was 360 μg/cm^2 self-supporting ^{159}Tb. Fusion-evaporation residues were separated using the He-filled recoil separator RITU and implanted into a double-sided silicon strip detector (DSSD) surrounded by a box array of silicon detectors of 28 Si PIN diodes in the GREAT spectrometer. Prompt γ rays were detected with the JUROGAM II array of 24 clover and 15 tapered Compton suppressed Ge detectors around the target position. A planar Ge detector was used to detect low-energy γ rays and x rays. Three clover Ge detectors around the DSSD chamber were used to detect higher-energy gamma rays. Measured Eγ, Iγ, $\gamma(\theta)$, E(x ray), I(x ray), Eα, $\gamma\gamma$- and (ce)γ-coin, recoil-gated γ singles, recoil-isomer decay tagged γ singles. Deduced high-spin levels, J^π, half-lives of isomers, K/(L+M+..) ratios, γ-ray multipolarities, configurations.

^{203}At Levels

E(level)†	J$^\pi$‡	T$_{1/2}$	Comments
0.0	9/2$^-$		
221.40 *20*	7/2$^-$		configuration: configuration=$\pi(f^{+1}_{7/2})$.
648.64 *15*	13/2$^-$		configuration: Dominant $\pi(h^{+1}_{9/2})\otimes 2^+$.
659.95 *16*	11/2$^-$		configuration: Dominant $\pi(h^{+1}_{9/2})\otimes 2^+$.
683.4 *3*	1/2$^+$	3.5 ms *6*	T$_{1/2}$: From recoil-ce(Δt) using events where ce are in coincidence with 462γ observed in the focal place and 178 and 442γ observed at the target position (2017Au05). configuration: $\pi(s^{+1}_{1/2})$.
861.3 *6*	3/2$^+$		configuration: $\pi(d^{+1}_{3/2})$.
871.81 *14*	13/2$^+$	2.8 ns *21*	T$_{1/2}$: Using 761γ-212γ(Δt) and the centroid-shift method (2018Au01). configuration: $\pi(i^{+1}_{13/2})$.
1017.8 *7*	5/2$^+$		configuration: $\pi(d^{+1}_{5/2})$.
1225.23 *21*	17/2$^-$		configuration: Dominant $\pi(h^{+1}_{9/2})\otimes 4^+$.
1303.6 *8*	7/2$^+$		configuration: $\pi(d^{+1}_{3/2})\otimes 2^+$.
1378.81 *19*	15/2$^+$		configuration: Dominant $\pi(i^{+1}_{13/2})\otimes 2^+$.
1503.8? *8*	(9/2$^+$)		configuration: $\pi(d^{+1}_{5/2})\otimes 2^+$.
1633.15 *19*	17/2$^+$		configuration: Dominant $\pi(i^{+1}_{13/2})\otimes 2^+$.
1636.3 *3*	21/2$^-$		configuration: Dominant $\pi(h^{+1}_{9/2})\otimes 6^+$.
1695.38 *19*	17/2$^+$		configuration: Dominant $\pi(h^{+1}_{9/2})\otimes\nu(i^{-1}_{13/2},p^{-1}_{3/2})$.
1870.0 *12*	11/2$^+$		configuration: $\pi(d_{3/2})^{+1}\otimes 4^+$.
1941.83 *20*	19/2$^+$		configuration: Dominant $\pi(h^{+1}_{9/2})\otimes\nu(i^{-1}_{13/2},p^{-1}_{3/2})$.
1964.3 *3*	23/2$^-$		configuration: Dominant $\pi(h^{+1}_{9/2})\otimes 6^+$.
1980.4? *3*	(21/2$^+$)		configuration: Dominant $\pi(h^{+1}_{9/2})\otimes\nu(i^{-1}_{13/2},p^{-1}_{3/2})$. E(level): since the ordering of the 64-39 γ cascade is not established, level is either at 1980 or 2006 keV.
1992.6? *9*	(23/2$^+$)		
2044.2 *3*	25/2$^+$	13.9 ns *14*	T$_{1/2}$: From 286γ-309γ(Δt) and the centroid-shift method (2018Au01). configuration: Dominant $\pi(h^{+1}_{9/2})\otimes\nu(i^{-1}_{13/2},f^{-1}_{5/2})$.
2072.0 *5*	21/2$^-$		
2098.5? *10*	(13/2$^+$)		configuration: Dominant $\pi(d^{+1}_{5/2})\otimes 4^+$.
2330.0 *3*	29/2$^+$	9.77 μs *21*	T$_{1/2}$: From recoil-γ(Δt) spectrum produced by summing recoil-366γ(Δt) and 577γ(Δt) time spectra in 2018Au01; Other (2018Au01): 9.84 μs *28* from recoil-γ(Δt) spectrum produced by summing recoil-286γ(Δt) and recoil-761γ(Δt) time spectra. configuration: Dominant $\pi(h^{+2}_{9/2},i^{+1}_{13/2})$.
2490.7 *6*			
2536.9? *9*	(25/2$^+$)		
2639.9 *8*	(25/2$^-$)		
2751.2? *10*			
2756.1 *7*			
2887.6 *8*			
2952.8 *8*			

