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Observation of Decays $B^0 \to D_s^{(*)+}\pi^-$ and $B^0 \to D_s^{(*)-}K^+$

BABAR Collaboration

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Abstract

We report the observation of decays $B^0 \to D_s^{(*)+}\pi^-$ and $B^0 \to D_s^{(*)-}K^+$ in a sample of 230×10^6 $\Upsilon(4S) \to B\overline{B}$ events recorded with the *BABAR* detector at the PEP-II asymmetric-energy e^+e^- storage ring. We measure the branching fractions $\mathcal{B}(B^0 \to D_s^+\pi^-) = (1.3 \pm 0.3\ \text{(stat)}\ \pm 0.2\ \text{(syst)}) \times 10^{-5}$, $\mathcal{B}(B^0 \to D_s^-K^+) = (2.5 \pm 0.4\ \text{(stat)}\ \pm 0.4\ \text{(syst)}) \times 10^{-5}$, $\mathcal{B}(B^0 \to D_s^{*+}\pi^-) = (2.8 \pm 0.6\ \text{(stat)}\ \pm 0.5\ \text{(syst)}) \times 10^{-5}$, and $\mathcal{B}(B^0 \to D_s^{*-}K^+) = (2.0 \pm 0.5\ \text{(stat)}\ \pm 0.4\ \text{(syst)}) \times 10^{-5}$. The significance of the measurements to differ from zero are 5, 9, 6, and 5 standard deviations, respectively.

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Observation of Decays $B^0 \to D_s^{(*)+}\pi^-$ and $B^0 \to D_s^{(*)-}K^+$

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We report the observation of decays $B^0 \to D_s^{(*)+}\pi^-$ and $B^0 \to D_s^{(*)-}K^+$ in a sample of 230×10^6 $\Upsilon(4S) \to B\overline{B}$ events recorded with the *BABAR* detector at the PEP-II asymmetric-energy e^+e^- storage ring. We measure the branching fractions $\mathcal{B}(B^0 \to D_s^+\pi^-) = (1.3\pm0.3\ \text{(stat)}\ \pm0.2\ \text{(syst)})\times 10^{-5}$, $\mathcal{B}(B^0 \to D_s^-K^+) = (2.5\pm0.4\ \text{(stat)}\ \pm0.4\ \text{(syst)})\times10^{-5}$, $\mathcal{B}(B^0 \to D_s^{*+}\pi^-) = (2.8\pm0.6\ \text{(stat)}\ \pm 0.5\ \text{(syst)}) \times 10^{-5}$, and $\mathcal{B}(B^0 \to D_s^{*-}K^+) = (2.0 \pm 0.5\ \text{(stat)}\ \pm 0.4\ \text{(syst)}) \times 10^{-5}$. The significance of the measurements to differ from zero are 5, 9, 6, and 5 standard deviations, respectively.

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Within the Cabibbo-Kobayashi-Maskawa (CKM) model of quark-flavor mixing [1], *CP* violation manifests itself as a non-zero area of the unitarity triangle [2]. One of the important experimental tests of the model is the determination of the angle $\gamma = \arg(-V_{ud}V_{ub}^*/V_{cd}V_{cb}^*)$ of the unitarity triangle. A measurement of $\sin(2\beta+\gamma)$ can be obtained from the study of the time dependence of the $B^0, \overline{B}^0 \to D^{(*)-}\pi^+$ [3] decay rates, and specifically of the interference between the CKM-favored B^0 decay amplitude and CKM-suppressed $\overline{B}^0$ amplitude [4]. The first measurements of the *CP* asymmetry in decays $B^0 \to D^{(*)\mp}\pi^\pm$ have recently been published [5].

