Low p_T direct photon production from small to large systems

Wenqing Fan for PHENIX Collaboration
Stony Brook University

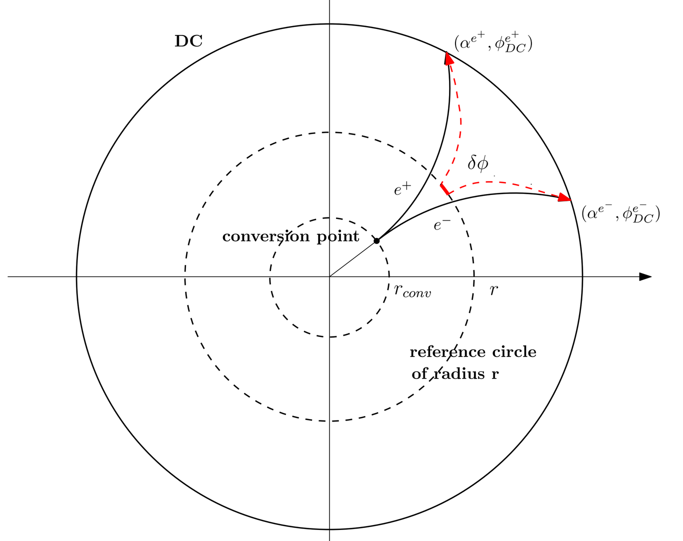
Abstract

Direct photons are unique probes to study both the thermal and collective properties of the Quark Gluon Plasma (QGP). PHENIX has discovered a large excess of the direct photon yield as well as a large azimuthal anisotropy at the low p_T region in Au+Au collisions at 200 GeV. The two observations of large yield and anisotropy are quite challenging for the current theoretical models to reconcile simultaneously. To provide more constrains and insights to the theoretical picture, PHENIX is making a more precise measurements for both yield and anisotropy using the high statistics data sample of Au+Au collisions taken in 2014, where photons are reconstructed via conversions to e^+e^- pairs. As evidence mounts for a collective behavior in small systems, PHENIX also measured the direct photon production in p+Au collisions to see if there is any thermal signal in small systems. In this poster we will present the updated result on direct photon azimuthal anisotropy v_2 in Au+Au collisions at 200 GeV and the direct photon yields in p+Au collisions at the same beam energy.

Photon Identification

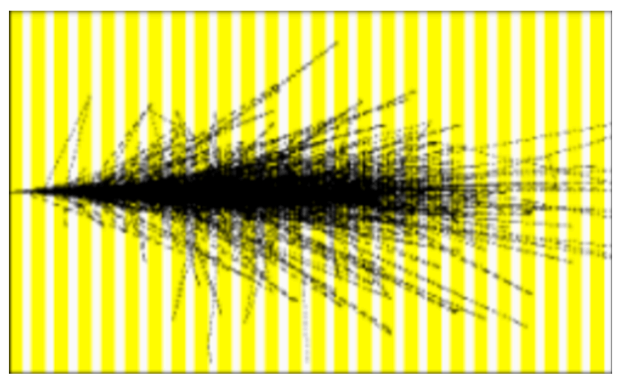
Conversion photon sample (conversions at VTX):

