

The Measurement Of Direct Photon Azimuthal Anisotropy At RHIC-PHENIX Experiment



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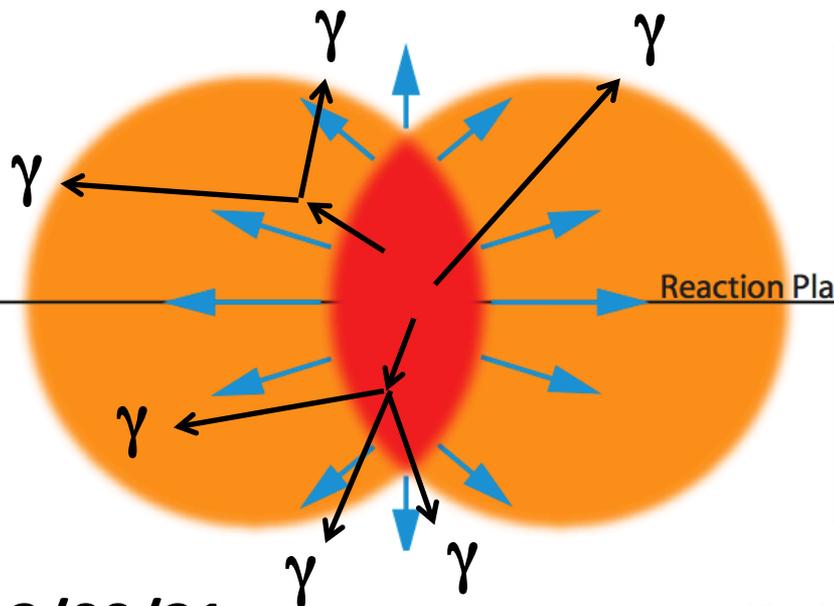
21pSA-6

Direct Photon is powerful probe

Direct photon is all photon except for the decay photon from hadron.

- It doesn't strongly interact with QGP.
- It is created by several sources.

The challenge is identification the photon source.



photon sources

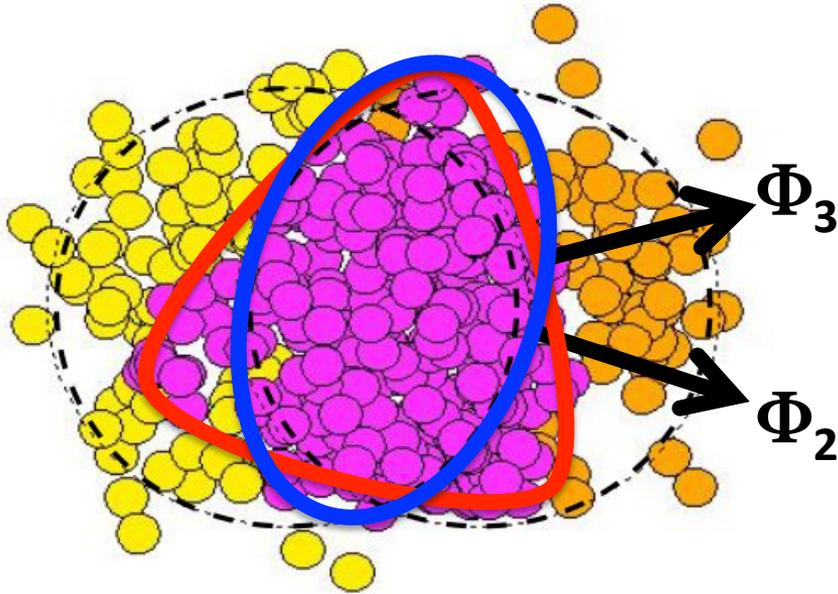
initial hard scattering

bremsstrahlung by scattered parton

Energy loss by high mom parton

hadron decay

Azimuthal anisotropy



$$E \frac{d^3 N}{dp^3} \propto \left[1 + 2 \sum_{n=1}^{\infty} \nu_n \cos\{n(\phi - \Phi_n)\} \right]$$

$$\nu_n = \langle \cos\{n(\phi - \Phi_n)\} \rangle$$

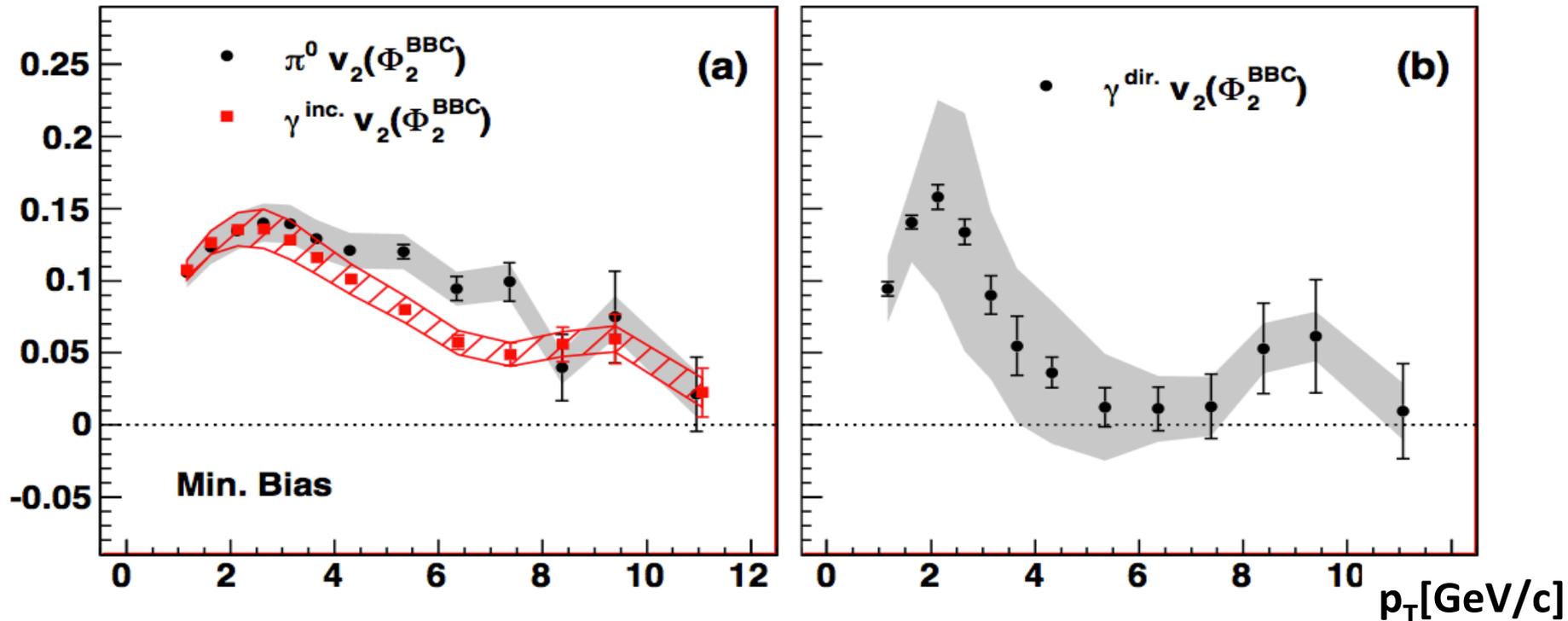
Event Plane(Φ_n)

