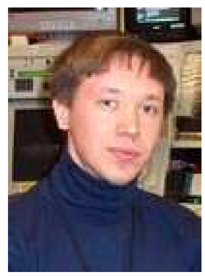
FERMILAB-CONF-05-192-E

B_s^0 MIXING, LIFETIME DIFFERENCE AND RARE DECAYS AT THE TEVATRON

S. BURDIN (for the CDF and DØ collaborations)
Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA



Recent results on B_s^0 mixing, lifetime difference and rare decays obtained by the CDF and DØ collaborations using the data samples collected at the Tevatron Collider in the period 2002 – 2005 are presented.

1 Introduction

Run II at the Tevatron Collider started in 2001. The CDF and DØ experiments successfully collect data since that time. Until March 2005 each experiment recorded data corresponding to an integrated luminosity of about 600 pb^{-1}. The analyses described in this paper are based on samples corresponding to luminosity from 170 to 510 pb^{-1}.

An important and currently unique capability of the Tevatron is production of all species of B hadrons. In particular, B_s meson studies together with the precise B_d measurements at B factories [1] allow the overconstraint of the CKM matrix elements or the measurement of their ratios that are free from some theoretical uncertainties.

2 B_s^0 mixing and lifetime difference

The mass eigenstates of the two neutral $B - \overline{B}$ systems, $B_d^0 - \overline{B_d^0}$ and $B_s^0 - \overline{B_s^0}$, do not coincide with the corresponding flavor states but can be expressed as their linear combinations. The $B_{d(s)}$ mass eigenstates have different masses and probably lifetimes leading to a property of B_d^0 and B_s^0 mesons to change flavor and transform into their antiparticles. This phenomenon is called oscillation or mixing. The oscillation frequency is proportional to the mass difference $\Delta m_{d(s)}$. The B_d^0 oscillation frequency is very well measured with the highest accuracy achieved at the BABAR and BELLE experiments [3]. A comparison of this frequency with the CKM matrix element V_{td} involves hadronic parameters that can be calculated from Lattice QCD and currently

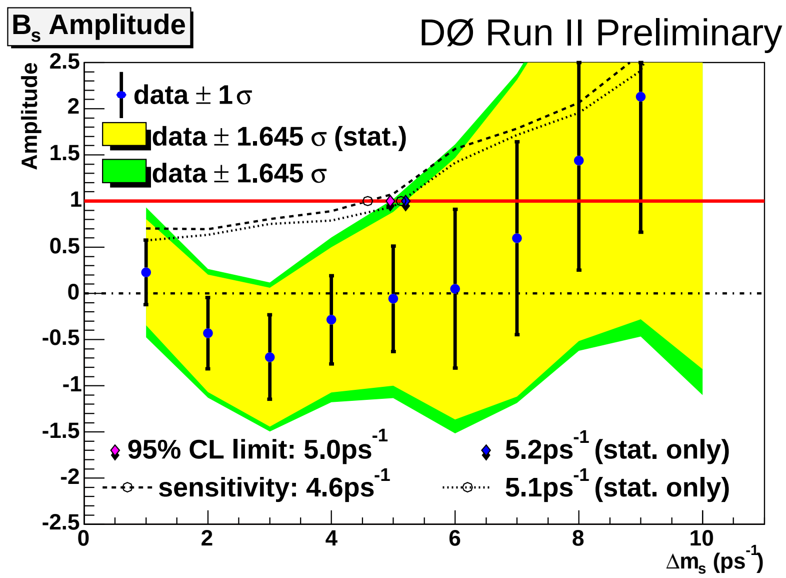


Figure 1: DØ Collaboration: B_s^0 oscillation amplitude with statistical and systematic errors.

have large uncertainties ($\sim 15\%$) [2]. Measurement of the B_s^0 oscillation frequency, which is at least 30 times higher than that of the B_d^0 meson, will allow to determine the $\Delta m_d/\Delta m_s$ ratio which is related to the CKM matrix elements V_{td}/V_{ts} through the hadronic parameters ratio ξ. The ξ parameter is known with much less uncertainty ($\sim 5\%$) [2].

