SLAC-PUB-11825

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 $B^- \to D(\to \pi^+\pi^-\pi^0)K^-$, $B^0 \to \overline{D}^0(D^0)DK^+\pi^-$ 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 $B \to J/\psi\overline{D}$. Because the results presented in this paper are preliminary, they are based on different amount of data samples.

International Europhysics Conference on High Energy Physics
July 21st - 27th 2005
Lisboa, Portugal

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Work supported in part by Department of Energy contract DE-AC02-76SF00515

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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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