^{65}Cu(p,p′γ) 1977Ha13

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

1977Ha13: E=5.25 and 6.0 MeV proton beams were produced from the T11/25 tandem Van de Graaff accelerator of the NRC Demokritos. Target was a 3.5 mg/cm^2 self-supporting copper foil (enriched to 99.69% in ^{65}Cu). γ rays were detected with two Ge(Li) detectors. Measured Eγ, Iγ, γ(θ), Doppler-shift attenuation. Deduced levels, J, π, $T_{1/2}$, γ-ray branching ratios, multipolarities and mixing ratios, transition strengths. Comparisons with available data and theoretical calculations.

1968Sm07: E=6.5 MeV proton beam was produced from the MIT-ONR Van de Graaff accelerator. Target was 99.7% enriched ^{65}Cu with a thickness of about 250-280 μg/cm^2. Scattered protons were momentum-analyzed with the MIT multiple-gap magnetic spectrograph; γ rays were detected with a NaI(Tl) detector. Measured Eγ, Iγ, pγ-coin. Deduced levels, J, π, γ-ray branching ratios.

Others:

1976Kr16: E<3.0 MeV. Measured σ.

1978Be40: E=5.0-6.2 MeV. Measured σ. See also (p,p′):IAR.

2021Ta28: E<3 MeV. Measured Eγ, Iγ, σ.

^{65}Cu Levels

E(level)[†][‡]	Jπ[#]	$T_{1/2}$[@]	Comments
0	3/2$^-$		
770.60 *14*	1/2$^-$		
1115.87 *5*	5/2$^-$		
1481.64 *5*	7/2$^-$		Jπ: spin=7/2 from 365.6γ(θ) in 1977Ha13; no conclusive result from 1481.6γ(θ).
1623.70 *7*	5/2$^-$		Jπ: spin=3/2,5/2 from 1623.8γ(θ) in 1977Ha13.
1725.24 *21*	3/2$^-$	68 fs *+28−16*	Jπ: spin=3/2,5/2 from 1724.7γ(θ) in 1977Ha13.
2096.8 *4*	7/2$^-$		
2209.2 *4*	(1/2)$^-$		
2525.55 *11*	9/2$^+$		Jπ: spin=9/2 from 1043.9γ(θ) in 1977Ha13. J=9 from γ(θ).
2593.33 *25*	(5/2$^-$)		
2642.63 *33*	(5/2$^-$)		
2655.0 *5*	5/2$^-$	58 fs *+18−13*	Jπ: spin=5/2 from 2655.5γ(θ) in 1977Ha13.

[†] Additional information 1.
[‡] From a least-squares fit to γ-ray energies.
[#] From Adopted Levels. Supporting arguments from this dataset are given under comments.
[@] From DSAM in 1977Ha13.

γ(^{65}Cu)

A_2 and A_4 under comments are from 1977Ha13.

E_i(level)	J_i^π	E_γ[‡]	I_γ[‡]	E_f	J_f^π	Mult.[#]	δ[#]	Comments
770.60	1/2$^-$	770.7 *3*	100	0	3/2$^-$			
1115.87	5/2$^-$	345.1[@] *3*		770.60	1/2$^-$			Reported as a tentative transition in 1977Ha13, probably not seen or very weak.
		1115.83 *5*	100	0	3/2$^-$			
1481.64	7/2$^-$	365.6 *3*	13.8 *29*	1115.87	5/2$^-$	D(+Q)	−0.07 *+7−14*	I_γ: other: 18 *4* (1968Sm07). Mult.: other: +4.5 *12* also from γ(θ) in 1977Ha13, but the large E2 or M2 component is ruled out based on RUL and

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^{65}Cu(p,p′γ) 1977Ha13 (continued)

γ(^{65}Cu) (continued)

