^{228}**Fr** β^- **decay** **1998Gu09,1982Ru04,1982RuZW**

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Khalifeh Abusaleem	NDS 116, 163 (2014)	31-Dec-2012

Parent: ^{228}Fr: E=0; $J^\pi=2^-$; $T_{1/2}$=38 s *1*; Q(β^-)=4427 *14*; %β^- decay=100.0

1998Gu09: Two sets of conversion electron measurement have been performed. The first was carried using ^{228}Fr source that was produced in a spallation reaction of $^{238}UC_2$ induced by 600 MeV proton beams at CERN Synchrotron and extracted from other reaction channels with ISOLDE II Facility. $\beta\gamma\gamma$(t) and second conversion electron measurements have carried using Francium produced by a spallation reaction in a $^{232}ThC_2$ target induced by 1 GeV protons from the CERN PS-Booster.

1982Ru04 and 1982RuZW report the results of the same study: γ-rays following β-decay have been investigated (singles and $\gamma\gamma$ coincidences) using Ge(Li) detectors. ^{228}Fr source was produced in a spallation reaction of ^{238}U induced by 600 MeV proton beams at CERN Synchrotron and extracted from other reaction channels with ISOLDE II Facility. Measured: E_γ, I_γ, and $T_{1/2}$. Obtained half life is in good agreement with the adopted value.

^{228}Ra Levels

Level lifetime was measured with the $\beta\gamma\gamma$(t) method. NE111A plastic scintillator detector was used as fast response detector to β, BaF_2 as fast response γ-detector, and two Ge for γ rays. Time information was obtained from the time-delayed between the fast response β^- and γ-detectors, while the other two Ge detectors were used to select the desired decay branch.

E(level)[#][@]	J^π[†]	$T_{1/2}$[‡]	Comments
0[&]	0^+		
63.823[&] *20*	2^+	550 ps *20*	J^π: E2 γ-ray to 0^+; member of g.s. band. $T_{1/2}$: Also obtained from shape de-convolution measurement which is in full agreement with the value obtained using $\beta\gamma\gamma$(t) method.
204.68[&] *3*	4^+	181 ps *3*	J^π: E2 γ-ray to 2^+; member of g.s. band. $T_{1/2}$: Also obtained from shape de-convolution measurement which is in full agreement with the value obtained using $\beta\gamma\gamma$(t) method.
411.68[&] *5*	(6^+)		J^π: possible member of g.s. band.
474.18[a] *4*	1^-	≤7 ps	J^π: E1 γ-ray to 2^+. $T_{1/2}$: Represents average of four independent measurements. 2σ limit.
537.49[a] *4*	3^-	≤6 ps	J^π: E1 γ-ray to 4^+. $T_{1/2}$: Represents average of ten time-delayed measurements. 2σ limit.
655.96[a] *5*	(5^-)		J^π: γ's to 4^+ and (6^+). Probable member of K=0 octupole band.
721.19[b] *8*	0^+		J^π: E0 γ-ray to 0^+.
770.71[b] *4*	2^+		J^π: Strong E0 component of E0+M1+E2 γ-ray to 2^+ state of the g.s. band.
846.14[c] *9*	2^+		J^π: E0 γ-ray from 2^+.
880.30[b] *6*	4^+		J^π: Strong E0 component of E0+M1+E2 γ-ray to 4^+ level of the g.s. band.
898.85[c] *8*	(3^+)		
966.99 *19*	$(2^+,4^+)$		
1013.24[d] *14*	2^+		J^π: E0 γ-ray to 2^+.
1042.01 *11*	(0^+)		
1052.78 *13*	$(2^+,3,4^+)$		
1070.23[d] *7*	(3^+)		
1087.28 *7*	$(1^-,2,3^-)$		
1109.10 *19*	$(2^+,3,4^+)$		
1157.59 *21*	$(2^+,3,4^+)$		
1182.26 *8*	$(3^-,4^+)$		
1219.97 *13*	(2^+)		
1238.5 *3*	$(0^+,1,2,3^-)$		
1349.5 *4*	(4^+)		
1471.75 *12*	$(1^-,2,3,4^+)$		

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^{228}Fr β^- decay 1998Gu09,1982Ru04,1982RuZW (continued)

^{228}Ra Levels (continued)

E(level)[#][@]	J^{π}[†]	E(level)[#][@]	J^{π}[†]	E(level)[#][@]	J^{π}[†]	E(level)[#][@]	J^{π}[†]
1495.34 *13*	$(1^+,2,3,4^+)$	1579.8 *3*	$(1^-,2,3^-)$	2041.1 *3*	(2^+)	2138.3 *6*	2^+
1507.14 *17*	$(2^+,3^-)$	1911.82 *16*	$1,2^+$	2107.93 *19*	$(2^+,3,4^+)$	2161.3 *5*	2^+
1518.87? *21*	$(0^+,1,2,3^-)$	1974.61 *24*	$1,2^+$	2110.8 *4*	$(2,3^-)$	2168.2 *7*	$(2^+,3,4^+)$

[†] From 1998Gu09, up to the (3^+) level at 1070 keV. J^{π} for higher levels are from 1982Ru04. The conversion electron and the fast timing data confirm the previously tentatively assigned spins.

[‡] From 1998Gu09 from $\beta\gamma\gamma$(t) method, except otherwise noted.

[#] From a least-squares fit to the Eγ.

[@] A 0^+ level at 981.1 keV is proposed by 1998Gu09 based on observing electron peak at 150.0 keV. The peak is interpreted as the K-line of 259.9 keV, E0 transition. The upper limit of Iγ of the transition is 0.3 with respect to Iγ(Eγ=140.86). Further support for this transition comes from the measured α(K/L1+L2) of 4.3(14) that is comparable to the theoretical prediction of 5.30. The state is not placed in the level scheme since no evidence for γ-rays connecting any other level. For details see the discussion in 1998Gu09.

[&] Band(A): $K^{\pi}=0^+$ g.s. band.

[a] Band(B): $K^{\pi}=0^-$ octupole-vibrational band.

[b] Band(C): K^{π}=second 0^+ band.

[c] Band(D): K^{π}=2+? band.

