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A peak in the $\eta\omega$ mass spectrum from diffractive photoproduction

Omega Photon Collaboration

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Abstract

The $\eta\omega$ mass spectrum resulting from diffractive photoproduction, by photons of 25-50 GeV, shows a peak at a mass of 1.61±0.04 GeV and width of 0.23±0.08 GeV. Comparison with the corresponding $\eta\rho^0$ mass spectrum suggests that a resonance interpretation is favoured.

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This letter reports a peak in the $\eta\omega$ mass spectrum from the reaction

$$\gamma p \to \eta\omega p \tag{1}$$

Such a peak could indicate a resonance, or be a non-resonant threshold peak due to mechanisms such as those of Drell and Hiida [1] or Deck [2]. Comparison with the $\eta\rho^0$ mass spectrum from the reaction

$$\gamma p \to \eta\rho^0 p \tag{2}$$

shows that the interpretation as a threshold peak is unlikely so that the resonance interpretation is favoured.

The data were obtained from the WA57 experiment in the Omega spectrometer at CERN [3]. Events were initially selected having outgoing charged particles consistent with either $\pi^+\pi^-$ or $\pi^+\pi^-p$, and four gamma-rays of which two had a mass consistent with the π^0-meson and the other two had a mass between 0.4 and 0.7 GeV and so would include η-meson candidates. Further initial requirements were that the incident photons had an energy between 25 and 50 GeV, and that $\triangle$E, the difference between the incident photon energy and the energy of the $\pi\pi(4\gamma)$ system was less than 10 GeV. The resulting mass spectrum of the second $\gamma\gamma$ pair is shown in Fig.1a. Eta-mesons were selected with $0.49 < M(\gamma\gamma) < 0.59$ GeV, and backgrounds, deduced from side-band regions ($0.44 < M(\gamma\gamma) < 0.49$ GeV or $0.59 < M(\gamma\gamma) < 0.64$ GeV), were subtracted in following plots. Events due to the reaction

$$\gamma p \to \pi^+\pi^-\pi^0\eta p \tag{3}$$

were then selected by requiring $-1.5 < \triangle E < 1.5$ GeV.

The $\pi^+\pi^-\pi^0$ mass spectrum from reaction (3) is shown in Fig.1b, where a peak due to the ω-meson is seen, with low background. Events corresponding to reaction (1) were then selected by requiring $0.75 < M(\pi^+\pi^-\pi^0) < 0.82$ GeV. Cross sections were obtained from a full simulation of the experiment, assuming an isotropic $\eta\omega$ angular distribution. The resulting $\eta\omega$ mass spectrum is shown in Fig. 2, where the errors shown are statistical; there is a further systematic uncertainty of 25% on the overall normalisation of the cross section. The cross section for production of $\eta\omega$ in the peak ($M(\eta\omega) < 1.8$ GeV) is deduced to be ~ 40 nb.

This peak could be due to a threshold effect. From general features of the mechanisms [1],[2] for production of such threshold peaks, one would expect a similar peak in the $\eta\rho^0$ mass spectrum from reaction (2), with intensities in the ratio

$$(\eta\omega)/(\eta\rho^0) \simeq \Gamma(\omega \to \eta\gamma)/\Gamma(\rho^0 \to \eta\gamma)$$

as this is the ratio of the initial electromagnetic couplings, while all following interactions should be the same in both cases. These radiative widths are not well measured, but systematic studies of such radiative decays (see [4],[5] for reviews and [6] for a recent study) indicate this ratio is in the range 0 to 2 times the SU(3) prediction of 1/9.

The $\eta\rho^0$ mass spectrum from reaction (2), (from [7],[8]) with the cross sections divided by a factor of 9, is therefore compared with the $\eta\omega$ mass spectrum in Fig.2. The absence of any corresponding peak in the $\eta\rho^0$ mass spectrum is striking, giving a strong argument against the peak in the $\eta\omega$ mass spectrum being due to a threshold effect. (The peak in the $\eta\rho$ mass spectrum below the nominal threshold results from the finite width of the ρ.) Therefore a resonance interpretation is favoured.

