NEW RESULTS IN MESON SPECTROSCOPY

Amsterdam-CERN-Nijmegen-Oxford-Collaboration

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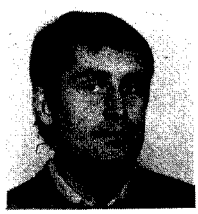

Abstract: We review some of the observations made on meson systems in a ∿ 100 events per microbarn 4 GeV K^-p bubble chamber experiment. The properties or existence of f'(1514), $K^*(1420)$. E(1420), D(1283), $A_1(1100)$, Q bump, δ(980), B(1235) are briefly reviewed.

Résumé: Nous passons en revue les observations faites sur les systèmes mésoniques dans une expérience de chambre à bulles K^-p de ∿ 100 événements par microbarn. L'existence ou les propriétés du f'(1514), $K^*(1420)$, E(1420), D(128), $A_1(1100)$, Q bump, δ(980) B(1235) sont rapidement présentés.

1. INTRODUCTION

We do not intend to give an exhaustive presentation of new experimental results in meson spectroscopy, nor even to give a complete review of the observations made with the new large statistics experiment which study 4.2 GeV/c K^-p interactions in the 2 m hydrogen bubble chamber at a level of $\sim$ 100 events per microbarn. But this experiment will illustrate how a "large statistics" classical bubble chamber experiment may give numerous important results in the field of meson spectroscopy.

Previous similar experiments, done at the level of a few events per microbarn have given interesting results on 1^{--} and 2^{++} mesons. They also led to original but often contradictory results on 0^{++}, 1^{++} and 1^{+-} nonets. We shall see how the 4.2 GeV K^-p experiment, which aims at an order of magnitude larger statistics, may help to clarify several pending problems in meson spectroscopy.

The 4.2 GeV/c K^-p experiment is a work done in collaboration by Amsterdam-Nijmegen-Oxford Universities and CERN.

2. THE 2^{++} NONET

We see a clean f'(1514) in two channels:

$$K^-p \rightarrow \Lambda K^+K^- \qquad 2935 \text{ events} \qquad (1)$$

$$K^-p \rightarrow (\Lambda,\ \Sigma^0)\ K^0_s\ K^0_s \qquad 318 \text{ events} \qquad (2)$$

with all Λ^0, and K^0_s seen (fig. 1).

The mass and width measured in reaction (2) are:

$$M = (1522 \pm 5)\ \text{MeV} \qquad \Gamma \leqslant (40)\ \text{MeV}.$$

Notice the different shapes of background, in particular in the A_2 region. This may be due to the interference effects advocated by H. Lipkin[1).

The 3-body decay mode of the $K^*(1420)$ has been studied in the charge exchange reaction:

$K^- p \to \bar{K}^o \pi^+ \pi^- n$ 20371 events   (3)

A partial wave analysis (Ascoli-type)[2] gives a good representation of the data if we introduce $J^P = 0^-, 1^-$, 1^+ and 2^+ waves for the $K\pi\pi$ system. The 2^+ wave (25%) goes entirely through $K^*\pi$ and $K\rho$ quasi 2-body states (fig. 2). The mass dependence of this wave is well described by a Breit-Wigner function.

The production of the 2^+ wave occurs mainly via unnatural parity exchange with m = 0 but there is also a m = 1 component accounting for 28% of the total. The cross section $K^- p \to K^*(1420)n$ with $K^*(1420) \to (K\pi\pi)^o$ is $(153 \pm 21)\mu b$ after accounting for all corrections.

The branching ratio:

$$R = \frac{K^*(1420) \to K\rho}{K^*(1420) \to K^*\pi} = .36 \pm .10$$

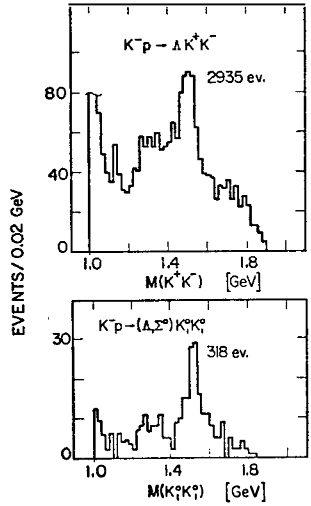

Fig. 1

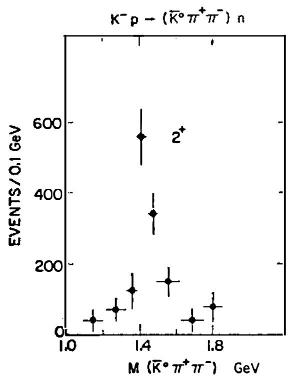

Fig. 2

3. STRANGE AXIAL VECTOR MESONS

The existence of the strange members of the 1^{++} and 1^{+-} nonets is not yet well established. Partial wave analyses (3) of the low mass $K\pi\pi$

system produced in diffractive-like reactions $K^{\pm}p \rightarrow (K\pi\pi)^{\pm}p$ have identified two 1^{+} states in the Q region, one decaying into $K^{*}\pi$, the other into $K\rho$, but with different production properties. There is also an old observation made in $\bar{p}p$ annihilations suggesting the existence of a $K\pi\pi$ resonance (the "C" meson) with $J^{PC} = 1^{++}$, M = 1243 MeV and Γ = 127 MeV[4].

