PHENIX measurements of reaction plane dependence of high p_T photons and pions

V S Pantuev for the PHENIX Collaboration

University at Stony Brook, Stony Brook, New York 11794, USA

E-mail: pantuev@skipper.physics.sunysb.edu

Abstract. Direct photon and neutral pion production with respect to the reaction plane at high p_T were measured with the PHENIX experiment in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV at mid-rapidity. The azimuthal asymmetry parameter v_2 for direct photons was found to be consistent with zero for all centrality classes. We evaluate the dependence of π^0 suppression at high p_T on the emission angle $\Delta\phi$ with respect to the event reaction plane for 7 centrality bins. For the peripheral bins we observe no suppression for neutral pions aligned with the reaction plane while π^0's produced perpendicular to the reaction plane are suppressed by factor 2. We found that a simple geometric picture can explain the observed suppression pattern.

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1. Introduction

Direct photons are a unique probe of dense matter produced at RHIC. Photons leave the interaction zone with very small interaction probability thus allowing access to the initial state of the collision. The direct photon yield in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV follows binary collision scaling [1]. The lack of suppression of direct photons is evidence in favor of the final-state effect in hadron suppression [2]. Binary scaling of hard photons could be in part due to a counteracting of two effects. Some fraction of the photons may originate from partons having experienced energy loss [3], similar to hadron suppression of these photons. While on the other hand, parton energy loss may enhance the photon yield via the bremsstrahlung process [3]. There are recent theoretical predictions which show that such different mechanisms may have very different distributions in the azimuthal direction [4].

Predictions of high p_T particle suppression were made before RHIC operation started [5] and were confirmed by the first measurements [2]. The suppression of high p_T hadrons was predicted to result from parton energy loss in the hot and dense QCD medium produced at RHIC. The properties of the created medium are not *a priori* known, the energy loss calculations necessarily use the observed suppression to tune parameters internal to a model. However, such calculations should account for changes in the initial properties of the medium with centrality or the system size. There is another way of measurement by keeping initial conditions the same and varying the path length of the medium by selecting high p_T particles at different angles with respect to the reaction plane at the same initial conditions.

In this conference we present measurements of high p_T photons and neutral pions with respect to the reaction plane. For photons we extend our previous analysis of Run-2 data [6] by use of the PHENIX preliminary data obtained in Run-4 operation of RHIC in 2004, and for π^0 we use the final results from Run-2 obtained with the PHENIX Level-2 trigger [7].

2. Analysis and Results

To extract azimuthal asymmetry parameter v_2 for direct photons we follow the standard procedure [6]. The parameter v_2 is defined by equation

$$dN/d\phi \propto 1 + 2\, v_2 \cos(2(\phi - \Phi_{\mathrm{RP}})), \tag{1}$$

where ϕ is the azimuthal direction of the particle and Φ_{RP} is the direction of the nuclear impact parameter (reaction plane) in a given collision. The measurement of direct photons is a difficult task because of a large background of decay photons from π^0 and η and can be done only by a statistical subtraction method. The $v_2^{incl.\gamma}$ of the inclusive photons, the hadron decay and direct photon sum, can be expressed as the following,

$$v_2^{incl.\gamma} = (v_2^{dir.\gamma} N_{dir.\gamma} + v_2^{b.g.} N_{b.g.})/(N_{dir.\gamma} + N_{b.g.}), \tag{2}$$

where $v_2^{dir.\gamma}$ is the direct photon v_2. $N_{dir.\gamma}$ is the direct photon yield and $N_{b.g.}$ is the background photon yield. Using the relative yield ratio $R = (N_{dir.\gamma} + N_{b.g.})/N_{b.g.}$, measured by PHENIX and presented at this conference by T. Isobe, one can express the direct photon v_2 as follows :

$$v_2^{dir.\gamma} = (R v_2^{incl.\gamma} - v_2^{b.g.})/(R - 1). \tag{3}$$

The results are shown in Figure 1 for different centrality selections. The major source of systematic errors is the uncertainty in R. Within statistical and systematic errors $v_2^{dire.\gamma}$ is consistent with zero.

