Real-time Gluon Spectral Function within FRG

Chuang Huang

Dalian University of Technology

第十八届全国中高能核物理大会, Changsha, June 21-25, 2019

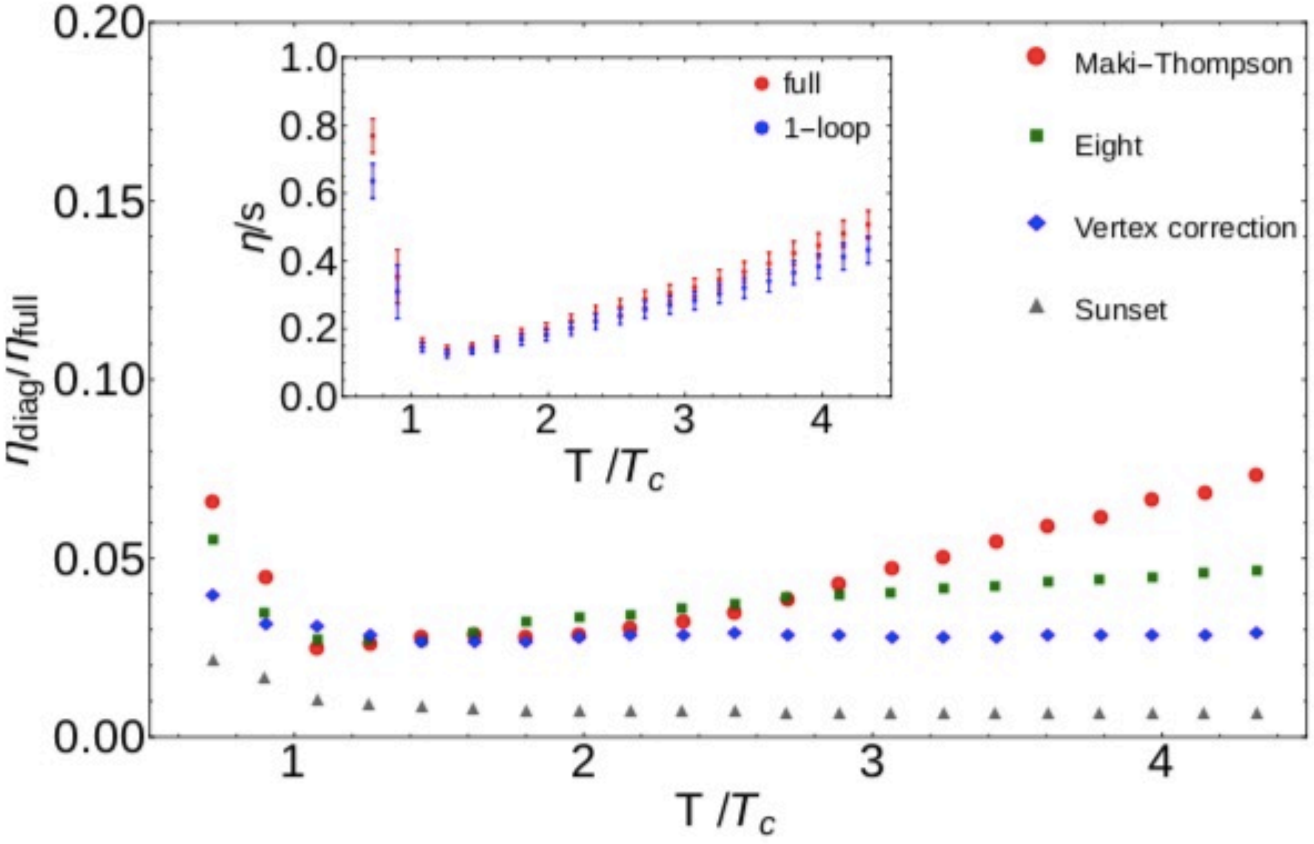
C.Huang ,W-j Fu.,in preparation

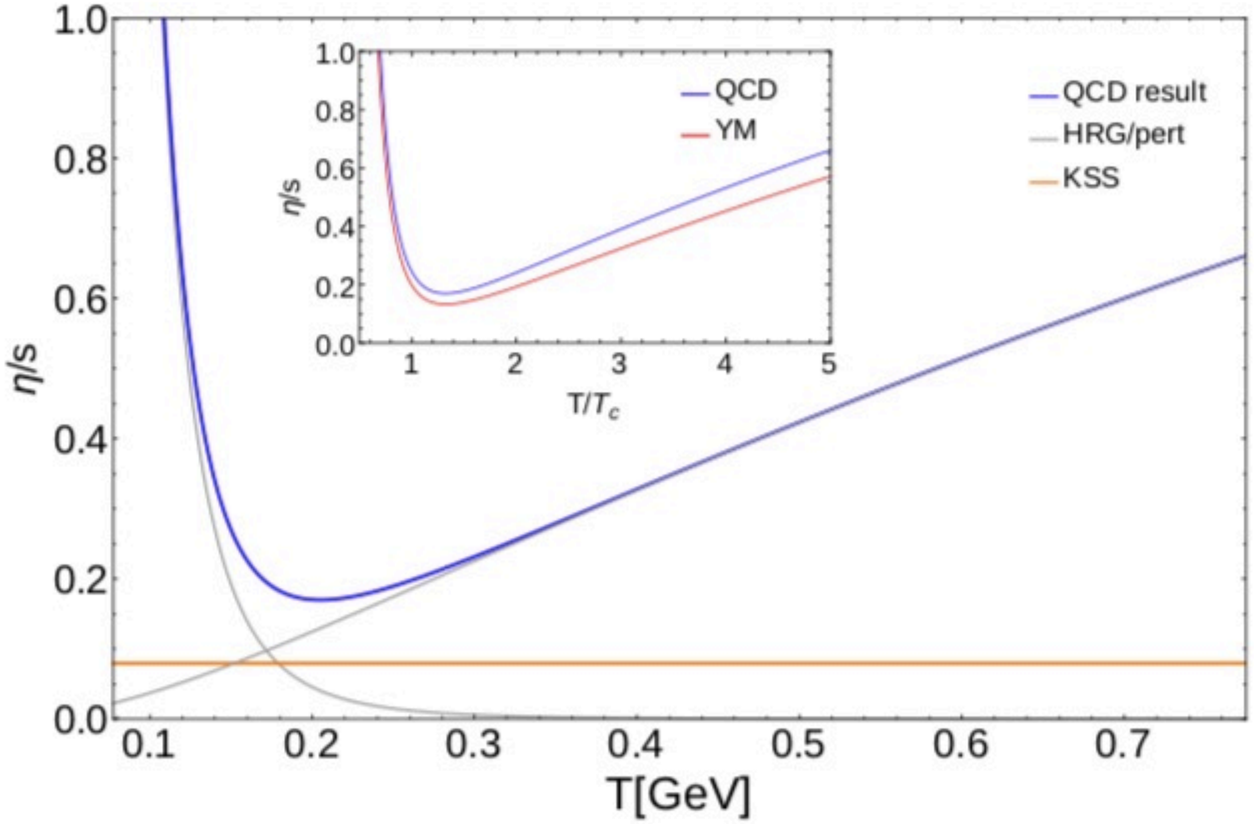
Outline

- Introduction
- Rebosonized-QCD action and the non-perturbative information
- Real-time gluon effective action and spectral function within FRG
- Some results under different temperature
- Summary and outlook

