K-MESON PRODUCTION IN $\bar{p}p$ ANNIHILATION AT 3.69 GeV/c *

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(Presented by H. TAFT)

In a continuing study of high energy $p\bar{p}$ interactions [1] we have examined 250, 000 pictures from the Brookhaven National Laboratory 20″ hydrogen bubble chamber exposed to a separated beam of 3.69 Gev/c antiprotons with a typical intensity of 15 $\bar{p}$ per pulse. For the results reported here, only events with at least one visible K_1^0 decay (into $\pi^+ + \pi^-$) were used. A total of 4050 such events were found and analysed. Of these only 2175 events allowed unambiguous identification of the final state by kinematic fitting procedures and visual bubble density estimates. For the majority of the analysis presented below, only the unambiguous events were used. A careful study indicates that the restriction to unambiguous events does not cause substantial distortion of effective mass spectra.

I. CROSS SECTIONS

Table 1 shows the numbers of events observed in the various topologies used in the experiment.

Table 1

	$K_1^0 - 0$ pr	$K_1^0 - 2$ pr	$K_1^0 - 4$ pr	$2K_1^0 - 0$ pr [a]	$2K_1^0 - 2$ pr	$2K_1^0 - 4$ pr
Number of Events	202	1885	1504	28	336	96

[a] This topology was studied in about half the film only

The determination of the detection efficiencies for these events is complicated by the identification ambiguities mentioned above and by the possibility of correlations between the decays (as K_1^0 or K_2^0) of the K-mesons for those Astudy events with a pair of neutral K-mesons. of these effects and of the geometrical factors for this experiment indicate that the average detection efficiency for observing at least one K_1^0 decay in the chamber is 0.50 ± 05. Furthermore the detection efficiency is approximately the same for all the various subclasses of events. Table 2 lists some of the cross sections which have been measured.

Table 2

Cross section for annihilation into K-mesons and pions at 3.69 GeV/c

Final State (s)	σ, mb
$K^0 + \bar{K}^+ + n\pi$ and charge conjugate ($n=0, 1, 2 \ldots$)	1.7—.2
$K + \bar{K} + n\pi$ ($n=0, 1, 2 \ldots$)	2.3—.3*
Fraction $K\bar{K} + n\pi$/all $p\bar{p}$ annihilation	.064
$K^+ + K^-$	$<$. 025
$K^0 + K^0$	$<$. 002

* Calculated with the assumption that $K^+\bar{K}^0$, K^+K^-, $K^0\bar{K}^0$, K^-K^0 are produced with equal probability.

The angular distribution of the charged and neutral K-mesons has been studied for the unambiguous events. Although this sample is strongly biased in favor of charged K-mesons emitted backwards in the center of mass system the forward to backward ratio for K^+ (or K^-) and for K^0 (or $\bar{K}^0$) can be determined by using the symmetry for the $\bar{p}p$ system. In particular the angular distribution of the K^+ relative to the proton is the same (by C invariance) as that of the K^- with respect to the antiproton. The K^- and $\bar{K}^0$ are observed to be emitted preferentially in the forward direction. For total particle multiplicities in the range 4

