

Low- p_T direct photons in heavy ion collisions in PHENIX

----- with many contributions from
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Outline

- Photon measurement techniques
- Elliptic flow and yield
- Direct photon puzzle
- New results from PHENIX
- Summary

Photon measurements

Partially overlapping results obtained with the three basic methods: very consistent

- **Calorimeter method**

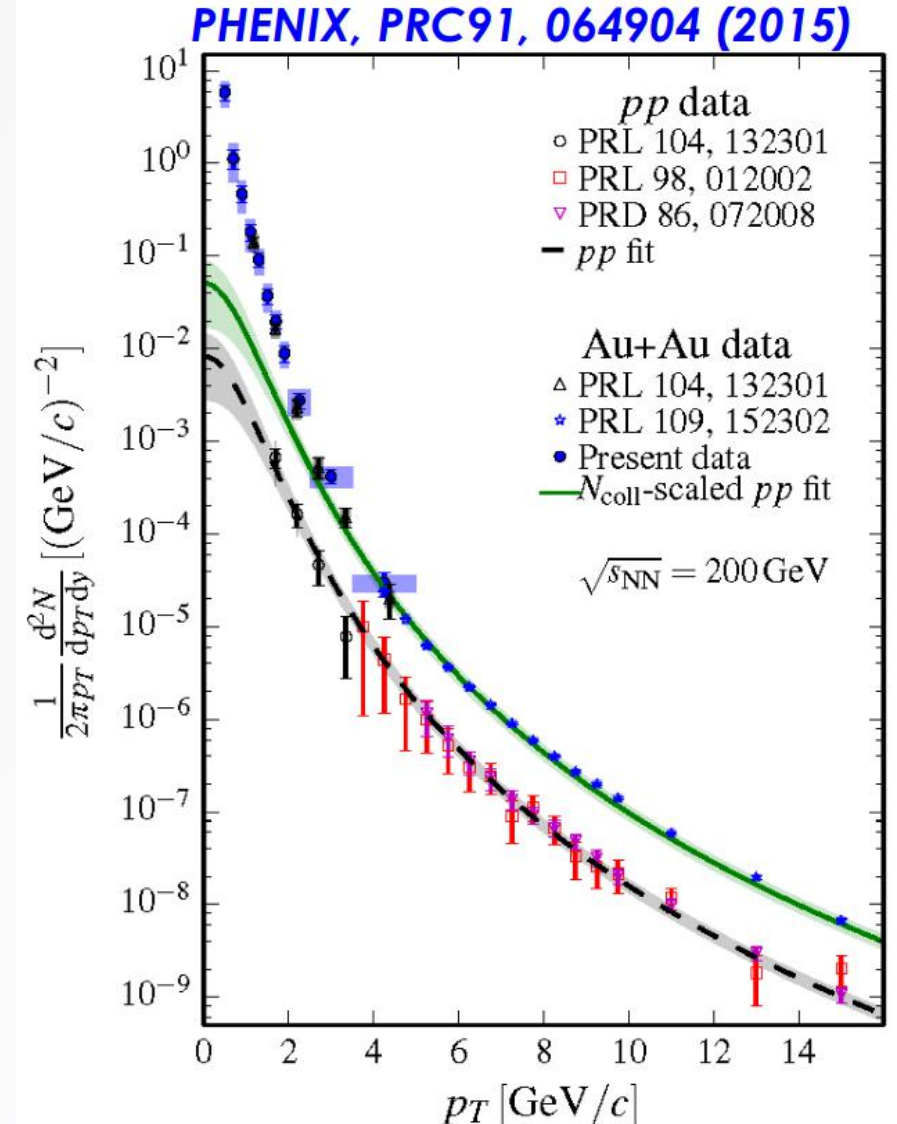
- Good resolution and statistics at high p_T
- Low p_T contaminated by hadrons

- **Internal photon conversions**

- ≡ Measure virtual photons
- ≡ Low p_T reach is limited (above 1GeV) as well as high p_T

- **External photon conversions**

- ≡ Measure real photons
- ≡ Extends to $p_T \ll 1$ GeV
- ≡ High p_T reach is limited
- ≡ Little Hadron contamination
- a. HBD conversions(old)
- b. VTX conversions(new)

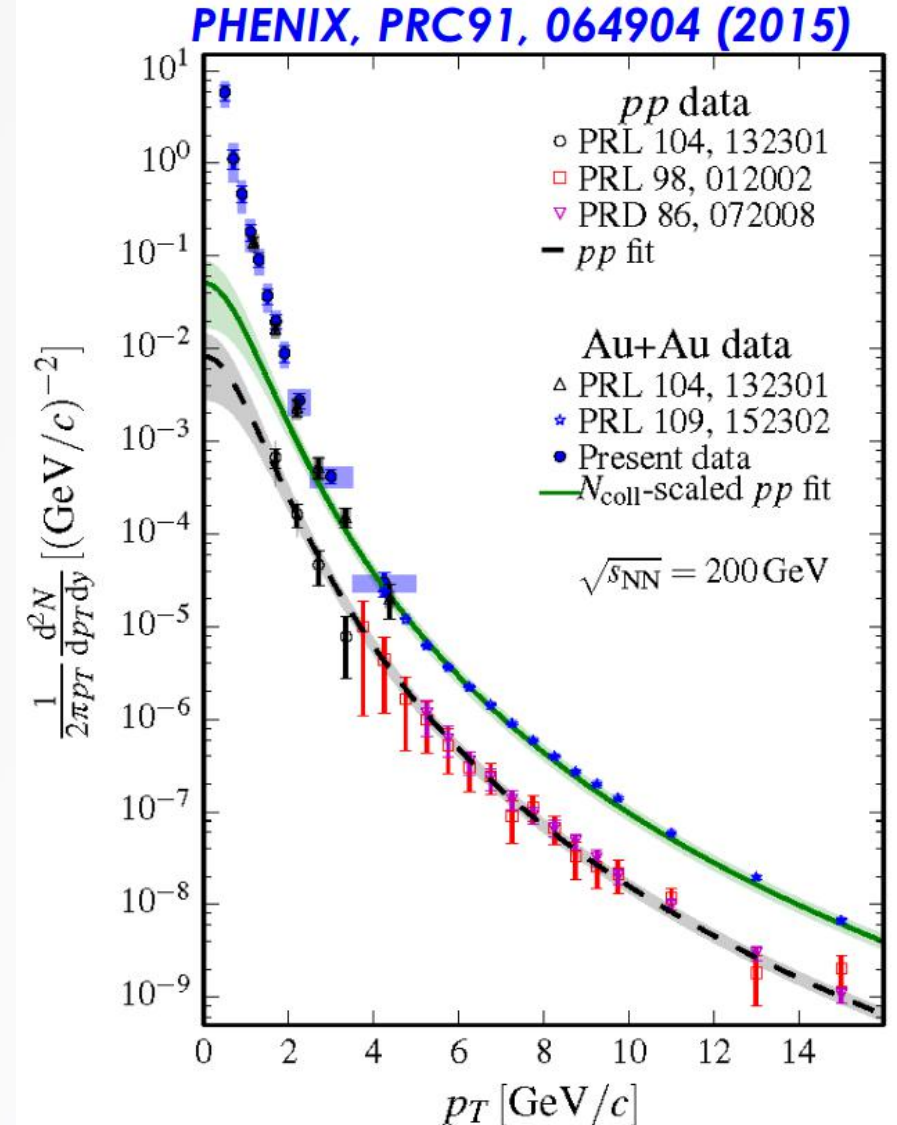


Photon measurements

Partially overlapping results obtained with the three basic methods: very consistent