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^{159}Tb(^{48}Ca,4nγ) 2018Au01,2017Au05 (continued)

^{203}At Levels (continued)

E(level)[†]	J$^{\pi}$[‡]	Comments
2989.2? *10*		
3013.3? *10*		
3071.4? *10*		
3174.9? *11*		
3250.2 *6*	33/2$^+$	configuration: Dominant $\pi(h^{+2}_{9/2},i^{+1}_{13/2})\otimes 2^+$.
3311.2 *8*		
3318.6? *11*		
3349.5 *11*	(29/2$^-$)	
3485.5?[#] *8*	(27/2$^+$)	
3547.9 *9*		
3616.2 *7*		
3619.3?[#] *9*	(29/2$^+$)	
3768.5 *10*		
3770.4 *8*	37/2$^+$	configuration: Dominant $\pi(h^{+2}_{9/2},i^{+1}_{13/2})\otimes 4^+$.
3772.8 *12*		
3842.7?[#] *10*	(31/2$^+$)	
3947.3? *8*		
4102.1?[#] *10*	(33/2$^+$)	
4385.4?[#] *11*	(35/2$^+$)	
4638.8?[#] *12*	(37/2$^+$)	
4817.6?[#] *13*	(39/2$^+$)	
5011.2?[#] *13*	(41/2$^+$)	
5332.9?[#] *15*	(43/2$^+$)	
5713.9?[#] *16*	(45/2$^+$)	

[†] From a least-squares fit to Eγ.
[‡] From 2017Au05 and 2018Au01.
[#] Band(A): Dipole band. Configuration=$\pi(i^{+1}_{13/2})\otimes\nu(i^{-2}_{13/2})$ below the band crossing and $\pi(h^{+2}_{9/2}i^{+1}_{13/2})\otimes\nu(i^{-2}_{13/2})$ above the band crossing.

$\gamma(^{203}$At)

E$_\gamma$[†]	I$_\gamma$[†]	E$_i$(level)	J$_i^\pi$	E$_f$	J$_f^\pi$	Mult.[‡]	Comments
(12.2 *10*)		1992.6?	(23/2$^+$)	1980.4?	(21/2$^+$)	[M1]	E$_\gamma$: From level energy difference.
38.5[#] *2*		1980.4?	(21/2$^+$)	1941.83	19/2$^+$	M1	Mult.: From intensity balance.
(50.6 *12*)		1992.6?	(23/2$^+$)	1941.83	19/2$^+$	[E2]	E$_\gamma$: From parallel γ-ray cascades depopulating the 3485.5-keV level: (1155.5 keV *8* + 285.8 keV *2* + 63.5 keV *3* + 38.5 keV *2*) − (948.5 keV *7* + 544.2 keV *5*).
63.5[#] *3*	2.5 *8*	2044.2	25/2$^+$	1980.4?	(21/2$^+$)	E2	I$_\gamma$: From I(γ+ce)=160 *50* (2018Au01) and α. Mult.: From intensity balance.
(80.0 *3*)	6.8 *17*	2044.2	25/2$^+$	1964.3	23/2$^-$	(E1)	E$_\gamma$: Derived from 285.8 keV *2* and 365.8 keV *2* γ-ray energies depopulating the 2330 keV isomer. I$_\gamma$: From I(γ+ce)=8 *2* (2018Au01) and α. Mult.: from intensity balance.
[x]101.7 *4*	1.9[b] *2*						
[x]110.1 *4*	2.2[b] *2*						A$_2$<0
[x]127.8 *4*	2.1[b] *2*						

