^{156}Tm ε decay (83.8 s) 1975Ag02,1980Zo02

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	C. W. Reich	NDS 113, 2537 (2012)	1-Mar-2012

Parent: ^{156}Tm: E=0; J$^\pi$=2$^-$; $T_{1/2}$=83.8 s *18*; Q(ε)=7373 *28*; %ε+%β^+ decay=100.0

^{156}Tm-J$^\pi$: Additional information 1.

^{156}Tm-$T_{1/2}$: Additional information 2.

^{156}Tm-Q(ε): Additional information 3.

Additional information 4.

2003NaZX, using total-absorption γ spectroscopy, measured the Gamow-Teller strength distribution in the ^{156}Tm decay to ^{156}Er. This information is presented in graphical form only.

1975Ag02: ^{156}Tm source material produced by the (p,xn) reaction (E(p)=157 MeV) on natural Er, followed by isotope separation. Measured γ singles, $\gamma\gamma$ coincidences using two Ge(Li) detectors of volumes 30 cm^3 and 40 cm^3. ce spectra measured using a 150 mm^2×3 mm Si(Li) detector. Report Eγ, Iγ, $\gamma\gamma$, ce(K).

1980Zo02: ^{156}Tm produced via the ^{148}Sm(^{14}N,6n) reaction on isotope-separated targets. E(^{14}N)=109,113,119 MeV. Reaction products collected and transported to counting station using a He-jet system. γ spectra studied using 30 cm^3 and 55 cm^3 Ge(Li) detectors and a 1 cm^3 planar Ge(Li) detector. ce spectra measured using a 2 cm^2×3 mm Si(Li) detector. Measured γ singles, $\gamma\gamma$ coincidences and α(K)exp values.

^{156}Er Levels

The two published decay schemes differ substantially in that several levels are reported in only one scheme: there are 5 levels reported by 1975Ag02 only, 9 levels by 1980Zo02 only, and 11 levels reported by both. There is, however, only 1 γ that is differently placed.

The coincidences indicated on the level scheme drawing are from 1975Ag02.

No ε+β^+ intensities or log *ft* values are given on the level scheme drawing since the values deduced from the γ-intensity balances are clearly not meaningful. For example, they give log f^1t ≈8.1 for some unique first-forbidden transitions; and the ε+β^+ intensities are comparable for ordinary and first-forbidden, unique transitions. These computed ε+β^+ intensities are most probably too large because, with a decay energy above 7 MeV, there are many higher-lying levels that are not observed, whose deexciting γ's would influence the deduced intensity balance for a number of levels.

E(level)[†]	J$^\pi$[‡]	$T_{1/2}$	Comments
0[&]	0$^+$	19.5 min *10*	$T_{1/2}$: From the Adopted Levels data set.
344.51[&] *6*	2$^+$		
797.38[&] *8*	4$^+$		
930.35[a] *9*	0$^+$		E(level): Level is unresolved from 2$^+$ level.
930.46[b] *7*	2$^+$		E(level): Level is unresolved from 0$^+$ level.
1220.80[a] *9*	2$^+$		
1243.02[#] *21*			J$^\pi$: Assigned as the 3$^+$ member of the γ-vibrational band by 1980Zo02, but this band member is placed elsewhere (at 1350 keV) in the level scheme in the high-spin study of 2011Re06. γ's to 2$^+$ levels indicate J$^\pi$ values from 0$^+$ to 4$^+$.
1303.52[c] *11*	3$^-$		
1304.8?[@]			
1340.88[@&] *17*	6$^+$		
1351.31[b] *9*	3$^+$		J$^\pi$: From 1975Ag02 and the high-spin study of 2011Re06. Assigned as 4$^+$ by 1980Zo02.
1381.9?[@]			
1406.1 *1*	4$^+$		J$^\pi$: From the high-spin study of 2011Re06. Assigned as the 2$^+$ member of an even-spin positive-parity band by 1980Zo02.
1517.89[#c] *18*	(1$^-$)		
1546.72[a] *11*	4$^+$		

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^{156}Tm ε decay (83.8 s) 1975Ag02,1980Zo02 (continued)

^{156}Er Levels (continued)

