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B MASS EFFECTS IN MULTIJET EVENTS WITH THE DELPHI DETECTOR AT LEP

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The effect of the b quark mass has been observed in the normalized n-jet rates of b quarks with respect to light quarks (light $= \ell = u, d, s$), R_n^{bl} (n=2-4), with data collected by the Delphi detector at the Z peak. For the case of the three-jet rate, a comparison with the massive NLO calculations performed with Cambridge and Durham jet clustering algorithms has enabled to determine the b quark mass at high energy. Consistent results were obtained with the four-jet observable using an approximation of the NLO theoretical prediction.

1 Introduction

The b quark mass is a free parameter in the Standard Model Lagrangian and therefore needs to be determined experimentally with the highest possible precision. However, confinement of quarks inside the observed hadrons introduces an additional complication with respect to mass determinations of free particles. Quark masses need then to be defined within a theoretical convention. Among the different quark mass definitions, the most commonly used are the pole mass M_b and the running mass $m_b(Q)$.

The motivation of the present analysis was to get a more precise determination of $m_b(M_Z)$ with respect to previous results [1,2,3,4].

2 Experimental determination of the observables

The observables used in this analysis is defined as:

$$R_n^{b\ell}(y_{cut}) = \frac{[\Gamma_n(y_{cut})/\Gamma_{tot}]^{Z\rightarrow b\bar{b}}}{[\Gamma_n(y_{cut})/\Gamma_{tot}]^{Z\rightarrow \ell\bar{\ell}}}, \qquad n = 2,3,4-jets, \tag{1}$$

being $\Gamma_n(y_c)$ and Γ_{tot}, respectively, the n-jet and total decay widths of the Z into $q\overline{q}$, where $q = (b$ or $\ell \equiv uds$ quarks). The flavour q of the hadronic event was defined as that of the quarks coupling to the Z. The Cambridge algorithm was used for jet reconstruction for all observables and Durham was used as a consistency check for the three jets case.

A sample of Z hadronic decays was selected from the data taken by Delphi from 1994 to 2000 at the Z peak. From those events, the b and ℓ quark initiated events were separated using Delphi flavour tagging methods [5,6]. For the four-jet rate, the tagging was done over those events reconstructed to four jets and the normalization to total rates was obtained from the latest determination of R_b and R_c [7].

Data was then corrected for detector and tagging effects and the hadronization process to bring the observable to parton level.

The complete Delphi simulation (Delsim), which uses Jetset 7.3 to generate the events that go through the detector simulation, was used to compute the detector correction. A reweighting of the events was done in order to reproduce the measured heavy quark gluon splitting rates [8] in the simulation. The result obtained for $R_n^{b\ell-had}$ $(n = 2,3,4)$ at hadron level are shown in Figure 1 together with the predictions given by Pythia 6.131, Herwig 6.1 and Ariadne 4.08 event generators [9,10,11].

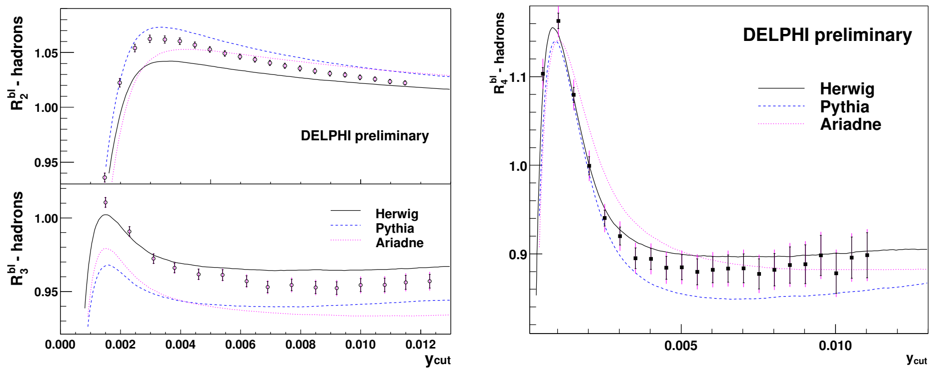

Figure 1. Comparison between measured $R_n^{b\ell-had}$ rates and predictions from the Pythia 6.131, Herwig 6.1 and Ariadne 4.08 generators. None of the three models describes all the measurements simultaneously.

The Pythia 6.131 generator, tuned to Delphi data [12], was used to correct for the hadronization process. The kinematical b quark mass parameter used in the parton shower was identified as the b pole mass and therefore was set to $M_b = 4.99 \pm 0.13$ GeV/c^2 (extracted from the world average running mass of [13]) in the generator.

