Study of strange mesons in p+p, d+Au and Cu+Cu collisions at $\sqrt{s_{NN}} = 200$ GeV

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Abstract. The PHENIX experiment at RHIC has measured invariant transverse momentum (p_T) spectra and nuclear modification factor (R_{AB}) of strange mesons K^{*0} and K_S^0, in p+p, d+Au and Cu+Cu collisions at center of mass energy 200 GeV. The p_T range of these measurements spans from 1.1 to 8.5 GeV/c for K^{*0} and from 2 to 13 GeV/c for K_S^0. Similar to the other light-quark mesons measurements, both these strange mesons show no cold-nuclear-matter effects in the measured p_T range in d+Au collisions. The nuclear modification factor for d+Au (R_{dAu}) ≈ 1 and is almost constant as a function of p_T. In case of Cu+Cu peripheral collisions, no suppression is registered with respect to the p+p yields scaled with number of binary collisions. In central Cu+Cu collisions, both mesons suffer substantial amount of suppression at high p_T (> 5 GeV/c), which is similar to the suppression suffered by light-quark mesons. In the intermediate p_T range ($2 < p_T < 5$ (GeV/c)), the strange mesons are less suppressed than light-quark mesons (π^0) and more suppressed than baryons (p, $\bar{p}$).

1. Introduction

Lattice QCD calculations predict phase transition from hadronic phase to quark gluon plasma (QGP) above an energy density of 1 GeV/fm^3 [1]. The high energy heavy ion colliders, RHIC and LHC, provide the means to create a quark gluon plasma in the laboratory and study its properties. Particles traversing this hot/dense medium suffer significant energy loss which results in the modification of fragmentation functions and softening of the particle spectra. The modification of the spectra due to the medium can be quantified by the "nuclear modification factor", defined as the ratio of the yield in heavy ion collisions (A+B) to the yield in p+p collisions scaled by the number of binary collisions (N_{coll}). Analytically, it is expressed as, $R_{AB} = \frac{d^2N_{AB}/dy\,dp_T}{N_{coll}.\,d^2N_{pp}/dy\,dp_T}$. The deviation of the value of R_{AB} from 1, is a manifestation of medium effects. In heavy ion collisions, the energy loss by high p_T partons is reflected by the suppression of the yield (i.e. $R_{AB} < 1$). Figure 1 shows the R_{AA} for different particles for the most central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. It is seen that for $p_T > 5$ GeV/c, the R_{AA} value is around 0.2 which is similar for all particles irrespective of quark content. At intermediate p_T (2 $< p_T$ GeV/$c < 5$), the medium-effects for particles with different quark content are different. Different bulk phenomenons (e.g. flow, recombination, Cronin effect) may play important roles towards hadron production in this p_T range. The measurement of strange hadrons is important to study collective effects in the intermediate p_T and the parton energy-loss effects in the high p_T range. These proceedings present the overview of K_S^0 and K^{*0} measurements at midrapidity by PHENIX detector in p+p, d+Au and Cu+Cu collisions at $\sqrt{s_{NN}} = 200$ GeV. The measurements

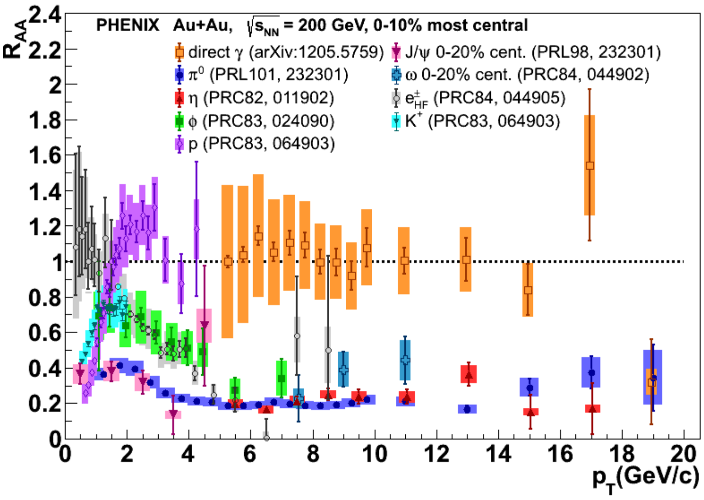

Figure 1. (color online) Nuclear modification factor as a function of p_T for π^0, p, γ, η, ϕ, J/ψ, ω, $e^{\pm}$, $K^{\pm}$ for the most central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Plot taken from Ref. [3].

include the invariant yield transverse momentum spectra and nuclear modification factor for different centrality bins [2]. This article mainly focuses on the results related to the nuclear modification factor obtained in d+Au and Cu+Cu collisions.

