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

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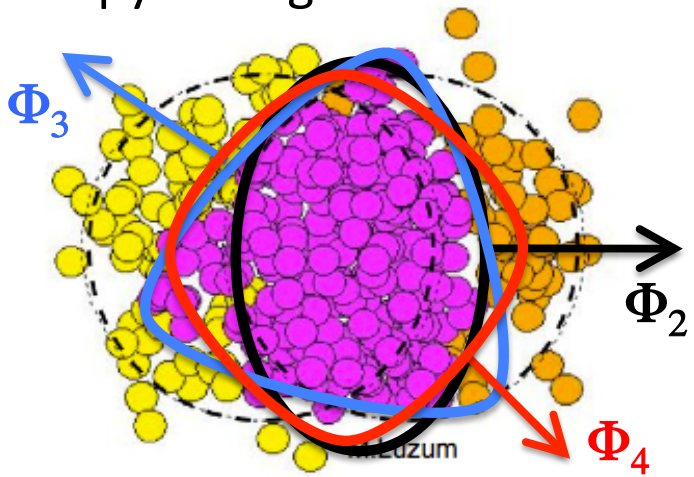
JPS 2011 Autumn Meeting at Hirosaki University

Higher harmonic plane & flow

- Fluctuations of initial collision geometry result in higher harmonic deformation
- Transferred to momentum space by collective expansion (hydrodynamics)
  - higher harmonic anisotropy emerge



Azimuth. distribution

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

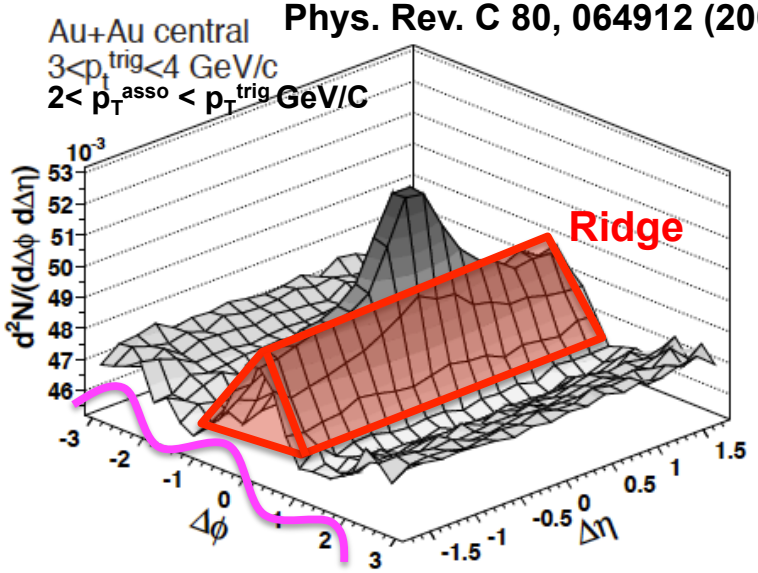
Correlation among Φ_2 - Φ_3 - Φ_4

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

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

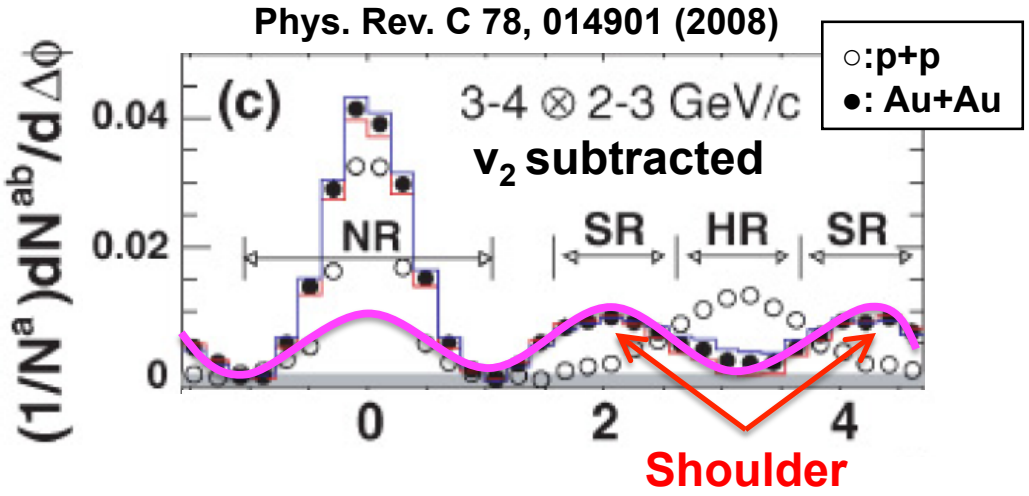
$$Jet(\Delta\phi) = C_2(\Delta\phi) - b_0 Flow(\Delta\phi)$$

Phys. Rev. C 80, 064912 (2009)



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

Phys. Rev. C 78, 014901 (2008)

