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Search for B_s Oscillations at CDF II

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Abstract. We report updated results in the search for B_s flavor oscillations performed at CDF II. We analyze a dataset of approximately 355 pb^{-1} from proton-antiproton collisions at a center-of-mass energy of 1.96 TeV collected in 2002-2004 with the CDF II detector at the Tevatron Collider. Samples of both fully reconstructed $B_s \to D_s(3)\pi$, and partially reconstructed, $B_s \to D_s\ell X$, decays have been studied. A combination of opposite side tagging algorithms has been used to determine the flavor of the B_s mesons at production time. Information about the oscillation frequency of the system, Δm_s, is obtained by performing an amplitude scan of the data, from which an exclusion limit

$$\Delta m_s \geq 8.6\text{ps}^{-1} \text{ (@ 95\% C.L.)},$$

with a measured sensitivity of 13.0 ps^{-1} has been derived; Combination with previously available measurements increases the world exclusion limit from 14.5 ps^{-1} to 16.6 ps^{-1} (@ 95% C.L.).

Keywords: B_s mixing, flavor oscillation, unitary triangle, CKM
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MOTIVATION

The heavy and light mass eigenstates of neutral B mesons do not correspond to their weak interaction eigenstates. Therefore neutral B mesons are known to mix. While the mixing frequency (Δm_d) of the B^0 has been precisely measured, the B_s mixing frequency (Δm_s) has not yet been resolved. From indirect measurements it is predicted to be below 24 ps^{-1} within the Standard Model. The mixing frequencies are related to fundamental Standard Model parameters which are not very well determined so far. Uncertainties related to theoretical input almost cancel by studying the ratio $\frac{\Delta m_s}{\Delta m_d}$. Thus the precision measurements of Δm_s will be a stringent test of the Standard Model.

B_s MIXING ANALYSIS

A mixing analysis involves several steps. First B_s signals have to be reconstructed. Then their proper decay time needs to be measured. Next we need to determine if the B_s has mixed or not between production and decay. The B flavor at decay is obtained from its decay products. To determine the production flavor additional informations from the event are used, involving so-called flavor tagging algorithms. Finally the time-dependent asymmetry can be determined:

$$\mathscr{A}(t) = \frac{N(t)_{mixed} - N(t)_{unmixed}}{N(t)_{mixed} + N(t)_{unmixed}} = \mathscr{D}\cos(\Delta m_s t);$$

where $\mathscr{D}$ is a damping term related to imperfect flavor tagging. It is defined as $1-2*P_w$, with P_w being the probability of a wrong flavor tag.

B_s **Signals.** Both fully reconstructed and semileptonic decay modes have been studied for this analysis:

- $B_s \to D_s\pi$, $(D_s \to \phi\pi,\ D_s \to K^*K\ \&\ D_s \to 3\pi)$
- $B_s \to D_s 3\pi$, $(D_s \to \phi\pi\ \&\ D_s \to K^*K)$
- $B_s \to D_s\ell X$, $(D_s \to \phi\pi,\ D_s \to K^*K\ \&\ D_s \to 3\pi)$

About 1,100 hadronic and 16,800 semileptonic B_s decays have been reconstructed.

Proper Time Measurement & Proper Time Resolution. The proper decay time can be computed out of the proper decay length and the momentum of the B meson, both in the x/y plane.

$$ct = \frac{L_{xy}}{p_T(B)}$$

The bias on the lifetime distribution due to trigger and reconstruction cuts, is adjusted by adding an efficiency function. A correction factor (k factor) to compensate in average for the momentum of the missing particles for the partially reconstructed decay modes has been introduced.
For evaluating the sensitivity and the limit of our mixing analysis a good knowledge of the uncertanties on the proper decay time is needed. We measure these quantities directly from our data by exploiting our high statistics sample of prompt D mesons. We found about $\sigma_{ct} = 30\ \mu$m for the hadronic and $\sigma_{ct} = 50\ \mu$m for the semileptonic decays (k factor not included).

