Two particle hadron correlations with higher harmonic reaction plane in Au+Au 200 GeV collisions at RHIC-PHENIX

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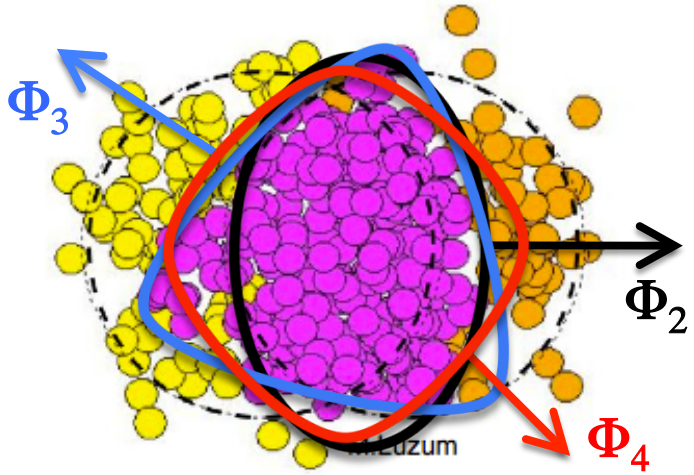
WPCF 2011 at University of Tokyo

Outline

- Introduction
  - Higher harmonic plane and flow
  - Ridge and Shoulder
  - Previous 2 particle correlation results
- Motivation
- Data set and measured values
- Results
  - v_2 v_3 and v_4 subtracted correlations
  - η_{trig} dependent $\Delta\eta$ correlations

Higher harmonic plane & flow

- Fluctuations of initial collision geometry lead to higher harmonic deformation
- Deformation is transferred to momentum space by collective expansion (hydrodynamics)
  - higher harmonic anisotropy emerged



Azimuth. distribution

$$\frac{dN}{d\phi} \propto 1 + 2v_2 \cos 2(\phi - \Phi_2) + 2v_3 \cos 3(\phi - \Phi_3) + 2v_4[\Phi_4] \cos 4(\phi - \Phi_4)$$

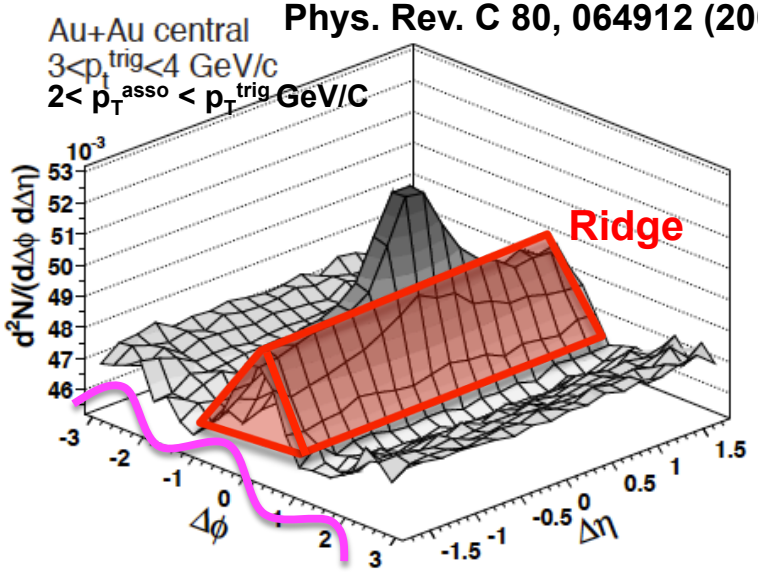
Correlation among Φ_2 - Φ_3 - Φ_4

$$\langle cos6(\Phi_3 - \Phi_2)\rangle = 0 \quad \langle cos4(\Phi_4 - \Phi_2)\rangle = v_4(\Phi_2)/v_4(\Phi_4)$$

v_3 : possible source of "Ridge" and "Shoulder"

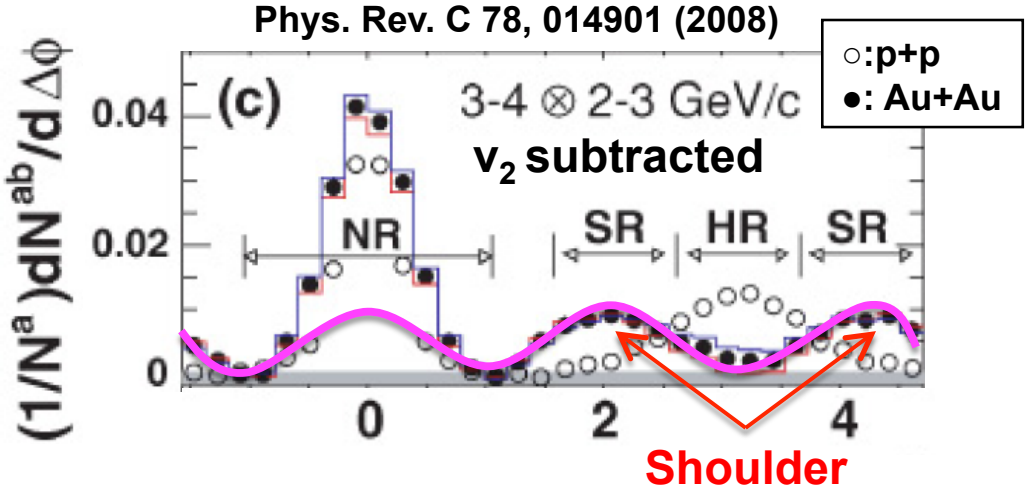
$$Jet(\Delta\phi) = C_2(\Delta\phi) - b_0 Flow(\Delta\phi)$$

Phys. Rev. C 80, 064912 (2009)



Ridge : near side long range $\Delta\eta$ correlations

Phys. Rev. C 78, 014901 (2008)

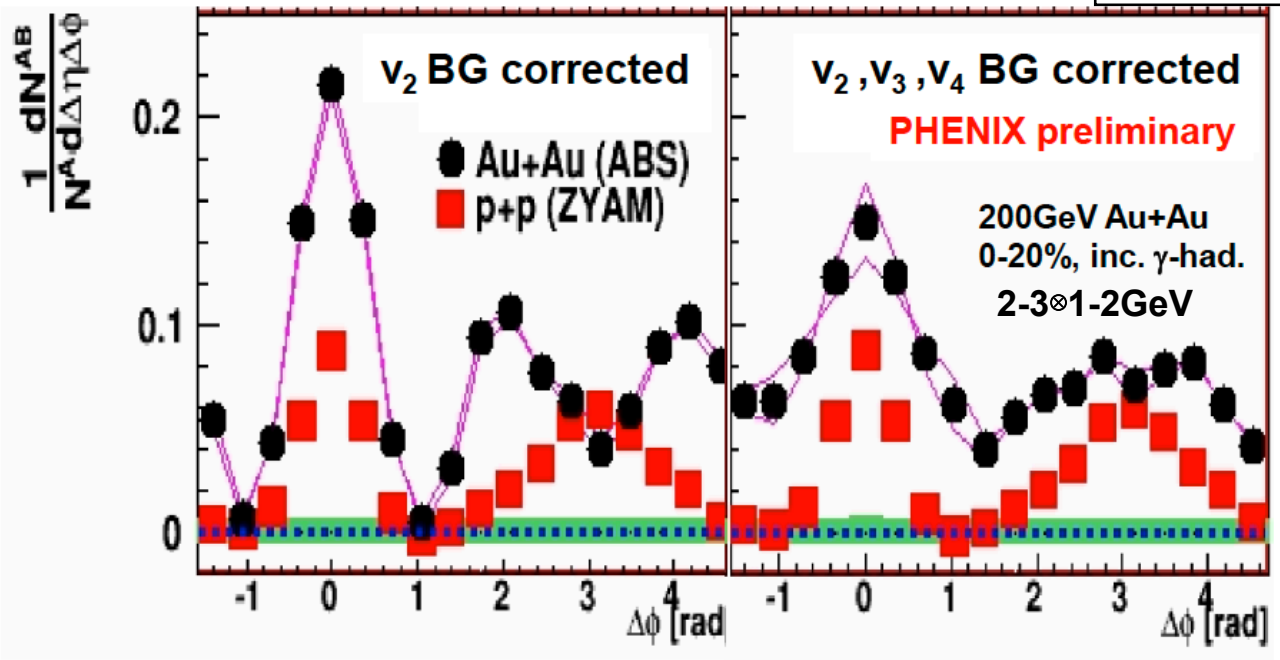


Shoulder: double hump at away side of $\Delta\phi$ correlations (also long in $\Delta\eta$)

- Flow correlation from v_3 term ~ $b_0 2 v_3^{trig} v_3^{asso} \cos 3\Delta\phi$
  - v_3 subtraction would reduce Ridge and Shoulder ⇒ possible source