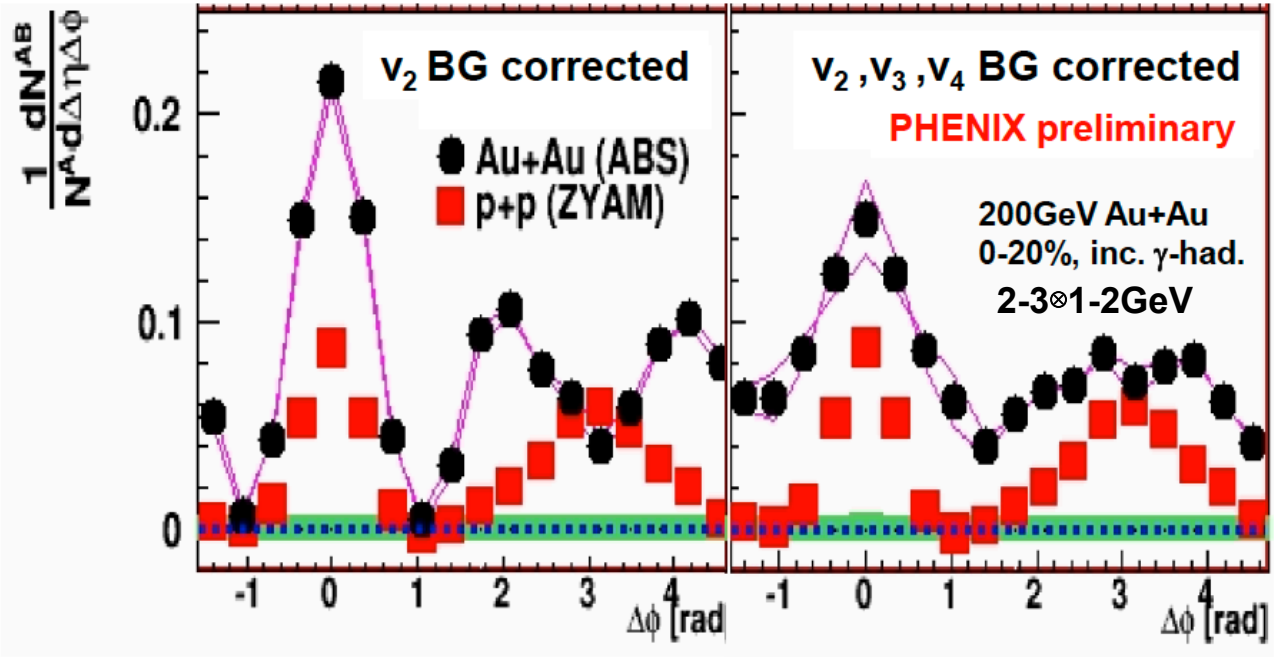


Shoulder: double hump at away side (also long in $\Delta\eta$)

- 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 $|\Delta\eta|<0.7$ with measured v_n subtractions

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



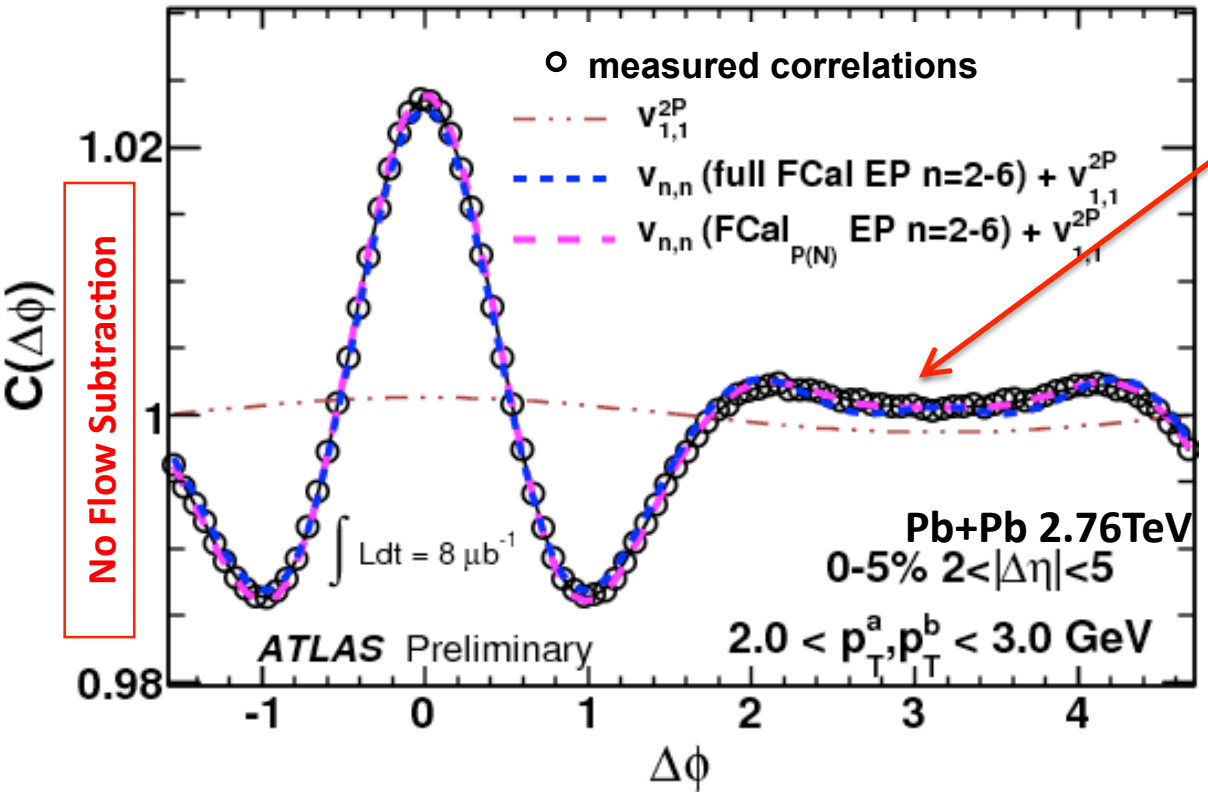
- Shoulder structures almost disappeared at 0-20%
  - v_3 and $v_4\{\Phi_4\}$ explains shoulder at small $|\Delta\eta|$

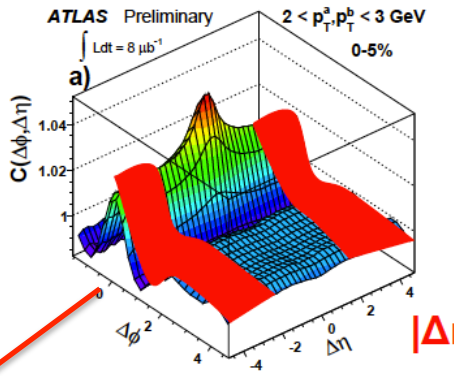
Superposition of v_n contributions reproduce $\Delta\phi$ correlation at large $2<|\Delta\eta|<5$

