The following full text is a publisher’s version.

For additional information about this publication click this link.
http://hdl.handle.net/2066/128734

Please be advised that this information was generated on 2019-10-26 and may be subject to change.
Measurement of the $B^0 \to D^{*-} \phi \pi^+$ branching fractions

MEASUREMENT OF THE $B^0 \rightarrow D^{*-} D^{+}_{s*}$ AND $D^{+}_{s} \rightarrow \phi \pi^+$

PHYSICAL REVIEW D 71, 091104 (2005)

23 Universität Dortmund, Institut für Physik, D-44221 Dortmund, Germany
24 Technische Universität Dresden, Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany
25 Ecole Polytechnique, LLR, F-91128 Palaiseau, France
26 University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom
27 Università di Ferrara, Dipartimento di Fisica and INFN, I-44100 Ferrara, Italy
28 Laboratori Nazionali di Frascati dell’INFN, I-00044 Frascati, Italy
29 Università di Genova, Dipartimento di Fisica and INFN, I-16146 Genova, Italy
30 Harvard University, Cambridge, Massachusetts 02138, USA
31 Universität Heidelberg, Physikalisches Institut, Philosophenweg 12, D-69120 Heidelberg, Germany
32 Imperial College London, London, SW7 2AZ, United Kingdom
33 University of Iowa, Iowa City, Iowa 52242, USA
34 Iowa State University, Ames, Iowa 50011-3160, USA
35 Laboratoire de l’Accélérateur Linéaire, F-91898 Orsay, France
36 Lawrence Livermore National Laboratory, Livermore, California 94550, USA
37 University of Liverpool, Liverpool L69 7ZE, United Kingdom
38 Queen Mary, University of London, E1 4NS, United Kingdom
39 University of London, Royal Holloway and Bedford New College, Egham, Surrey TW20 0EX, United Kingdom
40 University of Louisville, Louisville, Kentucky 40292, USA
41 University of Manchester, Manchester M13 9PL, United Kingdom
42 University of Maryland, College Park, Maryland 20742, USA
43 University of Massachusetts, Amherst, Massachusetts 01003, USA
44 Massachusetts Institute of Technology, Laboratory for Nuclear Science, Cambridge, Massachusetts 02139, USA
45 McGill University, Montréal, Quebec, Canada H3A 2T8
46 Università di Milano, Dipartimento di Fisica and INFN, I-20133 Milano, Italy
47 University of Mississippi, University, Mississippi 38677, USA
48 Université de Montréal, Laboratoire René J. A. Lévesque, Montréal, Quebec, Canada H3C 3J7
49 Mount Holyoke College, South Hadley, Massachusetts 01075, USA
50 Università di Napoli Federico II, Dipartimento di Scienze Fisiche and INFN, I-80126, Napoli, Italy
51 NIKHEF, National Institute for Nuclear Physics and High Energy Physics, NL-1009 DB Amsterdam, The Netherlands
52 University of Notre Dame, Notre Dame, Indiana 46556, USA
53 Ohio State University, Columbus, Ohio 43210, USA
54 University of Oregon, Eugene, Oregon 97403, USA
55 Università di Padova, Dipartimento di Fisica and INFN, I-35131 Padova, Italy
56 Universités Paris VI et VII, Laboratoire de Physique Nucléaire et de Hautes Energies, F-75252 Paris, France
57 University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA
58 Università di Perugia, Dipartimento di Fisica and INFN, I-06100 Perugia, Italy
59 Università di Pisa, Dipartimento di Fisica, Scuola Normale Superiore and INFN, I-56127 Pisa, Italy
60 Prairie View A&M University, Prairie View, Texas 77446, USA
61 Princeton University, Princeton, New Jersey 08544, USA
62 Università di Roma La Sapienza, Dipartimento di Fisica and INFN, I-00185 Roma, Italy
63 Universität Rostock, D-18051 Rostock, Germany
64 Rutherford Appleton Laboratory, Didcot, Didcot, Oxon, OX11 0QX, United Kingdom
65 DSM/Dapnia, CEA/Saclay, F-91191 Gif-sur-Yvette, France
66 University of South Carolina, Columbia, South Carolina 29208, USA
67 Stanford Linear Accelerator Center, Stanford, California 94309, USA
68 Stanford University, Stanford, California 94305-4060, USA
69 State University of New York, Albany, New York 12222, USA
70 University of Tennessee, Knoxville, Tennessee 37996, USA
71 University of Texas at Austin, Austin, Texas 78712, USA
72 University of Texas at Dallas, Richardson, Texas 75083, USA
73 Università di Torino, Dipartimento di Fisica Sperimentale and INFN, I-10125 Torino, Italy
74 Università di Trieste, Dipartimento di Fisica and INFN, I-34127 Trieste, Italy
75 IFIC, Universitat de Valencia-CSIC, E-46071 Valencia, Spain
76 Vanderbilt University, Nashville, Tennessee 37235, USA
77 University of Victoria, Victoria, British Columbia, Canada V8W 3P6
78 Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom
79 University of Wisconsin, Madison, Wisconsin 53706, USA

