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Light Quark Spectroscopy Results from FOCUS and E687

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Abstract

Using the FOCUS spectrometer (experiments 687 and 831 at Fermilab) we confirm the existence of a diffractively photoproduced enhancement in K^+K^- at $1750 \text{ MeV}/c^2$ with nearly 100 times the statistics of previous experiments. We also observe a narrow dip structure at $1.9 \text{ GeV}/c^2$ in a study of diffractive photoproduction of the $3\pi^+3\pi^-$ final state.

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In this paper we present results on the spectroscopy of high-energy light meson photoproduction from the FOCUS (E831) and E687 experiments at Fermilab. Although both experiments were focused on charm physics, a very large sample of diffractively photoproduced light-meson events was also recorded. Details on the detector can be found in Ref. [1], Ref. [2], and references therein.

1 Observation of a 1750 MeV/c² Structure in the Diffractive Photoproduction of K^+K^-

The data for this analysis was collected by the Wideband photoproduction experiment FOCUS during the Fermilab 1996–1997 fixed-target run. In FOCUS, a forward multi-particle spectrometer is used to measure the interactions of high energy photons on a segmented BeO target. A photon beam is derived from the bremsstrahlung of secondary electrons and positrons with an ≈ 300 GeV endpoint energy produced from the 800 GeV/c Tevatron proton beam. The FOCUS detector is a large aperture, fixed-target spectrometer with excellent vertexing, particle identification, and reconstruction capabilities for photons, π^0 's, and K_S .

Our sample of K^+K^- events, selected using the criteria described in detail in Ref. [1], shows a clear $\phi(1020)$ signal dominating the spectrum (Fig. 1). The diffractive component of the production of the $\phi(1020)$ shows up as a peak in the p_T spectrum. Cutting around this peak by requiring $p_T < 0.15$ GeV/c, we select a diffractive sample of K^+K^- events, in which a clear enhancement appears in the mass spectrum near 1750 MeV/c² (Fig. 2.a). Figure 2.b confirms that the enhancement appears at only low p_T . Plotting the p_T spectra in the 1750 region (1640–1860 MeV/c²) and in the two sideband regions (1500–1600 MeV/c² and 1900–2100 MeV/c²), it is seen that the 1750 region has a peak in the p_T spectrum in nearly the same place as the $\phi(1020)$ peak, but the sideband regions have significantly smaller p_T peaks, indicating that the background under the X(1750) signal is largely non-diffractive. Fitting the 1750 MeV/c² mass region with a non-relativistic Breit-Wigner distribution and a quadratic background, we find

$$\text{Yield} = 11,700 \pm 480 \text{ Events}$$

$$M = 1753.5 \pm 1.5 \pm 2.3 \text{ MeV}/c^2$$

$$\Gamma = 122.2 \pm 6.2 \pm 8.0 \text{ MeV}/c^2$$

There is a region near 1600 MeV/c² where there is some discrepancy in our fit to the K^+K^- mass spectrum. The residuals show that the statistical significance of this discrepancy is not strong (Fig. 2.d). Finally, we searched for the X(1750) enhancement in

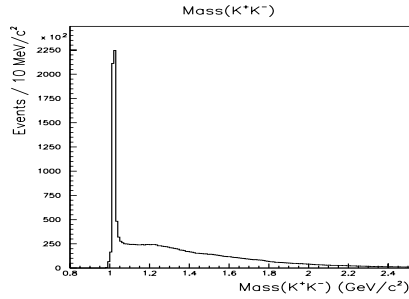


Figure 1: The K^+K^- sample with no cut on p_T .

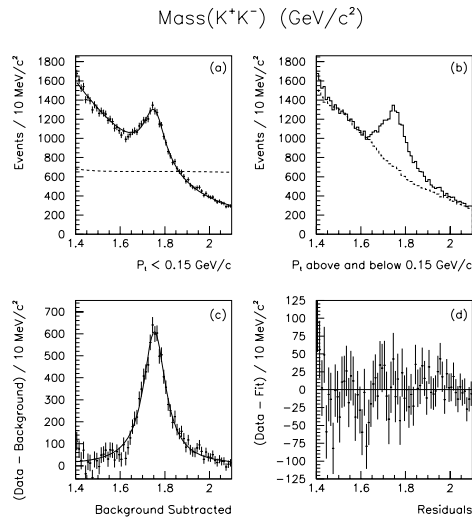


Figure 2: (a) The K^+K^- mass spectrum with the requirement that $p_T < 0.15$ GeV/c. The spectrum is fit with a non-relativistic Breit-Wigner distribution and a quadratic background. The dotted line is the Monte Carlo efficiency on a scale from 0 to 100%. (b) The solid line is the K^+K^- mass spectrum with the requirement that $p_T < 0.15$ GeV/c. The dotted line is the K^+K^- mass spectrum with $p_T > 0.15$ GeV/c scaled to the size of the low p_T spectrum for comparison. (c) The data and fit after subtracting the quadratic polynomial background shape. (d) The data minus the fit.

