Non-perturbative aspects of the Higgs-Yukawa model on the lattice

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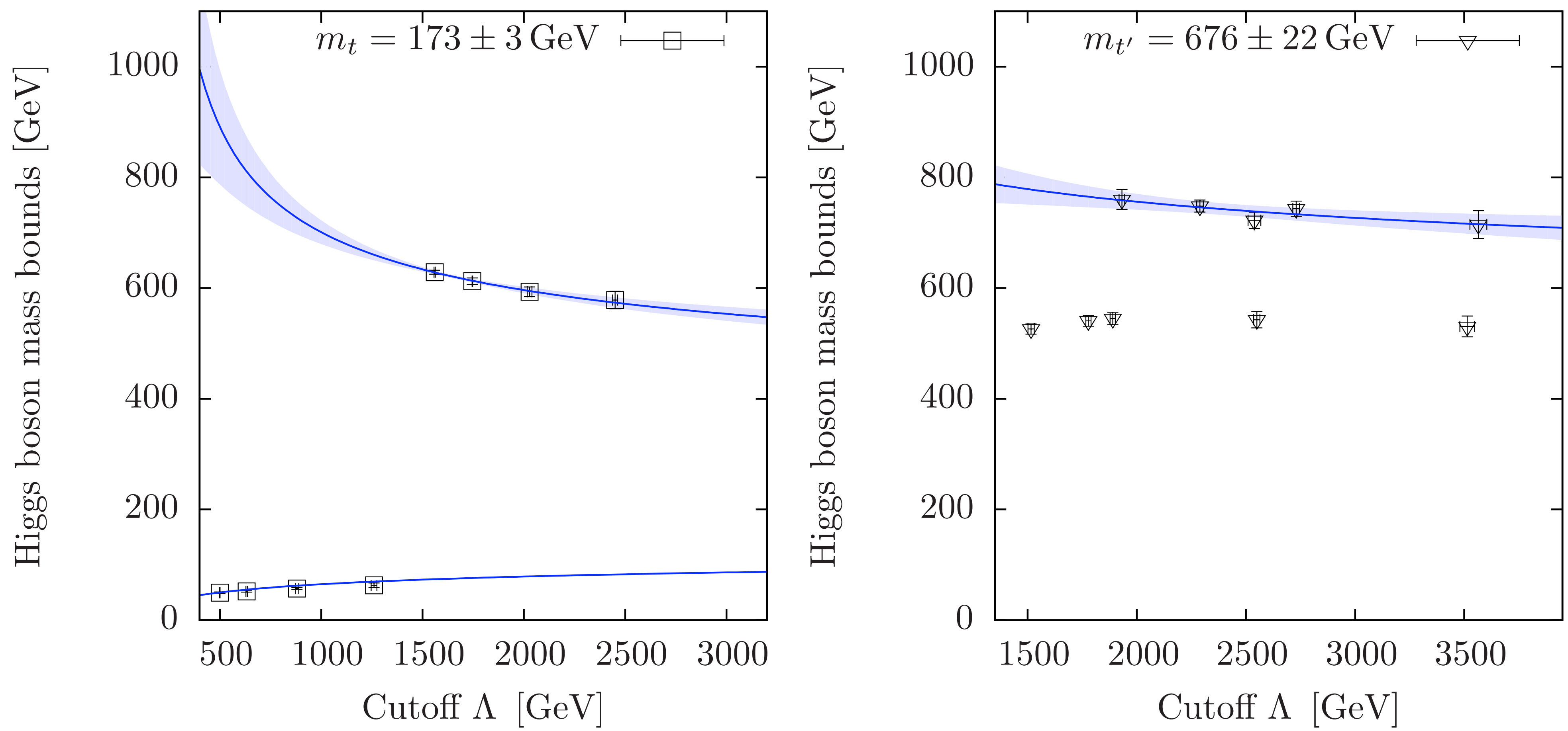
Outline

- Motivation.
- Do Higgs and Yukawa live close to a critical point?
  --- ideas and strategy.
- Preliminary results from our on-going study.
- Outlook.

Motivation



P. Gerhold and K. Jansen, 2011

* Constraints on the masses of extra-generation fermions from the 125 GeV scalar.

The 125 GeV scalar

- It may be a dilaton in a strongly-coupled theory:

➡ Does it have to be walking technicolour?
➡ HY model exhibits nearly scale inavariance?

