Deconfinement transition in two-flavour lattice QCD with dynamical overlap fermions in an external magnetic field.

Oleg A. Kochetkov in collaboration with V. G. Bornyakov, P. V. Buividovich, N. Cundy and A. Schäfer

Regensburg University

oleg.kochetkov@physik.uni-regensburg.de

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Abstract

We study the influence of an external magnetic field on the deconfinement transition in two-flavour lattice QCD with physical quark charges. We use dynamical overlap fermions without any approximation such as fixed topology and perform simulations on a $16^3 \times 6$ lattice and at a pion mass around $500\,\mathrm{MeV}$. The pion mass (as well as the lattice spacing) was determined in independent runs on $12^3 \times 24$ lattices. We consider two temperatures, one of which is close to the deconfinement transition and one which is above. Within our limited statistics the dependence of the Polyakov loop and chiral condensate on the magnetic field supports the "inverse magnetic catalysis" scenario in which the transition temperature decreases as the field strength grows for temperature not to far above the critical temperature [3].

Motivation

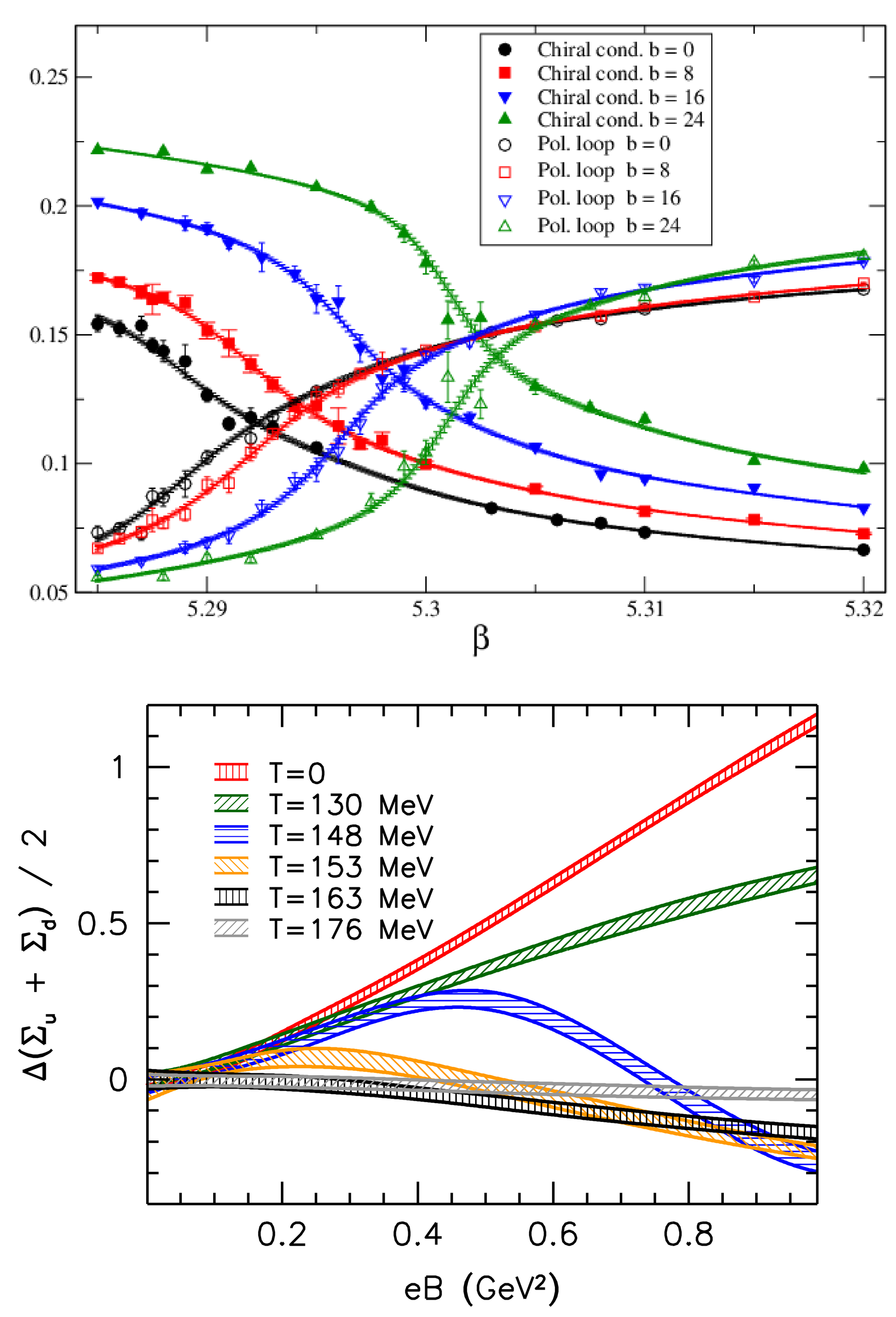

Figure 1: *Magnetic Catalysis (on the top plot) [1] vs Inverse Magnetic Catalysis (on the bottom plot) [2]*

Numerical setup

We use the massive overlap Dirac operator,

$$D[\mu] = 1 + \mu/2 + \gamma_5 (1 - \mu/2)\,\mathrm{sign}\,(K), \qquad (1)$$

where $K = \gamma_5 (D_W - \rho)$ and D_W is the Wilson-Dirac operator with one level of over-improved stout smearing.

