B^0 AND B^+ LIFETIME MEASUREMENTS AT LEP

Invited talk presented at the XXVI. International Conference
on High Energy Physics, Dallas, August 1992

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Abstract

Using either $D^{(*)}$ lepton correlations or secondary vertex charge measurements, b-quark jets are separated into B^+ and $\bar{B}^0$ enriched samples. Preliminary results on lifetimes of these separated b-samples are presented, exploiting the good vertex resolution of the DELPHI and ALEPH silicon microvertex detectors. Within errors, the B^+ and $\bar{B}^0$ lifetimes appear to be equal.

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MOTIVATION

By now, very accurate measurements of the “mean” b lifetime are available. Since a b-quark has enough time to form hadrons before it decays weakly, a “b” might actually be a $\bar{B}^0$, a B^- or B_s^0 meson, or a Λ_b baryon. A priori it is not clear whether all of these lifetimes are equal. In case there are large differences between the lifetimes of different b hadron species, the concept of a “mean” b lifetime appears senseless, since the decay length distribution will no longer be described by a single exponential.

In the charmed sector, big lifetime differences appear: $\tau(D^+)/\tau(D^0) = 2.5 \pm 0.1$. These can be understood at least qualitatively in terms of quark interference effects in non-

leptonic decay modes. For many important decay modes, e.g. $D \rightarrow K\pi$, there are two diagrams leading to the same final state (see fig.1): a “spectator” diagram as well as an “internal conversion” diagram. Simple quark line diagrams show that in the case of the D^+ both diagrams lead to the same final state ($\bar{K}^0\pi^+$), whereas in case of the D^0 they lead to the two final states $K^+\pi^-$ and $\bar{K}^0\pi^0$. The main cause of the lifetime difference is a destructive interference between both graphs in D^+ decay. No such interference is possible for D^0 decays, the final states actually being distinguishable.

For B decays, one usually expects the spectator diagrams to dominate by far over the internal conversion diagram, mainly due to the larger b-quark mass (see e.g. the discussions about Heavy Quark Effective Theory [1] and Effective Heavy Quark Theory [2]). Thus, interference effects are believed to be much smaller than in the charm sector and a lifetime ratio around 1 is expected.

This paper reports about direct lifetime determinations on enriched B^0 and B^+ samples, on the basis of decay length measurements using the DELPHI and ALEPH detectors at LEP. Key devices for such analyses are

Figure 1. Spectator and internal conversion diagrams in nonleptonic heavy quark decays

Figure 2. B^0 and B^+ semileptonic decay quark flow lines

the silicon microvertex- detectors, which allow for track-vertex extrapolation accuracies in the order of $100\mu\text{m}$. Details of the analyses presented here may be found in [1–3].

$D^{(*)}$ LEPTON CORRELATIONS

Fig. 2 shows the quark line diagrams for semileptonic B decays into $D^{(*)}$ (which stands for both, D and D^* mesons). It can be seen that neutral B mesons always decay into charged $D^{(*)}$, whereas charged B mesons decay only into neutral $D^{(*)}$ mesons. Furthermore, the weak decay properties of the D mesons ensure that charged kaons from D decays must have the same charge as the lepton of the $B \rightarrow D l \nu$ transition.

Fig. 3 shows the vertex geometry: First $K\pi$ vertices V_D are searched, the D^0 candidates are extrapolated back to search for a vertex V_B with an identified lepton. The B decay length is the distance between the primary vertex and V_B .

Fig. 4 shows the evidence for charmed mesons in multihadronic events with an identified lepton in the same hemisphere: 92 $D^0 \rightarrow K^- \pi^+$ candidates, 35 $D^+ \rightarrow K^- \pi^+ \pi^-$ and

Figure 3. $B \rightarrow D^{(*)} l \nu$ vertex geometry

together 61 $D^{*+} \rightarrow \pi^+ D^0$ candidates (30 in $D^0 \rightarrow K\pi$, 31 in $D^0 \rightarrow K3\pi$) are found by DELPHI. ALEPH obtained very similar event samples (71 $D^0 \rightarrow K\pi$, 71 $D^{*+} \rightarrow \pi^+ D^0$). The lifetimes are determined using an event-by-event maximum likelihood fit. The results are (in picoseconds):

reaction	DELPHI	ALEPH
$\bar{B} \rightarrow D^0 l^- X$	$1.27^{+0.22}_{-0.18} \pm 0.15$	$1.32^{+0.19}_{-0.18}$
$\bar{B} \rightarrow D^+ l^- X$	$1.18^{+0.39}_{-0.27} \pm 0.15$	— — —
$\bar{B} \rightarrow D^{*+} l^- X$	$1.19^{+0.25}_{-0.19} \pm 0.15$	$1.62^{+0.24}_{-0.31}$

