Cu+Au collisions with an integrated dynamical approach

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Outline

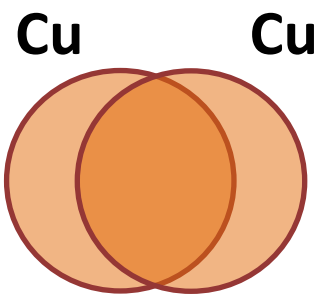
1. Introduction
2. Integrated dynamical approach: Our framework
3. Result: $v_1\{RP\}$ vs. η, centrality, p_T
4. Result: $v_3\{RP\}$ vs. η, p_T
5. Summary

Introduction

- Compare Cu+Au with Cu+Cu
- Cu+Cu, symmetric collision

  → $v_1\{RP\} = v_3\{RP\} = 0$

  at mid-rapidity

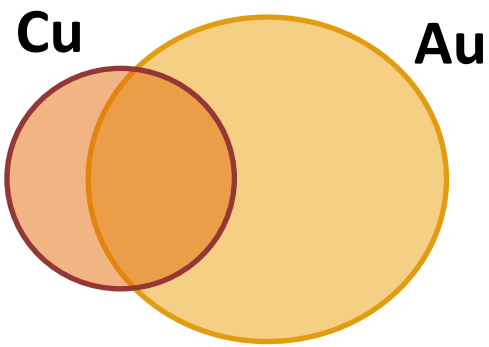


- Cu+Au, asymmetric collision

  → $v_1\{RP\} \neq 0$, $v_3\{RP\} \neq 0$

  ? ?

  at mid-rapidity



Integrated dynamical approach

Multi-module simulation framework

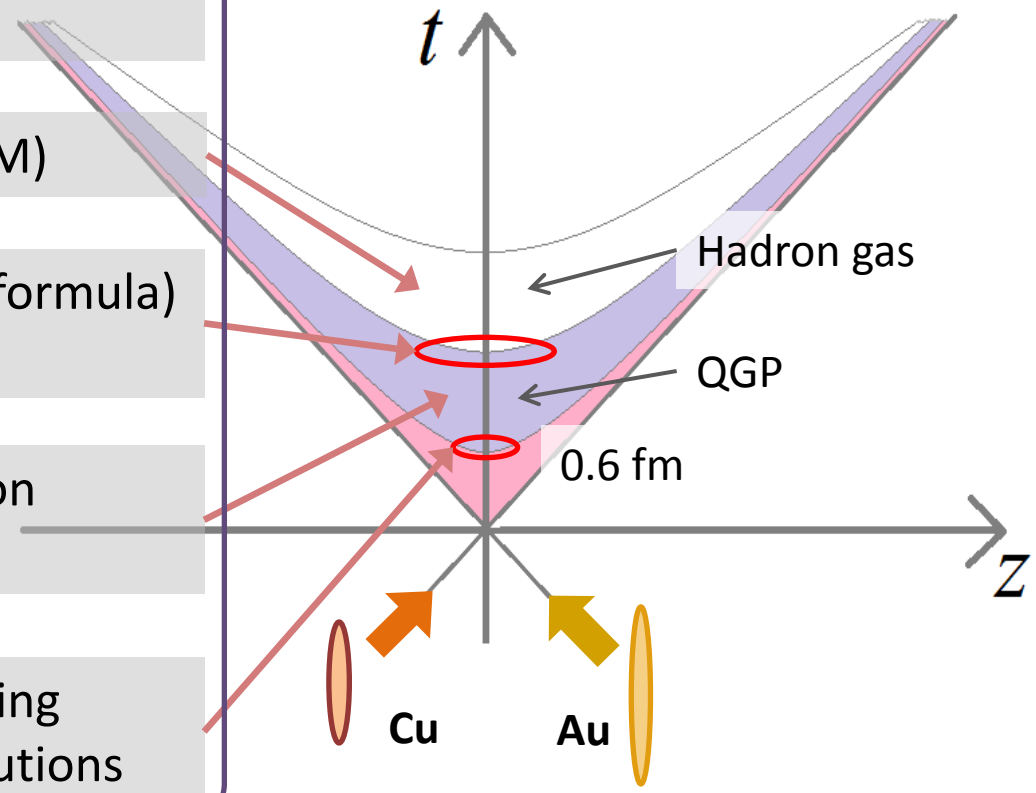
5. Analysis of hadron distribution

4. Hadron-cascade simulation (JAM)

3. Fluid to particles (Cooper-Frye formula) at T_{sw} = 155 MeV

2. (3+1) dim. ideal hydro simulation
EoS: lattice QCD (HRG at low T)

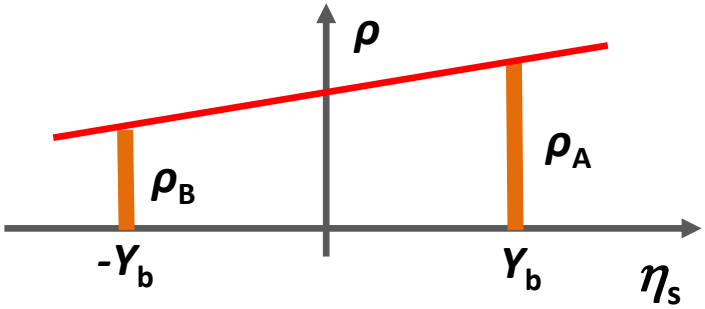
1. Generating initial conditions using event-by-event nucleon distributions



T. Hirano, P. Huovinen, K. Murase, Y. Nara, PPNP **70**, 108 (2012) [arXiv:1204.5814]

Initial conditions (1)

- Transverse profile: MC-Glauber
- Rapidity dependence: "*Modified BGK*"



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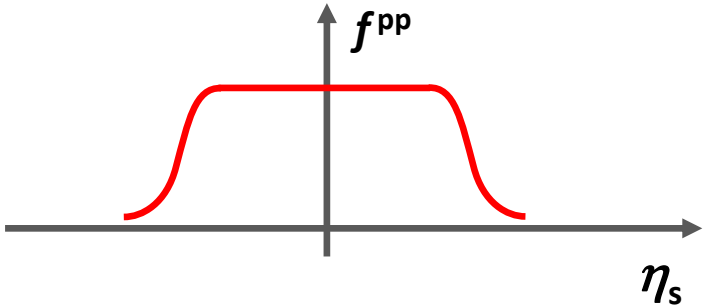
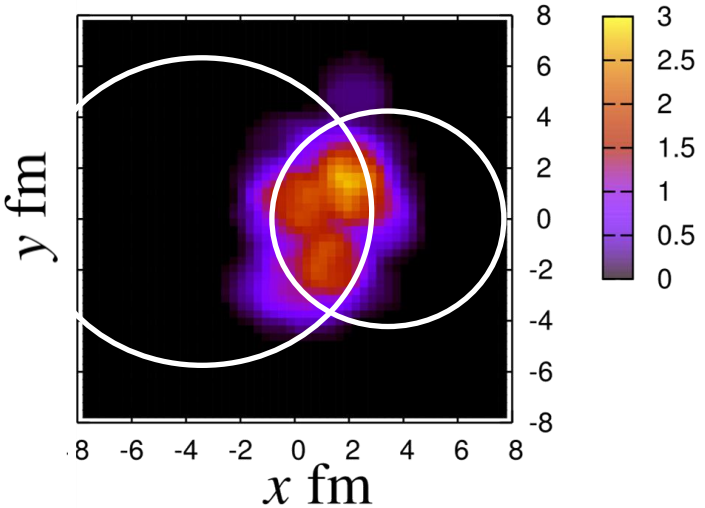
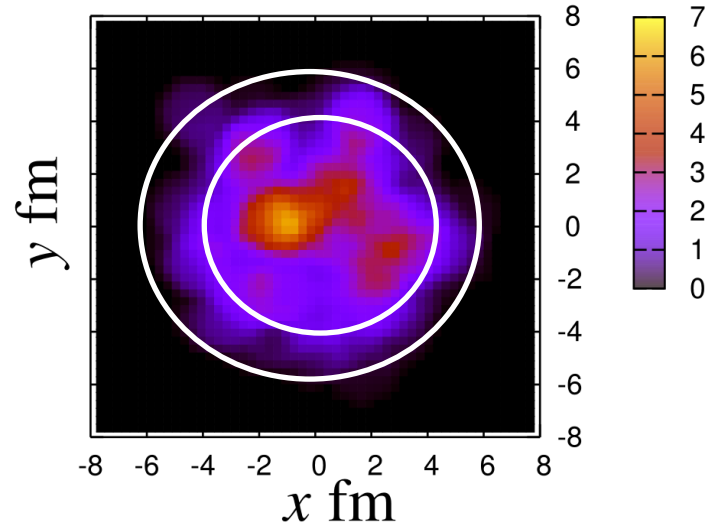


