^{63}Cu(p,nγ) 1982Pa01

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	Jun Chen	NDS 196,17 (2024)	30-Sep-2023

1982Pa01: E=5-7.8 MeV proton beams were produced from the T11/25 tandem Van de Graaff accelerator of the Nuclear Research Center Demokritos. Target was 3.8 mg/cm^2 self-supporting 99.7% enriched ^{63}Cu. γ rays were detected with Ge(Li) detectors. Measured Eγ, Iγ, $\gamma(\theta)$, $\gamma\gamma$-coin, Doppler-shift attenuation. Deduced levels, J, π, $T_{1/2}$, γ-ray branching ratios, mixing ratios, transition strengths. Comparisons with available data.

1978Me17: E=6 MeV proton beam was produced from the McMaster FN tandem. Target was natural metallic copper. γ rays were detected with Ge(Li) detectors. Measured Eγ, Iγ. Deduced levels. 1978Me17 also report data on ^{60}Ni(α,nγ), ^{54}Fe(^{12}C,2pnγ). All Eγ data from the three measurements are combined by 1978Me17 and are all presented by the evaluator in ^{60}Ni(α,nγ) dataset together with $\gamma(\theta)$ data in that measurement.

Others:

1975Ro25: E=10 MeV at Amsterdam. Measured 193γ(t).

1968Bi03,1968Bi01: E=4.6-5.2 MeV at Hebrew University. Measured $\gamma(\theta)$ of 190γ. See also 1967Bi04 with E=7.0-7.8 MeV and 1966Bi07 with E=4-9 MeV.

1967Me18: E=5.8 MeV at Zurich. Measured Eγ, Iγ, E(ce), I(ce), $\gamma(\theta)$. Deduced conversion coefficient, mixing ratio of 193γ.

^{63}Zn Levels

E(level)[†]	J$^\pi$[‡]	$T_{1/2}$[#]	Comments
0.0	3/2$^-$		J$^\pi$: from Adopted Levels.
192.912 *39*	5/2$^-$	<1.8 ns	J$^\pi$: 5/2 from $\gamma(\theta)$ in 1982Pa01, 1968Bi03, and 1967Me18. $T_{1/2}$: from 193γ(t) in 1975Ro25.
247.84 *5*	1/2		J$^\pi$: from $\gamma(\theta)$ of 247.8γ to g.s. and 1036.3γ from 1284 level.
627.11 *6*	1/2,3/2,5/2		
637.07 *5*	1/2,3/2	>0.53 ps	$T_{1/2}$: from τ>760 fs.
650.112 *40*	5/2$^-$	>0.28 ps	J$^\pi$: parity from 1210.7γ E2 from 9/2$^-$. $T_{1/2}$: from τ>400 fs.
1023.23 *5*	3/2$^-$	>0.35 ps	$T_{1/2}$: from τ>500 fs.
1063.25 *7*	7/2$^-$	>0.29 ps	J$^\pi$: parity from 1063.2γ E2 to 3/2$^-$. $T_{1/2}$: from τ>420 fs.
1065.24 *10*	5/2	>0.22 ps	J$^\pi$: 1/2$^-$ in Adopted Levels. $T_{1/2}$: from τ>320 fs.
1206.36 *7*	7/2$^-$	>0.42 ps	J$^\pi$: parity from 1206.3γ E2 to 3/2$^-$. $T_{1/2}$: from τ>600 fs.
1284.26 *6*	5/2	>0.40 ps	$T_{1/2}$: from τ>580 fs.
1395.44 *10*	3/2$^-$	0.13 ps *+6−3*	J$^\pi$: parity from 1395.4γ M1+E2 to 3/2$^-$. $T_{1/2}$: from τ=190 fs *+80−50*.
1436.21 *11*	9/2$^-$	>0.30 ps	J$^\pi$: parity from 1243.3γ E2 to 5/2$^-$. $T_{1/2}$: from τ>440 fs.
1664.90 *9*	3/2,5/2,7/2	0.26 ps *+12−8*	$T_{1/2}$: from τ=370 fs *+180−110*.
1691.22 *9*	5/2$^-$	0.062 ps *+19−14*	J$^\pi$: parity from 1691.2γ M1+E2 to 3/2$^-$. $T_{1/2}$: from τ=90 fs *+27−20*.
1702.91 *10*	5/2,9/2	>0.25 ps	$T_{1/2}$: from τ>360 fs.
1860.81 *14*	9/2$^-$	0.33 ps *+70−15*	J$^\pi$: parity from 797.5γ M1+E2 to 7/2$^-$. $T_{1/2}$: from τ=480 fs *+1000−220*.
1909.26 *13*	5/2	>0.28 ps	J$^\pi$: 3/2$^-$ in Adopted Levels. $T_{1/2}$: from τ>400 fs.
1978.40 *19*	3/2,5/2,7/2	0.19 ps *+7−5*	$T_{1/2}$: from τ=270 fs *+100−70*.
2050.38 *19*	9/2	>0.31 ps	$T_{1/2}$: from τ>450 fs.
2158.10 *22*	3/2$^-$	0.028 ps *+14−10*	J$^\pi$: pairty from 1910.4γ M1+E2 to 5/2$^-$. $T_{1/2}$: from τ=40 fs *+20−14*.
2249.99 *15*	5/2,7/2	0.17 ps *+7−5*	$T_{1/2}$: from τ=240 fs *+100−70*.
2261.53 *17*	(3/2)	0.07 ps *+3−2*	$T_{1/2}$: from τ=95 fs *+45−20*.
2288.32 *17*	7/2	>0.21 ps	$T_{1/2}$: from τ>300 fs.

