Using Dijet Correlations to Study the QGP

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August 25, 2016

Abstract

Jet hadron correlations for Au+Au collisions and p+p collisions at $\sqrt{S_{NN}} = 200GeV$ have been performed that require only one jet to be produced in collisions. It is expected that requiring a di-jet to be produced in Au+Au collisions instead should not alter those results significantly. The correlation we are interested in is of $\Delta\phi = \phi_{Jet} - \phi_{Particle}$

1 Introduction

Through heavy ion collisions we can study a pseudo-early universe. The medium created is expected to be the same as that of about 1 μs after the big bang, the so called quark-gluon plasma (QGP). A_J, The momentum difference between the near-side and away-side jets from Au+Au collisions is more imbalanced than that of p+p collisions which allows us to study the QGP, despite it only being present for about 10^{-23} seconds, specifically by comparing the charged particle correlations of Au+Au collisions to that of p+p collisions. Such measurements can help us to learn about the properties of the QGP [2]. An azimuthal correlation of the charged particles, scaled by the number of jets above the constituent cut of $p_T > 2$ GeV and background subtracted, are useful to compare p+p and Au+Au data. By having the constituent cut at 2 GeV, the heavy-ion background is effectively eliminated, making the results meaningful. The main focus of the correlations was to create the azimuthal correlation for events with a requirement that a di-jet pair was present and juxtapose them with events that only require a jet be formed.

Outline The remainder of this article is organized as follows. Our analysis is given in Section 2. Our new results are described in Section 2.4. Finally, Section 3 gives the conclusions.

2 Data Analysis

2.1 Coordinate System

The data used iare STAR data from the Relativistic Heavy Ion Collider (RHIC), both Au+Au and p+p collisions at $\sqrt{S_{NN}} = 200GeV$. Due to the velocities being ultra-relativistic, Cartesian coordinates are not sufficient to use. Instead, we consider a four-vector (x^0, x^1, x^2, x^3) where the first coordinate is time equivalent and the other three are spatial (ct, x_T, ϕ, z), where x_T is given by equation 1.

$$x_T^2 = x^2 + y^2 \tag{1}$$

ϕ, the azimuthal angle, is defined as $\arctan \frac{p_x}{p_y}$, and z is the beam axis. The azimuthal correlation is created by finding $\Delta\phi = \phi_{Jet} - \phi_{Particle}$ for each of the two jets highest in p_T. Because the Time Projection Chamber (TPC) is cylindrical, we use the analogous momentum four-vector, (p_T, η, ϕ, m) that uses the transverse momentum, p_T given by equation 2.

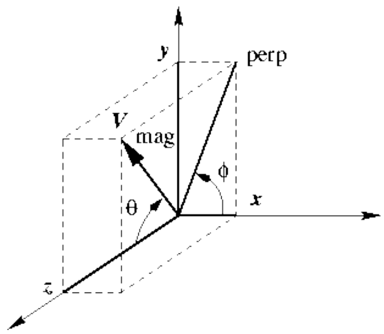
$$p_T^2 = p_x^2 + p_y^2 \tag{2}$$

$$\eta = -\ln \tan \theta/2 \tag{3}$$

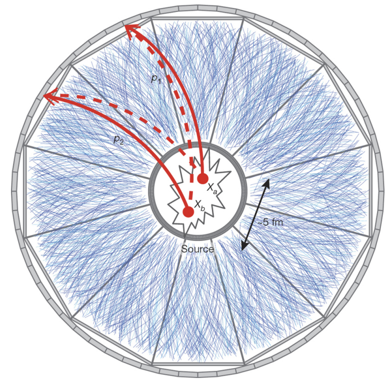
The pseudorapidity, η, is defined by equation 3, where θ is the angle from the beam line. The pseudorapidity is an approximation of the actual rapidity. An approximation is used because using the rapidity requires m of the particle to be known, which is difficult. For our correlations we use the azimuthal angle of the near-side jet as the jet axis and subtract the ϕ for each charged particle detected from the jet ϕ.

