

Profiling hot and dense nuclear medium with high transverse momentum hadrons produced in d+Au and Au+Au collisions by the PHENIX experiment at RHIC

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Abstract. PHENIX measurements of high transverse momentum (p_T) identified hadrons in d+Au and Au+Au collisions are presented. The nuclear modification factors (R_{dA} and R_{AA}) for π^0 and η are found to be very consistent in both collision systems, respectively. Using large amount of $p + p$ and Au+Au datasets, the fractional momentum loss (S_{loss}) and the path-length dependent yield of π^0 in Au+Au collisions are obtained. The hadron spectra in the most central d+Au and the most peripheral Au+Au collisions are studied. The spectra shapes are found to be similar in both systems, but the yield is suppressed in the most peripheral Au+Au collisions.

1 Introduction

The interaction of hard scattered partons with the medium created by heavy ion collisions (i.e., quark-gluon plasma, QGP) has been of interest since the beginning of the RHIC running [1]. A large suppression of the yields of high transverse momentum (p_T) hadrons which are the fragments of such partons was observed, suggesting that the matter is sufficiently dense to cause parton-energy loss prior to hadronization [2]. Absence of the hadron suppression in d+Au collisions supported the parton-energy loss scenario [3]. After accumulating a large amount of $p + p$, d+Au, and Au+Au collision events, we substantially extended the degree of freedom in high p_T hadron measurements. In this paper, we show the recent studies of the QGP using high p_T hadrons by the PHENIX experiment.

2 π^0 and η measurements in d+Au and Au+Au collisions

The PHENIX experiment [4] has been exploring the highest p_T region with single π^0 and η mesons. They are leading hadrons of jets, and thus provide a good measure of momentum of hard scattered partons. Here, we present the results obtained from d+Au collisions collected in the RHIC Year-2008 run (80 nb^{-1}) and Au+Au collisions in the Year-2007 run (0.81 nb^{-1}). Figure 1 shows the nuclear modification factors ($R_{dA} \equiv (dN_{dA}/dydp_T)/(\langle T_{dA} \rangle d\sigma_{pp}/dydp_T)$) for π^0 , η and fully-reconstructed jets in d+Au collisions at $\sqrt{s_{NN}}=200 \text{ GeV}$. They are very consistent each other, and also consistent with unity at low p_T in both most central and peripheral collisions. However, at high p_T , the yields are suppressed in most central collisions and enhanced in most peripheral collisions. The consistency of

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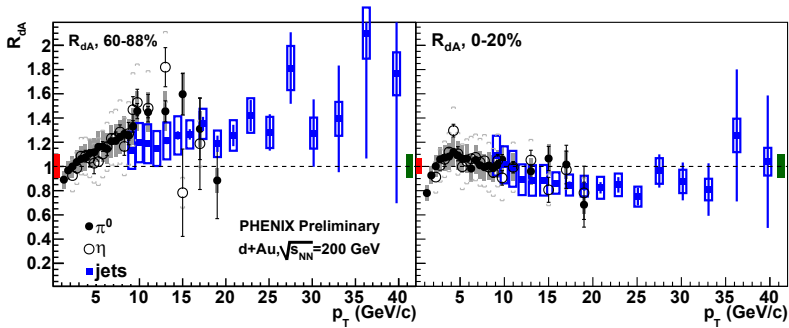


Figure 1. R_{dA} for π^0 , η and fully-reconstructed jets in $d+Au$ collisions.

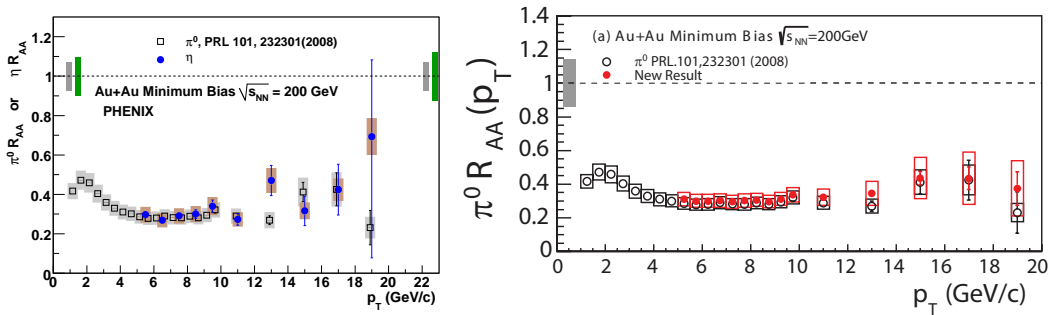


Figure 2. (a, left) R_{AA} for π^0 and η in minimum bias Au+Au collisions. (b, right) R_{AA} for π^0 from the RHIC Year-2004 run and Year-2007 run.