The measurement of $\sin(2\beta+\gamma)$ in $B^0 \to D^{(*)\mp}\pi^\pm$ decays requires knowledge of the ratios of the decay amplitudes, $r(D^{(*)}\pi) = |A(B^0 \to D^{(*)+}\pi^-)/A(B^0 \to D^{(*)-}\pi^+)|$. However, direct measurement of the branching fractions $\mathcal{B}(B^0 \to D^{(*)+}\pi^-)$ is not possible with the currently available data sample due to the presence of the overwhelming background from $\overline{B}^0 \to D^{(*)+}\pi^-$. However, assuming SU(3) flavor symmetry, $r(D^{(*)}\pi)$ can be related to the branching fraction (BF) of the decay $B^0 \to D_s^{(*)+}\pi^-$ [4]:

$$r(D^{(*)}\pi) = \tan\theta_c \frac{f_{D^{(*)}}}{f_{D_s^{(*)}}} \sqrt{\frac{\mathcal{B}(B^0 \to D_s^{(*)+}\pi^-)}{\mathcal{B}(B^0 \to D^{(*)-}\pi^+)}}\ , \quad (1)$$

where θ_c is the Cabibbo angle, and $f_{D^{(*)}}/f_{D_s^{(*)}}$ is the ratio of $D^{(*)}$ and $D_s^{(*)}$ meson decay constants [6]. Other SU(3)-breaking effects are believed to affect $r(D^{(*)}\pi)$ by less than 30% [5].

Since $B^0 \to D_s^{(*)+}\pi^-$ has four different quark flavors in the final state, only a single amplitude contributes to the decay (Fig. 1c). On the other hand, there are two diagrams contributing to $B^0 \to D^{(*)-}\pi^+$ and $B^0 \to D^{(*)+}\pi^-$: tree amplitudes (Fig. 1a,b) and color-suppressed direct W-exchange amplitudes (Fig. 1d,e). The latter are assumed to be negligibly small in Eq. (1). The decays $B^0 \to D_s^{(*)-}K^+$ (Fig. 1f) probe the size of the W-exchange amplitudes relative to the dominant processes $B^0 \to D^{(*)-}\pi^+$. The rate of $B^0 \to D_s^{(*)-}K^+$ decays could be enhanced by final state rescattering [7], in addition to the W-exchange amplitude.

The branching fractions $\mathcal{B}(B^0 \to D_s^+\pi^-)$ and $\mathcal{B}(B^0 \to D_s^-K^+)$ have been measured previously by the *BABAR* [8] and Belle [9] collaborations, but the decays $B^0 \to D_s^{*+}\pi^-$ and $B^0 \to D_s^{*-}K^+$ have never been observed. In this Letter we present new measurements

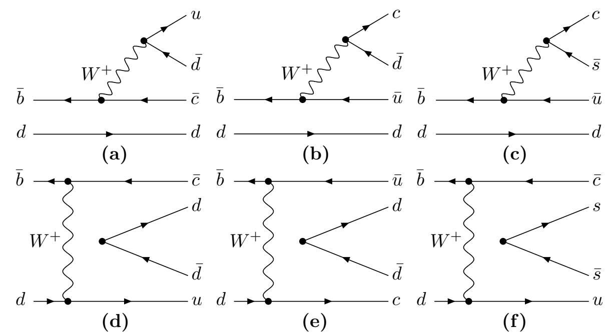

FIG. 1: Dominant Feynman diagrams for (a) CKM-favored decay $B^0 \to D^{(*)-}\pi^+$, (b) doubly CKM-suppressed decay $B^0 \to D^{(*)+}\pi^-$, and (c) the SU(3) flavor symmetry related decays $B^0 \to D_s^{(*)+}\pi^-$; (d) the color-suppressed W-exchange contributions to $B^0 \to D^{(*)-}\pi^+$, (e) $B^0 \to D^{(*)+}\pi^-$, and (f) decay $B^0 \to D_s^{(*)-}K^+$.

of the decays $B^0 \to D_s^{(*)+}\pi^-$ and $B^0 \to D_s^{(*)-}K^+$. The analysis uses a sample of 230×10^6 $\Upsilon(4S)$ decays into $B\overline{B}$ pairs collected with the *BABAR* detector at the PEP-II asymmetric-energy B factory [10].

Since the *BABAR* detector is described in detail elsewhere [11], only the components that are crucial to this analysis are summarized here. Charged particle tracking is provided by a five-layer double-sided silicon vertex tracker (SVT) and a 40-layer drift chamber (DCH). Ionization energy loss (dE/dx) in the DCH and SVT and Cherenkov radiation detected in a ring-imaging device are used for charged-particle identification. Photons are identified and measured using the electromagnetic calorimeter (EMC), which is comprised of 6580 thallium-doped CsI crystals. These systems are mounted inside a 1.5 T solenoidal superconducting magnet. We use the GEANT4 [12] software to simulate interactions of particles traversing the *BABAR* detector, taking into account the varying detector conditions and beam backgrounds.

