^{61}Ni(α,nγ),^{56}Fe(^{11}B,2npγ) 1980Si02,1978Si02

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh and Jun Chen	NDS 178, 41 (2021).	12-Nov-2021

1980Si02, 1978Si02 (also 1978Si10): ^{61}Ni(α,nγ) E=7.8, 8.6, 9.35 MeV; ^{56}Fe(^{11}B,2npγ) E=30 MeV. Measured Eγ, Iγ, $\gamma\gamma$- and nγ-coin, $\gamma(\theta)$, γ(lin pol), $T_{1/2}$ by DSA method at Liverpool University EN Tandem van de Graaff accelerator facility. Main results are reported in 1978Si02 for levels below 3.1 MeV and in 1980Si02 for higher levels. 1978Si10 discussed data for 3994, 4237 and 4636 levels.

^{64}Zn Levels

E(level)[†]	J$^\pi$[‡]	$T_{1/2}$[#]	Comments
0.0	0^+		
991.8 *2*	2^+	>1.0 ps	
1799.2 *2*	2^+	>1.0 ps	
1910.4 *4*	0^+	>1.0 ps	
2306.5 *3*	4^+	291 fs *83*	
2608.7 *4*	0^+	0.36 ps *10*	
2736.5 *4*	4^+	1.25 ps *28*	$T_{1/2}$: from 1980Si02. Other: >1.0 ps (1978Si02).
2794.0 *5*	2^+	49 fs *14*	
2979.5 *3*	3^+	>1.0 ps	
2997.6 *4*	3^-	80 fs *21*	
3005.3 *2*	2^+	80 fs *21*	
3077.7 *4*	4^+	0.42 ps *11*	
3092.9 *6*	$(3)^+$	87 fs *21*	J$^\pi$: 3^+ is favored while 2^+ is not completely ruled out.
3187.5 *4*	1	0.26 ps *13*	
3196.1 *4*			
3205.9 *4*	3^+	153 fs *49*	$T_{1/2}$: other: 0.33 ps *+14−8* (1976Ch11). J$^\pi$: $(3)^+$ in the Adopted Levels.
3261.9 *5*	1	42 fs *14*	J$^\pi$: from the Adopted Levels.
3296.8 *5*	$(2)^+$	229 fs *66*	J$^\pi$: $\gamma(\theta$,pol) gives ≤3. $(2)^+$ in Adopted Levels.
3306.6 *5*	4^+	263 fs *76*	J$^\pi$: $\gamma(\theta)$ data gives minimum χ^2 for J=4, although χ^2 for J=6 is only somewhat larger. Possible γ to 2^+ supports 4^+.
3366.0 *5*	1^+	23 fs *8*	J$^\pi$: from the Adopted Levels.
3368.4 *4*	3^+	0.35 ps *+14−10*	J$^\pi$: see also Adopted Levels.
3424.9 *4*	1^+	31 fs *7*	J$^\pi$: from the Adopted Levels.
3458.1 *4*	(2,3)	236 fs *62*	J$^\pi$: from the Adopted Levels.
3552.4 *4*	4^+	>1.0 ps	
3597.8 *4*	$(2)^+$		
3606.8 *6*			
3620.5 *11*			
3628.7 *6*		159 fs *45*	
3718.4 *6*		31 fs *10*	
3815.2 *6*			
3850.7 *4*		<0.7 ps	
3853.4 *5*	5^+	>2.1 ps	
3863.5 *11*			
3898.1 *6*		38 fs *10*	
3922.9 *4*	5^-	>0.35 ps	
3931.9 *5*	$(4^-,5^+,6^-)$		J$^\pi$: if 935γ to 3^- exists, then $J^\pi=4^-$ is most likely.
3952.3 *7*			
3993.6 *5*	6^+	121 fs *35*	
4020.9 *7*			
4039.5 *7*			
4077.1 *5*	5^+	0.49 ps *+24−17*	J$^\pi$: $\gamma(\theta$,pol) give 5^+; but $\gamma(\theta)$ data from 1980Si02 and 1978Ne02 disagree in A_2 and A_4 coefficients. Note that placement of a 999γ from this level, in addition to that from the 3007

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^{61}Ni(α,nγ),^{56}Fe(^{11}B,2npγ) 1980Si02,1978Si02 (continued)