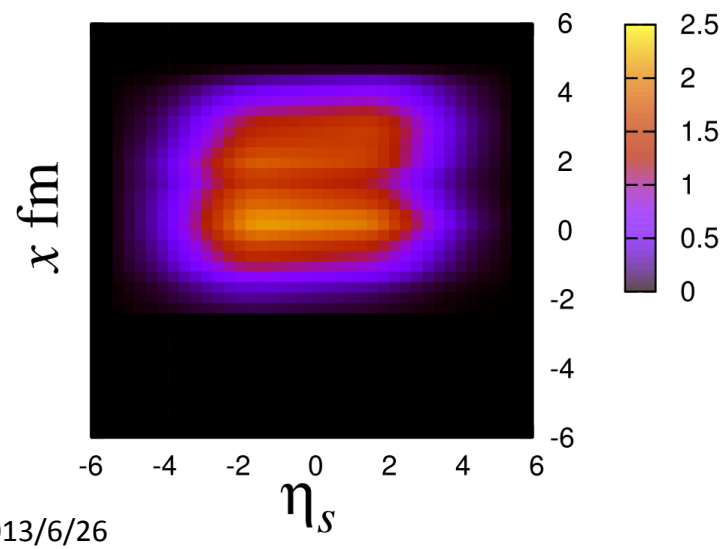
- Parameters are fixed
  using Au+Au 200 GeV data
- Cu+Au, 200 GeV: 500 k events
- Cu+Cu, 200 GeV: 500 k events

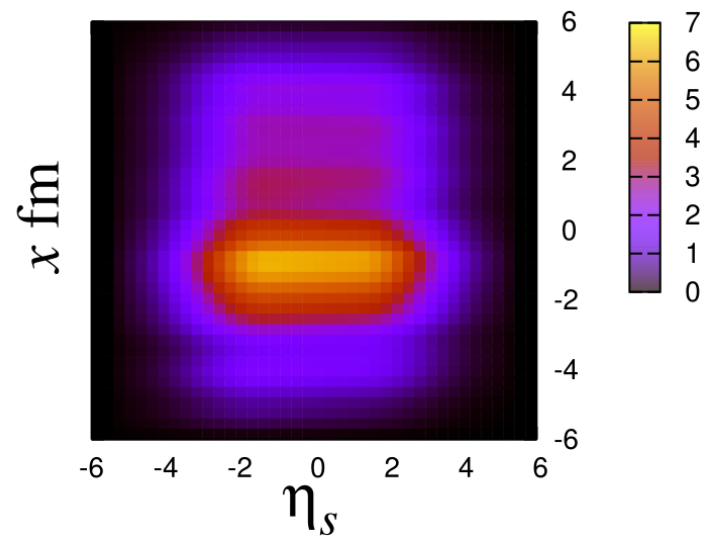
Initial conditions (2)

