Measurement of away-side jet broadening in Au+Au collisions at 200 GeV in STAR

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Motivation

- Energetic partons lose energy due to interactions in the dense medium

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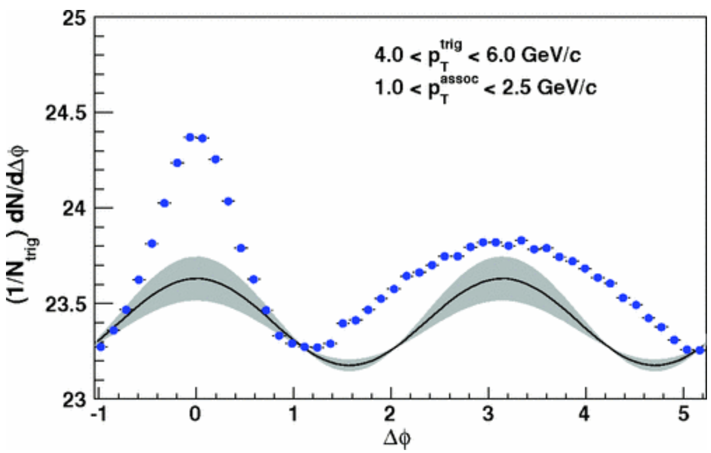
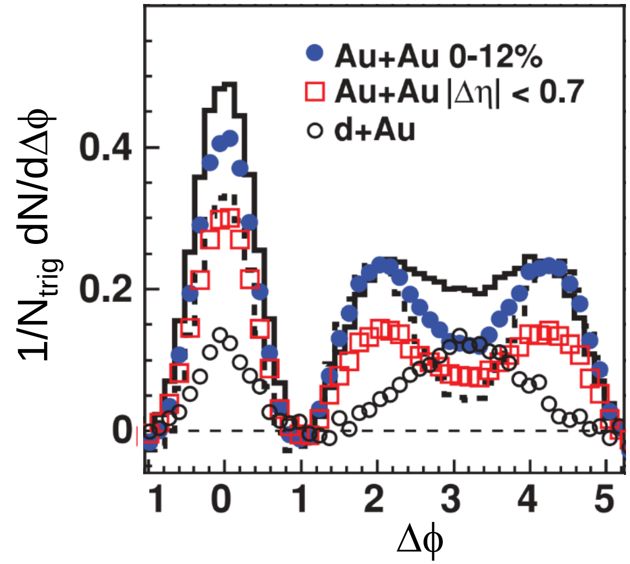
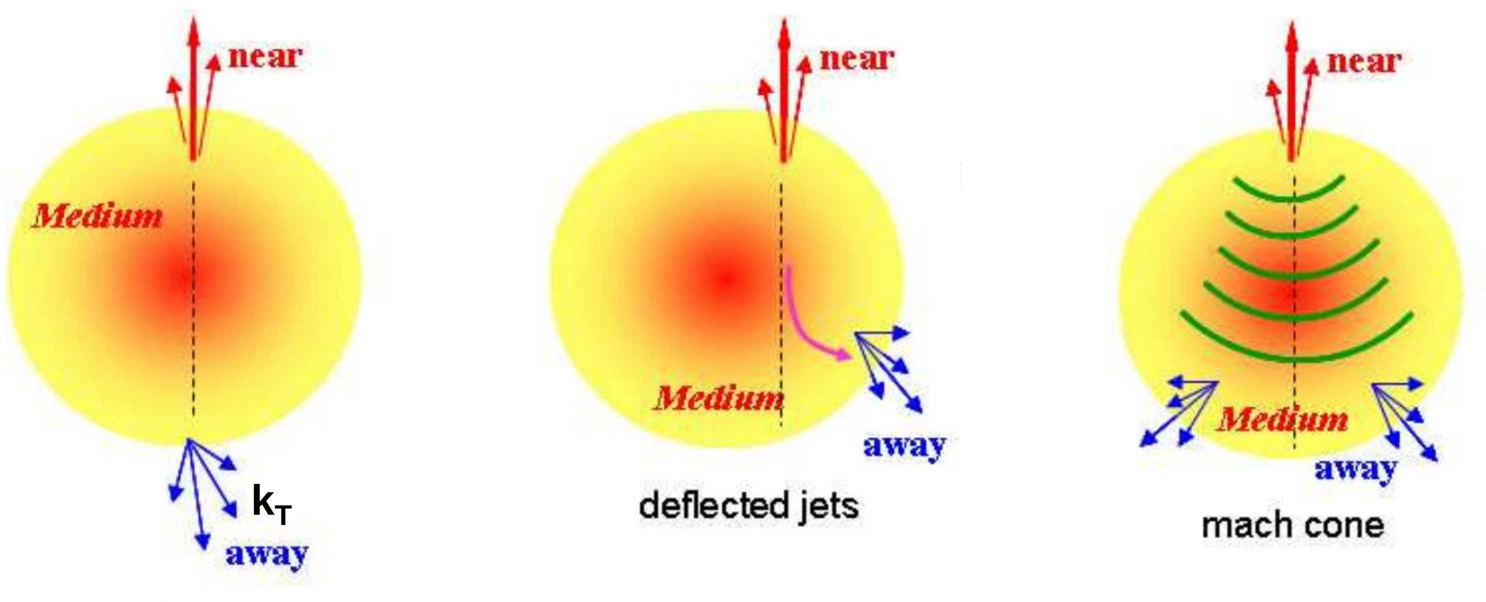




- Measurements of medium modifications of jets have so far been obscured by the large anisotropic flow background. Flow shape and amplitude are not precisely known.
- All orders of v_n are possible and need to be subtracted
- We devise a method to subtract flow background using data

k_T effect and jet-medium interactions

- Nuclear k_T effect
- Event averaging of away-side jets deflected by medium flow
- Collective medium excitation by Mach cone shock waves

