Nuclear Modification Factors at Forward Rapidity in Au-Au and CuCu collisions at $\sqrt{s_{NN}} = 62.4$ GeV

Truls Martin Larsen, Niels Bohr Institute
University of Copenhagen
for the BRAHMS Collaboration

Abstract. Jet quenching in heavy ion collisions at the RHIC top energy has been one of many indicators of the creation of strongly interacting quark gluon matter. In heavy ion collisions at $\sqrt{s_{NN}} = 200$ GeV, totally new physics has been observed at the RHIC. Au-Au, Cu-Cu and p+p collisions at $\sqrt{s_{NN}} = 62.4$ GeV have been measured by the BRAHMS experiment from mid to forward rapidity. A comprehensive study of these transverse momentum spectra will set constraints on models, such as shadowing, jet quenching and recombination. More specifically, high p_{T} particles can reveal the energy loss hard partons suffer as they traverse the medium. Nuclear modification factors R_{AA} at forward rapidity, with p_{T} up to more than half the kinematic limit, will be presented together with results from mid rapidity for Au-Au and Cu-Cu collisions. They will also be shown as a function of centrality.

1. Introduction

Nucleon-nucleon collisions are defined to undergo one incoherent binary collision. As heavier nuclei consist of many nucleons one might expect behaviour in heavy ion collisions to scale with the number of binary collisions. The nuclear modification factor is a ratio that is expected to scale with the number of incoherent binary parton collisions for high p_{T} particles if there are no final state or collective effects. Any deviation from 1 can reveal information of the heavy ion collision. In general high p_{T} partons will fragment and form a jet around one leading high p_{T} particle. Such reactions are seen in ultra relativistic p+p and heavy ion collisions. Since the incoherent parton collisions occurs during the initial stage of the collision, the high p_{T} partons then have to traverse the created medium.

Proton-nucleon collisions in the mid 70's at the FERMILAB, with $\sqrt{s_{NN}} = 19.4$ GeV to $\sqrt{s_{NN}} = 27.4$ GeV, showed Cronin enhancement of high p_{T} particles [1, 2] at mid rapidity. This effect can be attributed to p_{T} broadening from multiple scatterings of the partons as they traverse the cold matter of the nucleon [3]. This Cronin effect has also later been reported at SPS at $\sqrt{s_{NN}} = 17.4$ GeV in Pb-Pb collisions [4].

After the the first heavy ion run at maximum energy at the RHIC, all four experiments reported observations of suppression of high p_{T} hadrons relative to nucleon-nucleon collisions. Many more measurements have later been done [5], and it is now established that at $\sqrt{s_{NN}} = 200$ GeV the suppression saturates at ~ 4 GeV/c and stays constant up to > 20 GeV/c, well within the momentum region where one can do pQCD calculation. BRAHMS measurements has also shown this suppression to be independent of rapidity. Studies of asymmetric collisions and comparison of these with symmetric heavy ion collisions has prompted interpretations that the suppression is a final state effect due to the medium.

At the SPS the initial energy density for Pb-Pb collisions was estimated to be ~ 3 GeV/fm^3 using Bjorken hydrodynamical model [6]. At the RHIC, using the same model estimation vary from $\sim 5 - 60$ GeV/fm^3 [5]. As there is a difference in the initial energy density at the SPS and at the RHIC, the RHIC has performed a intermediate energy program. Collisions of Au-Au, Cu-Cu and p+p at $\sqrt{s_{NN}} = 62.4$ GeV have been performed during the last three years. This article presents the first BRAHMS results of these collisions as a function of pseudorapidity and centrality.

2. The analysis

The BRAHMS experiment consists of two movable spectrometers, covering -0.1< η <3.5, and a set of global detectors [7], which were used during the heavy ion collisions. There was an extra set of global detector during the p+p collisions. These were Čherenkov radiators, positioned around the beam pipe at -3 m, 1.8 m and 3 m away from the nominal interaction point. They were used to measure the point of interaction, with a resolution of ~ 2 cm. From dedicated runs, Vernier Scans, it was determined that their coverage of the total cross section was 12 mb out of the 36 mb. This information was used when the minimum bias transverse momentum spectrum was calculated.

