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Constraints on the CKM angle α in the $B \to \rho\rho$ decays

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Using a data sample of 122 million $\Upsilon(4S) \to B\overline{B}$ decays collected with *BABAR* detector at the PEP-II asymmetric B factory at SLAC, we measure the time-dependent-asymmetry parameters of the longitudinally polarized component in the $B^0 \to \rho^+\rho^-$ decay as $C_L = -0.23 \pm 0.24(\text{stat}) \pm 0.14(\text{syst})$ and $S_L = -0.19 \pm 0.33(\text{stat}) \pm 0.11(\text{syst})$. The $B^0 \to \rho^0\rho^0$ decay mode is also searched for in a data sample of about 227 million $B\overline{B}$ pairs. No significant signal is observed, and an upper limit of 1.1×10^{-6} (90% C.L.) on the branching fraction is set. The penguin contribution to the CKM angle α uncertainty is measured to be 11^o. All results are preliminary.

Keywords: time-dependent-asymmetry; CKM angle; longitudinal polarization.

1. Introduction

The time-dependent CP asymmetry in a $b \to u\bar{u}d$ decay of a B^0 to a CP eigenstate allows for a measurement of the angle $\alpha = arg[-V_{\text{td}}V^*_{\text{tb}}/V_{\text{ud}}V^*_{\text{ub}}]$ if the decay is dominated by the tree amplitude. The contribution from penguin diagrams gives rise to a correction $\Delta\alpha = \alpha_{\text{eff}} - \alpha$ that can be inferred through an isospin analysis [1]. The recent experimental results [2] indicate a small penguin contributions in $B \to \rho\rho$. The CP analysis in $B \to \rho^+\rho^-$ is complicated by the presence of three helicity states. However, the measured polarizations in $\rho^+\rho^-$ and $\rho^+\rho^0$ modes indicate a dominance of the helicity 0 state (longitudinal polarization), that is a $CP = +1$ eigenstate. A measurement of the polarization in $B^0 \to \rho^0\rho^0$ would complete the isospin triangle, but this mode has not been observed so for. Knowledge of the $B^0 \to \rho^0\rho^0$ rate is still expected to be limiting factor to the accuracy of the α measurement with $\rho\rho$ decays.

In this paper, we present a time-dependent analysis of $B^0 \to \rho^+\rho^-$ based on a sample of 122 million $B\overline{B}$ pairs, and a search for the $\rho^0\rho^0$ final state on a sample of 227 million $B\overline{B}$ pairs at *BABAR*.

2. Analysis Method

We reconstruct $\rho^+\rho^-$ candidates from combinations of two charged tracks and two π^0 candidates. In the $\rho^0\rho^0$ mode, the B^0 candidates are reconstructed from their

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decay products $\rho^0 \to \pi^+\pi^-$ with four charged tracks which are required to originate from a single vertex near the interaction point. The π^0 candidates are formed from pairs of photons that have measured energies greater than 50 MeV. The reconstructed π^0 mass must satisfy $0.10 < m_{\gamma\gamma} < 0.16$ GeV/c^2. The mass of the ρ candidates, $m_{\pi^\pm\pi^0}$, must satisfy $|m_{\pi^\pm\pi^0} - 0.770\,\mathrm{GeV}/c^2| < 0.375$ GeV/c^2, and the mass, $m_{\pi^+\pi^-}$, must satisfy $0.55 < m_{\pi^+\pi^-} < 1.0$ GeV/c^2. Combinatorial backgrounds dominate near $|\cos\theta_i| = 1$, where θ_i, $i = 1, 2$ is defined for each ρ meson as the angle between the π^0 (π^+) momentum in the $\rho^\pm$ (ρ^0) rest frame and the flight direction of the B^0 in this frame, We reduce these backgrounds with the requirement $-0.8 < \cos\theta_i < 0.98$ in $\rho^+\rho^-$ modes and $|\cos\theta_i| < 0.99$ in $\rho^0\rho^0$ mode. Two kinematic variables [3], ΔE and $m_{\rm ES}$, allow the discrimination of signal B decays from random combinations of tracks and π^0 candidates. For $\rho^+\rho^-$ we require that $5.21 < m_{\rm ES} < 5.29$ GeV/c^2 and $-0.12 < \Delta E < 0.15$ GeV/c^2. The asymmetric ΔE window suppresses background from higher-multiplicity B decays. For $\rho^0\rho^0$ we require $m_{\rm ES} > 5.24$ GeV/c^2 and $|\Delta E| < 85$ MeV/c^2.