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

From 2PC method

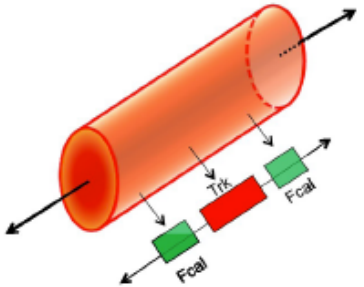
From EP method





|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. $|\Delta\eta|>2$

- Higher v_n explain ridge and shoulder at large $|\Delta\eta|$

Motivation

- Ridge and shoulder explained by higher harmonic v_n at central collisions

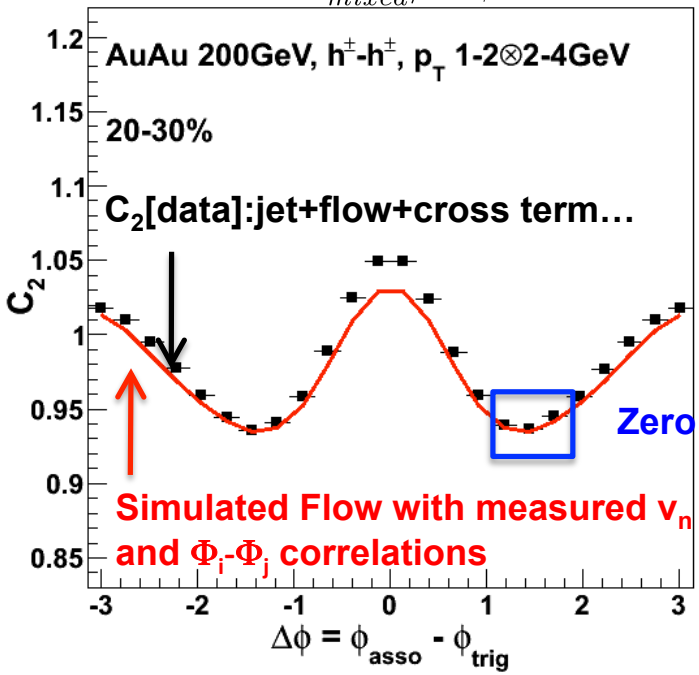
Central collisions	Ridge	Shoulder
small $\|\Delta\eta\|$ (Au+Au 200GeV)	---------	**Explained**
large $\|\Delta\eta\|$ (Pb+Pb 2.76TeV)	**Explained**	**Explained**

- Whether Ridge and Shoulder explained by higher harmonic v_n at peripheral collisions?
  - this analysis focus small $|\Delta\eta|$ range
    - » confirm shoulder explained by v_n or not at peripheral

Analysis

- 2007, Au+Au 200GeV, Minimum Bias Events, 3.2 billion Events
- 2 particle charged hadron $\Delta\phi$ correlations at $|\Delta\eta|<0.7$, Centrality : 0- 50%
  - Trigger p_T = 2~4 GeV, Associate p_T = 1~2 GeV
- $v_n\{\Phi_n\}$ measurements by central track with forward Event Plane ($|\eta|$:1.0−2.8)

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

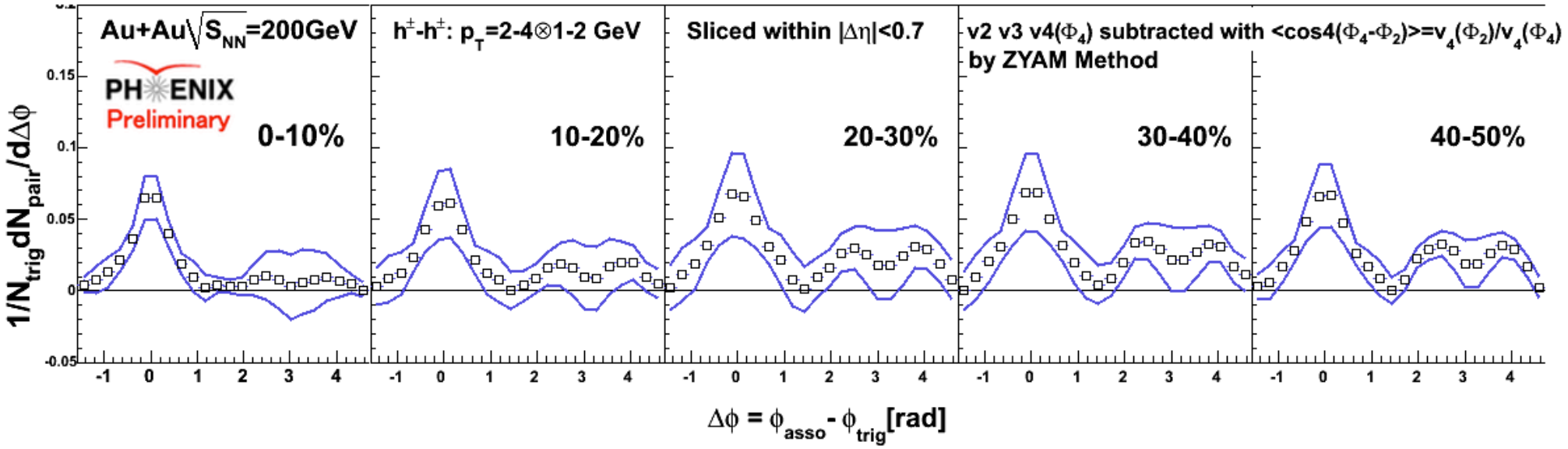


$$C_2[\text{Data-flow}] \times \frac{1}{\varepsilon}\frac{N^{pair}_{same}}{N^{trig}}$$

