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Measurement of the B^+ and B^0 Meson Lifetimes Using Exclusive $B \to \psi K$ Decays at CDF

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ABSTRACT

We present recent CDF measurements of τ^+, τ^0, and τ^+/τ^0 using exclusive $B \to \psi K$ decays, where $B = B^+$ or B^0, $\psi = J/\psi$ or $\psi(2S)$, and $K = K^+$, $K^*(892)^0$, K^0_S, or $K^*(892)^+$. The precision of these results is less than 10% and is nearly identical to that previously reported at LEP.

1. Introduction

During the 1992-95 Tevatron collider Run I, the Collider Detector at Fermilab (CDF)[1] has so far collected a data sample of $\overline{p}p$ collisions at $\sqrt{s} = 1.8$ TeV with an integrated luminosity of > 105 pb^{-1}. This was split into two separate data-taking runs: Run 1a (~ 20 pb^{-1}) and the present Run 1b (> 85 pb^{-1}). Data-taking is planned to continue until February, 1996 and a total sample of at least 120 pb^{-1} is expected. This data sample, in combination with improvements to the data acquisition system, the muon coverage, and most importantly, the installation of the CDF SVX silicon vertex detector,[2] has allowed precision measurements of the B^+ and B^0 lifetimes. In this paper we report on recent CDF measurements of τ^+, τ^0, and τ^+/τ^0 using exclusive $B \to \psi K$ decays.

2. Lifetime Analysis

Increasingly precise measurements of the B^+ and B^0 lifetimes are important for testing the predicted B hadron lifetime hierarchy and to measure the relative contributions from non-spectator decays. Only small lifetime differences are expected between the B^+ and B^0 mesons ($\sim 5\%$[3]) and experiments are now approaching this precision.

At CDF, the measurement of the charged and neutral B meson lifetimes has been performed using fully reconstructed B decays in the following modes[4]:

$$\begin{array}{lllllll}
B^+ & \to J/\psi K^+ & \to \mu^+\mu^- K^+; & B^+ & \to J/\psi K^*(892)^+ & \to \mu^+\mu^- K^0_S\pi^+ \\
B^+ & \to \psi(2S) K^+ & \to \mu^+\mu^-\pi^+\pi^- K^+; & B^+ & \to \psi(2S) K^*(892)^+ & \to \mu^+\mu^-\pi^+\pi^- K^0_S\pi^+ \\
B^0 & \to J/\psi K^0_S & \to \mu^+\mu^- K^0_S; & B^0 & \to J/\psi K^*(892)^0 & \to \mu^+\mu^- K^+\pi^- \\
B^0 & \to \psi(2S) K^0_S & \to \mu^+\mu^-\pi^+\pi^- K^0_S; & B^0 & \to \psi(2S) K^*(892)^0 & \to \mu^+\mu^-\pi^+\pi^- K^+\pi^-
\end{array}$$

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The capability of using exclusive decay modes is unique to CDF, no other experiment has large samples of fully reconstructed B decays that can be used for lifetime measurements. B^+ and B^0 lifetime measurements using exclusive decays have been previously published for the $\sim$ 20 pb^{-1} Run 1a data sample.[5]

CDF has recently added an additional $\sim$ 48 pb^{-1} of $J/\psi \to \mu^+\mu^-$ data from Run 1b, bringing the total data sample to 67.7 pb^{-1}. As in the Run 1a analysis, reconstruction of $J/\psi \to \mu^+\mu^-$ candidates is the starting point. The $\psi(2S) \to J/\psi\pi^+\pi^-$ decays are then searched for in that data sample. Two track combinations are used to find the $K^*(892)^0$ and K^0_S candidates. The $\psi(2S)$ and K^0_S candidates are required to be within 20 MeV/c^2, while J/ψ and K^* candidates are required to be within 80 MeV/c^2 of their respective world average values.[6] The invariant mass distributions of the J/ψ and $\psi(2S)$ are shown in Figure 1.

