The QGP Phase and the Coupling

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with

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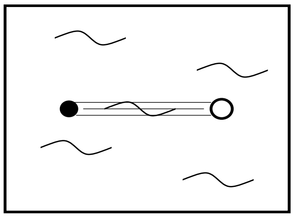
Why should we study the Coupling at finite T?

- Potential Models,
  i.e. *Matsui-Satz*-like studies
- so-called 'sQCD',
  i.e. *E. Shuryak, I. Zahed (2003)*
- Properties of the QGP,
  i.e. *E. Shuryak, I. Zahed (2004)*
  G. E. Brown, C.-H. Lee, M. Rho (2004)

Polyakov Loop Correlations (PLCs)?

L.D. McLerran, B. Svetitsky (1981):

$$\frac{\mathcal{Z}_{\mathbf{Q\bar{Q}}}}{\mathcal{Z}(\mathbf{T})} \simeq \frac{1}{\mathcal{Z}(\mathbf{T})}\int \mathcal{D}\mathbf{A}\ldots\ \mathbf{L(x)}\ \mathbf{L^{\dagger}(y)}\ \exp\left(-\int_0^{\mathbf{1/T}} \mathbf{dt} \int \mathbf{d^3x}\mathcal{L}[\mathbf{A},\ldots]\right)$$



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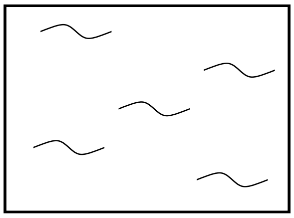


$$= \quad -\mathbf{F_{Q\bar{Q}}(r,T)/T}$$

$$\ln \mathcal{Z}_{\mathbf{L,L^{\dagger}}} \quad - \quad \ln \mathcal{Z}$$

$\mathbf{Q\bar{Q}} \ = \ \mathbf{1, 8, av}$

See recent discussions by
O. Philipsen (2002);
O. Philipsen, O. Jahn (2004)

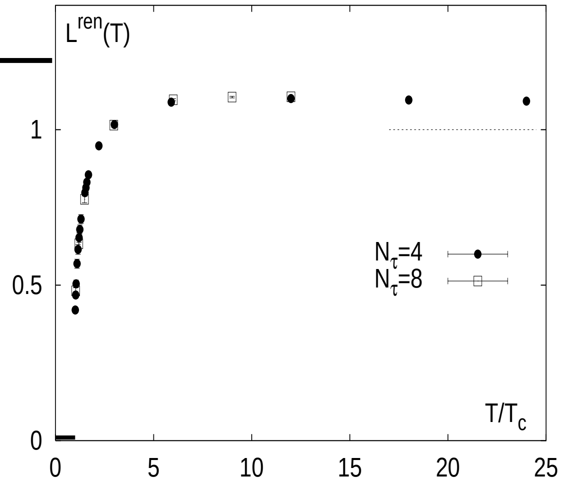
"PLCs give a measure for $Q\bar{Q}$ interactions ($\sim$ change in Free Energy)"

Basic Concepts and Interests

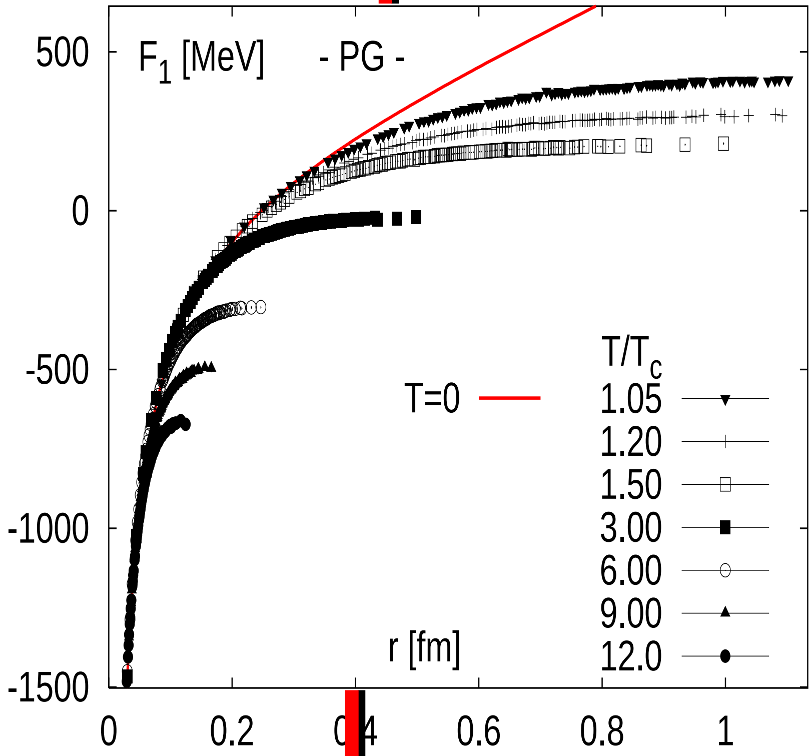
- An Overview -

Lattice:

