Measurements of long-range angular correlation and identified particle v_2 in 200 GeV d+Au collisions from PHENIX

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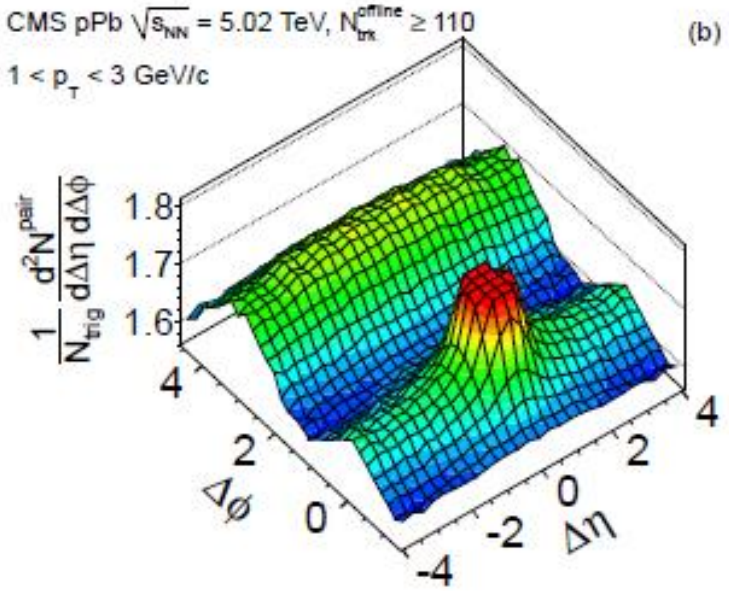
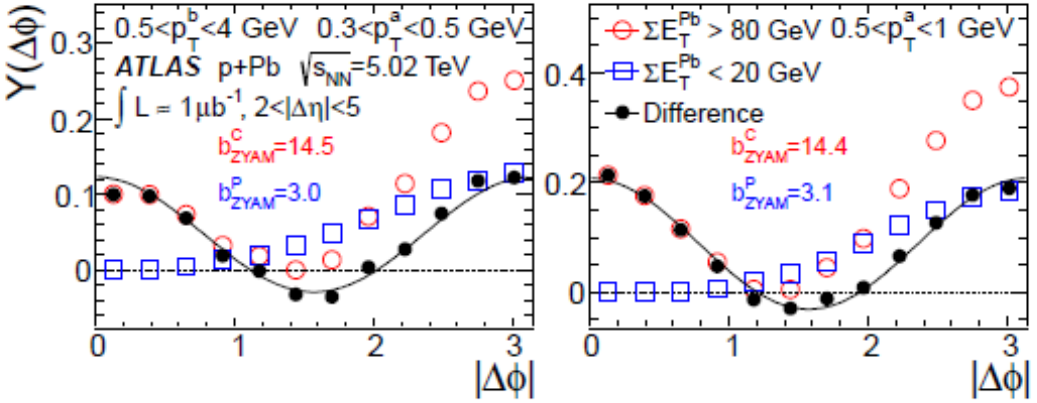
Outline

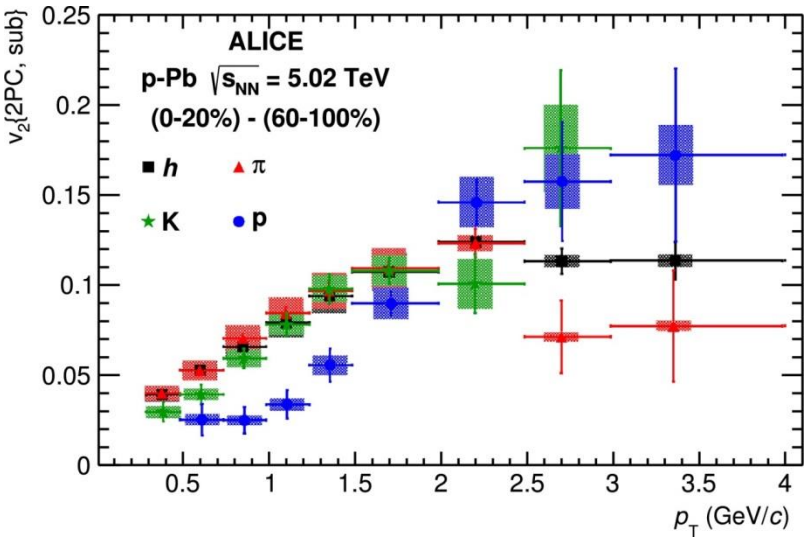
- Motivations
- Long-range angular correlations across
  Rapidity, Centrality and Trigger p_T
- Identified particles v_2 using event-plane method
- Summary

“Ridge” and ”v_2” in p+Pb@5.02 TeV



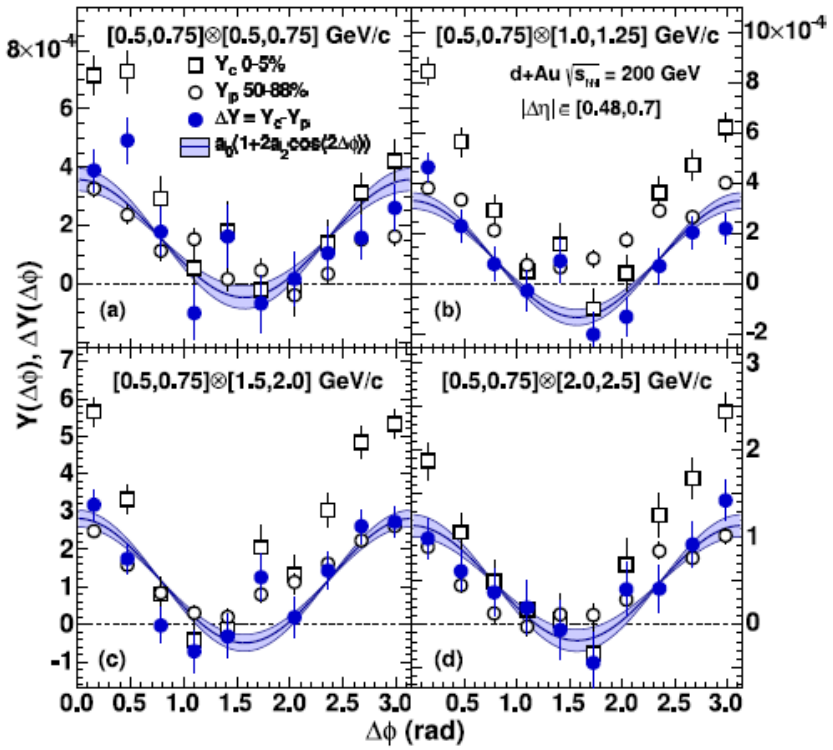
ALICE: Physics Letters B 726 (2013)
ATLAS: Phys. Rev. Lett. 110(2013)
CMS: Phys. Lett. B 7198(2013

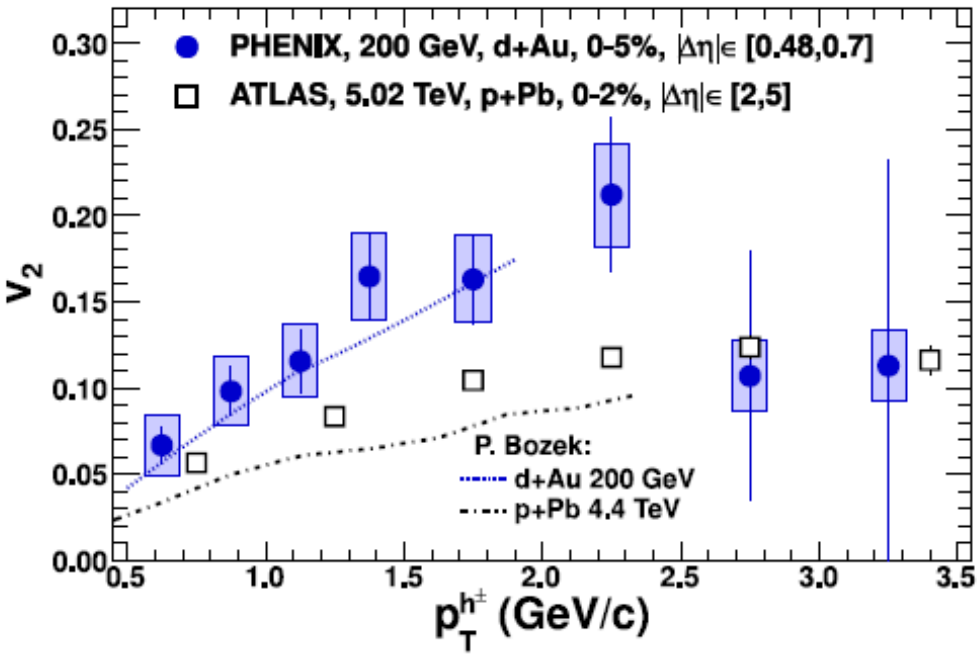




- A “ridge” is observed in the central p + Pb@5.02 TeV
- The Δϕ distribution shows a cos(2Δϕ) structure
- The identified particle v_2 shows a mass ordering

