LEP2FF/00-02
ALEPH 2000-023 PHYSIC 2000-004
DELPHI 2000-037 PHYS 852
L3 Internal note 2515
OPAL TN645

Combination of Heavy Flavour Measurements at LEP2

LEPEWWG Heavy Flavour at LEP2 Subgroup
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March 17, 2000

Abstract

A preliminary average of heavy flavour electroweak measurements at LEP2 is presented. Datasets recorded in the years 1995 to 1999 are used, corresponding to centre of mass energies in the range of 130 to 202 GeV.

1 Average of Heavy Flavour measurements

This note presents a combination of measurements of $\mathrm{R_b}$, $\mathrm{R_c}$[1] and the forward-backward asymmetries $\mathrm{A_{FB}^b}$ and $\mathrm{A_{FB}^c}$ from the LEP collaborations. For the purpose of averaging, a common signal definition has been defined for all the measurements, requiring:

- The effective centre of mass energy $\sqrt{\mathrm{s}'} > 0.85\sqrt{\mathrm{s}}$
- The inclusion of ISR and FSR photon interference contribution
- Extrapolation to full angular acceptance.

Results are given at centre of mass energies in the range 130 GeV to 202 GeV. Measurements at 130 GeV and 136 GeV, as well as measurements at 161 GeV and 172 GeV, have been combined respectively into nominal 133 GeV and 167 GeV centre of mass energies. Each experiment provides tables of their available measurements of $\mathrm{R_b}$, $\mathrm{R_c}$, $\mathrm{A_{FB}^b}$ and $\mathrm{A_{FB}^c}$. These are either published results [1] or preliminary [2]. Table 1 summarises the inputs that have been combined. When necessary, these measurements have been corrected to the common signal definition using ZFITTER [3] predictions.

The averaging procedure follows the method described in [4], in particular the dependencies of each of the measurements on the other parameters are explicitly accounted for in the fit. Systematic errors are divided into 3 main categories:

- internal errors
- errors correlated between the measurements of each experiment

[1] Unlike at LEP1, $\mathrm{R_q}$ is defined as $\frac{\sigma_{\mathrm{q\bar{q}}}}{\sigma_{\mathrm{had}}}$.

cms energy GeV	R_b	R_c	A_{FB}^b	A_{FB}^c
133.2	**A** **D** L **O**	x x x x	x **D** x **O**	x **D** x **O**
166.6	**A** **D** L **O**	x x x x	x **D** x **O**	x **D** x **O**
182.7	**A** D L **O**	**A** x x x	**A** x x **O**	A x x **O**
188.6	A D L **O**	x x x x	A D L **O**	x x x **O**
192 to 202	x D x x	x x x x	x D x x	x x x x

Table 1: **Published** and preliminary inputs (Aleph, Delphi, L3 and Opal)

- errors common to all experiments

The list of error types is given in the next section. The breakdown of errors for each measurement and experiment are given in the appendixes A, B, C and D.

2 Error definition

The following lists the detail the systematic errors that are considered uncorrelated, correlated between measurements of each LEP experiment and common to all experiments. These common systematic uncertainties, which arise primarily from the b and c modelling, require the use of or correction to a consistent set of systematic definitions to obtain the best averages. It is the aim of the group to continue working towards this in future, however as the common systematic contribution to the total uncertainty is typically less than 20 % we expect only small changes due to these improvements.

Error definition table for 2000 winter conferences

uncorrelated:

Monte Carlo stat
detector effects
internal

correlated within each experiment:

<u>ALEPH</u>

a - btag
a - hadronic sel
a - c selection

<u>DELPHI</u>

d - correlated
d - 97 b-effi
d - 98 b-effi

d - 99 b-effi
d - accept corr
d - c modelling
d - uds-effi
d - sprime cut var
d - dilution fac
d - theta dep

L3

OPAL

o - event selection
o - detector resol.
o - lepton/pion ID
o - input modelling
o - fitting proc
o - l/pi bkg asy
o - radiative asy

common:

double rad
ISR/FSR inter
4f background
fin.state QCD
lumi (theo)
b modelling
b fragm
b mixing
b mult
b hadr frac
b lifetime
c fragm
c mult
c hadr frac
c lifetime
semil.model
f(b->k)
f(b->l)
f(c->l)
f(b/c->D*)

3 Experimental input tables

Input tables from each experiment are given in appendixes. They include, under the line "parameters", the type of measurements they refer to. Then, in the line "results", they contain the measured value extrapolated to the common signal definition in the order of the parameters list. Then, the breakdown of errors follows.

They contain explicitly the dependencies, which have to be understood in the following way:

- uX is the SM value considered for X
- dX is the variation considered for X,(in general it is 1.)
- X is the resulting change on the quantity in the column for the variation dX of uX

For convenience, there can be more than one input table per experiment.

4 Results

The results of the combination and the Standard Model predictions are presented in table 2 and figures (1) and (2). A list of the error contributions from the combination at 189 GeV is shown in table 3.

The full correlation matrix is given in table 4.

5 Summary

A preliminary combination of the LEP2 heavy flavour electroweak measurements for the 130 to 202 GeV datasets has been performed. Future improvements to the treatment of common systematic uncertainties are expected to cause only small changes in these averages.

It is also forseen to use these combined results in conjunction with other $e^+e^- \rightarrow f\bar{f}$ results to constrain parameters of the Standard Model and to place limits on possible extensions.