* Also with Università della Basilicata, Potenza, Italy
† Deceased
We present measurements of the branching fractions $B(B^0 \to D^{*-} D_s^{(*)})$ and $B(D_s^+ \to \phi \pi^+)$, based on $123 \times 10^6 \ Y(4S) \to B\bar{B}$ decays collected by the BABAR detector at the PEP-II asymmetric-energy $e^+e^-$ B factory. A partial reconstruction technique is used to measure $B(B^0 \to D^{*-} D_s^{(*)})$ and the decay chain is fully reconstructed to measure the branching fraction product $B(B^0 \to D^{*-} D_s^+) \times B(D_s^+ \to \phi \pi^+)$. Comparing these two measurements provides a model-independent determination of the $D_s^+ \to \phi \pi^+$ branching fraction. We obtain $B(B^0 \to D^{*-} D_s^+) = (1.88 \pm 0.09 \pm 0.17\%)$ and $B(D_s^+ \to \phi \pi^+) = (4.81 \pm 0.52 \pm 0.38\%)$, where the first uncertainties are statistical and the second systematic.

PACS numbers: 13.25.Hw, 12.39.St, 13.25.Ft

DOI: 10.1103/PhysRevD.71.091104

Published measurements of $B(B^0 \to D^{*-} D_s^+)$ [1,2] are limited by the uncertainties on the $D_s^+$ partial decay rates. A substantial improvement can therefore be obtained using a partial reconstruction technique where the $D_s^+$ is not explicitly reconstructed. The measurement of $B(B^0 \to D^{*-} D_s^+)$ provides a test of the details of the factorization assumption [3] in the relatively high $q^2$ regime [4]. Partial reconstruction in addition allows an unbiased measurement of the $D_s^+ \to \phi \pi^+$ branching fraction, which has important implications for a wide range of $D_s$ and $B$ physics, as most of the $D_s$ decay branching fractions are normalized to it [1]. As an example, an improved measurement of $B(D_s^+ \to \phi \pi^+)$ would reduce the experimental uncertainty on the constraint on the Unitary Triangle parameter $\gamma$ from the measurement of the $C P$ violating asymmetry in $B^0 \to D^{\pm} \pi^\mp$ decays [5].

We used $123 \times 10^6 \ B\bar{B}$ decays collected at the PEP-II asymmetric-energy $e^+e^-$ B factory with the BABAR detector, which is described in detail elsewhere [6]. We provide here a brief description of the detector components relevant for this analysis. Charged-particle trajectories are measured by a silicon vertex tracker (SVT) and a drift chamber (DCH) immersed in a 1.5 T solenoidal magnetic field. The five-layer SVT enables tracks with low transverse momentum to be reconstructed. The energy and direction of photons and electrons are measured by a CsI(Tl)-crystal electromagnetic calorimeter (EMC). Charged-particle identification is obtained from the measurement of energy loss in the tracking system, and from the measurement of the number and the angle of Cherenkov photons in a ring-imaging Cherenkov detector (DIRC).

To study efficiencies and backgrounds and to validate the analysis we use several event samples produced with a Monte Carlo (MC) simulation of the BABAR detector based on GEANT4 [7] and reconstructed through the same chain as the data.

