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Abstract

Using the ARGUS detector at the e^+e^- storage ring DORIS II at DESY we have measured the parameters of a charmed strange meson $D_{s2}^{*+}(2573)$ decaying into D^0K^+. The mass of this state was found to be $(2574.5 \pm 3.3 \pm 1.6)$ MeV/c^2. The measured value of its width is $(10.4 \pm 8.3 \pm 3.0)$ MeV and the product of the production cross section and branching ratio for this channel was determined to be $(10.6 \pm 4.2^{+2.3}_{-1.2})$ pb.

1 Introduction

Experimental studies of heavy-light quark-antiquark systems offer an important possibility to test theoretical models, including quark-gluon strings and semirelativistic approximations [1], along with basic QCD approaches such as HQET and QCD sum rules [2]. Furthermore, the experimental investigation of charmed resonances will lead to a better understanding of B meson excited state properties, important for B "tagging" in future studies of B mesons, including searches for CP violation [3]. Since the first observation of a charmed P-wave meson resonance [4], there has been significant progress in the investigation of charmed excited states. In fact, five out of six predicted narrow P-wave charmed mesons have been observed [5].

Recently, CLEO observed the last predicted narrow P-wave charmed strange meson $D_{s2}^{*+}(2573)$ decaying into D^0K^+ [6]. The values of its mass and natural width were found to be equal to $(2573.2^{+1.7}_{-1.6} \pm 0.8 \pm 0.5)$ MeV/c^2 and $(16^{+5}_{-4} \pm 3)$ MeV, respectively. The spin-parity quantum number 2^+ was assigned to this state.

In this paper we present a confirmation of that observation along with a study of the decay of this charmed strange resonance through a measurement of its parameters.

2 Event selection procedure

The data sample used for this study corresponds to an integrated luminosity of 450 pb^{-1} obtained with the ARGUS detector at the DORIS II e^+e^- storage ring while running on the $\Upsilon(1S)$, $\Upsilon(2S)$ and $\Upsilon(4S)$ resonances, and in the nearby continuum. The ARGUS detector is a 4π spectrometer described in detail elsewhere [7].

Charged particles from the main vertex were required to have a momentum transverse to the beam direction greater than 60 MeV/c and to have a polar angle θ in the range $|\cos\theta| \leq 0.92$. These particles were identified on the basis of specific ionization, time of flight, energy deposition in the shower counters and penetration to the muon chambers, and treated as $\pi^\pm$ or $K^\pm$ if the likelihood ratio for the hypothesis under consideration exceeded 1%.

The measurement of the charmed strange excited state has been made using the decay channel $D_{s2}^{*+} \to D^0K^+$ with a subsequent decay $D^0 \to K^-\pi^+$ or $D^0 \to K^-\pi^-\pi^+\pi^+$.[1]

All $K\pi(K3\pi)$ combinations with an invariant mass within 30(20) MeV$/c^2$ of the D^0 mass [8] were accepted as D^0 candidates. It was also required that a kaon in each combination has a likelihood ratio in excess of 5%. In order to reduce the background arising from random combinations of kaons with a large number of slow pion candidates in each event, $\cos\theta_K^*$ was forced to be less than 0.7(0.0) in the $K\pi(K3\pi)$ case, where θ_K^* is the angle between the K^- momentum direction in the D^0 rest frame and the D^0 boost direction. This cut is effective in reducing background because the signal is flat in $\cos\theta_K^*$ while the background peaks strongly towards $\cos\theta_K^* = 1$. All D^0 candidates successfully passing this cut were then kinematically fit to the nominal D^0 mass and combined with each positively charged track in the event consistent with the kaon hypothesis. To suppress the background from combinations with misidentified pions, the likelihood ratio for K^+ in each D^0K^+ pair was required to be greater than 10%. This cut also leads to a considerable reduction of reflections from the decays $D_2^{*+}(2460) \to D^0\pi^+$, $D_2^{*+}(2460) \to D^{*0}\pi^+$, and $D_1^+(2420) \to D^{*0}\pi^+$ followed by $D^{*0} \to D^0\pi^0(\gamma)$. These feed-down contributions were evaluated by simulating such processes with a Monte Carlo simulation using the previously measured parameters and production cross sections for these resonances [5].

