Direct measurement of Br($D_s^+ \to \overline{K}^{*0}X$) and Br($D_s^+ \to K^{*0}X$)

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1. INTRODUCTION

During the last two decades much progress in heavy flavor physics have been made. Up to now more and more precise measurements of exclusive decay branching fractions of charmed mesons have been done. However, experimental study of inclusive decay properties of the charmed mesons are still limited. Previously, we reported the inclusive branching fractions of $D_s^+ \to e^+X$[1], and $D_s^+ \to \phi X$[2]. In this paper, we report a direct measurement of the inclusive decay branching fractions for $D_s^+ \to \overline{K}^{*0}X$ and $D_s^+ \to K^{*0}X$ using the data collected with BES[3] detector at BEPC[4] e^+e^-Collider at $\sqrt{s} = 4.03$ GeV.

2. SINGLE D_s^- TAGS

D_s^- mesons are reconstructed in five hadronic decay modes $\phi\pi^-$, $K^{*0}K^-$, $K_S^0K^-$, $K_S^0K^+\pi^-\pi^-$, and $f_0\pi^-$ with subresonances decaying as $\phi \to K^+K^-$, $K^{*0} \to K^+\pi^-$, $K_S^0 \to \pi^+\pi^-$, and $f_0 \to \pi^+\pi^-$. Events used in the single tag are required to contain at least three reconstructed charged tracks with good helix fits. In order to ensure good momentum resolution and charged particle identification, the tracks are required to be within $|cos\theta|$ <0.8, where θ is the polar angle. All tracks, save those from K_S^0 decays, must originate from the interaction region. Pions and kaons are identified by means of TOF and dE/dx measurements. Identification requires consistency with the pion or kaon hypothesis at a confidence level greater than 0.1% (or 1%). In order to reduce misidentification, kaon candidates are further required to have a larger confidence level for the kaon hypothesis than for the pion hypothesis. For the $f_0\pi^-$ mode, all pion candidates are required to have a larger confidence level for the pion hypothesis than for the kaon and electron hypothesis.

In order to reduce background, the difference between the measured energy of the D_s^- candidates and the beam energy $|E_{diff}|$ is required to be less than 50 MeV for $\phi\pi^-$ and $K^{*0}K^-$ modes, and 30 MeV for $f_0\pi^-$ mode. For the modes containing a K^0 an asymmetric cut -50MeV< E_{diff} < 20 MeV is imposed. Candidate D_s^- decays are subject to beam energy constraint kinematic fit and are required to have the fit confidence level greater than 1% for $\phi\pi^-$ or $K^{*0}K^-$ modes, greater than 6% for $K_S^0K^-$ or $K_S^0K^+\pi^-\pi^-$ modes, and greater than 10% for $f_0\pi^-$ mode. Backgrounds can be further reduced by applying a mass cut on the subresonances which are defined as follows: $|M_{K^+K^-} - M_\phi| < 18$ MeV/c^2, $|M_{K^+\pi^-} - M_{K^{*0}}| < 70$ MeV/c^2, $|M_{\pi^+\pi^-} - M_{K_S^0}| < 22$ MeV/c^2, and $|M_{\pi^+\pi^-} -$

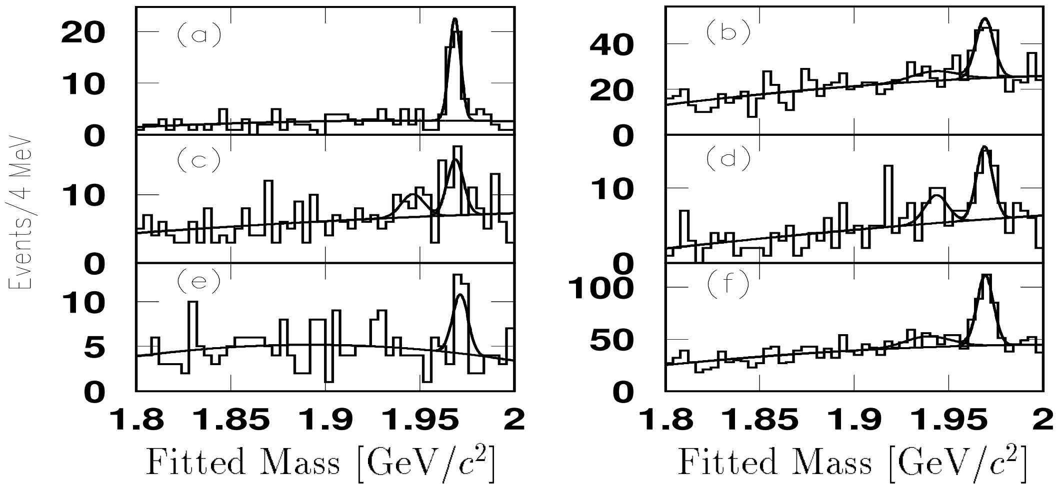

Figure 1. Distributions of invariant masses of (a) $\phi\pi^-$, (b) $K^{*0}K^-$, (c) $K^0_SK^-$, (d) $K^0_SK^+\pi^-\pi^-$, (e) $f_0\pi^-$ and (f) combined the $\phi\pi^-$, $K^{*0}K^-$, $K^0_SK^-$, $K^0_SK^+\pi^-\pi^-$ and $f_0\pi^-$ together.

