Scaling of elliptic flow, recombination and sequential freeze-out of hadrons in heavy-ion collisions

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Quark recombination has been identified as an efficient particle production mechanism for hadrons with intermediate transverse momentum p_T in ultrarelativistic heavy-ion collisions [1]. In particular, it explained the constituent-quark number scaling of elliptic flow of mesons and baryons at $2 < p_T < 6$ GeV: $v_2(p_T)=n_q v_2^q(p_T/n_q)$, where n_q is the number of valence quarks contained in a hadron. However, the conventional quark recombination models suffer the drawback of energy non-conservation and thus their application is limited to intermediate p_T. In the present work [2], we employ the Resonance Recombination Model (RRM) [3] to investigate the scaling properties of elliptic flow in the low-p_T regime where particles are in (or close to) equilibrium. Since the RRM satisfies energy conservation and detailed balance, it provides an equilibrium mapping from quark distributions to the formed hadron distributions, as shown in Fig. 1.

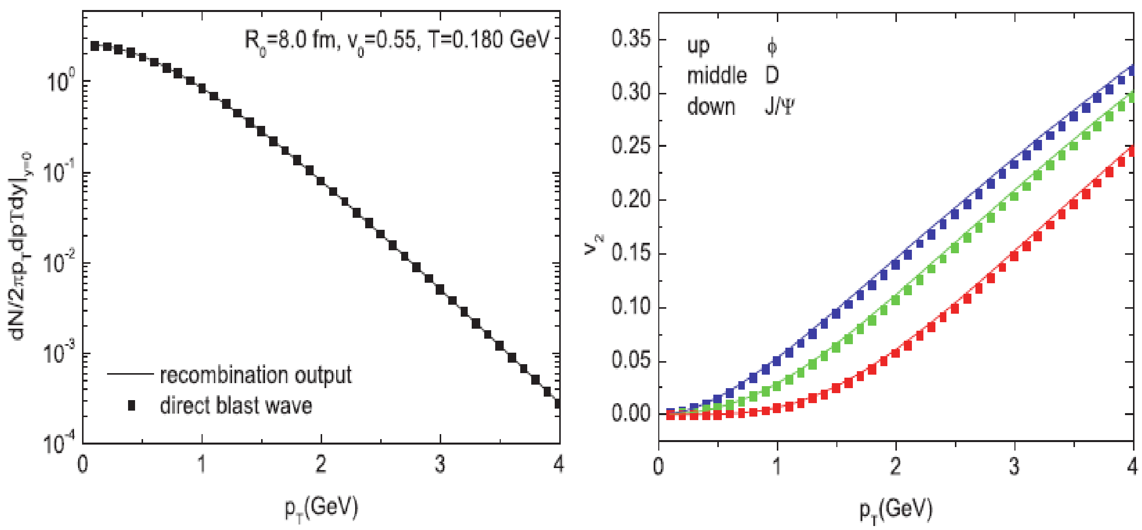

FIG. 1. Equilibrium mapping from quark to meson distributions as realized in RRM [2]. Left panel:phi-meson p_T spectrum. Right panel: phi, D and Jpsi-meson v_2. The solid lines are direct blast wave calculations and the symbols are output of RRM calculations.

Based on this equilibrium mapping in RRM, we extract the quark distributions around hadronization (see Fig. 2) from an empirical fireball source which is parameterized according to the multi-strange hadron spectra in semi-central Au-Au collisions at RHIC. Multi-strange hadrons are believed to freeze out close to hadronization since their hadronic cross sections are believed to be small [4] and thus their observed spectra reflect the source information at T_c~180 MeV.

