Jet effects in high-multiplicity pp events

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1 Introduction

The study of the high-multiplicity pp events has become important because we need to understand the origin of the fluid-like features which have been found in such small systems \cite{1-4}.

In this work we concentrate on the radial flow signatures, which not only hydrodynamical models can explain. Namely, the effect has been also found in \textsc{Pythia} \cite{5} and it is attributed to multi-parton interactions (MPI) and color reconnection (CR) via boosted color strings \cite{6}. For high-multiplicity events, the blast-wave parametrization, a hydro inspired model, has been found to fit very well the transverse momentum ($p_T$) spectra of different particle species \cite{7}. Although, the quality of the fits become worse for low-multiplicity events, we see that the parameter related to the average transverse expansion velocity ($\langle \beta_T \rangle$) increases with increasing multiplicity. This effect is qualitatively similar to what has been seen at the LHC \cite{8}.

In \textsc{Pythia}, color reconnection was originally introduced in order to explain the rise of the average $p_T$ with the event multiplicity. In short, the model allows the interaction among the partons which originate from MPI and initial-/final-state radiation. There are different implementations, e.g., the default MPI-based model of \textsc{Pythia}8.212 introduces a probability which is the largest for a low-$p_T$ system to be reconnected with one of a harder $p_T$ scale. And the interaction between two systems of high-$p_T$ scales is not allowed. Such a soft-hard interaction also suggests that jets may play a role in the observed radial flow-like patterns as highlighted in \cite{7,9}.

In this work, the role of jets in high-multiplicity pp collisions is investigated using \textsc{Pythia} 8.212. The inclusive $p_T$ spectra of identified particles are studied for events with and without jets, where the jets are reconstructed using the anti-$k_T$ algorithm implemented in FastJet \cite{10}.
2 Results

Proton-proton collisions at $\sqrt{s} = 7$ TeV were simulated with Pythia8.212 using the tune Monash 2013 [11]. Events were classified according with their event multiplicity ($N_{ch}$) and leading jet $p_T$ ($p_T^{\text{jet}}$). All the observables were calculated counting particles within $|\eta|<1$. For the jet finder only detectable particles (including charged and neutral particles) are considered within cone radius of 0.4, while for the $p_T$ spectra and event multiplicity only charged particles are taken into account.

To investigate on the radial flow-like effects in jets we first study the proton-to-pion ratio in low-multiplicity events and as a function of $p_T^{\text{jet}}$ (see Fig. 1). It is worth noticing that events without jets dominate for momenta below 2 GeV/$c$, while at larger momenta, jets start playing a more important role. In addition, a bump at intermediate $p_T$ is observed in all the event classes. The $p_T$, where the peak emerges, increases with increasing $p_T^{\text{jet}}$. This structure resembles one observed in the different colliding systems at the LHC [1, 12] and which sometimes is referred as a “flow peak” [6]. This effect is the same in events generated with and without color reconnection.

The blast-wave analysis of the $p_T$ spectra has been performed using the same particle species and $p_T$ intervals described in [7]. Figure 2 shows that the hydro model can describe the Pythia $p_T$ spectra when jets with momentum above 5 GeV/$c$ are part of the event. Actually, a $\langle \beta_T \rangle$ of $\approx 0.5$ can be achieved when the jet $p_T$ is larger than 20 GeV/$c$. Contrarily, the model does not describe the spectra in events without jets. This result is consistent with the spherocity analysis reported in [7], where it was argued that the fast parent parton being a boosted system can mimic radial flow too. The same analysis was also implemented for high-multiplicity events, in that case, thanks to color reconnection, the quality of the fit improves in events without jets, however a small $\langle \beta_T \rangle$ ($\approx 0.37$) is obtained and it increases up to $\approx 0.51$ when a high-$p_T$ jet is identified in the

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1 Events without jets are those where the jet finder can not reconstruct one with $p_T^{\text{jet}} > 5$ GeV/$c$.
Figure 2: (Color online). Leading jet $p_T$ dependence of the transverse momentum spectra for low (top) and high (bottom) multiplicity pp collisions at $\sqrt{s} = 7$ TeV. The blast-wave parametrization is shown with solid lines.
event. Actually, when a high-\(p_T\) jet was required, a very weak multiplicity dependence of \(\langle \beta_T \rangle\) is observed.

3 Summary
In summary, we have studied the role of jets in the radial flow-like features of PYTHIA. We have found that even in low-multiplicity events the blast-wave model is able to describe the \(p_T\) spectra of different particle species only when jets are part of the event. At high-multiplicity, \(\langle \beta_T \rangle\) can be very small in events without jets (\(\approx 0.37\)). The interaction of jets with the soft component is therefore important to produce the observed effects in PYTHIA. This seems to be a promising tool which could be exploited by the experiments in order to understand better the LHC data.

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