LAPP-EXP-96.03
JANVIER 1996

Semileptonic Decays of the B mesons at LEP

Sylvie Rosier-Lees
LAPP-IN2P3-CNRS, F-74019 Annecy-Le-Vieux Cedex

SW 9611

Contribution to advanced study conference on Production and Decay of Hyperons
Charm and Beauty Hadrons, Strasbourg, Sept. 5-8, 1995.

Semileptonic Decays of the B mesons at LEP

Sylvie Rosier-Lees^a

^aLAPP ,
IN2P3-CNRS , F-74019 Annecy le Vieux Cedex

We review the semileptonic b -hadron branching ratio $\text{Br}(b \rightarrow l\nu X)$ measurements from LEP. Both the inclusive and exclusive measurements are presented and different methods for the inclusive measurements (decay Model dependent or not) are contrasted. From those measurements we extract a value of $|V_{cb}|$. An updated measurement of the branching ratio $\text{Br}(b \rightarrow \tau\nu X)$ is also given.

1. INTRODUCTION

One of the most important motivations in the measurement of $\text{Br}(b \rightarrow l\nu X)$ is that it can be used to extract the CKM matrix element V_{cb} . This can be performed using two independent methods:

- By combining the inclusive measurements of $\text{Br}(b \rightarrow l\nu X)$ and the mean b hadron lifetime τ_b

$$\frac{\text{Br}(b \rightarrow l\nu X)}{\tau_b} = \frac{G_F m_b^5}{192\pi^3} \times (f_c g_c V_{cb}^2 + f_u g_u V_{ub}^2) \quad (1)$$

Equation (1) becomes if we neglect V_{ub} :

$$\frac{\text{Br}(b \rightarrow l\nu X)}{\tau_b} = \gamma_c^2 \times V_{cb}^2 \quad (2)$$

- In the exclusive decay $\bar{B}^0 \rightarrow D^{*+} \ell^- \bar{\nu}_\ell$, $|V_{cb}| \cdot \tau_{B^0}^{1/2}$ is estimated by extrapolating the partial width $d\text{Br}(\bar{B}^0 \rightarrow D^{*+} \ell^- \bar{\nu}_\ell)/d\omega$ to $\omega=1$:

$$\frac{d\text{Br}(\bar{B}^0 \rightarrow D^{*+} \ell^- \bar{\nu}_\ell)}{d\omega} \propto V_{cb}^2 \tau_{B^0} \times F(\omega)^2 \quad (3)$$

where ω is the scalar product of the four velocities of the $\bar{B}^0$ and D^{*+} mesons: $\omega = v_{B^0} \cdot v_{D^{*+}}$ and $F(\omega)$ is the Isgur Wise function with $F(1)$ equal to 0.93 ± 0.03 according to [1]. Therefore we will give a review of the inclusive and exclusive $\text{Br}(b \rightarrow l\nu X)$ measurements.

In a complete different domain, the measurement of the branching ratio $\text{Br}(b \rightarrow \tau\nu X)$ allows to explore new physics, as explained in the last section.

1.1. Theoretical predictions

Since the lifetimes of the B^0 and $B^\pm$ mesons are equal within 10%, the spectator model provides

a good starting point for predictions. The naïve spectator model predicts $\text{Br}(b \rightarrow l\nu X) = 0.16$.

$\alpha_S(m_Z)$	Parton Model [2]	HQE[3]	HQE [4]
0.117	0.13	0.128	0.118
0.124	0.125	0.123	0.113

Table 1: Theoretical predictions for the semileptonic branching ratio $\text{Br}(b \rightarrow l\nu X)$ depending on $\alpha_S(m_Z)$

As the exchange of hard gluons between quarks enhances the non leptonic rates, the introduction of perturbative QCD corrections decreases significantly the naïve spectator model prediction. The prediction for $\text{Br}(b \rightarrow l\nu X)$ is further reduced by 2% by introducing non perturbative corrections of order $O(1/m_b^2)$ in HQE.

Theoretical predictions for $\text{Br}(b \rightarrow l\nu X)$ are quoted in table 1 for pole masses values $m_b=4.8$ GeV and $m_c=1.33$ GeV.

