# $^{186}$Tl ε decay (27.5 s) 1994De25,1977Be23,1977Co21

History

| Type | Author | Citation | Literature Cutoff Date |
|---|---|---|---|
| Full Evaluation | J. C. Batchelder and A. M. Hurst, M. S. Basunia | NDS 183, 1 (2022) | 1-Mar-2022 |

Parent: $^{186}$Tl: E=40 *39*; $J^\pi=(7^+)$; $T_{1/2}$=27.5 s *10*; Q(ε)=8656 *24*; %ε+%$β^+$ decay≈100.0

Others: 1994Jo13, 1993Jo15, 1975Be52, 1975Ha27, 1973Pr16.

Sources produced via $^{197}$Au($^3$He,14n) (1977Be23,1994De25) and $^{182}$W($^{14}$N,10n) (1977Co21,1975Ha27).

The decay scheme is that of 1977Be23, modified to accommodate levels newly proposed in 1994De25 (same facility and two common co-autors) ; consequently, the 1194 and 1232 levels from 1977Be23 are now omitted, leaving the 421γ unplaced, and the 478γ, 574γ, 788γ and 826γ from 1977Be23 have been relocated. Band structure is from 1994De25.

## $^{186}$Hg Levels

| E(level)† | $J^\pi$‡ | $T_{1/2}$# | Comments |
|---|---|---|---|
| 0.0@ | $0^+$ | 1.38 min *10* | |
| 405.33@ *13* | $2^+$ | 18 ps *3* | $T_{1/2}$: from 1974Pr02. |
| 523.0& *3* | $0^+$ | ≤52 ps | |
| 621.07& *16* | $2^+$ | 48 ps *27* | $T_{1/2}$: Revised value of 66 ps *37* (1993JoZV). |
| 807.95& *17* | $4^+$ | 9 ps *3* | $T_{1/2}$: from 1974Pr02. |
| 1080.32@ *17* | $4^+$ | | |
| 1096.59a *23* | $2^+$ | | $J^\pi$: 2 from 691γ-405γ(θ) (1994De25). |
| 1164.66& *20* | $6^+$ | 5 ps *2* | $T_{1/2}$: from 1974Pr02. |
| 1228.4 *3* | $(4^+)$ | | $J^\pi$: (1,2,3$^-$) in 1977Be23. |
| 1433.81a *21* | $(3^+)$ | | |
| 1578.01 *24* | $(6^+)$ | | $J^\pi$: ($5^-$) in 1994De25. |
| 1588.86& *25* | $8^+$ | 3 ps | $T_{1/2}$: from 1974Pr02. |
| 1614.9 *6* | | | |
| 1659.4b *3* | $(2^+)$ | | |
| 1677.87@ *20* | $6^+$ | | |
| 1868.48a *22* | $(5^+)$ | | |
| 1906.7 *3* | (5,6) | | E(level): observed in 1994De25, but no details given. |
| 1965.9 *3* | $4^+$,5,$6^+$ | | |
| 1975.9 *3* | $(8^+)$ | | $J^\pi$: From Adopted Levels. Other: ($7^-$) in 1994De25. |
| 2055.5 *5* | $6^+$ | | |
| 2078.1& | $10^+$ | | E(level): from Adopted Levels; observed by 1994De25, but no details given. |
| 2130.4 *4* | | | |
| 2138.0b *3* | $(3^+)$ | | |
| 2155.4@ *4* | $(8^+)$ | | E(level): From Adopted Levels. See comments for the depopulating 477.9γ. |
| 2211.7 *3* | | | |
| 2268.1 *4* | (7) | | |
| 2349.1 *3* | $(6^+,7^+)$ | | |
| 2427.9a *3* | $(7^+)$ | | |

† From a least-squares adjustment of Eγ, allowing 1 keV uncertainty in Eγ whenever $\Delta E_\gamma$ is missing.

‡ From Adopted Levels.

# From triple coin, centroid shift (1994Jo13). 1994Jo13 supersedes 1993JoZV; the technique is further discussed in 1993Jo15.

@ Band(A): $K^\pi=0^+$ g.s. band. Slightly-deformed oblate band.

& Band(B): $K^\pi=0^+$ β band. Prolate band.

a Band(C): Possible $K^\pi=2^+$ quasi-γ band. Assignment of levels to band based on comparison between observed and calculated level energies, and consistency of observed γ deexcitation.

b Band(D): Possible second γ band. Assignment of levels to band based on comparison between observed and calculated level energies, and consistency of observed γ deexcitation.