- Examples



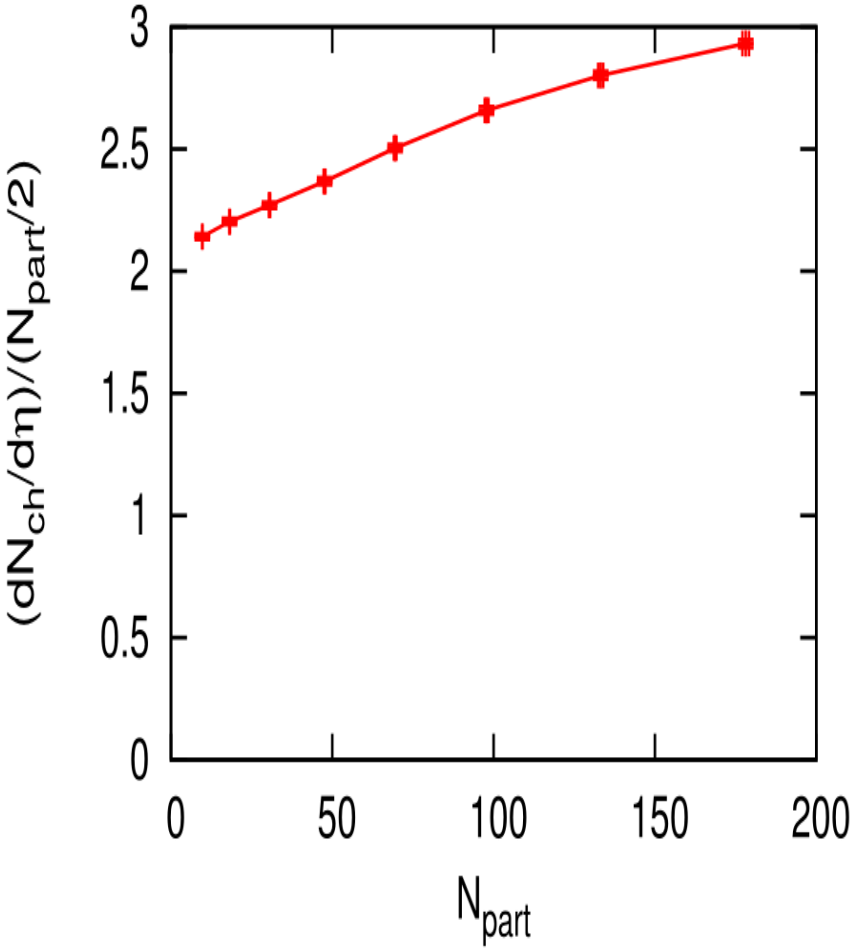


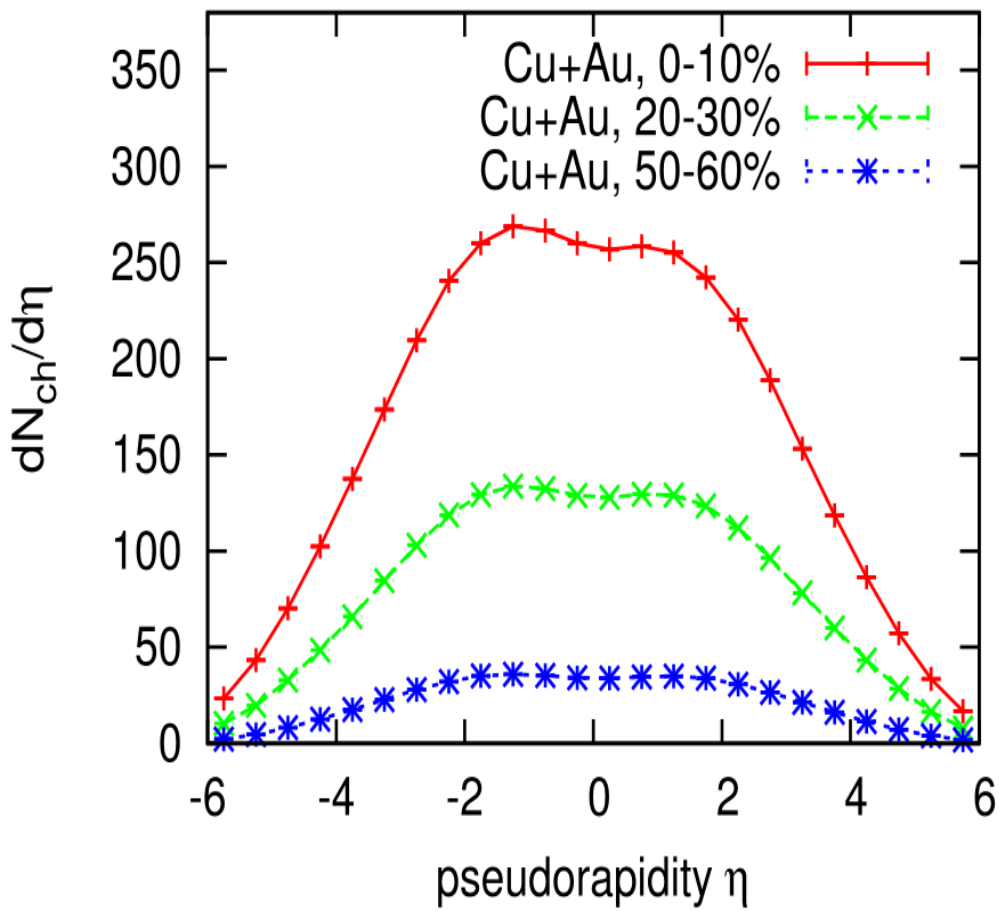




RESULTS

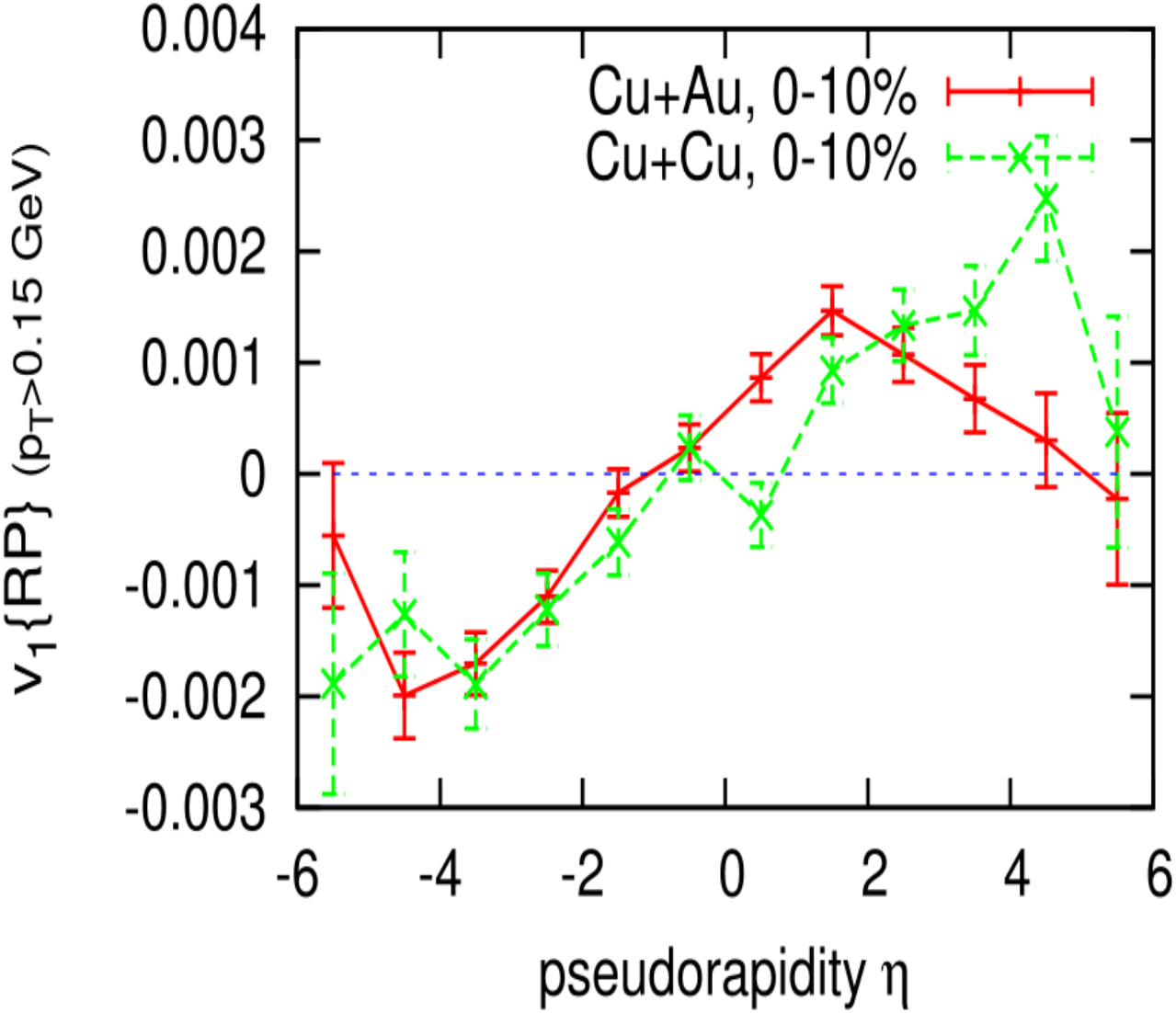
Charged-particle multiplicity

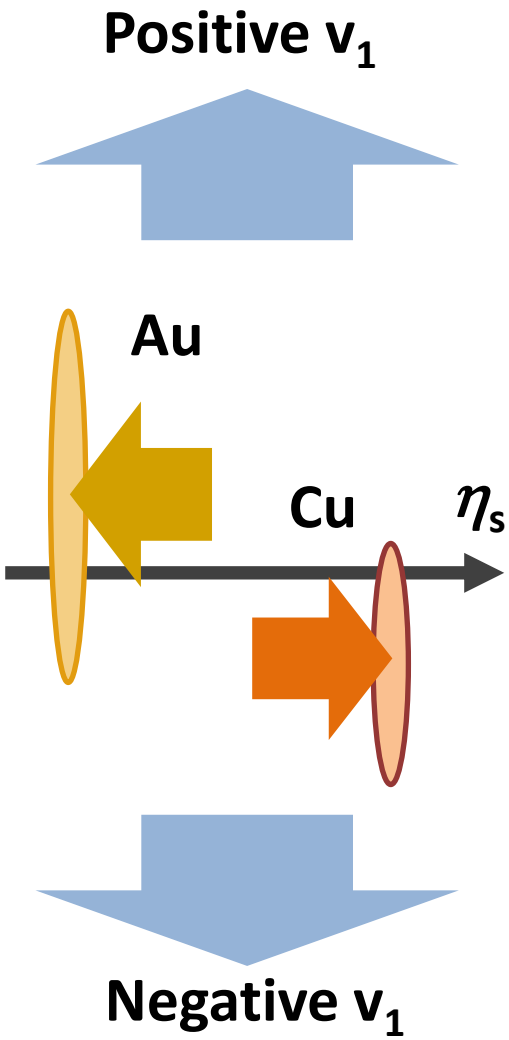




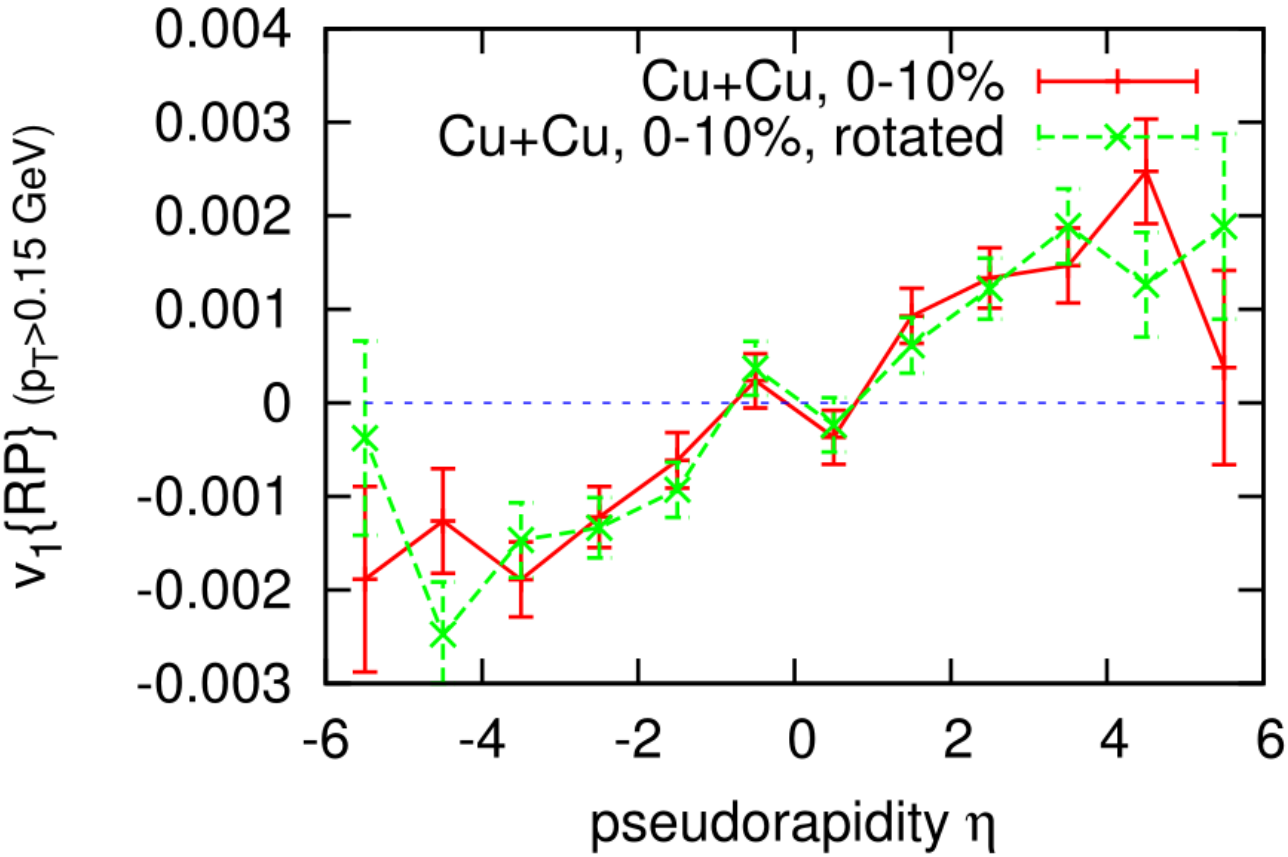
- Backward: ~7% larger than forward in central collisions

Rapidity dependence of $v_1\{RP\}$, 0-10% (1)

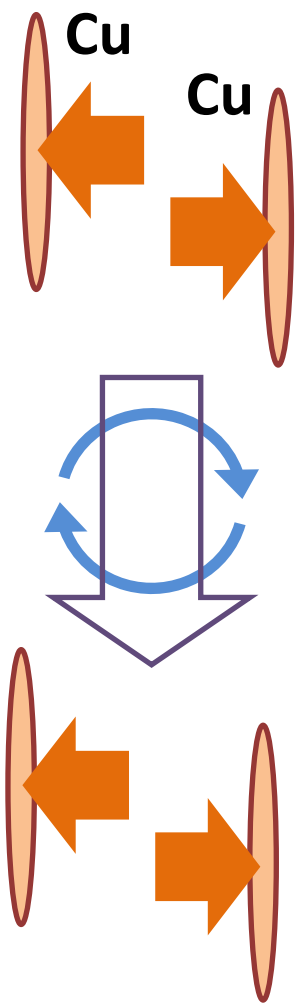




Rapidity dependence of $v_1\{RP\}$, 0-10% (2)