At 4.2 GeV/c, the reaction

$$K^{-}p \rightarrow p\overline{K^{o}\pi^{-}\pi^{o}} \qquad 32772 \text{ events} \qquad (4)$$

reveals a double peak structure in the Q-bump region which may indicate the presence of two-resonances superimposed to a large Deck background with $J^{P}\eta = 1^{+}0^{+}$. Both structures are observed when K^{*} or ρ selections are applied (fig. 3). A partial wave analysis is in progress.

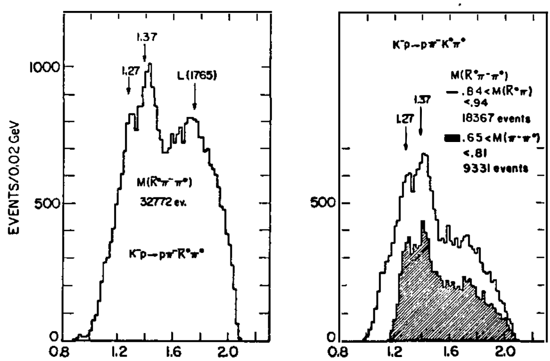

Fig. 3

The charge exchange reaction (3) gives also interesting information on the $K\pi\pi$ system. There the diffractive background is absent. The partial wave analysis of the channel shows that the 1^{+} S-wave $(K^{*}\pi)$ and 1^{+} S-wave $(K\rho)$ contributions have a different behaviour. The $1^{+}(K^{*}\pi)$ mode occupies all magnetic substates whereas $1^{+}(K\rho)$ is almost only produced with m = 0. The mass dependences of the two quasi 2-body states are also different.

4. THE E-MESON

The E-meson was first observed in $\bar{p}p$ annihilations as a $K\bar{K}\pi$ enhancement with M = 1420 MeV and Γ = 50 MeV[5].

The reaction

$$K^- p \to \Lambda^o K^o K^{\pm} \pi^{\mp} \qquad \text{822 events} \qquad (5)$$

with all V^o's seen, gives excellent data to study the $K\bar{K}\pi$ system. A narrow peak is effectively observed at the mass of the E-meson (fig. 4), a Breit-Wigner fit gives:

$$M = (1.429 \pm 4)\ \text{MeV} \qquad \Gamma = (12 \pm 11)\ \text{MeV}$$

after unfolding mass-resolution (of the order of 5 MeV).

The narrowness of this peak and the fact that it seems to be 100% $K^*\bar{K}$ + c.c. (compared to 50% for the E observed in $\bar{p}p$ annihilations) makes questionable the assignment of these two effects to the same physical phenomenon.

The second enhancement observed in the $K\bar{K}\pi$ mass spectrum, centered at M ∿ 1520 MeV with Γ ∿ 100 MeV is probably due to the mixture of several states. Two of them could be the $K^*\bar{K}$ decay of f'(1514) and of the rarely observed F_1(1550) meson.

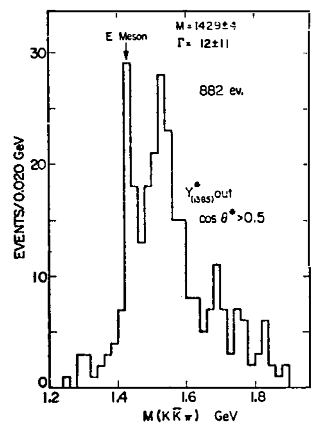

Fig. 4

5. THE D^o MESON

For the first time, to our knowledge, the D(1285) meson decay is observed in the same experiment into three decay modes (fig. 4 and 5):

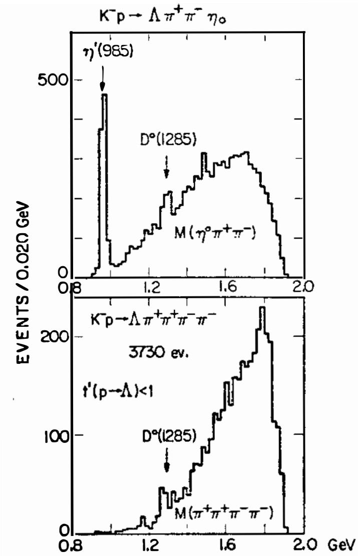

Fig. 5

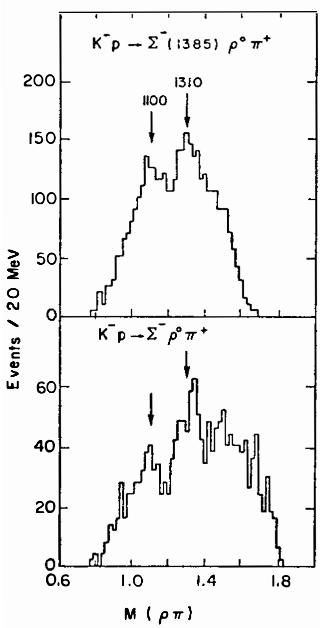

Fig. 6

$K^-p \to D^0\Lambda^0$, $D^0 \to K^0K^{\pm}\pi^{\mp}$ (only 2σ effect)

