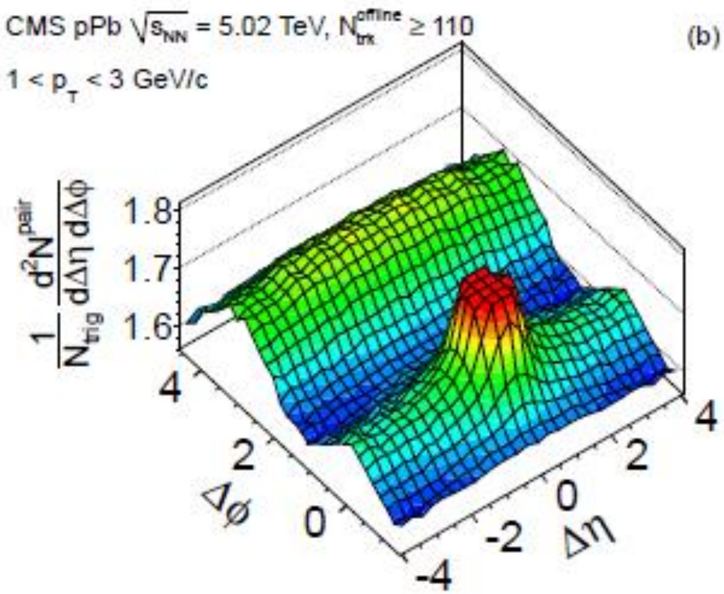
Measurements of long-range angular correlation and anisotropy in d+Au collisions at 200 GeV from PHENIX

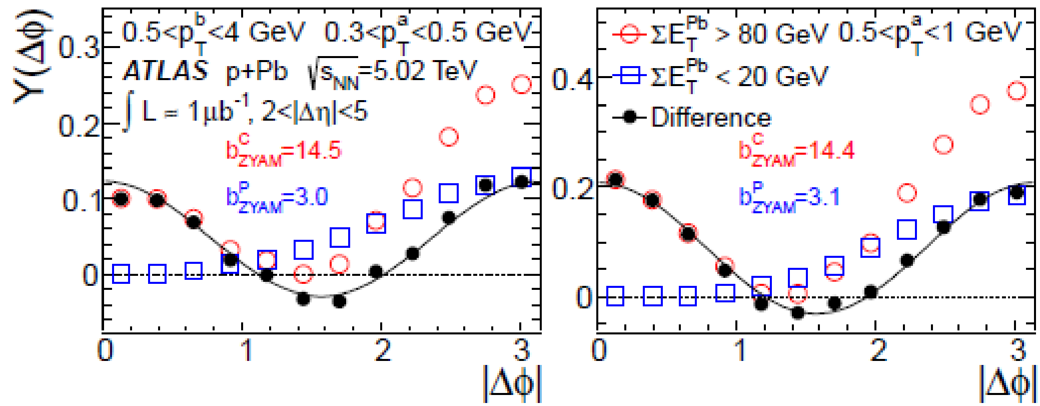
Shengli Huang
Vanderbilt University
for the PHENIX Collaboration

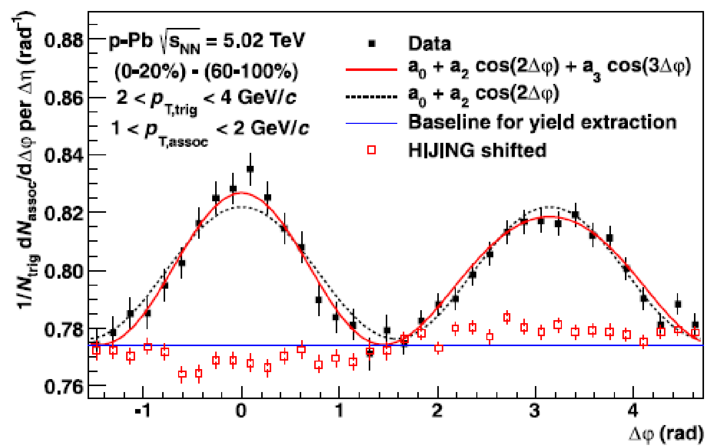
Outline

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

Ridge in p+Pb at 5.02 TeV



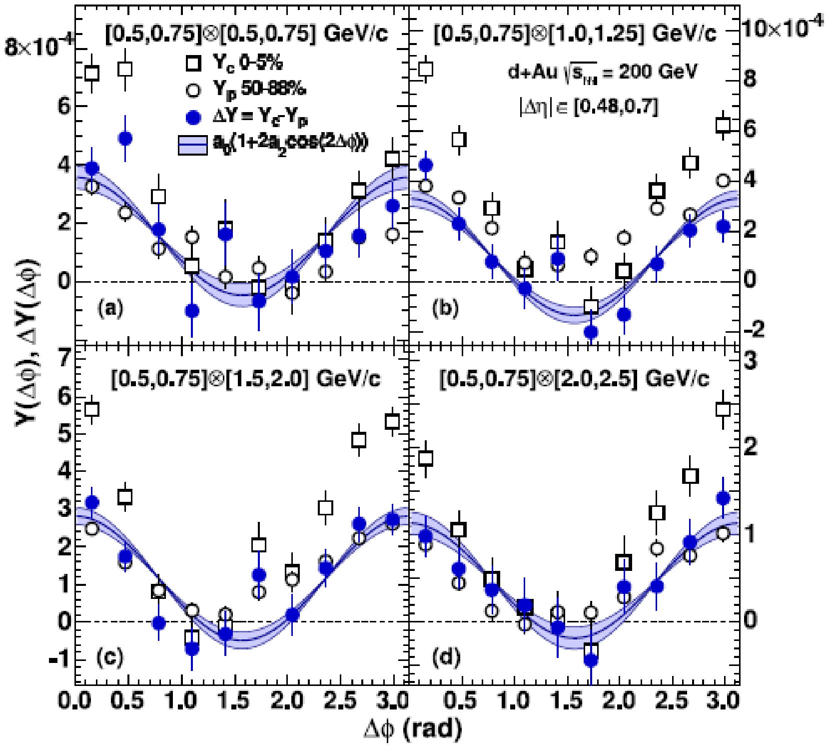


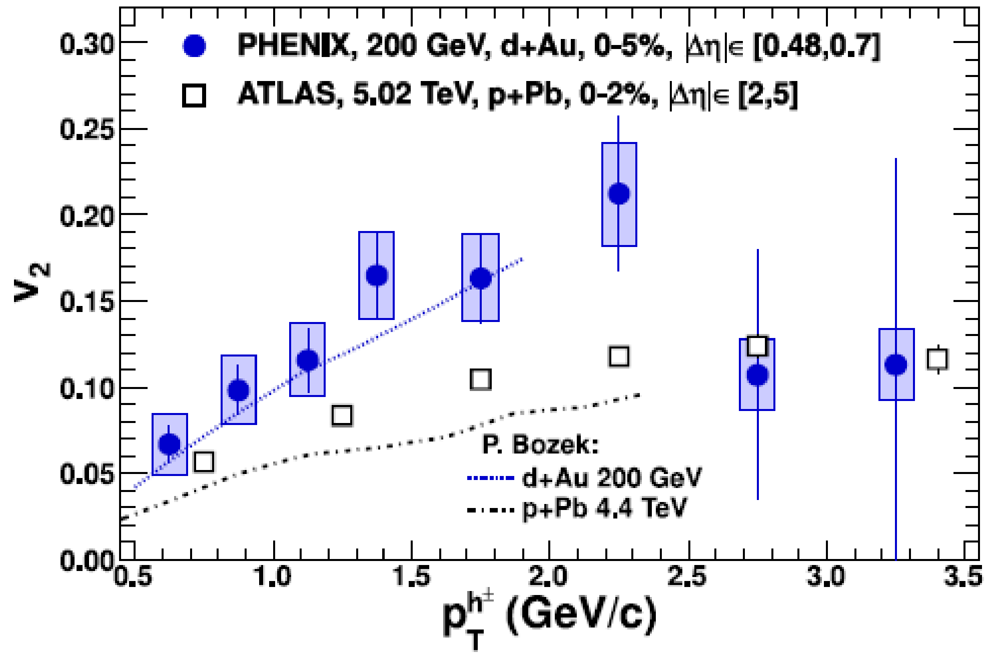


ALICE: Phys. Lett. B 719 (2013)
ATLAS: Phys. Rev. Lett. 110(2013)
CMS: Phys. Lett. B 7198(2013

- ❑ A “ridge” is observed in the small system of high multiplicity p + Pb collisions
- ❑ The $\Delta\phi$ distribution shows a $\cos(2\Delta\phi)$ structure

V_2 in d+Au at 200 GeV

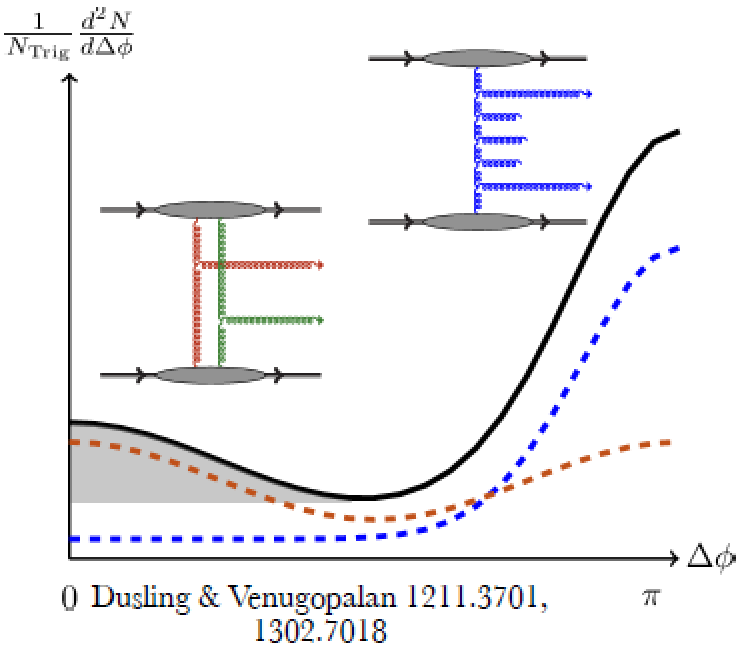


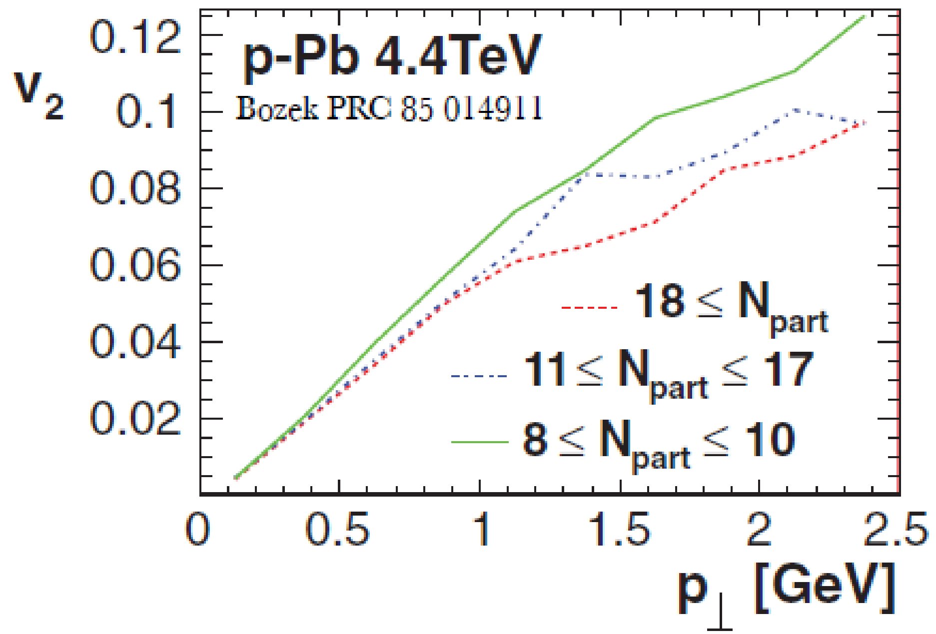


PHENIX: nucl-ex/1303.1794 (Accepted by PRL)

- 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 P.Bozek hydro calculation
- The measurement with large |Δη| is required!

