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Shape dependence of two-cylinder Renyi entropies for a free boson lattice field theory

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We study the bipartite von Neumann and $\alpha = 2$ Renyi entanglement entropies for a system of free bosons put on a torus cut into two cylinders. The torus is formed out of the $L \times L$ square lattice, and the entropy is supposed to scale as $S = aL + c\gamma(L_A/L) + \cdots$, with L_A being the size of the partitioned region. c and a are some constants and the function $\gamma(L_A/L)$ that is not known analytically is supposed to reflect some universality. We compute $\gamma(L_A/L)$ numerically and compare the results to several candidate functions derived from Quantum Lifshitz model, anti de-Sitter gravity in $3+1$ dimensions, and an Extensive Mutual Information model. Using lattices of different size, we explore the finite-size-scaling behaviour of the residuals for each fit, to attempt to discern which function most effectively describes the thermodynamic limit of the free boson system.

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