Particle production at forward rapidity in d+Au and Au+Au collisions in the STAR experiment at RHIC

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We present the recent results from the STAR experiment on charged and neutral particle measurements at the forward rapidity in d+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV and Au+Au collisions at $\sqrt{s_{\rm NN}} = 62.4$ GeV. The nuclear modification factor for charged and neutral hadrons in d+Au collisions are presented. Measurements of Λ and $\bar{\Lambda}$ production at forward rapidity and the variation of net baryon density as a function of collision centrality are discussed. We have also studied the limiting fragmentation of photons and charged particles in Au+Au collisions. The photons and charged particles separately follow the energy independent limiting fragmentation behaviour. However they have been observed to follow a different centrality dependence of limiting fragmentation.

1. INTRODUCTION

The STAR experiment at the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory has a unique capability of precise measurement of charged and neutral hadrons and photon multiplicity at forward rapidity. Through this capability we can carry out a systematic study of various aspects of particle production in relativistic heavy ion collisions. The study of nuclear modification factor ($R_{\rm AB}$) as a function of transverse momentum ($p_{\rm T}$) and pseudorapidity (η) can reveal interesting information on the mechanism of particle production. A $R_{\rm AB}(p_{\rm T})$ of unity will indicate the absence of nuclear effects such as shadowing, multiple scattering (Cronin effect) and gluon saturation. In a color glass condensate picture (CGC) of particle production it is expected that the nuclear modification factor will decrease with the increase in rapidity [1]. Measurement of baryons at forward rapidity will help in understanding the baryon transport and quantifying the nuclear stopping in high energy collisions. Forward rapidity is also the region where we observe the particle production per participating nucleon pair as a function of η - $y_{\rm beam}$, where $y_{\rm beam}$ is the beam rapidity, to be independent of beam energy. This phenomenon is known as limiting fragmentation (LF) [2]. A detailed study of energy, centrality and species dependence of LF behaviour will provided useful insight to particle production mechanism in forward rapidity. Comparative study of LF for photons (primarily from decay of π^0 mesons) and charged particles will help in understanding the centrality dependence LF behaviour.

*For the full list of STAR authors and acknowledgments, see appendix 'Collaborations' of this volume.

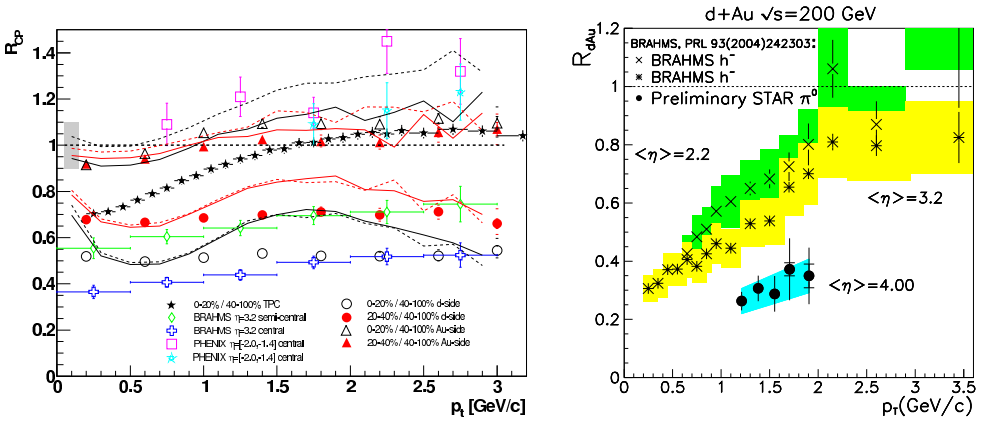

Figure 1. Nuclear Modification factors for charged (left) and neutral (right) hadrons in d+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV. The results are compared to BRAHMS and PHENIX results. The charged hadron measurements are also compared to HIJING.

2. DETECTORS AT FORWARD RAPIDITY IN STAR

The detectors at the forward rapidity [3] in STAR experiment are Forward Time Projection Chamber (FTPC), Photon Multiplicity Detector (PMD) and Forward π^0 Detector (FPD). The FTPCs detect charged particles in the pseudorapidity region $2.5 < \mid \eta \mid < 4.0$. The PMD consists of two planes of an array of cellular gas proportional counters separated by a lead converter. It detects photons within $2.3 < \eta < 3.7$. The FPD consists of lead-glass cells 21 radiation lengths deep. It detects high energy π^0 mesons within $3.3 < \eta < 4.1$.