V_2 in d+Au@ 200 GeV

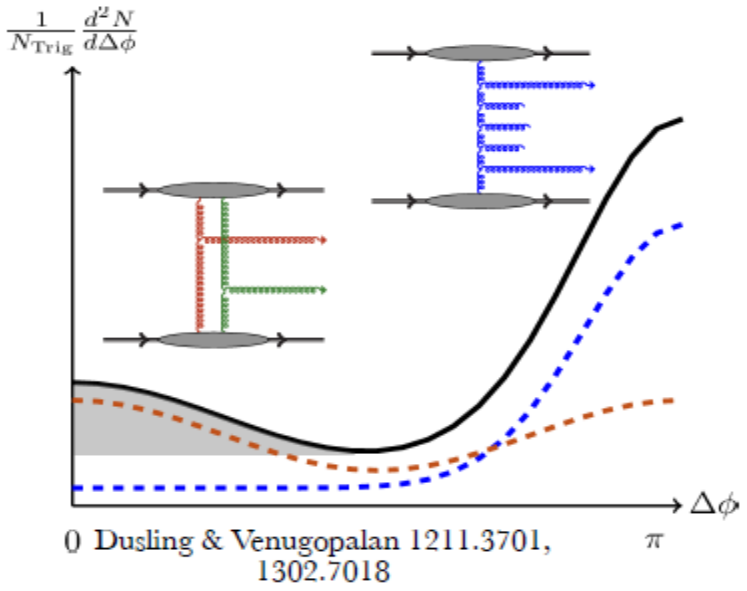




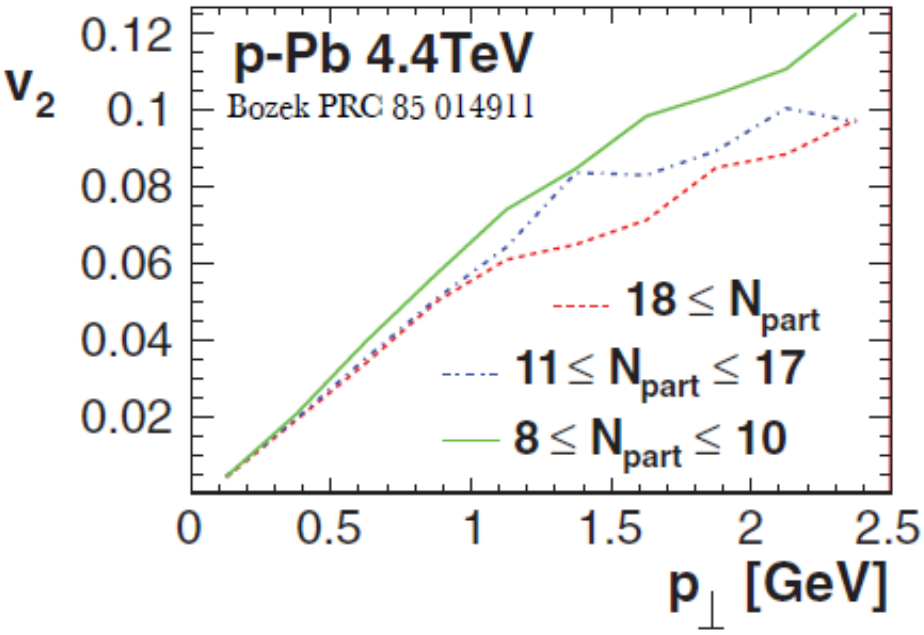
PHENIX: Phys. Rev. Lett. 111, 212301 (2013)

- The cos(2Δφ) structure is also seen in 0-5% d+Au. The cut of |Δη|>0.48 is the limit of our central arm acceptance
- The v_2 in 0-5% d+Au is higher than that in 0-2% p+Pb collisions, which is consistent with hydro calculation
- The measurement with large |Δη| is required!

Initial or final state effect?



Dusling & Venugopalan 1211.3701, 1302.7018

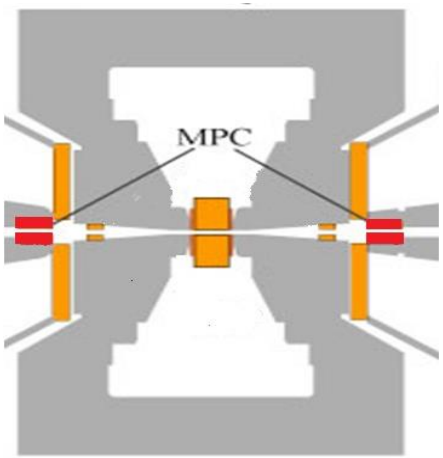


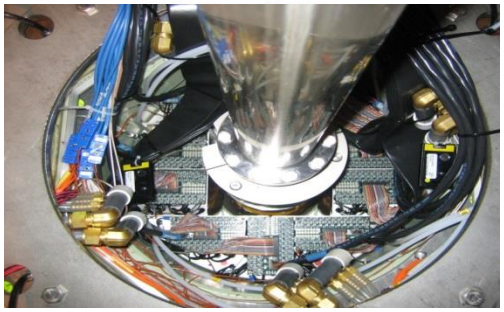
CGC

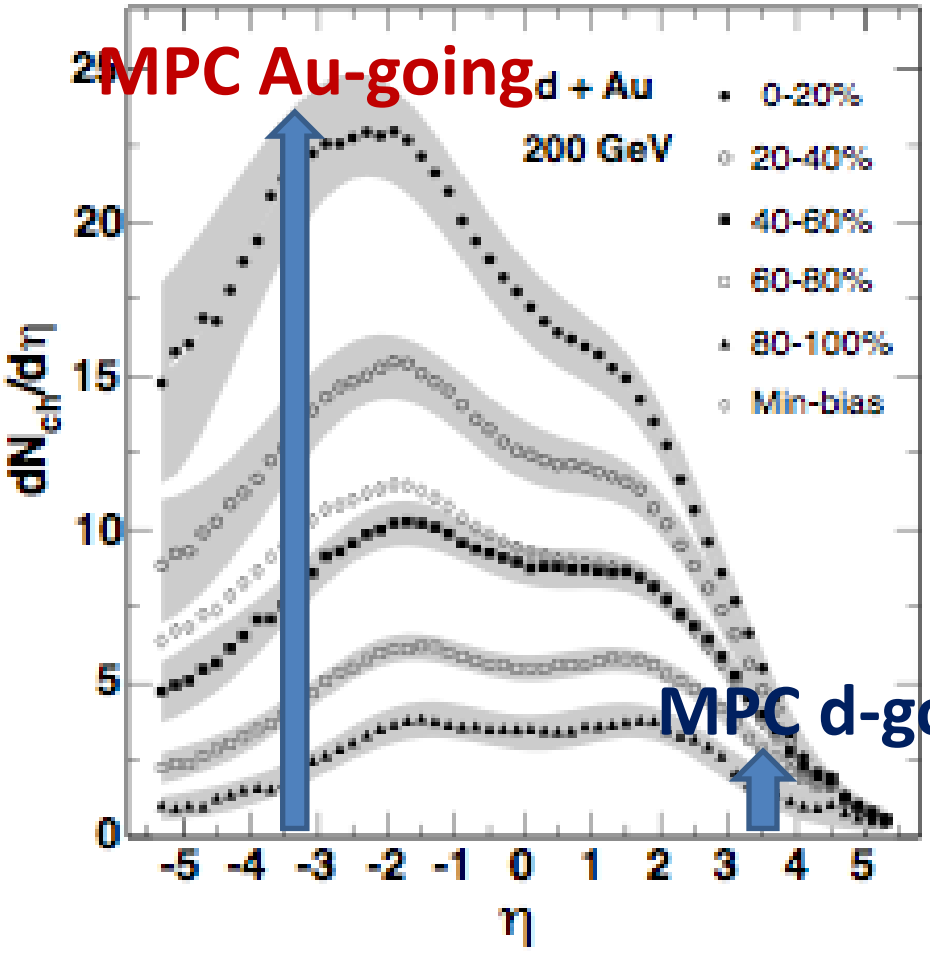
Hydrodynamics

- Is there "ridge" in dAu collisions?
- How about the difference between the v_2 in dAu and pPb?
- Is there mass ordering for identified particle v_2 in dAu?

