LEPHF/95-01
ALEPH Note 95-037 PHYSIC 95-035
DELPHI 95-28 PHYS 479
L3 Note 1735
OPAL Technical Note TN283
16 March 1995

LEP Electroweak Heavy Flavour Results for Winter 1995 Conferences Internal Note

The LEP Electroweak Heavy Flavours Working Group*

Abstract

In this note we present the LEP electroweak results from heavy flavour analyses. Average values for the Standard Model parameters R_b, R_c, $A_{FB}^{b\bar{b}}$ and $A_{FB}^{c\bar{c}}$ are derived. The document is based on the analyses available on 1 March 1995. Each LEP experiment has been responsible for providing their results in a common format.

Two fits are investigated: an 11 parameter fit, where the asymmetries are averaged at each of three centre-of-mass energies, and only the peak asymmetries are used to derive the pole asymmetries, $A_{FB}^{0,b}$ or $A_{FB}^{0,c}$, and a 7 parameter fit where all the asymmetry measurements are taken to be a measure of the pole asymmetries. The results of the 11 parameter fit give the combined LEP values:

$$\begin{aligned} R_b &= 0.2204 \pm 0.0020 \\ R_c &= 0.1606 \pm 0.0095 \\ A_{FB}^{0,b} &= 0.1015 \pm 0.0036 \\ A_{FB}^{0,c} &= 0.0760 \pm 0.0089 \end{aligned}$$

There is a large correlation coefficient of –0.36 between R_b and R_c. Fixing R_c to the value predicted by the Standard Model yields:

$$R_b = 0.2196 \pm 0.0019 \text{ with } R_c = 0.171 \text{ (fixed)}.$$

* The current members of the LEP Electroweak Heavy Flavour Working Group are:
D. Abbaneo, P. Antilogus P. Arce, G. Borisov, I. C. Brock, D. G. Charlton, R. Clare, T. S. Dai, A. Halley, R. W. L. Jones, K. Moenig, A. Nippe, A. Passeri, P. Perret, R. Tenchini, P. S. Wells.

1 Introduction

The LEP Electroweak Heavy Flavour Working Group has developed a procedure for combining measurements of the ratios of partial widths $R_{\rm b} = \Gamma_{\rm b\overline{b}}/\Gamma_{\rm had}$ and $R_{\rm c} = \Gamma_{\rm c\overline{c}}/\Gamma_{\rm had}$ and the forward-backward asymmetries $A_{\rm FB}^{\rm b\overline{b}}$ and $A_{\rm FB}^{\rm c\overline{c}}$ [1–3]. New results available for the Spring 1995 conferences are included here. Several of the analyses also determine other quantities, in particular the average mixing parameter, $\overline{\chi}$, the fragmentation parameters $\langle x_E \rangle_{\rm b}$ and $\langle x_E \rangle_{\rm c}$, and the semileptonic branching fractions for b- and c-quarks. Where these quantities are not measured, they often contribute a systematic uncertainty to the Standard Model measurements. Motivated by the lepton fit analyses, the combined values of seven parameters have been determined: the four parameters of interest in the electroweak sector, $R_{\rm b}$, $R_{\rm c}$, $A_{\rm FB}^{\rm b\overline{b}}$ and $A_{\rm FB}^{\rm c\overline{c}}$, and in addition $\overline{\chi}$, Br(b $\rightarrow \ell$) and Br(b $\rightarrow$ c $\rightarrow \ell^+$), to take into account their correlations with the electroweak parameters. The asymmetries vary rapidly with centre-of-mass energy. The asymmetry measurements on-peak, above peak and below peak have therefore been combined separately. Up to now, only the on-peak asymmetries were used to derive the pole asymmetries, $A_{\rm FB}^{0,\,\rm b}$ and $A_{\rm FB}^{0,\,\rm c}$. Here, the effect of including the off-peak asymmetries is investigated, where the Standard Model variation of the asymmetries with centre-of-mass energy is predicted by ZFITTER [20].

The understanding of the effects of the semileptonic decay model uncertainty has progressed since last Summer, when there were inconsistencies in the sign convention. We now consider the average values of Br(b $\rightarrow \ell$), Br(b $\rightarrow$ c $\rightarrow \ell^+$) and $\overline{\chi}$ to be much more reliable. In addition, the dependence of any of the measurements on the semileptonic branching ratios has been taken into account more completely than before.

In the rest of this note, we first list the new measurements. We then describe the corrections made to the asymmetries to derive the pole asymmetries, and discuss one or two new details of the averaging procedure. Finally the updated averages are presented. The full set of measurements to be averaged are provided in standardised tables by the four LEP experiments. Where necessary, the experiments applied small corrections to the results quoted in their papers and notes to use agreed default values and ranges for systematic inputs. These tables are all given in the appendices to the note.

2 New Results

The following have been updated since the ICHEP '94 conference in Glasgow:

ALEPH

- No new results since Glasgow.

DELPHI

- The charm asymmetry with a $\rm D^*$ tag is now published (91+92 data) [19].
- The bottom asymmetry from a lifetime tag and jet charge measure – the 92 measurement is now published, and a preliminary number including 93 data is available [14].
- The bottom asymmetry from a lepton tag – the 91+92 measurement is now published. The preliminary number including 93 data from Glasgow is still valid [14].

- The lepton fit analysis is published (91+92 data) [8]
- The R_b double tag measurement is published (91+92 data) [8].

L3

- R_b and Br(b $\to \ell$) – sign of semilptonic decay model error corrected (90-91 prel)
- $A_{FB}^{b\bar{b}}$, $A_{FB}^{c\bar{c}}$ and $\overline{\chi}$ – sign of semileptonic decay model error corrected (90-93 prel)

OPAL

- R_c measured with a D^* tag is now published [16] (90-92 pub)
- $A_{FB}^{b\bar{b}}$ and $A_{FB}^{c\bar{c}}$ with a lepton tag have been updated [6] (90-94 prel)
- $A_{FB}^{b\bar{b}}$ with a lifetime tag and jet charge measure has been updated. The energy dependence is now also measured [13] (91-94 prel)

3 Treatment of asymmetry measurements

Following the procedure adopted last summer, each asymmetry measurement was propagated to the nearest of the following centre-of-mass energies using the predicted dependence from ZFITTER:

$$\begin{aligned} \sqrt{s} &= 89.55\text{GeV (“peak–2”)}, \\ \sqrt{s} &= 91.26\text{GeV (“peak”)}, \\ \sqrt{s} &= 92.94\text{GeV (“peak+2”)} \end{aligned}$$

These values were chosen as being close to all the $\sqrt{s}$ values at which the measurements were made, and the corrections are in general small. A fit for 11 parameters was made, including $A_{FB}^{b\bar{b}}$ and $A_{FB}^{c\bar{c}}$ at each of these energy points.

An additional 7 parameter fit was also made, in which the off-peak asymmetries were also corrected to $\sqrt{s} = 91.26$ GeV, using the predicted dependence from ZFITTER. In this case additional information was then used to evaluate the pole asymmetries.

After calculating the overall averages, the corrections described below were made to the combined on-peak asymmetries to derive the pole asymmetries. The input measured asymmetries are all corrected to full acceptance and use the thrust axis as an estimate of the quark direction before gluon radiation. To relate $\sin^2\theta_{\text{eff}}$ to these numbers a few corrections that are summarized in table 1 have to be applied:

- Energy shift to $\sqrt{s} = M_Z$ and QED corrections: The slope of the asymmetry around M_Z depends only on the axial coupling and the charge of the initial and final state fermions and is thus independent of the pole asymmetry itself. The corrections due to the energy shift and initial state radiation have been calculated using ZFITTER [20].

- QCD corrections: The QCD corrections using the thrust axis have been calculated recently by Djouardi, Lampe and Zerwas [21] in first order QCD including mass corrections. They have been found to be $A_{FB}^{QCD} = A_{FB}^{noQCD}(1 + c\frac{\alpha_s}{\pi})$ with $c = -0.87$ for charm and $c = -0.79$ for bottom quarks.
  Assuming $\alpha_s(m_Z^2) = 0.12$ and a scale of $\mu^2 = (m_Z/2)^2$ the correction factor is $1 - 0.034 \pm 0.004$ ($1 - 0.037 \pm 0.004$) for b (c) quarks where the error is deduced from a variation of the renormalization scale between $(m_Z/4)^2$ and m_Z^2.
  This result is valid under the assumption of a full acceptance. However it has not yet been studied carefully how far events with very hard gluon radiation contribute in the same way to the asymmetry measurement as two jet events. For that reason another 25% error is assigned to the size of the QCD correction.

- γ exchange, γZ interference: These very small corrections have again been calculated using ZFITTER.

The lifetime/jet-charge measurements of asymmetries take into account QCD effects as an inherent part of the analysis, but the measured asymmetries for the analyses using a lepton or D^* tag need to be corrected for the effects of QCD on the event thrust axis direction. So that the averages could be made at the same level, the jet-charge measurements were adjusted by hand so as to be consistent with the other asymmetry measurements (i.e. 0.0033 was subtracted from each of the three $A_{\rm FB}^{\rm b\bar{b}}$(pk) jet-charge measurements before averaging).

source	δA_{FB}^b	δA_{FB}^c
$\sqrt{s} = M_z$	–0.0013	–0.0034
QED corrections	+0.0041	+0.0104
QCD corrections	$+0.0033 \pm 0.0010$	$+0.0023 \pm 0.0007$
γ, γZ	–0.0003	–0.0008
total	$+0.0058 \pm 0.0010$	$+0.0085 \pm 0.0007$

Table 1: Corrections to be applied to the quark asymmetries. The corrections are to be understood as $A_{FB}^0 = A_{FB}^{meas} + \sum_i (\delta A_{FB})_i$

4 Modifications to the Averaging Procedure

Average values for the following 11 parameters, x^μ, are found from the input results, r_i.

$$
\begin{aligned}
x^\mu \;=\; & R_{\rm b}, \\
& R_{\rm c}, \\
& {\rm Br(b} \to \ell), \\
& {\rm Br(b} \to {\rm c} \to \ell^+) \equiv \text{“Br(bc}\ell\text{)”}, \\
& \overline{\chi}, \\
& A_{\rm FB}^{\rm b\bar{b}}(-2), \\
& A_{\rm FB}^{\rm c\bar{c}}(-2), \\
& A_{\rm FB}^{\rm b\bar{b}}({\rm pk}), \\
& A_{\rm FB}^{\rm c\bar{c}}({\rm pk}), \\
& A_{\rm FB}^{\rm b\bar{b}}(+2), \\
& A_{\rm FB}^{\rm c\bar{c}}(+2)
\end{aligned}
$$

For the 7 parameter fit, $A_{\rm FB}^{\rm b\bar{b}}(-2)$, $A_{\rm FB}^{\rm c\bar{c}}(-2)$, $A_{\rm FB}^{\rm b\bar{b}}(+2)$ and $A_{\rm FB}^{\rm c\bar{c}}(+2)$ are not averaged separately but are interpreted as additional measurements of $A_{\rm FB}^{\rm b\bar{b}}({\rm pk})$ and $A_{\rm FB}^{\rm c\bar{c}}({\rm pk})$.

