EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-EP/88-40
March 23rd, 1988

# PHOTON DIFFRACTIVE DISSOCIATION TO $\rho\rho\pi$ AND $\rho\pi\pi\pi$ STATES

**Omega Photon Collaboration**

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## Abstract

This paper reports studies of the reactions $\gamma p \to \rho\pi\pi\pi p$ and $\gamma p \to \rho\rho\pi p$. In particular a peak is reported in the $\rho\rho\pi$ mass spectrum with closely similar mass and width to those of the $\omega\rho\pi$ peak previously reported in the reaction $\gamma p \to \omega\rho\pi p$. The ratio of production cross sections is found to be $\rho\rho\pi/\omega\rho\pi = 0.96 \pm 0.19$, in serious disagreement with the expectation from Vector Meson Dominance. A possible explanation is indicated.

(Submitted to Zeitschrift für Physik C)

## 1. Introduction

This paper reports studies of the reactions

$$\gamma p \to \rho\pi\pi\pi p \qquad (1)$$

and

$$\gamma p \to \rho\rho\pi p \qquad (2)$$

where in (1) no pair of $\pi's$ is in a second $\rho$-meson state.

In particular a prominent peak is reported in the $\rho\rho\pi$ mass spectrum from (2) at a mass of $2.33 \pm 0.03$ GeV and a width of $0.435 \pm 0.075$ GeV. The charge states in which this $\rho\rho\pi$ state is found to occur point to it having $I = 0$, in accord with expectations from diffractive dissociation of the photon. This complements the observation [1] of a similar peak, of mass $2.28 \pm 0.05$ GeV and width $0.44 \pm 0.11$ GeV, in the mass spectrum of the $I = 1\,\omega\rho\pi$ state from the reaction

$$\gamma p \to \omega\rho\pi p \qquad (3)$$

The measured ratio of production cross sections is found to be $\rho\rho\pi/\omega\rho\pi = 0.96 \pm 0.19$, which is higher than the range $\frac{1}{9} - \frac{1}{3}$ expected for diffractive production, assuming Vector Meson Dominance (VMD). This discrepancy with VMD is similar to that found in the ratio between cross sections for production of $\omega\pi$ and $\rho\pi$ states, with $J^\pi = 1-$ and masses in the region 1.2-2 GeV, in the reactions

$$\gamma p \to \omega\pi p \qquad (4)$$

(see [2]) and

$$\gamma p \to \rho\pi p \qquad (5)$$

(see [3]). The $\omega\pi$ mass spectrum from (4) has been shown[4] to have an intensity compatible with expectation from the tail of the $\rho$-meson. One then expects the intensity of $\rho\pi$ from reaction (5), on taking the different charge states into account, to have an intensity lower by a factor of $\frac{1}{3}$, while the experimental results are higher than this expectation by a factor of ~3. A model where diffractive photoproduction of $I = 0$ states can be enhanced, which could explain these observations, has been proposed[5].

## 2. Outline of Experimental details

The data sample used in the present work came from the WA57 experiment at the CERN Omega Spectrometer. The data for the reaction

$$\gamma p \to \pi^+\pi^-\pi^+\pi^-\pi^0 p \qquad (6)$$

were selected by the same procedure as used [6] in a study of dissociation of the photon to $\omega\pi\pi$ states.

The events were produced by interaction of 25-50 GeV tagged photons in a 60cm liquid hydrogen target. The experimental trigger required between 2 and 5 charged particles to be detected in a forward MWPC, together with a least one gamma-ray with energy > 2 GeV, detected in a large photon detector. Events were then selected for the present work by requiring 4 or 5 charged particles, consistent with either $\pi^+\pi^-\pi^+\pi^-$ or $\pi^+\pi^-\pi^+\pi^-p$, to be detected in the Omega Spectrometer, together with two gamma-rays consistent with decay of a $\pi^0$ meson. Reaction (6) was then selected by requiring any missing energy, carried by unobserved particles or by the proton when detected, to be within the range $-1.5$ to 1.0 GeV.

The experimental acceptance, for which a major contribution was due to the aperture of the photon detector, was deduced from a full simulation of both apparatus and software. No correction for acceptance is made to the histograms in Figs. 1, 3, 4, 5 as their shapes would not be changed significantly. The calculated acceptance is used to deduce the magnitudes of the cross sections for (1) and (2). The cross sections reported in this paper are presented with statistical uncertainties only; there is a further overall systematic uncertainty of 20%.

The events selected for (6) contain a major contribution from the reaction

$$\gamma p \rightarrow \omega\pi\pi p \tag{7}$$

which has a similar cross section to those found for (1) and (2), but no cut was applied to remove events due to (7). As the $\pi\pi$ pair from (7) showed no evidence for any $\rho$-meson contribution the events from (7) contribute only to the combinational backgrounds under $\rho$-meson peaks, and so worsen the statistical accuracy with which the intensities of $\rho$-mesons are determined. This loss in accuracy is more than compensated by the avoiding of the systematic distortions that would be caused in $\rho\pi\pi\pi$ and $\rho\rho\pi$ mass spectra and by the simplification of the Monte Carlo calculation of acceptances.

## 3. Data analysis

This section describes the analysis of events from (6) to deduce, from the $5\pi$ data, $\rho\pi\pi\pi$ mass spectra corresponding to (1) and $\rho\rho\pi$ mass spectra corresponding to (2).

Firstly $\pi^{\pm}\pi^{o}$ and $\pi^{+}\pi^{-}$ mass spectra (each with 4 entries/event) were studied for ranges of $5\pi$ mass. The quality of the data and of the procedure for its analysis are illustrated in Fig. 1, where Figs. 1(a-c) show $\pi^{\pm}\pi^{0}$ mass spectra and Figs. 1(d-f) show $\pi^{+}\pi^{-}$ mass spectra, in both cases for 0.4 GeV ranges of $5\pi$ mass from 1.8 to 3.0 GeV. On all these mass spectra $\rho$-meson peaks are evident. Quantitative estimates of $\rho^{\pm}$ and $\rho^{0}$ intensities were then made by fitting such $\pi\pi$ mass spectra, over suitable ranges of $\pi\pi$ mass, with a Breit Wigner peak plus a cubic polynomial background. Good fits were obtained with a mass of the $\rho$-meson of 0.764 GeV and a width of 0.140 GeV (in reasonable accord with published values [7]), so these parameters were fixed at these values in the fits used to determine $\rho$-meson intensities. Results of such fits made to the mass spectra for 0.4 GeV bins of $5\pi$ mass are presented in Fig. 1; the range fitted is indicated by the fits shown. To obtain more detailed information, $\rho$-meson intensities were then determined from fits to $\pi\pi$ mass spectra for 0.2 GeV bins of $5\pi$ mass from 1.6 to 3.0 GeV. Using the calculated acceptances, these $\rho$-meson intensities were converted to cross sections which are presented in Fig. 2. It should be noted that $\rho^{\pm}\rho^{o}\pi^{\mp}$ states would contribute to both of Figs. 2a and 2b while $\rho^{o}\rho^{o}\pi^{o}$ states would contribute twice to Fig. 2b.

