^{65}Cu(p,nγ) 1974Ez01,1977Ch14

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	Jun Chen	NDS 202,59 (2025)	25-Feb-2025

1974Ez01: E(p)=2.60-4.55 MeV from the University of Georgia Van de Graaff. Target was 2.3 mg/cm^2 ^{65}Cu. γ rays were detected with a Ge(Li) detector; neutrons were detected with an liquid scintillator. Measured Eγ, Iγ, γ(θ), nγ-coin, nγ(θ). Deduced levels, J, π, γ-ray branching ratios, multipolarities, mixing ratios. Hauser-Feshbach analysis of nγ(θ).

1977Ch14: E(p)=3.4 and 3.9 MeV from the Lyon University 4 MV Van de Graaff accelerator. Target was 99.5% enriched ^{65}Cu. γ rays were detected with a Ge(Li) detector. Measured Eγ, Iγ, Doppler-shift attenuation. Deduced levels, $T_{1/2}$.

1976Wh01: E(p)=4 MeV (pulsed beam) from University of Alberta Van de Graaff. γ rays were detected with a Ge(Li) detector. Measured γγ(t). Deduced $T_{1/2}$.

1970Ro26: E(p)=2.6-3.1 MeV. Measured Ice, Iγ and γ(θ). α(K)exp normalized to α(K)(662γ ^{137}Ba)=0.091 *2*. See also 1970RoZX thesis.

1970We02: E(p)=2.80-4.05 MeV from HMI van de Graaff. γ rays were detected with a Ge(Li) detector. Measured Eγ, Iγ and γ excitation functions.

1967Me18: E(p)=5.8 MeV. Measured Ice and γ(θ). Deduced levels, J, π, conversion coefficients, γ-ray multipolarties and mixing ratios.

1961Lo03: E(p)=4 MeV. Measured Eγ, Iγ, γγ and n-γ coincidences with NaI detectors. Statistical model theory.

1973VaYC: E(p)=2.5-5.0 MeV. Measured Eγ, γ(θ), γ excitation function and nγ-coin. Report level scheme only.

1958Ch34: E(p)=3.7 MeV. Measured Eγ with a curved-crystal spectrometer.

1966Tu02: E(p)=2.35-2.95 MeV Measured $T_{1/2}$ by delayed coincidences.

Others: 1957Be44, 1959Va12, 1971Da32 and 1976AsZY.

^{65}Zn Levels

E(level)[†‡]	J$^\pi$[#]	$T_{1/2}$[@]	Comments
0	5/2$^-$		
53.928 *10*	1/2$^-$		
115.126 *13*	3/2$^-$	0.444 ns *9*	$T_{1/2}$: from pulsed-beam delayed γ coincidences (1976Wh01). Other: <300 ps (1966Tu02).
206.96 *13*	3/2$^-$	150 ps *7*	$T_{1/2}$: from pulsed-beam delayed γ coincidences (1976Wh01). Other: <300 ps (1966Tu02).
768.87 *10*	5/2$^-$	10 ps *9*	J$^\pi$: spin=5/2 from γ(θ) in 1974Ez01. $T_{1/2}$: from >1.0 ps by DSA (1977Ch14) and <18 ps from pulsed-beam delayed γ coincidences (1976Wh01).
864.34 *13*	7/2$^-$	>1.4 ps	J$^\pi$: spin=7/2 from γ(θ) in 1974Ez01.
866.96 *16*	1/2$^-$	0.40 ps *+37−22*	J$^\pi$: spin=1/2,3/2 from γ(θ) (1974Ez01). $T_{1/2}$: other: <26 ps from pulsed-beam delayed γ coincidences (1976Wh01).
909.64 *11*	3/2$^-$	12 ps *11*	J$^\pi$: spin=3/2 from γ(θ) in 1974Ez01. $T_{1/2}$: from >1.0 ps by DSA (1977Ch14) and <22 ps from pulsed-beam delayed γ coincidences (1976Wh01).
1047.28 *12*	5/2$^-$	0.42 ps *+42−20*	J$^\pi$: spin=5/2 from γ(θ) in 1974Ez01. $T_{1/2}$: other: <15 ps from pulsed-beam delayed γ coincidences (1976Wh01).
1062.2? *4*			
1065.89 *19*	9/2$^+$	0.575 ns *26*	$T_{1/2}$: from pulsed-beam delayed γ coincidences (1976Wh01). Other: >0.46 ps by DSA (1977Ch14); <2000 ps from pulsed-beam delayed γ coincidences (1975Ro25).
1252.71 *12*	7/2$^-$	0.59 ps *+38−28*	J$^\pi$: spin=7/2 from γ(θ) in 1974Ez01. $T_{1/2}$: other: <13 ps from pulsed-beam delayed γ coincidences (1976Wh01).
1263.45 *17*	9/2$^-$	0.42 ps *+37−18*	J$^\pi$: spin=9/2 preferred over J=7/2. $T_{1/2}$: <16 ps from pulsed-beam delayed γ coincidences (1976Wh01).
1343.77 *12*	5/2$^-$	0.8 ps *+11−6*	J$^\pi$: spin=5/2 from (γ) in 1974Ez01. $T_{1/2}$: other: <13 ps from pulsed-beam delayed γ coincidences (1976Wh01).
1369.46 *17*	5/2$^+$	0.69 ps *+63−35*	J$^\pi$: spin=5/2 from γ(θ) in 1974Ez01. $T_{1/2}$: other: <14 ps from pulsed-beam delayed γ coincidences (1976Wh01).
1469.40 *14*	3/2$^-$	0.19 ps *+9−7*	J$^\pi$: spin=1/2,3/2 from γ(θ) in 1974Ez01.
1577.17 *26*	3/2$^-$		J$^\pi$: ≤5/2 from γ(θ) in 1974Ez01.

