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OBSERVATION OF A PEAK AT 1.28 GeV IN THE $\eta\pi\pi$ SYSTEM IN THE REACTION $\gamma p \rightarrow \eta\pi^+\pi^-p$

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ABSTRACT

A peak is reported in the $\eta\pi^+\pi^-$ system, produced in the reaction $\gamma p \rightarrow \eta\pi^+\pi^-p$, at a mass of 1.28 ± 0.01 GeV with a width of 0.08 ± 0.02 GeV. Possible spin-parity assignments for the peak are shown to be $J^\pi = 1-$, $J^\pi = 1+$ or $J^\pi = 2+$ and interpretations of these assignments are discussed.

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1. INTRODUCTION

Meson systems produced by diffractive association of the photon have been shown to include vector mesons, resonances of other J^π and non-resonant systems. It is of particular interest to use diffractive dissociation of the photon, together with complementary information from electron-positron annihilation, to establish higher vector mesons. Candidates for such higher vector meson nonets of quark-antiquark states, including both a $^3S_1$ radial recurrence and a $^3D_1$ state, are predicted in the mass region 1.2-1.8 GeV [1].

The following candidates, for a nonet at masses around 1.6 GeV, have been reported:

i) The $\rho'(1600)$: seen to decay into $\pi^+\pi^-\pi^+\pi^-$ (see [2] for a summary), $\pi^+\pi^-\pi^0\pi^0$ [3] and $\pi^+\pi^-$ [4,5].

ii) An $\omega' \rightarrow \pi^+\pi^-\pi^0$ candidate at a mass of 1.67 GeV [6].

iii) A ϕ' candidate reported, in electron-positron annihilation, to decay into $K\bar{K}$ [7,8], $K\bar{K}\pi$ [9] and $\omega\pi\pi$ [10]. However, doubt has been raised by the present experiment which has failed to observe these relatively narrow peaks in the $\omega\pi\pi$ [11] or $K\bar{K}\pi$ [12] states at the level where statistically significant signals are expected.

At lower masses a peak at a mass of 1.24 GeV in the $\omega\pi^0$ state has been observed in diffractive dissociation of the photon (see [13] for a summary). However, detailed analysis shows that this peak is probably due to the J^π = 1+ B meson [13], a conclusion which is supported by a failure to see a corresponding peak in electron-positron annihilation [14].

The present paper reports diffractive dissociation of the photon to produce a peak in the $\eta\pi\pi$ system at a mass of 1.28 ± 0.01 GeV. Observations are reported for the decay mode: $\eta \rightarrow \gamma\gamma$. They are consistent with, but improve on, earlier measurements [15] for the decay mode $\eta \rightarrow \pi^+\pi^-\pi^0$ for which the statistical accuracy was worse. Analysis shows three possible spin-parity assignments for the peak: 1-, 1+, or 2+. The J^π = 1+ assignment could indicate a new decay mode of the B meson.

This possibility cannot be ruled out, but it requires a considerably larger D-wave/S-wave ratio for the decay $B \to \eta\rho^o$ than is observed for $B \to \omega\pi^o$, which would be unlikely as the former is closer to threshold. The other two possibilities imply either a new vector meson, or a new $I^G = 1+$, $J^\pi = 2+$ state which would be exotic.

2. EXPERIMENT AND DATA SELECTION

An 80 GeV electron beam from the CERN SPS was used to produce tagged photons of energy 20-70 GeV [16], which were incident on a 60 cm target of liquid hydrogen. The particles produced were detected in the Omega spectrometer and a large aperture photon detector. The trigger for the experiment required between two and five charged particles to be detected in a forward MWPC, together with at least one gamma-ray, with energy > 2 GeV, to be detected in the photon detector. Off-line software selected a data sample where two or three charged particles, consistent with $\pi^+\pi^-$ or $\pi^+\pi^-p$, respectively, were detected together with two γ-rays with a mass in the range 0.4-0.7 GeV. A further selection was made on ΔE = incident photon energy - Σ(π-meson energies) - Σ(γ-ray energies), requiring it to be less than 10 GeV.

The $\gamma\gamma$ mass spectrum for this data sample is shown in Fig. 1. Events with an η meson were then selected as those with $0.49 < M(\gamma\gamma) < 0.59$ GeV, and a background was deduced from events with $0.44 < M(\gamma\gamma) < 0.49$ GeV or $0.59 < M(\gamma\gamma) < 0.64$ GeV. This background has been subtracted bin by bin in all succeeding distributions. The observed ΔE distribution for the $\eta\pi\pi$ mass range 1.1-1.5 GeV, relevant to the present paper, is shown in Fig. 2. Events corresponding to the reaction

$$\gamma p \to \eta\pi^+\pi^- p \qquad (1)$$

were selected by requiring $-1.0 < \Delta E < 1.5$ GeV. It is estimated that the background from events where further, undetected, particles are produced is $\leq 20\%$. (It will be noted that an appreciable fraction of these background events can also be due to diffractive dissociation of the photon, with the proton also being dissociated.)

3. RESULTS

The $\eta\pi^+\pi^-$ mass spectrum resulting from reaction (1) is shown in Fig. 3. A relatively narrow peak is seen at a mass ~ 1.28 GeV. In this paper attention is concentrated on this peak, restricting the study to $\eta\pi\pi$ masses < 1.5 GeV. The peaking around 1.6 GeV, which could be due (at least in part) to the $\rho'(1600)$, will be discussed in a later publication.

The t distribution, for events with $1.1 < M(\eta\pi\pi) < 1.5$ GeV, is shown in Fig. 4. This distribution was fitted with A exp (bt) giving $b = 4.70 \pm \pm 0.4\ (\mathrm{GeV/c})^2$. Such a forward peaked distribution indicates production by a peripheral process, which can include diffractive dissociation.

To determine cross-sections, a Monte Carlo simulation programme was used to study the acceptance of the apparatus. This programme simulated the effects of the detectors and of the analysis programmes on both charged particles and gamma-rays. In particular a full simulation of showering in the photon detector and the resulting effects on the analysis programme was made, successfully reproducing the observed width of the η-meson peak shown in Fig. 1. The normalization of the cross-section was determined by counting the number of incident photons detected by the tagging system.

Both the acceptance and the number of incident photons fall rapidly with increasing incident photon energy, so that no useful measurement of cross-section was obtained for incident photon energy $E_\gamma > 55$ GeV. The resulting cross-sections for producing $\eta\pi^+\pi^-$ systems with masses 1.1-1.5 GeV are shown in Fig. 5. These cross-sections have been corrected for:

i) Acceptance of apparatus and analysis programmes, as calculated by simulation.

ii) Losses of incident photons due to double bremsstrahlung in the radiator, or the failure to reconstruct tracks in the tagging system.

iii) η-meson branching ratio.

