Detailed shape analysis of azimuthal distribution with respect to the reaction plane at RHIC – PHENIX

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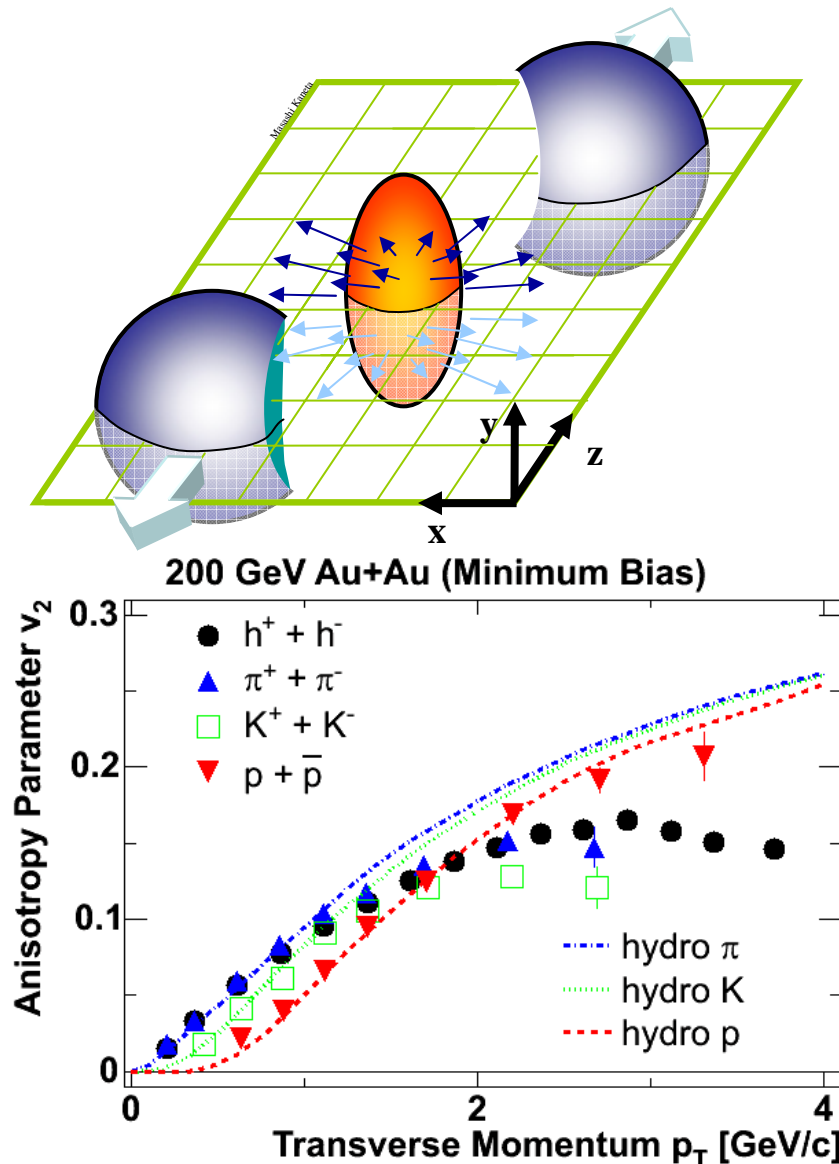Univ. of Tsukuba

JPS meeting @ Tokyo University of Science, Noda Campus

Outline

- Introduction
- Experimental Setup
- Method
- Results
- Summary

Introduction
Azimuthal anisotropy


200 GeV Au+Au (Minimum Bias)

- Azimuthal anisotropy is expected as sensitive probe in the early stage of relativistic heavy ion collisions
  - Spatial anisotropy in the coordinate space.
  - Parton energy loss in the medium (Jet Quench).
- More detailed study of azimuthal distribution might tell us the origin of v_2.
  - 2 particle correlation with respect to the reaction plane.
  - Higher harmonics of collective flow (ex. v_4)
  - Flow + jet correlation
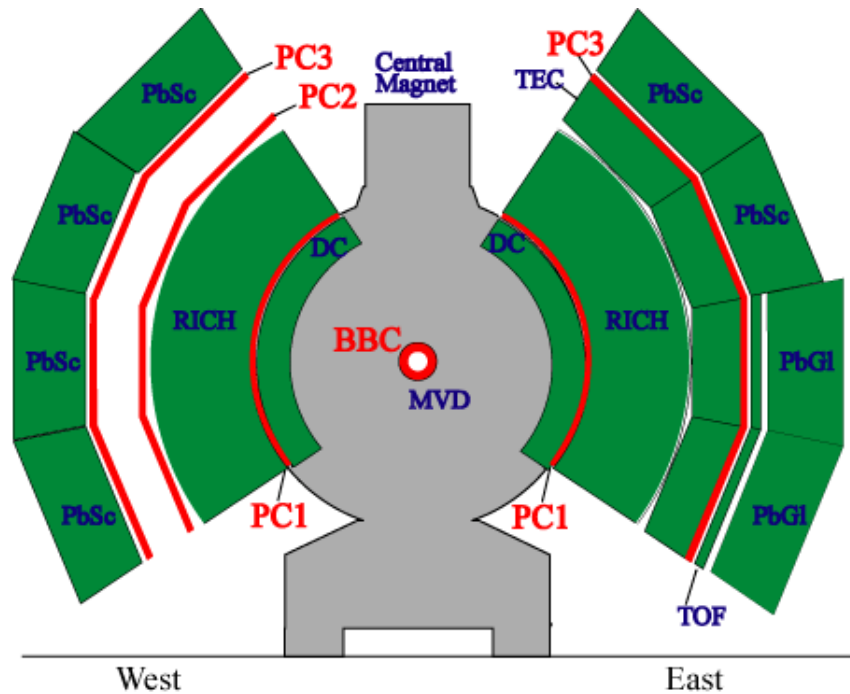
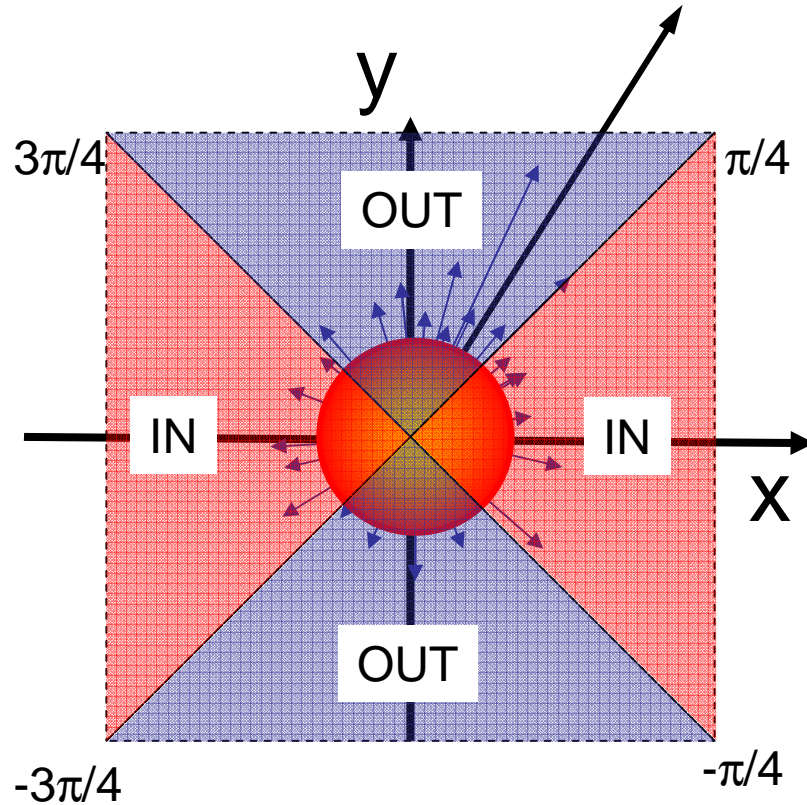# Experimental Setup

