**K* production in Heavy Ion Collisions at RHIC**

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**Abstract**

Study of resonances with their short life-times provides useful tools to probe the properties of hot and dense matter produced in relativistic heavy ion collisions. The high density and/or high temperature of the medium can modify resonance properties such as mass and width. Therefore, measurement of these properties can reveal important information about the evolution dynamics in heavy ion collisions. We report the measurements of $K^*$ transverse momentum ($p_T$) spectra at mid-rapidity via its hadronic decay channel up to intermediate $p_T$ of 2.9 GeV/c using the STAR detector in Au+Au and Cu+Cu collisions at $\sqrt{s_{NN}} = 62.4$ GeV and 200 GeV. These results are compared to previously reported $K^*$ results from Au+Au collisions at RHIC. Integrated yield ratios of $K^*/K$ and $K^*/\phi$ are used to understand the rescattering and regeneration effects on $K^*$ production. PACS

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**1 Introduction**

Ultrarelativistic heavy ion collisions are used to study the quantum chromodynamics at the extreme conditions of high temperature and high energy density[1]. The $K^*$s have a very short life time ($\sim 4 fm/c$) which is comparable to the expected life time of the fireball created in heavy ion collisions[2, 5]. In the dense medium created, resonances are produced in close proximity with other strongly interacting hadrons, and hence in-medium effects related to the high density/or high temperature of the medium can modify the characteristic properties such as masses, widths, and spectra shapes. Therefore, studies of resonance production mechanism can be a useful tool in understanding the properties of the high density matter[2, 3].

Due to the short life time, some of the $K^*$s produced at hadronization can decay in the medium before the kinetic freezeout, and are less likely to be reconstructed.
These two competing processes determine the final $K^*$ yield which depends on the time elapsed between the chemical and kinetic freeze-out, the source size and the interaction cross section of daughter hadrons. Since the $\pi\pi$ total interaction cross section\cite{7} is significantly larger (about a factor $\sim 5$) than the $\pi K$ total interaction cross-section, the final observable $K^*$ yield in heavy ion collisions at RHIC is expected to be smaller than the primordial yield. This should be evident in a suppression of the $K^*/K$ and $K^*/\phi$ yield ratios in AA compared to elementary pp collisions at similar collision energy. Comparison of those ratios can then be used to roughly estimate the lower limit on the time difference between chemical freeze-out and kinetic freeze-out\cite{2}. Central independence of this suppression can be used to gauge the size of the fireball. The system size and energy dependence studies can shed additional light on the different in-medium effects, particularly the interplay between regeneration and rescattering mechanisms.

2 Experiment and Data Analysis

The primary tracking device, TPC(Time Projection Chamber) within STAR was used to measure the $K^*$ production via its hadronic decay channel. TPC provides the particle identification and the momentum information of the charged particles by measuring the ionisation energy loss ($dE/dx$)\cite{4}. The results discussed here are taken from Au+Au $\sqrt{s_{NN}} = 62.4$ GeV and Cu+Cu collisions at $\sqrt{s_{NN}} = 200$ GeV and $\sqrt{s_{NN}} = 62.4$ GeV at RHIC.

Charged kaons and pions were selected from the primary tracks whose distance closest approach to the primary vertex have values less than 1.5 cm. The kaons and pions were selected requiring the $dE/dx$ to be within two standard deviations ($2\sigma$) from the Bethe-Bloch expectation for energy loss. Both the kaons and pions were required to have at least 15 fit points for the tracks reconstructed inside the TPC and the ratio of the number of fit points to the number of maximum possible fit points was greater than 0.55 to avoid selecting split tracks. Further kaon and pion tracks were selected with both momentum and $p_T$ greater than 0.2 GeV/c.

The unlike-sign $K\pi$ invariant mass distribution was reconstructed from random combination of pairs from an event. The combinatorial background distribution was built by using mixed-event technique where the unlike-sign $K\pi$ invariant mass was obtained from different events\cite{9}. The data sample was divided into 10 bins in multiplicity $V_z$ position. The pairs from events in same multiplicity and vertex position bins were selected for mixing to ensure that the event characteristic remain similar between different events. The mixed event generated was normalized to subtract the background in the same event unlike-sign invariant mass spectrum. The normalisation factor was evaluated by taking the ratio between the number of entries in the unlike-sign same event and mixed event distributions for invariant mass greater than 1.1 GeV/c as pairs with invariant mass greater than 1.1 GeV are less likely to be correlated.
Kπ mass resonant states and nonresonant correlations due to particle misidentification, which contribute significantly to the residual correlations near the signal. These contributions are not present in the mixed event spectrum and thus the mixed event only removes the uncorrelated background pairs from the unlike sign spectrum.

