Event-plane Dependence of Jet-like Correlations in Au+Au Collisions at 200 GeV in STAR

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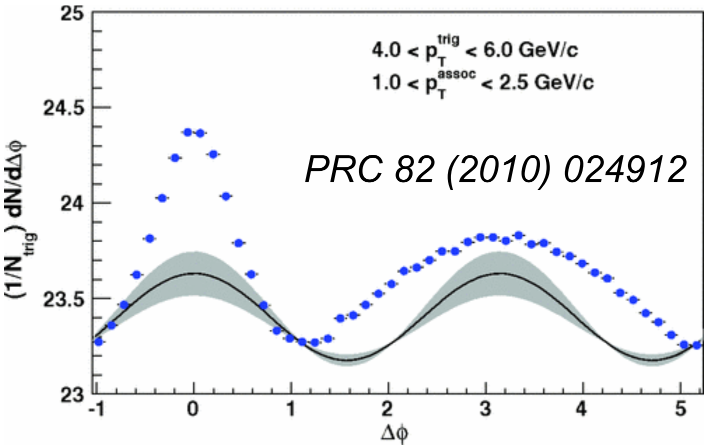
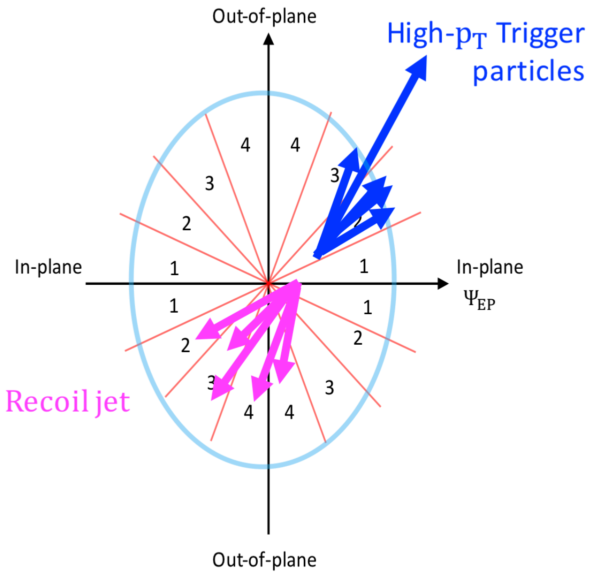
Motivation

- Energetic partons lose energy due to interactions in the dense medium
- Flow background removal is challenging in measurements of medium modifications of jets especially on the away-side
- All orders of v_n are possible and need to be subtracted
- Jet modification depends on path length (emission-angle dependent in non-central heavy-ion collisions)





More differentially: Event Shape Engineering

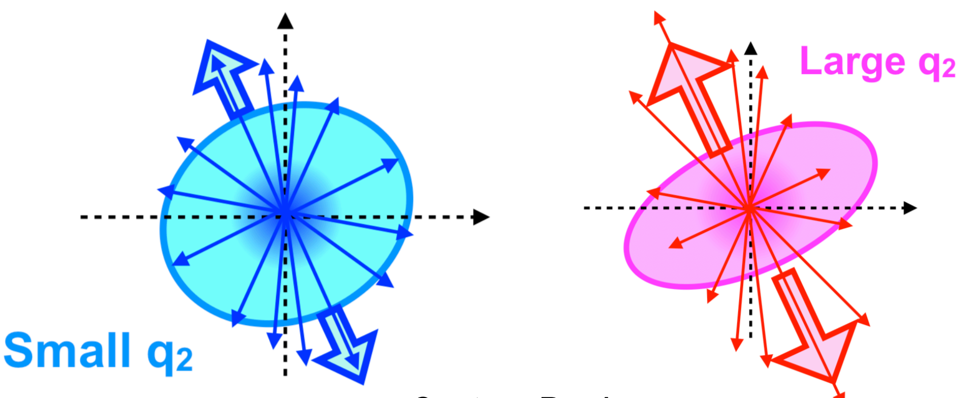
- Possibility to control the initial geometry / fluctuating v_2 by selecting the magnitude of flow vector q_2
- Combination of centrality selection and event shape engineering allows control of the initial geometry while keeping the average energy density (multiplicity) fixed
- Separation of volume effect and geometry effect

$$Q_{2,x} = \sum w_i \cos(2\phi_i) / \sqrt{\sum w_i}$$
$$Q_{2,y} = \sum w_i \sin(2\phi_i) / \sqrt{\sum w_i}$$
$$q_2 = \sqrt{Q_{2,x}^2 + Q_{2,y}^2}$$

w_i : weighting factor

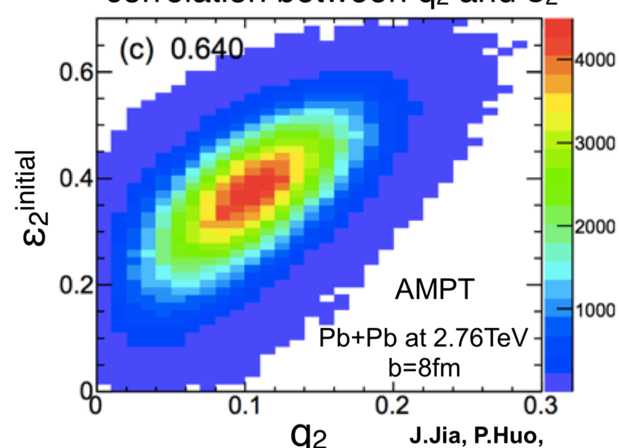
A.M.Poskanzer, S.A.Voloshin, PRC 58 (1998), 1671-1678

initial eccentricity $\varepsilon_2 = \frac{\langle x^2 - y^2 \rangle}{\langle x^2 + y^2 \rangle}$



