Proton Particle States in 28Si and 29P Studied by the 27A1(d,n) and 28Si(d,n) Reactions at Ed = 25 MeV

著者	Satoh A., Nakagawa T., Tohei T., Furukawa K., Kawamura T., Kabasawa M., Takahashi Y., Niizeki T., Orihara T., Ishimatsu T., Maeda K., Miura K., Ohnuma H.
journal or publication title	CYRIC annual report
volume	1985
page range	23-29
year	1985
URL	http://hdl.handle.net/10097/49269

I. 5 Proton Particle States in ^{28}Si and ^{29}P Studied by the ^{27}Al(d,n) and ^{28}Si(d,n) Reactions at E_d = 25 MeV

Satoh A., Nakagawa T., Tohei T., Furukawa K., Kawamura T., Kabasawa M., Takahashi Y., Niizeki T.*, Orihara H.*, Ishimatsu T., Maeda K.**, Miura K.*** and Ohnuma H.****
Department of Physics, Faculty of Science, Tohoku University
Cyclotron and Radioisotope Center, Tohoku University*
College of General Education, Tohoku University**
Tohoku Institute of Technology***
Department of Physics, Tokyo Institute of Technology****

Proton particle states have been so far studied through the (^{3}He,d) reaction mainly due to feasibilities to analyze an emitted particle. We have carried out a systematic study of the proton parentage by means of the (d,n) stripping reaction at E_d = 25 MeV by using a high-resolution neutron time-of-flight technique. In this note we report a study for spectroscopic information of ^{29}P and ^{28}Si obtained by the (d,n) reactions on ^{28}Si and ^{27}Al.

It is well known, for the $T_i = T_{iz} = 0$ case, that a streight forward conclusion may be drawn for the transfer momentum ℓ and proton occupation. An interest should be focused, for the ^{28}Si(d,n)^{29}P reaction, on the location of the g9/2-orbit. Other proton single-particle states in ^{29}P are well known. Comparisons for them, therefore, may provide us the validity of the present analyses as discussed later on. After we make sure a reasonable analysis for the (d,n) reaction by the simple ^{28}Si(d,n) case, we discuss the ^{27}Al(d,n)^{28}Si reaction, by which currently interested stretched 6^-, T=0 and T=1 states[1,2] is expected to be excited together with other members of the $[\pi f7/2, \nu d5/2^{-1}]$ particle-hole multiplet.

The experiment was performed with use of a 25-MeV deuteron beam from the CYRIC AVF cyclotron and the time-of-flight facilities[3]. By utilizing a beam swinger system, we have measured angular distributions of emitted neutrons between 0° and 90°(lab.). The typical time resolution for neutrons was about 2 nsec, corresponding to 100∿200 keV in the energy resolution with a flight path of 44m. Self-supporting Si and Al foils with natural abundances were used as targets. Their thickness were 2.1 and 6.7 mg/cm^2 for ^{28}Si and ^{27}Al, respectively.

Figure 1 shows a typical neutron energy spectrum taken for the ^{28}Si(d,n)^{29}P reaction at $\theta_{lab.}$ = 30°. In Fig. 2, that for the ^{27}Al(d,n)^{28}Si reaction is also presented. Angular distributions of emitted neutrons leading to the 23 residual states in ^{29}P are illustrated in Fig. 3 and 4. Curves in a figure are DWBA predictions obtained by the code DWUCK4[4] with a modification as described soon after. In the DWBA calculation, adiabatic deuteron break-up theory proposed by Harvey and Johnson[5] are applied to obtain the deuteron optical potential parameters. Those for neutrons are self-consistent potential parameters derived by Carlson et al.[6] from the work by Becchetti and Gleenlees[7]. Generally in the stripping reaction, it is very often that nucleons are transferred into a unbound state, making it rather difficult to get accurate DWBA cross sections using the usual integration techniques. Fortunately, modified version[8] of the code DWUCK4 is available, where an accurate account for the tail part of the unbound particle wave function is possible following the method developed by Vincent and Fortune[9]. The spectroscopic information, thus obtained for the proton particle states in ^{29}P, is compared in Table 1 with those from the (^{3}He,d) reaction[10-15], and with the shell-model predictions[16]. As seen in Table 1, comparison is quite reasonable. Weakly populated transitions to E_x = 5.00, 9.15 and 9.36 MeV have been assigned to be $\ell = 4$.