We pre-select events which have a minimum of four reconstructed charged tracks and a total measured energy greater than 4.5 GeV, determined using all charged tracks and neutral clusters with energy above 30 MeV. In order to reduce "continuum" $e^+e^- \to q\bar{q}$ $(q = u, d, s, c)$ background, the ratio of the second and zeroth order Fox-Wolfram moments [13] must be less than 0.5.

Candidates for D_s^+ mesons are reconstructed in the modes $D_s^+ \to \phi\pi^+$, $K_S^0K^+$ and $\overline{K}^{*0}K^+$, with $\phi \to K^+K^-$, $K_S^0 \to \pi^+\pi^-$, and $\overline{K}^{*0} \to K^-\pi^+$. The K_S^0 candidates are reconstructed from two oppositely-charged tracks, and their momenta are required to make an angle $|\theta_{\rm flight}| < 11^\circ$ with the line connecting their vertex and e^+e^- interaction point. All other tracks are required to originate from the e^+e^- interaction region. In order to reject background from $D^+ \to K^0_S\pi^+$ or $\overline{K}^{*0}\pi^+$, the K^+ candidate in the reconstruction of $D_s^+ \to K^0_S K^+$ or $\overline{K}^{*0}K^+$ is required to satisfy positive kaon identification criteria with an efficiency of 85% and 5% pion misidentification probability. The same selection is used to identify kaon daughters of the B mesons in decays $B^0 \to D_s^{(*)-}K^+$. In all other cases, kaons are not positively identified, but instead candidates passing pion selection are rejected. Such "pion veto" has an efficiency of 95% for kaons and 20% for pions. Pion daughters of B mesons in the decays $B^0 \to D_s^{(*)+}\pi^-$ are required to be positively identified. Decay products of ϕ, $\overline{K}^{*0}$, K^0_S, D_s^+, and B^0 candidates are constrained to originate from a single vertex.

We reconstruct D_s^{*+} candidates in the mode $D_s^{*+} \to D_s^+\gamma$ by combining D_s^+ and photon candidates. Photon candidates are required to be consistent with an electromagnetic shower in the EMC, and have an energy greater than 100 MeV in the laboratory frame. When forming a D_s^{*+}, the D_s^+ candidate is required to have invariant mass within 10 MeV/c^2 of the nominal value [14].

After an initial pre-selection, we identify candidates for $B^0 \to D_s^{(*)+}\pi^-$ and $B^0 \to D_s^{(*)-}K^+$ using a likelihood ratio $R_L = \mathcal{L}_{\rm sig}/(\mathcal{L}_{\rm sig} + \mathcal{L}_{\rm bkg})$, where $\mathcal{L}_{\rm sig} = \prod_i \mathcal{P}_{\rm sig}(x_i)$ is the multivariate likelihood for signal events and $\mathcal{L}_{\rm bkg} = \prod_i \mathcal{P}_{\rm bkg}(x_i)$ is the likelihood for background events. The ratio R_L has a maximum at $R_L = 1$ for signal events, and at $R_L = 0$ for background originating from continuum events. It also discriminates well against generic B decays without a real D_s^+ meson in the final state. The likelihoods for signal and background events are computed as a product of the probability density functions (PDFs) $\mathcal{P}_{\rm sig}(x_i)$ and $\mathcal{P}_{\rm bkg}(x_i)$ for a number of selection variables x_i: invariant masses of the ϕ, $\overline{K}^{*0}$ and K^0_S candidates, χ^2 confidence level of the vertex fit for the B^0 and D_s^+ mesons, the helicity angles of the ϕ, $\overline{K}^{*0}$, and D_s^{*+} meson decays, the mass difference $\Delta m(D_s^{*+}) = m(D_s^{*+}) - m(D_s^+)$, the polar angle θ_B of the B candidate momentum vector with respect to the beam axis in the e^+e^- center-of-mass (c.m.) frame, the angle θ_T between the thrust axis of the B candidate and the thrust axis of all other particles in the event in c.m. frame, and event topology variable $\mathcal{F}$. Correlations among these variables are small. The helicity angle θ_H is defined as the angle between one of the decay products of a vector meson and the flight direction of its parent particle, in the meson's rest frame. Polarization of the vector mesons in the signal decays causes their helicity angles to be distributed as $\cos^2\theta_H$ (ϕ and $\overline{K}^{*0}$) or $\sin^2\theta_H$ (D_s^{*+}), while the random background combinations tend to produce a more uniform distribution in $\cos\theta_H$.

