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Inclusive jet and charged hadron nuclear modification factors in PbPb collisions at 2.76 TeV with CMS

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Abstract

Measurements are reported for charged hadron and inclusive jet transverse momentum (p_{T}) spectra in pp and PbPb collisions at a nucleon-nucleon center-of-mass energy of 2.76 TeV with the CMS detector. These measurements make use of the high-statistics jet-triggered data recorded in 2011, including the total available PbPb luminosity of 150μb^{-1}. Charged particles are reconstructed using an iterative algorithm and spurious high-p_{T} tracks are suppressed by requiring appropriate energy deposits in the calorimeter system. Jets are reconstructed with the anti-k_{T} algorithm, using combined information from tracking and calorimetry. The charged particle p_{T} distributions are measured in the pseudorapidity range of $|\eta| < 1$, and p_{T} up to 100 GeV/c. The jet p_{T} distributions are measured in the pseudorapidity range of $|\eta| < 2$, and p_{T} from 100 to 300 GeV/c. The nuclear modification factors, $\mathrm{R_{AA}}$, for charged hadrons and jets are presented as a function of p_{T} and collision centrality. In the range p_{T} = 5-10 GeV/c the charged hadron production in PbPb collisions is suppressed by up to a factor of seven, compared to the pp yield scaled by the number of incoherent nucleon-nucleon collisions. The charged hadron $\mathrm{R_{AA}}$ increases at higher p_{T} and approaches a value of approximately 0.5 in the range p_{T} = 40-100 GeV/c for the most central collisions.

1. Introduction

The CMS detector is used to study the production of charged particles and jets at high energy density in collisions of PbPb at $\sqrt{s_{NN}}$ = 2.76 TeV recorded at the LHC in 2010 and 2011. The nuclear modification factor R_{AA} is constructed in comparison to pp collisions at $\sqrt{s}$ = 2.76 TeV, and is defined as

$$R_{\mathrm{AA}} = \frac{dN^{AA}/dp_{\mathrm{T}}}{\langle N_{\mathrm{coll}}\rangle\, dN^{pp}/dp_{\mathrm{T}}} = \frac{dN^{AA}/dp_{\mathrm{T}}}{\langle T_{\mathrm{AA}}\rangle\, d\sigma^{pp}/dp_{\mathrm{T}}}. \tag{1}$$

$\langle N_{\mathrm{coll}}\rangle$ is the average number of nucleon-nucleon collisions in heavy-ion (AA) interactions and $\langle T_{\mathrm{AA}}\rangle$ is the nuclear overlap function. $\langle N_{\mathrm{coll}}\rangle$ is equal to $\langle T_{\mathrm{AA}}\rangle \times \sigma^{NN}_{\mathrm{inel}}$, and is calculated with a Glauber model using a detailed description of the nuclear collision geometry.

The CMS detector is described elsewhere [1]. This analysis uses the standard CMS Minimum Bias trigger and heavy-ion event selection [2]. For the charged particle analysis, the statistical

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

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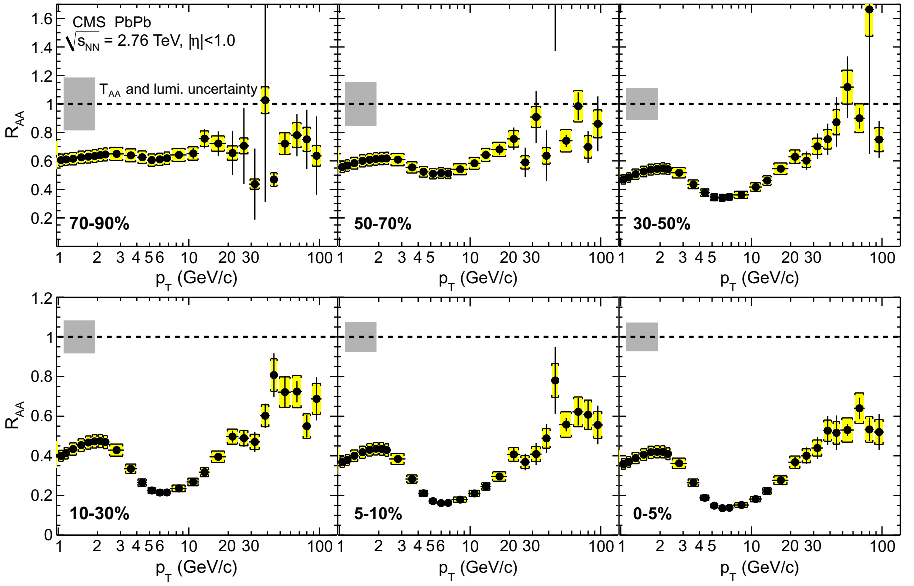

