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

Shengli Huang
Vanderbilt University
for the PHENIX Collaboration
Outline

- Motivations

- Long-range angular correlations across Rapidity, Centrality and Trigger $p_T$

- Identified particles $v_2$ using event-plane method

- Summary
A “ridge” is observed in the central p + Pb@5.02 TeV
The $\Delta \phi$ distribution shows a $\cos(2\Delta \phi)$ structure
The identified particle $v_2$ shows a mass ordering
The \( \cos(2\Delta\phi) \) structure is also seen in 0-5\% d+Au. The cut of \( |\Delta\eta| > 0.48 \) 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 \( |\Delta\eta| \) is required!

Initial or final state effect?

- 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: $|\Delta\eta|>2.75$!
Angular correlations between Track and Tower: $C(\Delta \phi)$

- $s(\Delta \phi) = \frac{d(\omega_{\text{tower}} N_{\text{track-tower}})}{d(\Delta \phi)}$
  
  - $\omega_{\text{tower}}$ is the transverse energy of each tower
  - $N_{\text{track-tower}}$ is number of pair of track-tower in same event
  - $\Delta \phi = \phi_{\text{tower}} - \phi_{\text{track}}$

- $C(\Delta \phi) = \frac{\int M(\Delta \phi) S(\Delta \phi)}{\int S(\Delta \phi) M(\Delta \phi)}$
  
  - $M(\Delta \phi)$ is track-tower correlation in mixed events
C(Δϕ,p_Τ) of pp and 0-5% dAu

In pp, the distribution is dominated by the dipole term cos(Δϕ), 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.

arXiv:1404.7461
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 $c_2^{dAu}$

arXiv:1404.7461
“Au-going” vs “d-going”
The mid-forward rapidity correlation in central d+Au is different from that in peripheral, even though there is no near-side peak.
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 $|\Delta \eta| > 6.0$

- Correlation between Au-going and d-going MPC towers
Event-plane method for $v_2$

Muon piston Calorimeter
**MPC** $(3.1<|\eta|<3.9)$

$\Psi_{2,MPC_S}$ **Au-going**

Central Arm tracking $(|\eta|<0.35)$

$\Psi_{2,CNT}$

Zero Degree Calorimeters (**ZDC**)

Shower Max Detectors (**SMD**)

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

$\Psi_{1,smd_s}$ 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 $\Psi_{2,MPC_S}$ resolution is estimated from three-sub events which include the $\Psi_{2,CNT}$ and $\Psi_{1,SMD_S}$
The charged hadron $v_2$ measured by the event plane method in central dAu is similar to that in central pPb.
Mass ordering is observed in 0-5% d+Au
This ordering can be reproduced in hydro calculation from P. Romatschke et al.
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: $\langle \mu Q \rangle$

- In heavy ion collision:
  
  $\langle \mu Q \rangle = \langle \Sigma \cos(2(\phi_{pt} - \phi_j)) \rangle$
  
  $= M \times v_2^{2}(pt) \times \bar{v}_2 + \text{nonflow}$
  
  $= M \times c_2^{2}(pt)$

  The nonflow in AA(dA) is same as pp

- For the tower of MPC
  
  $Q = (\Sigma \omega_i \cos(2\phi_{\text{tower},i}), \Sigma \omega_i \sin(2\phi_{\text{tower},i}))$

  $\omega_i$ is $E_T$ of each MPC tower of Au-going

  $\langle \mu Q \rangle = \Sigma E_T \times c_2^{2}(pt)$

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


PRC72, 014904(2005)
The $c_3$ is close to 0, comparing with the sizeable $c_2$. 
a) d+Au 0-5% (BBC_Au)  
1.0<p_{T,\text{trig}}<3.0 \text{ GeV/c}  
|\eta_{\text{trig}}|<0.35  
Asso. d-going, 3.1<|\eta|<3.9

b) d+Au 5-10%  
$1+2c_\phi \cos(\Delta\phi)$  
$1+2c_2 \cos(2\Delta\phi)$  
$1+2c_3 \cos(3\Delta\phi)$  
$1+2c_4 \cos(4\Delta\phi)$  
$1+\sum 2c_n \cos(n\Delta\phi)$

c) d+Au 10-20%  


d) d+Au 20-40%  


e) d+Au 40-60%  


f) d+Au 60-88%