[d] Band(E): K^{π}=second 2^+ band.

β^- radiations

E(decay)	E(level)	Iβ^-[†][‡]	Log *ft*	Comments
(2259 *14*)	2168.2	0.89 *10*	7.17 *6*	av Eβ=827.0 *59*
(2266 *14*)	2161.3	2.29 *24*	6.76 *5*	av Eβ=829.8 *59*
(2289 *14*)	2138.3	1.22 *13*	7.05 *5*	av Eβ=839.4 *59*
(2316 *14*)	2110.8	5.4 *6*	6.43 *5*	av Eβ=850.8 *59*
(2319 *14*)	2107.93	1.05 *12*	7.14 *6*	av Eβ=852.0 *59*
(2386 *14*)	2041.1	1.89 *18*	6.93 *5*	av Eβ=879.9 *59*
(2452 *14*)	1974.61	1.79 *17*	7.00 *5*	av Eβ=907.6 *59*
(2515 *14*)	1911.82	2.34 *23*	6.93 *5*	av Eβ=933.9 *59*
(2847 *14*)	1579.8	1.38 *25*	7.36 *8*	av Eβ=1073.3 *59*
(2908[#] *14*)	1518.87?	1.38 *25*	7.40 *8*	av Eβ=1099.0 *59*
(2920 *14*)	1507.14	0.55 *10*	7.81 *8*	av Eβ=1103.9 *59*
(2932 *14*)	1495.34	0.32 *6*	8.05 *9*	av Eβ=1108.9 *59*
(2955 *14*)	1471.75	0.67 *7*	7.74 *5*	av Eβ=1118.8 *59*
(3078 *14*)	1349.5	0.49 *6*	9.33^{1u} *6*	av Eβ=1128.6 *59*
(3189 *14*)	1238.5	1.64 *16*	7.48 *5*	av Eβ=1217.4 *60*
(3207 *14*)	1219.97	0.12 *6*	8.63 *22*	av Eβ=1225.3 *60*
(3245 *14*)	1182.26	0.62 *6*	7.93 *5*	av Eβ=1241.2 *60*
(3269 *14*)	1157.59	1.11 *13*	7.69 *6*	av Eβ=1251.7 *60*
(3318 *14*)	1109.10	0.64 *9*	7.96 *7*	av Eβ=1272.2 *60*
(3340 *14*)	1087.28	2.13 *23*	7.45 *5*	av Eβ=1281.5 *60*
(3357 *14*)	1070.23	3.6 *8*	7.23 *10*	av Eβ=1288.7 *60*
(3374 *14*)	1052.78	1.30 *15*	7.68 *6*	av Eβ=1296.1 *60*
(3385 *14*)	1042.01	0.21 *4*	8.48 *9*	av Eβ=1300.7 *60*
(3414 *14*)	1013.24	2.8 *4*	7.37 *7*	av Eβ=1312.9 *60*
(3528 *14*)	898.85	1.7 *8*	7.64 *21*	av Eβ=1361.4 *60*
(3547 *14*)	880.30	0.19 *5*	10.11^{1u} *12*	av Eβ=1325.9 *60*
(3581 *14*)	846.14	3.0 *3*	7.42 *5*	av Eβ=1383.8 *60*
(3656 *14*)	770.71	1.85 *19*	7.66 *5*	av Eβ=1415.8 *60*

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^{228}Fr β^- decay 1998Gu09,1982Ru04,1982RuZW (continued)

β^- radiations (continued)

E(decay)	E(level)	Iβ^-[†‡]	Log *ft*	Comments
(3890 *14*)	537.49	7.4 *13*	7.17 *8*	av Eβ=1514.9 *60*
(3953 *14*)	474.18	7.16 *6*	7.209 *14*	av Eβ=1541.8 *60*
(4222 *14*)	204.68	7.8 *18*	8.94^{1u} *11*	av Eβ=1614.5 *61*
(4363 *14*)	63.823	22 *8*	6.89 *16*	av Eβ=1716.2 *60*
(4427 *14*)	0	12 *11*	8.9^{1u} *4*	av Eβ=1702.8 *61* Iβ^-: from log $f^{1u}t\geq8.5$.

[†] The Iβ from I(γ+ce) imbalance at each level with Iβ(g.s.)<24% from log $f^{1u}t>8.5$.

[‡] Absolute intensity per 100 decays.

[#] Existence of this branch is questionable.

γ(^{228}Ra)

Iγ normalization: From ΣI(γ+ce)(g.s.)=88 *12* (Iβ(g.s.)<24 from log $f^{1u}t\geq$8.5). Note that 1982Ru04 adopt Iβ(g.s.)=0 on the assumption that J(^{228}Fr)=3. J=2 was determined in a later experiment.

Iγ normalization: There has also been a suggestion that the 63.8γ may be a doublet including a weak 63.31γ from the 537.49 level. From intensity balance I(63.3γ)<1.8 which would make I(63.8γ)>15.7 and the normalization factor <0.0593. This limit is barely outside the uncertainty of the normalization factor of 0.0534 *46*.