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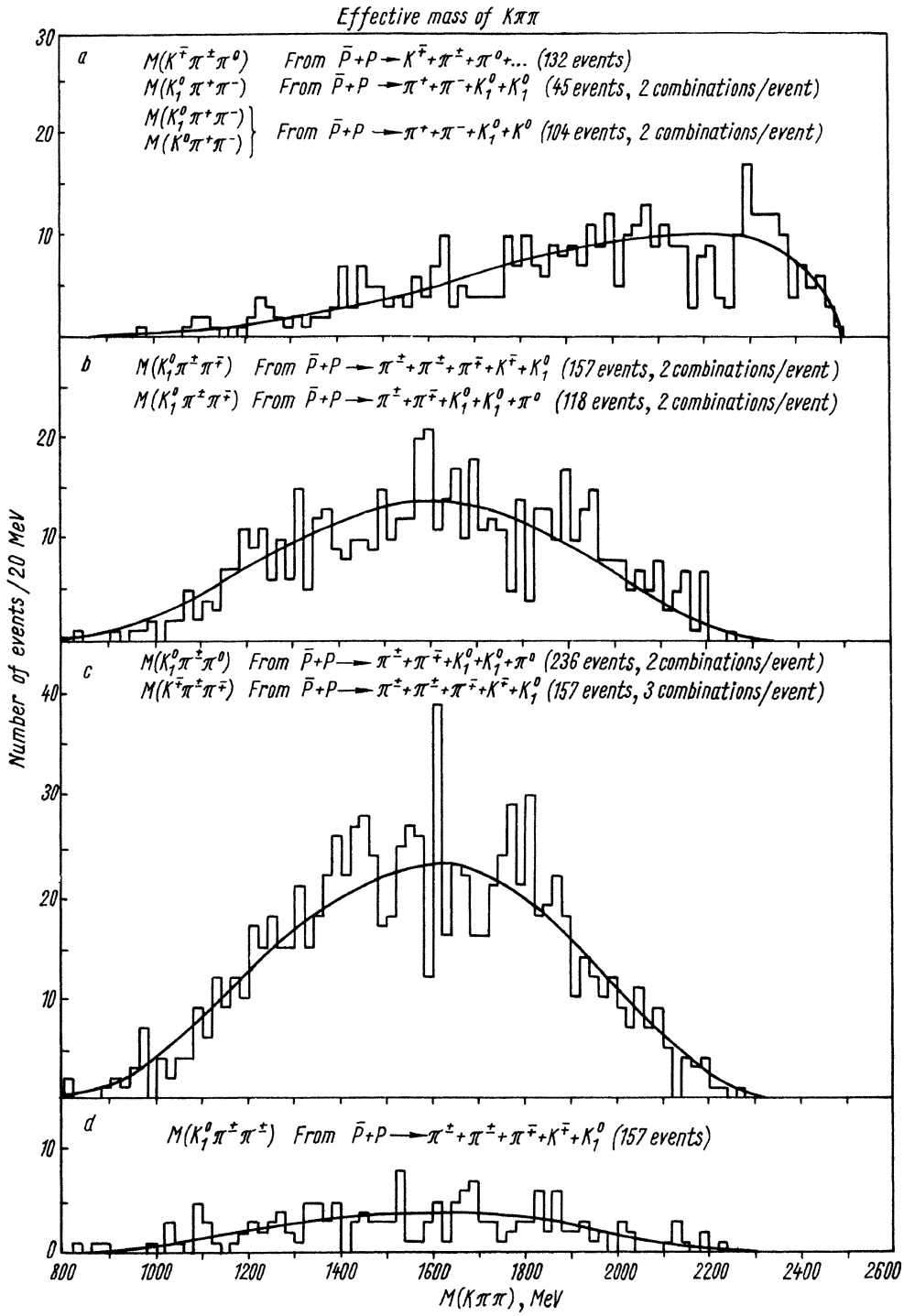

Fig. 1. Effective mass spectra for charged and neutral $K\pi\pi$ combinations from four and five-body final states. The solid curves are calculated according to the Lorentz invariant phase space.

to 6 the effect is essentially independent of multiplicity and has the average values presented in Table 3.

Table 3

Forward to backward ratios for 4, 5, 6-body final states

	F/B
K^-	1.46 ± 0.15
K^0	1.39 ± 0.14

II. RATIO OF φ^0 TO ω^0 PRODUCTION

Because of the possibility of substantial $\varphi - \omega$ mixing [2] it is of interest to measure the ratio of φ to ω production in various processes. The annihilation reactions in particular involve many final states of angular momentum and isotopic spin for any given set of final products so that approximately equal production of the φ and ω states might be expected. As noted below this is not observed. The reaction $\bar{p} + p \to 2\pi^+ + 2\pi^- + \omega^0$ has been observed [1, 3] to proceed at 3.69 GeV/c incident momentum with a cross section of 900 ± 200 μb. The corresponding reaction

