PROCEEDINGS OF SCIENCE

High p_{T} single identified particles in various collision systems with the PHENIX detector at RHIC

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Jet quenching in the hot, dense medium formed in Au + Au collisions leads to the suppression of high p_{T} particles which can be studied with the measurement of the leading hadrons, like π^0 . They can be used to investigate the mechanism of energy loss of partons in a QGP when varying the collision geometry. Asymmetric Cu + Au collisions provide a system with similar energy density but different collision geometry when compared to Au+Au, with the same number of nucleon-nucleon collisions. Furthermore, at RHIC we can study different highly asymmetric collisions, such as p+Au, d+Au and ^{3}He+Au . The observation of collective behavior in these systems suggests the creation of a medium, but alternate explanations exist. The systematic study of the π^0 production could give us deeper understanding of the physics in these very asymmetric systems.

We present new measurements of π^0 with PHENIX in the asymmetric collisions at midrapidity η <0.35 with collision energy $\sqrt{s_{NN}}$ = 200 GeV.

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1. Introduction

In heavy-ion (HI) collisions the hard scattering of individual quarks and gluons (partons), the constituents of the nucleons will happen in the first place. In vacuum (in $p+p$ collisions), the outgoing partons lose energy during the fragmentation process. Additional radiation that leads to the suppression of high-p_{T} particles, is induced in HI-collisions by the produced dense medium. This phenomena is labeled ”jet-quenching”. High-p_{T} direct photon production is not affected by the created medium and its unmodified yield in heavy ion collisions provides a strong proof of the jet suppression [1].

Jet-quenching in HI-collisions can be used to study the energy loss mechanism in QGP. New results of apparent collective behavior were observed in highly asymmetric systems, d+Au [2] or p+Pb [3]. It suggests a formation of a small, hot medium which can be similarly described with the same hydrodynamics tools as the medium created in HI-collisions. How do other signatures of the quark-gluon plasma behave in these small collisions? In the following we describe the jet-quenching phenomena using the leading hadron as a proxy in various collision systems, measured with the PHENIX detector at RHIC and compare it to various models, all at mid-rapidities $|\eta| <$ 0.35. Due to its abundance in production π^0 are being used as leading hadrons.

In order to quantify the change in single particle production, we define the nuclear modification factor

$$R_{AA} = \frac{(1/N_{AA}^{\mathrm{evt}})\, d^2N_{AA}/dp_{\mathrm{T}}\,dy}{\langle T_{AA}\rangle \cdot d^2\sigma_{pp}/dp_{\mathrm{T}}\,dy}, \tag{1.1}$$

where $d^2N_{AA}/dp_{\mathrm{T}}\,dy$ is the invariant yield in A+A collisions, σ_{pp} is the production cross section in $p+p$ collisions, and T_{AA} is the nuclear thickness function calculated from the Glauber model. In the case where there is no $p+p$ reference, one can similarly define the R_{CP}, where we divide by the invariant yield from the peripheral collisions instead of the $p+p$ reference. Usually, one refers to $R_{AA} < 1$ as suppression and $R_{AA} > 1$ as enhancement.

2. Comparison of Systems and Centralities and Models

In small systems and minimum bias a hint of suppression can be seen in Fig. 1: the invariant yield of neutral pion was measured in p+Au and ^{3}He+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV and compared with our earlier measurement in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV [4]. Fig. 1 shows the comparison of the nuclear modification factor in $p/d/^3$He+Au collisions. A small enhancement can be observed around $p_{\mathrm{T}} \sim 5$ GeV$/c$ which depends on the collision system. The data indicates that the enhancement is more pronounced in p+Au collisions than in the d+Au and ^{3}He+Au collision systems. The nuclear modification factor falls below unity for $p_{\mathrm{T}} > 10$ GeV$/c$ and the value of the R_{AA} for each system is consistent within their uncertainties. Small systems as p+Au show a large centrality dependency, see Fig. 2, shown for various centrality bins. Furthermore, at high-p_{T}, where the hard scattering is the dominant process, all three systems show a comparable nuclear modification factor for all centralities. The most central values fall below unity, while in more peripheral collisions the data are consistent with unity within the experimental uncertainties. The current data suggest a suppression in the most central of $p/d/^3$He+Au collisions, which could be a result of energy loss in cold nuclear matter [5].