Courtesy: Ryo Aoyama

correlation between q_2 and ε_2



J.Jia, P.Huo, PRC 90 (2014), 034915

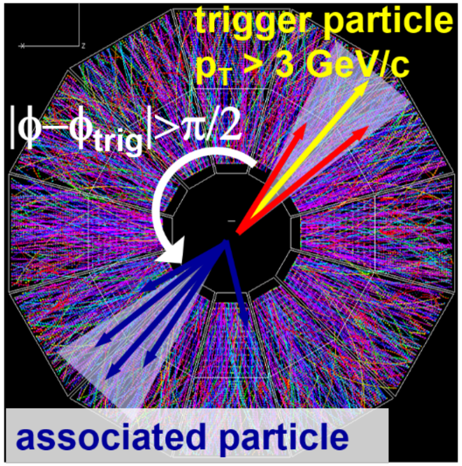
Event-plane Dependent Two-particle Jet-like Correlations

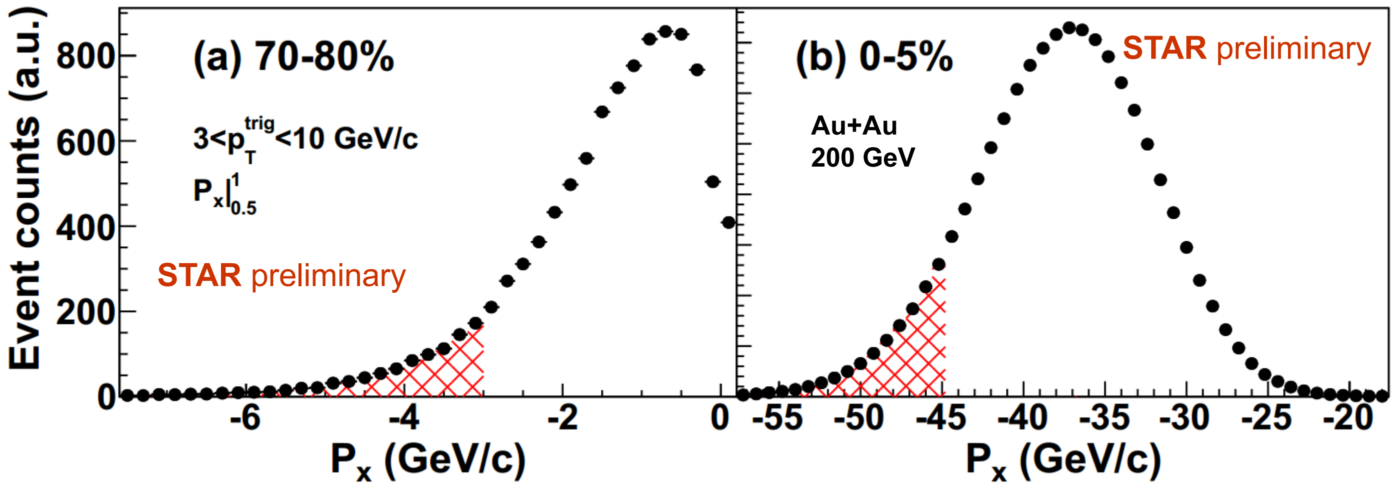
Enhanced Away-side Momentum Flow

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 × efficiency

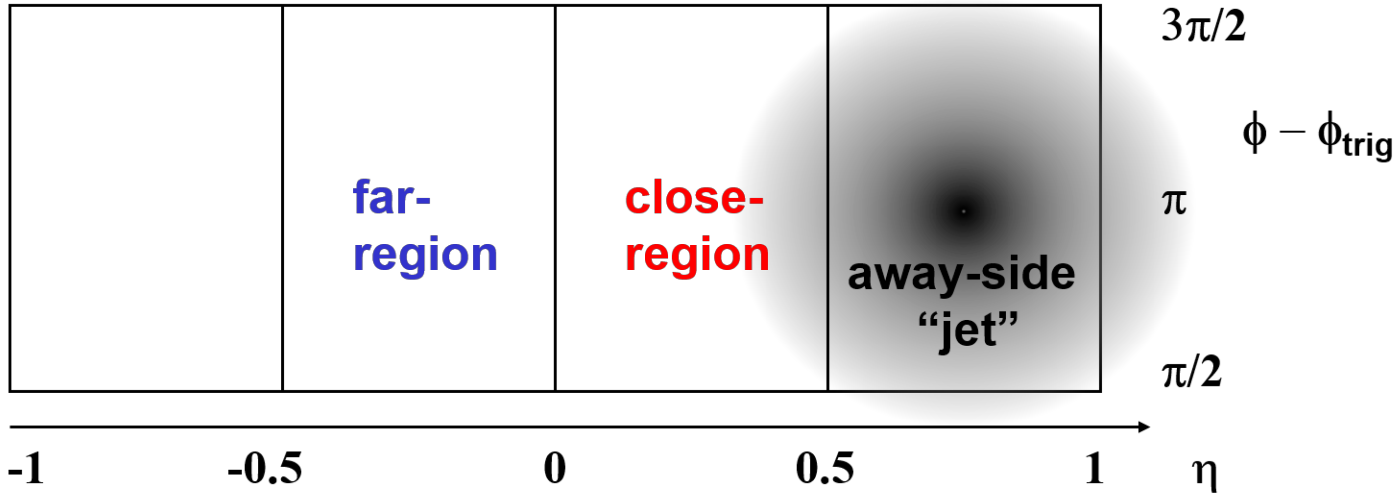




- For each centrality, cut on the lowest 10% of events to enhance **away-side momentum flow → "jet" = jet + jet-like hotspots**