The base direction for expansion
 ν_n is strength of anisotropy

Azimuthal anisotropy is strongly related to initial geometry and expansion of QGP.

Direct Photon v_2

PRL 109, 122302(2012)

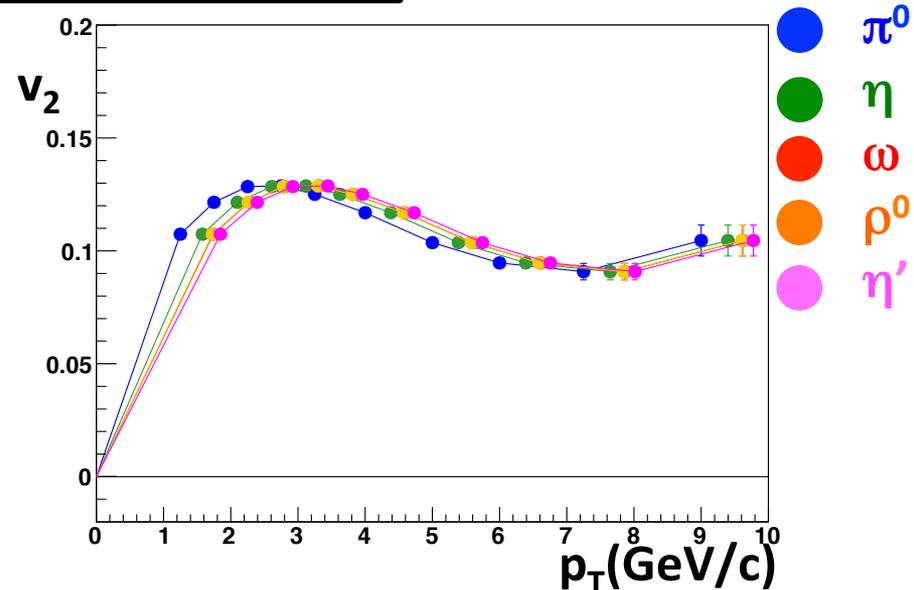


- $\gamma^{\text{dir.}}$ v_2 is close to 0 in high p_T , which is consistent with expectation.
- It has as strong v_2 as hadron in low p_T .

$\gamma^{\text{dir.}}$ v_3 is needed to understand photon production mechanism.

Measurement Direct photon v_n

Measurement of π^0 and $\gamma^{inc.}$ v_n
 π^0 v_3 results are shown.



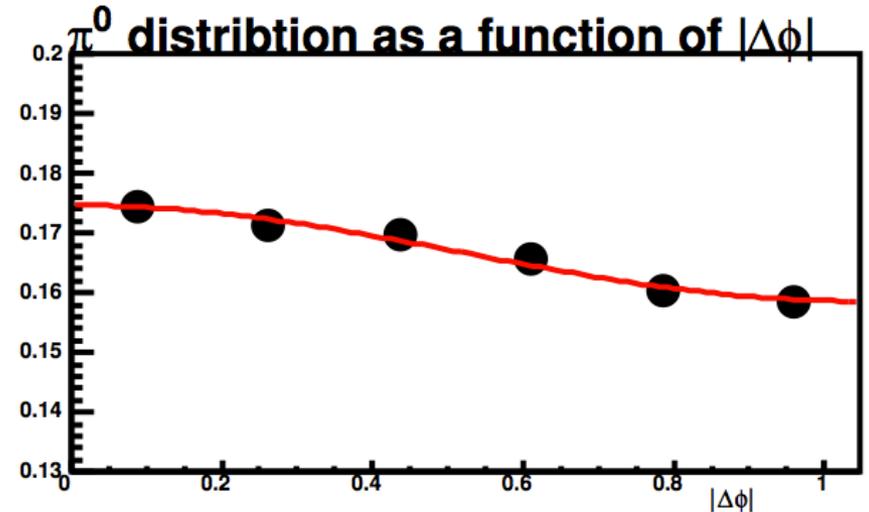
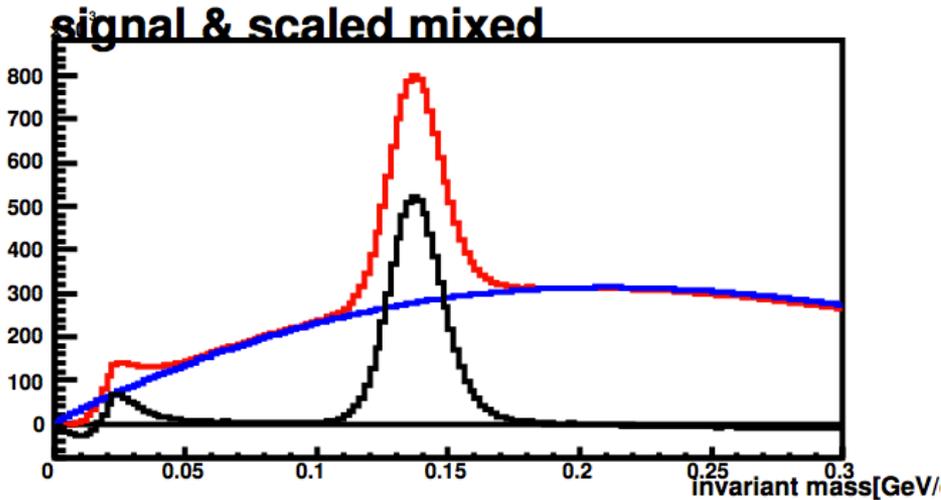
Simulation of decay photon v_n from π^0 and other meson(η , ω etc.)
 η , ω etc. are estimated from π^0 by KE_T and N_q scaling.

