

Determination of the effect of final state energy loss on the acoplanarity and momentum imbalance in jets

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The energy loss of partons leaving the hot media created in the heavy ion collisions has been at the center of the interest of the experimental and theoretical communities of the field. Hence an increase in the transverse momentum imbalance and acoplanarity of dijets may be a way to study the parton energy loss [1]. In order to study the effect, we have made simulations of dijet events where the intrinsic k_t of the partons, the initial and final state radiation are taken into account. The results of these simulations as a function of the center of mass energy of collision will be presented.

I. INTRODUCTION

Pairs of high- p_t partons are produced in hard scatterings in the initial state of nucleus-nucleus collisions. They undergo multiple interactions with the dense medium inside the collision region prior to fragmentation and hadronisation. In particular they loose energy through medium induced gluon radiation. The measurement of the energy loss has been proposed as a tool to characterize the properties of the QGP [1, 2].

Instead of being back-to-back in the transverse plane the partons are affected by additional transverse momentum contributions from the intrinsic k_t of the scattering partons and from NLO processes. In nucleus-nucleus collisions the interaction with the medium further increases the acoplanarity of the parton pair. The amount of additional transverse momentum of the di-jet system relative to the pp or pA baseline has been proposed as another possibility to measure the transport parameter \hat{q} [3].

The two components of the vector \vec{k}_t , $k_{T,x}$ and $k_{T,y}$, are Gaussian distributed and result in different experimentally measurable effects. $k_{T,y}$ leads to the acoplanarity of the di-jet pair while $k_{T,x}$ makes the momentum of the jets unequal [2].

Acoplanarity (p_{out}) is defined as the average transverse momentum component of the away-side jet $\vec{p}_{T,a}$ perpendicular to the plane formed by the beam and the near side jet $\vec{p}_{T,t}$.

$$p_{\text{out}} = |p_{T,a}| \sin \Delta\phi = \sqrt{2}k_{T,y}$$

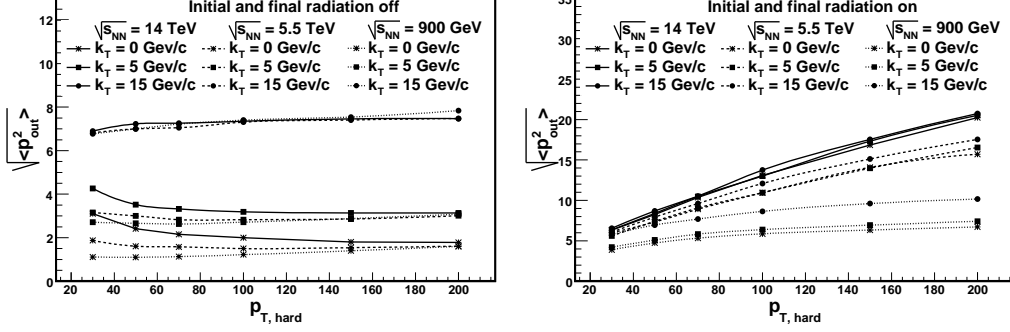
The transverse momentum imbalance ($p_{t,\text{diff}}$) is the difference between the trigger jet ($\vec{p}_{T,t}$) and the away-side jet ($\vec{p}_{T,a}$) transverse momentum in the trigger jet-beam plane.

$$p_{\text{max}} - p_{\text{proj}} = |p_{T,t}| - |p_{T,a} \text{Proj}(p_{T,t})| = \sqrt{2}k_{T,x}$$

This analysis uses di-jet azimuthal correlations to study p_{out} and $p_{t,\text{diff}}$ for pp and Pb-Pb collisions at LHC energies with different values of intrinsic k_t and initial temperature. For this purpose we use the PYTHIA 6.2 Monte Carlo generator to simulate pp collisions, PYTHIA modified with PYQUEN to simulate energy loss of hard partons in Pb-Pb collisions [4] and a modified UA1 cone algorithm implemented in the AliRoot JETAN [5] module to reconstruct charged particle jets.