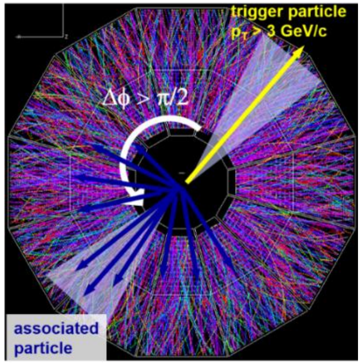


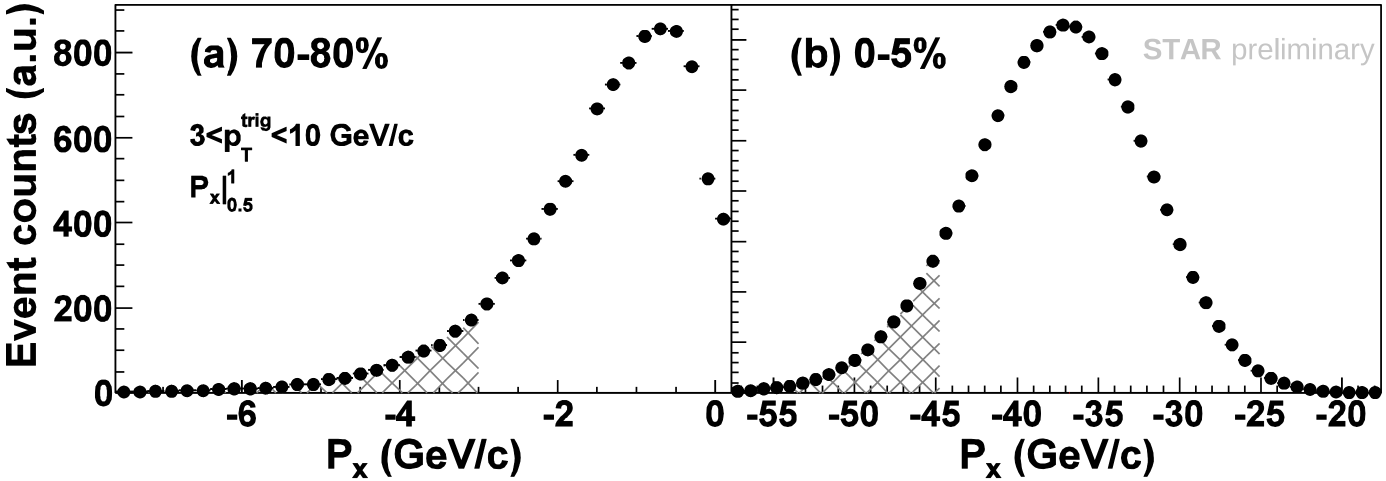
Two-particle correlation results

P_x: projection of away-side p_T onto trigger axis

$$P_x \Big|_{\eta_1}^{\eta_2} = \sum_{\eta_1<\eta<\eta_2, |\phi-\phi_{trig}|>\pi/2} p_T \cdot \cos(\phi - \phi_{trig}) \cdot \frac{1}{\varepsilon}$$

ε: single-particle acceptance $\times$ efficiency

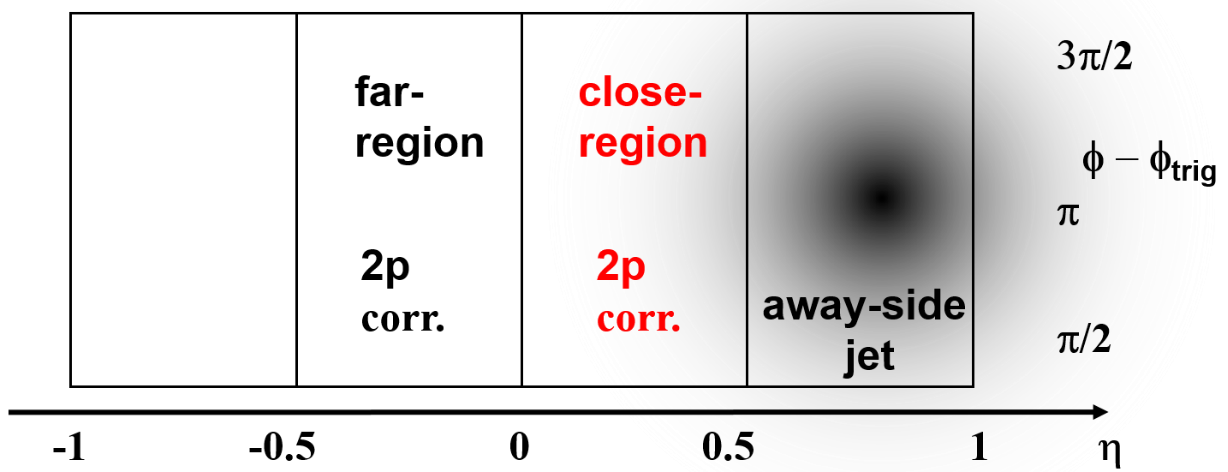




- For each centrality, cut on the left tail of the distribution (fraction of events) to enhance away-side jet population

