

CERN LIBRARIES, GENEVA



CM-P00065553

STUDY OF THE  $\omega^0$  MESON IN ANNIHILATIONS  $\bar{p} + p \rightarrow K + \bar{K} + \omega^0$  AT REST

R. Armenteros, R. Budde, L. Montanet, D.R.O. Morrison, A. Shapira  
S. Nilsson and J. Vandermeulen\*, CERN

C. d'Andlau, A. Astier, C. Ghosquière, B. Gregory, D. Rahm\*\*, P. Rivet  
and F. Solmitz\*\*\*, Collège de France and Ecole Polytechnique (Paris)

- \* On leave of absence from the "Institut Interuniversitaire des Sciences Nucléaires", Belgium
- \*\* Now at Brookhaven National Laboratory
- \*\*\* On leave of absence from the Lawrence Radiation Laboratory, University of California, Berkeley

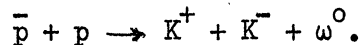
- 1 -

Introduction

The  $\omega^0$ -meson has been studied in  $p\bar{p}$  annihilations at rest with production of charged and neutral K-mesons. The experiment was carried out in the 81 cm hydrogen bubble chamber at the CERN P.S. The branching ratio of the  $\omega^0$  decay into neutral particles and the  $\pi^+\pi^-\pi^0$  mode has been measured. A value is given for the mass and limits are given for the width. The  $\pi^+\pi^-\pi^0$  decay mode yields good evidence for the  $1^-$  attribution of the quantum numbers. Information about the production  $p\bar{p} \rightarrow K\bar{K} \omega^0$  is also given.

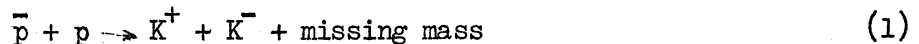
1.  $\omega^0$  branching ratio into charged and neutral decay modes (based on  $K^+K^-\omega^0$  events)

This determination comes from events



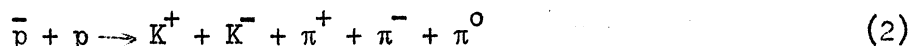
About 30 o/o of the total number of photographs have been scanned for the detection of annihilations leading to the production of at least one charged K. The identification of the  $K^-$  was made through its decay or interaction. The second charged K was essentially identified by ionization measurements (Gap counting). In order to reduce as much as possible the contamination from annihilations in flight, only the events occurring in a well defined fiducial region of the chamber were selected for further analysis.

In Fig. 1a the missing mass spectrum of events



is shown.

In Fig. 1b a similar spectrum is shown for events kinematically identified as due to reaction



This spectrum was obtained in exactly the same way as that for reaction (1), i.e. only the measured - as distinct from the fitted - values of the  $K^+K^-$  pair were used to calculate the mass of the  $(\pi^+\pi^-\pi^0)$  - system; this to allow direct comparison of the missing mass spectra in reactions (1) and (2).

- 2 -

Altogether we obtained 43 ( $K^+K^- + \text{neutrals}$ )-events and 77 ( $K^+K^-\pi^+\pi^-\pi^0$ )-events in the missing mass range between 500 MeV and 900 MeV.

The histograms show marked peaks in the expected  $\omega^0$  mass region with a very small background contamination. The background of non-resonant events - estimated from the mean number of events per unit energy interval in the region  $600 \text{ MeV} < M < 730 \text{ MeV}$  - was about 0.6 events per 10 MeV interval, both in the ( $K^+K^- + \text{neutrals}$ )-events and in the ( $K^+K^-\pi^+\pi^-\pi^0$ )-events.

In the resonant region (defined by  $740 \text{ MeV} < M < 840 \text{ MeV}$ ) there remain 16.1 and 76.5 events from reactions (1) and (2) respectively. These figures are obtained after applying the following corrections: possible contamination of ( $K^+K^- + \text{neutrals}$ ) by annihilations in flight, which can however be easily recognized for the ( $K^+K^-\pi^+\pi^-\pi^0$ )-events; and mainly, poor measurability and hence ambiguity in the classification of some events.

All possible measurements on the sample considered (456 events) have been completed. The events (30 events) for which no definite kinematical results have been obtained, have been classified from the available information. The events (26 events) for which some ambiguity remained have been attributed to their possible classes according to the proportions obtained in the completely defined events.

The resulting correction factor for the events in the  $\omega^0$  region is of the order of 20 o/o.

Errors on the numbers of ( $K^+K^-\pi^+\pi^-\pi^0$ ) and ( $K^+K^- + \text{neutrals}$ ) events were computed, taking into account fluctuations on the initial figures and uncertainties in the background correction and in the number of events added or subtracted.

The branching ratio obtained is then:

$$\frac{\omega^0 \rightarrow \text{neutrals}}{\omega^0 \rightarrow \text{charged}} = \frac{16.1 \pm 5.2}{76.5 \pm 9.5} = (21 \pm 7.5) \text{ o/o}$$

Remark: The mean value of the missing masses in the  $\omega^0$  region ( $720 \text{ MeV} < M < 870 \text{ MeV}$ ) and the observed width of the distribution are :

- 3 -

$\langle M \rangle = (789.9 \pm 1.6) \text{ MeV} \quad \sigma = 12.9 \text{ MeV}$   
 for the  $(K^+K^-\pi^+\pi^-\pi^0)$  annihilations (64 events).

$\langle M \rangle = (789.3 \pm 3.4) \text{ MeV} \quad \sigma = 14.5 \text{ MeV}$   
 for the  $(K^+K^- + \text{neutrals})$  annihilations (18 events).

## 2. Mass and width of the $\omega^0$ (based on $K_1^0 K_1^0 \omega^0$ events)

We have also looked for the possible presence of the  $\omega^0$  mesons in events of the type  $(K_1^0 K_1^0 + \text{neutrals})$  and  $(K_1^0 K_1^0 \pi^+\pi^-\pi^0)$  in a well defined fiducial region of the chamber. In Fig. 2 the distribution of the missing mass in the  $(K_1^0 K_1^0 + \text{neutrals})$  is shown. The data is very scanty, but a small peak appears in the  $\omega^0$  region. The estimated number of  $\omega^0$ -events is about 9. It is difficult, however, to estimate the background and for this reason we do not use the  $K_1^0 K_1^0 \omega^0$ -events to establish the  $\omega^0$ -branching ratio.

