Particle Suppression at High-x_F in Au+Au Collisions at RHIC

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Abstract. Measurements of x_F-dependent nuclear modification factors of charged mesons and protons in Au+Au collisions at $\sqrt{s}$ = 200 and 62.4 GeV at RHIC are presented. Particle suppression at high-x_F is discussed in the context of kinematic constraints of particle production competing with dynamically induced nuclear modification mechanisms.

The partonic QCD phases in the highly excited state of matter are predicted to be accessible by collisions between two heavy nuclei at extreme high energy [1]. The vast body of the measurements at mid-rapidity in central Au+Au collisions obtained by the four experiments at RHIC for the last 6 years in conjunction with the available theoretical studies indicate that the matter created by heavy-ion collisions at RHIC cannot be characterized solely by hadronic degrees of freedom [2, 3]. In order to characterize the nature of the created nuclear (partonic or hadronic) matter, it is imperative to study the particle production in a wide kinematic range beyond the mid-rapidity region to provide stringent constraints on theoretical interpretations of matter formed in heavy-ion collisions. In particular, studying nuclear modification beyond the mid-rapidity region can provide an important way of investigating how matter with high energy density is distributed in the longitudinal direction [4, 5]. Particle production at forward rapidities in relativistic heavy-ion collisions are complicated by interplay between various dynamical nuclear modification processes and kinematically limiting processes [6, 7, 8]. The available kinematic phase-space at large Feynman-x approaching the kinematic limit demands the probability of particle production to be constrained. In the nuclear medium, the effect is expected to be enhanced by multiple interactions of the projectile parton. This effect, referred to as the Sudakov suppression [9] is expected to be scaled with x_F defined as x_F=$2p_L/\sqrt{s_{NN}}$ where p_L is the longitudinal momentum. The centrality dependence of charged particle multiplicity has been shown to be factorized from the energy dependence of particle production at near the beam rapidities in Au+Au collisions at RHIC energies [10]. Such longitudinal scaling behavior has also been seen in proton-nucleus collisions at lower energies [11]. To understand the dynamic nature of nuclear collisions, it is important to distinguish

‡ For the full author list and acknowledgments, see the appendix of this volume.

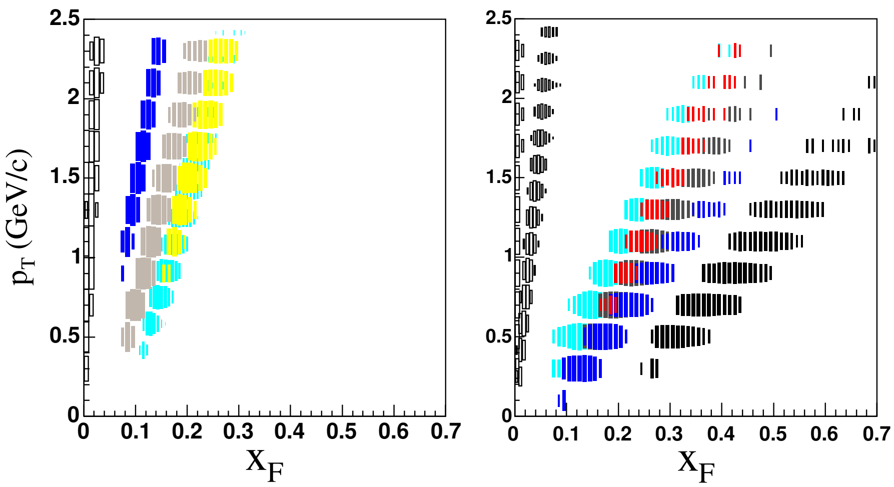

Figure 1. p_T vs. x_F for the data used in the analysis at $\sqrt{s} = 200$ GeV (left Panel) and 62.4 GeV (right panel). The open boxes at low-x_F ($\lesssim$0.1) are the measurements from the Mid-Rapidity Spectrometer and closed boxes are from the Forward Spectrometer data.

such kinematically dominated effects from dynamically driven processes, such as parton energy loss in the hot nuclear medium [12], and gluon saturation in the initial state [13]. We have measured x_F-dependent nuclear modification factors of mesons ($\pi + K$) and protons in Au+Au collisions up to intermediate p_T regions ($p_T \lesssim 2$ GeV/c) to investigate the medium dependence of particle production as it approaches the kinematic limit. The nuclear modification factor R_{CP} is defined as the ratio of the particle yield in central collisions to the particle yield in peripheral collisions, each normalized by the average number of nucleon-nucleon binary collisions ($\langle N_{coll} \rangle$):

$$R_{CP} = \frac{\frac{1}{\langle N_{coll} \rangle^{central}} \left(\frac{dN}{dx_F dp_T} \right)^{central}}{\frac{1}{\langle N_{coll} \rangle^{peripheral}} \left(\frac{dN}{dx_F dp_T} \right)^{peripheral}} \tag{1}$$

