Physics at Forward Rapidities - BRAHMS Experiment at RHIC

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Abstract. The BRAHMS measurement of particle ratios in p+p collisions at $\sqrt{s}$ = 62.4 GeV and $\sqrt{s}$ = 200 GeV is presented as a function of transverse momentum within the pseudorapidity range $0 \leq \eta \leq 3.6$. The antiparticle-to-particle baryon and meson ratio at both energies has a similar tendency showing slight dependency on pseudorapidity. The p/π ratio measured in elementary collisions at $\sqrt{s}$ = 62.4 GeV, $\eta \approx 3$ reaches astounding value of 8-10 at $p_T \geq 1.5$ GeV/c. Moreover, a remarkable overlap of net-proton $\frac{dN}{dy}$ is observed at all energies when viewed in their projectile frame.

Keywords: elementary collisions, forward rapidity, particle ratios, limiting fragmentation
PACS: 25.75.Dw

INTRODUCTION

Recently, the intensive studies of proton-proton collisions at ultra-relativistic energies brought a new possibilities to explore the particle production in the wide range of rapidity. Although, the p+p data at RHIC (as the reference to heavy ion collisions) is considered as the medium where there is no nuclear effects, fetched the new tasks to accomplish. From the BRAHMS experiment standpoint, last achievements of pQCD theory [1] described the invariant cross section of identified hadrons at $\sqrt{s}$ = 200 GeV [2] and transverse single spin asymmetries at $\sqrt{s}$ = 62.4 GeV [3] in p+p reactions in the forward rapidity region are worth pointing out.

The following comparison of particles ratios as a function of transverse momentum at two RHIC's energies displays the basic features of hadrons production in elementary reactions depending on rapidity. At forward rapidities in p+p reactions the produced particles are from the kinematic region where large-x valence quarks ($0.3 < x < 0.7$) from the beam side interact on small-x gluons ($0.001 < x < 0.1$).

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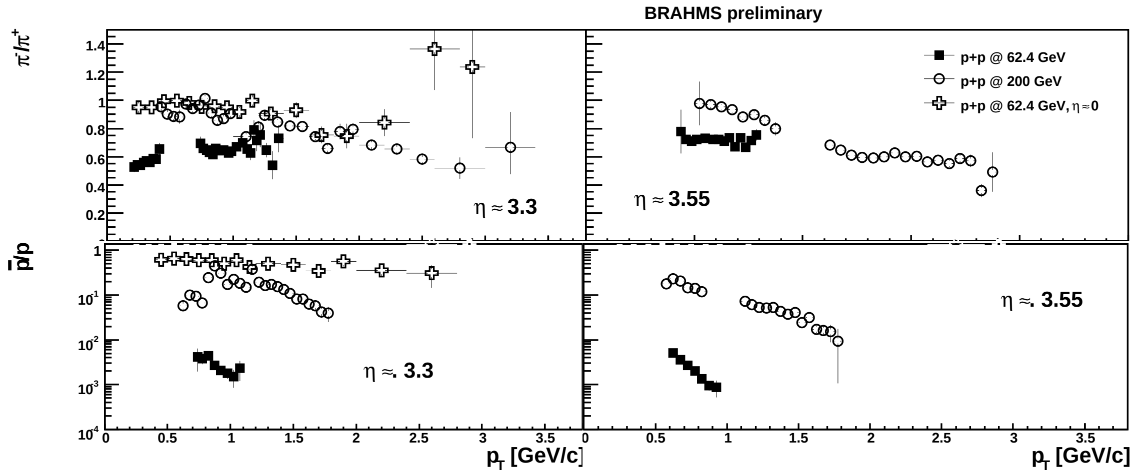

FIGURE 1. Antiparticle-to-particle ratio at $\sqrt{s}$ = 62.4 GeV and $\sqrt{s}$ = 200 GeV in proton-proton collisions for different pseudorapidities. The errors are statistical only.

EXPERIMENTAL LAYOUT AND ANALYSIS

The BRAHMS detector setup [4] consists of two movable, narrow spectrometer arms: the Midrapidity Spectrometer which operates in the polar angle interval from $90^\circ \leq \Theta \leq 30^\circ$ (that corresponds with the pseudorapidity interval $0 \leq \eta \leq 1.3$) and the Forward Spectrometer that operates in the polar angle range from $2.3^\circ \leq \Theta \leq 15^\circ$ ($2 \leq \eta \leq 4$). Moreover, the overall particle multiplicity, collision vertex and centrality are determined using the global detectors.

