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$\psi(3095)$ DECAYS INVOLVING KAONS*

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ABSTRACT

Some specific decay modes of the $\psi(3095)$ involving kaons have been studied to provide information on the SU_3 character of the new meson. The data favor an SU_3 singlet assignment of the $\psi(3095)$ although quantitative tests do not agree with the hypothesis of a pure state and exact SU_3 conservation.

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The meson $\psi(3095)$, referred in the following as ψ, being an I=0 state[(1)] can in principle be either an SU_3 singlet, or the eight component of an octet, or a mixture of both.

It has been emphasized[2)] that the SU_3 character of the ψ can be tested by studying certain exclusive decay channels, especially those involving kaons. In particular, if SU_3 is conserved in the decay process, then an SU_3 singlet ψ is forbidden to decay into two mesons belonging to the same SU_3 multiplet or more generally belonging to two multiplets whose $I_3 = Y = 0$ members have the same charge conjugation quantum number. This rule then forbids the decay of such a singlet into $K^o\bar{K}^o$, $K\bar{K}^*(1420)$ and $K^*(892)\bar{K}^*(892)$ while it allows such modes as $K\bar{K}^*(892)$, $K^*(892)\bar{K}^*(1420)$.

The tests presented here have been undertaken with approximately 150,000 hadronic decays of the ψ recorded in the SLAC-LBL magnetic detector[3)] at SPEAR. This sample corresponds to an integrated luminosity of 140 nb^{-1}.

Search for the Decay into K_SK_L

In the sample of 2-prong events having opposite charge, the invariant mass is computed assuming both particles to be pions. Fig. 1a shows a clear signal at the K^o mass. For the events with 470 $MeV/c^2 < m_{\pi\pi} < 520$ MeV/c^2, the missing mass recoiling against the possible K_S is plotted in Fig. 1b. Three events, compatible with the background present under the K_S peak, are seen in the region of the K^o mass within the experimental resolution. The detection efficiency for a K_SK_L decay is found by a Monte Carlo calculation to be (25 ± 3)%. This leads to a 90% confidence limit for the branching fraction of:

$$\frac{\psi \to K_S K_L}{\psi \to \mathrm{all}} < 0.8 \cdot 10^{-4} .$$

A limit of 6 x 10^{-4} has been reported for the mode K^+K^-.[4)]

Search for the Decays into KK*

These decays can be studied for different charge states and various configurations of 2 or 4 tracks detected in the apparatus. Each configuration relative to a given decay mode has its own detection efficiency and its own systematic problems, thus the analysis provides a direct check of internal consistency.

In the 4-prong events which conserve the total momentum within 100 MeV/c we have looked for the decay $K_S K^{\pm}\pi^{\mp}$ by first selecting a K_S going into $\pi^+\pi^-$ ($m_{\pi^+\pi^-}$ within ± 30 MeV of the K^o mass). Of the two remaining charged prongs the $K^{\pm}$ is chosen such that the mass of the system $K_S K^{\pm}\pi^{\mp}$ falls within 50 MeV of m_{ψ}. In the selected sample the masses $K^{\pm}\pi^{\mp}$ and $K_S^o\pi^{\mp}$ are reconstructed and the result is shown on the two-dimensional plot of Fig. 2a. Most of the events accumulate in two bands indicating the formation of K^{*o}(892) and $K^{*\pm}$(892). The two bands are roughly equally populated as predicted for the direct decay of an I = 0 state. Assuming SU_3 conservation, a decay via an intermediate photon would have given a ratio 4 to 1 between the two intensities. There is no corresponding evidence for the decays into KK^*(1420).

In the 2-prong events with missing momentum greater than 200 MeV/c, one can search for the mode $K^{\pm}\pi K^{o}_{miss}$ when the K^{o} is not seen. For this decay it is necessary to rely on the time-of-flight information to identify the kaon in order to lower the background. The cut used keeps 90% of the kaons while rejecting 85% of the pions. Figure 2b shows the scatter plot of the mass $K^{\pm}\pi^{\mp}$ versus the mass $K^{o}\pi^{\pm}$. Again here one notices the accumulation of events along the bands corresponding to $K^{*}(892)$ formation. The background comes from the channel $\pi\pi KK$ with two prongs escaping detection.

Table 1 summarizes the results for the different detected modes corresponding to the decay $\psi \rightarrow KK^{*}$, with their detection efficiency and the number of events seen in each channel. The results are consistent and have been averaged to give the branching fractions of the last column.

