

## A Combination of $B_s^0 - \bar{B}_s^0$ Oscillations Results from DØ

The DØ Collaboration  
URL <http://www-d0.fnal.gov>

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A combination of  $B_s^0 - \bar{B}_s^0$  oscillations results from DØ based on a  $1 \text{ fb}^{-1}$  data sample was performed. The combined amplitude scan allows the setting of a 95% C.L. limit on the  $B_s^0 - \bar{B}_s^0$  oscillation frequency  $\Delta m_s > 15.0 \text{ ps}^{-1}$  with the corresponding expected limit at  $16.5 \text{ ps}^{-1}$ . The combined likelihood curve has a preferred value of  $\Delta m_s = 19 \text{ ps}^{-1}$ , with a 90% confidence level interval of  $17 < \Delta m_s < 21 \text{ ps}^{-1}$ , assuming Gaussian uncertainties. The probability for a background fluctuation to give a similar dip in the same interval is estimated to be approximately 8%.

*Preliminary Results for Summer 2006 Conferences*

## I. INTRODUCTION

The  $D\bar{O}$  collaboration produced results on  $B_s^0 - \bar{B}_s^0$  oscillations using three  $B_s^0$  decay modes:

- $B_s^0 \rightarrow D_s^- \mu^+ \nu X$ ,  $D_s^- \rightarrow \phi \pi^-$  [1] (Fig. 1).
- $B_s^0 \rightarrow D_s^- \mu^+ \nu X$ ,  $D_s^- \rightarrow K^* K^-$  [2] (Fig. 2).
- $B_s^0 \rightarrow D_s^- e^+ \nu X$ ,  $D_s^- \rightarrow \phi \pi^-$  [3] (Fig. 3).

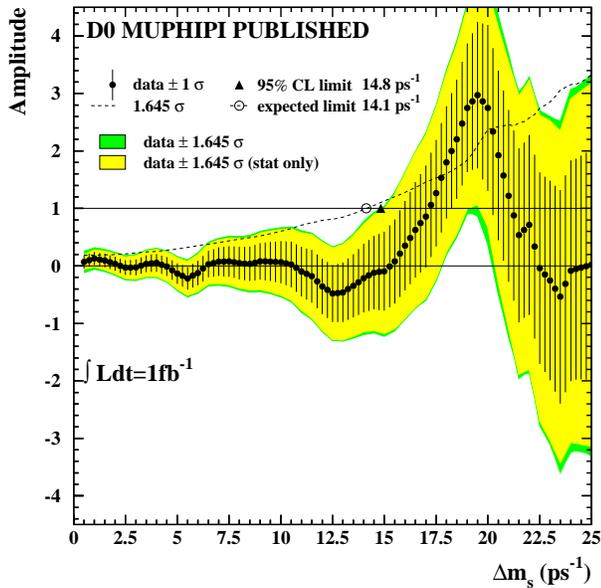


FIG. 1:  $B_s^0$  oscillation amplitude with statistical and systematic errors for  $B_s^0 \rightarrow D_s^- \mu^+ \nu X$ , ( $D_s^- \rightarrow \phi \pi^-$ ) decay mode.

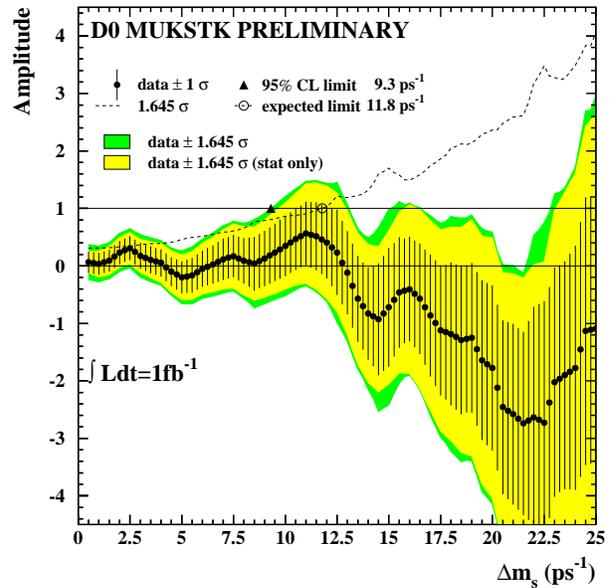


FIG. 2:  $B_s^0$  oscillation amplitude with statistical and systematic errors for  $B_s^0 \rightarrow D_s^- \mu^+ \nu X$ , ( $D_s^- \rightarrow K^* K^-$ ) decay mode.

