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RESONANCE PRODUCTION IN DIFFRACTIVE $\pi^-N \rightarrow K_S^0K_S^0\pi^-N'$ AT 200 GeV/c

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Abstract

The reaction $\pi^- N \to K^0_s K^0_s \pi^- N'$ at 200 GeV/c has been observed with a sensitivity of 450 $\pm$ 150 events/μb. The $K^0_s K^0_s \pi^-$ system exhibits copious $K^{*-}(890)K^0$ and $f^0(1270)\pi^-$ production, as well as $f'(1515)\pi^-$, $K^{*-}(1430)K^0$ and $K^{*-}(1780)K^0$. These resonances occur predominantly at threshold. The diffractive $K^0_s K^0_s \pi^-$ cross section is 3.4 $\pm$ 1.1 μb. Diffractive production of $A_3^-(1680)$ is observed when $f^0\pi^-$ and $K^{*-}(890)K^0$ are seen.

Although diffraction dissociation has been widely observed in high energy hadroproduction experiments,[1] relatively little information[2] is available on the flavor dependence of this process. We present results on the diffraction dissociation of a 200 GeV/c π^- beam into $K^0_s K^0_s \pi^-$, observe resonance production in this final state, and make comparisons with diffractive $\pi \rightarrow 3\pi$.[3]

The experiment (E-580) was carried out in a 200 GeV/c π^- beam in the M6W line using the Fermilab Multiparticle Spectrometer.[4] A 20-element 13 cm long scintillator target which provided longitudinal primary vertex location was followed by a 2m-helium filled decay region where neutral strange particles (V^o's) materialized into charged tracks. A bending magnet, which imparted a 696 MeV/c transverse momentum change to each charged particle, was followed by a 30 cell atmospheric Cherenkov counter and by 24 large spark chamber planes. A proportional wire chamber (PWC) system with 10^4 wires measured the incident beam, as well as primary and decay charged particle trajectories before and after the magnet, and provided fast trigger information.

The V^oV^o trigger required a charged particle multiplicity increase of 4 ± 1 in the decay volume by sampling two PWC's before and 5 PWC's after the decay volume. In addition, the primary charged multiplicity, measured before the decay volume, was less than 6. The incident beam rate of $6 \times 10^5 \pi^-$ per sec. yielded 1.2×10^6 triggers.

All triggers were processed through pattern recognition and geometry programs which performed three dimensional fits to all track parameters using a detailed magnetic field map. The K^o

effective mass had a FWHM of 14 MeV/c^2 and the Λ a FWHM of 5 MeV/c^2. Constrained fits were made to the V° mass, V° decay vertex, and V°-V°-beam primary vertex. Approximately 70,500 events with fit probabilities greater than 10^{-5}, 3 x 10^{-3}, and 3 x 10^{-3} respectively were accepted, of which 62% were $K_s^o K_s^o$, 16% $K_s^o \Lambda$, 13% $K_s^o \bar{\Lambda}$, 8%$\Lambda\bar{\Lambda}$, and 1%$\Lambda\Lambda$ or $\bar{\Lambda}\bar{\Lambda}$.

This paper is based on a sample of 4257 $K_s^o K_s^o$ events which had one and only one negatively charged primary track passing through the spectrometer. The estimated Λ, $\bar{\Lambda}$ contamination in this sample is 2%. The angular acceptance of the spectrometer magnet was ± 84 mrad. horizontally and ±50 mrad. vertically. As evaluated by Monte Carlo simulation the total geometric acceptance for diffractive events of the magnet, downstream tracking chambers, and 1 in^2 downstream beam veto was 91% (16.7% if the K_s^o decay probability is included). Trigger and track reconstruction inefficiencies lead to systematic uncertainties in the cross section. Therefore we normalize our data by parametrizing the inclusive ($K_s^o K_s^o$) data of ref. 5 by e^{-6x} where $x = 2P_L^{cm}/ s$, and taking our x-dependent acceptance from Monte Carlo, we find an average sensitivity for diffractive $K_s^o K_s^o$ events to be 450 ± 150 events/μb.

