In-medium Decay widths of strange mesons

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Abstract

The in-medium decay widths of vector strange mesons ($\phi$ and $K^*$) to pseudoscalar (strange) mesons are studied. The decay widths $\phi \rightarrow K\bar{K}$ and $K^* \rightarrow K\pi$ are modified due to the changes in the masses of the open strange mesons in the hadronic medium. The effects of the isospin asymmetry, strangeness and density on these masses are investigated using a chiral SU(3) model. The decay widths are computed using a field theoretic model of composite hadrons with quark/antiquark constituents, from the matrix element of the light quark-antiquark pair creation term of the free Dirac Hamiltonian between the initial and final states. The matrix element is multiplied with a coupling strength parameter for the light quark-antiquark pair creation, which is fitted to the observed vacuum decay width of the decay process. There are observed to be substantial modifications of the decay widths from isospin asymmetry as well as strangeness at high densities. These should show in the experimental observables, e.g. in the production and propagation of the hidden and open strange mesons arising from the isospin asymmetric high energy heavy ion collisions at the CBM experiments at the future facility at GSI.

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I. INTRODUCTION

The study of the in-medium properties of the strange mesons is relevant in the heavy ion collision experiments, as these can affect the experimental observables, e.g., the yield, spectra and collective flow of these mesons in the strongly interacting matter created from high energy nuclear collisions. The possibility of antikaon condensation \[1\] in the interior of the neutron stars, due to the mass drop of the antikaons arising from attractive interaction with the nucleons, initiated a lot of work on the study of in-medium properties of these open strange mesons. The effects of the isospin asymmetry of the hadronic medium on the hadron properties are important to study in the context of heavy ion collision experiments \[2\] as the initial system, consisting of heavy ions has large asymmetry in the number of protons and neutrons. The isospin asymmetry effects can affect observables like the $\pi^-/\pi^+$ ratio, the n/p ratio, the $\Delta^-/\Delta^{++}$ ratio \[3\] for neutron rich heavy ion collisions. The modifications of the decay widths of $\phi \rightarrow K\bar{K}$ and $K^* \rightarrow K\pi$, arising due to the mass modifications of the open strange mesons ($K$ and $K^*$) can modify the production of the hidden ($\phi$) and open strange ($K$ and $K^*$) mesons, and show in the experimental observables, e.g., the $K^+/K^0$ \[4\] ratio, the $K^-/\bar{K}^0$ ratio, as well as the yield, spectra and collective flow of the strange mesons. In the present work, we study the in-medium decay widths of the processes $\phi \rightarrow K\bar{K}$ and $K^* \rightarrow K\pi$ from the modifications of the masses of the kaons and antikaons in the hadronic medium \[5-8\], calculated using a chiral SU(3) model \[9, 10\]. The mass modifications of the $K$ and $\bar{K}$ mesons arise due to their interactions with the baryons and the scalar mesons in the isospin asymmetric hyperonic matter. The interactions of the kaons and antikaons include the vectorial interaction with the baryons given by the Weinberg – Tomozawa term, as well as, the scalar exchange and the range terms in the chiral SU(3) model. The effects of the isospin asymmetry and the strangeness are observed to be large at high densities on the masses of these mesons. These lead to significant modifications of the $\phi$ and $K^*$ decay widths, which should have observable consequences on the production of the hidden and open strange mesons in asymmetric heavy ion collisions at the compressed baryonic matter (CBM) experiments planned at the future facility at GSI.

The outline of the paper is as follows: In section II we discuss briefly the medium modifications of the masses of the kaons and antikaons in isospin asymmetric strange hadronic
matter using a chiral SU(3) model. The in-medium mass of the vector open strange meson, the $K^*$ meson, which has the same quark-antiquark constituents as the $K$ meson ($q\bar{s}$, $q = u, d$), is assumed to be proportional to the in-medium mass of the $K$ meson. The decay widths of the $\phi$ meson to $K\bar{K}$ and of the $K^*$ meson to $K\pi$, are calculated using a field theoretical model of composite hadrons with quark/antiquark constituents. The medium modifications of the decay widths are obtained from the mass modifications of the $K^*$, $K$ and $\bar{K}$ mesons. In section III, we discuss the results of the masses and decay widths of the strange mesons. Section IV summarizes the findings of the present investigation.

