International Journal of Modern Physics E

Centrality Dependence of Charged Hadron Spectra at Forward Rapidities in Cu+Cu Collisions at $\sqrt{s_{NN}} = 200$ GeV

Selemon Bekele for the BRAHMS Collaboration

Department of Physics and Astronomy, University of Kansas,
Lawrence, Kansas 66045, USA
bekeleku@ku.edu

Received (received date)
Revised (revised date)

We present preliminary results for Cu+Cu collisions at $\sqrt{s_{NN}} = 200$GeV at the BRAHMS experiment from charged hadron spectra and nuclear modification factors as a function of centrality and pseudo-rapidity. Deviations from binary scaling at intermediate and high-p_T reveal themselves as a suppression in the transverse momentum distribution of produced particles. The observed suppression depends on the volume of the interaction region through which produced hadrons have to travel. While there is still significant suppression, R_{cp} seems to depend very little on pseudo-rapidity.

1. Introduction

It is believed that a strongly interacting Quark Gluon Plasma (QGP) has been created in high energy heavy ion collisions at the Relativistic Heavy Ion Collider (RHIC). The QGP is a deconfined state of matter that lives for a very short time ($2 \sim 10$ fm/c), its properties can be studied only indirectly by investigating the particles formed after hadronization. Thus, the study of the hadron spectra can provide information about the formation and development of the QGP. At low p_T, particle production is dominated by soft QCD processes and the particle spectra are well described by hydrodynamical models. In the intermediate p_T range ($2 < p_T < 6$), recombination (parton coalescence) seems to play a role in hadronization. At high p_T, particle production is dominated by parton fragmentation.

Recent results from Au+Au collisions at $\sqrt{s_{NN}} = 200$GeV at RHIC show substantial suppression of both the neutral and charged hadron spectra at mid-rapidity with respect to spectra from pp collisions scaled by the average number of binary nucleon-nucleon collisions[7]. Surprisingly, comparable suppression at forward rapidity has also been observed. Understanding the mechanism of hadron suppression has been one of the major undertakings of each of the RHIC experiments. The suppression at mid rapidity is believed to result from final state effects while the cause of the suppression at forward rapidity is not very well understood yet. Experiments were also carried out with dAu [8] collisions with the expectation that there would be no suppression but rather an enhancement, due to the Cronin effect [1], of the hadron yield if the suppression was a final state effect. On the other hand, if initial state effects play a major role, then there would be a significant reduction in particle production. The transverse momentum spectra in this case did not exhibit a suppression at all at mid-rapidity unlike the case in AuAu collisions lending support to the idea that final state interactions might actually be responsible for the suppression at mid-rapidity. However, measurements at forward rapidities have shown a clear suppression suggesting not only final state effects but also initial state effects play a role in the particle production mechanism.

The CuCu system serves as a bridge between the dAu and AuAu systems. Since the total particle production in heavy ion collisions gets contributions from soft processes that scale with the number of participants, and hard processes that scale with the number of binary collisions, the CuCu system offers the possibility to study the dependence of hadron suppression in terms of the number of participants N_{part} and the number of binary collisions N_{coll}. In particular, the system size dependence of the nuclear modification factor may be investigated in terms of N_{part}. Together with results from dAu and AuAu collisions, the data from CuCu collisions also allows us to study the energy dependence of the spectra and the dependence on the shape of the reaction zone created in the collision.

Theoretical models have been developed to describe certain aspects of the experimental data in terms of final state effects such as parton recombination, energy loss, or initial state effects such as CGC. Recombination models [2], for example, seem to give adequate explanation for the different behavior of intermediate and high-p_T suppression of mesons and baryons. Jet quenching [1,3] is another mechanism invoked to explain the suppression of particle production where high energy partons traveling through the hot and dense medium created in a heavy ion collision lose energy leading to a suppression. This may also be related to the initial conditions, in particular to the possible existence of the color glass condensate(CGC)[4,5]. According to the theory of the CGC, a very high energy hadron has contributions to its wave function from gluons, quarks and anti-quarks. In terms of the momentum fraction x of the partons inside an interacting hadron, low x phenomena correspond to large rapidity. The density of low x gluons grows as energy increases leading to gluon saturation. Parton scattering centers are reduced due to gluon-gluon fusion and, as a result, there should be fewer hard scatterings leading to a reduction in the production of hadrons.

A comparison of results from pp , dAu, AuAu, and CuCu (intermediate between the lightest and heavy systems) collisions is expected to shed light on the actual particle production mechanism in heavy ion collisions and thereby constrain the various theoretical models used to explain the existing experimental data.