- **Minimum Bias Trigger**
  - BBC (Beam Beam Counter)
- **Collision Vertex**
  - BBC
- **Centrality**
  - BBC, ZDC (Zero Degree Calorimeter)
- **Reaction Plane**
  - BBC
- **Tracking / Momentum**
  - Drift Chamber, Pad Chamber

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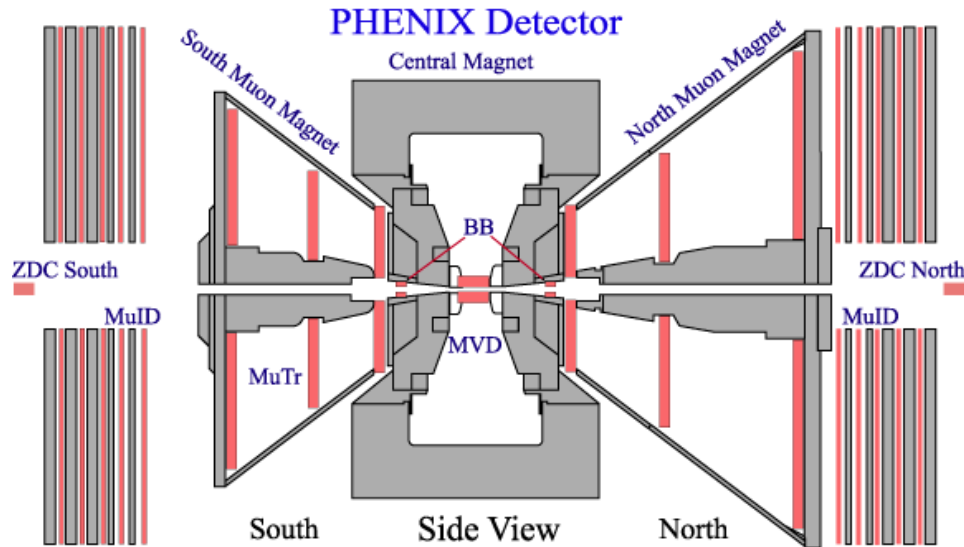
Method

