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Lifetimes and Lifetime Ratios of b Hadrons Obtained at DØ

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On behalf of the DØ Collaboration

The DØ collaboration has measured the following lifetimes and ratios of lifetimes of b hadrons in both semileptonic and hadronic decay channels: The lifetime of ${B_s}^0$, based on flavor-specific semileptonic decays, provides the best single measurement of 1.420±0.043 (stat)± 0.057 (syst) ps; a new ratio of B^+/B^0 meson lifetimes of 1.080± 0.016 (stat) ± 0.014 (syst) is the most precise measurement of this quantity at the Tevatron; a ratio of ${\Lambda_b}^0/{B_d}^0$ lifetimes of 0.87 +0.17/-0.14 (stat) ±0.03 (syst), based on the first published measurement of the lifetime of ${\Lambda_b}^0$ in a fully reconstructed exclusive channel; and the lifetime of ${B_c}^+$ of 0.45 +0.12/-0.10 (stat) ±0.12 (syst) ps, which is based on the first analysis of data containing a ${B_c}^+$ signal with a significance in excess of five standard deviations.

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Hadrons containing a b quark, such as B_d, B_s, B_c mesons and Λ_b baryons, are produced at Tevatron energies at sufficiently high transverse momenta (p_T) to have relatively large boosts, which helps greatly in measuring their lifetimes. With Heavy-Quark Effective Field Theory predicting a clear hierarchy of hadronic lifetimes in the decays of b quarks, it is important to measure with precision the lifetimes of these hadrons. Absolute lifetimes are of major interest, but ratios are even more valuable to compare with theory, as many sources of systematic uncertainty tend to cancel when any two lifetimes, especially based on similar topologies, are measured in one experiment (or calculated at NLO to some given order of corrections in $\frac{1}{M_b}$).

In what follows, we discuss: (i) Abstract 196, which provides a new (and best) measurement of the lifetime of the B_s^0 meson, based on 400 events/pb $\mu^+\nu D_s^- X$ data (with $D_s^- \to \phi\pi^- \to K^+K^-\pi^-$), (ii) Abstract 195, reporting the ratio of B^+/B^0 lifetimes, based on recently published [PRL **94**, 182001 (2005)] reconstructed semileptonic decays in $\mu^+\nu D^0 X$ and $\mu^+\nu D^{*-}X$ states (with $D^{*-} \to D^0\pi^- \to K^+\pi^-\pi^-$), (iii) Abstract 201, concerning a measurement of lifetimes of Λ_b^0, B_s^0 and B_d^0 in the exclusive modes $\Lambda_b^0 \to J/\psi(\mu^+\mu^-)\Lambda^0(p\pi^-), B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$, and $B_d^0 \to J/\psi(\mu^+\mu^-)K^{*0}(K^+\pi^-)$ and $B_d^0 \to J/\psi(\mu^+\mu^-)K_S^0(\pi^+\pi^-)$ (The first measurement of the lifetime of Λ_b in a fully reconstructed channel, and of B_s^0, is available in PRL **94**, 102001 (2005), and in PRL **94**, 042001 (2005), respectively), and (iv) Abstract 199, dealing with the lifetime and mass of $B_c^+ \to J/\psi(\mu^+\mu^-)\mu^+\nu$ for reconstructed $\mu^+\mu^-\mu^+$ systems.

Tracking at DØ is performed using silicon microstrips and scintillating fibers in a central field of ≈2T. The muon system, which is an important element of these analyses, has drift tubes and scintillation trigger counters, with good coverage for pseudorapidity $|\eta| < 2$. Lifetimes are measured by reconstructing primary and decay vertexes of b-hadron candidates, and calculating a proper decay length λ in the transverse plane, based on a signed transverse decay length L_{xy}. For semileptonic channels, we define an effective decay length "λ" for only the observed parts of the parent hadron, and correct this on a statistical basis for total momentum.

For hadronic modes, we use dimuon J/ψ events, and then search for a long-lived neutral decaying to two oppositely charged tracks that point to the vertex of the J/ψ: $\Lambda_b^0 \to J/\psi(\mu^+\mu^-)\Lambda^0(p\pi^-)$ or $B_d^0 \to J/\psi(\mu^+\mu^-)K_S^0(\pi^+\pi^-)$, or, for two tracks that originate from the J/ψ vertex: for $B_s^0 \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$, or $B_d^0 \to J/\psi(\mu^+\mu^-)K^{*0}(K^+\pi^-)$.