## II. COMBINATION

The program “combos” [4] developed at LEP to combine the results with statistical and systematic uncertainties with different correlations has been used to perform the combination of different decay modes. Figures 4, 5, 6 show combinations of  $\mu\phi\pi$  and  $\mu K^* K$ ;  $\mu\phi\pi$  and  $e\phi\pi$ ; and all three decay modes. Uncertainties in the following parameters were considered as correlated:

- $Br(B_s \rightarrow X\mu D_s)$ .
- $Br(B_s \rightarrow X D_s D_s)$ .
- Signal decay length resolution for  $\mu\phi\pi$  and  $\mu K^* K$  decay modes.
- $\Delta\Gamma/\Gamma$ .

Although some degree of correlation is expected between the systematic uncertainty due to dilution uncertainty of the different channels, the way this systematic is currently assessed makes it difficult to quantify the correlation. Tests including or excluding this systematic uncertainty in individual channels indicate that ignoring this one correlation leads to negligible differences in the combined results.

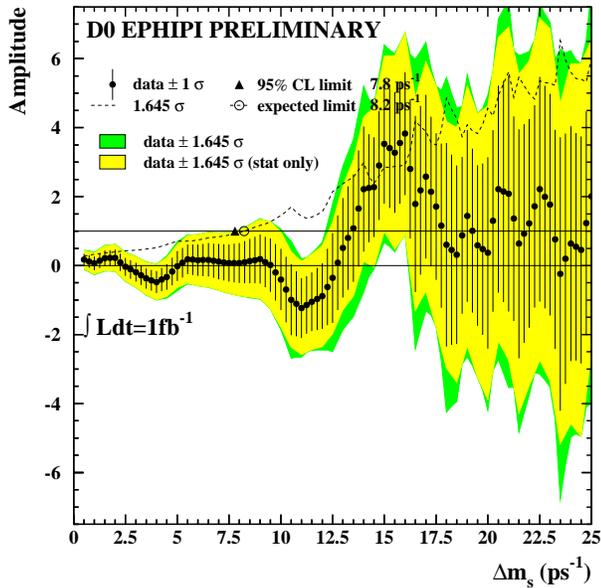


FIG. 3:  $B_s^0$  oscillation amplitude with statistical and systematic errors for  $B_s^0 \rightarrow D_s^- e^+ \nu X$ , ( $D_s^- \rightarrow \phi \pi^-$ ) decay mode.

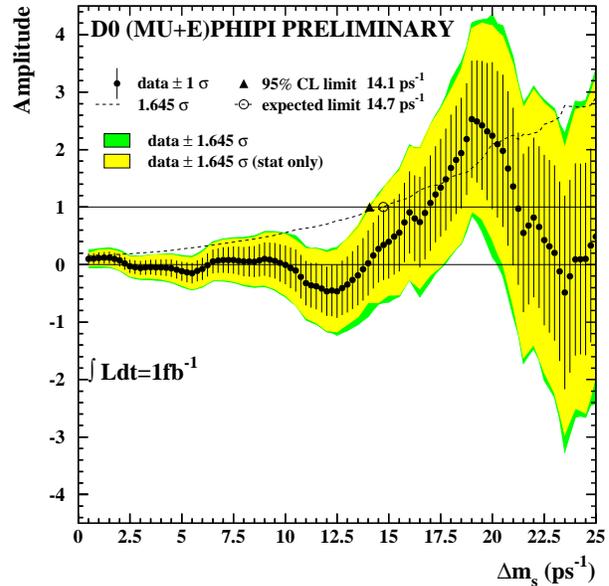


FIG. 4:  $B_s^0$  oscillation amplitude with statistical and systematic errors for  $B_s^0 \rightarrow D_s^- e^+ \nu X$  and  $B_s^0 \rightarrow D_s^- \mu^+ \nu X$  ( $D_s^- \rightarrow \phi \pi^-$ ) decay modes.

### III. LOG LIKELIHOOD SCAN

An amplitude scan can be transformed to a log likelihood scan using the following formula [5, 6]:

$$-\Delta \log(L) = \left( \frac{1}{2} \left( \frac{1 - \bar{A}}{\sigma_A} \right)^2 - \frac{1}{2} \left( \frac{\bar{A}}{\sigma_A} \right)^2 \right) \quad (1)$$

This formula can be tested using the  $B_s^0 \rightarrow D_s^- \mu^+ \nu X$ ,  $D_s^- \rightarrow \phi \pi^-$  decay mode where the log likelihood scan was obtained directly from the fitting procedure. Figures 7 and 8 show the log likelihood scans obtained in two different ways.

A log likelihood scan obtained from the combined amplitude scan (Fig. 6) is shown in Fig. 9. The combined likelihood curve has a preferred value of the oscillation frequency  $\Delta m_s = 19 \text{ ps}^{-1}$ , with a 90% confidence level interval of  $17 < \Delta m_s < 21 \text{ ps}^{-1}$ , assuming Gaussian uncertainties.

