Direct Photon v_2 Study in 200 GeV AuAu Collisions at RHIC

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For STAR Collaboration

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Outline

- Motivation
- Analysis
  - Photon identification
  - Inclusive photon v_2
  - Decay photon v_2
- Conclusion & outlook

Motivation (I)

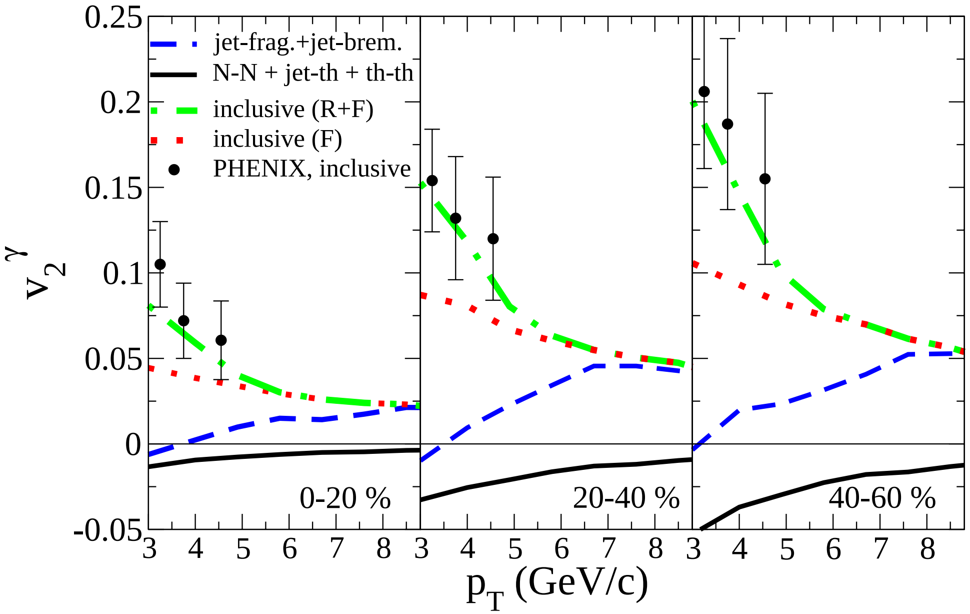
➢ QGP is an important source of direct photons. Studying direct photon v_2 involving QGP is a remarkable step toward establishing its existence and would provide a stringent test of the reaction dynamics.

➢ Different models predict different direct photon v_2 behaviors in mid-p_t range.

Negative direct photon v_2 is predicted:

• A mechanism works by absorption of particles or jets going through the medium (bremsstrahlung photon, Compton scattering).

• Positive strong space-momentum correlation.