The corrections to the asymmetries for QED, QCD and energy dependence effects were discussed in the previous section. There are additional corrections to the results $r_i(\mu)$, where the μ indicates that result i is a measurement of parameter μ. These arise from the fact the measured value may depend on the value assumed for one of the other heavy flavour parameters $x^\nu, \nu \neq \mu$. This dependence is put into the fit explicitly, and no separate error due to the uncertainty in $x^\nu, \nu \neq \mu$ is assigned to $r_i(\mu)$. For example, the value of $R_{\rm b}$ almost always depends on the value of $R_{\rm c}$. If for a particular measurement k, this dependence was quoted as:

$$r_k(R_{\rm b}) = R_{\rm b}(R_{\rm c} = 0.171) + a_k \frac{dR_{\rm c}}{R_{\rm c}},$$

then when constructing the χ^2 for the overall fit we make the substitution:

$$r_k(R_{\rm b}) \rightarrow R_{\rm b}(R_{\rm c} = 0.171) + a_k \frac{R_{\rm c} - 0.171}{0.171}$$

where $R_{\rm c}$ is the current estimate of $R_{\rm c}$. These dependences are given in the tables in the apendices, either by quoting the value of a_k, or by quoting the change in the result $r_i(\mu)$ due to varying one of the other electroweak parameters in a specified range. For the previous results [3] the explicit dependences on ${\rm Br(b} \rightarrow \ell)$ and ${\rm Br(b} \rightarrow {\rm c} \rightarrow \ell^+)$ were not included. This has now been rectified, and the dependences taken into account are listed in the tables. There were previously inconsistencies in the sign convention used for the semileptonic decay model. This has also been fixed, which leads to an increase in the error in ${\rm Br(b} \rightarrow \ell)$ to 0.31%. Further checks are in progress to verify the magnitude of the quoted error due to semileptonic decay model by the experiments. The current values are: ALEPH: –0.25%, DELPHI: –0.40%, L3: –0.21%, OPAL: –0.50%. These differences may be due to the use of different kinematic regions in the analyses, and to the details of the techniques used to simulate the different models.

5 Results and cross checks

5.1 Results of the 11 parameter fit

Using the averaging procedure defined in the previous section gives the following combined results for the 11 parameter fit:

$$\begin{aligned}
R_{\rm b} &= 0.2204 \pm 0.0020 \\
R_{\rm c} &= 0.1606 \pm 0.0095 \\
{\rm Br(b} \rightarrow \ell) &= (11.08 \pm 0.31)\% \\
{\rm Br(b} \rightarrow {\rm c} \rightarrow \ell^+) &= (8.22 \pm 0.46)\% \\
\overline{\chi} &= 0.1160 \pm 0.0060 \\
A_{\rm FB}^{\rm b\bar{b}}(-2) &= (4.5 \pm 1.4)\% \\
A_{\rm FB}^{\rm c\bar{c}}(-2) &= (-20.2 \pm 4.3)\% \\
A_{\rm FB}^{\rm b\bar{b}}({\rm pk}) &= (9.57 \pm 0.35)\% \\
A_{\rm FB}^{\rm c\bar{c}}({\rm pk}) &= (6.74 \pm 0.89)\% \\
A_{\rm FB}^{\rm b\bar{b}}(+2) &= (11.9 \pm 1.2)\% \\
A_{\rm FB}^{\rm c\bar{c}}(+2) &= (10.5 \pm 3.7)\%
\end{aligned}$$

With a χ^2/dof of $37.1/(60-11)$, and the correlation matrix (where $Br(1)$ represents Br(b $\to \ell$) and $Br(2)$ represents Br(b $\to$ c $\to \ell^+$)):

	R_b	R_c	$Br(1)$	$Br(2)$	$\overline{\chi}$	$A_{FB}^{b\bar{b}}$ (–2)	$A_{FB}^{c\bar{c}}$ (–2)	$A_{FB}^{b\bar{b}}$ (pk)	$A_{FB}^{c\bar{c}}$ (pk)	$A_{FB}^{b\bar{b}}$ (+2)	$A_{FB}^{c\bar{c}}$ (+2)
R_b	1.000	–.356	–.329	.045	–.052	–.026	–.048	–.006	.110	–.022	.048
R_c	–.356	1.000	.266	.019	–.056	.007	.061	.064	–.134	.021	–.037
$Br(1)$	–.329	.266	1.000	–.119	.284	.001	.073	.090	.170	.008	.036
$Br(2)$	.045	.019	–.119	1.000	–.755	–.025	–.055	–.206	–.262	–.067	–.058
$\overline{\chi}$	–.052	–.056	.284	–.755	1.000	.042	.039	.300	.091	.101	.022
$A_{FB}^{b\bar{b}}(-2)$	–.026	.007	.001	–.025	.042	1.000	.047	–.003	–.024	–.047	–.069
$A_{FB}^{c\bar{c}}(-2)$	–.048	.061	.073	–.055	.039	.047	1.000	–.004	–.102	–.067	–.080
$A_{FB}^{b\bar{b}}$(pk)	–.006	.064	.090	–.206	.300	–.003	–.004	1.000	.234	.026	.078
$A_{FB}^{c\bar{c}}$(pk)	.110	–.134	.170	–.262	.091	–.024	–.102	.234	1.000	.051	.149
$A_{FB}^{b\bar{b}}(+2)$	–.022	.021	.008	–.067	.101	–.047	–.067	.026	.051	1.000	.196
$A_{FB}^{c\bar{c}}(+2)$	.048	–.037	.036	–.058	.022	–.069	–.080	.078	.149	.196	1.000

There is a correlation of—0.36 between R_b and R_c. The total corrections for the on peak asymmetries to give the pole asymmetries are $+0.0058 \pm 0.0010$ and $+0.0085 \pm 0.0007$ for b and c respectively. The main results to be used in electroweak fits are then:

$$\begin{aligned} R_b &= 0.2204 \pm 0.0020 \\ R_c &= 0.1606 \pm 0.0095 \\ A_{FB}^{0,b} &= 0.1015 \pm 0.0036 \\ A_{FB}^{0,c} &= 0.0760 \pm 0.0089 \end{aligned}$$

with their correlation matrix:

	R_b	R_c	$A_{FB}^{0,b}$	$A_{FB}^{0,c}$
R_b	1.000	–.356	–.006	.110
R_c	–.356	1.000	.064	–.134
$A_{FB}^{0,b}$	–.006	.064	1.000	.234
$A_{FB}^{0,c}$	.110	–.134	.234	1.000

If R_c is fixed to 0.171, then the value of R_b is:

$$R_b = 0.2196 \pm 0.0019 \ (R_c = 0.171).$$

5.2 Results of the 7 parameter fit

If the off-peak asymmetries are corrected to $\sqrt{s} = 91.26$ GeVand treated as measurements of the peak asymmetry, the results of the 7 parameter fit are:

$$\begin{aligned} R_b &= 0.2198 \pm 0.0020 \\ R_c &= 0.1637 \pm 0.0095 \\ \text{Br}(b \to \ell) &= (11.09 \pm 0.31)\% \\ \text{Br}(b \to c \to \ell^+) &= (8.21 \pm 0.46)\% \\ \overline{\chi} &= 0.1160 \pm 0.0060 \\ A_{FB}^{b\bar{b}}(\text{pk}) &= (9.47 \pm 0.33)\% \end{aligned}$$

$$A_{FB}^{c\bar{c}}(\mathrm{pk}) \quad = \quad (5.70 \pm 0.85)\%$$

With the χ^2/dof of $53.4/(60-7)$, and a correlation matrix:

	R_b	R_c	$Br(1)$	$Br(2)$	$\overline{\chi}$	$A_{FB}^{b\bar{b}}(\mathrm{pk})$	$A_{FB}^{c\bar{c}}(\mathrm{pk})$
R_b	1.000	–.368	–.285	.075	–.037	–.008	.077
R_c	–.368	1.000	.173	–.035	–.076	.095	–.090
$Br(1)$	–.285	.173	1.000	–.061	.295	.060	.152
$Br(2)$	.075	–.035	–.061	1.000	–.710	–.195	–.292
$\overline{\chi}$	–.037	–.076	.295	–.710	1.000	.311	.079
$A_{FB}^{b\bar{b}}(\mathrm{pk})$	–.008	.095	.060	–.195	.311	1.000	.206
$A_{FB}^{c\bar{c}}(\mathrm{pk})$	.077	–.090	.152	–.292	.079	.206	1.000

There is a correlation of—0.37 between R_b and R_c. The total corrections for the on peak asymmetries to give the pole asymmetries are $+0.0058 \pm 0.0010$ and $+0.0085 \pm 0.0007$ for b and c respectively. The main results to be used in electroweak fits are then:

$$\begin{aligned} R_b &= 0.2198 \pm 0.0020 \\ R_c &= 0.1637 \pm 0.0095 \\ A_{FB}^{0,b} &= 0.1005 \pm 0.0034 \\ A_{FB}^{0,c} &= 0.0655 \pm 0.0086 \end{aligned}$$

with their correlation matrix:

	R_b	R_c	$A_{FB}^{0,b}$	$A_{FB}^{0,c}$
R_b	1.000	–.368	–.008	.077
R_c	–.368	1.000	.095	–.090
$A_{FB}^{0,b}$	–.008	.095	1.000	.206
$A_{FB}^{0,c}$	.077	–.090	.206	1.000

If R_c is fixed to 0.171, then the value of R_b is:

$$R_b = 0.2192 \pm 0.0018 \ (R_c = 0.171).$$

5.3 Cross checks

The parameter whose error has largest contribution from systematic uncertainties is R_b. The full fit result for R_b with $R_c = 0.171$ (fixed) is

$$R_b = 0.2196 \pm 0.0019 \ (\text{Full fit})$$

This value for R_b is dominated by the precise results of the dedicated double-tag analyses for this parameter alone. It is relatively straightforward to combine these single parameter measurements, taking into account the correlated errors. Adding the extra information from the multiparameter lepton fits is much more complicated.