<u>Search for the Decays into $K^{*}K^{*}$</u>

The mode $\psi \rightarrow \pi^{+}\pi^{-}K^{+}K^{-}$ has also been detected in the sample of 4-prong events conserving the total momentum within 50 MeV/c. Again the time-of-flight is used in order to identify the kaons. With a total of 203 events the branching ratio is found to be:

$$\frac{\psi \rightarrow \pi^{+}\pi^{-}K^{+}K^{-}}{\psi \rightarrow \text{all}} = (4.0 \pm 1.2)10^{-3}$$

The somewhat large error reflects the uncertainty in the production mechanism and in the estimate of the acceptance. The events corresponding to $\phi\pi^{+}\pi^{-}$ with $\phi \rightarrow K^{+}K^{-}$ have been rejected. In the remaining sample one can reconstruct the invariant masses corresponding to the neutral combinations $K^{\pm}\pi^{\mp}$. Figure 3 shows the mass $K^{+}\pi^{-}$ plotted versus the mass $K^-\pi^+$. The different K^*K^* channels are evaluated and the results are listed in Table 1. The data shows that the decay of the ψ into two identical K^* seems suppressed while the decay into $K^*(892)K^*(1420)$ is observed. Recalling the observation of the decay into $KK^*(892)$ and the non-observation of the channels K_SK_L and $KK^*(1420)$ one concludes that there is a systematic suppression of decay modes prohibited for an SU_3 singlet having $C = -1$ while decay modes that are allowed are indeed seen.

This indicates that SU_3 is operative and that the ψ behaves in these decays like a singlet as required for a $c\bar{c}$ bound state. However a pure SU_3 singlet state is predicted to give equal decay rates into $\pi^+\rho^-$, $K^+K^{*-}(892)$ and $\eta^8\omega^8$ where η^8 and ω^8 denote the pure octet combinations. This gives the following relative intensities for the physical channels, after correction for phase space and $\phi\omega$ mixing:

$$\pi^+\rho^- : K^+K^{*-}(892) : \phi\eta = 1 : 0.85 : 0.50$$

The experimental branching ratios[1,5] are respectively:

$$(.43 \pm .10)10^{-2} : (.11 \pm .025)10^{-2} : (.04 \pm .02)10^{-2}$$

The disagreement with the SU_3 singlet prediction cannot be explained by interference with the amplitudes arising from the electromagnetic decay proceeding through a virtual photon: assuming SU_3 conservation for this process, it gives the same relative amplitudes as does a singlet state. Therefore we conclude that, either SU_3 is broken in the decay process, or the ψ is not a pure state. In this last hypothesis the observed discrepancy could be accounted for if one assumes a mixture of approximately 20% octet amplitude in the dominantly singlet amplitude of the ψ.

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References

1. B. Jean-Marie *et al.*, Phys. Rev. Lett. 36, 291 (1976).

2. H. Harari, SLAC-PUB-1514 (unpublished); F. J. Gilman, Invited Talk, IV International Conference on High-Energy Physics and Nuclear Structure, Santa Fe, June 9-13, 1975; SLAC-PUB-1600; V. Gupta and R. Kogerler, Phys. Lett. 56B, 473 (1975).

3. A. M. Boyarski *et al.*, Phys. Rev. Lett. 34, 4 (1975).

4. W. Braunschweig *et al.*, Phys. Lett. 57B, 297 (1975).

5. The analysis of the $\phi\eta$ decay will be given in a forthcoming article.

Table Caption

Summary of the analysis for the decays of ψ into strange mesons. Branching ratios for the decays of K_S and K^* are not included in the detection efficiency.

Figure Captions

1a. Invariant $\pi^+\pi^-$ mass for the sample of 2-prong events

1b. Missing mass recoiling against two pions with $470 < m_{\pi\pi} < 520$ MeV/c^2