The momentum spectrum of a meson containing a leading charm quark is expected to be hard compared to the combinatorial background. We therefore reduced our background by imposing a cut $x_p > 0.6$ on each D^0K^+ combination, where $x_p = p/p_{max}$ and $p_{max} = \sqrt{E_{beam}^2 - [M(D^0K^+)]^2}$.

3 Data analysis

The resulting D^0K^+ invariant mass spectrum is shown in Fig.1 by points with error bars. A peak is observed at a mass of approximately 2575 MeV$/c^2$. The narrow structure at about 2400 MeV$/c^2$ corresponds to the reflection from the partially reconstructed decay chain $D_{s1}^+(2536) \to D^{*0}K^+$, $D^{*0} \to D^0\pi^0(\gamma)$, where the π^0 or γ is disregarded. Contributions of reflections from $D_1^+(2420)$ and $D_2^{*+}(2460)$ are shown with an open histogram at the bottom of Fig.1.

Figure 2 shows the D^0K^+ invariant mass spectrum after subtraction of feed-down contributions. It was fitted with a sum of a second order polynomial and a Breit-Wigner function convoluted with a Gaussian of fixed width. This Gaussian represents the mass resolution of the detector, which was determined to be (5.0 ± 0.2) MeV$/c^2$ through a Monte Carlo study. The fit yields 93 ± 37 events at a mass of $(2574.5 \pm 3.3 \pm 1.6)$ MeV$/c^2$ and a natural width of $(10.4 \pm 8.3 \pm 3.0)$ MeV$/c^2$, in agreement with the CLEO measurements [6].

The invariant mass spectrum was also fitted with the same function while the mass and natural width were fixed to the central values of those measured by CLEO [6]. The fit yields 109 ± 30 events in the signal peak.

[1] References to a specific particle state should be interpreted as implying the charge-conjugate state also