$(\mathbf{F}_{\mathbf{Q\bar{Q}}} + \mathbf{c})/\mathbf{T}$



O. Kaczmarek,
F. Karsch,
P. Petreczky,
F. Z. (2002)



Similar in QCD:
O. Kaczmarek,
F. Karsch,
F. Z.
(in preparation)

$\mathbf{F(r,T) = V(r,T) - T\,S(r,T)}$

Related Talks:
O. Kaczmarek
S. Digal

O. Kaczmarek,
F. Karsch,
P. Petreczky,
F. Z. (2004)

PT /
non-PT
Behavior

Coupling $\alpha(r,T)$

$\simeq$ **finite-T Potential**

Further Topics - Visit f.i. *www.Physik.Uni-Bielefeld.de*
See also the recent study by *K. Petrov, P. Petreczky (2004)*

The running Coupling at finite Temperature

- The r- and T-dependence of α -

(I) At zero T: Define α_V and α_{qq} from the potential, $V(r) \simeq -4\alpha_V/3r + \sigma r$

Y. Schröder (1999); R. Sommer, S. Necco (2001)

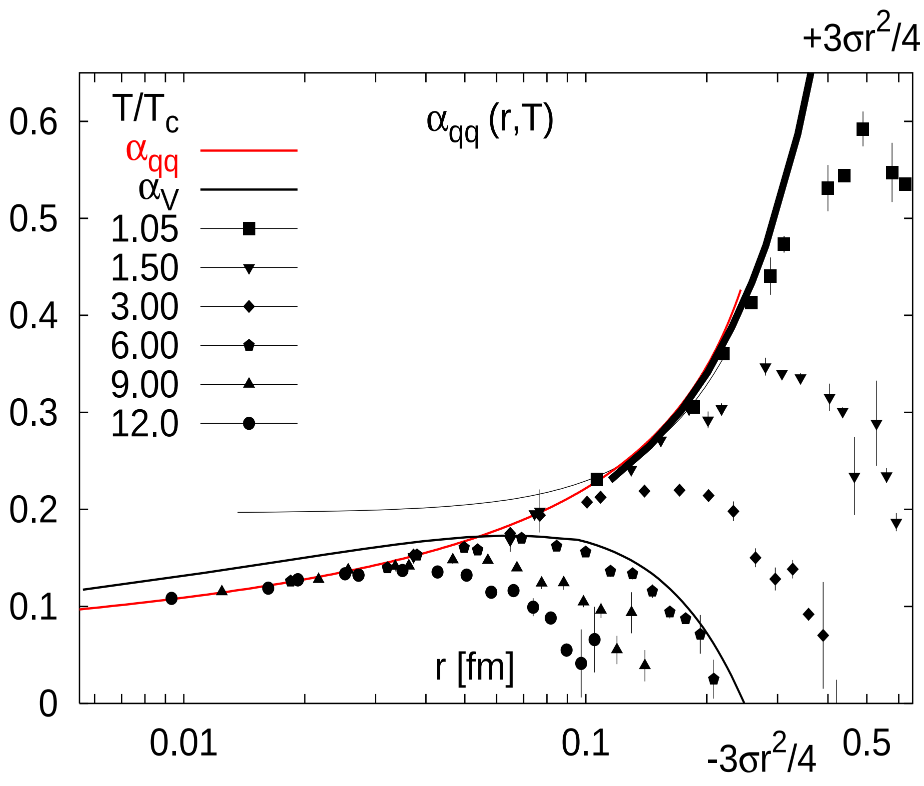
$$\alpha_V(r) = -\frac{3}{4} r \times V(r)\ , \qquad \alpha_{qq}(r) \ = \ \frac{3}{4} r^2 \times \frac{dV(r)}{dr}$$