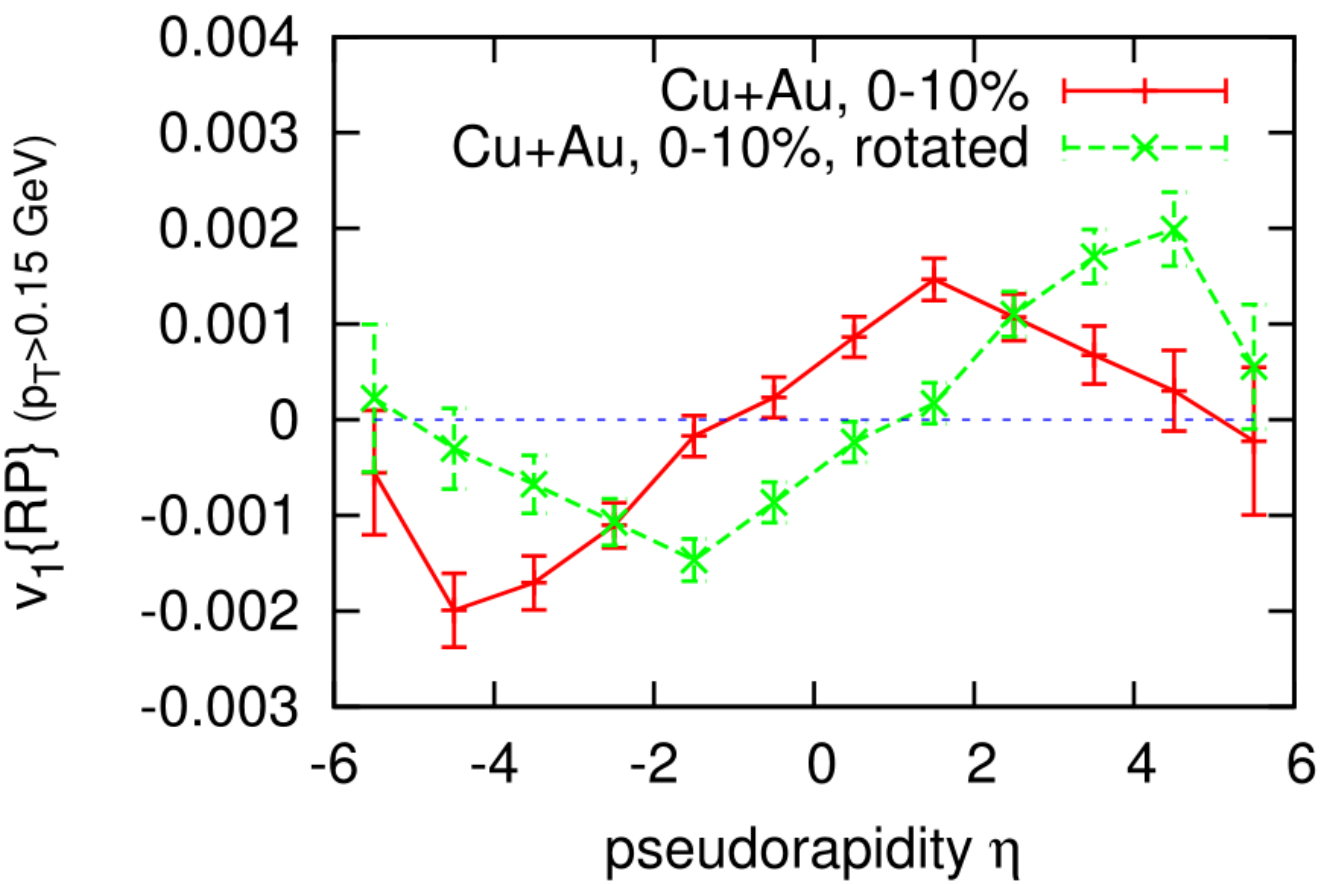


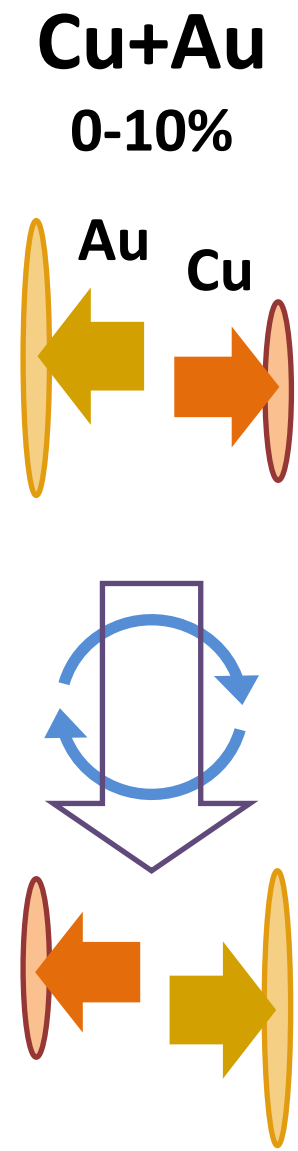
Cu+Cu



- Odd w.r.t. rapidity
  as expected from the symmetry

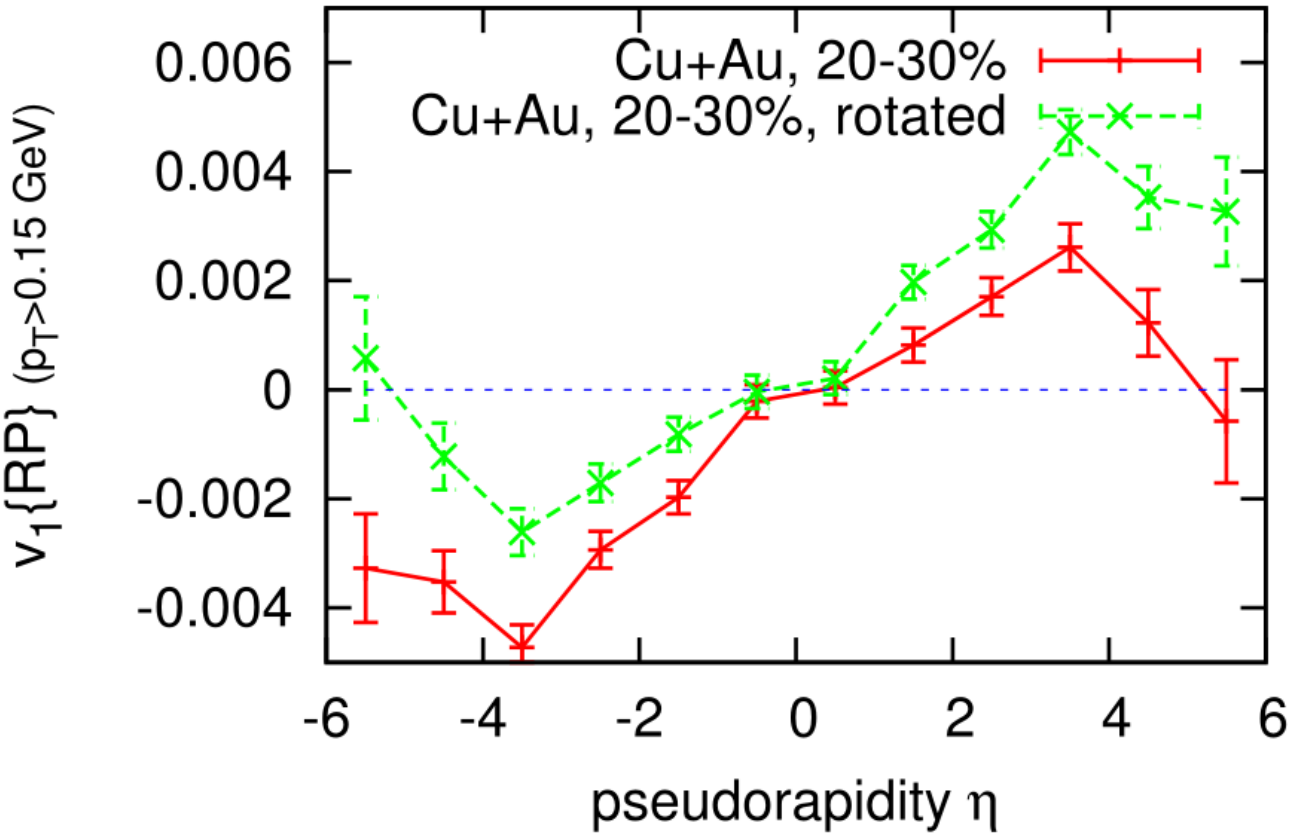
Rapidity dependence of $v_1\{RP\}$, 0-10% (3)