The errors shown in Fig. 5 are statistical, and a further overall systematic uncertainty of ±20% is estimated. The slow fall in cross-section with increasing energy is consistent with related processes in which there is an important contribution from diffractive dissociation [2,11].

4. SPIN-PARITY ANALYSIS

A spin-parity analysis of the $\eta\pi\pi$ system was made in two stages:

i) Analysis of the density of events on the $\eta\pi\pi$ Dalitz plot, this being independent of the alignment of the $\eta\pi\pi$ system. This analysis indicated a $J^{\pi} = 1+$ background, together with a peak for which there were three possible J^{π} assignments.

ii) Analysis of the distribution of the direction of the normal to the $\eta\pi\pi$ plane, with respect to the s-channel helicity axis in the $\eta\pi\pi$ c.m. system, which, in principle, provides information about both the J^{π} and the spin alignment. In practice this did not constrain the spin and parity further, and so only provided information about the alignment.

An $\eta\pi\pi$ system from fragmentation of a photon should have $C = -1$ and hence $I = 1$. Therefore the $\pi\pi$ system should have $C = -1$ and $I = 1$, so that there should be a ρ meson final state interaction. The analysis therefore assumed an $\eta\rho$ state for $\eta\pi\pi < 1.5$ GeV. In accord with this assumption no significant peak was seen in the $\eta\pi$ mass spectra. In particular the absence of a peak due to the $\delta(975)$ argues against any significant contribution to the 1.28 GeV peak from either the D(1280) [17] for the reported $\eta(1275)$ [18] as the $\eta\pi\pi$ decay of both these states is reported to be largely through $\delta\pi$. As both these states have $C = +1$, their absence is in accord with the expectation that the $\eta\pi\pi$ state reported here should have $C = -1$, and therefore with the assumption of $\eta\rho$. At and below $\eta\rho^{o}$ threshold, the assumption is only tested by the success of the analysis, but at higher $\eta\pi\pi$ masses the ρ meson peak is visible.

The following values of L and J^{π} were considered (where L is the angular momentum of $\eta\rho$):

L	J^{π}
0(S)	1+
1(P)	0–, 1–, 2–
2(D)	1+, 2+, 3+

For these assignments the $\eta\pi\pi$ Dalitz plot was studied with a Monte Carlo calculation, which included the ρ meson final state interaction as a Watson final state interaction (as described previously [2]), the $\pi\pi$ angular distribution, and the factor p_{η}^{2L} where p_{η} is the η momentum in the $\eta\pi\pi$ c.m. system. The effect of experimental acceptance on the Dalitz plot density was studied and found not to change the shapes of distributions in any significant way.

Separate analyses were made for 100 MeV bins of $\eta\pi\pi$ mass, for two projections of the $\eta\pi\pi$ Dalitz plot:

a) $y = T_{\eta}/T_{\eta max}$, where T_{η} denotes the kinetic energy of the η meson in the $\eta\pi\pi$ c.m. system, and $T_{\eta max}$ denotes the maximum value of T_{η} for the $\eta\pi\pi$ mass of that event.

b) $\cos \theta_{\pi}$, where θ_{π} denotes the angle of the π^{+} meson with respect to the η meson direction in the $\pi\pi$ c.m. system.

The general features of the results, which indicate the area in which detailed analysis should be made, were:

i) For all $\eta\pi\pi$ masses for the range 1.1-1.5 GeV, there is a strong contribution at small y as is shown in Fig. 6, indicating a major contribution with $L = 0$.

ii) $L = 0$ on its own would give an isotropic θ_{π} distribution, but, in the particular mass range $1.2 < M(\eta\pi\pi) < 1.4$ GeV, the θ_{π} distribution was found to be anisotropic: if expressed as $A(1 + B \sin^{2} \theta_{\pi})$, B was positive. An increase of anisotropy with y, such as indicated in Fig. 7, would be expected if there were two contributions, one with $L = 0$ and the other with higher L.

For the θ_π distribution resulting from combining 1 + S with one other J^π with L = 1 or 2, B would be negative for all except 1 + D (interfering with L = 0), or 1 - P, or 2 + D (for these last two there is no interference effect in the Dalitz plot distribution). Fits were therefore made to y and cos θ_π distributions for 100 MeV bins of $\eta\pi\pi$ mass from 1.1 to 1.5 GeV, assuming contributions from 1 + S combined with each one of the above three possibilities in turn (fits assuming three contributions were unstable). On combining 1 + S with 1 + D the interference was taken, at this stage, to be maximal. The results of these fits are shown in Table 1. (The fits were made with the programme MINUIT [19] and the errors presented are those produced by that programme.) In all three cases the 1 + S intensity shows a smooth variation rising slowly with $\eta\pi\pi$ mass, while the other intensity is small for $M(\eta\pi\pi) < 1.2$ GeV and for $M(\eta\pi\pi) > 1.4$ GeV, but is strong for $1.2 < M(\eta\pi\pi) < 1.4$ GeV (for fits with 1 + D the square root of that intensity was calculated for the intereference term, so this intensity was restricted to be ≥ 0). These results therefore indicate a non-resonant background in the 1 + S state, with the peak being in one of the 1 - P, 1 + D or 2 + D states.

More information was obtained by fitting the density of events on the Dalitz plot for $1.2 < M(\eta\pi\pi) < 1.4$ GeV. The data set used for this study consisted of a distribution of events as a function of y and two distributions of events as a function of cos θ_π, separately for $y < 0.4$ and $y > 0.4$. Three separate fits were made to this data set, each assuming two contributions: a 1 + S contribution in each case combined with, respectively, 1 - P, 1 + D or 2 + D contributions. Details of the three fits are presented in Table 2, and the fitted curves are shown in Figs. 6 and 7. The fit shown in the figures which combines 1 + S and 1 + D assumes maximal interference. In an alternative fit, producing almost identical results, this interference term was multiplied by a coherence factor, which was found to be large. These fits confirm the conclusions in Table 1, and show that the 1 + D assignment to the peak is less probable than 1 - P or 2 + D, but is not ruled out.

