

# Near- and Away-side “Long-Range” Angular Correlations in d+Au Collisions at $\sqrt{s_{NN}} = 200$ GeV

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for the PHENIX Collaboration



15 April 2013

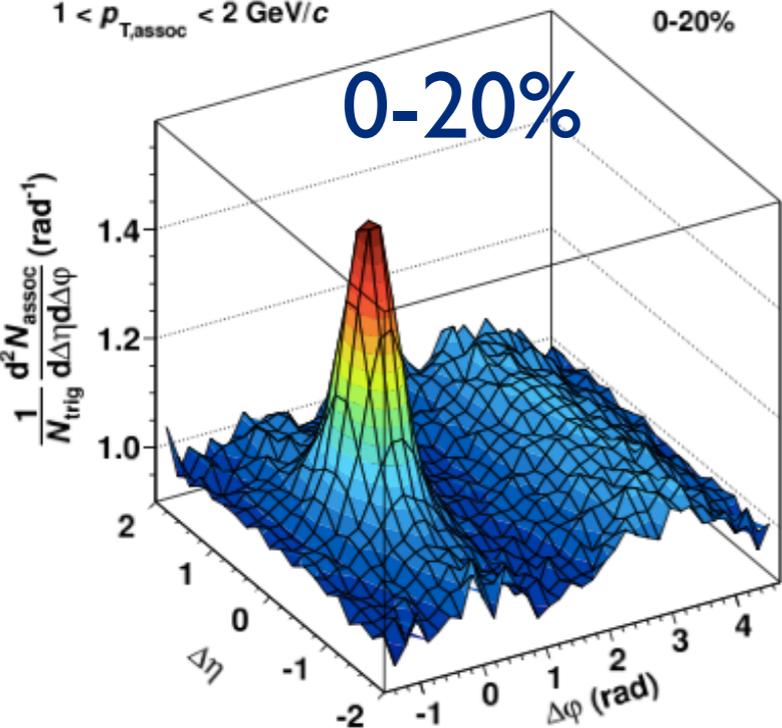
**p+Pb**

from **ALICE**, Phys.Lett. B719 (2013) 29-41

$2 < p_{T, \text{trig}} < 4 \text{ GeV}/c$   
 $1 < p_{T, \text{assoc}} < 2 \text{ GeV}/c$

p-Pb  $\sqrt{s_{NN}} = 5.02 \text{ TeV}$   
 0-20%

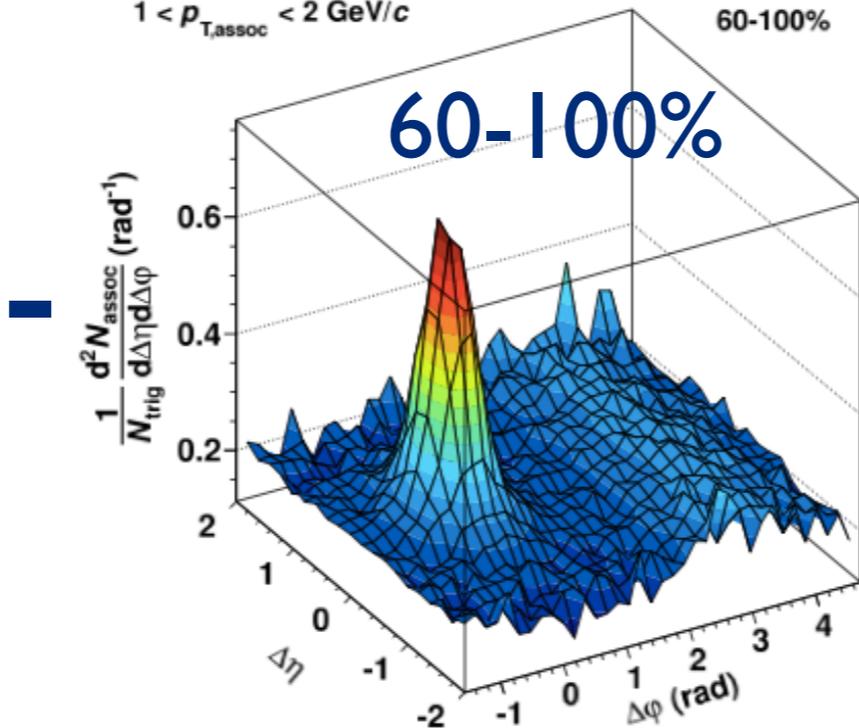
**0-20%**



$2 < p_{T, \text{trig}} < 4 \text{ GeV}/c$   
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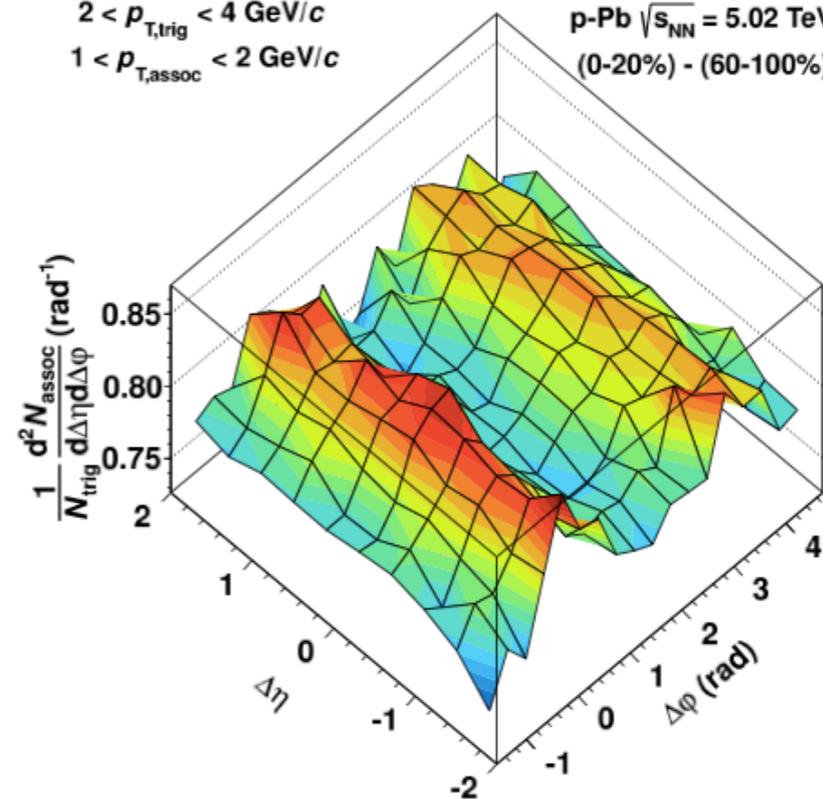
p-Pb  $\sqrt{s_{NN}} = 5.02 \text{ TeV}$   
 60-100%

**60-100%**

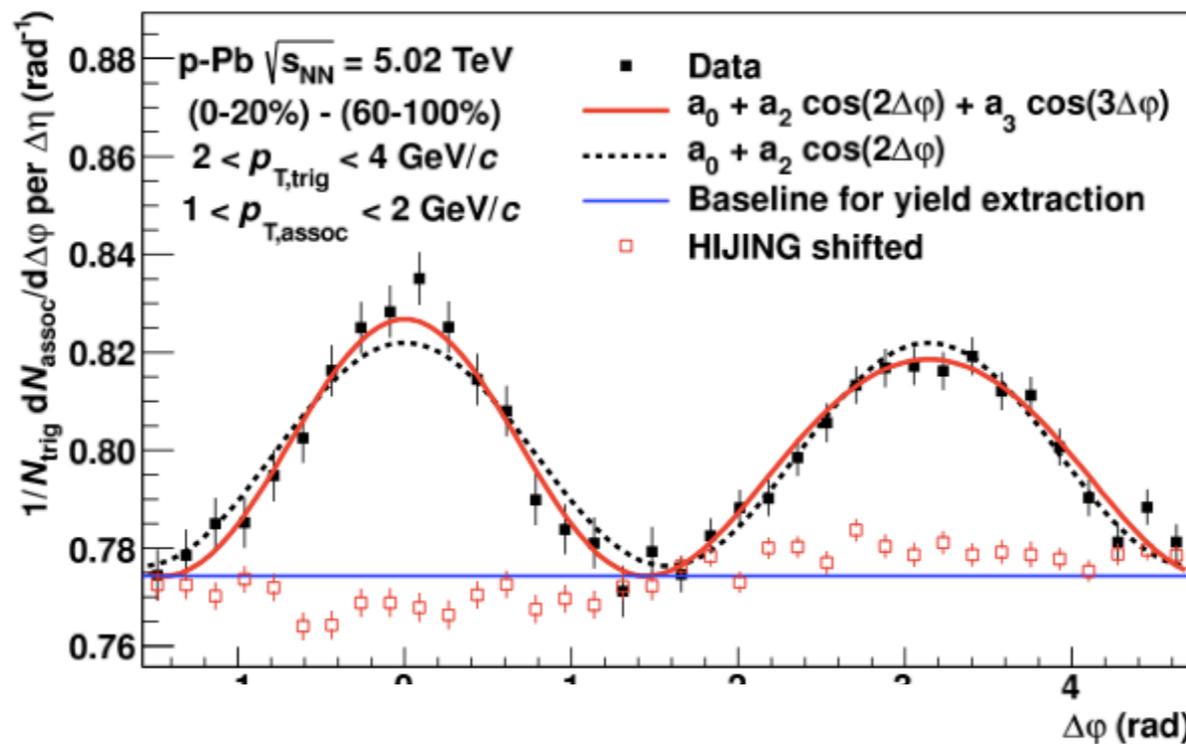


$2 < p_{T, \text{trig}} < 4 \text{ GeV}/c$   
 $1 < p_{T, \text{assoc}} < 2 \text{ GeV}/c$

p-Pb  $\sqrt{s_{NN}} = 5.02 \text{ TeV}$   
 (0-20%) - (60-100%)



**=**



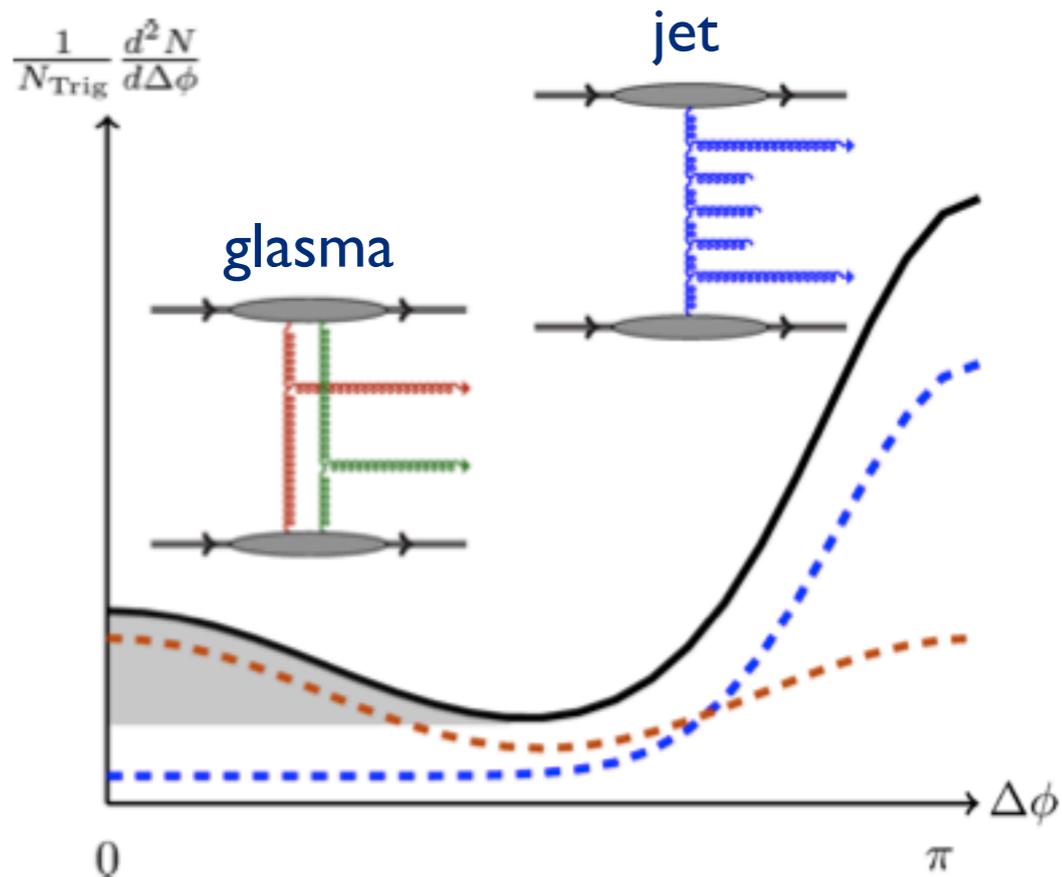
see also similar results from **ATLAS** and **CMS**

