^{48}Ti(p,p′),(pol p,p′) 1989Hi05

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	Jun Chen	NDS 179, 1 (2022)	30-Nov-2021

(pol p,p′):

1989Hi05: E=65 MeV polarized proton beam was produced from the Research Center for Nuclear Physics cyclotron. Target was a 0.495 mg/cm^2 self-supporting metallic ^{48}Ti (99.25% enriched). Scattered protons were detected with the magnetic spectrograph RAIDEN (FWHM≈30 keV) and detected with a telescope of gas proportional counters as ΔE detectors and a plastic scintillation E counter. Measured $\sigma(\theta)$ and analyzing power (θ=8° to 52°). Deduced levels, J, π, deformation parameters, energy-weighted sum rule (EWSR) fractions. Comparisons with available data and theoretical calculations. Uncertainty in absolute cross section is less than 10%. Report 82 levels.

1990To05,1990To16: E=11.18 MeV from the Tandem Accelerator Center, University of Tsukuba (UTTAC). Measured $\sigma(\theta)$, analyzing power, spin-flip probability for the first 2$^+$ level.

(p,p′):

1965Be09: E=7.010 MeV proton beam was produced from the MIT-ONR electrostatic generator. Target was ≈50 μg/cm^2 TiO_2 (99.7% in ^{48}Ti). Scattered protons were momentum-analyzed with the MIT broad-range, multi-gap spectrograph (FWHM=8 keV). Measured σ(θ=30° to 172.5°). Deduced levels.

1967Ri02: E=155 MeV proton beam was produced from the Orsay synchrocyclotron. Target was 0.2 g/cm^2 metallic ^{48}Ti. Scattered protons were momentum-analyzed with a magnetic spectrometer. Measured $\sigma(\theta)$. Deduced levels, J, π, transition strengths.

1969Lu04: E=14.4 MeV proton beam was produced from the Livermore variable-energy cyclotron. Target was 1 mg/cm^2 self-supporting metallic film of ^{48}Ti (99.0% enriched). Scattered protons were detected with a single Si(Li) detector (FWHM≈40 keV). Measured $\sigma(\theta_{cm}$=10° to 160°). Deduced levels, deformation parameters from DWBA analysis. Report 32 levels. See also 1974Lu07 for coupled-channel analysis of the first 4 excited states.

1989Wi13: E=201 MeV proton beam was produced from the Orsay synchrocyclotron. Target was 11.81 mg/cm^2 ^{48}Ti (99.1% enriched). Measured $\sigma(\theta)$, FWHM=70 keV. Deduced levels. 1989Wi13 use E=3000 of 0$^+$ and E=3370 of 2$^+$ level for energy calibration. Report 14 levels.

1984Wo03: E=101.3 MeV proton from University of Maryland Sectored isochronous Cyclotron. Measured $\sigma(\theta)$. Deduced deformation parameter for the first 2$^+$ level.

1961Ha41: E=2.3-4.2 MeV proton beams were produced from the University of Copenhagen electrostatic generator. Reaction products were momentum-analyzed with the heavy-particle spectrograph (FWHM≈0.1%). Measured spectra. Deduced levels.

Others: 1983ChZI, 1981Ko29, 1976An08, 1973El08, 1969Mo09, 1967Er03.

^{48}Ti Levels

Σ%EWSR(quadrupole)=7.12, Σ%EWSR(octupole)=9.35, and Σ%EWSR(hexadecapole)=1.22, for states up to 8.2 MeV (1989Hi05). 1989Wi13 also report dσ/dΩ(3°) for several unresolved groups of states between 8.86 MeV and 13.55 MeV. See 1989Wi13 for details. σ from 1969Lu04 as given under comments are for integrated cross sections.

