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Nuclear Physics A 931 (2014) 455–459

NUCLEAR PHYSICS A

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Angular correlations of jets in lead–lead collisions at 2.76 TeV using the ATLAS detector at the LHC

Martin Rybar for the ATLAS Collaboration

Charles University in Prague, Institute of Particle and Nuclear Physics, V Holesovickach 2, 180 00 Prague 8, Czech Republic

Received 1 August 2014; accepted 5 August 2014

Available online 11 August 2014

Abstract

Highly energetic jets produced in nuclear collisions are considered to be a direct probe of hot and dense QCD medium created in these collisions. Jet measurements performed both at the LHC and RHIC indicate a presence of "jet quenching" – strong energy loss of fast partons in the hot and dense QCD medium. This note reports study of properties of the multi-jet production in heavy ion collisions presented in terms of jet angular correlations. The jet angular correlations are a valuable tool to study the beyond-leading-order effects in QCD and are expected to shed a light on the process of the parton energy loss. The study is performed using Pb + Pb data collected in 2011 by the ATLAS detector at the center of mass energy of 2.76 TeV.

Keywords: Heavy Ion; Neighbouring jet; Jet quenching

1. Introduction

Studies of jet production in Pb + Pb collisions at the LHC provide a means to investigate, through the mechanism of "jet quenching", the properties of the quark gluon plasma created in the collisions. Measurements of the dijet balance modification with increasing collision centrality [1,2] provided the first direct evidence of jet quenching at the LHC. Further measurements of inclusive jet suppression [3] and the variation of the jet suppression with the jet azimuthal angle respective to the elliptic flow plane [4] have quantified the size of the suppression of jet yields and demonstrated a dependence of the suppression on the path length of the parton shower in the plasma.

http://dx.doi.org/10.1016/j.nuclphysa.2014.08.024

The single jet measurements are sensitive to the average energy loss while the dijet measurements probe differences in the quenching between the two parton showers traversing the medium. Those differences can arise from the unequal path lengths of the two showers in the medium or from fluctuations in the parton energy loss. This note presents measurement of the production of neighbouring jets which may help to disentangle different contributions to the jet quenching. The neighbouring jets originating from the same hard interaction propagate in approximately the same direction and should have similar path lengths in the medium. Therefore, measuring neighbouring jets can probe differences in the quenching of the two jets that do not result from the difference in path length.

2. Data and the jet reconstruction

This analysis [5] uses data from Pb + Pb collisions recorded by ATLAS [6] in 2011. A total integrated luminosity of 0.14 nb^{-1} is used for events triggered by the jet High Level Trigger (HLT), a total luminosity of 7 $\mu\mathrm{b}^{-1}$ is used for events triggered by the minimum-bias (MB) trigger. MB events were identified by MB triggers using the zero degree calorimeter (ZDC) with pseudorapidity range $|\eta| > 8.3$, the inner detector (ID), and minimum-bias trigger scintillators (MBTS) covering $2.1 < |\eta| < 3.9$. Events with high-p_T jets were selected using the HLT triggering on jets. The HLT jet trigger ran the offline Pb + Pb jet reconstruction, described below, except for the application of the final hadronic energy scale correction. The HLT trigger selected events containing a $d = 0.2$ jet with transverse energy greater than 20 GeV. The data were compared to Monte Carlo (MC) event sample that was obtained by overlaying simulated PYTHIA [7] p + p hard-scattering events onto minimum-bias Pb + Pb events recorded in 2011.

All events were required to have a reconstructed primary vertex and a good MBTS timing. The centrality of Pb + Pb collisions was characterized by the total transverse energy, $\sum E_\mathrm{T}^\mathrm{FCal}$, in the forward calorimeter (FCal) [8] covering $3.1 < |\eta| < 4.9$.

The detailed description of the jet reconstruction can be found in Ref. [3]. To remove jets originating from the UE fluctuations we require matching of calorimeter jets to at least one track-jet or a single electro-magnetic cluster with $p_\mathrm{T} > 7$ GeV. Track jets were reconstructed using the anti-k_t algorithm with $d = 0.4$ running over tracks with $p_\mathrm{T} > 4$ GeV. These requirements restrict presented measurements to $|\eta| < 2.1$.

3. Neighbouring jet rates and corrections

The rate of the neighbouring jets that accompany a testjet, $R_{\Delta R}$, is defined as

$$R_{\Delta R} = \frac{1}{\mathrm{d}N_\mathrm{jet}^\mathrm{test}/\mathrm{d}E_\mathrm{T}^\mathrm{test}} \sum_{i=1}^{N_\mathrm{jet}^\mathrm{test}} \frac{\mathrm{d}N_{\mathrm{jet},i}^\mathrm{nbr}}{\mathrm{d}E_\mathrm{T}^\mathrm{test}} \left(E_\mathrm{T}^\mathrm{test}, E_\mathrm{T,min}^\mathrm{nbr}, \Delta R\right), \tag{1}$$

where $E_\mathrm{T}^\mathrm{test}$ and $E_\mathrm{T}^\mathrm{nbr}$ are the transverse energies of the test and neighbouring jet, respectively; $N_\mathrm{jet}^\mathrm{test}$ is the number of testjets in a given $E_\mathrm{T}^\mathrm{test}$ bin and $N_\mathrm{jet}^\mathrm{nbr}$ is number of neighbouring jets. For each choice of d, neighbouring jets are considered if they lie within a specific annulus in ΔR away from the test jet: $0.5 < \Delta R < 1.6$, $0.6 < \Delta R < 1.6$, and $0.8 < \Delta R < 1.6$ for $d = 0.2$, $d = 0.3$, and $d = 0.4$ jets, respectively. Previous measurements of the correlated production of neighbouring jets were performed by the DØ experiment in p–$\bar{p}$ collisions at the Tevatron [9] to extract the strong coupling constant.