PROCEEDINGS OF SCIENCE

Measurements of dijet azimuthal decorrelations and extraction of α_S at ATLAS

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The production of jets at hadron colliders provides stringent tests of perturbative QCD. We present a measurement of the rapidity and transverse momentum dependence of dijet azimuthal decorrelations, using the quantity $R_{\Delta\phi}$. This quantity specifies the fraction of the inclusive dijet events in which the azimuthal opening angle of the two jets with the highest transverse momenta is less than a given value of the parameter $\Delta\phi_{\max}$. The variable $R_{\Delta\phi}$ is measured in proton-proton collisions at $\sqrt{s} = 8$ TeV as a function of the dijet rapidity interval, the event total scalar transverse momentum, and $\Delta\phi_{\max}$. Predictions of a perturbative QCD calculation at next-to-leading order in the strong coupling with corrections for non-perturbative effects describe the data well in the whole kinematic region. The data are used to determine the strong coupling α_S and to study its running for momentum transfers from 260 GeV to above 1.6 TeV. An analysis that combines data at all momentum transfers results in $\alpha_S(m_Z) = 0.1127^{+0.0063}_{-0.0027}$.

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1. Introduction

The strong coupling constant α_S is one of the fundamental parameters of the Standard Model (SM) which determines the strength of the strong nuclear force in the context of the Quantum Chromodynamics (QCD). The parameter is in fact not a constant, but due to the underlying quantum field theory it depends on the energy scale of a given process. The value of the parameter is not predicted by the theory, only its dependency on the energy scale is governed by the so called renormalization group equation (RGE) or beta function:

$$\beta(g) = \frac{\partial g}{\partial \log(\mu)}. \tag{1.1}$$

The one-loop beta function in QCD with n_f flavours reads

$$\beta(\alpha_S) = -\left(11 - \frac{2n_f}{3}\right)\frac{{\alpha_S}^2}{2\pi}. \tag{1.2}$$

For a number of flavours $n_f \leq 16$, the beta function dictates that the coupling decreases with increasing energy scale, a phenomenon called asymptotic freedom. The experiments are trying to measure the value of the coupling constant at some energy scale (conventionally at the mass of the Z-boson m_Z) and test its running in the scale regime allowed by the corresponding experiment. In this short note we describe the measurement of the dijet azimuthal decorrelations [1] by the ATLAS Experiment [2] at the Large Hadron Collider [3] followed by the extraction of α_S, as well as testing of its running at energy scales up to 1.675 TeV.

Measurements of α_S at hadron colliders are limited by theoretical uncertainties related to the scale dependence of the fixed order perturbative QCD (pQCD) calculations as well as the uncertainties coming from the parton distribution functions (PDF). Some of the recent measurements taken from the Particle Data Group [4] are shown in Fig. 1.

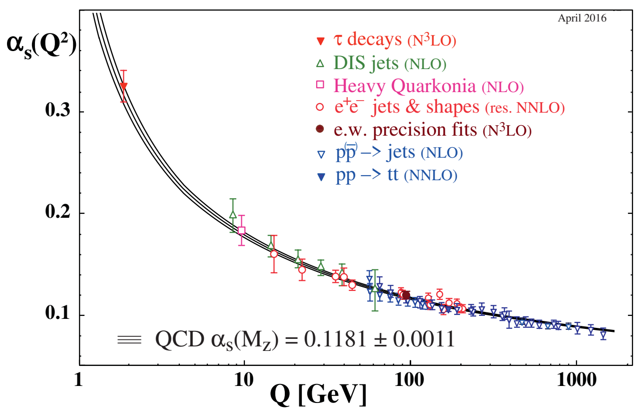

Figure 1: Summary of measurements of α_S as a function of the energy scale Q from the Particle Data Group [4].

