Jet-like correlations from d+Au to Au+Au collisions measured by STAR, using back-to-back leading hadrons

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1 Abstract

In this work jet-medium interactions are studied via a multi-hadron "2+1"correlation technique, where a pair of back-to-back hadron triggers with large transverse momentum is used as a proxy for a di-jet axis. This work extends the previous analysis [1] to higher energy of the primary trigger, allowing the asymmetry of the back-to-back trigger pair to potentially control the surface bias of the hard-scattering and the path-length traversed by the jet. The correlation functions and associated charged-particle spectra around each trigger ($|\Delta\eta|<0.5$ and $|\Delta\phi|<0.5$) are measured and compared between central Au+Au events and minimum bias d+Au. In contrast to the di-hadron correlation results with single triggers, the correlation function and spectra in the "2+1" analysis show no significant modifications (no suppression, no ridge, no double peaks) in $\sqrt{s}NN$ = 200 GeV central Au+Au collisions for the di-jets studied.

However, we report first quantitative measurements of the energy imbalance found for such di-jets. The total transverse momentum of each jet, ΣE_T, was calculated by summing the p_T for all associated charged particles plus the trigger hadron. The relative energy imbalance for di-jets was determined by taking the difference of ΣE_T on the near- and away-side and comparing with the d+Au reference to account for trivial k_T effects. The excess of the energy imbalance ($\Delta\Sigma E_T$) in Au+Au vs. d+Au data is found to increase with the asymmetry of the trigger pairs. In addition, this relative $\Delta\Sigma E_T$ is found to increase with the transverse momenta of associated hadrons. Such an evolution indicates that the energy missing at higher p_T-associated is converted into softer hadrons, and provides discriminating power of the theoretical models of the medium effect on jets.

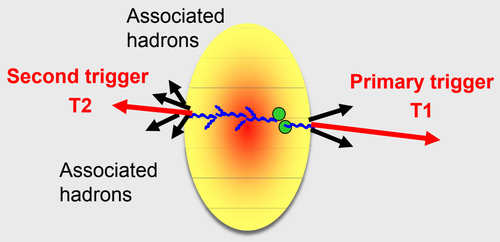
2 Data sets and Analysis Method

Data used: $\sqrt{s_{NN}}$ **= 200 GeV** from years
2003 (d+Au),
2004 (Au+Au, central trigger, top 12%),
2007 (Au+Au 20% most central),
2008 (d+Au)

Analysis selection (low thresholds):
Charged triggers: TPC tracks p_T>4 GeV/c
Neutral triggers: BEMC clusters E_T >8 GeV/c,
Associated hadrons: TPC tracks p_T >1 GeV/c

Di-jet selection:

Primary trigger (T1) – highest energy in the event
Secondary trigger (T2) – back-to-back with T1 ($|\phi_{T1} - \phi_{T2} - \pi| < 0.2$)
Correlation function relative to each trigger (**Eq. 1**)



$$\frac{d^2N}{d\Delta\eta d\Delta\phi} = \frac{1}{N_{trig}\epsilon_{\rm pair}}\left(\frac{d^2N_{raw}}{d\Delta\eta d\Delta\phi}\right) - a_{zyam}\frac{d^2N_{Bg}}{d\Delta\eta d\Delta\phi} \quad (1)$$

Where ε_{pair} – pair acceptance correction from mixed events and single-track efficiency (**Fig.1**); a_{zyam} – background level estimated with the Zero-Yield at Minimum (ZYAM) method, and N_{Bg}– combinatoric background modulated by elliptic flow (**Eq.2**)

$$N_{Bg} \propto 1 + \frac{2v_2^{T1(orT2)}v_2^{assoc} + 2v_2^{T2(orT1)}v_2^{assoc}\frac{\sin(2\alpha)}{2\alpha}}{1 + 2v_2^{T1}v_2^{T2}\frac{\sin(2\alpha)}{2\alpha}}\cos(2\Delta\phi) \quad (2)$$

Here $\alpha = 0.2$ the width of the back-to-back trigger selection window.

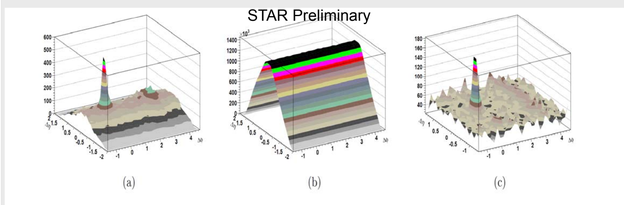


FIG. 1: Central 20% Au+Au, T1 [8,10] GeV, T2 [4,10] GeV/c, associated [1.5,10] GeV/c. (a) A sample of two-dimensional raw correlation function before efficiency and acceptance correction. (b) The corresponding two-dimensional mixing-event background acceptance plot. (c) The two-dimensional correlation function after single efficiency and pair acceptance correction.