- $m_q = \mu/((1-\mu)\rho) = 0.087$
- $\rho = 1.368, \mu = 0.106$
- $\beta = 7.5$, $a = 0.15\,\mathrm{fm}$ and $T = 220\,\mathrm{MeV}$
- $\beta = 8.3$, $a = 0.12\,\mathrm{fm}$ and $T = 280\,\mathrm{MeV}$

Chiral condensate and the distribution of Dirac eigenvalues

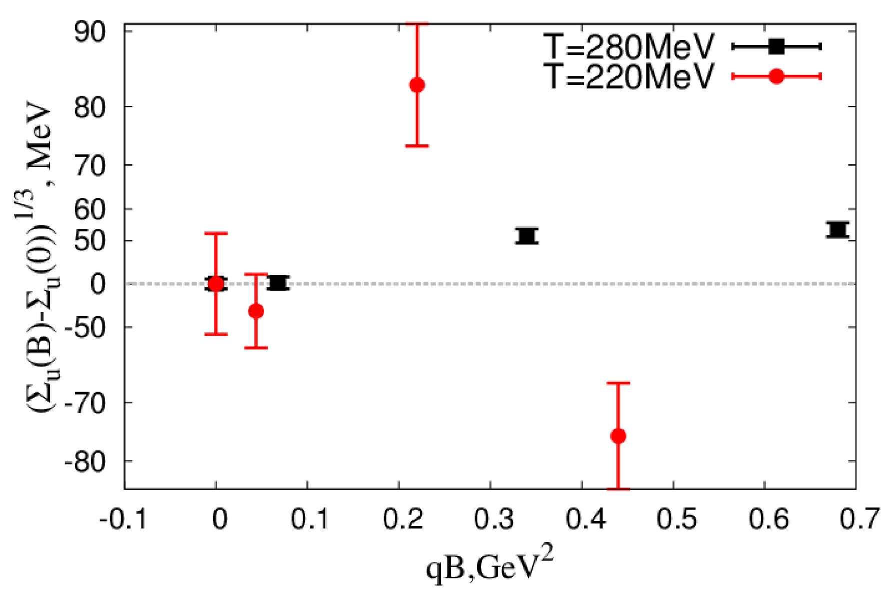

Figure 2: *The difference $\Sigma(B,T) - \Sigma(0,T)$ in the values of the chiral condensate at zero and nonzero external magnetic field for $T = 220\,\mathrm{MeV}$ and $T = 280\,\mathrm{MeV}$ (vertical axis is chosen to be the cubic scale).*

We have also considered the distributions of the low-lying eigenvalues λ of the projected massless Dirac operator

$$\tilde{D}_0 = \frac{2\rho D_0}{2 - D_0}, \qquad D_0 = 1 + \gamma_5 \mathrm{sign}\,(K) \qquad (2)$$

