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[7]Events in Reactions (1) and (2) were processed through the Purdue version of TVGP-SQUAW. If an event has an unseen spectator proton, SQUAW, in fitting the event, sets the spectator momentum equal to zero with errors in P_x, P_y, and P_z equal to 30, 30, and 40 MeV/c, respectively. Events were said to be consistent with Reaction (3) if the missing neutrals had an effective mass greater than the mass of two π^0's. For further discussion of event processing and selection for Reaction (3) see R. J. Miller, S. Lichtman, and R. B. Willmann, Phys. Rev. 178, 2061 (1969).

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[9]With the knowledge of the cross sections for Reactions (2) and (3) and the charged-to-neutral branching ratio for the η decay we find that there should be 175 ± 40 η events in Reaction (3).

[10]35 events lie in the $\eta\pi^+$ band, 44 events lie in the $\eta\pi^-$ band, and six events lie in the overlap region.

[11]The technique of folding the Dalitz plot about the 45° line is free of kinematic ambiguity unless the crossing region of the two δ bands occurs well inside of the Dalitz plot. This ambiguity only becomes important for $M(\eta\pi^+\pi^-) > 1.4$ GeV/c^2.

[12]We have searched for possible kinematic effects or interferences in the overlap of the D and δ bands and have found none. There is no evidence for $\Delta(1236)$ or structure in the $\pi^-\pi^+$ system for these events. Indeed for true D events the $\pi^-\pi^+$ system is in an $I=0$ state and there should be no ρ production which is in agreement with our data.

[13]Phase space for the folded $M(\eta\pi)$ spectrum was interpolated from the distributions obtained by projecting the $M(\eta\pi)$ distributions from bands on either side of the D region. Similarly phase space for the $M(\eta\pi^+\pi^-)$ spectrum was interpolated from the two spectra obtained by requiring that one $M(\eta\pi)$ combination lie in an 80-MeV/c^2 band below the δ region and one $M(\eta\pi)$ combination lie in an 80-MeV/c^2 band above the δ region.

[14]The calculated resolution function for the η' agrees with the experimentally observed width of 20 MeV. We have assumed, therefore, that the calculated resolution functions are also correct in the D and the δ regions.

IS THE L A MESON?*

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The $K\pi\pi$ enhancement at 1780 MeV (the "L meson") is copiously produced in our K^+p experiment at 12 GeV/c. We show that this "meson" can be explained as a threshold enhancement in the $K_N(1420)\pi$ system. We see no evidence for this enhancement in channels other than $K_N(1420)\pi$.

A $K\pi\pi$ enhancement at about 1780 MeV has been observed in a number of experiments studying $K^\pm p$ and K^-d interactions.[1-5] Observations of this enhancement in the $K^*(890)\pi$, $K_N(1420)\pi$, $K\rho$, and $K\omega$ channels have been reported.

In this experiment the L enhancement is studied in the reaction $K^+p \rightarrow L^+p$ with incident K^+ momentum of 12 GeV/c. We find that it can be explained as a threshold enhancement in the $K_N(1420)\pi$ system in the reaction $K^+p \rightarrow K_N(1420)\pi p$. In addition we find a similar peak starting at $K\pi\pi$ threshold for any restricted $K\pi$ mass interval independent of $K\pi$ resonance formation. This suggests that the L enhancement is due to the general behavior of the $K\pi\pi$ mass distribution for a restricted $K\pi$ mass interval, rather than to the production of a resonance. We find no evidence for an L enhancement in the $K^*(890)\pi$, $K\rho$, or $K\omega$ channels.

The data for this experiment were obtained in a 600 000-picture exposure of the Stanford Linear Accelerator Center 82-in. hydrogen bubble chamber to an rf-separated 12-GeV/c K^+ beam.[6]

The properties of the L enhancement were studied by using the reactions

$$K^+p \rightarrow K^+p\pi^+\pi^- \quad (14\,310 \text{ events}), \tag{1}$$

$$K^+p \rightarrow K^+p\pi^+\pi^-\pi^0 \quad (10\,288 \text{ events}). \tag{2}$$

These events come from an analysis of approximately $\frac{1}{3}$ of the total 30-event/μb path length.[7] Only events of Reaction (2) with lab momentum of the proton less than 1 GeV/c were included in this analysis. This cut does not affect the L signal in this channel, since almost all of the L events produced in Reaction (1) are associated with $P_p < 1$ GeV/c.