The distributions of θ_N, the angle between the normal to the $\eta\pi\pi$ plane and the s-channel axis in the $\eta\pi\pi$ c.m. system, were studied, following the procedures of Berman and Jacob [20]. Analysis in 100 MeV bins of mass, assuming 1 + S and + + D, gave values of the spin density matrix element, ρ^{+}_{oo}, which did not vary significantly with $\eta\pi\pi$ mass. The mean result for $1.2 < M(\eta\pi\pi) < 1.4$ GeV is $\rho^{+}_{oo} = 0.24 \pm 0.18$. Assuming 1 + S and + − P and the intensities in Table 1, a fit was made to the Θ_N distributions in 100 MeV bins, assuming that the two spin density matrix elements, ρ^{+}_{oo} and ρ^{-}_{oo}, did not vary with $\eta\pi\pi$ mass. This fit gave

$$p^{+}_{oo} = 0.77 \pm 0.25$$

$$\rho^{-}_{oo} = 0.48 \pm 0.11$$

with $\chi^2/\text{dof} = 3.9/6$. This value of ρ^{-}_{oo} differs significantly from the value of $\rho^{-}_{oo} = 0$ corresponding to s-channel helicity conservation. No results are given for the alignment of the combination 1 + S and 2 + D as three independent spin density matrix elements are involved and there was insufficient experimental information to determine them.

Fits were made to the $\eta\pi\pi$ mass spectrum from 1.1 to 1.5 GeV, assuming a Breit-Wigner formula for the peak and a smoothly varying background. The results were found to be sensitive to assumptions about the background; in particular there was a strong correlation between the general level of the background and the width of the resonance. For each fit the smooth background was therefore constrained to fit one of the 1 + S intensities in Table 1, so assuming that all of the other intensity is due to the peak. Since the peak is at the $\eta\rho^{o}$ threshold, the Breit-Wigner formula was distorted by a correction calculated by integrating over Dalitz plots from the Monte Carlo calculation referred to earlier. The fits and their results are:

Fit I: Took background as for the 1 − P peak and fitted it with a linear function. The fit has $\chi^2/\text{dof} = 8.7/7$. The peak was found at $M = 1.279 \pm$ ± 0.009 MeV, with $\Gamma = 0.087 \pm 0.017$ MeV.

Fit II: Took background as for the 1 + D peak and fitted it with a quadratic function (a fit with a linear function was poor). The fit has $\chi^2/\text{dof} = 8.2/6$. The peak was found at $M = 1.278 \pm 0.009$ GeV, with $\Gamma =$ $= 0.077 \pm 0.018$ GeV.

(The χ^2 quoted includes contributions from fitting the background to the 1+ S intensity.) Since a possible candidate for the $J^\pi = 1+$ peak is a decay mode of the B meson, which has [19] $M = 1.233 \pm 0.010$ GeV, $\Gamma = 0.137 \pm 0.010$ GeV, Fit II was repeated (Fit III) with this mass and width taken as two extra data points. The resulting fit has $\chi^2 =$ $= 17.8/8$, which cannot be ruled out, as it has a probability of 2%.

5. DISCUSSION AND CONCLUSIONS

Of the three possible assignments to the peak, the $J^\pi = 1+$ assignment seems the most reasonable as it can then be ascribed to a new decay mode of the known B meson and so does not require a new state. Although the actual fit for $J^\pi = 1+$ is poorer than for $J^\pi = 1-$ or $2+$, the $J^\pi = 1+$ assignment is not ruled out.

To provide further information the D/S ratio for the possible decay $B \to \eta\rho$ is compared with the ratio (of intensities) of 0.084 found for $B \to \omega\pi$ [18]. Since no 1 + S peak is seen, an experimental estimate of the D/S ratio of $B \to \eta\rho$ would seem to be large. However, there could be an appreciable S-wave decay, since Bowler et al. [21] (see also Pumplin [22]) have shown how the interaction between production of a meson system M by a direct mechanism, with a basic amplitude C, and by a resonance, with a phase shift, δ, can hide the resonance peak. The resulting production of M is described by an amplitude:

$$[C \cos \delta + A \sin \delta] \exp (i\delta)$$

where the first term includes the modification of the direct mechanism by the resonance and the second is due to direct production of the resonance. If this model is applied to the 1 + S state, and $A \simeq$ the value of C at resonance, there would be a variation of cross-section consistent with the observed 1 + S intensity. Further, if C and A were in phase, the 1 + S and 1 + D amplitudes would be in phase, and the maximal interference between these amplitudes would be explained. Thus an upper limit on a resonant 1 + S intensity can be a peak approximately as high as the observed smoothly varying intensity. The resulting estimate for maximum 1 + S resonance intensity gives a limit on the D/S ratio ≥ 2.2 for the possible $B \to \eta\rho$ decay.

As B → $\eta\rho$ is closer to threshold, a smaller D/S ratio would be expected for B → $\eta\rho$ than for B → $\pi\omega$. An estimate (allowing for the effects of the width of the ρ meson) was made by integrating over the calculated Dalitz plots for 1 + S and 1 + D $\eta\rho$ and dividing the ratio of the integrals by corresponding results for $\pi\omega$ to give

$$\left(\frac{D}{S}\right)_{\eta\rho} \Big/ \left(\frac{D}{S}\right)_{\pi\omega} \sim 0.47 \ .$$

Thus, if the reduced widths are the same, a D/S ratio ~ 0.04 would be expected for B → $\eta\rho$. Since the experimental limit, $\gtrsim 2.2$, is so much larger than this estimate, this makes the B-meson interpretation of the peak uncertain.

If nevertheless the peak is taken to be due to the B meson, the cross-section for its production can be compared with that for photoproduction of the $\pi\omega$ decay mode of the B meson [13], to deduce an estimate of a branching ratio:

$$\frac{B \to \eta\rho(\text{D-wave})}{B \to \pi\omega(\text{all})} \simeq 0.07 \ .$$

With the limit on S-wave $\eta\rho$ decay this becomes

$$\frac{B \to \eta\rho(\text{all})}{B \to \pi\omega(\text{all})} \leq 0.10 \ .$$

As the J^{π} = 1+ interpretation of the peak is uncertain, these branching ratios can only be taken as upper limits.

A possible argument against the 1 - P assignment is that it is not produced by an s-channel helicity conserving mechanism, such as is observed for other vector mesons: ρ, ω, ϕ, $\rho'(1600)$ [2,23,24]. However, such a mechanism may only be typical of elastic diffractive dissociation, and might be modified in other cases, as, for example, production of a $^3D_1$ quark-antiquark state by inelastic scattering of a virtual ρ meson.

A J^{π} = 2+ state with I = 1, G = + would be exotic as it can be neither a quark-antiquark state nor a glueball.

We therefore conclude that all three assignments (J^{π} = 1+, 1-, 2+) have to be considered as possible. Although the J^{π} = 1+ assignment has the advantage of not requiring a new meson state, it has been shown that there is uncertainty in the B-meson interpretation.

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REFERENCES

[1] N. Isgur, Proc. 16th Rencontre de Moriond (1981), Vol. II, p. 247.
H. Schnitzer, ibid, p. 293.

[2] D. Aston et al., Nucl. Phys. B189 (1981) 15.

[3] M. Atkinson et al., Phys. Lett. 108B (1982) 55.

[4] M.S. Atiya et al., Phys. Rev. Lett. 43 (1979) 1691.