Tagger Calibration. Opposite Side Taggers (OST), using the information from the other B meson in the event to retrieve the flavor of the signal B at production, are supposed to have the same performance independently of the signal B flavor. Thus we perform a B_d mixing analysis for two main purposes. First we like to test our setup of the fitter framework and second we fit at the same time for Δm_d and for the OST dilution. The knowledge of the performance of the taggers is an neccessary ingredient to determine a lower limit on Δm_s. Two different types of OST algorithms have been used in this analysis, one is tagging on the charge of the lepton from a potential semileptonic decay on the opposite side [1], while the second one exploits the correlation between the opposite B flavor and the charge of the opposite (B) jet [2]. A combined tagging performance of

$$\varepsilon\mathscr{D}^2 = 1.55 \pm 0.08\ \text{(stat)} \pm 0.03\ \text{(syst) (semileptonic modes) and}$$
$$\varepsilon\mathscr{D}^2 = 1.55 \pm 0.16\ \text{(stat)} \pm 0.05\ \text{(syst) (hadronic modes)}$$

has been measured, where ε is the tagging efficiency. Our results on Δm_d are compatible to the world average:

$$\Delta m_d = 0.511 \pm 0.020\ \text{(stat)} \pm 0.014\ \text{(syst) ps}^{-1}\ \text{(semileptonic modes) and}$$
$$\Delta m_d = 0.536 \pm 0.028\ \text{(stat)} \pm 0.006\ \text{(syst) ps}^{-1}\ \text{(hadronic modes)}$$

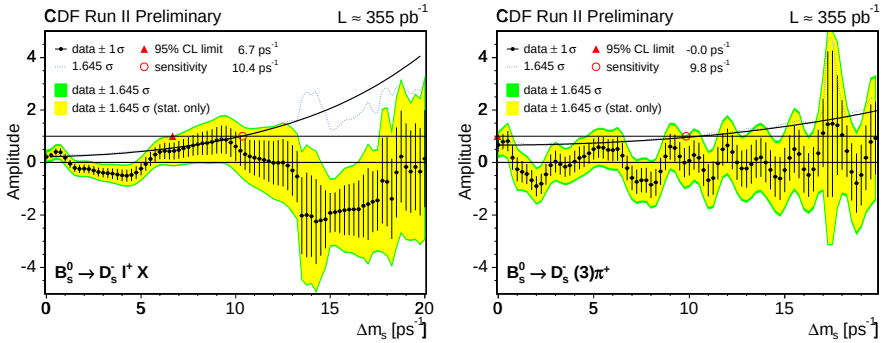

FIGURE 1. Amplitude scan of semileptonic (left) and hadronic (right) B_s decay modes.

RESULTS

In order to determine the limit on Δm_s we use the so-called amplitude scan method [3]. Figure 1 shows the results for the hadronic and semileptonic decay modes respectively. The starting point of the sensitivity curve is given by statistics, tagger performance and S/B, while the slope is determined by the proper time resolution. Thus we gain a lot with the semileptonics at lower Δm_s values, while the hadronic ones take over at high values. The CDF II combined limit is 8.6 ps^{-1}@95% CL and the measured sensitivity 13.0 ps^{-1}. This analysis is completely limited by statistics, all systematic sources are well under control and their contributions are negligible.

SUMMARY & OUTLOOK

Significant progress has been achieved in the B_s mixing analysis compared to our previous results [4]. Further improvements are expected to come soon. One of the most promising ones is the Same Side Tagger. This tagger heavily depends on the signal side. Its performance can not be determined in the B_d system but has to be evaluated using Monte Carlo samples. Additional statistics with almost the same resolution as the fully reconstruced modes can be gained by using the B_s mass sattelite peaks from those modes. A factor two times more data has been already taken and is ready to be analysed. Using additional triggers path is expected to give some improvement as well. Based on the current analysis and expected improvements we are confident to cover the whole Standard Model range for the B_s mixing frequency within Run II.

REFERENCES

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