Figure 1(a) shows the $K^+\pi^-$ invariant-mass distribution for all events of Reaction (1). $K^*(890)$ and $K_N(1420)$ production is evident. Figure 1(b) displays the $K\pi\pi$ invariant mass for the same events. The well-known Q enhancement[5] appears as a very striking peak centered near 1300 MeV with a width of about 250 MeV. The L enhancement is also clearly seen as a broad peak centered at about 1780 MeV.[8] Figure 1(c) displays the $K\pi\pi$ mass distribution for events whose $K\pi$ invariant mass lies in a band centered around the $K_N(1420)$.[9] This selection is seen to greatly enhance the L signal; in fact, the L enhancement in Fig. 1(b) appears undiminished by the selections which gave Fig. 1(c). When the Δ^{++} events are removed [shaded histogram of Fig. 1(c)] an especially clean L signal is seen, reduced in size, however.[10]

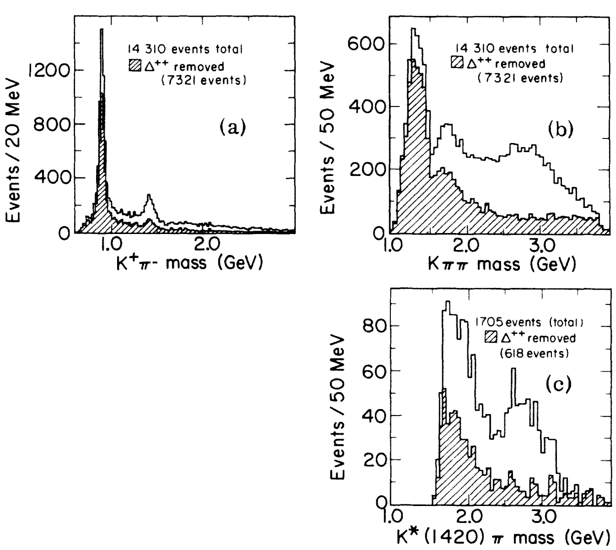

FIG. 1. (a) $K^+\pi^-$ invariant mass for Reaction (1). (b) $K\pi\pi$ invariant mass for Reaction (1). (c) $K\pi\pi$ invariant mass for the $K^*(1420)$ events of Reaction (1).

It appears from Fig. 1(c) that the enhancement at 1780 MeV in Fig. 1(b) is associated with the threshold of a single channel, $K_N(1420)\pi$.

In order to further clarify this observation we have looked at the $K\pi\pi$ mass distribution for different bands of $K\pi$ mass in 180-MeV intervals. We find the results shown in Fig. 2. Each interval in the $K\pi$ mass produces a threshold enhancement similar to the L (or Q) at a mass value which moves with the threshold.[11] This general behavior of the $K\pi\pi$ mass distribution when a restriction is imposed on the $K\pi$ mass implies that for every $K\pi$ enhancement there will be a corresponding threshold enchancement in the $K\pi\pi$ mass distribution.[12]

A crucial test of the possible resonant nature of the L enhancement is the existence of other decay modes. We have made a search for the $K^*(890)\pi$, $K\rho$, and $K\omega$ decay modes which have been previously reported. Figure 3(a) is a plot of the $K\pi\pi$ mass of Reaction (1) for events whose $K^+\pi^-$ mass forms a $K^*(892)$ (Δ^{++} events have been removed). This distribution shows no evidence for a $K^*(890)\pi$ enhancement at 1780 MeV. Although one could envision a background distribution that would indicate an excess of events in the L region, there is no indication of a Breit-Wigner–type structure at 1780 MeV. Some experimenters have concluded that the L enhancement does exist in $K^*(890)\pi$.[13] However, their evidence appears inconclusive in view of the uncertainty in the background and the relatively limited statistics of their experiments.

Figure 3(b) shows the $K\pi\pi$ mass distribution of Reaction (1) for events whose $\pi\pi$ invariant mass lies in the ρ band. The shaded part of the histo-

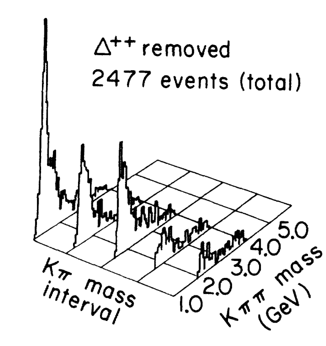

FIG. 2. $K\pi\pi$ invariant-mass distribution of Reaction (1) for various intervals of $K\pi$ invariant mass. The $K\pi$ mass intervals (in GeV) chosen are (from left to right): 0.97 to 1.15, 1.15 to 1.33, 1.33 to 1.51, 1.51 to 1.69, and 1.69 to 1.87.

