Universal Parameterization of In-Medium Dilepton Emission Rates

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Abstract/Motivation

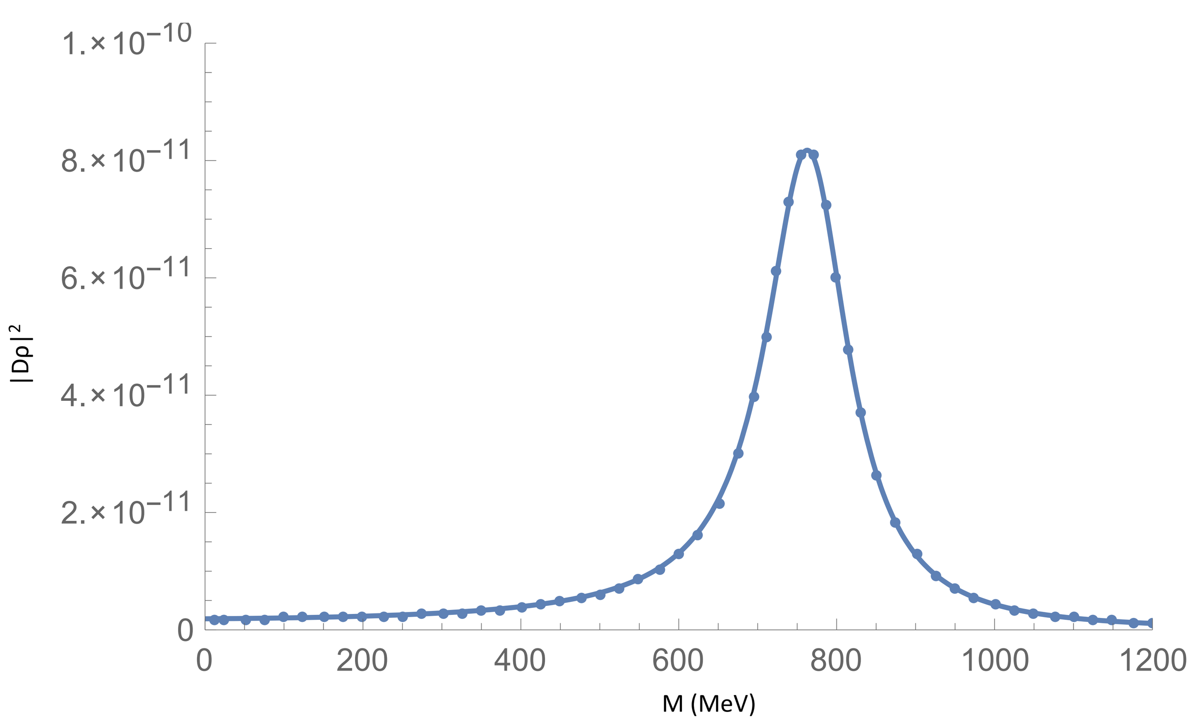
Dilepton emission from strongly-interacting matter is a key source of information about the evolution of strongly interacting matter produced in heavy-ion collisions (HIC). However, the calculations of dilepton emission rates from first principles are usually rather involved, and therefore not typically accessible for application in HIC evolution models for comparison with experiment. Thus, an accurate parameterization for these rates would be invaluable for the development of the theory behind the dilepton spectra. In this work, such a parameterization was produced for emission of dileptons by in-medium ρ mesons. This was achieved by first producing a parameterization for the in-medium ρ meson propagator that included contributions to the ρ meson self-energy from ππ resonances. Contributions from in-medium meson interactions and baryon interactions were then included. These parameterizations were generated for ρ meson invariant masses from 0 to 1600 MeV and momenta from 0 to 5000 MeV, at temperatures ranging from 100 to 180 MeV.

Background

The quark-gluon plasma is an exotic phase of strongly-interacting matter only recently available for study in a laboratory setting. This phase of matter is produced in high energy heavy-ion collisions and exists only in the early stages of the collision. To compare theoretical models to experimental data, "fireball" models of heavy ion collisions are used.

One key observable from the HICs is the emission of dileptons. These can provide information about the early stages of the fireball, as they do not re-interact with the medium after they are produced. Inclusion of these emissions in theoretical simulations is therefore highly useful. However, due to the complexity of the calculation of in-medium emission rates, a parameterization is necessary.

