Chiral and Deconfinement Transitions in SC-LQCD

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Villasimius Sardinia Italy

References

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- K.Miura, T.Z Nakano, A.Ohnishi, Prog.Theor.Phys.122,('09).
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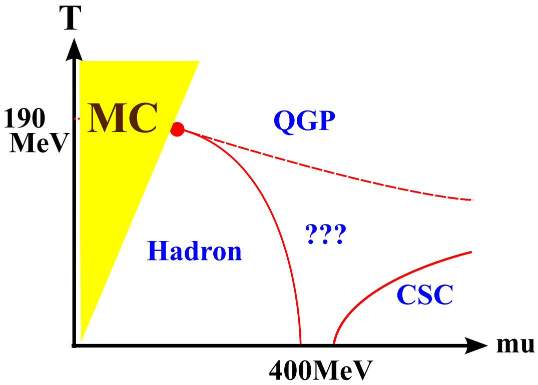
QCD Phase Diagram



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SC-LQCD!!

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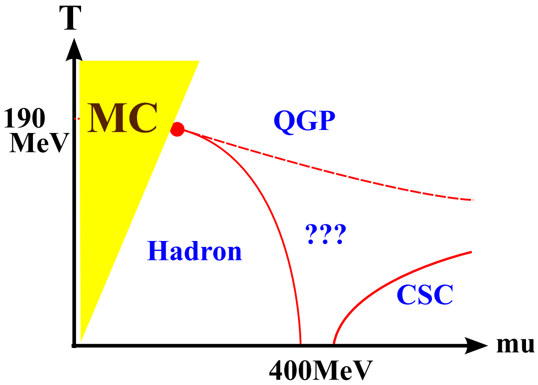

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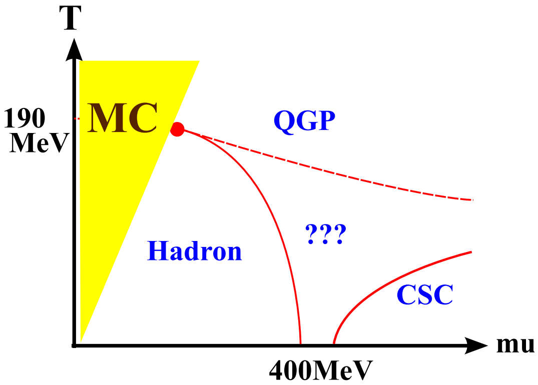

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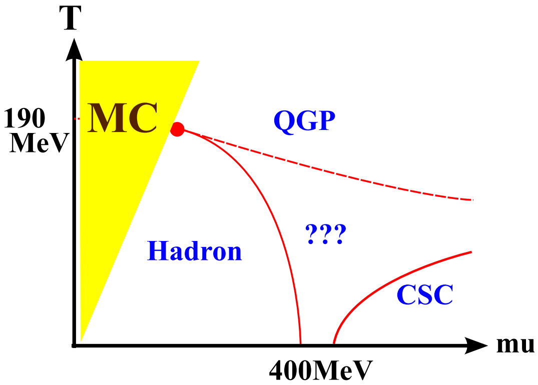

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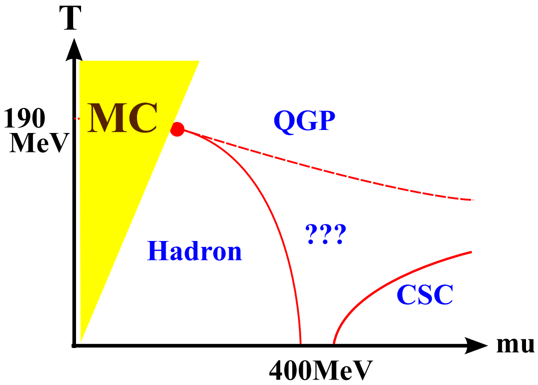

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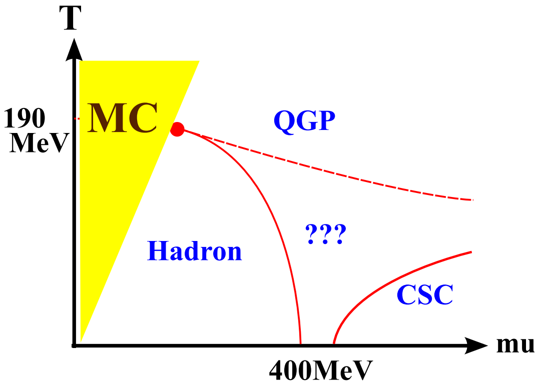

