Medium effects of charged-hadron production in XeXe collisions at $\sqrt{s_{\rm NN}} = 5.44$ TeV using modified Tsallis distribution.

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Introduction

Charged-hadron are the most abundant produced particles in proton-proton (pp), proton-Lead (pPb), and heavy-ion (AuAu, PbPb, and XeXe) collisions at relativistic energies that needs to be understand at both perturbative and non-perturbative part of Quantum Chromodynamics [1]. Charged-hadron's transverse momentum ($p_{\rm T}$) spectra can be used to describe the particle production in pp, pPb, AuAu, PbPb, and XeXe collisons. In the article, we used the modified Tsallis distribution function to study the final state effects such as collective flow, and energy loss in XeXe collisions at $\sqrt{s_{\rm NN}} = 5.44$ TeV.

Modified Tsallis Distribution Function

Generally, the Tsallis distribution function [2, 3] is used to describe the $p_{\rm T}$ spectrum of the charged-hadrons in pp collisions at all Relativistic heavy-ion collider (RHIC) and Large Hadron Collider (LHC) energy ranges. Phenomenologically, There are available various functional forms of Tsallis distribution function which includes the transverse collective flow (at low $p_{\rm T}$) and energy loss (at high $p_{\rm T}$) to describe the $p_{\rm T}$ spectrum in pPb, and heavy-ion collisions. In the present work, we use the following functional form of modified Tsallis distrubution function [4] which includes the final state effects for different $p_{\rm T}$ regions in XeXe collisions at $\sqrt{s_{\rm NN}} = 5.44$ TeV.

$$E\frac{d^3N}{dp^3} = \begin{cases} f_1(p_{\rm T}) : p_{\rm T} < 7 \text{ GeV/c} . \\ f_2(p_{\rm T}) : p_{\rm T} > 7 \text{ GeV/c} . \end{cases} \quad (1)$$

$$\text{Here,} \quad f_1(p_{\rm T}) = A_1 \left[\exp\left(-\frac{\beta p_{\rm T}}{p_1}\right) + \frac{m_{\rm T}}{p_1} \right]^{-n_1} , \quad (2)$$

$$f_2(p_{\rm T}) = A_2 \left[\frac{B}{p_2} \left(\frac{p_{\rm T}}{q_0} \right)^{\alpha} + \frac{m_{\rm T}}{p_2} \right]^{-n_2} . \quad (3)$$

The fitting parameters temperature $T = p_1/n$ and the average transverse flow velocity β (which are governed by $f_1(p_{\rm T})$ of Eq.(2)) show the thermal and collective behaviour of the $p_{\rm T}$ spectrum. $f_2(p_{\rm T})$ of Eq.(3) governs the energy loss behaviour at high $p_{\rm T}$ region. The parameter p_2 in function $f_2(p_{\rm T})$ is proportional to the medium size and the parameter α quantifies different energy loss regimes for light quarks in the medium.

Results and Discussions

Figure (1) shows the invariant yields of the charged-hadron as a function of $p_{\rm T}$ for different centrality classes for pp and XeXe collisions at $\sqrt{s_{\rm NN}} = 5.44$ TeV measured by

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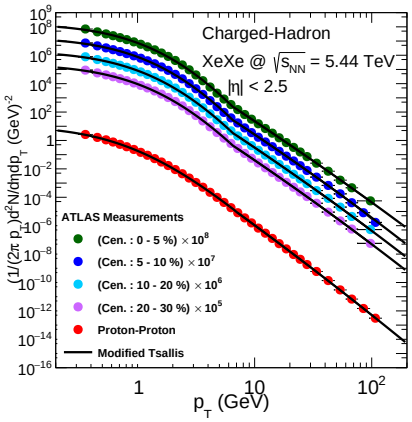

FIG. 1: Invariant yields of the charged-hadron as a function of p_{T} for pp and XeXe collisions at $\sqrt{s_{\mathrm{NN}}} = 5.44$ TeV.

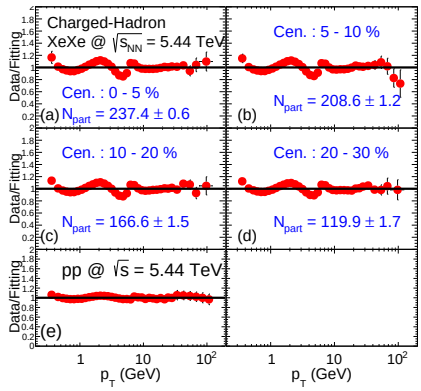

FIG. 2: Ratio of the charged-hadron's yields data and their Modified Tsallis fits as a function of p_{T} for pp and XeXe collisions at $\sqrt{s_{\mathrm{NN}}} = 5.44$ TeV.

the ATLAS experiment [5]. The solid curves are the modified Tsallis distributions given by Eqs.(1, 2, and 3). Figure (2) shows the ratio of the data and the fit function by the modified Tsallis distribution function. The ratio of the data and the fit function shows that modified Tsallis distribution function gives excellent description of the measured ATLAS data in full p_{T} range and for different centrality classes for all the systems (pp and XeXe).

The fitting parameters of the modified Tsallis distribution are given in the Tables (I) and (II). The values of the parameters (n_1, p_1, and β) of the first function ($f_1(p_{\mathrm{T}})$) are constant for differnt centrality classes. While fitting the second function ($f_2(p_{\mathrm{T}})$), we fix the parameter $n_2 = 7.66$ guided by pp value. The exponent α which decides the variation of the energy loss of partons as a function of their energy remains same (≈ 0.6).

TABLE I: The parameters of the modified Tsallis function.

System	Centrality (%)	N_{part}	n_1	p_1 (GeV/c)	β
XeXe	0 - 5	237.40 ± 0.60	10.46 ± 0.53	2.00 ± 1.67	0.18 ± 0.10
XeXe	5 - 10	208.60 ± 1.20	10.32 ± 0.55	2.00 ± 1.59	0.16 ± 0.10
XeXe	10 - 20	166.60 ± 1.50	10.14 ± 0.59	2.00 ± 1.52	0.13 ± 0.10
XeXe	20 - 30	119.90 ± 1.70	9.82 ± 1.24	1.96 ± 1.58	0.10 ± 0.06
pp	-	2	6.95 ± 2.35	0.88 ± 0.46	0.12 ± 0.11

TABLE II: The parameters of the modified Tsallis function.

System	Centrality (%)	N_{part}	α	B (GeV/c)	$\frac{\chi^2}{\mathrm{NDF}}$
XeXe	0 - 5	237.40 ± 0.60	0.64 ± 0.04	8.47 ± 1.91	0.07
XeXe	5 - 10	208.60 ± 1.20	0.60 ± 0.05	5.72 ± 1.13	0.07
XeXe	10 - 20	166.60 ± 1.50	0.62 ± 0.04	5.99 ± 0.62	0.06
XeXe	20 - 30	119.90 ± 1.70	0.62 ± 0.04	5.65 ± 0.61	0.05
pp	-	2	0.66 ± 0.06	3.40 ± 0.54	0.01

Conclusions

The modified Tsallis distribution function described excellently the measured p_{T} spectrum of charged-hadron over wide range of p_{T} with its fitting parameters indicating different physics effects in the XeXe collisions.

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