Introduction

$$\eta = \lim_{\omega \to 0} \frac{1}{20} \frac{\rho_{\pi\pi}(\omega, \vec{0})}{\omega}$$

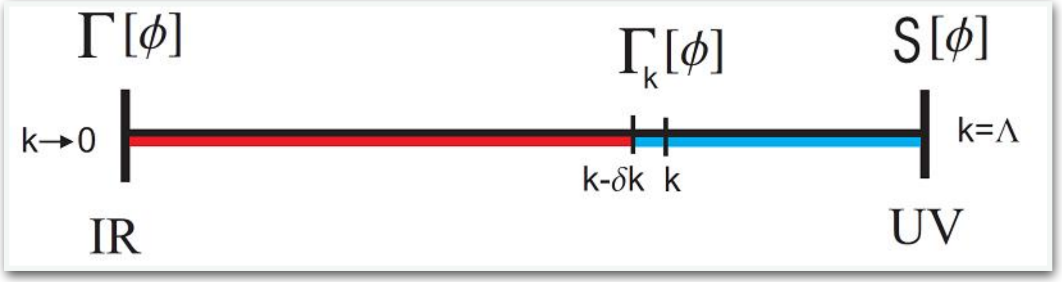




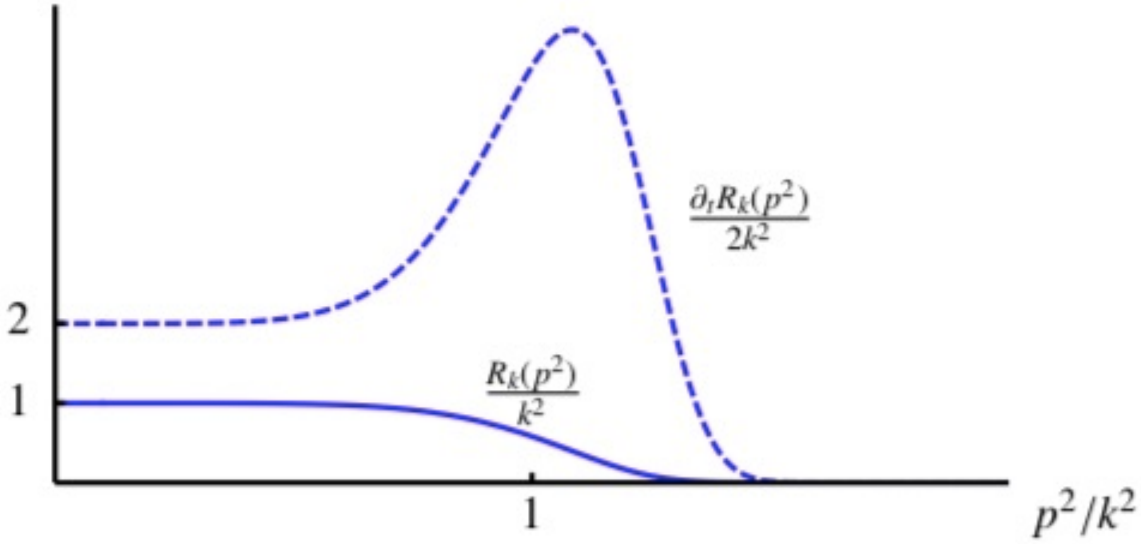
N.Christiansen et al.,PRL.115.112002(2015)

FRG method and Wetterich Equation

FRG



Regulator



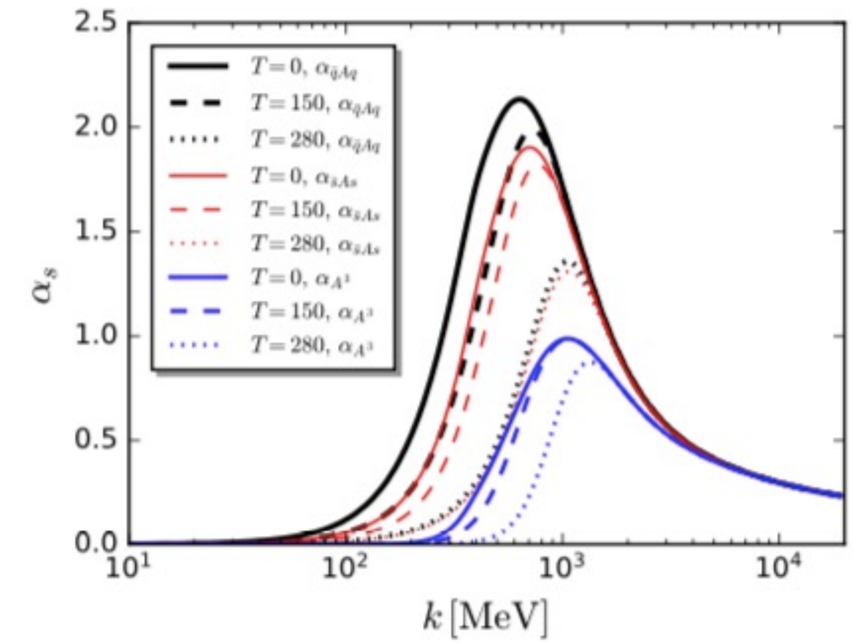
Wetterich Equation

$$\partial_t \Gamma_k[\phi] = \frac{1}{2} \mathrm{Tr} \frac{1}{\Gamma_k^{(2)}[\phi] + R_k} \partial_t R_k$$

Effective Model in Euclidean within FRG

ReBosonized-QCD action

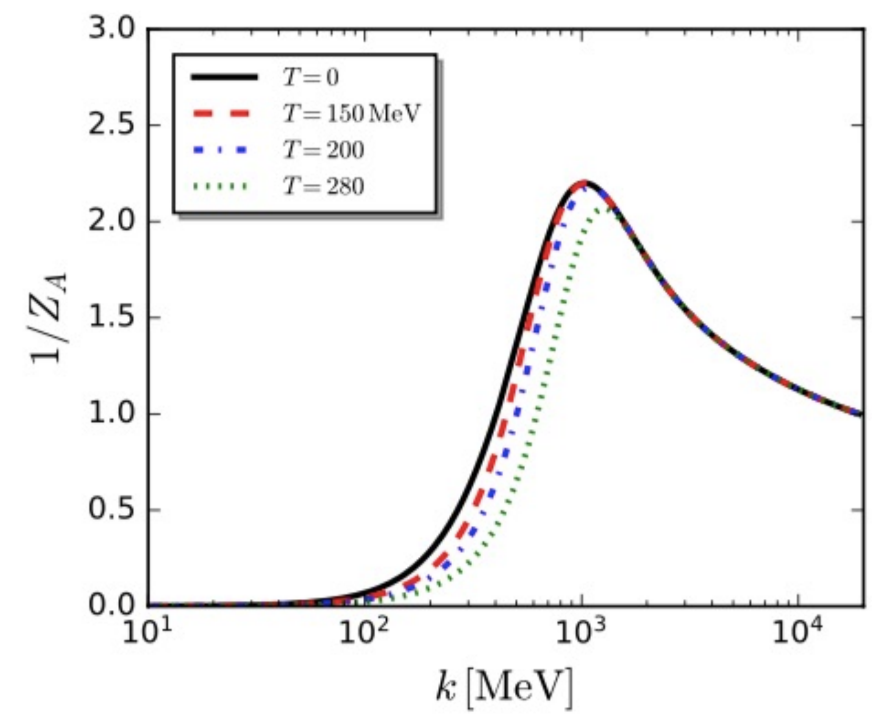
$$\Gamma_k = \int_x \Big\{ \frac{1}{4} F^a_{\mu\nu} F^a_{\mu\nu} + Z_c \left(\partial_\mu \bar{c}^a\right) D^{ab}_\mu c^b + \frac{1}{2\xi} \left(\partial_\mu A^a_\mu\right)^2$$
$$+ Z_q \bar{q} \left(\gamma_\mu D_\mu + m^s_0\right) q$$
$$- \lambda_q \left[\left(\bar{q}\tau^0 q\right)^2 + \left(\bar{q}\vec{\tau} q\right)^2 \right] + h_k \bar{q} \left(\tau^0 \sigma + \vec{\tau} \cdot \vec{\pi}\right) q$$
$$+ \frac{1}{2} Z_\phi \left(\partial_\mu \phi\right)^2 + V_k(\rho) - c_\sigma \sigma \Big\}$$