Initial or final state effect?

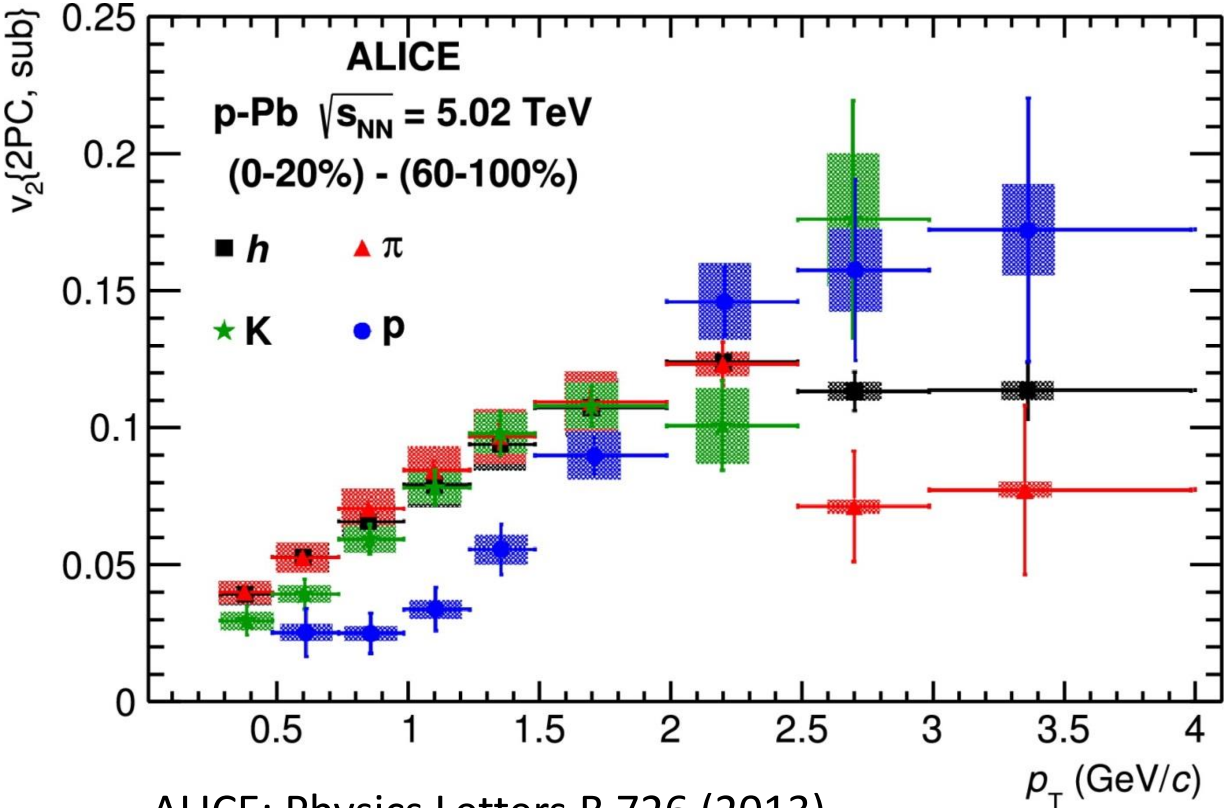




CGC **Hydrodynamics**

- The study of long-range correlation and precise measurements of anisotropy in d + Au collisions will be helpful in investigating these models.

Mass ordering in p+Pb at 5.02TeV

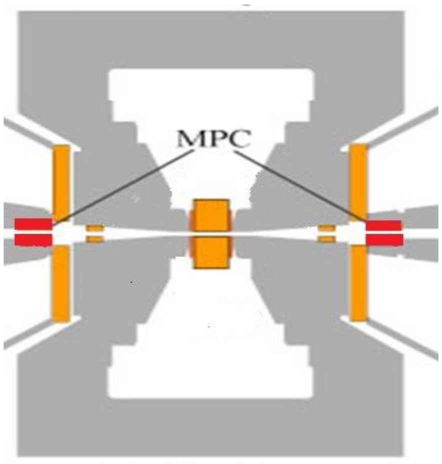


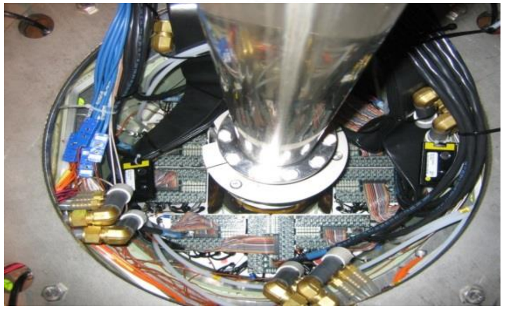
ALICE: Physics Letters B 726 (2013)

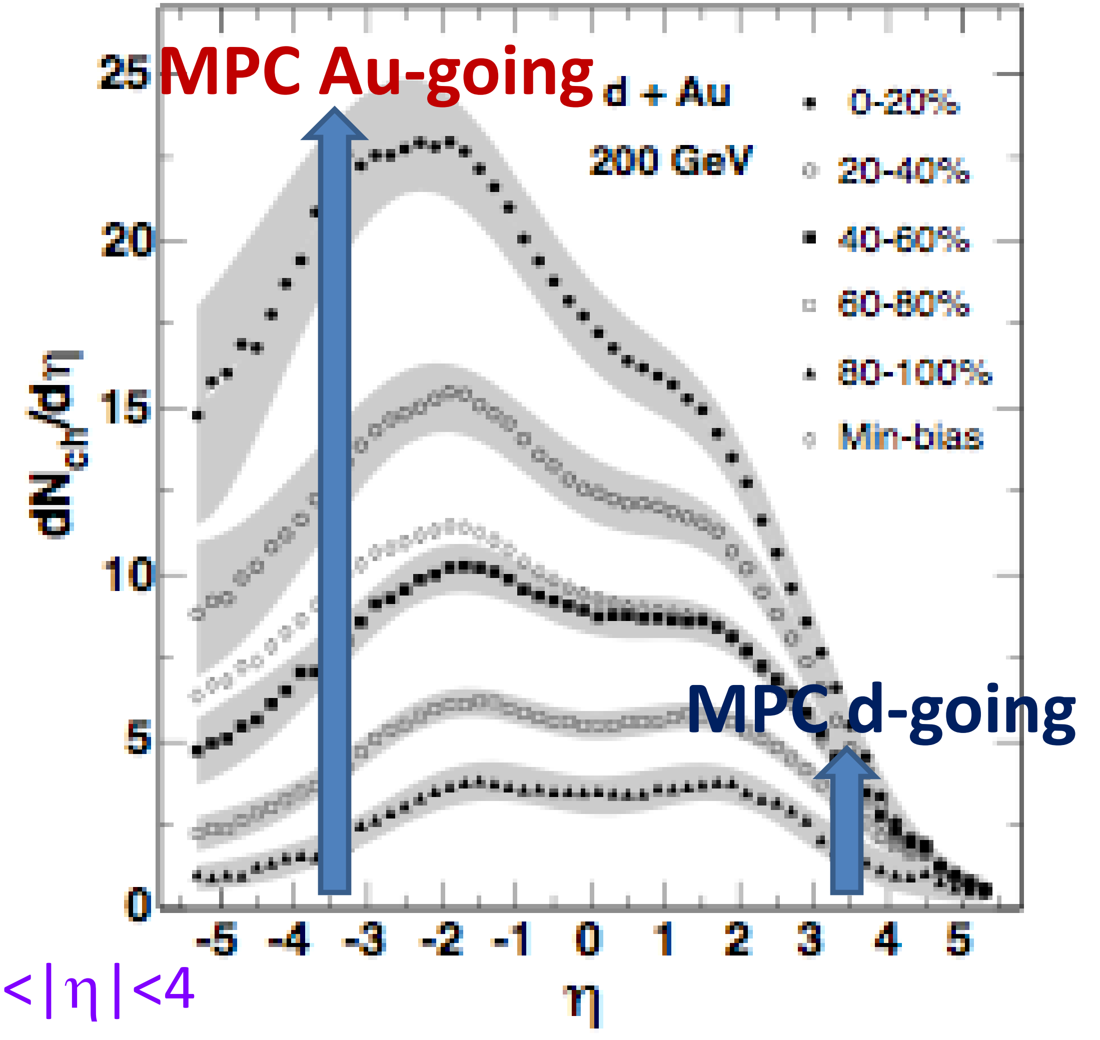
- ❑ Mass ordering of v_2 for identified particles is observed in p+Pb collisions, as we did in AA collisions

- ❑ What do we see in d+Au collisions?

