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Dynamics of isolated-photon plus jet production in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector ☆

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Abstract

The dynamics of isolated-photon plus jet production in pp collisions at a centre-of-mass energy of 7 TeV has been studied with the ATLAS detector at the LHC using an integrated luminosity of 37 pb^{-1}. Measurements of isolated-photon plus jet bin-averaged cross sections are presented as functions of photon transverse energy, jet transverse momentum and jet rapidity. In addition, the bin-averaged cross sections as functions of the difference between the azimuthal angles of the photon and the jet, the photon–jet invariant mass and the scattering angle in the photon–jet centre-of-mass frame have been measured. Next-to-leading-order QCD calculations are compared to the measurements and provide a good description of the data, except for the case of the azimuthal opening angle.

Keywords: QCD; Photon; Jet

1. Introduction

The production of prompt photons in association with a jet in proton–proton collisions, $pp \to \gamma + \text{jet} + \text{X}$, provides a testing ground for perturbative QCD (pQCD) in a cleaner environment than in jet production, since the photon originates directly from the hard interaction. The measurements of angular correlations between the photon and the jet can be used to probe the dynamics of the hard-scattering process. Since the dominant production mechanism in pp collisions at the LHC is through the $qg \to q\gamma$ process, measurements of prompt-photon plus jet production have been used to constrain the gluon density in the proton [1,2]. Furthermore, precise measurements of photon plus jet production are also useful for the tuning of the Monte

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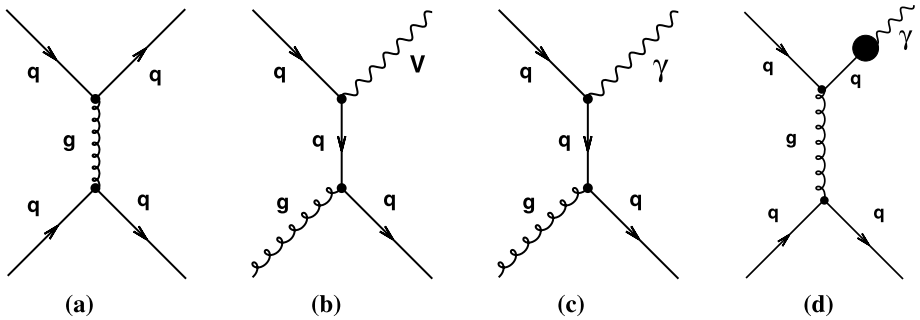

Fig. 1. Examples of Feynman diagrams for (a) dijet production, (b) V + jet production with $V = W$ or Z, (c) γ + jet production through direct-photon processes and (d) γ + jet production through fragmentation processes.

Carlo (MC) models. In addition, these events constitute the main reducible background in the identification of Higgs bosons decaying to a photon pair.

The dynamics of the underlying processes in $2 \to 2$ hard collinear scattering can be investigated using the variable θ^*, where $\cos\theta^* \equiv \tanh(\Delta y/2)$ and Δy is the difference between the rapidities[1] of the two final-state particles. The variable θ^* coincides with the scattering angle in the centre-of-mass frame, and its distribution is sensitive to the spin of the exchanged particle. For processes dominated by t-channel gluon exchange, such as dijet production in pp collisions shown in Fig. 1(a), the differential cross section behaves as $(1 - |\cos\theta^*|)^{-2}$ when $|\cos\theta^*| \to 1$. In contrast, processes dominated by t-channel quark exchange, such as W/Z + jet production shown in Fig. 1(b), are expected to have an asymptotic $(1 - |\cos\theta^*|)^{-1}$ behaviour. This fundamental prediction of QCD can be tested in photon plus jet production at the centre-of-mass energy of the LHC.

At leading order (LO) in pQCD, the process $pp \to \gamma + \text{jet} + \text{X}$ proceeds via two production mechanisms: direct photons (DP), which originate from the hard process, and fragmentation photons (F), which arise from the fragmentation of a coloured high transverse momentum (p_{T}) parton [3,4]. The direct-photon contribution, as shown in Fig. 1(c), is expected to exhibit a $(1 - |\cos\theta^*|)^{-1}$ dependence when $|\cos\theta^*| \to 1$, whereas that of fragmentation processes, as shown in Fig. 1(d), is predicted to be the same as in dijet production, namely $(1 - |\cos\theta^*|)^{-2}$. For both processes, there are also s-channel contributions which are, however, non-singular when $|\cos\theta^*| \to 1$. As a result, a measurement of the cross section for prompt-photon plus jet production as a function of $|\cos\theta^*|$ provides a handle on the relative contributions of the direct-photon and fragmentation components as well as the possibility to test the dominance of t-channel quark exchange, such as that shown in Fig. 1(c).

Measurements of prompt-photon production in a final state with accompanying hadrons necessitates of an isolation requirement on the photon to avoid the large contribution from neutral-hadron decays into photons. The production of inclusive isolated photons in pp collisions has been studied previously by ATLAS [5,6] and CMS [7,8]. Recently, the differential cross sections

[1] The ATLAS reference system is a Cartesian right-handed coordinate system, with the nominal collision point at the origin. The anticlockwise beam direction defines the positive z-axis, while the positive x-axis is defined as pointing from the collision point to the centre of the LHC ring and the positive y-axis points upwards. The azimuthal angle ϕ is measured around the beam axis, and the polar angle θ is measured with respect to the z-axis. Pseudorapidity is defined as $\eta = -\ln\tan(\theta/2)$, rapidity is defined as $y = 0.5\ln[(E + p_z)/(E - p_z)]$, where E is the energy and p_z is the z-component of the momentum, and transverse energy is defined as $E_{\text{T}} = E\sin\theta$.