Continued on next page (footnotes at end of table)

^{65}Cu(p,nγ) 1974Ez01,1977Ch14 (continued)

^{65}Zn Levels (continued)

E(level)[†‡]	Jπ[#]	Comments
1588.20 *27*	7/2⁻	Jπ: ≤7/2 from γ(θ) in 1974Ez01.
1779.6? *7*		
1793.5? *7*		
1941.2? *6*	(1/2,3/2)	

† Additional information 1.
‡ From a least-squares fit to γ-ray energies.
# From Adopted Levels. Supporting arguments from this dataset are given under comments where available.
@ From DSAM 1977Ch14, unless otherwise noted. A 20% uncertainty in stopping power is already included in the final uncertainty reported in 1977Ch14.

^{65}Cu(p,nγ) 1974Ez01,1977Ch14 (continued)

γ(^{65}Zn)

A_2 and A_4 values under comments are from 1974Ez01, unless otherwise noted.

E_i(level)	J_i^π	E_γ[†]	I_γ[‡]	E_f	J_f^π	Mult.[#]	δ[#]	Comments
53.928	1/2⁻	53.93 *1*	100	0	5/2⁻	E2[&]		α(K)exp=6.0 *10* (1970Ro26) E_γ: from 1958Ch34. Other: 53.8 (1977Ch14). Mult.: α(K)exp=6.0 *10* in 1970Ro26 gives δ(M3/E2)<0.14, but RUL=10 for B(M3)(W.u.) and adopted $T_{1/2}$=1.59 μs *5* requires δ<0.00003.
115.126	3/2⁻	61.20 *1*	19.5	53.928	1/2⁻	M1(+E2)[&]	<0.1[&]	α(K)exp=0.30 *10* (1970Ro26) E_γ: from 1958Ch34. Other: 61.2 (1977Ch14). δ: α(K)exp=0.30 *10* gives δ<0.24, but RUL=100 for B(E2)(W.u.) requires δ<0.1.
		115.09 *4*	81.5	0	5/2⁻	M1+E2[&]	0.29[&] *3*	α(K)exp=0.058 *5* (1970Ro26); α(K)exp=0.065 *7* (1967Me18) E_γ: from 1958Ch34. Other: 115.2 (1977Ch14).
206.96	3/2⁻	92.0	0.6	115.126	3/2⁻			α(K)exp≈0.65 (1970Ro26)
		153.1	77.0	53.928	1/2⁻	M1+E2[&]	0.21[&] *+4−5*	α(K)exp=0.024 *3* (1970Ro26); α(K)exp=0.0204 *16* (1967Me18) α(L)exp+α(M)exp=0.0029 *3* (1967Me18) I_γ: other: 80 from 1970We02.
		207.0	22.5	0	5/2⁻	M1+E2[&]	0.87[&] *+20−17*	α(K)exp=0.021 *3* (1970Ro26) I_γ: other: 20 from 1970We02.
768.87	5/2⁻	562.1[a] *5*	0.4 *1*	206.96	3/2⁻			
		653.7 *2*	33.2 *15*	115.126	3/2⁻	M1+E2	−0.9 *6*	E_γ: weighted average of 653.6 *2* (1977Ch14) and 654.0 *3* (1974Ez01). I_γ: other: 34.8 *8* (1974Ez01). δ: from −1.53<δ<−0.30 (1974Ez01). A_2=−0.169 *32*, A_4=−0.008 *42*.
		714.8 *3*	6.9 *6*	53.928	1/2⁻			E_γ: weighted average of 714.9 *3* (1977Ch14) and 714.7 *3* (1974Ez01). I_γ: other: 7.0 *11* (1974Ez01).
		768.8 *2*	59.5 *16*	0	5/2⁻	M1+E2		E_γ: weighted average of 768.8 *2* (1977Ch14) and 769.1 *5* (1974Ez01). I_γ: other: 58 *3* (1974Ez01). δ: +0.20 *6* or +1.08 *10* (1974Ez01). A_2=+0.104 *21*, A_4=0.001 *28*.
864.34	7/2⁻	657.4 *6*	0.6 *1*	206.96	3/2⁻			
		749.3 *3*	15.3 *12*	115.126	3/2⁻			