## γ($^{186}$Hg)

Iγ normalization: 0.948 *5*, can be obtained assuming Σ I(γ+ce) to g.s.=100 (no significant g.s. branch is expected) with assumptions ΔIγ=20% (621.3γ) and ΔIγ=0 (405.30γ − i.e. propagated to other Iγ); however, not been normalized for significant ε feeding of $2^+$, $4^+$, $6^+$ and $8^+$ states, suggesting more than one parent state. A low spin level close to the $^{186}$Tl ($7^+$) level is expected and may ε decay, but it might not be noticed if its $T_{1/2}$ were similar to that of the ($7^+$) state; such a scenario is in fact suggested by analogy with higher mass Tl isotopes. The evaluators presume that this decay does have mixed parentage. The scheme may also be incomplete, considering the large Q value.

| $E_\gamma$ [†] | $I_\gamma$ [b] | $E_i$(level) | $J_i^\pi$ | $E_f$ | $J_f^\pi$ | Mult.[c] | α[d] | Comments |
|---|---|---|---|---|---|---|---|---|
| 98.2[‡] *7* | 0.6 *3* | 621.07 | $2^+$ | 523.0 | $0^+$ | [E2] | 5.99 *21* | α(K)=0.622 *9*; α(L)=4.01 *15*; α(M)=1.05 *4*<br>α(N)=0.260 *10*; α(O)=0.0431 *16*; α(P)=0.000124 *3* |
| [x]117.0[‡] | <0.3 | | | | | | | |
| 186.4[‡] *4* | 2.5 *5* | 807.95 | $4^+$ | 621.07 | $2^+$ | (E2) | 0.499 *8* | α(K)=0.201 *3*; α(L)=0.224 *4*; α(M)=0.0580 *10*<br>α(N)=0.01440 *25*; α(O)=0.00243 *4*; α(P)=2.51×10$^{-5}$ *4* |
| 215.53 *17* | 4.0 *3* | 621.07 | $2^+$ | 405.33 | $2^+$ | E0+M1+E2 | 3.5 *5* | α: Calculated from α(K)exp=2.8 *3* (1977Be23) and K/L=5.3 *14* (1977Co21), assuming M+/L=0.33. Other α(K)exp: 3.1 *7* (1977Co21). |
| 271.9[@] *3* | 0.9[@] | 1080.32 | $4^+$ | 807.95 | $4^+$ | | | |
| 287.97 *24* | 1.5 *2* | 1965.9 | $4^+$,5,$6^+$ | 1677.87 | $6^+$ | | | $E_\gamma$: 1977Co21 and 1977Be23 report that γ of this energy definitely belongs in $^{186}$Hg (from γγ coin), but this Eγ is also present in the $^{186}$Au daughter of $^{186}$Hg. Presumably, Iγ may include some contribution from the latter. |
| 337.1[@] *3* | ≈0.3[@] | 1433.81 | ($3^+$) | 1096.59 | $2^+$ | [M1] | 0.263 | α(K)=0.216 *3*; α(L)=0.0359 *6*; α(M)=0.00835 *12*<br>α(N)=0.00210 *3*; α(O)=0.000397 *6*; α(P)=3.04×10$^{-5}$ *5* |
| 356.74 *13* | 32.0 *9* | 1164.66 | $6^+$ | 807.95 | $4^+$ | E2 | 0.0647 | α(K)exp=0.04 *1* (1977Be23); α(K)exp=0.049 *9* (1977Co21)<br>α(K)=0.0417 *6*; α(L)=0.01732 *25*; α(M)=0.00435 *7*<br>α(N)=0.001083 *16*; α(O)=0.000189 *3*; α(P)=5.45×10$^{-6}$ *8* |
| 397.84[a] *24* | 1.30[a] *20* | 1975.9 | ($8^+$) | 1578.01 | ($6^+$) | (E2) | 0.0481 | α(K)exp=0.062 *20* (1977Be23)<br>α(K)=0.0324 *5*; α(L)=0.01186 *17*; α(M)=0.00296 *5*<br>α(N)=0.000737 *11*; α(O)=0.0001294 *19*; α(P)=4.26×10$^{-6}$ *6*<br>Mult.: from adopted gammas. Mult=M1+E2 (δ=1.7 *+16−6*) from α(K)exp for probable doublet. |
| 399.6[@] *3* | 0.5[@] | 2268.1 | (7) | 1868.48 | ($5^+$) | | | |
| 402.60 *13* | 50.0 *9* | 807.95 | $4^+$ | 405.33 | $2^+$ | E2 | 0.0466 | α(K)=0.0315 *5*; α(L)=0.01139 *16*; α(M)=0.00284 *4*<br>α(N)=0.000707 *10*; α(O)=0.0001243 *18*; α(P)=4.15×10$^{-6}$ *6*<br>Mult.: from adopted gammas. |
| 405.30 *14* | 100 | 405.33 | $2^+$ | 0.0 | $0^+$ | E2 | 0.0458 | α(K)=0.0311 *5*; α(L)=0.01113 *16*; α(M)=0.00277 *4*<br>α(N)=0.000691 *10*; α(O)=0.0001215 *17*; α(P)=4.09×10$^{-6}$ *6*<br>Mult.: from Adopted Gammas. |
| [x]412.49 *24* | 1.65 *15* | | | | | | 0.0437 | α(K)=0.0299 *5*; α(L)=0.01049 *15*; α(M)=0.00261 *4*<br>α(N)=0.000651 *10*; α(O)=0.0001145 *17*; α(P)=3.93×10$^{-6}$ *6* |