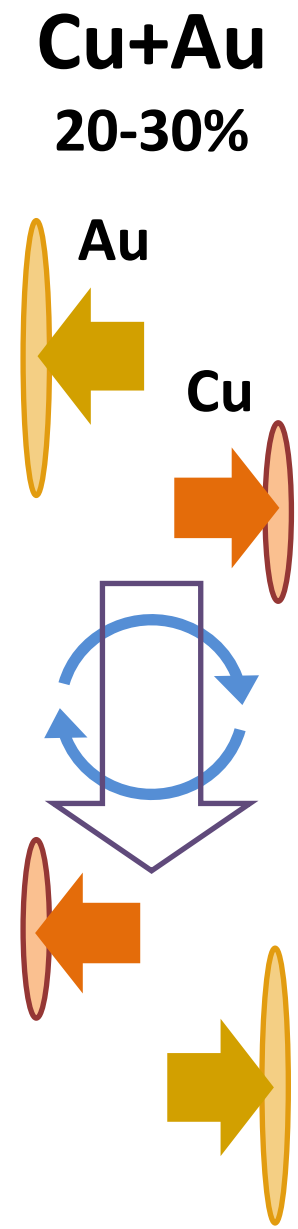




- Asymmetric behavior
- Finite value at mid-rapidity

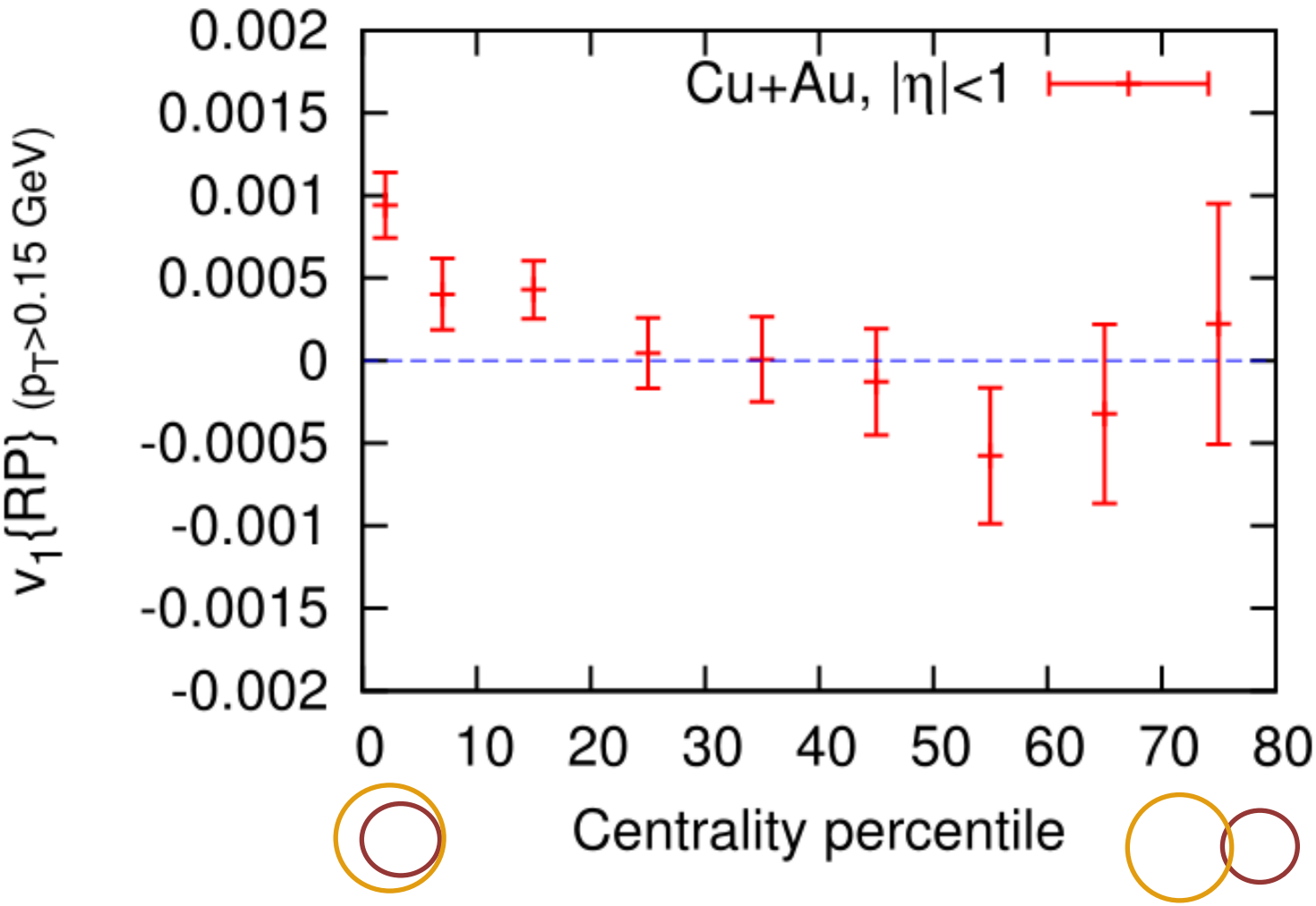
Rapidity dependence of $v_1\{RP\}$, 20-30%





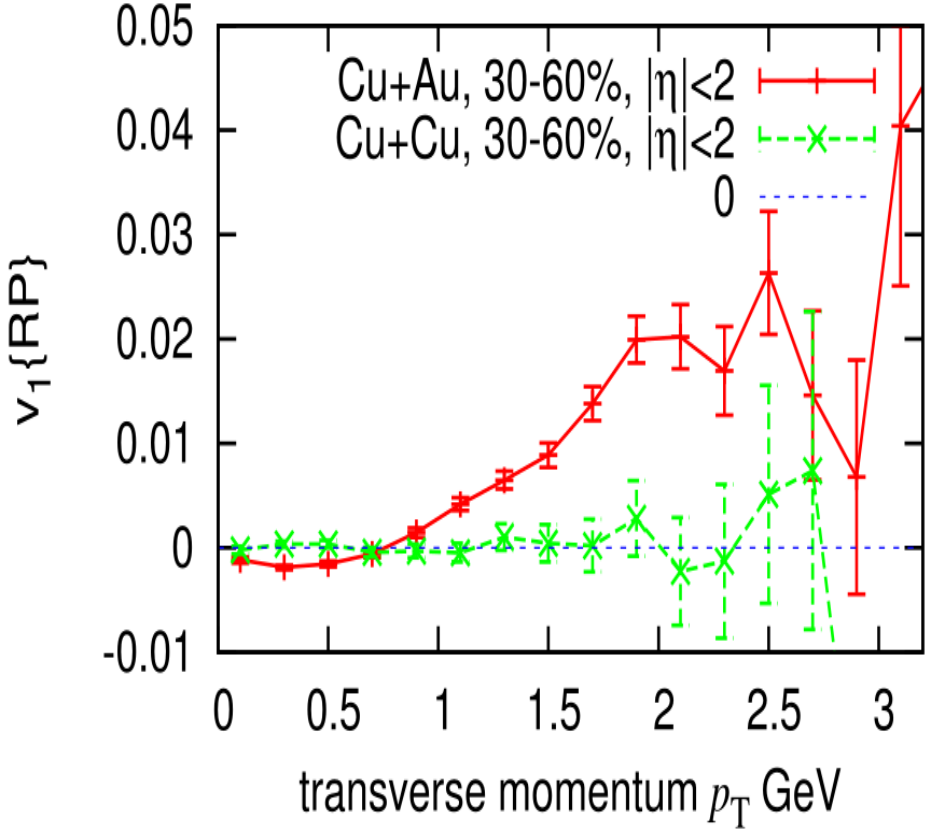
- Vanishing at mid-rapidity
- Asymmetry in forward/backward

