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A Preliminary Measurement of $sin^2\theta_W^{eff}$ from $A_{FB}^{b\bar{b}}$ in the 1992 Lifetime Tagged Heavy-Flavour Sample

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Abstract

This note briefly describes the measurement of $sin^2\theta_W^{eff}$ from $A_{FB}^{b\bar{b}}$ in the ALEPH 1992 data sample using a jet-charge method and a lifetime tagging algorithm. The *preliminary* results and full error break-down are given.

1 Measurement of the Asymmetry

The jet-charge method is applied in a sample of hadronic events which has been enriched with b events using a lifetime tag. Using the 1992 data, and selecting events where *at least one* hemisphere passes the impact parameter cut, a sample of 70,849 events is obtained. Using the results of the Lifetime-Tagged $\Gamma_{b\bar{b}}$ analysis, this sample is shown to have a purity of :

$$b\ Purity \ = \ 88.1\ (\pm 1.3)\% \tag{1}$$

This selection has been optimised using the expected efficiencies, statistics and charge dilutions to reduce the (dominant) statistical uncertainty on $sin^2\theta_W^{eff}$. The remaining backgrounds in this sample are 8.7 ($\pm$ 0.7)% from charm and 3.2 ($\pm$ 0.6)% from light flavoured quarks.

Within this sample each event is split into two hemispheres defined by the direction of the thrust axis derived from both charged and neutral objects. The forward hemisphere is defined to be the one that has the z-component parallel to the direction of the initial state electron. The mean forward-backward charge asymmetry $\langle Q_{FB}\rangle$ is then evaluated as:

$$\langle Q_{FB}\rangle = \langle Q_F - Q_B\rangle, \tag{2}$$

where for each event Q_F is defined as :

$$Q_F = \frac{\sum_{i=1}^{n} q_i\, |p_i^l|^\kappa}{\sum_{i=1}^{n} |p_i^l|^\kappa}, \tag{3}$$

with the summation over all tracks in the forward hemisphere. q_i and p_i^l are the charge and longitudinal momentum of track i w.r.t. the thrust axis, and κ is a weighting parameter which is fixed to be 0.5 in order to optimise the statistical sensitivity of the measurement. Q_B is defined similarly for the backward hemisphere.

The mean charge asymmetry is measured in this sample to be :

$$Q_{FB} \ = \ -0.01096\ \pm 0.00122\,(\text{stat.})\ \pm 0.00026\,(\text{syst.}) \tag{4}$$

This represents an 8.8σ measurement in the 1992 data alone. The dominant source of systematic error is the estimate of the measured value's stability to including and excluding tracks close to the edge of the acceptance cuts. The systematic error increases the total error to 0.00125, an increase over the statistical error of only 2%.

2 Measurements of the b Hemisphere-Charge

In order to evaluate how much of this measured asymmetry arises from electroweak effects, it is essential to know the degree of charge dilution involved in the above method. The amount of charge retention in b hemispheres is evaluated in terms of :

$$\textit{The b Charge Separation} = \delta_b \qquad (5)$$

which is equal to twice the *visible* charge of a b quark hemisphere measured using the ALEPH detector. As the event sample is dominated by b's, it is δ_b which is of the greatest importance. Two measurements of this quantity in data are available. The first uses high (p,p_t) leptons to tag b events and measures the hemisphere-charge in the opposite hemisphere. A measurement in 1990 $\rightarrow$ 1992 data at a κ weighting of 0.5 yields :

$$(\delta_b)^{leptons} = 0.1465 \pm 0.0042(\text{stat.}) \pm 0.0038(\text{syst.}) \pm 0.0042(\chi.) \qquad (6)$$