Fig. 3 shows the distribution of the  $(\pi^+\pi^-\pi^0)$  effective mass in the  $(K_1^0 K_1^0 \pi^+\pi^-\pi^0)$ -events. Here again the peak in the  $\omega^0$  region is fairly prominent over a small background. To compute the mass of the  $\omega^0$ , we take <sup>\*</sup>) all the events in the mass region between 760 MeV and 800 MeV and obtain  $\langle M_{\omega^0} \rangle = (779.4 \pm 1.4) \text{ MeV}$ . The width of the distribution is given by  $\sigma = 10 \text{ MeV}$ , which is consistent with our estimated experimental resolution.

Systematic errors may distort the values given. The  $\omega^0$  mass obtained from the charged K-events is significantly higher:  $\langle M_{\omega^0} \rangle = (789.9 \pm 1.6) \text{ MeV}$ . We are more confident in the mass obtained from the  $K_1^0 K_1^0 \omega^0$  events. While the measurement of events with neutral K's is fairly straightforward, the measurement of slow charged particles depend critically on the effects of the energy loss and multiple scattering and the correct determination of the initial direction of the particle is difficult. In fact, the mass of the  $\pi^0$ 's in events identified as  $K_1^0 K_1^0 \pi^0$  is about 140 MeV, while the missing mass in the few  $K^+K^-\pi^0$  we have observed appears to be higher (see fig. 1).

We thus propose :  $\langle M_{\omega^0} \rangle = (779 \pm 1.4 \left[ \pm 5 \right]) \text{ MeV}$ ,

where the figure in the square brackets corresponds to the estimation of a possible systematic error.

\* ) The choice of another interval, say between 750 MeV and 810 MeV, changes the mean value by only  $-0.4 \text{ MeV}$ .

- 4 -

In the same way, the best information about the natural width of the  $\omega^0$  is given by :  $0 \leq \Gamma/2 \leq 10$  MeV.

### 3. Quantum numbers of the $\omega^0$

Of the possible assignment of quantum numbers allowing a decay into 3 pions without a strong damping due to centrifugal barriers, the  $1^{++}$  assignment should give rise to an appreciable decay rate into 4 pions<sup>2)</sup>; this mode has been looked for but was never found<sup>1-3)</sup>. The  $0^{-+}$  assignment is predicted<sup>2)</sup> to give a branching ratio  $\frac{\omega^0 \rightarrow 3\pi^0}{\omega^0 \rightarrow \pi^+ \pi^- \pi^0} = \frac{3}{2}$ ; the results of Stevenson et al.<sup>1)</sup> and

our branching ratio  $\frac{\omega^0 \rightarrow \text{neutrals}}{\omega^0 \rightarrow \pi^+ \pi^- \pi^0} \sim 20$  o/o rule out this assignment.

The three remaining assignments  $0^{--}$ ,  $1^{+-}$  and  $1^{--}$  will now be compared with our data. The elegant treatment of the triangular Dalitz-plot introduced by Stevenson et al. will be used.

Fig. 4 shows the 6-folded Dalitz-plot of the 3 decay pions. The 6-folding is justified theoretically by the symmetry between the pions in the  $I = 0$  state; this expected symmetry manifests itself in our data as we can see in Fig. 5, where the effective mass distribution of the three  $2\pi$ -combinations is shown. The curves drawn on the Dalitz-plot correspond to constant value of the simplest matrix element for the assignment  $1^{--}$ . Furthermore, the plot has been divided into two subsectors to take into account the strong azimuthal variation of the density in the  $1^{+-}$  and  $0^{--}$  cases. The experimental results are shown in Fig. 6 together with the curves expected for the three cases:  $1^{--}$ ,  $0^{--}$  and  $1^{+-}$ . The incompatibility of the experimental results with the assignment  $1^{+-}$  and  $0^{--}$  is obvious and, in agreement with Stevenson et al., we conclude that the  $\omega^0$  is, indeed, a  $1^{--}$  meson.

- 5 -

4. Production of  $\omega^0$  in annihilations at rest ( $\bar{p} + p \rightarrow \bar{K}K \omega^0$ )

In Fig. 7 we show the Dalitz-plot at production for both reactions  $\bar{p}p \rightarrow K^+K^-\omega^0$  and  $\bar{p}p \rightarrow K_1^0 K_1^0 \omega^0$  assuming - given the narrow width of the  $\omega^0$  - that they can be considered as three-body reactions. The population of the Dalitz-plot does not show any significant deviation from uniformity. Evidence for a  $\bar{K}K$  resonance in an energy region accessible in the annihilation mode  $\bar{p} + p \rightarrow \bar{K}K\omega^0$  has been presented at this Conference. The  $\bar{K}K$  mass distribution shown in Fig. 8 is in agreement with the prediction of the usual covariant phase space. We see therefore no narrow  $\bar{K}K$  resonance in the above type of annihilation. It must be noted, however, that the range of Q-values for the system  $\bar{K}K$  in this particular reaction is small ( $\sim 90$  MeV) and thus we cannot exclude a rather broad  $\bar{K}K$  resonance. It is also interesting to remark that the (0,0) configuration must be the dominant one in the reaction we are considering <sup>4)</sup> and thus the occurrence of a strong  $\bar{K}K$  interaction with an  $\ell = 2$  relative orbital momentum should be inhibited by centrifugal barrier effects.

The production rate of the annihilation channel  $K^+K^-\omega^0$  is estimated to be  $(2.14 \pm 0.24) \cdot 10^{-3}$ , where the error includes the uncertainty in the observation of the fastest  $K^\pm$ 's.