Both CDF and DØ experiments have preliminary results on B_s^0 mixing measurements [4]. The DØ Collaboration used the semileptonic data sample corresponding to an integrated luminosity of 460 pb^{-1}. About 13,300 B_s^0 candidates have been reconstructed in the decay mode $B_s^0 \to D_s^- \mu^+ \nu,\ D_s^- \to \phi\pi^-, \phi \to K^+K^-$. The opposite-side tagging technique was used to determine the initial state flavor of the B_s^0 meson. A muon on the opposite side was always required. The muon charge information was combined with the muon transverse momenta (absolute and relative to the jet axis) and the opposite side secondary vertex charge in order to improve the tagging. The mistag rate has been determined from $\mu^+\overline{D^0}$ (mainly B_u decays) and $\mu^+ D^{*-}$ (mainly B_d^0 decays) samples to be equal to $(26.6 \pm 1.5)\%$ for B_u and $(27.6 \pm 2.1)\%$ for B_d^0 mesons. No B_s^0 oscillations were observed in the analysis and an amplitude scan [5] was used to determine a limit on the B_s^0 oscillation frequency. Figure 1 shows the result of this scan which gave the 95% C.L. limit of 5.0 ps^{-1} and sensitivity of 4.6 ps^{-1}.

The CDF and DØ experiments used the $B_s^0 \to J/\psi\phi$ decays with no tagging requirement to determine the lifetime difference in the $B_s^0 - \overline{B_s^0}$ system [6,7]. The DØ reconstructed 483 ± 32 $\underline{B_s^0} \to J/\psi(\to \mu^+\mu^-)\phi(\to K^+K^-)$ candidates in 450 pb^{-1}. The average lifetime of the $B_s^0 - \overline{B_s^0}$ system was determined to be $\overline{\tau}_s = 1.39^{+0.15}_{-0.19}$ ps and the relative width difference $\Delta\Gamma_s/\overline{\Gamma}_s \equiv (\Gamma_{Ls} - \Gamma_{Hs})/\overline{\Gamma}_s = 0.21^{+0.33}_{-0.45}$. The constraint from the world average (WA) of the B_s^0 lifetime measurements using semileptonic decays allows to decrease the relative width difference uncertainty, $\Delta\Gamma_s/\overline{\Gamma}_s = 0.23^{+0.16}_{-0.17}$. This result is in agreement with the CDF result [6] $\Delta\Gamma_s/\overline{\Gamma}_s = 0.65^{+0.25}_{-0.33} \pm 0.01$ and theoretical predictions [8] (see Fig. 2).

The precisions of the B_s^0 mixing and lifetime difference measurements are statistically limited for both detectors and one can expect significant improvements in the near future.