[5] D. Aston et al., Phys. Lett. 92B (1980) 215.

[6] M. Atkinson et al., Phys. Lett. 127B (1983) 132.

[7] B. Delcourt et al., Phys. Lett. 99B (1981) 257.

[8] F. Mane et al., Phys. Lett. 99B (1981) 261.

[9] F. Mane et al., Phys. Lett. 112B (1982) 178.

[10] A. Cordier et al., Phys. Lett. 106B (1981) 155.

[11] M. Atkinson et al., CERN-EP/83-28, to appear in Nucl. Phys. B (1983).

[12] M. Atkinson et al., CERN-EP/83-80, submitted to Nucl. Phys. B (1983).

[13] M. Atkinson et al., A spin-parity analysis of the $\omega\pi^o$ enhancement photoproduced in the energy range 20 to 70 GeV, to be submitted to Nucl. Phys. B.

[14] V. Sidorov, Proc. 1979 Int. Symp. on Lepton and Photon Interactions at High Energies (Fermilab, 1979), p. 490.

[15] D. Aston et al., Nucl. Phys. B174 (1980) 269.

[16] D. Aston et al., Nucl. Instrum. Methods 197 (1982) 287.

[17] Particle Data Group, Phys. Lett. 111B (1982) 1.

[18] N.R. Stanton et al., Phys. Rev. Lett. 42 (1979) 346.

[19] F. James and M. Roos, CERN Computer Centre Long Write-Up D506, (1979).

[20] S.M. Berman and M. Jacob, Phys. Rev. 139 (1965) 1023.

[21] M.V. Bowler, M.A.V. Game, I.J.R. Aitchison and J.B. Dainton, Nucl. Phys. B97 (1975) 227.

[22] J. Pumplin, Phys. Rev. D 2 (1970) 1859.

[23] T.H. Bauer, R.D. Spital, D.R. Yennie and F.M. Pipkin, Rev. Mod. Phys. 50 (1978) 261.

[24] H.H. Bingham et al., Phys. Lett. 41B (1972) 635.

Table 1

Results of fits to Dalitz plots in 100 MeV bins of mass
(intensities given as numbers of events)

i) $L = 0$, $J^\pi = 1+$, and $L = 1$, $J^\pi = 1-$

Mass (GeV)	1+ intensity	1- intensity	χ^2/dof
1.1-1.2	31.6 ± 10.8	-2.1 ± 10.3	26.5/18
1.2-1.3	44.7 ± 12.5	95.8 ± 14.0	23.9/18
1.3-1.4	38.5 ± 15.6	77.1 ± 15.7	10.1/18
1.4-1.5	82.9 ± 19.6	6.1 ± 19.2	30.0/18

ii) $L = 0$, $J^\pi = 1+$, and $L = 2$, $J^\pi = 1+$

Mass (GeV)	L = 0 intensity	L = 2 intensity	χ^2/dof
1.1-1.2	29.6 ± 6.5	0.0	26.5/18
1.2-1.3	56.6 ± 10.7	83.7 ± 12.3	25.4/18
1.3-1.4	47.2 ± 13.2	67.4 ± 13.6	12.0/18
1.4-1.5	88.3 ± 8.7	0.0	30.1/18

iii) $L = 0$, $J^\pi = 1+$, and $L = 2$, $J^\pi = 2+$

Mass (GeV)	1+ intensity	2+ intensity	χ^2/dof
1.1-1.2	29.1 ± 9.7	0.8 ± 9.0	26.6/18
1.2-1.3	56.6 ± 11.4	83.9 ± 12.4	24.5/18
1.3-1.4	49.6 ± 14.2	65.2 ± 13.9	11.6/18
1.4-1.5	83.4 ± 18.2	6.3 ± 17.3	28.9/18

Table 2

Results of fits to data in Figs. 6 and 7

$L = 0$ $J^{\pi} = 1+$ combined with		Prob. of χ^2	Interference assumed
$L = 1$, $J^{\pi} = 1-$	39.1/28	8%	None
$L = 2$, $J^{\pi} = 1+$	51.1/28	0.5%	Maximal
$L = 2$, $J^{\pi} = 1+$	50.9/27	0.4%	Coherence factor: 0.94 ± 0.17
$L = 2$, $J^{\pi} = 2+$	39.1/28	8%	None

Figure captions

Fig. 1 : $\gamma\gamma$ mass spectrum for total event sample used in present work.

Fig. 2 : Plot of ΔE (missing energy) for events with $1.1 < M(\eta\pi\pi) < 1.5$ GeV.

Fig. 3 : $\eta\pi\pi$ mass spectrum, from reaction $\gamma p \rightarrow \eta\pi\pi p$.

Fig. 4 : t distribution for $1.1 < M(\eta\pi\pi) < 1.5$ GeV.

Fig. 5 : Cross-section for γ reaction $\gamma p \rightarrow \eta\pi\pi p$, with $1.1 < M(\eta\pi\pi\pi) < 1.5$ GeV, as function of incident photon energy.

Fig. 6 : Observed distribution of events as function of $y = T_\eta/T_{max}$ (as defined in text) for $1.2 < M(\eta\pi\pi) < 1.4$ GeV. The curves correspond to fits assuming:

__________ 1 + S combined with 1 - P
- - - - - 1 + S combined with 1 + D
.... 1 + S combined with 2 + D.

Fig. 7 : Observed distribution of events, for $1.2 < M(\eta\pi\pi) < 1.4$ GeV, as function of $\cos\theta_\pi$ for:

a) $y < 0.4$.
b) $y > 0.4$.

The curves correspond to fits assuming:

