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 $\tau^K_{fo} = 1.2$ 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 ($\Delta_0$) 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 $E_{beam} = 6$ AGeV. The data reveals a large proton flow with a slope of $F = d\langle p_x \rangle/d(y/y_{cm}) \sim 180$ 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.

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 $F \approx -127 \pm 20$ 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 $t \approx 5$ 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
with respect to the nucleons. However, the

\[ \langle p_y \rangle \]

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 $K^0$ flow
data as seen in Fig. 2. Setting the kaon
formation time $\tau^K_0$ 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 $\langle p_y \rangle$ 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

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