Figure 1: The Kπ pair invariant mass spectrum after mixed-event background subtraction fitted to SBW + RB. Left panel: Au+Au at 62.4 GeV Right panel: Cu+Cu at 62.4 GeV

3 Results

Figure 2: $K^* (0)$ mass (left panel) and width (right panel) as a function of $p_T$ in minimum bias Au+Au collisions at 62.4 GeV and Cu+Cu collisions at 200 and 62.4 GeV. The solid line stand for the PDG values.

Figure 1 shows the unlike sign Kπ invariant mass spectrum after normalized mixed event subtraction.
the non relativistic Breit wigner function and RBG is the linear function describing residual background[2]. The variation of \( K^* \) mass and width with respect to \( p_T \) minimum bias Au+Au and Cu+Cu collisions is shown in Figure [2]. Within the errors, we do not observe a large difference in the measured \( K^* \) mass from the PDG[10] value for most of the \( p_T \) range studied. The \( K^* \) width measured is comparable to the PDG value. The systematic uncertainties in the mass and width were calculated by varying the particle types, background subtraction functions and the dynamical cuts.

Figure 3 shows the \( K^* \) mid-rapidity transverse momentum spectra for different centralities of Au+Au and Cu+Cu collisions at \( \sqrt{s_{NN}} = 62.4 \) GeV. The raw spectra yield, corrected for efficiency and detector acceptance are well described by exponential function.

The \( K^* \) yield at midrapidity is calculated from the data points in the measured range and exponential fit was used to extract the yield outside the fiducial range. The \( K^* \) invariant yield increases with number of participants in both Au+Au and Cu+Cu collisions. The systematic uncertainties on \( K^* \) dN/dy is estimated by using different functions, particle types and dynamical cuts. The variation of measured \( K^* \) dN/dy with respect to number of participants is depicted in Figure 4. The \( K^* \) mean \( p_T \) was evaluated using the data points in the measured range of the \( p_T \) spectrum while assuming exponential behaviour outside the fiducial range. The systematic uncertainty includes the differences between the direct calculation and from all other sources mentioned earlier. The \( K^* \) mean \( p_T \) as a function of number of participants is shown in Figure 4 (right panel) for all the collision systems discussed. No significant centrality and system size dependence of mean \( p_T \) is observed for \( K^* \) in Au+Au and Cu+Cu collisions at given colliding energy.

The measurement of \( K^* / K^- \) yield ratio can provide vital information on the
collisions at the same beam energy \[2, 5\]. Figure 5(left panel) shows that \(K^0/\phi\) ratio decreases with number of participants in Au+Au collisions at 62.4 and 200 GeV. This may indicate that the rescattering effect is dominant over the regeneration effect and the fireball created in central collisions has comparatively larger lifetime than peripheral collisions. Similarly \(\phi/K^0\) ratio may also give us an idea on rescattering and regeneration effect as both \(\phi\) amd \(K^0\) have same spin and similar mass but different strangeness number and lifetime. In Figure 5(right panel), we observe that \(\phi/K^0\) ratio increases with number of participants in Au+Au collisions at 62.4 and 200 GeV favouring the dominance of rescattering effect. Since \(\phi\) and \(K^0\) have different strangeness number the observed increase may be due to the possible strangeness enhancement in more central collisions.

![Graphs showing the invariant yield and mean p_T as a function of number of participants.](image)

Figure 4: \(K^0\) invariant yield (left panel) and mean \(p_T\)(right panel)as a function number of participants.

![Graphs showing the \(K^0/\phi\) and \(\phi/K^0\) ratios as a function of number of participants.](image)

Figure 5: \(K^0/\phi\) ratio (left panel) and \(\phi/K^0\) ratio(right panel) as a function of number of participants.
4 Summary

The preliminary results on the $K^*$ production in Au+Au and Cu+Cu collisions measured with the STAR detector at RHIC at $\sqrt{s_{NN}} = 62.4$ GeV and $\sqrt{s_{NN}} = 200$ GeV are presented. The $K^*$ integrated yield increases with number of participants in both Au+Au and Cu+Cu collision systems. No significant dependence of mean $p_T$ on system size is observed. The particle ratio measurement highlights the dominance of rescattering effect over the regeneration mechanism in $K^*$ production in heavy ion collisions.

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\frac{d^2N}{d\eta d\rho_T} (\text{GeV/c})^{-2}
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**STAR Preliminary**

- **K*0 (0-20)%**
- **K*0 (20-40)%**
- **K*0 (40-60)%**