For semileptonic modes, there is no specific muon selection at the trigger level, but offline there is a requirement on muon momentum of $p_T > 2$ GeV/c and $p > 3$ GeV/c (with both limits depending on the analysis). The ${B_c}^+ \to J/\psi\mu^+\nu X$ channel uses dimuon decays of the J/ψ and a third muon at the decay vertex, to fit the $\mu^+\mu^-\mu^+$ system to a mass and lifetime. The ${B_d}^0 \to \mu^+D^{*-}(D^0\pi^-)X$ and $B^+ \to \mu^+D^0(K^+\pi^-)X$ are used in the direct measurement of the ratio of lifetimes of ${B_d}^0$ and B^+. The ${B_s}^0 \to {D_s}^-\mu^+\nu X$ channel, where ${D_s}^- \to \phi(K^+K^-)\pi^-$, is used to extract the ${B_s}^0$ lifetime from a pseudo-proper decay length "λ" that reflects only the observed decay products of the signal, and is smeared with a "K factor" distribution based on Monte Carlo that accounts for the full momentum of the ${B_s}^0$.

The mass distribution of $\phi(K^+K^-)\pi^-$ systems in semileptonic $\mu^+\phi(K^+K^-)\pi^-$ channels (not shown) displays a clear signal at the D_s^- mass value (as well as a smaller peak at the mass of the D^-). Requiring the significance on "λ" in each event to exceed 5 standard deviations, leads to the result shown in the left pane of Fig. 1. The darker points correspond to "correct" ${D_s}^-\mu^+$ charge combinations, and crosses to wrong combinations, where no resonances are expected. The smooth curve is a fit to right-sign combinations. (Both ${D_s}^-\mu^+$ and their charge conjugate pairs are used in the analysis.) The distribution in "λ" for ${B_s}^0$ signal and a superimposed fit (dashed) using all events, with combinatorial background represented by the dotted curve, are shown in the right pane of Fig. 1. The results of such fits for the semileptonic and $B_s \rightarrow J/\psi\phi$ hadronic modes yield, respectively, the lifetimes 1.420±0.043 (stat) ±0.057 (syst) ps and 1.444 +0.10/-0.09 (stat) ±0.20 (syst) ps. Both agree with previous world averages, and our semileptonic result for ${B_s}^0$ is currently most precise at 1.420 ± 0.071 ps.

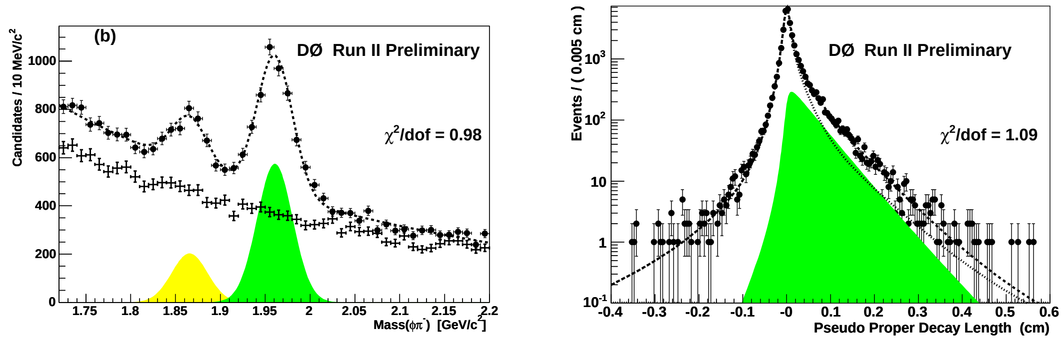

Figure 1: The left pane shows the distribution in the mass of $\phi(K^+K^-)\pi^-$ systems in semileptonic $\mu^+\phi(K^+K^-)\pi^-$ channels when the significance on "λ" in each event is required to exceed 5 standard deviations. A large and clean signal is seen at the ${D_s}^-$ mass value (as well as a smaller peak at the mass of the D^-). The right pane shows the distribution in "λ" for ${B_s}^0$ signal and a superimposed fit (dashed), with combinatorial background represented by the dotted curve.

We have developed a new method for extracting the ratio of $B^+/{B_d}^0$. This is established through: (i) fitting to the number of $D^*\mu$ candidates ($\approx$ 85% contribution from B^0) as a function of visible proper decay length "λ", (ii) fitting to the number of $D^0\mu$ candidates ($\approx$ 83% from B^+) as a function of "λ", (iii) finding the ratio of the numbers as a function of "λ", (iv) if this ratio is independent of "λ", the lifetimes are equal, and any difference manifests itself as a slope in this ratio vs "λ". Clearly, this new DØ technique can be used in other measurements of ratios. The left pane of Fig. 2 displays the ratio as a function of "λ" for our large and clean sample of $\mu^+\nu D^0X$ and $\mu^+\nu D^{*-}X$ events, and indicates from the fit that there is a significant difference in the lifetimes observed from the extracted ratio of 1.080± 0.016 (stat) ± 0.014 (syst).