To conclude, predictions on the semileptonic branching fraction depend on our knowledge of the effective quark masses and on a precise estimate of the QCD corrections, which as it was shown are important and tend to push $\text{Br}(b \rightarrow l\nu X)$ down.

1.2. Measurements of $\text{Br}(b \rightarrow l\nu X)$

The semileptonic branching fraction is measured at the $\Upsilon(4s)$ experiments and at LEP experiments. Assuming the semileptonic decay width Γ_{SL} is the same for all b flavored hadrons, $\text{Br}(b \rightarrow l\nu X)$ should be different at LEP compared to $\Upsilon(4s)$ since different particles are pro-

duced, which leads to the following relation :

$$\text{Br}(b \rightarrow l)(Z_0) = \frac{2\tau_b}{\tau_B^+ + \tau_B^0} \times \text{Br}(b \rightarrow l)(\Upsilon(4s))$$

Including the LEP lifetime measurements [5] , $\tau_{B^+} = 1.55 \pm 0.06$ ps, $\tau_{B^0} = 1.63 \pm 0.06$ ps and $\tau_b = 1.57 \pm 0.02$ ps, it becomes :

$$\text{Br}(b \rightarrow l)(Z_0)/\text{Br}(b \rightarrow l)(\Upsilon(4s)) = 0.98 \pm 0.03$$

Compared to the $\Upsilon(4s)$ measurement, the additional contribution of other hadrons like (Λ_b or B_s) reduces slightly the expected average $\text{Br}(b \rightarrow l\nu X)$ at the Z_0 .

2. INCLUSIVE MEASUREMENTS

We distinguish two approaches in this measurement. In the traditional approach the measurement depends on the phenomenological models describing the momentum spectrum of the lepton while in the other approach the measurement is independent of the knowledge of these models.

2.1. Traditional approach

To select the semileptonic decays of the b quark, these well known properties are used :

- The fragmentation of the b quark ($\langle x_e^b \rangle \sim 0.70$) is hard which provides a high momentum to the lepton (usually the momentum p has to be greater than 2-4 GeV/c)
- b is heavy which provides to the lepton a high transverse momentum p_t with respect to the jet (typically p_t has to be greater to 1-1.5 GeV/c)

After applying these selection criteria, an overall purity of 80 % with an efficiency varying from 30 to 60 % is achieved.

To enrich the sample in b events, the long lifetime property of the b hadrons is used by tagging the $b\bar{b}$ with the microvertex detector. A purity of 90 % is achieved with an efficiency varying from 30 to 60 % depending on detector performances.

The main experimental problem comes from the leptonic cascade ($b \rightarrow c \rightarrow l$) contamination which is the main background at high p_T ; so usually both $\text{Br}(b \rightarrow l\nu X)$ and $\text{Br}(b \rightarrow c \rightarrow l)$ are measured simultaneously.

2.1.1. Single Tag- $\Gamma_{b\bar{b}}$ dependent method

According to equation (4)

$$\frac{N_l}{N_{\text{had}}} = 2\text{Br}_{\text{SL}}(1 - \text{Br}_{\text{SL}}) \frac{\Gamma_{b\bar{b}}}{\Gamma_{\text{had}}} \quad (4)$$

$\text{Br}(b \rightarrow l\nu X)$ and also $\Gamma_{b\bar{b}}$ or $\text{Br}(b \rightarrow c \rightarrow l)$ can be extracted from a fit on the momentum p and the transverse momentum p_T spectra. In this case, the product $\text{Br}(b \rightarrow l\nu X) \times \Gamma_{b\bar{b}}$ is measured, where $\Gamma_{b\bar{b}}$ is either assumed from the standard model [6] or measured [7],[8],[9]. As the single lepton tag events are used, this method has the advantage to be not statistically limited.

