High-Resolution Study of ^{48}Ca$(p,t)^{46}$Ca at $E_p = 39$ MeV*

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The ^{46}Ca nucleus was studied using the (p,t) reaction. A number of spin-parity assignments are clarified for the low-lying states. Many new energy levels are reported up to an excitation energy of 6.3 MeV including an additional 0^+ state at 4.76 MeV. Distorted-wave calculations with f-p shell wave functions give reasonable agreement for the first 0^+, 2^+, 4^+, and 6^+ states and for two weak 0^+ states near 5.5 MeV which were strongly excited in the ^{44}Ca(t,p) reaction.

I. INTRODUCTION

There are still many difficulties in using two-neutron-transfer reactions to check detailed nuclear wave functions. One useful technique is to compare the cross sections for the excitation of the same states, particularly 0^+ states, in the same final nucleus reached by both (p,t) and (t,p) reactions.[1] This method was recently used by Broglia, Kolltveit, and Nilsson[2] in the calcium isotopes to study 0^+ states. Such a study would benefit by more precise data on the ^{48}Ca(p,t) reaction since the complementary reaction ^{44}Ca(t,p) has already been carried out by Bjerregaard *et al.*[3] In this stripping experiment a number of 0^+ states were observed between 5 and 6.5 MeV with cross sections from 9 to 55% of the ground-state cross section. In the (p,t) experiments on ^{48}Ca[4-7] to date, the energy resolution has not been sufficient to extract these 0^+ states from the high density of states above 5 MeV. In addition the spin assignments for a number of states below 5 MeV from the ^{48}Ca(p,t) experiments did not agree with those from the ^{44}Ca(t,p) experiment.[3] Finally another (t,p) experiment[8] on ^{44}Ca with lower resolution suggested different 0^+ states above 6 MeV. It was therefore decided to carry out the ^{48}Ca(p,t) experiment to check these discrepancies and to compare with the ^{44}Ca(t,p) experiment. A preliminary report of this work has been presented elsewhere.[9]

II. EXPERIMENT

The experiment used the 39-MeV proton beam from the Michigan State University cyclotron. This gave a maximum triton energy of about 30 MeV, the maximum rigidity particle which could be bent by the Enge split-pole spectrograph. The experiment was performed in two stages which nicely complemented each other. In one case, a single-wire proportional counter was used in the focal plane of the Enge spectrometer with a 1.1-

mg/cm^2 self-supporting ^{48}Ca target (96.3% ^{48}Ca) obtained from the Oak Ridge National Laboratory. The energy resolution, primarily limited by the target thickness, was about 50 keV. However, this arrangement allowed very accurate angular distributions to be obtained for a number of the strong low-lying excited states from 3 to 70° in the laboratory. Special care was taken to trace out the deep minima, particularly for the 0^+ angular distributions.

A high-resolution study was also carried out in which the tritons were detected in Kodak NTB photographic emulsions. In this case a 50-μg/cm^2 ^{48}Ca target was used. This metallic target was prepared from the carbonate by vacuum evaporation from a tantalum tube. The calcium (enriched to 97.2% ^{48}Ca) was deposited on a 20-μg/cm^2 carbon foil which was supported by one layer of Formvar. The target was stored and transferred to the scattering chamber under vacuum. The resolution of the system was optimized by observing tritons in the focal-plane speculator system.[10] A total resolution of 11 keV full width at half maximum was obtained. The plate data were not as extensive as those from the proportional counter because of the limitation of scanning many plates, and extended from 10 to 50° in 4° steps.

III. RESULTS

A spectrum of tritons from the photographic plate data is shown in Fig. 1. The regions around 3.6, 4.4, and 4.7 MeV are also shown expanded to better illustrate the doublet structure. (See Fig. 2.) Note also the state at 3.987 MeV which has not been observed previously. No evidence is seen at any angle for the state at 3.780 MeV observed in an inelastic scattering experiment on ^{46}Ca.[11] Many more states were observed above 5 MeV than had been observed previously.

