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Conical emission: p_T and system dependences and the first result with identified particles from STAR

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Abstract : We present the analysis of three-particle correlation with respect to reaction system, transverse momentum (p_T) of associated and trigger particles measured by STAR experiment at RHIC. Our preliminary results indicate presence of conical emission of charge particles correlated with high p_T trigger particles in central A+A collisions. The measured conical emission angle is independent of p_T of associate hadrons, possibly consistent with Mach cone shock wave mechanism. The first result on PID three-particle correlation with identified associated particles is also reported.

Keywords : Mach cone, quark gluon plasma, jet quenching

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1. Introduction

Multi-particle azimuthal correlations are useful probes to explore the properties of the strongly interacting partonic matter created in Au+Au collisions at the Relativistic Heavy Ion Collider (RHIC). [1]. The modification of away side in di-hadron azimuthal correlation has been observed [2,3], which indicates that away side jets quench and lose energy into the nearby dense medium [4]. For selected kinematic regions, the away-side correlation is even double-peaked [5]. In order to explain its origin, many ideas have been proposed, such as Mach cone shock wave [6–8], Cherenkov radiation [9, 10], the correlation between jets and the flowing medium [11]. While two-particle correlations are ambiguous, three-particle correlation method is able to discriminate these different mechanisms [12, 13].

In this article we present a systematic measurement of three-particle azimuthal correlation from STAR, as a function of the collision system, both the trigger and associated pt's, and associated particle species. We observed evidence of conical emissions in the central A+A collisions at RHIC.

2. Analysis detail

The event is treated as composed of two components: one is the part correlated with the trigger (including jets and other correlations such as resonance decays), and the other is background uncorrelated with the trigger except the indirect correlation *via* anisotropic flow. The background includes the following three parts: (1) hard-soft background, in which one associated particle is jet-like correlated with the trigger and the other is not. In analysis this background is constructed by folding the 2-particle correlation and its flow modulated background (2) soft-soft background arises from combining a trigger from one event with two background particles from one inclusive event, which contains all correlations between the two background particles but is unrelated to the trigger. In analysis this background is by mixing a trigger particle in one event with two associated particles from another (inclusive) event. (3) trigger flow background, the flow correlation between the trigger particle and the two associated particles. This background is constructed by mixing the trigger with two associated particles from two different inclusive events with flow correlation added in by hand. For other analysis details and systematic uncertainty studies, [12, 14, 15].

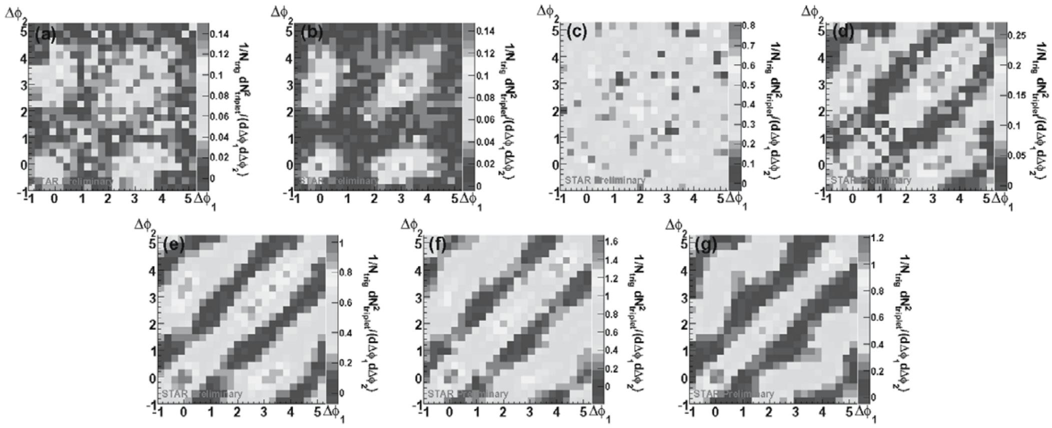

Figure 1. Background subtracted 3-particle correlations, for (a) pp, (b) d+Au, (c) Cu+Cu (10-0%), (d) Au+Au (80-50%), (e) Au+Au (50-30%), (f) Au+Au (30-10%), and (g) Au+Au (12-0%) at $\sqrt{s_{NN}}$ =200 GeV. The pp, d+Au and Au+Au data are from Ref. [14].