The peak in the $\eta\omega$ mass spectrum was fitted with a Breit-Wigner resonance shape, giving a mass of 1.61±0.04 GeV and a width of 0.23±0.08 GeV. One sees that the $\eta\omega$ state has $C = -1$, $I = 0$, so that it can be produced by diffractive dissociation, as is indicated by its relatively strong exclusive production. It has been a common view that diffractive photoproduction should be elastic diffraction and so only produce $J^\pi = 1-$ states. This assumption has been shown to be in error, by strong diffractive production of the $b_1(1235)$ [9], $h_1(1190)$ [3] and $\rho_3(1690)$ [8], and by direct demonstration of a major contribution of inelastic diffraction to photoproduction [10]. The spin and parity of the $\eta\omega$ system can be investigated by studying the ω angular distribution in the $\eta\omega$ CM-system, or the ω alignment as indicated by the angular distribution of the normal to its decay plane. As the first of these distributions is distorted by acceptance effects, only the second has been studied. Fig.3 shows the distribution of $|\cos\theta_\omega|$, where θ_ω is the angle between the ω normal and the η direction in the ω-meson CM-system, for events with $1.4 < M(\eta\omega) < 1.8$ GeV. It is compared with fits for each possible J^π with L = 0,1, where L denotes the orbital angular momentum of $\eta\omega$. For these fits, the values of χ^2 are (for 4 degrees of freedom):

L	J^π	χ^2
0	1+	0.34
1	0−	10.2
1	1−	2.93
1	2−	0.78

J^π = 0− is unlikely but all other J^π listed are possible.

The one resonance with C = −1, I = 0 firmly reported [11] in this mass region is the J^π = 3− $\omega_3(1670)$. Decay of this resonance to $\eta\omega$ would have L = 3, and thus, so close to threshold, should not be strong. The cross section for exclusive photoproduction of the $\omega_3(1670)$ should be 1/9 of that for photoproduction of the $\rho_3(1690)$ [8], and so only be $\sim$ 23 nb. This must include all decay modes, of which only $b_1\pi$ and $\rho\pi$ are known [11]. A cross section of $\sim$ 10 nb is reported [12] for photoproduction of the $b_1^\pm\pi^\mp$ decay mode. Therefore identification of the $\eta\omega$ peak with the $\omega_3(1670)$ is doubtful. Other possibly related states are the $\phi(1680)$ reported in electron-positron annihilation but not seen at the expected intensity in photoproduction results [11], a peak in photoproduced $\pi^+\pi^-\pi^0$[3], and a peak in photoproduced $K\bar{K}$ [13, 14].

In conclusion the peak in the $\eta\omega$ mass spectrum reported here is a probable indication of a meson state. As the η-meson is involved in its decay, it could be any admixture of $(u\bar{u} - d\bar{d})$ or of $s\bar{s}$ quarks. The complexity of this region of mass in the quark model, where both D orbital excitations and S radial excitations are expected, has been pointed out [15].

Supporting evidence has recently been presented [16, 17] that such complexity is needed in the interpretation of 4π states photoproduced in this mass region.

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REFERENCES

1. S.D. Drell and K. Hiida, Phys. Rev. Lett. 7 (1961) 199.
2. R.T. Deck, Phys. Rev. Lett. 13 (1964) 169.
3. M. Atkinson et al., Nucl. Phys. B231 (1984) 15.
4. T. Ohshima, Phys. Rev. D22 (1980) 707.
5. P.J. O'Donnell, Rev. Mod. Phys. 53 (1981) 673.
6. R.S. Chivukula and J.M. Flynn, Phys. Lett. 168B (1986) 127.
7. M. Atkinson et al., Nucl. Phys. B242 (1984) 269.
8. M. Atkinson et al., Z. Phys. C30 (1986) 531.
9. M. Atkinson et al., Nucl. Phys. B243 (1984) 1.
10. T.J. Chapin et al., Phys. Rev. D31 (1985) 17.
11. Particle Data Group, Phys. Lett. 170B (1986) 1.
12. M. Atkinson et al., submitted to Z. Phys. C.
13. D. Aston et al. Phys. Lett. 104B (1981) 231.
14. M. Atkinson et al., Z. Phys. C27 (1985) 233.

15. S. Godfrey and N. Isgur, Phys. Rev. D32 (1985) 189.

16. M. Atkinson et al., Z. Phys. C26 (1985) 499.

17. A. Donnachie and H. Mirzaie, Manchester preprint M/C TH 86/12, to appear in Z. Phys. C.

Figure Captions

1(a). Mass spectrum for 2nd $\gamma\gamma$ pair, including η-meson candidates.