__________ 1 + S combined with 1 - P
- - - - - 1 + S combined with 1 + D
.... 1 + S combined with 2 + D.

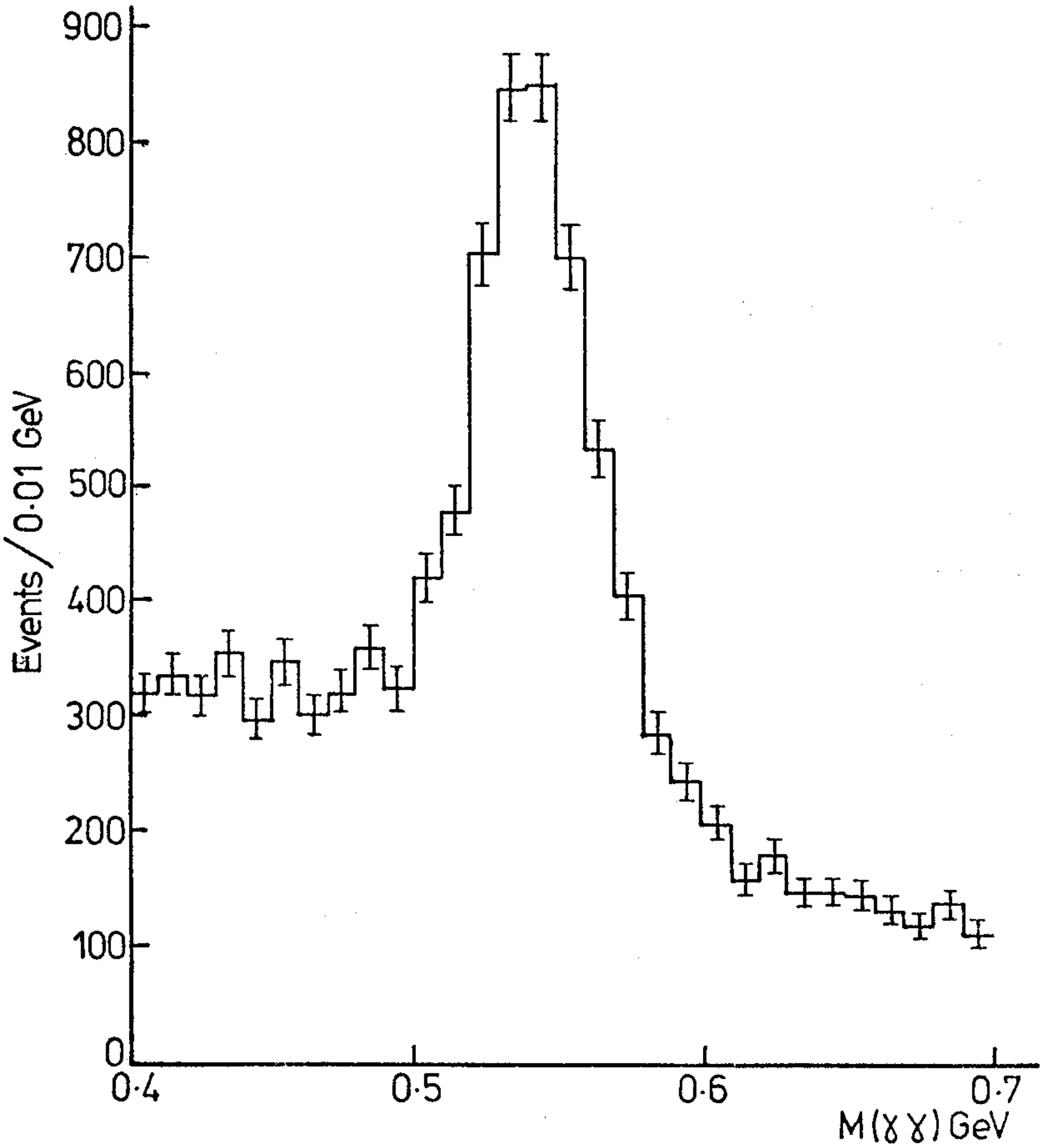
Events / 0·01 GeV
900
800
700
600
500
400
300
200
100
0
0·4
0·5
0·6
0·7
M(γγ) GeV

Fig. 1

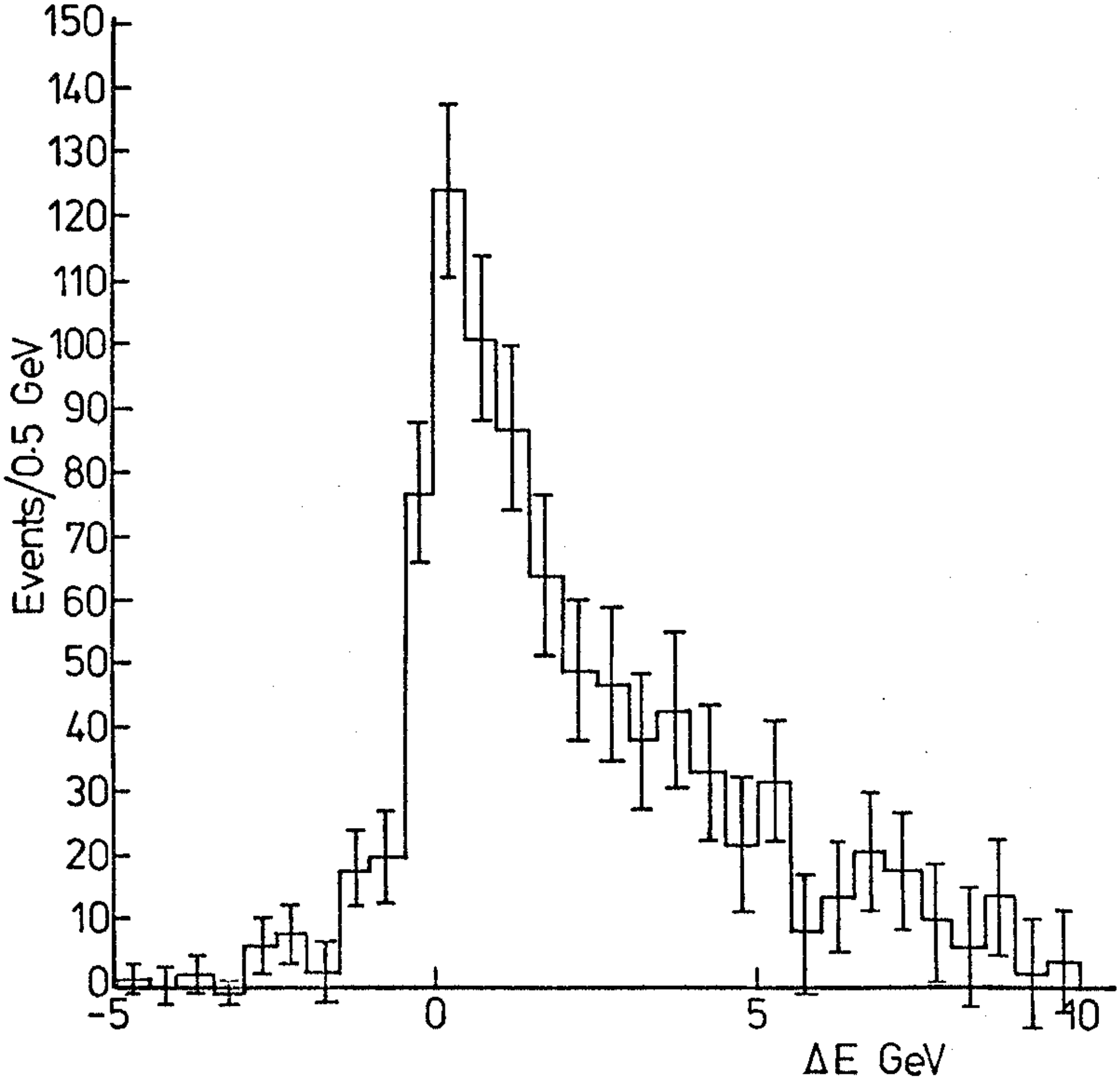
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Events/0.5 GeV
-5
0
5
10
ΔE GeV