The single dipole magnet (D5 - notations like in [4]) placed between two TPCs, which were used for tracking, compose the midrapidity arm. Particle identification is based on the Cherenkov detector (C4) and Time of Flight Wall (TOFW) measurement.

The front forward arm is composed of two Time Projection Chambers (constituting track recognition in a high multiplicity enviroment), the back part - of three Drift Chambers and in the aggregate deliver particle track segments with high momentum resolution using three dipole magnets. Particle identification is provided via the hodoscope H2 and Ring Imaging Cherenkov detector (RICH, situated behind H2 detector), respectively, for low and high momentum particles.

The present forward rapidity data analysis was done with hadrons that originate from polarized protons collisions within the range of vertexes ± 50 cm (± 15 cm at $\eta \approx 0$). The particles yield have been corrected for efficiency, geometrical acceptance, interactions of emitted particles with the beampipe, the spectrometers material budget and for the weak decays in flight.

PARTICLE PRODUCTION

In the Fig. 1 we present the antiparticle-to-particle ratio for pions and protons at $\sqrt{s}$ = 62.4 GeV and $\sqrt{s}$ = 200 GeV for various pseudorapidities. At $\eta \approx 3.55$ one should

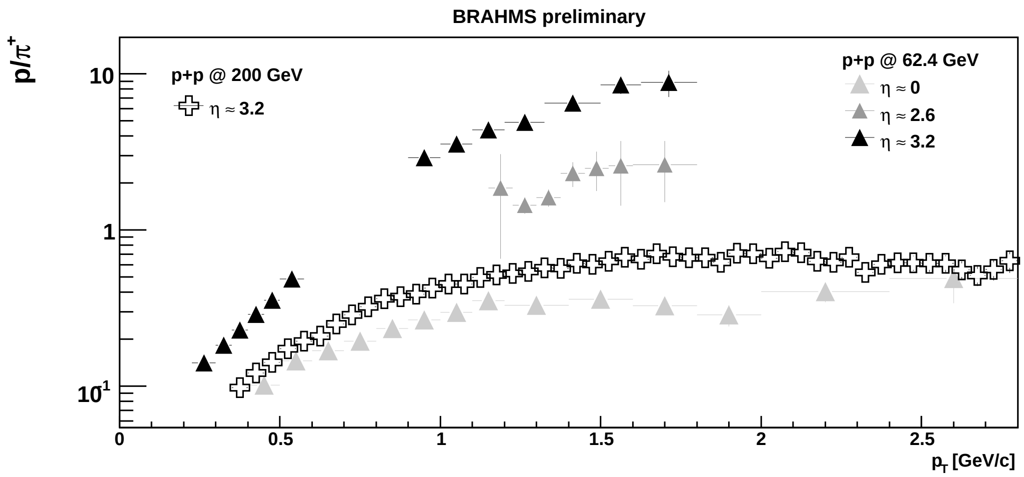

FIGURE 2. Proton-to-pion ratio at $\sqrt{s}$ = 62.4 GeV and $\sqrt{s}$ = 200 GeV in elementary reactions for different pseudorapidities. The errors are statistical only.

stress that RICH inefficiency causes that estimated systematic error of (anti)proton yield starts with the order of 7% and decreases with higher p_T bins. In the midrapidity region at lower energy we measure balance between matter and antimatter. For the π^-/π^+ for forward pseudorapidities we can see gradual fall with rising p_T that can be explained as a domination of valence quark fragmentation at higher p_T. That domain becomes more important also with regard to charge and isospin conservation. The antiproton-to-proton ratio is astonishingly small at both energies in the beam fragmentation regime. As it was depicted in [2], the p and $\overline{\mathrm{p}}$ data at $\sqrt{s}$ = 200 GeV might have been a new insight of baryon production in the elementary collisions. The $\overline{\mathrm{p}}$/p ratio at $\sqrt{s}$ = 62.4 GeV displays the same tendency for the forward rapidity, but the value of ratio is lower by the order of magnitude if observed at the same value of η.

Fig. 2 shows the proton-to-pion ratio as function of transverse momentum in p+p collisions at $\sqrt{s}$ = 62.4 GeV (closed triangles). Additionally, it is shown the p/π ratio in elementary reactions at $\sqrt{s}$ = 200 GeV for $\eta \approx 3.2$ (crosses), the data which was a puzzle in the face of the fragmentation issue [2]. At lower energy, going from midrapidity to forward rapidity regimes, it can be observed significant increase of baryon-to-meson ratio for positive charges, reaching an astounding high value of p/$\pi(\mathrm{p_T}) \approx$ 8-10 at $p_T \geq$ 1.5 GeV/c for $\eta \approx 3.2$. Taking that into consideration, it indicates that mechanism of baryon-to-meson yield in forward rapidity domain is still an open question in high energy physics.

