

Two-particle correlations in 2D p_t space in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV at STAR

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Abstract. Measurements of 2D transverse momentum correlations on (p_{t1}, p_{t2}) from minimum-bias Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV at STAR are presented and discussed. These correlations, formed from all charged particles with $p_t \geq 0.15$ GeV/c, $|\eta| \leq 1$, and 2π in azimuth, show a broad peak extending from $p_t=0.5-4.0$ GeV/c. The broad peak is observed in both like- and unlike-sign charge combinations and for same- and away-side relative azimuth angles. Interestingly, the peak in the data for away-side or back-to-back pairs persists even in more-central collisions, remaining at approximately the same p_t for all centralities. These data are compared to theoretical models and the p_t dependence of the same-side angular correlation structure.

1. Introduction

Two-particle correlations provide greater access to the dynamics of heavy-ion collisions than that enabled with single-particle measurements as discussed in [1]. Observations of charged particle pair number correlations in relative angle space ($\eta_\Delta = \eta_1 - \eta_2, \phi_\Delta = \phi_1 - \phi_2$) have shown unexpected trends (e.g. ridge formation and anomalous centrality trends) in heavy-ion collisions relative to N-N binary-collision scaling [1]. Two particle correlations on (p_{t1}, p_{t2}) , discussed in this paper, provide complementary information.

2. Two-particle correlation measure

The correlation quantity used in this analysis measures the number of correlated pairs per final-state particle and is defined as $\frac{\Delta\rho}{\sqrt{\rho_{ref}}} = \sqrt{\rho_{ref}} \frac{\rho_{sib} - \rho_{mix}}{\rho_{ref}}$ where ρ_{sib} and ρ_{mix} are the densities of sibling and mixed-event pairs, respectively. The pair density, ρ_{ref} , represents a reference distribution which excludes the physics signal(s) of interest.

In angular space mixed-event pairs provide an accurate representation of ρ_{ref} because the physics signal(s) (e.g. jets, flows) are randomly distributed in the primary (η, ϕ) space. Mixed-event pairs cannot produce statistically significant structures on $(\eta_\Delta, \phi_\Delta)$ due to those processes. However, because dynamical processes (e.g. jets) likely produce particles at similar transverse momentum in different collisions, mixed-event particle pairs on (p_{t1}, p_{t2}) will have a similar structure as that from sibling pairs (from the same event). Given that most interesting angular correlation structures follow (or even exceed) binary collision scaling [1], and may be jet-related, we select a ρ_{ref} that is absent such scaling, or one where multiplicity is proportional to the number of participants (N_{part}). The soft particle spectrum of the two-component model [2]

