Dyson-Schwinger Approach to Structure of Thermal Quasi-Particle and Phase Transition

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in collaboration with

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Hard-Thermal-Loop Resummed Dyson-Schwinger Equations(Real Time Formalism)

$$-i\Sigma_R(P) = -\frac{e^2}{2}\int \frac{d^4K}{(2\pi)^4}\times\Big[\Gamma^{\mu}_{RAA} S_R(K)\Gamma^{\nu}_{RAA} G_{C,\mu\nu}(P-K)$$
$$+\Gamma^{\mu}_{RAA} S_C(K)\,\Gamma^{\nu}_{AAR} G_{R,\mu\nu}(P-K)\;\Big]$$

$$G_R^{\mu\nu}(K) = \frac{1}{\Pi_T^R - K^2 - i\varepsilon k_0}A^{\mu\nu} + \frac{1}{\Pi_L^R - K^2 - i\varepsilon k_0}B^{\mu\nu} - \frac{\xi}{K^2 + i\varepsilon k_0}D^{\mu\nu}$$

$$A^{\mu\nu} = g^{\mu\nu} - B^{\mu\nu} - D^{\mu\nu}, B^{\mu\nu} = -\frac{\tilde{K}^{\mu}\tilde{K}^{\nu}}{K^2}, D^{\mu\nu} = \frac{K^{\mu}K^{\nu}}{K^2}, \tilde{K} = (k, -k_0\vec{k})$$

$$\Gamma^{\mu} = \gamma^{\mu}$$ ← Ladder 近似

$$\Sigma_R(P) = (1 - A(P)\;)\,p_i\gamma^i - B(P)\gamma_0 + C(P)$$

Gauge invariance
(Ward Identity)

T=0 のとき Landau gauge($\xi=0$) で $Z_1 = Z_2$

A(P)=1 for the point vertex

T.Maskawa and H.Nakajima,PTP 52,1326(1974)

PTP 54,860(1975)

