Kaons and Antikaons in Multi-Phase Transport Model

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Abstract

We investigate the impact of medium modifications of kaons and antikaons on their rapidity distribution and production ratio using A Multi-Phase transport (AMPT) model. The medium modified masses of kaons and antikaons, which are used as input in AMPT model, are calculated using the chiral SU(3) mean field model. Within chiral SU(3) model along with the Weinberg Tomozawa term, the contribution of explicit symmetry breaking term and three range terms is incorporated to study their impact on the above listed experimental observables. The repulsive contribution to the masses of meson from the Weinberg term and one range term dominate over the attractive contribution from explicit symmetry breaking as well as other two range terms. For the K- meson repulsive contribution comes from first range terms only whereas all other terms have attractive contribution. Considering all these features from chiral effective model on properties of K^+ and K^- mesons, we explore the rapidity distributions in of kaons and antikaons.

Introduction

Experimental properties of kaons and antikaons have been studied using AMPT-A Multi-Phase Transport Model for heavy-ion collisions [1]. It consists of four main components: the initial conditions (obtained from HIJING model), partonic interactions(modeled by Zhang's parton cascade (ZPC)), the conversion from the partonic to the hadronic matter (quark coalescence model is used in String Melting and Default version is based on Lund string fragmentation model), and hadronic interactions (described by ART model which includes baryon-baryon, baryon-meson, and meson-meson elastic and inelastic scatterings). We have used the string melting version to analyze Au-Au collisions with values 2.28 fm^{-1} of parton screening mass, strong coupling constant α_s=0.47 at center of mass energies $\sqrt{s}_{nn}$=7.7, 11.5, 19.6 GeV. We have compared the rapidity distributions of K^+ and K^- in absence and presence of a mean field, incorporated using Chiral SU(3) model.

The Chiral SU(3) Model

The Lagrangian for Chiral model is given as [4]

$$\mathrm{L_{chiral}} = \mathcal{L}_{\mathrm{kin}} + \Sigma_{M=S,V}\,\mathcal{L}_{BM} + \mathcal{L}_{vec} + \mathcal{L}_0 + \mathcal{L}_{SB}.$$

The model includes the baryon-meson interactions based on trace anomaly and non-linear realization of chiral symmetry. The self-energy of kaons and antiakons is modified by scalar and vector densities of baryons which are modified due to scalar and vector fields. We have obtained the dispersion relation by doing the Fourier transform of interaction Lagrangian of K^+ and K^- as

$$-\omega^2 + \vec{k}^2 + m^2_{K(\bar{K})} - \Pi^*(\omega, |\vec{k}|) = 0.$$

where Π^* symbolize the in-medium self-energy of kaons [3] and is given by [2]

$$\Pi^*_K(\omega, |\bar{k}|) = -\tfrac{1}{4f_K^2}[3(\rho_p^v+\rho_n^v \pm (\rho_p^v - p_n^v)]\omega + \tfrac{d_1}{2f_K^2}(\rho_s^p + \rho_s^n) \pm (\rho_p^s - \rho_n^s)) + \tfrac{d_2}{4f_K^2}((\rho_p^s+\rho_n^s) \pm (\rho_p^s - \rho_n^s))(\omega^2 - \vec{k}^2).$$

where the $\pm$ sign gives the self energy for K^+ and K^0 respectively, and for antikaons it is

$$\Pi^*_K(\omega, |\bar{k}|) = \tfrac{1}{4f_K^2}[3(\rho_p^v+\rho_n^v \pm (\rho_p^v - p_n^v)]\omega + \tfrac{d_1}{2f_K^2}(\rho_s^p + \rho_s^n) \pm (\rho_p^s - \rho_n^s)) + \tfrac{d_2}{4f_K^2}((\rho_p^s+\rho_n^s) \pm (\rho_p^s - \rho_n^s))(\omega^2 - \vec{k}^2).$$