Methodology for two-particle correlations

Trigger particle |η| < 1

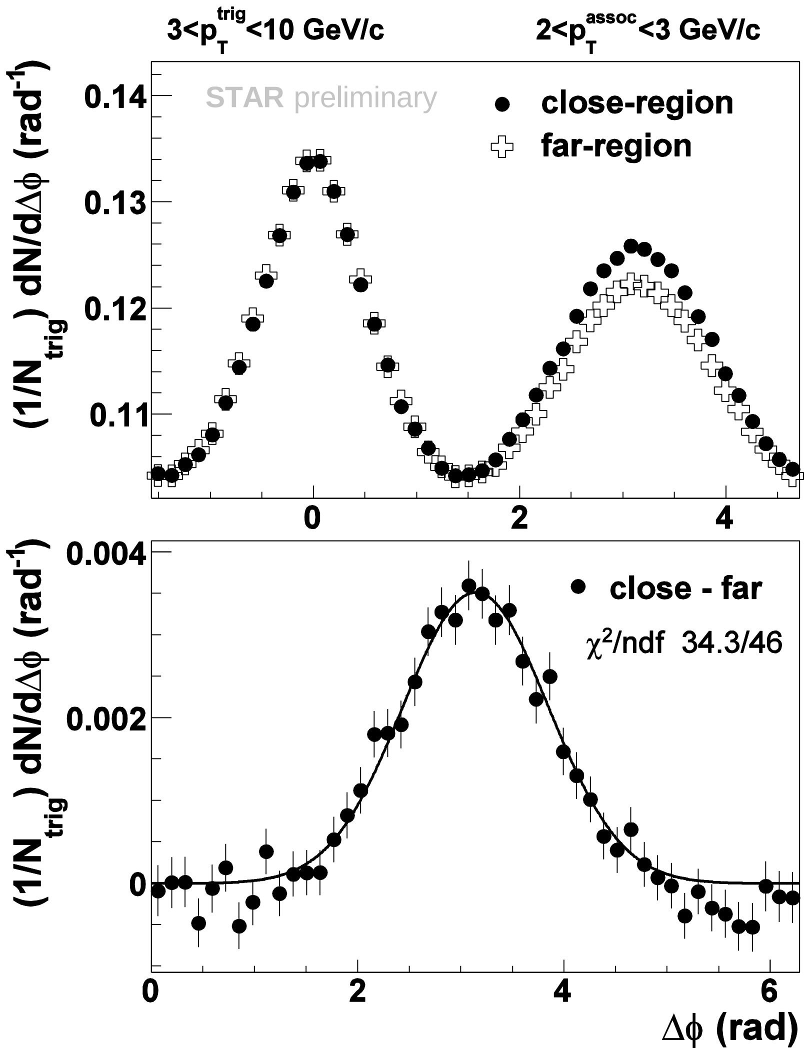


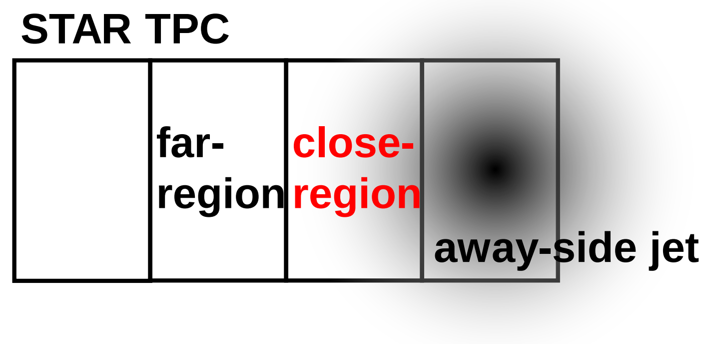
- Select events with a large recoil momentum (P_x) within a given η window (cartoon 0.5<η<1) from a high-p_T trigger particle to enhance away-side jet population
- Analyze di-hadron correlations in close-region and far-region respectively
- Flow contributions to close-region and far-region are equal

