Finite temperature phase transition in the $4\mathrm{d}$ abelian LGT?

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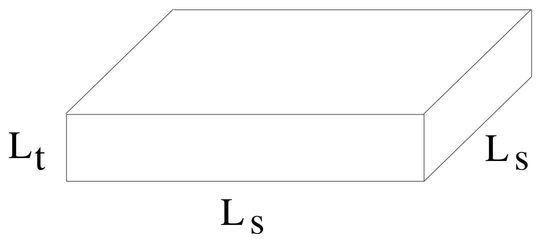
Definition of the model

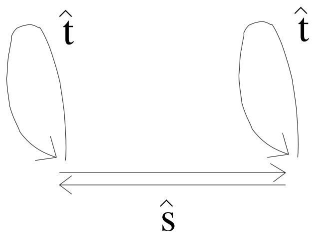
4d Abelian compact U(1) with
Wilson action (fixed $L_t \ll L_s$, $L_s \to \infty$)

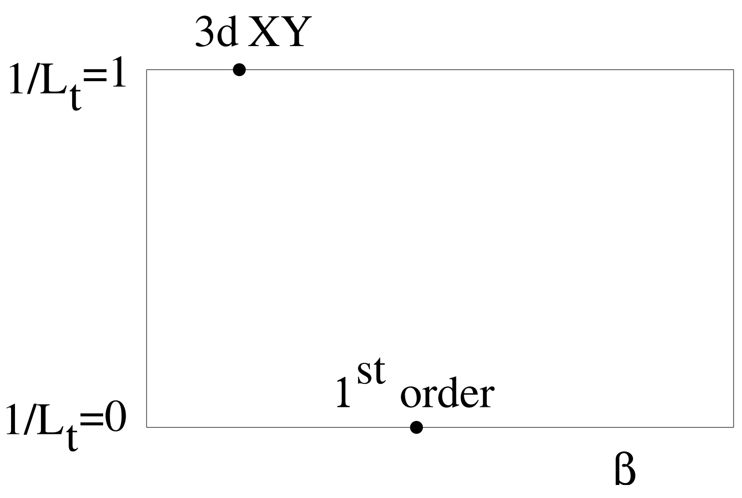
$$S = \beta \sum_{\Box} \cos \theta_{\Box}$$



- $L_t = \infty$: 1^{st} order phase transition
- $L_t = 1$: uncoupled Polyakov loops

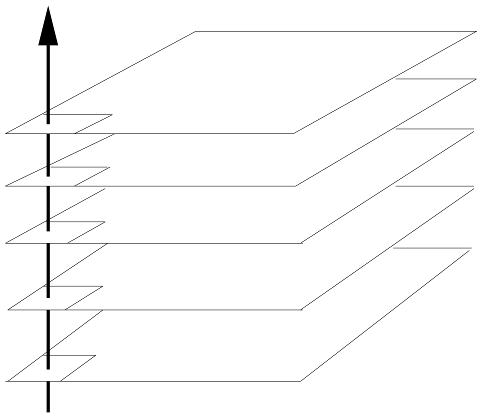
$$Z = Z_{3d\,XY} \cdot Z_{3d\,U(1)\,GT}$$





The order parameter

Response function to
an external static flux ($\equiv$ twisted b.c.)



• Confined phase: system insensitive to an external flux Φ (ξ finite, response $\sim e^{-L/\xi}$)

• Coulomb phase: system sensitive to an external flux ($\xi = \infty$)