A recent analysis [6], using different technique was performed by the L3 experiment. The branching ratio $\text{Br}(b \rightarrow \nu X)$ is measured using the missing energy spectrum of the jets in the two jets events assuming $E_\nu = E_{\text{beam}} - E_{\text{jets}}$. This measurement with energetic neutrino is complementary to the traditional $\text{Br}(b \rightarrow l\nu X)$ measurement (looking for electrons, muons) as it is sensitive to $\text{Br}(b \rightarrow \tau\nu X)$. The total semileptonic branching fraction measured is as shown on Figure 1.

$$\text{Br}(b \rightarrow \nu X) = 23.08 \pm 0.77_{\text{stat}} \pm 1.24_{\text{sys}}\%$$

$\text{Br}(b \rightarrow l\nu X)$ can be extracted if we assume a contribution of 1:1:0.25 for e, μ, τ in the ν spectrum.

2.1.2. Double Tag- $\Gamma_{b\bar{b}}$ independent method

In the limit of no background, $\text{Br}(b \rightarrow l\nu X)$ is proportional to the ratio of the number of dilepton events to the number of single lepton events.

$$\frac{N_{ll}}{N_l} \propto \frac{\text{Br}_{\text{SL}}}{2 \times (1 - \text{Br}_{\text{SL}})} \quad (5)$$

This method [11] has the advantage to be independent at the first order of $\Gamma_{b\bar{b}}$ but is statistically limited as it is based on the dilepton events sample.

In a recent measurement, performed by the ALEPH experiment [10], the Z^0 decays into b quarks are selected with high efficiency ($\sim 60\%$) and a very good purity ($\sim 95\%$) on the basis of the long b-hadron lifetimes. The lepton yield and spectra in hemispheres containing

Figure 1. The jet energy spectrum in the L3 data and the results of the fit for the measurement of $\text{Br}(b \rightarrow \nu X)$

one lepton candidate or two opposite charge leptons candidates are used. Both $\text{Br}(b \rightarrow \nu X)$ and $\text{Br}(b \rightarrow c \rightarrow l)$ are extracted from the fit on the p_T spectrum of the single lepton and lower p_T of dilepton events, the result on the fit is shown on Figure 2. Compared to the dilepton technique, this measurement is not statistically limited.

2.1.3. Models dependence

In all the methods described previously, the $\text{Br}(b \rightarrow \nu X)$ measurement depends on the efficiency which is highly dependent on the lepton momentum spectrum. If we soften the lepton momentum spectrum, we decrease the efficiency and consequently the $\text{Br}(b \rightarrow \nu X)$ increases. The momentum spectrum of the lepton in the b decays at LEP depends on:

- The momentum spectrum of the b hadrons itself; for a harder fragmentation the $\text{Br}(b \rightarrow \nu X)$ is lower: typically by varying the fragmentation from 0.68 to 0.72 the $\text{Br}(b \rightarrow \nu X)$ decreases by about 0.05
- The momentum of the lepton in the b, c rest frame. Addition of D^{**} softens the lepton spectrum and we expect a higher

Figure 2. ALEPH data. Comparison between measured spectra and fits results for Single lepton spectrum (top) and dilepton sample (bottom)

$\text{Br}(b \rightarrow \nu X)$. According to the recommendations of the LEP electroweak working group [12] all LEP experiments use the same models: ACCMM, ISGW, ISGW** [13],[14] for $b \rightarrow l$ decays with parameters extracted from a fit on the CLEO data [15] and DELCO and MARK III[16] concerning the $c \rightarrow l$ decays.

2.1.4. Summary of the model dependent LEP results

In Table 2 all the measurements are quoted with as a first error the statistical error, the second one is the systematic uncertainty due to the detector performances and the inclusive lepton analysis proper to each experiment and the last error is due the modelling (the central value is obtained when using ACCMM model, the ISGW and ISGW** are used as extremes). We took into account this last correlated uncertainty in the estimation of the average value. If we assume $R_b = 0.22$ and $\langle x_e^b \rangle = 0.70$, the LEP average $\text{Br}(b \rightarrow \nu X)$ is (the last measurement quoted in Table 2 is not included in this average as it is statistically correlated to the third measurement):

$$\text{Br}(b \rightarrow l) = 11.07 \pm 0.07_{\text{stat}} \pm 0.16_{\text{syst}} \pm 0.37_{\text{mod}}\%$$

