The search for the chiral phase transition in three flavor QCD at imaginary chemical potential

Bálint Tóth

Bergische Universität Wuppertal, Germany

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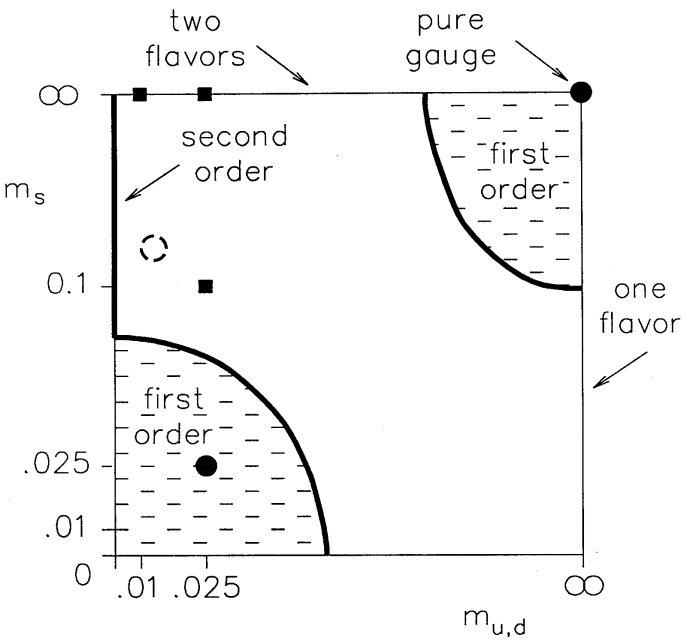
Phase diagram

- $N_f = 2 + 1$, physical quark masses $\longrightarrow$ crossover

  [Aoki et al. Nature 443 (2006) 675]

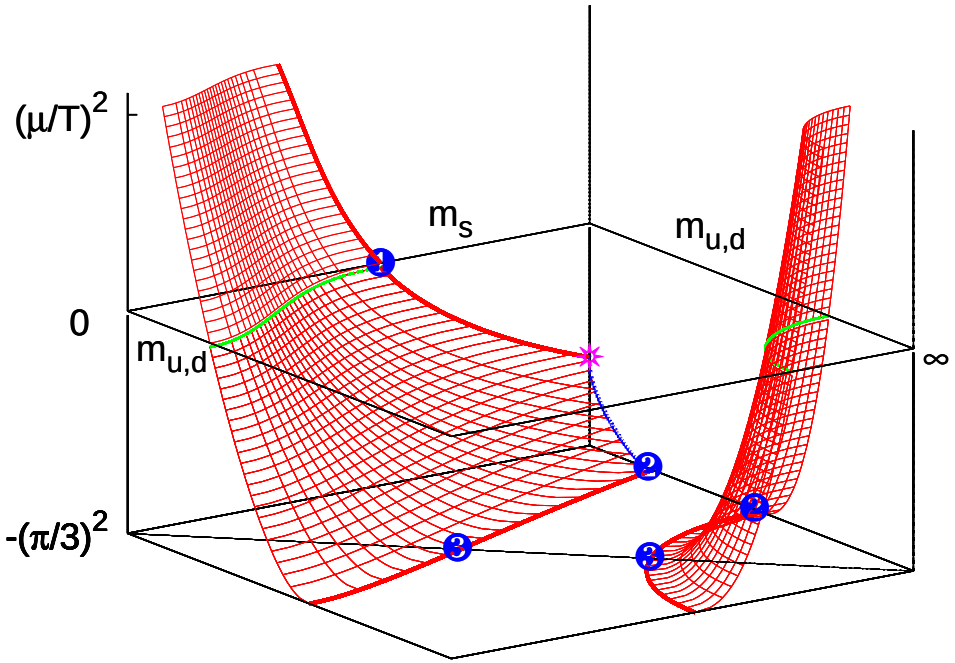
- $N_f = 0$ $\longrightarrow$ 1st order phase transition

  [Kajantie et al. Z.Phys. C9 (1981) 253]
  [McLerran & Svetitsky Phys. Lett. 98B, 195 (1981)]
  [Kuti et al. Phys. Lett. 98B, 199 (1981)]



[Brown et. al Phys.Rev.Lett. 65 (1990) 2491]