^{64}Zn Levels (continued)

E(level)[†]	J$^\pi$[‡]	T$_{1/2}$[#]	Comments
			level, proposed in 1978Ne02 was rejected by 1980Si02. But in later in-beam studies (2004Ka18,1998Ga11,1994Cr05) a 1000γ is shown to deexcite the 4077 level also.
4156.4 *4*	(5)$^-$	111 fs *35*	
4181.5 *6*			
4236.7 *6*	6$^+$	132 fs *42*	T$_{1/2}$: other: 42 ps *21* (1977Al14) is in disagreement. 1980Si02 pointed out that the uncorrected feeding in 1977We10 and 1977Al14 from the 4635 level (T$_{1/2}$=94 ps) was probably responsible for this discrepancy.
4288.5 *5*			
4635.5 *5*	7$^-$		
4979.3 *6*	(7)$^-$	>2.1 ps	
5681.1 *7*	(9)$^-$	>2.1 ps	E(level): with the reassignment of 1046γ in the Adopted dataset, based on results in 2004Ka18, this level corresponds to 6998, (11$^-$) in the Adopted Levels. J$^\pi$: $\gamma(\theta$,pol) data give 9$^-$ or 7$^-$, but heavy-ion excitation favors 9$^-$. J=8 assignment by 1978Ne02, not supported by 1980Si02.

[†] From a least-squares fit to Eγ data. Reduced χ^2 of 1.9 is slightly higher than critical χ^2=1.7.
[‡] From $\gamma(\theta)$, γ(lin pol) and excitation function (1978Si02,1980Si02), unless otherwise indicated.
[#] From DSAM, corrected for feeding time. Values are from 1978Si02 for levels below 3.1 MeV and from 1980Si02 for levels above this energy, unless noted otherwise.

$\gamma(^{64}$Zn)

E$_i$(level)	J$_i^\pi$	E$_\gamma$[†]	I$_\gamma$[†]	E$_f$	J$_f^\pi$	Mult.[@]	δ[@]	Comments
991.8	2$^+$	991.6 *3*	100	0.0	0$^+$	E2		A$_2$=+0.11 *1*; A$_4$=−0.01 *1*; pol=+0.13 *1*
1799.2	2$^+$	807	75 *2*	991.8	2$^+$	M1+E2	−3.3 *7*	A$_2$=−0.08 *1*; A$_4$=−0.01 *1*; pol=+0.01 *1* Additional information 1.
		1799.4 *4*	25 *2*	0.0	0$^+$	E2		A$_2$=+0.11 *3*; A$_4$=−0.03 *1*; pol=+0.16 *4*
1910.4	0$^+$	918.9 *3*	100	991.8	2$^+$			pol=+0.01 *5* $\gamma(\theta)$: assumed isotropic and used for normalization (1978Si02).
2306.5	4$^+$	1314.9 *3*	100	991.8	2$^+$	E2		A$_2$=+0.33 *1*; A$_4$=−0.05 *1*; pol=+0.49 *2*
2608.7	0$^+$	809	<0.5	1799.2	2$^+$			E$_\gamma$,I$_\gamma$: from $\gamma\gamma$-coin data in 1980Si02.
		1616.9 *3*	100	991.8	2$^+$			A$_2$=+0.02 *2*; A$_4$=+0.02 *2*; pol=+0.02 *9*
2736.5	4$^+$	430	9 *2*	2306.5	4$^+$	M1+E2	−0.25 *9*	E$_\gamma$,I$_\gamma$: from $\gamma\gamma$-coin data in 1980Si02. δ: from 1980Si02.
		937.4 *3*	87 *2*	1799.2	2$^+$	E2		A$_2$=+0.32 *2*; A$_4$=−0.08 *2*; pol=+0.46 *4* I$_\gamma$: from 1980Si02. In 1978Si02, value was 96.4 *10*, as the 430-keV transition was reported later in 1980Si02.
		1745.0 *10*	4 *2*	991.8	2$^+$	(E2)		A$_2$=+0.25 *10*; A$_4$=−0.10 *11* (1978Si02) I$_\gamma$: from 1980Si02. In 1978Si02, value was 3.6 *10*.
2794.0	2$^+$	1802.1 *4*	100	991.8	2$^+$	M1+E2	+0.7 *5*	A$_2$=+0.15 *2*; A$_4$=+0.01 *2*; pol=0.0 *1*
2979.5	3$^+$	1180.9 *3*	62 *3*	1799.2	2$^+$	M1+E2	−0.05 *3*	A$_2$=−0.28 *1*; A$_4$=+0.04 *2*; pol=−0.30 *6*
		1986.6 *4*	38 *3*	991.8	2$^+$	M1+E2	+0.26 *3*	A$_2$=+0.05 *2*; A$_4$=+0.10 *2*; pol=−0.40 *15*
2997.6	3$^-$	2005.6 *4*	99.5 *3*	991.8	2$^+$	D		A$_2$=−0.16 *1*; A$_4$=+0.04 *1*; pol=−0.18 *25* I$_\gamma$: 100 in 1978Si02 adjusted for branching ratio of 2997γ. δ(M2/E1)=0.0 *1* (1978Si02).
		2997	0.5 *3*	0.0	0$^+$	[E3]		E$_\gamma$,I$_\gamma$: from $\gamma\gamma$-coin data in 1980Si02.
3005.3	2$^+$	1205.8 *3*	32 *2*	1799.2	2$^+$	M1+E2	+0.6 *5*	A$_2$=+0.19 *3*; A$_4$=+0.03 *3*; pol=+0.14 *21* I$_\gamma$: misprinted as 42 *3* in Table 1 of 1978Si02 as per authors' discussion in text for the 3305 level.

