Revisiting Limiting Fragmentation in Heavy Ion Collisions at the LHC

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Introduction

Understanding the particle productions mechanism in high energy nuclear collisions have always been fascinating. During the late 1960s, the hypothesis of limiting fragmentation became important to understand the particle production [1]. According to this hypothesis the produced particles, in the rest frame of one of the projectile become independent of centre of mass energies, thus following a possible scaling (as a function of $\eta' = \eta \pm y_{\rm beam}$), known as limiting fragmentation (LF). As (pseudo)rapidity is a longitudinal variable it is also called longitudinal scaling. Here $y_{\rm beam} = \ln(\sqrt{s_{\rm NN}}/m_{\rm p})$, is beam rapidity and $m_{\rm p}$ is the mass of proton.

The cross-section plays an important role in fragmentation regions [2] and the LF phenomenon is observed in the differential cross-section per unit pseudorapidity in proton+nucleus collisions at RHIC energies [3]. As the particle production in heavy-ion collisions depends on the hadronic cross-section, longitudinal variables are expected to be sensitive to the available energy and the multiplicity of the produced secondaries. Also, total hadronic cross-section is not a constant from lower RHIC energy to highest LHC energy but is a slowly increasing function of $\sqrt{s}$ [4]. Thus, the study of possible longitudinal scaling of the final state multiplicity as a function of collision energy becomes important, in view of increasing inelastic particle production cross-sections at LHC energies. In this work, we revisit the phenomenon of limiting fragmentation for nucleus-nucleus (A+A) collisions taking into account, the effect of increasing inelastic particle production cross-sections from $\sqrt{s_{\rm NN}}$ = 19.6 GeV −5.02 TeV.

Limiting Fragmentation study at LHC

We studied the limiting fragmentation phenomenon in the experimental data of $dN_{\rm ch}^{\rm AA}/d\eta$ from $\sqrt{s_{\rm NN}}$ = 19.6 GeV to 2.76 TeV and as shown in Fig. 1, it is observed to be violated at $\sqrt{s_{\rm NN}}$ = 5.02 TeV. Here, the double Gaussian function was used to extrapolate the experimental data in the fragmentation region. To study the effect of increasing inelastic particle production cross-sections from RHIC to LHC energies, we use energy dependent $\sigma_{\rm in}$ to transform the charged particle pseudorapidity distributions ($dN_{ch}^{\rm AA}/d\eta$) into differential cross-section per unit pseudorapidity ($d\sigma^{\rm AA}/d\eta$) of charged particles, given as

$$\frac{d\sigma^{\rm AA}}{d\eta} = \frac{{\rm A}^2\sigma_{\rm in}\left(\frac{dN_{\rm ch}^{\rm AA}}{d\eta}\right)}{\left((1-x)\frac{<N_{\rm part}>}{2} + x < N_{\rm coll} >\right)}. \quad (1)$$

Now, we evaluate $d\sigma^{\rm AA}/d\eta$ using Eq. 1 for $\sqrt{s_{\rm NN}}$ = 19.6 to 5.02 TeV using x parameters from Ref. [5], which is almost energy independent from RHIC to LHC energies. The Monte Carlo Glauber model is used to calculate number of participants ($N_{\rm part}$) and number of binary collisions ($N_{\rm coll}$) at different energies. The differential cross-section per unit pseudorapidity for various center-of-mass energies starting from $\sqrt{s_{\rm NN}}$ = 19.6 to 5.02 TeV are shown in Fig. 2 with respect to $\eta - y_{\rm beam}$. We notice that the limiting fragmentation hy-

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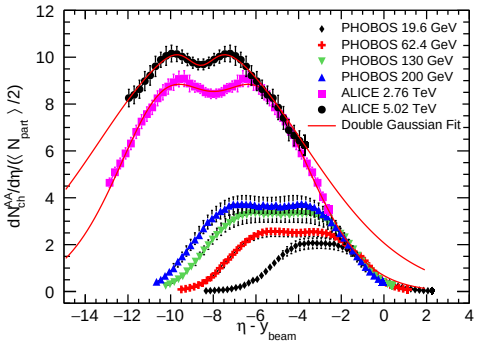

FIG. 1: The number of participant pair normalized pseudorapidity distribution of charged particles ($dN_{\rm ch}^{\rm AA}/d\eta$) in heavy-ion collisions versus $\eta - y_{\rm beam}$ for various energies.

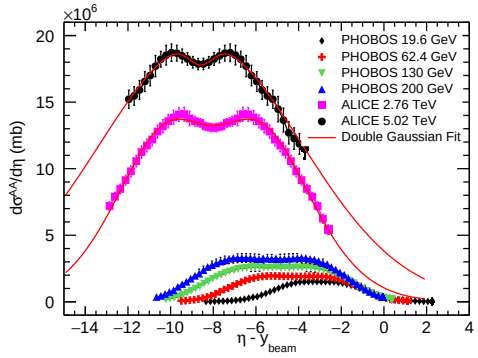

FIG. 2: The differential cross-section per unit pseudorapidity ($d\sigma^{\rm AA}/d\eta$) as a function of $\eta - y_{\rm beam}$ for various collision energies. The symbols are experimental points and the lines are double Gaussian fits.

pothesis appears to be violated at LHC energies, *i.e.* at $\sqrt{s_{\rm NN}}$ = 2.76 and 5.02 TeV. We also perform the similar exercise with AMPT model in string melting scenario. We convert the $dN_{\rm ch}^{\rm AA}/d\eta$ obtained from AMPT into $d\sigma^{\rm AA}/d\eta$ using Eq. 1. In Fig. 3, $d\sigma^{\rm AA}/d\eta$ versus $\eta - y_{\rm beam}$ is shown to check longitudinal scaling for $\sqrt{s_{\rm NN}}$ = 19.6 GeV to 5.02 TeV. This shows a similar behaviour as in the experimental data i.e. LF is observed up to RHIC energies and seems to be violated for LHC energies. The details of this work can be found

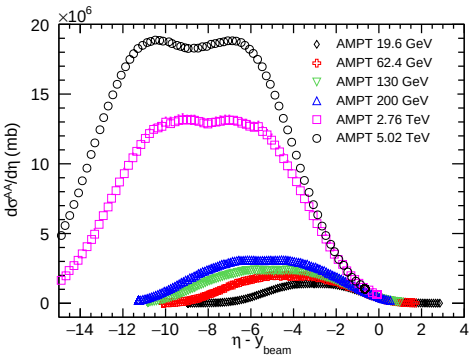

FIG. 3: $d\sigma^{\rm AA}/d\eta$ versus $\eta - y_{\rm beam}$ for AMPT model.

in Ref. [6]. Theses findings are very important while discussing the longitudinal scaling hypothesis at LHC energies.

Summary

We found that when $dN_{\rm ch}^{\rm AA}/d\eta$ is transformed to $d\sigma^{\rm AA}/d\eta$ the LF hypothesis seems to be violated at both LHC energies i.e. $\sqrt{s_{\rm NN}}$ = 2.76 and 5.02 TeV, if one considers the energy dependent inelastic cross-section. Our similar studies using AMPT model, also shows a possible violation of limiting fragmentation phenomenon for $d\sigma^{\rm AA}/d\eta$ at LHC energies. We find that LF works fine, when the hadronic cross-section is assumed to be almost independent of energy, and the violation is observed at LHC energies while using the energy dependent cross-section.

References

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