Entanglement and quantum noise: Is it possible to measure entanglement entropies?

Colloquium at the Perimeter Institute, Waterloo, Ontario (Canada), April 27, 2011

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April 25, 2011

Physics Illinois

Collaborators and References

- Benjamin Hsu
- Eytan Grosfeld

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- Eduardo Fradkin, *Scaling of Entanglement Entropy at 2D quantum Lifshitz fixed points and topological fluids*, Journal of Physics A: Mathematical and Theoretical **42**, 504011 (2009), (special issue on Entanglement Entropy, P. Calabrese, J. Cardy and B. Doyon, editors); arXiv:0906.1569v1.

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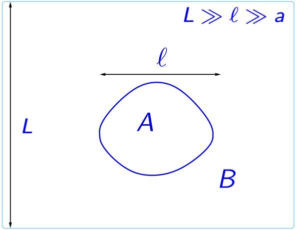

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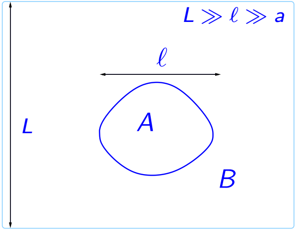

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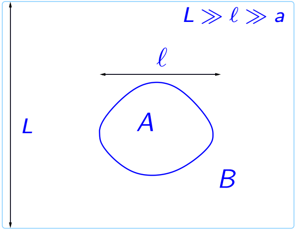

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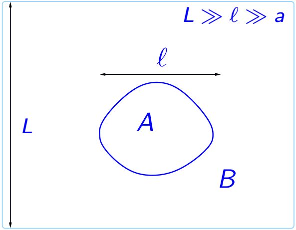

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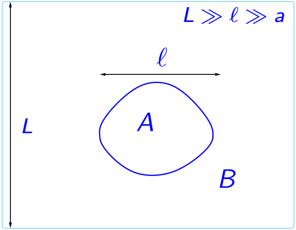

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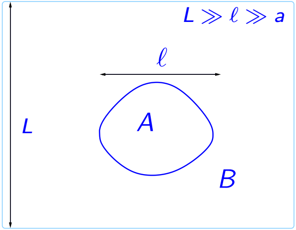

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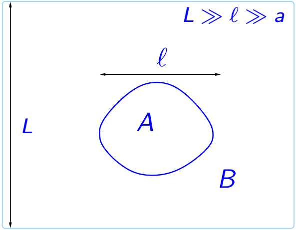

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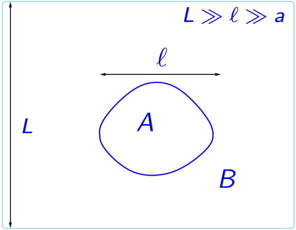

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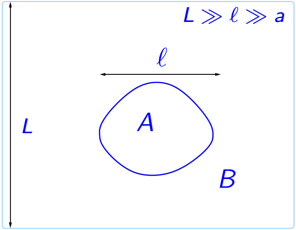

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The excitations are vortices with fractional charge $q = e/m$ and fractional (braid) statistics $\theta = \pi/m$.

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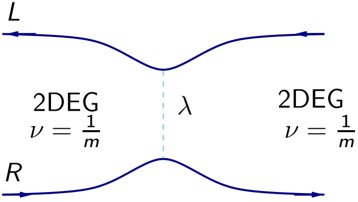

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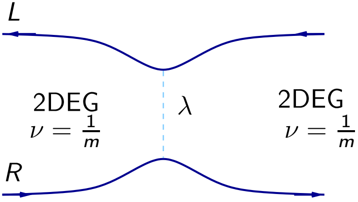

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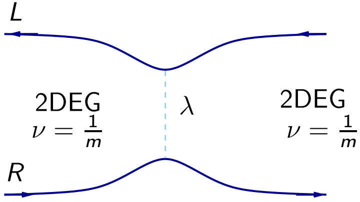

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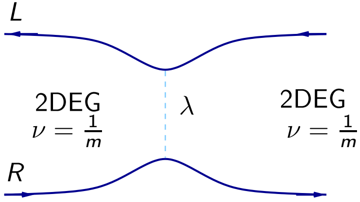

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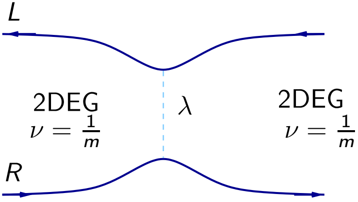

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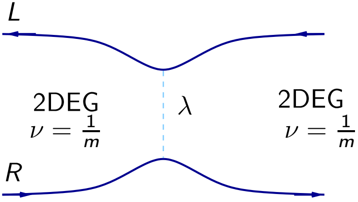

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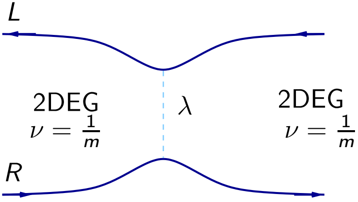

