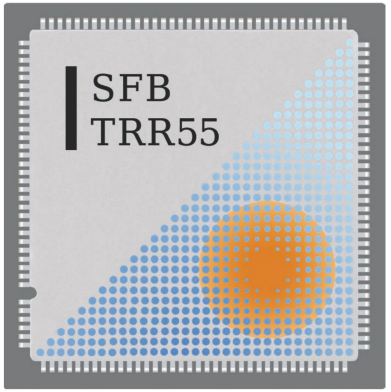

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Thermodynamics with overlap fermions

And update on the charmed EOS

S. Borsanyi, Y. Delgado, S. Durr, Z. Fodor, S.D. Katz, S.K., T. Lippert, D. Nogradi, C. Ratti, C. Schroeder, K.K. Szabo

Overlap: motivation

Staggered calculations are 'mature':

- Handle on finite volume & lattice spacing artifacts,
- Results at physical mass parameters.

But:

- Suffer from taste breaking,
- Rely on 'rooting'.

Wilson calculations are advancing ($\rightarrow$ talk by D. Nogradi)

- Several lattice spacings,
- Appoach (slowly) physical mass parameters.

But:

- Explicitly break chiral symmetry.

$\Rightarrow$ Additional cross-check welcome

Overlap: motivation

Use chiral fermions to study chiral properties of finite temperature QCD

- Domain-wall fermions already in use
- Overlap fermions have a 'lattice chiral symmetry'

This study:

- Checks the feasibility of dynamical overlap simulations
- Performs a first cross check of staggered results

Overlap: simulation setup

- Tree level Symanzik improved gauge action
- $N_f = 2$ overlap fermions, $2\times$ HEX smearing

$$D_{ov} = \left(m_0 - \frac{m}{2}\right)\left(1 + \gamma_5 \mathrm{sgn}\left(\gamma_5 D_W(-m_0)\right)\right) + m$$

- Reduce computational costs: topology fixing

JLQCD, Fujaya et al., *Phys. Rev.* **D74** (2006) 094505

$$S_E = \sum_x \left\{\bar{\psi}_E D_W(-m_0)\psi_E + \phi^\dagger [D_W(-m_0) + i m_B \gamma_5 \tau_3]\phi\right\}$$

$$det\left[\frac{H^2(-m_0)}{H^2(-m_0) + m_B^2}\right]$$

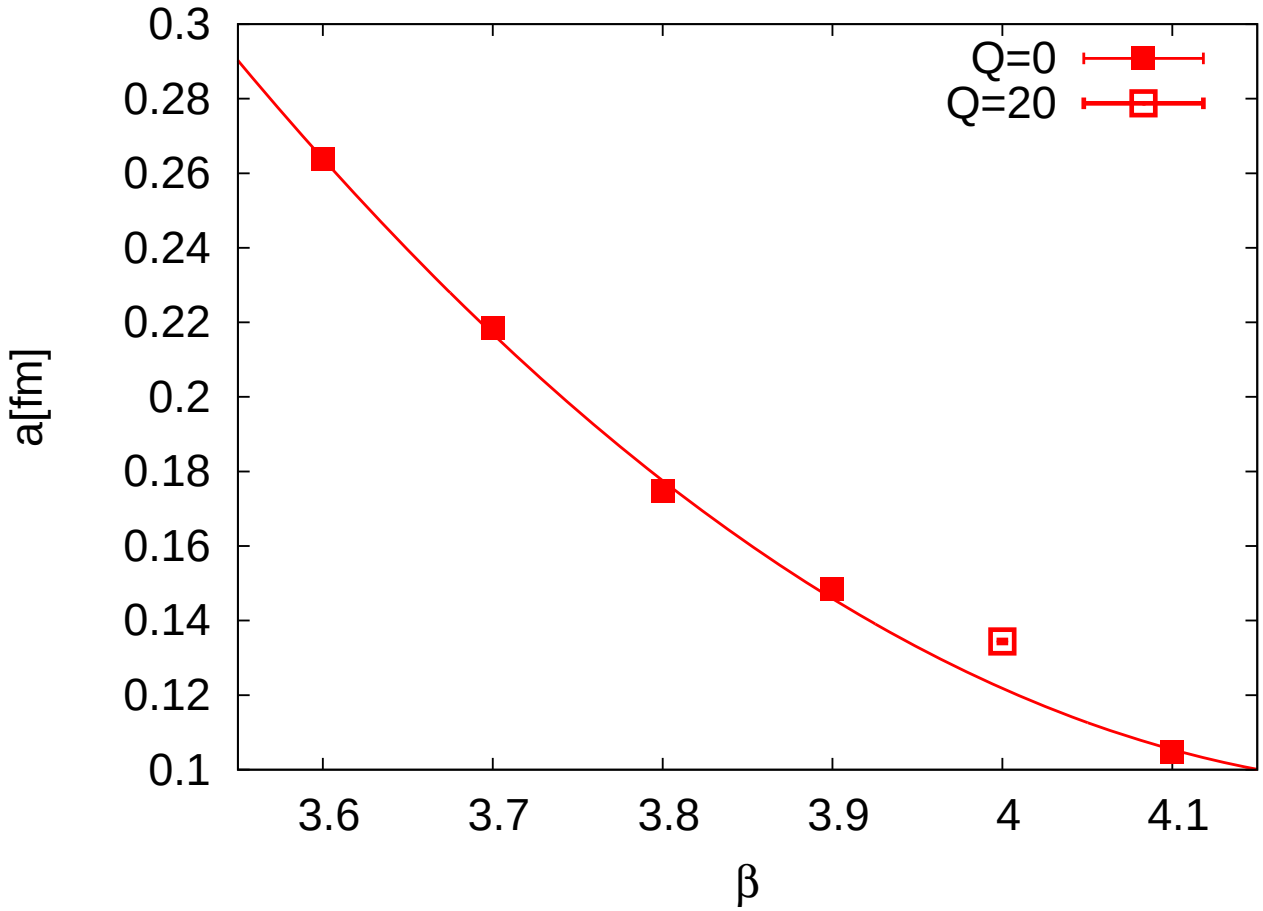
$\rightarrow$ potentially significant power like finite volume effects

