

Update of U+U and Cu+Au results from PHENIX

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For PHENIX Collaboration

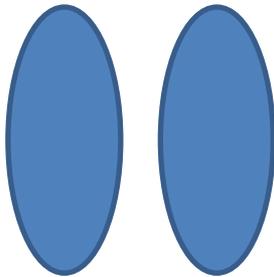
Outline

- Introduction and Motivation
- Energy density and elliptic flow in UU
- Anisotropic flow(v_1, v_2) in CuAu
- Particle production in CuAu collisions
- Summary

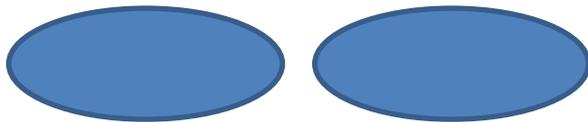
Elliptic Flow in UU

The geometry and density effect

U + U 193 GeV



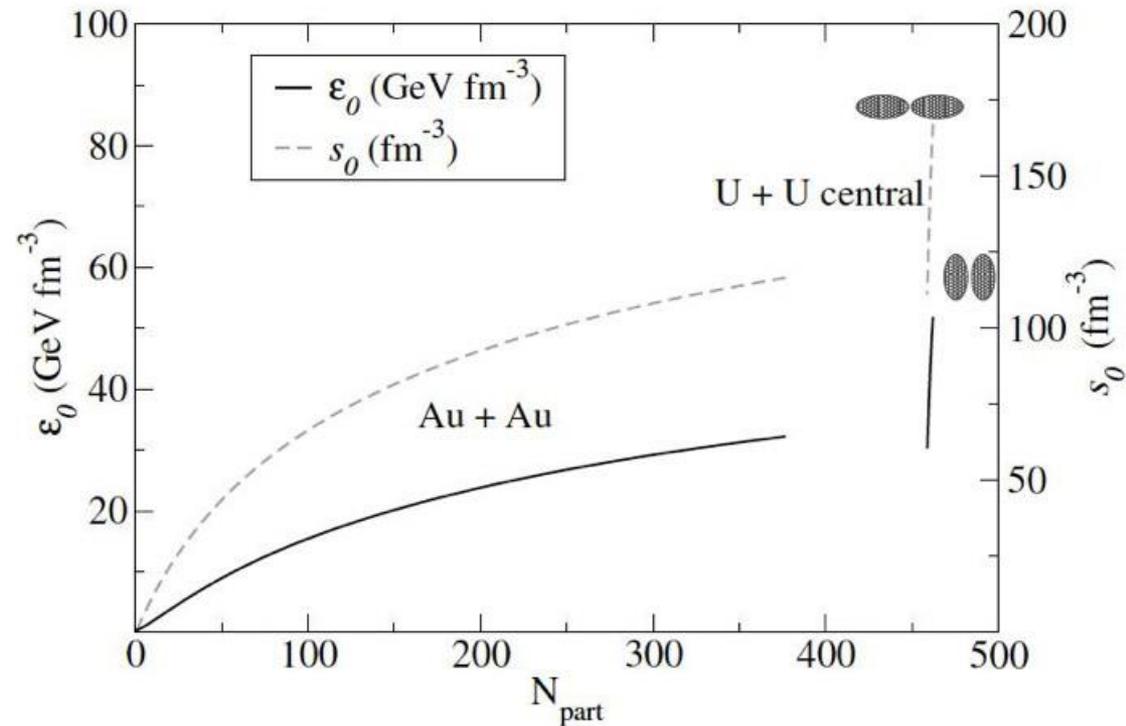
Body-body



Tip-tip

U. Heinz and A. Kuhlman,
PRL **94**, 132301 (2005)

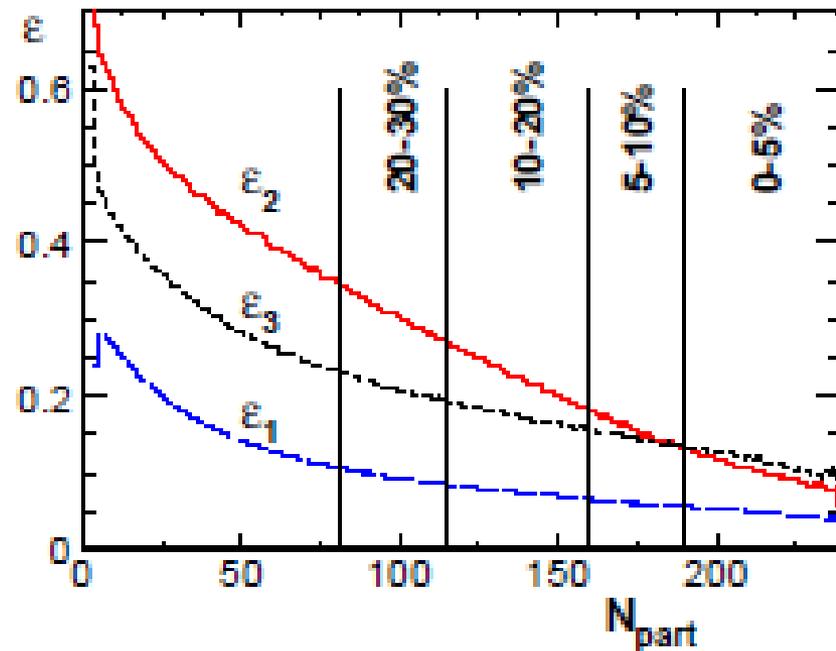
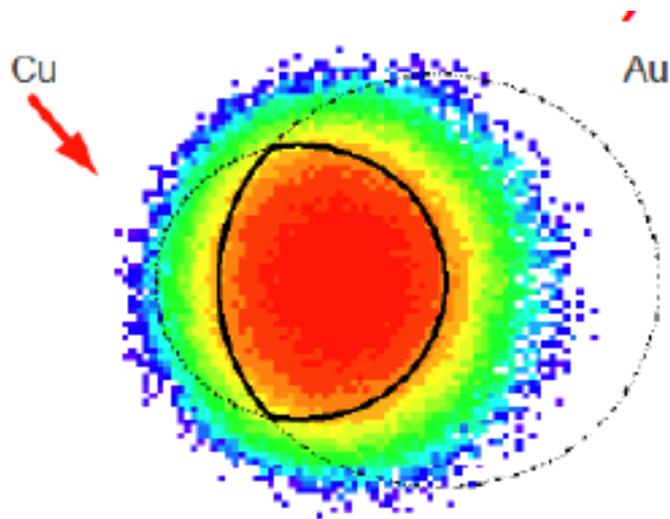
6/10/2013



