Spin Glass to Ferromagnet: Ageing Simulations on GPUs

(DY 15.2)

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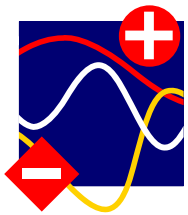

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Edwards-Anderson model

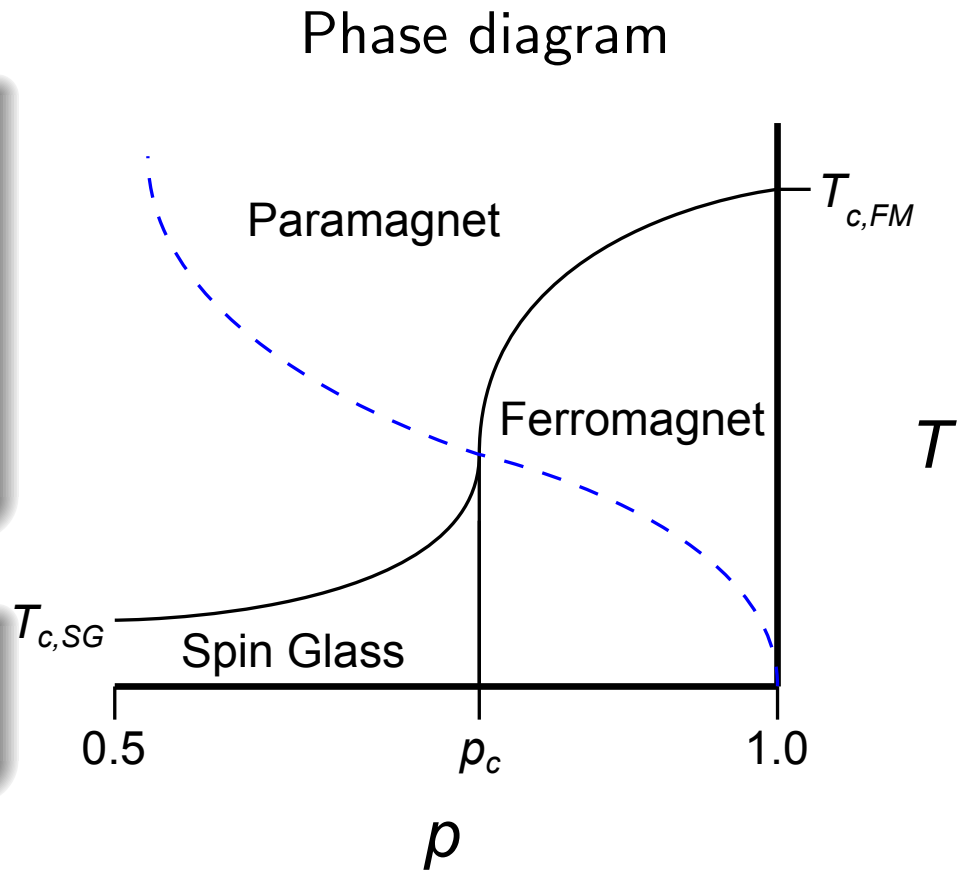
Hamiltonian

$$H(S) = -\sum_{i,j} J_{ij} S_i S_j$$

Ising spins $S_i = \pm 1$,
