Rapidity Dependence of Identified Hadron Production in d+Au Collisions at $\sqrt{s_{NN}} = 200$ GeV

Hongyan Yang, for the BRAHMS Collaboration
Department of Physics and Technology, University of Bergen, Norway

Abstract We present the transverse momentum spectra in d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV for identified hadrons at $\eta = 0, 1, 3.2$, and the ratio R_{CP} of the identified hadron production in central (0-20%) and the semi-central (30-50%) d+Au collisions to the more peripheral(60-80%) ones, scaled by the number of binary collisions in different centrality classes. The net protons' dN/dy at different rapidities in different centrality classes are given.

I. INTRODUCTION

The d+Au collisions at RHIC are an ideal experimental method to disentangle initial and final state effect heavy-ion collisions, because the effects of the initial stages remain mostly unchanged till the measurement is performed[1]. In another word, compared to Au+Au system, d+Au collisions provide an important system to study the initial state effect since one does not expect the final state interactions to play a dominant role in such a small system. It is also interesting to study the rapidity dependence of the identified hadrons, especially the measurement on the net-protons' yield in the d+Au system might shield light on the baryon transport mechanism in the heavy ion collisions, which enable us understand the high energy collision scenarios better[2,3].

II. THE BRAHMS EXPERIMENT AND PARTICLE IDENTIFICATION

BRAHMS, the Broad Range Hadron Magnetic Spectrometer is one of the four detectors at RHIC, located at 2 o'clock experimental hall of the RHIC collider. It has two rotatable magnetic spectrometers with particle identification capabilities for hadrons, which gives the unique capability to study particle production in a broad range of both transverse momenta and rapidities.

The reaction centrality is determined by using a geometry weighted average of two global subsystems, the SiMA (Si Multiplicity Array) and the TMA (Tile Multiplicity Array) detectors, which select a fraction of events with a certain multiplicity within the pseudo-rapidity ranges of both multiplicity detectors.

The purpose of the mid-rapidity spectrometer (MRS) is to detect and identify the particles emitted at mid-rapidity. Particles at forward rapidities are detected by the Forward Spectrometer (FS). Both spectrometers have dipole magnets with tracking chambers located on each side of the magnet gaps. BRAHMS uses the Time-of-Flight (TOF) technique in both spectrometers, and a Ring Imaging Čerenkov (RICH) detector at the back of the FS for the identification of particles with high momentum. The left panel of the FIG. 1 shows the PID performance by time-of-flight wall (TOFW) achieved in MRS in d+Au data: a 2-σ cut was implemented on $\Delta(1/\beta)$, which stands for the difference between the theoretical value $1/\beta$ and the experimental measurement. In MRS, pions and kaons can be separated up to 1.6 GeV/c in momentum by the TOFW. The identification for pions and kaons is extended up to 25-30 GeV/c in FS by the RICH: a 2-σ cut on the masses for each species was used, see the right panel of the FIG. 1. Details on the BRAHMS detector system can be found in[4].

III. DATA ANALYSIS AND PRELIMINARY RESULTS

The differential invariant cross-sections for identified hadrons, namely $\pi^{\pm}$, $K^{\pm}$ and $p/\bar{p}$ are shown in FIG. 2. The data has been corrected for the spectrometer acceptance, tracking and PID efficiencies, in-flight decay and multiple scattering. The details for the method can be found in Ref. [5]. After each data setting is corrected, all settings are combined and normalized by the number of events to make the spectra.

The ratio R_{CP} for the identified particles is defined as the yields from a given centrality class (0-20%, or 30-50%) divided by the yields from more peripheral collisions (60-80%), scaled by the mean number of binary collisions in each sample, namely