P.Q. Hung and C. Xiong, 2009

- It may be the Standard Model Higgs:

➡ Evade the hierarchy problem w/o SUSY?

- Both require non-perturbative studies:

➡ Second-order non-thermal phase transitions.

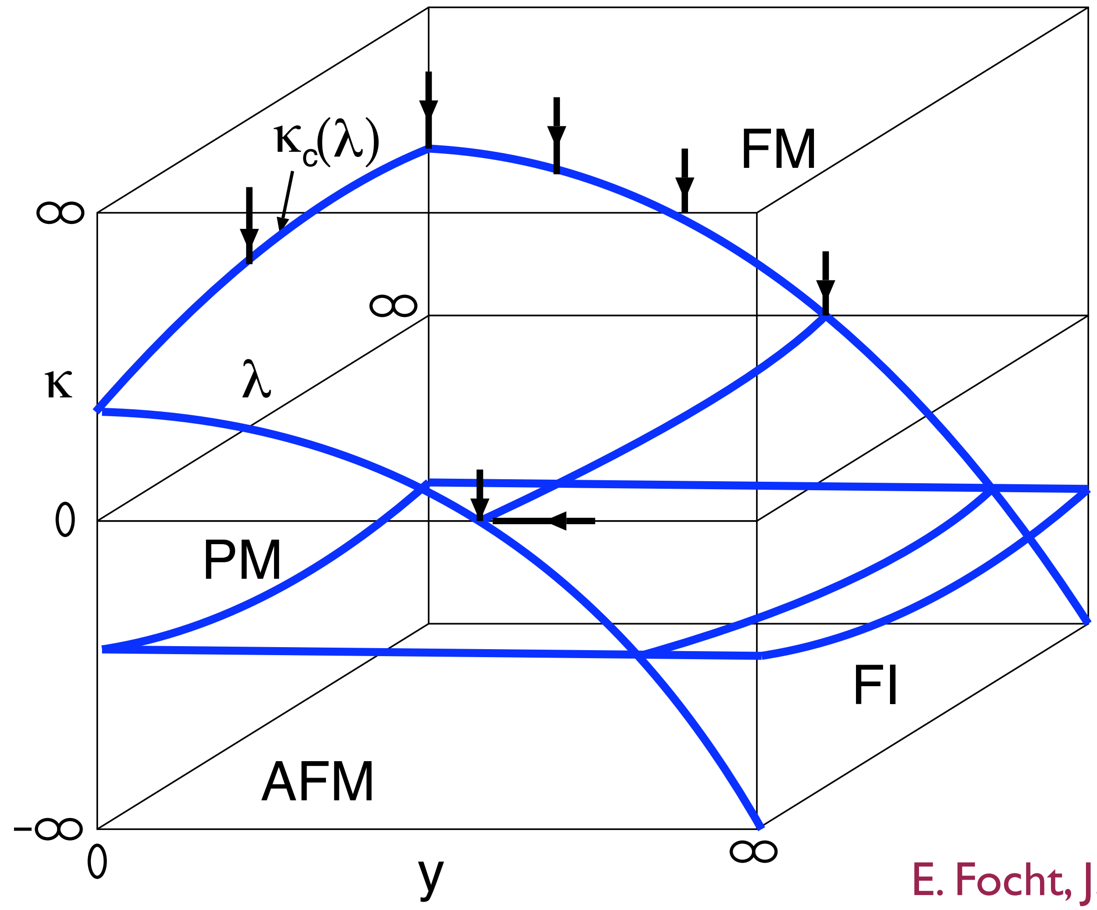
The scalar field theory as a spin model

- Take the scalar theory with the quartic coupling.
- Perform the change of variables,

$$\Phi^\alpha = \sqrt{2\kappa}\phi^\alpha, \quad \lambda_0 = \frac{\hat{\lambda}}{\kappa^2}, \quad \bar{m}_0^2 = \frac{1 - 2\hat{\lambda} - 8\kappa}{\kappa}.$$

- Renders it into the form of a spin model.
- Study bulk and thermal phase structures.