E$_\gamma$[†]	I$_\gamma$[†][b]	E$_i$(level)	J$^\pi_i$	E$_f$	J$^\pi_f$	Mult.[a]	α[c]	I$_{(\gamma+ce)}$[b]	Comments
63.83[#] *2*	17.5 *15*	63.823	2^+	0	0^+	E2	81.9		α(L)=59.9; α(M)=16.2; α(N+..)=5.82 Mult.: α(exp)=133 *40* (from I(322γ)(63.8γ)/I(322γ)(141γ), assuming the 141γ is E2). Mult.: from (L1+L2)/L3/M/(N+...)=100/83.5 *23*/60 *4*/18.7 *20*; theory: (100/82.5/50/15.6) for E2 γ-ray (1998Gu09).
140.86[#] *2*	100 *9*	204.68	4^+	63.823	2^+	E2	2.30		B(E2)$\downarrow$=17.16$\times10^3$ *37*; B(E2)(W.u.)=207 *4* α(K)=0.287; α(L)=1.47; α(M)=0.400; α(N+..)=0.145 Mult.: (L1+L2)/L3/M/(N+...)=100/57.4 *34*/39.6 *27*/13.6 *16*; theory: (100/56.9/37.7/15.1),α(K)exp=0.27 *5*;α(K)theory=0.29 for E2 (1998Gu09).
167.1[@] *3*	<0.5[@]	1013.24	2^+	846.14	2^+	E0[&]		≈7.4	I$_{(\gamma+ce)}$: I(γ+ce)/Iγ(949)≈0.095 from I(K x ray) in $\gamma\gamma$ (1982RuZW).
171.4 *1*	1.8 *2*	1070.23	(3^+)	898.85	(3^+)	E0+M1+E2[&]	16 *7*		Mult.: From α(L1+L2)(exp)=1.0 *3*; theory: 0.017 for E1, 0.41 for E2, and 0.53 for M1. These values reveal strong component of E0 (1998Gu09). α: from α(K)exp (value not given) from I(K x ray) in $\gamma\gamma$ and α/α(K) (theory, value not given).
172.4 *2*	0.6 *1*	1052.78	(2^+,3,4^+)	880.30	4^+				
206.98 *4*	4.7 *4*	411.68	(6^+)	204.68	4^+	[E2]	0.527		α(K)=0.154; α(L)=0.274; α(M)=0.0737; α(N+..)=0.0264
224.35 *8*	2.3 *2*	880.30	4^+	655.96	(5^-)	[E1]	0.0693		α(K)=0.0554; α(L)=0.0105; α(M)=0.00251; α(N+..)=0.00087
233.25 *4*	7.0 *6*	770.71	2^+	537.49	3^-	[E1]	0.0632		α(K)=0.0506; α(L)=0.0096; α(M)=0.00228; α(N+..)=0.00079
244.4 *1*	0.9 *2*	655.96	(5^-)	411.68	(6^+)	[E1]	0.0567		α(K)=0.0454; α(L)=0.00853; α(M)=0.00203; α(N+..)=0.00071
247.01 *8*	2.1 *2*	721.19	0^+	474.18	1^-	[E1]	0.0553		α(K)=0.0443; α(L)=0.00831; α(M)=0.00198; α(N+..)=0.00069
296.53 *5*	7.6 *7*	770.71	2^+	474.18	1^-	[E1]	0.0363		α(K)=0.0293; α(L)=0.00536; α(M)=0.00128; α(N+..)=0.00044
332.91 *5*	47 *3*	537.49	3^-	204.68	4^+	E1	0.0280		B(E1)(W.u.)$\geq1.5\times10^{-4}$ α(K)=0.0226; α(L)=0.00409; α(M)=0.00097; α(N+..)=0.00034 Mult.: α(K)exp=0.032 *7*;α(K)theory=0.023 for E1 (1998Gu09).
342.88 *6*	4.8 *4*	880.30	4^+	537.49	3^-	[E1]	0.0263		α(K)=0.0212; α(L)=0.00382; α(M)=0.00091; α(N+..)=0.00032

γ(^{228}Ra) (continued)

E_γ[†]	I_γ[†b]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[a]	α[c]	Comments
^{x}365.64 *6*	5.2 *4*							
^{x}377.5 *2*	0.9 *2*							
^{x}379.0 *2*	1.0 *2*							
^{x}405.91 *8*	3.2 *3*							
410.40 *6*	115 *6*	474.18	1^-	63.823	2^+	E1	0.0179	B(E1)(W.u.)≥1.5×10^{-4} α(K)=0.0145; α(L)=0.00255; α(M)=0.00060; α(N+..)=0.00021 Mult.: α(K)exp=0.017 *3* (1998Gu09);α(K)theory=0.015 for E1.
422.3 *2*	1.5 *2*	1579.8	$(1^-,2,3^-)$	1157.59	$(2^+,3,4^+)$			
425.1 *1*	1.1 *2*	1495.34	$(1^+,2,3,4^+)$	1070.23	(3^+)			
451.20 *6*	18.6 *10*	655.96	(5^-)	204.68	4^+	[E1]	0.0147	α(K)=0.0119; α(L)=0.00207; α(M)=0.00049; α(N+..)=0.00017
468.4 *1*	1.0 *3*	880.30	4^+	411.68	(6^+)	[E2]	0.0459	α(K)=0.0290; α(L)=0.0126; α(M)=0.00324; α(N+..)=0.00116
473.7 *1*	187[‡] *20*	537.49	3^-	63.823	2^+	[E1]	0.0133	B(E1)(W.u.)≥2.2×10^{-4} α(K)=0.0108; α(L)=0.00187; α(M)=0.00044; α(N+..)=0.00015
474.0 *1*	140[‡] *26*	474.18	1^-	0	0^+	[E1]	0.0133	B(E1)(W.u.)≥1.2×10^{-4} α(K)=0.0108; α(L)=0.00187; α(M)=0.00044; α(N+..)=0.00015
493.9 *1*	2.4 *2*	1507.14	$(2^+,3^-)$	1013.24	2^+			
498.8 *1*	1.6 *2*	1219.97	(2^+)	721.19	0^+	[E2]	0.0394	α(K)=0.0256; α(L)=0.0103; α(M)=0.00164; α(N+..)=0.00094
515.2 *2*	3.2 *8*	1052.78	$(2^+,3,4^+)$	537.49	3^-			
526.22 *8*	2.7 *2*	1182.26	$(3^-,4^+)$	655.96	(5^-)			
532.68 *8*	2.0 *2*	1070.23	(3^+)	537.49	3^-	[E1]	0.0105	α(K)=0.0085; α(L)=0.00146
549.83 *7*	23.8 *17*	1087.28	$(1^-,2,3^-)$	537.49	3^-			
551.9 *1*	1.8 *3*	1518.87?	$(0^+,1,2,3^-)$	966.99	$(2^+,4^+)$			
565.8 *1*	6.4 *4*	770.71	2^+	204.68	4^+	[E2]	0.0293	α(K)=0.0200; α(L)=0.00698
567.8 *1*	10.0 *5*	1042.01	(0^+)	474.18	1^-			
^{x}595.8 *1*	2.0 *2*							
600.8 *1*	3.7 *2*	2107.93	$(2^+,3,4^+)$	1507.14	$(2^+,3^-)$			
613.06 *8*	25.2 *13*	1087.28	$(1^-,2,3^-)$	474.18	1^-			
625.6 *1*	3.3 *2*	1471.75	$(1^-,2,3,4^+)$	846.14	2^+			
644.9 *1*	8.9 *5*	1182.26	$(3^-,4^+)$	537.49	3^-			
657.4 *2*	4.8 *3*	721.19	0^+	63.823	2^+	[E2]	0.0211	α(K)=0.0151; α(L)=0.00453
675.6 *5*	2.1 *3*	880.30	4^+	204.68	4^+	E0+M1+E2	1.3 *3*	α(K)=0.04 *3*; α(L)=0.008 *4* Mult.: α(K)exp=1.3 *3*;α(K)theory=0.0.0054 for E1, 0.068 for M1, and 0.014 for E2 (1998Gu09).
694.2 *1*	11.2 *6*	898.85	(3^+)	204.68	4^+	[M1,E2]	0.05 *3*	α(K)=0.039 *25*; α(L)=0.008 *4*
706.9 *1*	9.1 *5*	770.71	2^+	63.823	2^+	E0+M1+E2	0.55 *8*	α(K)=0.037 *24*; α(L)=0.007 *4* Mult.: α(K)exp=0.55 *8*;α(K)theory=0.0.0049 for E1, 0.061 for M1, and 0.013 for E2 (1998Gu09).
(721.2 *5*)		721.19	0^+	0	0^+	E0		E_γ: proposed by 1998Gu09 based on conversion electron spectrum. Mult.: α(K)exp≥1.4 ;α(K)theory=0.0048 for E1, 0.057 for M1, and 0.013 for E2 (1998Gu09).
^{x}751.5 *3*	2.9 *3*							
762.4 *2*	11.9 *6*	966.99	$(2^+,4^+)$	204.68	4^+			
764.5 *3*	6.6 *4*	1238.5	$(0^+,1,2,3^-)$	474.18	1^-			

