Developing a Universal Parameterization of Dilepton Emission Rates

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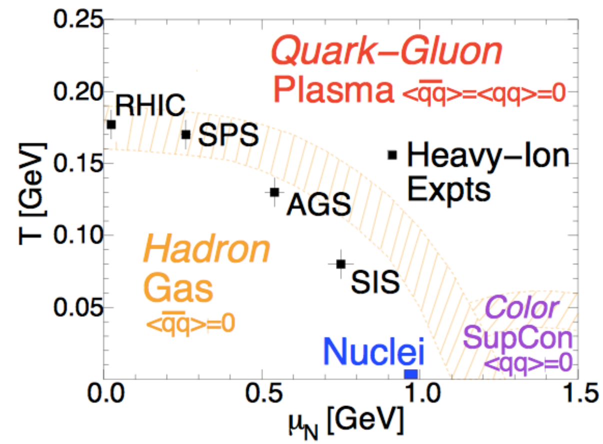
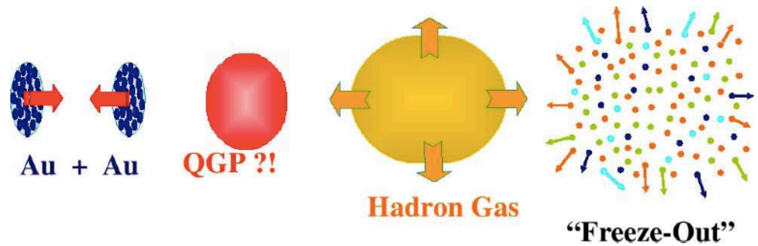
Background

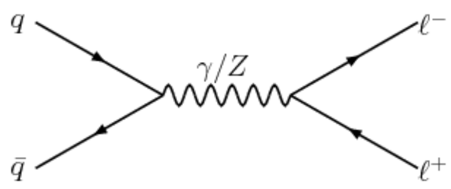
- The Quark-Gluon Plasma
  - A phase of exotic, strongly-interacting matter
  - Deconfinement of quarks/restoration of chiral symmetry
  - Only recently available for study in heavy ion collisions





Motivation

- Theory is tested using "fireball" evolution models of heavy ion collisions (HICs)
- Dilepton emissions provide information about the early stages of the collision



- The complexity of calculating in-medium emission rates limits implementation of these into HIC models

Previous Work

- Work by one of Dr. Rapp's previous REU students resulted in a parameterization of photon emission rates
- Photons are also a good probe of HICs, as they also do not re-interact with the medium
- There are differences that make the method used previously inapplicable to dilepton rates

This Work

- In order to parameterize the complicated resonance structure of the dilepton emission rates, a physically motivated ansatz must be used
- First, a parameterization for the in-medium ρ propagator was to be made
- The propagator is then easily related to the dilepton emission rate via the ρ spectral function

The Vacuum Propagator

- First, a parameterization for the vacuum ρ propagator was achieved using the ansatz:

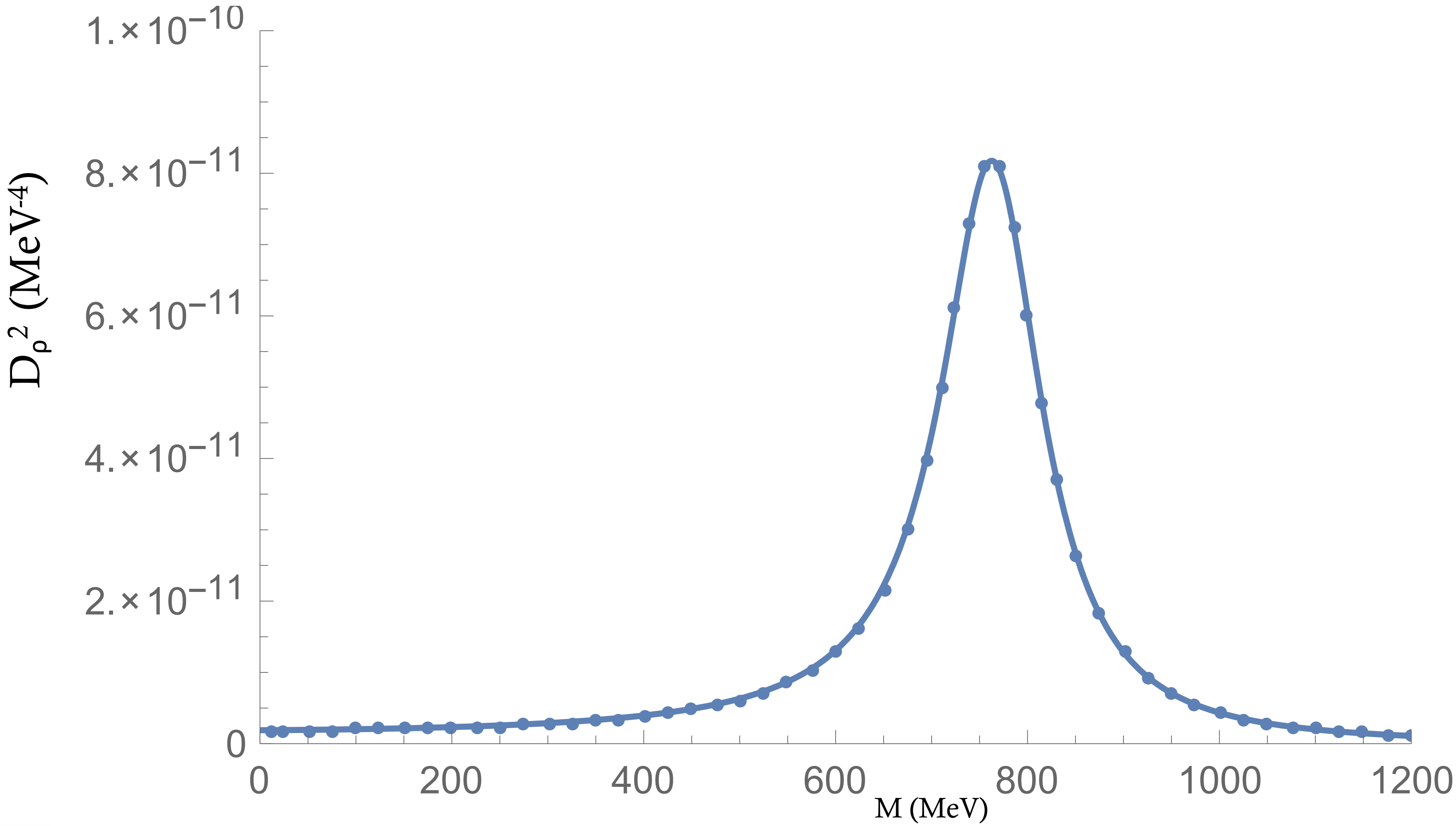
$$D_\rho = \frac{1}{M^2 - {m_\rho^0}^2 - \Sigma_\rho^{vac}} \qquad m_\rho^0 = 853\ MeV$$

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

- The fit was achieved when:

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

The Vacuum Propagator



Meson Interaction Contribution

- Next, a contribution to the ρ self-energy due to interactions with in-medium mesons was added

- This extended to the parameterization to nonzero T, but only T where meson interactions dominated (T~100-130 MeV)

Meson Interaction Contribution

- This contribution was parameterized using the ansatz:

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

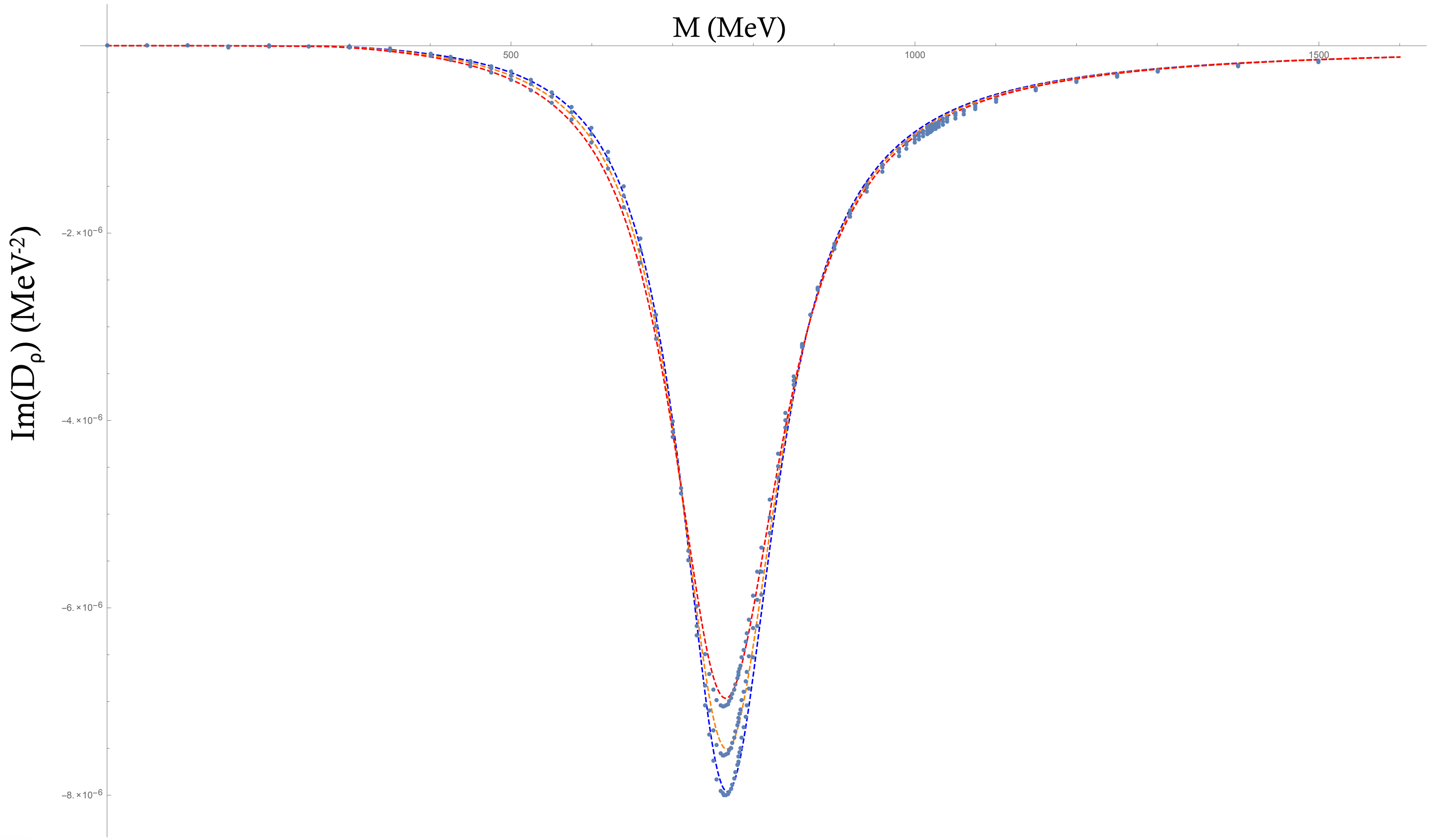
$$Re\left(\Sigma_\rho^{mes}\right) = \begin{cases} m_\rho \left(\frac{T}{T_0}\right)^\alpha (-10) & M < 750 \\ m_\rho \left(\frac{T}{T_0}\right)^\alpha \left(\frac{M - 850}{10}\right) & 750 < M < 1200 \\ m_\rho \left(\frac{T}{T_0}\right)^\alpha (35) & M > 1200 \end{cases}$$

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

- The best fit was achieved by using:

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

Meson Interaction Contribution



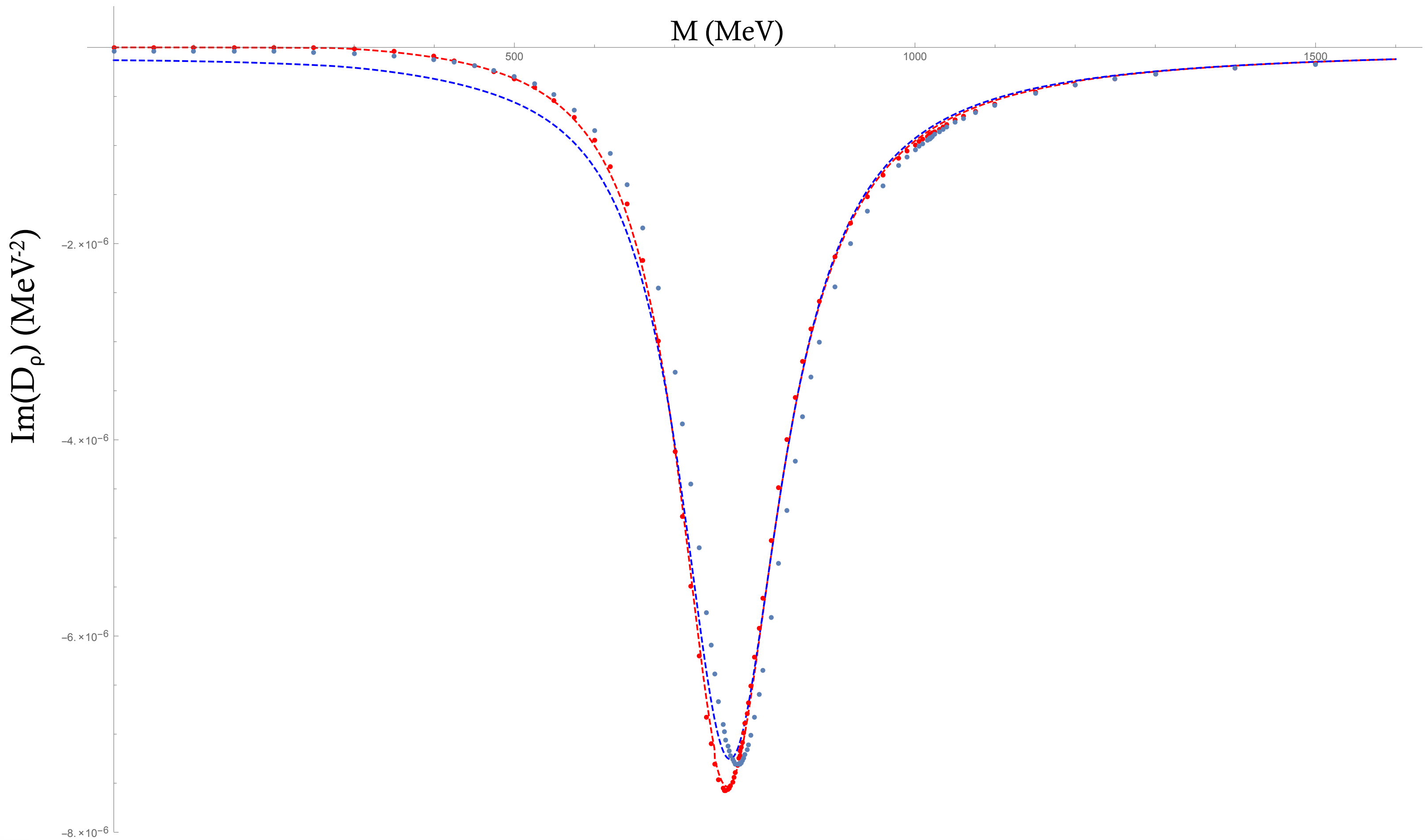
Momentum Dependence

- An attempt was made to extend the parameterization to nonzero momentum using the ansatz:

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

- A successful parameterization could not be achieved

Momentum Dependence



Momentum Dependence

- Further attempts were made to improve the momentum dependence of the parameterization
- None so far have resulted in a desirable fit

Conclusion

- A parameterization for the zero-momentum in-medium ρ meson propagator was achieved for invariant masses M ~ 0-1600 MeV and temperatures T ~ 0-130 MeV
- Attempts to extend the parameterization to nonzero momentum have thus far been unfruitful

Future Plans

- The parameterization must be extended to nonzero momentum
- With this accomplished, it should then be extended to nonzero baryon density (and equivalently, higher temperature)
- Once a good parameterization has been achieved, it should be related to the dilepton emission rates to be used in HIC models

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