Forward backward multiplicity correlation at energy range from NICA up to LHC *

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Forward-backward multiplicity correlation is presented from NICA project to LHC energies. We present a study of the correlations splitting into soft and hard QCD processes. Harder processes produce lower strength of the correlation than soft ones at central pseudorapidity, but both kind of processes increase with the wide of pseudorapidity. The correlation produced with hadrons from hard $gg \to gg$ and $qq \to qq$ QCD process are presented.

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1. Introduction

Multiplicity distribution is one of the most useful variables to measure the global properties of the events, and it is also possible to extract physical information through it. Forward-backward multiplicity correlation has been measured in the experiment at different energies [1]. Theoretical models, like Dual Parton Model (DPM) and Color Glass Condensate (CGC) have predictions of this correlation. Dual Parton Model is useful to explain the interaction between partons through the color strings, which represent the color field interaction between partons. This model has been used successfully to describe for instance particle scattering in terms of string/chains in the DPM. In this model, short-range forward-backward multiplicity correlations arise from particles created in the same partonic collision, while the long-range correlation is originated from the fluctuation in the number of partonic collisions and unitary constraints [2]. Furthermore, DPM predicts that long-range correlations will grow with system size and energy.
Color glass condensate can be used to describe the system inmediately before a heavy-ion collision occurs. In this picture, the nuclei are sheets of color because of the relativistic Lorentz length contraction and their color

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charge degree of freedom. The system is described as a condensate due to the high density of gluons, which makes the QCD coupling constant small. CGC has been used to explain long-range forward-backward rapidity correlations due to fluctuations in the number of gluons at early stages [3]. The long-range correlation strength is predicted to be smaller for baryons than for pions. However, at high p_{T} the measured correlation for inclusive charged hadrons may not have such large correlations for central collisions as contributions from baryons at higher p_{T}.

Color reconnection (CR) has been examined by several models over the last years. New models were incorporated to study uncertainties in the top quark mass measurements and study the effect of CR on its decays [4]. Modelling and testing the CR in hadronic collisions is slightly more complicated. However, the estimation of the average transverse momentum with the increasing charged multiplicity plays an important role.
The Future Circular Collider (FCC) which should be a W's factory includes the research on CR hadronization mechanism, as well as Higgs boson properties and many other related topics, as has been discussed in Ref. [5]. Consequently, hadron production throught color reconnection should be of interest to study on different colliding systems.
Research on multiple parton interactions has gained more interest given that its development [6] helps to understand the non-perturbative QCD processes and could also be related to physics at the LHC energies.
Of course, the average n_{MPI} and CR are multiplicity-dependent and the first one seems to saturate according to the previous calculation [7], increasing for long-range pseudorapidity region compared to central ones, meanwhile, the second one increase produce a decrease of the strength of the correlation as was reported [8].
Here we present a study of forward-backward multiplicity correlation splitting the QCD processes into soft and hard. The hardness of the processes was modulated by the minimum transfer momentum between interacting partons ($p_{T,HatMin}$), the main variable to the present results. The calculations were done using PYTHIA 8.2 event generator.

2. Multiplicity correlations from $gg \to gg$ versus $qq \to qq$

Multiplicity fluctuation show a $\mathrm{F}-\mathrm{B}$ multiplicity correlations defined by

$$b_{Corr}(\delta\eta) = \frac{\langle \mathrm{n_F n_B} \rangle - \langle \mathrm{n_F} \rangle \langle \mathrm{n_B} \rangle}{\langle \mathrm{n_F^2} \rangle - \langle \mathrm{n_F} \rangle^2}, \tag{1}$$

where n_F and n_B are the charged particle multiplicity in two symmetric windows of pseudorapidity ($\delta\eta$), separated by a central pseudorapidity gap,

η_{gap}.
Using Eq. 1, the forward-backward multiplicity correlations are computed and analyzed with the results described below. The increases of collision energy produce higher multiplicity and consequently an enhancement of the forward-backward multiplicity correlation. Fig. 1 a) illustrate b_{Corr} for computed for energy plans of NICA complex accelerator up to LHC. In the same plot is show for comparison experimental data from ALICE [1] at two energies. Weak correlation is observed for lower energy. The Fig. 1 b), upper right shows the strength of the correlations when hadrons are produced by $gg \to gg$ processes with three degrees of hardness given by the transferred transverse momentum between the interacting partons ($p_{T,HatMin}$). The strength of the correlation grows but it seems to saturate for harder processes. Almost the same behavior is observed for the case of hadrons produced by $qq \to qq$, showed in Fig. 1 c). The small discrepancy between both kind processes are explained due to the fact that $gg \to gg$ cross section is larger compared to those obtained in $qq \to qq$, consequently one expects higher multiplicity in the first case and therefore b_{Corr} will increase for this kind of processes. The ratio between correlation from quarks to those coming from gluons are shown in Fig. 1d) and allow to quantify the results. It is interesting to observe in the ratio the crossing point at $\delta\eta$ =0.4, for these energies.