Variables $\cos\theta_B$, $\cos\theta_T$, and $\mathcal{F}$ discriminate between spherically-symmetric $B\overline{B}$ events and jetty continuum background using event topology. $B\overline{B}$ pairs form a nearly uniform $|\cos\theta_T|$ distribution, while $|\cos\theta_T|$ distribution for the continuum peaks at 1. A linear (Fisher) discriminant $\mathcal{F}$ is derived from the values of sphericity and thrust for the event, and the two Legendre moments L_0 and L_2 of the energy flow around the B-candidate thrust axis [15]. Finally, the polar angle θ_B is distributed as $\sin^2\theta_B$ for real B decays, while being nearly flat in $\cos\theta_B$ for the continuum.

We select $B^0 \to D_s^+\pi^-$ and $B^0 \to D_s^-K^+$ candidates that satisfy $R_L > 0.75$, and accept $B^0 \to D_s^{*+}\pi^-$ and $B^0 \to D_s^{*-}K^+$ candidates with $R_L > 0.8$. We measure the relative efficiency ε_{R_L} of the R_L selection in a copious data sample of decays $B^0 \to D^-\pi^+$ ($D^- \to K^+\pi^-\pi^-$, $K^0_S\pi^-$) and $B^+ \to \overline{D}^{*0}\pi^+$ ($\overline{D}^{*0} \to \overline{D}^0\gamma$, $D^0 \to K^-\pi^+$) in which the kinematics is similar to that of our signal events, and find that it is consistent with Monte Carlo estimates $\varepsilon_{R_L} \approx 70\%$. The fraction of continuum background events passing the selection varies between 2% and 15%, depending on the mode.

We identify the signal using the invariant mass $m(D_s)$ of D_s candidates and two kinematic variables $m_{\rm ES}$ and ΔE. The first is the beam-energy-substituted mass $m_{\rm ES} = \sqrt{(s/2 + \mathbf{p}_i\cdot\mathbf{p}_B)^2/E_i^2 - \mathbf{p}_B^2}$, where $\sqrt{s}$ is the total c.m. energy, $(E_i, \mathbf{p}_i)$ is the four-momentum of the initial e^+e^- system and $\mathbf{p}_B$ is the B^0 candidate momentum, both measured in the laboratory frame. The second variable is $\Delta E = E_B^* - \sqrt{s}/2$, where E_B^* is the B^0 candidate energy in the c.m. frame. For signal events, the $m_{\rm ES}$ distribution is gaussian centered at the B meson mass with a resolution of about 2.5 MeV/c^2, and the ΔE distribution has a maximum near zero with a resolution of about 17 MeV. The invariant mass $m(D_s)$ has a resolution of $(5-6)$ MeV/c^2, depending on the D_s^+ decay mode. We define a fit region $5.2 < m_{\rm ES} < 5.3$ GeV/c^2, $|\Delta E| < 36$ MeV, and $|m(D_s) - m(D_s)_{\rm PDG}| < 50$ MeV/c^2 for $B^0 \to D_s^+\pi^-$ and $B^0 \to D_s^-K^+$ candidates, where $m(D_s)_{\rm PDG}$ is the world average D_s mass [14]. For $B^0 \to D_s^{*+}\pi^-$ and $B^0 \to D_s^{*-}K^+$, we require $|m(D_s) - m(D_s)_{\rm PDG}| < 10$ MeV/c^2.

Less than 20% of the selected events in the $B^0 \to D_s^{*+}\pi^-$ and $B^0 \to D_s^{*-}K^+$ channels ($< 4\%$ in $B^0 \to D_s^+\pi^-$ and $B^0 \to D_s^-K^+$) contain two or more candidates that satisfy the criteria listed above. In such events we select a single B^0 candidate based on an event χ^2 formed with $m(D_s)$ and $\Delta m(D_s^{*+})$ and their uncertainties, and the ΔE variable. Such selection does not bias background distributions significantly.