II. STRANGE MESONS IN ASYMMETRIC HYPERONIC MATTER

A. MASSES:

The isospin asymmetric strange hadronic matter is described by a chiral SU(3) model based on a nonlinear realization of chiral symmetry \[11–13\] and broken scale invariance \[14, 15\]. The model describes the interactions of the baryons and the mesons (scalar, vector, pseudoscalar and axialvector) and the dilaton field, $\chi$, which is incorporated in the model to mimick the scale symmetry breaking of Quantum Chromodynamics (QCD). The model has been described in detail in Refs. \[9, 10\]. The hadronic matter is described using the mean field approximation, which replaces the meson fields with their expectation values. The expectation values of the meson fields are determined by solving the coupled equations of motion of these fields \[10\] in the mean field approximation, additionally assuming that $\bar{\psi}_i\psi_j = \delta_{ij}\langle \bar{\psi}_i\psi_i \rangle \equiv \delta_{ij}\rho_i^s$ and $\bar{\psi}_i\gamma^\mu\psi_j = \delta_{ij}\delta^{\mu0}\langle \bar{\psi}_i\gamma^0\psi_i \rangle \equiv \delta_{ij}\delta^{\mu0}\rho_i$, where, $\rho_i^s$ and $\rho_i$ are the scalar and number density of baryon of species $i$ described by the fermion field $\psi_i$, with $i = p, n, \Lambda, \Sigma^+, \Sigma^0, \Sigma^-, \Xi^-, \Xi^0$. These are calculated for given values of the isospin asymmetry parameter, $\eta = -\frac{\sum_i I_{3i}\rho_i}{\sum_i \rho_i}$, and the strangeness fraction, $f_s = \frac{\sum_i s_i\rho_i}{\sum_i \rho_i}$, where $I_{3i}$ is the third component of the isospin of the baryon of species, $i$ and $s_i$ is the number of strange quarks in the $i$-th baryon.

The modifications of the masses of the kaon and antikaon in the isospin asymmetric strange hadronic matter are calculated from the interactions of these mesons with the baryons and the scalar mesons in the chiral SU(3) model. These interactions include the
The vacuum expectation value of \( \delta \) modification in the hadronic medium is negligible. \( \delta \) has been neglected in the present work, as it is related to the gluon condensate, whose isospin symmetry of the vacuum. The fluctuation of the dilaton field in the medium terms in the next to leading order of chiral perturbation theory. The dispersion relations of the \( K \) and \( \bar{K} \) mesons are obtained by Fourier transformations of the equations of motion of these mesons \( [8] \). These are given as

\[
-\omega^2 + k^2 + m_K^2 - \Pi_{K(\bar{K})}(\omega, |k|) = 0,
\]

where \( \Pi(\omega, |k|) \) denotes the kaon (antikaon) self energy in the medium.

Explicitly, the self energy \( \Pi(\omega, |k|) \) for the kaon doublet, \( (K^+, K^0) \) is given as

\[
\Pi_K(\omega, |k|) = -\frac{1}{4f_K^2}[3(\rho_p + \rho_n) \pm (\rho_p - \rho_n) \pm 2(\rho_{\Sigma^+} - \rho_{\Sigma^-}) - (3(\rho_{\Xi^-} + \rho_{\Xi^0}) \pm (\rho_{\Xi^-} - \rho_{\Xi^0})) |\omega
\]

\[
+ \frac{m_K^2}{2f_K^2}(\sigma' + \sqrt{2}\zeta' \pm \delta')
\]

\[
+ \left[-\frac{1}{f_K}(\sigma' + \sqrt{2}\zeta' \pm \delta') + \frac{d_1}{2f_K^2}(\rho_p^s + \rho_n^s + \rho_{\Sigma^+}^s + \rho_{\Sigma^-}^s + \rho_{\Xi^-}^s + \rho_{\Xi^0}^s)
\]

\[
+ \frac{d_2}{4f_K^2}\left((\rho_{\rho}^s + \rho_{-}^s) \pm (\rho_{p}^s - \rho_{n}^s) + \rho_{\Sigma^+}^s + \rho_{\Sigma^-}^s + \rho_{\Xi^-}^s + \rho_{\Xi^0}^s\right) + \frac{5}{3}\rho_{\Lambda^0}^s + (\rho_{\Sigma^+}^s + \rho_{\Sigma^-}^s) \pm (\rho_{\Sigma^+}^s - \rho_{\Sigma^-}^s)
\]

