^{162}Eu β^- decay: mixed source 2021Wa04,2018Ha19

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	N. Nica	NDS 195,1 (2024)	19-Sep-2023

Parent: ^{162}Eu: E=0.0; J$^\pi$=(6$^+$); T$_{1/2}$=11.4 s *6*; Q(β^-)=5558 *4*; %β^- decay=100

Parent: ^{162}Eu: E=158.4 *24*; J$^\pi$=(3$^-$); Q(β^-)=5558 *4*; %β^- decay=?

^{162}Eu-Q(β^-): From 2021Wa16.

^{162}Eu-J: Proposed by 2021Wa16 (in order to explain the relatively strong β feeding of the 2$^+$, 3$^+$, 4$^+$, 6$^+$ and 6$^-$ levels) to be: 6$^+$, ν5/2[413]$\otimes\nu$7/2[633] for g.s. and 3$^-$, ν5/2[413]$\otimes\nu$1/2[521] for isomer, respectively, by comparing with neighboring nuclei (see 2021Wa04 for the list of them).

^{162}Eu-T$_{1/2}$: From ^{162}Eu Adopted Levels, Gammas dataset. The following values (all in seconds) were measured by 2021Wa04: 12.3 *6* (205γ(t) and 330γ(t)), 12.0 *2* (165γ(t)), 11.6 *4* (254γ(t)), 11.7 *12* (863γ(t)), 10.8 *5* (72γ(t)) and 11.6 *3* (K$_\alpha$(t)). According to 2021Wa04, 205γ(t) and 330γ(t) were expected to give the T$_{1/2}$ of the isomeric ^{162}Eu 158.4 state and the others the T$_{1/2}$ of the g.s. As the two groups are not statistically different, 2021Wa04 concluded that either T$_{1/2}$'s of g.s. and isomeric states are very close, or that the isomeric state is not seen in the data of this experiment.

2021Wa04 compiled for XUNDL database by N. Nica (Texas A&M University).

2021Wa04: 50 MeV proton beam on UCx target at the Holifield Radioactive Ion Beam Facility (HRIBF) at ORNL. Induced fission fragments selected by two-stage dipole magnet separator implanted in moving tape and displaced ≈50 cm to measuring low background station of four HPGe detectors for γ decay and two plastic scintillators for β decay. Measured $\beta\gamma$, $\beta\gamma\gamma$, γ(t) and K$_\alpha$(t) spectra. Deduced common level scheme of ^{162}Eu β^- g.s. and 158.4 isomer decays. Performed Projected Shell Model calculations.

2018Ha19, 2019KoZX: ^{162}Eu produced from CARIBU source facility consisting of ≈1 Ci ^{252}Cf inside large volume gas catcher. Ions extracted in charge state 2$^+$, mass separated, and collected in an rf quadrupole cooler/buncher. Beam purification using multireflection time-of-flight mass separator (δ-tof). Measured cyclotron frequencies using Canadian Penning Trap (CPT) with phase-imaging ion-cyclotron-resonance (PI-ICR) technique. Used β-decay counting station composed of SATURN moving tape system, four scintillator detectors for β-particle detection, and the X-Array spectrometer with four Ge clover detectors and one low-energy photon spectrometer for γ-ray detection.

2010NaZY: ^{162}Eu produced by 32-MeV proton-induced fission on UCx 630 mg/cm^2 target at Japan Atomic Energy Agency-Tokai tandem accelerator facility and the isotope separator on-line (ISOL). Reaction products were ionized in the ion source, extracted and mass-separated by ISOL. Mass-separated ^{162}Eu ions were collected to aluminized Mylar tape system and transported to the detection location by moving the tape every 20 s. The detection location was equipped with 1-mm thick plastic scintillator and 5-mm thick BaF$_2$ scintillator to detect β and γ rays, respectively, plus a Ge detector to monitor implanted beam. Time signals of plastic scintillator and BaF$_2$ scintillator generated by constant fraction differential discriminators were fed into a time-to-amplitude converter (TAC) in order to measure the time intervals in between them. Lifetimes deduced from the slope of time interval spectra.

Additional information 1.

The existence of g.s. and 158.4 isomeric state was established by two precise independent Penning trap atomic mass measurements done by 2020Or03 and 2020Vi04, with T$_{1/2}$ values associated with the two states: 11.0 s *10* (weighted average of 10.6 s *10* (1987Gr12) and 11.8 s *14* (2017Wu04)) for the g.s., and 15.0 s *5* (2018Ha19) for the isomer.