Figure 5 shows angular distributions for the $^{27}Al(d,n)^{28}Si$ reaction leading to the high-lying states $E_x \gtrsim 11$ MeV where high-spin stretched states are expected. Indeed, ℓ=3 transitions to T=0, and T=1 6^- states at 11.61 and 14.37 MeV are well fitted by the DWBA calculations. Spectroscopic factors are compare with those obtained by other reactions in Table 2.

In conclusion we have obtained comprehensive spectroscopic information from the $^{28}Si(d,n)^{29}P$ by the aid of DWBA theory. Based on this successful analysis we have added evidences for the g9/2 and/or g7/2 single particle state at 5.00, 9.15 and 9.36 MeV. Furthermore, we have reduced proton parentage for the T=0, T=1 stretched particle-hole states in ^{28}Si by the $^{27}Al(d,n)^{28}Si$ reaction. The present spectroscopic factors are rather large comparing with those previously reported by the (^{3}He,d) reaction.

References

1) Snover K. A. et al., Phys. Rev. C 27 (1983) 493.
2) Amusa A. and Lawson R. D., Phys. Rev. Lett. 51 (1983) 103.
3) Orihara H. and Murakami T., Nucl. Instrum. and Methods 188 (1981) 15.
4) Kunz P. D., program DWUCK4, University of Colorado (unpublished).
5) Harvey J. D. and Johnson R. C., Phys. Rev. C 3 (1971) 636.
6) Carlson J. D. et al., Nucl. Phys. A249 (1975) 29.
7) Becchetti F. D. and Greenlees G. W., Phys. Rev. 182 (1969) 1190.
8) Comfort J. R., private communication.
9) Vincent C. M. and Fortune H. T., Phys. Rev. C 2 (1970) 782.
10) Dykoshin W. W. and Dehnhard D., Phys. Rev. C 13 (1976) 80.
11) Leleux P. et al., Z. Phys. 271 (1974) 139.
12) Koyama K. et al., J. Phys. Soc. Japan 43 (1977) 755.
13) Peterson R. J. and Ristinen R. A., Nucl. Phys. A246 (1975) 402.
14) Djaloeis A. et al., Phys. Rev. C 28 (1983) 561.
15) Spadafora A. and Fortune H. T., Phys. Rev. C 17 (1978) 1256.
16) Wildenthal B. H. and McGrory J. B., Phys. Rev. C 7 (1973) 714.
17) Nann H., Nucl. Phys. A376 (1982) 61.

18) Kato S. and Okada K., J. Phys. Soc, Japan 50 (1981) 1440.
19) Yasue M. et al., Nucl. Phys. A391 (1982) 377.

Table 1. Spectroscopic factor (^{29}P proton stripping)