The average of the five single parameter analyses, with fixed $R_c = 0.171$ is

$$R_b = 0.2197 \pm 0.0020 \ (\text{Double tags only})$$

The χ^2/dof is $2.80/(5-1)$. If the multiparameter lepton fits are combined using the full procedure, with all the usual parameters free except for $R_c = 0.171$, the value of R_b is:

$$R_b = 0.2208 \pm 0.0048 \text{ (Lepton fits only)}$$

To a good approximation, the double-tag and lepton multiparameter fit measurements of R_b are uncorrelated. A simple weighted average of these two measurements gives:

$$R_b = 0.2199 \pm 0.0018 \text{ (Double tag plus lepton fits)}$$

This is in extremely good agreement with the result of the full fit with $R_c = 0.171$.

In the following appendices, the relevant results from the papers and notes by the four LEP experiments are tabulated. The errors are quoted in the order: uncorrelated, experiment internal (may be correlated with error on other measurements by the same experiments) and finally fully correlated (can lead to a correlation between results by different experiments) Finally, any dependences on other electroweak parameters are given.

The results in these tables have in some cases been corrected **by the experiments** to use agreed default values and ranges for input parameters. The experiments were also responsible for combining where necessary the results of their different analyses and calculating their internal correlation matrices.

A ALEPH tables

	R_b
results	0.2187
statistics	0.00220
Monte Carlo stat	0.00135
track resolution	0.00145
internal	0.00091
$\langle x_E(c) \rangle$	–0.00012
$f(D^+)$	–0.00073
$f(D^0 + D^+)$	–0.00041
$f(\Lambda_c)$	–0.00019
D^0 lifetime	–0.00028
D^+ lifetime	–0.00036
D_s lifetime	–0.00022
B decay multip.	–0.00029
D decay multip.	–0.00057
$g \to b\overline{b}$	–0.00027
$g \to c\overline{c}$	–0.00019
Long-lived light hadrons	–0.00024
Total systematic	0.0025
Use $R_c = 0.171$	$-0.01378\ dR_c/R_c$

Table 2: Error breakdown for ALEPH lifetime double-tag R_b [7]

	R_b
results	0.228
statistics	0.0054
internal	0.0025
Monte Carlo Stat	0.0023
elec effic	–0.0001
elec misid	+0.0010
muon effic	–0.0002
punch	–0.0017
track resoln	0.
Non-hadronic backgr	–0.0003
acceptance corr	–0.0003
Detector effects	–0.0007
$\langle x_E(\mathrm{b})\rangle$	0.
$\langle x_E(\mathrm{c})\rangle$	0.
b frag function	0.
c frag function	+0.0008
$\mathrm{Br}(\mathrm{b}\to\ell)$	0.
$\mathrm{Br}(\mathrm{b}\to\mathrm{c}\to\ell^+)$	0.
$\mathrm{Br}(\mathrm{b}\to\overline{\mathrm{c}}\to\ell^-)$	0.
$\mathrm{Br}(\mathrm{b}\to\tau\to\ell)$	0.
$\mathrm{Br}(\mathrm{b}\to\mathrm{J}/\psi\to\ell^+\ell^-)$	0.
$\mathrm{Br}(\mathrm{c}\to\ell)$	+0.0006
$\mathrm{Br}(\mathrm{c}\to\mathrm{D}^*\to\mathrm{K}\pi\pi_s)$	0.
Semilept model $\mathrm{b}\to\ell$	–0.0013
Semilept model $\mathrm{c}\to\ell$	–0.0021
$\mathrm{b}\to\mathrm{D}$ model.	0.
$f(\mathrm{D}^0)$	0.
$f(\mathrm{D}^+)$	0.
$f(\mathrm{D}^0+\mathrm{D}^+)$	0.
$f(\mathrm{D}_s)$	0.
$f(\Lambda_c)$	0.
D^0 lifetime	0.
D^+ lifetime	0.
D_s lifetime	0.
Λ_c lifetime	0.
B decay multip.	0.
D decay multip.	0.
$\mathrm{g}\to\mathrm{b}\overline{\mathrm{b}}$	0.
$\mathrm{g}\to\mathrm{c}\overline{\mathrm{c}}$	0.
Long-lived light hadrons	0.
Light quark frag	0.
Total systematic	0.0048
Use $R_c = 0.165 \pm 0.020$	–0.0005

Table 3: Error breakdown for ALEPH neural-net R_b [10]; note that this is 20% statistically correlated with the ALEPH R_b from the multiparameter lepton fit.

	$A_{FB}^{b\bar{b}}$(pk)
results	0.0992
roots	91.187
statistics	0.0085
Monte Carlo stat	0.0022
elec id efficiency	0
elec misid	0
elec conversions	0
muon id efficiency	0
muon id background	0
track resoln	0.0017
internal	0.0012
$\langle x_E(\mathrm{b})\rangle$	0
$\langle x_E(\mathrm{c})\rangle$	0
b frag function	0
c frag function	0
Br(b $\to \ell$)	0
Br(b $\to$ c $\to \ell^+$)	0
Br(b $\to \bar{\mathrm{c}} \to \ell^-$)	0
Br(b $\to \tau \to \ell$)	0
Br(b $\to$ J/$\psi \to \ell^+\ell^-$)	0
Br(c $\to \ell$)	0
Br(c $\to$ D* $\to$ K$\pi\pi_s$)	0
Semilept model b $\to \ell$	0
Semilept model c $\to \ell$	0
b $\to$ D model.	0
$f(\mathrm{D}^0)$	0
$f(\mathrm{D}^+)$	0
$f(\mathrm{D}^0 + \mathrm{D}^+)$	0
$f(\mathrm{D_s})$	0
$f(\Lambda_c)$	0
D^0 lifetime	0
D^+ lifetime	0
$\mathrm{D_s}$ lifetime	0
Λ_c lifetime	0
B decay multip.	0
D decay multip.	0
g $\to \mathrm{b\bar{b}}$	0
g $\to \mathrm{c\bar{c}}$	0
Long-lived light h	0
Light quark frag	0.0023
Total systematic	0.0038
Use $R_b = 0.2188$	$-0.0307\ dR_b/R_b$
Use $R_c = 0.171$	$+0.0257\ dR_c/R_c$

Table 4: Error breakdown for ALEPH jet charge $A_{FB}^{b\bar{b}}$(pk) [12]

	R_b	R_c	$\overline{\chi}$	Br($b \to \ell$)	Br($bc\ell$)	$A_{FB}^{b\bar{b}}$(pk)	$A_{FB}^{c\bar{c}}$(pk)
roots						91.26	91.26
results	0.2162	0.1670	0.0993	0.1120	0.0881	8.43	9.1
statistics	0.0062	0.0054	0.0073	0.0033	0.0025	0.68	2.0
Monte Carlo stat	0.	0.	0.0027	0.	0.	0.03	0.
elec effic	0.0002	−0.0047	0.	−0.0018	−0.0015	0.	0.16
muon effic	−0.0002	−0.0040	0.	−0.0015	−0.0018	0.	0.07
elec conversions	−0.0006	−0.0062	0.	0.0013	−0.0006	0.	0.31
elec misid	+0.0002	−0.0024	−0.0002	−0.0008	−0.0001	0.	0.11
pi/K decays	−0.0016	−0.0057	−0.0005	0.0004	−0.0015	0.01	−0.37
punchthrough	−0.0028	−0.0103	−0.0006	0.0016	−0.0028	0.03	+0.42
lepton effic	0.	0.	0.0001	0.	0.	0.	0.
kaon production	0.	0.	−0.0002	0.	0.	+0.01	0.
backgr chrg corr	0.	0.	0.0002	0.	0.	0.	0.
btocbartol model	0.	0.	0.0002	0.	0.	0.	0.
background asy	0.	0.	0.	0.	0.	−0.02	1.38
track resoln	0.	0.	0.	0.	0.	0.03	0.
internal	0.	0.	0.	0.	0.	0.06	0.
$\langle x_E(b) \rangle$	0.	0.	0.	0.	0.	0.	0.
$\langle x_E(c) \rangle$	0.	0.	0.	0.	0.	+0.07	0.
b frag function	0.	0.	0.	0.	0.	−0.01	0.
c frag function	0.	0.	0.	0.	0.	0.	0.
Br($c \to \ell$)	0.0010	−0.0093	0.	−0.0005	−0.0002	0.05	0.04
Br($b \to \tau \to \ell$)	−0.0003	−0.0006	0.	−0.0003	−0.0009	0.	0.11
Br($b \to \overline{c} \to \ell^-$)	−0.0006	−0.0050	0.0002	−0.0003	−0.0020	0.	0.47
Br($b \to J/\psi \to \ell^+\ell^-$)	+0.0003	+0.0006	0.	−0.0002	−0.0006	0.	−0.02
$BR(b \to u)$	−0.0022	−0.0006	0.0016	+0.0004	+0.0041	−0.03	−0.15
Br($c \to D^* \to K\pi\pi_s$)	0.	0.	0.	0.	0.	0.	0.
Semilept model $c \to \ell$	−0.0008	−0.0010	0.0045	−0.0003	+0.0002	−0.05	−0.17
$b \to D$ model.	−0.0005	−0.0012	0.0004	+0.0006	−0.0004	−0.01	−0.08
Semilept model $b \to \ell$	−0.0027	+0.0041	-0.0017	−0.0025	+0.0051	−0.03	−0.90
$f(D^0)$	0.	0.	0.	0.	0.	0.	0.
$f(D^+)$	0.	0.	0.	0.	0.	0.	0.
$f(D^0 + D^+)$	0.	0.	0.	0.	0.	0.	0.
$f(D_s)$	0.	0.	0.	0.	0.	0.	0.
$f(\Lambda_c)$	0.	0.	0.	0.	0.	0.	0.
D^0 lifetime	0.	0.	0.	0.	0.	0.	0.
D^+ lifetime	0.	0.	0.	0.	0.	0.	0.
D_s lifetime	0.	0.	0.	0.	0.	0.	0.
Λ_c lifetime	0.	0.	0.	0.	0.	0.	0.
B decay multip.	0.	0.	0.	0.	0.	0.	0.
D decay multip.	0.	0.	0.	0.	0.	0.	0.
$g \to b\overline{b}$	0.	0.	−0.0001	0.	0.	+0.01	0.
$g \to c\overline{c}$	0.	0.	−0.0001	0.	0.	+0.01	0.
Long-lived light h	0.	0.	0.	0.	0.	0.	0.
Light quark frag	0.	0.	0.	0.	0.	0.	0.
Total systematic	0.0050	0.0188	0.0058	0.0042	0.0080	0.14	1.9

Table 5: Results of the published ALEPH multiparameter lepton fit and the ALEPH measurement of $A_{FB}^{b\bar{b}}$ and $\overline{\chi}$ using high p_T leptons. These two analyses are combined here by ALEPH for the purpose of averaging with other LEP results [4]

	R_b	R_c	χ	$b \to \ell$	$b \to c \to \ell$	A_b	A_c
R_b	1.00	–0.48	0.00	–0.94	–0.38	0.05	0.05
R_c	–0.48	1.00	0.00	0.47	–0.31	0.00	–0.07
χ	0.00	0.00	1.00	0.27	–0.23	0.25	0.00
$b \to \ell$	–0.94	0.47	0.27	1.00	0.25	–0.04	–0.04
$b \to c \to \ell$	–0.38	–0.31	–0.23	0.25	1.00	–0.01	–0.01
A_b	0.05	0.00	0.25	–0.04	–0.01	1.00	0.01
A_c	0.05	–0.07	0.00	–0.04	–0.01	0.01	1.00

Table 6: ALEPH statistical correlation matrix for lepton measurements.

