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OBSERVATION OF A NARROW CHARGED STATE AT 1876 MeV/c^2 DECAYING TO AN EXOTIC COMBINATION OF $K\pi\pi$*

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ABSTRACT

We report evidence for the production of a new narrow charged state in e^+e^- annihilation at a center of mass energy of 4.03 GeV. This state, which has a mass of 1876 ± 15 MeV/c^2 and a decay width less than 40 MeV/c^2, is observed as a sharp peak in the invariant mass spectra of the exotic channel $K^+\pi^-\pi^+\pi^-$, but not in the corresponding non-exotic channel $K^+\pi^+\pi^-$. It is produced primarily in association with a system of mass 2.01 ± 0.02 GeV/c^2. These production and decay characteristics are just those expected of a charged charmed meson. Furthermore, the proximity of its mass to that of the previously reported neutral state with mass 1865 MeV/c^2 suggests that they are members of the same isospin multiplet.

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In a previous Letter we reported the observation in e^+e^- annihilation of a new narrow neutral state of mass 1865 MeV/c^2 which decays into $K^\pm\pi^\mp$ and $K^\pm\pi^\mp\pi^+\pi^-$.[1] This state was observed in 29,000 hadronic events in the center of mass energy (E_{cm}) range 3.9 to 4.6 GeV. To study the properties of this state and to search for other new states, we subsequently obtained 19,000 additional events at a fixed E_{cm} of 4.03 GeV. In these new data, there is clear evidence for a new narrow charged state of mass 1876 ± 15 MeV/c^2 which decays into the exotic channel $K^\pm\pi^\mp\pi^\pm\pi^\pm$, but not into the normal K^* channel $K^\pm\pi^+\pi^-$. This behavior is just that expected for the weak decay of a charged charmed meson.[2]

The data were obtained with the SLAC-LBL magnetic detector at SPEAR.[3] E_{cm} was chosen to be 4.03 GeV because the total hadronic cross section appears to peak at this energy after a very sharp rise, indicating the possible existence of a resonance or a threshold for new channels.[4] The analysis techniques are substantially the same as those used in Ref. 1. Briefly, each particle in a multihadronic event is assigned a weight proportional to the probability that it is a π or K. These weights are determined from the measured momentum and time of flight over a 1.5 to 2.0 m flight path using a Gaussian time distribution with 0.4 ns standard deviation. The π-K weights are normalized so that for each track their sum is unity. All possible combinations of tracks and particle hypotheses are made with each combination weighted by the joint probability that the tracks satisfy the particular particle hypotheses assigned to them.

Invariant mass spectra for $K\pi\pi$ mass combinations weighted in the manner explained above are presented in Fig. 1. In Fig. 1(a) there is a peak near 1.87 GeV/c^2 in the exotic channel $K^\pm\pi^\mp\pi^\pm$ with a statistical significance of greater than five standard deviations.[5] No structure is seen in the corres-

ponding non-exotic channel, $K^{\mp}\pi^{+}\pi^{-}$ (Fig. 1(b)), nor in any other combination of three charged particles. There is also no structure observed in doubly charged modes such as $K^{\mp}\pi^{\mp}$, $K^{\mp}\pi^{\mp}\pi^{+}\pi^{-}$, or $K^{\mp}\pi^{\mp}\pi^{+}\pi^{-}$.

We have plotted the data shown in Fig. 1 in finer bins and have fit them to Gaussian peaks with backgrounds given by quadratic polynomials. The mass of the $K^{\mp}\pi^{-}\pi^{+}$ peak is 1876 ± 15 MeV/c^2 where the quoted uncertainty includes both statistical and systematic contributions. The observed width of the $K^{\mp}\pi^{-}\pi^{+}$ peak is consistent with what is expected from experimental resolution alone. At the 90% confidence level, the decay (full) width of this state is less than 40 MeV/c^2

Figure 2 shows the mass spectrum recoiling against the $K^{\mp}\pi^{-}\pi^{+}$ peak in Fig. 1(a). The background is derived from the mass spectrum recoiling against the same mass region in the $K^{\mp}\pi^{+}\pi^{-}$ mode. The $K^{\mp}\pi^{-}\pi^{+}$ peak appears to recoil primarily against a narrow system of mass $2.01 \pm .02$ GeV/c^2, whose observed width is consistent with experimental resolution.