2. PHENIX detector

The results presented here are obtained with the help of global, tracking and PID detectors of PHENIX [4]. The event information is obtained from the Beam Beam Counters (BBC), located at $|\eta| < 0.35$ and covering 2π in azimuth. The track reconstruction and momentum determination are done with the help of the Drift Chambers (DC) and first layer of the Pad Chambers (PC). The second and third layers of PC help to suppress contribution of the secondary tracks originating from the decay of long-lived particles or from the interaction of tracks with the detector material. The Time of Flight (TOF) detector identifies charged hadrons. The Electro-Magnetic Calorimeter (EMCal) measures the position and the energy of photons and electrons.

3. Analysis

The K^0_S and K^{*0} mesons are reconstructed from $K^0_S \to \pi^0(\to \gamma\gamma)\pi^0(\to \gamma\gamma)$ and $K^{*0} \to K^{\pm}\pi^{\mp}$ channels respectively. K^0_S reconstruction is done in two steps. Initially, π^0s are reconstructed from photon pairs after applying kinematic and analysis cuts. Then K^0_S meson is reconstructed from π^0 pairs within the same event. For K^{*0} reconstruction, a pair of oppositely charged tracks with $p_T > 0.3$ GeV/c is required. To have measurement in a wider p_T range, three different exclusive and statistically independent techniques are used for K^{*0} analysis. In one of the techniques both tracks are identified in TOF as pions and kaons; it is used to measure K^{*0} production at low p_T. In other approach, tracks are not identified but matched in PC3 and given the masses of kaons and pions. This technique extends the measurement to highest possible p_T. The intermediate p_T range is obtained by identifying kaon in TOF and matching the other track in PC3 before assigning the mass of pion. For analysis details one may refer [2].

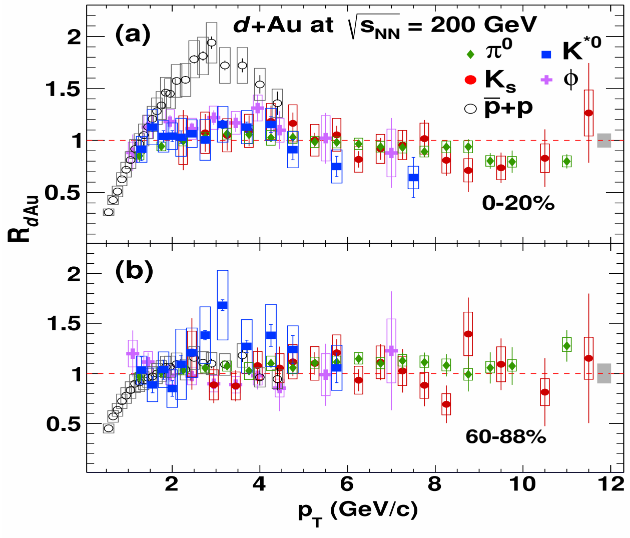

Figure 2. (color online) Nuclear modification factor as a function of p_T for K^0_S and K^{*0} for (a) the most central (0-20%) and (b) the most peripheral (60-88%) d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. Results from π^0 [5], ϕ [6] and protons [7] are also shown.

4. Results

The nuclear modification factor for K^0_S and K^{*0} in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV for the most central and the most peripheral bins are shown in Fig. 2. A comparison with π^0 [5], ϕ [6] and protons [7] are also shown. The statistical and systematic errors are shown with error bars and boxes respectively. It is observed that R_{dAu} is consistent with unity within uncertainties for all measured centrality bins for $p_T > 1$ GeV/c. In the most central bin, there is a slight hint of Cronin enhancement in the intermediate p_T (2-5 GeV/c) range and suppression at $p_T >$ 6-8 GeV/c. The comparisons with π^0 and ϕ mesons show that cold nuclear matter effects do not play a significant role in these mesons productions. However, the proton shows an enhancement in the central collisions at intermediate p_T, which can be explained by recombination models [8].

