ALEPH 93-172
PHYSIC 93-147
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4.11.1993

Addendum to the Measurement of the b Quark Hemisphere Charge Using a Lifetime-Tag

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4^{th} November 1993

Abstract

An update of the measurement of δ_b is presented. The changes with respect to the ALEPH Note 93-161 come from a correction to the lifetime-tagging algorithm when running on the new MINI-DST, an improved understanding of the lifetime-dependence of the hemisphere-charge distributions and a more comprehensive study of the systematic errors arising from correlations between the hemisphere charge-finding on opposite sides of the same event. These changes are fully documented here, to support the forthcoming $A_{FB}^{b\bar{b}}$ and $\langle Q_{FB} \rangle$ analyses which make use of the combined δ_b values.

1 Introduction

The measurement of δ_b presented in [1] describes in detail the techniques used to extract the b quark's hemisphere-charge from lifetime-tagged events. Subsequent to this, a difference was detected in the efficiency of events selected by QIPBTAG and that assumed from [2] to determine the b-purity of the event samples. This has now been fixed, and the analysis repeated. In addition, systematic checks on the lifetime dependence of the hemisphere-charges at low b-purities have been performed. Finally, the fragmentation systematic error from the correlation between the charge-finding in hemispheres of the same event have been recalculated to a higher accuracy and are now available for the full range of κ used in the $A_{FB}^{b\bar{b}}$ and $\langle Q_{FB} \rangle$ analyses.

The following Sections discuss these issues in detail, where it is assumed that the reader is familiar with the terminology and definitions of the original ALEPH Note. The effects of these new contributions, on the fit and extrapolation, are then shown in Section 5 whilst the updated values of δ_b and its errors are given in Section 6.

2 Correction to the b-Tagging Efficiency

As δ_b is extracted from a fit to $\bar{\delta}(\kappa, \mathcal{P}_b)$ versus $\mathcal{P}_b$ it is important to ensure that purities taken from [2] agree with that found in the data used for the analysis. This was recently found *not* to be the case due to an inconsistency between the QIPBTAG package and the recent MINI-DST [1] productions used for the δ_b analysis. This resulted in a significantly lower tagging efficiency ($\sim$ 10%) than that expected. The analysis has since been corrected, and re-run, and the results cross-checked against those from [2]. The results of this comparison are shown in Table 1 and are compatible with that expected. The dominant effect of the previous under-estimation of the b-tagging efficiency is to introduce a systematic bias to the gradient of the $\bar{\delta}(\kappa, \mathcal{P}_b)$ versus $\mathcal{P}_b$ fitting procedure, and to the values of $\bar{\delta}_b$ obtained from the extrapolation to 100% b-purity. The actual change to the measured values of δ_b presented previously, is small however as the extrapolation is only over a very small range of b-purity.

[1] As explained in the Offline ALNEWS of the 21st of October 1993.

Tag-Cut	*Measured Total Efficiency*	*Expected Total Efficiency*
1.00000	100.0 (±0.0) %	100.0 %
0.01000	24.29 (±0.07) %	24.38 %
0.00100	15.73 (±0.06) %	15.79 %
0.00010	10.58 (±0.05) %	10.63 %
0.00001	6.98 (±0.04) %	7.02 %

Table 1: *Comparison of the measured and predicted tagging efficiencies within a $\cos\theta$ cut of 0.7. The errors shown are statistical only.*

3 Lifetime Dependence of the Hemisphere-Charges

It was noted in [1] that the hemisphere-charges of events tagged with the lifetime-tag differed from those in untagged hemispheres. This was found to be due to the `QIPBTAG` track and event selection which preferentially selects events with a slightly higher charged multiplicity and harder momentum spectra. These in turn, influence the degree of charge retention visible within tagged jets. The effect of such a lifetime dependence is well modelled in simulated Monte Carlo events which are used to remove any bias from data.