This Work



First, a parameterization of the vacuum ρ meson propagator was made using the ansatz:

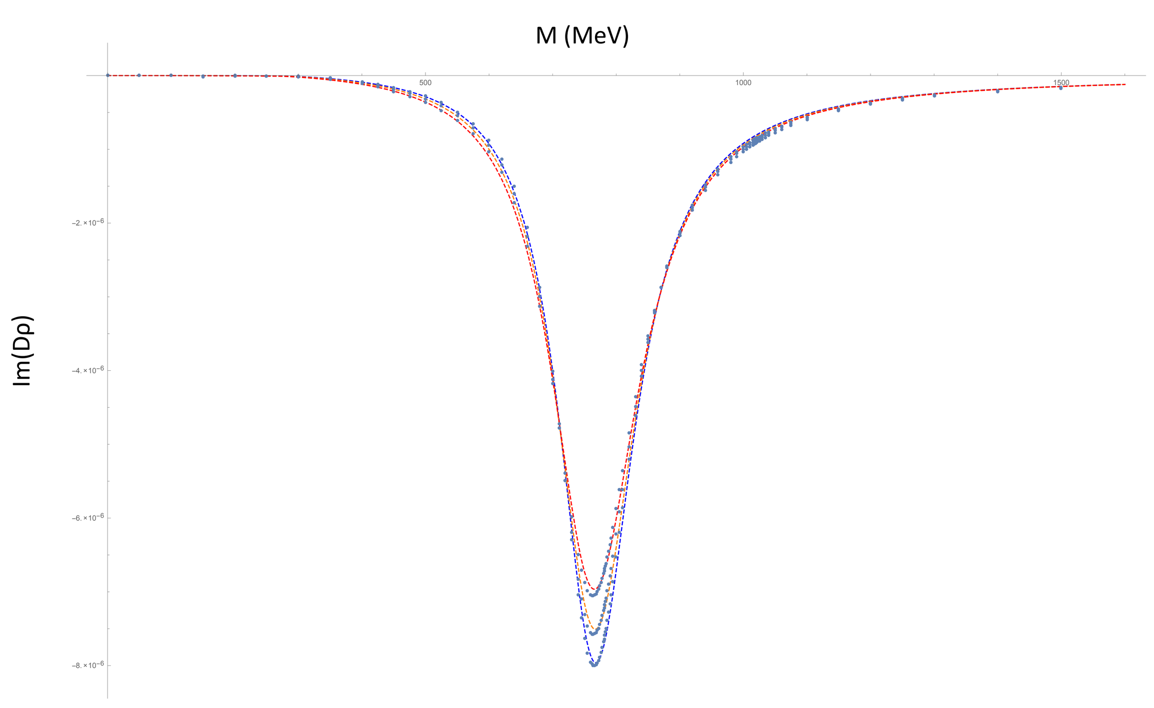
$$D_\rho = \frac{1}{M^2 - m_\rho^{0\,2} - \Sigma_\rho^{vac}}$$

with

$$m_\rho^0 = 853\ MeV \qquad \Sigma_\rho^{vac} = -aM - \frac{g_\rho^2}{6\pi}\frac{\left(\frac{1}{4}M^2 - m_\pi{}^2\right)^{\frac{3}{2}}}{M}i$$

The best fit was found when:

$$\begin{cases} a = 162 \\ g_\rho = 5.86 \end{cases}$$



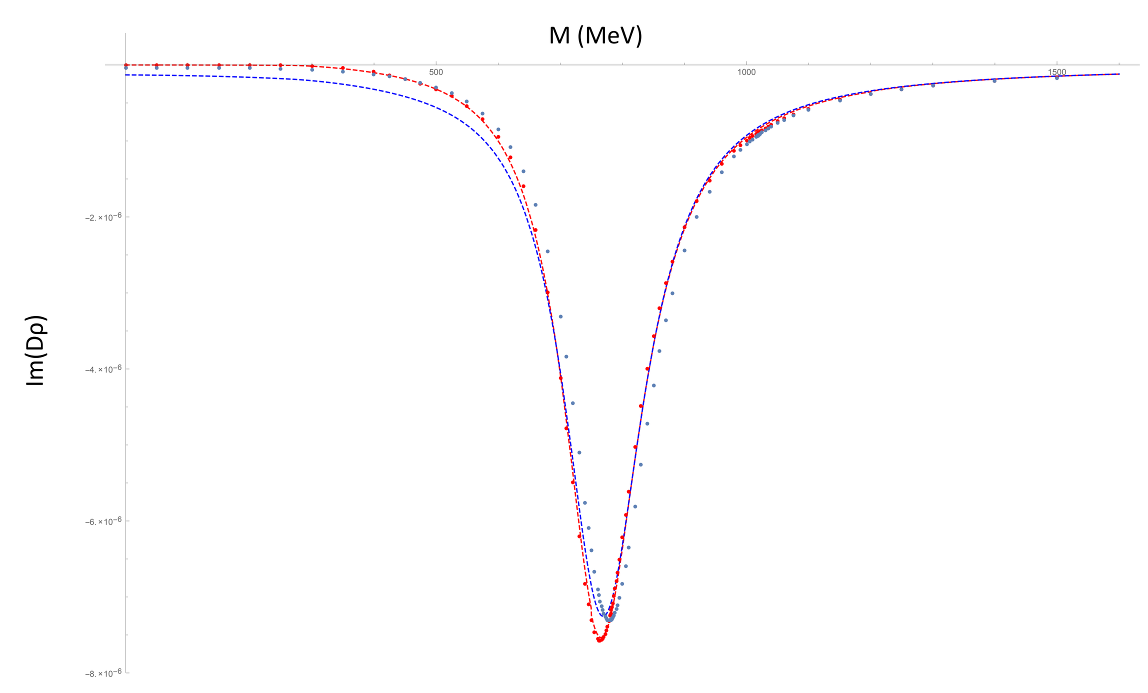
Next, a contribution to the self energy from scattering interactions with in-medium mesons was included:

$$D_\rho = \frac{1}{M^2 - m_\rho^{0\,2} - \Sigma_\rho^{vac} - \Sigma_\rho^{mes}}$$

$$Re(\Sigma_\rho^{mes}) = \begin{cases} m_\rho\left(\frac{T}{T_0}\right)^\alpha(-10) & M < 750 \\ m_\rho\left(\frac{T}{T_0}\right)^\alpha\left(\frac{M-850}{10}\right) & 750 < M < 1200 \\ m_\rho\left(\frac{T}{T_0}\right)^\alpha(35) & M > 1200 \end{cases}$$

$$Im(\Sigma_\rho^{mes}) = -m_\rho\left(\frac{T}{T_0}\right)^\alpha \gamma_0\left(\frac{M+100}{1300}\right)^4\left(\frac{\Lambda_M^2 + (770\ MeV)^2}{\Lambda_M^2 + M^2}\right)^{12} \stackrel{\text{def}}{=} -m_\rho\left(\frac{T}{T_0}\right)^\alpha \gamma_1$$

$$\begin{cases} \alpha = 5 \\ T_0 = 158\ MeV \quad \gamma_0 = 431\ MeV \\ \Lambda_M = 2000\ MeV \end{cases}$$



An attempt was made to include the momentum dependence of the self-energy by modifying the ansatz:

$$Im(\Sigma_\rho^{mes}) = -m_\rho\left(\frac{T}{T_0}\right)^\alpha\left(\gamma_1 + \left(\frac{q}{145}\right)^2\left(\frac{\Lambda_q^2 + (770\ MeV)^2}{\Lambda_q^2 + q^2}\right)^2 \frac{1}{1 + 25\left(\frac{M}{1000}\right)^6}\right)$$

However, this did not successfully fit the complex temperature and mass-dependent structure of the self-energy's momentum dependence. Further attempts have been made, but none so far have resulted in a desirable fit.

Conclusions

A parameterization for the in-medium ρ meson propagator was made which accurately reproduces calculated values (within 10%) for zero momentum at temperatures ranging from 100 to 130 MeV, where contributions to the ρ self-energy from meson interactions dominate. An attempt was made to extend the parameterization to nonzero momentum; however, a parameterization of the 3-momentum dependence has not yet been achieved.

Future Plans

In the future, this parameterization should be modified to extend to nonzero momentum. It should also be extended to higher temperature and nonzero baryon density by including a contribution to the ρ self-energy from baryon interactions.

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