A list of states including energies and spin-pari-

ties are shown in Table I together with those from previous (p, t) and (t, p) experiments. Each run was calibrated using known energy levels up to 3.858 MeV in ^{46}Ca from a recent compilation.[12] Because of the small differences between the average excitation energies from a number of runs and the calibration points and because other measurements with the Enge spectrometer[13] indicate an accuracy of $\leqslant 2$ keV, the errors on the excitation energies up to 3.9 MeV are given to ± 2 keV. Above 3.9 MeV, an additional error of 1 keV per MeV of excitation was added to allow for uncertainty in extrapolation.[13] The excitation energies were internally very consistent. The standard deviations of the mean energy values quoted in Table I were all less than 1 keV except for five levels where the standard deviation of the mean was less than 2 keV.

Angular distributions for a number of states observed using the proportional counter are shown in Fig. 3. At this energy, these angular distributions are quite characteristic of the l transfer in the reaction and can be used to assign spins and parities to states in ^{46}Ca. For example, the solid line through the angular distribution of the 3.86-

MeV state represents the measured angular distribution for the known 4$^+$ states at 2.58 MeV. Since distorted-wave calculations (Sec. IV) give virtually identical angular distributions for an $l = 4$ angular momentum transfer to states at these excitation energies, the similarity of the angular distributions observed indicates a J^π of 4$^+$ for the 3.86-MeV state.

The angular distributions for the 4.19- and 4.73-MeV states are also very similar, as is indicated by the identical solid lines drawn through both. As can be noted from the plate data, there is a weak state within 30 keV of the 4.73-MeV state which is not resolved in the proportional counter data. However, the plate data indicate that this weak satellite is always at least a factor of 10 weaker than the 4.73-MeV state and so does not significantly affect the angular distribution. Spin and parity of 5$^-$ have been assigned to the 4.74-MeV state from a previous (p, t) experiment.[4] The present angular distribution supports this assignment and is clearly inconsistent with spin and parity of 4$^+$ assigned tentatively from the (t, p) experiment.[3] A spin-parity of 5$^-$ has therefore also been assigned to the 4.19-MeV state.
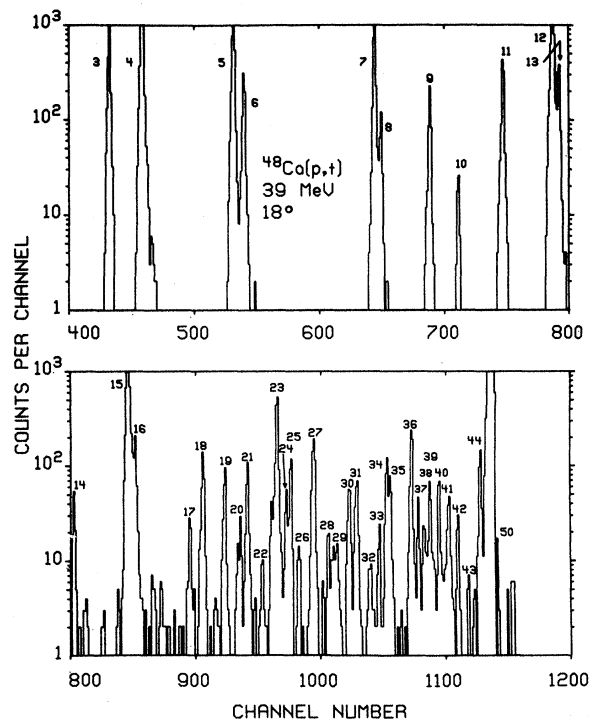

FIG. 1. A triton momentum spectrum obtained with a nuclear emulsion plate. The peak numbers correspond to those in Table I. The channel width represents a distance of 0.2 mm along the focal plane, or approximately 6 keV.
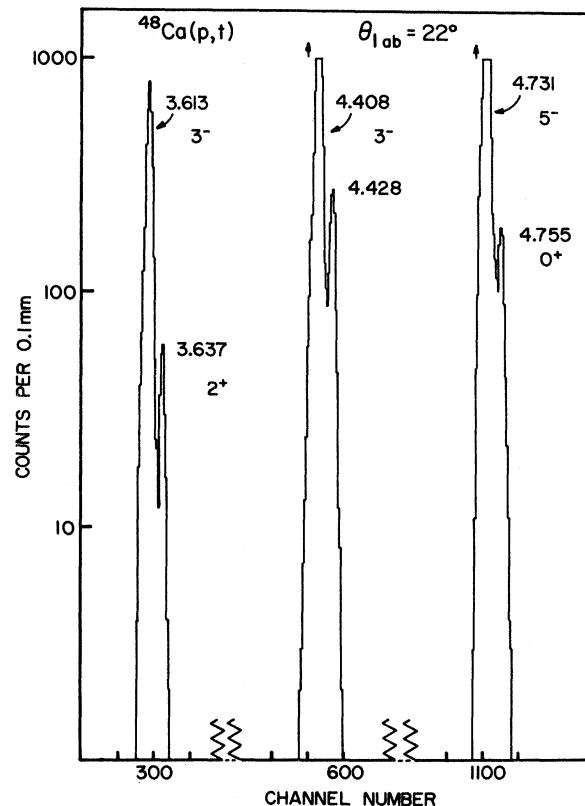

