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**DISCLAIMER**

# EVIDENCE FOR STRUCTURE IN THE $K\pi$ MASS SYSTEM NEAR 1.85 GeV*

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ABSTRACT

We present evidence for structure in the $K\pi$ system at a mass near 1.85 GeV in the reaction $K^+n \to K^+\pi^-p$ at 12 GeV/c. One interpretation of the observations is the production by pion exchange of a $J^P = 3^-$ $K^*$ resonance at about this mass, which interferes strongly with other processes.

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As part of a systematic study of the reaction $K^+n \to K^+\pi^-p$, we have investigated $K^+\pi^-$ scattering in the mass region above the $K^*(1420)$. The data are from a 500 000-picture exposure of the SLAC 82-inch bubble chamber, filled with deuterium, to a 12-GeV/c rf-separated $K^+$ beam. This film has been analyzed and has yielded a sample of some 6400 $K^+n \to K^+\pi^-p$ events. The experimental details have been reported previously.[1-3]

There is good evidence that $K^*$ production in this reaction is dominated at low momentum transfers by the pion exchange mechanism.[2,3] Therefore, in order to enhance this process, we have imposed on all the data presented in this Letter a cut on the momentum transfer from the incident neutron to the final proton $|t'| < 0.2$ $(\text{GeV}/c)^2$, where $t' = t - t_{min}$. The distributions in the Treiman-Yang angle are then consistent with isotropy, and the distributions in $t'$ are exponential with a slope of about 10 $(\text{GeV}/c)^{-2}$, throughout the $K^+\pi^-$ mass range under consideration in this analysis.

The Dalitz plot for this reaction has been published previously.[3] In

Fig. 1a we show a scatter plot of cos $\theta$ vs $M(K^+\pi^-)$, where $\theta$ is the polar angle in the Gottfried-Jackson frame; i.e., the angle of the outgoing $K^+$ with respect to the beam in the $K^+\pi^-$ rest frame. In this plot vertical bands corresponding to the $K^*(890)$ and $K^*(1420)$ and a horizontal band corresponding to $N^*$ production are very clear. In addition, we observe a concentration of events in the region $-0.8 < \cos\theta < -0.2$ and $M(K\pi) \sim 1.85$ GeV. We shall be concerned in the rest of this Letter with the interpretation of this effect.

Figure 1b shows the $M(K^+\pi^-)$ mass projection, in which no cut other than $|t'| < 0.2\ (\text{GeV}/c)^2$ has been made. Besides the $K^*(890)$ and the $K^*(1420)$, there is a suggestion of a mass enhancement at about 1.85 GeV.

In Fig. 2 we show the distributions as functions of $M(K\pi)$ of the quantities $N\langle Y_1^0\rangle$ to $N\langle Y_6^0\rangle$, which are the products of the average values of the particular spherical harmonics with the actual number of events in each bin. In the region of interest $[M(K^+\pi^-) \sim 1.85$ GeV] we observe substantial increases in the values of $N\langle Y_3^0\rangle$ and $N\langle Y_5^0\rangle$. These increases occur over a mass range of about 150 MeV. In addition, $N\langle Y_6^0\rangle$ begins to show a significant nonzero value at a mass of about 1.85 GeV. There is no evidence for any appreciable deviation from zero of $N\langle Y_\ell^0\rangle$, where $\ell > 6$, for $K\pi$ masses below 2.0 GeV. Thus if we consider only waves with $j \leq 3$, these sharp increases are most naturally attributable to the interference of a rapidly increasing F-wave amplitude at a $K\pi$ mass value of about 1.85 GeV, with waves of opposite parity; e.g., S and D waves.

