PROCEEDINGS

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Measurements of heavy flavour forward-backward asymmetries at LEP I

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ABSTRACT: New measurements of $A_{\rm FB}^{b}$ from the ALEPH and DELPHI experiments are presented at this conference. They significantly reduce the error on the LEP average pole asymmetry, which becomes:

$$A_{\rm FB}^{b,0} = 0.0990 \pm 0.0017 \ ,$$

corresponding to

$$\sin^2\theta_{\rm W}^{\rm eff} = 0.23226 \pm 0.00031$$

In this presentation, two new measurements using inclusive b-hadron final states are discussed.

1. Methods

The measurements of the b quark forward-backward asymmetry at the Z pole provide the most precise determination of $\sin^2\theta_{\rm W}$ at LEP, hence the interest in improving these measurements. Significant improvements have been achieved by ALEPH and DELPHI with three new results submitted to this conference: A final measurement using inclusive b hadron final states from ALEPH [1], an updated preliminary measurement also using b hadron final states from DELPHI [2], and a new measurement from DELPHI using $K^{\pm}$ tagging [3]. The two inclusive measurements are discussed here, since they carry the largest statistical weight in the average.

The ALEPH measurement uses the jet charge method in a sample of mostly $Z \to b\bar{b}$. The difference between the jet charges in the forward and backward hemispheres is:

$$\langle Q_{\rm FB}\rangle \ = \ \langle Q_{\rm F} - Q_{\rm B}\rangle \ = \sum_{f=u,d,s,c,b} P_f\,\delta_f\,A_{\rm FB}^{f}\,\frac{8}{3}\,\frac{\cos\theta}{1+\cos\theta^2}$$

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where θ is the polar angle of the event axis. The flavour purities, P_f, are measured in data using double tag fits to the conditional probability density of hemisphere b-tags. The charge separations, δ_f, are calibrated using fits to measurements of

$$\bar{\delta}^2 = \sigma^2(Q_{\rm FB}) - \sigma^2(Q_{\rm tot}) = \sum_f P_f \, \bar{\delta}_f^2 ,$$

where the fitted $\bar{\delta}_f$'s are equal to the δ_f's within a MC correction from hemisphere charge correlations of about 9% .

The DELPHI measurement uses the counting method for hemispheres with a good secondary vertex:

$$\frac{N_{\rm F}^+ + N_{\rm B}^- - N_{\rm F}^- - N_{\rm B}^+}{N_{\rm tot}} = \sum_{f=u,d,s,c,b} P_f \, (2 * w_f - 1) \, A_{\rm FB}^f \, \frac{8}{3} \, \frac{\cos\theta}{1+\cos\theta^2}$$

where w_b is the fraction of correctly signed hemispheres, which is calibrated in the selected data using the ratio between *opposite-sign* and *same-sign* events:

$$\frac{N_{opp}}{N_{same}} \approx \frac{w_b^2 + (1-w_b)^2}{2\, w_b \, (1-w_b)} ,$$

where, again, the equality holds up to a small MC correction from charge correlations and background.

2. Flavour and charge tags

ALEPH uses a neural net hemisphere b-tag composed of lifetime information, event shapes and lepton p_T, extending the analysis to $\cos\theta_{thrust} < 0.95$. A large sample of 670K events, of which 88% are $b\bar{b}$, are chosen on the basis of the b-tag. This is a 30% increase in statistics compared with previous results [4].

DELPHI Uses a b-tag based on reconstructed secondary vertices and selects a 96% pure $b\bar{b}$ sample of about 200K events. Here, the small c and light flavor efficiencies are taken from MC. The differences in event selection between ALEPH and DELPHI causes a high degree of independence in the systematic errors.

Both experiments use neural nets to estimate the quark charge in each hemisphere. Typical inputs to the nets are:

- Jet charges, secondary and primary vertex charges (for various weighting powers κ).
- Information from particle ID (note that lepton-ID is not used in ALEPH, and only indirectly in DELPHI. This is in order to minimize correlations with the measurements based on leptonic final states.)