		864.5 *2*	84.1 *12*	0	5/2⁻	M1+E2		E_γ: other: 864.6 *3* (1974Ez01). I_γ: other: 100 (1974Ez01). δ: −0.28 *1* or −1.77 *2* (1974Ez01). Main component of γ doublet (1977Ch14). A_2=−0.335 *7*, A_4=+0.028 *10*.
866.96	1/2⁻	660.0 *4*	4.6 *9*	206.96	3/2⁻			
		751.8 *2*	90.5 *11*	115.126	3/2⁻			E_γ: other: 751.9 *3* (1974Ez01).
		813.6 *5*	3.0 *4*	53.928	1/2⁻			

^{65}Cu(p,nγ) 1974Ez01,1977Ch14 (continued)

γ(^{65}Zn) (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[‡]	E_f	J_f^π	Mult.[#]	δ[#]	Comments
866.96	1/2⁻	866.6 *6*	1.9 *3*	0	5/2⁻			
909.64	3/2⁻	140.2 *4*	1.9 *3*	768.87	5/2⁻			
		702.9 *3*	9.3 *4*	206.96	3/2⁻			E_γ: weighted average of 702.7 *3* (1977Ch14) and 703.1 *3* (1974Ez01). I_γ: other: 7.1 *19* (1974Ez01).
		794.6 *2*	24.6 *15*	115.126	3/2⁻	M1+E2	+0.77 *+42−30*	E_γ: weighted average of 794.5 *2* (1977Ch14) and 794.8 *3* (1974Ez01). I_γ: other: 24.8 *9* (1974Ez01). A_2=+0.062 *21*, A_4=0.
		855.7 *2*	14.5 *10*	53.928	1/2⁻	M1+E2	−0.6 *3*	E_γ,I_γ: other: 855.8 *3* with Iγ=15.4 *5* (1974Ez01). δ: from −0.95<δ<−0.30 (1974Ez01). A_2=−0.035 *24*, A_4=0.
		909.6 *2*	49.7 *20*	0	5/2⁻	M1+E2	+1.5 *8*	E_γ: 909.8 *3* (1974Ez01). I_γ: 52.7 *12* (1974Ez01). δ: from +0.74<δ<+2.24 (1974Ez01). A_2=−0.040 *10*, A_4=0.
1047.28	5/2⁻	278.2 *5*	0.5 *1*	768.87	5/2⁻			
		840.3[a]	<2	206.96	3/2⁻			
		932.2 *2*	63 *3*	115.126	3/2⁻	(M1+E2)		E_γ: weighted average of 932.1 *2* (1977Ch14) and 932.4 *3* (1974Ez01). I_γ: other: 65.3 *9* (1974Ez01). δ: −0.45 *8* or −1.23 *11* (1974Ez01). A_2=−0.145 *10*, A_4=−0.016 *13*.
		993.5 *4*	1.9 *4*	53.928	1/2⁻			
		1047.3 *2*	33 *3*	0	5/2⁻	M1+E2		E_γ: other: 1047.5 *4* (1974Ez01). I_γ: other: 34.7 *9* (1974Ez01). δ: −0.40 *7* or +6.4 *+15−19* (1974Ez01). A_2=+0.016 *30*, A_4=−0.023 *38*.
1062.2?		197.9[@a]		864.34	7/2⁻			
		855.2[@a]		206.96	3/2⁻			
1065.89	9/2⁺	201.5 *2*	91.0 *9*	864.34	7/2⁻			E_γ,I_γ: other: 201 *1* with Iγ=100 (1974Ez01).
		1066.0 *3*	9.0 *9*	0	5/2⁻			
1252.71	7/2⁻	483.9 *2*	15.3 *15*	768.87	5/2⁻	D+Q		E_γ,I_γ: other: 484.0 *4* with Iγ=29.0 *18* (1974Ez01). δ: +0.02 *3* or −4.7 *+6−8* (1974Ez01). A_2=−0.130 *39*, A_4=+0.011 *50*.
		1045.7 *2*	54.3 *22*	206.96	3/2⁻			E_γ,I_γ: other: 1046.0 *5* with Iγ=50.6 *30* (1974Ez01).
		1137.5 *2*	20.7 *15*	115.126	3/2⁻	(E2)		E_γ,I_γ: 1137.8 *4* with Iγ=20.4 *26* (1974Ez01). Main component of γ doublet (1977Ch14). Mult.,δ: too large uncertainty in analysis of σ(θ), δ quoted as ≈+0.07, but pure E2 is assumed (1974Ez01).
		1252.8 *3*	9.7 *12*	0	5/2⁻			
1263.45	9/2⁻	399.4 *3*	4.3 *5*	864.34	7/2⁻			
		1263.3 *2*	95.7 *5*	0	5/2⁻			E_γ,I_γ: other: 1263.9 *6* with Iγ=100 (1974Ez01). Main component of γ doublet (1977Ch14).