Overlap: line of constant physics

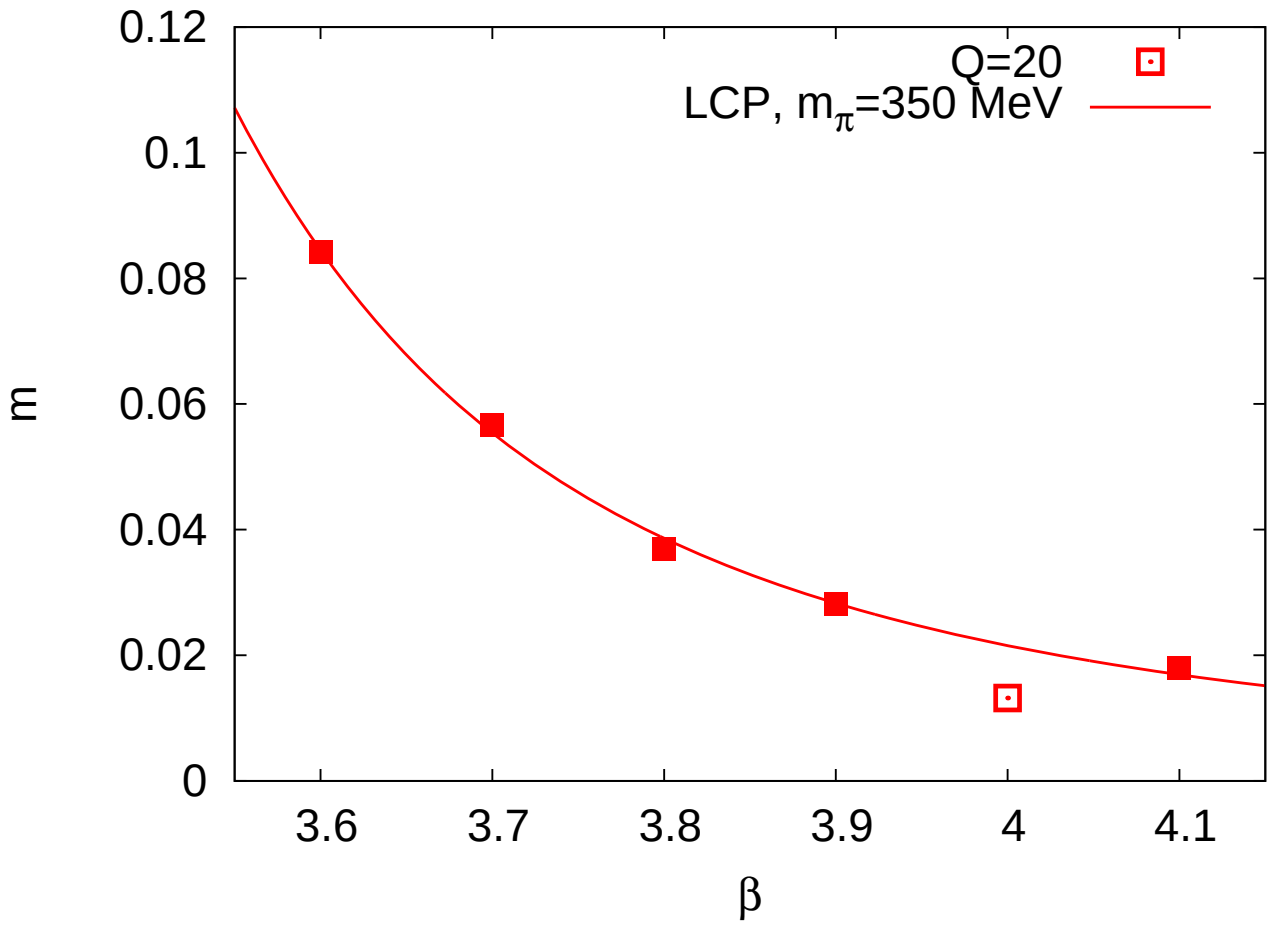
- Based on w_0 scale setting ($\rightarrow$ talk by T. Kurth)
- w_0 is based on the 'Wilson flow' and is related to 't_0' scale