However, a new T$_{1/2}$ measurement done by 2021Wa04 using the decay curves of five γ rays plus the K$_\alpha$ x rays from ^{162}Eu β^- decay found all six T$_{1/2}$ fit values rather closely distributed around their weighted value of 11.8 s *2*, including the 12.3 s *6* value measured from 205γ(t)+330γ(t) decay and counted by 2021Wa04 as best candidate for T$_{1/2}$ of the isomeric state. Based on their measurement, 2021Wa04 concluded that either T$_{1/2}$'s of g.s. and isomeric states are very close, or that the isomeric state is not seen in the data of this experiment. Consequently their ^{162}Eu β^- decay level scheme (see the decay dataset with this name at ^{162}Gd in this evalution) corresponds most likely to both g.s. and isomer decays (unless only g.s. of ^{162}Eu was populated, which is difficult to prove with the existing data).

It is difficult to assess the data of 2018Ha19 and 2021Wa04. One can observe that the decay curve of 2018Ha19 (Fig. 3(b), corresponding to 165γ+254γ decay) spans a larger interval of counts than the decay curve of 2021Wa04 (Fig. 7(b), corresponding to 165γ decay) which would favor the overall conclusions of 2018Ha19. However, all six measured T$_{1/2}$ values of 2021Wa04 consistent with an undifferentiated value makes judicious the assessment done by 2021Wa04 that most likely one cannot separate at this stage the β decay schemes of ^{162}Eu g.s. and isomeric state.

For these reasons the level scheme corresponding to the undifferentiated β^- decays of both the g.s. and the 158.4 isomer of ^{162}Eu parent built by 2021Wa04 is presented.

Unless mentioned otherwise all experimental data are from 2021Wa04.

^{162}Eu β^- decay: mixed source 2021Wa04,2018Ha19 (continued)

^{162}Gd Levels

E(level)[†]	Jπ[‡]	$T_{1/2}$	Comments
0.0[@]	0^+	8.4 min *2*	$\%\beta^-$=100 $T_{1/2}$,$\%\beta^-$: From the adopted values.
71.68[@] *19*	(2^+)	2.76 ns *6*	$T_{1/2}$: From least-χ^2 fit of β-γ time interval spectrum (2010NaZY).
236.4[@] *3*	(4^+)		
490.1[@] *4*	(6^+)		
826.0[@] *5*	(8^+)		
863.0[&] *3*	2^+[#]		
927.3[&] *3*	(3^+)		
1012.7[&] *3*	(4^+)		
1118.6[&] *3*	(5^+)		
1243.5[&] *4*	(6^+)		
1354.1[c] *3*	(4^+)		configuration: ν3/2[411]⊗ν5/2[413] (2021Wa04).
1388.6[&] *4*	(7^+)		
1427.8[b] *11*	0^+[#]		
1448.6[a] *4*	(6^-)	99 μs *5*	$T_{1/2}$: measured by β time difference with 205γ and 330γ. configuration: ν5/2[523]⊗ν7/2[633] (2021Wa04 and 2018Ha19).
1456.7[c] *4*	(5^+)		
1493.0[b] *7*	(2^+)		
1519.7 *4*			
1579.0[c] *4*	(6^+)		
1581.4[a] *4*	(7^-)		
1645.2[b] *7*	(4^+)		
1701.0[d] *11*	0^+[#]		
1714.5 *5*			
1720.8[c] *4*	(7^+)		
1733.3[a] *4*	(8^-)		
1781.0[d] *11*	(2^+)		
1897.9[b] *7*	(6^+)		
1975.4 *6*			
2014.4 *11*			
2030.4 *11*			
2148?			
2304.7 *11*			
2321.3? *13*			
2337.0 *7*			
2413.7 *11*			
2417.7 *11*			
2590.4 *11*			
2655.1 *11*			
3423.4 *11*			
3510.4 *11*			
3572.7 *11*			
3596.1 *8*			
3660.3 *8*			

[†] From a least-squares fit on Eγ values.
[‡] Tentatively assigned by 2021Wa04 based on band structures, assigned configurations and other theoretical arguments. Same values are adopted.
[#] Firm assignments based on L values measured in ^{160}Gd(t,p) dataset (1986Lo15).