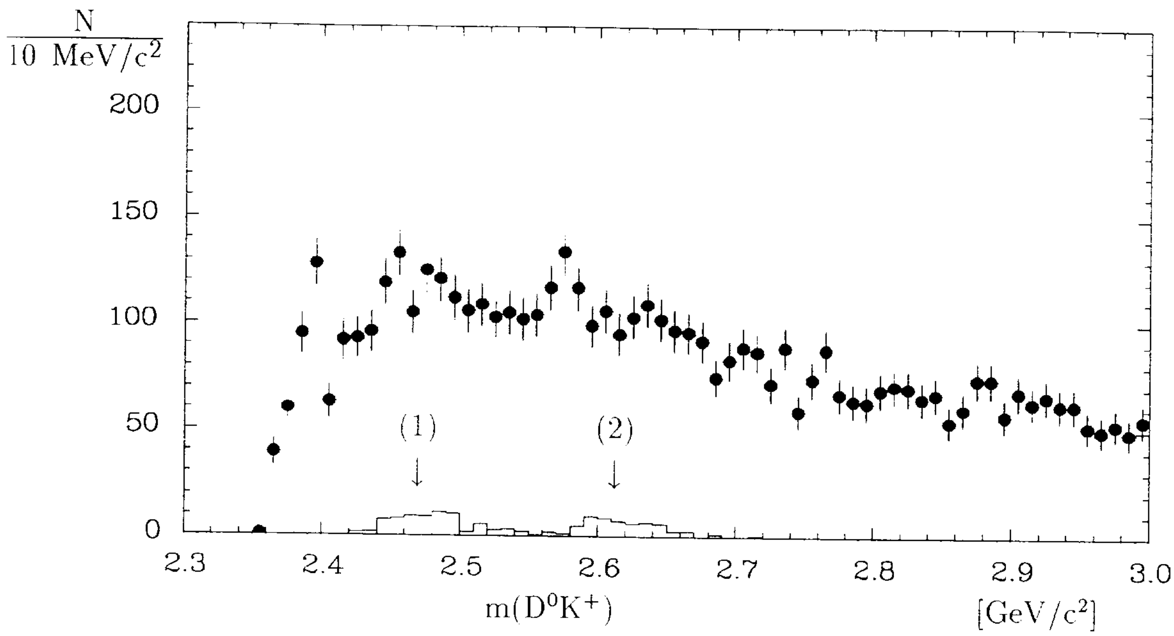

Figure 1: Invariant mass spectrum for all accepted D^0K^+ combinations. The histogram at the bottom represents the total contribution of feed-down structures described in the text. The arrows (1) and (2) point to the region populated by the reflections from decays $D_1^+(2420) \rightarrow D^{*0}\pi^+$ and $D_2^{*+}(2460) \rightarrow D^{*0}\pi^+$, and the feed-down from the decay $D_2^{*+}(2460) \rightarrow D^0\pi^+$ respectively.

Systematic errors were obtained by varying the cuts, the feed-down contributions, the background parametrization and the mass resolution.

In order to demonstrate that the signal is not an artifact of the selection criteria, a sideband study was performed. The sideband D^0 candidates were reconstructed from $K\pi(K3\pi)$ combinations with invariant mass lying in 30(20) MeV/c^2 wide sidebands centered at above and below 55(40) MeV/c^2 the nominal D^0 mass. The invariant mass distribution for the sideband is shown in Fig.2 by the solid histogram. It shows no enhancement in the signal area.

In addition we have checked that the measured signal parameters are stable against a variation of x_p and kaon identification requirements.

We have also investigated the $D^{*+}K^0_S$ invariant mass spectrum and found no peak corresponding to the signal observed in the D^0K^+ distribution. This is in agreement with theoretical models which predict D^*K modes to be suppressed due to the limited phase space [1].

The fragmentation function of the $D_{s2}^{*+}(2573)$ was determined by fitting the observed mass spectrum in four x_p bins, fixing the mass and width to the values measured from the overall fit. The resulting acceptance corrected x_p distribution is shown in Fig.3, along with a fit to the Peterson fragmentation function [9] which has the form:

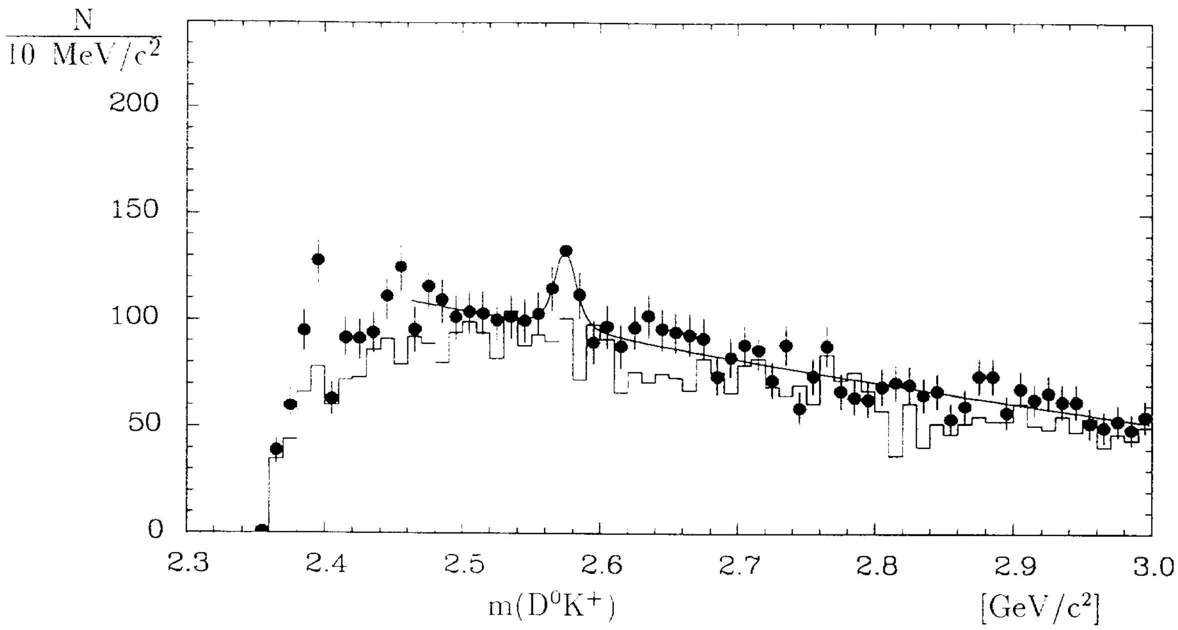

Figure 2: D^0K^+ invariant mass distribution after subtraction of feed-down contributions. The solid histogram corresponds to the D^0 sidebands. The curve corresponds to the fit described in the text.