References :

- 1) B.C. Maglić, L.W. Alvarez, A.H. Rosenfeld and M.L. Stevenson,  
Phys. Rev. Letters 7, 178 (1961)  
and  
M.L. Stevenson, L.W. Alvarez, B.C. Maglić and A.H. Rosenfeld  
Phys. Rev. 125, 687 (1962) and  
125, 2208(1962)
- 2) H.P. Duerr and W. Heisenberg, Nuovo Cimento XXIII, 807 (1962)
- 3) N.H. Xuong and G.R. Lynch, Results quoted by Stevenson et al.
- 4) G.A. Snow, Physics Letters 1, 213 (1962)

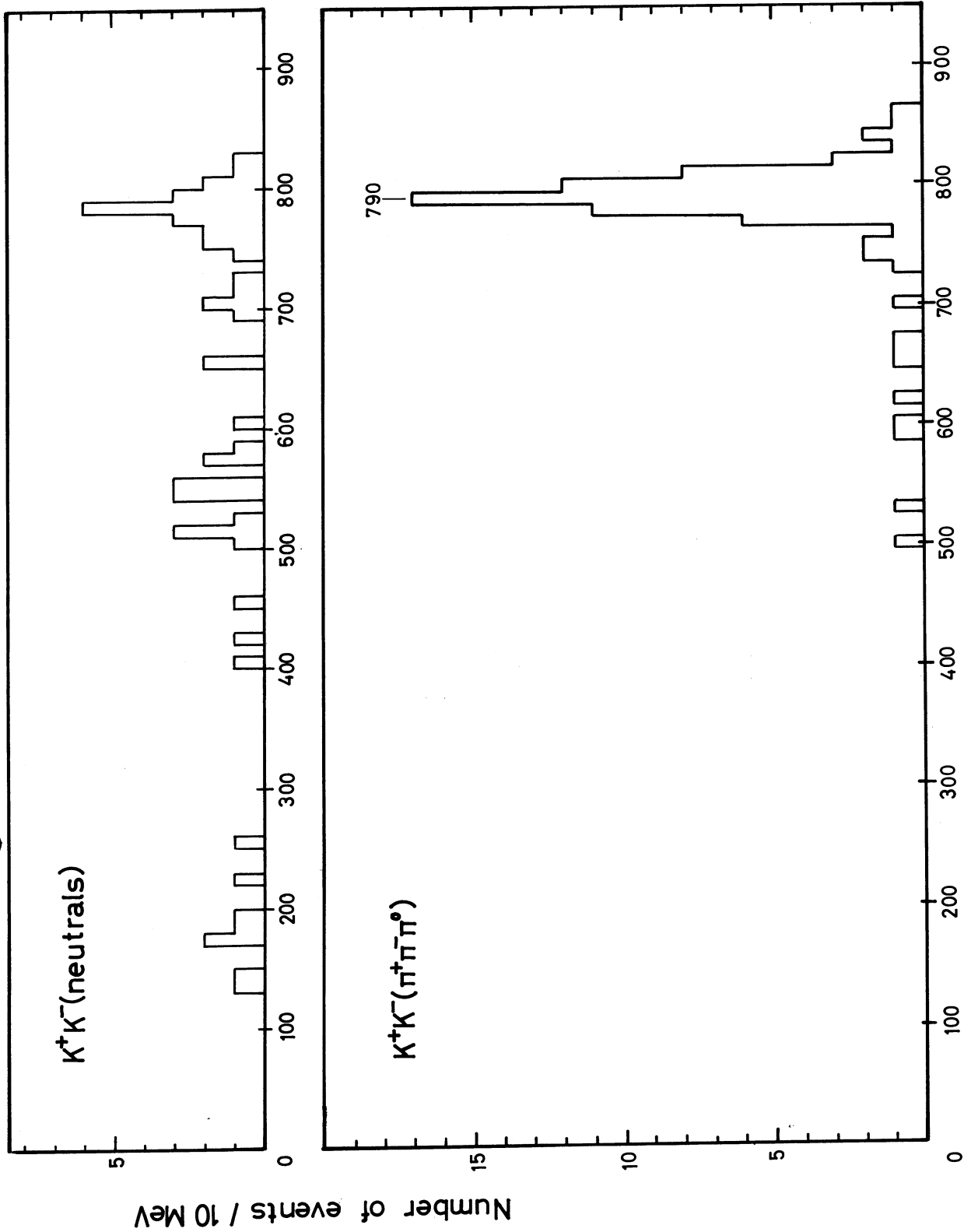


Fig.1



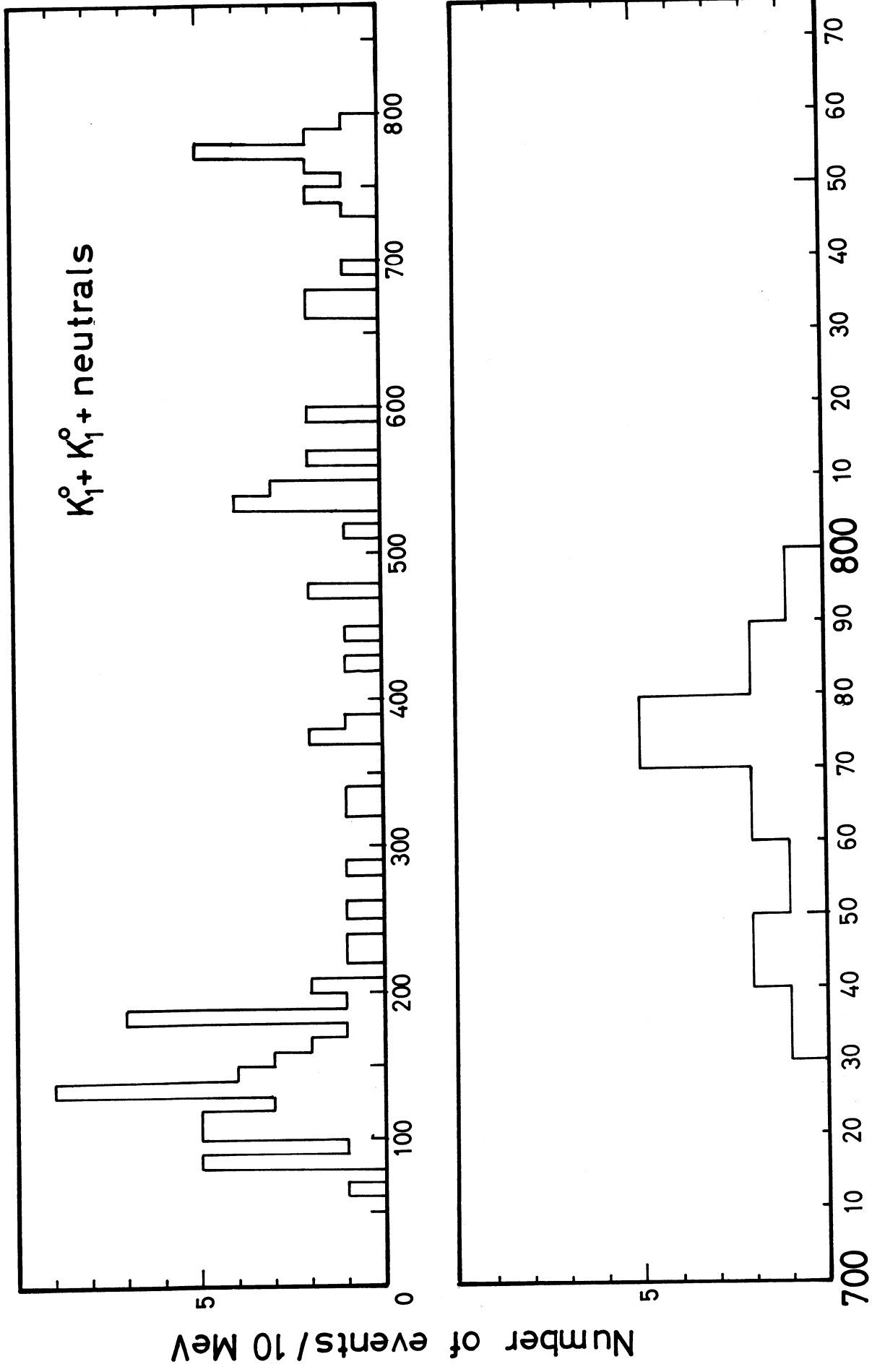


Fig. 2

Missing mass of neutrals (MeV)

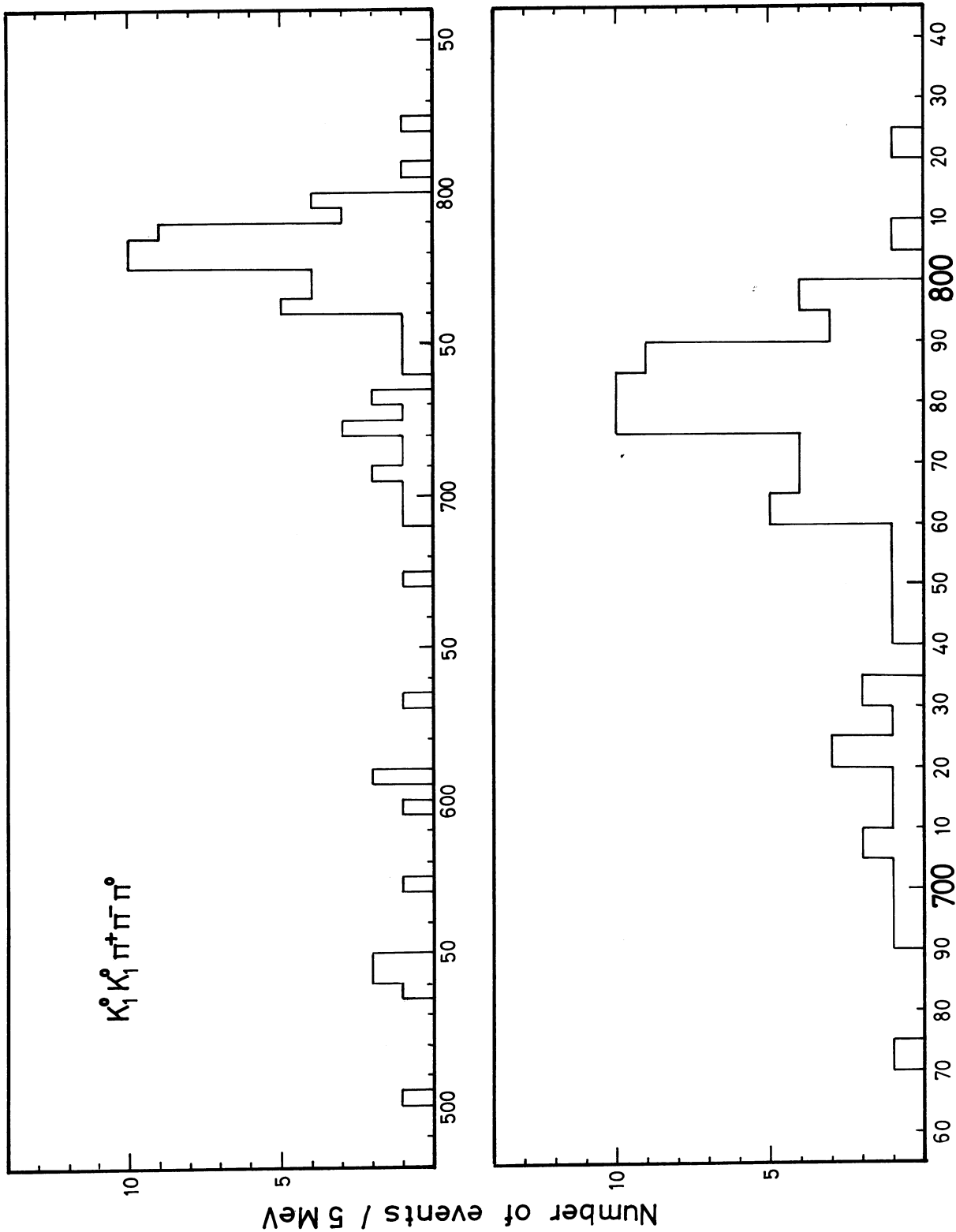
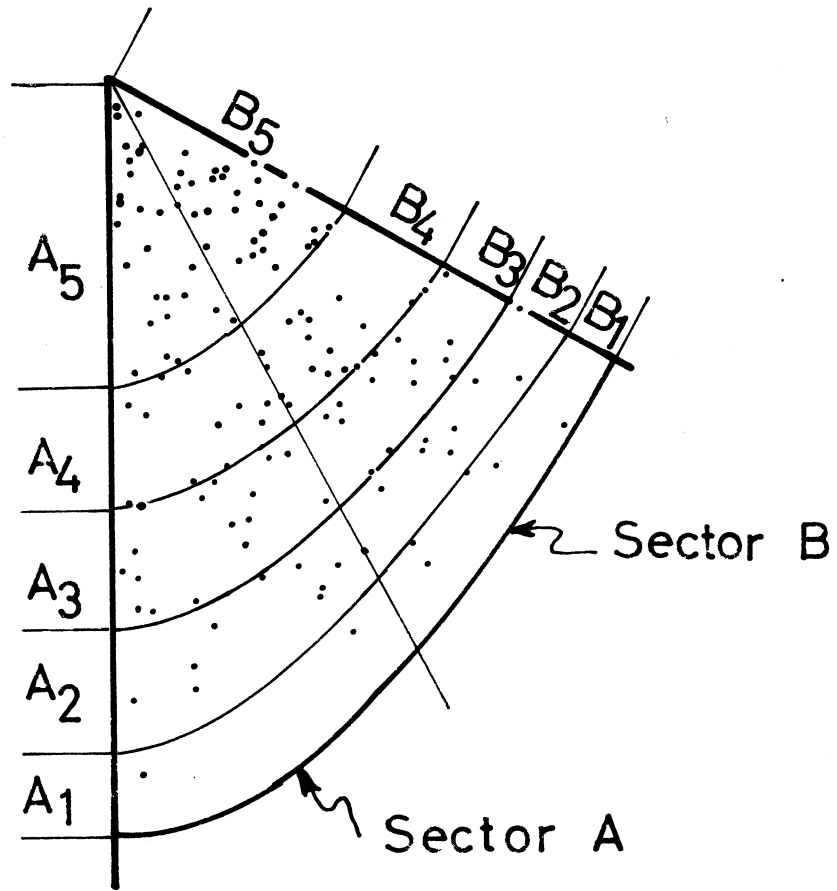
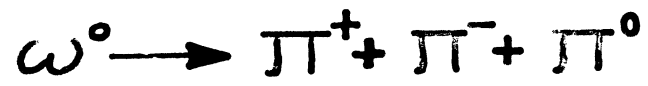