In contrast to multi-strange hadrons, bulk particles (pions, kaons and protons) freeze out much later owing to efficient hadronic (elastic) resonant interactions. We show that the bulk-particle spectra

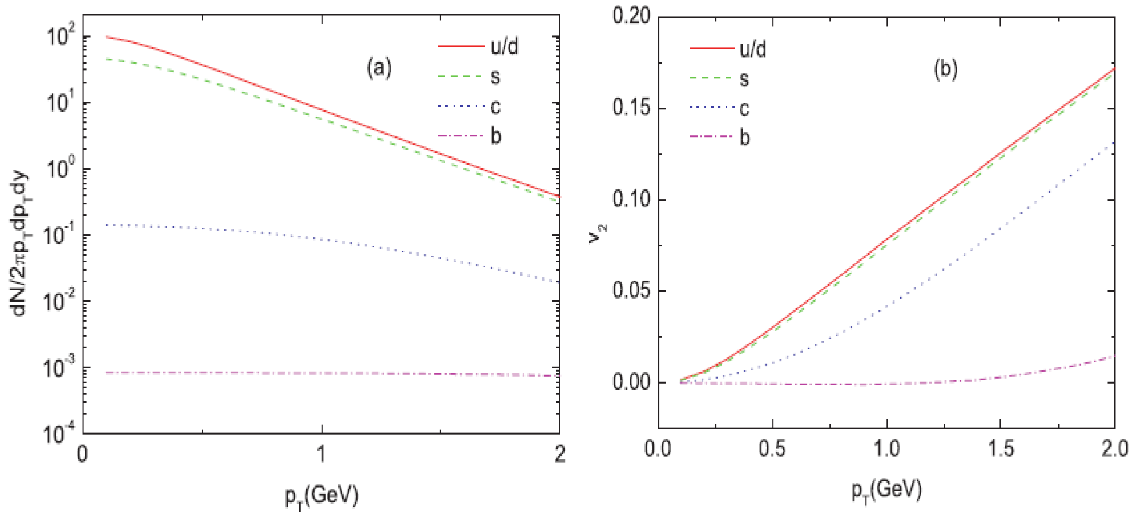

FIG. 2. Extracted equilibrium quark distributions from empirical fits of multi-strange hadron spectra at hadronization with T_c~180 MeV. Left panel: quark spectra. Right panel: quark v_2.

can be fitted fairly well at T_{kin}~110 MeV with a source of larger flow [2]. Based on this sequential freeze-out scenario, we verify that the resulting elliptic flow of various hadrons from empirical fits exhibit transverse-kinetic energy (KE_T) and valence-quark number scaling [2], see Fig. 3. We thus conclude that elliptic-flow scaling in the low-p_T regime bridges equilibrium hydrodynamics and quark recombination.

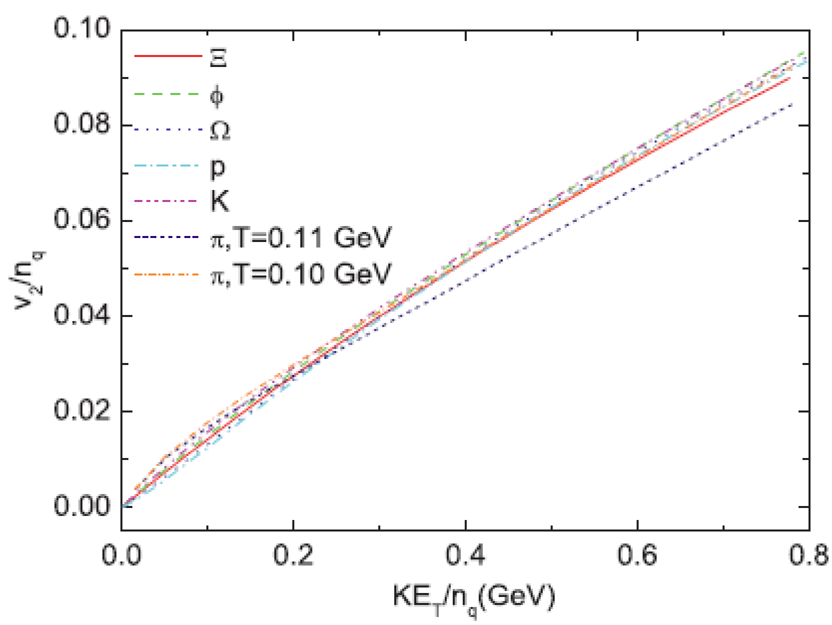

FIG. 3. KE_T and n_q scaling of v_2 for different hadrons obtained within the sequential freeze-out scenario. A slightly later freeze-out for pions at T=100 MeV further improves the scaling.

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