The data presented here were collected with the BRAHMS detector system [14] in Au+Au collisions at energies of $\sqrt{s_{NN}} = 200$ and 62.4 GeV at RHIC. The Forward Spectrometer (FS) in BRAHMS has the unique capability of measuring tracks in forward kinematic region ($\theta = 2.3^\circ - 15^\circ$) with good momentum resolution and particle identification (PID). The PID separation of pions and kaons using the Ring Image Cherenkov (RICH) detector is up to $p \sim 35$ GeV/c and protons can be identified up to 45 GeV/c. The Mid-Rapidity Spectrometer (MRS) measures charged hadrons produced near mid-rapidity with particle identification by Time-of-Flight hodoscope detectors. The kinematic coverage of the data used in the analysis as a function of p_T and x_F are shown in Fig. 1. The narrow p_T-x_F correlated band at a given setting is due to the small aperture of the spectrometer. For characterizing the centrality of collisions, a multiplicity array (MA) consisting of a coaxial arrangement of Si strip detectors and scintillator tiles surrounding the intersection region is employed. Details of the BRAHMS experimental set-up can be found in [14]. The numbers of binary collisions

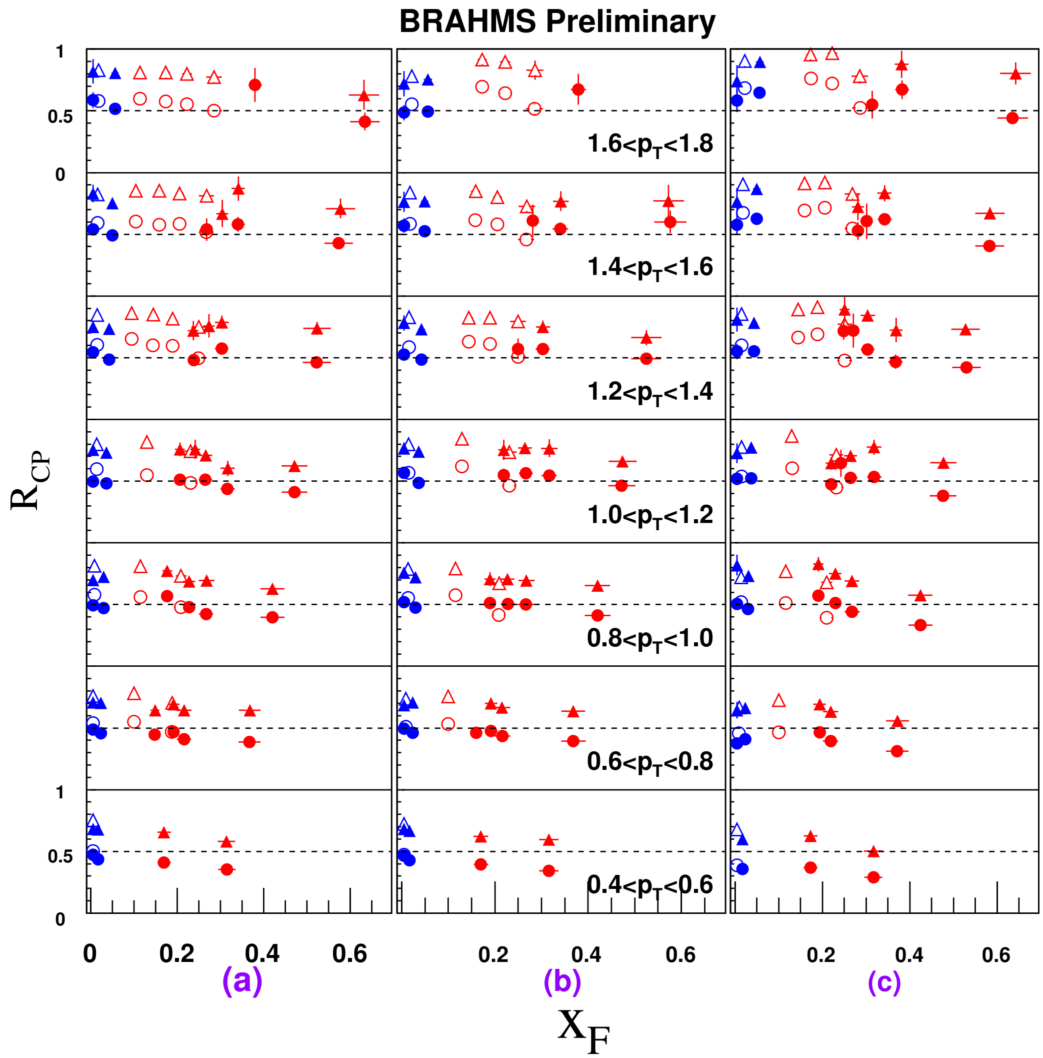

Figure 2. Nuclear modification factor R_{CP} as a function of x_F for (a): negatively charged mesons (π^-+K^-), (b): positively charged mesons (π^++K^+), and (c): protons. Transverse-momentum ranges used for the plots are displayed in units of GeV/c in panel (b). Solid symbols are from $\sqrt{s_{NN}}$ = 62 GeV and open symbols are from 200 GeV. $R_{CP}(0-20\%/40-70\%)$ are shown with circles and $R_{CP}(20-40\%/40-70\%)$ are displayed with triangles. Measurements from MRS and FS are distinguished by color. Only statistical errors are shown where larger than symbols. Error bars in x are rms values of the x_F distribution at given p_T. Systematic uncertainties are estimated to be ≈ 15%. See the text for the uncertainties on normalization.

used in Eq. 1 are estimated with the Glauber Monte Carlo HIJING calculation [15]. The overall scaling errors associated with uncertainties of determining relative ratios of the number of collisions, $\mathcal{N} = \frac{\langle N_{coll}\rangle^{central}}{\langle N_{coll}\rangle^{peripheral}}$ are estimated to be 15 - 30%. The values for $\mathcal{N}$ used for $R_{CP}(0-20\%/40-70\%)$ and $R_{CP}(20-40\%/40-70\%)$ are 11.3(+2.7 − 2.5), 4.0(+1.3 − 0.6) for $\sqrt{s_{NN}}$ = 62.4 GeV, and 13.1(+2.9 − 2.6), 4.5(+1.4 − 0.6) for 200 GeV, respectively.

The nuclear modification factors $R_{CP}(0-20\%/40-70\%)$ and $R_{CP}(20-40\%/40-$

