
Auxiliary field Monte-Carlo study of the QCD phase diagram at strong coupling

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in collaboration with

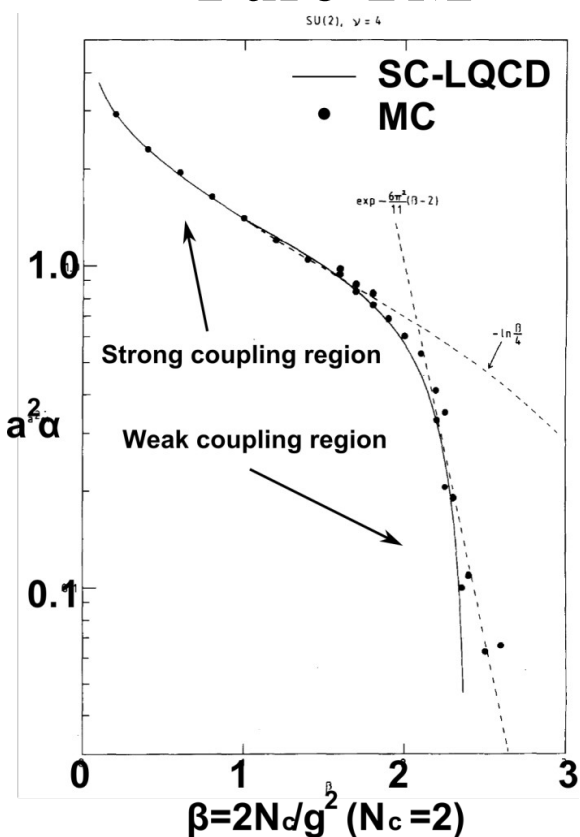
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Work in progress

- QCD phase diagram → HIC, Early Universe, Compact Stars, ...
- Lattice QCD at finite density
→ Taylor expansion, Imaginary μ , Canonical, Reweighting,
Fugacity expansion, Strong Coupling Lattice QCD, ...
- SC-LQCD study of phase diagram
 - Mean Field (Strong Coupling Limit, Finite Coupling Correction, ..)
 - Monomer-Dimer-Polymer simulation (Fromm, Unger, de Forcrand)
 - Auxiliary Field Monte-Carlo (present work)

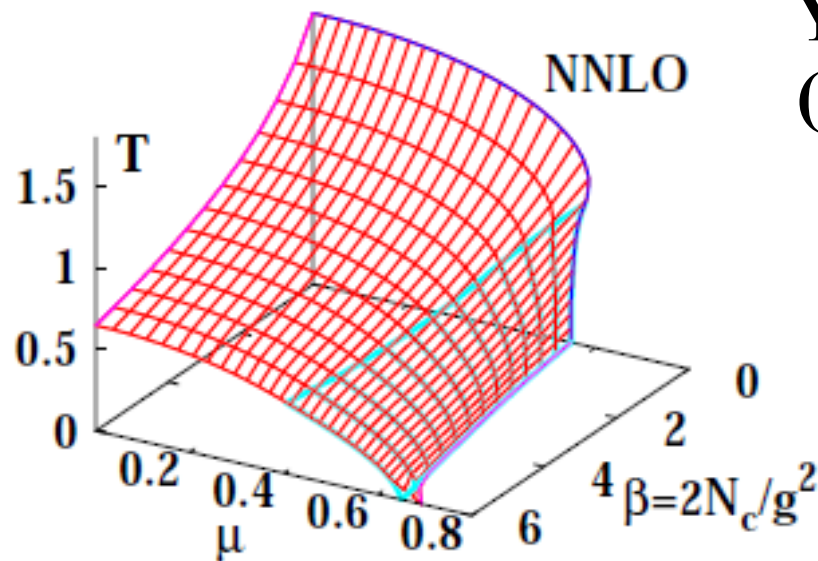
Strong Coupling Lattice QCD

Pure YM



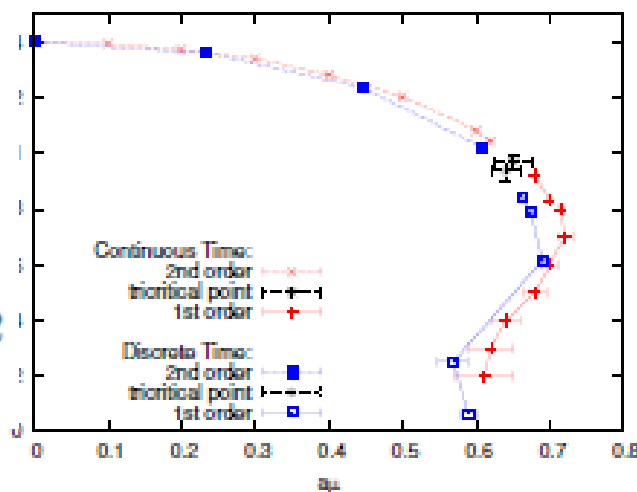
*Wilson ('74), Creutz ('80),
 Munster ('80, '81), Lottini,
 Philipsen, Langelage's ('11)*

