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Studies of dijet and photon-jet properties in pp, pPb, and PbPb collisions with CMS

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Abstract

Studies of dijet and photon-jet properties in pPb collisions are of great importance for establishing a QCD baseline for hadronic interactions with cold nuclear matter. Dijet and photon-jet production has been measured in pPb collisions at a nucleon–nucleon center-of-mass energy of 5.02 TeV. The transverse momentum balance and azimuthal angle correlations are studied in both dijet and photon-jet channels, leading to the observation that there is no significant modification, which allows these systems to be used as tools to probe the nuclear modifications of the parton distribution functions (PDFs). In the dijet system, pseudorapidity distributions are studied as a function of the transverse energy in the forward calorimeters (E_T^{HF}). The mean value of the dijet pseudorapidity is found to change monotonically with increasing E_T^{HF}, indicating a correlation between the energy emitted at large pseudorapidity and the longitudinal motion of the dijet frame. The pseudorapidity distribution of the dijet system is compared with next-to-leading-order perturbative QCD predictions obtained from both nucleon and nuclear PDFs, and the data more closely match the latter. In addition to the studies of initial state, the photon-jet measurements related to quenching in PbPb are updated to have a more precise pp reference based on the 2013 LHC run at 2.76 TeV.

Keywords: CMS; Heavy ion; Photon jet; PDF; nPDF; Dijet

[1] A list of members of the CMS Collaboration and acknowledgements can be found at the end of this issue.

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1. Introduction

A strongly interacting medium, called the Quark–Gluon Plasma (QGP) is formed in relativistic heavy ion collisions at RHIC and the LHC. Because of the short lifetime of the QGP, high transverse-momentum (p_T) partons created by hard scatterings within the collision are used as probes. Colored probes are modified by the QGP medium during traversal, while electroweak probes like photons remain unmodified [1]. Therefore, photon + jet production in which the photon is used as a "tag" of the initial parton energy and the jet as a "tag" of the final parton energy can be used to gain information about the structure of the QGP.

Additionally, pPb collisions can be used as a reference to study the effect of cold nuclear matter on jets when no formation of QGP is expected. This influences the interpretation of PbPb results which include both hot and cold nuclear matter effects. A precise measurement of the nuclear parton distribution functions (nPDFs) is possible in dijet systems in pPb collisions by studying the pseudo-rapidity production rate of dijets [2–7].

2. Datasets, reconstruction, analysis

The analysis presented here is performed on 150 μb^{-1} of PbPb and 5.3 pb^{-1} pp data at $\sqrt{s_{NN}} = 2.76$ TeV and 35 nb^{-1} pPb data at $\sqrt{s_{NN}} = 5.02$ TeV collected with the Compact Muon Solenoid (CMS) detector in 2011 and 2013 [8]. Events with a reconstructed photon with $p_T^{\gamma} > 40$ GeV/c or jet with $p_T^{Jet} > 120$ GeV/c are recorded for further analysis. The PbPb collisions are characterized in terms of the centrality of the collision.

Photons are reconstructed from clusters of energy in the ECAL according to the algorithm in Ref. [9] for pp and pPb collisions and Ref. [1] for PbPb collisions. Only photons found within the barrel region of the ECAL, $|\eta^{\gamma}| < 1.44$, and with $p_T^{\gamma} > 40$ GeV/c are used in the analysis.

Jets are reconstructed according to the CMS "particle flow" algorithm, using the FastJet anti-k_T implementation and a resolution parameter of 0.3 [10–13]. In the case of PbPb collisions a background subtraction method based on a $\mu + \sigma$ subtraction, further described in Ref. [14], is also applied. When paired with photons, jets with $p_T^{Jet} > 30$ GeV/c and within $|\eta^{Jet}| < 1.6$ are used. In the dijet study, leading jets with $p_T^{Jet} > 120$ GeV/c are paired with other jets in each event with $p_T^{Jet} > 30$ GeV/c and the azimuthal distance $\Delta\phi_{1,2} > 2\pi/3$ where both jets are within $|\eta| < 3$. In the photon study the pp reference data has the jet spectra smeared to match the reduced p_T^{Jet} resolution in PbPb collisions.

3. Results

A subset of the results of Ref. [15] and Ref. [16] are reproduced here. In Fig. 1(middle, right), a significant loss of jet partners as a function of centrality is observed, and as a function of p_T^{γ} this loss is constant. Fig. 2(middle, right) shows a decrease in ratio of p_T^{Jet} to p_T^{γ}, $x_{J\gamma}$ as a function of p_T^{γ} in central events. This is consistent with Fig. 1(middle, right); as p_T^{γ} increases, more jets at low p_T^{Jet} compared to p_T^{γ} will shift $x_{J\gamma}$ if $R_{J\gamma}$ remains constant compared to pp.

The pPb results shown in Figs. 1(left) and 2(left) are consistent with the pp reference at $\sqrt{s_{NN}} = 2.76$ TeV, but interpreting the deviation from the PYTHIA+HIJING [17,18] reference is difficult without a proper pp reference at $\sqrt{s_{NN}} = 5.02$ TeV. There is no significant jet quenching compared to PbPb collisions.

Fig. 3 shows a shift of jets in PbPb from high p_T^{Jet} to low p_T^{Jet} in central events. In the first p_T^{γ} bin only a deficit in I_{AA} is apparent, but an excess at low p_T^{Jet} in the high p_T^{γ} bin indicates jets