

Study of Tsallis distribution in pp and Pb-Pb collisions

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The thermodynamically consistent form of the Tsallis distribution has been used to fit the transverse momentum spectra of $\pi^+ + \pi^-$, $K^+ + K^-$ and $p + \bar{p}$ measured by the ALICE experiment in $p - p$ and also in central (0-5%) and peripheral (60-80%) $Pb - Pb$ collisions at $\sqrt{s} = 2.76 TeV$. The Tsallis distribution fits the p_T spectra very well upto 20 GeV/c with a minimum χ^2/NDF values. The particle yield and the density per unit area per unit rapidity have been calculated for both $p - p$ and $Pb - Pb$ collisions using Tsallis framework.

1. Introduction

The thermal models employing Tsallis distribution have gained popularity since LHC has started operating. It describes the p_T spectra of charged hadrons in low- p_T range fairly well and goes upto 200 GeV/c [1].

In the work presented here, the proposed form of the Tsallis distribution is used to describe the p_T spectra of π^\pm , K^\pm and $p(\bar{p})$ measured by the ALICE experiment at mid-rapidity in pp, central (0-5%) and peripheral (60-80%) $Pb - Pb$ collisions at 2.76 TeV CMS energy. The transverse momentum spectra are fitted upto 20 GeV/c.

The particle yield and density in both pp, $Pb - Pb$ (central and peripheral) collisions are computed using the fit parameters.

2. Tsallis Distribution

The proposed distribution is the generalization of the standard Boltzmann-Gibbs distribution. In the framework of Tsallis statistics [2] the particle number, N , is given by an integral over the Tsallis distribution:

$$N = gV \int \frac{d^3p}{(2\pi)^3} \left[1 + (q-1) \frac{E - \mu}{T} \right]^{\frac{-q}{q-1}} \quad (1)$$

where T and μ are the temperature and the chemical potential, V is the volume and g is the degeneracy factor.

The corresponding momentum distribution deduced from Eq. (1) in terms of rapidity, y , and transverse mass, m_T , variable ($E = m_T \cosh y$) at mid-rapidity and $\mu=0$ is given by:

$$\frac{d^2N}{dp_T dy} \Big|_{y=0} = gV \frac{p_T m_T}{(2\pi)^2} \left[1 + (q-1) \frac{m_T}{T} \right]^{\frac{-q}{q-1}} \quad (2)$$

Furthermore, integration of Eq. (2) over the transverse momentum gives:

$$\frac{dN}{dy} \Big|_{y=0} = \frac{gVT}{2\pi^2} \left[\frac{(2-q)m_0^2 + 2m_0T + 2T^2}{(2-q)(3-2q)} \right] X \left[1 + (q-1) \frac{m_0}{T} \right]^{\frac{-1}{q-1}} \quad (3)$$

where m_0 is the rest mass.

The following formula is used to compute the density of the *pions*, *kaons* and *protons* using the inputs obtained from the Tsallis distribution:

$$\rho = \frac{1}{\pi R^2} \frac{dN}{dy} \quad (4)$$

where R is the radius. In this case, it is derived from the parameter $V (= \frac{4}{3}\pi R^3)$.

3. Figures and Tables

The Tsallis fits to the p_T spectra of $\pi^+ + \pi^-$, $K^+ + K^-$ and $p + \bar{p}$ measured by the ALICE experiment in pp, central (0-5%) and peripheral (60-80%) $Pb - Pb$ collisions at $\sqrt{s}=2.76$ TeV are shown in Fig. 1.

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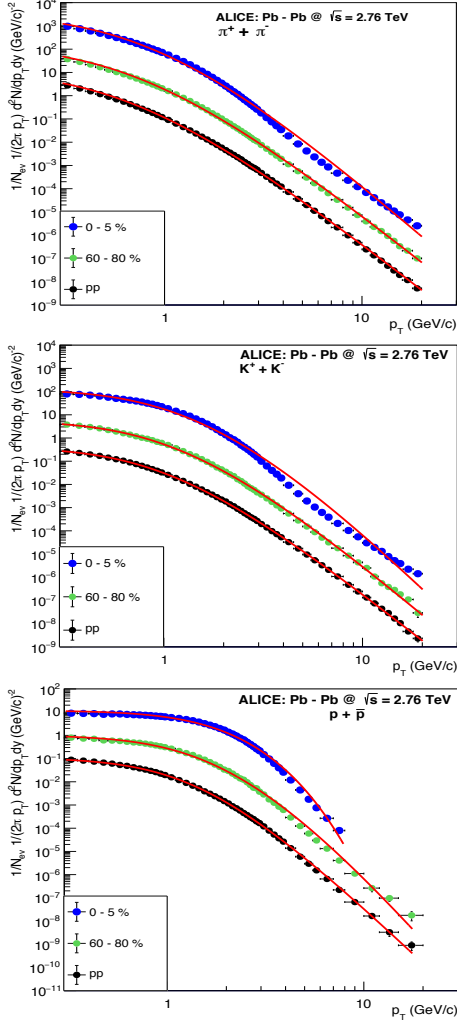


FIG. 1: p_T spectra of $\pi^+ + \pi^-$ (top), $K^+ + K^-$ (middle) and $p + \bar{p}$ (bottom) fitted with Tsallis distribution.

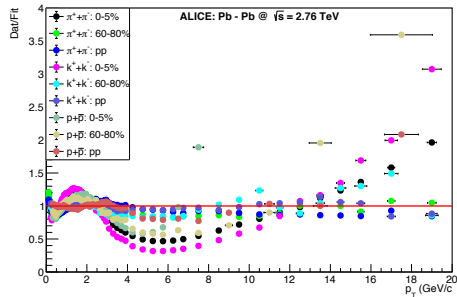


FIG. 2: Ratios of the data measured by ALICE to the fit values.

Figure 2 shows the ratio of the data values to the values obtained from Tsallis fits.

4. Results and discussions

It is observed from Fig. 1 that the Tsallis distribution fits well the p_T spectra for all kind of particles measured in pp and Pb-Pb (central and peripheral) collisions by the ALICE detector at $\sqrt{s}=2.76$ TeV.

The ratios of the experimental data over the fit values, depicted in Fig. 2, is oscillating around 1 in most of the cases. However, it can be noticed that it is higher for few points at large p_T values.

The χ^2/NDF values obtained from the Tsallis fits are given in Table 1. The calculated values of particle multiplicities and density are also given in Table 1.

TABLE I: Table for particle multiplicities and density.

Particles	Collisions	χ^2/NDF	dN/dy	$\rho \times 10^{-4}$ (GeV^2)
$\pi^+ + \pi^-$	0 - 5%	81.52/60	1519.7	253.70
	60 - 80%	28.28/60	57.00	62.16
	pp	20.63/60	3.96676	21.34
$K^+ + K^-$	0 - 5%	149.67/55	214.67	230.16
	60 - 80%	12.06/55	7.36	37.39
	pp	2.54/55	0.463	9.09
$p + \bar{p}$	0 - 5%	57.61/42	66.21	1356.7
	60 - 80%	29.47/46	2.84	50.57
	pp	3.67/46	0.209	2.50

5. Conclusions

It can be concluded that the proposed version of the Tsallis distribution fits the transverse momentum spectra measured in both pp and Pb-Pb collisions with minimal χ^2 values. The values obtained for particle multiplicities and particle densities shows a clear increase from smaller ($p-p$) to larger ($Pb-Pb$) system and also from peripheral to central collisions which is expected.

References

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