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Hadronic B decays at *BABAR*

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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 in CP-related analyses of $B^- \to D(\to \pi^+\pi^-\pi^0)K^-$, $B^0 \to \bar{D}^0(D^0)DK^+\pi^-$ and $B^0 \to D_s^+ a_{0(2)}^-$ and in non-CP-related analyses of $B^+ \to D^{(*)+}K^0$, $B^- \to D_s^{(*)-}\phi$ and $B \to J/\psi\bar{D}$. Because the results presented in this paper are preliminary, they are based on different amount of 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 identifications, and a CsI(Tl) electromagnetic calorimeter (EMC) for photon reconstruction and electron identification. A superconducting solenoid provides a magnetic field of 1.5T, and the iron of the flux return is instrumented with resistive plate chambers (IFR) to provide muon identification and neutral hadron reconstruction.

2. *CP* related analyses

Decay modes of the type $B \to DK$ is utilized in a theoretically clean method of measuring the angle $\gamma = \arg(-V_{ud}V^*_{ub}/V_{cd}V^*_{cb})$ in the CKM unitary triangle. Gronau and Wyler, for example, have proposed to constrain the relative phase, γ, of $b \to u\bar{c}s$ to $b \to c\bar{u}s$ processes.[3] However, extraction of γ in this method suffers from an eight-fold ambiguity due to *a priori* unknown strong phases. In addition, the $b \to u\bar{c}s$ amplitude is suppressed by CKM element factor $|V_{ub}V_{cs}/V_{cb}V_{us}| \approx 0.4$ and color suppression factor of $0.2-0.5$. We present results from two recent proposals for measuring γ in decays modes of $B^- \to D(\to \pi^+\pi^-\pi^0)K^-$ and $B^0 \to \overline{D}^0(D^0)DK^+\pi^-$.

The value of $\sin(2\beta+\gamma)$ can be extracted from the measurement of the time dependent *CP* asymmetry in $B \to D^- X^+_{light}$ decays with, for instance, $X^+_{light} \to a^+_0, a^+_2$. In this case the asymmetry is given by : $\mathscr{A}_{CP}(\Delta t) = r \times sin(2\beta+\gamma) \times sin(\Delta m_d \Delta t)$ where $r = \mathscr{B}(B^0 \to D^+X^-_{light})/\mathscr{B}(B^0 \to D^-X^+_{light})$. The decay $B^0 \to D^+X^-_{light}$ is doubly Cabibbo suppressed and difficult to measure directly. However, using $SU(3)$ flavor symmetry, it is possible to infer the value of $\mathscr{B}(B^0 \to D^+X^-_{light})$ from the value of $\mathscr{B}(B \to D^+_s X_{light})$, the latter being less suppressed. We present the results of one analysis utilizing such a method, where $X^+_{light} = a^+_{0(2)}$.

2.1 Study of $B^- \to D(\to \pi^+\pi^-\pi^0)K^-$ decays

The decays $B \to D^{(*)0}K^{(*)}$ can be used to measure the angle γ taking advantage of the interference between $b \to u\bar{c}s$ and $b \to c\bar{u}s$ decay amplitudes. Different approaches have been developed, and among which, γ measurements involving D decays to multi-body, using a Dalitz plot analysis technique as described in reference [4]. In this analysis, we study the decay mode $B^- \to DK^-$ with the D-decay: $D \to \pi^+\pi^-\pi^0$ which is Cabibbo suppressed. This yields a much smaller event sample compared to Cabibbo allowed decay but its interfering D^0 and $\overline{D}^0$ amplitudes have similar magnitudes. Due to these interferences, the production rate might be different from the product $\mathscr{B}_{prod} \equiv \mathscr{B}(B^- \to D^0K^-) \times \mathscr{B}(D^0 \to \pi^+\pi^-\pi^0) = (4.1 \pm 1.6) \times 10^{-6}$[5]. From a sample of 229 million of BB pairs, we found 133 ± 23 signal events which correspond to a branching ratio of $\mathscr{B}(B^- \to D_{\pi^+\pi^-\pi^0}K^-) = (5.5 \pm 1.0 \pm 0.7) \times 10^{-6}$. We determine the raw asymmetry and do not find any significant deviation from zero: $\mathscr{A}^{raw}_{CP} = 0.02 \pm 0.16 \pm 0.03$. The γ extraction needs a full Dalitz analysis of the *D*-decay.

2.2 Study of three-body $B^0 \to \bar{D}^0(D^0)DK^+\pi^-$ decays

In the three-body decays of $B \to DK\pi$, the CKM suppressed $b \to u\bar{c}s$ processes contain color-allowed diagrams, which could result in larger rates and more significant *CP* violation effect. The 8-fold ambiguity in strong phase could be reduced 2-fold by using the Dalitz plot. To assess the feasibility of this method, which was proposed by R. Aleksan, *et al*[6], we study the decays $B^0 \to \bar{D}^0(D^0)DK^+\pi^-$, where $D^0 \to K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+$ using 205 fb^{-1} of on-resonance data. In this measurement, the contribution from $B \to D^*K$ is excluded. While the branching fraction for the CKM favored mode is determined to be $\mathscr{B}$ $(B^0 \to \bar{D}^0K^+\pi^-)= (8.6 \pm 1.5 \pm 1.0) \times 10^{-5}$, no significant signal events are found for the CKM suppressed mode. We, therefore, set the upper limit for the suppressed mode with 90% C.L.: $\mathscr{B}$ $(B^0 \to D^0K^+\pi^-)< 1.9 \times 10^{-5}$. As we do not observe a significant signal for the $b \to u$ mode, measuring the CKM angle γ with this mode is determined to be very difficult.

