HIGH-PT HADRON PRODUCTION AND TRIGGERED PARTICLE CORRELATIONS

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The STAR experiment at the Relativistic Heavy-Ion Collider has performed measurements of high transverse momentum particle production in ultra-relativistic heavy-ion collisions. High-p_{T} hadrons are generated from hard parton scatterings early in the collision. The outgoing partons probe the surrounded hot and dense matter through interactions. Recent results on high-p_{T} inclusive particle production and leading particle correlations in p+p, d+Au and Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV are reviewed.

1 Introduction

The aim of studying ultra-relativistic heavy-ion collisions is to find evidence for the production of a new state of strongly interacting matter, the Quark-Gluon Plasma, where quarks and gluons are deconfined. The Relativistic Heavy-Ion Collider (RHIC) at Brookhaven National Laboratory provides Au+Au collisions at the highest energy presently available of $\sqrt{s_{\mathrm{NN}}} = 200$ GeV. In this energy range parton hard scattering in the initial state plays a significant role. The scattered partons can be used to probe the medium produced in the collision. Theoretical models [1] predict partonic energy loss via medium induced gluon Bremsstrahlung (jet-quenching) and jet broadening due to parton rescattering in the extremely dense medium. This parton energy loss is sensitive to the medium density.

Parton energy loss in the medium can be studied by measuring the production of high-p_{T} particle yields and azimuthal correlations. A strong suppression (factor of 4–5) of high-p_{T} hadron production relative to a simple binary collision scaling from proton-proton collisions has been

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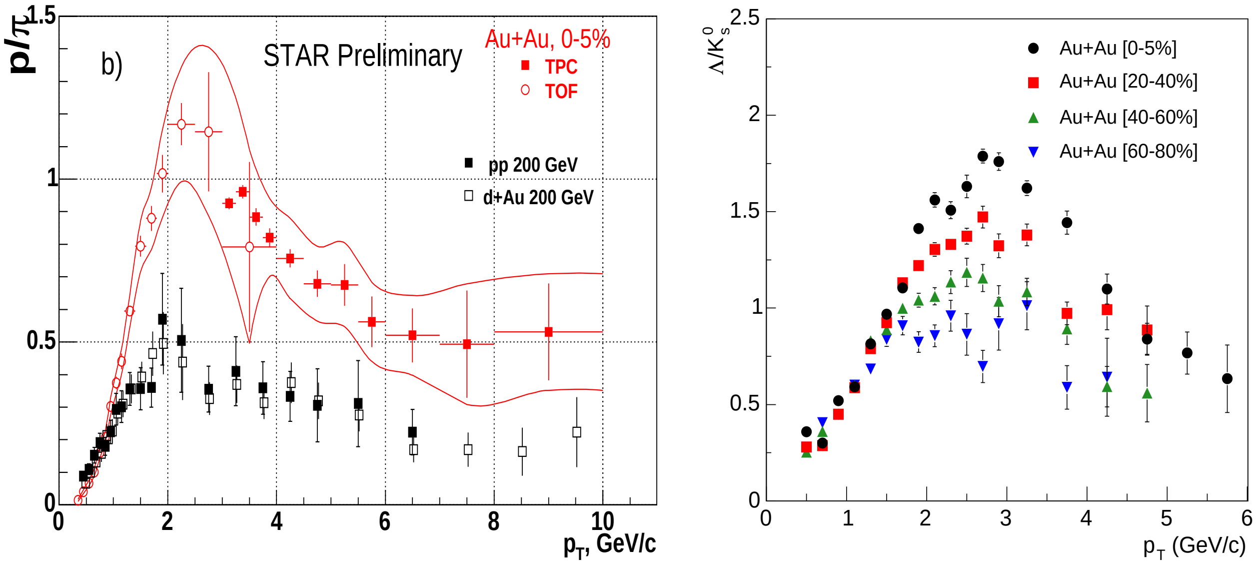

Figure 1: Left: Proton-to-pion ratio as a function of transverse momentum (p_{T}) for the 10% most central Au+Au collisions as well as for p+p and d+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV. The error bars for Au+Au are statistical and the error bands indicate the systematic uncertainties. For p+p, the error bars are combined statistical and systematic. Right: p_{T} dependence of the lambda-to-kaon ratio for different centralities in Au+Au collisions.

observed in central Au+Au collisions [2,3]. Additionally, it was found that jet-like correlations opposite to trigger hadrons are strongly suppressed [4]. In contrast, no suppression effects were observed in d+Au collisions [5], which reflects the effects in cold nuclear matter. These results are consistent with the jet-quenching mechanism as a final state effect. Further RHIC results are reviewed in references [6,7].