The BRAHMS spectrometers were put at the same angles and magnetic fields during the p+p run, as during the heavy ion runs. This was done to reduce systematic uncertainties in the comparison of p+p to N-N collisions.

The nuclear modification factor, as described above is mathematically given as: $R_{AA}(\eta, p_{\mathrm{T}}) = \left(\frac{d^2N^{AA}}{\langle N_{bin}^{AA} \rangle dp_T d\eta} \right) \cdot \left(\frac{d^2N^{pp}}{dp_T d\eta} \right)^{-1}$. The results presented here will use a parametrisation of the transverse momentum spectra from ISR [8] at midrapidity, $\eta = 0, 0.9$, and BRAHMS own p+p spectra at $\eta = 3.1$. The parametrisation of the ISR spectra has an estimated uncertainty of about $\sim 20\%$.

Another quantity one can study to avoid these large uncertainties is the central-to-peripheral ratio: $R_{cp} = \left(\frac{d^2N^{AA}_{0-10\%}}{\langle N^{AA}_{0-10\%} \rangle dp_T d\eta} \right) \cdot \left(\frac{d^2N^{AA}_{40-60\%}}{\langle N^{AA}_{40-60\%} \rangle dp_T d\eta} \right)^{-1}$ The central, $0 - 10\%$, and peripheral, $40 - 60\%$ transverse momentum spectra are both taken at the same time, and is therefore largely free of systematic errors.

3. Results

The central-to-peripheral ratio is shown in fig 1 for Cu-Cu and Au-Au collisions. Both species are very similar, though the geometric volume in Au-Au is much bigger than in

Cu-Cu collisions. The forward R_{cp} has a smaller ratio than the midrapidity R_{cp}, but has the same p_{T} dependence as midrapidity. No dependence on the charge at forward rapidity has been seen.

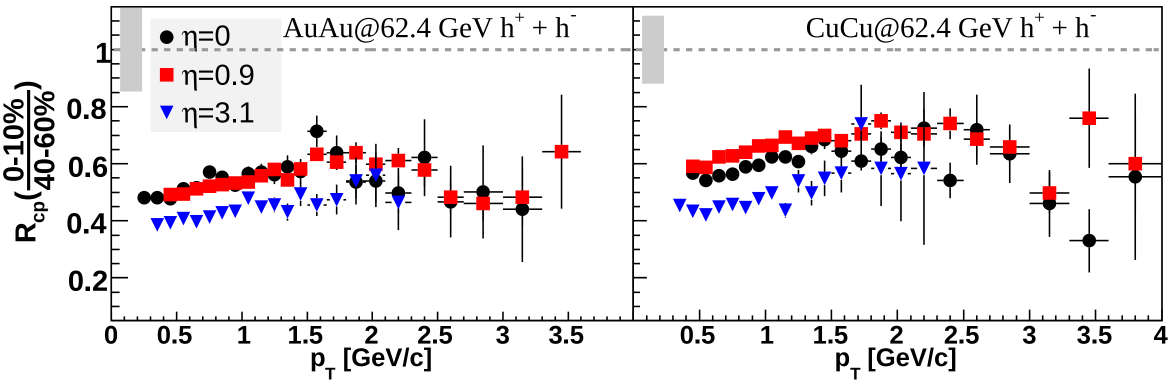

Figure 1. R_{cp} in Au-Au and Cu-Cu collisions at $\sqrt{s_{NN}} = 62.4$ GeV. The shaded bar at 1 show the errors on the scale.

The R_{AA} for Cu-Cu and Au-Au collisions at $\sqrt{s_{NN}} = 62.4$ GeV are shown in figure 2 and 3. The p+p transverse momentum spectra at forward rapidity used in the ratio goes up to $\sim 60\%$ of the kinematic limit. There is no difference between the measurements at midrapidity and at forward rapidity. There is more enhancement or less suppression in Cu-Cu R_{AA} when comparing the two systems central collisions. The same trend is seen as one goes to more peripheral collisions, indicating, as expected that the R_{AA} depends on the geometry of the system.