Extend the Rapidity Range







- ❑ Muon Piston Calorimeter
Forward/backward-rapidity 3<|η|<4
- ❑ Extend the rapidity range by measuring the correlation between Tracks (<|η|<0.35) and MPC towers

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

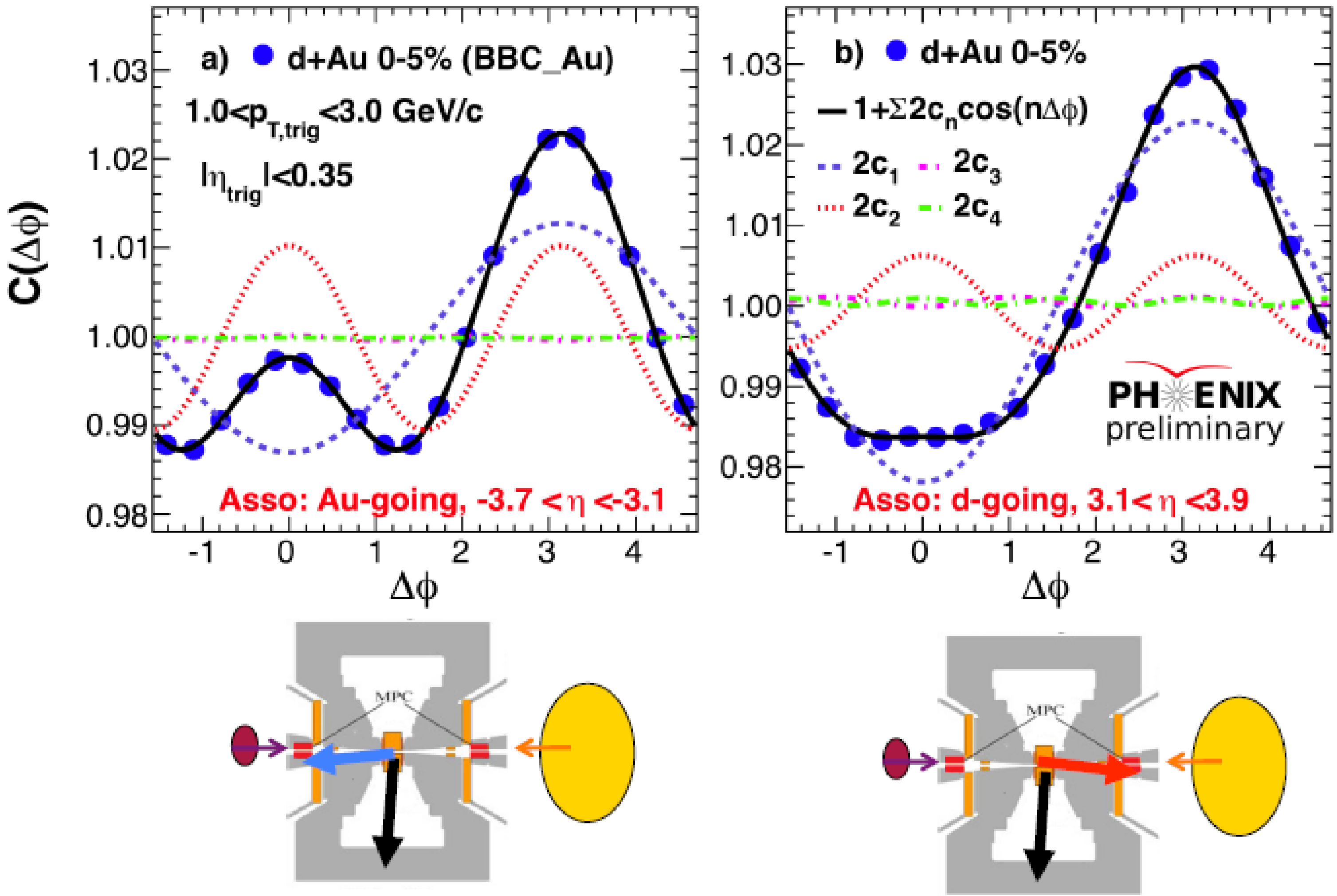
✓ $N_{same}^{track-tower}$ is number of pair of track-tower in same event

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

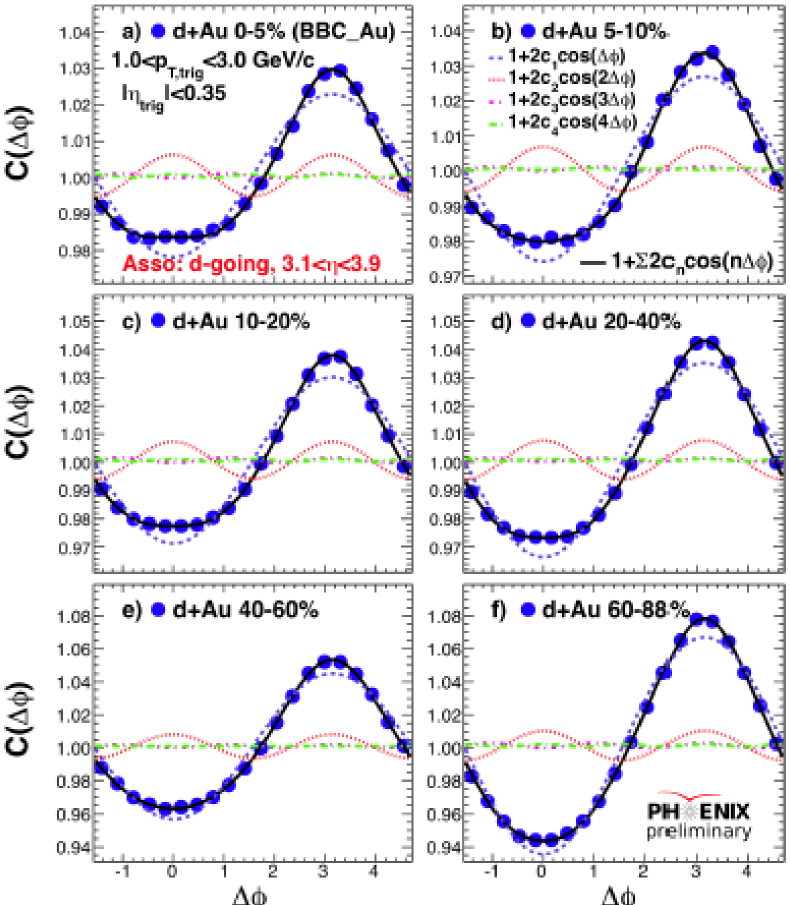
- $\boldsymbol{C(\Delta\phi) = \frac{\int M(\Delta\phi) S(\Delta\phi)}{\int S(\Delta\phi) M(\Delta\phi)}}$

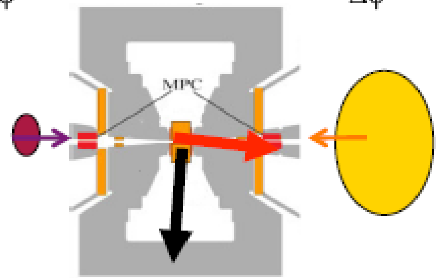
✓ M($\Delta\phi$) is track-tower correlation in mixed events

"Ridge" in d+Au collisions



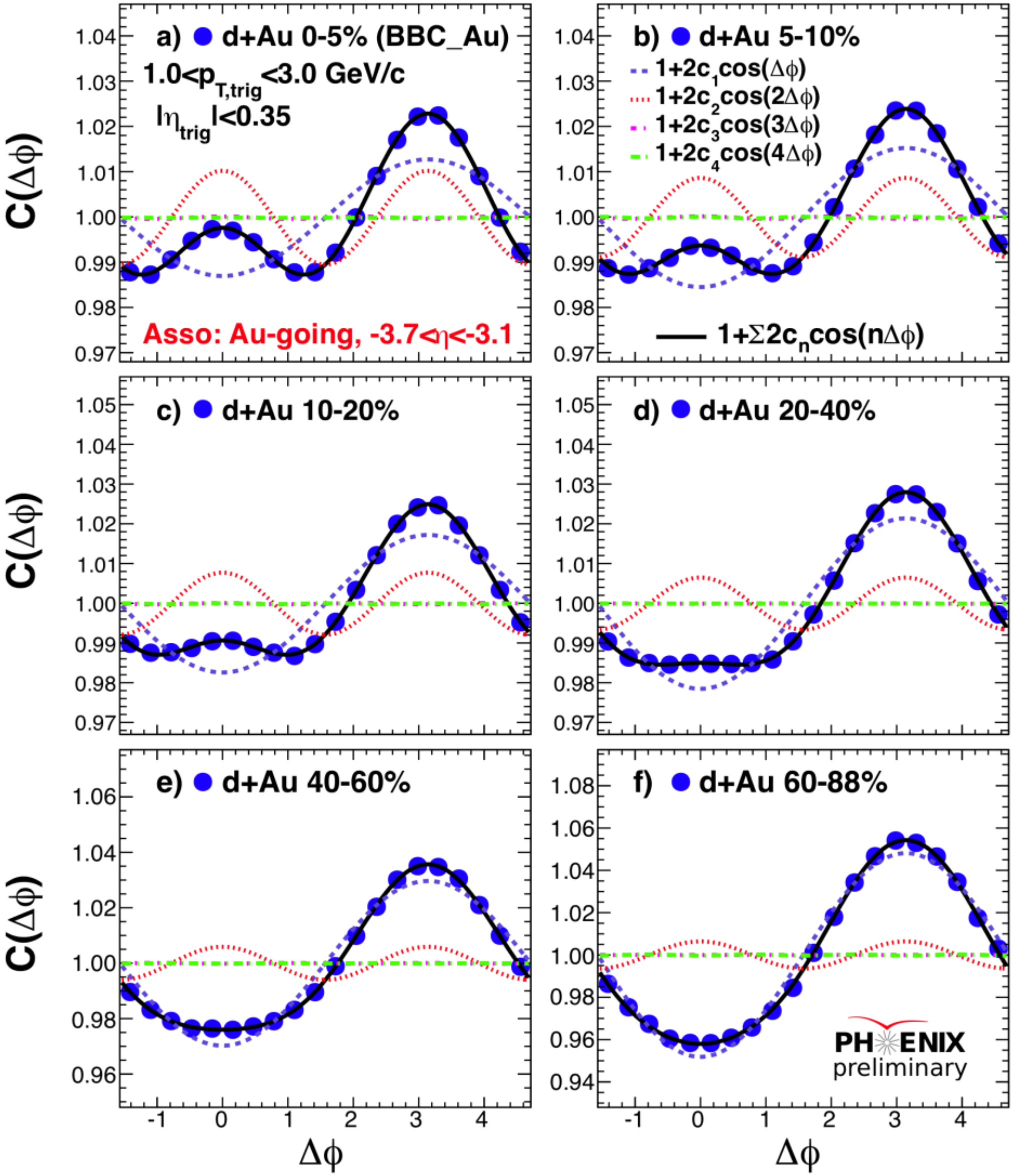
Correlation between Track(mid-rapidity) and Tower(d-going) vs. centrality

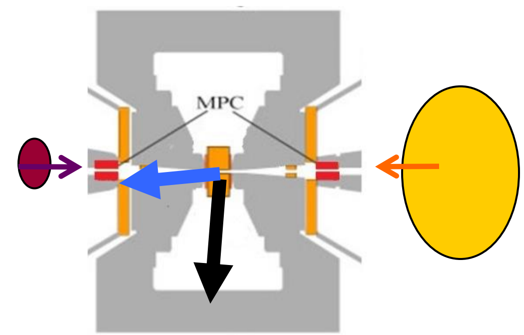




- In peripheral collision, the distribution is dominated by the dipole term cos(Δϕ) from Fourier fitting
- It indicates there is a strong contribution from momentum conservation in d+Au
- The mid-forward rapidity correlation in central d+Au is different from that in peripheral, even though there is no near-side peak