3. Conclusions

Forward-Backward multiplicity correlations have been presented for the energy range from NICA complex accelerator plans up to LHC. The outcomes revealed a clear enhancement of the correlations when the collision energy increase for analyzed data in the central pseudorapidity region as DPM predicts. Our results of forward-backward multiplicity correlations for hard processes present a stronger correlation for hadrons produced by $gg \to gg$ than $gg \to gg$ dispersion. Furthermore, the ratio between correlations strength shows a clear change on the slope which is independent on the hardness of the event, illustrated by a cross point around $\delta\eta \approx 0.4$, meaning that the partonic processes encode and essential information on the boundary between perturbative and non-perturbative physics.

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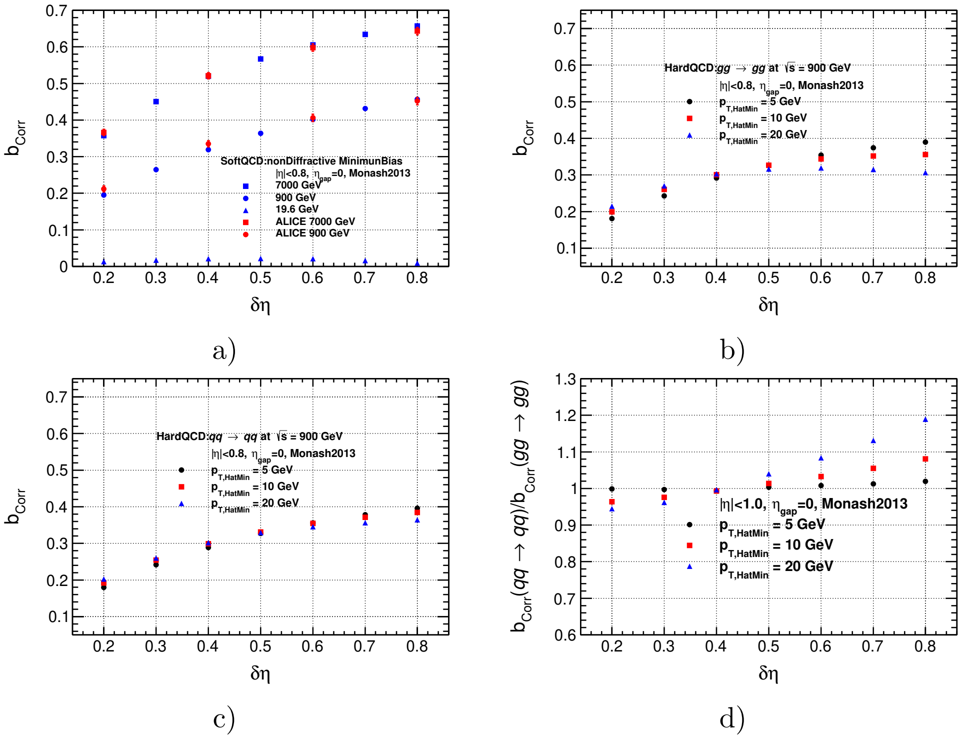

Fig. 1. $b_{\rm Corr}$ for soft QCD processes at different energies compared to data (a). Correlations are computed considering hard p+p collisions at $\sqrt{s} = 900$ for different degree of hardness given by transfer transverse momentum, 5, 10, 20 GeV/c. Correlation for $gg \to gg$ processes (b) and $qq \to qq$ (c), while the ratio between both are showed in (d).

REFERENCES

[1] ALICE Collaboration, Jaroslav Adam, et al., JHEP 2015 097 (2015)

[2] A. Capella and A. Krzywicki, Phys. Rev. D 18, 4120 (1978).

[3] Y. Kovchegov, E. Levin and L. McLerran, Phys. Rev. C 63 024903 (2001).

[4] S. Argyropoulos and T. Sj strand, JHEP 1411, 043 (2014)

[5] Nelli Pukhaeva: EPJ web of conferences 204, 05013 (2019)

[6] T. Sjostran, The Development of MPI Modelling in PYTHIA. arXiv:1706.02166 [hep-ph]

[7] Cuautle, E. Ortiz, A. Paic, G, Nucl. Phys. A 956, 749 (2016).

[8] Cuautle, E., Dominguez, E. and Maldonado, I. Eur. Phys. J. C 79, 626 (2019).