Continued on next page (footnotes at end of table)

^{63}Cu(p,nγ) 1982Pa01 (continued)

^{63}Zn Levels (continued)

E(level)[†]	J$^\pi$[‡]	$T_{1/2}$[#]	Comments
2291.47 *15*	3/2	0.06 ps *+3−2*	$T_{1/2}$: from τ=93 fs *+37−27*.
2292.98 *30*	3/2	0.030 ps *+15−10*	$T_{1/2}$: from τ=43 fs *+22−15*.
2377.81 *22*	7/2,9/2	>0.21 ps	J$^\pi$: 7/2,9/2 from $\gamma(\theta)$ in 1982Pa01. $T_{1/2}$: from τ>300 fs.
2403.28 *19*	1/2,3/2,5/2	0.11 ps *+7−4*	$T_{1/2}$: from τ=160 fs *+100−60*.
2522.10 *15*			
2600.09 *27*			
2609.12 *36*			
2634.52 *22*			
2690.9 *10*			
2750.72 *34*			

† From a least-squares fit to γ-ray energies.

‡ Spin from $\gamma(\theta)$ in 1982Pa01, unless otherwise noted.

From DSAM in 1982Pa01, unless otherwise noted.

^{63}Cu(p,nγ) 1982Pa01 (continued)

γ(^{63}Zn)

A_2 and A_4 values are from 1982Pa01, unless otherwise noted.