Fig . 3  
Effective mass of  $\pi^+ \pi^- \pi^0$  (MeV)



Folded Dalitz plot

Fig. 4

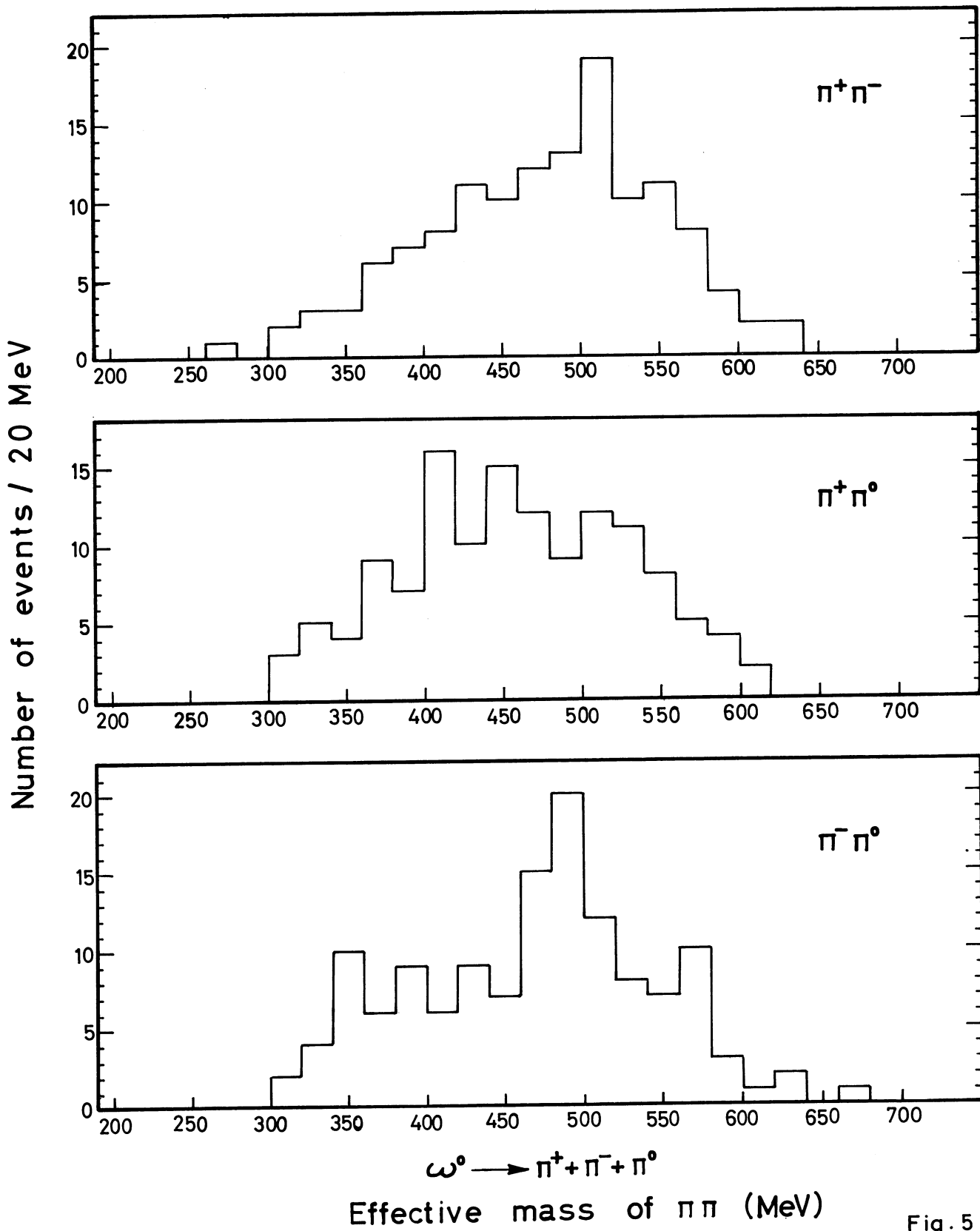