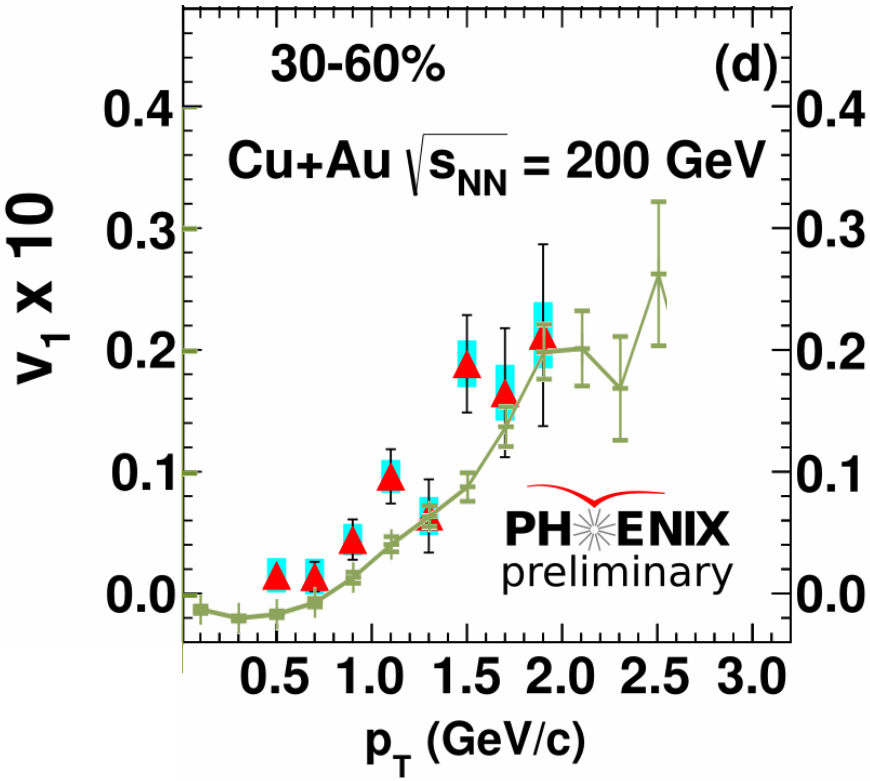
Centrality dependence of $v_1\{RP\}$



- Decreasing with centrality

Transverse momentum dependence of $v_1\{RP\}$

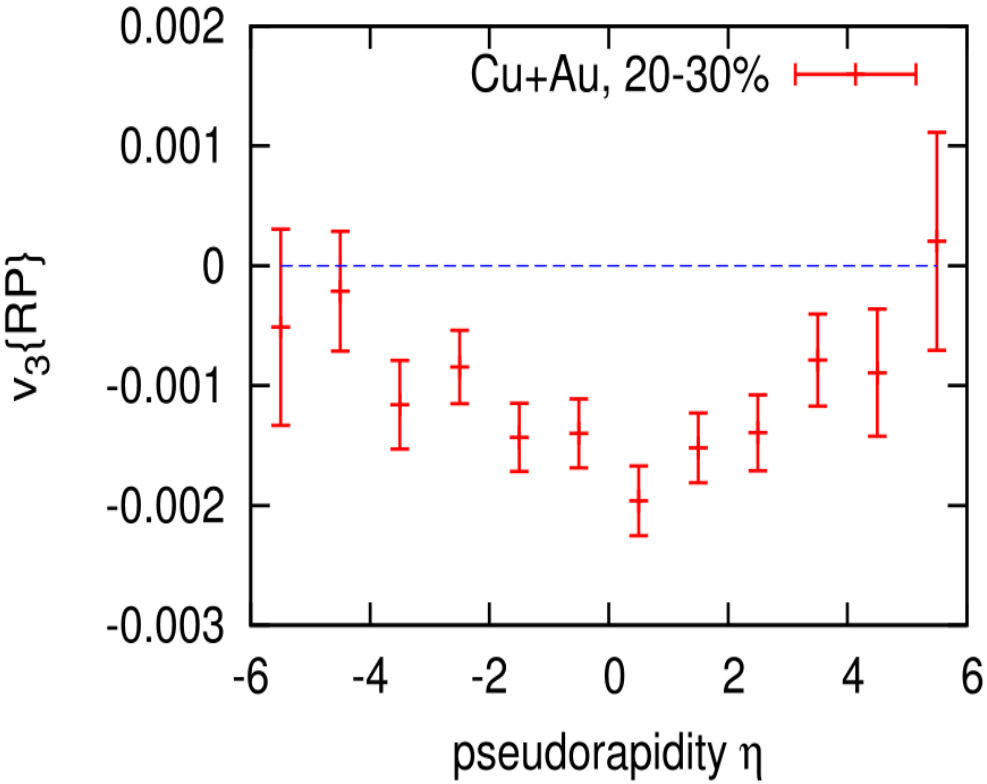


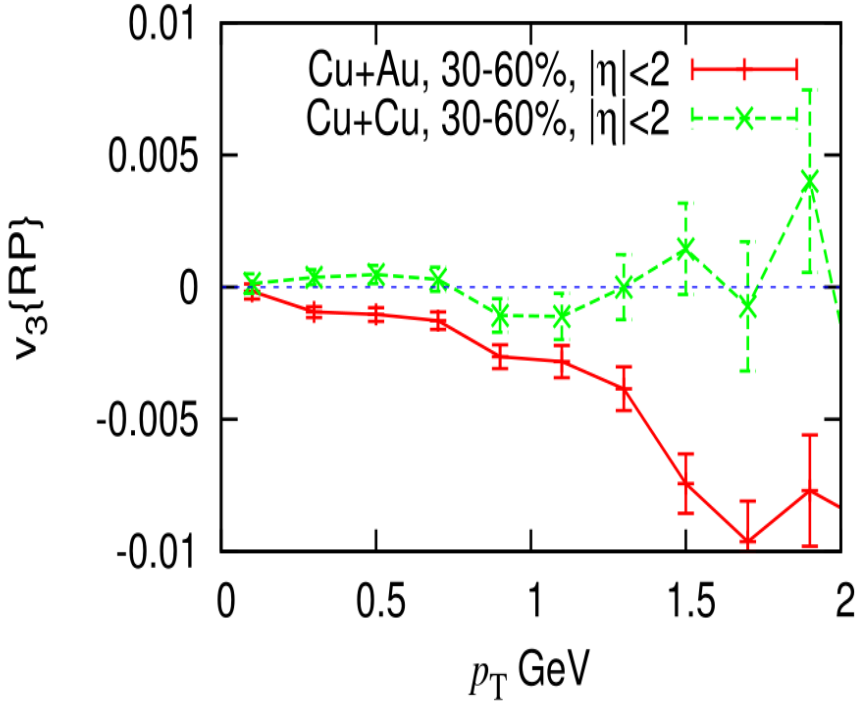


S. Huang (PHENIX), Nucl.Phys.A904-905 2013 (2013) 417c-420c [arXiv:1210.5570]

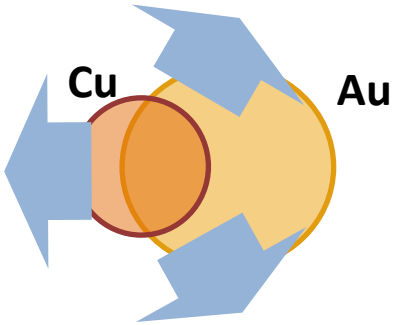
- Comparable to experimental data

Triangular flow $v_3\{RP\}$



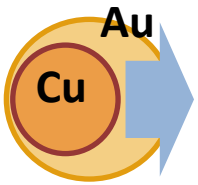


- Negative value
- Even w.r.t. rapidity

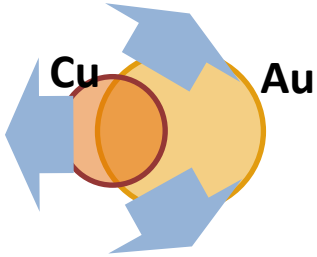


Summary

- Integrated $v_1\{RP\}$ at mid-rapidity is finite and positive in central collisions.



- $v_1\{RP\}$ as a function of p_T is comparable to the experimental data.
- $v_3\{RP\}$ is negative in a broad range of rapidity.



BACKUP

Initial condition

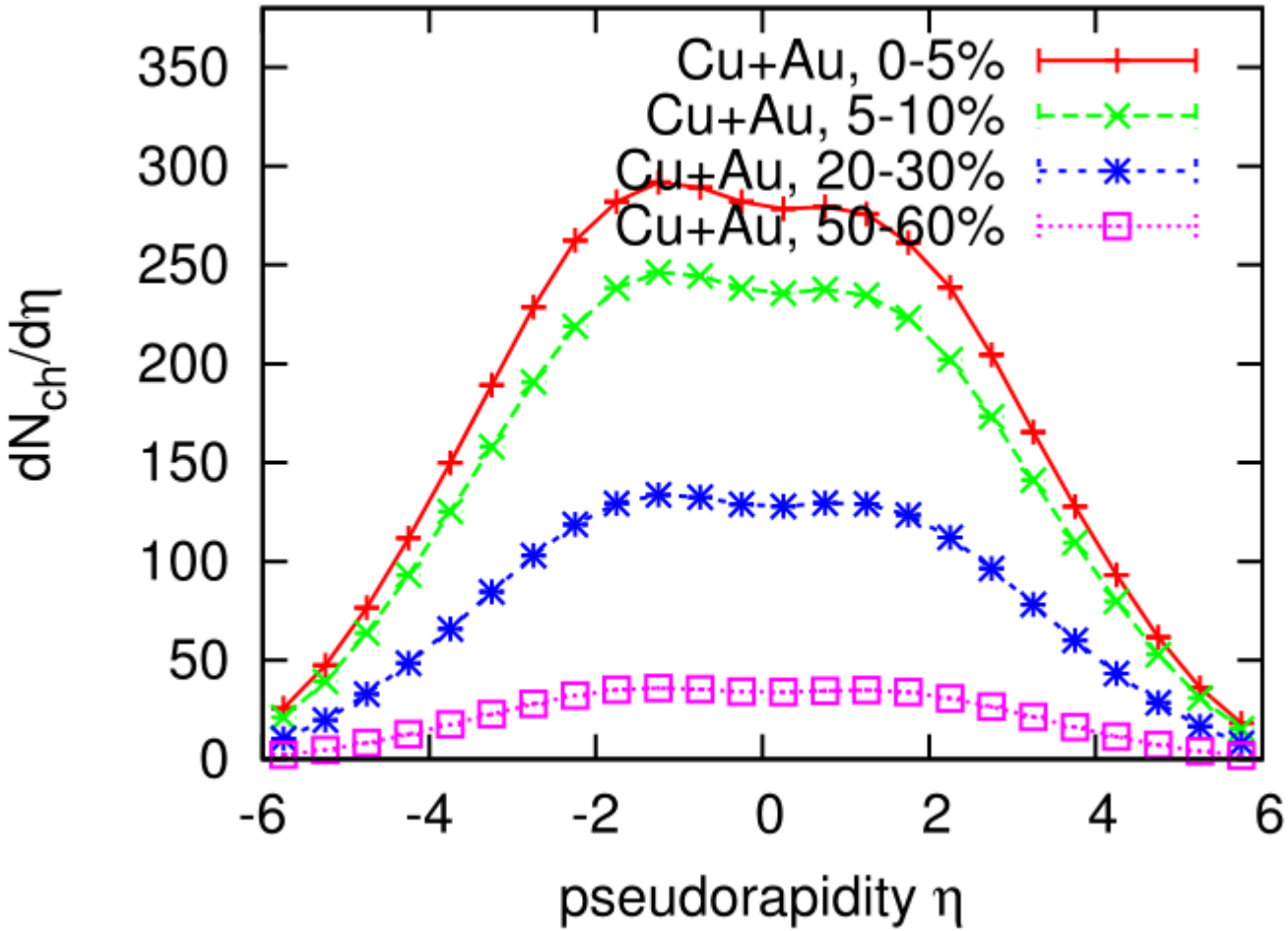
- MC-Glauber with modified BGK model

$$
\begin{aligned}
s_0(\tau_0, \eta_s, \boldsymbol{r}_\perp) &= \frac{dS}{\tau_0 d\eta_s d^2 r_\perp} \\
&= \frac{C}{\tau_0}\theta\big(Y_b - |\eta_s|\big)\, f^{pp}(\eta_s)\left[\frac{1-\alpha}{2}\left(\frac{Y_b - \eta_s}{Y_b}\,\rho_A(\boldsymbol{r}_\perp) + \frac{Y_b + \eta_s}{Y_b}\,\rho_B(\boldsymbol{r}_\perp)\right) + \alpha\,\rho_{\mathrm{coll}}(\boldsymbol{r}_\perp)\right] \\
f^{pp}(\eta_s) &= \exp\left[-\theta(|\eta_s| - \Delta\eta)\,\frac{(|\eta_s| - \Delta\eta)^2}{\sigma_\eta^2}\right]
\end{aligned}
$$

