Baryon Stopping in Au+Au and p+p collisions at 62 and 200 GeV

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Abstract

BRAHMS have measured rapidity density distributions of protons and antiprotons in both p+p and Au+Au collisions at 62 GeV and 200 GeV. From these, the yields of so-called 'net-protons', that is the difference between the proton and antiproton yields, can be determined. The net-proton distribution can be used together with model calculations to find the net-baryon yield and thus the amount of stopping in these collisions. This, then, allows us to extract information on baryon transport, as well as to calculate the average rapidity loss.

Furthermore BRAHMS data can be used to study scaling from p+p collision systems to peripheral Au+Au collisions. A resemblance is observed between these two systems.

1. p+p and peripheral Au+Au

In p+p collisions we expect that $\frac{dN}{dy'}$ where $y' = y - y_{beam}$ should follow an exponential in y' and this behaviour is confirmed by BRAHMS p+p data [1]. The right panel of figure 1 shows $\frac{dN}{dy'}$ from peripheral 200 GeV Au+Au collisions overlaid with the exponential curve found for p+p collisions. It is seen that the two systems follow essentially the same kind of scaling. This confirms that some aspects of p+p collisions and peripheral Au+Au are very alike. As a reference, the left panel of figure 1 shows $\frac{dN}{dy'}$ for central Au+Au collisions overlaid with the p+p scaling curve. It is evident that central Au+Au and p+p collisions do not follow the same scaling.

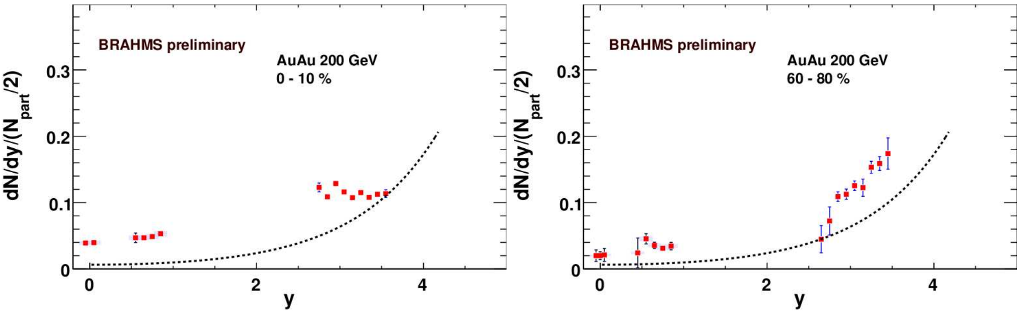

Figure 1: Scaling of Au+Au collisions compared to the scaling observed for p+p collisions [1]. Left panel: Central collisions. Right panel: Peripheral collisions.

2. Baryon stopping

In an earlier paper, BRAHMS have measured the stopping in Au+Au collisions at $\sqrt{s_{NN}} =$ 200 GeV [4]. Results from $\sqrt{s_{NN}} = 62.4$ GeV Au+Au collisions can be used to expand the understanding of the stopping in the 'energy gap' between the SPS top energy of $\sqrt{s_{NN}} = 17$ GeV and the RHIC top energy of 200 GeV. The left panel of figure 2 shows the proton and antiproton spectra in four rapidity intervals. Corrections have been applied to the data for geometrical acceptance, efficiency and detector effects such as multiple scatterings. The right panel of figure 2 shows the extrapolated yields versus rapidity. The extrapolation was done using a fit function of the form $f(p_T) \propto \exp(-p_T^2/2\sigma^2)$. Using protons and antiproton yields the net-proton yield can be created as net-$p = p - \overline{p}$. The net-proton yields are also shown in figure 2. Also included in the figure are comparisons to HIJING [11]. It is seen that HIJING reproduces the anti-protons well but deviates from the protons. This could indicate that the baryon transport description in HIJING in not completely accurate.

