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A measurement of $\Gamma(b\bar{b})/\Gamma(had)$ using leptons

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Abstract

In about 1,000,000 hadronic Z decays, recorded with the ALEPH detector at LEP, the partial width ratio $\Gamma(b\bar{b})/\Gamma(had)$ is measured using leptons. We combine the measurement of a double tag method using high $P_\perp$ leptons in 1992 data and the measurement of the global lepton analysis in 1990 and 1991 data, we find :

$$\Gamma(b\bar{b})/\Gamma(had) = 0.2223 \pm 0.0042(\text{stat}) \pm 0.0057(\text{syst})$$

1 Introduction

In this note we will discuss three points :

- A description of the double tag analysis with high $P_\perp$ lepton
- The presentation of the global lepton analysis result for (90+91) data .
- The third point is devoted to combine the results of this two analyses.

2 Measurement of $\Gamma(b\bar{b})/\Gamma(had)$ with high $P_\perp$leptons

Using leptons with $P_\perp$ over 1.25 GeV/c, the fraction of hadronic events which are $b\bar{b}$ has been measured.

The method uses single and double tagged events to eliminate the uncertainties on the details of B decays and fragmentation. Events with high $P_\perp$ leptons are split into two hemispheres with respect to the thrust axis. They are then divided into two categories: a double tagged sample in which both hemispheres contain at least one high $P_\perp$ lepton, and a single tagged sample when one of the hemispheres do not contain a lepton. The value of $\Gamma(b\bar{b})/\Gamma(had)$ is then derived from counting the numbers N_{st} and N_{dt} of single tagged and double tagged events by solving the system :

$$\left\{\begin{array}{lllll} N_{st} & = & 2P_b(1-CP_b)N_{b\bar{b}} & + & N_{st}^{light} \quad (1) \\ N_{dt} & = & CP_b^2N_{b\bar{b}} & + & N_{dt}^{light} \quad (2) \end{array}\right.$$

Where:

$N_{b\bar{b}}$ is the number of Z → $b\bar{b}$ produced events in the hadronic sample.

P_b is the probability to tag one hemisphere of a $b\bar{b}$ event. It is the sum of the different b decay mode tagging probabilities. This quantity is extracted from data and contains all the uncertainties related to b physics: branching ratios and b quark fragmentation.

P_b and $N_{b\bar{b}}$ are the two unknowns which are measured.

$C = P_{b\bar{b}}/P_b^2$ where $P_{b\bar{b}}$ is the probability to tag the two hemispheres in a $b\bar{b}$ event. This factor accounts for possible correlations between the tagging efficiencies of the two hemispheres. To prevent the analysis of lower lepton efficiencies at large $\mid cos\theta \mid$, the thrust axis of the event is required to be in the limit $\mid cos\theta \mid < 0.9$.

N_{st}^{light} and N_{dt}^{light} are the number of single and double $udsc$ tagged events respectively. C, N_{st}^{light} and N_{dt}^{light} are estimated from Monte Carlo simulation.

Tag of the hemispheres using high $P_\perp$ leptons As the only input from Monte Carlo simulation concerns the light quark contribution to single tag events, it is desirable to reduce this to a minimum. This can be achieved by demanding the latter to be in the high P $P_\perp$ region. Table 1 shows the expected contributions in the single and double tagged samples as a function of $P_\perp$.

$P_\perp$ cut	0.75	1.0	1.25	1.5
$b\bar{b}(st)$	0.75	0.82	0.870	0.900
$c\bar{c}(st)$	0.15	0.11	0.075	0.055
$uds(st)$	0.10	0.07	0.055	0.045
$b\bar{b}(dt)$	0.960	0.980	0.996	0.997
$c\bar{c}(dt)$	0.036	0.013	0.004	0.003
$uds(dt)$	0.004	0.007	0.000	0.000

Table 1: Fractions of events from various sources in the single (st) and double (dt) tagged samples as a function of the $P_\perp$ cut.

A $b\bar{b}$ purity of 87% in the single tag sample can be achieved for $P_\perp \geq 1.25$ GeV/c, for which the b purity of the double tagged sample is almost 100%. Later on, the results are given for the cuts used in table 1.

Computation of the C factor. The C factor has been estimated by using 719,892 full simulated $b\bar{b}$ events. The value $C = 0.994 \pm 0.013$ is very consistent with 1. It was checked that C does not depend on the $P_\perp$ cut hence is independent of the physical origin of the leptons.

Results for 90 and 91 data

Following the $| cos_{thrust} | < 0.9$ cut, there are 380,604 hadronic Z decays. For the $P_\perp$ cut at 1.25 GeV/c 16,241 single tag and 710 double events. Solving equations 1 and 2 with the light quark contribution taken from Monte carlo simulation yields:

$$\begin{aligned} R_b &= 0.2215 \pm 0.007 \quad (stat.) \\ P_b &= 0.0908 \pm 0.003 \quad (stat.) \end{aligned}$$

The values of R_b as a function of the $P_\perp$ cut are given in figure 1.

