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Charm Meson Decay into the Final States $K^0_s K^+$ and $K^0_s K^{*+}$

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Abstract

We have made a new measurement of the branching ratio $\Gamma(D^+ \rightarrow \overline{K^0}K^+)/\Gamma(D^+ \rightarrow \overline{K^0}\pi^+)$ and the first measurement of $\Gamma(D^+ \rightarrow$

$\overline{K^0}K^{*+})/\Gamma(D^+ \rightarrow \overline{K^0}\pi^+)$. The data were accumulated in the 1990-1991 fixed target running period of Fermilab high energy photoproduction experiment E687. We measure $\Gamma(D^+ \rightarrow \overline{K^0}K^+)/\Gamma(D^+ \rightarrow \overline{K^0}\pi^+) = 0.25 \pm 0.04 \pm 0.02$ and $\Gamma(D^+ \rightarrow \overline{K^0}K^{*+})/\Gamma(D^+ \rightarrow \overline{K^0}\pi^+) = 1.1 \pm 0.3 \pm 0.4$.

We have searched for charm meson decays into the final states $K_s^0\pi^+$, $K_s^0K^+$ and $K_s^0K^{*+}$ (charge conjugate states are assumed unless stated otherwise). The decay channels $D^+ \rightarrow \overline{K^0}K$ and $D^+ \rightarrow \overline{K^0}\pi$ are Cabibbo-suppressed and Cabibbo-allowed respectively. Destructive interference arises in the Cabibbo-allowed case because there are two spectator diagrams which contribute to non-leptonic D^+ decays. As a result of destructive interference, final-state interactions, and differences in phase space, the branching ratio of the Cabibbo-suppressed to Cabibbo-allowed D^+ decays can be larger than the naively expected value of $\tan^2\theta_c$.

The data for this analysis were collected in 1990 and 1991 in Fermilab photoproduction experiment E687. The E687 detector is a a large aperture spectrometer, with excellent particle identification capabilities for charged particles and vertexing capabilities via a silicon microstrip vertex detector. A detailed description of the E687 detector and analysis methods can be found in reference [1].

The K_s^0 candidates are identified via their decay to $\pi^+\pi^-$. The error on the K_s^0 mass is calculated for each candidate, and the invariant $\pi^+\pi^-$ mass is required to be within 2 σ of the known K_s^0 mass. There are no particle identification requirements for the daughter pion tracks of the K_s^0 candidate. The pion candidates opposite the K_s^0 are required to be inconsistent with a Čerenkov hypothesis of an electron, kaon or proton. The K^+ candidates are required to be consistent with a kaon Čerenkov hypothesis.

The signal-to-noise of the charm signals can be improved by utilizing the vertex information from the silicon microstrip detector. A candidate driven vertexing algorithm [1] is used to identify primary and secondary vertices of the decay. A seed plane is determined by the charged track direction and the candidate D direction. The seed plane is combined with available tracks to form a primary vertex. The significance of detachment of the vertices, or ℓ/σ_ℓ, is defined as the distance (ℓ) between the two vertices divided by its error, (σ_ℓ). The vertexing algorithm also provides two estimators of the relative isolation of the vertices. The first isolation estimator is the confidence level of the hypothesis that a track in the secondary vertex was also in the primary vertex. The second estimator is the confidence level that any track not already used in either vertex came from the secondary vertex. In this analysis we require these two estimators to be less than 0.25 and 0.0005 respectively.

The invariant mass distributions for $K_s^0\pi^+$ and $K_s^0K^+$, with the requirement that $\ell/\sigma_\ell > 8$, are shown in figs. 1-2, with a D^+ signal evident in both decay modes. The mass distributions are fitted with two Gaussian functions (with the width fixed to the Monte Carlo value), plus a second degree polynomial background function. The fitted D^+ yield is 129.2 $\pm$ 18.3 events for $K_s^0K^+$, and 702.6 $\pm$ 37.7 events for $K_s^0\pi^+$. After correcting the fitted yields by the (Monte Carlo determined) efficiencies, we measure $\Gamma(D^+ \to \overline{K^0}K^+)/\Gamma(D^+ \to \overline{K^0}\pi^+)$ = 0.25 $\pm$ 0.04 $\pm$ 0.02, which is in agreement with the world average value [2] of 0.28 $\pm$ 0.06. The systematic uncertainty is dominated by the choice of analysis requirements and fitting techniques.

