Observation of a Narrow $K^*(1760)$ in the $K\pi$ System*

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We have observed $\gtrsim 4\sigma$ signals at mass 1760 MeV and width <80 MeV in both the $K\pi$ mass and the Y_2^0-moment spectra from a sample of 5330 events of the type $K^-p \to K^-\pi^+n$ at 7.3 GeV/c. Our evidence for a $K\pi\pi$ decay mode of this resonance is only of marginal statistical significance. We may be observing the same object as that reported previously by Carmony *et al.*, although the detailed structure in our data is different.

It has been apparent for some time that a K^* meson should exist at a mass of about 1750 MeV, an $I=\frac{1}{2}$ companion to the well-established $I=1$ g meson[1] ($J^P=3^-$). Endeavors to find such a K^*, however, have been hampered by the presence of the diffractively produced $L(1770)$,[2] which presumably belongs to the unnatural-parity series. An obvious way to search for such a K^* is to examine the $K\pi$ spectrum; two recent investigations by Carmony *et al.*[3] and Firestone *et al.*[4] indicate that the $K\pi$ spectrum in the 1750-MeV region might harbor more than one resonance in this region, the only clear structure being a sharp rise in the mass spectrum below 1750 MeV.[5] In contrast, our own investigations based on comparable statistics show a single clear peak at 1760 MeV with width less than 80 MeV in both the $K\pi$ mass and the Y_l^m-moment spectra. Although from our data we can only conclude that this resonance must have spin greater than 0 (and belong to the natural-parity series), it is plausible to assume that this $K^*(1760)$ is indeed the $I=\frac{1}{2}$ SU(3) companion to the g meson.

Evidence for this narrow ($\Gamma<80$ MeV) K^* resonant state with mass ~ 1760 MeV comes from a study of the reaction

$$K^-p \to K^-\pi^+n, \quad 5330 \text{ events}, \tag{1}$$

at an incident K^- momentum of 7.3 GeV/c. The data come from a portion (~ 9 eV/μb) of a 500 000-picture exposure of the 80-in. hydrogen bubble chamber at Brookhaven National Laboratory. Other relevant reactions for this study are

$$K^-p \to \bar{K}^0\pi^+\pi^-n, \quad 920 \text{ events}; \tag{2}$$

$$\to K^-\pi^0p, \quad 2430 \text{ events}; \tag{3}$$

$$\to \bar{K}^0(\text{unseen})\pi^-p, \quad 1910 \text{ events}; \tag{4a}$$

$$\to \bar{K}^0(\text{seen})\pi^-p, \quad 490 \text{ events}. \tag{4b}$$

In these reactions the evidence for a narrow 1760-MeV state is not as strong as in Reaction (1).[6]

For one-constraint (1C) fits [Reactions (1)–(3) and (4a)], we have only kept events with a confidence level (CL) (kinematic-fit probability) $>10^{-2}$ and rejected any that has a 4C fit [7C for Reaction (2)] with a CL$>10^{-5}$, while for Reaction (4b) we have retained all those with a CL$>10^{-5}$. Approximately 10% of $K^-\pi^+n$ events are ambiguous with $\pi^+\pi^-\Lambda$ events, and the $\bar{K}^0\pi^+\pi^-n$ events have about the same level of ambiguity with reactions $\bar{K}^0\pi^-\pi^0p$ and $\Lambda\pi^+\pi^-\pi^0$. In both cases we have retained the ambiguous events.[7] About 25% of final states $K^-\pi^0p$ and $\bar{K}^0$(unseen)π^-p are also ambiguous with each other, but this does not affect the $K\pi$ mass distribution or the Y_l^0 moments for l even when both reactions are added together. To avoid double counting, whichever hypothesis has the higher confidence level has been chosen as the correct one.

The $K^-\pi^+$ mass distribution from Reaction (1) is shown in Fig. 1(a). In addition to the $K^*(890)$ and $K^*(1420)$, there is a clear 4σ signal at 1760 MeV with a width less than 80 MeV. We estimate the signal to consist of approximately 65 ± 16 events above a smooth hand-drawn background.[9] In addition we observe $\sim 3\sigma$ effects in the Y_1^0 and Y_3^0 moments (not shown) and a narrow 4σ signal at 1760 MeV in Y_2^0 moment[8] [Fig. 1(b)], while none of the higher moments show any significant structure at this mass. Combining the statistical significances in both the mass and the Y_2^0 moment, we obtain $\chi^2=25.4$ (which includes the correlation) for two degrees of freedom, corresponding to the probability $\sim 10^{-5}$ that the observed bumps are due to a statistical fluctuation.