Preliminary Result for 92 data

For the 92 data we use 653,938 hadronic Z events. For the $P_\perp$ cut at 1.25 GeV/c 28,886 single tag and 1281 double tag events are identified. Solving equations 1 and 2 yields:

$$\begin{aligned} R_b &= 0.2260 \pm 0.0053 \quad (stat.) \\ P_b &= 0.0916 \pm 0.0024 \quad (stat.) \end{aligned}$$

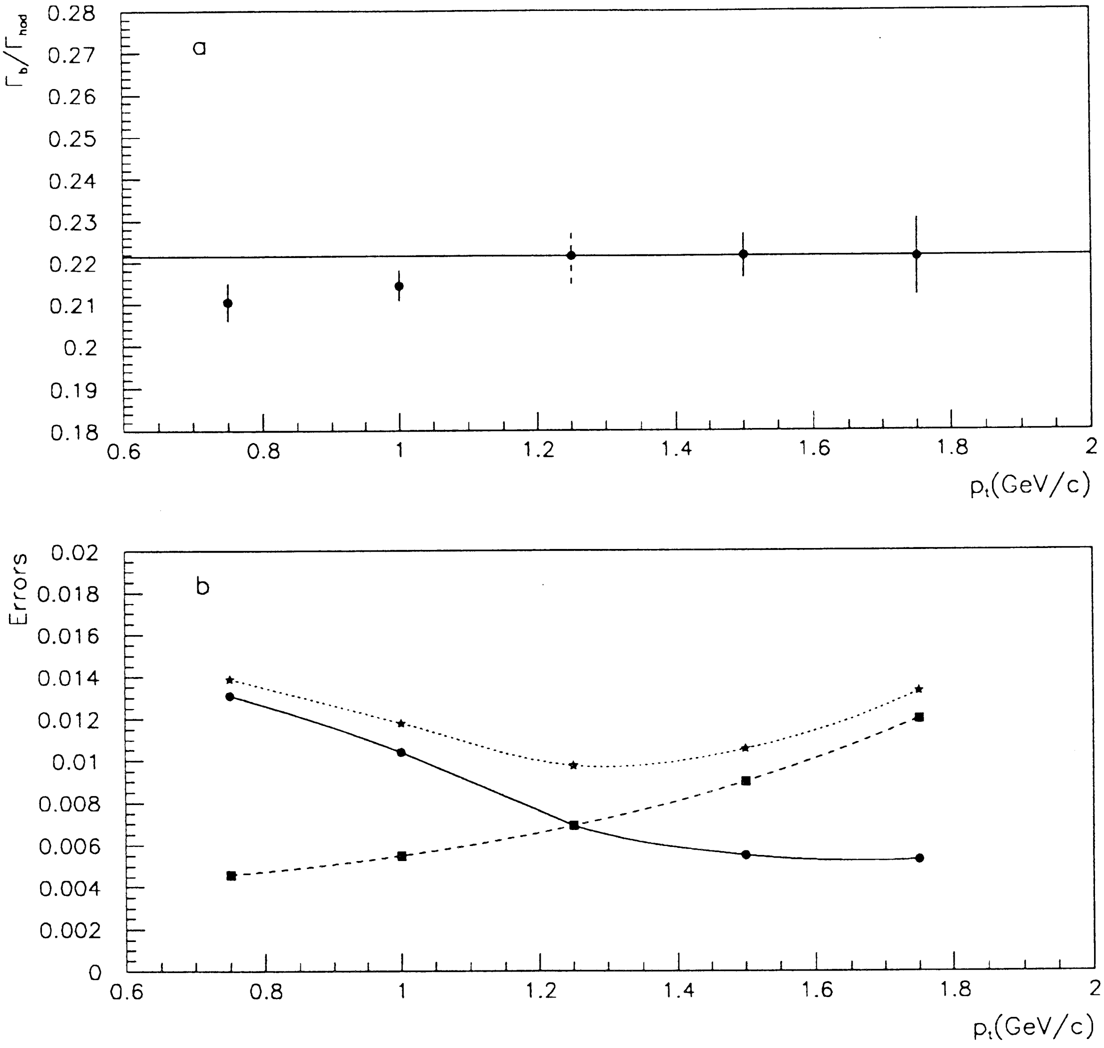

Figure 1: (a) Γ_b/Γ_{had} variation with $P_\perp$ in '1990 + '1991 data; the errors are uncorrelated statistical error except for 1.25 GeV/c were this is the true statistical error. (b) The full line gives the systematical error variation with $P_\perp$, the dashed line is the statistical error and the dotted line is the total error.

Systematic uncertainties in the measurement of $\Gamma(b\bar{b})/\Gamma(had)$ As this method is independent of all aspects of b fragmentation model, b decay models and experimental tagging, only a restricted list of sources for uncertainties needs to be considered. These are given in table 2.