^{65}Cu(p,nγ) 1974Ez01,1977Ch14 (continued)

γ(^{65}Zn) (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[‡]	E_f	J_f^π	Mult.[#]	δ[#]	Comments
1343.77	5/2⁻	479.7 *3*	2.4 *4*	864.34	7/2⁻			
		574.9 *4*	1.2 *2*	768.87	5/2⁻			
		1136.7 *4*	12.5 *13*	206.96	3/2⁻	D+Q		E_γ: weighted average of 1136.5 *4* (1977Ch14) and 1137.0 *5* (1974Ez01). I_γ: other: 15.8 *19* (1974Ez01). δ: +0.16 *20* or ≤−3.2 (1974Ez01). A_2=+0.031 *117*, A_4=−0.061 *151*.
		1228.6 *2*	63.5 *22*	115.126	3/2⁻	M1+E2		E_γ: weighted average of 1228.5 *2* (1977Ch14) and 1228.8 *3* (1974Ez01). I_γ: other: 64.1 *17* (1974Ez01). δ: −0.44 *12* or −1.25 *20* (1974Ez01). A_2=−0.162 *15*, A_4=−0.009 *20*.
		1289.8 *4*	1.9 *3*	53.928	1/2⁻			
		1343.7 *2*	18.5 *17*	0	5/2⁻	M1+E2		E_γ,I_γ: other: 1343.8 *4* with Iγ=20.1 *9* (1974Ez01). δ: −0.50 *+19−27* or ≥+4.3 (1974Ez01). A_2=+0.004 *41*, A_4=+0.016 *53*.
1369.46	5/2⁺	1254.2 *2*	59.0 *15*	115.126	3/2⁻	E1		E_γ: other: 1254.3 *3* (1974Ez01). I_γ: weighted average of 63 *3* (1977Ch14) and 58.4 *11* (1974Ez01). Mult.: for δ(Q/D)=+0.14 *2* in 1974Ez01, M2 component is unlikely based on RUL; M1+E2 is inconsistent with π(1369)=+ from γ(lin pol) in (α,nγ). Main component of γ doublet (1977Ch14). A_2=−0.139 *14*, A_4=+0.014 *19*.
		1369.7 *3*	41.0 *15*	0	5/2⁻	E1		E_γ: other: 1369.6 *4* (1974Ez01). I_γ: weighted average 37 *3* (1977Ch14) and 41.6 *11* (1974Ez01). Mult.: for δ(Q/D)=+0.11 *8* in 1974Ez01, M2 component is unlikely based on RUL; M1+E2 is inconsistent with π(1369)=+ from γ(lin pol) in (α,nγ). A_2=+0.063 *23*, A_4=+0.017 *30*.
1469.40	3/2⁻	422.5 *4*	4.1 *6*	1047.28	5/2⁻			
		602.6 *5*	4.9 *7*	866.96	1/2⁻			
		700.8[@a] *10*		768.87	5/2⁻			
		1262.3 *8*	5.7 *9*	206.96	3/2⁻			E_γ: unweighted average of 1261.5 *3* (1977Ch14) and 1263.0 *4* (1974Ez01). I_γ: other: 8 *1* (1974Ez01). A_2=−0.261 *244*, A_4=0.
		1354.4 *2*	62.8 *24*	115.126	3/2⁻	D+Q		E_γ: weighted average of 1354.3 *2* (1977Ch14) and 1354.8 *4* (1974Ez01). I_γ: other: 67 *2* (1974Ez01). δ: −0.16<δ(D+Q)<+10.7 for J(1470)=3/2 (1974Ez01). A_2=+0.013 *20*, A_4=0.
		1414.5 *3*	18.4 *15*	53.928	1/2⁻			E_γ,I_γ: other: 1416 with Iγ=19 *1* (1974Ez01).
		1470.0 *4*	4.1 *6*	0	5/2⁻			E_γ: weighted average of 1470.2 *5* (1977Ch14) and 1469.9 *4* (1974Ez01). I_γ: other: 6 *1* (1974Ez01).
1577.17	3/2⁻	807.6[@a] *10*		768.87	5/2⁻			
		1461.9[@a] *10*		115.126	3/2⁻			
		1523.3 *4*	39.0 *16*	53.928	1/2⁻	D+Q	>+0.46	Mult.,δ: for J(1577)=3/2. Other: δ(O/QQ)=−0.09 *+52−45* for J(1577)=5/2