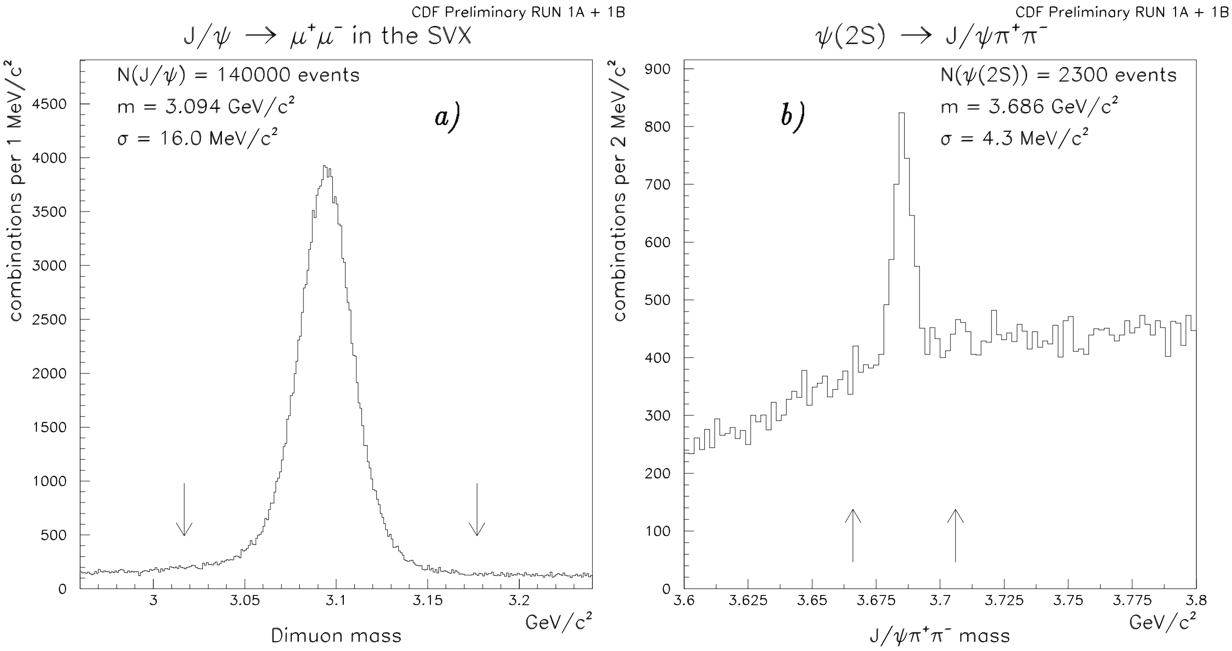

Figure 1: Mass distributions of the a) J/ψ and b) $\psi(2S)$. The mass cuts are indicated.

The K^+, K^0_S, and $K^*(892)$ candidates must have $p_T > 1.25$ GeV/c in order to be combined with a J/ψ or $\psi(2S)$ to reconstruct a B meson. Individual cuts of $p_T(K) > 1.0$ and $p_T(\pi) > 0.5$ GeV/c are also required for $K^*(892)^0$ candidates.

In the final B reconstruction, all the decay tracks, except those from a K^0_S, are vertex constrained, and the J/ψ and $\psi(2S)$ candidates are mass constrained to their world average values. Any B mesons with $p_T < 6.0$ GeV/c are rejected. In the case of multiple candidates per event, only the one with the best χ^2 from the constrained fit is kept.

The upper plots in Figure 2 show the invariant mass distributions of all B^+ and B^0 candidates. Background in these distributions comes from combinations of J/ψ's with tracks produced during the b-quark fragmentation or with other remnants of the

