Probing QCD matter via $K^{*0}(892)$ and $\phi(1020)$ resonance production at RHIC

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Abstract. We present the measurements of invariant yields of K^{*0} and ϕ resonances at midrapidity in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7 - 200 GeV using the STAR detector. The transverse momentum (p_T) spectra and p_T-integrated yields of K^{*0} and ϕ have been studied. The ratios between resonance (K^{*0} and ϕ) to non-resonance particles (K) are presented as a function of centrality. It is found that K^{*0}/K^- ratios are suppressed in the most central collisions as compared to peripheral ones for all studied collision energies. On the other hand, ϕ/K^- ratios are weakly depend on centrality. These results can be understood by considering the effect of more hadronic rescattering for K^{*0} (lifetime $\sim$ 4 fm/c) as compared to ϕ (lifetime $\sim$ 42 fm/c). We have also presented the measurement of the first-order azimuthal anisotropy (known as directed flow, v_1) of ϕ meson as a function of rapidity (y) at midrapidity in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7 - 200 GeV. The slope of ϕ-meson v_1 (dv_1/dy) has been compared to the dv_1/dy of other identified particles. We have found that all particles that consist of produced quarks show similar behaviour for $\sqrt{s_{NN}} > 14.5$ GeV.

Keywords: Hadronic rescattering, resonances, directed flow, heavy-ion collisions

1 Introduction

The aim of the STAR experiment at Relativistic Heavy Ion Collider (RHIC) is to study the QCD matter by colliding nuclei at ultra-relativistic speeds [1]. The study of K^{*0} (lifetime $\sim$ 4 fm/c) and ϕ (lifetime $\sim$ 42 fm/c) production in heavy-ion collisions can be used to probe the medium created after the collision [2]. The K^{*0} resonance has a short lifetime, therefore it may decay during the hadronic phase and its decay products may undergo elastic or pseudoelastic scatterings [3]. Due to elastic or pseudoelastic scatterings, the final yield of K^{*0} resonance may get changed. The K^{*0} resonance yields may get reduced due to rescattering of its daughters through elastic scattering or the yields may be regenerated through pseudoelastic scattering between chemical and kinetic freeze-out [2]. However, due to longer lifetime as compared to the fireball, ϕ mesons mostly decay outside of the fireball and its daughters are not affected by late-stage hadronic scatterings. Hence, the study of K^{*0} and ϕ resonances provides an important information about the late-stage hadronic scatterings. In high-energy heavy-ion collisions, particles are produced with an azimuthally anisotropic momentum distribution. Directed flow (v_1) is a measure of azimuthal angular anisotropy of the produced particles with respect to the first-order event plane [4]. The v_1 is an initial state effect and expected to be sensitive to the equation of state of the system formed in the collision. The ϕ meson freezes out early and is expected to have small hadronic interaction cross section. The measured v_1 of ϕ meson can be used as a clean probe to study the QCD matter [5].

2 Data sets and methods

The results presented here are based on data collected at $\sqrt{s_{NN}}$ = 7.7, 11.5, 14.5, 19.6, 27, 39, 62.4 and 200 GeV in Au+Au collisions by the STAR detector using a minimum-bias trigger. The Time Projection Chamber (TPC) [6] and Time of Flight (TOF) [7] detectors with full 2π coverage are used for particle identification in the central pseudorapidity (η) region ($|\eta|< 1.0$). The K^{*0} and ϕ resonances are reconstructed from the following hadronic decay channels: $K^{*0} \longrightarrow K^{\pm} + \pi^{\mp}$ and $\phi \longrightarrow K^{+} + K^{-}$. Event mixing technique has been used for combinatorial background estimation [8]. Figure 1 shows invariant mass distribution of $K^{\pm}\pi^{\mp}$ and $K^{+}K^{-}$ pairs after mixed event background subtraction.

The first harmonic coefficient of the Fourier decomposition of azimuthal distribution with respect to the first-order event plane angle (ψ_1) can be expressed as $v_1 = \langle\cos(\varphi - \psi_1)\rangle$, where φ is the azimuthal angle of the produced particle. The first-order event plane angles are calculated using a forward rapidity detectors (Beam-Beam Counters or Zero-Degree Calorimeters) [9]. The measured v_1 with respect to the first-order event plane has been corrected for the finite event plane resolution. The more details about v_1 measurement in STAR can be found in Ref. [10].

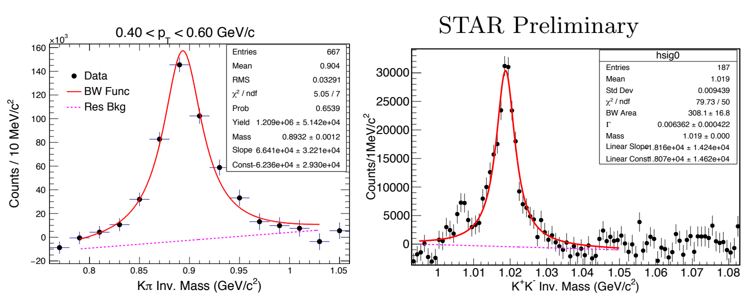

Fig. 1. Invariant mass distribution of $K^{\pm}\pi^{\mp}$ and $K^{+}K^{-}$ pairs after mixed event background subtraction for miminum bias (0-80%) Au+Au collisions at $\sqrt{s_{NN}}$ =11.5 GeV for 0.4 < p_T <0.6 GeV/c.

