ALEPH 93-128
PHYSIC 93-109
I. ten Have
30.7.1993

Comparison of the χ-dependence of the $A^{b\bar{b}}_{FB}$measurement using high p_T leptons or a jet-charge method

Ingrid ten Have

July 30, 1993

Abstract

The forward-backward asymmetries for b-quarks as extracted from the high p_T leptons and from a jet-charge method applied to an impact parameter tagged sample, contributed to the summer conferences, are different by 1.8 σ. The two measurements have a different dependence on the mixing probability. This note looks at the nature of the mixing dependences. It will show that mixing dependences are of opposite sign and of different magnitudes. Finally it will show that the fact that the two measurements evaluate the forward-backward asymmetry at different mixing probabilities does not explain the difference between the two measurements.

Two measurements of the forward-backward asymmetry for b-quarks have been presented to the summer conferences by ALEPH.

1 The high p_T lepton measurement

The first method [1] is carried out in a b-enhanced sample based on a high p_T lepton tag, where subsequently the lepton is used to measure the forward-backward asymmetry. The directly measured $A^{b\bar{b}}_{FB}$has to be corrected for the probability that the B mixed before decaying and thus produced a lepton that has a charge opposite to that of the originally produced by b-quark.
The mixing probability is given by:

$$\chi \equiv \frac{\Gamma(b\,hadron \rightarrow l^+X)}{\Gamma(b\,hadron \rightarrow l^\pm X)} \qquad (1)$$

which compares the probability of a b hadron producing a wrong-sign to any-sign lepton. The mixing correction that is to be applied to the observed $A_{FB}^{b\bar{b}}$is of the form of $1/(1-2\chi)$. Figure 1 shows an extrapolation[1] based on this correction from the high p_T measurement (open circle) over a rather a large range, χ = 0.1-0.15. The derivative in the $A_{FB}^{b\bar{b}}$,χ-plane is given by:

$$\frac{dA_{FB}^{b\bar{b}}}{d\chi} = \frac{2 \cdot A_{FB}^{b\bar{b}}}{(1-2\chi)}. \tag{2}$$

At the high p_T lepton working point this gives a numerical value of 0.2. Subsequently 5 additional points were calculated covering the range χ = 0.1-0.15. As the behaviour across the $A_{FB}^{b\bar{b}}$,χ-plane in this range is fairly linear, a straight line fit was carried out yielding a slope of 0.22. This corresponds more to the slope at the centre of the range, $\chi = 0.125$.

2 The jet-charge method

In the second method [2] a b-enhanced sample is created using QIPBTAG [3]. The asymmetry measurement is subsequently based on a measurement of the hemisphere charges, or rather on a measurement of the charge flow, Q_{FB}, which is defined as the charge of the forward minus the charge in the backward hemisphere.
In a background-free environment the extraction of $A_{FB}^{b\bar{b}}$can to a good approximation be written as:

$$A_{FB}^{b\bar{b}} \approx \frac{\langle Q_{FB} \rangle}{C_{acc} \cdot \delta^b} \tag{3}$$

where $\langle Q_{FB} \rangle$ is the average charge flow measured, C_{acc} is an acceptance factor and δ^b is the charge separation for b quarks (which equals two times the b hemisphere charge).
The important point in this measurement is that the b charge separation has been measured in the data. So the fact is that $\langle Q_{FB} \rangle$ and δ^b are both influenced by mixing taking place in the hemisphere(s), but as both are taken from the data, they have the "correct" mixing incorporated. Moreover in the extraction of $A_{FB}^{b\bar{b}}$(or $\sin^2\theta_W^{eff}$) the effects of mixing on $\langle Q_{FB} \rangle$ and δ^b completely cancel (see eq. 3). Hence this measurement has **NO** mixing correction in terms of the one that needs to be applied to the $A_{FB}^{observed}$ in the high p_T lepton measurement.
However, some mixing dependence enters through a completely different route. The b charge separation is measured through two methods:

- An extrapolation of the average charge separation, averaged over the samples flavour composition, in a VDET tagged sample with increasing purity to that of a pure b-sample.
- A measurement of the hemisphere charge in a lepton tagged sample, measuring the charge in the hemisphere opposite the lepton.

[1]Note that in a simultaneous fit to $A_{FB}^{b\bar{b}}$and χ the $1/(1-2\chi)$-extrapolation may undergo some slight modification.

