Characterizing the away-side jet, devoid of flow background, via two- and three-particle correlations in Au+Au collisions at 200 GeV in STAR

Kun Jiang, *for the STAR Collaboration*

University of Science and Technology of China & Purdue University

2015 KOBE JAPAN

Abstract

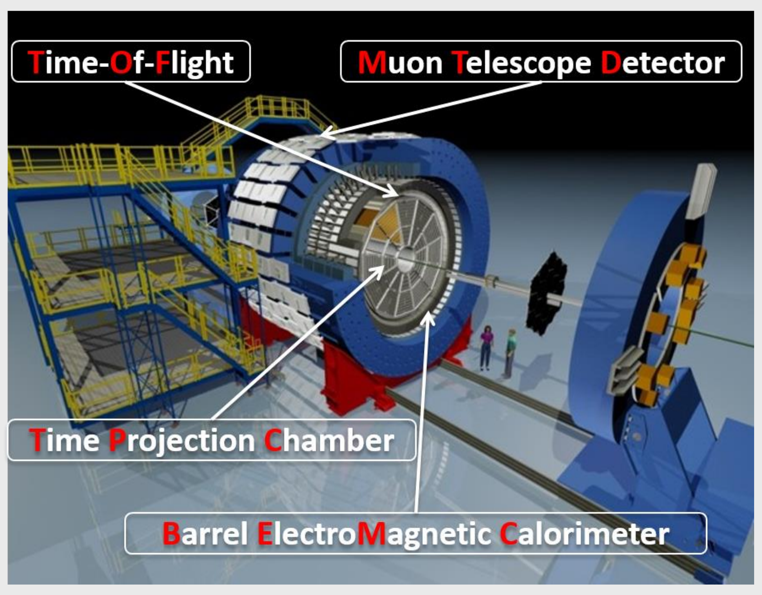
Jets are modified in relativistic heavy-ion collisions due to jet-medium interactions. Measurements of jet medium modifications have so far been obscure because of the large underlying anisotropic flow background. In this analysis we devise a novel method to subtract the flow background using data themselves. The away-side jet correlation width is studied as a function of centrality and associated particle p_T. The width is found to increase with centrality at modest to high associated particle p_T. The increase can arise from jet-medium modifications, event averaging of away-side jets deflected by medium flow, and/or simply nuclear k_T broadening. To further discriminate various physics mechanisms, a three-particle correlation analysis is conducted with robust flow background subtraction also using data themselves. Based on this analysis we discuss possible physics mechanisms of away-side broadening of jet-like correlations.

1. Experiment Setup

The Solenoidal Tracker at RHIC (STAR) covers 2π in azimuth and two units of pseudorapidity $|\eta|<1$

- Time Projection Chamber (TPC) – tracking
- Event selection
  - $|V_z|<30$cm: RHIC run 2010 (MB 240M, central trigger 150M)
  - $|V_z|<30$cm: RHIC run 2011 (MB 320M)
  - $|V_z|<6$ cm: RHIC run 2014 (MB 520M)
  - $|V_z\text{-vpd}V_z|<3$cm (VPD: vertex position detectors)
  - $|V_r|<2$cm
- Track selection
  - Pseudo-rapidity $|\eta|<1$
  - Number of TPC hits>20
  - distance of closest approach<2 cm
  - Ratio of fit points to maximum fit points>0.52

FIG. 1. Picture of the STAR detector



2. Methodology (Robust, automatic flow subtraction)

- **Two-particle azimuthal correlations**

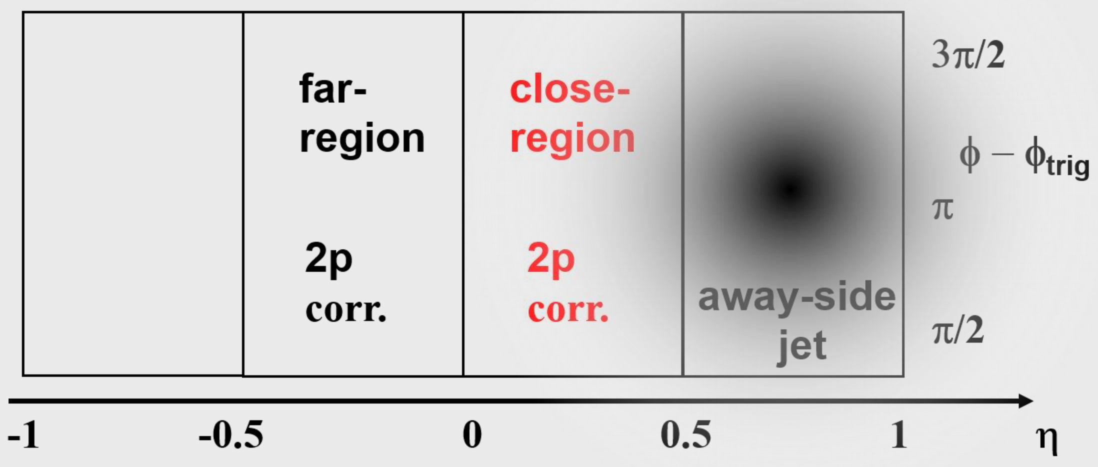


Fig. 2: Cartoon: methodology for two-particle correlations.

