SLAC-PUB-8690
BABAR-PROC-00/28
hep-ex/0011006
November 2000

A study of $B^0\overline{B}^0$ oscillations with full reconstructed B mesons with the *BABAR* detector

Shahram Rahatlou
University of California, San Diego
Physics Department, 9500 Gilman Drive, La Jolla CA 94306, USA
representing the *BABAR* Collaboration

Abstract

Time–dependent $B^0\overline{B}^0$ flavor oscillations are studied in e^+e^- annihilation data collected with the *BABAR* detector at center-of-mass energies near the $\Upsilon(4S)$ resonance. We report a preliminary result for the time-dependent $B^0\overline{B}^0$ oscillation frequency, $\Delta m_d = 0.512 \pm\ 0.017 \pm\ 0.022\ \hbar\,\mathrm{ps}^{-1}$.

Contribued to
The Meeting of
The Division of Particle and Fields
of the American Physical Society
Columbus, Ohio, USA
August 9 - August 12, 2000

Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309

Work supported in part by Department of Energy contract DE-AC03-76SF00515.

1 Introduction

We have performed a measurement of time-dependent mixing at the PEP-II asymmetric e^+e^- collider at SLAC, where resonant production of the $\Upsilon(4S)$ provides a copious source of $B^0\overline{B}^0$ pairs. The data set used for this analysis corresponds to an integrated luminosity of $8.9\,\mathrm{fb}^{-1}$ on the $\Upsilon(4S)$ resonance and $0.8\,\mathrm{fb}^{-1}$ collected 40 MeV below the resonance. This corresponds to about 10.1×10^6 produced $B\overline{B}$ pairs.

The *BABAR* detector is described in detail elsewhere [1]. The analysis described here uses all the detector capabilities, including high resolution tracking and calorimetry, particle identification and vertexing.

2 Event Reconstruction

We fully reconstruct one B meson (B_{REC}) in hadronic ($B^0\rightarrow D^{(*)-}\pi^+$, $D^{(*)-}\rho^+$, $D^{(*)-}a_1^+$ and $J/\psi K^{*0}$) or semileptonic ($B^0\rightarrow D^{*-}\ell^+\nu$) decay mode [1]. A total of 2577 neutral B candidates is reconstructed in hadronic decay modes, with an average purity close to 90%. The main background for these modes is combinatorial. 7517 B^0 candidates are reconstructed in the semileptonic mode, with an average purity close to 84%. Backgrounds to the semileptonic mode are due to combinatorial D^* fake leptons, uncorrelated $D^*\ l$ combinations, $c\bar{c}$ events, and charged B decays from $B^-\rightarrow D^{*+}(n\pi)l^-\nu$.

The other two important ingredients for this analysis are the vertex reconstruction and the identification of the flavor of the other B meson (B_{TAG}) in the event. The flavor of the B_{TAG} is determined from the correlation between the particle types and the charge of its decay products [2]. If there is an identified lepton its charge is used; otherwise the summed charge of identified kaons provides the tag. An event with no tagging leptons or kaons can still be tagged by the use of a neural network that exploits the flavor information carried by other decay products, such as soft leptons from charm semileptonic decays and soft pions from D^* decays.

At PEP-II the B meson pairs produced in the decay of the $\Upsilon(4S)$ resonance are moving in the lab frame along the beam axis (z direction) with a Lorentz boost of $\beta_z\gamma = 0.56$. The separation between the two B vertices along the boost direction, $\Delta z = z_{\mathrm{REC}} - z_{\mathrm{TAG}}$, is measured and used to estimate the decay time difference, $\Delta t \approx \Delta z/\beta_z\gamma c$. The B_{TAG} vertex is determined via an inclusive procedure applied to all tracks not associated with the B_{REC} meson [3]. The typical separation between the two vertices is $\Delta z = \beta_z\gamma c\tau_B \approx 260\,\mu\mathrm{m}$, to be compared to the experimental resolution $\sim 100\,\mu\mathrm{m}$. The Δt resolution is limited by the precision on the B_{TAG} vertex, and has little dependence on the decay mode of the B_{REC}. The Δt resolution function is well described by three Gaussians: core, tail and outlier. We calculate the uncertainty on Δt by using a globally-fitted rescaling of the event-by-event vertex separation errors. Most of the events, $\sim 70\%$, are in the core Gaussian, with $\sigma \sim 0.6$ ps.