R_b	$\langle x_e^b \rangle$	$\text{Br}(b \rightarrow l\nu X) (\%)$	Experiment
.219	.714	$11.20 \pm 0.30_{\text{stat}} \pm 0.32_{\text{syst}} \pm 0.27_{\text{mod}}$	ALEPH (90-91) [7]
.221	.702	$11.06 \pm 0.39_{\text{stat}} \pm 0.19_{\text{syst}} \pm 0.19_{\text{mod}}$	DELPHI (91-92)[8]
.216	.720	$10.73 \pm 0.11_{\text{stat}} \pm 0.30_{\text{syst}} \pm 0.35_{\text{mod}}$	L3 (91-92) [6]
.225	.697	$10.60 \pm 0.60_{\text{stat}} \pm 0.60_{\text{syst}} \pm 0.40_{\text{mod}}$	OPAL (90-91)[9]
(indep)	.715	$11.34 \pm 0.13_{\text{stat}} \pm 0.28_{\text{syst}} \pm 0.35_{\text{mod}}$	ALEPH (92-93)[10]
(indep)	.685	$11.44 \pm 0.48_{\text{stat}} \pm 0.43_{\text{syst}} \pm 0.31_{\text{mod}}$	L3 (90-91) [11]

Table 2:LEP $\text{Br}(b \rightarrow l\nu X)$ measurements dependent on the models

This measurement is clearly systematics limited as $\Delta\text{Br}(b \rightarrow l)/(\text{Br}(b \rightarrow l)) \sim 3 - 4\%$; the weakness in those analyses is the dependence on lepton for model spectrum.

2.2. Model Independent method. Charge Correlation method in ALEPH

The ARGUS collaboration [17] has introduced a new method using dilepton events that allowed to separate the contributions of primary and secondary lepton without relying on model dependent shapes. This method is also used by the CLEO experiment [18]. A recent measurement described in [10] uses no prediction for p_T spectra: Direct and cascade leptons can be distinguished based on the correlation of their charge with that of the b quark. Two independent measurements are needed to separate them, for that two independent samples of $b\bar{b}$ events are selected.

- In the first sample $b\bar{b}$ events are selected by applying impact parameter tag to one hemisphere, therefore a purity of $\sim 99\%$ is achieved: after that the number F1 of events containing a single lepton in the opposite hemisphere is measured

$$F1 \sim \text{Br}(b \rightarrow c \rightarrow l) + \text{Br}(b \rightarrow l\nu X)$$

- In the second sample, opposite side dilepton events are selected. One tags one side with a high p_t lepton or by using the jet charge technique (to increase the statistics), therefore the charge of the tag lepton gives b quark charge. Opposite sign lepton on the other side are selected with looser cuts on the momentum ($p > 1\text{GeV}/c$) in order to be less sensitive to the model. Then one counts how often the signal lepton charge and the tag lepton charge are opposite, F_{0S} is the number of those events. $F_{0s} \sim \text{Br}(b \rightarrow l\nu X) / (\text{Br}(b \rightarrow l\nu X) + \text{Br}(b \rightarrow c \rightarrow l))$ Two quantities are measured F1 and FOS for two

unknowns : $\text{Br}(b \rightarrow l\nu X)$, $\text{Br}(b \rightarrow c \rightarrow l)$ the extracted $\text{Br}(b \rightarrow l\nu X)$ is then :

$$\text{Br}(b \rightarrow l) = 11.01 \pm 0.23_{\text{stat}} \pm 0.28_{\text{syst}} \pm 0.11_{\text{mod}}\%$$

Value consistent with the model dependent measurement; Here the model dependence has been further reduced at the cost of enlarging the statistical error by using charge correlations rather than fits to the p_T spectra.

2.3. Comparison with measurements at the $\Upsilon(4s)$

To compare $\Upsilon(4s)$ to LEP results we apply the factor correction estimated in section 1.2

Model dependent Method

$$\text{Br}(b \rightarrow l) = 10.3 \pm 0.40\% \quad \Upsilon(4s)$$

$$\text{Br}(b \rightarrow l) = 11.07 \pm 0.40\% \quad \text{LEP}$$

Model independent Method

$$\text{Br}(b \rightarrow l) = 10.20 \pm 0.40\% \quad \Upsilon(4s)$$

$$\text{Br}(b \rightarrow l) = 11.01 \pm 0.38\% \quad \text{LEP}$$

We observe that for both measurements, $\text{Br}(b \rightarrow l\nu X)$ is measured at LEP and in $\Upsilon(4s)$ experiments with equivalent accuracy; we also notice that $\text{Br}(b \rightarrow l\nu X)$ measurements at LEP are slightly higher than those obtained at the $\Upsilon(4s)$ by 1 to 1.5 σ .