*pair excess in central events well-described by small order moments*

*competing theoretical descriptions of the effect...*

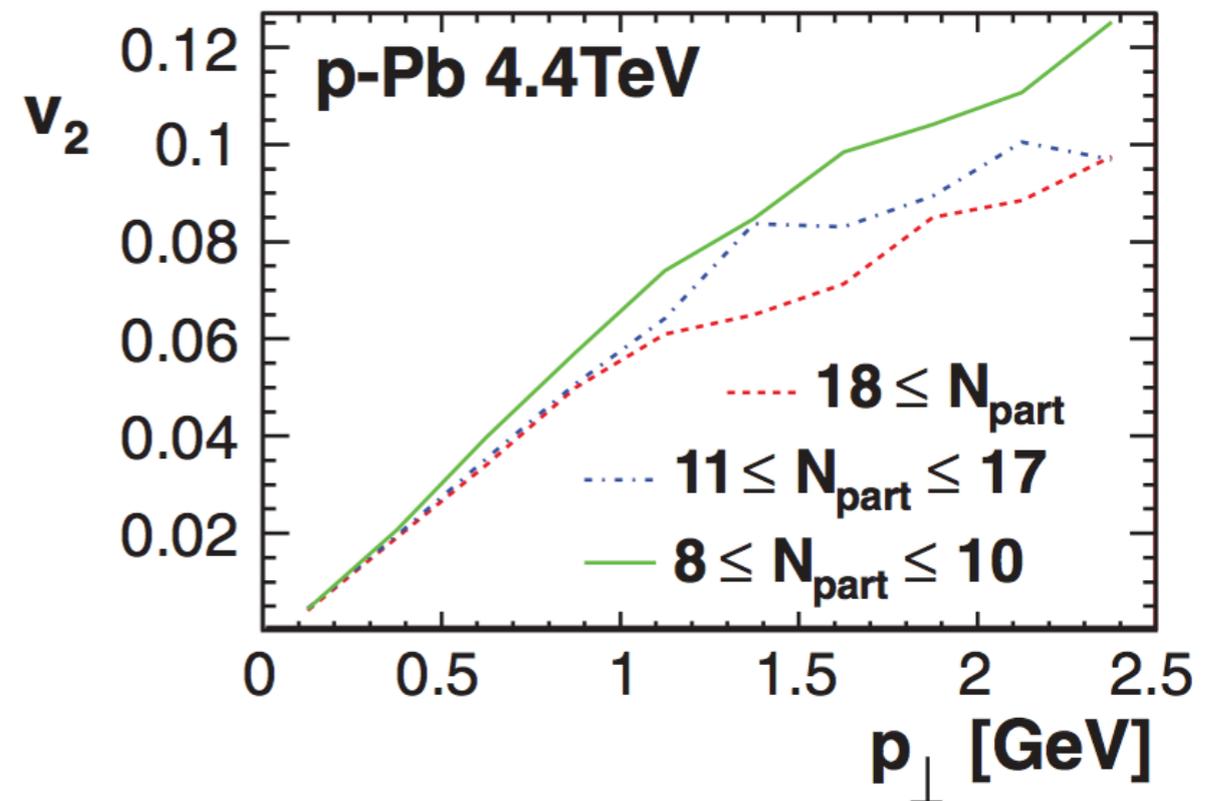
## CGC/Glasma

(correlated emission off a flux tube)



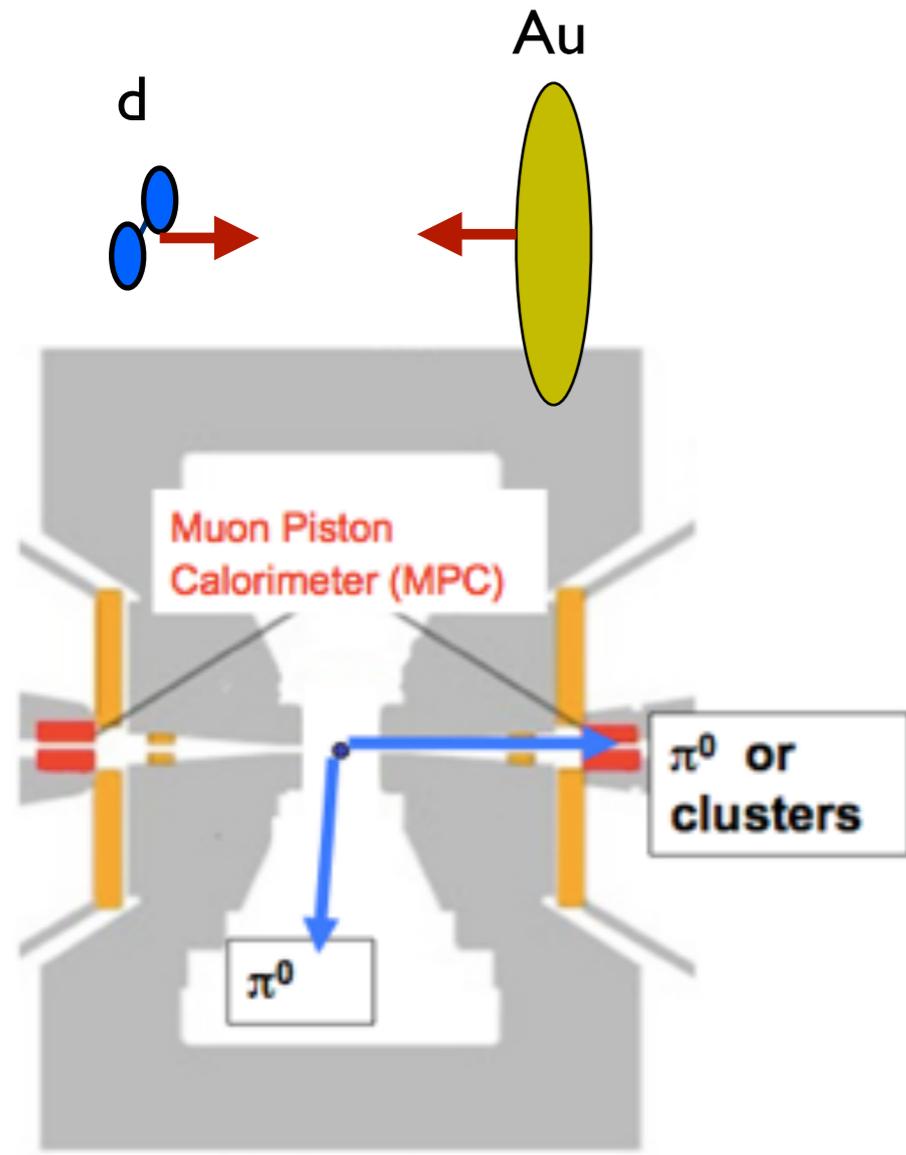
## Hydrodynamics

(final state re-scattering and thermal expansion)



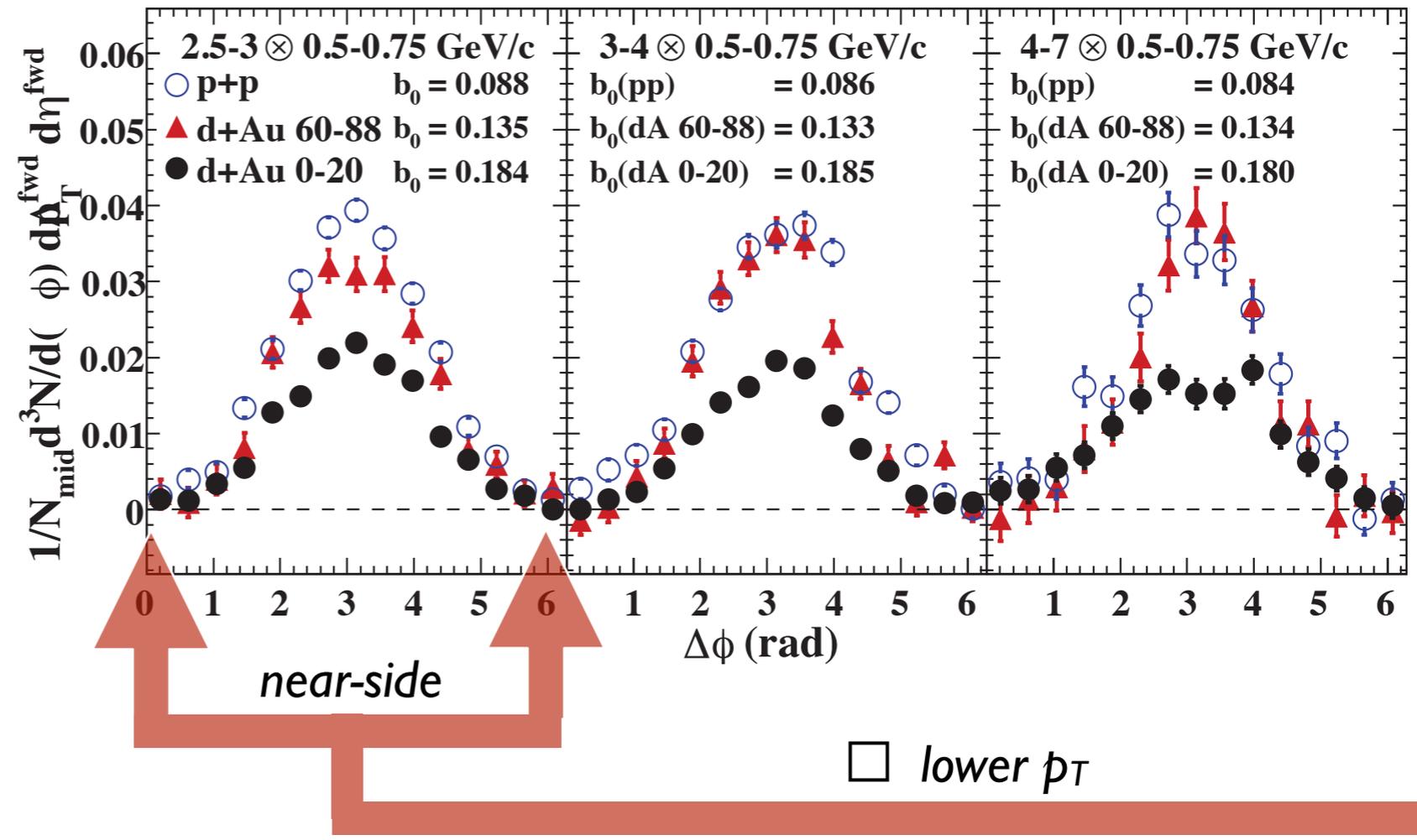
*so is this phenomena present at RHIC energies?*