The possibility of there being two $\rho$-mesons in the same event was then explored by selecting events in the $\rho$ peak region of a $\pi\pi$ mass spectrum and then looking at the mass spectra of coincident $\pi\pi$ pairs from the same event. The $\pi\pi$ mass spectrum coincident with the background under the $\rho$-meson peak was estimated from side-band regions in the first $\pi\pi$ mass spectrum and subtracted. In detail the $\rho$ peak region in the first $\pi\pi$ mass spectrum was taken to be the range 0.6 - 0.9 GeV, and the side-band regions were taken to be the ranges 0.45 - 0.6 GeV and 0.9 - 1.05 GeV. The resulting mass spectrum of the second, coincident, $\pi\pi$ pair should have three components:

(i) a peak due to any second $\rho$-meson in coincidence with the $\rho$-meson in the first $\pi\pi$ mass spectrum.

(ii) a more continuous distribution due to any non-resonant $\pi\pi$ pairs in coincidence with the $\rho$-meson in the first $\pi\pi$ mass spectrum.

(iii) a smooth background around zero, which background can be either positive or negative depending on whether the background under the $\rho$-meson peak in the first $\pi\pi$ mass spectrum is concave or convex upwards.

This procedure has been applied for three charge combinations:

| 1st pair | 2nd pair | possible entries/event |
|---|---|---|
| $\rho^{\pm}$ | $\pi^{+}\pi^{-}$ | 8 |
| $\rho^{0}$ | $\pi^{\pm}\pi^{0}$ | 8 |
| $\rho^{0}$ | $\pi^{+}\pi^{-}$ | 4 |

As an illustration of this analysis procedure, mass spectra of $\pi\pi$ combinations deduced as being in coincidence with $\rho$-mesons are shown in Figs. 3-5, for the three charge combinations for 0.4 GeV ranges of $5\pi$ mass. Inspection of Fig. 5 shows that there is no significant indication of any $\rho^0\rho^0$ coincidences, while Figs. 3-4 show evidence of relatively strong yields of $\rho^{\pm}\rho^0$ coincidences, particularly for $2.2 < M(5\pi) < 2.6 GeV$. Quantitative estimates of numbers of $\rho\rho$ coincidences were made by fitting such coincident mass spectra with a Breit Wigner peak, with the same parameters as above, and a cubic polynomial background. Such fits were made to the mass spectra in Figs. 3-5 and the results are presented. To provide more detailed information such fits were then made to coincident mass spectra for bins of 0.2 GeV in $5\pi$ mass. Using the calculated acceptances, the resulting $\rho\rho$ intensities were converted to cross sections which are shown in Fig. 6. Fig. 6a shows the two separate estimates of the intensity of $\rho^{\pm}\rho^0$ coincidences which are in good agreement, while Fig. 6b confirms the absence of any comparable intensity of $\rho^0\rho^0$ coincidences.

The mean of the two estimates of the $\rho^{\pm}\rho^{o}\pi^{\mp}$ mass spectrum from Fig. 6a was then subtracted from the mass spectra in Fig. 2, to yield estimates of photoproduction of $\rho^{\pm}\pi^{\mp}\pi^{+}\pi^{-}$ and $\rho^{o}\pi^{+}\pi^{-}\pi^{o}$ states (where now these states involve only a single $\rho$-meson) which are shown in Fig. 7. (In Fig. 7 the bin size has been increased, to compensate for the worsening of the statistical errors).

## 4. Comparison of $\rho\rho\pi$ and $\omega\rho\pi$ peaks

The peak in the $\rho\rho\pi$ mass spectrum in Fig.6a has a similar mass and width to the peak reported earlier [1] in the photoproduced $\omega\rho\pi$ state. To make this comparison quantitative the peak in Fig. 6a was fitted with a Breit-Wigner formula (with $\chi^2/dof = 2.5/3$), finding a mass of $2.33 \pm 0.03$ GeV and a width of $0.435 \pm 0.075$ GeV to be compared with the mass of $2.28 \pm 0.05$ GeV and width of $0.44 \pm 0.11$ GeV found for the $\omega\rho\pi$ peak. Attempts were made to improve the fit to the $\rho\rho\pi$ peak by including a flat background, but this fit found a small negative background and so was discarded.

For the $\omega\rho\pi$ peak, the charge states found for the $\rho\pi$ system indicate it has $I = 1$, so that this $\omega\rho\pi$ state has $I = 1,\ C = -1$, which is consistent with appreciable production by diffractive dissociation of the photon. The observation, reported in the present paper, of a similar peak in the $\rho^{\pm}\rho^0\pi^{\mp}$ state, with the absence of corresponding production of $\rho^0\rho^0\pi^0$ state, can then be explained as production of the related $I = 0, C = -1$ state. (In passing it should be noted that this $I = 0$ assignment means that it is unlikely that the peak reported here can be related to the $\rho^0\rho^0\pi^+$ peak, reported by Baltay et al[8] with a mass of $2.34 \pm 0.02$ GeV and a width of $0.18 \pm 0.06$ GeV, as that peak must be due to a state with $I \geq 1$). It has been shown, in the general classification of multipion isotopic spin wave-functions of Pais[9], that there is only one $5\pi$ isotopic spin state with $I = 0$, corresponding to the class [311] and which has the ratio of charge states $(\pi^+\pi^-\pi^0\pi^0\pi^0)/(\pi^+\pi^-\pi^+\pi^-\pi^0) = 1/2$. For the particular case of $\rho\rho\pi$ this ratio results from the three charge states $\rho^+\rho^-\pi^0, \rho^+\rho^0\pi^-$ and $\rho^-\rho^0\pi^+$ having equal intensities. For the $\omega\rho\pi$ state the $\rho\pi$ combination has $I = 1$, so, as it includes a $\rho$-meson, this $3\pi$ state must be in the class [21] and so be entirely in the charge state $\pi^+\pi^-\pi^0$. Hence the $\omega\rho\pi$ state should occur only in the observed $\omega\rho^{\pm}\pi^{\mp}$ states.

The ratio of the measured cross sections (for $\rho^{\pm}\rho^0\pi^{\mp}/\omega\rho\pi$), summed over the mass range $1.8 < M < 3.0$ GeV, is $0.64 \pm 0.13$ (As the results are from the same experiment, some of the systematic errors, on the overall normalisation, do not contribute). A comparison between the measured $\omega\rho\pi$ cross section [1] and the $\rho^{\pm}\rho^0\pi^{\mp}$ cross section, renormalised by a factor of 1/0.64, is shown as Fig. 8 (the $\chi^2$ of the difference between the two sets of data in Fig. 8 is 6.7 for 5 dof). Multiplying the ratio by 1.5, to correct for the unobserved $\rho^+\rho^-\pi^0$ state one finds $\sigma(\rho\rho\pi)/\sigma(\omega\rho\pi) = 0.96 \pm 0.19$. The cross section for producing either the $\omega\rho\pi$ or $\rho\rho\pi$ peak is $\sim 130$ nbarn.