γ(^{228}Ra) (continued)

E$_\gamma$ †	I$_\gamma$ †b	E$_i$(level)	J$^\pi_i$	E$_f$	J$^\pi_f$	Mult.a	αc	Comments
^{x}767.1 *5*	2.4 *4*							
770.7 *1*	12.0 *6*	770.71	2^+	0	0^+	[E2]	0.0150	α(K)=0.0113; α(L)=0.00296
782.3 *1*	38.8 *20*	846.14	2^+	63.823	2^+	M1+E2	0.034 *20*	α(K)=0.029 *18*; α(L)=0.006 *3* Mult.: α(K)exp=0.012 *5*;α(K)theory=0.0041 for E1, 0.046 for M1, and 0.010 for E2 (1998Gu09).
^{x}790.5 *5*	1.9 *2*							
816.5 *3*	8.7 *5*	1974.61	$1,2^+$	1157.59	$(2^+,3,4^+)$			
821.7 *5*	3.8 *3*	2041.1	(2^+)	1219.97	(2^+)	[M1,E2]	0.030 *18*	α(K)=0.025 *15*; α(L)=0.0049 *24*
824.4 *5*	4.4 *3*	1911.82	$1,2^+$	1087.28	$(1^-,2,3^-)$			
835.0 *2*	53 *3*	898.85	(3^+)	63.823	2^+	[M1,E2]	0.031 *18*	α(K)=0.024 *15*; α(L)=0.0047 *24*
846.2 *2*	27.8 *14*	846.14	2^+	0	0^+	[E2]	0.0125	α(K)=0.0095; α(L)=0.00234
^{x}852.5 *5*	2.9 *3*							
865.8 *2*	18.0 *9*	1070.23	(3^+)	204.68	4^+	[M1,E2]	0.027 *15*	α(K)=0.022 *14*; α(L)=0.0043 *21*
869.7 *2*	6.1 *4*	1911.82	$1,2^+$	1042.01	(0^+)			
898.7 *2*	15.1 *8*	1911.82	$1,2^+$	1013.24	2^+			
904.4 *2*	19.0 *10*	1109.10	$(2^+,3,4^+)$	204.68	4^+			
^{x}919.5 *3*	6.2 *5*							
922.3 *3*	10.5 *6*	1974.61	$1,2^+$	1052.78	$(2^+,3,4^+)$			
^{x}925.8 *2*	19.8 *10*							
934.3 *2*	6.3 *4*	1471.75	$(1^-,2,3,4^+)$	537.49	3^-			
937.6 *5*	2.7 *3*	1349.5	(4^+)	411.68	(6^+)	[E2]	0.0103	α(K)=0.00789; α(L)=0.00182
949.4 *2*	78 *4*	1013.24	2^+	63.823	2^+	[M1,E2]	0.022 *13*	α(K)=0.018 *10*; α(L)=0.0034 *16*
952.9 *3*	8.6 *6*	1157.59	$(2^+,3,4^+)$	204.68	4^+			
^{x}983.6 *3*	6.7 *4*							
989.8 *3*	31.1 *16*	1052.78	$(2^+,3,4^+)$	63.823	2^+			
1001.6 *5*	3.3 *5*	2110.8	$(2,3^-)$	1109.10	$(2^+,3,4^+)$			
^{x}1005.0 *5*	9.9 *20*							
1006.5 *5*	17.1 *25*	1070.23	(3^+)	63.823	2^+			
1013.7^d *10*	2.0^d *5*	1013.24	2^+	0	0^+			
1013.7^d *10*	2.0^d *5*	1911.82	$1,2^+$	898.85	(3^+)			
1015.7 *8*	4.5 *10*	1219.97	(2^+)	204.68	4^+			
1024.4 *10*	4.8 *10*	2110.8	$(2,3^-)$	1087.28	$(1^-,2,3^-)$			
1027.2 *5*	4.9 *10*	2041.1	(2^+)	1013.24	2^+			
1033.0 *10*	7.9 *15*	1507.14	$(2^+,3^-)$	474.18	1^-			
1041.6 *8*	10 *2*	1579.8	$(1^-,2,3^-)$	537.49	3^-			
1043.2 *8*	20 *4*	1518.87?	$(0^+,1,2,3^-)$	474.18	1^-			
^{x}1048.8 *10*	5.4 *5*							
1052.4 *10*	3.7 *5*	2161.3	2^+	1109.10	$(2^+,3,4^+)$			
^{x}1083.2 *10*	5.2 *5*							
1092.8 *5*	22.4 *12*	1157.59	$(2^+,3,4^+)$	63.823	2^+			
1096.9 *8*	14.8 *8*	2110.8	$(2,3^-)$	1013.24	2^+			
1105.6 *8*	11.6 *7*	1579.8	$(1^-,2,3^-)$	474.18	1^-			
^{x}1137.3 *10*	4.3 *5*							

