Jet-Hadron Correlations in pp and Pb-Pb Collisions with ALICE

Megan Connors

Yale University, New Haven, CT 06520

E-mail: `Megan.Connors@Yale.edu`

Abstract. Jet quenching has been observed at both RHIC and LHC energies, indicating that partons lose energy as they traverse the medium. To probe the effects of this partonic energy loss, measurements of the angular correlations between fully reconstructed jets and charged tracks in Pb-Pb collisions are studied. Fully reconstructing a jet provides access to the kinematics of the initial hard scattering while allowing us to study the distribution of hadrons on the away side from the modified recoil jet. Here we present first measurements of jet-hadron correlations in pp collisions at $\sqrt{s}$=2.76 TeV and an outlook for Pb-Pb collisions. The jets in this analysis are reconstructed from the 2011 data set using both charged tracks and neutral energy measured in the ALICE tracking system and the electromagnetic calorimeter respectively.

1. Introduction

Jets are the result of a hard scattering process in the initial phase of the collision. In heavy ion collisions the partons from the hard scattering process are modified by the presence of the quark-gluon plasma (QGP). This modification has been observed as a suppression of high-momentum particles at both RHIC and LHC energies [1, 2, 3, 4]. This suppression has also been observed for di-jets via two-particle correlations. A high-momentum particle is used as a trigger particle and is paired with all other particles in the event, referred to as associated particles. In pp collisions, the distribution of associated particles shows a peak on the near side at $\Delta\varphi = 0$ and on the away side at $\Delta\varphi = \pi$, where $\Delta\varphi$ is the azimuthal angle between the two particles. The near-side peak results from the jet particles associated with the same jet as the trigger particle. The away-side jet peak results from the opposing jet created in the hard scattering. In heavy ion collsions the away-side jet peak is suppressed [5, 6]. In addition to the suppression on the away side, modifications to the shape have also been observed on both the near and away side. In this analysis we reconstruct the jet and use the reconstructed jet axis to measure $\Delta\varphi$ distributions with associated charged tracks, instead of using a single trigger particle as a proxy for the jet.

Fully reconstructed jets are very versatile triggers because there are several variables associated with jet reconstruction that can be adjusted. In principle, by varying the different cuts such as minimum constituent p_T, we can vary how surface biased the trigger jet is and thereby adjust the pathlength traversed by the opposing jet. This would allow us to map out energy loss as a function of path length and do true jet tomography. However, lowering the constituent cut to probe deeper into the medium also introduces more background from the underlying event which would need to be handled with care. By fully reconstructing the jet close to the QGP surface, we can better approximate the initial energy of the parton on the

opposing side. While biasing the jet used as the trigger in our correlations to have a shorter pathlength through the medium, we also bias its fragmentation but the opposing jet is not biased by these cuts.

Jet-hadron correlations have been studied by the STAR collaboration at RHIC in Au+Au collisions at 200 GeV [7]. The results show that the suppression of pairs at high p_T is compensated by the production of additional low momentum particles. An apparent increase in the away-side width in the heavy ion environment compared to pp collsions was also observed but the significance of this difference is limited by the uncertainties due to the ambiguity in the jet v_n. Only very recently, ATLAS and STAR presented measurements of the jet v_2 for central collisions at 2.76 TeV and 200 GeV respectively [8, 9]. The impact of these measurements on the jet-hadron correlations is still being explored.

Making similar measurements at the LHC is important to help constrain theories which can teach us about how the partons lose energy in the QGP. These proceedings present a measure of the baseline jet-hadron correlations from pp data at 2.76 TeV and discuss the status of the jet-hadron measurement in PbPb collisons at ALICE.

2. The Data Sample

The data used in this analysis were collected by ALICE during the 2.76 TeV pp and 2.76 Pb-Pb LHC runs in 2011. The pp data include events that were triggered by using the ALICE electromagnetic calorimeter (EMCal). If a shower contained at least 3 GeV of energy, the event was accepted by the EMCal trigger. The statistics for the jet analysis is enhanced by using the triggered data sample. However, tracks from the minimum bias events are used for event mixing to exclude the correlations due to the EMCal trigger. The Pb-Pb analysis shown in these proceedings use a combination of the minimum bias, central and semi central triggered events. This results in a relatively flat centrality distribution for the 0-10% most central events.

