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Jet transverse fragmentation momentum from h–h correlations in pp and p–Pb collisions

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Abstract

QCD color coherence phenomena, like angular ordering, can be studied by looking at jet fragmentation. As the jet is fragmenting, it is expected to go through two different phases. First, there is QCD branching that is calculable in perturbative QCD. Next, the produced partons hadronize in a non-perturbative way later in a hadronization process. The jet fragmentation can be studied using the method of two particle correlations. A useful observable is the jet transverse fragmentation momentum j_{T}, which describes the angular width of the jet. In this contribution, a differential study will be presented in which separate j_{T} components for branching and hadronization will be distinguished from the data measured by the ALICE experiment. The p_{Tt} dependence of the hadronization component $\sqrt{\left\langle j_{\mathrm{T}}^2 \right\rangle}$ is found to be rather flat, which is consistent with universal hadronization assumption. However, the branching component shows slightly rising trend in p_{Tt}. The $\sqrt{s}$ = 7 TeV pp and $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV p–Pb data give the same results within error bars, suggesting that this observable is not affected by cold nuclear matter effects in p–Pb collisions. The measured data will also be compared to the results obtained from PYTHIA8 simulations.

Keywords: jet, transverse, fragmentation, momentum, showering, branching, hadronization, QCD, ALICE, pp, p–Pb

1. Introduction

In this work we study the jet transverse fragmentation momentum j_{T}, which is defined as the transverse momentum component of the jet fragment with respect to the jet axis. An illustration of j_{T} is shown in Figure 1. This quantity can be connected to two particle correlations by requiring that the trigger particle is the particle with the highest transverse momentum in an event (leading particle) and that this transverse momentum is sufficiently high. In this case the trigger particle momentum vector approximates the jet axis. Identifying the associated particle as the jet fragment, $\vec{j}_{\mathrm{T}}$ becomes the transverse momentum component of the associated particle momentum $\vec{p}_{\mathrm{a}}$ with respect to the trigger particle momentum $\vec{p}_{\mathrm{t}}$. The length of the $\vec{j}_{\mathrm{T}}$ vector is

$$j_{\mathrm{T}} = \frac{|\vec{p}_{\mathrm{t}} \times \vec{p}_{\mathrm{a}}|}{|\vec{p}_{\mathrm{t}}|} \,. \quad (1)$$

In the analysis, the results are obtained as a function of the fragmentation variable $x_{\parallel}$. This is defined as the projection of the associated particle momentum to the trigger particle divided by the trigger particle momentum:

$$x_{\parallel} = \frac{\vec{p}_{\mathrm{t}} \cdot \vec{p}_{\mathrm{a}}}{\vec{p}_{\mathrm{t}}^{\,2}} \,. \quad (2)$$

Binning in $x_{\parallel}$ rather than p_{Ta} is chosen because $x_{\parallel}$ scales with the trigger p_{T}. We measure bins where the associated particles have similar momentum fraction relative to trigger.

Because $x_{\parallel}$ follows the jet axis by construction, it is intuitive to define the near side with respect to this axis rather than using only azimuthal angle difference. The associated particle is defined to be in the near side if it is in the same hemisphere as the trigger particle:

$$\vec{p}_{\mathrm{t}} \cdot \vec{p}_{\mathrm{a}} > 0 \,. \quad (3)$$

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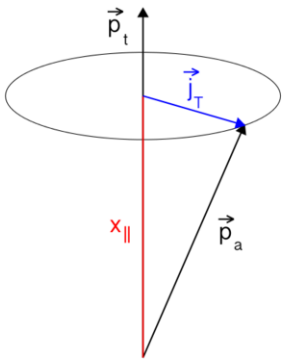

Figure 1: Illustration of $\vec{j}_T$ and $x_{\|}$. When the trigger particle is a high-p_T particle that approximates the jet axis sufficiently well, the $\vec{j}_T$ can be written as the transverse momentum component of the associated particle momentum $\vec{p}_a$ with respect to the trigger particle momentum $\vec{p}_t$. The fragmentation variable $x_{\|}$ is the projection of $\vec{p}_a$ to $\vec{p}_t$ divided by p_t.