γ(^{228}Ra) (continued)

E$_\gamma$[†]	I$_\gamma$[†b]	E$_i$(level)	J$_i^\pi$	E$_f$	J$_f^\pi$
1145.0 *5*	6.4 *6*	1349.5	(4^+)	204.68	4^+
1162.0 *10*	6.5 *6*	2041.1	(2^+)	880.30	4^+
1171.0 *10*	7.4 *6*	2138.3	2^+	966.99	$(2^+,4^+)$
1174.2 *5*	24.1 *12*	1238.5	$(0^+,1,2,3^-)$	63.823	2^+
^{x}1180.3 *10*	3.0 *5*				
1190.8 *15*	4.1 *8*	1911.82	$1,2^+$	721.19	0^+
1194.2[d] *15*	3.3[d] *6*	2041.1	(2^+)	846.14	2^+
1194.2[d] *15*	3.3[d] *6*	2161.3	2^+	966.99	$(2^+,4^+)$
^{x}1206.0 *15*	3.4 *6*				
1211.5 *15*	2.5 *5*	2110.8	$(2,3^-)$	898.85	(3^+)
^{x}1224.6 *5*	8.6 *5*				
^{x}1234.9 *15*	3.5 *7*				
^{x}1246.6 *10*	7.4 *5*				
^{x}1259.5 *10*	6.4 *5*				
1303.1 *10*	3.7 *4*	1507.14	$(2^+,3^-)$	204.68	4^+
^{x}1310.9 *10*	5.3 *5*				
1318.8 *10*	3.7 *7*	2041.1	(2^+)	721.19	0^+
^{x}1332.6 *10*	5.7 *5*				
1340.2 *10*	5.0 *10*	2110.8	$(2,3^-)$	770.71	2^+
^{x}1342.7 *10*	3.0 *6*				
^{x}1359.2 *15*	2.3 *4*				
1390.8 *10*	4.0 *4*	2161.3	2^+	770.71	2^+
1406.4 *15*	3.0 *6*	1471.75	$(1^-,2,3,4^+)$	63.823	2^+
^{x}1429.2 *15*	3.2 *6*				
1432.9 *15*	4.8 *8*	1495.34	$(1^+,2,3,4^+)$	63.823	2^+
1454.7 *10*	4.0 *4*	1518.87?	$(0^+,1,2,3^-)$	63.823	2^+
^{x}1468.0 *10*	3.9 *4*				
^{x}1484.8 *15*	3.6 *7*				
^{x}1487.7 *15*	2.7 *5*				
^{x}1491.8 *15*	3.0 *3*				
1501.6 *15*	3.8 *4*	1974.61	$1,2^+$	474.18	1^-
1514.9 *15*	2.7 *3*	1579.8	$(1^-,2,3^-)$	63.823	2^+
^{x}1532.2 *15*	4.9 *4*				
1566.9 *10*	13.0 *8*	2041.1	(2^+)	474.18	1^-
1572.4 *10*	25.6 *16*	2110.8	$(2,3^-)$	537.49	3^-
1601.1 *15*	4.3 *8*	2138.3	2^+	537.49	3^-
1631.0 *15*	2.6 *4*	2168.2	$(2^+,3,4^+)$	537.49	3^-
1637.7 *10*	4.4 *4*	2110.8	$(2,3^-)$	474.18	1^-
^{x}1644.2 *10*	5.8 *5*				
^{x}1656.7 *15*	3.0 *3*				
1663.7 *15*	3.9 *5*	2138.3	2^+	474.18	1^-
^{x}1695.6 *10*	4.3 *4*				
^{x}1715.5 *10*	5.4 *4*				
^{x}1725.9 *15*	2.8 *3*				
^{x}1754.8 *10*	6.2 *12*				
^{x}1800.5 *15*	3.2 *3*				
^{x}1811.3 *10*	8.6 *6*				
^{x}1844.8 *10*	10.4 *7*				
1847.5 *10*	7.0 *10*	1911.82	$1,2^+$	63.823	2^+
^{x}1858.8 *10*	3.1 *3*				
^{x}1865.5 *15*	2.0 *5*				
^{x}1879.3 *15*	2.1 *6*				
^{x}1885.9 *10*	8.3 *6*				
1902.8 *10*	2.9 *3*	2107.93	$(2^+,3,4^+)$	204.68	4^+
1911.5[d] *10*	5.2[d] *4*	1911.82	$1,2^+$	0	0^+
1911.5[d] *10*	5.2[d] *4*	1974.61	$1,2^+$	63.823	2^+
^{x}1930.5 *10*	7.9 *5*				
1934.8 *15*	3.8 *3*	2138.3	2^+	204.68	4^+
^{x}1943.4 *10*	5.2 *4*				
1955.9 *10*	5.2 *4*	2161.3	2^+	204.68	4^+
1963.0 *10*	4.7 *4*	2168.2	$(2^+,3,4^+)$	204.68	4^+
1973.8 *10*	5.3 *4*	1974.61	$1,2^+$	0	0^+
^{x}1991.5 *10*	5.5 *10*				
^{x}1996.0 *15*	5.2 *10*				
^{x}2007.0 *10*	4.4 *7*				
^{x}2033.7 *10*	14.2 *14*				
2043.5 *10*	13.0 *13*	2107.93	$(2^+,3,4^+)$	63.823	2^+
2047.8 *10*	41 *4*	2110.8	$(2,3^-)$	63.823	2^+
^{x}2063.2 *10*	4.3 *4*				
^{x}2077.6 *10*	11.1 *11*				
2097.4 *10*	23.1 *23*	2161.3	2^+	63.823	2^+
2104.7 *10*	9.4 *9*	2168.2	$(2^+,3,4^+)$	63.823	2^+
^{x}2114.1 *10*	5.1 *5*				
^{x}2131.4 *10*	7.7 *6*				
2137.8 *15*	3.4 *4*	2138.3	2^+	0	0^+
^{x}2156.0 *15*	2.8 *4*				
2162.4 *15*	3.5 *5*	2161.3	2^+	0	0^+
^{x}2170.7 *15*	2.5 *4*				
^{x}2177.8 *10*	6.4 *7*				
^{x}2181.7 *15*	3.1 *5*				
^{x}2193.8 *15*	1.6 *3*				
^{x}2206.7 *15*	2.3 *3*				
^{x}2219.8 *15*	1.9 *5*				
^{x}2283.4 *15*	3.1 *5*				
^{x}2286.6 *15*	4.4 *5*				
^{x}2392.3 *10*	4.5 *6*				