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^{162}Eu β^- decay: mixed source 2021Wa04,2018Ha19 (continued)

^{162}Gd Levels (continued)

@ Band(A): $K^\pi = 0^+$ ground-state band.
& Band(B): $K^\pi = 2^+$ γ-vibrational band.
a Band(C): $K^\pi = (6^-)$ band.
b Band(D): $K^\pi = 0^+$ β-vibrational band.
c Band(E): $K^\pi = (4^+)$ band.
d Band(F): K^π = Second 0^+ band.

γ(^{162}Gd)

E_γ[‡]	I_γ	E_i(level)	J^π_i	E_f	J^π_f	Mult.	α[†]	Comments
64.4[#] *2*	<1	927.3	(3$^+$)	863.0	2$^+$			
71.1 *2*	1.2 *2*	1519.7		1448.6	(6$^-$)			
71.7 *2*	29 *3*	71.68	(2$^+$)	0.0	0$^+$	[E2]	8.85 *16*	α(K)=2.48 *4*; α(L)=4.92 *10*; α(M)=1.164 *23* α(N)=0.259 *5*; α(O)=0.0335 *6*; α(P)=0.0001250 *19*
102.7 *2*	2.6 *6*	1456.7	(5$^+$)	1354.1	(4$^+$)			
122.2 *2*	2.2 *7*	1579.0	(6$^+$)	1456.7	(5$^+$)			
125 *1*	<0.5	1243.5	(6$^+$)	1118.6	(5$^+$)			
133.1 *2*	5.4 *7*	1581.4	(7$^-$)	1448.6	(6$^-$)			
133.1 *2*	0.4 *1*	1714.5		1581.4	(7$^-$)			
141.6 *2*	1.7 *6*	1720.8	(7$^+$)	1579.0	(6$^+$)			
152.1 *2*	1.3 *2*	1733.3	(8$^-$)	1581.4	(7$^-$)			
152.2 *2*	0.1 *1*	1645.2	(4$^+$)	1493.0	(2$^+$)			
164.8 *2*	100 *5*	236.4	(4$^+$)	71.68	(2$^+$)	[E2]	0.428 *6*	α(K)=0.278 *4*; α(L)=0.1162 *17*; α(M)=0.0270 *4* α(N)=0.00605 *9*; α(O)=0.000819 *12*; α(P)=1.523×10^{-5} *22*
191.4 *2*	1.0 *2*	1118.6	(5$^+$)	927.3	(3$^+$)			
205.2 *2*	8.9 *5*	1448.6	(6$^-$)	1243.5	(6$^+$)			
230.7 *3*	0.8 *1*	1243.5	(6$^+$)	1012.7	(4$^+$)			
252.7 *3*	<0.6	1897.9	(6$^+$)	1645.2	(4$^+$)			
253.6 *3*	51 *3*	490.1	(6$^+$)	236.4	(4$^+$)	[E2]	0.1021 *15*	α(K)=0.0756 *11*; α(L)=0.02059 *30*; α(M)=0.00470 *7* α(N)=0.001060 *16*; α(O)=0.0001484 *22*; α(P)=4.58×10^{-6} *7*
264.5 *3*	1.1 *3*	1720.8	(7$^+$)	1456.7	(5$^+$)			
270.0 *3*	0.7 *2*	1388.6	(7$^+$)	1118.6	(5$^+$)			
284.0 *3*	0.8 *2*	1733.3	(8$^-$)	1448.6	(6$^-$)			
329.9 *3*	42 *2*	1448.6	(6$^-$)	1118.6	(5$^+$)			
335.9 *3*	10 *1*	826.0	(8$^+$)	490.1	(6$^+$)	[E2]	0.0428 *6*	α(K)=0.0333 *5*; α(L)=0.00739 *11*; α(M)=0.001665 *24* α(N)=0.000377 *5*; α(O)=5.41×10^{-5} *8*; α(P)=2.121×10^{-6} *30*
341.9 *3*	1.4 *2*	1354.1	(4$^+$)	1012.7	(4$^+$)			
426.5 *3*	5.4 *3*	1354.1	(4$^+$)	927.3	(3$^+$)			
443.4 *3*	0.9 *2*	1456.7	(5$^+$)	1012.7	(4$^+$)			
491.0 *3*	13 *2*	1354.1	(4$^+$)	863.0	2$^+$			
526.8 *4*	9.7 *5*	1975.4		1448.6	(6$^-$)			
529.8 *4*	2.0 *4*	1456.7	(5$^+$)	927.3	(3$^+$)			
628.4 *4*	9.3 *7*	1118.6	(5$^+$)	490.1	(6$^+$)			
691.4 *4*	5.2 *4*	927.3	(3$^+$)	236.4	(4$^+$)			
753.7 *5*	10 *1*	1243.5	(6$^+$)	490.1	(6$^+$)			
755.5 *5*	1.4 *4*	2337.0		1581.4	(7$^-$)			
776.5 *5*	7.1 *6*	1012.7	(4$^+$)	236.4	(4$^+$)			
791.4 *5*	27 *3*	863.0	2$^+$	71.68	(2$^+$)			
838 *1*	1.5 *5*	1701.0	0$^+$	863.0	2$^+$			