E(level)[†]	J^{π}[‡]	Comments
1570.74[d] *15*	2^+	
1611.68[#c] *22*	5^-	
1630.50[e] *13*	2^-	
1663.40[#b] *16*		J^{π}: Assigned as the 5^+ member of the γ-vibrational band by 1980Zo02, but this band member is placed elsewhere (at 1834 keV) in the level scheme in the high-spin study of 2011Re06. γ to 4^+ level indicates J^{π} values from 2^+ to 6^+.
1710.52[#] *21*		J^{π}: γ to 2^+ indicates J^{π} from 0^+ through 4^+. ce data suggest an E0 component in this transition (1975Ag02).
1814.48[#e] *22*	4^-	
1836.1?[@]		This level may be the same as the 1834 level reported in the high-spin study of 2011Re06.
1860.8[#d] *6*	(3^+)	
1909.54[#] *19*	2^+,3,4^+	J^{π}: Assigned as the 3^- member of some octupole-related states by 1980Zo02, but that 3^- level is placed at 1303 in the high-spin study of 2009Pa17.
2014.60 *18*		
2169.8[#] *3*		
2249.81[@] *22*		

[†] From least-squares fit to γ energies.
[‡] From ^{156}Er Adopted Levels.
[#] Level from 1980Zo02 only.
[@] Level from 1975Ag02 only.
[&] Band(A): $K^{\pi}=0^+$ ground-state band.
[a] Band(B): First excited $K^{\pi}=0^+$ band.
[b] Band(C): $K^{\pi}=2^+$ γ-vibrational band.
[c] Band(D): $K^{\pi}=0^-$ octupole band. From the systematics of octupole states in the neighboring N=88 nuclides, 1980Zo02 infer that these states form an octupole band. Note, however, that the configurational make-up of this band is thought to change at higher spin values (see, e.g., 1980Zo02 in (HI,xnγ) and the comment on the associated band in the Adopted Levels data set).
[d] Band(E): $K^{\pi}=2^+$ band. Possible two-phonon $\beta\gamma$-vibration.
[e] Band(F): Probable octupole-related states. From consideration of the systematics of octupole excitations in the N=88 nuclides in this mass region, as well as from results of a quadrupole-octupole coupling calculation, 1980Zo02 infer that these levels have octupole character.

γ(^{156}Er)

Iγ normalization: calculated to give 100% feeding to the ground state for this decay scheme. The listed uncertainty includes only the contributions from the intensities in this scheme. However, there is probably a significant systematic error to be considered due to incompleteness of the decay scheme. With a decay energy of over 7 MeV, there will be ε decay to many levels above the highest one reported here. This incompleteness is supported by the unreasonable log *ft* values computed from the γ-intensity balances. This problem is somewhat mitigated by the fact that most of the decays will pass through the 344 keV 2^+ level, rather than bypassing it to the ground state. A second significant error may come from the direct $\varepsilon+\beta^+$ feeding of the ground state. From systematics (1973Ra10) one expects log $f^1t\geq8.5$ or an intensity $\leq4\%$ for this branch.

γ's that are only tentatively assigned to this decay by 1975Ag02, not reported by 1980Zo02, and not placed in the decay scheme are not included in this table. These γ's are at 763.9, 974.9, 1415.2, 1545.5, and 1573.4 keV.

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^{156}Tm ε decay (83.8 s) 1975Ag02,1980Zo02 (continued)

γ(^{156}Er) (continued)

