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OBSERVATION OF A Ξ^* (2370) PRODUCED IN 8.25 GeV/c K^-p INTERACTIONS

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ABSTRACT

We observe production of a Ξ^* (2370) in the reactions $K^-p \rightarrow [Y\bar{K}\pi]K$, $[Y\bar{K}\pi]K\pi$ and $[\Omega K]$ (K or $K\pi$) at 8.25 GeV/c in a high statistics bubble chamber experiment. The mass and width are determined to be 2373 ± 8 MeV and 80 ± 25 MeV respectively. The $I = 1/2$ assignment is strongly favoured.

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In this letter we report on the observation of a Ξ^* with decay modes $\Lambda\bar{K}\pi$, $\Sigma\bar{K}\pi$ (and possibly $\Sigma(1385)\bar{K}$ and $Y\bar{K}^*(892)$) and $\Omega\bar{K}$. The mass and width are $M = (2373 \pm 8)$ MeV and $\Gamma = (80 \pm 25)$ MeV respectively. The data favour an isotopic spin assignment of one-half. Hereafter, we refer to this object as $\Xi^*(2370)$.

The data reported here come from an analysis of a high statistics exposure of $\bar{K}^-p$ interactions in the CERN 2m bubble chamber at 8.25 GeV/c. At this time, approximately 50% of a total of 5.3×10^6 pictures have been scanned and measured for events involving at least one neutral vee, corresponding to a sensitivity of ~ 100 events/ μb . Events with conflicting kinematic interpretations have been resolved, where possible, using estimates of track ionization. All events are restricted to be within a limited fiducial region, corresponding to a 130 cm zone for the primary production vertex and an additional 20 cm zone beyond the end of the primary zone for secondary decay vertices.

The reaction channels (*) which contribute to the study of the $\Xi^*(2370)$ are (including primary vertex constraint class and number of events)

$\bar{K}^-p \rightarrow \Sigma_1^0 \bar{K}_1^0 \pi^- K^+$	2C	148	(1)
$\rightarrow \Lambda_1^0 \bar{K}_1^0 \pi^- K^+$	4C	310	(2)
$\rightarrow \Sigma^- \bar{K}_1^0 \pi^0 K^+$	1C	170	(3)
$\rightarrow \Sigma_1^0 K^- \pi^+ K_1^0$	2C	168	(4)
$\rightarrow \Lambda_1^0 K^- \pi^+ K_1^0$	4C	372	(5)
$\rightarrow \Sigma^+ K^- \pi^0 K_1^0$	1C	231	(6)
$\rightarrow \Lambda_1^0 \bar{K}_1^0 \pi^- K^+ \pi^0$	1C	536	(7)
$\rightarrow \Lambda_1^0 K^- \pi^0 K_1^0 \pi^+$	1C	553	(8)
$\rightarrow \Sigma^+ K^- \pi^- K_1^0 \pi^+$	4C	124	(9)
$\rightarrow \Sigma^- K^- \pi^+ K_1^0 \pi^+$	4C	130	(10)
$\rightarrow \Sigma^+ \bar{K}_1^0 \pi^- K^+ \pi^-$	4C	106	(11)

(*) Events with two neutral kaons in the final state are not included due to the lack of explicit identification of the strangeness of these kaons.

$$\rightarrow \Sigma^- \bar{K}_1^0 \pi^+ K^+ \pi^- \quad 4C \quad 180 \quad (12)$$

$$\rightarrow \Omega_1^- K^0 K^+ \quad 1,4C \quad 9 \quad (13)$$

$$\rightarrow \Omega_1^- K_1^0 K^+ \pi^0 \quad 1C \quad 2 \quad (14)$$

$$\rightarrow \Omega_1^- K^0 K_1^0 \pi^+ \quad 1,4C \quad 8 \quad (15)$$

$$\rightarrow \Omega_1^- K^+ K^+ \pi^- \quad 4C \quad 4 \quad (16)$$

where the subscript 1 indicates that a visible vee was required for the particle identification.