It has been shown [1] how the $\rho\pi$ state produced as part of the $\omega\rho\pi$ system has the same quantum numbers as the $a_1(1270)$ meson, so that an appreciable contribution from this meson should be expected. Various results were found[1] to be in accord with this expectation if the $a_1$ had suitably high mass and width. Particularly the initial rise in cross section for production of the $\omega\rho\pi$ system can be understood as being due to the threshold production of an $\omega a_1$ system. This conclusion depends on assuming a relatively high mass for the $a_1(1270)$, such as is indicated from its production in $\pi p$ collisions, but is not in accord with lower masses reported more recently from observations of $\tau$-lepton decay (see Bowler [10] for summary and analysis). However the differences between these masses have been shown [10] to be due to assumptions made about the threshold behaviours of $a_1$ production. Arguments have been presented for a threshold behaviour which results in an appreciably higher mass for the $a_1$-meson from $\tau$ decay, so the possibility of the initial rise in the $\omega\rho\pi$ mass spectrum being due to the $\omega a_1$ threshold persists. Similarly one can argue that the $\rho\rho\pi$ peak reported here would be due to production of a $\rho a_1$ system, with the similar initial rise in the $\rho\rho\pi$ mass spectrum being due to the $\rho a_1$ threshold.

This recognition of the possible effects of $\omega a_1$ and $\rho a_1$ thresholds raises the possibility that the $\omega\rho\pi$ and $\rho\rho\pi$ peaks can be due to non-resonant threshold effects, from mechanisms such as those of Drell and Hiida[11] and Deck[12]. In the Appendix limits on the intensities of such non-resonant threshold effects in other states are presented for comparison with this possibility. In particular it is shown in the Appendix, that such a $\pi a_1$ threshold peak, which would be at a lower mass than the $\omega a_1$ and $\rho a_1$ peaks, must be produced with a cross section which is less than or approximately equal to those found for production of the $\omega a_1$ and $\rho a_1$ peaks. As the $\rho\pi a_1$ coupling is indicated, by the big $a_1$ width, to be large, the non-resonant threshold peak interpretations of production of the $\omega a_1$ peak would indicate a $\rho\omega a_1$ coupling which is at least as strong. Alternatively we have to consider the possibility of the peaks being due to resonances. Then the observed cross section for production of the $I = 1$ $\omega\rho\pi$ state is about $\frac{1}{5}$ of that for production of either of the two $I = 1$ $\rho'$ states at masses of about 1.47 and 1.70 GeV[4].

From VMD one can deduce, for the non-resonant threshold interpretation and assuming that the ratio of $\phi\rho a_1$ coupling to $\omega\rho a_1$ coupling is $k$, that the expected ratio of $\rho a_1/\omega a_1$ should be $\frac{1}{3}(1+k)$, and that the ratio of production of $\phi a_1/\rho a_1$ should be $k$. Goodman et al.[13] have reported a cross section for production of all $\phi\pi^+\pi^-\pi^0$ states of $1.6\pm1.1$ nbarn. This provides a limit on $\phi a_1$ production which indicates $k$ must be very small, in accord with expectation from the quark content of $\rho, \omega$ and $a_1$. For the resonant interpretation, and similarly disregarding contributions from hidden strangeness, one deduces a production ratio $\rho a_1/\omega a_1 = 1/9$, on taking the observed peaks to show the only decay modes of the resonances. To make any major change in this ratio one would need there to be some other strong decay mode of the $I = 1$ state so that the total cross section for production of this state would be much larger.

It therefore seems that the large observed ratio of $\rho a_1$ production to $\omega a_1$ production signals a major discrepancy with VMD. A possible interpretation is that there is some further mode of production of $I = 0$ states, in addition to that from VMD. Donnachie and Webb[5] have suggested how, in the corresponding problem of the $\rho\pi/\omega\pi$ production ratio, an additional production of the $I = 0$ state could result from the gluon content of the Pomeron. If this model were also the explanation of the ratio reported here, it would indicate either in the nonresonant threshold peak interpretation a strong gluon coupling to the $I = 0$ $\rho a_1$ system, or in the resonant interpretation a strong gluon coupling to the $I = 0$ resonance.

## Appendix

This appendix uses the basic features of the Drell-Hiida-Deck mechanism [11,12] for production of non-resonant threshold peaks to deduce estimates of ratios of such cross sections. The assumptions made are simple and should be successful for cases where similar masses and the same angular momenta are involved. The model is applied here to production of $b_1\pi_1, a_1\pi$ and $h_1\pi$ states, where these conditions are satisfied. One can then combine these ratios with an experimental limit for such production of a $b_1\pi$ system to deduce limits on productions of non-resonant threshold peaks in $a_1\pi$ and $h_1\pi$ systems.

This model assumes there are three factors:

(i) the coupling of the photon to the initial vector meson, $V$, which coupling is $\sim 1$ if $V = \rho$ and $\sim \frac{1}{9}$ if $V = \omega$.

(ii) the coupling of $V$ to $X\pi$, which is taken to be proportional to the width for $X \rightarrow V\pi$

(iii) the subsequent scattering, which is complicated, but is taken to be the same where similar masses and the same angular momentum are involved, so that this factor cancels in ratios.

Then the only remaining problem is to take all relevant charge states into account in each case. One then predicts ratios of photoproduction of non-resonant threshold peaks:

$$a_1\pi/b_1\pi : 8.0$$

(taking 400 MeV for the $a_1$ width, from Bowler[10])

$$h_1\pi/b_1\pi : 6.4$$

There is a peak observed[14] in photoproduction of $b_1\pi$ near threshold in the mass spectrum with a cross section of 30 nb, summed over all charge states. However a major contribution to this peak from a resonant state has been identified, so that one judges that the contribution of any non-resonant threshold effect is $\leq 15$ nb. From this limit one estimates upper limits for related non-resonant threshold effects:

$$a_1\pi \leq 120nb$$
$$h_1\pi \leq 96nb$$

These latter threshold effects would contribute to photoproduction of $\pi^+\pi^-\pi^+\pi^-$ and $\pi^+\pi^-\pi^0\pi^0$ states, where production is observed of peaks with cross sections $\sim$ 600 nb in each charge state, which peaks are identified with two $\rho'$ resonances (see Donnachie and Mirzaie[4] for summary and references). The present demonstration of the relative unimportance of these non-resonant threshold peaks supports that identification.

## Acknowledgments

We are grateful to the Omega group at CERN for their help in running the spectrometer and providing on-line and off-line software. The work of the technical support staff in our home institutions and the support at the computer centres at the Rutherford Appleton Laboratory, CERN, and the RHRZ at Bonn have been invaluable. We thank the SERC (UK), the BMFT (Fed. Rep. Germany): Foerderkennzeichen 054bn4p/0, and the IN2P3 (France) for financial support.

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**Figure Captions**

1. (a) $\pi^{\pm}\pi^{0}$ mass spectrum for $1.8 < M(5\pi) < 2.2$ GeV

   (b) $\pi^{\pm}\pi^{0}$ mass spectrum for $2.2 < M(5\pi) < 2.6$ GeV

   (c) $\pi^{\pm}\pi^{0}$ mass spectrum for $2.6 < M(5\pi) < 3.0$ GeV

   (d) $\pi^{+}\pi^{-}$ mass spectrum for $1.8 < M(5\pi) < 2.2$ GeV

   (e) $\pi^{+}\pi^{-}$ mass spectrum for $2.2 < M(5\pi) < 2.6$ GeV

   (f) $\pi^{+}\pi^{-}$ mass spectrum for $2.6 < M(5\pi) < 3.0$ GeV

   The full lines are the results of fits with a Breit-Wigner peak plus polynomial background, while the dashed lines show the polynomial background.