Trigger hadron

p_T = 3 – 6 GeV/c

y

$3\pi/4$ $\pi/4$

OUT

IN   IN

X

OUT

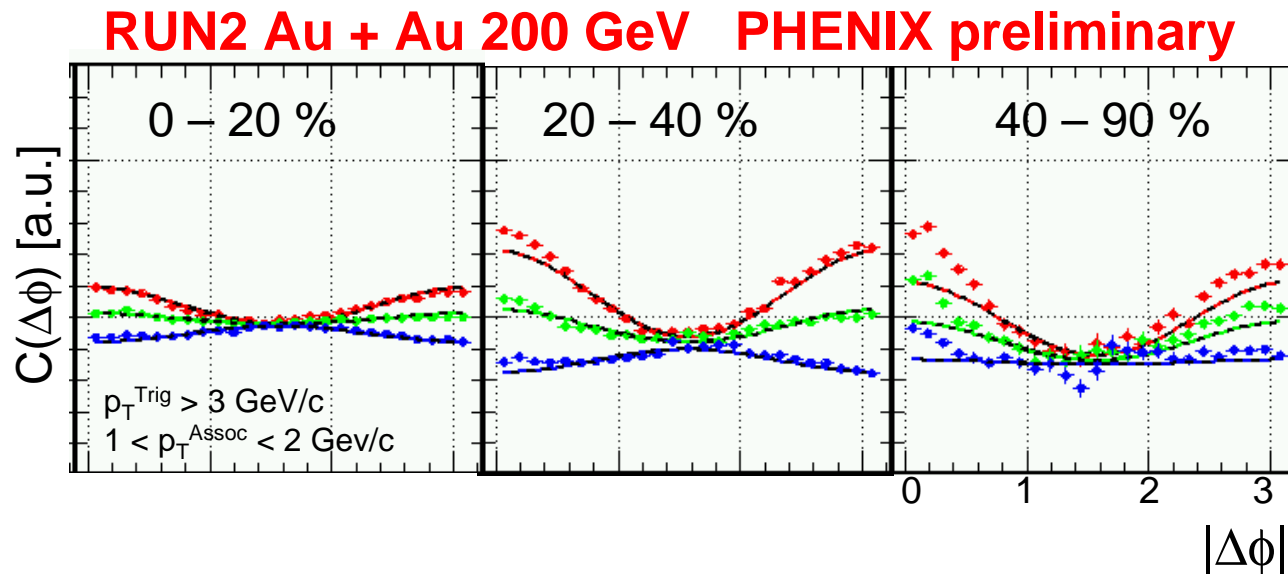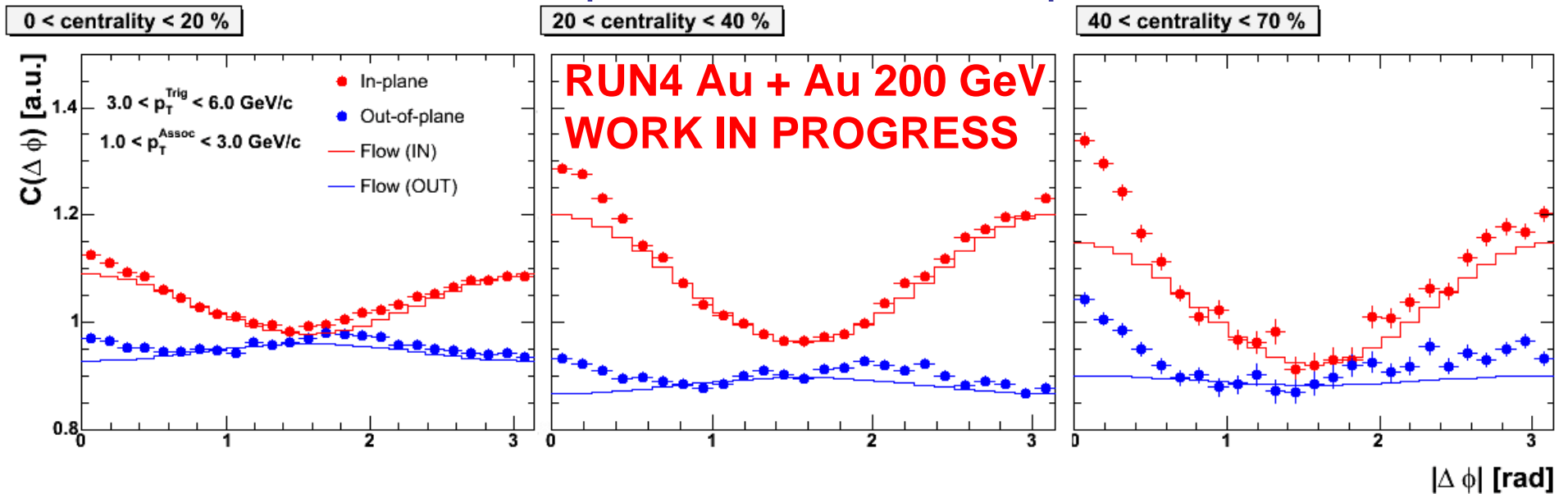$-3\pi/4$ $-\pi/4$

- 2 particle correlation with respect to the reaction plane

- Trigger hadron is divided into two event class

  - In-plane : $|\phi - \Psi| < \pi/4$
  - Out-of-plane : $|\phi - \Psi| > \pi/4$

- Flow contribution can be subtracted

  - Measure v_2 by independent analysis.
  - Neglect higher order (v_4 etc.) contribution

Flow pattern is shifted by $\pi/2$:

J. Bielcikova, S. Esumi, K. Filimonov, S. Voloshin, and J.P. Wurm, Phys. Rev. C69 021901 (2004)

$$\frac{dn^{\text{in}}}{d\Delta\phi} \propto 1 + 2v_2 \frac{\pi v_2 + 2\langle\cos 2\Delta\Psi\rangle}{\pi + 4v_2\langle\cos 2\Delta\Psi\rangle} \cos 2\Delta\phi;$$
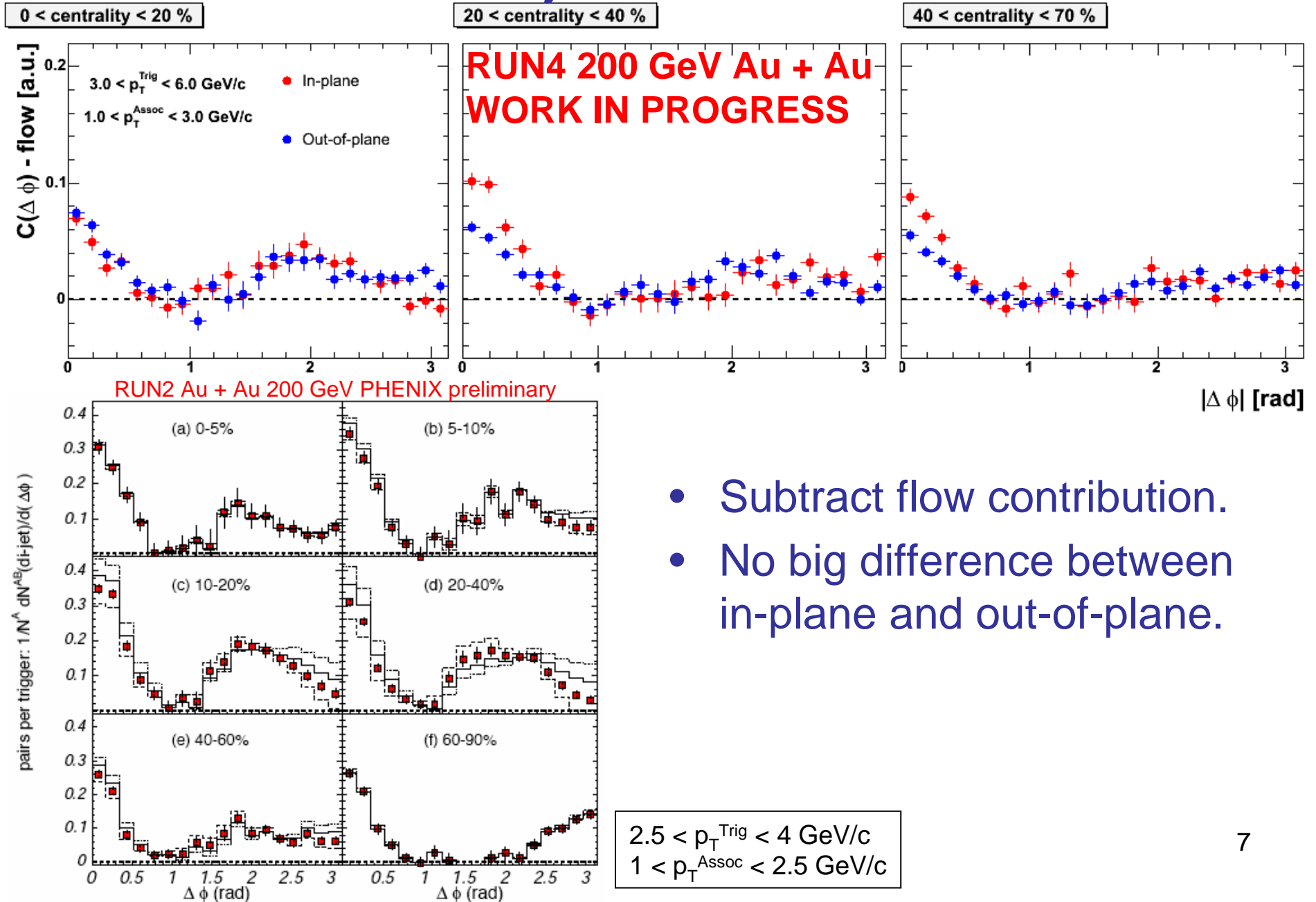
$$\frac{dn^{\text{out}}}{d\Delta\phi} \propto 1 + 2v_2 \frac{\pi v_2 - 2\langle\cos 2\Delta\Psi\rangle}{\pi - 4v_2\langle\cos 2\Delta\Psi\rangle} \cos 2\Delta\phi,$$

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Di-hadron correlation function
with respect to the reaction plane

0 < centrality < 20 %
20 < centrality < 40 %
40 < centrality < 70 %

RUN4 Au + Au 200 GeV WORK IN PROGRESS

$3.0 < p_T^{Trig} < 6.0$ GeV/c
$1.0 < p_T^{Assoc} < 3.0$ GeV/c

In-plane
Out-of-plane
Flow (IN)
Flow (OUT)

$C(\Delta\phi)$ [a.u.]

$|\Delta\phi|$ [rad]

RUN2 Au + Au 200 GeV   PHENIX preliminary

0 – 20 %
20 – 40 %
40 – 90 %

$C(\Delta\phi)$ [a.u.]

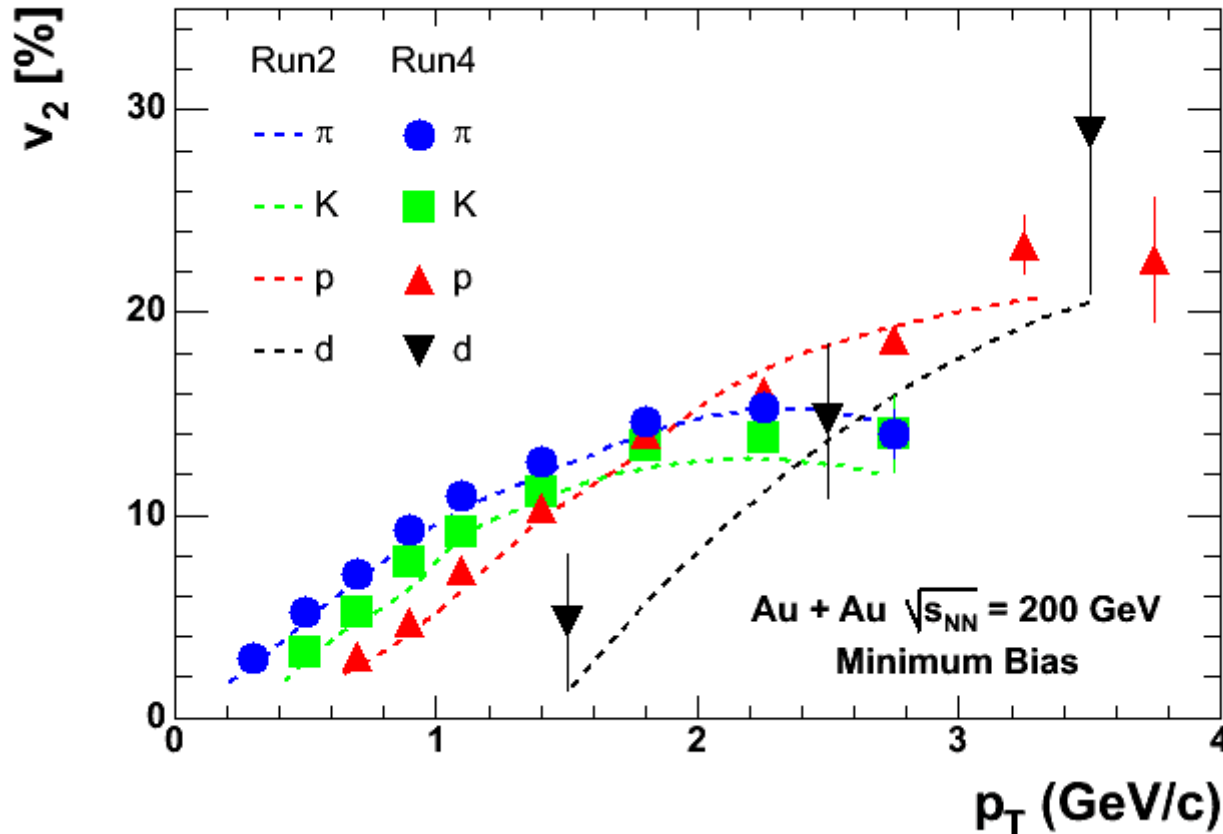$p_T^{Trig} > 3$ GeV/c
$1 < p_T^{Assoc} < 2$ Gev/c