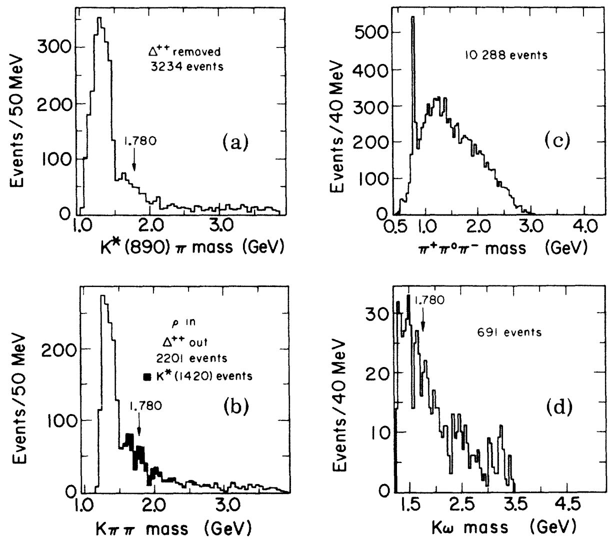

FIG. 3. Search for non-$K^*(1420)\pi$ decay modes of the L enhancement. (a) $K\pi\pi$ invariant mass of Reaction (1) for $K^*(890)$ events. (b) $K\pi\pi$ invariant mass of Reaction (1) for events whose $\pi\pi$ mass lies in the ρ band. Shaded events are the contribution of the $K^*(1420)$ events which overlap the ρ band. (c) Invariant mass of $\pi^+\pi^-\pi^0$ for events of Reaction (2). (d) $K\pi\pi\pi$ invariant mass of Reaction (2) for ω events.

gram represents the contribution from the $K_N(1420)$ events which contaminate the ρ sample. As is seen, the excess of events in the L region is associated with the $K_N(1420)$ rather than with a genuine $K\rho$ decay mode of the L.

Figure 3(c) displays the $\pi^+\pi^-\pi^0$ invariant mass for Reaction (2). The ω meson is clearly seen. Figure 3(d) shows the plot of $K^+\pi^+\pi^-\pi^0$ mass for the ω events. There is no evidence for a $K\omega$ enhancement at 1780 MeV.

We do not report upper limits for the branching ratios which are consistent with zero because they might be misleading. Such limits are very highly dependent on the form of the background that is assumed.

In conclusion, our data show that the L enhancement is a result of copious production of $K_N(1420)$ with no evidence for the other previously reported decay modes. Whether or not such broad threshold enhancements appearing in a single channel are regarded as resonances is a question of current theoretical interest.[14]

We gratefully acknowledge the assistance of the staff of the Stanford Linear Accelerator and the 82-in. bubble chamber in obtaining the data for this experiment. We also acknowledge the Lawrence Radiation Laboratory Group A Scanning and Measuring Group for their help in data reduction. We thank Dr. E. L. Berger for helpful discussions concerning the multiperipheral model.

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[7]Events with a $K^0\pi^0$ instead of $K^+\pi^-$ in Reaction (1) have also been analyzed, and are consistent with the results reported here.

[8]It is very difficult to estimate the width for this enhancement, since it depends on the background estimate. However, the width is larger than observed in other experiments, where the values range from 60 to 130 MeV (see Refs. 1-5). The resolution of this experiment is about 12 MeV in this mass region. We have plotted the data of Fig. 1(b) in smaller mass intervals, but no significant fine structure has appeared. In particular we have no evidence for the $K^*(1660)$ reported in Ref. 4.

[9]The bands in invariant mass used to define events of various resonances are the following:

$K_N(1420)$, $1.33 < M(K^+\pi^-) < 1.51$;

$K^*(892)$, $0.84 < M(K^+\pi^-) < 0.94$;

$\Delta^{++}(1236)$, $M(p\pi^+) < 1.5$;

ρ, $0.66 < M(\pi^+\pi^-) < 0.86$;

ω, $0.75 < M(\pi^+\pi^-\pi^0) < 0.81$.