2. The BRAHMS Experiment

The BRAHMS detector system [6] consists of global detectors for event characterization, a Mid Rapidity Spectrometer(MRS) and a Forward Spectrometer(FS) covering forward rapidities. Collision centrality is characterized by a multiplicity array(MA) consisting of scintillator tiles and silicon strip detectors mounted coaxially around the beam axis. For the present studies, the forward spectrometer was positioned at $12^o, 8^o$, and 4^o with respect to the beam direction, corresponding to $\eta \sim 2.2, \eta \sim 2.6$, and $\eta \sim 3.2$ respectively. Events within ± 20 cm of the nominal interaction vertex were considered.

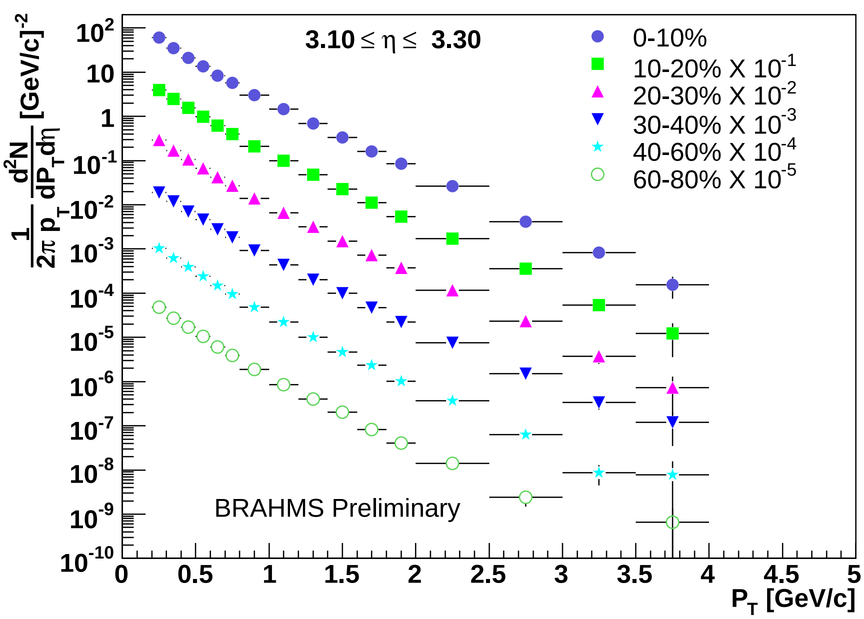

Fig. 1. p_T spectra at η 3.2 in CuCu Collisions. The data are for six centrality bins and are scaled down for clarity by the indicated factors.

3. Results from CuCu $\sqrt{s_{NN}} = 200$ GeV

Suppression of particle production is described in terms of the nuclear modification factor R_{AA}. This is the ratio of the measured hadron spectra to reference spectra from pp collisions scaled by the average number of binary nucleon-nucleon collisions N_{coll}. The value of R_{AA} is expected to be unity if a nucleus-nucleus collision were just a superposition of independent nucleon-nucleon collisions.

