PHOTOPRODUCTION OF CHARMED F MESONS AT γ ENERGIES OF 20-70 GeV

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ABSTRACT

Evidence is presented for inclusive photoproduction of $F^\pm$ mesons in three decay modes, $\eta\pi^\pm$, $\eta\pi^\pm\pi^+\pi^-$ and $\eta\pi^\pm\pi^+\pi^-\pi^-$. The average mass of the $F^\pm$ is found to be 2.020 ± 0.010 GeV.

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In a previous paper¹⁾ we reported on the photoproduction of charmed D mesons. Evidence for the F meson containing both charm and strangeness has been found in e^+e^- annihilation²⁾. We report here on the photoproduction of F mesons observed through their decay into states containing an η meson.

The experiment was carried out using the Omega Spectrometer at the CERN SPS^{3),4)}. A tagged photon facility provided a beam intensity of $2 \cdot 10^5$ photons/burst over an energy range 20-70 GeV. Gamma rays from interactions in the 67 cm long liquid hydrogen target were measured in a photon detector consisting of an active converter, made up of 42 blocks of lead glass of thickness 3 radiation lengths, followed by a position detector of 792 scintillation counters and then an array of 343 lead glass blocks, each of area 140×140 mm² and depth 470 mm (18.5 radiation lengths). This photon detector subtended a solid angle of 0.4 steradian about the forward direction and measured the photon direction to an accuracy $\approx \pm 0.4$ mrad.

The data presented here come from two triggers, T1 and T2. In T1 the spectrometer was triggered by requiring at least four charged particles at a plane 1.5 m downstream of the centre of the target. The integrated luminosity for T1 was 60 events/nb. In T2 we required a secondary photon with transverse momentum greater than 800 MeV, together with at least one charged particle leaving the target. The integrated luminosity of T2 was 50 events/nb.

The η mesons were detected via their decay into two photons. To reduce combinatorial background under the η we eliminated photons that could be associated to make π^0 's.

We consider first the T1 data. For this trigger the background remaining after the π^0 's were removed was due to low energy γ 's from non-reconstructed π^0 's. To reduce this background we rejected photons with energy below 2 GeV; this rejects a negligible number of η 's. The γ 's from η decay are likely to have larger p_T than γ 's from non-reconstructed π^0 's. We find that a suitable cut to exploit this feature is that the sum of the p_T^2 of the two γ 's forming an η candidate be greater than $m_\eta^2/2$. The relevant part of the resulting $\gamma\gamma$ mass spectrum, Fig. 1a, shows an η peak at 552 MeV with an FWHM of 72 MeV. In order to improve the resolution, $\gamma\gamma$ mass combinations were selected between 500 and 600 MeV and a 1C fit was performed imposing the η mass. The $\eta\pi^+\pi^-$ inclusive mass spectrum of Fig. 1b shows the $\eta'(958)$; its width agrees with our calculated mass resolution (see Table 1).

We have plotted inclusive mass distributions for charge ± 1 states $\eta(m\pi)^\pm$ ($m = 1, 3, 5$) and for the corresponding subsamples $\eta'(n\pi)^\pm$ ($n = 1, 3$). Evidence for F is found in $\eta\pi^+\pi^+\pi^-$ (Fig. 2a) and in $\eta\pi^+\pi^+\pi^+\pi^-\pi^-$ (Fig. 2c). There is no

indication that the signal appears more strongly in one charge state than in the other. The $\eta\pi^+\pi^+\pi^-\pi^-$ signal originates, for the most part, from $\eta'\pi^+\pi^-$ (Fig. 3a); there is no evidence for F on the $\eta'\pi^\pm$ mass spectrum (Fig. 3b). The widths of the F peaks are consistent with the experimental resolutions (Table 1) and the masses agree with the mass of $F^\pm$ published by the DORIS group²⁾. Assuming a polynomial shape for the background and counting events in an interval equal to the expected FWHM, the significance of the signals is about 4σ for $\eta(3\pi)$ and 3σ for $\eta(5\pi)$. No significant F signal is observed in $\eta\pi^\pm$ (Fig. 2b).