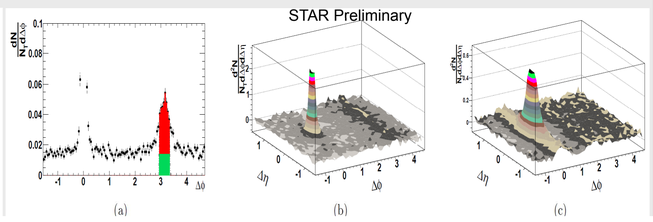


FIG.2:Central 20% Au+Au,T1 [8,10] GeV, T2 [4,10] GeV/c, assoc [1.5,10] GeV/c. In panel a) back-to-back dijet trigger pair include true signal(red) and fake background (green). The effect of such fake dijets is two independent 2-particle correlation on b) near-side of 2+1, and c) away-side of 2+1.

Correlated background (due to randomly associated triggers) is estimated from signal to background ratio (**Fig.2 *a***) and single-trigger di-hadron correlation for T1 and T2 thresholds (**Fig.2 *b* and *c***).

4 Discussion: theoretical models via energy imbalance and di-jet rates

Relative di-jet energy imbalance: $\Delta(\Sigma E_T) = (\Sigma E_T^{near} - \Sigma E_T^{away})^{Au+Au} - (\Sigma E_T^{near} - \Sigma E_T^{away})^{d+Au}$

Symmetric triggers [1]: $\Delta\Sigma E_T \sim 0$

- Disfavors energy loss in the medium.
- **Indicates** a strong surface-bias for both near-/away-side jets.

Asymmetric triggers: $\Delta\Sigma E_T > 0$

- Significant relative imbalance $\Delta\Sigma E_T$
- Increasing $\Delta\Sigma E_T$ with trigger pair asymmetry; possible dependence on the associated hadron p_T
- **Indicates** softening of fragmentation function for di-jets selected.

❖ Theoretical model with path-length dependent energy loss[2]

- Similar trend, ***but*** much larger total energy deposition into the medium was predicted from such models.
- New calculations are desirable for more direct comparison with experimental data.

❖ The "core/corona" scheme

- Glauber-based MC model with **core** (full jet absorption) and **corona** (no jet-medium interactions).
- Consistent with centrality trend for survival of di-jets with symmetric triggers[1].
- New $\Delta\Sigma E_T$ measurements and possible dependence of di-jet survival on trigger asymmetry favor a path-length dependent energy loss.

❑ **References**: [1] Phys. Rev. C 83 (2011) 016901, [2] T. Renk Phys. Rev. C 78 (2008) 014903

3 Results

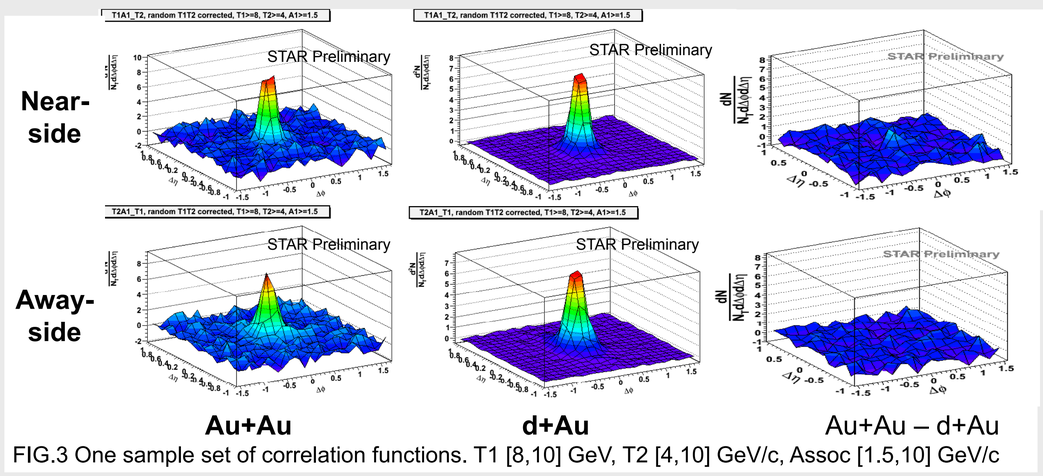
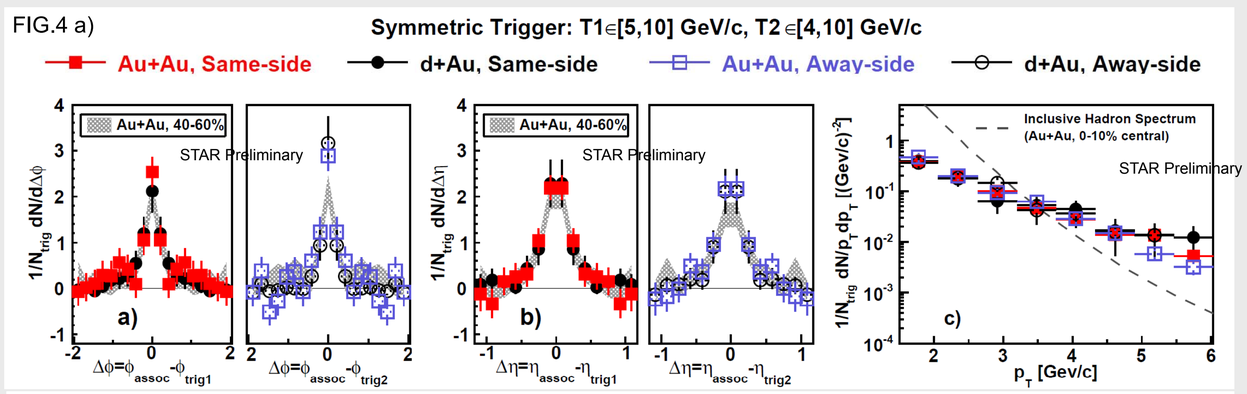