E_i(level)	J^π_i	E_γ †	I_γ †	E_f	J^π_f	Mult. ‡	δ ‡	Comments
192.912	5/2$^-$	192.94 *6*	100	0.0	3/2$^-$	M1+E2	−0.08 *+3−4*	A_2=−0.12 *1*; A_4=+0.003 *1* A_2=−0.105 *19*; A_4=−0.014 *25* (1968Bi03) A_2=+0.078 *9*; A_4=−0.014 *10* (1967Me18) Mult.: D+Q from $\gamma(\theta)$, not pure E1 or pure E2 from ce data in 1967Me18. δ: from −0.08 *+3−4* or −2.5 *+2−3* (1982Pa01), with the smaller value adopted by the evaluator from comparisons with earlier values: −0.07 *3* (1968Bi03), 0.4 *1* (1967Me18), 0.3 *2* (1978Me17). K/(L+M)=7.41 *11* (1967Me18). α_K(exp)=0.00886 *45*, α_{L+M}(exp)=0.00119 *7* (1967Me18).
247.84	1/2	247.84 *7*	100	0.0	3/2$^-$	D+Q		A_2=−0.01 *1*; A_4=+0.03 *1* δ: −0.14 *10* or +9.5 *+∞−48* for J=3/2, +0.24 *+4−6* or pure E2 for J=5/2.
627.11	1/2,3/2,5/2	627.10 *7*	100	0.0	3/2$^-$	D+Q		A_2=−0.01 *1*; A_4=+0.01 *1* δ: −0.12 *+13−10* for J=3/2, +0.22 *4* for J=5/2.
637.07	1/2,3/2	389.26 *9*	4.0 *4*	247.84	1/2	D+Q		A_2=0.00 *4*; A_4=−0.10 *5* δ: 0.0 *+2−3* or +1.8 *+8−17* for J=3/2.
		637.04 *7*	96.0 *4*	0.0	3/2$^-$	D+Q		A_2=−0.02 *1*; A_4=0.00 *1* δ: −0.09 *18* for J=3/2 (1982Pa01).
650.112	5/2$^-$	457.19 *6*	13.4 *9*	192.912	5/2$^-$	D+Q		A_2=+0.09 *2*; A_4=+0.02 *2* δ: +0.07 *6* or +1.5 *+3−2*.
		650.14 *6*	86.6 *9*	0.0	3/2$^-$	D+Q	−0.75 *18*	A_2=−0.25 *2*; A_4=0.00 *2*
1023.23	3/2$^-$	373.06 *8*	38.8 *19*	650.112	5/2$^-$	D+Q		A_2=−0.01 *2*; A_4=+0.04 *2* δ: −0.32 *+21−28* or +1.7 *+6−8*.
		396.1 *1*	6.5 *5*	627.11	1/2,3/2,5/2			
		775.43 *8*	27.7 *14*	247.84	1/2	D+Q		A_2=−0.05 *2*; A_4=0.00 *2* δ: 0.00 *8* or −1.7 *+3−4*.
		1023.22 *8*	27.0 *13*	0.0	3/2$^-$	D(+Q)	+0.8 *+9−7*	A_2=+0.09 *2*; A_4=0.00 *2* δ: +0.8 *+9−7*.
1063.25	7/2$^-$	413.2 *1*	18.5 *13*	650.112	5/2$^-$	D+Q		A_2=−0.26 *2*; A_4=+0.02 *2* δ: −0.17 *3* or −2.5 *2*.
		870.25 *10*	15.9 *9*	192.912	5/2$^-$	D+Q		A_2=+0.24 *2*; A_4=+0.01 *2* δ: +0.58 *4* or +3.5 *3*.
		1063.2 *2*	65.6 *16*	0.0	3/2$^-$	E2		A_2=+0.19 *2*; A_4=−0.02 *2* Mult.: Q(+O) with δ=0.00 *3* from $\gamma(\theta)$ in 1982Pa01; M2,E3,M3 ruled out by RUL.
1065.24	5/2	415.2 *2*	3.8 *4*	650.112	5/2$^-$	D+Q		A_2=−0.04 *5*; A_4=+0.02 *6* δ: −0.6 *4* for J=5/2 (1982Pa01).

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γ(^{63}Zn) (continued)

