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α_s from jet cross section measurements in deep-inelastic ep scattering

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The value of $\alpha_s(m_Z)$ is determined from inclusive jet and di-jet cross sections in neutral-current deep-inelastic ep scattering (DIS) measured at HERA by the H1 collaboration using next-to-next-to-leading order (NNLO) perturbative QCD predictions. Using inclusive jet and di-jet data together, the strong coupling constant is determined to be $\alpha_s(m_Z) = 0.1157(20)_{\text{exp}}(29)_{\text{th}}$. Complementary, $\alpha_s(m_Z)$ is determined together with parton distribution functions of the proton (PDFs) from jet and inclusive DIS data and the value is determined to be $\alpha_s(m_Z) = 0.1142(28)_{\text{tot}}$. Both results are found to be consistent. The running of the strong coupling is tested at different values of the renormalisation scale and the results are found to be in agreement with expectations.

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Introduction

Jet production cross sections in neutral-current deep-inelastic scattering (NC DIS) are measured in the Breit frame, where the virtual photon and the proton collide head on. These measurements are directly sensitive to the value of $\alpha_s(m_Z)$, since the predictions in perturbative QCD are proportional to $\mathcal{O}(\alpha_s)$ already at leading order. Inclusive jet and di-jet cross sections have been measured by the H1 experiment in *ep* collisions at HERA in the years 1995–2007 [**?**, **?**, **?**, **?**, **?**], at center-of-mass energies of $\sqrt{s} = 300\,\text{GeV}$ and $320\,\text{GeV}$, and for a wide kinematic range in the photon virtuality Q^2. For all data, jets are defined using the k_t jet-algorithm with a parameter $R = 1.0$. Inclusive jet cross sections have been measured double-differentially as a function of Q^2 and jet transverse momenta, P_T^{jet}, with values typically exceeding $P_T^{\text{jet}} \gtrsim 5\,\text{GeV}$, and di-jet cross sections as a function of Q^2 and the average P_T^{jet} of the two leading jets, $\langle P_T^{\text{jet}} \rangle$. Already in the past, all these data have been used for determinations of $\alpha_s(m_Z)$ using next-to-leading order pQCD predictions. In the work presented [**?**], the cross section predictions are performed now for the first time in next-to-next-to-leading order (NNLO) accuracy. These calculations are implemented in the program NNLOJET [**?**, **?**], and the coefficients are stored in the fastNLO format [**?**] to enable a repeated calculation with different values of $\alpha_s(m_Z)$. Using these new and improved predictions, the strong coupling constant $\alpha_s(m_Z)$ is determined in two approaches.

The α_s-fit

In the first approach, which is denoted as 'α_s-fit', the value of $\alpha_s(m_Z)$ is determined in a fit of NNLO predictions to the inclusive jet and di-jet data, where a statistical goodness-of-fit quantity, χ^2, is minimised. In this fit, both of the α_s-dependencies in the predictions, namely in the partonic cross sections and in the PDF, are taken into account. The latter is accounted for by setting the DGLAP-evolution starting-scale to $\mu_0 = 20\,\text{GeV}$, and thus, the α_s-dependence of the evolution kernel can also be considered in the fit. For the central result, the NNPDF3.1 PDF set is used [**?**]. The renormalisation and factorisation scales are chosen to be $\mu_R^2 = \mu_F^2 = Q^2 + P_T^2$, where P_T denotes P_T^{jet} in case of inclusive jet cross sections, and $\langle P_T^{\text{jet}} \rangle$ in case of di-jets. Subsequently, a representative scale value $\tilde{\mu}$, which is closely related to μ_R and μ_F, is assigned to each data point and is used for additional cuts, as discussed below.

In the fits of $\alpha_s(m_Z)$ to each of the nine individual data sets it is found that the results are all consistent, and the data are all found to be well described by the NNLO predictions [**?**]. The smallest experimental uncertainty ('exp') is then achieved in a fit to all inclusive jet and di-jet cross section data[1], denoted as 'H1 jets', with a value $\alpha_s(m_Z) = 0.1143\,(9)_{\text{exp}}\,(43)_{\text{th}}$. The theoretical uncertainty ('th') comprises multiple uncertainties: various uncertainties of the PDFs (called 'PDF', 'PDFα_s', and 'PDFset'), hadronisation uncertainties ('had'), and scale uncertainties. The latter are the dominant source of uncertainty. The main result of this approach is obtained from H1 jet data restricted to $\tilde{\mu} > 28\,\text{GeV}$. In this fit the value of $\alpha_s(m_Z)$ is determined to

$$\alpha_s(m_Z) = 0.1157\,(20)_{\text{exp}}\,(3)_{\text{PDF}}\,(2)_{\text{PDF}\alpha_s}\,(3)_{\text{PDFset}}\,(6)_{\text{had}}\,(27)_{\text{scale}}\,,$$

[1] Some di-jet data are omitted, since their statistical correlations with the respective inclusive jet data have not been determined, and additionally, all data are restricted to twice the *b*-quark mass, $\tilde{\mu} > 2m_b$, since the NNLO predictions are performed with five massless quark flavours.