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

Sabita Das[1] (for the STAR Collaboration)*
[1]*Institute of Physics, Bhubaneswar - 751005, INDIA*

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 (μ_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.

*Electronic address: sabitads@iopb.res.in

Results

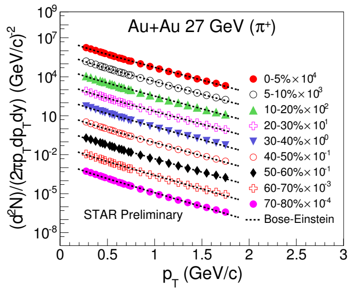

FIG. 1: The p_T spectra of π^+ measured in Au+Au collisions in mid-rapidity ($|y| < 0.1$) at $\sqrt{s_{NN}}$ = 27 GeV for nine centralities. Spectra are scaled for plot clarity. Curves represent Bose-Einstein functions. The statistical and systematic errors are added in quadrature.

Figure 1 shows the p_T spectra of π^+ in Au+Au collisions at $\sqrt{s_{NN}} = 27$ GeV for nine centralities. The spectra are fitted with Bose-Einstein functions to extract the yields from the unmeasured regions. The steepening of the pion spectra at low p_T is mainly due to the significant contributions of resonance decays. Figure 2 shows the energy dependence of $\langle m_T \rangle - m$, where m is the rest mass of hadron and $m_T = \sqrt{m^2 + p_T^2}$ is the transverse mass, for $\pi^{\pm}$, $K^{\pm}$, and p ($\bar{p}$) in central (0–5%) Au+Au collisions at $\sqrt{s_{NN}} = 27$ GeV along with other BES-I energies and at AGS, SPS, top RHIC and LHC energies [3]. We found that at lower energies, the $\langle m_T \rangle - m$ increases with energy, remains almost constant at SPS and lower BES-I energies, and then it increases again towards LHC energy. This type of behaviour of $\langle m_T \rangle - m$ might indicate the onset of the phase transition. The

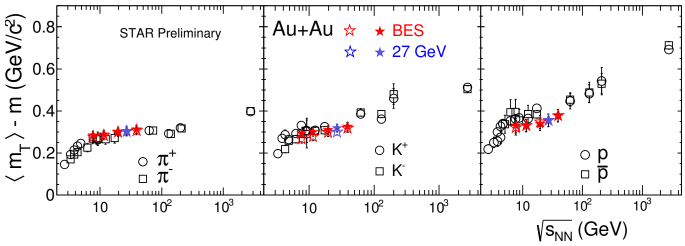

FIG. 2: The variation of $\langle m_T \rangle - m$ of $\pi^{\pm}, \mathrm{K}^{\pm}$, and p ($\bar{\mathrm{p}}$) as a function of $\sqrt{s_{\mathrm{NN}}}$ measured in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 27$ GeV along with other BES-I energies and published results at AGS, SPS, top RHIC, and LHC energies [3]. The statistical and systematic errors are added in quadrature.

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_{ch} and μ_B. The particle yields of π^+,

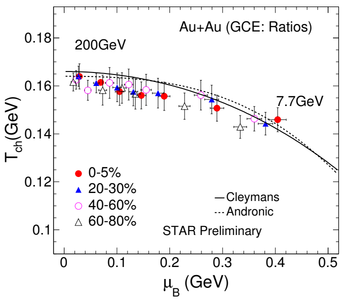

FIG. 3: The T_{ch} vs. μ_B obtained from a statistical model fit [5] using particle ratios in different centrality bins in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 7.7, 11.5, 19.6, 27, 39, 62.4 and 200 GeV in GCE.

K^+, p, Λ, and Ξ^- 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 $T_{\mathrm{ch}} - \mu_B$ variation obtained from the particle ratios in grand-canonical ensemble (GCE). The centrality dependence of freeze-out parameters T_{ch} vs. μ_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_{kin}) and the average transverse flow velocity ($\langle \beta \rangle$) have been extracted from the simultaneous fitting of $\pi^{\pm}$, $\mathrm{K}^{\pm}$, p, and $\bar{\mathrm{p}}$ spectra with the Blast-wave model [7]. Figure 4 shows the T_{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_{kin} increases from central to peripheral collisions. The T_{kin} and $\langle \beta \rangle$ show

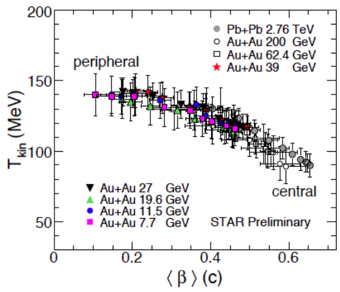

FIG. 4: The T_{kin} vs. $\langle \beta \rangle$ for different energies and centralities.

an anti-correlation behaviour i.e. with an increase in T_{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

[1] E. S. Bowman and J. I. Kapusta, Phys. Rev. C 79, 015202 (2009).

[2] K. H. Ackermann *et al.*, Nucl. Instr. Meth. A 499, 624 (2003).

[3] L. Kumar (for the STAR collaboration), Nucl. Phys. A 931, 1114c (2014).

[4] L. Van Hove, Phys. Lett. B 118, 138 (1982).

[5] S. Wheaton *et al.*, Comput. Phys. Commun. 180, 84 (2009).

[6] S. Das (for the STAR collaboration), Nucl. Phys. A 904, 891c (2013);

[7] E. Schnedermann *et al.*, Phys. Rev. C 48, 2462 (1993).