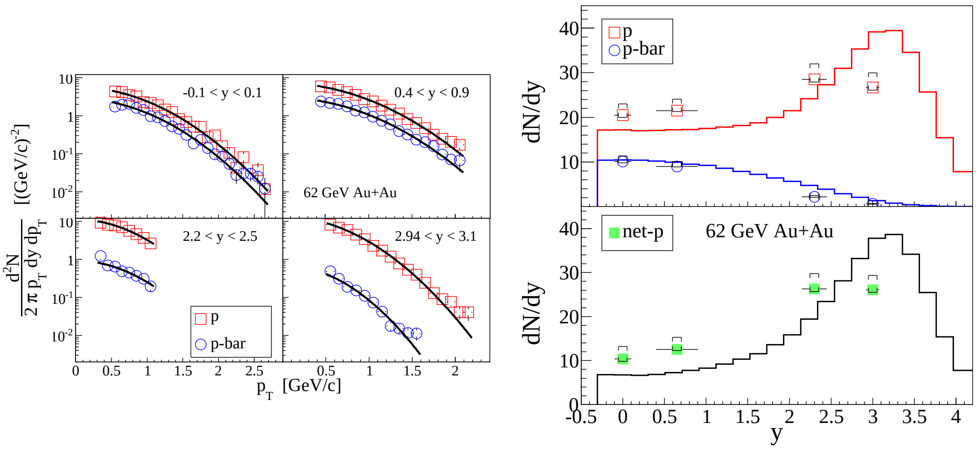

Figure 2: Spectra and yields of identified protons and antiprotons and the resulting net-protons.

To quantify the stopping we use the average rapidity loss defined as [6]:

$$\delta y = y_b - \frac{2}{N_{part}} \int_0^{y_b} y \frac{dN_{B-\bar{B}}}{dy} dy \tag{1}$$

Here N_{part} is the number of participants and $\frac{dN_{B-\bar{B}}}{dy}$ is the net-baryons. y_{beam} is the rapidity of the beam (for $\sqrt{s_{NN}} = 62.4$ GeV it is $y_b = 4.2$. Since BRAHMS do not measure neutrons or Λ's we must make a conversion from net-protons based on simulations and data from other experiments. For details of this procedure see . The conversion used here is $\frac{dN_{B-\bar{B}}}{dy} = (2 \pm 0.1) \cdot \frac{dN_{p-\bar{p}}}{dy}$ at mid-rapidity and $\frac{dN_{B-\bar{B}}}{dy} = (2.1 \pm 0.1) \cdot \frac{dN_{p-\bar{p}}}{dy}$ at forward rapidities (the larger correction at forward rapidities is due to a small increase in the n/p ratio here).

To calculate the rapidity loss we fit the resulting net-baryon distribution with a third degree polynomial in y^2. This fit is shown as the inset in figure 3. The rapidity loss for $\sqrt{s_{NN}} = 62.4$ GeV is measured to be (stat. + syst. error):

$$\delta y = 2.01 \pm 0.14 \pm 0.12$$

Figure 3 shows rapidity losses from AGS [2, 8, 9], SPS [3, 7], and RHIC [4]. The new

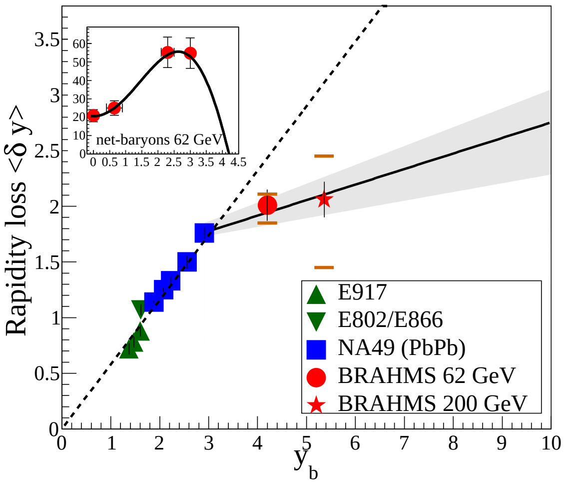

Figure 3: Rapidity losses from AGS [2, 8, 9], SPS [3, 7] and RHIC [4]. The rapidity seems to saturate above SPS energies.