	R_b	R_c	χ	$b \to \ell$	$b \to c \to \ell$	A_b	A_c
R_b	1.00	0.30	0.00	–0.20	–0.24	0.27	0.12
R_c	0.30	1.00	–0.02	–0.05	0.16	–0.02	–0.29
χ	0.00	–0.02	1.00	0.28	–0.38	–0.12	–0.02
$b \to \ell$	–0.20	–0.05	0.28	1.00	0.02	–0.02	0.23
$b \to c \to \ell$	–0.24	0.16	–0.38	0.02	1.00	–0.24	–0.45
A_b	0.27	–0.02	–0.12	–0.02	–0.24	1.00	0.19
A_c	0.12	–0.29	–0.02	0.23	–0.45	0.19	1.00

Table 7: ALEPH systematic correlation matrix for lepton measurements.

	$A_{\rm FB}^{\rm c\bar{c}}$(pk)
results	7.12
$\sqrt{s}$	91.25
statistics	2.11
D* back rate	0.20
D* back asy	0.65
Rate c-D* / b-D*	0.10
W to D*	0.10
effective chi	0.20
Total systematic	0.72
Use $A_{\rm FB}^{\rm b\bar{b}}$(pk) = 8.46 $\pm$ 0.72%	–0.10

Table 8: Error table for ALEPH D* measurement of $A_{\rm FB}^{\rm c\bar{c}}$(pk) [17]

	$A_{\rm FB}^{\rm b\bar{b}}$	$A_{\rm FB}^{\rm b\bar{b}}$	$A_{\rm FB}^{\rm b\bar{b}}$	$A_{\rm FB}^{\rm b\bar{b}}$	$A_{\rm FB}^{\rm b\bar{b}}$	$A_{\rm FB}^{\rm b\bar{b}}$
results	–0.031	0.033	0.093	0.051	0.105	0.118
roots	88.363	89.424	90.214	92.065	93.023	93.930
statistics	0.110	0.030	0.058	0.049	0.024	0.075
internal	0.001	0.001	0.003	0.002	0.003	0.003

Table 9: ALEPH measurements of $A_{\rm FB}^{\rm b\bar{b}}$ off-peak [4]

B DELPHI tables

results	0.2217
statistics	0.0020
Hemisph correl	0.0011
track Resoln	0.0016
internal	0.0005
$\langle x_E(\mathrm{b})\rangle$	0
$\langle x_E(\mathrm{c})\rangle$	–0.0005
b frag function	0
c frag function	0
$\mathrm{Br}(\mathrm{b} \to \ell)$	0
$\mathrm{Br}(\mathrm{b} \to \mathrm{c} \to \ell^+)$	0
$\mathrm{Br}(\mathrm{b} \to \overline{\mathrm{c}} \to \ell^-)$	0
$\mathrm{Br}(\mathrm{b} \to \tau \to \ell)$	0
$\mathrm{Br}(\mathrm{b} \to \mathrm{J}/\psi \to \ell^+\ell^-)$	0
$\mathrm{Br}(\mathrm{c} \to \ell)$	0.0003
$\mathrm{Br}(\mathrm{c} \to \mathrm{D}^* \to \mathrm{K}\pi\pi_\mathrm{s})$	0
Semilept model $\mathrm{b} \to \ell$	0.0003
Semilept model $\mathrm{c} \to \ell$	–0.0002
$\mathrm{b} \to \mathrm{D}$ model.	0
$f(\mathrm{D}^0)$	–0.0001
$f(\mathrm{D}^+)$	–0.0012
$f(\mathrm{D}^0 + \mathrm{D}^+)$	–0.0007
$f(\mathrm{D_s})$	–0.0005
$f(\Lambda_\mathrm{c})$	0.
D^0 lifetime	–0.0003
D^+ lifetime	–0.0004
$\mathrm{D_s}$ lifetime	–0.0003
Λ_c lifetime	0.
B decay multip.	0.
D decay multip.	–0.0005
$\mathrm{g} \to \mathrm{b\overline{b}}$	–0.0002
$\mathrm{g} \to \mathrm{c\overline{c}}$	–0.0001
Long-lived light h	–0.0008
Light quark frag	0
$\mathrm{Br}(D \to K^0)$	+0.0007
Total systematic	0.0029
Use $R_\mathrm{c} = 0.171 \pm 0.014$	–0.0016

Table 10: Error breakdown for DELPHI R_b [8]

	R_c
results	0.209
statistics	0.019
Monte Carlo stat	0.0054
track resolution	0.0100
b hadron lifetime	0.0013
$\langle x_E(\mathrm{b})\rangle$	–0.0065
Light quark frag	0.0021
Statistical error from Υ_{4S} data	0.0127
Systematics from Υ_{4S} data	0.0180
Total systematic	0.026

Table 11: Breakdown of errors for DELPHI R_c measured using D mesons [15]

	R_b	Br(b $\to \ell$)	Br(bcℓ)	R_c	$\overline{\chi}$
results	0.2145	11.21	7.70	0.1625	0.150
statistics	0.0089	0.45	0.49	0.0085	0.020
Monte Carlo stat	0.	0.	0.	0.	0.
muon backgr	−0.0054	+0.30	−0.91	−0.0160	+0.010
muon effic ec	−0.0004	−0.03	−0.04	−0.0014	0.
muon effic bar	+0.0014	−0.32	−0.25	−0.0038	0.
elec backgr	−0.0029	+0.24	+0.05	−0.0031	−0.003
BR(b $\to$ u)	0	0	−0.03	+0.0002	−0.004
$\langle x_E$(b)$\rangle$	0.	0.	0.	0.	0.
$\langle x_E$(c)$\rangle$	+0.0015	−0.17	+0.28	−0.0056	−0.003
b frag function	−0.0008	+0.11	−0.03	+0.0008	−0.002
c frag function	0.	0.	0.	0.	0.
Br(b $\to \ell$)	0.	0.	0.	0.	0.
Br(b $\to$ c $\to \ell^+$)	0.	0.	0.	0.	0.
Br(b $\to \overline{\text{c}} \to \ell^-$)	+0.0003	+0.01	−0.33	+0.0013	+0.003
Br(b $\to \tau \to \ell$)	−0.0002	−0.03	−0.13	−0.0002	+0.001
Br(b $\to$ J/$\psi \to \ell^+\ell^-$)	+0.0002	−0.06	+0.02	0	−0.002
Br(c $\to \ell$)	+0.0014	−0.06	−0.04	−0.0098	−0.002
Br(c $\to$ D* $\to$ K$\pi\pi_s$)	0.	0.	0.	0.	0.
Semilept model b $\to \ell$	−0.0001	−0.40	+0.69	+0.0004	−0.008
Semilept model c $\to \ell$	+0.0007	−0.16	−0.03	+0.0049	−0.006
b $\to$ D model.	0.	0.	0.	0.	0.
f(D^0)	0.	0.	0.	0.	0.
f(D$^+$)	0.	0.	0.	0.	0.
f(D^0 + D$^+$)	0.	0.	0.	0.	0.
f(D$_s$)	0.	0.	0.	0.	0.
$f(\Lambda_c)$	0.	0.	0.	0.	0.
D^0 lifetime	0.	0.	0.	0.	0.
D$^+$ lifetime	0.	0.	0.	0.	0.
D$_s$ lifetime	0.	0.	0.	0.	0.
Λ_c lifetime	0.	0.	0.	0.	0.
B decay multip.	0.	0.	0.	0.	0.
D decay multip.	0.	0.	0.	0.	0.
g $\to$ b$\overline{\text{b}}$	0.	0.	0.	0.	0.
g $\to$ c$\overline{\text{c}}$	0.	0.	0.	0.	0.
Long-lived light h	0.	0.	0.	0.	0.
Light quark frag	0.	0.	0.	0.	0.
Total systematic	0.0067	0.70	1.26	0.021	0.016

Table 12: DELPHI lepton fit results [8]

	R_b	Br(b $\to \ell$)	Br(bcℓ)	R_c	$\overline{\chi}$
R_b	1.00	–0.95	–0.38	–0.42	–0.09
Br(b $\to \ell$)	–0.95	1.00	0.29	0.37	0.11
Br(bcℓ)	–0.38	0.29	1.00	–0.40	–0.17
R_c	–0.42	0.37	–0.40	1.00	0.17
$\overline{\chi}$	–0.09	0.11	–0.17	0.17	1.00