## $^{186}$Tl ε decay (27.5 s) 1994De25,1977Be23,1977Co21 (continued)

### γ($^{186}$Hg) (continued)

| $E_\gamma$[†] | $I_\gamma$[b] | $E_i$(level) | $J_i^\pi$ | $E_f$ | $J_f^\pi$ | Mult.[c] | α[d] | $I_{(\gamma+ce)}$ | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | $E_\gamma$: close to 413.3 *4* required for the 1578 to 1165 transition known from Adopted Levels, gammas; however, mult=E1 is expected for that transition. |
| [x]420.9 *3* | 0.72 *9* | | | | | | | | |
| 424.16 *17* | 13.1 *4* | 1588.86 | $8^+$ | 1164.66 | $6^+$ | E2 | 0.0407 | | α(K)exp=0.031 *6* (1977Be23); α(K)exp=0.045 *19* (1977Co21)<br>α(K)=0.0280 *4*; α(L)=0.00956 *14*; α(M)=0.00238 *4*<br>α(N)=0.000592 *9*; α(O)=0.0001044 *15*; α(P)=3.70×10$^{-6}$ *6* |
| 434.7[@] *3* | ≈2[@] | 1868.48 | $(5^+)$ | 1433.81 | $(3^+)$ | | | | |
| 442.5[@] *3* | 0.5[@] | 2349.1 | $(6^+,7^+)$ | 1906.7 | (5,6) | | | | |
| 459.2 *2* | 2.5 *3* | 1080.32 | $4^+$ | 621.07 | $2^+$ | E2 | 0.0332 | | α(K)exp=0.020 *7* (1977Be23)<br>α(K)=0.0235 *4*; α(L)=0.00739 *11*; α(M)=0.00183 *3*<br>α(N)=0.000455 *7*; α(O)=8.07×10$^{-5}$ *12*; α(P)=3.10×10$^{-6}$ *5* |
| 477.9[&] *3* | ≈0.8[&] | 2155.4 | $(8^+)$ | 1677.87 | $6^+$ | | 0.0301 | | α(K)exp=0.021 *10* (1977Be23)<br>α(K)=0.0215 *3*; α(L)=0.00651 *10*; α(M)=0.001604 *23*<br>α(N)=0.000400 *6*; α(O)=7.11×10$^{-5}$ *10*; α(P)=2.85×10$^{-6}$ *4*<br>$E_\gamma$: From 1977Be23; placement by evaluators, based on HI data.<br>$I_\gamma$: 1.8 *2* from 1977Be23 is presumably for 477.9γ+478.6γ; Iγ≈1 for 478.6γ in 1994De25, leaving Iγ≈0.8 for this placement.<br>Mult.: E2 for presumed doublet (from α(K)exp). |
| 478.6[&] *3* | ≈1[&] | 2138.0 | $(3^+)$ | 1659.4 | $(2^+)$ | | | | $E_\gamma$,$I_\gamma$: From 1994De25. |
| 480.6[@] *3* | 1.5[@] | 2349.1 | $(6^+,7^+)$ | 1868.48 | $(5^+)$ | | | | |
| 497.6 *3* | 0.60 *15* | 1578.01 | $(6^+)$ | 1080.32 | $4^+$ | | | | $E_\gamma$,$I_\gamma$: from 1977Be23; Iγ=2.0 *10* in 1977Co21. |
| 522.5 *7* | | 523.0 | $0^+$ | 0.0 | $0^+$ | E0 | | 3.7 *4* | α(K)exp>6.2 (1977Be23); α(K)exp>6.0 (1977Co21); K/L=5.7 *8* (1977Co21)<br>K/L≈6 (1977Be23)<br>$I_{(\gamma+ce)}$: calculated from I(523ce(K)) (normalized so α(K)exp(216)=2.8 *3*) (1977Be23) and K/L=5.7 *8* (1977Co21). |
| 559.7[@] *3* | 0.8[@] | 2427.9 | $(7^+)$ | 1868.48 | $(5^+)$ | | | | |
| 562.8[@] *3* | 1.0[@] | 1659.4 | $(2^+)$ | 1096.59 | $2^+$ | | | | |
| 573.57 *24* | 1.5 *3* | 1096.59 | $2^+$ | 523.0 | $0^+$ | E2 | 0.0195 | | α(K)exp=0.020 *8* (1977Be23)<br>α(K)=0.01456 *21*; α(L)=0.00376 *6*; α(M)=0.000916 *13*<br>α(N)=0.000229 *4*; α(O)=4.11×10$^{-5}$ *6*; α(P)=1.93×10$^{-6}$ *3*<br>Placement from (1994De25).<br>Mult.: E2(+M1) (δ≥1.4) from α(K)exp; feeds $0^+$ state.<br>Placement from 1994De25. |
| 579.2[@] *3* | ≈3[@] | 1659.4 | $(2^+)$ | 1080.32 | $4^+$ | | | | |
| 597.52 *18* | 4.45 *21* | 1677.87 | $6^+$ | 1080.32 | $4^+$ | E2 | 0.01775 | | α(K)exp=0.011 *4* (1977Be23)<br>α(K)=0.01336 *19*; α(L)=0.00334 *5*; α(M)=0.000812 *12*<br>α(N)=0.000203 *3*; α(O)=3.65×10$^{-5}$ *6*; α(P)=1.773×10$^{-6}$ *25* |
| 607.35 *21* | 7.2 *7* | 1228.4 | $(4^+)$ | 621.07 | $2^+$ | [E2] | 0.0171 *1* | | α(K)=0.01291 *19*; α(L)=0.00319 *5*; α(M)=0.000774 *11*<br>α(N)=0.000193 *3*; α(O)=3.49×10$^{-5}$ *5*; α(P)=1.714×10$^{-6}$ *24* |