The nuclear modification factor for K^0_S and K^{*0} along with π^0 [9] and ϕ [6] in Cu+Cu collisions at $\sqrt{s_{NN}}$ = 200 GeV for the most central (0-20%), minimum bias (0-94%) and the most peripheral (60-94%) collisions are shown in the left panel of Fig. 3. The statistical and systematic errors are shown with error bars and boxes respectively. Particles are suppressed in minimum-bias and most central collisions for $p_T > 5$ GeV/c, whereas, in the most central collisions, R_{CuCu} reaches a value around 0.5. In the intermediate p_T (2-5 GeV/c) range, K^{*0} and ϕ are less suppressed than π^0 and below 2 GeV/c, neither of K^{*0} and ϕ are suppressed. Peripheral collisions follow binary scaling within uncertainties for all these mesons in the measured p_T range. Figure 3 (right panel), compares the suppression of mesons and baryons for the central and peripheral collisions. The data for K^{*0}, ϕ [6] and π^0 [9] are shown for Cu+Cu collisions and the data for $K^{\pm}$ [7] and protons [7] are shown for Au+Au collisions for similar $\langle N_{part}\rangle$ values. The statistical and systematic errors are shown with error bars and boxes respectively. For the central collisions, π^0 is the most suppressed meson and has a flat behavior in the measured p_T range. In the intermediate p_T, the mesons, K^{*0} and ϕ are less suppressed than π^0 but more suppressed than protons. At high p_T, all particles are suppressed and seem to have similar R_{AA} values within uncertainties, irrespective of their valence quark content. In peripheral collisions, R_{AA} for all particles, except protons are consistent with unity within error bars for $p_T > 2$

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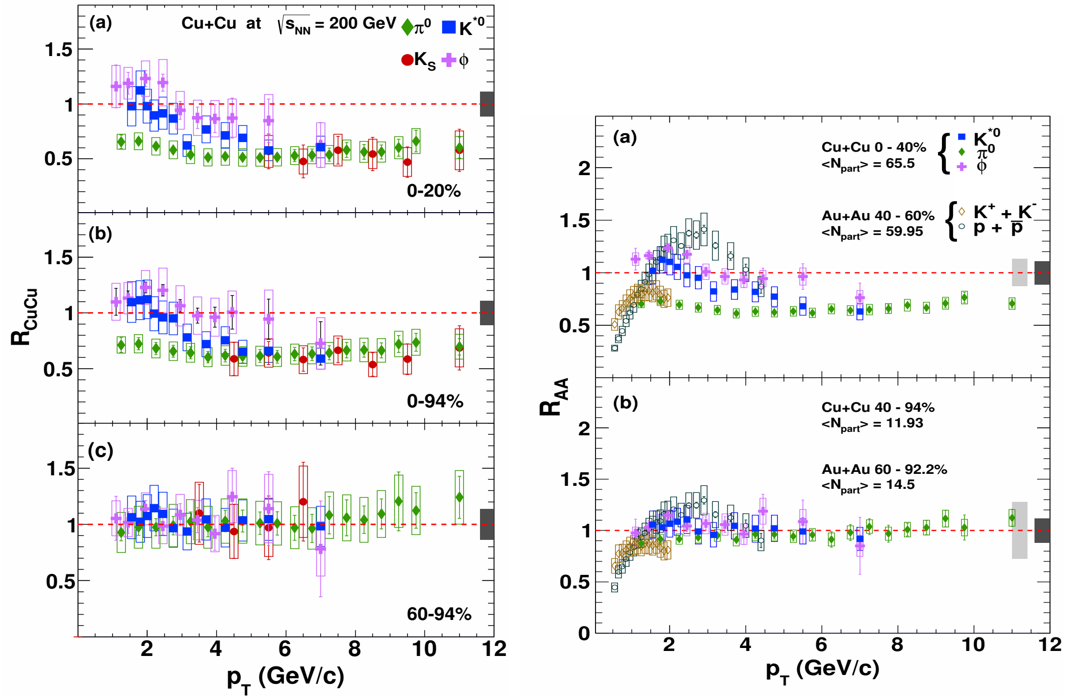

Figure 3. (color online) Left panel : Nuclear modification factor as a function of p_T for K_S^0, K^{*0} for different centralities in Cu+Cu collisions at $\sqrt{s_{NN}} = 200$ GeV. Results from π^0 [9] and ϕ [6] are also shown. Right panel : Comparison of the nuclear modification factor of π^0 [9], ϕ [6], and K^{*0} in Cu+Cu collisions and proton [7] and kaon [7] in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. For details see text.

GeV/c.

5. Conclusions

Measurements of K_S^0 and K^{*0} mesons via $\pi^0\pi^0$ and $K^{\pm}\pi^{\mp}$ decays respectively, in p+p, d+Au and Cu+Cu collisions at $\sqrt{s_{NN}} = 200$ GeV, with PHENIX are presented. In d+Au collisions, in the measured p_T range, no significant cold nuclear matter effect is seen for both mesons. In Cu+Cu collisions, no suppression is observed in peripheral collisions. In the most central collisions, for $p_T > 5$ GeV/c, K_S^0 and K^{*0} show a suppression similar to π^0 and ϕ within uncertainties. However, for $2 < p_T$ (GeV/c) < 5, baryons show no suppression, π^0s are the most suppressed species and particles with strange quark content show an intermediate behavior. These results provide additional constraints to the modelisation of hadron energy loss in medium.

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