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^{61}Ni(α,nγ),^{56}Fe(^{11}B,2npγ) 1980Si02,1978Si02 (continued)

$\gamma(^{64}Zn)$ (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[@]	δ[@]	Comments
3005.3	2^+	2013.6 *4*	42 *3*	991.8	2^+	M1(+E2)	−0.06 *10*	A_2=+0.05 *3*; A_4=+0.05 *3*; pol=+0.18 *8* I_γ: misprinted as 32 *2* in Table 1 of 1978Si02 as per authors′ discussion in text for the 3305 level. I_γ: see also comment for 1205.8γ.
		3005.2 *3*	26 *3*	0.0	0^+	(E2)		A_2=+0.11 *3*; A_4=−0.02 *3*; pol=−0.2 *3*
3077.7	4^+	341	36 *4*	2736.5	4^+	M1(+E2)	<0.5	E_γ,I_γ: from 1980Si02. Expected Iγ≈9 from the Adopted Gammas. δ: from RUL(E2)<300 (see Adopted Gammas). 1980Si02 give δ=−1.2 *2* in Table 2, but it is in contradiction with a footnote in their table that δ for this transition is undetermined experimentally. In addition, no $\gamma(\theta)$ data for the 341γ are available in 1980Si02.
		771.4 *3*	30 *3*	2306.5	4^+	M1+E2	−0.19 *8*	A_2=+0.25 *4*; A_4=−0.06 *4*; pol=+0.16 *16* I_γ: from 1980Si02. Earlier value was 47 *3* in 1978Si02 where 341γ was not reported.
		2086.3 *4*	34 *3*	991.8	2^+	E2		A_2=+0.40 *2*; A_4=+0.10 *3*; pol=+0.35 *21* I_γ: from 1980Si02. Earlier value was 53 *3* in 1978Si02 where 341γ was not reported. Note that the sign of A_4 should be negative for stretched E2, probably a misprint in the Table 1 of 1978Si02.
3092.9	$(3)^+$	2101.0 *5*	100	991.8	2^+	M1+E2		A_2=+0.17 *2*; A_4=+0.05 *2*; pol=+0.02 *13* δ: +9.4 *15* or +0.40 *5* for J(3095)=3; +0.6 *4* for J(3095)=2.
3187.5	1	1277.7 *4*	40 *1*	1910.4	0^+	D		A_2=−0.12 *2*; A_4=−0.03 *2*; pol=+0.27 *17*
		1388.4 *4*	11 *1*	1799.2	2^+			pol=−0.27 *16* I_γ: Iγ(1388γ)/Iγ(1278γ) low by a factor of ≈8 when compared to that in other reactions.
		2195.0 *4*	49 *1*	991.8	2^+			A_2=+0.04 *12*; A_4=−0.24 *12*; pol=−0.25 *27* E_γ: 2193.0 listed in Table 1 of 1980Si02 fits poorly. In authors′ Table 2, level-scheme Fig. 1 and text value is 2195 keV. Evaluators assume that the value is a misprint in Table 1.
3196.1		1397.0 *5*	34 *3*	1799.2	2^+			
		2204.2 *4*	66 *3*	991.8	2^+			A_2≈+0.85
3205.9	3^+	1406.7 *4*	97 *1*	1799.2	2^+	M1+E2	−0.25 *9*	A_2=−0.38 *1*; A_4=+0.01 *1*; pol=−0.12 *10*
		2214.0 *5*	3 *1*	991.8	2^+			
3261.9	1	2270.0 *4*	100	991.8	2^+			A_2=+0.02 *1*; A_4=−0.02 *1*; pol=+0.09 *15* E_γ: uncertainty of 0.04 keV in Table 1 of 1980Si02 seems a misprint.
3296.8	$(2)^+$	2304.9 *4*	100	991.8	2^+			A_2=+0.02 *1*; A_4=+0.01 *1*; pol=−0.11 *11*
3306.6	4^+	512[&]	0.5 *5*	2794.0	2^+			E_γ: from $\gamma\gamma$-coin data. Intensity implied by branching ratio of 1000.2γ.
		1000.2 *4*	99.5 *5*	2306.5	4^+	M1(+E2)	+0.07 *20*	A_2=+0.16 *2*; A_4=−0.22 *4*; pol=+0.22 *4* I_γ: >99 in 1980Si02. See comment with 998.7γ from 4077 level.
3366.0	1^+	2374.0 *6*		991.8	2^+			
		3366.0 *6*		0.0	0^+			A_2=+0.07 *2*; A_4=+0.02 *2*
3368.4	3^+	1569.0 *4*	62 *3*	1799.2	2^+	M1+E2	−0.40 *6*	A_2=−0.45 *1*; A_4=−0.04 *2*; pol=+0.02 *10*
		2376.6 *4*	38 *3*	991.8	2^+			
3424.9	1^+	419.5[&] *4*	0.5 *5*	3005.3	2^+			E_γ: from $\gamma\gamma$-coin. Iγ implied by branching ratio for 3425γ.
		3425.2 *6*	99.5 *5*	0.0	0^+			A_2=+0.05 *2*; A_4=−0.02 *2* I_γ: >99 in 1980Si02.