π^0 and η are also seen in $R_{AA} (\equiv (dN_{AA}/dydp_T)/(\langle T_{AA} \rangle d\sigma_{pp}/dydp_T))$ in 200 GeV Au+Au collisions as shown in Figure 2(a) [5]. Because η has four times larger mass compared to that of π^0 , one can resolve two photons decaying from η up to four times larger p_T of π^0 , resulting in a higher p_T reach with smaller systematic errors with η . Figure 2(b) demonstrates that the π^0 from the Year-2007 run has smaller errors and is consistent with that from the Year-2004 run [6].

The recent result of single electron measurement shows that the R_{dA} and R_{AA} for light hadrons and electrons from heavy flavor hadrons have similar trend of enhancement and suppression, except for low p_T region, where soft production is dominant [7]. This fact suggests that the interaction of light hadrons and heavy hadrons with medium has same system dependence.

3 Fractional momentum loss of hadrons in Au+Au collisions

The large amount of events collected in $p + p$ and Au+Au collisions made us possible to quantify the energy loss effect from a different aspect. Experiments have been looking at the suppression of the yield to see the effect. However, the suppression is primarily the consequence of the reduction of momentum of hadrons which have exponential p_T distributions. We have statistically extracted the fractional momentum loss ($S_{\text{loss}} \equiv \delta p_T/p_T$, $\delta p_T \equiv p_T - p'_T$, where p_T is the transverse momentum of $p + p$ data, and p'_T is that of Au+Au data) of the partons using the hadron p_T spectra measured in $p + p$

and Au+Au collisions [6]. Figure 3(a) depicts the method to compute the S_{loss} . Using this method, we computed the S_{loss} in Au+Au collisions at $\sqrt{s_{NN}}=39, 62,$ and 200 GeV as shown in Figure 3(b) [8]. We also computed the S_{loss} in 2.76 TeV Pb+Pb collisions using charged hadron spectra measured by the ALICE experiment [9] as shown in Figure 3(c). S_{loss} 's vary by a factor of six from 39 GeV Au+Au to 2.76 TeV Pb+Pb collisions.

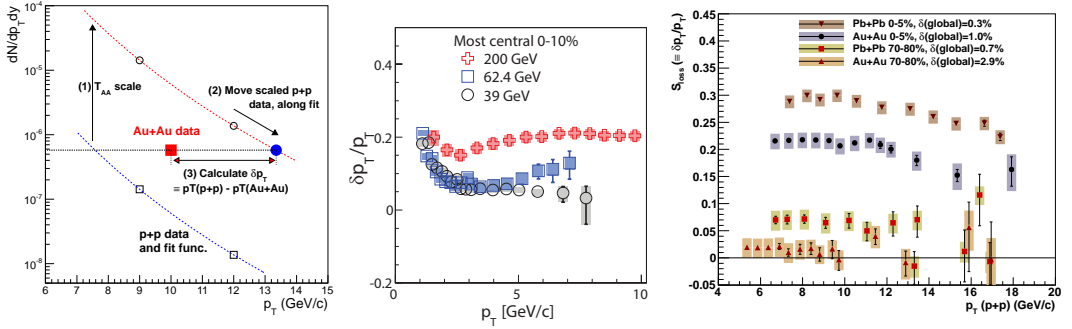


Figure 3. (a, left) Method of calculating average S_{loss} . We scaled the p+p data by T_{AA} corresponding to centrality selection of Au+Au data, shifted the p+p points closest to Au+Au in yield, and calculated momentum difference of p+p and Au+Au points. (b, middle) S_{loss} for π^0 for 0-10% centrality 39, 62, and 200 GeV Au+Au collisions. (c, right) S_{loss} for π^0 in 200 GeV Au+Au collisions and charged hadrons in 2.76 TeV Pb+Pb collisions.