\[
+ 2\rho_{\Xi^-}^s + 2\rho_{\Xi^0}^s\right)](\omega^2 - k^2),
\]

where the \( \pm \) signs refer to the \( K^+ \) and \( K^0 \) respectively. In the above, \( \sigma' (= \sigma - \sigma_0) \), \( \zeta' (= \zeta - \zeta_0) \) and \( \delta' (= \delta - \delta_0) \) are the fluctuations of the scalar-isoscalar fields \( \sigma \) and \( \zeta \), and the third component of the scalar-isovector field, \( \delta \), from their vacuum expectation values. The vacuum expectation value of \( \delta \) is zero \( (\delta_0 = 0) \), since a nonzero value for it will break the isospin symmetry of the vacuum. The fluctuation of the dilaton field in the medium has been neglected in the present work, as it is related to the gluon condensate, whose modification in the hadronic medium is negligible.

Similarly, for the antikaon doublet, \( (K^-, \bar{K}^0) \), the self-energy is calculated as

\[
\Pi_{\bar{K}}(\omega, |k|) = \frac{1}{4f_{\bar{K}}^2}[3(\rho_p + \rho_n) \pm (\rho_p - \rho_n) \pm 2(\rho_{\Sigma^+} - \rho_{\Sigma^-}) - (3(\rho_{\Xi^-} + \rho_{\Xi^0}) \pm (\rho_{\Xi^-} - \rho_{\Xi^0})) |\omega
\]

\[
+ \frac{m_{\bar{K}}^2}{2f_{\bar{K}}^2}(\sigma' + \sqrt{2}\zeta' \pm \delta')
\]

\[
+ \left[-\frac{1}{f_{\bar{K}}}(\sigma' + \sqrt{2}\zeta' \pm \delta') + \frac{d_1}{2f_{\bar{K}}^2}(\rho_p^s + \rho_n^s + \rho_{\Sigma^+}^s + \rho_{\Sigma^-}^s + \rho_{\Xi^-}^s + \rho_{\Xi^0}^s)
\]

\[
+ \frac{d_2}{4f_{\bar{K}}^2}\left((\rho_{\rho}^s + \rho_{-}^s) \pm (\rho_{p}^s - \rho_{n}^s) + \rho_{\Sigma^+}^s + \rho_{\Sigma^-}^s + \rho_{\Xi^-}^s + \rho_{\Xi^0}^s\right) + \frac{5}{3}\rho_{\Lambda^0}^s + (\rho_{\Sigma^+}^s + \rho_{\Sigma^-}^s) \pm (\rho_{\Sigma^+}^s - \rho_{\Sigma^-}^s)
\]

\[
+ 2\rho_{\Xi^-}^s + 2\rho_{\Xi^0}^s\right)](\omega^2 - k^2),
\]
FIG. 1: The masses of $K^+$ and $K^0$ in the (strange) hadronic matter with strangeness fractions, $f_s = 0, 0.3, 0.5$ for isospin asymmetric parameter $\eta=0.3$. These are compared with the isospin symmetric case ($\eta=0$) shown as dotted lines.

where the ± signs refer to the $K^-$ and $\bar{K}^0$ respectively. In the equations (2) and (3), the first term is due to the vectorial Weinberg-Tomozawa term, the second term is the contribution due to the scalar exchange, and, the last three terms are the range terms. The parameters $d_1$ and $d_2$ of the range terms are determined to be $2.56/m_K$ and $0.73/m_K$, by a fit of the
FIG. 2: Same as figure 1 for the masses of $K^-$ and $\bar{K}^0$.

