Reaction plane dependence of neutral pion production in center-of-mass energy of 200 GeV Au+Au collisions at RHIC-PHENIX

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Abstract

The integrated luminosity of RHIC-Year 2007 Au+Au run is 813 \( \mu b^{-1} \), which is 3.5 times larger than that in RHIC-Year 2004 Au+Au run. Additionally, a new detector was installed to determine reaction plane more precisely. This detector is expected to provide better resolution for reaction plane determination. These advantages enable us to precisely measure the path length dependence of \( \pi^0 \) suppression and discuss parton energy loss mechanism more thoroughly. We report the recent results for the reaction plane dependence of \( \pi^0 \) production.

Key words: Parton energy loss, Collective flow

PACS: 25.75.-q, 25.75.Ld, 21.65.Qr

1. Introduction

It has been observed in central Au+Au collisions at Relativistic Heavy Ion Collider (RHIC) that the yield of neutral pions at high transverse momentum \((p_T>5\text{ GeV}/c)\) is strongly suppressed compared to the one expected from p+p collisions scaled by the number of binary collisions. This suppression is considered to be due to the energy lost by hard scattered partons in the medium (jet quenching), which results in a decrease of the yield at a given \(p_T\). Many theoretical models have been proposed to understand the parton energy loss mechanism. For one thing, GLV method[1] as one of the calculations predicts that the magnitude of energy loss is proportional to the path length if the medium has static density. Studying the path length dependence of energy loss should help the understanding of energy loss process.

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Preprint submitted to Elsevier 21 May 2009
2. Azimuthal angle dependence of $R_{AA}$

Recently theoretical models (ASW[2], HT[3] and AMY[4]) to describe parton energy loss mechanism which involve the time-evolution of the medium produced at RHIC have been proposed. These models succeeded in reproducing the centrality dependence of $R_{AA}(p_T)$. These theoretical curves and the preliminary data from PHENIX is shown in Fig. 1[5]. The central Fig. 1 shows expected curves from these models.

As shown on the right panel of Fig. 1, these models are still unable to reproduce the azimuthal angle dependence of $R_{AA}$, even if we compare the curve with the largest variation, the $p_T = 15$ GeV/c of the ASW model to data at much lower $p_T (5<p_T<8$ GeV/c).

When partons lose energy in the medium, the ratio of $R_{AA}(\Delta \phi = 0)$ to $R_{AA}(\Delta \phi = \pi/2)$ should be different for each centrality bin. Fig. 2 shows the azimuthal angle dependence of $R_{AA}$ at $3<p_T<5$ GeV/c. As shown in Fig. 2, $R_{AA}(3<p_T<5$ GeV/c, $\Delta \phi = 0)$ is about two times larger than $R_{AA}(3<p_T<5$ GeV/c, $\Delta \phi = \pi/2)$ for all centrality bins. This may be in part be an effect of collective flow. Since the influence of collective flow at high $p_T$ should be small, we need to measure $R_{AA}(p_T, \Delta \phi)$ at higher $p_T$ to minimize its effect.

3. $v_2(\pi^0)$ at high $p_T$

Reaction plane detector (RxNP) was installed in RHIC-Year 2007 and reaction plane determination accuracy has been improved by a factor of two as compared to that in RHIC-Year 2004. Fig. 3 shows $v_2(\pi^0)$ as a function of $p_T$ for each 20 % centrality bin. This detector enabled us to measure $v_2(\pi^0)$ up to 14 GeV/c. Measured $v_2(\pi^0)$ are non-zero for all centrality bins. Additionally, two assumed function is fitted to this data. One is linear function ($f(v_2) = a \cdot p_T + b$) and the other is constant value ($f(v_2) = c$). At centrality 0-20 %, values of $\chi^2$/NDF for constant and linear function are 4.45/5 and 4.34/4, respectively. At centrality 20-40 %, values of $\chi^2$/NDF for
constant and linear function are $4.39/5$ and $1.49/4$, respectively. At centrality $40-60\%$, values of $\chi^2/NDF$ for constant and linear function are $2.23/5$ and $2.21/4$, respectively. These results indicate that the values of $v_2(\pi^0)$ in most central and peripheral collisions tend to be constant while in mid-central collisions tend to decrease.

![Fig. 3. $v_2(\pi^0)$ as a function of $p_T$ for each 20\% centrality bin. Red and blue lines show constant and linear function, respectively. Red and blue lines are fitted to data from 6 GeV/c.](image)

4. Summary and outlook

Study of path length and azimuthal angle dependence of $R_{AA}$ with the new reaction plane detector has been started. The nuclear modification factor, $R_{AA}(5<p_T<8\text{ GeV/c})$ as a function of azimuthal angle has been compared to theoretical models. Even though the models are in good agreement with the (azimuthally integrated) $R_{AA}$, so far they could not reproduce the measured azimuthal angle dependence. The measurement of $v_2(\pi^0)$ has now been extended to 14 GeV/c. For the most central (0-20\%) and peripheral (40-60\%) collisions, the elliptic flow tends to be constant (instead of decreasing monotonically with $p_T$), while for mid-central collisions (20-40\%) we observe a decrease with $p_T$.

With the new data we will be able to measure the dependence of $R_{AA}$ on azimuthal angle up to higher transverse momenta than ever before. We can also estimate the path length by measuring the azimuthal angle from reaction plane and mapping it into the shape of the participant region, which can be calculated by Glauber model for each impact parameter (centrality).

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