FIG.3 One sample set of correlation functions. T1 [8,10] GeV, T2 [4,10] GeV/c, Assoc [1.5,10] GeV/c

Fig.3 Sample set of 2-D correlation functions: clear jet-like peaks on near- and away-sides in central Au+Au data of similar magnitude with d+Au reference. No "ridge" or "double-peaks" are evident in the Au+Au – d+Au **difference**.



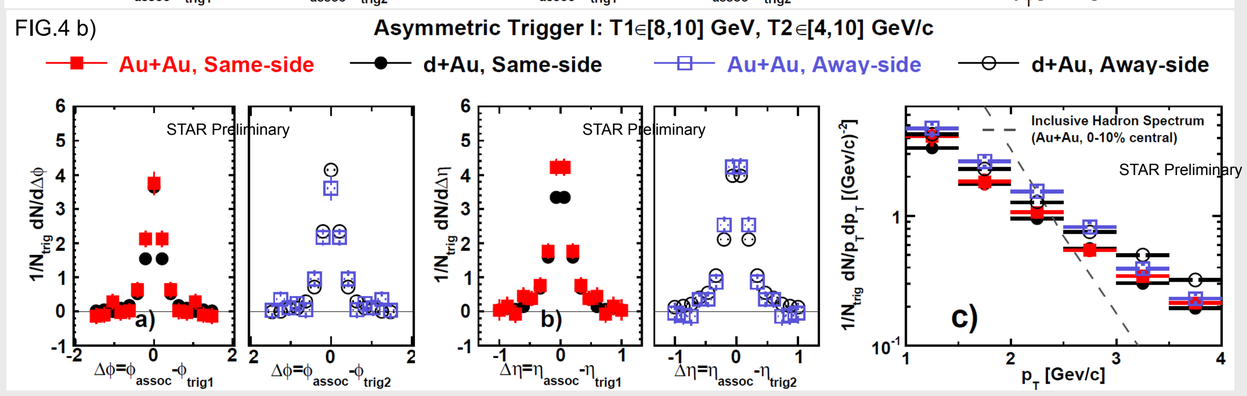


Fig.4 $\Delta\phi$ and $\Delta\eta$ projection and spectra comparison for a)nearly-symmetric and b)asymmetric trigger-pair cases. The Au+Au and d+Au associated hadron transverse momentum spectra are also similar on either near- or away-side.

Relative energy imbalance

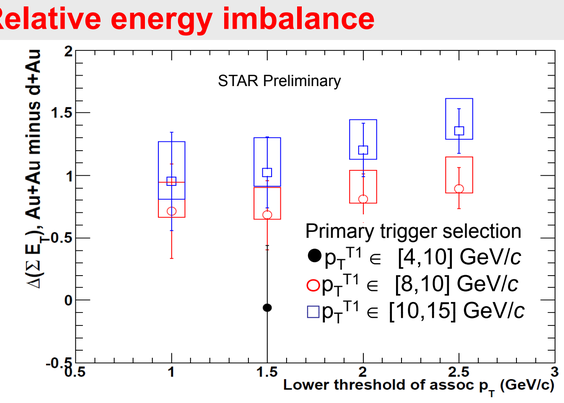


FIG.5 The excess of di-jet energy imbalance in Au+Au over d+Au

Primary trigger T1 p_T selections are indicated in the plot.
All $p_T^{T2} \in$ [4,10] GeV/*c*.

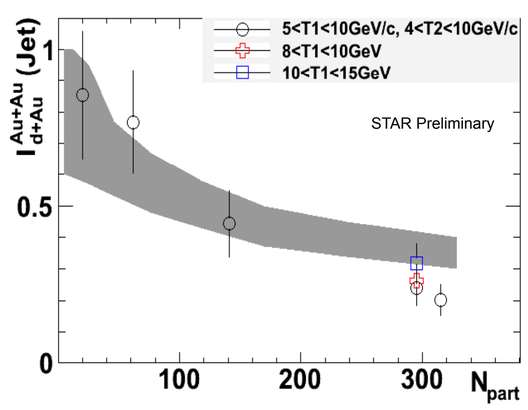


FIG.6 The relative suppression ofdi-jet production rates

$$I_{d+Au}^{Au+Au} = \frac{Au+Au_{singlejet}^{di-jet}}{d+Au_{singlejet}^{di-jet}}$$