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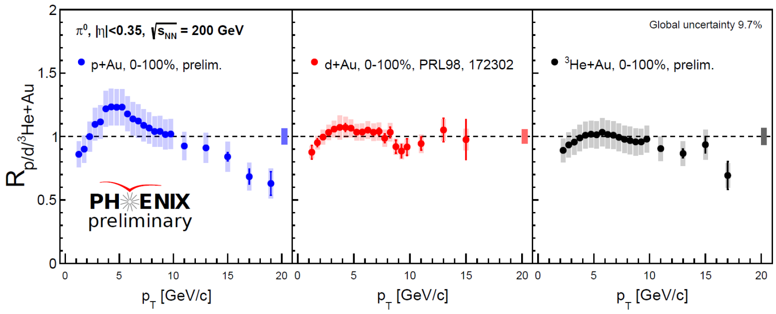

Figure 1: The nuclear modification factor of π^0 measured in minimum bias of p+Au (left panel), d+Au (middle panel) and ^{3}He+Au (right panel) collisions at $\sqrt{s_{NN}} = 200$ GeV. The global uncertainty of 9.7% originates from the uncertainty of the $p+p$ cross section.

At intermediate p_T an ordering phenomena in the most central centrality is visible: $R_{pAu} > R_{dAu} > R_{^3HeAu}$ (see Fig. 2 top left panel).

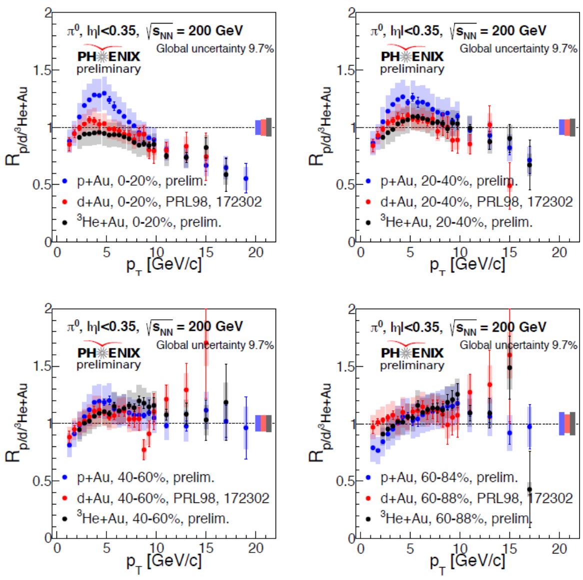

Figure 2: The comparison of π^0 nuclear modification factor measured in different centralities in p+Au , d+Au and ^{3}He+Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

For different collision systems but similar N_{part} it is observed (Fig. 3) that the suppression pattern is in good agreement with Au + Au and Cu + Cu collision systems. This indicates that the production is dependent on nuclear overlap but not on shape. In peripheral collisions one can see a hint of enhancement in Cu + Au , a suppression in Au + Au and a situation in between enhancement and suppression for Cu + Cu collision systems.

Various model comparisons were performed. The models used were *1. Cold Nuclear Energy Loss* [5], *2. HIJING++* [6], and *3. High-x Proton Size Fluctuation* [7]. Fig. 4 indicates that model 1., based on the generalization of the DGLAP evolution equations to include final-state medium-induced parton showers, combined with initial-state effects for applications to jet quenching phenomenology does not properly describe the enhancement, neither the system dependence, but has

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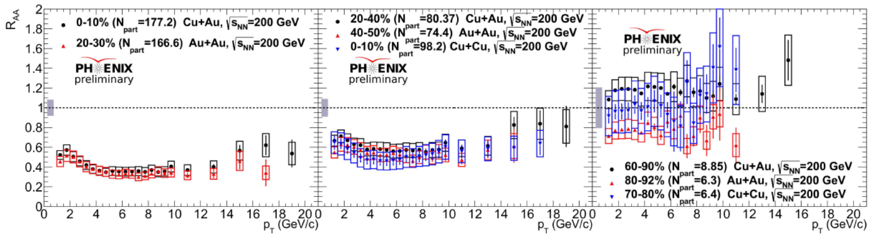