E_i(level)	J^π_i	E_γ†	I_γ†	E_f	J^π_f	Mult.‡	δ‡	Comments
1065.24	5/2	818.2# 5	10	247.84	1/2			I(818.2γ)/I(1065.2γ)=10/90 from 1978Me17, but this γ is not seen in any other studies. It is considered questionable by the evaluator.
		872.4 2	4.8 4	192.912	5/2⁻			
		1065.2 2	91.4 6	0.0	3/2⁻	D+Q		A_2=−0.19 2; A_4=+0.02 2 δ: −0.30 7 or −1.6 2 for J=5/2 (1982Pa01).
1206.36	7/2⁻	556.3 2	2.2 2	650.112	5/2⁻	D+Q		A_2=−0.35 11; A_4=+0.03 14 δ: −0.32 6 or −1.8 2 for J=7/2 (1982Pa01).
		1013.45 10	46.9 20	192.912	5/2⁻			
		1206.34 11	50.9 22	0.0	3/2⁻	E2		A_2=+0.19 2; A_4=−0.01 2 Mult.: Q(+O) with δ=+0.01 2 from $\gamma(\theta)$ in 1982Pa01; M2,E3,M3 ruled out by RUL.
1284.26	5/2	634.5 5	7.7 6	650.112	5/2⁻			
		1036.34 8	27.6 13	247.84	1/2	E2		A_2=+0.13 2; A_4=+0.03 2 Mult.: Q(+O) with δ=+0.02 5 from $\gamma(\theta)$ in 1982Pa01; M2,E3,M3 ruled out by RUL.
		1091.40 8	58.1 15	192.912	5/2⁻	D+Q		A_2=−0.02 2; A_4=−0.02 2 δ: −0.50 8 or +10 +19 −4.
		1284.21 15	6.6 5	0.0	3/2⁻	D+Q	−0.75 +30−20	A_2=−0.34 8; A_4=+0.04 9
1395.44	3/2⁻	768.36 12	19.3 12	627.11	1/2,3/2,5/2	M1+E2		A_2=+0.02 4; A_4=−0.01 4 δ: +0.37 +25−18 or ≥3.
		1147.3 4	6.7 8	247.84	1/2	D+Q		
		1202.8 5	4.0 5	192.912	5/2⁻	D+Q		
		1395.39 15	70.0 13	0.0	3/2⁻	M1+E2	+0.78 +45−33	A_2=+0.10 2; A_4=−0.02 2
1436.21	9/2⁻	1243.28 10	100	192.912	5/2⁻	E2		A_2=+0.25 2; A_4=−0.06 2 Mult.: Q(+O) with δ=−0.02 3 from $\gamma(\theta)$ in 1982Pa01; M2,E3,M3 ruled out by RUL.
1664.90	3/2,5/2,7/2	1014 1	13.2 12	650.112	5/2⁻			
		1027.8 2	12.1 8	637.07	1/2,3/2			A_2=+0.11 5; A_4=+0.01 5 Mult.,δ: δ(Q/D)=+0.7 +13−5 for J=3/2, +0.50 14 or +7 +10−3 for J=5/2, δ(O/Q)=−0.18 10 or −3.7 +10−20 for J=7/2 (1982Pa01).
		1472.0 1	59.8 25	192.912	5/2⁻	M1+E2	+0.11 3	A_2=−0.04 2; A_4=+0.01 2 δ: +0.30 +23−11 or E2 for J=5/2, −0.64 9 or E2 for J=5/2, +0.11 3 for J=7/2.
		1664.8 2	14.9 10	0.0	3/2⁻			A_2=−0.07 4; A_4=+0.09 5 Mult.,δ: δ(Q/D)≤0.2 for J=3/2, +0.10 9 for J=5/2, −1.9≤δ(O/Q)<−0.05 for J=7/2.
1691.22	5/2⁻	1054.1 3	5.3 7	637.07	1/2,3/2			
		1498.3 2	10.0 7	192.912	5/2⁻	D+Q		A_2=+0.09 7; A_4=+0.09 8 δ: −0.2≤δ≤+2.8.
		1691.2 1	84.7 1	0.0	3/2⁻	M1+E2		A_2=−0.17 2; A_4=+0.01 2 δ: −0.19 6 or −2.0 3.

γ(^{63}Zn) (continued)