empirical values of the KN scattering lengths for $I=0$ and $I=1$ channels [6–8], taken as $a_{KN}(I = 0) \approx -0.09$ fm and $a_{KN}(I = 1) \approx -0.31$ fm [16–18]. The masses of the kaons and antikaons in the medium, $m_{K(\bar{K})}^{\text{eff}}$, are obtained from the solution of the dispersion relation (1) for $k = 0$. The in-medium decay widths of $\phi \rightarrow K\bar{K}$ and $K^* \rightarrow K\pi$ are calculated from the mass modifications of the kaons and antikaons as studied in isospin asymmetric (nuclear) hyperonic matter, using the chiral SU(3) model [8] and, assuming the mass modification
FIG. 3: Decay widths of the charged open strange vector meson, $K^{*+}$ to $(K\pi)^+$ for $f_s = 0, 0.3, 0.5$ for isospin asymmetric matter ($\eta = 0.3$) and symmetric matter ($\eta = 0$).

of the vector open strange meson, $K^*$ (which has same quark-antiquark constituents as $K$ meson) as given by $m^{\text{eff}}_{K^*}/m^{\text{vac}}_{K^*} = m^{\text{eff}}_K/m^{\text{vac}}_K$. These decay widths are calculated using a field theoretical model with quark (antiquark) constituents as described in the following subsection.
FIG. 4: Same as figure 3 for the decay width of $K^{*0}$ meson.

B. DECAY WIDTHS:

The decay widths of $\phi \rightarrow K\bar{K}$ and $K^{*} \rightarrow K\pi$ are calculated using a field theoretic model of composite hadrons [19, 20]. These are evaluated from the matrix element of the light quark-antiquark pair creation term of the free Dirac Hamiltonian between initial and final states [21, 25]. For a generic decay process $A \rightarrow B + C$, the matrix element is multiplied
FIG. 5: Decay widths of $\phi$ to charged and neutral $K\bar{K}$ in strange hadronic matter, for $f_s = 0, 0.3, 0.5$ for $\eta=0.3$. These are compared with the isospin symmetric matter shown as dotted lines.

with a parameter $\gamma_A$, which is a measure of the light quark-antiquark pair creation strength to form the final mesons $B$ and $C$ from the decay of the parent meson $A$. This parameter is fitted from the observed decay width of $A \rightarrow B + C$ in vacuum. This is similar to the calculation of the decay width of $A \rightarrow B + C$ in the $^3P_0$ model $[26, 27]$, where the decay of
In the field theoretical model of composite hadrons considered in the present work, we study the medium modifications of the decay widths of $\phi \rightarrow K\bar{K}$ and $K^* \rightarrow K\pi$ from the mass modifications of the open strange mesons. These decay widths are calculated from the matrix element of the free Dirac Hamiltonian between the initial and final states, assuming the harmonic oscillator wave functions in the explicit constructions for these mesons [25].

The mesons $K, \bar{K}, K^*, \pi$ and $\phi$ are assumed to be in the $1S$ state. The model has been used to study the decay widths of charmonium state to $D\bar{D}$ as well as $D^* \rightarrow D\pi$ [21] and of bottomonium states to $B\bar{B}$ in isospin asymmetric strange hadronic matter [22]. The effect of strong magnetic fields has also been considered on the charmonium decay widths to $D\bar{D}$ [23], $D^* \rightarrow D\pi$ [24] as well as $K^* \rightarrow K\pi$ [25], where the pseudoscalar vector meson mixing effect is observed to have significant contributions to the masses of these mesons, in addition to the Landau level contributions to the masses of charged mesons.

The decay width of vector meson $A$ at rest decaying to pseudoscalar mesons $B(p)$ and $C(-p)$ is given as

$$
\Gamma (A(0) \rightarrow B(p) + C(-p)) = \gamma_A^2 g^2 \frac{8\pi^2 p_B^0 p_C^0}{3m_A} A_A(|p|^2|p|^3),
$$

where $p_B^0 = (|p|^2 + m_B^2)^{1/2}$ and $p_C^0 = (|p|^2 + m_C^2)^{1/2}$ are the energies of the outgoing $B$ and $C$ mesons, respectively.
where, in terms of the magnitude of the 3-momentum of $B(C)$ meson, $|p|$, given as

$$|p| = \left( \frac{m_A^2}{4} - \frac{m_B^2 + m_C^2}{2} + \frac{(m_B^2 - m_C^2)^2}{4m_A^2} \right)^{1/2}. \quad (5)$$

