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Measurement of charged particle R_{AA} at high p_T in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV with CMS

Krisztián Krajczár on behalf of the CMS Collaboration

Massachusetts Institute of Technology, Cambridge, MA 02139, USA

Abstract

Charged particle transverse momentum (p_T) spectra have been measured by CMS for pp and PbPb collisions at the same $\sqrt{s_{NN}} = 2.76$ TeV collision energy per nucleon pairs. Calorimeter-based jet triggers are employed to enhance the statistical reach of the high- p_T measurements. The nuclear modification factor (R_{AA}) is obtained in bins of collision centrality for the PbPb data sample dividing by the measured pp reference spectrum. In the range $p_T = 5 - 10$ GeV/c, the charged particle yield in the most central PbPb collisions is suppressed by up to a factor of 7. At higher p_T , this suppression is significantly reduced, approaching a factor of 2 for particles with $p_T = 40 - 100$ GeV/c.

Keywords: Nuclear modification factor, particle suppression, CMS, LHC

1. Introduction

The inclusive charged particle p_T spectrum in nucleus-nucleus (AA) collisions is an important tool for studying high- p_T particle suppression in the dense QCD medium produced in high-energy AA collisions [1]. The suppression (or enhancement) of high- p_T particles can be quantified by the ratio of charged particle p_T spectra in AA collisions to those in pp collisions scaled by the number of binary nucleon-nucleon collisions (N_{coll}), known as the nuclear modification factor R_{AA} [1]:

$$R_{AA}(p_T) = \frac{1}{T_{AA}} \frac{d^2 N^{AA}/dp_T d\eta}{d^2 \sigma^{NN}/dp_T d\eta}, \quad (1)$$

where N^{AA} represents the charged particle yield per event in AA collisions, and the nuclear overlap function, $T_{AA} = \langle N_{coll} \rangle / \sigma_{inel}^{NN}$, can be calculated from a Glauber model accounting for the nuclear collision geometry [2].

2. Data samples and analysis procedure

The measurement presented here is based on $\sqrt{s_{NN}} = 2.76$ TeV PbPb data samples corresponding to integrated luminosities of $7 \mu\text{b}^{-1}$ and $150 \mu\text{b}^{-1}$, collected by the CMS experiment in 2010 and 2011, respectively. The pp reference spectrum measured at the same nucleon-nucleon collision energy corresponds to an integrated luminosity of $230 \mu\text{b}^{-1}$.

Email address: krisztian.krajczar@cern.ch (Krisztián Krajczár on behalf of the CMS Collaboration)

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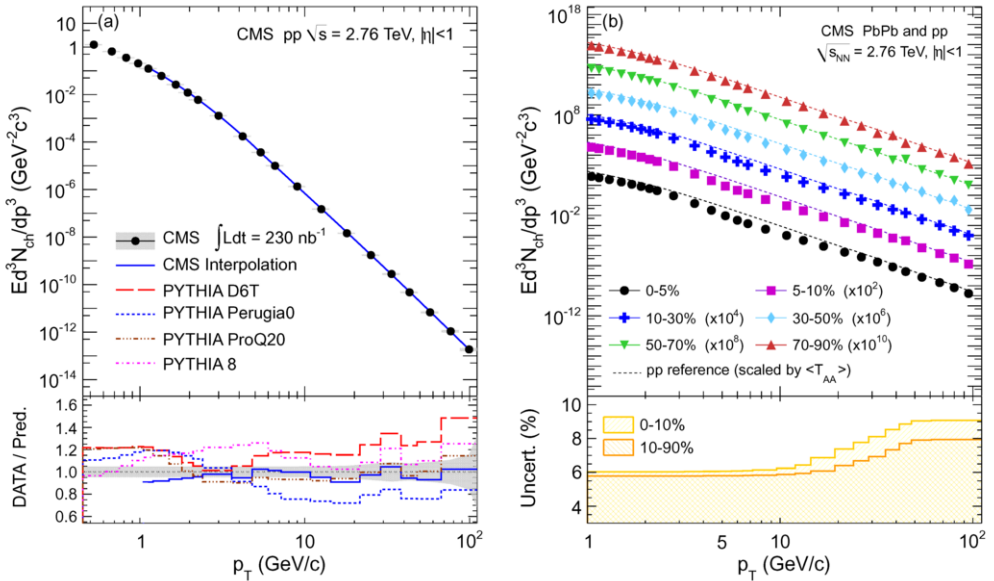


Figure 1: (a) Upper panel: Invariant charged particle differential yield for $|\eta| < 1.0$ in pp collisions at $\sqrt{s} = 2.76$ TeV compared to PYTHIA predictions and to the interpolated CMS spectrum [5]. Lower panel: the ratio of the measured spectrum to the predictions. The grey band corresponds to the statistical and systematic uncertainties of the measurement added in quadrature. (b) Upper panel: Invariant charged particle differential yield in PbPb collisions at 2.76 TeV in bins of collision centrality (symbols), compared to the normalized pp reference spectra (dashed lines). Lower panel: The relative systematic uncertainties of the PbPb differential yields for the 0–10% and 10–90% centrality intervals.