Methodology for Two-particle Correlations

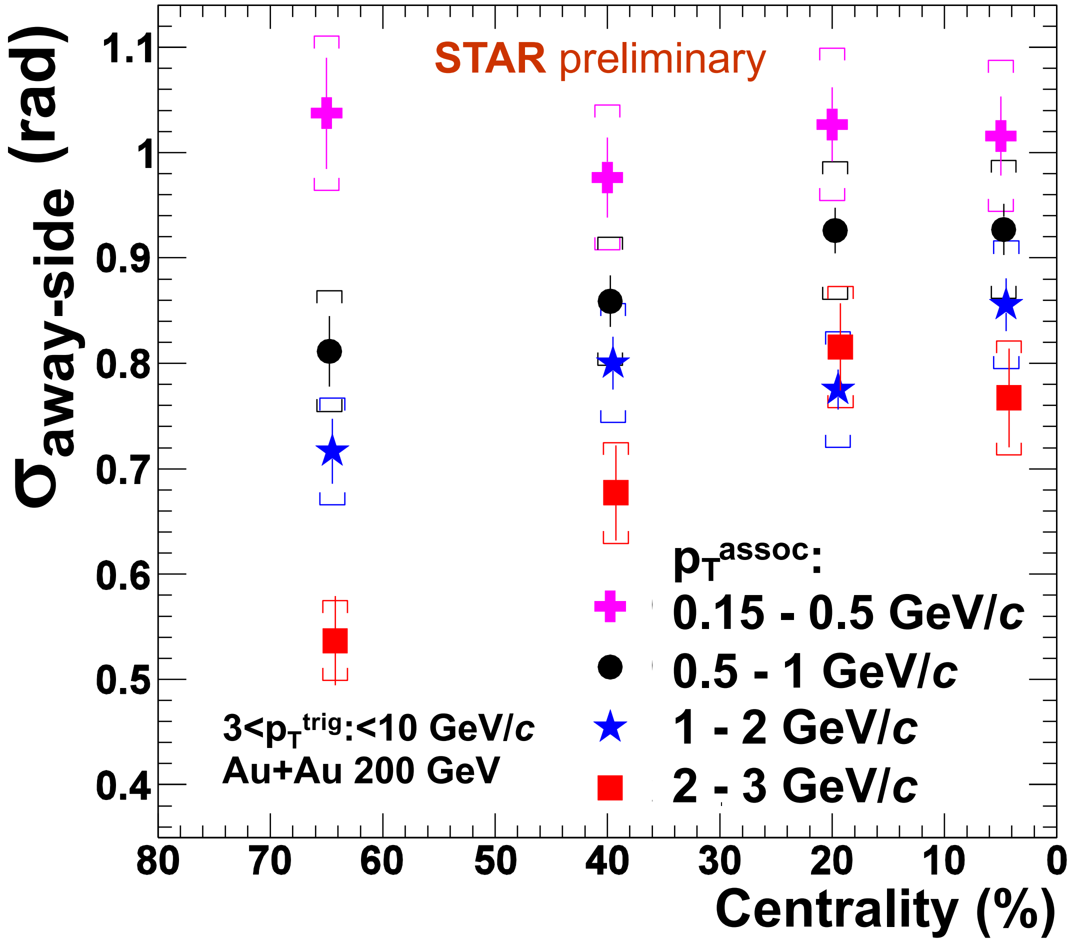
Trigger particle |η| < 1



- Away-side: large recoil momentum region opposite to trigger particle
- Analyze correlations in **close-region** and **far-region**, respectively
- Flow contributions to close-region and far-region are equal
  →cancelled in their difference

close-region = flow + near-side "jet" + away-side "jet" ∗ fraction_{close}
far-region = flow + near-side "jet" + away-side "jet" ∗ fraction_{far}
diff = away-side "jet" ∗ fraction

Away-side Jet-like Correlation Widths

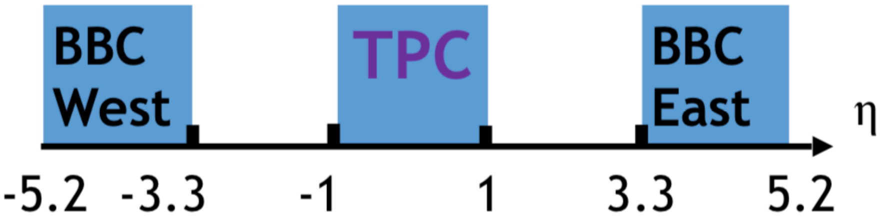


Kun Jiang, QM2018

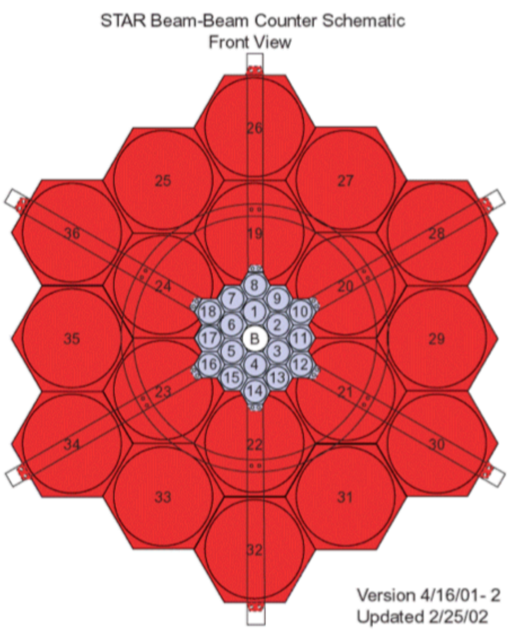
More central →

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

BBC Event-plane Ψ_2 Determination



- Large η gaps between BBCs and TPC
- Minimal non-flow between trigger particles and BBC

