Elliptic Flow Measurement of Direct Photon in $\sqrt{s_{\rm NN}}$=200GeV Au+Au Collisions at RHIC-PHENIX

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Abstract Azimuthal anisotropy of direct photon is measured in $\sqrt{s_{\rm NN}}$=200GeV Au+Au collisions at RHIC-PHENIX. Direct photon is one of the most effective probes to study properties of hot dence medium at initial state (also QGP state) of heavy ion collisions because photons almost do not interact strongly with any other particles caused by its long mean free path and they keep their conditions when they are created. Within statistical and systematic errors, the elliptic flow parameter (v_2) of direct photon is consistent with zero. Direct photon v_2 is estimated by hadron decay photon contamination are subtracted from inclusive photon v_2 in intermediate to high transverse momentum ($p_{\rm T}$) region (0 to 10GeV/c) for 3 centrality selections (20% steps) and minimum bias.

Key words elliptic flow, hot dense matter, direct photon

1 Introduction

In the study of Quark Gluon Plasma (QGP) state by the experiment of heavy ion collisions, it is very important to study properties of hot dence medium at initial state of collisions. Direct photon which emitted from initial state of collisions is one of the most effective probes to study properties of initial state because photons almost do not interact strongly with any other particles and they keep their conditions when they are created. Especially in high $p_{\rm T}$ region, direct photon could be measured with enough accuracy because yield of hadrons which are main back ground of direct photon are suppressed by hot dense medium of heavy ion collisions (jet quenching effect[1]).

Photons are emitted from several states such as the initial state, QGP state, and the hadron-gas state[2]. The photon from initial state of parton-parton collisions is called prompt photon. The thermal photon is emitted from QGP state. And there is also photon that releted jet fragmentation (Compton like scattering of jet partons). The contamination of hadron decay photon needs to remove from all of measured photons to see inital state of collisions because they are emitted from final state of collisions. All of measured photons are called inclusive photons, and we define the direct photon as photons such that hadron decay contamintation is subtracted from inclusive photon. The most of photons from heavy ion collisions are created at hadron-gas stage, and they could be main back ground for direct photon analysis.

Then, we have another interesting measurement as probes of initial collisions. The elliptic flow (v_2) is defined by the average of azimuthal angle of generated particles to the reaction plane direction. The direct photon v_2 can be expected that they have unique value at each components of them because v_2 of each particles reflect initial spatial anisotropy of emission particles. Prompt photon v_2 should be equal to zero because paricles are emitted with several azimuthal angle in parton-parton collisions at initial stage. Thermal photon v_2 could be reflected the

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expansion direction of hot dense matter, then they make positive v_2. And photons also emitted from jet which is created by hard scattering. The jet fragmentation photon should be emitted to in-plane direct photon caused by jet quenching effect. These photons make positive v_2. In other hand, the energy from quenching particles makes photons according to Bremsstrahlung. This effect makes more particles emission to out-plane direction than in-plane, then makes negative v_2[3].

The $p_{\rm T}$ dependence of direct photon is also interested. The direct photon yields measured in heavy ion collisions by the PHENIX are in good agreement with a NLO pQCD calculation scaled by the number of binary nucleon collisions within errors and theoretical uncertainties[4]. Fig. 1 shows invariant yield estimation of direct photon at $\sqrt{s_{\rm NN}}$=200GeV Au+Au collisions. The prompt photon is the most effective in high $p_{\rm T}$ region (6∼[GeV/c]) because it is generated by initial hard scatter. In other hand, thermal photon from QGP are emitted in low $p_{\rm T}$ region (1∼3[GeV/c]).

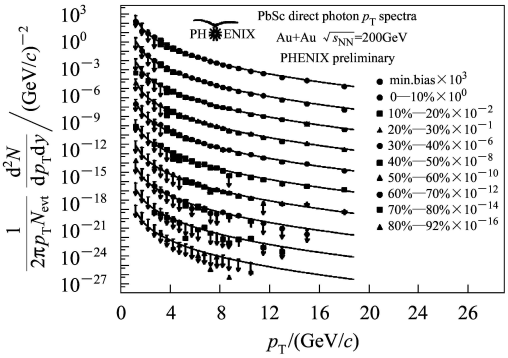

Fig. 1. Invariant yield of direct photon as a function of transverse momentum for 9 centrality selections and minimum bias at $\sqrt{s_{\rm NN}}$=200GeV Au+Au collisions.

2 Analysis method

The elliptic flow parameter (v_2) is defined by the average of azimuthal angle of emission particles to reaction plane direction. Reaction plane is definded by an impact parameter and a horizontal plane make the plane. The emission particle v_2 is estimated by the 2nd coefficient of Fourier expansion as following[5],

$$\frac{{\rm d}N}{{\rm d}(\phi-\Psi)} \propto N_0[1+2v_2\cos\{2(\phi-\Psi)\}], \qquad (1)$$

where ϕ is the azimuthal angle of the particle and Ψ is the direction of the reaction plane in a given collision. Reaction plane direction is measured in the two Beam-Beam Counters (BBC) which counts charged particles produced in pseudo-rapidity range $3.0<|\eta|<3.9$, and photons are detected by Electro Magnetic Calorimeter (EMCal) which has a acceptance of $-0.35<|\eta|<0.35$ and π radians in azimuth[6].