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^{61}Ni(α,nγ),^{56}Fe(^{11}B,2npγ) 1980Si02,1978Si02 (continued)

γ(^{64}Zn) (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[†]	E_f	J_f^π	Mult.[@]	δ[@]	Comments
3458.1	(2,3)	1658.6 *5*	55 *5*	1799.2	2^+			A_2=+0.17 *2*; A_4=+0.02 *2*; pol=−0.41 *20*
		2466.4 *4*	45 *5*	991.8	2^+			A_2=+0.13 *2*; A_4=+0.01 *2*; pol=+0.55 *21*
3552.4	4^+	1246.7 *4*	54 *3*	2306.5	4^+	M1+E2	−0.16 *10*	A_2=+0.25 *2*; A_4=−0.10 *2*; pol=+0.74 *18*
		2559.7 *4*	46 *3*	991.8	2^+			A_2≈+0.02
3597.8	$(2)^+$	1291.3 *4*	55 *5*	2306.5	4^+			
		2606.0 *5*	45 *5*	991.8	2^+			
3606.8		2614.9 *5*	100	991.8	2^+			
3620.5		1314.0 *10*	100	2306.5	4^+			
3628.7		2636.8 *5*	100	991.8	2^+			A_2=+0.05 *3*; A_4=+0.01 *4*
3718.4		2726.5 *5*	100	991.8	2^+			A_2=+0.04 *2*; A_4=+0.03 *2*; pol=−0.42 *22*
3815.2		2016.0 *5*	100	1799.2	2^+			
3850.7		1116[&]		2736.5	4^+			Evidence for this γ from $\gamma\gamma$-coin data in 1980Si02.
		2051.0 *4*	18 *2*	1799.2	2^+			
		2859.2 *6*	82 *3*	991.8	2^+			
3853.4	5^+	1116.9 *4*	99.5 *5*	2736.5	4^+	M1+E2	−1.00 *15*	A_2=−0.84 *2*; A_4=+0.12 *2*; pol=+0.54 *14* I_γ: >99 in 1980Si02. POL is from heavy-ion reaction. Other: POL=+0.09 *9* from (α,nγ).
		1547[&]	0.5 *5*	2306.5	4^+			Evidence for this γ from $\gamma\gamma$-coin data in 1980Si02; branching implied from that of the 1116.9γ.
3863.5		1557.0 *10*	100	2306.5	4^+			
3898.1		2906.2 *5*	100	991.8	2^+			A_2=+0.13 *3*; A_4=−0.07 *3*
3922.9	5^-	924.5 *5*	14 *5*	2997.6	3^-	(E2)		A_2=−0.24 *2*; A_4=−0.01 *4*; pol=−0.05 *11* Sign of A_2 disagrees with positive sign expected for stretched E2. 924γ peak contaminated by contribution from ^{62}Cu.
		1617.0 *4*	86 *5*	2306.5	4^+	E1(+M2)		A_2=−0.45 *3*; A_4=+0.18 *3*; pol=+0.20 *16*
3931.9	$(4^-,5^+,6^-)$	935[&]		2997.6	3^-			Evidence for this γ from $\gamma\gamma$-coin data in 1980Si02.
		1625.3 *4*	100	2306.5	4^+			A_2=+0.43 *3*; A_4=+0.09 *4*; pol=+0.42 *21*