close-region 2p corr. = flow + near-side jet + away-side jet ∗ fraction_close

far-region 2p corr. = flow + near-side jet + away-side jet ∗ fraction_far

STAR Au+Au 200 GeV



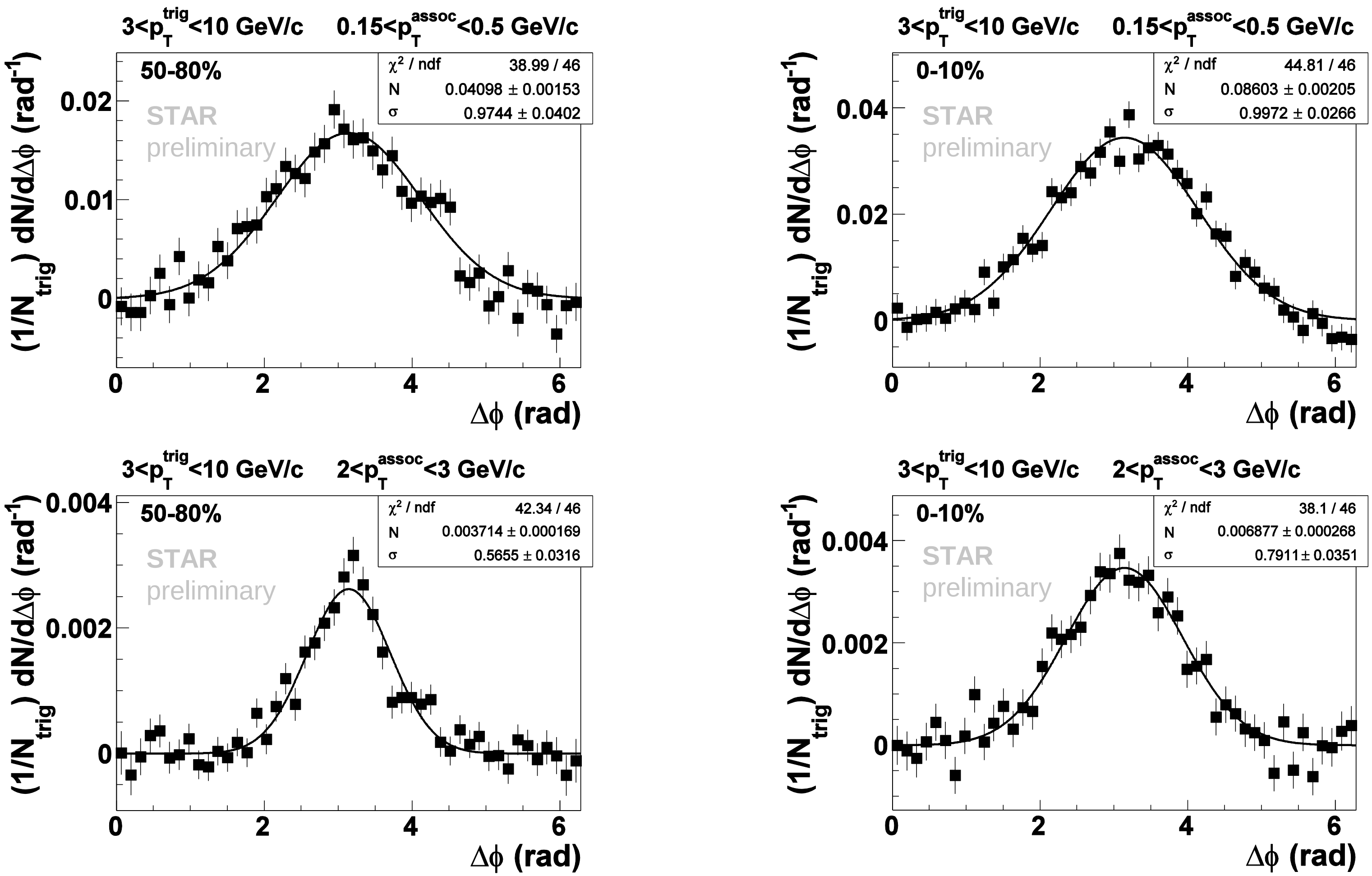


close-region 2p corr. = flow + near-side jet + away-side jet × fraction_close

far-region 2p corr. = flow + near-side jet + away-side jet × fraction_far

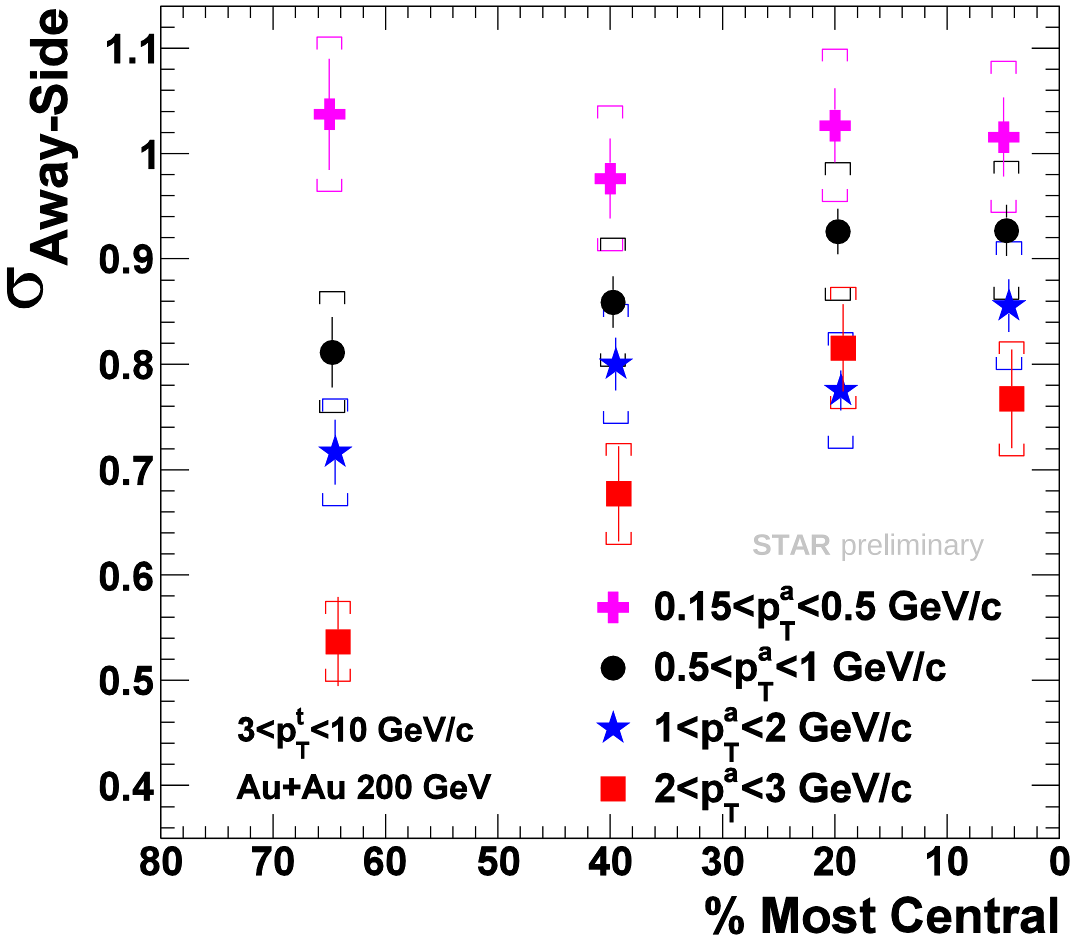
- Near-side almost equal as expected
- Flow backgrounds are the same in close-region and far-region, cancelled in their difference
- Quantify the shape by Gaussian fit σ

Away-side jet correlation shape



- The correlation shape is consistent with Gaussian.