$$v_n^{dir.} = \frac{R_\gamma v_n^{inc.} - v_n^{BG}}{R_\gamma - 1}$$

Calculation of direct photon v_n

$$R_\gamma = N^{inc.} / N^{BG}$$

Method to measuring $\pi^0 \nu_3$



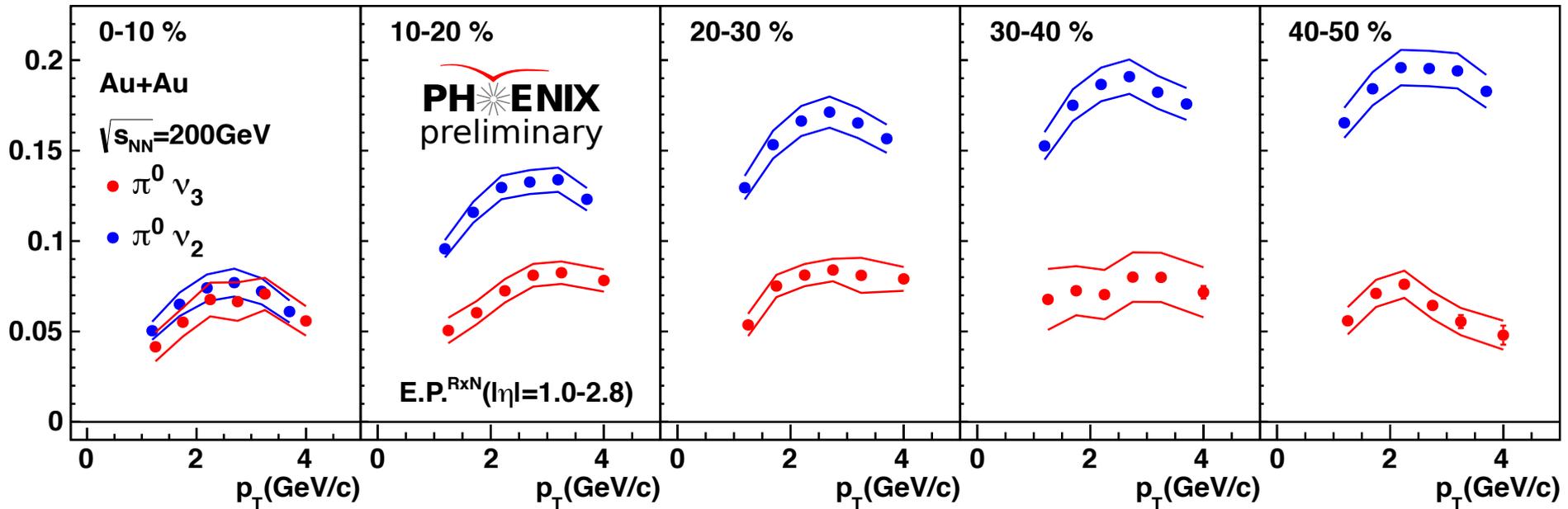
π^0 invariant mass is measured by combined $\gamma+\gamma$ with same event and mixed event.

π^0 yield as a function of $|\phi-\Phi_3|$ is created, and then ν_n is extracted by fitting.

$$N_0[1 + 2\{\nu_3 \cos\{3(\phi - \Phi_3)\}\}]$$

$$\nu_n = \langle \cos\{n(\phi - \Phi_n)\} \rangle$$

The result of $\pi^0 v_3$



$\pi^0 v_3$ is measured up to 4.0 GeV/c.

They are confirmed to be consistent with $\pi^\pm v_3$.

Decay photon v_3 will be simulated from these results.

Summary

Direct photon study is powerful probe.

- $\gamma^{\text{dir.}}$ has as strong v_2 as hadron v_2 in low p_T .
- v_3 study is important in order to understand photon production mechanisms.

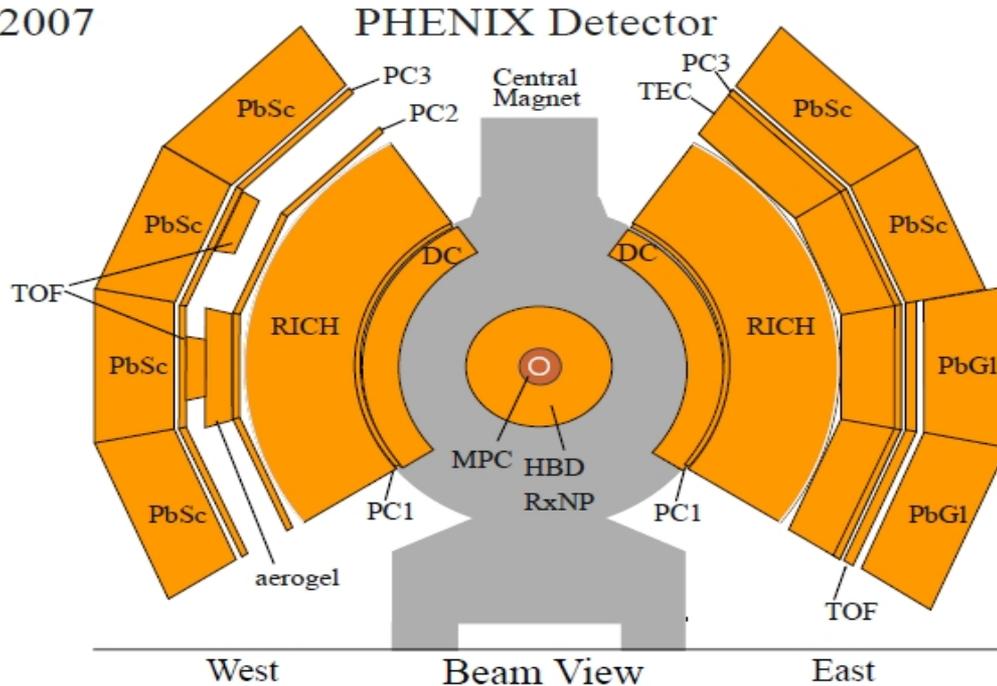
π^0 v_3 result are shown.

- It is checked to be consistent with $\pi^\pm v_3$.
- Decay photon v_3 will be simulated.
- $\gamma^{\text{dir.}}$ v_3 will be measured.

