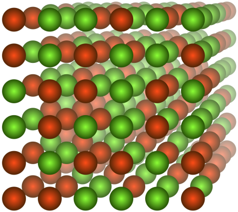
Two-Colour QCD at Finite Density with Two Flavours of Staggered Quarks

LATTICE 2016

Lukas Holicki Jonas Wilhelm Dominik Smith Björn Wellegehausen Lorenz von Smekal

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Outline

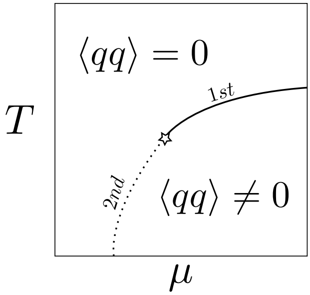


Introduction

Results at High Density

Conclusion

Introduction



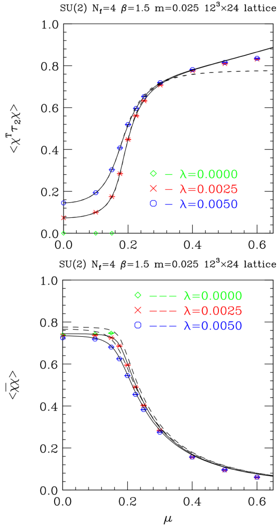
$$S_f = \overline{\psi} D(\mu) \psi + \frac{\lambda}{2} \left(\psi^T (C\gamma_5) \tau_2 \psi + \overline{\psi} (C\gamma_5) \tau_2 \overline{\psi}^T \right)$$

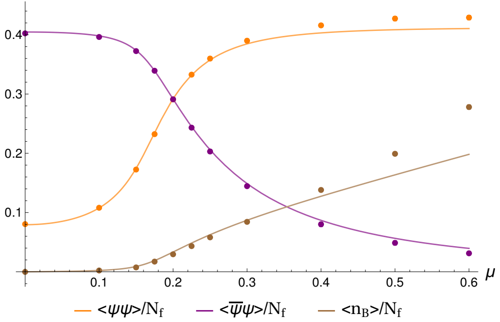
- D = rooted staggered kernel
  $N_f = 2$

- study diquark condensation transition, $\lambda \to 0$

Previous studies

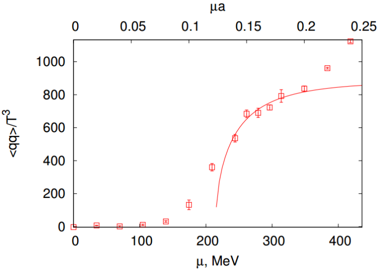
[Kogut, Toublan, PRD68, 054507 (2003)]

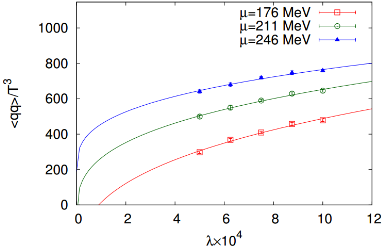




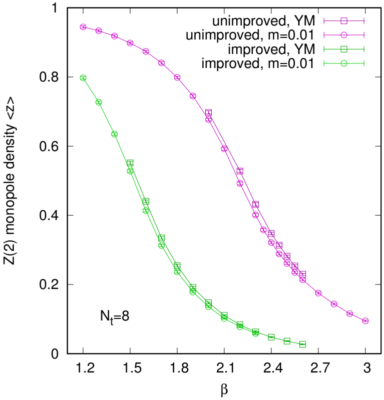
Previous studies

[Braguta, Ilgenfritz, Kotov, Molochkov, Nikolaev, arXiv:1605.04090v3 (2016)]



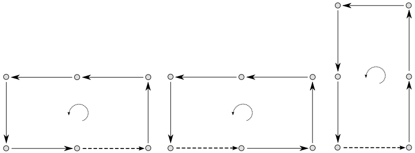


The Bulk Phase

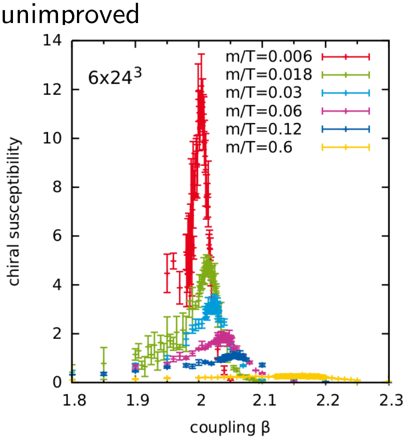


$\langle z \rangle = 1 - \frac{1}{N_C} \sum_C \prod_{P \in \partial C} \operatorname{sgn} \operatorname{tr} P$