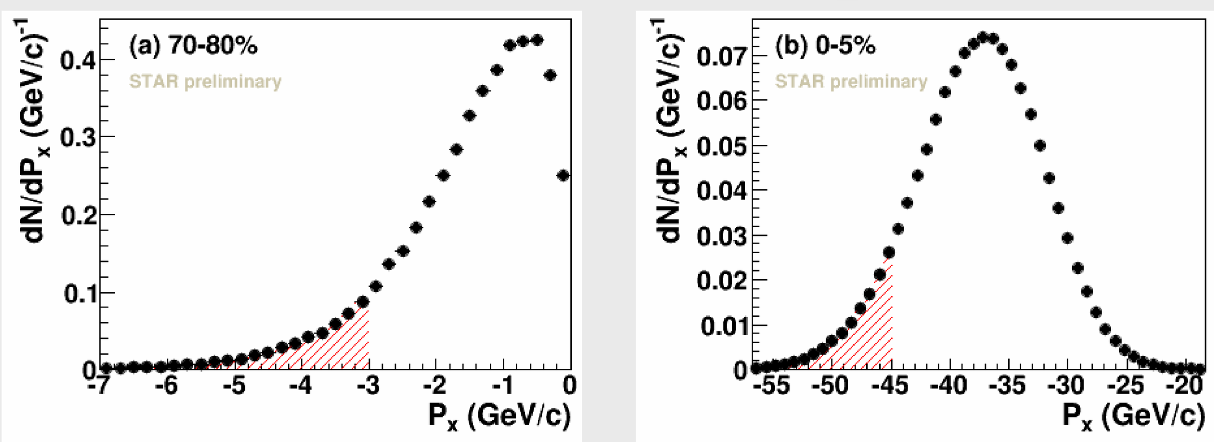


Fig. 3: Distributions of recoil momentum (P_x) from a high-p_T trigger particle with $3<p_T^{trig}<10$ GeV/c.

Select 10% of events on the left tail of the distribution to enhance away-side jet population inside acceptance of $0.5<\eta<1$ (or $-1<\eta<-0.5$)

a) Trigger particle ($3<p_T^{trig}<10$ GeV/c) over all η range ($|\eta|<1$)
b) P_x is corrected by run-by-run ϕ-dependent efficiency*acceptance
c) η-dependent correction: treat symmetrized $dN/d\eta$ distribution from $|z_{vtex}|<2$cm as the baseline. The ratio of the $dN/d\eta$ distribution from each z_{vtex} bin to this baseline is the η- and z_{vtex}-dependent correction
d) **Di-hadron $\Delta\phi$ correlations are analyzed for associated particles ($0.15<p_T^{assoc}<3$ GeV/c) in two η ranges symmetric about midrapidity, one close to and the other far away from the P_x η window**
e) Correlations are corrected for η– and p_T- dependent efficiency*acceptance and then by mixed events
f) **Flow backgrounds are the same in close-region and far-region, and thus cancelled in their difference. What's left in the difference is away-side short-range correlations.**

- **Three-particle azimuthal correlations**

Suppose an event is composed of:
(besides the trigger particle **T**)
- **A**: Jets correlated with the trigger (di-jet)
- **f**: flow background
- **a**: jets uncorrelated with the trigger

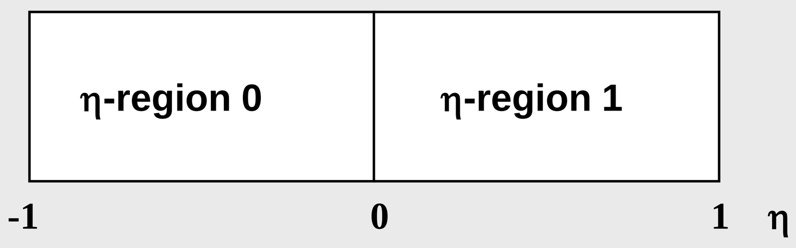


Fig. 4: Cartoon: methodology for three-particle correlations

a) **same η-region pairs** = TAf+TAa+TfA+Tff+Tfa+TaA+Taf+TAA+Taa
b) **cross η-region pairs** = TAf+TAa+TfA+Tff+Tfa+TaA+Taf
c) **same η-region pairs - cross η-region pairs** = TAA + Taa
d) **Background jets Taa:** Background jets in triggered events = jets in min-bias events (no requirement of a trigger, normalized per event)