# Previous RHIC studies



PRL 107, 172301 (2011) PHYSICAL REVIEW LETTERS week ending 21 OCTOBER 2011

Suppression of Back-to-Back Hadron Pairs at Forward Rapidity in  $d + Au$  Collisions at  $\sqrt{s_{NN}} = 200$  GeV



*no evidence across a large rapidity gap towards forward eta  
larger momentum selection than optimal for bulk physics*

Limited eta separation at mid-rapidity:

$$\Delta\eta \in [0.48, 0.7]$$

Acceptance correction:

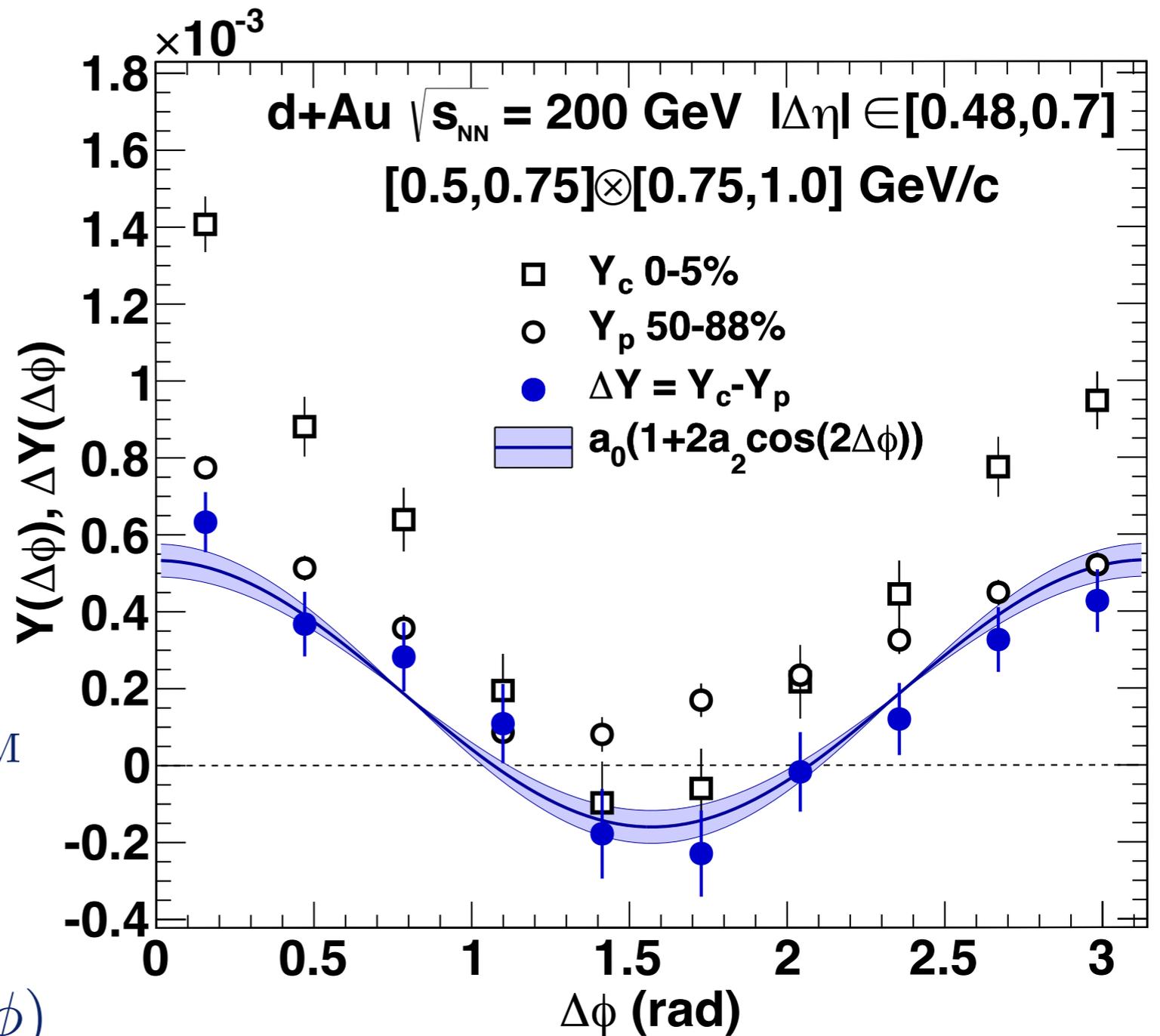
$$\frac{1}{N^t} \frac{dN^{\text{pairs}}}{d\Delta\phi} \propto \frac{dN_{\text{same}}^{\text{pairs}}/d\Delta\phi}{dN_{\text{mix}}^{\text{pairs}}/d\Delta\phi}$$

Pedestal removal:

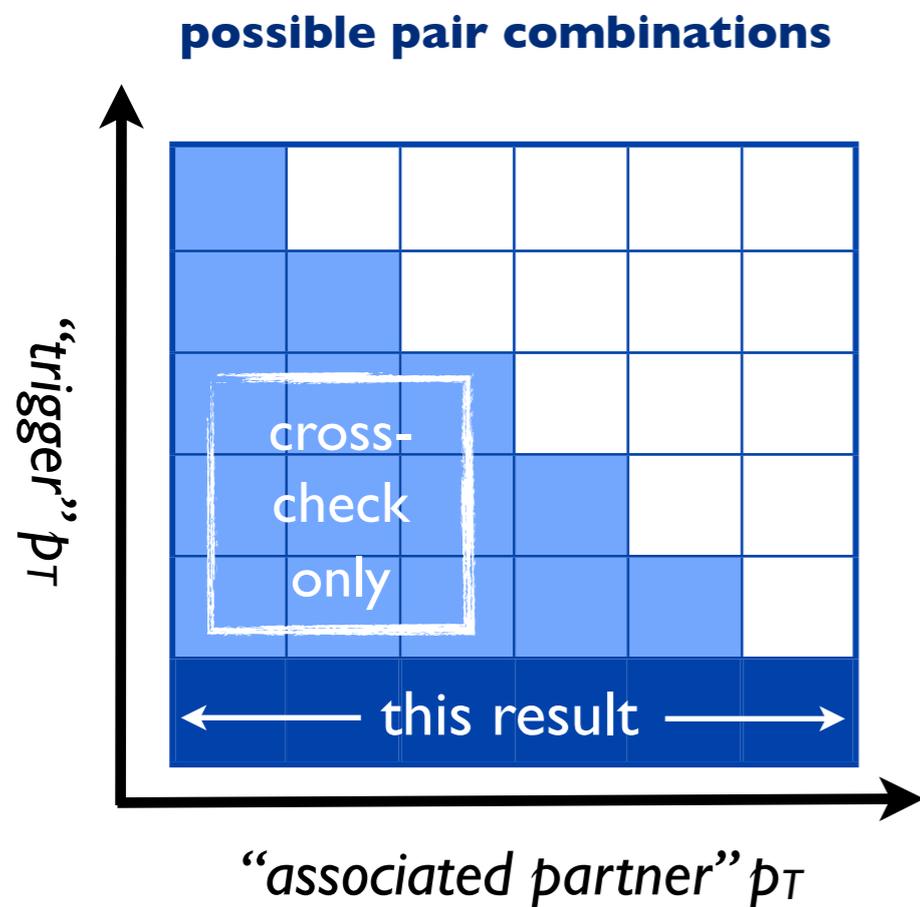
$$Y(\Delta\phi) \equiv \frac{1}{N^t} \frac{dN^{\text{pairs}}}{d\Delta\phi} - b_{\text{ZYAM}}$$

Centrality Difference:

$$\Delta Y(\Delta\phi) = Y_c(\Delta\phi) - Y_p(\Delta\phi)$$

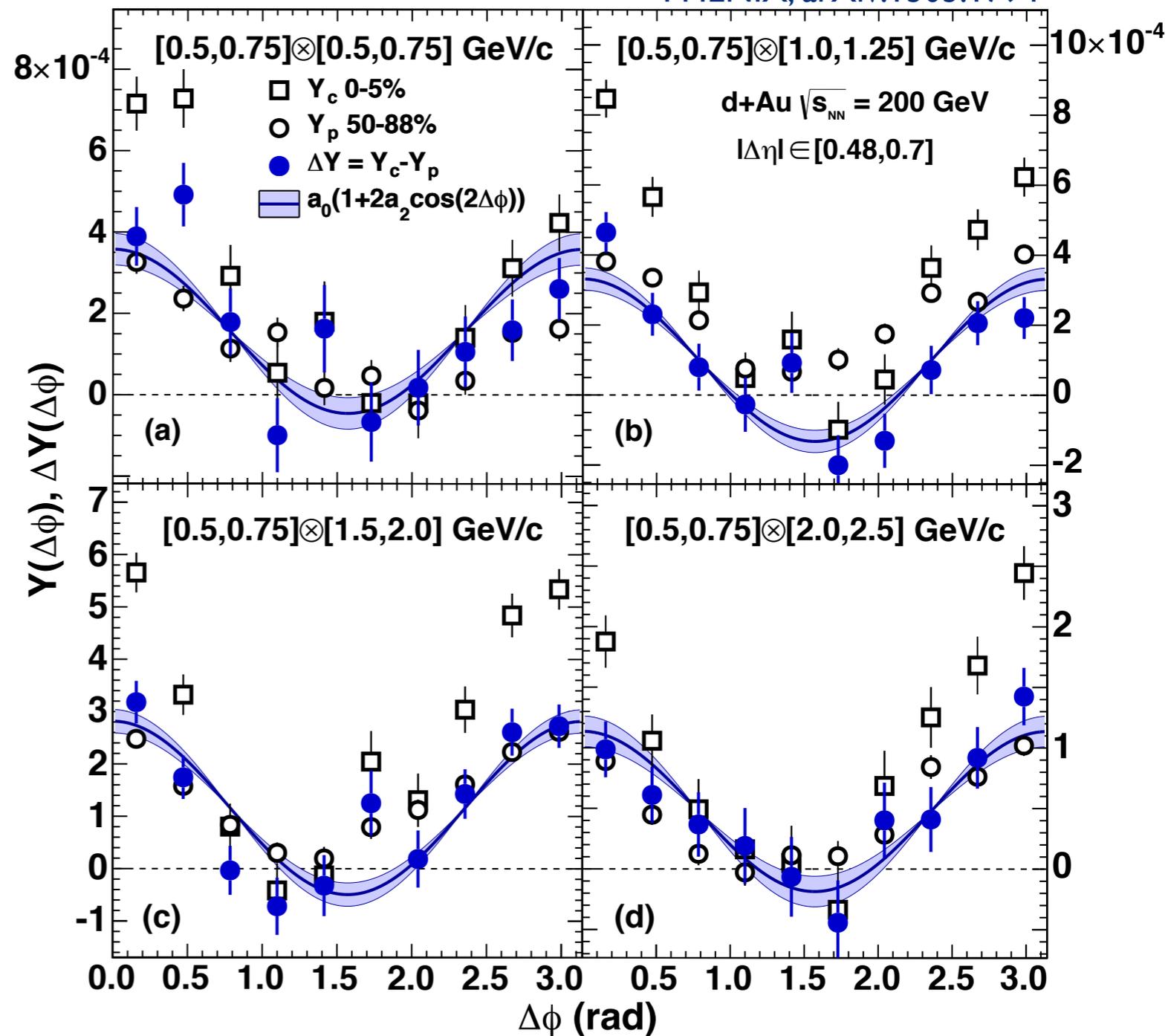


*the centrality difference is well-described by a 2nd-order moment*



some examples...

