Signature of early freeze-out of strangeness in relativistic heavy ion collisions

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Freeze-out scenarios with separate freeze-out 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 favours 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 mid rapidity hadron yields [1]. We implement the flavor dependent freeze-out scenarios within a relativistic viscous hydrodynamic framework by performing separate Cooper-Frye freeze-out of the strange and non strange hadrons. Our study suggests such flavor differential freeze-out scenarios have unique signature on the phase space dependence of produced particles. In particular spectra ratio of lambda to proton are most sensitive to such freeze-out systematics.

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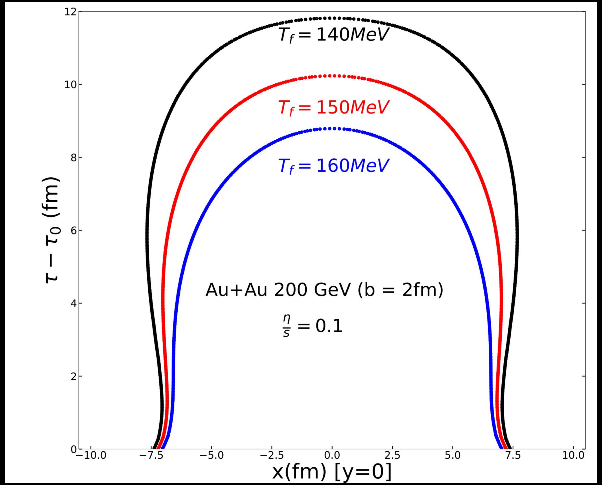
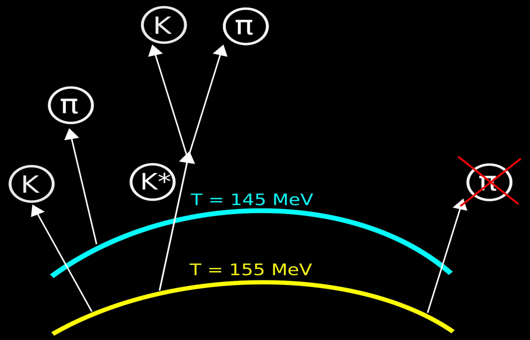
Motivation :

- Observables based on flavor specific fluctuations as well as correlation between different flavors obtained from lattice QCD simulation indicate a flavor separation in the transition region of QCD [2].
- In the hadronic stage of heavy ion collisions, there is a competition between system expansion and interaction among constituents. Flavor hierarchy in interaction cross-section leads to flavor hierarchy in freezeout [1].
- We have implemented 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 and studied the effect on momentum distribution of produced particles.

$$E\frac{dN_i}{d^3p} = \frac{g_i}{(2\pi)^3}\int_\Sigma \frac{1}{e^{\frac{p^\mu u_\mu - (\mu_B)_f B_i}{T_f}} \pm 1} p^\mu \Delta\sigma_\mu$$

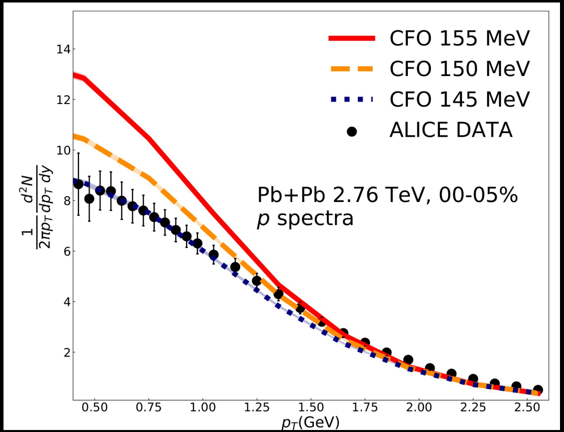


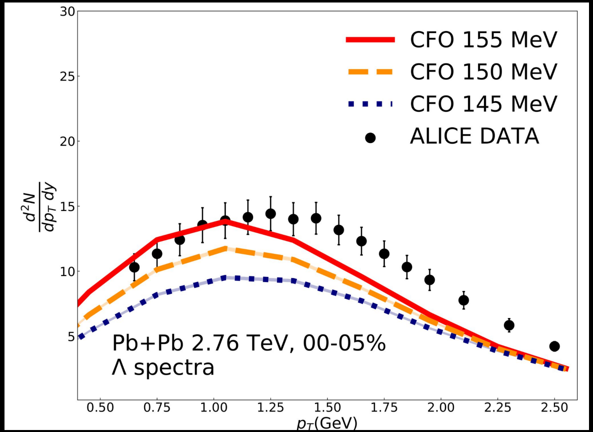


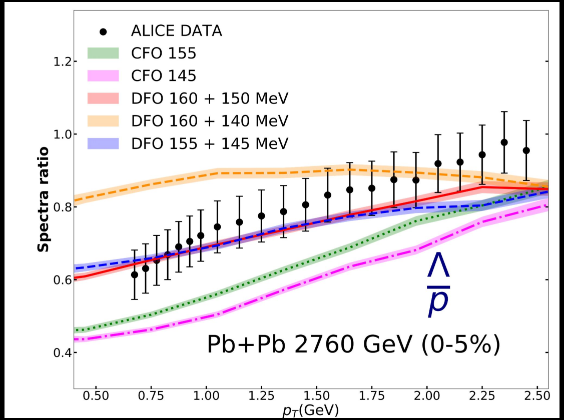
Framework and Results :

- The initial energy density profile for the hydrodynamic evolution is obtained from two component optical glauber model.
- We have performed boost invariant hydrodynamic evolution of the deposited matter.
- NEoSB [3] equation of state at zero baryon density has been used during hydro evolution.
- We have used THERMINATOR [4] for particle sampling from the isothermal freezeout hypersurface and then for decay of resonances. In this work, we have updated the particle data base of THERMINATOR with latest PDG.

CFO : Common Freeze-Out.
DFO : Different Freeze-Out temperatures for strange and Non-strange hadrons.







Conclusion and Outlook :

- Our study suggests that flavor differential freeze out scenarios have signature on the phase space dependence of produced particles.
- Common freezeout scheme has failed to explain the lambda and proton spectra simultaneously in Pb+Pb collisions at 2.76 GeV. However, if we allow strange hadrons to freeze early from a higher temperature hypersurface than the non-strange one then a better description of lambda to proton spectra ratio has been observed.
- Further investigations on freezeout systematics at RHIC energies could be done in a hydrodynamic model with non-zero net-baryon density evolution.

References :

[1] S. Chatterjee et. al., PLB 727 (2013).
[2] R. Bellwied et. al., Phys. Rev. Lett. 111, 202302 (2013).
[3] A. Monnai et. al., Phys. Rev. C100, 024907 (2019).
[4] M. Chojnacki et. al. arXiv:1102.0273.