In the previous analysis [1], the probability of a background fluctuation to give a minimum of equal or greater depth in this interval was determined to be 5% using ensemble tests. Comparing the change in likelihood at  $\Delta m_s = 19 \text{ ps}^{-1}$  and the likelihood at  $\Delta m_s = \infty$  [6] also yields a 5% expectation for a background fluctuation. For the current combined result, comparison of the change in likelihood between  $\Delta m_s = 19 \text{ ps}^{-1}$  and  $\Delta m_s = \infty$  yields an 8% expectation for a background fluctuation.

### IV. CONCLUSION

The combined amplitude scan allows the setting of a 95% C.L. limit on the  $B_s^0 - \bar{B}_s^0$  oscillation frequency  $\Delta m_s > 15.0 \text{ ps}^{-1}$  with the corresponding expected limit at  $16.5 \text{ ps}^{-1}$ . The combined likelihood curve has a preferred value of  $\Delta m_s = 19 \text{ ps}^{-1}$ , with a 90% confidence level interval of  $17 < \Delta m_s < 21 \text{ ps}^{-1}$ , assuming Gaussian uncertainties. The probability for a background fluctuation to give a similar dip in the same interval is estimated to be approximately 8%.

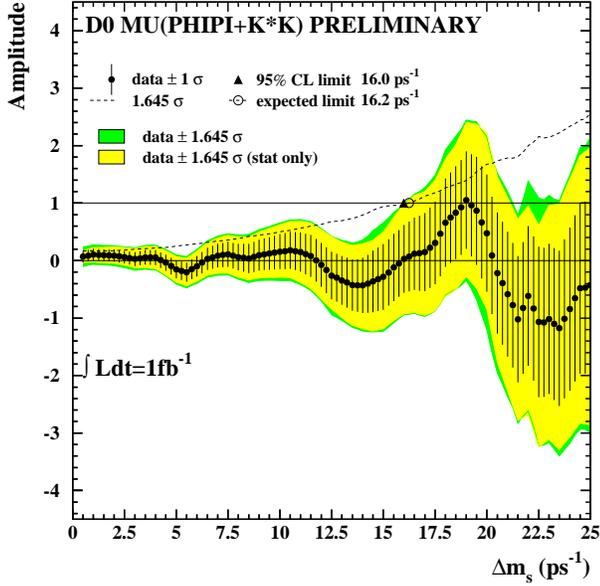


FIG. 5:  $B_s^0$  oscillation amplitude with statistical and systematic errors for  $B_s^0 \rightarrow D_s^- \mu^+ \nu X$  ( $D_s^- \rightarrow \phi \pi^-$  and  $D_s^- \rightarrow K^* K^-$ ) decay modes.

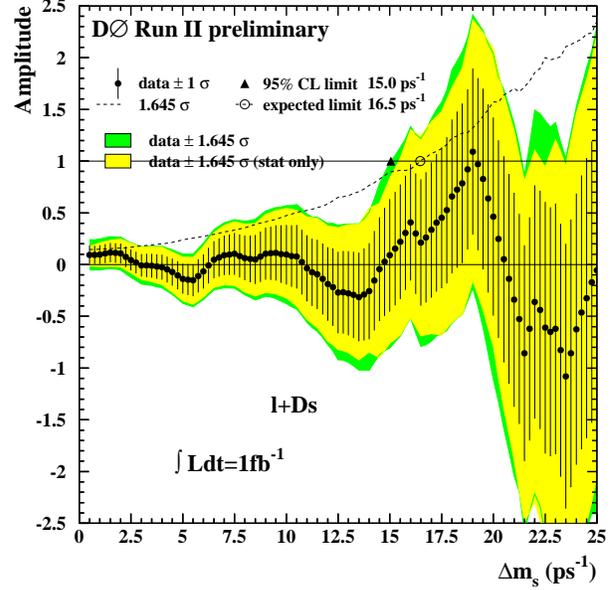


FIG. 6:  $B_s^0$  oscillation amplitude with statistical and systematic errors for  $B_s^0 \rightarrow D_s^- e^+ \nu X$  ( $D_s^- \rightarrow \phi \pi^-$ ) and  $B_s^0 \rightarrow D_s^- \mu^+ \nu X$  ( $D_s^- \rightarrow \phi \pi^-$  and  $D_s^- \rightarrow K^* K^-$ ) decay modes.