2 particle correlations at $|\Delta\eta|<0.7$

v_n : central track ($|\eta|<0.35$)
with forward EP($1.0<|\eta|<2.8$)



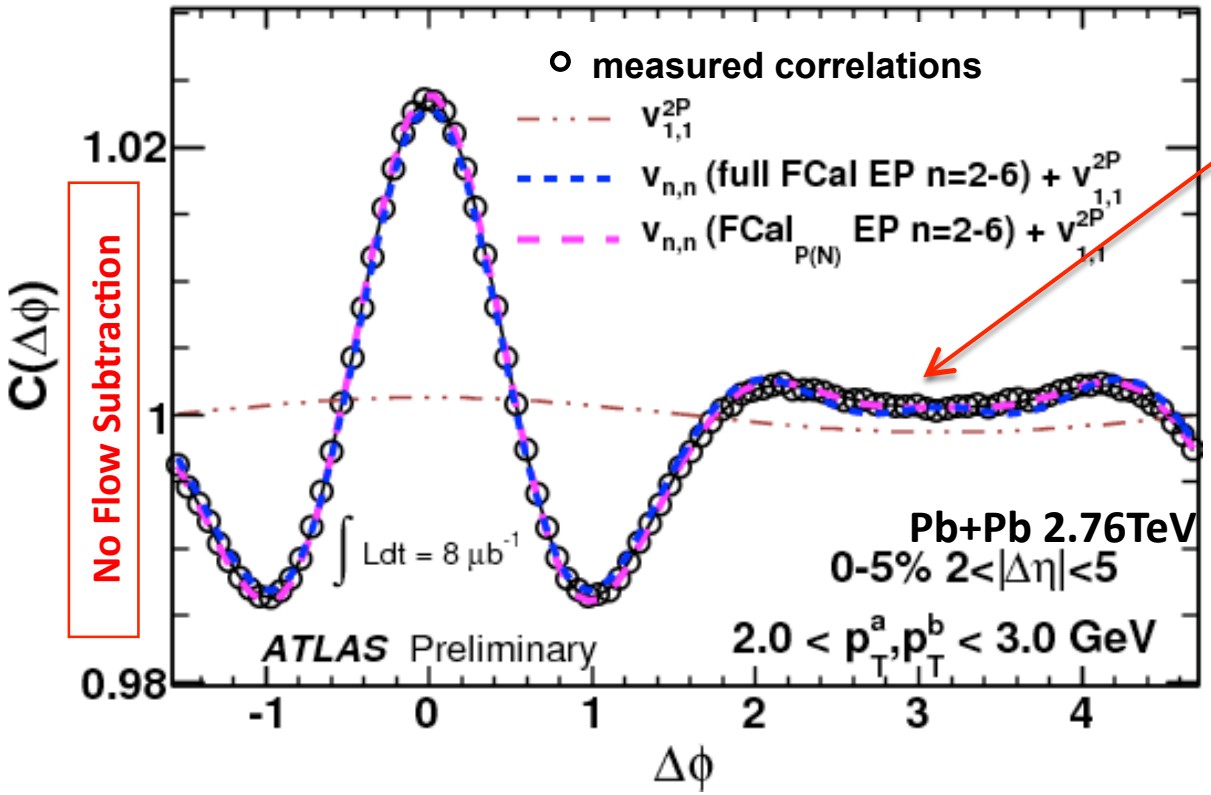
- Shoulder structures almost disappeared at 0-20%
  - Shoulder is described by v_3 and $v_4\{\Phi_4\}$ at small $|\Delta\eta|$

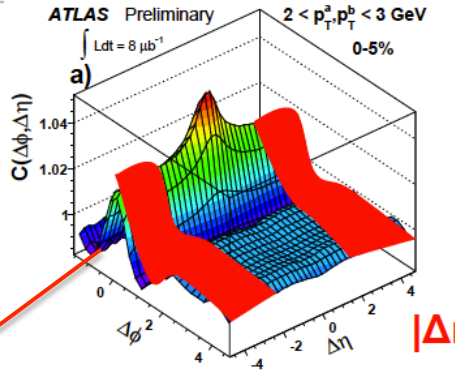
2 particle correlations at $2<|\Delta\eta|<5$

$$C(\Delta\phi) = b^{2P}(1 + 2v_{1,1}^{2P}\cos\Delta\phi + 2\sum_{n=2}^{6} v_n^{EP} v_n^{EP}\cos n\Delta\phi)$$

From 2PC method

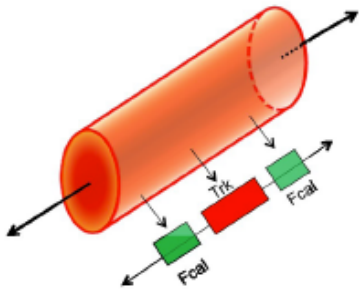
From EP method





|Δη|>2

v_n with EP Method



Track at $|\eta|<2.5$ with EP from full FCAL $3.3<|\eta|<4.8$

v_n with 2Par. Cor Method

Charged particle pair with large rapidity gap e.g. $|\Delta\eta|>2$

- Ridge and Shoulder are described by higher v_n at large $|\Delta\eta|$

Motivation

- Ridge and Shoulder can be described by v_n in central collisions

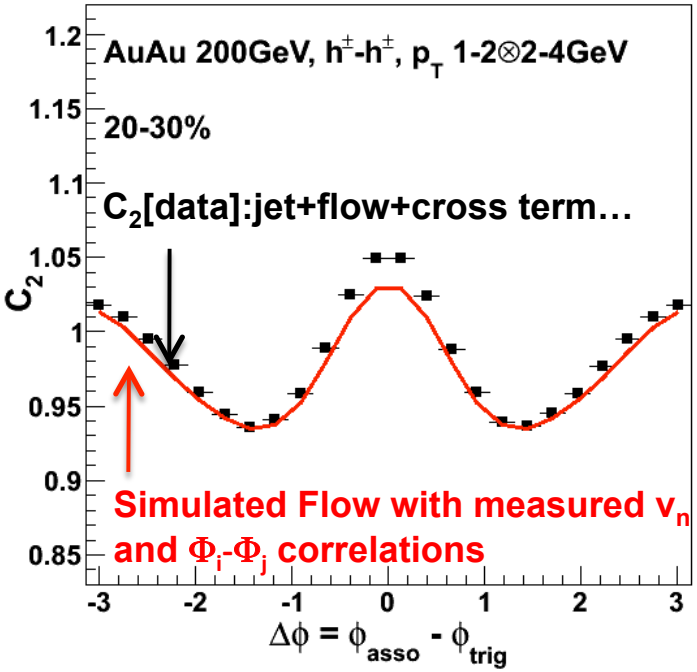
Central collisions	Ridge	Shoulder
small $\|\Delta\eta\|$ (Au+Au 200GeV)	**---------**	**Described**
large $\|\Delta\eta\|$ (Pb+Pb 2.76TeV)	**Described**	**Described**

- Whether Ridge and Shoulder can be described by v_n at peripheral collisions?
  - How is the correlation changed depending on $|\Delta\eta|$ gap
    - Shoulder structure in small $|\Delta\eta|$ gap is tested with v_2 v_3 and v_4 subtractions

Peripheral collisions	Ridge	Shoulder
small $\|\Delta\eta\|$	**---------**	**tested**
large $\|\Delta\eta\|$	**not yet**	**not yet**

Data set & measured value

- Au+Au 200GeV, 3.2 billion Minimum Bias Events taken in 2007
  - 2 particle charged hadron correlations at $|\Delta\eta|<0.7$, Centrality : 0-50%
    - Trigger p_T = 2~4 GeV, Associate p_T = 1~2 GeV
  - $v_n\{\Phi_n\}$ of central tracks ($|\eta|<0.35$) was measured with Event Plane method ($|\eta|$:1.0−2.8)



