Jet-like correlations between Forward- and Mid-rapidity in p+p, d+Au and Au+Au collisions from STAR at √s_{NN} = 200 GeV

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Abstract. In this proceedings we present STAR measurements of two particle azimuthal correlations between trigger particles at mid-rapidity (|η| < 1) and associated particles at forward rapidities (2.7 < |η| < 3.9) in p+p, d+Au and Au+Au collisions at √s_{NN} = 200 GeV. Two particle azimuthal correlations between a mid-rapidity trigger particle and forward-rapidity associated particles preferably probe large-x quarks scattered off small-x gluons in RHIC collisions. Comparison of the separate d- and Au-side measurements in d+Au collisions may potentially probe gluon saturation and the presence of Color Glass Condensate. In Au+Au collisions quark energy loss can be probed at large rapidities, which may be different from gluon energy loss measured at mid-rapidity.

1. Introduction

Jet-like azimuthal correlations at mid-rapidity in Au+Au collisions at RHIC energies have shown significant modifications, indicating the presence of a dense and strongly interacting medium [1]. Such measurements at mid-rapidity mainly probe the energy loss of gluons, due to the dominance of gluon-gluon scattering at RHIC energies [2]. STAR has the unique capability to extend two particle correlation measurements to forward rapidities (2.7 < |η| < 3.9) by utilizing the Forward Time Projection Chambers (FTPC) [3], with trigger particles at mid-rapidity (|η| < 1) in the STAR-TPC [4]. This kinematics is sensitive to hard scattering of small-x gluons (from which the trigger particles are mostly produced) and large-x quarks (which fragment into associated particles at forward rapidities). The measurements may address the question of gluon saturation in d+Au collisions, energy loss of quark jets at large rapidities and the possible presence of long range Δη correlations in Au+Au collisions [5].

2. Analysis details

High-p_T trigger particles (3 < p_T^{trig} < 10 GeV/c, |η^{trig}| < 1) and associated particles (0.2 < p_T^{assoc} < 2 GeV/c, 2.7 < |η^{assoc}| < 3.9) are selected in the TPC and FTPCs,
respectively. The two particle correlation functions are corrected for tracking efficiency and acceptance of the associated particles, and are normalized per trigger particle.

Figure 1. (color online) Correlation functions in d+Au collisions for the outgoing d-side (blue) and the Au-side (red) compared to pseudo-rapidity averaged p+p collisions (black) at $\sqrt{s_{NN}} = 200$ GeV/c.

The combinatorial background is constructed from the technique of event mixing. In p+p and d+Au collisions, combinatorial background is normalized to the signal region of $|\Delta \phi| < 1$, because in this region no correlation structure is observed. In Au+Au collisions, elliptic flow ($v_2$) modulation is added pairwise to the mixed-events background. The background is normalized to the range of $0.8 < |\Delta \phi| < 1.2$ by the Zero Yield At 1 (ZYA1) method \cite{6, 7}. Trigger particle $v_2$ is taken to be the average of the results from the modified reaction plane and the 4-particle cumulant methods, and the range of the two results is taken to be the systematic uncertainty, as in \cite{6}. The associated particle $v_2$ used here is a parameterization of 2-particle cumulant measurements at forward rapidities by STAR \cite{8}, while the centrality dependence is parameterized from preliminary STAR results. The FTPC $v_2$ results obtained from different methods are in good agreement \cite{8}. However, as a conservative estimate the same relative systematic uncertainty as at mid-rapidity is applied.