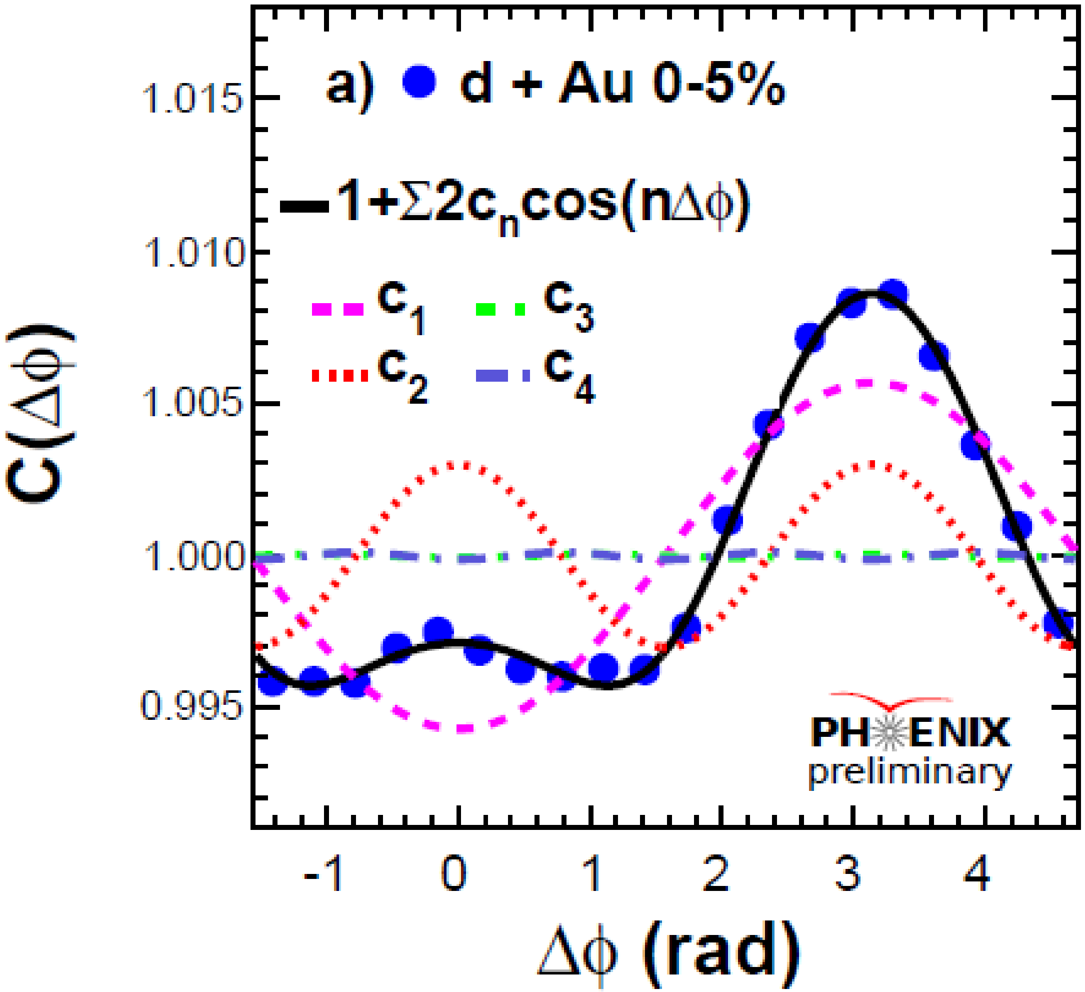
Correlation between Track(mid-rapidity) and Tower(Au-going) vs. centrality

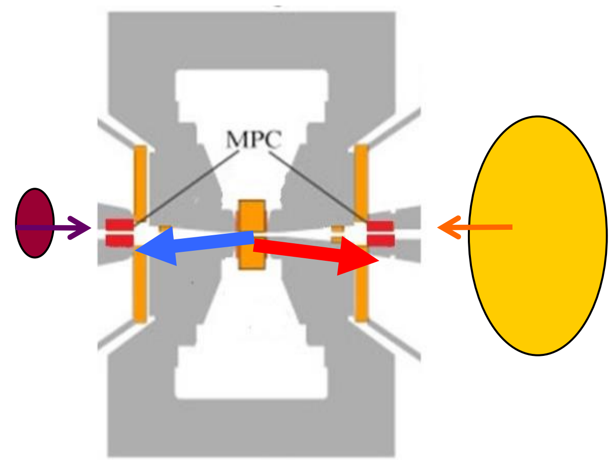




- The near-side peak is visible until 10-20% centrality
- In peripheral collisions, the Au-going correlation is similar to the d-going correlation

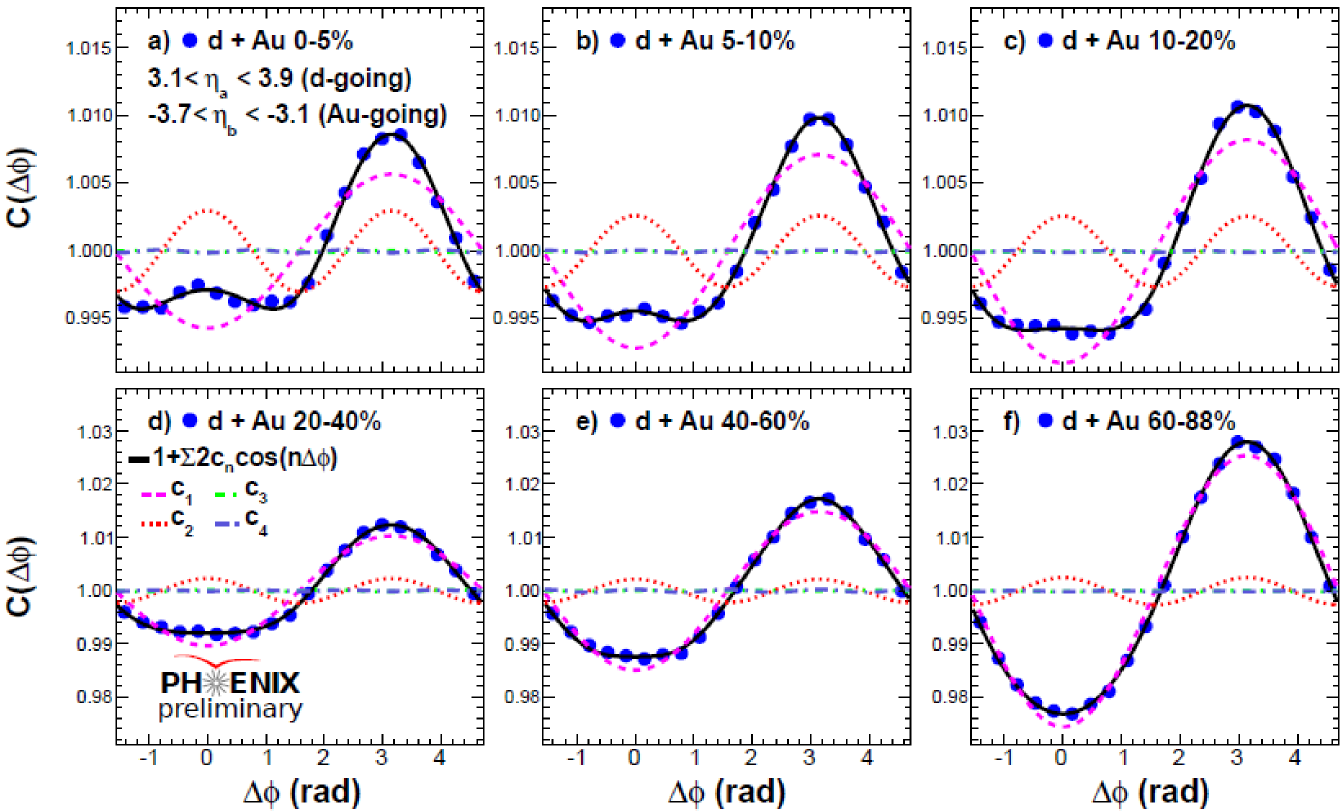
A ridge is observed with | Δη | >6.0

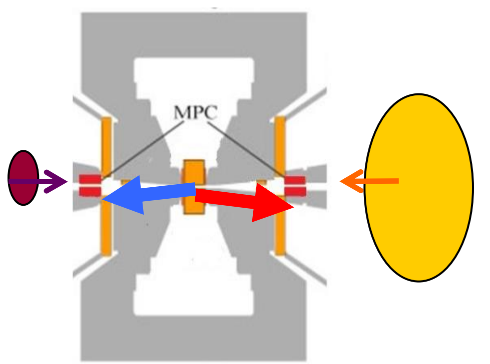




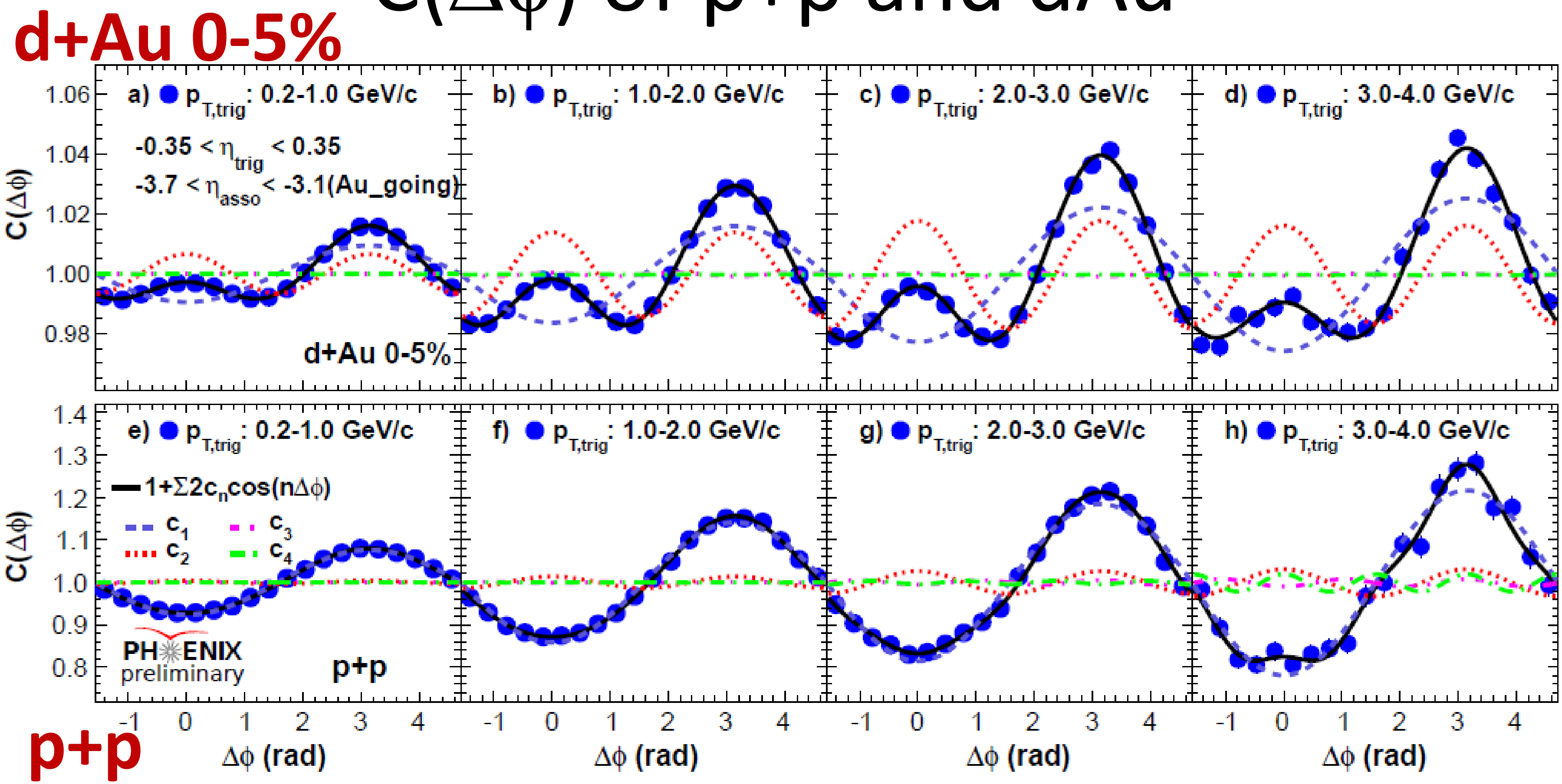
- ❑ Correlation between Au-going and d-going MPC towers