Ex*) (MeV)	Ex (MeV)	J^{π}	nlj*)	Spectroscopic factor (S)							
				(d,n)*) E=25	(h,d)a) E=25		(h,d)b) E=35.3	(h,d)c) E=29.3	(h,d)d) E=38.5	(h,d)e) E=130	shellg) model
0.	0.	$1/2^+$	2s1/s	0.56	0.65		0.88	0.54	0.51	0.45	0.50
1.38	1.38	$3/2^+$	1d3/2	0.86	0.88		0.88	0.78	0.87	0.23	0.59
1.95	1.95	$5/2^+$	1d5/2	0.12	0.12		0.12	0.10	0.09	0.09	0.11
2.42	2.42	$3/2^+$	1d3/2	0.02	0.04	f)			0.03		0.03
3.11	3.11	$5/2^+$	1d5/2	0.06	0.06	0.06	0.04	0.06	0.07		0.02
3.45	3.45	$7/2^-$	1f7/2	0.39	0.46	0.50	0.35	0.57	0.69	0.15	
4.34	4.34	$3/2^-$	2p3/2	0.60	0.43	0.64	0.28	0.33		0.23	
4.75	4.76	$1/2^+$			0.03	0.06	0.02				0.01
5.00			1d5/2	(0.02)							
			1g9/2	0.06							
5.75	5.74	$7/2^-$	1f7/2	0.14	0.16	0.23	0.19	0.15		0.06	
5.97	5.97	$3/2^+$	1d3/2	0.08	0.05	0.05	0.02	0.04			
6.32	6.33	$3/2^+$	1d3/2	0.04	(0.04)	0.02	0.02	0.03			
6.55	6.58	$1/2^+$	2s1/2	(0.06)							
7.49	7.50	$5/2^+$	1f5/2	0.03							
8.00			1f7/2	0.11						0.08	
8.18	8.22	$3/2^+$	1f7/2	0.04							
8.89			1d3/2	(0.04)							
			1f7/2	0.02							
9.15	9.12		1g9/2	0.03							
9.36	9.37		1g9/2	0.03							
9.64	9.66	$7/2^-$	1f7/2	0.01							
9.93			1f7/2	0.01							
10.13			1f7/2							0.07	
10.24			1f7/2								
10.76			1f7/2								

*) Present work a) Ref. 10 b) Ref. 11 c) Ref. 12 d) Ref. 13 e) Ref. 14 f) Ref. 15
g) Ref. 16

E: incident energy (MeV)

Table 2. Spectroscopic factor (^{28}Si proton stripping)

J^{π}; T	Spectroscopic factor (S)						
	(d,n)*) E=25 MeV	(h,d)a) E=35 MeV	(h,d)b) E=25 MeV	(α,t)c) E=65 MeV	(h,d)d) E=40 MeV	(h,d)d) E=60 MeV	Pure j-j
6^-; 0	0.60	0.48	0.39	0.32	0.41	0.37	1
6^-; 1	0.58	0.38	0.42	0.40	0.35	0.36	1

*) Present work a) Ref. 17 b) Ref. 18 c) Ref. 19 d) Ref. 1

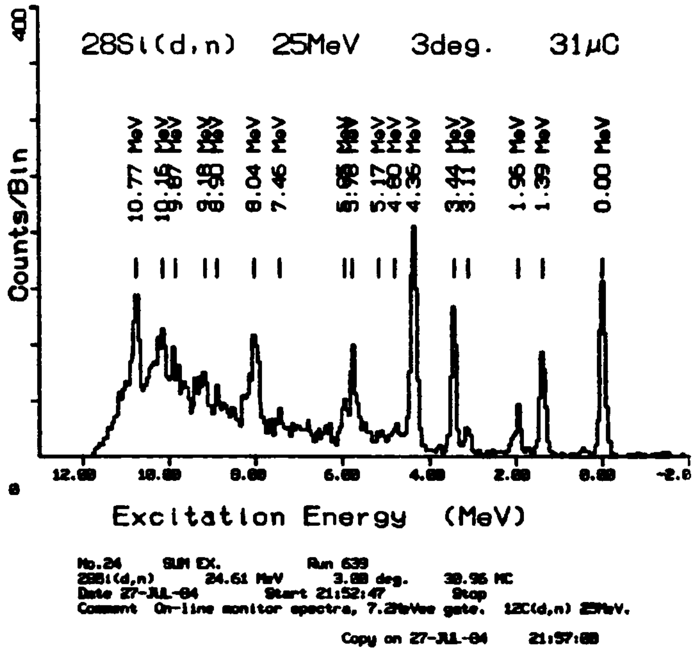

Fig. 1. Neutron energy spectrum for the $^{28}Si(d,n)^{29}P$ reaction at θ=30° measured with 25-MeV deuterons at a neutron flight path of 44.3 m.