In general, a 1C or 2C hypothesis was accepted when the confidence level exceeded 5%. For 4C events, 1% was required. In the case of ambiguity, the higher constraint class was always selected, or in the same constraint class the hypothesis with the higher confidence level was taken. In the case of Ω^- events, only events giving a fit to $\Omega^- \rightarrow \Lambda_1^0 K^-$ were utilized^(*).

We show in fig. 1(a) for the four-body channels (1), (2) and (3) the negatively charged $Y\bar{K}\pi$ mass distribution recoiling against the K^+ . The requirement that the cosine of the centre of mass production angle, θ^* , of the $Y\bar{K}\pi$ system be larger than 0.6 has been imposed. Such a cut enhances the effects of baryon-exchange mechanisms, which have been previously demonstrated to be important in Ξ^* production experiments (see, for examples [2,3]). In the interval 2320-2440 MeV one notes an enhancement of ~ 18 events over a background of ~ 9 events. In fig. 1(b) the $[Y\bar{K}\pi]^-$ mass distribution is shown for the five-body channels (7), (8), (9) and (10), in this case recoiling against the $(K\pi)^+$ system. An enhancement is also seen at 2320-2440 MeV, with ~ 44 events observed over a background of ~ 33 events. The combined data of figs 1(a) and (b) are shown in fig. 1(c). Here the significance of the three bin enhancement is greater than six standard deviations (62 events over a background of 42 events). We have fitted this distribution with an incoherent sum of a simple Breit-Wigner function and a polynomial background, and have unfolded the experimental resolution. For the charged Ξ^* (2370) we obtain $M = (2371 \pm 7) \text{ MeV}$ and $\Gamma = (70 \pm 20) \text{ MeV}$. The errors quoted are statistical only.

(*) For more discussion of the selection of Ω^- events see ref. [1].

We have also studied the neutral $Y\bar{K}\pi$ system, again with $\cos\theta^* > 0.6$. The data for the four-body (4)-(6) and five-body channels (7), (8), (11) and (12), as well as combined, are shown in figs 2(a-c) respectively. An enhancement centred at ~ 2370 MeV is apparent, particularly in the five-body channels. The significance of the enhancement in fig. 2(c) is greater than three-standard deviations, with an excess of ~ 26 events above a background of ~ 33 events in the 2320-2440 MeV interval. The observed ratio of charged-to-neutral production of the $\Xi^*(2370)$ is 2.5 ± 0.7 . We conclude that both neutral and charged baryon exchange mechanisms are involved in the production of the $\Xi^*(2370)$.

In figs 3(a) and 3(b) we show the charged and neutral ΩK mass distributions from reactions (13)-(15) and (13), (14) and (16) respectively, combining the four and five-body reactions. For the $(\Omega K)^-$ distribution, in the 2320-2440 MeV interval an enhancement of seven events over a background of less than one is observed. While this effect, in itself, is not strong independent evidence for the $\Xi^*(2370)$, when considered with the previous results we interpret the $(\Omega K)^-$ enhancement as a manifestation of the $\Xi^*(2370)$. We find no evidence for $\Xi^*(2370)$ decaying into $\Omega K\pi$. Possible structures in the ΩK mass spectrum in this mass region have been reported in other experiments [4,5].

In view of strong $\Sigma(1385)$ and $K^*(892)$ production observed in these reactions, we have studied the question of whether the enhancement seen at 2370 MeV is merely a reflection of these states. For this purpose, we have removed events where the Λ^0 , $\bar{K}$ or π in the $Y\bar{K}\pi$ system and a recoiling K or π give an effective mass in the interval 1.36-1.44 GeV ($\Lambda^0\pi$) or 0.86 - 0.92 GeV ($K\pi$). The resultant distributions are shown shaded in figs 1 and 2. The $\Xi^*(2370)$ is clearly evident in fig. 1, ruling out the possibility of reflections from the $\Sigma(1385)$ and $K^*(892)$ being solely responsible.

