Antiflow of Kaons in Relativistic Heavy Ion Collisions

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Recently, the E895 Collaboration at AGS/BNL has measured the directed flow of neutral strange K_s^0 mesons in 6 AGeV Au+Au collisions for central and mid-central events [1]. The K_s^0 was found to have a much larger antiflow than that measured in heavy ion collisions at much lower energy at SIS/GSI [2], where the vanishing kaon flow was found to be due to the repulsive kaon potential in dense matter. To understand this surprising result, we have used a relativistic transport model (ART) [3] for heavy ion collisions to see if it can also be explained by the repulsive kaon potential [4].

The ART model includes kaon production from baryon-baryon, meson-baryon, and meson-meson scatterings with a formation time of $\tau_{\rm fo}^{K}$ = 1.2 fm/c and the scattering of kaons with other hadrons. As to the mean-field potential for the kaon, two forms have been adopted. One of these is based on the kaon dispersion relation determined from the kaon-nucleon scattering length using the impulse approximation [5]. This yields a repulsive potential of 30 MeV at normal nuclear density (Δ_0) for kaon at zero momentum. The other form of kaon potential used here is the scalar-vector potential determined from the chiral Lagrangian [6].

We first show in Fig. 1 the proton directed transverse flow $\langle p_x \rangle$ as a function of normalized rapidity y/y_{cm} in Au+Au collisions at $E_{\rm beam}$ = 6 AGeV. The data reveals a large proton flow with a slope of $F = d\langle p_x \rangle / d(y/y_{c.m.}) \sim 180$ MeV/c at midrapidity. The ART model with a soft nuclear equation of state with a compressibility of 200 MeV (solid line) provides a good agreement with the data over a large rapidity range. On the other hand, the stiff EOS with a compressibility of 380 MeV (dashed line) results in a much stronger proton flow compared to the data.

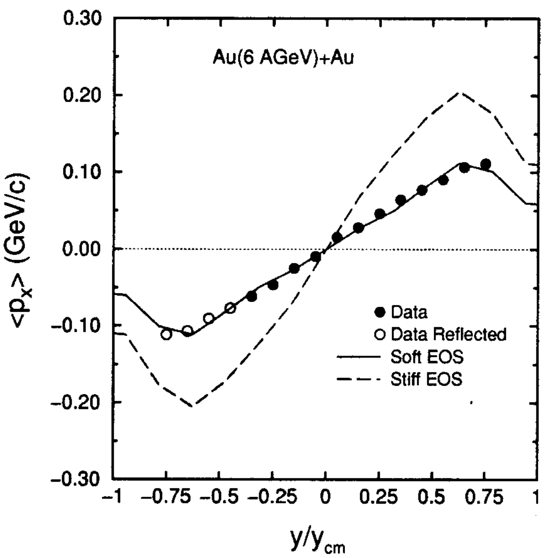

Figure 1: The proton directed transverse flow $\langle p_x \rangle$ as a function of normalized rapidity y/y_{cm} in Au+Au collisions at $E_{\rm beam}$ = 6 AGeV. The ART model calculations for a soft (solid line) and stiff (dashed line) nuclear EOS at an impact parameter b = 5-7 fm are compared with the E895 data (filled circles).

In Fig. 2, the ART model predictions of the sideward kaon flow as a function of rapidity are compared with the E895 data K_s^0 mesons [1]. In contrast to the protons, a pronounced in-plane antiflow for the K_s^0 is observed in the data with a slope of $F \simeq$ -127 ± 20 MeV/c. In the absence of kaon mean field, the K^0's have a flow pattern similar to that of the nucleons. This is not surprising as most of the K^0's are produced in the early compression stage of the reaction at time t ≲ 5 fm/c and the rescattering of the kaons with the nucleons in the dense matter thus causes them to flow in the direction of the nucleons.

Using the kaon potential determined from the impulse approximation, the K^0's are repelled from the nucleons resulting in antiflow

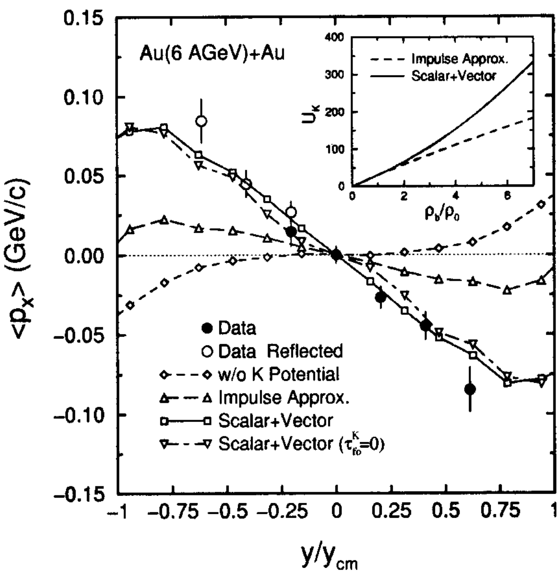

Figure 2: The kaon directed transverse flow $\langle p_x \rangle$ as a function of normalized rapidity y/y_{cm} in Au+Au collisions at $E_{\rm beam}$ = 6 AgeV. The filled circles are the E895 data while the other curves correspond to ART model calculations (b ≲ 7 fm and $p_t \leq$ 700 MeV/c) without kaon mean field potential and with kaon dispersion relations obtained from impulse approximation and scalar-vector potential. For the latter kaon potential, results with zero kaon formation time τ^k_{fo} is also shown. The inset shows the density dependence of the kaon potential U_K at zero momentum obtained in the impulse approximation and scalar-vector potential.

with respect to the nucleons. However, the $\langle p_x \rangle$ for kaon is found to underestimate the data as in Ref [7]. The scalar-vector potential has clearly a stronger density dependence compared to the impulse approximation (see inset of Fig. 2) since the vector potential dominates over the scalar potential at densities above the normal nuclear matter value. The kaon flow predicted from the scalar-vector potential is found to have a strikingly good agreement with the K^0_s flow data as seen in Fig. 2. Setting the kaon formation time $\tau^K_{\rm fo}$ to zero suppresses slightly the kaon antiflow especially near the midrapidity. Although the final kaon flow is opposite to the proton flow, the primordial kaons flow with the nucleons up to the maximum compression stage of the collision, and their $\langle p_x \rangle$ values are nearly identical irrespective of the kaon potential employed. This suggests that at the AGS energies, kaon flow may provide information about the kaon dispersion relation for densities below ~ $4\Delta_0$.

References

[1] P. Chung *et al.* (E895 Collaboration), Phys. Rev. Lett. **85**, 940 (2000).

[2] J. Ritman *et al.* (FOPI Collaboration), Z. Phys. A **352**, 355 (1995).

[3] B. A. Li and C. M. Ko, Phys. Rev. C **52**, 2037 (1995).

[4] S. Pal, C. M. Ko, Z. W. Lin, and B. Zhang, Phys. Rev. C **62**, 061903 (2000).

[5] C. M. Ko and G. Q. Li, J. Phys. G **22**, 1673 (1996).

[6] D. B. Kaplan and A. E. Nelson, Phys. Lett. **B175**, 57 (1986); **192**, 193 (1987).

[7] B. Zhang, C. M. Ko, B. A. Li, and A. T. Sustich, J. Phys. G **26**, 1665 (2000).