3. Results and discussion

3.1. d+Au results - probing small-x gluons in nucleus

Figure 1 shows the two particle azimuthal correlations for p+p and d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The outgoing d- and Au-sides are shown separately. The p+p points are averaged over the positive and negative rapidities. As shown in Fig. 1, the away-side correlation shapes are similar. The d-side yield is suppressed by about a factor of two compared to the Au-side. The p+p result lies approximately at the average in between. Suppression of the d-side yield may be understood as the suppression of small-x gluons in the Au nucleus, as predicted by the Color Glass Condensate (CGC) picture \cite{9}. On the
Jet-like correlations between Forward - and Mid - rapidity

Figure 2. (color online) Left panel: correlation functions in 60-80% and 20-40% Au+Au collisions at 200 GeV/c. Right panel: correlation functions for two associated momentum ranges in 0-10% Au+Au collisions at 200 GeV/c. Curve represents a fit to the correlation function in p+p collisions at \( \sqrt{s_{NN}} = 200 \) GeV/c.

other hand, reduction of the d-side yield may arise from the energy degradation of the d-side quarks due to multiple scattering in the Au nucleus. Gluon anti-shadowing [10] and the EMC effect [11] would enhance the d-side yield relative to the Au-side.

3.2. Au+Au results - rapidity dependence of energy loss

Figure 2 shows the azimuthal correlations for 60-80% and 20-40% (left panel) and for 0-10% (right panel) Au+Au collisions at \( \sqrt{s_{NN}} = 200 \) GeV. Results for two associated \( p_T \) ranges are shown for the 0-10% Au+Au data. The near-side correlations for \( 0.2 < p_T^{assoc} < 2 \) GeV/c are consistent with zero within the systematic uncertainties. However, the central data at high associated \( p_T \), with the reduced systematic uncertainty, are suggestive of non-zero correlation on the near-side. This result indicates that long range \( \Delta \eta \) correlations, first observed in \( \Delta \eta < 2 \) [5], may extend out to \( \Delta \eta \sim 4 \) in the FTPCs.

The away-side correlation shapes in Au+Au collisions are broadened with respect to p+p as shown in Fig. 2. The broadening is present for each centrality and is similar to mid-rapidity measurements. Figure 3 shows the comparison of the azimuthal

Figure 3. (color online) Comparison of correlation functions from TPC (blue) and FTPC (red) for d+Au, peripheral (60-80%) and central (0-10%) Au+Au collisions at \( \sqrt{s_{NN}} = 200 \) GeV/c. The TPC data are scaled to compare the correlation shapes. Dashed lines represent systematic uncertainties of the Au+Au data.
correlations measured at forward rapidity (red) and at mid-rapidity (blue). The away-side correlation shapes are identical within the systematic uncertainties. To understand the contributing physical processes of energy loss at mid- and forward-rapidities quantitative theory calculations are essential.

4. Summary

In summary, we have presented two particle azimuthal correlations of charged hadrons at forward rapidities \(2.7 < |\eta| < 3.9\) with trigger particles selected at mid-rapidity \(|\eta| < 1\) in p+p, d+Au and Au+Au collisions at \(\sqrt{s_{NN}} = 200\) GeV.

Near-side correlation is not observed in p+p and d+Au collisions. Near-side correlations in Au+Au collisions are consistent with zero with the systematic uncertainties for \(0.2 < p_T^{assoc} < 2\) GeV/c. However, the high associated \(p_T\) data \((p_T > 1\) GeV/c\) in central Au+Au collisions suggest a finite near-side correlation, which may indicate the presence of long range \(\Delta \eta\) correlations at forward rapidities.

Significant away-side correlations are observed for all systems. In d+Au collisions, a factor of two suppression is observed for the d-side compared to the Au-side. The p+p measurement is approximately the average of the d-side and Au-side correlations. While the Color Glass Condensate gives a qualitative description of the observed relative d- and Au-side yields, due to suppression of small-x gluons in Au nucleus, other mechanisms may be also at work, such as d energy degrading. Quantitative model calculations are needed for further understanding. The away-side correlation shape broadens from peripheral to central Au+Au collisions, similar to mid-rapidity observations. Moreover, the away-side correlation shapes are almost identical to those measured at mid-rapidity. To understand the contributing physical processes of energy loss at mid- and forward-rapidities quantitative theory calculations are essential.

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