2.4. $|V_{cb}|$ extraction from inclusive measurement

To calculate $|V_{cb}|$ from $\text{Br}(b \rightarrow l\nu X)$, we first combine the branching fraction and the b lifetimes at LEP (τ_b) and then use the theoretical calculations which predict the constant γ_c (eq. 2). A good summary of all the theoretical models

Model	γ_c (ps $^{-1}$)	$ V_{cb} \times 1000$
ACCMM	$40. \pm 8.$	$42.0 \pm 1._{exp} \pm 4._{the}$
Shifman et al	$41.3 \pm 4.$	$41.4 \pm 1._{exp} \pm 2._{the}$
Ball et al	$43.2 \pm 4.$	$40.5 \pm 1._{exp} \pm 2._{the}$

Table 3: $|V_{cb}|$ from inclusive $\text{Br}(b \rightarrow l\nu X)$ measurement at LEP

giving γ_c is given in [19]. For different theoretical models, we quote in Table 3 $|V_{cb}|$ values obtained with the measurement of inclusive $\text{Br}(b \rightarrow l\nu X)$. This inclusive measurement yield :

$$|V_{cb}| = (41.2 \pm 1_{exp} \pm 3_{the}) \times 10^{-3}$$

3. THE EXCLUSIVE MEASUREMENTS

3.1. $\text{Br}(B_d^0 \rightarrow D^* l \nu)$ measurement

ALEPH [21] and DELPHI [22] measure this branching ratio while extracting $|V_{cb}|$.

3.1.1. $D^* l \nu$ selection

First in the final state, a high p_T lepton is required then D^0 are exclusively reconstructed for both experiments into $K^+ \pi^-$, $K^+ \pi^- \pi^+ \pi^-$ or $K_s^0 \pi^- \pi^+$ modes as illustrated on Figure 3. An

Figure 3. Example of exclusive D^0 reconstruction in DELPHI

inclusive D^0 analysis is also performed by the

DELPHI experiment; After that a low momentum pion with an opposite charge to the lepton is added to D^0 to build D^* . Finally the candidates are selected by cutting on $\Delta m = m(D^*) - m(D^0)$

3.1.2. The $B_d^0 \rightarrow D^* l \nu X$ background

The main background source and therefore the main contribution to the systematic uncertainty is the contribution of the D^{**} decaying into $D^* \pi$ resonant or non resonant. In the analysis done by the ALEPH experiment this background is minimized as much as possible by :

- using the vertex information where there should be no additional pions consistent with the $D^* l$ vertex
- demanding a low missing mass (less than $1 \text{ GeV}^2/c^4$) as $M_V^2 \sim M_{miss}^2 = (P_B - P_{D^* l})^2$

In the DELPHI analysis, the contribution of the D^{**} is directly measured.

3.1.3. Results

Assuming a fraction of $b \rightarrow B^0$ equal to 0.39 ± 0.02 the total branching fraction $\text{Br}(B_d^0 \rightarrow D^* l \nu)$ is determined to be in ALEPH and DELPHI (respectively):

$$\text{Br}(B_d^0 \rightarrow D^* l \nu) = 5.08 \pm 0.10_{stat} \pm 0.63_{syst} \% \quad [21]$$

$$\text{Br}(B_d^0 \rightarrow D^* l \nu) = 3.51 \pm 0.07_{stat} \pm 0.53_{syst} \% \quad [22]$$

Both measurements are consistent within the errors and are clearly dominated by the systematics. This leads to the LEP average value consistent with the measurement obtained at the $\Upsilon(4s)$ experiments.