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

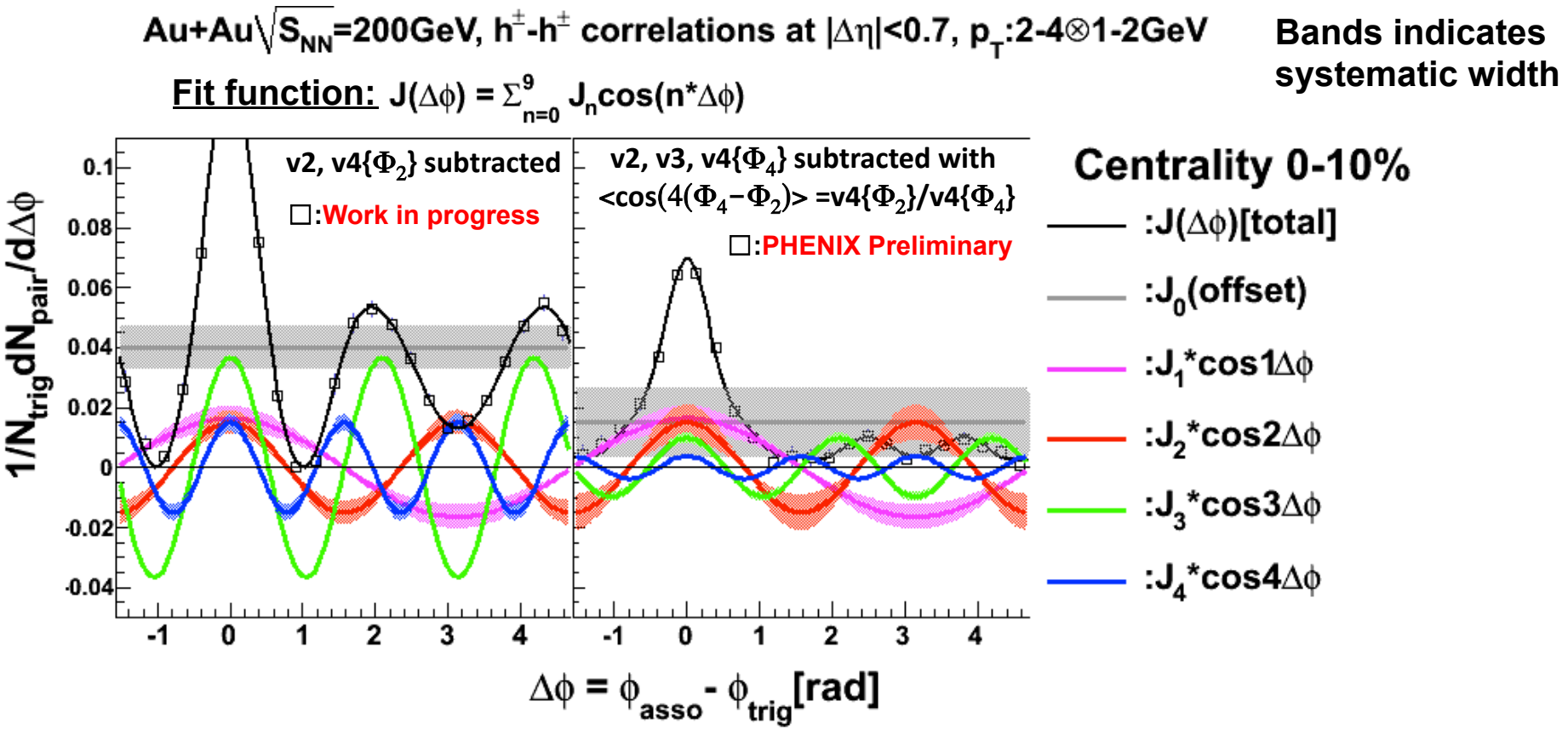
Zero Yield at Minimum Subtraction

v2, v3 and v4{Φ_4} subtracted correlations



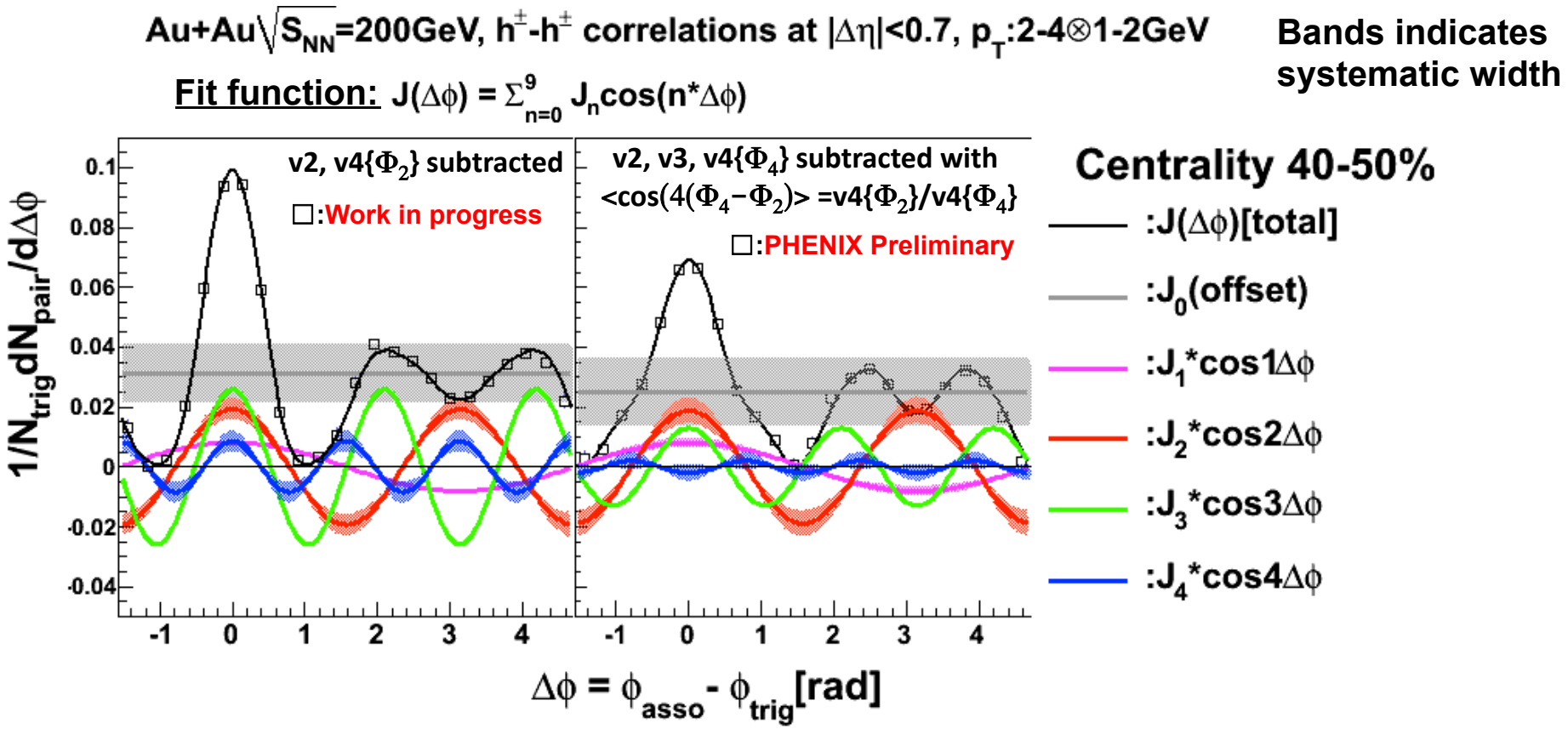
- Shoulder almost disappeared at centrality 0-10% as before
- "New" shoulder emerge in peripheral collisions
  - with relatively-large systematic error…

