Identified Particle Production and Freeze-out Dynamics in STAR at RHIC Beam Energy Scan Program

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Introduction

Quantum Chromodynamics (QCD) predicts a transition from hadronic matter to Quark-Gluon Plasma (QGP) phase at sufficiently high temperature and/or high energy density. The QCD phase diagram is usually plotted as the temperature ($T$) vs. baryon chemical potential ($\mu_B$). It contains information about different phases such as QGP and hadron gas, and the transition between them [1]. QCD critical point is the point at which the first-order phase transition ends in the QCD phase diagram. The first phase of Beam Energy Scan (BES-I) program of RHIC has completed the data taking at several collision energies with the specific aim to explore the QCD phase diagram and to search for the critical point. The measured particle yields and transverse momentum ($p_T$) spectra have been used to study the chemical and kinetic freeze-out properties of the system at RHIC BES-I energies.

Here, we present the particle production of pions ($\pi^\pm$), kaons ($K^\pm$), protons ($p$) and antiprotons ($\bar{p}$) in Au+Au collisions at $\sqrt{s_{NN}} = 27$ GeV. The chemical and kinetic freeze-out dynamics at BES-I energies, $\sqrt{s_{NN}} = 7.7$, 11.5, 19.6, 27 and 39 GeV, have been discussed.

Analysis Details

The Solenoidal Tracker at RHIC (STAR) detector [2] with a large uniform acceptance has been used for this analysis. In order to identify the charged particles, the Time Projection Chamber (TPC) was used at low $p_T$ and the Time-Of-Flight (TOF) detector was used at high $p_T$. The $\pi^\pm$, $K^\pm$, and p ($\bar{p}$) yields have been measured in the mid-rapidity region $|y| < 0.1$. The pion yields were feed-down corrected whereas the proton yields were inclusive.

Results

Figure 1 shows the $p_T$ spectra of $\pi^+$ measured in Au+Au collisions in mid-rapidity ($|y| < 0.1$) at $\sqrt{s_{NN}} = 27$ GeV for nine centralities. Spectra are scaled for plot clarity. Curves represent Bose-Einstein functions. The statistical and systematic errors are added in quadrature.

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constant value of \( \langle m_T \rangle - m \) can be interpreted as a signature of first order phase transition [4].

We have used THERMUS [5] model to extract the chemical freeze-out parameters such as \( T_{\text{ch}} \) and \( \mu_B \). The particle yields of \( \pi^+ \), \( K^+ \), \( p \), \( \Lambda \), and \( \Xi^- \) and their corresponding antiparticles along with the corresponding particle ratios are used as inputs. The energy and centrality dependence of the extracted freeze-out parameters for Au+Au collisions in 7 centralities 0–5%, 5–10%, 10–20%, 20–30%, 30–40%, 40–60% and 60–80% at BES-I energies have been studied. Figure 3 shows the \( T_{\text{ch}} - \mu_B \) variation obtained from the particle ratios in grand-canonical ensemble (GCE). The centrality dependence of freeze-out parameters \( T_{\text{ch}} \) vs. \( \mu_B \) for BES-I energies is observed, which is not observed in top RHIC energies [6].

The kinetic freeze-out parameters such as temperature \( T_{\text{kin}} \) and the average transverse flow velocity \( \langle \beta \rangle \) have been extracted from the simultaneous fitting of \( \pi^\pm \), \( K^\pm \), \( p \), and \( \bar{p} \) spectra with the Blast-wave model [7]. Figure 4 shows the \( T_{\text{kin}} \) vs. \( \langle \beta \rangle \) for different energies and centralities. The \( \langle \beta \rangle \) decreases from central to peripheral collisions which suggest more rapid expansion in central collisions, whereas \( T_{\text{kin}} \) increases from central to peripheral collisions. The \( T_{\text{kin}} \) and \( \langle \beta \rangle \) show an anti-correlation behaviour i.e. with an increase in \( T_{\text{kin}} \), \( \langle \beta \rangle \) decreases and vice-versa.

In addition, the thesis also reports (a) reanalysis within a common framework of all data available in heavy-ion collisions for chemical freeze-out dynamics and (b) performance of Gas Electron Multiplier (GEM) based detector to monitor the TPC tracking.

References


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