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MEASUREMENT OF THE B^+ AND B^0 LIFETIMES AT CDF

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Two measurements of the lifetime of neutral and charged B mesons in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV by the CDF experiment are presented. The first relies on the study of exclusive decays of the type $B \to \psi K$, the second on semileptonic decays of a B meson into a D^* or a D. The combined results are $\tau(B^+) = 1.62 \pm 0.09$ ps , $\tau(B^0) = 1.60 \pm 0.09$ ps and $\tau(B^+)/\tau(B^0) = 1.00 \pm 0.07$.

1 Introduction

The measurement of the lifetimes of B mesons is important to probe B decay mechanisms beyond the spectator model. Theoretical models predict the lifetimes of the neutral and charged B meson to be equal within 5-10 %. This is in sharp contrast to the D system where $\tau(D^+) \approx 2.5\tau(D^0)$. In this paper, we report two complementary measurements of the B meson lifetimes by the CDF experiment.[1] The first measurement, using fully reconstructed B decays, is based on a sample of 19.3 pb^{-1} collected in 1992-1993 (run 1a) and 48.4 pb^{-1} from the present data taking (run 1b). The second measurement with partially reconstructed B semileptonic decay uses the run 1a sample.

2 B lifetimes from the exclusive decays

The large cross section for B production at the Tevatron allows CDF to measure the B lifetime in the following exclusive decay modes: $B^+ \to J/\psi K^+$, $B^+ \to J/\psi K^{*+}(892)$, $B^+ \to \psi(2S)K^+$, $B^+ \to \psi(2S)K^{*+}(892)$, $B^0 \to J/\psi K^0_S$, $B^0 \to J/\psi K^{*0}(892)$, $B^0 \to \psi(2S)K^0_S$, $B^0 \to \psi(2S)K^{*0}(892)$. Results of a similar analysis on a smaller data sample have been already published.[2] Herein, an update of the measurement with a sample of 67.7 pb^{-1} is presented. We reconstruct $J/\psi \to \mu^+\mu^-$ and $\psi(2S) \to J/\psi\pi^+\pi^-$. Two track combinations are used to find the K^{*0} and K^0_S candidates. The K^+, K^0_S and $K^*(892)$ candidates must have $p_T > 1.25$ GeV/c. All tracks are vertex constrained for the B reconstruction, except those from a K^0_S. The J/ψ and $\psi(2S)$ are mass constrained to their world average values.[3] We require the B candidates to have transverse momentum $p_T(B) > 6$ GeV/c and in case of multiple candidates in the same event we keep the one with the best χ^2 from the constrained fit.

For the lifetimes analysis we define the signal region to be within 30 MeV/c^2 of the world average B mass while the sideband regions are from 60 to 120 MeV/c^2. The decay length L_{xy} is defined as the displacement in the transverse plane of the secondary from the primary vertex projected along the direction of $p_T(B)$. Then $c\tau = L_{xy}m(B)/p_T(B)$ where $m(B)$ is the B mass. The B^+ and B^0 proper decay length distributions for the signal and sideband region are shown in Figures 1 and 2. The superimposed curves are the results of separate unbinned likelihood fits. We fit the signal region with an exponential convoluted with a Gaussian resolution function. The background is modeled with a Gaussian plus asymmetric exponential tails. The simultaneous fit to the signal and the background distributions yield 524 ± 29 charged B and 285 ± 21 neutral B mesons. The result of the fits to the $c\tau$ distributions are $c\tau^+$=503 ± 26 μm and $c\tau^0$=492 ± 34 μm. Residual misalignment, trigger bias and beam stability give the dominant contributions to the systematic uncertainty but cancel in the measurement of τ^+/τ^0. The results from the exclusive decays are τ^+=$1.68 \pm 0.09 \pm 0.06$ ps, τ^0=$1.64 \pm 0.11 \pm 0.06$ ps and τ^+/τ^0=$1.02 \pm 0.09 \pm 0.01$ where the first is the statistical and the second is the systematic uncertainty.

3 B lifetimes from semileptonic decays

Another approach to measure the B lifetime is to use the large inclusive lepton sample and to search for charm decays in a cone around the trigger lepton. We consider four decays: $D^0 \to K^+\pi^-$ and $D^{*+} \to D^0\pi^+$ with $D^0 \to K^+\pi^-$,$D^0 \to K^+\pi^-\pi^+\pi^-$ or $D^0 \to K^+\pi^-\pi^0$. A correlation between the sign of the lepton and that of the kaon is present if the D originates from a B decay. A clear $D^{*+} \to D^0\pi^+$ with $D^0 \to K^-\pi^+$ signal is seen in the "right sign" distribution shown in fig. 3. We find 1213, 202, 364 and 694 events in the signal region of the four modes while the estimated background fractions are 0.54 ± 0.03, 0.11 ± 0.03, 0.19 ± 0.03 and 0.40 ± 0.03.