(b). $\pi^+\pi^-\pi^0$ mass spectrum.

2. ———— $\eta\omega$ mass spectrum

- - - - - - $\eta\rho^0$ mass spectrum (with cross section divided by 9).

3. Number of $\eta\omega$ events, for $1.4 < M(\eta\omega) < 1.8$ GeV, as function of $|\cos\theta_\omega|$ where θ_ω is angle between normal to ω decay plane and η direction in ω-meson CM-system. Also shown are fits, asssuming various J^π for $\eta\omega$ system:

- - - - - - - 1+

.... 0-

._._._._. 1-

_.._.._.._ 2-

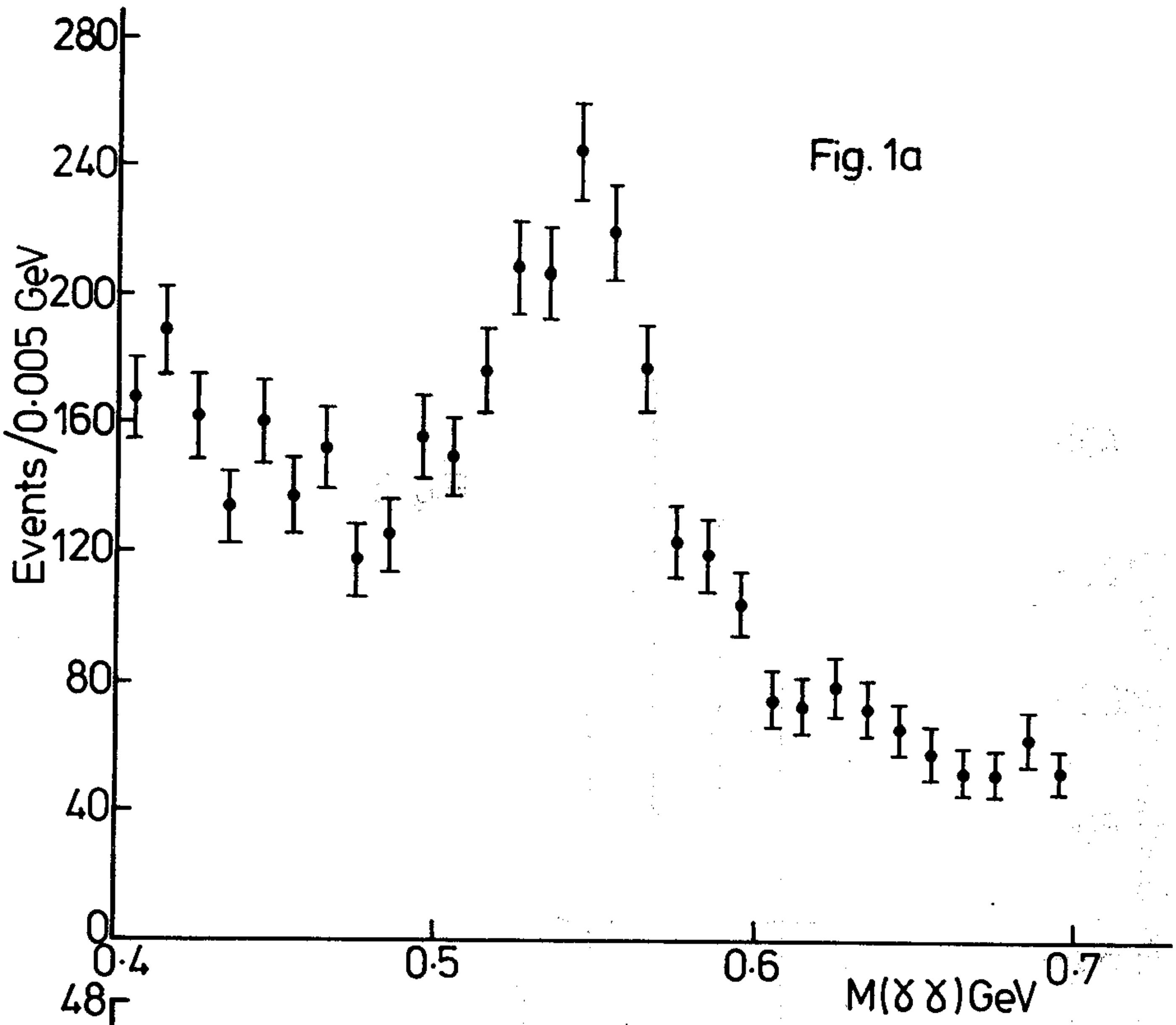
Events/0·005 GeV
280
240
200
160
120
80
40
0
0·4
0·5
0·6
0·7
M(γγ)GeV