BACK UP

PHENIX detector

2007



CNT

coverage $|\eta| < 0.35$

$\phi : 180$

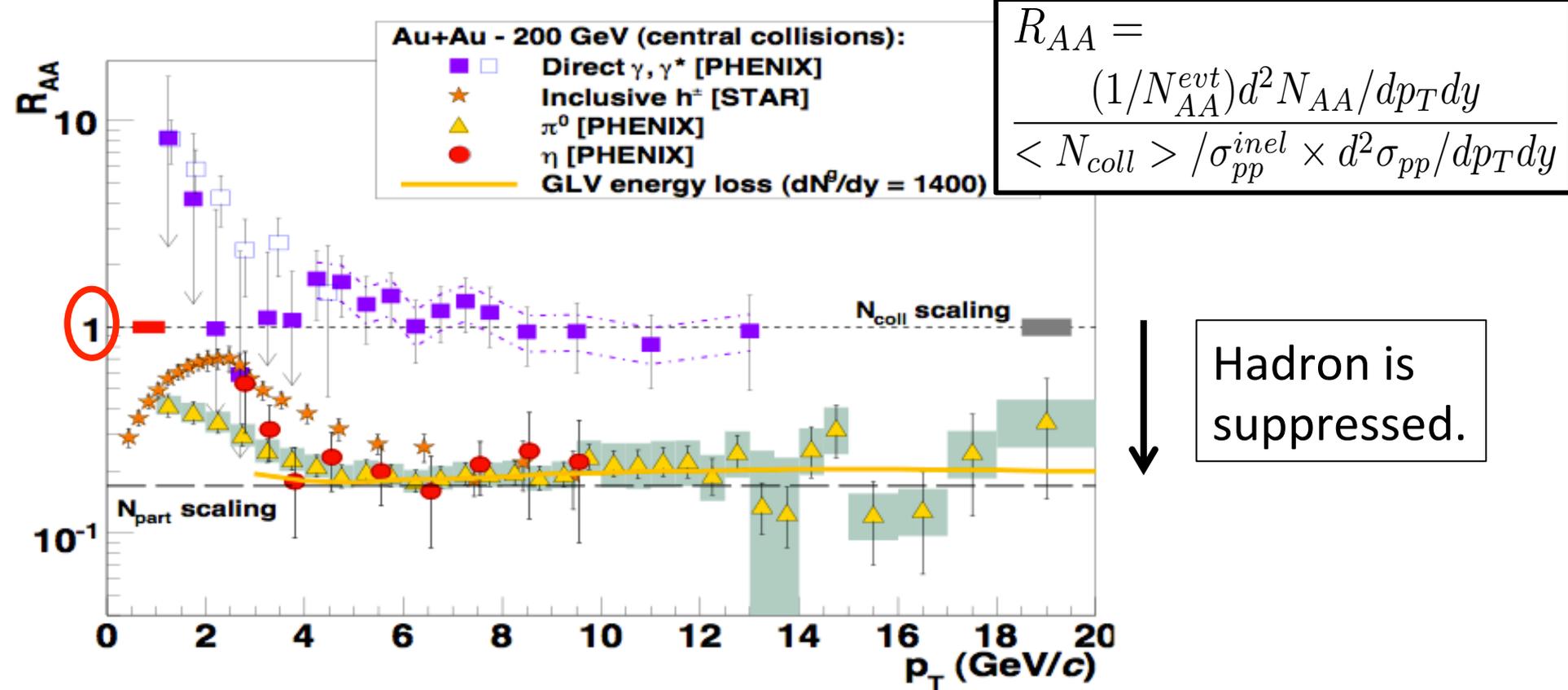
- Tracking detector
DC, PC1, PC2, **PC3**
- particle identification
RICH, TOF, AGEL, **EMCal**

EMCal is used to detect photon.

PC3 is used to remove charged particle.

Event Plane is measured by RxN detector.

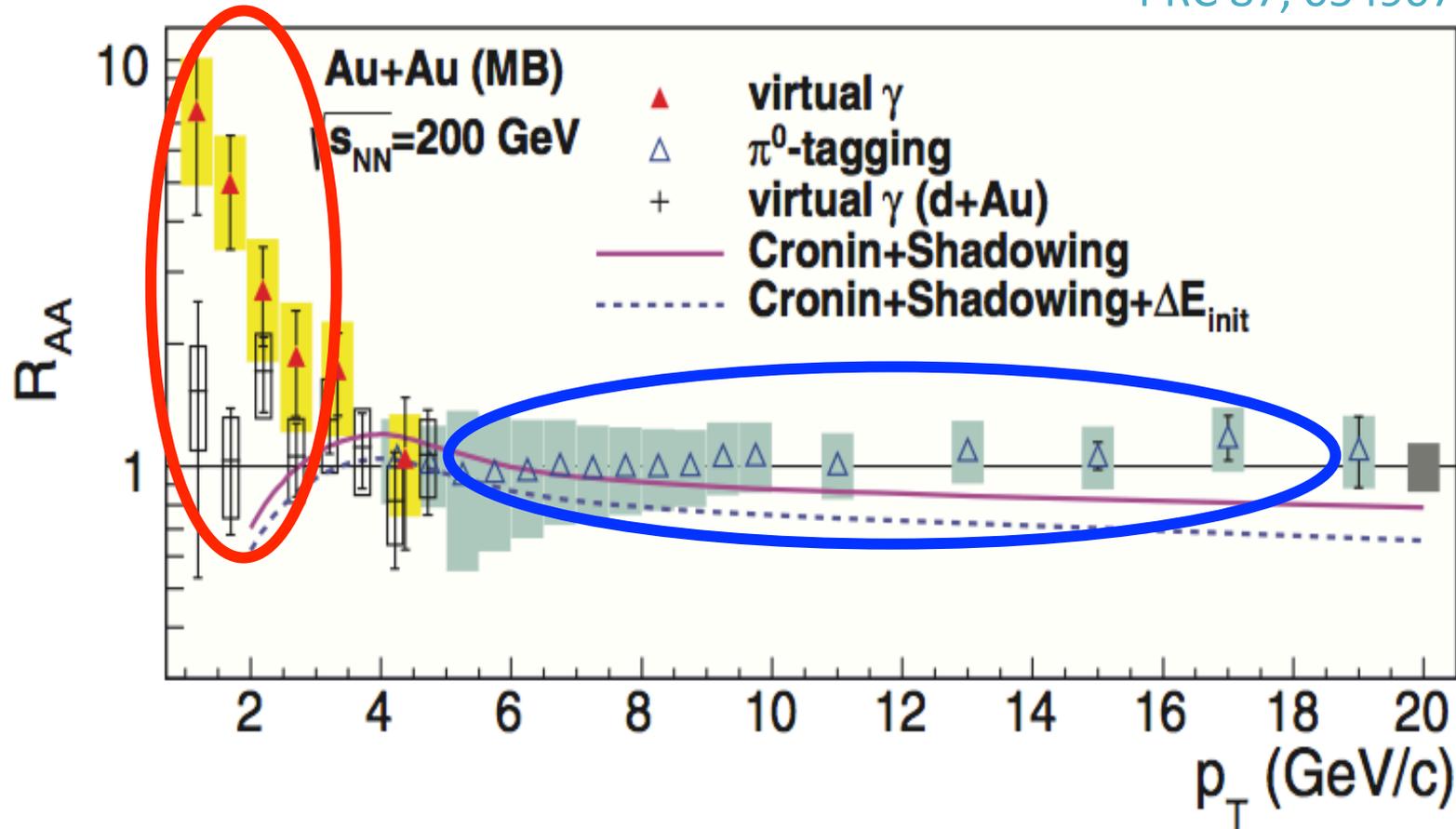
Direct Photon is not suppressed.