Details of the analysis for π^0 with respect to the reaction plane are published in [7]. Two-photon decay of neutral pions were measured in the PHENIX electromagnetic calorimeter, which has a pseudo-rapidity acceptance of -0.35 $< \eta <$ 0.35 and covers π radians in azimuth. The event reaction plane was measured in the two Beam-Beam Counters, which counts charged particles produced in pseudo-rapidity range $3.0 < |\eta| < 3.9$. Reaction plane measurements were corrected for the centrality dependent reaction plane resolution.

Suppression of high p_T π^0 is described by the nuclear modification factor R_{AA}, which is the particle yield normalized to the expectation yield from p+p collisions scaled by the number of binary collisions. The results of R_{AA} dependence versus the angle in the reaction plane are shown in Figure 2 for six centrality bins. As expected, there is

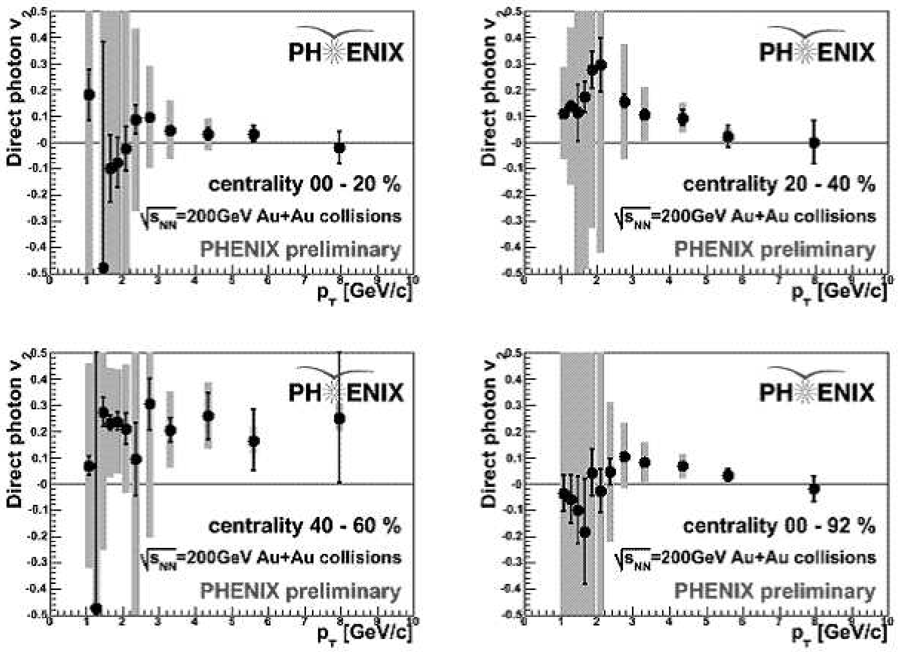

Figure 1. Direct Photon v_2 values for 3 centrality classes and minimum bias events. Systematic errors are shown by shaded boxes.

less suppression in the reaction plane direction. The difference of the yields in- and out the reaction plane is at about factor two. Strikingly, for more peripheral collisions, centrality bins above 50%, there is no absorption in the reaction plane. Although the in plane path length is smaller than out of plane, the suppression, according parton energy loss models can not vanish, in contradiction to the data.

R_{AA} is a measure of particle suppression at fixed momentum as a "vertical" reduction of the yield. This equally well be taked as a "horizontal" shift of the momentum spectrum. If spectrum has the pure power law shape, $Ed^3\sigma/dp^3 \propto p_T^{-n}$, the shift or fractional energy loss S_{loss} can be expressed via R_{AA} as [7]:

$$S_{loss} = 1 - R_{AA}^{1/(n-2)}. \qquad (4)$$

As it was mentioned in the Introduction, we vary thickness of the medium traversing by the fast parton by changing $\Delta\phi$ angle versus the reaction plane. In Figure 3 we present values of R_{AA} and S_{loss} for different centralities versus the distance, L_ϵ, from the center of the interaction region to the edge at particular $\Delta\phi$. The most important observation of this plot is the absence of suppression for the value of $L_\epsilon < 2$ fm. This may suggest more a complex energy loss picture than previously accounted for, such as "formation time effect" [8].

