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B decays to $D_s^{(*)}$ and D^*

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Abstract

The e^+e^- annihilation data recorded with the *BABAR* detector has been used to study B^0 decays to $D_s^{(*)+}$ and D^{*-} mesons. The production fraction of inclusive $D_s^{(*)+}$ 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 ratios have been measured. Fully reconstructed B^0 decays in the hadronic modes $B^0 \to D^{*-}\pi^+$ and $B^0 \to D^{*-}\rho^+$ have been also studied and the measurement of their absolute branching fractions is reported.

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1 Introduction

The study of $D_s^{(*)+}$ production in B^0 decays allows us to understand the mechanisms leading to the creation of $c\bar{s}$ quark pairs. The precise measurement of the momentum spectrum determines the fraction of two body and multibody decay modes, and consequently helps to understand the $b \to c\bar{c}s$ transitions. In this study we report a new measurement of the inclusive $D_s^{(*)+}$ production rate in B^0 decays and the branching fraction of two specific two-body B^0 decay modes involving a $D_s^{(*)+}$ meson. We also have performed a study, with full reconstruction, of the decay modes $B^0 \to D^{*-}\pi^+$ and $B^0 \to D^{*-}\rho^+$ and measured the corresponding branching fractions. These measurements are interesting for testing factorization models of B decays to open charm. Throughout this paper, conjugate modes are implied.

2 The dataset

The data were collected with the *BABAR* detector while operating in the PEP-II storage ring at the Stanford Linear Accelerator Center. For the inclusive $D_s^{(*)+}$ production in B^0 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 $\Upsilon(4S)$ resonance and a sample of 1.2 fb^{-1} collected 40 MeV below the $B\bar{B}$ threshold. The measurements of the branching fractions $B^0 \to D^{*-}\pi^+$ and $B^0 \to D^{*-}\rho^+$ use a subset of the same data sample corresponding to an integrated luminosity of 5.2 fb^{-1}.

3 Inclusive $D_s^{(*)+}$ production in B^0 decay

The D_s^+ mesons are reconstructed in the decay mode $D_s^+ \to \phi\pi^+$ where $\phi \to K^+K^-$. Particle identification is crucial to obtain a clean sample. Three charged tracks combining to from a common vertex are considered to be a D_s^+ candidate. Two of this tracks, with opposite charge, are required to be identified as kaons and their invariant mass must be within 8 MeV of the nominal ϕ mass. In this decay channel, 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. The D_s^{*+} are reconstructed in the decay channel $D_s^{*+} \to D_s^+\gamma$ where $D_s^+ \to \phi\pi^+$. $\phi\pi^+$ combinations within 2.5σ of the nominal D_s^+ mass are taken as D_s^+ candidate. Photons must have a minimum energy of at least 50 MeV. The number of D_s^+ mesons is extracted by a Gaussian fit of the $\phi\pi^+$ invariant mass distribution for different momentum ranges in the $\Upsilon(4S)$ rest frame. Similarly, the number of D_s^{*+} is extracted by fitting the mass difference $m_{D_s^{*+}} - m_{D_s^+}$ distribution. The efficiency-corrected number of reconstructed D_s^+ as a function of their momentum is shown in Fig. 1.

In order to determine the $D_s^{(*)+}$ momentum spectrum for the continuum, on resonance data with momentum higher than 2.45 GeV$/c$ and off resonance data, scaled according to the luminosity ratio, have been fitted after efficiency correction using the Peterson fragmentation function. The momentum spectrum of $D_s^{(*)+}$ produced in B^0 decays is obtained by subtracting the value of the fit function from the on resonance data after correcting for efficiency. The measured branching fractions are $(11.9 \pm 0.3 \pm 1.1) \times 10^{-2}$ and $(6.8 \pm 0.7 \pm 0.8) \times 10^{-2}$ for $B^0 \to D_s^+X$ and $B^0 \to D_s^{*+}X$ respectively, assuming a $D_s^+ \to \phi\pi^+$ branching fractions of $3.6 \pm 0.9\%$.

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, but no attempt is

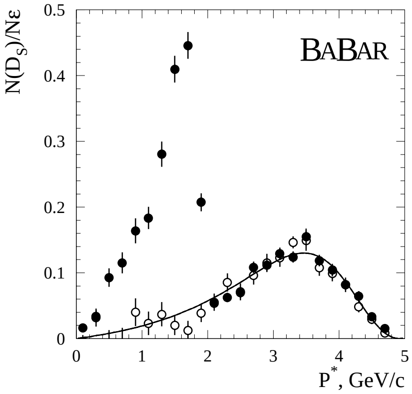

Figure 1: Momentum spectrum efficiency-corrected for D_s^+. Solid circles indicate the on resonance data point, while open circles are for data collected off resonance scaled according to the luminosity. The solid line shows the result of the fit with a Peterson fragmentation function.