To isolate the diffractive component in our $K_s^o K_s^o \pi^-$ data, we plot the recoiling mass squared (MM^2) in Fig. 1(a) assuming a nucleon target. We observe a prominent low mass peak whose FWHM is only slightly greater than the calculated spectrometer resolution of 7.6 (GeV/c^2)^2. The curve in Fig. 1(a) is the result of a fit using a log-normal distribution[6], plus polynomial background. The shape of the peak indicates the presence of diffractively excited nucleon states which we are unable to resolve from an unexcited nucleon. This double diffraction, whose $1/M^2$ behavior[7] is reproduced by our fitted distribution, is estimated to be ~ 1/3 of the MM^2 peak.[8] In the discussions that follow we require $MM^2 < 16\ (GeV/c^2)^2$ in order to minimize the background from inelastic processes. This background is still 25 ± 2%, while double diffraction is ~ 7% of the 992 surviving events. This implies a diffractive $\pi^- \rightarrow K^o_s K^o_s \pi^-$ cross section of 3.4 ± 1.1 μb. When compared with lower energy results,[9] these data indicate a weak ($P_{LAB}^{-.3 \pm .15}$) energy dependence.

In Fig. 1(b) we plot the variable t', defined as $t' = |t - t_{min}|$ where t is the square of the four-momentum transfer from the beam to the $K^o_s K^o_s \pi^-$ system. A fit to the distribution of the form $dN/dt' = Ae^{-Bt'} + Ce^{-Dt'}$ yields A = 127.0 ± 14.8 events/0.4 $(GeV/c)^2$, B = 9.6 ± 1.9 $(GeV/c)^{-2}$, C = 48.1 ± 9.9 events/.04 $(GeV/c)^2$, and D = 2.0 ± 0.2 $(GeV/c)^{-2}$. The value of the slope parameter B is consistent with values found at lower energies[10], to that found for 3π diffractive production[3], and to values for pion-nucleon elastic scattering.[11] The value of the slope parameter D is consistent with that obtained in fitting the t' distribution for events with $MM^2 > (16\ GeV/c^2)^2$. Our t' resolution is such that coherent production from carbon in our target would appear in the first bin of Fig. 1(b). The lack of this enhancement at low t' reflects a trigger bias which required a pulse height from the active target corresponding to greater than minimum ionization and would not be satisfied by a low t' recoiling carbon nucleus.

The $K_s^oK_s^o$ mass distribution for our 992 event sample is shown in Fig. 2(a). The curve uses a polynomial in mass for the background and Breit Wigner resonance forms for the f° and f', which constitute 8 ± 4% and 6 ± 2% of the $K_s^oK_s^o$ data. In Fig. 2(b) we show the $K_s^o\pi^-$ mass distribution (2 combinations/event) and estimate the amount of $K^{*-}(890)$ to be 21 ± 3% of the data. We have added Breit Wigner resonance forms for the higher mass K*'s [($K^{*-}(1430)$, $K^{*-}(1780)$, and $K^{*-}(2200)$)], but although the χ^2/DOF for the fit improves the evidence in Fig. 2(b) for K*(1430) is not compelling.

When we look at the $K_s^oK_s^o$ and $K_s^o\pi^-$ mass distributions for various intervals of $K_s^oK_s^o\pi^-$ mass, the underlying resonance structure becomes clearer. In Fig. 2(c) we show the $K_s^o\pi^-$ mass when we require the $K_s^oK_s^o\pi^-$ mass to lie between 2.1 and 2.4 GeV/c^2 and note the significant $K^{*-}(1430)$ signal. We summarize our results in Fig. 3. We plot the $K_s^oK_s^o\pi^-$ mass in rather course bins [Fig. 3(a)]. In Fig. 3(b-c) we plot the number of f° and f' events and in Fig. 3(d-f) the number of K* events per GeV/c^2 of $K_s^oK_s^o\pi^-$ mass. One can clearly see in Fig. 3(d-f) the $K^{*-}(1430)$ and $K^{*-}(1780)$ being produced once their thresholds are crossed. The f° and f' in Fig. 3(b-c) are also most prominent at threshold.