FIG. 2. Sections of a spectrum showing the details of the doublets observed at excitation energies of 3.6, 4.4, and 4.7 MeV.

One more example, although somewhat less clear, is the pair of doublets at 3.6 and 4.4 MeV. Both of these doublets are clearly resolved in the plate data but are combined in the proportional counter data. The doublet at 4.4 MeV has one very weak member so that the angular distribution for the strong member is practically unaffected. But in the 3.6-MeV doublet, the 2^+ state at 3.64 MeV can modify the angular distribution, particularly near the maximum in the $l = 2$ angular distribution at a center-of-mass angle of 32°. The similarity of the distributions except near 30° does, however,

TABLE I. Levels in ^{46}Ca below 6.4 MeV from (p, t) and (t, p) experiments.

Level No.	Present $E_x \pm \Delta E_x$ (MeV)	Expt. J^π	σ_{max} (μb/sr)	at $\theta_{c.m.}$ (deg)	^{44}Ca(t,p) Ref. 3 E_x (MeV)	J^π	^{44}Ca(t,p) Ref. 8 E_x (MeV)	J^π	^{48}Ca(p,t) Ref. 4 E_x (MeV)	J^π
1	0.0	0^+	432	21	0.0	0^+	0.0	0^+	0.0	0^+
2	1.347 ± 0.002	2^+	482	5	1.350	2^+	1.347	2^+	1.35	2^+
3	2.423 ± 0.002	0^+	42	23	2.427	0^+	2.425	0^+	2.43	0^+
4	2.576 ± 0.002	4^+	270	6	2.573	4^+	2.578	4^+	2.57	4^+
5	2.978 ± 0.002	6^+	95	27	2.980				2.98	(6^+)
6	3.024 ± 0.002	2^+	71	10	3.024	2^+	3.022	2^+	3.02	(2^+)
7	3.613 ± 0.002	3^-	51	15	3.611	3^-			3.62	3^-
8	3.637 ± 0.002	2^+	12	10	3.637	2^+				
9	3.860 ± 0.002	4^+	12	8	3.857		3.858		3.86	
10	3.987 ± 0.003	(3^-)	1.6	15						
11	4.185 ± 0.003	5^-	21	21	4.280				4.19	(5^-)
12	4.409 ± 0.003	3^-	393	5					4.43	3^-
13	4.431 ± 0.003		29	15	4.429	2^+	4.433	2^+		
14	4.493 ± 0.003	(4^+)	5.7	10						
15	4.734 ± 0.003	5^-	210	21	4.742	(4^+)	4.754	4^+	4.74	5^-
16	4.758 ± 0.003	0^+	11	23						
17	4.997 ± 0.003	(4^+)	4.5	10	4.993	(2^+)				
18	5.056 ± 0.004		7.2	19			5.011		5.07	
19	5.153 ± 0.004		4.6	19						
20	5.218 ± 0.004		1.8	15						
21	5.251 ± 0.004	4^+	5.3	19						
22	5.316 ± 0.004	(0^+)	1.6	15	5.316	0^+	5.328	0^+		
23	5.380 ± 0.004	(3^-)	39	10	5.389					
24	5.418 ± 0.004		2.5	19					5.40	
25	5.438 ± 0.004	4^+	7.5	15						
26	5.474 ± 0.004	(3^-)	1.2	15						
27	5.538 ± 0.004		15.0	10	5.531		5.544			
28	5.601 ± 0.004		1.5	23	5.595	0^+			5.60	
29	5.639 ± 0.004		2.8	10	5.628	0^+	5.617	0^+	5.63	
30	5.691 ± 0.004		5.9	10	5.682					
31	5.724 ± 0.004		8.3	10						
32	5.785 ± 0.004		0.8	19	5.776					
33	5.821 ± 0.004		1.4	10						
34	5.852 ± 0.004		5.4	23	5.850					
35	5.864 ± 0.004	(6^+)	7.8	23						
36	5.959 ± 0.004	(2^+)	23	10	5.954				5.88	
37	5.987 ± 0.004	(6^+)	3.4	31						
38	6.010 ± 0.005		3.3	10						
39	6.037 ± 0.005	(4^+)	4.9	15	6.047	(0^+)				
40	6.077 ± 0.005		5.3	10						
41	6.116 ± 0.005	(2^+)	11	10						
42	6.156 ± 0.005		3.6	48						
43	6.201 ± 0.005		1.0	31						
44	6.252 ± 0.005	(4^+)	7.2	19	6.264					
45	6.267 ± 0.005		5.7	10			6.275	2^+		
46	6.309 ± 0.005		6.2	10						