What is it like with the Yukawa coupling

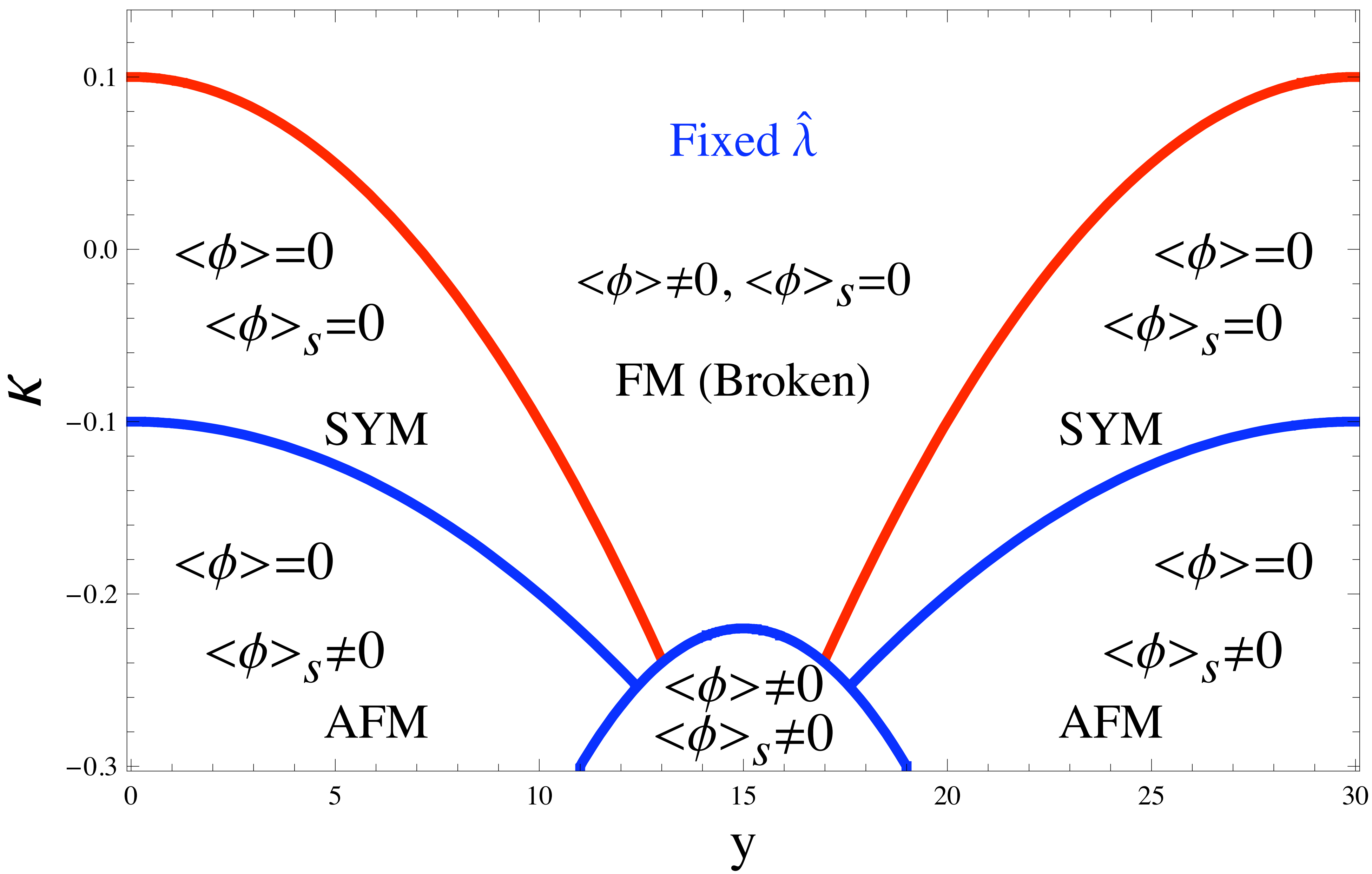


E. Focht, J. Jersak, J. Paul, 1995

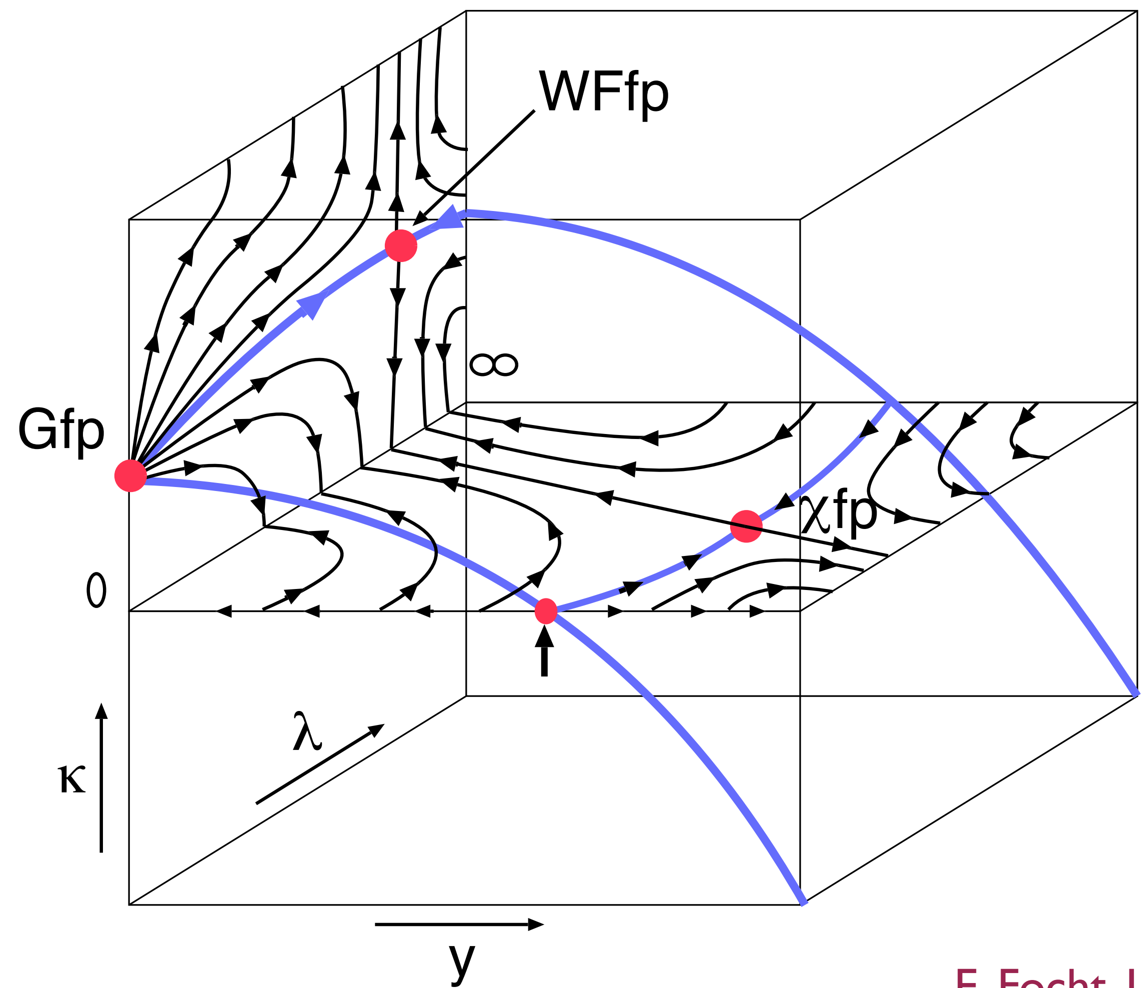
Second-order phase transitions ⟶ Natural scale separation (continuum limit)

* Question: Is the theory non-trivial in 4D?

At stronger bare Yukawa coupling



The bulk phase structure (3D)



E. Focht, J. Jersak, J. Paul, 1995

Only the Gfp remains in 4D scalar sector....

*The hierarchy problem is a consequence of triviality in 4D

Finite-size scaling (*a'la* M. Fisher)

- Renormalisation Group near fixed points.
- Central statement: "Universal" function

$$\frac{P_L(t)}{P_\infty(t)} = f\left(\frac{L}{\xi_\infty(t)}\right)$$, with observable P.

- Magnetic susceptibility and Binder's cumulant:

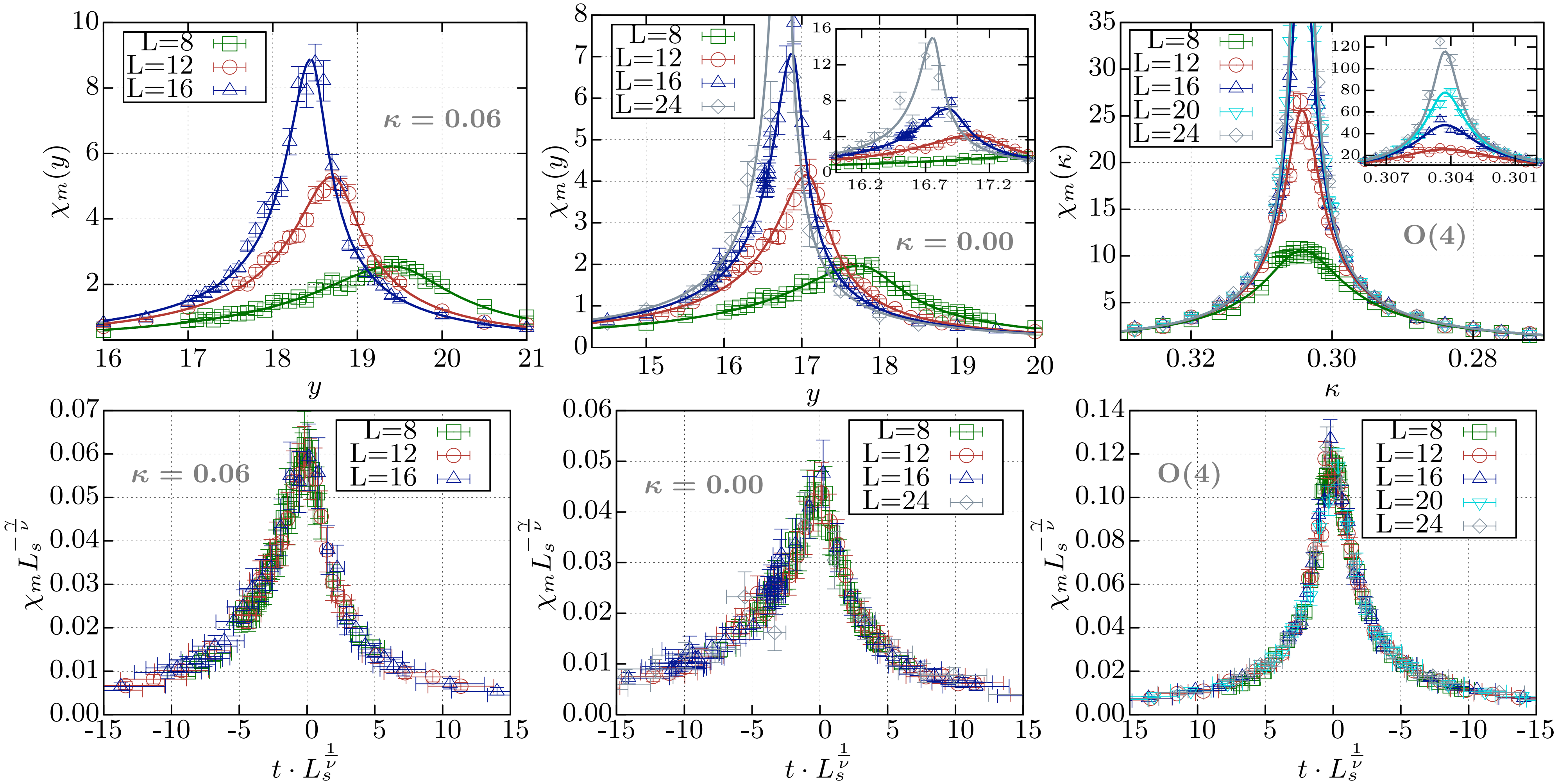
$$\chi_m(t,L)\cdot L_s^{-\gamma/\nu} = g\left(\hat{t}L_s^{1/\nu}\right), \text{ with } \hat{t} = \left[T/\left(T_c^{(L=\infty)} - C\cdot L_s^{-b}\right) - 1\right]$$

$$Q_L = g_{Q_L}\left(tL^{1/\nu}\right)$$

- γ and ν are the critical exponents.

