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Eric Andrew Appelt for the CMS Collaboration

Abstract

One of the signatures of the strongly interacting medium produced in central PbPbcollisions is the suppression of high-p_{T} jets and charged particles. Inorder to to disentangle the initial state and final state effects in heavy ioncollisions, the nuclear modification factor of both jets and of charged-particlesin pPb (R_{pPb}) and PbPb (R_{PbPb}) collisions are presented. Thespectra of both jets and charged-particles in pp collisions at $\sqrt{s} = 2.76$,PbPb collisions at $\sqrt{s_{_{NN}}} = 2.76$ TeV, and pPb collisions at$\sqrt{s_{_{NN}}} = 5.02$ TeV, have been measured with the CMS detector using highstatistics samples. The R_{pPb} of charged particles is determined bydividing the measured pPb spectrum by a pp reference spectrum constructed usinginterpolation methods, or alternatively from PYTHIA simulations.

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Jet and Charged Hadron Nuclear Modification Factors in pPb Collisions with CMS

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Abstract

One of the signatures of the strongly interacting medium produced in central PbPb collisions is the suppression of high-p_T jets and charged particles. In order to to disentangle the initial state and final state effects in heavy ion collisions, the nuclear modification factor of both jets and of charged-particles in pPb (R_{pPb}) and PbPb (R_{PbPb}) collisions are presented. The spectra of both jets and charged-particles in pp collisions at $\sqrt{s}$ = 2.76, PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, and pPb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, have been measured with the CMS detector using high statistics samples. The R_{pPb} of charged particles is determined by dividing the measured pPb spectrum by a pp reference spectrum constructed using interpolation methods, or alternatively from PYTHIA simulations.

Keywords: quark gluon plasma, nuclear modification factor, spectra

1. Introduction

The CMS detector is used to study the production of jets and charged particles in pPb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV recorded at the LHC in 2013. The nuclear modification factor, R_{pPb}, is defined as

$$R_{pPb} = \frac{dN^{pPb}/dp_T}{\left\langle T_{pPb} \right\rangle d\sigma^{pp}/dp_T}, \quad (1)$$

where $\langle T_{pPb} \rangle$ is the nuclear overlap function defined as $\langle N_{coll} \rangle / \sigma^{NN}_{inel}$, where σ^{NN}_{inel} is the inelastic nucleon-nucleon cross section and $\langle N_{coll} \rangle$ is the average number of binary nucleon-nucleon collisions calculated from a Glauber model. As there exist no pp collision data at $\sqrt{s}$ = 5.02 TeV at the time of writing, the pp reference spectra must be artificially constructed using previous measurements performed at different center-of-mass energies.

The CMS detector is described elsewhere [1]. The jet and charged particle measurements are based on a sample of pPb collisions with $\sqrt{s_{NN}}$ = 5.02 TeV and an integrated luminosity of 35 nb^{-1}, although a subsample of 29 nb^{-1} was used for the preliminary charged particle measurement. The minimum bias event sample was obtained by requiring a filled pPb bunch crossing and the presence of a track with $p_T > 0.4$ GeV/c reconstructed using only the silicon pixel detector. As the trigger used to produce the minimum bias event sample was heavily prescaled, additional trigger selections were used to increase the transverse momentum reach of the measurements. For the jet spectra, high-level trigger (HLT) selections were utilized to select events based on the presence of a single jet with $p_T < 20$, 40, 60, 80, or 100 GeV/c. For the charged particle spectra, HLT selections were utilized to select events based on the presence of a reconstructed charged particle in the silicon tracker with $p_T < 12$, 20, or 30 GeV/c.

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

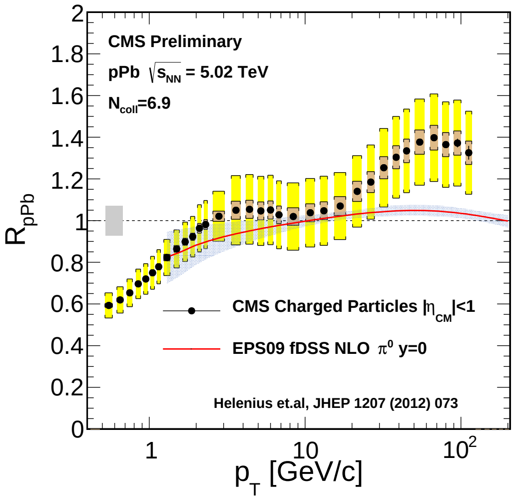

Figure 1. Measured nuclear modification factor for charged particles in $|\eta_{CM}| < 1$ shown along with the theoretical nuclear modification factor for neutral pions at $y = 0$ as determined using an EPS09 fDSS NLO calculation [8]. The light gray uncertainty band represents the uncertainty of the Glauber calculation of N_{coll}. The light brown uncertainty band around the measured values shows the uncertainty coming from the following sources that are strongly correlated in specific p_T regions: combination of spectra, track selection, and trigger efficiency. All other uncertainties are shown by the yellow band.

