Thermal Photons in Heavy Ion Collisions Measured with the PHENIX Detector

Richard Petti† for the PHENIX Collaboration

Department of Physics and Astronomy

Stony Brook University

1. Abstract

The hot and dense fireball produced in high energy heavy ion collisions, such as that at RHIC, exhibits complicated dynamics and time evolution. Thermal photons have a negligible cross-section with the medium and so pass through unmodified, thus measuring their properties gives access to the entire time evolution of the fireball. Thermal photons are expected to be observable at low momentum. They compete in yield with photons from hadron decays and, at high momentum (above roughly 4 GeV), direct photons that result from initial hard scatterings of partons in the colliding nuclei. The latest results on low momentum direct photons measured from their conversion with material is shown, including the elliptic flow.

2. Motivation

Low momentum direct photons produced in heavy ion collisions are thought to be thermal in origin. Studying thermal photons can give an estimate of the average temperature of the plasma [1]. In addition, studying the yield can put constraints on theory calculations of photon production. Recent theory work [2],[3] also suggests that the elliptic flow of thermal photons is sensitive to the thermalization time of the medium and the emission time of the photon from the medium.

3. Method

Low momentum direct photons are notoriously difficult to measure, due to very large decay photon background and poorer energy resolution in the emcal. The approach of this analysis is to measure photons via external conversion to dielectron pairs. We focus on a localized source, conversions from the backplane of the HBD (radius ≈ 60cm) [4].

PHENIX tracks outside the magnetic field and so the event vertex is assumed to be the origin of each track. This is not true for these conversions. This leads to an apparent mass. This mass is recalibrated with an alternate track model assumption that all tracks originate at a radius of 60cm. The photon conversion pairs are isolated by cutting on the masses calculated from each track model, see Fig 1.

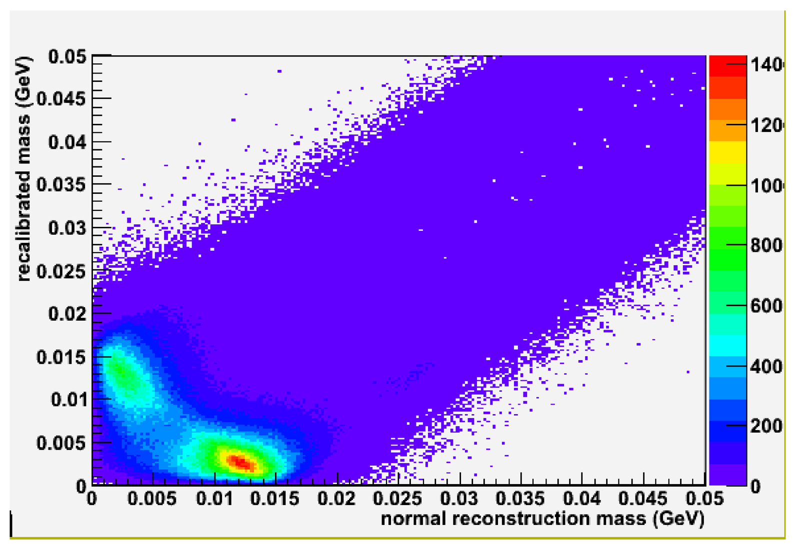

Figure 1: A 2D histogram of the normally reconstructed invariant mass and the alternate mapping invariant mass. A clear separation of the Dalitz and HBD conversion pairs can be seen.