We now consider the T2 data. The absence of an F signal in $\eta\pi^\pm$ with the T1 trigger could indicate a suppression coming from the multiplicity requirement in that trigger. To check this possibility we have analyzed the T2 data using only events with a forward charged particle multiplicity less than or equal to four. The η mesons were selected using the high p_T photon plus any photon with energy greater than 500 MeV. The $\gamma\gamma$ mass spectrum (not shown) is similar to that in Fig. 1.

As before, the $\gamma\gamma$ pairs were fitted to the η mass. To reduce combinatorial background in $\eta\pi^\pm$ mass combinations we eliminated charged pions with $p_T < 300$ MeV. This selection would reject only a small fraction of F mesons decaying into $\eta\pi$. With an additional cut requiring the total visible mass to be > 4.0 GeV, we obtain the spectrum on Fig. 2d showing evidence for F. The statistical significance of this signal is 4.5σ . Within statistics, the F signal appears equally in both F^+ and F^- . The mass and width are given in Table 1.

Estimation of cross-section is clearly model dependent. Assuming that the F's are produced in pairs and that the pair carries most of the incident photon energy, the acceptances are essentially independent of the details of the production mechanism and vary smoothly with $\eta\pi\pi$ mass. The efficiency, as defined by the product of the geometrical acceptance and the η decay branching ratio into $\gamma\gamma$, is given in Table 2, which also gives the values of the product $B \cdot \sigma$, where σ is the cross-section for $F\bar{F}$ production, for the three observed decay modes. Averaging the three modes we find for the mass

$$M_F = 2.010 \pm 0.010 \text{ GeV}$$

where the error is statistical only. We estimate that the systematic errors are less than 20 MeV.

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Table 1

Characteristics of the observed signals^{a)}

	Expected width FWHM (MeV)	Observed width FWHM (MeV)	Observed mass GeV
$\eta \rightarrow \gamma\gamma$	----	72 ± 4	0.552 ± 0.001
$\eta \rightarrow \eta\pi^+\pi^-$	14	17 ± 6	0.960 ± 0.003
$F \rightarrow \eta\pi$	75	108 ± 31	2.047 ± 0.025
$F \rightarrow \eta 3\pi$	50	38 ± 24	2.021 ± 0.015
$F \rightarrow \eta 5\pi$	40	48 ± 34	2.008 ± 0.020

a) The observed width of the η is used to normalize the errors.

Table 2

Inclusive $F\bar{F}$ photoproduction cross-section

Mode	Efficiency (%)	$B \cdot \sigma$ (nb)
$\eta 3\pi$	10	60 ± 15
$\eta' 5\pi$	5	20 ± 8
$\eta\pi$ (T2)	7	12 ± 3

REFERENCES

- 1) D. Aston et al., Phys. Lett. 94B (1980) 113.
- 2) R. Brandelik et al., Phys. Lett. 70B (1977) 132 and 80B (1979) 412.
- 3) For details of the Omega Spectrometer and the tagging system, see D. Aston et al., Nucl. Phys. B166 (1980) 1.
- 4) F. Bourgeois, H. Grote and J.-C. Lassalle, Pattern recognition methods for Omega and SFM spark chamber experiments, CERN/DD/DH/101;
H. Grote, M. Hansroul, J.-C. Lassalle and P. Zanella, Identification of digitized particle trajectories, Proc. Int. Computing Symp., Davos, 1973 (North-Holland, Amsterdam, 1974) p. 413.

Figure Captions

Fig. 1 : a) $\gamma\gamma$ mass for Trigger 1 data (see text for the γ selection)
 b) $\eta\pi^+\pi^-$ mass for Trigger 1 data
 The curves are obtained from polynomial plus Breit-Wigner fits.

Fig. 2 : Inclusive $\eta(n\pi)$ mass spectra

- a) $\eta\pi^+\pi^+\pi^-$ Trigger 1
- b) $\eta\pi^\pm$ Trigger 1
- c) $\eta\pi^+\pi^+\pi^-\pi^-$ Trigger 1
- d) $\eta\pi^\pm$ Trigger 2

The curves are obtained from polynomial plus Breit-Wigner fits.

Fig. 3 : Inclusive $\eta'(n\pi)$ mass spectra

- a) $\eta'\pi^+\pi^+\pi^-$
- b) $\eta'\pi^\pm$

The curves are obtained from polynomial plus Breit-Wigner fits.

Fig. 1

Fig. 2

Fig. 3