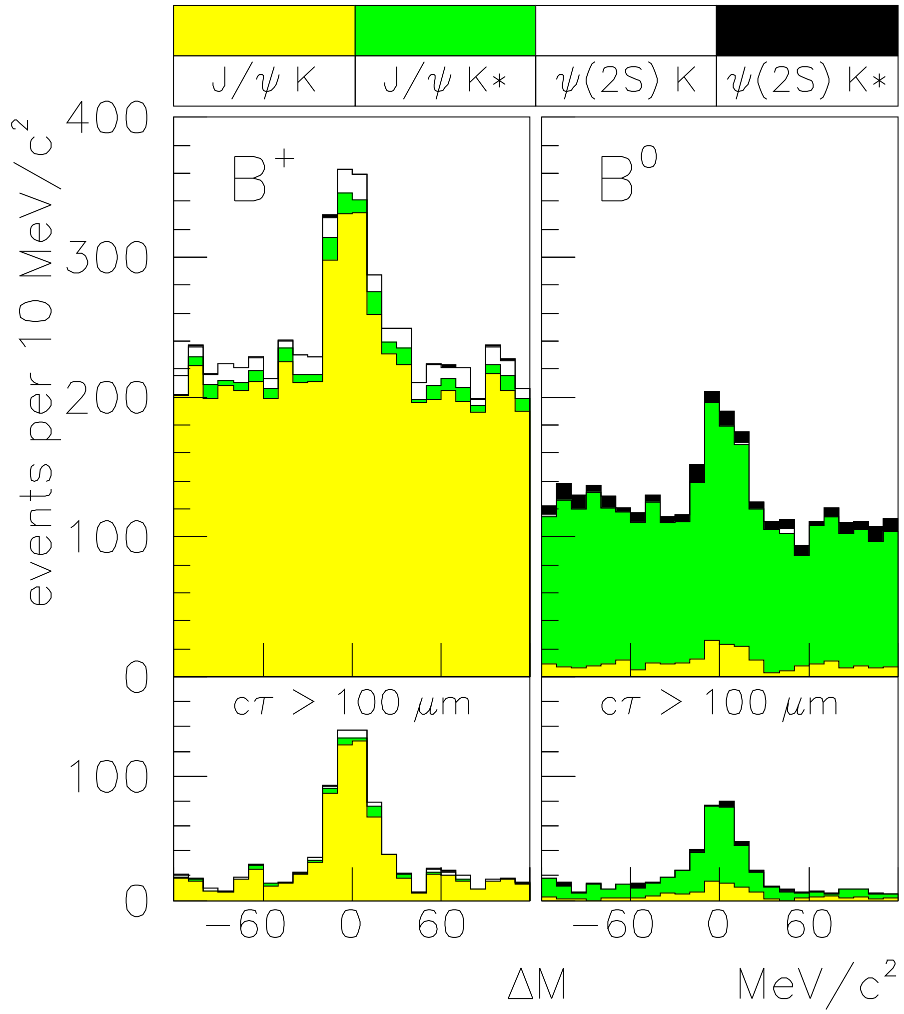

Figure 2: Mass distributions of the fully reconstructed B samples, both with (upper) and without (lower) a $c\tau > 100$ μm cut. (CDF Preliminary)

$p\overline{p}$ collision. These tracks should reconstruct to the primary vertex and consequently the background is smallest for events where the decay distance is large. This is demonstrated in the lower plots of Figure 2 where a $c\tau > 100$ μm cut is made to illustrate this point. The contributions from the different decay modes is given by the shading and, as expected, the $B^+ \to J/\psi K^+$ decay is dominant for charged B's and the $B^0 \to J/\psi K^*(892)^0$ channel has the largest rate for neutral B's.

For the lifetime analysis, we define the signal region to be within ± 30 MeV/c^2 of the world average B mass.[6] Sideband regions are defined to be between 60 and 120 MeV/c^2 away from the world average. This selection excludes the mass region where B's with a missing π would be typically reconstructed.

The B^+ and B^0 proper decay length distributions, for both the signal and sideband regions, are shown in Figure 3. The superimposed curves are the results of sepa-

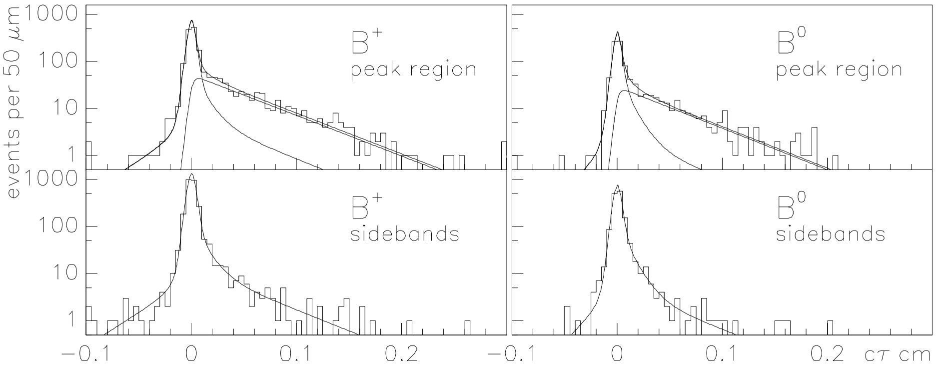

Figure 3: The proper decay length ($c\tau$) distributions of the fully reconstructed B samples. The fits (curves) are described in the text. (CDF Preliminary)

rate unbinned likelihood fits for the B^+ and B^0 lifetimes. The signal region fit consists of a lifetime exponential convoluted with a Gaussian resolution function, while the background is modeled with a Gaussian plus asymmetric exponential tails. The signal and background distributions are fit simultaneously. The fits indicate that there are 524 ± 29 charged and 285 ± 21 neutral B mesons in the signal regions. There is some residual positive lifetime component to the background due to resolution effects in which $B \to \psi K \pi^0$ decays are reconstructed in the B mass sideband region. The results of the lifetime fits to the $c\tau$ distributions are $c\tau^+ = 503 \pm 26\,\mu$m and $c\tau^0 = 492 \pm 34\,\mu$m.