PHENIX, arXiv:1303.1794



*a similar effect found across multiple  $p_T$  values*

PHENIX, arXiv:1303.1794

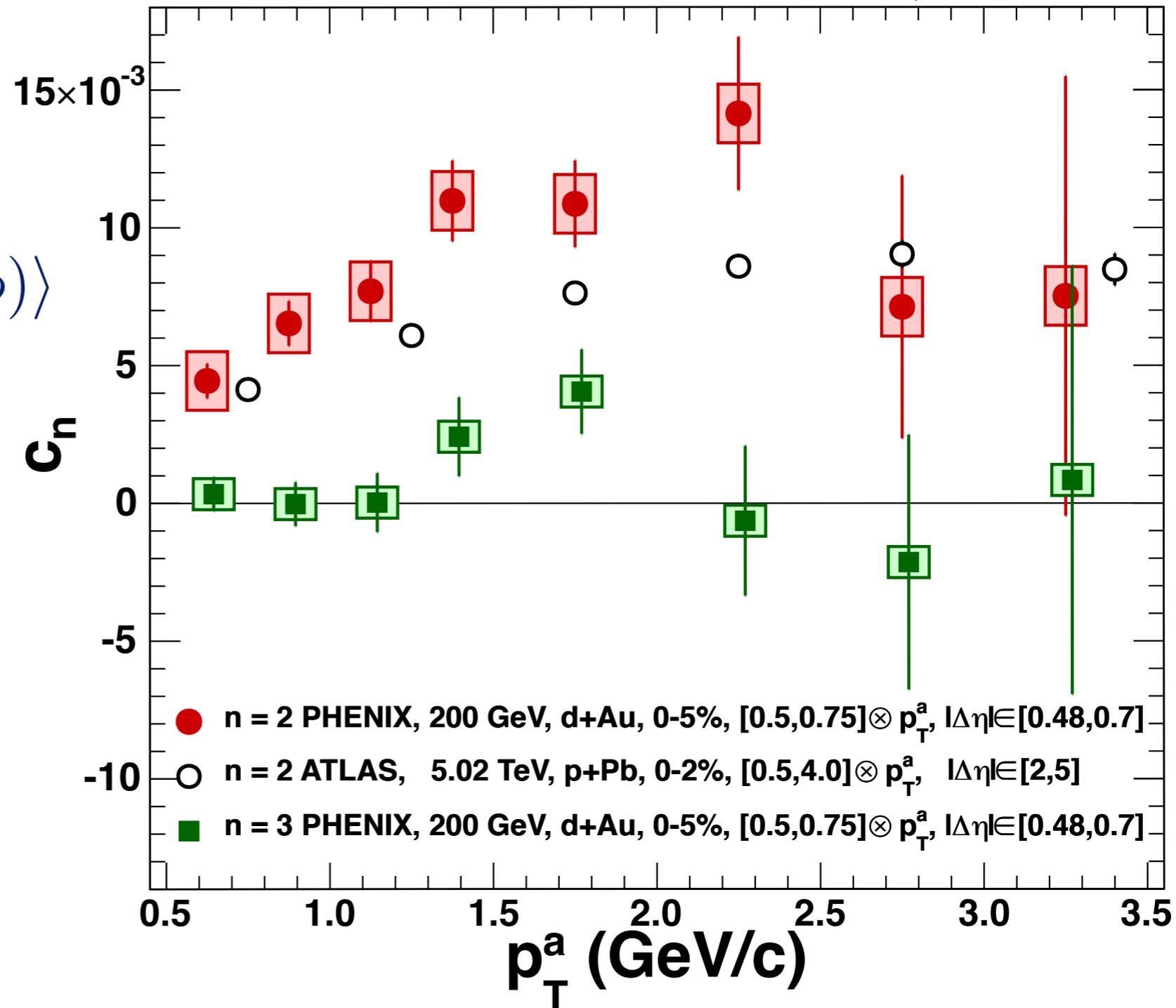
Moment extraction:

$$a_n = \langle \Delta Y (\Delta\phi) \cos(\Delta\phi) \rangle$$

Moment relation to

Removed Pedestal:

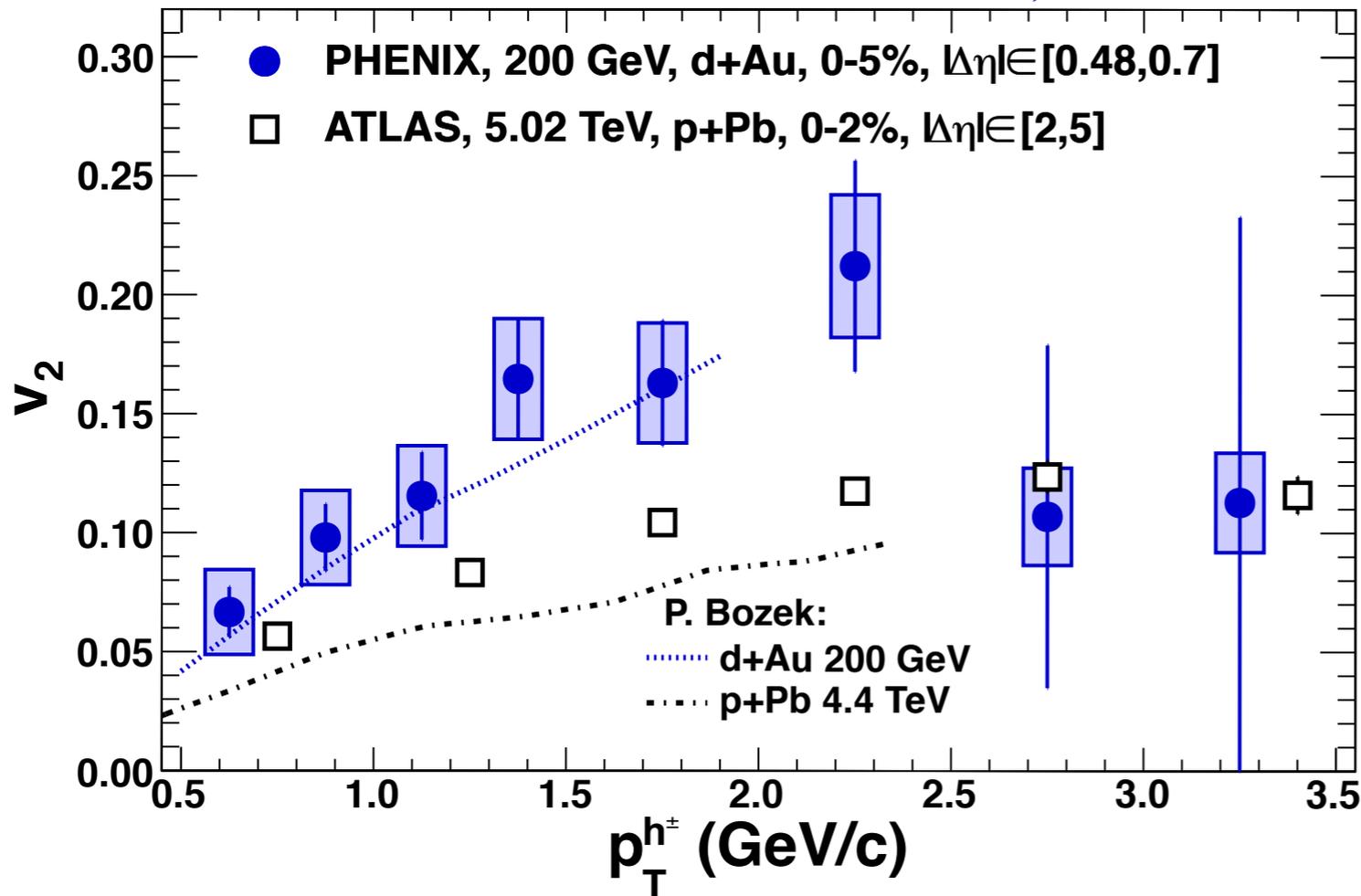
$$c_n \equiv \frac{a_n}{a_0 + b_{ZYAM}^c}$$



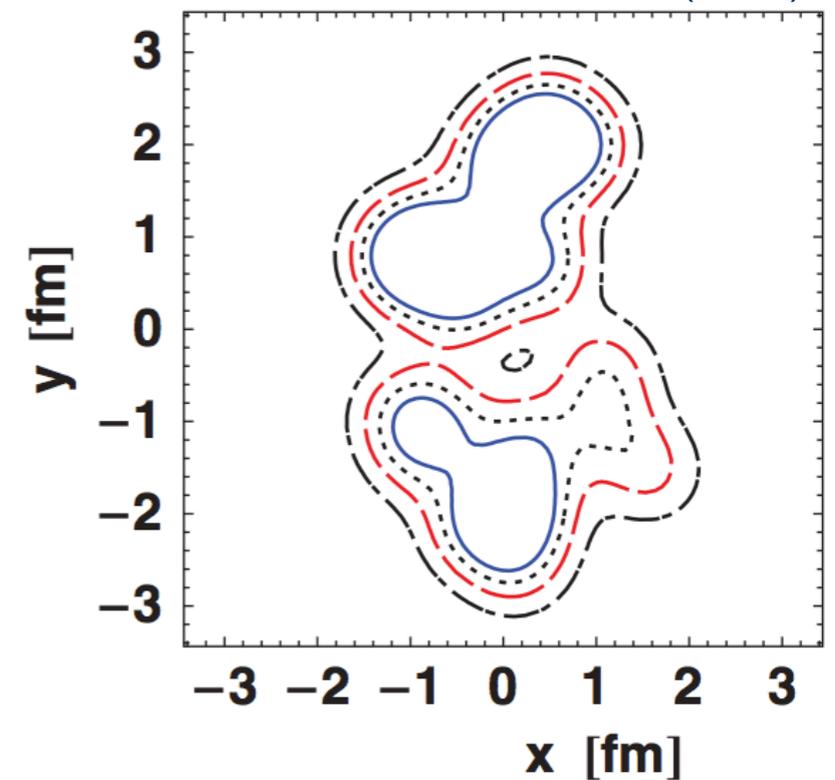
*large 2nd-order pair moment, very small 3rd-order*

