Measurement-induced criticality in (2+1)-dimensional hybrid quantum circuits

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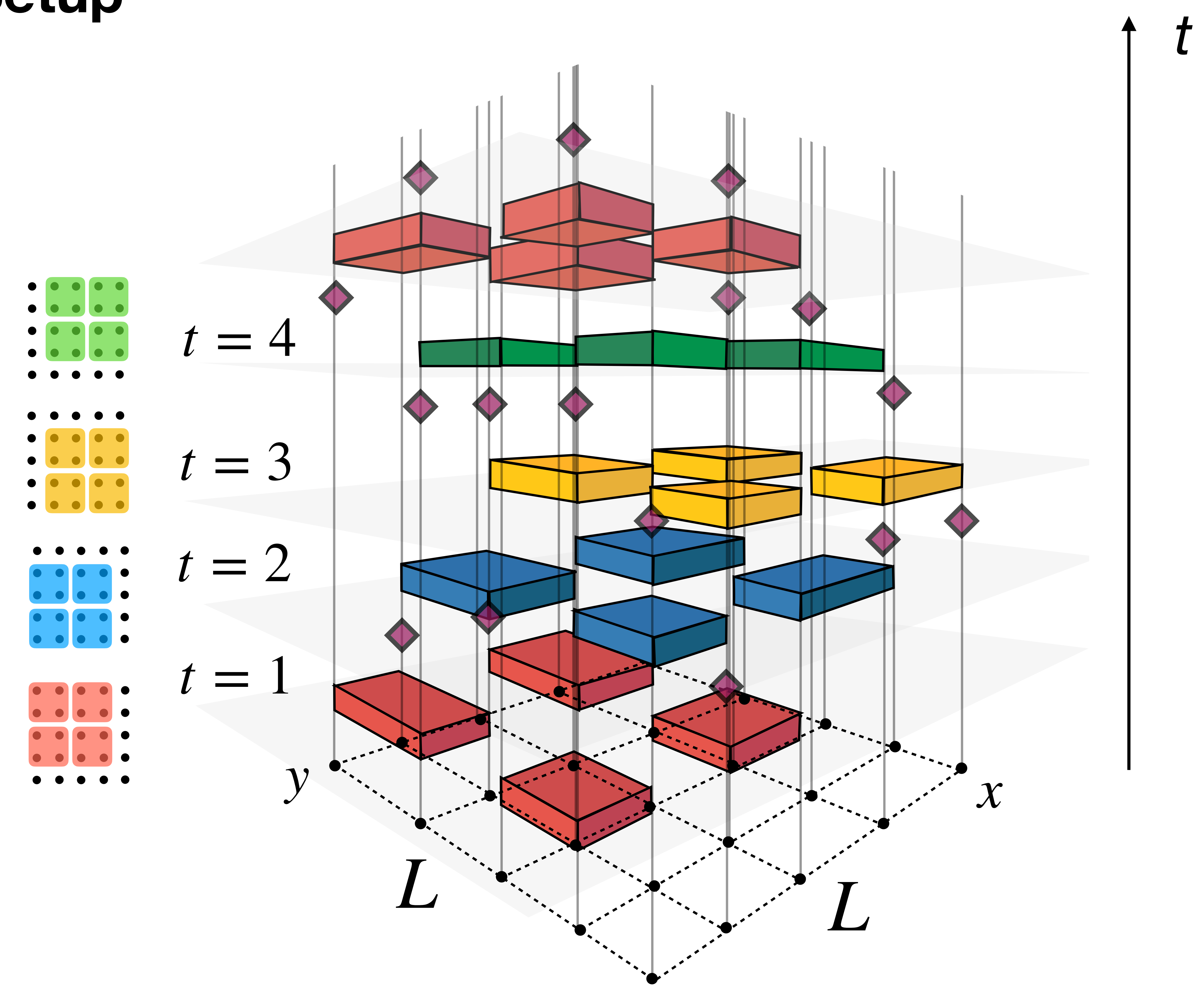
Setup