^{65}Cu(p,nγ) 1974Ez01,1977Ch14 (continued)

γ(^{65}Zn) (continued)

E_i(level)	J_i^π	E_γ[†]	I_γ[‡]	E_f	J_f^π	Mult.[#]	δ[#]	Comments
								(1974Ez01). A_2=+0.092 *58*, A_4=0 for J=3/2. A_2=+0.094 *64*, A_4=−0.005 *85* for J=5/2.
1577.17	3/2−	1577.2 *4*	61.0 *16*	0	5/2−	D+Q	+1.2 *+12−7*	Mult.,δ: for J(1577)=3/2. Other: −7.1<δ(Q/D)<−0.8 for J(1577)=5/2 (1974Ez01). A_2=−0.064 *34*, A_4=0 for J=3/2. A_2=−0.089 *34*, A_4=+0.051 *47* for J=5/2.
1588.20	7/2−	818.9[@a] *10*		768.87	5/2−			
		1473.1 *4*	24.8 *25*	115.126	3/2−			
		1588.2 *4*	75.2 *25*	0	5/2−	D+Q		δ: +0.29 *4* or +20 *+10−5* for J=7/2. For δ values for other possible spins, see 1974Ez01. A_2=+0.096 *38*, A_4=+0.048 *50* for J=7/2.
1779.6?		1725.6[@a] *10*		53.928	1/2−			
		1779.6[@a] *10*		0	5/2−			
1793.5?		1739.5[@a] *10*		53.928	1/2−			
		1793.5[@a] *10*		0	5/2−			
1941.2?	(1/2,3/2)	1826.1[@a] *10*		115.126	3/2−			
		1887.1[@a] *10*		53.928	1/2−			
		1941.1[@a] *10*		0	5/2−			

[†] From 1977Ch14 up to 1469 level and from 1974Ez01 above that, unless otherwise noted.

[‡] Percent photon branching from each level. Quoted values with uncertainties up to 1469 level are deduced by the evaluator from the relative photon branchings of 1977Ch14 and values for E(level)<769 are read from the level scheme in FIG.1 of 1977Ch14, and values for E(level)>1469 are from 1974Ez01, unless otherwise noted. Values from 1974Ez01 for levels up to 1469 are in a good agreement with those in 1977Ch14, but less complete.

[#] From γ(θ) in 1974Ez01, with magnetic or electric characters determined based on RUL and measured $T_{1/2}$ where available, unless otherwise noted.