E(level)[†]	J$^\pi$[#]	L[#]	β_L[#]	Comments
0.0	0$^+$			
982 *4*	2$^+$	2	0.201	B(E2)↑=0.050 *15* (1967Ri02) E(level): weighted average of 984 *5* (1989Hi05) and 981 *4* (1961Ha41). Others: 985 (1969Lu04), 980 *80* (1967Ri02), 985 *10* (1965Be09). β_L: other: 0.20 (1984Wo03), 0.22 *3* (1969Lu04), 0.26 (1967Er03). σ=33.3 mb (1969Lu04). dσ/dΩ(max)=9 mb/sr *2* (1967Ri02).
2295 *5*	4$^+$	4	0.03	E(level): weighted average of 2295 *5* (1989Hi05), 2301 *10* (1965Be09), and 2293 *8* (1961Ha41). Other: 2301 (1969Lu04). σ=2.7 mb (1969Lu04).
2421 *5*	(2$^+$)	(2)	0.037	B(E2)↑=0.0050 *15* (1967Ri02) E(level): weighted average of 2421 *5* (1989Hi05), 2425 *10* (1965Be09), and 2420 *8* (1961Ha41).

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^{48}Ti(p,p′),(pol p,p′) 1989Hi05 (continued)

^{48}Ti Levels (continued)

E(level)[†]	Jπ[#]	L[#]	β_L[#]	Comments
				Others: 2425 (1969Lu04), 2500 *200* (1967Ri02).
				σ=2.6 mb (1969Lu04).
				dσ/dΩ(max)=0.9 mb/sr *2* (1967Ri02).
2465 *5*				
2998 *5*				E(level): weighted average of 2997 *5* (1989Hi05) and 3004 *10* (1965Be09). Other: 3004 (1969Lu04).
				σ=1.9 mb (1969Lu04).
3062 *5*				
3230 *10*				E(level): from 1965Be09. It is indicated by 1965Be09 that their 3230 and 3248 levels correspond to the 3229 and 3240 levels from previous work.
3239 *5*	4^+	4	0.078[b]	E(level): other: 3248 *10* (1965Be09).
				β_L: other: 0.15 2 (1969Lu04).
				σ=5.4 mb for 3230+3249(1969Lu04).
3358 *5*	3^-	3	0.110	B(E3)↑=0.0044 *14* (1967Ri02)
				E(level): other: 3365 (1969Lu04), 3600 *100* (1967Ri02).
				β_L: other: 0.18 *3* (1969Lu04).
				dσ/dΩ(max)=2.4 mb/sr *2* (1967Ri02).
3365 *10*				E(level): from 1965Be09.
3376 *10*				E(level): from 1965Be09. Other: 3376 also from 1969Lu04.
				σ=8.8 mb for 3365+3376 (1969Lu04).
3511 *5*	6^+	6	0.019	E(level): other: 3520 (1969Lu04).
				σ=0.7 mb (1969Lu04).
3619 *5*	2^+	2	0.038	E(level): weighted average of 3618 *5* (1989Hi05) and 3625 *10* (1965Be09). Other: 3625 (1969Lu04).
				σ=1.8 mb (1969Lu04).
3703 *5*				E(level): weighted average of 3702 *5* (1989Hi05) and 3707 *10* (1965Be09). Other: 3707 (1969Lu04).
				σ=1.2 mb (1969Lu04).
3745 *10*	*a*			E(level): from 1965Be09. Other: 3740 (1989Wi13).
				dσ/dΩ(3°)=125 μb/sr *45* (1989Wi13).
3789 *5*				E(level): other: 3780 (1969Lu04).
				σ=0.7 mb (1969Lu04).
3856 *5*	3^-	3	0.057[b]	E(level): other: 3850 (1969Lu04).
				β_L: other: 0.10 2 (1969Lu04).
				σ=2.1 mb (1969Lu04).
4046 *5*	(5^-)[@]			E(level): other: 4048 (1969Lu04).
4077 *5*				σ=4.0 mb for 4048+4087 (1969Lu04).
4157 *5*				
4206 *5*	2^+	2	0.011	E(level): other: 4203 (1969Lu04).
				σ=1.0 mb (1969Lu04).
4260[‡]	*a*			dσ/dΩ(3°)=95 μb/sr *30* (1989Wi13).
4310 *5*				E(level): other: 4315 (1969Lu04).
				σ=1.1 mb (1969Lu04).
4348 *5*	(2^+)[@]			
4392 *5*	4^+	4	0.022	E(level): other: 4385 (1969Lu04).
				σ=2.8 mb (1969Lu04).
4472 *5*	3^-	3	0.011	
4532 *5*				
4591 *5*	3^-	3	0.073[b]	B(E3)↑=0.0022 *7* (1967Ri02)
				E(level): other: 4590 (1969Lu04), 4500 *200* (1967Ri02).
				β_L: other: 0.17 3 (1969Lu04).
				σ=4.8 mb (1969Lu04).
				dσ/dΩ(max)=1.2 mb/sr *2* (1967Ri02).
4726 *5*	4^+	4	0.014	
4802 *5*	$(2^+,3^-,4^+)$[@]			E(level): other: 4806 (1969Lu04).
				σ=2.6 mb (1969Lu04).