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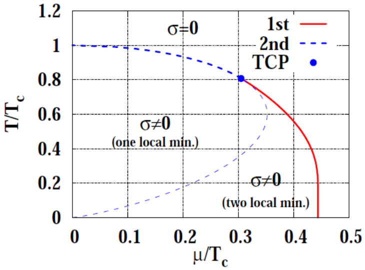
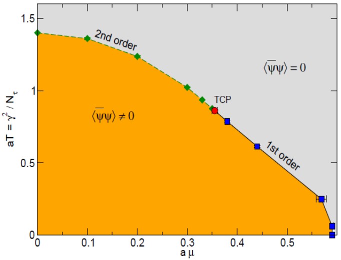
Phase Diagram at Strong Coupling Limit

Kawamoto-Miura-Ohnishi-Ohnuma ('07)



Forcrand Fromm (2009)



c.f. A. Ohnishi, Friday 18.

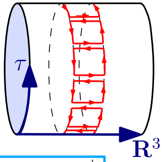
Outline of Analyses ($\beta = 6/g^2$)

$$Z_{\mathrm{LQCD}} = \int_{\chi,\bar{\chi},U_0,U_j} \exp[-S_F^{(\tau)} - S_F^{(s)} - S_G]$$

$\bar{\chi}$ $e^{\mu}U_0$ χ

$\bar{\chi}$ U_j χ

$1/g^2$

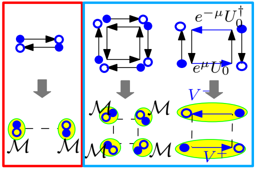


$\int \mathcal{D}U_j$ with $1/g^2$ expansion

$1/d$ expansion Leading

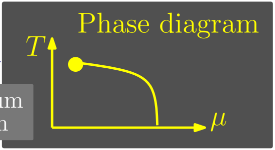
Mean Field Approx.
$\sigma \sim \langle \mathcal{M} \rangle$ $\rho_q \sim \langle V_+ + V_- \rangle$

$\int \mathcal{D}[\chi, \bar{\chi}, U_0]$

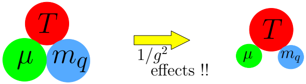


$$\exp[-\mathcal{F}_{\mathrm{eff}}(\mathbf{T}, \mu, \sigma, \rho_{\mathbf{q}}, \mathbf{l_p}, \beta)]$$

minimum search



Thermal Excitations



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\begin{aligned}
Z \quad &\sim \quad \prod \left[(1 + e^{-(\epsilon-\mu)/T})(1 + e^{-(\epsilon+\mu)/T}) \right] , \quad (Free) \\
&\to \quad \prod \mathrm{det}_c \left[(1 + L_p e^{-(E_q(\sigma)-\mu)/T})(1 + L_p^\dagger e^{-(E_q(\sigma)+\mu)/T}) \right] , \\
&\qquad \text{(Gocsch-Ogilvie and Ilgenfritz-Kripfganz ('84),Fukushima ('03))} \\
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\end{aligned}
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\tilde{\mu}(\beta, \omega_\tau) \quad \simeq \quad \mu - \beta\omega_\tau/18 \ , \quad \omega_\tau = -\frac{\partial F_{\mathrm{eff}}}{\partial \mu} \equiv \rho_q \ . \qquad (1)
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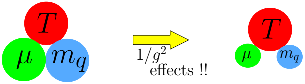

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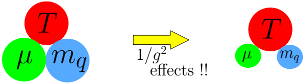

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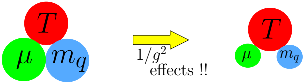

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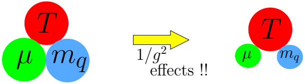

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- **Chiral Symmetry:** $U_\chi(1)$ Symmetry breaking and restorations without anomaly.
- **Approximations:**
  1. NLO $\mathcal{O}(1/g^2)$ in Strong coupling expansion,
  2. Leading pure YM contributions for Polyakov loop (c.f. NNLO, T-Z. Nakano, Next talk),
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  4. Mean field approximation.
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Simplest Laboratory to See Interplays among Chiral and Deconfinement Transitions with Dynamical Density!!

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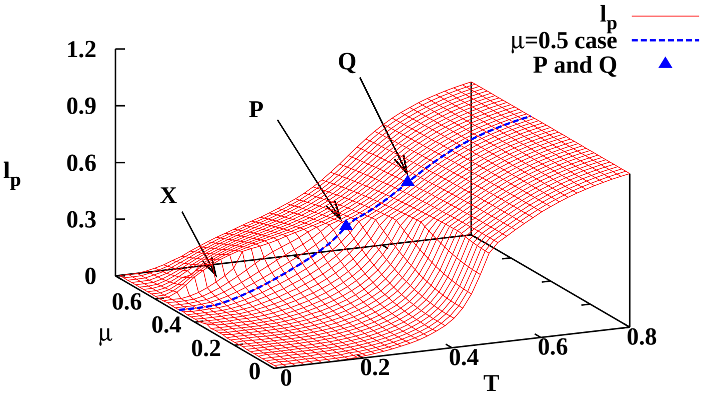
Polyakov Loop (PNLO,$(\beta, m_0) = (4.0, 0.0)$)

Miura,Nakano and Ohnishi, Preliminary!