Four classes of background contribute to the fit region. First is the *combinatorial background*, in which a true or fake $D_s^{(*)}$ candidate is combined with a randomly-selected pion or kaon. Second, B meson decays such as $\overline{B}^0 \to D^{(*)+}\pi^-, \rho^-$ with $D^+ \to K^0_S\pi^+$ or $\overline{K}^{*0}\pi^+$ can constitute a background for the $B^0 \to D_s^{(*)+}\pi^-$ modes if the pion in the D decay is misidentified as a kaon (*reflection background*). The reflection background has nearly the same $m_{\rm ES}$ distribution as the signal but different distributions in ΔE and $m(D_s)$. The corresponding backgrounds for the $B^0 \to D_s^- K^+$ mode ($B^0 \to D^- K^{(*)+}$) are negligible. Third, rare B decays into the same final state, such as $B^0 \to \overline{K}^{(*)0} K^+\pi^-$ or $\overline{K}^{(*)0} K^+ K^-$ (*charmless background*), have the same $m_{\rm ES}$ and ΔE distributions as the $B^0 \to D_s^+\pi^-$ or $B^0 \to D_s^- K^+$ signal, but are nearly flat in $m(D_s)$. The charmless background is significant in $B^0 \to D_s^+\pi^-$ and $B^0 \to D_s^- K^+$ decays, but is negligible for $B^0 \to D_s^{*+}\pi^-$ and $B^0 \to D_s^{*-} K^+$. Finally, *crossfeed background* from misidentification of $\overline{B}^0 \to D_s^{(*)-}\pi^+$ events as $B^0 \to D_s^{(*)-} K^+$ signal, and vice versa, needs to be taken into account.

We perform a two-dimensional unbinned extended maximum-likelihood fit to the $m_{\rm ES}$ and $m(D_s)$ distributions to extract $\mathcal{B}(B^0 \to D_s^+\pi^-)$ and $\mathcal{B}(B^0 \to D_s^- K^+)$ and constrain the contributions from charmless background modes. Charmless backgrounds are negligible for $B^0 \to D_s^{*+}\pi^-$ and $B^0 \to D_s^{*-} K^+$, and we determine the BFs of these decays with a one-dimensional fit to the $m_{\rm ES}$ distribution. For each B decay, we simultaneously fit distributions in three D_s^+ decay modes, constraining the signal BFs to a common value. The likelihood function contains the contributions of the signal and the four background components discussed above. The combinatorial background is described in $m_{\rm ES}$ by a threshold function [16], $dN/dx \propto x\sqrt{1-2x^2/s}\exp\left[-\xi\left(1-2x^2/s\right)\right]$. In $m(D_s)$, the combinatorial background is well described by a combination of a first-order polynomial (fake D_s^+ candidates) and a gaussian with $(5-6)$ MeV/c^2 resolution (true D_s^+ candidates). The charmless background is parameterized by the signal gaussian shape in $m_{\rm ES}$ and a first order polynomial in $m(D_s)$.

For $B^0 \to D_s^+\pi^-$ and $B^0 \to D_s^- K^+$ decays, the fit constrains 14 free parameters: the shape of the combinatorial background ξ (1 parameter for all D_s^+ modes), the slope of the combinatorial and charmless backgrounds in $m(D_s)$ (3 parameters), the fraction of true D_s^+ candidates in combinatorial background (3), the number of combinatorial background events (3), the number of charmless events (3), and the BF of the signal mode (1). The signal yields for each D_s^+ mode are expressed as $N_{{\rm sig}\,i} = N_{B\overline{B}}\,\mathcal{B}_{\rm sig}\,\mathcal{B}_i\,\varepsilon_i$, where $N_{B\overline{B}} = 230\times 10^6$, $\mathcal{B}_i$ is the D_s^+ BF for the mode, ε_i is the reconstruction efficiency, and $\mathcal{B}_{\rm sig}$ is the BF (fit parameter) for the decay. For the $B^0 \to D_s^{*+}\pi^-$ and $B^0 \to D_s^{*-} K^+$ decays, 5 free parameters are determined by the fit: ξ (1 parameter for all D_s^+ modes), the number of combinatorial background events (3), and the BF of the signal mode (1). The BFs of the channels contributing to the reflection background are fixed in the fit to the current world average values [14], and the BFs of the crossfeed backgrounds are determined by iterating the fits over each B decay mode. The results