The first method uses the b-hemispheres as measured in the data, so includes the "correct" influence of mixing on the hemisphere charge. If this were the only measurement of the b charge separation the jet-charge method would still be completely free of any mixing influence. However, in second method the hemisphere charge is measured using the lepton as a reference charge; the so-called lepton-signed hemisphere charge is formed:

$$Q_{lH} = -q_l \times Q_H^{opposite}, \tag{4}$$

where q_l is the charge of the lepton and $Q_H^{opposite}$ is the charge measured in the hemisphere opposite the lepton.
From this the b charge separation is extracted by the simple relationship:

$$\delta^b = \frac{2 \cdot \langle Q_{lH} \rangle}{(1 - 2\chi)}. \tag{5}$$

Here the $(1 - 2\chi)$ appears as the lepton-side needs to be corrected for mixing (the hemisphere opposite the lepton again contains the "correct" influence of mixing). This is the reason the mixing has some influence on the jet-charge measurement.
In the extraction of the forward-backward asymmetry (or $\sin^2\theta_W^{eff}$) the b charge separations from both methods are used. So, as the two measurements are averaged, the influence of mixing, entering through the measurement of δ^b in the semi-leptonic sample, is reduced. The change of $A_{FB}^{b\bar{b}}$with χ for the jet-charge method is again shown in figure 1, where the open square represents the measurement at the present LEP average of χ: $\chi = 0.115 \pm 0.011$ [4]. The curve shown is the result of a recalculation of the b charge separation from leptons at different χ-values, which is fed into the δ^b average with its updated errors and then taken through the full fit procedure [5].
The derivative for this measurement can be written as:

$$\frac{dA_{FB}^{b\bar{b}}}{d\chi} = -\frac{2 \cdot A_{FB}^{b\bar{b}}}{(1 - 2\chi)} \cdot w_l \cdot \frac{\delta_{lepton}^b}{\delta_{average}^b} \tag{6}$$

where w_l is the relative weight carried by the measurement of the δ^b from leptons, which is determined by the total errors of the two δ^b measurements. This gives a slope of -0.13 at the jet-charge working point. A fit to 6 points in the range $\chi = 0.1$ - 0.15 is performed, a linear approximation results in a slope again of -0.13.
Comparing this slope to the one of the high p_T lepton measurement shows it is of opposite sign and is approximately a factor 0.6 smaller in the magnitude.

3 Comparison of the two measurements

The $A_{FB}^{b\bar{b}}$values measured by the two methods are:

$$A_{FB}^{b\bar{b}} = (7.90 \pm 0.93_{stat} \pm 0.29_{sys} \pm 0.13_{models})\% \tag{7}$$

for the high p_T lepton measurement and:

$$A_{FB}^{b\bar{b}} = (10.94 \pm 1.20_{stat} \pm 0.50_{sys})\% \quad (8)$$

for the jet-charge measurement.
Treating the measurements as independent, which should be true apart from the shared systematics that enters through the δ^b measurement in the lepton sample and a small overlap in the event samples, the two measurements are different by 1.8 σ. Again looking at figure 1 it is clear that the difference does not find its origin in the fact that the $A_{FB}^{b\bar{b}}$'s were evaluated at different values of χ.

4 Conclusions

In this note it has been shown that the influence of mixing on the two $A_{FB}^{b\bar{b}}$measurements enters in a completely different way. This leads to an **opposite** behaviour in the χ, $A_{FB}^{b\bar{b}}$-plane, where the jet-charge measurement is influenced about **a factor 1.7 less** by mixing than the high p_T lepton measurement. The exercise also shows that the difference between the two measurements is not due to the fact that they were done at two different values of χ .

References

[1] D.Abbaneo et al., "B^0-$\bar{B}^0$ Mixing and the $b\bar{b}$ Asymmetry from High p_T Leptons (Update), ALEPH 93-100.

[2] A. Halley et al., A Preliminary Measurement of $sin^2\theta_W^{eff}$ from $A_{FB}^{b\bar{b}}$ in the 1992 Lifetime Tagged Heavy-Flavour Sample, Contribution to the EPS in Marseille.

[3] D. Brown, M. Frank, "Tagging b Hadrons using Track Impact Parameters", ALEPH 92-135.

[4] LEP Electroweak Working Group, "Updated Parameters of the Z^0 Resonance from Combined Preliminary Data of the LEP Experiments", informal note for the EPS conference in Marseille.

[5] Many thanks to Andy Halley for letting me run his fitting program.