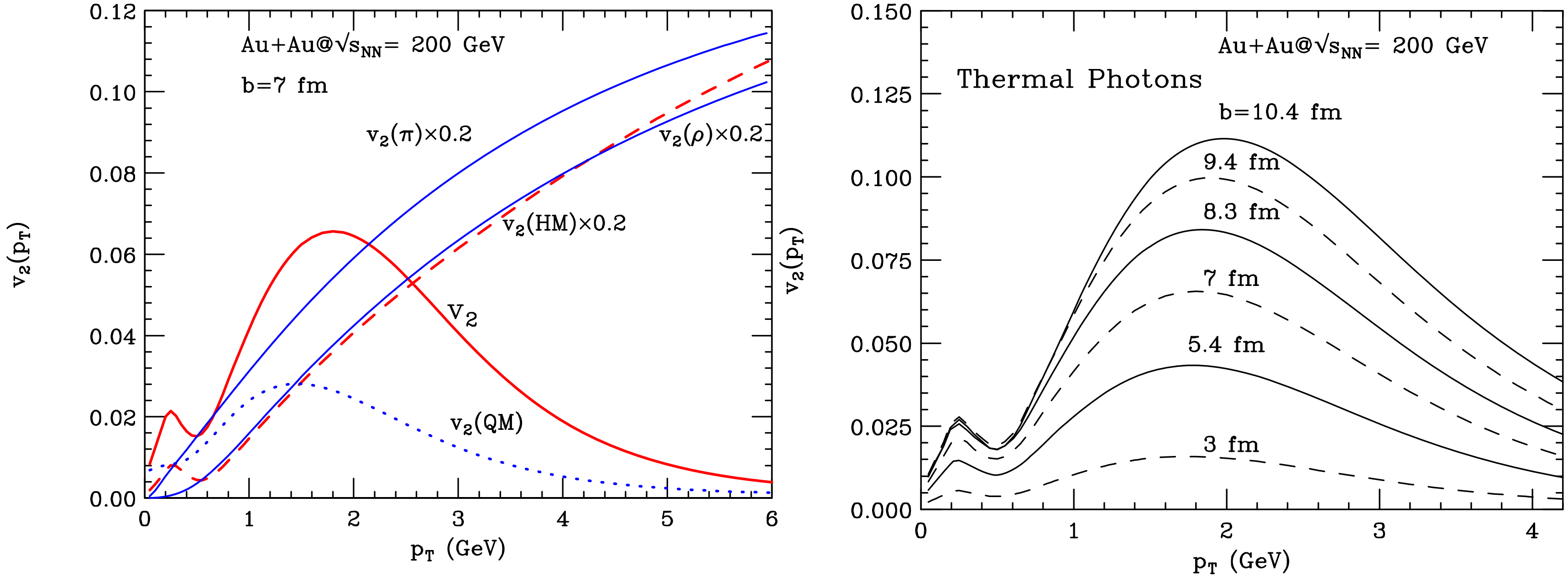
S. Turbide etc., PRL 96 (2006) 032303

Motivation (II)

Rich structure of thermal photon v_2 is predicted:

➢ At low p_t a reduction of photon v_2 around p_t~0.4 GeV. Hadronic photon flow tracks the elliptic flow of thermal π (ρ) mesons when p_t< (>) 0.4 GeV.

➢ At high p_t the overall photon v_2 approaches the v_2 of QGP thermal photons.

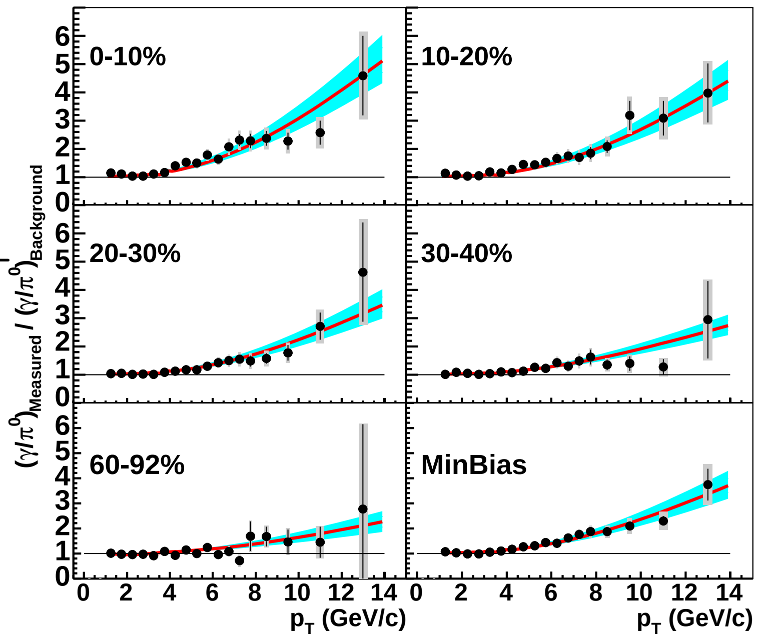


R. Chatterjee etc., nucl-th/0511079

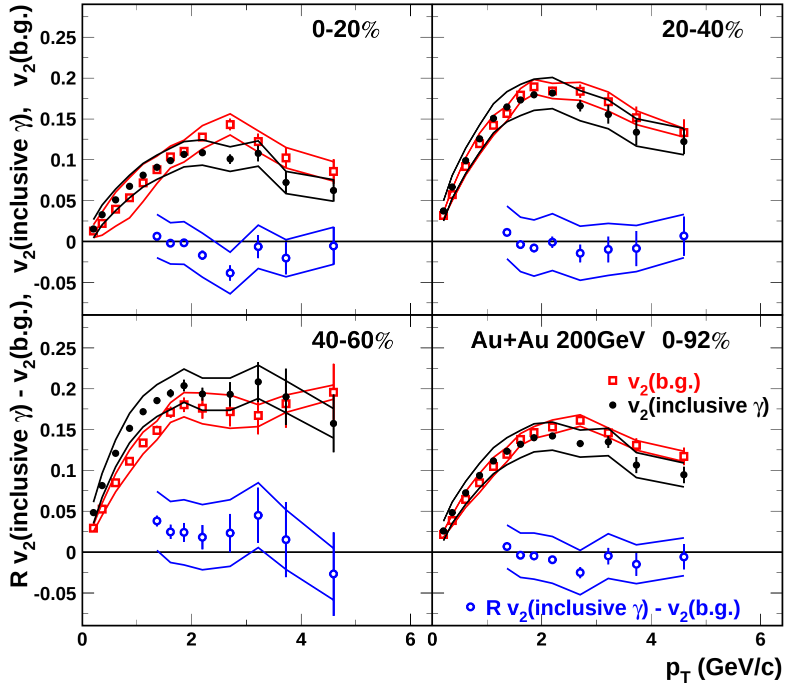
Motivation (III)