The direct photon v_2 is estimated by hadron decay photon contamination is subtracted from inclusive photon v_2, because v_2 should have unique value at each kind of particles as following.

$$v_2^{\rm direct} = \frac{R\cdot v_2^{\rm inclusive} - v_2^{\rm B.G.}}{R-1}, \qquad (2)$$

$$R = N^{\rm inclusive}/N^{\rm B.G.}. \qquad (3)$$

where $v_2^{\rm direct}$, $v_2^{\rm inclusive}$ and $v_2^{\rm B.G.}$ is direct photon v_2, inclusive photon v_2 and hadron decay photon v_2. R which is called double ratio, means yield of inclusive to hadronic back ground photon ratio. Fig. 2 shows double ratio which was measured in PHENIX (with preliminary). According to Fig. 2, we can find the excess of direct photon in high $p_{\rm T}$ region expecially central collisions. The effect of hadronic photon contamination could remove from inclusive photon to this double ratio considered as weight.

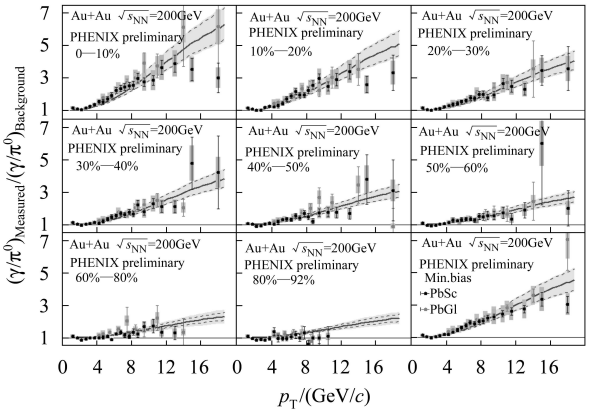

Fig. 2. Double ratio which definded by $N^{\rm inclusive}/N^{\rm background}$ as a function of transverse momentum for 8 centrality selections and minimum bias at $\sqrt{s_{\rm NN}}$=200GeV Au+Au collision.

The most effective component is π^0 and η as contamination of hadronic back ground. Then, there is necessity to measure the π^0 v_2 for estimate the hadron decay photon contamination. Since almost π^0 decay

to 2γ, it can be detected by invariant mass method. The η contamination is estimated also and include to hadron decay contamination.

3 Result

Direct photon v_2 is estimated by subtracted hadron contamination. Fig. 3 show direct photon v_2 as a function of $p_{\rm T}$ (0 to 10[GeV/c]) for 3 centrality selections and minimum bias. Systematic errors (draw band in Fig. 3 are counted from following effect: particle identification uncertainty ($\sim 6\%$), nutral hadron effect ($\sim 2,3\%$), reaction plane determination ($\sim 6\%$) and errors from double ratio. Owing to the strong suppresstion of neutral hadrons by a jet quenching effect in heavy ion collisions, direct photons v_2 can be extracted in high $p_{\rm T}$.

According to these figures, direct photon v_2 is consistent with zero within statistical and systematic errors. This result support that most effective contamination of direct photon is prompt photon (especially in high $p_{\rm T}$ region) because its v_2 should be zero. In other hand, posive v_2 might be seen a little in intermediate $p_{\rm T}$ region. In addition, this v_2 seems to have centrality dependence.

Direct photon v_2 needs more accuracy in low $p_{\rm T}$ (thermal photon region) to study the initial state of collisions as an initial probes and to compare with theorical prediction. Then this analysis is preparing to see more statistics, new method, and new detector in PHENIX.

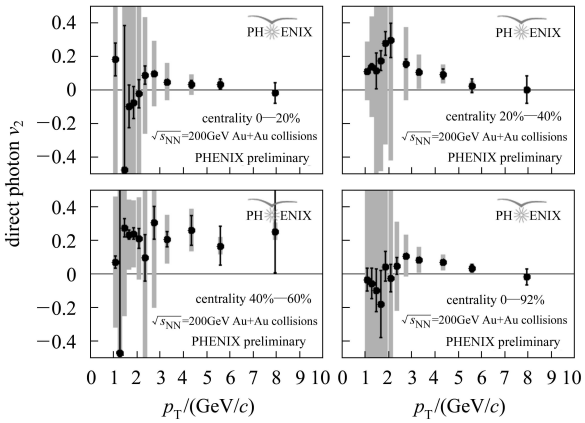

Fig. 3. Direct photon v_2 as a function of $p_{\rm T}$ for 3 centrality selections and minimum bias in $\sqrt{s_{\rm NN}}$=200GeV Au+Au collisions.

4 Summary

Elliptic flow parameter (v_2) of direct photons is measured in $\sqrt{s_{\rm NN}}$=200GeV Au+Au collisions at RHIC-PHENIX. Direct photon v_2 is estimated by hadron decay photon contamination are subtracted from inclusive photon v_2 in intermediate to high $p_{\rm T}$ region (0 to 10GeV/c) for 3 centrality selections and minimum bias. Within statistical and systematic errors, the elliptic flow parameter (v_2) of direct photons is consistent with zero.

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