  Lüscher *Comm. Math. Phys.* **293** (2010) 899 , *JHEP* **1008** (2010) 071
- $T = 0$ ensembles:
  $V = 12^3 \times 24$ for $\beta = 3.6, 3.7$, and 3.8
  $V = 16^3 \times 32$ for $\beta = 4.0$ and 4.1
- Tune m such that $M_\pi \times w_0 = 0.312$
- Using $w_0 = 0.1755$ fm ($N_f = 2 + 1$ with $M_\pi / M_\Omega, M_K / M_\Omega =$ phys.), we have $M_\pi = 350$ MeV
- One data point with $Q_{top} = 20$, showing finite volume effects

Overlap: line of constant physics



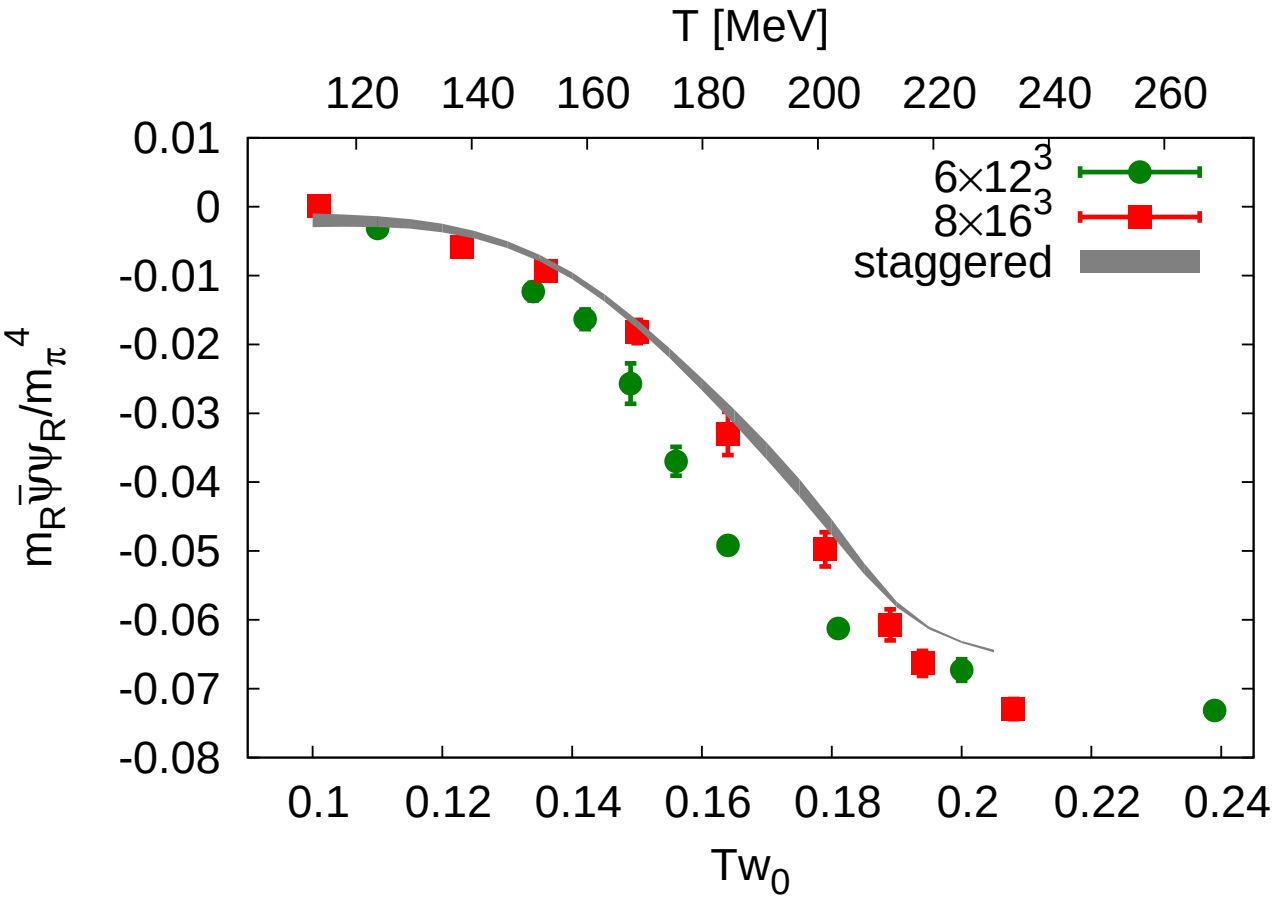
Overlap: line of constant physics



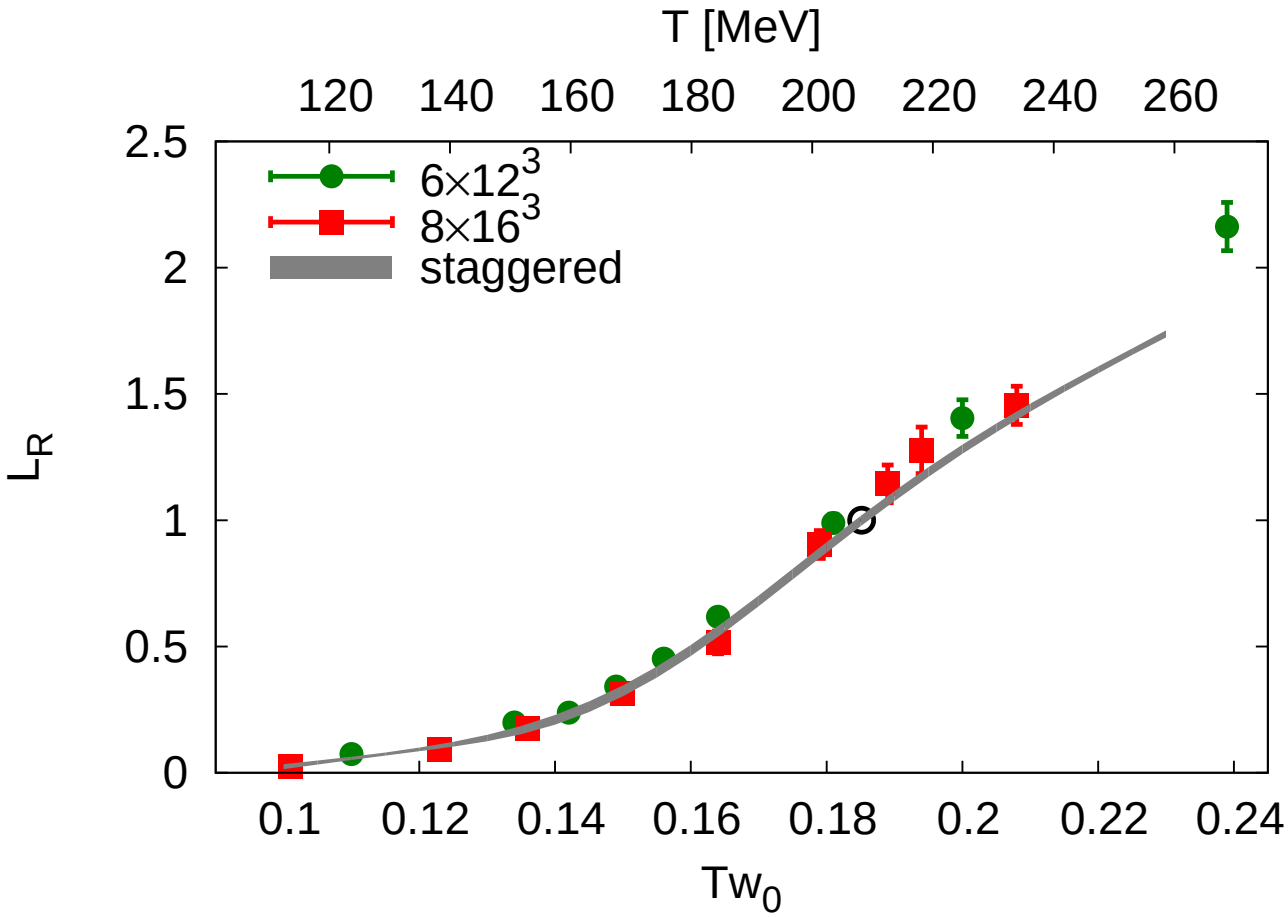
Overlap: setup staggered reference

- Tree level Symanzik improved gauge action
- $N_f = 2$ staggered fermions, $4\times$ stout smearing using $\rho = 0.125$
- $N_f = 2$ LCP analogous to overlap (based on 16 ensembles, $\beta = 3.8 \ldots 4.1$)
- $N_t = 6, 8$, and 10 simulations
- 'staggered estimate' from overlapping N_t curves