In Fig. 2 we show the $\bar{K}^0\pi^+\pi^-$ mass distribution from Reaction (2). There is no clear resonant signal at 1760 MeV when all events are plotted; however, when $K^*(890)$ and ρ are selected ($\bar{K}^0\pi^-$ mass between 0.79 and 0.99 GeV, and $\pi^+\pi^-$ mass between 0.61 and 0.91 GeV) there can be seen, in addition to the $K^*(1420)$, a signal ($\sim 2\sigma$) at 1760 MeV, as shown in the shaded histogram of Fig. 2.

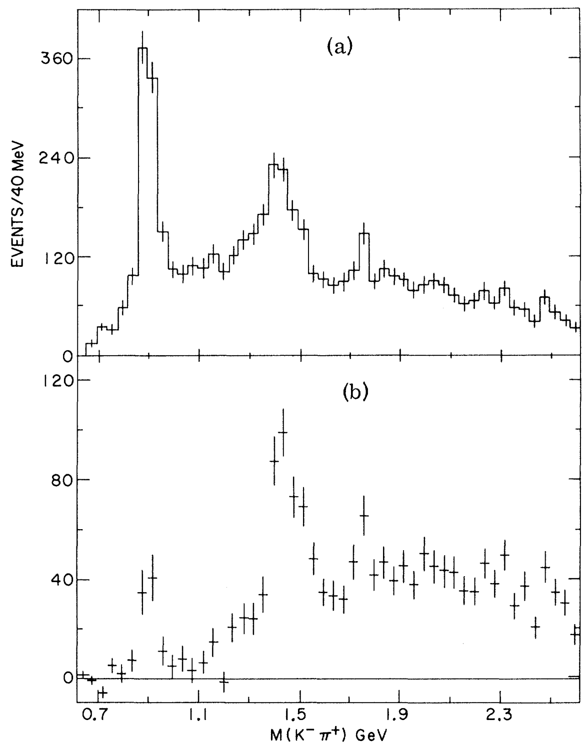

FIG. 1. (a) $K^-\pi^+$ mass $[M(K^-\pi^+)]$ spectrum from the final state $K^-\pi^+n$. (b) Y_2^0 moment as a function of $M(K^-\pi^+)$ from the same final state (see Ref. 8 for the definition of the moments).

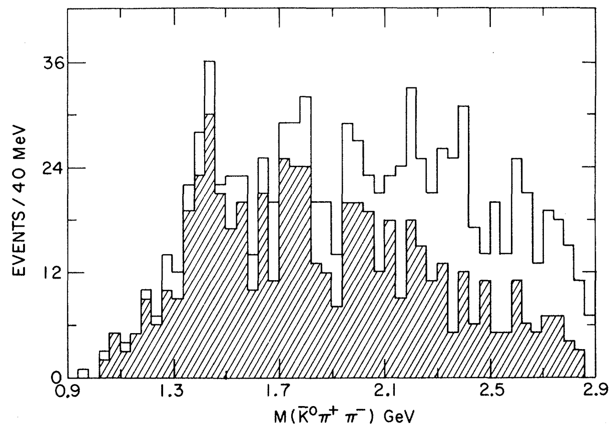

FIG. 2. $\bar{K}^0\pi^+\pi^-$ mass spectrum from the final state $\bar{K}^0\pi^+\pi^-n$. The shaded histogram results from selecting either $K^*(890)$ or ρ intermediate states in the $\bar{K}^0\pi^+\pi^-$ system.

We estimate the bump to consist of about 20 ± 10 events above a hand-drawn background (the quoted error includes the systematic error associated with estimating the background level).