Fig. 5

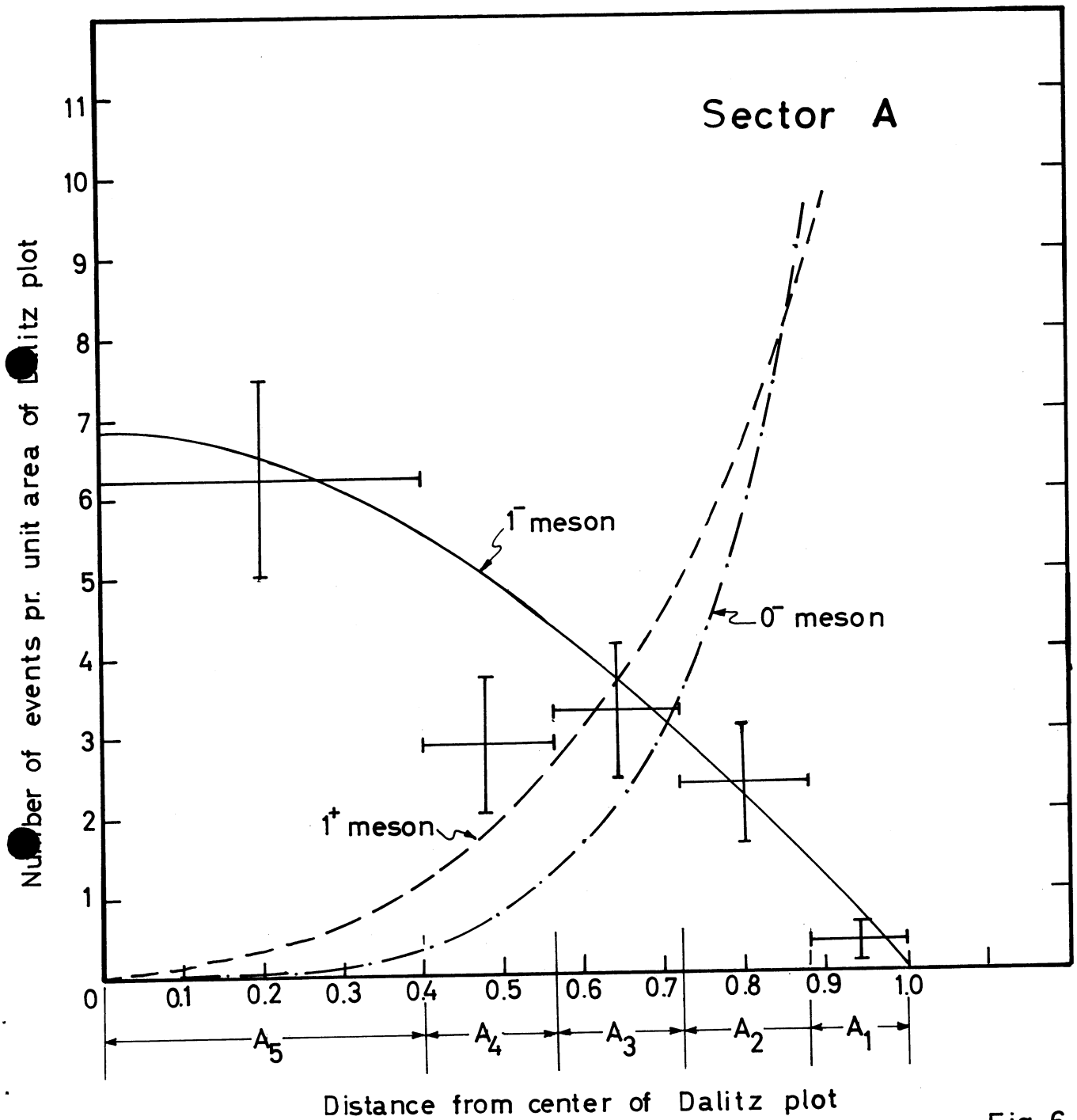
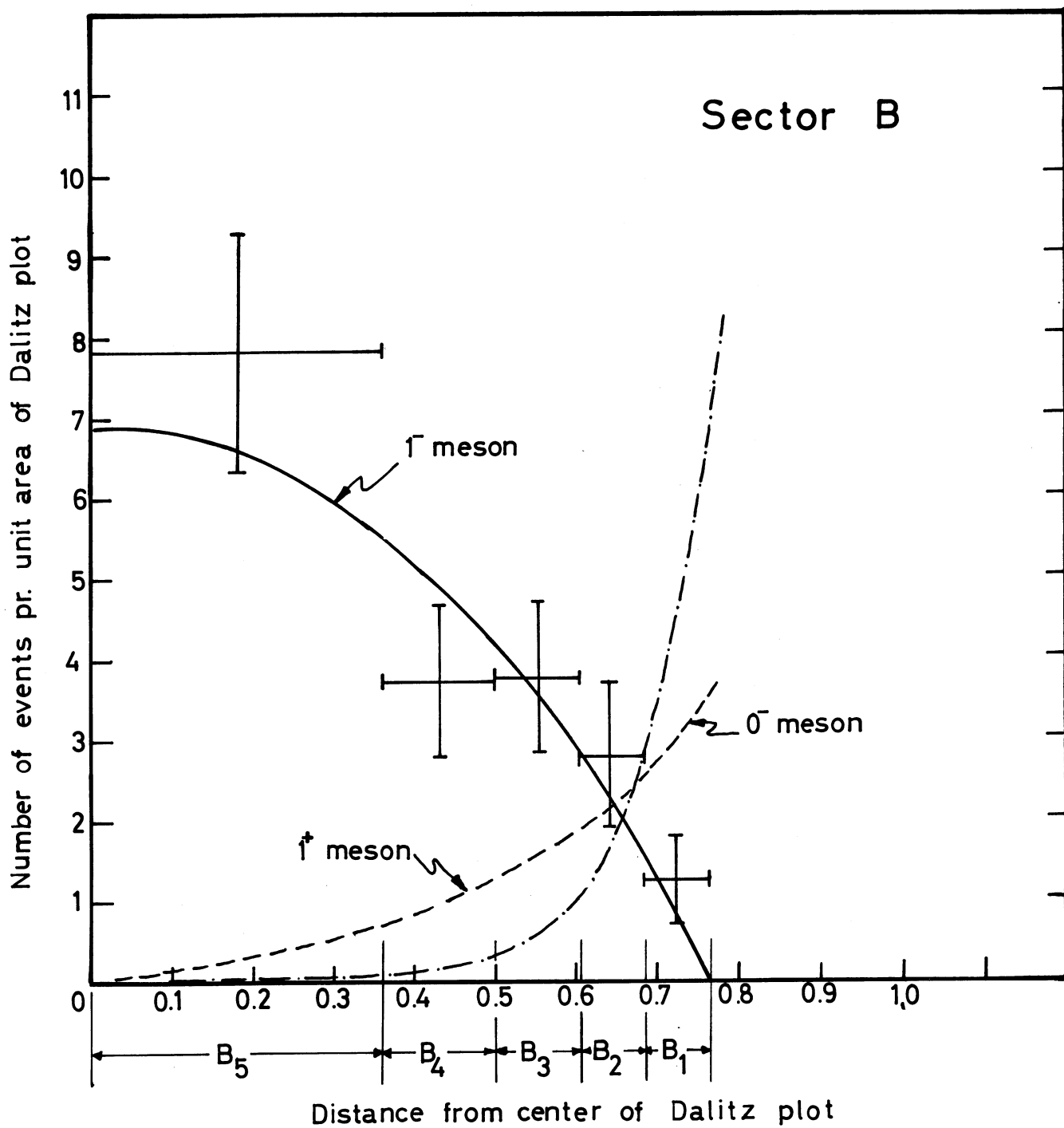