一方

$T \neq 0 \quad A(P) \neq 1$

A(P)=1 を満たすような ξ を求める

Constant ξ ではできない

↓

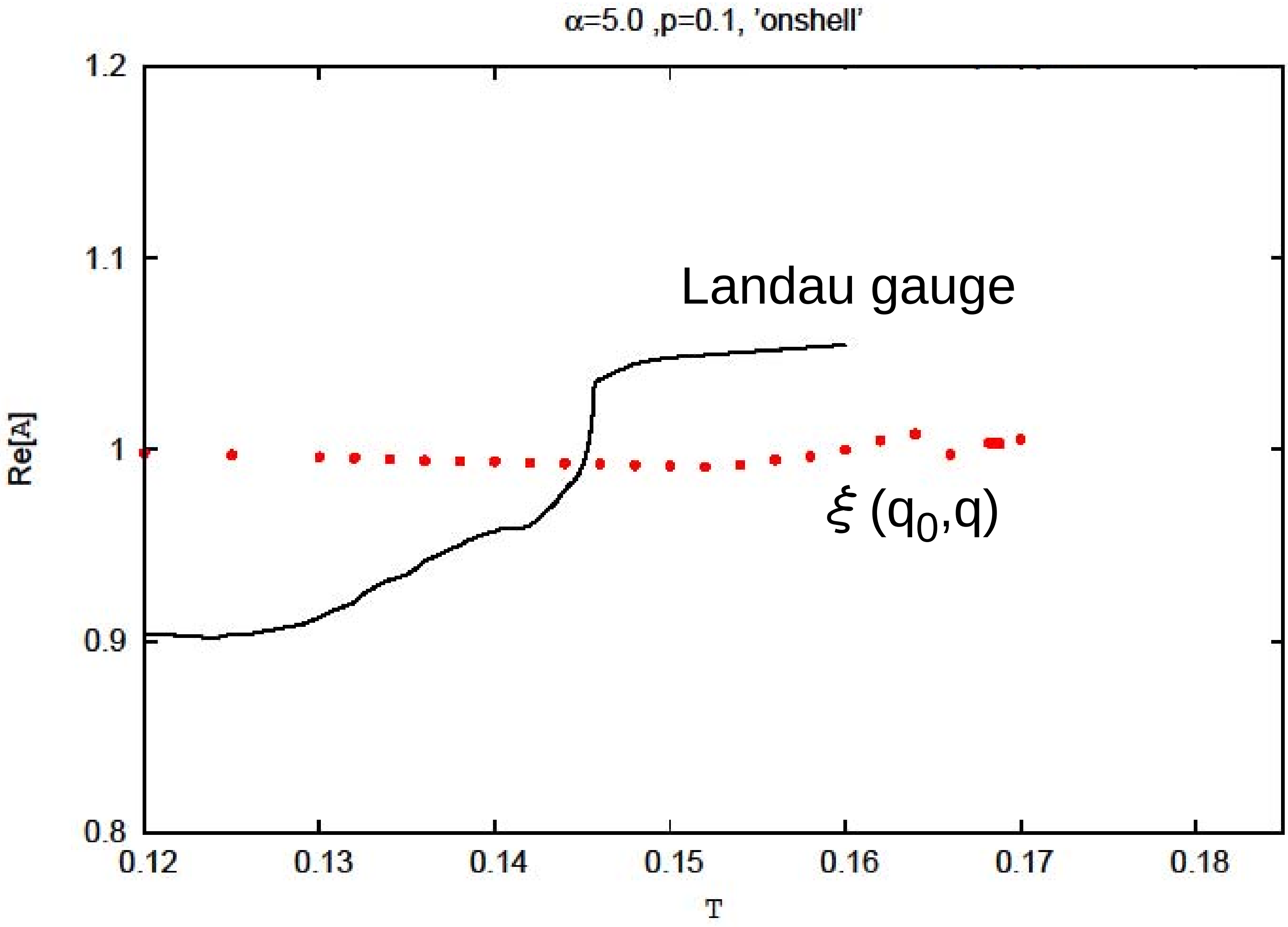
Gauge parameter をenergy-momentumに依存させ