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^{162}Eu β^- decay: mixed source 2021Wa04,2018Ha19 (continued)

$\gamma(^{162}$Gd) (continued)

Eγ‡	Iγ	Ei(level)	J^π_i	Ef	J^π_f
855.7 5	29 3	927.3	(3+)	71.68	(2+)
862.9 5	22 1	863.0	2+	0.0	0+
874# 1	<0.2	2321.3?		1448.6	(6−)
881.9 5	44 2	1118.6	(5+)	236.4	(4+)
898.2 5	3.5 4	1388.6	(7+)	490.1	(6+)
918 1	2.8 8	1781.0	(2+)	863.0	2+
940.7 5	0.9 3	1012.7	(4+)	71.68	(2+)
1007.1 10	7.5 6	1243.5	(6+)	236.4	(4+)
1256.6 10	4.8 5	1493.0	(2+)	236.4	(4+)
1339 1	<1	3660.3		2321.3?	
1356.1 10	5.1 12	1427.8	0+	71.68	(2+)
1407.9 10	<0.6	1897.9	(6+)	490.1	(6+)
1408.8 10	<0.6	1645.2	(4+)	236.4	(4+)
1661.5# 10	<0.5	1897.9	(6+)	236.4	(4+)
1778 1	1.5 4	2014.4		236.4	(4+)
1794 1	1.8 5	2030.4		236.4	(4+)
2148# 1	<0.3	2148?		0.0	0+
2165 1	1.6 5	2655.1		490.1	(6+)
2233 1	5.9 19	2304.7		71.68	(2+)
2342 1	2.5 12	2413.7		71.68	(2+)
2346 1	3.0 13	2417.7		71.68	(2+)
2354 1	1.2 4	2590.4		236.4	(4+)
2770 1	1.4 4	3596.1		826.0	(8+)
3106 1	3.4 9	3596.1		490.1	(6+)
3170 1	2.1 6	3660.3		490.1	(6+)
3187 1	2.6 7	3423.4		236.4	(4+)
3274 1	0.7 3	3510.4		236.4	(4+)
3424 1	1.0 4	3660.3		236.4	(4+)
3501 1	4.9 20	3572.7		71.68	(2+)

† Additional information 2.