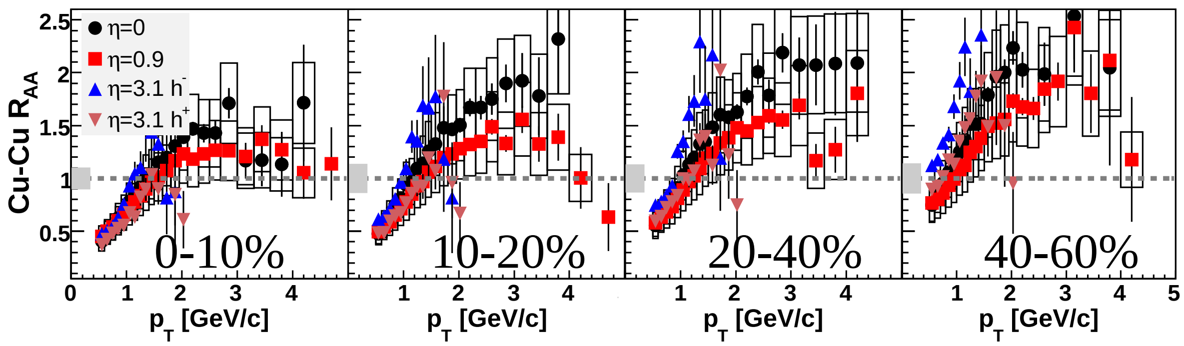

Figure 2. R_{AA} in Cu-Cu and collisions at $\sqrt{s_{NN}} = 62.4$ GeV. The midrapidity results, $\eta = 0$ and 0.9, uses p+p reference spectra from ISR [8]. The systematic errors are shown as boxes around the points. The $\eta = 3.1$ uses BRAHMS own preliminary p+p reference data taken in the exact same pseudorapidity bin. Systematic errors for these results should be $\sim 5\%$ on the scale. The shaded bar at 1 show the errors on the scale.

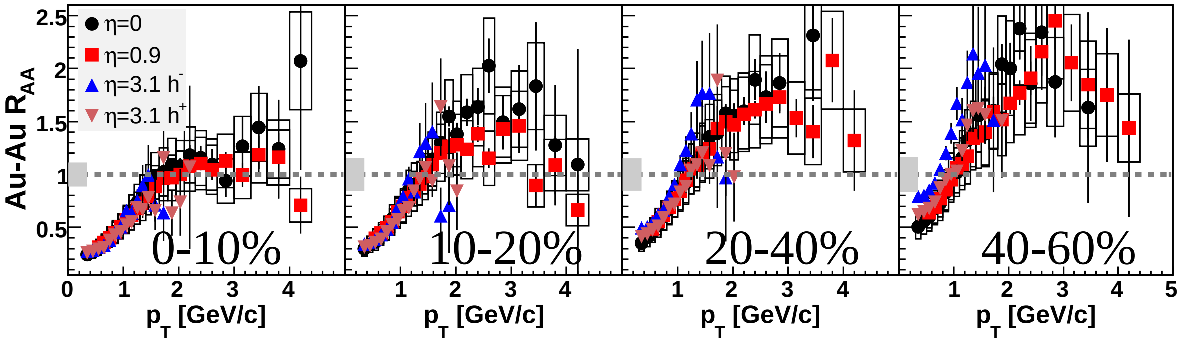

Figure 3. R_{AA} in Au-Au and collisions at $\sqrt{s_{NN}}$ = 62.4 GeV. The midrapidity results, $\eta = 0$ and 0.9 see [9], The systematic are shown as boxes around the points. The $\eta = 3.1$ uses BRAHMS own preliminary p+p reference data taken in the exact same pseudorapidity bin. The shaded bar at 1 show the errors on the scale. Only statistical errors are shown for the forward result, but they have an $\sim 5\%$ uncertainty on the scale.

4. Conclusion

The new forward measurements of the nuclear modification factor has been shown to have the same p_{T} dependence as midrapidity. In $\sqrt{s_{NN}} = 200$ GeV collisions, BRAHMS has previously [10] shown that R_{AA} has no dependence on pseudorapidity. The same is seen here for $\sqrt{s_{NN}} = 62.4$ GeV. If it is the final state medium that affects the high momentum partons, the suppression/enhancement only affect the transverse momentum component, and not the longitudinal one.

The data presented constrain models that include jet quenching, coalescence and/or other medium effects. A more systematic study through identified particles is currently work in progress, and will yield even further constraints.

References

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