v1.0 - 7th December 1998.Ω00 ¡00

MEASUREMENTS OF THE BOTTOM QUARK MASS

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I will review new measurements of the b quark mass, presented at this conference by ALEPH and DELPHI. A large set of observables has been used and detailed studies on jet algorithms have been performed. These measurements at the Z peak are consistent with the results obtained at the Υ scale when assuming the running of the b quark mass as predicted by perturbative QCD.

1 Introduction

The b quark mass is one of the fundamental parameters of the QCD Lagrangian. However, due to confinement, quarks do not appear as asymptotically free particles and therefore the definition of their mass is ambiguous. In the framework of perturbative QCD, quark masses can either be defined as the position of the pole of the quark propagator, or they can be interpreted as effective coupling constants in the Lagrangian. In the former definition the mass is called "pole mass" and does not depend on an energy scale; in the latter the mass is called "running mass", since it is a function of the renormalization scale.

The effects of the b mass become very small with increasing energy for inclusive observables such as the total cross section, since they are proportional to m_b^2/M_Z^2 ($\mathcal{O}$ (0.1%)). However, for semi-inclusive quantities such as jet rates, the effects are enhanced, up to a few percent. Such quantities are sensitive to the amount of gluon radiation, which is suppressed in the case of massive quarks.

At this conference new measurements have been presented by ALEPH[1] and by DELPHI[2]. Previously measurements had been published by DELPHI [3] and by Brandenburg *et al.* [4] who had analysed SLD data.

2 Analysis Method

The method for extracting the b quark mass is based on the measurement of the ratio $R_{b/uds} = O_b/O_{uds}$ of an infrared safe observable O computed for b and uds induced events and assuming α_s universality.

This ratio is either directly obtained by tagging b and uds induced events (DELPHI), or by measuring first the ratio $R_{b/inc} = O_b/O_{inc}$ (inc=all flavours inclusive) and then inferring from that the ratio $R_{b/uds}$, using the precise knowledge of the partial widths of the Z to b and c quarks (ALEPH). The tag of b (uds) events is mainly based on lifetime information. The ratio is then corrected for hadronization, detector and tagging biases.

The b quark mass is extracted by comparing the corrected measured ratio $R_{b/uds}^P$ with the predictions for the observable under study. In general the NLO prediction for $R_{b/uds}^P$ as a function of the b quark mass is of the form

$$R_{b/uds}^P = 1 + \frac{m_b^2}{M_Z^2}\left[b_0(m_b) + \frac{\alpha_s}{2\pi}b_1(m_b)\right] \quad (1)$$

where the coefficient functions b_0 and b_1 are obtained from the integration of the massive and massless matrix elements in terms of the pole or running mass.

Systematic uncertainties arise from imperfections of the detector modelling, from the limited knowledge of the hadronization corrections and B decays, which are particularly important for this analysis, and from theoretical ambiguities because of the renormalization scale and the quark mass scheme employed to compute b_0 and b_1.

3 Results from ALEPH

ALEPH has studied the first and second moments of a large set of event shape variables such as thrust, jet broadenings, or the transition resolution value y_3 for going from three to two jets when applying the Durham [5] algorithm. Furthermore, they have used the ratio of three-jet rates with $y_{cut} = 0.02$. Then the set of observables is reduced by requiring that the NLO contributions to the perturbative prediction be clearly smaller then the LO terms, and that the hadronization corrections do not exceed the measured mass effect in size. These requirements leave only the three-jet rate and the first moment of y_3 as observables. The latter turns out to give the smallest total uncertainties, and the result for the running mass in the $\overline{\text{MS}}$ scheme is $m_b(M_Z) = (3.27 \pm 0.22_{stat} \pm 0.22_{syst} \pm 0.38_{had} \pm 0.16_{theo})$ GeV/c^2.

4 Results from DELPHI

They have updated their previous analysis [3] by including data from 1995, improving the b-tag algorithm, and by studying also the Cambridge jet clustering algorithm [6] for the ratio of three-jet rates. It turns out that with this algorithm the perturbative expansion for $R_{b/uds}^P$ converges more rapidly in the running mass scheme than in the pole mass scheme, and the theoretical uncertainties are smaller than with the Durham algorithm. However, the measurement based on the Cambridge algorithm still suffers from rather large hadronization uncertainties. The result is $m_b(M_Z) = (2.61 \pm 0.18_{stat} \pm 0.18_{syst} \pm 0.47_{had} \pm 0.07_{theo})$GeV/$c^2$.

5 Conclusions

The new measurements of the b quark mass by ALEPH and DELPHI are in good agreement with determinations at lower scales [7], extrapolated to the Z pole by using the
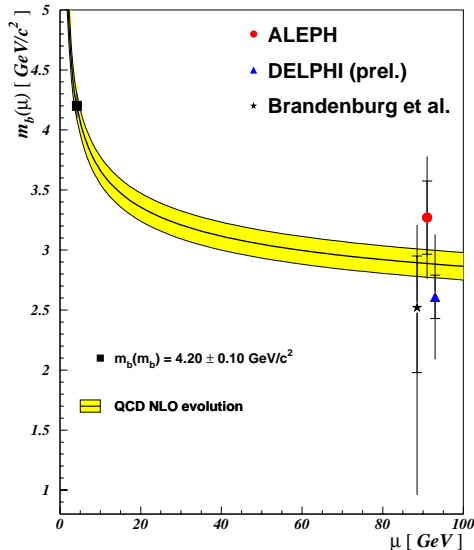

Figure 1. The running of the b quark mass

running predicted by perturbative QCD, as shown in figure 1. There are some indications for still uncontrolled biases from hadronization and/or uncomputed higher orders, since the results based on the three-jet rate tend to be systematically lower than the one obtained from the first moment of an event shape distribution.

References

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