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Measurement of Lifetime Ratio for the Neutral and Charged B Mesons

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1 Introduction

Measurement of the lifetime ratios for B meson and baryons is an important topic because these ratios can be calculated in theory with a better precision than the absolute lifetimes.

Similarly from the experimental point of view some uncertainties of measurements can cancel out when the ratio rather than separate lifetime is determined. In this note we describe a novel technique to measure the ratio of the lifetimes for neutral and charged B meson.

2 Method

We exploit the large semileptonic sample accumulated by D0 during the period from April 2002 to September 2003 corresponding to approximately 200 pb . The method is based on comparison of number of $D^0$and D^{*-}events in different proper lifetime bins. We define the $D^0$and D^{*-}samples to have similar reconstruction efficiencies and similar vertex properties so the dependence of the ratio on those parameters is minimized. Analysis of the samples composition shows that the D^0sample is dominated by decay products of B^+mesons and correspondingly the D^{*-}sample is dominated by decay products of B_d^0mesons. We calculate the number of $B^+$and B_d^0events in each proper time bin by correcting the number of $D^0$and D^{*-}events by the sample composition and efficiency of reconstruction of the soft pion for D^{*-}. The ratio of the $B_d^0$and B^+lifetimes is determined by fitting the ratio of $B_d^0$and B^+events in the proper time bins. In the case of equal lifetimes the ratio does not depend on the proper time and is a constant equal to 1. If the lifetimes are not equal the ratio will have a slope described by

$$C \cdot \exp\left(-\tau/\tau^0 \cdot R\right)$$

where $R = (\tau^+ - \tau^0)/\tau^0$ is the ratio of the lifetimes.

The number of B^+ and B_d^0 events can be determined using the following formula :

$$N_{D^0} = N_{B^+\to D^0} + N_{B_d^0\to D^{*-}} \cdot (1-\epsilon_{\pi^*}) + N_{B_d^0\to D^{**}\to D^0} + N_{B^+\to D^{**}\to D^0}$$

$$N_{D^{*-}} = N_{B_d^0\to D^{*-}} \cdot \epsilon_{\pi^*} + N_{B_d^0\to D^{**}\to D^{*-}} \cdot \epsilon_{\pi^*} + N_{B^+\to D^{**}\to D^{*-}} \cdot \epsilon_{\pi^*}$$

where ϵ_{π^*} is efficiency to reconstruct the soft pion from the D^{*-} decay.

3 Data Sample

4 Monte Carlo samples

5 Selections

6 Final sample composition

6.1 D^{**} contributions

D^{**} mesons could be produced in B meson decays and are an important background to consider for our analysis. B_d^0 mesons may decay directly to D^0 through D^{**} without forming D^*. Similarly B^+ mesons may decay to D^* via D^{**}. We use 3 methods to estimate the fraction of B_d^0 in B^+ coming from D^{**} and vice versa.

- We estimate the contribution of D^{**} meson using the measured branching fractions for decays of B mesons from PDG2002 [1].
- We use the Monte Carlo described in Section 4 to determine this contribution
- We estimate this contribution using the selected D^0 and D^* data samples. We look for charged particles that can be associated with B decay vertex to determine if the event originated from a B meson with a charge different that we assumed.

Metod 1: We use the Web edition of PDG listings (as checked in October 2003) to determine the following branching fractions for decays contributing to the D^0 and D^* samples:

$$Br(B^+ \to l^+\nu\bar{D}^0) \quad 2.15 \pm 0.22\% \tag{1}$$
$$Br(B^+ \to l^+\nu\bar{D}^{*0}) \quad 6.5 \pm 0.5\% \tag{2}$$
$$Br(\bar{D}^{*0} \to \bar{D}^0\pi^0; \bar{D}^0\gamma) \quad 100\%$$
$$Br(B_d^0 \to l^+\nu D^{*-}) \quad 5.53 \pm 0.23\% \tag{3}$$
$$Br(D^{*-} \to \bar{D}^0\pi^-) \quad 67.7\%$$

$$Br(B \to \quad l^+\nu\bar{D}^0\pi^- X) \quad 1.07 \pm 0.27\% \tag{4}$$

$$Br(B \to \quad l^+\nu\bar{D}^0\pi^+ X) \quad 0.23 \pm 0.16\% \tag{5}$$

$$Br(B \to \quad l^+\nu D^{*-}\pi^- X) \quad 0.48 \pm 0.10\% \tag{6}$$

$$Br(B \to \quad l^+\nu D^{*-}\pi^+ X) \quad 0.06 \pm 0.07\% \tag{7}$$

Note that the channels (1), (2), (3) as listed above are main sources of $D^0$and D^*in our samples. Total number of $B \to l^+\nu D^{*-}X \to l^+\nu\bar{D}^0\pi^- X$ is $5.53 \cdot 0.677 = 3.74 \pm 0.16\%$. Total number of $B \to l^+\nu\bar{D}^0 X$ is $2.15(\mathrm{D}^0) + 6.5(\mathrm{D}^{*0}) + 3.74(\mathrm{D}^*) = 12.39 \pm 0.57\%$. To evaluate contributions from D^{**}we need to make some assumptions.

One possible approach is to assume that D^{**}decays to $D^0$and $D^*$are saturated by decays (5), (6), (7), (8). These decay modes change the charge of the B-meson under consideration therefore contributing to the background in our samples. The analysis measures the lifetime ratio of charged and neutral B-mesons so if the charge of B is not changed the influence is minimal (though it may exist through different kinematical selections). Then the total number of $B \to l^+\nu D^{*-}X \to l^+\nu\bar{D}^0\pi^- X$ is $(5.53 + 0.48 + 0.06) \cdot 0.677 = 4.11 \pm 0.16\%$ and the total number of $B \to l^+\nu\bar{D}^0 X$ is $2.15(\mathrm{D}^0) + 6.5(\mathrm{D}^{*0}) + 3.74(\mathrm{D}^*) + 1.07 + 0.23 = 13.69 \pm 0.65\%$. Thus this estimates the contributions from D^{**}decay channels that change the charge of B-meson as $(0.48+0.06)/(5.53+0.48+0.06) = 8.9 \pm 2.0\%$ for the D^*sample and $(1.07+0.23)/(12.39+1.07+0.23) = 9.5 \pm 2.3\%$ for the D^0sample.

7 Results

8 Systematic errors

9 Discussion

10 Conclusion

References

[1] Particle Data Group, K. Hagiwara *et al.*, Phys. Rev. **D66**, (2002) 010001.