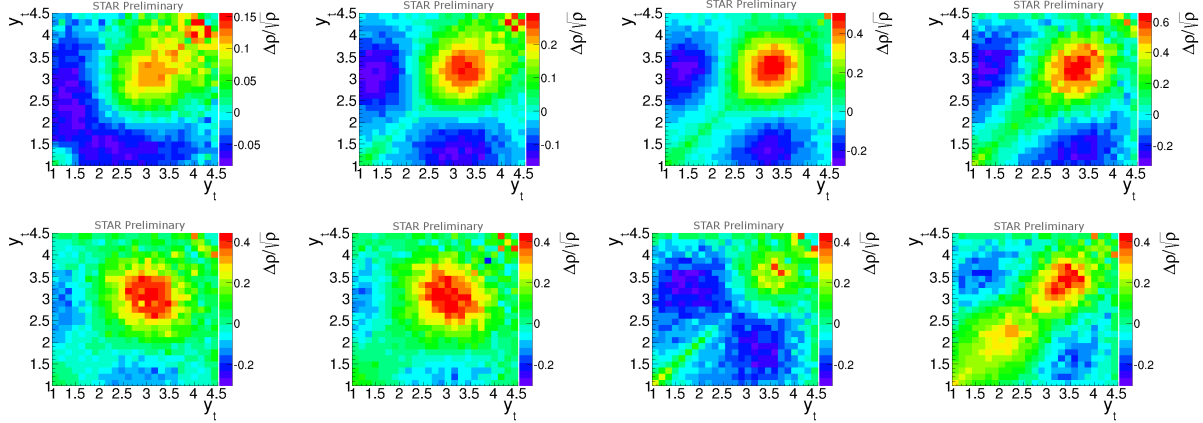


Figure 1. (Color online) Two-dimensional (y_{t1}, y_{t2}) correlations for Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The upper panels display charge-independent results in centralities 74-84%, 46-55%, 18-28%, and 0-5% (left to right). The lower left [right] two panels are formed from pairs with $|\phi_{\Delta}| > \pi/2$ (away-side) [$|\phi_{\Delta}| < \pi/2$ (same-side)] in 0-5% central events. The lower first and third panels display same-sign pairs; the lower second and fourth panels are for unlike-sign pairs.

provides a good estimate; it is represented with a single Levy distribution

$$\frac{d^2 N_{ch,soft}}{dy_t d\eta} = 2\pi p_t m_{t,\pi} \frac{N_{part}}{2} \left[\frac{A}{[1 + (m_{t,\pi} - m_{\pi})/(nT)]^n} \right] \quad (1)$$

where $A=5.81$ c/GeV^2 , $T = 0.169$ GeV, $n = 13.8$, $m_{t,\pi} = \sqrt{p_t^2 + m_{\pi}^2}$, and m_{π} is the pion mass.

3. Results

For best visual access the two-particle correlation data will be presented as a function of the transverse rapidity, defined as $y_t = \log[(m_{t,\pi} + p_t)/m_{\pi}]$. The momentum correlations of all particles with $p_t > 0.15$ GeV/ c in the upper panels of Fig. 1 show a bump around $(y_{t1}, y_{t2})=(3,3)$ ($p_t=1.4$ GeV/ c). The amplitude of the bump increases with centrality but remains in approximately the same location. In angular correlations we observe a sharp transition in the features of the correlations around the 46-55% centrality [1] but we observe no sharp transition in momentum space.

The lower panels in Fig. 1 display momentum correlations for the most central 0-5% events for particle pairs distinguished by charge type and azimuthal opening angle. A signal from back-to-back jet fragmentation is expected in the away-side projections (two left panels) and a peak is indeed observed around $(y_{t1}, y_{t2})=(3,3)$. Surprisingly this peak persists in higher centralities, increases in amplitude, as well as remaining in approximately the same location. Interestingly for unlike-sign, same-side pairs a single broad peak is observed in the peripheral bins which then appears to separate into two peaks near the same centrality where a sharp “transition” in the centrality trend occurs in angular correlations [1]. The above centrality trends are represented by the fit model parameters, see Fig. 2. The like-sign, same-side plots show HBT correlations along the diagonal ($y_{t1} = y_{t2}$) as well as a weaker bump at higher momentum.

The main characteristics of the peak at $(y_{t1}, y_{t2})=(3,3)$ in the momentum correlation data are quantified as a function of centrality using a simple fit model within a cut window. The rectangular fitting window, oriented along the $y_{t\Sigma} = y_{t1} + y_{t2}$ and $y_{t\Delta} = y_{t1} - y_{t2}$ axes, was generally defined as $|y_{t\Delta}| \leq 2.0$, $4 < |y_{t\Sigma}| < 8$. This window excluded structure along the edges and at lower y_t . The complete fit model function was defined as $A_0 + A_1 \exp[-0.5 * (((y_{t\Sigma} - 2 *$

