Nuclear modification factor and energy loss of charged particles and jets in PbPb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV

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Introduction

The aim of heavy ion collisions at RHIC and LHC is to create matter at high energy density which is known as the Quark-Gluon Plasma (QGP). The transverse momentum spectra of the hadrons can be used to describe the particle production mechanism in pp collisions. The hadron spectra in pp collisions are described by the Tsallis distribution functions in terms of only two parameters T and n.

In this work, we study the nuclear modification factor of charged particles and jets in PbPb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV. The study tells us about the energy loss in the medium. The energy loss as a function of the transverse momentum is found to be of the power law.

Methodology

The transverse momentum ($p_{\rm T}$) distribution of particles produced in hadronic collisions can be described by the Tsallis distribution function [1]. The energy loss $\Delta p_{\rm T}$ of the charged particles and jets in the medium is calculated using the nuclear modification factor $R_{\rm AA}$. $R_{\rm AA}$ fitting function is defined as

$$R_{\rm AA} = \Big(1 + \frac{\Delta p_{\rm T}}{p_0 + p_{\rm T}}\Big)^{-n}\Big(\frac{p_{\rm T} + \Delta p_{\rm T}}{p_{\rm T}}\Big)\Big(1 + \frac{d(\Delta p_{\rm T})}{dp_{\rm T}}\Big) \; . \quad (1)$$

The functional form of $\Delta p_{\rm T}$ is defined as

$$\Delta p_{\rm T} = a \; (p_{\rm T} - C)^{\alpha} \; . \quad (2)$$

Here a, C and α are the fit parameters.

Results and Discussions

The Tsallis parameters n and p_0 (given in Table I and II) are obtained by fitting the measured $p_{\rm T}$ spectra of the charged particles [2] and of jets [3] in pp collision at $\sqrt{s} = 2.76$ TeV.

Figure 1 shows the nuclear modification factor $R_{\rm AA}$ of the charged particles as a function of $p_{\rm T}$ for different centrality classes in PbPb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV measured by the CMS [2]. The solid curve is the $R_{\rm AA}$ fitting function (1). Fitting gives good descrition of the $R_{\rm AA}$ spectra. It can be seen from the values of χ^2/NDF which is given in the TableI. Figure 2 shows the energy loss $\Delta p_{\rm T}$ of the charged particles as a function of $p_{\rm T}$ for different centrality classes in PbPb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV. The black solid curve is the power law distribution function (Eq.2). The fitting describes the data very well. The blue dotted curve is the energy loss calculation (Eq.2) which is obtained using the fitting parameters (a, C, α) given in the TableI.

Figure 3 shows the nuclear modification factor $R_{\rm AA}$ of the jets as a function of $p_{\rm T}$ for different centrality classes and for different rapidity ranges in PbPb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV measured by the ATLAS [3]. The solid curve is the $R_{\rm AA}$ fitting function (1). Fitting gives good descrition of the $R_{\rm AA}$ spectra. It can be seen from the values of χ^2/NDF which is given in the TableII. Figure 4 shows the energy loss $\Delta p_{\rm T}$ of the jets as a function of $p_{\rm T}$ for different centrality classes and for different rapidity ranges in PbPb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV. The black solid curve is the power law distribution function (Eq.2). The fitting describes the data very well. The blue dotted curve is the energy loss calculation (Eq.2) which is obtained using the fitting parameters (a, C, α) given in the TableII.

TABLE I: Parameters for charged particles $R_{\rm AA}$ fitting in PbPb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV

Centrality (%)	a	α	C	n	p_0 (GeV)	$\frac{\chi^2}{\rm NDF}$
0 - 5	1.938 ± 0.004	0.400	2.500	7.257	1.025	9.076
5 - 10	1.754 ± 0.004	0.400	2.500	7.257	1.025	7.101
10 - 20	1.530 ± 0.004	0.400	2.500	7.257	1.025	7.528
20 - 30	1.262 ± 0.004	0.400	2.500	7.257	1.025	7.973
30 - 40	1.026 ± 0.004	0.400	2.500	7.257	1.025	3.216
40 - 50	0.793 ± 0.004	0.400	2.500	7.257	1.025	2.260
50 - 60	0.613 ± 0.004	0.400	2.500	7.257	1.025	2.253
60 - 70	0.441 ± 0.005	0.400	2.500	7.257	1.025	0.443
70 - 80	0.351 ± 0.006	0.400	2.500	7.257	1.025	0.853