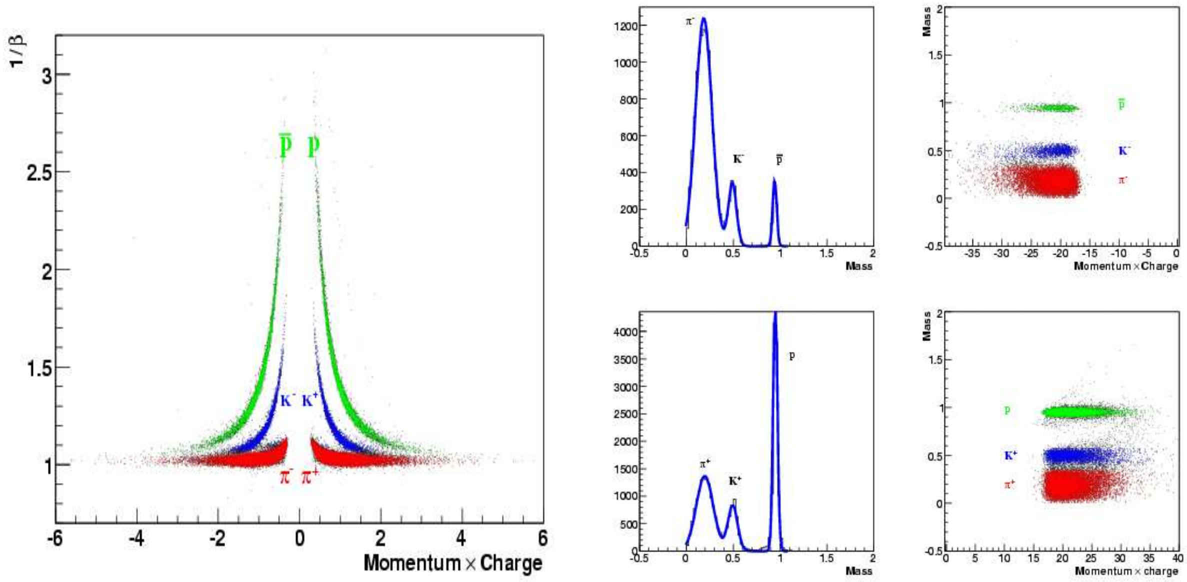

FIG. 1: Left panel: particle identification in the MRS using TOFW, in which $1/\beta = \sqrt{1 + m^2/p^2}$, right panel: particle identification in the FS by RICH, the hadron mass (GeV/c^2) vs momentum×charge (GeV/c) were used. Right-upper and right-lower plots stand for the settings at 4 degree with A and B polarities correspondingly under full magnetic field.

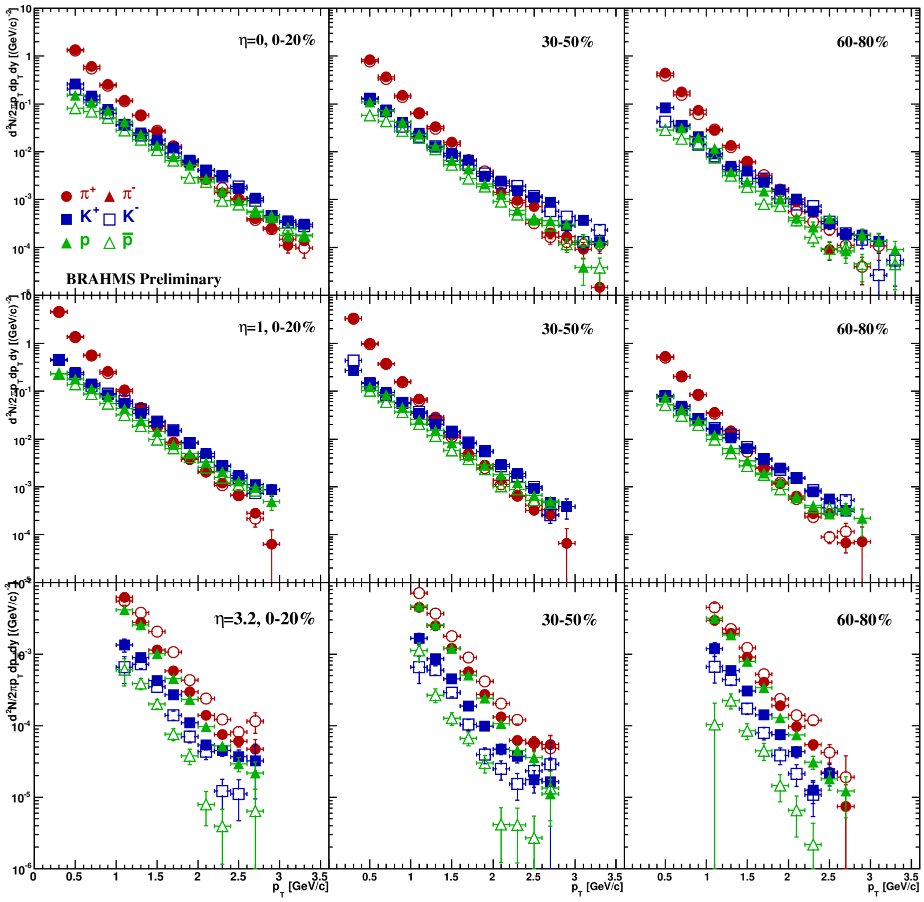

FIG. 2: Differential invariant p_T spectra of identified particles at different rapidity and different centrality intervals, in which pseudo-rapidity $\eta = 0, 1, 3.2$ correspond to rapidity range (-0.2,0.2), (0.7,1.3) and (3.0,3.4).

