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OBSERVATION OF A ($K\pi\pi$) RESONANCE NEAR 1800 MeV

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Abstract:

Both in the reaction :

$$K^- p \rightarrow pK^-\pi^+\pi^- \qquad (1)$$

and in the reaction :

$$K^- p \rightarrow p\bar{K}^0\pi^-\pi^0 \qquad (2)$$

induced by 10 GeV/c negative kaons on hydrogen, an enhancement is observed in the $(K\pi\pi)^-$ effective mass distribution, at mass $M = 1789 \pm 10$ MeV and with full width at half height $\Gamma = 80 {}^{+20}_{-40}$ MeV. Evidence is presented which is consistent with the interpretation of this enhancement as a resonant state of isospin $I = 1/2$, with possible decay modes into $K\rho$, $K^*\pi$ and $K\omega$. It is proposed to name this resonance the L-meson.

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About 200,000 photographs of 10 GeV/c negative kaons, with an average of 5 kaons/picture, were taken at the CERN proton-synchrotron in the 150 cm British hydrogen bubble chamber. This was the first experiment performed with a high energy radio-frequency separated beam[1].

The events with 2 and 4 prongs, whether or not a strange particle is seen to decay, were measured on IEP or similar machines and analysed with the THRESH-GRIND-SLICE-SUMX system of programs. Out of ~9000 events for which kinematic fits were obtained, 994 events were classified[2], as belonging to reaction (1) and 425 events to reaction (2). Since in reaction (1) the positive pion frequently combines with the proton to form the $N^{*++}(1238)$ isobar, in the following analysis of the $(K\pi\pi)$ system only 699 events of this reaction have been used, for which no $(p\pi^+)$ combination is in the mass region 1.12 to 1.34 GeV. In Fig. 1a and 1b are shown the $(K\pi\pi)^-$ effective mass distributions for reaction (1), N^{*++} excluded, and for reaction (2). The shaded areas correspond to the events for which the square four-momentum, $|t|$, transferred to the proton, satisfies the condition $|t| < 0.6\ (\mathrm{GeV}/c)^2$. In Fig. 1c is shown the sum of these distributions for $|t| < 0.6\ (\mathrm{GeV}/c)^2$.

It can be seen in the figures that there is a broad peak near 1330 MeV and a narrower peak near 1800 MeV. The first peak may contain several of the enhancements reported in the literature[3]. In this letter we are concerned with the second peak which is observed here for the first time.

Since there exists at present no adequate means of calculating the shape of the non-resonant background in the distribution of Fig. 1c, several "backgrounds" have been drawn by hand in the region $M(K\pi\pi) > 1.50$ GeV, and fits have been made to the experimental distribution in Fig. 1c with such background shapes and with a Breit-Wigner curve to describe the peak near 1800 MeV. The fits indicate that the $(K\pi\pi)$ enhancement occurs at a mass $M = 1789 \pm 10$ MeV, and has a full width at half height $\Gamma = 80^{+20}_{-40}$ MeV. The errors given above contain allowance for the systematic uncertainty deriving from the lack of knowledge of the true background shape. The asymmetric error in Γ derives from the fact that the experimental resolution is not much smaller than the peak width itself[4]. In the mass region of the enhancement (1.71 to 1.87 GeV), the background accounts for 40 to 50 %, depending on the background chosen, of the events observed, and the peak stands 5 to 7 standard deviations above background.

As our data offer no other explanation of this enhancement (e.g. reflection or other kinematic effect), we are led to conclude that there exists a $K\pi\pi$ resonant state at this mass and propose to name it the L-meson.

Reactions (1) and (2), therefore, partly proceed via formation of the two body intermediate state :

$$K^- p \rightarrow pL^- . \qquad (3)$$

It may be noted that the restriction to small $|t|$ does not alter substantially the number of events in the L-meson region.

The cross section for the production of the L-meson in reaction (3) is of the order of 100 μb.

The isospin of this resonance can be I = 1/2 or 3/2.

