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Preliminary *BABAR* results on B^0 mixing with dileptons and on lifetime with partially reconstructed B^0 decays

Christophe Yèche
(for the *BABAR* Collaboration)
CEA Saclay, DAPNIA/SPP, Bat 141, 91191 Gif-Sur-Yvette cedex, France
E-mail: yeche@slac.stanford.edu

Abstract

With an integrated luminosity of 7.7 fb^{-1} collected on resonance by *BABAR* at the PEP-II asymmetric B Factory, we measure the difference in mass between the neutral B eigenstates, Δm_{B^0}, to be $(0.507 \pm 0.015 \pm 0.022) \times 10^{12}\,\hbar\, s^{-1}$ with dileptons events and present preliminary results for the B^0 lifetime, $\tau_{B^0} = 1.55 \pm 0.05 \pm 0.07$ ps and $\tau_{B^0} = 1.62 \pm 0.02 \pm 0.09$ ps obtained from partial reconstruction of the two B^0 decay processes respectively $B^0 \to D^{*-}\pi^+$ and $B^0 \to D^{*-}\ell^+\nu_\ell$.

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

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1 Introduction

This paper presents three analyses designed to select large samples of B^0 mesons using inclusive reconstruction techniques. The first method proposes a precise measurement of the mixing parameter Δm_{B^0} using direct dilepton events which represent 4% of the $\Upsilon(4S) \to B\overline{B}$ decays. The two other methods provide a measurement of the B^0 lifetime by selecting $B^0 \to D^{*-}\pi^+$ and $B^0 \to D^{*-}\ell^+\nu_\ell$ decays; while the two techniques are different in detail, they both share the common feature of making no attempt to reconstruct the D^0 produced in the $D^{*-} \to D^0\pi^-$ decay, thereby achieving high efficiency compared to the exclusive reconstruction.

2 Measurement of B^0 mixing with dileptons

2.1 Selection of dilepton events and determination of Δt

In this study[1] of the oscillation frequency Δm_{B^0}, the flavor of the B meson at decay is determined by the sign of leptons produced in semileptonic B decays. For this analysis, electron and muon candidates are required to pass the *very tight* selection criteria fully described in reference[2]; electrons are essentially selected by specific requirements on energy deposited in the Electromagnetic Calorimeter and muons are identified by the use of information provided by the the Instrumented Flux Return.
Non $B\bar{B}$ events (radiative Bhabhas, two-photon and continuum events) are suppressed by applying cuts on the Fox-Wolfram ratio of second to zeroth order moments, on the event squared invariant mass, the event aplanarity and the number of charged tracks. Finally, events with a lepton coming from J/ψ decays are rejected.
The discrimination between direct and cascade leptons is based on a neural network which combines five discriminating variables, all calculated in the $\Upsilon(4S)$ center of mass system: the momenta of the two leptons with highest momenta, the total visible energy, the missing momentum of the event and the opening angle between the two leptons.
The combined effect of the above cuts gives, from Monte Carlo events, a signal purity of 78%. The main source of background consists of $B\bar{B}$ events (12% direct-cascade events). The total number of selected on-resonance events is 36631 (10742 electron pairs, 7836 muon pairs, and 18053 electron-muon pairs).
The z coordinate of the B decay vertex is determined by taking the z position of the point of closest approach of the track to an estimate of the position for $\Upsilon(4S)$ decay, obtained by minimizing a χ^2 based on the relative position of the tracks and the beam spot in tranverse plane. A two-Gaussian fit to the resulting Δz resolution function from simulated dilepton events gives $\sigma_n = 87\,\mu$m and $\sigma_w = 195\,\mu$m for the narrow and wide Gaussian, respectively, with 76% of the events in the narrow Gaussian. Then, the time difference between the two B decay times is defined as $\Delta t = \Delta z/(< \beta\gamma > c)$, with $< \beta\gamma >= 0.554$.

