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Identified particles at large transverse momenta in STAR in Au+Au collisions @ $\sqrt{s_{NN}}$ = 200 GeV

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Abstract

We report measurements of the ratios of identified hadrons (π, K, p, Λ) in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV as a function of both collision centrality and transverse momentum (p_T). Ratios of anti-baryon to baryon yields are independent of p_T within $2 < p_T < 6$ GeV/c indicating that, for such a range, our measurements are inconsistent with theoretical pQCD calculations predicting a decrease due to a stronger contribution from valence quark scattering. For both strange and non-strange species, a strong baryon enhancement relative to meson yields is observed as a function of collision centrality in this intermediate p_T region, leading to p/π and Λ/K ratios greater than unity. The nuclear modification factor, R_{cp} (central relative to peripheral collisions), is used to illustrate the interplay between jet quenching and hadron production. The physics implications of these measurements are discussed with reference to different theoretical models (Fries *et al* 2003 *Phys. Rev.* C **68** 044902; Gyulassy *et al* 2001 *Phys. Rev. Lett.* **86** 2537; Greco *et al* 2003 *Phys. Rev.* C **68** 034904).[2]

(Some figures in this article are in colour only in the electronic version)

1. Introduction

At large transverse momenta, particle production in ultra-relativistic heavy ion collisions is dominated by jet fragmentation and at low momenta by soft particle production which can be well described by hydrodynamical models [5]. In the intermediate p_T region, ($2 < p_T < \sim 6$ GeV/c), the mechanisms of particle production are still to be investigated. It has been reported that the $\overline{\text{p}}$/p ratio is approximately constant as a function of p_T up to 4 GeV/c [6], in disagreement with pQCD calculations which predict a decrease with increasing p_T [2].

[1] For the full author list and acknowledgments, see the appendix 'Collaborations' in this volume.
[2] For discussion on strange particle correlations which were presented at this conference, refer to [4].

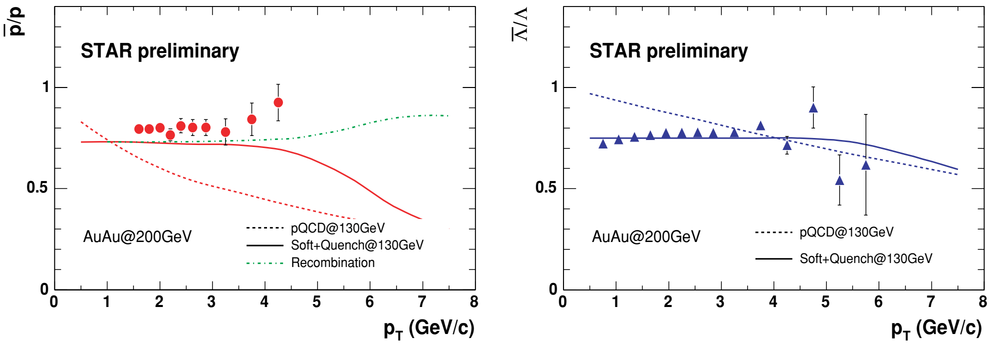

Figure 1. The $\bar{p}/p$ and $\bar{\Lambda}/\Lambda$ ratios versus p_T, together with different theoretical models.

Also, the p/π ratio rises with increasing p_T up to 4 GeV/c, where it reaches unity [6]. This is much larger than the ratio found in elementary collisions [7]. It has also been shown that at higher p_T, particle production does not scale with the number of binary collisions in the most central Au+Au collisions, but rather is suppressed [8, 9]. The particle dependence of this quantity, R_{cp} (the ratio between the yields in central and peripheral collisions as a function of p_T), exhibits a difference between the lighter (π, K) and the heavier particles (Λ, p).

In this paper we present the $\bar{p}/p$ and $\bar{\Lambda}/\Lambda$ ratios as a function of p_T in the most central collisions, extending the p_T coverage to 6 GeV/c. The $\bar{p}/\pi^-$ and Λ/K^0_s ratios are presented as a function of both p_T and the centrality of the collision, extending the measurement of the baryon/meson ratio reported in [6]. The R_{cp} ratios for the Ξ and $K^*(892)$ are also presented, giving further information on the baryon and meson production differences.

2. Analysis and results

In this analysis, 1.6×10^6 minimum-bias triggers and 1.5×10^6 central triggers in the STAR detector system were used [10]. The charged hadrons (p, π) were identified using a small acceptance ($\Delta\eta < 0.3$, $\Delta\phi = 20°$) CsI based ring imaging cherenkov detector (RICH), located at mid-rapidity in the STAR setup [11], extending the p_T coverage of the particle identification of the π and K up to 3 GeV/c and the p to 5 GeV/c, well beyond the range achieved through specific ionization in the time projection chamber (TPC) [12]. Meanwhile, the strange hadrons (Λ and K^0_s) are identified at mid-rapidity ($|y| < 1.0$) in the TPC through their charged decay channels : $\Lambda \to p + \pi^-(64\%)$, $\bar{\Lambda} \to \bar{p} + \pi^+(64\%)$ and $K^0_s \to \pi^+ + \pi^-(69\%)$ [13].