Extend the rapidity range







- Muon Piston Calorimeter
  Forward/backward-rapidity $3<|\eta|<4$
- Extend the rapidity range by measuring the correlation between Tracks ($<|\eta|<0.35$) and MPC towers: **$|\Delta\eta|>2.75$!**

PHOBOS Phys. Rev. C72, 031901

Angular correlations between Track and Tower: C($\Delta\phi$)

- $\boldsymbol{S(\Delta\phi) = \frac{d(\omega_{tower} N_{same}^{track-tower})}{d(\Delta\phi)}}$

✓ ω_{tower} is the transverse energy of each tower

✓ $N_{same}^{track-tower}$ is number of pair of track-tower in same event

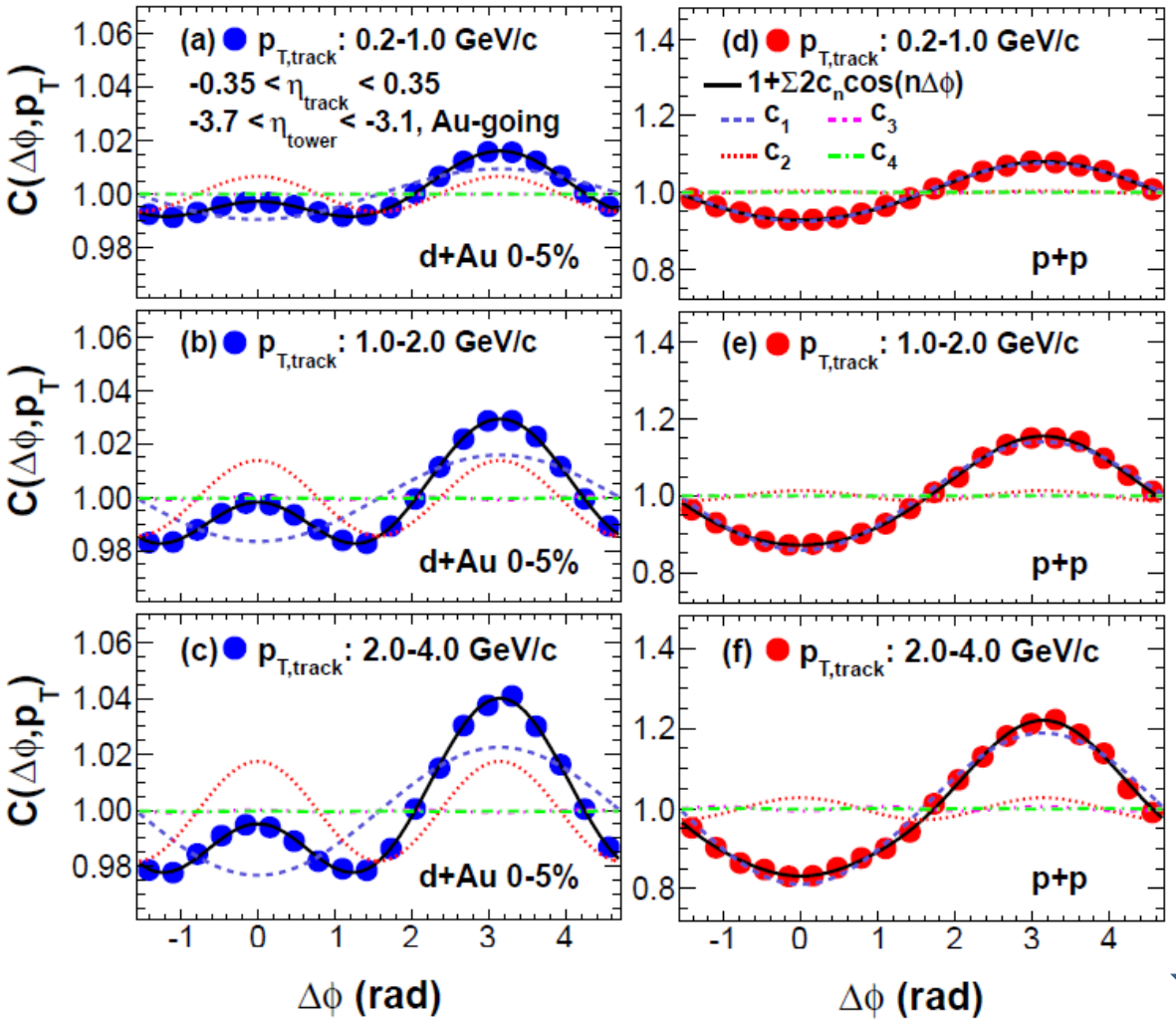
✓ $\Delta\phi = \phi_{tower} - \phi_{track}$

- $\boldsymbol{C(\Delta\phi) = \frac{\int M(\Delta\phi) S(\Delta\phi)}{\int S(\Delta\phi) M(\Delta\phi)}}$