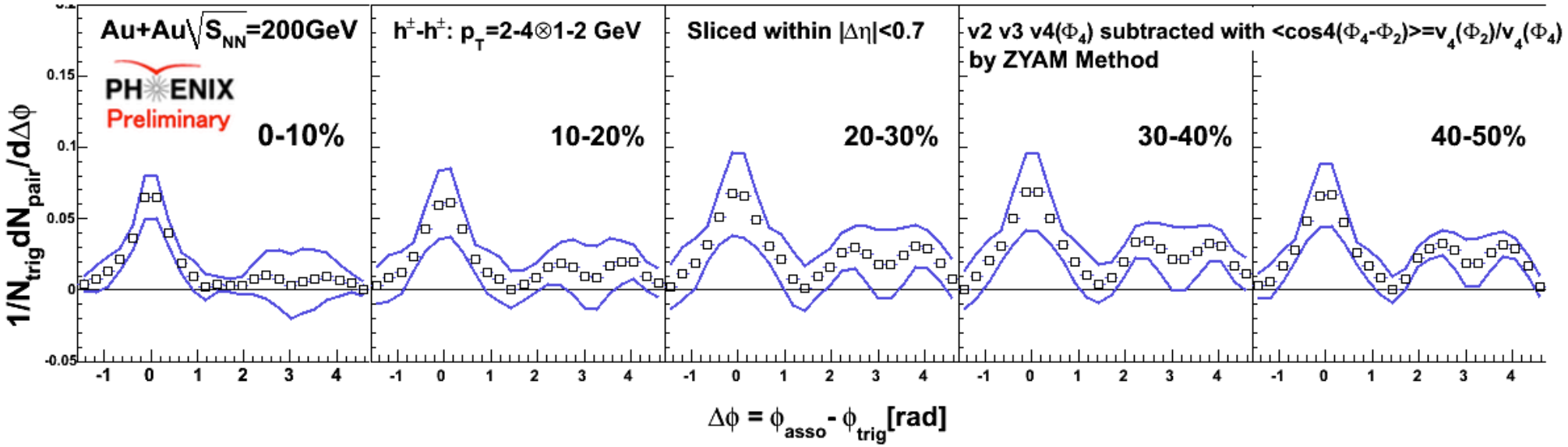
$$C_2[\text{Data-flow}] \times \frac{1}{\varepsilon}\frac{N^{pair}_{same}}{N^{trig}}$$

Pair yield per a trigger
$1/N_{trig}dN_{pair}/d\Delta\phi$

ZYAM Method Subtraction Applied

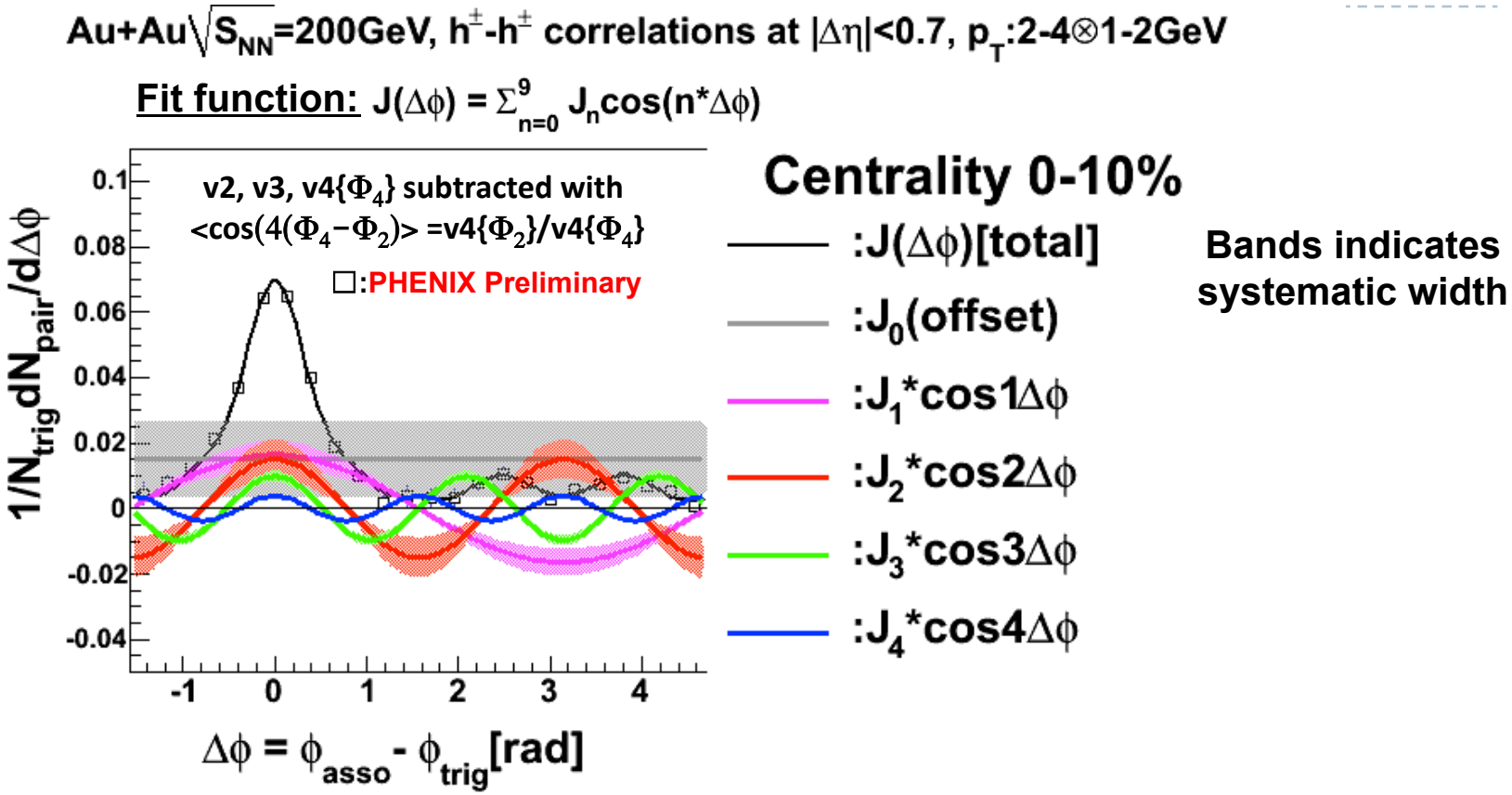
$$C_2(\Delta\phi) \equiv \frac{dN^{pair}_{same}/d\Delta\phi}{dN^{pair}_{mixed}/d\Delta\phi}\frac{N^{pair}_{mixed}}{N^{pair}_{same}}$$

v2, v3 and v4{Φ_4} subtracted correlations at $|\Delta\eta|<0.7$



- Shoulder almost disappeared at centrality 0-10% as previous results
- "New" shoulders emerged in peripheral collisions
  - systematic error is relatively large

Fitting to flow subtracted correlations



- cos3($\Delta\phi$) and cos4($\Delta\phi$) terms are balanced at $\Delta\phi=\pi$ in central collisions
- cos4($\Delta\phi$) term is almost 0 in peripheral collisions
  - cos3($\Delta\phi$) and cos4($\Delta\phi$) terms aren't balanced, dip at $\Delta\phi=\pi$ is emphasized

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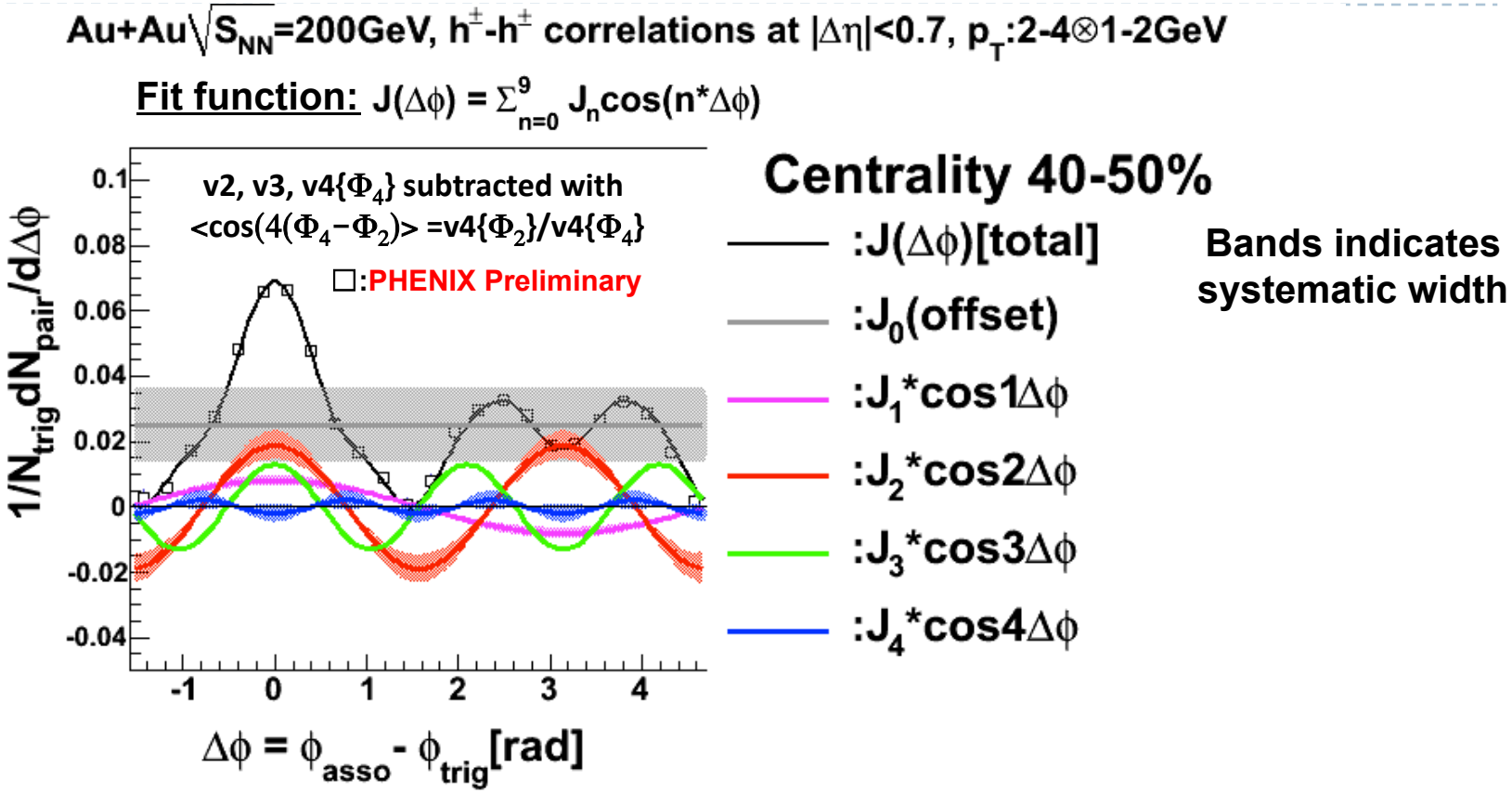