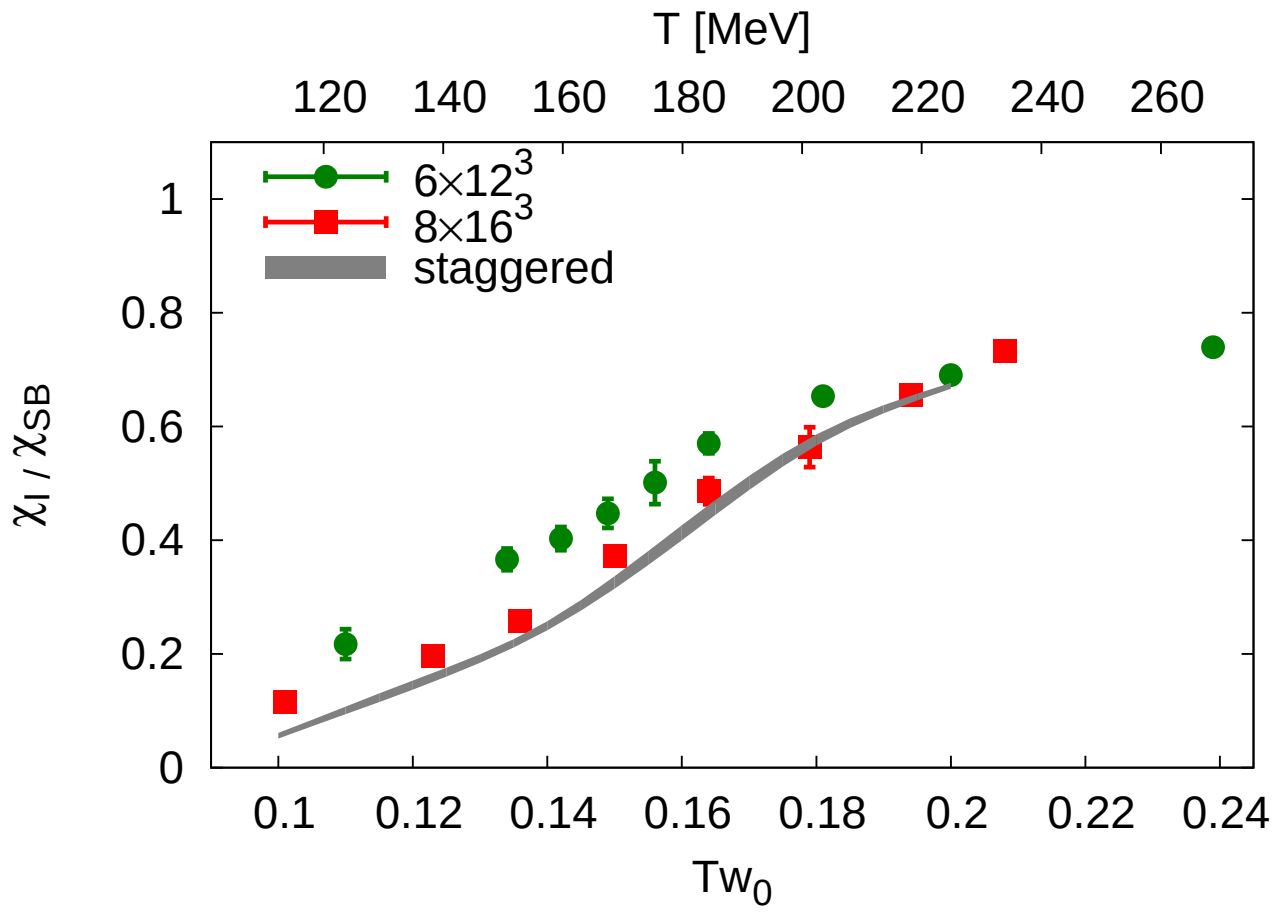
Overlap: chiral condensate



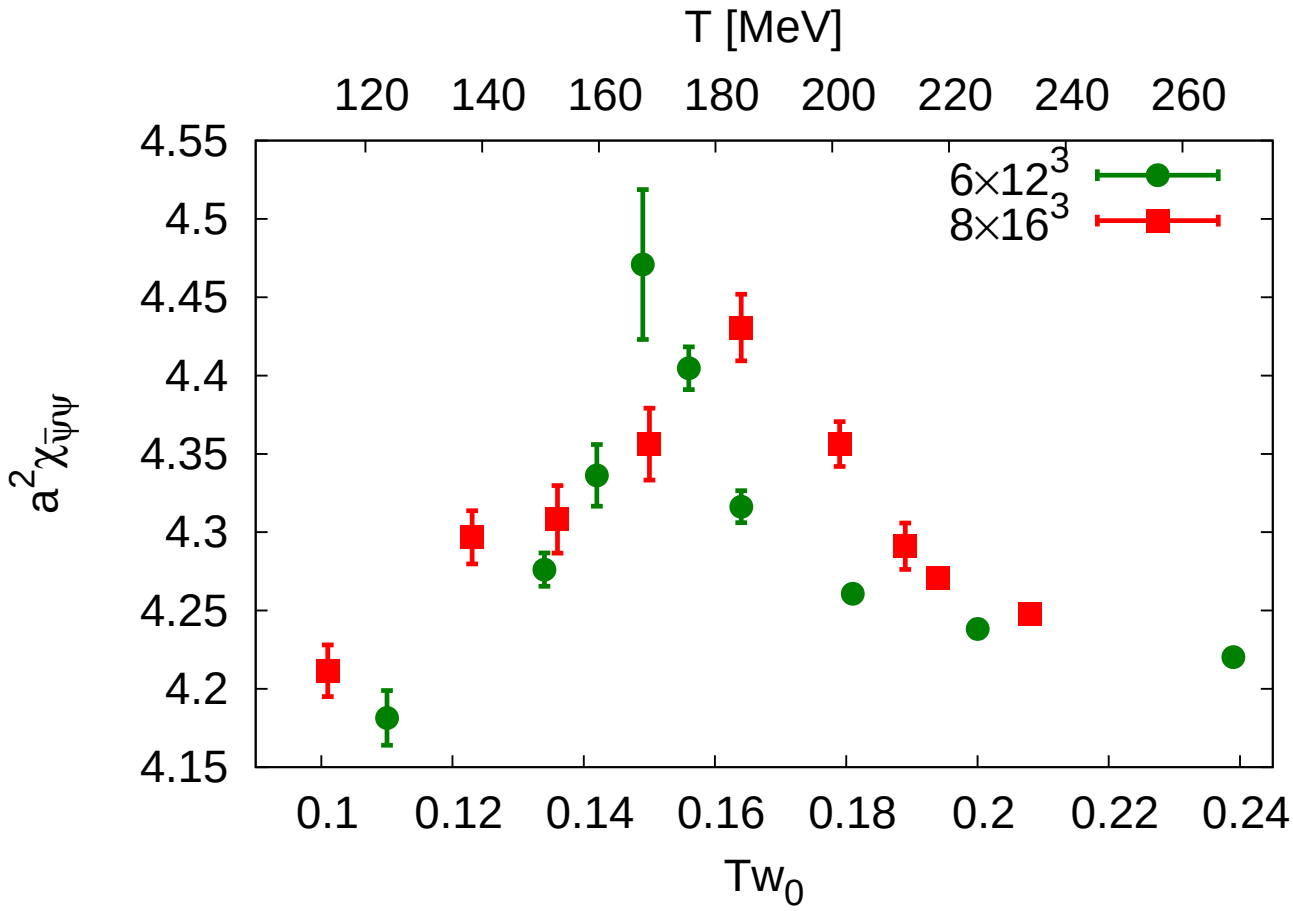
Overlap: Polyakov loop



Overlap: isospin susceptibility



Overlap: chrial susceptiblity