where the $\pm$ sign gives the self energy for K^- and $\bar{K}^0$ respectively. In this calculation,we assume the matter to be symmetric and contribution of fields in self energy expression is neglected. The value of m_k=494 MeV, f_k=122.14 MeV, $d_1 = 2.56/m_k$ and $d_2 = 0.73/m_k$ is considered.Weinberg-Tomozawa term is obtained from kinetic energy term of the interaction. The output of AMPT have been analyzed to obtain rapidity distributions for kaons and antiakons in medium modified potential. In future work, we aim to include contribution of all hyperons, in Weinberg Tomozawa term, also the contribution of fields will be considered to study the splitting of elliptical flow and other experimental observables.The rapidity distributions and flow serve as an powerful probe to study effects of in-medium potentials.

Results and Discussions

We have plotted K^+/K^- vs rapidity at center of mass energies 7.7, 11.5, 19.6 at parton screening cross-section of 6 mb

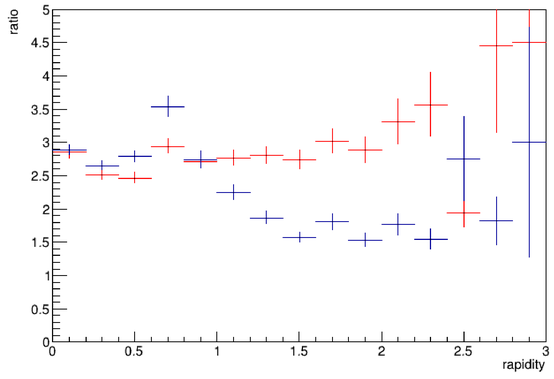

Figure 1:7.7GeV

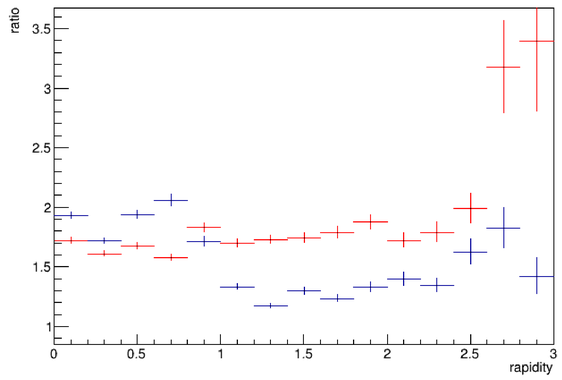

Figure 2:11.5GeV

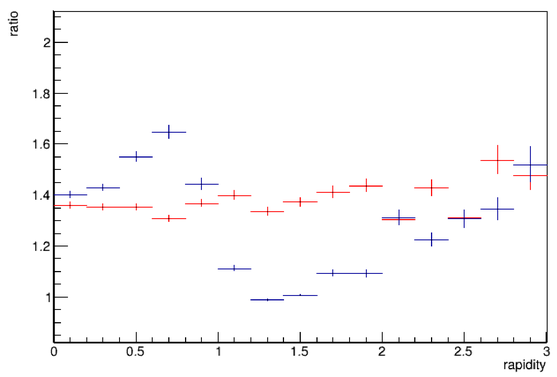

Figure 3:19.6GeV

with potential

without potential

- We observe that presence of mean field makes kaons less energetic and hence a drop in K^+/K^- observed at mid rapidity.
- The rapidity distributions changes very slightly as the center of mass energy rises.
- In future we plan to incorporate full chiral model to study elliptical flow splitting and other experimental observables.

Summary

- We find that due to effective potential of kaons and antiakons there is a subsatnial drop in ratio of K^+/K^- in mid rapidity region.
- As energy is increased beyond 20 GeV there is no significant change observed in rapidity distribution.

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References

[1] Lin, Zi-Wei, arXiv:nucl-th/**0411110**, (2005).

[2] Philip Rau, arXiv:**1306.3352v1**, (2013).

[3] Rajesh Kumar and Arvind Kumar, arXiv:**2005.05133v1**, (2020).

[4] Zschiesche, D., Nuclear Physics A,**0375 – 9474**, (2000)

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