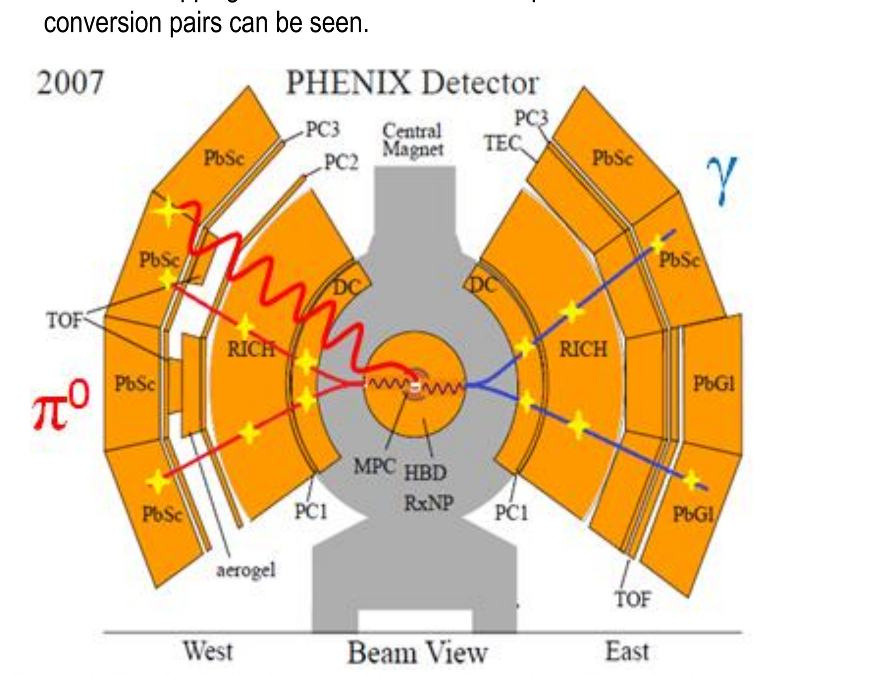

Figure 2: The PHENIX detector, 2007 configuration. The blue lines indicate e+ and e- tracks from a photon converting in the HBD. The red lines indicate a pi0 that decayed into photons, one of which converts in the HBD. This is how we tag inclusive photons as coming from a π^0.

3a. Direct Photon Fraction

The direct photon fraction is estimated through a double ratio, so that major sources of systematic error cancel (dielectron pair acceptance and efficiency and conversion length). It is measured through a combination of data and data driven Monte Carlo simulations. π^0 yield is measured by tagging inclusive photons that come from a π^0, see Fig 2 and Eqn. 1.

$$R_\gamma = \frac{\gamma^{incl}(p_T)}{\gamma^{hadr}(p_T)} = \frac{\varepsilon_\gamma(p_T)\, f(p_T)\cdot\left(\frac{N_\gamma^{incl}(p_T)}{N_\gamma^{\pi^0 tag}(p_T)}\right)_{Data}}{\left(\frac{N_\gamma^{hadr}(p_T)}{N_\gamma^{\pi^0}(p_T)}\right)_{Sim}} \qquad (1)$$

3b. Direct Photon Elliptic Flow

The direct photon elliptic flow is calculated by subtracting the hadron decay photon flow from the inclusive photon flow, see Eqn. 2. The R_γ (Fig. 4) and v_2^{inc} (Fig. 5) and are measured via the external conversions method. The v_2^{BG} is estimated in the same manner as in a previous analysis [5]. The π^0 flow shape (Fig. 8) is used as input into a Monte Carlo decay simulator. The spectral shape of other mesons is assumed from m_T scaling and the v_2 of other hadrons from KE_T scaling.

$$v_2^{dir.} = \frac{R_\gamma v_2^{inc.} - v_2^{BG}}{R_\gamma - 1} \qquad (2)$$

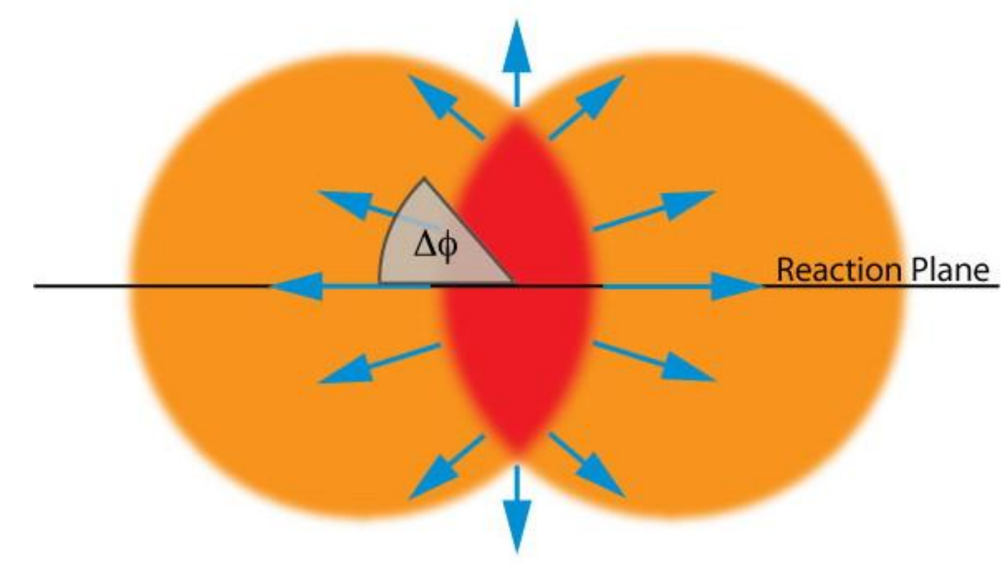

Figure 3: A cartoon illustrating the reaction plane and the almond shaped interaction region in a non-central collision.