We estimate the cross section times branching ratio to be 0.3 nb at $E_{cm} = 4.03$ GeV, with a systematic uncertainty which could be as large as $\pm$ 50%. This value is about half as large as that for the $K^{\mp}\pi^{-}$ mode of the neutral state at this E_{cm}. The total hadronic cross section at 4.03 GeV is 33 ± 5 nb.[4]

In summary, we have observed a significant peak in the $K^{\mp}\pi^{-}\pi^{+}$ mass spectrum that we associate with the decay of a new state of mass 1876 ± 15 MeV/c^2 and width less than 40 MeV/c^2. At $E_{cm} = 4.03$ GeV, the state is produced primarily in association with a system of mass $2.01 \pm .02$ GeV/c^2. If this $K\pi\pi$ peak were to arise from the strong decay of a strange meson resonance, the isospin of that resonance would have to be 3/2 or 5/2. One might then expect to observe doubly charged decay modes, but no evidence for such modes has been observed. Furthermore, no strange meson resonance of isospin other than 1/2 has ever

been observed. On the other hand, the charm theory predicts that the necessarily weak decay of the lowest lying charged meson with unit charm and zero strangeness will strongly prefer exotic over non-exotic decay modes. Thus, the similarity in mass of this charged state and the previously reported neutral state, their narrow widths, their recoil mass spectra, their decays to strange channels, and the decay of the charged state to an exotic channel but not to the corresponding normal channels all strongly suggest that they are the predicted (D^+, D^0) isodoublet of charmed mesons.[6]

These data were obtained in a new mode of SPEAR running in which beams were injected directly into the operating configuration. Substantial gains in both peak and time-averaged luminosities were achieved using this method. We would particularly like to thank the SPEAR operating staff for their enthusiastic efforts.

REFERENCES

1. G. Goldhaber, F.M. Pierre, et al., SLAC report number SLAC-PUB-1762 (1976), to be published in Phys. Rev. Letters.

2. In the charm model the Cabibbo favored decays involve a c quark going to an s quark, giving $\Delta C = \Delta S$. Thus the D^+ with C = + 1, decays to a system with S = - 1 and positive charge, which is exotic.

3. J.-E. Augustin et al., Phys. Rev. Lett. 34, 233 (1975); 34 764 (1975).

4. J. Siegrist et al., Phys. Rev. Lett. 36, 700 (1976).

5. The 2.7 standard deviation peak near 2.05 GeV/c^2 in the $K^{\pm}\pi^{\mp}\pi^{\pm}$ mass spectrum does not contain 1.865 GeV/c^2 $K^{\pm}\pi^{\mp}$ combinations and its recoil mass spectrum does not contain any clear structure. We do not consider it significant.

6. J.D. Bjorken and S.L. Glashow, Phys. Lett. 11, 255 (1964); S.L. Glashow, J. Iliopoulos, and L. Maiani, Phys. Rev. D2, 1285 (1970); M.K. Gaillard, B.W. Lee, and J.L. Rosner, Rev. Mod. Phys. 47, 277 (1975); A. De Rújula, H. Georgi, and S.L. Glashow, "Is Charm Found?", Harvard preprint (1976).

FIGURE CAPTIONS

1. Invariant mass spectra for $K\pi\pi$ combinations from 19,000 multihadronic events at $E_{cm} = 4.03$ GeV. a) $K^{\pm}\pi^{\mp}\pi^{\pm}$, b) $K^{\pm}\pi^{+}\pi^{-}$.
2. Recoil mass spectra for the $K^{\pm}\pi^{\mp}\pi^{\pm}$ peak mass region, 1.86 to 1.90 GeV/c^2. The smooth curve is an estimate of the background obtained from the same region in the $K^{\pm}\pi^{+}\pi^{-}$ spectrum.

