The Compact Muon Solenoid Experiment

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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 to establish a QCD baseline for hadronic interactions with cold nuclear matter. Dijet and photon-jet production have 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.

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Isolated photon measurements in pp and PbPb collisions with CMS

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Abstract

Studies of dijet and photon-jet properties in pPb collisions are of great importance to establish a QCD baseline for hadronic interactions with cold nuclear matter. Dijet and photon-jet production have 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, physics, heavy ion, photon, jet, gamma, gamma-jet, PDF, nPDF, dijet

1. Introduction

A strongly interacting medium, called the Quark-Gluon Plasma (QGP) is thought to be 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. At the LHC, 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, 3, 4, 5, 6, 7].

2. Datasets, Reconstruction, Analysis

The analysis presented here is performed on $150 \mu\text{b}^{-1}$ of PbPb and 5.3 pb^{-1} pp data at $\sqrt{s_{NN}} = 2.76 \text{ TeV}$ and 35 nb^{-1} pPb data at $\sqrt{s_{NN}} = 5.02 \text{ TeV}$ collected with the Compact Muon Solenoid (CMS) detector in 2011 and

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

Figure 1. Fraction of photons associated to a jet ($R_{J\gamma}$) as a function of leading photon p_T in (left) pPb, unsmeared pp, and PYTHIA+HIJING, (middle) smeared pp and peripheral PbPb, and (right) smeared pp and central PbPb. The shaded boxes represent the systematic uncertainty while the lines through the points represent the statistical uncertainty.[15]

2013 [8]. Events with a reconstructed photon with $p_T^\gamma > 40$ GeV/c or jet with $p_T^{\text{jet}} > 120$ 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, 11, 12, 13]. In the case of PbPb collisions a background subtraction method described in Ref. [14] is also applied. When paired with photons, jets with $p_T^{\text{jet}} > 30$ GeV/c and within $|\eta^{\text{jet}}| < 1.6$ are used. In the dijet study, leading jets with $p_T^{\text{jet}} > 120$ GeV/c are paired with other jets in each event with $p_T^{\text{jet}} > 30$ GeV/c and $\Delta\phi_{1,2} > 2\pi/3$ where both jets are within $|\eta| < 3$.

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. Figs. 2(middle,right) show a decrease in $x_{J\gamma}$ as a function of p_T^γ in central events. In all cases the PYTHIA+HYDJET reference agrees within errors with the smeared pp reference, confirming the conclusion of Ref. [1] that jets are quenched as a function of collision centrality.

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

Fig. 3 shows a shift of jet partners in PbPb from high p_T^{jet} to low p_T^{jet} in the central case; 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 movement of jets to lower p_T^{jet} . This suggests that jets in central PbPb are being quenched, losing energy and showing up as a deficit in I_{AA} at high p_T^{jet} and an excess at low p_T^{jet} relative to p_T^γ .

With no jet quenching seen in pPb collisions in the photon+jet system, deviations of jet behavior from predictions are expected to originate mostly from cold nuclear matter effects like nuclear modifications to PDFs. Fig. 4 shows the difference between the measured dijet production in pPb and NLO predictions as a function of pseudo-rapidity. The measured data is outside the bands of the CT10 PDF predictions, but the nuclear corrections made by the EPS09 collaboration bring the data and prediction into agreement.

The results shown here offer a cohesive picture of jet behavior, from cold nuclear matter effects changing the dijet production in pPb collisions to the growing importance of quenching as a function of centrality in PbPb collisions.

Figure 2. Average jet over photon transverse momentum ratio ($\langle x_{J\gamma} \rangle$) of the recoiled jets in (left) pPb, unsmeared pp, and PYTHIA+HIJING, (middle) smeared pp and peripheral PbPb, and (right) smeared pp and central PbPb. The shaded boxes represent the systematic uncertainty while the lines through the points represent the statistical uncertainty.[15]

Figure 3. Ratio of jet yield in PbPb to smeared pp. The shaded boxes represent the systematic uncertainty while the lines through the points represent the statistical uncertainty.[15]

Figure 4. The difference between Data and NLO predictions of dijet production as a function of pseudo-rapidity is shown. The CT10 results are excluded, while the EPS09 predictions are within the errors of the measurement [16].

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