As a cross check both collaborations also reconstructed the D lifetimes from the $V_B - V_D$ distance and found them to be compatible with the world averages.

The caveat of this method lies in the fact that $D^{(*)0}$ might denote next to D^0 , D^{*0} also higher spin D resonances (D^{**}) or non-resonant $D^{(*)} + n \cdot \pi$. Formerly usually neglected, recent measurements by ARGUS and CLEO II indicate that these contributions might be as large as 40% of the semileptonic branching ratio. Decaying strongly, isospin considerations show that the D^{**} charge is mixed into $D^{(*)}$ and pion charges with some uncertainties, such diffusing the simple B - D charge correlation. First direct evidence for higher D resonance production was presented

DELPHI

Figure 4. D^0 signal in $K\pi$, D^+ signal in $K\pi\pi$, and D^* signals from Δm plots using $D^0 \rightarrow K\pi$ and $D^0 \rightarrow K3\pi$

at this conference [6]. One has to unfold the charge mixing due to this effect using a model for D^{**} production and using measured branching ratios.

To fit B^0 and B^+ lifetimes, simultaneous fits to the D^0 and $D^{(*)+}$ decays are performed, the corresponding sample compositions taken from a model calculation taking into account charge mixing due to D^{**} production and tracking inefficiencies. DELPHI and ALEPH use slightly different assumptions in this model, which leads to a more diagonal matrix in the latter analysis. Also, ALEPH includes the production *rates* in the fit, since $N(B^0)/N(B^+)$ also slightly depends on τ^+/τ^0 . The final results are displayed in fig. 6.

SECONDARY VERTEX CHARGE

In this method, pioneered by the DELPHI Collaboration [5], one tries to separate all charged particles of a jet uniquely into two vertices; one primary vertex compatible with the beam spot, and a secondary vertex from the B decay. The finite path length of the D mesons can be neglected compared to the much larger b decay length. All possible

Figure 5. Proper time distributions of charged and neutral secondary vertices

Figure 6. Results on charged and neutral B-lifetimes

permutations of tracks are tried, and an event is kept only if both the primary and the secondary vertex fits have χ^2 probabilities in excess of 10%, and there is one and only one such track combination in the jet. The charge measurement is about 80% correct, with misidentification rates of 10% for $\Delta Q = \pm 1$ and $\approx 1\%$ for $\Delta Q = \pm 2$, as determined from the rate of doubly charged vertices and cross-checked with Monte Carlo. The results of a maximum likelihood fit are: $\tau_{neutral} = 1.81 \pm 0.29 ps$ and $\tau_{charged} = 0.93 \pm 0.21 ps$ (see fig.5). These results have been obtained by actually measuring the *excess decay length* beyond the minimum visible decay length which is determined event-by-event from the data. One such is less dependent on Monte Carlo simulations and achieves smaller systematic errors. The results have been checked to be consistent with those obtained using a usual fit method with acceptance correction calculated from Monte Carlo.

Neutral b vertices may stem from $\bar{B}^0$, B_s^0 and Λ_b hadrons, whereas charged b vertices mainly stem from B^+ mesons (and perhaps a very small contribution from Σ_b^+ baryons). For the extraction of B^+ and B^0 lifetimes one

has to unfold charge mismeasurements and, mainly for the B^0 lifetime, the influence of B_s^0 and Λ_b decays, for which one has to model production fractions and lifetimes.

All the results are collected in fig. 6, along with former measurements.

CONCLUSIONS

Within errors, the B^+ and B^0 lifetimes measured in e^+e^- reactions are equal to the average b -lifetime. The results from E653 reported at this conference [7] are however only hardly compatible with the measurements presented here. Disregarding that, one can conclude that for B-mesons there is not such an effect as observed in the charm sector.

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