FURTHER EVIDENCE FOR PHOTOPRODUCTION OF CHARMED F MESONSBonn¹-CERN²-Glasgow³-Lancaster⁴-Manchester⁵-Paris VI⁶-
Rutherford⁷-Sheffield⁸ Collaboration

M. Atkinson⁷, T.J. Axon⁵, D. Barberis⁵, T.J. Brodbeck⁴, G.R. Brookes⁸,
J.J. Bunn⁸, P.J. Bussey³, A.B. Clegg⁴, J.B. Dainton³, M. Davenport⁷,
B. Dickinson⁵, B. Diekmann¹, A. Donnachie⁵, R.J. Ellison⁵, P. Flower⁷,
P.J. Flynn⁴, W. Galbraith⁸, K. Heinloth¹, R.C.W. Henderson⁴,
R.E. Hughes-Jones⁵, J.S. Hutton⁷, M. Ibbotson⁵, H.P. Jakob¹, M. Jung¹,
M.A.R. Kemp⁷, B.R. Kumar⁷, J. Laberique⁶, G.D. Lafferty⁵, J.B. Lane⁵,
J.C. Lassalle², J.M. Levy⁶, V. Liebenau¹, R. McClatchey⁸, D. Mercer⁵,
J.A.G. Morris⁷, J.V. Morris⁷, D. Newton⁴, C. Paterson³, G.N. Patrick²,
E. Paul¹, C. Raine³, M. Reidenbach¹, H. Rotscheidt¹, A. Schlösser¹,
P.H. Sharp⁷, I.O. Skillicorn³, K.M. Smith³, K.M. Storr², R.J. Thompson⁵,
Ch. de la Vaissière⁶, A.P. Waite⁵ and T.P. Yiou⁶

ABSTRACT

Further experimental evidence is given for the F meson through its decay into η 's. Results are presented for the decay channels $\eta\pi^{\pm}$, $\eta\pi^0\pi^{\pm}$, and $\eta\pi^+\pi^-\pi^{\pm}$, and confirm those obtained in a previous experiment.

(To be submitted to Physics Letters)

Experimental evidence for the charmed F meson is still sparse¹⁻³⁾. On the model of a spectator quark, F mesons are expected to decay giving final states preferentially containing a pair of strange quarks which couple to η , η' or ϕ . In a previous photoproduction experiment, using the Omega spectrometer equipped with optical spark chambers signals were reported in the channels $\eta\pi^\pm$, $\eta\pi^+\pi^-\pi^\pm$, $\eta'\pi^+\pi^-\pi^\pm$ and $\phi\rho^\pm$ ^{2,3)}. In this letter we present new results involving η mesons from an experiment at CERN (WA57) carried out with the upgraded Omega spectrometer and a tagged photon beam having energies between 20 and 70 GeV (Fig. 1). The Omega spectrometer was equipped with multiwire proportional chambers and two downstream drift chambers for charged particle detection. Gamma rays produced from interactions in the 600 mm hydrogen target were measured in a lead-glass photon detector giving the photon direction to ± 0.4 mr and an energy resolution (σ_E) of $\pm 0.10 E^{+1/2}$ GeV⁴⁾.

The data presented here were derived from a trigger requiring a forward charged multiplicity between 2 and 5 together with at least one photon with energy greater than 2 GeV. Electron-positron pairs were rejected by vetoing events having large pulse height in median plane shower counters.

Pattern recognition of the charged particles and geometrical reconstruction of events were carried out using the program TRIDENT⁵⁾. We required that the charged tracks be well measured and that the observed charge of the final state be +1 or 0. The vertex of the event was required to be within the hydrogen target. π^0 and η mesons were detected through their decay into two photons. A cut on the incident photon energy was made requiring that the energy be greater than 50 GeV to enhance the charm signal with respect to background, giving an effective integrated luminosity (L) of 33 nb^{-1} .

Events containing an η meson were selected using two alternative methods. In the first method a broad mass cut was made on $\gamma\text{-}\gamma$ pairs such that $450 < M_{\gamma\gamma} < 650$ MeV after removing photons that can be associated to make π^0 mesons; in the second, a procedure was carried out to allocate a probability of a particular photon pair belonging to a π^0 or an η meson⁶⁾. Both methods gave a similar number of η mesons. The latter method was used

as the background was smaller. Since the photons from η decay have on average a larger p_t than those from non-reconstructed π^0 's, we required as in a previous experiment²⁾ that the sum of the p_t^2 of the two photons forming an η candidate be greater than $\frac{1}{2}m_\eta^2$. Figure 2a shows the $\gamma\gamma$ mass spectrum near the η for the remaining events in the sample. An η meson peak is seen having a mass at 544 MeV and a FWHM of 49 MeV. In order to improve the mass resolution of combinations of η mesons with other particles, a 1C fit was performed with the η mass fixed. As a check on our resolution, we compare the expected width and observed width for the $\eta(548) \rightarrow \gamma\gamma$, $\eta'(958) \rightarrow \eta\pi^+\pi^-$ and $\delta^\pm(980) \rightarrow \eta\pi^\pm$. The results are shown in Table 1 and Fig. 2.

We consider combinations of our sample of η mesons with charged and neutral pions having total charge ± 1 , and apply additional cuts such that the $\eta(n\pi)^\pm$ system has an energy greater than 20 GeV and transverse momentum greater than 800 MeV/c. Figures 3a, b and c show the inclusive distributions $\eta(n\pi)^\pm$ ($n = 1, 2, 3$). The enhancement in the region of 2.02 GeV in $\eta\pi^\pm$ is statistically significant at the 3σ level, and is compatible with an expected decay of the F meson. The $\eta\pi^0\pi^\pm$ and $\eta\pi^+\pi^-\pi^\pm$ spectra allow such an enhancement but do not require it. There is no significant signal for the $\eta\pi^+\pi^-\pi^0\pi^\pm$ combination, a probable consequence of the low acceptance due to the low multiplicity requirement in the trigger.