Some possible decay modes of the L-meson are suggested by the distributions in Fig. 2. Fig. 2a shows the effective mass distribution for the system $(K^-\omega)$ as obtained from the events of reaction :

$$K^- p \rightarrow pK^-\pi^+\pi^-\pi^o , \qquad (4)$$

by excluding $N^{*++}(1238)$ and requiring that the three-pion system be in the mass region of the omega-meson (0.75 to 0.81 GeV). Fig. 2b shows the $(K\pi)^-$ mass distribution for the events of the reactions :

$$K^- p \rightarrow pK^-\pi^o \qquad (5)$$

and $$K^- p \rightarrow p\bar{K}^o\pi^- . \qquad (6)$$

The distribution in Fig. 2c is obtained for the events of reactions (1) and (2) by setting the conditions that the dipion systems considered are those with effective mass in the region of the rho-meson (0.62 to 0.88 GeV) and the distribution in Fig. 2d is similarly obtained by requiring that the $(K\pi)$ systems considered are those with effective mass in the region of the $K^*(890)$ resonance (0.85 to 0.93 GeV).

It can be seen that the distributions in Fig. 2a, 2c and 2d all present enhancements at around 1300 MeV and 1800 MeV, while no enhancements at those masses are seen in Fig. 2b, where, however, the resonances $K^*(890)$ and $K^*(1400)$ stand out clearly. Thus, no evidence is obtained for the decay $L \rightarrow K\pi$, while the results in Fig. 2a may be considered as evidence for the decay $L \rightarrow K\omega$. In fact, in the mass region of the L-meson, 2 events are expected from the background, and 12 events are observed. The existence of the decay $L \rightarrow K\omega$ would imply that the isospin of the L-meson is $I = 1/2$. The enhancements observed at around 1800 MeV in the $(K\rho)$ and $(K^*\pi)$ mass distribution do not prove, but are consistent with the decays $L \rightarrow K\rho$ and $L \rightarrow K^*\pi$. If the assumption is made that the enhancements at 1800 MeV observed in the various charge states of $(K^*\pi)$ mass distributions do represent the decay $L \rightarrow K^*\pi$, then the data confirm the assignment $I = 1/2$. This is shown in Table I, where the experimental values for the ratios indicated are given along with the values expected for $I = 1/2$ and $I = 3/2$.

A $K\pi\pi$ resonance cannot have spin and parity, $J^P = 0^+$. If the decay $L \rightarrow K\pi$ really does not exist, it may be that the L-meson has spin and parity incompatible with such a decay, i.e., that the L-meson has J^P in the series 0^-, 1^+, 2^-, ...

We are deeply indebted to the operating crews of the CERN proton synchrotron, of the 150 cm British hydrogen bubble chamber, and to the constructors of the RF separated beam. We would like to thank the scanning, measuring and computing staffs at each of our laboratories. We are pleased to acknowledge helpful discussions with Dr. R. Armenteros and Prof. Ch. Peyrou.

REFERENCES

1) P. Bramham, R.D. Fortune, E. Keil, H. Lengeler, B.W. Montague and W.W. Neale, Physics Letters 15 (1965) 290.

2) The fiducial region in which events of reaction (2) were studied is about twice as large as the region in which events of reaction (1) were taken.

3) For a summary of the references on ($K\pi\pi$) resonances with mass of 1170, 1215, 1275, 1320 and 1400 MeV, see J.M. Bishop, A.T. Goshaw, A.R. Erwin, M.A. Thompson, W.D. Walker and A. Weinberg, Phys. Rev. Letters, 16 (1966) 1069.

4) The experimental resolution in this experiment is of ≈40 MeV, as estimated from the fitted value of the full width at half height of the omega-peak observed in the effective mass distribution of the three-pion system in reaction $K^-p \rightarrow pK^-\pi^+\pi^-\pi^o$.

FIGURE CAPTIONS

Fig. 1 a) Effective mass distribution of the $(K\pi\pi)^-$ system for events of reaction (1) for which the $(p\pi^+)$ system is not in the mass region of the N^*. The shaded area corresponds to the events with $|t| < 0.6$ $(GeV/c)^2$.

b) Effective mass distribution of the $(K\pi\pi)^-$ system for the events of reaction (2). The shaded area corresponds to the events with $|t| < 0.6$ $(GeV/c)^2$.

c) Sum of the two above distributions, for the events in which the squared four momentum transferred to the proton is $|t| < 0.6$ $(GeV/c)^2$.

Fig. 2 a) $(K\omega)^-$ effective mass distribution obtained from reaction (4).

b) $(K\pi)^-$ effective mass distribution obtained from reactions (5) and (6).

c) $(K\rho)^-$ effective mass distribution obtained from reactions (1) and (2).

d) $(K^*\pi)^-$ effective mass distribution obtained from reactions (1) and (2).