The $B^0 \to D^{*-} D_s^+ \to (D_s^+ \gamma)(D^0 \pi^-)$ decay [8] is reconstructed using two different methods. The first method combines the fully reconstructed $D^{*-}$ decay with the photon from the $D_s^+ \to D_s^+ \gamma$ decay, without explicit $D_s^+$ reconstruction. Denoting the measured yield by $N_{D_s}$, we can write:

$$B(B^0 \to D^{*-} D_s^+) \equiv B_1 = \frac{N_{D_s}}{K \sum_i (e_i/B_i)}.$$  

Here $K \equiv 2N_{B\bar{B}}\int_0^t B(D_s^+ \to D_s^+ \gamma)B(D^{*-} \to D^0 \pi^-)$, $N_{B\bar{B}}$ is the number of $B$-meson pairs, $f_{00} = 0.499 \pm 0.012$ [9] is the fraction of $Y(4S) \to B\bar{B}$ decays, $B$, is the branching fraction of $D^0$ decay mode $i$, $e_i$ is the efficiency for partially reconstructing the $B^0$ with a photon, a low momentum ("soft") pion and a $D^0$ reconstructed in mode $i$.

The second method, based on full reconstruction of the $B^0 \to D^{*-} D_s^+$ decay via $D_s^+ \to \phi \pi^+(\phi \to K^+ K^-)$, measures the branching fraction product $B_2 \equiv B(B^0 \to D^{*-} D_s^+) \times B(D_s^+ \to \phi \pi^+):$  

$$B_2 = \frac{N_{D_s \to \phi \pi}}{K B(\phi \to K^+ K^-) \sum_i (e_i/B_i)}.$$  

where $N_{D_s \to \phi \pi}$ is the number of reconstructed decays and $e_i$ is the efficiency for fully reconstructing the $B^0$, including reconstruction of $\phi \to K^+ K^-$. The $D_s^+ \to \phi \pi^+$ branching fraction is measured from the $B_2/B_1$ ratio:

$$B(D_s^+ \to \phi \pi^+) = \frac{B_2}{B_1} = \frac{N_{D_s \to \phi \pi} \sum_i (e_i/B_i)}{N_{D_s} B(\phi \to K^+ K^-) \sum_i (e_i/B_i)}.$$  

where the factor $K$ drops out. Although the efficiencies $e_i$ and $e_i'$ are in general different, they include common factors and many systematic uncertainties cancel in the ratio.

To extract the signal in partially reconstructed events, we compute the "missing mass" recoiling against the $D^{*-} \gamma$ system, assuming that a $B^0 \to D^{*-} \gamma X$ decay took place:

$$m_{\text{miss}} = \sqrt{(E_B - E_{D^0} - E_{\gamma})^2 - (p_B - p_{D^0} - p_{\gamma})^2},$$  

where all quantities are defined in the $Y(4S)$ center-of-mass (CM) frame. While the photon and $D^{*-}$ energies ($E_{\gamma}$, $E_{D^0}$) and their three-momenta ($p_{\gamma}$, $p_{D^0}$) are measured, kinematical constraints are needed to determine the $B$ four-momentum ($E_B$, $p_B$). In order to do that we equate the $B$-meson energy with $E_{\text{beam}}$, the beam energy in the CM

091104-4
frame, and calculate the cosine of the opening angle \( \theta_{BD} \) between the \( B \) and the \( D^{*+} \) momentum vectors from 4-momentum conservation in the \( B^0 \to D^{*-} D_s^{+} \) decay. This leaves the azimuthal angle of the \( B \) meson around the \( D^{*-} \) direction as the only undetermined parameter in the kinematics of the decay. MC studies show that an arbitrary choice of this angle (we fix \( \cos \theta_{BD} = 0 \)) introduces a negligible spread (of the order of 1.5 MeV/c^2) in the \( m_{\text{miss}} \) distribution. The \( m_{\text{miss}} \) distribution of signal events peaks at the nominal \( D_s^+ \) mass [1] with a width of about 15 MeV/c^2.

We suppress unphysical \( D^{*-} \gamma \) combinations by requiring \( |\cos \theta_{BD}| \leq 1.2 \) and events from \( e^+e^- \to u\bar{u}, d\bar{d}, s\bar{s}, c\bar{c} \) production by requiring the ratio of the second to the zeroth Fox-Wolfram moments [10] to be less than 0.3.

