SLAC-PUB-8733
BABAR-PROC-00/20
hep-ex/0012027
December, 2000

B decyas to final states including $D_s^{(*)}$ and D^*

Benjamin Brau
bbrau@slac.stanford.edu
(representing the *BABAR* collaboration)

Laboratory for Nuclear Science
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge MA 02139, USA

Abstract

The e^+e^- annihilation data recorded with the *BABAR* detector has been used to study B decays to $D_s^{(*)\pm}$ and $D^{*\pm}$ mesons. The production fraction of inclusive $D_s^{(*)\pm}$ and the corresponding momentum spectra have been determined. Exclusive decays $B^0 \to D^{*-} D_s^{(*)+}$ have been identified with a partial reconstruction technique and their branching fractions have been measured. We also report branching fraction measurements for the exclusive hadronic modes $B^0 \to D^{*-}\pi^+$ and $B^0 \to D^{*-}\rho^+$.

Contribued to the Proceedings of the
Meeting of the Division of Particles and Fields of the American Physical Society,
8/9/2000—8/12/2000, Columbus, Ohio, USA

Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309

Work supported in part by Department of Energy contract DE-AC03-76SF00515.

1 Introduction

The study of $D_s^{(*)}$ production in B decays allows us to understand the mechanisms leading to the creation of $c\bar{s}$ quark pairs. The precise measurement of the momentum spectrum allows a determination of the fraction of two-body and multi-body decay modes, and helps in understanding $b \to c\bar{c}s$ transitions. In this study we report a new measurement of the inclusive $D_s^{(*)\pm}$ production rate in B decays and the branching fractions of two specific two-body B decay modes involving a $D_s^{(*)\pm}$ meson. We have also studied the decay modes $B^0 \to D^{*-}\pi^+$ and $B^0 \to D^{*-}\rho^+$ and measured the corresponding branching fractions using fully-reconstructed events. Those measurements are interesting for testing factorization models of B decays to open charm.

2 Dataset

The data were collected with the *BABAR* detector operating at the PEP-II storage ring at the Stanford Linear Accelerator Center. For the inclusive $D_s^{(*)}$ production in B decays and the $B^0 \to D^{*-}D_s^{(*)+}$ branching fraction measurements we used a data sample equivalent to 7.7 fb^{-1} of integrated luminosity collected while running on the $\Upsilon(4S) \to B\overline{B}$ resonance and a sample of 1.2 fb^{-1} collected 40 MeV$/c^2$ below the $B\bar{B}$ threshold. Branching fraction measurements for the $B^0 \to D^{*-}\pi^+$ and $B^0 \to D^{*-}\rho^+$ modes use a subset corresponding to an integrated luminosity of 5.2 fb^{-1}.

3 Inclusive $D_s^{(*)}$ Production in B Decay

The $D_s^\pm$ mesons are reconstructed in the $D_s^\pm \to \phi\pi^\pm$ decay mode with $\phi \to K^+K^-$. Particle identification is used to obtain a clean sample. Three charged tracks coming from a common vertex are combined to form a $D_s^\pm$. Two of them, with opposite charge, are required to be positively identified as kaons and their invariant mass must be within 8 MeV of the nominal ϕ mass. In this decay the ϕ meson is polarized longitudinally which means the helicity angle of the decay, θ_H has a $\cos^2\theta_H$ dependence[1]. The requirement $|\cos\theta_H| > 0.3$ keeps 97.5% of the signal while rejecting 30% of the background. Candidate $D_s^{*\pm}$ mesons are reconstructed in the decay channel $D_s^{*\pm} \to D_s^\pm\gamma$ with $D_s^\pm \to \phi\pi^\pm$. $D_s^\pm$ candidates are required to be within 2.5σ of the $\phi\pi$ invariant mass. Photon candidates must deposit a minimum energy of 50 MeV$/c^2$ in the calorimeter. The number of $D_s^\pm$ mesons is extracted from a Gaussian fit of the $\phi\pi^\pm$ invariant mass distribution for different momentum ranges in the $\Upsilon(4S) \to B\overline{B}$ rest frame. Similarly, the number of $D_s^{*\pm}$ is extracted by fitting the mass difference $m_{D_s^*} - m_{D_s}$ distribution. The efficiency-corrected number of reconstructed $D_s^{(*)\pm}$ as a function of momentum is shown in Fig. 1. To determine the $D_s^{(*)\pm}$ momentum spectrum for the continuum, the on-resonance spectrum with momentum higher than 2.45 GeV$/c$ and luminosity-scaled off-resonance spectrum are corrected for efficiency and then fit with the Peterson fragmentation function. The momentum spectrum of $D_s^{(*)\pm}$ produced in B decays is obtained by subtracting the fitted Peterson function from the efficiency-corrected on-resonance spectrum. The measured branching fractions are:

$$\mathcal{B}(B \to D_s^\pm X) = \left[(11.9 \pm 0.3 \pm 1.1) \times \frac{3.6 \pm 0.9\%}{\mathcal{B}(D_s^\pm \to \phi\pi^\pm)}\right]\% \qquad (1)$$

$$\mathcal{B}(B \to D_s^{*\pm} X) = \left[(6.8 \pm 0.8 \pm 1.7) \times \frac{3.6 \pm 0.9\%}{\mathcal{B}(D_s^\pm \to \phi\pi^\pm)}\right]\% \qquad (2)$$

