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Particle-Hole Excitations in ^{16}F*

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Abstract

Levels of ^{16}F have been investigated by means of the $^{19}F(^{3}He,^{6}He)$ reaction at 70 MeV bombarding energy and the $^{16}O(^{3}He,t)$ reaction at 35 MeV. Three new states at 4.71, 6.05, and 6.93 MeV have been found. Based on all available information about ^{16}F, particle-hole configurations for several states are suggested.

NUCLEAR REACTIONS $^{19}F(^{3}He,^{6}He)$, $E_{^{3}He}$ = 70 MeV, $^{16}O(^{3}He,t)$, $E_{^{3}He}$ = 35 MeV. ^{16}F deduced levels.

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In the past there has been considerable interest in the structure of the A = 16, T = 1 isobaric triplet. Among these nuclei, ^{16}F is the least studied since it can be reached only by a few reactions[1-4]. We have studied the $^{19}F(^{3}He,^{6}He)^{16}F$ and $^{16}O(^{3}He,t)^{16}F$ reactions with the aim of obtaining additional information about the level structure of ^{16}F.

The two experiments were performed with 70 MeV and 35 MeV ^{3}He-particle beams from the Michigan State University cyclotron. The reaction products were detected in the focal plane of an Enge split-pole spectrograph with a position sensitive proportional counter. The proportional counter was backed by a scintillation counter which was run in coincidence with it to provide particle identification by measuring the time of flight through the spectrograph. As targets, CaF_2 evaporated onto a thin carbon backing and a mylar foil were used. Figure 1 shows a ^{6}He-spectrum from the $^{19}F(^{3}He,^{6}He)$ reaction, whereas in Fig. 2 a triton spectrum from the $^{16}O(^{3}He,t)$ reaction is displayed. The energy resolution in the $(^{3}He,^{6}He)$ experiment was about 80 keV and in the $(^{3}He,t)$ experiment about 60 keV. Three new states which were found in ^{16}F via the $^{19}F(^{3}He,^{6}He)$ reaction are marked by an asterisk in Fig. 1.

A search for a sharp peak in the $^{19}F(^{3}He,^{6}He)$ reaction near E_x = 10.5 MeV, which would correspond to the lowest T = 2 states in ^{16}F was not successful. The ^{16}F excitation energies deduced from the present $^{19}F(^{3}He,^{6}He)$ and $^{16}O(^{3}He,t)$ spectra are collected in Table 1. Also included are the results of the $^{14}N(^{3}He,n)$ work of Bohne et al.[1]

The ground state of ^{19}F can be described in terms of the simple shell model as

$$|^{16}O \otimes (\nu d_{5/2})^2 \otimes (\pi d_{5/2} \text{ or } \pi s_{1/2})\rangle_{1/2+}$$

In the $(^3He,^6He)$ reaction, one can pick up the two neutrons from the $d_{5/2}$ orbital and the third neutron from the $p_{1/2}$ or $p_{3/2}$ orbitals, whereas the proton configuration is expected to remain mainly unperturbed. This leads to the following 1p - 1h configurations in ^{16}F: $(p_{1/2}{}^{-1}d_{5/2})$, $(p_{1/2}{}^{-1}s_{1/2})$, $(p_{3/2}{}^{-1},d_{5/2})$, and $(p_{3/2}{}^{-1},s_{1/2})$. The first two configurations are the predominant configurations of the ground state quartet in ^{16}F, and the latter two configurations are expected to lie around 6 MeV in excitation.

Due to momentum mismatch between the entrance and exit channels, large values of the transferred orbital angular momentum are kinematically favoured over small values in the $(^3He,^6He)$ reaction. Consequently, states with high spins tend to be more strongly excited than low spin states (e.g. see Ref. 5). The (2^-) and (3^-) states at 0.42 and 0.72 MeV which have a predominant $(p_{1/2}{}^{-1}d_{5/2})$ configuration are the most strongly excited states in the $^{19}F(^3He,^6He)$ reactions. The ground and 0.19 MeV states, which have a predominant $(p_{1/2}{}^{-1}s_{1/2})$ configuration, are much more weakly excited. The transition strengths observed in the present $^{19}F(^3He,^6He)$ experiment favour the spin sequence 0^-, 1^-, 2^-, 3^- for the ground state quartet of ^{16}F. This agrees with the conjectures of Bohne et al.[1] and Pehl and Cerny[4], but not with the results of Otsubo et al.[2], who claim that the order of the 0^- and 1^- states is inverted.