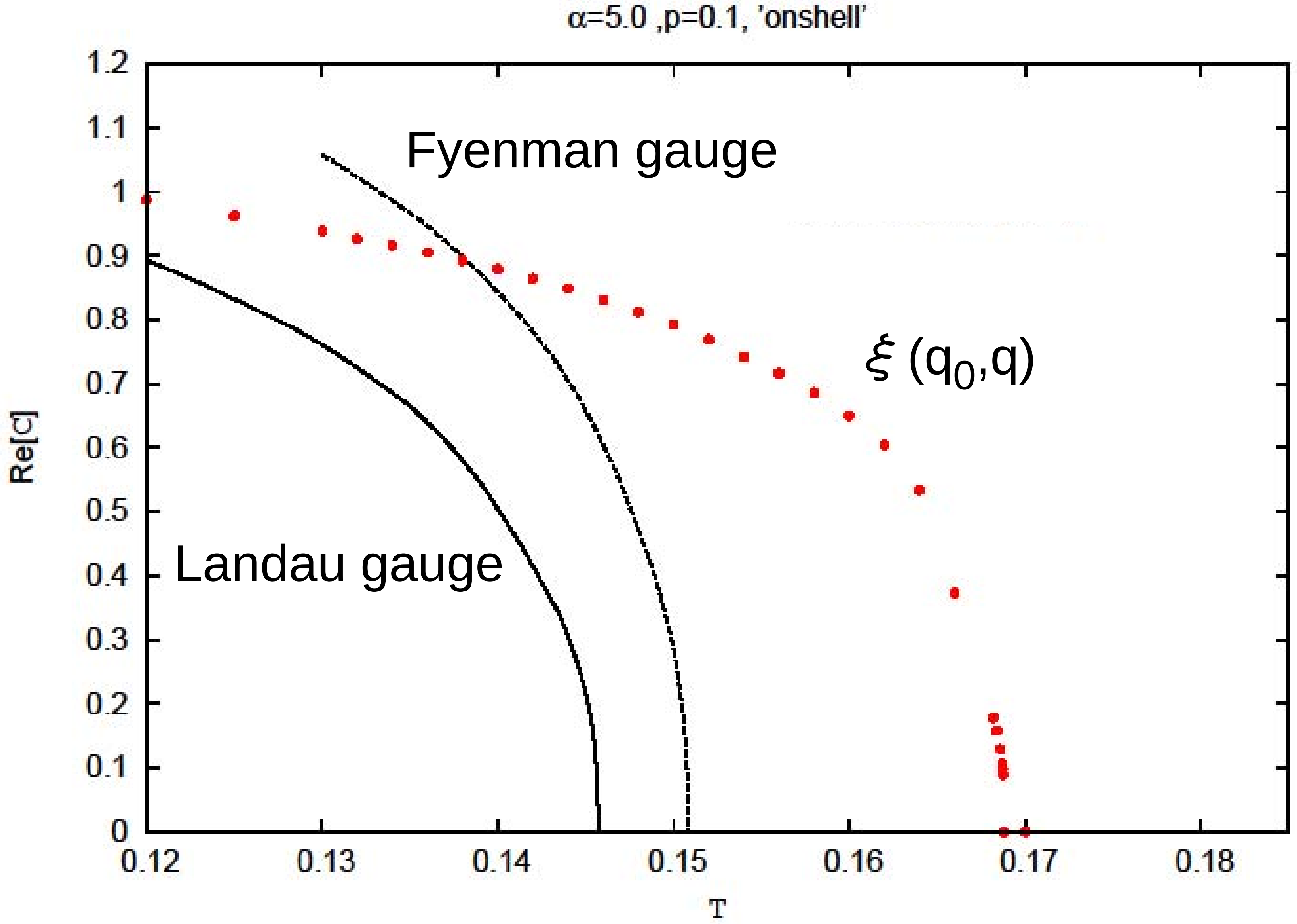
$$\xi \to \xi(q_0, q)$$

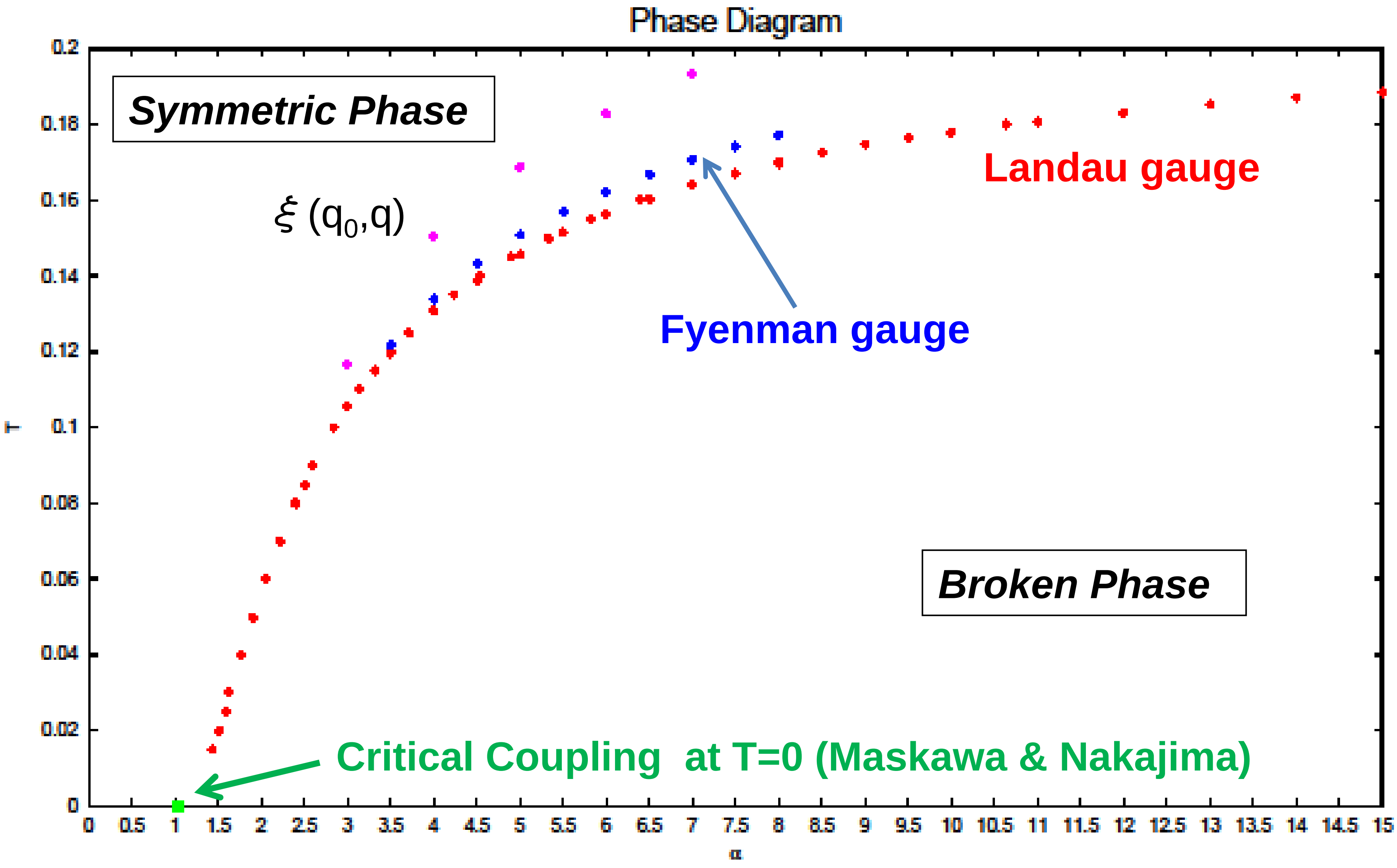
$$\xi(q_0, q) = \sum_{mn} C_{mn} F_m(q_0)\, G_n(q)$$