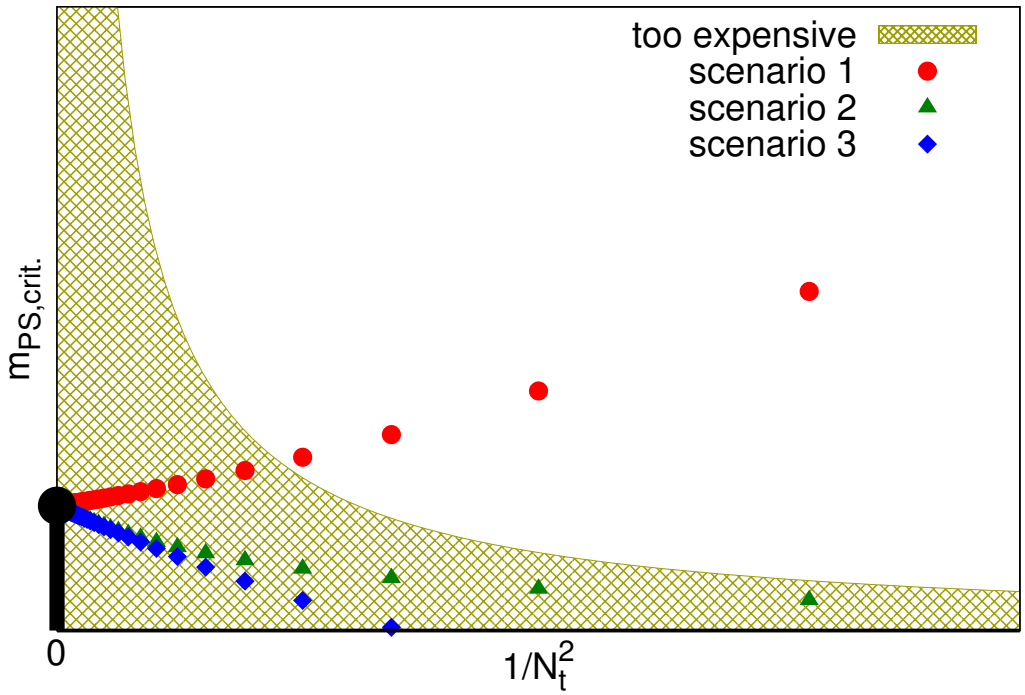
Phase diagram



[de Forcrand & Philipsen, 2012]

- Imaginary chemical potential $\longrightarrow$ increased $m_{\text{crit.}}$
- Our choice: $\dfrac{\mu}{T} = \dfrac{15}{16} \cdot \dfrac{\pi}{3} i$

Possible scenarios?



Strategy

Staggered fermions.

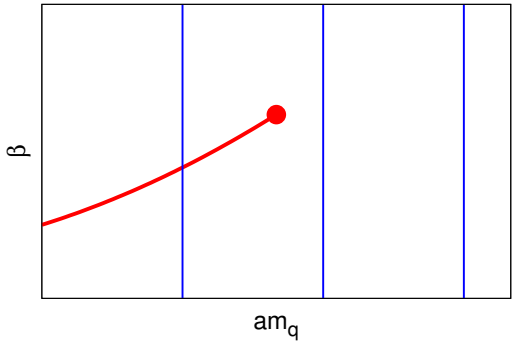
- Pros:
  - Cheap
  - Remnant of chiral symmetry

    $\longrightarrow$ no additive mass renormalization
- Cons:
  - Rooting
  - Taste breaking $\longrightarrow$ large $m_{\pi,\mathrm{rms}}$

Strategy:

- am_q fixed
- vary only β

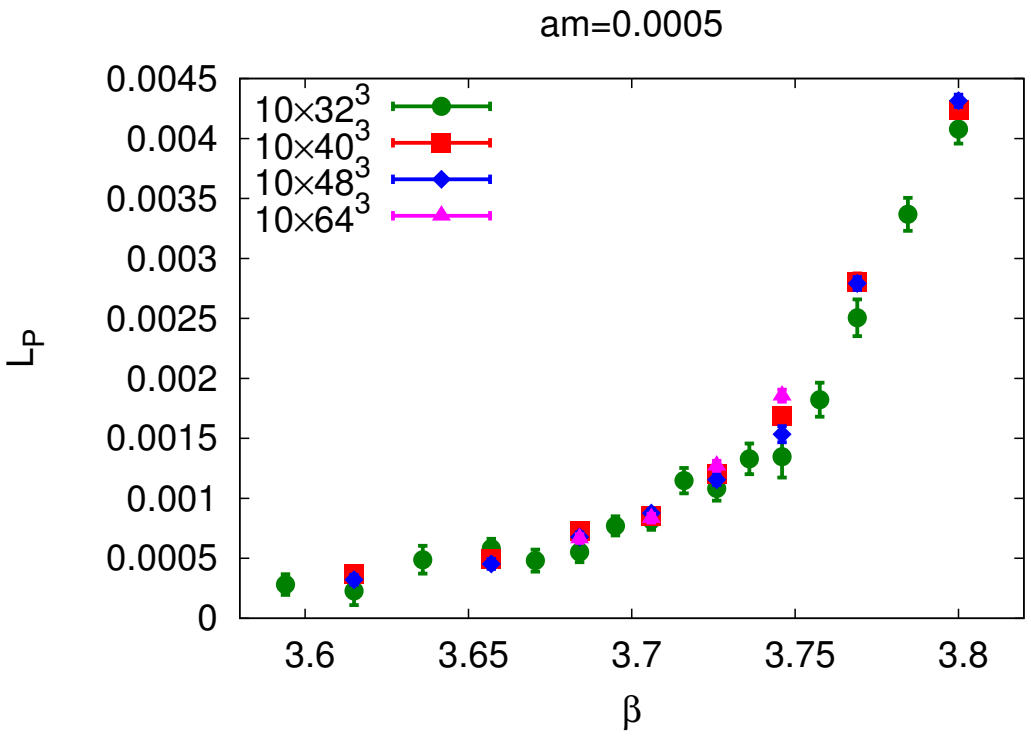
$\longrightarrow$ LCP only at β_c, $am_{q,c}$