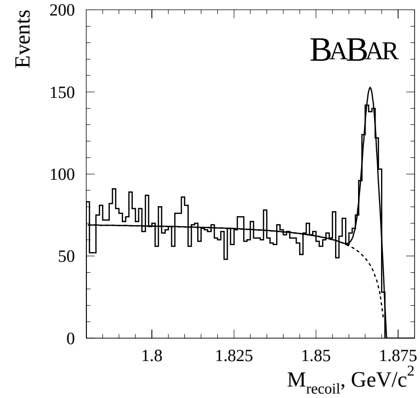

Figure 2: Missing mass distributions for the $D_s^{\pm} - \pi$ systems before background subtraction.

made to identify the $\bar{D}^0$ coming from the D^{*-} decay. Instead, we combine a $D_s^{(*)+}$ candidate with a π^- and assume their origin is a B^0 meson. We then calculate the missing invariant mass which should be the $\bar{D}^0$ 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 a Gaussian and a background function[1]. The measured branching fractions are $(7.1 \pm 2.4 \pm 2.5 \pm 1.8) \times 10^{-3}$ for the cannel $B^0 \to D^{*-}D_s^+$ and for $B^0 \to D^{*-}D_s^{*+}$ $(2.5 \pm 0.4 \pm 0.5 \pm 0.6) \times 10^{-2}$ assuming a $D_s^+ \to \phi\pi^+$ branching fractions of $3.6 \pm 0.9\%$[2].

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

B^0 candidates in the channel $D^{*-}\pi^+$ and $D^{*-}\rho^+$ are fully reconstructed using the decay chain $D^{*-} \to \bar{D}^0\pi^-$, followed by $\bar{D}^0 \to K^+\pi^-$. The ρ^+ is seen in its decay to $\pi^+\pi^0$. The selection of events is based on a few simple criteria. Tracks are required to originate from the beam spot and no particle identification is used. Photons with energy greater than 30 MeV are combined to form π^0 candidates. Kaons and pions with opposite charge and coming from the same vertex must have an invariant mass within $\pm 2.5\sigma$ of the nominal D^0 mass to form a D^0 candidate. The D^0 candidates are required to have a momentum greater than 1.3 GeV/c in the $\Upsilon(4S)$ frame and are combined with a pion to form a charged D^* candidate. We require $\Delta m = m(\bar{D}^0\pi^-) - m(\bar{D}^0)$ to be within 2.5σ of the nominal mass difference $D^{*-} - \bar{D}^0$. The D^{*-} is combine with a π^+ candidate, with a momentum greater than 500 MeV/c or a ρ^+ to form B^0 candidates. In the decay $B^0 \to D^{*-}\pi^+$ the longitudinal polarization of the D^{*-} is used to reduce background[3]. For the $B^0 \to D^{*-}\rho^+$ mode, ρ^+ candidate are selected requiring the $\pi^+\pi^0$ invariant mass within 150 MeV/c^2 of the ρ^+ nominal mass. Event shape variables are also used to remove continuum background.

For correctly reconstructed B^0 mesons, the energy of the B^0 candidate, $E^*_{B^0}$ must be equal to the beam energy E^*_b were both are evaluated at the $\Upsilon(4S)$ frame. We define $\Delta E = E^*_{B^0} - E^*_b$. The beam energy substituted mass, m_{ES} is defined as $m_{ES}^2 = (E_b^*)^2 - (\sum_i \boldsymbol{p}_i)^2$, 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

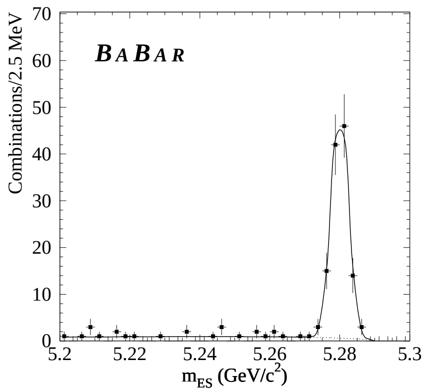

Figure 3: Distribution of m_{ES} for $|\Delta E| < 2.5\sigma_{\Delta E}$ for the cannel $B^0 \to D^{*-}\pi^+$.

in m_{ES} and between ±300 MeV in ΔE is used to study signal and background properties. By staying below $|\Delta E| = m_\pi$, we avoid correlated background from B decays where a real final state pion is either not included in the reconstruction or a random one is added to the observed state.

The measurement of branching fractions requires an estimate of the number of signal events. A Gaussian distribution and a background function[4], which parametrize how the phase space approach zero as the energy approaches E_b^*, are used to fit the m_{ES} distribution obtained requiring $|\Delta E| < 2.5\sigma_{\Delta E}$ as shown in Fig. 3. 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 $(2.9\pm0.3\pm0.3)\times10^{-3}$ and $(11.2\pm1.1\pm2.5)\times10^{-3}$ 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 $D^{*+}\rho^+$ so that, combined with the known branching fraction for this mode, the non-resonant contribution to our result is expected to be quite small. Both branching fraction results compare well with previous measurements and with the world average[2].

References

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