3 Likelihood Fit method

The time-dependent asymmetry between same sign $B^0B^0/\overline{B}^0\overline{B}^0$ (unmixed) and opposite sign $B^0\overline{B}^0$ (mixed) events, $A(\Delta t) = (N_{unmix} - N_{mix})/(N_{unmix} + N_{mix})$ is calculated as a function of Δt and is given by

[1] Throughout this paper, charge conjugate modes are implied.

$$A(\Delta t) \approx (1-2w)\cos\Delta m_d \Delta t \otimes \mathcal{R}(\Delta t|\hat{a}),$$

where $\hat{a}$ are the parameters of the Δt resolution function [2] and w is the probability of incorrect tagging (mistag fraction). A simultaneous unbinned likelihood fit to the Δt distribution of mixed and unmixed events in all tagging categories, assuming a common resolution function, allows the simultaneous determination of both Δm_d and the mistag fractions, w_i. An empirical description of the Δt structure of the backgrounds is determined from a fit to background control samples taken from data, allowing for the following components: zero lifetime, non-zero lifetime with no mixing, non-zero lifetime with mixing.

4 Results and Conclusions

We measure the $B^0\overline{B}^0$ oscillation frequency to be $\Delta m_d = 0.516 \pm 0.031$ (stat) ± 0.018(syst) $\hbar\mathrm{ps}^{-1}$ in the hadronic sample and $\Delta m_d = 0.508 \pm 0.020$ (stat) ± 0.022(syst) $\hbar\mathrm{ps}^{-1}$ in the $D^{*-}\ell^+\nu$ sample . Figure 1 shows the asymmetry $A(\Delta t)$ distributions for each sample with the fit result superimposed.

The systematic errors include uncertainty due to Monte Carlo statistics, Δt resolution function, background Δt shape, fraction of background events, B^0 lifetime, z scale and the boost. In addition, we have looked at the uncertainty due to feeddown from $B^- \to D^{*+}(n\pi)l^-\nu$ in the semileptonic sample. The dominant contribution in the hadronic sample comes from the Δt resolution function, while the semileptonic sample is dominated by the uncertainty on the fraction of background events (see [2] for details).

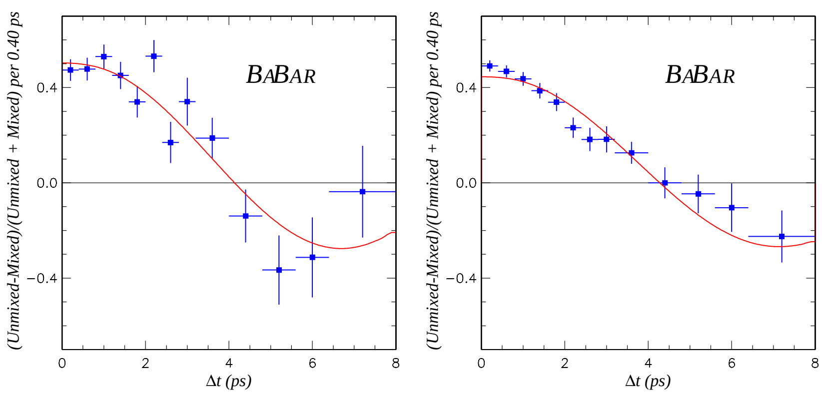

Figure 1: Time-dependent asymmetry $A(\Delta t)$ between unmixed and mixed events for (left) hadronic B candidates with $m_{\mathrm{ES}} > 5.27\,\mathrm{GeV}/c^2$and (right) for $B \to D^* l\nu$ candidates.

Combining the two Δm_d results, we obtain the preliminary result:

$$\Delta m_d \quad = \quad 0.512 \pm 0.017(\mathrm{stat}) \pm 0.022(\mathrm{syst})\ \hbar\mathrm{ps}^{-1}.$$

The effective flavor tagging efficiency is given by $Q = \sum_i \epsilon_i(1-2w_i)^2$ where the sum is over tagging categories, each characterized by a tagging efficiency ϵ_i and a mistag fraction w_i. Q is related to the statistical significance of the measurement ($1/\sigma^2_{stat} \sim N_{B_{\mathrm{TAG}}}Q$) and is found to be $(27.9 \pm 1.6)\%$. The mistag fractions and the Δt resolution function parameters are used in the *CP* asymmetry measurement [3].

The results for Δm_d are consistent with previous measurements [4] and are of similar precision. They are also compatible with other *BABAR* measurements [5, 6]. Significant improvements are expected in the near future with the accumulation of more data and further systematic studies.

References

[1] *BABAR* Collaboration, B. Aubert *et al.*, SLAC-PUB-8540, BABAR-CONF-00/01, contributed to ICHEP2000

[2] *BABAR* Collaboration, B. Aubert *et al.*, Preprint hep-ex/0008052.

[3] *BABAR* Collaboration, B. Aubert *et al.*, Preprint hep-ex/0008048.

[4] D.E. Groom, *et al.*, Eur. Phys. Jour. C **15**(2000) 1.

[5] *BABAR* Collaboration, B. Aubert *et al.*, Preprint hep-ex/0008053.

[6] *BABAR* Collaboration, B. Aubert *et al.*, Preprint hep-ex/0008054.