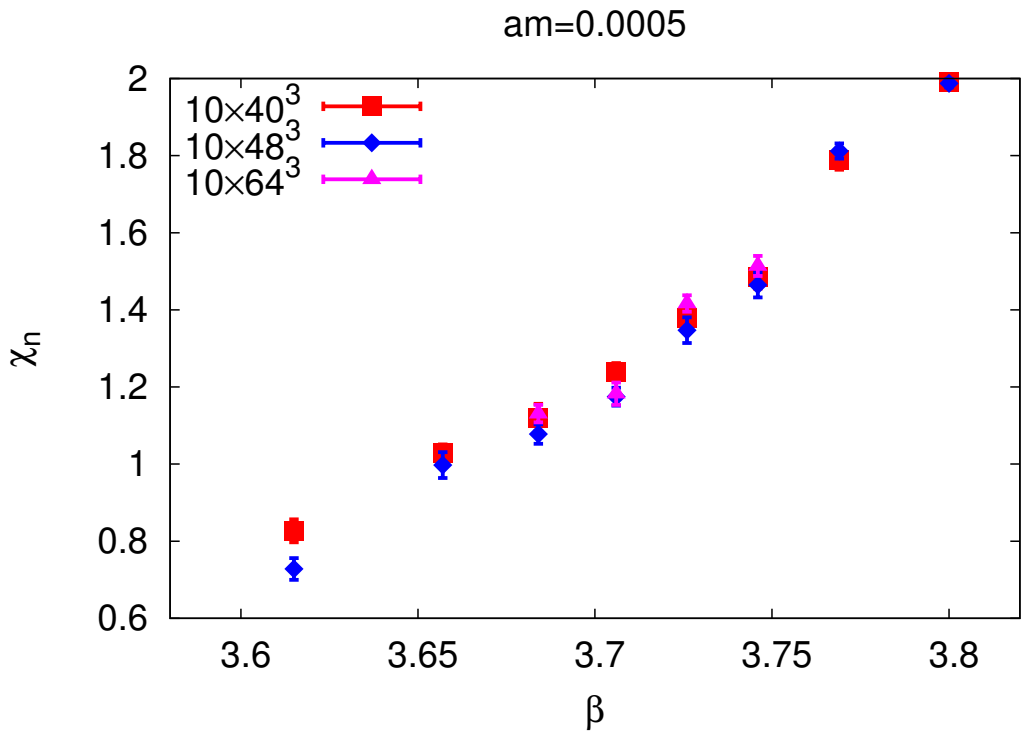
Fine lattice results

- $N_f = 3, \quad am = 0.0005$
- $N_t = 10$
- Symanzik tree-level improved gauge action
- 4 steps of stout smearing, $\quad \varrho = 0.125$
- $\dfrac{\mu}{T} = \dfrac{15}{16} \cdot \dfrac{\pi}{3} i$
- $a = 0.14\,\mathrm{fm}$
- m_{PS} determinantion is still running