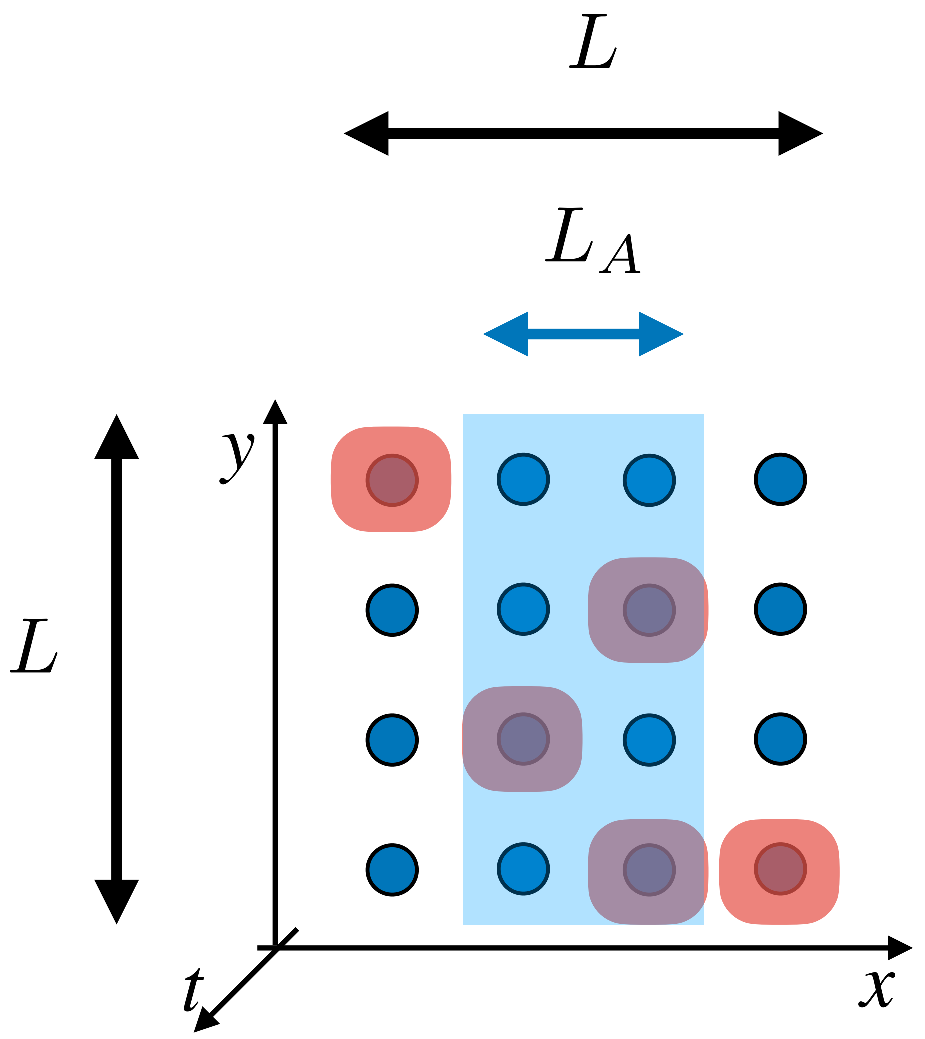


- Unitaries: 4-body Clifford random unitaries alternating over 4 sublattices
- Measurements: projective single spin and two-spin measurements along z axis.

Questions:

Is there a transition?
How does entanglement entropy scale?
Are properties '*universal*'?