- $\beta = 1.5 \rightarrow \langle z \rangle \approx 0.95$
- gauge action Symanzik improvement

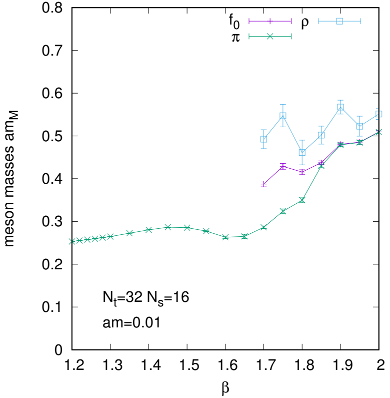


The Bulk Phase



[D. Scheffler, PhD Thesis, Technische Universität Darmstadt (2015)]

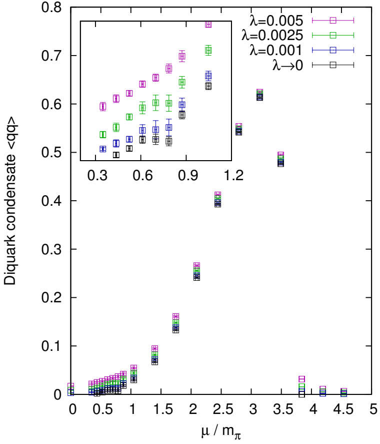
Parameters



- Compromise:
  $\beta = 1.7$, $\frac{m_\pi}{m_\rho} = 0.5816(27)$
- $N_s = 16$, $N_t = 32$
- standard rooted staggered quarks ($N_f = 2$), improved gauge action

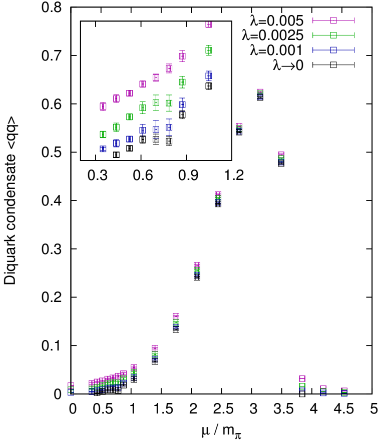
[D. Scheffler, PhD Thesis, Technische Universität Darmstadt (2015)]

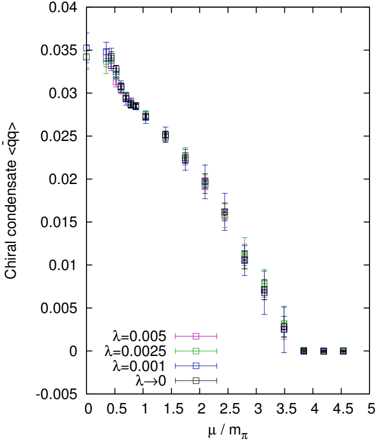
The diquark onset



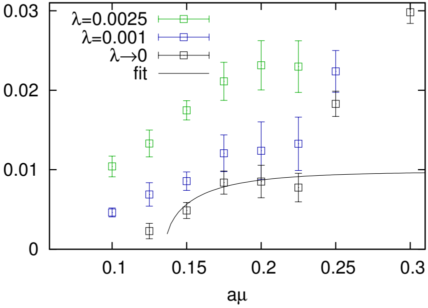
- condensation of diquarks for $\mu \geq_{\pi} /2$
- $\langle \overline{q} q \rangle$ rotates to $\langle qq \rangle$

The diquark onset





The diquark onset



from chiral effective Lagrangian:

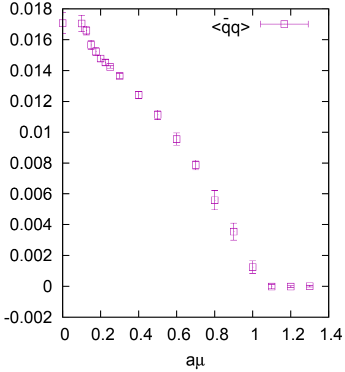
$$\langle qq\rangle = \langle\overline{q}q\rangle_0\sqrt{1-\left(\frac{\mu_c}{\mu}\right)^4}$$