γ(^{228}Ra) (continued)

E_γ[†]	I_γ[†b]	E_i(level)
[x]2414.2 *10*	10.8 *9*	
[x]2442.9 *15*	3.6 *4*	
[x]2454.3 *15*	3.9 *4*	

[†] From 1982RuZW, except otherwise noted.

[‡] From coincidence spectrum.

[#] Weighted average of value from ^{228}Fr β^- decay and authors′ unpublished data from ^{232}Th α decay. Neither value is given separately.

[@] From coincidence measurements (1982RuZW).

[&] Existence and multipolarity of 167γ and E0 component in 171γ inferred from excess of K x ray in coincidence spectrum gated by the 782, 835 and 846 γ′s (1982Ru04).

[a] From 1998Gu09 based on conversion electron, except otherwise noted.

[b] For absolute intensity per 100 decays, multiply by 0.0534 *46*.

[c] 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.

[d] Multiply placed with undivided intensity.

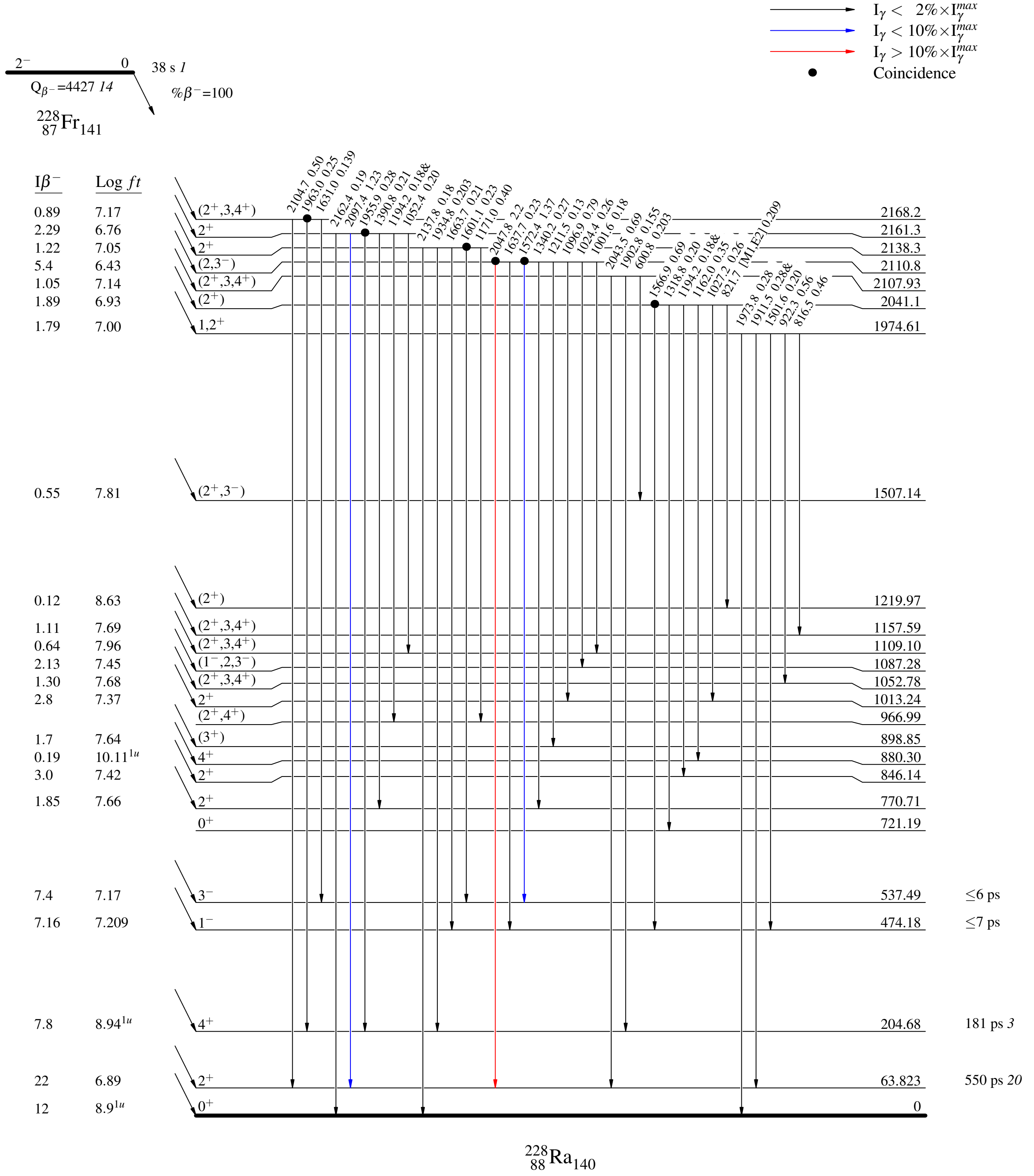
[x] γ ray not placed in level scheme.