Anomalous dimensions and couplings

$$\eta_{A/q/c,k} = -\frac{\partial_t Z_{A/q/c,k}}{Z_{A/q/c,k}}$$

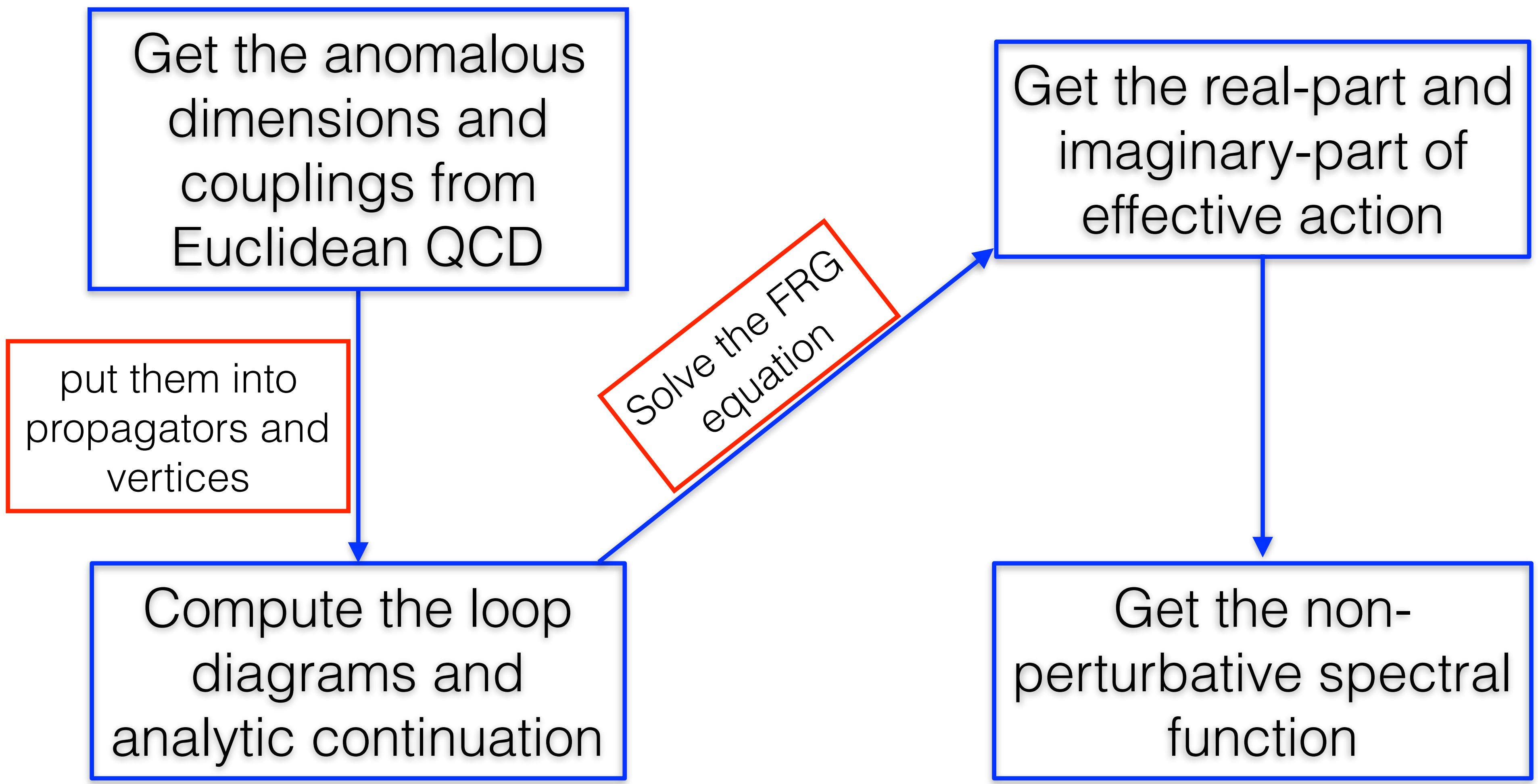
$$g^k_{3A} = g^k_{4A} \qquad g^k_{A\bar{q}q} = g^k_{A\bar{c}c}$$



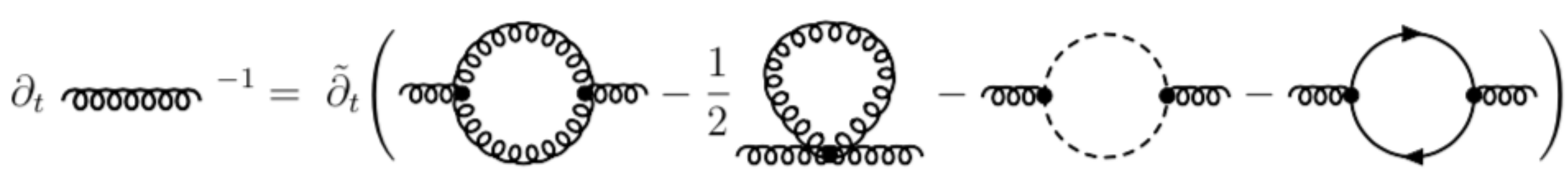
W-j Fu et al.,in preparation

Computation Steps and the Diagrams

Computation steps



Feynman diagrams



Some Definition and Mathematical Skills

Project operator

$$\Pi^M_{\mu\nu}(p) = \delta_{ij} - \frac{p_i p_j}{p^2}$$

$$\Pi^E_{\mu\nu}(p) = \delta_{\mu\nu} - \frac{p_\mu p_\nu}{p^2} - (\delta_{ij} - \frac{p_i p_j}{p^2})$$

3D regulator

$$R^{A/c}_k(p) = \vec{p}^2 r^{A/c}_k(\frac{\vec{p}^2}{k^2})$$

$$R^q_k(p) = (i\vec{p}\cdot\vec{\gamma}) r^q_k(\frac{\vec{p}^2}{k^2})$$

Where

$$r^{A/c}_k(\frac{\vec{p}^2}{k^2}) = \left[\frac{k^2}{(\vec{p})^2} - 1\right]\theta(1 - \frac{(\vec{p})^2}{k^2})$$

$$r^q_k(\frac{\vec{p}^2}{k^2}) = \left[\sqrt{\frac{k^2}{(\vec{p})^2}} - 1\right]\theta(1 - \frac{(\vec{p})^2}{k^2})$$