E_i(level)	J^π_i	E_γ†	I_γ†	E_f	J^π_f	Mult.‡	δ‡	Comments
1702.91	5/2,9/2	496.56 12	15.1 13	1206.36	7/2−	D(+Q)	−0.01 3	A_2=−0.24 3; A_4=+0.02 4 δ: +1.2 +9−5 for J=5/2, −0.01 3 for J=9/2.
		639.64 10	84.9 13	1063.25	7/2−	D(+Q)	+0.00 2	A_2=−0.17 2; A_4=−0.01 2 δ: +0.54 +13−10 or +2.7 8 for J=5/2, 0.00 2 for J=9/2.
1860.81	9/2−	797.5 2	23.4 14	1063.25	7/2−	M1+E2	−0.07 4	A_2=−0.25 4; A_4=−0.06 5
		1210.7 2	61.3 20	650.112	5/2−	E2		A_2=+0.30 2; A_4=+0.01 2 Mult.: Q(+O) with δ=+0.02 3 from γ(θ) in 1982Pa01; M2,E3,M3 ruled out by RUL.
		1668.0 4	15.3 20	192.912	5/2−			
1909.26	5/2	1272.3 2	6.8 5	637.07	1/2,3/2	D+Q		A_2=−0.08 8; A_4=0.00 10 δ: 0.0 2 or −3.6 +17−60.
		1716.3 2	22.7 14	192.912	5/2−	D+Q		A_2=+0.06 3; A_4=+0.02 4 δ: −0.15 11 or +2.5 7.
		1909.0 3	70.5 14	0.0	3/2−	D+Q		A_2=−0.17 2; A_4=+0.02 2 δ: −0.18 5 or −2.1 2.
1978.40	3/2,5/2,7/2	1328.0 5	26.3 24	650.112	5/2−			
		1785.5 2	73.7 24	192.912	5/2−	D+Q		A_2=−0.08 2; A_4=+0.01 2 δ: +0.6≤δ≤+3.2 for J=3/2, −0.8 1 or −9 +4−10 for J=5/2, +0.12 +5−3 for J=7/2.
2050.38	9/2	844.1 4	39 3	1206.36	7/2−			
		987.1 2	61 3	1063.25	7/2−	D+Q		A_2=−0.50 4; A_4=+0.07 4 δ: −0.20 4 or −2.2 2.
2158.10	3/2−	1530.8 3	40 2	627.11	1/2,3/2,5/2	M1+E2	≥0.4	A_2=+0.08 4; A_4=−0.09 5
		1910.4 3	60 2	247.84	1/2	M1+E2	+1.7 +26−8	A_2=−0.50 4; A_4=+0.07 4
2249.99	5/2,7/2	1184.8 2	50 2	1065.24	5/2	D+Q		A_2=+0.14 7; A_4=−0.06 8 δ: +0.1 +5−2 or +1.5 +11−8 for J=5/2, +0.3 1 for J=7/2.
		1599.8 2	50 2	650.112	5/2−	D+Q		A_2=−0.13 7; A_4=−0.10 8 δ: −2 +1−8 for J=5/2, +0.05 6 or −5 +1−2 for J=7/2.
2261.53	(3/2)	1634.4 2	74 2	627.11	1/2,3/2,5/2	M1+E2	−0.5 +3−4	A_2=−0.21 5; A_4=+0.05 6
		2261.5 3	26 2	0.0	3/2−	D+Q		A_2=−0.19 13; A_4=+0.22 17
2288.32	7/2	1081.9 3	32 2	1206.36	7/2−			
		1638.2 2	68 2	650.112	5/2−	D+Q		A_2=−0.42 4; A_4=−0.03 3 δ: −2.0 2 or −0.25 4.
2291.47	3/2	1641.7 3	34 2	650.112	5/2−			
		1654.2 2	39 2	637.07	1/2,3/2	D+Q		A_2=−0.01 6; A_4=+0.04 8 δ: $>$−0.5.
		2043.6 3	27 2	247.84	1/2	D+Q	−0.5 +3−5	A_2=−0.31 10; A_4=+0.11 10
2292.98	3/2	2045.1 3	100	247.84	1/2	M1+E2	+1.7 +78−10	A_2=+0.33 10; A_4=−0.11 11
2377.81	7/2,9/2	674.9 2	100	1702.91	5/2,9/2	D+Q	−0.53 5	A_2=+0.02 2; A_4=−0.02 2 δ: −0.11 4 or −5.1 +8−12 for J=7/2, −0.53 5 for J=9/2.
2403.28	1/2,3/2,5/2	1380.0 2	65 5	1023.23	3/2−	D+Q		A_2=−0.06 7; A_4=+0.04 9 δ: $<$0 for J=3/2, +0.09 +15−12 for J=5/2.

^{63}Cu(p,nγ) 1982Pa01 (continued)

γ(^{63}Zn) (continued)

E_i(level)	J^{π}_i	E_γ †	I_γ †	E_f	J^{π}_f
2403.28	1/2,3/2,5/2	1776.4 *5*	35 *5*	627.11	1/2,3/2,5/2
2522.10		1456.9 *2*	51 *4*	1065.24	5/2
		1871.9 *2*	49 *4*	650.112	5/2$^-$
2600.09		1950.5 *4*	43 *4*	650.112	5/2$^-$
		2351.7 *4*	44 *4*	247.84	1/2
		2599.8 *8*	13 *3*	0.0	3/2$^-$
2609.12		1959.0 *7*	45 *5*	650.112	5/2$^-$
2609.12		1971.9 *8*	17 *5*	637.07	1/2,3/2
		2609.1 *5*	38 *5*	0.0	3/2$^-$
2634.52		1428.1 *3*	45 *3*	1206.36	7/2$^-$
		2441.6 *3*	55 *3*	192.912	5/2$^-$
2690.9		2443 *1*	100	247.84	1/2
2750.72		2100.6 *4*	54 *8*	650.112	5/2$^-$
		2557.7 *6*	46 *8*	192.912	5/2$^-$

† From 1982Pa01. Intensity values are %photon branching from each level.

‡ From 1982Pa01 deduced based on measured $\gamma(\theta)$, unless otherwise noted. Where level $T_{1/2}$ are present, RUL is used to determine the magnetic or electric nature of a transition.

\# Placement of transition in the level scheme is uncertain.