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^{159}Tb(^{48}Ca,4nγ) 2018Au01,2017Au05 (continued)

$\gamma(^{203}At)$ (continued)

E_γ †	I_γ †	E_i(level)	J_i^π	E_f	J_f^π	Mult. ‡	Comments
133.8 *4*	5.1[a] *10*	3619.3?	(29/2$^+$)	3485.5?	(27/2$^+$)		A_2<0
156.6[f] *5*	15.7[f] *11*	1017.8	5/2$^+$	861.3	3/2$^+$	(M1+E2)	
177.9[f] *5*	100[f] *5*	861.3	3/2$^+$	683.4	1/2$^+$	(M1+E2)	
178.8 *5*	3.3[a] *9*	4817.6?	(39/2$^+$)	4638.8?	(37/2$^+$)		(A_2<0).
193.6 *4*	3.5[a] *6*	5011.2?	(41/2$^+$)	4817.6?	(39/2$^+$)		(A_2<0).
200.1[fg] *5*	10.8[f] *9*	1503.8?	(9/2$^+$)	1303.6	7/2$^+$		A_2(<0) (2017Au05).
211.9 *2*	47.6[@] *15*	871.81	13/2$^+$	659.95	11/2$^-$		
[x]213.2 *4*	2.7[b] *2*						
214.3[g] *4*	10.8[d] *10*	2751.2?		2536.9?	(25/2$^+$)		
221.4 *2*		221.40	7/2$^-$	0.0	9/2$^-$	M1+E2	E_γ: From 2017Au05. Mult.: K/LM=1.67 *10* (2017Au05).
223.2 *2*	7.5 *5*	871.81	13/2$^+$	648.64	13/2$^-$		I_γ: intensity from the 649-keV gated $\gamma\gamma$-coin data, and normalized to the intensity of the 577-keV transition in the singles spectrum.
223.4 *4*	13[a] *3*	3842.7?	(31/2$^+$)	3619.3?	(29/2$^+$)		A_2<0
[x]228.9 *4*	2.9[b] *2*						A_2>0
246.5 *2*	10.1[&] *6*	1941.83	19/2$^+$	1695.38	17/2$^+$		A_2<0
253.4 *4*	10[a] *2*	4638.8?	(37/2$^+$)	4385.4?	(35/2$^+$)		A_2<0
254.3 *2*	15.4[&] *8*	1633.15	17/2$^+$	1378.81	15/2$^+$		A_2<0
259.4 *4*	16[a] *3*	4102.1?	(33/2$^+$)	3842.7?	(31/2$^+$)		A_2<0
265.4 *5*	1.6[c] *6*	2756.1		2490.7			A_2>0
283.3 *4*	13[a] *2*	4385.4?	(35/2$^+$)	4102.1?	(33/2$^+$)		A_2<0
285.8 *2*	100 *10*	2330.0	29/2$^+$	2044.2	25/2$^+$	E2	I_γ: From I(γ+ce)=115 *12* (2018Au01) and α. Mult.: from measured K/(L+M+..)=0.99 *22* (2018Au01).
[x]287.3 *4*	2.2[b] *2*						A_2<0
308.7 *2*	36.3[@] *12*	1941.83	19/2$^+$	1633.15	17/2$^+$	(M1)	A_2<0 Mult.: measured K/LM+ (2018Au01) consistent with M1 or E1, however, angular distribution data and previous measurements support M1.
316.5 *2*	8.5[@] *6*	1695.38	17/2$^+$	1378.81	15/2$^+$		A_2<0
[x]321.7 *5*	4.1[c] *8*						A_2>0
321.7 *6*	4.0[a] *11*	5332.9?	(43/2$^+$)	5011.2?	(41/2$^+$)		A_2<0
328.1 *2*	15.2[@] *10*	1964.3	23/2$^-$	1636.3	21/2$^-$		A_2<0
331.1[g] *4*	8.8[b] *6*	3947.3?		3616.2			A_2<0
365.8 *2*	82 *8*	2330.0	29/2$^+$	1964.3	23/2$^-$	E3	I_γ: From I(γ+ce)=110 *11* (2018Au01) and α. Mult.: from measured K/(L+M+..)=0.55 *8*(2018Au01).
365.8 *4*	9.3[b] *6*	3616.2		3250.2	33/2$^+$		A_2>0
381.0 *6*	4.4[a] *13*	5713.9?	(45/2$^+$)	5332.9?	(43/2$^+$)		A_2<0
411.2 *2*	41.8[@] *14*	1636.3	21/2$^-$	1225.23	17/2$^-$		A_2>0
423.3[g] *6*	4.6[c] *14*	3772.8		3349.5	(29/2$^-$)		
423.7[g] *5*	5.4[d] *7*	3174.9?		2751.2?			A_2<0
[x]429.0 *6*	2.1[d] *5*						
[x]430.1 *13*	4.3[c] *24*						
435.5 *6*	9.5[c] *24*	2072.0	21/2$^-$	1636.3	21/2$^-$		A_2>0
442.2[f] *6*	82[f] *4*	1303.6	7/2$^+$	861.3	3/2$^+$	(E2)	Mult.: A_2>0 (2017Au05).
452.3[g] *5*	8.5[d] *8*	2989.2?		2536.9?	(25/2$^+$)		A_2<0
462.0 *2*		683.4	1/2$^+$	221.40	7/2$^-$	E3	E_γ: From 2017Au05. Mult.: K/LM=0.85 *8* (2017Au05).