R_{AA} of direct photon is consistent with unity in high p_T . This is consistent with the expectation that $\gamma^{dir.}$ coming from initial scattering is dominant.

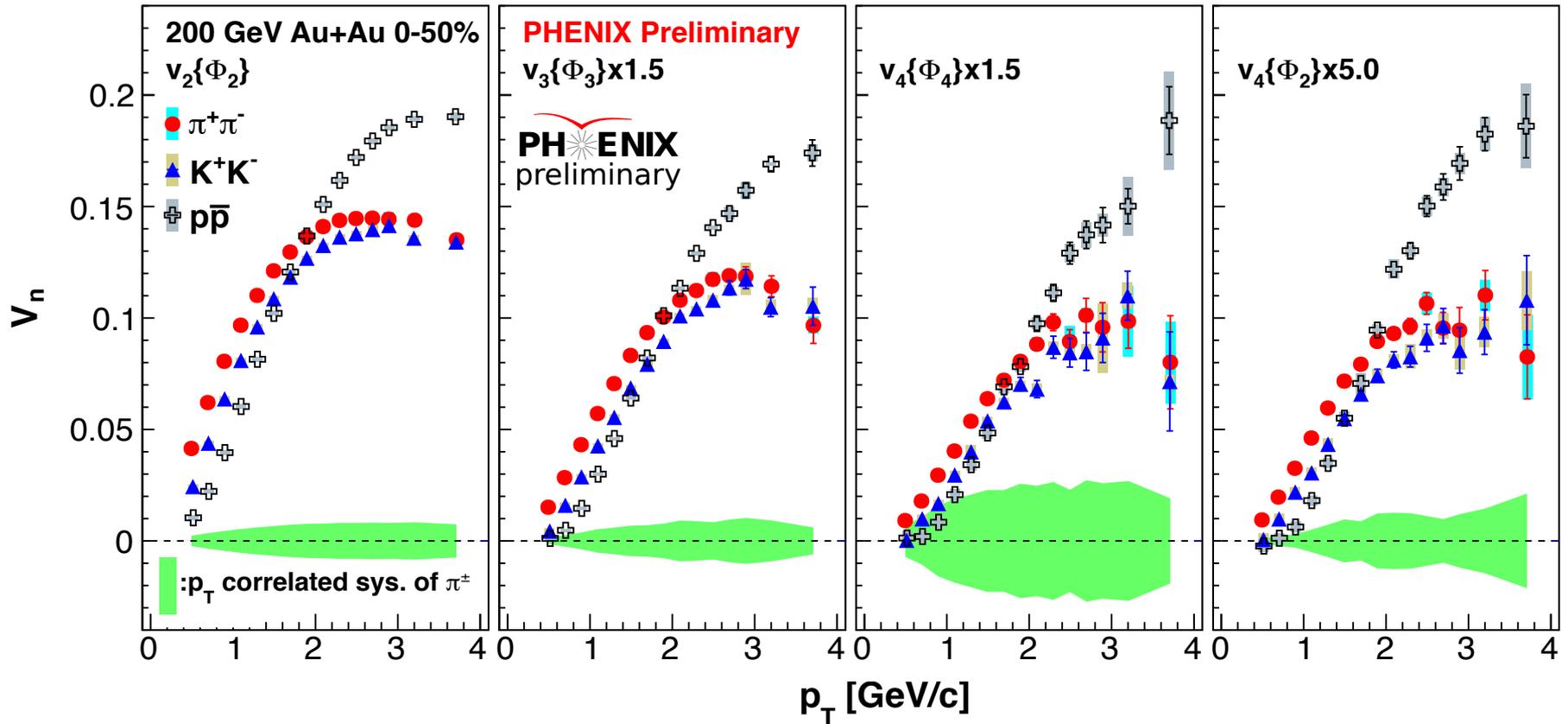
Existence of additional photon sources

PRC 87, 054907(2013)



Enhancement of R_{AA} may indicate existence of a medium effect as an additional photon source in low p_T .