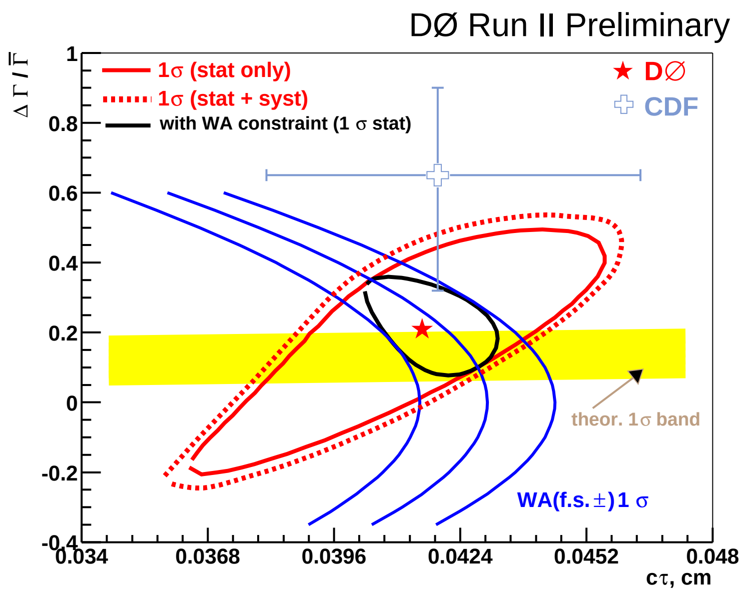


Figure 2: The 1-σ contour for the lifetime difference in the $B_s^0 - \overline{B_s^0}$ system from the fit to the DØ data, compared to a 1-σ band for the World Average (WA) measurement based on semileptonic decays, $c\tau_{WA} = 430.0 \pm 15.0$ μm. A simultaneous fit to the data and WA gives a 1-σ range $c\tau_s = 418^{+14}_{-15}$ μm and $\Delta\Gamma_s/\overline{\Gamma}_s = 0.23^{+0.16}_{-0.17}$ (stat.+syst.).

3 Rare decays

Large B and D samples collected with the CDF and DØ detectors allow the search for and observation of rare beauty and charm decays.

The CDF Collaboration used a 180 pb^{-1} data sample collected with the displaced track trigger for observation of the $b \to sss$ decays of B_s^0 mesons: 12 $B_s^0 \to \phi\phi$ candidate events have been observed with 1.95 background events expected [9]. This gives the branching ratio $BR(B_s^0 \to \phi\phi) = (1.4^{+0.6}_{-0.5}(stat.) \pm 0.6(syst.)) \times 10^{-5}$ that is at the lower limit of the theoretical expectation in the Standard Model: $BR(B_s^0 \to \phi\phi) = (2.5 - 5.0) \times 10^{-5}$.

The large coverage of the muon system in the DØ detector helped the observation of 18.5±5.5 $B_s^0 \to \mu D_{s1}(\to D^{*\pm} K_s^0)X$ events in a 483 pb^{-1} data sample[10] (see Fig. 3). It is a first observation of this B_s^0 decay mode.

Rare B_s^0 flavor-changing neutral current (FCNC) decays attract close attention from both theoretical and experimental sides. B_s^0 dimuon decays represent particular interest. The CDF and DØ collaborations already achieved the sensitivity that is enough to constrain some theoretical models predicting enhancement for such decays. Both CDF and DØ have results on the decay $B_s^0 \to \mu^+\mu^-$ [11]. CDF constrained the branching ratio $BR(B_s^0 \to \mu^+\mu^-) < 7.5 \times 10^{-7}$ at 95% C.L. using a 171 pb^{-1} data sample and an update of the similar analysis from the DØ detector sets the upper limit $BR(B_s^0 \to \mu^+\mu^-) < 3.7 \times 10^{-7}$ (95% C.L.) with an integrated luminosity of 300 pb^{-1}.

Another FCNC decay, $B_s^0 \to \mu^+\mu^-\phi$ was searched for with the DØ detector [12]. The expected sensitivity at 95% C.L. has been determined: $\langle BR(B_s^0 \to \mu^+\mu^-\phi)\rangle = 1.2 \times 10^{-5}$. It can be compared with the upper limit $BR(B_s^0 \to \mu^+\mu^-\phi) < 6.7 \times 10^{-5}$ set at 95% C.L. with the CDF detector in Run I [13].

The DØ Collaboration [14] searched for the FCNC charm decays $c \to u\mu^+\mu^-$ using the data sample corresponding to 508 pb^{-1}. The first step is an observation of the $D_s^+ \to \pi^+\phi(\to \mu^+\mu^-)$ decay (see Fig. 4) which will be used as a normalization process in search for events where the $\mu^+\mu^-$ system is not produced through a resonance.