Table 13: DELPHI lepton fit statistical correlation matrix

	$A_{FB}^{b\bar{b}}$(pk)	$A_{FB}^{c\bar{c}}$(pk)	$A_{FB}^{b\bar{b}}(-2)$	$A_{FB}^{b\bar{b}}(+2)$
$\sqrt{s}$	91.255	91.269	89.43	93.017
results	0.1065	0.0802	0.0629	0.1489
statistics	0.011	0.022	0.038	0.036
muon id	0.0021	0.0051	0.0013	0.0040
elec id	0.0014	0.0025	0.0	0.0
track resoln	0.0013	0.0009	0.0006	0.0020
backgr asy	–0.001	+0.0102	–0.0001	0.0001
internal	0.0013	0.0045	0.0006	0.0020
$\langle x_E(\mathrm{b})\rangle$	–0.0001	–0.0005	+0.0002	–0.0001
$\langle x_E(\mathrm{c})\rangle$	+0.0011	+0.0001	–0.0001	+0.0014
b frag function	0.	0.	0.	0.
c frag function	0.	0.	0.	0.
$\mathrm{Br}(\mathrm{b}\to\overline{\mathrm{c}}\to\ell^-)$	0.0007	0.0038	0.0001	0.0017
$\mathrm{Br}(\mathrm{b}\to\tau\to\ell)$	0.	0.	0.	0.
$\mathrm{Br}(\mathrm{b}\to \mathrm{J}/\psi\to\ell^+\ell^-)$	0.	0.	0.	0.
$\mathrm{Br}(\mathrm{c}\to\ell)$	0.0004	–0.0037	0.0003	–0.0007
$\mathrm{Br}(\mathrm{c}\to \mathrm{D}^*\to \mathrm{K}\pi\pi_s)$	0.	0.	0.	0.
Semilept model $\mathrm{b}\to\ell$	0.0004	–0.0060	0.0015	0.0015
Semilept model $\mathrm{c}\to\ell$	0.0018	–0.0013	0.0004	0.0022
$\mathrm{b}\to\mathrm{D}$ model.	0.	0.	0.	0.
$f(\mathrm{D}^0)$	0.	0.	0.	0.
$f(\mathrm{D}^+)$	0.	0.	0.	0.
$f(\mathrm{D}^0+\mathrm{D}^+)$	0.	0.	0.	0.
$f(\mathrm{D}_s)$	0.	0.	0.	0.
$f(\Lambda_c)$	0.	0.	0.	0.
D^0 lifetime	0.	0.	0.	0.
D^+ lifetime	0.	0.	0.	0.
D_s lifetime	0.	0.	0.	0.
Λ_c lifetime	0.	0.	0.	0.
B decay multip.	0.	0.	0.	0.
D decay multip.	0.	0.	0.	0.
$\mathrm{g}\to\mathrm{b}\overline{\mathrm{b}}$	0.	0.	0.	0.
$\mathrm{g}\to\mathrm{c}\overline{\mathrm{c}}$	0.	0.	0.	0.
Long-lived light h	0.	0.	0.	0.
Light quark frag	0.	0.	0.	0.
Total systematic	0.0040	0.015	0.0023	0.0061
Use $R_b = 0.217 \pm 0.003$	–0.0004	+0.0004	–0.0001	–0.0004
Use $R_c = 0.171 \pm 0.014$	+0.0009	–0.0053	+0.0001	–0.0008
Use $\overline{\chi} = 0.121 \pm 0.0165$	0.0046	0.	+0.0028	+0.0065
Use $\mathrm{Br}(\mathrm{b}\to\ell) = 11.0 \pm 0.34$	–0.0012	0.0015	–0.0003	–0.0010
Use $\mathrm{Br}(\mathrm{b}\to\mathrm{c}\to\ell^+) = 7.9 \pm 0.5$	0.0003	–0.0025	0.0001	0.0003

Table 14: DELPHI measurements of asymmetries using a lepton tag [14]

	$A_{FB}^{b\bar{b}}$(pk)	$A_{FB}^{c\bar{c}}$(pk)	$A_{FB}^{b\bar{b}}(-2)$	$A_{FB}^{b\bar{b}}(+2)$
$A_{FB}^{b\bar{b}}$(pk)	1.000	0.23	0.	0.
$A_{FB}^{c\bar{c}}$(pk)	0.23	1.000	0.	0.
$A_{FB}^{b\bar{b}}(-2)$	0.	0.	1.000	0.
$A_{FB}^{b\bar{b}}(+2)$	0.	0.	0.	1.000

Table 15: DELPHI lepton tag asymmetries statistical correlation matrix

	$A_{FB}^{b\bar{b}}$(pk)	$A_{FB}^{c\bar{c}}$(pk)
$\sqrt{s}$	91.27	91.27
results	.059	.077
statistics	.062	.029
Monte Carlo stat	–.009	.005
internal	.015	.006
detector effects	.002	.004
rate of pi_s	.009	–.006
D* b sample	.005	–.002
D* back rate	.002	.003
b hadron lifetime	–.004	.002
effective chi	.012	–.003
thrust resoln	.001	.001
$\langle x_E(\mathrm{b})\rangle$	–.001	.001
$\langle x_E(\mathrm{c})\rangle$	.002	.001
Total systematic	.024	.012

Table 16: Asymmetry measurements with a D^* tag from DELPHI [19]

	$A_{FB}^{b\bar{b}}$(pk)	$A_{FB}^{c\bar{c}}$(pk)
$A_{FB}^{b\bar{b}}$(pk)	1.0	–.38
$A_{FB}^{c\bar{c}}$(pk)	–.38	1.0

Table 17: Statistical correlation matrix for asymmetry measurements with a D^* tag from DELPHI

	$A_{FB}^{b\bar{b}}$(pk)	$A_{FB}^{c\bar{c}}$(pk)
$A_{FB}^{b\bar{b}}$(pk)	1.00	–.22
$A_{FB}^{c\bar{c}}$(pk)	–.22	1.0

Table 18: Systematic correlation matrix for asymmetry measurements with a D^* tag from DELPHI

	$A_{\rm FB}^{\rm b\bar{b}}$(pk)
results	0.115
$\sqrt{s}$	91.258
statistics	0.013
Monte Carlo stat	0
lepton id	–0.0014
track resoln	0.
internal	0.0055
$\langle x_E(\mathrm{b})\rangle$	–0.0001
$\langle x_E(\mathrm{c})\rangle$	+0.0022
b frag function	0
c frag function	0
Br($\mathrm{b} \to \bar{\mathrm{c}} \to \ell^-$)	0.0001
Br($\mathrm{b} \to \tau \to \ell$)	0
Br($\mathrm{b} \to \mathrm{J}/\psi \to \ell^+\ell^-$)	0
Br($\mathrm{c} \to \ell$)	0.0003
Br($\mathrm{c} \to \mathrm{D}^* \to \mathrm{K}\pi\pi_\mathrm{s}$)	0
Semilept model $\mathrm{b} \to \ell$	–0.0003
Semilept model $\mathrm{c} \to \ell$	0.0004
$\mathrm{b} \to \mathrm{D}$ model.	0
$f(\mathrm{D}^0)$	0
$f(\mathrm{D}^+)$	0
$f(\mathrm{D}^0 + \mathrm{D}^+)$	0
$f(\mathrm{D_s})$	0
$f(\Lambda_\mathrm{c})$	0
D^0 lifetime	0
D^+ lifetime	0
$\mathrm{D_s}$ lifetime	0
Λ_c lifetime	0
B decay multip.	0
D decay multip.	0
$\mathrm{g} \to \mathrm{b\bar{b}}$	0
$\mathrm{g} \to \mathrm{c\bar{c}}$	0
Long-lived light h	0
Light quark frag	0.0018
Total systematic	0.0064
Use $R_\mathrm{b} = 0.217$	$-0.0495\ dR_\mathrm{b}/R_\mathrm{b}$
Use $R_\mathrm{c} = 0.171$	$+0.0167\ dR_\mathrm{c}/R_\mathrm{c}$
Use $\overline{\chi} = 0.115$	$+0.0313\ d\overline{\chi}/\overline{\chi}$
Use $\mathrm{Br}(\mathrm{b} \to \ell) = 11.0 \pm 0.34$	0.0006
Use $\mathrm{Br}(\mathrm{b} \to \mathrm{c} \to \ell^+) = 7.9 \pm 0.5$	–0.0006

Table 19: DELPHI $A_{\rm FB}^{\rm b\bar{b}}$(pk) from jet charge [14]

C L3 tables

	R_b
results	0.222
statistics	0.003
internal	0.0021
$\langle x_E(b)\rangle$	–0.0031
$\langle x_E(c)\rangle$	+0.0018
b frag function	0.
c frag function	0.
Br($b \to c \to \ell^+$)	0.
Br($b \to \bar{c} \to \ell^-$)	0.
Br($b \to \tau \to \ell$)	0.
Br($b \to J/\psi \to \ell^+\ell^-$)	0.
Br($c \to \ell$)	0.
Br($c \to D^* \to K\pi\pi_s$)	0.
Semilept model $b \to \ell$	0.
Semilept model $c \to \ell$	0.
$b \to D$ model.	0.
$f(D^0)$	0.
$f(D^+)$	0.
$f(D^0 + D^+)$	0.
$f(D_s)$	0.
$f(\Lambda_c)$	0.
D^0 lifetime	0.
D^+ lifetime	0.
D_s lifetime	0.
Λ_c lifetime	0.
B decay multip.	0.
D decay multip.	0.
$g \to b\bar{b}$	0.
$g \to c\bar{c}$	0.
Long-lived light hadrons	0.
Light quark frag.	+0.0049
Total systematic	0.007
Use $R_c = 0.171 \pm 0.009$	–0.0011
Use Br($b \to \ell$) $= 10.5 \pm 0.5$	–0.0010

Table 20: Error breakdown for L3 neural net R_b [11]

	R_b	Br(b $\to \ell$)
results	0.2187	0.1144
statistics	0.0081	0.0048
internal	0.0047	0.0028
$\langle x_E(b) \rangle$	0.0029	–0.0024
$\langle x_E(c) \rangle$	0.0004	–0.0002
Br(c $\to \ell$)	–0.0012	0.0003
Semilept model b $\to \ell$	+0.0009	–0.0021
Semilept model c $\to \ell$	0.0007	0.0003
Total systematic	0.0058	0.0043
Use $R_c = 0.171 \pm 0.014$	–0.0019	0.0005
Use Br(b $\to$ c $\to \ell^+$) $= 10.5 \pm 0.5$	0.0052	0.0007

Table 21: Error breakdown for L3 R_b and Br(b $\to \ell$) measurement using leptons [5]

	R_b	Br(b $\to \ell$)
R_b	1.	–0.98
Br(b $\to \ell$)	–0.98	1.

Table 22: Statistical correlation matrix for L3 R_b and Br(b $\to \ell$)

	R_b	Br(b $\to \ell$)
R_b	1.	–0.32
Br(b $\to \ell$)	–0.32	1.