2.2 Measurement of Δm_{B^0}

The value of Δm_{B^0} is extracted with a χ^2 minimization fit to the dilepton asymmetry:

$$A_{\ell\ell}(|\Delta t|) = \frac{N(\ell^+,\ell^-) - N(\ell^\pm,\ell^\pm)}{N(\ell^+,\ell^-) + N(\ell^\pm,\ell^\pm)}. \quad (1)$$

The fit function takes into account the various time distributions of the dilepton signal and the cascade lepton and the non-$B\overline{B}$ background. The time dependence of this last and its absolute normalization is obtained from off-resonance data. In the fit, three additional parameters are left free: the fraction of charged B, the mistag fraction and the time-dependence of the mistagged events. From a data sample equivalent to $7.73\,fb^{-1}$, we obtain $\Delta m_{B^0} = (0.507\pm0.015\pm0.022)\times10^{12}\,\hbar\,s^{-1}$ (see Figure 1) , the main sources of systematic uncertainties are related to the time dependence of the cascade and mis-identified lepton and to the uncertainty on the resolution function (see Table 1).

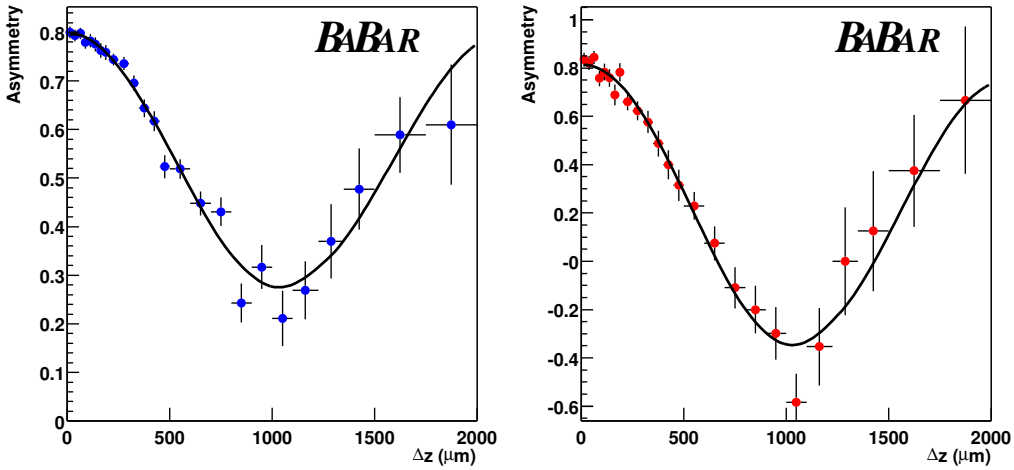

Figure 1: Time-dependent asymmetry $A_{\ell\ell}(|\Delta t|)$ for (a) the inclusive dilepton sample and (b) the dilepton sample enriched with soft pions with a method similar of section 3. The curve represents the result of the fit.

Table 1: Systematic uncertainty on Δm_{B^0}

Source of systematic uncertainty	$\sigma(\Delta m_{B^0})$ ($10^{12}\,\hbar\,s^{-1}$)
Non-$B\overline{B}$ background	0.005
Mis-Identification	0.011
Cascade events	0.009
Boost approximation	0.001
Beam spot motion ($\leq 20\,\mu$m)	0.001
Δz resolution function	0.009
Tails of the resolution function	0.004
Time-dependence of the resolution function	0.006
Sensitivity to Γ^+ and Γ^0 (PDG 98 $\pm 1\sigma$)	0.010
Total	0.022

