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Hadronic B decays at *BABAR*

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Abstract

We present preliminary results on hadronic decays of B mesons, based on data recorded at the $\Upsilon(4S)$ resonance with the *BABAR* detector at the PEP-II B-factory at SLAC. We measure branching fractions of many B decay modes, including decays to $J/\psi\,\phi K$, $J/\psi\,\pi^+\pi^-$ and $\eta_c K$ final states. We report the observation of the decay $B \to D_s^+\pi^-$ and the first measurement of the flavor-tagged D meson production in B^0 decays. Since their preliminary nature, the results presented in this paper are based on different data samples.

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1 The *BABAR* detector

The *BABAR* detector [1] at the PEP-II asymmetric-energy B-factory [2] at SLAC consists of a silicon vertex tracker (SVT) for precise decay vertex determination, a 40-layer drift chamber (DCH) for momentum and track angles measurement, a detector of internally reflected Cherenkov radiation (DIRC) for charged hadron identification, and a CsI(Tl) electromagnetic calorimeter (EMC) for photon reconstruction and electron identification. A superconducting solenoid provides a magnetic field of 1.5 T, and the iron of the flux return is instrumented with resistive plate chambers (IFR) to provide muon identification and neutral hadron reconstruction.

2 Hadronic B decays to charmonium

Color suppressed transitions $b \rightarrow c\bar{c}s(d)$ are responsible for hadronic B decays to final states containing a charmonium. Theoretical predictions are based on the factorization hypothesis, that can be accurately tested with extensive and precise branching fraction determinations [3].

2.1 Rare B decays to states with a J/ψ

The Cabibbo-suppressed decays $B \rightarrow J/\psi\,\eta(\eta')$ are described by a $b \rightarrow c\bar{c}d$ transition, as the observed decay $B \rightarrow J/\psi\,\pi$. An upper limit on the decay $B \rightarrow J/\psi\,\eta$ has been set by the L3 Collaboration [4], while there is no published result for the $B \rightarrow J/\psi\,\eta'$ channel.

The decay $B \rightarrow J/\psi\,\phi K$ is described by a $b\bar{q} \rightarrow c\bar{c}s\bar{s}s\bar{q}$ transition, in which the $s\bar{s}$ pair is produced from sea quarks or via gluon emission. This mode has been observed by the CLEO Collaboration [5] with a branching fraction of $\mathcal{B}(B \rightarrow J/\psi\,\phi K) = (8.8^{+3.5}_{-3.0} \pm 1.3) \times 10^{-5}$.

The decay $B \rightarrow J/\psi\,\phi$, which has not yet been observed, is explained with the occurrence of $c\bar{c}d\bar{d}$ rescattering into a $c\bar{c}s\bar{s}$ state.

The above decay modes have been studied at *BABAR*. The η is reconstructed in $\gamma\gamma$ or $\pi^+\pi^-\pi^0$ final states and the η' in the $\eta(\rightarrow \gamma\gamma)\pi^+\pi^-$ channel. The ϕ is reconstructed in the K^+K^- final state. Table 1 shows the preliminary results [1] obtained from the analysis of 50.9 fb^{-1} of data recorded at the $\Upsilon(4S)$ resonance [6].

2.2 Measurement of $B \rightarrow J/\psi\,\pi^+\pi^-$

In the decay $B \rightarrow J/\psi\,\pi^+\pi^-$, the $\pi^+\pi^-$ pair comes from the $B^0 \rightarrow J/\psi\,\rho^0(\rightarrow \pi^+\pi^-)$ channel or can be produced in a non-resonant state. The $B^0 \rightarrow J/\psi\,\rho^0$ mode is useful for the measurement of $\sin 2\beta$ and possible interference with higher order diagrams could produce a sizeble deviation of the branching fraction from the tree level expectation. An upper limit on this decay has been set by the CLEO Collaboration [7].

At *BABAR*, the decay $B^0 \rightarrow J/\psi\,\pi^+\pi^-$ is exclusively reconstructed and the signal yield is extracted from an unbinned maximum likelihood fit to the $\pi^+\pi^-$ invariant mass of the selected candidates [8]. The preliminary result obtained from a sample of 51.7 fb^{-1} of data recorded at the $\Upsilon(4S)$ resonance is $\mathcal{B}(B \rightarrow J/\psi\,\pi^+\pi^-) = (5.0 \pm 0.7 \pm 0.6) \times 10^{-5}$.