Energy GeV	R_b	R_c	A^b_{FB}	A^c_{FB}
133.2	0.1806 ± 0.0134 (0.1853)	- -	0.357 ± 0.251 (0.487)	0.579 ± 0.314 (0.681)
166.6	0.1477 ± 0.0128 (0.1708)	- -	0.616 ± 0.254 (0.561)	0.927 ± 0.344 (0.671)
182.7	0.1619 ± 0.0102 (0.1671)	0.270 ± 0.043 (0.250)	0.525 ± 0.155 (0.578)	0.667 ± 0.209 (0.656)
188.6	0.1552 ± 0.0063 (0.1660)	- -	0.505 ± 0.095 (0.583)	0.451 ± 0.193 (0.649)
191.6	0.1698 ± 0.0266 (0.1655)	- -	0.372 ± 0.302 (0.585)	- -
195.5	0.1663 ± 0.0156 (0.1648)	- -	0.724 ± 0.194 (0.587)	- -
199.5	0.1845 ± 0.0166 (0.1642)	- -	0.744 ± 0.206 (0.590)	- -
201.6	0.1786 ± 0.0234 (0.1638)	- -	0.594 ± 0.284 (0.591)	- -

Table 2: Results of the global fit, compared to the Standard Model predictions for the signal definition in parentheses. Quoted errors represent the statistical and systematic errors added in quadrature. Due to the large correlation with the measurement of R_c at 183 GeV, the error on the measurement of R_b at 183 GeV receives an additional contribution, absent at the other energy points. If R_c is fixed to the Standard Model value, R_b becomes 0.1636 ± 0.0095 at 183 GeV

Error list	R_b (189 GeV)	A^b_{FB} (189 GeV)	A^c_{FB} (189 GeV)
statistics	0.00577	0.0888	0.1742
internal syst	0.00217	0.0317	0.0650
common syst	0.00121	0.0085	0.0511
total syst	0.00248	0.0328	0.0827
total error	0.00628	0.0947	0.1928

Table 3: Error breakdown at 189 GeV

	R_b 133.2	A_{FB}^b 133.2	A_{FB}^c 133.2	R_b 166.6	A_{FB}^b 166.6	A_{FB}^c 166.6	R_b 182.7	R_c 182.7	A_{FB}^b 182.7	A_{FB}^c 182.7	R_b 188.6	A_{FB}^b 188.6	A_{FB}^c 188.6	R_b 191.6	A_{FB}^b 191.6	R_b 195.5	A_{FB}^b 195.5	R_b 199.5	A_{FB}^b 199.5	R_b 201.6	A_{FB}^b 201.6
R_b(133.2)	1.00	-.02	.03	.04	.01	.01	.04	.00	.01	.01	.06	.03	.01	.00	.00	.00	.00	.00	.00	.00	.00
A_{FB}^b(133.2)	-.02	1.00	.07	.01	.02	.01	.02	.00	.03	.02	.02	.04	.03	.00	.00	.00	.00	.00	.00	.00	.00
A_{FB}^c(133.2)	.03	.07	1.00	.01	.01	.04	.01	.01	.02	.05	.02	.04	.08	.00	.00	.00	.00	.00	.00	.00	.00
R_b(166.6)	.04	.01	.01	1.00	.00	.03	.04	.00	.01	.01	.05	.02	.01	.00	.00	.00	.00	.00	.00	.00	.00
A_{FB}^b(166.6)	.01	.02	.01	.00	1.00	-.02	.01	.00	.02	.00	.01	.02	.01	.00	.00	.00	.00	.00	.00	.00	.00
A_{FB}^c(166.6)	.01	.01	.04	.03	-.02	1.00	.01	.01	.01	.05	.02	.03	.08	.01	.00	.01	.01	.01	.01	.01	.01
R_b(182.7)	.04	.02	.01	.04	.01	.01	1.00	-.36	-.10	.14	.08	.03	.03	.01	.00	.02	.01	.02	.01	.02	.00
R_c(182.7)	.00	.00	.01	.00	.00	.01	-.36	1.00	.16	-.16	.00	.00	.01	.00	.00	.00	.00	.00	.00	.00	.00
A_{FB}^b(182.7)	.01	.03	.02	.01	.02	.01	-.10	.16	1.00	.21	.02	.05	.03	.00	.00	.00	.00	.00	.00	.00	.00
A_{FB}^c(182.7)	.01	.02	.05	.01	.00	.05	.14	-.16	.21	1.00	.03	.04	.10	.01	.00	.01	.01	.02	.01	.01	.01
R_b(188.6)	.06	.02	.02	.05	.01	.02	.08	.00	.02	.03	1.00	.00	.08	.02	.00	.04	.01	.04	.01	.03	.00
A_{FB}^b(188.6)	.03	.04	.04	.02	.02	.03	.03	.00	.05	.04	.00	1.00	.34	.00	.03	.00	.09	.00	.08	.00	.05
A_{FB}^c(188.6)	.01	.03	.08	.01	.01	.08	.03	.01	.03	.10	.08	.34	1.00	.01	.01	.02	.04	.03	.04	.02	.02
R_b(191.6)	.00	.00	.00	.00	.00	.01	.01	.00	.00	.01	.02	.00	.01	1.00	.00	.04	.00	.04	.00	.03	.00
A_{FB}^b(191.6)	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.03	.01	.00	1.00	.00	.05	.00	.04	.00	.03
R_b(195.5)	.00	.00	.00	.00	.00	.01	.02	.00	.00	.01	.04	.00	.02	.04	.00	1.00	.01	.06	.01	.04	.00
A_{FB}^b(195.5)	.00	.00	.00	.00	.00	.01	.01	.00	.00	.01	.01	.09	.04	.00	.05	.01	1.00	.01	.14	.01	.08
R_b(199.5)	.00	.00	.00	.00	.00	.01	.02	.00	.00	.02	.04	.00	.03	.04	.00	.06	.01	1.00	.01	.05	.00
A_{FB}^b(199.5)	.00	.00	.00	.00	.00	.01	.01	.00	.00	.01	.01	.08	.04	.00	.04	.01	.14	.01	1.00	.01	.08
R_b(201.6)	.00	.00	.00	.00	.00	.01	.02	.00	.00	.01	.03	.00	.02	.03	.00	.04	.01	.05	.01	1.00	.00
A_{FB}^b(201.6)	.00	.00	.00	.00	.00	.01	.00	.00	.00	.01	.00	.05	.02	.00	.03	.00	.08	.00	.08	.00	1.00

Table 4: Full correlation matrix. Given the present errors on b asymmetries, some dependencies (Appendix B) were neglected. It was checked that the influence was negligible in the global fit (less than 3% of the error at 189 GeV).

