International Journal of Modern Physics A

A STUDY OF $B \to D_{sJ}^{(*)+}\overline{D}^{(*)}$ DECAYS WITH BABAR

JÜRGEN KROSEBERG
(on behalf of the *BABAR* collaboration)
Santa Cruz Institute for Particle Physics, University of California, Santa Cruz
1156 High Street, Santa Cruz, CA 95064, USA

We present a study of $D_{sJ}^*(2317)^+$ and $D_{sJ}(2460)^+$ meson production in B decays based on a data sample of 122 million $B\overline{B}$ pairs collected with the *BABAR* experiment.

Keywords: Decays of bottom mesons; charmed mesons; *BABAR*.

1. Introduction

The unexpected observation of a narrow $D_s^+\pi^0$ resonance with a mass of $2317\,\mathrm{MeV}/c^2$ was recently reported by the *BABAR* collaboration[1] and confirmed by the CLEO experiment.[2] CLEO observed a second $D_s^{*+}\pi^0$ resonance[2] with a mass close to $2460\,\mathrm{MeV}/c^2$, previously suggested[1] and later confirmed[3] by *BABAR*. The Belle collaboration confirmed both resonances[4], which are usually interpreted as P-wave $c\bar{s}$ quark states and will be referred to in the following as $D_{sJ}^*(2317)^+$ and $D_{sJ}(2460)^+$. The new states were first observed in $e^+e^- \to c\bar{c}$ collisions. Their observation in exclusive $B \to D_{sJ}^{(*)+}\overline{D}^{(*)}$ decays allows additional properties of the $D_{sJ}^{(*)+}$ states to be studied. The analysis presented here[5] uses $113\,\mathrm{fb}^{-1}$ of data, collected at the $\Upsilon(4S)$ resonance with the *BABAR* detector[7] at the PEP-II asymmetric-energy B factory, and considers the modes $B^+ \to D_{sJ}^{(*)+}\overline{D}^{(*)0}$ and $B^0 \to D_{sJ}^{(*)+}D^{(*)-}$ with $D_{sJ}^*(2317)^+ \to D_s^+\pi^0$, $D_{sJ}(2460)^+ \to D_s^{*+}\pi^0$, and $D_{sJ}(2460)^+ \to D_s^+\gamma$.

2. Data Selection

$\overline{D}$ and D_s^+ mesons are reconstructed in the modes $\overline{D}^0 \to K^+\pi^-$, $K^+\pi^-\pi^0$, $K^+\pi^-\pi^+\pi^-$; $D^- \to K^+\pi^-\pi^-$; and $D_s^+ \to \phi\pi^+$ ($\phi \to K^+K^-$), $\overline{K}^{*0}K^+$ ($\overline{K}^{*0} \to K^-\pi^+$). D^* candidates are reconstructed in the decays $D^{*+} \to D^0\pi^+$, $D^{*0} \to D^0\pi^0$, $D^0\gamma$, and $D_s^{*+} \to D_s^+\gamma$ and selected based on the mass difference Δm between the D^* and D candidates. The selected pairs of $D_s^{(*)+}$ and $\overline{D}^{(*)}$ candidates are combined with a photon or a π^0 to form B candidates. Events compatible with being two-body decays $B \to D_s^{(*)+}\overline{D}^{(*)}$ are rejected. A B signal region is defined by

$5.272 < m_{\mathrm{ES}} < 5.288\,\mathrm{GeV}/c^2$ and $|\Delta E| < 32(40)\,\mathrm{MeV}$ for π^0 (γ) final states.[a] Only the smallest $|\Delta E|$ B signal candidate in an event is kept for further analysis.