- Single cut: eID cut
- Pair cut: conversion position cut



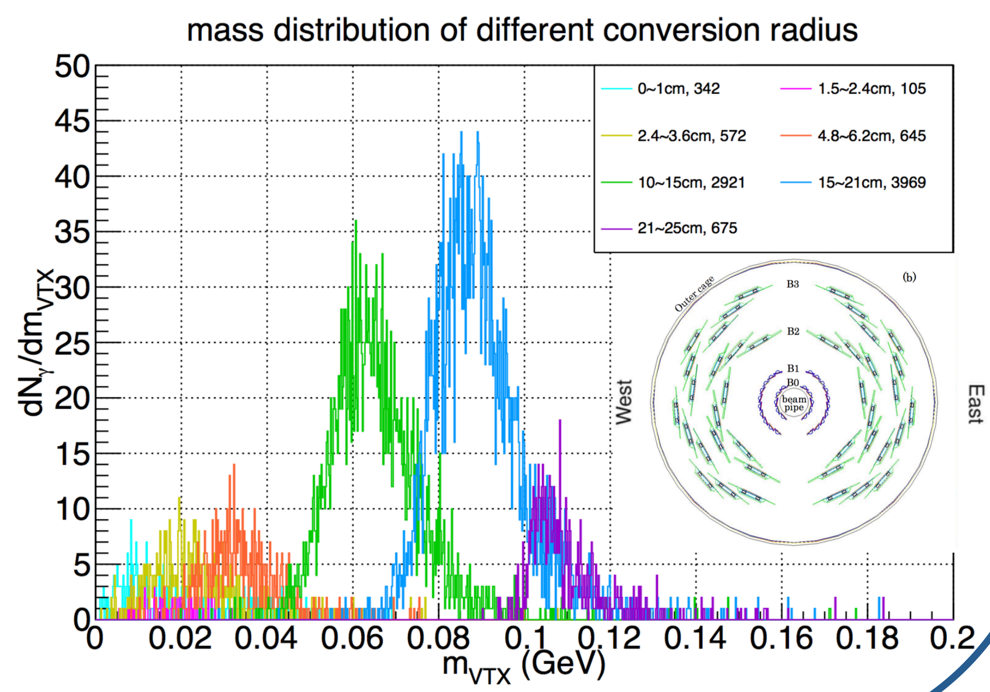
Calorimeter photon sample (real photons in EMCal):

- Shower shape cut



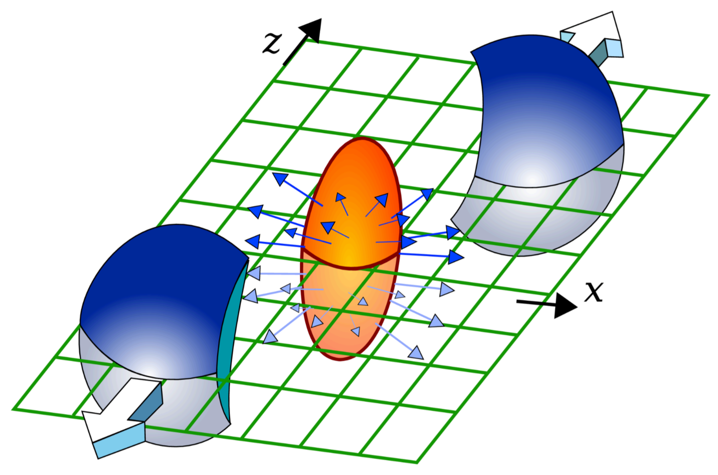
New Reconstruction Method:

- Reconstruct all tracks to the real conversion point
- Conversions at any material (mainly VTX 3rd and 4th layer, ~5% for each strip)
- Could be used in various systems (Cu+Au, Au+Au, He3+Au, p+p, p+Au)



From High p_T to Low p_T

Measure azimuthal distribution of inclusive photons with respect to event plane:



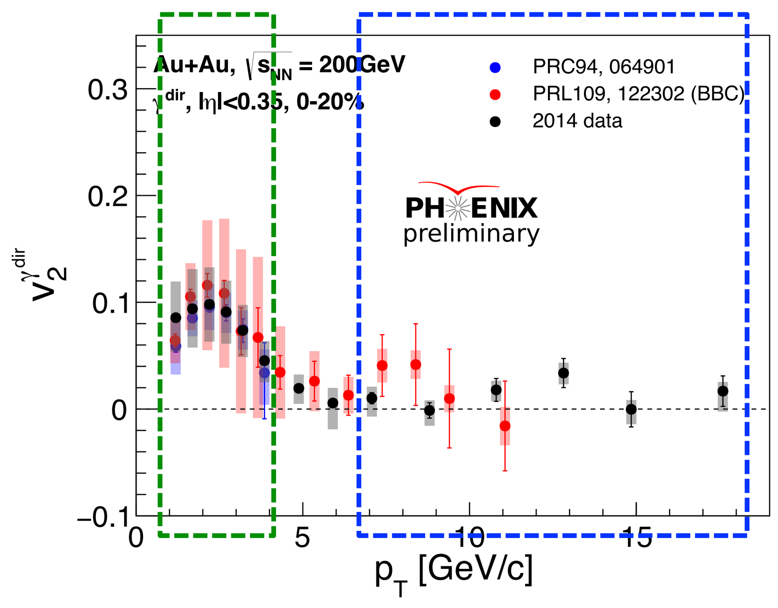
$$\frac{dN}{d\Delta\phi} = N_0\left[1 + 2v_2^{obs}\cos(2\Delta\phi) + 2v_4^{obs}\cos(4\Delta\phi)\right]$$