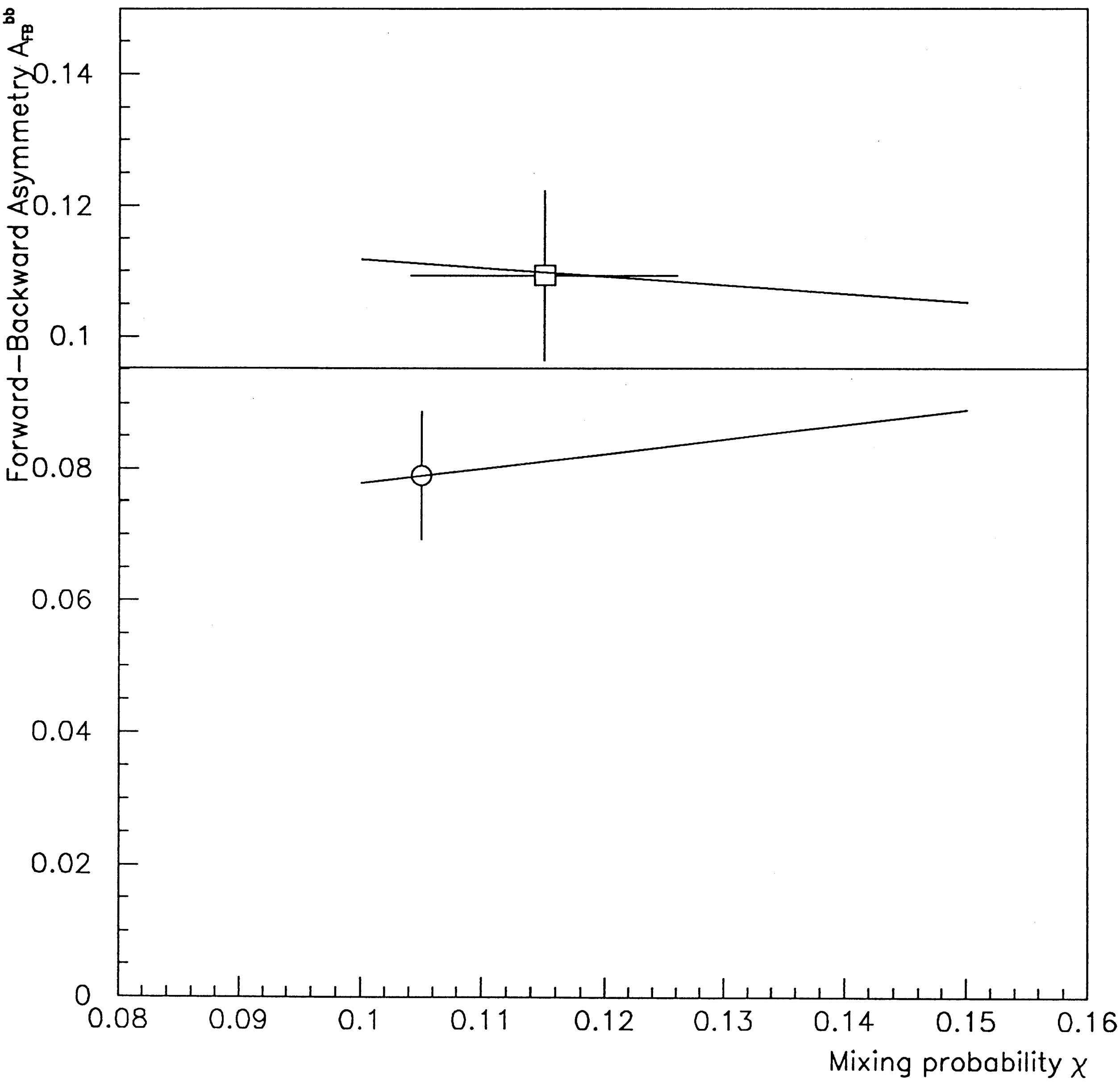

Figure 1: *Comparison in the* $A_{FB}^{b\bar{b}}$-χ *plane of the* $A_{FB}^{b\bar{b}}$*measurement using high* p_T *leptons (open circle + corresponding* χ*-dependence) and a jet-charge measurement on a lifetime tagged sample (open square + corresponding* χ*-dependence). The two measurements have an opposite dependence on* χ*, which also differs in magnitude. The horizontal line indicates the* $A_{FB}^{b\bar{b}}$ *expected from theory.*