✓ M($\Delta\phi$) is track-tower correlation in mixed events

$C(\Delta\phi,p_T)$ of pp and 0-5% dAu

arXiv:1404.7461

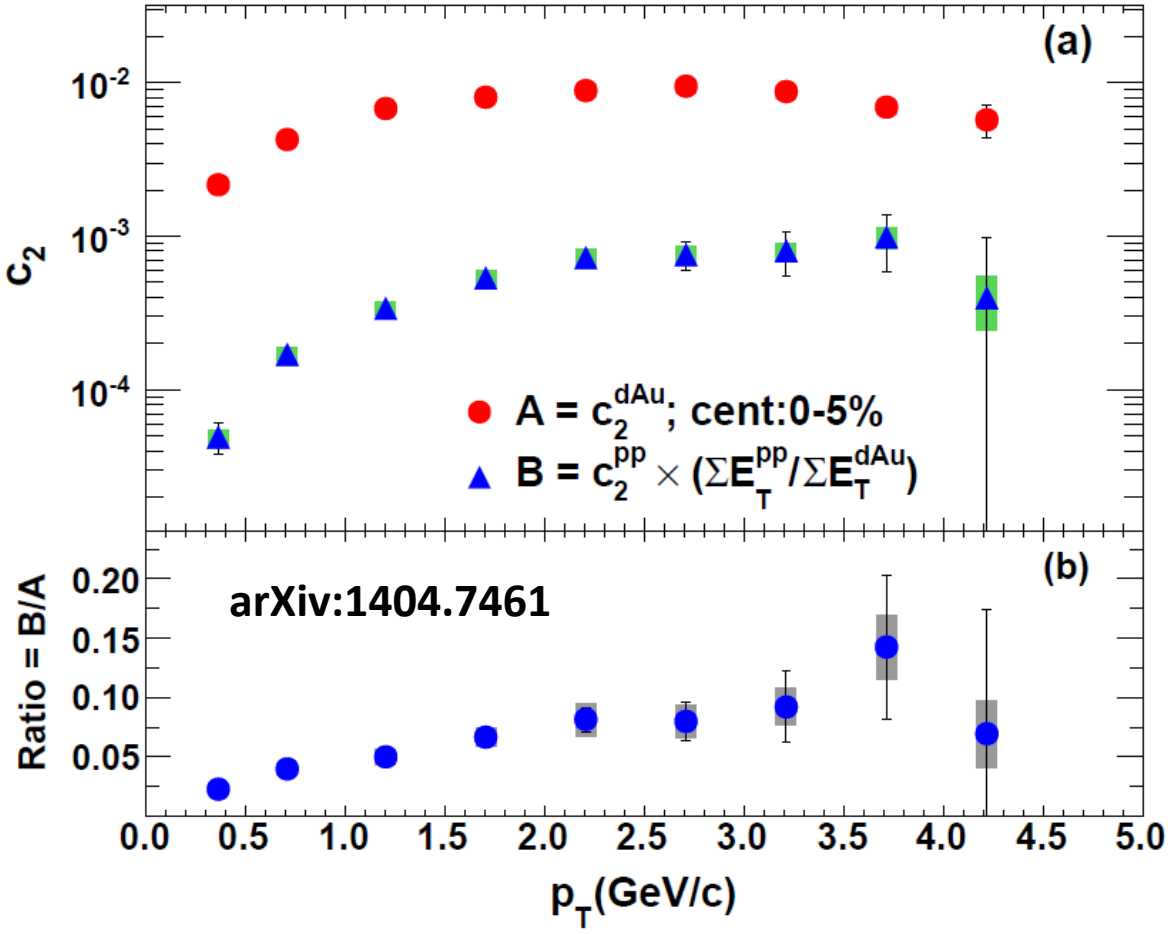


d+Au 0-5% **p+p**

p_T

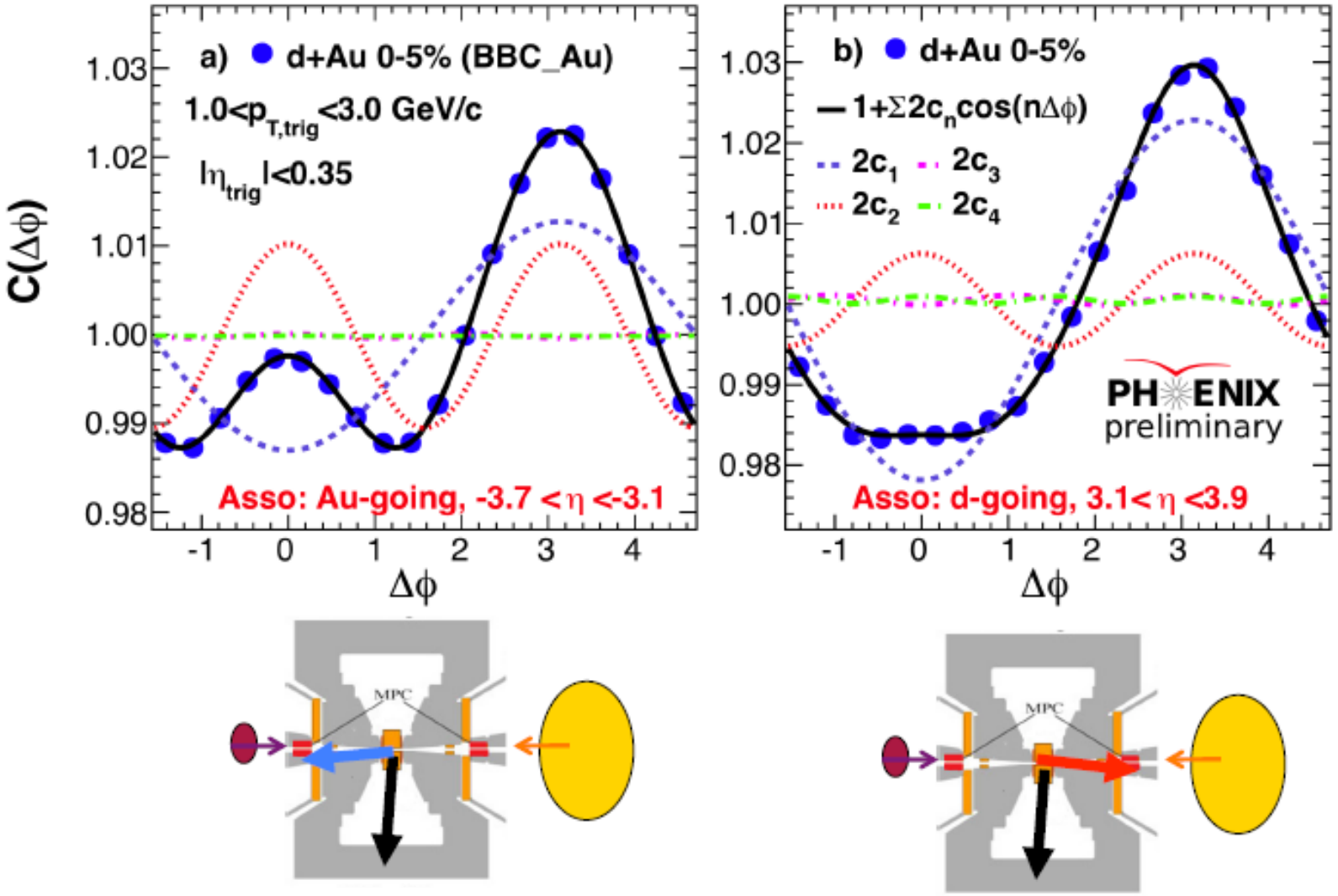
- In pp, the distribution is dominated by the dipole term $\cos(\Delta\phi)$, which may due to the momentum conservation
- In dAu, the distribution shows a near side peak
- Dijet contribution can't be taken out by subtracting the conditional yield of pp from dAu
- Dijet contributions to c_2 in dAu can be estimated from c_2 in pp

Compare c_2 from d+Au and p+p

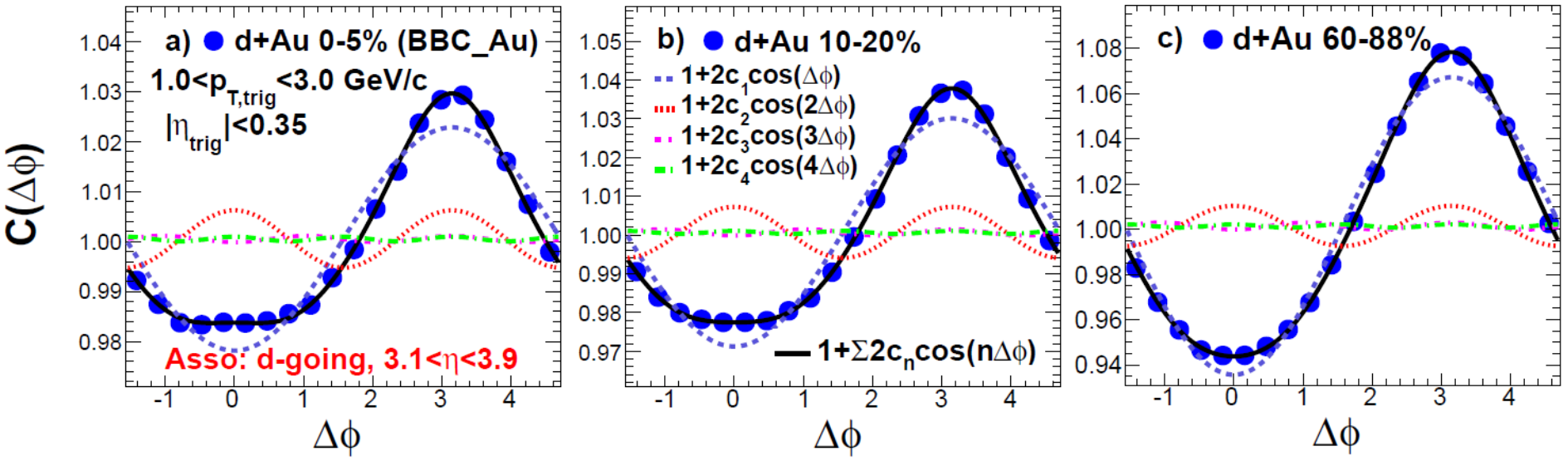


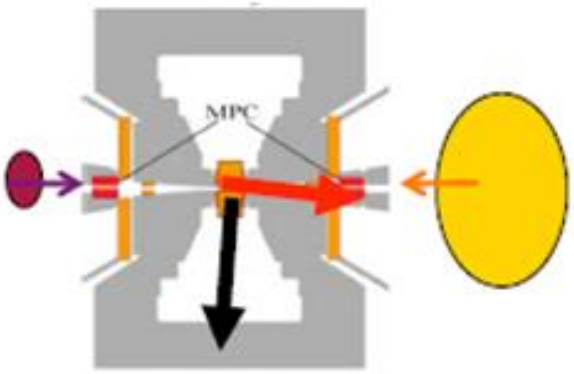
The difference indicates that the contribution from di-jet, resonance decay … is less than 10% for c_2^{dAu}

“Au-going” vs “d-going”