substantiate the spin assignments of 3⁻ to both the 3.61- and 4.41-MeV states. This result is also confirmed by the plate data.

There are a few other points to note from these angular distributions. First the angular distributions of the two 0⁺ states are very similar even down to a scattering angle of 3°. The ratio of the two cross sections is about 10.5 to 1. Another feature is the rather strong excitation of the high-spin, $J^\pi = 4^+$, 6^+, and 5⁻ states at 2.58, 2.98, and 4.73 MeV, particularly when compared to data taken at lower energies.[4,6]

The spin-parity assignments in Table I, were made by comparison with the angular distributions for low-lying states of known spin, with the knowledge that the distorted-wave Born-approximation (DWBA) calculations of the shapes of the angular distributions with the same l-value change very little up to an excitation energy of 7 MeV. The assignments shown in parentheses are less certain. Angular distributions for many of the levels observed in nuclear emulsions are shown in Figs. 4 and 5 although some of the strong low-lying states, resolved in the counter data, are not repeated.
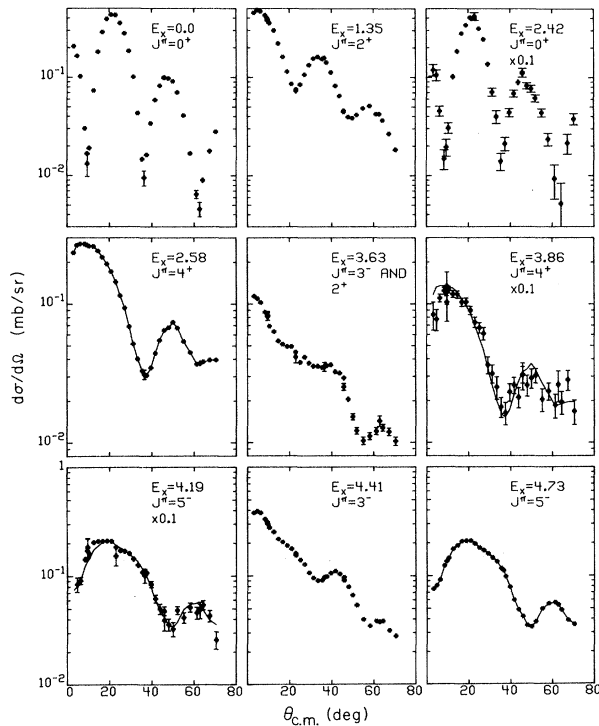
Spin-parity assignments can be made for nearly all the levels below an excitation energy of 5 MeV with good reliability because the different l transfers have quite characteristic angular distributions. Spin assignments of 6⁺ and 2⁺ were confirmed for the 2.98- and 3.64-MeV states and a value of 4⁺ could be assigned to the 3.86-MeV state. Some difficulty has been noted around 4.4 and 4.7 MeV where unresolved doublets have possibly confused previous analyses. A state at 4.43 MeV was assigned a J^π of 2⁺ in previous (t, p)[3,8] measurements but was thought to be 3⁻ from the (p, t) reaction.[4] In the present experiment a close doublet is observed with states at 4.409 and 4.431 MeV. The lower member was assigned $J^\pi = 3^-$, but the state at 4.43 MeV does not have a characteristic l transfer. In particular it does not appear to be a typical $l = 2$ shape as required for a J^π of 2⁺. Perhaps this state has unnatural parity and a second-order process mediates the transfer.