In this paper a selection of recent results on hard probes in nuclear collisions from the STAR experiment is presented. The STAR experiment [8] has extended its high-p_{T} measurements in a recent high statistics run in 2004 with 30M minimum-bias and 18M central events.

2 Inclusive identified particle spectra

Measurements of identified particle yields have shown that baryons are more abundant than mesons at intermediate p_{T} (2–6 GeV/c) in heavy-ion collisions. This is illustrated in Figure 1 where both the p/π (left) and $\Lambda/\mathrm{K}^0_{\mathrm{s}}$ ratio (right) is shown as a function of transverse momentum [9,10]. Both ratios increase up to approximately 3 GeV/c and exceed unity for the most central collisions. The p/π ratio in p+p and d+Au collisions is shown for comparison, with values below 0.5 for the entire p_{T} range. If fragmentation is the dominant production mechanisms, one would expect the p/π ratio in Au+Au collisions to be similar to p+p collisions. The observed enhancement in central Au+Au collisions therefore indicates that additional non-perturbative effects dominate at intermediate p_{T}. From the present statistics it seems that vacuum fragmentation is approached in Au+Au collisions above 6 GeV/c. In addition, the $\Lambda/\mathrm{K}^0_{\mathrm{s}}$ ratio exhibits a continuous evolution from peripheral to central collisions.

3 Particle azimuthal correlations

Due to full azimuthal coverage the STAR detector has good capabilities to study leading particle correlations. Recent STAR results on di-hadron azimuthal correlations at high-p_{T} are reviewed