Scalar part of Propagators

$$G^k_q(\omega, \vec{p}) = \frac{1}{\omega^2 + (\vec{p})^2(1 + r^q_k(\frac{\vec{p}^2}{k^2}))^2}$$

$$G^k_{A/c}(\omega, \vec{p}) = \frac{1}{\omega^2 + (\vec{p})^2(1 + r^{A/c}_k(\frac{\vec{p}^2}{k^2}))}$$

Derivative of k

$$\partial_t q_F = \vec{q}\partial_t r_F = \vec{q}\cdot\left[(1 - \eta_{q,k})x^{-\frac{1}{2}} + \eta_{q,k}\right]$$

$$\partial_t G^k_q(p) = -2k^2(G^k_q(p))^2\left[(1 - \eta_{q,k}) + \eta_{q,k}x^{\frac{1}{2}}\right]\theta(1 - x)$$

$$\partial_t G^k_{A/c}(p) = -k^2(G^k_{A/c}(p))^2\left[(2 - \eta_{A/c,k}) + \eta_{A/c,k}x\right]\theta(1 - x)$$

Where $x = \vec{p}^2/k^2$

Analytic continuation

$$\omega \to -i\omega + \delta$$

Where the δ is a numerical finite number

Threshold Functions and Spectral Function

Threshold Function

For Boson-Boson

$$T\sum_n G_B^k\left(i\omega_n, E_1\right) G_B^k\left(i\left(\omega-\omega_n\right), E2\right) = -\frac{s_1 s_2}{4E_1 E_2}\frac{1+n_B\left(s_1 E_1\right)+n_B\left(s_2 E_2\right)}{i\omega - s_1 E_1 - s_2 E_2}$$

For Fermion-antifermion

$$T\sum_n G_F^k\left(i\omega_n, E_1\right) G_F^k\left(i\left(\omega-\omega_n\right), E2\right) = -\frac{s_1 s_2}{4E_1 E_2}\frac{1-n_F\left(s_1 E_1\right)-n_F\left(s_2 E_2\right)}{i\omega - s_1 E_1 - s_2 E_2}$$

Where $s = \pm 1$

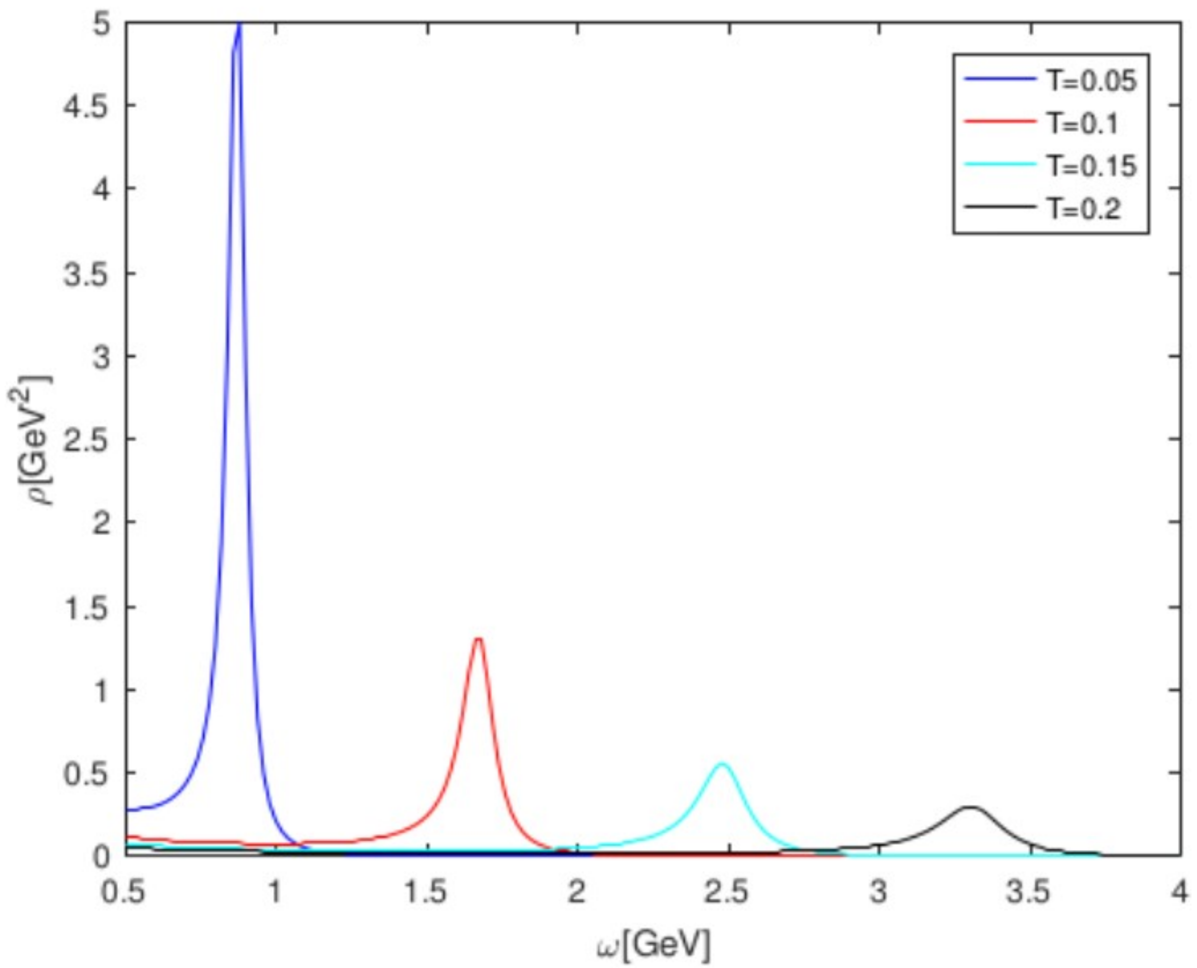
Spectral Function

$$\rho = \mathrm{Im} G(\omega + i\delta, \vec{p}) = -\frac{1}{\pi}\frac{\mathrm{Im}\,\Gamma_k}{\left(\mathrm{Im}\,\Gamma_k\right)^2 + \left(\mathrm{Re}\,\Gamma_k\right)^2}$$

