MEASUREMENT OF R_{uds}

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A first direct measurement of the Z^0 decay fraction into light quarks, R_{uds}, has been made by ALEPH. The tag for light quark events is based on high-energetic particles, lifetime information and low P_T tracks from $D^* \rightarrow D\pi^{\pm}$. Using a double tag method, a preliminary value of $R_{uds} = (61.42 \pm 0.45(stat.) \pm 1.32(syst.))\%$ has been obtained, in good agreement with the Standard Model prediction.

1 Introduction

There has been much effort in recent years to measure the Z^0 partial decay width to $b\bar{b}$ and $c\bar{c}$ quarks to high precision. A direct measurement of the partial decay width to light quarks, $R_{uds} = \Gamma_{Z^0 \rightarrow u\bar{u}, d\bar{d}, s\bar{s}} / \Gamma_{Z^0 \rightarrow hadrons} = 1 - R_b - R_c$ is thus a useful tool for understanding any possible deviations of R_b and R_c from Standard Model predictions. It also permits an indirect measurement of R_c. A preliminary first measurement of R_{uds}, made by ALEPH, is described in a paper submitted to this conference [1] and summarised here.

2 Tagging light quark events

For a measurement of R_{uds}, it is necessary to separate uds from c and b events. Each hadronic event is divided into two hemispheres by a plane perpendicular to the thrust axis. Three types of tag are then applied in each hemisphere:

Momentum: The charged or neutral particle with the highest momentum is found. When the scaled momentum distribution of these particles, $X_P^{max} = P_{max}/E_{beam}$, is examined, it is found that high momentum particles are a signature for uds hemispheres. The reason for this is that there are no D or B hadrons in light quark events.

Lifetime: The signed impact parameters for the charged tracks in a hemisphere are used to calculate the probability, P_H, that they are all compatible with the primary vertex.[2] By requiring P_H to be large, uds events can be selected.

Transverse momentum: The track which has the minimum transverse momentum with respect to the jet axis, P_T^{min}, is selected. A soft pion with a small P_T is a signal [3] for $D^* \rightarrow D\pi^{\pm}$. Charm events containing this decay can be rejected by requiring that the minimum transverse momentum be large.

Instead of using these tags individually, they are combined with an arbitrary scale factor, k, to form a single tag variable X_{tag}:

$$X_{tag} = k \cdot f_1(X_P^{max}) \cdot f_2(P_H) \cdot f_3(P_T^{min}) \qquad (1)$$

The function f_1 is calculated from the distributions of X_P^{max} for light and heavy quark events $f_1(X_P^{max}) = N_{uds}(X_P^{max})/N_{cb}(X_P^{max})$. The function f_2 and f_3 are the analogous quantities for lifetime and minimum P_T respectively.

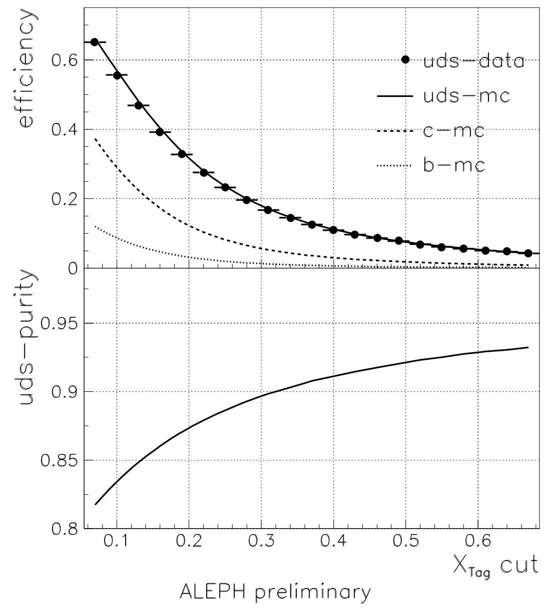

Figure 1: Efficiency of the tag. For the measurement of R_{uds}, a cut was made at $X_{tag} = 0.22$

It is possible to select a sample enriched in light quark events by requiring a large value of

X_{tag}. The efficiency and purity of this selection along with the c and b background, as predicted by Monte Carlo, are shown in Figure 1. The double tag method described in Section 3 also allows the efficiency for tagging uds hemispheres to be calculated from data. Good agreement is found between data and Monte Carlo.

3 Measuring R_{uds}

The high statistics available at LEP make it possible to use the double tag technique to measure R_{uds}. The light quark tag described in Section 2 is applied to both hemispheres of hadronic events, so that each has the potential to tag twice. The number of tagged hemispheres, N_s, the number of events in which both hemispheres have been tagged, N_d, and the total number of hadronic events, N_h, are then used as inputs to the equations:

$$\frac{N_s}{2N_h} = R_{uds}\epsilon_{uds} + R_c\epsilon_c + R_b\epsilon_b \qquad (2)$$

$$\frac{N_d}{N_h} = R_{uds}\epsilon_{uds}^2(1+\rho_x) + R_c\epsilon_c^2 + R_b\epsilon_b^2 \qquad (3)$$

Here, ϵ_{uds}, ϵ_c and ϵ_b are the probability of tagging hemispheres from uds, c or b events respectively, R_b is the ratio $\Gamma_{Z^0\to b\bar{b}}/\Gamma_{Z^0\to hadrons}$, R_c is $(1 - R_b - R_{uds})$ and ρ_x is the correlation between hemispheres. This last is needed to correct for the fact that the probability of tagging both hemispheres of a light quark event is not exactly ϵ_{uds}^2. In principle, similar factors should be incorporated into the terms containing ϵ_b and ϵ_c, but these are strongly suppressed by the small probability to tag b and c events.

