

Motivation

- Explore finite temperature phase transition/crossover for $N_f = 2$ QCD
- Order of transition in the chiral limit not known yet for two flavors
- Argued to be in universality class of $O(4)$ 3-dim spin model, however 1st order not ruled out.
- Provide thermodynamic equation of state (pressure and energy density) for hydrodynamic description of heavy ion collision experiments.

Methods

- Hybrid Monte Carlo simulation of QCD path integral
- Wilson twisted mass discretization: $\Rightarrow \mathcal{O}(a)$ **improvement** at maximal twist:

$$S_f[U, \psi, \bar{\psi}] = \sum \bar{\chi}(x) \left(1 - \kappa H[U] + 2i\kappa a \mu \gamma_5 \tau^3 \right) \chi(x), \quad \psi = \frac{1}{\sqrt{2}}(1 + i\gamma_5 \tau^3) \chi$$
- Tree level improved gauge sector:

$$S_g[U] = \beta \left(c_0 \sum_P \left[1 - \frac{1}{3} \text{ReTr}(U_P) \right] + c_1 \sum_R \left[1 - \frac{1}{3} \text{ReTr}(U_R) \right] \right)$$

Some Details

Pseudo-critical temperatures:

From the maximum of the susceptibility of $\langle \bar{\psi}\psi \rangle$ we obtain the following mass dependence of the pseudo-critical temperature:

$m_\pi[\text{MeV}]$	316(16)	398(20)	469(24)
$T_c[\text{MeV}]$	202(7)	217(5)	229(5)

Trace anomaly

$$\begin{aligned} \frac{I}{T^4} &= \frac{\epsilon - 3p}{T^4} = -\frac{T}{T^4} V \left\langle \frac{d \ln Z}{d \ln a} \right\rangle_{\text{sub}} \\ &= N_\tau^4 \left(\frac{d\beta}{da} \right) \left(\frac{c_0}{3} \langle \text{ReTr} U_P \rangle_{\text{sub}} + \frac{c_1}{3} \langle \text{ReTr} U_R \rangle_{\text{sub}} \right. \\ &\quad \left. + \frac{\partial \kappa_c}{\partial \beta} \langle \bar{\chi} H[U] \chi \rangle_{\text{sub}} - \left(2a\mu \frac{\partial \kappa_c}{\partial \beta} + 2\kappa_c \frac{\partial(a\mu)}{\partial \beta} \right) \langle \bar{\chi} i\gamma_5 \tau^3 \chi \rangle_{\text{sub}} \right) \end{aligned}$$

Integral method

$$\frac{I}{T^4} = T \frac{\partial}{\partial T} \left(\frac{p}{T^4} \right) \Rightarrow \frac{p}{T^4} - \frac{p_0}{T_0^4} = \int_{T_0}^T d\tau \frac{\epsilon - 3p}{\tau^5} \Big|_{\text{LCP}}$$