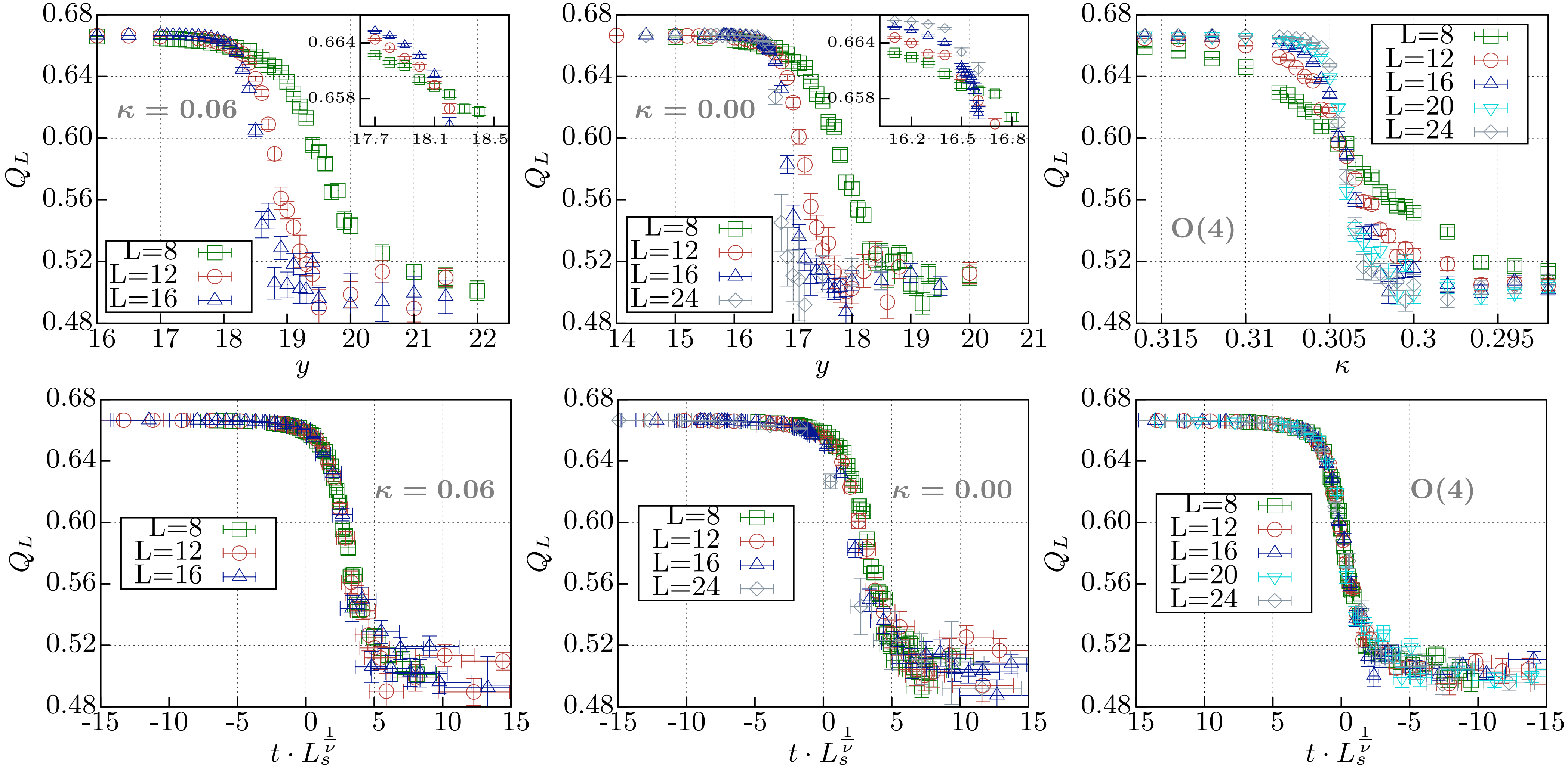
➡ How different are they from the mean-field values?

4D Scaling test, susceptibility



	$T_c^{(L=\infty)}$	ν	γ	C	b	fit interval
$\kappa = 0.06$	18.119(67)	0.576(28)	1.038(30)	4.7(1.6)	1.95(18)	17.5, 20.0
$\kappa = 0.00$	16.676(15)	0.541(22)	0.996(15)	10(2)	2.42(10)	15.0, 19.0
O(4)	0.304268(27)	0.499(12)	1.086(19)	N/A	N/A	0.300, 0.308

4D Scaling test, Binder's cumulant



	$T_c^{(L=\infty)}$	ν	interval
$\kappa = 0.06$	18.147(24)	0.550(1)	17.4, 18.8
$\kappa = 0.00$	16.667(27)	0.525(6)	16.0, 17.2
O(4)	0.3005(34)	0.50000(3)	0.294, 0.314

Concluding remarks and Outlook

- Evidence for chiral FP in the HY model.
- Complication in 4d (work in progress)

➡ Gaussian FP in the scalar sector.
➡ Does it remain in the HY model?
➡ Logarithmic corrections to FSS.

- Spectrum calculation (future work).