Absence of gapless Majorana edge modes in few-leg bosonic flux ladders

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The search for Majorana excitations has seen tremendous efforts in recent years, ultimately aiming for their individual controllability in future topological quantum computers. A promising framework to realize such exotic Majorana fermions are topologically ordered non-Abelian phases of matter, such as certain fractional quantum Hall states. Quantum simulators provide unprecedented controllability and versatility to investigate such states, and developing experimentally feasible schemes to realize and identify them is of immediate relevance. Motivated by recent experiments, we consider bosons on coupled chains, subjected to a magnetic flux and experiencing Hubbard repulsion. At magnetic filling factor $\nu = 1$, similar systems on cylinders have been found to host the non-Abelian Moore-Read Pfaffian state in the bulk. Here, we address the question of whether more realistic few-leg ladders can host this exotic state and its chiral Majorana edge states. To this end, we perform extensive density-matrix renormalization-group simulations and determine the central charge of the ground state. While we do not find any evidence of gapless Majorana edge modes in systems of up to six legs, exact diagonalization of small systems reveals evidence for the Pfaffian state in the entanglement structure. By systematically varying the number of legs and monitoring the appearance and disappearance of this signal, our work highlights the importance of finite-size effects for the realization of exotic states in experimentally realistic systems.