We display in Fig. 4(a), unshaded, the $K_s^oK_s^o\pi^-$ mass distribution. If we select events with f°, we observe an enhancement at low $K_s^oK_s^o\pi^-$ mass. Fitting to a polynomial background plus Breit Wigner resonance form using the $A_3^-(1680)$ resonance parameters of Daum et al.,[3] we find an A_3^- contribution of 74 ± 22 events. We reduce this number by 32% to account for

MM2 plot. This implies a diffractive $A_3^-(1680)$ signal 51 ± 16 events or a cross section times branching ratio of 0.11 ± 0.04 μb. Taking the measured diffractive A_3^- cross section of ref. 3 scaled to 200 GeV/c using $P_{LAB}^{-0.42}$ and correcting for f° decay modes gives $\sigma(\pi^- \to A_3^- \to f^\circ\pi^-) = 32 \pm 3\mu b$. Using the $f^\circ \to K\bar{K}$ branching ratio[12] (2.9×10^{-2}) yields $\sigma(\pi^- \to A_3^- \to f^\circ\pi^- \to K_s^\circ K_s^\circ \pi^- \to \pi^+\pi^-\pi^+\pi^-\pi^-) = 0.10 \pm 0.01$ μb, in excellent agreement with our determination.

A similar analysis on the $K_s^\circ K_s^\circ \pi^-$ mass distribution has been performed requiring $K^{*-}(890)$ production, Fig. 4(b). The fit reveals 51 ± 16 events corrected for inelastic and double diffractive background which fit $A_3^- \to K^{*-}K^\circ \to K_s^\circ K_s^\circ \pi^-$ and gives a partial width ratio $\Gamma(A_3^- \to f^\circ\pi^- \to K_s^\circ K_s^\circ \pi^-)/\Gamma(A_3^- \to K^{*-}K^\circ \to K_s^\circ K_s^\circ \pi^-) = 1.0 \pm 0.4$. A partial wave analysis at 16 GeV/c[13] based on $A_3^- \to K^+K^-\pi^-$ gives the partial width ratio $\Gamma(A_3^- \to K^*\bar{K})/\Gamma(A_3^- \to f\pi^-) = 0.075 \pm 0.025$ which when corrected for decay modes gives $\Gamma(A_3^- \to f^\circ\pi^- \to K^\circ\bar{K}^\circ\pi^-)/\Gamma(A_3^- \to K^{*-}K^\circ \to K^\circ\bar{K}^\circ\pi^-) = 1.16 \pm 0.39$ in good agreement with our result. The data of Daum et al.[3] indicate the ratio $\Gamma(A_3^- \to f^\circ\pi^- \to \pi^+\pi^-\pi^-)/\Gamma(A_3^- \to \rho^\circ\pi^- \to \pi^+\pi^-\pi^-) = 1.75 \pm .09$. When SU(3) symmetry, phase space, and branching fractions are considered these data imply a partial width ratio $\Gamma(A_3^- \to f^\circ\pi^- \to K^\circ\bar{K}^\circ\pi^-)/\Gamma(A_3^- \to K^{*-}K^\circ \to K^\circ\bar{K}^\circ\pi^-) = 0.85 \pm .04$ which also agrees with our result.