The decorrelation in the azimuthal angle between two leading jets has been studied in a number of measurements at several colliders as a particular observable sensitive to the α_S. The variable $\Delta\phi_{\rm dijet} = |\phi_1 - \phi_2|$ investigated in these measurements is defined between the two jets with the highest transverse momenta p_T in the event. In the exclusive two jet final state, the two jets are back-to-back in the azimuthal plane from the conservation laws and $\Delta\phi_{\rm dijet} = \pi$. Deviations from this value are from the additional activity in the final state. An additional observable $R_{\Delta\phi}$ has been proposed in Ref. [5]. The quantity $R_{\Delta\phi}$ is defined as the fraction of all inclusive dijet events in which $\Delta\phi_{\rm dijet}$ is less than a specified value $\Delta\phi_{\rm max}$. This quantity is used to extend the scope of the previous analyses towards studies of the rapidity dependence of dijet azimuthal decorrelations. It is defined as a ratio of multijet cross sections so the PDF related uncertainties cancel to a large extent.

2. Measurement of dijet azimuthal decorrelation

In this measurement, the jets are defined using the anti-k_T jet algorithm with the radius parameter $R = 0.6$. An inclusive dijet sample consists of all events with two or more jets, where the two jets with the highest transverse momenta satisfy the following cuts on the transverse momenta and rapidities $p_T > 100$ GeV, $y_{\rm boost}^{\rm max} < 0.5$, $y^\star_{\rm max} < 2.0$ and $p_{T1}/H_T > 1/3$. The variables $y_{\rm boost}$ and $y^\star$ are calculated from the rapidities of the two leading jets y_1, y_2 as $y_{\rm boost} = (y_1 + y_2)/2$ and $y^\star = |y_1 - y_2|/2$. The H_T variable is the scalar sum of all jets in the event which satisfy $p_T > 100$ GeV. The quantity $R_{\Delta\phi}$ defined as

$$R_{\Delta\phi}(H_T, y^\star, \Delta\phi_{\rm max}) = \frac{\frac{{\rm d}^2\sigma_{\rm dijet}(\Delta\phi_{\rm dijet} < \Delta\phi_{\rm max})}{{\rm d}H_T{\rm d}y^\star}}{\frac{{\rm d}^2\sigma_{\rm dijet}(\text{inclusive})}{{\rm d}H_T{\rm d}y^\star}}. \tag{2.1}$$

is measured in nine intervals of H_T, three intervals of $y^\star$ and for four values of $\Delta\phi_{max}$ in the dataset collected in 2012 at the centre-of-mass energy $\sqrt{s} = 8$ TeV.

The theoretical predictions for the analysis are obtained from the pQCD calculations at fixed order in α_S with additional corrections for nonperturbative effects. The calculations are carried out using NLOJET++ [6, 7] interfaced to FASTNLO [8, 9]. The renormalization and factorization scales are set to $\mu_R = \mu_F = H_T/2$. The MMHT2014 PDFs [10, 11] are used to obtain the central results in the α_S determination. Other global PDF fits are used to assess systematic uncertainties. The corrections for nonperturbative effects are estimated using the event generators PYTHIA 6.246 [12] and HERWIG 6.520 [13, 14].

There are two sources of statistical uncertainties (from data and from the unfolding correction factors) and 62 sources of systematic uncertainties. The dominant source of uncertainty is coming from the jet energy calibration, which is typically between 1.0–1.5% and always below 3.1% in the two highest $\Delta\phi_{\rm max}$ bins, and can be up to 4–9% in the lower $\Delta\phi_{\rm max}$ bins. The measurement of the $R_{\Delta\phi}$ observable is shown in Fig. 2 and the detailed ratio of the measurement and the theoretical predictions is shown in Fig. 3. The measurement is well described by the perturbative QCD calculation.

