A Thermal Approach to RHIC and LHC

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Introduction

The Relativistic Heavy Ion Collider (RHIC) at BNL and the Large Hadron Collider (LHC) at CERN are the two world-class experimental facility to produce Quark Gluon Plasma by colliding two heavy ions at relativistic speeds. The Quark Gluon Plasma, is a thermalized state of deconfined quarks, anti-quarks and gluons, which is beleived to have existed just after the Big-Bang. Collective behaviour of particles in heavy ion collisions is an unavoidable consequence of thermalization. Thermalization generates thermodynamic pressure in the matter created in the collisions, which acts against the surrounding vacuum and causes rapid collective expansion ("flow") of the reaction zone. If there is no thermalization, then it could be taken as a proof that no such plasma was ever formed [1].

RHIC collides heavy ions such as $Au + Au$, $Cu + Cu$ and $U + U$ and LHC collides heavy ions such as $Pb + Pb$ at various center of mass energies. In the present paper, we mainly focus on $Au+Au$ collisions at $\sqrt{s_{NN}} = 200$ GeV and $Pb + Pb$ collisions at $\sqrt{s_{NN}} = 2.76$ TeV. The hadron spectra at high p_T follow power law distribution and are important for QGP studies as they measure jet quenching effect in QGP. The low p_T hadrons form the bulk of the spectra arising from multiple scatterings and follow exponential distribution depictive of particle distribution in a thermal system which may be more meaningful for heavy ion system.

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Phenomenological Fit functions

Particle spectra from a thermalized system follow Boltzmann distribution, which is given by:

$$G(E) = C \exp\left(\frac{-E}{T}\right), \quad (1)$$

where $E = m_T = \sqrt{p_T^2 + m^2}$ is the energy at mid-rapidity and this distribution holds good for low p_T range. To describe the data at intermediate and high p_T range, Tsallis developed a new phenomenological fit function. The Tsallis distribution [2] describes at near thermal system in terms of two parameters T and q, is given by

$$E\frac{d^3N}{dp^3} = C_q\left(1 + (q-1)\frac{E}{T}\right)^{-1/(q-1)}. \quad (2)$$

Here C_q is the normalization constant, E is the particle energy, T is the temperature and q is the so-called nonextensivity parameter which measures the temperature fluctuations in the system as: $q - 1 = Var(T)/ < T >^2$. The values of q lie between $1 < q < 4/3$. For $q \to 1$, the Tsallis distribution becomes Boltzmann distribution. To describe the collective behaviour [3] of particles in heavy ion collisions, we propose a fit function, which is given by:

$$E\frac{d^3N}{dp^3} = C_n\left(\exp\left(\frac{-\gamma\beta p_T}{nT}\right) + \frac{\gamma m_T}{nT}\right)^{-n}. (3)$$

This is a modification of Tsallis distribution. Here the low p_T represents a thermalized system with collective flow and high p_T indicates a power law which mimics "QCD inspired" quark interchange model.

Results and Discussions

Figure 1 shows the variation of q parameter as a function of system size at $\sqrt{s_{NN}} = 200$

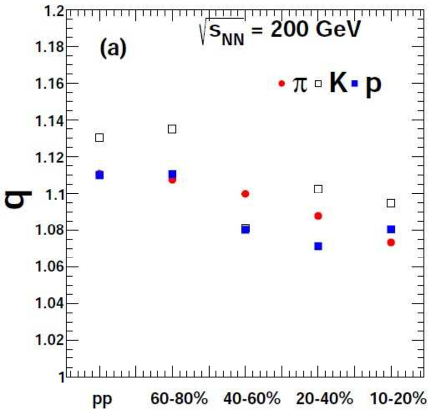

FIG. 1: (Color online) The variation of q parameter as a function of system size at $\sqrt{s_{NN}} = 200$ GeV for pions, kaons and protons.

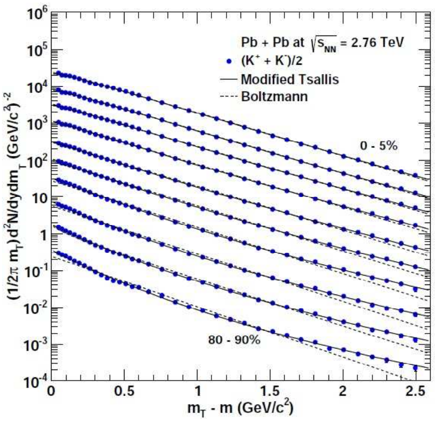

FIG. 2: (Color online) The invariant yields of kaons $((K^+ + K^-)/2)$ as a function of m_T for $Pb + Pb$ collisions at $\sqrt{s} = 2.76$ TeV for various centralities. The solid lines are the modified Tsallis distribution (Eq. 3) and the dotted lines are the Boltzmann distribution.

GeV for pions, kaons and protons. Here we see that the non-thermalization parameter (q) decreases with centrality. That means a thermalized system is obtained at central collisions which gives an indication of collectivity.

Figure 2 shows the plot of invariant yields of kaons $((K^+ + K^-)/2)$ as a function of m_T for

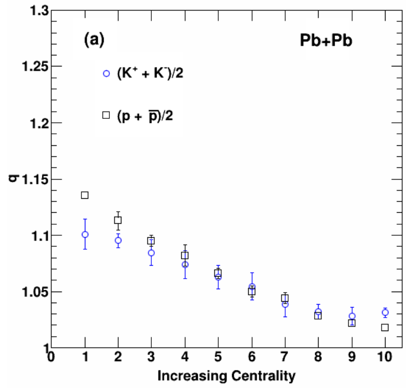

FIG. 3: (Color online) The variation of q parameter in $Pb + Pb$ collisions at $\sqrt{s_{NN}} = 2.76$ TeV of kaons and protons for various centralities.

$Pb + Pb$ collisions at $\sqrt{s} = 2.76$ TeV for various centralities. The solid lines are the modified Tsallis distribution (Eq. 3) and the dotted lines. are the Boltzmann distribution. Here it is clearly seen that the modified Tsallis distribution approaches Boltzmann distribution with increasing system size, which implied a typical thermal system.

Figure 3 shows the variation of q parameter in $Pb + Pb$ collisions at $\sqrt{s_{NN}} = 2.76$ TeV for kaons and protons at various centralities. We observe that the parameter q is approaching towards unity for more centrality cases. So we can say that this also gives an indication of collective behaviour of particles and a typical thermal system.

References

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