It is also possible to study hadron production by comparing the p_T spectrum

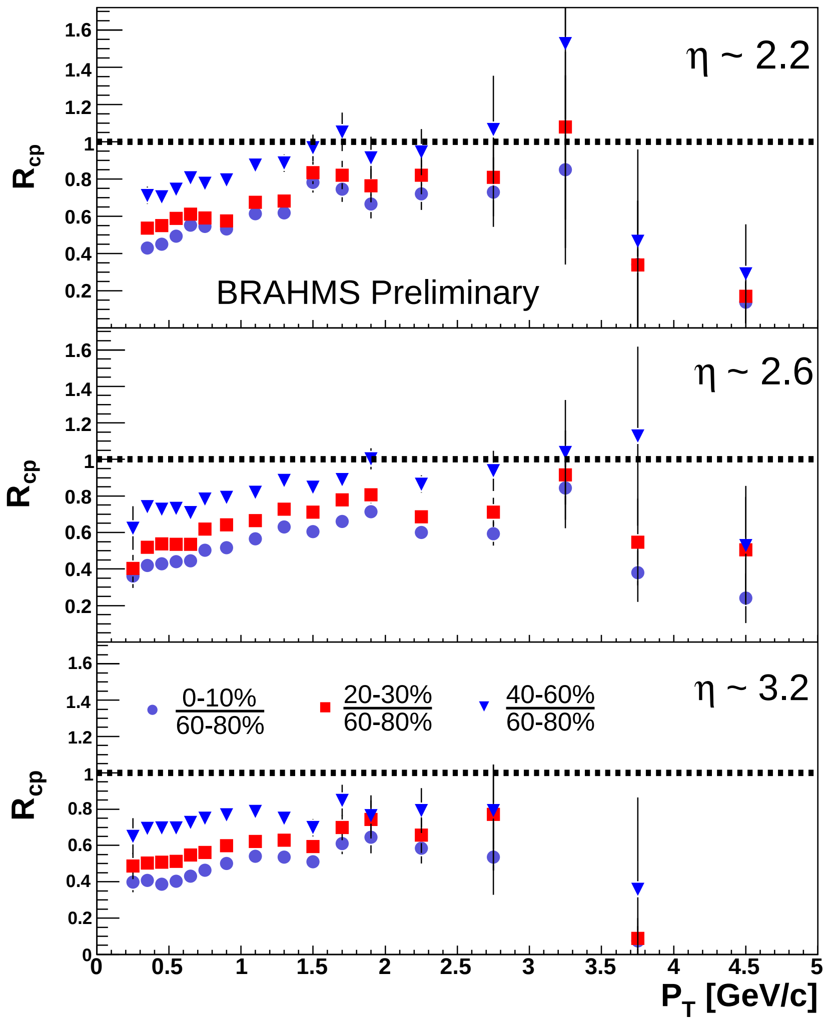

Fig. 2. R_{cp} as a function of p_T in CuCu Collisions. The top panel is for $\eta \sim 2.2$, the middle one for $\eta \sim 2.6$, and the bottom panel is for $\eta \sim 3.2$.

in central collisions to that of peripheral collisions, scaled by the number of the underlying binary nucleon-nucleon inelastic collisions calculated from the Glauber model. The ratio of the central to peripheral data scaled by the appropriate number of binary collisions is referred to as R_{cp} and is given by

$$R_{cp} = \frac{< N_{coll}^{per} >}{< N_{coll}^{cen} >} \frac{d^2 N_{cen}/d\eta dp_T}{d^2 N_{per}/d\eta dp_T}. \qquad (1)$$

One advantage of using R_{cp} to characterize the suppression is that systematic errors cancel out when taking the ratio of the central to peripheral data.

Figure 1 shows the positive hadron momentum spectra at $\eta = 3.2$ from CuCu collisions. The data are for six centrality bins and are scaled down for clarity. Figure 2 shows the ratio R_{cp} of a given centrality class to yields from the most peripheral collisions(60-80%), as a function of p_T for different pseudo-rapidity values, scaled by the number of binary collisions in each sample. The data for the different centrality classes correspond to the same collider run. As a result, the ratios are largely free of run-dependent systematic errors associated with collider and detector performance. The dominant systematic error in the R_{cp} ratios come from the determination of N_{coll} in the centrality bins. One can see that there is more suppression as the collisions become more central. However, there seems to be very little dependence of R_{cp} on η over the pseudo-rapidity range presented here. This result is similar to what is observed in AuAu collisions at the same energy [9]

4. Summary

In summary, we have presented preliminary results on p_T spectra and R_{cp} in CuCu collisions at $\sqrt{s_{NN}} = 200$ GeV. The centrality dependence of R_{cp} show that the magnitude of the observed suppression depends on the volume of the interaction region through which produced hadrons have to travel. While there is still significant suppression, there seems to be very little dependence of R_{cp} on pseudo rapidity.

The CuCu system serves as a bridge between dAu and AuAu systems making it possible to investigate the dependence of high-p_T suppression on system size. Additionally, the data from CuCu collisions allows us to study the dependence of the spectra on the shape of the reaction zone created in the collision. Comparison of various results from different collision systems will come in the near future.

Acknowledgments

This work was supported by the office of Nuclear Physics of the U.S. Department of energy, the Danish Natural Science Research Council, the Research Council of Norway, the Polish State Committee for Scientific Research (KBN), and the Romanian Ministry of Research.

References

1. R.C. Hwa and X.-N. Wang, eds Quark-Gluon Plasma (World Scientific,Singapore,2004) p.123, M.Guylassy, I.Vitev, X.N.Wang, and B.W.Zhang, arXiv:nucl-th/0302077.
2. R. J. Fries, B. Muller, and C. Nonaka, Phys. Rev. C**68**, 044902 (2003).
3. R. Baier, D. Schiff and B.G. Zakarov, Ann. Rev. Nucl. Part. Sci. **50**, 37 (2000).
4. L.V. Gribov, E. M. Levin, M.G.Ryskin, Phys. Rep. **100**, 1 (1983).
5. D. Kharzeev, E. Levin, L. McLerran, Phys. Lett. B**561**, 93 (2003).
6. The BRAHMS Collaboration, Nuclear Instruments and Methods A**499**, 437 (2003).
7. The BRAHMS Collaboration, Phys. Rev. Lett. **91**, 072305 (2003).
8. The BRAHMS Collaboration, Phys. Rev. Lett. **93**, 242303 (2004).

9. The BRAHMS Collaboration, Catalin Ristea, these proceedings