$$\text{Br}(B_d^0 \rightarrow D^* l \nu) = 4.16 \pm 0.4 \% \quad \text{LEP}$$

$$\text{Br}(B_d^0 \rightarrow D^* l \nu) = 4.66 \pm 0.4 \% \quad \Upsilon(4s)$$

3.1.4. $|V_{cb}|$ determination

From fits to the distributions of transfer momentum (q^2) (for more details see [21],[22]) the product of $|V_{cb}|$ times the normalization of the form factor $F(q_{max}^2)=F(1)$ are extracted.

$$|V_{cb}| \times F(1) = (31.4 \pm 2.3_{\text{stat}} \pm 2.5_{\text{syst}})10^{-3} \quad [21]$$

$$|V_{cb}| \times F(1) = (37.4 \pm 2.1_{\text{stat}} \pm 3.4_{\text{syst}})10^{-3} \quad [22]$$

Using the value $F(1) = 0.93 \pm 0.03$ [1], the following values for $|V_{cb}|$ are obtained:

$$|V_{cb}| = (33.8 \pm 2.5_{\text{stat}} \pm 2.7_{\text{syst}} \pm 1.3_{\text{theo}})10^{-3} \quad [21]$$

$$|V_{cb}| = (40.2 \pm 2.3_{\text{stat}} \pm 3.7_{\text{syst}} \pm 1.3_{\text{theo}})10^{-3} \quad [22]$$

Both results are consistent within the errors and are consistent with the value obtained with the inclusive measurement of $\text{Br}(b \rightarrow l\nu X)$.

3.2. $\text{Br}(B_d^0 \rightarrow D^{**}l\nu)$ measurement

If we add the previous measurement $\text{Br}(B_d^0 \rightarrow D^*l\nu) = 4.16 \pm 0.41\%$ to $\text{Br}(B_d^0 \rightarrow Dl\nu) = 1.80 \pm 0.41\%$ measured at the $\Upsilon(4s)$ and compare to the inclusive $\text{Br}(b \rightarrow l\nu X)$, clearly some exclusive decays are missing. Furthermore there is clear indications of B decays into D^{**} (The agreement between the CLEO data and ISGW^{**} is better when increasing the contribution of the D^{**} compared to the ISGW model). In fact we expect four neutral and four charged states D^{**} mesons.

Two narrow states (D_1 with a mass equal to 2421 ± 2 MeV and D_2^* with a mass equal to 2458 ± 2 MeV) can be observed as mass peaks; the wide resonances are treated as non resonant four body decays ($D^*l\nu\pi(X)$)

§ 2.1. Narrow D^{**} search

First D^*l candidates are selected as it was described in the previous section, then a pion is associated to the D^*l system and finally one looks for peaks in $\Delta m = m_{D^*\pi} - m_{D^*}$. The D_2^* decays into $D^*\pi$ or $D\pi$ while the D_1 decays only into $D^*\pi$. In other words, D_2^* and D_1 contribute to the $D^*\pi$ channel in one peak due to the resolution of the detectors while in the channel $D\pi$, we expect to see two peaks:

- The first peak is a mixture of D_2^* and D_1 states decaying into $D^*\pi$ with a D^* decaying into $D\pi^0$ where the π^0 is unseen

Figures 4: Δm^{**} distributions for the right-sign, wrong-sign and anti-tagged sign samples for ALEPH [21] (top) and in different channels for OPAL [23] (bottom)

- The second peak is the pure contribution of the D_2^* .

From the Figures 4 we clearly see a peak in the $D^*\pi$ channel the pure D_2^* state is less clearly identified, due to the low statistics.

3.2.2. Wide D^{**} or non resonant $D^*\pi$

The four body decays $D^*\pi l\nu(X)$ analysis is based on vertex topology. Again at a starting point the $D^*l\nu$ analysis is applied, then a second pion so called π_{**} with the same lepton charge is selected

only if it is consistent with the B decay point.