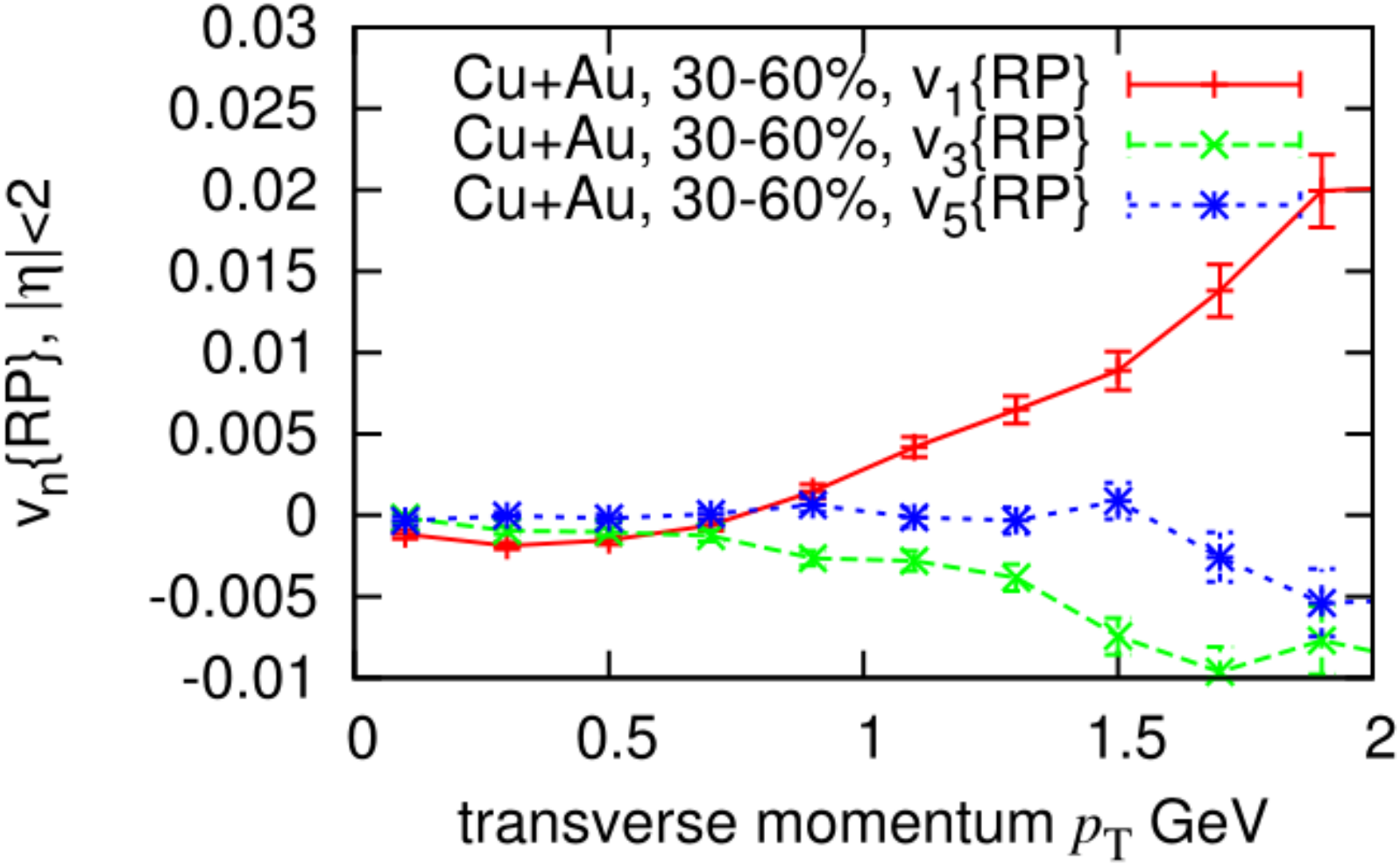
- Parameters

  $C = 25$, $\alpha = 0.18$, $\Delta\eta = 1.2$, $\sigma_\eta = 2.1$

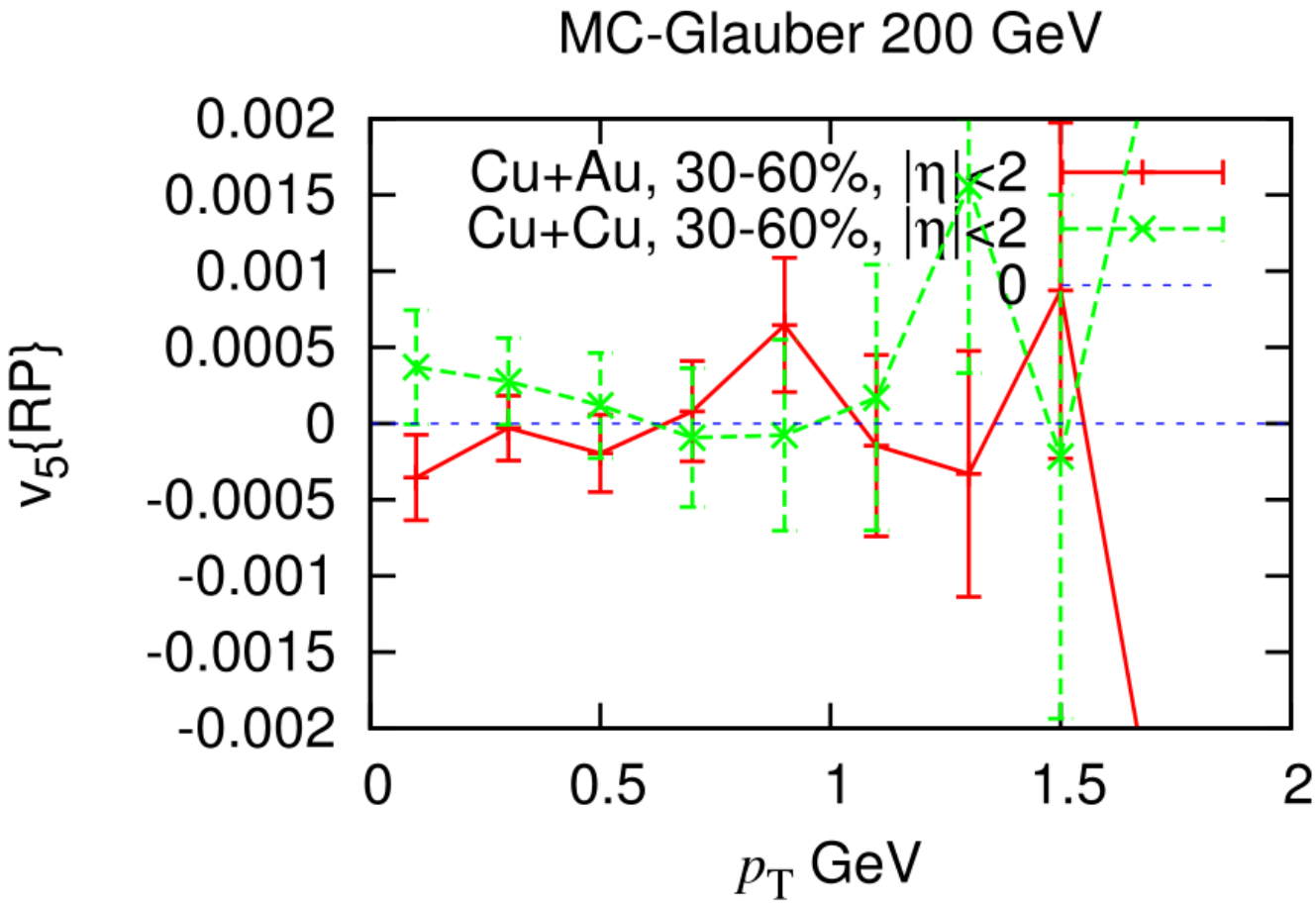
Charged-particle multiplicity



$v_n\{RP\}$ vs. pT

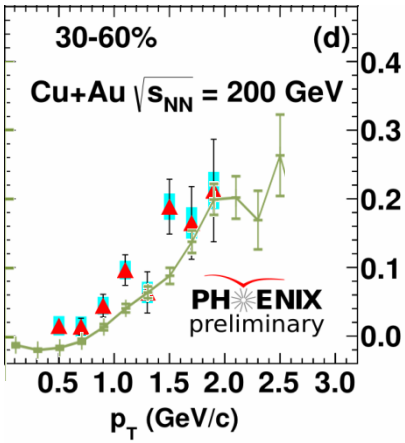

Cu+Au, 30-60%, v1{RP}
Cu+Au, 30-60%, v3{RP}
Cu+Au, 30-60%, v5{RP}
vn{RP}, |η|<2
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
-0.01
0
0.5
1
1.5
2
transverse momentum pT GeV