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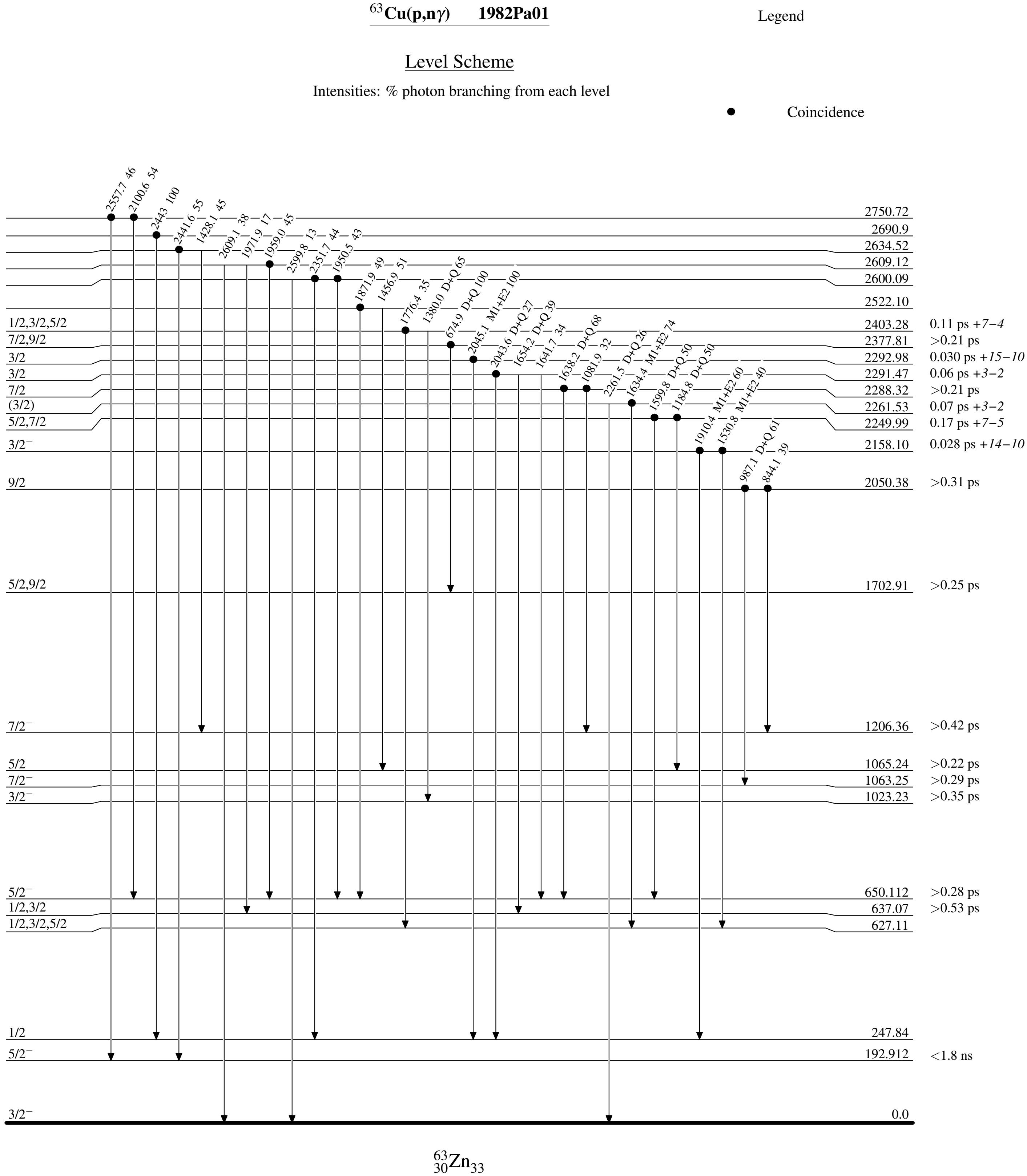
$^{63}Cu(p,n\gamma)$ 1982Pa01