E_γ[†]	I_γ[‡e]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[#]	α[f]	Comments
290.68 *14*	0.44 *7*	1220.80	2^+	930.35	0^+	[E2]	0.0760	α(K)=0.0553 *8*; α(L)=0.01605 *23*; α(M)=0.00376 *6*; α(N+..)=0.000973 *14* α(N)=0.000860 *13*; α(O)=0.0001102 *16*; α(P)=2.83×10^{-6} *4*
312.4[bh] *4*	0.3 *1*	1243.02		930.46	2^+			
326.00 *10*	0.28 *4*	1546.72	4^+	1220.80	2^+	[E2]	0.0538	α(K)=0.0401 *6*; α(L)=0.01059 *15*; α(M)=0.00247 *4*; α(N+..)=0.000641 *9* α(N)=0.000565 *8*; α(O)=7.33×10^{-5} *11*; α(P)=2.10×10^{-6} *3*
344.55 *7*	100 *3*	344.51	2^+	0	0^+	E2	0.0457	α(K)=0.0345 *5*; α(L)=0.00871 *13*; α(M)=0.00202 *3*; α(N+..)=0.000527 *8* α(N)=0.000464 *7*; α(O)=6.05×10^{-5} *9*; α(P)=1.82×10^{-6} *3* I_γ: Listed uncertainty is assumed by the evaluator. Mult.: From γ(θ) in (HI,xnγ) (1973Be43), mult=Q. RUL eliminates M2.
350.0[@] *5*	0.20 *8*	1570.74	2^+	1220.80	2^+	[M1,E2]	0.066 *23*	α(K)=0.054 *21*; α(L)=0.0096 *14*; α(M)=0.0022 *3*; α(N+..)=0.00057 *8* α(N)=0.00050 *7*; α(O)=6.9×10^{-5} *13*; α(P)=3.1×10^{-6} *14*
[x]406.9[@] *3*	0.11 *4*							
420.78 *9*	1.8 *3*	1351.31	3^+	930.46	2^+	E2	0.0260	α(K)=0.0202 *3*; α(L)=0.00445 *7*; α(M)=0.001025 *15*; α(N+..)=0.000268 *4* α(N)=0.000236 *4*; α(O)=3.14×10^{-5} *5*; α(P)=1.100×10^{-6} *16* Additional information 10.
423.40 *17*	0.51 *8*	1220.80	2^+	797.38	4^+	[E2]	0.0256	α(K)=0.0199 *3*; α(L)=0.00437 *7*; α(M)=0.001004 *15*; α(N+..)=0.000263 *4* α(N)=0.000231 *4*; α(O)=3.08×10^{-5} *5*; α(P)=1.083×10^{-6} *16*
[x]429.90[@] *15*	0.15 *4*							
451.5[h] *4*	<0.15	1381.9?		930.35	0^+			
452.85 *7*	20.1 *10*	797.38	4^+	344.51	2^+	E2	0.0213	α(K)=0.01677 *24*; α(L)=0.00353 *5*; α(M)=0.000808 *12*; α(N+..)=0.000212 *3* α(N)=0.000186 *3*; α(O)=2.50×10^{-5} *4*; α(P)=9.19×10^{-7} *13* Additional information 5.
475.63 *11*	1.06 *9*	1406.1	4^+	930.46	2^+			
484.85[ch] *15*	0.53 *7*	1836.1?		1351.31	3^+			
507.4[h] *4*	<0.2	1304.8?		797.38	4^+			
543.50[@] *15*	0.32 *6*	1340.88	6^+	797.38	4^+	E2	0.01331	α(K)=0.01069 *15*; α(L)=0.00203 *3*; α(M)=0.000463 *7*; α(N+..)=0.0001219 *18* α(N)=0.0001068 *15*; α(O)=1.456×10^{-5} *21*; α(P)=5.96×10^{-7} *9* Mult.: From α(K)exp=0.0110 *17*, in (HI,xnγ) (1974Go14).
553.98 *13*	1.04 *9*	1351.31	3^+	797.38	4^+			
557.9[b] *4*	0.4 *2*	1909.54	2^+,3,4^+	1351.31	3^+			

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^{156}Tm ε decay (83.8 s) 1975Ag02,1980Zo02 (continued)

γ(^{156}Er) (continued)