Since the existence of F waves in this mass region appears necessary, we may investigate this effect further by a judicious cut on the angular distribution to enhance the F-wave signal. Since $|Y_3^0|^2$ has zeros at $\cos\theta = 0$ and $\cos\theta = \pm 0.77$ and maxima at $\cos\theta = \pm 0.45$ and $\cos\theta = \pm 1$, we divide the data into four regions of cos $\theta$: $\cos\theta > 0.77$, $0 < \cos\theta \leq 0.77$,

$-0.77 < \cos\theta \leq 0$, and $\cos\theta \leq -0.77$; and show the resulting distributions in $M(K\pi)$ in Figs. 1c through 1f. The enhancement at $M(K\pi) \sim 1.85$ GeV with a width of about 300 MeV is very clear in Fig. 1e ($-0.77 < \cos\theta \leq 0$).

In Fig. 3 we show the distribution in $\cos\theta$ in three regions of $M(K^+\pi^-)$: 1.5-1.75 GeV, 1.75-2.0 GeV, and 2.0-2.25 GeV. The change in the angular distribution across this mass region is striking. The smooth curve in each figure is the result of a fit to a sum of Legendre polynomials up to sixth order, i.e., $\sum_{n=0}^{N_{max}} a_n P_n(\cos\theta)$, where $N_{max} = 6$. The $\chi^2$ and resulting parameters are shown in Table I. With the present statistical accuracy we cannot determine with precision the relative amounts of each wave present.

It should be noted that in the angular distributions of Fig. 3 the large forward peak is a consequence of the strong production of low-mass $N^*$'s. It might appear that some or all of this contribution should be considered as a background to $K\pi$ scattering which ought to be subtracted out. However, the duality picture, as applied by Chew and Pignotti,[4] regards $K\pi$ scattering in this reaction as dual to $N^*$ production, and argues against such a subtraction. Since extrapolation to the pion pole should in principle give the correct $K\pi$ scattering distribution, we have examined the t-dependence of the ratio of the forward peak to the remainder of the angular distribution in this $K\pi$ mass region. We find that there is no significant variation of this ratio with $t'$, for $|t'| < 0.2$ $(\mathrm{GeV}/c)^2$; consistent with the view that the angular distributions of Fig. 3 in fact represent $K\pi$ scattering.

We have also fit the angular distribution of Fig. 3b using only the region $\cos\theta < 0.7$ to a sum of Legendre polynomials, and have found excellent agreement with the results of the fit to the entire distribution, i.e., the forward peak is reasonably well reproduced. However this truncated distribution may also be fit with reasonable $\chi^2$ with a sum of Legendre polynomials only up to fourth order, i.e., no F wave is required. In this case, however, the predicted forward peak is only about one fourth of the observed peak, and thus the bulk of the events in this forward peak would not reflect $K\pi$ scattering. Such a view would contradict the notion of duality discussed above.

It should be emphasized that if the L meson, as seen in reactions like $K^{\pm}p \rightarrow K^{\pm}\pi^{+}\pi^{-}p$, is in fact produced by a diffraction process, as is generally supposed (and hence has unnatural spin parity), then the enhancement observed in this charge-exchange reaction cannot be the L meson.[5] Preliminary results from a study of the $K^{+}d$ reaction at 9 GeV/c showing an effect similar to the one observed here have been reported by the Purdue-Davis collaboration.[6]

In conclusion we have observed a rapid change in the $K\pi$ scattering angular distribution in the mass region around 1.85 GeV. This effect can be most simply interpreted in terms of a rapid increase of an F-wave amplitude, which interferes with several other waves present. If interpreted as a resonance this $J^P = 3^-$ $K^*$ could belong to the same $SU_3$ octet as the g-meson. Because of the strong interference effects observed in this experiment we cannot obtain precise values for the mass and width.

We gratefully acknowledge the help of the SLAC accelerator operation group, and in particular we thank J. Murray, R. Gearhart, R. Watt, and the staff of the 82-inch bubble chamber for help with the exposure. We acknowledge the valuable support given by our scanning and programming staffs, especially E. R. Burns, A. Habegger, B. Sieh, and H. White and the FSD staff.