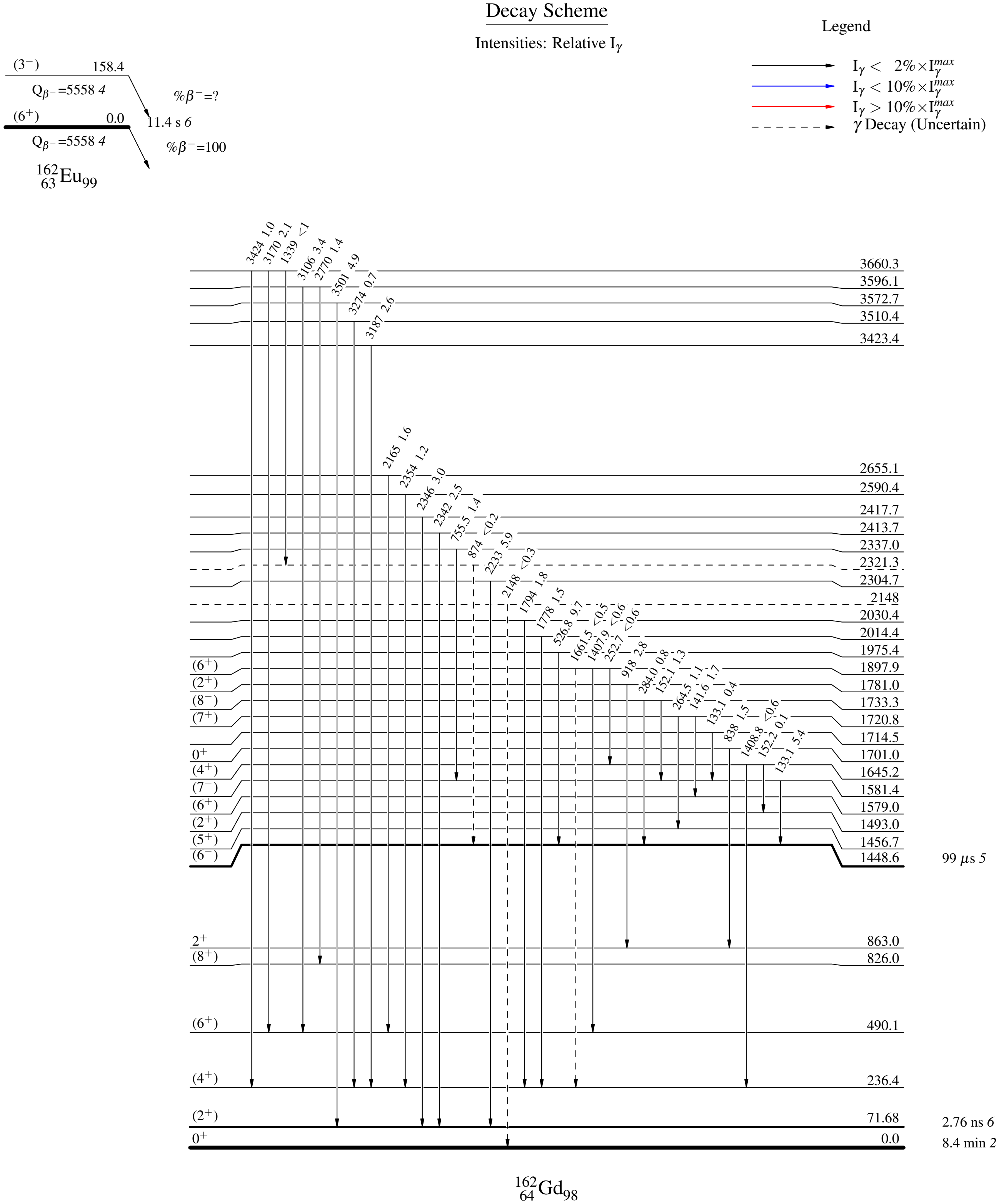
‡ According to 2021Wa04, uncertainties associated with Eγ values are 0.2 keV at 0 keV, 0.5 keV below 1 MeV, and 1 keV above 1 MeV. This statement is interpreted by the evaluator as ΔEγ=0.2 keV for Eγ's in the 0-250 keV interval, ΔEγ=0.3 keV for Eγ's in the 250-500 keV interval, ΔEγ=0.4 keV for Eγ's in the 500-750 keV interval, ΔEγ=0.5 keV for Eγ's in the 750-1000 keV interval, and ΔEγ=1 keV for Eγ's greater than 1 MeV. For Eγ's reported without decimal point ΔEγ=1 keV was adopted by evaluator.

Placement of transition in the level scheme is uncertain.