For the decay $K^* \rightarrow K\pi$, $A_{K^*}(|p|)$ is given as

$$A_{K^*}(|p|) = 6c_{K^*} \left( \frac{\pi}{a_{K^*}} \right)^{3/2} \exp \left[ \left( a_{K^*}b_{K^*}^2 - \frac{1}{2} \left( \frac{3}{4}b_{K^*}^2 - \frac{1}{4}b_{K^*} + \frac{7}{16} \right) \right)|p|^2 \right] \left[ F_{0_{K^*}} + \left( \frac{3F_{1_{K^*}}}{2a_{K^*}} \right) \right]. \quad (6)$$

where,

$$F_{0_{K^*}} = (b_{K^*} - 1) \left( 1 - \frac{1}{8m_q^2} |p|^2 (\lambda_2 - \frac{1}{2}) \right)$$

$$- (b_{K^*} - \lambda_2) \left( \frac{1}{2} + \frac{1}{4m_q^2} |p|^2 \left( \frac{3}{2}b_{K^*}^2 - \frac{5}{4}b_{K^*} + \frac{7}{16} \right) \right)$$

$$- (b_{K^*} - \frac{1}{2}) \left[ \frac{1}{2} + \frac{1}{4m_q^2} |p|^2 \left( \frac{3}{4}b_{K^*}^2 - (1 + \frac{1}{2}\lambda_2)b_{K^*} + \lambda_2 - \frac{1}{4}\lambda_2^2 \right) \right] \quad (7)$$

$$F_{1_{K^*}} = -\frac{1}{4m_q^2} \left[ \frac{5}{2}b_{K^*} - \frac{9}{8} - \frac{11}{12}\lambda_2 \right]. \quad (8)$$

The parameters $a_{K^*}$, $b_{K^*}$, $c_{K^*}$ are given as

$$a_{K^*} = \frac{(R_{K^*}^2 + R_{\pi}^2 + R_{\phi}^2)}{2}, \quad b_{K^*} = \frac{1}{2a_{K^*}} \left( R_{K^*}^2 \lambda_2 + \frac{1}{2}R_{\pi}^2 \right), \quad c_{K^*} = \frac{1}{12\sqrt{3}} \left( \frac{R_{K^*}^2 \cdot R_{\pi}^2 \cdot R_{\phi}^2}{\pi^3} \right)^{3/4}. (9)$$

In equations (7)–(8), $m_q$ is the constituent light quark ($q = u, d$) mass. In equation (4), for the decay of $K^* \rightarrow K\pi$, the value of $g^2 = 1(2)$ for the neutral (charged) pion in the final state.

For the decay process $\phi \rightarrow K\bar{K}$, $A_{\phi}(|p|)$ in equation (4) is given as

$$A_{\phi}(|p|) = 6c_{\phi} \exp \left[ (a_{\phi}b_{\phi}^2 - R_{K^*}^2 \lambda_2^2)|p|^2 \right] \left( \frac{\pi}{a_{\phi}} \right)^{\frac{3}{2}} \left[ F_{0_{\phi}} + F_{1_{\phi}} \frac{3}{2a_{\phi}} \right], \quad (10)$$

where $|p|$ is the momentum of the outgoing $K(\bar{K})$ meson arising from the decay of $\phi$ meson at rest, which is given by equation (5), with particles (A,B,C) given by ($\phi, K, \bar{K}$). In equation (10),

$$F_{0_{\phi}} = (\lambda_2 - 1) - \frac{1}{2m_q^2} |p|^2 (b_{\phi} - \lambda_2) \left( \frac{3}{4}b_{\phi}^2 - (1 + \frac{1}{2}\lambda_2)b_{\phi} + \lambda_2 - \frac{1}{4}\lambda_2^2 \right),$$

$$F_{1_{\phi}} = \frac{1}{4m_q^2} \left[ -\frac{5}{2}b_{\phi} + \frac{2}{3} + \frac{11}{6}\lambda_2 \right]. \quad (11)$$

and the parameters $a_{\phi}$, $b_{\phi}$ and $c_{\phi}$ given as

$$a_{\phi} = \frac{1}{2}R_{\phi}^2 + R_{K^*}^2, \quad b_{\phi} = R_{K^*}^2 \lambda_2 / a_{\phi}, \quad c_{\phi} = \frac{1}{6\sqrt{6}} \cdot \left( \frac{R_{\phi}^2}{\pi} \right)^{3/4} \cdot \left( \frac{R_{K^*}^2}{\pi} \right)^{3/2}.$$
III. RESULTS AND DISCUSSIONS