Fitting to flow subtracted correlations



- cos3($\Delta\phi$) term survives both in central and peripheral
- cos4($\Delta\phi$) term has plus value in central but does almost 0 in peripheral
  - dip at $\Delta\phi=\pi$ is emphasized

Fitting to flow subtracted correlations



- cos3(Δφ) term survives both in central and peripheral
- cos4(Δφ) term has plus value in central but does almost 0 in peripheral
  - dip at Δφ=π is emphasized

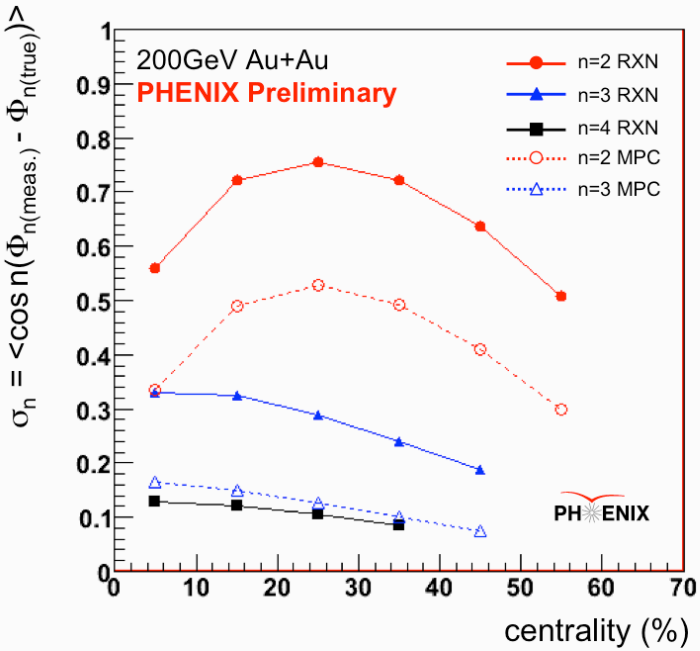
Summary & Outlook

- Measured v2, v3 and v4{Φ_4} ZYAM subtracted correlations within $|\Delta\eta| < 0.7$ up to centrality 50%
  - Shoulder almost disappeared in central collisions as before
  - "New" shoulder emerge in peripheral collisions
    - » cos3($\Delta\phi$) term survives in both in central and peripheral
    - » cos4($\Delta\phi$) term survives in central but disappeared in peripheral
      - dip at $\Delta\phi=\pi$ is emphasized at peripheral
    - » with relatively-large systematic error…
- Outlook
  - reduce systematic error width
  - more peripheral centrality range

Backup Slides

Φ_n resolution and Φ_i - Φ_j correlations

arXiv:1105.3928v1 [nucl-ex]