Fig. 2

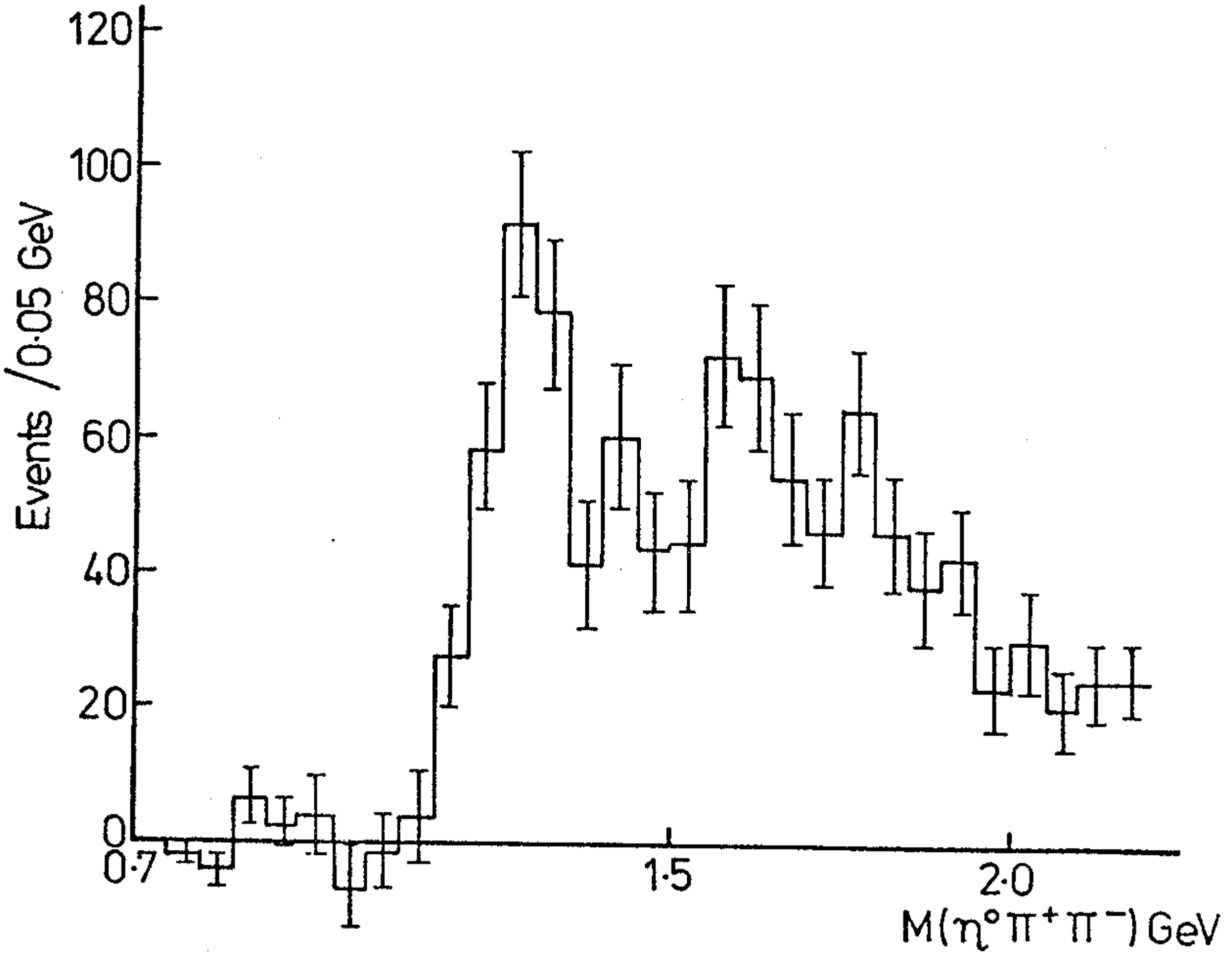

Fig. 3

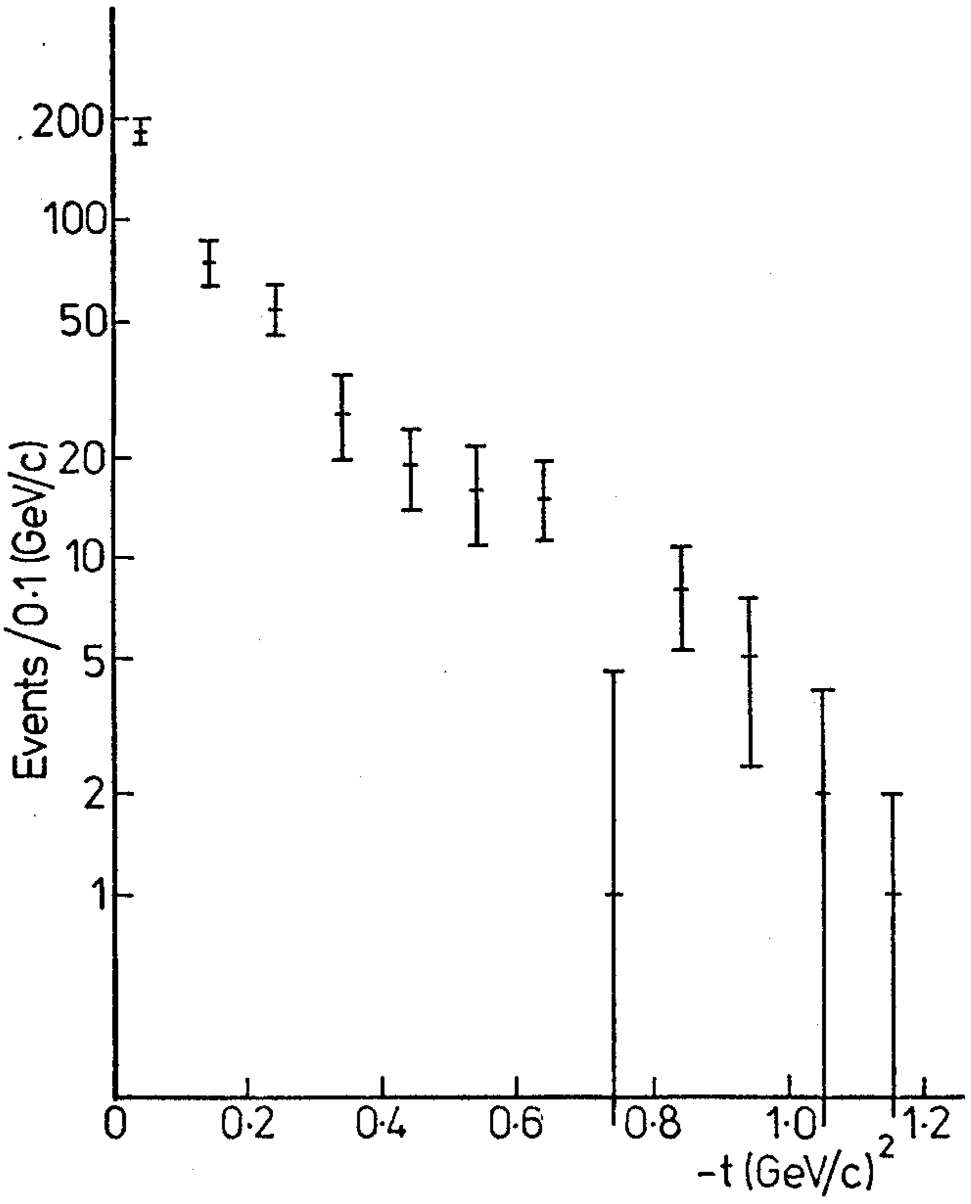