What's left in three-particle correlations are the short range correlations on both the near side and away side

3. Data Analysis

- **Two-particle correlations**

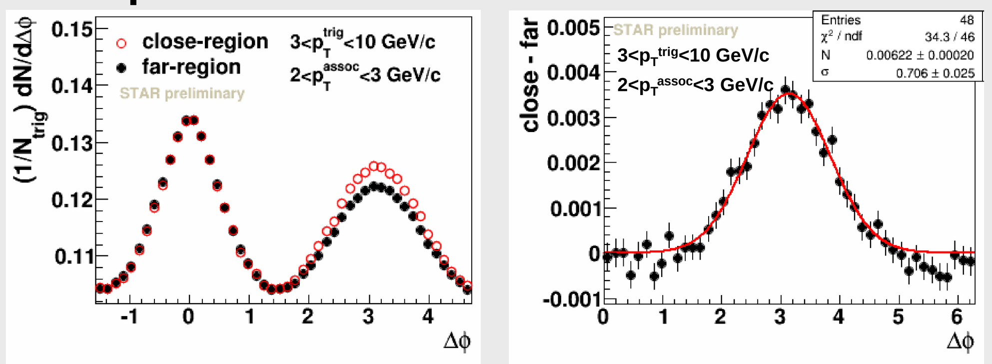


Fig. 5: (left) Di-hadron $\Delta\phi$ correlations in close-region and far-region in min-bias Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. (right) The difference between close- and far-regions $\Delta\phi$ correlations.

- **Three-particle correlations**

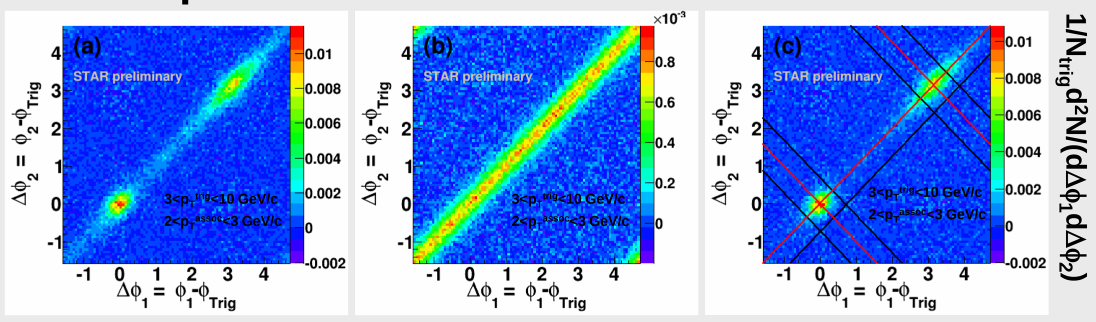


Fig. 6: 60-80% Au+Au. (a) Same η-region correlations minus cross η-region correlations. (b) Background jet correlations. (c) Background-subtracted three-particle correlations. The red lines indicate the diagonal and off-diagonal and the black lines indicate the projection ranges.

Different physics mechanisms for away-side broadening give distinctive 3-particle correlation structures

4. Systematic Error Evaluation

- **Two-particle azimuthal correlations**
  - ✓ P_x cut > {2%, 5%, 10%, 15%, 20%, 30%, 50%}
  - ✓ DCA < {1, 2, 3}
  - ✓ NFitPoint > {15, 20, 25}
- **Three-particle azimuthal correlations**
  - ✓ DCA < {1, 2, 3}
  - ✓ NFitPoint > {15, 20, 25}

5. Results

PRD 74 (2006) 072002
PRC 73 (2006) 054903
PLB 743 (2015) 333-339
PLB 747 (2015) 265-271

- **Two-particle azimuthal correlations**

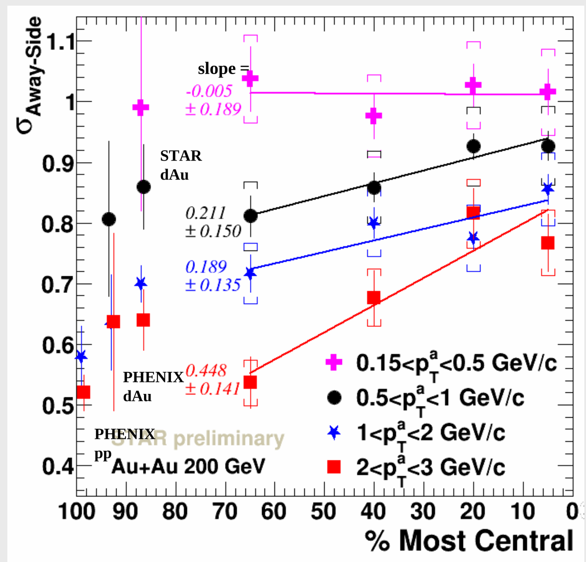


FIG. 7. Away-side jet correlation width as a function of centrality for $3<p_T^{trig}<10$ GeV/c and various p_T^{assoc} bins in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