In order to reject the dominated quark-antiquark continuum background, we require $|\cos\theta_T| < 0.8$, where θ_T is the the angle between the B thrust axis and the thrust axis of the rest of the events (ROE). The other event-shape discriminating variables are combined in a neural network [4] ($\mathcal{N}$). The $\mathcal{N}$s for $\rho^+\rho^-$ and $\rho^0\rho^0$ analysis weight the discriminating variables differently, according to training on off-resonance data and the relevant Mote Carlo (MC) simulated signal events.

When multiple B candidates can be formed we select the one that minimizes the sum of the deviations of the reconstructed π^0 mass in $\rho^+\rho^-$ mode, while, for $\rho^0\rho^0$, one candidate is selected randomly. The selection efficiency is 7% (13%) for the longitudinaly (transversely) polarized $\rho^+\rho^+$ signal, and it is 27% (32%) for the $\rho^0\rho^0$ signal. B in the event.

To study the time-dependent asymmetry one needs to measure the proper time difference, Δt, between the two B decays in the events, and to determine the flavor tag of the other B-meson. The time difference between the decays of the two neutral B mesons ($B_{\rm rec}$, $B_{\rm tag}$) is calculated from the measured separation Δz between the B_{rec} and B_{tag} decay vertices [5]. The flavor of the $B_{\rm tag}$ is determined with a multivariate technique [3] that has a total effective tagging efficiency of (28.4±0.7)%.

An unbinned likelihood fit is finally performed on the selected event, a probability density function is built from discriminating variables, including the angular distribution and the Δt-dependence. The signal decay-rate distribution f_+ (f_-) for $B_{\rm tag} = B^0$ ($\overline{B}^0$) is given by:

$$f_\pm(\Delta t) = \frac{e^{-|\Delta t|/\tau}}{4\tau}[1 \pm S_L \sin(\Delta m_d \Delta t) \mp C_L \cos(\Delta m_d \Delta t)], \tag{1}$$

where τ is the mean B^0 lifetime, Δm_d is the $B^0 - \overline{B}^0$ mixing frequency, and S_L and C_L are the CP asymmetry parameters for the longitudinal polarized signal.

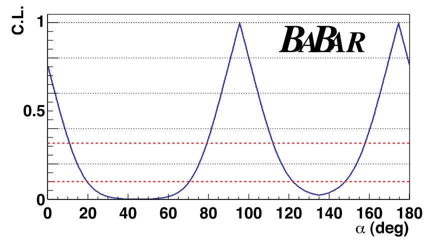

Fig. 1. Confidence Level on α (solid curve) obtained for this results. The red dashed lines correspond to the 68% (top) and 90% (bottom) confidence intervals.

3. Results

We measure the CP violating asymmetries in the $B^0 \to \rho^+\rho^-$ longitudinal component decay on 122 million $B^0\overline{B}^0$ pairs. A detailed analysis of the background due to other B decays is performed. The main systematic uncertainty on the asymmetries is found to be the unknown CP violation in B background events. Our results are $S_L = -0.19 \pm 0.33(\text{stat}) \pm 0.11(\text{syst})$ and $C_L = -0.23 \pm 0.24(\text{stat}) \pm 0.14(\text{syst})$. With a sample of 227 million $B^0\overline{B}^0$ pairs we have searched for the decay mode $B^0 \to \rho^0\rho^0$, the measured value for the branching fraction is $(0.54^{+0.36}_{-0.32} \pm 0.19) \times 10^{-6}$ or an upper limit of 1.1×10^{-6} at 90% confidence level (C.L.).

Using the Grossman-Quinn bound [1,6] with the recent results [2] on $B^\pm \to \rho^\pm\rho^0$ we limit $|\alpha_{\text{eff}} - \alpha| < 11^o$ (68% C.L.). Ignoring possible non-resonant contributions, and $I = 1$ amplitudes [7] one can relate CP parameters S_L and C_L to α, up to a four-fold ambiguity. If we select the solution closest to the CKM best fit central value [8], with the new limit on the $B^0 \to \rho^0\rho^0$ rate we improve the constraint on α due to the penguin contribution, the measured CP parameters of the longitudinal polarization correspond to $\alpha = (96 \pm 10(\text{stat}) \pm 4(\text{syst}) \pm 11(\text{penguin}))^o$. Figure 1 shows the confidence level as a function of α from the isospin analysis.

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