Helicity modulus

$$h(\beta) = \frac{\partial^2 F(\phi;\beta)}{\partial \phi^2}\,|_{\phi=0}$$

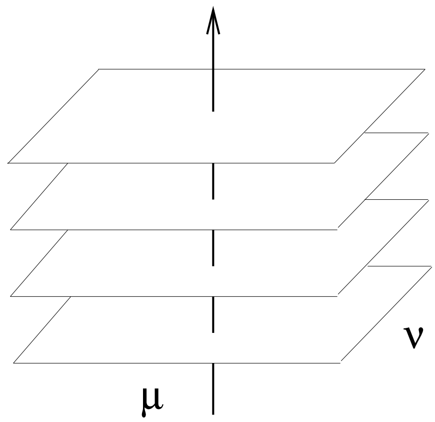
More about the order parameter

Chose an orientation (μ, ν) to impose Φ

N.B., it can be

- Spatial orientation
- Temporal orientation

Suppose that Φ spreads homogeneously through parallel planes



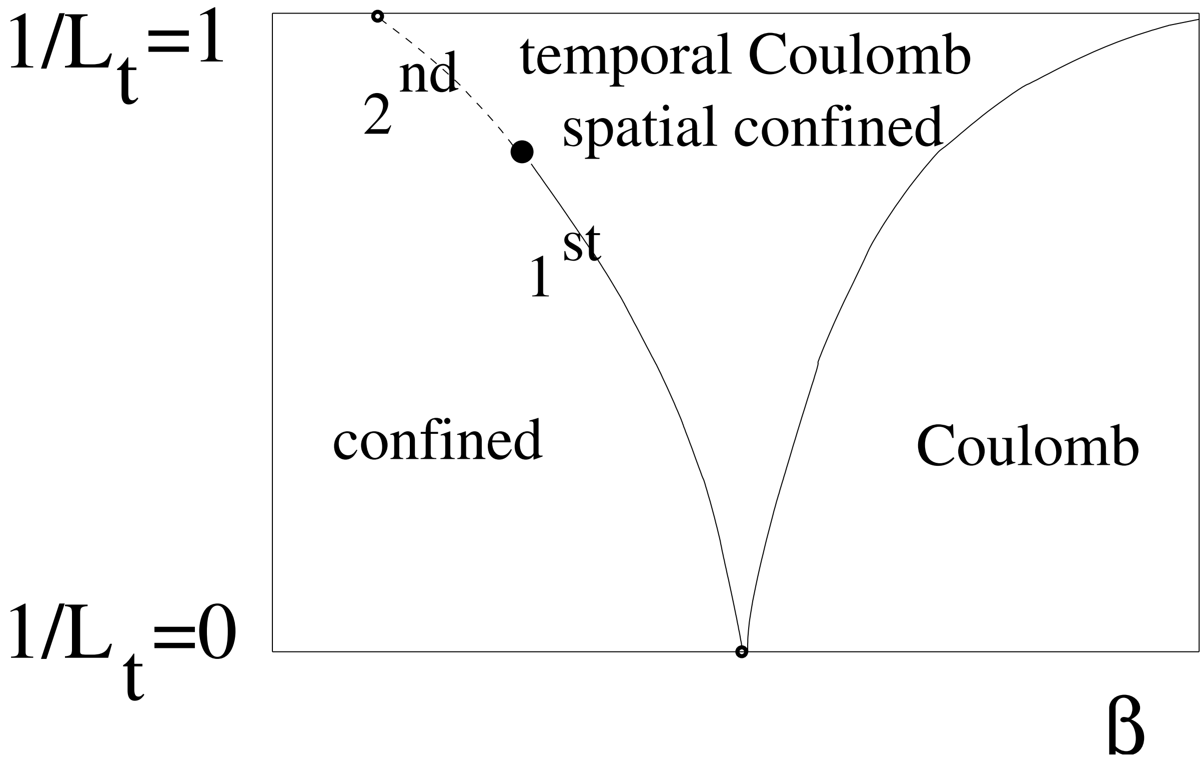
Classical limit $(\beta \to \infty)$, $\theta_\Box = \frac{\Phi}{L_\mu L_\nu}$