In summary, we have studied the diffractive dissociation of π^- into $K_s^\circ K_s^\circ \pi^-$ and found evidence for considerable resonance production. Requiring an $f^\circ \to K_s^\circ K_s^\circ$ decay or $K^{*-}(890)$ enhances the low mass portion of the $K_s^\circ K_s^\circ \pi^-$ spectrum[14] and shows some evidence for the $A_3^-(1680)$. The production of higher mass K^{*-}'s is most prominent at threshold.

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Footnotes and References

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Figure Captions

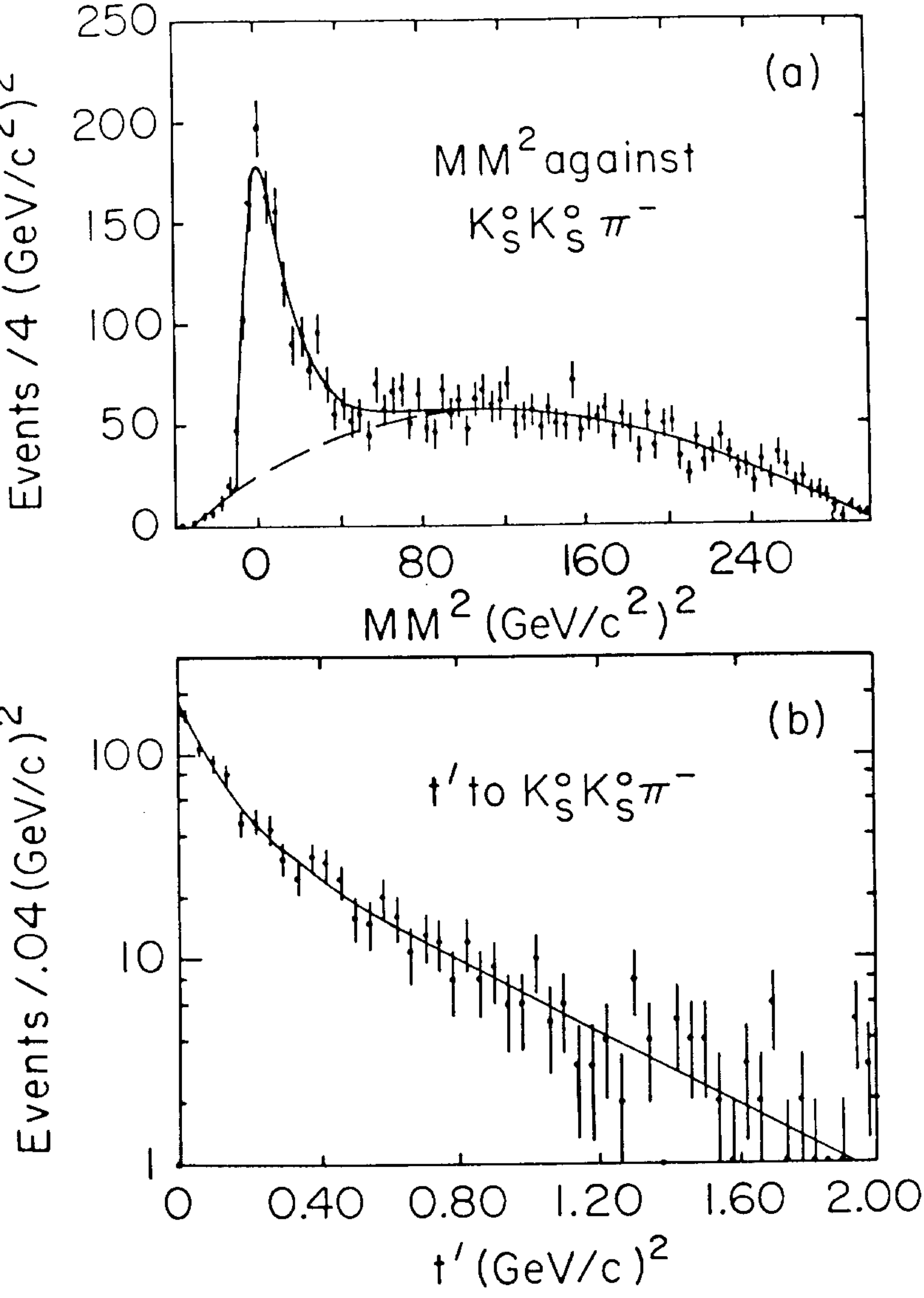
1. (a) Missing mass squared for all $K^o_sK^o_s\pi^-$ final state events.
(b) t' for the sample of events with $MM^2(KK\pi) \lesssim 16(GeV/c^2)^2$. The curves are explained in the text.

