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Baryon Stopping in 200 GeV/A S+Au Collisions

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ABSTRACT

Measurements of rapidity and transverse momentum distributions of negative hadrons and of "protons" obtained by subtracting negative hadron distributions from positive hadron distributions are presented for 200 GeV/A S+Au collisions. The distributions are shown as a function of event centrality and are indicative of a system exhibiting a large degree of nuclear stopping.

INTRODUCTION

The extent of the nuclear stopping of a system can be determined by observing the nucleon rapidity distribution, particularly near the beam rapidity. Prior to the collision, all nucleons exist exclusively at the target and beam rapidities. After the collision, the nucleons will be shifted towards the system's center-of-mass rapidity by some amount. The larger the resulting rapidity shift, the larger the extent of stopping. Proton rapidity distributions for 14.6 GeV/A Si+Pb [1] and 11.6 GeV/A Au+Au [2] collisions indicate that these are completely stopped systems. Recent models predict that a stopped system is also present in 200 GeV/A nucleus-nucleus collisions [3,4]. We present "proton" rapidity distributions of 200 GeV/A S+Au collisions in order to investigate the extent of stopping at these higher energies. The distributions are also shown as a function of event centrality to observe their evolution from central collisions to peripheral collisions, which should most resemble the distributions before the collision.

CORRECTIONS

The measurements were performed using the NA35 spectrometer consisting of a $2.4 \times 1.2 \times 1.08 \text{ m}^3$ Time Projection Chamber (TPC) [5] whose center was placed 6.8 meters away from the target. The charge of each particle was determined by its bend direction within a 1.5 T magnet placed between the target and the TPC. Charged particle tracks were reconstructed from up to 60 samples along their trajectory in the TPC.

Two types of triggers were employed for this analysis. Central collisions covering the upper 6% of the total interaction cross section were selected by examining the amount of energy deposited into a "veto" calorimeter covering less than 0.3 degrees about the beam axis. The second trigger selected minimum bias events by requiring that an interaction has occurred by examining a set of scintillators placed near the target. The minimum bias data set was further split into three centrality levels, labelled "Low b", "Mid b", and "High b", corresponding to veto calorimeter energy, E_{veto} , ranging from $400 < E_{\text{veto}} < 2600$ GeV, $2600 \leq E_{\text{veto}} < 4800$ GeV, and $E_{\text{veto}} \geq 4800$ GeV, respectively. Here, "b" refers to the impact parameter.

The TPC was positioned with the beam passing through its center to measure charged particles near beam rapidity. The TPC is able to detect pions above rapidity 4 and protons with rapidity $3.4 < y < 5.6$. All data have been corrected for acceptance efficiency as a function of rapidity and p_t using the GEANT simulation package.

Heavy ion collisions create a high track density environment that can become a problem for the NA35 TPC, whose two-track resolution is about 2.5 cm. This problem is handled by examining the energy loss information available for each track. If the track's energy loss is consistent with that of two minimum ionizing particles, the track is assumed to have merged and is treated as two tracks with the same rapidity and p_t . The detector geometry and size of the y and p_t bins used makes this a valid assumption. 4% of the tracks near rapidity 4 are merged. This value increases to 8% near beam rapidity, but does not change as a function of event centrality.

A fraction of the recorded minimum bias events are due to interactions that did not occur within the target. These events are isolated by determining the percentage of tracks in an event that project to the target in the non-bend direction. If the percentage is below 75%, the event has originated outside of the target, and is not considered in the analysis. 40% of the minimum bias events are eliminated in this manner.

RESULTS

The rapidity distributions of negative hadrons were obtained by fitting the transverse mass distributions of negative hadrons in 0.2 unit wide rapidity bins calculated using the pion mass, to the function $f(m_t) = A \exp(-m_t/T)$, where T is called the inverse slope parameter (also referred to as the temperature). The dN/dy value was obtained by integrating over the curve extrapolated over all m_t . Figure 1a shows the distribution for central collisions along with the predictions of the RQMD (version 1.08) [4] model with excellent agreement. Figure 2a shows the expected decrease in the number of produced negative hadrons as the collisions become more peripheral, reflecting the reduced total number of nucleon-nucleon collisions occurring in the more peripheral events.

Figure 1b shows the inverse slope parameters of negative hadrons as a function of rapidity for each centrality region along with the RQMD predictions, which again reproduce the data well. Figure 2b plots the inverse slope parameter for the different centrality ranges. This plot shows that although the slopes vary strongly as a function of rapidity, they do not vary as a function of centrality. A similar behavior is seen in the "proton" spectra. This result means either that the temperature of the system does not change significantly for different impact parameters, or that this observable is dominated by kinematical considerations.

Figure 1. a) Negative hadron rapidity distribution for central 200 GeV/A S+Au collisions. b) Negative hadron inverse slope parameters as a function of rapidity for central 200 GeV/A S+Au collisions. Shown are the TPC data and the RQMD predictions over the entire rapidity range.

"Proton" distributions are obtained by subtracting negative hadron distributions from positive hadron distributions. These spectra are treated as outlined above, only using the proton mass to calculate the rapidity. In addition, the spectra are corrected for kaon contamination as estimated by the VENUS (version 4.02) [6] model. The resulting rapidity distributions are shown in Figures 3a and 3b for all centrality regions. The error bars in this figure are statistical only. Figure 3a yields the total "proton" rapidity shift, $\langle \Delta y_p \rangle$, for central collisions of -1.98 ± 0.05 . This is a very large shift indicative of a large extent of stopping in these collisions. This shift is also consistent with that measured for 200 GeV/A p+Au collisions [7]. RQMD predicts a slightly larger proton total rapidity shift. Figure 3b illustrates the expected shift of the "protons" back to the projectile rapidity as the collisions become more peripheral. Most of the protons in the "High b" distribution most likely do not exhibit enough of a rapidity shift to be measured by the TPC.

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Figure 2. a) Negative hadron rapidity distributions for 200 GeV/A S+Au collisions divided into three centrality ranges. b) Negative hadron inverse slope parameters as a function of rapidity and centrality.

Figure 3. a) Positive minus negative hadron, or "proton" rapidity distributions for central 200 GeV/A S+Au collisions. Shown are the TPC data and RQMD predictions over the entire rapidity range. b) "Proton" rapidity distributions for three centrality ranges.

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