In the previous study, the bias was corrected for, relative to the measured values of $\bar{\delta}$ in events where "almost" no tag-cut had been applied[2]. Such a selection barely alters the flavour composition with respect to a completely untagged sample. Recent studies indicate however, that there is even a small change of $\bar{\delta}$ from the event selection criteria of `QIPBTAG` *without* cutting on the hemisphere lifetime-tag probabilites. Consequently the lifetime dependent corrections are now applied relative to the $\bar{\delta}$ measured in data and simulated events without *any* lifetime-tag selection cuts applied. The effect of this difference can be seen from the measured values of $\bar{\delta}$ in events passing the lifetime-tag selection cut of 0.79 and those measured with no cut applied whatsoever. These values are compared in Table 2. As shown, this has the effect of increasing

κ	$\bar{\delta}$ Cut at 0.79		$\bar{\delta}$ With No Cut	
0.30	0.2009	0.0009	0.2056	0.0009
0.40	0.2078	0.0010	0.2133	0.0010
0.50	0.2180	0.0012	0.2240	0.0012
0.90	0.2705	0.0020	0.2770	0.0020
1.00	0.2833	0.0022	0.2897	0.0022
1.50	0.3343	0.0033	0.3405	0.0031
2.0	0.3659	0.0042	0.3720	0.0040
∞	0.4310	0.0096	0.4383	0.0090

Table 2: *Summary of differences between $\bar{\delta}$ measured in an untagged sample and that passing the* `QIPBTAG` *selection criteria and a "soft" cut of 0.79 of the hemisphere-tag probabilities.*

the low b-purity values of $\bar{\delta}$ by approximately ~ 0.006 for all κ . However, as the lifetime dependent corrections increase with b-purity then the relative importance of such a correction decreases, and in the end it has almost no effect on the extrapolated value of $\bar{\delta}_b$.

[2] This corresponded to a lifetime-tag cut of 0.79 which has a total event tagging efficiency of 94.334%.

4 Systematic Error Calculations

The systematic errors presented in [1] have been updated to take into account the following considerations :

- An updated treatment of the fragmentation uncertainties on the corrections applied to take into account the correlations between the hemisphere-charge measurements in opposite hemispheres of the same event. These calculations have been performed using the quantity :

$$- 4 \left[\langle Q_F^b Q_B^b \rangle \; - \; \langle Q_F^b \rangle \langle Q_B^b \rangle \right] \tag{1}$$

  as opposed to the less accurately defined difference in widths :

$$\left(\sigma_{FB}^b\right)^2 - \left(\sigma_Q^b\right)^2 \tag{2}$$

  used previously[3]. The systematic error on δ_b is now estimated from the sum in quadrature of all *statistically significant* dependencies of the correlation corrections on a given fragmentation parameter. These assume new parameter ranges from the most recent QCD fits [3]. For example, in the case of a κ of 0.5, these are summarised in Table 3.

Model Parameter	*Parameter Range*		*Correlation Correction*		Δ *Correlation & Error*		Δ δ_b *& Error*	
λ_{QCD}	0.296	0.346	0.0073	0.0074	0.0001	0.0002	0.0003	0.0008
M_{min}	1.530	1.770	0.0068	0.0075	0.0004	0.0001	0.0013	0.0005
σ	0.342	0.352	0.0072	0.0071	0.0001	0.0001	0.0002	0.0003
ϵ_b	0.002	0.007	0.0067	0.0071	0.0001	0.0003	0.0005	0.0012
$V/\left(V+PS\right)_{u,d}$	0.520	0.580	0.0076	0.0074	0.0001	0.0001	0.0003	0.0002
$V/\left(V+PS\right)_{s}$	0.570	0.630	0.0076	0.0074	0.0001	0.0001	0.0003	0.0004
$V/\left(V+PS\right)_{c,b}$	0.510	0.690	0.0071	0.0074	0.0002	0.0002	0.0007	0.0008
$\frac{s}{u}$	0.291	0.311	0.0072	0.0074	0.0001	0.0001	0.0004	0.0003
χ_d	0.118	0.180	0.0081	0.0072	0.0004	0.0006	0.0017	0.0023
χ_s	0.250	0.499	0.0075	0.0074	0.0000	0.0010	0.0002	0.0036
Baryon Fraction	0.099	0.110	0.0074	0.0080	0.0003	0.0002	0.0013	0.0009
Popcorn Parameter	0.350	0.550	0.0075	0.0076	0.0000	0.0001	0.0001	0.0002

Table 3: *The effect of varying different fragmentation model parameters on the correlation corrections at κ = 0.5. The upper and lower values for the correlation corrections are given and the resulting uncertainty on the extraction of δ_b from $\bar{\delta}_b$, together with their statistical errors from the finite size of the* KINGAL *event samples used.*

- The uncertainties on the sample purities at the various points are now converted to an equivalent uncertainty in the values of $\bar{\delta}\left(\kappa, \mathcal{P}_b\right)$ and included in the fit versus $\mathcal{P}_b$. This contribution is now included in the the value of $\Delta\left(\delta_b\right)^{Data}_{Stat.}$ in the final summary table of results and errors.