Away side jet correlation width

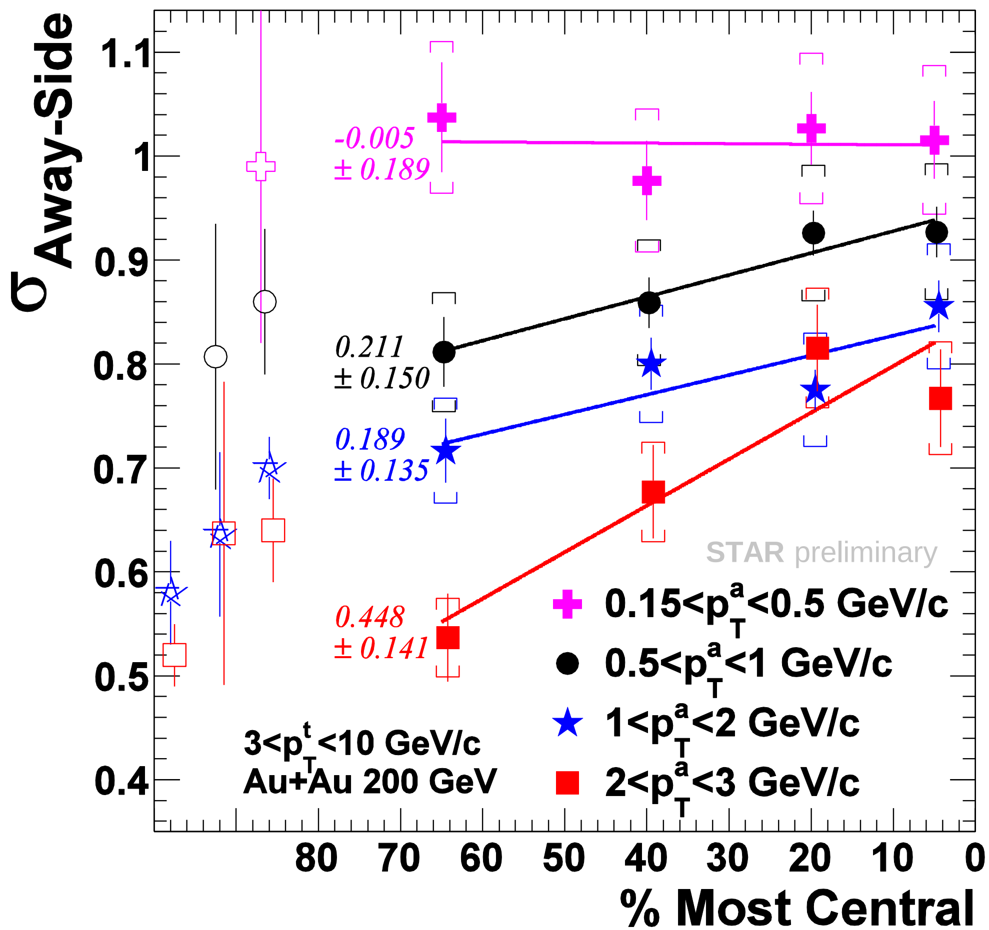


Away-side jets are modified:

- Moderate to high p_T associated particles: broaden with increasing centrality
- Shape for all p_T more similar in central than in peripheral collisions

The horizontal caps indicate the systematic error

Comparison to pp and dAu



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PLB 743 (2015) 333-339

The leftmost 3 sets of data are for
PHENIX p+p
PHENIX d+Au
STAR d+Au
Minbias

pp and dAu:
No P_x cut is applied.
Momentum cuts in the ref. are slightly different

- Peripheral data are consistent with pp/dAu

Three-particle correlation results

Methodology for three-particle correlations

Suppose an event is composed of: (besides the High-p_T trigger particle **T**)

- ✓ **A**: Jets correlated with the trigger (di-jet)
- ✓ **f**: flow background
- ✓ **a**: jets uncorrelated with the trigger

Two lower p_T associated particles

- **same η-region pairs**

= TAA+TAf+TAa+TfA+Tff+Tfa+TaA+Taf+Taa

(signal + combinatorial bkg + bkg jets)

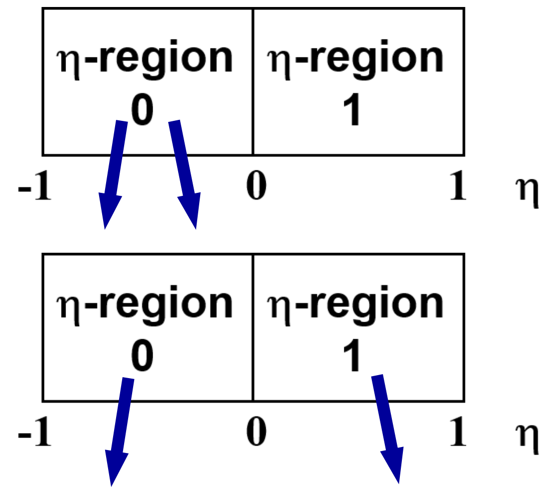
- **cross η-region pairs**

= TAf+TAa+TfA+Tff+Tfa+TaA+Taf

(combinatorial bkg)

- **same η-region pairs - cross η-region pairs**

= TAA + Taa (signal + bkg jets)



No P_x cut is applied in 3-p correlations

Background jets Taa

Background jets in triggered events = jets in min-bias events
(no requirement of a trigger, normalized per event)

• Suppose the number of jets is Poisson distributed with an average of λ. the probability to have n jets per event is

$$P_n = \lambda^n e^{-\lambda} / n!$$

The probability of having a trigger particle with (n-1) background jets is

$$nP_n / \sum_{m=1}^{\infty} mP_m = \lambda^{n-1} e^{-\lambda} /(n-1)! = P_{n-1}$$

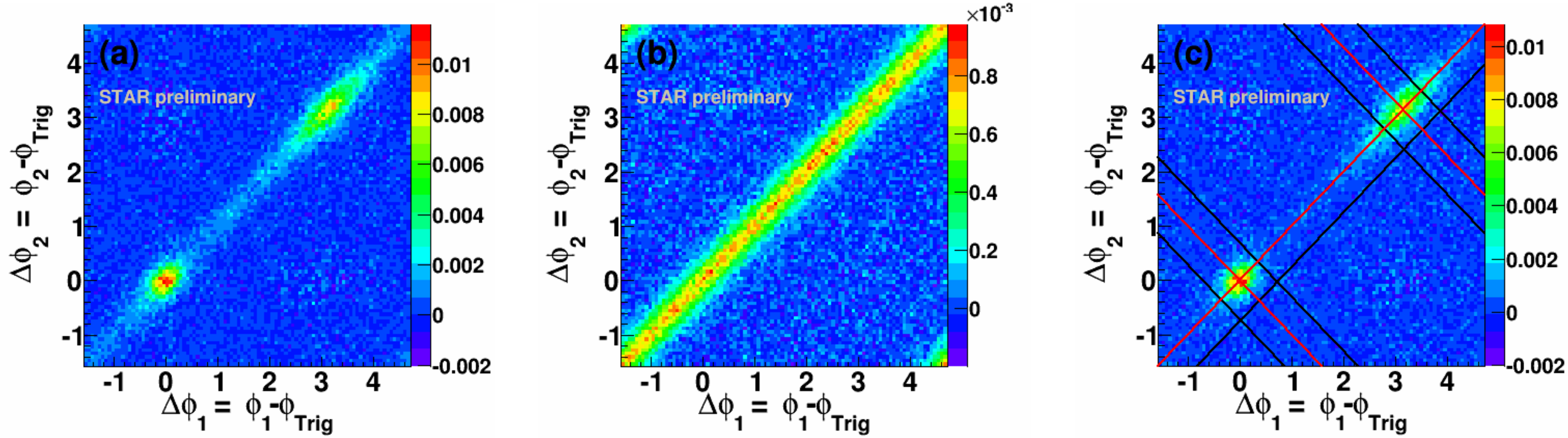
This is identical to the probability to have (n-1) jets per event for minbias events