Deconfinement Cross-over (PNLO,$(\beta, m_0) = (4.0, 0.0)$)

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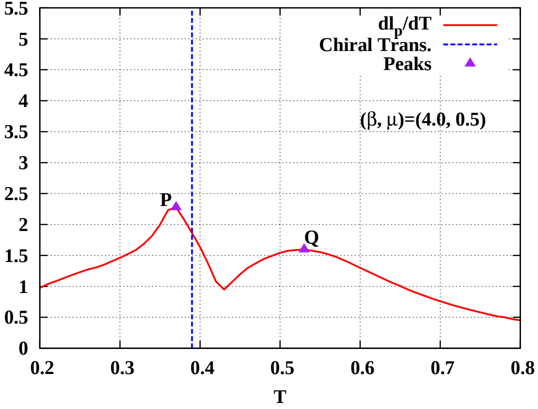

P: Chiral Induced Deconfinement , Q: ????

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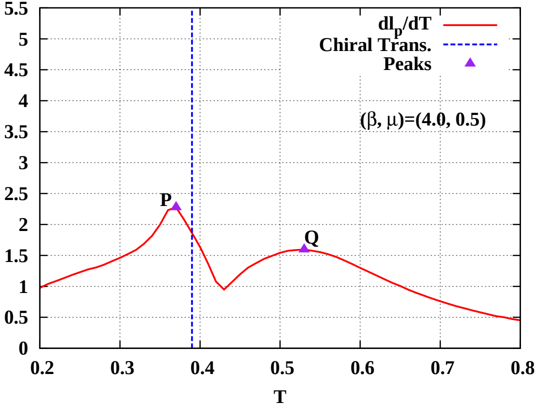

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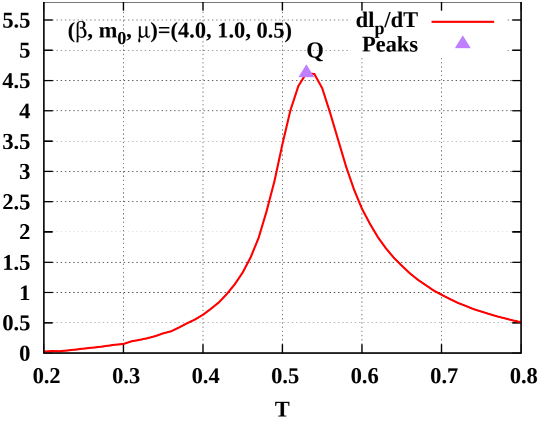
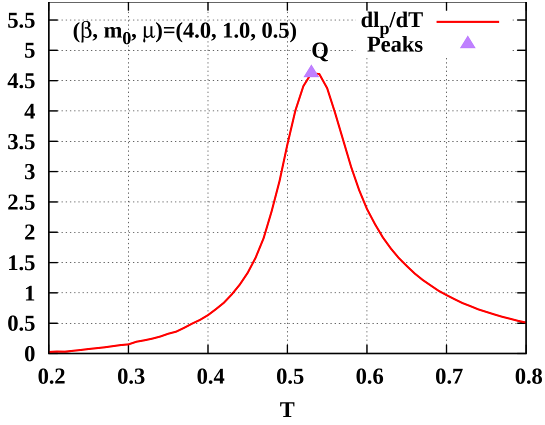


Q: Z_3 Induced Deconfinement

Deconfinement Cross-over (PNLO,$(\beta, m_0) = (4.0, 1.0)$)

Miura,Nakano and Ohnishi, Preliminary!



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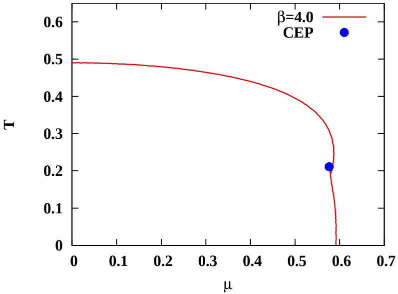
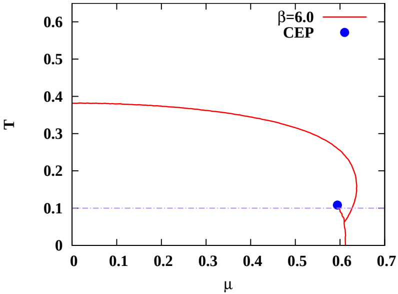
Phase Diagram PNLO

Miura,Nakano and Ohnishi, Preliminary!