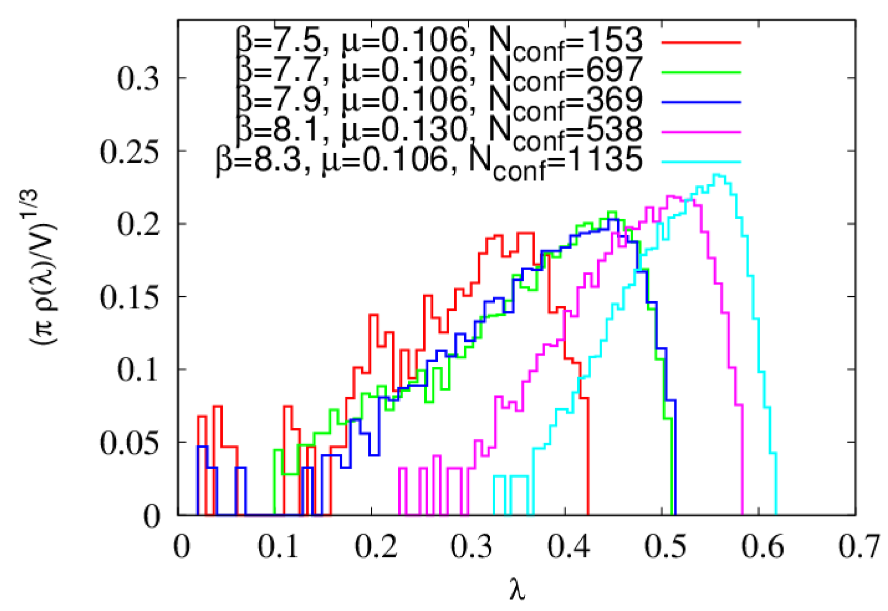

Figure 3: *Histograms of the eigenvalues λ of the overlap Dirac operator (2) in lattice units at different values of the inverse coupling constant β which correspond to different temperatures in the range $220\,\mathrm{MeV} < T < 280\,\mathrm{MeV}$.*

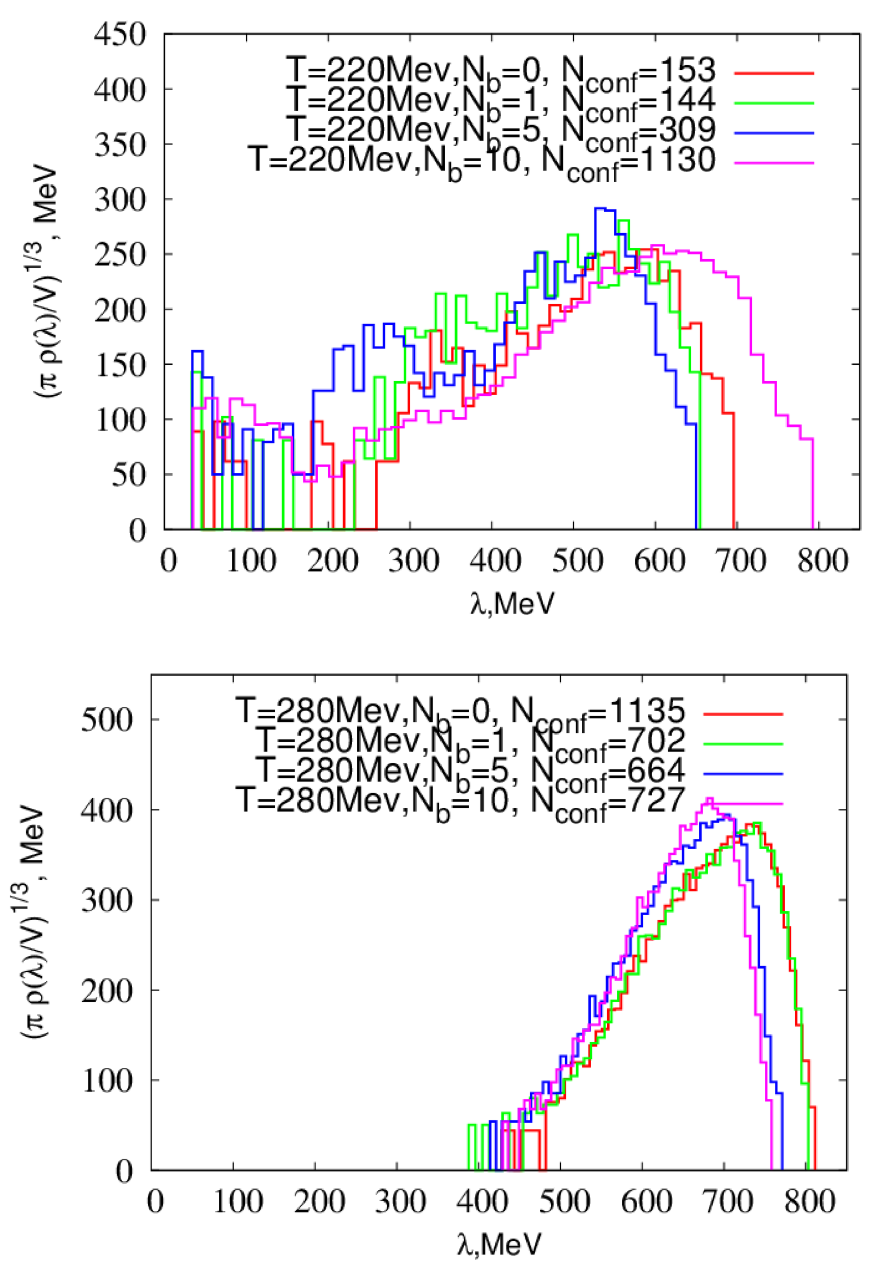

Figure 4: *Histograms of the eigenvalues λ of the operator (2) at temperatures $T = 220\,\mathrm{MeV}$ ($\beta = 7.5$, on the top) and $T = 280\,\mathrm{MeV}$ ($\beta = 8.3$, on the bottom) and at different values of the magnetic field flux.*