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^{48}Ti(p,p′),(pol p,p′) 1989Hi05 (continued)

^{48}Ti Levels (continued)

E(level)[†]	Jπ[#]	L[#]	β_L[#]	Comments
4900 *5*				E(level): other: 4930 (1969Lu04). σ=2.9 mb (1969Lu04).
4978 *5*				
5000 *5*				
5161 *10*	4^+	4	0.031	E(level): other: 5160 (1969Lu04). σ=1.8 mb (1969Lu04).
5277 *10*				
5329 *10*				E(level): other: 5310 (1969Lu04). σ=1.7 mb (1969Lu04).
5400 *10*	4^+	4	0.027	E(level): other: 5400 (1969Lu04). σ=1.2 mb (1969Lu04).
5537 *10*	3^-	3	0.052[b]	E(level): other: 5540 (1969Lu04). β_L: other: 0.11 2 (1969Lu04). σ=3.0 mb (1969Lu04).
5578 *10*	(3^-)[@]			
5633 *10*	(2^+)	(2)		E(level): other: 5620 (1989Wi13), 5630 (1969Lu04), 5600 *200* (1967Ri02). L: other: L=2&(0) from 1989Wi13. σ=3.1 mb (1969Lu04).
5777 *10*				
5844 *10*	3^-	3	0.039[b]	E(level): other: 5800 (1969Lu04). β_L: other: 0.10 2 (1969Lu04). σ=1.9 mb (1969Lu04).
5928 *10*	2^+	2	0.022	E(level): other: 5900 (1969Lu04). σ=1.6 mb (1969Lu04).
6025 *10*				
6083 *10*	(3^-)	(3)	0.034	E(level): other: 6090 (1969Lu04). σ=1.7 mb (1969Lu04).
6139 *10*				
6200 *10*				
6258 *10*	3^-	3	0.039	E(level): other: 6240 (1969Lu04). σ=1.4 mb (1969Lu04).
6332 *10*				
6362 *10*	3^-	3	0.040	E(level): other: 6380 (1989Wi13), 6360 (1969Lu04). dσ/dΩ(3°)=70 μb/sr *7* (1989Wi13). σ=1.5 mb (1969Lu04).
6484 *10*	3^-	3	0.035[b]	B(E2)↑=0.0116 *43* (1967Ri02) E(level): other: 6470 (1969Lu04), 6400 *200* (1967Ri02). L,β_L: other: 0.09 2 for L=2 (1969Lu04). σ=2.3 mb (1969Lu04). dσ/dΩ(max)=2.1 mb/sr *3* (1967Ri02).
6503 *10*				
6542 *10*				
6604 *10*				
6641 *10*				
6687 *10*				
6722 *10*	3^-	3	0.019	
6757 *10*				
6816 *10*	(3^-)[@]			dσ/dΩ(3°)=70 μb/sr *45* for a group at 6790 (1989Wi13).
6839 *10*	3^-	3	0.029	
6963 *10*	3^-	3	0.039	E(level): other: 6970 (1989Wi13). dσ/dΩ(3°)=143 μb/sr *14* (1989Wi13).
7036 *10*	(4^+)[@]			
7082 *10*	$(3^-,4^+)$[@]			
7116 *10*				
7129 *10*	(2^+)	(2)	0.014	