YM+Quarks (MF)



*Kawamoto ('80), Kawamoto, Smit ('81),
 Damagaard, Hochberg, Kawamoto ('85),
 Bilic, Karsch, Redlich ('92),
 Fukushima ('03); Nishida ('03),
 Kawamoto, Miura, AO, Ohnuma ('07).
 Miura, Nakano, AO, Kawamoto ('09)
 Nakano, Miura, AO ('10)*

YM+Q+Fluc. (MDP) (SCL($1/g^2=0$))



*Mutter, Karsch ('89),
 de Forcrand, Fromm ('10),
 de Forcrand, Unger ('11)*

Challenge: YM+Q+Fluc.+Finite Coupling Effects

de Forcrand, Fromm, Langelage, Miura, Philipsen, Unger ('11), AO, Nakano, Ichihara (in prep.)

Auxiliary Field MC in SC-LQCD

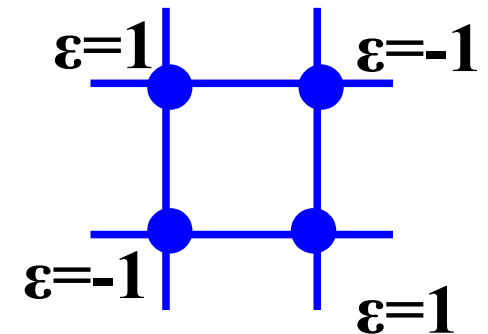
- **Strong coupling expansion in the strong coupling limit ($1/g^2=0$)**
- + **1/d expansion + link integral**
- + **Bosonization (Extended Hubbard-Stratonovich transf.)**
- + **Monte-Carlo Integral over Auxiliary Fields (σ MC)**

$$S_{\text{eff}} = \frac{L^3 N_\tau}{4 N_c \gamma^2} \sum_{k, f_M(\mathbf{k}) > 0} f_M(\mathbf{k}) \left[\sigma_k^* \sigma_k + \pi_k^* \pi_k \right] - \sum_{\mathbf{x}} \log R(\mathbf{x})$$

$$R(\mathbf{x}) = X_N(\mathbf{x})^3 - 2 X_N(\mathbf{x}) + 2 \cosh(3 N_\tau \mu) \quad (\text{local Fermion determinant})$$

$$X_N = 2 \cosh[\text{arcsinh}(d \sigma / 2 N_c + m_0)] \quad (\text{for const. } \sigma, \pi)$$