^{162}Eu β^- decay: mixed source 2021Wa04,2018Ha19

Decay Scheme

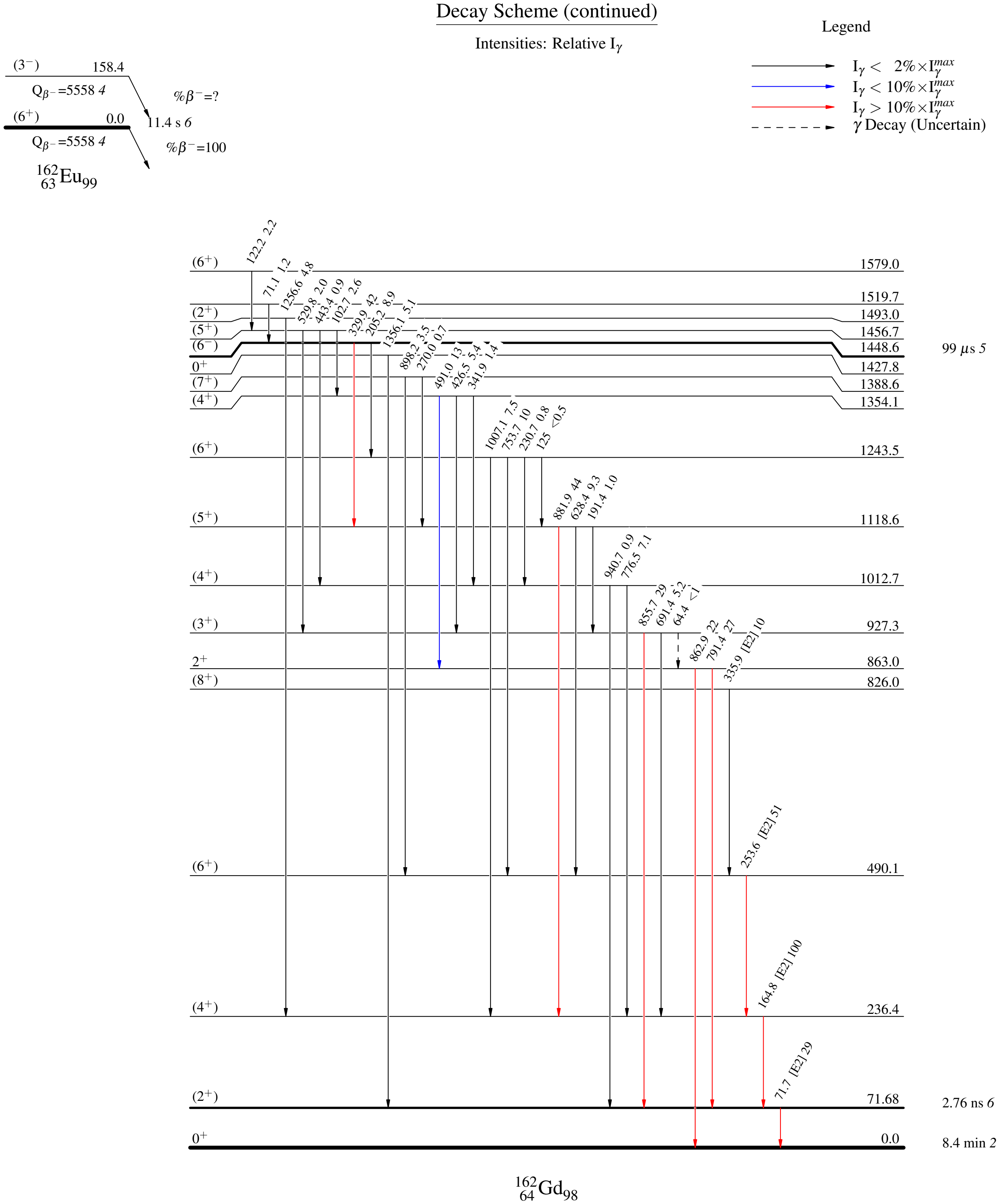
Intensities: Relative I_γ

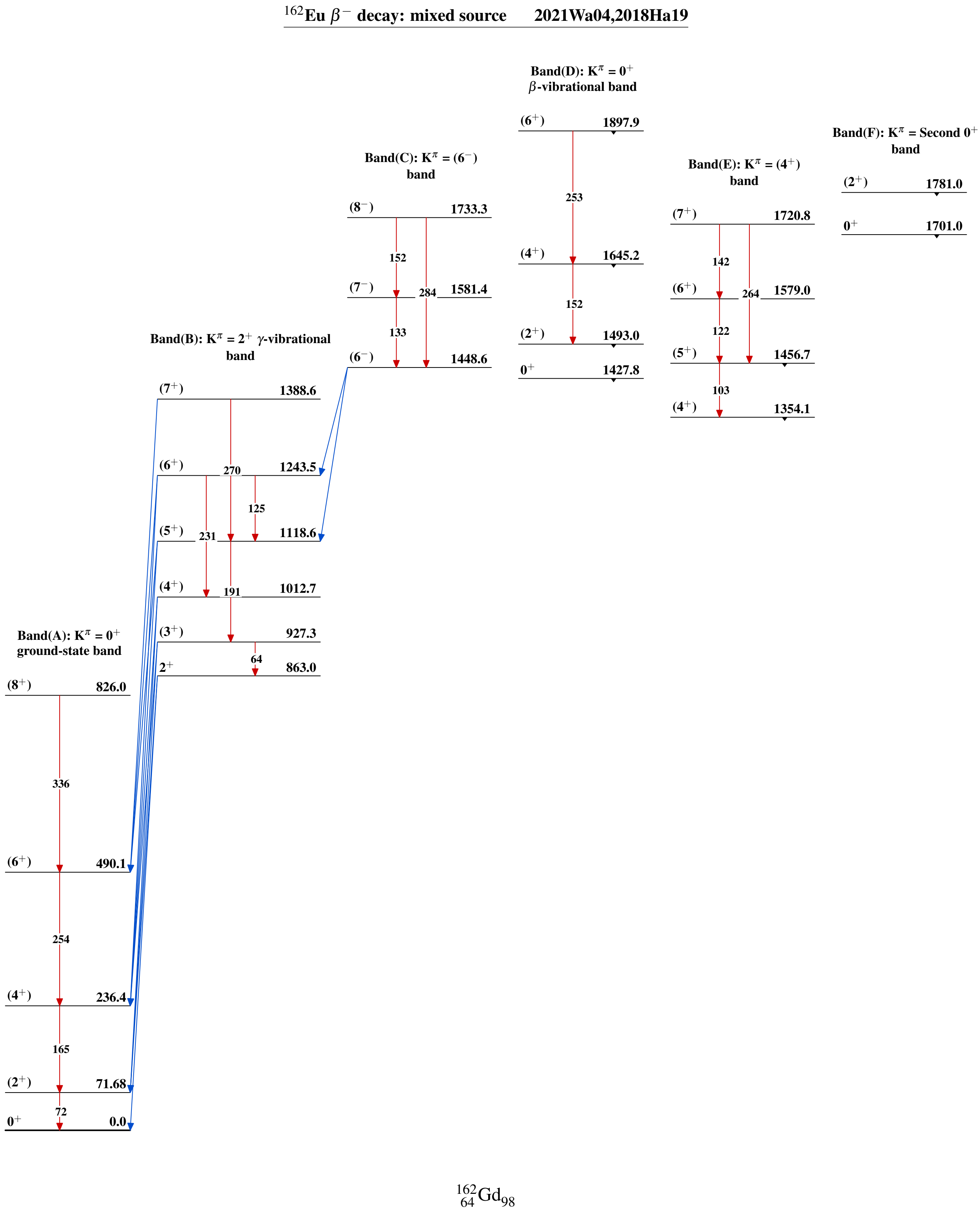


^{162}Eu β^- decay: mixed source 2021Wa04,2018Ha19

Decay Scheme (continued)

Intensities: Relative I_γ




^{162}Eu β^- decay: mixed source 2021Wa04,2018Ha19
Band(A): K$^\pi$ = 0$^+$ ground-state band
Band(B): K$^\pi$ = 2$^+$ γ-vibrational band
Band(C): K$^\pi$ = (6$^-$) band
Band(D): K$^\pi$ = 0$^+$ β-vibrational band
Band(E): K$^\pi$ = (4$^+$) band
Band(F): K$^\pi$ = Second 0$^+$ band
(8$^+$) 826.0
(6$^+$) 490.1
(4$^+$) 236.4
(2$^+$) 71.68
0$^+$ 0.0
336
254
165
72
(7$^+$) 1388.6
(6$^+$) 1243.5
(5$^+$) 1118.6
(4$^+$) 1012.7
(3$^+$) 927.3
2$^+$ 863.0
270
125
231
191
64
(8$^-$) 1733.3
(7$^-$) 1581.4
(6$^-$) 1448.6
152
284
133
(6$^+$) 1897.9
(4$^+$) 1645.2
(2$^+$) 1493.0
0$^+$ 1427.8
253
152
(7$^+$) 1720.8
(6$^+$) 1579.0
(5$^+$) 1456.7
(4$^+$) 1354.1
142
264
122
103
(2$^+$) 1781.0
0$^+$ 1701.0
$^{162}_{64}Gd_{98}$