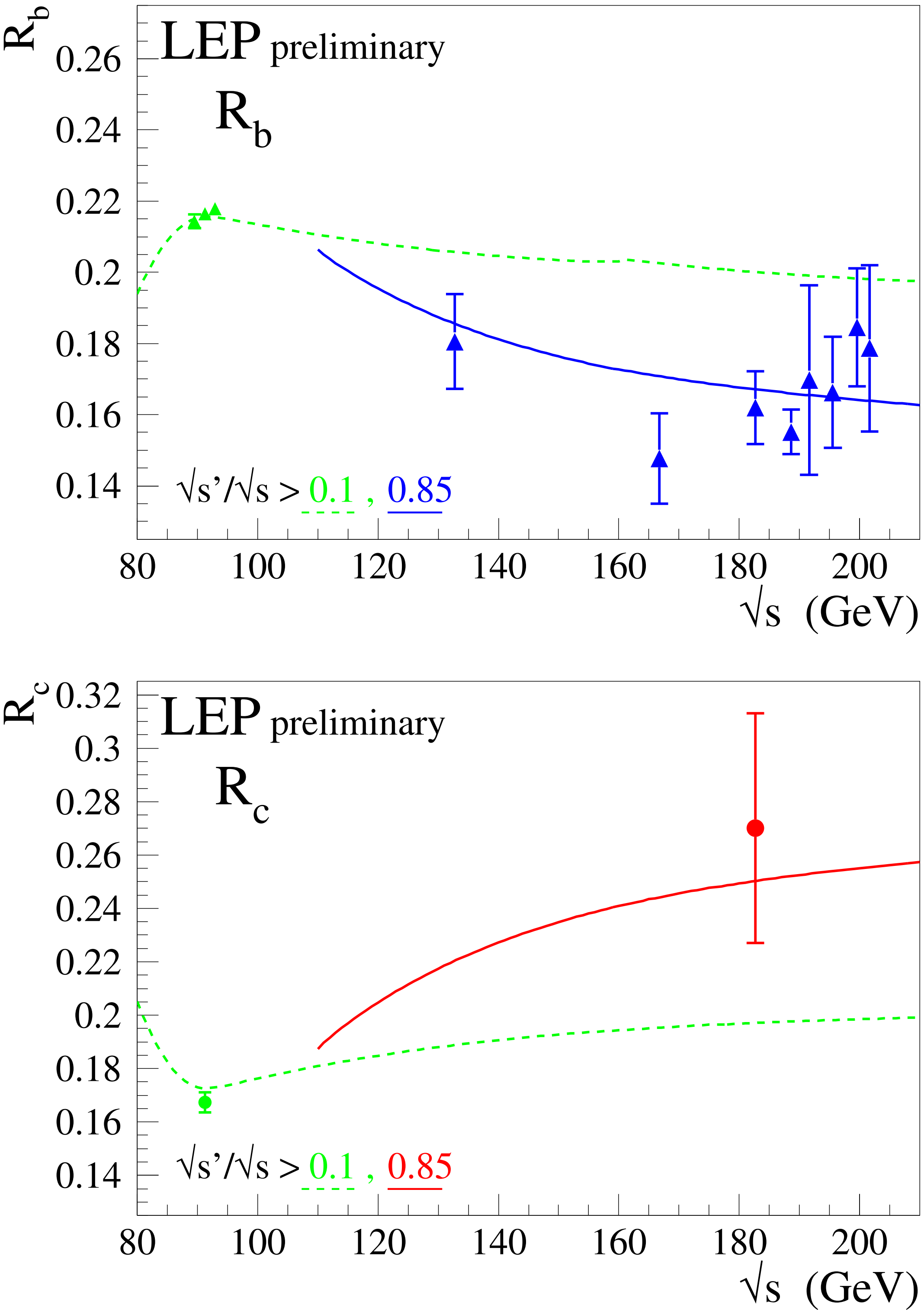

Figure 1: Preliminary combined LEP measurements of R_b and R_c. Solid lines represent the Standard Model prediction for the signal definition and dotted lines the inclusive prediction. Both are computed with ZFITTER[3]. The LEP1 measurements have been taken from [5].