- Below 4 GeV decay photons are dominating.
- Difficult to extract direct photon v_2 information at low p_t.
- Target for the middle or high p_t range.

$$\frac{N_{inclusive}}{N_{decay}}$$



PHENIX, PRL 94, 232301 (2005)



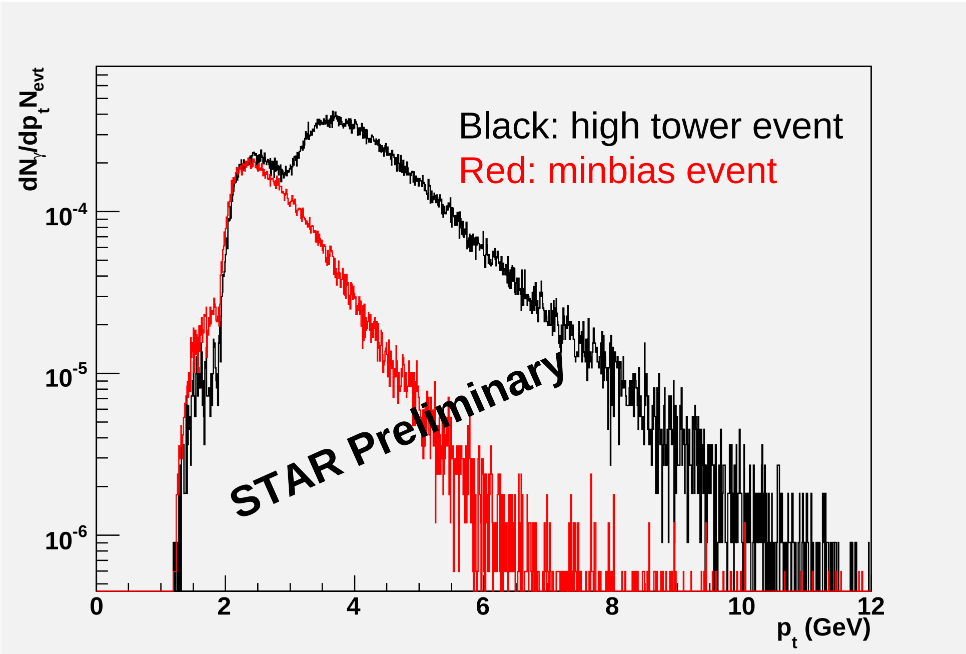
PHENIX, PRL 96, 032302 (2006)

Data Set

3.2M 200 GeV AuAu high tower events from year 4 productionLow&Mid&High.
2.3m 200 GeV pp high tower events from year 5 pp production

Reason for high tower events:

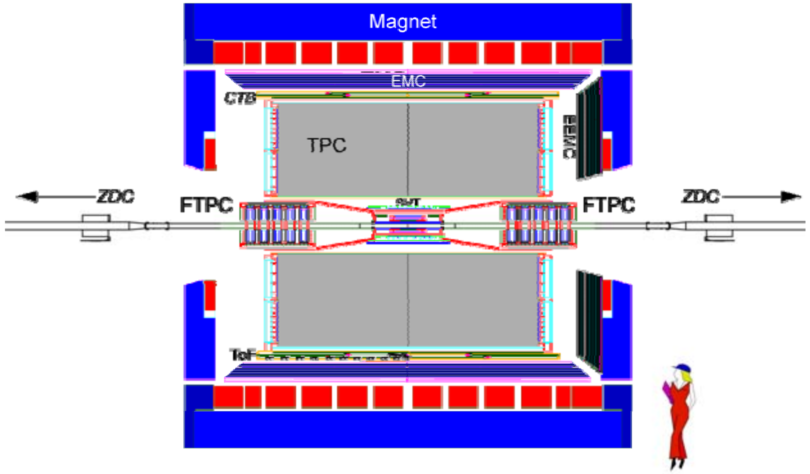
- Relatively more direct photon at high p_t.
- High p_t photons are significantly enhanced by high tower trigger.