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^{159}Tb(^{48}Ca,4nγ) 2018Au01,2017Au05 (continued)

$\gamma(^{203}At)$ (continued)

E_γ †	I_γ †	E_i(level)	J_i^π	E_f	J_f^π	Comments
x467.8 8	1.4c 8					
476.4g 5	5.6d 7	3013.3?		2536.9?	(25/2$^+$)	
486.1fg 6	25f 2	1503.8?	(9/2$^+$)	1017.8	5/2$^+$	A_2>0 (2017Au05).
x506.8 5	3.8b 4					A_2<0
506.9 2	44& 3	1378.81	15/2$^+$	871.81	13/2$^+$	A_2<0
520.2 5	5.9b 4	3770.4	37/2$^+$	3250.2	33/2$^+$	A_2>0
x526.9 5	1.7b 3					A_2<0
534.5g 5	5.3d 8	3071.4?		2536.9?	(25/2$^+$)	A_2>0
544.2g 5	26.4e 9	2536.9?	(25/2$^+$)	1992.6?	(23/2$^+$)	A_2<0
566.4f 9	20f 2	1870.0	11/2$^+$	1303.6	7/2$^+$	A_2>0 (2017Au05).
567.4g 5	7.9d 10	3318.6?		2751.2?		A_2>0
567.9g 6	8.5c 15	2639.9	(25/2$^-$)	2072.0	21/2$^-$	A_2>0
576.5 2	79@ 3	1225.23	17/2$^-$	648.64	13/2$^-$	A_2>0
594.7fg 6	16.2f 13	2098.5?	(13/2$^+$)	1503.8?	(9/2$^+$)	
648.6 2	100@ 4	648.64	13/2$^-$	0.0	9/2$^-$	A_2>0
660.0 2	56@ 3	659.95	11/2$^-$	0.0	9/2$^-$	
684.1g 7	7.6c 15	2756.1		2072.0	21/2$^-$	A_2>0
709.6g 7	5.5c 15	3349.5	(29/2$^-$)	2639.9	(25/2$^-$)	A_2>0
716.4 2	10.8@ 4	1941.83	19/2$^+$	1225.23	17/2$^-$	
761.4 2	32.2@ 10	1633.15	17/2$^+$	871.81	13/2$^+$	A_2>0
823.7 2	10.8@ 4	1695.38	17/2$^+$	871.81	13/2$^+$	A_2>0
847.0 7	13c 2	2072.0	21/2$^-$	1225.23	17/2$^-$	A_2>0
854.3 7	11c 2	2490.7		1636.3	21/2$^-$	A_2>0
871.8 2	15.9@ 5	871.81	13/2$^+$	0.0	9/2$^-$	
919.7 7	20.7b 11	3250.2	33/2$^+$	2330.0	29/2$^+$	A_2>0
923.3 7	2.5c 8	2887.6		1964.3	23/2$^-$	
948.5g 7	8.6e 3	3485.5?	(27/2$^+$)	2536.9?	(25/2$^+$)	A_2<0
981.2g 7	4.7b 3	3311.2		2330.0	29/2$^+$	A_2<0
988.5 7	7.8c 14	2952.8		1964.3	23/2$^-$	A_2<0
1155.5g 8	2.24e 13	3485.5?	(27/2$^+$)	2330.0	29/2$^+$	A_2<0
1217.8g 8	1.5b 2	3547.9		2330.0	29/2$^+$	
1286.8 8	8.2b 5	3616.2		2330.0	29/2$^+$	
1438.4g 9	2.9b 3	3768.5		2330.0	29/2$^+$	(A_2<0).