$$\bar{p} + p \to 2\pi^+ + 2\pi^- + \varphi^0 \quad (1)$$
$$\qquad\qquad\qquad\qquad\quad \hookrightarrow K_1^0 + K_2^0$$

has been studied in the present experiment. For this study both ambiguous and unambiguous events were used and no significant peak in the $K_1^0\, K_2^0$ mass spectrum was observed. A maximum of 10 events could be attributed to φ decay into $K_1^0 K_2^0$. After correction for K^+K^- decay*[4] and $\pi\varrho$ decay **[5] of the φ, and for detection efficiency, an upper limit for the cross section for reaction (1) is found to be 25 μb. Thus

$$\frac{\bar{p} + p \to 2\pi^+ + 2\pi^- + \varphi}{\bar{p} + p \to 2\pi^+ + 2\pi^- + \omega} < 0.03$$

III. STUDY OF $K\pi\pi$-SYSTEMS

Resonant effects in the $K\pi\pi$-system have been reported recently [6]. A study of the effective mass spectrum of neutral and charged $K\pi\pi$-combinations from four and five-body final states has been carried out and is presented in Fig. 1. No significant deviations from the phase space distributions are observed.

IV. STUDY OF $K\bar{K}\pi$-SYSTEM

Resonant effects in the $K\bar{K}\pi$-system have been reported recently [7]. The reaction

$$\bar{p} + p \to K_1^0 + K^{\mp} + \pi^{\mp} + \pi^{\pm} + \pi^{\pm}$$

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* We have used $\frac{\varphi \to K_1^0 K_2^0}{\varphi \to K\bar{K}} = 0.45 \pm 0.10$ as given in [4] Connolly P. L. et al. Phys. Rev. Lett. **10**, 371 (1963).

** We have used $\frac{\varphi \to \pi\varrho}{\varphi \to K\bar{K}} = 0.10 \pm 0.10$ as given in [5]. Connolly P. L. et al. Proceedings of the Sienna International Conference on Elementary Particles **1**, p. 130, 1963.

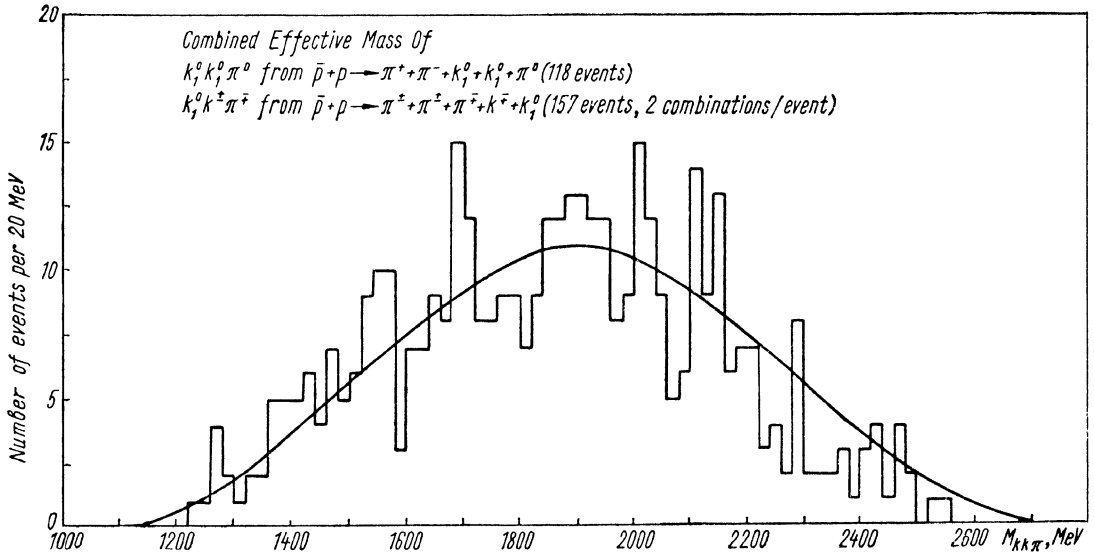

Fig. 2. Effective mass spectrum for neutral $K\bar{K}\pi^+$combinations in the final states $K_1^0 K^{\pm}\pi^{\pm}\pi^+\pi^+$ and $K_1^0 K_1^0 \pi^+\pi^-\pi^0$.