4. Results

4a. Direct Photon Fraction Results

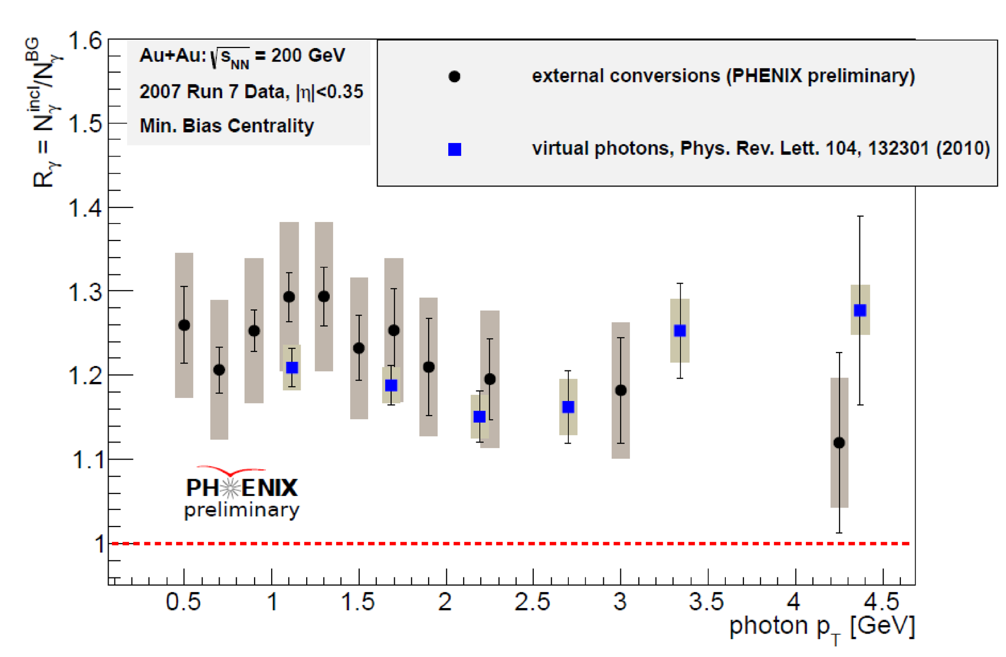

Figure 4: A comparison of the direct photon fraction, measured via the external conversion method in black circles and from the virtual photon method [1],[5] in the blue squares.