3. RESULTS FROM d+Au COLLISIONS AT $\sqrt{s_{\rm NN}} = 200$ GeV

3.1. Charged and neutral hadron production

In Fig. 1 (left) we show the nuclear modification factor ($R_{\rm CP} = \frac{(d^2N/dp_t d\eta/<N_{\rm bin}>)|_{\rm central}}{(d^2N/dp_t d\eta/<N_{bin}>)|_{\rm peripheral}}$) of charged hadrons for two centrality classes at $\mid \eta \mid \sim 3.1$ and up to $p_{\rm T} = 3$ GeV/c. $R_{\rm CP}$ is larger on the gold side than on the deuteron side. On the deuteron side we observe a stronger centrality dependence of $R_{\rm CP}$ compared to the gold side. Our measurement compares well with the results from BRAHMS and PHENIX experiments [4]. The lines are calculations from HIJING with (dashed) and without (solid) shadowing. The nuclear effects on particle production have been also quantified by studying the $R^{\pi^0}_{\rm dAu}$ (Fig. 1 (right)), the ratio of the inclusive yield of π^0 in d+Au to p+p collisions normalized by the number of nucleon-nucleon collisions. The ratio $R^{\pi^0}_{\rm dAu}$ at $\langle\eta\rangle = 4.0$ is significantly smaller than $R^{h^-}_{\rm dAu}$ at smaller η [4], consistent with the trend expected from CGC-based models [1].

3.2. Strange particle production and baryon stopping

In the FTPC's, Λ and $\bar{\Lambda}$ are reconstructed by obtaining the invariant mass of their dominant decay modes $\Lambda \rightarrow p\pi^-$ and $\Lambda \rightarrow \bar{p}\pi^+$ (branching ratio of 64%). In Fig. 2 (left) we show the ratio of the Λ rapidity density in central collisions to that in peripheral col-

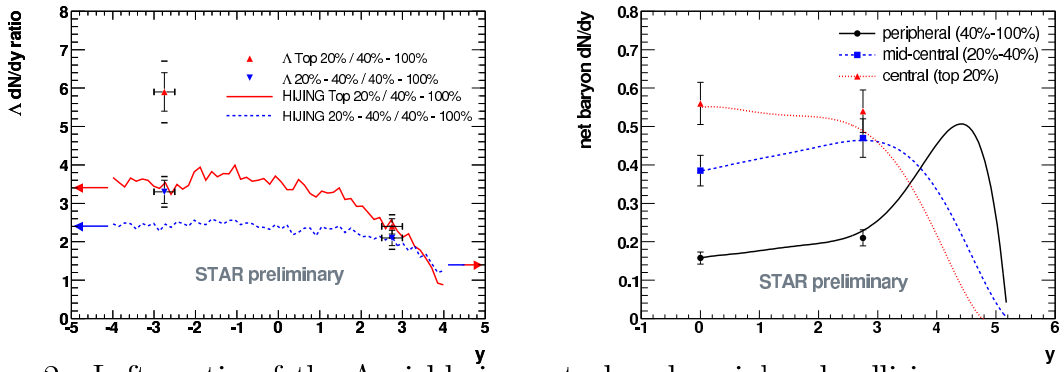

Figure 2. Left: ratio of the Λ yields in central and peripheral collisions compared to HIJING. Right: net baryon density for three centrality classes on the deuteron side of the collision.

lisions as a function of rapidity. The data show significant deviations from expectations from wounded nucleon scaling (arrows). The results when compared to HIJING calculations show a good agreement on the deuteron side of the collisions. On the gold side the data is above HIJING indicating possible presence of substantial nuclear effects. In Fig. 2 (right) we show the measured net baryon density for three centrality classes. The midrapidity results are from measured p and $\bar{p}$ in the Time-Of-Flight detector and at y = 2.75 on the deuteron side from the Λ measurements in FTPC. Lines show fits to the net baryon distributions with global constraints on the total number of baryons. Within such a model, we observe significant stopping in central collisions and a large degree of transparency in peripheral collisions.