\( D^{*-} \) candidates are reconstructed in the \( D^0 \pi^- \) mode using \( D^0 \) decays to \( K^+ \pi^- \), \( K^+ \pi^- \pi^+ \pi^- \), \( K^+ \pi^- \pi^0 \), and \( K^0 \pi^+ \pi^- \), listed here in order of decreasing purity. The \( \chi^2 \) probabilities of both the \( D^0 \) and \( D^{*-} \) vertex functions are required to be greater than 1%. The \( D^{*-} \) momentum in the \( Y(4S) \) frame must satisfy \( 1.4 < p_D < 1.9 \) GeV/c. We require the reconstructed mass of the \( D^0 \) to be within 3 standard deviations (\( \sigma_{m_D} \)) of the measured peak value, and \( Q_{D^{*}} = m_D - m_D^0 - m_\pi \) to satisfy \( Q_D < Q_{D^*} < Q_{h_1} \), where the choice of limits \( Q_{D^*} = 4.10 - 5.20 \) MeV/c^2 and \( Q_{h_1} = 6.80 - 7.90 \) MeV/c^2 around the nominal value \( Q_{D^{*0}} = 5.851 \) MeV/c^2 depends on the \( D^0 \) decay mode. Kaon identification is required in \( K^+ \pi^- \pi^0 \) and \( K^+ \pi^- \pi^+ \pi^- \) modes. The \( K_S^0 \) from the \( K_S^0 \pi^+ \pi^- \) mode must have an invariant mass within 15 MeV/c^2 of the nominal \( K_S^0 \) mass and a flight length greater than 3 mm.

If more than one \( D^{*-} \) candidate is found, we first retain those that have the \( D^0 \) reconstructed in the decay mode with the highest expected purity. If ambiguities persist at this stage, we choose the best candidate based on the track quality of the soft pion and finally on the minimum value of \( \chi^2 = [(Q_{D^{*-}} - Q_{D^{*-}\text{PDG}})/\sigma_{Q_{D^{*-}}}]^2 + [(m_{D^{*}} - m_{D^{*}\text{PDG}})/\sigma_{m_D}]^2 \), where \( \sigma_{Q_{D^{*-}}} \) is the measured resolution on \( Q_{D^{*}} \).

Photon candidates are chosen from clusters of energy deposited in the EMC that are not associated with any charged track. The energy spectrum of photons from the \( D_s^{*-} \to D_s^+ \gamma \) decay is rather soft (\( E_\gamma \leq 0.4 \) GeV) and this makes controlling the background due to random photon associations one of the main challenges in the analysis. We require \( E_\gamma > 142 \) MeV and use the energy profile of the cluster to refine the photon selection, requiring a minimum cluster lateral momentum [11] of 0.016, and a minimum Zernike moment \( A_{20} \) [12] of 0.82. We also reject photon candidates that form in combination with any other photon in the event a \( \pi^0 \) whose invariant mass is between 115 and 155 MeV/c^2 and whose momentum in the CM frame is greater than 200 MeV/c. This selection retains more than one photon candidate in about 10% of the events. In these occurrences we choose the one that maximizes the value of a likelihood ratio based on the energy and the shape of the reconstructed cluster.

The cuts are chosen to maximize the expected statistical significance of the selected signal using MC. The combinatorial background is dominated by \( B^0\bar{B}^0 \) events. None of the background components peak at the \( D_s^+ \) mass in the \( m_{\text{miss}} \) distribution. The reconstruction and selection efficiency, evaluated on simulated events, is \( \epsilon_B \). We extract the signal yield using an unbinned maximum-likelihood fit to the \( m_{\text{miss}} \) distribution. The signal peak is well described by a Gaussian probability density function (p.d.f.). We parameterize the combinatorial background with the threshold function \( B(m_{\text{miss}}) = B_0(1 - e^{-(m_{\text{miss}} - m_{\text{max}})/b})(m_{\text{miss}}/m_{\text{max}})^c \). Figure 1 shows the result of the fit to the missing-mass distribution. The width of the Gaussian signal distribution is taken from MC simulation. The signal yield is \( N_{D_s} = 7488 \pm 342 \) events, corresponding to a branching fraction \( B(B^0 \to D^* D^{*-}) = (1.88 \pm 0.09)\% \), where the quoted error is purely statistical.

We now describe the full reconstruction of the \( B^0 \to D^* D^{*-} \) \( (D_s^+ \gamma) (D^0 \pi^-) \) chain, with \( D^0 \) decaying into the four modes considered, and \( D_s^+ \to \phi \pi^+ \to K^- K^+ \pi^+ \). Two kinematical variables are used: \( \Delta E = E_B - E_{\text{beam}} \) and the energy-substituted mass \( m_{\text{ES}} = \sqrt{E^2_{\text{beam}} - p_B^2} \). The two variables have very little correlation; for signal events \( \Delta E \) peaks around zero and \( m_{\text{ES}} \) at the \( B \)-meson mass. After applying selection cuts (described below) on the \( D_s^{*-} \) and \( D^* \) candidates, we retain the combination with the smallest value of \( |\Delta E| \). The number of fully reconstructed \( B^0 \) candidates is then obtained from a fit to the \( m_{\text{ES}} \) spectrum.