Eγ[†]	Iγ[‡e]	Ei(level)	J^π_i	Ef	J^π_f	Mult.[#]	α[f]	Comments
585.93[g] *8*	<17.0[g]	930.35	0+	344.51	2+	[E2]	0.01106	α(K)=0.00895 *13*; α(L)=0.001643 *23*; α(M)=0.000372 *6*; α(N+..)=9.83×10^{-5} *14* α(N)=8.60×10^{-5} *12*; α(O)=1.180×10^{-5} *17*; α(P)=5.01×10^{-7} *7* Iγ: Only a minor part of this Iγ is from this level (1975Ag02).
585.93[g] *8*	17.0[g] *9*	930.46	2+	344.51	2+	E2	0.01106	α(K)=0.00895 *13*; α(L)=0.001643 *23*; α(M)=0.000372 *6*; α(N+..)=9.83×10^{-5} *14* α(N)=8.60×10^{-5} *12*; α(O)=1.180×10^{-5} *17*; α(P)=5.01×10^{-7} *7* Iγ: The major part of this Iγ is from this level (1975Ag02). Additional information 7.
608.84 *13*	1.70 *14*	1406.1	4+	797.38	4+			
640.44 *18*	0.58 *9*	1570.74	2+	930.46	2+	E0+M1+E2	0.11 *3*	α(K)exp=0.088 *26* α: Computed from α(K)exp and theoretical α/α(K) ratios. α(K)exp: From 1975Ag02.
699.9 *2*	1.47 *17*	1630.50	2−	930.46	2+	[E1]	0.00274	α(K)=0.00233 *4*; α(L)=0.000320 *5*; α(M)=7.01×10^{-5} *10*; α(N+..)=1.87×10^{-5} *3* α(N)=1.628×10^{-5} *23*; α(O)=2.34×10^{-6} *4*; α(P)=1.264×10^{-7} *18*
749.0 *2*	0.61 *14*	1546.72	4+	797.38	4+	E0+M1+E2	0.044 *19*	α(K)exp=0.037 *16* α: Computed from α(K)exp and theoretical α/α(K) ratios. α(K)exp: From 1975Ag02.
773.0[c] *3*	0.23 *6*	1570.74	2+	797.38	4+	[E2]	0.00582	α(K)=0.00480 *7*; α(L)=0.000791 *11*; α(M)=0.0001773 *25*; α(N+..)=4.71×10^{-5} *7* α(N)=4.11×10^{-5} *6*; α(O)=5.75×10^{-6} *8*; α(P)=2.72×10^{-7} *4*
814.3[a] *2*	0.68 *15*	1611.68	5−	797.38	4+	[E1]	0.00202	α(K)=0.001723 *25*; α(L)=0.000235 *4*; α(M)=5.15×10^{-5} *8*; α(N+..)=1.378×10^{-5} *20* α(N)=1.196×10^{-5} *17*; α(O)=1.720×10^{-6} *24*; α(P)=9.40×10^{-8} *14*
[x]826.0[@] *4*	0.19 *8*							
866.02[a] *14*	0.53 *7*	1663.40		797.38	4+			
876.20 *14*	2.7 *2*	1220.80	2+	344.51	2+	E0+E2(+M1)	0.043 *12*	α(K)exp=0.036 *10* α: Computed from α(K)exp and theoretical α/α(K) ratios. α(K)exp: Average of 0.042 *11* (1975Ag02) and 0.032 *8* (1980Zo02).
898.5[gd] *2*	1.50[g] *14*	1243.02		344.51	2+			
898.5[gd] *2*	1.50[g] *14*	2249.81		1351.31	3+			
930		930.35	0+	0	0+	E0		Iγ: The ce lines of this transition and those of the 930.46 γ from the 930-keV, 2+ level form a doublet structure. However, since this is an E0

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^{156}Tm ε decay (83.8 s) 1975Ag02,1980Zo02 (continued)

γ(^{156}Er) (continued)

E_γ[†]	I_γ[‡e]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[#]	α[f]	Comments
								transition, all of the γ intensity is assigned to the 930.42γ. Mult.: α(K)exp for 930+930.4 corresponds to M1 or M1,E2, and is interpreted as arising from an E0 transition and an E2 γ. Additional information 6.
930.42 *9*	5.9 *4*	930.46	2$^+$	0	0$^+$	E2	0.00390	α(K)=0.00325 *5*; α(L)=0.000507 *7*; α(M)=0.0001130 *16*; α(N+..)=3.01×10^{-5} *5* α(N)=2.62×10^{-5} *4*; α(O)=3.71×10^{-6} *6*; α(P)=1.85×10^{-7} *3* Mult.: α(K)exp for 930+930.4 corresponds to M1 or M1,E2, and is interpreted as arising from an E0 transition and an E2 γ. Additional information 8.
959.00 *9*	10.3 *6*	1303.52	3$^-$	344.51	2$^+$	E1	1.48×10^{-3}	α(K)=0.001262 *18*; α(L)=0.0001705 *24*; α(M)=3.73×10^{-5} *6*; α(N+..)=1.000×10^{-5} *14* α(N)=8.68×10^{-6} *13*; α(O)=1.252×10^{-6} *18*; α(P)=6.91×10^{-8} *10* Additional information 9.
1006.86 *16*	3.6 *3*	1351.31	3$^+$	344.51	2$^+$			
1017.1[a] *2*	1.27 *17*	1814.48	4$^-$	797.38	4$^+$	[E1]	1.33×10^{-3}	α(K)=0.001131 *16*; α(L)=0.0001524 *22*; α(M)=3.34×10^{-5} *5*; α(N+..)=8.94×10^{-6} *13* α(N)=7.76×10^{-6} *11*; α(O)=1.120×10^{-6} *16*; α(P)=6.20×10^{-8} *9*
1061.3[&] *4*	1.0 *3*	1406.1	4$^+$	344.51	2$^+$			E_γ: γ is questionable, since it was not reported by 1975Ag02 and weaker lines were reported by them in this energy region.
1084.4[@] *3*	0.25 *8*	2014.60		930.35	0$^+$			
[x]1160.5[@] *4*	0.19 *6*							
1173.34 *19*	≈0.5	1517.89	(1$^-$)	344.51	2$^+$	[E1]	1.04×10^{-3}	α(K)=0.000873 *13*; α(L)=0.0001169 *17*; α(M)=2.56×10^{-5} *4*; α(N+..)=2.02×10^{-5} *3* α(N)=5.95×10^{-6} *9*; α(O)=8.60×10^{-7} *12*; α(P)=4.80×10^{-8} *7*; α(IPF)=1.332×10^{-5} *20*
1202.2 *2*	1.05 *15*	1546.72	4$^+$	344.51	2$^+$	[E2]	0.00232	α(K)=0.00195 *3*; α(L)=0.000287 *4*; α(M)=6.36×10^{-5} *9*; α(N+..)=2.24×10^{-5} *4* α(N)=1.479×10^{-5} *21*; α(O)=2.11×10^{-6} *3*; α(P)=1.112×10^{-7} *16*; α(IPF)=5.36×10^{-6} *8*
1220.83 *17*	3.5 *3*	1220.80	2$^+$	0	0$^+$	[E2]	0.00226	α(K)=0.00189 *3*; α(L)=0.000278 *4*; α(M)=6.16×10^{-5} *9*; α(N+..)=2.39×10^{-5} *4* α(N)=1.431×10^{-5} *20*; α(O)=2.05×10^{-6} *3*; α(P)=1.079×10^{-7} *16*; α(IPF)=7.43×10^{-6} *11*
1226.1[h] *3*	1.40 *14*	1570.74	2$^+$	344.51	2$^+$			
1286.05 *14*	3.1 *4*	1630.50	2$^-$	344.51	2$^+$	[E1]	9.29×10^{-4}	α(K)=0.000742 *11*; α(L)=9.90×10^{-5} *14*;