3. Branching Fraction Measurement

The branching fraction measurement is based on the $D_s^+\pi^0$, $D_s^{*+}\pi^0$, and $D_s^+\gamma$ mass spectra for each of the twelve $D_s^{(*)+}\overline{D}^{(*)}\pi^0/\gamma$ final states. As shown in Fig. 1, signals for $B \to D_{sJ}^{(*)+}\overline{D}^{(*)}$ are observed in all channels. The results of likelihood fits to these

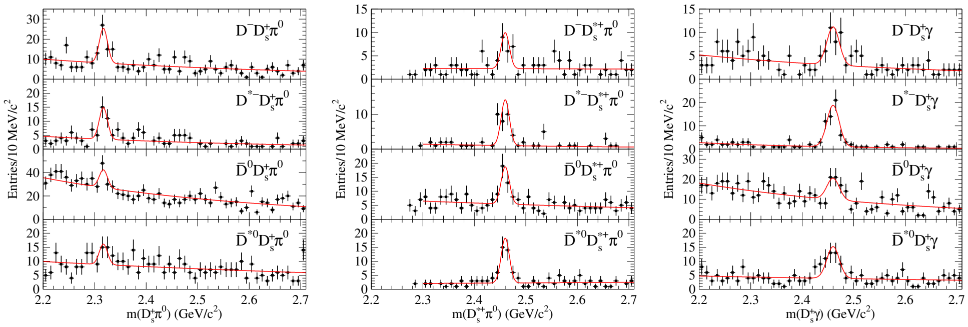


Fig. 1. $D_s^+\pi^0$ (left), $D_s^{*+}\pi^0$ (center), and $D_s^+\gamma$ (right) mass spectra of the selected B signal candidates for the 12 $\overline{D}^{(*)}D_{sJ}^{(*)+}$ final states. Curves are the results of the fits (see text).

distributions, using a Gaussian[b] signal and an exponential background function, are overlaid. From the $D_{sJ}^{(*)+}$ event yields, cross-feed-corrected branching fractions are computed, using the signal efficiency and the relative contributions from cross-feed between the different $D_{sJ}^{(*)+}$ decay modes as obtained from simulated signal events. The results are summarized in Table 1. For the decays $B \to D_{sJ}^{(*)+}\overline{D}$ good agreement with an earlier Belle measurement[6] is found, see Fig. 2(a). The modes involving a $\overline{D}^*$ are seen for the first time.[c] The dominant systematic errors are associated with the reconstruction efficiency for charged tracks and neutral particles, the Δm and ΔE selection requirements, and the fit model.[d]

4. Angular Analysis

In addition, a helicity analysis of the $D_{sJ}(2460)^+$ state is performed, using the decays $B^+ \to D_{sJ}(2460)^+\overline{D}^0$ and $B^0 \to D_{sJ}(2460)^+D^-$, with $D_{sJ}(2460)^+ \to D_s^+\gamma$. The helicity angle θ_h is defined as the angle between the $D_{sJ}^{(*)+}$ momentum in the

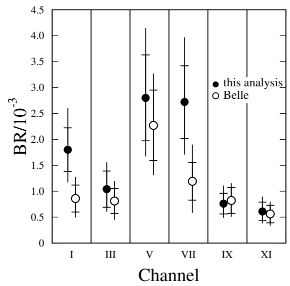
[a] $m_{\mathrm{ES}} \equiv \sqrt{s/4 - {p_B^*}^2}$ and $\Delta E \equiv E_B^* - \sqrt{s}/2$, where $\sqrt{s}$ is the total energy in the $\Upsilon(4S)$ center-of-mass frame and E_B^* (p_B^*) is the energy (momentum) of the B candidate in the same frame.
[b] Here, the Gaussian mean value is fixed to the nominal $D_{sJ}^{(*)+}$mass values. Its width is fixed to 8 (12) MeV/c^2 for π^0 (γ) final states, as obtained from the simulation and confirmed with the data.
[c] A new Belle analyisis, including $B \to D_{sJ}^{(*)+}\overline{D}^*$ results, was presented at this meeting.[8]
[d] The errors from the individual $\overline{D}^{(*)}$ and $D_s^{(*)}$ branching fractions, which are dominated by the 25% relative error on $\mathcal{B}(D_s^+ \to \phi\pi^+)$ are given separately in Table 1.

Table 1. Event yields (including internal cross-feed contributions), number of events from internal cross-feed, and branching fractions, $\mathcal{B}$. The first error on $\mathcal{B}$ is statistical, the second is systematic, and the third is from the $\overline{D}$ and D_s^+ branching fractions.