Table 23: Systematic correlation matrix for L3 R_b and Br(b $\to \ell$)

	$A_{FB}^{b\bar{b}}(-2)$	$A_{FB}^{b\bar{b}}(pk)$	$A_{FB}^{b\bar{b}}(+2)$	$A_{FB}^{c\bar{c}}(pk)$	$\overline{\chi}$
$A_{FB}^{b\bar{b}}(-2)$	1.00	0.00	0.00	0.0	0.06
$A_{FB}^{b\bar{b}}(pk)$	0.00	1.00	0.00	0.0	0.30
$A_{FB}^{b\bar{b}}(+2)$	0.00	0.00	1.00	0.0	0.10
$A_{FB}^{c\bar{c}}(pk)$	0.0	0.0	0.0	1.00	0.00
$\overline{\chi}$	0.06	0.30	0.10	0.00	1.00

Table 24: Statistical correlation matrix for lepton fit for asymmetries from L3

	$A_{FB}^{b\bar{b}}(-2)$	$A_{FB}^{b\bar{b}}(pk)$	$A_{FB}^{b\bar{b}}(+2)$	$A_{FB}^{c\bar{c}}(pk)$	$\overline{\chi}$
$A_{FB}^{b\bar{b}}(-2)$	1.00	1.00	1.00	0.00	0.14
$A_{FB}^{b\bar{b}}(pk)$	1.00	1.00	1.00	0.00	0.27
$A_{FB}^{b\bar{b}}(+2)$	1.00	1.00	1.00	0.00	0.27
$A_{FB}^{c\bar{c}}(pk)$	0.00	0.00	0.00	1.00	0.00
$\overline{\chi}$	0.14	0.27	0.27	0.00	1.00

Table 25: Systematic correlation matrix for lepton fit for asymmetries from L3

	$A_{FB}^{b\bar{b}}(-2)$	$A_{FB}^{b\bar{b}}(pk)$	$A_{FB}^{b\bar{b}}(+2)$	$A_{FB}^{c\bar{c}}(pk)$	$\overline{\chi}$
$\sqrt{s}$	89.56	91.27	92.93	91.24	0.
results	7.02	10.28	11.02	7.84	0.1253
statistics	3.50	1.00	2.90	3.70	0.0110
internal	+0.3500	+0.3600	+0.3610	+2.4000	+0.005160
$\langle x_E(b)\rangle$	+0.0293	+0.0227	+0.0227	−0.4444	−0.001000
$\langle x_E(c)\rangle$	−0.0120	−0.0120	−0.0120	−0.2000	+0.000030
b frag function	0.	0.	0.	0.	0.
c frag function	0.	0.	0.	0.	0.
$Br(b \to \overline{c} \to \ell^-)$	−0.0110	−0.0085	−0.0080	0.	+0.000430
$Br(b \to \tau \to \ell)$	0.	0.	0.	0.	0.
$Br(b \to J/\psi \to \ell^+\ell^-)$	0.	0.	0.	0.	0.
$Br(c \to \ell)$	+0.0467	+0.0467	+0.0471	−0.3333	+0.000033
$Br(c \to D^* \to K\pi\pi_s)$	0.	0.	0.	0.	0.
Semilept model $b \to \ell$	−0.0850	−0.0870	−0.0870	0.	−0.000300
Semilept model $c \to \ell$	−0.0550	−0.0430	−0.0420	0.	+0.001860
$b \to D$ model.	+0.0410	+0.0470	+0.0470	0.	+0.001530
$f(D^0)$	0.	0.	0.	0.	0.
$f(D^+)$	0.	0.	0.	0.	0.
$f(D^0 + D^+)$	0.	0.	0.	0.	0.
$f(D_s)$	0.	0.	0.	0.	0.
$f(\Lambda_c)$	0.	0.	0.	0.	0.
D^0 lifetime	0.	0.	0.	0.	0.
D^+ lifetime	0.	0.	0.	0.	0.
D_s lifetime	0.	0.	0.	0.	0.
Λ_c lifetime	0.	0.	0.	0.	0.
B decay multip.	0.	0.	0.	0.	0.
D decay multip.	0.	0.	0.	0.	0.
$g \to b\overline{b}$	0.	0.	0.	0.	0.
$g \to c\overline{c}$	0.	0.	0.	0.	0.
Long-lived light h	0.	0.	0.	0.	0.
Light quark frag	0.	0.	0.	0.	0.
Total systematic	0.38	0.38	0.39	2.5	0.0081
Use $R_b = 0.216 \pm 0.005$	−0.0380	−0.0380	−0.0380	+0.1000	+0.000020
Use $R_c = 0.169 \pm 0.005$	+0.0270	+0.0270	+0.0270	−0.2000	+0.000020
Use $A_{FB}^{c\bar{c}}(-2) = -2.90 \pm 1.50$	+0.1380	0.	0.	0.	0.
Use $A_{FB}^{c\bar{c}}(pk) = 6.30 \pm 1.50$	0.	+0.1380	0.	0.	0.
Use $A_{FB}^{c\bar{c}}(+2) = 12.10 \pm 1.50$	0.	0.	+0.1380	0.	0.
Use $A_{FB}^{b\bar{b}}(pk) = 8.8 \pm 1.1$	0.	0.	0.	0.8	0.
Use $Br(b \to \ell) = 10.5 \pm 0.5$	−0.0442	−0.0308	−0.0300	+0.1667	+0.002200
Use $Br(b \to c \to \ell^+) = 7.9 \pm 1.2$	−0.0100	−0.0430	−0.0460	−0.5000	−0.005190

Table 26: Results of the lepton fits from L3 [5]

D OPAL tables

	R_b
Result	0.2171
Statistics	0.00207
Monte Carlo stat	0.00049
Elec id efficiency	0.00012
Elec misid	0.00027
Elec conversions	0.00027
Muon id efficiency	0.00005
Muon id background	0.00041
Track resolution	0.00071
Efficiency correlation	0.00069
Event selection	0.00025
$\langle x_E(\mathrm{b})\rangle$	0.0
$\langle x_E(\mathrm{c})\rangle$	–0.00072
b frag function	0.0
c frag function	0.0
$\mathrm{Br}(\mathrm{b}\to\ell)$	0.0
$\mathrm{Br}(\mathrm{b}\to\mathrm{c}\to\ell^+)$	0.0
$\mathrm{Br}(\mathrm{b}\to\overline{\mathrm{c}}\to\ell^-)$	0.0
$\mathrm{Br}(\mathrm{b}\to\tau\to\ell)$	0.0
$\mathrm{Br}(\mathrm{b}\to\mathrm{J}/\psi\to\ell^+\ell^-)$	0.0
$\mathrm{Br}(\mathrm{c}\to\ell)$	–0.00028
$\mathrm{Br}(\mathrm{c}\to\mathrm{D}^*\to\mathrm{K}\pi\pi_s)$	0.0
Semilept model $\mathrm{b}\to\ell$	0.0
Semilept model $\mathrm{c}\to\ell$	–0.00024
$\mathrm{b}\to\mathrm{D}$ model.	0.0
$f(\mathrm{D}^0)$	+0.00002
$f(\mathrm{D}^+)$	–0.00065
$f(\mathrm{D}^0+\mathrm{D}^+)$	–0.00036
$f(\mathrm{D}_s)$	–0.00049
$f(\Lambda_c)$	0.
D^0 lifetime	–0.00022
D^+ lifetime	–0.00028
D_s lifetime	–0.00017
Λ_c lifetime	–0.00005
B decay multip.	0.0
D decay multip.	–0.00073
$\mathrm{Br}(D\to K^0)$	+0.00057
$\mathrm{g}\to\mathrm{b}\overline{\mathrm{b}}$	0.
$\mathrm{g}\to\mathrm{c}\overline{\mathrm{c}}$	–0.00048
Long-lived light h	–0.00049
Light quark frag	0.0
Total systematic	0.00210
R_c	$-0.01867\, dR_c/R_c$

Table 27: Error breakdown for OPAL double-tag R_b. Entries marked "0.0" are negligible. [9]

	R_b	$Br(b \to \ell)$	$Br(b \to c \to \ell^+)$	$\overline{\chi}$
$\sqrt{s}$	–	–	–	–
Results	.225	10.5	8.3	.144
Statistics	.011	.60	.40	.022
Monte Carlo statistics	.003	.22	.14	.003
Λ_b polarisation	0.0	–.01	.08	0.0
$Br(b \to c \to \ell^+)$ syst.	–.0014	.072	–.49	.0042
Muon ID efficiency	.001	.24	.13	.001
Muon polar angle	.001	–.02	–.01	0.0
Elec ID efficiency	–.001	.18	.14	.001
e bremsstrahlung	0.0	0.0	0.0	0.0
Muon ID background	.002	–.09	.06	–.001
Elec misid	.001	–.02	.03	0.0
Elec conversions	.001	–.02	–.09	0.0
e decay background	0.0	.01	–.08	.001
Elec source dep	0.0	0.0	0.0	0.0
Track resolution	0.0	0.0	0.0	0.0
Track charge error	0.0	0.0	0.0	0.0
$\langle x_E \rangle_b$	0.0	0.0	0.0	0.0
$\langle x_E \rangle_c$	–.002	.04	.05	.001
b frag function	–.001	–.16	–.07	.001
c frag function	0.0	0.0	0.0	0.0
$Br(b \to \overline{c} \to \ell^-)$	.001	–.06	–.07	0.0
$Br(b \to \tau \to \ell)$	.001	–.07	–.04	0.0
$Br(b \to J/\psi \to \ell^+\ell^-)$	0.0	0.0	0.0	0.0
$Br(c \to \ell)$	–.00045	–.0045	.018	.0009
$Br(c \to D^* \to K\pi\pi_s)$	0.0	0.0	0.0	0.0
Semilept model $b \to \ell$	–.004	–.50	.20	–.002
Semilept model $c \to \ell$	–.001	–.03	–.31	–.001
$b \to D$ model.	0.0	0.0	0.0	0.0
$f(D^0)$	0.0	0.0	0.0	0.0
$f(D^+)$	0.0	0.0	0.0	0.0
$f(D^0 + D^+)$	0.0	0.0	0.0	0.0
$f(D_s)$	0.0	0.0	0.0	0.0
$f(\Lambda_c)$	0.0	0.0	0.0	0.0
D^0 lifetime	0.0	0.0	0.0	0.0
D^+ lifetime	0.0	0.0	0.0	0.0
D_s lifetime	0.0	0.0	0.0	0.0
Λ_c lifetime	0.0	0.0	0.0	0.0
B decay multip.	0.0	0.0	0.0	0.0
D decay multip.	0.0	0.0	0.0	0.0
$g \to b\overline{b}$	0.0	0.0	0.0	0.0
$g \to c\overline{c}$	0.0	0.0	0.0	0.0
Long-lived light h	0.0	0.0	0.0	0.0
Light quark frag	0.0	0.0	0.0	0.0
Total systematic	.0066	0.66	0.69	0.0062
Use $R_c = 0.171 \pm 0.013$	–0.001	0.017	0.001	–0.05