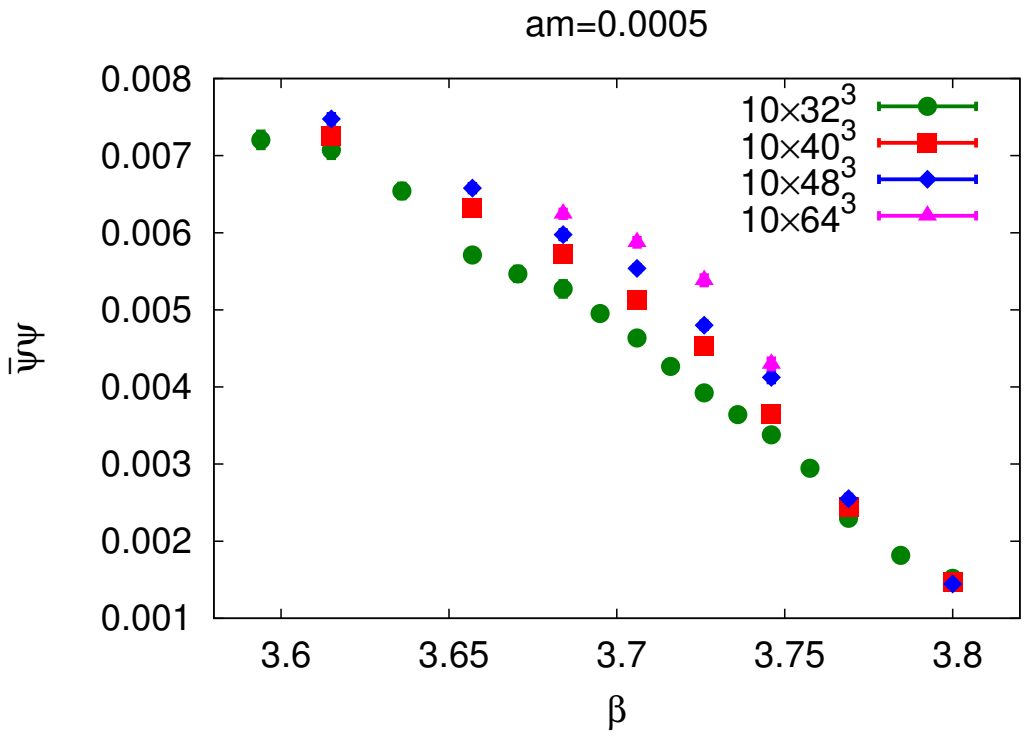
$N_t = 10$, Polyakov-loop



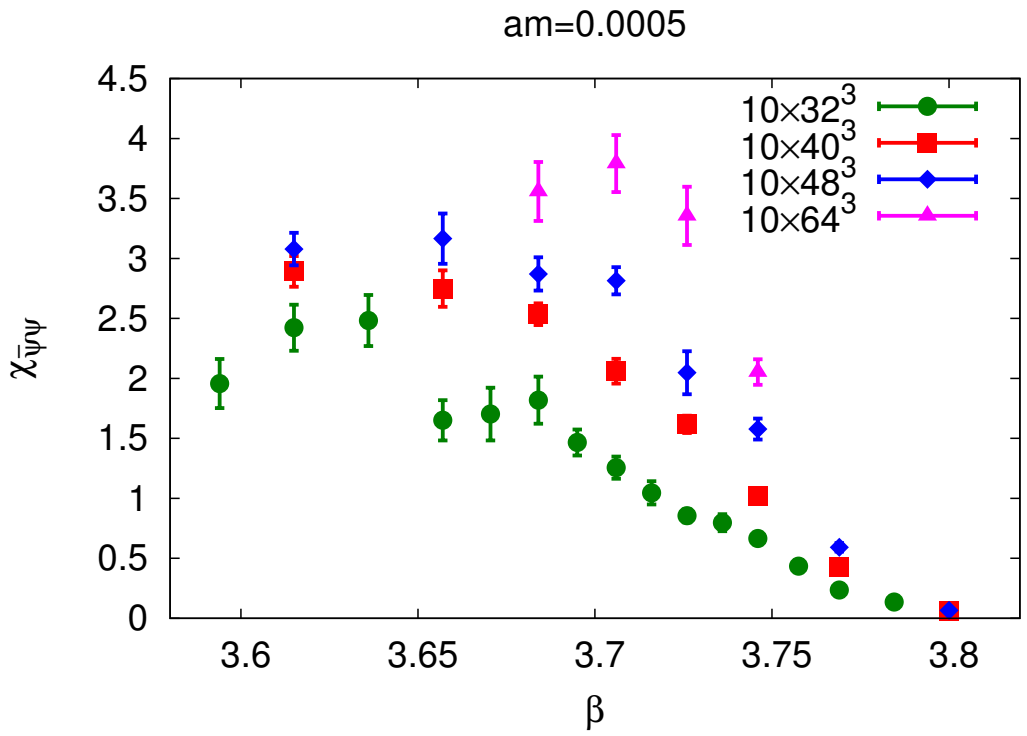
$N_t = 10$, Quark number susceptibility



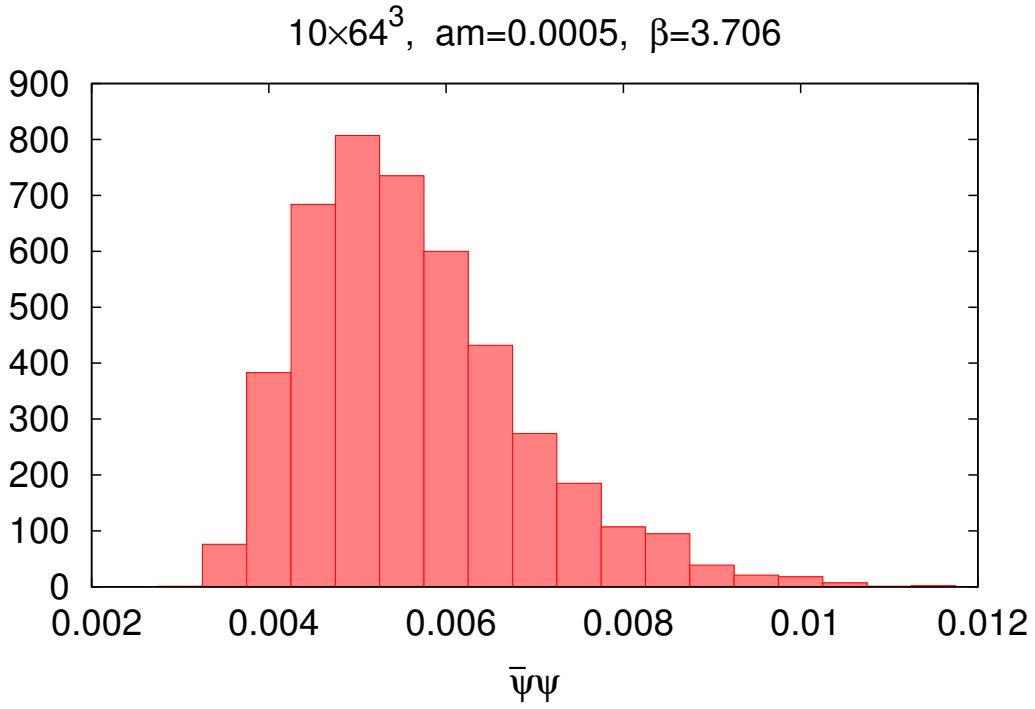
$N_t = 10$, Chiral condensate



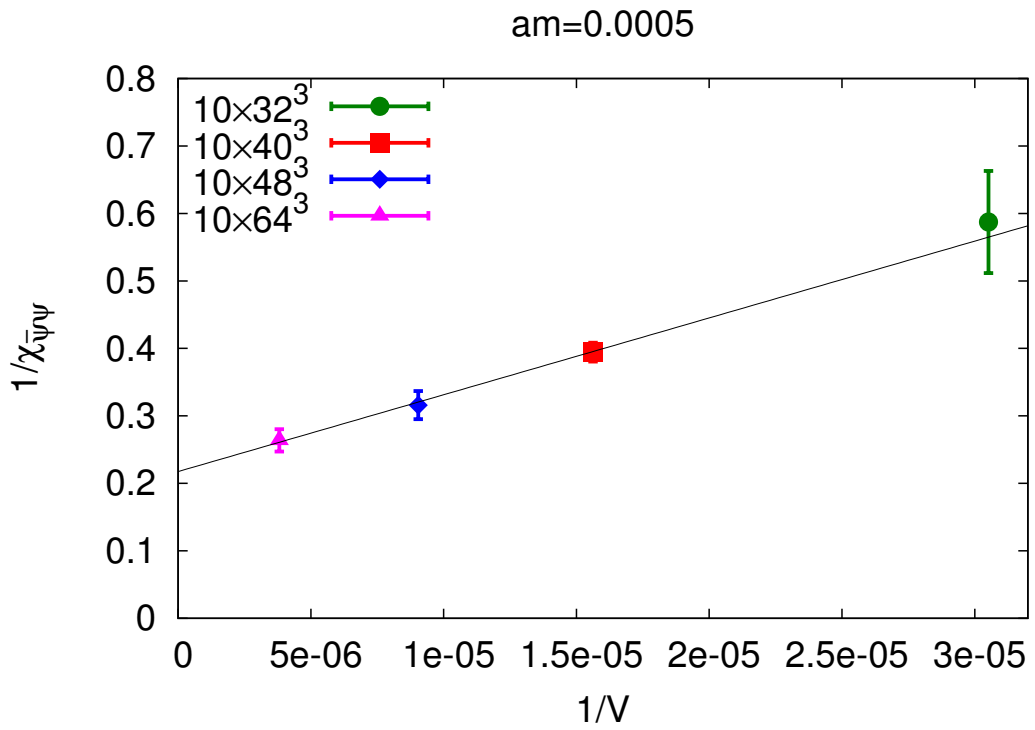