nearest-neighbour bonds $J_{ij} = \pm 1$

Bond distribution

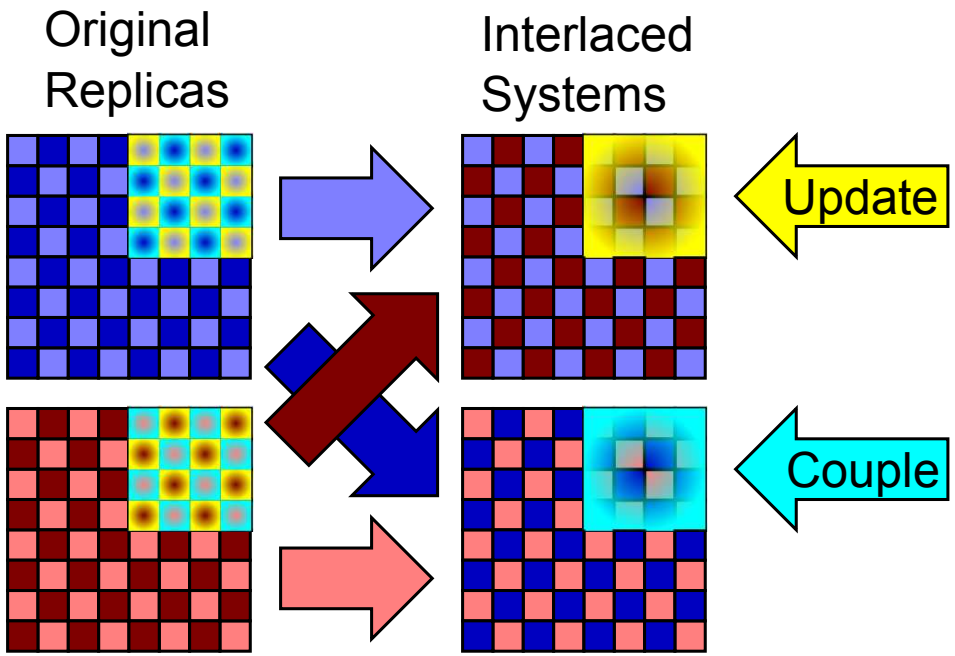
$$P(J) = p\delta(J-1) + (1-p)\delta(J+1)$$



Checkerboard Monte Carlo simulation

Metropolis criterion for accepting a spin flip

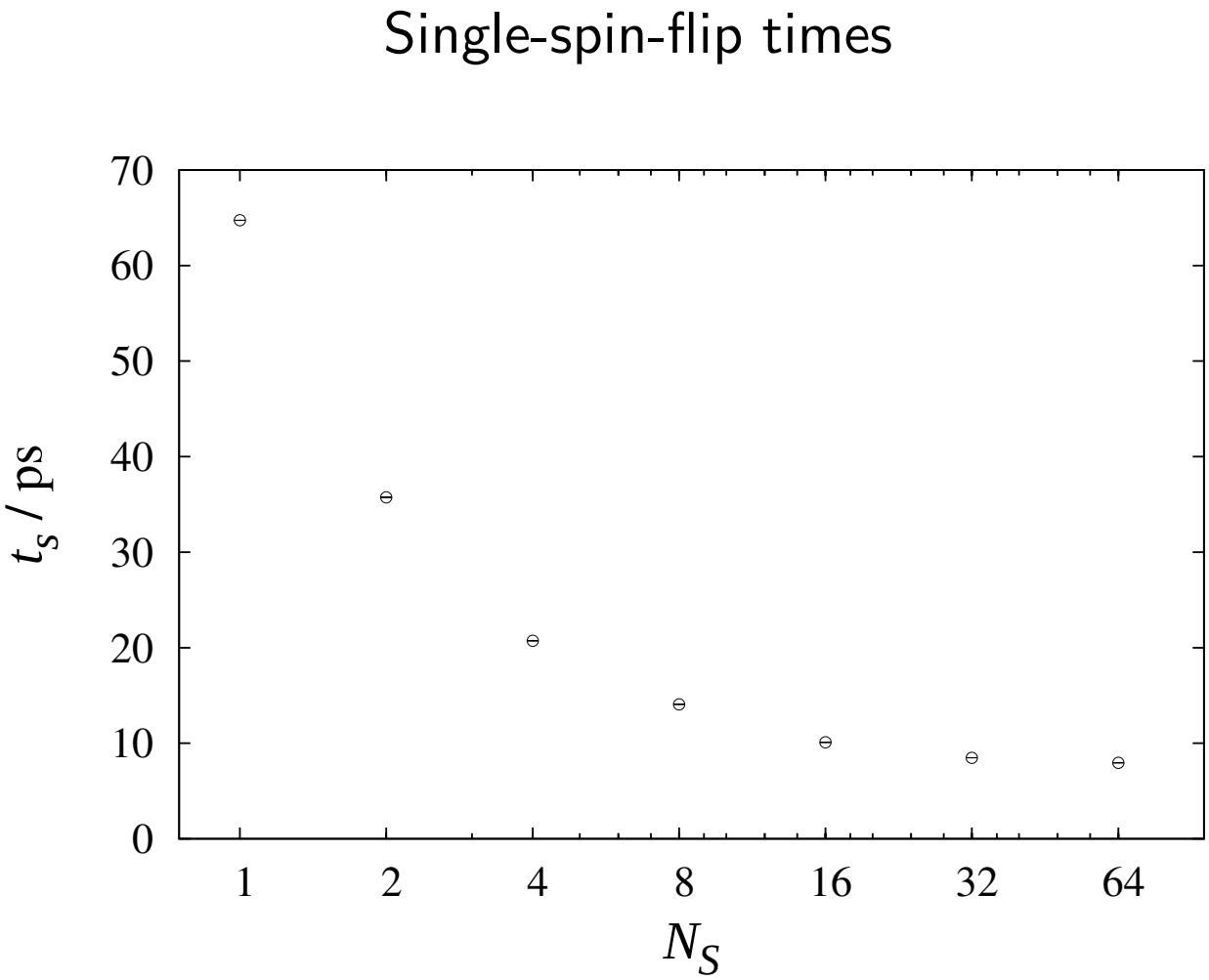
$$p_{\text{accept}} = \min\left(1, \exp\left(-\frac{2}{T}\sum_j J_{ij} S_i S_j\right)\right)$$