The in-medium decay widths $\phi \to K\bar{K}$ and $K^* \to K\pi$ are calculated using the field theoretic model of composite hadrons [25] described in the previous section. These arise from the mass modifications of the open strange mesons in the hadronic medium. The masses of the kaons and antikaons in the isospin asymmetric strange hadronic medium have been calculated within a chiral SU(3) model [8]. For the sake of completeness, the in-medium masses of the kaons and antikaons are shown in figures 1 and 2 respectively, illustrating the effects from strangeness and isospin asymmetry of the hadronic medium.

For the isospin symmetric nuclear matter ($\eta=0, f_s=0$), the Weinberg Tomozawa term leads to a rise (drop) of the mass of the $K^0(\bar{K})$ meson. The scalar exchange term as well as the $d_1$ and $d_2$ range terms are attractive, whereas, the first range term is repulsive for both the kaons and antikaons. In the presence of isospin asymmetry in the medium ($\eta \neq 0$), there are explicitly contributions arising from the Weinberg-Tomozawa, $\delta$ term in the scalar exchange term as well as first range term, and the $d_2$ range term. The $d_1$ term also implicitly depends on the isospin asymmetry where the values of the scalar densities of the baryons are obtained from the coupled equations of motion of the scalar fields, $\sigma$, $\zeta$ and $\delta$. For nonzero strangeness in the medium, there are contributions from the hyperons to the Weinberg-Tomozawa term and the $d_1$ and $d_2$ range terms.

As can be seen from figure 1, the isospin asymmetry of the medium is observed to lead to a drop (increase) in the mass of the $K^+(K^0)$ meson for the nuclear as well as hyperonic matter and these effects are observed to be larger for $K^0$ as compared to $K^+$ meson. In isospin symmetric nuclear matter ($\eta=0, f_s=0$), the drop in the masses of the antikaons in the medium as shown in figure 2 is due to the attractive contributions from the Weinberg-Tomozawa term, scalar exchange as well as the $d_1$ and $d_2$ range terms, which dominates over the repulsive contribution from the first range term. There is observed to be a rise (drop) of the mass of the $K^- (\bar{K}^0)$ meson mass due to isospin asymmetry both in the nuclear as well as hyperonic matter. The effects of isospin asymmetry (opposite in sign for $K^+$ and $K^0$ mesons in kaon doublet as well as for $K^-$ and $\bar{K}^0$ in antikaon doublet) lead to mass differences in the $K^+$ and $K^0$ as well as for $K^-$ and $\bar{K}^0$ mesons. These should show in experimental observables, e.g, the $K^+/K^0$ and $K^-/\bar{K}^0$ ratios in the neutron rich heavy ion
collision experiments.

The mass modifications of the kaons and antikaons as evaluated in the chiral SU(3) model, and assuming mass modifications of $K^*$ mesons to be proportional to $K$ meson, the decay widths $K^* \rightarrow K\pi$ are computed within the field theoretic model of composite hadrons, using equations (3) and (4), with (A,B,C)=(K*, K, π) and equations (6, 7) and (9). The parameter, $\lambda_2$ in the expression for the decay width of $K^* \rightarrow K\pi$ is the fraction of the mass (energy) of the $K$ meson at rest (in motion) by the constituent light (u,d) quark. Assuming the binding energy of the meson shared by the quark (antiquark) constituent to be inversely proportional to the quark (antiquark) mass [20], and using the vacuum mass (in MeV) of $K^+(K^0)$ meson to be given as 493.677 (497.61), $M_{u,d}=330$ MeV [21], and $M_s=480$ MeV, the value of $\lambda_2$ is obtained as 0.71 [25]. The harmonic oscillator strengths of the $K$ and $\pi$ states are taken to be $R_K=(238.3 \text{ MeV})^{-1}$, $R_\pi=(211 \text{ MeV})^{-1}$ [20, 21] from the charge radii squared of pion and kaon to be 0.4 fm$^2$ and (0.56 fm)$^2$ respectively [30]. The value of $R_\phi$ is obtained from the observed decay width of $\phi \rightarrow e^+e^-$ of 1.26377 keV [30] to be (290.7 MeV)$^{-1}$. The value of $R_{K^*}$ is assumed to be same as $R_K$ in the present work.

