Production of K^{*0} in Au+Au collisions at $\sqrt{s_{NN}}$= 19.6 GeV in BES-II from STAR

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Abstract

The short-lived resonances, like K^{*0}, are a good candidate to probe the hadronic phase of the matter formed in heavy-ion collisions. Due to its short lifetime, the decay daughters may interact with the hadronic medium, resulting in a change in the properties of the resonances. The decay daughters may undergo various in-medium effects like rescattering and re-generation. Hence K^{*0}/K is a unique tool to investigate the interplay between these effects in the hadronic phase during the evolution of heavy-ion collisions. The high statistics Au+Au data collected by STAR in its BES-II program with enhanced detector capabilities and a wider pseudorapdiity coverage will enable more differential measurements with reduced statistical uncertainties than those achieved in BES-I.

We will report invariant yields, p_T integrated yield (dN/dy), mean transeverse momentum ($\langle p_T \rangle$) of K^{*0} using the Au+Au collisions at $\sqrt{s_{NN}}$ = 19.6 GeV recorded during BES-II. The results will be compared with previous BES-I measurements. The average transverse momentum of K^{*0} will be compared with other hadrons. The resonance to non-resonance ratio will be shown as a function of centrality to study the rescattering vs. regeneration effects. Measurement of the lower limit of hadronic phase lifetime will be shown as a function of centrality and will be compared with measurements at other RHIC and LHC energies.

1 Introduction

Relativistic heavy-ion collisions aim to study the de-confined state of matter, known as the Quark-Gluon-Plasma (QGP). Resonances usually have a smaller lifetime compared to that of the fireball, which makes them a useful probe to the late-stage evolution of heavy-ion collisions [1]. K^{*0} mesons have a lifetime of ~ 4.16 fm/c, hence they mostly decay within the medium and their daughters experience various in-medium effects.

During the evolution of a heavy-ion collision, the temperature at which all inelastic collisions cease is called the chemical freeze-out temperature (T_{ch}), and the temperature at which all elastic collisions cease as the distances between particles become larger than their mean free path, is known as the kinetic freeze-out temperature (T_{kin}). When a K^{*0} meson decays in between these two stages, its daughter particles, π and K, may re-scatter with other particles present in the medium and their momenta may be modified. This makes the reconstruction of the K^{*0} less probable and we may lose the means to reconstruct the prompt resonance created in the medium. Meanwhile it also can happen that π and K coming from different sources regenerate a K^{*0} via pseudo-elastic scattering. Hence the properties and yield of K^{*0} are highly dependent on the relative contribution of re-scattering and regeneration effects. Its comparison to the ϕ meson is of particular interest as the ϕ meson has a lifetime 10 times larger (~ 46 fm/c) than that of K^{*0}. Hence, the daughter particles of a ϕ meson are mostly immune to the in-medium effects and there is a smaller probability of alteration in its properties and yield.

2 Data Sets and Analysis Details

In these proceedings, the production of K^{*0} meson is reported in Au+Au collisions at $\sqrt{s_{NN}} = 19.6$ GeV, recorded by STAR experiment as part of RHIC Beam Energy Scan (BES)- II program. The vertex position along the longitudinal (V_z) and radial (V_r) direction is kept within $|V_z| < 145$ cm and $|V_r| < 2$ cm. The daughter particles are identified using both the Time Projection Chamber (TPC) and Time of Flight (TOF) detectors. In 2019, the TPC has been upgraded with the inclusion of iTPC, providing better momentum resolution and wider pseudo-rapidity coverage.

Here the $K^{*0}(\overline{K}^{*0})$ meson is reconstructed via its decay channel $K^{*0}(\overline{K}^{*0}) \rightarrow K^{\pm}\pi^{\mp}$, with the branching ratio of 66.6%.

3 Results and Discussion

3.1 Particle ratios

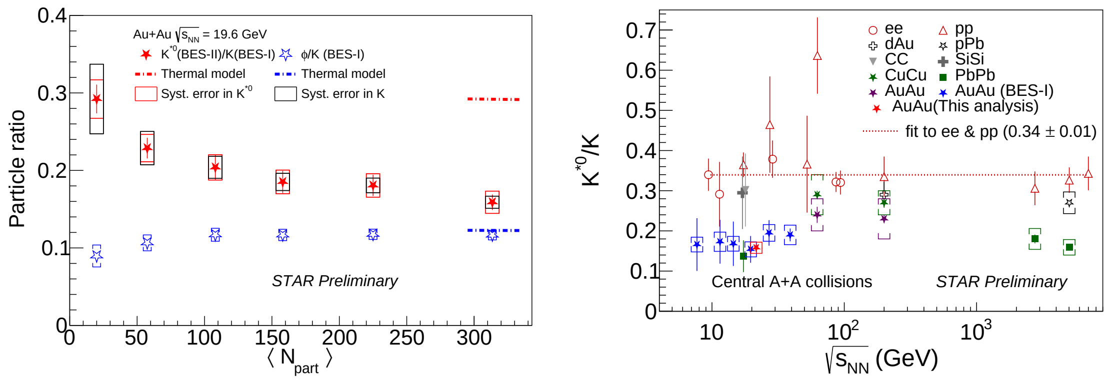

Figure 1: Left panel: Resonance to non-resonance ratio as a function of $\langle N_{part} \rangle$ for Au+Au collision at $\sqrt{s_{NN}}$ = 19.6 GeV. Right panel: K^{*0}/K ratio for elementary and central heavy-ion collisions as a function of collision energy. The statistical and systematic uncertainties are plotted as bars and caps (boxes).