$$\delta A = \int d^4P \left|A - 1\right|^2, \ \Rightarrow \ \frac{\partial \delta A}{\partial C_{mn}} = 0$$

point： “on-shell”での重みを大きく


α=5.0 ,p=0.1, 'onshell'
1.2
1.1
1
0.9
0.8
Re[A]
0.12
0.13
0.14
0.15
0.16
0.17
0.18
T
Landau gauge
ξ (q0,q)


α=5.0 ,p=0.1, 'onshell'
Fyenman gauge
Landau gauge
ξ (q0,q)
Re[C]
T
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.12
0.13
0.14
0.15
0.16
0.17
0.18


Phase Diagram
Symmetric Phase
ξ (q0,q)
Landau gauge
Fyenman gauge
Broken Phase
Critical Coupling at T=0 (Maskawa & Nakajima)
T
α
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15

Themal Quasi-Particleの振る舞い

Symmetric Phase（C=0）、Landau gauge

$$S_R = \frac{1}{2}\left[\frac{1}{D_+}\left(\gamma^0 + \frac{p_i\gamma^i}{p}\right) + \frac{1}{D_-}\left(\gamma^0 - \frac{p_i\gamma^i}{p}\right)\right]$$

Spectral Function

$$\rho_\pm(p_0, p) = -\frac{1}{\pi}\mathrm{Im}\frac{1}{D_\pm(p_0, p)} = -\frac{1}{\pi}\mathrm{Im}\frac{1}{p_0 + B(p_0, p) \mp pA(p_0, p)}$$