v_n of charged π, K, p result

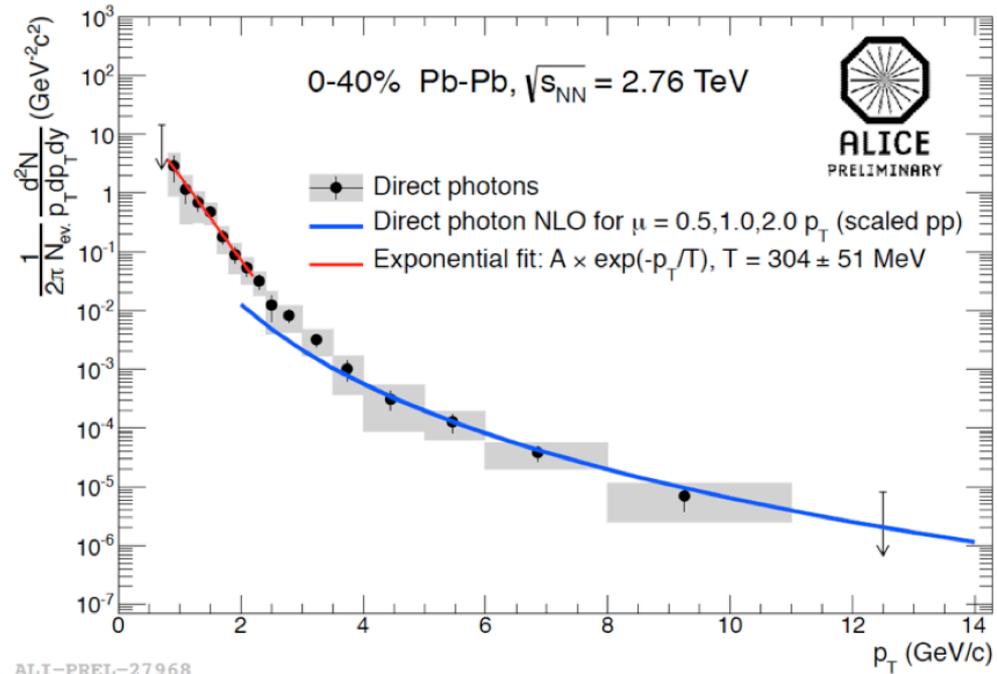
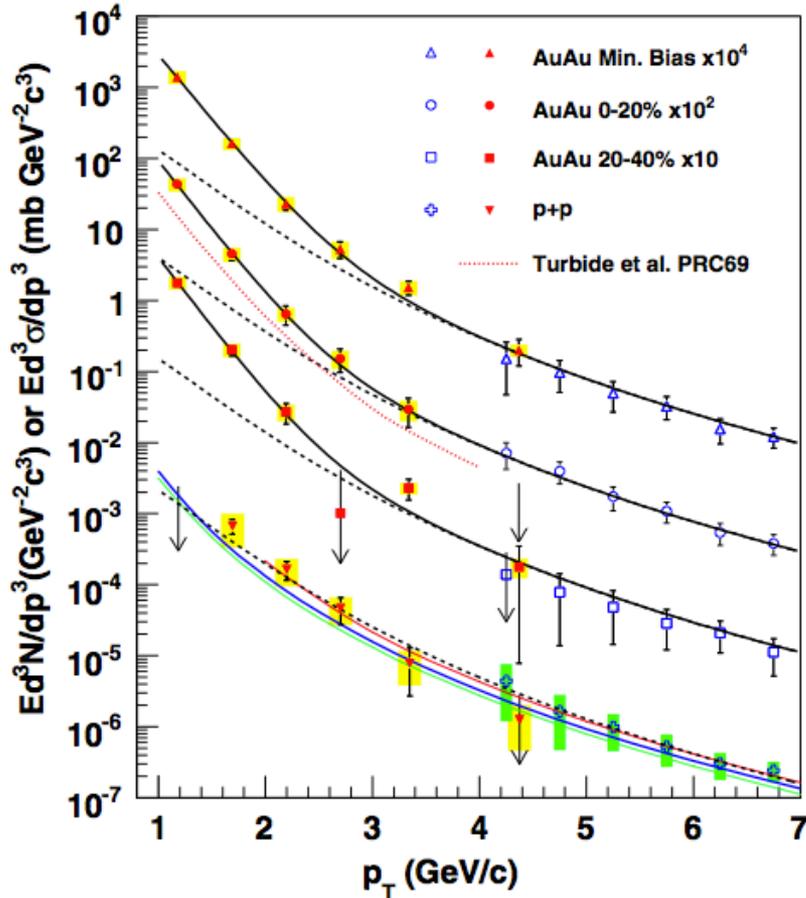


Azimuthal anisotropy has particle species dependence, which are mass dependence and meson/baryon dependence.

Higher harmonics are created from initial geometry deformation, they are affected by the effect of QGP expansion.

STUDY TEMPERATURE

PRL 104, 132301(2010)



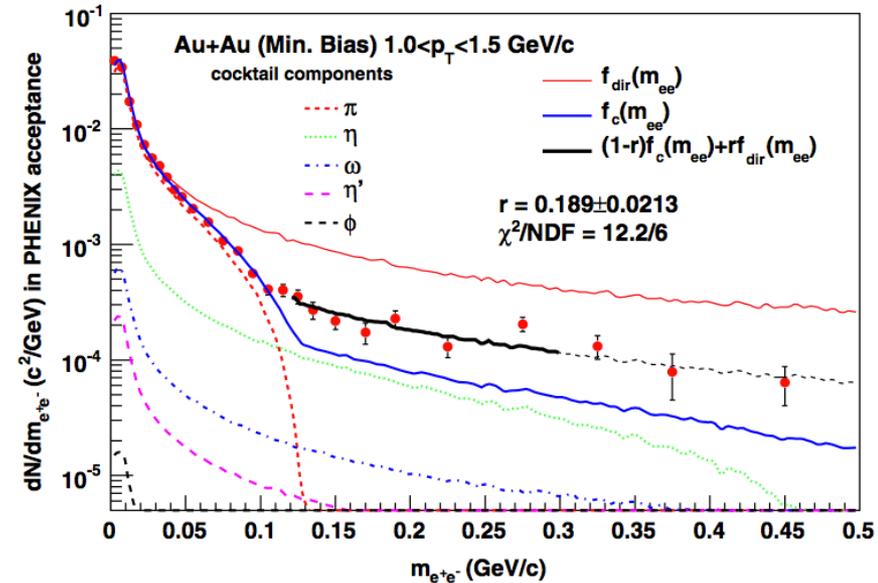
$$T_{\text{RHIC}} = 233 \pm 24 \text{ MeV}$$

$$T_{\text{LHC}} = 304 \pm 51 \text{ MeV}$$

T_{LHC} is $\sim 30\%$ higher than T_{RHIC} .

Measurement Direct photon ν_n

Measurement of π^0 and $\gamma^{inc.}$ ν_n
 $\pi^0 \nu_3$ results are shown.



