Color reconnection: a fundamental ingredient of the hadronisation in p-p collisions

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Color reconnection: a fundamental ingredient of the hadronisation in p-p collisions

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Abstract. At the LHC very interesting similarities among different colliding systems (p-p, p-Pb and Pb-Pb) where observed in the multiplicity evolution of the transverse momentum spectra. This has prompted a number of analyses that have explained the results in terms of collective hydrodynamic flow. The explanation in terms of hydrodynamics has recognized problems with the smallness of the interaction volume in the systems created in p-p and p-Pb collisions. On the other hand, some event generators based on QCD produce a reasonable qualitative, and sometimes quantitative, agreement with the data. Those results can be achieved introducing in the hadronisation model the so-called color reconnection which produces flow-like patterns via boosted strings. In this work we present the behavior of the various color reconnection (CR) schemes compared to those without the CR case for different center-of-mass energies at the LHC (0.9, 7 and 13 TeV).

1. Introduction

Heavy-ion collisions at ultra-relativistic energies are used to study the matter at high energy density, where the formation of a strongly-coupled Quark-Gluon-Plasma (sQGP) has been established. The discovery at the LHC is that in small systems, like those created in p-p and p-Pb collisions, collective features have been found [1]. It has been shown that the QCD based color reconnection may induce collective-like effects. In this work we demonstrate the influence of different CR models on the observed transverse momentum spectra.

There is evidence that in p-p collisions multiple partonic interactions (MPI) may occur within the same collision[2]. The partons belonging to two different MPI can be reconnected by color strings and merged into one in such a way that the total string length becomes as short as possible.

There are three different CR models included in PYTHIA 8.210 [3]

- **MPI-based model:** The partons of a lower-p_T MPI system are merged with the ones in a higher-p_T MPI.
- **New scheme:** The QCD color rules are used to determine the reconnection probability.
- **Gluon motion:** Partons can be moved from one location to another so as to reduce the total string length.

These models are used to generate the transverse momentum spectra to compare the collective-like effects previously studied[5].

2. Results and discussion

For this analysis 100 million events were generated for each simulation(three CR models plus the no CR case) of inelastic p-p collisions at $\sqrt{s} = 0.9$, 7 and 13 TeV. For the particle selection we only take the charged particles within $|\eta| < 0.8$, removing products of weak decays. All the PYTHIA parameters were set to Monash Tune[4], except for the CR model.

In figure 1 we show the multiplicity distributions for different energies and different CR models. There are little differences between the three CR models if we look at the same $\sqrt{s}$ but there are notorious differences from the no CR case, it increase as the energy do. This behaviour is explained in the way that with CR we have the merging of different MPI's and this reconnection produces lesser number of particles[6].

After the low multiplicity part dominated by diffractive events we observes a clear indication of the increasing importance of the high multiplicity events in the total multiplicity.

To quantify the different CR models we define multiplicity classes $z = N_{ch}/\langle N_{ch}\rangle$ for the p_T spectra. In figure 2 the CR-to-noCR ratio as function of p_T is presented for two multiplicity classes for p-p collisions at $\sqrt{s} = 7$ TeV, the spectra used for the ratio are normalized to the number of events in each multiplicity region. We observe that the effects of CR are stronger for the high multiplicity events (right panel). The CR at high multiplicity depletes the low