- 64bit mixed multispin coding

Performance

- one random number for multiple samples
- on Geforce GTX 570



Simulation details

- system size $N = 128^3$
- $N_S = 64$ samples per multispin
- 64 Samples $\times$ 2 Replicas
- temperature $T = 0.8$
- bond probability $p \in [0.5, 1.0]$
- 10^8 time steps
- $\approx$ 63h per simulation on a Geforce GTX 570

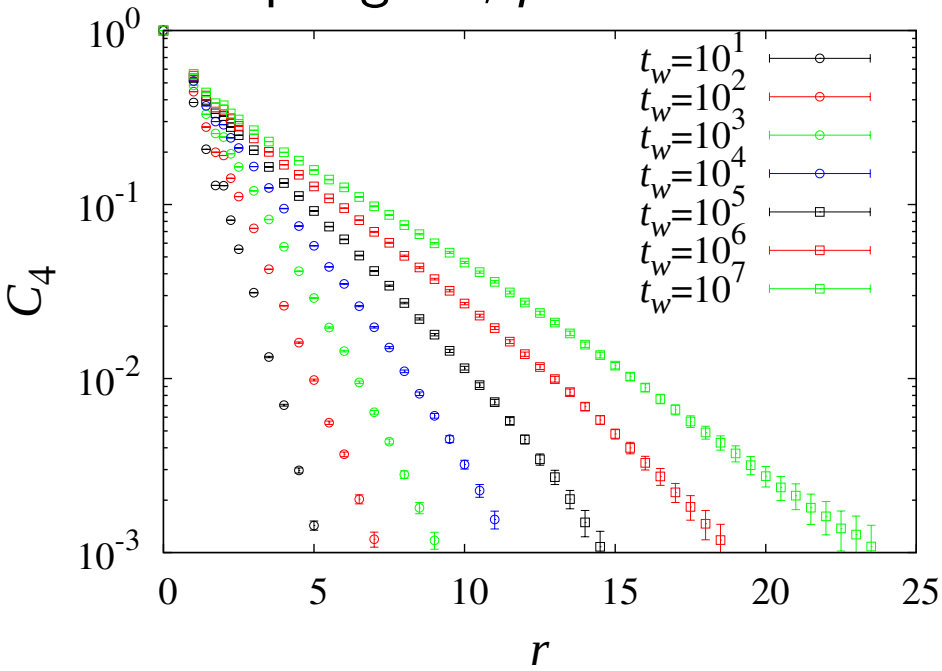
Spatial correlation

Definition

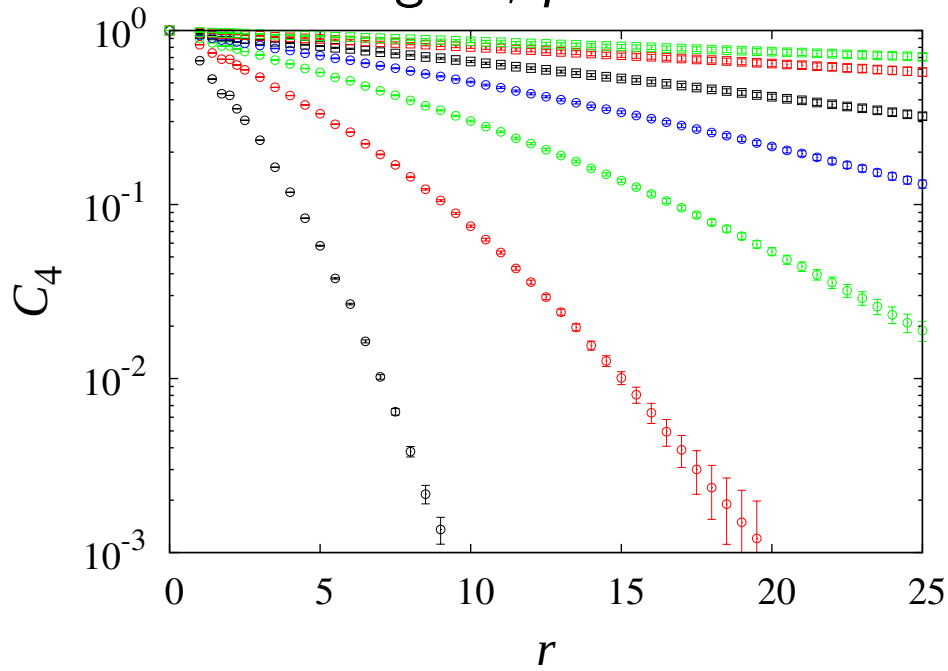