† From 2018Au01, unless otherwise stated.
‡ From CE and angular distribution data in 2018Au01, unless otherwise stated.
# Ordering of the 64- and 39-keV transitions is not firmly established.
@ Intensities are normalized to Iγ=100 *4* for the 648.6γ, depopulating the 649 keV level, and obtained from recoil-gated γ-ray data (2018Au01).
& Intensity from the 660-keV gated $\gamma\gamma$-coin data, and normalized to the intensity of the 761-keV transition in singles spectrum (2018Au01).
a Intensities are normalized to Iγ=16 *3* for the 259.4γ in the cascade, and obtained from $\gamma\gamma$-coin data gated with 949-keV transition depopulating the 3486-keV level (2018Au01).
b Intensities are normalized to Iγ=20.7 *11* for the 919.7γ depopulating the 3250-keV level, and obtained from recoil-isomer-decay tagged, singles data.

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^{159}Tb(^{48}Ca,4nγ) 2018Au01,2017Au05 (continued)

$\gamma(^{203}At)$ (continued)

[c] Intensities are normalized to Iγ=41.8 *14* for the 411.2γ depopulating the 1636-keV level in the recoil-gated singles spectrum, and obtained from $\gamma\gamma\gamma$-coin data produced by gating on the 649- and 577-keV transition depopulating the 649-keV and 1225-keV levels, respectively.
[d] Intensities are normalized to Iγ=10.8 *10* for the 214.3γ depopulating the 2751-keV level, and obtained from $\gamma\gamma$-coin data produced by gating on the 544-keV transition depopulating the 2537-keV level.
[e] From recoil gated singles spectrum.
[f] From 2017Au05.
[g] Placement of transition in the level scheme is uncertain.
[x] γ ray not placed in level scheme.