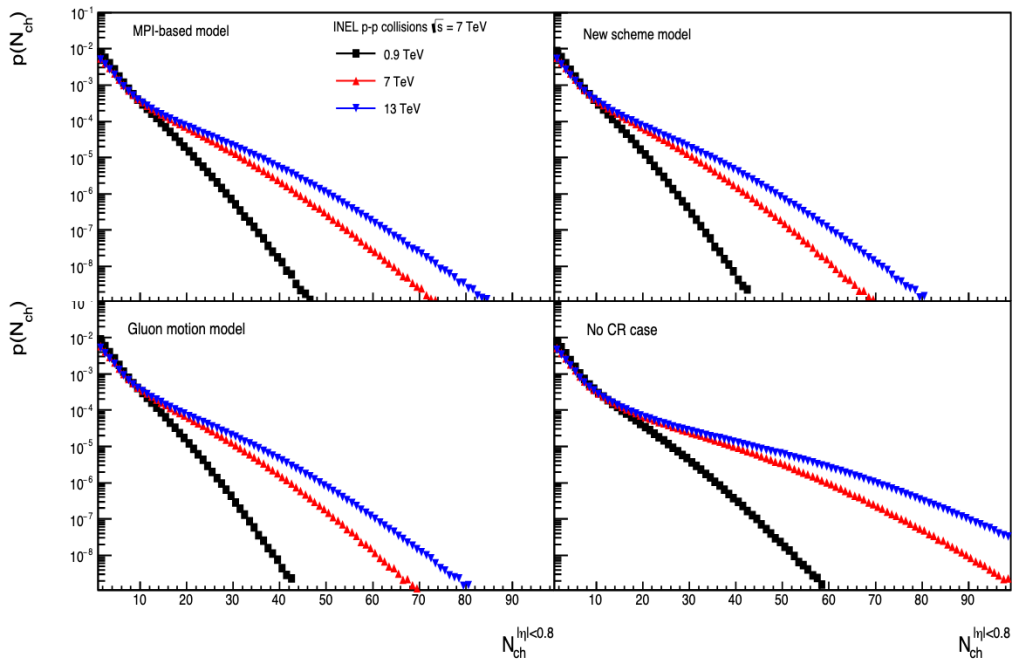

Figure 1. Multiplicity distributions for different energies and CR models: MPI-based (top left), new scheme (top right), gluon motion (bottom left) and without CR (bottom right).

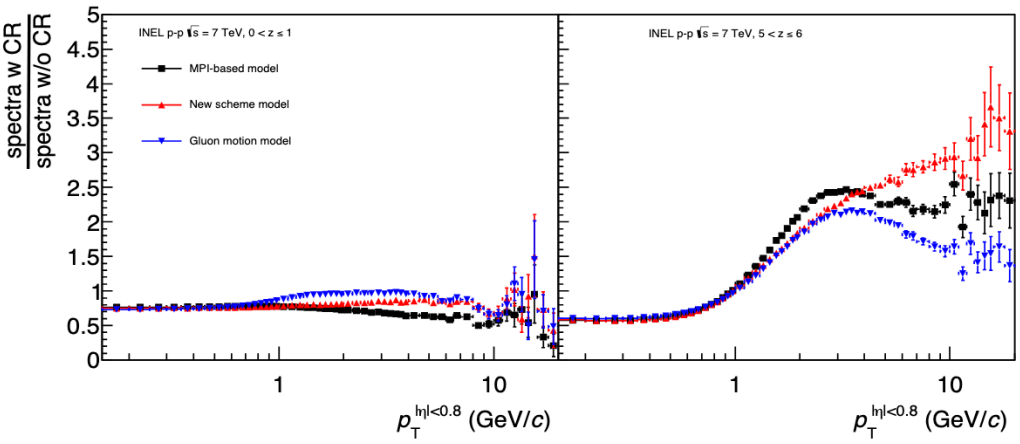

Figure 2. CR-to-noCR ratios of the inclusive p_T spectra for different CR models at $\sqrt{s} = 7$ TeV for low multiplicity class $0 < z \leq 0.5$ (left) and high multiplicity class $5 < z \leq 6$ (right).

momentum region and enhance the high momentum one. This ratio trends to a constant for the low multiplicity region (figure 2 left panel) and goes closer to one if we normalize the spectra for the ratios to the area instead of the number of particles[7], suggesting that there are no CR effects on events of low multiplicity (lower number of MPI's). The same trends is observed for other energies.

In figure 3 we show the p_T distribution of the particle with the largest p_T of the event (leading p_T), the spectra are normalized to the number of events in each multiplicity interval. The leading p_T distributions are presented for events with different multiplicities and different CR cases. We see that for high multiplicity events a shift of the maximum of the distribution at higher p_T values occurs for the CR case (MPI-based model) with respect to the no CR one, we see this shift too in the other two CR models (new scheme and gluons motion).

In table 1 we show the mean leading p_T values for three multiplicity intervals and for the CR MPI-based model compared to the no CR case in function of the center of mass energy. An increase with the multiplicity is observed, the effect is bigger with CR.

In figure 4 we show the CR-to-noCR ratio for the leading p_T spectra showed in figure 3.