A similar situation arises at 4.7 MeV where a J^π of 4⁺ was tentatively assigned to a state at 4.74 MeV in the (t, p) reaction[3] but a $J^\pi = 5^-$ in (p, t).[4] The present experiment shows two states, one at 4.73 MeV with $J^\pi = 5^-$ and one at 4.76 MeV with

FIG. 3. Angular distributions for the ^{48}Ca$(p, t)^{46}$Ca reaction, measured with a position-sensitive proportional counter in the spectrograph focal plane. The cross sections for some levels have been divided by the indicated factors in order to place three sets of data on a common scale.
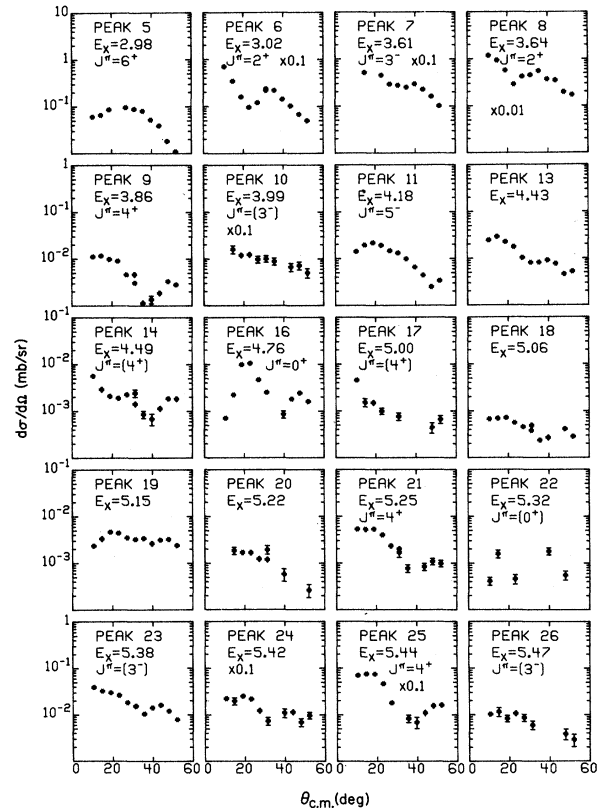

FIG. 4. Angular distributions from the nuclear emulsion data for peak numbers 5–26. See caption to Fig. 3 for explanation of the scale factors.
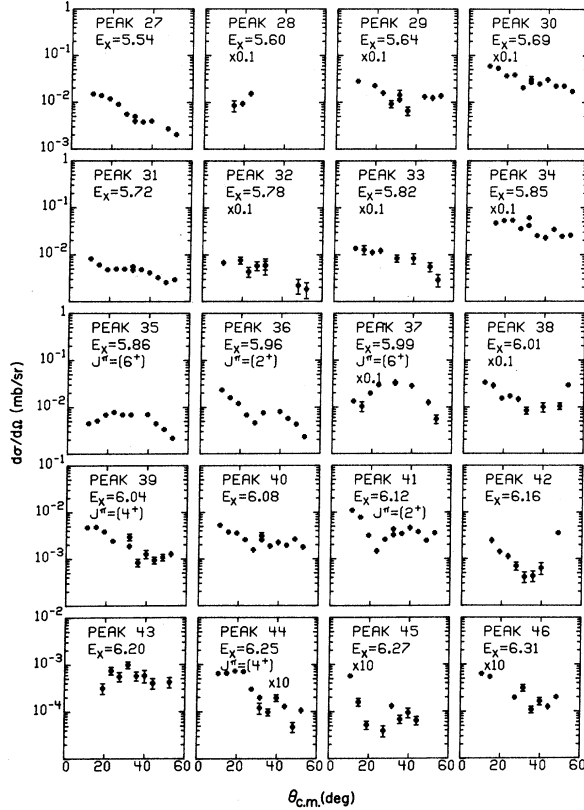
FIG. 5. Angular distributions from the nuclear emulsion data for peak numbers 27–46. See caption to Fig. 3 for explanation of the scale factors.

$J^\pi = 0^+$. This latter states is apparently not strongly excited in the (t, p) process,[3] since no forward-angle peaking is observed in the angular distribution.