Figure 1 (a)-(g) shows the background subtracted 3-particle correlations for p+p, d+Au, Cu+Cu (0-10%), Au+Au (80-50%), Au+Au (50-30%) Au+Au (30-10%) and Au+Au (12-0%) at $\sqrt{s_{NN}}$ =200 GeV. The signal shape varies with reaction system, but four peaks at $(\Delta\phi_1, \Delta\phi_2)$ = (0, 0), (π, π), (0, π) and (π, 0) are observed for all systems, which indicates di-jet or its remanents. For A+A collisions, the away-side signal is distributed along both diagonal and off-diagonal directions. The observation of the off-diagonal peaks provides direct evidence of conical emission of charged hadrons correlated with high p_T trigger particles. Meanwhile, the side peaks along the diagonal projection contain conical emission and possibly other contributions such as k_T broadening, large angle gluon radiation, and deflected jets.

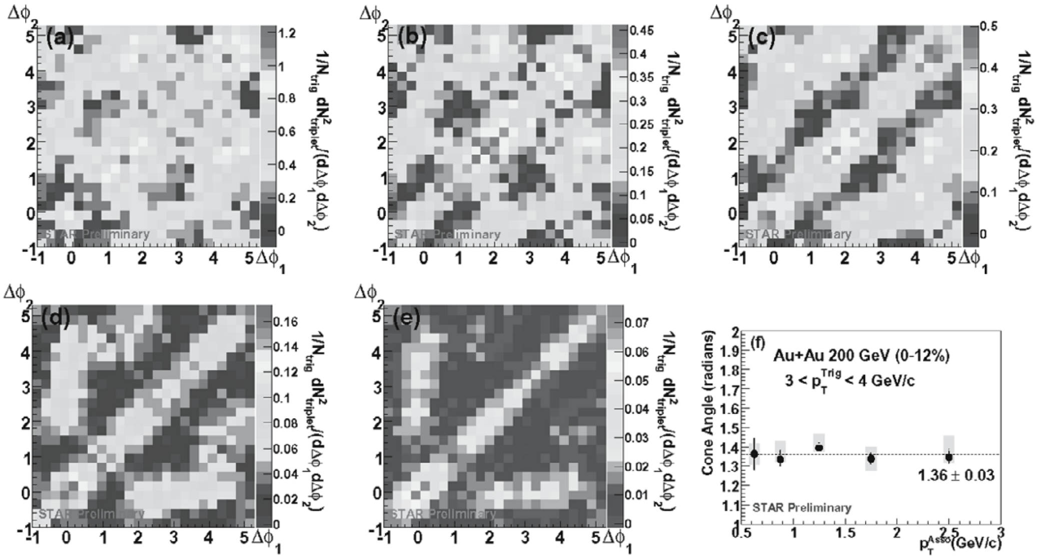

Figure 2. Background subtracted 3-particle correlations for Au+Au collisions (12-0%) at 200 GeV [15]. p_T of Trigger particle p_T is 3 < p_T < 4 GeV/c and associated particle p_T is (a) 0.5 < p_T < 0.75, (b) 0.75 < p_T < 1, (c) 1 < p_T < 1.5, (d) 1.5 < p_T < 2, and (e) 2 < p_T < 3 GeV/c. (f) Associated p_T dependence of the conical emission angle, where the shaded areas show the systematic errors.

Figure 2 (a)-(e) show the background subtracted three-particle correlation with trigger particles of 3 < p_T^{Trig} < 4 GeV/c, but with associated particles of different p_T^{Asso} for Au+Au collisions (12-0%) at $\sqrt{s_{NN}}$ = 200 GeV. Figure 2 (f) shows the conical emission angle as a function of the associate p_T . No associated p_T dependence is observed in the emission angle, suggesting Mach cone shock wave as the underlying physics mechanism. The average angle value is 1.36 ± 0.03 rad.

