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Title : Nucleus-Nucleus Collision at High and Intermediate Energies: Particle Production, Collective Flow and De-confinement Phenomenon.

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ABSTRACT

Heavy-ion collisions at high energies allow us to study the elementary components of matter and the interactions between them. Relativistic heavy-ion collisions give also the possibility to study the behavior of nuclear matter under extreme conditions of pressure and temperature. It is supposed that such conditions were present during first few microseconds after the Big Bang. They can be recreated experimentally in heavy-ion collisions at ultra-relativistic energies, using the colliders, such as BNL-AGS and CERN-SPS and Relativistic Heavy Ion Collider (RHIC) and the upcoming Large Hadron Collider (LHC) in the ALICE project.

We analyze the experimental data on pion multiplicity from La + La collision at $E_{lab}^{kin} = 1.35\ \mathrm{GeV/A}$ and its kinetic energy spectrum. We discuss the freeze-out scenario, the possible role of the delta and strange particles and whether the hadronic repulsion (leading to an excluded volume effect) plays any role at the thermo-chemical and the hydrodynamical freeze-out stage. The importance of collective flow is realized in explaining the pion spectrum at this collision energy. The analysis also provides evidence of the presence of strange particles and the delta resonance in partial chemical equilibrium, at an *initial* chemical freeze-out stage when the hydrodynamic flow has not developed to have any significant effect. At the final "hydrodynamical freeze-out" we do not find any evidence of the deltas and the strange particles (such as lambda etc.), when the thermal temperature has dropped considerably. The importance of the collective flow vis a vis the resonance decay contribution is also discussed in explaining the pion kinetic energy spectra. Further all the model parameters are determined uniquely unlike previous analysis, thus avoiding any arbitrariness.

We use extended statistical thermal model to describe various hadron rapidity spectra at the highest RHIC energy. The model assumes the formation of several fireballs (hot regions) moving along the rapidity axis with increasing rapidities y_{FB}. Bacattini and Cleymans have attempted to provide an explanation of the net proton flow i.e. $p - \bar{p}$, ratio $\bar{p}/p$ and the pion rapidity spectra. In this chapter we have attempted to show that in addition to these, this model can also successfully describe the individual rapidity spectra

protons, antiprotons, Kaons, antiKaons and pions. The experimental data set provided by BRAHMS collaboration at the highest energy of Relativistic Heavy Ion Collider, $\surd S_{NN}$ = 200 GeV is used for this. We have also shown the rapidity spectra of $\bar{\Lambda}/\Lambda$ and the $\bar{\Xi}/\Xi$. The mid-rapidity data (for IyI < 1) available (from STAR) fit quite well in both these cases. In this we use single set of model parameters including single value of the temperature parameter T for all the regions of the hot and dense matter formed (fireballs). This is unlike the previous analyses wherein a varying temperature has been assumed for the fireballs formed along the rapidity axis. The chemical potentials in our analysis are however still assumed to be dependent on the fireball rapidity y_{FB}. We have analyzed the contribution of the decay products of the heavier resonances. It is found that the rapidity spectra of the product hadron is almost same that of the parent hadron. We have also imposed the criteria of exact strangeness conservation in each fireball separately. We also discuss what can be learned about the nuclear transparency effect at the highest RHIC energy from the net proton rapidity distribution. Invoking a scenario of sequential freeze-out we find that it is possible to explain proton (antiproton), kaon (antikaon) and pion data. Under this scenario not only all particle spectra are reproduced correctly but a much better value of the relative yield of $\bar{K}/K$, K^+/π^+, K^-/π^- and $K^*(892)/K(492)$ are obtained. We find that when the protons (antiprotons) freeze-out earlier the temperature is T=175 MeV, however at a later stage when the kaons (antikaons) freeze-out the temperature drops to a value T=135 MeV and finally when pion freeze- out the temperature falls to a value of 120 MeV. If we treat the system to be (almost) spherically symmetrical we find that the freeze-out radii of protons, Kaons and pions are approximately 3 fermi, 5 fermi and 7 fermi, respectively. This is obviously due to the expansion and the subsequent cooling of the hot system. Hence the above scenario of a sequential freeze-out appears to be more likely. We have discussed how the degree of chemical equilibration in QGP varies, with system size, and reaction energy at SPS and RHIC energy. The result follows from glue-based strangeness production.

Hadronization of the fireball of matter formed in heavy ion reactions leads to quite different spectra and yields of hadrons than we expect based on elementary pp reactions. This change in reaction mechanism favours, in particular, the production of multi strange baryons and antibaryons. The enhancement we see is what statistical recombination of quarks predicts, both as function of centrality and energy. At the very high RHIC energies: Strange antibaryon enhancement suggests that at least down to 40 AGeV we have s (strange) - q (quark) - g (gluon) - matter. The simplest of all possible observables, the K^+/π^+ ratio shows a threshold between 20 and 30 AGeV projectile energy. This would certainty help us understand the possibility of the QGP, both its formation and threshold as function of centrality and reaction energy. This will further lead to detailed understanding of the phases of QCD.