Excitation Function of Nucleon and Pion Elliptic Flow in Relativistic Heavy-Ion Collisions

B. A. Li*, C. M. Ko, A. T. Sustich*, and B. Zhang

The elliptic flow of particles in heavy ion collisions measures the anisotropy in their transverse momentum (p_t) distribution at midrapidity, i.e., $v_2 \equiv < (p_x^2 - p_y^2)/p_t^2 >$ [1]. This is a subject of great interest as it may reveal the signatures of possible QGP phase transition in heavy ion collisions. Using a Relativistic Transport (ART) Model [2] we have studied the beam energy and transverse momentum dependence of both nucleon and pion elliptic flow in heavy ion collisions at AGS energies [3].

In the upper window of Fig. 1, we compare the excitation function of v_2 for protons in mid-central Au+Au reactions obtained by using the stiff (cross), soft (filled square) equation of state (EOS) and the cascade model (open square) with the experimental data (open circles) of Ref. [4]. In agreement with other model calculations [5, 6], our calculated results show that the transition energy $E_{\rm tr}$ at which the proton elliptic flow changes sign is very sensitive to the nuclear EOS. The value of $E_{\rm tr}$ is more than 4 GeV/nucleon in the case of a stiff EOS but decreases to below 3 GeV/nucleon for a soft EOS due to a smaller sound velocity in the latter [6]. In the case of cascade calculations, the absence of a repulsive potential further reduces the squeeze-out contribution and results in an essentially in-plane flow in the beam energy range considered here. On the other hand, the value of v_2 in our calculations is insensitive to the nuclear EOS for incident energies above about 6 GeV/nucleon. This is different from the results of Ref. [6], where a distinct difference is seen between the elliptic flow due to a soft and a stiff EOS. Moreover, in our study the experimental data are found to be consistent with the calculated results using the stiff EOS in this beam energy range. These results are thus also different from that of Ref. [4], where calculations based on the relativistic Boltzmann-Equation model show that the experimental data suggest a softening of the EOS from a stiff one at low beam energies to a softer one at higher energies. Since different model calculations lead to different dependence of the proton elliptical flow on the nuclear EOS, it is thus not possible at present to draw conclusions from comparisons of the theoretical results with the experimental data.

We have also studied the elliptical flow of pions, and the results are shown in the lower window of Fig. 1. It is seen that pions also show a transition from out-of-plane to in-plane elliptic flow as the beam energy increases. However, both the magnitude of pion elliptic flow and the transition energy at which it changes sign are significantly smaller than those for nucleons.

In Fig. 2, we show the p_t dependence of both nucleon and pion elliptic flow in a mid-central collision of Au+Au at a beam momentum of 6 GeV/c per nucleon for the case of a soft nuclear EOS. For protons, the elliptic

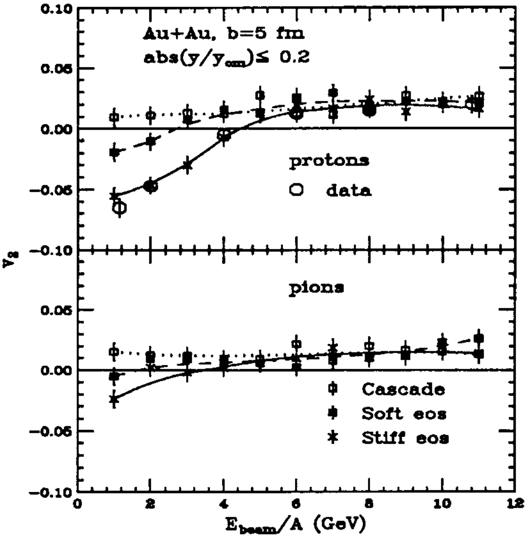

Figure 1: The excitation function of proton (upper) and pion (lower) elliptic flow in mid-central Au+Au reactions.

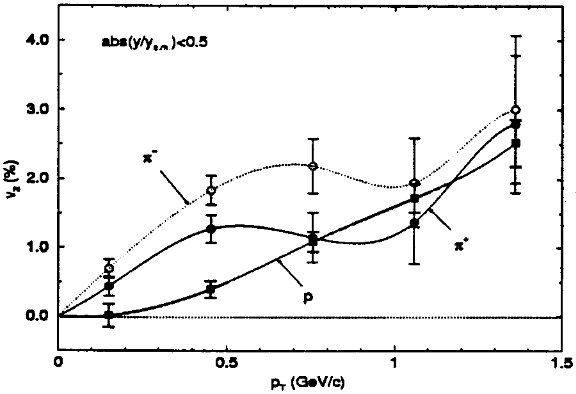

Figure 2: The transverse momentum dependence of nucleon and pion elliptic flow in the reaction of Au+Au at $p_{\mathrm{beam}}/nucleon = 6$ GeV/c and an impact parameter of 4 fm using a soft nuclear equation of state.

flow increases approximately quadratically at low p_t and then increases linearly at high p_t, as expected from the nucleon azimuthal angle distributions [7, 8]. For pions, their v_2 value is larger than that for protons at low p_t but becomes similar at high p_t. The p_t dependence of v_2 for nucleons and pions in heavy ion collisions at AGS energies is remarkably similar to what one finds at both Bevalac/SIS [7, 9] and SPS energies [10], indicating the similarity of the collision dynamics at these different energies. We note that negative pions have higher in-plane flow than the positive ones as a result of the Coulomb potential from protons, i.e., negative pions are attracted to while positive ones are repelled away from protons.

Our results have thus shown that the study of the excitation function of both nucleon and pion flow is useful in understanding the transition from an out-of-plane to an in-plane elliptic flow as the incident energies increases.

*Department of Chemistry and Physics, P.O. Box 419, Arkansas State University, State University, AR 72467-0419

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