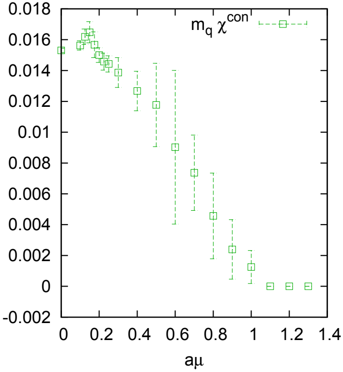
$$\langle\overline{q}q\rangle_0 = 0.00490(65)$$
$$a\mu_c = 0.1356(86)$$
$$am_\pi/2 = 0.1428(26)$$

Renormalization of $\langle \overline{q} q \rangle_{m_q} = \langle \overline{q} q \rangle_0 + c_2 m_q + \frac{c_{UV}}{a^2} m_q + \mathcal{O}(m_q^3)$

$$\chi_{m_q} = c_2 + \frac{c_{UV}}{a^2} + \mathcal{O}(m_q^2)$$

$$\Rightarrow \Sigma := \langle \overline{q} q \rangle_{m_q} - m_q \chi_{m_q}$$

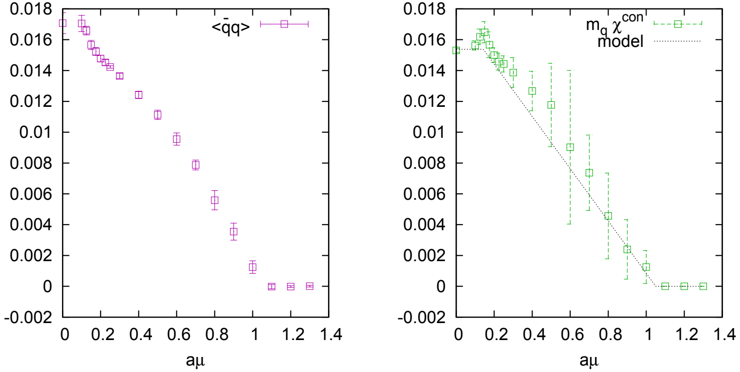




Renormalization of $\langle\overline{q}q\rangle_{m_q} = \langle\overline{q}q\rangle_0 + c_2 m_q + \frac{c_{UV}}{a^2} m_q + \mathcal{O}(m_q^3)$

$$\chi_{m_q} = c_2 + \frac{c_{UV}}{a^2} + \mathcal{O}(m_q^2)$$

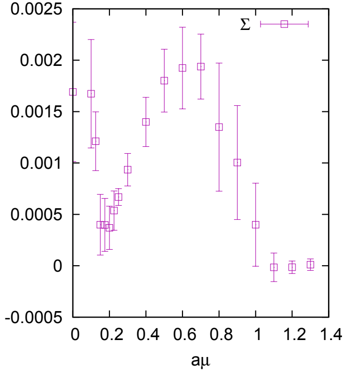
$$\Rightarrow \Sigma := \langle\overline{q}q\rangle_{m_q} - m_q \chi_{m_q}$$

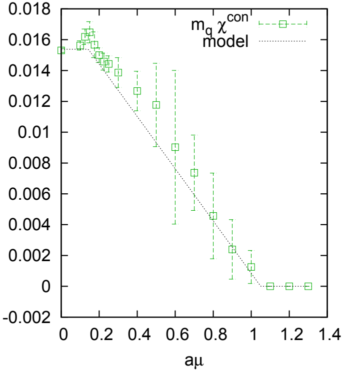


Renormalization of $\langle \bar{q}q \rangle_{m_q} = \langle \bar{q}q \rangle_0 + c_2 m_q + \frac{c_{UV}}{a^2} m_q + \mathcal{O}(m_q^3)$