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

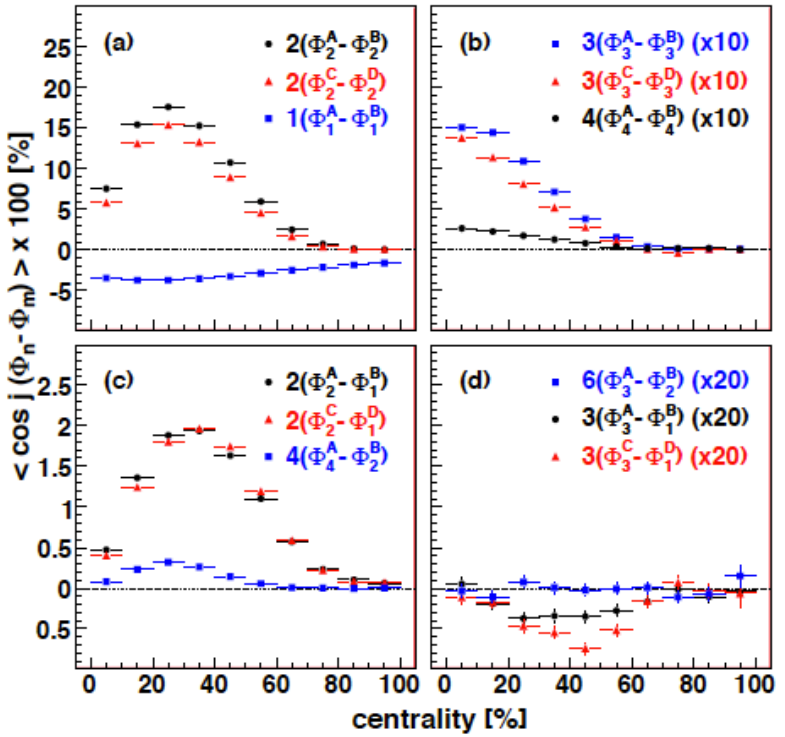
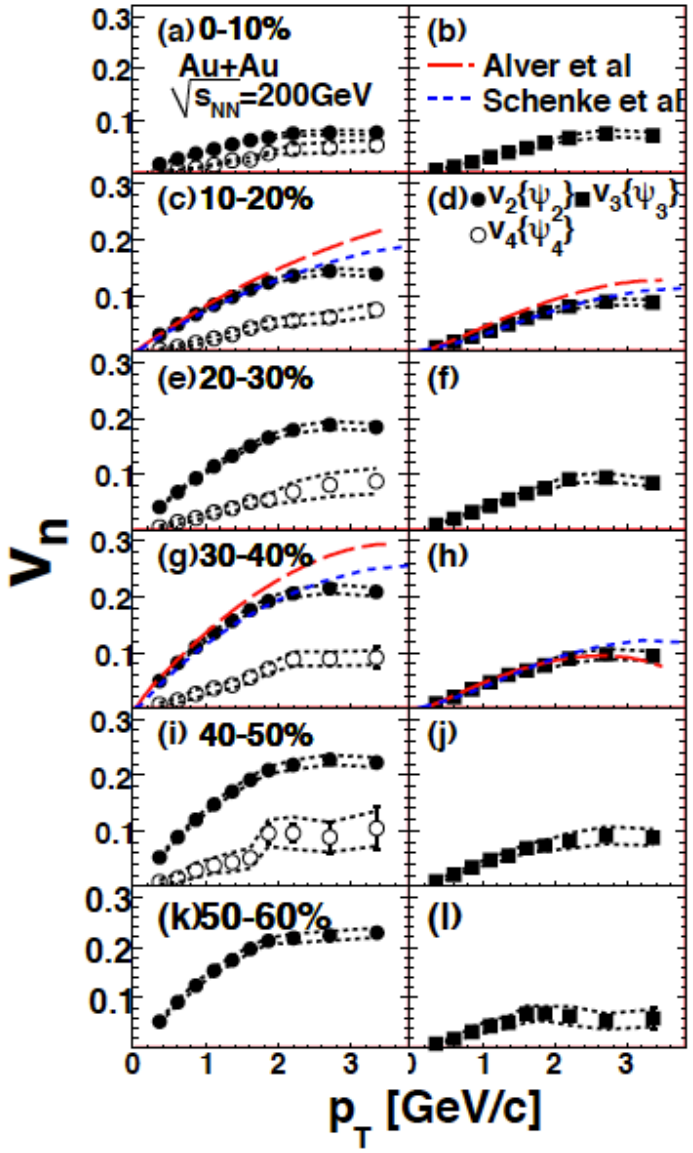


FIG. 1: (color online) Raw correlation strengths (see text) of the event planes for various detector combinations as a function of collision centrality. The detectors in which the event plane is measured are: (a) RXN North, (b) BBC South, (c) MPC North, and (d) MPC South.

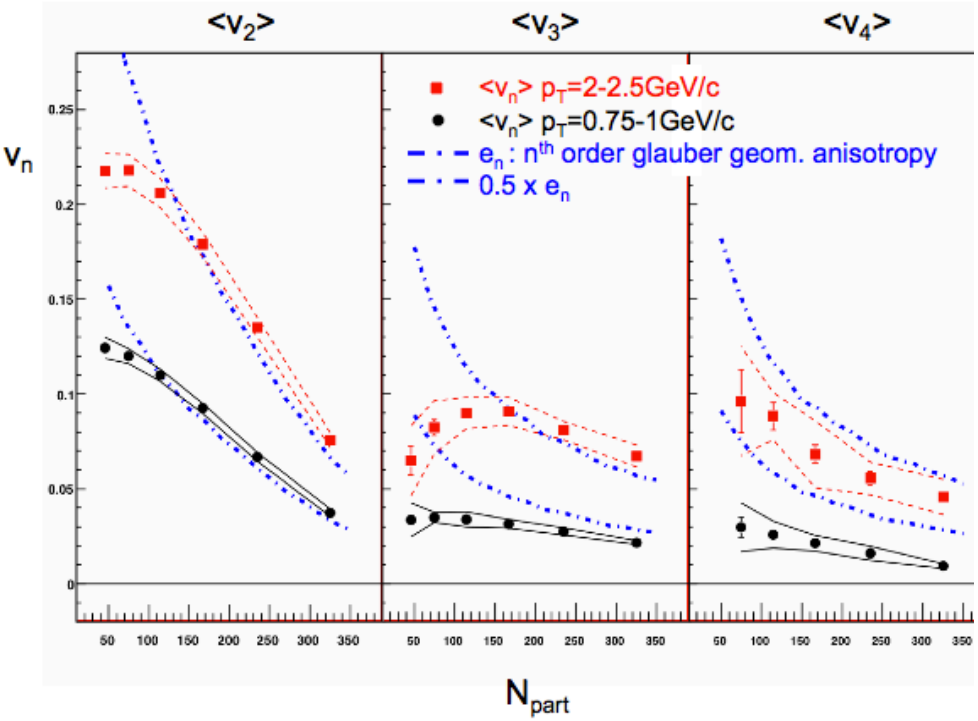
Higher harmonic flow



arXiv:1105.3928v1 [nucl-ex]

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

QM2011 Flow Plenary S. Esumi



arXiv:1105.3928v1 [nucl-ex]