4b. Direct Photon Elliptic Flow Results

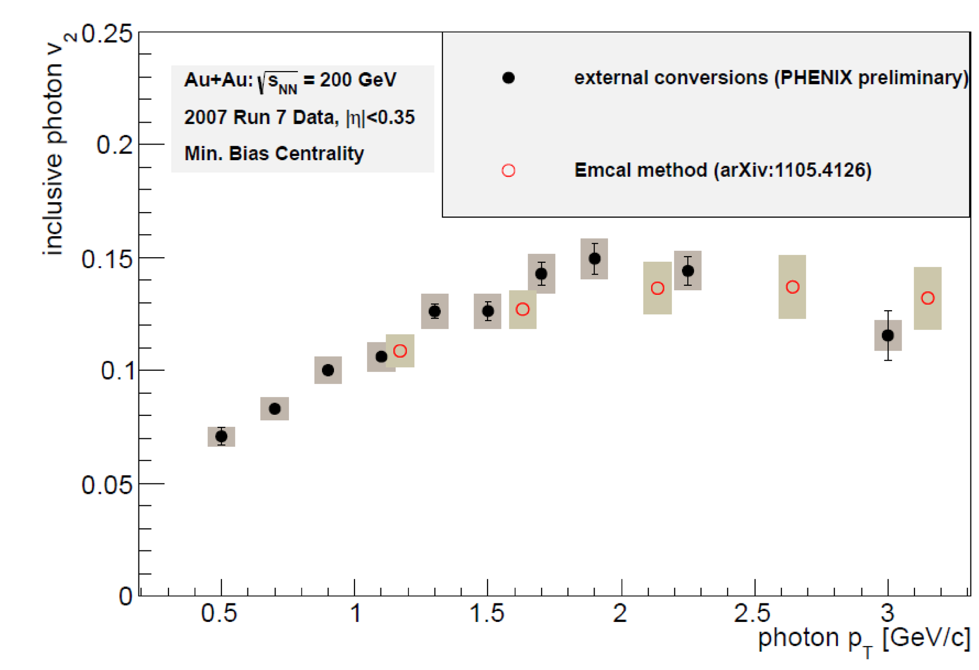

Figure 5: A comparison of the inclusive photon elliptic flow from the external conversion method (black circles) and the flow from an emcal analysis [5] (open red circles).

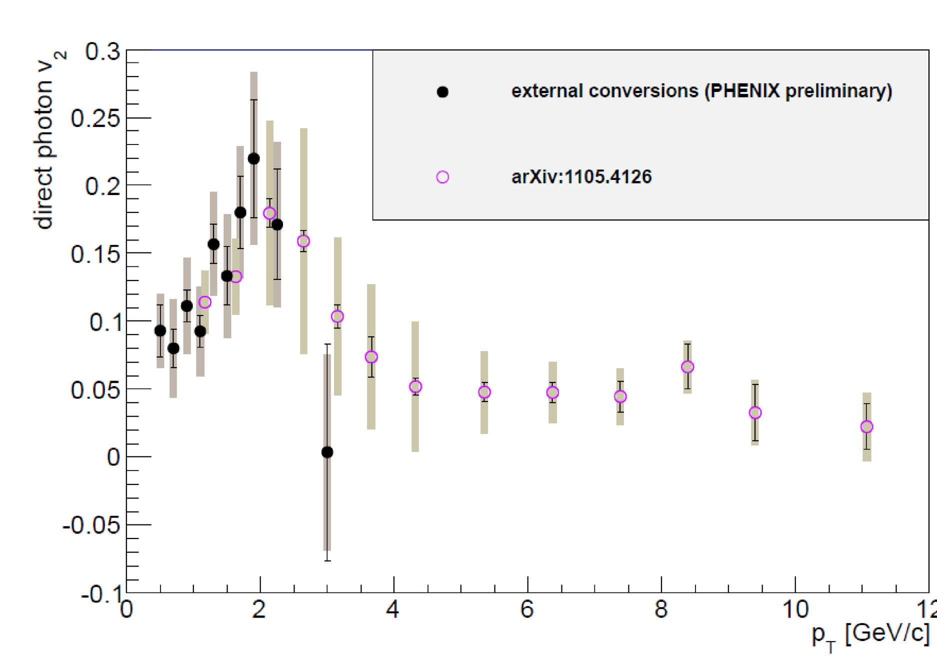

Figure 6: A comparison of the direct photon elliptic flow calculated via the external conversion method (black circles) and the flow from [5] (open purple circles).