$$R_{CP} = \frac{\left\langle N_{bin}^{Peripheral} \right\rangle d^2N^{Central}/dp_T dy}{\left\langle N_{bin}^{Central} \right\rangle d^2N^{Peripheral}/dp_T dy} \tag{1}$$

By assuming that the nuclear modification is relatively small in the peripheral collisions, the deviation from unity of the R_{CP} is dominated by the nuclear effects in the more central collisions, which enable us to study the nuclear modification independent of the p+p reference spectra. Here, the numbers of binary collisions used in our analysis are $N_{bin}^{0-20\%} = 13.6 \pm 0.3$, $N_{bin}^{30-50\%} = 7.9 \pm 0.4$ and $N_{bin}^{60-80\%} = 3.3 \pm 0.4$.

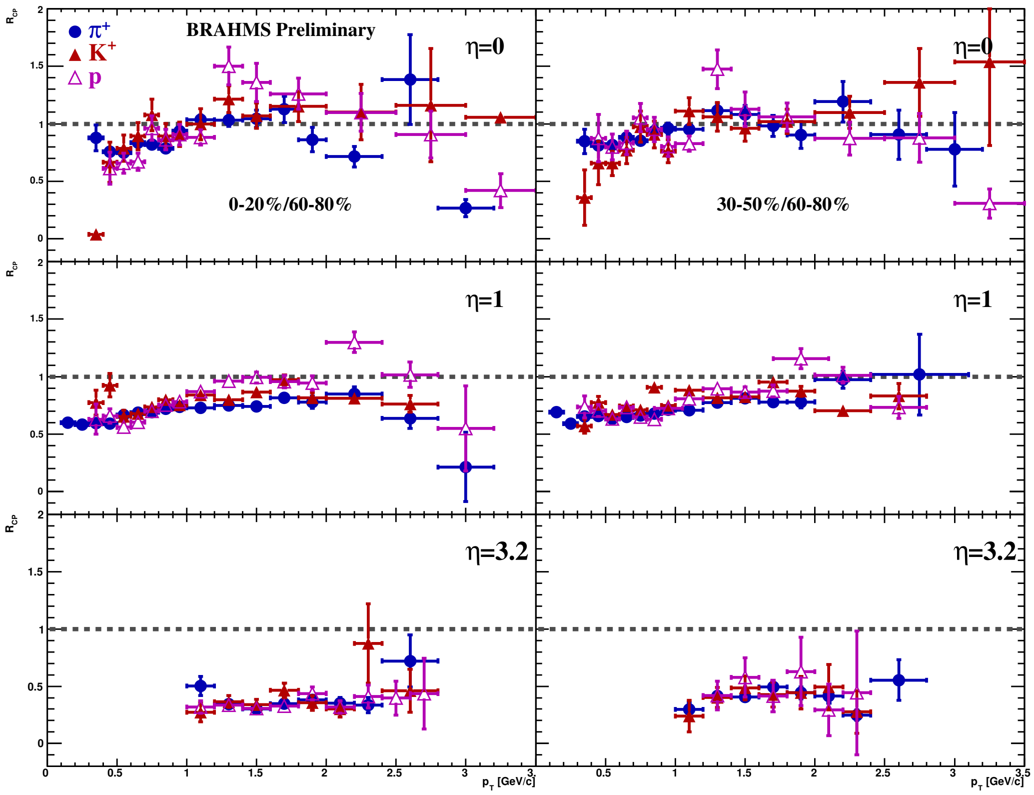

FIG. 3: R_{CP} as a function of p_T for identified hadrons at different rapidity, and comparisons of the ratio of central (0-20%) to peripheral(60-80%) and semi-central (30-50%) to peripheral are shown.

The evolution of R_{CP} with rapidity for identified particles is shown in FIG. 3. At mid-rapidity, the central-to-peripheral ratio is slightly larger than the semi-central-to-peripheral ratio for each identified particle species, with very similar behavior as what we observed for that of the un-identified hadrons, suggesting the increased role of Cronin-like multiple scattering effects in the more violent collisions. At forward rapidity, R_{CP} is very much suppressed in both cases, and no dependence on hadron species is observed.

