# LEPTONIC DECAYS OF THE $D_s$ MESON AT LEP

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Results on $BR(D_s \to \tau\nu)$ from the LEP experiments are presented here. With a recent measurement the ALEPH collaboration has also explored the channel $D_s \to \mu\nu$ showing the first evidence at LEP for such a signal. The $D_s$ decay constant is extracted from the measurements of the two branching ratios showing consistency between all the results.

## 1 Introduction

The leptonic decay $D_s \to l\nu$ is the second–generation analog of the charged pion leptonic decay and it proceeds via the Cabibbo allowed annihilation of the c and $\overline{s}$ quarks in the $D_s$ meson. Standard Model predictions for the $BR(D_s \to l\nu)$ branching fraction are based on the following expression:

$$\frac{G_F^2}{8\pi}\tau_{D_s} f_{D_s}^2 \mid V_{cs} \mid^2 m_{D_s} m_l^2 \left(1 - \frac{m_l^2}{m_{D_s}^2}\right)^2, \quad (1)$$

where $\tau_{D_s}$ is the mean lifetime of the $D_s$, $V_{cs}$ is the relevant CKM matrix element, $m_{D_s}$ is the $D_s$ mass, $m_l$ is the mass of the lepton and $f_{D_s}$ is the decay constant. Extracting $f_{D_s}$ from the measurement of the branching fraction is the ultimate purpose of such an analysis because it allows verification of various theoretical calculations [1,2,3]. The experimentally accessible channels are $D_s \to \tau\nu$ and $D_s \to \mu\nu$, $D_s \to e\nu$ being strongly helicity suppressed.

## 2 Analysis Methods

The general strategy for selecting events in the $D_s \to \tau\nu$ channel ($\tau \to e\nu\overline{\nu}$ or $\tau \to \mu\nu\overline{\nu}$) is searching for hemispheres containing a high momentum lepton associated with large missing energy. ALEPH [4] looks for the decay chain $e^+e^- \to c\overline{c}, c \to D_s, D_s \to \tau\nu$ distinguishing between muons and electrons, while DELPHI and L3 [5,6] reconstruct the decay chain $e^+e^- \to c\overline{c}, c \to D_s^* \to D_s\gamma, D_s \to \tau\nu$, by requiring a high energy photon in the hemisphere containing the lepton.

The selection is optimized for $Z \to c\overline{c}$ events while rejecting $Z \to b\overline{b}$ where the $D_s$'s have a softer energy spectrum and are harder to detect. The rejection of the background, mostly due to semileptonic decays in charm and bottom events, is achieved mainly by cutting on the reconstructed $D_s$ energy or on the mass difference $M(D_s\gamma)$-$M(D_s)$. Lifetime based variables are used to discriminate the signal from the b background, exploiting the fact that in charm hemispheres containing a $D_s \to l\nu$ decay all particles but the lepton originate from the primary vertex. In the ALEPH analysis the physical background from $D^+ \to l\nu$ is indistinguishable from the $D_s \to l\nu$ so it is treated as signal and related to $f_{D_s}$ using the prediction $f_{D_s}/f_{D^+} = 1.11^{+0.06}_{-0.05}$ [3].

The background due to $b\overline{b}$, $c\overline{c}$ and light flavour events still present in the selected sample has to be subtracted in order to extract the $D_s \to \tau\nu$ component. This is estimated from the $M(D_s\gamma)$ Monte Carlo distribution for DELPHI and L3, while ALEPH use a linear combination of hemisphere variables suitably chosen with the help of the Monte Carlo simulation, according to their discriminant power (Linear Discriminant Variables technique). Two variables, $U_b$ and $U_c$, are optimized in order to discriminate the signal from background in $b\overline{b}$ and $c\overline{c}$ events respectively, as shown in Fig. 1.

A fit is then performed to the data with

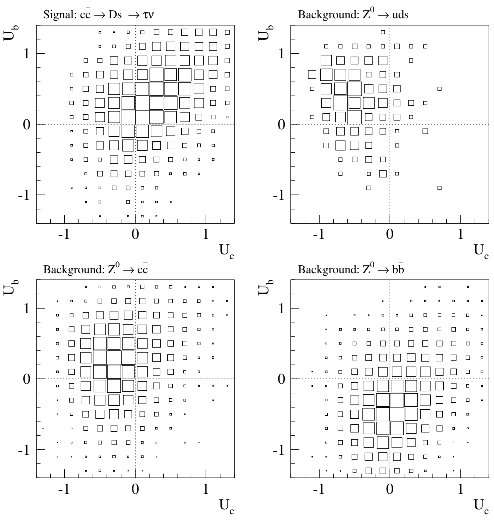


Figure 1. Monte Carlo $U_b$ vs $U_c$ distributions in the electron channel for the ALEPH $D_s \to \tau\nu$ analysis.