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^{156}Tm ε decay (83.8 s) 1975Ag02,1980Zo02 (continued)

γ(^{156}Er) (continued)

E_γ[†]	I_γ[‡e]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[#]	α[f]	Comments
								α(M)=2.17×10^{-5} *3*; α(N+..)=6.63×10^{-5} *10* α(N)=5.04×10^{-6} *7*; α(O)=7.29×10^{-7} *11*; α(P)=4.08×10^{-8} *6*; α(IPF)=6.05×10^{-5} *9*
1366.0[a] *2*	1.8 *3*	1710.52		344.51	2$^+$			
[x]1405.0 *5*	0.5 *1*							Placed from the 1406 level by 1980Zo02, but this level has subsequently been assigned as 4$^+$ in the high-spin study of 2011Re06. 1975Ag02 do not place this γ, stating that it is not firmly associated with this decay.
1516.3[a] *6*	1.4 *5*	1860.8	(3$^+$)	344.51	2$^+$	[M1,E2]	0.0020 *4*	α(K)=0.0016 *4*; α(L)=0.00022 *5*; α(M)=4.9×10^{-5} *10*; α(N+..)=9.9×10^{-5} *12* α(N)=1.15×10^{-5} *24*; α(O)=1.7×10^{-6} *4*; α(P)=9.3×10^{-8} *22*; α(IPF)=8.6×10^{-5} *9* I_γ: From 1980Zo02. 1975Ag02 report a single value (3.2 6) for the combined 1516.3 and 1518.0 γ's.
1518.0 *4*	2.2 *5*	1517.89	(1$^-$)	0	0$^+$	[E1]	8.62×10^{-4}	α(K)=0.000558 *8*; α(L)=7.40×10^{-5} *11*; α(M)=1.619×10^{-5} *23*; α(N+..)=0.000214 *3* α(N)=3.77×10^{-6} *6*; α(O)=5.46×10^{-7} *8*; α(P)=3.08×10^{-8} *5*; α(IPF)=0.000210 *3* I_γ: From 1980Zo02. 1975Ag02 report a single value (3.2 6) for the combined 1516.3 and 1518.0 γ's.
[x]1529.3[@] *4*	0.47 *13*							
1565.1[a] *2*	1.9 *3*	1909.54	2$^+$,3,4$^+$	344.51	2$^+$			
[x]1663.9 *3*	1.35 *21*							
1670.0 *2*	1.6 *2*	2014.60		344.51	2$^+$			
[x]1677.2[@] *5*	0.28 *9*							
[x]1711.7[@] *10*	0.25 *9*							
[x]1722.5[@] *8*	0.36 *9*							
[x]1738.7[@] *10*	0.28 *9*							
[x]1760.5[@] *8*	0.43 *13*							
[x]1767.3[@] *8*	0.19 *8*							
[x]1779.4[@] *9*	0.19 *8*							
1825.3[a] *3*	0.95 *14*	2169.8		344.51	2$^+$			

† From weighted average of values of 1975Ag02 and 1980Zo02.