- Previously, some error calculations were carried out over a subset of κ values used for the forthcoming $A_{FB}^{b\bar{b}}$ and $\langle Q_{FB} \rangle$ analyses. These contributions have now been updated to form a larger *superset* of those used in the two analyses.

The complete error breakdown as a function of κ is presented later in Section 6.

[3] This is discussed in the the appendix of [1].

5 Effect on the Fitting Procedure and Extraction of δ_b

Figure 1 shows the results of these improvements for the case of a κ of 0.5. The updated

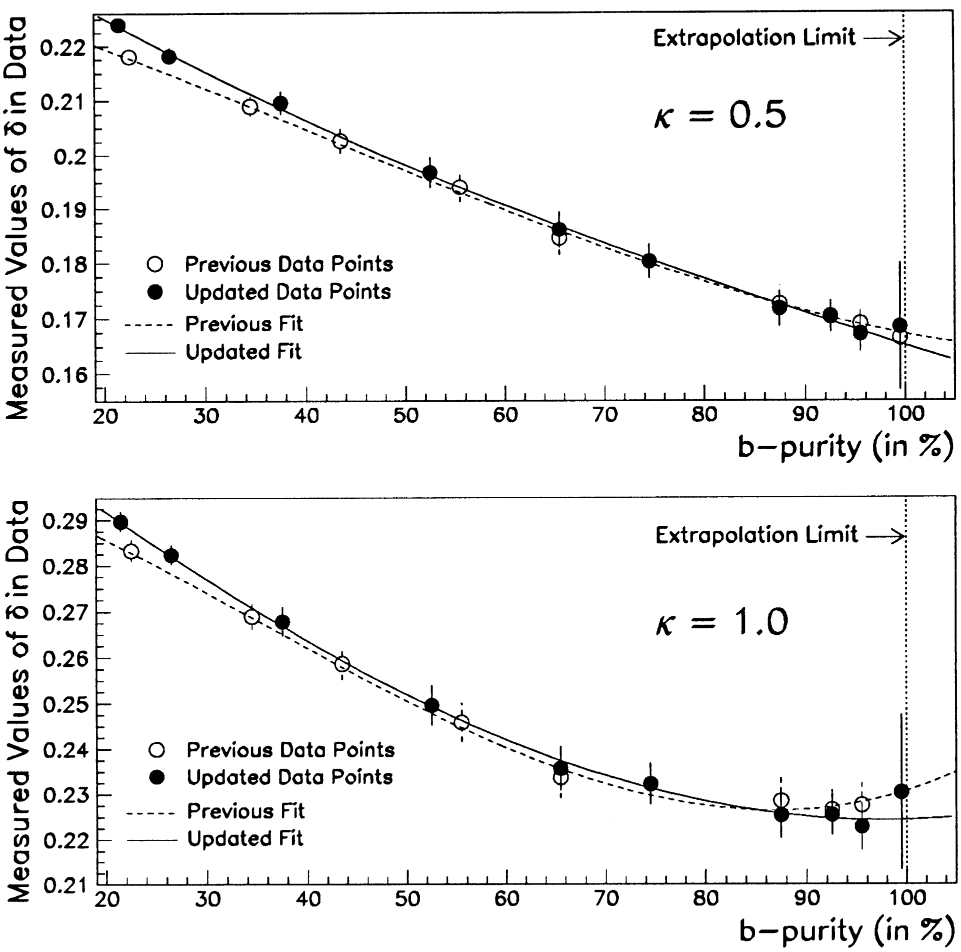

Figure 1: *Comparison of the extrapolation fits to* $\bar{\delta}\,(\kappa,\mathcal{P}_b)$ *versus* $\mathcal{P}_b$ *for the previous and updated calculations. These are shown for* κ *values of 0.5 and 1.0*

calculations show quite clearly the effect of the changes in the analysis discussed in the preceding Sections. The most important effect is the change in the overall gradient of the fits. This is due to the improved understanding of the tagging efficiencies and purities from `QIPBTAG`. At low b-purities the effect of applying the lifetime dependent corrections in an untagged sample adds a fixed offset. However, this rapidly becomes becomes negligible towards higher purities.

The extrapolation to 100% b-purity is largely unaffected, except perhaps at higher κ values, where $\bar{\delta}$ is seen to be slightly lower than that seen previously.