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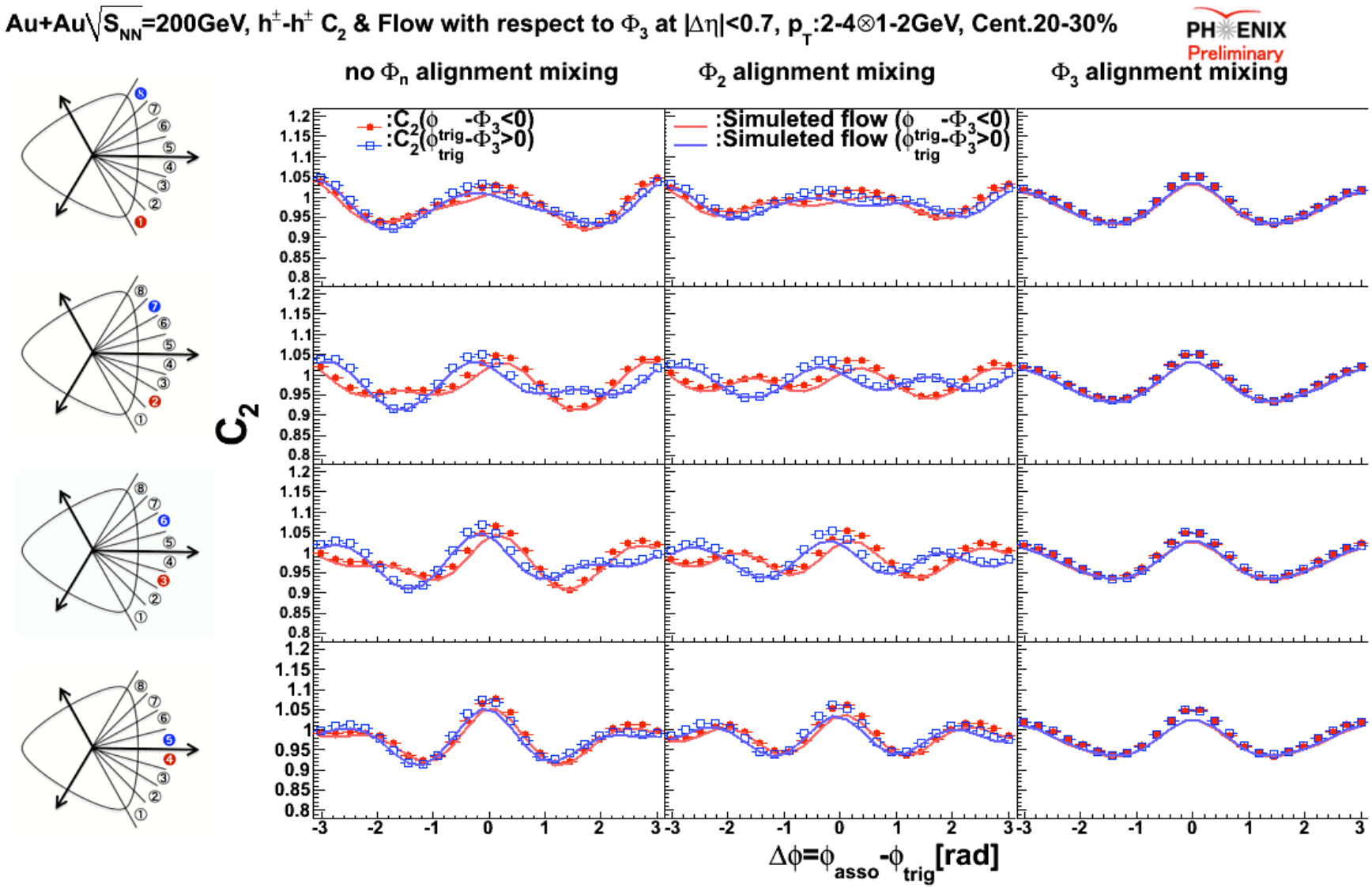
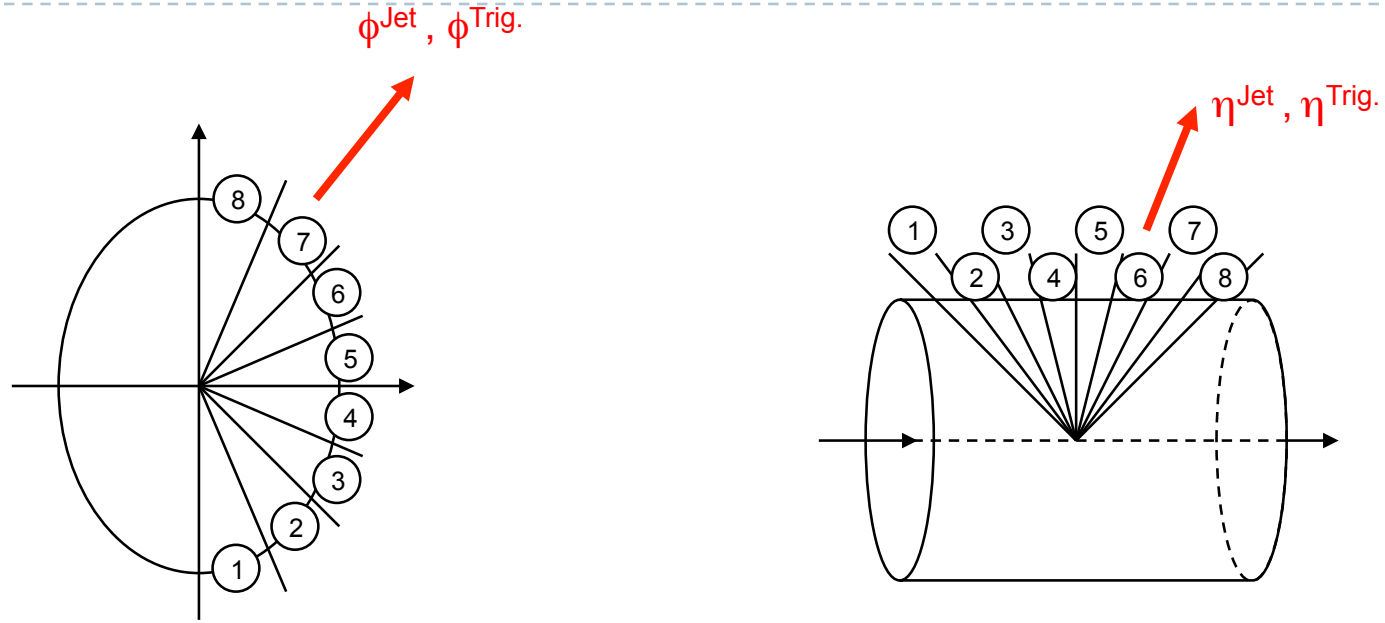
Φ_2 & Φ_3 dependent analyses are in progress

