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

Hans Hjersing Dalsgaard for the BRAHMS Collaboration

[a] *Niels Bohr Institute, University of Copenhagen, Blegdamsvej 17, 2100 , Denmark*

Abstract

BRAHMS has measured rapidity density distributions of protons and antiprotons in both p+p and Au+Au collisions at 62 GeV and 200 GeV. From these distributions the yields of so-called 'net-protons', that is the difference between the proton and antiproton yields, can be determined. The rapidity dependence of the net-proton yields from peripheral Au+Au collisions is found to have a similar behaviour to that found for the p+p results, while a quite different rapidity dependence is found for central Au+Au collisions. The net-proton distributions can be used together with model calculations to find the net-baryon yields as a function of rapidity, thus yielding information on the average rapidity loss of beam particles, the baryon transport properties of the medium, and the amount of 'stopping' in these collisions.

1. p+p and peripheral Au+Au

In p+p collisions we expect that $\frac{dN}{dy'}$ where $y' = y - y_b$ (y_b is the beam rapidity) should follow an exponential in y' and this behaviour is confirmed by BRAHMS p+p data [1]. The right panel of Fig. 1 shows $\frac{dN}{dy'}$ from peripheral 200 GeV Au+Au collisions scaled by N_{part} (N_{part} is the number of participants) overlaid with the exponential curve found for p+p collisions. It is seen that the two systems show quantitatively similar dependence. This confirms that some aspects of p+p collisions and peripheral Au+Au are very much alike. As a reference, the left panel of Fig. 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 type of scaling. This indicates that there are more collective stopping mechanisms in play for central collisions.

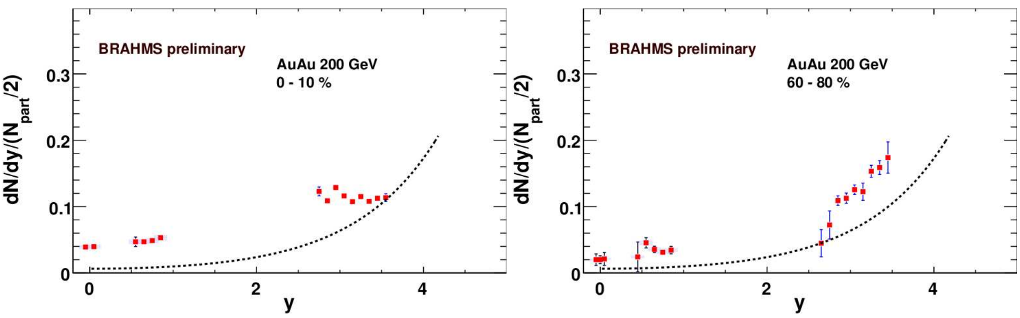

Figure 1: Net-proton distributions from Au+Au collisions compared to the scaling observed for p+p collisions [1]. Left panel: Central collisions. Right panel: Peripheral collisions.

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2. Baryon stopping

BRAHMS [2] has measured the stopping in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV [3]. 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 Fig. 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 Fig. 2 shows the extrapolated yields versus rapidity. The extrapolation was done using a fit function of the form $f(p_T) \propto \exp(-p_T^2/2\sigma^2)$. The net-proton yields are also shown in the bottom panel of Fig. 2. Also included in the figure are comparisons to HIJING/$B\overline{B}$ [4]. It is seen that HIJING reproduces the anti-protons well but deviates from the proton yields. This indicates that the baryon transport description in HIJING/$B\overline{B}$ underpredicts stopping in central Au+Au collisions and is not sufficient to describe the data.

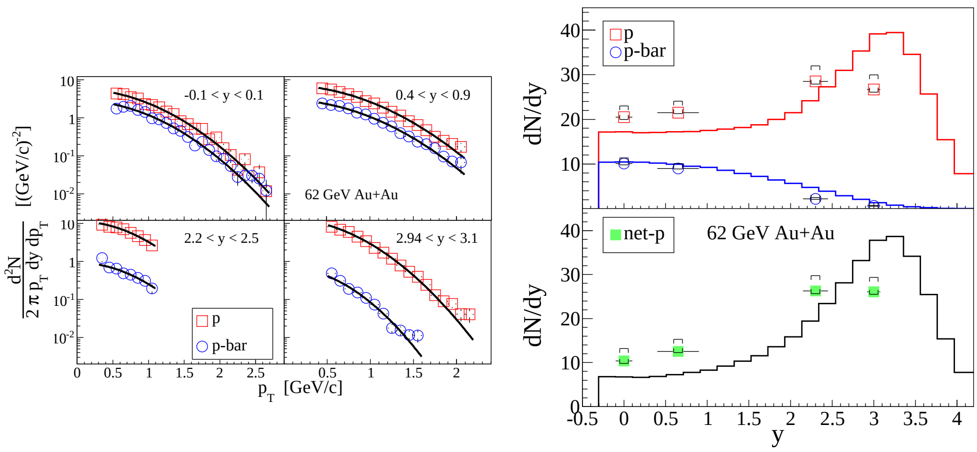

Figure 2: Spectra and yields of identified protons and antiprotons and the resulting net-protons.