- Secondary vertex quality, estimated b-hadron momentum and lifetime and other items intended to optimize the weight of each charge estimator according to the event topology.

Different strategies are used to combine the information in the two experiments, but in each case they enhance the correct sign probability by $\approx 10\%$ over the simple jet-charge estimate.

3. Systematic errors

As mentioned, the differences in event selection give rise to rather different systematic errors in the two experiments as illustrated by the Table below. In ALEPH the purities and charge resolutions, also for non-b flavours, are found from fits to data. Thus, the uncertainties due to flavour composition are of statistical nature. The uncertainty due to charge correlations is unusually small in ALEPH. It comes from varying the assumed heavy flavour parameters in the MC. Assumptions regarding light quark and gluon hadronization have not been varied, however. Instead a series of comparisons between data and MC final states are used to estimate the uncertainty due to fragmentation effects. A check is provided by the charge separation in events with a high p_T lepton, since the lepton-ID information is not used in building the hemisphere charges. The sign of the lepton charge then provides independent information on the forward-backward orientation of the event, and by comparing the signed charge separation in data and MC, the predicted charge correlation is confirmed within a 0.7% statistical precision.

DELPHI uses a very pure sample of $b\bar{b}$ and therefore the contribution to the error from A_{FB}^{c} is relatively small, whereas other contributions are relatively large. A check is in the DELPHI case provided by the correct sign probability in events with an identified D^*. This confirms the assumed value within a statistical error of 3.6% .

Source of systematic uncertainty $\Delta A_{\mathrm{FB}}^{b}$	**ALEPH**	**DELPHI** prel.
flavor purities and quark charges	0.00083	0.00155
b-hadron production and decay parameters	0.00014	0.00021
c-hadron production and decay parameters	0.00019	0.00017
charge correlations	0.00028	0.00120
QCD effects	0.00019	0.00042
A_{FB}^{c}, R_b and R_c	0.00047	0.00014
Detector resolution	0.00023	0.00056
Total systematic error on A_{FB}^{b}	± 0.0012	± 0.0021

4. Results

Summarizing the measurements of the forward-backward b-asymmetry at LEP, we have:

New final inclusive result (ALEPH) [1]:

$$A_{\mathrm{FB}}^{b,0} = 0.1011 \pm 0.0027(stat) \pm 0.0012(syst)$$

New preliminary inclusive result (DELPHI) [2]:

$$A_{\rm FB}^{b,0} = 0.0997 \pm 0.0036(stat) \pm 0.0021(syst)$$

All LEP inclusive analysis [1, 2, 6, 7]:

$$A_{\rm FB}^{b,0} = 0.1009 \pm 0.0020$$

New preliminary $K^{\pm}$ tag result (DELPHI) [3]:

$$A_{\rm FB}^{b,0} = 0.1069 \pm 0.0089(stat) \pm 0.0068(syst)$$

All LEP lepton/D/K analysis [8, 9, 10, 11, 12, 13, 3]:

$$A_{\rm FB}^{b,0} = 0.0968 \pm 0.0026$$

All LEP and SLD measurements:

$$\underline{A_{\rm FB}^{b,0} = 0.0990 \pm 0.0017}$$

It is interesting to note that:

- The inclusive measurements have been significantly improved over the earlier measurements [4, 5, 6, 7].
- However, the errors are still statistics dominated.
- There are correlations of 25-30% between the inclusive and leptonic measurements
- The different LEP measurements are internally consistent within 1.4σ.
- A 3.2σ difference still remains between the $\sin^2\theta_{\rm W}^{\rm eff}$ derived from $A_{\rm FB}^{b}$ and the one derived from the SLD measurement of $A_{\rm LR}$ [14].

Further progress in these measurements would be very wellcome. However, all ongoing analysis are approaching final numbers.

References

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