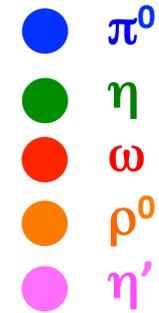
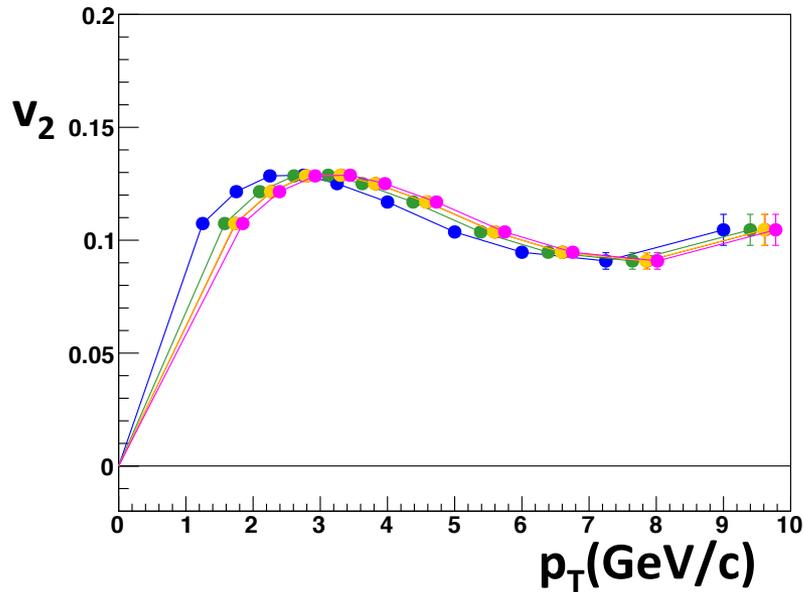
Simulation of decay photon ν_n from π^0 and other meson(η , ω etc.)
 η , ω etc. are estimated from π^0 by KE_T and N_q scaling.

$$\nu_n^{dir.} = \frac{R_\gamma \nu_n^{inc.} - \nu_n^{BG}}{R_\gamma - 1}$$

Calculation of direct photon ν_n

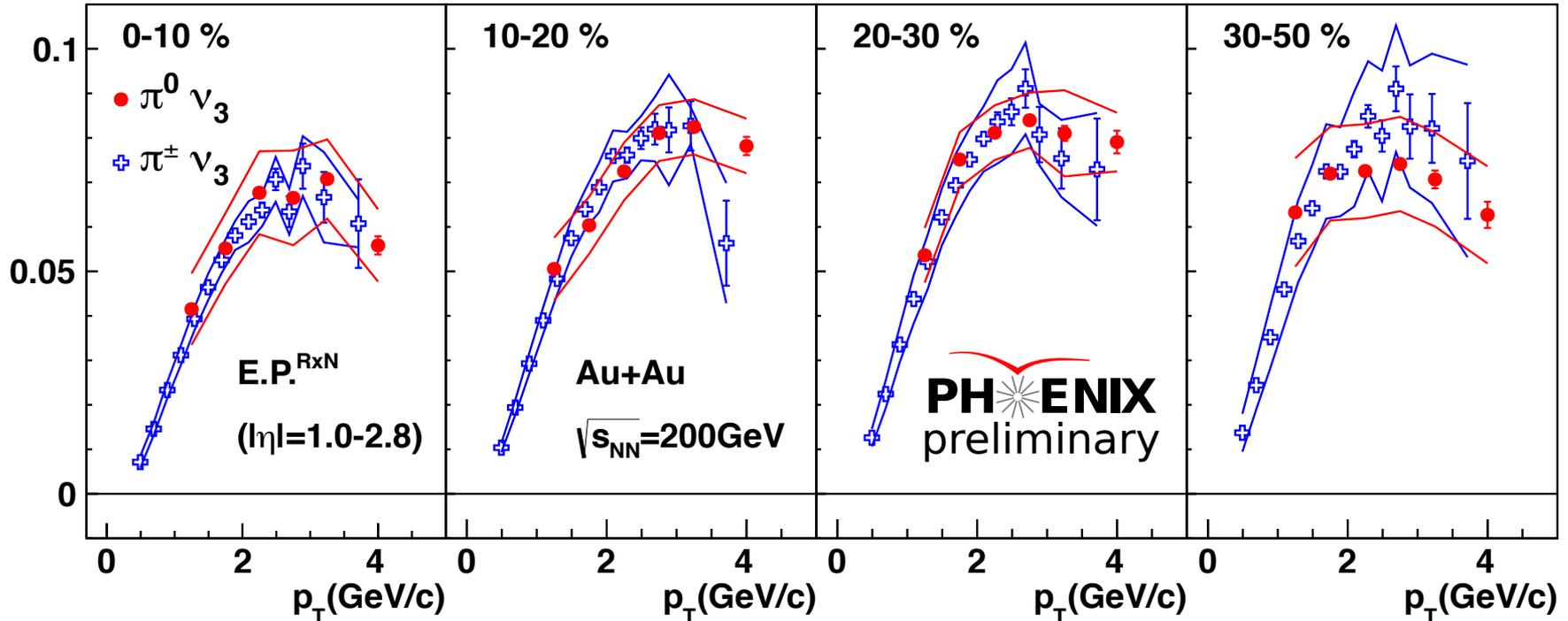
$$R_\gamma = N^{inc.} / N^{BG}$$

Estimation of meson v_2



Meson's v_2 are estimated from $\pi^0 v_2$ by using KE_T and N_q scaling.

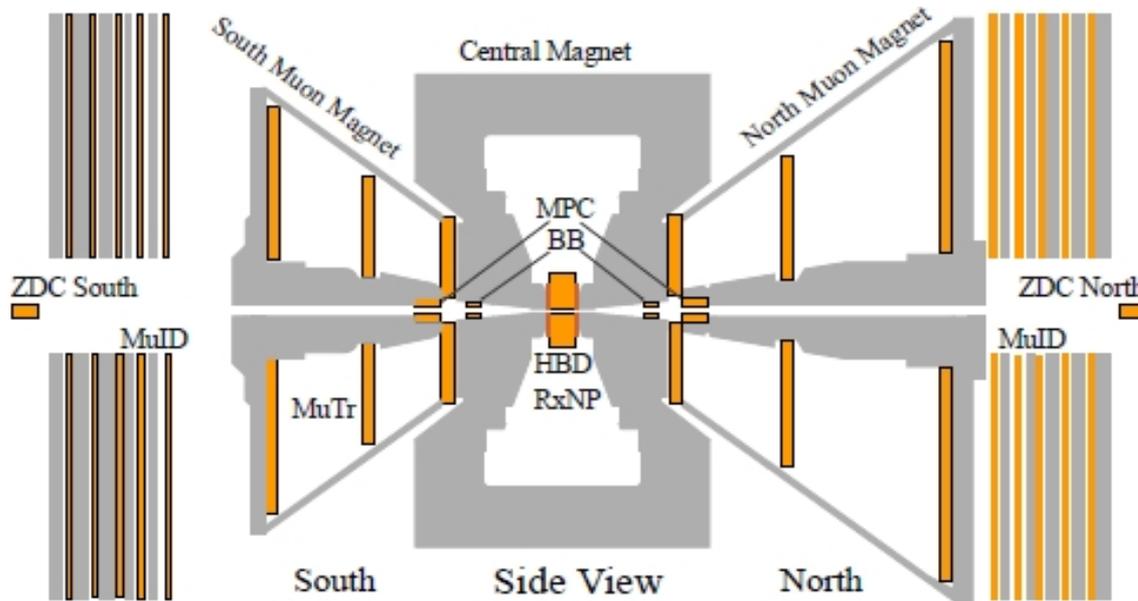
Check to be consistent with $\pi^\pm v_3$