Inclusive photon p_t distributions from high tower events and minbias events using the same cuts.

Photon identification

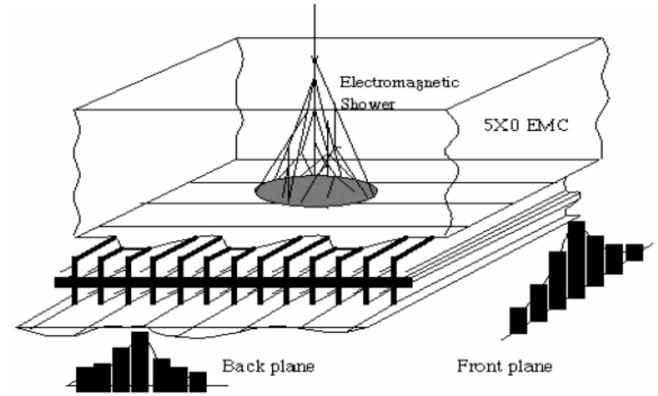
The photons are identified from the energy deposited (BEMC points) in the STAR BEMC.



- Both SMD η and φ clusters are required.

- Charged particles are rejected within (Δη, Δφ)=(0.05, 0.05). Keep photon candidates if only low momentum charged tracks hit on it. Here my cut is Σp_{track}<1 GeV.

- High tower trigger is required: each EMC photon has at least one tower hit with energy > 3 GeV*sin(θ).



Inclusive Photon v_2 Calculation

Non-flow effect has to be considered carefully in high p_t range.

- 4 particle cumulant method.
- Scalar product method.

Non-flow effect

$$\left\langle u_p Q^* \right\rangle^{AA} \approx v_b v_p M^{AA} + \left\langle u_p Q^* \right\rangle^{pp}$$

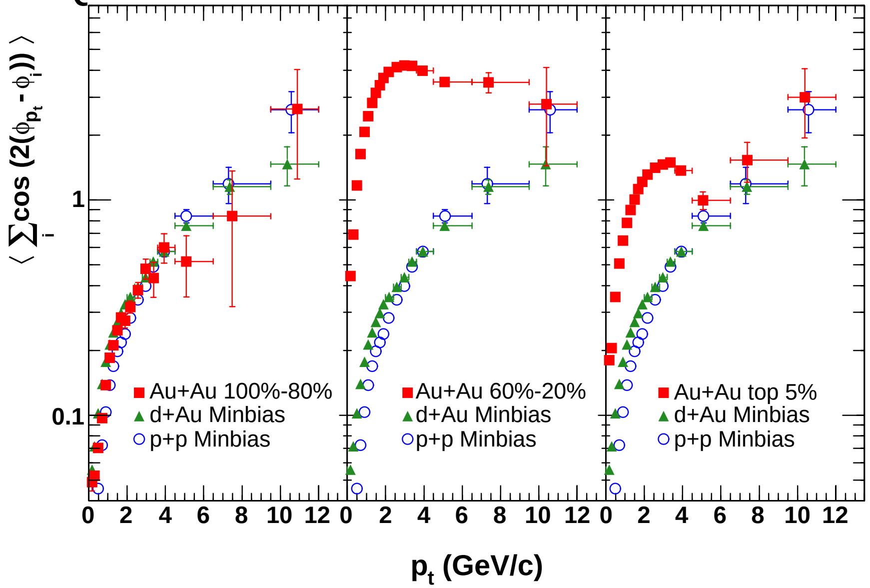
$$Q = \sum_{i \in \text{"pool"}} u_i; \quad u_i = e^{i2\phi_i}$$

v_p - Flow in a particle pt/eta "bin"

v_b - Average flow for particles used ("pool particles") to define RP

M^{AA} - # of charged tracks used to define RP

<uQ*>



<uQ*> of charged particles in different collision systems.

