THREE-PARTICLE CORRELATION MEASUREMENTS AT RHIC*

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(Received October 16, 2008)

Two-particle jet-like correlations have shown medium modification in central Au+Au collisions. This modification can be explained by different physics mechanisms such as: large angle gluon radiation [2], jets deflected by radial flow [3] or path-length dependent energy loss [4], Mach-cone shock waves [5], and Čerenkov gluon radiation [6]. Three-particle correlations can be used to distinguish the mechanisms with conical emission, Mach-cone shock waves and Čerenkov radiation. This paper reviews three 3-particle correlation analyses at RHIC and discuss the physics extracted from them.

PACS numbers: 25.75.–q, 25.75.Dw

1. PHENIX 3-particle jet-like correlation

The PHENIX 3-particle correlation analysis is performed using a trigger particle of $2.5 < p_{\mathrm{T}}^{\mathrm{Assoc}} < 4$ GeV/c with associated particles of $1 < p_{\mathrm{T}}^{\mathrm{Assoc}} < 2.5$ GeV/c. This analysis is performed in a polar coordinate system (Fig. 1) where Θ^* is the angle between an associated particle and the trigger particle and $\Delta\phi^*$ is the angle between the two associated particles in the plane normal to the trigger particle direction [7]. Fig. 1(b) shows the raw 3-particle correlation. The radial axis is Θ^* and the polar axis is $\Delta\phi^*$. The near-side peak is at the center and the away-side structure around the outside. Fig. 1(c) shows the v_2 subtracted correlation function. Fig. 1(d) shows the projection to the $\Delta\phi^*$ axis of the v_2 and 2-particle subtracted 3-particle correlation function. The shapes of the projections of simulated Mach-cone and deflected jets signals are also shown in red and blue, respectively. Although errors are large, the data favors Mach-cone emission. However, the details of background subtraction and systematics are unknown in this analysis and should be investigated.

* Presented at the XXXVII International Symposium on Multiparticle Dynamics, Berkeley, USA, August 4–9, 2007.

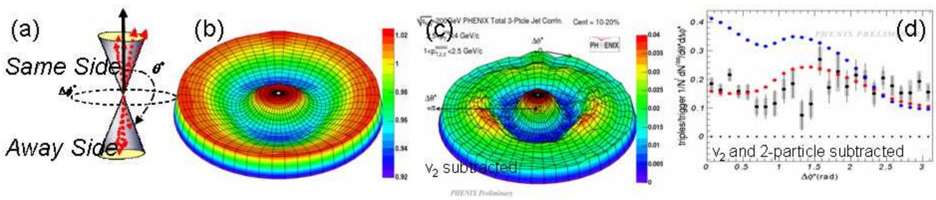

Fig. 1. (a) Cartoon of the coordinate system. (b) Raw 3-particle data. (c) v_2 background subtracted 3-particle data. (d) $\Delta\phi^*$ projection for v_2 and 2-particle background subtracted data. Simulated results for conical emission (red, lower dotted line) and deflected jets (blue, upper dotted line). Data is from 10–20% Au+Au collisions [7].

2. STAR three-particle cumulant

The 3-particle cumulant analysis is defined by the equation [8]:

$$C_3(\Delta\phi_1, \Delta\phi_2) \; = \; \rho_3 - \rho_2^{(\mathrm{T1})}\rho_3^{(2)} - \rho_2^{(\mathrm{T2})}\rho_1^{(1)} - \rho_2^{(12)}\rho_1^{\mathrm{T}} - 2\rho_1\rho_1\rho_1 \, , \quad (1)$$

where ρ_n is the n-particle density and $\Delta\phi_i = \phi_{\mathrm{T}} - \phi_i$. Fig. 2 shows each of the terms on the right hand side of the equation with a structure.

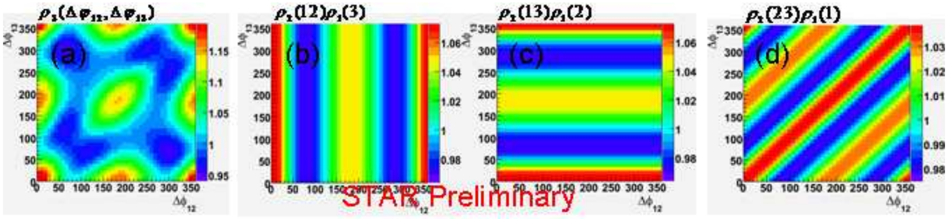

Fig. 2. (a) Three-particle density, $\rho_3(\Delta\phi_1, \Delta\phi_2)$ (b) $\rho_2(\Delta\phi_1)\rho_1(\phi_2)$ (c) $\rho_2(\Delta\phi_2)$ $\rho_1(\phi_1)$ (d) $\rho_2(\phi_1 - \phi_2)\rho_1(\phi_T)$. Data from [8].