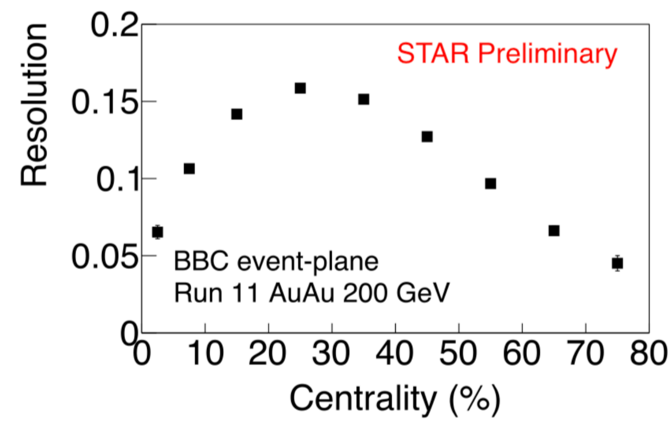


$$\Psi_2 = (\tan^{-1}\frac{Q_{2y}}{Q_{2x}})/2,$$

$$Q_{2x} = \sum_i w_i \cos(2\phi_i)$$

$$Q_{2y} = \sum_i w_i \sin(2\phi_i)$$

w_i: ADC signal weight

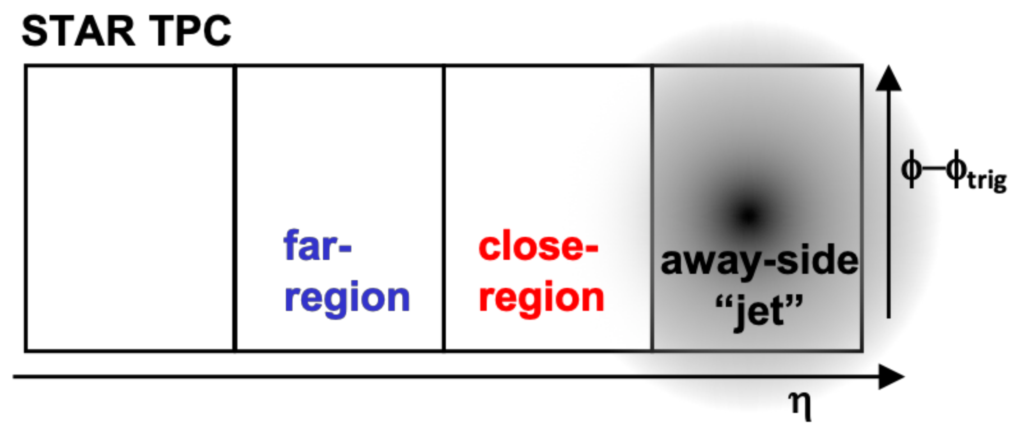


$$R \approx \sqrt{2\cos 2(\Psi_2^{East} - \Psi_2^{West})}$$

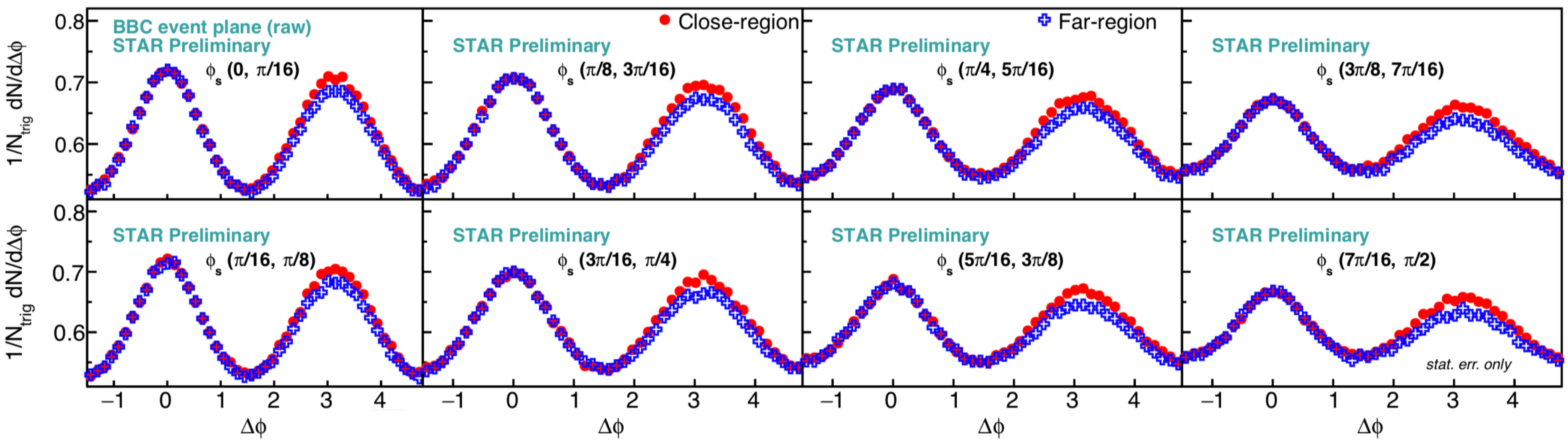
Raw Event-plane Dependent Correlations

20-60% Au+Au @ 200 GeV
$3<p_T^{trig}<10$ GeV/c
$1<p_T^{assoc}<2$ GeV/c

$\phi_s = \phi^{trig} - \Psi_{2,EP}$
$\Delta\phi = \phi^{assoc} - \phi^{trig}$