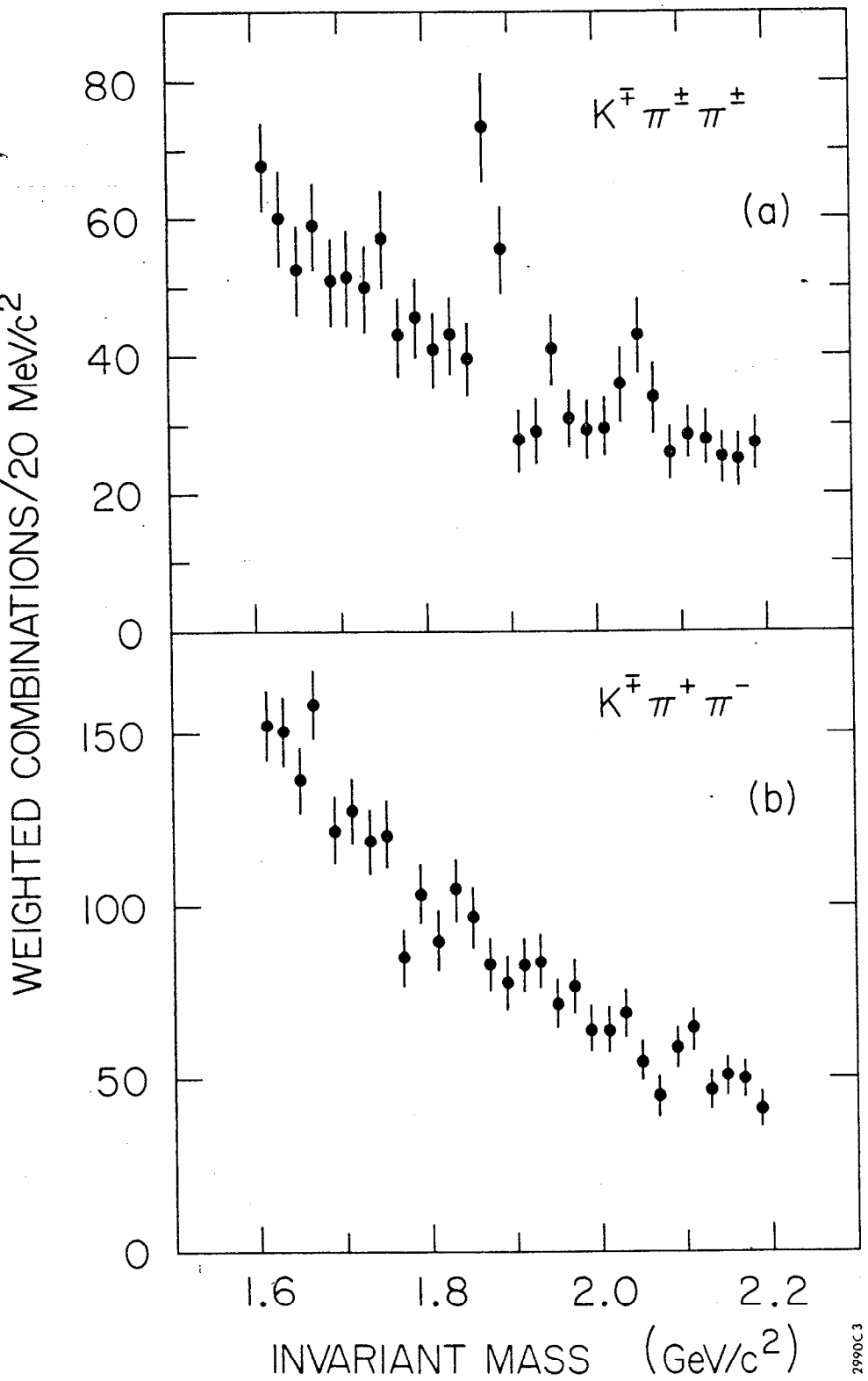
80
60
40
20
0
$K^{\mp}\pi^{\pm}\pi^{\pm}$
(a)
150
100
50
0
$K^{\mp}\pi^{+}\pi^{-}$
(b)
WEIGHTED COMBINATIONS/20 MeV/c^2
1.6
1.8
2.0
2.2
INVARIANT MASS (GeV/c^2)
2990C3