4 Path-length and collision system dependence of parton energy loss

With larger statistics, we were able to measure the R_{AA} of π^0 for in- and out-of event planes. Figure 4 shows the ones for π^0 s in 20-30% central 200 GeV Au+Au collisions [6]. The difference of the

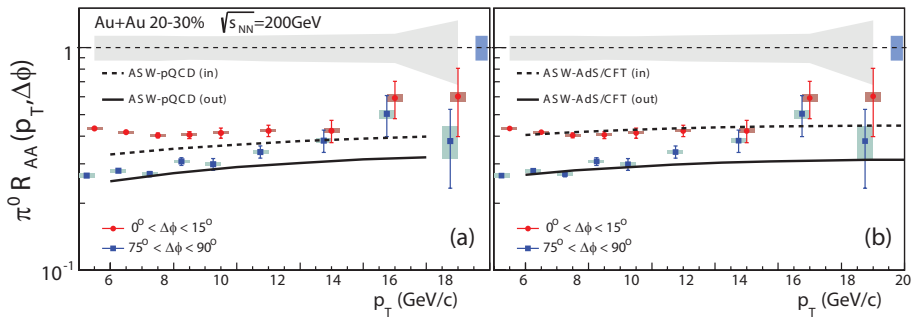


Figure 4. $R_{AA}(\phi)$ of π^0 in 20–30% centrality for in-plane and out-of-plane. Data are compared with a pQCD-inspired model (left), and an AdS/CFT-inspired model (right).

yield provides path-length dependence of yield modification. Depending on the energy loss models, the powers of the path-length dependence change. The data favors an AdS/CFT-inspired (strongly coupled) model rather than pQCD-inspired (weakly coupled) model, implying that the energy loss is L^3 dependent rather than L^2 dependence, where L denotes the path-length of partons in the medium.

We note that the N_{coll} and N_{part} values are quite consistent in certain central d +Au and peripheral Au+Au collisions. The ratio of N_{coll} in 0-20% d +Au to that in 60-92% Au+Au is 1.02 ± 0.22 , and the same ratio for N_{part} values is 1.04 ± 0.21 . Motivated by this fact, we took the ratio of the spectra in 60-92% Au+Au to 0-20% d +Au collisions for identified particles as shown in Figure 5 [10]. The

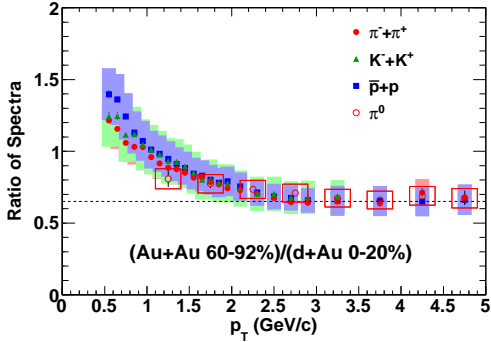


Figure 5. Ratio of invariant yield of particles in peripheral Au+Au (60–92 %) to central d +Au (0–20 %) collisions as a function of p_T .

ratios tend to the same value of roughly 0.65 for each particle species at and above 2.5-3 GeV/ c . This universal scaling is strongly suggestive of a common particle production mechanism between peripheral Au+Au and central d +Au collisions. The trend of overall rise in low p_T may come from rapidity shift in asymmetric collisions in d +Au. There is also mass dependence of the rise seen in lower p_T . Assuming that the cold nuclear effect scales with N_{coll} or N_{part} , the ratio 0.65 may be attributable to the parton energy loss in peripheral Au+Au collisions.

5 Summary

PHENIX measurement of high p_T identified hadrons in d +Au and Au+Au collisions are presented. The R_{AA} for π^0 and η are found to be very consistent in both collision systems, respectively. The S_{loss} 's of high p_T hadrons are computed from 39 GeV Au+Au over to 2.76 TeV Pb+Pb, and found that they vary by a factor of six. The path-length dependent π^0 yield deduced that the energy loss of partons is L^3 dependent. It was found that the hadron production mechanism in central d +Au and peripheral Au+Au is similar, but the ratio of the yields is ~ 0.65 which may be attributable to the parton energy loss in peripheral Au+Au collisions.

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