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MEASUREMENT OF THE \bar{B}^0 and B^- MESON LIFETIMES IN ALEPH

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The lifetimes of the \bar{B}^0 and B^- meson lifetimes are measured using data recorded on the Z peak with the ALEPH detector at LEP. An improved analysis based on partially reconstructed $\bar{B}^0 \rightarrow D^{*+}\ell^-\bar{\nu}$ and $B^- \rightarrow D^0\ell^-\bar{\nu}$ decays is presented.

1. Introduction

Measurements of the individual b hadron lifetimes provide an important test of our understanding of b hadron decay dynamics beyond the simple spectator model. Using the heavy quark expansion formalism, the lifetime hierarchy of b hadrons is predicted to be $\tau_{\Lambda_b} < \tau_{\bar{B}^0} \sim \tau_{B_s^0} < \tau_{B^-}$, with differences at the level of a few percent. Precise measurements are therefore needed in order to test the theory.

This paper reports an improved measurement of the \bar{B}^0 and B^- lifetimes with the ALEPH detector at LEP based on D^0 - and D^{*+} -lepton samples from semileptonic B decays ¹. The LEP1 data sample was recently reprocessed using refined reconstruction algorithms. The main improvements concern the track reconstruction and particle identification, resulting in enhanced reconstruction efficiencies for charmed mesons ranging from 10 to 30% with respect to a previous analysis ².

2. Event Selection and B Reconstruction

Semileptonic \bar{B}^0 and B^- decays are partially reconstructed in the decay modes $\bar{B}^0 \rightarrow D^{*+}\ell^-X$ and $B^- \rightarrow D^0\ell^-X$ by selecting muon and electron candidates in association with a fully reconstructed D^0 or D^{*+} meson. The D^0 and D^{*+} are reconstructed from charged tracks and π^0 's in the decay channels listed in Table 1. The tracks are required to come from a common vertex, and additional quality cuts on the momenta of the D^0 candidates and the invariant mass of the $D^{(*)}\ell$ system are applied in order to improve the signal to background ratio and to ensure well measured decay lengths. For the D^{*+} candidates, the difference in mass between the reconstructed D^{*+} and the subsequent D^0 is required to be within twice the experimental resolution of the nominal value of $145.4 \text{ MeV}/c^2$. Events reconstructed within two standard deviations of the fitted D^0 mass are then selected for the lifetime analysis, resulting in 1880 $D^{*+}\ell^-$ and 2856 $D^0\ell^-$ combinations.

The decay length is calculated for these events from the distance between the primary and B decay vertices, projected onto the direction defined by the momentum of the $D^{(*)}\ell$ system. To reconstruct the momentum of the B meson, an energy flow technique is used, taking into account the missing energy from the undetected

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neutrino.

Table 1. Number of D^0 candidates and fraction of background events in the signal mass window.

Subsample		Candidates	Background fraction
$D^{*+}\ell^-$	$D^0 \rightarrow K^-\pi^+$	651	0.066 ± 0.004
	$D^0 \rightarrow K^-\pi^+\pi^-\pi^+$	670	0.096 ± 0.004
	$D^0 \rightarrow K^-\pi^+\pi^0$	394	0.127 ± 0.008
	$D^0 \rightarrow K_S^0\pi^+\pi^-$	165	0.061 ± 0.006
$D^0\ell^-$	$D^0 \rightarrow K^-\pi^+$	1312	0.133 ± 0.006
	$D^0 \rightarrow K^-\pi^+\pi^-\pi^+$	664	0.232 ± 0.012
	$D^0 \rightarrow K^-\pi^+\pi^0$	563	0.258 ± 0.012
	$D^0 \rightarrow K_S^0\pi^+\pi^-$	317	0.139 ± 0.009