$|\Delta\phi|$

- Consistent with Run2 results.
- Jet like structure ($\Delta\phi = 0$ and π), and flow (v_2) contribution.

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Pair jet distribution

0 < centrality < 20 %

20 < centrality < 40 %

40 < centrality < 70 %

RUN4 200 GeV Au + Au
WORK IN PROGRESS

$3.0 < p_T^{Trig} < 6.0$ GeV/c

$1.0 < p_T^{Assoc} < 3.0$ GeV/c

● In-plane

● Out-of-plane

$C(\Delta\phi)$ - flow [a.u.]

$|\Delta\phi|$ [rad]

RUN2 Au + Au 200 GeV PHENIX preliminary

pairs per trigger: $1/N^A \, dN^{AB}(di\text{-}jet)/d(\Delta\phi)$

(a) 0-5%

(b) 5-10%

(c) 10-20%

(d) 20-40%

(e) 40-60%

(f) 60-90%

$\Delta\phi$ (rad)

- Subtract flow contribution.
- No big difference between in-plane and out-of-plane.

$2.5 < p_T^{Trig} < 4$ GeV/c
$1 < p_T^{Assoc} < 2.5$ GeV/c

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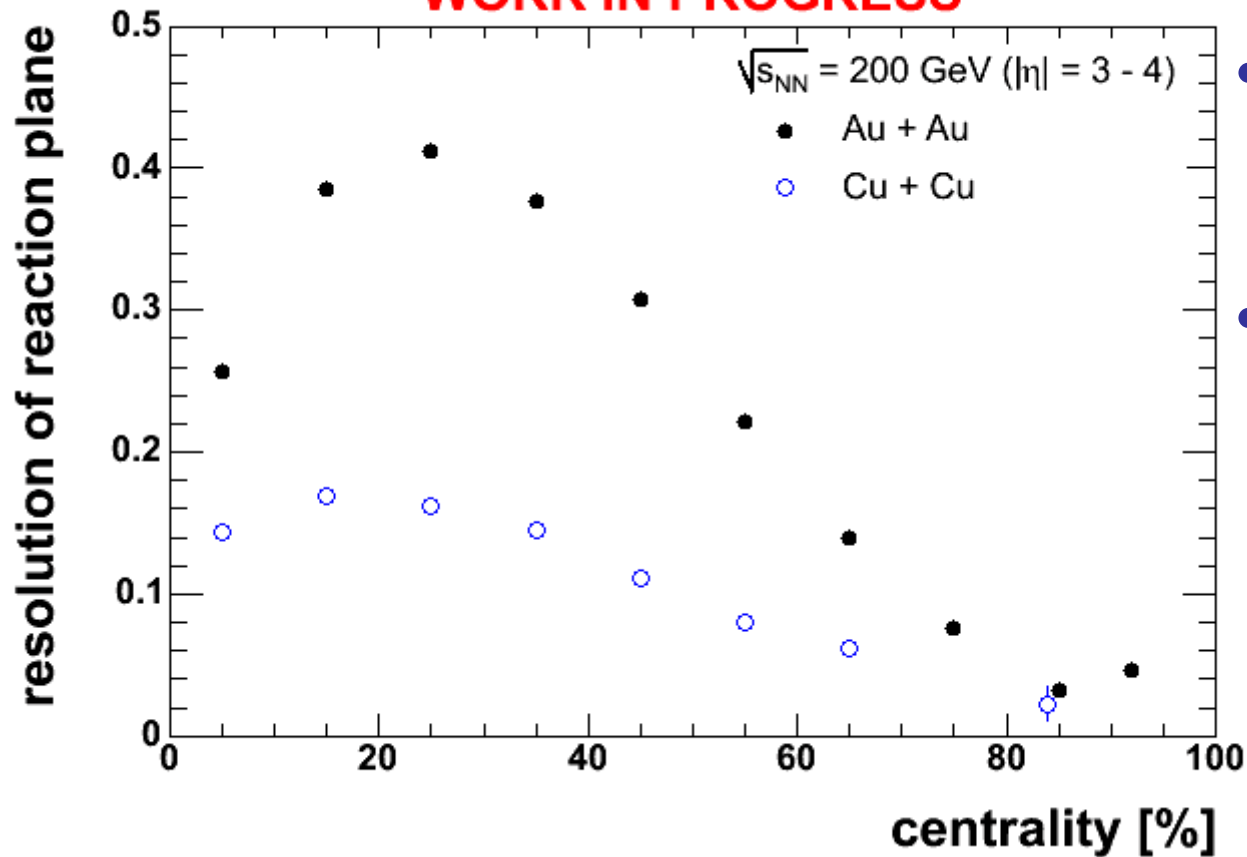# PID hadron v_2 in Au + Au @ $\sqrt{s_{NN}} = 200$ GeV