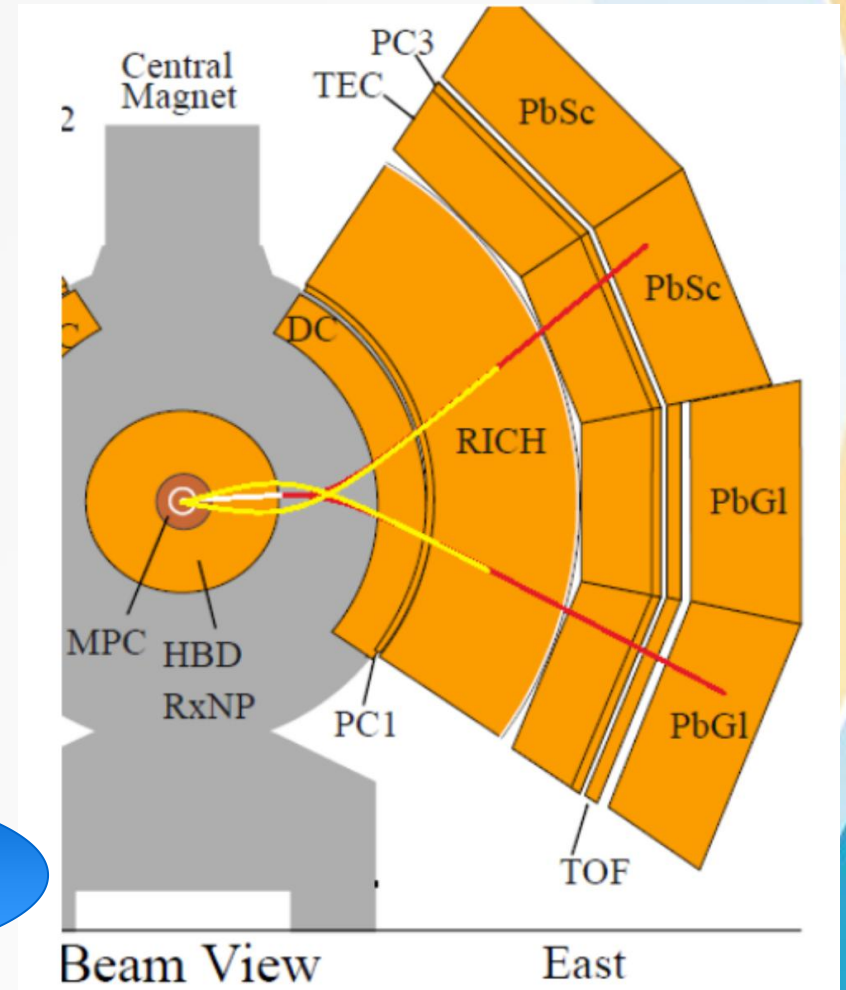
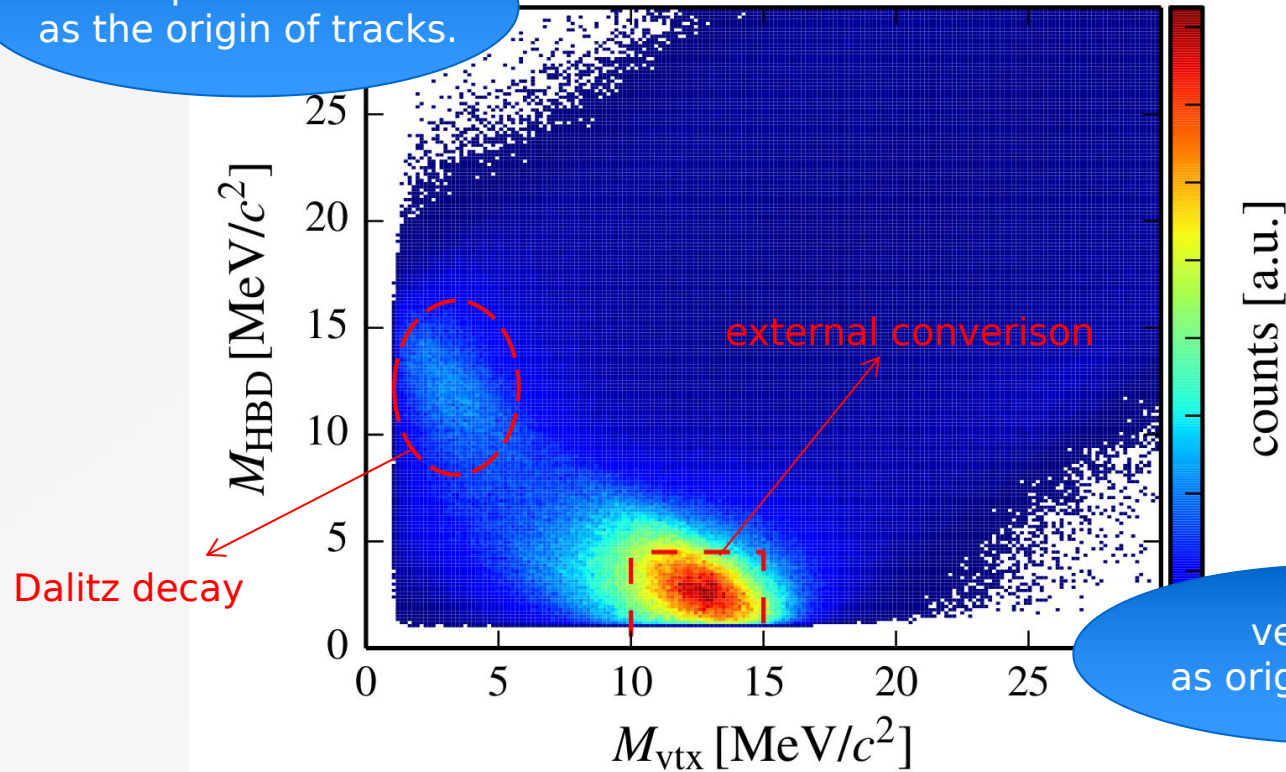
Direct photon yield from heavy ion collisions:

- p+p collisions are consistent with the pQCD
- Au+Au collisions at $p_T > 4$ GeV/c are consistent with the N_{coll} scaled p+p
- Excess photons in Au+Au at $p_T < 3$ GeV/c with the inverse exponential slope of $T \sim 240$ MeV



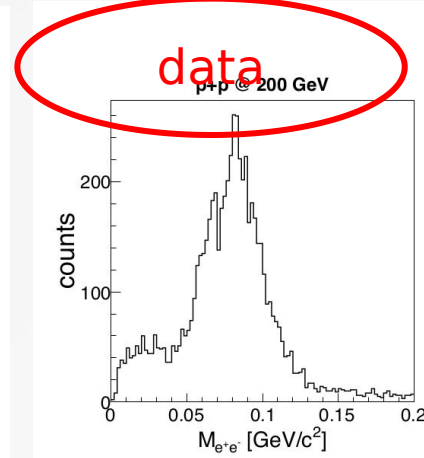
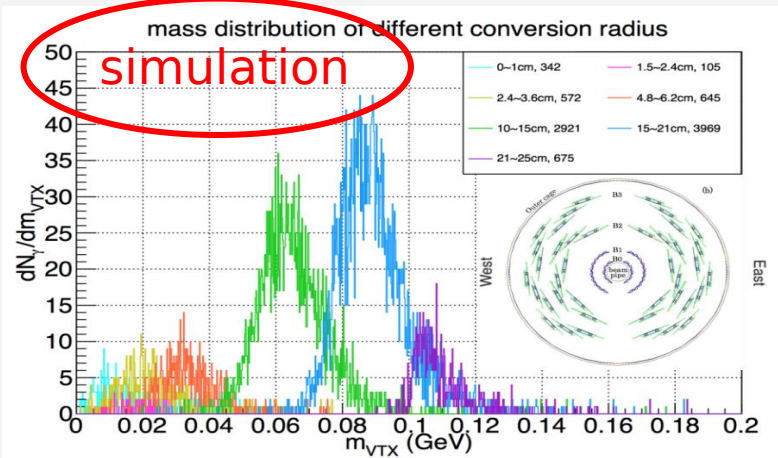
HBD conversion method

Back plane of HBD as the origin of tracks.

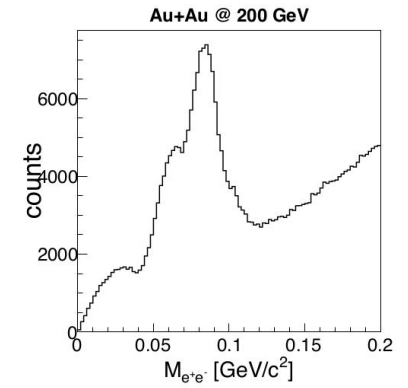
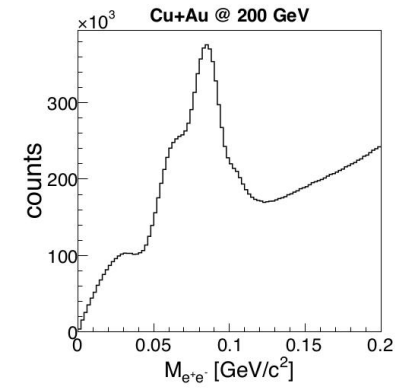
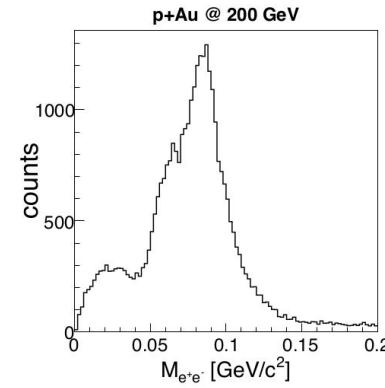


- This method has been used for 39GeV, 62.4GeV and 200GeV in Au+Au collisions.

