Energy Dissipation and Charged Particle Production in Heavy Ion Collisions

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Introduction

In this paper, we use a model combining the constituent quark picture with Landau relativistic hydrodynamics [1, 2]. Within this model, the secondary particle production in nucleus-nucleus or nucleon-nucleon (pp/ pp) collisions is basically driven by the amount of the initial effective energy deposited by participants (quarks or nucleons) into the Lorentz contracted overlap region. In pp/ pp collisions single constituent (or dressed) quark takes part in collision and rest are considered as spectators. Thus the effective energy for the production of secondary particles is the energy carried by the single quark i.e. 1/3 of entire nucleon energy. However, in the most central heavy ion collisions, the density of matter is very high, so one can consider that all three constituent quarks from each nucleon participate in collisions. Therefore, entire energy of the participant nucleus is available for the secondary particle production. Thus one can expect that the bulk observables per participant pair in the most central heavy ion collisions to be similar to those in pp/ pp collisions but at a three times larger center of mass energy i.e. √sNN ≃ 3√sNN.

The relation between charged particle rapidity density per participant pair ρ(y) = ⟨2/Npart⟩dNch/dy at mid-rapidity (y=0) in heavy ion collisions and that in pp/ pp collisions reads [1]

\[
\frac{ρ(0)}{ρ_{pp}(0)} = \frac{2N_{ch}^{AA}}{N_{part}^{pp}} \sqrt{\frac{L_{pp}}{L_{NN}}}. \tag{1}
\]

Here, Npart is the number of participants, Nch and Nch are the mean multiplicity in nucleus-nucleus and nucleon-nucleon collisions, respectively, and L = ln 2/s with m being considered [2] as the proton mass in nucleus-nucleus collisions and the constituent quark mass in pp/ pp collisions. At given ρ(0), ρpp(0) and Nch, one finds [2]

\[
\frac{2N_{ch}^{AA}}{N_{ch}^{pp}} \rho(0) N_{pp}^{ch} \rho_{pp}(0) \left[ \frac{1 - \frac{2}{3} \ln 3}{\ln(4.5\sqrt{s_{NN}/m_p})} \right]. \tag{2}
\]

For given ρpp(0) , Nch and Nch , one gets

\[
\rho(0) = ρ_{pp}(0) \frac{2N_{ch}^{AA}}{N_{part}^{pp} N_{ch}^{pp}} \left[ \frac{1 - \frac{4}{3} \ln 3}{\ln(4m_p^{pp}/s_{NN})} \right]. \tag{3}
\]

Analysis

The charged particle mean multiplicity per participant pair, Nch/(Npart/2) measured in most central nucleus-nucleus collisions are shown in Figure 1 as a function of √sNN versus those

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FIG. 2: Charged particle pseudorapidity density for Au+Au collisions as a function of collision centrality measured at RHIC and calculated from the model based on constituent quark picture and Landau hydrodynamics at \( \sqrt{s_{NN}} \) as indicated. The lines show energy-dissipation calculations based on the fits to energy dependence of the charged-particle mid-rapidity densities in the most central nucleus-nucleus collisions.

calculated for \( \bar{p}p/pp \) collisions using Eq (2) at \( \sqrt{s_{pp}} = 3\sqrt{s_{NN}} \). For our calculation we use \( \rho_{pp}(0) \) and \( N_{ch}^{pp} \) from published data and \( \rho(0) \) from a hybrid fit [3]. One can see that \( N_{ch}^{pp}/(N_{part}/2) \) values calculated from the \( \bar{p}p/pp \) data are in very good agreement with the measurements in nucleus-nucleus collisions, and are well reproduced by the power-law fit and hybrid fit for the wide energy range spanning from the Bubble chamber to the LHC experiments. We show here as well the \( e^+e^- \) data for entire available energy range. One can find that for \( \sqrt{s_{ee}} < 10 \text{ GeV} \) the \( e^+e^- \) measurements exceed those from the nucleus-nucleus data, but for \( \sqrt{s_{ee}} > 10 \text{ GeV} \) the leptonic data is in very good agreement with the nucleus-nucleus measurements.

We can conclude that there is an interrelation among nucleon-nucleon, \( e^+e^- \) and nucleus-nucleus data for all available energies, which leads to a universality in multi-particle production at the energy scale \( \sqrt{s_{pp}}/3 \approx \sqrt{s_{NN}} \approx \sqrt{s_{ee}} \).

The centrality dependence of pseudorapidity charged particle density per participant pair measured in AA collisions and calculated from \( pp/pp \) collisions using Eq (3) for the PHOBOS at RHIC experiment and for three experiments at the LHC are shown in Figure 2 and Figure 3, respectively.

To calculate \( \rho(0) \), the \( \bar{p}p/pp \) multiplicity E735 power-law fit \( N_{ch}^{pp} = 3.102s_{pp}^{0.178} \) [4] is used and \( N_{AA}^{ch} \) and \( \rho_{pp}(0) \) are taken from the hybrid fits:

\[
N_{ch}^{AA} = -4.9 + 1.03\ln\sqrt{s_{NN}} + 3.23(\sqrt{s_{NN}})^{0.42},
\]

\[
\rho_{pp}(0) = -0.081 + 0.43\ln\sqrt{s_{NN}} + 0.018(\sqrt{s_{NN}})^{0.53}
\]

One can see that the model [2] based on constituent quark picture along with Landau hydrodynamics gives a good agreement with the experimental data up to LHC energies in describing the particle production. A detailed study of bulk observables in this framework will be presented.

References


