PROCEEDINGS OF SCIENCE

Measurement of soft photon collective flow in $\sqrt{s_{NN}}$=200GeV Au+Au collisions at RHIC-PHENIX

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Direct photons have been measured to investigate the properties of quark-gluon plasma because they are very good probes. Third order azimuthal anisotropy (v_3) of direct photon is measured at PHENIX experiment. It is found that the magnitude of direct photon v_3 are comparable to that of neutral pion v_3 as already measured for direct photon v_2. It could suggest that photons are mainly originated from late stage where the medium itself has large v_n. Recently, photons converting e^+e^- pairs at materials are measured and it extend lower limit down to 400 GeV/c. The photon v_n is compared with theoretical models and models including photons generating from hadron phase relatively describe experimental measurement. Measurement of photon v_3 helps to understand photon production mechanism.

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1. Introduction

High energy heavy ion collision experiments have been carried out more than 15 years at Relativistic Heavy Ion Collider (RHIC) to study the properties of quark-gluon plasma (QGP). Direct photons are defined as all photons except for those coming from hadron decays. Photons do not strongly interact because of their properties of color-less. Furthermore, they are created from various sources such as primordial initial hard scattering, jet fragmentation, and thermal radiation, during all stages of collisions. Thus, they are very important probes to investigate the time evolution and properties of QGP.

The PHENIX experiment has been continued to study the property of QGP. The reaction plane detector (RxN) which consists of the inner ring ($1.5 < |\eta| < 2.8$) and outer ring ($1 < |\eta| < 1.5$) is utilized to determine event plane. The event plane resolution is achieved to 50-80% and 15-30% for second and third order, respectively. The Electromagnetic calorimeter (EMCal) in central arm detectors ($|\eta| < 0.35$) covering azimuthal angle ($\Delta\phi = \pi$) is used to detect photons.

2. Direct photon

We have measured direct photon p_T spectra [1] at PHENIX experiment. It is found that the p_T spectra of Au+Au collisions include an additional exponential p_T spectra compared to those of p+p collisions scaled by the number of the binary collisions. It is expected that the excess of p_T spectra indicates that thermal photons are created in Au+Au collisions and their effective temperature is obtained from the inverse slope of the exponential p_T spectra, it is approximately 240 MeV. It suggests that most of thermal photons are radiated from the early time of the collisions because the kinetic freeze-out temperature is known about 100 MeV.

Additionally photon second order azimuthal anisotropy (v_2) has been measured [2]. It is observed that the magnitude of direct photon v_2 is comparable to that of neutral pion v_2 in $p_T < 4$ GeV/c. It is anticipated that the medium expands and its v_2 gets large with time. Photons at late stage of the collisions could be dominant in order to get large v_2 because photons in low p_T are thermally radiated from the expanding medium.

There is a discrepancy between the physics obtained from p_T spectra and v_2. They are called "direct photon puzzle" and significant theoretical efforts have been working to explain both yield and v_2 simultaneously. Direct photon v_3 are measured in order to provide additional constraint on photon production mechanisms.

3. Results

Third order azimuthal anisotropy of neutral pion, inclusive photon, and direct photon in 1 $< p_T$ 4 GeV/c are measured with event plane estimated via RxN. Figure 3 show the centrality dependence of comparison of neutral pion and direct photon v_3. It is found that the magnitudes of them are comparable in p_T = 2-3 GeV/c in all centrality bins. It suggests that photons are dominantly emitted at the late stage of the collisions as introduced in previous section.

Recently, photons converting to e^+e^- pairs at the material have been actively measured because they are very sensitive to lower p_T [1]. Figure 3 shows the comparison of direct photon v_n

between calorimeter method and conversion photon method. It is confirmed that photons detected by conversion photon method extend the lower limit of p_T while they have large uncertainty due to small statistics. They are very important because photons in low p_T region are much sensitive to those coming from QGP phase.

Figure 3 shows the comparison of photon v_n in 20-40 % centrality bin with theoretical calculations. Fireball phenomenological calculations [3], PHSD transport model [4] include photons originating from hadron phase, namely late stage of the event. Hydrodynamical calculations [6, 7] describe photon v_n with several initial information and expanding condition, which calculate photons radiated from parton phase at high temperature. Photons affected by magnetic field are calculated in [5] show only upper limit while emitting angle is only modified in this model. It is found that models including photons created at late stage could relatively describe rather than hydrodynamical calculations. It could suggest that photons generated during hadron gas phase are important to get large v_2. These results would be helpful for understanding the photon production mechanism.