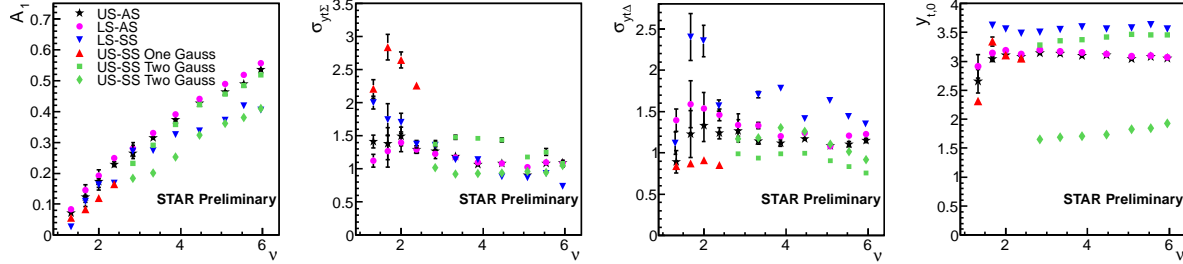


Figure 2. (Color online) Fit parameters for (y_{t1}, y_{t2}) correlation data versus centrality measure $\nu = 2 \langle N_{\text{binary}} \rangle / \langle N_{\text{participant}} \rangle$.

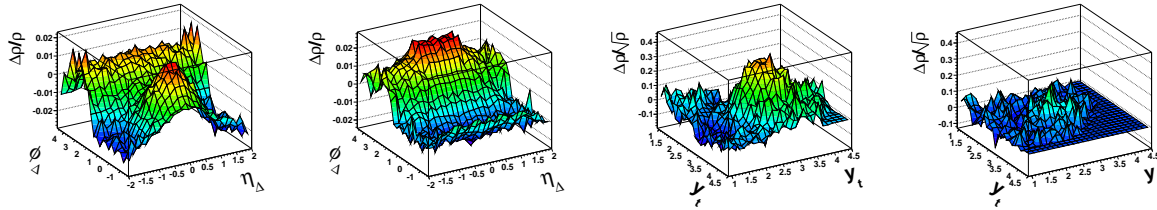


Figure 3. (Color online) Two-particle correlations from HIJING for 75-85% central events. The first and third panels show results with jets on; the second and fourth are with jets off.

$y_{t,0}/\sigma_{yt\Sigma})^2 + (y_{t\Delta}/\sigma_{yt\Delta})^2$]. For the unlike-sign same-side correlations a second 2D Gaussian at lower momentum was required. The fit results are shown in Fig. 2. The amplitudes of the peaks in all four cases increase monotonically with centrality. The peaks also remain in approximately the same location from most-peripheral to most-central collisions.

These momentum correlations, specifically the peak around $(y_{t1}, y_{t2})=(3,3)$, reveal an important new component of the data with which to test theoretical models. Predictions of two models, HIJING [3] and AMPT [4] are shown in Figs. 3 and 4. HIJING [3], based on the LUND string model and semi-hard jet fragmentation (PYTHIA), describes angular correlation data from peripheral heavy-ion collisions fairly well [1]. HIJING with jets off and on (no jet quenching) suggests that most of the pairs in the peak at $(y_{t1}, y_{t2})=(3,3)$ are from jet fragmentation.

AMPT [4] is a hybrid transport model that includes a period of parton-parton re-scattering. It successfully reproduces the quadrupole (v_2) component in heavy-ion collisions. For this study the partonic re-scattering cross section was increased until the quadrupole amplitude matched the data and then the corresponding correlations in momentum space were observed (Fig. 4). The correlation study was done using partons after the cascade because the hadron correlations produced by AMPT's coalescence algorithm display non-intuitive dependence on the partonic cross section. When the partonic cross section increased to 6 mb the fitted quadrupole amplitude matched the experimental value as well as other general features of the angular correlation data. However, the peak around $(y_{t1}, y_{t2}) \approx (2.5, 2.5)$, evident in the 0 mb case, dissipates and the features deviate from that observed in data.