WORK IN PROGRESS

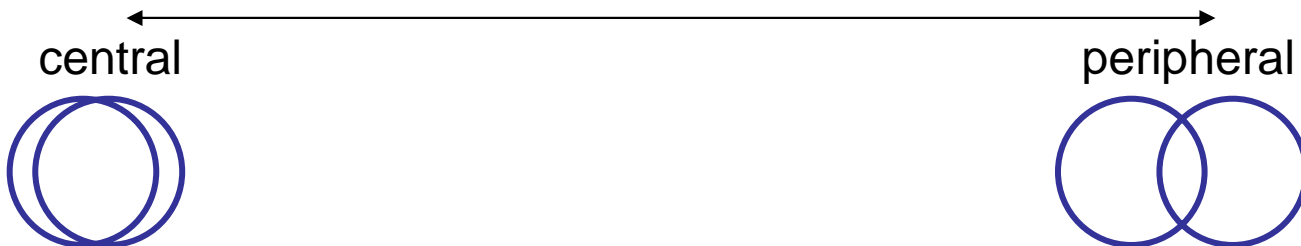

- v_2 of identified hadrons in Au + Au collisions.
  - Run4 analysis is ongoing.
    - ~ 1/10 of total amount of data.
  - The Run4 results are consistent with Run2 data.

Elliptic flow in Cu + Cu

WORK IN PROGRESS

$\sqrt{s_{NN}} = 200$ GeV ($|\eta| = 3 - 4$)

- Au + Au
- Cu + Cu

- Resolution of Reaction plane $\sim v_2 \times \sqrt{M}$
- Sizeable elliptic flow @ $|\eta| \sim 3 - 4$.
  - Au + Au is better than Cu + Cu because of higher multiplicity in Au + Au.

central   peripheral

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Summary

- ## Correlation

  - No big difference can be seen between in-plane and out-of-plane

    - Not enough reaction plane resolution to measure difference of in and out ?

    - Due to flowing jet ?

- ## PID hadron v_2

  - Systematic study of v_2 for identified hadron will be done soon

    - Energy dependence (200 GeV vs. 62.4 GeV)

    - System dependence (Au + Au vs. Cu + Cu)

# Back up

Reaction plane method in PHENIX

- R.P. determination @ BBC
  - $|\eta| = 3 - 4$, Full azimuthal coverage.
  - 3 unit rapidity away from mid-rapidity.
    - Expect to reduce non-flow contribution

- For improvement of flow measurement
  - MVD ($|\eta| = 1 - 3$)
  - R.P. @ Beam rapidity (SMD, FCL)
    - Help to v_1 measurement
    - Sensitivity to non-flow contribution

BBC SOUTH 2nd vs BBC NORTH 2nd
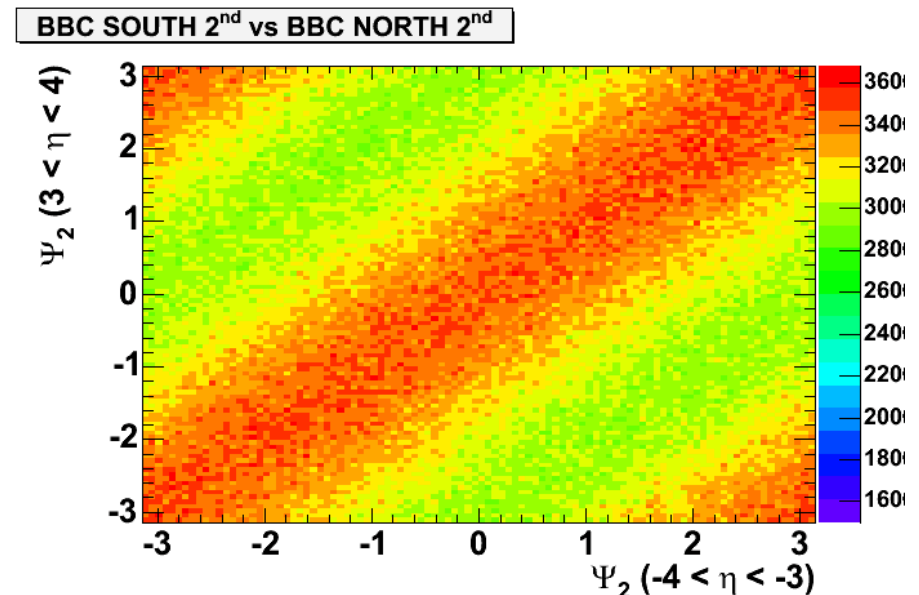
$$\Psi_n = \frac{1}{n} \tan^{-1} \left(\frac{\langle w \sin(n\phi) \rangle}{\langle w \cos(n\phi) \rangle} \right)$$

Non flow (azimuthal correlation not related to R.P.)
ex. Resonance decay, jets etc …