Correlation of Tower on Au-going and d-going vs. centrality



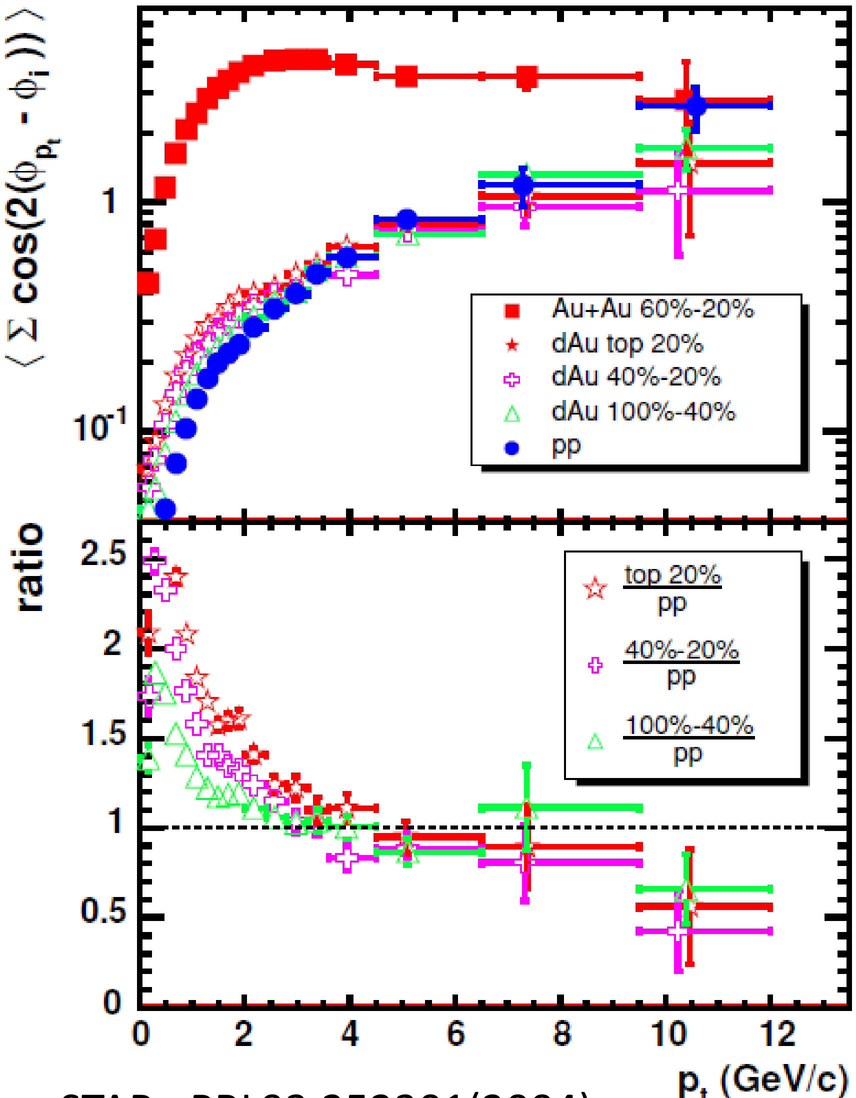


C(Δϕ) of p+p and dAu



- ZYAM normalization does not work due to the significant dipole contribution. Conditional yield of p+p can't be subtracted out correctly from d+Au
- Dijet, resonance *et al* contributions to c_2 can be estimated by an approach similar to the Scalar Product method

Scalar Product Method: <μQ>



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

- In heavy ion collision:

$<\mu Q> = <\Sigma\cos(2(\phi_{pt} - \phi_j))>$

$= M \times v_2(pt) \times \bar{v}_2 + nonflow$

$= M \times c_2(pt)$

The nonflow in AA(dA) is same as pp

- For the tower of MPC

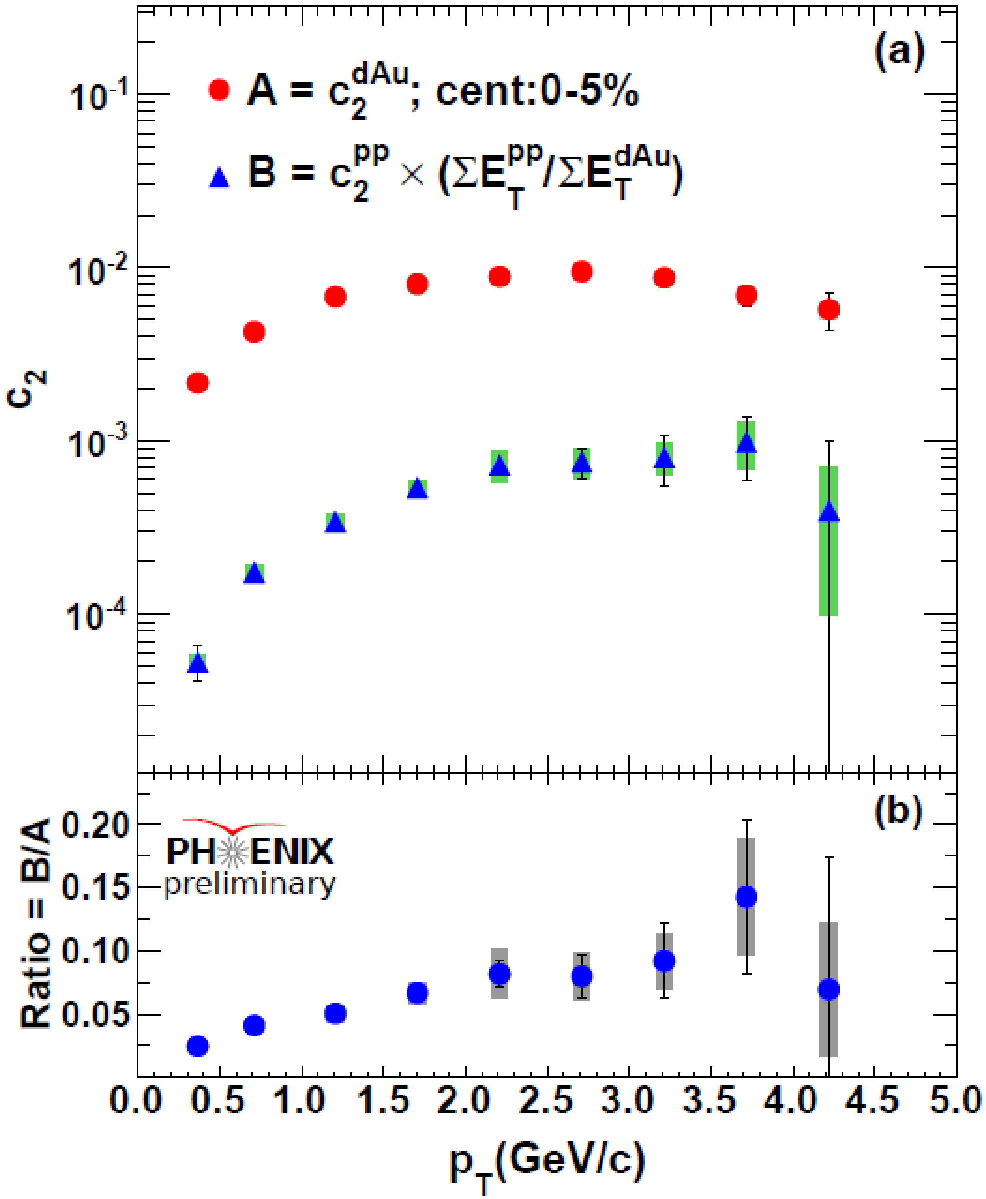
$Q = (\Sigma\omega_i\cos(2\phi_{tower,i}), \Sigma\omega_i\sin(2\phi_{tower,i}))$

ω_i is E_T of each MPC tower of Au-going

$<\mu Q> = \Sigma E_T \times c_2(pt)$

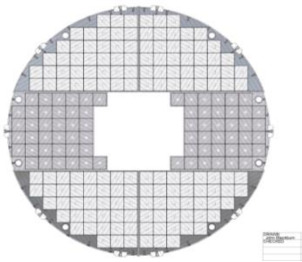
- The dijet, resonance *et al* contributions in d+Au collisions can be estimated in p+p collisions with the scale of $\Sigma E_T^{pp} / \Sigma E_T^{dAu}$

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}
- The $|\Delta\eta|$~3 significantly suppress the contribution from di-jets, resonance decay … comparing with previous measurements, which is around 60% at p_T = 2 GeV/c

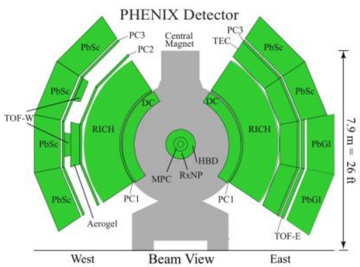
Event-plane method for v_2



Muon piston Calorimeter

MPC ($3.1<|\eta|<3.9$)

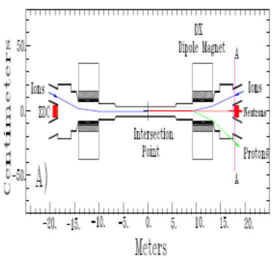
Ψ_{2,MPC_S} **Au-going**



Central Arm tracking

($|\eta|<0.35$)