Away-side correlation broadens with centrality except very low pT

- **Three-particle azimuthal correlations**

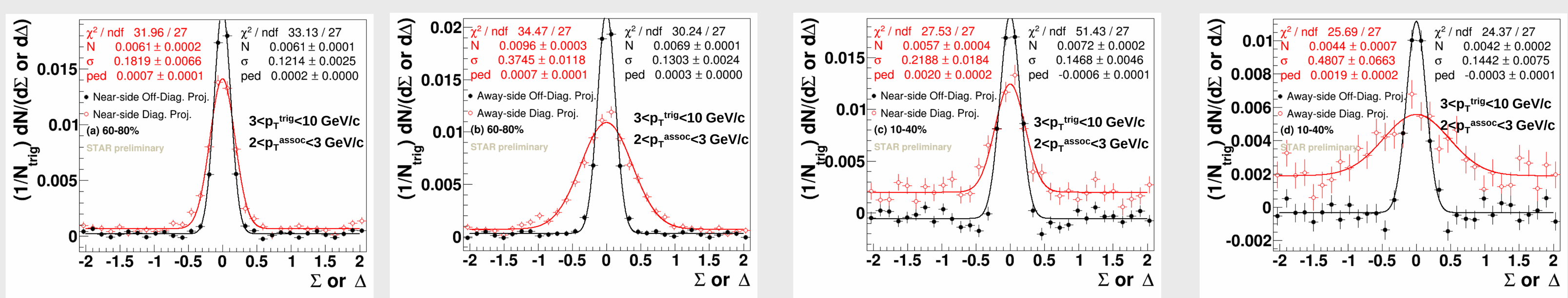


FIG. 8. Projections of near-side and away-side three-particle correlations along the diagonal Σ within $0<\Delta<0.35$ and off-diagonal Δ within $|\Sigma|<0.35$.

$\Sigma = (\Delta\phi_1+\Delta\phi_2)/2-\pi$ (away-side) or
$\Sigma = (\Delta\phi_1+\Delta\phi_2)/2$ (near-side)
$\Delta = (\Delta\phi_1-\Delta\phi_2)/2$

Off-diagonal projection: intra-jet correlations
Diagonal projection: inter-jet correlations

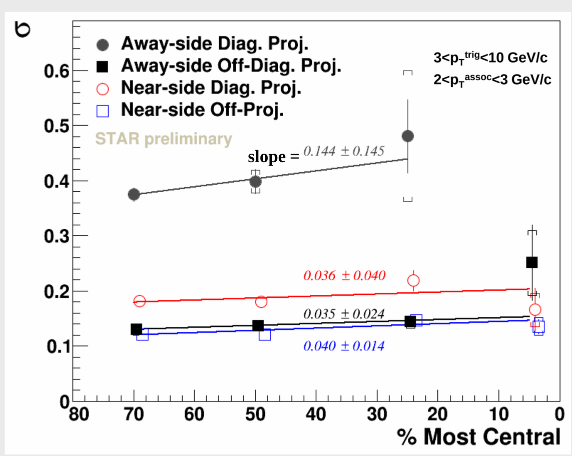


FIG. 9. Width of the diagonal and off-diagonal projections of the three-particle correlations.

- **Near σ diag > off-diag. → jet axis swing effect? (the trigger and the two associated particles are likely on different sides of the jet axis)**
- **Away σ diag >> off-diag. → significant k_T and/or flow deflection.**
- **Off-diagonal σ near = away and no centrality dependence → little jet modification?**

6. Summary

- Novel methods were devised to measure away-side jet correlations with clean, robust flow subtraction
- Away-side correlation broadens with centrality except low p_T (where the correlation is broad in all centralities).
- Near-side diagonal projection broader than off-diagonal projection → Jet axis swing effect?
- Away-side diagonal projection is significantly broader than off-diag. → significant k_T and/or flow deflection. Need d+Au data to better quantify relative strengths.
- Off-diagonal width similar between near- and away-side, and no centrality dependence is found. → Little jet-shape modification on the away side?