At RHIC in elementary collisions one can expect two kinds of particle production. At midrapidity, according to Bjorken picture [5] the ratio of produced antiparticle-to-particle should be close to 1. In the forward rapidity regime cross section should be prevailed by leading particles and projectile fragments. It is known as the limiting fragmentation hypothesis [6] states that the excitation of the leading protons saturates at a moderate energy, leaving more available kinetic energy for particles produced at central rapidities. Fig. 3 presents the net-proton distribution in proton-proton collisions

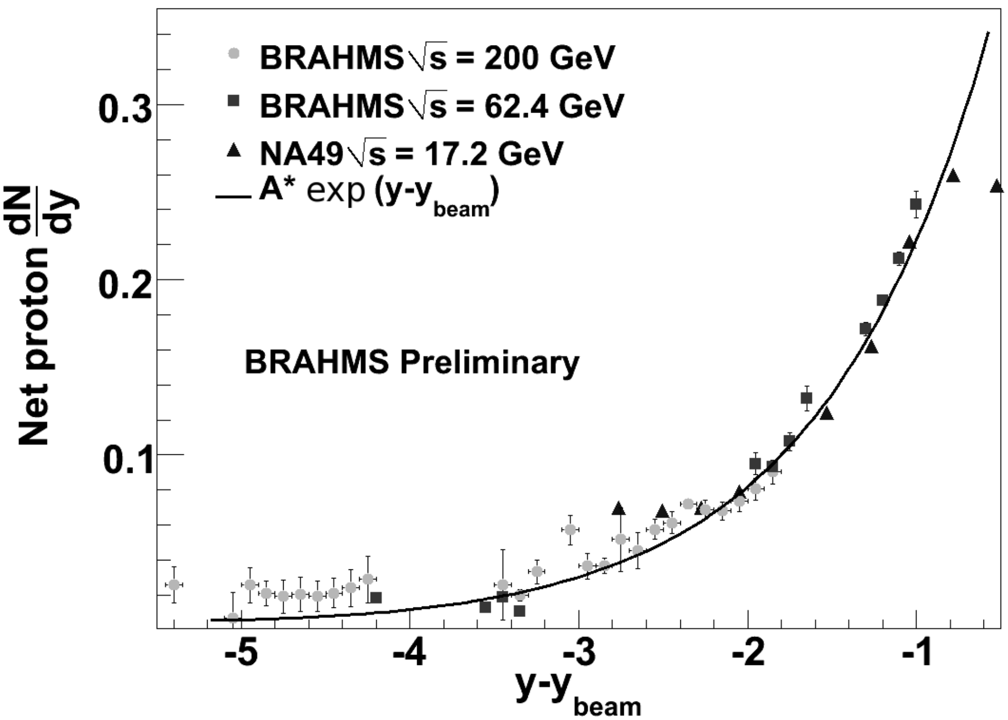

FIGURE 3. The net-proton distribution in p+p collisions as a function of rapidity shifted by y_{beam}, $y - y_{beam}$, compared with data from NA49 at $\sqrt{s_{NN}}$ = 17.2 GeV.

at both energies: $\sqrt{s}$ = 62.4 GeV ($y_{beam} = 4.2$) and $\sqrt{s}$ = 200 GeV ($y_{beam} = 5.3$) as a function of rapidity shifted by y_{beam}. The results of NA49 experiment [7] are also shown. As it has been observed the increasing difference between antiproton and proton yield with increasing rapidity, viewing from the rest frame of one of the protons, does not depend on the incident beam energy.

SUMMARY

Concluding, the BRAHMS experiment has presented the antiparticle-to-particle ratios in p+p collisions at $\sqrt{s}$ = 62.4 GeV and $\sqrt{s}$ = 200 GeV as a function of transverse momentum. Furthermore, the displayed value of baryon-to-meson ratio of measured particles increases with increasing pseudorapidity, reaches the highest value in p+p collisions at $\sqrt{s}$ = 62.4 GeV for $\eta \approx 3.2$. The shown net-proton distribution at both energies, compared with the results of NA49 experiment, give the possibility of studying production of charged hadrons in the wide range of rapidity. It reveals extremely overlap of the data when viewed in their projectile frame.

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 Commitee for Scientific Research (KBN), and the Romanian Ministry of Research.

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