$^{186}_{80}Hg_{106}$-3

## $^{186}$Tl ε decay (27.5 s) 1994De25,1977Be23,1977Co21 (continued)

### γ($^{186}$Hg) (continued)

| $E_\gamma$ [†] | $I_\gamma$ [b] | $E_i$(level) | $J_i^\pi$ | $E_f$ | $J_f^\pi$ | Mult.[c] | δ | α[d] | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | $I_\gamma$: a 607γ depopulates levels in both $^{186}$Hg and the $^{186}$Pt granddaughter (1977Co21, based on observation of K x ray(Hg)−607γ coin and K x ray(Pt)−607γ coin). Therefore, 1977Co21 determine Iγ from on-line data (Iγ=14.5 in one off-line run).<br>Mult.: Other: E1 from α(K)exp=0.0055 *20* (1977Be23); however, if line were a doublet (as in (HI,xnγ)), α(K)exp would be consistent with an E2 component of ≤31%. |
| 621.3[@] *3* | ≈0.7[@] | 621.07 | 2+ | 0.0 | 0+ | | | | $E_\gamma$: 1977Be23, 1977Co21 both report this transition but left unplaced. |
| 626.1[#] *3* | 3.1[#] *2* | 1433.81 | (3+) | 807.95 | 4+ | | | | $E_\gamma$,$I_\gamma$: from 1977Be23. Iγ=2.1 in 1994De25. |
| 675.30 *21* | 15.4 *6* | 1080.32 | 4+ | 405.33 | 2+ | E2 | | 0.01354 | α(K)exp=0.010 *3* (1977Be23)<br>α(K)=0.01040 *15*; α(L)=0.00239 *4*; α(M)=0.000575 *8*<br>α(N)=0.0001436 *21*; α(O)=2.61×10$^{-5}$ *4*; α(P)=1.379×10$^{-6}$ *20* |
| 691.2[@] *3* | ≈3[@] | 1096.59 | 2+ | 405.33 | 2+ | M1+E2 | +5.7 *+20−12* | 0.0137 *5* | α(K)=0.0106 *5*; α(L)=0.00233 *7*; α(M)=0.000560 *15*<br>α(N)=0.000140 *4*; α(O)=2.55×10$^{-5}$ *7*; α(P)=1.41×10$^{-6}$ *6*<br>$A_2$=−0.29 *12*, $A_4$=+0.47 *17* for 691γ-405γ(θ) (1994De25). |
| 696.6[@] *3* | 0.5[@] | 2130.4 | | 1433.81 | (3+) | | | | |
| 704.0[@] *3* | ≈2[@] | 1868.48 | (5+) | 1164.66 | 6+ | | | | |
| [x]726.0[#] *7* | 1.4[#] *4* | | | | | | | | $E_\gamma$,$I_\gamma$: from 1977Be23. |
| 749.8[@] *3* | 0.3[@] | 2427.9 | (7+) | 1677.87 | 6+ | | | | |
| 760.1[@] *3* | 0.6[@] | 2349.1 | (6+,7+) | 1588.86 | 8+ | | | | |
| 770.06 *24* | 5.0 *3* | 1578.01 | (6+) | 807.95 | 4+ | | | | |
| 777.9[@] *3* | 1.4[@] | 2211.7 | | 1433.81 | (3+) | | | | |
| 788.2 *3* | 2.9 *3* | 1868.48 | (5+) | 1080.32 | 4+ | M1(+E2) | | 0.0189 *92* | α(K)=0.0154 *78*; α(L)=0.0027 *11*; α(M)=6.3×10$^{-4}$ *25*<br>α(N)=1.57×10$^{-4}$ *62*; α(O)=2.9×10$^{-5}$ *12*; α(P)=2.1×10$^{-6}$ *11*<br>Mult.: From Adopted Gammas. |
| 811.4 *4* | 2.7 *4* | 1975.9 | (8+) | 1164.66 | 6+ | | | | |
| 812.7[@] *3* | 3.3[@] | 1433.81 | (3+) | 621.07 | 2+ | | | | |
| 826.5 *3* | 2.6 *4* | 1906.7 | (5,6) | 1080.32 | 4+ | | | | Placed from a 1232 level by 1977Co21 and 1977Be23; relocated by evaluators to be consistent with reported observation of 1906 level in $^{186}$Tl ε decay (1994De25) and with adopted placement of the 826.0γ from that level in ($^{36}$S,4nγ). |
| 869.8 *2* | 1.00 *20* | 1677.87 | 6+ | 807.95 | 4+ | | | | |
| 886.4 | 0.7 | 1965.9 | 4+,5,6+ | 1080.32 | 4+ | | | | $E_\gamma$,$I_\gamma$: From fig. 5 of 1977Be23. |
| 1057.6[@] *3* | 3.3[@] | 2138.0 | (3+) | 1080.32 | 4+ | | | | |
| 1131.3[@] *3* | 0.3[@] | 2211.7 | | 1080.32 | 4+ | | | | |
| [x]1177.2 *4* | 0.80 *18* | | | | | | | | |





$^{186}_{80}Hg_{106}$-4

## $^{186}$Tl $\varepsilon$ decay (27.5 s) 1994De25,1977Be23,1977Co21 (continued)

### $\gamma(^{186}Hg)$ (continued)

| $E_\gamma$[†] | $I_\gamma$[b] | $E_i$(level) | $J_i^\pi$ | $E_f$ | $J_f^\pi$ |
|---|---|---|---|---|---|
| 1209.6 *5* | 1.2 *6* | 1614.9 | | 405.33 | $2^+$ |
| 1247.5[a] *4* | 1.40[a] *19* | 2055.5 | $6^+$ | 807.95 | $4^+$ |
| [x]1272.5 *4* | 1.40 *18* | | | | |