TABLE I

Isopsin of L-meson	$\frac{K^{*-}(890)\pi^0 \to (K^0\pi^-)\pi^0}{K^{*0}(890)\pi^- \to (K^0\pi^0)\pi^-}$		$\frac{K^{*0}(890)\pi^- \to (K^-\pi^+)\pi^- + (K^0\pi^0)\pi^-}{K^{*-}(890)\pi^0 \to (K^0\pi^-)\pi^0}$	
	Theor.	Expt.	Theor.	Expt.
1/2	1	0.9 ± 0.6	4	3.0 ± 1.5
3/2	4		1	

CAPTION FOR TABLE

Table 1. Expected values of the ratios indicated, for isospin 1/2 and 3/2 of the L-meson, and corresponding experimental values deduced from reactions (1) and (2). The expected values are calculated correcting for unobservable decay modes, probability of detecting the K^0, and difference in size of fiducial regions for reactions (1) and (2).

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FIG. 1

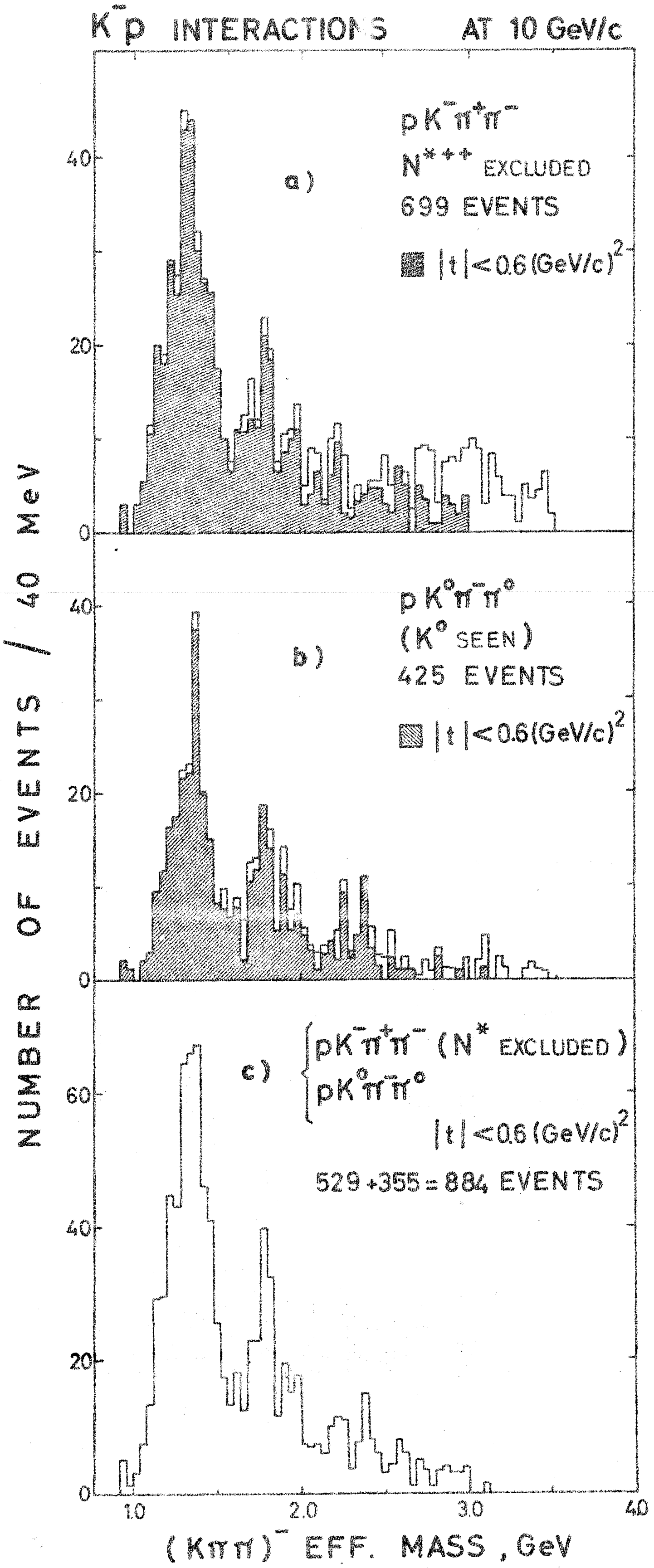