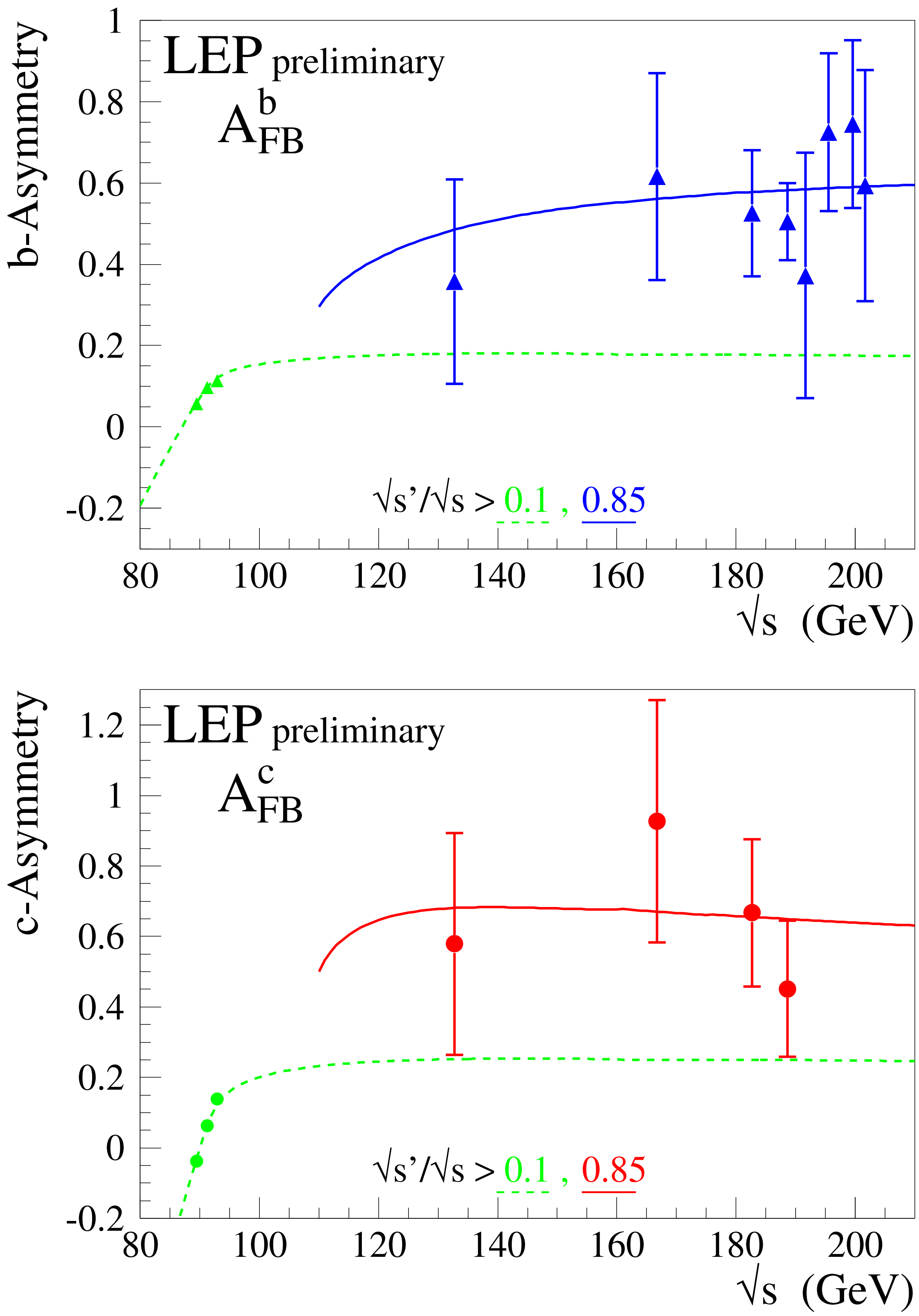

Figure 2: Preliminary combined LEP measurements of the forward-backward asymmetries A_{FB}^{b} and A_{FB}^{c}. Solid lines represent the Standard Model prediction for the signal definition and dotted lines the inclusive prediction. Both are computed with ZFITTER[3]. The LEP1 measurements have been taken from [5].

References

[1] ALEPH Collaboration, *Eur. Phys. J.* C **12** (2000);
P.Abreu *et al.*, DELPHI Collaboration, *Eur. Phys. J.* C **11** (1999);
G.Abbiendi *et al.*, OPAL Collaboration, (Accepted by *Eur. Phys. J.* C) *CERN-EP* **99-170.**

[2] ALEPH Collaboration, EPS-HEP99 **6** 694;
DELPHI Collaboration, DELPHI 2000-038 CONF 356;
L3 Collaboration, L3 Internal note **2417** (1999);
L3 Collaboration, L3 Internal note **2502** (2000);

[3] ZFITTER V6.23 is used.
D. Bardin *et al.*, Preprint hep-ph/9908433.
The following ZFITTER flags have been set to: FINR=0 and INTF=1.

[4] The LEP Experiments: ALEPH, DELPHI, L3 and OPAL, *Nucl. Instrum. Methods* A **378** (1998) 101-115.

[5] P.Abreu et al., DELPHI Collaboration, *Eur. Phys. J.* C **10** (1999) 415-442.
The LEP collaborations *et al.*, *CERN-EP* **2000-016.**