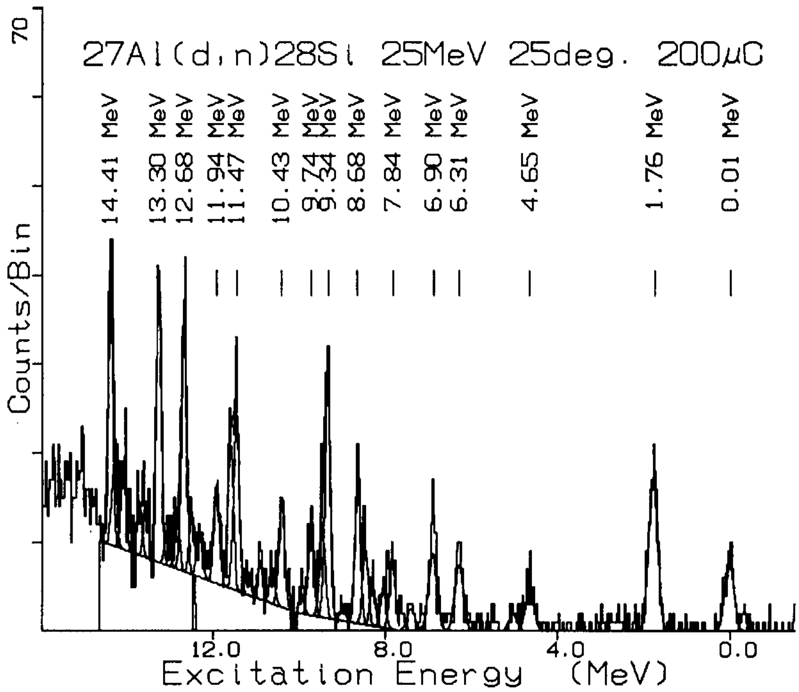

Fig. 2. Same with Fig. 1 but for the $^{27}Al(d,n)^{28}Si$ reaction.

