A Precise Determination of $\alpha_s(M_Z)$ from Oriented Event Shape Distributions in e^+e^- Annihilation

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Abstract

An updated analysis using about 1.5 million events recorded at $\sqrt{s} = M_Z$ with the DELPHI detector in 1994 is presented. Eighteen infrared and collinear safe event shape observables are measured as a function of the polar angle of the thrust axis. The data are compared to theoretical calculations in $\mathcal{O}(\alpha_s^2)$ including the event orientation.

Detailed studies of the renormalization scale dependence of the $\mathcal{O}(\alpha_s^2)$ predictions have been performed, including fits applying experimentally optimized renormalization scale values as well as theoretically motivated scale setting prescriptions. It is found, that in general the predictions fail to describe the data if a renormalization scale value $\mu^2 = M_Z^2$ is applied. In this case, the slope of the observed distributions is not well described and the stability of $\alpha_s(M_z^2)$ with respect to a variation of the fit range is poor. The deviations with respect to the data propagate into the matched predictions of $\mathcal{O}(\alpha_s^2)$ and next-to-leading log approximation (NLLA), making them also inappropriate for an accurate description of the high precision data.

An excellent description of the 18 event shape distributions in $\mathcal{O}(\alpha_s^2)$ precision is obtained if the renormalization scale value is fitted to the individual data distributions. The stability of the fits with respect to a variation of the fit range is very good. The scale values obtained from the fits are found to be similar to those predicted by the effective charge method (ECH) and the principle of minimal sensitivity (PMS).

The influence of higher order contributions was also investigated by using the method of Padé approximants for an estimate of the uncalculated $\mathcal{O}(\alpha_s^3)$ contribution and for the sum of the perturbative series. The renormalization scale dependence of the Padé predictions is largely reduced with respect to the $\mathcal{O}(\alpha_s^2)$ predictions.

A combined fit of α_s and of the renormalization scale x_μ in $\mathcal{O}(\alpha_s^2)$ to the 18 oriented event shape distributions yields a perfectly consistent set of 18 measurements of the strong coupling. A weighted average from 18 observables including quark mass effects and correlations yields $\alpha_s(M_Z^2) = 0.1174 \pm 0.0026$.

The final result, derived from the jet cone energy fraction, the observable with the smallest theoretical and experimental uncertainty, is

$$\alpha_s(M_Z^2) = 0.1180 \pm 0.0006(exp.) \pm 0.0013(hadr.) \pm 0.0008(scale) \pm 0.0007(mass).$$

This value is in perfect agreement with recent α_s determinations from renormalization group improved predictions for the Bjorken sum rule and the hadronic decay of the τ lepton.