Entanglement entropy scaling



= $P^{(1,\pm)}_{(x,y)}$

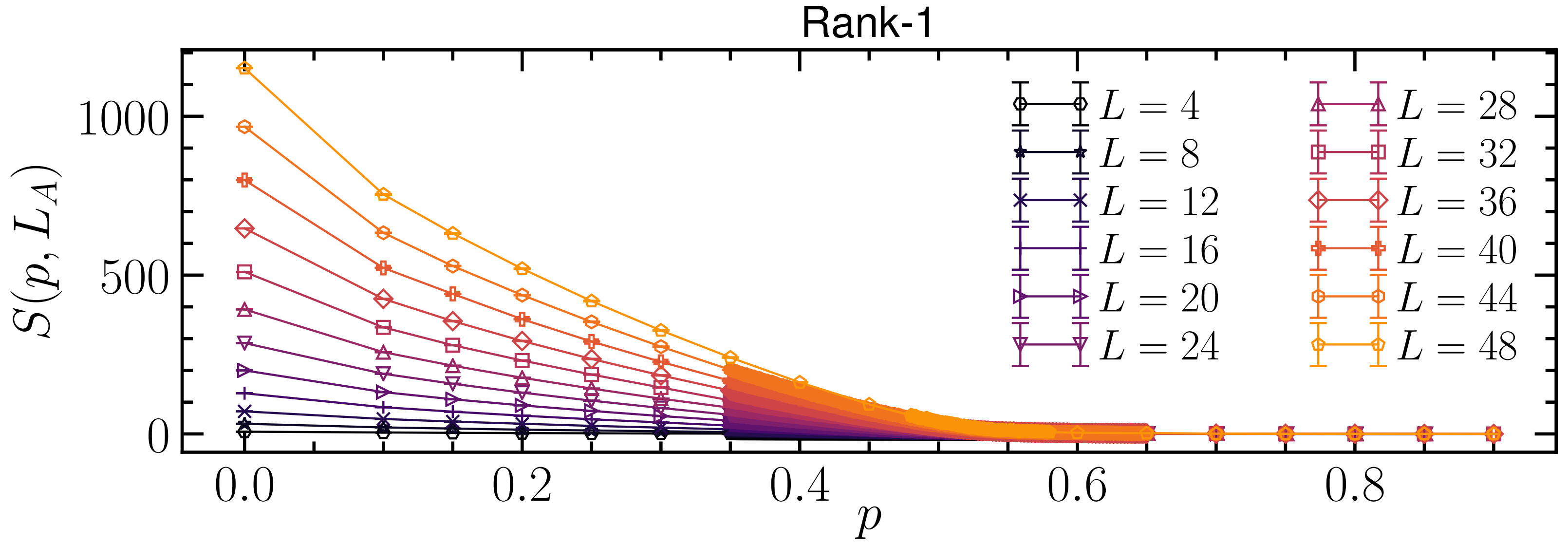
$P^{(1,-)} = |\downarrow\rangle\langle\downarrow|$

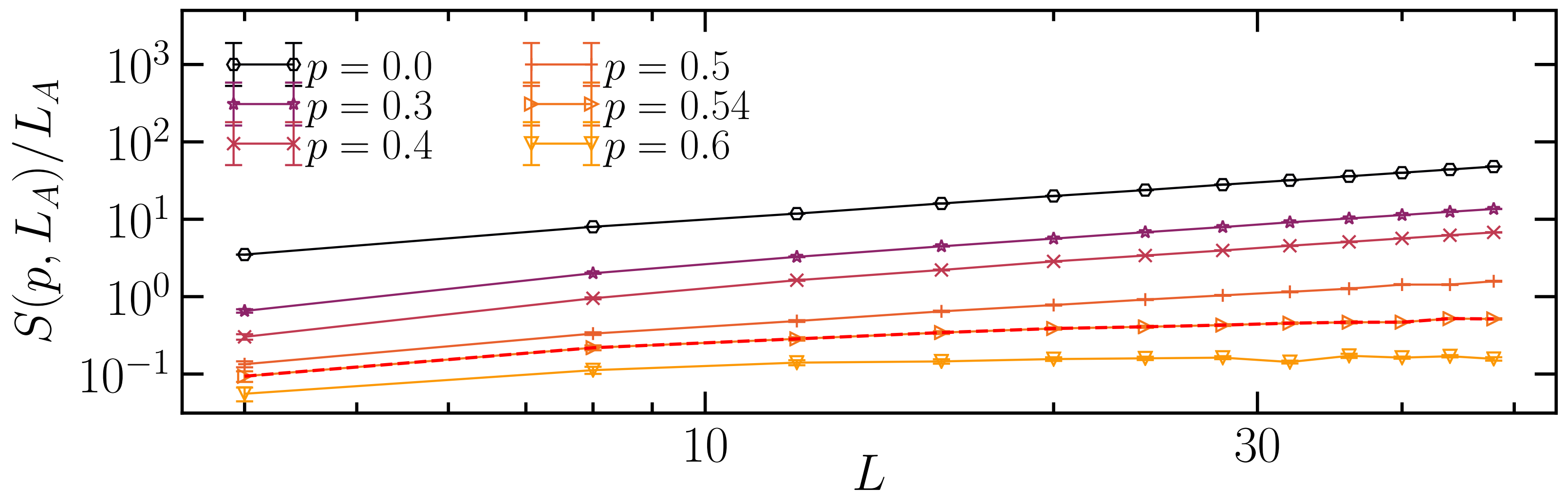
$P^{(1,+)} = |\uparrow\rangle\langle\uparrow|$

i) no corners
ii) aspect ratio can be kept fixed, or
iii) total size fixed, partition size varies