$\Psi_{2,CNT}$

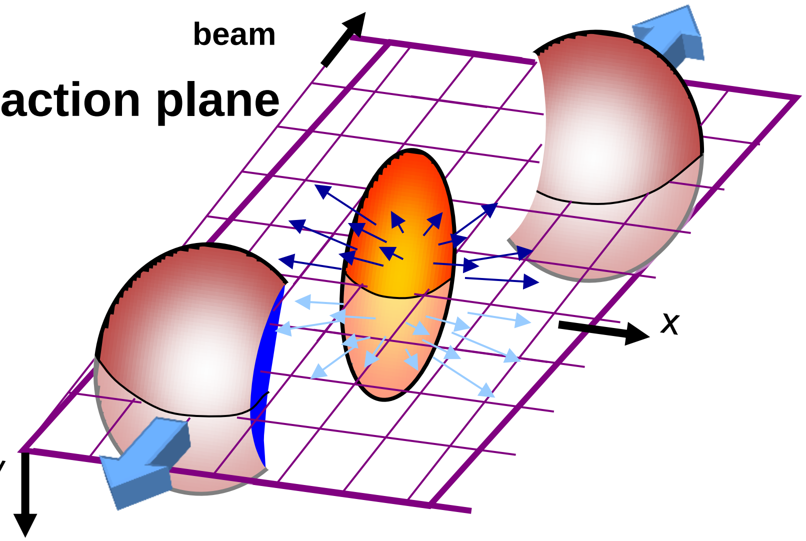


Zero Degree Calorimeters(**ZDC**)

Shower Max Detectors(**SMD**)

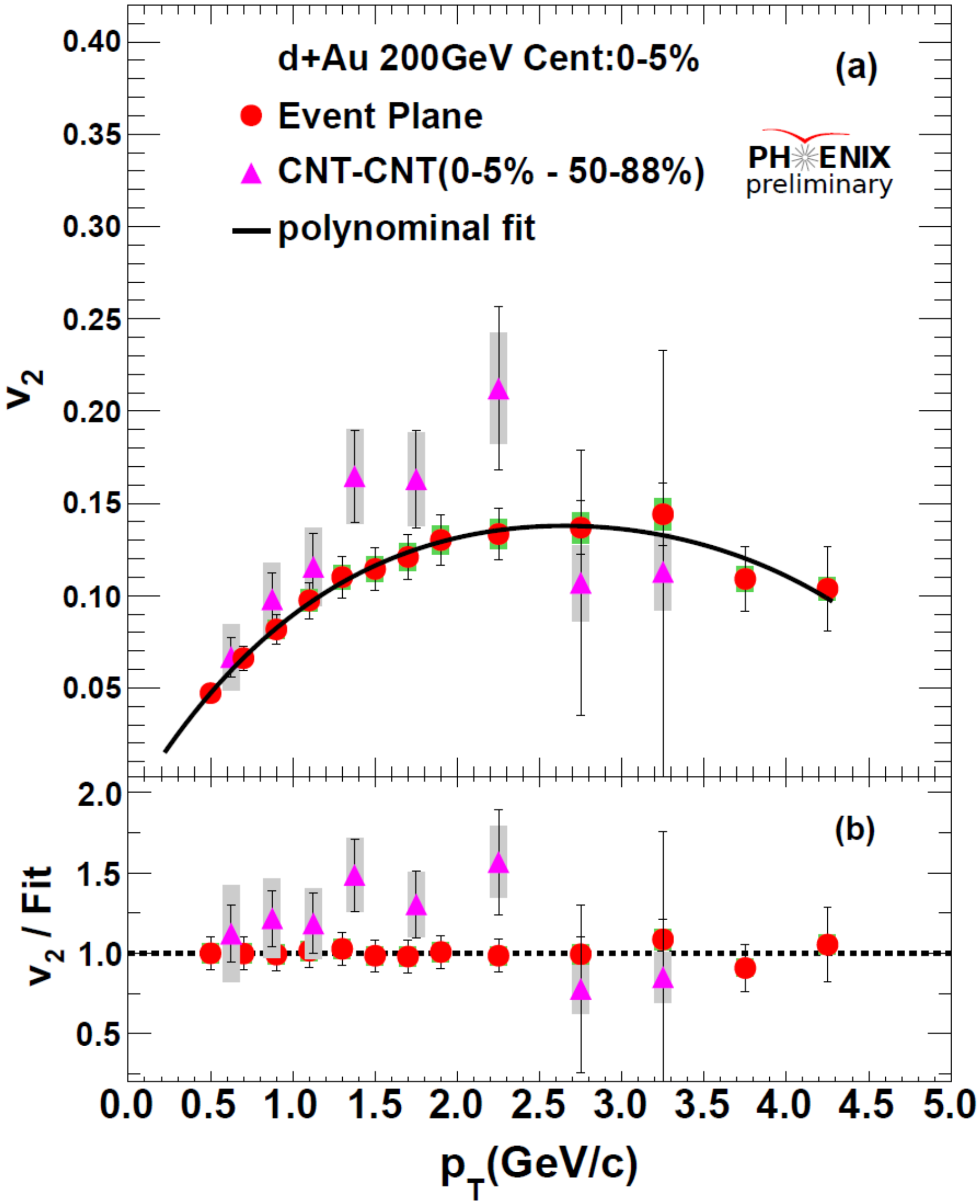
ZDC-SMD ($|\eta|>6.5$)

Ψ_{1,smd_s} **by Au-going spectator**



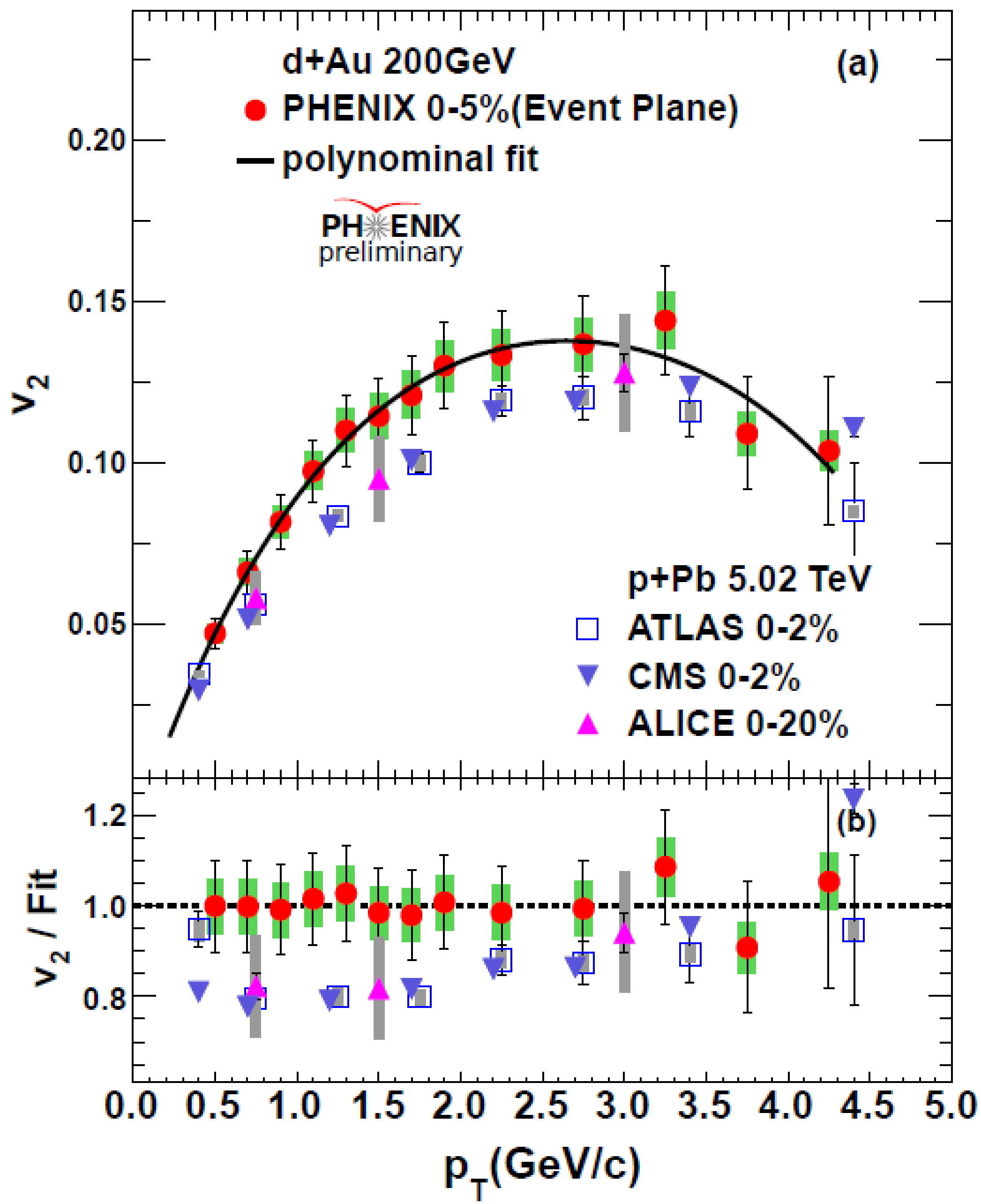
- The difference between c_2(dAu) and c_2(pp) indicates that in EP methods, the contribution from dijet, resonance … is less than 10% for pT up to 4.5 GeV/c
- The event-plane Ψ_{2,MPC_S} resolution is estimated from three-sub events which include the $\Psi_{2,CNT}$ and Ψ_{1,SMD_S}