A detailed description of the CMS detector can be found in Ref. [3]. The central feature of the CMS apparatus is a superconducting solenoid, providing a magnetic field of 3.8 T. Immersed in the magnetic field are the silicon pixels and strip tracker, which are designed to provide a transverse momentum resolution of about 0.7 (2.0)% for 1 (100) GeV/c charged particles at normal incidence, the lead-tungstate electromagnetic calorimeter, the brass/scintillator hadron calorimeter, and the gas ionization muon detectors.

In this analysis the coincidence signals of the beam scintillator counters ($3.23 < |\eta| < 4.65$) or the hadron forward calorimeters (HF: $2.9 < |\eta| < 5.2$) were used for triggering on minimum bias events. In order to extend the statistical reach of the p_T spectra, single-jet triggers with calibrated transverse energy thresholds were applied. The collision event centrality, specified as a fraction of the total inelastic cross section, is determined from the event-by-event total energy deposition in the HF calorimeters.

3. Results

The inclusive charged particle invariant differential yield averaged over the pseudorapidity $|\eta| < 1$ in pp collisions is shown in Fig. 1(a) [4]. Also shown are the ratios of the data to various generator-level predictions from the PYTHIA MC [6]. The PbPb spectrum is shown in Fig. 1(b) [4] for six centrality bins compared to the measured pp reference spectrum scaled by T_{AA} . In order to keep the reconstruction probability of spurious tracks at the percent level in PbPb collisions using the standard tracking algorithm, the number of silicon hits required on a track is increased compared to pp collisions. This implies larger minimal p_T for tracks in PbPb than in pp collisions. It is possible to go down to $p_T = 200$ MeV/c by using a dedicated tracking algorithm [7]. By comparing the PbPb measurements to the dashed

lines representing the scaled pp reference spectrum, it is clear that the charged particle spectrum is strongly suppressed in central PbPb events compared to pp, with the most pronounced suppression at around 5–10 GeV/c.

The computed nuclear modification factor R_{AA} is shown in Fig. 2 [4]. The yellow boxes around the points show the systematic uncertainties, including those from the pp reference spectrum. An additional systematic uncertainty from the T_{AA} normalization, common to all points, is displayed as the shaded band around unity. In case of the peripheral 70–90% centrality bin, a moderate suppression of about a factor of 2 is observed at low p_T , with R_{AA} rising slightly with increasing transverse momentum. The suppression becomes more pronounced with increasing collision centrality. In the 0–5% most central centrality bin, R_{AA} reaches a minimum value of about 0.13 at $p_T = 6–7$ GeV/c, corresponding to a suppression factor of 7. At higher p_T , the value of R_{AA} rises approaching roughly a suppression factor of 2 between 40 and 100 GeV/c.

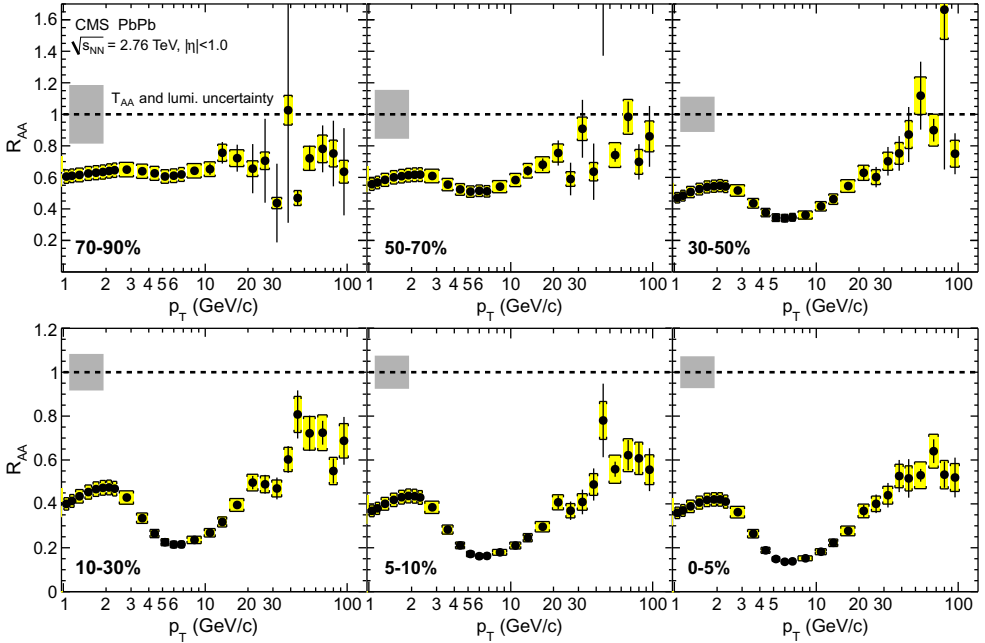


Figure 2: R_{AA} (black dots) as a function of p_T for six PbPb centrality bins. The error bars represent the statistical uncertainties and the yellow boxes represent the p_T -dependent systematic uncertainties. An additional systematic uncertainty corresponding to the normalization factor T_{AA} and the pp integrated luminosity, common to all points, is shown as the shaded band around unity.

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