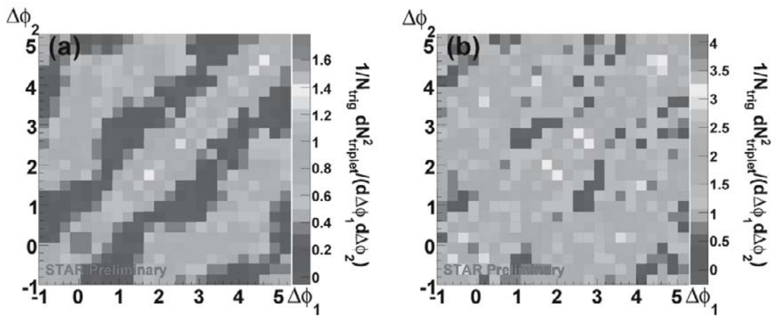

Figure 3. Three-particle correlations with trigger particles of 4 < p_T^{Trig} < 6 GeV/c (a) and 6 < p_T^{Trig} < 10 GeV/c (b) with associated particles of 1 < p_T^{Trig} < 2 GeV/c for Au+Au collisions (12-0%) at 200 GeV [15].

On the other hand, Fig. 3 (a) and (b) (also Fig. 1 (g)) show the background subtracted threeparticle correlation for associated 1 < p_T < 2 GeV/c and different trigger p_T ranges for central Au+Au collisions (12-0%) at $\sqrt{s_{NN}}$ = 200 GeV. We found that the conical emission structure of three-particle correlation exists from 3< p_T^{Trig} <4 to 6< p_T^{Trig} <10 GeV/c. The magnitude of signal increases with p_T^{Trig} consistent with the increase of jet energy. We observe evidence of conical emission for all measured trigger p_T.

4. Identified hadron correlation results

To gain more insights, we study three-particle correlation with identified associated hadrons with (unidentified) trigger particles. We identify associated particles by the specific ionization energy loss (dE/dx) in the STAR-TPC. The tracks within $\pm 2\sigma$ of the Bethe-Bloch expectation dE/dx [16] are selected as pion and (anti-)proton candidates. We restrict the associated p_T to 0.7 < p_T < 1.4 GeV/c where the lower cut eliminates proton background and the higher cut is imposed by the dE/dx particle identification limit. Two types of PID three-particle correlations have been studied: (1) h-$\pi\pi$, *i.e.* charge hadrons as trigger and identified pions as associated particles, and (2) h-pp, *i.e.* charge hadrons as trigger and identified protons as associated particles. It is expected to reflect the properties of different components inside the conical emission cone.