Figure 3: Comparison between Cu + Au , Cu + Cu , and Au + Au collision systems at various centralities.

agreement with a moderate cold nuclear energy loss model to high-p_T data. For model 2. it is ap-

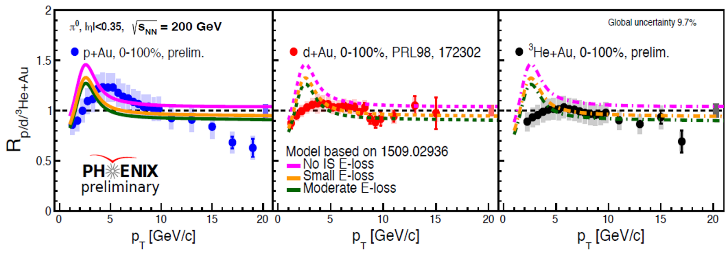

Figure 4: Comparison of cold nuclear energy models with minimum bias measurements of small systems $p/d/^3$He+Au .

parent from Fig. 5 that the Cronin peak is at much lower p_T in simulation. A similar trend in the simulation and data is seen based on multiple scattering and shadowing effects. A clear ordering in

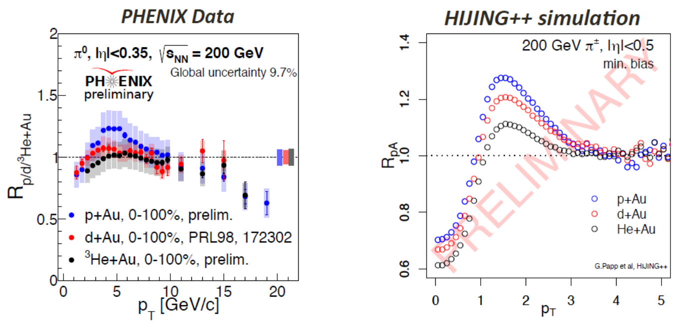

Figure 5: Comparison of minimum bias measurements with HIJING++ simulated data.

model 3. can be seen: Fig. 6. However, the trend in the model does not agree with data.

3. Summary

PHENIX measured π^0 production at mid-rapidity in collisions of p+Au , d+Au , ^{3}He+Au , and Cu + Au at $\sqrt{s_{NN}}$ =200 GeV. For small asymmetric collision systems, $p/d/^3$He+Au it was found that the nuclear modification factors were smaller than one at high p_T . In the range of intermediate p_T an indication of small systems' ordering in minimum bias and most central collisions becomes visible. The comparison between models described in this work showed no conclusion.

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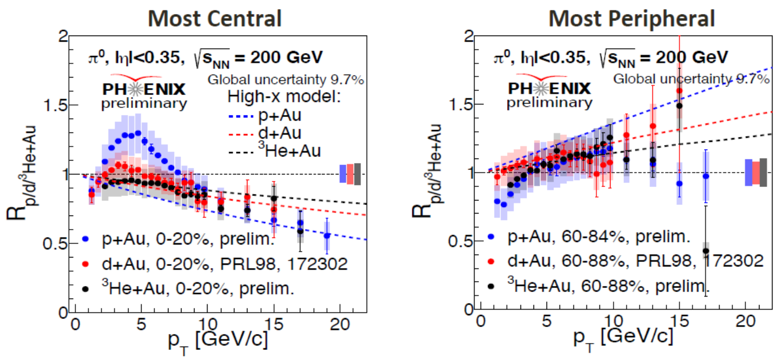

Figure 6: Comparison of a high-x proton size fluctuation model with most central (left) and most peripheral (right) data measured with the PHENIX detector.

In central and semi-central Cu + Au collisions an indication of suppression is seen at similar N_{part} . This suggests that the suppression level depends on overlap size and not on its geometry. A hint of enhancement in peripheral Cu + Au collisions is seen.

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