Exploring energy balance in multihadron production: from hadronic to nuclear collisions

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Introduction

Study of global observables of multiparticle production and their universality in different types of high-energy collisions is one of the most intriguing topics in high-energy interaction studies. Recently, the center of mass energy, $\sqrt{s_{NN}}$, dependence of the midrapidity pseudorapidity density and the transverse energy density in the midrapidity of charged particles measured in the head-on nucleus-nucleus collisions using the effective energy approach based on $pp/p\bar{p}$ data and the centrality dependence of these two variables within the dissipating participant energy approach have been demonstrated to be well described [**?**].

In the present work, the energy and centrality dependences are studied for the charged particle mean multiplicity, extending the earlier energy-dependence analysis done in Ref. [**?**] to LHC energies and adding to that the centrality dependence study. Within the approach, combining the constituent quark picture together with Landau relativistic hydrodynamics [**?**], one can calculate multiplicity, $N_{\rm ch}$, for a given rapidity density $\rho(0)$ at $\sqrt{s_{NN}}$, and the rapidity density $\rho_{pp}(0)$ and the multiplicity $N_{\rm ch}^{pp}$ at $3\sqrt{s_{NN}}$, as:

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

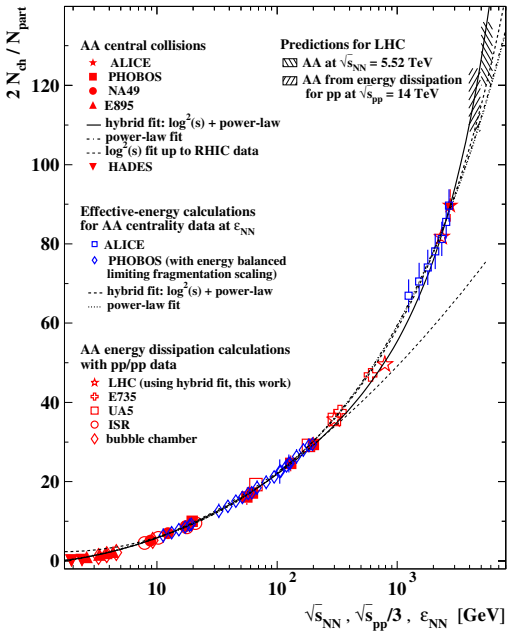

FIG. 1: Charged particle mean multiplicity per participant pair as a function of center of mass energy, $\sqrt{s_{NN}}$.

We introduce a new scaling, called the energy balanced limiting fragmentation scaling, which leads to the scaling between the measured pseudorapidity distribution and the distribution calculated within the dissipating participant energy approach using the effective-energy concept. Using this scaling, a complementarity of the multiplicities in head-on nuclear collisions and centrality data is obtained.

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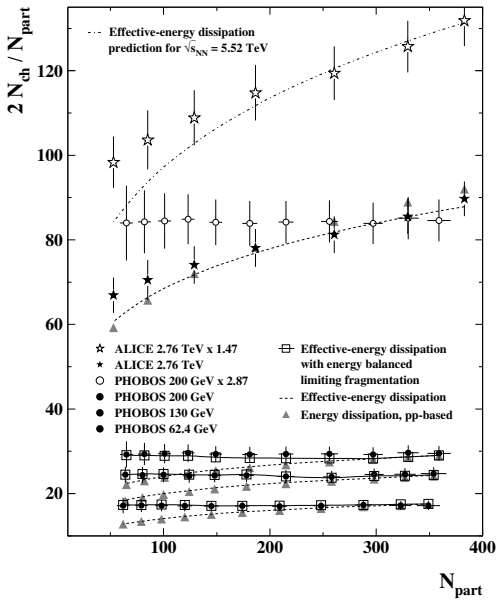

FIG. 2: Charged particle mean multiplicity per participant pair as a function of the number of participants, $N_{\rm part}$.

Result and Discussion

Figure **??** shows the c.m. energy dependence of the multiplicity measured in head-on nucleus-nucleus collisions in the energy range of $\sqrt{s_{NN}}$ = 2 GeV to 2.76 TeV. We fit the head-on data by the "hybrid" function [**?**], which shows a good agreement with data. One can see that the power-law fit well describes the data and is almost indistinguishable from the hybrid fit upto the LHC data. Some minor deviation between the two fits can be seen in the range from the top RHIC energy to the LHC energy. Meanwhile, the 2nd-order logplynomial fit lies below at $\sqrt{s_{NN}} > 200$ GeV. This observation supports a possible transition to a new regime in high energy heavy-ion collisions at $\sqrt{s_{NN}}$ at about 1 TeV, as also indicated [**?**] in the studies of midrapidity pseudorapidity particle and transverse energy densities. We also show that the mean multiplicity per participant-pair, calculated from Eq. **??** for nucleus-nucleus interactions using the $pp/p\bar{p}$ measurements follow the nuclear measurements for the entire available collision energy range. The RHIC centrality data, after removing the energy balanced limiting fragmentation scaling ingredient, shows energy dependent behaviour similar to head-on data measurements as soon as the centrality data are considered in terms of the effective energy. Fig. **??** shows charged particle mean multiplicity per participant pair, $N_{\rm ch}/(N_{\rm part}/2)$ as a function of the number of participants, $N_{\rm part}$. The dotted lines represent the effective-energy approach calculations based on the hybrid fit to the c.m. energy dependence of the midrapidity density in the most central heavy-ion collisions shown in Fig. **??**. One can see that the calculations, which are driven by the centrality-defined effective c.m. energy ϵ_{NN}, well reproduce the LHC data except slightly underestimating a couple of the most peripheral measurements. However, for the RHIC data, there is a significant difference between the calculations and the measurements. This difference in data and calculation is explained by a new effective energy calculation including the energy balanced limiting fragmentation scaling.

Energy balanced limiting fragmentation scaling provides a solution of the RHIC "puzzle" of the difference between the centrality independence of the mean multiplicity vs. the monotonic decrease of the midrapidity pseudorapidity density with the increase of centrality (more details can be found in Ref. [**?**]). The mean multiplicity is shown to get a fraction of additional contribution to account for the balance between the collision c.m. energy shared by all nucleons and the effective energy of the participants. Meantime, the midrapidity pseudorapidity density is fully defined by the effective energy of colliding participants.

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