2. (a) $\rho^{\pm}\pi^{\mp}\pi^{+}\pi^{-}$ mass spectrum

   (b) $\rho^{0}\pi^{+}\pi^{-}\pi^{0}$ mass spectrum

   In these mass spectra events with a second $\rho$-meson are not excluded.

3. $\pi^{+}\pi^{-}$ mass spectra in coincidence with $\rho^{\pm}$ mesons for $5\pi$ mass ranges:

   (a) $1.8 < M(5\pi) < 2.2$ GeV

   (b) $2.2 < M(5\pi) < 2.6$ GeV

   (c) $2.6 < M(5\pi) < 3.0$ GeV

   The full lines are the results of fits with a Breit-Wigner peak plus polynomial background, while the dashed lines show the polynomial background.

4. $\pi^{\pm}\pi^{0}$ mass spectra in coincidence with $\rho^{0}$ mesons for $5\pi$ mass ranges:

   (a) $1.8 < M(5\pi) < 2.2$ GeV

   (b) $2.2 < M(5\pi) < 2.6$ GeV

   (c) $2.6 < M(5\pi) < 3.0$ GeV

   The full lines are the results of fits with a Breit-Wigner peak plus polynomial background, while the dashed lines show the polynomial background.

5. $\pi^{+}\pi^{-}$ mass spectra in coincidence with $\rho^{0}$ mesons for $5\pi$ mass ranges:

   (a) $1.8 < M(5\pi) < 2.2$ GeV

   (b) $2.2 < M(5\pi) < 2.6$ GeV

   (c) $2.6 < M(5\pi) < 3.0$ GeV

   The full lines are the results of fits with a Breit-Wigner peak plus polynomial background, while the dashed lines show the polynomial background.

6. $\rho\rho\pi$ mass spectra as function of $5\pi$ mass

   (a) $\rho^{\pm}\rho^{0}\pi^{\mp}$: full lines show results from seeking $\rho^{\pm}$ in $\pi^{\pm}\pi^{0}$ mass spectra in coincidence with $\rho^{0}$, and dashed lines show results from inverse procedure.

(b) $\rho^0\rho^0\pi^0$ mass spectrum.

7. $\rho\pi\pi\pi$ mass spectra, where events with two $\rho$-mesons have been excluded, as function of $5\pi$ mass:

   (a) $\rho^\pm\pi^\mp\pi^+\pi^-$

   (b) $\rho^0\pi^+\pi^-\pi^0$

8. Comparison of photoproduced $\omega\rho\pi$ mass spectra, with photoproduced $\rho\rho\pi$ cross section with latter renormalised by a factor of $1/0.64$.

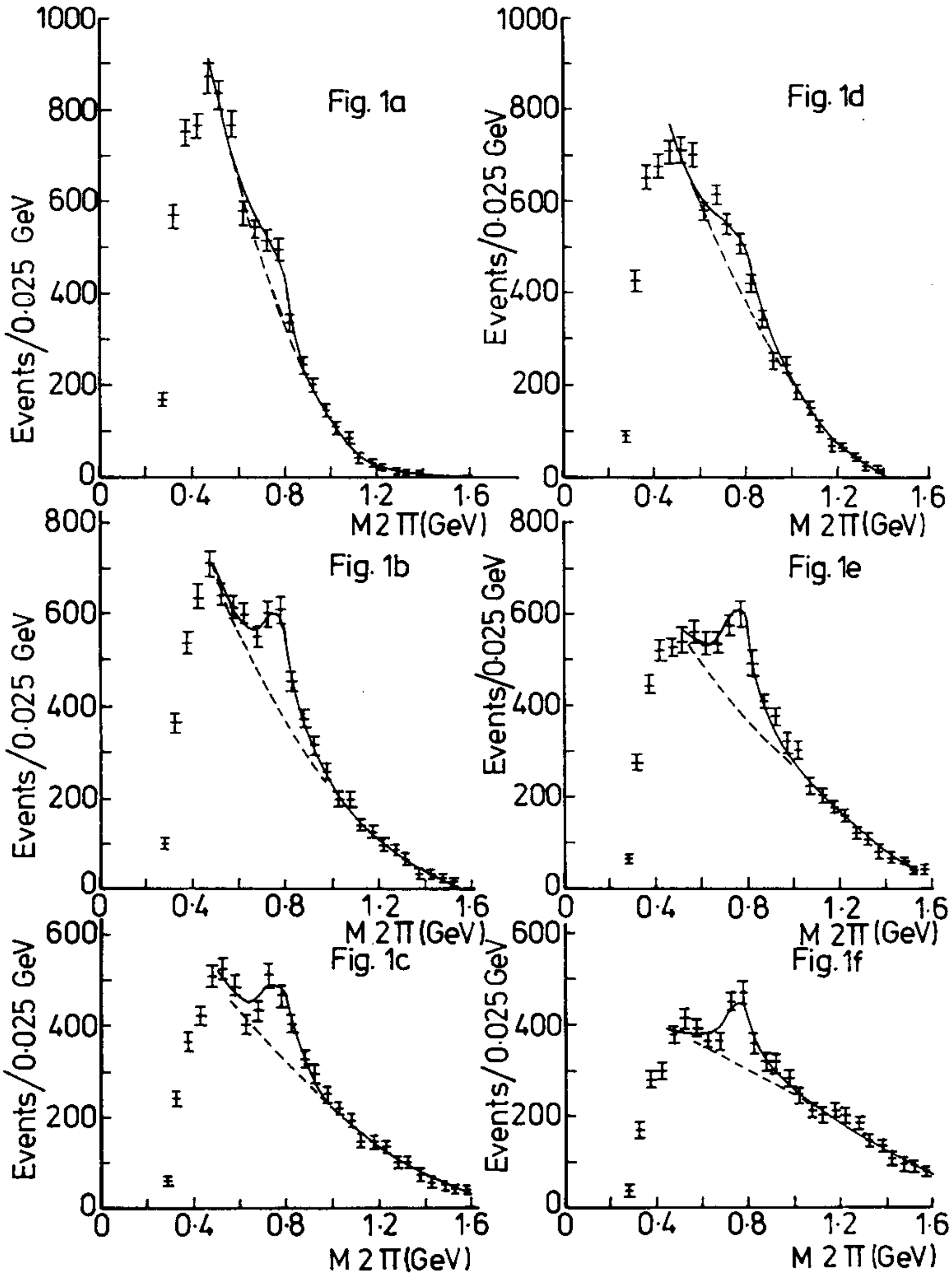


Fig. 1a
Fig. 1b
Fig. 1c
Fig. 1d
Fig. 1e
Fig. 1f
Events/0·025 GeV
M 2 π (GeV)
0
0·4
0·8
1·2
1·6
200
400
600
800
1000

