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Prospects for Measuring $A_{FB}^{b\bar{b}}$ and $sin^2\theta_w^{eff}$ at LEP I

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Abstract

A summary of the prospects for the lifetime-tag and lepton measurements of $A_{FB}^{b\bar{b}}$ throughout the period of LEP I operation is presented. This is then used to derive the maximum precision on $sin^2\theta_w^{eff}$ which may be expected by realistic increases in statistics from running on the Z.

1 Introduction and Assumptions

The measurement of $A_{FB}^{b\bar{b}}$ is currently statistically limited. Hence, it is of interest to calculate the maximum precision which may be obtained by running at the Z. ALEPH has two independent methods of making these measurements; the lifetime-tag and using leptons. These are interesting to compare. For the case of the leptons, there are also the high-p_T and "Global" analyses to be considered.

To avoid ambiguities when comparing the precision of various measurements for different numbers of events, it is found to be simpler dealing with the quantities $(\Delta A_{FB}^{b\bar{b}})_{stat.}$ and $(\Delta A_{FB}^{b\bar{b}})_{syst.}$ directly and then translating these through to corresponding errors on $sin^2\theta_w^{eff}$. Then the problem reduces to that of separating which systematic contributions also depend on statistics and those which are constant, or irreducible.

In order to predict the possible accuracies which may be achieved, it is useful to estimate the number of Z collisions which may be recorded by ALEPH in subsequent years. These are summarised in Table 1 for the lifetime-tag analysis, where the presence of the VDET is required. and for the lepton analyses. The particular details relevant to the two types of analyses are

Year of run	1992	1993	1994(?)	1995(?)
Data for Lifetime Analyses	0.92	1.60	2.80	4.30
Data for Lepton Analyses	1.10	1.78	2.98	4.48

Table 1: *Accumulated statistics (in units of* 10^6 *Z) available for lifetime-tag and lepton analyses at the end of each year of running. These assume* 1.2×10^6 *Z's in 1994 and* 1.5×10^6 *Z's in 1995.*

given in the following Sections. The comparison and predictions are made using the absolute error on $A_{FB}^{b\bar{b}}$ which is independent of the $A_{FB}^{b\bar{b}}$ value itself obtained from the various analyses.

An additional consideration is the range of energies used during the 1991 and, more significantly, the 1993 runs. For example, in 1993, over 126 kZ were accumulated at 93.0 GeV/c whilst only 86 kZ at 89.5 GeV/c. To first order however, the linear behaviour of $A_{FB}^{b\bar{b}}$ as a function of energy means that this difference remains negligible when combined with the on-peak total of 472 kZ.

2 Error Breakdown for the Lifetime-Tag Measurement

The current measurement[1] of $A_{FB}^{b\bar{b}}$ using the lifetime-tag yields a value of :

$$A_{FB}^{b\bar{b}} = 11.56 \pm 1.27\,stat. \pm 0.46\,syst.\% \qquad (1)$$

The systematic error may be broken down as shown in Table 2. Some of the systematic contri-

Source of systematic error	$\Delta A_{FB}^{b\bar{b}}$ (in units of 10^{-2})
Systematic error on δ_b	0.29
Stat. + syst. error on tag purity	0.20
Statistical error on δ_b	0.19
Experimental systematics	0.13
χ error on δ_b^{lepton} entering via $(\delta_b)^{combined}$	0.11
Systematic fragmentation error on δ_{udsc}	0.10
Statistical error tag acceptance	0.06
Systematic error on tag acceptance	0.06
Uncertainty on QCD radiative correction to $A_{FB}^{b\bar{b}}$	0.04
Statistical fragmentation error on δ_{udsc}	0.03
Statistically independent systematic	0.33
Statistically dependent systematic	0.32
Total systematic error	0.46

Table 2: *Systematic error breakdown for the lifetime-tag $A_{FB}^{b\bar{b}}$ measurement.*

butions are in turn also dependent on the statistics of the measurement. This may be further broadened to include the situation where the Monte Carlo statistics keeps pace with data. The "systematic" errors which are affected are :

- The statistical error on δ_b,
- The χ error on δ_b^{lepton},
- The statistical error on the tag acceptance in $cos\,\theta$,
- The Monte Carlo statistical error from the lifetime-dependent corrections to δ_b from $\bar{\delta}$.

This leaves an irreducible, or statistics independent, error contribution of 0.33 % and a statistically dependent systematic of 0.32 %. This calculation assumes that the analysis is repeated as now. Further improvements have already been made to the QIPBTAG algorithm [3] resulting both in an increased overall efficiency and in an extended angular coverage. These improvements are likely to lead to a 5 → 10% increase in the measurement's sensitivity but are not yet included here.