$M_{f_0}| < 30$ MeV/c^2. For the $f_0\pi^-$ mode, the cosine of the D_s^- production angle relative to beam direction is required to be $|cos\theta| < 0.6$. For the K^0_S reconstruction, we require the momentum vector of the two oppositely charged pions to be aligned with the position vector of the secondary vertex in the xy plane with a confidence level greater than 10%. The secondary vertex is required to be at least 0.4 cm away from the collision point in xy plane, and the z coordinates of the two pion tracks to be within 4 cm of the secondary vertex. There is an additional restriction imposed on the data for the $K^{*0}K^-$ mode. Since this decay involves a spin-zero particle decaying into a spin-one K^{*0} and a spin-zero K^-, the K^{*0} must be aligned in helicity-zero state, giving a $cos^2\theta_{K^+}$ distribution to the kaons, where θ_{K^+} is the helicity angle between the K^+ direction in the K^{*0} rest frame and the K^{*0} direction in the D_s^- rest frame. The helicity angle of the K^+ in the K^{*0} helicity frame is required to be $|\cos\theta_{K^+}| > 0.35$ to reduce background in the $K^{*0}K^-$ mode.

After applying the above cuts, signals for D_s^- are clearly evident in the invariant mass spectra for each decay mode as shown in Figure 1(a-e). The figure 1(f) shows the combined invariant masses of the $(nKm\pi)^-$ (where the n=0, 1 or 2 and the m=1, 2, 3 or 4) from the five tagged modes. In the figure the lower peak beside D_s^- is mainly due to $D^- \to K^0_S\pi^-$ and $D^- \to K^0_S\pi^+\pi^-\pi^-$ produced via $e^+e^- \to DD^*$, where the pion is misidentified as a kaon. A fit to the mass spectra with a Gaussian function for the D_s^- signal and a quadratic function for combinatorial background and another Gaussian function for the $D^- \to K^0_S\pi^-$ and $D^- \to K^0_S\pi^+\pi^-\pi^-$ background yields a total number of $183.6 \pm 24 \pm 6.5$ singly tagged D_s^- mesons. The first error is statistical, the second systematic estimated by varying the parameterization of the background.

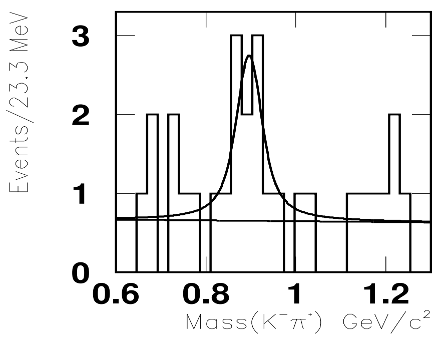

Figure 2. Distribution of invariant masses of the $K^-\pi^+$ combinations opposite the D_s^- tags.

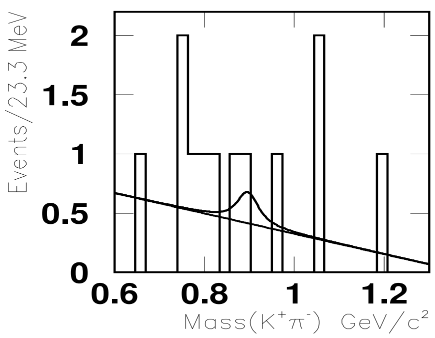

Figure 3. Distribution of invariant masses of the $K^+\pi^-$ combinations opposite the D_s^- tags.

3. CANDIDATES OF $D_s^+ \to \overline{\mathrm{K}}^{*0}$X AND $D_s^+ \to K^{*0}$X

To measure the inclusive $\overline{\mathrm{K}}^{*0}$and K^{*0} decay branching fractions of D_s^+ meson, the $\overline{\mathrm{K}}^{*0}$and K^{*0} mesons need to be searched for in the system recoiling against the tagged D_s^-. The $\overline{\mathrm{K}}^{*0}(K^{*0})$ meson is reconstructed through its decay to $K^-\pi^+$ $(K^+\pi^-)$.

Figure 2 shows the invariant masses of the $K^-\pi^+$ combinations opposite the D_s^- tags. There is a $\overline{\mathrm{K}}^{*0}$signal in the figure. A fit to the $K^-\pi^+$ mass spectra with a Breit-Wigner function convoluted a Gaussian resolution function plus a first order polynomial gives 8.5 ± 4.2 candidate events. Similarly, figure 3 shows the distribution of invariant masses of the $K^+\pi^-$ combinations opposite the D_s^- tags. No significant K^{*0} signal is found. Fitting to this $K^+\pi^-$ mass spectrum with the fixed peak at 0.896 GeV/c^2 as well as the fixed standard deviation of 8.7 MeV/c^2 obtained from the data, we got 1.2 ± 2.3 inclusive K^{*0} events.