1. The geometry is significantly different for body-body and tip-tip collisions
2. Theory predicts that maximum medium density from tip-tip is around 60% higher than that of central AuAu

Flow in Cu + Au

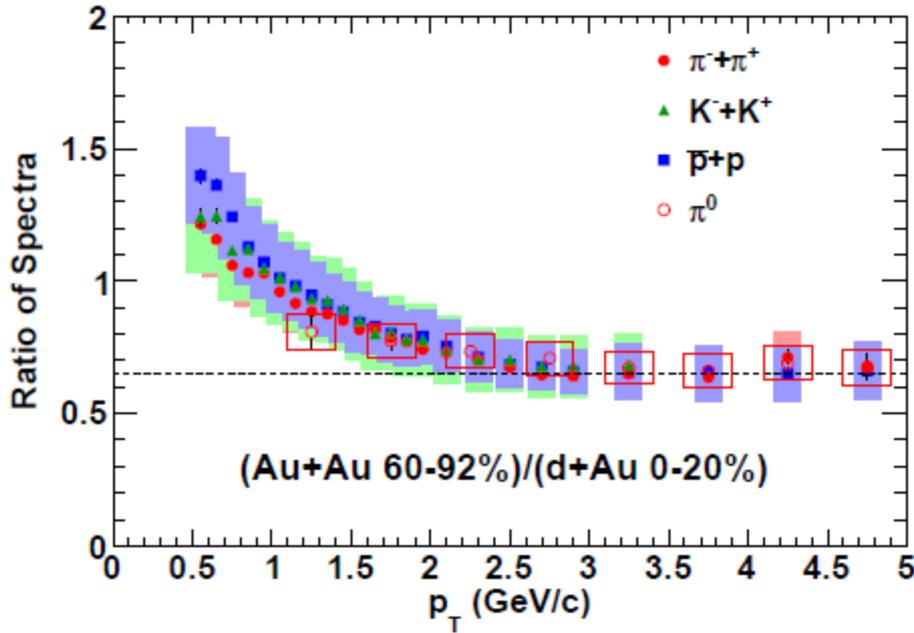
Initial geometry and its fluctuation



[Piotr Bozek](#) Phys. Lett. B717 (2012) 287

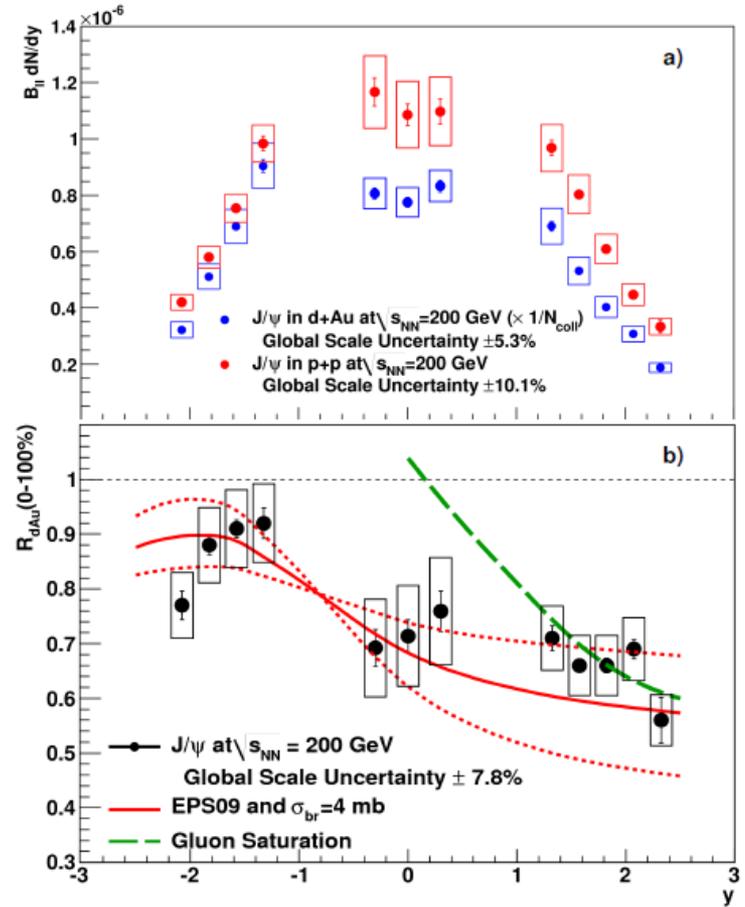
1. An asymmetric initial geometry has been produced in Cu + Au
2. Odd order collective flow such as v_1 , v_3 come not only from fluctuation as they do in Au+Au, but also from original geometry

Particle production dAu



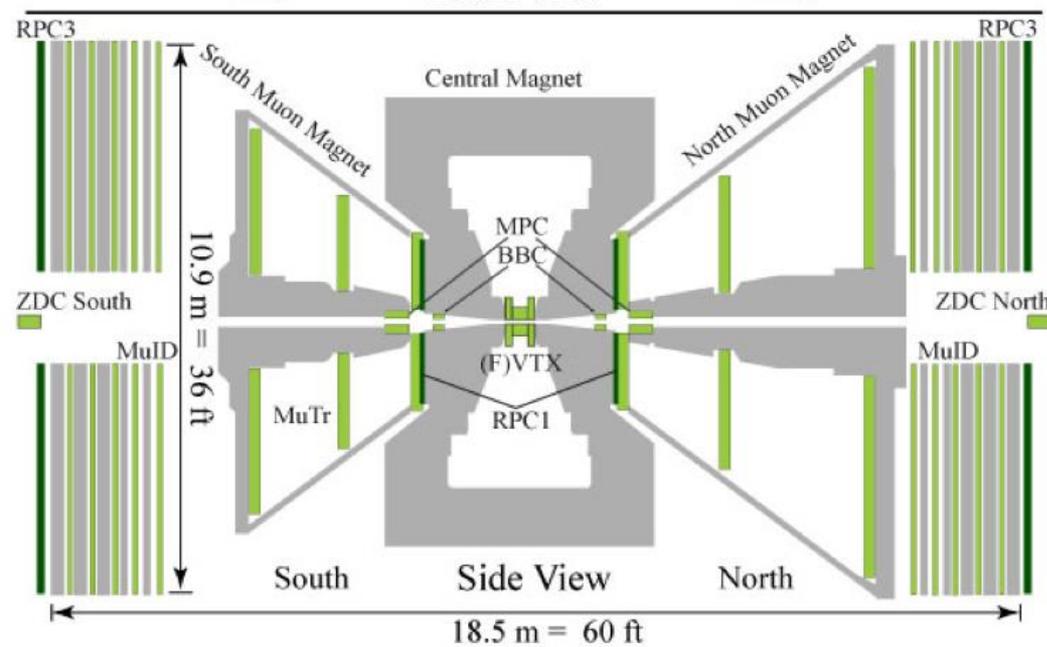
PHENIX: [arXiv:1304.3410](https://arxiv.org/abs/1304.3410)