The distribution in the mass of $J/\psi(\mu^+\mu^-)\Lambda^0(p\pi^-)$ combinations (not shown) has a clear signal at the mass of Λ_b, and the right pane of Fig. 2 displays the distribution of the events in that peak (Λ_b candidates) as a function of λ. Superposed is the fit to the lifetime for signal and background. Finally, in Fig. 3, we present the distributions in mass and effective "λ" of reconstructed $\mu^+\mu^-\mu^+$ systems for B_c^+ candidates, with superimposed fits to signal and background. The excess above background corresponds to 95 ± 17 B_c^+ events.

In summary, DØ has new and many emerging results in the area of b-hadronic lifetimes. The ${B_s}^0$ lifetime extracted from the semileptonic mode is the best available measurement. The measurement of the Λ_b lifetime in the hadronic mode is best thus far for a fully reconstructed channel. These results provide many significant contributions to world averages of b-hadron lifetimes and their ratios. Unfortunately, all these measurements are consistent with HQET and with present

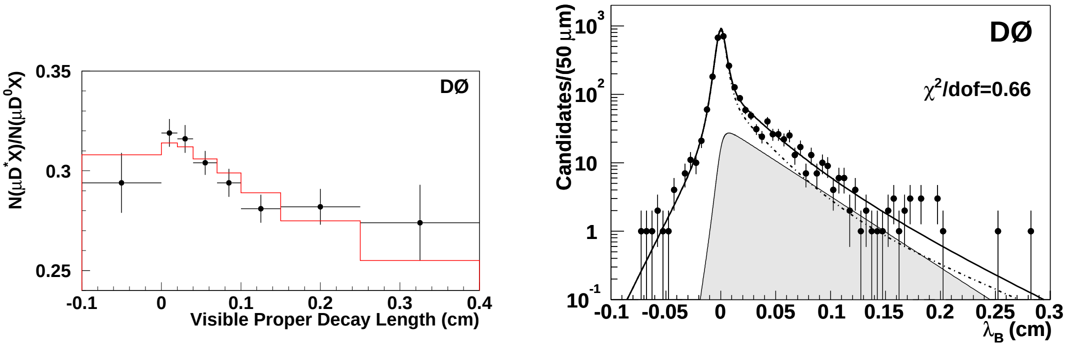

Figure 2: Left pane shows the ratio of $B^+/B_d{}^0$ as a function of "λ". Right pane shows the distribution of events in the mass region of Λ_b candidates as a function of λ. Superposed in both figures are likelihood fits to the data that provide, respectively, the ratio of $B^+/B_d{}^0$ and the Λ_b lifetimes.

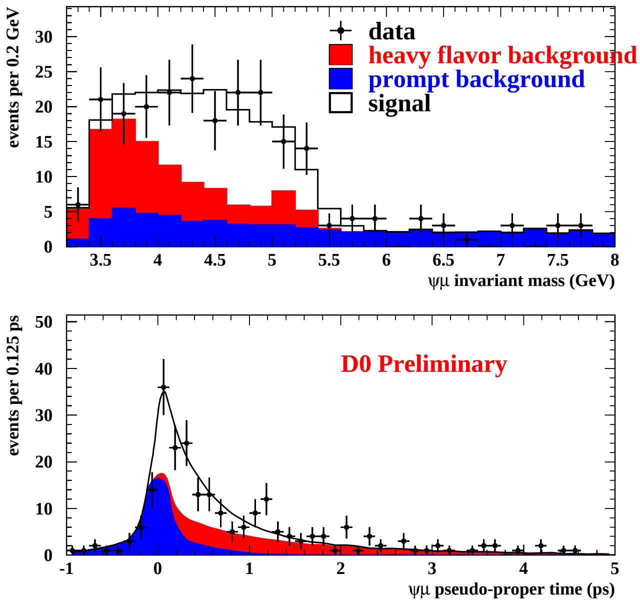

Figure 3: Distributions in mass and effective "λ" of reconstructed $\mu^+\mu^-\mu^+$ systems for B_c^+ candidates. The superimposed likelihood fits to the data provide the extracted mass and lifetime of the B_c^+.

world averages, and so DØ will have to work harder to search for any deviations from the Standard Model.

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