STAR, Phys. Rev. C 72 (2005) 014904

Correction of Inclusive Photon v_2

The measured inclusive photon v_2 is smaller than the true value because of the charged particle veto cut: a photon is more likely to be rejected in the reaction plane direction.

We assume the number of charged particle is N ($0<\varphi<2pi$, $0<\eta<1$), their average v_2 is $v_{2;ch}$, then the charged particle distribution is:

$$\frac{d^2N}{d\varphi d\eta} = \frac{N}{2\pi}[1+2v_{2;ch}\cos(2\varphi)]$$

For one charged particle, the probability that it is in a 0.1*0.1 box centered at (η_0,φ_0), which is the position of a photon, is:

$$p_{in} = \frac{0.1*0.1}{2\pi}[1+2v_{2;ch}\cos(2\varphi_0)]$$

So for all charged particles, if none of them is in this 0.1*0.1 box, the probability is:

$$p = (1-p_{in})^N \simeq 1 - Np_{in} = 1 - \frac{0.01N}{2\pi}[1+2v_{2;ch}\cos(2\varphi_0)]$$

So after the charged particle veto cut, the photon distribution will be:

$$\frac{d^2N_\gamma}{d\varphi d\eta} \propto [1+2v_{2;\gamma}\cos(2\varphi)]*p = [1+2v_{2;\gamma}\cos(2\varphi)]\{1-\frac{0.01N}{2\pi}[1+2v_{2;ch}\cos(2\varphi)]\}$$

$$\simeq 1-c+2(1-c)v_{2;\gamma}\cos(2\varphi)-2cv_{2;ch}\cos(2\varphi) \qquad (c\equiv\frac{0.01N}{2\pi})$$

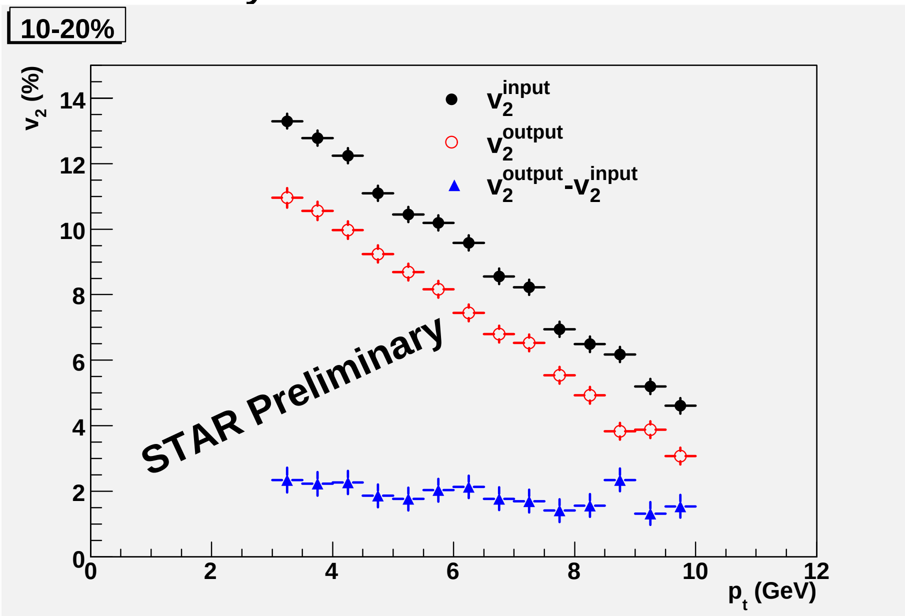
$$=(1-c)[1+2(v_{2;\gamma}-\frac{c}{1-c}v_{2;ch})\cos(2\varphi)]$$