Level Scheme

Intensities: % photon branching from each level



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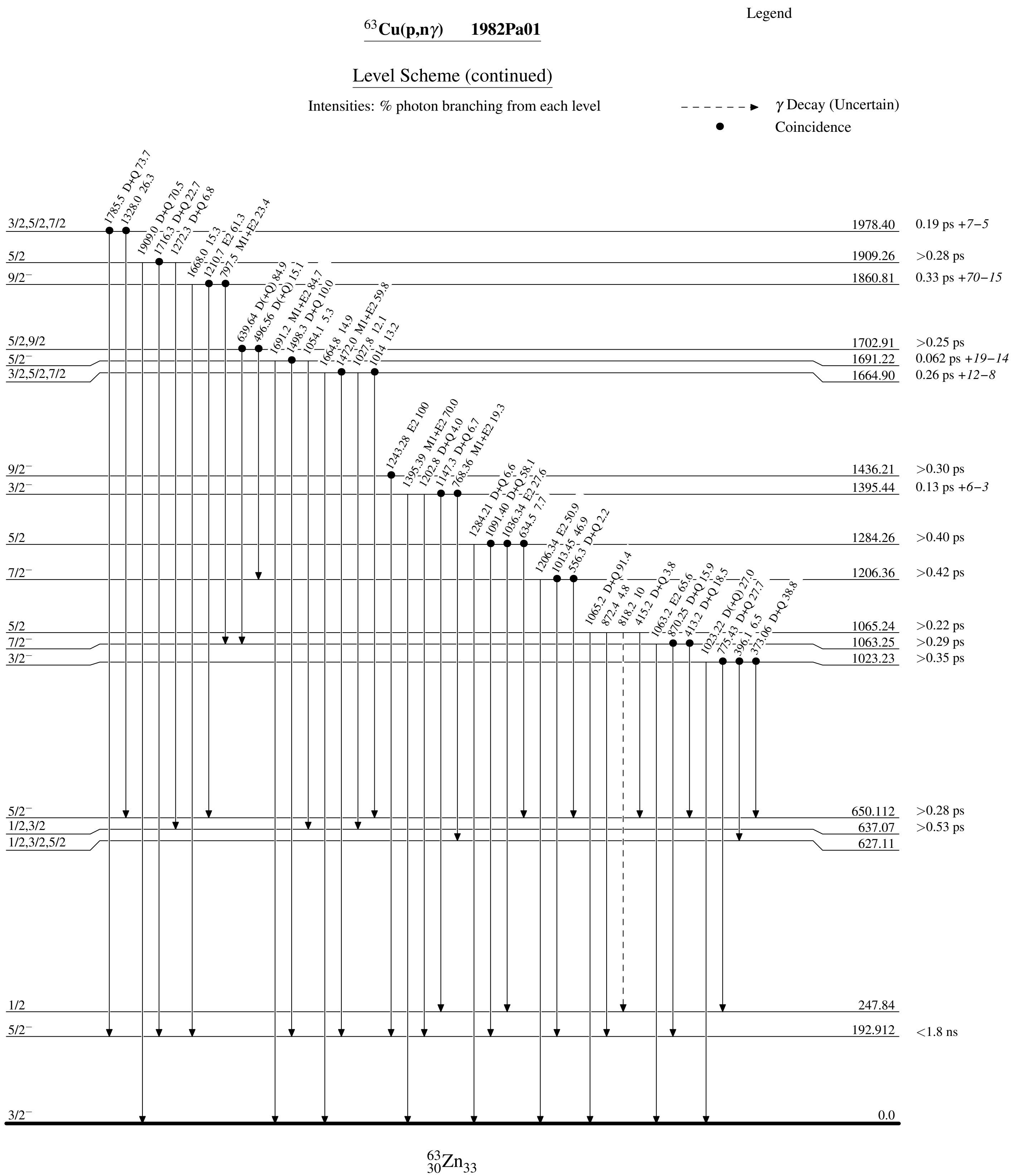
Level Scheme (continued)

Intensities: % photon branching from each level

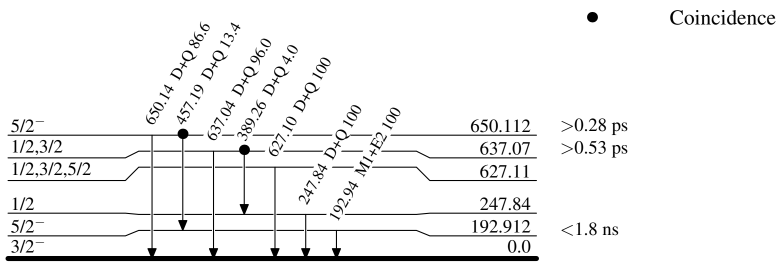


^{63}Cu(p,nγ) 1982Pa01

Legend

Level Scheme (continued)

Intensities: % photon branching from each level



$^{63}_{30}Zn_{33}$