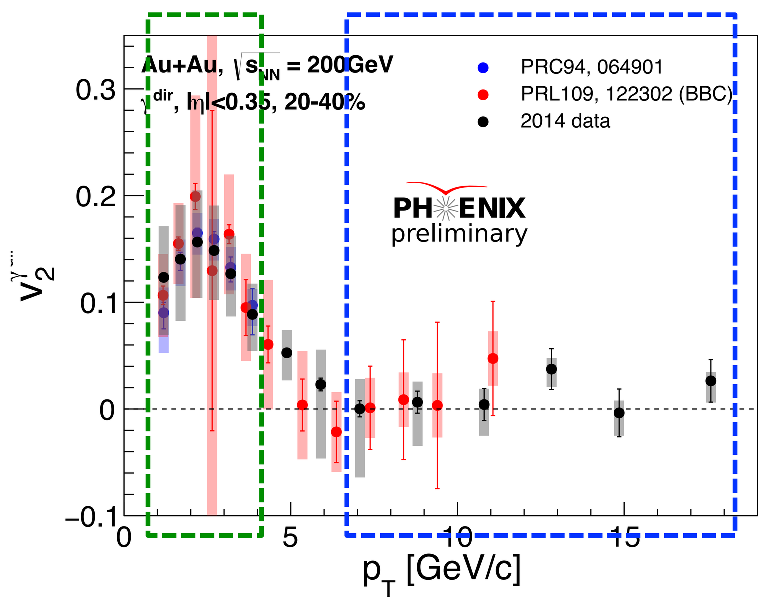
$$v_{2k} = \frac{v_{2k}^{obs}}{Res\{2k\Psi\}} = \frac{\langle\cos(2k[\phi-\Psi])\rangle}{\langle\cos(2k[\Psi-\Phi])\rangle}$$

Subtract the decay photon contribution from inclusive

$$v_n^{dir} = \frac{R_\gamma v_n^{incl} - v_n^{dec}}{R_\gamma - 1}$$

Direct photon v_2 at high p_T: ~0 azimuthal anisotropy ↔ **Dominant source of direct photon is from initial scattering**





Direct photon v_2 at low p_T: large azimuthal anisotropy ↔ **Mixture of direct photon from initial hard scattering and thermal radiation (QGP and HG)**

From High p_T to Low p_T

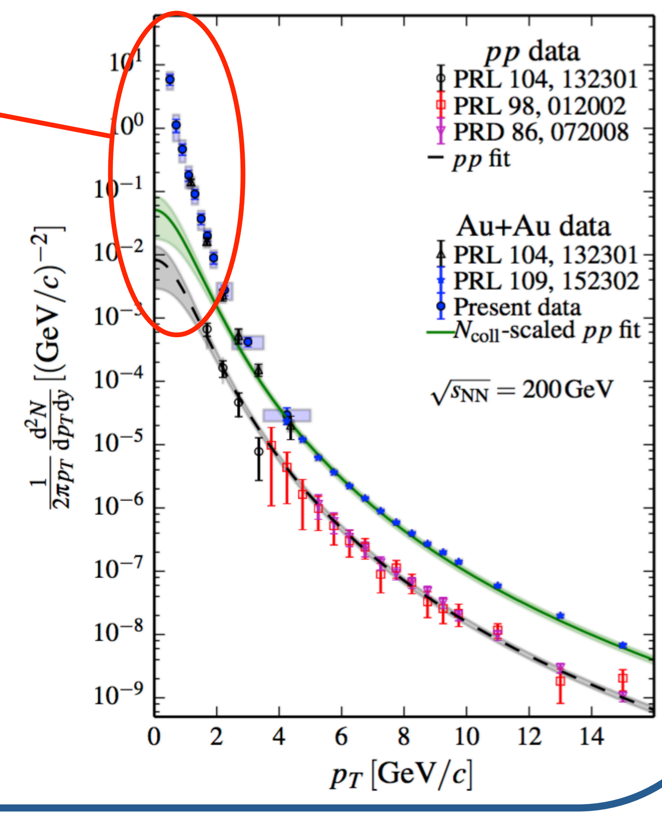
Large excess of low p_T (<3 GeV) direct photons above N_{coll} scaled p+p?