The Cabibbo-suppressed decay $D_s^+ \to K_s^0\pi^+$ has not yet been observed [3]. The $K_s^0\pi^+$ mass distribution in fig. 1 shows a possible enhancement of events near the expected D_s^+ mass. The result of the fit (with the width fixed to the Monte Carlo value) is a yield of 22 $\pm$ 25 events. Fig. 2 shows a clear D_s^+ signal in the (Cabibbo-allowed) final state $K_s^0K^+$ with a fitted yield of 75.6 $\pm$ 15.2 events. Correcting these yields by the efficiencies determined from Monte Carlo gives a branching ratio of $\Gamma(D_s^+ \to K^0\pi^+)/\Gamma(D_s^+ \to \overline{K^0}K^+) = 0.18 \pm 0.21$, or $\Gamma(D_s^+ \to K^0\pi^+)/\Gamma(D_s^+ \to \overline{K^0}K^+) < 0.53$ (90% C.L.). The existing limit [2] is $\Gamma(D_s^+ \to K^0\pi^+)/\Gamma(D_s^+ \to \overline{K^0}K^+) < 0.21$ (90% C.L.).

The invariant mass distribution for $K_s^0K^{*+}$, with the requirement that $\ell/\sigma_\ell > 4$, is shown in fig. 3. The K^{*+} candidates are identified by their decay to $K_s^0\pi^+$, in which one of the $K_s^0\pi^+$ combinations has an invariant mass within 50 MeV/c^2 of 892 MeV/c^2. A D^+ signal is evident, and the yield of the fit is 67.1 ± 18.1 events. (The $K_s^0\pi^+$ mass distribution, for both K_s^0 combinations, is shown in fig. 4, with a requirement that the $K_s^0 K_s^0 \pi^+$ invariant mass be within ± 1.25 σ of the known D^+ mass. We note that when a sideband subtraction of the K^{*+} mass is performed, the D^+ yield agrees within the statistical errors). After correcting for the Monte Carlo determined efficiency and the branching ratio of $K^{*+} \to K_s^0\pi^+$, we measure $\Gamma(D^+ \to \overline{K^0}K^{*+})/\Gamma(D^+ \to \overline{K^0}\pi^+) = 1.1 \pm 0.3 \pm 0.4$.

There has been one previous measurement of the decay $D_s^+ \to \overline{K_s^0}K^{*+}$ [4]. We see no evidence for $D_s^+ \to \overline{K_s^0}K^{*+}$, and measure the upper limit to be $\Gamma(D_s^+ \to \overline{K^0}K^{*+})/\Gamma(D_s^+ \to \overline{K^0}K^+) < 0.9$ (90% C.L.). This is consistent with the existing measurement [2] of $\Gamma(D_s^+ \to \overline{K^0}K^{*+})/\Gamma(D_s^+ \to \overline{K^0}K^+) = 1.2 \pm 0.4$.

In conclusion, we have reported a new branching ratio measurement of $\Gamma(D^+ \to \overline{K^0}K^+)/\Gamma(D^+ \to \overline{K^0}\pi^+) = 0.25 \pm 0.04 \pm 0.02$ in agreement with previous measurements [2], and the first measurement of $\Gamma(D^+ \to \overline{K^0}K^{*+})/\Gamma(D^+ \to \overline{K^0}\pi^+) = 1.1 \pm 0.3 \pm 0.4$. We observe a possible enhancement of events near the D_s^+ mass in the final state $K_s^0\pi^+$, but see no evidence for D_s^+ in the final state $K_s^0K^{*+}$.

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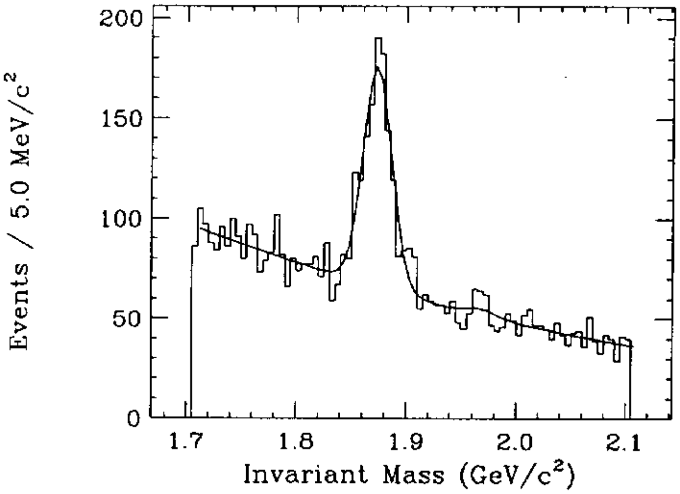

Fig. 1. Invariant mass distribution and fit for $K_s^0\pi^+$.