$N_t = 10$, Chiral susceptibility



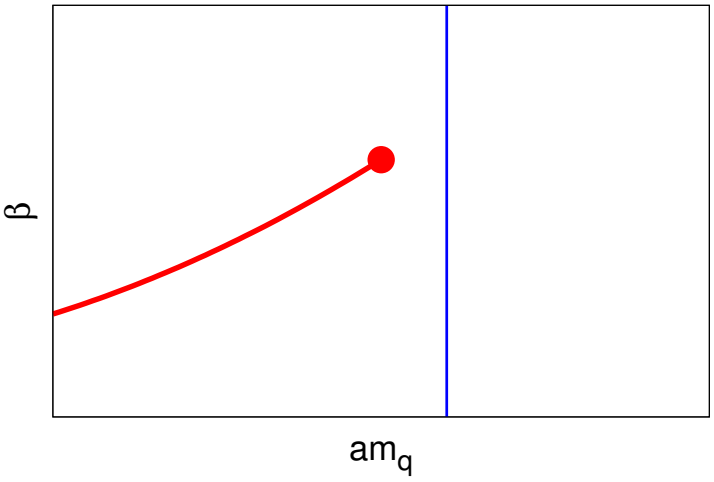
$N_t = 10$, Chiral condensate

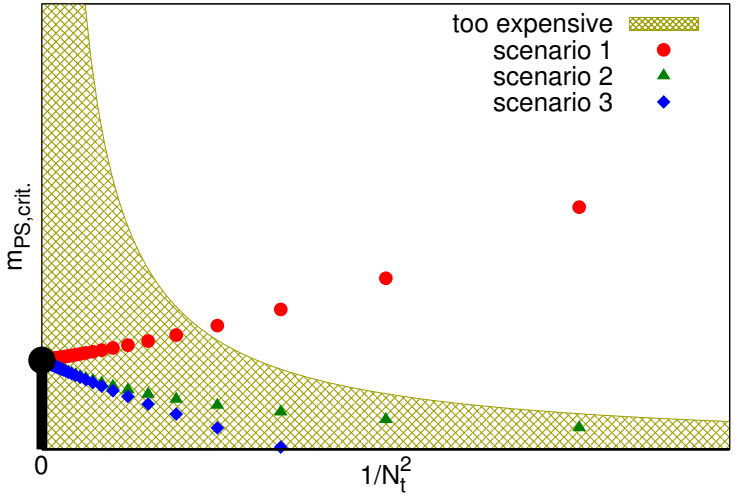


$N_t = 10$, Chiral susceptibility



$N_t = 10$, Conclusions