A fit to the data was obtained in each channel using a polynomial for the background, and a Gaussian with variable mass and width for the peak; the widths are consistent with the experimental resolutions (Table 1). Making the assumption that an F signal is present in the $\eta\pi$ channel, we investigate the level of a corresponding signal in $\eta 2\pi$ and $\eta 3\pi$; we let the positions of the peaks vary between 2.00 and 2.04 GeV to be consistent with the $\eta\pi$ value, and fix the widths at the expected values. We obtain in this way the curves shown in Fig. 3 and estimate 17 ± 6 reconstructed F's for $\eta\pi^\pm$, 14 ± 9 for $\eta\pi^0\pi^\pm$ and 20 ± 11 for $\eta\pi^+\pi^-\pi^\pm$.

To make estimates of channel cross-sections we have calculated the acceptance of the apparatus by assuming a particular model, namely that the F mesons are produced in pairs in a photon-gluon fusion model⁷⁾ and carry the same forward momentum as the $c\bar{c}$ pair. The cut requiring the observed

$F^\pm$ to have a momentum greater than 20 GeV is equivalent to $x_F > 0.25$, varying slightly with the incident photon energy. The detection efficiency^{*)} for each channel is given in Table 2, together with the estimated products $\sigma \cdot B$, where σ is the photoproduction cross section for an F^+F^- pair at a mean incident energy of 60 GeV.

The cross-sections for the $\eta\pi^\pm$ and $\eta\pi^+\pi^-\pi^\pm$ channels are consistent with those obtained in our previous experiment²⁾ as also is the mass obtained in the $\eta\pi^\pm$ channel.

We are grateful to the Omega group at CERN for their help in maintaining and running the spectrometer and providing on-line and off-line software. The support of our technical support staff in our home institutions is much appreciated. We thank IN2P3 (France), BMFT (W. Germany) and SERC (UK) for their financial support.

*) The detection efficiency (ϵ) includes the trigger acceptance, reconstruction efficiency and the cuts as described in the text. The cross-section ($\sigma \cdot B$) is given by $\frac{1}{2}N/[L \cdot \epsilon \cdot BR(\eta \rightarrow \gamma\gamma)]$, where N is the number of events in the peak.

REFERENCES

- 1) R. Brandelik et al., Phys. Lett. 80B (1979) 412.
V. Lüth, Proc. 1979 Int. Symp. Lepton/Photon Interactions, p. 78.
- 2) D. Aston et al., Phys. Lett. 100B (1981) 91.
- 3) D. Aston et al., Nucl. Phys. B189 (1981) 205.
- 4) R.H. McClatchey, Ph.D. Thesis (1981) University of Sheffield. Rutherford
Appleton Laboratory Report HEP/T/92 (1982).
- 5) J.-C. Lassalle, F. Carena and S. Pensotti, CERN-DD/EE/79-2 (1979).
- 6) Omega Photon Collaboration. Internal Report (1981) Ch. de la Vaissière.
D. Barberis, University of Manchester Ph.D. Thesis (to be submitted).
- 7) L.M. Jones and H.W. Wyld, Phys. Rev. D 17 (1978) 759.
J. Babcock, D. Sivers and S. Wolfram, Phys. Rev. D 18 (1978) 162.

Table 1

Masses and widths for the observed signals

	Expected width FWHM (MeV)	Observed width FWHM (MeV)	Observed mass (GeV)
$\eta \rightarrow \gamma\gamma$	53	49 ± 1	0.544 ± 0.0005
$\eta' \rightarrow \eta\pi^+\pi^-$	15	17.5 ± 1.5	0.959 ± 0.001
$\delta \rightarrow \eta\pi^\pm$	71	71 ± 5	0.978 ± 0.002
$F \rightarrow \eta\pi^\pm$	70	69 ± 28	2.017 ± 0.013
$F \rightarrow \eta\pi^0\pi^\pm$	75	153 ± 82	2.050 ± 0.024
$F \rightarrow \eta\pi^+\pi^-\pi^\pm$	65	30 ± 25	2.002 ± 0.016
$F \rightarrow \eta\pi^+\pi^-\pi^0\pi^\pm$	70	-	-

Table 2

Estimated inclusive cross-section
for photoproduction of an F^+F^- pair

Decay channel	Number of observed events	Efficiency (%)	$\sigma \cdot B$ (nb)
$\eta\pi^\pm$	17 ± 6	1.83	38 ± 14
$\eta\pi^0\pi^\pm$	14 ± 9	0.85	66 ± 42
$\eta\pi^+\pi^-\pi^\pm$	20 ± 11	0.87	93 ± 52
$\eta\pi^+\pi^-\pi^0\pi^\pm$	< 10	0.19	< 216

Figure captions

- Fig. 1 : A schematic diagram of the upgraded Omega spectrometer.
- Fig. 2 : a) $\gamma\gamma$ mass spectrum in the region of the η meson.
b) The $\eta\pi^+\pi^-$ mass spectrum showing the $\eta'(958)$.
c) The $\eta\pi^\pm$ mass spectrum showing the $\delta^\pm(980)$.
The fits shown in (b) and (c) are obtained after performing a LC fit with the η mass fixed.
- Fig. 3 : Inclusive $\eta(n\pi)^\pm$ mass spectra. The fits shown are obtained with a polynomial plus Gaussian as described in the text.

Fig. 1

Fig. 2

Fig. 3