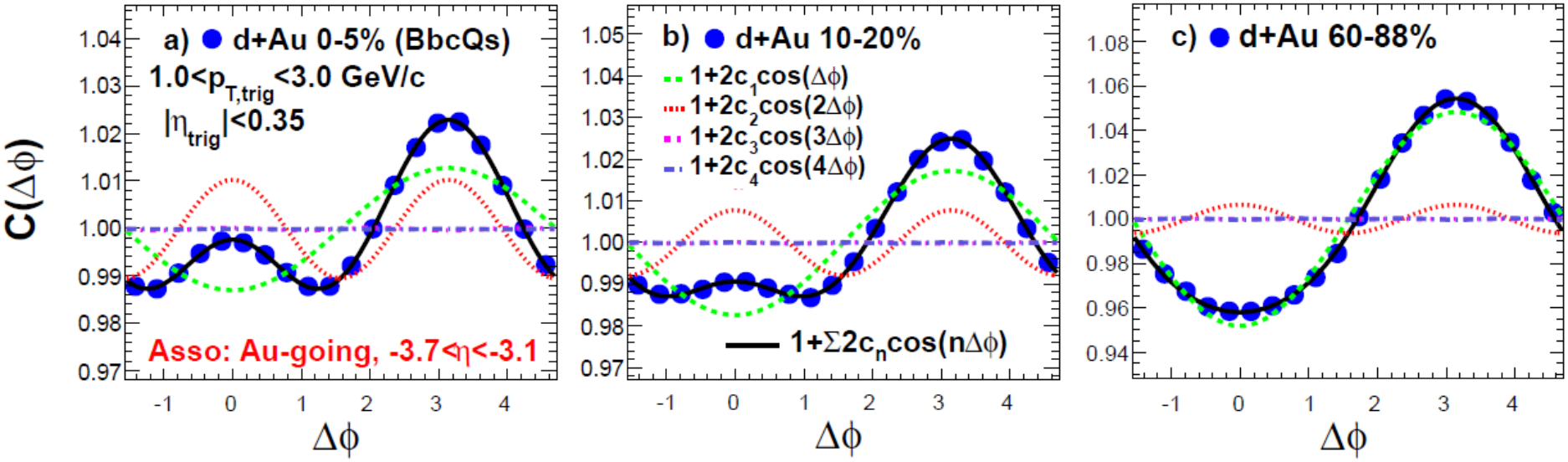
mid-forward(d-going) correlation

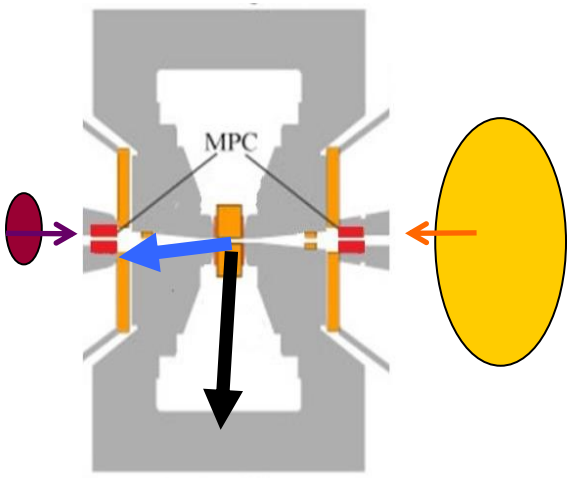




- The mid-forward rapidity correlation in central d+Au is different from that in peripheral, even though there is no near-side peak

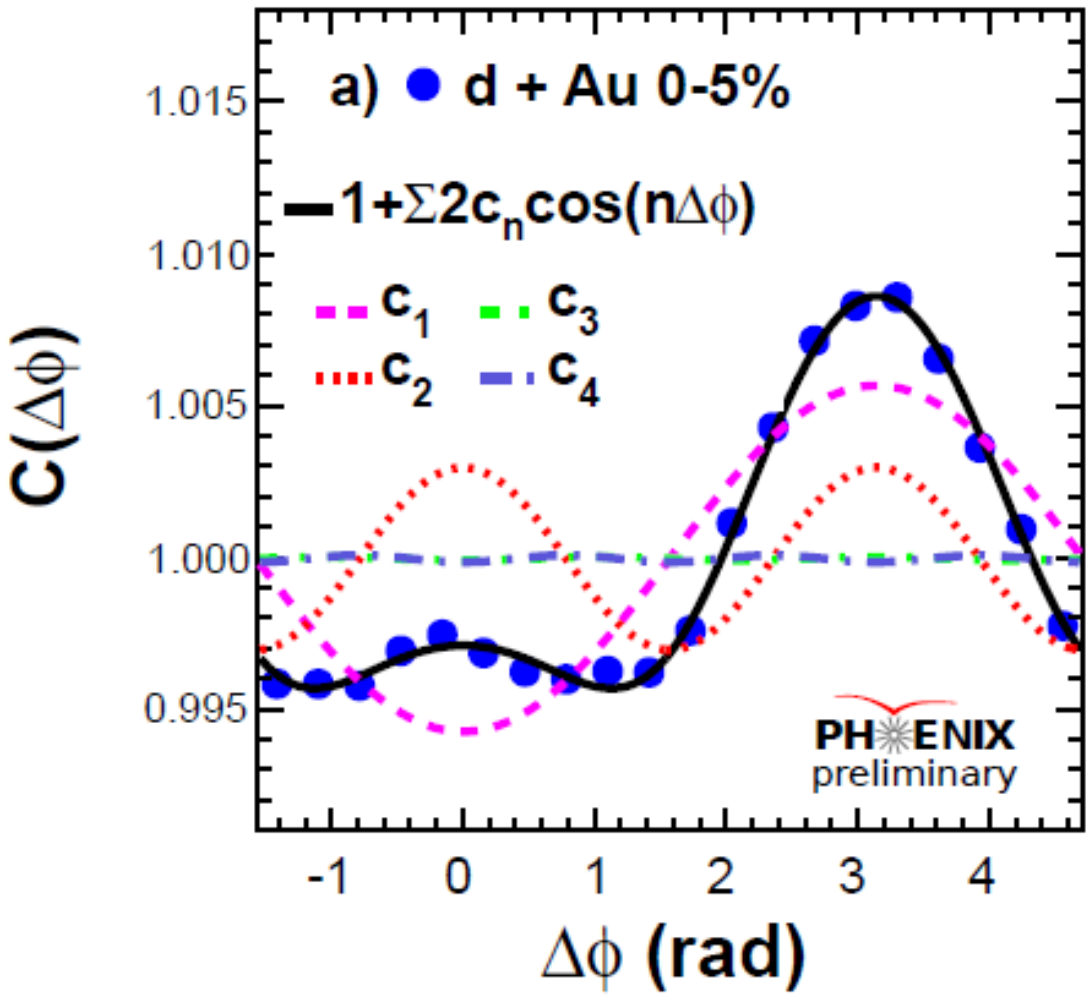
Mid-backward(Au-going) correlation

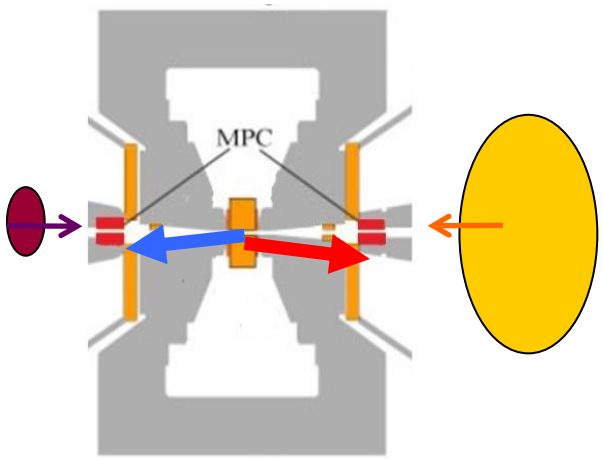




- The near-side peak is visible until 10-20% centrality
- In peripheral collisions, the Au-going correlation is similar to the d-going correlation

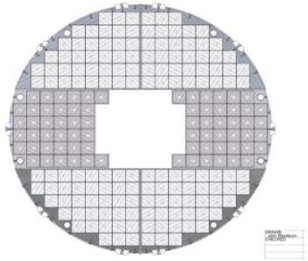
A ridge is observed with| Δη |>6.0





- Correlation between Au-going and d-going MPC towers

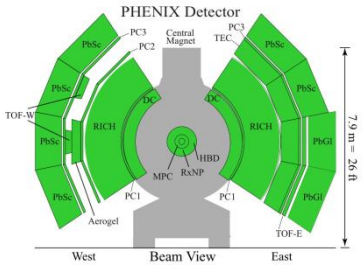
Event-plane method for v_2



Muon piston Calorimeter

MPC (3.1<|η|<3.9)

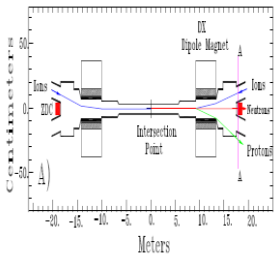
Ψ_{2,MPC_S} Au-going



Central Arm tracking

(|η|<0.35)

$\Psi_{2,CNT}$

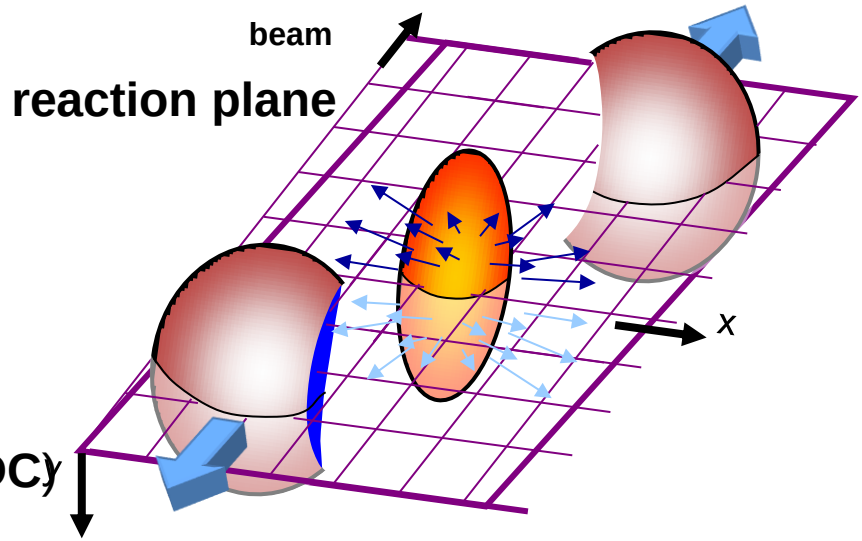


Zero Degree Calorimeters(**ZDC**)