We therefore note that our data are, in some respects, different from the results of Carmony *et al.*[3] We observe a significant narrow structure in the $K\pi$ system at 1760, which in their case may be masked by additional nearby states or a very different type of background. Unlike Carmony *et al.*, we do not see any evidence of a peak in the Y_6^0 moment to favor the $J^P = 3^-$ hypothesis; we can only conclude from the structure of our moments that the spin must be greater than zero.[10] On the other hand, Carmony *et al.* estimate that the $K^*(1760)$ is more strongly coupled to the $K\pi\pi$ channel than to $K\pi$. They obtained $R \equiv \Gamma(K\pi)/\Gamma(K^*(890)\pi + \rho K) = 0.4 \pm 0.1$ (after correcting for unseen decay modes). In our case, the signal in the $K\pi\pi$ channel is of marginal statistical significance, the major signal occuring in the $K\pi$ channel. However, our data are not inconsistent with their branching ratio. Assuming that we are indeed observing events from the $K\pi\pi$ decay mode of the $K^*(1760)$, we obtain $R' \equiv R^{-1} = 1.6 \pm 0.9$.[11] This number can be compared with the result of Carmony *et al.* by taking the product $RR' = 0.64 \pm 0.39$, which is consistent with 1, indicating that the two branching ratios are statistically compatible.

We will now discuss Reactions (3) and (4) and contrast them with Reaction (1). We show in Fig. 3(a) the $(K\pi)^-$ mass spectrum for $\bar{K}^0\pi^- + K^-\pi^0$ and the $\bar{K}^0$(seen)π^- mass spectrum. There is a dip and then a rising edge beyond the $K^*(1420)$ reaching a maximum near 1800 MeV. The Y_2^0 moment shows similar structure [Fig. 3(b)], while no significant structure is seen in higher moments. It is clear that, if a narrow $K^*(1760)$ is produced in this reaction, it is masked by a very different type of background. We find that the $\pi^0 p$ mass distribution is more sharply peaked at low mass than the $\pi^+ n$ system. This tends to give larger background at high $(K\pi)^-$ mass (>1.7 GeV) and may make it more difficult to observe the $K^*(1760)$. The same type of background is also present to a somewhat lesser extent in $\bar{K}^0$(unseen)$\pi^- p$ [Reaction (4a)] because of ambiguities with $K^-\pi^0 p$. We do not observe this kind of background with the $\bar{K}^0$(seen)$\pi^- p$ events [Reaction (4b)]; however, the number of events is too small to observe any statistically significant signal near 1760 MeV [see the shaded histogram of Fig. 3(a)].

In addition, we have searched for the $K\pi\pi$ decay mode of the $K^*(1760)$ in the $K^-\pi^+\pi^- p$ and $\bar{K}^0\pi^-\pi^0 p$ final states. However, in these reactions there is a broad $K^*(1420)\pi$ enhancement (the L meson) which can mask the presence of a narrow $K^*(1760)$ meson. These final states need to be studied in

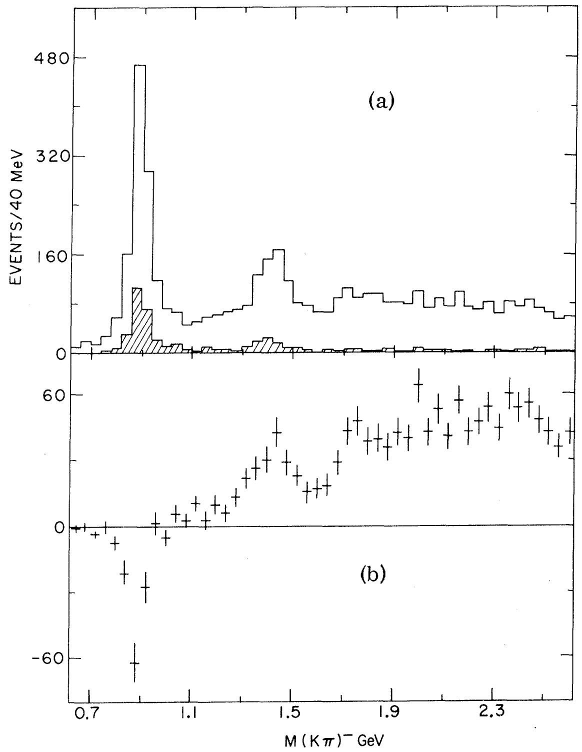

FIG. 3. (a) $(K\pi)^-$ mass spectrum from the final states $\bar{K}^0\pi^-p$ and $K^-\pi^0p$. The shaded histogram corresponds to selecting the $\bar{K}^0\pi^-p$ events with $\bar{K}^0$ decays seen in the bubble chamber. (b) Y_2^0 moment as a function of $M(K\pi)^-$ from the same final states (see Ref. 8 for the definition of the moments).

more detail and shall be the subject of a future publication.