In-plane → out-of-plane

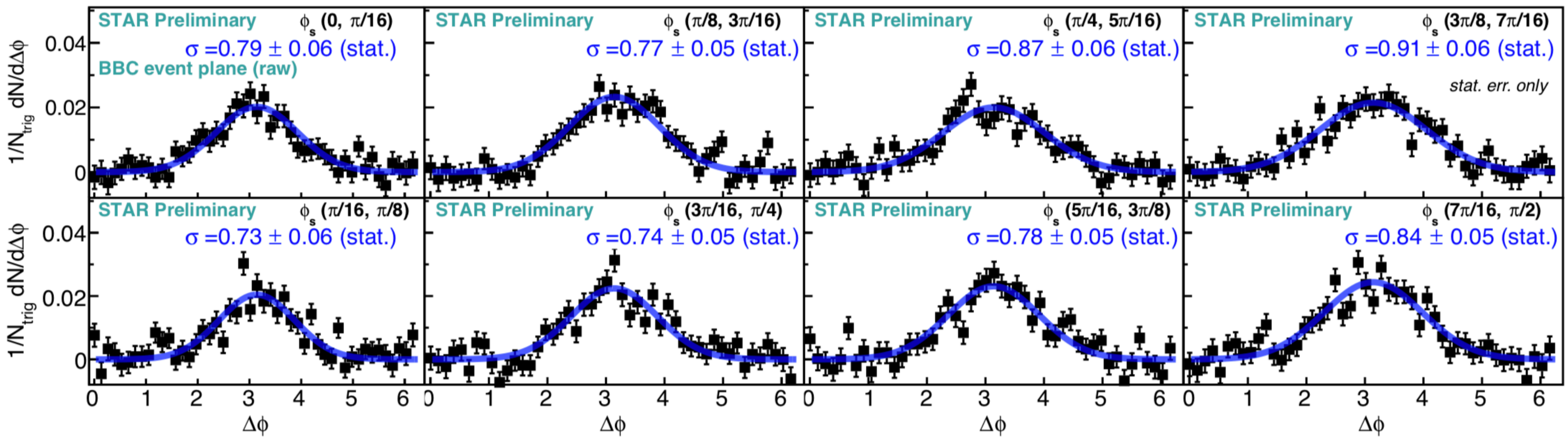


Away-side Correlation Shape

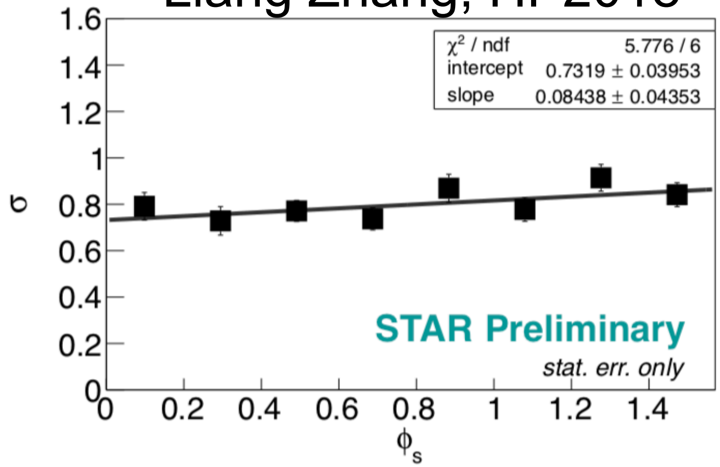
Close - Far

20-60% Au+Au @ 200 GeV

$3<p_T^{trig}<10$ GeV/c
$1<p_T^{assoc}<2$ GeV/c



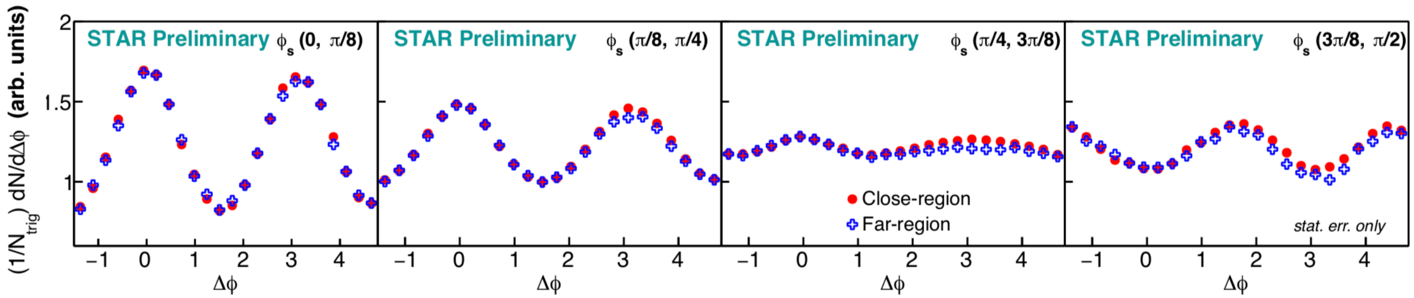
Liang Zhang, HP2018



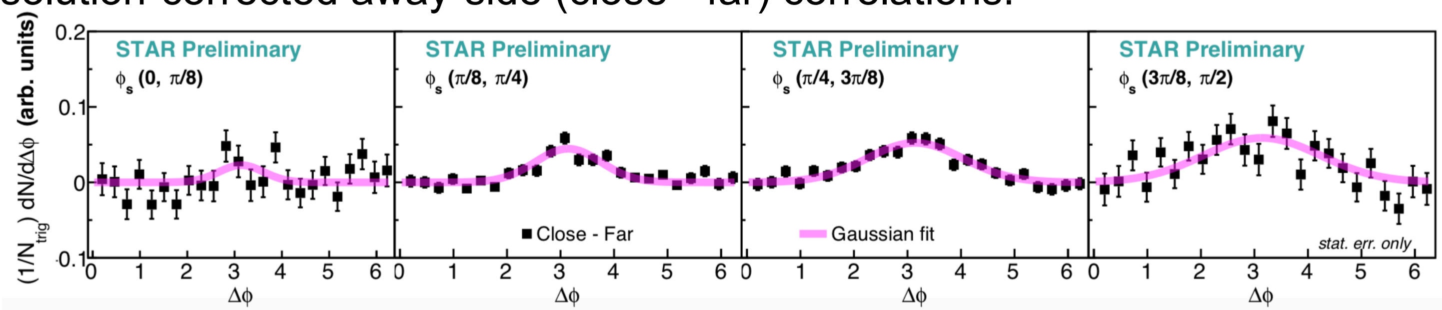
- Blue curves are Gaussian fits
- Gaussian width (σ) increases with ϕ_s
- Slope = 0.08 ± 0.04
- Poor BBC Ψ_2 resolution (R = 0.136 ± 0.002) → correct via unfolding