Fig. 4

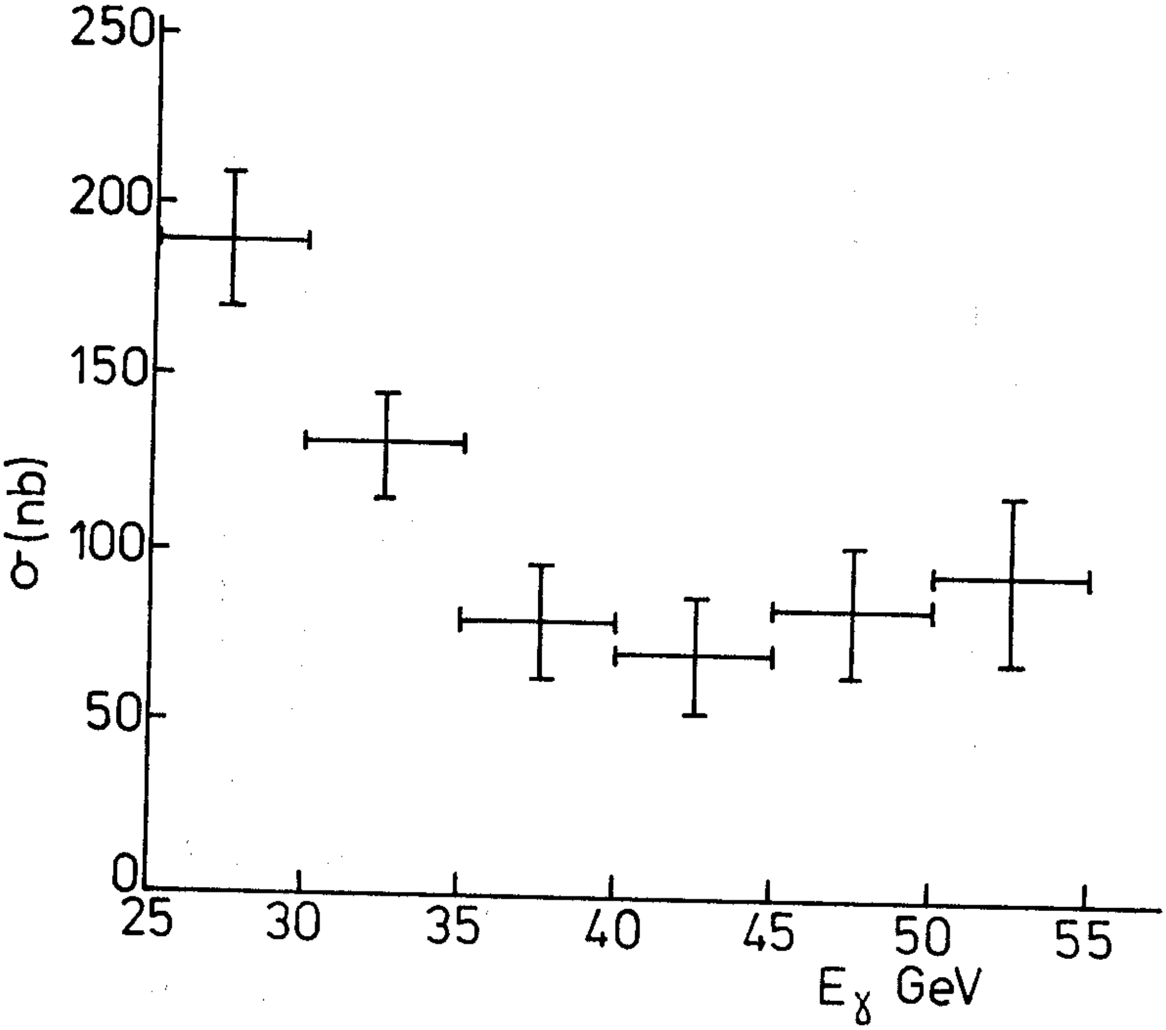

Fig. 5

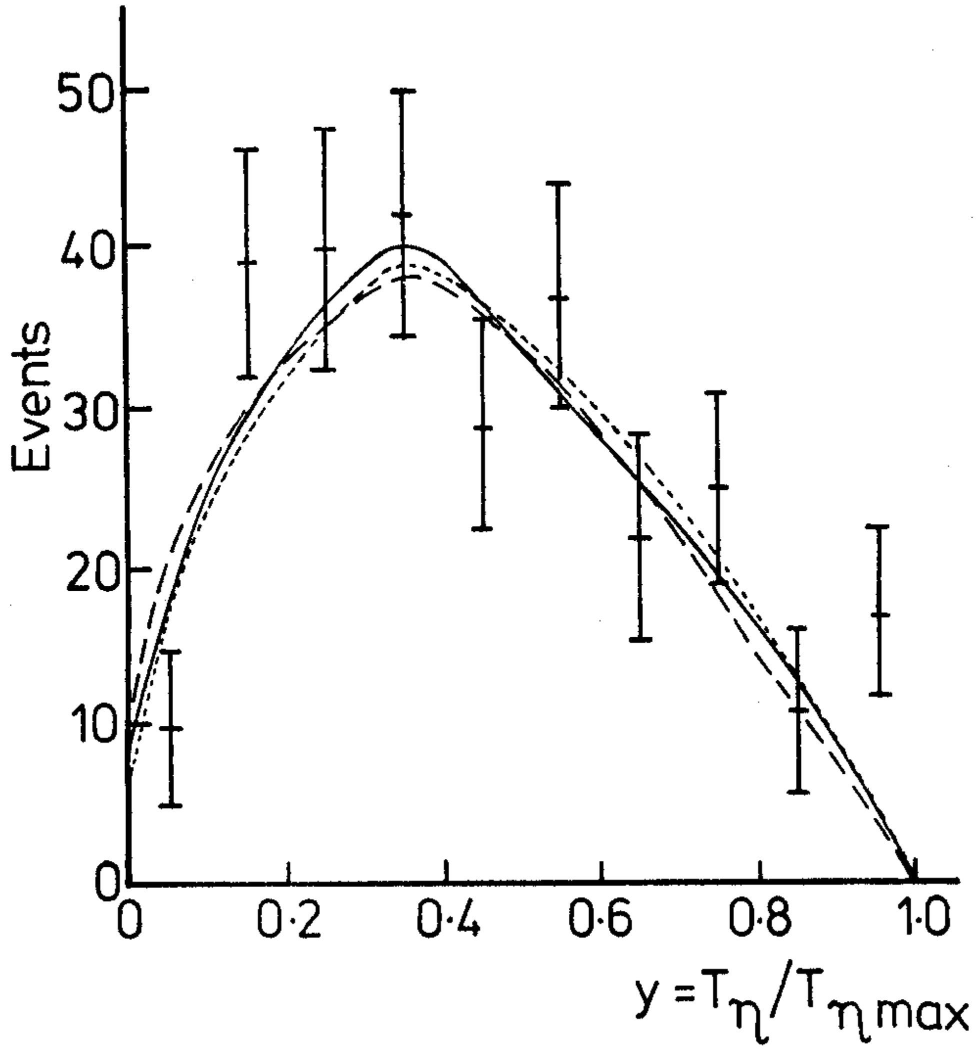

Fig. 6