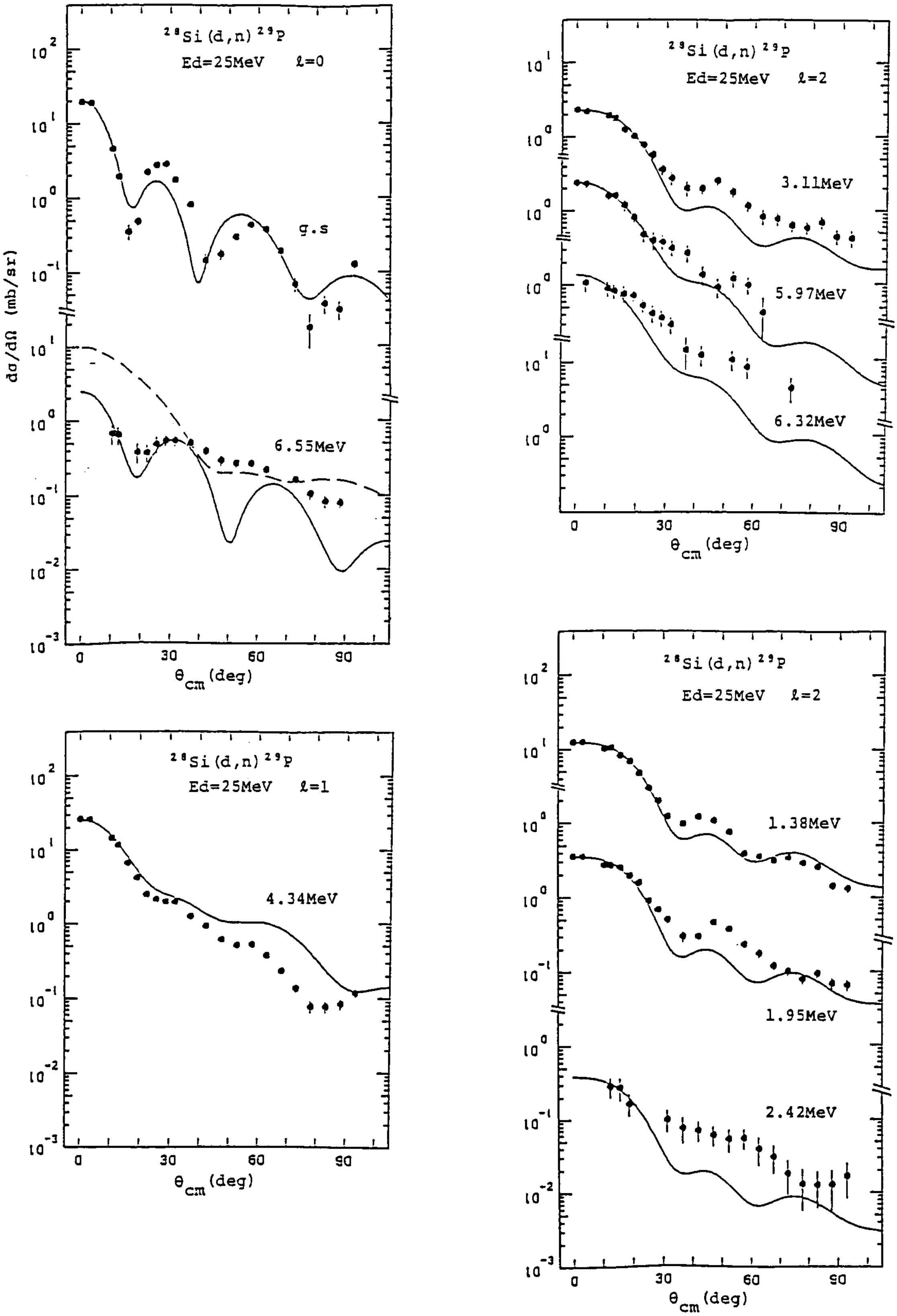

Fig. 3. Differential cross sections for the ℓ=0 through ℓ=2 transitions leading to the excited states in ^{29}P denoted in figure. Curves are DWBA predictions described in the text.

