Flavour dependent freezeout scenarios within relativistic hydrodynamics framework.

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Introduction

Freezeout scenarios with separate freezeout hypersurfaces for strange and non-strange hadrons have been shown to successfully resolve the proton anomaly at the LHC and further improve the description of hadron yields across beam energy. These studies suggest that data favors an early freeze out of strangeness. Such studies have been so far restricted within the framework of the hadron resonance gas thermal models to describe midrapidity hadron yields [1]. We implement the flavour dependent freezeout scenarios within a relativistic viscous hydrodynamics framework by performing separate Cooper-Frye freeze out of the strange and non-strange hadrons. Our study suggests such flavour differential freezeout scenarios have unique signature on the phase space dependence of produced particles that may be experimentally verified.

Framework

In this work, we have used relativistic viscous hydrodynamics framework to simulate fluid dynamical evolution of the matter produced in heavy ion collisions(HIC). The hydrodynamic equations are

$$\partial_\mu T^{\mu\nu} = 0 \tag{1}$$

$T^{\mu\nu}$ is the energy momentum tensor and has the following form

$$T^{\mu\nu} = \epsilon u^\mu u^\nu - (P + \Pi)(g^{\mu\nu} - u^\mu u^\nu) + \pi^{\mu\nu} \tag{2}$$

ϵ, P and u^μ are the local energy density, pressure and fluid four velocity respectively. In this work we do not consider the effect of bulk viscous paper($\Pi = 0$). The evolution of any conserved charges are not taken into consideration. Along with Eq. [1], the shear stress tensor($\pi^{\mu\nu}$) is also evolved according to a relaxation type of equation proposed by Israel-Stewart. Additional second order terms shown in DNMR theory are also included. Hydrodynamic equations are solved together with a lattice QCD based Equation of State.

Cooper frye formula has been used to switch from a fluid description to particle emission on a constant temperature hypersurface. The invariant yield of a particular species i is given by,

$$E\frac{dN_i}{d^3p} = \frac{g_i}{2\pi^3}\int p^\mu d^3\sigma_\mu f_0\left(x^\mu, p, T_f\right) + \delta f\left(x^\mu, p\right) \tag{3}$$

The integration goes over all hypersurface elements. $d^3\sigma_\mu$ is the normal vector to the hypersurface. g_i is the degeneracy factor. f_0 is the thermal equilibrium distribution and δf represents the deviation from local thermal equilibrium due to viscous effect. T_f is the freezeout temperature. We have taken same freezeout temperatures for strange and non-strange hadrons in a common freezeout scenario(CFO) and different freezeout temperatures in a double freezeout scenario(DFO). In DFO the strange hadrons are taken to freezeout early.

We have used the open-source THERMINATOR [2] code package for particlization and further resonance decays. In our work the particle data base used in THERMINATOR has been updated by latest PDG. We have taken those decay channels which are allowed by strong interaction in Pb+Pb 2.76TeV simulation. For Au+Au 200GeV we have taken both strong and weak decay channels.

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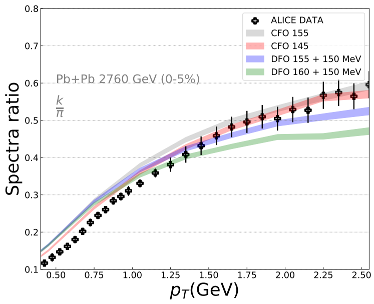

FIG. 1: kaon to pion spectra ratio for different CFO and DFO scenario in 0-5% Pb+Pb 2.76 TeV collisions. The experimental data is taken from [3].

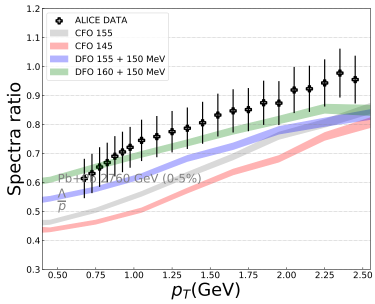

FIG. 2: Λ to p spectra ratio for different CFO and DFO scenario in 0-5% Pb+Pb 2.76 TeV collisions. The experimental data has been reconstructed from individual particle spectra [3, 4].

Results

We have calculated the spectra ratio of same and different flavour hadrons in Au+Au 200GeV and Pb+Pb 2.76 TeV collisions. The spectra ratio of kaon(k) to pion(π) and Λ to p in Pb+Pb 2.76TeV for $0-5\%$ centrality has been plotted in FIG. 1 and FIG. 2 respectively. k to π spectra ratio for 10-20% Au+Au 200GeV collisions has shown in 3. We observed that the spectra ratio is affected by DFO in different p_T regions. Experimental data suggests an early freezeout of strange hadrons than non-strange which can be seen in FIG. 2 and FIG. 3 . It is to be noted that the experimental data plotted in FIG. 2 was not directly available so we have constructed that from individual measured identified particle spectra.

Discussion

HRG model was suggesting an early freezeout of strange hadrons by analysing it's effect on the yield ratio. Here with the hydro framework we have shown that not only the yield but also the momentum space distribution of produced particles will be affected by separate freezeout of different flavour hadrons. One can also expect DFO will affect mean p_T ratio of strange and non-strange hadrons as the strange one is coming from a relatively higher temperature region.

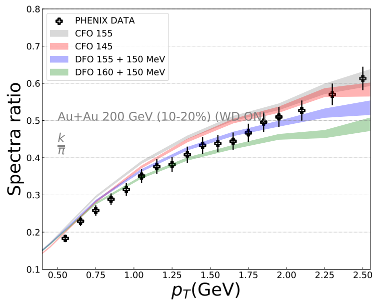

FIG. 3: kaon to pion spectra ratio for different CFO and DFO scenario in 10-20% Au+Au 200 GeV collisions. Experimental data is taken from [5].

References

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