3 Results

Figure 2 shows K^{*0}/K^- and ϕ/K^- ratios as a function of $(dN_{ch}/d\eta)^{1/3}$ (the cubic root of the charged-particle multiplicity density measured at midrapidity) in Au+Au collisions at various center-of-mass energies measured by STAR experiment [8, 11–14]. The results are compared to the measurements performed at $\sqrt{s_{NN}}$ =2.76 TeV in Pb+Pb collision by the ALICE collaboration. The K^{*0}/K^- ratios decrease with increasing $(dN_{ch}/d\eta)^{1/3}$ (proxy for system size) for all studied collisions energies. On the other-hand, ϕ/K^- ratios are almost independent of $(dN_{ch}/d\eta)^{1/3}$. The observed suppression of the K^{*0}/K^- ratios could be due to rescattering effect as discussed earlier.

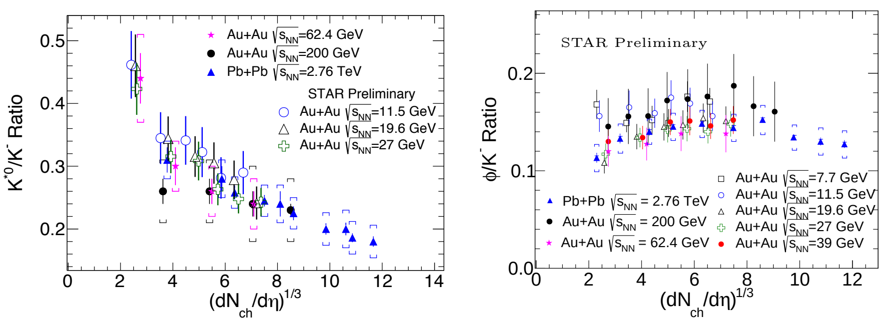

Fig. 2. Ratios K^{*0}/K^- and ϕ/K^- as a function of $(dN_{ch}/d\eta)^{1/3}$ in Au+Au and Pb+Pb collisions at various $\sqrt{s_{NN}}$ [8, 11–14].

Directed flow slope, dv_1/dy, versus beam energy for ϕ, $\bar{\Lambda}$, p and $\bar{p}$ is presented in Fig. 3 for 10-40% central Au+Au collisions [10]. The slope for $\bar{\Lambda}$ is negative for all energies and is consistent within errors with that for $\bar{p}$. The $\bar{p}$, ϕ and $\bar{\Lambda}$ are seen to have similar $v_1(y)$ for $\sqrt{s_{NN}} > 14.5$ GeV. All these species consist from quarks that are produced in the collision. For $\sqrt{s_{NN}} < 14.5$ GeV, the current statistical uncertainty is too large to make any conclusion.

4 Summary

We report the measurement of K^{*0} and ϕ resonance production at midrapidity in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7-200 GeV recorded by the STAR detector. The K^{*0}/K^- and ϕ/K^- ratios as a function of $(dN_{ch}/d\eta)^{1/3}$ is presented for different center-of-mass energies. The K^{*0}/K^- ratios are found to decrease with increasing $(dN_{ch}/d\eta)^{1/3}$. Whereas, ϕ/K^- ratios are nearly independent of $(dN_{ch}/d\eta)^{1/3}$. The observed suppression of K^{*0}/K^- ratios in central collisions could be due to the effect of hadronic rescattering which reduce the measured yield of short-lived resonances. The directed flow of ϕ meson is presented for

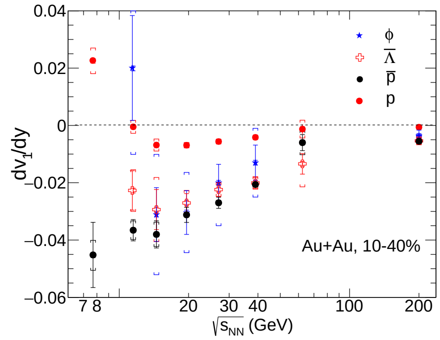

Fig. 3. Directed flow slope (dv_1/dy) versus beam energy for 10-40% centrality in Au+Au collisions for ϕ, $\bar{\Lambda}$, p and $\bar{p}$ [10].

different collision energies. Directed flow slope (dv_1/dy) of ϕ meson is found to be consistent within errors with that of $\bar{\Lambda}$ and $\bar{p}$ for $\sqrt{s_{NN}} > 14.5$ GeV.

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