3. Lifetime Measurement

The \bar{B}^0 and B^- lifetimes are extracted using an unbinned likelihood fit. Because the $D^0\ell^-$ and $D^{*+}\ell^-$ events contain a mixture of \bar{B}^0 and B^- , a simultaneous fit is performed to the proper time distributions of both event samples. Important inputs for this measurement are the branching ratios for decay modes involving higher excited charm states, $B \rightarrow D^{**}\ell\nu(X)$, which spoil the \bar{B}^0 and B^- purity of the respective $D^0\ell^-$ or $D^{*+}\ell^-$ samples. For the evaluation of the cross contamination, the most recent ALEPH and DELPHI results ^{3,4} for these branching ratios are used, leading to a significant reduction in the resulting uncertainty compared to a previous analysis ². The fit yields $\tau_{\bar{B}^0} = 1.518 \pm 0.053$ ps and $\tau_{B^-} = 1.648 \pm 0.049$ ps, where the errors are statistical only, and the statistical correlation is -0.35 . The ratio of the lifetimes is found to be $\tau_{B^-}/\tau_{\bar{B}^0} = 1.085 \pm 0.059$, taking into account the correlation. The proper time distributions of the two samples are shown in Fig. 1, with the results of the fit superimposed. Systematic uncertainties due to detector and physics modeling, as well as those related to the fitting procedure, are summarized in Table 2.

Table 2. Summary of systematic uncertainties evaluated on the fitted lifetimes.

Source	$\tau_{\bar{B}^0}$ (ps)	τ_{B^-} (ps)	$\tau_{B^-}/\tau_{\bar{B}^0}$
B momentum reconstruction	± 0.025	± 0.026	± 0.009
Background treatment	± 0.020	± 0.020	± 0.010
Sample compositions	± 0.003	± 0.003	± 0.004
$D^{(*)}\pi\ell^- \nu$ relative efficiency	± 0.006	± 0.006	± 0.006
Decay length resolution	± 0.008	± 0.008	± 0.008
Total	± 0.034	± 0.035	± 0.018

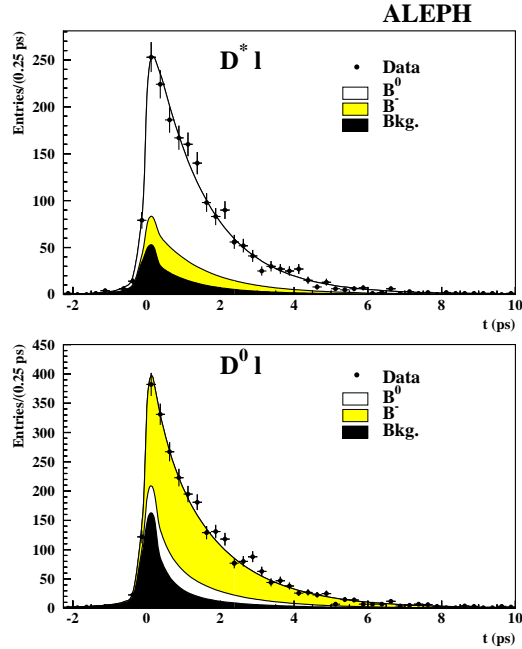


Fig. 1. Proper time distributions for the $D^{*+}\ell^-$ and $D^0\ell^-$ samples, with the results of the fit superimposed. Also shown are the background contributions and the respective \bar{B}^0 and B^- components.

4. Summary

The lifetimes of the charged and neutral B mesons have been measured using data gathered with the ALEPH detector at LEP from 1991 to 1995. A likelihood fit to the proper time distributions of 1880 $D^{*+}\ell^-$ and 2856 $D^0\ell^-$ candidates yields the following results for the \bar{B}^0 and B^- lifetimes and their ratio: $\tau_{\bar{B}^0} = 1.518 \pm 0.053 \pm 0.034$ ps, $\tau_{B^-} = 1.648 \pm 0.049 \pm 0.035$ ps, $\tau_{B^-}/\tau_{\bar{B}^0} = 1.085 \pm 0.059 \pm 0.018$.

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