The selection of \( D^{*-} \) candidates and most of the requirements on photon candidates are identical to those adopted in the partial reconstruction analysis. Because of the addi-

![FIG. 1 (color online). Fit (solid line) to the measured missing-mass distribution. The background component is shown as the dashed line.](image-url)
tional kinematical constraints on fully reconstructed $B$ decays, the combinatorial background level is much smaller; we can therefore relax the requirement on $E_y$, thus improving the statistical significance of our sample. We reconstruct $\phi$ candidates from pairs of oppositely charged tracks, with at least one track satisfying kaon selection criteria; $D^+_s$ candidates are formed by combination with an additional track, with charge opposite to the soft pion from the $D^{*-}\pi^+$ decay. A mass within $\pm 50$ MeV/c$^2$ of the nominal $D^+_s$ mass [1] is required. Finally, $D^{*-}$ and $D^{*+}$ mass constraints are imposed in order to improve the $m_{ES}$ and $\Delta E$ resolution of the $B^0$ candidate. We require the $m_{D^*} - m_{D_s}$ mass difference to be between 125 and 160 MeV/c$^2$, the reconstructed $\phi$ mass to be between 1.008 and 1.035 GeV/c$^2$, $E_y$ to be greater than 90 MeV, and $|\Delta E|$ to be less than 50 MeV.

We perform an unbinned maximum-likelihood fit to the $m_{ES}$ distribution with the sum of a Crystal Ball [13] function, and a threshold ARGUS [14] function; the latter accounts for the combinatorial background. From the fit to the data sample, shown in Fig. 2, we obtain (247 ± 19) events in the signal region defined as $m_{ES} > 5.27$ GeV/c$^2$.

MC studies indicate a peaking contribution due to real $B^0 \rightarrow D^{*-} D_s^{*+}$ events, where either the $D^0$ does not decay into the reconstructed modes, or the $D_s^+$ does not decay into $K\pi^+$. We subtract the peaking background applying a correction factor to take into account that the values of the $B^0 \rightarrow D^{*-} D_s^{*+}$ and $D_s^+ \rightarrow \phi \pi^+$ branching fractions that we have measured are different from those used in the simulation, with an iterative procedure. The resulting number of peaking background events expected in the data sample is $35 \pm 6$ events; this uncertainty is taken into account in the systematic error. After subtraction of the peaking background events, the final signal event yield is $N_{D_s^+ \rightarrow \phi \pi} = (212 \pm 19)$. Taking into account the reconstruction and selection efficiency $\epsilon' B = \sum \epsilon_i B_i = (6.16 \pm 0.24) \times 10^{-3}$, evaluated on simulated events, we determine $B(D^0 \rightarrow D^{*-} D_s^{*+}) = (8.81 \pm 0.86) \times 10^{-4}$, where the error is statistical only.

The main sources of systematic uncertainties on the $B^0 \rightarrow D^{*-} D_s^{*+}$ branching fraction measurement are listed in the second column ($B_1$) of Table I. We compared the resolution of the Gaussian p.d.f. in data and MC by fitting the missing-mass distribution in the very clean sample of fully reconstructed $B^0 \rightarrow D^{*-} D_s^{*+}$ events. We disentangle in this way the effect of the experimental resolution on the width of the signal peak from the correlations in the fit between the width and the background parameters. We obtain $\sigma_{data}/\sigma_{MC} = (1.01 \pm 0.05)$. We repeated the $m_{miss}$ fits changing the Gaussian width by this uncertainty, and varying the background parameters by their errors. We also considered alternative parametrizations for the background shape. We assign the maximum deviation from the central value as systematic uncertainty, labeled in Table I as “p.d.f. modeling”. The MC statistics uncertainty is the statistical error on the efficiency determination. The systematic uncertainties due to tracking, vertexing, photon and $\pi^0$ reconstruction efficiencies, and particle identification are evaluated using independent control samples. The effect of the $\pi^0$ veto is evaluated from fully reconstructed events. The uncertainty due to the dependence of the efficiency on the polarization of the $B^0 \rightarrow D^{*-} D_s^{*+}$ decay is assessed from MC samples generated with complete longitudinal and transverse polarization. In the full reconstruction analysis the error on peaking background is due to the MC statistics and to the uncertainty on the relevant $D^0$ and $D_s^+$ branching fractions; the uncertainty on the com-