PHENIX: [PRL\(107\) 142301 \(2011\)](https://arxiv.org/abs/142301)



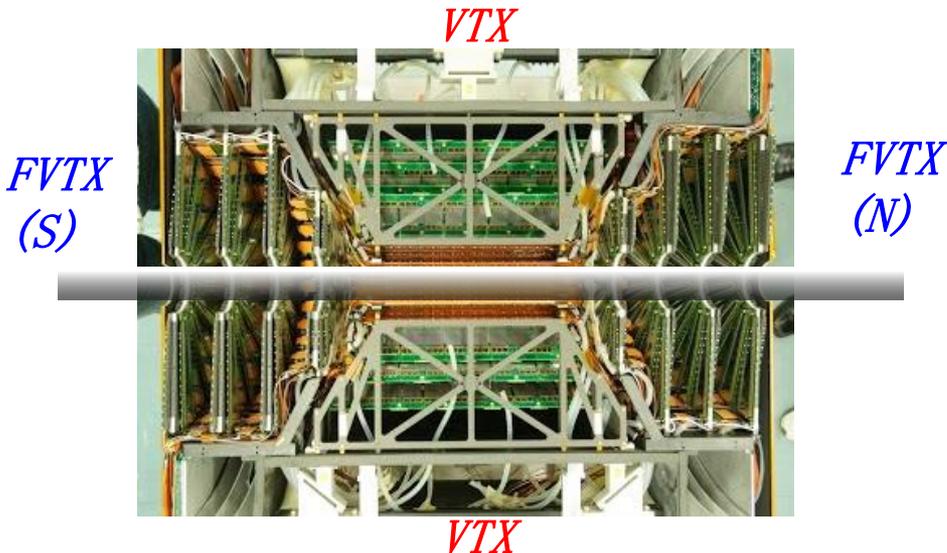
- At middle rapidity, the spectra ratio of AuAu(60-92%)/dAu(0-20%) has no species dependence. The J/Ψ production is asymmetric at forward/backward rapidity
- Measurement of the identified particle production in CuAu will help us to further study the initial state and final state effect, which play different roles in particle production in dAu and AuAu collisions

PHENIX in Run 2012



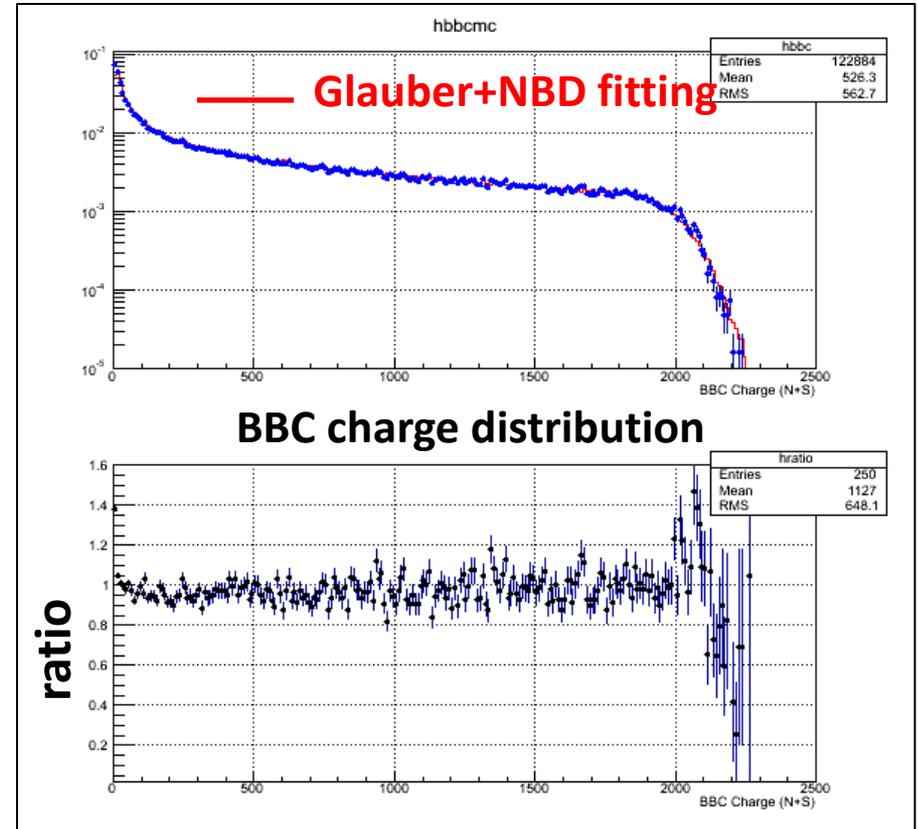
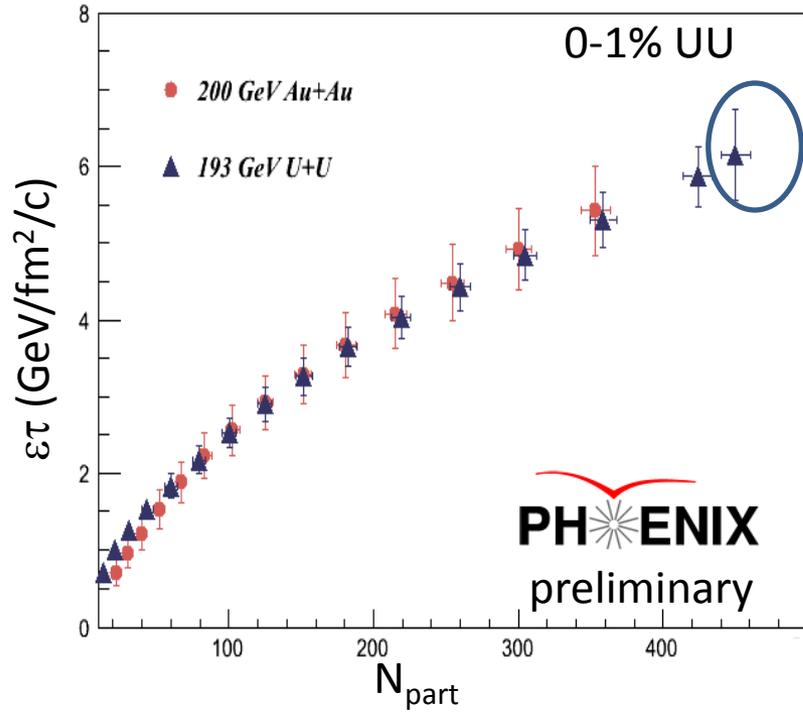
1. 1.2B and 7.6B MB events are recorded in $|bbcz| < 30\text{cm}$ for UU and CuAu collisions respectively.