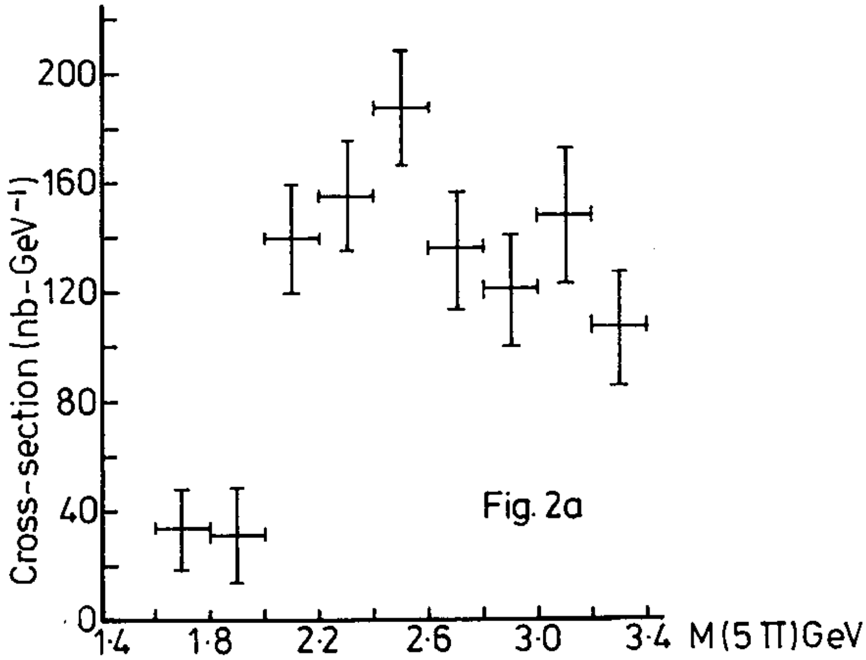

Cross-section (nb-GeV-1)
0
40
80
120
160
200
1·4
1·8
2·2
2·6
3·0
3·4
M(5π)GeV

Fig. 2a

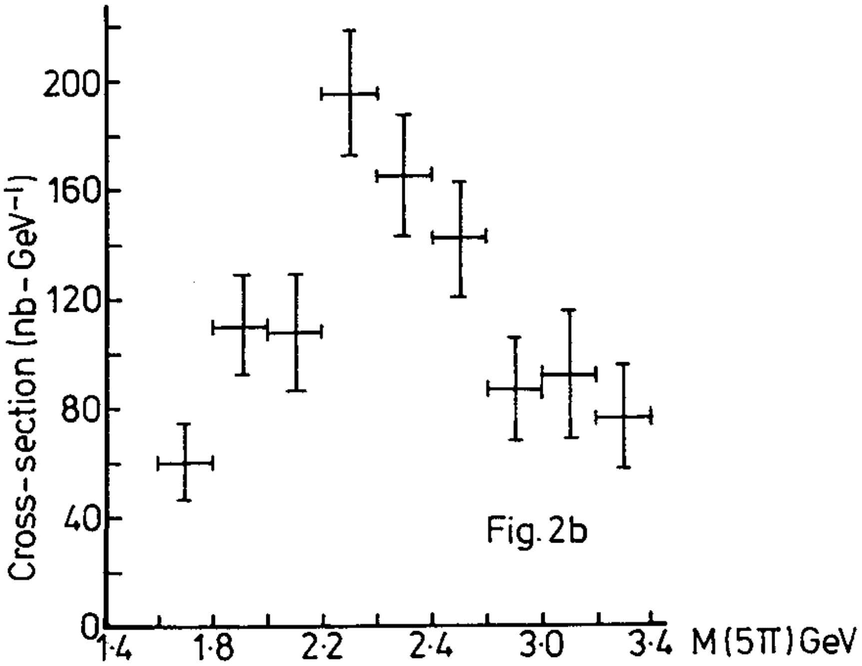

Cross-section (nb-GeV-1)
0
40
80
120
160
200
1·4
1·8
2·2
2·4
3·0
3·4
M(5π)GeV

Fig. 2b

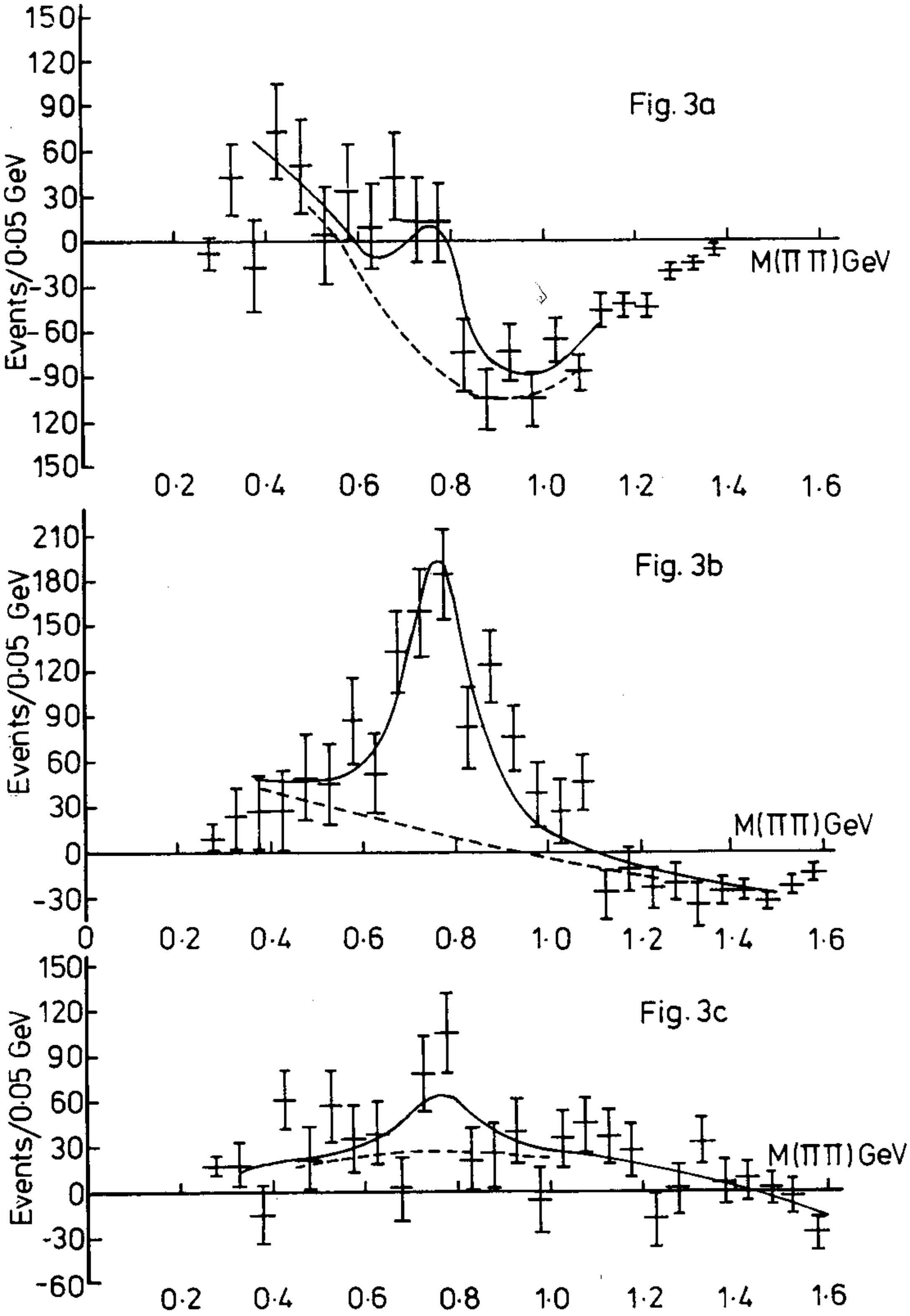


Fig. 3a
Fig. 3b
Fig. 3c
Events/0·05 GeV
M(ππ) GeV
150
120
90
60
30
0
-30
-60
-90
120
150
210
180
-60
0
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6