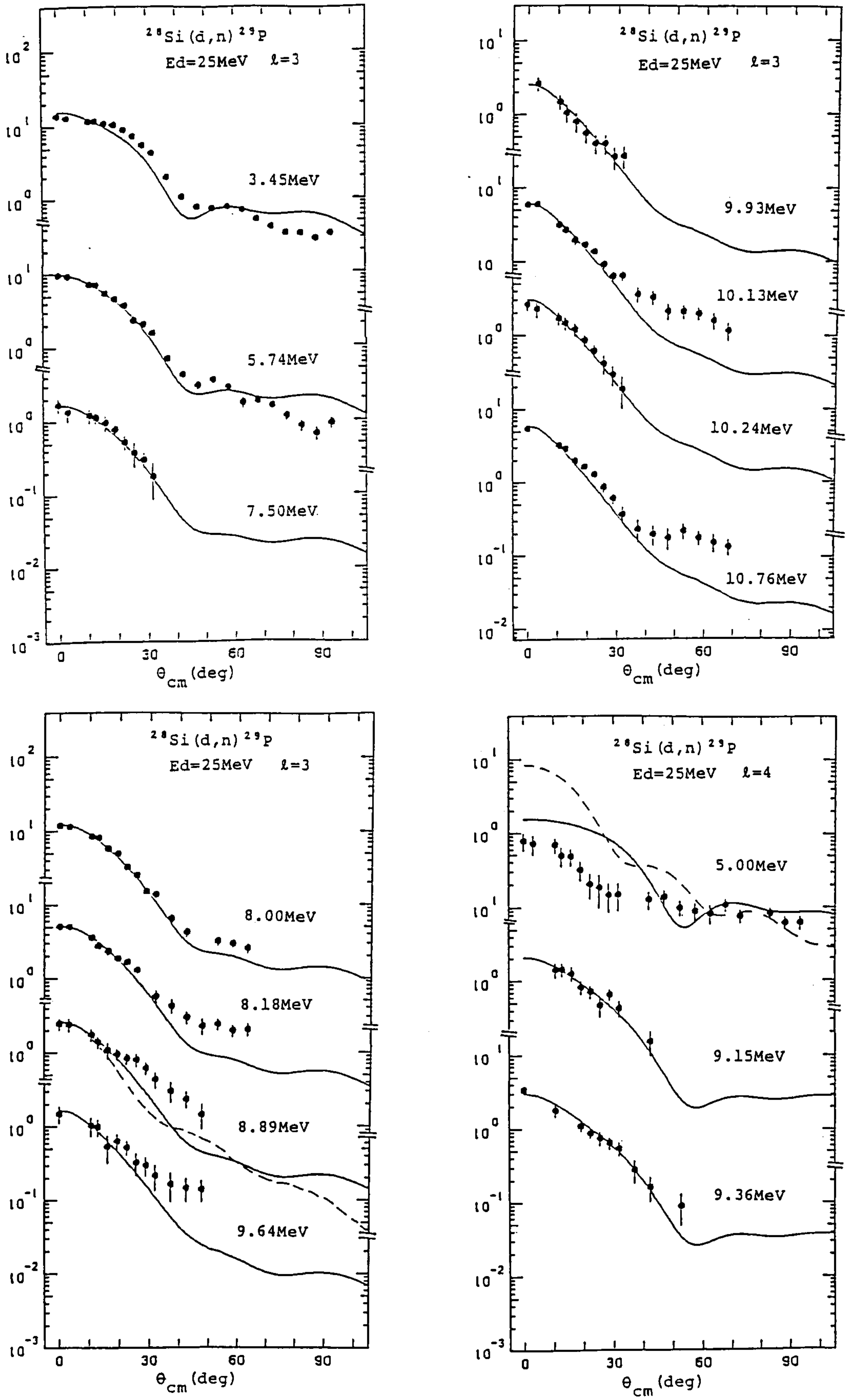

Fig. 4. Same with Fig. 3 but for the ℓ=3 and 4 transitions.

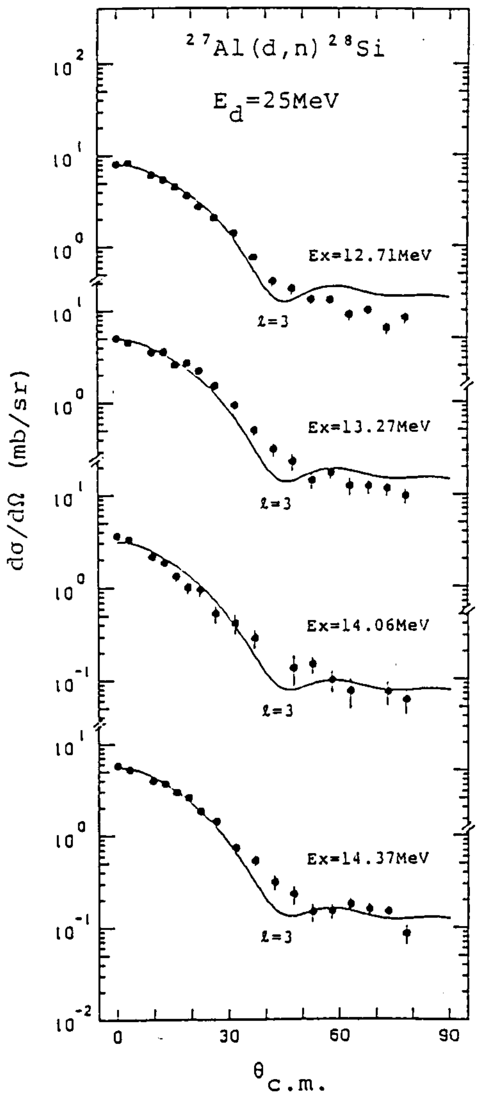

Fig. 5. Differential cross sections of the peaks leading to the high-lying states in ^{28}Si formed by the ℓ=3 transition.