2. The key FVTX upgrade performs well in its first heavy ion run such as CuAu



3. FVTX :
- Separate the muon from C/B decay
 - Enhance S/B for J/Ψ and ψ'
 - Event plane

Energy density and Multiplicity in UU



60% higher $\epsilon\tau$ from theory prediction for TT



The top 1% central UU $\epsilon\tau$ is only 20% higher than that of AuAu.

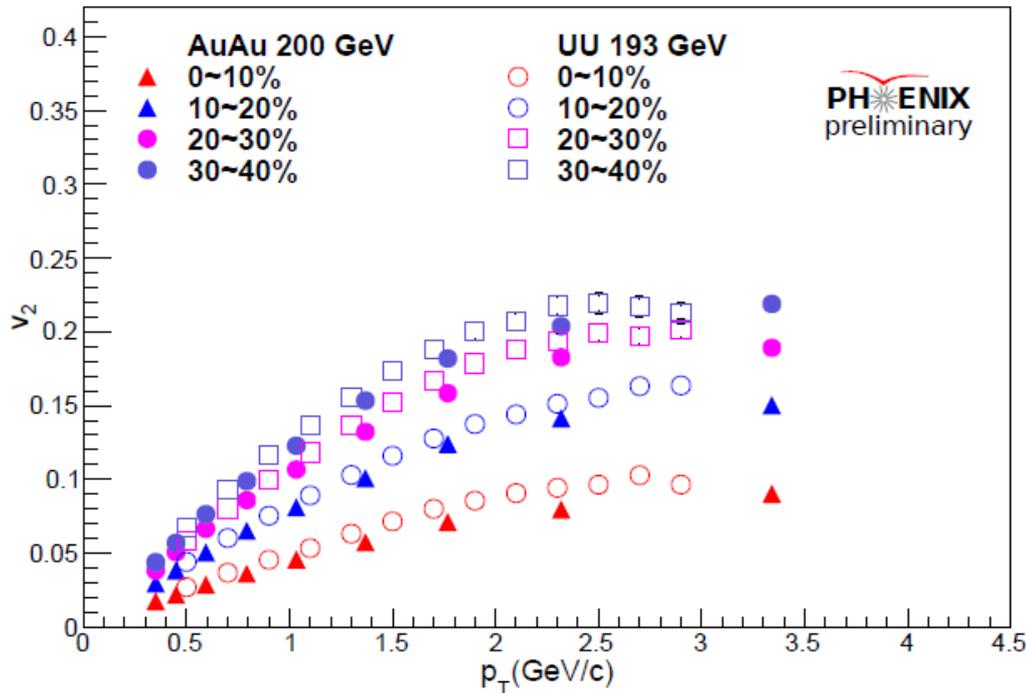
A tail is expected due to extra N_{coll}



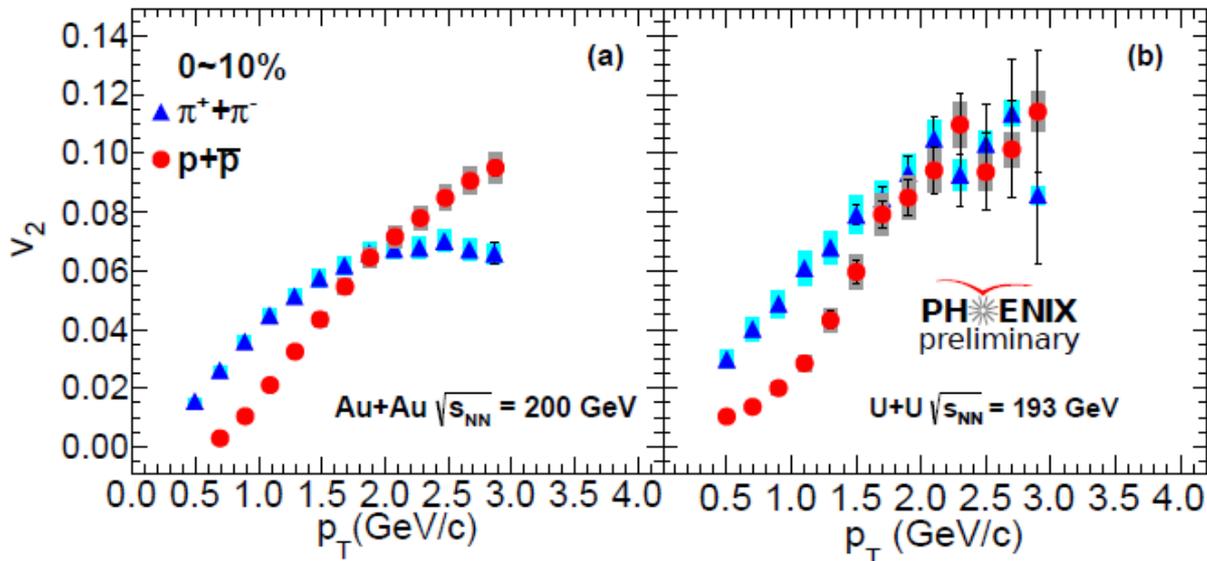
NBD(negative binominal distribution) fold only with N_{part} can reproduce the BBC charge distribution well.