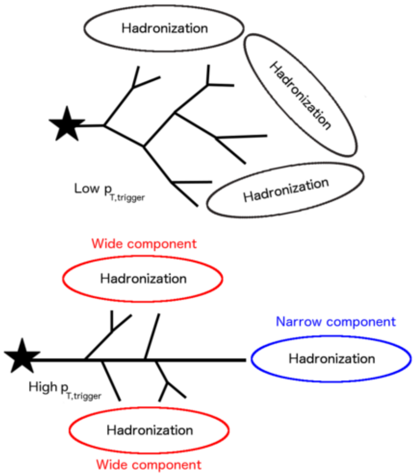

Figure 2: *Up:* If there is no high p_T particle in the event, the showering and hadronization components of jet fragmentation are folded together. *Down:* In the presence of a high p_T particle, the showering and hadronization components can be separated from the data.

Previously j_T has been measured for example by correlating the particles inside a jet cone with the reconstructed jet axis [1, 2, 3] or by calculating it from the azimuthal correlation function [4]. Only one component for j_T is extracted in these studies, describing the whole time evolution of the jet. In our study we want to be able to isolate different components for parton shower and hadronization. To do this, we follow a similar approach as is taken in PYTHIA [5]. In this model jet fragmentation consists of two phases, a perturbative showering phase where partons lose their virtuality by emitting gluons followed by a non-perturbative hadronization phase where the partons combine to hadrons.

Our working hypothesis is illustrated in Figure 2. If there are no sufficiently high p_T particles in an event, the showering and hadronization components are folded together, as illustrated by the upper half of the figure. But if we restrict ourselves to events with a high p_T leading particle, the folding is weaker and we are able to separate these two. Based on pQCD predictions like angular ordered parton cascades [6], we expect that the leading parton emits soft gluons preferably to rather wide angles. Also the leading parton is not much affected by this soft emission. On the other hand, based on Lund string model [5], we assume that the non-perturbative hadronization produces particles in relatively narrow angles with respect to the hadronizing parton. Thus, if the leading particle is a good approximation for the leading parton, the particles near the leading particle are mainly coming from the hadronization of the leading parton. As the showering produces partons to wide angles and their direction is not changed much by the hadronization, the orientation of the produced particles with respect to the trigger particle is mainly determined by the showering phase. A two component fit to the j_T distribution could allow us to separate the two phases.

To see if the separation of two components is justifiable, a PYTHIA8 study was conducted. In this study a two gluon initial state was created to get as clean dijet samples as possible. Then the final state particles were produced controlling the presence of the final state radiation. Without final state radiation, the final state particles come purely from the hadronization of the leading parton. When the final state radiation is allowed, the partons go through both showering and hadronization before becoming final state particles. The results of this study are presented in Figure 3. When the final state radiation is turned off, the component from hadronization appears as a narrow, Gaussian like distribution with a short tail. When the final state radiation is turned back on, a long tail appears after this peak. These observations support the idea behind the two component model.

2. Analysis methods

The analysis is done using $\sqrt{s}$ = 7 TeV pp ($3.0 \cdot 10^8$ events) and $\sqrt{s_{NN}}$ = 5.02 TeV p–Pb ($1.3 \cdot 10^8$ events) data recorded by the ALICE detector [7]. The tracks are measured by the Inner Tracking System (ITS) and the Time Projection Chamber (TPC). One out of six possible hits is required in ITS and 70/159 in TPC. The innermost layer of ITS ($|\eta| < 2$) and the V0 detector ($2.8 < \eta < 5.1$ and $-3.7 < \eta < -1.7$) are used for triggering. Charged tracks with $p_T > 0.3$ GeV/c in TPC acceptance ($|\eta| < 0.8$) are selected for the analysis.