Rapidity densities dN/dy are obtained by integrating the particle spectra over the full p_T range. Due to the lack of data at very low and high p_T, spectra are fitted to functions which describe them well. The fit function is then used to extrapolate to regions outside the acceptance. The protons spectra for different centrality classes, are fitted by the Boltzmann function in m_T, i.e. $Bm_T e^{[-(m_T-m)/T]}$, which describes the particle distribution emitted from a classical thermalized source at temperature T, where particles in the source are moving randomly according to the classical statistical laws. FIG. 4 shows the rapidity dependence of dN/dy of net-protons. From the centrality dependence of net-proton distribution in d+Au collisions, we can see that in the central and semi-central collisions, the net-proton yield increase at mid-rapidity. But in the most peripheral collisions, the net-protons increase at forward rapidity. This asymmetric net-proton rapidity density distribution can be understood as a strong baryon source on the gold fragmentation side and a weak one on the deuteron side.

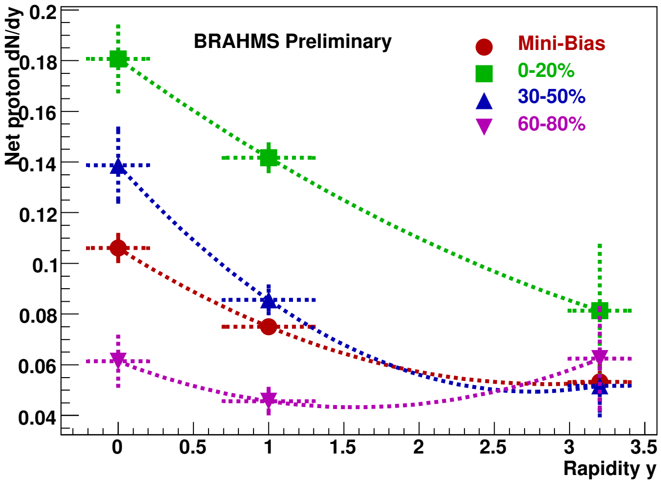

FIG. 4: Rapidity density distribution for net-proton dN/dy in d+Au collisons. Errors are statistical only, and the dashed curves in the figure are just to guide the eye.

IV. DISCUSSIONS

In d+Au collisions, the Cronin effect at mid-rapidity is observed for pions, kaons and protons. The R_{CP} shows a suppression at forward rapidities for all species, which is consistent with what we have seen before for charged hadrons[6]. As what has been discussed in [7], the peripheral Au+Au collisions are not equivalent to the pp collisions, in which the R_{CP} is more suppressed in central Au+Au collisions, compared to R_{AA}. While qualitatively, in d+Au collisions, comparing to the R_{dAu} for identified particles estimated by pQCD model with homogeneous shadowing considered[8], the R_{CP} measured by BRAHMS agree with the R_{dAu} calculated by the model at the same momentum region at mid-rapidity, but at forward rapidity, the suppression in R_{CP} for pions and kaons is very different from the model, in which charged hadron spectra are given to leading order by using standard fragmentation functions and shadowing parameterizations to study how modifications to the nucleon parton distributions affects production of high p_T hadrons in d+Au collisions. The rapidity density distribution of net-proton shows a maximum at mid-rapidity and decrease significantly as y increases for central collision. The tendency of the rapidity distribution is consistent with the results by NA35[9] at SPS energies.

Acknowledgements

This work was supported by the Division of Nuclear Physics of the Office of Science of the U.S. Department of Energy, the Danish Research Council, the Research Council of Norway, the Jagiellonian University Grants, and the Romanian Ministry of Research.

[1] L. McLerran and R. Venugopalan, Phys. Rev. **D 49**,(1994)2233; Phys. Rev. **D 59**, (1999)094002;
E. Iancu, A. Leonidov and L. D. McLerran, Nucl. Phys. **A 692**, (2001)583, and references therein.
[2] F. Videbaek, O. Hansen, Physical Review **C 52**,(1995)2684
[3] P. Christiansen, Ph.D Dissertation, Copenhagen University, May 2003
[4] M. Adamczyk *et al.*, [BRAHMS Collaboration], Nucl. Inst. Meth. **A 499**, (2003)437
[5] D. Ouerdane, Ph.D Dissertation, Copenhagen University (DK), August 2003.
[6] I. Arsene *et al.*, [BRAHMS Collaboration], Phys. Rev. Lett. **93**, (2004)242303
[7] P. Staszel for the BRAHMS Collaboration, proceeding for the Quark Matter Conference, Budapest, 2005
[8] R. Vogt, hep-ph/0405060, Phys. Rev. **C** in print
[9] T. Alber*et al.*, [NA35 Collaboration], Eur. Phys. J. **C 2**, (1998)643.