The $\bar{p}/p$ and $\bar{\Lambda}/\Lambda$ ratios are presented as a function of p_T for the most central collisions (0–10%) in figure 1.[3] Along with the data, predictions are also plotted for the $\bar{p}/p$ ratio from the 'soft+quench' (solid) model (and pQCD (dashed) model from the same authors) at 130 GeV [2, 14], and a recombination (dash-dot) model at 200 GeV [1]. Predictions from the 'soft+quench' and pQCD models at 130 GeV are also shown for the $\bar{\Lambda}/\Lambda$ ratio [14].

Allowing for the discrepancies in energy between some of the model predictions and the data, both the recombination and 'soft+quench' models are in agreement with the data, whilst the pQCD prediction shows a decrease in the ratio over all p_T. This pQCD calculation

[3] The $\bar{p}/p$ ratio presented here is different to that presented at the previous conference in this series [15], where the ratio showed a clear decrease with increasing p_T. Since then, experimental effects have been better modelled (mainly space charge distortions) leading to an improved analysis.

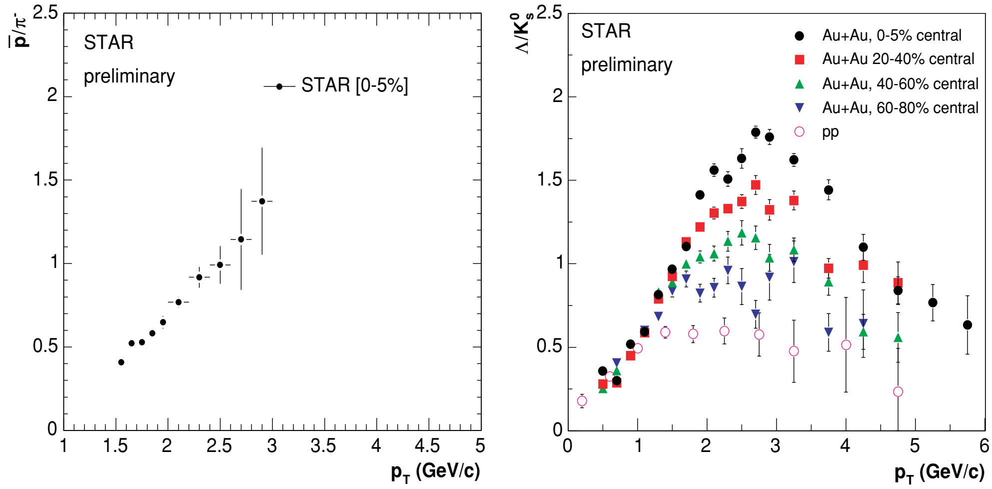

Figure 2. Baryon/meson ratios as a function of p_T: (left) $\overline{\mathrm{p}}/\pi^-$ for the 5% most central collisions; (right) Λ/K^0_s as a function of collision centrality.

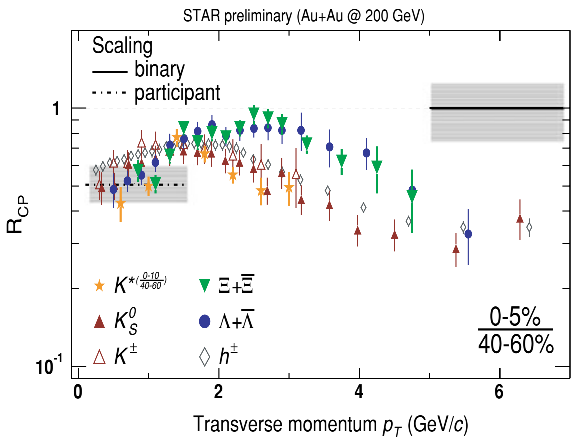

Figure 3. The R_{cp} for different mass hadrons. A clear difference exists between baryons and mesons.

therefore fails to describe the data in this p_T range, though the uncertainties in PDFs and fragmentation functions need to be addressed.

The baryon/meson ratios can also be studied in both the non-strange and strange sector via the $\overline{\mathrm{p}}/\pi^-$ and Λ/K^0_s ratios and are presented in figure 2. For the $\overline{\mathrm{p}}/\pi^-$ ratio, which is in agreement with earlier measurements [6], the p_T range is limited to 3 GeV/c due to the need for unambiguous identification of the π^-, whilst the p_T coverage of the Λ/K^0_s ratio is governed by the (lack of) statistics.

The R_{cp} measurements for the $\mathrm{K}^*(892)$ and the Ξ are plotted in figure 3, along with the Λ and kaon, where the shaded regions show what is expected for participant and binary scaling respectively. The variable R_{cp}, plots the relative yield of particles in the most central Au+Au collisions to the yield in peripheral Au+Au collisions, normalizing each yield to the number of binary collisions, as a function of p_T.