Resolution-corrected Correlation Functions

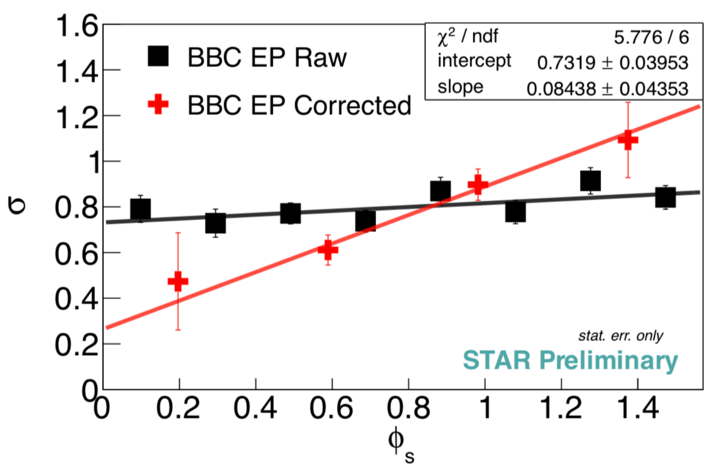
Resolution-corrected two-particle correlations:



Resolution-corrected away-side (close - far) correlations:



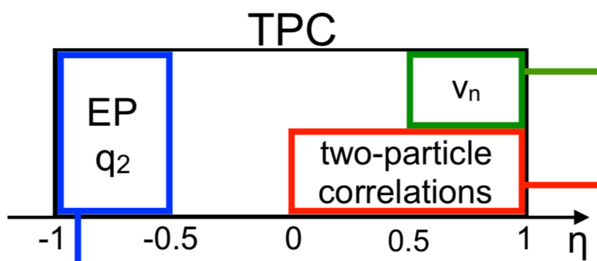
20-60%
AuAu 200 GeV
$3<p_T^{trig}<10$ GeV/c
$1<p_T^{assoc}<2$ GeV/c



- EP resolution is corrected via unfolding
- BBC Ψ_2 resolution = 0.136 ± 0.002
- Measured slope = 0.08 ± 0.04 (stat.)
- Corrected slope = 0.66 ± 0.27 (stat.)

Event-plane Dependent Two-particle Jet-like Correlations with Event Shape Engineering

Two-particle Correlations with ESE



✦ v_n measurement via EP method

✦ Two-particle correlations

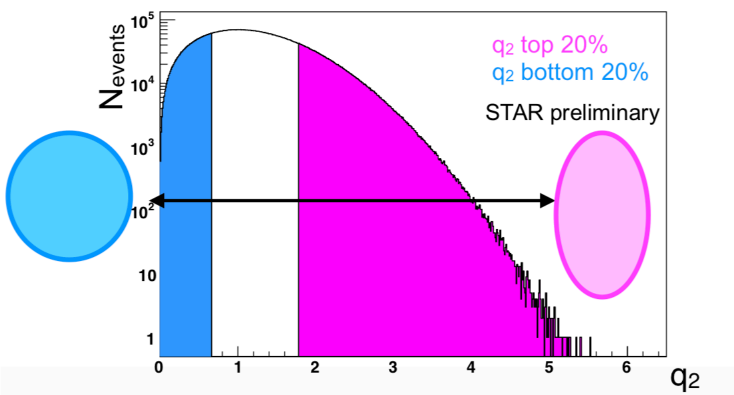
$$C(\Delta\phi) \propto \frac{N^{real}_{pair}(\Delta\phi)}{N^{mix}_{pair}(\Delta\phi)}$$