[†] Weighted average of data from 1977Be23 and 1977Co21, except otherwise noted.
[‡] From 1977Co21.
[#] Reported as doublet with long half-life component (1977Co21).
[@] From 1994De25; authors do not state $\Delta I_\gamma$.
[&] E=478.3 *5*, I$\gamma$=3.0 *12* multiplet with long half-life component is unplaced in 1977Co21; E=477.9 *3*, I$\gamma$=1.8 *2* (1977Be23), and E=478.6 *3*, I$\gamma\approx$1 (1994De25) transitions are placed by authors from 2057 (1977Be23) and 2138 (1994De25) levels, respectively. Additional comment with the $\gamma$.
[a] 398-keV gammas are reported from both the 1976 and the 2268 levels in (HI,xn$\gamma$) reactions, and 1994De25 report I$\gamma$=0.5 for a 399.6$\gamma$ from the 2268 level in $^{186}$Tl $\varepsilon$ decay. 1977Co21 and 1977Be23 report one E$\gamma$=397.84 *24*, I$\gamma$=1.80 *20* transition; this is presumably a doublet. Since I$\gamma$=0.5 from the 2268 level (1994De25), I$\gamma$ from 1978 level must be 1.30 *20*.
[b] Weighted average of data from 1977Be23 and 1977Co21 except as noted.
[c] From adopted gammas, mostly based on $\alpha$(K)exp of this dataset.
[d] Additional information 1.
[x] $\gamma$ ray not placed in level scheme.