VTX conversion method



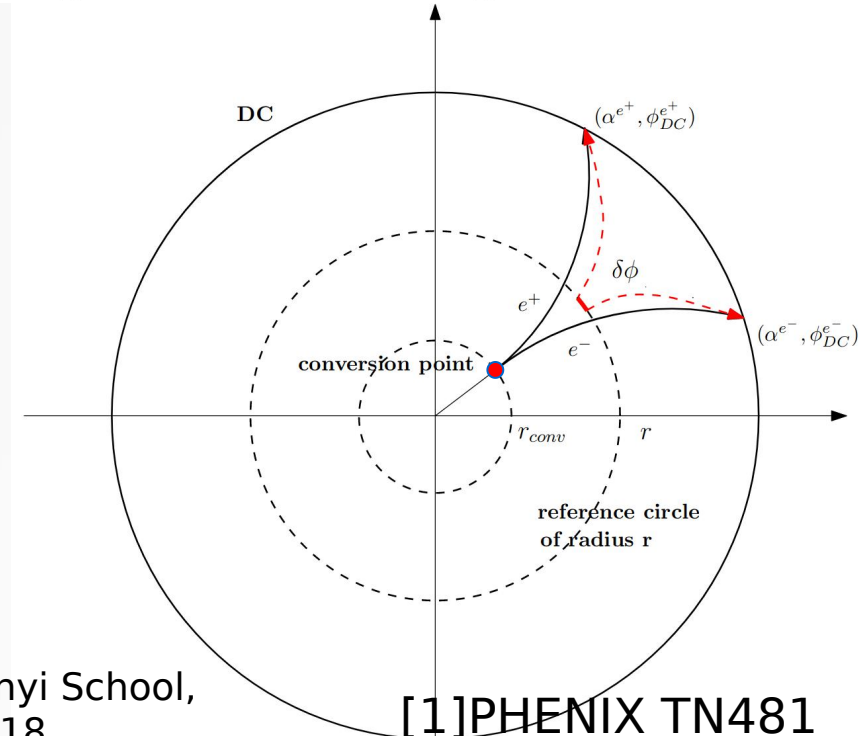
$2.0 < p_T < 2.5$ GeV/c



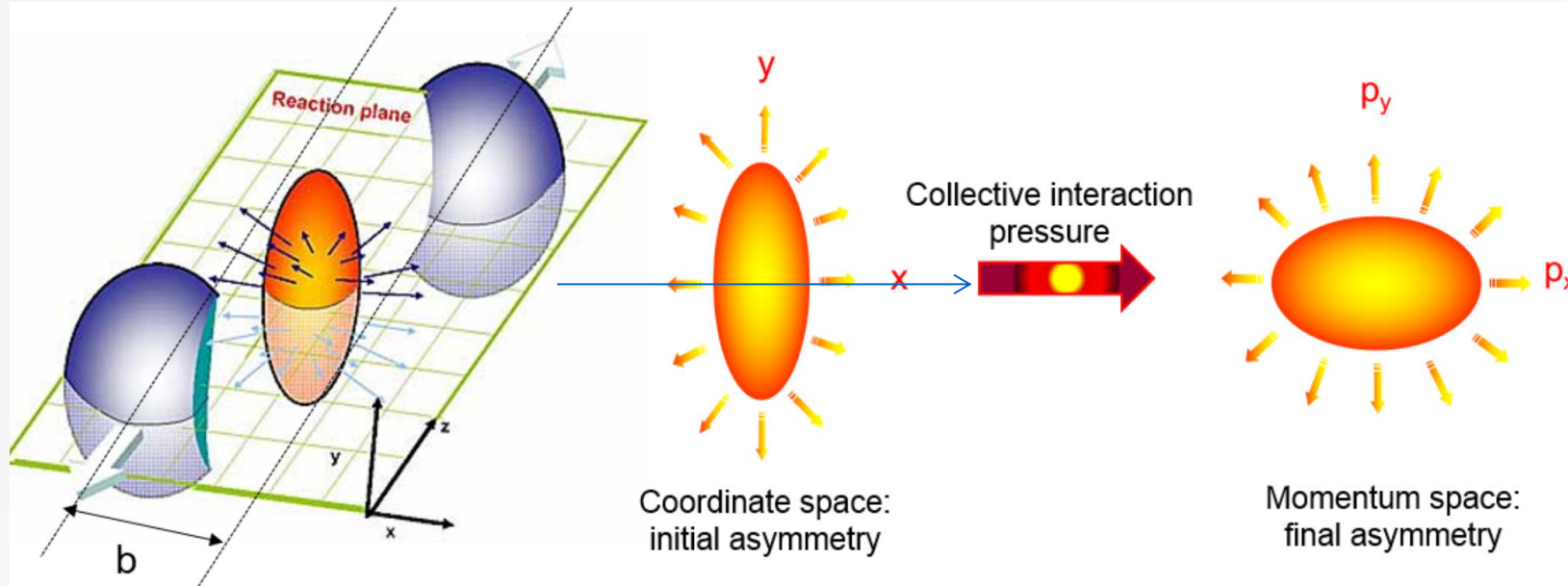
Track pair selection:

1. Tracks intersect
2. At the intersection opening angle $\delta\Phi = 0^\circ$

The photon selected with our new method have a high purity.



Elliptic flow



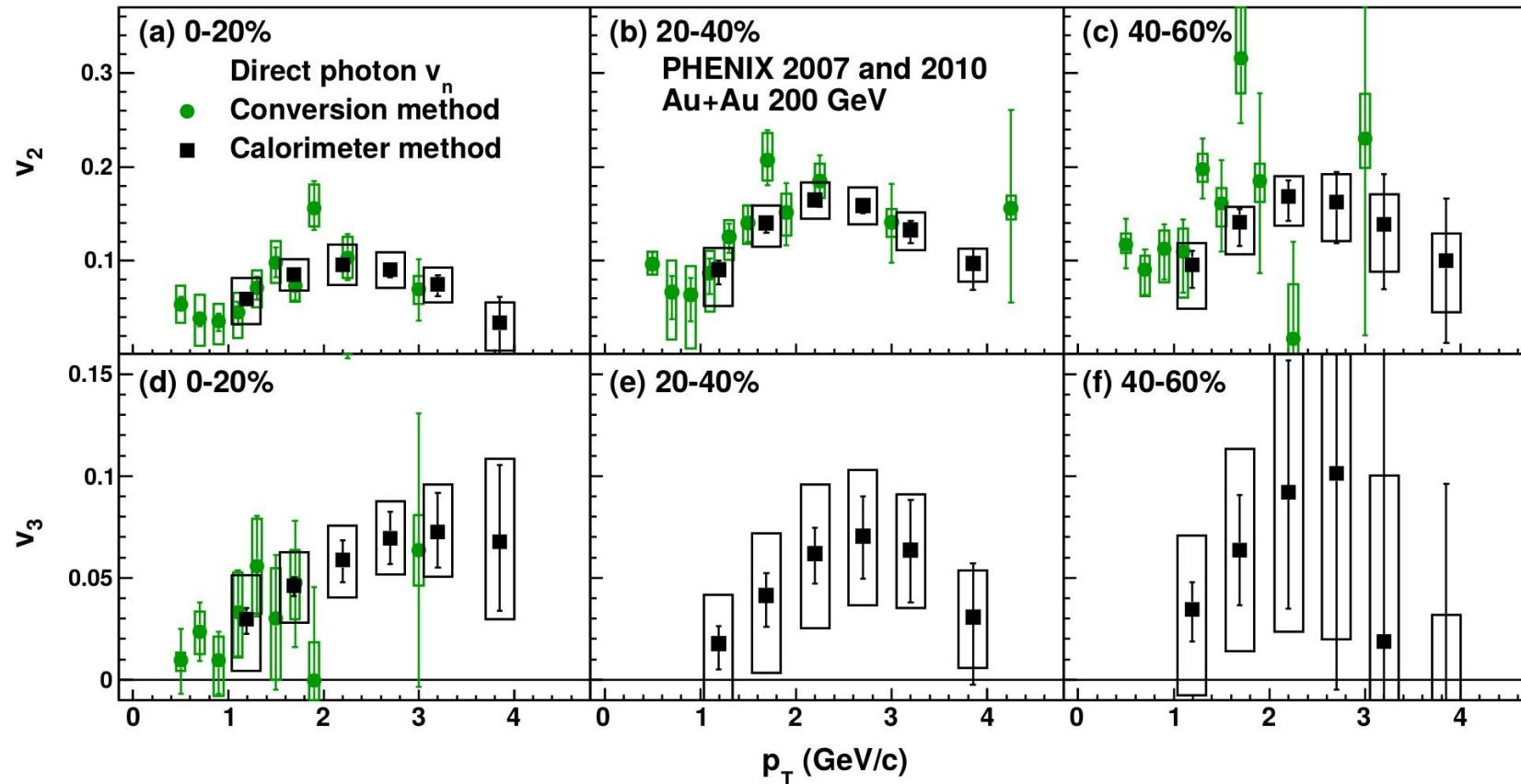
Elliptic Flow

$$dN/d\varphi \propto N_0(1+2\mathbf{v}_2\cos(2\varphi))$$

where φ is the relative azimuthal angle with respect to the reaction plane. \mathbf{v}_2 is a powerful probe of the initial state of high energy heavy ion collisions.

