Forward-backward correlations in proton-proton collisions

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Abstract. The correlation multiplicity in forward-backward pseudorapidity is really important for the overall event characterization and to extract information on non-pertubative hadronic processes. In this work we present a study of the correlation conditions at LHC. Subsequently, the study is extended using p+p simulations of events to different energies, the correlations in multiplicity are studied with different initial conditions of the events in order to show how it is related to the mechanisms of hadronization, as well as concerning multiple partonic interactions, and consequently the degree of hardness of the collision. The sensitivity to the QCD color reconnection strength is reported.

1. Introduction
Forward-backward (F-B) correlations are quantified by the strength of the factor, \( b_{\text{corr}} \), which is the slope obtained from the relationship between the average multiplicity measured in the forward rapidity \( \langle n_B \rangle_{\text{nf}} \) and the multiplicity in the forward rapidity hemisphere, \( n_F \). this relationship can be expressed as\[1\]:
\[
\langle n_B \rangle_{\text{nf}} = a + b_{\text{corr}} \cdot n_F. \tag{1}
\]
This linear relation has been observed\[2\] in ALICE experiment. An alternative definition of the correlation coefficient is possible through the direct calculations of the corresponding correlation factor \[3\]:
\[
b_{\text{corr}} = \frac{\langle n_B n_F \rangle - \langle n_B \rangle \langle n_F \rangle}{\langle n_F^2 \rangle - \langle n_F \rangle^2}. \tag{2}
\]
This correlation factor has been studied in a variety of collisions systems, from the simplest to the most complicated, and what is certain is that at higher collision energy of the center of mass, larger strength is obtained for these correlations, then it is interesting to investigate the meaning of this multiplicity F-B correlations\[4\] using other like long-range multiplicity correlations\[5\]. One of the recent results to incorporate flow-like effects in p+p \[6\] using the so called Color reconnection (CR) among partons in the final state can produce important effects to this correlation factor.
2. Results

The pseudorapidity values to extract $n_F$ and $n_b$ are shown on figure 1. The simulation data were Minimum Bias (MB) generated with PYTHIA 8.186 [7] tune Monash 2013 [4] at different energies: 0.9, 2.76 and 7 TeV, which allows us to compare with ALICE data [2]. The correlation factors have been calculated in the $|\eta| < 0.9$ and in the momentum range $0.3 \text{ GeV}/c \leq p_T \leq 1.5 \text{ GeV}/c$.

Variables used to estimate the correlation factor are: the window size is $\delta\eta$, in which the particles were counted, both in front and behind; $\eta_{\text{gap}}$ is the separation between $\delta\eta$ in front and behind, i.e., the distance between the windows.

**Figure 1.** Sketch of the pseudorapidity variables used for the present simulations.

**Figure 2.** (Color online) Correlation factor for two different energies comparing ALICE data with the PYTHIA Monash 2013 generator in function of the width of the window $\delta\eta$, with $\eta_{\text{gap}} = 0$. 

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Figure 3. (Color Online) Correlation factor as function of $\eta_{\text{gap}}$ for $\delta\eta = 0.2$. The results show the behavior for two different energies, comparing PYTHIA to ALICE data[2].

Figure 4. (Color online) Correlation factor as function of $\delta\eta$ for p+p at 7 TeV with PYTHIA Monash 2013, comparing model with three different ranges of color reconnection and with ALICE data.

Figure 2 shows how the F-B correlation factor increases as function of $\delta\eta$, and the collision energy. One can observe a complete agreement between ALICE data[2] and PYTHIA event generator.

The figure 3 shows the behavior of $b_{\text{corr}}$ with respect to $\eta_{\text{gap}}$ keeping $\delta\eta$ fixed to 0.2, it shows a downward trend, which is expected because we are changing the analyzed windows, from higher to lower number of particles to compute the correlations. Again a very good description with the existing data is observed.
Finally we wanted to investigate whether the color reconnection [6] model explains the observed correlations. In the figure 4 we present the results of the simulation with three different values of the color reconnection strength. Indeed one observes a very strong dependence of the correlation factor with the reconnection strength. With the extreme value of 10 for the CR one observes a much lower correlation factor at 7 TeV and with a value zero one undershoots the data. The default value of 1.8 for CR seems to reproduce well the data.

3. Conclusion
We have compared simulations with an up to date generator to the published FB correlations. The excellent agreement has led us to study the details of the influence of an important ingredient of the generator use i.e the color reconnection.
The present work links, to our knowledge, for the first time explicitly the QCD process of color reconnection in a very obvious manner indicating an interesting alley of investigation. It also suggests that FB correlations can be used to determine the intensity of the CR strength.

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