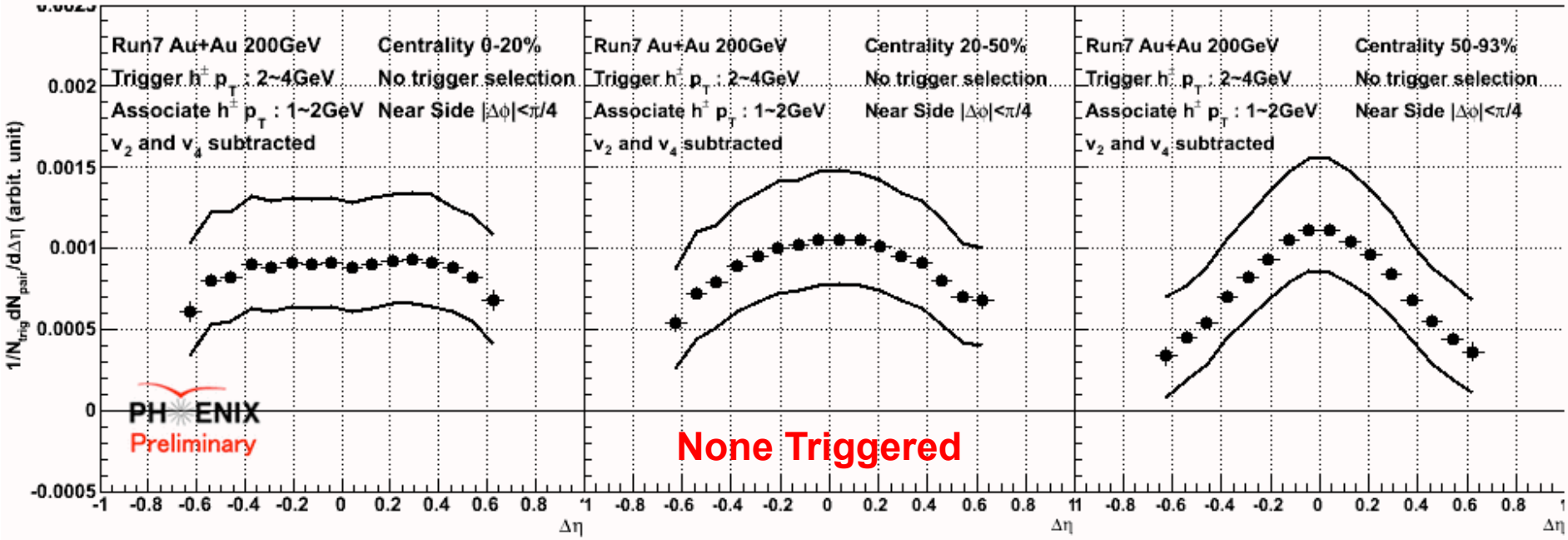


η_{trig} dependent $\Delta\eta$ correlations



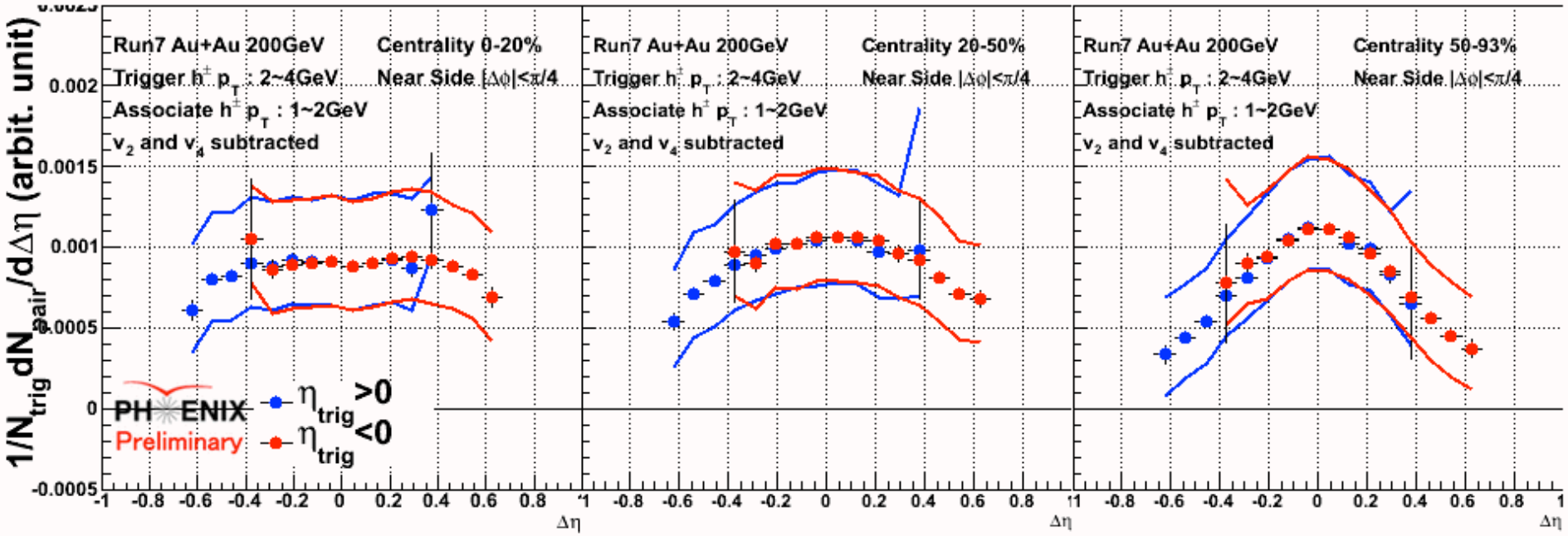
- Trigger η selected $\Delta\eta$ correlation could be the probe to survey the geometry and/or dynamics of QGP bulk in pseudo rapidity directions with same analogy of Reaction Plane dependent $\Delta\phi$ correlations

Triggered Δη correlations



- plus/minus triggered correlations have same shape with none triggered correlations
  - jet-bulk interaction was not observed
    - experimental sensitivity might be not enough due to limited pseudo rapidity coverage

Triggered Δη correlations



- plus/minus triggered correlations have same shape with none triggered correlations
  - jet-bulk interaction was not observed
    - experimental sensitivity might be not enough due to limited pseudo rapidity coverage

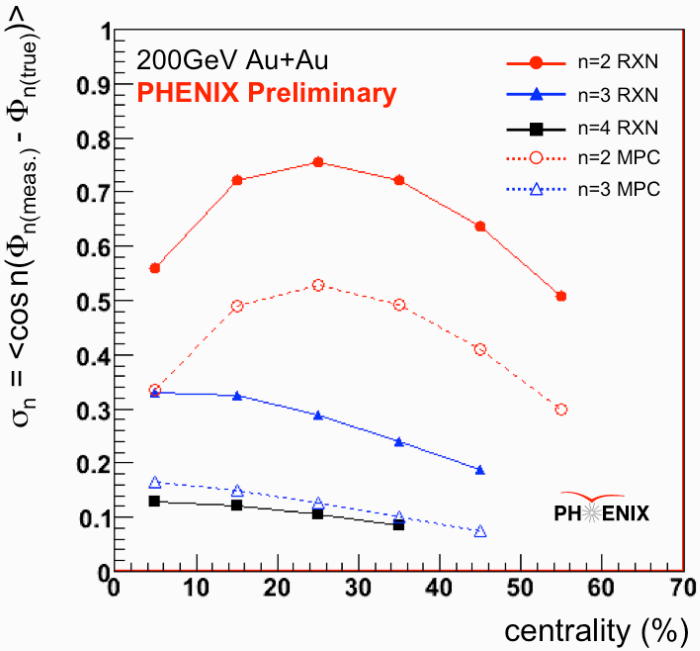
Summary & Outlook

- v2 v3 and v4{Φ_4} subtracted $\Delta\phi$ correlations are measured within $|\Delta\eta|<0.7$ in Au+Au 200GeV collisions
  - Shoulder almost disappeared in central collisions as previous results
  - "New" shoulder emerged in peripheral collisions
    - this was due to the imbalance of cos3$\Delta\phi$ and cos4$\Delta\phi$ components
- η_{trig} dependent $\Delta\eta$ correlations
  - Jet correlation might be independent of η_{trig}
  - experimental sensitivity might be not enough
- Outlook for $\Delta\phi$ correlations
  - reduce systematic error width
  - include v_5 and v_6 contributions
  - Φ_2 & Φ_3 dependent analyses are in progress!!