The secondary vertex in semileptonic decays is obtained by intersecting the trajectories of the ℓ^- and the D candidate. The decay length L_{xy} is projected along the direction of $p_T(\ell^- D)$. We calculate the $\beta\gamma$ factor

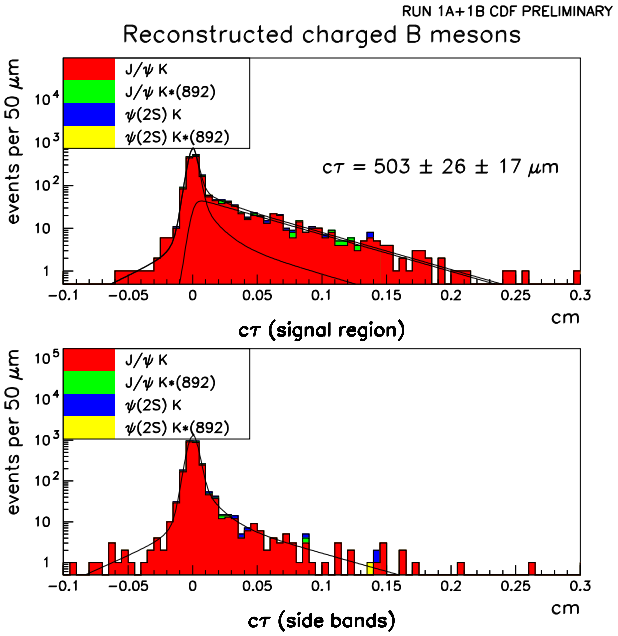

Figure 1: The proper decay length ($c\tau$) distributions for the fully reconstructed charged B sample.

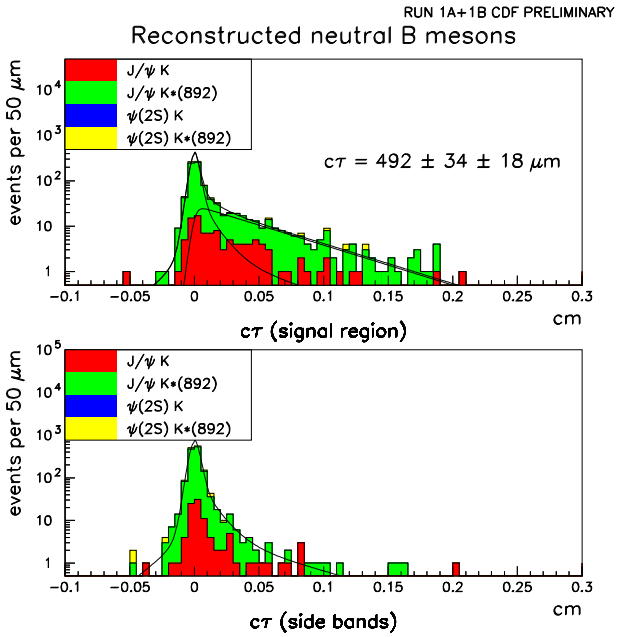

Figure 2: The proper decay length ($c\tau$) distributions for the fully reconstructed neutral B sample.

for the $c\tau$ determination using $p_T(\ell^- D)$ and use Monte Carlo to account for the missing neutrino.

Most of the $\ell^- D^{*+}$ and $\ell^- D^0$ combinations arise from $\bar{B}^0$ and $\bar{B}^-$ decays respectively. Nonetheless, the relative amount of neutral and charged B mesons in each of the samples due to D^{**}, $D^*\pi$ non-resonant and detector inefficiencies is modeled with Monte Carlo. The dependence of the sample composition on the B lifetimes is taken into account in the lifetime fits. Our final results are $\tau^- = 1.51 \pm 0.12 \pm 0.08$ ps, $\tau^0 = 1.57 \pm 0.08 \pm 0.07$ ps, and $\tau^-/\tau^0 = 0.96 \pm 0.10 \pm 0.05$ where the first is the statistical and the second is the systematic uncertainty. Major sources of systematic error are the sample composition, the shape of the background, residual SVX misalignment and the stability of the beam. Some of these uncertainties cancel in the determination of τ^-/τ^0.

4 Conclusions

In order to combine these results we have to account for the correlation between the exclusive and semileptonic lifetime measurements due to residual misalignment and beam stability. The final CDF averages are: $\tau^- = 1.62 \pm 0.09$ ps, $\tau^0 = 1.60 \pm 0.09$ ps, and $\tau^-/\tau^0 = 1.00 \pm 0.07$.

In conclusion the lifetime of neutral and charged mesons appear to be equal within 7 %. These results are in good agreement with the LEP measurement presented by Gunther-Moser.[4] The error in our measurement is still dominated by the statistical uncertainty and will improve by the end of run 1b.

Acknowledgments

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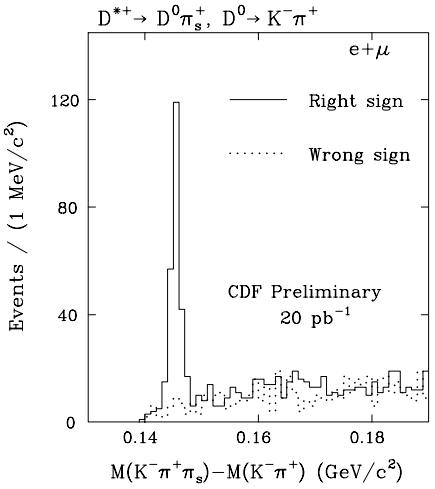

Figure 3: The $\delta m = m(K^-\pi^+\pi^+) - m(K^-\pi^+)$ distribution.