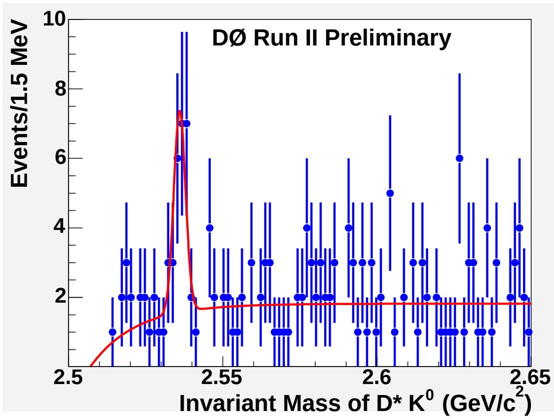


Figure 3: DØ Collaboration: Invariant mass of $D^*K_s^0$. Shown is the result of the fit of the $D^*K_s^0$ mass with a Gaussian function plus an exponential function with a threshold cut-off at $M(D^*) + M(K_s^0)$ to model the background. The total number of candidates in the peak is 18.5 ± 5.5.

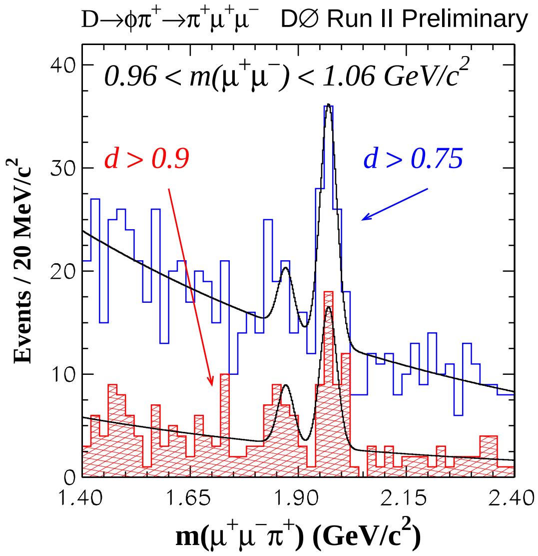


Figure 4: DØ Collaboration: The $m(\pi^+\mu^+\mu^-)$ mass spectrum for events with the likelihood ratio requirement $d > 0.75$ (empty) and $d > 0.9$ (hatched). The results of binned likelihood fits to the distributions including contributions for D_s^+, D^+, and combinatoric background are overlaid on the histograms.

References

1. BABAR, http://www.slac.stanford.edu/BFROOT/;
   BELLE, http://belle.kek.jp/.
2. M. Wingate, Status of Lattice Flavor Physics (talk at Lattice2004), arXiv:hep-lat/0410008.
   C. Bernard's presentation at CKM2005,
   http://ckm2005.ucsd.edu/agenda/wed1/bernard.pdf.
3. Heavy Flavor Averaging Group, Averages of b-hadron Properties as of Summer 2004, arXiv:hep-ex/0412073.
4. The CDF B_s^0 mixing result is described in the F. Bedeschi's paper of these proceedings and at http://www-cdf.fnal.gov/physics/new/bottom/050310.bsmix-combined/.
   The DØ B_s^0 mixing analysis is available at
   http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/B/B20/.
5. H. G. Moser and A. Roussarie, *Nucl. Instrum. Methods* A**384**, 491 (1997).
6. CDF Collaboration: D. Acosta *et al.*, *Phys. Rev. Lett.* **94** (2005) 101803.
7. DØ Collaboration: http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/B/B17/.
8. A. Lenz, arXiv:hep-ph/0412007.
9. CDF Collaboration: D. Acosta *et al.*, First Evidence for $B_s \to \phi\phi$ Decay and Measurements of Branching Ratio and A_{CP} for $B^+ \to \phi K^+$, arXiv:hep-ex/0502044.
10. DØ Collaboration: http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/B/B19/.
11. CDF collaboration: D. Acosta *et al.*, *Phys. Rev. Lett.* **93** (2004) 032001.
    DØ Collaboration: V. M. Abazov *et al.*, *Phys. Rev. Lett.* **94** (2005) 071802,
    DØ update: http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/B/B21/.
12. DØ Collaboration: http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/B/B18/.
13. CDF Collaboration: D. Acosta *et al.*, *Phys. Rev.* D65 (2002) 111101.
14. DØ Collaboration: http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/B/B22/.