• We can construct the jet background Taa by min-bias events w.r.t. a random “trigger” ϕ

Three-particle azimuthal correlations

$3<p_T^{trig}<10$ GeV/c, $2<p_T^{assoc}<3$ GeV/c
60-80% Au+Au @ 200 GeV

$\Delta\phi_i = \phi_i - \phi_{Trig}$ **(i = 1, 2)**



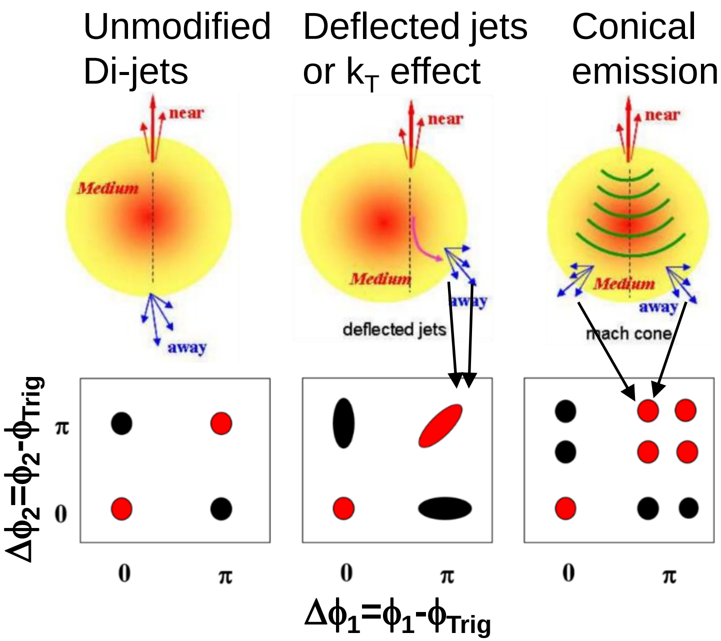
TAA + Taa
Same η-region correlations
- cross η-region correlations

Taa
Backgroud jet correlations

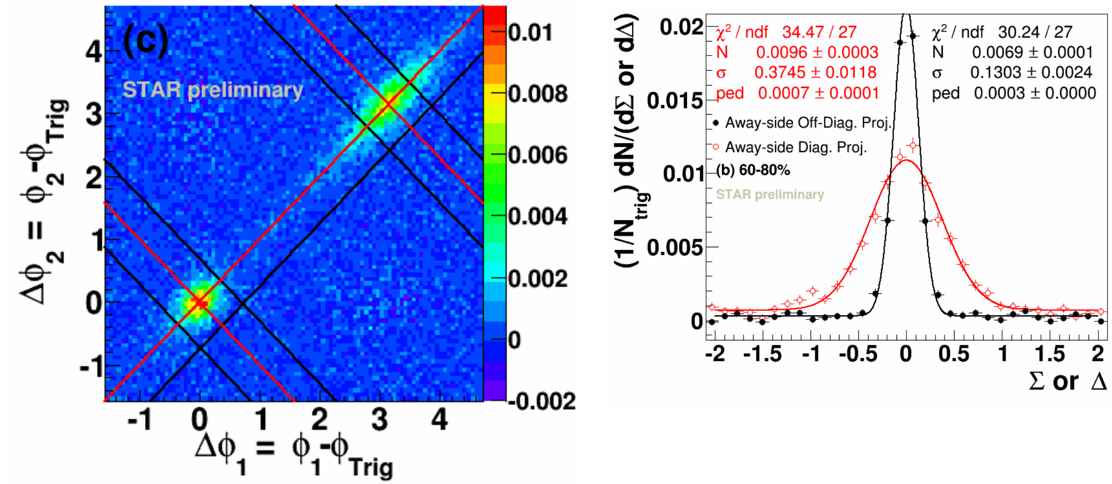
TAA
Background-subtracted
three-particle correlations

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

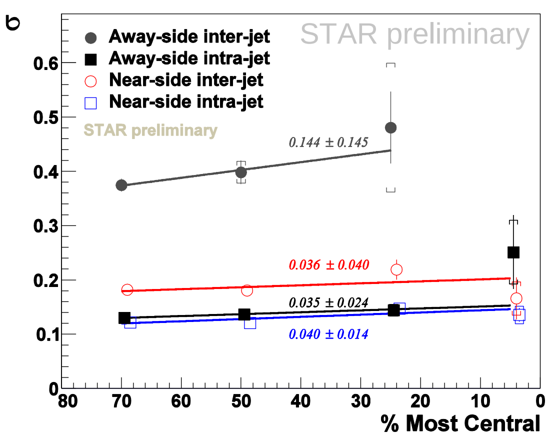
Intra-jet and inter-jet correlation width



$\Sigma = (\Delta\phi_1+\Delta\phi_2)/2-\pi$, $\Delta = (\Delta\phi_1-\Delta\phi_2)/2$



Off-diagonal projection: intra-jet correlations ($|\Sigma|<0.35$)
Diagonal projection: inter-jet correlations ($0<\Delta<0.35$)



- **Away side: inter-jet correlation >> intra-jet correlation → significant k_T and/or flow deflection.**
- **Intra-jet correlation: σ near = away and no centrality dependence → little jet modification?**
- **Requirement of a trigger (p_T > 3 GeV/c) and two associated particles (2 < p_T < 3 GeV/c) bias towards unmodified jets?**

Conclusions

- Methods were used to measure away-side jet correlations with clean, robust flow subtraction using data.
- Away-side jets are modified
  - Correlation broadens with centrality except low p_T
- Three-particle azimuthal correlations
  - Away-side: inter-jet correlations is significantly broader than intra-jet correlations $\rightarrow$ significant k_T and/or flow deflection.
  - Intra-jet correlations: similar between near- and away-side, and no centrality dependence is found. $\rightarrow$ Little jet-shape modification on the away side?
  - p_T cuts bias towards unmodified jets?