2.2 Measurements

The Time Projection Chamber (TPC) measures all charged particles from a collision event, and the EMCal measures the neutral particles. The TPC is a cylinder that encompasses the collision and surrounds it with a noble gas.



(a) Coordinate system used, with r of the cylinder defined by $x^2 + y^2 = r^2$ and the z-axis is the beam line [5]



(b) Event display in the TPC with the two distances k_{ti} and k_{tj} as $p1$ and $p2$ [3]

When a charged particle product interacts with a gas molecule it transfers its energy to an electron, which is then guided by a magnetic field in a spiral track to the outside of the TPC where it impacts a detector, which detects how much energy the particle has. Neutral particles are unaffected by the magnetic field and travel along the axis of the cylinder to the EMCal, which is a block of metal used to stop the neutral particles. The distance the particle travels into the block before it completely stops is proportional to the energy of the particle.

2.3 Jet Finding

Criteria for jets are implemented as selectors. The jet definition sets the maximum absolute value of rapidity at 0.6, and the minimum p_T for near-side and away-side jets at 20 GeV and 10 GeV, respectively. The selectors also include the constituent cuts on p_T of 0.2 and 2.0 GeV, done to minimize the effect of heavy ion background, as well as a cut of $\eta < 1.0$. The maximum track p_T is 30 GeV. The clustering sequence uses the particles that pass the 2.0 GeV and $\eta < 1.0$ selectors, and the anti-kt algorithm to find jets in events by recombining particles with the smallest separations above an explicit value and above the distance from each particle to the beam line. If the distance to the beam line is smaller than the cut value, it is considered part of the beam and ignored. The recombination process continues until the smallest separation of particles, and the distance from the particles to the beam line is larger than the known value. It uses the fast jet jet definition and parameter to recombine particles into an almost perfect cone, in our case a parameter .4, which refers to the jet resolution parameter. It uses k_t^{-2}, instead of k_t^2 as the kt algorithm uses, to find the minimum distance between particles, and takes differences in rapidity and azimuthal angle into account. The minimum distance is given, when $R = 1$, by

$$d_{ij} = min(k_{ti}^{-2}, k_{tj}^{-2})\Delta R_{ij}^2/R^2 \tag{4}$$

where

$$\Delta R_{ij}^2 = 5(y_i - y_j)^2 + (\phi_i - \phi_j)^2 \tag{5}$$

and k_{ti}^{-2} is the distance from a particle to the beam line; y_i is the rapidity of dparticle i. Jets returned by this process are then sorted by p_T and correlated for the two highest in momentum. The particles used are taken from charged tracks by an algorithm to produce only charged particles [4]. To ensure a di-jet is produced in the collision, the p_T sorted jets and the two highest in p_T are compared. The highest jet in p_T is set as the jet axis, and to ensure a di-jet, $|\pi - \Delta\phi_{jets}| < .4$.

2.4 Results

My correlations focus on the correlation from di-jet triggered events. Figure 2 shows the correlation for single jet events. Figure 3 shows the raw correlation, before background subtraction, for the near-side with Au+Au and p+p jets shown. To subtract background, I used the pedestal method. I took the plateau of the Gaussian fit to the raw data and subtracted it from the histogram and the fit. The goal was to test the results shown in Figure 2, but with di-jets instead of single jet triggers. The correlation is cut into two graphs, one at low p_T, 0.5-2.0 GeV and one at high p_T, above 4 GeV. Figures 4 and 5 show the near-side jet, and figures 6 and 7 show the away-side jet. The histograms have Gaussian fits, and the integrals of the Gaussians for each p_T range are given by figure 8 for each jet in each collision.