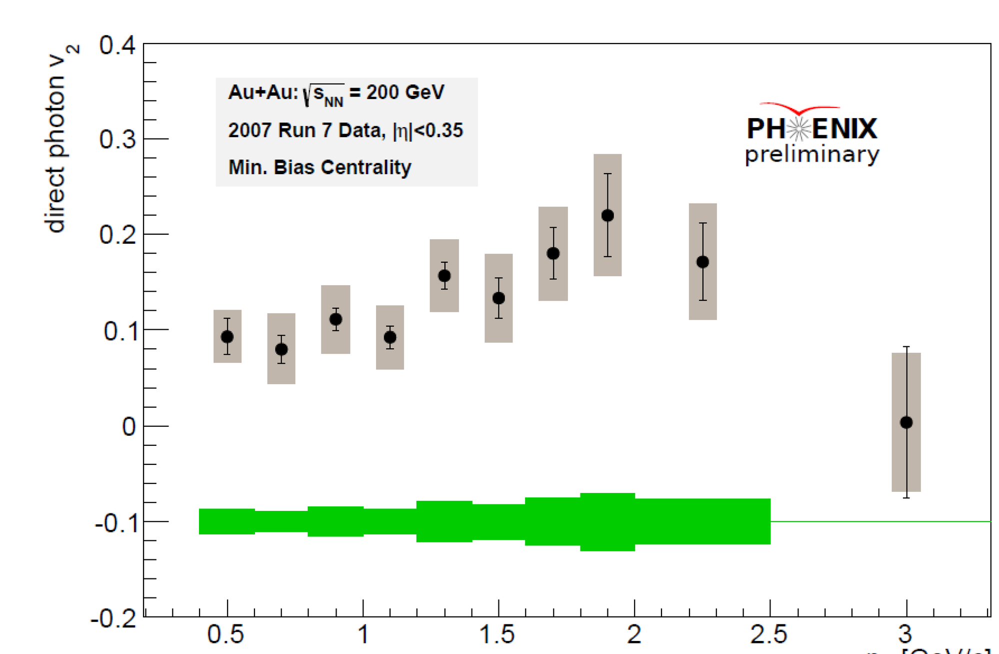

Figure 7: The elliptic flow of direct photons from the external conversion method. The gray boxes represent p_T correlated systematic errors and the green shaded region represents the global uncertainty. The error bars represent statistical errors.

5. Conclusions and Outlook

The flow of direct photons is measured to be quite large and of the same order as for hadrons, see Fig. 7. This seems to hint that the thermal photons measured are dominated by late time emission after flow has fully developed [3] and also seems roughly consistent with an early thermaliztion time [5].

The results derived from the external conversion analysis are consistent with previous measurements, [1],[5]. This represents an independent analysis with mostly independent systematic errors (the reaction plane resolution systematic error is common).

We have also extended the p_T range to lower p_T with this measurement.

Results that can be expected in the near future are the above results in centrality bins, as well as extending the analysis to measure higher flow moments. The work to measure the π^0 elliptic flow via external conversions and the tagging method is also ongoing. The direct photon cross-section will also be calculated, allowing another estimate of the effective temperature of these presumably thermal photons (in the same fashion as in [1]).

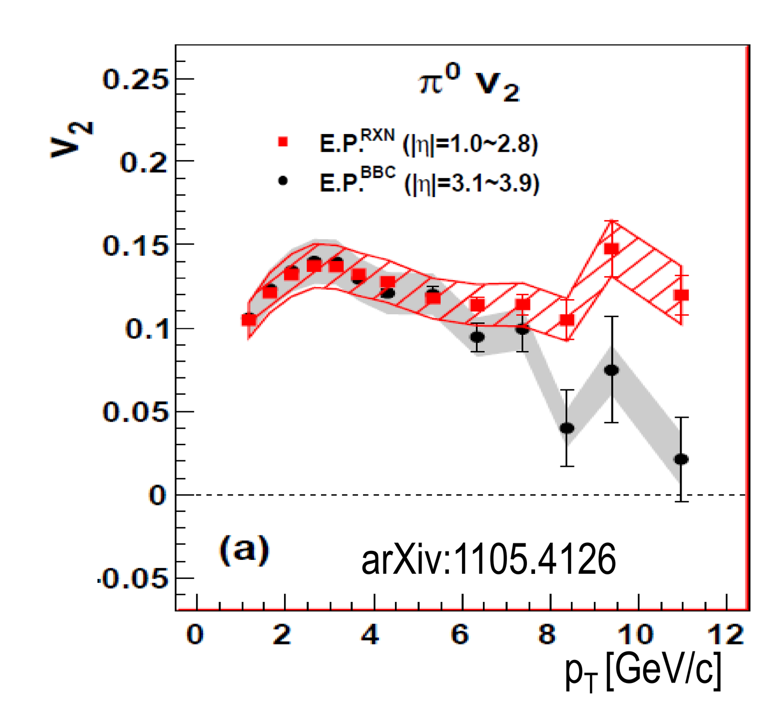

Figure 8: The neutral pion v_2 measured from [5] and used as input to calculate the hadron decay photon v_2.

6. References

[1] Phys. Rev. Lett. 104, 132301 (2010)
[2] Chatterjee, Srivastava, Phys. Rev. C79, 021901,'09
[3] H. van Hees, et.al Phys. Rev. C 84, 054906 (2011)
[4] arXiv:1107.5379
[5] arXiv:1105.4126

†- richard.petti@gmail.com