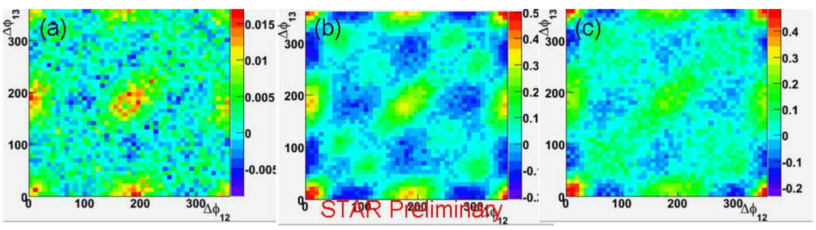

Fig. 3. Three-particle cumulants for Au+Au collisions in centrality bins (a) 50–80%, (b) 10–30%, (c) 0–10% with $3 < p_{\mathrm{T}}^{\mathrm{Trig}} < 4$ and $1 < p_{\mathrm{T}}^{\mathrm{Assoc}} < 2\,\mathrm{GeV}/c$. Data from [8].

If the events are Poisson, the 2-particle correlations are removed and C_3 is a measure of all correlations of 3 or more particles, including flow and correlations between jets and flow. Fig. 3 shows the 3-particle cumulant, C_3, in three centralities of Au+Au collisions. A signal is seen in all bins, indicating the presence 3 or more particle correlations if the events are Poisson. Further interpretation is complicated and model dependent.

3. STAR 3-particle jet-like correlation

Another analysis assumes the event can be decomposed into particles that are jet-like correlated with the trigger particle and background particles. It attempts to obtain the true jet-like 3-particle correlation and can be represented by the equation (with terms shown in Fig. 4) [9]:

$$\hat{J}_3(\Delta\phi_1, \Delta\phi_2) \;=\; J_3 - 2\hat{J}_2 a B_2^{\rm inc} - a^2 b[B_3^{\rm inc} + B_3^{\rm inc,TF}]\,, \tag{2}$$

where J_3 is the raw 3-particle correlation, $\hat{J}_2$ is the background subtracted 2-particle correlation, $B_2^{\rm inc}$ is the 2-particle background with flow, $B_3^{\rm inc}$ is the background with the two associated particles from one event and the trigger from another, $B_3^{\rm inc,TF}$ is the background were all three particles are from different events and the flow (v_2 and v_4) between the trigger particles and the associated particles added from measurements [10], and a and b are the normalization factors. The factor a is determined by 2-particle zero yield at $\Delta\phi = 1$ (ZYA1). The factor b accounts for different deviations from Poisson statistics for the background events and the underlying background.

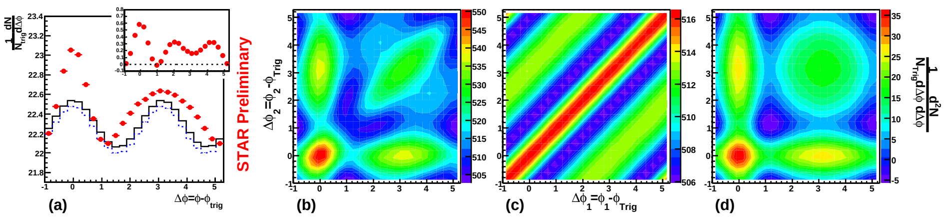

Fig. 4. (a) J_2 (red points), $B_2^{\rm inc}$ (solid line), $aB_2^{\rm inc}$, (dashed line) and $\hat{J}_2$, (b) J_3, (c) $B_3^{\rm inc}$, (d) $2a\hat{J}_2 B_2^{\rm inc} + a^2 b B_2^{\rm inc,TF}$. Plots are 0–12% Au+Au from [9].

Fig. 5 shows the background subtracted 3-particle correlations for pp, d+Au, and two centralities of Au+Au collisions. In pp and d+Au collisions, the away-side peak (π,π) is elongated along the diagonal which is consistent with $k_{\rm T}$ broadening. In Au+Au collisions, additional on-diagonal elongation of the away-side peak is seen. In central Au+Au collisions, off-diagonal away-side peaks are seen which signal for conical emission. The systematics for this study need to be fully understood.

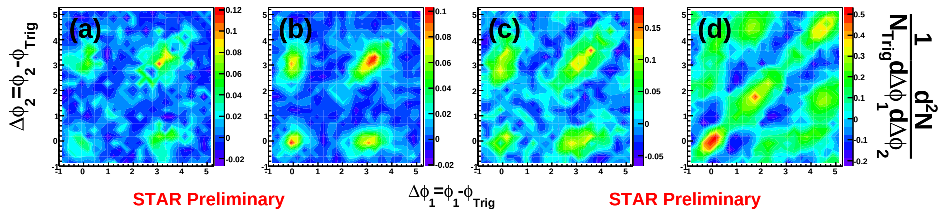

Fig. 5. Background subtracted 3-particle correlations in (a) *pp*, (b) *d*+Au, and (c) Au+Au 50–80% and (d) ZDC triggered 0–12% for $3 < p_{\mathrm{T}}^{\mathrm{Trig}} < 4$ GeV/c and $1 < p_{\mathrm{T}}^{\mathrm{Assoc}} < 2$ GeV/c. Data from [9].

4. Summary

Three 3-particle correlation analyses from RHIC are reviewed. The PHENIX analysis shows a 3-particle correlation shape more similar to the shape of their simulated Mach-cone signal than their simulated deflected jets signal. The STAR cumulant analysis shows finite 3-particle correlation, under a Poisson assumption. Further interpretation is complicated. The STAR 3-particle jet-like correlation analysis shows a conical emission signal in central Au+Au collisions.

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