[@] Unconfirmed γ reported in 1973VaYC. Uncertainty not given but estimated to be approximately 1.0 by the evaluator.

[&] From α(K)exp values as given under comments, with mixing ratio deduced by the evaluator using the BrIccMixing code or from RUL as noted in comments.

[a] Placement of transition in the level scheme is uncertain.

$^{65}_{30}Zn_{35}$-6

Legend

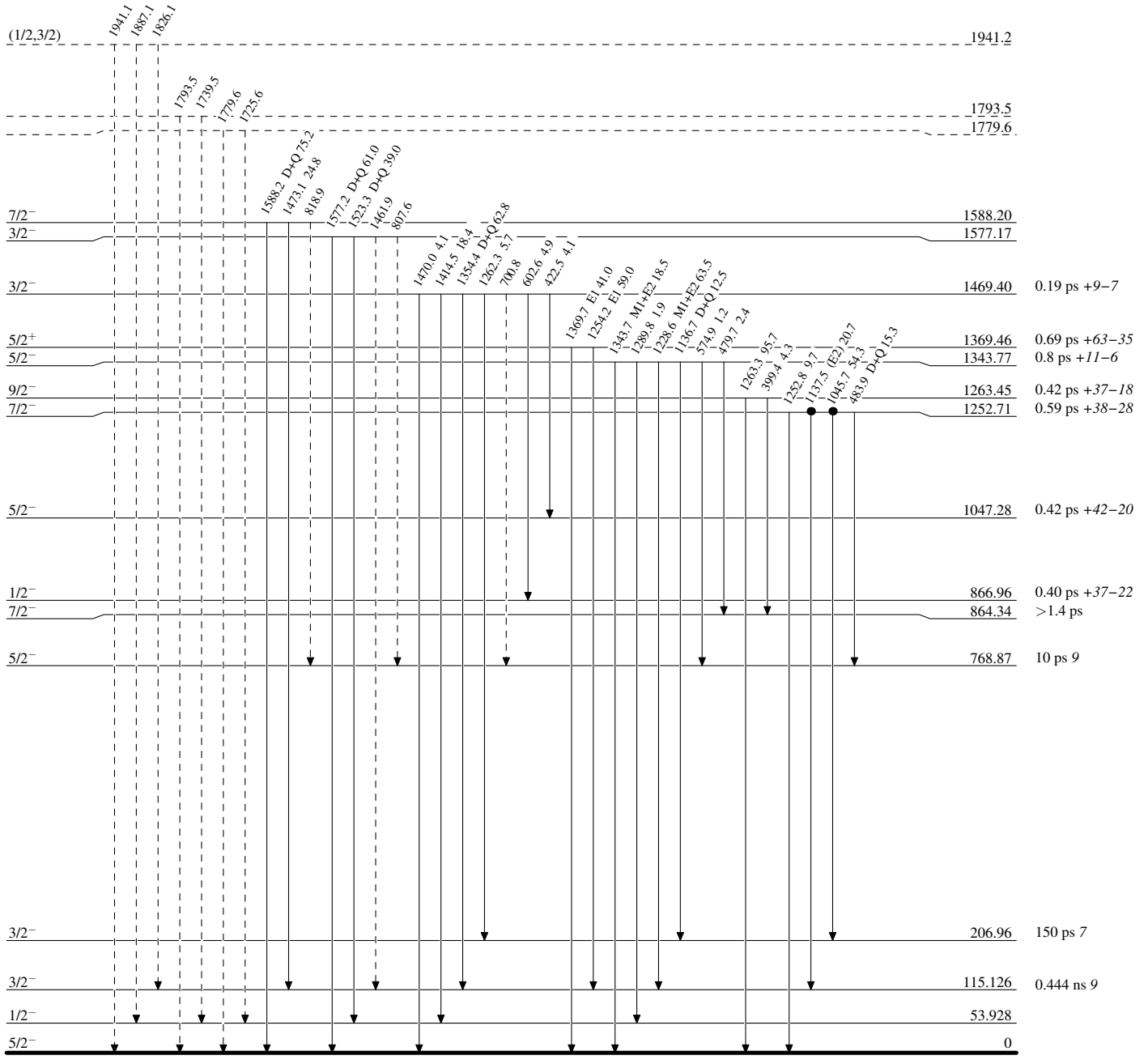
^{65}Cu(p,nγ) 1974Ez01,1977Ch14

Level Scheme

Intensities: % photon branching from each level

γ Decay (Uncertain)