II. THE PP REFERENCE

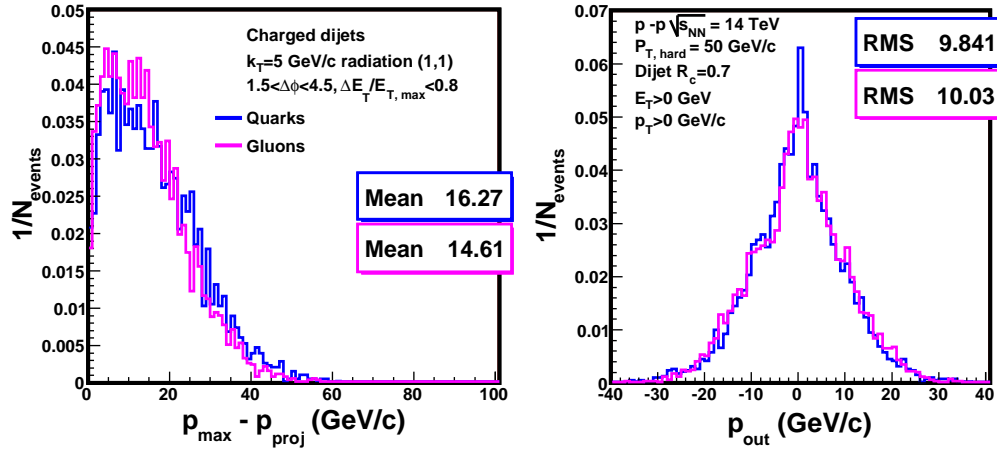
PYTHIA 6.2	CONE ALGORITHM	Minimize “fake” di-jets
$\sqrt{s_{NN}} = 900 \text{ GeV}, 5.5 \text{ TeV}$ and 14 TeV	$R_c < 0.7$	$1.5 < \Delta\phi < 4.5$
$p_t^{\text{hard}} = 30, 50, 70, 100, 150, 200 \text{ GeV}/c$	$ \eta < 0.9$	$\Delta E_t/E_t^{\text{max}} < 0.8$
$k_t = 0, 5, 7.5, 10$ and $15 \text{ GeV}/c$	No p_t^{cut}	
IR and FR off/on	$E_t > 0 \text{ GeV}$	



As expected, the acoplanarity between two jets is increased due to the intrinsic k_t (left). p_{out} increase with increasing p_t^{hard} and cms energy. At high cms energies p_{out} shows a small dependence on the unknown intrinsic k_t due to the dominance of initial state radiation (right).

III. QUARK AND GLUON JETS IN PP COLLISIONS

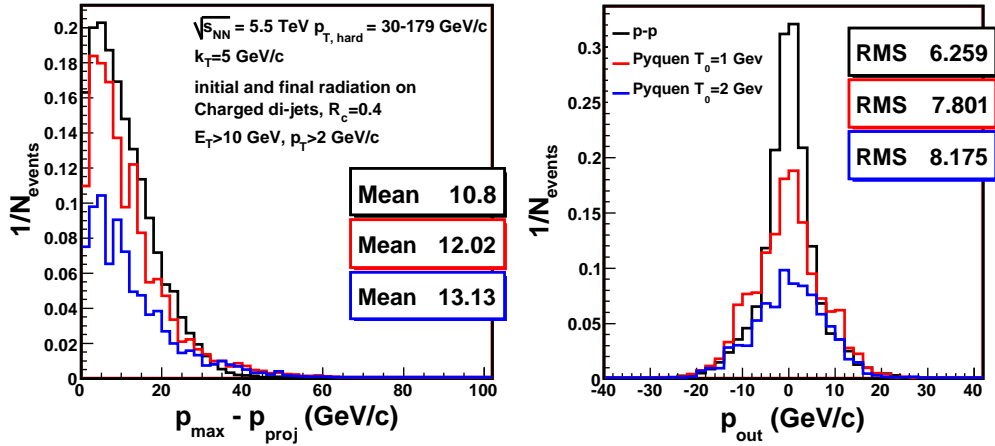
PYTHIA 6.2	CONE ALGORITHM	Minimize “fake” di-jets	q process	g process
$\sqrt{s_{NN}} = 14 \text{ TeV}$	$R_c < 0.7$	$1.5 < \Delta\phi < 4.5$	$qq \rightarrow qq$	$q\bar{q} \rightarrow gg$
$p_t^{\text{hard}} = 50 \text{ GeV}/c$	$ \eta < 0.9$	$\Delta E_t/E_t^{\text{max}} < 0.8$	$q\bar{q} \rightarrow q\bar{q}$	$gg \rightarrow gg$
$k_t = 5 \text{ GeV}/c$	No p_t^{cut}		$gg \rightarrow q\bar{q}$	
IR and FR on	$E_t > 0 \text{ GeV}$			



Initial state radiation is the dominant contribution, so that the k_t effect is the same when quark jets (blue line) and gluon jets (magenta line) were observed separately.