^{228}Fr β^- decay 1998Gu09,1982Ru04,1982RuZW

Decay Scheme

Intensities: $I_{(\gamma+ce)}$ per 100 parent decays
& Multiply placed: undivided intensity given

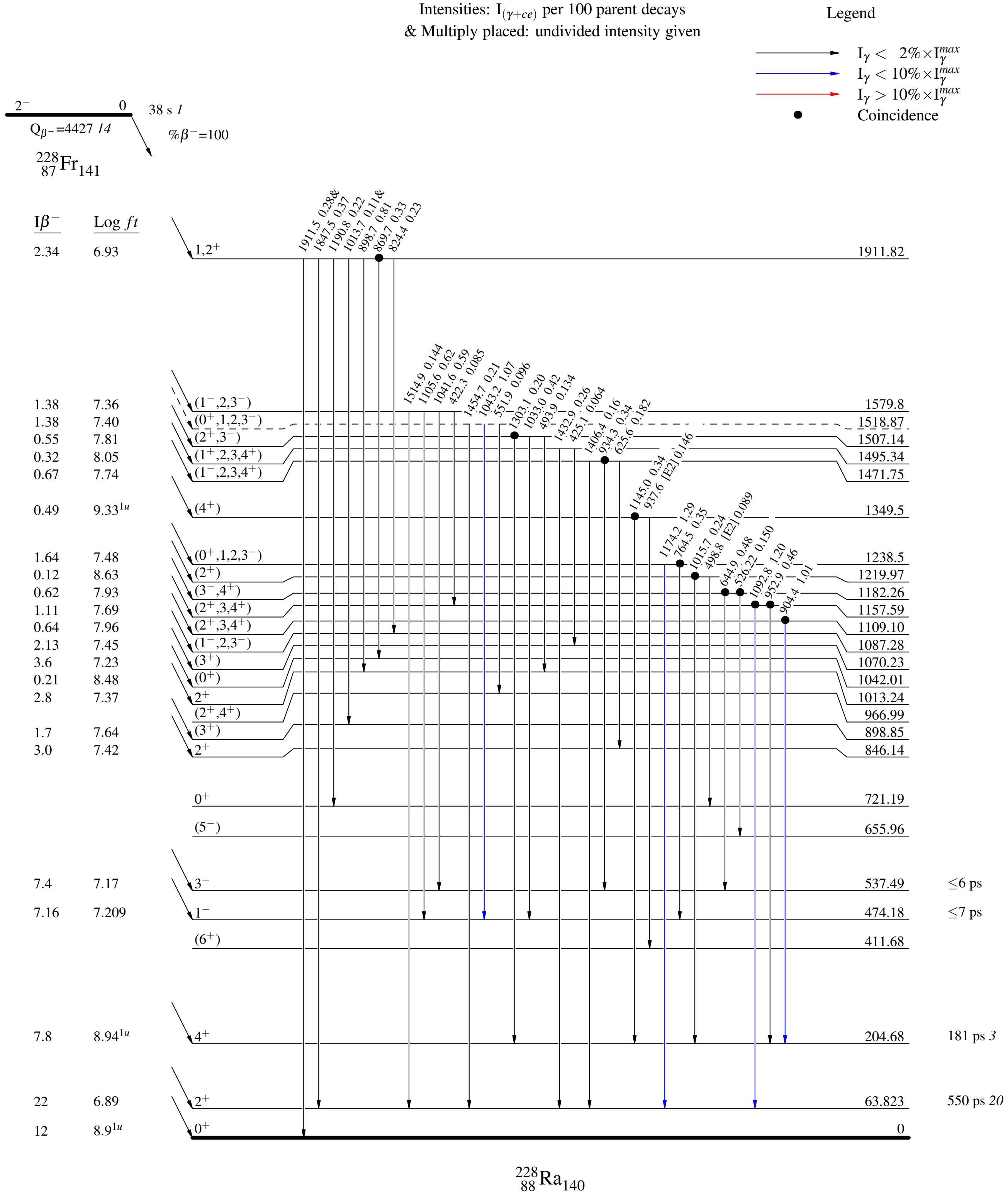
Legend



^{228}Fr β^- decay 1998Gu09,1982Ru04,1982RuZW

Decay Scheme (continued)

Intensities: $I_{(\gamma+ce)}$ per 100 parent decays
& Multiply placed: undivided intensity given