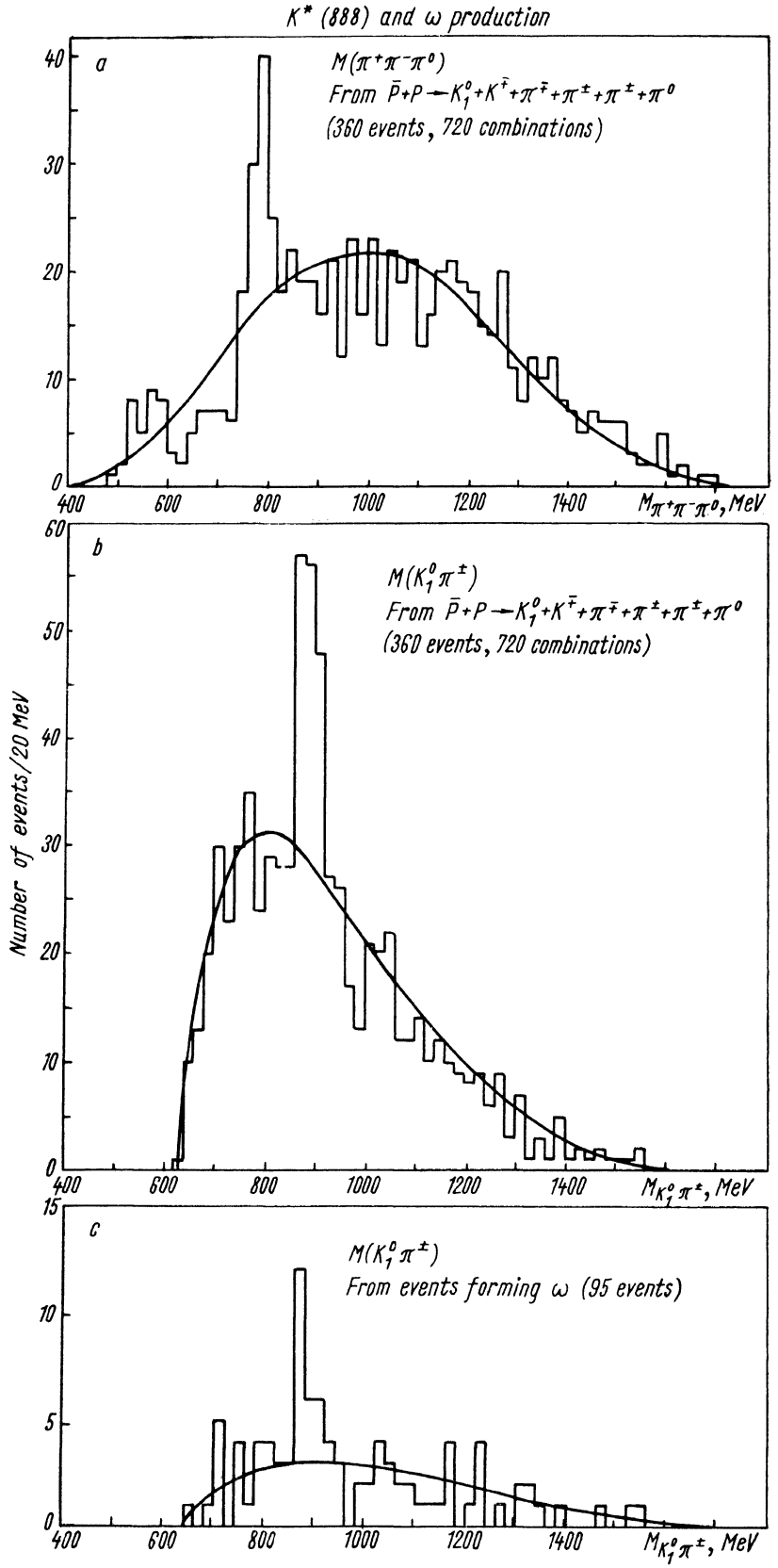

Fig. 3. Effective mass spectra for $\pi^+\pi^-\pi^0$ combinations, $K^0\pi^\pm$ combinations and $K_1^0\pi^\pm$ combinations for events with $\pi^+\pi^-\pi^0$-mass in the ω^0 peak.