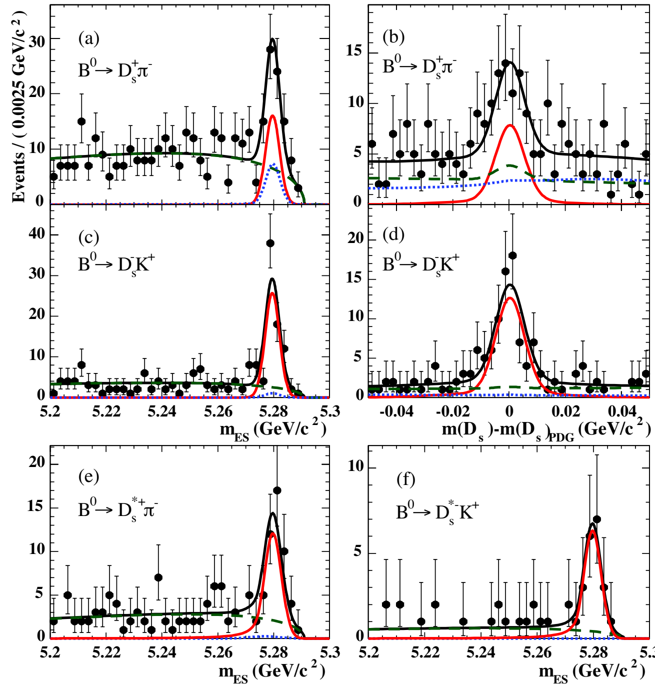

FIG. 2: (a,c,e,f) $m_{\rm ES}$ projection of the fit with $|m(D_s^+) - m(D_s^+)_{\rm PDG}| < 10$ MeV/c^2 and (b,d) $m(D_s)$ projection with $5.275 < m_{\rm ES} < 5.285$ GeV for (a,b) $B^0 \to D_s^+\pi^-$, (c,d) $B^0 \to D_s^- K^+$, (e) $B^0 \to D_s^{*+}\pi^-$, and (f) $B^0 \to D_s^{*-} K^+$. The black solid curve corresponds to the full PDF from the combined fit to all D_s^+ decay modes. Individual contributions are shown as solid red (signal PDF), green dashed (combinatorial background), and blue dotted (sum of reflection, charmless, and crossfeed backgrounds) curves.

of the fits are shown in Fig. 2 and summarized in Table I.

The systematic errors are dominated by the 13% relative uncertainty for $\mathcal{B}(D_s^+ \to \phi\pi^+)$ [17]. The uncertainties in the relative BFs $\mathcal{B}(D_s^+ \to \overline{K}^{*0} K^+)/\mathcal{B}(D_s^+ \to \phi\pi^+)$ and $\mathcal{B}(D_s^+ \to K_S^0 K^+)/\mathcal{B}(D_s^+ \to \phi\pi^+)$ contribute $(5-7)$%, depending on the decay channel. Uncertainties in the selection efficiency are estimated to be 3% for $B^0 \to D_s^+\pi^-$ and $B^0 \to D_s^- K^+$, and 7% for $B^0 \to D_s^{*+}\pi^-$ and $B^0 \to D_s^{*-} K^+$. The uncertainties in the reflection and crossfeed backgrounds are below 1% for all decay channels. The rest of the systematic errors, which include the uncertainties in tracking, photon and K_S^0 reconstruction, charged-kaon identification efficiencies, and variations of the PDF shapes between data and Monte Carlo, amount to $(6-7)$%.