V_2(EP) for central-arm tracks in 0-5% d+Au



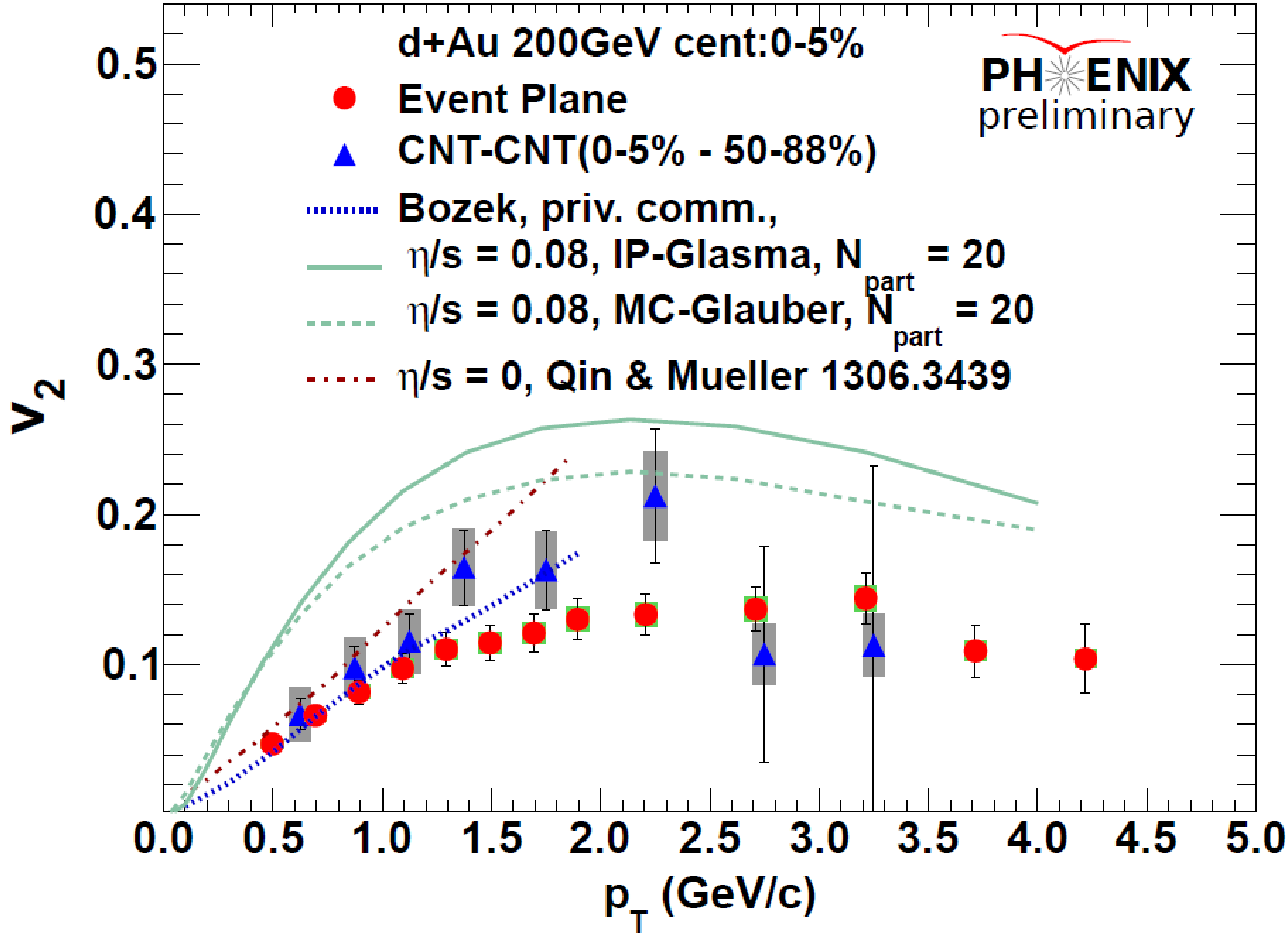
- A extended p_T range and improved statistical and systematic errors are obtained with the event plane method
- The v_2(CNT-CNT) is higher than v_2(EP), which may due to remaining jet and different method
- The two measurements are still close within statistical and systematic errors

V_2 in central d+Au and p+Pb

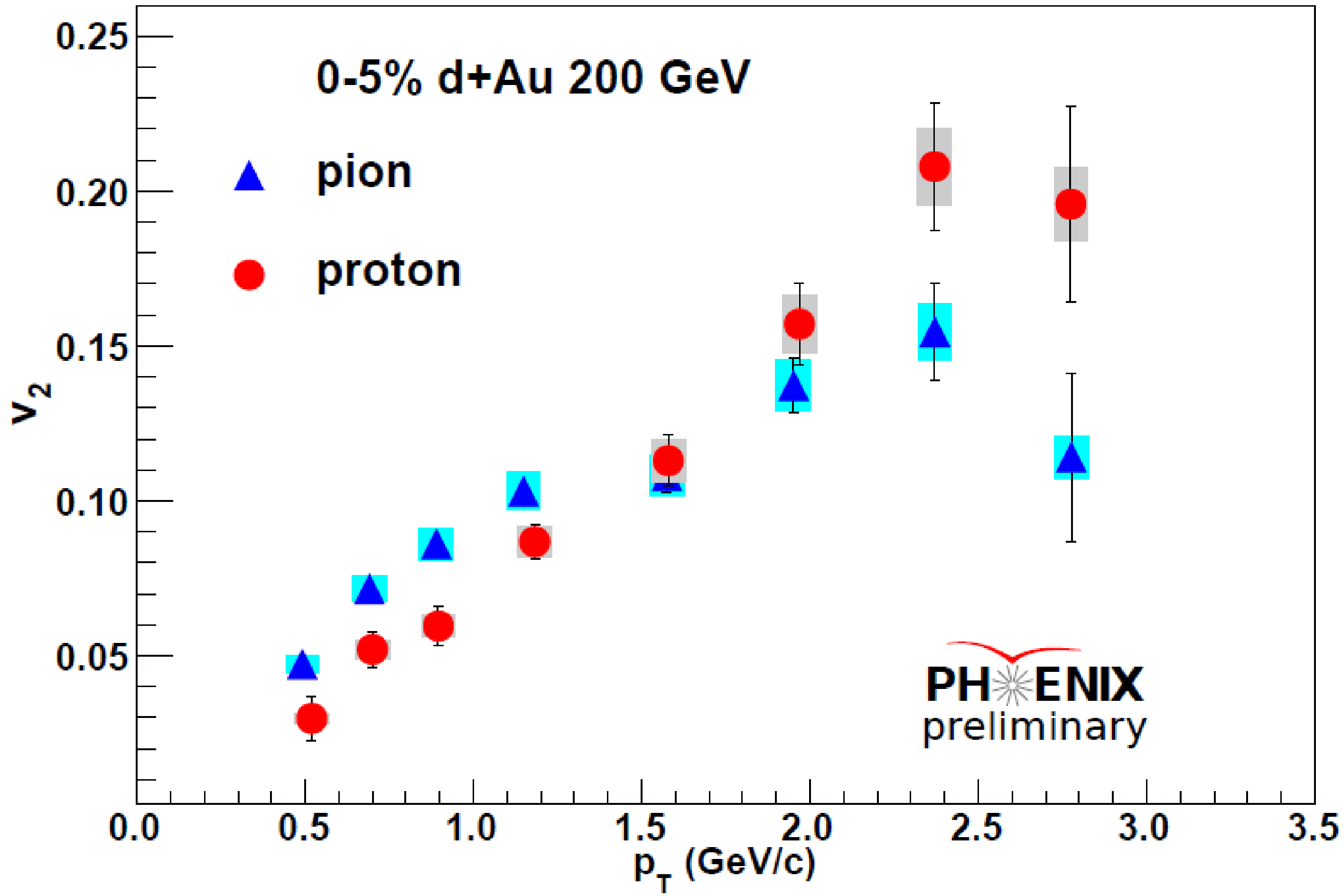


- The difference in v_2 between central d+Au and p+Pb collisions is about 20%
- The multiplicity and eccentricity are quite different between d+Au and p+Pb collisions