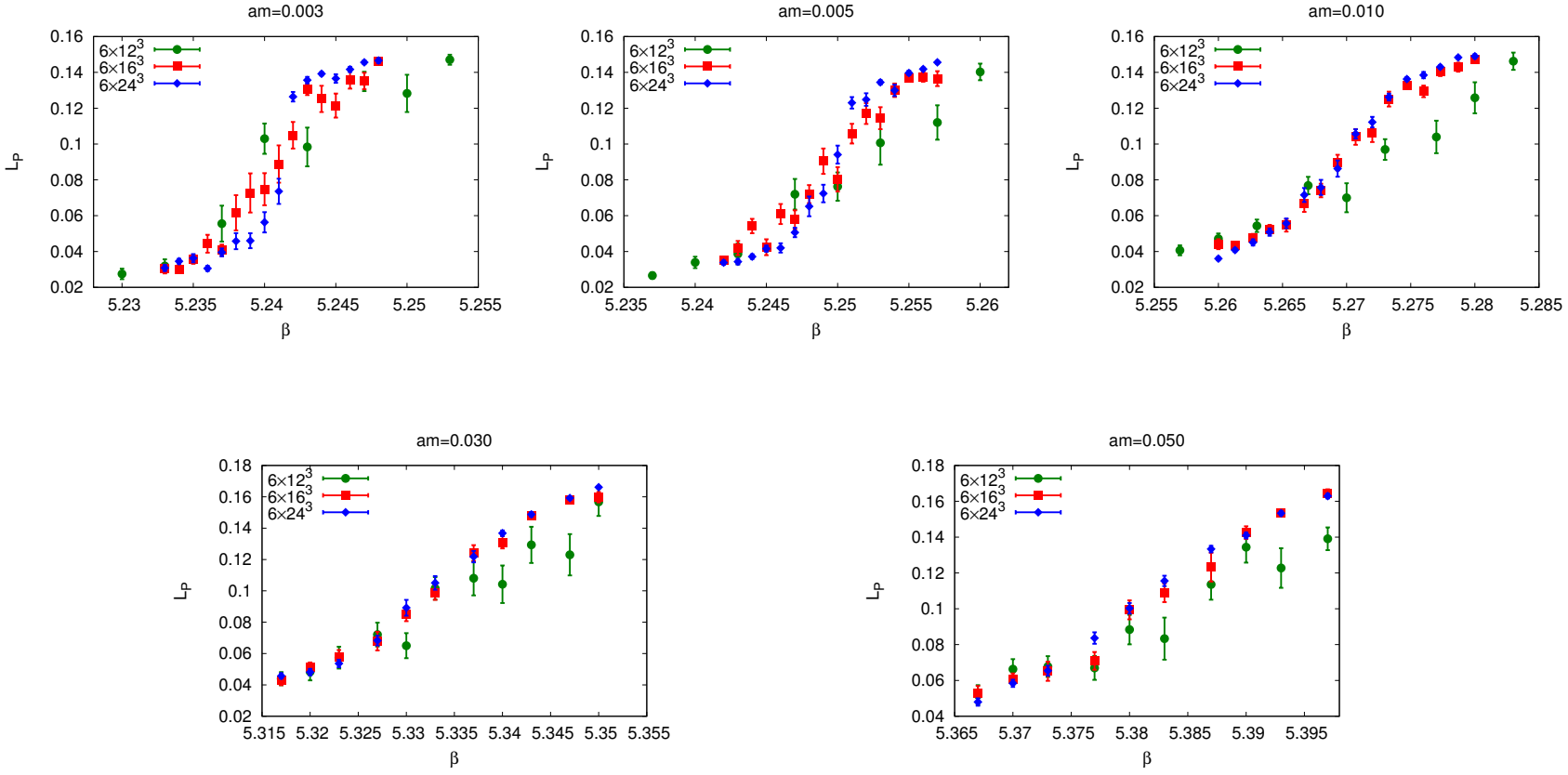




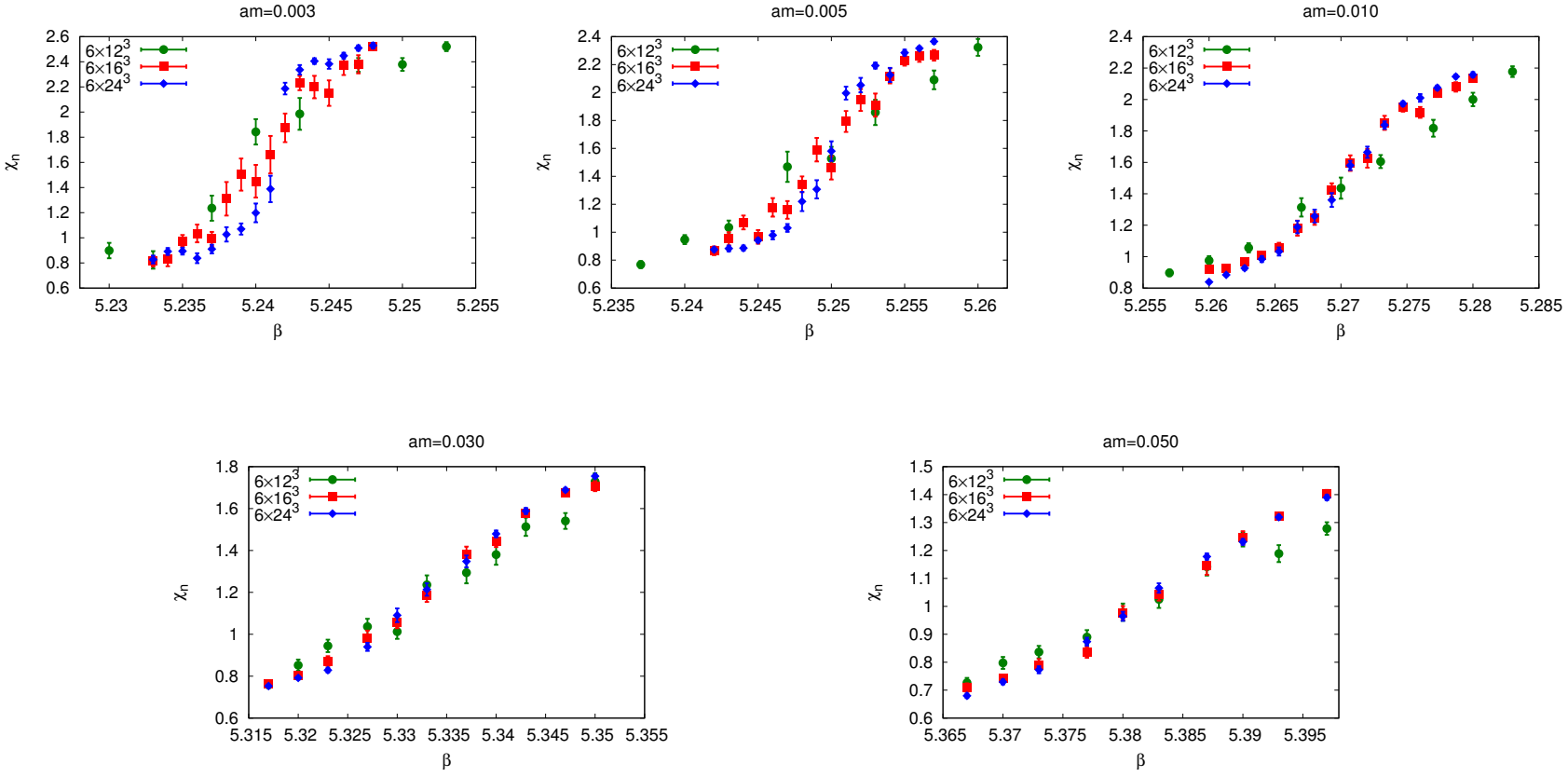
Coarse lattice results

- $N_f = 3, \quad am = 0.003 \ldots 0.050$
- $N_t = 6$
- Wilson plaquette gauge action
- no smearing
- $\frac{\mu}{T} = \frac{15}{16} \cdot \frac{\pi}{3} i$