3 Measurement of B^0 lifetime with partially reconstructed B^0

3.1 Event selection and determination of Δz

In studies[3] of the decays $B^0 \to D^{*-}\pi^+$ and $B^0 \to D^{*-}\ell^+\nu_\ell$ reported here, no attempt is made to reconstruct the D^0 decays. Thus, in the hadronic channel, a search is made for a pair of oppositely-charged pions (π_f, π_s) and, assuming that their origin is a B^0 meson and using the beam energy as a constraint, calculates the missing mass M_{miss}. This should be the D^0 mass if the hypothesis was correct. The signal region is taken to be the interval $M_{miss} > 1.854$ GeV/c^2. In the case of the semileptonic decay, due to the limited phase space available in the decay $D^{*-} \to D^0\pi^-$, the D^{*-} four-momentum can be computed by approximating its polar and azimuth angles with those of the slow pion π_s, and parametrizing its momentum as a linear function of the π_s momentum. Then a cut is applied on the invariant mass of the neutrino M_ν^2 estimated from the B^0, D^{*-} and ℓ^+ four-momenta ($M_\nu{}^2 > -2\,(\,\mathrm{GeV}/c^2)^2$).

The methods for rejection of the non $B\bar{B}$ background and the identification of the lepton are very similar to those described in section 2.1. For the $B^0 \to D^{*-}\pi^+$, the combinatorial background is reduced by using a Fisher discriminant method combining topological variables relating the position of the tracks and the pseudo-direction of the D^0.

The z of the first B^0 is obtained by fitting a vertex between the slow pion and the fast pion

or the direct lepton with the beam spot constrained. A fit with the other tracks outside an exclusion cone around the D^0 is performed to determine the z of the second B^0.

3.2 τ_{B^0} measurement

The B^0 lifetime is determined by means of an unbinned maximum likelihood fit, accounting for the event-by-event error determined by the vertex reconstruction algorithm. The fit function is the sum of the probability density function (pdf) for B^0 $B^{\pm}$, and combinatorial background. The different features of this background (time-dependence, resolution function, etc) are deduced both from Monte Carlo and data with wrong charge association. The results are:

$$\tau_{B^0} = 1.55 \pm 0.05 \pm 0.07\,\text{ps} \quad (D^*\pi),$$
$$\tau_{B^0} = 1.62 \pm 0.02 \pm 0.09\,\text{ps} \quad (D^*\ell\nu).$$

The dominant systematics come from the uncertainty on the fraction and the time-dependence of the backgrounds, the resolution function and the bias due to tracks related to the unconstructed D^0.

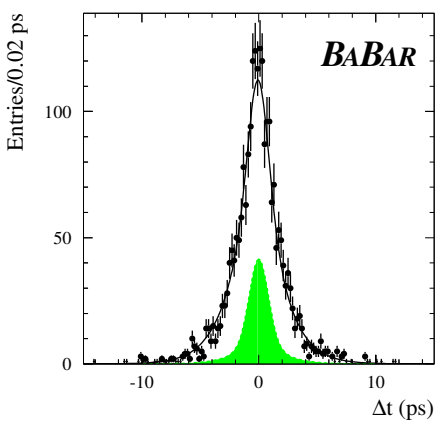

Figure 2: Distribution of Δt in ps for $(D^*\pi)$ events. The continuous line shows the result of the fit and the shaded area shows the contribution of the combinatorial background (27% of the sample).

4 Conclusions

We present a preliminary study of the $B^0\overline{B}^0$ oscillation frequency with an inclusive sample of dilepton events where an accuracy already comparable with the current world average is obtained. The partial reconstuction of $D^{*-}\pi^+$ and $D^{*-}\ell^+\nu_\ell$ gives measurements of the B^0 lifetime and will allow another determination of Δm_{B^0} in the future.

References

[1] *BABAR* "Measurement of the time dependence of $B^0\overline{B}^0$ oscillations using inclusive dilepton events", SLAC-PUB-8532, hep-ex/008054.

[2] *BABAR* "The first year of the *BABAR* experiment at PEP-II", SLAC-PUB-8539.

[3] *BABAR* "Measurement of the $\boldsymbol{B^0}$ meson properties using partially reconstructed $\boldsymbol{B^0}$ to $\boldsymbol{D^{*-}\pi^+}$ and $\boldsymbol{B^0}$ to $\boldsymbol{D^{*-}\ell^+\nu_\ell}$ decays", SLAC-PUB-8531, hep-ex/008053.