Partonic Equation of State in Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$GeV at RHIC

Nu Xu

Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA

At RHIC, the mid-rapidity invariant momentum distributions have been measured for pions, kaons, protons, ϕ, Λ, Ξ, Ω [1, 2] and J/ψ [3] from $\sqrt{s_{\rm NN}} = 200$ GeV $Au+Au$ collisions. While pion spectra show a p_T-power-law shape, most of the hadron spectra are m_T-exponential, especially the strange hadrons like K, ϕ, Ξ, Ω and J/ψ. In order to characterize the transverse motion, it is instructive to analyze the systematic mass dependence of the slope parameters extracted from the exponential fit: $f_{exp} = A \cdot e^{-m_T/T}$, where A and T are the normalization constant and inverse slope parameter, respectively. The m_T is defined as $m_T = \sqrt{p_T^2 + m^2}$. The slope parameters from the central $Au + Au$ collisions at RHIC are shown in Figure 1. For comparison, also shown in the figure is the slope parameters from $Pb + Pb$ collisions at SPS top energy [4–6].

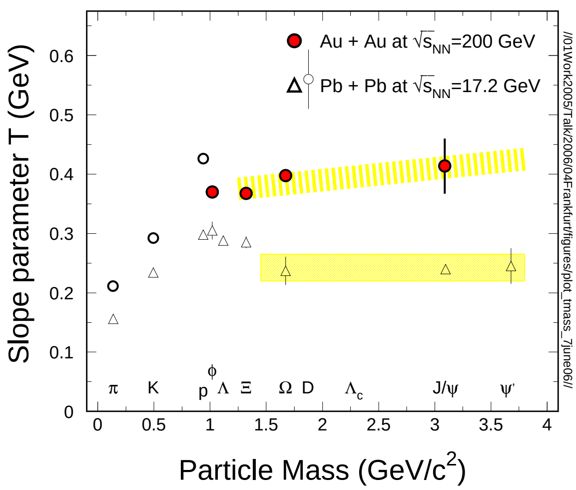

FIG. 1: Mid-rapidity hadron alope parameters, as a function of mass, from central Pb+Pb collisions at SPS at $\sqrt{s_{\rm NN}} =$ 17.2 GeV (triangles) and central $Au + Au$ collisions at $\sqrt{s_{\rm NN}}$ = 200 GeV (circles). Errors are statistical only.

As expected, the slope parameters increase as the hadron mass. However, the mass dependence appears to have two branches:

1. For copiously produced hadrons, π, K, p and d. Here the mass dependent is strong, indicating an explosive expansion occured in such heavy-ion collisions. A much stronger collective expansion is observed for collisions at RHIC when compared with that from SPS energy.

2. Multi-strange hadrons ϕ, Λ, Ξ, Ω and heavy flavor J/ψ. Here the slope parameter dependent on hadron mass is weaker compared with other lighter hadrons. At the SPS energy, on the other hand, there is no clear mass dependence, see the hatched band in Fig. 1. The finite values of the slope parameters at the SPS energy may reflect the string tension at hadronization [6].

As discussed in Ref. [5], mult-strange and heavy flavor hadrons do not participate in hadronic rescatterings and the collective motion can only be developed at the prehadronic stage, *i.e.* partonic stage for these hadrons. The clear mass dependence of the slope parameters in $Au + Au$ collisions at RHIC therefore provide a strong evidence for the partonic collectivity at RHIC.

From the hydrodynamics motivated fits [1], at the most central collisions, the freeze-out parameters are $(T_{fo}, \langle\beta_T\rangle) = (0.1 \pm 0.02$ (GeV), 0.6 ± 0.05 (c)) and $(0.165 \pm 0.05$ (GeV), ≥ 0.2(c)) for π, K and p and multi-strange hadron ϕ and Ω, respectively. Since there are still large uncertainties in the determination of pre-equilibrium contribution to the extracted velocity parameters, we only have the lower limit for the partonic velocity $\langle\beta_T\rangle_p \geq 0.2$c. However, these results are also consistent with the approach [4] where we assume both thermal motion and collective motion contribute to the measured slope parameter T:

$$T = T_{thermal} + A \cdot mass \cdot \langle\beta_T\rangle^2.$$

It is interesting to note that the freeze-out temperature parameter for multi-strange and heavy flavor hadrons are almost identical to the chemical freeze-out temperature [1, 6–8]. The temperature turns out to coincide with the phase transition temperature predicted by the Lattice QCD calculations. More importantly, the non-zero collective velocity for heavy flavor and J/ψ, shown in Fig. 1, is the first indication of light-flavor thermalization in central $Au + Au$ collisions at RHIC.

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