‡ From weighted average of values of 1975Ag02 and 1980Zo02.

Except for the 344 and 543 γ's, the assignments are those of 1975Ag02 and 1980Zo02 and are based on the α(K)exp values. In deducing these values, the normalization of the ce and γ intensity scales was done using the theoretical α(K) value for the 344 γ, assuming a pure E2 multipolarity.

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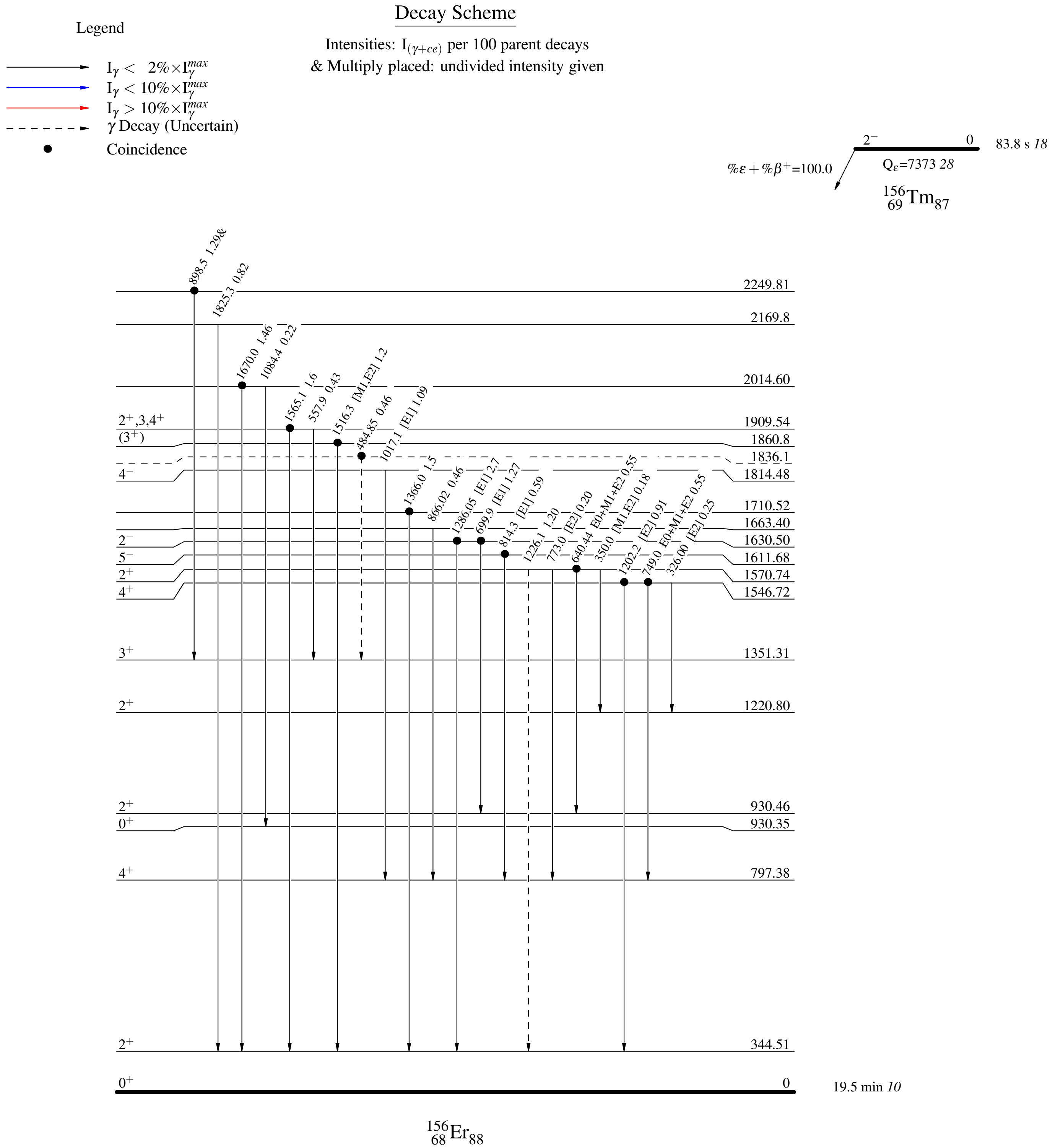
^{156}Tm ε decay (83.8 s) 1975Ag02,1980Zo02 (continued)