Table 28: Results of the OPAL multiparameter lepton fit – part I [6]

	$A_{FB}^{b\bar{b}}(-2)$	$A_{FB}^{c\bar{c}}(-2)$	$A_{FB}^{b\bar{b}}(pk)$	$A_{FB}^{c\bar{c}}(pk)$	$A_{FB}^{b\bar{b}}(+2)$	$A_{FB}^{c\bar{c}}(+2)$
$\sqrt{s}$	89.54	89.54	91.24	91.24	92.94	92.94
Results	3.3	-21.1	10.3	5.2	12.1	9.0
Statistics	3.0	4.8	0.9	1.0	2.7	4.0
Monte Carlo stat	0.0	0.0	0.0	0.0	0.0	0.0
Λ_b polarisation	–0.02	– 0.05	0.01	– 0.05	0.02	–0.05
Br($b \to c \to \ell^+$) syst.	0.08	0.45	0.05	0.22	0.02	0.18
Muon id efficiency	0.0	0.0	0.0	0.0	0.0	0.0
Muon polar angle	0.0	0.0	0.0	0.0	0.0	0.0
Elec id efficiency	0.0	0.0	0.0	0.0	0.0	0.0
e bremsstrahlung	0.0	0.0	0.0	0.0	0.0	0.0
Muon id background	–0.09	–0.56	0.13	0.31	0.18	0.37
Elec misid	–0.08	–0.84	0.07	0.18	0.23	0.14
Elec conversions	–0.72	–2.52	0.18	0.68	0.52	1.70
e decay background	0.0	0.0	0.0	0.0	0.0	0.0
Elec source dep	0.01	–0.26	0.03	–0.06	0.04	–0.06
Track resolution	–0.01	–0.12	0.02	0.07	0.01	0.12
Track charge error	0.01	0.07	0.03	0.01	0.04	0.03
$\langle x_E \rangle_b$	–0.01	–0.30	–0.04	–0.11	–0.07	–0.14
$\langle x_E \rangle_c$	–0.21	0.29	0.19	–0.17	0.27	–0.18
b frag function	0.0	0.0	0.0	0.0	0.0	0.0
c frag function	0.0	0.0	0.0	0.0	0.0	0.0
Br($b \to \bar{c} \to \ell^-$)	–0.05	–0.17	0.07	0.40	0.11	0.52
Br($b \to \tau \to \ell$)	0.0	–0.07	0.02	0.18	0.01	0.21
Br($b \to J/\psi \to \ell^+\ell^-$)	0.04	0.22	0.01	0.07	–0.03	0.03
Br($c \to \ell$)	–0.03	0.59	0.09	–0.20	0.14	–0.23
Br($c \to D^* \to K\pi\pi_s$)	0.0	0.0	0.0	0.0	0.0	0.0
Semilept model $b \to \ell$	–0.05	0.20	–0.05	–0.63	0.08	–0.64
Semilept model $c \to \ell$	–0.09	0.27	0.13	–0.06	0.22	0.02
$b \to D$ model.	0.0	0.0	0.0	0.0	0.0	0.0
$f(D^0)$	0.0	0.0	0.0	0.0	0.0	0.0
$f(D^+)$	0.0	0.0	0.0	0.0	0.0	0.0
$f(D^0 + D^+)$	0.0	0.0	0.0	0.0	0.0	0.0
$f(D_s)$	0.0	0.0	0.0	0.0	0.0	0.0
$f(\Lambda_c)$	0.0	0.0	0.0	0.0	0.0	0.0
D^0 lifetime	0.0	0.0	0.0	0.0	0.0	0.0
D^+ lifetime	0.0	0.0	0.0	0.0	0.0	0.0
D_s lifetime	0.0	0.0	0.0	0.0	0.0	0.0
Λ_c lifetime	0.0	0.0	0.0	0.0	0.0	0.0
B decay multip.	0.0	0.0	0.0	0.0	0.0	0.0
D decay multip.	0.0	0.0	0.0	0.0	0.0	0.0
$g \to b\bar{b}$	0.0	0.0	0.0	0.0	0.0	0.0
$g \to c\bar{c}$	0.0	0.0	0.0	0.0	0.0	0.0
Long-lived light h	0.0	0.0	0.0	0.0	0.0	0.0
Light quark frag	0.0	0.0	0.0	0.0	0.0	0.0
Total systematic	0.8	3.0	0.4	1.2	0.7	2.0
Use $R_c = 0.171 \pm 0.013$	–0.05	+0.91	+0.13	–0.29	+0.20	–0.36

Table 29: Results of the OPAL multiparameter lepton fit – part II [6]

	$A_{FB}^{b\bar{b}}$(pk)	$A_{FB}^{b\bar{b}}$(–2)	$A_{FB}^{b\bar{b}}$(+2)
$\sqrt{s}$	91.25	89.52	92.94
Result	0.0973	0.063	0.173
Statistics	0.0067	0.034	0.029
Monte Carlo stat	0.0013	0.0003	0.0024
Track resolution	0.0021	0.0014	0.0036
Internal	0.0018	0.0011	0.0034
$\langle x_E(\mathrm{b})\rangle$	0	0	0
$\langle x_E(\mathrm{c})\rangle$	0	0	0
b frag function	0	0	0
c frag function	0	0	0
Br(b $\to \ell$)	0	0	0
Br(b $\to$ c $\to \ell^+$)	0	0	0
Br(b $\to \bar{\mathrm{c}} \to \ell^-$)	0	0	0
Br(b $\to \tau \to \ell$)	0	0	0
Br(b $\to$ J/$\psi \to \ell^+\ell^-$)	0	0	0
Br(c $\to \ell$)	0	0	0
Br(c $\to$ D* $\to$ K$\pi\pi_s$)	0	0	0
Semilept model b $\to \ell$	0	0	0
Semilept model c $\to \ell$	0	0	0
b $\to$ D model.	0	0	0
$f(\mathrm{D}^0)$	0	0	0
$f(\mathrm{D}^+)$	0	0	0
$f(\mathrm{D}^0 + \mathrm{D}^+)$	0	0	0
$f(\mathrm{D_s})$	0	0	0
$f(\Lambda_c)$	0	0	0
D^0 lifetime	0	0	0
D^+ lifetime	0	0	0
$\mathrm{D_s}$ lifetime	0	0	0
Λ_c lifetime	0	0	0
B decay multip.	0.0005	0.0003	0.0006
D decay multip.	0	0	0
g $\to$ b$\bar{\mathrm{b}}$	0	0	0
g $\to$ c$\bar{\mathrm{c}}$	0	0	0
Long-lived light h	0	0	0
Light quark frag	0.0024	0.0011	0.0044
Total systematic	0.0039	0.0022	0.0070
Use $R_b = 0.216$	-0.01009 dR_b/R_b	-0.018 dR_b/R_b	-0.183dR_b/R_b
Use $R_c = 0.173$	+0.0011 dR_b/R_c	+0.0001 dR_b/R_c	+0.0016 dR_b/R_c
Use $A_{FB}^{c\bar{c}}$(pk)=0.061	+0.0071 $dA_{FB}^{c\bar{c}}/A_{FB}^{c\bar{c}}$	0.0	0.0
Use $A_{FB}^{c\bar{c}}(-2) = -0.0316$	0.0	-0.0021$dA_{FB}^{c\bar{c}}/A_{FB}^{c\bar{c}}$	0.0
Use $A_{FB}^{c\bar{c}}(+2) = 0.12$	0.0	0.0	+0.0068$dA_{FB}^{c\bar{c}}/A_{FB}^{c\bar{c}}$

Table 30: OPAL Asymmetry measurement using jet charge and a vertex tag [13]

	$A_{FB}^{b\bar{b}}(-2)$	$A_{FB}^{c\bar{c}}(-2)$	$A_{FB}^{b\bar{b}}(pk)$	$A_{FB}^{c\bar{c}}(pk)$	$A_{FB}^{b\bar{b}}(+2)$	$A_{FB}^{c\bar{c}}(+2)$
$\sqrt{s}$	89.54	89.54	91.26	91.26	92.94	92.94
Results	–.2400	–.070	.042	.1100	–.4100	.3200
Statistics	.2700	.1200	.079	.037	.2300	.1100
D^* back acceptance	.015	.0010	.0050	.0040	.021	.013
D^* backgr rate	.027	.011	.0070	.0040	.023	.012
D^* backgr asymmetry	–.016	.0020	–.016	–.0010	–.016	–.0010
Detector effects	.0060	.0020	.0060	.0020	.0060	.0020
$x(D^*)$ scale	.0070	.0010	.0060	.0020	.028	.010
Rate c to D^*	–.0040	–.0010	–.0020	–.0010	–.016	–.0050
Rate b to D^*	.0080	.0010	.0040	.0020	.031	.010
Shape b to D*	.013	.0070	.013	.0070	.013	.0070
W to D*	–.013	0.0	.0030	0.0	–.022	0.0
Effective mixing χ	–.021	0.0	.0040	0.0	–.035	0.0
Thrust resoln	.0010	.0010	.0010	.0010	.0010	.0010
$\langle x_E \rangle_b$	.0020	–.0020	.0030	–.0070	.0090	–.012
$\langle x_E \rangle_c$	–.0090	.0040	–.0040	.0020	–.023	.010
b frag function	0.0	0.0	0.0	0.0	0.0	0.0
c frag function	0.0	0.0	0.0	0.0	0.0	0.0
$Br(b \to \ell)$	0.0	0.0	0.0	0.0	0.0	0.0
$Br(b \to c \to \ell^+)$	0.0	0.0	0.0	0.0	0.0	0.0
$Br(b \to \bar{c} \to \ell^-)$	0.0	0.0	0.0	0.0	0.0	0.0
$Br(b \to \tau \to \ell)$	0.0	0.0	0.0	0.0	0.0	0.0
$Br(b \to J/\psi \to \ell^+\ell^-)$	0.0	0.0	0.0	0.0	0.0	0.0
$Br(c \to \ell)$	0.0	0.0	0.0	0.0	0.0	0.0
$Br(c \to D^* \to K\pi\pi_s)$	0.0	0.0	0.0	0.0	0.0	0.0
Semilept model $b \to \ell$	0.0	0.0	0.0	0.0	0.0	0.0
Semilept model $c \to \ell$	0.0	0.0	0.0	0.0	0.0	0.0
$b \to D$ model.	0.0	0.0	0.0	0.0	0.0	0.0
$f(D^0)$	0.0	0.0	0.0	0.0	0.0	0.0
$f(D^+)$	0.0	0.0	0.0	0.0	0.0	0.0
$f(D^0 + D^+)$	0.0	0.0	0.0	0.0	0.0	0.0
$f(D_s)$	0.0	0.0	0.0	0.0	0.0	0.0
$f(\Lambda_c)$	0.0	0.0	0.0	0.0	0.0	0.0
D^0 lifetime	0.0	0.0	0.0	0.0	0.0	0.0
D^+ lifetime	0.0	0.0	0.0	0.0	0.0	0.0
D_s lifetime	0.0	0.0	0.0	0.0	0.0	0.0
Λ_c lifetime	0.0	0.0	0.0	0.0	0.0	0.0
B decay multip.	0.0	0.0	0.0	0.0	0.0	0.0
D decay multip.	0.0	0.0	0.0	0.0	0.0	0.0
$g \to b\bar{b}$	0.0	0.0	0.0	0.0	0.0	0.0
$g \to c\bar{c}$	0.0	0.0	0.0	0.0	0.0	0.0
Long-lived light h	0.0	0.0	0.0	0.0	0.0	0.0
Light quark frag	0.0	0.0	0.0	0.0	0.0	0.0
Total systematic	.047	.014	.025	.012	.076	.029