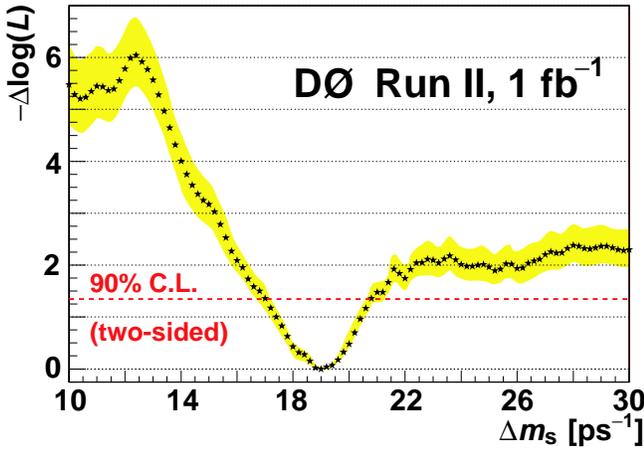


FIG. 7: Log likelihood scan for  $B_s^0 \rightarrow D_s^- \mu^+ \nu X$  ( $D_s^- \rightarrow \phi \pi^-$ ) decay mode obtained from the fitting procedure.

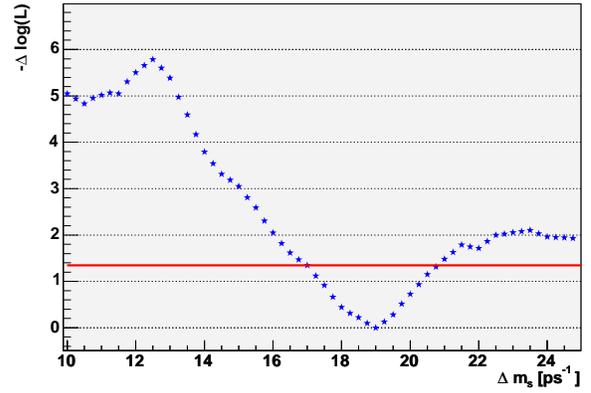


FIG. 8: Log likelihood scan for  $B_s^0 \rightarrow D_s^- \mu^+ \nu X$  ( $D_s^- \rightarrow \phi \pi^-$ ) decay mode obtained from the amplitude scan using the total errors (stat.  $\oplus$  syst.).

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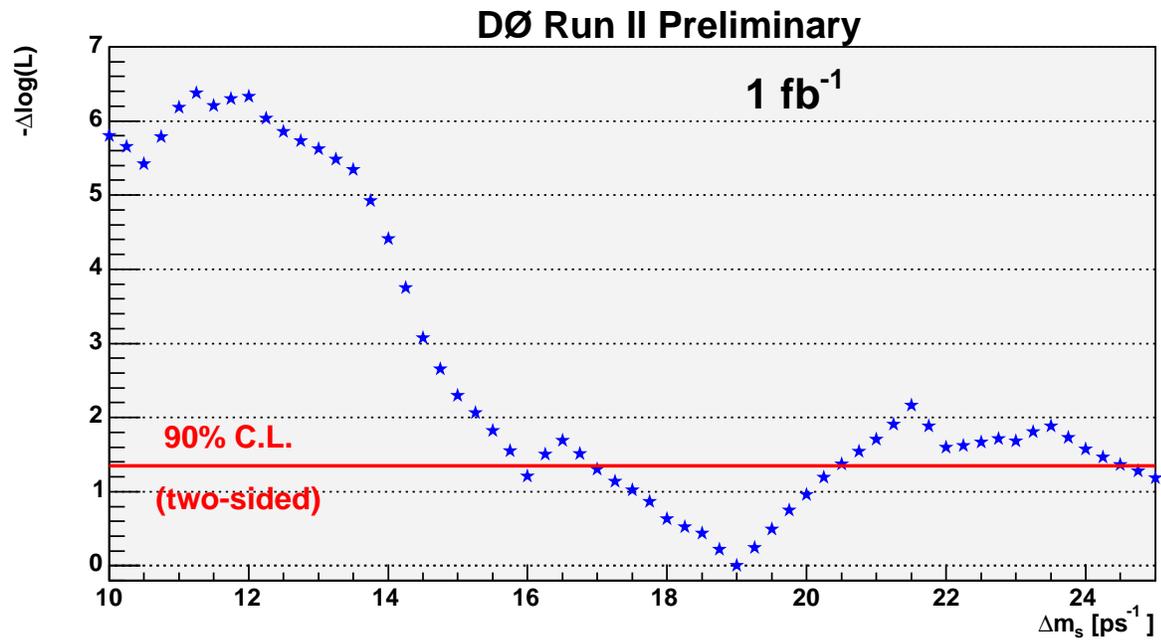


FIG. 9: Log likelihood scan obtained from the combined amplitude scan using the total errors. The horizontal line indicates the 90% C.L. (two-sided) log likelihood difference.

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  - [2] The DØ Collaboration, DØ Note 5172, “ $B_s$  Mixing studies with  $B_s \rightarrow D_s \mu X$  ( $D_s \rightarrow K^* K$ ) Decay using unbinned Fit”.
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  - [4] <http://lepbose.web.cern.ch/LEPBOSC/combo/>.
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  - [6] D. Abbaneo, G. Boix, JHEP **08** (1999) 004.