Correction of Inclusive Photon v_2

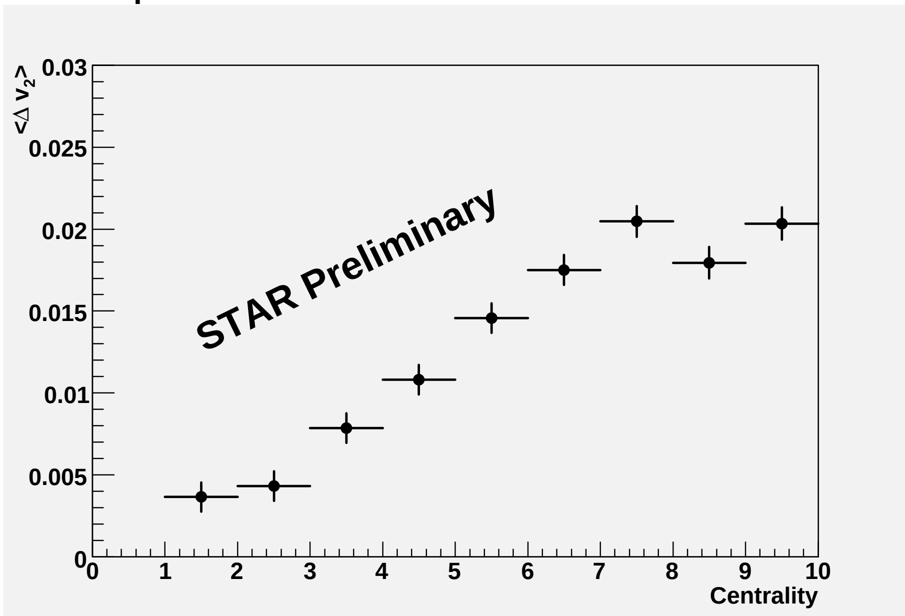
So the outcome of v_2 should be

$$v_{2;\gamma}^{measure} = v_{2;\gamma}^{real} - \frac{c}{1-c} v_{2;ch} \quad c \equiv \frac{0.01N}{2\pi}$$

The difference between the true v_2 and the measured v_2 is a constant, which only depends on the charged particle v_2 and multiplicity. The actual correction is done by simulation because of the more complicated cut.

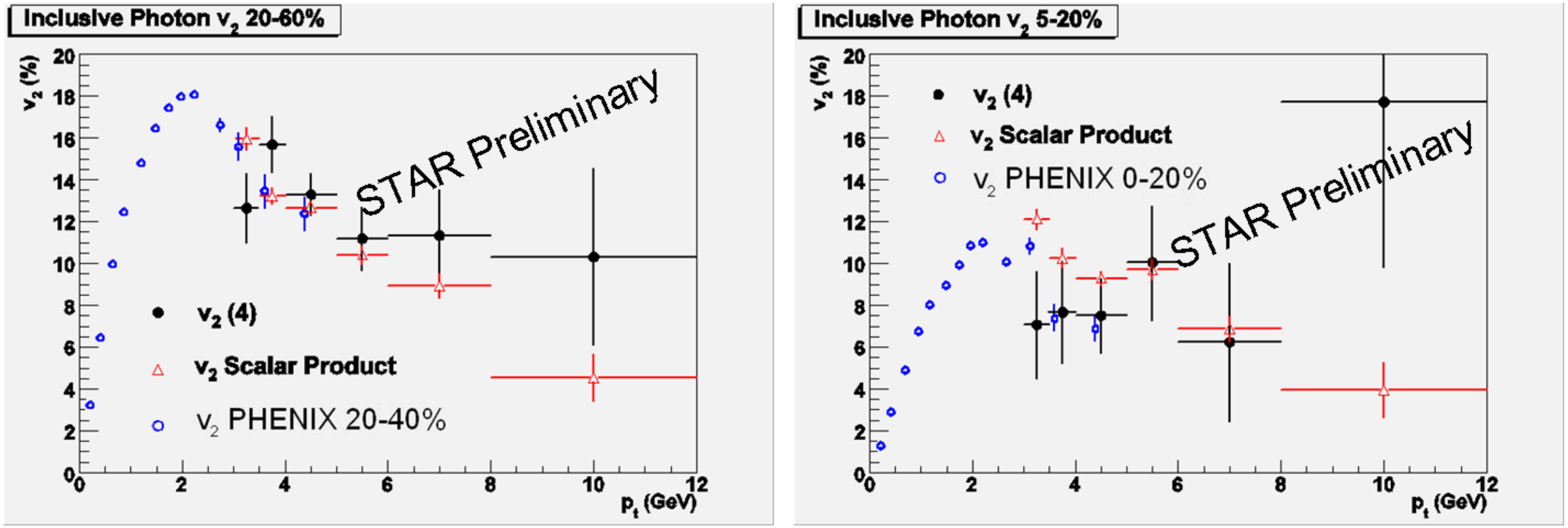


Simulation result of 10-20%



Average correction vs. centrality

Inclusive Photon v_2



- Statistical errors only.
- A trend of decreasing as the increase of p_t.
- The results using two different methods are consistent within error bars.
- Consistent with PHENIX results, extended to high p_t.