3952.3		2960.4 *6*	100	991.8	2^+			
3993.6	6^+	1687.0 *5*	100	2306.5	4^+	E2		A_2=+0.35 *1*; A_4=−0.15 *1*; pol=+0.88 *17*
4020.9		3029.0 *6*	100	991.8	2^+			
4039.5		3047.6 *6*	100	991.8	2^+			
4077.1	5^+	1340.6 *4*	100	2736.5	4^+	M1+E2	−0.49 *11*	A_2=−1.13 *7*; A_4=+0.15 *10*; pol=−0.33 *7* I_γ: with the placement of a 999γ from this level, the branching ratio of this transition is reduced by about 50%.
4156.4	$(5)^-$	1079.6 *4*	27 *5*	3077.7	4^+			A_2=−0.05 *3*; A_4=−0.01 *4*; pol=+0.06 *20*
		1159.0 *4*	23 *5*	2997.6	3^-			A_2=−0.07 *4*; A_4=−0.06 *5*; pol=+0.32 *26*
		1848.8 *4*	50 *5*	2306.5	4^+			
4181.5		1875.0 *5*	100	2306.5	4^+			
4236.7	6^+	1500.4 *6*	100	2736.5	4^+	E2		A_2=+0.32 *2*; A_4=−0.08 *3*; pol=+0.63 *30* A_2=+0.31 *2*; A_4=−0.08 *2*; pol=+0.70 *20* First set of $\gamma(\theta)$ and Pol data from heavy-ion reaction, second from (α,nγ).
4288.5		1552.0 *4*	100	2736.5	4^+			
4635.5	7^-	398.8 *3*	23 *3*	4236.7	6^+	E1		A_2=−0.23 *3*; A_4=−0.05 *3*; pol=+0.23 *15*
		641.8 *3*	77 *3*	3993.6	6^+	E1		A_2=−0.25 *1*; A_4=0.00 *1*; pol=+0.35 *7*
4979.3	$(7)^-$	1056.3 *4*	100	3922.9	5^-	E2		A_2=+0.26 *3*; A_4=−0.09 *3*; pol=+0.47 *22*
5681.1	$(9)^-$	1045.6 *4*	100	4635.5	7^-	E2		A_2=+0.43 *6*; A_4=−0.16 *6*; pol=+0.46 *20* δ(E2/M1)=−0.60 *40* in 1980Si02 based on 8^- to 7^- transition.

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^{61}Ni(α,nγ),^{56}Fe(^{11}B,2npγ) 1980Si02,1978Si02 (continued)

γ(^{64}Zn) (continued)

† From 1978Si02 for levels below 3.1 MeV, and from 1980Si02 for levels above 3.1 MeV. Exceptions are noted.
‡ Weak unplaced γ observed in singles spectrum (1980Si02).
# Observed in coincidence with 992γ from the first 2^+ (1980Si02).
@ From $\gamma(\theta)$ and/or γ(lin pol) data (1978Si02,1980Si02). RUL (for E2 and M2) also considered when level half-life is known.
& Placement of transition in the level scheme is uncertain.
x γ ray not placed in level scheme.