The left panel of Fig. 1 shows the particle ratios as a function of centrality. Here the K^{*0}/K and ϕ/K denote $(K^{*0} + \overline{K}^{*0})/(K^+ + K^-)$ and $2\phi/(K^+ + K^-)$ [2] respectively. The ratios are taken by the total yields of particles, which is the full p_T integrated. Since the K^{*0} measurement is from BES-II data and measurements of K^+ and K^- are from BES-I [3] analysis, their associated systematic uncertainties are denoted by different colored boxes. Here the K^{*0}/K ratio decreases from peripheral to central collisions, while ϕ/K ratio remains independent of centrality. Also the prediction from thermal model [4] overestimates the K^{*0}/K ratio while being consistent with that of ϕ/K ratio. The right panel of Fig. 1 shows the K^{*0}/K ratio for both elementary and heavy-ion collisions [5]. The ratio in central heavy ion collision is smaller compared to $e+e/p+p$ collisions [5]. These observations elucidates hadronic re-scattering might be dominant over regeneration in central heavy-ion collisions. Moreover, ϕ meson, having relatively longer lifetime ($\sim$ 46 fm/c) remains unaffected by the medium effects [5].

3.2 Lower limit of hadronic phase lifetime

The time span between the chemical freeze out (CFO) and the kinetic freeze out (KFO) is considered to be the lower limit of the hadronic phase lifetime [1]. Since it is impossible to directly measure this time span experimentally, we attempted to estimate it by employing a toy-model approximation developed in Ref. [6]:

$$\left(\frac{K^{*0}}{K}\right)_{Kin} = \left(\frac{K^{*0}}{K}\right)_{Chem} \times e^{-\Delta t/\tau_{K^{*0}}}, \tag{1}$$

This relation holds along with the assumptions that the $(K^{*0}/K)_{Chem}$ and $(K^{*0}/K)_{Kin}$ are similar to the ratios measured in elementary and heavy-ion collisions, respectively. Since we do not have the (K^{*0}/K) ratio for p+p collision at $\sqrt{s_{NN}} = 19.6$ GeV, we have taken it to be 0.34 ± 0.01, which is the fit result to the available e+e /p+p data. Also, it is assumed that there is no regeneration of K^{*0} taking place in between chemical and kinetic freeze out and all the K^{*0} decay before the kinetic freeze out. Here the Δt denoted the hadronic phase lifetime and $\tau_{K^{*0}}$ is the lifetime of the K^{*0} meson. After the calculation, the Δt is boosted by the Lorentz factor, which is denoted by $\sqrt{1 + (\langle p_T\rangle/mc)^2}$.

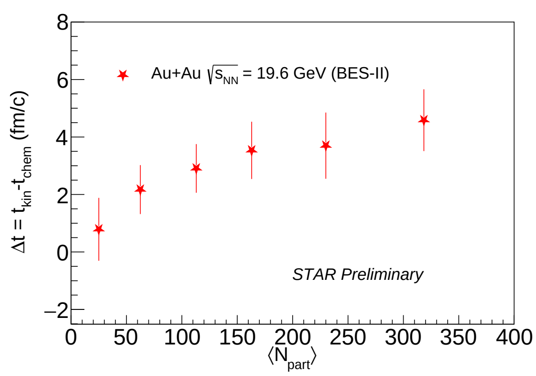

Figure 2: Lower limit of hadronic phase lifetime as a function of $\langle N_{part}\rangle$ for Au+Au collision at $\sqrt{s_{NN}} = 19.6$ GeV. The error bars are the quadrature sum of the statistical and systematic uncertainties.

Figure 2 denotes the lower limit of the hadronic phase lifetime (Δt) as a function of centrality. There is a hint of increasing Δt with increasing centrality.

4 Conclusion

We have presented the K^{*0} measurement at mid-rapidity ($|y| < 1.0$) in Au+Au collisions at $\sqrt{s_{NN}} = 19.6$ GeV (BES-II). The K^{*0}/K ratio is found to be suppressed in central collisions as compared to that in peripheral collisions, also the ratio in heavy-ion collisions is observed to be smaller than in elementary collisions. On the other hand ϕ/K ratio remains almost constant through out all centralities.This suggests that hadrons experience re-scatterings during the hadronic phase at the late stage of a heavy-ion collision. The lower limit of hadronic phase lifetime is estimated based on the K^{*0}/K ratios using a toy model, and we observe a hint of increase towards more central collisions.

References

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