4. RESULTS FROM Au+Au COLLISIONS AT $\sqrt{s_{\rm NN}} = 62.4$ GeV

In Fig. 3 we present the energy dependence of LF for inclusive photons and charged particles. Our data from central collisions has been compared to corresponding measurements from nucleus-nucleus collisions at different $\sqrt{s_{\rm NN}}$ in PHOBOS, BRAHMS, WA98, WA93 experiments and p+p($\bar{p}$) collisions in ISR and UA5 experiments [2]. The $\frac{dN}{d\eta}$ per participant pair as a function of η - $y_{\rm beam}$ is observed to be independent of beam energy. In Fig. 3 we show the centrality dependence of LF for charged particles and photons. At forward rapidity in Au+Au collisions at $\sqrt{s_{\rm NN}} = 62.4$ GeV the charged particle yield normalized to number of participating nucleons ($N_{\rm part}$) as a function of η - $y_{\rm beam}$ is higher for peripheral collisions compared to central collisions, whereas within the measured η range of 2.3 to 3.7, the photon yield normalized to $N_{\rm part}$ as a function of η - $y_{\rm beam}$ is independent of centrality [2]. We also observe that the photon results in the forward rapidity region from $p\bar{p}$ collisions at $\sqrt{s_{\rm NN}} = 540$ GeV are in close agreement with the measured photon yield in Au+Au collisions at $\sqrt{s_{\rm NN}} = 62.4$ GeV. However, the pp and $p\bar{p}$ inclusive charged particle results are very different from those for Au+Au collisions at $\sqrt{s_{\rm NN}} = 62.4$ GeV. The photon results and comparison with p+p($\bar{p}$) collisions indicate that, in the η region studied, there is apparently a significant charged baryon contribution in Au+Au collisions and such a contribution may be responsible for the observed centrality dependent

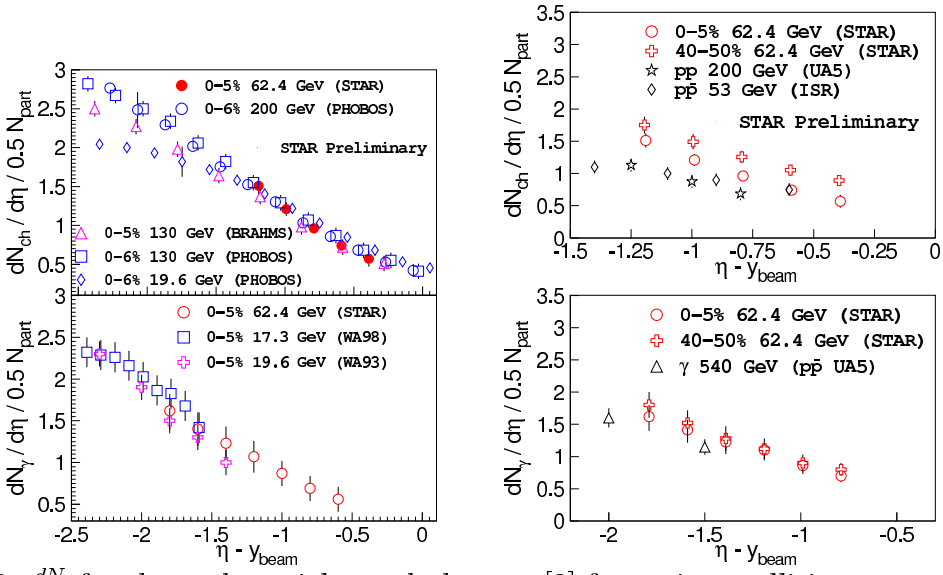

Figure 3. $\frac{dN}{d\eta}$ for charged particles and photons [2] for various collision systems : (left) at different $\sqrt{s_{\rm NN}}$ and (right) for various event centrality classes at $\sqrt{s_{\rm NN}} = 62.4$ GeV.

LF behaviour in charged particles.

5. SUMMARY

We have presented the results from the STAR experiment on charged hadrons, neutral hadrons and photons at forward rapidity in d+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV and Au+Au collisions at $\sqrt{s_{\rm NN}} = 62.4$ GeV. The nuclear modification factor in d+Au collisions is observed to decrease with increasing rapidity, which is consistent with predictions from CGC based models. $R_{\rm CP}$ is larger on the gold side than on the deuteron side in d+Au collisions. From the net baryon density measurements we conclude that there is significant stopping in central d+Au collisions and large transparency in peripheral collisions. Our measurements of photons and charged particle multiplicity show that photons follow centrality independent limiting fragmentation behaviour whereas charged particles follow a centrality dependent behaviour.

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