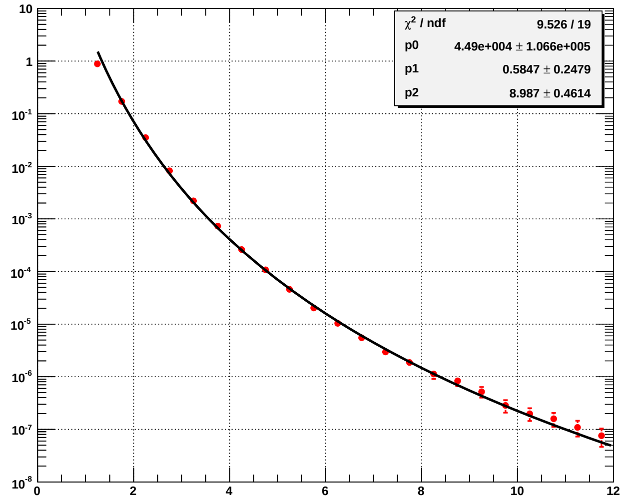
Decay Photon v_2--Simulation

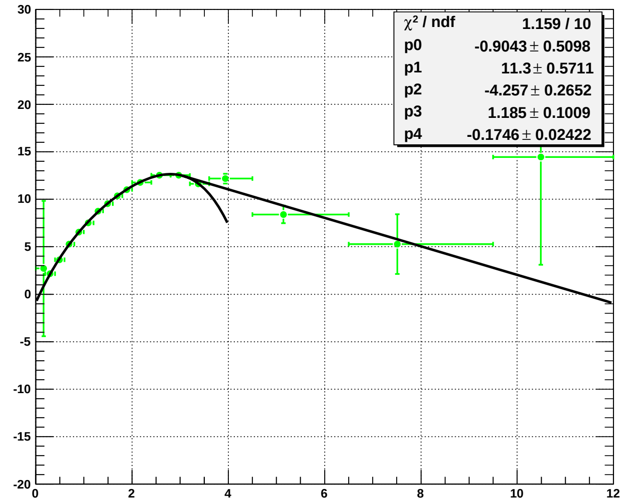
π^0 generation:

- neutral pions are generated according to the spectrum from PHENIX.
- neutral pion v_2 is assumed to be the same as charged particle v_2, from the fitting of real data measurement ($v_2(4)$).
- the upper and lower limits of v_2 error bars are fitted and used to calculate the error bars of the decay photon v_2.
- η distribution is flat.

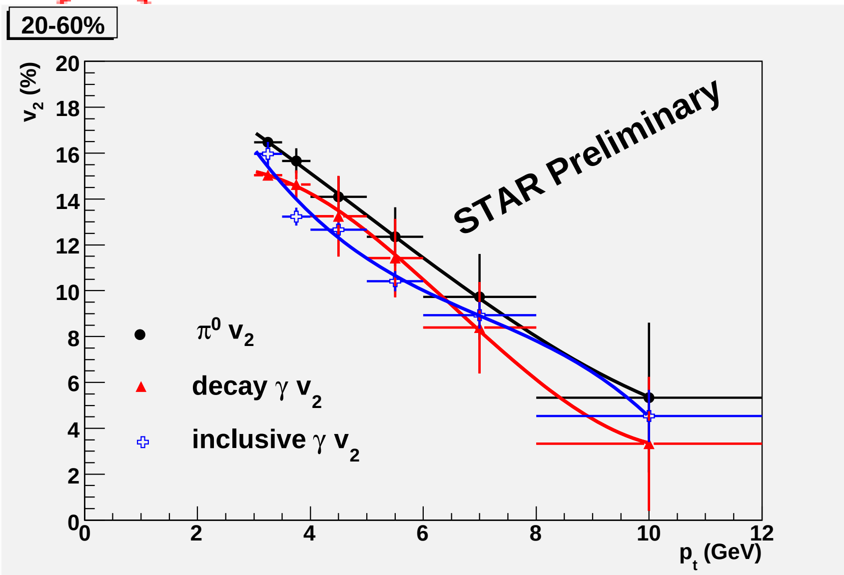
Photon:

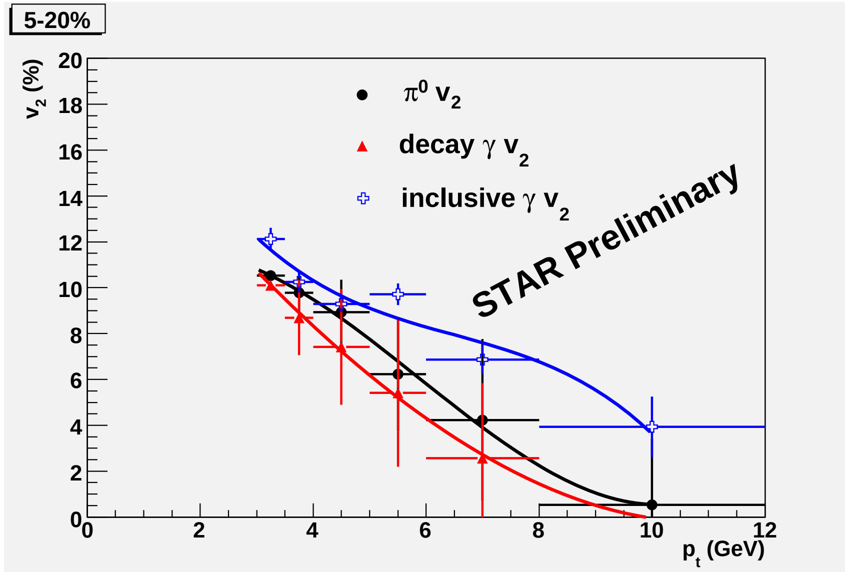
- the efficiency of smd response to photons is applied.
- the photon energy is smeared by 15%/sqrt(E).

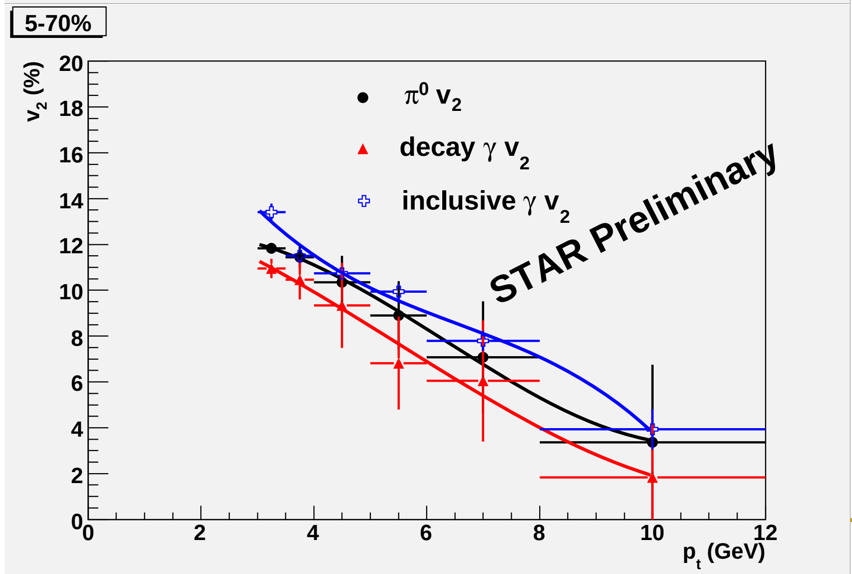




Decay Photon v_2--Result







Statistical errors only.

20-60%: decay photon v_2 and inclusive photon v_2 are close together.

5-20% & 5-70%: inclusive photon v_2 looks systematically higher than decay photon v_2.

$$v_2^{\text{direct}} = \frac{R v_2^{\text{inclusive}} - v_2^{\text{decay}}}{R-1}, \text{ where } R = \frac{N_{\text{direct}} + N_{\text{decay}}}{N_{\text{decay}}}$$

Conclusion & Outlook

- Conclusion
  - Inclusive photon v_2 is measured up to 10 GeV using scalar product and 4 particle cumulant methods. Results are reasonable and consistent.
  - Decay photon v_2 is calculated by simulation and compared to the inclusive photon v_2.
- What to do next?
  - Use FTPC to measure the inclusive photon v_2.
  - π^0 v_2
  - Add η contribution to decay photon v_2 study.
  - Other systematic errors.

Back up