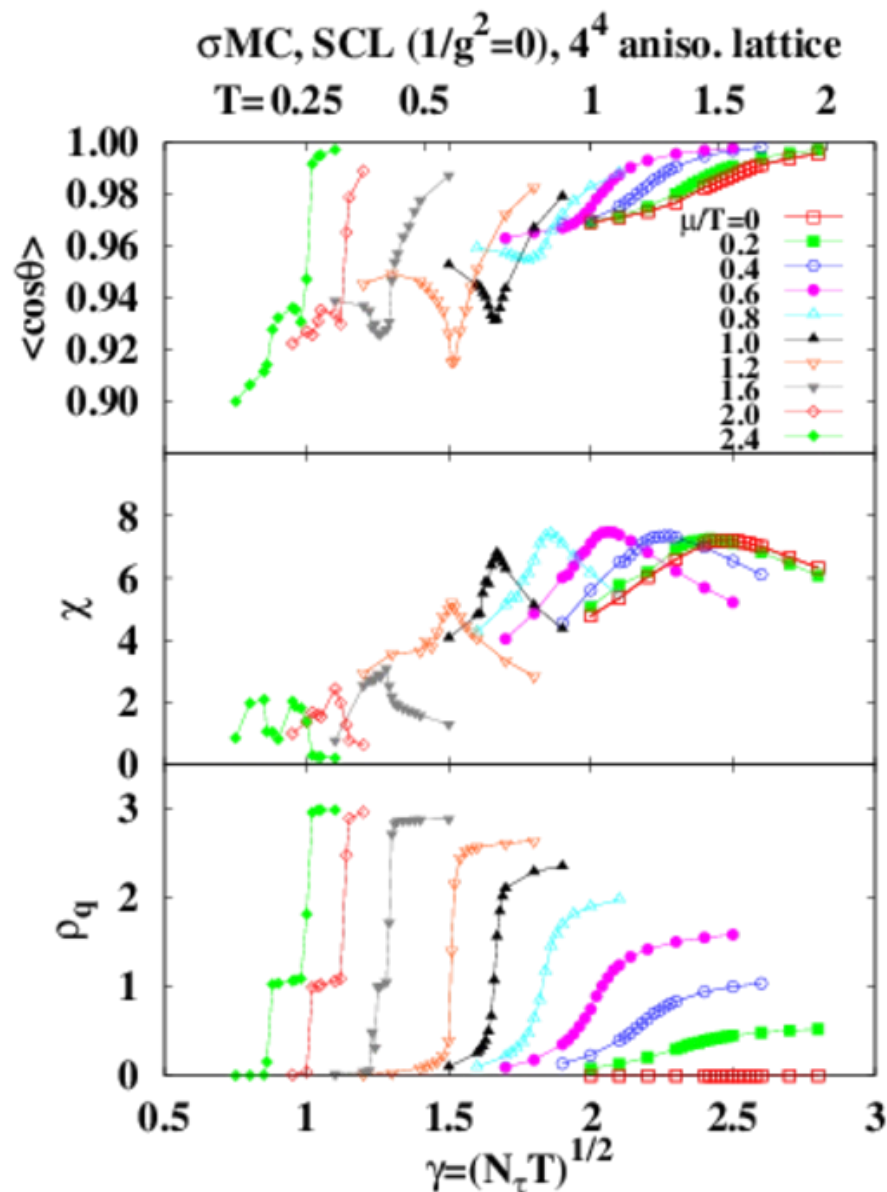
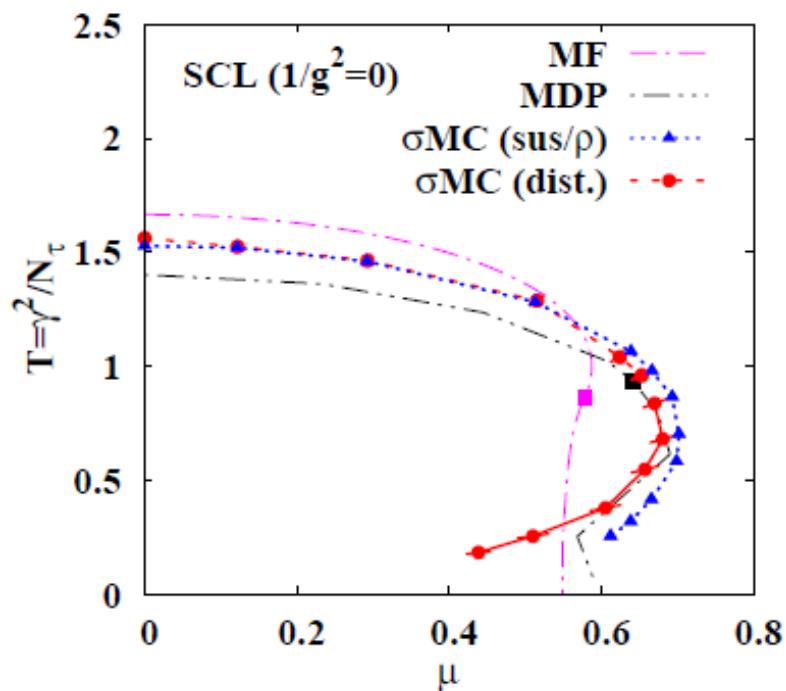
- $X_N(\mathbf{x})$ = easily calculated from $\sigma(\mathbf{x})$ and $\pi(\mathbf{x})$ (complex).
- Imaginary part (π) involves $\varepsilon_{\mathbf{x}} \rightarrow$ Phase cancellation for low \mathbf{k} .
- Sign problem is less severe at larger μ .
- Extension to Finite Coupling is straightforward.



Phase diagram

■ σ MC results of phase diagram

- Sign problem is weak in small lattice.
- PhdF & Fromm & Unger results are confirmed qualitatively !



Come to my talk Next Week

Ohnishi @NTFL (Feb. 17, 2012)