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*Work supported by the U. S. Atomic Energy Commission.

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2. A. Firestone, G. Goldhaber, and D. Lissauer, Lawrence Radiation Laboratory Report UCRL-20076 (1970), unpublished.
3. A. Firestone, G. Goldhaber, and D. Lissauer, Phys. Rev. Letters 26, 1460 (1971).
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5. See, for example, C.-Y. Chien in Experimental Meson Spectroscopy, edited by C. Baltay and A. H. Rosenfeld (Columbia University Press, New York, 1970), p. 275 and references therein.
6. H. W. Clopp et al., Bull. Am. Phys. Soc. 16, 547 (1971).

## FIGURE CAPTIONS

Fig. 1. (a) Scatter plot of $\cos\theta$ vs $M(K^+\pi^-)$; distributions of $M(K^+\pi^-)$ for (b) no cut in $\cos\theta$, (c) $\cos\theta > 0.77$, (d) $0 < \cos\theta \leq 0.77$, (e) $-0.77 < \cos\theta \leq 0$, and (f) $\cos\theta \leq -0.77$. A cut at $|t'| < 0.2$ $(\mathrm{GeV}/c)^2$ has been applied to the data shown here.

Fig. 2. (a) through (f): Distributions of $N\langle Y_\ell^0\rangle$ for $\ell = 1$ through 6 as functions of $M(K^+\pi^-)$. A cut at $|t'| < 0.2$ $(\mathrm{GeV}/c)^2$ has been applied to the data shown here.

Fig. 3. Distribution of $\cos\theta$ for (a) 1.5 GeV $< M(K^+\pi^-) <$ 1.75 GeV, (b) 1.75 GeV $< M(K^+\pi^-) <$ 2.0 GeV, and (c) 2.0 GeV $< M(K^+\pi^-) <$ 2.25 GeV. The smooth curves show the results of fits to sums of Legendre polynomials up to sixth order. A cut at $|t'| < 0.2$ $(\mathrm{GeV}/c)^2$ has been applied to the data shown here.

Table I. Coefficients of Legendre expansion $\sum_{n=0}^{N_{max}} a_n P_n(\cos\theta)$.

| $M(K^+\pi^-)$ bin: | 1.5-1.75 GeV | 1.75-2.0 GeV | 2.0-2.25 GeV |
|---|---|---|---|
| Number of events | 424 | 536 | 446 |
| $\chi^2$ | 12.4 | 10.2 | 20.9 |
| Degrees of freedom | 13 | 13 | 13 |
| Confidence level | 49.9% | 67.4% | 7.5% |
| $(a_1/a_0)$ | 1.02±0.11 | 1.73±0.07 | 2.20±0.06 |
| $(a_2/a_0)$ | 2.38±0.09 | 2.62±0.08 | 2.99±0.07 |
| $(a_3/a_0)$ | 1.04±0.16 | 2.76±0.10 | 3.03±0.08 |
| $(a_4/a_0)$ | 1.17±0.18 | 1.65±0.12 | 2.29±0.10 |
| $(a_5/a_0)$ | 0.20±0.16 | 0.94±0.11 | 1.46±0.09 |
| $(a_6/a_0)$ | 0.26±0.18 | 0.72±0.11 | 0.46±0.11 |