[1] Unless otherwise stated, charged conjugate modes are implied throughout the paper

Table 1: Preliminary branching fraction determinations for rare B decays to final states with a J/ψ. When the signal yield is not statistically significant, a 90% C.L. upper limit is reported.

Decay Mode	Branching Fraction
$B^0 \to J/\psi\, \eta(\to \gamma\gamma)$	$< 3.0 \times 10^{-5}$
$B^0 \to J/\psi\, \eta(\to \pi^+\pi^-\pi^0)$	$< 5.2 \times 10^{-5}$
$B^0 \to J/\psi\, \eta(\text{combined})$	$< 2.7 \times 10^{-5}$
$B^0 \to J/\psi\, \eta'(\to \eta(\gamma\gamma)\, \pi^+\pi^-)$	$< 6.4 \times 10^{-5}$
$B^+ \to J/\psi\, \phi K^+$	$(4.4 \pm 1.4 \pm 0.7) \times 10^{-5}$
$B^0 \to J/\psi\, \phi K^0$	$(10.2 \pm 3.8 \pm 1.8) \times 10^{-5}$
$B \to J/\psi\, \phi K$ (combined)	$(5.0 \pm 1.3 \pm 0.7) \times 10^{-5}$
$B^0 \to J/\psi\, \phi$	$< 0.95 \times 10^{-5}$

2.3 Measurement of $B \to \eta_c K$

The decay $B^0 \to \eta_c K_S$ can be used for a theoretically clean determination of $\sin 2\beta$, in the same way as the "golden" mode $B^0 \to J/\psi\, K_S$. Previous studies of the neutral and charged decay modes were performed by the CLEO Collaboration [9].

At *BABAR*, the decay $B \to \eta_c K$ is exclusively reconstructed, with the η_c decaying in $K_S K^\pm \pi^\pm$, $K^+K^-\pi^0$ or $K^+K^-K^+K^-$ final states [10]. The preliminary results obtained from a data sample of 20.7 fb^{-1} recorded at the $\Upsilon(4S)$ resonance are $\mathcal{B}(B^+ \to \eta_c K^+) = (1.50 \pm 0.19 \pm 0.15 \pm 0.46) \times 10^{-3}$ and $\mathcal{B}(B^0 \to \eta_c K^0) = (1.06 \pm 0.28 \pm 0.11 \pm 0.33) \times 10^{-3}$, where the third error contribution is due to the uncertainty on the value of $\mathcal{B}(\eta_c \to KK\pi)$, as reported in the PDG [11].

3 Observation of $B^0 \to D_s^+\pi^-$

One of the methods to determine the angle γ of the unitarity triangle [12] is the measurement of $\sin(2\beta + \gamma)$ from the time dependent CP-asymmetry of the decay $B^0 \to D^+\pi^-$ [13]. The asymmetry evolution depends on the parameter $\lambda_{D\pi} \equiv A(B^0 \to D^+\pi^-)/A(B^0 \to D^-\pi^+)$ which can be determined from the branching fraction measurement of $B^0 \to D_s^+\pi^-$ through the relation:

$$\mathcal{B}(B^0 \to D_s^+\pi^-) \approx \frac{\mathcal{B}(B^0 \to D^+\pi^-)}{\cos^2\theta_C} \left(\frac{f_{D_s}^2}{f_D^2}\right) |\lambda_{D\pi}|^2 \,. \quad (1)$$

The above equation is valid in the limit of the tree diagram dominance for $D_s^+\pi^-$ and $D^+\pi^-$ modes.

At *BABAR*, the decay $B^0 \to D_s^+\pi^-$ is exclusively reconstructed, with the D_s^+ decaying in $\phi\pi^+$, $\bar{K}^{*0}K^+$ or $K_S K^+$ final states. From the analysis of a data sample of 56.4 fb^{-1} recorded at the

Table 2: Preliminary branching fraction measurements of flavor-tagged D meson production in B^0 decays. World data values for D meson production in B decays are reported for comparison. Here "B" is an admixture of charged and neutral B mesons at the $\Upsilon(4S)$.