The latter error term arises from the uncertainty of the mixing correction that needs to be applied to the lepton. The current combined LEP average value of $\chi = 11.5\,(\pm 1.1)\,\%$ is used for this calculation of $(\delta_b)^{leptons}$. A second method measures the degree of charge retention via the difference between the widths of the Q_{FB} and $Q = Q_{\text{F}} + Q_{\text{B}}$ distributions. This quantity may be written as :

$$\bar{\delta}^2 = \sigma^2_{\text{FB}} - \sigma^2_{\text{Q}} \qquad (7)$$

The value of $\bar{\delta}^2$ in a pure b sample, ie. $\bar{\delta}^2_b$, can be related to δ_b using a small correction to account for the correlations between the charge finding in the two hemispheres of an event. This correlation correction is taken from Monte Carlo and is studied for it's dependence on the fragmentation used. This method has been used for the 1992 data so far and yields the following value :

$$(\delta_b)^{widths} = 0.1432 \pm 0.0048(\text{stat.}) \pm 0.0039(\text{syst.}) \qquad (8)$$

These measurements are made in data samples with a very small overlap, and with different systematic contributions and so may be combined to give :

$$(\delta_b)^{combined} = 0.1446 \pm 0.0032(\text{stat.}) \pm 0.0035(\text{syst.} + \chi) \qquad (9)$$

The agreement between these two independent analysis is seen to be satisfactory and the combined measurement is used to interpret the measured asymmetry. A small correction is applied to this value of $(\delta_b)^{combined}$ to take into account the lifetime dependence of the b hemisphere charge. This correction has value -0.0018 (± 0.0006) and so the δ_b used for the extraction of $sin^2\theta^{eff}_{\text{W}}$ is :

$$(\delta_b)^{combined}_{corrected} = 0.1428 \pm 0.0032(\text{stat.}) \pm 0.0036(\text{syst.} + \chi) \qquad (10)$$

3 Interpretation in Terms of $sin^2\theta^{eff}_{\text{W}}$

The interpretation of the measured charge asymmetry in terms of $sin^2\theta^{eff}_{\text{W}}$ is performed using the expression :

$$\langle Q_{FB}\rangle^{measured} = \sum_{flavour=u}^{...b} \delta_f C_f \, A^{f\bar{f}}_{FB} \, \frac{\varepsilon^e_f}{\varepsilon^e_{total}} \, \frac{\Gamma_{f\bar{f}}}{\Gamma_{had}} \; . \qquad (11)$$

The ZFITTER package is used to calculate the $A^{f\bar{f}}_{FB}$ as functions of $sin^2\theta^{eff}_{\text{W}}$. Within the Standard Model implementation of ZFITTER the Higgs mass is set at 300 GeV. QCD corrections are *not* applied as the thrust axis is used to define the quark directions. A top mass is then chosen to minimise the difference between the measured asymmetry and that expected. Corresponding to this optimal top mass, the $sin^2\theta_{\rm w}^{eff}$ of the electron channel is evaluated. The non-b δ_f's are taken from Monte Carlo. Their small effects, and errors due to fragmentation, are taken into account and propagated through as a systematic error.

The $cos\,\theta$ coverage of the inner and outer layers of ALEPH microvertex detector are 0.84 and 0.69 respectively. As a result, the efficiency of the lifetime tag decreases towards the edge of acceptance.

The angular dependence of the tagging efficiency is different for b, c and uds quarks, due to the different distribution of lifetime within their hemispheres. These separate distributions are required in the fit to $sin^2\theta_w$ and are taken from Monte Carlo. However, with a b-purity of 90% the systematic error arising from any uncertainty in these distributions is dominated by that of the b-quark. Furthermore, the agreement between data and Monte Carlo demonstrates that the angular dependence of the b-efficiency is well modelled in the Monte Carlo. The small differences between data and Monte Carlo acceptances are propogated through as a systematic error.