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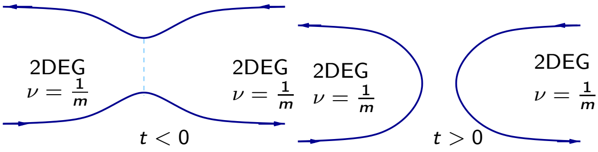

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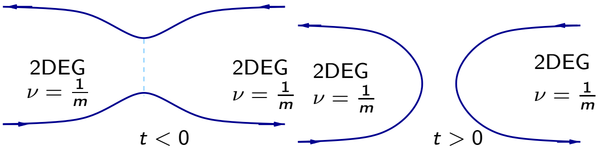

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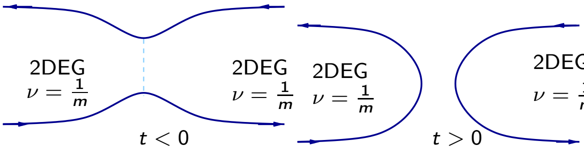

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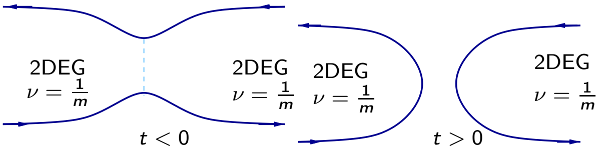

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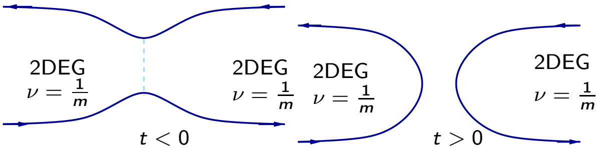

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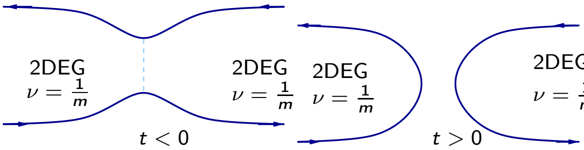

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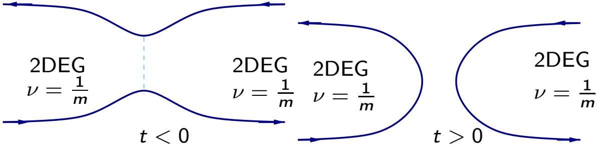

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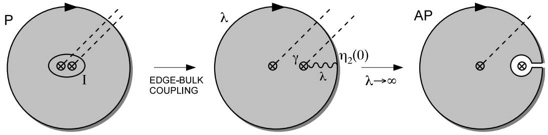

Two σ_2 operators are drawn from the vacuum. Tunneling (of strength λ) is introduced between one of the σ_2 operators and the edge. Finally, in the limit $\lambda \to \infty$, the edge circumvents the σ_2 operator.

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$$\langle Q_{\Delta t}^2 \rangle = \int_0^{\Delta t} dt_1 \int_0^{\Delta t} dt_2 \frac{\langle \sigma_2(0) I_b(t_1) I_b(t_2) \sigma_2(0) \rangle}{\langle \sigma_2(0) \sigma_2(0) \rangle}$$

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$$E_2 = \frac{1}{\pi^2}\int_0^{\Delta t} dt_1 dt_2 \left(\frac{1}{t_1 - t_2 + i\delta}\right)^4 \simeq \frac{1}{3\pi^2\delta^2} + \frac{1}{\pi^2}\frac{1}{(\Delta t)^2}$$

- The entanglement entropy still grows as $S = \frac{1}{6}\ln(t/\delta) + \cdots$

Local quench in the Ising spin chain

$$H = \sum_{n=-N/2}^{N/2+1} \sigma_1(n) + \lambda \sum_{n=-N/2}^{N/2+1} \sigma_3(n)\sigma_3(n+1)$$

- @ link $(0,1)$: $\lambda(t) = 0$ for $t < 0$ and $\lambda(t) = 1$ for $t > 0$
- Chain split in two for $t < 0$; single uniform chain for $t > 0$
- Majorana fermion description of the critical quantum Ising model

$$\mathcal{L} = i\tilde{\eta}_R(\partial_t - \partial_x)\tilde{\eta}_R + i\eta_L(\partial_t - \partial_x)\eta_L + i\lambda(t)\delta(x)\eta_L\eta_R, \qquad \tilde{\eta}_R(x) = \eta_R(-x)$$

B.C: $\tilde{\eta}_R(0^+) = -\tilde{\eta}_L(0^-)$

- Locally conserved energy density: $\rho_E(x) = \eta_L i\partial_x \eta_L - \tilde{\eta}_R i\partial_x \tilde{\eta}_R$
- The rate of back-scattering of energy by the modified link is $I_E = \rho_E(0^+) - \rho_E(0^-)$
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