Figure 1: Nuclear modification factor R_{AA} as a function of p_T for six PbPb centralities. The error bars represent the statistical uncertainties and the yellow boxes represent the p_T-dependent systematic uncertainties. An additional systematic uncertainty from the normalization of T_{AA} and the pp integrated luminosity, common to all points, is shown as the shaded band around unity in each plot.

reach of track p_T is extended with jet-triggered data from 2011, with two jet triggered thresholds of 65 and 80 GeV. At the online trigger level, the electromagnetic calorimeter (ECAL) and hadron calorimeter (HCAL) information is used to reconstruct jets of a cone size of 0.5 with the iterative cone algorithm. The underlying soft PbPb background is removed using the iterative "noise/pedestal subtraction" technique [3]. Jet analysis is performed on events with jets triggered at a threshold of 80 GeV.

2. Charged particle R_{AA}

Charged particle tracks are reconstructed from hits in the silicon pixel and strip detectors of the tracker. The algorithm used is an iterative algorithm that finds tracks in consecutive steps, in which hits belonging to tracks are removed in each step. The tracks are merged based on the fraction of shared hits. Tracks above 30 GeV/c are matched to the closest calorimeter cells. The algorithm provides a high efficiency, low fake track rate at high p_T (details in [2]).

The charged particle spectra are measured in six centrality bins in PbPb (with 0-5% referring to the most central PbPb collisions), and in pp collisions. The PbPb spectra are divided by the pp spectra scaled by T_{AA} for each centrality. Figure 1 shows the charged particle R_{AA} as a function of p_T for peripheral (top left) to central (bottom right) collisions. A dip structure in the charged particle R_{AA} between p_T of 2 and 20 GeV/c increases as a function of centrality.

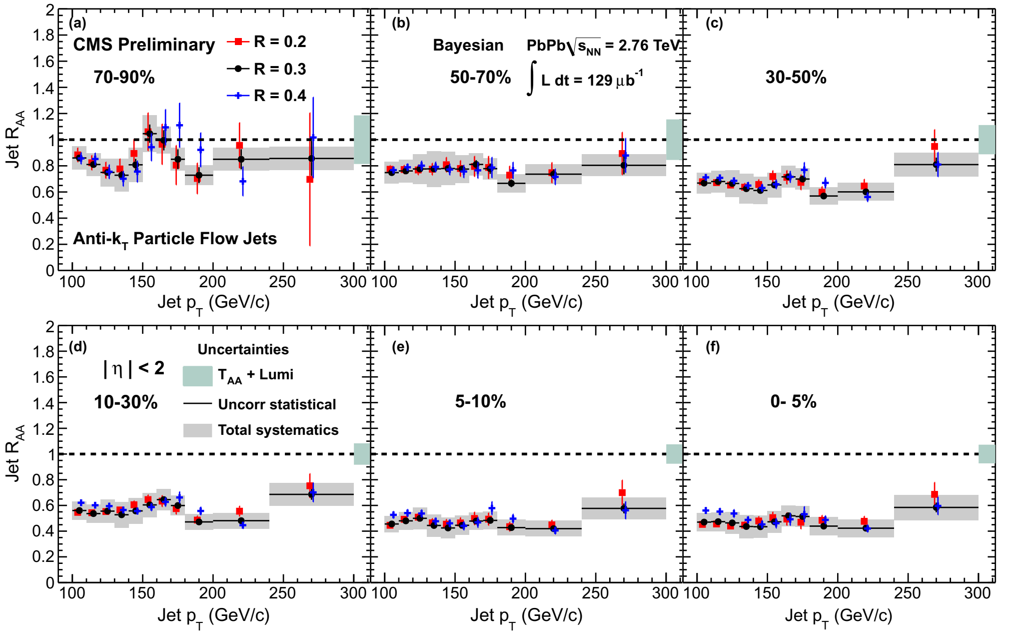

Figure 2: Jet R_{AA} in different effective cone sizes for anti$-k_T$ jets using the Bayesian unfolding method for the given centrality bins. The vertical lines indicate uncorrelated statistical uncertainty, and the wide band the systematic uncertainty for Bayesian unfolding R=0.3. The shaded box above 300 GeV$/c$ represents the overall combined uncertainty from T_{AA} and luminosities.