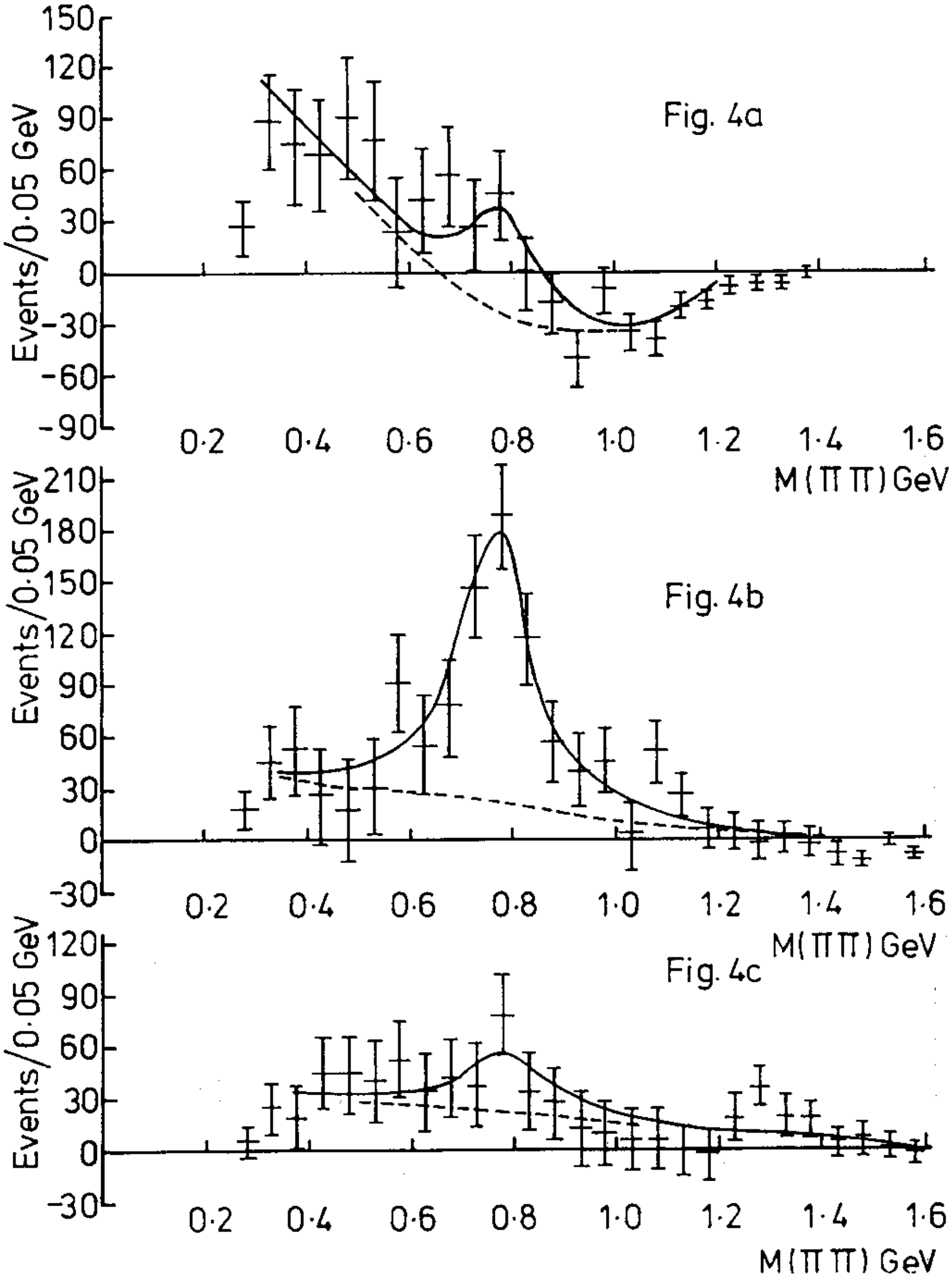
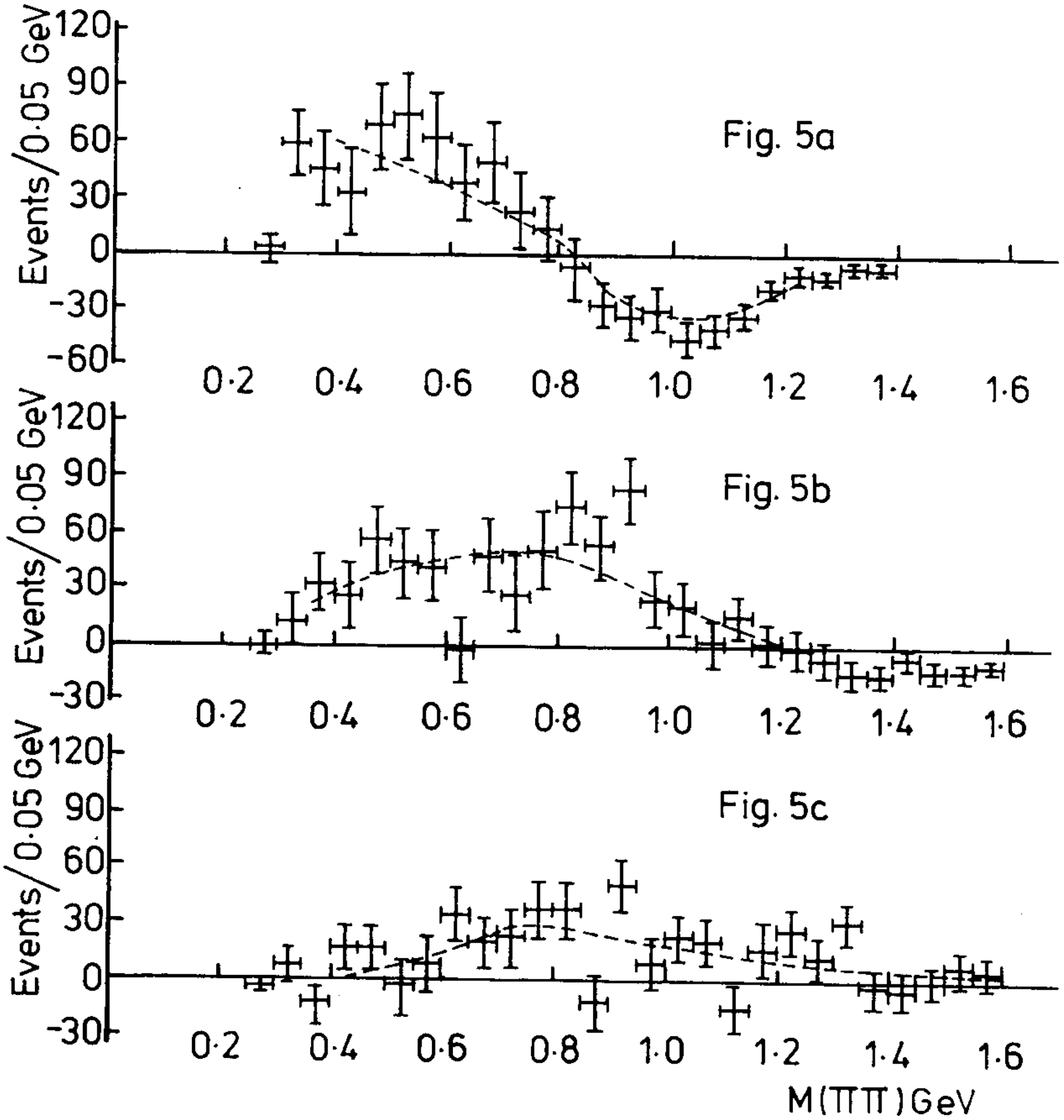