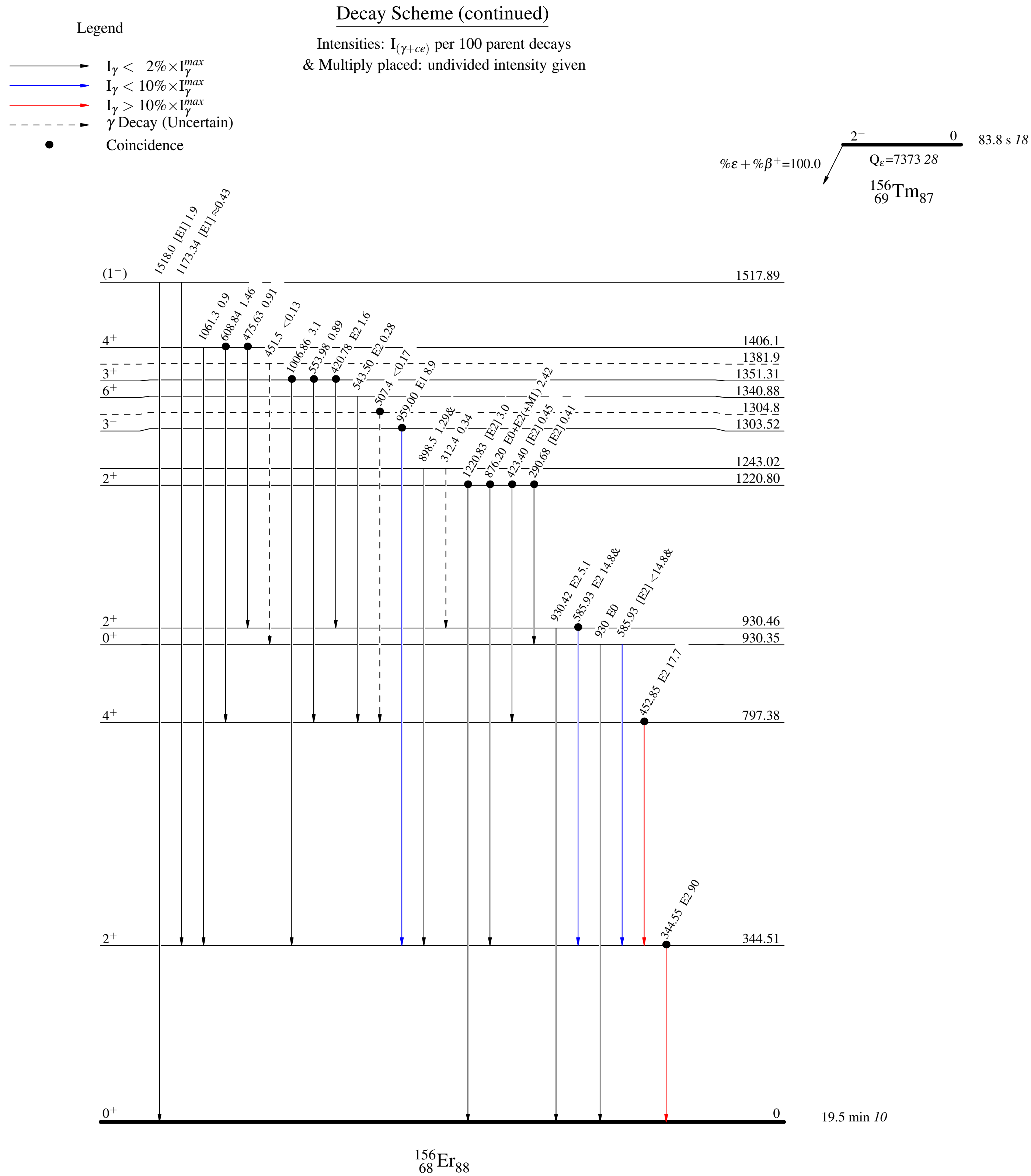
γ(^{156}Er) (continued)

[@] From 1975Ag02 only.
[&] From 1980Zo02 only.
[a] Placed only by 1980Zo02; but observed in both studies.
[b] Only tentatively assigned to this decay by 1980Zo02 and not reported by 1975Ag02.
[c] Only tentatively assigned to this decay by 1975Ag02 and not reported by 1980Zo02.
[d] γ placed from 1243-keV level by 1980Zo02 and from 2249-keV level by 1975Ag02.
[e] For absolute intensity per 100 decays, multiply by 0.86 *2*.
[f] Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.
[g] Multiply placed with undivided intensity.
[h] Placement of transition in the level scheme is uncertain.
[x] γ ray not placed in level scheme.