Event-by-event flow is required for the TT and BB separation

Elliptic Flow in U + U collision



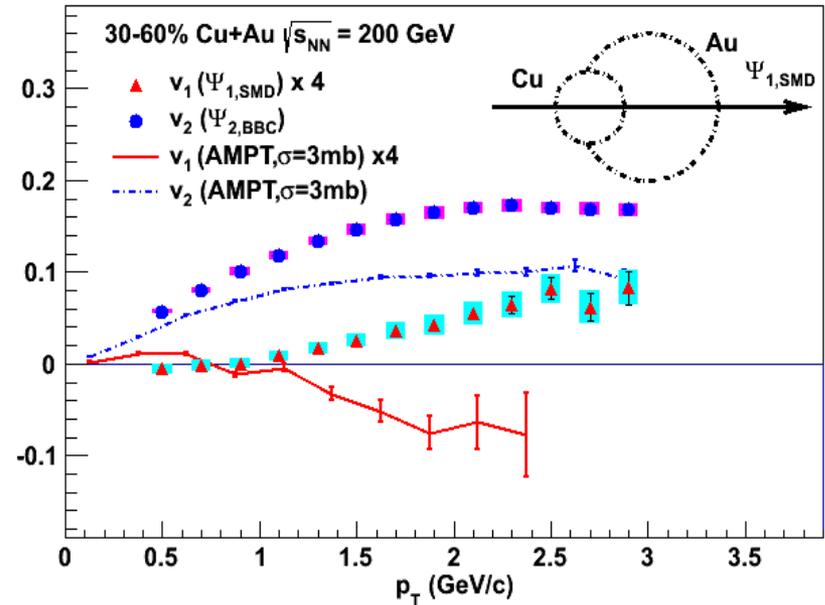
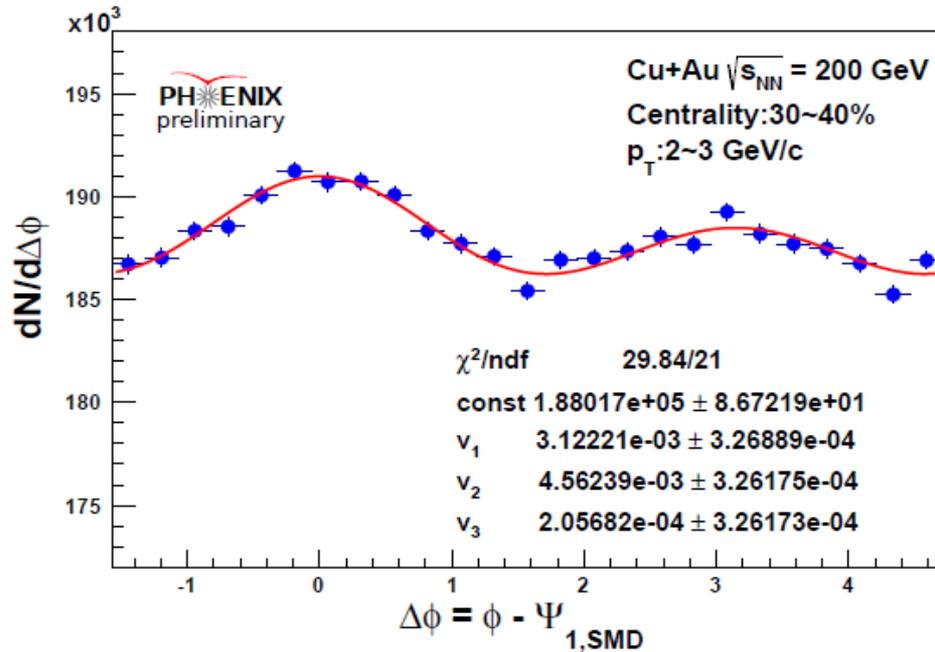
- ❖ The v_2 of charged hadron in UU collisions are higher than that of AuAu in different centrality
- ❖ Strong mass ordering for π & p v_2 in central U + U collision at 193 GeV are observed even though the increase in $\epsilon\tau$ is relatively small.



- ❖ **Radial flow or geometry?**

C. Shen, U. Heinz et al
Phys.Rev. C84, 044903 (2011)

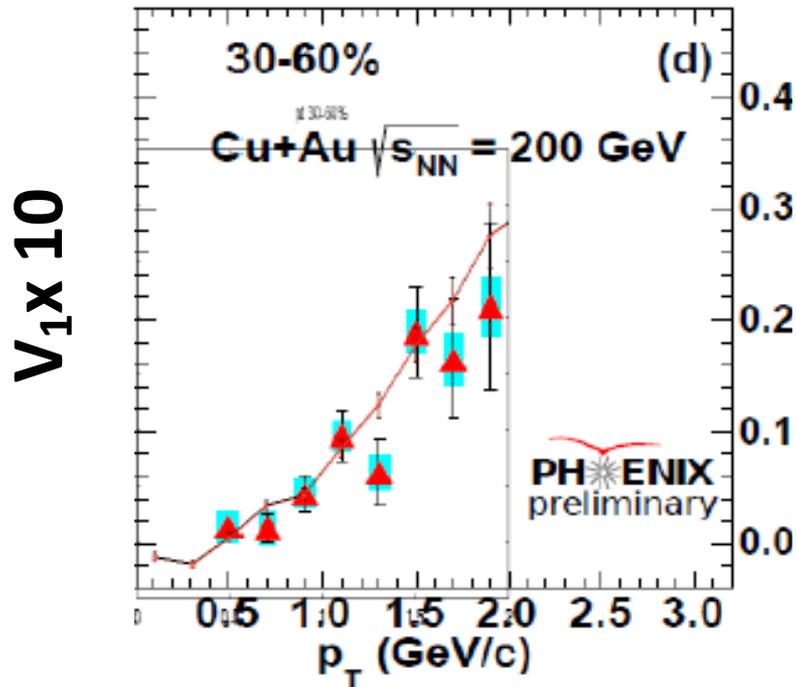
The direct flow measurement in CuAu



AMPT (v1.21) $\sigma = 3$ mb

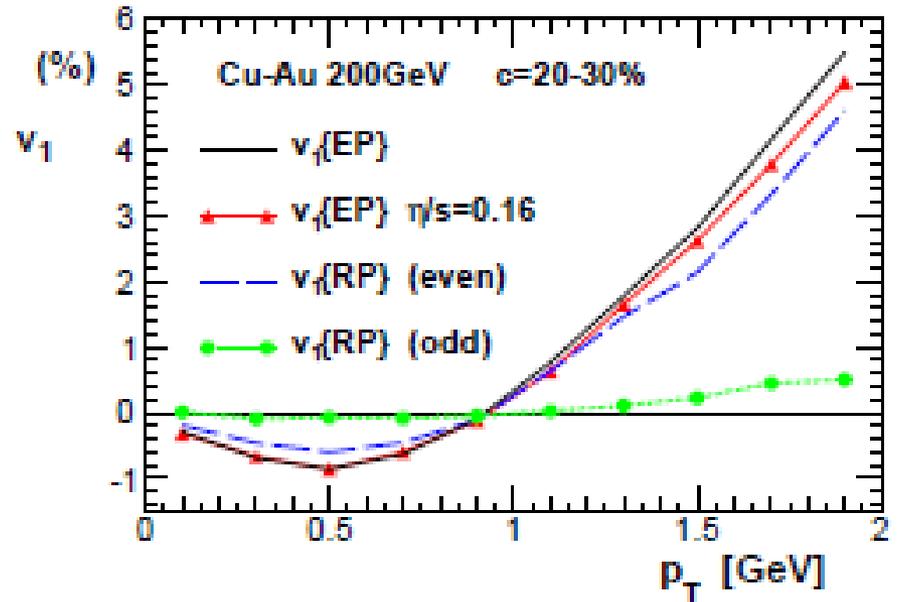
- An asymmetric azimuthal distribution with respect to Ψ_1 plane from Au-going spectators
- Both data and AMPT show sizeable v_1 but with opposite signs at $p_T > 1$ GeV/c
- 3 mb string melting cross section is not enough to reproduce the measured v_2