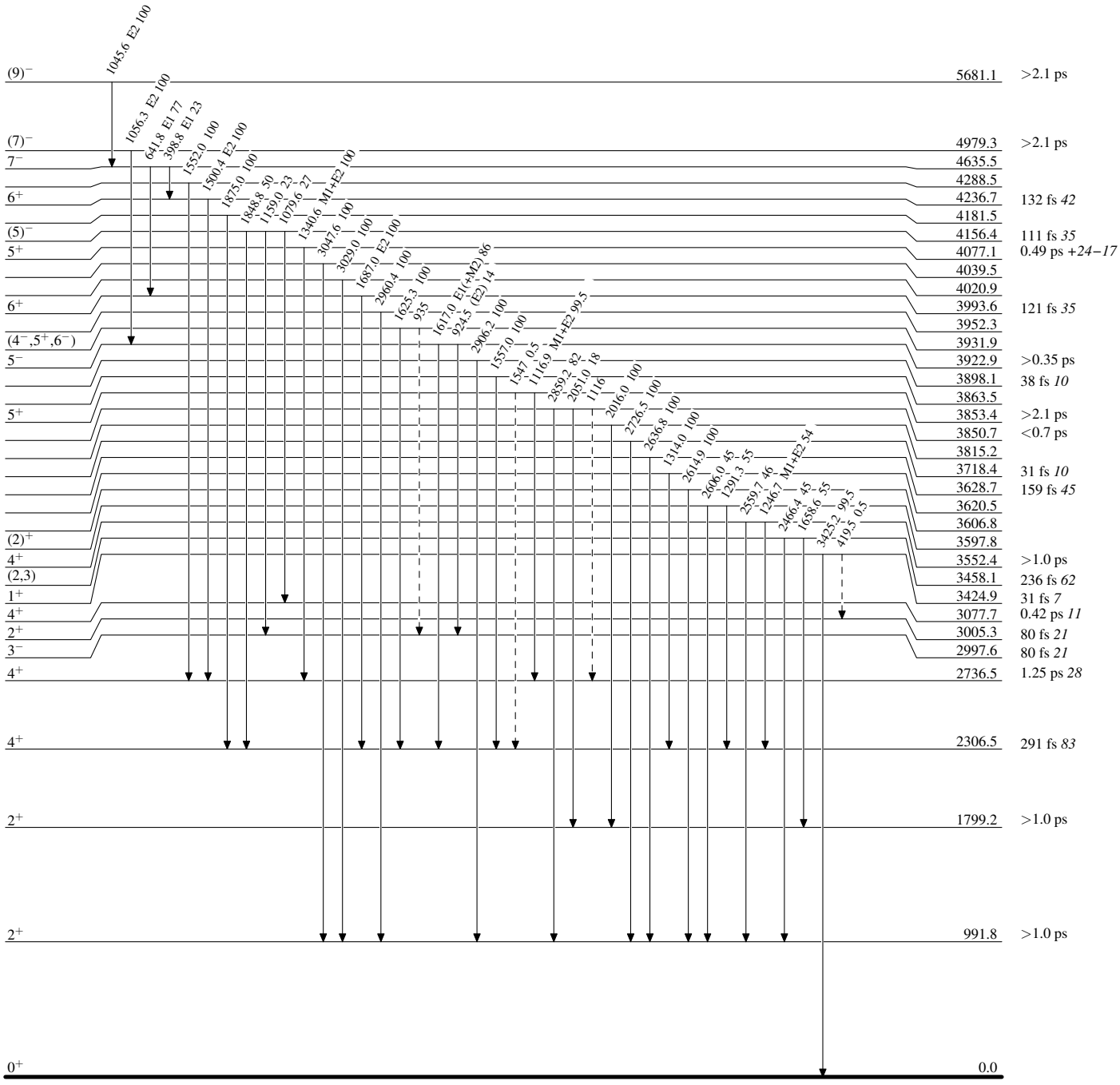
^{61}Ni(α,nγ),^{56}Fe(^{11}B,2npγ) 1980Si02,1978Si02