3. Jet Reconstruction

Jets are reconstructed using both clusters in the EMCal and charged particles reconstructed in the ALICE tracking system. Contribution from the deposition of energy by charged tracks in the EMCal has been removed from the clusters by subtracting up to 100% of the momentum of the tracks matched to a given cluster. If the sum of the momentum of matched tracks is greater than the energy in the cluster, the cluster is simply excluded. We use the anti-k_T algorithm with a resolution parameter, $R = 0.4$, from the FastJet package [10]. Only jets which are fully contained within the area of the EMCal are considered. To avoid contributions from the underlying event in heavy ion collisions, we require the jets to have an area $A > 0.4$ [11] and use a minimum constituent cut of 3 GeV/c for both clusters and tracks. The constituent cut also helps bias the trigger jet closer to the surface [12]. Note that a 3 GeV/c cut for jets in the range 20-60 GeV has a more significant effect on the surface bias than a 1 GeV/c cut has on a 100 GeV jet as shown in [13]. To increase the surface bias and reject more background, we require that the leading particle in the jet satifies a $p_T > 6$ GeV/c cut.
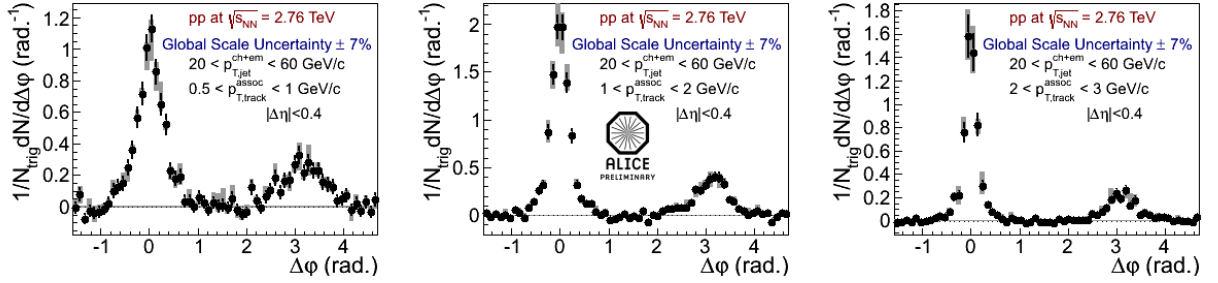
4. Correlations Measurement

4.1. pp

A correlation function is defined as the number of same-event pairs over the number of mixed-event pairs where the mixed-event pair distribution is normalized such that the bin at $\Delta\eta = \Delta\phi = 0$ is 1. For two-particle correlations the yield is typically expressed as number of pairs per trigger, N_{trig}, as in Eqn. 1, where ϵ is the efficiency of the associated particles.

$$\frac{1}{\mathrm{N_{trig}}}\frac{\mathrm{dN}}{\mathrm{d}\Delta\varphi} = \frac{1}{\epsilon \mathrm{N_{trig}}}\frac{\frac{\mathrm{dN^{same}_{pairs}}}{\mathrm{d}\Delta\varphi}}{\frac{\mathrm{dN^{mixed}_{pairs}}}{\mathrm{d}\Delta\varphi}} \quad (1)$$

Since the ALICE tracking detectors have full azimuthal coverage, the mixed-event pairs are approximately flat as a function of $\Delta\varphi$ while the finite η acceptance causes a drop towards large $\Delta\eta$. However, for jet-hadron correlations the $\Delta\eta$ dependence is rather flat in the range $|\Delta\eta| < 0.4$ since the range in η for the jets is more restricted than the η range of the associated tracks. To remove the contribution of the underlying event from the correlation function, a flat pedestal is subtracted. The resulting jet functions for three different associated momentum bins are shown in Fig. 1. The pedestal is determined from a fit which consists of two Gaussians plus the flat pedestal. The uncertainty on the pedestal subtraction is shown as a gray band around zero. There is an overall uncertainty of 7% on the normalization due to the uncertainty on the efficiency correction.

Figure 1. Jet-hadron $\Delta\varphi$ correlations from pp data. The underlying event has been subtracted.

The measured jet-hadron correlations qualitatively agree with expectations. The peaks of the near-side and away-side jets are clearly observed. The away-side peak appears broader and is lower than the near-side peak due to the effects of k_T, the intristic tranverse momentum [14, 15], which causes the two jets to not be directly back to back. Since we limit the correlations to be within $|\Delta\eta| < 0.4$, we do not capture all the jet particles.