Assuming as previously a $\text{Br}(b \rightarrow B^0, B^-)$ equal to 0.39 ± 0.02 , the results obtained by the LEP experiments are listed in Table 4 and are consistent within the errors. Applying the isospin rules it leads to :

$$\text{Br}(B^- \rightarrow D^* \pi l \nu) = 1.41 \pm 0.37\%$$

$$\text{Br}(B^0 \rightarrow D^* \pi l \nu) = 2.47 \pm 0.37\%$$

If we sum all the exclusive branching ratios and compare this sum to the inclusive measurement we get :

$$\text{Br}(B \rightarrow D, D^*, D^{**} l \nu) = 8 \pm 0.7\%$$

leaving some room for unidentified decays ($\sim 25\%$ of the total inclusive $\text{Br}(b \rightarrow l \nu X)$). We can perhaps suspect some other contributions like higher resonant states or non resonant $D^* l \nu \pi$ with $n > 1$ which are experimentally very difficult to measure.

4. THE $\text{Br}(b \rightarrow \tau \nu X)$ MEASUREMENT

The branching ratio $\text{Br}(b \rightarrow \tau \nu X)$ is expected to be equal to 2 to 3 % according to the Standard Model predictions. A higher $\text{Br}(b \rightarrow \tau \nu X)$ may indicate new physics : for instance models with two Higgs doublets enhance this branching fraction by 10-20 %.

4.1. Methods

The lifetime tags method is applied by three experiments (ALEPH [24], OPAL[26], L3 [6],[25]); then events with inclusive leptons ($b \rightarrow e, \mu$) which are sources of neutrinos are rejected (except in L3 analysis). The $\text{Br}(b \rightarrow \tau \nu X)$ is extracted from a fit on the missing energy spectrum or from an excess of events at large missing energy [24].

The systematic errors are dominated by the contamination of D , decaying into $\tau \nu X$, the knowledge of the fragmentation $\langle x_e^b \rangle$, the knowledge of the branching fraction $\text{Br}(b \rightarrow l \nu X)$ and the missing energy reconstruction.

4.2. Results

Preliminary results are listed in Table 5. It leads to a LEP average value on perfect agreement with

the standard model prediction. Therefore an upper limit of 0.50 is put for $\tan \beta / m_{H^+}$ at 90 % CL for all the models.

5. SUMMARY

Two LEP inclusive results are available; the first one which is clearly dominated by systematic due to the decay model.

$$\text{Br}(b \rightarrow l \nu X) = 11.07 \pm 0.07_{\text{stat}} \pm 0.16_{\text{syst}} \pm 0.35_{\text{mod}}\%$$

The recent one obtained only by the ALEPH experiment where the dependence on the model is significantly reduced. This new approach seems to be promising and will be certainly applied by the other experiments in the future.

$$\text{Br}(b \rightarrow l \nu X) = 11.01 \pm 0.24_{\text{stat}} \pm 0.28_{\text{syst}} \pm 0.11_{\text{mod}}\%$$

Compared to the results obtained at the $\Upsilon(4s)$ experiments with equivalent accuracies, those results are slightly higher by 1 to 1.5 σ .

Concerning the exclusive semileptonic b decay, the branching fraction $\text{Br}(B^0 \rightarrow D^* l \nu)$ is determined to be:

$$\text{Br}(B^0 \rightarrow D^* l \nu) = 4.16 \pm 0.41\%$$

Competitive and consistent with the $\Upsilon(4s)$ measurement. The decays $B \rightarrow D^{**} l \nu$ and $B \rightarrow D^{(*)} \pi l \nu$ are clearly seen at LEP. However it remains some missing decays as the sum of the exclusive branching fraction are lower than the inclusive $\text{Br}(b \rightarrow l \nu X)$.

An updated value also of $\text{Br}(b \rightarrow \tau \nu X)$ is given to be:

$$\text{Br}(b \rightarrow \tau \nu X) = 2.62 \pm 0.10_{\text{stat}} \pm 0.53_{\text{syst}}\%$$

This measurement is in perfect agreement with the standard model prediction.