Table 31: OPAL Asymmetry measurements with a D^* tag [18]

	R_c
Result	0.142
Statistics	0.008
Internal	0.0019
Track resolution	0.0010
D^* backgr. rate	0.0029
Effective mixing χ	0.0005
b hadron lifetime	0.0025
c frag function	0.0080
$Br(c \to D^* \to K\pi\pi_s)$	–0.0110
Total systematic	0.0014

Table 32: Breakdown of errors for OPAL R_c measured using a D^* tag [16]

	R_b	$Br(1)$	$Br(2)$	$\overline{\chi}$	$A_{FB}^{b\bar{b}}$ (–2)	$A_{FB}^{c\bar{c}}$ (–2)	$A_{FB}^{b\bar{b}}$ (pk)	$A_{FB}^{c\bar{c}}$ (pk)	$A_{FB}^{b\bar{b}}$ (+2)	$A_{FB}^{c\bar{c}}$ (+2)
R_b	1.0	–.93	.07	–.12	0.0	–.12	–.15	.15	–.07	.05
$Br(1)$	–.93	1.0	–.15	.14	0.0	.11	.16	–.14	.07	–.05
$Br(2)$	.07	–.15	1.0	–.14	–.01	–.01	–.10	.01	–.04	0.0
$\overline{\chi}$	–.12	.14	–.14	1.0	.07	.01	.71	–.02	.28	–.01
$A_{FB}^{b\bar{b}}(-2)$	0.0	0.0	–.01	.07	1.0	.31	0.0	0.0	0.0	0.0
$A_{FB}^{c\bar{c}}(-2)$	–.12	.11	–.01	.01	.31	1.0	0.0	0.0	0.0	0.0
$A_{FB}^{b\bar{b}}(pk)$	–.15	.16	–.10	.71	0.0	0.0	1.0	.20	0.0	0.0
$A_{FB}^{c\bar{c}}(pk)$	.15	–.14	.01	–.02	0.0	0.0	.20	1.0	0.0	0.0
$A_{FB}^{b\bar{b}}(+2)$	–.07	.07	–.04	.28	0.0	0.0	0.0	0.0	1.0	.30
$A_{FB}^{c\bar{c}}(+2)$	.05	–.05	0.0	–.01	0.0	0.0	0.0	0.0	.30	1.0

Table 33: Statistical correlation matrix for the OPAL multiparameter fit to lepton data. $Br(1)$ denotes $Br(b \to \ell)$, $Br(2)$ denotes $Br(b \to c \to \ell^+)$.

	$A_{FB}^{b\bar{b}}(-2)$	$A_{FB}^{c\bar{c}}(-2)$	$A_{FB}^{b\bar{b}}(pk)$	$A_{FB}^{c\bar{c}}(pk)$	$A_{FB}^{b\bar{b}}(+2)$	$A_{FB}^{c\bar{c}}(+2)$
$A_{FB}^{b\bar{b}}(-2)$	1.00	–.743	0.0	0.0	0.0	0.0
$A_{FB}^{c\bar{c}}(-2)$	–.743	1.00	0.0	0.0	0.0	0.0
$A_{FB}^{b\bar{b}}(pk)$	0.0	0.0	1.00	–.743	0.0	0.0
$A_{FB}^{c\bar{c}}(pk)$	0.0	0.0	–.743	1.00	0.0	0.0
$A_{FB}^{b\bar{b}}(+2)$	0.0	0.0	0.0	0.0	1.00	–.752
$A_{FB}^{c\bar{c}}(+2)$	0.0	0.0	0.0	0.0	–.752	1.00

Table 34: OPAL D^* asymmetry statistical correlation matrix

References

[1] *A Consistent Treatment of Systematic Errors for LEP Electroweak Heavy Flavour Analyses*, LEP Electroweak Working Group, LEPHF/94-01, ALEPH Note 94-30, DELPHI 94-23 Phys 357, L3 Note 1577, OPAL Technical Note TN213.

[2] *Presentation of LEP Electroweak Heavy Flavour Analyses for Summer 1994 Conferences*, LEP Electroweak Working Group, LEPHF/94-02, ALEPH Note 94-90, L3 Note 1613, OPAL Technical Note TN237.

[3] *LEP Electroweak Heavy Flavour Results for Summer 1994 Conferences*, LEP Electroweak Working Group, LEPHF/94-03, ALEPH Note 94-119 PHYSIC 94-103, DELPHI 94-108 Phys 425, L3 Note 1630, OPAL Technical Note TN242.

[4] *Heavy Flavour Lepton Contribution for Summer 1994 Conferences* ALEPH 94-123 PHYSIC 94-107
$B^0\overline{B^0}$ *mixing and* $b\overline{b}$ *asymmetry from high* p_t *leptons,* ALEPH 94-036 Contributed Paper to the La Thuile and Moriond Winter conferences, 1994;
ALEPH Collab., D. Buskulic *et al.*, Z. Phys. **C62** (1994) 179.

[5] *L3 Results on* $A_{FB}^{b\overline{b}}$, $A_{FB}^{c\overline{c}}$ *and* χ *for the Glasgow Conference* L3 Note 1624,
Measurement of the $B^0\overline{B^0}$ *mixing parameter and the* $Z^0 \to b\overline{b}$ *Forward-Backward asymmetry,* L3 Collab., CERN-PPE/94-89, Submitted to Phys. Lett. B;
L3 Collab., O. Adriani *et al.*, Phys. Lett. **B292** (1992) 454.
L3 Results on R_b *and* $Br(b \to \ell)$ *for the Glasgow Conference* L3 Note 1625,
Measurement of R_b *and* $Br(b \to \ell X)$ *from b-quark semi-leptonic decays,* L3 Collab., L3 internal note 1449, July 16 1993;

[6] *Measurement of the forward backward asymmetries of* $e^+e^- \to Z^0 \to b\overline{b}$ *and* $e^+e^- \to Z^0 \to c\overline{c}$ *from events tagged by a lepton, including 1994 data.* OPAL Physics Note PN165, Feb 27 1995; OPAL Collab, R. Akers *et al.*, Z. Phys. **C60** (1993) 199.

[7] ALEPH Collab., D. Buskulic *et al.*, Phys. Lett. **B313** (1993) 535.

[8] *Measurement of* $\Gamma_{b\overline{b}}/\Gamma_{had}$ *using impact parameter measurements and lepton identification,* DELPHI Collab., CERN-PPE/95-08.

[9] *Measurement of* $\Gamma_{b\overline{b}}/\Gamma_{had}$ *using a Double Tagging Method,* OPAL Collab., CERN-PPE/94-106, Z. Phys. **C65** (1995) 17-30.

[10] ALEPH Collab., D. Buskulic *et al.*, Phys. Lett. **B313** (1993) 549.

[11] L3 Collab., O. Adriani *et al.*, Phys. Lett. **B307** (1993) 237.

[12] *A Measurement of* $A_{FB}^{b\overline{b}}$ *in lifetime tagged heavy flavour Z Decays,* ALEPH Collab., CERN-PPE/94-84, Submitted to Phys. Lett. B

[13] *A Measurement of the Forward-Backward asymmetry of* $e^+e^- \to b\overline{b}$ *applying a jet charge algorithm to lifetime tagged events,* OPAL physics note PN168, 28 Feb 1995.

[14] *Measurement of the Forward-Backward asymmetry of* $e^+e^- \to Z^0 \to b\overline{b}$ *using prompt leptons and a microvertex tag,* DELPHI 94-62 PHYS 383 and CERN-PPE/94-161; *New measurement of the forward-backward asymemtry in* $Z^0 \to b\overline{b}$ *events using a lifetime tag and the jet charge algorithm,* DELPHI Note 95-27 PHYS 478.

[15] *Study of D, D* and D** Production in Z hadronic decays*, DELPHI Collab., DELPHI 94-103 PHYS 420

[16] *A Measurement of the Production of* $D^{*\pm}$ *Mesons on the* Z^0 *Resonance,* OPAL Collab., CERN-PPE/94-217, Submitted to Z. Phys. C.

[17] ALEPH Collab., D. Buskulic *et al.*, Z. Phys. **C62** (1994) 1-14.

[18] *Updated Measurement of the Forward-Backward Asymmetry of* $e^+e^- \to b\overline{b}$ *and* $e^+e^- \to c\overline{c}$ *on and near the* Z^0 *peak Using* $D^{*\pm}$ *Mesons,* OPAL Physics Note, PN125, 10 March 1994.

[19] *Measurement of the forward-backward asymmetry of charm and bottom quarks at the Z pole using* $D^{*\pm}$ *mesons,* DELPHI Collab., CERN-PPE/94-193.

[20] D. Bardin *et al.*, Z. Phys. **C44** (1989) 493; Comp. Phys. Comm. **59** (1990) 303; Nucl. Phys. **B351**(1991) 1; Phys. Lett. **B255** (1991) 290 and CERN-TH 6443/92 (May 1992).

[21] Djouardi, Lampe and Zerwas *A note on QCD corrections to Forward-Backward Asymmetries of Heavy-Quark Jets in Z Decays*, MPI-Ph/94-81.