6 Updated Results and Error Summary

The final results of the updated analysis and error calculations are given in Table 4. The $\langle Q_{FB}^{btag}\rangle$ corrections have also been updated from data processed with the correct `QIPBTAG` tagging efficiencies. This can be compared directly with Table 11 in [1]. The relative statistical and systematic errors are summarised as a function of κ in Figure 6. This shows that this technique provides a measure of δ_b which is most accurate at a κ value of 0.5.

κ	δ_b	$\Delta(\delta_b)^{Data}_{Stat.}$	$\Delta(\delta_b)^{Life}_{Stat.}$	$\Delta(\delta_b)^{Life}_{Syst.}$	$\Delta(\delta_b)^{Corr}_{Syst.}$	$\Delta(\delta_b)_{Total}$
0.3	0.1100	0.0026	0.0031	0.0013	0.0022	0.0048
0.4	0.1252	0.0027	0.0031	0.0015	0.0022	0.0049
0.5	0.1400	0.0029	0.0030	0.0016	0.0019	0.0049
0.7	0.1688	0.0036	0.0032	0.0020	0.0030	0.0060
0.9	0.1952	0.0045	0.0035	0.0022	0.0047	0.0077
1.0	0.2068	0.0049	0.0036	0.0023	0.0052	0.0083
1.2	0.2272	0.0058	0.0039	0.0025	0.0059	0.0095
1.5	0.2515	0.0077	0.0043	0.0027	0.0065	0.0113
2.0	0.2777	0.0088	0.0047	0.0027	0.0145	0.0178
∞	0.2848	0.0239	0.0062	0.0022	0.0220	0.0331
		(a)	*(b)*	*(c)*	*(d)*	

Table 4: *Summary of results and error contributions to δ_b from $\bar{\delta}$. The errors are from : (a) the statistics of the data sample, (b) the Monte Carlo statistics used to make the lifetime dependent corrections, (c) the systematic error applied to the lifetime dependent corrections and (d) the systematic error from the correlation corrections.*

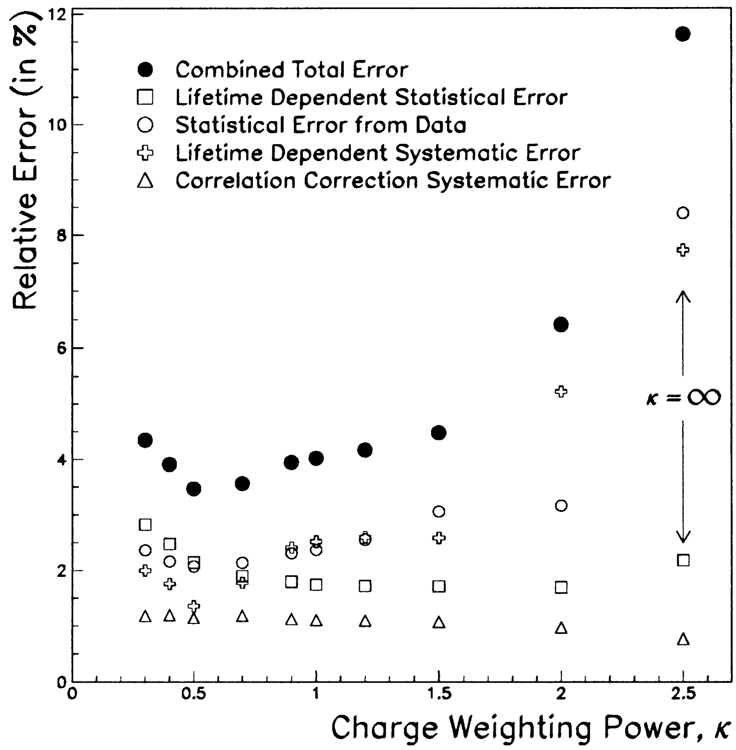

Figure 2: *Summary of the relative error contributions to δ_b as a function of the κ at which it is measured.*

7 Acknowledgements

The author would like to thank S. Haywood for useful discussions regarding the systematic error calculations and to D. Brown for support and fast response.

References

[1] A. Halley and P. Colrain, *A Measurement of the b Quark Hemisphere-Charge Using a Lifetime-Tag in the 1992 Data*, ALEPH Note 93-161, Physic 93-138, October 1993.

[2] D. Buskulic et al. (The ALEPH Collaboration), *"A Measurement of* $\Gamma_{b\bar{b}}/\Gamma_{had}$ *Using a Lifetime b-Tag"*, CERN Preprint PPE 93-108.

[3] Private communication with A. Blondel (ALEPH).