$\sqrt{s_{NN}}$ = 62.4 GeV data from BRAHMS is seen to establish that the apparent saturation of the rapidity losses sets in already around the top SPS energy.

3. Limiting Fragmentation

Since there seems to be a linear scaling of the average rapidity loss from the SPS top energy to the RHIC top energy we have studied if there exists some scaling of the yields. The left panel of figure 4 shows the yields from SPS and RHIC plotted versus $y' = y - y_{beam}$ and it is easily seen that there is no obvious scaling.

The idea is now to consider the yields in a 'limiting fragmentation' picture. We will do this by considering only one side of the collision which we denote the 'projectile' side of the collision inspired by fixed target experiments. The challenge is now to remove the 'target' side of the distributions. We use two different estimates to set limits for the 'target' contribution: (1) a simple exponential form $\exp(-y')$ [12] and (2) a gluon junction motivated form $\exp(-y'/2)$ [13]. The resulting 'target' distributions are shown as the grey bands in the left panel of figure 4 together with the measured dN/dy' distributions from SPS and RHIC.

The right panel of figure 4 shows the resulting 'projectile' distributions from SPS and RHIC and it seen that now we have a very clear scaling similar to limiting fragmentation.

4. Conclusions

BRAHMS have measured the rapidity loss in Au+Au collisions at $\sqrt{s_{NN}}$ = 62.4 GeV which bridges the gap between the SPS top energy and the RHIC top energy. The rapidity losses seem to saturate from the SPS top energy and the saturating behaviour is confirmed by the $\sqrt{s_{NN}}$ = 62.4 GeV data. Furthermore we have established a limiting fragmentation kind of scaling in dN/dy' distributions from SPS to RHIC.

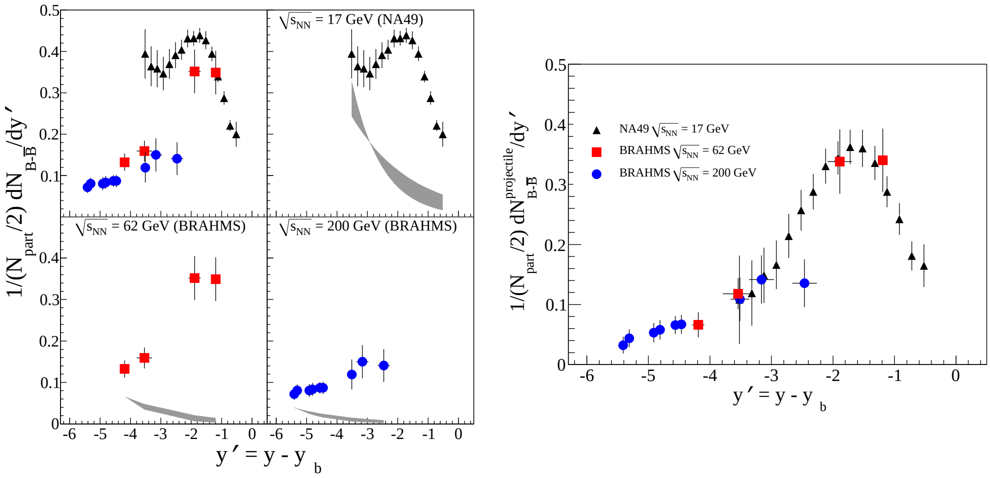

Figure 4: Left panel: dN/dy' distributions from SPS [3, 7] and RHIC [4] and their 'target' distributions (grey bands). Right panel: The resulting 'limiting fragmentation' distribution for SPS and RHIC data.

In these proceedings we have also studied the exponential scaling of the yields in p+p collisions from SPS to RHIC energies and this is confirmed by our data. Furthermore we have demonstrated the similarity between peripheral Au+Au collisions and p+p collisions.

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