4.2. Pb-Pb

In heavy ion collisions, the underlying event in the correlation functions is modulated by flow. To measure the effects of the QGP on the properties of the jet, we must remove the contribution to the correlation function from flow as in Eqn. 2. This requires a measure or an assumption of jet v_n.

$$\frac{1}{\mathrm{N_{trig}}}\frac{\mathrm{dN}}{\mathrm{d}\Delta\varphi} = \frac{1}{\epsilon \mathrm{N_{trig}}}\frac{\frac{\mathrm{dN^{same}_{pairs}}}{\mathrm{d}\Delta\varphi}}{\frac{\mathrm{dN^{mixed}_{pairs}}}{\mathrm{d}\Delta\varphi}} - b_0(1 + \Sigma v_\mathrm{n}^{\mathrm{trig}} v_\mathrm{n}^{\mathrm{assoc}} \cos(n\Delta\varphi)) \quad (2)$$

A first look at the jet-hadron correlations from the Pb-Pb data is shown in Fig. 2 as a function of $\Delta\varphi$ and $\Delta\eta$. Correlations due to flow have not been removed and the normalization scale has not been corrected for efficiency. There is a clear near-side jet peaked observed near $\Delta\varphi = \Delta\eta = 0$ but nothing more about the jets can be concluded until the flow is removed. Once this is done, one can compare the shapes and yields of the distributions observed in Pb-Pb to pp to study any potential modication due to the QGP.

Quantifying the modification of the jet-hadron correlations at LHC energies, will provide additional constraints on energy loss models and will lead to a better understanding of the energy loss mechanisms and properties of the QGP.
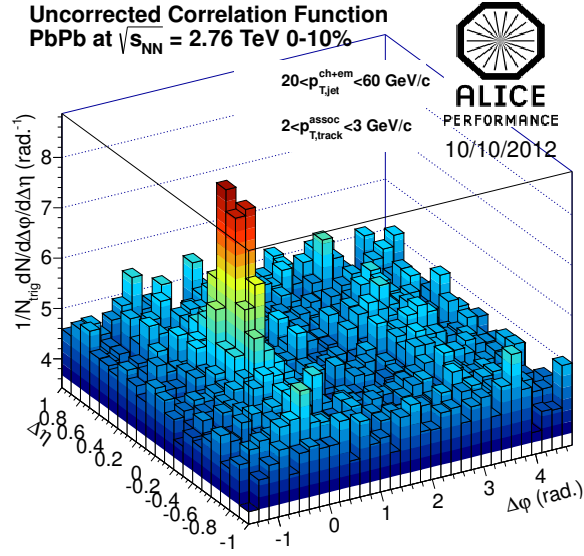
Figure 2. Jet-hadron $\Delta\eta - \Delta\varphi$ correlations from 0-10% most central Pb-Pb collisions at 2.76 TeV. Contributions from flow are not removed and efficiency corrections have not been applied.

5. References

[1] J. Adams et al. [STAR Collaboration], Phys. Rev. Lett. 91, 172302 (2003)
[2] K. Adcox et al. [PHENIX Collaboration], Phys. Lett. B 561, 82 (2003)
[3] K. Aamodt et al. [ALICE Collaboration], Phys. Lett. B 696, 30 (2011)
[4] S. Chatrchyan et al. [CMS Collaboration], Eur. Phys. J. C 72, 1945 (2012)
[5] K. Aamodt et al. Phys. Rev. Lett. 108, 092301 (2012)
[6] C. Adler et al. [STAR Collaboration], Phys. Rev. Lett. 90, 082302 (2003)
[7] Alice Ohlson (for the STAR collaboration) Quark Matter 2011 Proceedings arXiv:1106.6243
[8] Alice Ohlson (for the STAR collaboration) Quark Matter 2011 Proceedings
[9] ATLAS Collaboration ATLAS-CONF-2012-116
[10] M. Cacciari, G. P. Salam and G. Soyez, JHEP 0804, 063 (2008)
[11] Peter Jacobs, Nucl. Phys. A855, 299 (2011).
[12] Thorsten Renk arXiv:1210.1330 [hep-ph]
[13] Thorsten Renk arXiv:1202.4579v2 [hep-ph]
[14] S. S. Adler et al. [PHENIX Collaboration], Phys. Rev. D 74, 072002 (2006)
[15] R. P. Feynman, R. D. Field, and G. C. Fox, Nucl. Phys. B128, 1 (1977).