A ALEPH experimental inputs

```
&
&  ALEPH R_b 95-97
&  ===============
&
&  EP/99-042(published): 130-136 -> 133, 161+172 -> 167
&
parameters
Rb133
Rb133
Rb167
Rb167
Rb183
end

results             & 0.180   & 0.215   & 0.159   & 0.134   & 0.176   \\

error table

statistics          & 0.044   & 0.050   & 0.034   & 0.036   & 0.019   \\
internal            & 0.      & 0.      & 0.      & 0.      & 0.      \\
a - btag            & -0.004  & -0.005  &-0.006   &-0.007   &-0.005   \\

uRc133              & .2176   & .2238   & 0.      & 0.      & 0.      \\
dRc133              & 1.      & 1.      & 0.      & 0.      & 0.      \\
Rc133               & -0.031  & -0.031  & 0.      & 0.      & 0.      \\
uRc167              & 0.      & 0.      & .2416   & .2465   & 0.      \\
dRc167              & 0.      & 0.      & 1.      & 1.      & 0.      \\
Rc167               & 0.      & 0.      & -0.031  & -0.031  & 0.      \\
uRc183              & 0.      & 0.      & 0.      & 0.      & .2503   \\
```

```
dRc183             & 0.      & 0.      & 0.      & 0.      & 1.      \\
Rc183              & 0.      & 0.      & 0.      & 0.      & -0.031  \\
end

&
&  ALEPH Rc+Afbb 97 (@183 Gev/c2)
&  ================
&
&  EP/99-042 (published)
&  extrapolated to full acceptance and sqrt(s'/s) > 0.85
&
parameters
Rc183
Afbb183
end

results            & 0.276   & 0.34    \\

error table

statistics         & 0.041   & 0.19    \\
internal           & 0.010   & 0.010   \\
Monte Carlo stat   & 0.007   & 0.030   \\
a - btag           & 0.0     & -0.002  \\
a - hadronic sel   & -0.001  & 0.      \\
a - c selection    & -0.008  & 0.      \\

lumi (theo)        & 0.001   & 0.0     \\

f(b->l)            & 0.      & -0.002  \\
f(b->k)            & 0.      & -0.003  \\
B mixing           & 0.      & +0.002  \\
B mult             & 0.      & +0.017  \\
b hadr frac        & 0.      & 0.002

uRc183             & 0.0     & 0.2503  \\
dRc183             & 0.0     & 1.      \\
Rc183              & 0.0     & +0.187  \\
uRb183             & 0.171   & 0.1671  \\
dRb183             & 1.0     & 1.      \\
Rb183              &-0.390   & -0.165  \\
uAfbc183           & 0.0     & 0.65569 \\
dAfbc183           & 0.0     & 1.      \\
Afbc183            & 0.0     & 0.041   \\

end


&
&  ALEPH Afbc 97
&  ================
&
&  HEP-EPS99 6-694
&  (Tampere results - preliminary)
&  extrapolated to sqrt(s'/s) > 0.85 , full acceptance
&  original measurement sqrt(s'/s) > 0.9, theta < 0.9
&  0.91 +/- 0.27 +/- 0.11
parameters
```

```
Afbc183
end

results             & 0.96    \\

error table

statistics          & 0.270   \\
internal            & 0.073   \\
Monte Carlo stat    & 0.030   \\

a - c selection     & -0.073  \\

f(c->l)             & -0.010  \\
c mult              & 0.010   \\

uRb183              & 0.1671  \\
dRb183              & 1.0     \\
Rb183               & 2.138   \\
uAfbb183            & 0.5776  \\
dAfbb183            & 1.0     \\
Afbb183             & 0.1327  \\

end

&
&  ALEPH Rb+Afbb 98
&  =====================
&
&  EPS-HEP99 6-694
&  (Tampere results - preliminary)
&  extrapolated to sqrt(s'/s) > 0.95 , full acceptance
&
&
parameters
Rb189
Afbb189
end

results             & 0.151   & 0.35    \\

error table

statistics          & 0.011   & 0.19    \\
Monte Carlo stat    & 0.0011  & 0.010   \\
internal            & 0.0021  & 0.030   \\
a - btag            & -0.0024 & -0.002  \\
a - hadronic sel    & -0.0001 & 0.      \\

f(b->l)             & 0.      & -0.003  \\
f(b->k)             & 0.      & -0.006  \\
b mixing            & 0.      & 0.002   \\
b mult              & 0.      & 0.016   \\
b hadr frac         & 0.      & 0.003   \\

uRc189              & 0.2521  & 0.2521  \\
dRc189              & 1.0     & 1.      \\
Rc189               & -0.031  & +0.170  \\
```

```
uRb189              & 0.      & 0.1660  \\
dRb189              & 0.      & 1.      \\
Rb189               & 0.      & -.157   \\
uAfbc189            & 0.      & 0.64944 \\
dAfbc189            & 0.      & 1.      \\
Afbc189             & 0.      & +0.0349 \\

end
```