$^{186}_{80}Hg_{106}$-5

## $^{186}$Tl ε decay (27.5 s) 1994De25,1977Be23,1977Co21

### Decay Scheme

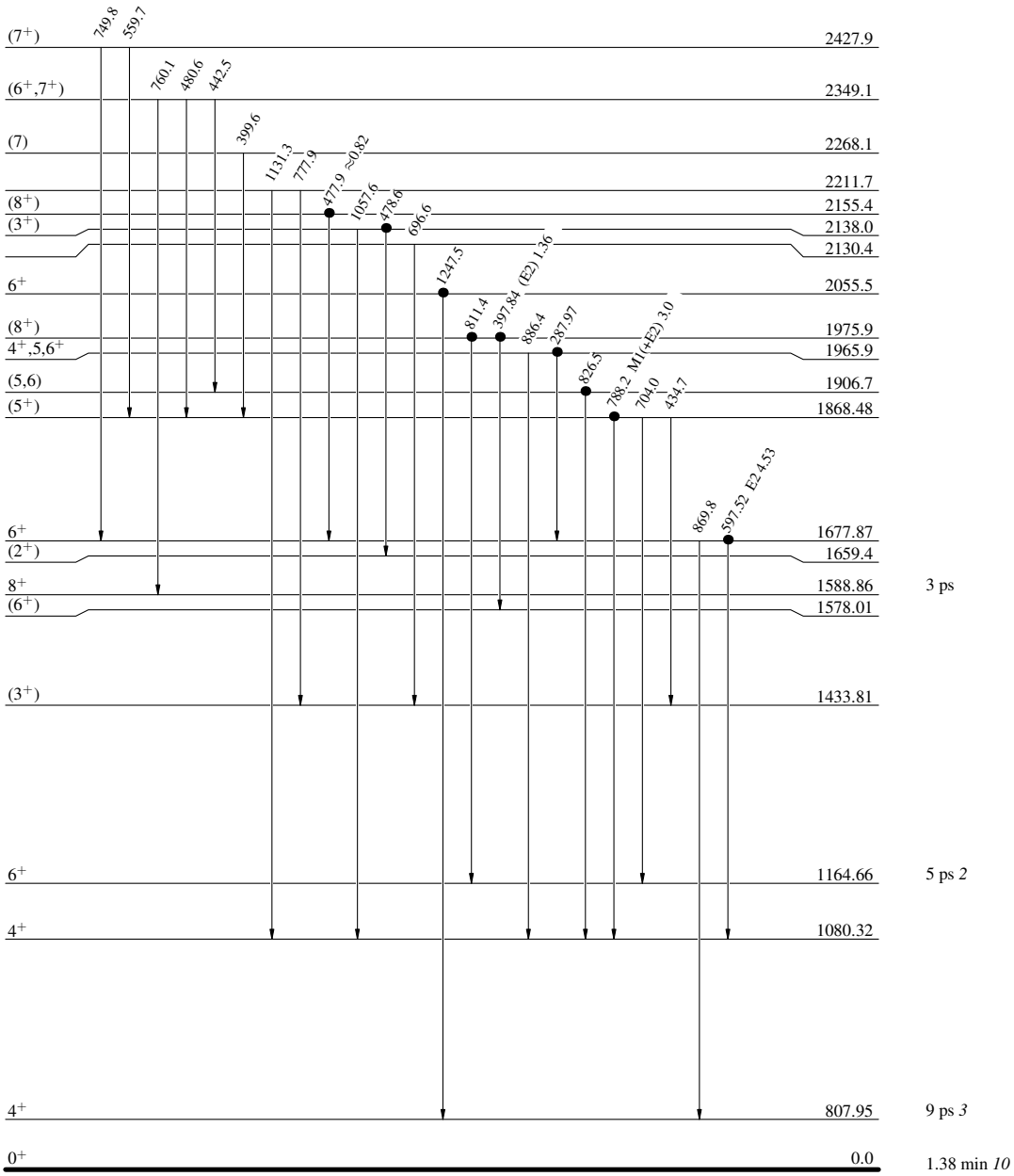
Intensities: Relative $I_{(\gamma+ce)}$

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