To quantify the stopping we use the average rapidity loss defined as [5]:

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

Here, $\frac{dN_{B-\bar{B}}}{dy}$ is the number of net-baryons and $y_b = 4.2$ for $\sqrt{s_{NN}} = 62.4$ GeV. Since BRAHMS does 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 [6] . 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 from HIJING/$B\overline{B}$).

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 Fig. 3. The rapidity loss for $\sqrt{s_{NN}} = 62.4$ GeV

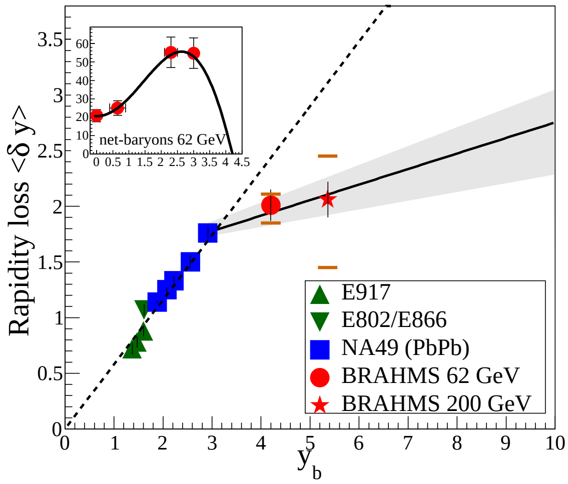

Figure 3: Rapidity losses from AGS [7, 8, 9], SPS [10, 11] and RHIC [3]. The rapidity seems to saturate above SPS energies.

is measured to be (stat. + syst. error):

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

Figure 3 shows rapidity losses from AGS [7, 8, 9], SPS [10, 11], and RHIC [3]. The new $\sqrt{s_{NN}}$ = 62.4 GeV data from BRAHMS are 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 increase 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 Fig. 4 shows the yields from SPS and RHIC plotted versus y' and it is easily seen that there is no obvious universal behaviour.

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 estimates for the contributions from the 'target' are shown as the grey bands in the left panel of Fig. 4 together with the measured dN/dy' distributions from SPS and RHIC.

The right panel of Fig. 4 shows the resulting 'projectile' distributions from SPS and RHIC and it seen that now we have a scaling behaviour between SPS and up to RHIC 62 GeV similar to limiting fragmentation. The stopping pattern in central Au+Au collisions at 200 GeV shows some deviation from the trend which suggests an energy dependence of the stopping mechanism.

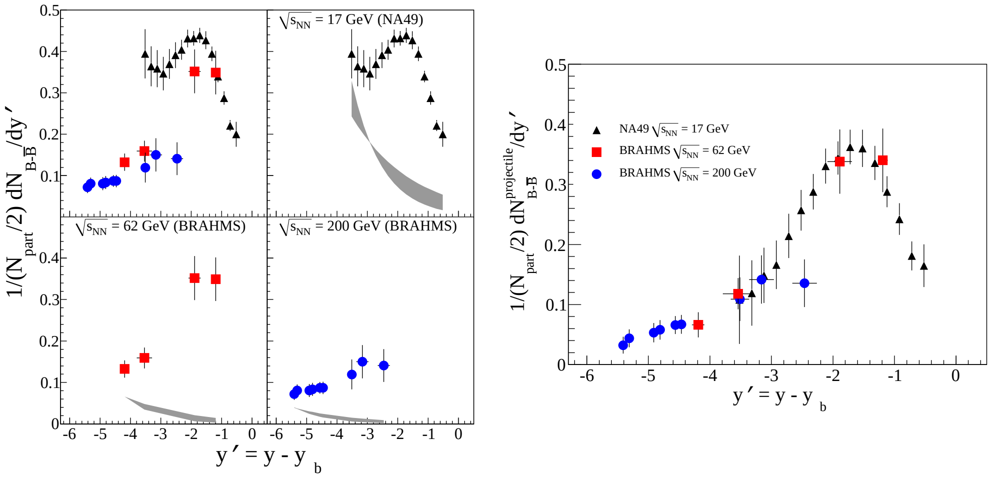

Figure 4: Left panel: dN/dy' distributions from SPS [10, 11] and RHIC [3] and their ‘target’ distributions (grey bands). Right panel: The resulting ‘limiting fragmentation’ distribution for SPS and RHIC data.

4. Conclusions

BRAHMS has 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.

In these proceedings we have also demonstrated the similarity between peripheral Au+Au collisions and p+p collisions using new BRAHMS data.

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