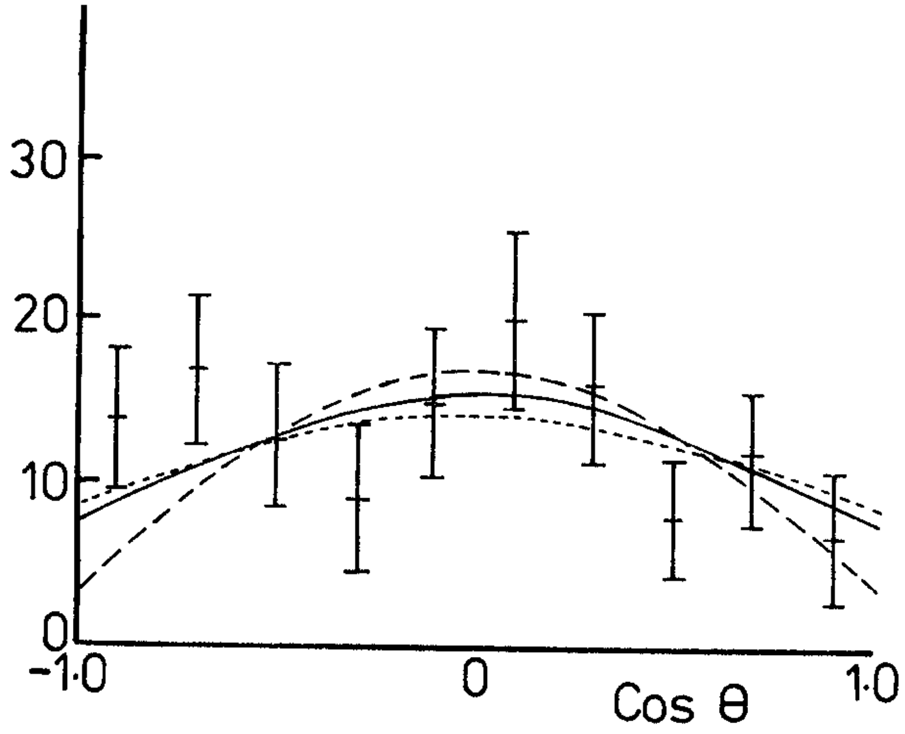

Fig. 7a

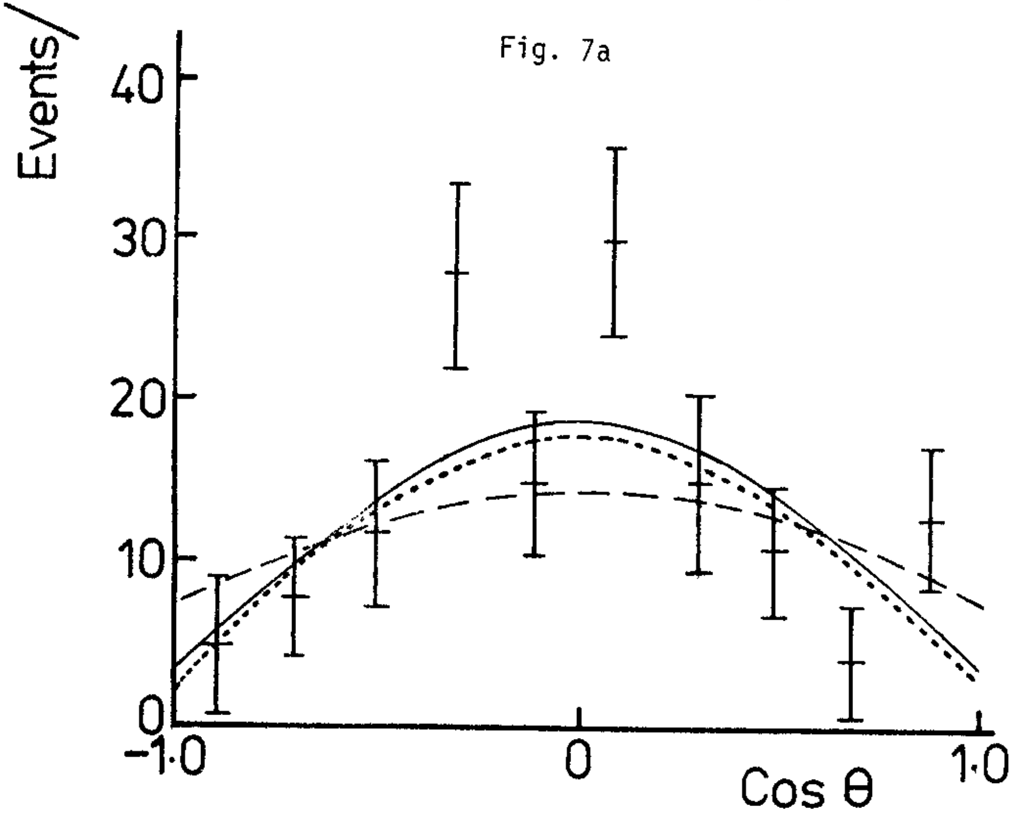

Fig. 7b