Dispersion Relation

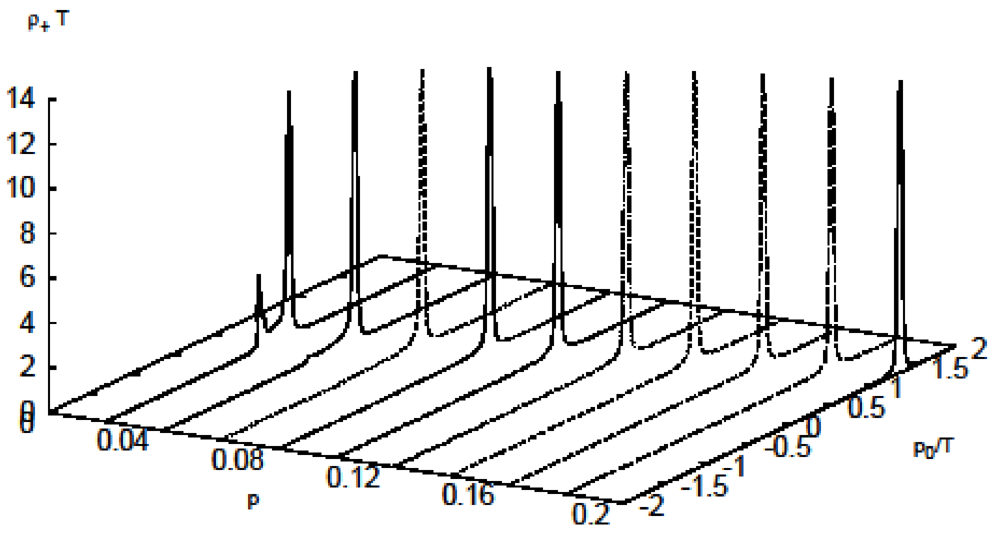
$$\mathrm{Re}\left[D_+(p_0 = \omega, p)\right] = 0$$

Decay Constant

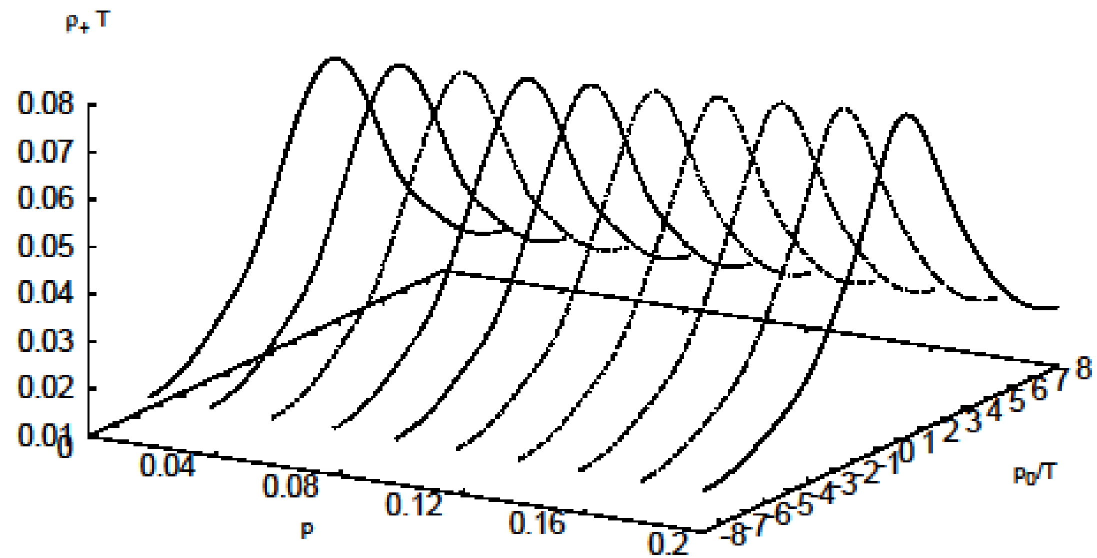
$$\gamma = \mathrm{Im}\left[B(p_0 = \omega, p)\right]$$