Fig. 1a

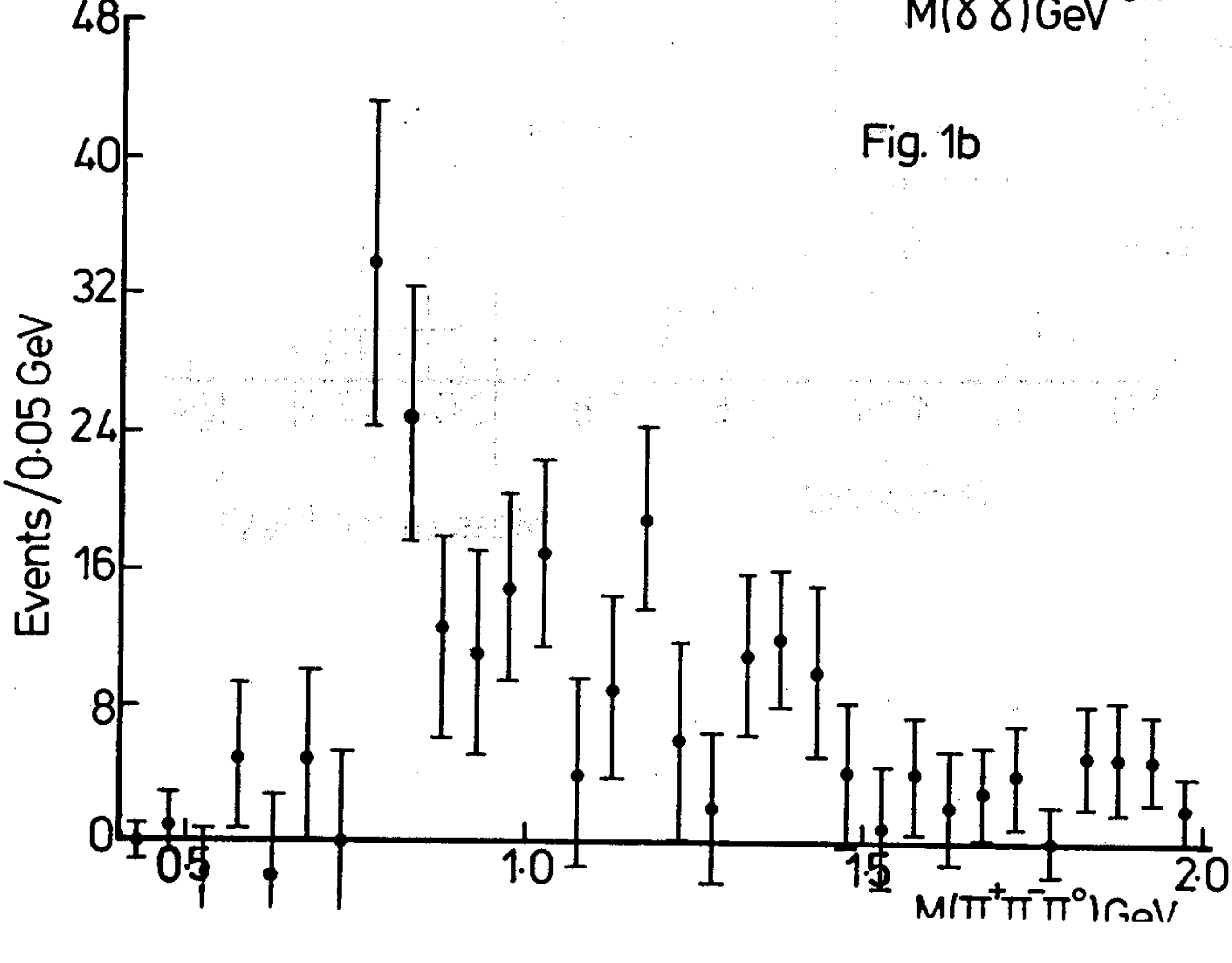
Events/0·05 GeV
48
40
32
24
16
8
0
0·5
1·0
1·5
2·0
M(π⁺π⁻π°)GeV