Large v_2: emission from the late stage when the collective flow is sufficiently built up

Large yield: emission from the early stage when temperature is high

⇩

Challenging for theoretical models to describe simultaneously (direct photon puzzle)



From Large to Small System

Strong flow signal like in A+A system is observed in small systems (p/d/³He+Au) ⇨ Is there hot medium created in small system?

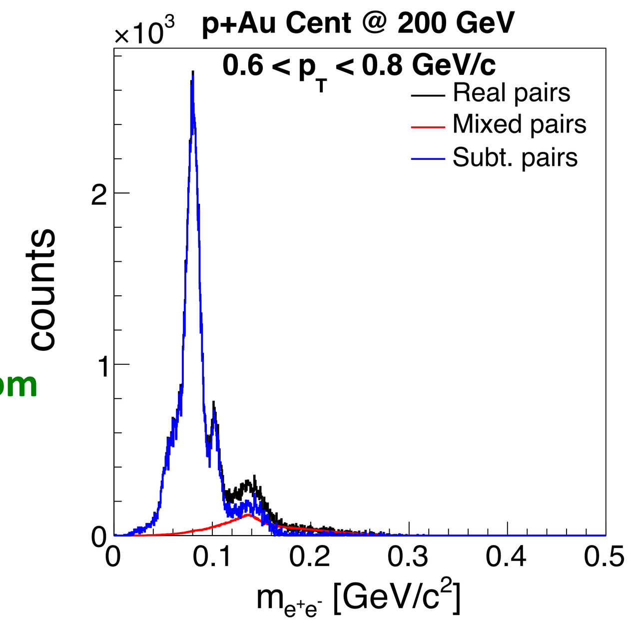
Direct photon signal (R_γ>1)?

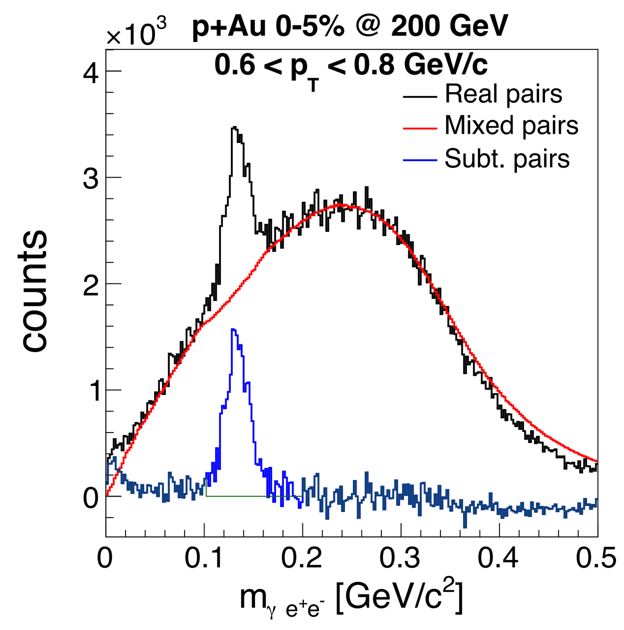
$$R_\gamma = \frac{\gamma^{incl}}{\gamma^{hadron}} = \frac{\langle\varepsilon_\gamma f\rangle \left(\frac{N_\gamma^{incl}}{N_\gamma^{\pi^0,tag}}\right)_{Data}}{\left(\frac{\gamma^{hadron}}{\gamma^{\pi^0}}\right)_{Sim}}$$