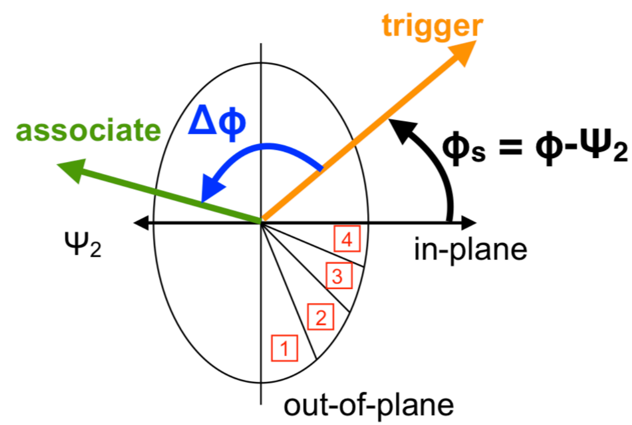
✦ Event Plane Ψ_n

✦ q_2 selection

- bottom 20% and top 20%

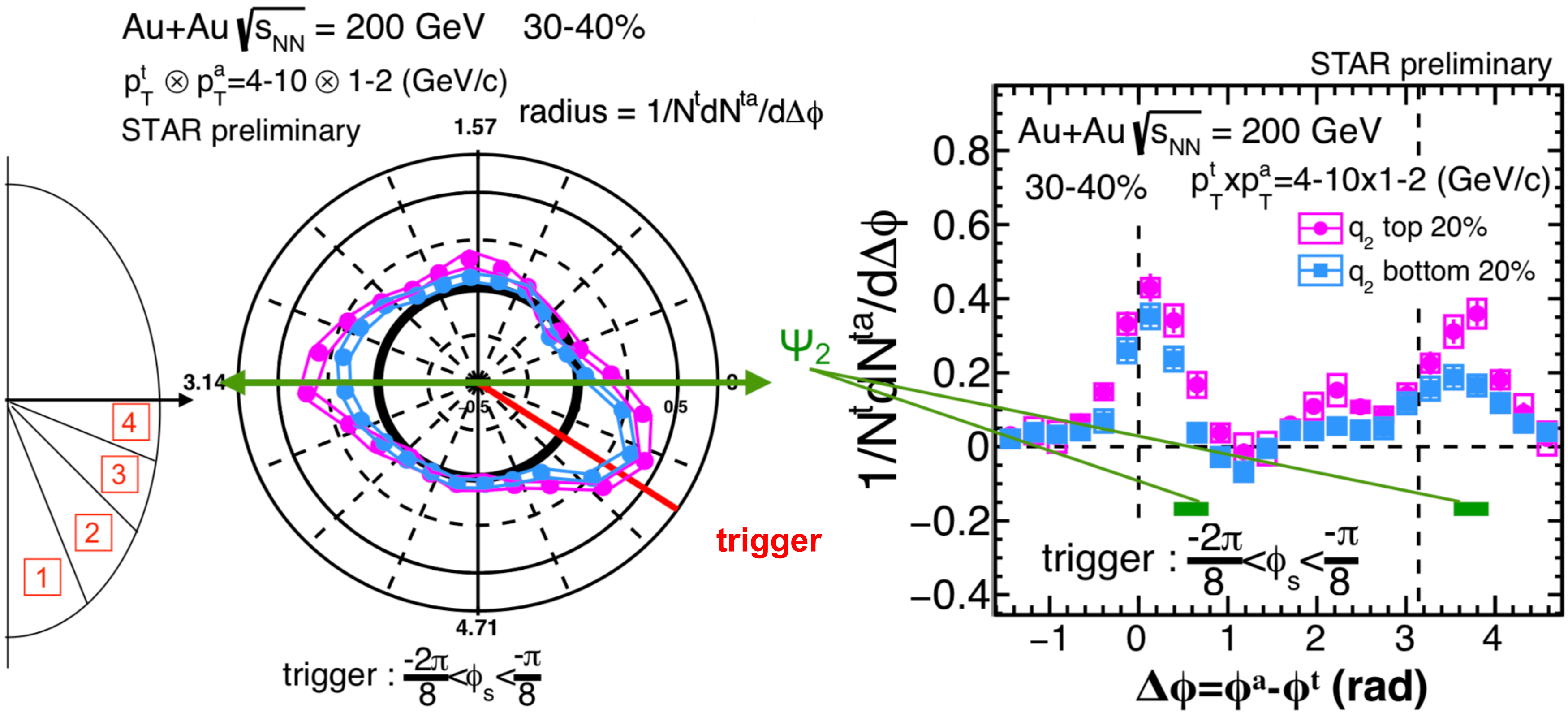
trigger angle selection w.r.t. EP



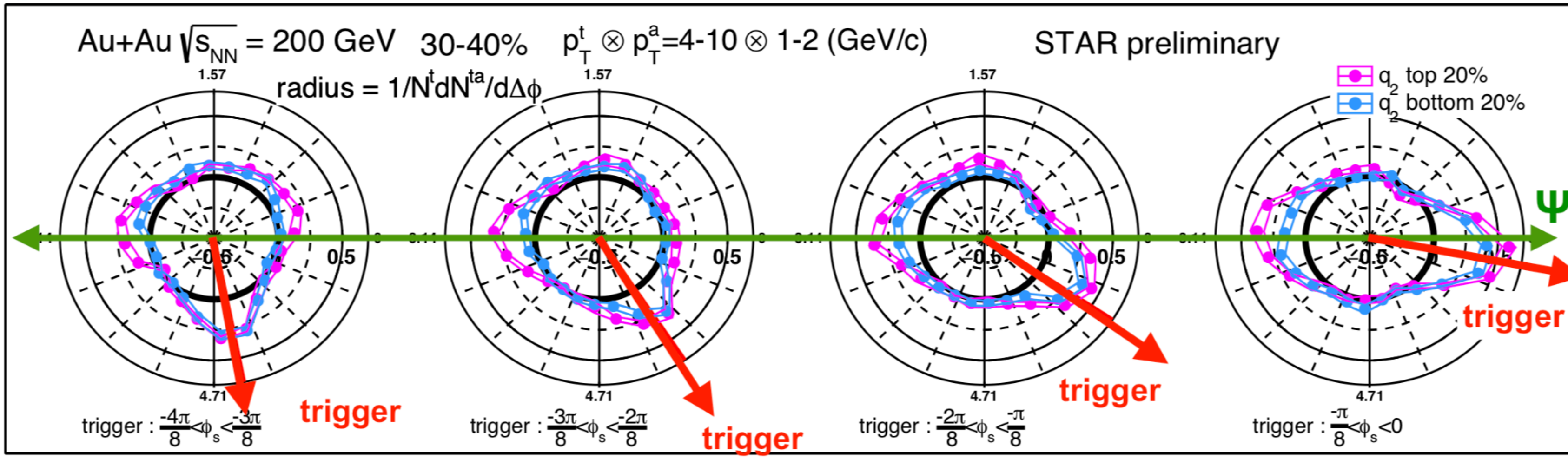


- Background subtraction: assuming ZYAM with inclusive-triggered correlations
- v_2, v_3 and v_4 contributions are subtracted