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Correlation function
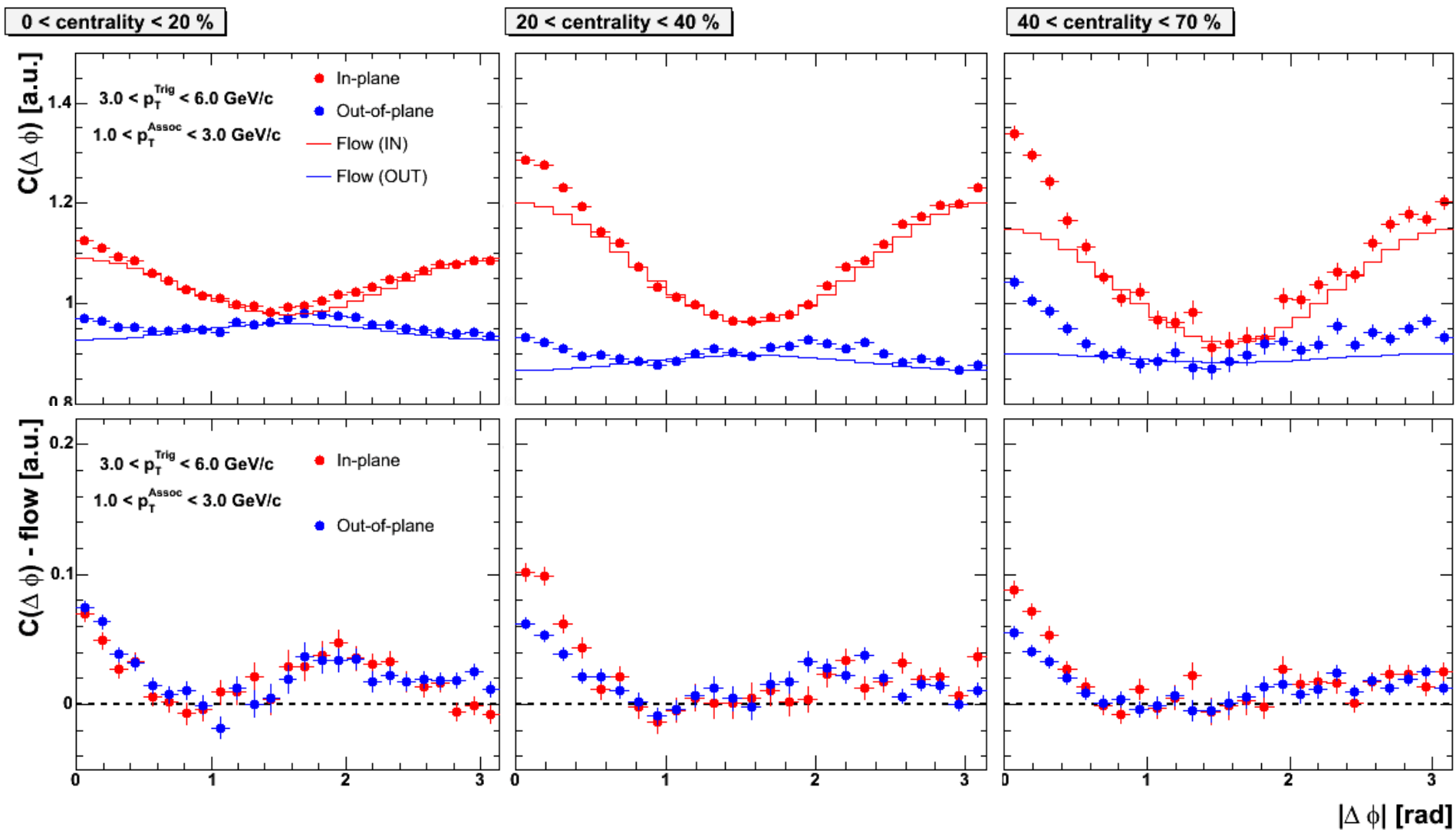
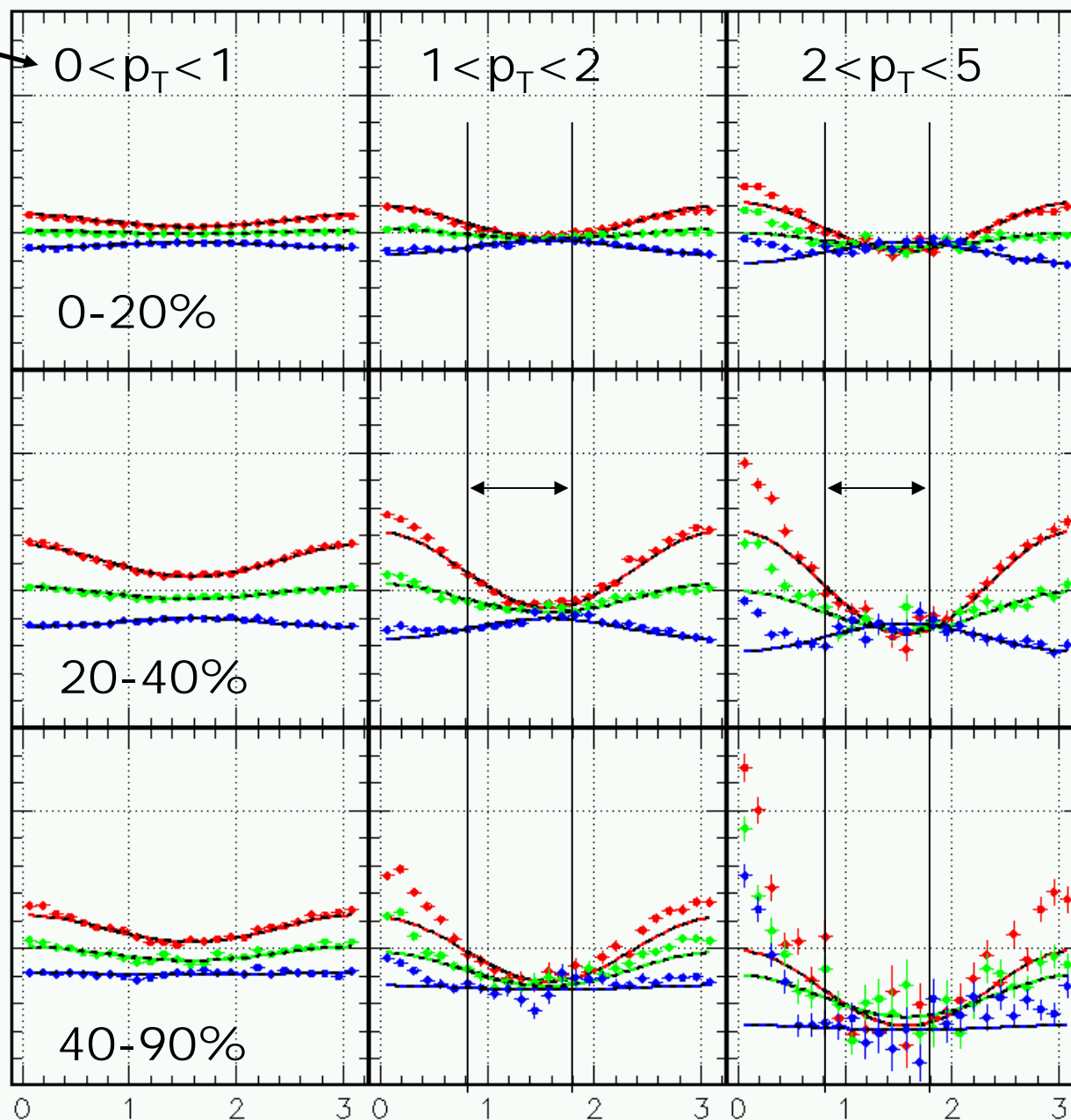associated hadron
p_T window