Spectral Function

α=0.01, T=0.150



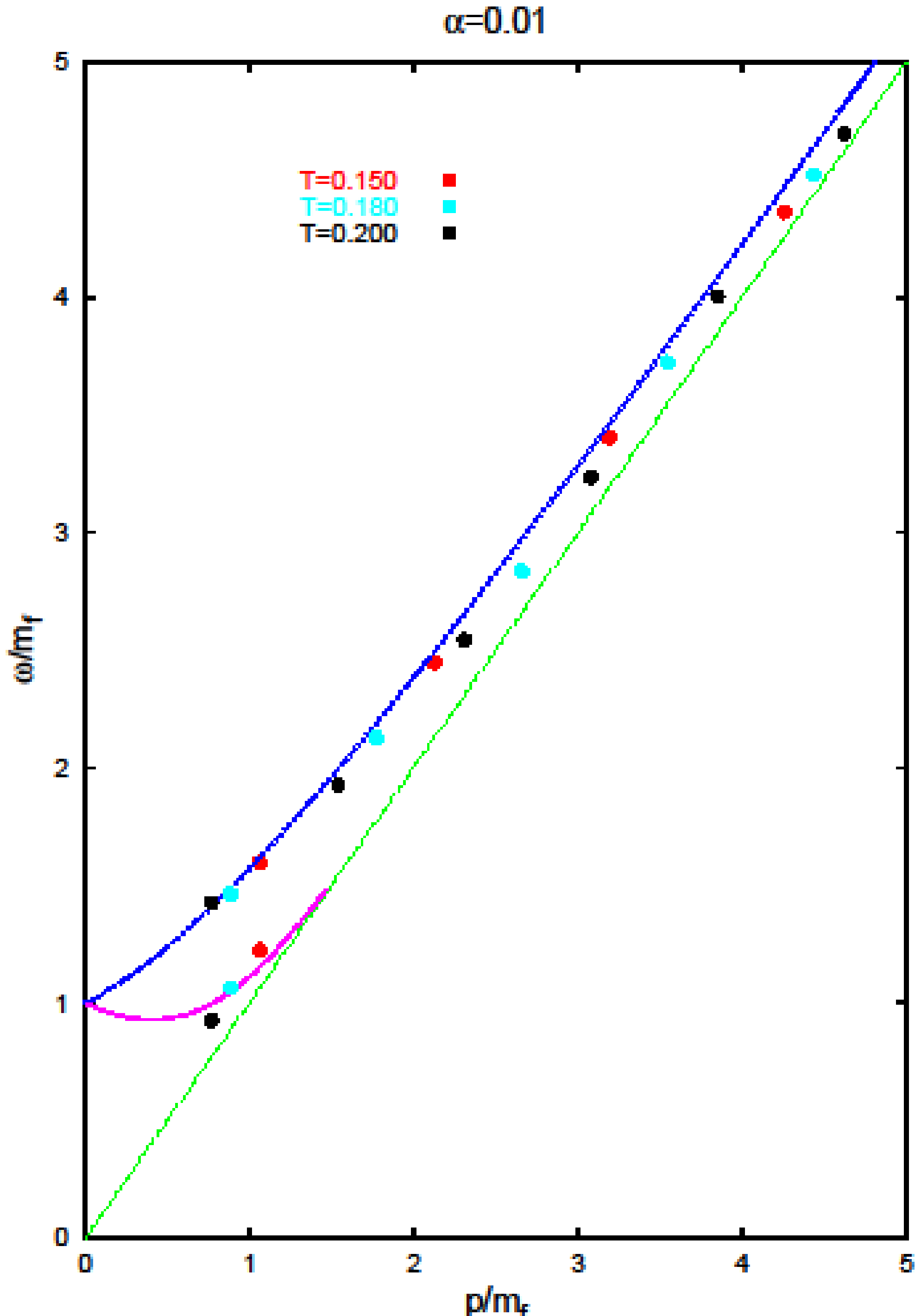
α=5.0, T=0.150



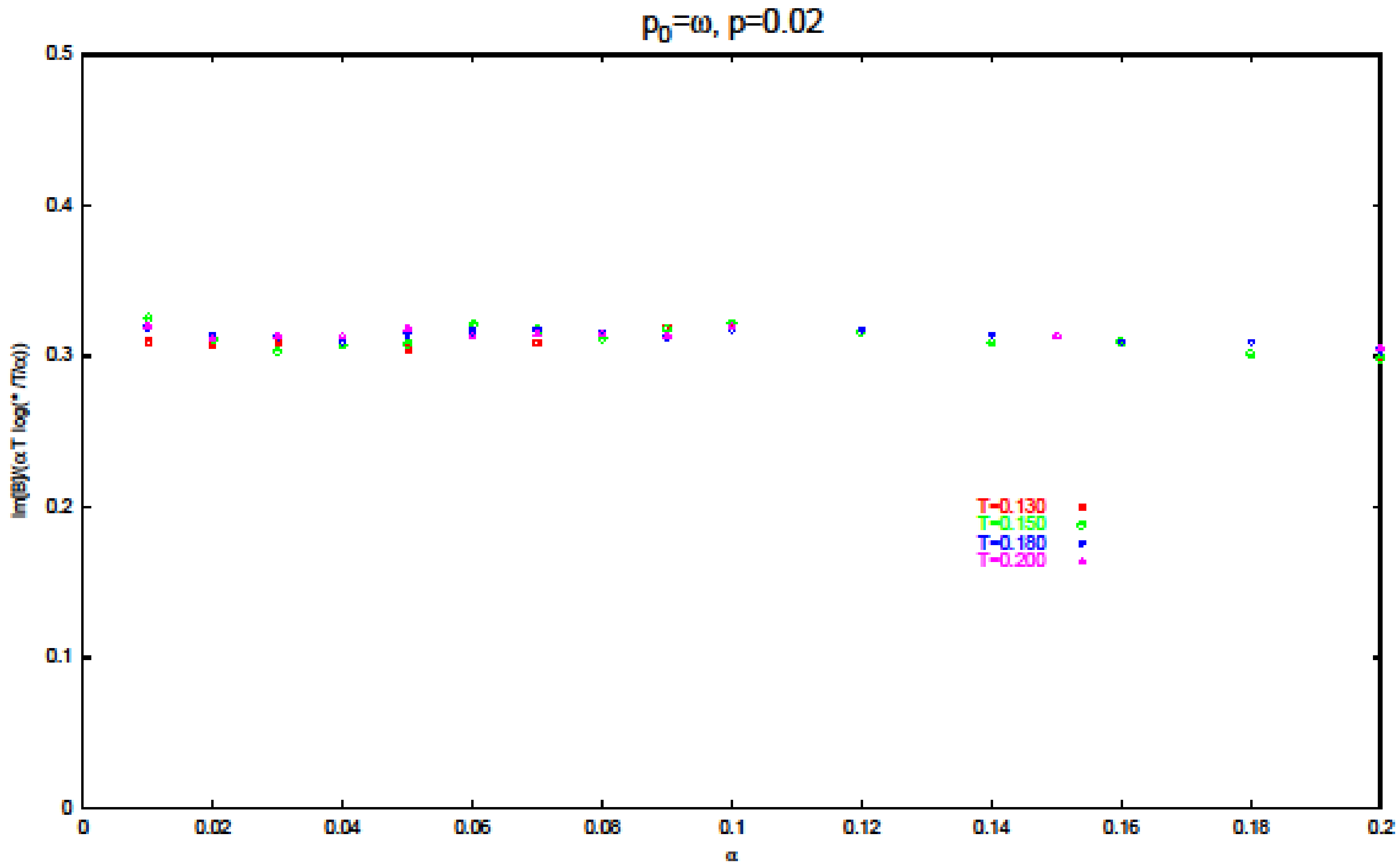
Dispersion relation

$$\mathrm{Re}[D_+(p_0=\omega, p)] = 0$$

small couplingのとき
HTLの振る舞いを再現
している



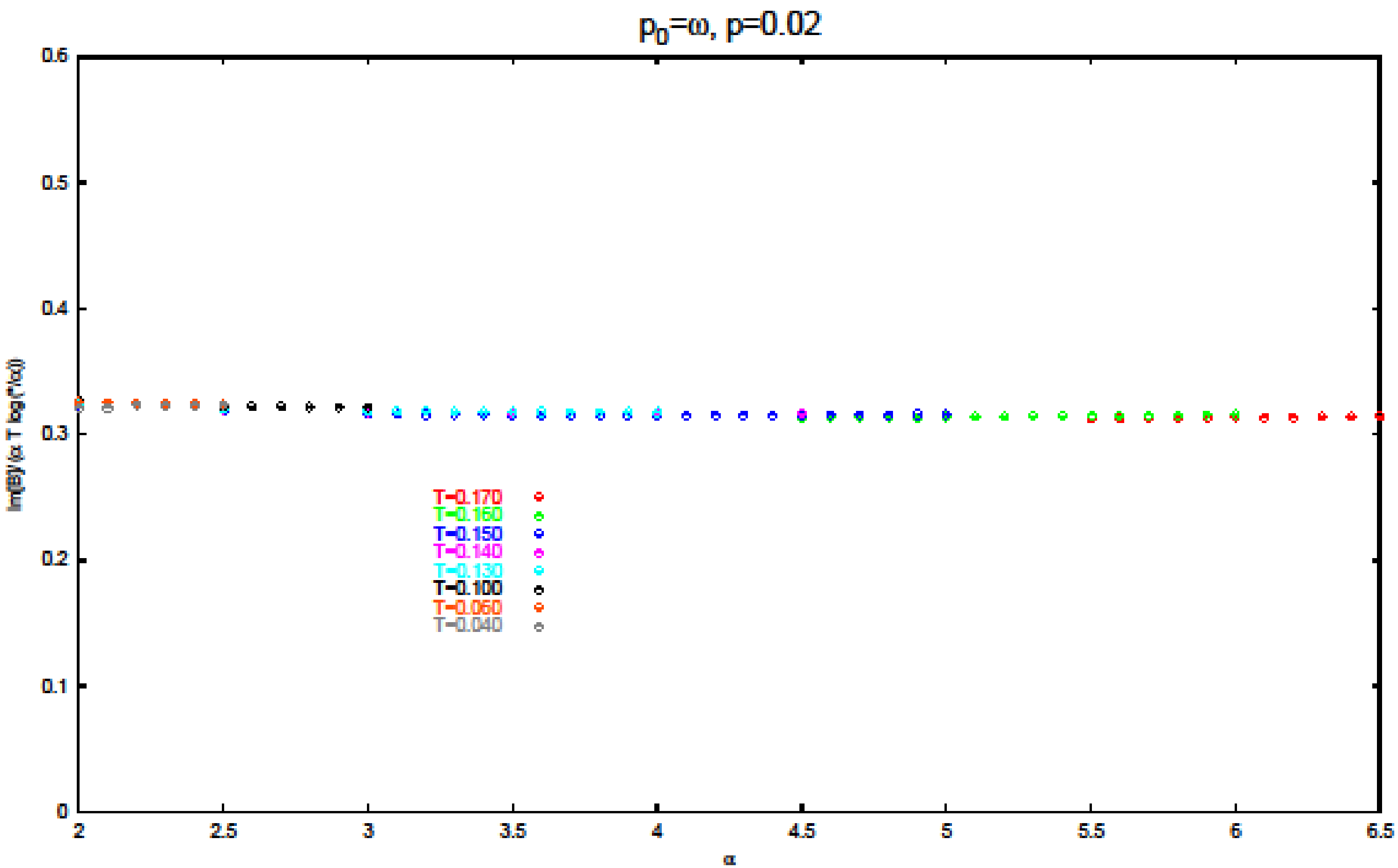
Small Coupling での Decay Constant



$$\gamma \sim \alpha T \log(1/\alpha T)$$

HTLでの振る舞いを再現

Large Coupling での Decay constant



$$\gamma \sim \alpha T \log(1/\alpha)$$

まとめ

・**Gauge parameter** ξ を エネルギー・運動量に依存させることにより、**"on-shell"**付近で **A～1**となる解を求めることができた

・**Quasi-particle** の振る舞い(**Symmetric phase)**

- **small coupling**では、HTLの振る舞いを再現
- **large coupling**での振る舞いも得られた

間の振る舞い等は、現在、検討中

今後

・詳細な相図の作成　&　臨界指数の確定

・3番目のピークの詰め(**p=0**の計算)　など

・**Running Coupling**(**QCD**)　&　$\mu \neq 0$ での解析(実行中)