Thank you！

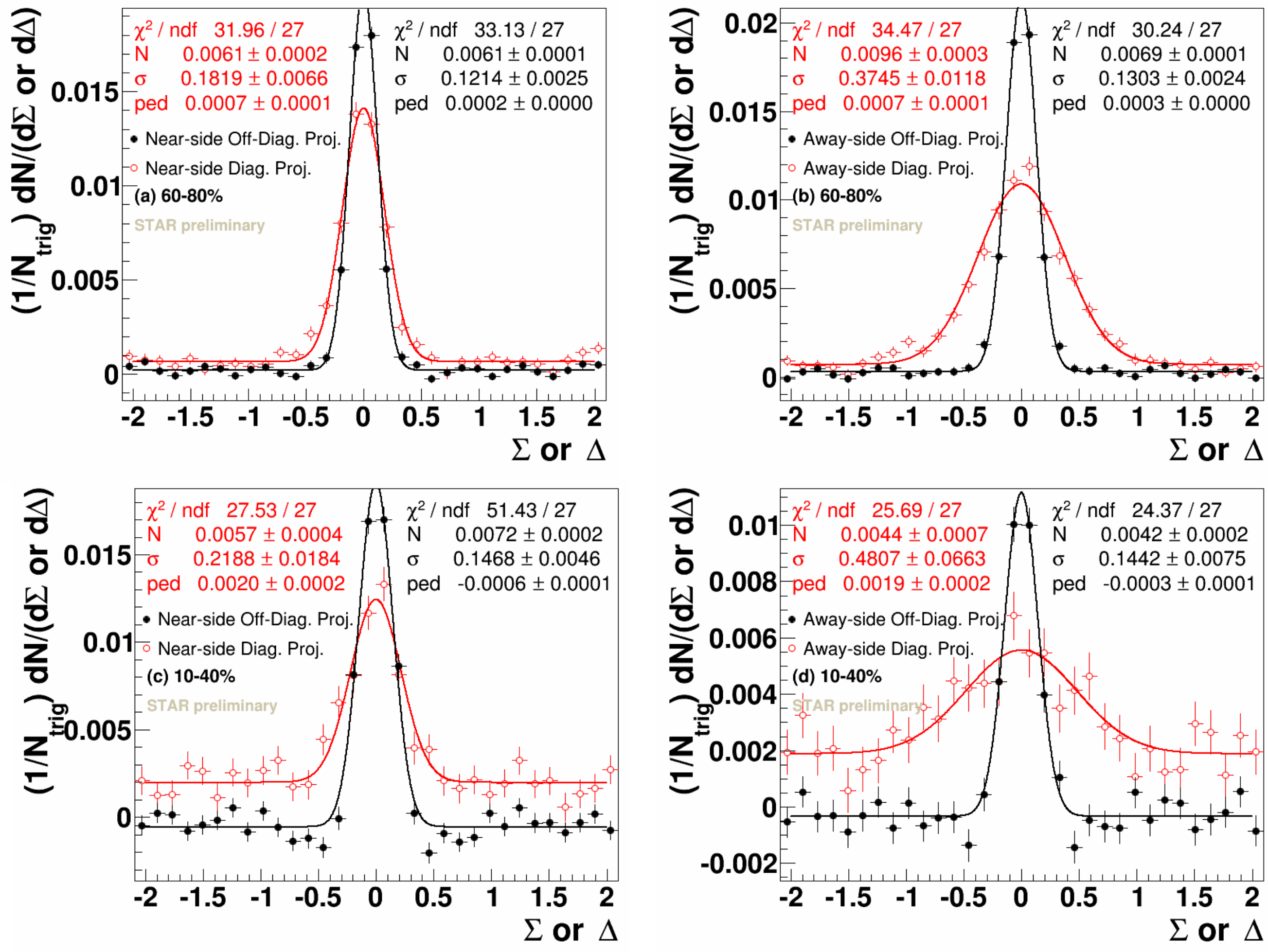
Backup slides

Intra-jet and inter-jet correlations

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

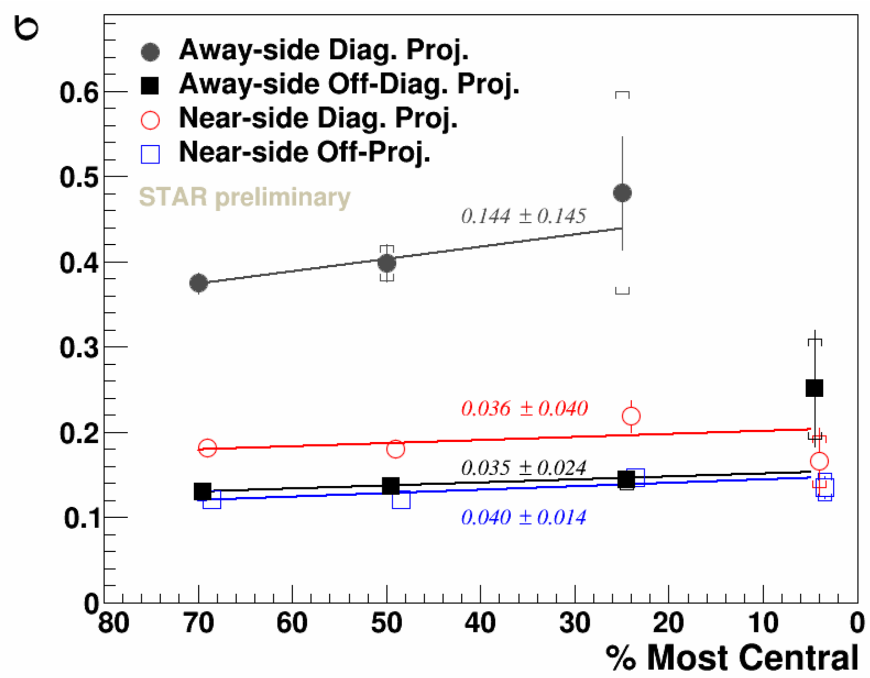
$\Sigma = (\Delta\phi_1+\Delta\phi_2)/2-\pi$ (away-side) or
$\Sigma = (\Delta\phi_1+\Delta\phi_2)/2$ (near-side)
$\Delta = (\Delta\phi_1-\Delta\phi_2)/2$