B DELPHI experimental inputs

```
&                                Last updated  4/02/00 (M.E.)
&  DELPHI R_b 95-96
&  ================
&
&  EP/99-03
&
parameters
Rb133
Rb167
end

results             & 0.174   & 0.142   \\

error table

statistics          & 0.028   & 0.024   \\
d - correlated      & 0.007   & 0.003   \\

uRc133              & 0.225   & 0       \\
dRc133              & 1.      & 0       \\
Rc133               &-0.20    & 0       \\
uRc167              & 0       & 0.250   \\
dRc167              & 0       & 1.      \\
Rc167               & 0       &-0.17    \\

end

&                                Last updated  4/02/00 (M.E.)
&  DELPHI Afbbc 95-96
&  ==================
&
&  EP/99-03
&
parameters
Afbb133
Afbc133
Afbb167
Afbc167
end

results             & 0.67    & 0.90    & 1.05    & 1.14    \\

error table

statistics          & 0.39    & 1.17    & 0.35    & 0.81    \\
internal            & 0.16    & 0.47    & 0.08    & 0.16    \\

uRc133              & 0.225   & 0.225   & 0.      & 0.      \\
dRc133              & 1.      & 1.      & 0.      & 0.      \\
Rc133               &-0.80    & 2.1     & 0.      & 0.      \\
uRc167              & 0       & 0.      & 0.250   & 0.250   \\
dRc167              & 0       & 0.      & 1.      & 1.      \\
Rc167               & 0       & 0.      &-0.77    & 1.8     \\

uRb133              & 0.182   & 0.182   & 0.      & 0.      \\
dRb133              & 1.      & 1.      & 0.      & 0.      \\
```

```
Rb133              & 1.0     &-1.6     & 0.      & 0.      \\
uRb167             & 0       & 0.      & 0.165   & 0.165   \\
dRb167             & 0       & 0.      & 1.      & 1.      \\
Rb167              & 0       & 0.      & 1.2     &-1.9     \\

uAfbb133           & 0       & 0.475   & 0.      & 0.      \\
dAfbb133           & 0       & 1.      & 0.      & 0.      \\
Afbb133            & 0       &-0.48    & 0.      & 0.      \\
uAfbb167           & 0       & 0.      & 0       & 0.545   \\
dAfbb167           & 0       & 0.      & 0.      & 1.      \\
Afbb167            & 0       & 0.      & 0.      &-0.48    \\

uAfbc133           & 0.679   & 0.      & 0.      & 0.      \\
dAfbc133           & 1       & 0.      & 0.      & 0.      \\
Afbc133            &-0.17    & 0.      & 0.      & 0.      \\
uAfbc167           & 0       & 0.      & 0.663   & 0.      \\
dAfbc167           & 0       & 0.      & 1.      & 0.      \\
Afbc167            & 0       & 0.      &-0.17    & 0.      \\

end

&                                Last updated  7/03/00 (M.E.)
&  DELPHI R_b 97-99 preliminary Winter 00
&  ================
&
parameters
Rb183
Rb189
Rb192
Rb196
Rb200
Rb202
end

results            & 0.1373  & 0.1563  & 0.1688  & 0.1653  & 0.1834  & 0.1775  \\

error table

statistics         & 0.0154  & 0.0103  & 0.0261  & 0.0150  & 0.0160  & 0.0229  \\
Monte Carlo stat   & 0.0006  & 0.0006  & 0.0022  & 0.0008  & 0.0008  & 0.0013  \\
detector effects   & 0.0018  & 0.0012  & 0.0015  & 0.0016  & 0.0016  & 0.0016  \\
d - 97 b-effi      & 0.0023  & 0       & 0       & 0       & 0       & 0       \\
d - 98 b-effi      & 0       & 0.0020  & 0       & 0       & 0       & 0       \\
d - 99 b-effi      & 0       & 0       & 0.0033  & 0.0019  & 0.0020  & 0.0024  \\
d - accept corr    & 0.0005  & 0.0007  & 0.0001  & 0.0004  & 0.0009  & 0.0009  \\
d - c modelling    &-0.0019  &-0.0023  &-0.0022  &-0.0024  &-0.0024  &-0.0025  \\
d - uds-effi       &-0.0012  &-0.0013  &-0.0013  &-0.0012  &-0.0014  &-0.0013  \\
d - sprime cut var &-0.0008  &-0.0005  &-0.0013  &-0.0007  &-0.0008  &-0.0011  \\
4f background      & 0.0010  & 0.0013  & 0.0015  & 0.0015  & 0.0020  & 0.0019  \\
ISR/FSR inter      & 0.0009  & 0.0009  & 0.0009  & 0.0009  & 0.0009  & 0.0009  \\

& Dependencies ---------------------------
uRc183             & 0.2503  & 0       & 0       & 0       & 0       & 0       \\
dRc183             & 1.      & 0       & 0       & 0       & 0       & 0       \\
Rc183              &-0.0473  & 0       & 0       & 0       & 0       & 0       \\
uRc189             & 0       & 0.2521  & 0       & 0       & 0       & 0       \\
dRc189             & 0       & 1.      & 0       & 0       & 0       & 0       \\
Rc189              & 0       &-0.0557  & 0       & 0       & 0       & 0       \\
```

```
uRc192             & 0       & 0       & 0.2529  & 0       & 0       & 0        \\
dRc192             & 0       & 0       & 1.      & 0       & 0       & 0        \\
Rc192              & 0       & 0       &-0.0540  & 0       & 0       & 0        \\
uRc196             & 0       & 0       & 0       & 0.2540  & 0       & 0        \\
dRc196             & 0       & 0       & 0       & 1.      & 0       & 0        \\
Rc196              & 0       & 0       & 0       &-0.0594  & 0       & 0        \\
uRc200             & 0       & 0       & 0       & 0       & 0.2550  & 0        \\
dRc200             & 0       & 0       & 0       & 0       & 1.      & 0        \\
Rc200              & 0       & 0       & 0       & 0       &-0.0581  & 0        \\
uRc202             & 0       & 0       & 0       & 0       & 0       & 0.2555   \\
dRc202             & 0       & 0       & 0       & 0       & 0       & 1.       \\
Rc202              & 0       & 0       & 0       & 0       & 0       &-0.0617   \\

end

&                              Last updated  7/03/00 (M.E.)
&  DELPHI AFB 97-99 preliminary Winter 00
&  ================
&
parameters
Afbb189
Afbb192
Afbb196
Afbb200
Afbb202
end

info               & 2       & 2       & 2       &  2      & 2       \\
results            & 0.50    & 0.37    & 0.72    & 0.74    & 0.59    \\

error table

& all errors are relative !
statistics         &   28    &   81    &   25    &   26    &   47    \\
d - dilution fac   &    9    &    9    &    9    &    9    &    9    \\
d - theta dep      &    5    &    5    &    5    &    5    &    5    \\
4f background      &    2    &    2    &    2    &    2    &    2    \\
ISR/FSR inter      &   0.5   &   0.5   &   0.5   &   0.5   &   0.5   \\

end
```