In conclusion, we observe a relatively narrow ($\Gamma < 80$ MeV) K^* resonance with mass near 1760 MeV decaying into $K\pi$ in the reaction $K^-p \to K^-\pi^+n$ (4σ in both the mass spectrum and the Y_2^0 moment), and thus cannot be an alternative decay mode of the $L(1770)$. The evidence for a decay into $K^*(890)\pi + K\rho$ is somewhat meager statistically; we obtain a branching ratio $\Gamma(K^*(890)\pi + K\rho)/\Gamma(K\pi) = 0.8 \pm 0.4$ after correcting for unseen decay modes. This resonance does not seem to be produced as strongly in the reaction $K^-p \to (K\pi)^-p$, although the presence of a large low-mass enhancement in the π^0p system makes this state more difficult to see. From its $K\pi$ decay mode we can conclude that it must belong to the natural-parity series and that the spin must be greater than zero from the structure in the Y_l^m moments. We find no evidence in the angular distribution to favor $J^P = 3^-$ assignment; however, because of its mass, this state may very well belong to the same SU(3) octet as the g meson.

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[1]For the most recent high-statistics data on the g meson, see G. Grayer *et al.*, Phys. Lett. 35B, 610 (1971). For previous results, see P. Söding *et al.*, Phys. Lett. 39B, 1 (1972).

[2]For references on L meson, see P. Söding *et al.*, Phys. Lett. 39B, 1 (1972).

[3]D. Carmony *et al.*, Phys. Rev. Lett. 27, 1160 (1971).

[4]A. Firestone *et al.*, Phys. Lett. 36B, 513 (1971).

[5]Carmony *et al.* observed a relatively narrow (3–4)σ signal in the $K\pi\pi$ mass distribution near 1760 MeV, from reactions $K^+n \to K^{+,0}\pi^{0,+}\pi^-p$ (~900 events). However, they do not observe such a peak in reaction $K^+n \to K^+\pi^-p$ (~3600 events) but do see a sharp rise below 1750 MeV [somewhat similar to our $(K\pi)^-$ spectrum from reaction $K^-p \to (K\pi)^-p$].

[6]In order to reject as many of the elastic events as possible while enriching the neutron sample, we have rejected all those two-prong events with clearly identifiable protons on the scan table. This scanning criterion does not affect the events of Reaction (1), but it results in abnormally high–momentum-transfer (to proton) events for Reactions (3) and (4a).

[7]Most of the $K^-\pi^+n$ events ambiguous with $\pi^+\pi^-\Lambda$ are likely to be the $K^-\pi^+n$ events, since the cross section for $\pi^+\pi^-\Lambda$ is relatively small.

[8]We use the symbol $Y_L^M(\theta, \phi)$ to denote $D_{M0}^{L*}(\phi, \theta, 0)$, so that the functions Y_L^M are normalized to $4\pi(2L+1)^{-1}$ and $Y_0^0 = 1$. We use unnormalized moments; i.e., "Y_L^M moment" $\equiv \sum_{i=1}^{n} Y_L^M(\theta_i, \phi_i)$, where n is the number of events in a given mass bin. The angles are defined in the Jackson frame.

[9]If we select only the best fits to $K^-\pi^+n$ (based on kinematic-fit probability), we find that the peak contains 56 $\pm$ 12 events above background, corresponding to a 4.5σ signal bump.

[10]Carmony *et al.* observed a peak in the Y_6^0 moment at 1760 MeV using only backward events. Our Y_6^0 moment is close to zero and shows no structure whatsoever. There is no significant difference (except for larger errors) if we consider only those events with $\cos\theta < 0$.

[11]We prefer to use R^{-1} to quote our branching ratio. The reason is that the $K\pi\pi$ decay mode is significantly smaller than the $K\pi$ mode in our case, so that the quantity R^{-1} has a nearly Gaussian distribution. We assume that the relative amounts of the $K^*\pi$ and $K\rho$ decay modes are 40% and 60%, as given in Ref. 3.