At excitation energies above 5 MeV very few spins have been even tentatively assigned from other experiments except for 0^+ states. The present (p, t) data suggest a number of J^π assignments

including two possible 6^+ states at 5.86 and 5.99 MeV. The 0^+ state observed at 5.32 MeV in the (t, p) reaction[3] is consistent with the few points obtained for a state seen at the same energy in this experiment. However, while states are observed near the energies of two other previously assigned 0^+ states at 5.60 and 5.63 MeV,[3] we did not observe characteristic $l = 0$ angular distributions for these states. The level at 5.60 MeV is very weak and was only observed at a few angles but the stronger state at 5.64 MeV appears more like an $l = 4$ transfer than an $l = 0$. We are only able, therefore, to assign upper limits to $l = 0$ states in this region. The other state at 6.05 MeV tentatively assigned $J^\pi = 0^+$ in the (t, p) reaction[3] again appears to have a more characteristic $l = 4$ shape in the present (p, t) experiment.

IV. DISTORTED-WAVE CALCULATIONS

Distorted-wave calculations were carried out using the code DWUCK72.[14] Two different sets of proton parameters were used, one due to Becchetti and Greenlees[15] and the other due to Perey.[16] Almost 30 different sets of triton optical parameters, taken from a variety of sources,[2, 17-19] with real well depths ranging from 113 to 215 MeV were tried in an attempt to get a good fit to the low-lying states. The proton optical parameters and some of the more promising triton parameters are shown in Table II.

Some examples of the fits are shown in Fig. 6. For the ground-state transition the comparison between theory and experiment is reasonable for angles greater than 10° but almost all the calculations have difficulty in fitting the forward angle data, which do not rise as rapidly as the calculations. One exception is the calculation with the S2 triton potential,[17] but this fails to reproduce the deep minima observed experimentally near $\theta_{c.m.} = 9$

TABLE II. Optical parameters.

Proton parameters	V_R (MeV)	r_R (fm)	a_R (fm)	W_V (MeV)	W_{SF}^f (MeV)	r_I (fm)	A_I (fm)	$V_{s.o.}$ [a] (MeV)	$r_{s.o.}$ (fm)	$a_{s.o.}$ (fm)
Becchetti-Greenlees (B-G) (Ref. 15)	47.7	1.17	0.75	5.9	4.0	1.32	0.63	6.2	1.01	0.75
Perey (Pe) (Ref. 16)	38.4	1.25	0.65	0	10.9	1.25	0.47	8.5	1.25	0.65

Triton parameters	V_R (MeV)	r_R (fm)	a_R (fm)	W_V (MeV)	r_I (fm)	a_I (fm)
Satchler et al. (S1) (Ref. 17)	203.3	1.048	0.745	14.1	1.604	0.866
Satchler et al. (S2) (Ref. 17)	165.0	0.941	0.854	11.95	1.778	0.702
Flynn et al. (F5) (Ref. 18)	170.1	1.16	0.752	17.0	1.498	0.817
Broglia et al. (B1) (Ref. 2)	144.0	1.24	0.678	30.0	1.45	0.841

[a] DWUCK72 uses values 4_{sf}^W and $4V_{s.o.}$.

and 37°. There is some evidence that this lack of a high maximum at very forward angles is not a sensitive function of the wave functions used. First, the shape of the $l = 0$ angular distribution calculated using $(d_{3/2})^2$ wave functions is very similar to the angular distribution calculated with $(f_{7/2})^2$ wave functions although the magnitudes are very different. Secondly, the excited 0^+ state at 2.42 MeV, which presumably has a very different structure from the ground state, has an observed angular distribution which is practically identical to the ground state.

Fits of comparable quality are obtained for the 2^+ and 4^+ states at 1.35 and 2.58 MeV, with again the worst discrepancies being at forward angles. The S2 set of triton parameters again gives angular distributions with too little structure. The comparison of the theoretical and experimental distributions for the 6^+ state at 2.98 MeV is generally worse than for the lower-spin states.

The wave functions used to obtain the spectroscopic amplitudes used in these calculations were taken from a paper by McGrory, Wildenthal, and Halbert.[20] These calculations (denoted f-p' in Ref. 20) placed particles in the $0f_{7/2}$, $1p_{3/2}$, $0f_{5/2}$, and $1p_{1/2}$ orbits and used a modified Kuo-Brown interaction. The calculated spectrum for ^{46}Ca was generally in good agreement with the observed low-lying positive-parity states except for the second 0^+ and 2^+ states at 2.42 and 3.02 MeV. Two 0^+ states were predicted at 5.13 and 5.49 MeV and these wave functions were also used in distorted-wave calculations in making comparisons with the possible 0^+ states observed in this region.

