Constituent Quarks and Charge Particle Production in Heavy-Ion Collisions

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Introduction

Relativistic heavy-ion collisions aims at producing a state of matter which is governed by partonic degree of freedom. The pseudorapidity density of particle multiplicity and transverse energy are the key observables which provide the properties of matter produced in heavy-ion collisions. Study of their dependence on centrality and collision energy is of paramount importance to understand the particle production mechanism. This may provide insight into the partonic phase that might be created in nuclear collisions. Here, in a constituent quarks framework, we study charged particle and transverse energy production in heavy-ion collisions both as a function of centrality and collision energy, and hence we give a prediction for Pb+Pb collisions at $\sqrt{s_{NN}} = 5.5$ TeV at LHC.

The concept of constituent quarks is very well known [1, 2] and established in the realm of the discovery of constituent quark scaling of identified particles elliptic flow at RHIC [3]. To study the constituent quarks dependence of particle production, we have estimated the number of participant quarks in the framework of a nuclear overlap model [4]. At lower center of mass energies, it has been found that the particle production scales with the number of participating nucleons, contrary to the case of high energies where hard processes dominate. However, the number of binary collisions increase with increase in collision centrality faster than the number of participants. As a result, the particle production per participant nucleon increases with centrality. By using constituent quark approach, we are going to show how the particle production at higher energies depends on the participating quarks in heavy-ion collisions.

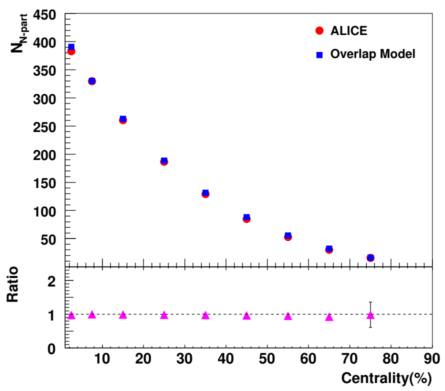

FIG. 1: Mean number of nucleon participants as a function of centrality in the overlap model (filled square) and from ALICE estimations (filled circles).The bottom panel shows the ratio of both.

Results and Discussion

In Figure 1, the mean number of participating nucleons are shown as a function of collision centrality. The lower panel of the figure, represents the ratio of ALICE values for Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV and the corresponding values estimated from overlap model. It is clear from the figure that the overlap model calculations are in good agreement with the ALICE calculations. After validating the overlap model for participant calculations, we calculate the number of constituent quarks participating in the collisions. In Figure 2, $\frac{dN_{ch}}{d\eta}$ normalized to both N_{N-part} and N_{q-part} is shown as a function of collision energy. Up to top RHIC energy N_{N-part}-normalized $\frac{dN_{ch}}{d\eta}$ is well described by logarithmic function given by Eq. 1. However, this fails to describe the ALICE data for 2.76 TeV. A power law function (dash-dotted line) given by Eq. 2, discribes both RHIC and LHC heavy-ion data but overestimate lower-energy measurements. Contrary, the collision cen-

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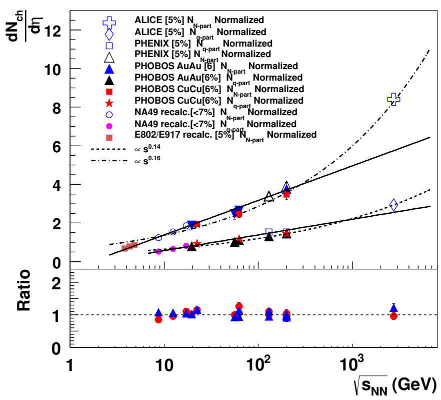

FIG. 2: Upper panel shows $0.5N_{N-part}$ and $0.5N_{q-part}$-normalized $\frac{dN_{ch}}{d\eta}$ as a function of $\sqrt{s_{NN}}$ and the lower panel shows the goodness of the fit of $0.5N_{q-part}$ normalized data (blue triangles for Eq. 1 and red circles for Eq. 2).

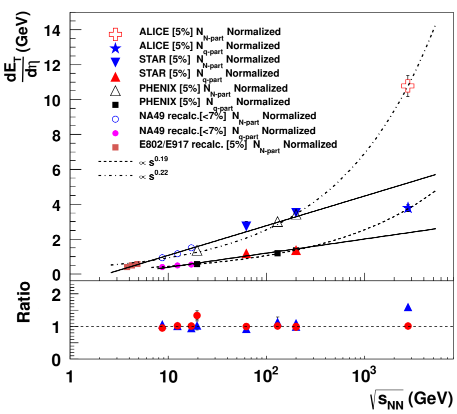

FIG. 3: Upper panel shows $0.5N_{N-part}$ and $0.5N_{q-part}$-normalized $\frac{dE_T}{d\eta}$ as a function of $\sqrt{s_{NN}}$ and the lower panel shows the goodness of the fit of $0.5N_{q-part}$ normalized data (blue triangles for Eq. 1 and red circle for Eq. 2).

ergy dependence of $\frac{dN_{ch}}{d\eta}$ normalized by N_{q-part} is very well described by logarithmic function for the whole range of energies under discussion. The lower panel of the figure shows that within errors, both logarithmic and power law functions describe the data equally well for the whole range of energies, when normalized to N_{q-part}. However, the power in the power law function, decreases from N_{N-part} to N_{q-part} normalization, thereby going towards a flatter behavior as a function of collision energy. The predicted value of $\frac{dN_{ch}}{d\eta}$ for Pb+Pb collisions at $\sqrt{s_{NN}} = 5.5$ TeV based on the extrapolation of power-law function fitted to N_{q-part} and N_{N-part}-normalization is around 1930 ± 128 and 1990 ± 122, respectively.

$$y = A + log\,\frac{\sqrt{s_{NN}}}{B} \tag{1}$$

$$y = C(s_{NN})^n \tag{2}$$

A similar analysis is done for $\frac{dE_T}{d\eta}$-normalized to N_{N-part} and N_{q-part} and is plotted as a function of collision energy, as is shown in Figure 3. We observe that power-law motivated functions better describe the transverse energy production with collision energy. The predicted value of $\frac{dE_T}{d\eta}$ for Pb+Pb collisions at $\sqrt{s_{NN}} = 5.5$ TeV based on the extrapolation of power-law function fitted to N_{q-part} and N_{N-part}-normalization is around 2645 ± 140 GeV and 2786 ± 124 GeV, respectively.

Conclusion

A systematic study of charge particle and transverse energy production with collision energy is done. It has been found that a power-law function describes particle production quite well. We give the predicted values of $\frac{dN_{ch}}{d\eta}$ and $\frac{dE_T}{d\eta}$ for Pb+Pb collisions at $\sqrt{s_{NN}} = 5.5$ TeV, in a constituent quark framework. A detailed analysis on centrality and collision energy dependence of particle production in a constituent quarks framework will be presented.

References

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