Residual misalignment, trigger bias, and beam stability give the dominant contributions to the systematic uncertainty. However, these are common to the B^+ and B^0 lifetime measurements and cancel in the lifetime ratio. The other systematic contributions are significantly reduced compared to the previous Run 1a analysis due to the increased stability of the $c\tau$ distributions from the larger statistics. Table 1 gives the sources of systematic uncertainty.

Source of Uncertainty	B^+	B^0
Residual misalignment	10 μm	10 μm
Trigger bias	11 μm	11 μm
Beam stability	8 μm	8 μm
Resolution (scale)	1 μm	1 μm
Resolution (tails)	1 μm	4 μm
Background shape	1 μm	2 μm
Fitting procedure bias	2 μm	1 μm
Total	17 μm	18 μm

Table 1. Summary of systematic uncertainties for the exclusive B^+ and B^0 lifetime measurements.

In the combined Run 1a + 1b data sample (67.7 pb^{-1}), the preliminary measurements of τ^+, τ^0, and τ^+/τ^0 using exclusive $B \to \psi K$ decays are:

$$\begin{aligned} \tau^+_{excl} &= 1.68 \pm 0.09\,(\mathrm{stat}) \pm 0.06\,(\mathrm{syst})\ \mathrm{ps} \\ \tau^0_{excl} &= 1.64 \pm 0.11\,(\mathrm{stat}) \pm 0.06\,(\mathrm{syst})\ \mathrm{ps} \\ (\tau^+/\tau^0)_{excl} &= 1.02 \pm 0.09\,(\mathrm{stat}) \pm 0.01\,(\mathrm{syst}) \end{aligned}$$

We see that the uncertainty on the B^+ (B^0) lifetime is only 6.4% (7.6%) and the precision on the lifetime ratio is dominated by statistics and is less than 10%.

We can combine these results with charged and neutral B lifetime measurements using semileptonic B decays previously reported by CDF.[7] The relatively small correlations between the exclusive and semileptonic mode lifetime measurements due to residual misalignment and beam stability can be separated out and CDF average values for τ^+, τ^0, and τ^+/τ^0 can be computed. We find:

$$\begin{aligned} \tau^+_{CDF} &= 1.62 \pm 0.09\ \mathrm{ps} \\ \tau^0_{CDF} &= 1.60 \pm 0.09\ \mathrm{ps} \\ (\tau^+/\tau^0)_{CDF} &= 1.00 \pm 0.07 \end{aligned}$$

These can be compared to the latest LEP B lifetime averages[8]:

$$\begin{aligned} \tau^+_{LEP} &= 1.68 \pm 0.07\ \mathrm{ps} \\ \tau^0_{LEP} &= 1.56 \pm 0.07\ \mathrm{ps} \\ (\tau^+/\tau^0)_{LEP} &= 1.08 \pm 0.08 \end{aligned}$$

These results are in good agreement and the precision on the CDF lifetime averages is now nearly identical to the latest LEP values.

3. Conclusions

The latest preliminary CDF results on τ^+, τ^0, and τ^+/τ^0 using exclusive $B \to \psi K$ decays have been presented. Additional data will continue to improve the precision of these measurements and they should approach the 5% level when the entire Run 1 data sample is analyzed. Limits on the contribution from non-spectator decays to the B^+ and B^0 lifetimes may then be possible.

References

1. F. Abe et al. (CDF Collaboration), *Nucl. Instrum. Methods Phys. Res., Sect. A* **271**, 387 (1988), and references therein.
2. D. Amidei et al., *Nucl. Instrum. Methods Phys. Res., Sect. A* **350**, 73 (1994); P. Azzi et al., preprint FERMILAB-CONF-94/205-E.
3. V. Chernyak, preprint BudkerINP 95-18; M. Shifman, preprint TPI-MINN-94/32-T.
4. Throughout this paper, references to a specific charge state imply the charge-conjugate state as well.
5. F. Abe et al. (CDF Collaboration), *Phys. Rev. Lett.* **72**, 3456 (1994).
6. L. Montanet et al. (Particle Data Group), *Phys. Rev.* **D50**, 1173 (1994).
7. J. Skarha (For the CDF Collaboration), preprint FERMILAB-CONF-95/135-E.
8. Moriond 95 lifetime averages from the LEP B Lifetimes Working Group.