E_i(level)	J_i^π	E_γ[‡]	I_γ[‡]	E_f	J_f^π	Mult.[#]	δ[#]	Comments
								adopted $T_{1/2}$.
								A_2=−0.17 *6*, A_4=+0.08 *7*.
1481.64	7/2−	1481.63 *5*	86.2 *29*	0	3/2−	(Q)		I_γ: other: 82 *4* (1968Sm07).
								δ: +0.24 *6* or +3.2 *+6−3* would require an unrealistically high M3 or E3 contribution (1977Ha13); the authors explain that the γ(θ) could be renderred by indirect feeding from higher levels and is insensitive to the determination of spin and mixing ratio.
								A_2=+0.10 *5*, A_4=−0.03 *5*.
1623.70	5/2−	507.7 *1*	36.9 *29*	1115.87	5/2−	D+Q		I_γ: other: 39 *4* (1968Sm07).
								δ: +0.25 *+72−39* or <−1.3 (1977Ha13).
								A_2=+0.02 *7*, A_4=+0.09 *9*.
		853.1[@] *2*	<10	770.60	1/2−			Reported as a tentative transition in 1977Ha13, probably not seen or very weak. The branching ratio of %Iγ=8 *1* from 1972Pa30 in ^{65}Ni β− decay is adopted in 1977Ha13 for normalizing intensities of 507.7γ and 1623.8γ from 1624 level.
		1623.8 *1*	55.0 *29*	0	3/2−	D+Q		I_γ: other: 12 *3* (1968Sm07).
								I_γ: other: 49 *5* (1968Sm07).
								δ: −0.03 *9* or +3.7 *+26−8* for J(1624)=5/2, +1.3 *+69−8* for J=3/2 (1977Ha13).
								A_2=−0.07 *7*, A_4=+0.01 *8*.
1725.24	3/2−	610.4[†] *3*	25 *6*	1115.87	5/2−			E_γ: uncertainty multiplied by a factor of 3 in the fitting; level-energy difference=609.37.
								I_γ: other: 32 *5* (1968Sm07).
		954.9[@] *3*	<5.7	770.60	1/2−			Not placed in the level scheme by 1977Ha13; not seen in 1968Sm07.
		1724.7[†] *1*	76 *6*	0	3/2−	M1+E2		E_γ: uncertainty multiplied by a factor of 3 in the fitting; level-energy difference=1725.22.
								I_γ: other: 68 *5* (1968Sm07).
								δ: >0.15 for J(1725)=3/2, −0.05 *+23−20* or +3.7 *+16−17* for J=5/2 (1977Ha13).
								A_2=−0.01 *5*, A_4=−0.08 *7*.
2096.8	7/2−	2096.8 *4*	100	0	3/2−			
2209.2	(1/2)−	1438.6 *4*	100	770.60	1/2−			
2525.55	9/2+	1043.9 *1*	100	1481.64	7/2−	D+Q	+0.18 *13*	δ: the other solution of +2.4 *+7−5* for J(2526)=9/2 is not within the confidence level of the analysis of γ(θ) in 1977Ha13.
								A_2=−0.54 *4*, A_4=+0.20 *5*.
2593.33	(5/2−)	1822.7 *2*	100	770.60	1/2−			
2642.63	(5/2−)	1872.0 *3*	100	770.60	1/2−			
2655.0	5/2−	929.2[†] *2*	69.3 *34*	1725.24	3/2−			E_γ: uncertainty multiplied by a factor of 3 in the fitting; level-energy difference=929.8.
		2655.5[†] *2*	30.7 *34*	0	3/2−	M1+E2		E_γ: uncertainty multiplied by a factor of 3 in the fitting; level-energy difference=2655.0.
								δ: +0.22 *11* or +1.9 *+7−5*, from Table 5 of 1977Ha13, as adopted by the authors. Note that authors′ Table 4 lists different values of +0.10 *10-5* and +2.3 *+12−7*, respectively.
								A_2=−0.16 *9*, +0.08 *9*.