Another type of state which is expected to be strongly excited in the $^{19}F(^3He,^6He)$ reaction is the 2p - 2h type. Here, one neutron is picked up from the $d_{5/2}$ orbital and two neutrons from the $p_{1/2}$ or $p_{3/2}$ orbitals. The $[(p_{1/2})^{-2}(d_{5/2})^2]$ and $[(p_{1/2})^{-2}(d_{5/2}s_{1/2})]$ configuration states have positive parity and should lie around 4 MeV of excitation. These states are also strongly excited in the $^{14}N(^3He,n)$ reaction in which they are characterized by even L transfers. From the juxtaposition of the present $^{19}F(^3He,^6He)$ and $^{16}O(^3He,t)$ reactions and the $^{14}N(^3He,n)$ results of Bohne et al.[1], we suggest that the states at 3.75, 3.86, 4.97, and 5.39 MeV have most probably such a 2p - 2h structure. From the observed features of the transitions to the 4.37 and 6.68 MeV states, we assign tentatively a $[(p_{3/2})^{-1}(d_{5/2}$ or $s_{1/2})^1]$ 1p - 1h configuration to these states.

Table I--Results of the $^{19}F(^3He,^6He)$ and $^{16}O(^3He,t)$ reactions. E_x is accurate within ± 20 keV.

Present Work $^{19}F(^3He,^6He)$ E_x(MeV)	Present Work $^{16}O(^3He,t)$ E_x(MeV)	Reference 1 $^{14}N(^3He,n)$ E_x(MeV)	Reference 1 L	Suggested Configurations
0	0	0	1	$(p_{1/2}^{-1}s_{1/2})$
0.19	0.19	0.192	1	$(p_{1/2}^{-1}s_{1/2})$
0.42	0.43	0.425	3	$(p_{1/2}^{-1}d_{5/2})$
0.72	0.72	0.722	(3)	$(p_{1/2}^{-1}d_{5/2})$
3.75	3.75	3.751	0	$(p_{1/2}^{-2}d_{5/2}^{2})$ or $(p_{1/2}^{-2}s_{1/2}^{2})$
3.86	3.86	3.861	2	$(p_{1/2}^{-2}d_{5/2}^{2})$ or $(p_{1/2}^{-2}s_{1/2}^{2})$
4.37	4.37	4.370		$(p_{3/2}^{-1}d_{5/2})$ or $(p_{3/2}^{-1}s_{1/2})$
4.66	4.66	4.646	0	
4.71				
4.97		4.973	2	$(p_{1/2}^{-2}d_{5/2}^{2})$ or $(p_{1/2}^{-2}s_{1/2}^{2})$
		5.264		
5.39		5.390	2	$(p_{1/2}^{-2}d_{5/2}^{2})$ or $(p_{1/2}^{-2}s_{1/2}^{2})$
		5.448		
5.53	5.53	5.528	2	$(p_{1/2}^{-2}d_{5/2}^{2})$ or $(p_{1/2}^{-2}s_{1/2}^{2})$
		5.840		
6.05				
		6.230		
		6.371		
6.68	6.68	6.678		$(p_{3/2}^{-1}d_{5/2})$ or $(p_{3/2}^{-1}s_{1/2})$
6.93				