2.3 Search for $B \to D_s^+ X_{light}$ with $X_{light} \equiv a_0^-, a_2^-$

In extracting $\sin(2\beta+\gamma)$ from time dependent *CP* asymmetry in $B \to D^- X^+_{light}$ decays, we analyze the case where $X^+_{light} = a^+_{0(2)}$. In this case, $r = \mathscr{B}(B^0 \to D^+ X^-_{light})/\mathscr{B}(B^0 \to D^- X^+_{light})$ may be quite large. This is due to the small coupling constant of the W to the a_0 scalar meson (a_2 meson of spin 2) which decreases the production rate of the Cabibbo allowed decay $B^0 \to D^- a_0^+ (a_2^+)$. The factorization hypothesis predicts a similar rate for Cabibbo allowed and Cabibbo suppressed decays, which results in $r \sim 1$[7]. These decays are not yet in the reach of the experiment (branching ratios around 10^{-6}); nevertheless, the theoretical predictions can be tested with the measurement of the branching ratio of the decay $B^0 \to D_s^+ a_0^- (a_2^-)$ expected at larger values : $\mathscr{B}(B^0 \to D_s^+ a_0^- (a_2^-) \approx 7.5(1.5) \times 10^{-5}$ [7]. From a sample of 230 million of $B\bar{B}$ pairs, we measure these two branching ratios. The $a_0^- (a_2^-)$ is reconstructed in $a^-_{0,2} \to \eta(\to \gamma\gamma)\pi^+$ which has a branching ratio of the order of 100% (only 15% for the a_2^- which lowers the experimental sensitivity). We do not find any significant signal and quote the upper limits of $\mathscr{B}(B^0 \to D_s^+ a^-_{0(2)}) < 4.0(25) \times 10^{-5}$ which shows a discrepancy of at least a factor two with the theoretical predictions.

3. Non *CP*-related analyses

3.1 Search for rare quark-annihilation decays $B^- \to D_s^{(*)-}\phi$

In the Standard Model (SM), the decay $B^- \to D_s^{(*)-}\phi$ occurs through annihilation of the two quarks in the B meson into a virtual W. Such a process is highly suppressed, and calculations of the $B^- \to D_s^-\phi$ branching fraction give predictions of 3×10^{-7} using a perturbative QCD approach [8], 1.9×10^{-6} using factorization [9], and 7×10^{-7} using QCD-improved factorization [9]. Since the current experimental limits are about three orders of magnitude higher than the SM expectations, searches for $B^- \to D_s^{(*)-}\phi$ could be sensitive to contributions from new physics. Enhancement of such kind has been calculated to be as high as 8×10^{-6} in a two-Higgs doublet model and 3×10^{-4} in minimal supersymmetric model with *R*-parity violation (RPV-MSSM), depending on the details of the parameters of the new physics.[9] Based on a sample of 234 million $B\bar{B}$ pairs, we reconstruct $B^- \to D_s^{(*)-}\phi$, where $D_s^{*-} \to D_s^-\gamma, D_s^- \to \phi\pi^-, K_s^0K^-, K^{*0}K^-$. We observe no significant signal and set upper limits with 90% C.L. of $\mathscr{B}(B^- \to D_s^- \phi) < 1.8 \times 10^{-6}$ and $\mathscr{B}(B^- \to D_s^{*-} \phi) < 1.1 \times 10^{-5}$. These limits are lower than the prediction based on RPV-MSSM.

3.2 Search for the rare decays $B^+ \to D^{(*)+} K^0$

This decay is expected to occur via a pure annihilation diagram. Such processes provide interesting insights into the internal dynamics of B mesons. This kind of diagram cannot be calculated in QCD factorization since both the quarks play a role. These amplitudes are expected to be suppressed, with respect to the amplitudes of spectator quark trees, by a factor $f_B/m_B \approx 0.04$ and have never been observed. Some studies indicate, though, that processes with a spectator quark can contribute to annihilation-mediated decays by rescattering.[10] The branching ratio is expected to be either at the level of the current sensitivity (10^{-5}) if large rescattering occurs, or three orders of magnitude below if not.[10] We reconstruct the two decay modes $B^+ \to D^{*+} K_s^0$ and $B^+ \to D^+ K_s^0$ with a sample of 226 million of $B\bar{B}$ pairs. We do not see any significant excess of signal and therefore set the upper limits with 90% C.L.: $\mathscr{B}$ ($B^+ \to D^+ K_s^0$) $< 0.5 \times 10^{-5}$ and $\mathscr{B}$ ($B^+ \to D^{*+} K_s^0$) $< 0.9 \times 10^{-5}$.

3.3 Search for $B \to J/\psi D$ Decays

The spectra of the momentum of inclusive $J/\psi D$ mesons in the $\Upsilon(4S)$ rest frame observed by CLEO and by BABAR, compared with calculations using non-relativistic QCD (NRQCD), show an excess at low momentum, corresponding to a branching fraction of approximately 6×10^{-4}. Many hypothesis have been proposed to explain this result but no experimental evidence has been found to support them. The presence of bucc components (intrinsic charm) in the B-meson wave function has also been suggested to enhance the branching ratio of decays such as $b \to J/\psi \bar{D}(\pi)$ to the order of 10^{-4} while pertubative QCD predicts a branching ratio for $B \to J/\psi \bar{D}$ to the order of 10^{-8} to 10^{-9}. We test the decay channels $B \to J/\psi D$ with a sample of 124 million of $B\bar{B}$ pairs. We do not find any evidence of signal and obtain upper limits of 1.3×10^{-5} for $B^0 \to J/\psi \bar{D}^0$ and 1.2×10^{-4} for $B^+ \to J/\psi D^+$ at 90% C.L. Therefore, we conclude that intrinsic charm is not supported as the explanation of low momentum J/ψ excess in B decays.

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