Elliptic flow

v_2 by HBD external conversion and calorimeter methods in AuAu at $\sqrt{s}=200$ GeV in Run07 and Run10



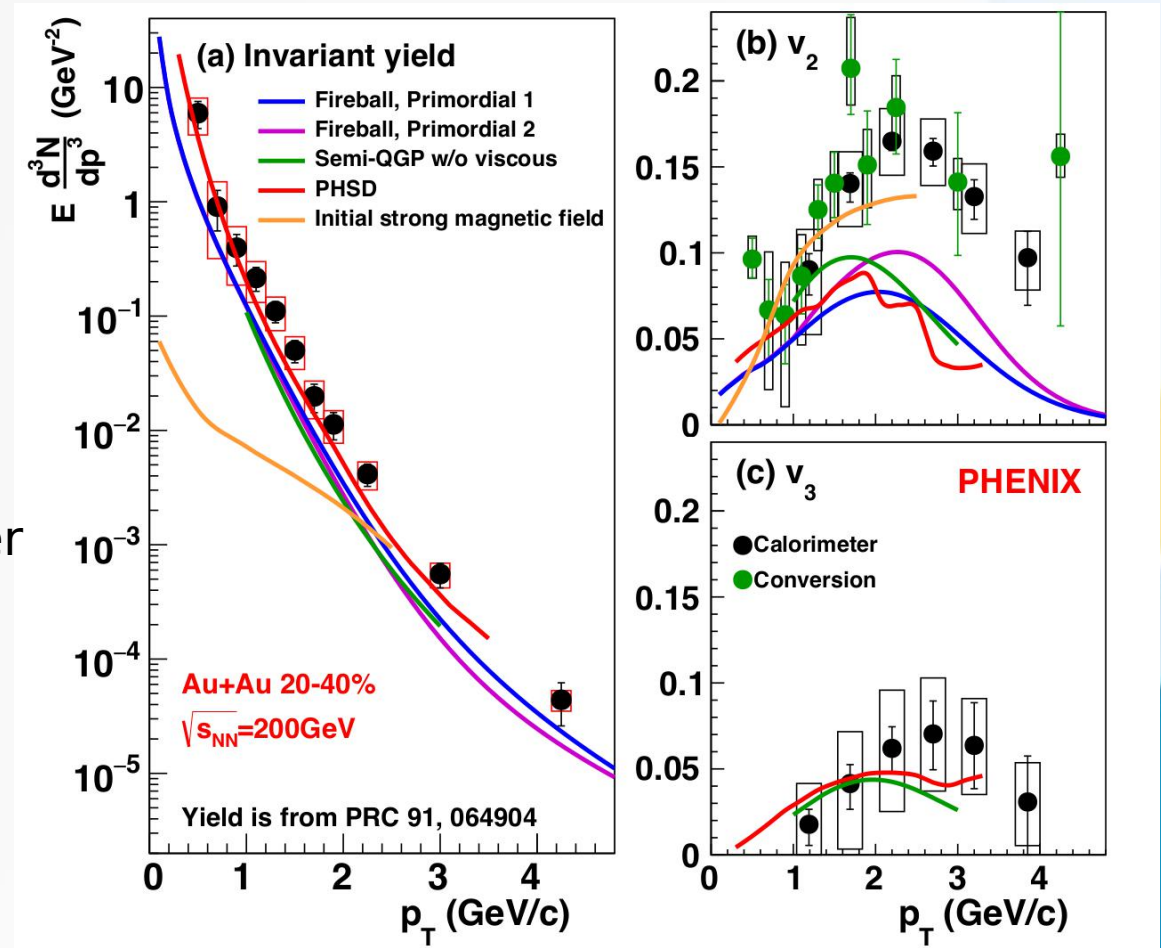
Anisotropic emission of direct photon with v_2 and v_3

[1]PRC 94, 064901

Direct photon puzzle

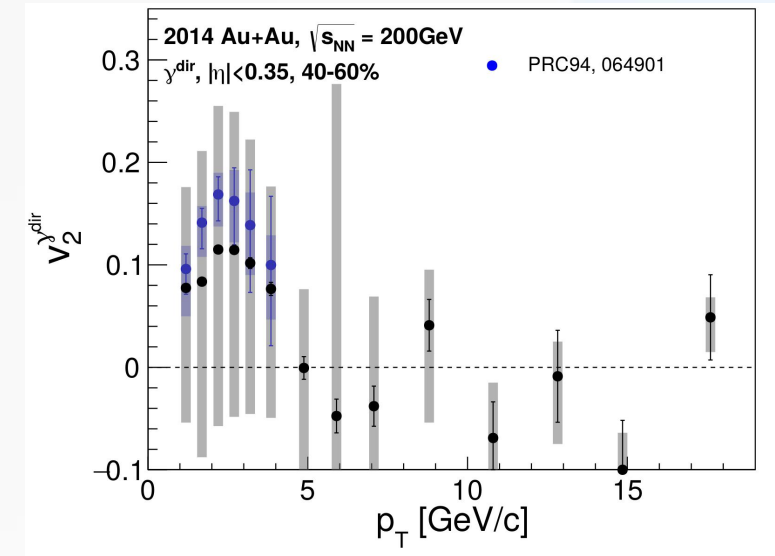
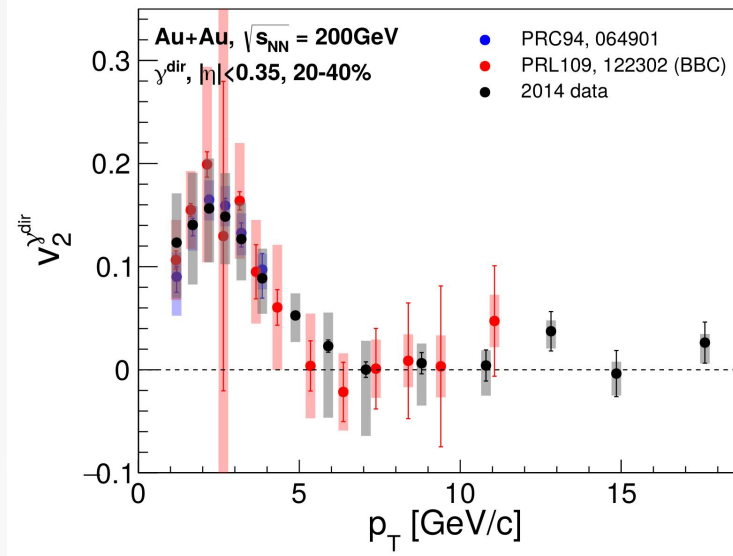
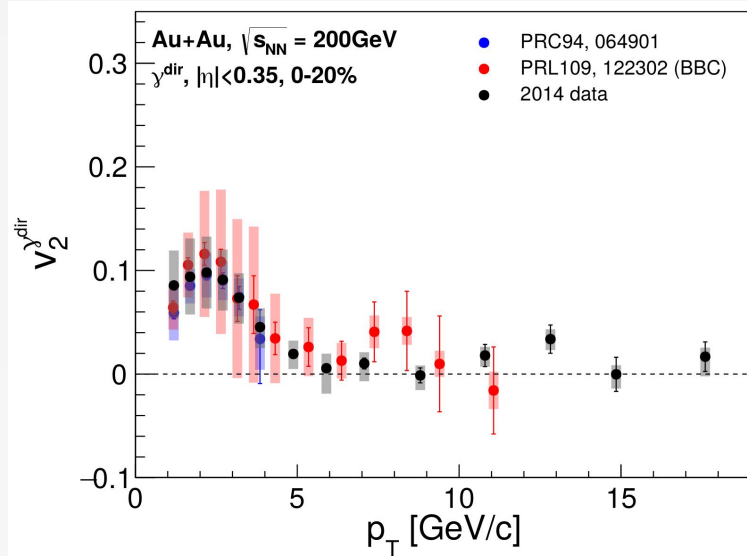
- Large yield
 - ≡ Emission from the early stage where temperature is high
- Large elliptic flow
 - ≡ Emission from the late stage where the collectivity is sufficiently built up
- Theoretical models
 - ≡ Comparison shows large deviation in either the yield or the v_2/v_3 .
 - ≡ New sources are considered from non-equilibrium states.
 - ≡ Extended emission time?