$S = -\beta \sum_{\text{plaq.}} \cos \frac{\Phi}{L_\mu L_\nu}$, expand

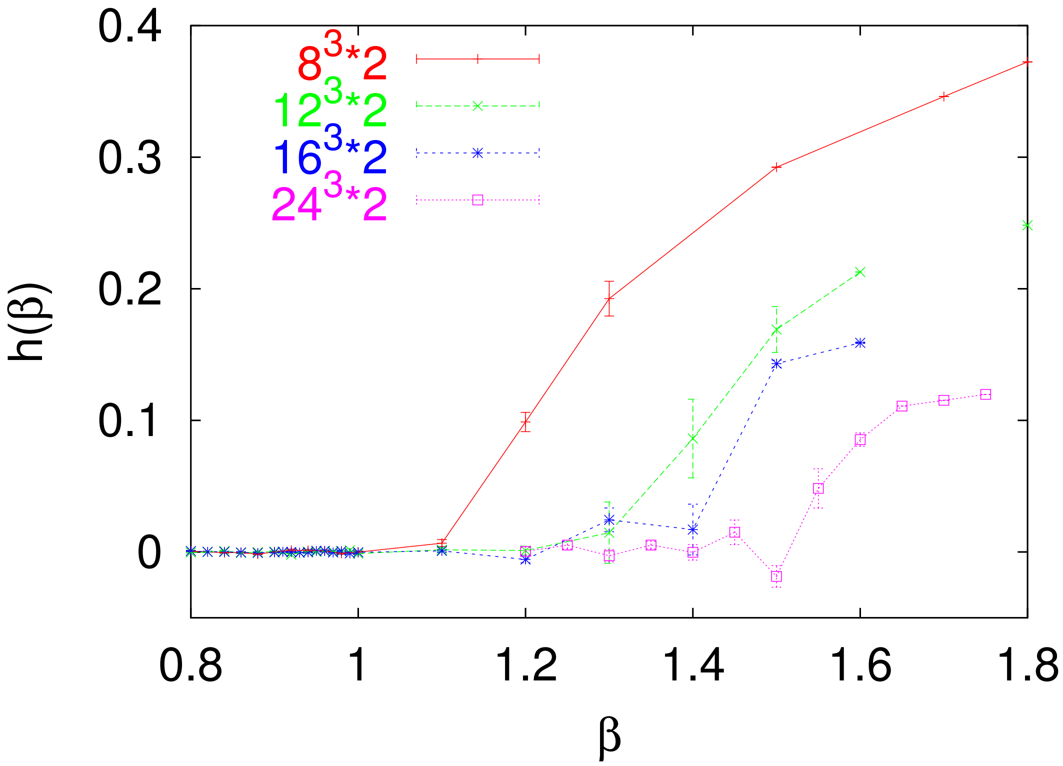
$$F(\Phi) = \frac{\beta}{2} \Phi^2 \frac{L_\rho L_\sigma}{L_\mu L_\nu} \to \frac{\beta_R(\beta)}{2} \Phi^2 \frac{L_\rho L_\sigma}{L_\mu L_\nu}, \forall \beta$$

Conjectured phase diagram

Decoupling of the transition temperature
for spatial and temporal loops



Transition to Coulomb phase



$$\beta_c \propto L_s?$$

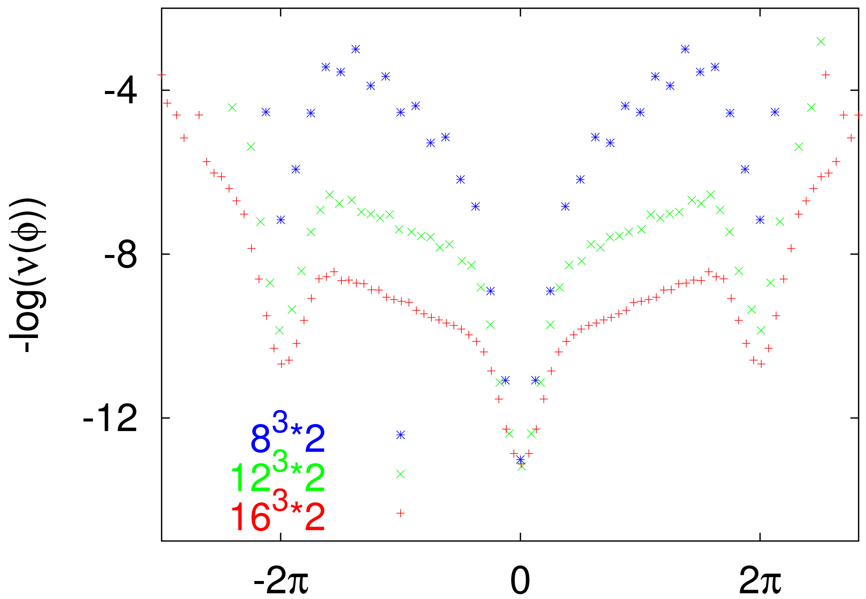
If this is the case, this transition disappears in the thermodynamic limit!