$(7^+)$ 40 27.5 s *10*

$\%\varepsilon + \%\beta^+ \approx 100.0$ $Q_\varepsilon$=8656 *24*

$^{186}_{81}Tl_{105}$

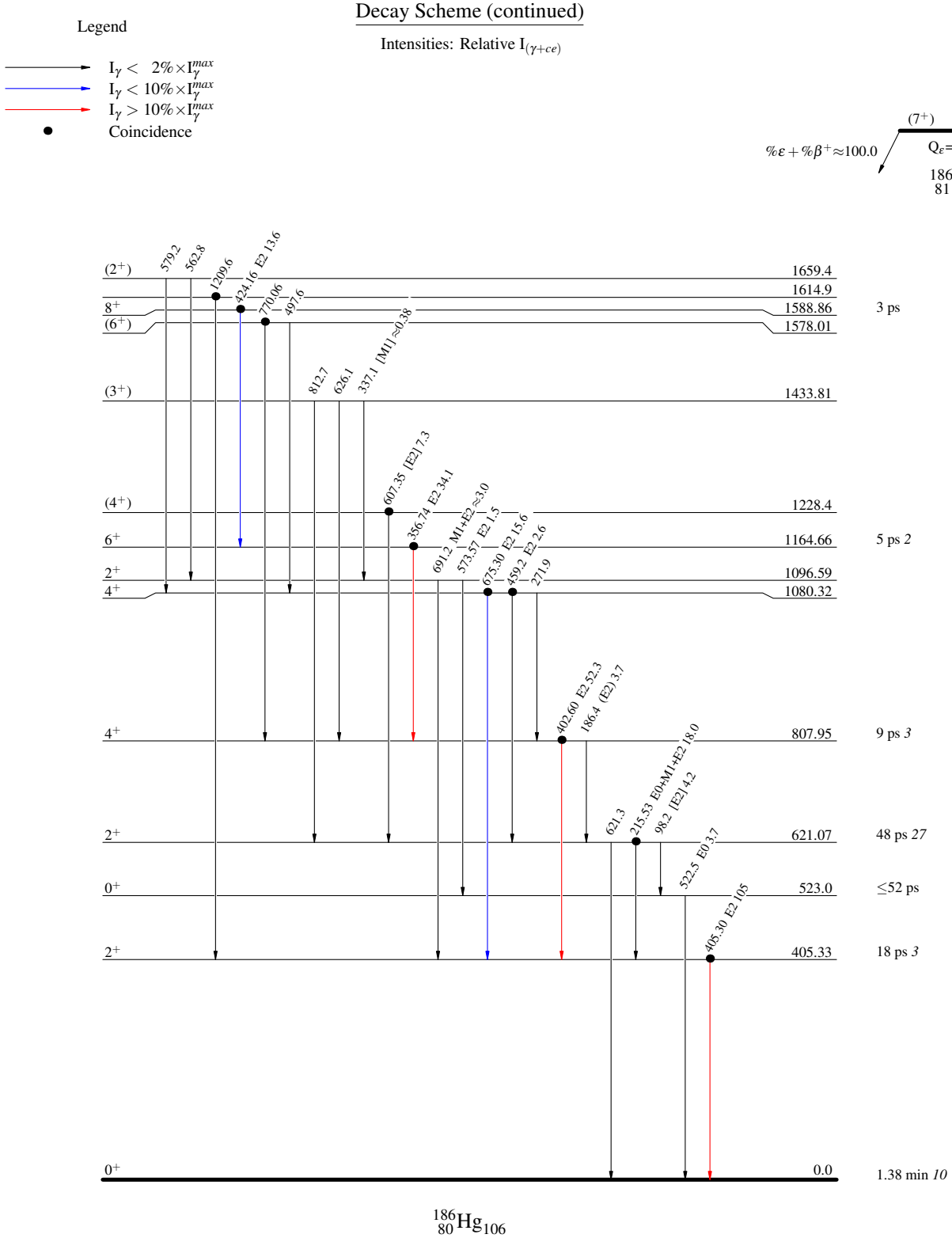



$^{186}_{80}Hg_{106}$

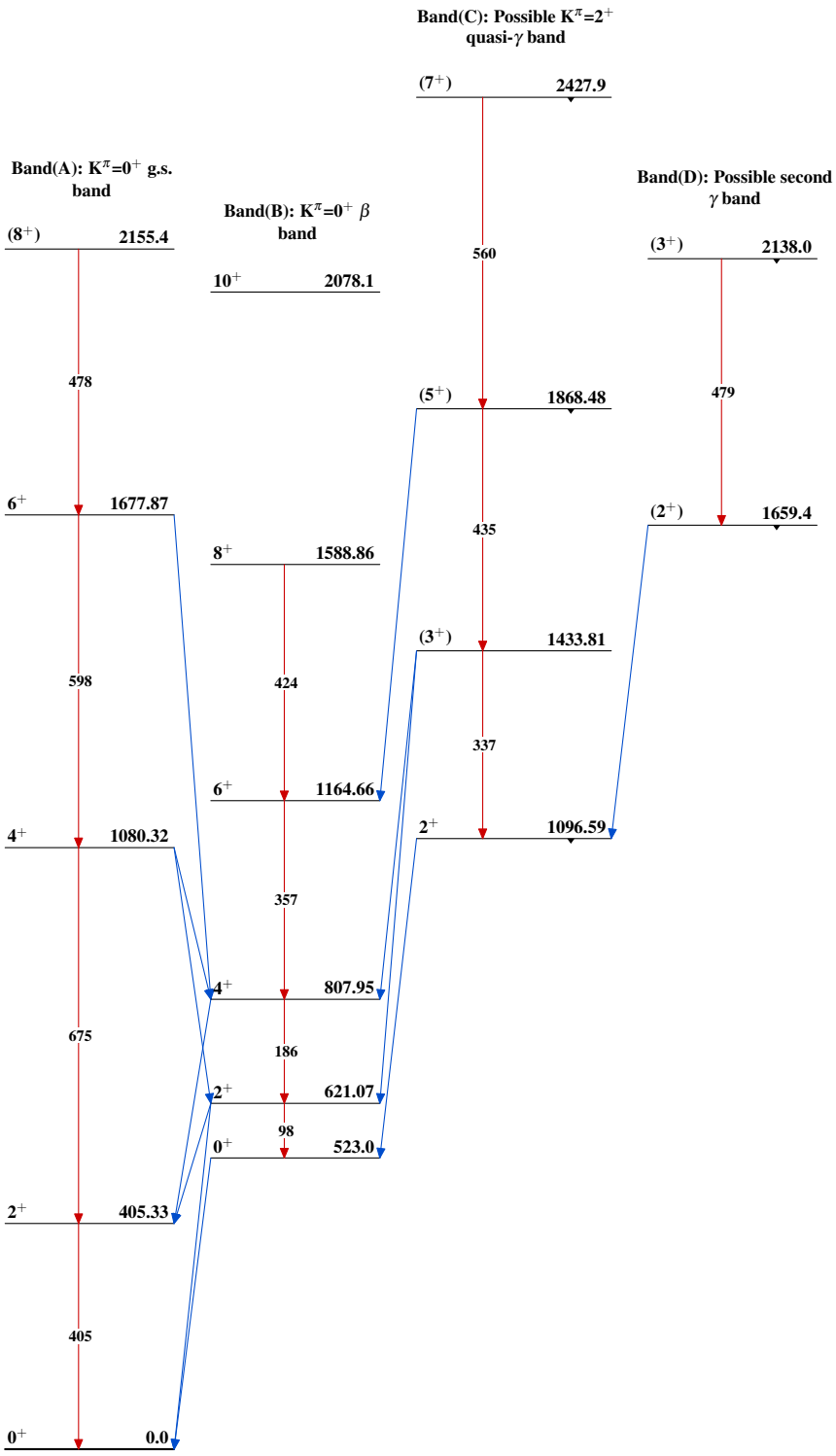
## $^{186}$Tl ε decay (27.5 s) 1994De25,1977Be23,1977Co21

### Decay Scheme (continued)

Intensities: Relative $I_{(\gamma+ce)}$



## $^{186}$Tl ε decay (27.5 s) 1994De25,1977Be23,1977Co21




$^{186}_{80}Hg_{106}$