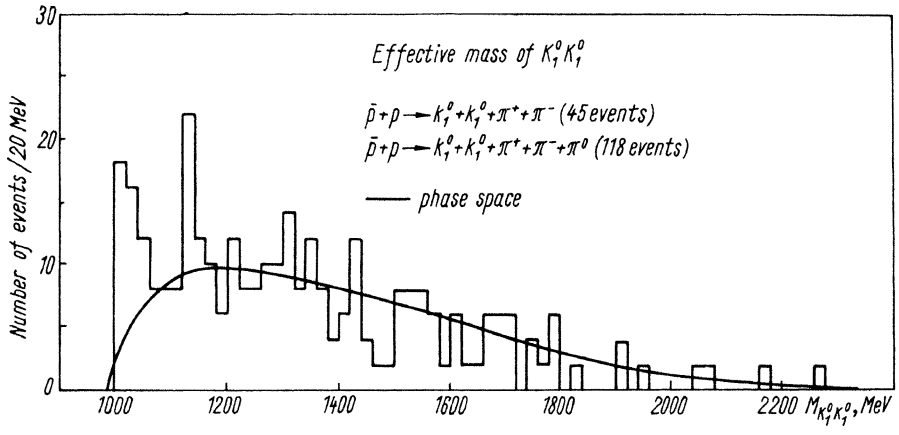

Fig. 4. Effective mass spectrum for $K_1^0K_1^0$-systems in four and five-body final states.

has been studied for charged and neutral $K\bar{K}\pi$-systems. The results for neutral combinations are shown in Fig. 2 . No significant deviations from phase space are observed for either charged or neutral $K\bar{K}\pi$-systems. These final states show substantial K^* (888) production as do the corresponding annihilations at rest. The effective mass spectrum of the $K_1^0K^+$-shows an enhancement at low $K_1^0K^+$-mass (28 events were observed between 1000 and 1060 MeV whereas phase space predicts 13 events).

V. STUDY OF K_1^0 K_1^0-SYSTEM

Erwin et al. [6] and Alexander et al. [7] have reported an effect in the $K^0\bar{K}^0$ system with even charge conjugation quantum number ($K_1^0K_1^0$ decay allowed). The reactions

$$\bar{p}+p\to K_1^0+K_1^0+\pi^+\pi^-+(0,1\pi^0) \quad (2)$$

have been examined for $K_1^0K_1^0$ interaction and the results are shown in Fig. 4. A significant enhancement at low KK mass is observed similar to that reported in References [6, 7]. As mentioned in Section IV the mass spectrum of K^0K^+-from five-body annihilations shows an enhancement at low masses but with poorer statistics than the $K_1^0K_1^0$ effect. It is not possible from out data to draw a definitive conclusion on the isotopic spin state of the $K_1^0K_1^0$ enhancement.

VI. PRODUCTION OF K^* AND ω RESONANCES

Analysis of the final states $K^\pm - K_1^0\pi^\pm - \pi^\mp\pi^\mp\pi^0$ shows that they involve substantial K^* (888) and ω^0 resonance production. The charged K^* ($K^{*+}\to K_1^0\pi^\mp$) is produced predominantly.

The relevant mass spectra are shown in Fig. 3. Although events in which the $\pi^+\pi^-\pi^0$ mass lies in the ω^0 peak shows a significant K^* peak the number of K^* in the peak is insufficient to prove the existence of simultaneous production of ω^0 and K^*.

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