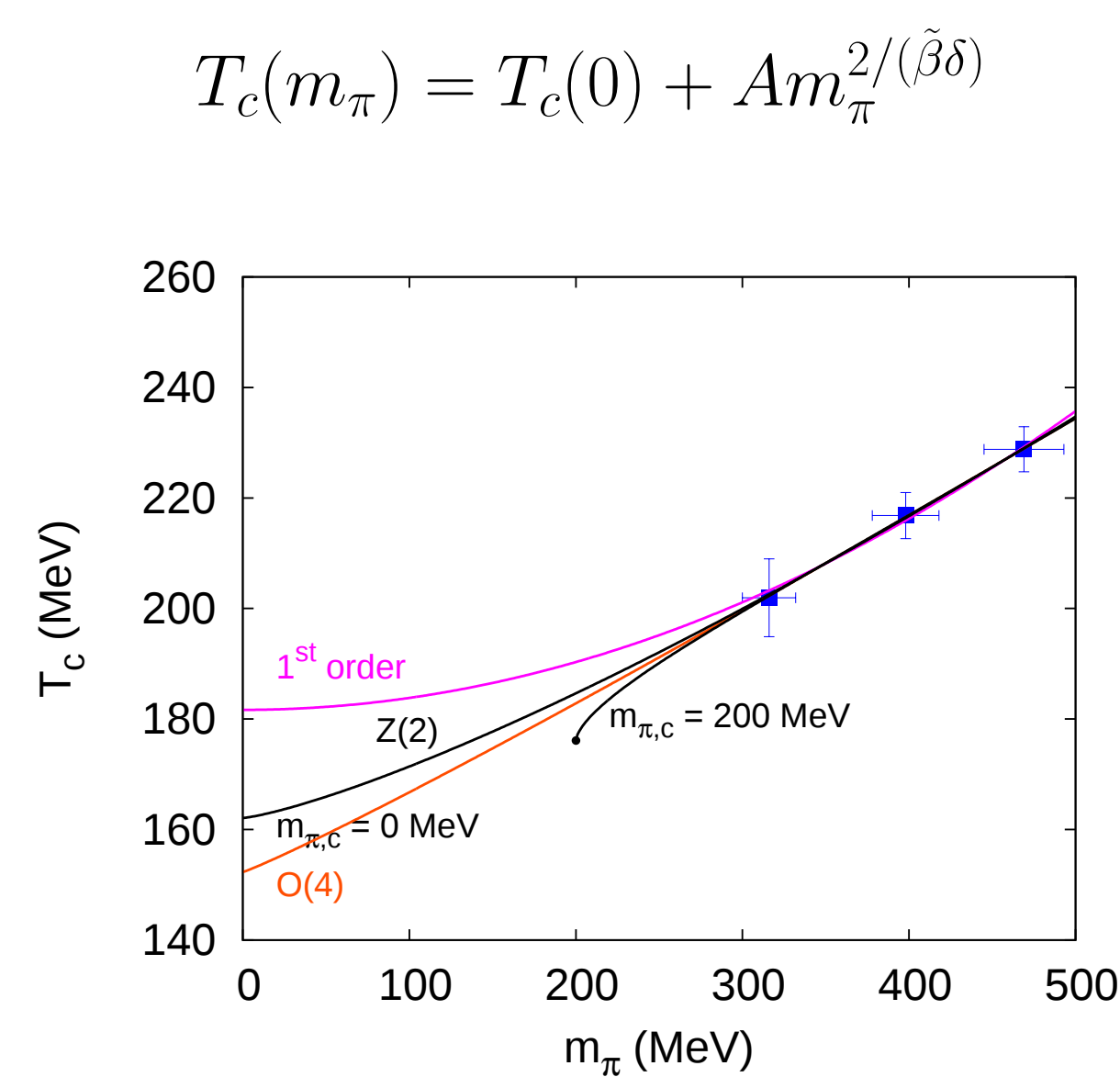
on lines of constant physics (LCP)