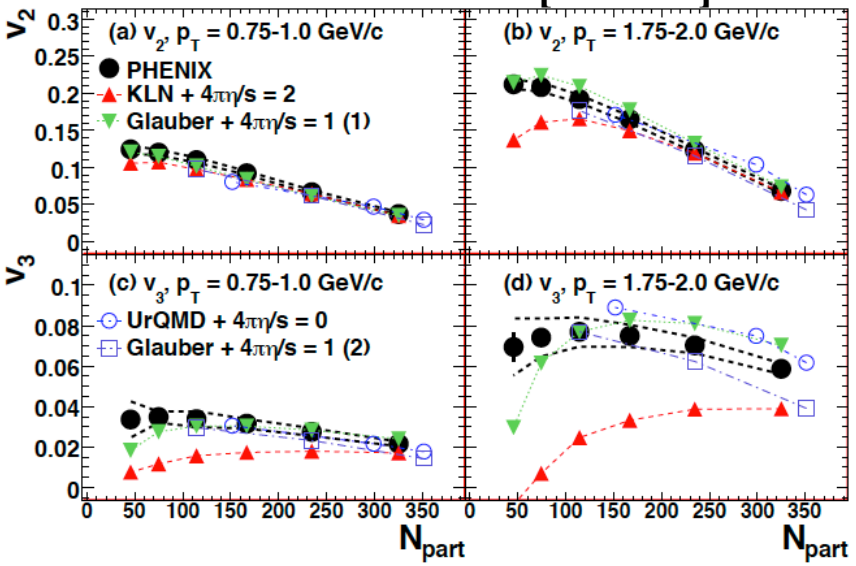
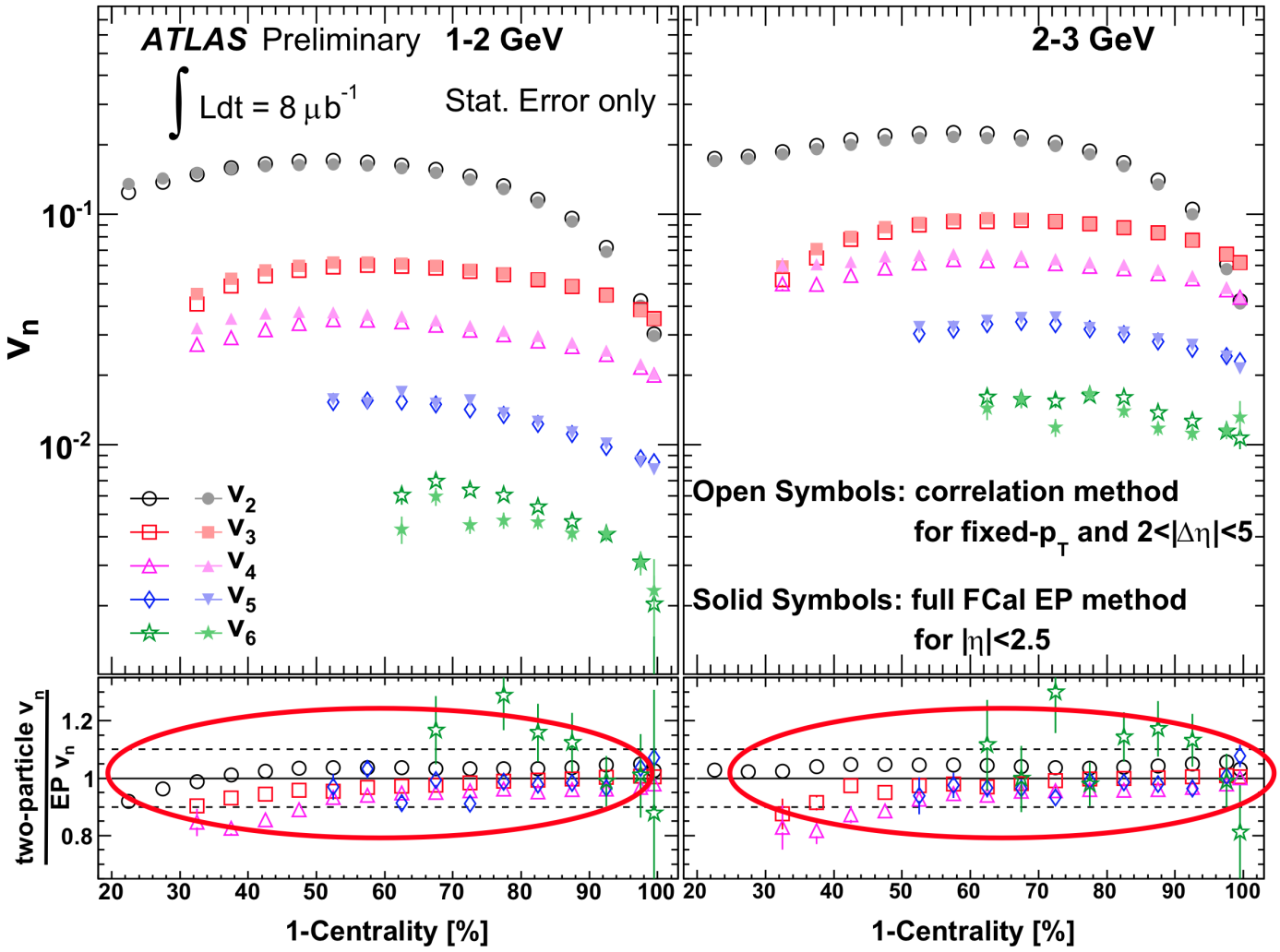


FIG. 3: (color online) Comparison of $v_n\{\Psi_n\}$ vs. $N_{\rm part}$ measurements and theoretical predictions (see text): "MC-KLN + $4\pi\frac{\eta}{s} = 2$" and "Glauber + $4\pi\frac{\eta}{s} = 1$ (1)" [16]; "Glauber + $4\pi\frac{\eta}{s} = 1$ (2)" [17]; "UrQMD" [26];. The dashed lines (black) around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