Hydro-dynamics calculation



Event by Event Hydro

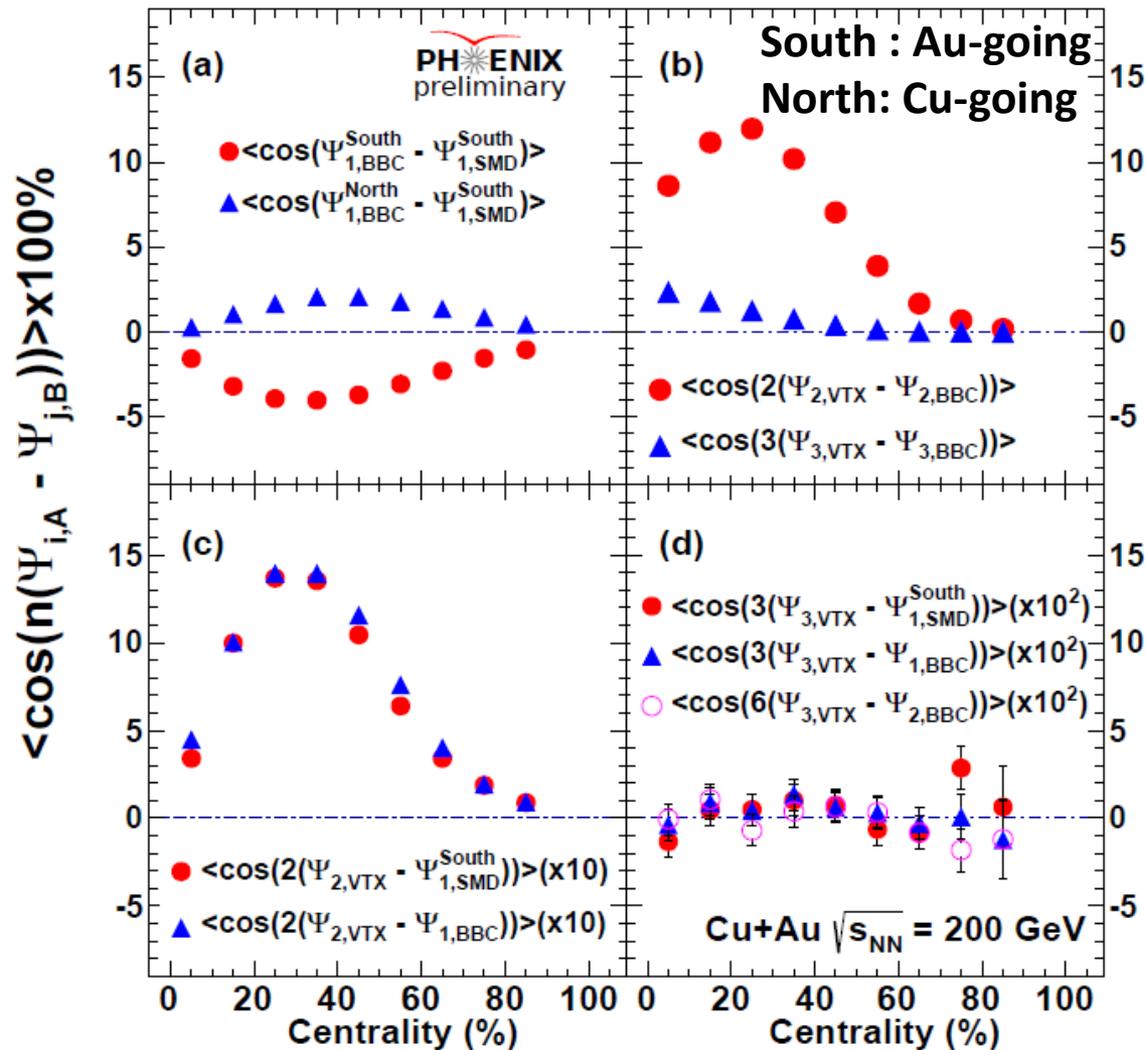
Hashimoto, Murase and Hirano, JPS13



[Piotr Bozek Phys. Lett. B717 \(2012\) 287](#)

1. Two groups can reproduce the v_1 sign by E-by-E hydro calculations
2. The asymmetric medium density in transversal plane plays an important role
3. The v_1 of proton/anti-proton will provide more information since the baryon/anti-baryon densities are quite different

Event plane correlation in Cu+Au Collision

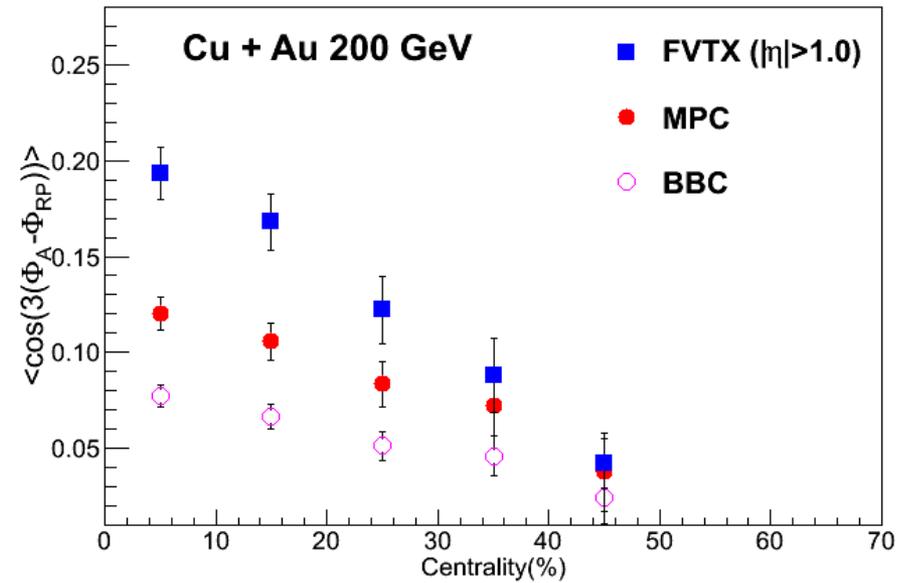
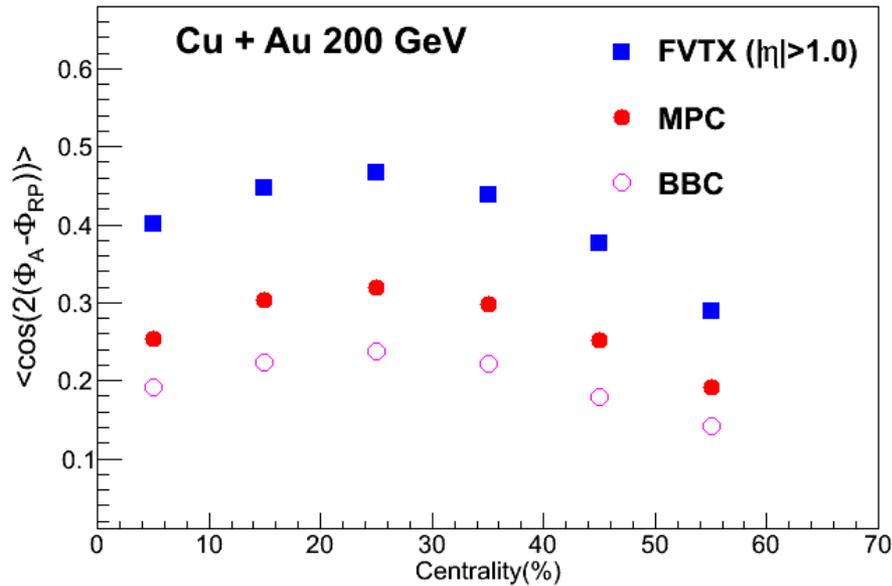