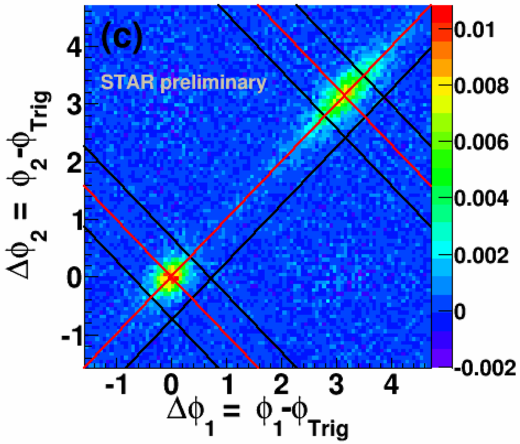
- Projections of near-side and away-side three-particle correlations along the diagonal Σ within $0<\Delta<0.35$ and off-diagonal Δ within $|\Sigma|<0.35$.

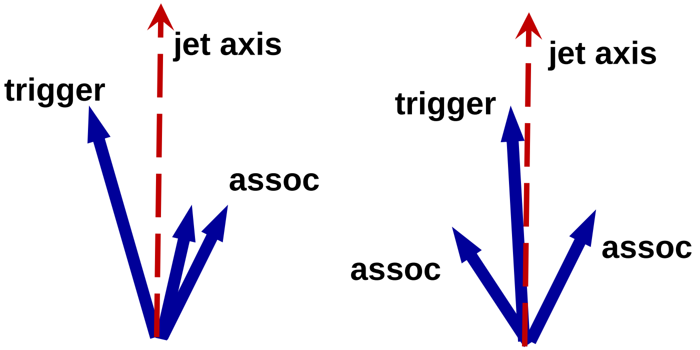


Intra-jet and inter-jet correlation width: near-side

Systematic errors are estimated by varying track quality cuts







- **Near-side: σ diag > off-diag. → jet axis swing effect?**
  (the trigger and the two associated particles are likely on different sides of the jet axis)

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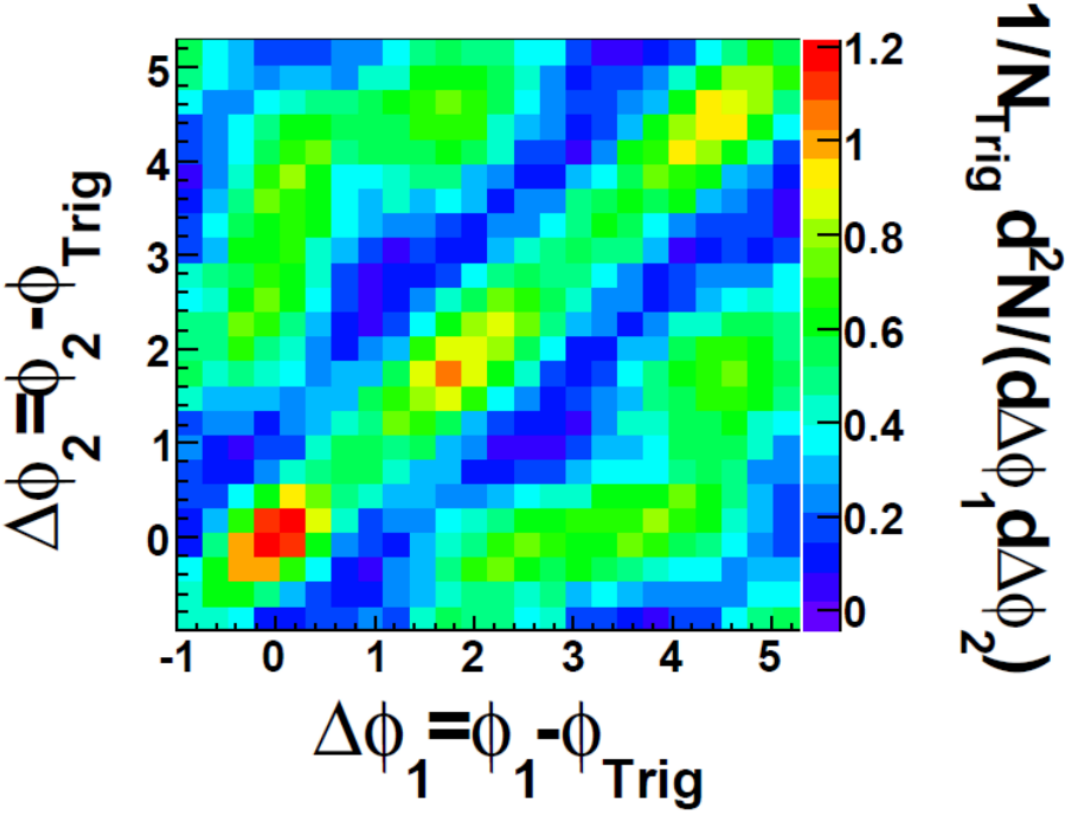

The v_2 and v_4 background subtracted three-particle correlations.
12% central Au+Au