The ratio $P_{\rm bkg} = \mathcal{L}_0/\mathcal{L}_{\rm max}$, where $\mathcal{L}_{\rm max}$ is the maximum likelihood value, and $\mathcal{L}_0$ is the likelihood for a fit with the signal contribution set to zero, describes the probability of the background to fluctuate to the observed number of events. Including systematic uncertainties and assuming gaussian-distributed errors, it corresponds to the significance of signal observation of 5 ($B^0 \to D_s^+\pi^-$), 6 ($B^0 \to D_s^{*+}\pi^-$), 9 ($B^0 \to D_s^- K^+$), and 5 ($B^0 \to D_s^{*-} K^+$) standard deviations. This is

TABLE I: The number of reconstructed candidates ($N_{\rm raw}$), the signal yield ($N_{\rm sig}$), computed from the fitted branching fractions, combinatorial background ($N_{\rm comb}$), and the sum of charmless, reflection, and crossfeed contributions ($N_{\rm peak}$), extracted from the likelihood fit. Also given are the reconstruction efficiency (ε), the probability ($P_{\rm bkg}$) of the data being consistent with the background in the absence of signal, and the measured branching fraction $\mathcal{B}$. The first uncertainty is statistical, and the second is systematic.

B mode	D_s mode	$N_{\rm raw}$	$N_{\rm sig}$	$N_{\rm comb}$	$N_{\rm peak}$	$\varepsilon(\%)$	$P_{\rm bkg}$	$\mathcal{B}(10^{-5})$	$\mathcal{B}\times\mathcal{B}(D_s^+\to\phi\pi^+)$ (10^{-6})
	$D_s^+\to\phi\pi^+$	405	21 ± 5	364 ± 20	21 ± 8	29.3			
$B^0\to D_s^+\pi^-$	$D_s^+\to\overline{K}^{*0}K^+$	677	16 ± 4	604 ± 26	58 ± 12	20.0	$3\cdot10^{-6}$	$1.3\pm0.3\pm0.2$	$0.63\pm0.15\pm0.05$
	$D_s^+\to K_S^0K^+$	223	11 ± 3	197 ± 15	16 ± 6	22.1			
	$D_s^+\to\phi\pi^+$	46	18 ± 4	29 ± 6	0	13.0			
$B^0\to D_s^{*+}\pi^-$	$D_s^+\to\overline{K}^{*0}K^+$	67	14 ± 3	48 ± 8	1	8.9	$3\cdot10^{-8}$	$2.8\pm0.6\pm0.5$	$1.32\pm0.27\pm0.15$
	$D_s^+\to K_S^0K^+$	19	10 ± 2	12 ± 4	1	9.6			
	$D_s^+\to\phi\pi^+$	197	32 ± 5	151 ± 13	8 ± 6	23.4			
$B^0\to D_s^-K^+$	$D_s^+\to\overline{K}^{*0}K^+$	331	27 ± 4	306 ± 18	-4 ± 6	17.6	$3\cdot10^{-19}$	$2.5\pm0.4\pm0.4$	$1.21\pm0.17\pm0.11$
	$D_s^+\to K_S^0K^+$	101	18 ± 3	82 ± 10	9 ± 5	19.0			
	$D_s^+\to\phi\pi^+$	15	9 ± 2	8 ± 3	-	8.9			
$B^0\to D_s^{*-}K^+$	$D_s^+\to\overline{K}^{*0}K^+$	16	8 ± 2	7 ± 3	-	6.6	$2\cdot10^{-5}$	$2.0\pm0.5\pm0.4$	$0.97\pm0.24\pm0.12$
	$D_s^+\to K_S^0K^+$	10	5 ± 1	5 ± 3	-	6.7			

the first observation of $B^0\to D_s^+\pi^-$, $B^0\to D_s^{*+}\pi^-$, and $B^0\to D_s^{*-}K^+$ decays.

The BF results are collected in Table I. Since the dominant uncertainty comes from the knowledge of the D_s^+ BFs, we also report the products $\mathcal{B}\times\mathcal{B}(D_s^+\to\phi\pi^+)$. The BFs for $B^0\to D_s^{(*)-}K^+$ are small compared to the dominant decays $B^0\to D^{(*)-}\pi^+$, implying relatively insignificant contributions from the color-suppressed W-exchange diagrams. Assuming SU(3) relation, Eq. (1), we determine $r(D\pi)=(1.3\pm0.2(\text{stat})\pm0.1(\text{syst}))\times10^{-2}$, and $r(D^*\pi)=(1.9\pm0.2(\text{stat})\pm0.2(\text{syst}))\times10^{-2}$, which implies small *CP* asymmetries in $B^0\to D^{(*)\mp}\pi^\pm$ decays. These results supersede our previously published measurements [8].

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