Polar Representation of Correlation Function

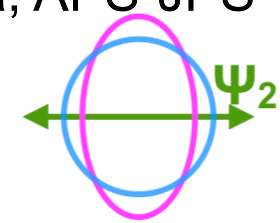


- Two axes: **trigger axis** and **EP axis**
- $\Delta\phi$ with starts from red line and rotate toward counter-clockwise direction
- Radius: the amplitudes of correlated yield



out-of-plane trigger ⟷ **in-plane trigger**

Ryo Aoyama, APS-JPS



- **Near-side**
  - Out-of-plane trigger: No difference between large-q_2 and small-q_2
  - In-plane trigger: peak height difference is enhanced
- **Away-side**
  - Out-of-plane trigger: yields are almost fully suppressed both in large-q_2 and small-q_2
  - Remnant yield in the EP direction has q_2 dependence
  - In-plane trigger: peak height difference is enhanced

Indications of low-p_T particles preferentially escaping towards in-plane direction

Conclusions

- **Event-plane dependent two-particle jet-like correlations shape in 200 GeV Au+Au collisions are reported**
  – Data-driven method to subtract away-side flow background of all harmonics
  – The width of the away-side jet-like peak is found to increase with ϕ_s
  – Consistent with in-medium path length dependence
- **Event-plane dependent two-particle correlations with event shape engineering are measured.**
  – Separation between large-q_2 and small-q_2 events enhances difference of correlation shape while preserving average multiplicity
  →new handle to differentially study partonic energy loss mechanisms
  – Low-p_T particles preferentially escape toward in-plane direction
  →path length dependent? escape mechanism?

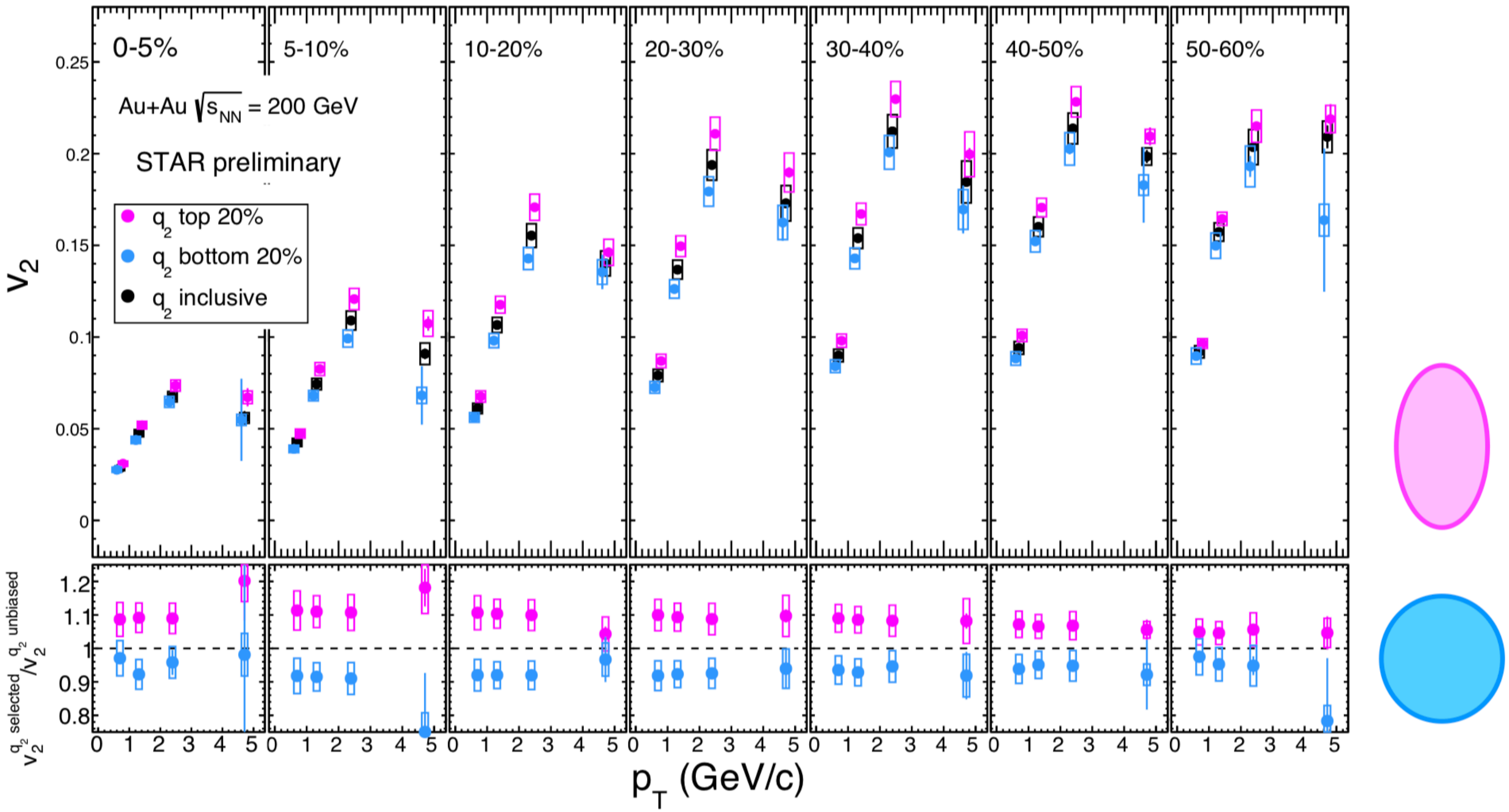
Outlook：

– Centrality and p_T dependencies
– New data with Event Plane Detector

Thank you！

Back-up slides

v_2 with ESE



- ✦ v_2 is measured via event plane method with TPC-EP with taking 1.0 η gap
- ✦ 20% largest and smallest q_2 vectors are selected with the same region as TPC-EP
- ✦ Top 20% q_2 selection leads to **~10% larger v_2 events**
- ✦ Bottom 20% q_2 selection leads to **~8% smaller v_2 events**