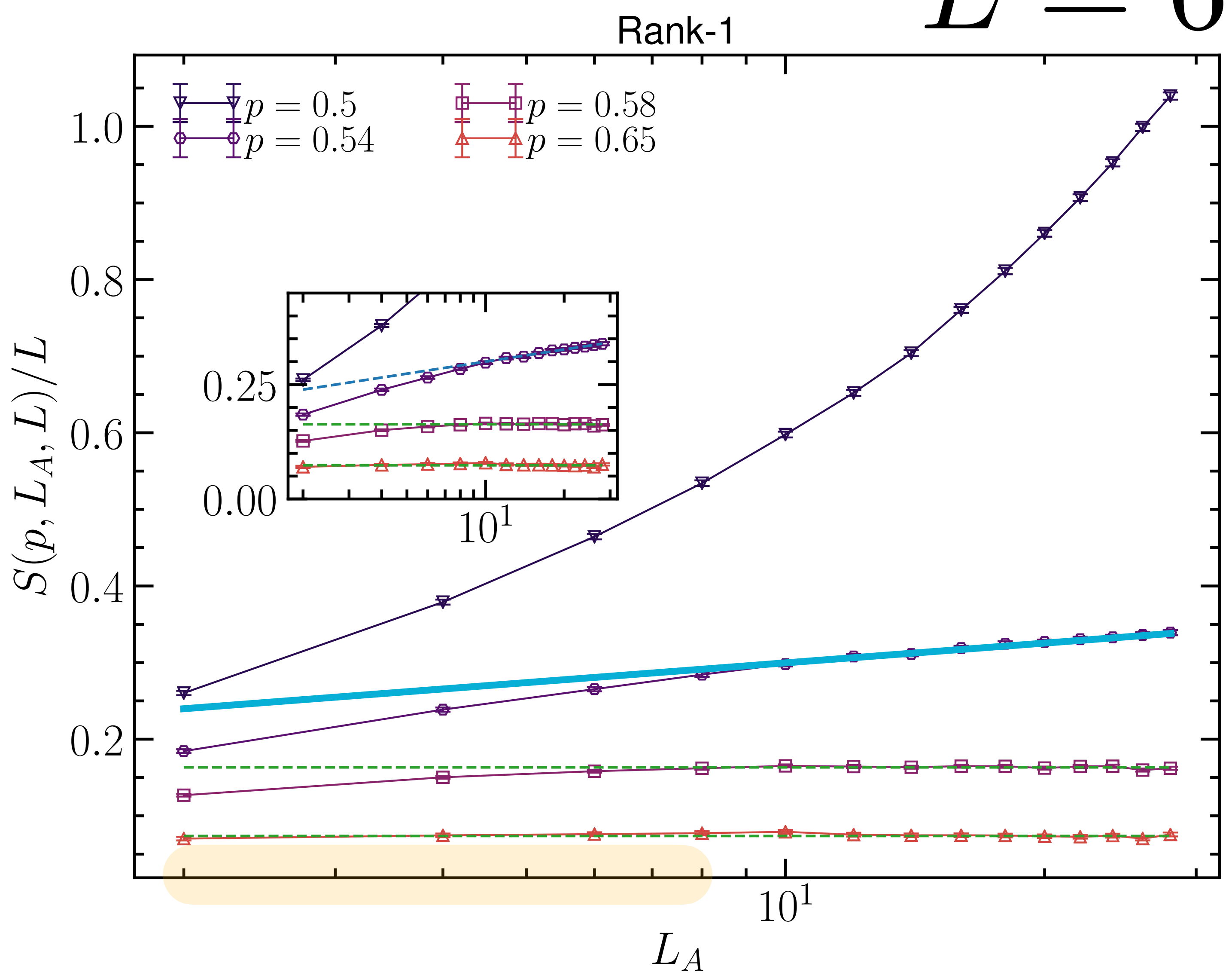
$$S_A(p,L) = -\overline{\mathrm{tr}_A \rho_A(t) \log \rho_A(t)}$$