Fig. 4a
Events/0·05 GeV
150
120
90
60
30
0
-30
-60
-90
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6
M(ππ) GeV
Fig. 4b
Events/0·05 GeV
210
180
150
120
90
60
30
0
-30
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6
M(ππ) GeV
Fig. 4c
Events/0·05 GeV
120
90
60
30
0
-30
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6
M(ππ) GeV



Events/0·05 GeV
120
90
60
30
0
-30
-60
Fig. 5a
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6
Events/0·05 GeV
120
90
60
30
0
-30
Fig. 5b
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6
Events/0·05 GeV
120
90
60
30
0
-30
Fig. 5c
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6
M(ππ) GeV

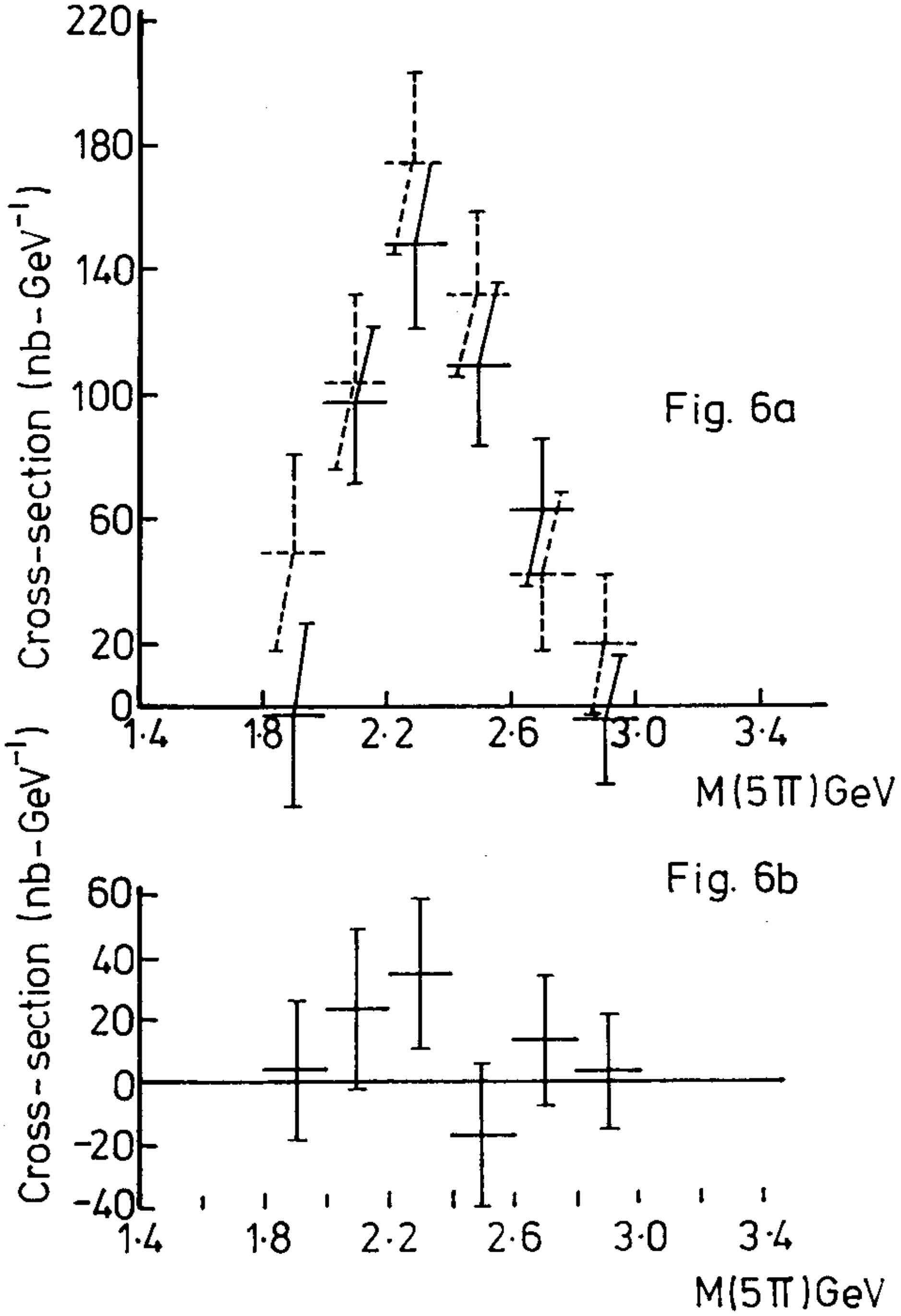


Fig. 6a
Cross-section (nb-GeV$^{-1}$)
220
180
140
100
60
20
0
1·4
1·8
2·2
2·6
3·0
3·4
M(5π)GeV
Fig. 6b
Cross-section (nb-GeV$^{-1}$)
60
40
20
0
-20
-40
1·4
1·8
2·2
2·6
3·0
3·4
M(5π)GeV