2. For the sample with $MM^2(KK\pi) \lesssim 16(GeV/c^2)^2$:
(a) the $K^o_sK^o_s$ effective mass distribution,
(b) the $K^o_s\pi^-$ effective mass distribution,
(c) the $K^o_s\pi^-$ effective mass distribution, with the $K^o_sK^o_s\pi^-$ mass between 2.1 and 2.4 (GeV/c^2). The curves are explained in the text.

3. For the sample with $MM^2 < 16$ $GeV/c^2)^2$:
(a) the total number of events per GeV/c^2 of $K^o_sK^o_s\pi^-$ mass
(b,c) respectively the number of $[f^o(1270)\pi^- \to K^o_sK^o_s\pi^-]$ events and $[f'(1515\pi^-) \to K^o_sK^o_s\pi^-]$ events per GeV/c^2 of $K^o_sK^o_s\pi^-$ mass.
(d,e,f) respectively the number of $[K^{*-}(890)K^o \to K^o_s\pi^-K^o_s]$, $[K^{*-}(1430)K^o \to K^o_s\pi^-K^o_s]$, and $[K^*(1780)K^o \to K^o_s\pi^-K^o_s]$ per GeV/c^2 of $K^o_sK^o_s\pi^-$ mass.

4. For the sample with $MM^2 < 16$ GeV/c^2:
(a) the $K^o_sK^o_s\pi^-$ effective mass distribution events. The shaded histogram requires $f^o(1270) \to K^o_sK^o_s$ and
(b) the effective mass distribution for diffractive $K^o_sK^o_s\pi^-$ events requiring $K^*(890) \to K^o_s\pi^-$. The curves are explained in the text.

Figure 1



(a)
MM^2 against
$K^o_S K^o_S \pi^-$
Events /4 (GeV/c^2)^2
250
200
150
100
50
0
0
80
160
240
MM^2 (GeV/c^2)^2
(b)
t' to $K^o_S K^o_S \pi^-$
Events /.04 (GeV/c)^2
100
10
1
0
0.40
0.80
1.20
1.60
2.00
t' (GeV/c)^2