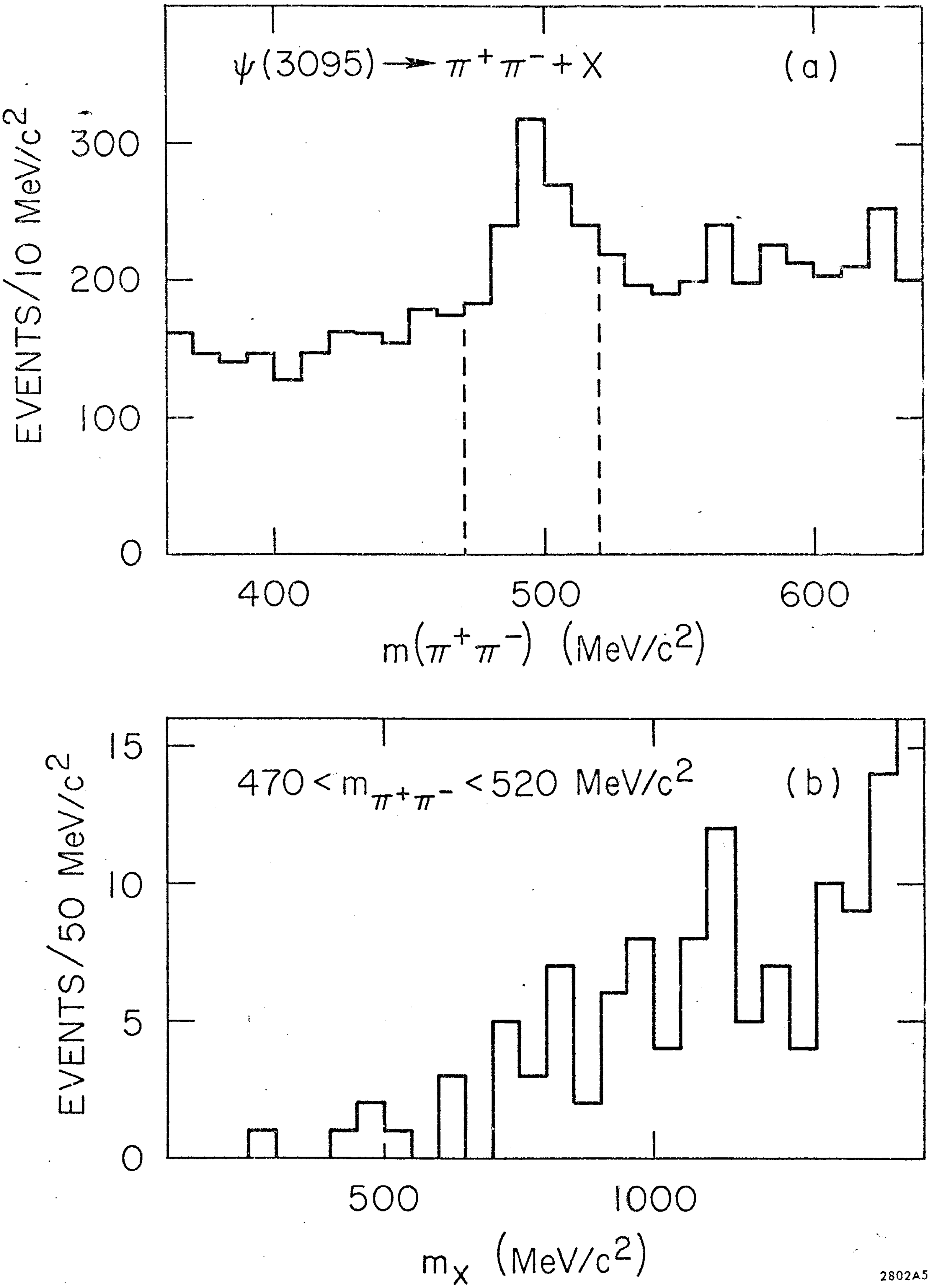
2a. Invariant masses $K^\pm\pi^\mp$ vs. $K_S\pi^\pm$ in the decay $\psi \rightarrow K_S K^\pm \pi^\mp$ with $K_S \rightarrow \pi^+\pi^-$

2b. Invariant masses $K^\pm\pi^\mp$ vs. $K^o\pi^\pm$ in the decay $\psi \rightarrow K^o K^\pm \pi^\mp$ with missing K^o