[10]The reflection of the decay angular distribution of the $\Delta^{++}(1236)$ produces the broad enhancement at a mass of about 2.8 GeV in Fig. 1(c). It also produces a broad enhancement of about the same number of events under the L region.

[11]An explanation for the $K\pi\pi$ peaking at threshold for any fixed $K\pi$ mass can be found in the double-Regge-pole model, which gives a good qualitative fit to the threshold enhancements that we see.

[12]We have investigated the momentum transfer and decay angular distribution of this threshold enhancement as a function of $K\pi$ mass and find no significant anomalies in the L region.

[13]See Refs. 1 and 3; also note that some other experimenters observed the absence of a $K^*(890)\pi$ decay mode for the L enhancement. [J. Andrews, J. Lach, T. Ludlum, J. Sandweiss, H. D. Taft, and E. L. Berger, Phys. Rev. Letters 22, 731 (1969).]

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MEASUREMENT OF THE BRANCHING RATIO $K_L^0 \rightarrow 2\pi^0/K_L^0 \rightarrow 3\pi^0$ †

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The rate of the CP-nonconserving decay $K_L^0 \rightarrow 2\pi^0$ has been measured relative to that of $K_L^0 \rightarrow 3\pi^0$ using a monoenergetic K beam and a nearly 4π solid-angle detector system employing lead-plate spark chambers and shower counters. The measured branching ratio $1.31\,\% \pm 0.18\,\%$ (statistical) $\pm 25\%$ (systematic) leads to a value for the CP-nonconservation parameter $|\eta_{00}|^2$ of $(14.1 \pm 3.4) \times 10^{-6}$.

We report a measurement of the branching ratio $(K_L^0 \rightarrow 2\pi^0)/(K_L^0 \rightarrow 3\pi^0)$ which is then used to determine the CP-nonconservation parameter $|\eta_{00}|^2$. A number of measurements of this important parameter have been published, but their disagreement, and the unusual experimental difficulties of the measurement, encourage further efforts. Some of the previously published values for $|\eta_{00}|^2$ are[1-6] $(18^{+11}_{-6}) \times 10^{-6}$, $(24 \pm 5) \times 10^{-6}$, $(-2 \pm 7) \times 10^{-6}$, $(5.1 \pm 1.2) \times 10^{-6}$, $(4.8 \pm 1.9) \times 10^{-6}$, and $(13 \pm 4) \times 10^{-6}$. Other results lying between these disparate values have emerged at topical conferences and in preliminary reports, but these have not yet reached publication.

This experiment was designed to detect all $K_L^0 \rightarrow 3\pi^0$ as well as $K_L^0 \rightarrow 2\pi^0$ decays and to provide internal checks on possible systematic errors. Important features included (a) a "monochromatic" K_L^0 beam, (b) a counter trigger which strongly rejected neutron-induced events while accepting $3\pi^0$ and $2\pi^0$ decays with nearly equal efficiency, (c) a thick lead-plate spark-chamber detector which subtended nearly 4π solid angle for $K_L^0 \rightarrow 2\pi^0$ decays, and (d) normalization to $K_L^0 \rightarrow 3\pi^0$ decays, which were observed mainly as five-shower and six-shower events. Photon energies were measured by spark counting.

K_L^0 mesons were produced from the reaction $\pi^- p \rightarrow K^0\Lambda^0$ just below $K^0\Sigma^0$ threshold; their decay was observed in the photon-converting chambers nearly surrounding an air-filled, 1-m^3 cubical volume centered 6 m from the hydrogen target. Those entering the decay volume had a momentum of 530 ± 50 MeV/c (full width at half-maximum). The momentum distribution was calculated from the measured π^- spectrum at the H_2 target and agrees with measurements of K_L^0 momentum from $\pi^+\pi^-\pi^0$ decays in which both showers are observed. To convert and reject photons from the hydrogen target, a filter, consisting of layers of lead and scintillator, was placed between the target and the chamber system. The lead thickness (10 cm) was optimized to remove photons and retain K_L^0's.

The rear (down-beam) spark chamber presented about 8 radiation lengths, and the four side-wall chambers about 7, to photons entering with normal incidence. For each chamber the first four-gap module had Al plates for identification of entering charged particles. In front of each