Backup Slides

Φ_n resolution and Φ_i - Φ_j correlations

arXiv:1105.3928v1 [nucl-ex]



RXN $|\eta|$ = 1.0 ~ 2.8
MPC $|\eta|$ = 3.1~ 3.7

positive correlation in Φ_3 between opposite η up to +/– 3 ~ 4
no-sign flipping in Φ_3, which is an indication initial geometrical fluctuation
Φ_n resolution estimated from Forward-Backward correlation
$\Phi_{n\{true\}}$ can be different for different order

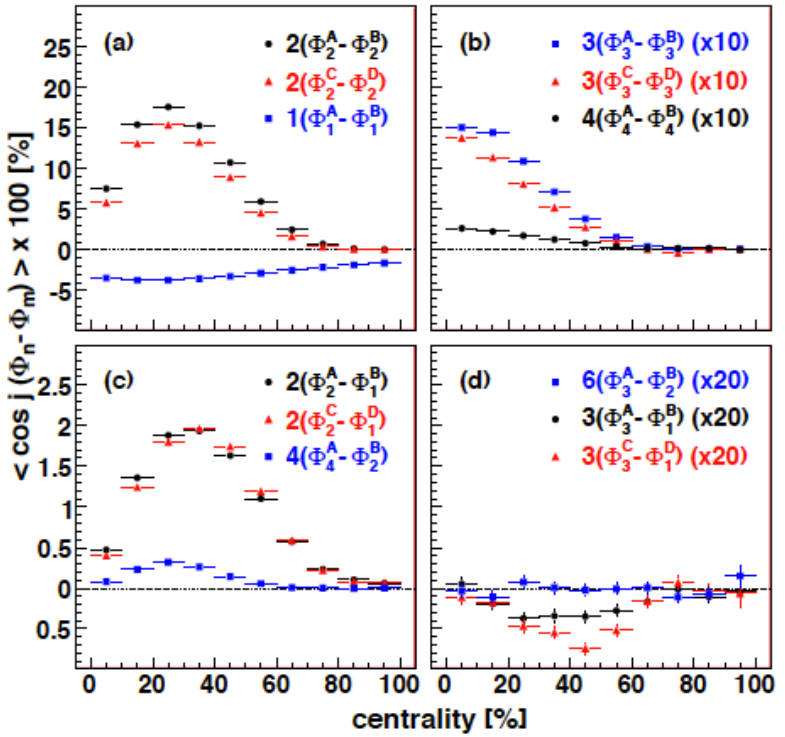
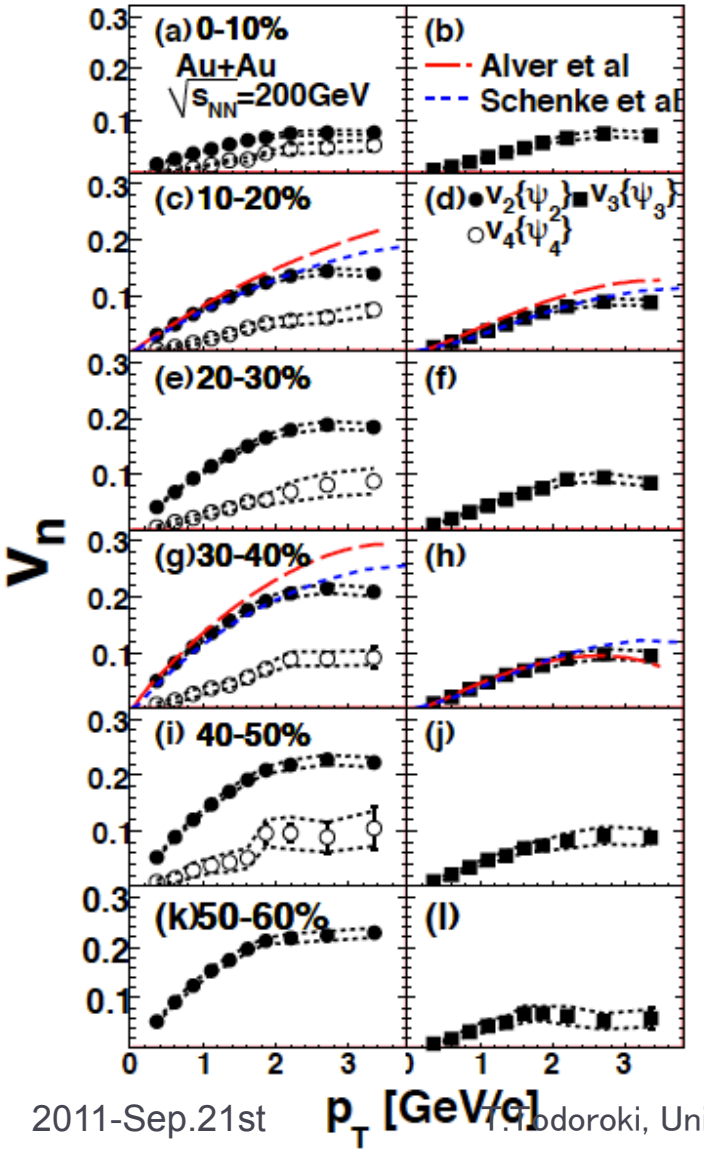


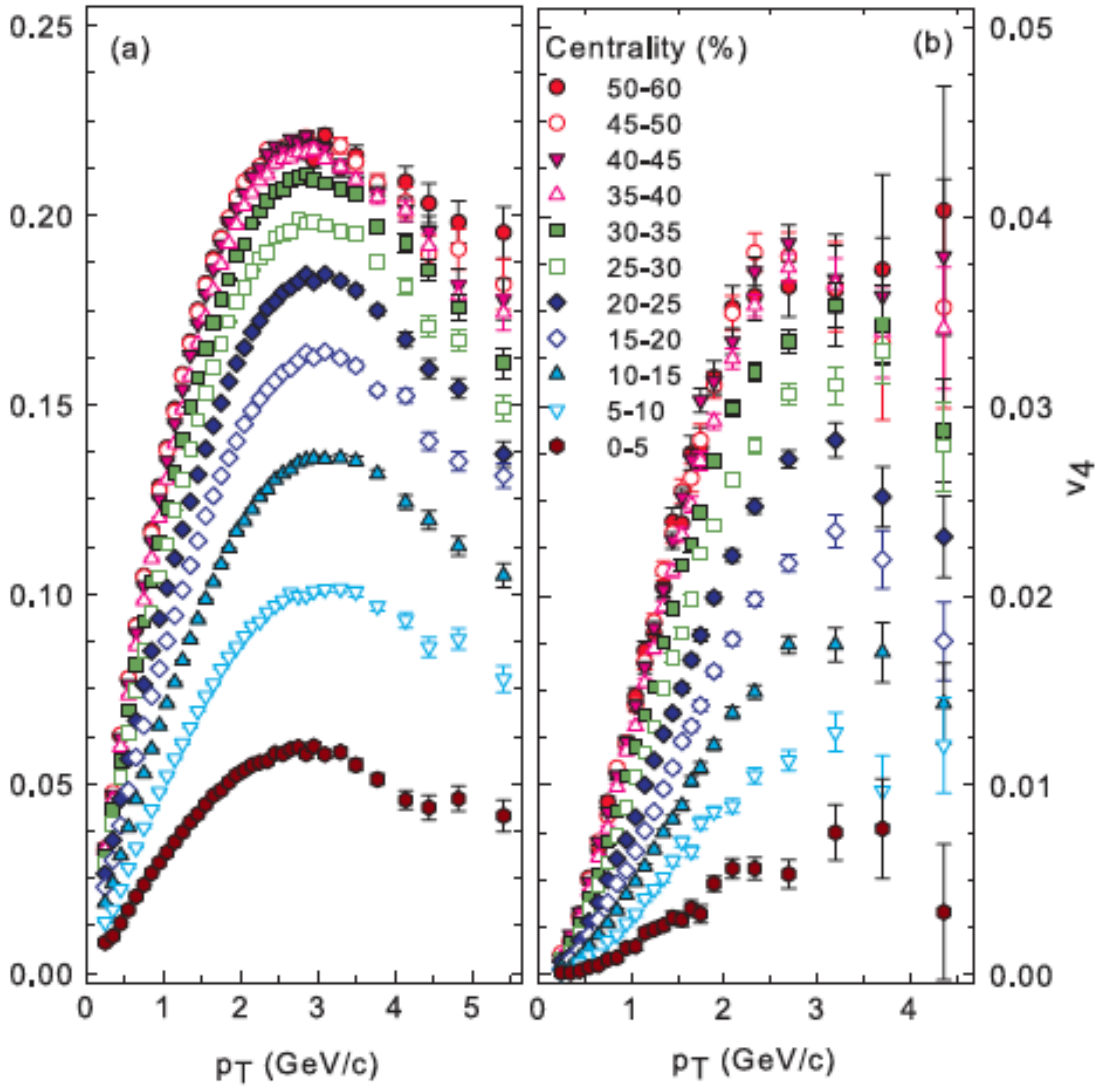
FIG. 1: (color online) Raw correlation strengths (see text) of the event planes for various detector combinations as a function of collision centrality. The detectors in which the event plane is measured are: (a) RXN North, (b) BBC South, (c) MPC North, and (d) MPC South.

