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B_s Mixing at SLD*

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Abstract

We set a preliminary 95% C.L. exclusion on the oscillation frequency of $B_s^0 - \overline{B_s^0}$ mixing using a sample of 400,000 hadronic Z^0 decays collected by the SLD experiment at the SLC during the 1996-98 run. Three analyses are presented in this paper. The first analysis partially reconstructs the B_s^0 by combining a fully reconstructed D_s with the remaining charged B decay tracks. The second analysis selects a sample of events with a partially reconstructed charm vertex and a lepton track. The third analysis reconstructs b-hadrons topologically and exploits the $b \to c$ cascade charge structure to determine the flavor of the b-hadron at decay. All three analyses take advantage of the large forward-backward asymmetry of the polarized $Z^0 \to b\overline{b}$ decays and information in the hemisphere opposite to the reconstructed B vertex to determine the b-hadron flavor at production. The results of the three analyses are combined to exclude the following values of the $B_s^0 - \overline{B_s^0}$ oscillation frequency: $\Delta m_s < 7.6\ ps^{-1}$ and $11.8 < \Delta m_s < 14.8\ ps^{-1}$ at the 95% confidence level.

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1 Introduction

The Standard Model allows $B^0 \leftrightarrow \overline{B^0}$ oscillations to occur via second order weak interactions. The frequency of oscillation is determined by the mass differences, Δm, between the mass eigenstates in the B^0 system. The mass difference in the B_s^0 system (Δm_s) and in the B_d^0 system (Δm_d) are proportional to the Cabibbo-Kobayashi-Maskawa (CKM) matrix elements $|V_{ts}|^2$ and $|V_{td}|^2$, respectively. A measurement of Δm_d can in principle be used to extract the CKM matrix element $|V_{td}|$. However, the extraction of $|V_{td}|$ from Δm_d is complicated by a large theoretical uncertainty on the hadronic matrix elements. The complication can be circumvented by taking the ratio of Δm_s and Δm_d. In the ratio, the theoretical uncertainty is reduced to the 5% level [1]. Therefore, a direct measurement of Δm_s, combined with the current measurement of Δm_d, can be translated to a precise value of $|V_{td}|$.

2 Experimental Technique

The results presented in this paper are based on 400,000 hadronic Z^0 decays collected during the 1996-98 run with an average electron beam polarization of 73%. A detailed description of the experimental apparatus can be found elsewhere [2]. The three main ingredients for measuring the time dependent $B_s^0 - \overline{B_s^0}$ oscillations are: (1) determination of the flavor at production (initial state tag), (2) determination of the flavor at the decay vertex (final state tag), and (3) reconstruction of the proper decay time of the B_s^0. Three methods were explored at SLD for studying the B_s^0 oscillations and the methods are referred to as "D_s+Tracks", "Lepton+D", and "Charge Dipole" [3,4]. All three analyses share the common initial state tag as well as the B energy reconstruction algorithms but differ in the event selection, decay length reconstruction, and the final state tag.

Several techniques are used to determine the initial state of the B_s^0. The most powerful method, unique to the SLD, is the polarization tag. In a polarized $Z^0 \to b\overline{b}$ decay, the outgoing quark is produced preferentially along the direction opposite to the spin of the Z^0 boson. Therefore by knowing the helicity of the electron beam and the direction of the jet, the flavor of the primary quark in the jet can be determined. To further enhance the initial state tag, information in the opposite hemisphere (e.g. momentum weighted jet charge, vertex charge, lepton and kaon tracks) is used. Combining all available tags, the average initial state correct tag probability is about 78%.

An ideal mixing analysis requires high efficiency, high B_s^0 purity, clean initial and final state tags, and excellent proper time resolution. In practice, experimental constraints necessitate trade-offs between the four key elements. The "D_s+tracks" is the most exclusive analysis at SLD. The analysis partially reconstructs the B_s^0 by combining a fully reconstructed D_s (via $\phi\pi$ and $K^{*0}K$ modes) with other secondary B decay tracks. By taking the exclusive approach, the analysis is able to achieve a high average B_s^0 purity of 38% and an excellent decay length resolution of $48\mu m$ (60% core resolution) for the B_s^0 events. However, the analysis suffers from low efficiency and only 361 candidates are selected in the final sample. The "Lepton+D" takes a slightly more inclusive approach by selecting events with a partially reconstructed D vertex and a lepton in the same hemi-