$L_A = L/2$





$L = 64$



Volume

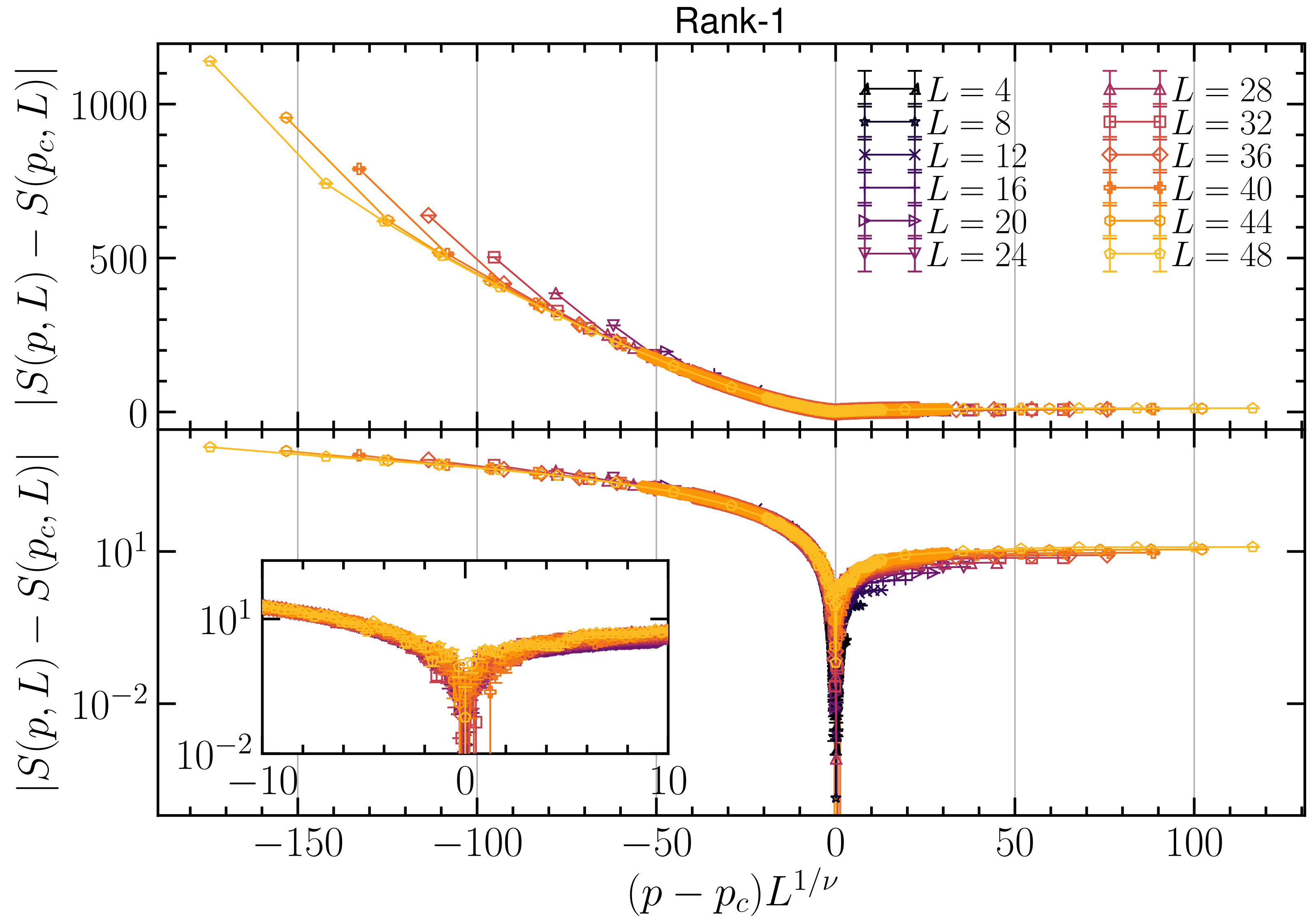
Transition

Area

Conclusion I:

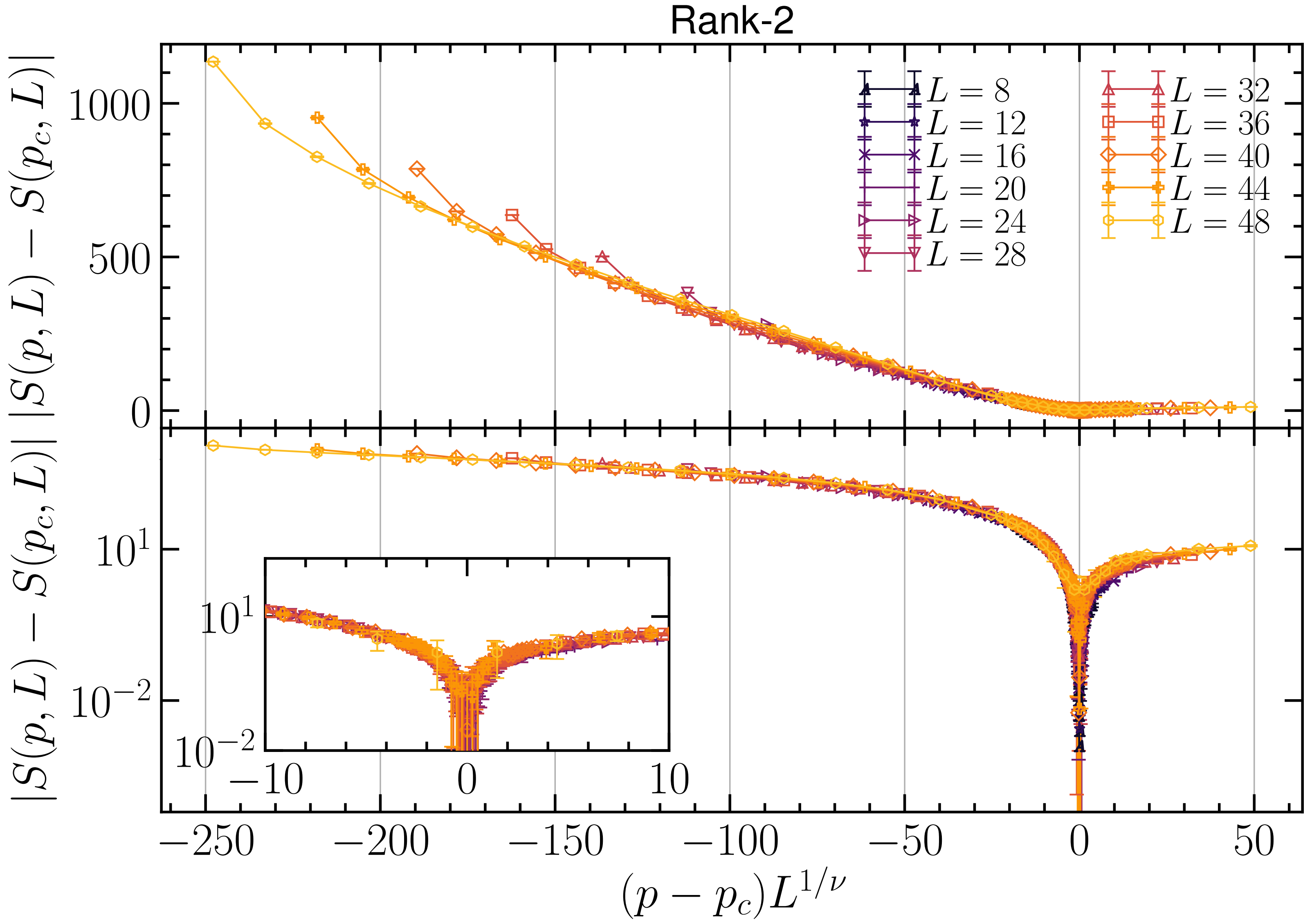
✓ entanglement transition features logarithmic violation of area law
- theory: emergent gauge fields + fermions? no equilibrium counterpart?

Universality and critical exponents



$$p_{c,rk1} = 0.54(1)$$

$$\nu_{rk1} = 0.67(1)$$



$$p_{c,rk2} = 0.84(1)$$

$$\nu_{rk2} = 0.68(1)$$

Conclusions II & III:

✓ ‘universal’ properties (i.e., same critical exponent) in 2D Clifford circuits

✓ incompatible with 3D percolation (0.877), which describes S0 in Haar circuits [Skinner et al., PRX 2019], and displays area law scaling

Next:

- gauge-invariant circuits?
- stat-mech model?
- other entanglement signatures (concurrence, …)?

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