Fig. 6



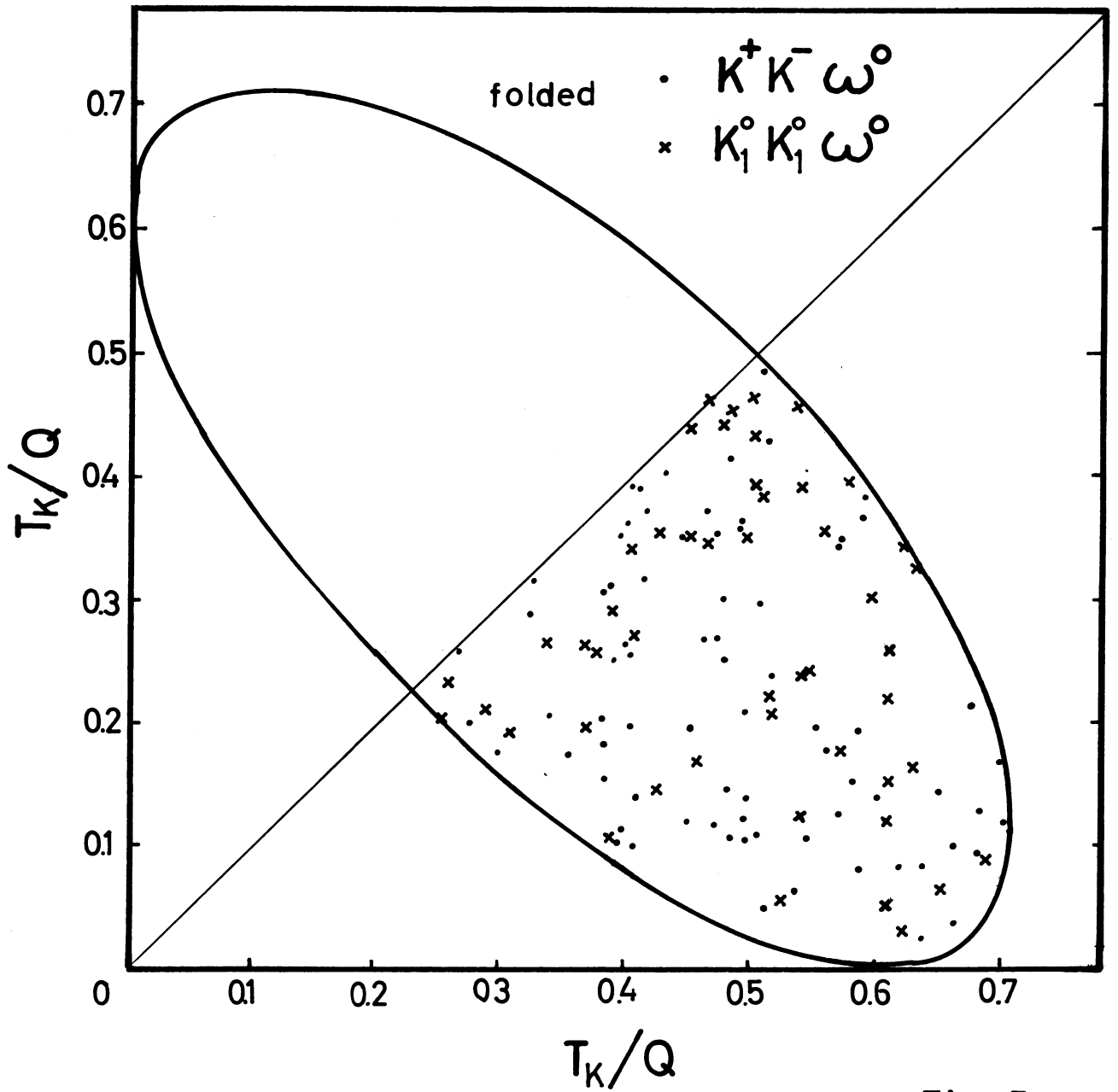
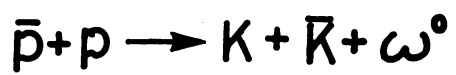
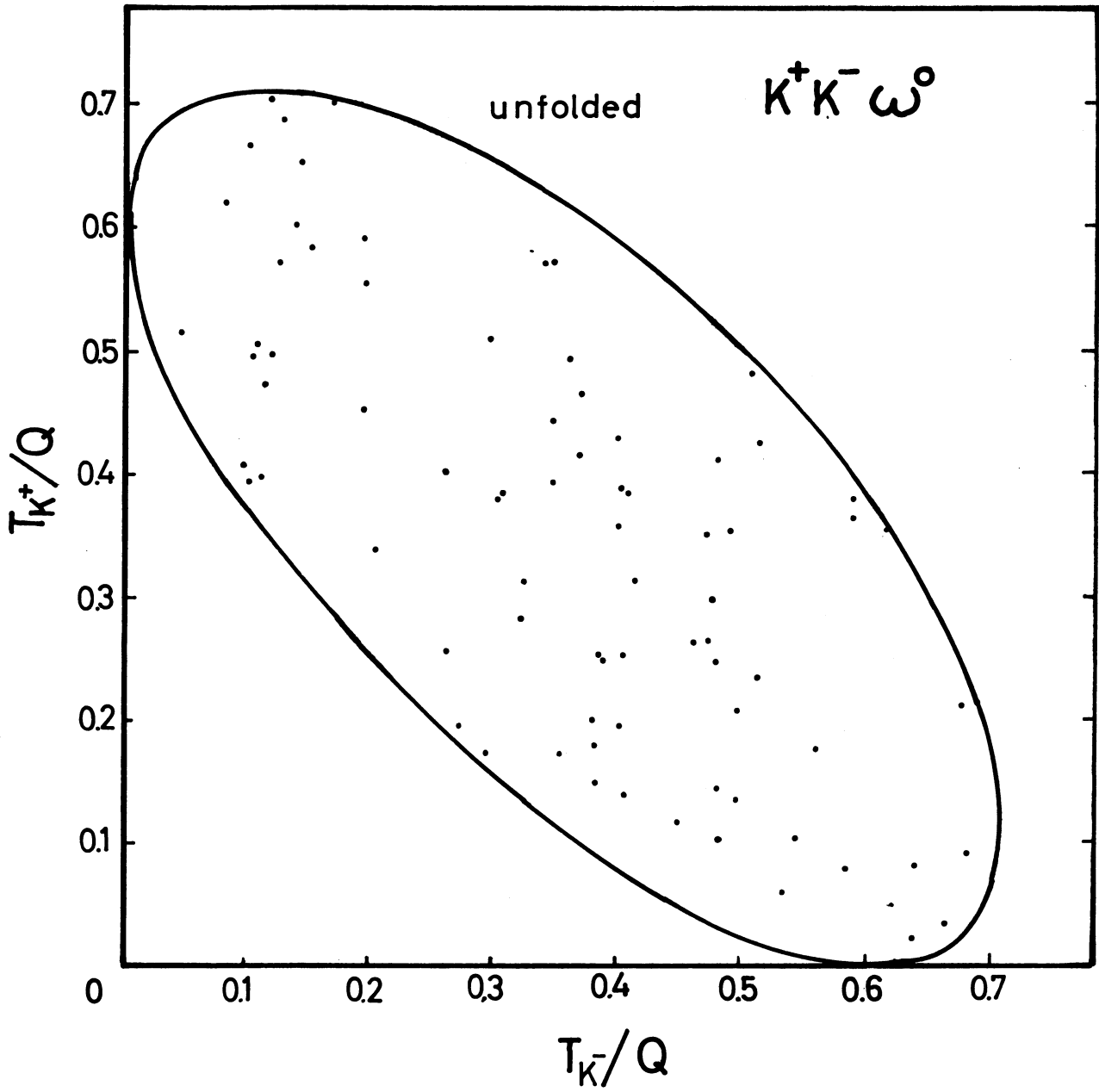