$$\frac{d\sigma}{dx_p} \propto \frac{1}{x_p(1-\frac{1}{x_p}-\frac{\epsilon}{1-x_p})^2}.$$

The value determined for the fragmentation parameter is $\epsilon = 0.027^{+0.043}_{-0.015} \pm 0.003$.

The production cross section was calculated by extrapolating the fragmentation function to $x_p = 0$ using the Peterson model. Based on the detector efficiency estimated by Monte-Carlo simulation we obtained:

$$\sigma(e^+e^- \to D^{*+}_{s2}X)Br(D^{*+}_{s2} \to D^0K^+) = (10.6 \pm 4.2^{+2.3}_{-1.2}) \text{ pb}$$

The systematic error includes the errors on the branching ratios, fit parameters and the extrapolation procedure.

For better comparison with CLEO's result [6] we calculated the production cross section times branching ratio for $x_p > 0.7$:

$$\sigma(x_p > 0.7)Br(D^{*+}_{s2} \to D^0K^+) = (7.2 \pm 2.9^{+0.7}_{-1.1}) \text{ pb}$$

This number coincides within the errors with the CLEO value $(4.1 \pm 0.9 \pm 0.7)$ pb.

The result on σBr depends on the efficiency of K^+ identification requirement. CLEO evaluated it using the $D^+_{s1}(2536)$ feed-down peak [6]. Since the K^+ momentum spectrum

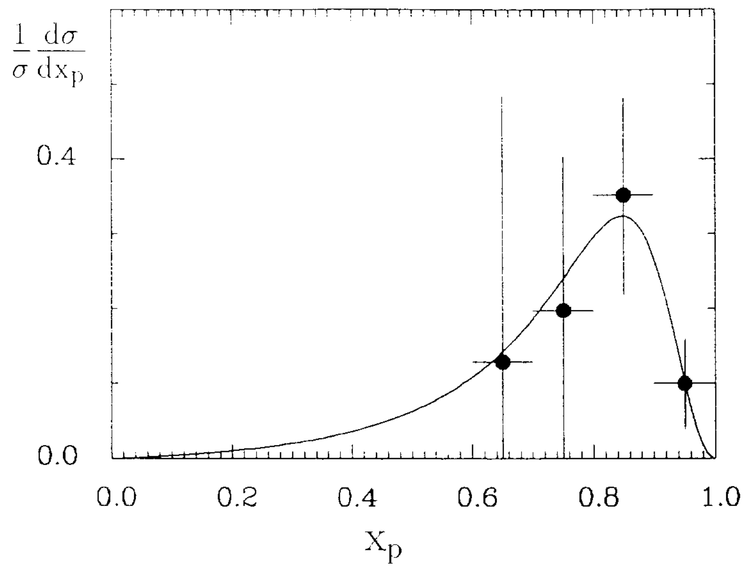

Figure 3: Acceptance corrected x_p spectrum.

from the $D_{s1}^{+}(2536)$ feed-down (near threshold) is softer than that from the $D_{s2}^{*+}(2573)$ decay, this procedure, if performed on ARGUS data, would lead to a substantial overestimation of the K^+ identification efficiency and, consequently, to the underestimation of the σBr. Therefore we determined this efficiency using Monte Carlo simulation.

4 Summary

We have confirmed the observation of the charmed strange resonant state $D_{s2}^{*+}(2573)$ in the decay mode D^0K^+. The measured values of its mass $M = (2574.5 \pm 3.3 \pm 1.6)$ MeV/c^2 and natural width $\Gamma = (10.4 \pm 8.3 \pm 3.0)$ MeV/c^2 are consistent with the values obtained by CLEO [6]. We have also determined the production cross section times branching ratio for this channel: $\sigma\mathrm{Br} = (10.6 \pm 4.2^{+2.3}_{-1.2})$ pb.

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