70%) for charged mesons ($\pi+K$) and protons at $\sqrt{s_{NN}} = 62.4$ and 200 GeV as a function of x_F are shown in Fig. 2. The p_T ranges for the data are displayed in the figure. The results show that R_{CP} is smaller for more central collisions in all measured kinematic region at 200 GeV as previously reported [4]. The suppression factors are similar at $\sqrt{s_{NN}} = 62.4$ GeV. R_{CP} at 200 GeV and 62 GeV show approximately similar centrality dependence of particle production in the kinematic region where two measurements overlap. As x_F increases, R_{CP} for central and semi-central both similarly show a slow decrease without significant differences in centrality dependencies. This implies that kinematic constraints might play a more significant role in nuclear modification competing with dynamical suppression mechanisms at large-x_F. Protons show similar trends even though the production mechanism is different as a significant fraction of the protons might still be from the beam fragments under the constraint of baryon conservation in this kinematic range.

In summary, the BRAHMS experiment has measured x_F-dependent nuclear modification factor in Au+Au at $\sqrt{s_{NN}} = 200$ and 62.4 GeV at RHIC. The results qualitatively indicate that kinematic constraints are partly responsible for the nuclear modification at high-x_F. Since it is imperative to understand kinematically driven mechanisms to disentangle the complex interplay among dynamical physics processes at forward rapidity region, these measurements will serve as an input for theoretical modeling.

References

[1] For a review, see J. Kapusta, B. Müller and J. Rafelski, *Quark-Gluon Plasma: Theoretical Foundations*, 2003 Chapter 2, Elsevier

[2] M. Gyulassy and L. McLerran 2005 *Nucl. Phys.* A **750** 30

[3] The "White papers"- BRAHMS, PHOBOS, PHENIX, and STAR Collaborations 2005 *Nucl. Phys.* A **757** 1

[4] I. Arsene *et al* (BRAHMS Collaboration) 2003 *Phys. Rev. Lett.* **91** 072305

[5] J.H. Lee *al.* (BRAHMS Collaboration) 2006 *J. Phys.* G **32** S61

[6] G.G. Barnaföldi *et al* 2006 arXiv:hep-ph/0609023

[7] T. Hirano and Y. Nara 2004 *Phys. Rev.* C **69** 034908

[8] R.C. Hwa and C.B. Yang 2006 arXiv:hep-ph/0605037

[9] B.Z. Kopeliovich *et al* 2005 *Phys. Rev.* C **72** 054606

[10] B.B. Back *et al* (PHOBOS Collaboration) 2006 *Phys. Rev.* C **74** 021901

[11] W. Busza 1992 *Nucl. Phys.* A **544** 49

[12] M. Gyulassy and M. Plümer 1990 *Phys. Lett.* B **243** 432
X.N. Wang and M. Gyulassy 1992 *Phys. Rev. Lett.* 68 1994

[13] R. Venugopalan 2003 arXiv:hep-ph/0412396 and references therein

[14] M. Adamczyk *al.* (BRAHMS Collaboration) 2003 *Nucl. Phys.* A **499** 437

[15] X.N. Wang and M. Gyulassy 1991 *Phys. Rev.* C **44** 3501;
http://www-nsdth.lbl.gov/~xnwang/hijing/