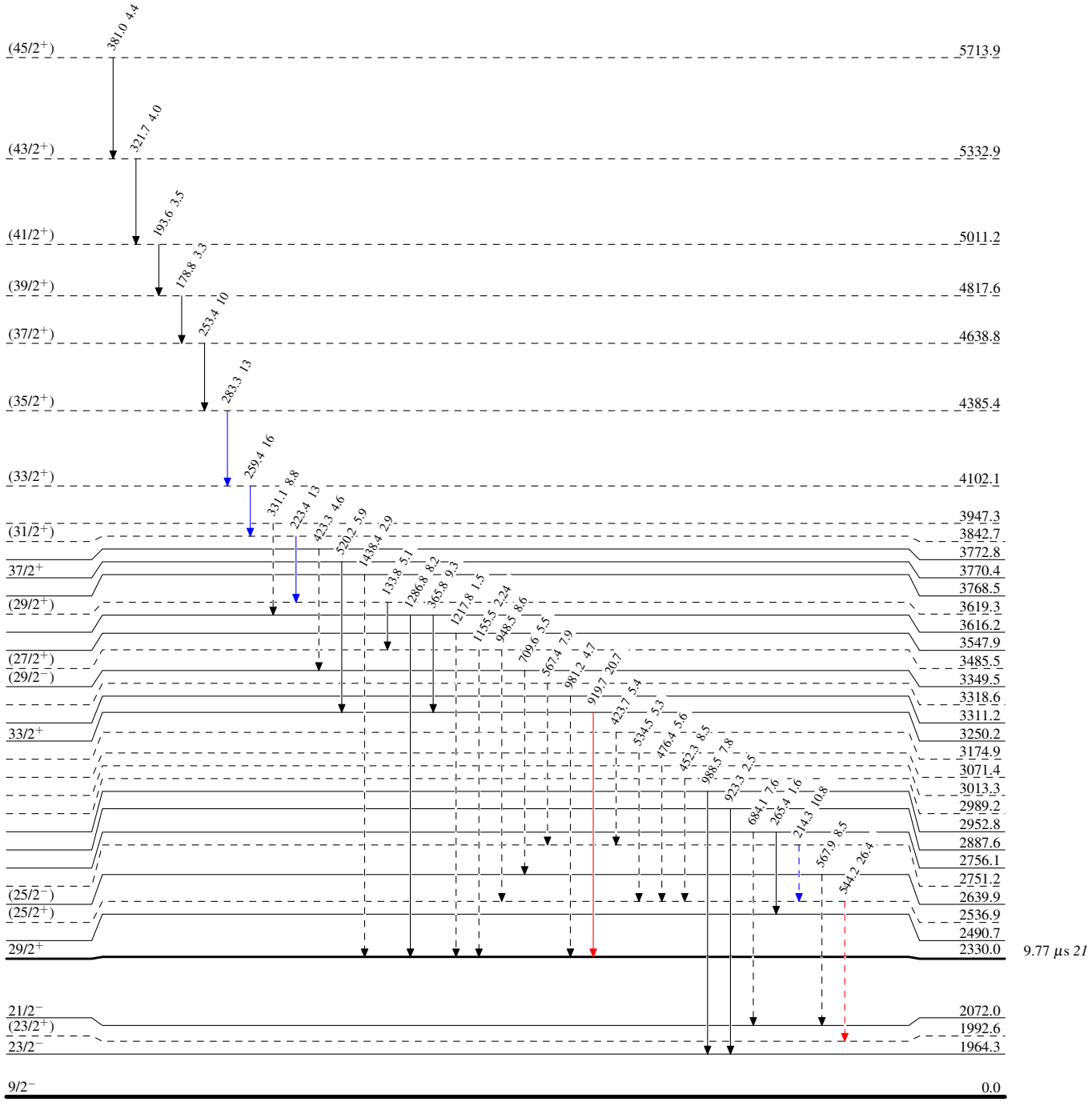
^{159}Tb(^{48}Ca,4nγ) 2018Au01,2017Au05

Level Scheme

Intensities: Relative I_γ

Legend

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



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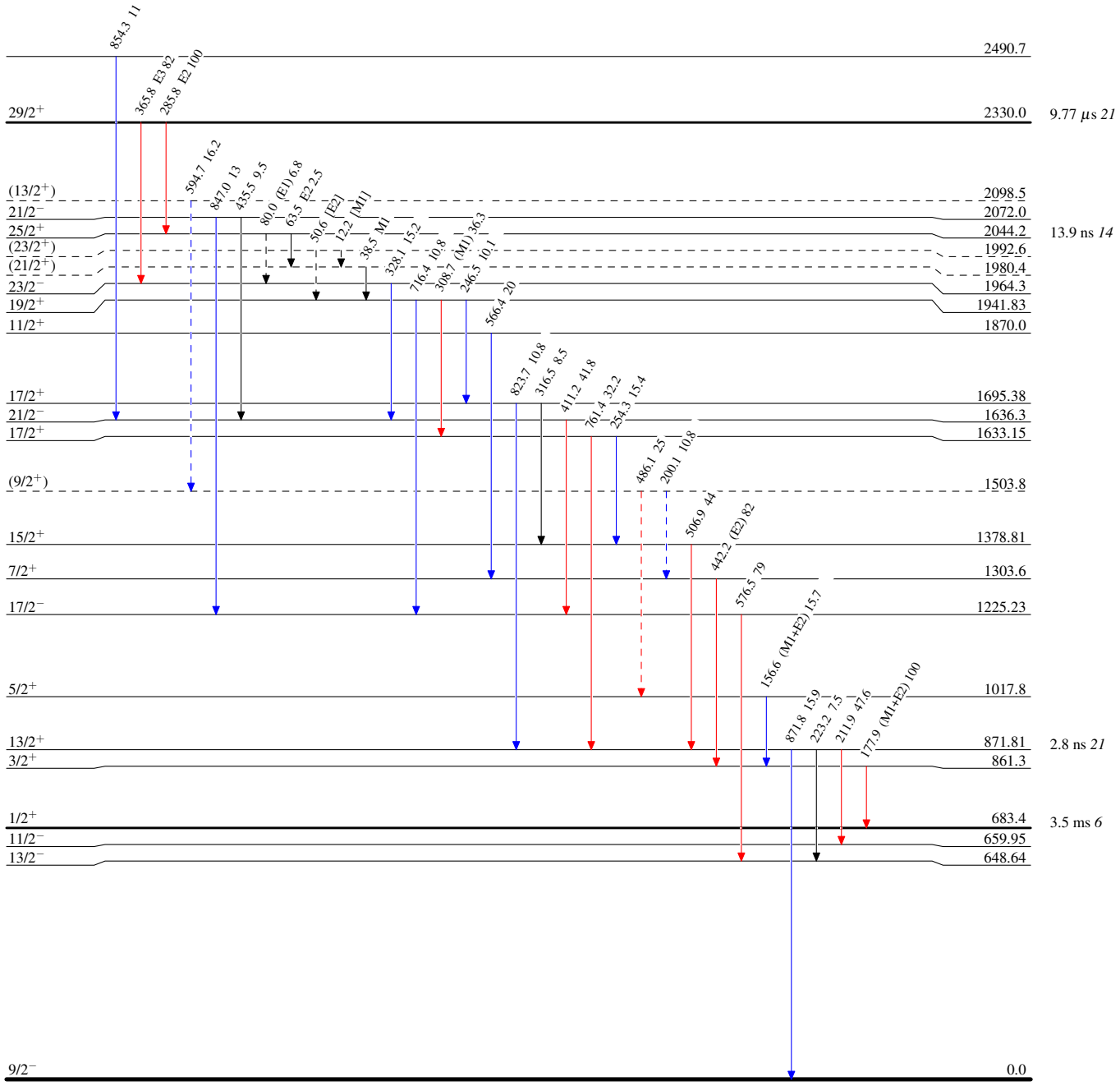
$^{159}Tb(^{48}Ca,4n\gamma)$ 2018Au01,2017Au05

Level Scheme (continued)

Intensities: Relative I_γ

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