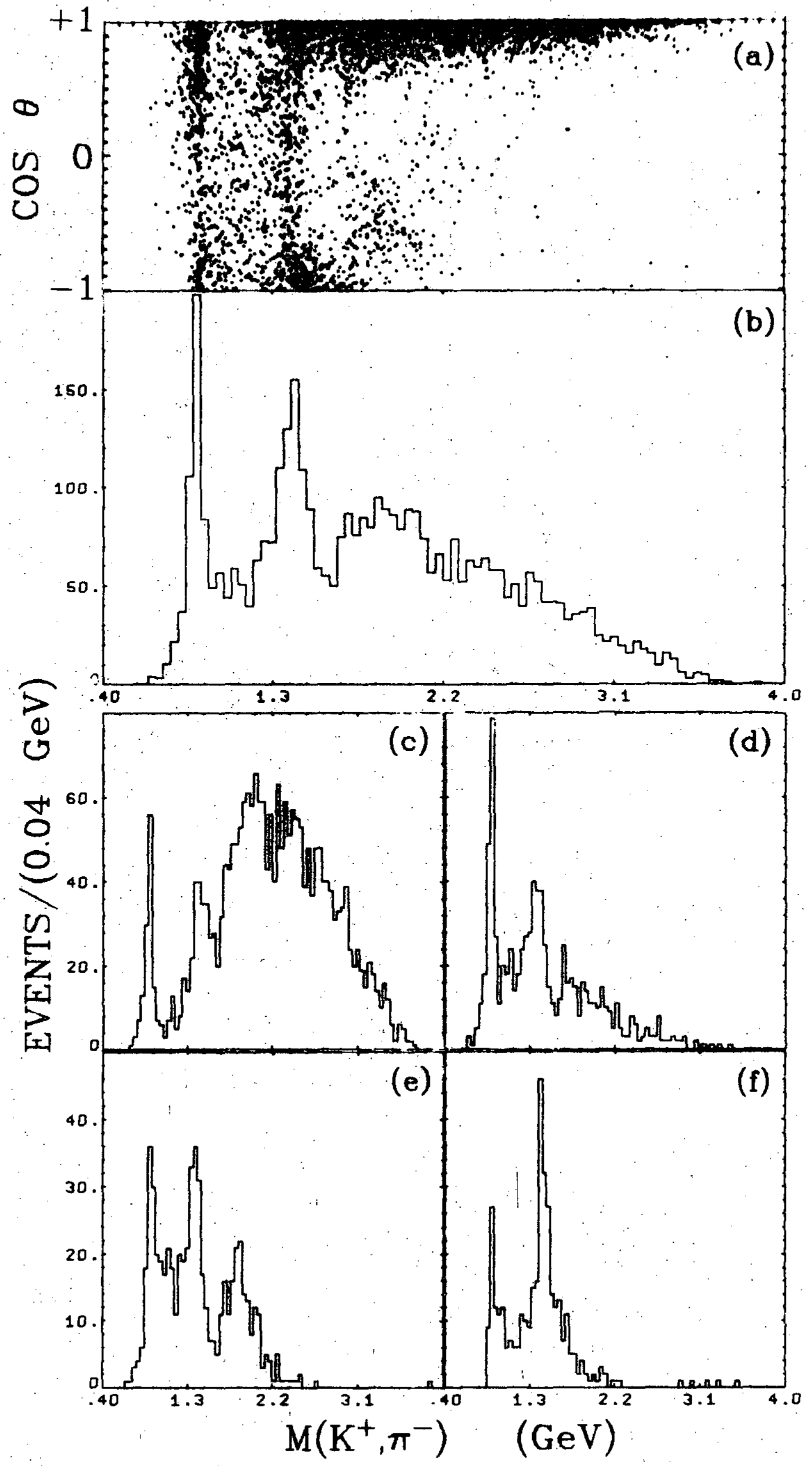


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Fig. 1

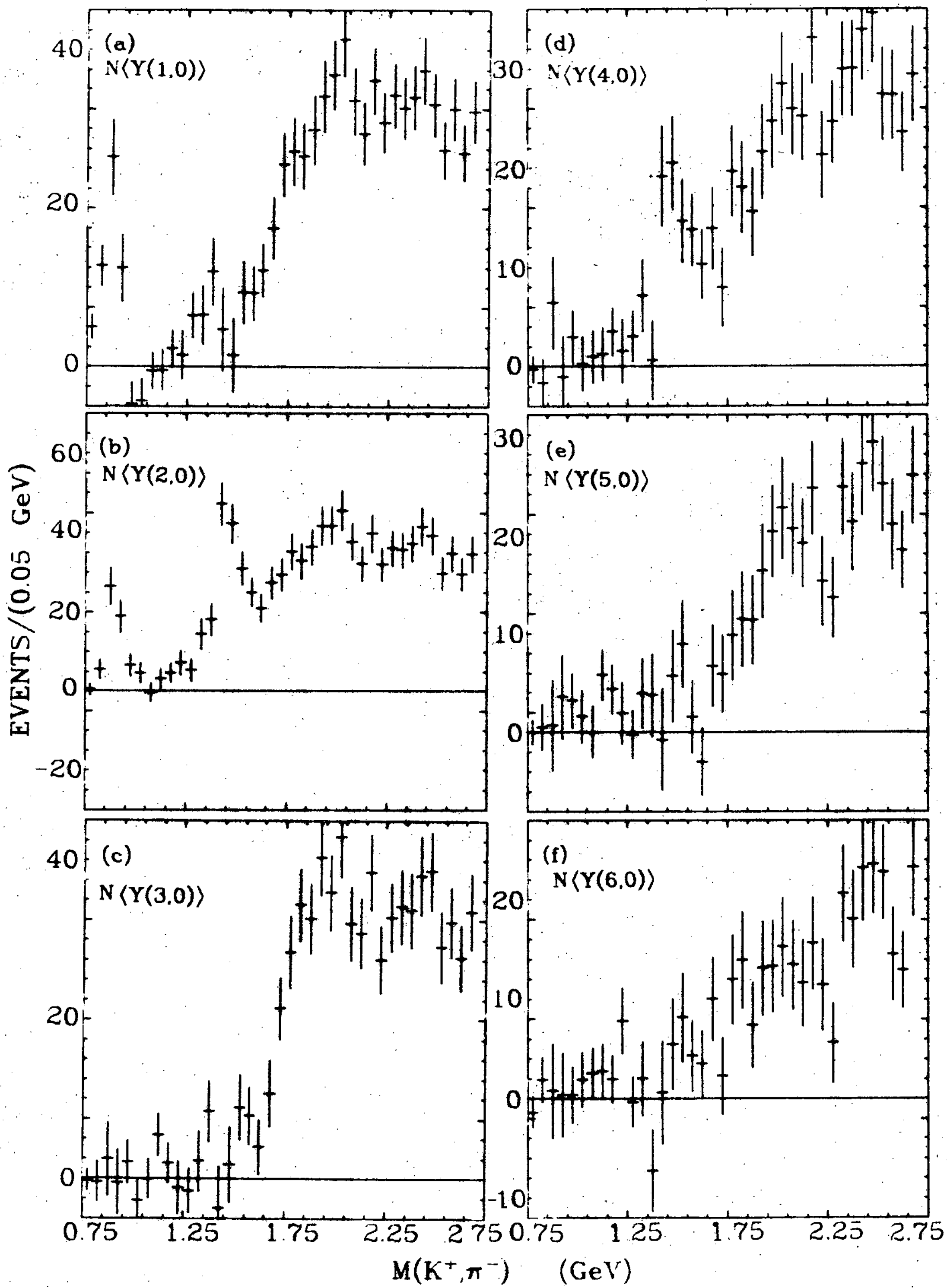
(a)
N⟨Y(1,0)⟩
(b)
N⟨Y(2,0)⟩
(c)
N⟨Y(3,0)⟩
(d)
N⟨Y(4,0)⟩
(e)
N⟨Y(5,0)⟩
(f)
N⟨Y(6,0)⟩
EVENTS/(0.05 GeV)
M(K+,π−) (GeV)
0.75 1.25 1.75 2.25 2.75
XBL 716-1129