$\pi^0 v_3$ is measured up to 4.0 GeV/c with several centralities.
It is confirmed to be consistent with $\pi^\pm v_3$.

Decay photon v_n is simulated from π^0 and the other meson v_3 .

PHENIX CNT DETECTORS IN SIDE VIEW



- BBC($3.1 < |\eta| < 3.8$)
- MPC($3.1 < |\eta| < 3.8$)
- RxN($1.0 < |\eta| < 2.8$)

Event are classified by these detectors.

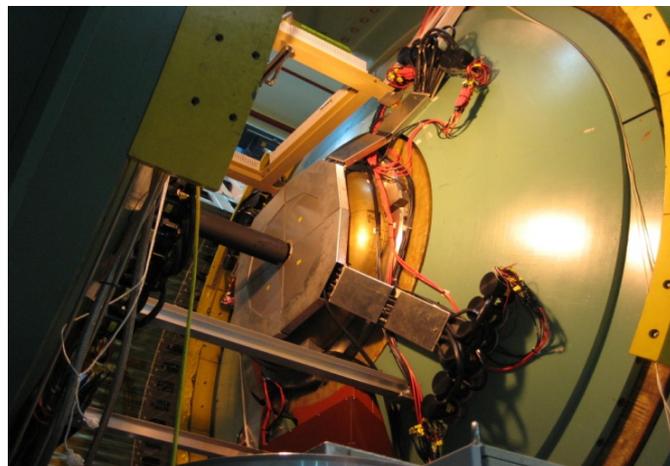
Event Plane are measured by these detectors.

Event Plane calculation

Event Plane is calculated by three steps.

1. gain correction
2. re-centering
3. flattening

$$\nu_{n,real} = \nu_{n,obs} / \text{Res}\{\Psi_n\}$$

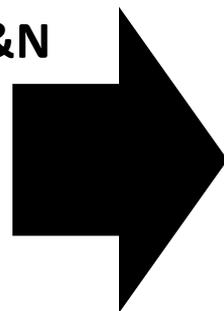
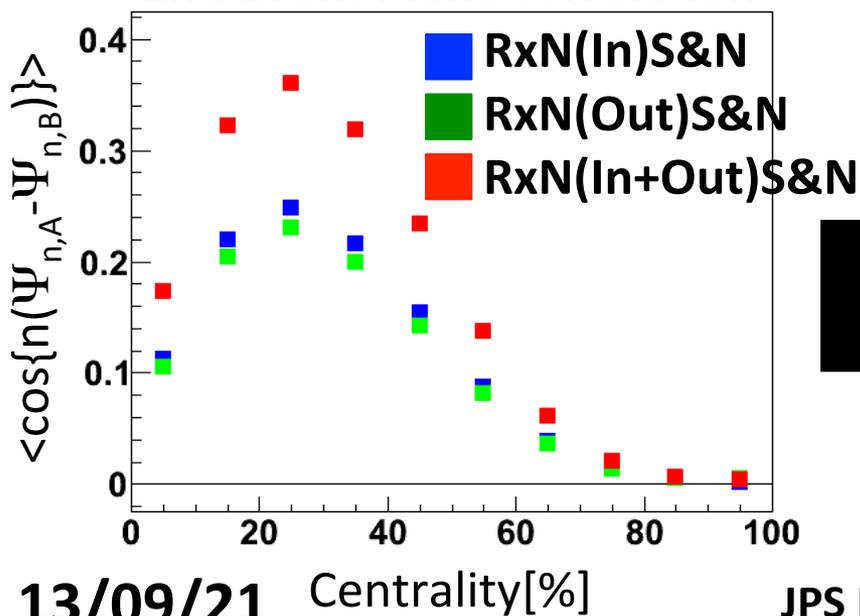


Reaction Plane detector(RxN)

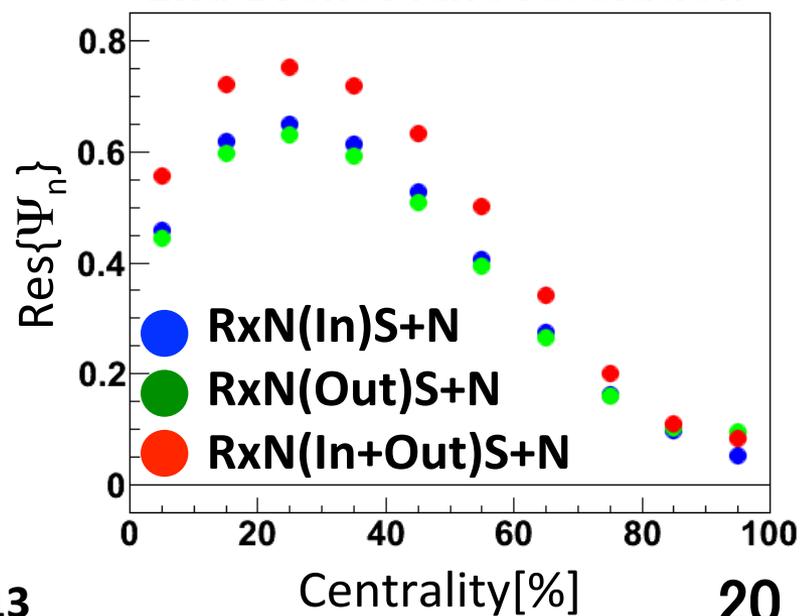
Inner : $1.5 < |\eta| < 2.8$

Outer : $1.0 < |\eta| < 1.5$

2nd Event Plane correlation



2nd Event Plane resolution



13/09/21

Centrality[%]

JPS Kochi 2013

Centrality[%]

20