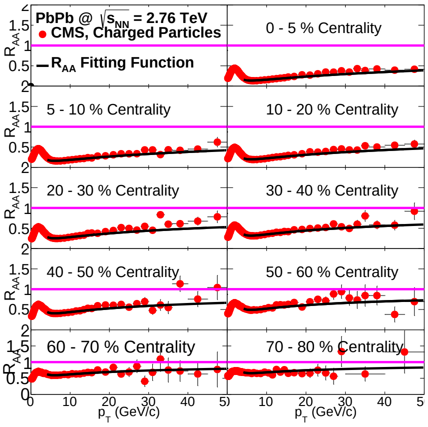

FIG. 1: Charged particles R_{AA} as a function of p_{T}

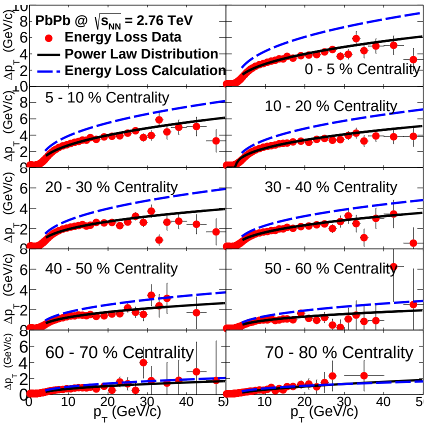

FIG. 2: Charged particles Δp_{T} as a function of p_{T}

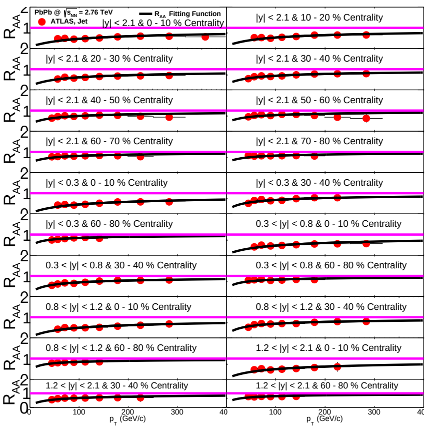

FIG. 3: Jet R_{AA} as a function of p_{T}

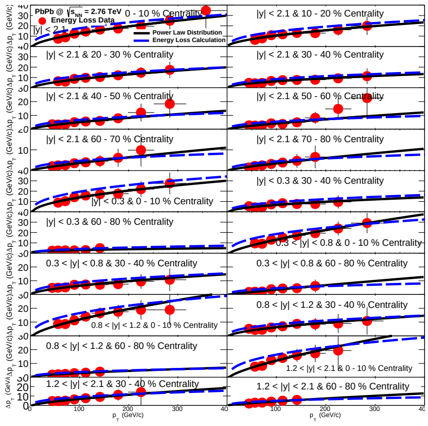

FIG. 4: Jet Δp_{T} as a function of p_{T}

TABLE II: Parameters for jet R_{AA} fitting in PbPb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV

Centrality (%)	Rapidity (y)	a	α	C	n	p_0	$\frac{\chi^2}{\mathrm{NDF}}$
$\lvert y\rvert < 2.1$	0 - 10	2.823 ± 0.248	0.400	3.000	6.214	1.795	0.237
$\lvert y\rvert < 2.1$	10 - 20	2.321 ± 0.204	0.400	3.000	6.214	1.795	0.157
$\lvert y\rvert < 2.1$	20 - 30	1.815 ± 0.173	0.400	3.000	6.214	1.795	0.407
$\lvert y\rvert < 2.1$	30 - 40	1.364 ± 0.159	0.400	3.000	6.214	1.795	0.149
$\lvert y\rvert < 2.1$	40 - 50	1.081 ± 0.162	0.400	3.000	6.214	1.795	0.298
$\lvert y\rvert < 2.1$	50 - 60	0.878 ± 0.163	0.400	3.000	6.214	1.795	0.613
$\lvert y\rvert < 2.1$	60 - 70	0.752 ± 0.154	0.400	3.000	6.214	1.795	0.188
$\lvert y\rvert < 2.1$	70 - 80	0.706 ± 0.175	0.400	3.000	6.214	1.795	0.106
$\lvert y\rvert < 0.3$	0 - 10	3.127 ± 0.283	0.400	3.000	5.852	0.138	0.153
$\lvert y\rvert < 0.3$	30 - 40	1.487 ± 0.188	0.400	3.000	5.852	0.138	0.288
$\lvert y\rvert < 0.3$	60 - 80	0.660 ± 0.187	0.400	3.000	5.852	0.138	0.020
$0.3 < \lvert y\rvert < 0.8$	0 - 10	2.978 ± 0.225	0.400	3.000	5.916	0.205	0.667
$0.3 < \lvert y\rvert < 0.8$	30 - 40	1.403 ± 0.162	0.400	3.000	5.916	0.205	0.129
$0.3 < \lvert y\rvert < 0.8$	60 - 80	0.734 ± 0.175	0.400	3.000	5.916	0.205	0.270
$0.8 < \lvert y\rvert < 1.2$	0 - 10	2.650 ± 0.266	0.400	3.000	6.093	0.083	0.379
$0.8 < \lvert y\rvert < 1.2$	30 - 40	1.347 ± 0.215	0.400	3.000	6.093	0.083	0.120
$0.8 < \lvert y\rvert < 1.2$	60 - 80	0.599 ± 0.175	0.400	3.000	6.093	0.083	0.014
$1.2 < \lvert y\rvert < 2.1$	0 - 10	2.628 ± 0.284	0.400	3.000	6.154	0.133	0.349
$1.2 < \lvert y\rvert < 2.1$	30 - 40	1.426 ± 0.220	0.400	3.000	6.154	0.133	0.165
$1.2 < \lvert y\rvert < 2.1$	60 - 80	0.781 ± 0.174	0.400	3.000	6.154	0.133	0.090

Conclusion

We carried out an analysis of the R_{NN} spectra of the charged particles and jets in PbPb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV using the R_{NN} fitting functions. This function gives good description of the R_{NN} spectra. We also calculate the energy loss in medium using the R_{NN} spectra. The energy loss as a function of the p_{T} is found to be of the power law.

References

[1] J. Phys. Commun. **2**, 035003 (2018).
[2] arXiv:1107.1862 [nucl-ex].
[3] Phys. Rev. Lett. **114**, 072302 (2015).