C L3 experimental inputs

```
*
&  L3 Rb 95-98, Afb 189 ... rbafbb133189.l3
&  ===================
&
& 09/03/00  (SCB)
&
&
&  Preliminary results corresponding to:
&
&       L3 Internal note 2417, 14 June 1999.
&         "Measurements of Rb and Ab fb at LEP2 with the L3 detector."
&
&       L3 Internal note 2502, 28 February 2000.
&         "Preliminary measurement of the b bbar production cross section
&          at 130 GeV < sqrt(s) < 189 GeV at LEP."
&
&     The Rb results in Note 2417 are superceded by those in Note 2502
&
parameters
Rb133
Rb167
Rb167
Rb183
Rb189
Afbb189
end
&
&                    133       161       172       183       189       189
&                  95+97       96        96        97        98        98
&
results            & 0.177   & 0.152   & 0.212   & 0.145   & 0.163   & 0.66    \\

&
& regarded as uncorrelated
&
error table
statistics         & 0.023   & 0.035   & 0.045   & 0.020   & 0.013   & 0.23     \\
internal           & 0.006   & 0.006   & 0.008   & 0.006   & 0.006   & 0.037    \\

&
& regarded as correlated
&

b modelling        & 0.005   & 0.004   & 0.006   & 0.004   & 0.005   & 0.040    \\


uRc133             & 0.2208  & 0.      & 0.      & 0.      & 0.      & 0.      \\
dRc133             & 1.      & 0.      & 0.      & 0.      & 0.      & 0.      \\
Rc133              &-0.113   & 0.      & 0.      & 0.      & 0.      & 0.      \\

uRc167             & 0.      & 0.2416  & 0.2465  & 0.      & 0.      & 0.      \\
dRc167             & 0.      & 1.      & 1.      & 0.      & 0.      & 0.      \\
Rc167              & 0.      &-0.117   &-0.107   & 0.      & 0.      & 0.      \\

uRc183             & 0.      & 0.      & 0.      & 0.2503  & 0.      & 0.      \\
```

```
dRc183          & 0.     & 0.     & 0.     & 1.     & 0.     & 0.      \\
Rc183           & 0.     & 0.     & 0.     &-0.098  & 0.     & 0.      \\

uRc189          & 0.     & 0.     & 0.     & 0.     & 0.2521 & 0.2521  \\
dRc189          & 0.     & 0.     & 0.     & 0.     & 1.     & 1.      \\
Rc189           & 0.     & 0.     & 0.     & 0.     &-0.099  & 2.22    \\

uRb189          & 0.     & 0.     & 0.     & 0.     & 0.     & 0.1660  \\
dRb189          & 0.     & 0.     & 0.     & 0.     & 0.     & 1.      \\
Rb189           & 0.     & 0.     & 0.     & 0.     & 0.     &-0.96    \\

uAfbc189        & 0.     & 0.     & 0.     & 0.     & 0.     & 0.66    \\
dAfbc189        & 0.     & 0.     & 0.     & 0.     & 0.     & 1.0     \\
Afbc189         & 0.     & 0.     & 0.     & 0.     & 0.     & 0.54    \\

end
```

