Production of identified hadrons in Au+Au collisions at $\sqrt{s_{NN}} = 54.4$ GeV at RHIC

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Introduction

Quantum chromodynamics (QCD) predicts that at sufficiently high temperature (T) and/or the baryon chemical potential (μ_B), a deconfined state of quarks and gluons, known as the quark–gluon plasma (QGP), is formed [1]. Understanding the QCD phase diagram is one of the primary goals of high-energy heavy-ion collision experiments. The study of spectra of identified hadrons provides crucial information about the equilibrium dynamics as well as the bulk properties of the system produced in heavy-ion collisions.

Analysis details

We study the transverse momentum spectra of $\pi^{\pm}$, $K^{\pm}$, and $p(\bar{p})$ at mid-rapidity ($|y| < 0.1$) for different centrality classes in Au+Au collisions at $\sqrt{s_{NN}} = 54.4$ GeV. This data was recorded by the STAR experiment in the year 2017 under the Beam Energy Scan (BES) program [2]. The identification of charged particles in STAR is performed using the Time Projection Chamber (TPC) and Time of Flight (TOF). For low transverse momentum (p_T) particles, TPC is used whereas for particles with intermediate or high momenta ($p_T >$ 1 GeV/c), the TOF detector is used. TPC uses the ionization energy loss (dE/dx) of the charged particles passing through TPC for particle identification. Using dE/dx information, the z variable is defined as:

$$z_X = ln\left(\frac{\langle dE/dx\rangle}{\langle dE/dx\rangle_X^B}\right),$$

where $\langle dE/dx\rangle_X^B$ is the expected energy loss based on the Bichsel function [3] and X is the particle type ($e^{\pm}$, $\pi^{\pm}$, $K^{\pm}$, p, or $\bar{p}$). Applying a multi-Gaussian fit, raw yields are extracted from z_X distributions.

For the TOF detector, we use mass square information, $m^2 = p^2(\frac{c^2T^2}{L^2} - 1)$, where m, p, L, T and c are the mass of particle, momentum of the particle, path length, time of travel by the particle and speed of light, respectively. From the above two methods, we obtain raw spectra. The TPC tracking efficiency and acceptance, energy loss correction, pion and proton background subtraction are applied to calculate corrected spectra. For the spectra obtained from TOF, the TOF matching efficiency is also applied.

Results and discussions

We calculate the p_T spectra of $\pi^{\pm}$, $K^{\pm}$, and $p(\bar{p})$ in Au+Au collisions at $\sqrt{s_{NN}}$ = 54.4 GeV. Figure 1 shows the p_T spectra of π^+, K^+, and p in different centrality classes (0-5% to 70-80%). The p_T spectra of identified hadrons show a clear centrality dependence. We fit the $\pi^{\pm}$ and $K^{\pm}$ spectra with the Levy function and $p(\bar{p})$ spectra with a double-exponential function, to calculate p_T-integrated particle yields (dN/dy).

Figure 2 shows the collision energy dependence of the particle ratios π^-/π^+, K^-/K^+, and $\bar{p}/p$ in most central collisions. The π^-/π^+ ratios have values larger than unity at low beam energies, which is mostly due to significant contributions from resonance decays like Δ baryons. The K^-/K^+ ratios at BES energies are much less than unity, which is likely due to the associated production of K^+. With increasing $\sqrt{s_{NN}}$, the K^-/K^+ ratio approaches unity, indicating the dominance of kaon pair production. The lower values of $\bar{p}/p$

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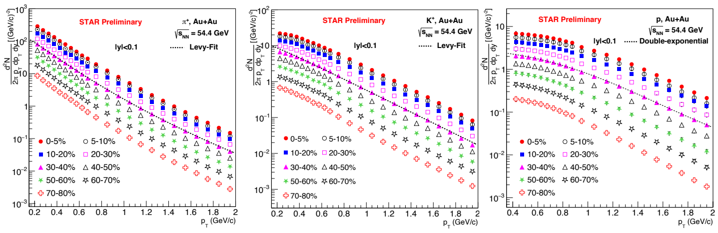

FIG. 1: p_T spectra of π^+, K^+, and p measured at mid-rapidity ($|y| < 0.1$) in Au+Au collisions at $\sqrt{s_{NN}} = 54.4$ GeV in different collision centralities.

ratio at BES energies indicate large baryon stopping in these collisions. The $\bar{p}/p$ ratio increases with increasing collision energy and approaches unity for top RHIC energy. The latest results from 54.4 GeV follow the trend shown from previous measurements of AGS, SPS, RHIC, and LHC [4].

A simultaneous fit to the p_T spectra of π, K, p and their anti-particles have been applied in 0-5% central Au+Au collisions at $\sqrt{s_{NN}} = 54.4$ GeV using the blast-wave model [5]. Figure 3 shows the variation of kinetic freeze-out temperature (T_{kin}) with average transverse radial flow velocity ($\langle\beta\rangle$) for the different center-of-mass energies and centralities. $\langle\beta\rangle$ decreases as we go from most central to peripheral collisions, whereas T_{kin} increases from central to peripheral collisions due to the short-lived fireball formed in peripheral collisions.

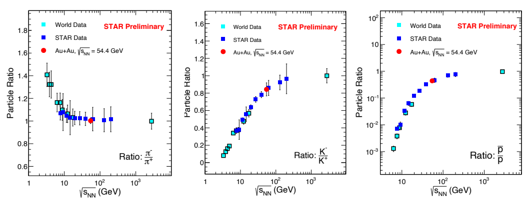

FIG. 2: π^-/π^+, K^-/K^+, and $\bar{p}/p$ ratios at mid-rapidity ($|y| < 0.1$) in 0–5% Au+Au collisions at $\sqrt{s_{NN}} = 7.7$-200 GeV.

Summary

We present the transverse momentum spectra for $\pi^{\pm}$, $K^{\pm}$, and $p(\bar{p})$ in Au+Au collisions at $\sqrt{s_{NN}} = 54.4$ GeV. The particle ratios from Au+Au collisions at $\sqrt{s_{NN}} = 54.4$ GeV follow the trend shown from previous measurements of AGS, SPS, RHIC, and LHC.

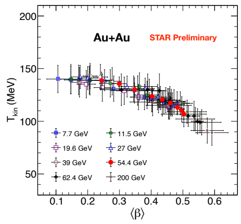

FIG. 3: Variation of T_{kin} with $\langle\beta\rangle$ for different energies and collision centralities.

The kinetic freeze-out temperature and transverse radial flow velocity show an anti-correlation.

Acknowledgments

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