References

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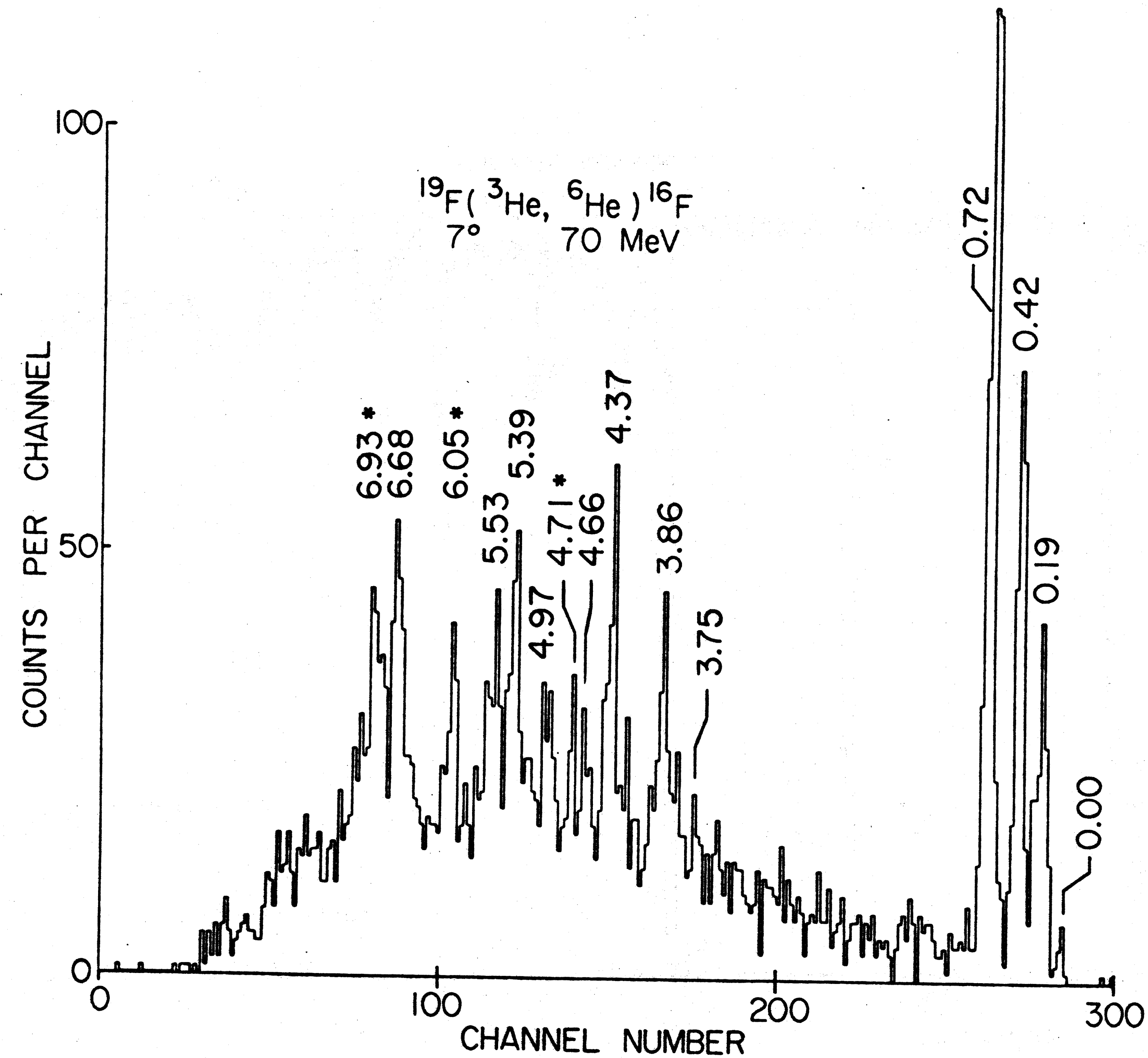
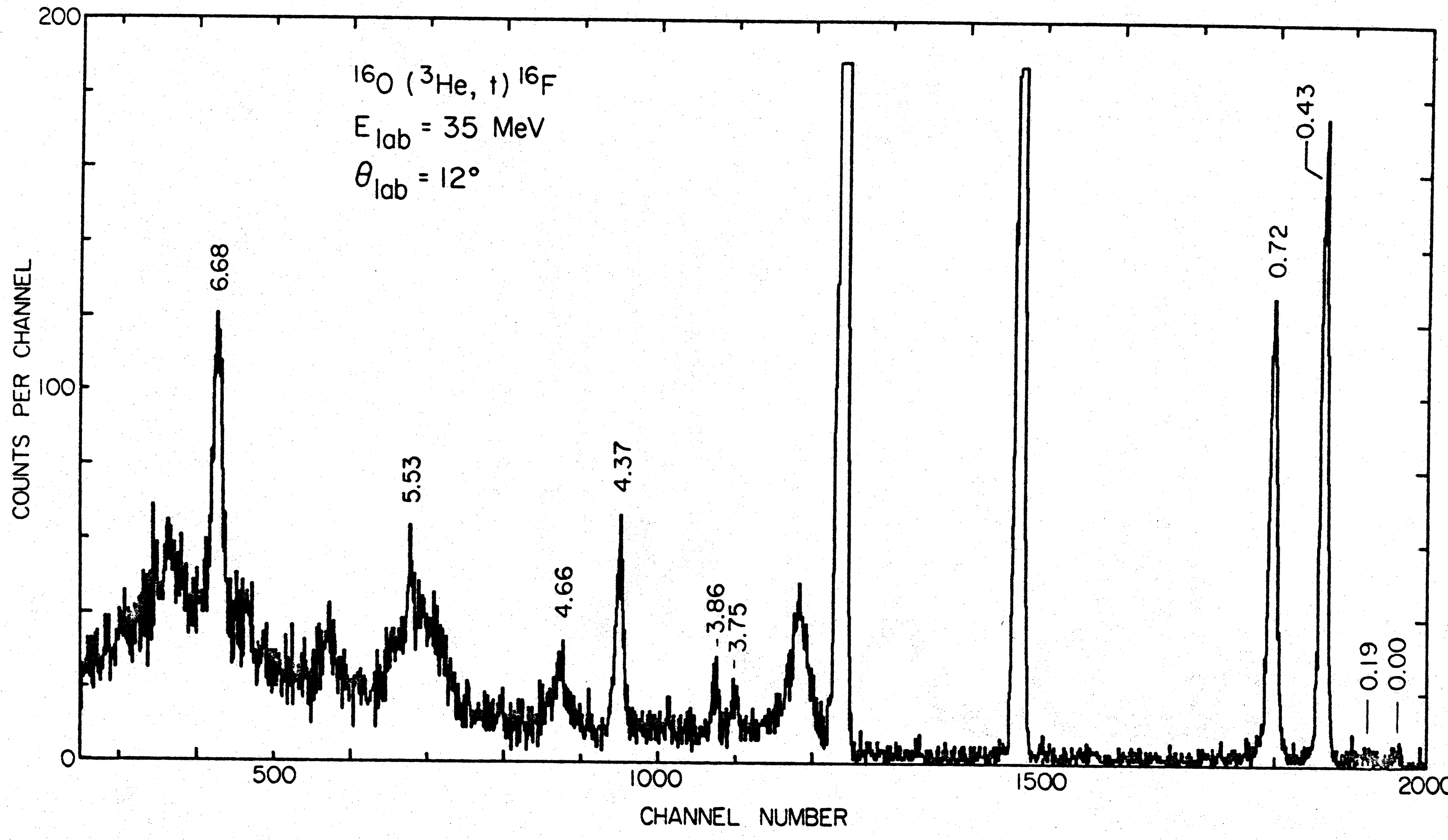
Figure Captions

Fig. 1. Spectrum from the $^{19}F(^{3}He,^{6}He)^{16}F$ reaction. The states are labeled by their excitation energy. New states are marked by an asterisk.

Fig. 2. Spectrum from the $^{16}O(^{3}He,t)^{16}F$ reaction. States in ^{16}F are labeled by their excitation energies. Unlabeled peaks correspond to contaminations in the target.



$^{19}F(^{3}He, ^{6}He)^{16}F$
7° 70 MeV
COUNTS PER CHANNEL
CHANNEL NUMBER
0
50
100
0
100
200
300
6.93 *
6.68
6.05 *
5.53
5.39
4.97
4.71 *
4.66
4.37
3.86
3.75
0.72
0.42
0.19
0.00


$^{16}O\,(^{3}He,t)\,^{16}F$
E_{lab} = 35 MeV
θ_{lab} = 12°
COUNTS PER CHANNEL
0
100
200
CHANNEL NUMBER
500
1000
1500
2000
6.68
5.53
4.66
4.37
3.86
3.75
0.72
0.43
0.19
0.00