Contribution of ρ–Mesons to Charge Fluctuations

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One major goal in heavy ion collisions is to produce evidence of the quark gluon plasma (QGP). A possible signature are reduced charge fluctuations due to the fractional charge of the quarks in the QGP. In the hadronic phase fluctuations may be screened or enhanced by hadronic interaction. Using an effective Lagrangian based on vector dominance, we calculate the charge fluctuations up to second order in a hot pion gas applying finite temperature field theory.

The observable sensitive to fractional charge is the ratio of charge fluctuations and the charge multiplicity [1]

$$\frac{\langle \delta Q^2 \rangle}{\langle N_{ch} \rangle}. \tag{1}$$

Since $\langle \delta Q^2 \rangle \sim q^2 \langle N_{ch} \rangle$, this quantity is sensitive to the squared charge q^2 and enhances the 1/3–charge effect of a QGP in contrast to a purely hadronic initial state with $|q| = 1$. We can compute the mean number of particles by assuming entropy conservation and exploiting $S \sim \langle N_{ch} \rangle$. Charge fluctuations can be linked to finite temperature field theory by

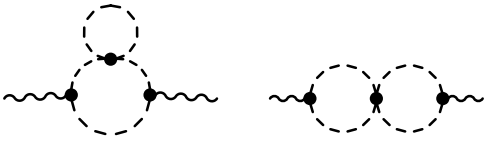
$$\langle \delta Q^2 \rangle = -VT\Pi^{00}(k_0 = 0, \mathbf{k} \to 0), \tag{2}$$

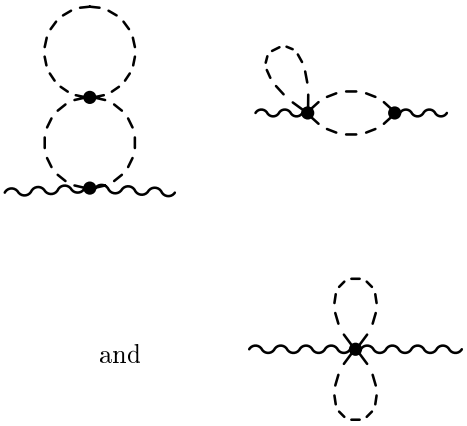
the photon self energy in the static limit.[2]

Assuming small momentum transfers in comparison with the ρ–mass of 770 MeV at the current temperature scale of 150 MeV, we use the effective Lagrangian

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}^2 - m_\pi^2|\phi|^2 + |D_\mu \phi|^2 - \frac{ig^2}{m_\rho^2}\left(\phi^\star \overset{\leftrightarrow}{D_\mu}\, \phi\right)^2 \tag{3}$$

with the ρ–resonance removed from the heatbath. This Lagrangian originates from the $\rho\pi\pi$ interaction in second order. Two 3–vertices are combined to a direct 4–vertex with derivative couplings containing the universal strong coupling constant $g \sim 6$. The Lagrangian is then gauged in the canonical way, leading to a set of couplings to the electromagnetic current by the covariant derivative $D_\mu = \partial_\mu + ieA_\mu$. Based on this Lagrangian, we investigate the first order corrections to the self energy in the order e^2g^2. In the imaginary time formalism this leads to the set of diagrams





(4)

involving pions and photons. We have verified that this class of diagrams satisfies the Ward–Takahashi identity. Carrying out the Matsubara summation by contour integration we get the correction as depicted in Fig. 1 ($\sigma = S/V$)

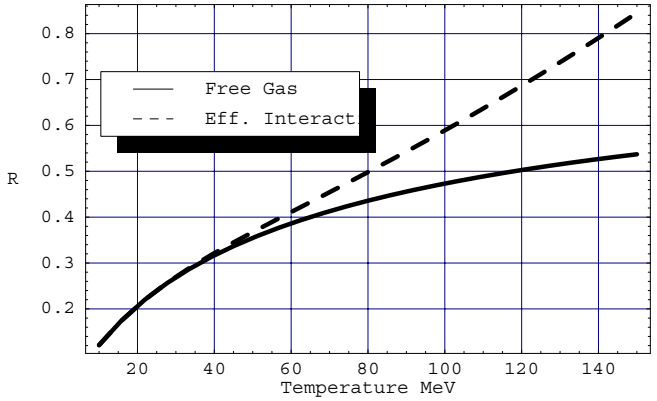


Figure 1: Correction to Charge Fluctuations per Entropy Density, $R = -VT\Pi^{00}_{0+1}(k_0 = 0, \mathbf{k} \to 0)(T)/\sigma_{0+1}(T)$, assuming effective ρ–interaction at the 2 loop level

We find that the effective interaction increases the charge fluctuations of the free pion gas. Both curves show the expected low temperature behaviour.

References

[1] S. Jeon, V. Koch, Phys.Rev.Lett.**85**:2076-2079,2000
[2] J.I. Kapusta, *Finite Temperature Field Theory*, Cambridge 1989