3. Jet R_{AA}

Jets analyzed are reconstructed offline with the anti$-k_T$ [4] algorithm on particle-flow objects that are formed by matching tracks from the tracker to ECAL and HCAL clusters. The underlying PbPb background is removed with the iterative "noise/pedestal subtraction" technique, and pp jets are evaluated without the background removal. The underlying PbPb background which is removed from the jets is analyzed in simulation and found to be in good agreement with the PbPb background measured in jets of the same centrality [5]. Jet reconstruction performance is evaluated in the analysis of Monte Carlo (MC) simulations of dijets embedded into minimum bias PbPb. The effect of jet momentum resolution and scale in PbPb and pp is removed by unfolding the jet spectrum based on the performance of the jets in Monte Carlo simulations, using primarily the Richardson–Lucy or "Bayesian" unfolding technique [6]. The Bayesian unfolded jet R_{AA} is found to be consistent with spectra corrected using bin-by-bin unfolding, generalized singular value decomposition unfolding, as well as smearing the pp data by the difference in jet p_T resolution and scale from PbPb. Figure 2 shows jets analyzed with different effective cone sizes, the nominal R=0.3 (shaded band representing the systematic uncertainty for that cone size), as well as R=0.2, and R=0.4. The jet R_{AA} shows a decrease from peripheral to central, and is flat within uncertainties from jet p_T of 100 to 300 GeV$/c$. Within the jet p_T measured and the uncertainties, there is no strong dependence on jet radius.

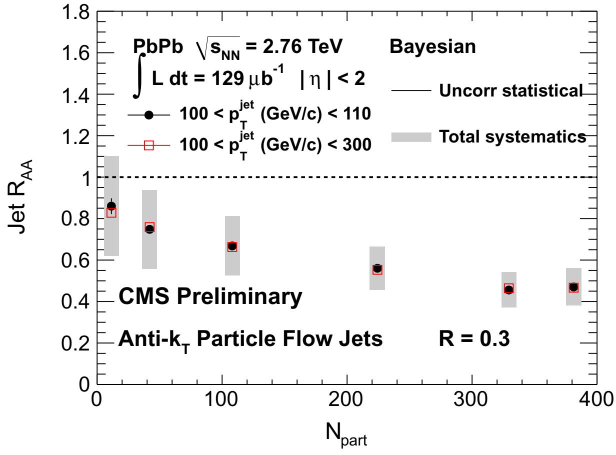

Figure 3: Bayesian unfolded jet R_{AA} for anti$-k_T$ jets of R=0.3 as a function of N_{part}. Closed circles represent the jet R_{AA} for $100 < p_T^{jet} < 110$ GeV/c, and open boxes the jet R_{AA} for $100 < p_T^{jet} < 300$ GeV/c. Vertical lines represent the uncorrelated statistical uncertainty and the wide grey bands represent the systematic uncertainty with the T_{AA} uncertainty included.

The quenching of the reconstructed jets can be seen in Fig. 3 for jet R_{AA} as a function of the average number of participants in the nucleon-nucleon collision, N_{part}. With an increasing number of participants, the jet R_{AA} decreases.

4. Summary

The charged particle R_{AA} has a dip structure that increases from peripheral to central collisions. The central charged particle R_{AA} has a dip structure, reaching a minimum of 0.13 at intermediate p_T, and then increasing to 0.5 at high p_T. The central jet R_{AA} is 0.5 for the jets measured. The jet R_{AA} is independent of cone size for jets of p_T from 100 to 300 GeV/c, within uncertainties. Considering the average p_T of jets that fragment into a charged particle with a given high p_T value, charged track measurements between 40 and 100 GeV/c represent approximately the same population as jet measurements between 100 and 200 GeV/c. In these ranges, the central charged particle R_{AA} and jet R_{AA} are consistent. Quenching of jets is observed in central PbPb collisions both with charged particles and reconstructed jets.

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