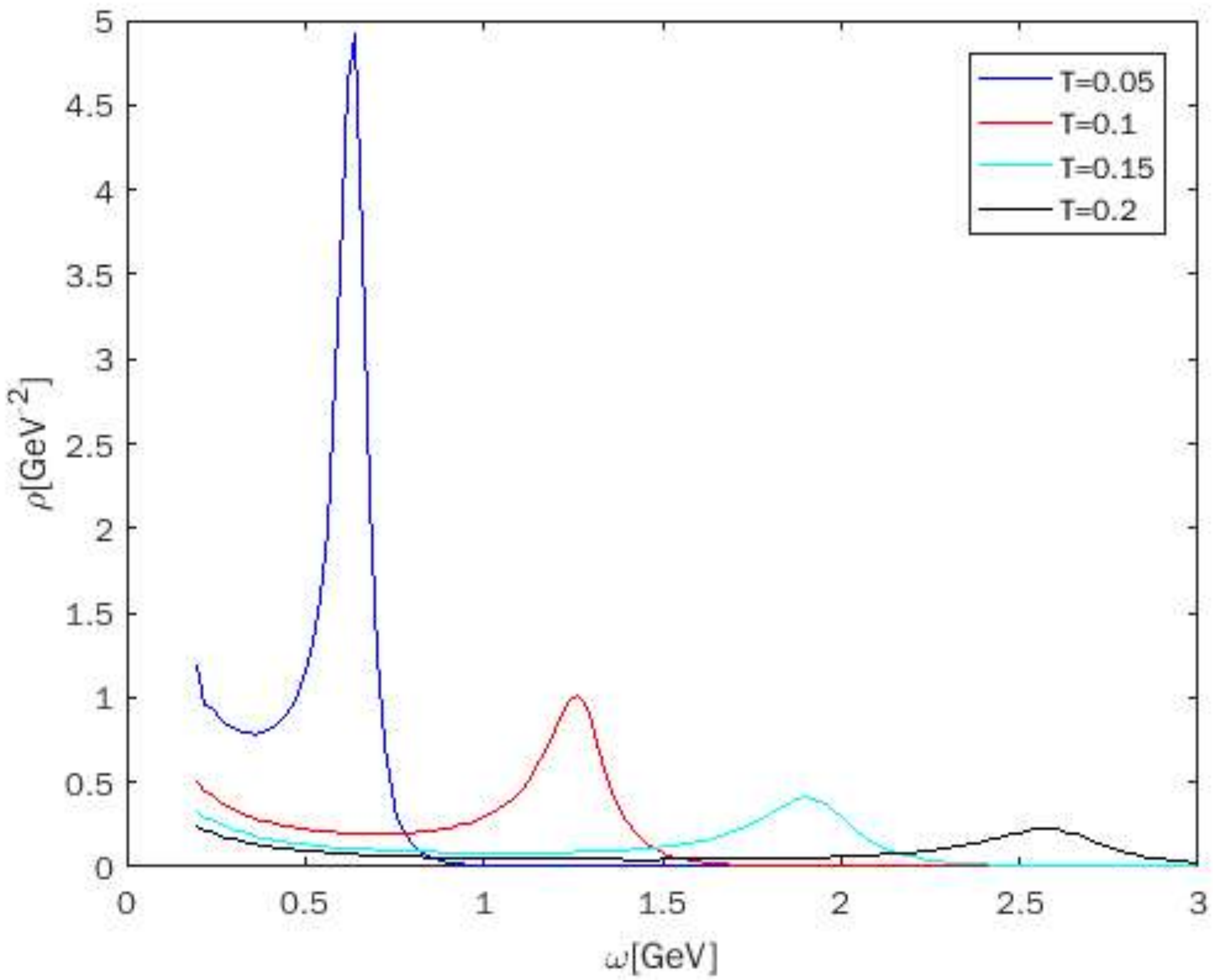
In our computation, let $\vec{p} = 0$

Perturbative Spectral Functions

Magnetic Part

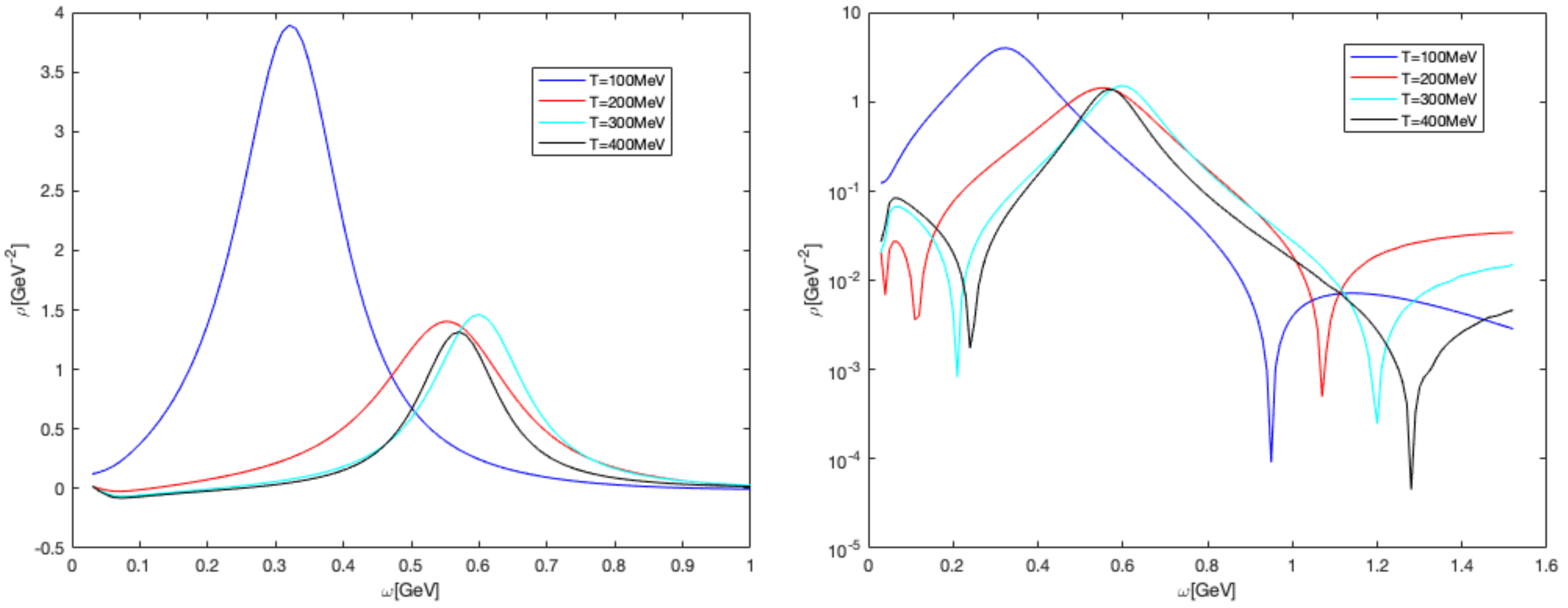