3 Conclusions

The azimuthal correlations (yield and width) show a significant difference at the away-side/sub-leading jet as expected with respect to the jet hadron correlation results.The expected result of the di-jet correlations was to find

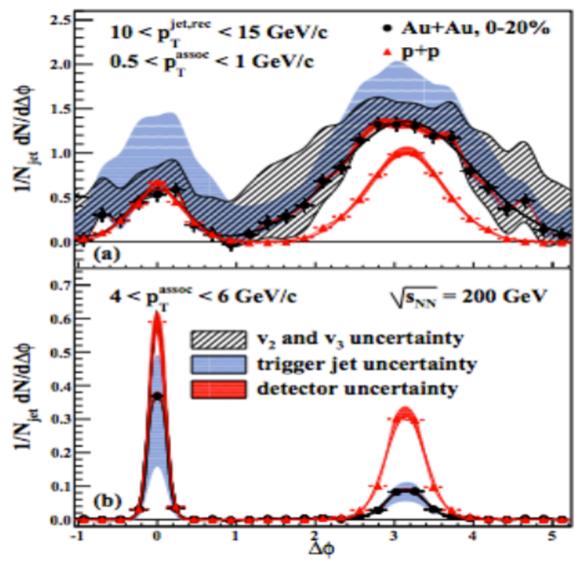


Figure 2: Previous correlation for single jet events with both jets shown [1].

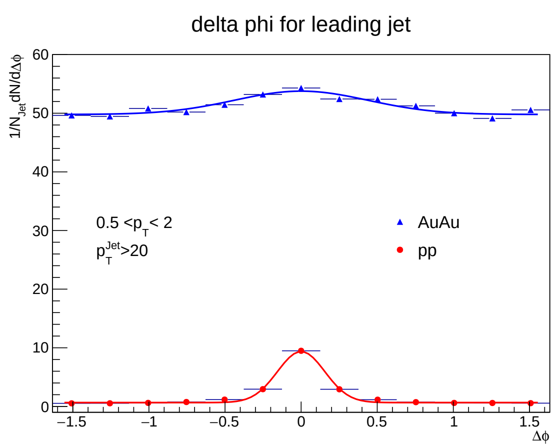


Figure 3: Correlation for near-side jets for $0.5 < p_T < 2$GeV before background subtraction for Au+Au and p+p

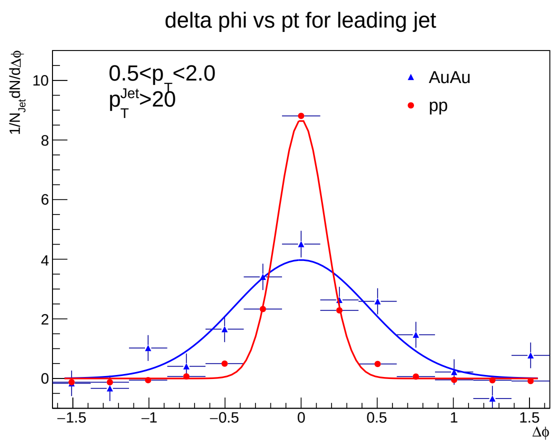


Figure 4: Correlation for the near-side jet for $0.5 < p_T > 2$GeV for Au+Au and p+p

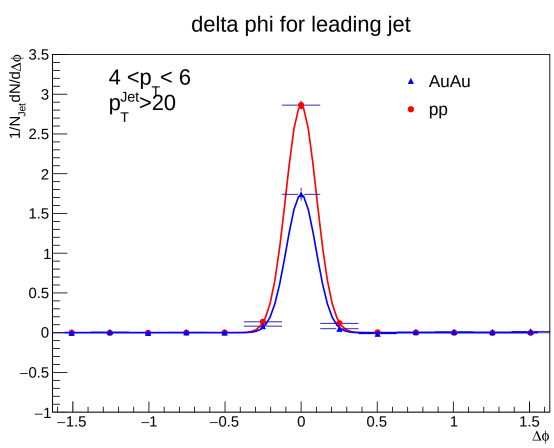


Figure 5: Correlation for the near-side jet for $4 > p_T > 6$GeV for Au+Au and p+p