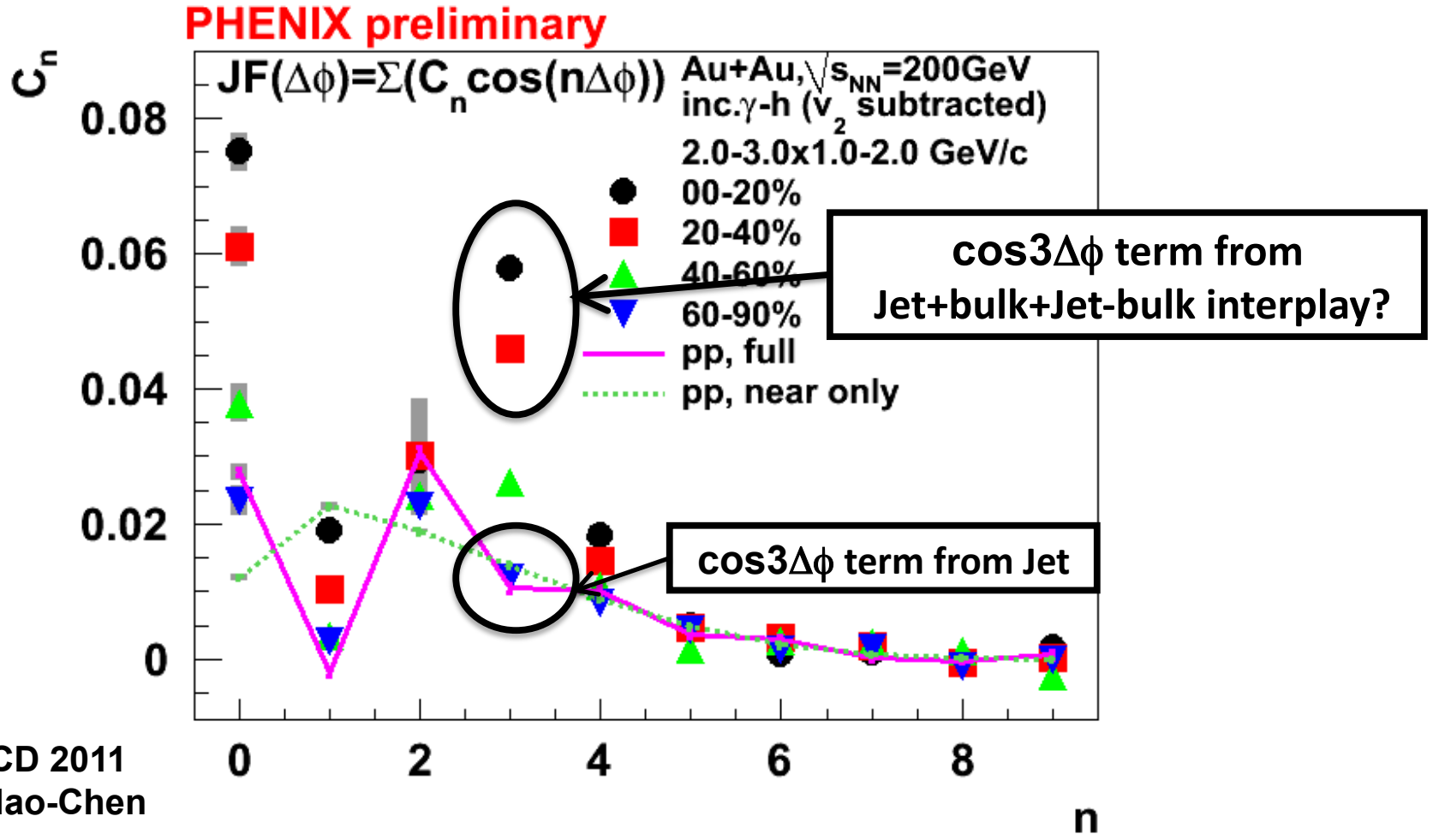
Compare with the Event Plane method



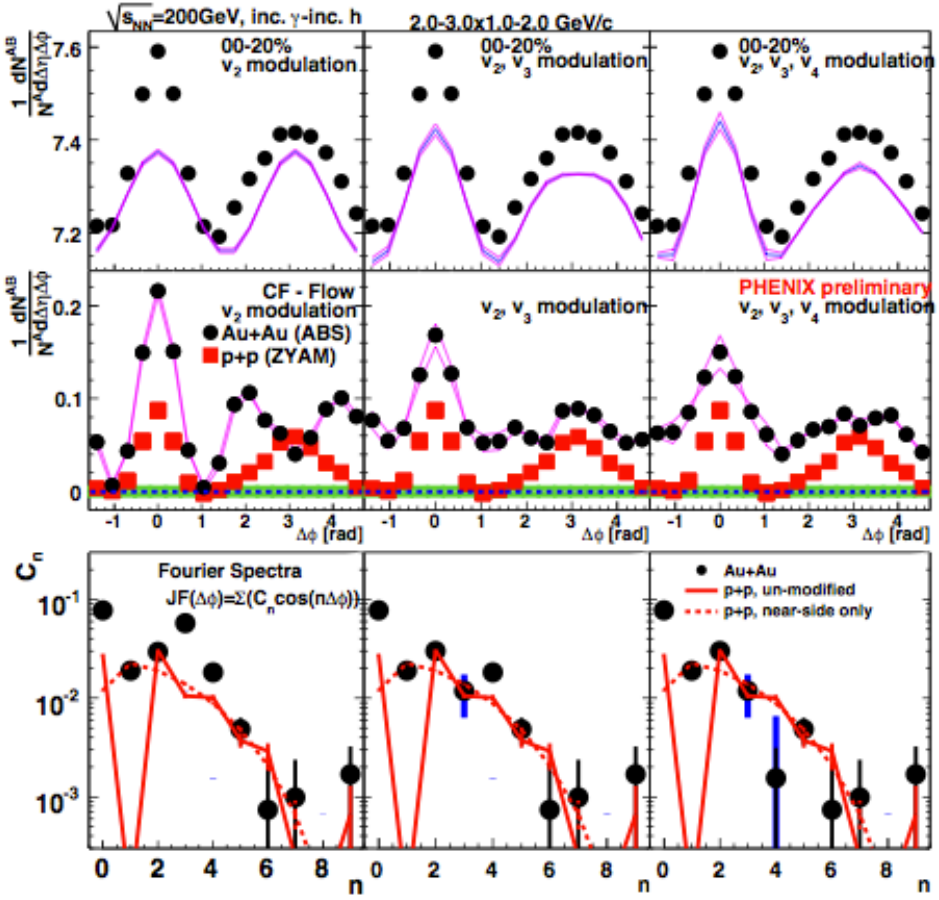
Jiangyong, Jia
QM11' Flow Plenary

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