Electric Part



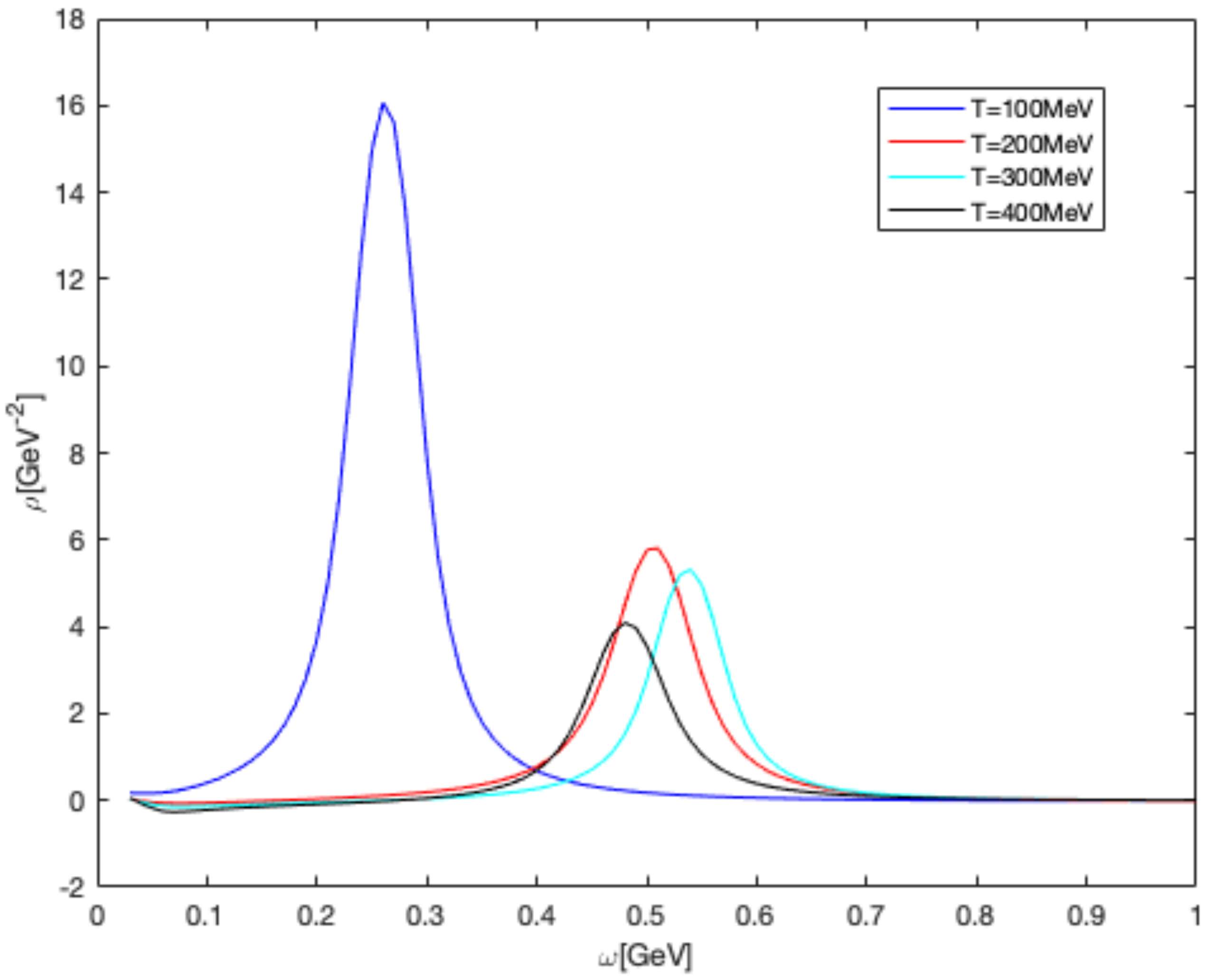
Non-perturbative Spectral Functions

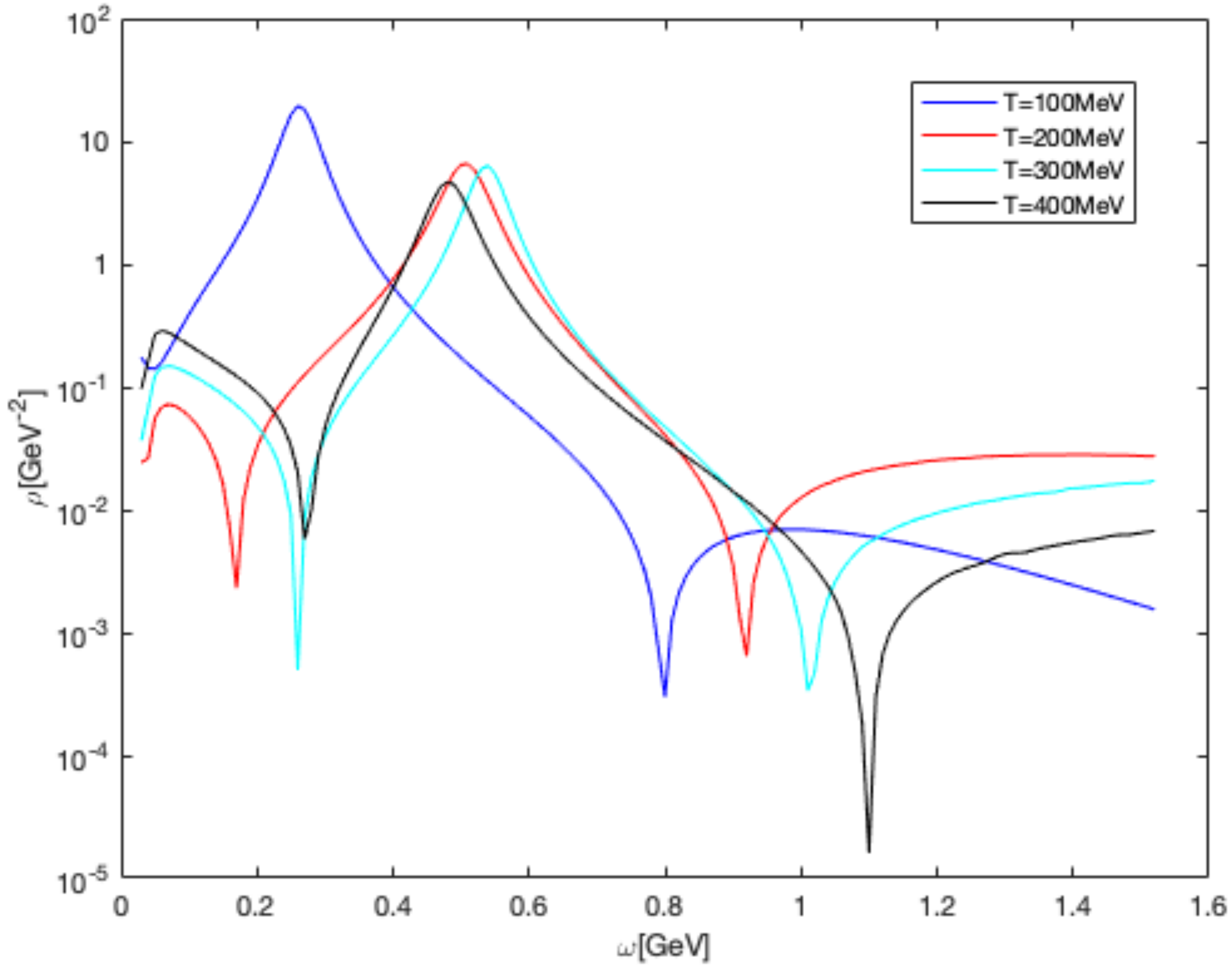
Magnetic Part