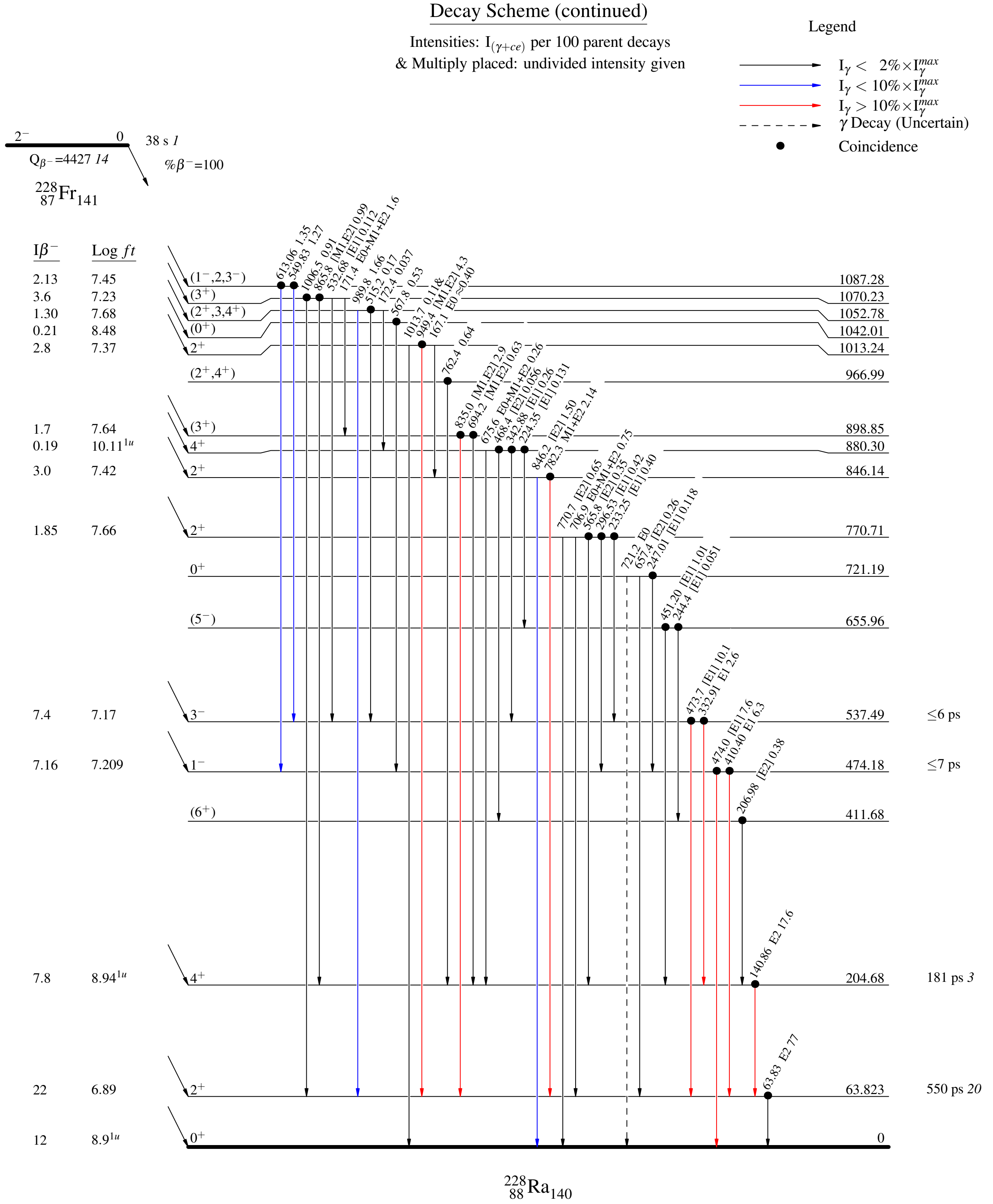


^{228}Fr β^- decay 1998Gu09,1982Ru04,1982RuZW

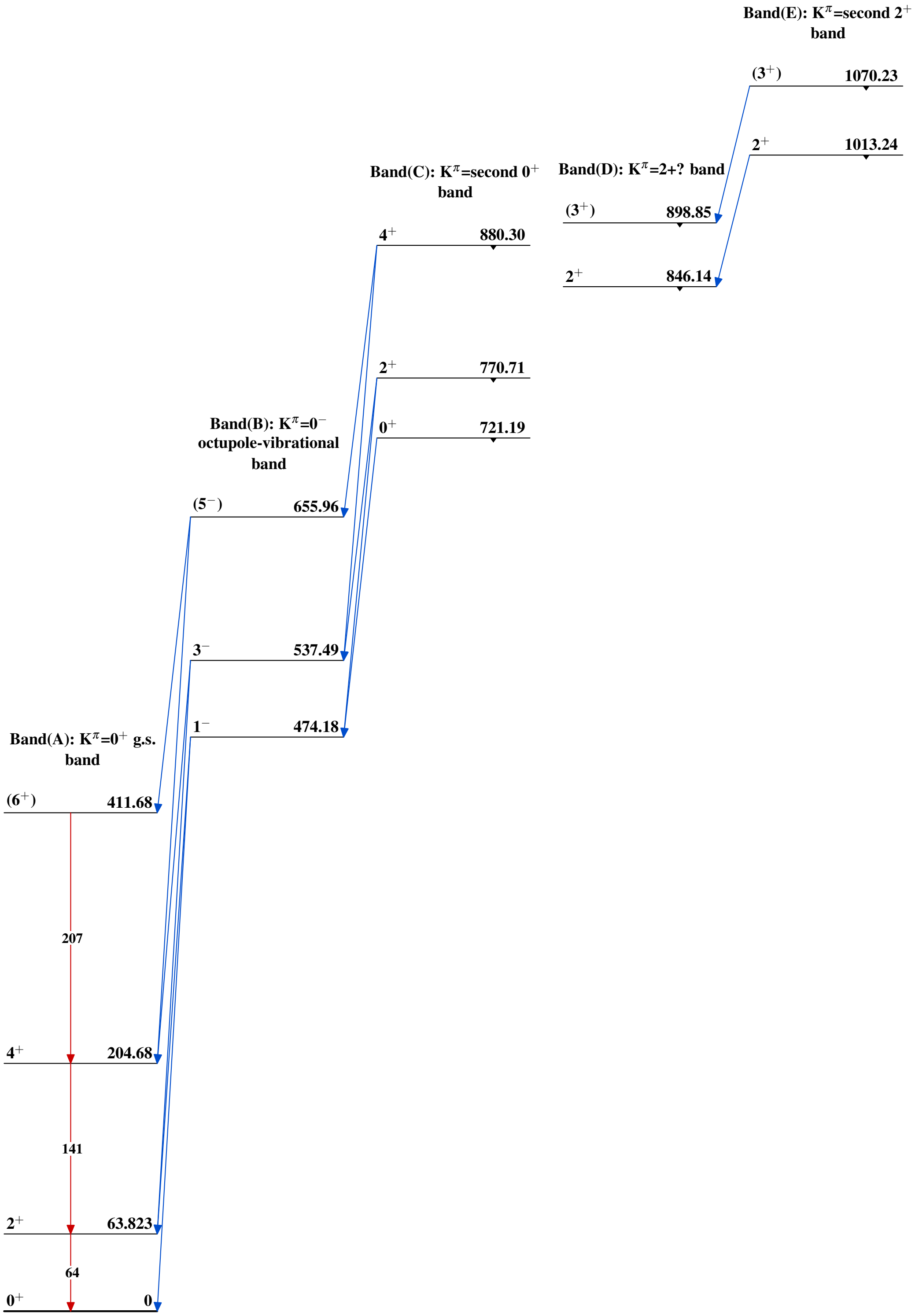
Decay Scheme (continued)

Intensities: $I_{(\gamma+ce)}$ per 100 parent decays

& Multiply placed: undivided intensity given



^{228}Fr β^- decay 1998Gu09,1982Ru04,1982RuZW



$^{228}_{88}$Ra$_{140}$