The separate b, c and uds efficiency distributions are fitted with 3 parameter functions of the form

$$\varepsilon^e_f(\cos\theta) = \begin{cases} \alpha_f & \text{if } \cos\theta < \beta_f \\ \alpha_f + \nu_f(\cos\theta - \beta_f)^2 & \text{if } \cos\theta > \beta_f \end{cases}$$

α_f is the value of the tagging efficiency in the centre of the detector. β_f is the $cos\theta$ value at which the finite acceptance effects begin and ν_f is the quadratic coefficient describing the fall in the efficiency at the edge of acceptance. These functional forms are used to calculate the flavour dependant acceptance constants C^f given by :

$$C^f A^f_{FB} = \frac{\int_{0.0}^{c} \frac{d\sigma^f}{d\cos\theta}\varepsilon^e_f(\cos\theta)d\cos\theta - \int_{-c}^{0.0} \frac{d\sigma^f}{d\cos\theta}\varepsilon^e_f(\cos\theta)d\cos\theta}{\int_{-c}^{c} \frac{d\sigma^f}{d\cos\theta}\varepsilon^e_f(\cos\theta)d\cos\theta} \tag{12}$$

where c is the maximum $\cos\theta$ acceptance chosen. The acceptance factors are the fraction of the asymmetry "seen" by the detector. The small increase in the acceptance achieved by going beyond 0.8 in $\cos\theta$ is outweighed by the lack of understanding of the performance of the lifetime-tag in that region. Choosing a maximal cosine theta cut of 0.8 on the thrust axis of the event, when folded with the acceptance, yields an acceptance coefficient of 0.62 for b quarks. The equivalent numbers for c and light quarks are 0.58 and 0.57 respectively. Increasing this cut to 0.9 results in an increase of only 1% in the measurable asymmetry whilst introducing increased systematic contributions.

4 Results and Systematic Errors

Using the 1992 data, the Charge Asymmetry observed in a $b\bar{b}$ enhanced sample is :

$$\langle Q_{FB}\rangle^{measured} = -109.6 \pm 12.2(stat) \pm 2.6(syst) \times 10^{-4} \ . \qquad (13)$$

Interpreted in terms of the Standard Model, without QCD corrections, this represents a $sin^2\theta_w^{eff}$ value of :

$$sin^2\theta_w^{eff} = 0.2296 \pm 0.0022\,(stat.) \pm 0.0009\,(syst.) \qquad (14)$$

The systematic contributions to the measured $sin^2\theta_w^{eff}$ arise from several sources. These are detailed in the following table :

Source of systematic error	$\Delta sin^2\theta_w^{eff}$	$\Delta A_{FB}^{b\bar{b}}$ (%)
Systematic error on δ_b	0.00049	0.26
Experimental systematics	0.00048	0.26
Statistical error on δ_b	0.00048	0.26
χ error on δ_b^{lepton} entering via $(\delta_b)^{combined}$	0.00025	0.13
Stat. + syst. error on tag purity	0.00020	0.11
Uncertainty on QCD radiative correction to $A_{FB}^{b\bar{b}}$	0.00020	0.11
Systematic fragmentation error on δ_{udsc}	0.00018	0.10
Statistical error tag acceptance	0.00007	0.04
Systematic error from lifetime dependence of δ_b	0.00004	0.02
Statistical fragmentation error on δ_{udsc}	0.00004	0.02
Systematic error on tag acceptance	0.00004	0.02
Total systematic error	0.00094	0.50
Combined statistical and systematic error	0.00240	1.30

These errors may be combined to give :

$$sin^2\theta_w^{eff} = 0.2296 \pm 0.0024. \qquad (15)$$

This corresponds to an acceptance corrected value for $A_{FB}^{b\bar{b}}$, measured at the mean 1992 LEP energy, of :

$$A_{FB}^{b\bar{b}} = 10.94 \pm 1.20(stat.) \pm 0.50(syst.)\% \qquad (16)$$

Unlike previous lepton results, the current measurement does not require a $(1-2\chi)$ correction to the measured A_{FB}. However, a slight χ dependence enters equation (11) through the average $(\delta_b)^{combined}$ from $(\delta_b)^{leptons}$. The effect of this is opposite to the χ correction applied to lepton measurements and currently only 0.6 of its magnitude.