Coincidence



$^{65}_{30}Zn_{35}$

^{65}Cu(p,nγ) 1974Ez01,1977Ch14

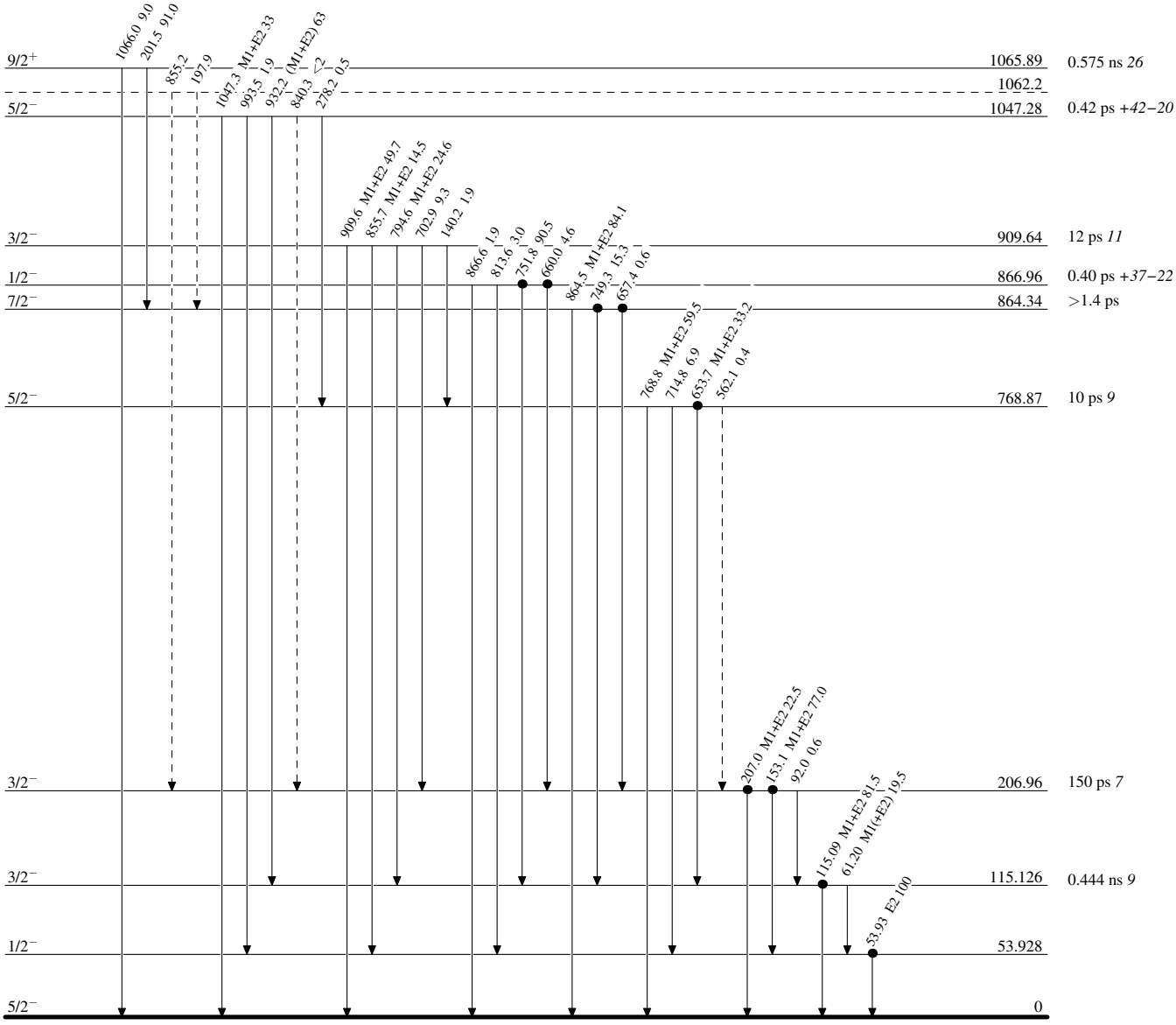
Legend

Level Scheme (continued)

Intensities: % photon branching from each level

γ Decay (Uncertain)

Coincidence



$^{65}_{30}Zn_{35}$