Legend

Level Scheme

Intensities: % photon branching from each level

γ Decay (Uncertain)



$^{64}_{30}Zn_{34}$

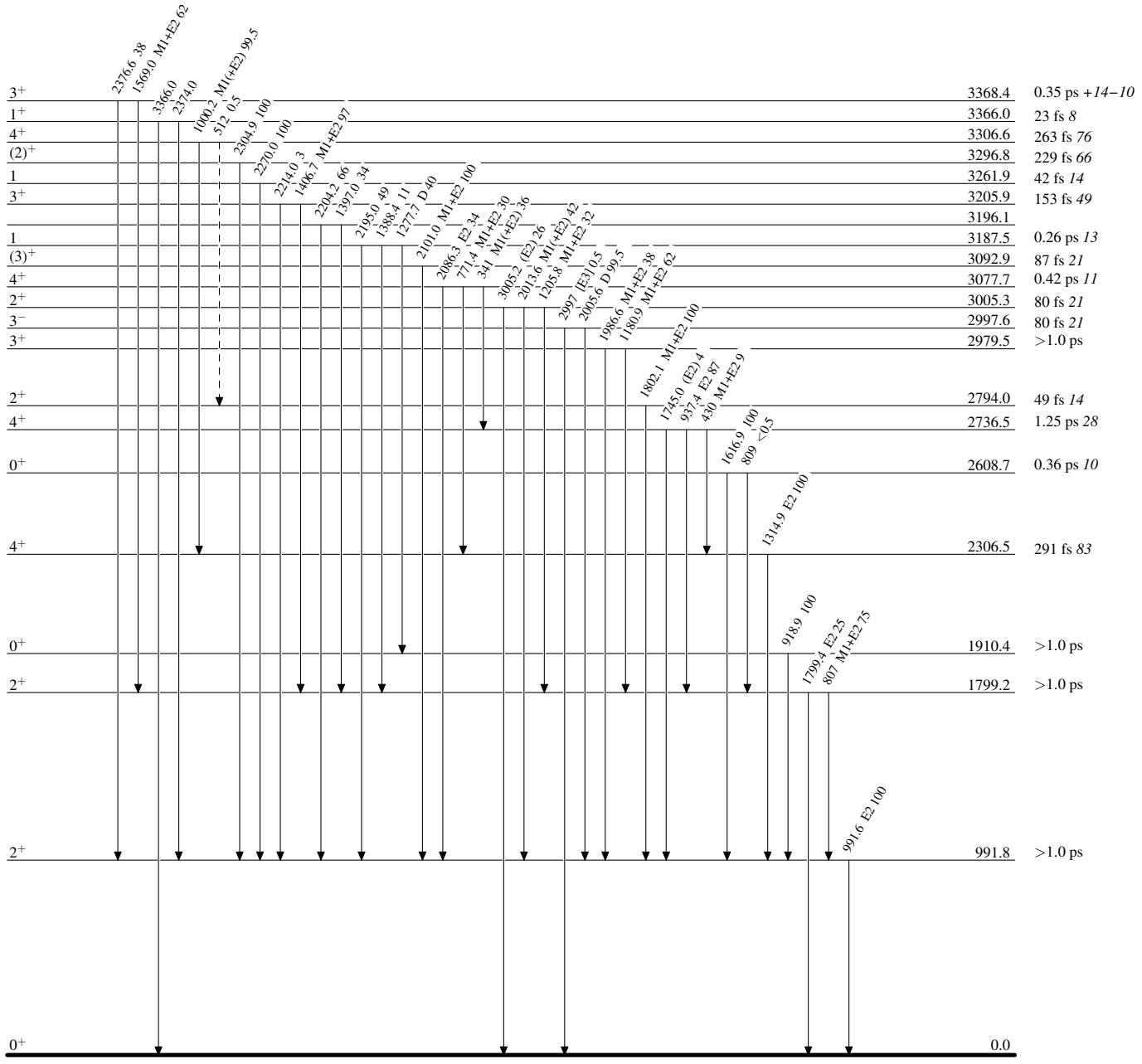
^{61}Ni(α,nγ),^{56}Fe(^{11}B,2npγ) 1980Si02,1978Si02

Legend

Level Scheme (continued)

Intensities: % photon branching from each level

γ Decay (Uncertain)



$^{64}_{30}Zn_{34}$