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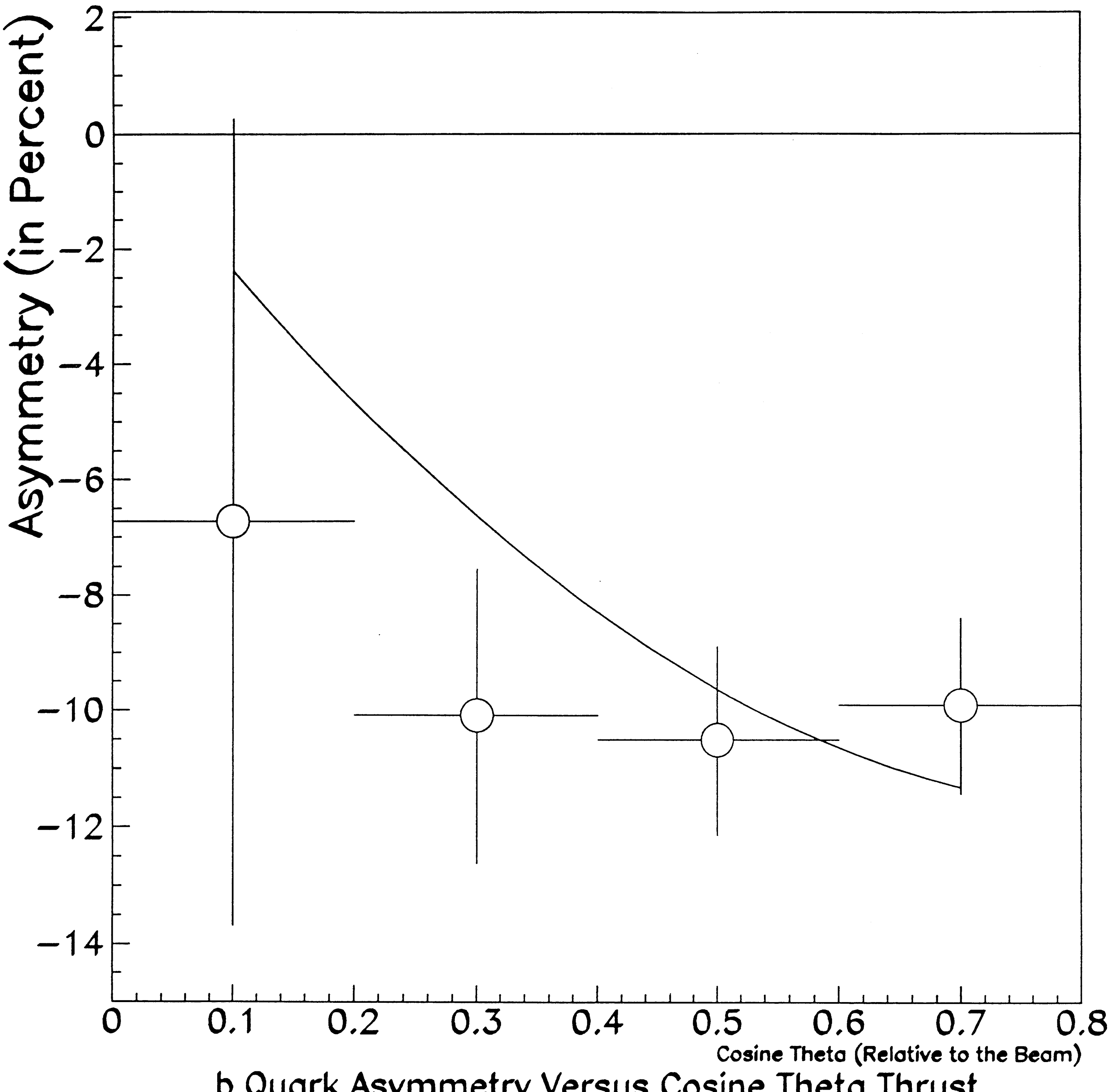

b Quark Asymmetry Versus Cosine Theta Thrust