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OBSERVATION OF A K^* RESONANCE AT 2088 MeV

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ABSTRACT

In a high statistics (180 events/ μb) bubble chamber study of the reaction $\bar{K}^- p \rightarrow \bar{K}^0 \pi^- p$ at 8.25 GeV/c, we observe a $\bar{K}^0 \pi^-$ state at 2088 ± 20 MeV with a width 170_{-50}^{+100} MeV, produced with a cross section of $3.6 \pm 1.2 \mu\text{b}$. In addition we observe this state in the channels $\bar{K}^*(890)\pi\pi$, $\rho\bar{K}\pi$, $\omega\bar{K}\pi$ with a combined cross section of $7.1 \pm 2.6 \mu\text{b}$, and possibly $\bar{K}^*(890)\pi\pi\pi$.

Two recent experiments [1,2] have reported the observation of a spin 4 K^* resonance in the 2.0-2.1 GeV mass region. Undetected in the mass spectra, this state has been observed in spherical harmonic analyses of the $K\pi$ scattering angles. The mass and width of the state have been measured as $M = 2023 \pm 10$, $\Gamma = 324 \pm 45$ and $M = 2070_{-40}^{+100}$, $\Gamma = 240_{-100}^{+500}$ MeV in refs [1] and [2] respectively. An indication of this state has been found in an earlier experiment [3].

We present a clear observation of a K^* state ($K^*(2090)$ in the following) in the $\bar{K}^0\pi^-$ mass spectrum at 2088 ± 20 MeV with a width of 170_{-50}^{+100} MeV, produced in the reaction $K^-p \rightarrow \bar{K}^*p$ at 8.25 GeV/c with a cross section of 3.6 ± 1.2 μ b. In addition, we observe this state in the inelastic channels $\bar{K}^*(890)\pi\pi$, $\rho\bar{K}\pi$, $\omega\bar{K}\pi$ and possibly $\bar{K}^*(890)\pi\pi\pi$. In spite of the clear enhancement observed in this experiment, we are unable to determine its spin and parity. The $K^*(2090)$ is most naturally interpreted as a member of the 4^{++} SU(3) nonet which contains the h(2040) meson [4].

The present analysis is based on a high statistics K^-p exposure at 8.25 GeV/c in the CERN 2m hydrogen bubble chamber, corresponding to a sensitivity of ~ 180 events/ μ b. We have searched for high mass $K\pi$ states in the 4 constraint reaction

$$K^-p \rightarrow \bar{K}^0\pi^-p \quad (1)$$

applying a probability cut of $P(\chi^2) > 0.1\%$ at the production vertex. A sample of 15096 events of this reaction has been identified with negligible background.

This search has then been extended to the channels

$$K^-p \rightarrow \bar{K}^0\pi^-\pi^0p \quad (46600 \text{ events}) \quad (2)$$

$$K^-p \rightarrow \bar{K}^0\pi^-\pi^+n \quad (27632 \text{ events}) \quad (3)$$

$$K^-p \rightarrow \bar{K}^0\pi^-\pi^+\pi^-p \quad (19504 \text{ events}) \quad (4)$$

and

$$K^-p \rightarrow \bar{K}^0\pi^-\pi^+\pi^-\pi^0p \quad (33668 \text{ events}) \quad (5)$$

For reactions (2), (3) and (5), a production probability cut $P(\chi^2) > 5\%$ was applied, while in the case of reaction (4), a probability cut of $P(\chi^2) > 0.1\%$ was used.

Reaction (1) is well known to be dominated by $K^*(890)$ and $K^*(1430)$ production. In fig. 1(a) we show the mass distribution of the $\bar{K}^0\pi^-$ system for $\cos\theta^* > 0.75$ in the K^-p centre of mass system. This $\cos\theta^*$ cut has been applied throughout the paper. In addition to three well established [4] K^* 's (890, 1430 and 1780), a fourth state is clearly seen at a mass of 2090 MeV (a signal of ~ 100 over a background of ~ 400 between 2000 and 2160 MeV). Fig. 1(b) shows the results of a fit using Breit-Wigner shapes for the $K\pi$ resonances and a smooth polynomial background. The resulting mass and width for the $K^*(2090)$ are $M = 2088 \pm 20$ and $\Gamma = 170_{-50}^{+100}$ MeV. The production cross section, based on the fitted number of events (200 ± 70) of the $K^*(2090)$, is $3.6 \pm 1.2 \mu\text{b}$, after correcting for geometrical losses and neutral decays of the K^0 .

The $p\pi^-$ mass distribution is shown in fig. 2(a) for the signal region (defined as 2000-2160 MeV) along with neighbouring control regions (1920-2000 and 2160-2240 MeV). We note a well defined $\Delta(1232)$, as well as possible structure in the 1500-1700 MeV region. In order to study the effects on the $K^*(2090)$ of the $p\pi^-$ resonances, we plot in figs 2(b,c,d) the $\bar{K}^0\pi^-$ mass distributions corresponding to three different π^-p mass regions, namely $M(p\pi^-) < 1360$, $1360 < M(p\pi^-) < 1760$ and $M(p\pi^-) > 1760$ MeV. The $K^*(2090)$ signal is seen in all cases. The curves show the result of fits using the masses and widths determined from fig. 1(b). No significant structure is observed in the Y_{LM} moments for $\bar{K}\pi^-$ masses greater than 1600 MeV.