$\Rightarrow$: Obtain pressure $p(T)$ and energy density $\epsilon(T)$

Recent Results

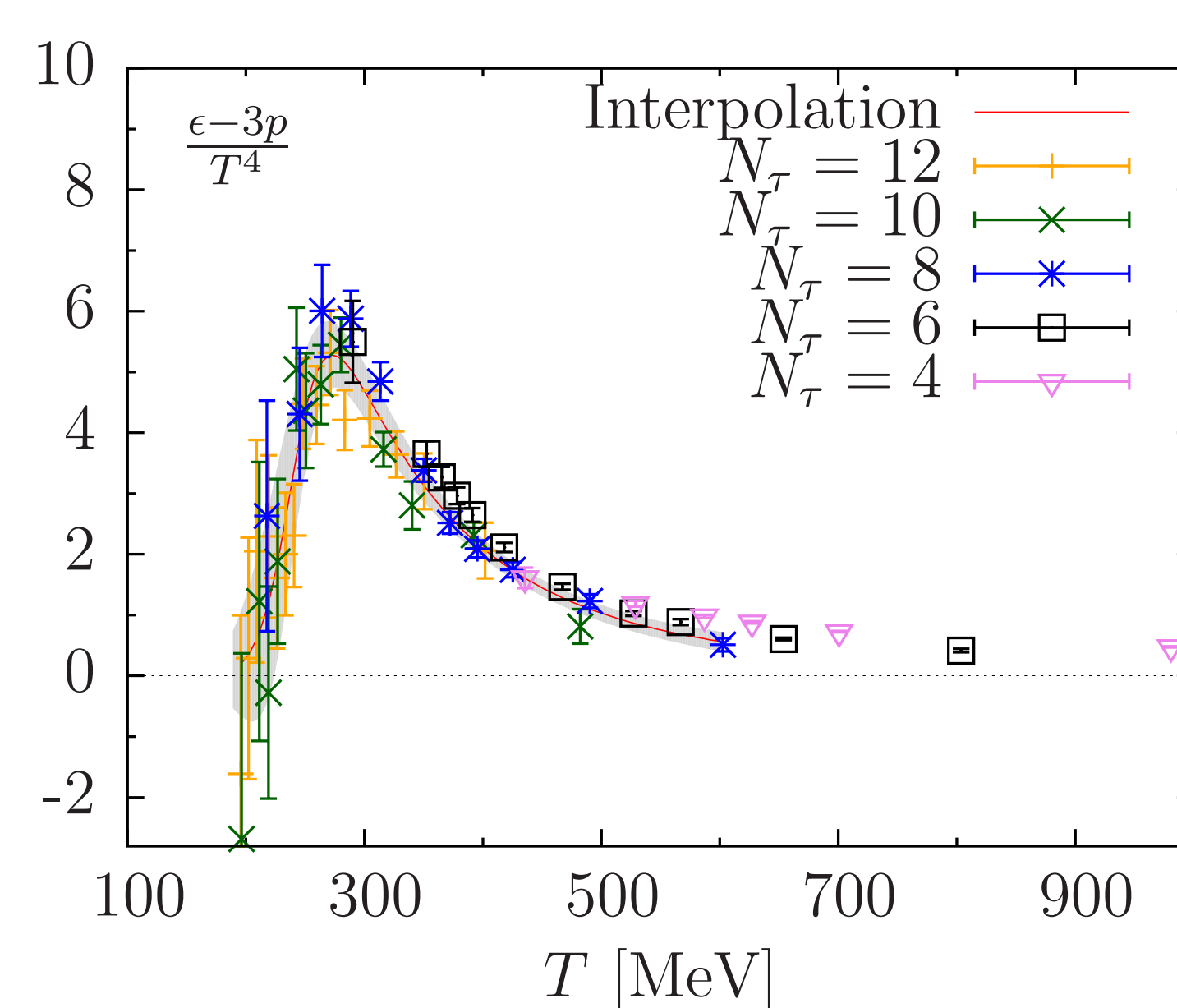
Chiral limit scenarios

Mass dependence of T_c :



