1. INTRODUCTION

The ultrarelativistic $p-p$ collisions serve as an important tool to understand the high-energy collision scenarios and the particle production mechanism. These are also often used as a simple hadronic reference system to disentangle nuclear effects in $p-A$ and $A-A$ collision systems. Experiments at Relativistic Heavy-Ion Collider (RHIC) continue to study the detailed properties of the strongly interacting matter formed in $p-p$ and $Au-Au$ systems at colliding energies with ranging from 7.7 GeV to 200 GeV. The formation of a quark gluon plasma (QGP) has already been pointed out by the measurements in $Au-Au$ collisions performed at RHIC [1–3]. The high-$p_T$ hadrons are found to be important for QGP studies because they measure the jet quenching [4] effect in the QGP, while the low-$p_T$ hadrons arise from multiple scatterings and follow an exponential distribution, suggesting particle production in a thermal system [5]. In addition, the hadron spectra at intermediate $p_T$ are sensitive to effects arising from quark recombination [6] in heavy-ion collisions. It is believed that the produced hadrons carry information about the collision dynamics and the subsequent space time evolution of the system. Hence, a precise measurement of the transverse momentum distributions of identified hadrons along with the rapidity spectra is essential for understanding the dynamics and properties of the created matter up to the final hydrodynamic freeze-out [7]. The particle momentum distributions reflect the conditions at the thermal freeze-out and the integrated effects of expansion from the beginning of the collision. Thus, transverse momentum distributions encode information about the collective transverse expansion and the thermal freeze-out temperature.

The applicability of the statistical model in small systems (e.g., $p-p$) has been the subject of several recent publications [8, 9]. In this paper, we use our earlier proposed unified statistical thermal freeze-out model [7], which assumes that the fireball produced in the collision reaches thermochemical equilibration at the final freeze-out. The model is found to be effectively suitable for the $p_T$ range that is dominated by the soft particle production. Also the particle production due to hard scatterings contributes less than a few percent at $\sqrt{s_{NN}} \leq 200$ GeV [10]. This motivates us to apply our model to $p-p$ collisions at $\sqrt{s_{NN}} = 200$ GeV to describe the particle production originating from the soft interactions in a thermalized system. The application of hydrodynamic models for $p-p$ collisions dates back to 1954, when multiple meson production was first observed at the Brookhaven Cosmotron in $n-p$ collisions [11]. This observation of multi-particle production occurring in $p-p$ collisions led Fermi and Landau to develop the statistical [12] and hydrodynamical [13] approaches to multi-particle production. Belenkij and Landau observed that...
although the statistical model of Fermi is sufficient to describe the particle numbers in terms of only the temperature and the chemical potential, this model has to be extended to hydrodynamics when particle spectra are considered. They also noted that the domain of the applicability of ideal relativistic hydrodynamics coincides with the domain of the applicability of thermodynamical models in high-energy \( p-p \) collisions \([13]\). Hydrodynamic models \([14, 15]\) that include radial flow successfully describe the measured \( p_T \) distributions in \( \text{Au–Au} \) collisions at \( \sqrt{s_{NN}} = 130 \text{ GeV} \) \([16]\)

The \( p_T \) spectra of identified charged hadrons below \( 2 \text{ GeV} \) in central collisions have been well reproduced in some models by two simple parameters: the transverse flow velocity \( \beta_T \) and the thermal freeze-out temperature \( T \) under the assumption of thermalization. Some statistical thermal models have successfully described the particle abundances at low \( p_T \) \([17]\). It has been shown earlier \([18]\) that our model can simultaneously explain the rapidity and transverse momentum distributions of hadrons, emitted from within an expanding fireball in the state of local thermal equilibrium, are characterized by the Lorentz-invariant coordinate transformation.

The transverse fireball radius \( R_{\tau} \) is parameterized as \([7]\]

\[
\beta_T(r) = \beta_T^0 \left( \frac{r}{R} \right)^{n},
\]

where \( r \leq R \) (the term \( r/R \) accounts for the change in the velocity as a function of the radial distance). Also, \( n \) is a velocity profile index and \( \beta_T^0 \) is the hadronic fluid surface transverse expansion velocity and is fixed in the model by using the parameterization \([7]\]

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\beta_T^0 = \beta_T^0 \left( \frac{r_0}{R} \right)^{n},
\]

The transverse fireball radius \( R \) is parameterized as \([7, 25]\]

\[
R = r_0 \exp \left( \frac{-z_0^2}{\sigma^2} \right),
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where the parameter \( r_0 \) fixes the transverse size of the hadronic matter and \( \sigma \) fixes the width of the matter.

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