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^{65}Cu(p,p′γ) 1977Ha13 (continued)

$\gamma(^{65}Cu)$ (continued)

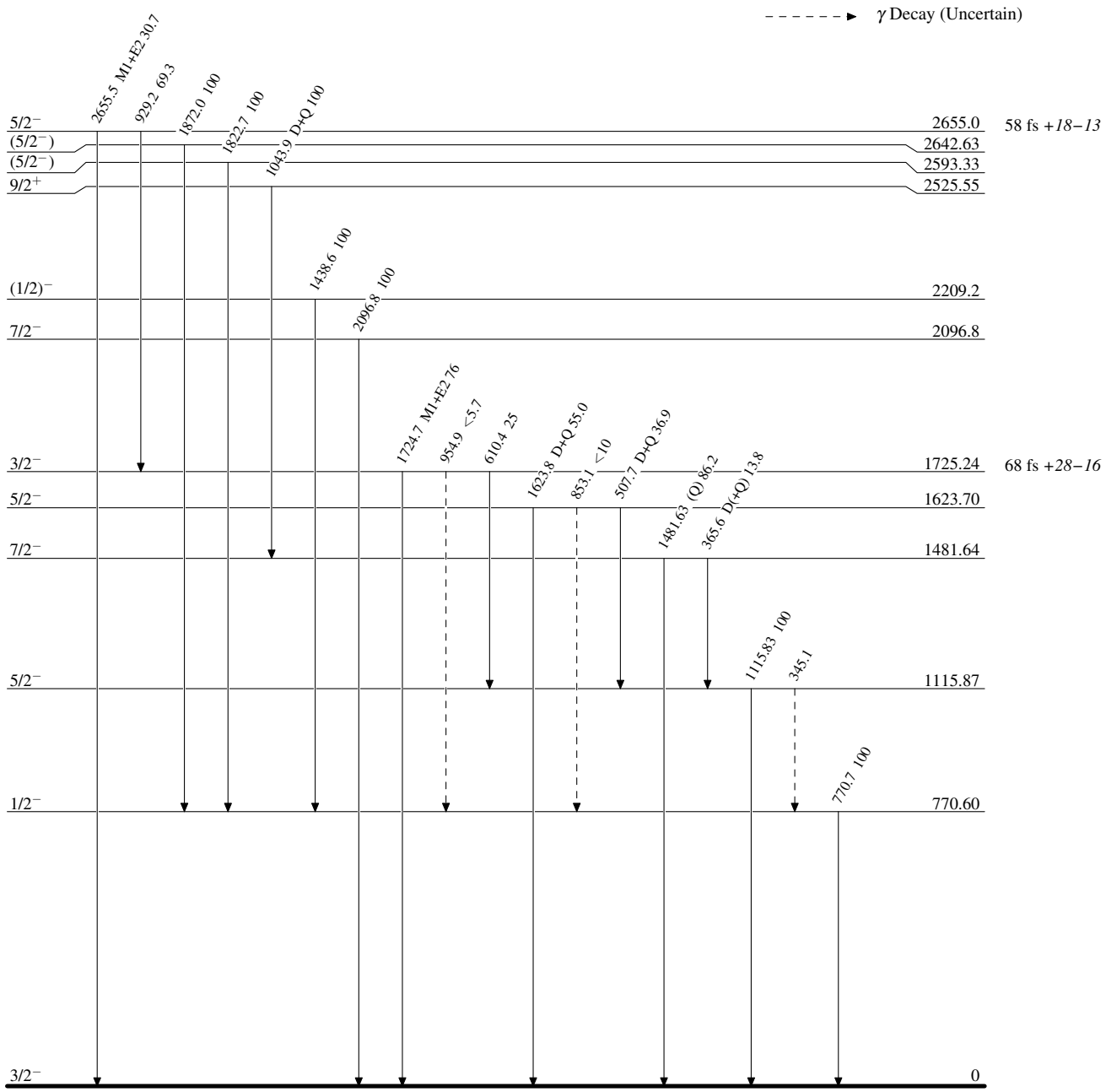
† Poor fit; uncertainty multiplied by a factor in the fitting.
‡ From 1977Ha13, unless otherwise noted.
# From $\gamma(\theta)$ in 1977Ha13, with magnetic and electric characters determined based on RUL where $T_{1/2}$ is available.
@ Placement of transition in the level scheme is uncertain.

^{65}Cu(p,p′γ) 1977Ha13

Legend

Level Scheme

Intensities: % photon branching from each level



$^{65}_{29}Cu_{36}$