2. Charged Particle Nuclear Modification Factor

Charged particles are reconstructed using the standard CMS combinatorial track finder (CTF). The proportion of misreconstructed tracks in the sample is reduced by applying an optimized standard set of tracking quality selections as described in Ref. [2]. To further select charged particles produced promptly in the collision, reconstructed charged particle trajectories were required to be compatible with the reconstructed primary collision vertex. Each reconstructed track is weighted by factors accounting for the geometric acceptance of the detector, the algorithmic efficiency of the reconstruction, the fraction of tracks resulting from secondary decay particles, the fraction of misreconstructed tracks, and the fraction of tracks that correspond to a multiply-reconstructed charged particle. Finite bin widths and finite transverse momentum resolution can deform a steeply falling p_T spectrum. The measured spectra are corrected for the finite bin width effect, and the finite transverse momentum resolution was found to be sufficiently precise that no correction was required.

The pPb spectra were measured for $0.4 < p_T < 100$ GeV/c in seven different pseudorapidity ranges: $|\eta_{CM}| < 1.0$, $0.3 < \pm\eta_{CM} < 0.8$, $0.8 < \pm\eta_{CM} < 1.3$, and $1.3 < \pm\eta_{CM} < 1.8$. The interpolated pp reference spectrum was determined for $|\eta_{CM}| < 1.0$ using a method developed in Ref. [3] applied to measured p_T spectra at collision energies of 0.63, 1.8, and 1.96 TeV from CDF [4, 5], and at 0.9, 2.76, and 7 TeV from CMS [3, 6]. A more detailed description of the measured and interpolated charged particle spectra can be found in Ref. [7].

In Fig. 1, the R_{PbPb} is shown as a function of p_T for $|\eta_{CM}| < 1.0$. The nuclear modification factor shows a rise to unity at $p_T \approx 4$ GeV/c, is flat to approximately 20 GeV/c, and then rises above unity, to an average value of approximately 1.38 ± 0.22 in the range $50 < p_T < 100$ GeV/c. A theoretical calculation of nuclear modification factor for neutral pions at $y = 0$ as determined using an EPS09 fDSS NLO calculation [8] is also shown for comparison. The theoretical result shows a slight rise above unity in the range $50 < p_T < 100$ GeV/c, which is expected due to anti-shadowing of the nuclear parton distribution functions. The observed rise in the measured charged particle R_{PbPb} is considerably larger than expected.

3. Jet Nuclear Modification Factor

Jets are reconstructed using an anti-k_T algorithm [9] with a distance parameter of $R = 0.3$ performed on particle-flow objects, which are constructed by using information from all CMS subdetector systems in order to identify stable

