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 yield of K^{*0} and ϕ resonances at mid-rapidity 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 yield of K^{*0} and ϕ has been studied. The ratios between resonance (K^{*0} and ϕ) to non-resonance particles (K) is presented as a function of centrality. It is found that K^{*0}/K^{-} ratios are suppressed in more central collisions compared to peripheral in all centre-of-mass energies studied. On the other hand, ϕ/K^{-} ratios are found to be almost independent of centrality. These results can be understood by considering the effect of more hadronic re-scattering for K^{*0} (lifetime $\sim$ 4 fm/c) compared to ϕ (lifetime $\sim$ 42 fm/c). We have also presented the measurement of first-order azimuthal anisotropy (known as directed flow, v_1) of ϕ meson as a function of rapidity (y) at mid-rapidity 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 other identified particle. 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 pseudo-elastic scatterings. Due to elastic or pseudo-elastic scatterings, the final yield of K^{*0} resonance may get changed. The K^{*0} resonance yields may get reduced due to re-scattering of its daughters through elastic scattering or the yields may be regenerated through pseudo-elastic scattering between chemical and kinetic freeze-out [2]. However, due to longer lifetime, ϕ mesons mostly decay outside the fireball and hence its daughters are not affected by late-stage hadronic scatterings. Hence, the study

of K^{*0} and ϕ resonances is useful to study 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 [3]. 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. Since ϕ meson freeze-out early and is expected to have small hadronic interaction cross-section, the measured v_1 of ϕ meson can be as a clean probe to study the QCD matter [4].

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) [5] and Time of Flight (TOF) [6] detectors with full 2π coverage are used for particle identification in the central pseudo-rapidity (η) region ($|\eta|<$ 1.0). K^{*0} and ϕ resonances are reconstructed from the following hadronic decay channel: $K^{*0} \longrightarrow K^{\pm} + \pi^{\mp}$ and $\phi \longrightarrow K^{+} + K^{-}$. Mixed event technique has been used for combinatorial background estimation [7]. Fig. 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 distri-

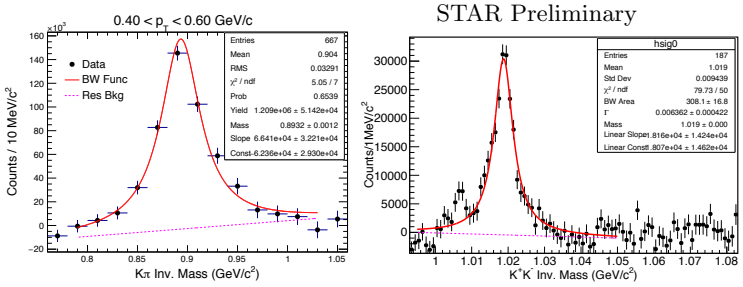

Fig. 1. Invariant mass distribution of $K^{\pm}\pi^{\mp}$ and $K^{+}K^{-}$ pairs after mixed event background subtraction for miminum bias (0-80%) Au+Au collision at $\sqrt{s_{NN}}$ =11.5 GeV for 0.4 < p_T <0.6 GeV/c.

bution 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 detector (Beam Beam Counter or Zero-Degree Calorimeter) [8]. The measured v_1 using first-order event plane was corrected by event plane resolution. The more details about v_1 measurement in STAR can be found at [9].

3 Results

Figure 2 shows K^{*0}/K^{-} and ϕ/K^{-} ratios as a function of $(dN_{ch}/d\eta)^{1/3}$ (the cube root of the charged-particle multiplicity density measured at mid-rapidity) in Au+Au at various centre-of-mass energies measured by STAR experiment [7, 10–13]. The results are also compared to measurements done at $\sqrt{s_{NN}}$ =2.76 TeV in Pb+Pb collision by ALICE collaboration. We can see in all energies, K^{*0}/K^{-} ratios are decreasing with increase in $(dN_{ch}/d\eta)^{1/3}$ (proxy for system size). 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 re-scattering effect as discussed earlier.

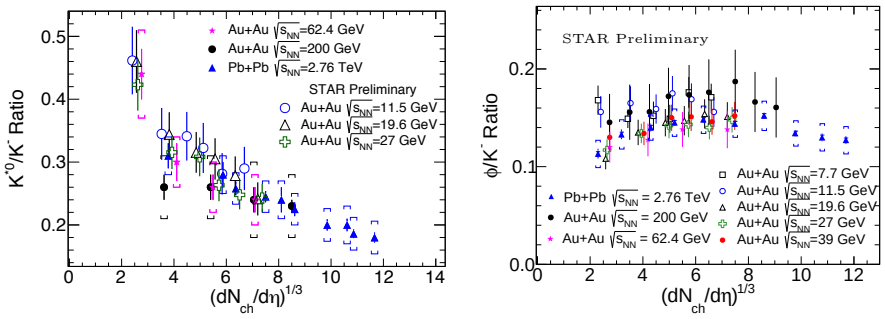

Fig. 2. Ratios K^{*0}/K^{-} and ϕ/K^{-} as a function of $(dN_{ch}/d\eta)^{1/3}$ in Au+Au and Pb+Pb collision at various $\sqrt{s_{NN}}$ [7, 10–13].

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% centrality in Au+Au collisions [9]. The slope for $\bar{\Lambda}$ is negative for all energies and is consistent within errors with that for $\bar{p}$. Antiprotons , ϕ and $\bar{\Lambda}$ are seen to have similar $v_1(y)$ for $\sqrt{s_{NN}} > 14.5$ GeV. All these species are composed of three constituent quarks all produced in the collision. For $\sqrt{s_{NN}} <$ 14.5 GeV, current statistical uncertainty is too large to make any conclusion.

4 Summary

We report the measurement of K^{*0} and ϕ resonances production at mid-rapidity 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 centre-of-mass energies. The K^{*0}/K^{-} ratios are found to be decreasing 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 on K^{*0}/K^{-} ratios in central collisions could be due to the effect of hadronic re-scattering which reduced the measured yield of very short-lived resonances. The directed flow of ϕ meson is presented

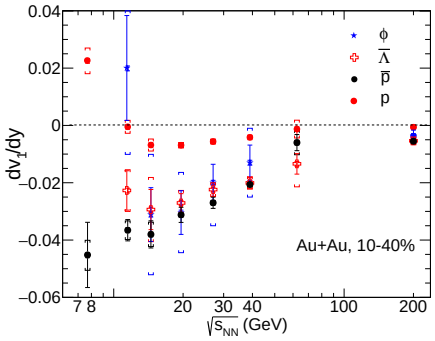

Fig. 3. Directed flow slope (dv_1/dy) versus beam energy for 10-40% centrality in Au+Au collisions for ϕ, $\bar{\Lambda}$, p and $\bar{p}$ [9].

for different centre-of-mass energies. Directed flow slope (dv_1/dy) of ϕ meson are 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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