BABAR Measurements		World Data	
Decay Mode	Branching Fraction	Decay Mode	Branching Fraction
$\bar{B}^0 \to D^0$	$(50.3 \pm 3.0 \pm 3.7)\%$		
$\bar{B}^0 \to D^+$	$(32.8 \pm 2.5 \pm 3.5)\%$		
$\bar{B}^0 \to D^0 + D^+$	$(83.1 \pm 6.4)\%$	$\bar{B} \to D^0 + D^+$	$(78.5 \pm 3.4)\%$ [11]
$\bar{B}^0 \to \bar{D}^0$	$(7.6 \pm 1.7 \pm 1.1)\%$	$\bar{B} \to \bar{D}^0$	$(7.3 \pm 3.8)\%$ [15]
$\bar{B}^0 \to D^-$	$(2.7 \pm 1.2 \pm 0.6)\%$	$\bar{B} \to D^-$	$(2.7 \pm 1.7)\%$ [15]

$\Upsilon(4S)$ resonance, the number of observed signal events is $N_{D_s\pi} = 14.9 \pm 4.1$ with a statistical significance of 3.5σ. The preliminary branching fraction is $\mathcal{B}(B^0 \to D_s^+\pi^-) \times \mathcal{B}(D_s^+ \to \phi\pi^+) = (1.11 \pm 0.37 \pm 0.24) \times 10^{-6}$. Using the value of $\mathcal{B}(D_s^+ \to \phi\pi^+)$ in the PDG, which has a 25% uncertainty, a branching fraction $\mathcal{B}(B^0 \to D_s^+\pi^-) = (3.1 \pm 1.0 \pm 1.0) \times 10^{-5}$ is obtained.

4 D meson production in B^0 decays

Inclusive branching fractions of charged and neutral B mesons to charmed hadrons will help to solve the longstanding n_c *puzzle* [14]: the mean number of charm quarks per B decay obtained from direct counting does not agree with theoretical estimates based on branching fraction measurements of semileptonic decays.

The analysis of D meson production in B^0 decays at *BABAR* is based on the exclusive reconstruction of one B meson coming from the decay of the $\Upsilon(4S)$ ($\equiv B^0_{reco}$) in a semileptonic ($D^*l\nu$, with $l = e, \mu$) or hadronic mode ($D^{(*)}\pi^-$, $D^{(*)}\rho^-$, $D^{(*)}a_1^-$). The recoil system is then analyzed to search for a neutral (charged) D in the $D^0 \to K\pi$ ($D^\pm \to K\pi\pi$) channel. The inclusive branching fractions $\mathcal{B}(B^0 \to D)$ and $\mathcal{B}(B^0 \to D^\pm)$ are determined from a fit to the invariant mass distribution of the selected D candidates.

In the inclusive decays $\bar{B}^0 \to D^0$ and $\bar{B}^0 \to D^+$ the charm quark comes directly from the decaying b quark, and the D meson is said to be of "right-sign". On the contrary, the D meson in the inclusive decays $\bar{B}^0 \to \bar{D}^0$ and $\bar{B}^0 \to D^-$ is said to be of "wrong-sign". The fraction w of decays with a "wrong-sign" D is determined by comparing the flavor of the B^0_{reco} with that of the D, after correcting for the B mixing probability χ_d:

$$\chi_{obs} = \chi_d + w \times (1 - 2\,\chi_d)\,. \qquad (2)$$

If Δt is the time difference between the decays of the two B mesons, events with $|\Delta t| > 2.5ps$ are discarded. Indeed, they do not contribute significantly to w measurement because $\chi_d(|\Delta t| > 2.5ps) = 1/2$. The requirement on $|\Delta t|$ increases the sensitivity to w, thereby improving the statistical error. It improves also the systematic error since the reduced contribution from the B mixing.

Preliminary measurements of $\mathcal{B}(B^0 \to D)$ and $\mathcal{B}(B^0 \to D^{\pm})$ are based on a sample of 30.4 fb^{-1}, while the fractions w are determined from a sample of 51.1 fb^{-1}, all recorded at the $\Upsilon(4S)$ resonance. These determinations are combined to obtain the first measurements of flavor tagged D^0 and $D^{\pm}$ production in B^0 decays. Preliminary results are shown in Table 2. They agree with existing measurements of flavor tagged D meson production in a $\Upsilon(4S)$ environment. The flavor of the spectator quark in the parent B appears to have a negligible effect in the production of "wrong-sign" D mesons. The increase in the central value of the measured branching fractions goes in the direction of a better agreement with theoretical predictions. However, in order to solve the n_c *puzzle* other inclusive branching fraction measurements are needed.

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