Factorization:  $c_2(p_T^t, p_T^a) = v_2(p_T^t) \times v_2(p_T^a)$

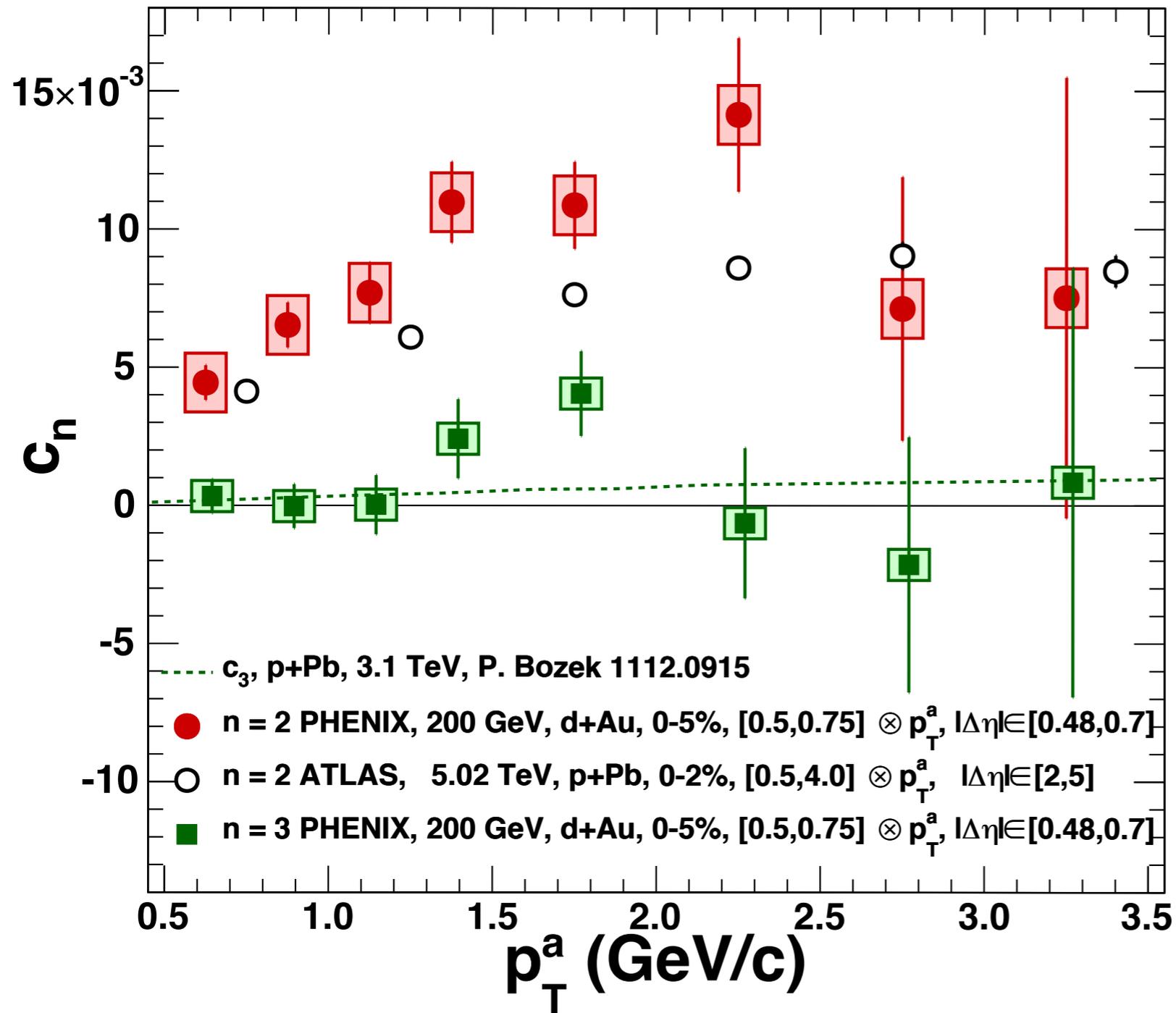
PHENIX, arXiv:1303.1794



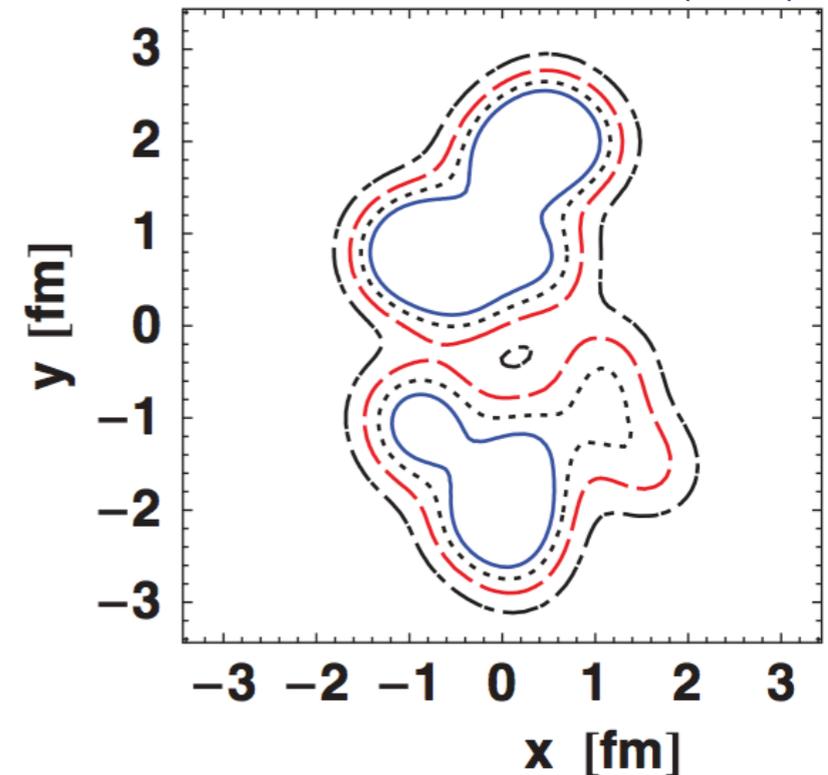
P. Bozek, PRC 85,014911 (2012)



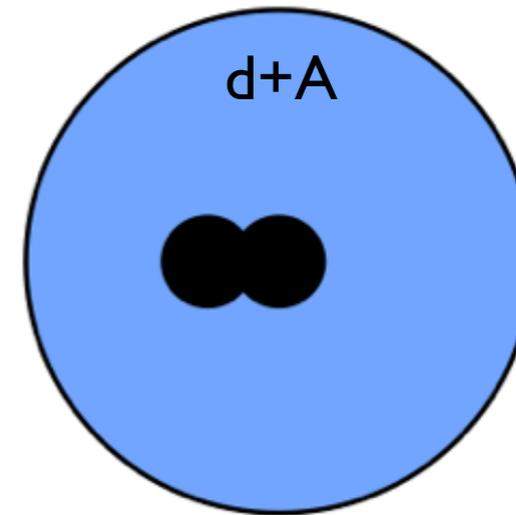
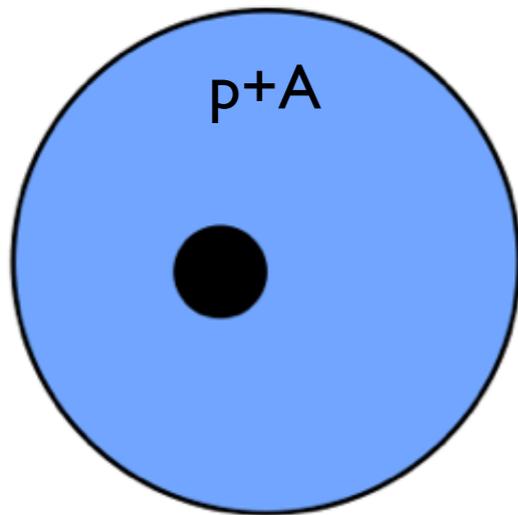
*larger values found than LHC studies,  
increase qualitatively characteristic of hydro models*



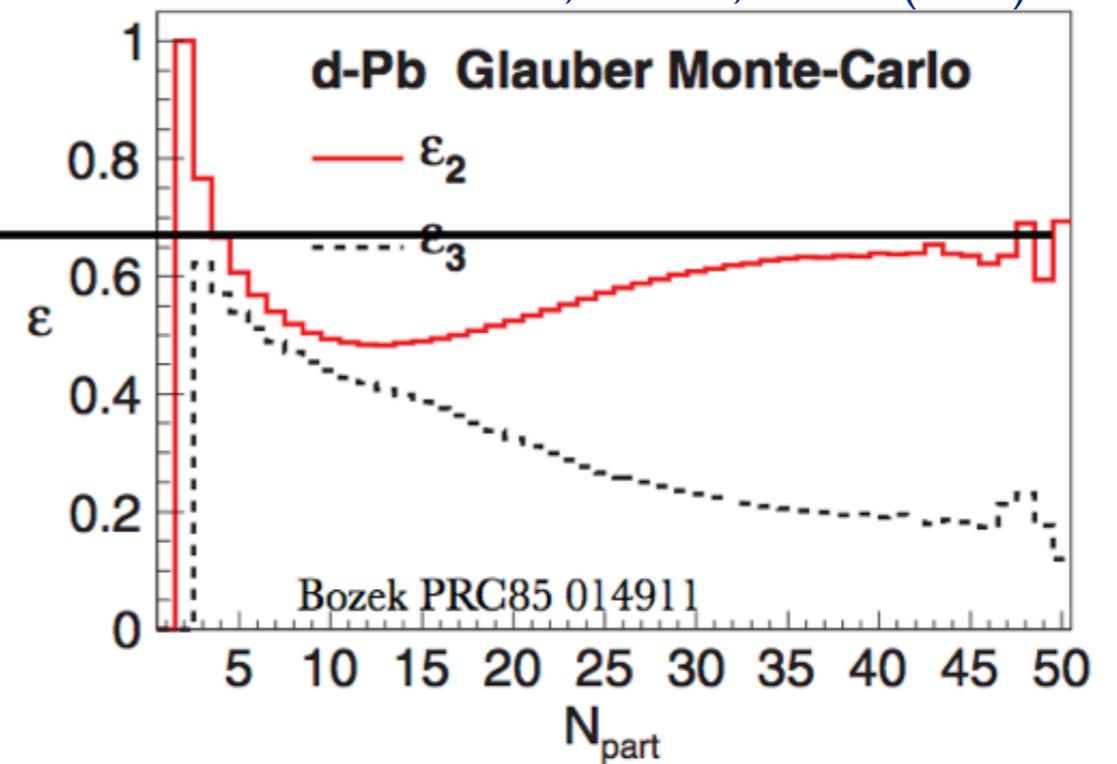
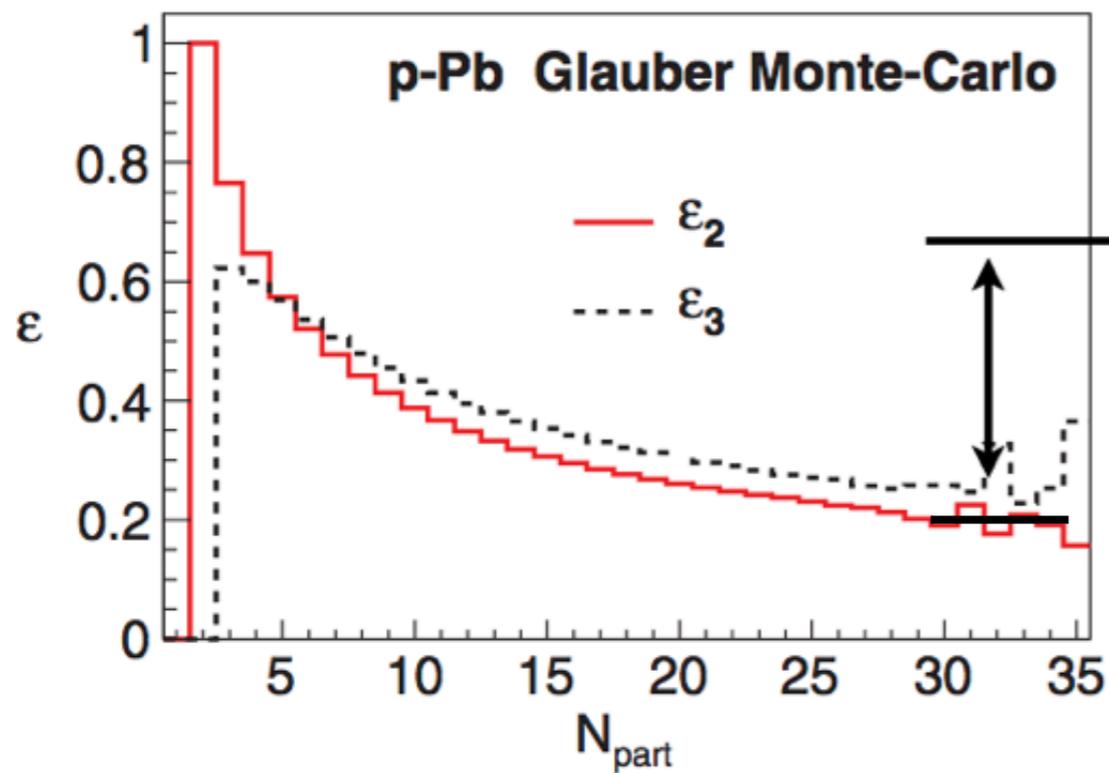
P. Bozek, PRC 85,014911 (2012)