Figure 2

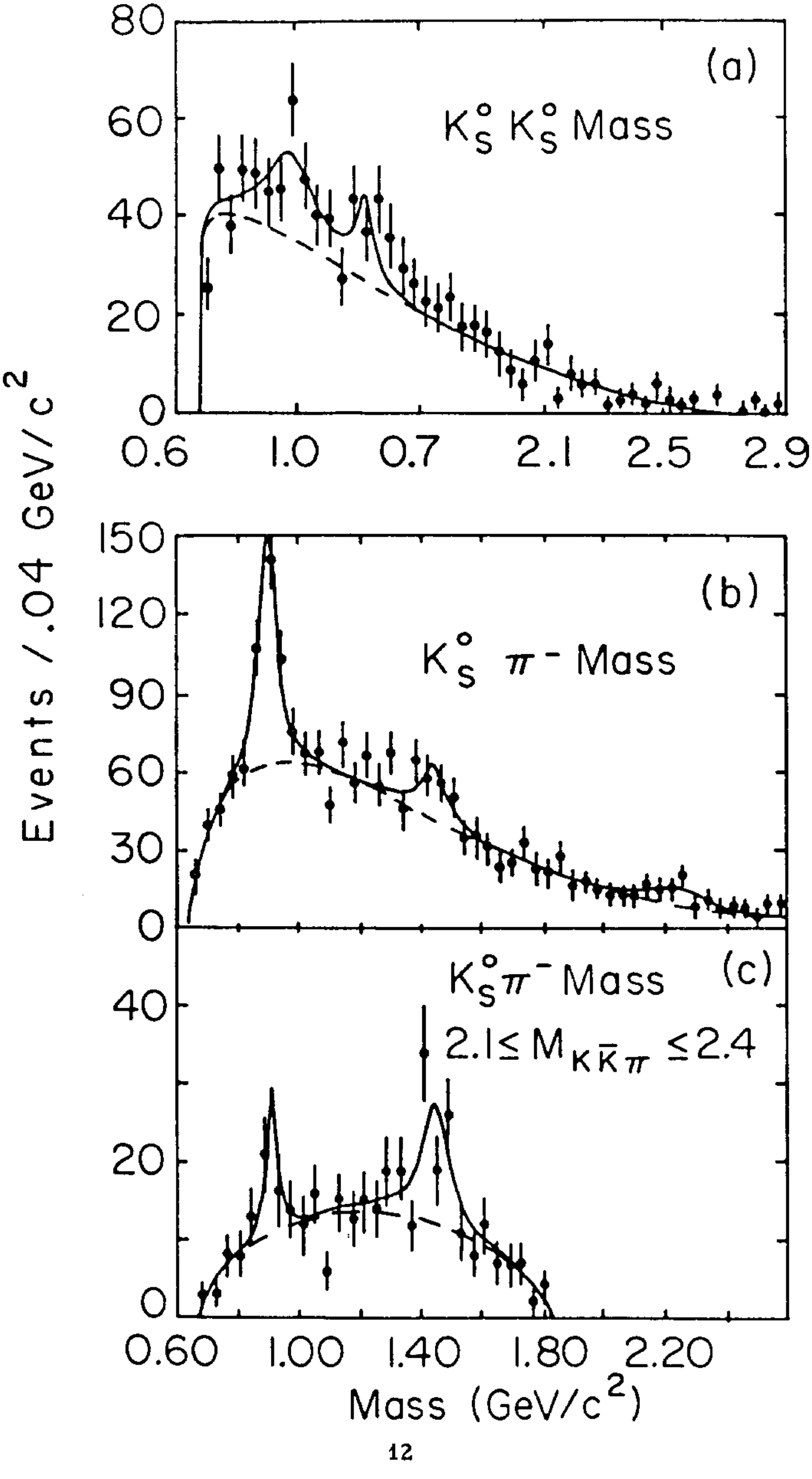
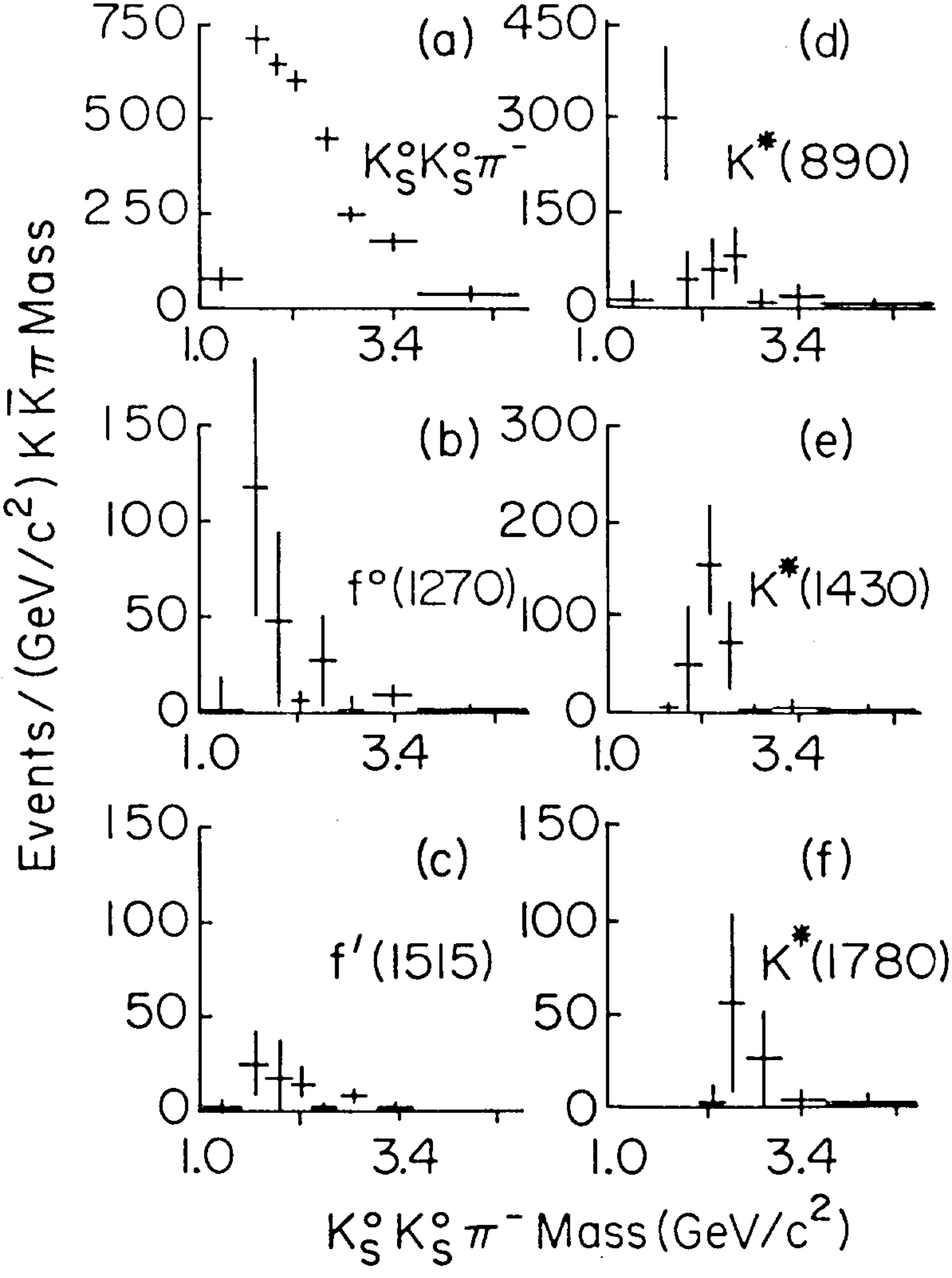
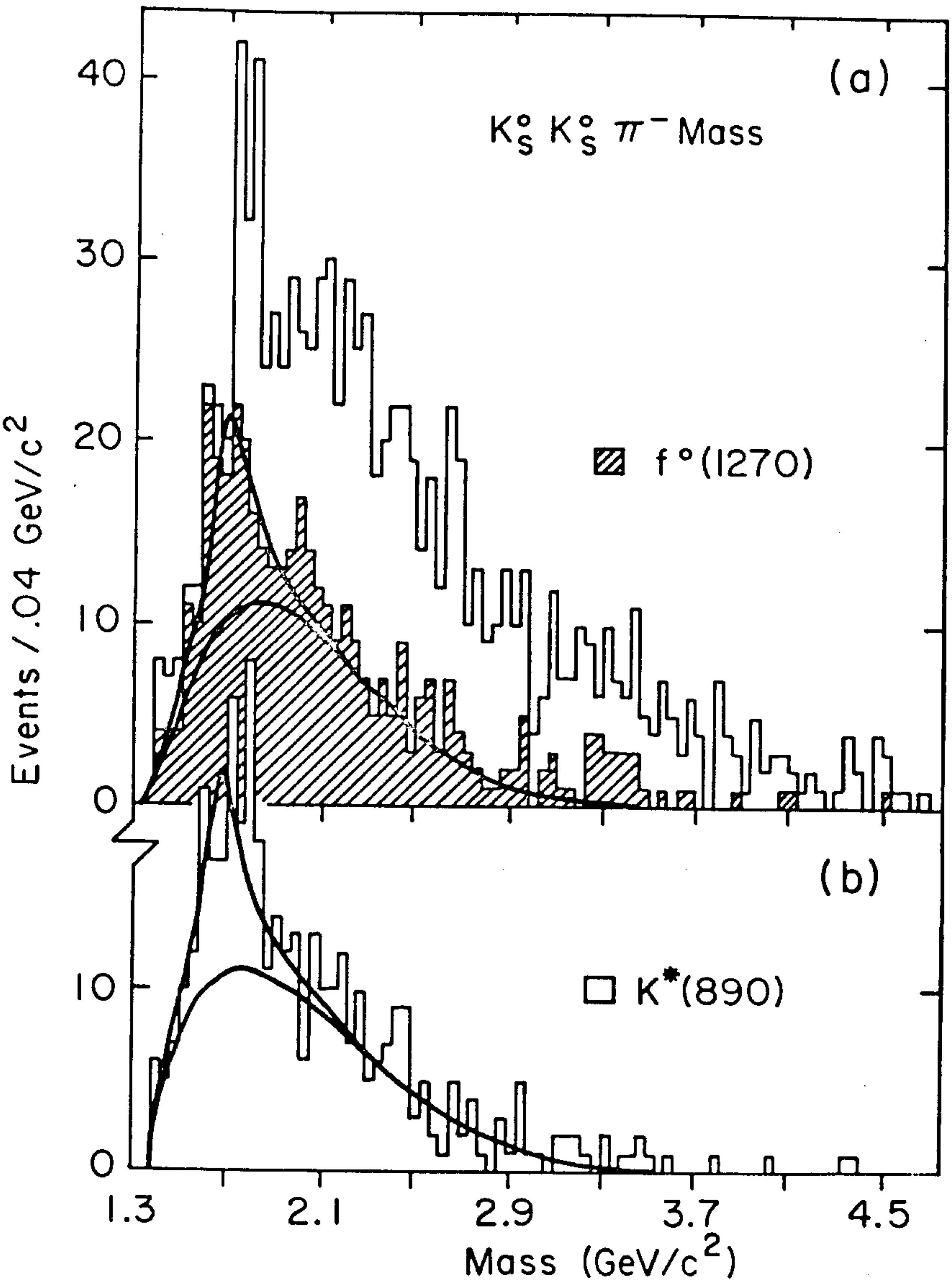

(a)
$K^o_S K^o_S$ Mass
(b)
$K^o_S\ \pi^-$ Mass
(c)
$K^o_S \pi^-$ Mass
$2.1 \leq M_{K\bar{K}\pi} \leq 2.4$
Events / .04 GeV/c^2
Mass (GeV/c^2)
0.6
1.0
0.7
2.1
2.5
2.9
0.60
1.00
1.40
1.80
2.20

Figure 3



(a)
$K_S^o K_S^o \pi^-$
(b)
f°(1270)
(c)
f′(1515)
(d)
K*(890)
(e)
K*(1430)
(f)
K*(1780)
Events / (GeV/c²) $K\bar{K}\pi$ Mass
$K_S^o K_S^o \pi^-$ Mass (GeV/c²)

Figure 4


(a)
$K_S^o K_S^o \pi^-$ Mass
f°(1270)
(b)
K*(890)
Events / .04 GeV/c²
40
30
20
10
0
10
0
1.3
2.1
2.9
3.7
4.5
Mass (GeV/c²)