Shower Max Detectors(**SMD**)

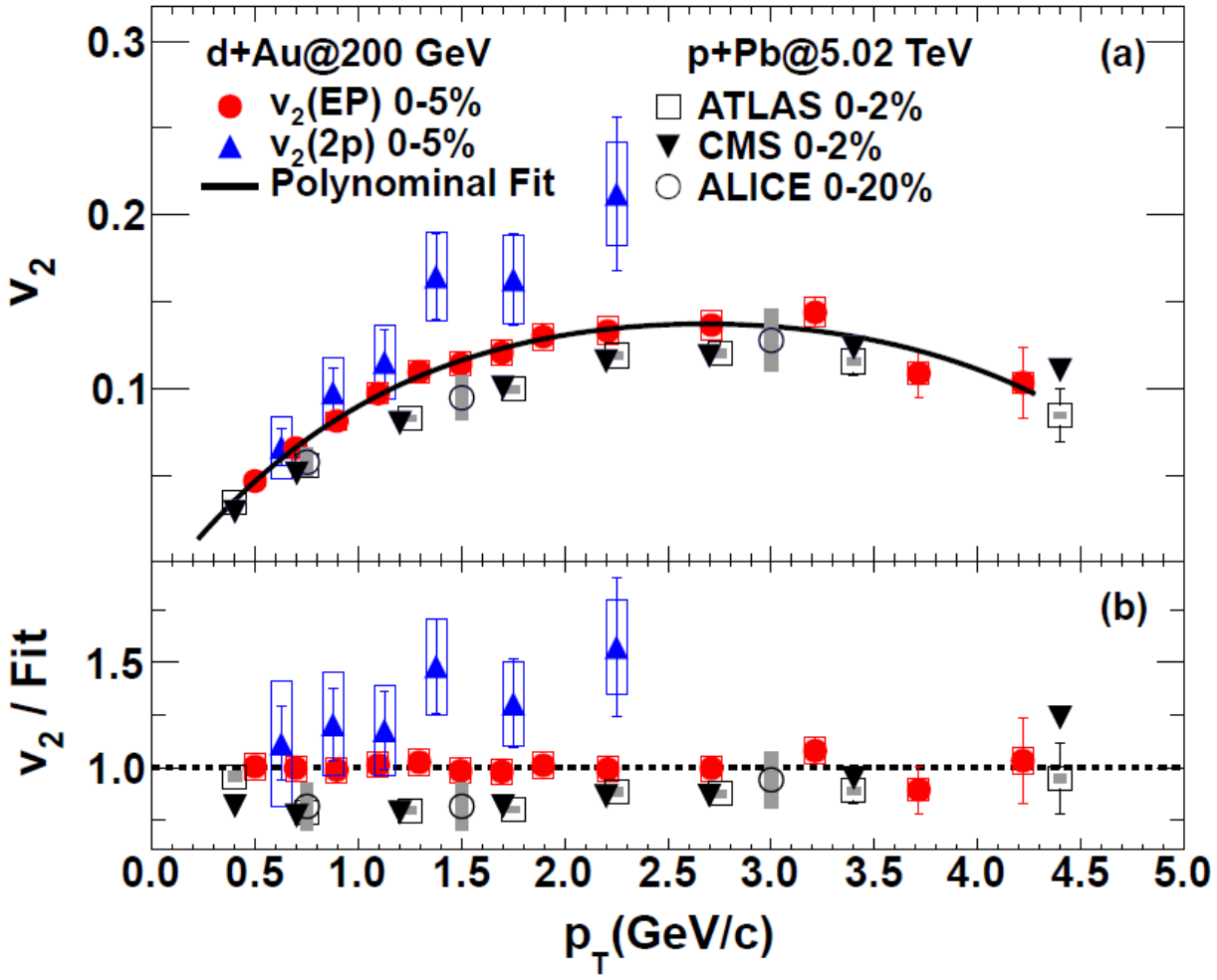
ZDC-SMD (|η|>6.5)

Ψ_{1,smd_s} by Au-going spectator



- The difference between c_2(dAu) and c_2(pp) indicates that in EP methods, the contribution from dijet, resonance … is less than 10% for pT up to 4.5 GeV/c
- The event-plane Ψ_{2,MPC_S} resolution is estimated from three-sub events which include the $\Psi_{2,CNT}$ and Ψ_{1,SMD_S}