Table 1 shows the values of ϵ_{uds}, ϵ_c, ϵ_b and ρ_x for a cut of 0.22 on the X_{tag} variable. This cut is placed at the point which minimises the combined systematic and statistical error on R_{uds}.

Equations 2 and 3 can be solved for the unknowns R_{uds} and ϵ_{uds}. The background efficiencies ϵ_c and ϵ_b and the correlation ρ_x are taken from data or Monte Carlo and R_b is from experiment. The individual tagging efficiencies for u, d and s events are found to be equal within 3% relative to one another.

Table 1: Efficiencies and correlation for a cut of 0.22

Variable	Value (stat. error only)/%
ϵ_{uds}	28.11 ± 0.30
Variable	Value ($\pm$stat. $\pm$ syst.)/%
ϵ_c	$10.39 \pm 0.05 \pm 0.53$
ϵ_b	$2.55 \pm 0.09 \pm 0.05$
ρ_x	$3.39 \pm 0.33 \pm 0.15$

4 Systematic errors

The systematic uncertainties in this measurement of R_{uds} derive from use of the background efficiencies ϵ_c and ϵ_b, the correlation ρ_x and the value of R_b as inputs to equations 2 and 3.

The charm background efficiency is taken from Monte Carlo prediction. Uncertainty in its value derives from the statistics of the Monte Carlo sample, imperfect knowledge of the charm physics parameters used as input to the Monte Carlo and imperfect simulation of the detector.

The efficiency to tag b hemispheres is measured from data, using the high-purity b-tag developed for the ALEPH R_b measurement. [4] A cut giving 99.5% b-purity is applied to one hemisphere and the number of opposite hemispheres passing the light quark tag is counted. A correction is necessary to allow for the correlation between a hemisphere passing the b-tag and the opposite hemisphere passing the light quark tag: $\rho_{bx} = (-0.7 \pm 0.45(stat.) \pm 1.32(syst.))\%$. This quantity is taken from the Monte Carlo and leads to a systematic uncertainty in the value of ϵ_b. Uncertainty in the value of ρ_{bx} derives from the statistics of the Monte Carlo sample, imperfect knowledge of the B physics parameters used as input to the Monte Carlo and imperfect simulation of the detector.

The correlation between tag probabilities in the two hemispheres, ρ_x, is mostly due to the high-momentum particle component of the tag. If a gluon is emitted by one of the primary quarks before fragmentation, less momentum is available for the jets that the quarks eventually create. Thus, the scaled momenta of the highest momentum particles are reduced, introducing a positive correlation between the X_{tag} variables in each hemisphere. The value of ρ_x is taken from the Monte Carlo and verified as far as possible with the data.

Uncertainty on the predicted value is due to Monte Carlo statistics, imperfect simulation of the detector and possible discrepancies between data and Monte Carlo.

Finally, there is a systematic error in the measurement of R_{uds} due to uncertainties in the value of R_b. The ALEPH preliminary measurement made with five tags [5] $R_b = (21.58 \pm 0.14)\%$ was used.

Table 2 shows the statistical and systematic errors contributing to the uncertainty in the value of R_{uds}.

Table 2: Uncertainties in the value of R_{uds}

Source	Absolute uncertainty/%
Data statistics	0.45
MC statistics	0.62
ϵ_c	1.11
ϵ_b	0.17
ρ_x	0.24
R_b	0.16
Total systematic error	1.32

5 Results

The value of R_{uds} was calculated with a cut of 0.22 on X_{tag}, which minimises the combined statistical and systematic error. Figure 2 shows the total error as a function of the cut, and the stability of R_{uds}. Note that the uncertainties on the measurements at different values of the cut are correlated. Using data from 1994 and 1995, the preliminary result from ALEPH is: $R_{uds} = (61.42 \pm 0.45(stat.) \pm 1.32(syst.))\%$

6 Discussion

The preliminary value $R_{uds} = (61.42 \pm 1.39)\%$ is consistent with the Standard Model prediction of $R_{uds} = 61.21\%$. By combining the measurement with the preliminary ALEPH value of R_b, it is possible to make an indirect measurement of $R_c = (17.00 \pm 0.45(stat.) \pm 1.32(syst.))\%$. This is compatible with the combination of preliminary direct measurements $R_c = (16.83 \pm 0.91)\%$ by ALEPH.[3] The uncertainty of this indirect measurement of R_c is comparable to the errors of the individual direct measurements.

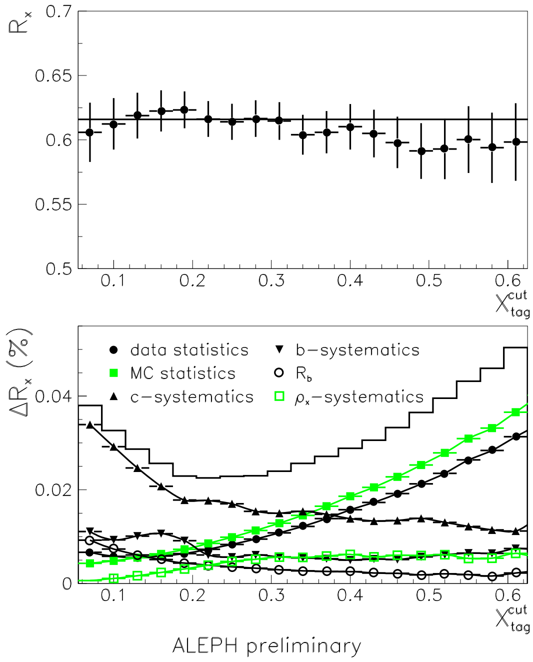

Figure 2: Measured value and error for R_{uds} (labelled R_x) as a function of the cut on X_{tag}. Note that the errors shown are correlated between different cut values.

Acknowledgements

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References

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