Theoretical models struggle in understanding the direct photon data in Au+Au collisions at 200 GeV



Elliptic flow(v_2)

v_2 by three methods including VTX external conversion method in AuAu at $\sqrt{s}=200$ GeV in Run14

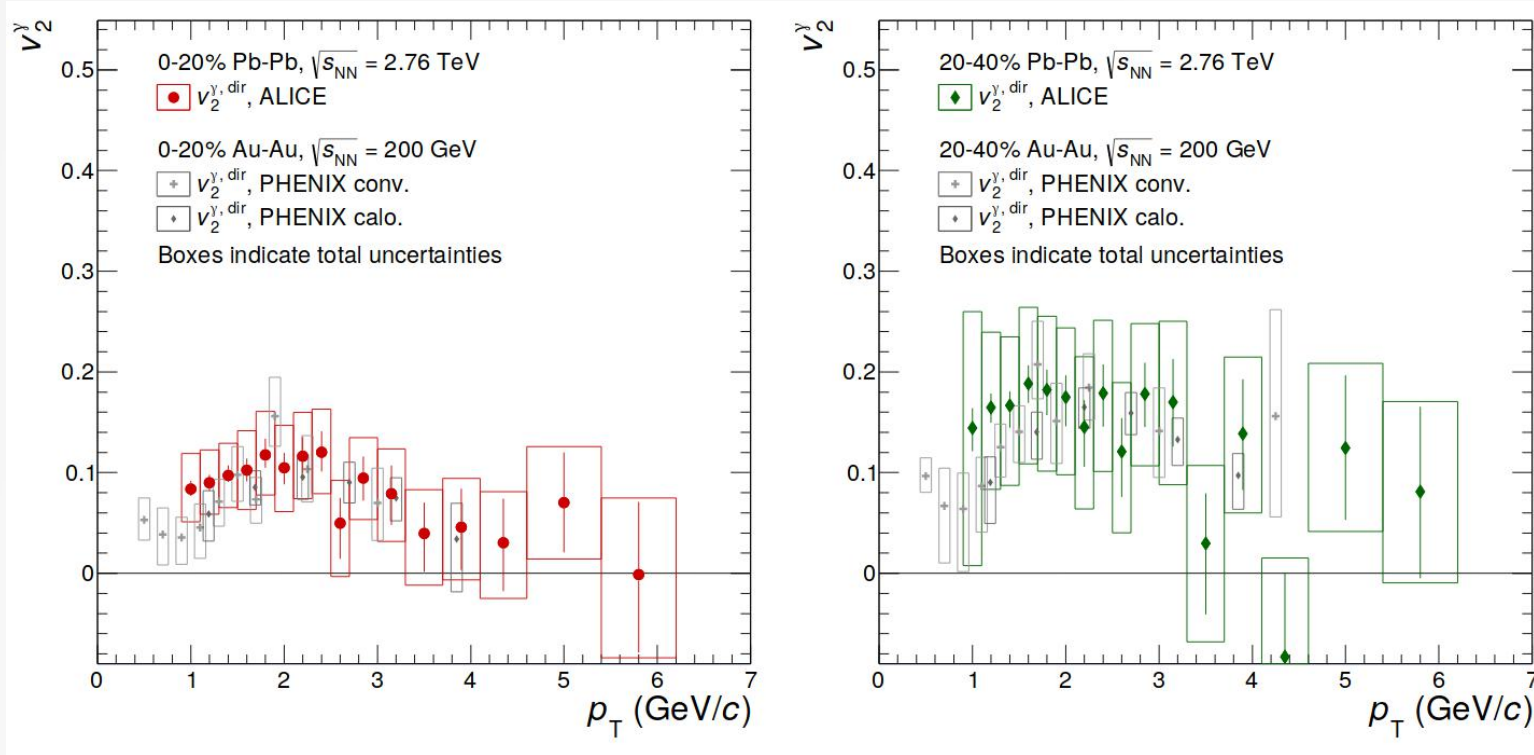


At high- p_T , v_2 remains constant around 0 because the majority of high-pt direct photons are from hard scattering which occurs before flow is built up.

[1]PHENIX AN1292

Elliptic flow(v_2)

v_2 in PbPb at $\sqrt{s}=2.76$ TeV at ALICE



In their final result ALICE now also finds significant direct photon flow in 2.76TeV Pb+Pb, similar to the PHENIX flow results in 200GeV AuAu.