Figure 2 shows the results obtained for n=3,4 jets at parton level as a function of y_c together with its statistical and overall uncertainties. The LO and NLO theoretical predictions in terms of the pole ($M_b = 4.99$ GeV/c^2) and the running mass ($m_b(M_Z) = 2.91$ GeV/c^2) are also shown in the plot [14,15,16]. For the case of n=4 the NLO correction has been approximated by assuming that most of the mass correction to the observable comes already at LO.

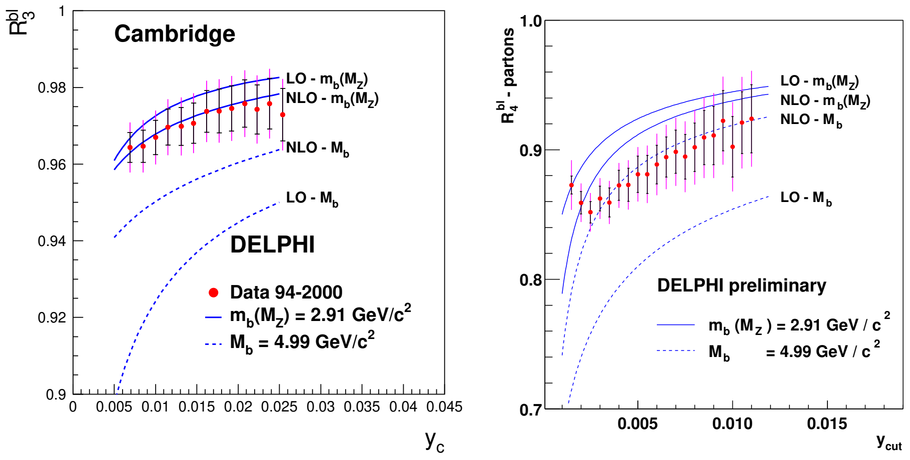

Figure 2. Experimental results for $R_n^{b\ell}$ obtained at parton level as a function of y_{cut}, for n = 3-jets (left) and n = 4-jets (right). Results are compared with the LO and NLO theoretical predictions calculated in terms of M_b and $m_b(M_Z)$ (in the case of $R_4^{b\ell}$ the NLO calculations are massless).

3 Results

From the 3-jet rate observable $R_3^{b\ell}$ with Cambridge the extracted b quark mass is:

$$m_b(M_Z) = 2.85^{+0.18}_{-0.19}\ \text{(stat)} \pm 0.13\ \text{(exp)}\ ^{+0.19}_{-0.20}\ \text{(had)} \pm 0.12\ \text{(theo)}\ \text{GeV}/c^2 \quad (2)$$

where the dominant contribution to the total error is due to the b mass parameter uncertainty of the generator. A consistent result is obtained with Durham $(3.20^{+0.43}_{-0.45})$ GeV$/c^2$.

The validity of approximating massive NLO corrections to $R_4^{b\ell}$ by their corresponding massless ones was shown. The measured value of $m_b(M_Z)$ was:

$$m_b(M_Z) = 3.60 \pm 0.32\ \text{(stat)} \pm 0.28\ \text{(exp)} \pm 0.20\ \text{(had)} \pm 0.40\ \text{(theo)}\ \text{GeV}/c^2 \quad (3)$$

which is dominated by the theoretical uncertainty of the approximated calculations. Both results agree with the scale evolution predicted by QCD when compared with low energy determinations (see Figure 3).

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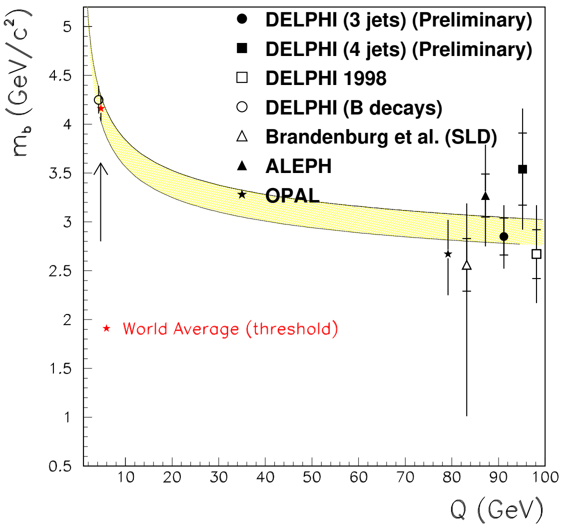

Figure 3. Results of $m_b(M_Z)$ obtained at LEP and SLC compared with the results obtained at threshold when evolved by RGE.

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