$D^0 \to \eta^0\pi^+\pi^-$ (8σ effect)

$D^0 \to 2\pi^+2\pi^-$ (5σ effect)

6. THE A_1 (1100) MESON?

It has been suggested the elusive A_1 meson ($J^{PC} = 1^{++}$) may show up in non-diffractive reactions like hypercharge or baryon exchange. We have looked for baryon exchange in our K^-p experiment and have found two channels which show a significant enhancement at $M \sim 1100$ MeV in the $\rho\pi$ system (fig. 6):

$$K^-p \to \Sigma^-(1385)\ \rho^0\pi^+, \qquad (6)$$

$$\Sigma^-(1385) \to \Lambda^0\pi^-,\ \rho^0 \to \pi^+\pi^-$$

and

$$K^-p \to \Sigma^-\ \rho^0\pi^+,\ \rho^0 \to \pi^+\pi^-. \qquad (7)$$

with $\cos(K^-, \Sigma^-) > .4$

The $\rho\pi$ enhancements are characterized by

$M \sim 1070$ MeV $\quad \Gamma \sim 130$ MeV

and, if attributed to $A_1^+ \to (\rho\pi)^+$ production, correspond to cross section for the processes

$$K^-p \to Y^- A_1^+ \qquad A_1 \to \rho\pi$$

$$\hookrightarrow \Sigma^- \text{ or } \Sigma^-(1385)$$

of 1 to 2 μb.

7. THE $\delta(980)$ MESON

We have been able to isolate a relatively narrow enhancement in the $\eta\pi$ system, with

$$M = (981 \pm 6)\ \text{MeV} \qquad \Gamma = (55 \pm 15)\ \text{MeV}$$

which may be attributed to the production of the $J^{PC} = 0^{++}$ $I = 1$ $\delta(980)$ meson in the reaction

$$K^-p \rightarrow \delta^-(980)\ \Sigma^+(1385) \qquad (8)$$

$$\delta^- \rightarrow \eta^o\pi^-, \quad \Sigma^+ \rightarrow \Lambda^o\pi^+ .$$

To obtain a good signal to noise ratio, we have used the events in which the $\Lambda^o \rightarrow p\pi^-$ and the $\eta^o \rightarrow \pi^+\pi^-\pi^o$ decays are observed. The results of this selection (including a t cut on the production of $\Sigma^+(1385)$) are shown on fig. 7(a). Fig. 7(b) shows a weighted histogram which selects reaction (8) from the observed final state $\Lambda 2\pi^+ 2\pi^- \pi^o$.

The production of $\delta^-(98C)$ in reaction (8), accounting for all corrections, is $\sigma = (6.2 \pm 1.3)\mu b$.

No significant $\delta^+(980)$ production is observed ($\sigma = 1.4 \pm 0.7)\mu b$.

Since the $\delta \rightarrow \eta\pi$ phenomenon can lead to a $K\bar{K}$ threshold enhancement, we also looked for this effect in the reaction

$$K^-p \rightarrow K^oK^-\ \Sigma^+(1385),\ \Sigma^+(1385) \rightarrow \Lambda^o\pi^+.$$

Fig. 7(c) suggests the presence of such an enhancement which agrees

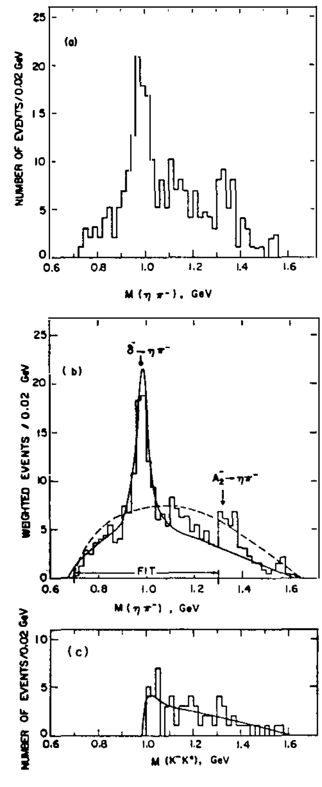

Fig. 7

with the expected $K\bar{K}/\eta\pi$ branching ratio for a 0^{++} isoscalar parent. Of course, the proximity of the $K\bar{K}$ threshold raises the question of the correct interpretation of this narrow $\eta\pi$ enhancement[6].

The decay angular properties of the $\delta \to \eta\pi$ are in agreement with $J^P = 0^+$ although other spin assignments cannot be excluded at this stage.

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