3. Invariant masses $K^+\pi^-$ vs. $K^-\pi^+$ in the decay $\psi \rightarrow \pi^+\pi^- K^+ K^-$

TABLE 1

Decay Modes	Channel Analyzed	Detection Efficiency	Number of Events	Branching Ratio
K_SK_L	$\pi^+\pi^-$ K^o_{miss}	0.36	<3	$<0.8 \cdot 10^{-4}$
$K^o\bar{K}^{*o}(892)$ + $\bar{K}^oK^{*o}(892)$	$K_SK^* \to \pi^+\pi^-, K^\pm\pi^\mp$	0.24	44	$(2.2 \pm .5)10^{-3}$
	$K^oK^* \to K^o_{miss}, K^\pm\pi^\mp$	0.07	28	
$K^+K^{*-}(892)$ + $K^-K^{*+}(892)$	$K^\pm K^* \to K^\pm, K_S\pi^\mp$	0.21	44	$(2.2 \pm .5)10^{-3}$
	$K^\pm K^* \to K^\pm, K^o_{miss}\pi^\mp$	0.06	19	
$K^o\bar{K}^{*o}(1420)$ + $\bar{K}^oK^{*o}(1420)$	$K_SK^* \to \pi^+\pi^-, K^\pm\pi^\mp$	0.12	<5	$<1.4 \cdot 10^{-3}$
$K^+K^{*-}(1420)$ + $K^-K^{*+}(1420)$	$K^\pm K^* \to K^\pm, K_S\pi^\mp$	0.10	<3	$<1.4 \cdot 10^{-3}$
$K^{*o}(892)\bar{K}^{*o}(1420)$ + $\bar{K}^{*o}(892)K^{*o}(1420)$	π^+K^-, π^-K^+	0.06	30	$(5.5 \pm 2.3)10^{-3}$
$K^{*o}(892)\bar{K}^{*o}(892)$	π^+K^-, π^-K^+	0.09	<5	$<0.6 \cdot 10^{-3}$



$\psi(3095) \rightarrow \pi^+\pi^- + X$
(a)
EVENTS/10 MeV/c^2
300
200
100
0
400
500
600
$m(\pi^+\pi^-)$ (MeV/c^2)
$470 < m_{\pi^+\pi^-} < 520$ MeV/c^2
(b)
EVENTS/50 MeV/c^2
15
10
5
0
500
1000
m_X (MeV/c^2)
2802A5