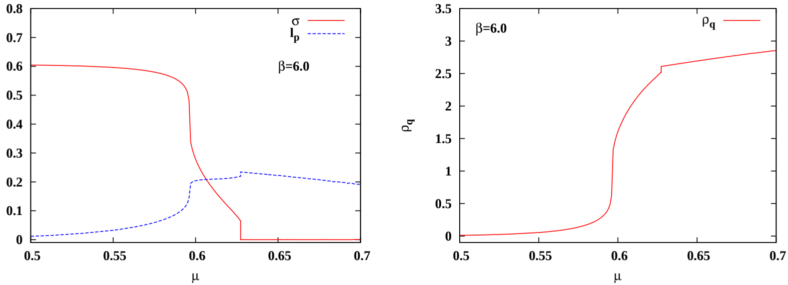




Left: $\beta = 4.0$ in the chiral limit ,
Right: $\beta = 6.0$ in the chiral limit

PCR Matter with Polyakov Loop Effects (PNLO,$(\beta, m_0) = (6.0, 0.0)$)

Miura,Nakano and Ohnishi, Preliminary!



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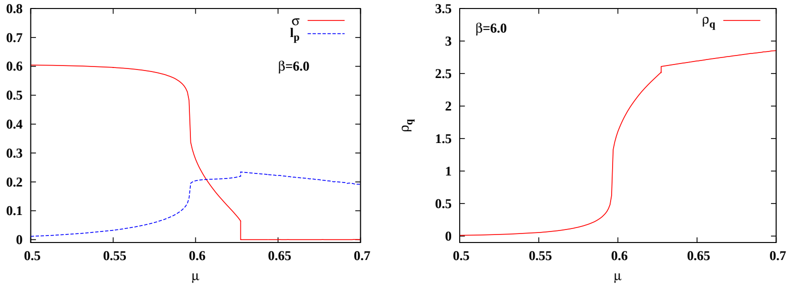

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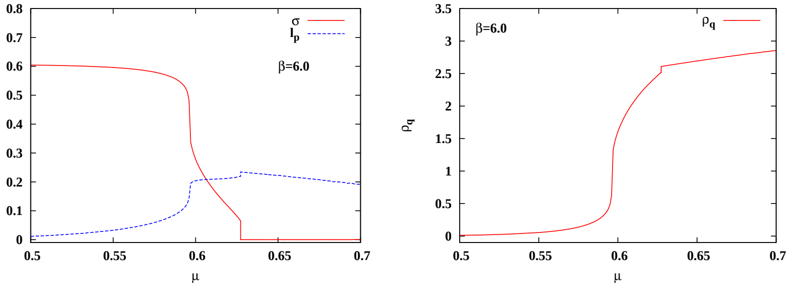

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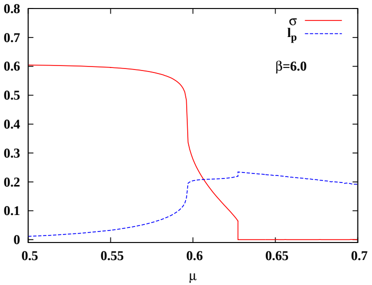

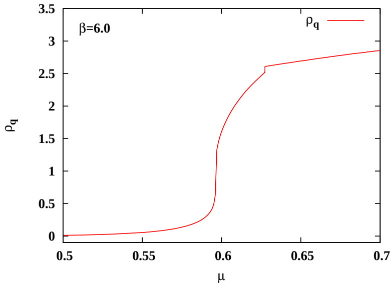

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Summary

Results

- We have investigated interplays between the chiral and deconfinement transitions with dynamical quark density effects based on the PNLO of SC-LQCD.
- We have found two sequential deconfinement cross-overs, Chiral induced and Z_{N_c} induced deconfinements.
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Further Developments

Toward Collaboration to LQCD-MC

- Imaginary chemical potential with Polyakov loop effects.
- Suggestion of analytic form of fitting functions in the extrapolations from μ_I region to μ region: $\rho_q(\mu_I) \to \rho_q(\mu)$, $(l_p(\mu_I), \bar{l}_p(\mu_I)) \to (l_p(\mu), \bar{l}_p(\mu))$,...
- TCP (CEP) with and without (μ/T) expansion $\to$ Test of Taylor expansion method used by MC.

EXTENSIVE INVESTIGATIONS !!

- **NNLO $\mathcal{O}(1/g^4)$ SC-LQCD with Polyakov loop (Weiss app.):** Mr. T-Z. Nakano, Next Talk!
- **NLO of $1/d$ Expansion $=$ Quark (Baryon) Hopping Effects:** Prof. A. Ohnishi, Friday 18.

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