(II) At finite T: Similar studies with $F_1(r,T)$

$$F_1(r) \quad \overset{r \ll 1/T}{\simeq} \quad -\frac{4}{3}\frac{\alpha_V(r)}{r}$$

$$\text{while} \quad F_1(r,T) \quad \overset{r \gg 1/T}{\simeq} \quad -\frac{4}{3}\frac{\alpha(T)}{r} e^{-m_D(T)r} + c(T)$$

$$\Longrightarrow \quad \alpha_V(r,T) \quad \text{and} \quad \alpha_{qq}(r,T)$$



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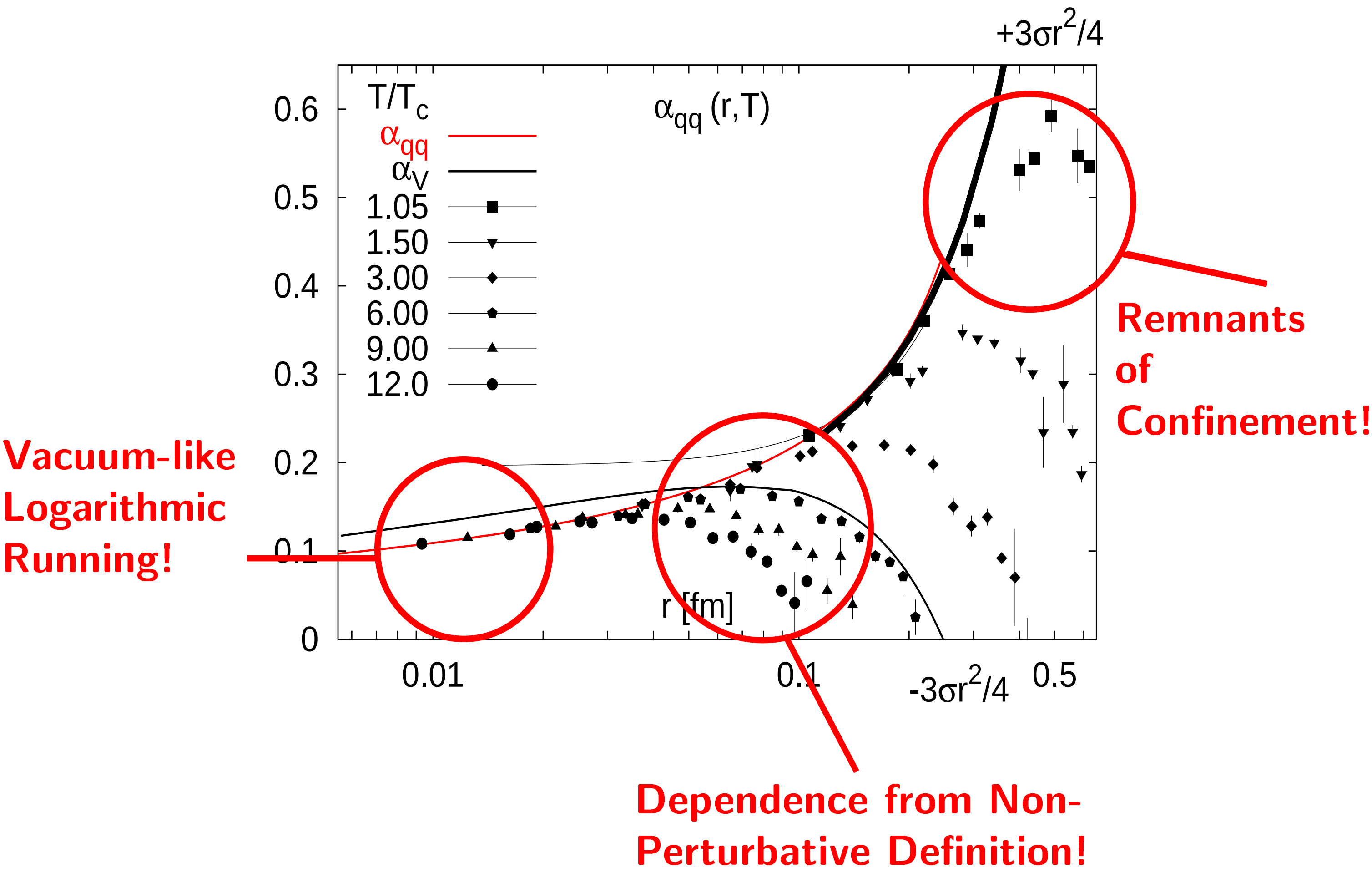


Temperature dependence of α

- Short and large distances -

From one-gluon exchange:

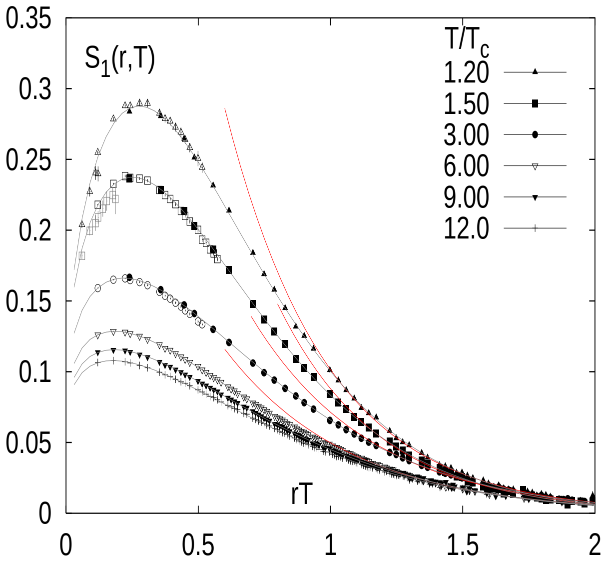
$$\delta \mathbf{F_1(r,T)} \equiv \mathbf{F_1(r,T) - F_1(\infty,T)}$$

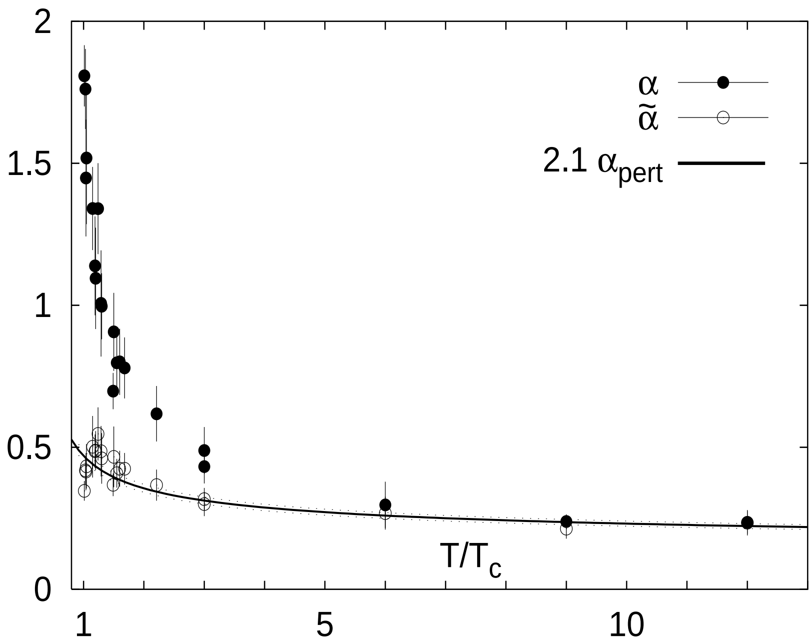
$$\overset{\mathbf{rT\gg 1}}{\simeq} -\frac{\mathbf{g^2(T)}}{\mathbf{3\pi rT}} \mathbf{e}^{-\mu(\mathbf{T})\mathbf{r}}$$

Define:

$$\mathbf{S_1(r,T)} \equiv -\frac{\mathbf{3}}{\mathbf{4}}\,\mathbf{rT} \times \frac{\delta\mathbf{F_1(r,T)}}{\mathbf{T}}$$

$$\overset{\mathbf{rT\gtrsim 1}}{\simeq} \alpha(\mathbf{T})\mathbf{e}^{-\mu(\mathbf{T})\mathbf{r}}$$





Def.:

$$\tilde{\alpha} \equiv \frac{\mathbf{1}}{\mathbf{4\pi}}\left(\frac{\mu(\mathbf{T})}{\mathbf{T}}\right)^{\mathbf{2}}$$

$$T \gtrsim T_c :$$

$$\alpha \simeq 4 \times \tilde{\alpha}$$

$$\tilde{\alpha} \simeq 2 \times \alpha_{pert}$$

$$\alpha \simeq 8 \times \alpha_{pert}$$

short vs. large distances:

$rT \equiv 1$	$T/T_C = 1.0$	$T/T_C = 1.1$	$T/T_C = 1.2$	$T/T_C = 2.0$	$T/T_C = 5.0$
r [fm]	1.18	1.07	0.98	0.59	0.24