□ $(\Psi_{1,BBC}^{South}, \Psi_{1,SMD}^{South})$ correlation is stronger than $(\Psi_{1,BBC}^{North}, \Psi_{1,SMD}^{South})$. It indicates that v_1 is larger in the Au-going direction

□ Ψ_3 is expected to be correlated with Ψ_1 and Ψ_2 due to the initial asymmetric geometry, while data shows a pretty weak raw correlation.

□ *The event-plane resolution correction and FVTX event plane will be helpful for further study*

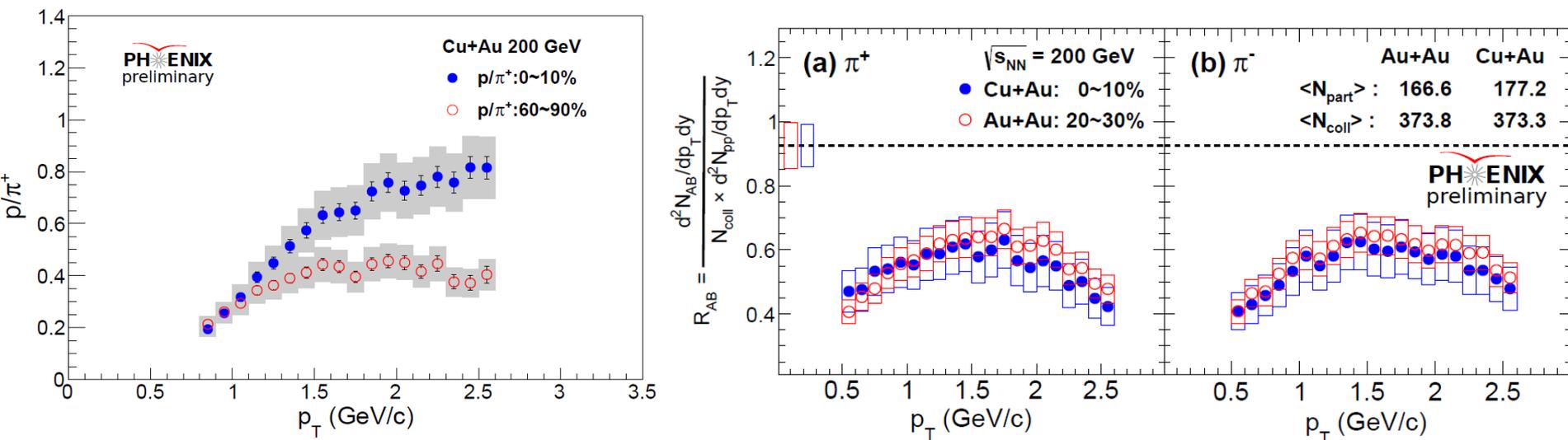
FVTX Event Plane



1. Event plane resolutions are significantly improved by FVTX detector for Ψ_2 and Ψ_3

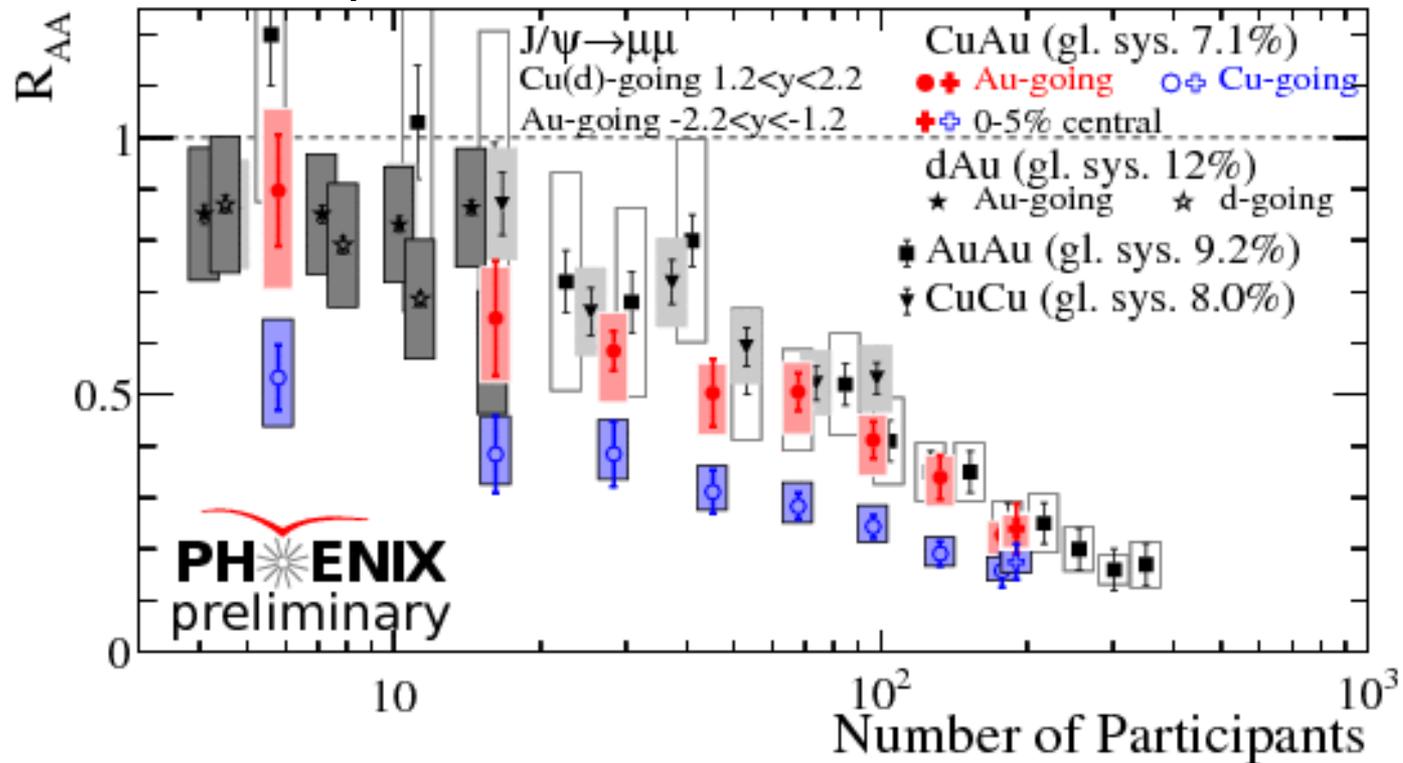
2. The measurements of v_3 and v_4 in CuAu will come out soon with FVTX EP and full statistics