D OPAL experimental inputs

```
&                              Last updated  9/02/00
&                  (Stefano Marcellini: detailed systmatic error breakdown)
&  OPAL  Rb 95-98
&  ==============
&
&  EP/99-170: 161-172 -> "167"
&
parameters
Rb133
Rb167
Rb167
Rb183
Rb189
end

results             & 0.189   & 0.193   & 0.089   & 0.212   & 0.157   \\

error table

statistics          & 0.023   & 0.035   & 0.034   & 0.020   & 0.012   \\

o - event selection & 0.0036  & 0.0036  & 0.0026  & 0.0046  & 0.0038  \\
o - detector resol. & 0.0048  & 0.0048  & 0.0034  & 0.0062  & 0.0051  \\

b fragm             &-0.0003  &-0.0003  &-0.0002  &-0.0004  &-0.0003  \\
b mult              &-0.0029  &-0.0029  &-0.0018  &-0.0033  &-0.0027  \\
b hadr frac         & 0.0016  & 0.0016  & 0.0012  & 0.0021  & 0.0017  \\
b lifetime          & 0.0     & 0.0     & 0.0     & 0.0     & 0.0     \\
c fragm             & 0.0     & 0.0     & 0.0     & 0.0     & 0.0     \\
c mult              & 0.0     & 0.0     & 0.0     & 0.0     & 0.0     \\
c hadr frac         & 0.0010  & 0.0010  & 0.0007  & 0.0013  & 0.0011  \\
c lifetime          & 0.0     & 0.0     & 0.0     & 0.0     & 0.0     \\
4f background       & 0.0     & 0.0004  & 0.0006  & 0.0010  & 0.0009  \\
B mixing            & 0.0     & 0.0     & 0.0     & 0.0     & 0.0     \\
fin.state QCD       & 0.0     & 0.0     & 0.0     & 0.0     & 0.0     \\



uRc133              & 0.223   & 0.      & 0.      & 0.      & 0.      \\
dRc133              & 1.      & 0.      & 0.      & 0.      & 0.      \\
Rc133               &-0.12    & 0.      & 0.      & 0.      & 0.      \\
uRc167              & 0.      & 0.244   & 0.249   & 0.      & 0.      \\
dRc167              & 0.      & 1.      & 1.      & 0.      & 0.      \\
Rc167               & 0.      &-0.11    &-0.11    & 0.      & 0.      \\
uRc183              & 0.      & 0.      & 0.      & 0.253   & 0.      \\
dRc183              & 0.      & 0.      & 0.      & 1.      & 0.      \\
Rc183               & 0.      & 0.      & 0.      &-0.12    & 0.      \\
uRc189              & 0.      & 0.      & 0.      & 0.      & 0.255   \\
dRc189              & 0.      & 0.      & 0.      & 0.      & 1.      \\
Rc189               & 0.      & 0.      & 0.      & 0.      &-0.13    \\

end

&                              Last updated  11/02/00
&       &                              Last updated  11/02/00
&                              (Frank Fiedler: detailed breakdown of systematics)
```

```
&  OPAL  afbbc 95-98
&  =================
&
&  EP/99-170: 161-172 -> "167"
&
parameters
Afbb133
Afbc133
Afbb167
Afbc167
Afbb167
Afbc167
Afbb183
Afbc183
Afbb189
Afbc189
end

results             & 0.19 & 0.50 &-0.03 & 0.87 & 0.82 & 0.69 & 0.77 & 0.55 & 0.63 & 0.50 \\

error table

statistics          & 0.30 & 0.315& 0.435& 0.59 & 0.695& 0.51 & 0.235& 0.275& 0.155& 0.185 \\
Monte Carlo stat    & 0.093& 0.073& 0.062& 0.050& 0.071& 0.050& 0.040& 0.032& 0.040& 0.032 \\

o - event selection & 0.006& 0.0  & 0.006& 0.0  & 0.016& 0.0  & 0.013& 0.0  & 0.014& 0.0   \\
o - detector resol. & 0.073& 0.070& 0.071& 0.070& 0.085& 0.070& 0.077& 0.070& 0.077& 0.070 \\
o - lepton/pion ID  & 0.006& 0.013& 0.006& 0.013& 0.006& 0.013& 0.006& 0.013& 0.006& 0.013 \\
o - input modelling & 0.030& 0.022& 0.029& 0.022& 0.032& 0.022& 0.028& 0.022& 0.028& 0.022 \\
o - fitting proc    & 0.013& 0.009& 0.037& 0.037& 0.072& 0.006& 0.004& 0.000& 0.005& 0.003 \\
o - l/pi bkg asy    & 0.011& 0.049& 0.011& 0.049& 0.011& 0.049& 0.010& 0.049& 0.010& 0.049 \\
o - radiative asy   & 0.005& 0.004& 0.005& 0.004& 0.005& 0.004& 0.005& 0.004& 0.005& 0.004 \\

b fragm             &-0.018& 0.005&-0.018& 0.005&-0.020& 0.005&-0.017& 0.005&-0.017& 0.005 \\
b mult              &-0.006& 0.0  &-0.006& 0.0  &-0.012& 0.0  &-0.007& 0.0  &-0.007& 0.0   \\
b hadr frac         & 0.002& 0.0  & 0.001& 0.0  & 0.005& 0.0  & 0.004& 0.0  & 0.004& 0.0   \\
b lifetime          & 0.0  & 0.0  & 0.0  & 0.0  & 0.0  & 0.0  & 0.0  & 0.0  & 0.0  & 0.0   \\
c fragm             & 0.004&-0.033& 0.004&-0.033& 0.007&-0.033& 0.006&-0.033& 0.006&-0.033 \\
c mult              & 0.000& 0.0  & 0.000& 0.0  & 0.001& 0.0  & 0.001& 0.0  & 0.001& 0.0   \\
c hadr frac         & 0.001& 0.0  & 0.001& 0.0  & 0.004& 0.0  & 0.005& 0.0  & 0.004& 0.0   \\
c lifetime          & 0.0  & 0.0  & 0.0  & 0.0  & 0.0  & 0.0  & 0.0  & 0.0  & 0.0  & 0.0   \\
4f background       & 0.0  & 0.0  &-0.010& 0.044&-0.010& 0.044&-0.010& 0.044&-0.010& 0.044 \\
B mixing            & 0.002&-0.001& 0.002&-0.001& 0.002&-0.001& 0.002&-0.001& 0.002&-0.001 \\
fin.state QCD       & 0.008& 0.011& 0.008& 0.011& 0.008& 0.011& 0.008& 0.011& 0.008& 0.011 \\
f(b->l)             &-0.003& 0.003&-0.003& 0.003&-0.003& 0.003&-0.003& 0.003&-0.003& 0.003 \\

f(c->l)             & 0.004&-0.004& 0.004&-0.004& 0.004&-0.004& 0.004&-0.004& 0.004&-0.004 \\
& add both to one error !!! -ME-
& f(c->l)             & 0.002&-0.002& 0.002&-0.002& 0.002&-0.002& 0.002&-0.002& 0.002&-0.002 \\
& f(b->c->l)          & 0.004& 0.004& 0.004& 0.004& 0.004& 0.004& 0.004& 0.004& 0.004& 0.004 \\

semil.model         & 0.005& 0.005& 0.004& 0.005& 0.005& 0.005& 0.004& 0.005& 0.004& 0.005 \\
f(b/c->D*)          &-0.001&-0.002&-0.001&-0.002&-0.001&-0.002&-0.001&-0.002&-0.001&-0.002 \\

uRb133              & 0.184& 0.184& 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.    \\
dRb133              & 0.184& 0.184& 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.    \\
Rb133               &-0.24 & 0.06 & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.    \\
```

```
uRc133          & 0.223& 0.223& 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.    \\
dRc133          & 0.223& 0.223& 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.    \\
Rc133           & 0.12 &-0.28 & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.    \\
uRb167          & 0.   & 0.   & 0.171& 0.171& 0.168& 0.168& 0.   & 0.   & 0.   & 0.    \\
dRb167          & 0.   & 0.   & 0.171& 0.171& 0.168& 0.168& 0.   & 0.   & 0.   & 0.    \\
Rb167           & 0.   & 0.   &-0.07 & 0.14 &-0.64 & 0.07 & 0.   & 0.   & 0.   & 0.    \\
uRc167          & 0.   & 0.   & 0.244& 0.244& 0.249& 0.249& 0.   & 0.   & 0.   & 0.    \\
dRc167          & 0.   & 0.   & 0.244& 0.244& 0.249& 0.249& 0.   & 0.   & 0.   & 0.    \\
Rc167           & 0.   & 0.   &-0.06 &-0.86 & 2.48 &-0.11 & 0.   & 0.   & 0.   & 0.    \\
uRb183          & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.165& 0.165& 0.   & 0.    \\
dRb183          & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.165& 0.165& 0.   & 0.    \\
Rb183           & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   &-0.40 & 0.07 & 0.   & 0.    \\
uRc183          & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.253& 0.253& 0.   & 0.    \\
dRc183          & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.253& 0.253& 0.   & 0.    \\
Rc183           & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.21 &-0.36 & 0.   & 0.    \\
uRb189          & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.164& 0.164 \\
dRb189          & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.164& 0.164 \\
Rb189           & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   &-0.38 & 0.10  \\
uRc189          & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.255& 0.255 \\
dRc189          & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.255& 0.255 \\
Rc189           & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.   & 0.23 &-0.30  \\
&

end
```