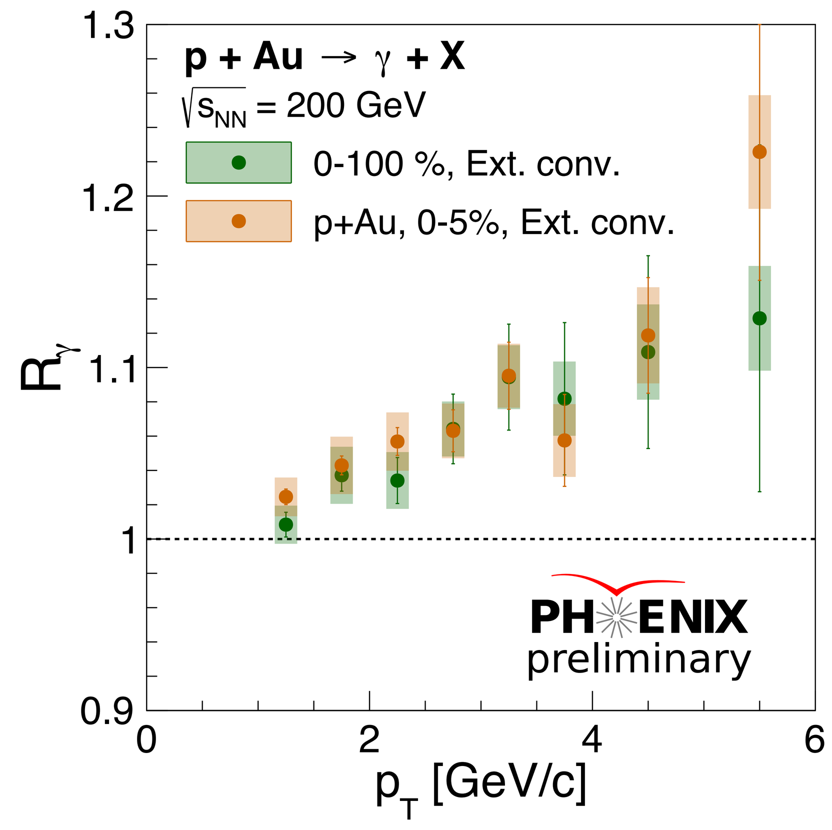
Conditional acceptance and efficiency

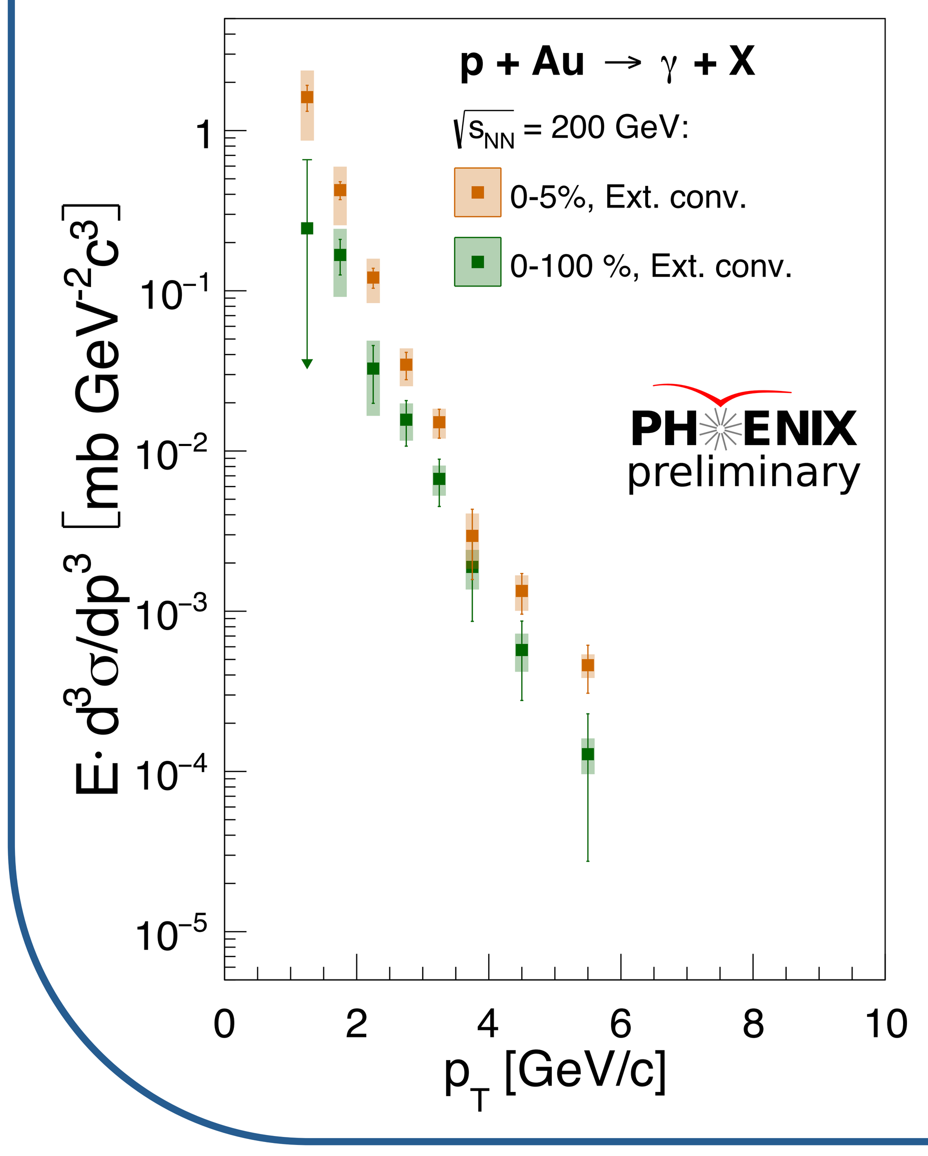
N^{incl}/N^{tag} from real data

Cocktail ratio from Exodus



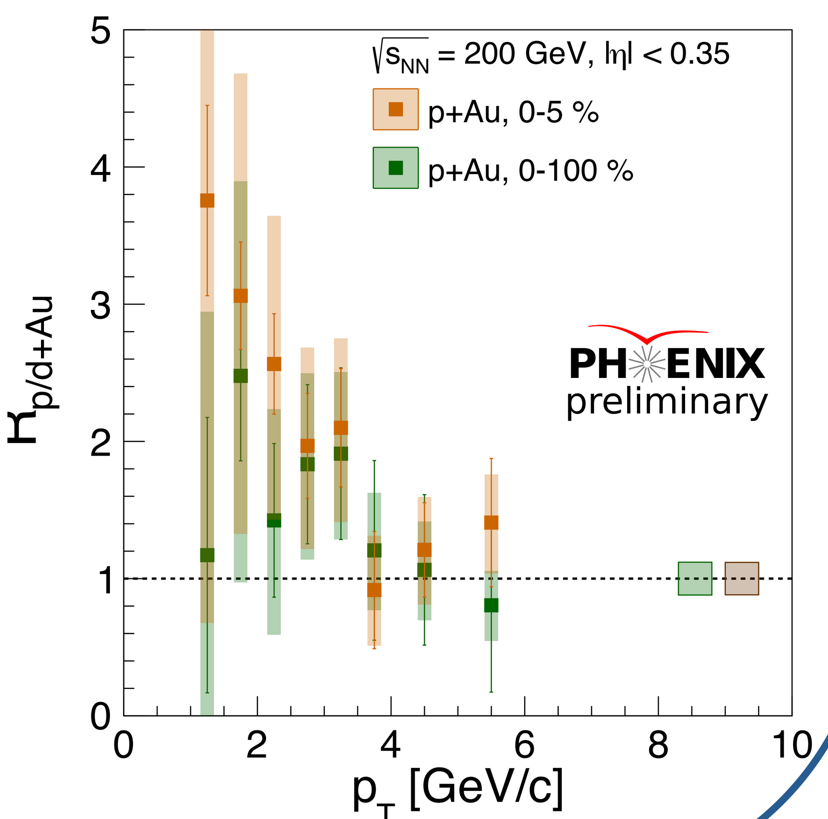






Excess of direct photon yield above N_{coll} scaled p+p (thermal photons) ?

$$R_{AA} = \frac{d^2N^{AA}/dp_T d\eta}{\langle N_{coll}\rangle d^2N^{pp}/dp_T d\eta}$$



Summary

New direct photon v_2 results in Au+Au 0-20% and 20-40% centralities:

- Good agreement with published results
- More precise direct photon v_2 at high p_T (consistent with 0)

New direct photon yield results in p+Au 0-5% and 0-100% centralities :

- Observation of direct photon signal at low p_T in 0-5%
- A hint of excess of direct photon yield above N_{coll} scaled p+p at low p_T in 0-5%

Contact: Wenqing Fan
Stony Brook University
Email: wenqing.fan@stonybrook.edu

References:

1. A.Adare et al, Phys. Rev. Lett. 109, 122302 (2012)
2. A.Adare et al, Physical Review C 91, 064904 (2015)
3. A.Adare et al, Physical Review C 94, 064901 (2016)
4. A.Adare et al, Phys. Rev. Lett. 109, 122302 (2012)