$^{203}_{85}At_{118}$

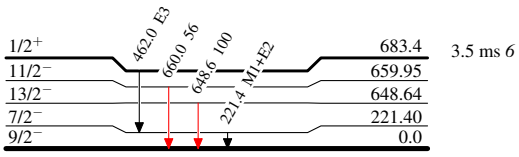
^{159}Tb(^{48}Ca,4nγ) 2018Au01,2017Au05

Level Scheme (continued)

Intensities: Relative I_γ

Legend

$I_\gamma < 2\% \times I_\gamma^{max}$
$I_\gamma < 10\% \times I_\gamma^{max}$
$I_\gamma > 10\% \times I_\gamma^{max}$



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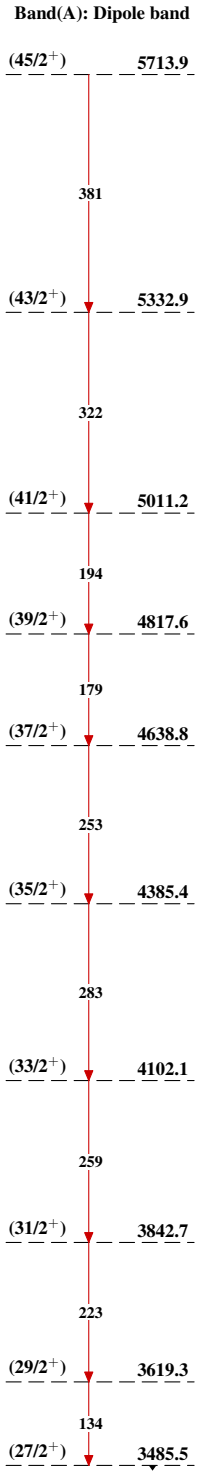

$^{203}_{85}At_{118}$