We have studied the $\Lambda\bar{K}$, $\Sigma\bar{K}$, $\Xi\pi$ and $\Xi\pi\pi$ mass distributions and find no evidence for the $\Xi^*(2370)$. We also find no evidence for the decay of the $\Xi^*(2370)$ into $\Xi^*(1820)\pi$ or $\Xi^*(2030)\pi$. We have examined the possibility

of $\Sigma(1385)\bar{K}$ or $\bar{K}^*(892)Y$ decay modes of the $E^*(2370)$. Due to limited statistics, no significant evidence is observed. In table 1 we summarize our results on the observed decay modes of the $E^*(2370)$ and limits for modes searched for, but not detected. In fig. 4 we show the combined data of figs 1(c), 2(c) and 3(a,b) to demonstrate the overall $E^*(2370)$ effect in our data. The curve is a fit as described previously, with $M = (2373 \pm 8) \text{ MeV}$ and $\Gamma = (80 \pm 25) \text{ MeV}$.

The observation of the decay of the $E^*(2370)$ into ΩK determines the isospin to be one half. Given the small number of events on which this is based, we have also considered $Y\bar{K}\pi$ data independently. The observed charged-to-neutral ratio of the $E^*(2370)$ suggests a dominance of Λ^0 exchange. Assuming $I = 1/2$ ($3/2$) for the $E^*(2370)$, the ratio $E^{*-} : E^{*0}$ in the $E^* K$ final state is predicted to be 1 : 4 (1 : 1) by simple isospin conservation arguments for pure Σ exchange. The small E^{*0} signal observed fails to support the Σ exchange hypothesis. Furthermore, we see no evidence for doubly charged states in the one channel $(\Sigma^- \bar{K}_1^0 \pi^-) K^+ \pi^+$ which is available to us. Thus the data are consistent with the dominance of Λ^0 exchange in which case the $I = 1/2$ hypothesis is mandated.

On the basis of the SU(3) model, Samios et al. [6] have predicted an $I = \frac{1}{2} E^*$ with a mass of $2370 \pm 230 \text{ MeV}$ as a member of a nonet with spin-parity $7/2^-$. The predicted two-body decays ($E\pi$, $\Sigma\bar{K}$, $E\eta$, $\Lambda\bar{K}$) are not seen in our experiment, and no attempt has been made to calculate three-body decays. However, considering that the $E^*(2370)$ is $\sim 700 \text{ MeV}$ above $Y\bar{K}$ threshold, it is not surprising that inelastic $Y\bar{K}\pi$ decay modes are present.

In conclusion, we observe a E^* of mass 2373 MeV and width 80 MeV with isotopic spin one half. Its decay modes are $\Lambda\bar{K}\pi$, $\Sigma\bar{K}\pi$ and ΩK .