$$C_4(r, t_w) = \frac{1}{N} \sum_i S_i^{(a)}(t_w) S_{i+r}^{(a)}(t_w) S_i^{(b)}(t_w) S_{i+r}^{(b)}(t_w)$$

with two Replicas $S^{(a)}$, $S^{(b)}$

Spin glass, $p = 0.5$



Ferromagnet, $p = 0.95$



Correlation length

Fit function [Marinari PhysRev1996]

$$C_4(r, t_w) \propto r^{-\alpha} g\left(\frac{r}{\xi(t_w)}\right)$$

with

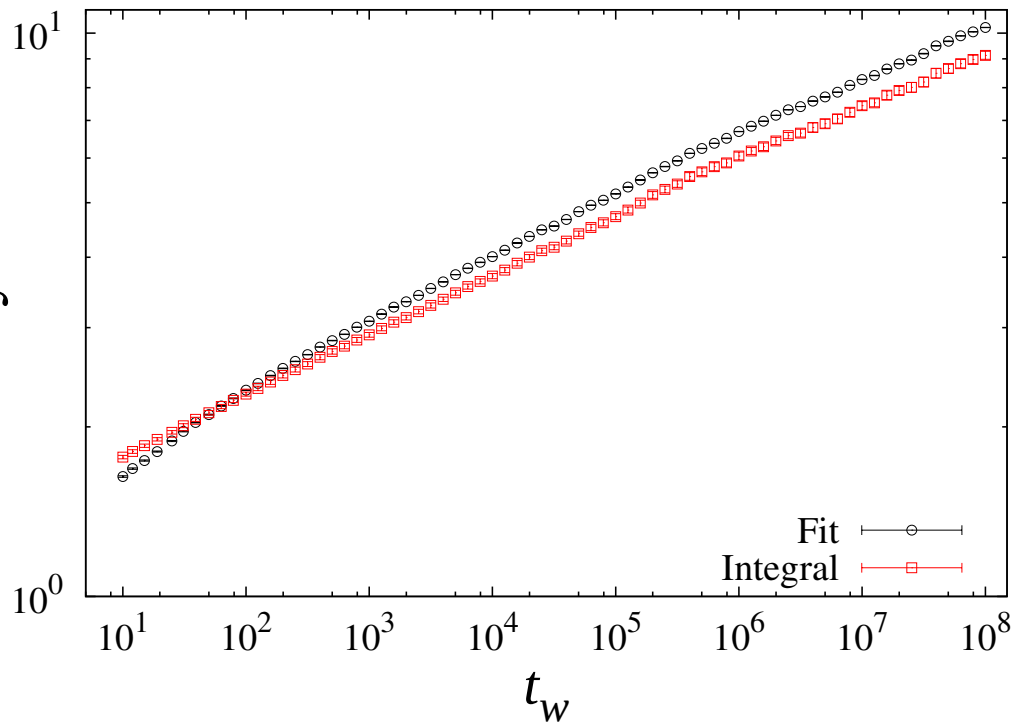
$$g(x) = \exp(-x^{\beta})$$

Integral estimator [Belletti PhysRev2008]