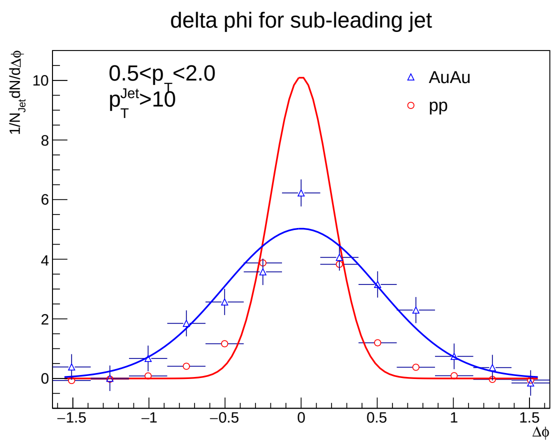


Figure 6: Correlation for the away-side jet for $0.5 < p_T > 2$GeV for Au+Au and p+p

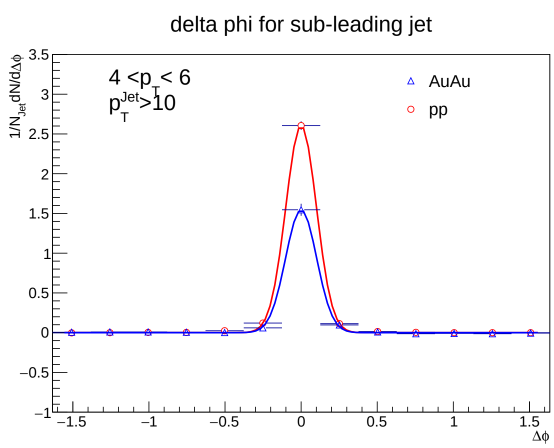


Figure 7: Correlation for the near-side jet for $4 > p_T > 6$GeV for Au+Au and p+p

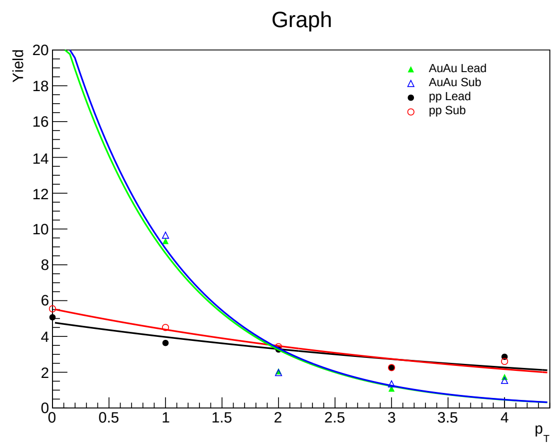


Figure 8: Integral of the Gaussian fit for both near- and away-side jets for Au+Au and p+p

more significant differences between the behavior of the leading vs sub leading jet in particular to find the away-side in Au+Au to be suppressed at high p_T and enhanced at low p_T . To further verify our expectations, the analysis would need to incorporate different background modulation so, mainly due to collective effects in the heavy ion event, as well as a more appropriate treatment of differences in the leading jet biases between p+p and Au+Au. Nonetheless, this study is an important first step and clearly demonstrated the feasibility of such a measurement at RHIC.

References

[1] L. Adamczyk *et al.* [STAR Collaboration], "Jet-Hadron Correlations in $\sqrt{S_{NN}} = 200$ GeV p+p and Central Au+Au Collisions," Phys. Rev. Lett. **112**, 122301 (2014) [arXiv:1302.6184 [nucl-ex]].

[2] CMS Collaboration, "Correlations between jets and charged particles in PbPb and pp collisions at $\sqrt{s_{NN}} = 2.76$ TeV," JHEP **02**, (2016) 156 [arXiv:1601.00079 [nucl-ex]].

[3] Heavy Ion collision (1 August 2016) `http://www.nature.com/nature/journal/v527/n7578/fig_tab/nature15724_F1.html`

[4] Matteo Cacciari, Gavin Salam, Gregory Soyez. Fastjet `www.fastjet.fr`

[5] Relativistic Cylindrical Coordinate System (1 August 2016) `https://root.cern.ch/root/html534/guides/users-guide/PhysicsVectors.html`