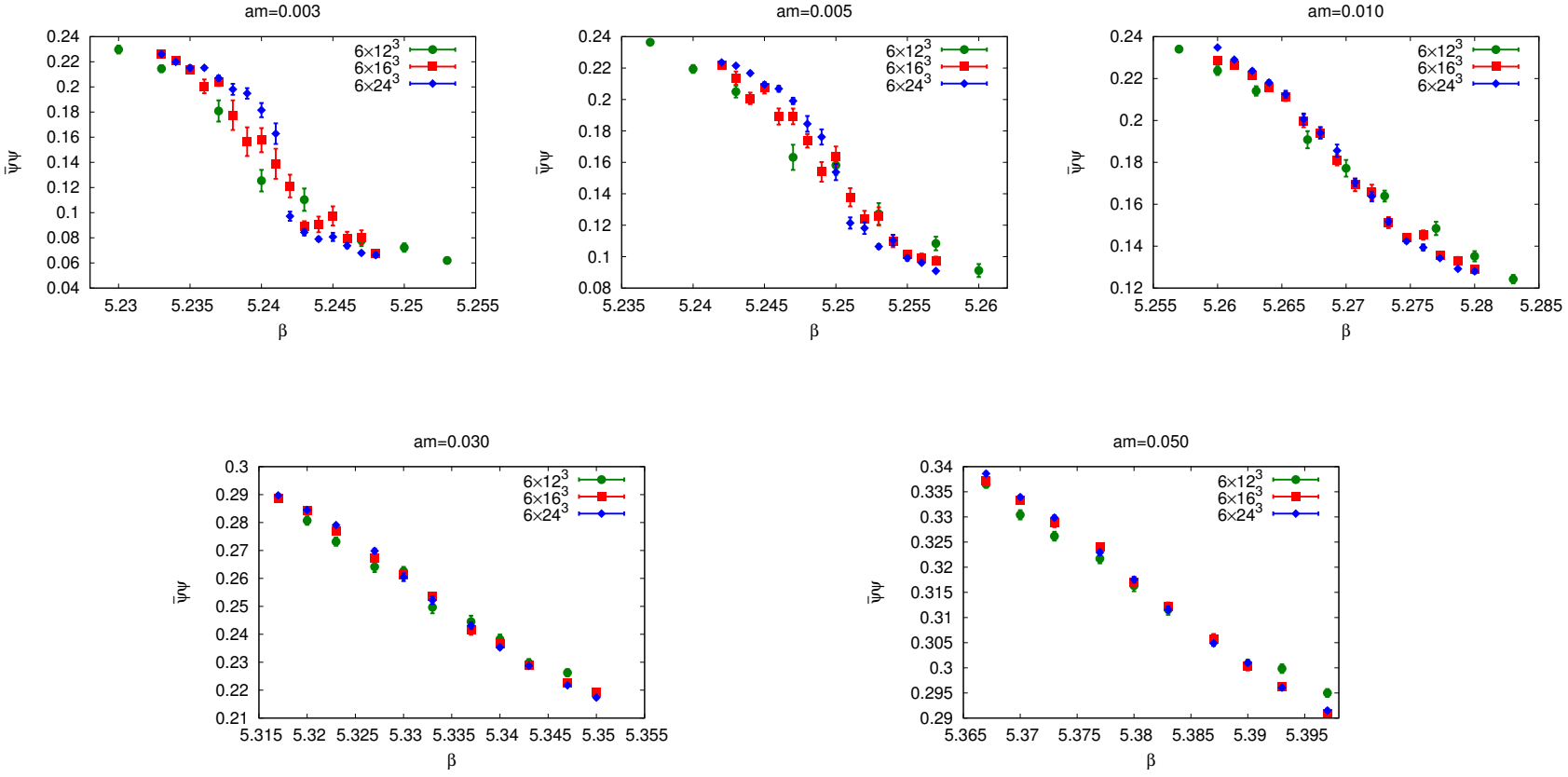
$N_t = 6$, Polyakov-loop



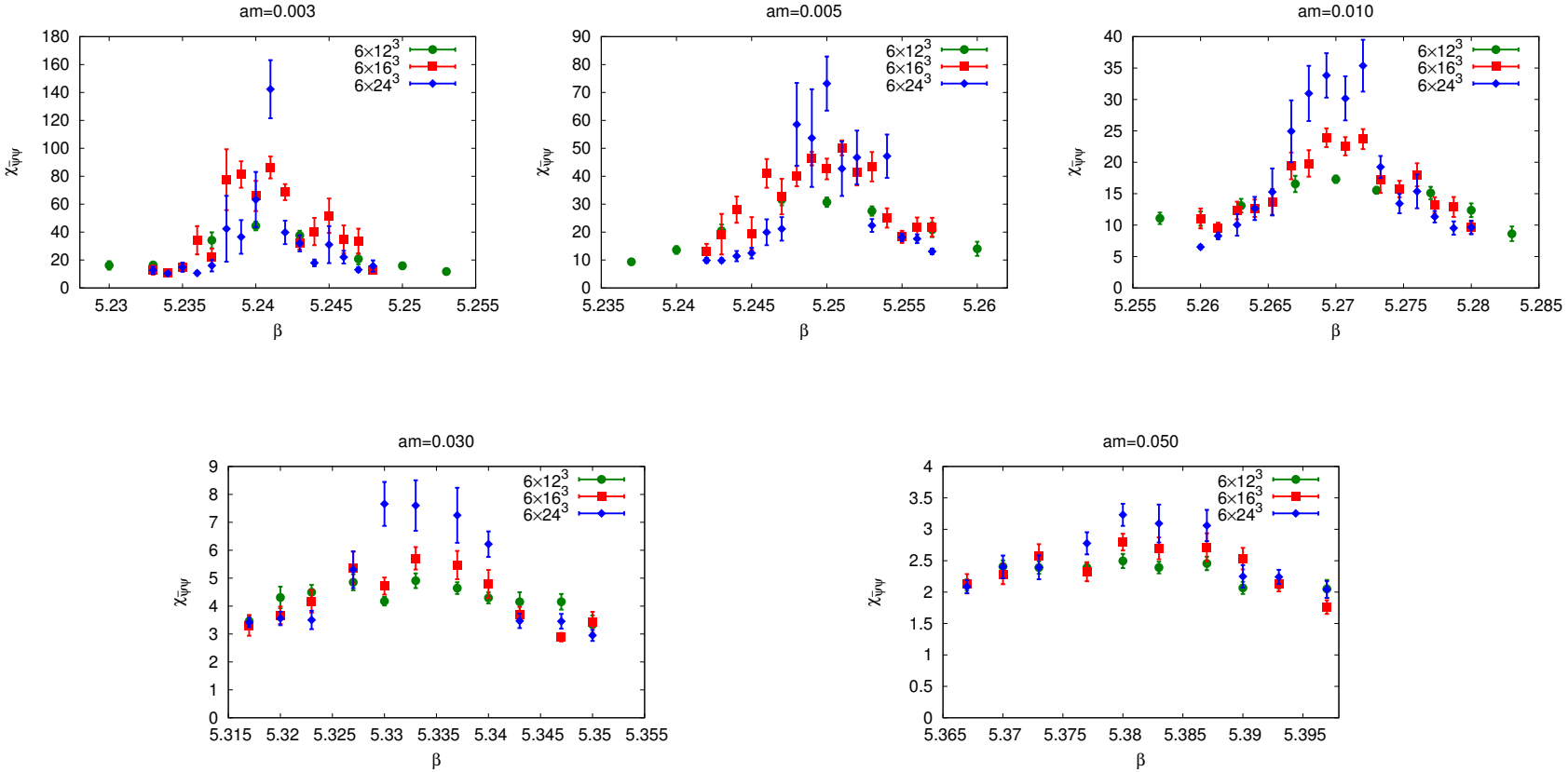
$N_t = 6$, Quark number susceptibility



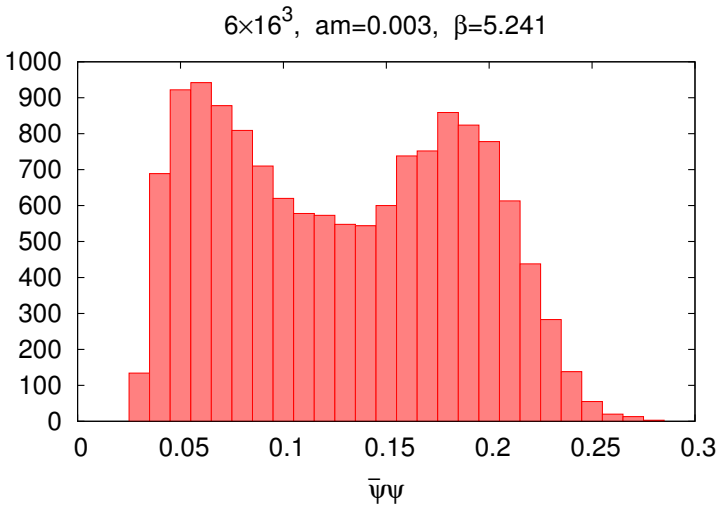
$N_t = 6$, Chiral condensate

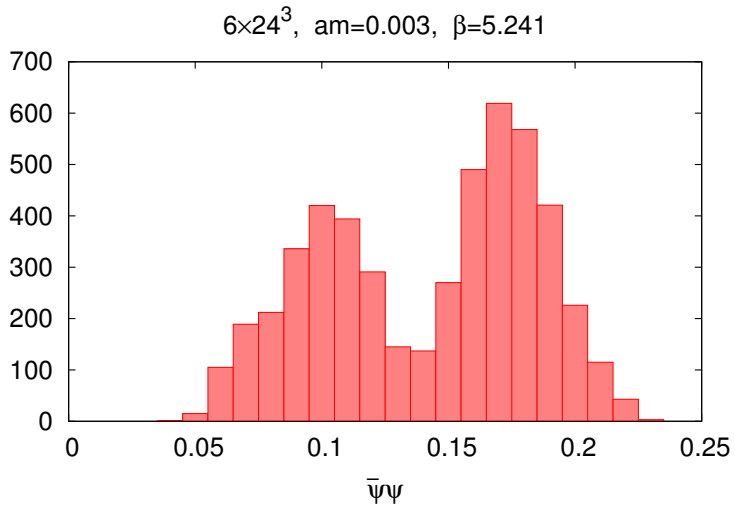


$N_t = 6$, Chiral susceptibility



$N_t = 6$, Chiral condensate





Conclusions & Outlook

- Conclusions
  - $N_t = 10$: no 1st order transition found
  - $N_t = 6$: 1st order transition found
- Outlook
  - Collect more statistics at $N_t = 6 \longrightarrow$ find $m_{\text{crit.}}$
  - $N_t = 8$ is already running