Higher harmonic flow

arXiv:1105.3928v1 [nucl-ex]

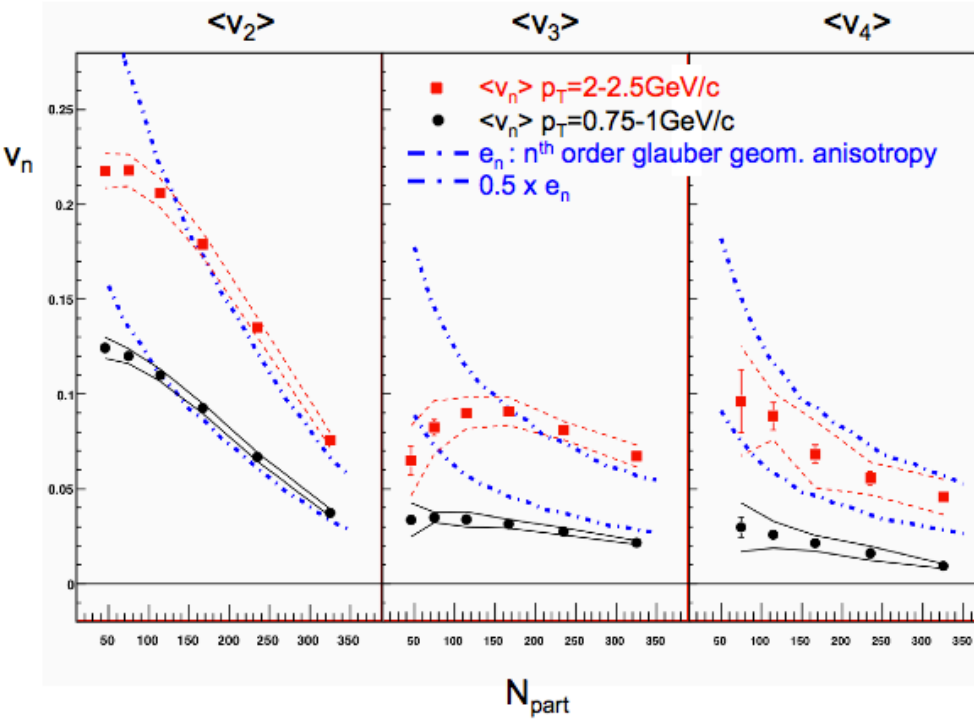
PRL 105, 062301(2010)





v_2 , v_3 and $v_4\{\Phi_4\}$ with model comparison

QM2011 Flow Plenary S. Esumi



arXiv:1105.3928v1 [nucl-ex]

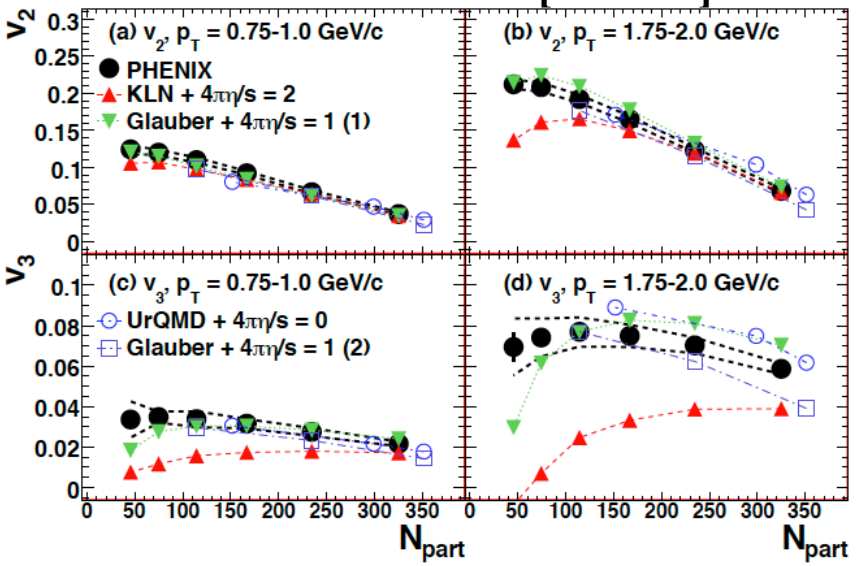
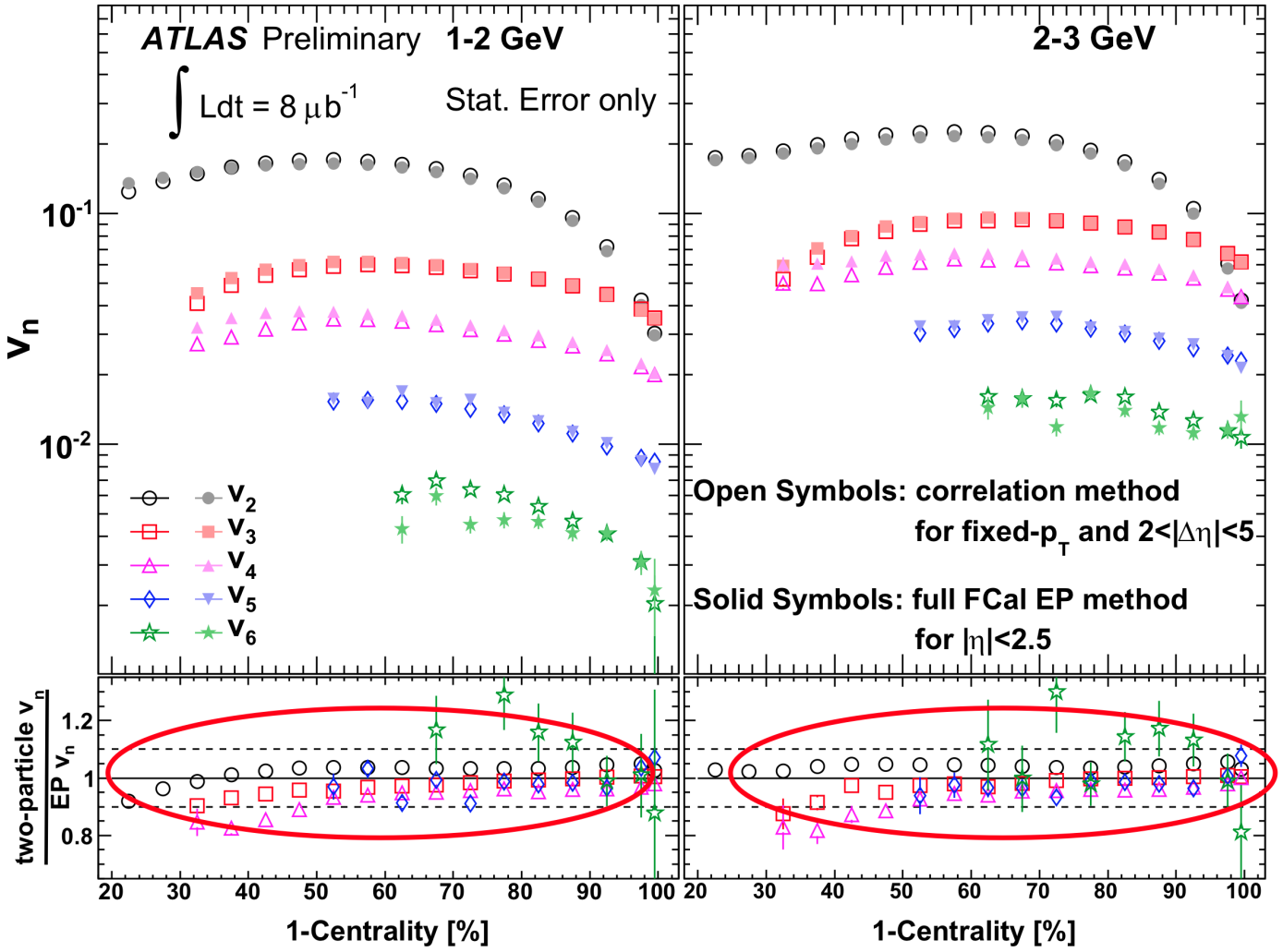


FIG. 3: (color online) Comparison of $v_n\{\Psi_n\}$ vs. $N_{\rm part}$ measurements and theoretical predictions (see text): "MC-KLN + $4\pi\frac{\eta}{s} = 2$" and "Glauber + $4\pi\frac{\eta}{s} = 1$ (1)" [16]; "Glauber + $4\pi\frac{\eta}{s} = 1$ (2)" [17]; "UrQMD" [26];. The dashed lines (black) around the data points indicate the size of the systematic uncertainty.

[16] B. Alver et al., Phys. Rev. C **82**, 034913 (2010).
[17] B. Schenke, S. Jeon, and C. Gale, Phys. Rev. Lett. **106**, 042301 (2011).
[26] H. Petersen et al., Phys. Rev. C **82**, 041901 (2010).