Fig. 1

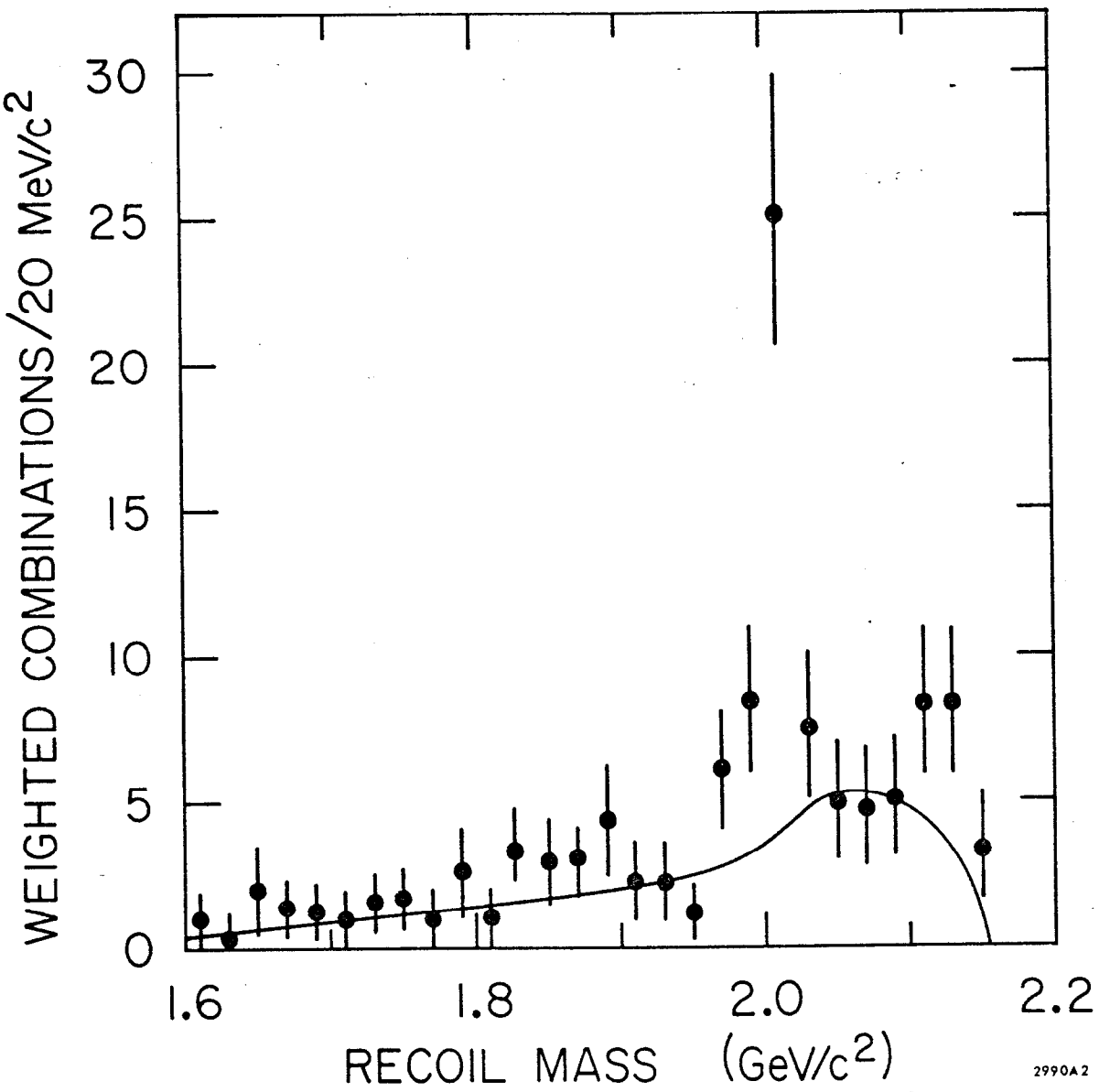
WEIGHTED COMBINATIONS/20 MeV/c²
30
25
20
15
10
5
0
1.6
1.8
2.0
2.2
RECOIL MASS (GeV/c²)
2990A2

Fig. 2