Flux free energy as $L_s \to \infty$

$$F(\Phi) = \frac{\beta_R}{2}\Phi\frac{L_s L_t}{L_s L_s} \sim \frac{\beta_R}{L_s}$$

At finite V competition between β_R and L_S!

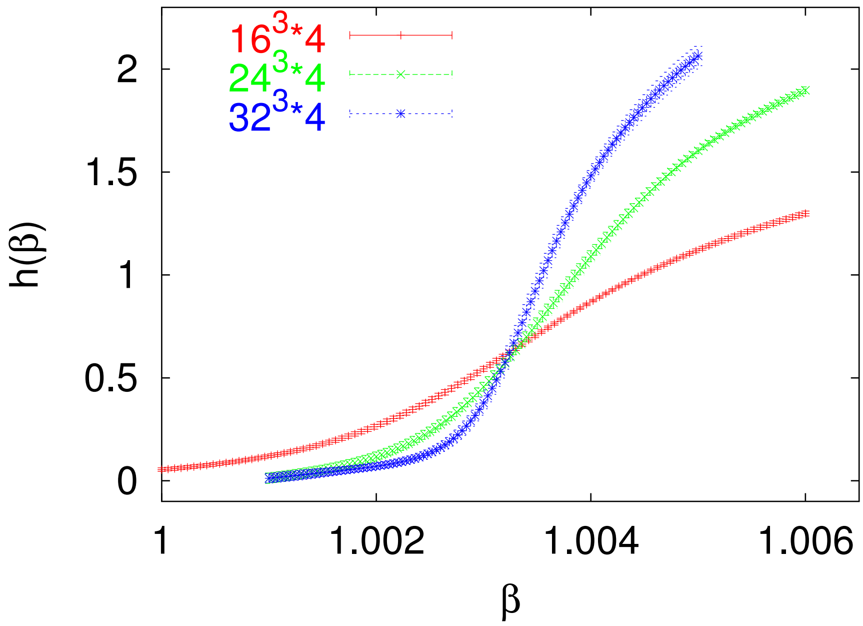
TEST:
measure flux distribution $\nu(\Phi)$ ($\propto e^{-F(\Phi)}$)
for different L_s



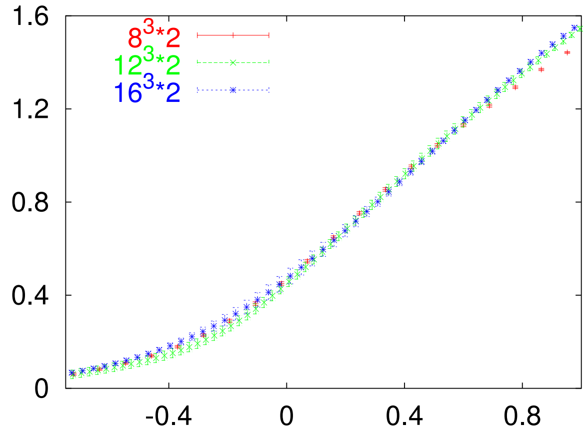
At any finite β, finite density of static monopoles (in time direction) which can disorder spatial loops