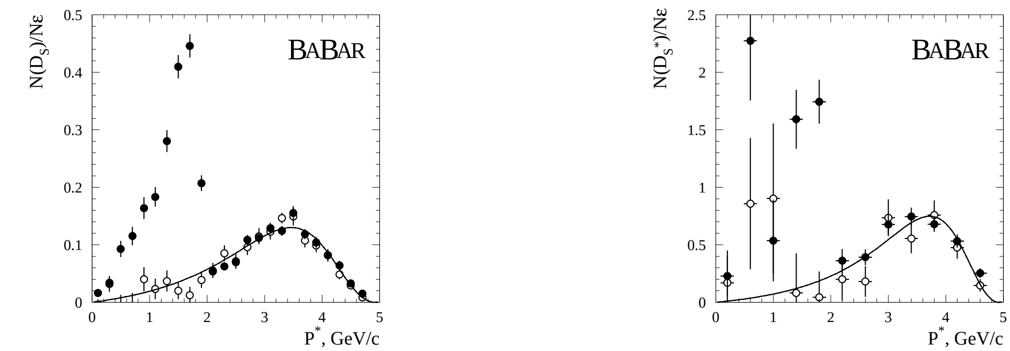

Figure 1: Efficiency-corrected momentum spectra for $D_s^{\pm}$ (right) and $D_s^{*\pm}$ (left). In both figures solid circles represent the on-resonance data, while open circles represent data collected off resonance scaled by luminosity. The solid line shows the fit to the Peterson fragmentation function used for subtracting the continuum component of the spectrum.

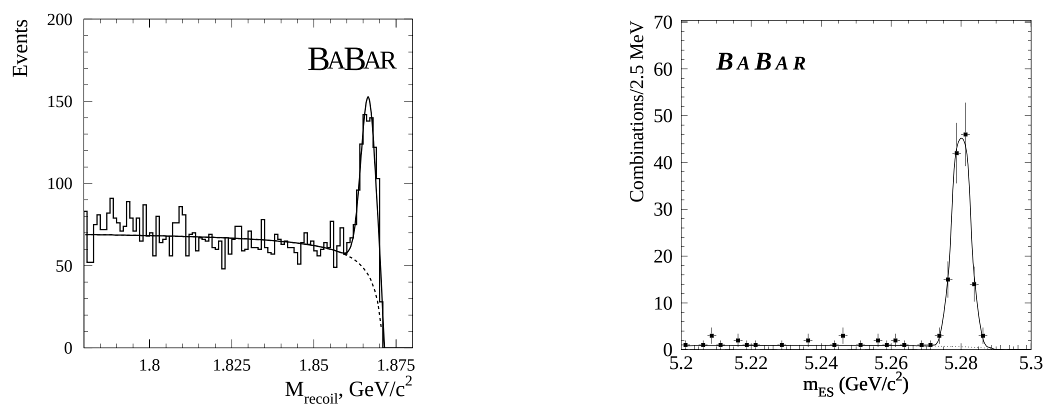

Figure 2: Left: Missing mass distributions for the $D_s^{\pm} - \pi$ systems before background subtraction. Right: Distribution of m_{ES} for $|\Delta E| < 2.5\sigma_{\Delta E}$ for the channel $B^0 \to D^{*-}\pi^+$.

where the first error is statistical, the second systematic and the third is due to the $D_s^{\pm} \to \phi\pi^{\pm}$ branching fraction uncertainty.

4 Measurement of $B^0 \to D^{*-}D_s^{(*)+}$ Branching Fractions

The measurement of the branching fractions for the decays $B^0 \to D^{*-}D_s^{+}$ and $B^0 \to D^{*-}D_s^{*+}$ uses a partial reconstruction technique. The $D_s^{(*)+}$ are fully reconstructed, we do not reconstruct the $\overline{D}^0$ coming from the D^{*-} decay. Instead, we combine a $D_s^{(*)+}$ candidate with a π^- and then calculate missing mass assuming that the $D_s^{(*)+}$ and π^- originate from the same B^0. This missing mass should be the D^0 mass if our hypothesis is correct. The yield of $B^0 \to D^{*-}D_s^{(*)+}$ is evaluated by fitting the missing mass distribution (Fig. 2) with the sum of a Gaussian and a background function[1]. The branching fractions we measure are $(7.1 \pm 2.4 \pm 2.5 \pm 1.8) \times 10^{-3}$ for the channel $B^0 \to D^{*-}D_s^{+}$, and $(2.5 \pm 0.4 \pm 0.5 \pm 0.6) \times 10^{-2}$ for the channel for $B^0 \to D^{*-}D_s^{*+}$.