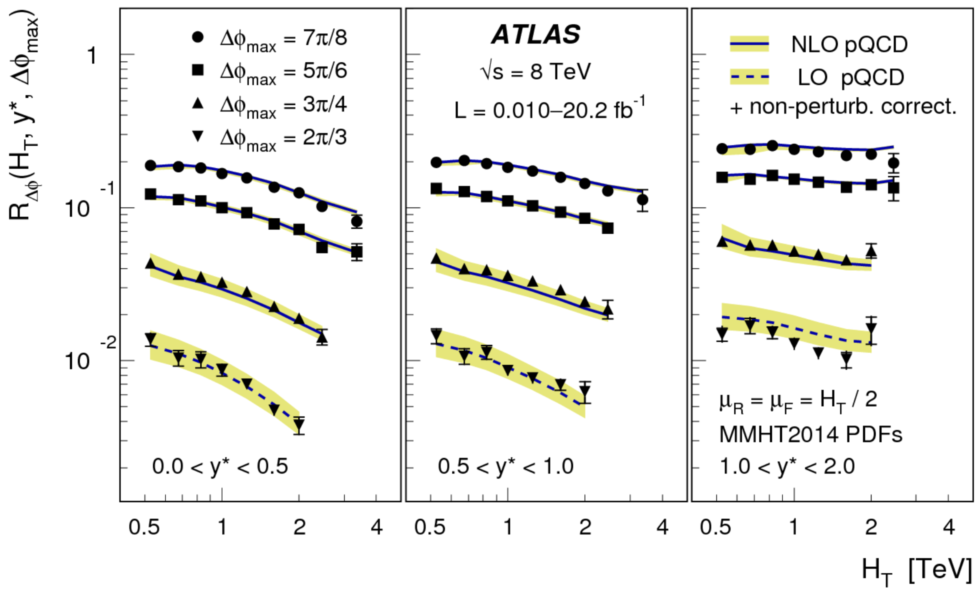

Figure 2: Measurement of the $R_{\Delta\phi}$ observable as a function of the scalar sum of jet transverse momenta H_T in three regions of $y^\star$ and four choices of $\Delta\phi_{\max}$. The theoretical predictions based on pQCD are shown in solid and dashed lines [1].

3. Extraction of the strong coupling constant

The $R_{\Delta\phi}$ measurements in selected kinematic regions are used to determine α_S and to test its running as a function of the energy scale $Q = H_T/2$ over the range 262–1675 GeV.

Assuming the validity of the RGE, all data points from the first two $y^\star$ bins for $\Delta\phi_{\max} = 7\pi/8$ are used to extract a combined $\alpha_S(m_Z)$ result. This combined fit yields the value $\alpha_S(m_Z) = 0.1127$ with the uncertainties listed in Tab. 1.

$\alpha_S(m_Z)$	Total unc.	Stat.	Experimental correlated	Non-perturbative corrections	MMHT2014 unc.	PDF set	$\mu_{R,F}$ variations
0.1127	$^{+6.3}_{-2.7}$	±0.5	$^{+1.8}_{-1.7}$	$^{+0.3}_{-0.1}$	$^{+0.6}_{-0.6}$	$^{+2.9}_{-0.0}$	$^{+5.2}_{-1.9}$

Table 1: Fit result for $\alpha_S(m_Z)$ determined from the $R_{\Delta\phi}$ data. All uncertainties have been multiplied by a factor of 1000.

4. Summary

The multijet cross section ratio $R_{\Delta\phi}$ is measured by the ATLAS Collaboration in proton-proton collisions at the Large Hadron Collider at a centre-of-mass energy of 8 TeV. The $R_{\Delta\phi}$ observable specifies the fraction of the inclusive dijet events in which the azimuthal separation between the two jets with the highest transverse momenta is less than a given value of the parameter $\Delta\phi_{\max}$. The $R_{\Delta\phi}$ measurement is well described by the pQCD theory predictions and is used to extract the value of the strong coupling constant α_S and test its running. A combined analysis yields a value of $\alpha_S(m_Z) = 0.1127^{+0.0063}_{-0.0027}$, with the largest uncertainty coming from the scale dependence of the