$$\xi_1(t_w) = \frac{I_2(t_w)}{I_1(t_w)}$$

$$I_k(t_w) = \int_0^{L/2} r^k C_4(r, t_w)\, \mathrm{d}r$$

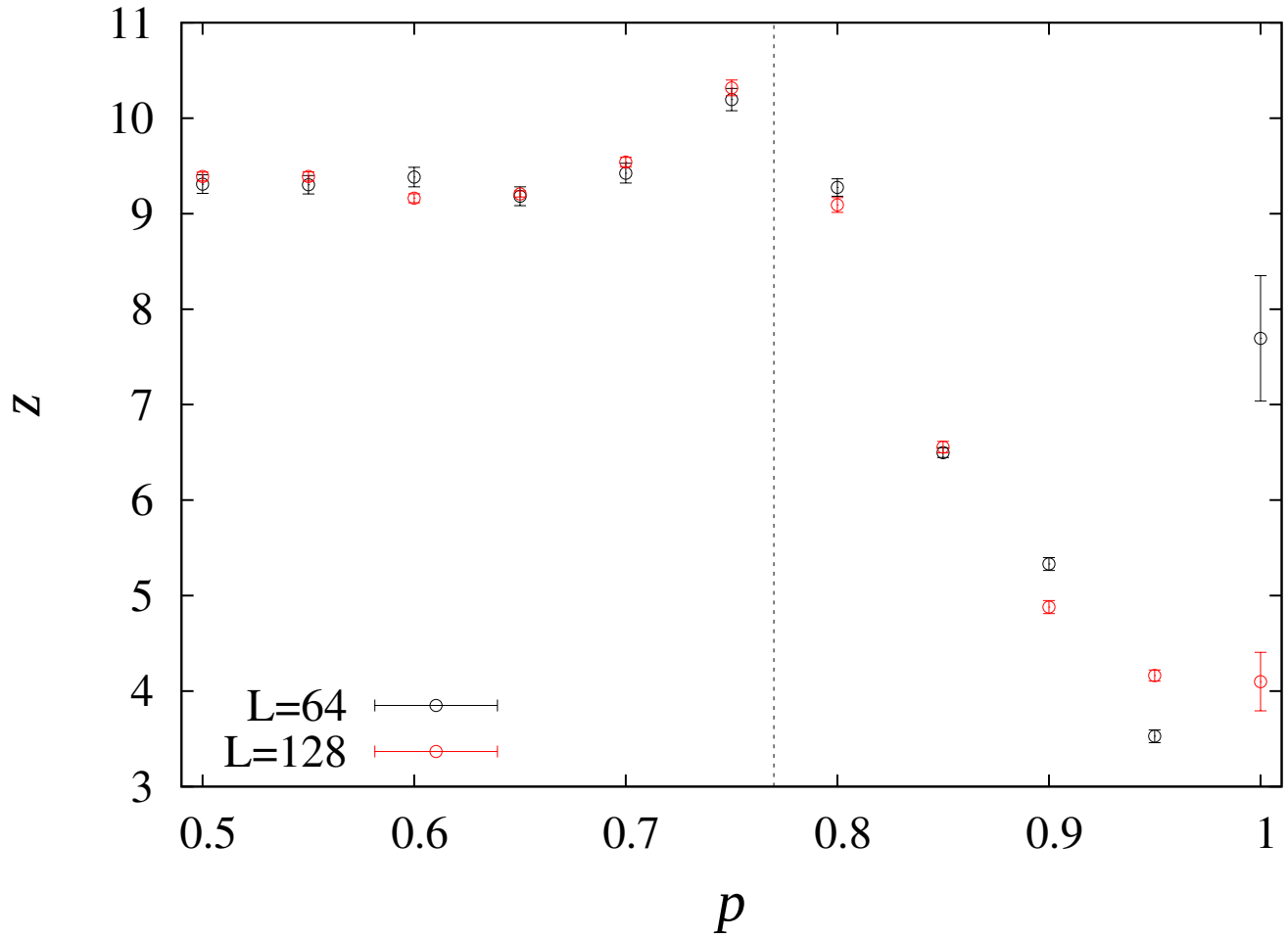
Spin glass, $p = 0.5$



Correlation length exponent

Power law

$$\xi(t_w) \propto t_w^{1/z}$$

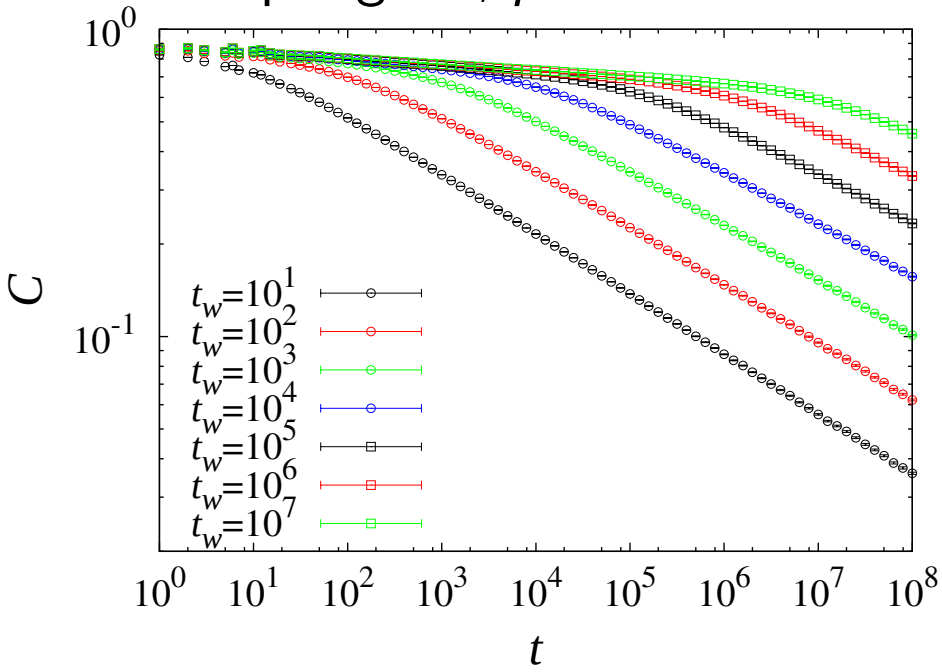


Autocorrelation