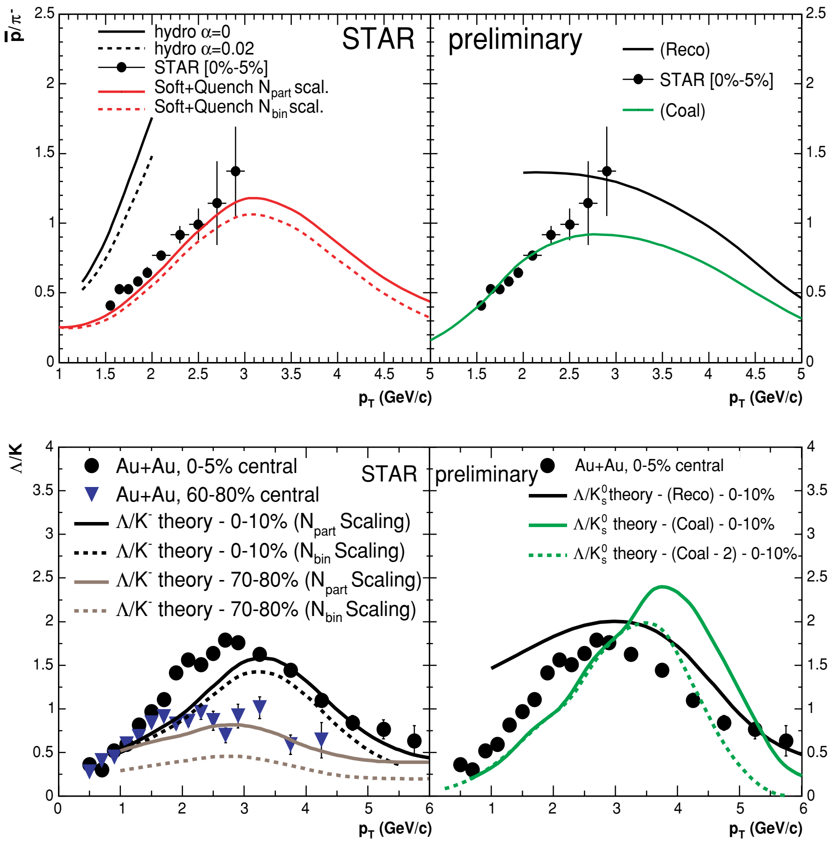

Figure 4. Baryon/meson ratios plotted with various theoretical models. The two top plots are for the $\bar{p}/\pi^-$ ratio and the two bottom plots for the Λ/K^0_s ratio.

3. Discussion

The Λ/K^0_s ratio shows a smooth increase with the number of participating nucleons, from minimum bias p+p collisions (at 200 GeV/c), up to the most central Au+Au collisions. For all centralities, there appears to be a constant increase of the ratio at low p_T, whereupon the ratio in that collision system plateaus and then falls off. The Λ/K^0_s (and hence the baryon/meson) ratio is greater than unity in the most central data for the range $2 < p_T < 6$ GeV/c. The data appears to tend to the same value for all centralities in the range $p_T \sim 5$–6 GeV/c, but is not yet down to the level exhibited in p+p collisions. This feature is also present in the $R_{\rm cp}$ ratios in figure 3. With the addition of the $K^*(892)$ and Ξ data, it is evident that baryons and mesons are suppressed at different transverse momenta and the differences previously reported between the π and p [6] and K^0_s and Λ [16] are not due to a mass effect. We note that the $R_{\rm cp}$ for the Λ and K^0_s come together at approximately the same p_T as the Λ/K^0_s ratios come together, perhaps indicating the onset of particle production from string fragmentation.

Theoretical models which use various mechanisms for baryon production such as gluon junctions (soft+quench) [2, 17], recombination [1] and quark coalescence [3] are compared to the data in figure 4. In the 'soft+quench' case, predictions for two different geometrical scalings of the junction mechanism are given. $N_{\rm part}$ *scal.* refers to scaling with the number of participants ($A^{1/3}$) whilst $N_{\rm bin}$ *scal*. refers to scaling with the number of binary collisions ($A^{4/3}$). The two different coalescence comparisons are for with (coal) and without (coal-2), the coalescence mechanism from within the same model. This is strongly dependent upon the wavefunction used for the Λ in the analysis [18]. The recombination and coalescence models require a large parton density and though they appear to be more natural than the gluon junction mechanism, all the models are in quite good agreement with the central data. In order to understand the data further and differentiate between the models, we require realistic calculations as a function of centrality.

4. Summary

In summary, we have shown that both the $\overline{\rm p}/{\rm p}$ and $\overline{\Lambda}/\Lambda$ ratios are independent of p_T up to 4.5 and 6 GeV/c respectively. This finding is inconsistent with the pQCD model presented in the p_T range considered. We have also found that the $\Lambda/{\rm K}_s^0$ ratio increases smoothly as a function of increasing centrality in the intermediate p_T region, to a plateau value of approximately 1.8 in the most central collisions. This ratio then falls again, reducing to below unity at a p_T of approximately 5 GeV/c, though the ratio is still above the value from p+p collisions at the same energy. We also presented the $R_{\rm cp}$ values for the K* and the Ξ, which showed that the observed suppression does not originate from the hadron mass, but rather that the suppression is different for baryons and mesons.

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