*same hydro model (for p+Pb) also gives small  $c_3$*



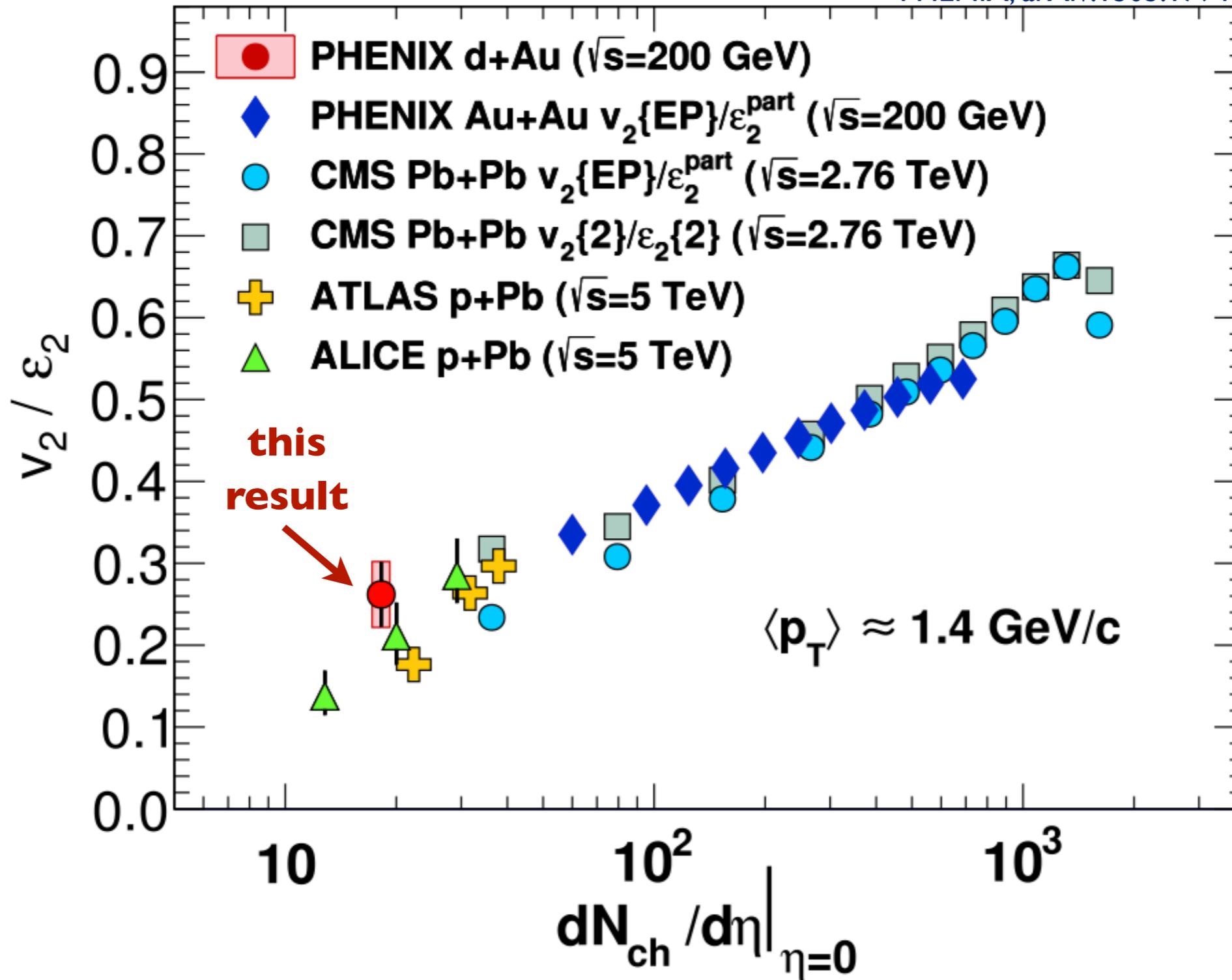
P. Bozek, PRC 85,014911 (2012)



*larger 2nd order eccentricity is expected from deuteron projectile  
only small 3rd order is expected*

# Eccentricity Scaling Test

PHENIX, arXiv:1303.1794



results from  $d(p)+A$  across beam energies follow similar trend

□ → does not imply different physics

We have observed a **strong 2nd-order moment difference** between central and peripheral d+Au events

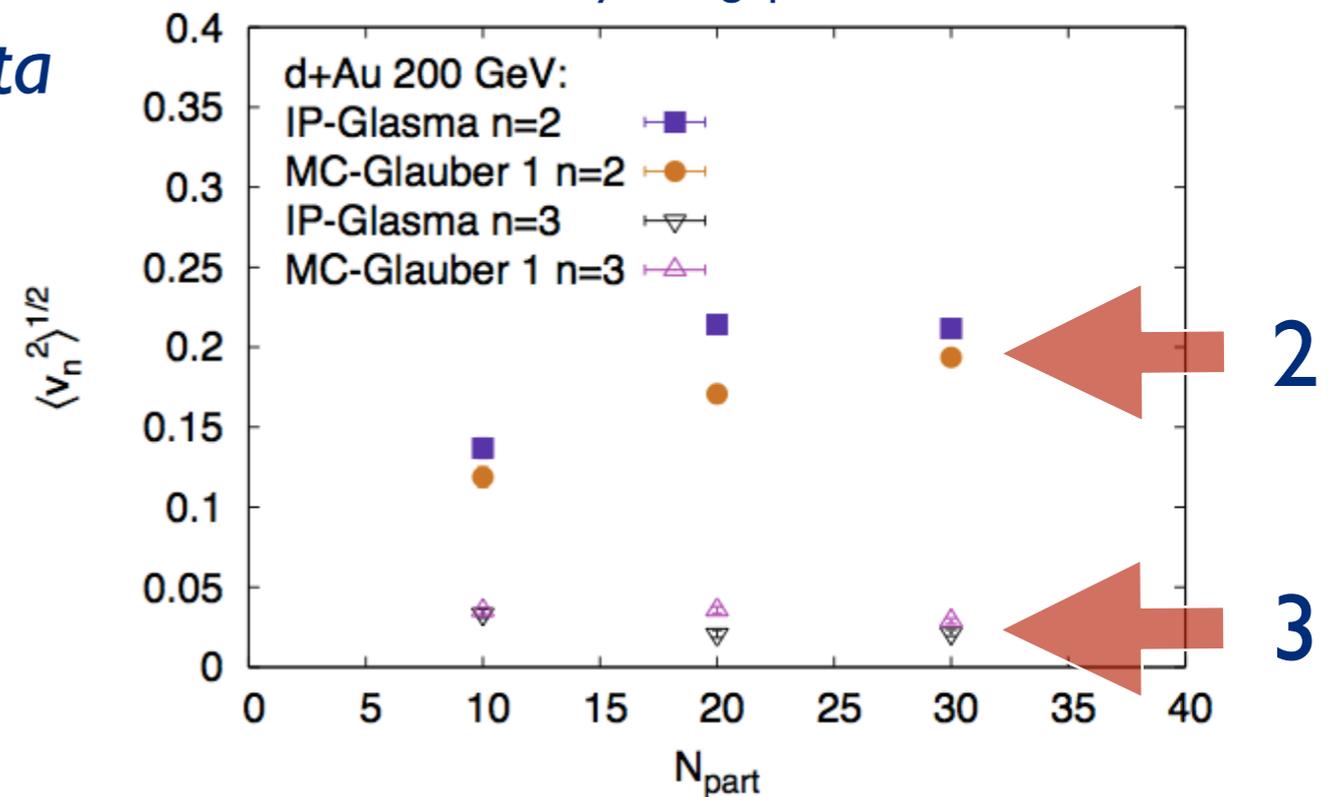
When interpreted as flow, these data show **qualitative features** of hydrodynamic models and eccentricity scaling, **not unique**, need additional model predictions learn more

We are currently studying the **forward & backward extent** of the signal... with more to come

RHIC can run **p+Au** and test a change in eccentricity directly, ~2015.

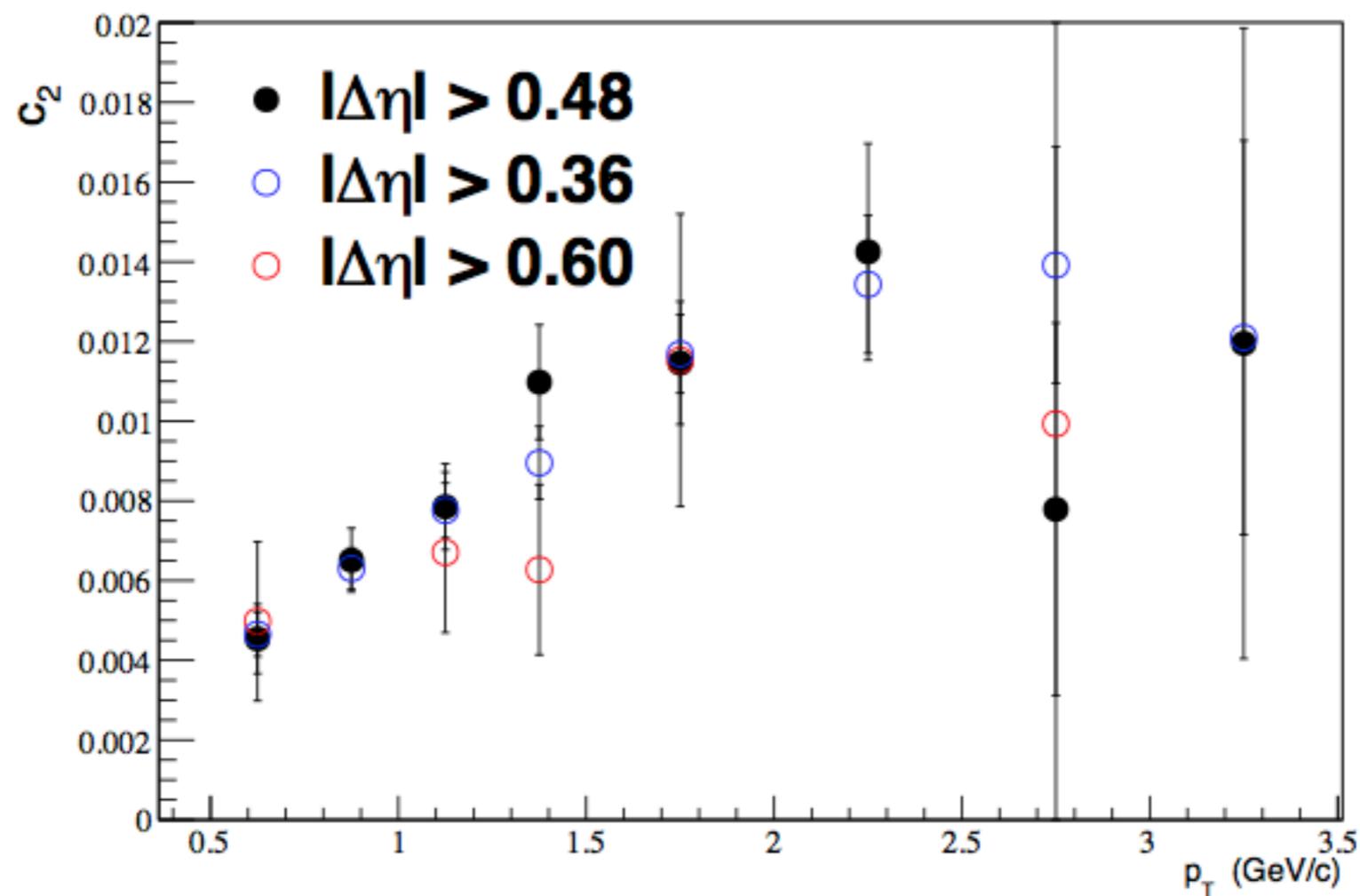
Glasma model: posted 3 days ago...