Figure 1

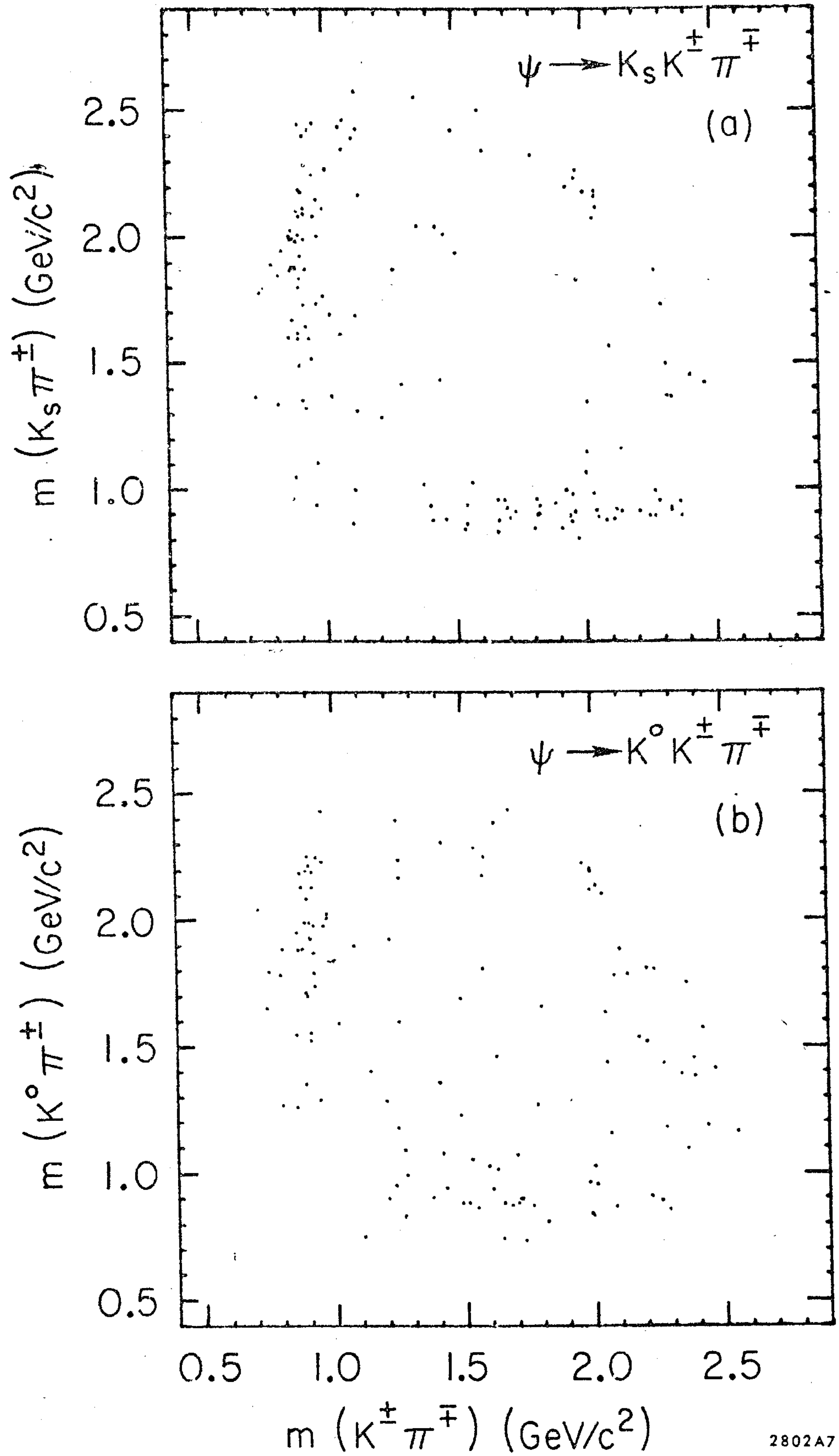

ψ → $K_s K^\pm \pi^\mp$
(a)
2.5
2.0
1.5
1.0
0.5
m $(K_s \pi^\pm)$ (GeV/c^2)
ψ → $K^0 K^\pm \pi^\mp$
(b)
2.5
2.0
1.5
1.0
0.5
m $(K^0 \pi^\pm)$ (GeV/c^2)
0.5
1.0
1.5
2.0
2.5
m $(K^\pm \pi^\mp)$ (GeV/c^2)
2802A7

Figure 2

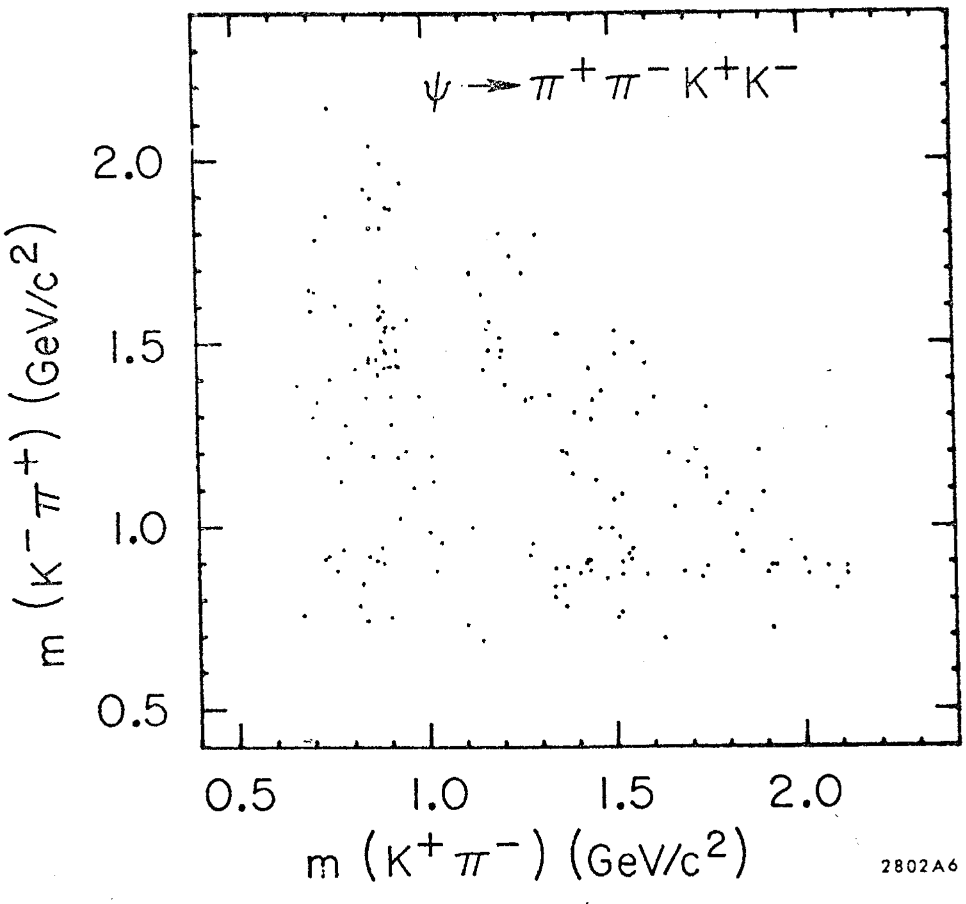

$\psi \to \pi^+\pi^- K^+K^-$
2.0
1.5
1.0
0.5
$m\ (K^-\pi^+)\ (GeV/c^2)$
0.5
1.0
1.5
2.0
$m\ (K^+\pi^-)\ (GeV/c^2)$
2802A6

Figure 3