trigger hadron $p_T > 3$GeV/c

in-plane
middle
out-of-plane

Fitted line shape
is given by :

with fixed
(1)v_2(trigger)
(2)v_2(associated)
(3)R.P. resolution
(4)in/out bin width
 (nucl-ex/0311007)

and one free
normalization
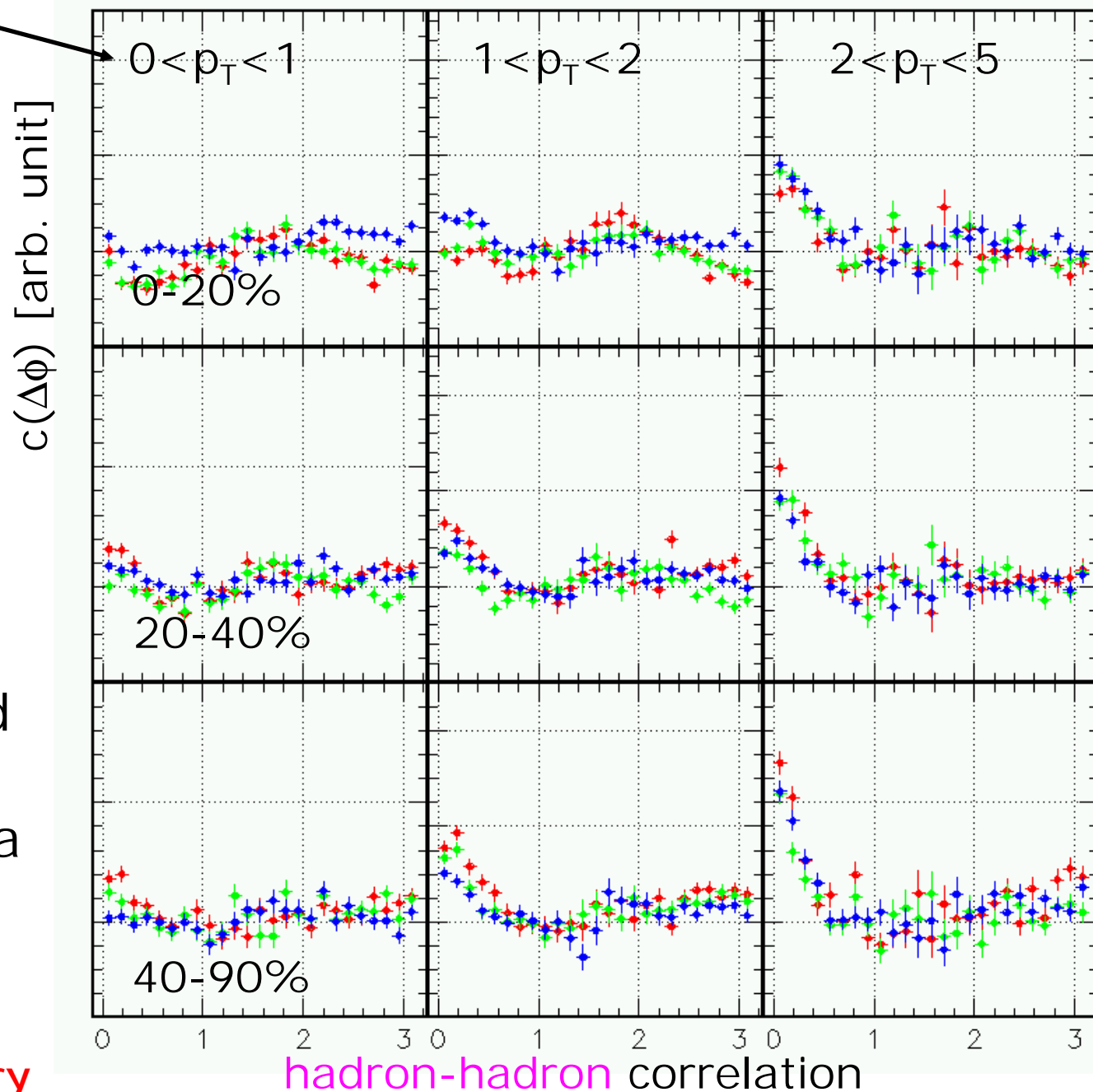parameter fit is
done in a limited
range shown

Au+Au 200GeV
PHENIX preliminary

$0 < p_T < 1$ $1 < p_T < 2$ $2 < p_T < 5$

0-20%

20-40%

40-90%

c($\Delta\phi$) [arb. unit]

hadron-hadron correlation

associated hadron p_T window

trigger hadron $p_T > 3$GeV/c

$0 < p_T < 1$ $1 < p_T < 2$ $2 < p_T < 5$

$c(\Delta\phi)$ [arb. unit]

0-20%

20-40%

40-90%

flow subtracted hadron-hadron correlation data

Au+Au 200GeV PHENIX preliminary

hadron-hadron correlation

Subtracted jet-pair distribution

Au+Au $\sqrt{s_{NN}}$ = 200 GeV; $1 < p_{T,assoc}^{B} < 2.5 < p_{T,trig}^{A} < 4$ GeV/c

(a) 0-5%

PHENIX PRELIMINARY

(b) 5-10%

(c) 10-20%

(d) 20-40%

(e) 40-60%

(f) 60-90%

ZYAM subtracted pairs per trigger: $1/N^A \; dN^{AB}(\text{di-jet})/d(\Delta\phi)$

$\Delta\phi$ (rad)

$\Delta\phi$ (rad)