Fig. 1b

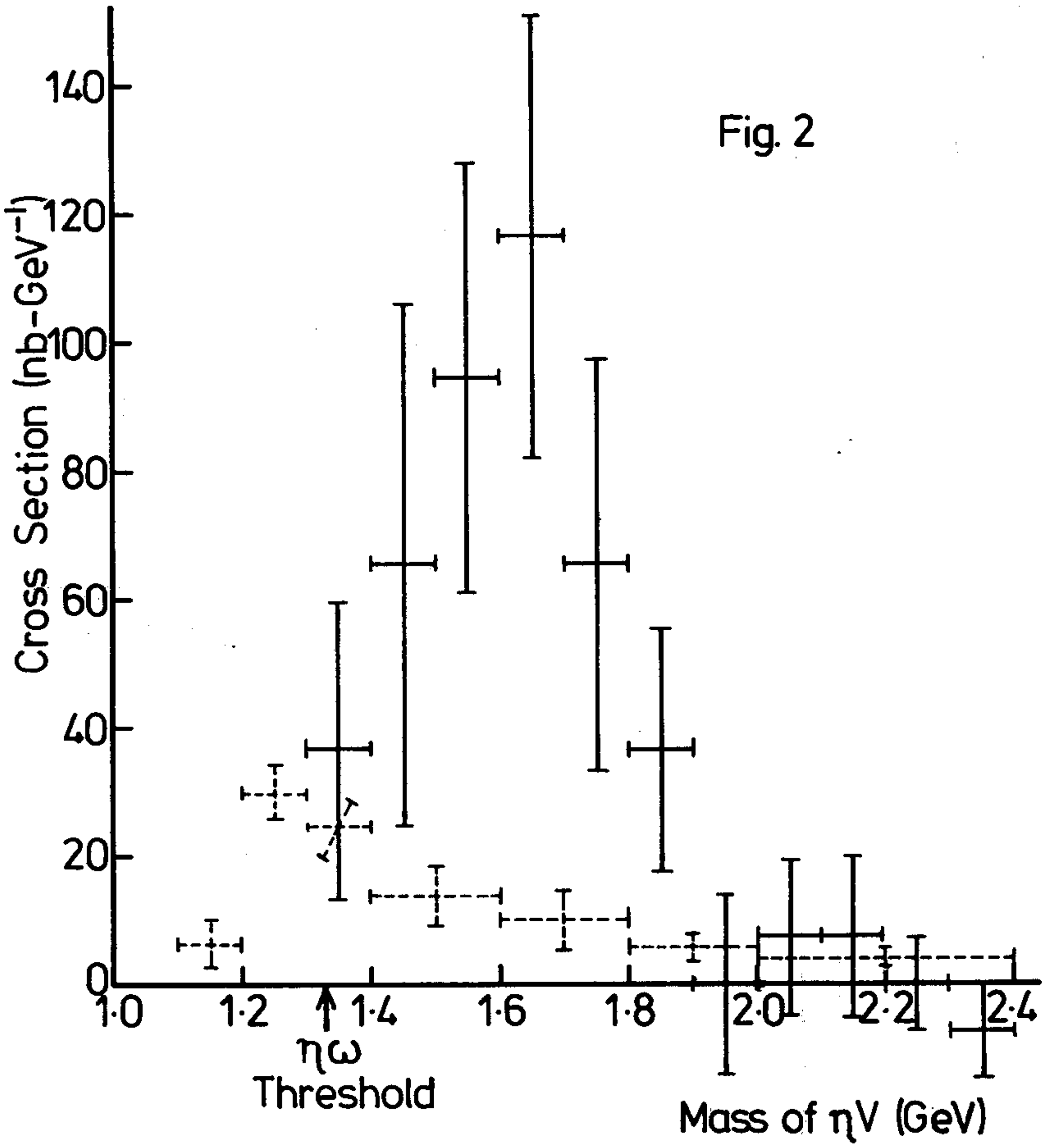

Fig. 2
Cross Section (nb-GeV^{-1})
140
120
100
80
60
40
20
0
1·0
1·2
1·4
1·6
1·8
2·0
2·2
2·4
ηω
Threshold
Mass of ηV (GeV)