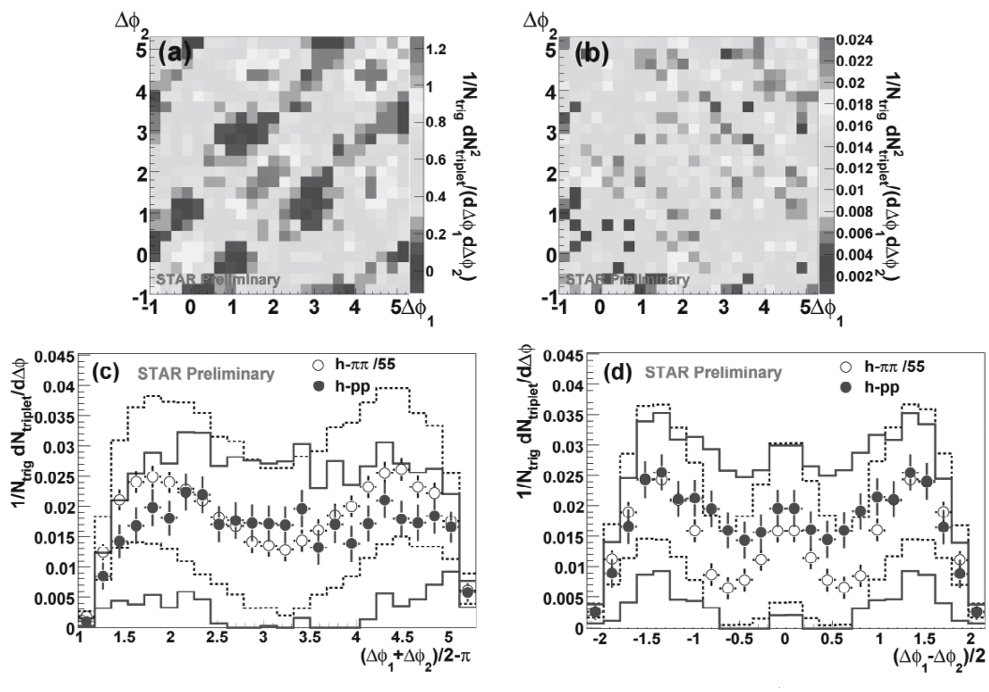

Figure 4. Background subtracted 3-particle correlations with identified associated $\pi^+ + \pi^-$ $(h - \pi\pi)$ (a) and $p + \bar{p}$ (h-pp) (b) for Au+Au 200 GeV collisions (12-0%), where 2.5 < p_T^{Trig} < 10 and 0.7 < p_T^{Asso} < 1.4 GeV/c; Diagonal (c) and off-diagonal (d) projections for $h - \pi\pi$ (open circle) and h-pp (solid circle), where dash and solid histograms are systematic errors for $h - \pi\pi$ and h-pp, respectively.

Figure 4 (a) and (b) show the background subtracted h-$\pi\pi$ and h-pp three-particle correlations with 2.5 < p_T^{Trig} < 10 and 0.7 < p_T^{Asso} < 1.4 GeV/c for Au+Au collisions (12-0%) at $\sqrt{s_{NN}}$ = 200 GeV. Figure 4 (c) and (d) show the comparison of diagonal and off-diagonal projections for h-$\pi\pi$ (open circle) and h-pp (solid circle), respectively. The histograms show the corresponding systematic errors, manly due to the background subtraction [14, 15]. The h-$\pi\pi$ correlation is scaled down by a factor of 1/55 in order to compare the correlation shapes on the same graph. The shapes are found to be the same with the systematic uncertainties. The present systematic uncertainties are large and will need further studies.

5. Summary

Three-particle correlation results from different reaction systems, including p+p, d+Au, Cu+Cu (10-0%) and Au+Au (80-50%, 50-30%, 30-10% and 12-0%) collisions at $\sqrt{s_{NN}}$ = 200 GeV are presented. The observation of off-diagonal peaks in central A+A collisions is evidence of conical emission of charge particles correlated with high p_T trigger particles. The p_T^{Asso} -independent conical emission angle is possibly consistent with formation of Mach cone shock waves. In addition, the first result on three-particle correlations with identified associated particles is reported. Within current systematic uncertainties, no difference is observed in the shapes between h-$\pi\pi$ and h-pp three-particle correlations.

References

[1] J Adames *et al.,* (STAR Collaboration) *Nucl. Phys.* **A 757** 102 (2005); S S Adler *et al.* (PHENIX Collaboration) *Nucl. Phys.* **A 757** 184 (2005)

[2] C Adler *et al.,* (STAR Collaboration) *Phys. Rev. Lett.* **90** 082302 (2003)

[3] J Adams *et al.,* (STAR Collaboration), *Phys. Rev. Lett.* **95** 152301 (2005)

[4] X-N Wang and M Gyulassy *Phys. Rev.* **D 44** 3501 (1991)

[5] J G Ulery (STAR Collaboration) *Nucl. Phys.* **A 774** 581 (2006); M J Horner (STAR Collaboration) arXiv:nucl-ex/0701069

[6] H Stöcker *Nucl. Phys.* **A 750** 121 (2005)

[7] J Casalderrey-Solana *et al., J. Phys. Conf. Ser.* **27** 22 (2005)

[8] J Ruppert, B Müller *Phys. Lett.* **B 618** 123 (2005)

[9] V Koch, A Majumder, Xin-Nian Wang *Phys. Rev. Lett.* **96** 172302 (2006)

[10] I M Dremin *Nucl. Phys.* **A767** 233 (2006)

[11] N Armesto, C A Salgado and Urs A Wiedemann *Phys. Rev. Lett.* **93** 242301 (2004)

[12] J G Ulery and Fuqiang Wang arXiv:nucl-ex/0609016, nucl-ex/0609017

[13] C A Pruneau *Phys. Rev.* **C 74** 064910 (2006)

[14] B I Abelev *et al.,* (STAR Collaboration), arXiv:0805.0622

[15] J G Ulery, arXiv:0801.4904, Ph.D. thesis, Purdue University (2007)

[16] H Bichsel *Nucl. Instrum. Meth.* **A 562** 154 (2006)