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^{48}Ti(p,p′),(pol p,p′) 1989Hi05 (continued)

^{48}Ti Levels (continued)

E(level)[†]	Jπ[#]	L[#]	β_L[#]	Comments
7162 *10*				
7221 *10*	(3⁻)	(3)	0.020	E(level): other: 7200 (1989Wi13). dσ/dΩ(3°)=270 μb/sr *20* (1989Wi13).
7245 *10*				
7324 *10*	3⁻	3	0.022	
7357 *10*				
7400[‡]				dσ/dΩ(3°)=90 μb/sr *10* (1989Wi13).
7506 *10*	(4⁺)	(4)	0.020	
7551 *10*	3⁻	3	0.019	E(level): other: 7580 (1989Wi13), 7500 *200* (1967Ri02). dσ/dΩ(3°)=114 μb/sr *11* (1989Wi13).
7618 *10*	(4⁺)[@]			
7683 *10*	(2⁺,3⁻)[@]			
7692 *10*				
7728 *10*	(3⁻)	(3)	0.011	dσ/dΩ(3°)=110 μb/sr *11* for a group at 7750 (1989Wi13).
7771 *10*				
7853 *10*	(4⁺)[&]	(4)	0.016	
7876 *10*				
7905 *10*				
7999 *10*	3⁻	3	0.020	
8057 *10*				
8093 *10*				
8178 *10*				E(level): other: 8150 (1989Wi13). dσ/dΩ(3°)=316 μb/sr *43* (1989Wi13).
8212 *10*	3⁻	3	0.022	
8246 *10*	(2⁺)	(2)	0.016	
8267 *10*				E(level): other: 8300 (1989Wi13). dσ/dΩ(3°)=316 μb/sr *43* (1989Wi13).
9260[‡]				dσ/dΩ(3°)=220 μb/sr *20* (1989Wi13).
9910[‡]				dσ/dΩ(3°)=127 μb/sr *20* (1989Wi13).
10460[‡]				dσ/dΩ(3°)=224 μb/sr *30* (1989Wi13).

[†] From 1989Hi05, unless otherwise noted.
[‡] From 1989Wi13.
[#] From DWBA analysis of measured σ(θ) and analyzing power in 1989Hi05, unless otherwise noted. Most states were assumed to be isoscalar natural-parity states since all the strongly excited natural-parity states of which σ(θ) are well described by DWBA are also observed in (α,α′) (1968Be23). Theory (F. Petrovich, *et al.* Ann. Rev. Nucl. Part. Sci. 36, 29 (1986)) predicts relatively weak excitation of unnatural-parity states at ≈65 MeV, and isovector natural-parity states are expected to appear above 10.672 MeV, estimated for the ground state analog (1989Hi05).
[@] Proposed by 1989Hi05, but with no σ(θ) or analyzing power given.
[&] Discrepant with adopted $J^\pi=1^+,3^+$.
[a] From comparison of measured σ(θ) for the total 1^+ strength to the model of B. A. Brown (priv comm to 1989Wi13). Assignment not adopted by evaluator due to model dependency.
[b] Differs significantly from β_L derived by 1969Lu04 in (p,p′) at 14.4 MeV but in good agreement with β_L derived by 1968Be23 in (α,α′).