5 Measurement of $B^0 \to D^{*-}\pi+$ and $B^0 \to D^{*-}\rho^+$ Branching Fractions

B^0 candidates in the channels $D^{*-}\pi^+$ and $D^{*-}\rho^+$ are fully reconstructed in the decay chain $D^{*-} \to \overline{D}^0\pi^-$, followed by $\overline{D}^0 \to K^+\pi^-$. The ρ^+ is reconstructed in the mode $\rho^+ \to \pi^+\pi^0$. Event selection is based on a few simple criteria. Tracks are required to originate from near the beam interaction point and no particle identification is used. Photons with energy grater than 30 MeV/c^2 are combined to form π^0 candidates. To form a D^0 candidate, kaons and pions with opposite charge and originating from the same vertex must have an invariant mass within $\pm 2.5\sigma$ of the nominal D^0 mass. The D^0 candidates are required to have a momentum grater than 1.3 GeV/c in the $\Upsilon(4S) \to B\overline{B}$ frame and are combined with a pion to form a charged D^* candidate. D^* candidates are required to have $\Delta m = m(\overline{D}^0\pi^-) - m(\overline{D}^0)$ within 2.5σ of the nominal mass difference. Finally, we combine D^*candidates with a π^+, with a momentum grater than 500 MeV/c or a ρ^+ candidate to form B^0 candidates. In the decay $B^0 \to D^{*-}\pi^+$ the longitudinal polarization of the D^{*-} is used to reduce background[2]. For the $B^0 \to D^{*-}\rho^+$ mode, ρ^+ candidates are selected requiring the $\pi^+\pi^0$ invariant mass within 150 MeV of the ρ^+ nominal mass. Event shape variables are also used to remove continuum background. For correctly reconstructed B mesons, the energy of the B candidate, $E^*_{B^0}$ evaluated in the $\Upsilon(4S) \to B\overline{B}$ frame must be equal to $\sqrt{s}/2$. We define $\Delta E = E^*_{B^0} - \sqrt{s}/2$. The beam energy substituted mass, m_{ES} is defined as $m^2_{ES} = (\sqrt{s}/2)^2 - (\sum_i \boldsymbol{p}_i)^2$, where $\boldsymbol{p}_i$ is the momentum of the ith daughter of the B candidate. The variables ΔE and m_{ES} are used to define the signal and sideband regions. For both modes, the region between 5.2 and 5.3 GeV/c^2 in m_{ES} and between ± 300 MeV/c^2 in ΔE is used to study signal and background properties. We discriminate against correlated background from B decays where a real final state pion (e.g. from higher-multiplicity B^0 decays) is either not included in the reconstruction, or a random one is added to the observed state, with a requirement on $|\Delta E|$. The measurement of branching fractions requires an estimate of the number of signal events. A Gaussian and a background function[3], which parametrizes how the phase space approaches zero as the energy approaches $\sqrt{s}/2$, are used to fit the m_{ES} distribution obtained by requiring $|\Delta E| < 2.5\sigma_{\Delta E}$ as shown in Fig. 2.

Based on the fitted yield of signal events the preliminary results for the branching fractions for $B^0 \to D^{*-}\pi^+$ and $B^0 \to D^{*-}\rho^+$ are $(2.9 \pm 0.3 \pm 0.3) \times 10^{-3}$ and $(11.2 \pm 1.1 \pm 2.5) \times 10^{-3}$, respectively. The branching fraction for $B^0 \to D^{*-}\rho^+$ includes all non-resonant and quasi-two-body contributions that lead to a $\pi^+\pi^0$ invariant mass in the ρ band; however, the acceptance for non-resonant $D^{*-}\pi^+\pi^0$ decays is about 15% of $D^{*+}\rho^+$. Moreover, previous measurements indicate that the non-resonant branching fraction is comparatively small. Therefore we estimate that the non-resonant contribution to our result is small. Both branching fraction results compare well with previous measurements and with the world average[4].

References

References

[1] *BABAR* collaboration, "Study of inclusive $D_s^{(*)\pm}$ production in B decays and measurement of $B^0 \to D^{*-}D_s^{(*)+}$ decays using a partial reconstruction technique", *BABAR*-CONF-00/13, SLAC-PUB-8535, submitted to the XXX$^{\text{th}}$ International Conference on High Energy Physics, Osaka, Japan, July 2000

[2] *BABAR* collaboration, "Measurement of the branching fractions of $B^0 \to D^{*-}\pi^+$ and $B^0 \to D^{*-}\rho^+$" *BABAR*-CONF-00/06, SLAC-PUB-8528 , submitted to the XXX$^{\text{th}}$ International Conference on High Energy Physics, Osaka, Japan, July 2000

[3] ARGUS Collaboration, H. Albrecht *et al.*, Z. Phys. **C48** (1990) 543; superseded results in *op cit.*, Phys. Lett. **B185** (1987) 218; Phys. Lett. **B182** (1986) 95.

[4] C. Caso *et al.*, Eur. Phys. Jour. C **3** (1998) 1.