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Decoupling of strange hadrons from an expanding medium

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We study the dynamics of chemical freeze-out of strange hadrons - K, Λ, Σ, from a homogeneous and isotropically expanding system consisting of π, ρ, K, N, Λ and Σ hadrons with zero net baryon density following a transport model[1]. Present calculation gives very clear indication of the temperature of decoupling of various species from the freeze out hyper surface within the ambit of this model.

It is vary important to understand whether all the hadron species produced in relativistic heavy ion collisions decouple at the same time/temperature from the expanding medium or they do gradually at different times/temperatures. It is very intuitive to consider that different particle species should decouple from the medium at different temperatures as they have different masses and interaction cross-sections. The known models which explain the experimental data from RHIC and LHC show that the decoupling of hadrons is consistent with almost a single freeze out scenario [2–6]. However some models also explain the same data with double freeze out scenario [7, 8]. Hence a detailed calculation in this regard is missing and we have made an attempt using transport approach.

The information of *kinetic and chemical freeze-outs* of all hadronic species are important for hydrodynamic calculations. But we know, most of these calculations[9–13] assume simultaneous and sudden freeze-out scenario (both for T_{ch} and T_k) and extract thermodynamic information of the produced system. When Cooper-Frye prescription is used to calculate the spectra of pion and kaon, similar assumption of "sudden kinetic freeze-out (T_k)" is also considered. In such cases the mean free paths of the various hadron species are assumed to become large through a thin freeze-out hyper surface suddenly. In hybrid-model calculations, chemical freeze-out temperatures for all species are also sometimes assumed to be same to stop hydrodynamic evolution of the fluid and to start transport calculation.

The dynamics related to chemical freeze-out is very complex in nature due to the lack of complete understanding of all interactions in a multi-component hadronic fluid. In this work, we focus to understand microscopically the chemical freeze-out of K, Λ, Σ in a hadronic system comprising π, K, $\bar{K}$, ρ, N, Λ, Σ in a different novel approach as mentioned in [1].

As mentioned above we follow an approach that is already discussed in [1] to study the freeze out of various species in case of early universe. Basically here the scattering rates(Γ) of the species of interest are calculated and compared with the expansion rate(H) of the system. The study is performed by considering both slower Bjorken expansion and faster Hubble-like expansion. Finally, the freeze out of K, Λ and Σ are discussed by comparing these rates in both cases. The details of the formalism may be referred from [14].

In Fig.1 the decoupling of the species are shown with temperature in the unit of T_c when the system follows Bjorken expnasion. Here $Y = n_i/s$ is the particle per total en-

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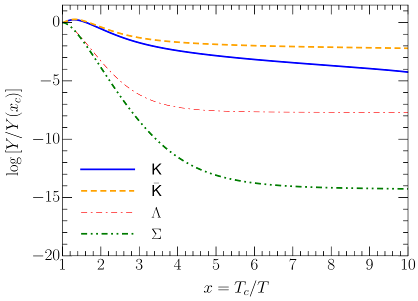

FIG. 1: Numerical solution of quations BJ case

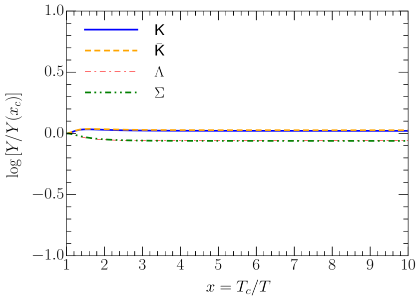

FIG. 2: Numerical solution of quations HB case

tropy. $Y(x_c)$ is the value at temperature $T_c = 155MeV$, when hadronic system starts evolving. The figure shows shows clearly when or at what temperature different particles decouple(depending their Γ/H ratio) indicating sequential behaviour. In Fig.2, same thing is also shown for Hubble expnasion. Incase of Hubble expansion with similar initial conditions, particle species try to decouple at a single temperature and seems like a simultaneous freeze out. We would discuss present these interesting results in the Symposium. We would also discuss the freeze-out scenario at top RHIC and LHC energies.

In summary, the *chemical freeze-out* of strange hadrons has been analysed microscopically with both slow (Bjorken) and fast expansion (Hubble-like) scenarios for a multi-component hadronic fluid using transport approach. We observe a simultaneous freeze out behaviour of species when system follows fast expansion and sequential behaviour when it follows slow expansion. Since statistical-hadronization models mostly predict a simultaneous freeze-out of different species at top RHIC and LHC energies, then it may indicate a fast expnasion of the hadronic matter in the last stage of the fireball. The deviation from a single *chemical freeze-out* temperature may be attributed to the slower expansion of the system.

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