Energy Dissipation and Charged Particle Production in Heavy Ion Collisions

Aditya Nath Mishra[1],* Raghunath Sahoo[1], and Edward K.G. Sarkisyan[2,3]
[1] *Indian Institute of Technology Indore, Indore-452001, India*
[2] *Department of Physics, CERN, 1211, Geneva23, Switzerland and*
[3] *Department of Physics, The University of Texas at Arlington, Arlington, TX 76019, USA*

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 ($\bar{p}p/pp$) 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 $\bar{p}p/pp$ 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 $\bar{p}p/pp$ collisions but at a three times larger center of mass energy i.e. $\sqrt{s_{pp}} \simeq 3\sqrt{s_{NN}}$.

The relation between charged particle rapidity density per participant pair $\rho(y) = (2/N_{part})dN_{ch}/dy$ at mid-rapidity (y=0) in heavy ion collisions and that in $\bar{p}p/pp$ collisions reads [1]

$$\frac{\rho(0)}{\rho_{pp}(0)} = \frac{2N_{ch}^{AA}}{N_{part}N_{ch}^{pp}}\sqrt{\frac{L_{pp}}{L_{NN}}}. \qquad (1)$$

Here, N_{part} is the number of participants, N_{ch} and N_{ch}^{pp} are the mean multiplicity in nucleus-nucleus and nucleon-nucleon collisions, respectively, and $L = \ln\frac{\sqrt{s}}{2m}$ with m being considered [2] as the proton mass in nucleus-nucleus collisions and the constituent quark mass in $\bar{p}p/pp$ collisions. At given $\rho(0)$, $\rho_{pp}(0)$ and N_{ch}^{pp}, one finds [2]

$$\frac{2N_{ch}^{AA}}{N_{part}} = N_{ch}^{pp}\frac{\rho(0)}{\rho_{pp}(0)}\sqrt{1-\frac{2\ \ln 3}{\ln(4.5\sqrt{s_{NN}}/m_p)}} \qquad (2)$$

For given $\rho_{pp}(0)$, N_{ch}^{pp} and N_{ch}^{AA}, one gets

$$\rho(0) = \rho_{pp}(0)\ \frac{2N_{ch}^{AA}}{N_{part}\ N_{ch}^{pp}}\sqrt{1-\frac{4\ \ln 3}{\ln(4m_p^2/s_{NN})}} \qquad (3)$$

*Electronic address: amishra@cern.ch

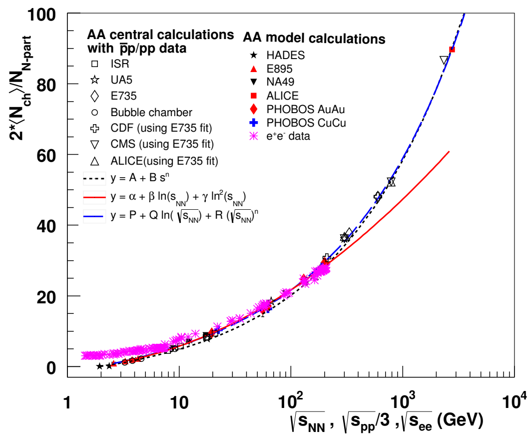

FIG. 1: The charged particle mean multiplicity per participant pair as a function of nucleon-nucleon center of mass energy, measured in most central nucleus-nucleus collisions and calculated from $\bar{p}p/pp$ data using Eq (2). The e^+e^- data and different types of fits to the nuclear data are also shown.

Analysis

The charged particle mean multiplicity per participant pair, $N_{ch}/(N_{part}/2)$ measured in most central nucleus-nucleus collisions are shown in Figure 1 as a function of $\sqrt{s_{NN}}$ versus those

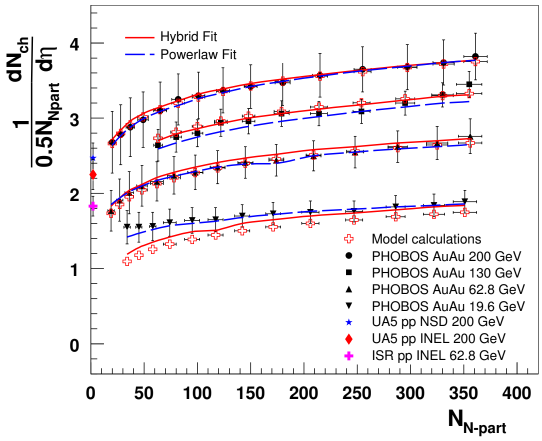

FIG. 2: Charged particle pseudorapidity density for Au+Au collisions as a function of collision centrality measured at RHIC and and calculated from the model based on constituent quark picture and Landau hydrodynamics at $\sqrt{s_{NN}}$ as indicated. The lines show energy-dissipation calculations based on the fits to energy dependence of the charged-particle midrapidity 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 $N_{ch}/(N_{part}/2)$ 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 GeV the e^+e^- measurements exceed those from the nucleus-nucleus data, but for $\sqrt{s_{ee}} > 10$ 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 $\sqrt{s_{pp}}/3 \simeq \sqrt{s_{NN}} \simeq \sqrt{s_{ee}}$.

The centrality dependence of pseudorapidity charged particle density per participant pair measured in AA collisions and calculated from $\bar{p}p/pp$ 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

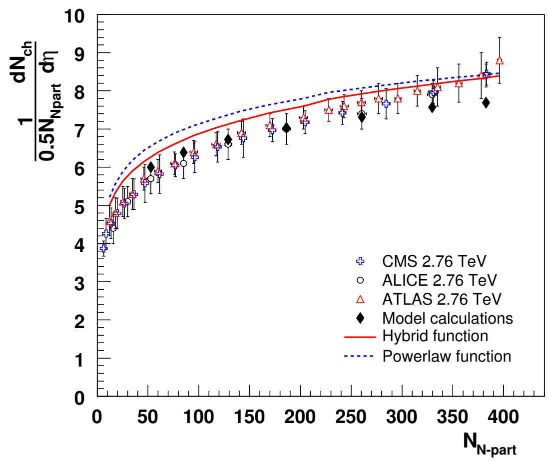

FIG. 3: Charged particle pseudorapidity density as a function of collision centrality measured in Pb+Pb collisions at the LHC and calculated in frames of the model based on constituent quark picture and Landau hydrodynamics for $\sqrt{s_{NN}} = 2.76$ TeV. The lines are the energy-dissipation calculations based on the fits to the energy dependence of the mid-rapidity densities in the most central nucleus-nucleus collisions.

power-law fit $N_{ch}^{pp} = 3.102 s_{pp}^{0.178}$[4] is used and N_{ch}^{AA} 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

[1] L. D. Landau, Izv. Akad. Nauk: Ser. Fiz. **17**, 51 (1953)

[2] E.K.G. Sarkisyan, A.S. Sakharov, Eur. Phys. J. C **70**, 533-541 (2010) and refs. therein

[3] Raghunath Sahoo, Aditya Nath Mishra, arXiv:1304.2113 [hep-ph]

[4] J.F. Grosse-Oetringhaus, K.Reygers, J. Phys. G **37**, 083001 (2010)