707: The Measurement of R_{uds} , R_c and R_b at LEP and SLD

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Abstract. The new measurements of the partial widths of the Z into quarks at LEP and SLD are reviewed.

1 Introduction

The precise measurement of the partial width of the Z into quarks $R_{q_i} = \Gamma_{Z \rightarrow q_i \bar{q}_i} / \Gamma_{Z \rightarrow had}$ is a good test of the standard model, because R_{q_i} has negligible dependence on α_s , on the top and Higgs masses. Only R_b is affected by electroweak corrections involving the top quark mass.

The crucial problem in these measurements is the identification of the quark flavour with high purity and efficiency. A very high efficiency is needed in order to minimize the statistical error; a very high purity and a good understanding of the background decrease the systematic error coming from the contamination of the other quark species. Any selection should aim to minimize the correlation between the 2 hemispheres and the corresponding systematic error. The high statistics collected during the LEP1 phase (about 3.5M hadronic Z decays per experiment) together with the analyses developed by the different LEP collaborations and SLD allow the measurement of the partial widths with very high precision.

2 The Measurement of R_u and R_{ds}

The measurement of R_{uds} has been done with a high purity (88%) and efficiency (25%) by ALEPH [1]. More difficult instead is to measure separately the three light quark flavour partial widths. A new measurement from OPAL [2] assumes flavour universality to measure $R_{d,s}$ and R_u separately. Identifying the high momentum stable particles (K, π, p, A) in each hemisphere as a tag of the primary quark, OPAL measures:

$$R'_u = 0.258 \pm 0.031 \pm 0.032, \quad R'_{d,s} = 0.371 \pm 0.016 \pm 0.016$$

where $R'_q = R_q / (R_u + R_d + R_s)$, thus independent of the measurement of the heavy flavour fractions. The results are in good agreement with the standard model expectations of 0.282 and 0.359 respectively. The largest systematic contribution come from the particle identification.

3 The new measurements of R_c

A deep understanding of the uncertainties dominating the measurement of R_c has been reached recently, and the value of R_c has been measured to be in agreement with the standard model expectation. The measurement of R_c is dominated by the large contamination of the b quark: only 7-10% precision has been achieved so far by each experiment.

Two new measurements of R_c come from ALEPH [3], using the *charm counting method* and all LEP1 statistics, and from OPAL [4] using the double tag methods with exclusive and inclusive D^* reconstruction. Both methods are systematically limited. The main contributions to the systematic error come from fragmentation, vertexing and b -background.

A new method to measure R_c has been proposed by SLD [5]. They developed a pure and efficient c -tag reconstructing secondary vertices [6] and computing their masses and momenta. The region of high momentum and of mass between 0.6-2.0 GeV is enriched in charm and a purity of 68% with an efficiency of 14% is achieved. Since b is the main background, in each hemisphere both a b and a c tag are performed, comparing then the rate of single, double and mixed tag. The reached precision is very high: the statistical error is comparable to the one of LEP experiments with a better systematic error. The main systematic left is from the charm tag hemisphere correlations.

The results are summarized in figure 1.a.

Fig. 1. a) The R_c results. b) The R_b results.

4 The new precise measurements of R_b

The measurement of the partial width of the Z into b quarks has reached very high precision (about 0.4%) and together with the discovery of the top allow good test of the standard model.

SLD and the LEP experiments are equipped with microvertex detectors (see table 1) allowing the identification of b -quarks with very high purity and efficiency via the reconstruction of secondary vertices or the measurement of the impact parameter distributions. The individual detector b -tag performance are shown in table 1.

Two of the largest contributions affecting the measurement of R_b , i.e. the charm background and the correlations between hemispheres, have been reduced considerably. The former by developing very pure b -tags and thus reducing considerably the other quark contaminations. The latter by fitting a primary vertex in each hemisphere, leaving the angular correlation and the gluon radiation as the only sources of correlation. The data, the simulation and the theoretical expectation [7] are in good agreement, resulting in a small systematic uncertainty on the correlation itself.

Three new measurement have been presented this year: the DELPHI result [8] is based on a new and very pure b -tag that combines impact parameter with reconstructed secondary vertices informations, reaching 98% purity at 32% efficiency (see table 1). The b -tag is used in a multivariate analysis that further decreases the statistical error reaching a precision of 0.55%. The systematic error coming from the detector resolution understanding is substantially smaller than for the other experiments, thanks to the 3 layers of the vertex detector that allows the pattern recognition and the tracking to be cleaner and less ambiguous. The result is very stable as a function of the cut and up to purity larger than 99.5% [8].

The measurement of L3 [9], a combined result from an impact parameter analysis and a lepton momentum spectra analysis, reaches a precision of 1.4%, due to the low purity of the working point.

The highest purity and efficiency is reached by the SLD detector that profits from the very small interaction region and thus to the small radius of the first vertex detector layer (see table 1). The b -tag is based on the mass of secondary vertices [6]. The result [10] suffers from the low statistics available.

The results from all the collaborations are listed in figure 1.b. The combined LEP and SLD result of $R_b = 0.2171 \pm 0.0009$ reaches the 0.4% precision and it is consistent with the standard model expectation of 0.2158 ± 0.0003 . The systematic error contributions for all the experiment are listed in table 2. The most precise results suffer from the uncertainty on the gluon splitting into b quark rate. With the final results from all the experiment based on the full available statistic and with the foreseeable improved measurements on various b and c related quantities the precision on R_b will likely decrease even more.

5 Summary

A very high precision has been reached in the measurement of the partial widths of the Z into quarks. The combined LEP and SLD results reached the 3% precision for the R_c measurement, while 0.4% precision has been achieved in the R_b measurement, thank to new powerful b identification techniques. All the measurements agree with the Standard Model expectations.

	ALEPH	DELPHI	L3	OPAL	SLD
Coordinates Used	$R\Phi, z$	$R\Phi, z$	$R\Phi, z$	$R\Phi$	$R\Phi, z$
Num. of layers	2	3	2	2	3
Radius of layers	6.5-11.3	6.3/11	6.4-7.9	6.1-7.5	2.9/4.1
$R\Phi$ I.P. resolution μm	25	20	30	18	13
z I.P. resolution μm	25	30	30		24
Primary Vtx resol. ($x \times y \times z \mu\text{m}$)	$58 \times 10 \times 60$	$22 \times 10 \times 22$	$42 \times 10 \times 42$	40×10	$6.4 \times 6.4 \times 15$
b Purity %	97.8	98.0	86.4	90.5	97.6
b Efficiency %	22.7	32.4	23.7	23.1	47.9

Table 1. Vertex Detector Characteristics and b -Tagging performance

	ALEPH	DELPHI	L3	OPAL	SLD
detector resolution	0.0005	0.0002	0.0004	0.0004	0.0011
ϵ_b correlation	0.0003	0.0004	0.0007	0.0010	0.0004
udsc simulation	0.0005	0.0005	0.0018	0.0009	0.0005
gluon splitting	0.0006	0.0005	0.0002	0.0006	0.0006
MC statistic	0.0005	0.0005	0.0008	0.0003	0.0009
event selection	0.0001	0.0001		0.0003	0.0003
total systematic	0.0011	0.0009	0.0026	0.0017	0.0016
statistics	0.0009	0.0008	0.0015	0.0014	0.0034

Table 2. R_b Error Breakdown

References

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