K^* meson decay width in magnetized nuclear matter

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Introduction

We study the in-medium decay widths of open strange (K^*) vector meson, decaying to two pseudoscalar mesons (Kaon and Pion), using a light quark-antiquark pair creation model, namely the $^3P_0$ model [1, 2]. The in-medium decay width of $K^* \to K\pi$ is studied from the mass modifications of the K^* and K mesons. The effects of high magnetic fields on these mesons are studied in nuclear medium with medium density equal to nuclear matter saturation density ($\rho_0 = 0.15\ fm^{-3}$). The medium modifications for K^* masses are calculated within the Quantum Chromodynamics Sum Rule (QCDSR) approach through the medium modifications of the light quark condensates ($< \bar{u}u >$, $< \bar{d}d >$, and $< \bar{s}s >$) and gluon condensates of the nuclear medium [3]. The in-medium masses for the pseudoscalar K meson are calculated within a chiral SU(3) model, where the modifications arise due to the interaction of these mesons with the nucleons and scalar meson within the model [4]. As the medium density is increased from $\rho = 0$ to ρ_0, the masses of vector mesons (K^{*+} and K^{*0}) are observed to decrease from their vacuum value. In chiral SU(3) model, the masses of Kaons (K^+ and K^0) are observed to increase as the medium density is increased. Moreover, the Lowest Landau level (LLL) contributions to the charged meson (K^{*+} and K^+) masses, in the presence of magnetic field, are also taken into account in this study. Therefore, the three polarization states ($S_z = 1, 0, -1$) of vector K^{*+} meson are no longer mass degenerate [5], since the energies for the pseudoscalar (P) and vector mesons (V) are given as

$$E_P(n=0, p_z) = \sqrt{m_P^2 + |eB| + p_z^2} \qquad (1)$$

$$E_V(n=0, p_z) = \sqrt{m_V^2 + p_z^2 + (1 + gS_z)|eB|} \qquad (2)$$

where g is the gyromagnetic ratio taken to be 2 (without considering the internal structure of the mesons). The effective masses after considering the lowest Landau level (n=0) contributions, are given by these energies at zero momentum in the z-direction ($p_z = 0$). Also, in the presence of magnetic field, there is mixing of pseudoscalar meson (P) and longitudinal part of vector meson ($V^{||}$). This pseudoscalar-vector (PV) mixing leads to a rise (drop) in the mass of $V^{||}(P)$ meson [5–7]. The mass modifications for the pseudoscalar pion (π), are not considered in this work.

The $^3P_0$ model

We investigate the in-medium decay widths for various decay channels of the decay $K^* \to K\pi$ in a $^3P_0$ model. In this model, a light quark-antiquark pair is assumed to be produced in the $^3P_0$ state. The quark (antiquark) of this produced pair combines with the antiquark (quark) of the parent meson, which is assumed to be at rest initially, to give the final state mesons. The wavefunctions for the produced $\bar{q}q$ pair are chosen to be simple harmonic oscillator (SHO) wavefunctions. The matrix element for the general decay $A \to BC$ in the $^3P_0$ model is given as

$$M_{A\to BC} = < A|\gamma[\bar{q}_s q_s]^{^3P_0}|BC > \qquad (3)$$

The coupling parameter γ_{K^*}, related to the probability of production of a quark-antiquark pair in the $^3P_0$ state, is fixed from the vacuum decay widths and vacuum masses for various

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decay channels separately. The vacuum decay widths for the decay channels ($K^{*+} \to K^+\pi^0$), ($K^{*+} \to K^0\pi^+$), ($K^{*0} \to K^0\pi^0$), and ($K^{*0} \to K^+\pi^-$) are taken to be 16.98, 33.77, 15.87, and 31.31 MeV respectively [8].

In-medium decay widths

We take into account the mass modifications of vector K^* and pseudoscalar K meson, to calculate the in-medium decay width for the decay ($K^* \to K\pi$), by using the $^3P_0$ model. In figure 1, the dashed (dotted) lines correspond to isospin symmetric nuclear matter (pure neutron matter). The effects of anomalous magnetic moments (AMMs) of the nucleons are also considered here. The qualitative behavior of decay width reflects the medium dependence of the masses of mesons involved. Due to PV mixing, the decay width of all decay channels is observed to increase due to an increase (decrease) in the mass of $V^{||}$ (P) meson, and this effect increases with magnetic field. The effects of Landau quantization are observed to be much more dominating than the PV mixing effects. This effect can also be seen from figure 1 that whenever a charged meson is involved in the decay channel, the decay widths are modified appreciably. The partial decay width of both the transverse components of K^{*0} meson, within a decay channel, will have the same modifications due to their similar mass modifications. The total decay width (Γ_{Total}) for the K^{*+} meson is observed to increase as the magnetic field is increased. The decay width splitting for the three polarization states of the K^{*+} meson is much more pronounced at higher magnetic fields. The present study of these open strange mesons (K^* and K) might have relevance in ultra-relativistic heavy ion collision experiments as well as in the study of certain astronomical objects, like the neutron stars, where huge magnetic fields are speculated to exist.

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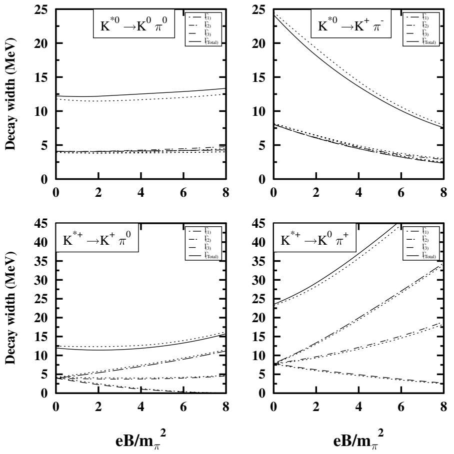

FIG. 1: The decay widths for various channels are plotted as a function of magnetic field eB (in terms of m_π^2) at nuclear matter saturation density (ρ_0). The subscripts (1,2,3) on Γ represent the partial decays of three polarisation states of vector K^* meson with $S_z = (+1, 0, -1)$.

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