[1]arXiv 1805.04403

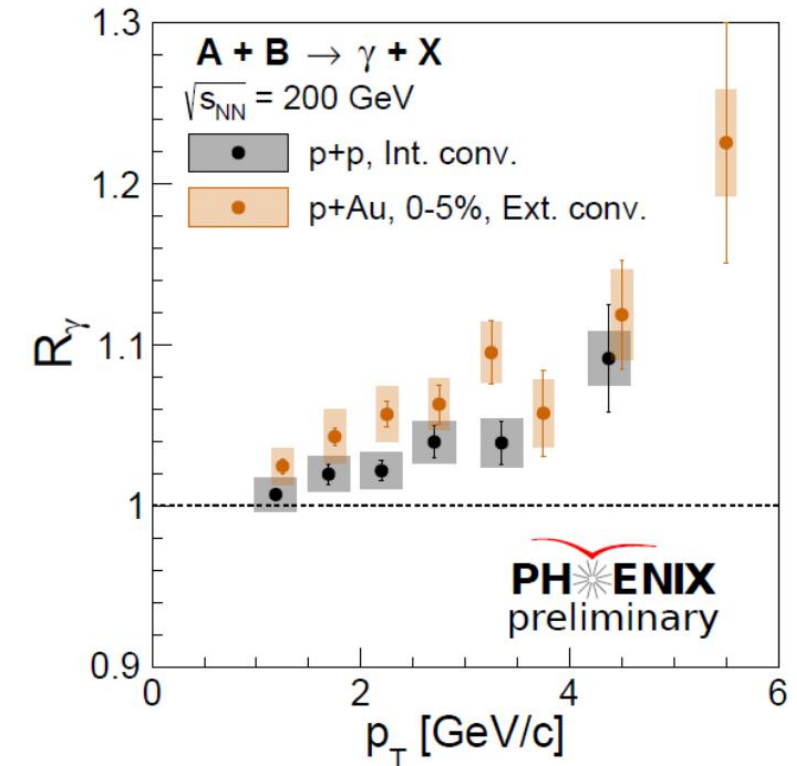
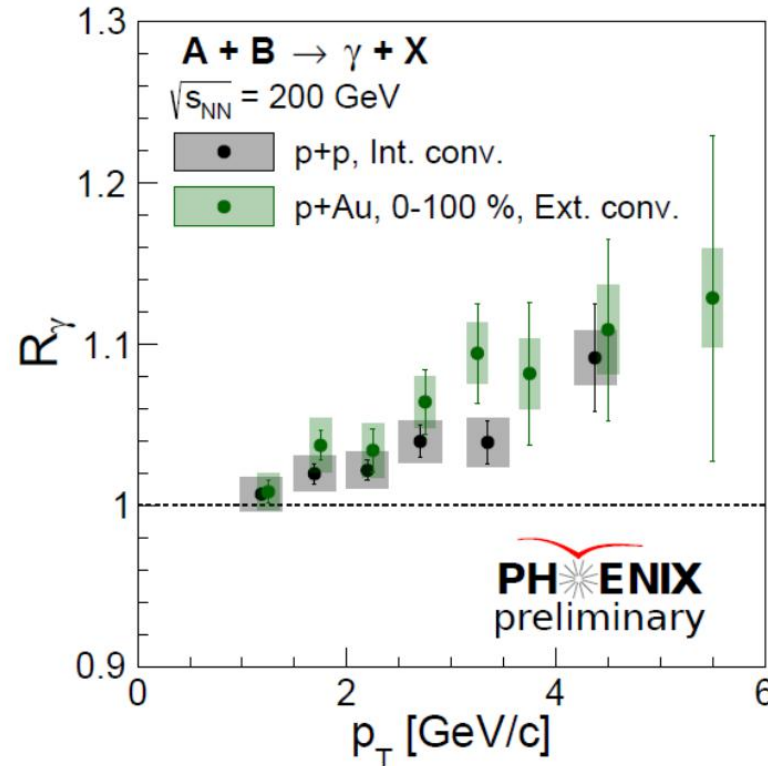
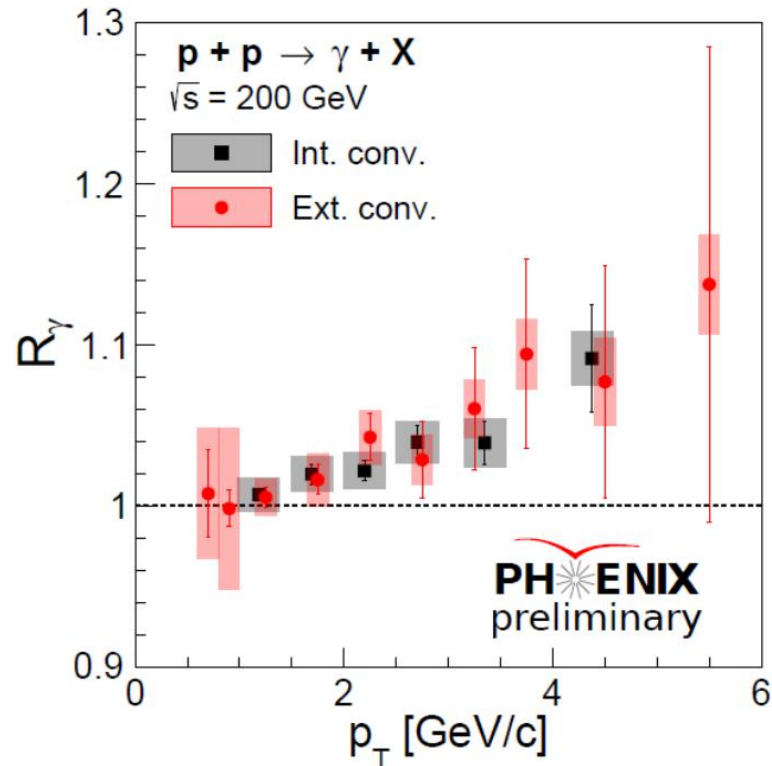
New results from PHENIX

[1] PPG086/088

$$R_\gamma = \frac{\gamma_{inclusive}}{\gamma_{decay}}$$

small systems:

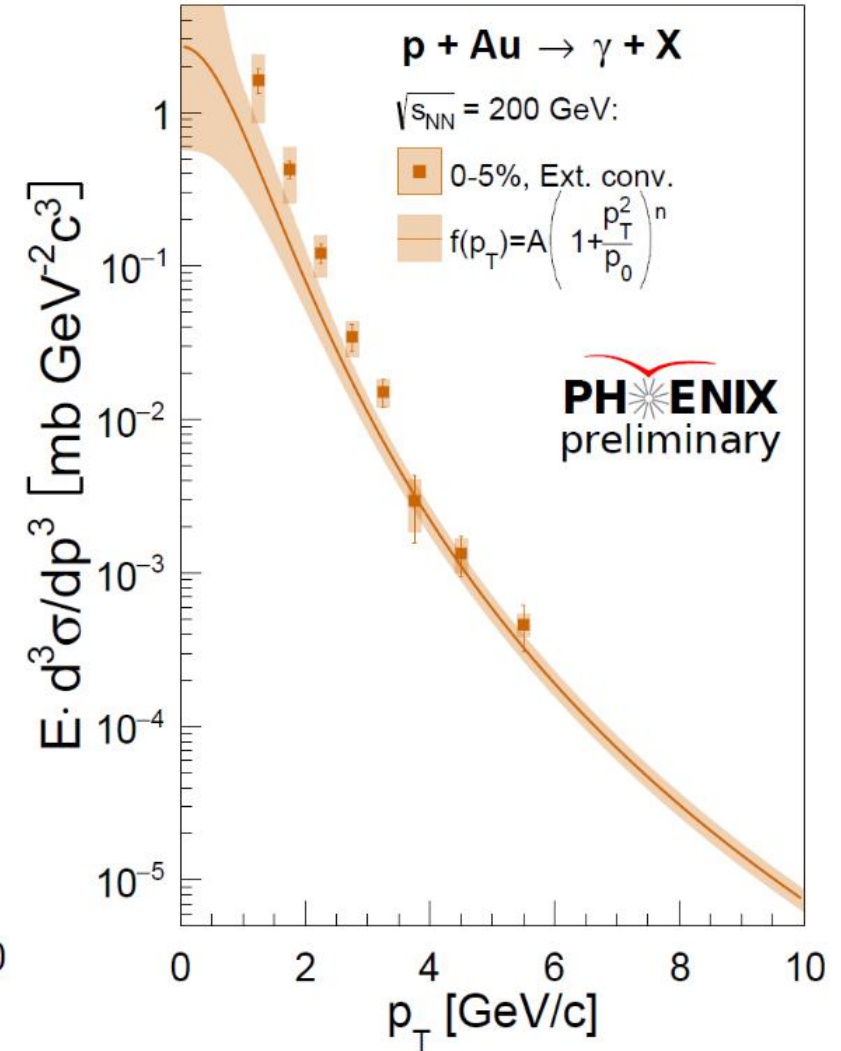
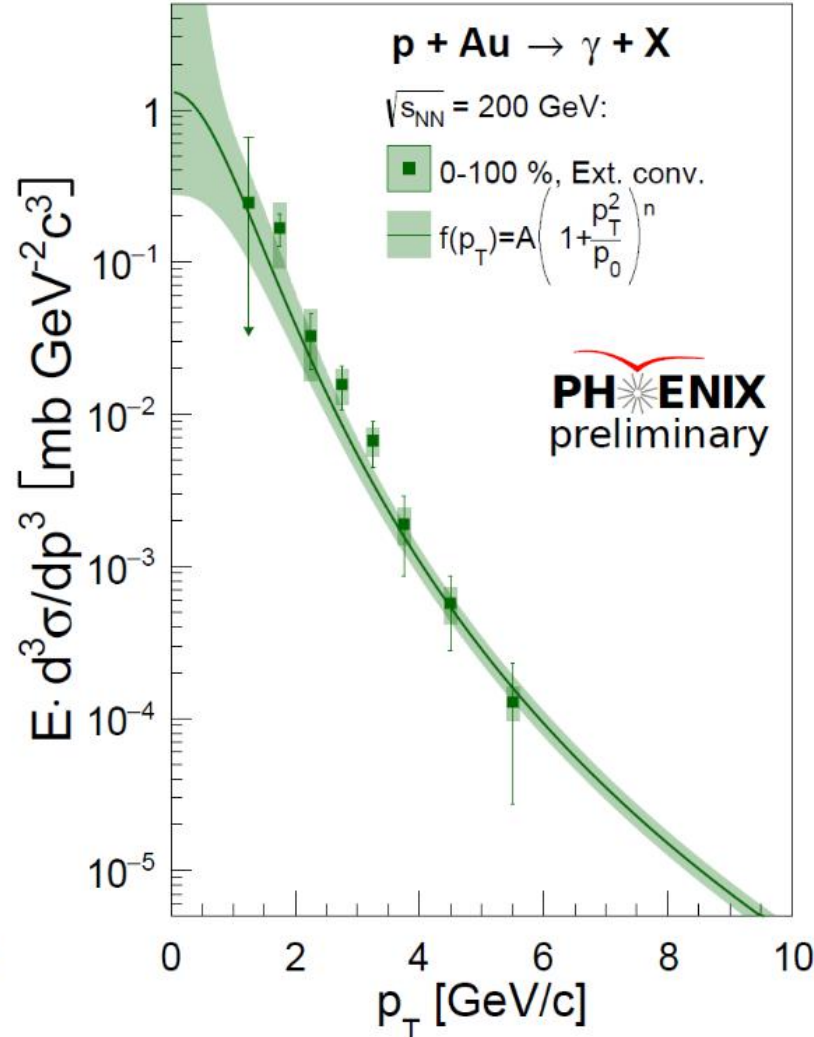
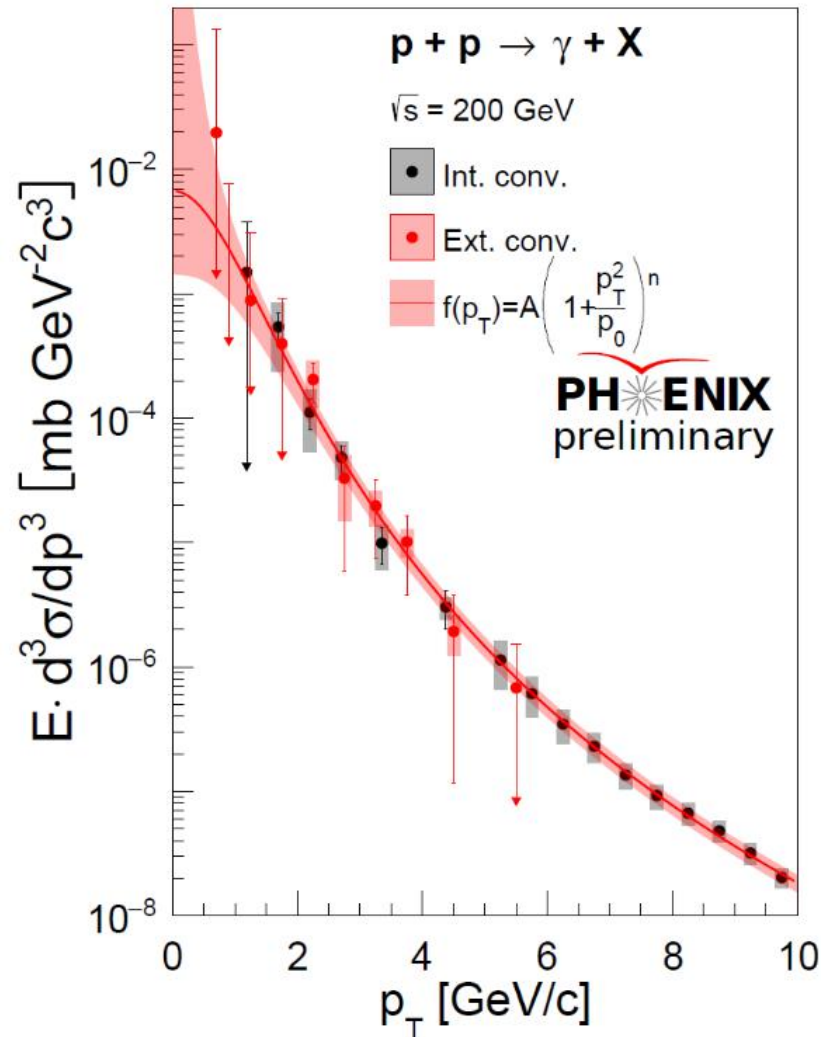
- R_γ in p+p and p+Au at 200GeV by External conversion and previous Internal conversion results^[1].



New results from PHENIX

small systems:

- p+p and p+Au at 200GeV



12/3/2018

Zhandong Sun, Zimanyi School,
Budapest, 2018

Summary

- Using three largely independent techniques, the consistent results both for the yields and azimuthal anisotropies of direct photons production in 200 GeV Au+Au collisions confirmed the 2011 observations by PHENIX that direct photon elliptic flow is comparable to that of hadrons at low- p_T .
- Recently ALICE published similar results at LHC energies.
- Excess photons in the most central p+Au collision are seen.



Thank you for your attention!