Non-perturbative Spectral Functions

Electric Part

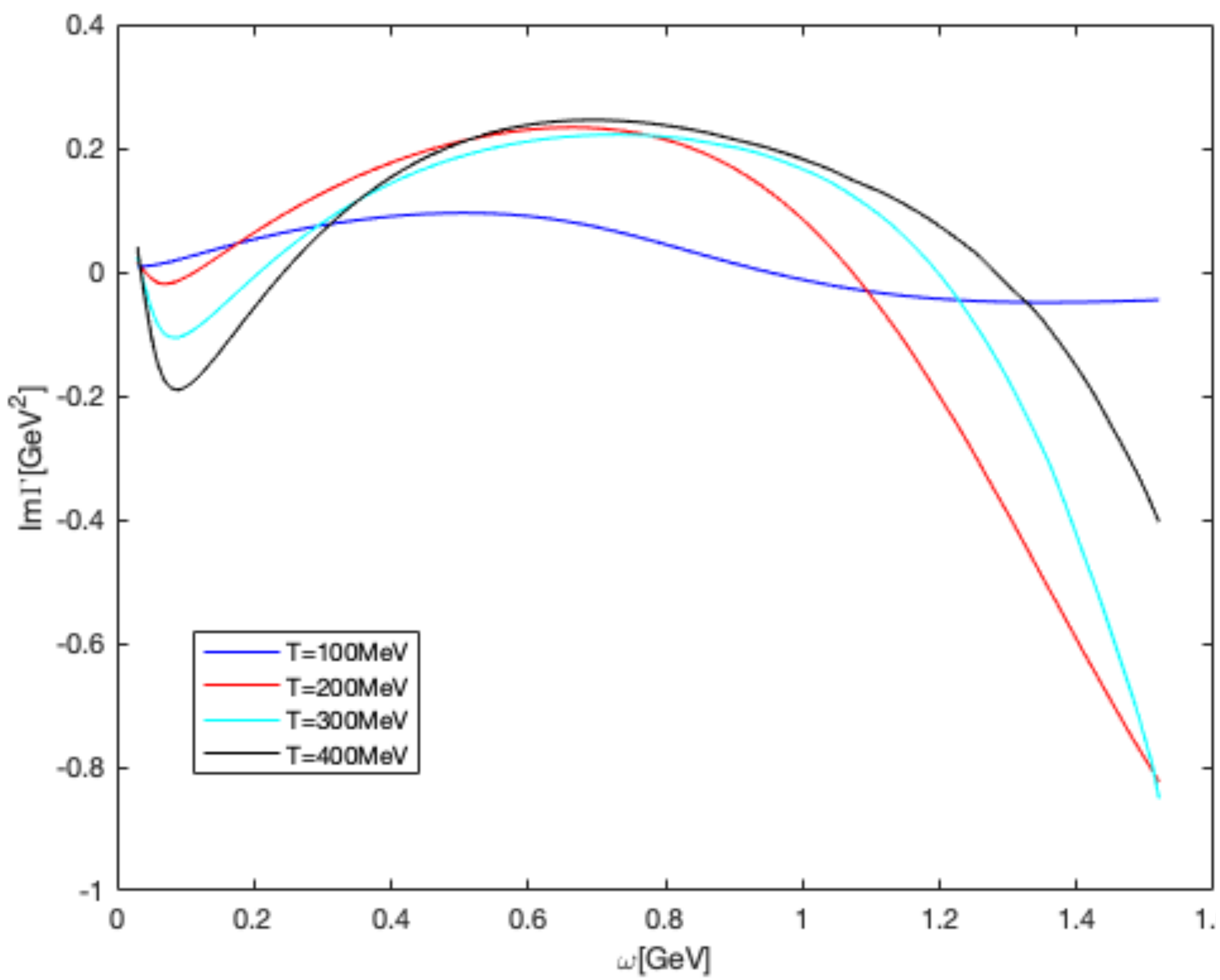




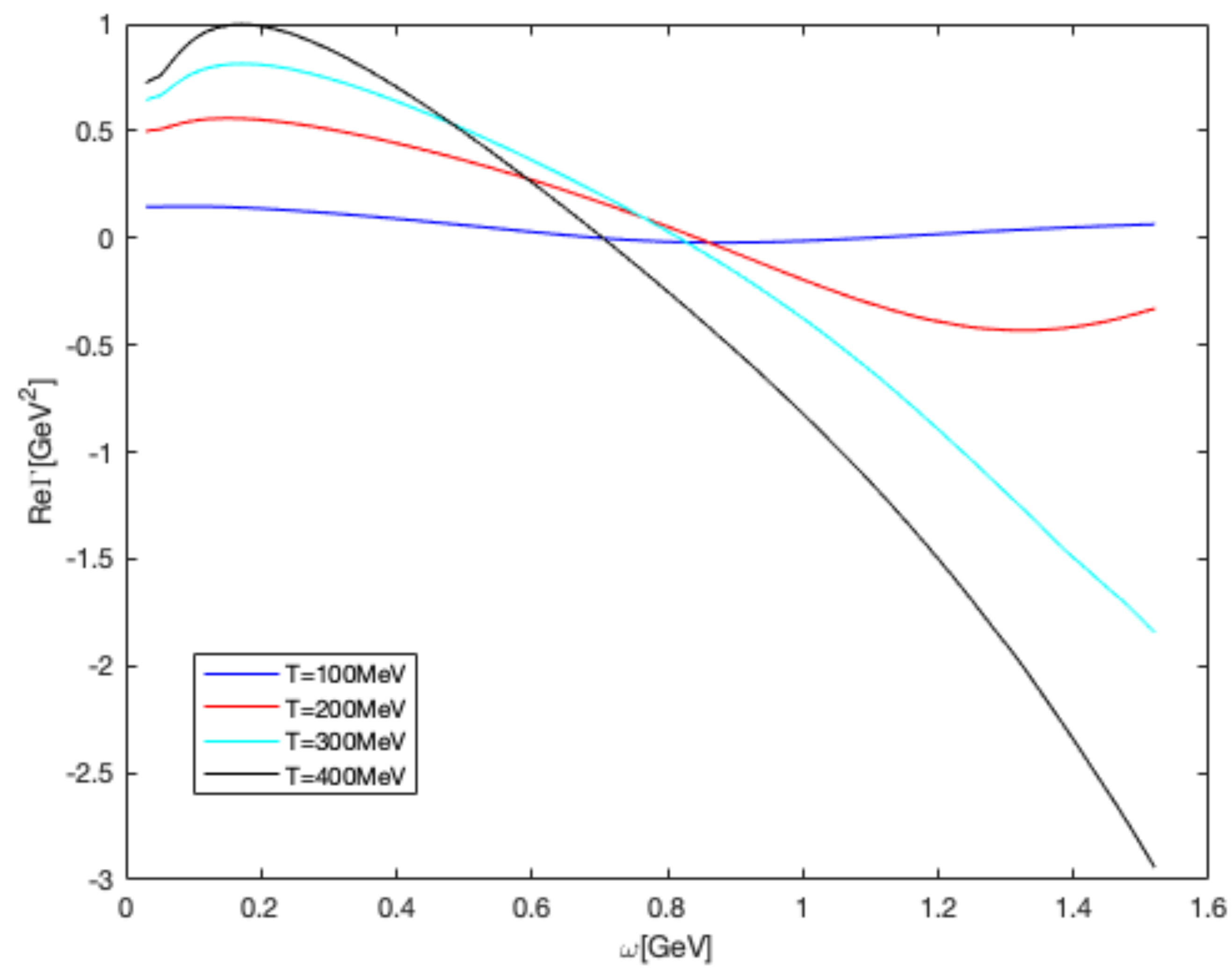
The Real and Imaginary Part of Effective Action