Comparing with Hydro

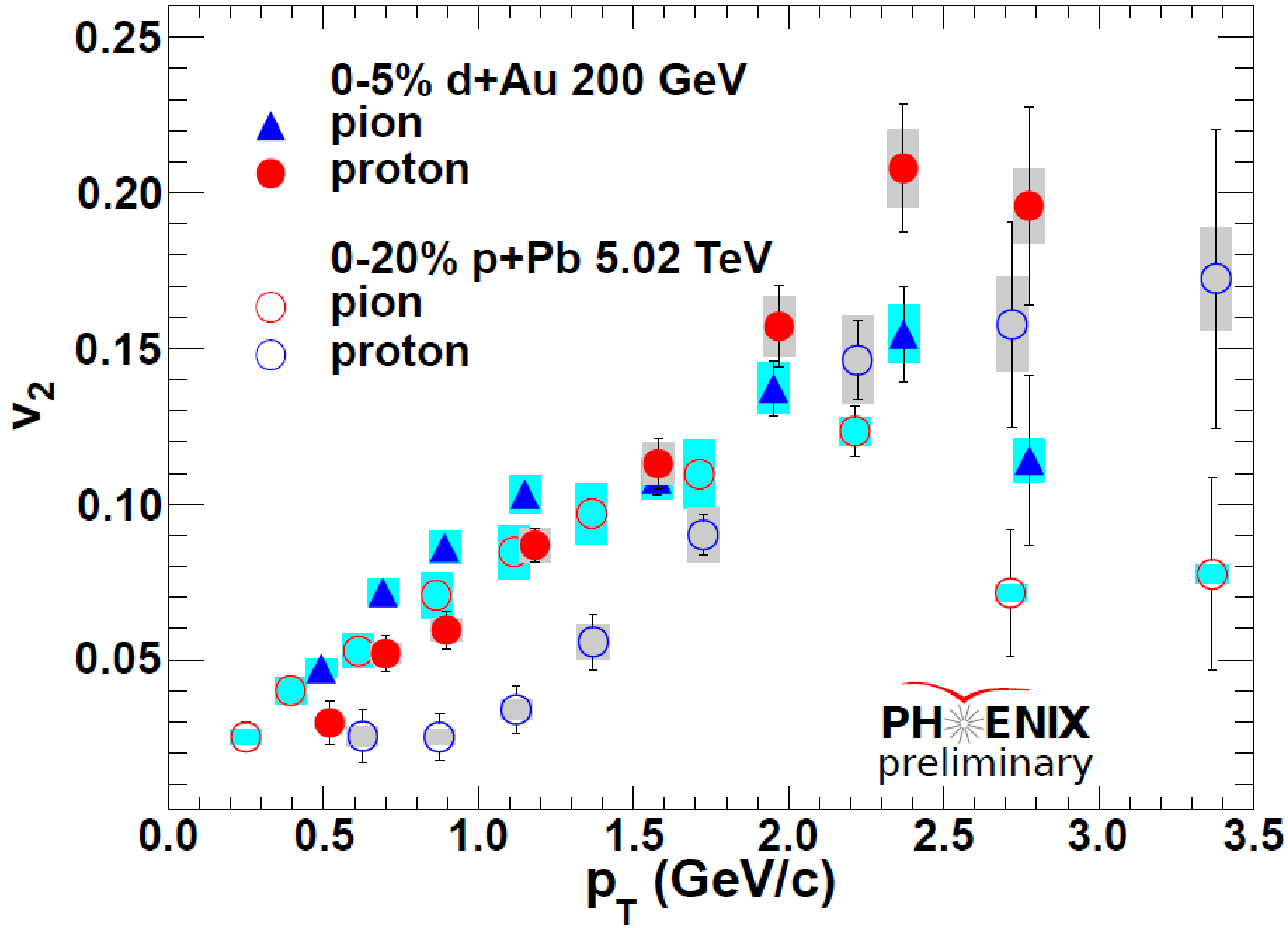


Identified particles' v_2 from EP methods



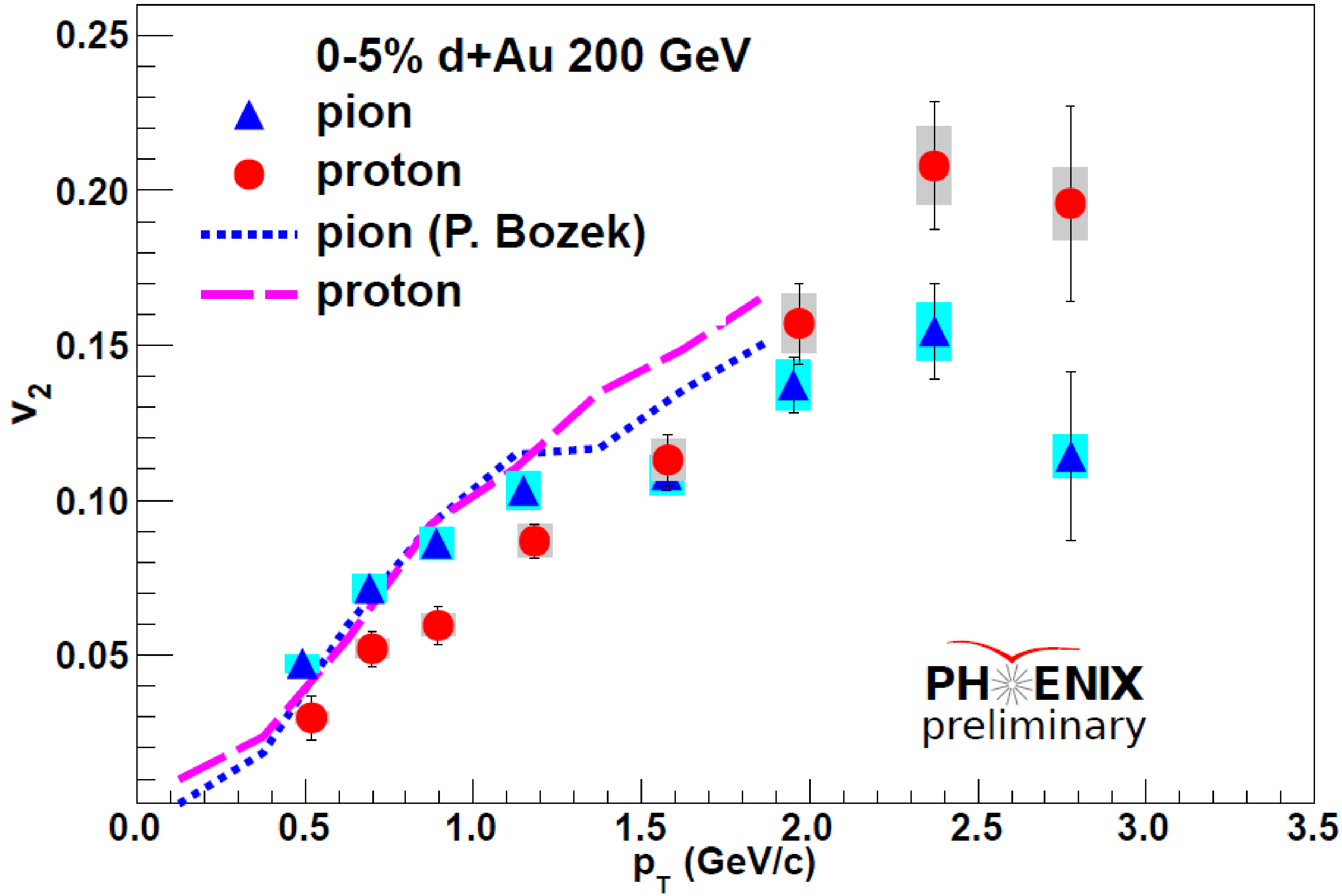
Mass ordering is observed in 0-5% d+Au

Weaker radial flow in dAu?



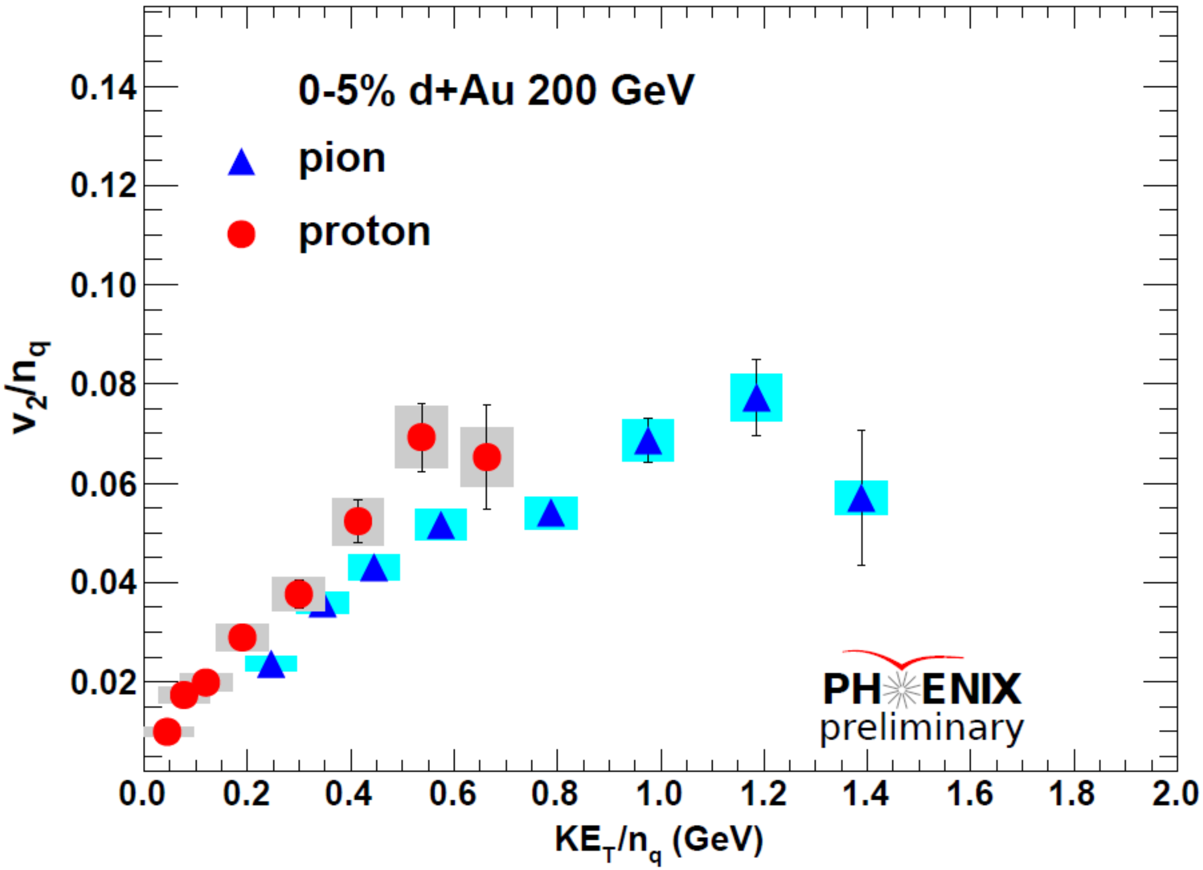
- ❑ The magnitude of mass ordering in p+Pb is larger than in d+Au
- ❑ Weaker radial flow in d+Au due to smaller energy density?

Hydro results of PID v_2 in dAu



- A quick hydro calculation from P.Bozek does not show mass ordering in d+Au collisions

Number of quark scaling

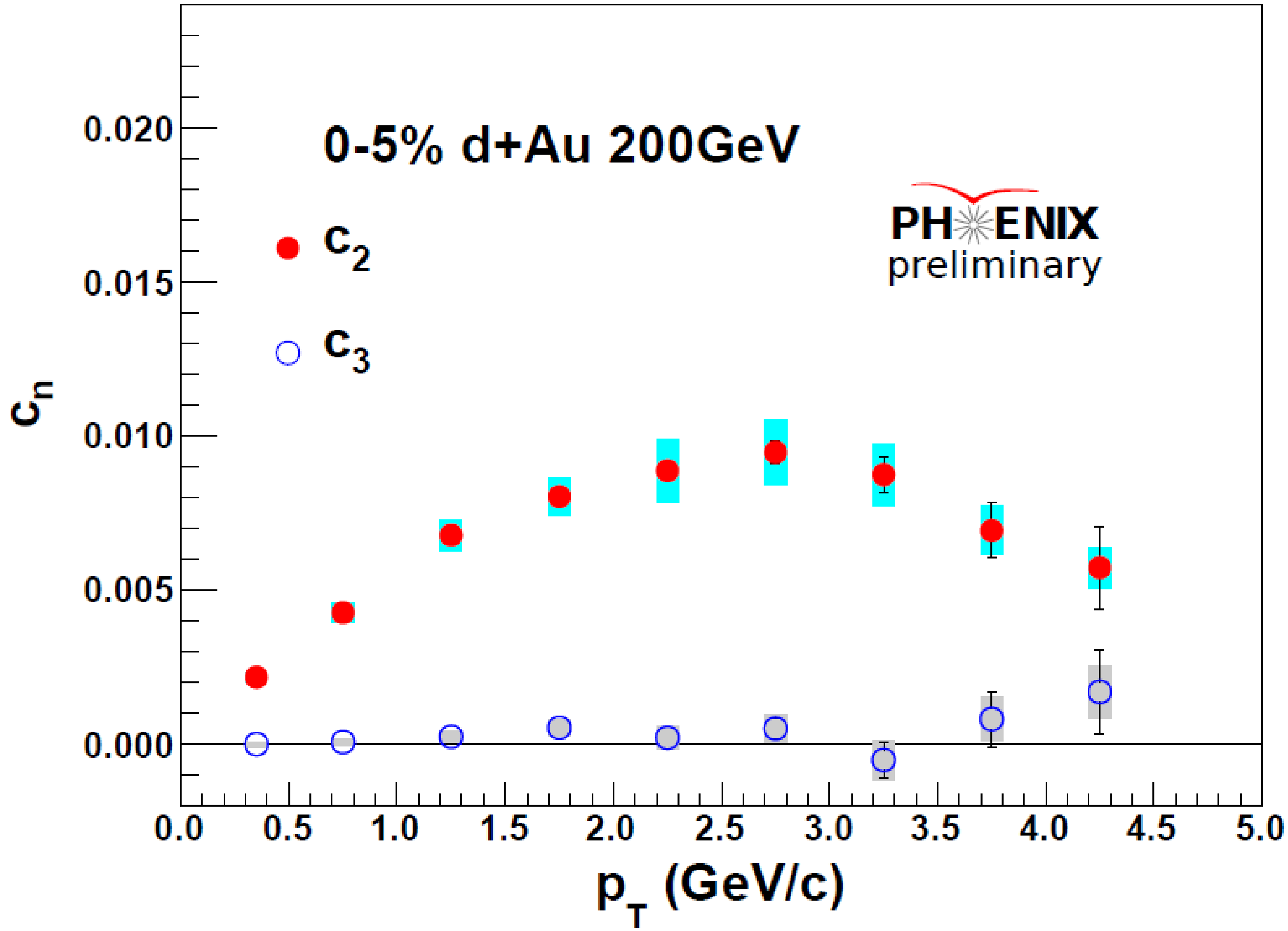


- The n_q scaling roughly holds in 0-5% d+Au collisions

Summary

- Using the Muon Piston Calorimeter (MPC), the ridge is observed in mid-backward (Au-going) and backward-forward rapidity correlation in 0-5% d+Au collisions
- The charged hadron v_2 from the event-plane method in 0-5% d+Au is close to that in 0-2% p+Pb collisions
- The v_2 of pions and protons shows a mass ordering at low p_T

c_2 and c_3 *vs* p_T



Scalar Product Method