Identified particle(π/p) production in CuAu



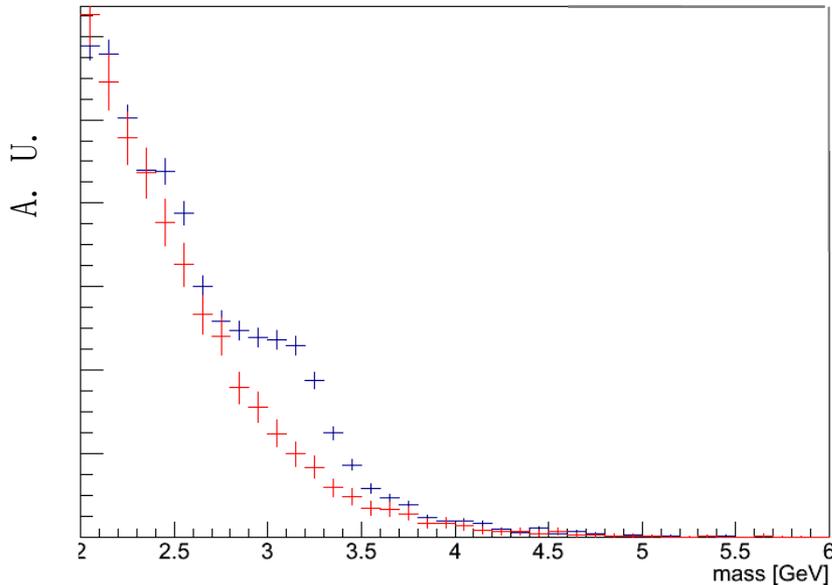
1. p/π ratio in 0-10% central CuAu collision is significant higher than that of peripheral collisions
2. The R_{AB} of π in 0-10% central CuAu collision is similar to that of 20-30% AuAu Collisions (similar N_{coll} and N_{part})
3. The particles production in CuAu and AuAu is similar at mid-rapidity

J/ ψ production in Cu+Au

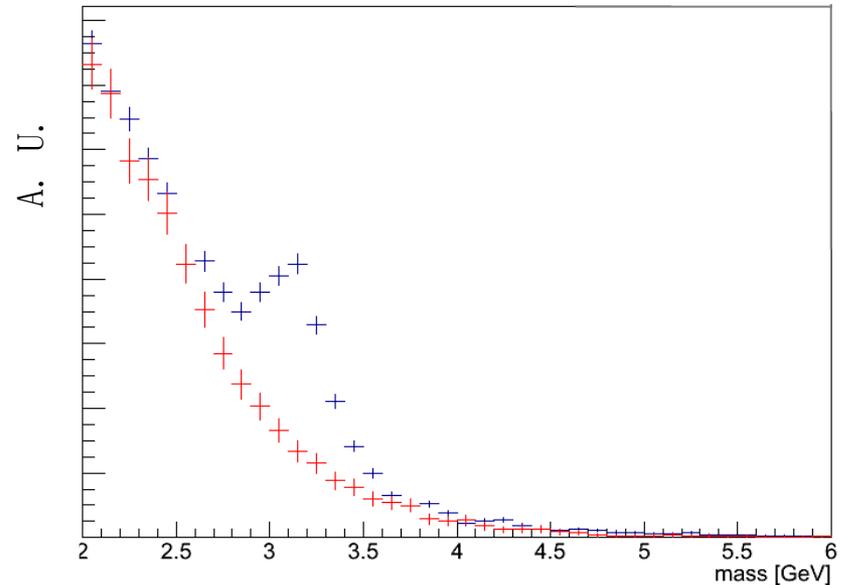


- ✓ In the Au-going direction, the J/ ψ suppression is comparable with that of AuAu and CuCu collision
- ✓ In the Cu-going direction, slightly more suppression is observed
- ✓ No significant suppression in completely swallowed-Cu (top 5%) events, which is contradicted with core-corona model expectation
- ✓ Currently, a full analysis with FVTX is going to further investigate the results in Cu-going direction

FVTX improvement for J/ψ



Basic muon cut



Basic muon cut + $DCA_R < 2\text{cm}$

Add $DCA_R < 2\text{cm}$

—————>
Cu-Au run sample

1. The signal to background ratio is improved by FVTX cut for primary muon trackers
2. The v_2 of J/ψ and open charm will be measured at both forward and backward rapidity by FVTX, which will shed the light on the charm production

Summary

- ❑ In the central UU collision, strong mass ordering is observed for the v_2 of pions and protons
- ❑ With the Ψ_1 measured by Au-going spectator, a positive v_1 is observed for the charged hadrons as $p_T > 1$ GeV/c. The sign of v_1 is different with AMPT calculation but consistent with other hydro calculations
- ❑ The Ψ_1 plane correlation between BBC and SMD indicates a larger v_1 in the Au-going direction. And the raw Ψ_3 plane is weakly correlated with Ψ_1 and Ψ_2 plane.
- ❑ The pion and proton production at mid-rapidity in Cu Au is similar to that of AuAu collision. But an asymmetric J/ Ψ suppression is observed at forward/backward rapidity in CuAu. On the Cu-going side, the suppression is little bit stronger than that on the Au-going side