<table>
<thead>
<tr>
<th>Source</th>
<th>$B_1$ [%]</th>
<th>$B_2$ [%]</th>
<th>$B_2/B_1$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>p.d.f. modeling</td>
<td>4.8</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>Comb. background</td>
<td>2.9</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>MC statistics</td>
<td>3.2</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>Peaking background</td>
<td>2.8</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>$B$ counting</td>
<td>1.1</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>$f_{iso}$</td>
<td>2.4</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>Soft pion efficiency</td>
<td>2.2</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>$D^{*-}$ Tracking eff.</td>
<td>2.4</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>$D^{*-}$ Vertexing eff.</td>
<td>2.0</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>$D_s^+$ Tracking eff.</td>
<td>2.6</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>$D_s^+$ Vertexing eff.</td>
<td>2.0</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Photon efficiency</td>
<td>1.8</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>$\pi^0$ eff. ($B^0 \rightarrow K^+\pi^-\pi^0$)</td>
<td>1.2</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>$\pi^0$ veto</td>
<td>4.7</td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td>Particle identification</td>
<td>0.4</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Polarization uncertainty</td>
<td>0.8</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>$D^0$ branch. frac.</td>
<td>3.2</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>$B(D^0 \rightarrow D^0\pi^-)$ [1]</td>
<td>0.7</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>$B(D_s^+ \rightarrow D_s^+\gamma)$ [15]</td>
<td>0.8</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>$B(\phi \rightarrow K^+K^-)$ [1]</td>
<td>1.2</td>
<td>1.2</td>
<td></td>
</tr>
</tbody>
</table>

Total systematic error
9.1 10.7 7.9

**FIG. 2 (color online).** Fit (solid line) to the measured $m_{ES}$ distribution. The background component is shown as the dashed line.
binatorial background is estimated using the $\Delta E$ sideband ($|\Delta E| > 200$ MeV) as an alternative way of computing the number of background events under the $m_{ES}$ peak. Several systematic uncertainties in the full reconstruction are in common with the partial reconstruction analysis, and therefore cancel in the ratio of Eq. (3). The single photon efficiency is well reproduced by the MC (the data/MC ratio is essentially flat and equal to 1) for $E_\gamma < 0.5$ GeV; the associated systematic uncertainty is therefore independent on the minimum photon energy requirement. All remaining sources are listed in the last column of Table I.

We repeated both the partial and the full reconstruction analyses on generic MC samples consisting of $B^0\bar{B}^0$, $B^+B^-$, and low-mass $q\bar{q}$ events, finding no bias. The result is also stable over different data-taking periods. Finally, the likelihoods of the fits to the data are in good agreement with the values expected from a large set of parametrized MC experiments.

In summary, we have measured the $B^0 \rightarrow D^{*-}D_s^{*+}$ branching fraction

$$B(B^0 \rightarrow D^{*-}D_s^{*+}) = (1.88 \pm 0.09 \pm 0.17)^{\%}$$

(5)

where the first uncertainty is statistical and the second is systematic. This result is independent of the partial decay rates of the $D_s^{*+}$ mesons. It is consistent with a previous $B^0\bar{B}^0$ = 1.006 ± 0.048 reported in $Babar$ Collab., B. Aubert et al. Phys. Rev. D 69, 071101 (2004).

[8] Charge conjugate decays are included implicitly throughout the paper.
[9] The value for $f_{D_s}$ quoted in the text is derived from the measurement of the ratio $\Gamma(Y(4S) \rightarrow B^+B^-)/\Gamma(Y(4S) \rightarrow B^0\bar{B}^0) = 1.006 \pm 0.048$ reported in $Babar$ Collab., B. Aubert et al. Phys. Rev. D 69, 071101 (2004).
[13] CB($m_{ES}$) = $e^{-a^2/2}|n/|\alpha||^2 |n/|\alpha||^2 |\alpha| - |y| - y$ for $y < \alpha$, CB($m_{ES}$) = $e^{-x^2/2}$ for $y > \alpha$, where $y = (m_{ES} - \pi)/\sigma$. D. Antreasyan, Crystal Ball Note 321 (1983).