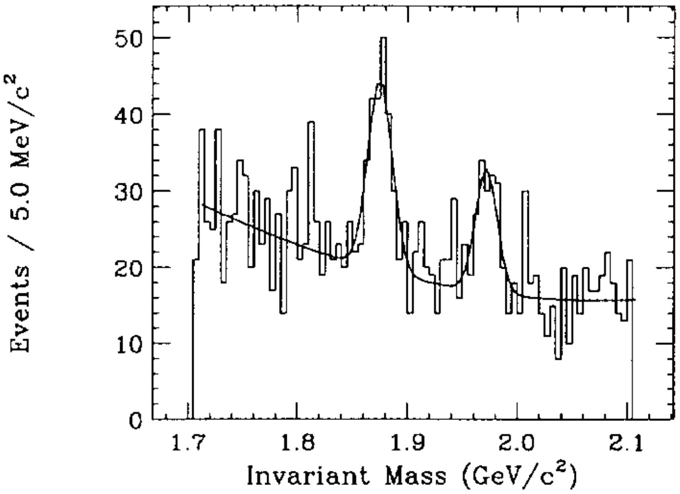

Fig. 2. Invariant mass distribution and fit for $K_s^0K^+$.

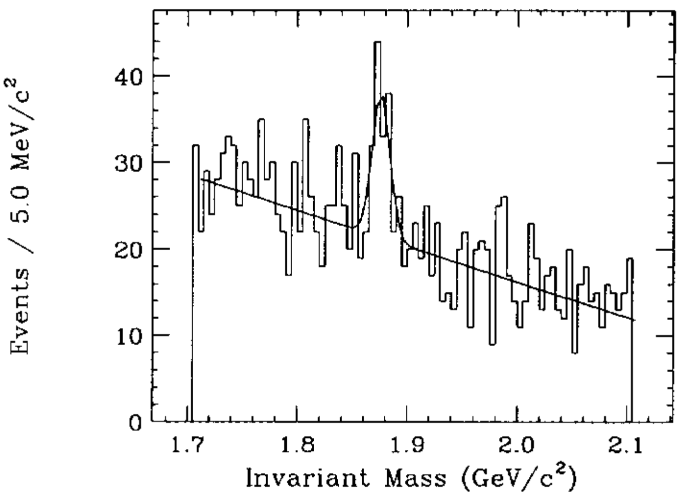

Fig. 3. Invariant mass distribution and fit for $K_s^0K^{*+}$.

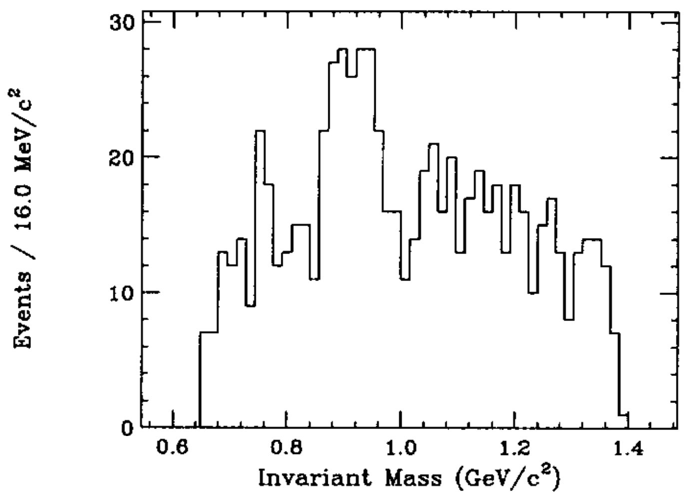

Fig. 4. Invariant mass distribution for $K_s^0\pi^+$.