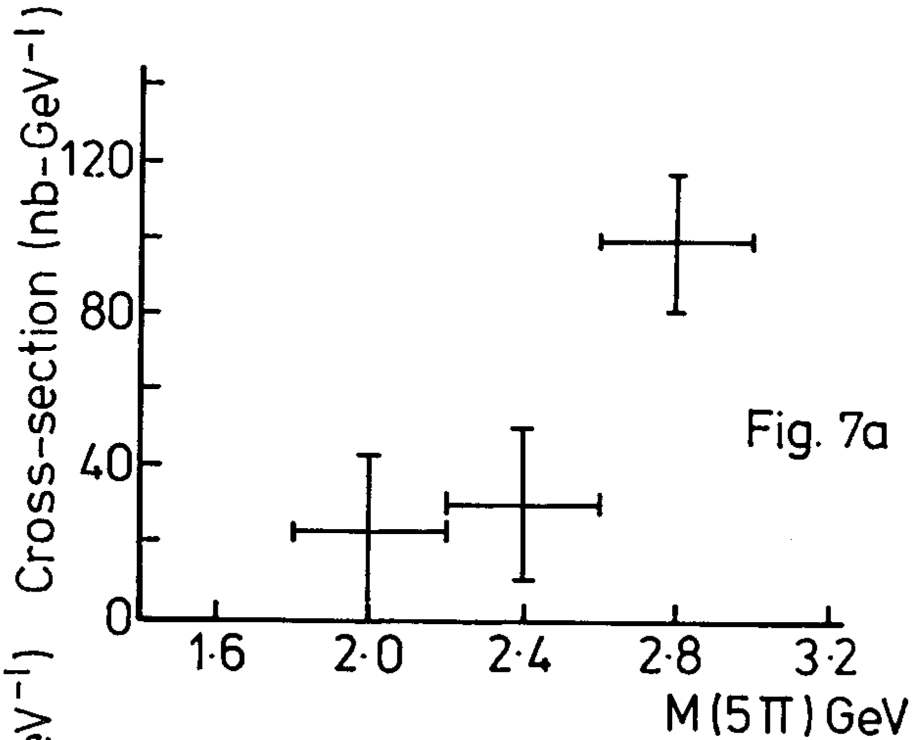

Cross-section (nb-GeV⁻¹)
0
40
80
120
1·6
2·0
2·4
2·8
3·2
M (5 π) GeV

Fig. 7a

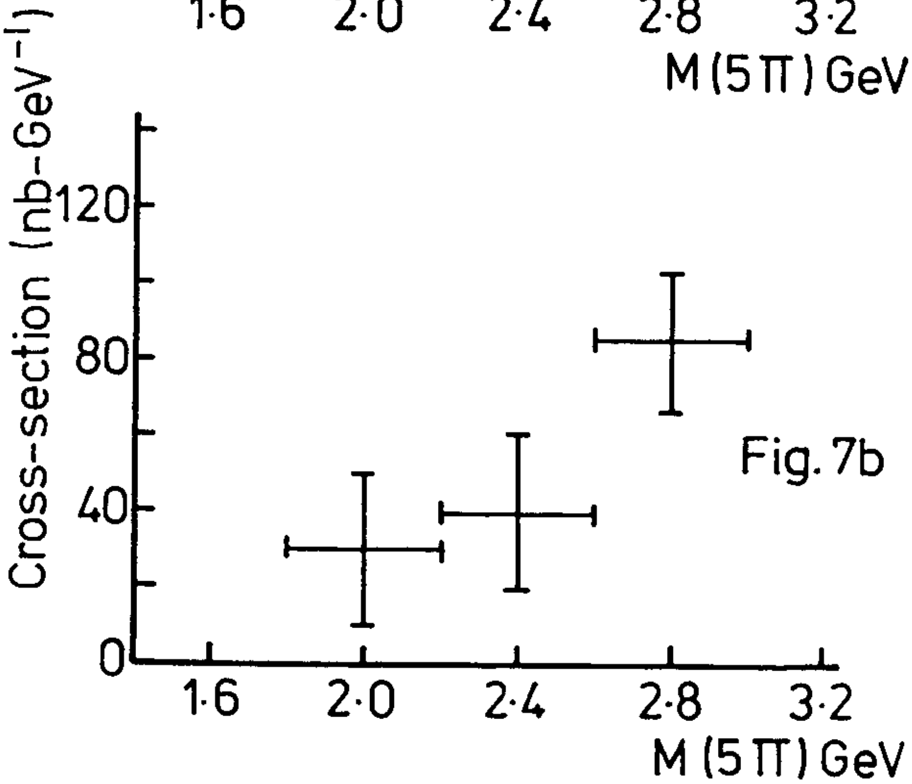

Cross-section (nb-GeV⁻¹)
0
40
80
120
1·6
2·0
2·4
2·8
3·2
M (5 π) GeV

Fig. 7b

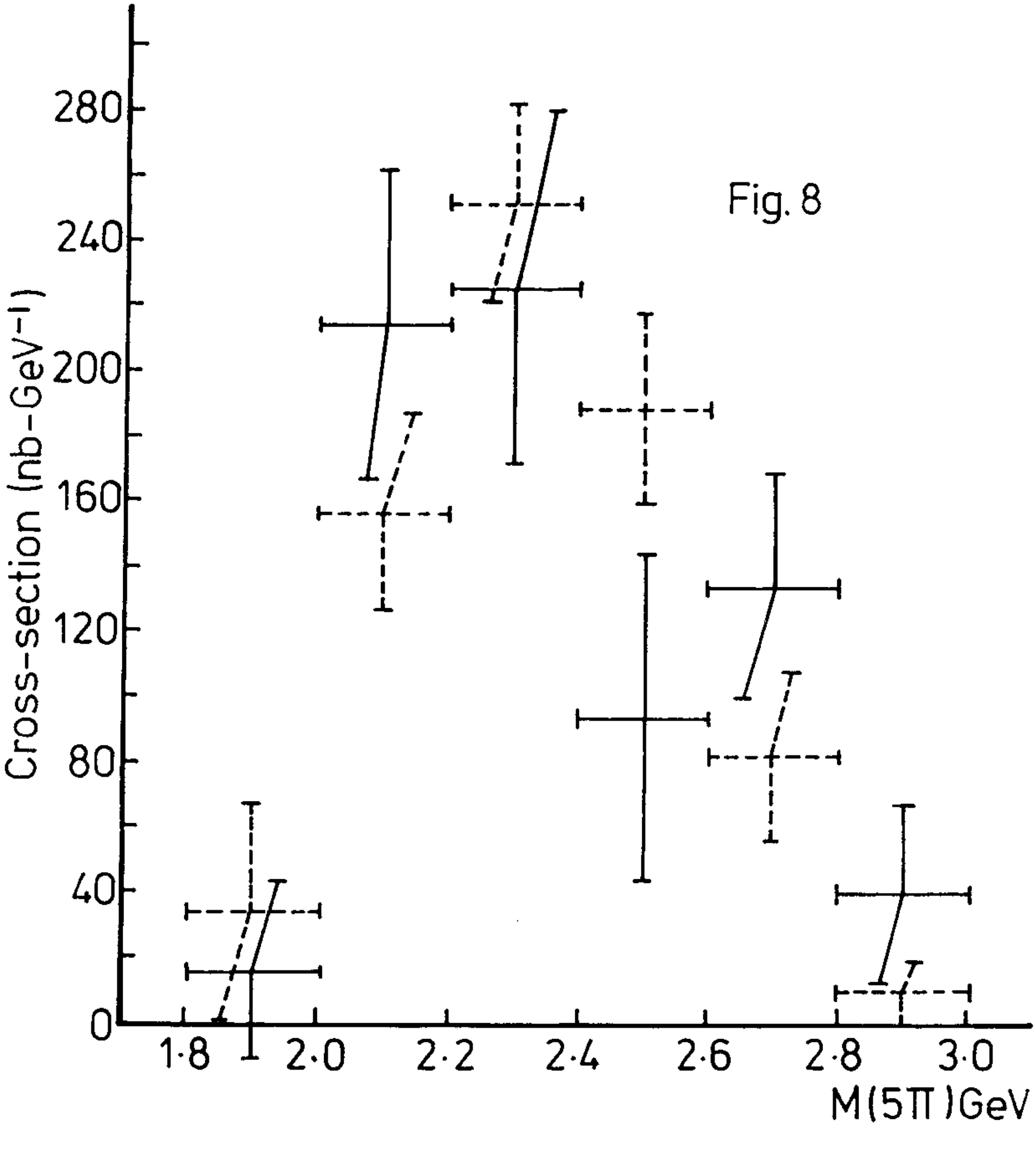


Fig. 8
Cross-section (nb-GeV⁻¹)
0
40
80
120
160
200
240
280
1·8
2·0
2·2
2·4
2·6
2·8
3·0
M(5π)GeV