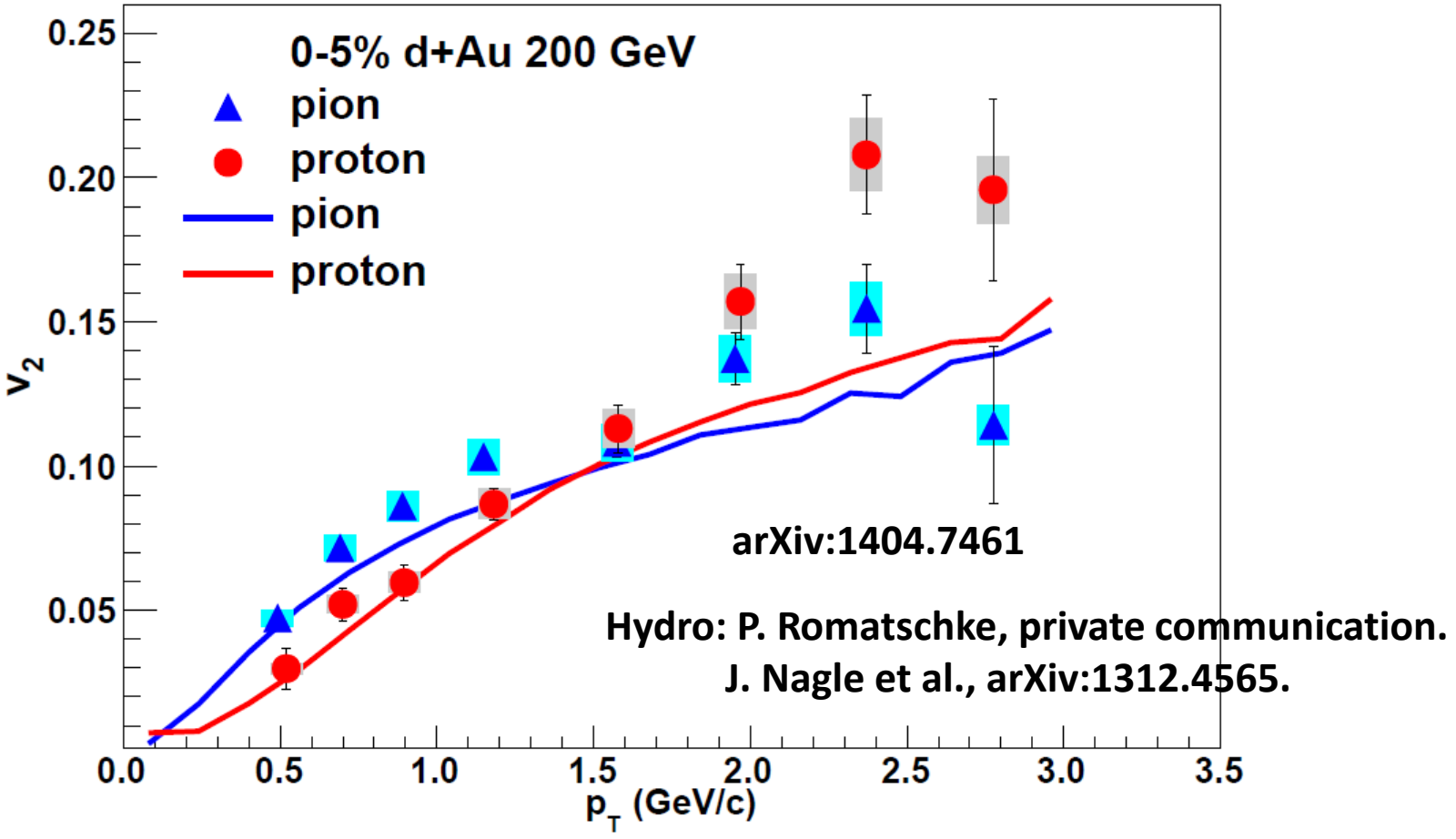
V_2(EP) of charged hadron in 0-5% d+Au



arXiv:1404.7461

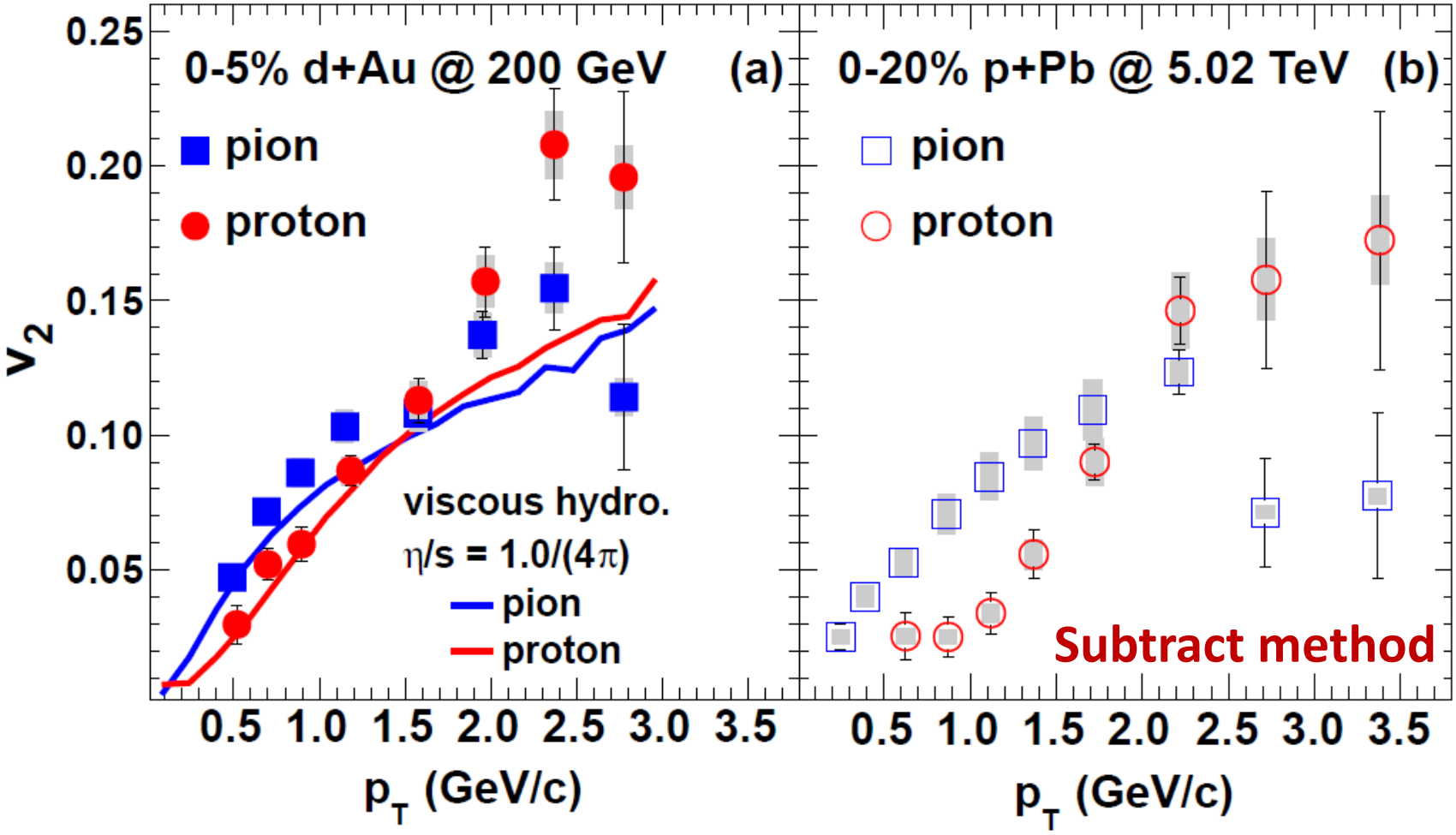
- The charged hadron v_2 measured by the event plane method in central dAu is similar to that in central pPb

Identified particles' v_2 from EP methods



- **Mass ordering is observed in 0-5% d+Au**
- **This ordering can be reproduced in hydro calculation from P. Romatschke et al.**

Weaker radial flow in dAu?



- The magnitude of mass ordering in p+Pb is larger than that in d+Au
- Weaker radial flow in d+Au?

Summary

- Is there "ridge" in dAu collisions?

There is "Ridge" in dAu even with $|\Delta\eta|>6.0$

- How about the difference between the v_2 in dAu and pPb?

v_2 in central dAu is similar to that in central pPb, while hydro calculation show a significant difference

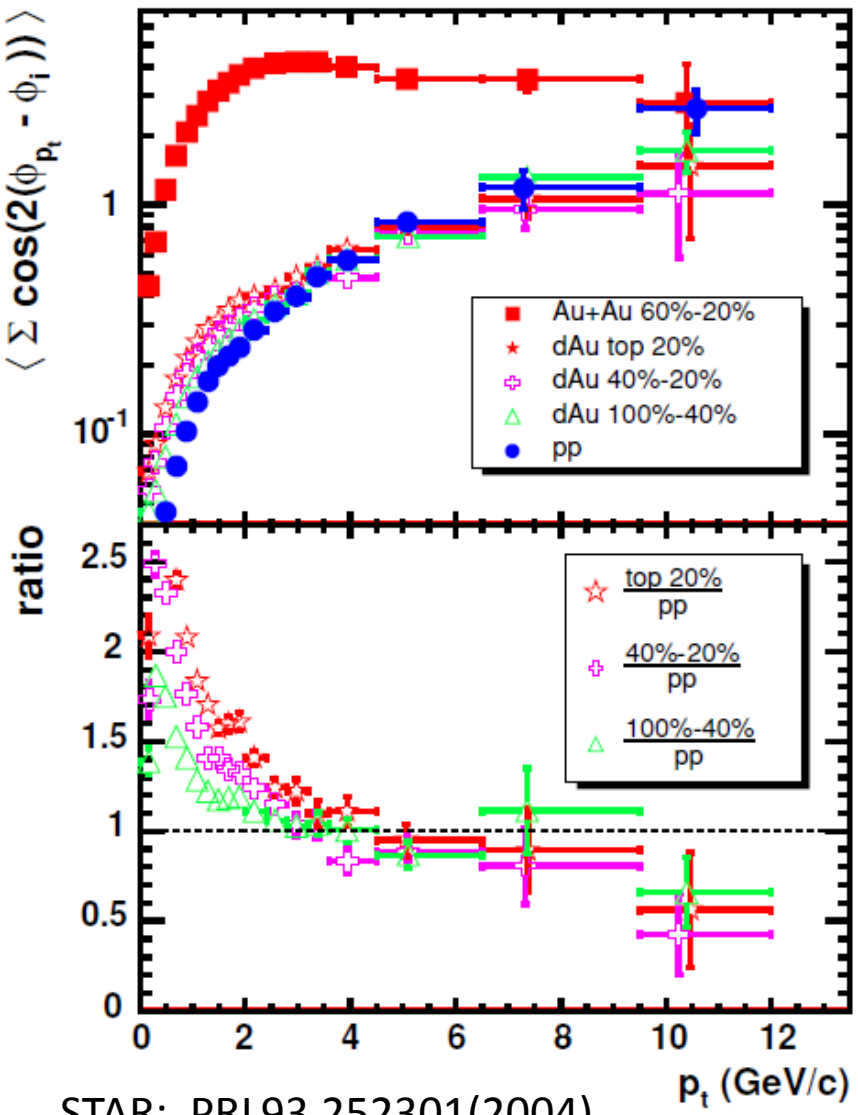
- Is there mass ordering for identified particle v_2 in dAu?