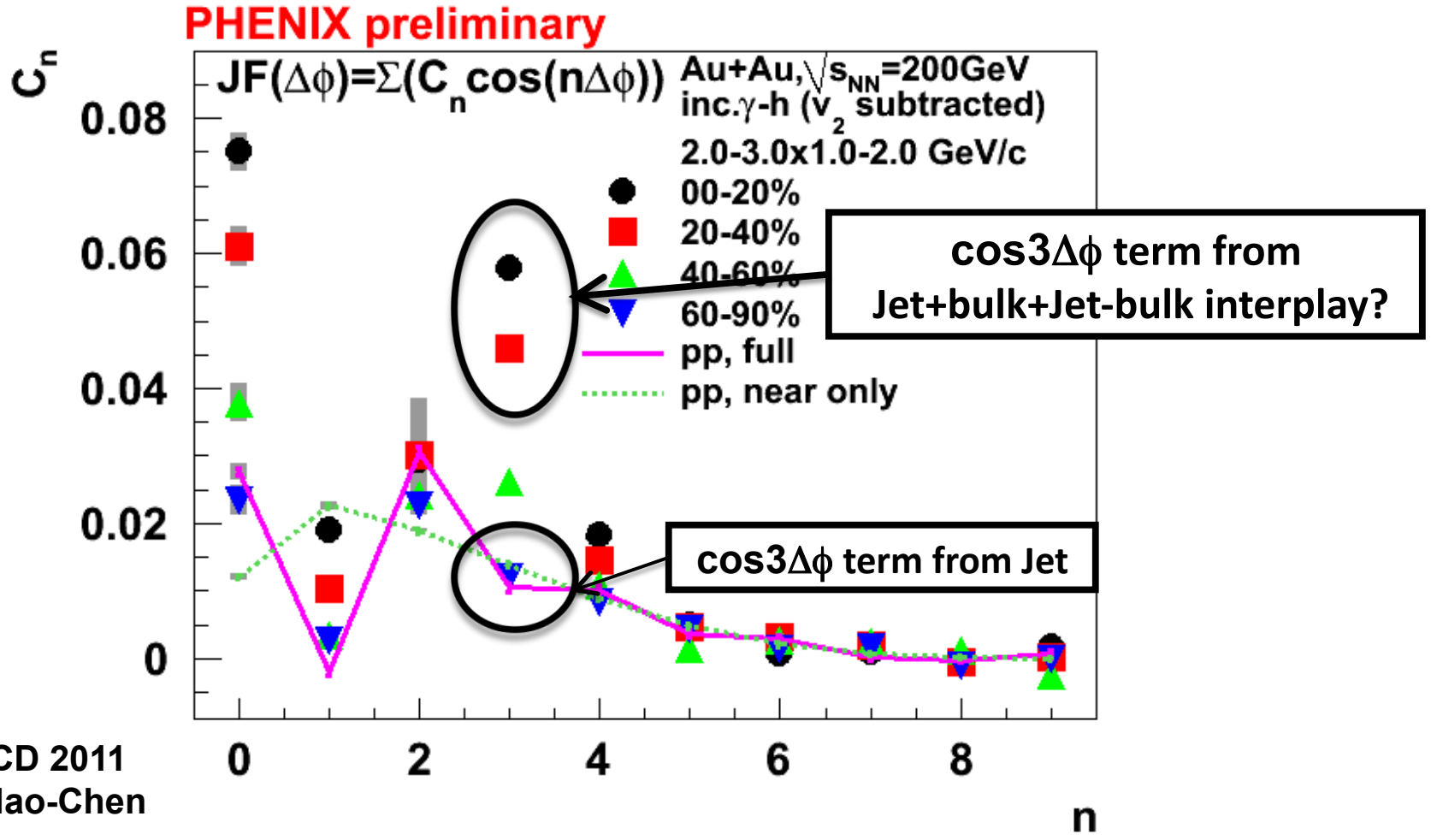
Compare with the Event Plane method



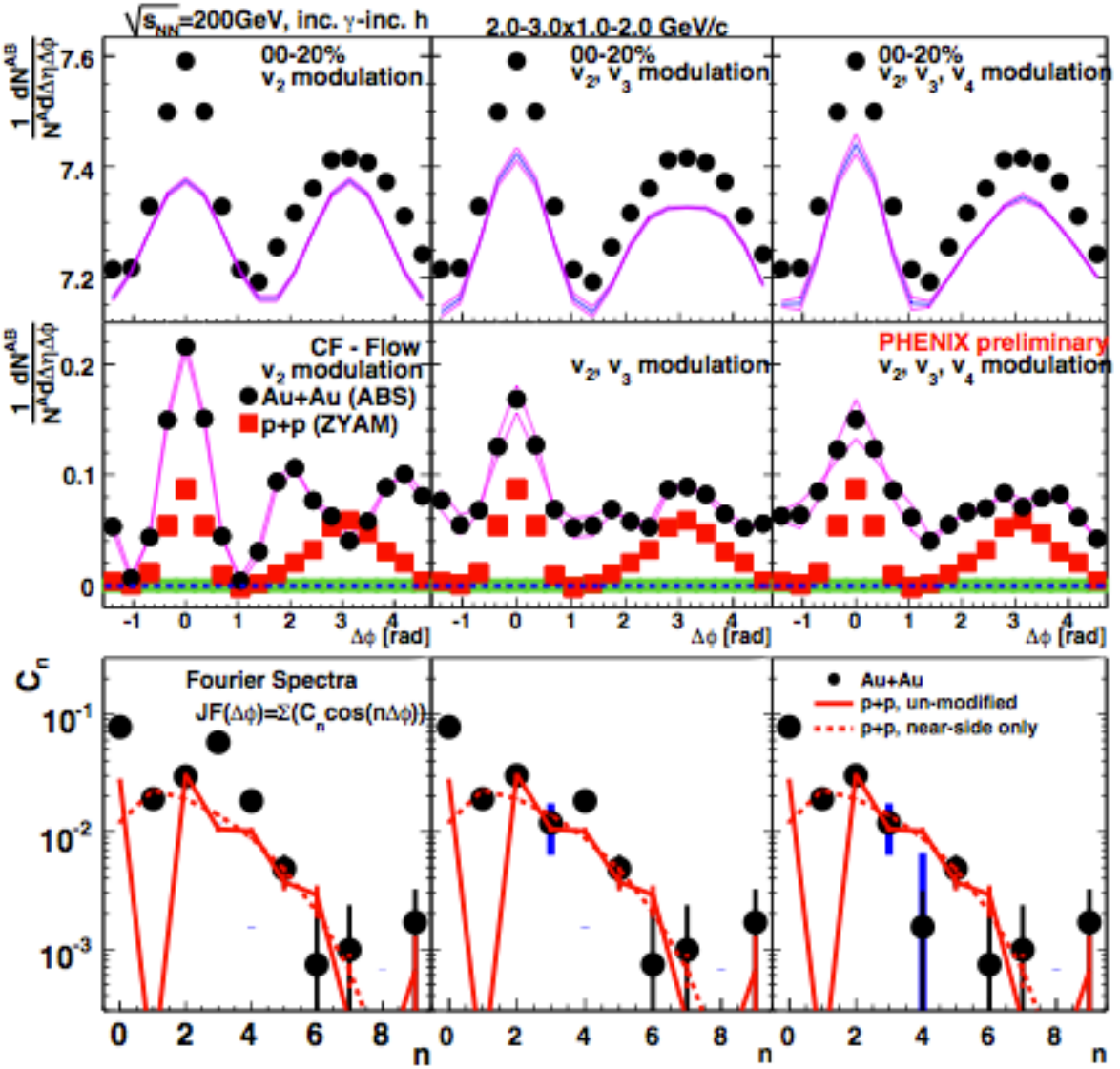
Jiangyong, Jia
QM11' Flow Plenary

Consistent between the 2PC and full FCal EP method (Similar for $FCal_{P(N)}$).

Fourier analysis of the per trigger yield jet function



Moriond QCD 2011
John-Chin-Hao-Chen


√sNN=200GeV, inc. γ-inc. h
2.0-3.0x1.0-2.0 GeV/c
00-20%
v2 modulation
00-20%
v2, v3 modulation
00-20%
v2, v3, v4 modulation
CF - Flow
v2 modulation
Au+Au (ABS)
p+p (ZYAM)
v2, v3 modulation
PHENIX preliminary
v2, v3, v4 modulation
Δφ [rad]
Fourier Spectra
JF(Δφ)=Σ(Cn cos(nΔφ))
Au+Au
p+p, un-modified
p+p, near-side only
n