Polyakov loop

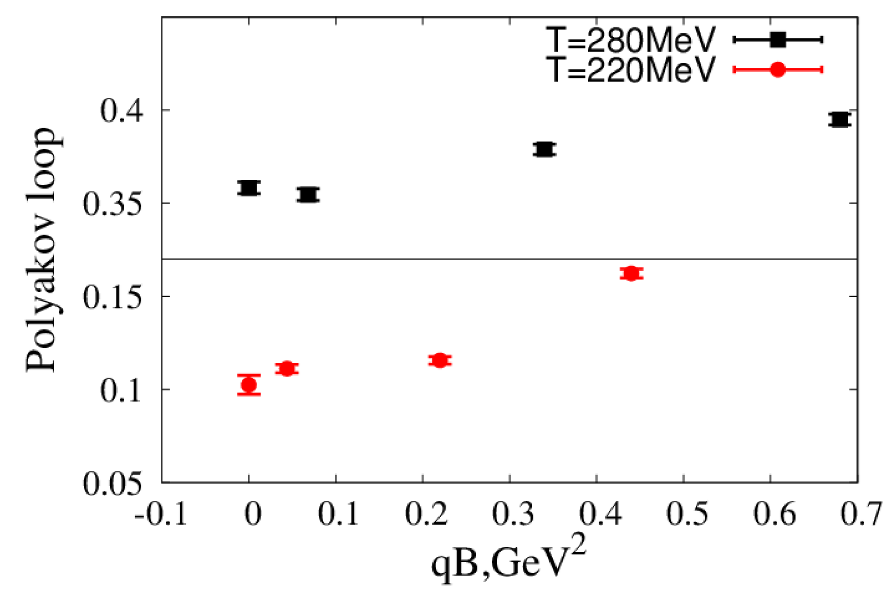

Figure 5: *The Polyakov loop as a function of magnetic field for $T = 220\,\mathrm{MeV}$ and $T = 280\,\mathrm{MeV}$.*

Topological charge

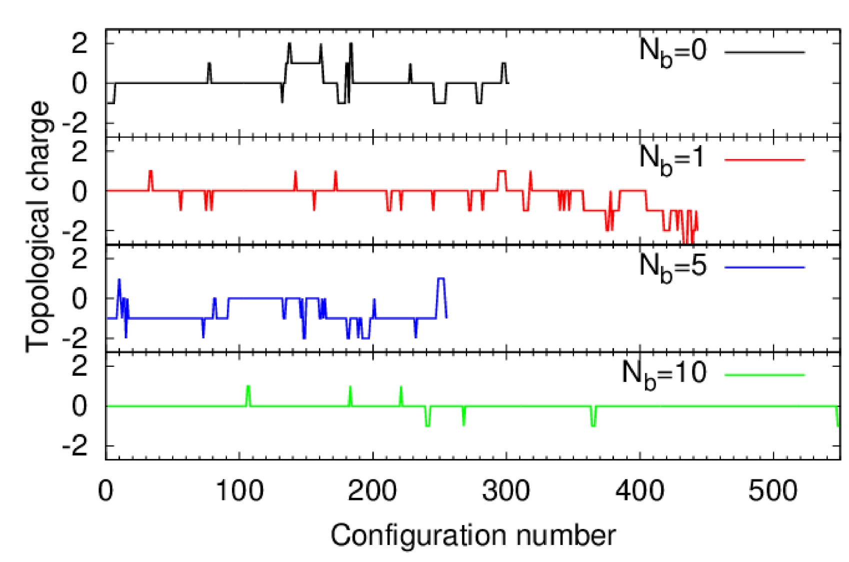

Figure 6: *Monte-Carlo histories of the topological charge in the confinement regime ($T = 220\,\mathrm{MeV}$).*

- With the present level of statistical uncertainties we cannot make quantitative conclusions on the dependence of $\langle Q^2 \rangle$ on the magnetic field strength.
- In the deconfinement regime ($T = 280\,\mathrm{MeV}$) we did not see any topological fluctuations for any value of the magnetic field.

Conclusion

- First-principle simulations without any restriction of topology fluctuations with OVERLAP FERMIONS
- Our results support the INVERSE MAGNETIC CATALYSIS scenario in which the deconfinement temperature decreases with increasing magnetic field.
- Good chiral properties seem to strengthen inverse magnetic catalysis , despite of relatively high pion mass.

References

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[2] M. D'Elia, S. Mukherjee, and F. Sanfilippo, Phys. Rev. D **82**, 051501 (2010).

[3] G. S. Bali, F. Bruckmann, G. Endrodi, Z. Fodor, S. D. Katz, and A. Schäfer, Phys. Rev. D **86**, 071502 (2012).