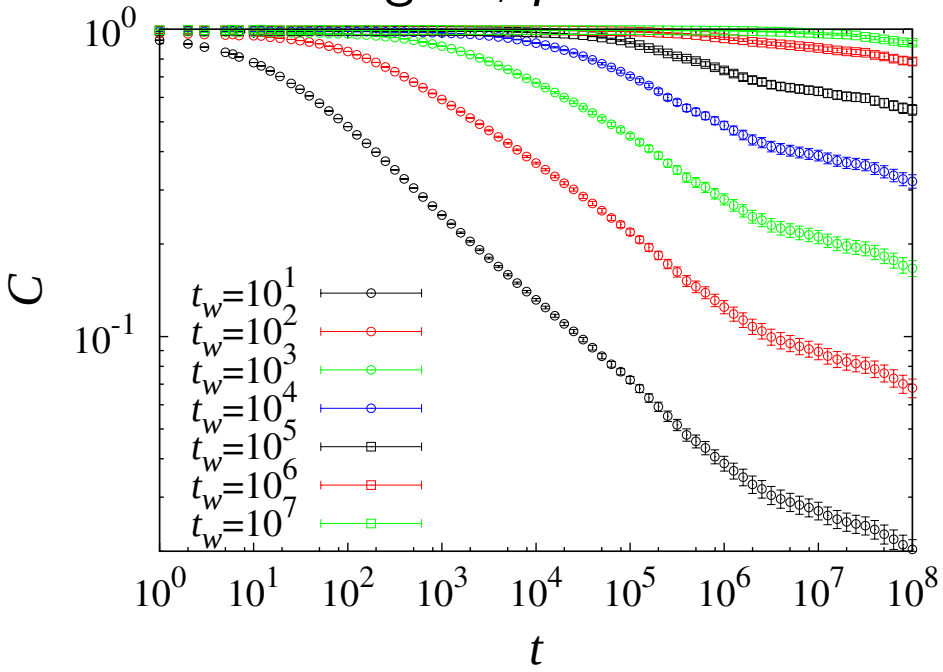
Definition

$$C(t, t_w) = \frac{1}{N} \sum_i S_i(t_w) S_i(t_w + t)$$

Spin glass, $p = 0.5$



Ferromagnet, $p = 0.95$

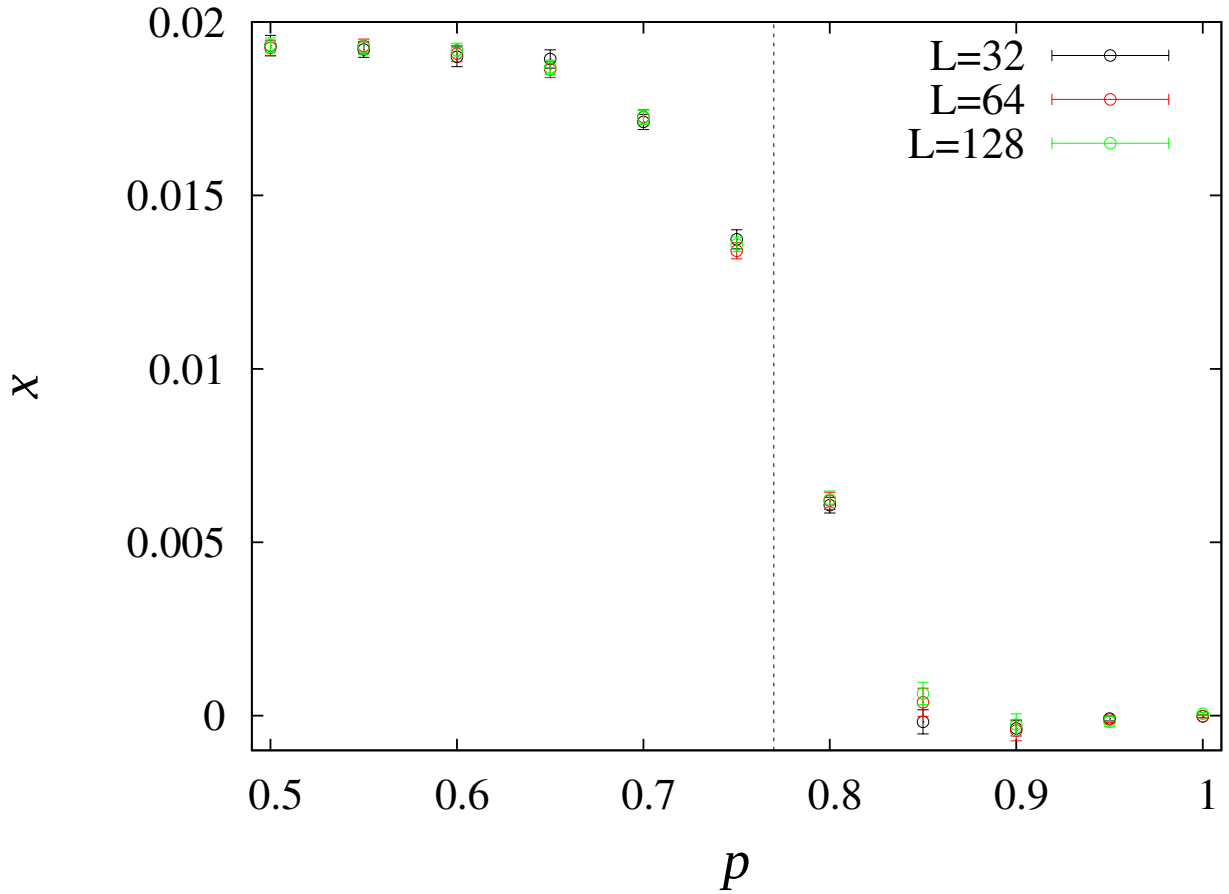


finite size effect for $p \longrightarrow 1$

Equilibrium exponent

Power law

$$C_{eq}(t) \propto t^{-x} \quad \text{for} \quad t \ll t_w$$



Conclusion

- simulated systems $N = 128^3$ for 10^8 timesteps
- phase transition visible in dynamics
- still many open questions
  - finite size effects for ferromagnet
  - no definite way to extract correlation length

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