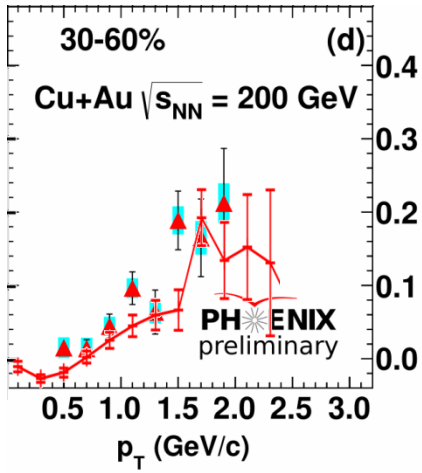
$v_5\{RP\}$ vs. pT



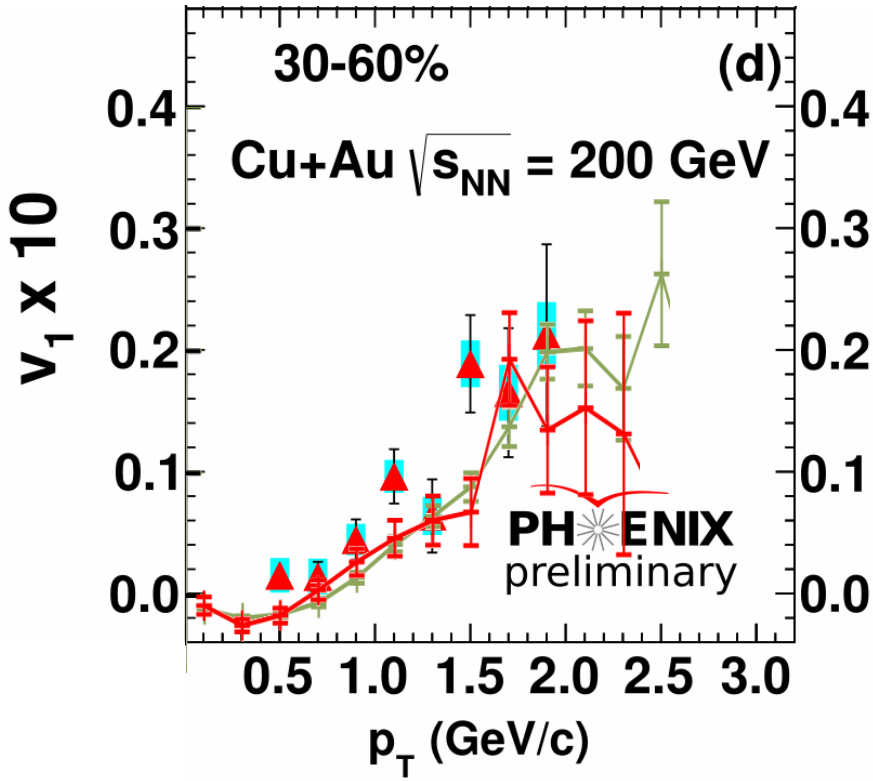
- $v_5\{RP\} \sim 0$

Compare our result with exp.

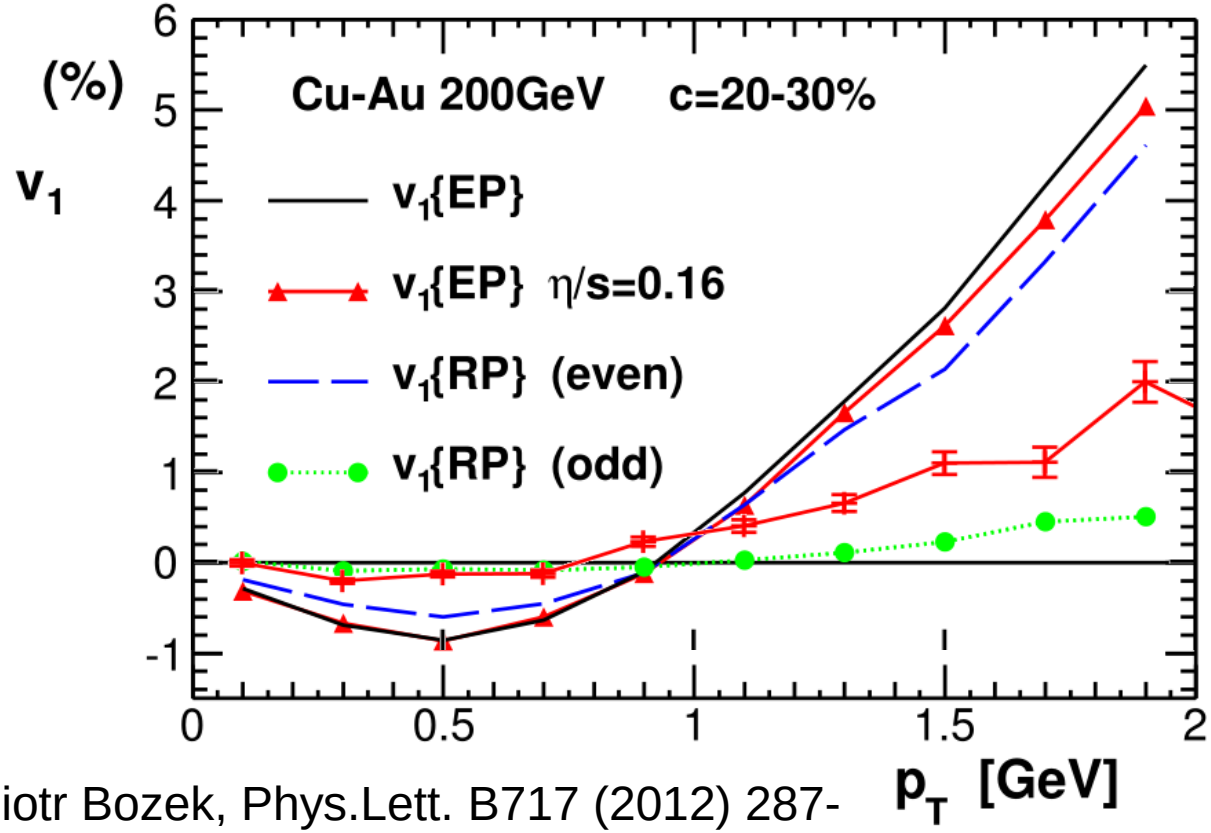




- Green: |eta|<2
- Red: |eta|<0.35



Compare our result with Bozek's



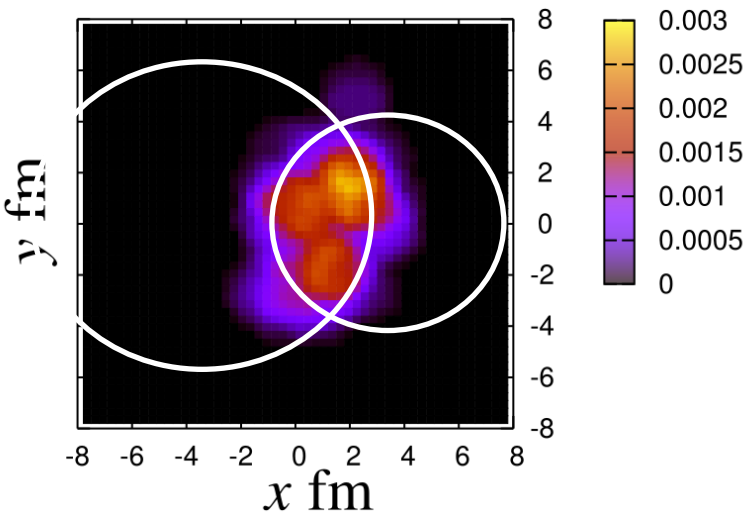
Piotr Bozek, Phys.Lett. B717 (2012) 287-290 [arXiv:1208.1887]

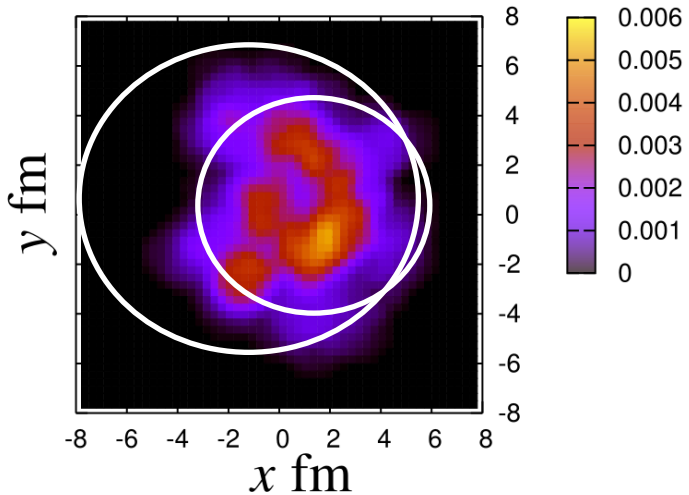
- Our framework: ideal
- Bozek's: viscous

BACKUP

Initial conditions (2)

- Examples





Introduction

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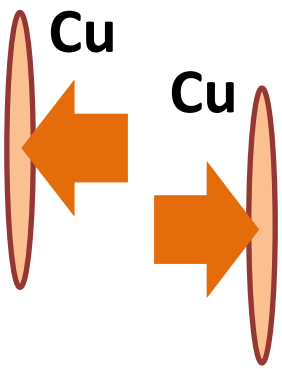
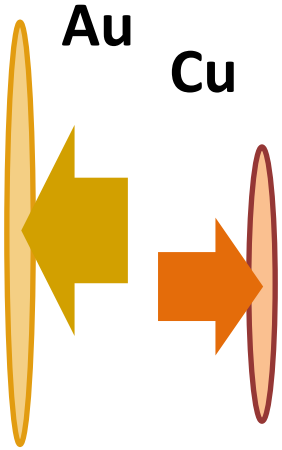
  → $v_1\{RP\} = v_3\{RP\} = 0$
  at mid-rapidity



- Cu+Au, asymmetric collision
  → $v_1\{RP\} \neq 0$, $v_3\{RP\} \neq 0$
  ? ?
  at mid-rapidity