Bzdak, Schenke, Tribedy, Venugopalan, arXiv:1303.3404

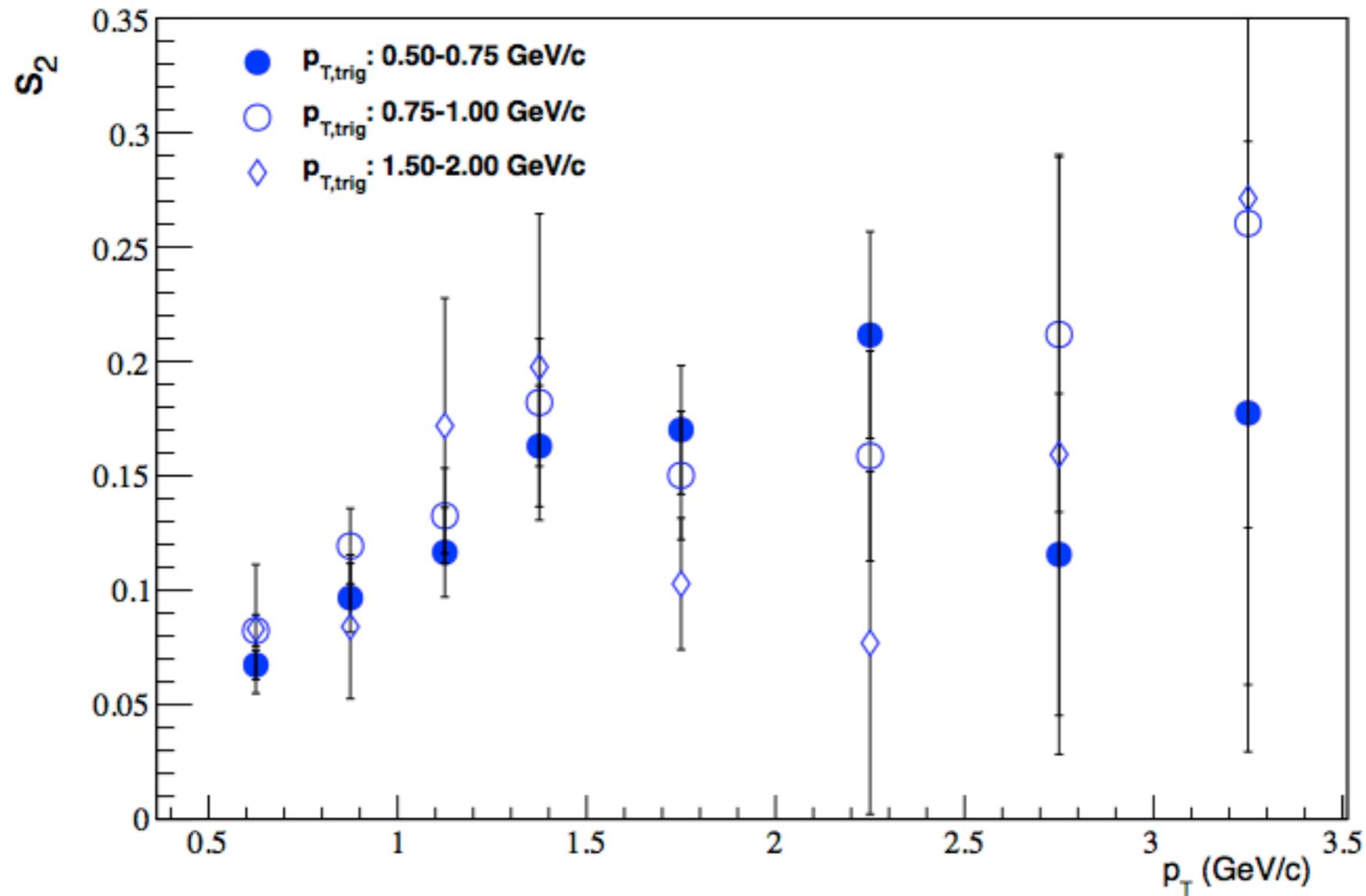


Extras

Extract flow moments and test eta-separation and subtraction with a variety of **different pseudorapidity separations**

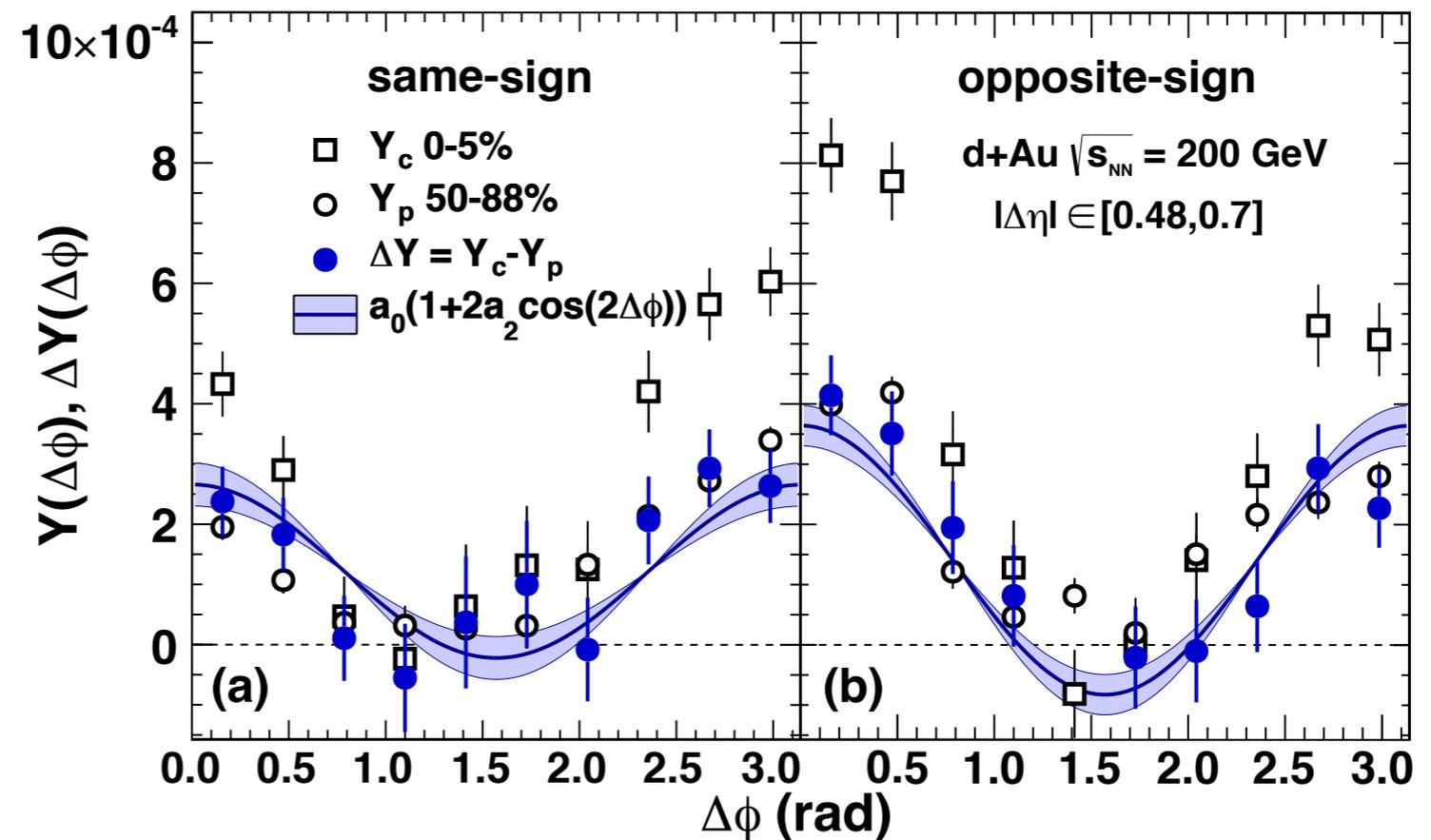
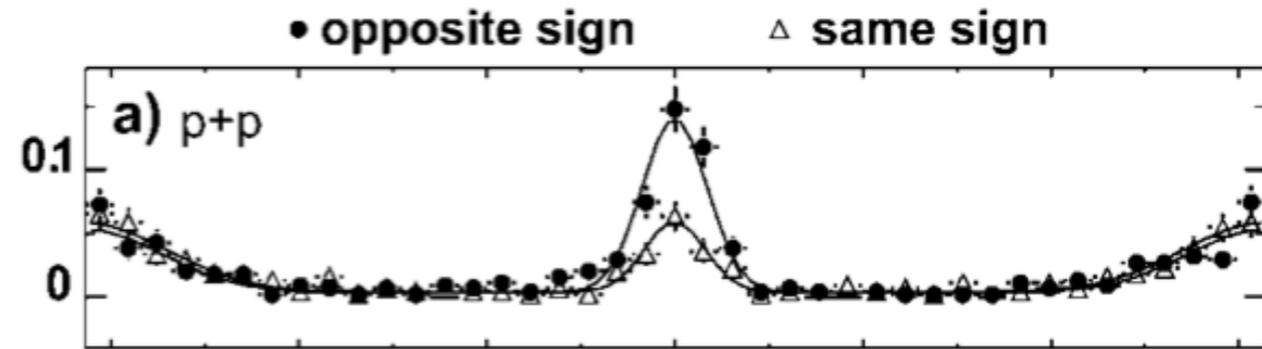