We now turn to our search for higher multiplicity decays of the $K^*(2090)$ from reactions (2) to (5). The $\bar{K}^0\pi^-\pi^0$ and $\bar{K}^0\pi^-\pi^+$ mass spectra (not shown) of reactions (2) and (3) respectively give little indication of the $K^*(2090)$ decaying into these channels. We have searched for the $K^*(2090)$ decaying into $\bar{K}^*(890)\pi$, $\bar{K}^*(1430)\pi$, $\rho\bar{K}^0$ and $f^0\bar{K}^0$. No statistically significant evidence for the $K^*(2090)$ is observed in any of these quasi-two-body channels; we quote, in table 1, 95% confidence level upper limits of the decays into these channels.

The $\bar{K}^0 \pi^- \pi^+ \pi^-$ mass distribution for reaction (4), on the other hand, shows a significant structure around 2090 MeV, while for the $\bar{K}^0 \pi^- \pi^+ \pi^- \pi^0$ mass distribution of reaction (5) a rapidly varying background around 2090 MeV renders a clear cut interpretation difficult. Noting a strong presence of the $K^*(890)$ in these reactions, as well as a strong signal of ρ and ω in reactions (4) and (5) respectively, we have studied the $\bar{K}^*(890) \pi^+ \pi^-$ and $\rho \bar{K}^0 \pi^-$ subchannels in reaction (4) and the $\bar{K}^*(890) \pi^+ \pi^- \pi^0$ and $\omega \bar{K}^0 \pi^-$ subchannels in reaction (5). These mass spectra are shown in fig. 3.

In figs 3(a), (b) and (d) corresponding to $\bar{K}^* \pi^+ \pi^-$, $\rho \bar{K}^0 \pi^-$ and $\omega \bar{K}^0 \pi^-$ channels respectively, enhancements are observed at 2090 MeV with widths compatible with that determined for the $\bar{K} \pi$ mode indicating the decays of the $K^*(2090)$ into these channels, while for $\bar{K}^*(890) \pi^+ \pi^- \pi^0$ (fig. 3(c)), there is no clear signal. We have fitted these mass spectra with two resonances (1780 and 2090) with the parameters determined from fig. 1(b), plus a smooth polynomial background. The results are superimposed on fig. 3. It should be noted that the introduction of the $K^*(2090)$ improved fits in all cases. The fitted number of events in these channels are given in table 1 together with the corresponding cross sections.

We find no significant evidence for possible $\bar{K}^* \rho^0$ and $\bar{K}^* \omega$ decays of the $K^*(2090)$ or for $K^*(2090)$ decaying into 3 kaons (with or without pions).

In conclusion we observe a $K \pi$ resonance with mass 2088 ± 20 MeV and width 170_{-50}^{+100} MeV in the $\bar{K}^0 \pi^-$ decay mode, with a cross section of $3.6 \pm 1.2 \mu\text{b}$. We further observe this state decaying into $\bar{K}^*(890) \pi^+ \pi^-$, $\rho \bar{K}^0 \pi^-$, $\omega \bar{K}^0 \pi^-$ with a combined cross section of $7.1 \pm 2.6 \mu\text{b}$.

REFERENCES

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TABLE 1

Decay channels and cross sections of $K^*(2090)$

Reaction	Channels	Fitted number of events	Cross section (μb) ^(a)
1	$\bar{K}^0 \pi^-$	200 ± 70	3.6 ± 1.2
4	$K^{*-}(890) \pi^+ \pi^-$	120 ± 56	3.2 ± 1.6
4	$\rho \bar{K}^0 \pi^-$	114 ± 52	$2.1 \pm .9$
5	$\omega \bar{K}^0 \pi^-$	89 ± 43	$1.8 \pm .9$
5	$K^{*-}(890) \pi^+ \pi^- \pi^0$	99 ± 55	2.7 ± 1.5
2	$\bar{K}^{*-}(890) \pi^-$ or $K^{*-}(890) \pi^0$	< 40	
3	$K^{*-}(890) \pi^+$	< 30	
2	$\bar{K}^{*-}(1430) \pi^-$ or $K^{*-}(1430) \pi^0$	< 40	
3	$K^{*-}(1430) \pi^+$	< 30	
2	$\rho^- \bar{K}^0$	< 30	
3	$\rho^0 \bar{K}^0$	< 30	
3	$f^0 \bar{K}^0$	< 30	

(a) The cross sections have been corrected for unseen $\bar{K}^0$, $\bar{K}^{*-}$ and ω^0 decay modes.

FIGURE CAPTIONS

- Fig. 1 (a) The $\bar{K}^0 \pi^-$ mass distribution from reaction (1) with $\cos \theta_{K\pi}^* > 0.75$ in the $K^- p$ c.m.s.
- (b) The $\bar{K}^0 \pi^-$ mass distribution with resonance curves described in the text.
- Fig. 2 (a) The $p \pi^-$ mass distribution for events in the $K^*(2090)$ signal (histograms) and control regions (dots).
- (b)-(d) The $K^0 \pi^-$ mass spectra for three different $\pi^- p$ mass regions; (b) $M < 1.36$, (c) $1.36 < M < 1.76$ and (d) $M > 1.76$ GeV. The curves show the result of fits described in the text.
- Fig. 3 (a,b) The $K^{*-} \pi^+ \pi^-$ and $\rho \bar{K}^0 \pi^-$ distributions from reaction (4);
- (c,d) The $K^{*-} \pi^+ \pi^- \pi^0$ and $\omega \bar{K}^0 \pi^-$ distributions from reaction (5). The curves show the result of fits described in the text.

Fig. 1

Fig. 2

Fig. 3