K^*K and we find

$$\frac{\Gamma(X(1750) \rightarrow \overline{K}^{*0} K^0 \rightarrow K^- \pi^+ K_S + c.c.)}{\Gamma(X(1750) \rightarrow K^+ K^-)} < 0.065 \text{ at } 90\% \text{ C.L.}$$

$$\frac{\Gamma(X(1750) \rightarrow K^{*+} K^- \rightarrow K_S \pi^+ K^- + c.c.)}{\Gamma(X(1750) \rightarrow K^+ K^-)} < 0.183 \text{ at } 90\% \text{ C.L.}$$

The two relative branching ratios were measured to be -0.083 ± 0.081 and 0.065 ± 0.072 , respectively. Because of the large discrepancies in mass and relative branching fractions to $K^+ K^-$ and $K^* K$, we do not believe it is reasonable to identify the X(1750) (which should be assigned the photon quantum numbers $J^{PC} = 1^{--}$) with the $\phi(1680)$. In fact, because the mass of the X(1750) is significantly higher than all known vector mesons, the most massive of which are the $\omega(1650)$, $\phi(1680)$, and $\rho(1700)$, an interpretation claiming the X(1750) is some combination of interfering vector mesons also seems highly unlikely. The interpretation of the X(1750) remains uncertain.

2 A Narrow Dip in A Study of Diffractive Photoproduction

The Fermilab experiment 687, FOCUS predecessor, collected data during the 1990/91 fixed-target runs at the Wideband Photon beamline at Fermilab. We report on a study of the diffractive photoproduction of the $3\pi^+ 3\pi^-$ final state and the observation of a narrow dip in the mass spectrum at 1.9 GeV/c². Pions are produced in photon interactions in the Be target. The data acquisition trigger requires a minimum energy deposition in the hadron calorimeters located behind the electromagnetic calorimeters and at least three charged tracks outside the pair region. Details of event selection, analysis cuts and fitting strategies are reported in [2]. The invariant mass distribution of diffractively produced $3\pi^+ 3\pi^-$ final states shows a dip structure at about 1.9 GeV/c². No evidence for structures is shown in the incoherent ($P_T^2 > 0.040 \text{ GeV}^2/c^2$ subsample (Fig.3a). Fig. 3b) shows the coherent mass distribution after correcting for efficiency and acceptance, and unfolding the spectrometer mass resolution. The dip structure has been characterized by a two-component fit, adding coherently a relativistic Breit-Wigner resonance to a diffractive continuum contribution. Fit values show consistent evidence for a narrow resonance at $M_r = 1.911 \pm 0.004 \pm 0.001 \text{ GeV}/c^2$ with a width $\Gamma = 29 \pm 11 \pm 4 \text{ MeV}/c^2$, where the errors quoted are statistic and systematic, respectively. Such a resonance could be assigned the photon quantum numbers ($J^{PC} = 1^{--}$) and $G=+1, I=1$ due to the final state multiplicity. There is little understanding of the specific mechanism responsible for this destructive interference.

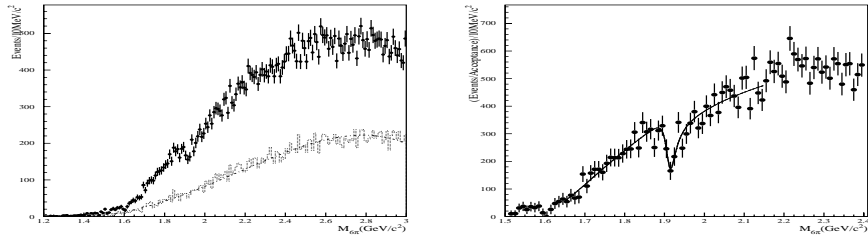


Figure 3: a) Distribution of $3\pi^+3\pi^-$ invariant mass in the 1.2–3.0 GeV/c^2 mass range: coherent plus incoherent contribution. Dotted distribution: incoherent contribution. b) Acceptance-corrected distribution of $3\pi^+3\pi^-$ invariant mass for diffractive events. The mass resolution has been unfolded.

3 Conclusions

We have reported on new results from fixed target photoproduction at Fermilab, which show how a high-resolution multiparticle spectrometer, coupled to a high-energy photon beam, constitutes a tremendously effective tool to explore the light vector meson spectroscopy and dynamics. More results will be coming soon.

References

- [1] J. M. Link *et al.* (FOCUS Coll.), Phys. Lett. B **545** (2002) 50 [arXiv:hep-ex/0208027].
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