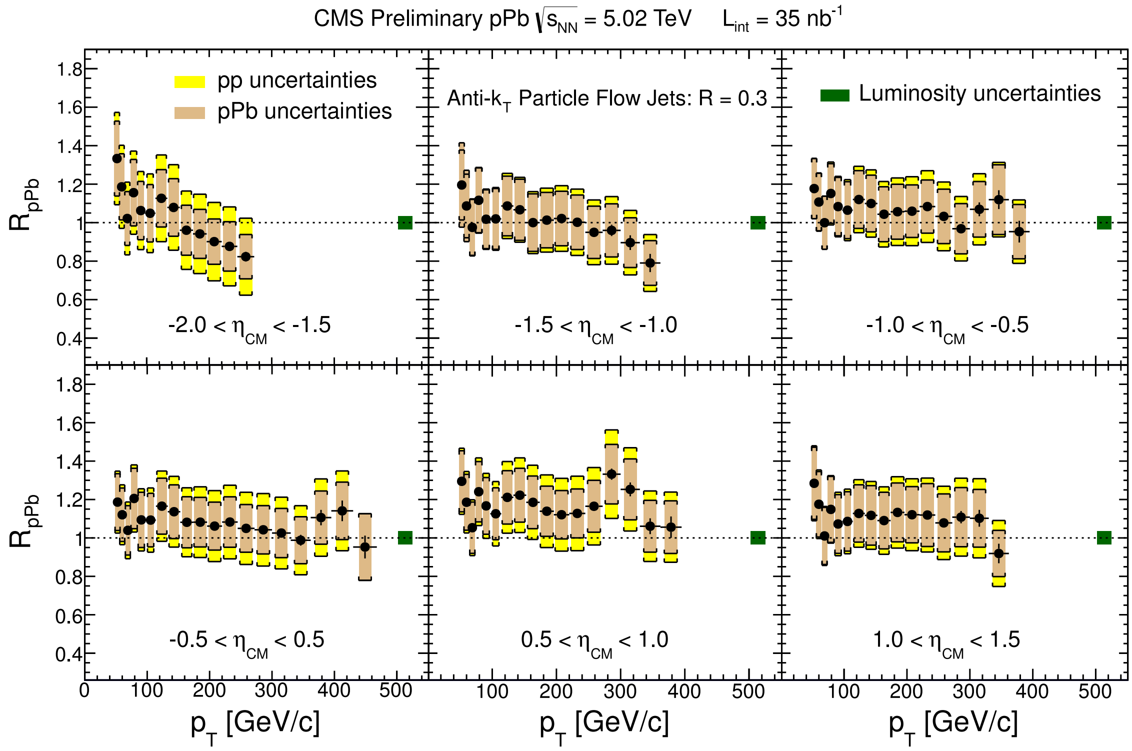

Figure 2. The inclusive jet nuclear modification factor R_{pPb} as a function of jet p_{T} in $\sqrt{s_{NN}}$ = 5.02 TeV pPb collisions using the extrapolated pp reference. The error bars on the data points are the statistical uncertainties and the open boxes represent the systematic uncertainties. The shaded boxes are the systematic uncertainties due to the pp reference extrapolation. The shaded area around $R_{\mathrm{pPb}} = 1$ represents the luminosity uncertainty in the pPb measurement.

particles and classify them into electrons, muons, photons, charged hadrons, and neutral hadrons. The energy of the reconstructed jets is corrected to remove the contribution from the underlying event using an iterative procedure described in Ref. [10]. The jet energies are then corrected to final state particle jets using a factorized multi-step approach derived using simulated events, as well as dijet and photon+jet pPb events. The distortion of the measured spectrum due to the finite resolution of the jet energy is corrected using a Bayesian unfolding procedure with four iterations.

The inclusive jet spectra were measured for six pseudorapidity intervals spanning the range $-2.0 < \eta_{\mathrm{CM}} < 1.5$, each with a width of $\Delta\eta_{\mathrm{CM}} = 0.5$. The pp reference spectra are extrapolated from published inclusive jet pp spectra at $\sqrt{s}$ = 7 TeV using an anti-k_{T} algorithm with distance parameters of $R = 0.5$ [11] and $R = 0.7$ [12] from CMS. The distance parameter dependence of the spectrum was found to be well described in simulation, which was then used to scale the measured spectra to $R = 0.3$. The ratio of the simulated spectrum at $\sqrt{s}$ = 7 to $\sqrt{s}$ = 5.02 TeV was then used to scale down the measured pp spectra to $\sqrt{s}$ = 5.02 TeV. A more detailed description of the jet measurement and reference extrapolation can be found in Ref [13].

The inclusive jet R_{pPb} is shown for the six pseudorapidity intervals as a function of p_{T} in Fig. 2. The jet R_{pPb} appears to be slightly enhanced in all pseudorapidity intervals, although this enhancement appears to be less than observed with the charged particles, and similar in magnitude to what may be expected from anti-shadowing of the nuclear parton distribution functions. In the most backward pseudorapidity interval, $-2.0 < \eta_{\mathrm{CM}} < -1.5$, a hint of decrease at high jet p_{T} is observed, and no significant p_{T} dependence is observed in any of the other five pseudorapidity intervals.