3 Error Breakdown for the Lepton-Tag Measurements

The current measurement of $A_{FB}^{b\bar{b}}$ using high-p_T leptons[2] yields a value of :

$$A_{FB}^{b\bar{b}} = 7.90 \pm 0.93\,stat. \pm 0.29\,syst. \pm 0.13\,models\% \qquad (2)$$

[1] This is currently based on 1992 data only and will be updated imminently.

[2] This is based on data from 1990, 1991 and 1992.

whereas that from the "Global" lepton analyses[3] yields :

$$A_{FB}^{b\bar{b}} = 8.70 \pm 1.40\, stat. \pm 0.16\, syst. \pm 0.13\, models\% \qquad (3)$$

The full error breakdowns are given in [1] and [2].

Part of the uncertainty in the high-p_T analysis comes from mixing which also depends on statistics. In the case of the "Global" fit, the correlation coefficient between the asymmetry and the corresponding mixing measurement is at the level of 0.214 [2]. In principle, this is related to the χ error of the lifetime-tag analysis except that the behaviour goes in the opposite direction. However in practice this correlation has an almost negligible effect, as shown in Table 2, due to the combination of lifetime-tagged and lepton-tagged δ_b measurements. The χ uncertainty is currently a factor of 2.5 smaller for the lifetime-tag measurement than for lepton analyses, and is likely to be reduced with further statistics.

4 Comparison and Total Accuracy as a Function of Statistics

The total absolute error for each of these measurements may be expressed as a function of the recorded statistics as :

$$Absolute\,Total\,Error\,(in\%) = \sqrt{\frac{\mathcal{X}^2}{N_Z} + \mathcal{Y}^2} \qquad (4)$$

where N_Z is the number of Z's collected in units of 10^6 and $\mathcal{X}$ and $\mathcal{Y}$ are the statistical $\oplus$ statistically dependent systematic contribution and irreducible systematic error respectively. The values of $\mathcal{X}$ and $\mathcal{Y}$ for the lifetime-tag analysis and the two types of lepton analyses are given in Table 3. In the calculation of the $\mathcal{X}$ values for lepton analyses, it is assumed that

Analysis Type	$\mathcal{X}$	$\mathcal{Y}$
Lifetime-Tag Analysis	1.080	0.33
High-p_T Analysis	0.963	0.17
"Global" Analysis	0.804	0.17

Table 3: *Values of $\mathcal{X}$ and $\mathcal{Y}$ (in %) for the lifetime-tag, high-p_T and "Global" lepton analyses.*

measurements of physics quantities used in the systematic calculations performed by ALEPH (eg. ϵ_c, $b \to l$ branching ratio etc.) are also updated while the statistics increase. In addition, $\mathcal{Y}$ for leptons may be expected to be reduced to ≈ 0.12 and 0.16 for the high-p_t and "Global" analyses respectively.

The values in Table 3 are then used to derive the maximum precision which may be obtained on the asymmetry for differing statistics recorded by ALEPH. Assuming a nominal $A_{FB}^{b\bar{b}}$ of 10% (corresponding to a $sin^2\theta_w^{eff}$ of 0.2314), the absolute errors on such an asymmetry for the various analyses are shown in Figures 1 and 2. In terms of the number of hadronic events expected for the forthcoming years, the precisions obtained are given for $sin^2\theta_w^{eff}$ in Table 4, together with the accuracy from most powerful of the independent methods, the lifetime-tag and the "Global" analyses.

5 Conclusions

The three analysis techniques for extracting $sin^2\theta_w^{eff}$ from $A_{FB}^{b\bar{b}}$ in ALEPH are capable of reaching a precision of better than 10^{-3} within the expected timescale of LEP I running. The "Global"

[3]This based on data taken in 1990 and 1991 only.