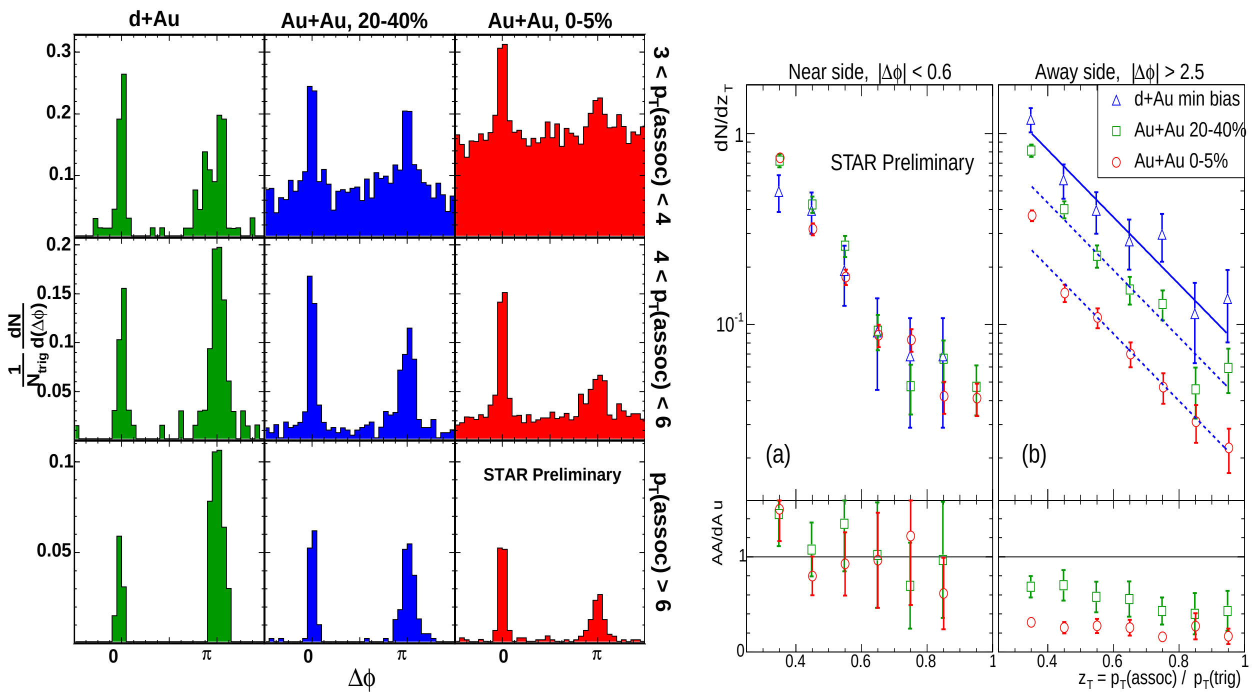

Figure 2: Left: Azimuthal correlation distribution of high-p_{T} charged hadrons selected in the transverse momentum range $8 < p_{\mathrm{T}}^{\mathrm{trig}} < 15$ GeV and associated with charged hadrons of three different p_{T} ranges in d+Au and Au+Au collisions (two different centralities) at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV. The distributions are not corrected for background contributions. Right: Trigger-normalized charged hadron fragmentation function (dN/dz_{T}) for near- (left) and away-side (right) correlations in d+Au and Au+Au collisions. The lines are described in the text. The lower panels show the ratio of dN/dz_{T} for Au+Au relative to d+Au collisions.

in this section.

It was observed that jet-like azimuthal angular ($\Delta\phi$) correlations opposite to trigger jets in the p_{T} range $4 < p_{\mathrm{T}}^{\mathrm{trig}} < 6$ GeV/c are suppressed for associate particles selected in $2 < p_{\mathrm{T}}^{\mathrm{assoc}} < 4$ GeV/c in central Au-Au collisions, whereas no suppression was measured in p+p, d+Au and peripheral collisions [5]. In the presence of final state energy loss the observation of high-p_{T} hadrons is biased towards production close to the surface. This surface bias is likely different in correlations where in particular the away side hadron should be more sensitive to medium properties. Since momentum has to be conserved the fragmentation products of the away-side jet cannot disappear. Instead the p_{T} spectrum of these particles is softened and the corresponding $\Delta\phi$ distribution using the low-p_{T} associate particles is similar to a momentum balanced shape [11].

The high statistics Au+Au run allows to extend the di-hadron azimuthal correlation analysis to much higher p_{T} thresholds for the trigger and associated particle [12]. Figure 2, left, shows the azimuthal correlation distribution of high-p_{T} charged hadrons selected in the transverse momentum range $8 < p_{\mathrm{T}}^{\mathrm{trig}} < 15$ GeV and associated with charged hadrons of three different p_{T} ranges in d+Au and Au+Au collisions (two different centralities) at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV. No background subtraction is applied to the distributions. A clear back-to-back peak is observed for all collision systems. However, this peak is suppressed in Au+Au collisions for all associate p_{T} ranges. This is shown in more detail in Figure 2, right, where the di-hadron fragmentation function of charged hadrons is plotted for the near- (left) and away-side (right) correlations in d+Au and Au+Au collisions as a function of z_{T} ($= p_{\mathrm{T}}^{\mathrm{assoc}}/p_{\mathrm{T}}^{\mathrm{trig}}$), as proposed in reference [13]. The near-side peak shows no significant modification from d+Au to central Au+Au whereas the away-side peak is strongly suppressed in Au+Au collisions. The solid line in Figure 2, right, is an exponential fit to the d+Au data points. The dashed lines represent the same exponential fit scaled down by a factor of 0.54 and 0.25 to approximate the Au+Au yields in the centrality bins 20–40% and 0–5%, respectively. The suppression in central Au+Au shows essentially no z_T dependence above approximately 0.3. The size of the suppression, a factor 4–5, is similar to the suppression factors measured for inclusive particle spectra at high-p_T ($p_T \gtrsim 6$ GeV/c). Remarkably, despite the suppression, the slope of the fragmentation distribution is the same in d+Au and central Au+Au collisions.

In a multiple scattering scenario, one would intuitively expect that the strong suppression also lead to a broadening of the away-side peak [14,15]. Such a broadening is not observed in central Au+Au collisions. Instead the width of the away-side peak is approximately independent of centrality.

4 Summary

In this paper recent high-p_T results from the STAR experiment are presented. The large enhancement of the particle ratios p/π and Λ/K^0_s in Au+Au collisions indicates that vacuum fragmentation is not the dominant source of particle production at intermediate p_T. Di-hadron azimuthal correlations at higher p_T exhibit a finite suppression of the back-to-back peak whereas the width of the away-side peak is similar for peripheral and central Au+Au collisions. These results provide stringent constraints for parton energy loss models and the medium density [12].

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