The cross section for the (p, t) reaction is given by[21]

$$\frac{d\sigma}{d\Omega} = \frac{D_0^2 \times 9.72}{(2J + 1)} \sigma_{DW}^{LSJ}$$

where σ_{DW} is the cross section calculated by the code DWUCK72 and J is the spin of the final state. D_0^2 is a normalization constant for the (p, t) reaction. The constant 9.72 comes from the choice of finite-range parameters in the code DWUCK72.[21]

The values of D_0^2, obtained by comparing the theoretical calculation with the ground-state cross section near $\theta_{c.m.} = 22°$, for the four sets of optical parameters which gave reasonable fits to the data, are given in Table III. These values differ by about a factor of 3 ranging from 22 to 65. The ratio of experimental to theoretical cross sections was calculated for a number of excited states which could be identified in the shell-model calculation. These ratios are also presented in Table III. In spite of the substantial differences in the D_0^2 values, the predictions for the remaining

states are fairly consistent for the different sets of optical parameters. An average value of the ratio of theoretical to experimental cross sections is therefore also presented in Table III. These values are smaller than unity for the high-spin states which probably indicate that the predicted cross section for the ground-state transition is too small, rather than that the predicted cross sections for the excited states are too large.

DWBA calculations were also carried out with the f-p' wave functions[20] for the two 0^+ states predicted around 5.5 MeV. In spite of the fact that the cross sections for these states are at least 300 times weaker than the ground state, the predictions are within about a factor of 2 of the experimental values. Since there is some doubt as to the spin assignments (e.g. peak 22), one might best regard the measured cross sections as upper limits for these 0^+ states, but the calculated magnitudes are seen to be qualitatively in agreement with the observations.

The main weakness in these calculations is the inability to predict the cross section for the remaining 0^+ states, one at 2.42 MeV and the other, a member of a close doublet at 4.76 MeV. These states have peak cross sections of 42 and 11 μb/sr at 22°, respectively, and so are much stronger than the states at around 5.5 MeV. These states, particularly the low-lying 0^+ at 2.42 MeV, presumably arise from two-particle excitations from the $1s, 0d$ shell, and it would therefore be interest-
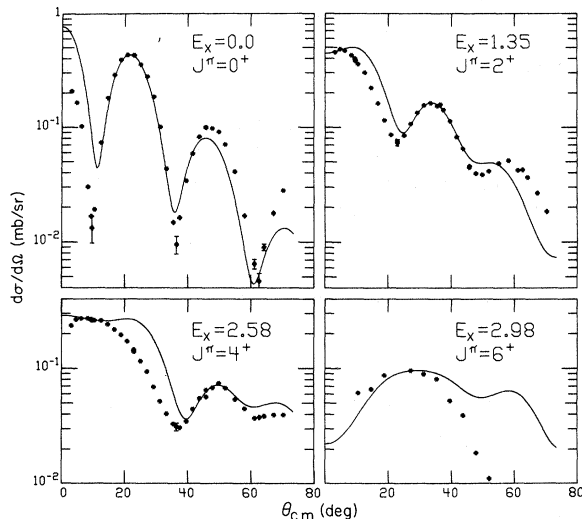

FIG. 6. Comparison between distorted-wave calculations and the measured angular distributions for four representative states that are excited strongly in the ^{48}Ca$(p, t)^{46}$Ca reaction. The optical-model parameters are given in Table II (B-G : B1). The calculated curves have been normalized to fit the observed maximum cross section.

TABLE III. Ratios of $\sigma_{exp}/\sigma_{theor}$ compared using MHW wave functions (Ref. 20).

J^π	D_0^2 (g.s.) E_x (theor)	E_x (exp)	21.8 Pe:S1	65.4 B-G:F5	27.3 B-G:S1	29.7 B-G:B1	Average
0^+	0.0	0.0	1.0	1.0	1.0	1.0	1.0
2^+	1.44	1.35	0.76	0.78	0.89	1.10	0.88
4^+	2.63	2.58	0.59	0.59	0.69	1.13	0.75
6^+	3.06	3.02	0.62	⋯	0.52	0.90	0.68
0^+	5.13	5.32	1.5	2.1	1.9	1.9	1.8
0^+	5.49	5.60	2.1	2.6	2.6	2.7	2.5

ing to attempt a shell-model calculation of ^{46}Ca including these orbits.