Deviations from pure Coulombic behavior for $\mathbf{rT} \lesssim \mathbf{1}$

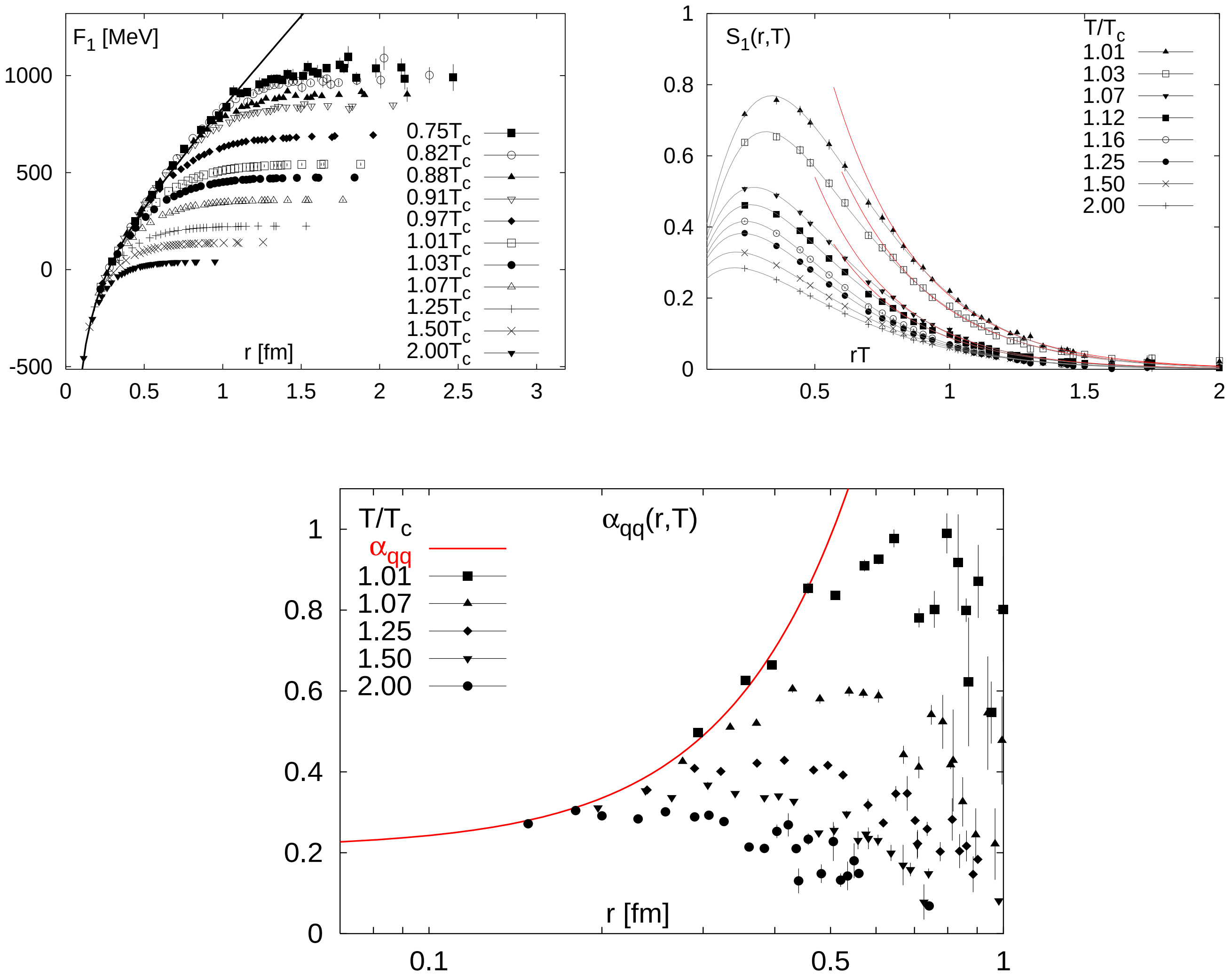
Summary ...

- ... and extended studies -

- r-dependence of the coupling at finite T becomes important
- Definition of $\alpha(r,T)$ strongly depends on the physical observable
- Remnants of the confinement forces survive the transition

Extended Studies: The Coupling in full QCD

O. Kaczmarek, F. Karsch, F. Z. (in preparation)
See also K. Petrov, P. Petreczky (2004)



See also the related talks by
O. Kaczmarek and S. Digal