The values of $\gamma_{K^*}$ for the decays $K^{*+} \rightarrow (K\pi)^+$ and $K^{*0} \rightarrow (K\pi)^0$, as fitted to their observed vacuum decay widths of 50.75 and 47.18 MeV [30], are obtained as 2.4742 and 2.347 respectively. These yield the values of the decay widths for the subchannels of the $K^{*+}$ meson to $K^+\pi^0$ and $K^0\pi^+$ to be 16.98 and 33.77 MeV and of decay widths of $K^{*0}$ to $K^0\pi^0$ and $K^+\pi^-$ to be 15.87 and 31.31 MeV respectively.

From figure 3, the decay width of $K^{*+}$ to $K^0\pi^+$ is observed to have much more pronounced effects from both the strangeness as well as isospin asymmetry parameter, as compared to the decay to $K^+\pi^0$. For the nuclear matter ($f_s=0$), the isospin asymmetry leads to a drop (rise) of the mass of $K^+(K^0)$ meson (and of $K^{*+}(K^{*0})$ meson), which leads to substantial decrease in the decay width of $K^{*+}$ to $K^0\pi^+$ as compared to $K^{*+}$ to $K^+\pi^0$. The effects of the strangeness and isospin asymmetry on the decay width of the neutral $K^*$ meson to the decay to $K^+\pi^-$ is observed to be much more appreciable as compared to the decay to $K^0\pi^0$, as can be seen from figure 4.

In figure 5, the decay widths of $\phi$ meson to $K^+K^-$ and $K^0\bar{K}^0$ are plotted in panels (a) and (b) for different values of the strangeness fraction, both for isospin symmetric ($\eta=0$) as
well as isospin asymmetric matter (with $\eta=0.3$). The effects from strangeness are observed to lead to much larger values of these decay widths at high densities. This should show as the production of $K\bar{K}$ pairs to be more abundant and suppression of the $\phi$ meson.

The significant effects of isospin asymmetry and strangness on the mass difference between $K^+$ and $K^0$ mesons (as compared to between $K^-$ and $\bar{K}^0$ mesons) should show as a dominant effect on the $K^+/K^0$ ratio in asymmetric heavy ion collision experiments. The effects of the strangeness and isospin asymmetry on the decay widths of the charged and neutral $K^*$ to $K\pi$, as well as $\phi \to K\bar{K}$, should modify the production of these open as well as hidden strange mesons arising from asymmetric heavy ion collisions at the compressed baryonic matter (CBM) experiments at the future facility at GSI.

IV. SUMMARY

We have investigated the in-medium decay widths of strange mesons from the mass modifications of these mesons in isospin asymmetric nuclear (hyperonic) matter. The decay widths $\phi \to K\bar{K}$ are computed using a field theoretic model of composite hadrons with quark (and antiquark) constituents. These are calculated from the matrix element of the quark-antiquark pair creation term of the free Dirac Hamiltonian between the initial and final states. The masses of the kaons and antikaons are calculated using a chiral SU(3) model and the in-medium mass of the vector $K^*$ meson is assumed to be proportional to the mass of $K$ meson in the hadronic medium. There is observed to be dominant contributions to the kaon and antikaon masses from the isospin asymmetry as well as strangeness at high densities, which is observed to lead to large mass difference of the $K^+$ and $K^0$ mesons. This should show in the experimental observable, e.g, the $K^+/K^0$ ratio in asymmetric heavy ion collision experiments. There are observed to be significant modifications of the decay widths of $(K^*)^{+,-,0} \to (K\pi)^{+,-,0}$ in the isospin asymmetric strange hadronic matter and the decay width of $\phi \to K\bar{K}$ is observed to be appreciable larger with increase in strangeness in the medium. These medium modifications of the masses and the decay widths of the strange mesons should modify the the production of the pseudoscalar and vector open strange mesons as well as $\phi$ mesons arising from asymmetric heavy ion collisions at the compressed baryonic matter (CBM) experiments at future facility at GSI.
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