In addition, these f-p' shell-model calculations do not predict the negative-parity states in ^{46}Ca, some of which are very strongly excited by the ^{48}Ca(p,t) reaction. Extended shell-model calculations to include these states would, therefore, be of interest.

V. SUMMARY

The ^{48}Ca(p,t)^{46}Ca experiment was carried out using both a proportional counter and nuclear emulsions to detect the tritons. Ambiguities in previous spin assignments to some low-lying states were resolved when these states were observed to be close doublets. Many new levels were observed up to an excitation energy of 6.3 MeV and a number of spin-parity assignments could be made. Distorted-wave calculations using DWUCK72 and $0f$, $1p$ shell-model wave functions were performed. The calculations were quite sensitive to the choice of optical parameters. For those pa-

rameters which gave reasonable fits to the 0^+, 2^+, 4^+, and 6^+ states, the predicted cross sections relative to the ground state were quite consistent with the data although the predictions were generally 20–40% lower for the higher-spin states. This probably reflects insufficient correlations in the ground-state shell-model wave functions. Calculations for 0^+ states near 5.5 MeV were also within factors of 2 to 3 of predictions even though the cross sections for these states were about 300 times weaker than the ground-state transition. Further calculations for the remaining states, including two other low-lying 0^+ states await more extensive shell-model calculations.

ACKNOWLEDGMENTS

[1]G. J. Igo, P. D. Barnes, and E. R. Flynn, Ann. Phys. (N.Y.) 66, 60 (1971).

[2]R. A. Broglia, K. Kolltveit, and B. Nilsson, Phys. Lett. 27B, 441 (1971).

[3]J. H. Bjerregaard, O. Hansen, O. Nathan. R. Chapman, S. Hinds, and R. Middleton, Nucl. Phys. A103, 33 (1967).

[4]H. Hefele, V. Lynen, and R. Santo, Nucl. Phys. A157, 93 (1970).

[5]Y. Dupont, P. Martin, and M. Chabre, Phys. Lett. 31B, 68 (1970).

[6]R. J. Peterson, Phys. Rev. 170, 1003 (1968).

[7]W. W. Daehnick and R. Sherr, Bull. Am. Phys. Soc. 17, 535 (1972); and to be published.

[8]D. C. Williams, J. D. Knight, and W. T. Leland, Phys. Rev. 164, 1419 (1967).

[9]G. M. Crawley, P. S. Miller, G. J. Igo, and J. Kulleck. Argonne, National Laboratory Report No. PHY-1972H, March 1972 (unpublished), p. 349.

[10]H. G. Blosser, G. M. Crawley, R. deForest, E. Kashy, and B. H. Wildenthal, Nucl. Instrum. Methods 91, 61 (1971).

[11]T. A. Belote, J. H. Bjerregaard, O. Hansen, and G. R. Satchler, Phys. Rev. 138, B1067 (1965).

[12]R. L. Auble, Nucl. Data B4, 269 (1970).

[13]E. Kashy, I. D. Proctor, J. A. Nolen and S. Ewald, Bull. Am. Phys. Soc. 17, 483 (1972).

[14]P. D. Kunz, University of Colorado (unpublished).

[15]F. D. Becchetti and G. W. Greenlees, Phys. Rev. 182, 1190 (1969).

[16]F. G. Perey, Phys. Rev. 131, 745 (1963).

[17]G. R. Satchler, D. D. Armstrong, A. G. Blair, E. R. Flynn, R. J. Philpott, and W. T. Pinkston, Phys. Rev. 183, 1141 (1969).

[18]E. R. Flynn, D. D. Armstrong, J. G. Berry, and A. G. Blair, Phys. Rev. 182, 1113 (1969).

[19]R. N. Glover and A. D. W. Jones, Nucl. Phys. 81, 268 (1966).

[20]J. B. McGrory, B. H. Wildenthal, and E. C. Halbert, Phys. Rev. C 2, 186 (1970).

[21]H. W. Baer, J. J. Kraushaar, C. E. Moss, N. S. P. King, R. B. L. Green, P. D, Kunz, and E. Rost, to be published.