Study of hadron production in nucleus nucleus interaction at Relativistic Heavy Ion Collider

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Introduction

Heavy-ion (A+A) collisions at relativistic energies are performed to study the properties of matter at high temperature and energy density where a phase transition to Quark Gluon Plasma (QGP) is expected. Quark Gluon Plasma is a thermalized state of deconfined quarks and gluons. The particle spectra provide information on the production mechanism and the interaction in the hadronic phases and in the QGP phases. So the transverse momentum (p_T) distributions of identified hadrons are the most common tools used to study the dynamics of high energy collisions.

In the present work, we give a systematic study of identified hadron spectra using the measured data of RHIC (Relativistic Heavy Ion Collider) and LHC (Large Hadron Collider) at various center of mass energies for different colliding systems such as $p+p$, d+Au and Au+Au. Measurements in $p+p$ collisions are used as a baseline for heavy-ion collisions. Here we study the p_T (transverse momentum) and m_T (transverse mass) spectra of hadrons using various phenomenological fit functions such as Tsallis distribution and Hagedorn distribution. The high p_T hadrons are important for QGP studies as they measure jet quenching effect in QGP and display a power law behaviour. The low p_T hadrons form the bulk of the spectra arising from multiple scatterings and follow exponential distribution depicting particle production in a thermal system. In addition, the hadron spectra at intermediate p_T are sensitive to the effects arising from quark recombination in heavy-ion collisions.

Hadron spectra in $p+p$ collisions

We describe the p_T spectra of identified charged hadrons in $p+p$ collisions [1] at RHIC ($\sqrt{s}$ = 62.4, 200 GeV) and at LHC ($\sqrt{s}$ = 0.9, 2.76 and 7.0 TeV) energies. Here we parametrize the measured hadron spectra using Tsallis distribution (given in Eq. 1) and study the energy dependence of Tsallis parameters (T and n) for different particles.

$$E\frac{d^3N}{dp^3} = \frac{1}{2\pi}\frac{dN}{dy}\frac{(n-1)(n-2)}{(nT+m(n-1))(nT+m)}\left(\frac{nT+m_T}{nT+m}\right)^{-n} \quad (1)$$

Here the parameter T governs the soft collisions and the parameter n governs the hard collisions. We observe that, there are less soft collisions and more hard collisions occur among partons at higher center of mass energies ($\sqrt{s}$). Another important observation is that, the production mechanism of mesons and baryons are same at highest LHC energy.

Transverse mass (m_T) scaling of hadron spectra

We present a systematic study of transverse mass spectra of mesons [2] at $\sqrt{s_{NN}}$ = 200 GeV. In this work, we parametrize experimentally measured pion spectra using modified Hagedorn function (given in Eq. 2) to obtain the m_T spectra of mesons using a property known as m_T scaling.

$$E\frac{d^3N}{dp^3} = \frac{A}{\left[\exp(-am_T - bm_T^2) + \frac{m_T}{p_0}\right]^n}, \\ = f_\pi\left(\sqrt{p_T^2 + m_\pi^2}\right), \quad (2)$$

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The m_T scaled spectra for each meson is compared with experimental data for $p+p$, d+Au and Au+Au systems. The agreement of the m_T scaled and experimental data shapes are excellent in most cases and their fitted relative normalization gives ratio of meson to pion m_T spectra. These ratios are useful to obtain the hadronic decay contribution in photonic and leptonic channels but also point to the quantitative changes in the dynamics of the heavy-ion collisions over $p+p$ collisions. It is shown that, the particles with strange and charm contents behave differently as compared to others. Strange and charm hadrons in the final products of high-energy nuclear collisions provide valuable insight into the properties of the created system, since they are not present inside the nuclei of the incoming beams.

System size dependence of hadron spectra

In heavy-ion collisions, there are large number of multiple scatterings occur among particles and due to this a collective motion develops. This type of collective behaviour is not seen in p+p collisions. When particles having different masses move with same velocity, then we say that there is a collective behaviour present among the particles. In this analysis, we show a collective transverse flow of hadrons [3] in Au+Au collisions. To explain the hadron spectra in Au+Au collisions in large p_T range, we propose a modified Tsallis function (given in Eq. 3) by introducing an additional parameter (β) which accounts for transverse flow.

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

We make a systematic study of the parameters of modified Tsallis function for pions, kaons, protons, $\Lambda(1115)$, and Ξ^- as a function of system size at $\sqrt{s_{NN}} = 200$ GeV using measured hadron spectra from PHENIX and STAR experiments. We observe that the flow velocity (β) extracted for all particles increases with centrality in Au+Au collisions. There is a clear separation of flow between mesons and baryons in the most central Au+Au collisions showing a dependence on number of constituent quarks. The behavior of freeze-out temperatures T can also be grouped into mesons and baryons. For baryons the increase of temperature is more rapid as compared to mesons. The baryons in general freeze-out earlier than mesons.

References

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