Transition to the confined phase

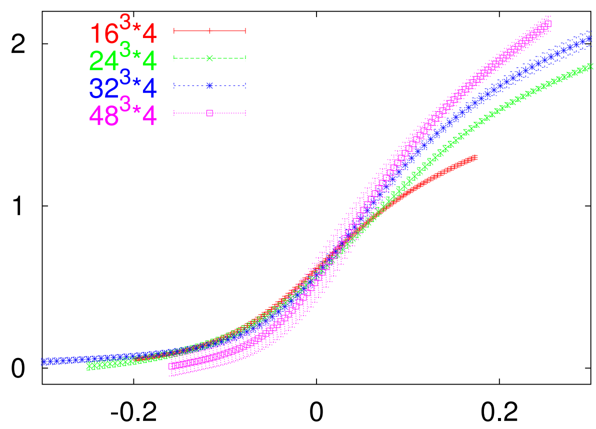
Flux through temporal planes



FSS analysis to determine position and order of the transition ($\nu = \nu_{\mathrm{3d\,XY}}$).



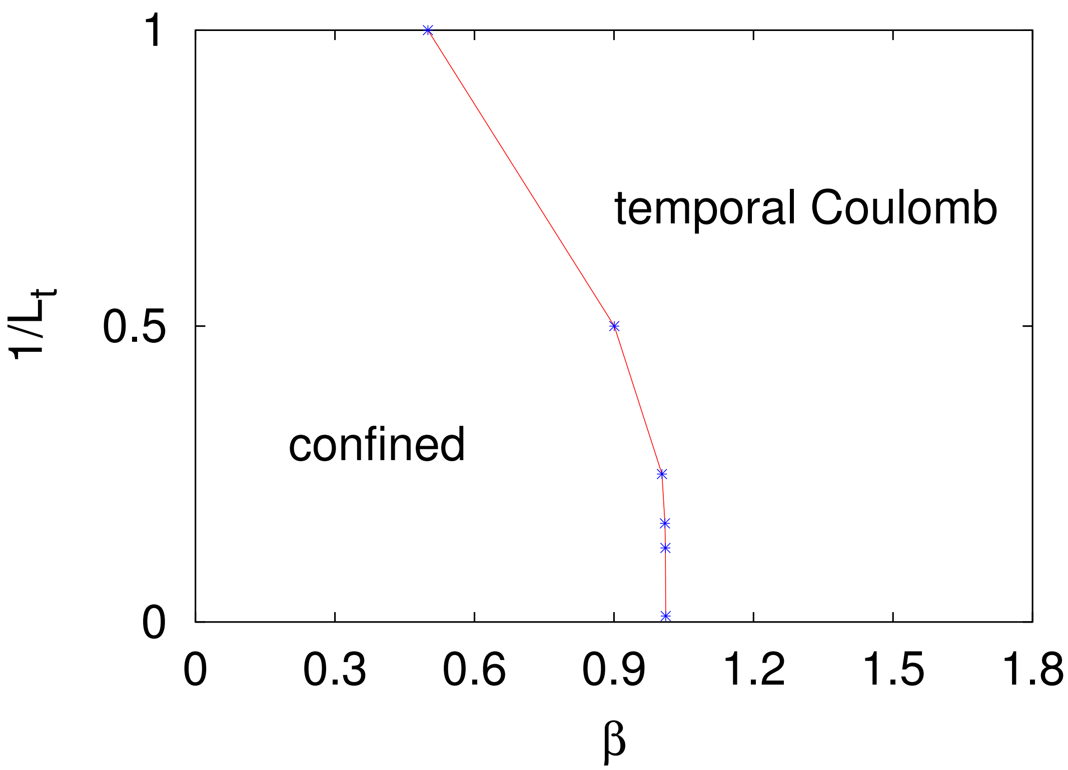
$L_t = 2$



$L_t = 4$

Location of the transition line

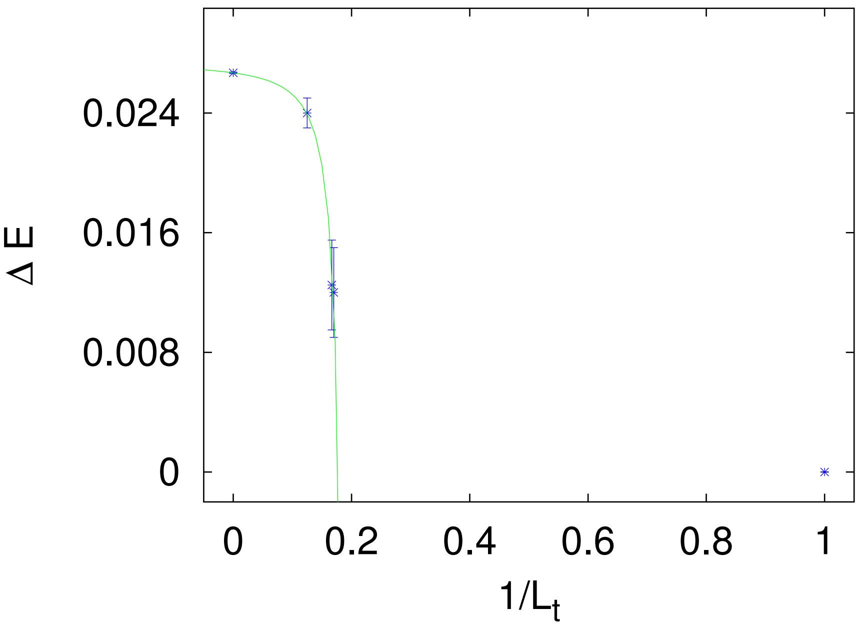
Possible to reconstruct with great precision the position of the phase boundary



What is the order of the phase transition along this curve?

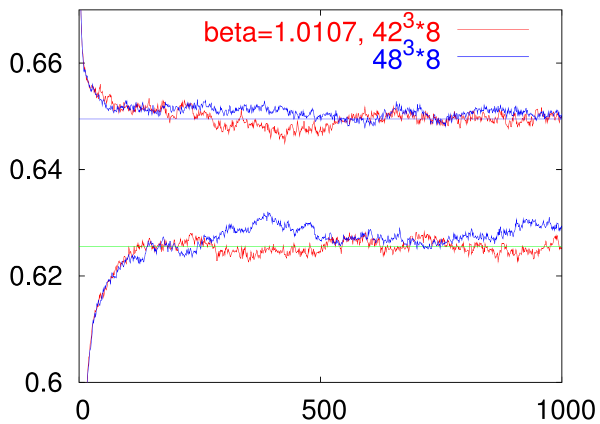
Order of the phase transition

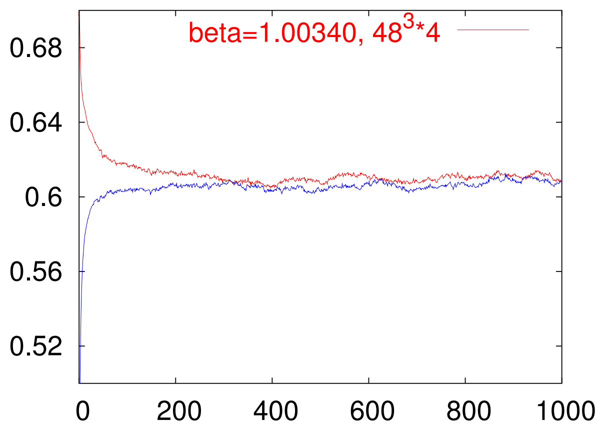
Consider how the latent heat of the (first order) transition changes with L_t



$\bar{L}_t \sim 4$ the latent heat seems to vanish

(with anisotropic couplings one could tune $\bar{L}_t$)





$L_t = 8$ $\qquad$ $L_t = 4$

Conclusions

Clarified the phase diagram of the system:

- There is only one phase boundary
- Coulomb phase only at $T = 0$ and $\beta > \beta_c$
- At finite T and $\beta > \beta_c$ spatial Wilson loops obey area law, temporal Wilson loops perimeter law (similar to Yang-Mills)
- At a certain number of temporal slices $\bar{L}_t$, the transition seems to turn from first to second order: continuum limit for a system of $3d$ coupled layers?