sphere. The identified lepton not only enhances the b-hadron fraction but also provides a clean final state tag (final state mistag $< 10\%$). The estimated B energy resolution is comparable to the other two analyses and is about 7% (60% core fraction) and 20% (tail) for the $B_s^0(b \to l)$ events. The "Lepton+D" has 2087 candidates in the final sample with an average B_s^0 purity of about 16%. The most inclusive method and also the analysis with the highest sensitivity at SLD is the "Charge Dipole". The "Charge Dipole" selects events that contain both a secondary and a tertiary vertex. To enhance the B_s^0 fraction, the total track charge (from secondary and tertiary) is required to be zero. The final state tag is based on the dipole value which is defined as the sign of the charge difference weighted by the distance between the secondary and the tertiary vertices. The final state correct tag probability using the dipole method is highly dependent on the decay toplogy and ranges from 53% for $B_s^0 \to D\overline{D}X$ to 91% for $B_s^0 \to D_s X$ decays. A total of 8556 decays is selected in the "Charge Dipole" analysis with a B_s^0 purity of 15%.

3 Results

The study of the B_s^0 oscillations is performed using the amplitude fit method [5]. In this method, the probability for mixing, which is proportional to $1 - cos(\Delta m_s \tau)$, is modified by introducing the amplitude **A** in front of the cosine (same modification for the unmixed expression). The amplitude plot is generated by scanning the Δm_s value over a specified range, and for each Δm_s value, fitting for the parameter **A**. We expect the fitted value of **A** to be consistent with zero when the chosen Δm_s is away from the true value and the amplitude **A** to reach the value 1 near the true Δm_s. If no signal is seen, a 95% C.L. lower limit can be set for frequencies at which $\mathbf{A} + 1.645\sigma_A < 1$. The 95% C.L. sensitivity is defined as the value of Δm_s at which $1.645\sigma_A = 1$.

The amplitude plot for the three SLD analyses combined is shown in Fig. 1. The combined plot takes into account the correlated systematic uncertainties. Furthermore, the samples were selected such as to remove any statistical overlap between analyses. No evidence of a signal is observed up to Δm_s of 25 ps^{-1}. The preliminary SLD results exclude the following values of Δm_s at the 95% C.L.: $\Delta m_s < 7.6$ ps^{-1} and $11.8 < \Delta m_s < 14.8$ ps^{-1}. The SLD combined sensitivity at the 95% C.L. is 13.0 ps^{-1}.

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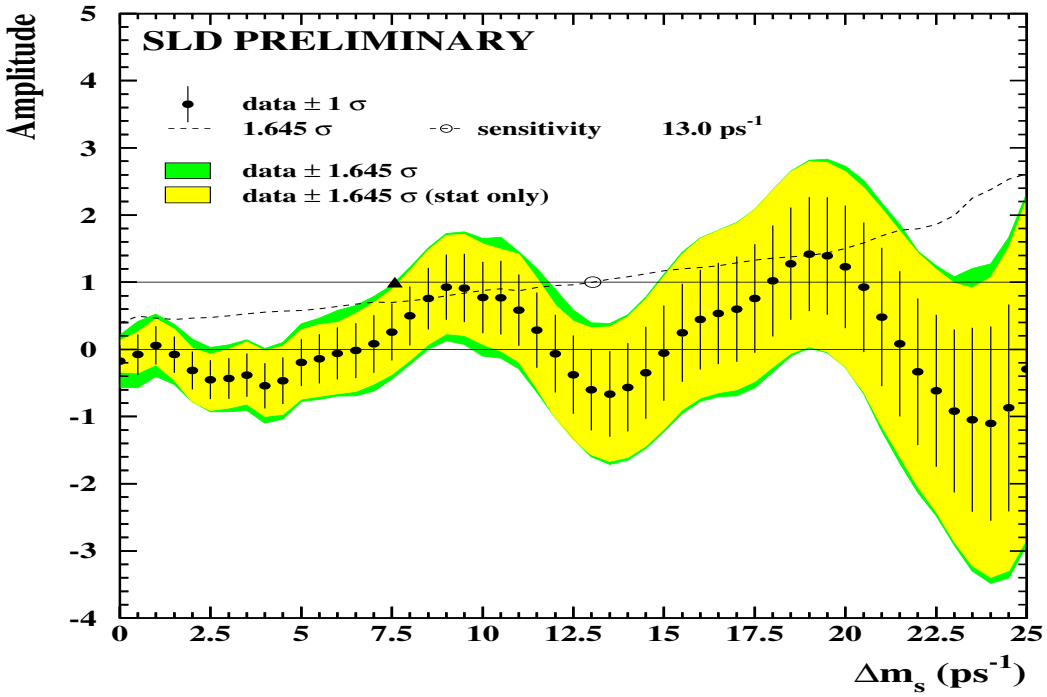

Figure 1: SLD preliminary amplitude plot.

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