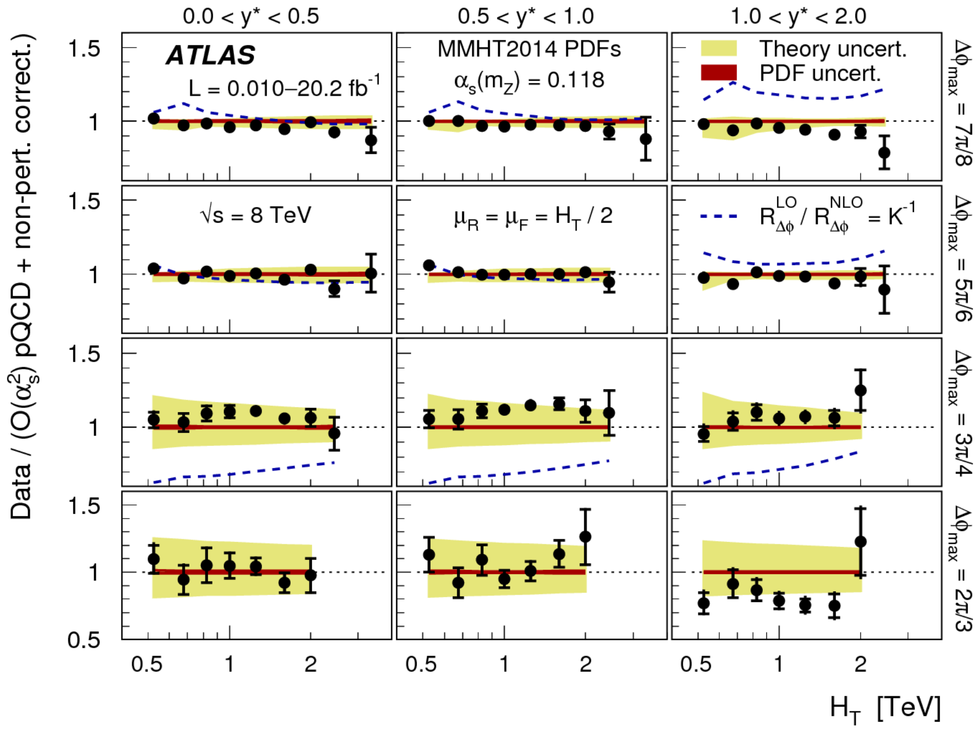

Figure 3: The ratios of the $R_{\Delta\phi}$ measurements and the theoretical predictions (obtained for MMHT2014 PDFs and α_S value of 0.118) [1].

pQCD predictions. The $\alpha_S(Q)$ results of this analysis are shown in Fig. 4 together with previous results from jet data in other experiments.

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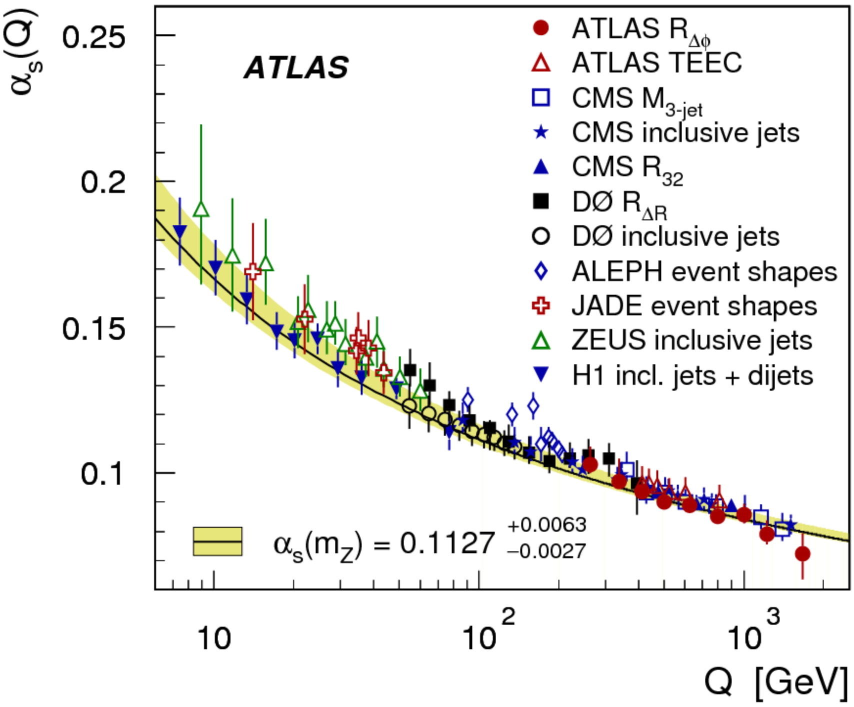

Figure 4: The $\alpha_S(Q)$ result compared to previous results from other experiments. The $\alpha_S(m_Z)$ value corresponds to the RGE equation prediction obtained from this analysis [1].

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