Magnetic Part

Imaginary Part



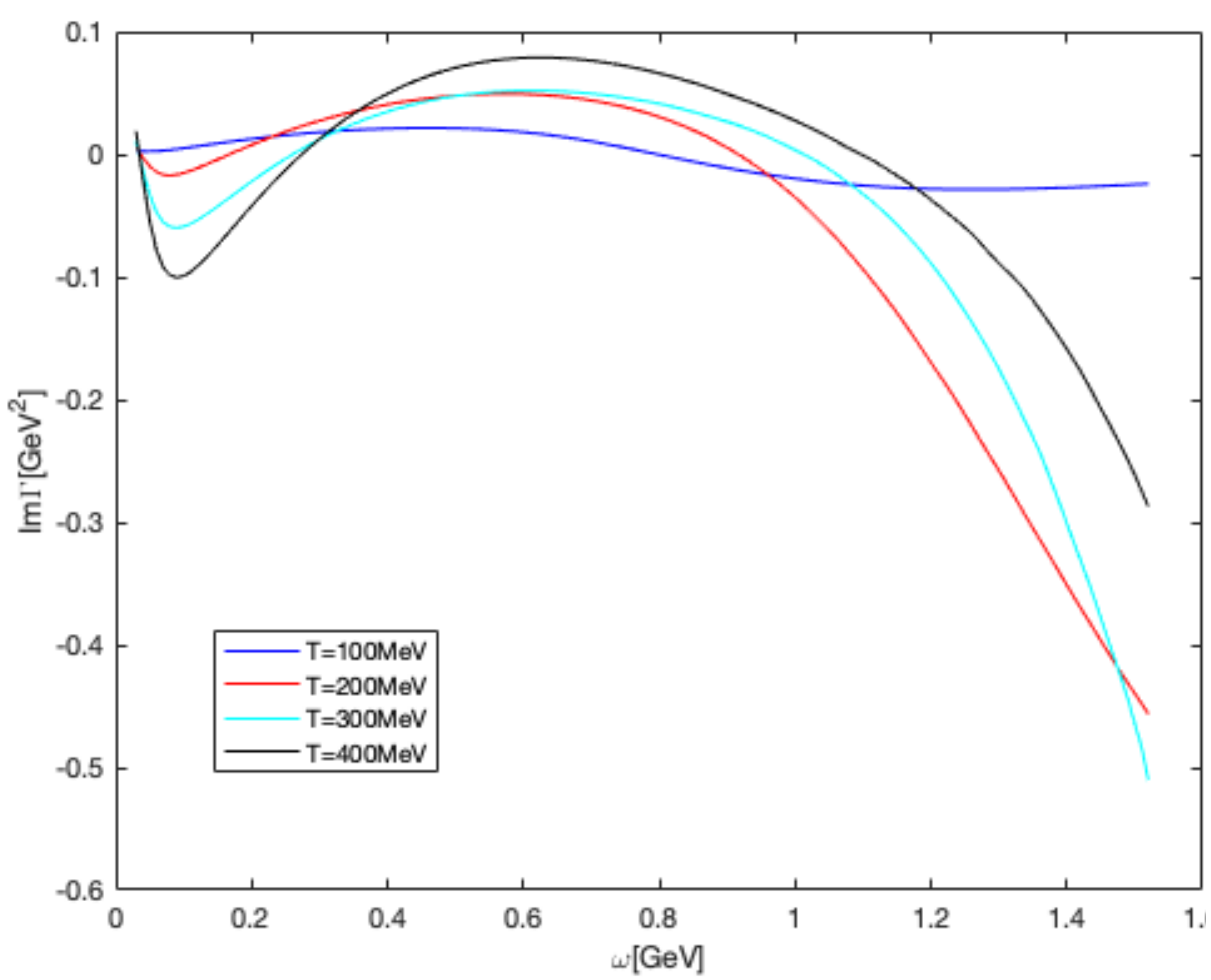
Real Part



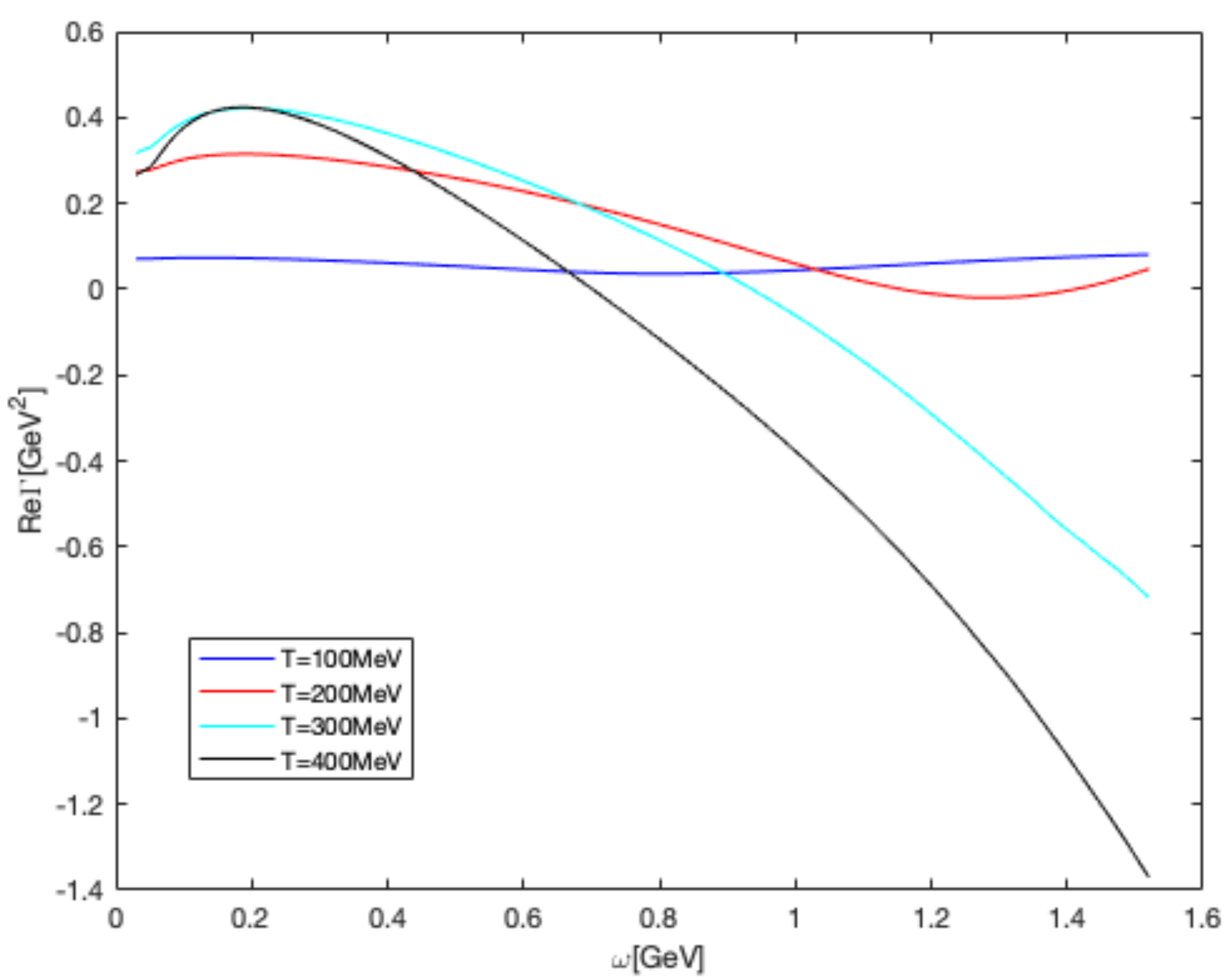
Real and Imaginary Part of Effective Action

Electric Part

Imaginary Part



Real Part



Summary and outlook

- ★ The perturbative gluon spectral function at finite temperature is obtained. It is consistent with the Hard Thermal Loop results.
- ★ Get the non-perturbative spectral function from QCD action.It's quite different from the perturbative results.
- ★ It's necessary to consider the relation between the external momental and spectral function in the future.

Thank you very much for your attentions!