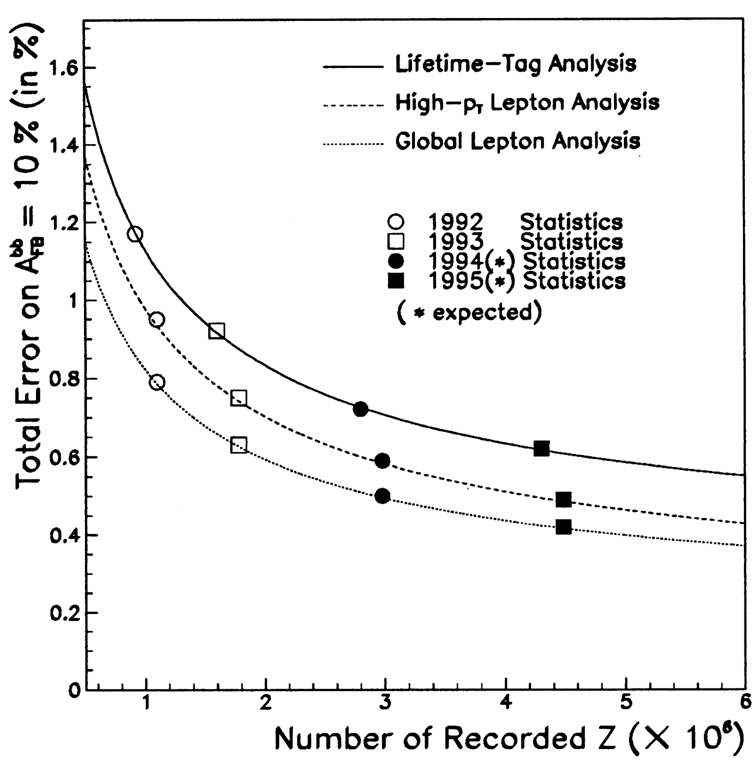

Figure 1: *The absolute error on $A_{FB}^{b\bar{b}}$ as a function of the number of Z's recorded by* ALEPH *(in %) for the three types of analysis method discussed in the text.*

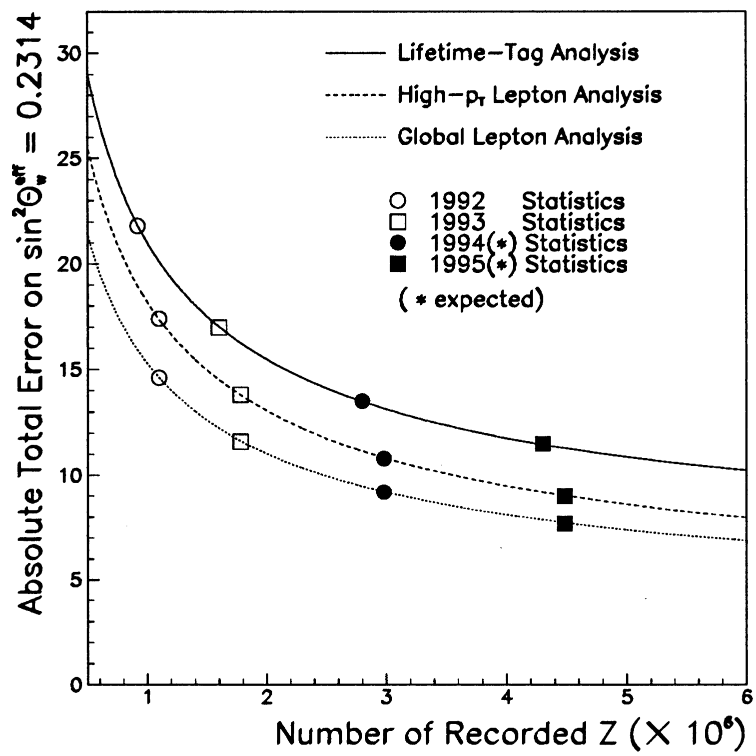

Figure 2: *The absolute error on $sin^2\theta_w^{eff}$ as a function of the number of z's recorded by* ALEPH *(in %) for the three types of analysis method discussed in the text.*

year of run	1992	1993	1994(?)	1995(?)
lifetime analysis	0.0022	0.0017	0.0013	0.0011
High-p_T Analysis	0.0017	0.0014	0.0011	0.0009
"Global" Analysis	0.0015	0.0012	0.0009	0.0008
Global & Lifetime Combined	0.0013	0.0010	0.0008	0.0007

Table 4: *Precisions on $A_{FB}^{b\bar{b}}$ and $sin^2\theta_w^{eff}$ obtained for the expected number of hadronic Z's recorded by* ALEPH *in 1992→1995.*

lepton analysis and the lifetime-tag analysis, using the hemisphere-charge, use independent data samples and so may be simply combined to yield a greater statistical power in the same data set. An ultimate precision of $\approx 8 \times 10^{-4}$ is likely to be achievable from the $b\bar{b}$ channel from the ALEPH detector alone.

6 Acknowledgements

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References

[1] D. Abbaneo et al. *"$B^0 - \bar{B}^0$ Mixing and $b\bar{b}$ Asymmetry from high-p_T Leptons (Update)"*, ALEPH Note 93-109, PHYSIC 93-90, 7^{th} July 1993.

[2] A. Falvard et al. *"Heavy Flavor Quark Production and Decay using Prompt Leptons in the ALEPH Detector. Global Lepton Analysis"*, ALEPH Note 93-136, PHYSIC 93-117, 13^{th} August 1993.

[3] Private Communication with D. Brown (MPI München).