The net numbers of observed $D_s^+ \to \overline{\mathrm{K}}^{*0}$X and $D_s^+ \to K^{*0}$X candidate events are obtained after background subtraction using the tag sideband information. After subtracting the background contributions to the D_s^+, we obtain the numbers of 7.5 ± 4.4 $D_s^+ \to \overline{\mathrm{K}}^{*0}$X signal events and 0.1 ± 2.4 $D_s^+ \to K^{*0}$X candidate signal events.

4. RESULT

The inclusive branching fraction is obtained based on the number of $D_s^+ \to \overline{\mathrm{K}}^{*0}/K^{*0}$X events $N(D_s^+ \to \overline{\mathrm{K}}^{*0}/K^{*0}\mathrm{X})$, the total number of the singly tagged D_s^- events $N_{D_s^-}$, and the efficiency $\epsilon_{D_s^+ \to \overline{K}^{*0}\mathrm{X}}$ by

$$Br(D_s^+ \to \overline{K}^{*0}/K^{*0}\mathrm{X}) = \frac{N(D_s^+ \to \overline{K}^{*0}/K^{*0}\mathrm{X})}{\epsilon_{D_s^+ \to \overline{K}^{*0}\mathrm{X}} \times N_{D_s^-}}.$$

The inclusive $\overline{\mathrm{K}}^{*0}$or K^{*0} double tag efficiency $\epsilon_{D_s^+ \to \overline{K}^{*0}\mathrm{X}}$ is determined by Monte Carlo simulation. The efficiency is found to be $\epsilon_{D_s^+ \to \overline{K}^{*0}\mathrm{X}} = 0.2014 \pm 0.009$.

Table 1
Decay branching fractions of D_s^+ to final states containing a $\overline{\mathrm{K}}^{*0}$or a K^{*0} meson.

Decay Mode	Branching Fraction (%)
$K^+\overline{\mathrm{K}}^{*0}$	3.3 ± 0.9
$K^{*+}\overline{\mathrm{K}}^{*0}$	5.8 ± 2.5
$K^{*0}\pi^+$	0.65 ± 0.28

Based on 7.5 ± 4.4 $D_s^+ \rightarrow \overline{\mathrm{K}}^{*0}\mathrm{X}$ events, and assuming 0.1 ± 2.4 $D_s^+ \rightarrow K^{*0}\mathrm{X}$ events, the inclusive branching fractions

$Br(D_s^+ \rightarrow \overline{K}^{*0}\mathrm{X}) = (20.3 \pm 11.9 \pm 2.9)\%$, (BES Preliminary!)

and

$Br(D_s^+ \rightarrow K^{*0}\mathrm{X}) < 7.5\%$ at 90% C.L. (BES Preliminary!)

are obtained, where the first error is statistical and the second systematic. The systematic error is estimated on the basis of the changes of $Br(D_s^+ \rightarrow \overline{\mathrm{K}}^{*0}\mathrm{X})$ due to uncertainty in MC efficiency and uncertainty in the number of the singly tagged D_s^- mesons. The upper limit of $Br(D_s^+ \rightarrow K^{*0}\mathrm{X}) < 7.5\%$ at 90% C.L. includes the systematic uncertainties.

Table 1 summarizes all decay branching fractions listed in PDG98[5] for the modes containing a $\overline{\mathrm{K}}^{*0}$or a K^{*0} in the final states. Summing up the exclusive branching fractions yields $Br(D_s^+ \rightarrow \overline{\mathrm{K}}^{*0}\mathrm{X}) = (9.1 \pm 2.7)\%$, whereas $Br(D_s^+ \rightarrow K^{*0}\mathrm{X}) = (0.65 \pm 0.28)\%$. The most probable value of the inclusive $\overline{\mathrm{K}}^{*0}$branching fraction of D_s^+ measured by BES is larger than the sum.

5. CONCLUSION

In summary, the inclusive $\overline{\mathrm{K}}^{*0}$and K^{*0} decay branching fractions of the D_s^+ meson have been directly measured. From singly tagged sample of $183.6 \pm 24 \pm 6.5$ $D_s^+D_s^-$ pairs, 7.5 ± 4.4 $D_s^+ \rightarrow \overline{\mathrm{K}}^{*0}\mathrm{X}$ events are observed, leading to the first measurement of $Br(D_s^+ \rightarrow \overline{\mathrm{K}}^{*0}\mathrm{X}) = (20.3 \pm 11.9 \pm 1.8)\%$. From this data sample, no $D_s^+ \rightarrow K^{*0}\mathrm{X}$ signal is observed. This leads to $Br(D_s^+ \rightarrow K^{*0}\mathrm{X}) < 7.5\%$ at 90% C.L..

Comparing with the sum of the existing measurements on the exclusive D_s^+ decays containing a $\overline{\mathrm{K}}^{*0}$in the final states, the most probable value of the inclusive $\overline{\mathrm{K}}^{*0}$decay branching fraction of D_s^+ meson measured by BES may indicate that some decays of D_s^+ to $\overline{\mathrm{K}}^{*0}$remain unseen.

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