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ANOMLOUS ENHANCEMENT OF DILEPTON PRODUCTION DUE TO DIQUARK FLUCTUATION IN DENSE QUARK MATTER

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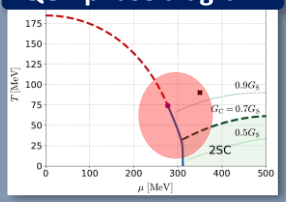
arXiv:2201.01963 (2022)

Color superconductivity (CSC)

- Induced by **diquark condensation**
- **Low-temperature** & **High-density**
- **Difficult to observe** in experiments

QCD phase diagram



Experiments for dense region with high statistics!

Heavy Ion Collisions

Two problems exist in observing CSC in HIC.

I. T of the system produced by HIC is **high**.
II. CSC may be realized only in the **early stage**.

We focus on two objects.

I. Soft modes due to diquark fluctuations
II. Dilepton production rate (DPR)

We calculate the effects of soft modes due to diquark fluctuations on DPR.

2-flavor NJL model

$$\mathcal{L} = \bar{\psi} i \partial \psi + \mathcal{L}_S + \mathcal{L}_C$$

$$\mathcal{L}_S = G_S[(\bar{\psi}\psi)^2 + (\bar{\psi} i\gamma_5 \tau \psi)^2]$$

$$\mathcal{L}_C = G_C(\bar{\psi} i\gamma_5 \tau_2 \lambda_A \psi^C)(\bar{\psi}^C i\gamma_5 \tau_2 \lambda_A \psi)$$

$$G_S = 5.01\text{MeV}, \Lambda = 650\text{MeV}$$

Kitazawa, Koide, Kunihiro, Nemoto (2002)

Soft modes

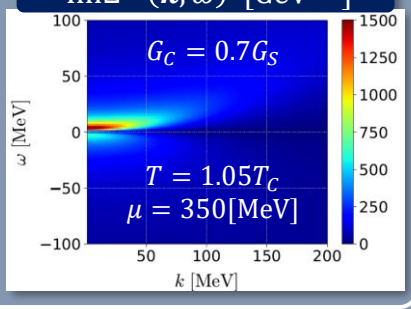
They develop **around T_C** of CSC.

$\Xi(k,\omega) =$

T-matrix approx.

Kitazawa, Koide, Kunihiro, Nemoto (2005)

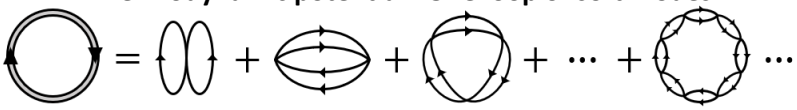
$\mathrm{Im}\Xi^R(k,\omega)$ [GeV^{-2}]



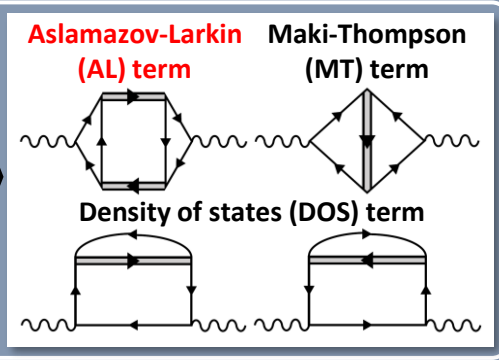
Photon self-energies : $\Pi^{\mu\nu}$

Two photons are attached to potentials

Thermodynamic potential : One loop of soft modes

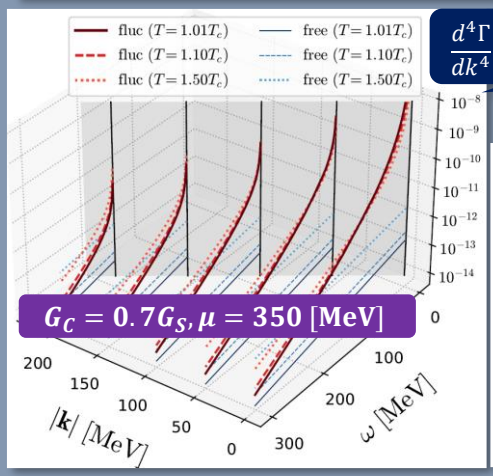


- They are known in condensed matter theory.
  : electric conductivity of metalicSC at $T > T_C$
- **Ward Identity of $\Pi^{\mu\nu}$** is satisfied by considering them.

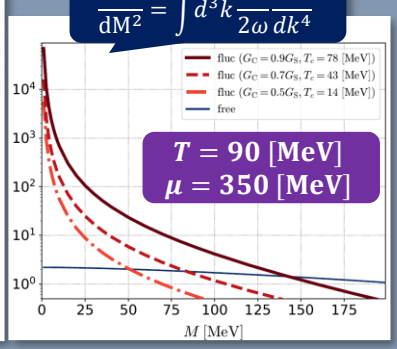


Results : Dilepton production rate (DPR)

$$\frac{d^4\Gamma}{dk^4} = \frac{\alpha}{12\pi^4}\frac{1}{k^2}\frac{1}{e^{\beta\omega}-1} g_{\mu\nu}\mathrm{Im}\,\Pi^{R\mu\nu}(k)$$



$$\frac{d\Gamma}{dM^2} = \int d^3k \frac{1}{2\omega}\frac{d^4\Gamma}{dk^4}$$



Summary

- We calculated the contribution of **"soft mode"** to the **"DPR"** to observe CSC at HIC.
- We considered **AL, MT** and **DOS** terms, which satisfy **W-I of $\Pi^{\mu\nu}$**.
- **Enhancement of DPR in low-M region** was observed.
- **The enhancement would be used for a signal of CSC in HIC!**