IV. JETS IN PB-PB COLLISIONS

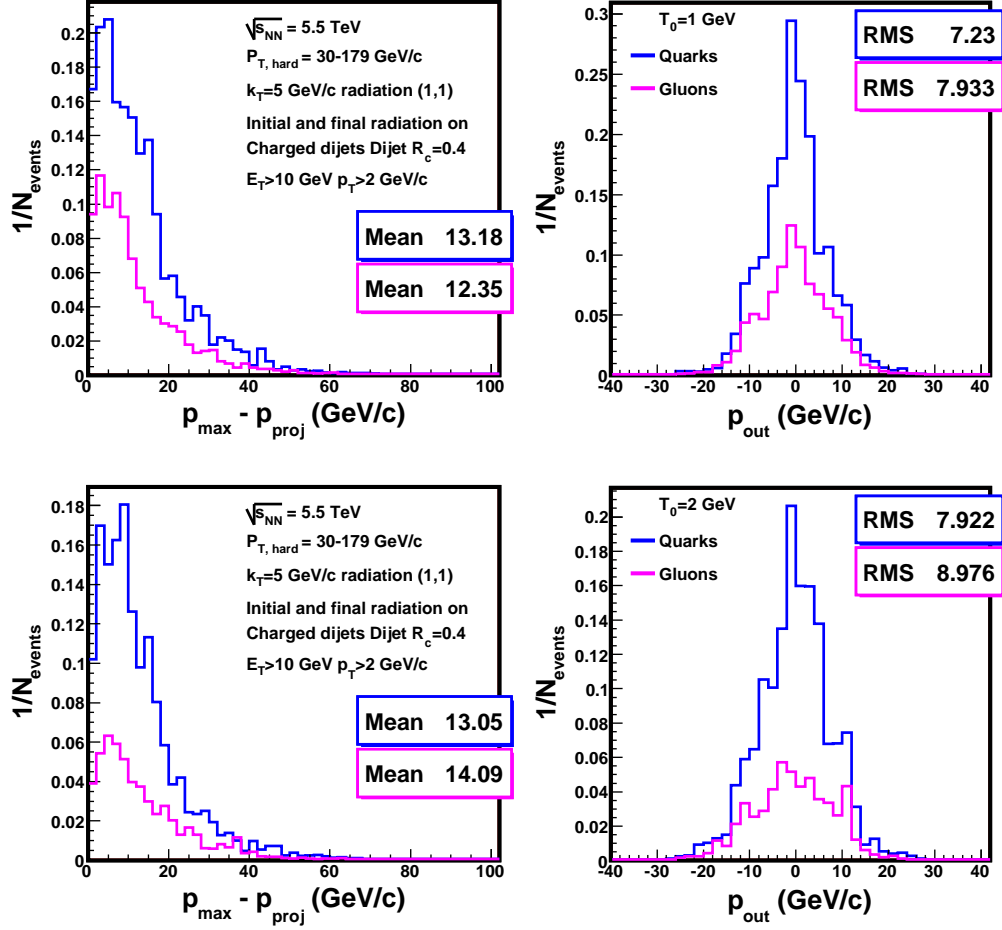
PYTHIA 6.2	PYQUEN	CONE ALGORITHM
$\sqrt{s_{NN}} = 5.5$ TeV	Initial temperature: $T_0 = 1$ and 2 GeV	$R_c < 0.4$
$p_t^{\text{hard}} = 39-172$ GeV/c	Proper time of formation: $\tau_0 = 0.1$ fm/c	$ \eta < 0.9$
$k_t = 5$ GeV	Number of active quark flavors: $n_f = 0$	$p_t^{\text{cut}} > 2$ GeV/c
IR and FR on	Energy loss: Only collisional	$E_t > 10$ GeV
	Angular distribution of emitted gluons: Small	



The transverse momentum imbalance and acoplanarity between di-jets is larger in Pb-Pb (red and blue line) collisions than in pp collisions (black line) due to the interactions of hard partons with the hot and dense medium. This effect depends on the initial temperature of the medium (red line $T_0 = 1$ GeV and blue line $T_0 = 2$ GeV).

V. QUARK AND GLUON JETS IN PB-PB COLLISIONS

PYTHIA 6.2	PYQUEN	CONE ALGORITHM	q process	g process
$\sqrt{s_{NN}} = 5.5$ TeV	$T_0 = 1$ and 2 GeV	$R_c < 0.4$	$qq \rightarrow qq$	$q\bar{q} \rightarrow gg$
$p_t^{\text{hard}} = 39-172$ GeV/c	$\tau_0 = 0.1$ fm/c	$ \eta < 0.9$	$q\bar{q} \rightarrow q\bar{q}$	$gg \rightarrow gg$
$k_t = 5$ GeV	$n_f = 0$	$p_t^{\text{cut}} > 2$ GeV/c	$gg \rightarrow q\bar{q}$	
IR and FR on	Only collisional	$E_t > 10$ GeV		
	Small angular dist.			



The transverse momentum imbalance and acoplanarity between di-jets is bigger for gluon jets than in quark jets and depends on the initial temperature of the medium ($T_0 = 1$ GeV top and $T_0 = 2$ GeV bottom).

VI. SUMMARY

Momentum imbalance and acoplanarity in charged di-jets simulated in pp and Pb–Pb collisions were studied to determine the sensitivity of the observed parameters on the magnitude of k_t .

In pp collisions the acoplanarity is dominated by initial state radiation. The expected pp baseline varies only slowly with the unknown intrinsic k_t . Final state effects have to be measured with respect to this base line.

Preliminary studies show that in Pb–Pb collisions the extra k_t from partonic interactions with the dense medium can be observed on top of the initial state radiation. The size of the effect depends on the initial temperature. Future simulations have to include energy loss and the trigger bias from the full input spectrum.

ACKNOWLEDGMENTS

We should like to thank J. Casalderrey-Solana for helpful discussion, to CONACyT projects 52162-F, 44268-F, PAPIIT project IN107105 and PAEP project, as well as the HELEN project for the support

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