	B mode		Yield	Cross-feed	$\mathcal{B}(10^{-3})$
I	$B^0 \to D_{sJ}^*(2317)^+ D^-$	$[D_s^+\pi^0]$	34.7 ± 8.0	0.3	$1.8 \pm 0.4 \pm 0.3^{+0.6}_{-0.4}$
II	$B^0 \to D_{sJ}^*(2317)^+ D^{*-}$	$[D_s^+\pi^0]$	23.5 ± 6.1	0.0	$1.5 \pm 0.4 \pm 0.2^{+0.5}_{-0.3}$
III	$B^+ \to D_{sJ}^*(2317)^+ \overline{D}^0$	$[D_s^+\pi^0]$	32.7 ± 10.8	0.3	$1.0 \pm 0.3 \pm 0.1^{+0.4}_{-0.2}$
IV	$B^+ \to D_{sJ}^*(2317)^+ \overline{D}^{*0}$	$[D_s^+\pi^0]$	17.6 ± 6.8	7.2	$0.9 \pm 0.6 \pm 0.2^{+0.3}_{-0.2}$
V	$B^0 \to D_{sJ}(2460)^+ D^-$	$[D_s^{*+}\pi^0]$	17.4 ± 5.1	0.1	$2.8 \pm 0.8 \pm 0.5^{+1.0}_{-0.6}$
VI	$B^0 \to D_{sJ}(2460)^+ D^{*-}$	$[D_s^{*+}\pi^0]$	26.5 ± 5.7	0.0	$5.5 \pm 1.2 \pm 1.0^{+1.9}_{-1.2}$
VII	$B^+ \to D_{sJ}(2460)^+ \overline{D}^0$	$[D_s^{*+}\pi^0]$	29.0 ± 6.8	2.2	$2.7 \pm 0.7 \pm 0.5^{+0.9}_{-0.6}$
VIII	$B^+ \to D_{sJ}(2460)^+ \overline{D}^{*0}$	$[D_s^{*+}\pi^0]$	30.5 ± 6.4	2.5	$7.6 \pm 1.7 \pm 1.8^{+2.6}_{-1.6}$
IX	$B^0 \to D_{sJ}(2460)^+ D^-$	$[D_s^+\gamma]$	24.8 ± 6.5	0.5	$0.8 \pm 0.2 \pm 0.1^{+0.3}_{-0.2}$
X	$B^0 \to D_{sJ}(2460)^+ D^{*-}$	$[D_s^+\gamma]$	53.0 ± 7.8	0.1	$2.3 \pm 0.3 \pm 0.3^{+0.8}_{-0.5}$
XI	$B^+ \to D_{sJ}(2460)^+ \overline{D}^0$	$[D_s^+\gamma]$	31.9 ± 9.0	1.4	$0.6 \pm 0.2 \pm 0.1^{+0.2}_{-0.1}$
XII	$B^+ \to D_{sJ}(2460)^+ \overline{D}^{*0}$	$[D_s^+\gamma]$	34.6 ± 7.6	6.5	$1.4 \pm 0.4 \pm 0.3^{+0.5}_{-0.3}$

B-meson rest frame and the D_s momentum in the $D_{sJ}^{(*)+}$ rest frame. The measured $\cos(\theta_h)$ distribution is shown in Figure 2(b), together with the predicted spectra for two different $D_{sJ}(2460)^+$ spins. The $J = 2$ hypothesis (χ^2/n.d.f.=36.4/4) is excluded and good agreement with $J = 1$ (χ^2/n.d.f.=4.0/4) is found. A $D_{sJ}(2460)^+$ spin $J = 0$ is ruled out by parity and angular momentum conservation.

(a)



(b)

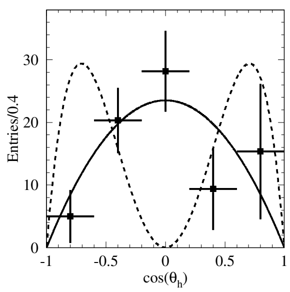


Fig. 2. (a) $B \to D_{sJ}^{(*)+}\overline{D}$ branching fractions measured by *BABAR* (full points) and Belle (open points), where the channels are labeled according to Table 1; (b) helicity distribution obtained from $m(D_s\gamma)$ fits in bins of $\cos(\theta_h)$ for data (points), after applying corrections for detector acceptance and selection efficiency, in comparison with the expectations for a $D_{sJ}(2460)^+$ spin $J = 1$ (solid line) and $J = 2$ (dashed line), respectively, after normalizing the predicted spectra to the data.

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