Fig. 2

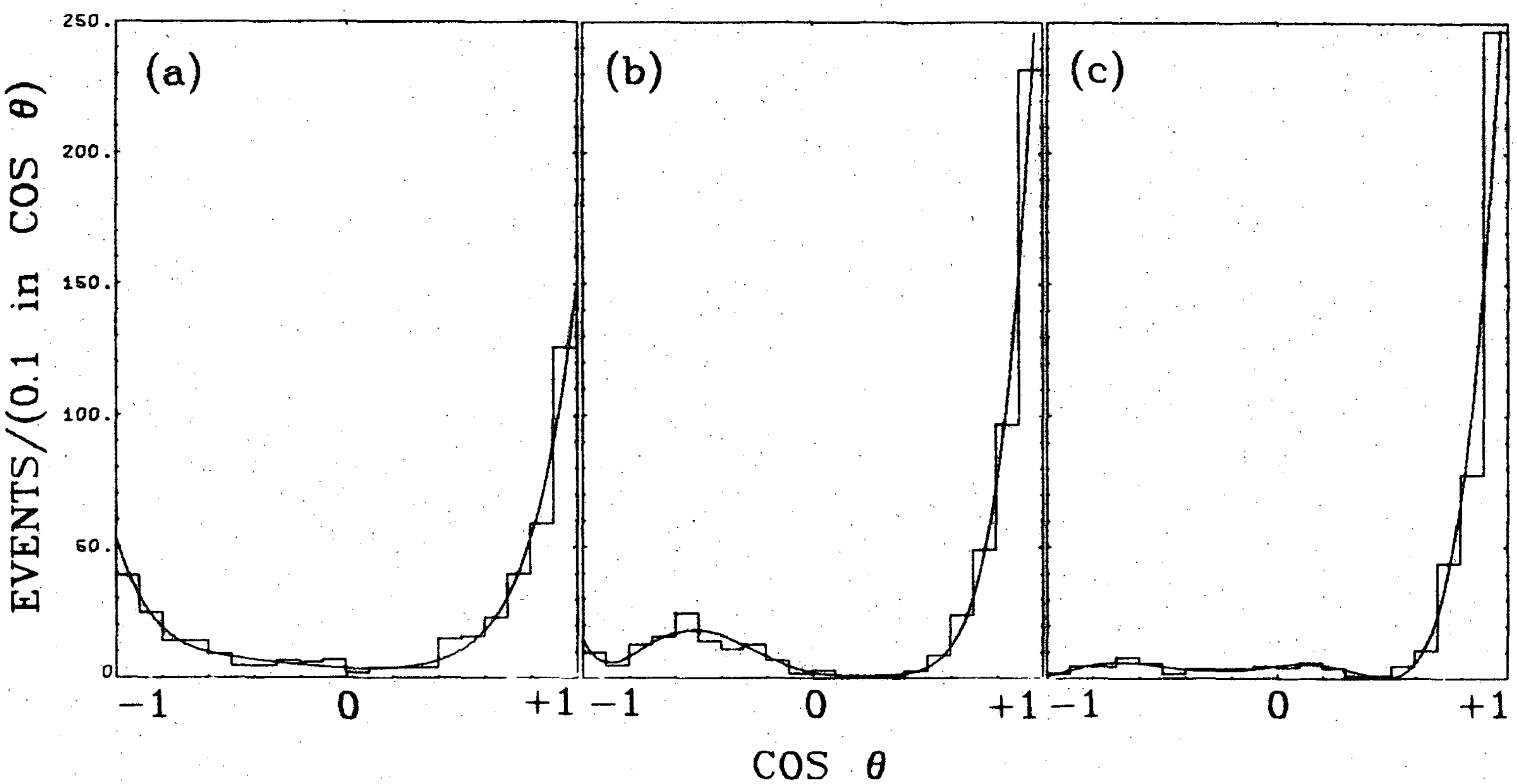


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Fig. 3

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