Experimental uncertainties for electrons :

For electrons the efficiencies of ECAL and dE/dx identifications are directly measured on data with quite large statistics. In particular the $P_\perp$ dependence for the dE/dx efficiency is very well known. Then a conservative total uncertainty of 3% is set on the electron identification efficiency. The misidentification probability for non electron particle is very small and directly measured on data and a remaining uncertainty of 10% is assumed.

The rate of electrons from γ materialization is controlled on data by the number of pairs observed with at least one track consistent with the electron identification criteria. The total rate is then controlled within 1% but a source of uncertainty is the efficiency of the algorithm used to reconstruct pairs. This is conservatively evaluated to be known with 10%.

Source	Variation	$\Delta\Gamma(b\bar{b})/\Gamma(had)(\%)$
Charm fragmentation ε_c	20 %	±0.13
$c \rightarrow \ell$model	50 %	±0.30
$\Gamma(c\bar{c})/\Gamma(had)$	12 %	±0.40
Lepton id. efficiency	3 %	±0.12
e misidentification	10 %	±0.02
γ conversion	10 %	±0.01
Punch through + μ decay	20 +10%	±0.27
Monte Carlo statistics	1σ	±0.16
$C = \frac{P_{b\bar{b}}}{P_b^2}$	1σ	±0.29
Selection correction C_b	1σ	±0.09
Total		±0.69

Table 2: Systematic errors on $\Gamma(b\bar{b})/\Gamma(had)$.

Experimental uncertainties for muons :

The muon identification efficiency has been computed from real isolated muons in function of the cosine of the polar angle. We have verified that it is independent of momentum. A global uncertainty on the muon identification efficiency of 3% has been calculated. The contamination from hadron punch-through and from pion and kaon decays has been evaluated with the Monte Carlo simulation. The performance of the simulation has been checked with an analysis based on real data using τ and K^0 decays. From this analysis we have assigned an error on the punch-through and decay rate of 30% and 10%, respectively.

Charm semileptonic decay modeling :
The lepton energy spectrum in the c-hadron rest frame from charm decays contains large uncertainties. The main source of experimental information is from DELCO [1]. In this experiment ψ'' decays are the source of D^0 and D^+ with approximately the same production rate, except for a small phase space effect. The shape of the energy spectrum generated in JETSET is softer that the DELCO results and is weighted to reproduce it. Half of the difference between the weighted and unweighted results is taken as the modelling uncertainty.

Results for 90, 91 and 92 data

We have measured the partial width $\Gamma(b\bar{b})/\Gamma(had)$ using one million hadronic Z events collected by ALEPH during 1990 , 1991 and 1992 :

$$R(b) = 0.2243 \pm 0.0042(\text{stat}) \pm 0.0069(\text{syst})$$

3 The global Lepton Analysis

All the results obtained with the 1990 and 1991 data are summarized in table 3. The statistical error on $R(b)$ takes into account the correlations between the fitted parameters. We evaluated the contribution due to the charm equal to 0.32 and the remain statistical error is 0.53 so the $R(b)$ result is :

Parameter	e+μ	Statistical Uncertainty	Systematic Uncertainty	Model Uncertainty
$R(b)(\%)$	21.9	0.62	0.42	0.23
$R(c)(\%)$	16.5	0.54	1.87	0.25
$< x_b >$	0.714	0.004	0.005	0.010
$< x_c >$	0.485	0.008	0.006	0.001
$BR(b \to l)$ (%)	11.4	0.33	0.37	0.20
$BR(b \to c \to l)(\%)$	8.2	0.25	1.00	0.60
$\chi(\%)$	11.4	1.40	0.68	0.44
$A^c_{FB}(\%)$	9.9	2.04	1.63	0.74
$A^b_{FB}(\%)$	8.7	1.4	0.16	0.13

Table 3: Global analysis: Final results

$$R(b) = 21.90 \pm 0.53 \text{ (stat)} \pm 0.23 \text{ (}b\text{ modeling)} \pm 0.53 \text{ (syst)}$$

where the first error is statistical, the second one is due to the B decay modeling and the last one is the systematic error including the part coming from the charm (0.32).

4 Combined result

To calculate a combined result of the two method discussed above, we use two statistical independent samples :

$$\begin{array}{llcll} (1) & R(b) & = & 21.90 \pm 0.53 \pm 0.23 \pm 0.53 & \text{Global lepton analysis} \\ (2) & \mathrm{R(b)} & = & 22.60 \pm 0.53 \pm 0.29 \pm 0.62 & \text{High } P_\perp \text{ leptons} \end{array}$$

The first error is statistical. The second one is a specific systematic uncertainty of each measurement. For the global lepton method it is due to the B decay modeling and in the high $P_\perp$ leptons method it originates from the C correction factor see section 2. The third error is due to common sources of uncertainties essentially coming from light quark.

To combine these results we assume that the last errors are fully correlated and we find :

$$R(b) = 22.23 \pm 0.42\text{(stat)} \pm 0.57\text{(syst)}$$

References

[1] DELCO Collaboration, W. Bacino *et al.*, Phys. Rev. Lett. **43** (1979) 1073.