Study of strongly interacting matter using light and heavy hadron production in heavy ion collisions

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Introduction

The heavy ion collisions at RHIC and LHC aim to create matter with high energy density required for the formation of Quark-Gluon Plasma (QGP). Quark-Gluon Plasma is a thermalized state of deconfined quarks and gluons. The heavy ion collisions basically study the strongly interacting matter in bulk. The quark-gluon matter once formed, presumbly with local thermal equilibrium, expands, cools and undergoes a phase transition to hadronic matter. The hadronic matter continues to expand and once the mean free path of hadrons become bigger than the system size, they decouple from the system and move towards the detectors.

Light charged particle production

In the thesis, we present a study of transverse momentum (p_T) spectra of unidentified charged particles in pp collisions at RHIC and LHC energies from $\sqrt{s}$ = 62.4 GeV to 13 TeV using Tsallis/Hagedorn functions. The power law of Tsallis/Hagedorn form gives excellent description of the hadron spectra in the p_T range 0.2 to 300 GeV/c. The power index n of the p_T distributions is found to follow a function of the type $a + b/\sqrt{s}$ with asymptotic value a = 5.72. The parameter T governing the soft bulk contribution to the spectra remains almost same over wide range of collision energy. We also provide a Tsallis/Hagedorn fit to the p_T spectra of hadrons in pPb and different centralities of PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. The data/fit shows deviations from the Tsallis distibution which become more pronounced as the system size increases. We suggest simple modifications in the Tsallis/Hagedorn power law function and show that the above deviations can be attributed to the transverse flow in low p_T region and to in-medium energy loss in high p_T region

Strange hadron production

The theoretical analysis of the p_T spectra of the strange hadrons in different multiplicity events produced in pp collision at $\sqrt{s} = 7$ TeV, pPb collision at $\sqrt{s_{NN}} = 5.02$ TeV and PbPb collision at $\sqrt{s_{NN}} = 2.76$ TeV is presented in the thesis. Both the single and differential freeze-out scenarios of the strange hadrons K_s^0, Λ and Ξ^- are considered while fitting using a Tsallis distribution, which is modified to include transverse flow. The p_T distributions of these hadrons in different systems are characterized in terms of the parameters namely, Tsallis temperature (T), power (n) and average transverse flow velocity (β). It is found that for all the systems, transverse flow increases as we move from lower to higher multiplicity events. In case of the differential freeze-out scenario, the degree of thermalization remains unchanged for events of different multiplicity classes in all the three systems. The Tsallis temperature increases with the mass of the hadrons and also increases with the event multiplicity in pp and pPb system but shows slight variation with the multiplicity in PbPb system. In case of the single freeze-out scenario, the difference between small (pp, pPb) and large (PbPb) systems becomes more evident. The high multiplicity PbPb events show higher degree of thermalization as compared to the events of pp and pPb systems. The temperature variation trend in PbPb with event multiplicity is opposite to what is found in the pp and pPb systems.

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Heavy quark production and energy loss

We study the production and evolution of charm and bottom quarks in hot partonic medium produced in heavy ion collisions. The energy loss of heavy quark (charm and bottom) due to elastic collisions and gluon radiation in hot and dense medium is calculated in the thesis. The collisional energy loss has been obtained using QCD calculations. The radiative energy loss is calculated using reaction operator formalism and generalized dead cone approach. We rederived the energy loss expression using same assumptions as generalized dead cone approach but obtained slightly different results. We also improved the model employed to calculate the path length and the system evolution. The nuclear modification factors R_{AA} including shadowing and energy loss are evaluated for B and D mesons and are compared with the measurements in PbPb collision at $\sqrt{s_{NN}} = 2.76$ TeV and with the D meson and Heavy flavour (HF) electrons measurements in AuAu collision at $\sqrt{s_{NN}} = 200$ GeV. The nuclear modification factors R_{AA} as a function of the transverse momentum including shadowing and the energy loss are calculated for D^0 and B^+ mesons in PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV and for D^0 mesons at $\sqrt{s_{NN}} = 2.76$ TeV and are compared with the recent measurements. The radiative energy loss calculated by reaction operator formalism added with collisional energy loss describes the RHIC HF electron suppression in high p_T range. It also describes the LHC measurement of B meson suppression but overestimates the suppression of D meson. The radiative energy loss from generalized dead cone approach describes the charm suppression at both RHIC as well as LHC energies and requires energy loss due to collisions to be added in order to describe the bottom suppression at LHC. The radiative energy loss from generalized dead cone approach alone is sufficient to produce D^0 meson R_{AA} at both the energies. The radiative energy loss from reaction operator formalism plus collisional energy loss gives good description of D^0 meson R_{AA}. For the case of B^+ meson, the radiative energy loss from generalized dead cone approach plus collisional energy loss gives good description of the CMS data. The radiative process is dominant for charm quark while for bottom quark both radiative and elastic collisions are important.

Acknowledgments

I am thankful to Dr. Venktesh Singh (supervisor), Dr. Prashant Shukla (external supervisor) and Dr. Vineet Kumar for their kind support and encouragement. I also acknowledges the financial support from UGC, Govt. of India, New Delhi.

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