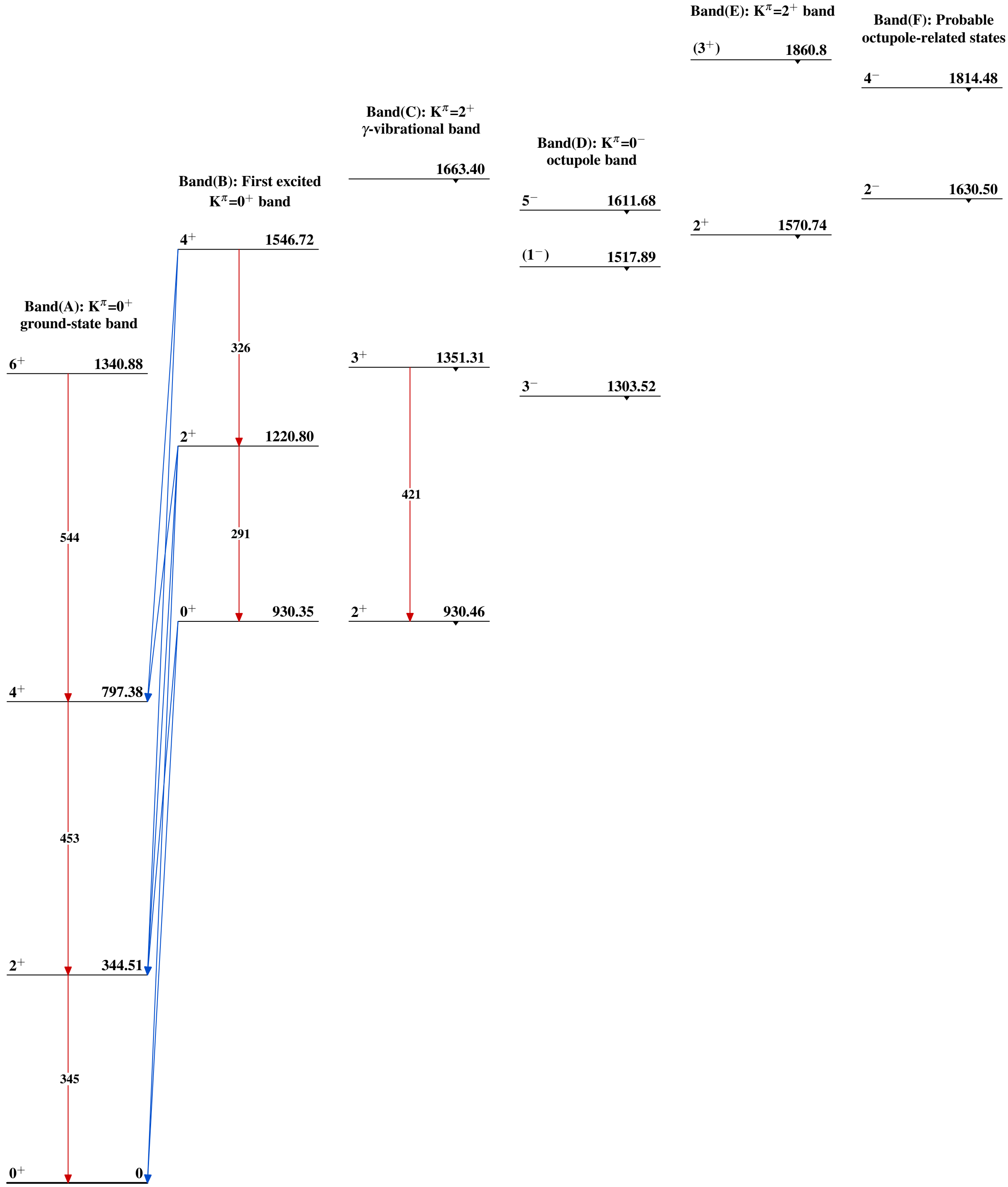
^{156}Tm ε decay (83.8 s) 1975Ag02,1980Zo02



^{156}Tm ε decay (83.8 s) 1975Ag02,1980Zo02



^{156}Tm ε decay (83.8 s) 1975Ag02,1980Zo02



$^{156}_{68}Er_{88}$