Measurement of the (y_{t1}, y_{t2}) dependence of 2D angular correlations completes the experimental determination of the six-dimensional two-particle correlations and provides access to the y_t dependence of angular correlation features such as the same-side 2D peak (ridge). In this analysis the (y_{t1}, y_{t2}) range $([1,4.5],[1,4.5])$ was divided into 28 unique, square cut bins with sides of length 0.5. The angular correlation of the pairs in each bin was formed and fit with the 11 parameter fit function in [1]. Figure 5 shows the (y_{t1}, y_{t2}) distribution of the volume (number

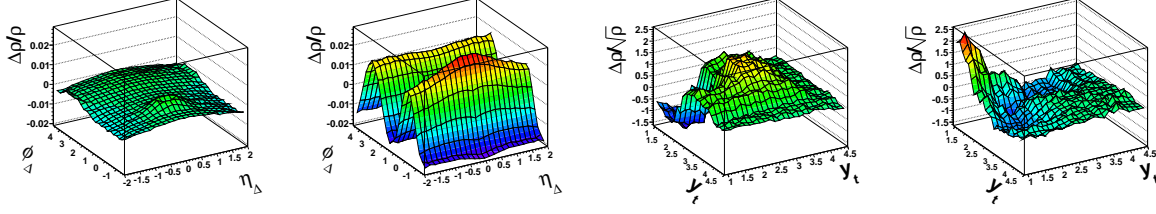


Figure 4. (Color online) Two-parton correlations from AMPT for collisions in the 45-55% centrality bin. The first and third (second and fourth) panels are for events with 0 mb (6 mb) partonic cross section in angular and momentum spaces, respectively.

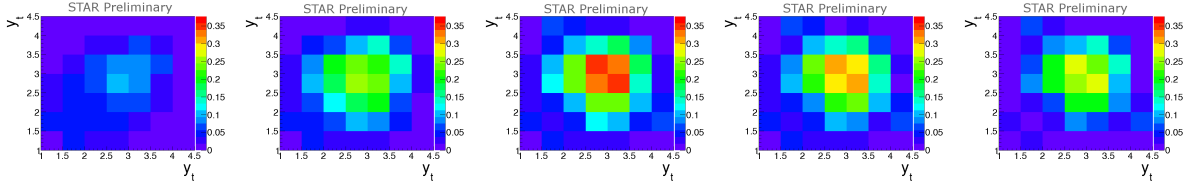


Figure 5. (Color online) The volume of the 2D Gaussian on (y_{t1}, y_{t2}) . The left three panels show the volume of the 2D Gaussian from $0 < |\eta_{\Delta}| < 2/3$ in three centrality bins, 38-46%, 18-28%, and 0-5% respectively. The fourth and fifth panels show the volume in the 0-5% centrality from $2/3 < |\eta_{\Delta}| < 4/3$ and $4/3 < |\eta_{\Delta}| < 2$ respectively.

of correlated pairs per final-state particle) of the same-side 2D Gaussian in various $|\eta_{\Delta}|$ ranges. Most of these correlated pairs are distributed near $(y_{t1}, y_{t2})=(3,3)$, similar to the momentum correlations in Fig. 1.

The y_t distribution of correlated pairs contributing to the same-side ridge as a function of η_{Δ} for the 0-5% centrality is shown in the three right-most panels in Fig. 5. The peak near $(3,3)$ remains in the same location as $|\eta_{\Delta}|$ increases. This shows that correlated pairs in the η elongated portion of the same-side angular peak structure come from roughly the same momentum distribution as pairs in the center near $\eta_{\Delta} = 0$.

4. Conclusion

The momentum dependent results presented here complete the measurement of six-dimensional, two-particle correlations and provide definitive tests for theoretical models. The results show a broad peak extending from 0.5-4.0 GeV/c in all charge and azimuth pair combinations which, as a function of centrality, remains at a fixed position while monotonically increasing in amplitude. HIJING predicts a similar broad peak when jets are turned on. Partons in AMPT do not follow the observed trends when sufficient interaction strength is included to reproduce v_2 ; the peak is strongly dissipated. In a complementary study the momentum distribution of angular correlation features was investigated. The momentum distribution of correlated pairs that contribute to the same-side 2D Gaussian, commonly referred to as the “ridge” and which may be due to minijets [1], peak near $(y_{t1}, y_{t2})=(3,3)$ ($p_T=1.4$ GeV/c) and do not soften with increased centrality or at larger $|\eta_{\Delta}|$.

References

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