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TABLE 1

Cross sections for $\Xi^*(2370)$ for $\cos \theta^*(K^-, Y\bar{K}\pi) > 0.6$

CROSS SECTIONS				
Decay mode	Observed channel	Observed No. of events	Weight ^(a)	Cross section (μb)
$(\Sigma\bar{K}\pi)^-$	$(\Sigma_1^0 \bar{K}_1^0 \pi^-) K^+$	8 ± 3	$1.30 \times \frac{15}{4}^{(b)}$	0.39 ± 0.14
	$(\Sigma^- \bar{K}_1^0 \pi^0) K^+$			
	$(\Sigma^+ K^- \pi^-) K_1^0 \pi^+$	14 ± 4	1.28×3	0.54 ± 0.15
	$(\Sigma^- K^- \pi^+) K_1^0 \pi^+$			
$(\Lambda\bar{K}\pi)^-$	$(\Lambda_1^0 \bar{K}_1^0 \pi^-) K^+$	10 ± 4	$1.30 \times \frac{9}{2}$	0.59 ± 0.24
	$(\Lambda_1^0 \bar{K}_1^0 \pi^-) K^+ \pi^0$	30 ± 8	$1.27 \times \frac{9}{2}$	1.71 ± 0.46
	$(\Lambda_1^0 K^- \pi^0) K_1^0 \pi^+$			
	Subtotal	62 ± 10		3.23 ± 0.52
$(\Sigma\bar{K}\pi)^0$	$(\Sigma_1^0 K^- \pi^+) K_1^0$	1 ± 1	$1.27 \times \frac{15}{4}^{(b)}$	0.05 ± 0.05
	$(\Sigma^+ K^- \pi^0) K_1^0$			
	$(\Sigma^+ \bar{K}_1^0 \pi^-) K^+ \pi^-$	11 ± 4	1.31×3	0.43 ± 0.16
	$(\Sigma^- \bar{K}_1^0 \pi^+) K^+ \pi^-$			
$(\Lambda\bar{K}\pi)^0$	$(\Lambda_1^0 K^- \pi^+) K_1^0$	3 ± 2	$1.25 \times \frac{9}{2}$	0.17 ± 0.11
	$(\Lambda_1^0 \bar{K}_1^0 \pi^0) K^+ \pi^-$	11 ± 6	$1.26 \times \frac{9}{2}$	0.62 ± 0.34
	$(\Lambda_1^0 K^- \pi^+) K^0 \pi^0$			
	Subtotal	26 ± 7		1.27 ± 0.34
$(\Omega K)^-$	$(\Omega_1^- K_1^0) K^+$	6 ± 2	$1.32 \times 4^{(b,c)}$	0.32 ± 0.11
	$(K\pi)^+$			
	Total	94 ± 12		4.82 ± 0.62

(a) Geometrical loss $\times$ neutral decay loss.

(b) We assume equal contributions from each reaction to arrive at an approximate average neutral decay weight.

(c) An additional weight for $(\Omega^- \rightarrow \text{all})/(\Omega^- \rightarrow \Lambda K) = 3/2$ has been applied.

TABLE 1 (Cont'd)

UPPER LIMITS			
Decay mode	Observed channel	Observed No. of events	Cross section (μb)
$(\Omega\text{K})^0$	$(\Omega_1^- \text{K}^+) \text{K}^0$ $(\text{K}\pi)^0$	< 2 (95% CL)	$< .10$
$(\Xi\pi)^-,^0$	$(\Xi_1^- \pi^0) \text{K}^+$ $(\Xi_1^- \pi^+) \text{K}^0$	< 8 (95% CL)	$< .17$
$(\Lambda\bar{\text{K}})^-,^0$	$(\Lambda_1^0 \text{K}^-) \text{K}^+$ $(\Lambda_1^0 \bar{\text{K}}^0) \text{K}_1^0$	< 9 (95% CL)	$< .26$
$(\Sigma\bar{\text{K}})^-,^0$	$(\Sigma_1^0 \text{K}^-) \text{K}^+$ $(\Sigma_1^0 \bar{\text{K}}^0) \text{K}_1^0$ $(\Sigma^+ \text{K}^-) \text{K}_1^0$ $(\Sigma^- \bar{\text{K}}_1^0) \text{K}^+$	< 5 (95% CL)	$< .17$
$(\Xi\pi\pi)^-,^0$	$(\Xi_1^- \pi^+ \pi^-) \text{K}^+$ $(\Xi_1^- \pi^+ \pi^0) \text{K}_1^0$	< 7 (95% CL)	$< .3$

FIGURE CAPTIONS

- Fig. 1 (a) $(Y\bar{K}\pi)^-$ effective mass distribution for four-body final states.
- (b) As in (a), but for five-body final states:
- (c) Sum of (a) and (b); $\cos \theta^*[K^-, Y\bar{K}\pi] > 0.6$ has been required. Shaded events have external $\Sigma(1385)$ and $\bar{K}^*(892)$ events removed. See text for further details.
- Fig. 2 Same as fig. 1 for $(Y\bar{K}\pi)^0$.
- Fig. 3 (a) $(\Omega K)^-$ effective mass distribution with $\cos \theta^*[K^-, \Omega^- K^0] > 0.6$.
- (b) Same as (a) but for $(\Omega K)^0$.
- Fig. 4 Sum of figs 1(c), 2(c), 3(a) and 3(b).

Fig.1

Fig.2

Fig.3

Fig.4