Identified hadrons transverse momentum distribution within multiple freeze-out scenario at LHC

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Introduction

Thermal models of hadron production serve as the basic tool to study the properties of the matter produced in heavy-ion collisions and characterisation of the freezeout hypersurface (FH). These models suggest the formation of the equilibrated system of quarks and gluons at earlier stages of the collisions. Approaches based on complete chemical and thermal equilibration assumption failed to explain the newest LHC data on hadron production and is reported as proton anomaly. Even the hydrodynamic calculations, that have been successfully used to reproduce the flow coefficients, failed to give correct predictions for pion spectra at LHC. This discepency created a lot of interest and various alternatives to describe the yields and spectra have been suggested including the effects of nonequilibrium physics, late stage baryon-antibaryon annihilations etc. The current work is based on equilibrium thermodynamics where hadrons with non zero strangeness content freeze-out earlier compared to those with vanishing strangeness (2FO) [1–3].

Cracow freeze out model

The Cracow model (CM) [4] implemented in THERMINATOR Monte-Carlo code [5] is used for this study. The program implements thermal models of particle production with single freeze-out (1FO). THERMINATOR includes all well established resonances from the PDG. The primordial distribution in the local rest frame has the form given by the famous Cooper-Frye formula that gives the rapidity and transverse momentum distribution of the produced hadrons at the surface of last scattering. In CM, boost invariance is assumed and the freeze-out takes place at a fixed invariant time τ^f. The natural parametrization of the FH is thus,

$$(\tau^f)^2 = t^2 - x^2 - y^2 - z^2 \ , \qquad (1)$$

where τ^f is fixed by data. A natural choice of coordinates to describe the FH are rapidity y_r, azimuthal angle ϕ and the distance ρ of the freeze-out surface from the beam line given by $\rho = \sqrt{x^2 + y^2}$.

We have extended the 1FO approach to 2FO where, hadrons with non zero strangeness content freeze-out earlier compared to the rest. This results in two FHs and Eq. 1 modifes accordingly. At last, we have six parameters in 2FO, T_s and T_{ns} are extracted from fits to the yield while ρ_s^{max}, ρ_{ns}^{max}, τ_s^f and τ_{ns}^f are extracted from fits to spectra. The subscripts 's' and 'ns' stand for the strange and non-strange FHs respectively.

Results and discussion

Figs. 1 and 2 show the transverse momentum (p_T) spectra in different centrality classes (top panel) and ratio of data [6] to model (bottom panel) for π^+ in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV in 1FO and 2FO approach respectively. From the ratios we can see that the 2FO gives a better description of p_T spectra in comparison to 1FO. To show the goodness of the fit we have plotted the χ^2/ndf as a function of centrality in Fig. 3. Here bin 1 corresponds to most central collisions (0-5)% and bin 6 corresponds to peripheral bin (60-80)%.

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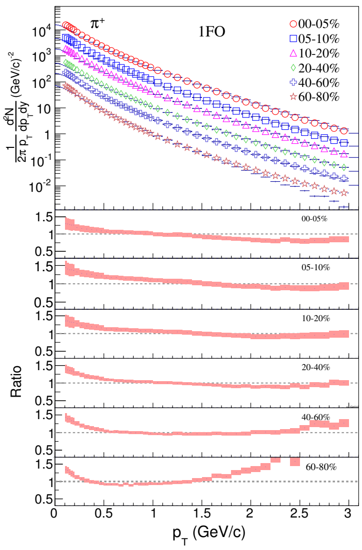

FIG. 1: p_T spectra of π^+ as obtained in 1FO. The top panel shows the comparison between data [6] and model and the lower panels shows the ratio = Data/Model for the different centrality classes.

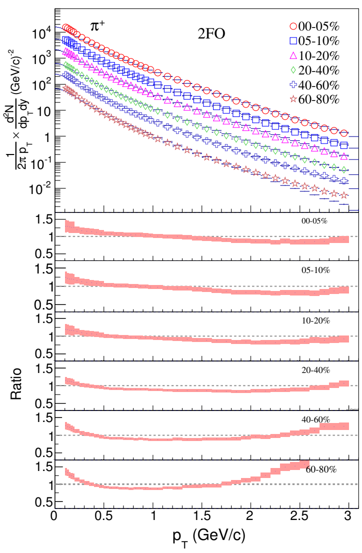

FIG. 2: p_T spectra of π^+ as obtained in 2FO. The top panel shows the comparison between data [6] and model and the lower panels shows the ratio = Data/Model for the different centrality classes.

The χ^2/ndf in case of 2FO is always lower. We have also constrained our parameters by applying conditions $(\rho_s/\tau_s) = (\rho_{ns}/\tau_{ns})$ and left with only five parameters. We further constrained our parameters with the condition $\tau_{ns}/\tau_s = 1.3$ and left with four parameters. In all the the cases 2FO has χ^2/ndf lower than 1FO. Hence by introducing an extra parameter in 2FO scheme, we are able to reduce χ^2/ndf by 40% across centrality classes ranging from (0-5)% to (20-40)%.

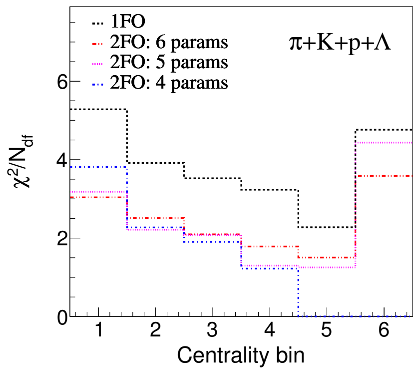

FIG. 3: χ^2/Ndf vs. centrality in 1FO and 2FO. The centrality bin numbers 1, 2, 3, 4, 5 and 6 refer to the (0-5)%, (5-10)%, (10-20)%, (20-40)%, (40-60)% and (60-80)% centrality classes respectively.

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