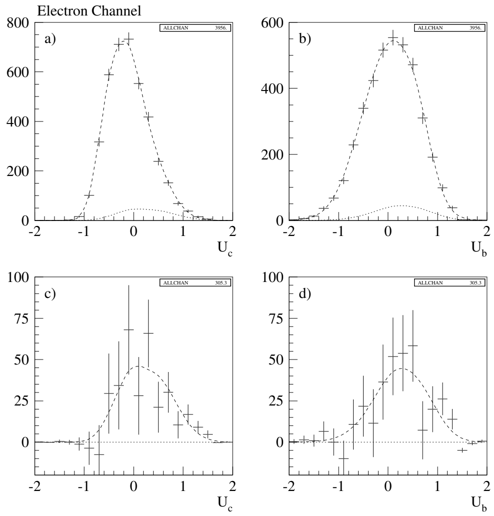


Figure 2. Projections of the fit to the data in the electron channel for the ALEPH $D_s \to \tau\nu$ analysis. (a) $U_c$ distribution; (b) $U_b$ distribution. (c) and (b) are the same distributions after subtracting the fitted background.

a function consisting of a signal plus three background (uds,$c\bar{c}$, $b\bar{b}$) components. The relative normalizations of the various contributions are fixed according to Eq. 1, the measured charm production rates [7,8], the predicted $f_{D_s}/f_{D^+}$ and other quantities [9]. In Fig. 2 the result of the fit is shown, projected along the two variables $U_b$ and $U_c$.

The first evidence of the $D_s \to \mu\nu$ signal has been observed by ALEPH [4]. The analysis technique follows what is done for the $D_s \to \tau\nu$ channel except that also the $M(\mu\nu)$ invariant mass is calculated and used as a third discriminant variable in the fit together with another pair of variables $U_b$, $U_c$, suitably optimized to distinguish $c\bar{c} \to D_s \to \mu\nu$ from $b\bar{b}$ and $c\bar{c}$ background. This analysis is also sensitive to $D_s \to \tau\nu$ decays so the extracted branching fraction refers to the combined signal. In Fig. 3 the three-dimensional fit is projected along the $M(\mu\nu)$ axis.

The main source of systematic error, common to all the analyses, is the uncertainty on the charm hadron production rates, (mostly due to P(c$\to$ $D_s$) for ALEPH and P(c $\to$ $D_s^*$) for DELPHI and L3, since they directly govern the number of $D_s$ ($D_s^*$) mesons present in the sample. Other important systematic uncertainties on the ALEPH measurements are due to the fragmentation of the charm quark, which directly affects the charmed hadron reconstructed energy, and the detector resolution.

## 3 Results

The measured branching fractions are summarized in Table 1.

The extracted values for $f_{D_s}$ are shown in Fig. 4. The quoted ALEPH result is obtained by the combination of $f_{D_s} = (273 \pm 18 \pm 42)$ MeV from the $D_s \to \tau\nu$ analysis and $f_{D_s} = (291 \pm 25 \pm 38)$ MeV from the $D_s \to \mu\nu$ analysis. The LEP measurements are compared with two more results from fixed target experiments and with the Lattice QCD prediction showing overall good agreement.

Table 1. Experimental results on $BR(D_s \to \tau\nu)$ and $BR(D_s \to \mu\nu)$.

| | $BR(D_s \to \tau\nu)$ |
|---|---|
| ALEPH $\tau \to e\nu\overline{\nu}$ | $(5.86 \pm 1.18 \pm 2.09)\%$ |
| ALEPH $\tau \to \mu\nu\overline{\nu}$ | $(5.78 \pm 0.85 \pm 1.76)\%$ |
| ALEPH Combined | $(5.79 \pm 0.76 \pm 1.78)\%$ |
| DELPHI | $(8.5 \pm 4.2 \pm 2.6)\%$ |
| L3 | $(7.4 \pm 2.8 \pm 2.4)\%$ |
| | $BR(D_s \to \mu\nu)$ |
| ALEPH | $(0.68 \pm 0.11 \pm 0.18)\%$ |

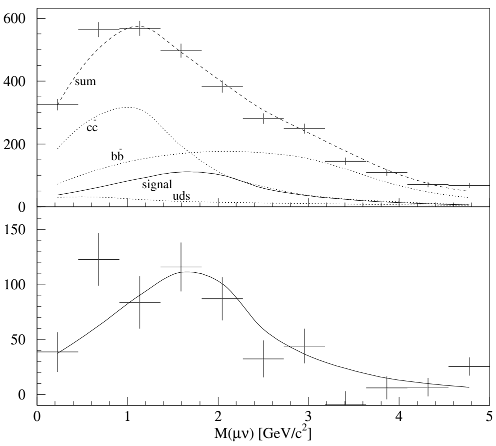


Figure 3. $M(\mu\nu)$ projection of fit to data in the ALEPH $D_s \to \mu\nu$ channel, before and after the background subtraction.

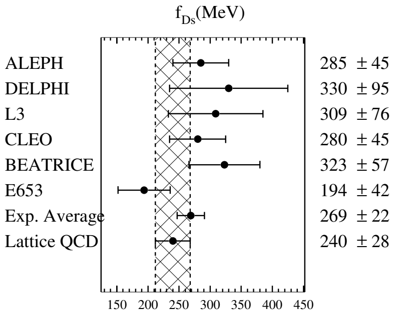


Figure 4. Experimental results for $f_{D_s}$ from the LEP experiments compared with fixed target experiments and theoretical predictions.

## References


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