ACKNOWLEDGEMENTS

In preparing this review, I have profited from many helpful discussions with colleagues from the LEP experiments: J.P. Lees, M. Schmitt, D. Bloch, P. Roudeau, T.S. Dai, G. Rahal-Callot, F. Behner, M. Wadhwa and M. Kobel. Many thanks

	ALEPH [20]	DELPHI [22]	LEP Average
$\text{Br}(B^- \rightarrow D^{*+} \pi^- \nu l^- X)$	$0.95 \pm 0.31\%$	$0.91 \pm 0.53\%$	$0.94 \pm 0.25\%$
$\text{Br}(B^0 \rightarrow D^{*0} \pi^+ \nu l^- X)$	$1.65 \pm 0.44\%$		$1.65 \pm 0.44\%$

Table 4: Exclusive non resonant $\text{Br}(B \rightarrow D^* \pi \nu l X)$ LEP measurements

$\text{Br}(b \rightarrow l \nu X) (\%)$	$\text{Br}(b \rightarrow \tau \nu X) (\%)$	Experiment
11.4	$2.75 \pm 0.30_{\text{stat}} \pm 0.37_{\text{yst}}$	ALEPH (91-93) [24]
10.8	$1.67 \pm 0.46_{\text{stat}} \pm 1.04_{\text{yst}}$	L3 (91-92)[6]
11.1	$2.66 \pm 0.11_{\text{stat}} \pm 0.52_{\text{yst}}$	OPAL (91-94) [26]
11.07	$2.62 \pm 0.10_{\text{stat}} \pm 0.53_{\text{yst}}$	LEP Average

Table 5: LEP $\text{Br}(b \rightarrow \tau \nu X)$ measurements.

for their help. I am also very grateful to the organizers of the conference for giving me the opportunity to participate to such a nice conference in the city of Strasbourg.

REFERENCES

- 1 M.Neubert, Phys.Lett B338 (194) 84.
- 2 G.Altarelli and S.Petrarca, Phys. Lett. B261 (1991) 303
- 3 I.Bigi et al, Phys. Lett. B323 (1994) 408.
- 4 E.Bagan et al., Phys. Lett. B342 (1995) 362.
- 5 B Lifetime measurements at LEP, S.Braibant. (these proceedings).
- 6 Measurement of the Branching ratio $b \rightarrow l \nu X$ with electrons, muons and neutrinos. L3 Collaboration submitted to The EPS Conference, Brussels 1995.
- 7 ALEPH Collaboration, 1994,Z.Phys. C **62**, 179.
- 8 Measurement of $\Gamma_{b\bar{b}}/\Gamma_{had}$ using impact parameter measurements and lepton identification. DELPHI Collaboration. CERN-PPE/95-08.
- 9 OPAL Collaboration, 1993, Z.Phys C **60**, 199.
- 10 Measurement of the semileptonic b branching ratios from inclusive leptons in Z decays.The ALEPH Collaboration, EPS-HEP 95 eps404.
- 11 L3 results on R_b and $\text{Br}(b \rightarrow l \nu X)$ for the Glasgow Conference (1994) and L3 internal note 1625.
- 12 HF of the LEP Electroweak working group. LEPHF/94-01.
- 13 G.Alterelli et al, Nucl. Phys. B 208 (1982) 365.
- 14 N.Isgur,D.Scora,B.Grinstein and M.Wise, Phys. reb. D39 (1989) 799.
- 15 CLEO Collaboration, Phys. Rev. D 45 (1992) 2212.
- 16 DELCO Collaboration, Phys. Rev. Lett. 43 (1979) 1073. The Mark III Collaboration, Phys. Rev. Lett. 54 (1985) 1976
- 17 ARGUS Collaboration, Phys. Lett. B 318 (1993) 397-404
- 18 Recent results on b and c physics from CLEO , V.Jain (these proceedings).
- 19 Leptonic and Semileptonic Decays of Charm and Bottom Hadrons, J.D. Richman and P.R. Burchat,Stanford-HEP-95-01.
- 20 ALEPH Collaboration , Phys. Lett. B345 (1995) 103 and EPS-HEP 95 eps0426
- 21 ALEPH Collaboration EPS-HEP 95 eps0635 and CERN/95-094
- 22 DELPHI Collaboration EPS-HEP 95 eps0569 and DELPHI internal note Phys 545
- 23 OPAL Collaboration, CERN-PPE/95-02 submitted to Zeit. für Physik.
- 24 ALEPH Collaboration, Phys. Lett. B 298 (1993) 479., Phys. Lett. B 343 (1995) 444.
- 25 L3 Collaboration, Phys. Lett. B 332 (1994) 201.
- 26 OPAL Collaboration EPS-HEP 95 eps0282 and note PN 186 (1995).