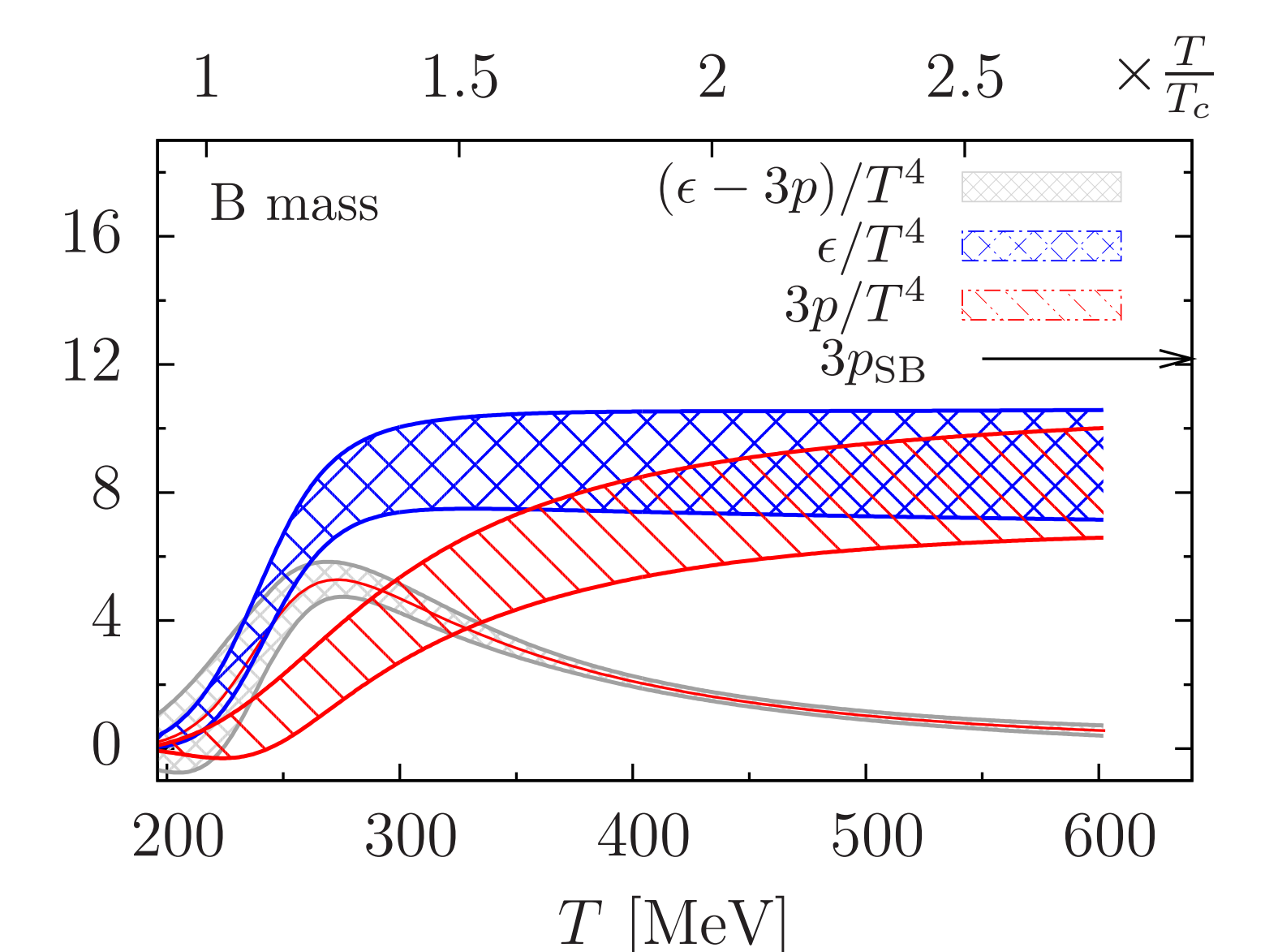
$\Rightarrow$ Different scenarios can not (yet) be discriminated.

Result: Trace anomaly



$\Rightarrow$ Lattice discretization effects under control
(by tree-level improvement, several N_τ , where $T = \frac{1}{N_\tau a}$).

p and ϵ from integral method:



$\Rightarrow$ Further improve precision for $p(T)$ and $\epsilon(T)$.

Publications

- [1] Aouane, R. *et al.*: Landau gauge gluon and ghost propagators from lattice QCD with $N_f=2$ twisted mass fermions at finite temperature. , 2012. arXiv:1212.1102.
- [2] Burger, F. *et al.*: The thermal QCD transition with two flavours of twisted mass fermions. , 2011. arXiv:1102.4530.
- [3] Burger, F. *et al.*: Pseudo-Critical Temperature and Thermal Equation of State from $N_f = 2$ Twisted Mass Lattice QCD. , 2012. arXiv:1212.0982.
- [4] Burger, F. *et al.*: Quark mass and chiral condensate from the Wilson twisted mass lattice quark propagator. , 2012. arXiv:1210.0838.

Selected Talks

- Workshop "Quarks, Gluons and Hadronic Matter under Extreme Conditions", St. Goar 03/2011 (poster presented)
- International Symposium on Lattice Field Theory 2011, Squaw Valley/USA, 10.7.2011: "Thermodynamics with $N_f = 2$ Wilson fermions at maximal twist"
- International Symposium on Lattice Field Theory 2012, Cairns/AUS, 24.6.2011: "Equation of state from $N_f = 2$ twisted mass lattice QCD"
- SFB/TR9 Arbeitsgruppentreffen, Karlsruhe 03/2012: "Lattice QCD with Wilson twisted mass fermions: the nonzero temperature case"
- ETMC Meeting, Frankfurt 10/2012: "Equation of state from $N_f = 2$ twisted mass lattice QCD"

Collaborations

- Twisted mass at finite temperature (tmfT)
- European Twisted Mass Collaboration (ETMC)
- DFG Sonderforschungsbereich Transregio 9, Projekt A4

Profit from the GK

- Broader view on the field due to half year Block Courses
- Additional travel budget

Contact Details and Further Information

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