The mass ordering is observed in central dAu , while it is smaller comparing with central pPb, it may be due to a weaker radial flow in dAu

The input from CGC model calculation is expected for the further understanding the physics of "ridge" and "v_2" in small collision system

BackUp

Scalar Product Method: <μQ>



STAR: PRL93,252301(2004)
PRC72,014904(2005)

- In heavy ion collision:

$$\langle \mu Q \rangle = \langle \Sigma \cos(2(\phi_{pt} - \phi_j)) \rangle$$
$$= M \times v_2(pt) \times \bar{v}_2 + nonflow$$
$$= M \times c_2(pt)$$

The nonflow in AA(dA) is same as pp

- For the tower of MPC

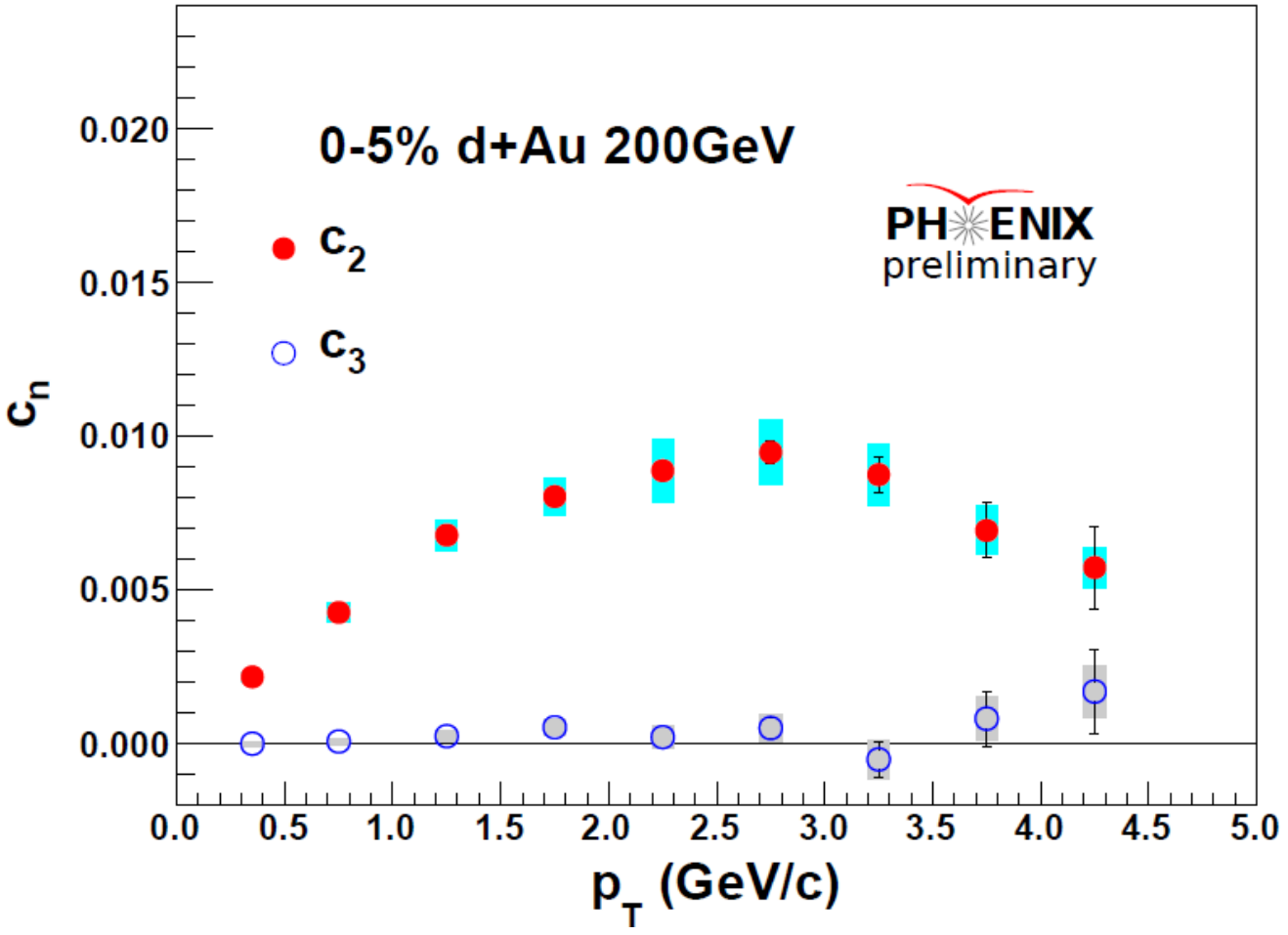
$Q = (\Sigma \omega_i \cos(2\phi_{tower,i}), \Sigma \omega_i \sin(2\phi_{tower,i}))$

ω_i is E_T of each MPC tower of Au-going

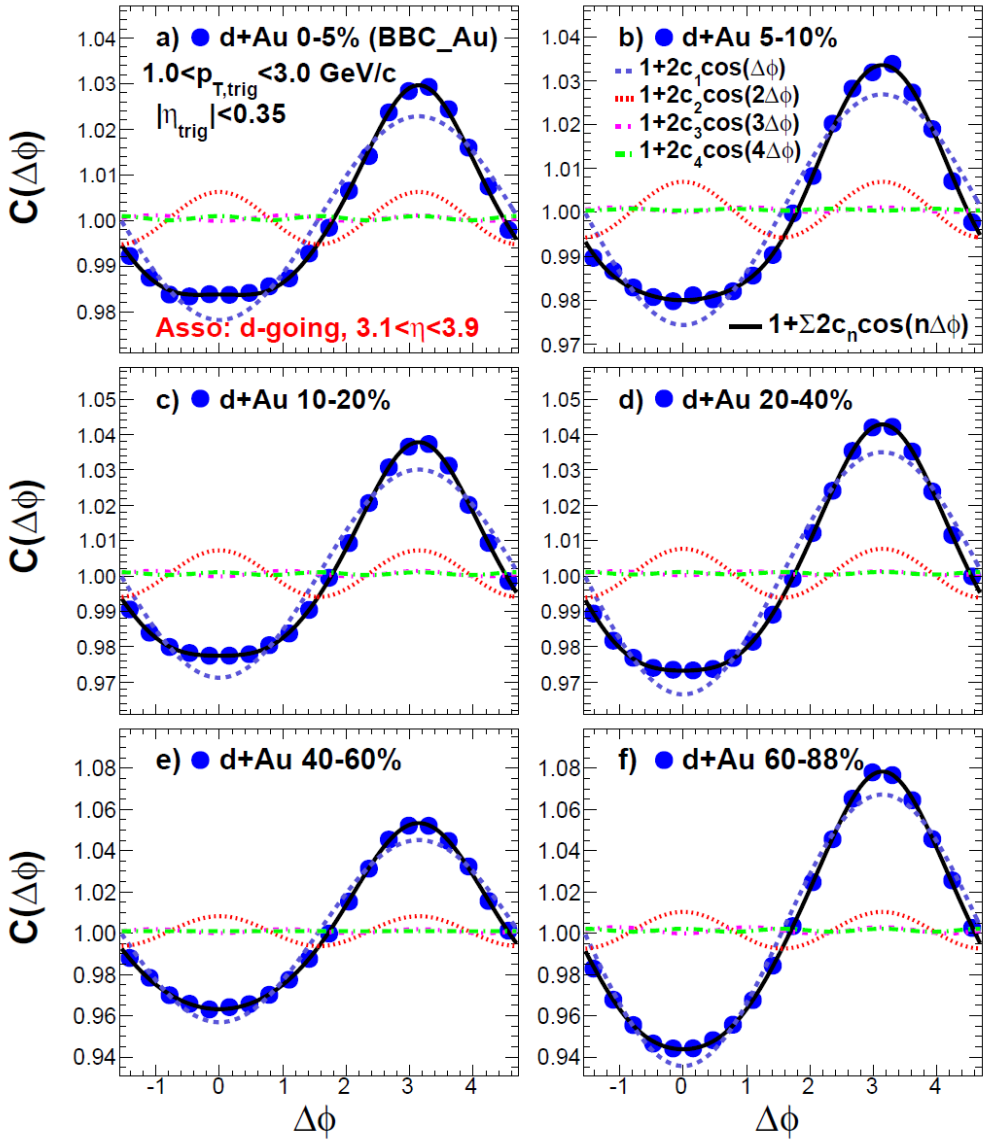
$\langle \mu Q \rangle = \Sigma E_T \times c_2(pt)$

- The dijet, resonance *et al* contributions in d+Au collisions can be estimated in p+p collisions with the scale of $\Sigma E_T^{pp} / \Sigma E_T^{dAu}$

c_2 and c_3 *vs* p_T



The c_3 is close to 0, comparing with the sizeable c_2


a) d+Au 0-5% (BBC_Au)
1.0<p_T,trig<3.0 GeV/c
|η_trig|<0.35
Asso: d-going, 3.1<η<3.9
b) d+Au 5-10%
1+2c_1cos(Δφ)
1+2c_2cos(2Δφ)
1+2c_3cos(3Δφ)
1+2c_4cos(4Δφ)
1+Σ2c_ncos(nΔφ)
c) d+Au 10-20%
d) d+Au 20-40%
e) d+Au 40-60%
f) d+Au 60-88%
C(Δφ)
Δφ