Extract flow moments to test factorization with a  
**different trigger  $p_T$**

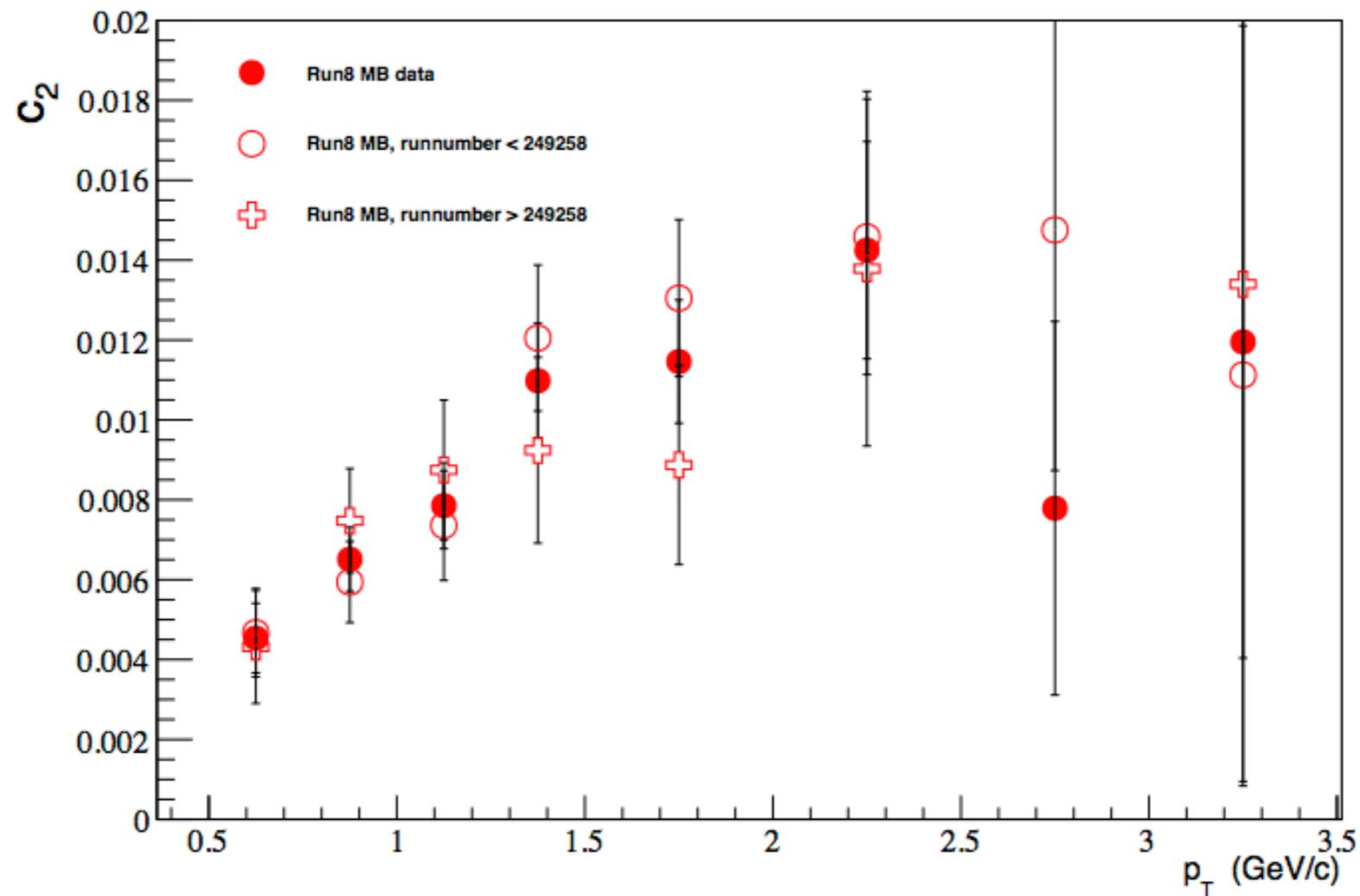


Jet pair correlations have a well-known **charge-ordering** and remaining contamination should show this signature

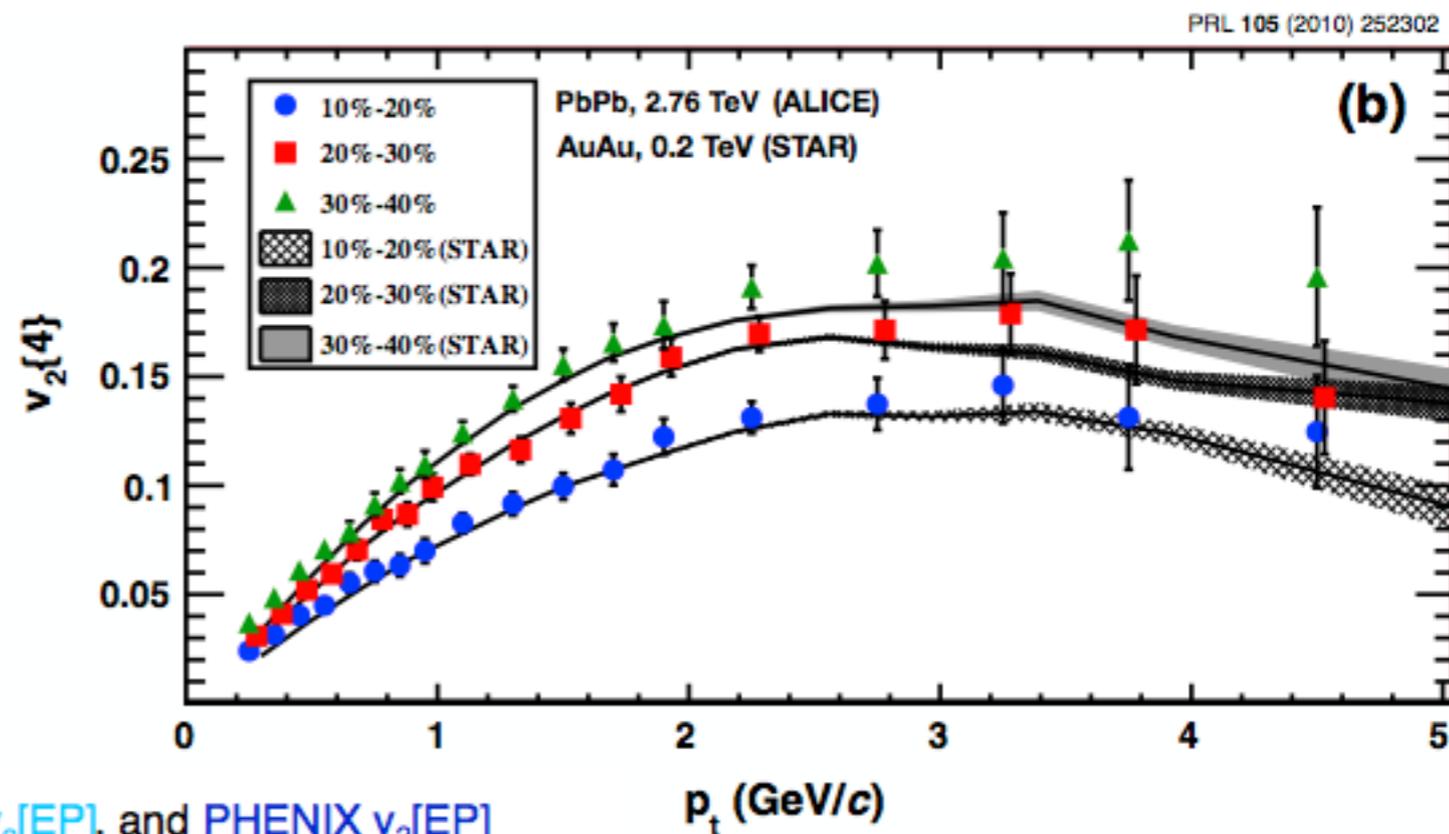
Not clear if the signal also has a correlation of this kind, we assume a worst case scenario



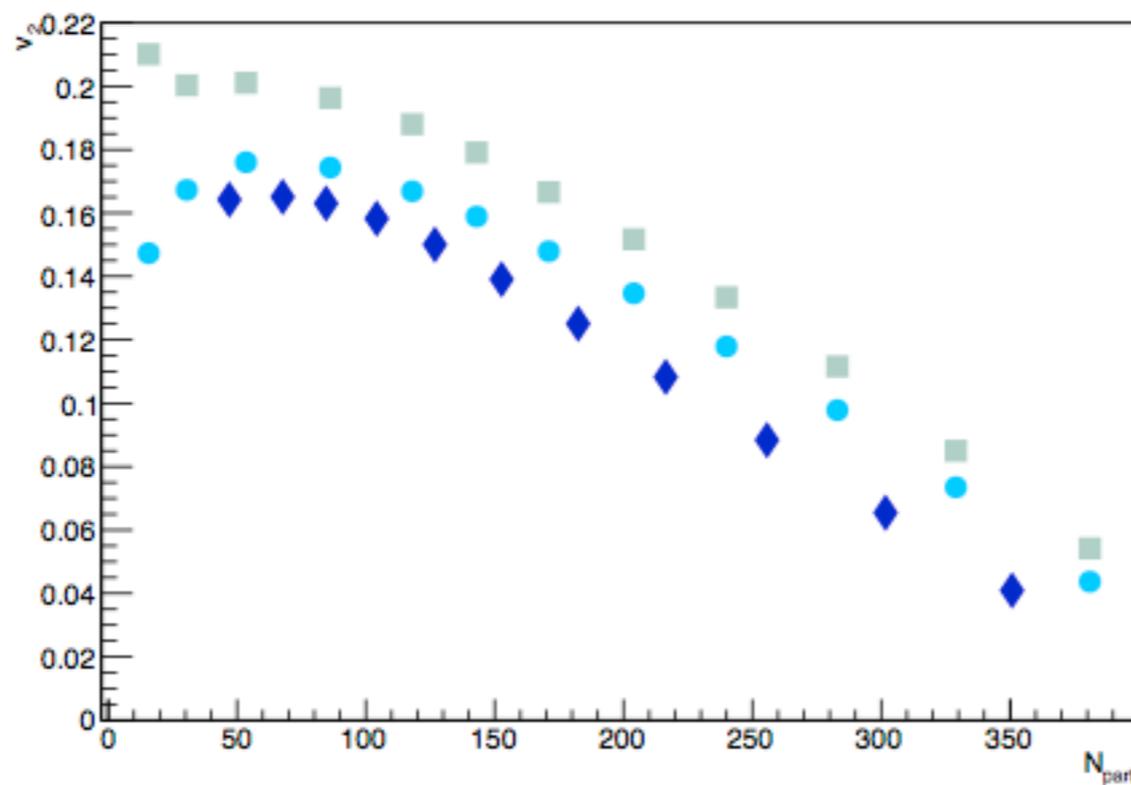
Extract flow moments and test double-interaction contamination with a  
**different beam luminosity**



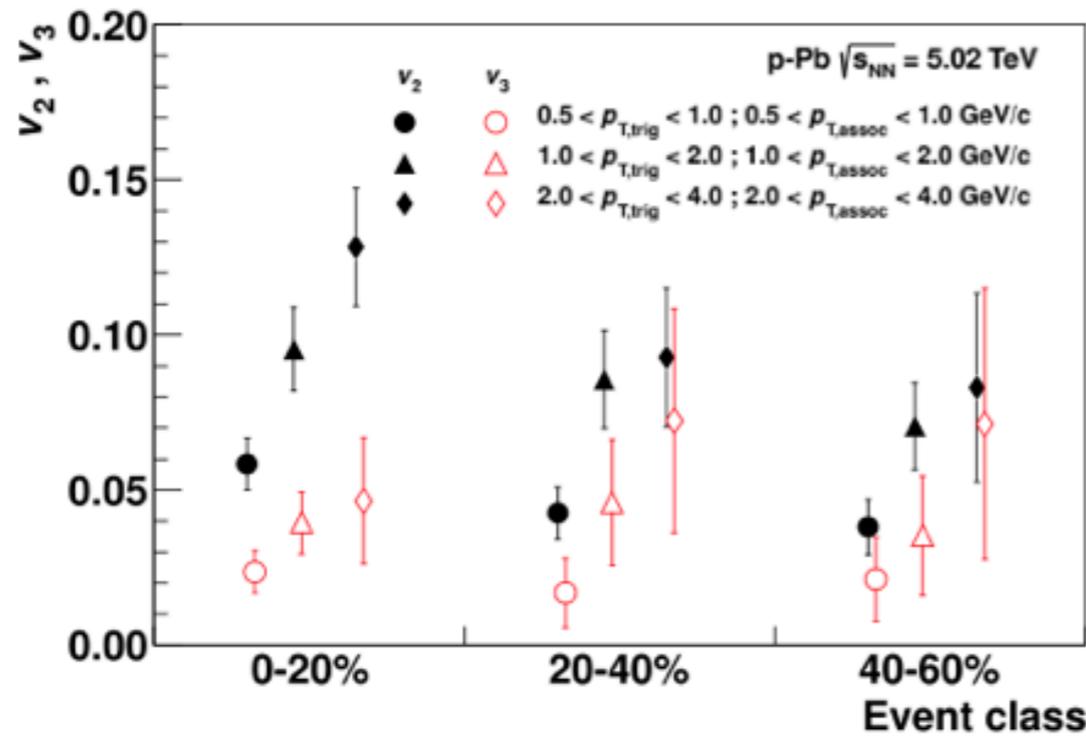
Only 4-particle cumulate v<sub>2</sub> extractions are similar between LHC and RHIC



CMS v<sub>2</sub>[2], CMS v<sub>2</sub>[EP], and PHENIX v<sub>2</sub>[EP]



PHENIX data for 1.2-1.6 GeV/c, CMS data at 1.38 GeV/c



intriguing, but not significantly non-zero result

ALICE sees  $v_3 > 0$ ,  
what about at RHIC?