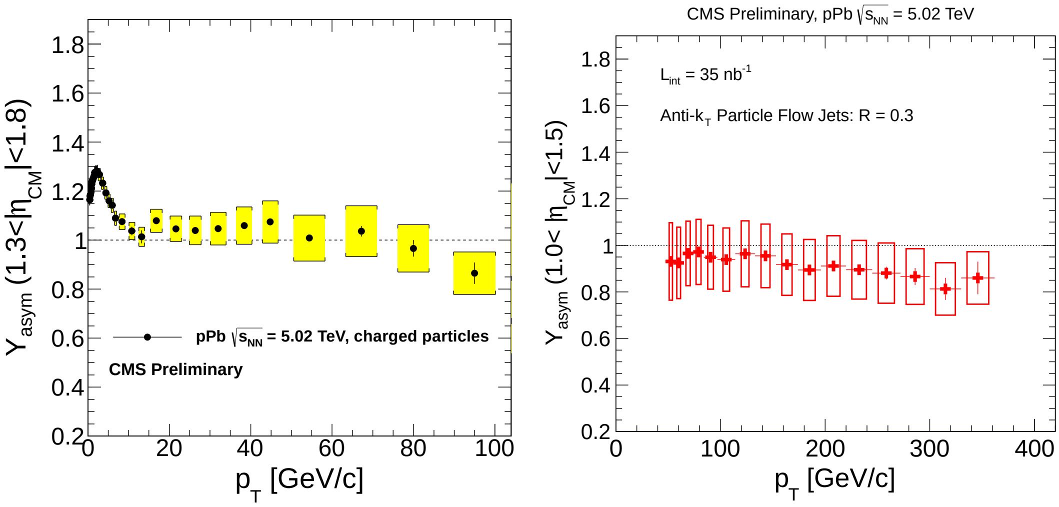

Figure 3. (Left) Charged particle asymmetry as a function of p_T for $1.3 < |\eta_{CM}| < 1.8$. The asymmetry is computed as the charged particle yields on the Pb-going side divided by the those on the p-going side. (Right) Inclusive jet asymmetry as a function of jet p_T for $1.0 < |\eta_{CM}| < 1.5$. The asymmetry is calculated as a ratio of jet yields in the Pb-going side to those on the p-going side. The error bars on the data points are the statistical uncertainties and the open boxes represent the systematic uncertainties.

4. Forward-Backward Asymmetry

The forward-backward asymmetry, Y_{asym}, is defined as

$$Y_{asym}(p_T) = \frac{d^2N(p_T)/d\eta dp_T|_{\eta_{CM}\in[-b,-a]}}{d^2N(p_T)/d\eta dp_T|_{\eta_{CM}\in[a,b]}}, \tag{2}$$

where a and b are always positive and refer to the proton beam direction, and $N(p_T)$ is the yield of either charged particles or jets. For the charged particles, Y_{asym} was calculated for three pseudorapidity intervals: $0.3 < |\eta_{CM}| < 0.8$, $0.8 < |\eta_{CM}| < 1.3$, and $1.3 < |\eta_{CM}| < 1.8$. In all of the three intervals the charged particle Y_{asym} shows enhancement at low-p_T and is then consistent with unity at high-p_T. This enhancement is most pronounced in the most forward pseudorapidity interval. For the jets, Y_{asym} was calculated for two pseudorapidity intervals: $0.5 < |\eta_{CM}| < 1.0$ and $1.0 < |\eta_{CM}| < 1.5$. There is no significant asymmetry observed in the jet production within the measured pseudorapidity range. The jet and charged particle Y_{asym} are shown in the most forward pseudorapidity intervals for each measurement in Fig. 3.

References

[1] CMS Collaboration, *JINST* **3** (2008)
[2] CMS Collaboration, CMS-PAS-TRK-10-001 (2010)
[3] CMS Collaboration, *JHEP* **08** (2011) 086
[4] CDF Collaboration, *Phys. Rev. Lett.* **61** (1988) 1819
[5] CDF Collaboration, *Phys. Rev. D* **82** (2010) 119903
[6] CMS Collaboration, *Eur. Phys. J. C* **72** (2012) 1945
[7] CMS Collaboration, CMS-PAS-HIN-12-017 (2013)
[8] I. Helenius et al., *JHEP* **1207** (2012) 073
[9] M. Cacciari, G. P. Salam, and G. Soyez, *Eur. Phys. J. C* **72** (2012) 1896.
[10] O. Kodolova et al., *Eur. Phys. J. C* **50** (2007) 117.
[11] CMS Collaboration, *Phys. Rev. Lett.* **107** (2013) 132001
[12] CMS Collaboration, *Phys. Rev. D* **87** (2012) 112002
[13] CMS Collaboration, CMS-PAS-HIN-14-001 (2014)