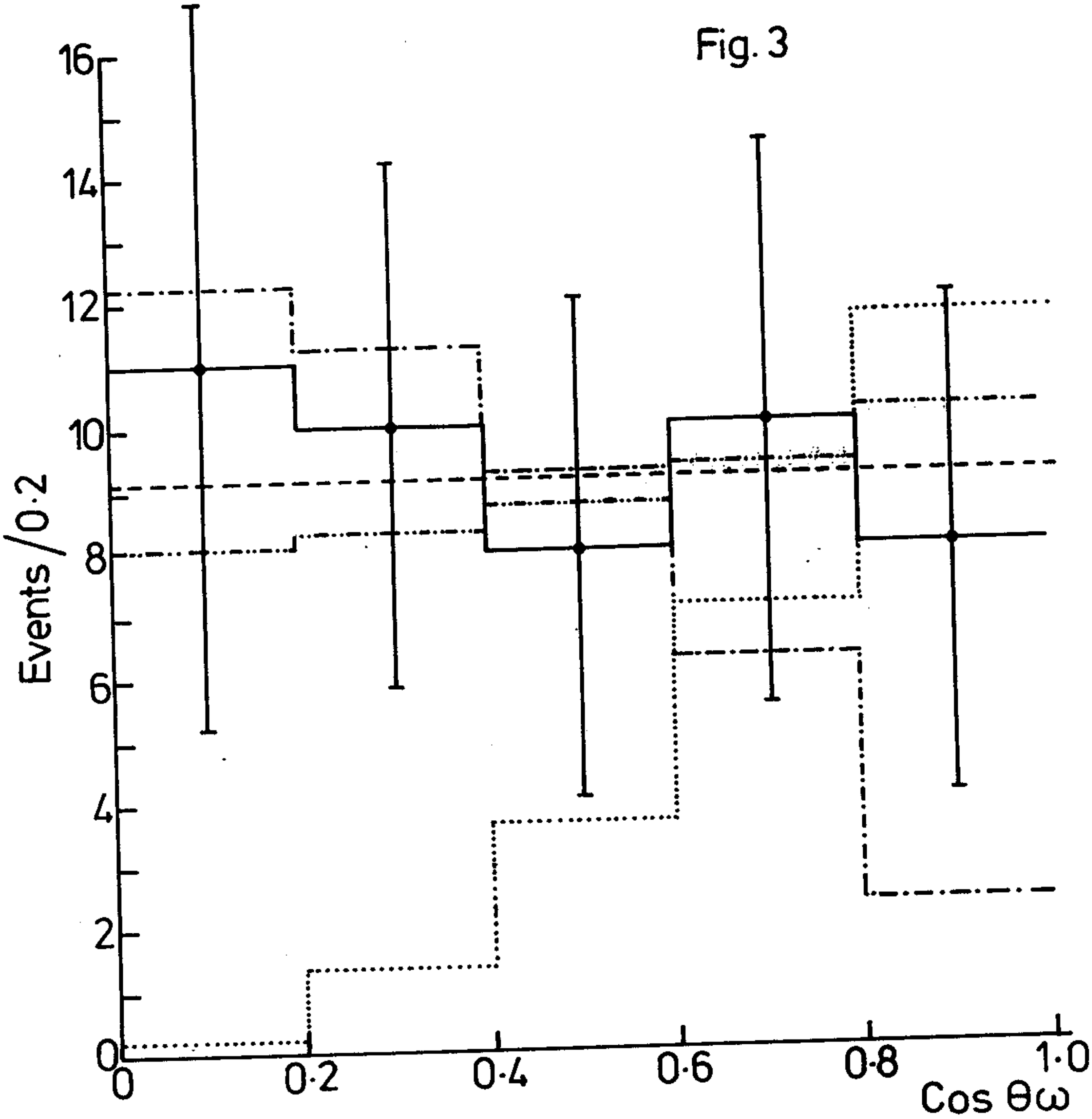

Fig. 3
Events /0·2
16
14
12
10
8
6
4
2
0
0
0·2
0·4
0·6
0·8
1·0
Cos θω