Fig. 7





Dalitz plot



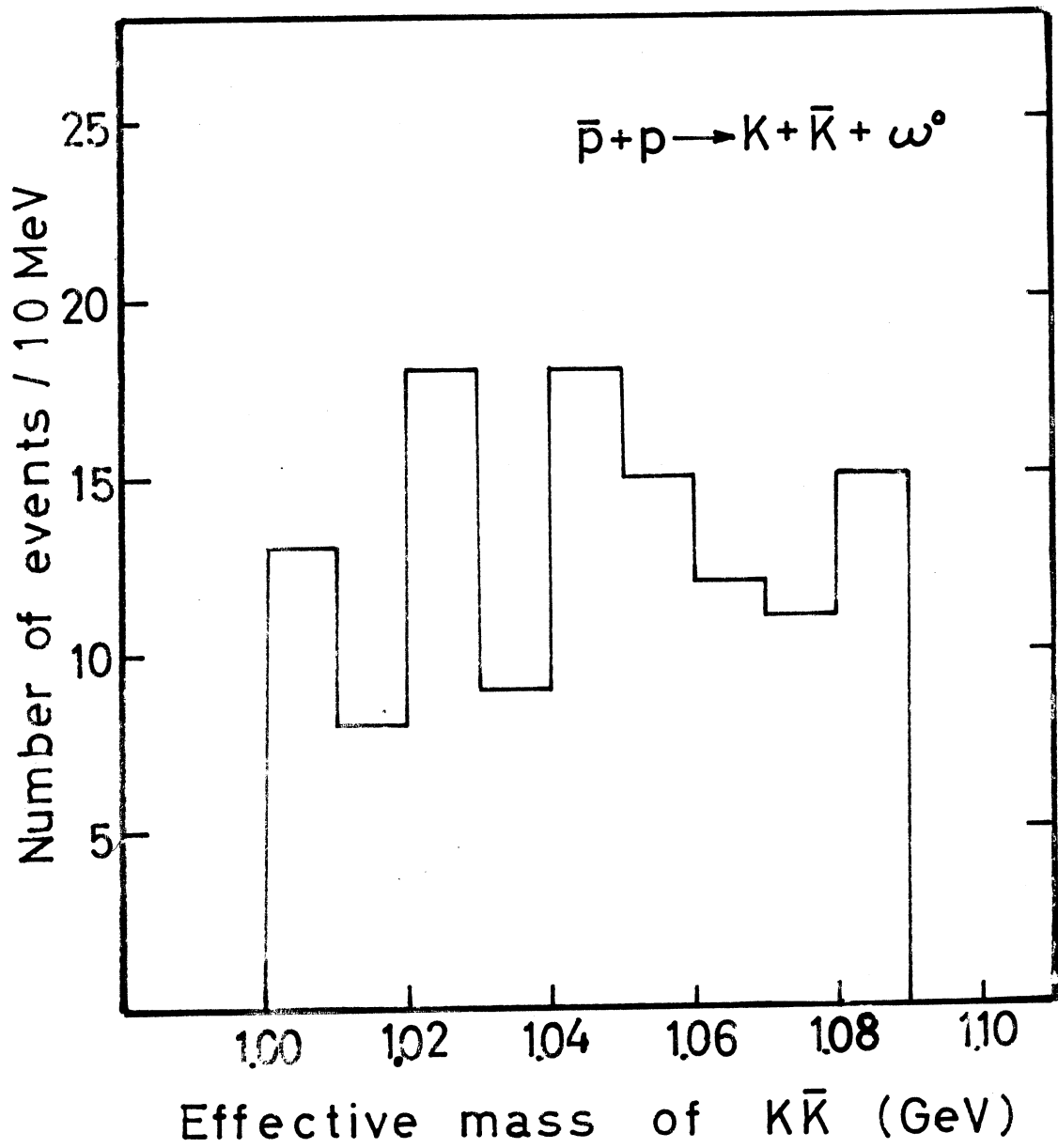


Fig . 8