	$\sqrt{s} = 0.9$ TeV		$\sqrt{s} = 7$ TeV		$\sqrt{s} = 13$ TeV	
z region	CR, MPI-based	No CR	CR, MPI-based	No CR	CR, MPI-based	No CR
$0 < z \leq 1$	0.71	0.71	0.85	0.85	0.89	0.90
$3 < z \leq 4$	1.81	1.53	2.73	2.19	3.00	2.39
$z > 5$	2.37	1.87	3.69	2.82	4.04	3.07

Table 1. Mean transverse momentum of the leading particle in z classes for different energies, comparison between CR MPI-based model and no CR.

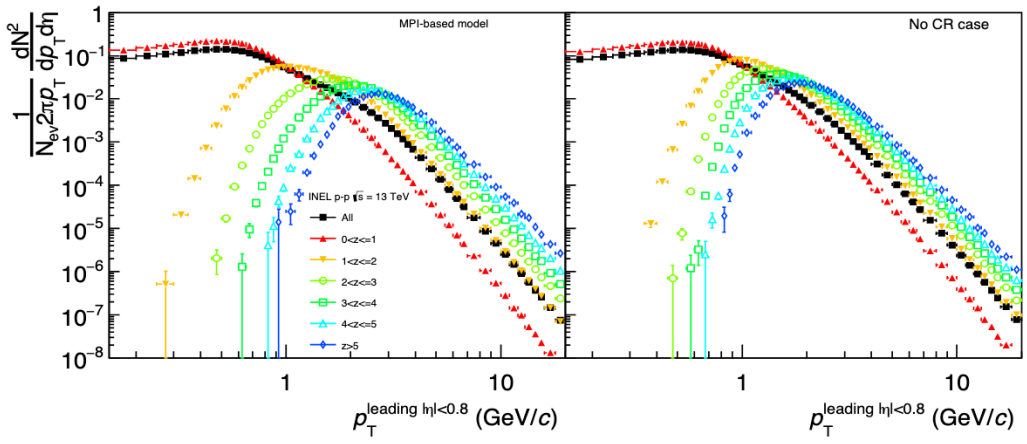

Figure 3. p_T leading distribution for different multiplicity classes at $\sqrt{s} = 13$ TeV for CR MPI-based model (left) and no CR (right).

Again we see that also for the leading particles the effects of the CR are very small for the lowest multiplicity class, showed in in Fig.3 for the case $0 < z < 1$. For the high multiplicity classes the main difference with the inclusive case (shown in figure 2) are at low p_T values, this shift effect is more notorious in the leading case.

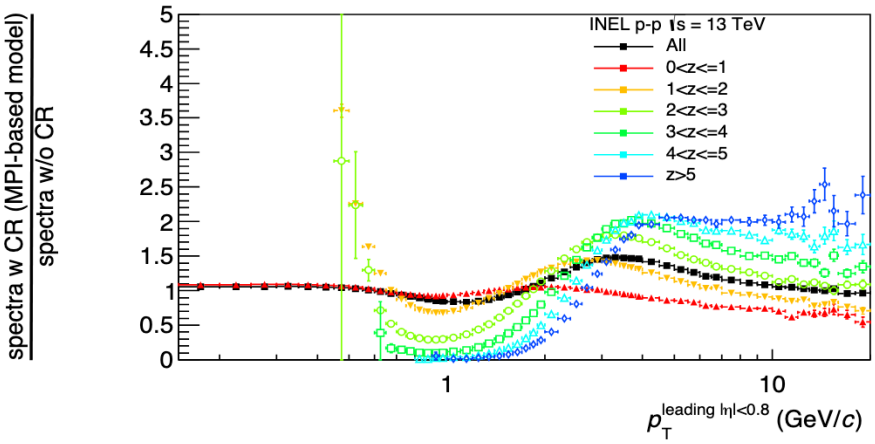

Figure 4. CR-to-noCR ratios of the leading p_T spectra in z classes for CR MPI-based model.

3. Conclusions

In the present work we demonstrated the effects of different color reconnection models to the p_T and leading p_T spectra in p-p collisions. The effects seems to have an increasing impact up to rather high momenta simulated in the present work increasing with the multiplicity of events. At very low multiplicity, events with less than half the mean multiplicity the effect of color reconnection is very weak, suggesting that the behaviour of the reconnection in experiments could be studied with respect to the lowest multiplicity region.

Acknowledgments

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