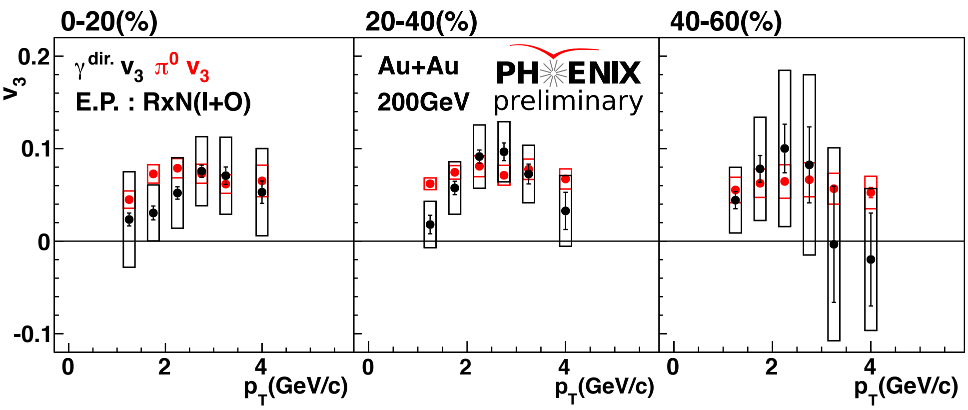

Figure 1: Direct photon (black) and neutral pion (red) v_3 with event plane estimated via reaction plane detector with 20 % centrality intervals from 0 to 60 %.

4. Conclusions

Direct photon v_3 with calorimeter method are measured in Au+Au 200 GeV by PHENIX detector. It is found that the magnitude of photon v_3 in p_T = 2-3 GeV/c is comparable to that of neutral pion in all centrality intervals. Photon v_n are detected via external conversion photon method and it extends the lower limit of the p_T to 400 MeV/c. The comparison with the theoretical calculations could suggest that photons generating from hadron phase at late stage of the collision are important to reproduce photon v_n. Measurement of photon v_3 could provide additional constraint to understand photon production mechanisms.

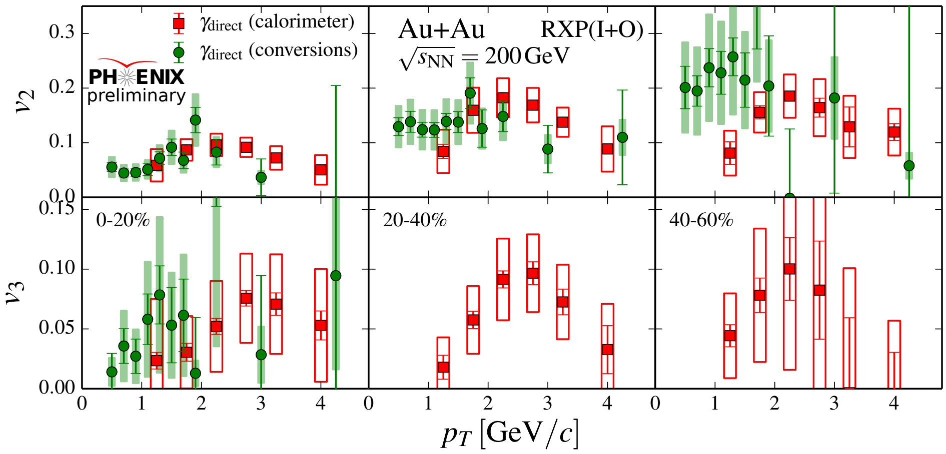

Figure 2: Direct photon v_2 (top) and v_3 (bottom) with event plane estimated via reaction plane detector with 20 % centrality intervals from 0 to 60 %. The comparison of photon detected calorimeter (red) and conversion photon method (green).

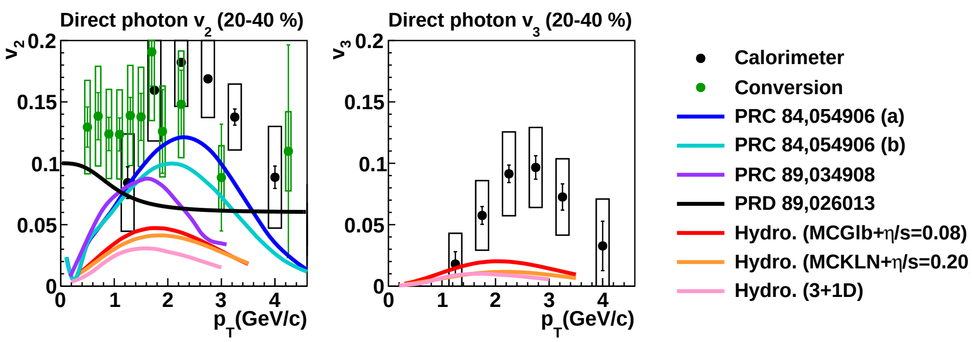

Figure 3: Direct photon v_2 (left) and v_3 (right) with calorimeter (black) and conversion photon method (green). Phenomenological calculations (dark violet and cyan) [3], PHSD transport model (magenta) [4], magnetic field effect (black) [5], hydrodynamic calculations (red, orange, and pink) [6, 7] are compared.

References

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