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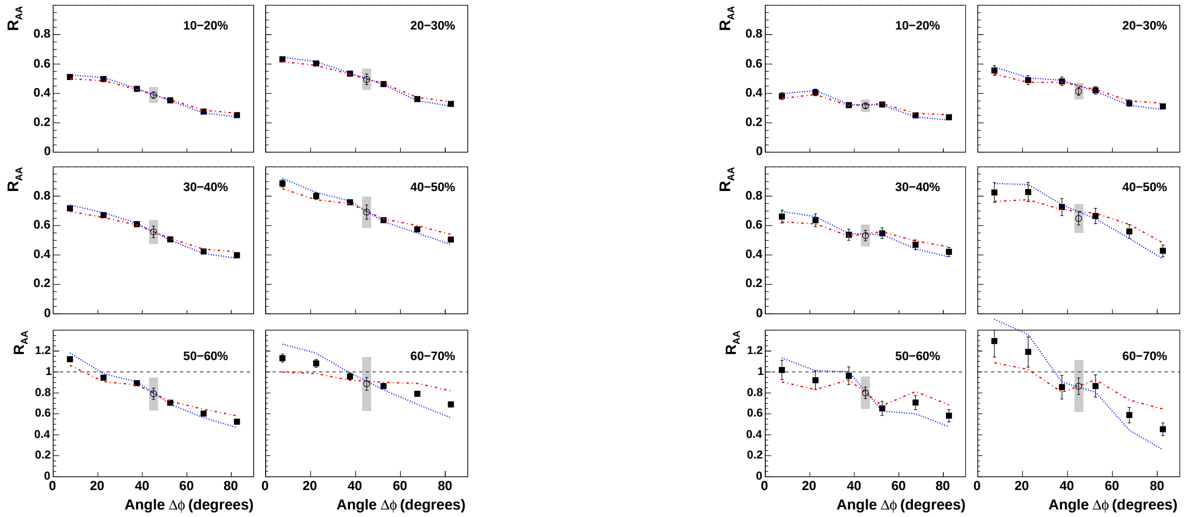

Figure 2. R_{AA} vs. $\Delta\phi$ for π^0 yields integrated over 3< p_T <5 GeV/c, left, and over 5< p_T <8 GeV/c, right. The lines show the uncertainty from the reaction plane resolution. The shaded band indicates the overal R_{AA} uncertainty.

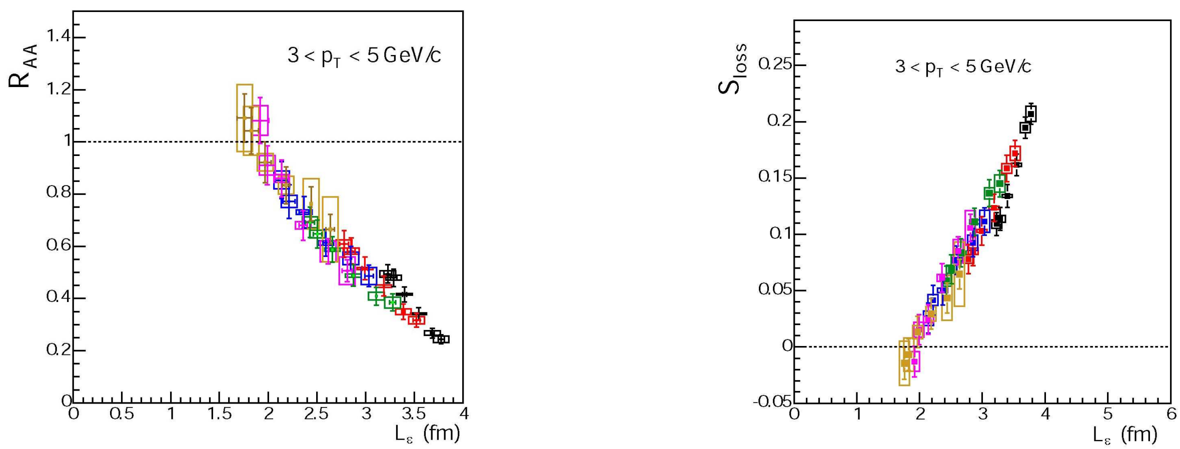

Figure 3. R_{AA} and S_{loss} vs. parameter L_ϵ at different centralities for 3< p_T <5 GeV/c.

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