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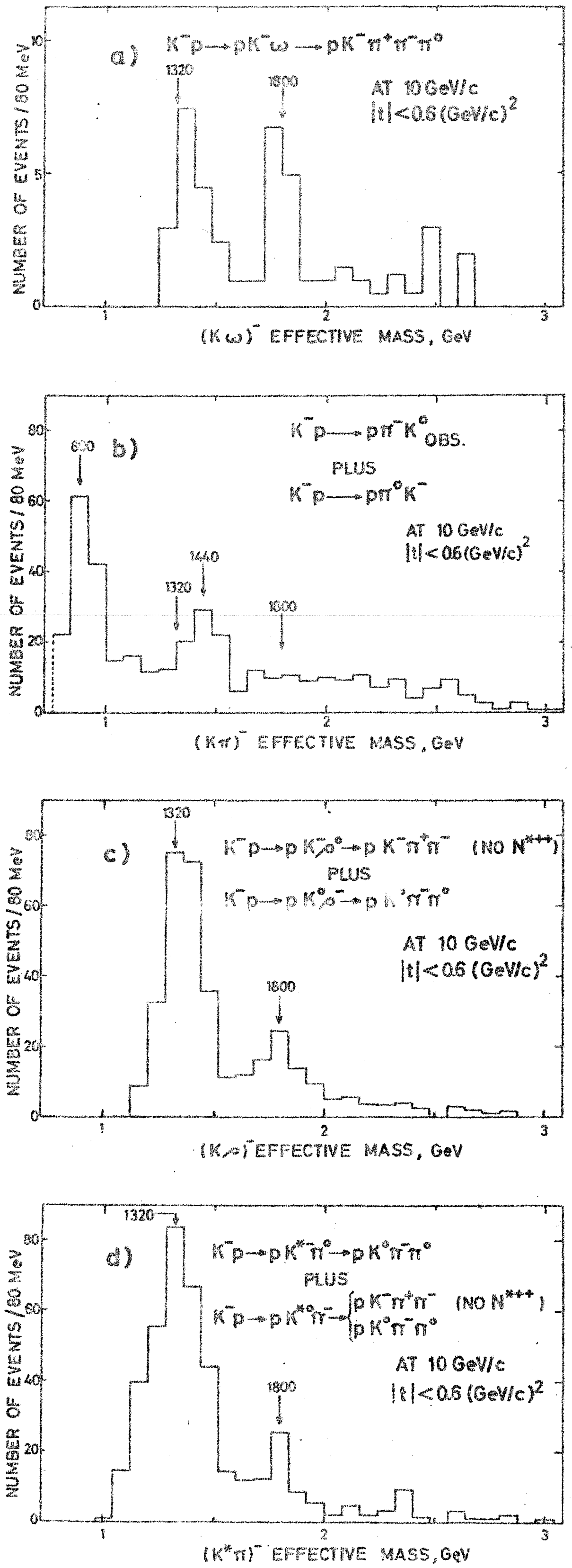
FIG. 2



a) K⁻p → pK⁻ω → pK⁻π⁺π⁻π⁰
1320
1800
AT 10 GeV/c
|t|<0.6 (GeV/c)²
NUMBER OF EVENTS / 80 MeV
(Kω)⁻ EFFECTIVE MASS, GeV
b) K⁻p → pπ⁻K⁰ OBS.
PLUS
K⁻p → pπ⁰K⁻
600
1320
1440
1800
AT 10 GeV/c
|t|<0.6 (GeV/c)²
NUMBER OF EVENTS / 80 MeV
(Kπ)⁻ EFFECTIVE MASS, GeV
c) K⁻p → p K⁻ρ⁰ → p K⁻π⁺π⁻ (NO N*⁺⁺)
PLUS
K⁻p → p K⁰ρ⁻ → p K⁰π⁻π⁰
1320
1800
AT 10 GeV/c
|t|<0.6 (GeV/c)²
NUMBER OF EVENTS / 80 MeV
(Kρ)⁻ EFFECTIVE MASS, GeV
d) K⁻p → pK*⁻π⁰ → pK⁰π⁻π⁰
PLUS
K⁻p → pK*⁰π⁻ → p K⁻π⁺π⁻ (NO N*⁺⁺) / p K⁰π⁻π⁰
1320
1800
AT 10 GeV/c
|t|<0.6 (GeV/c)²
NUMBER OF EVENTS / 80 MeV
(K*π)⁻ EFFECTIVE MASS, GeV

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