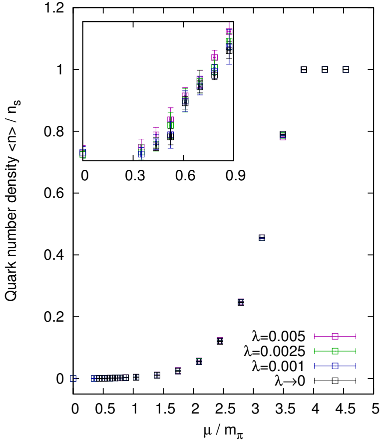
$$\chi_{m_q} = c_2 + \frac{c_{UV}}{a^2} + \mathcal{O}(m_q^2)$$

$$\Rightarrow \Sigma := \langle \bar{q}q \rangle_{m_q} - m_q \chi_{m_q}$$



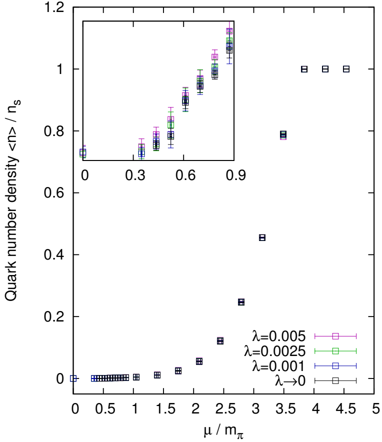


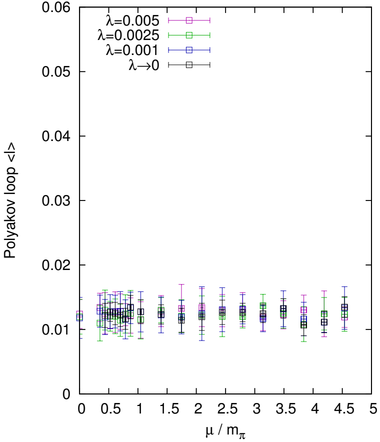
Lattice saturation



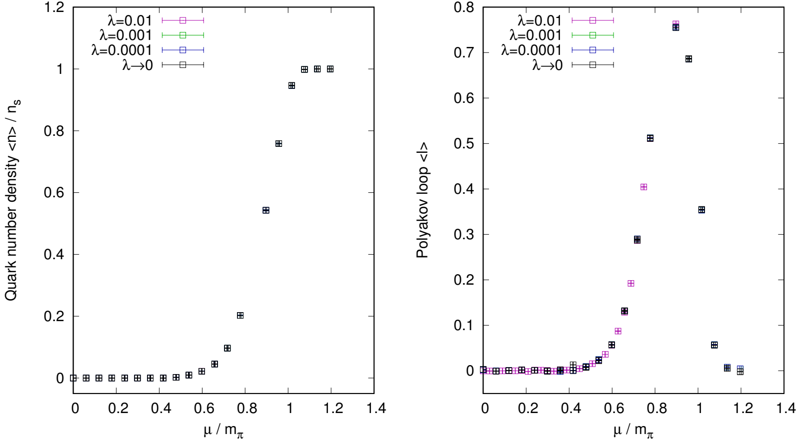
- lattice saturation
  $n_s = N_f N_c$

Lattice saturation





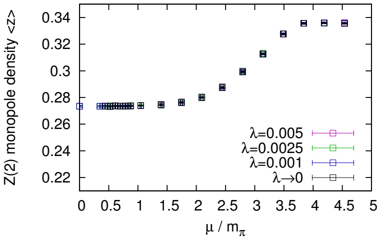
... with Wilson Quarks



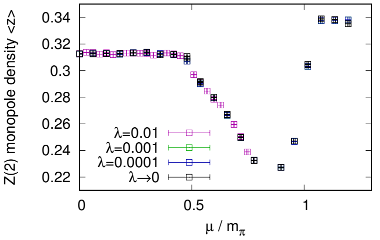
Quenching

- lattice saturation → re-quenching?
  - $\langle qq \rangle \to 0$
  - $\langle l \rangle \to 0$

Staggered quarks:

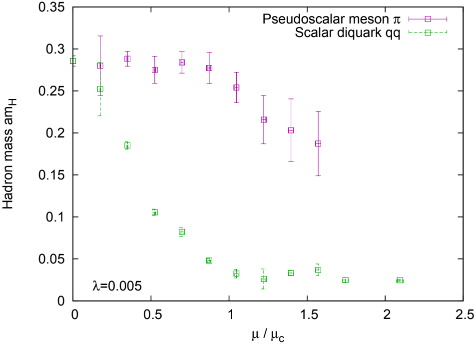


Wilson quarks:



The Goldstone modes

- $qq \to$ true Goldstone boson
- $\overline{q}q$ constant until onset



Conclusion

- study diquark condensation at $\mu = \frac{m_\pi}{2}$
    - severe effects of the bulk phase
    - gauge improvement
      $\rightarrow$ finite size effects
    - renormalization effects
- Polyakov loop insensitive to μ for staggered fermions