Overlap: conclusions

- Simulations with fixed topology are feasible
- Overlap results at higher than physical M_π show agreement with staggered fermions
- Agreement on the location of the crossover region

Near future:

- Deal with finite volume/fixed topology related effects
- Increase statistics
- Add $N_t = 10$ and perform continuum estimate

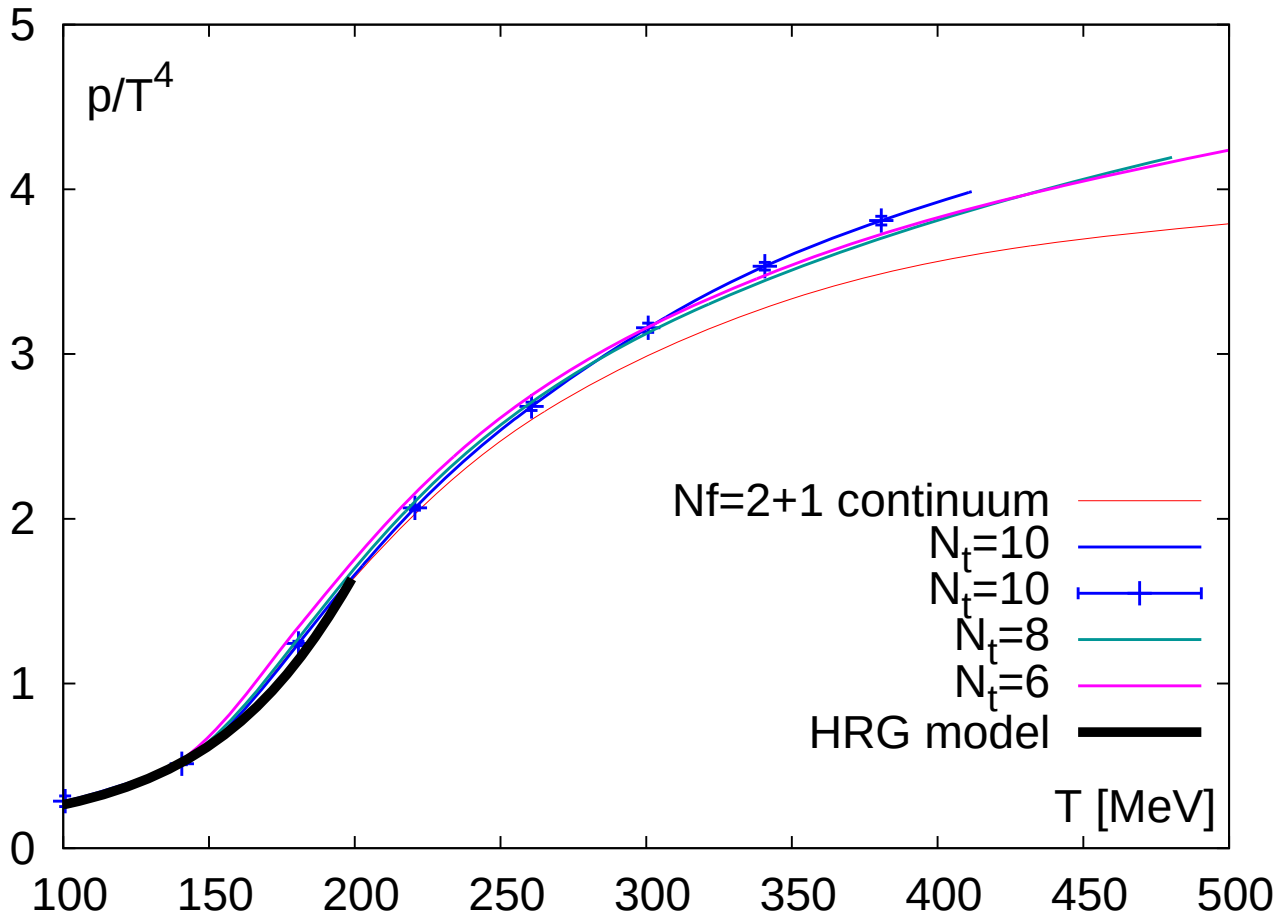
Long term goals:

- Include strange quark
- Perform cross-check at smaller M_π

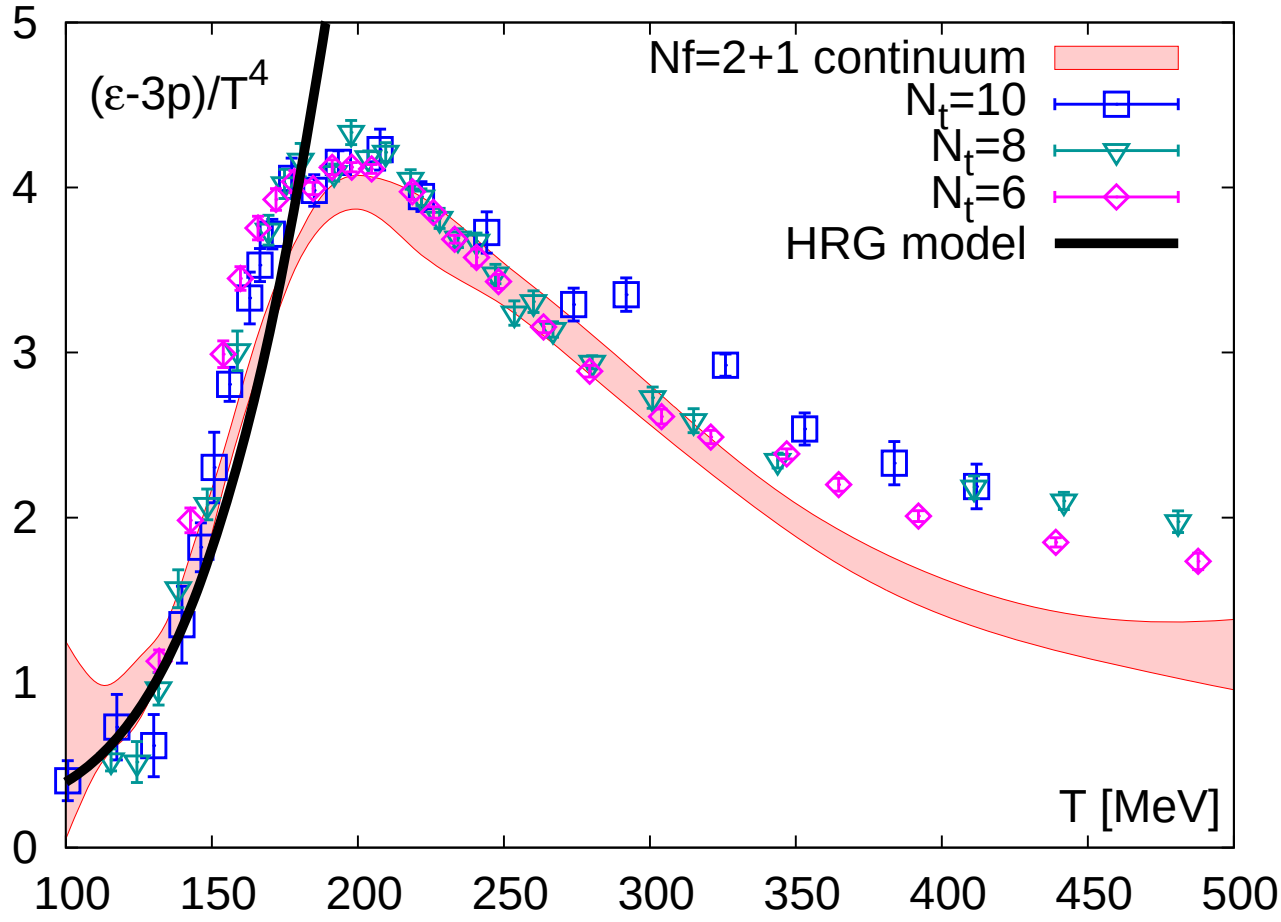
charmed EOS: update

- Increased statistics
- Computed trace anomaly and entropy
- Comparison to perturbative results

charmed EOS: pressure (update)



charmed EOS: trace anomaly



charmed EOS: entropy