The ground state with the finite thickness effect at $\nu = 7/3, 8/3$
In the N=1 Landau level

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The Laughlin state successfully describe the fractional quantum Hall state at $\nu = 1/3$ in the lowest Landau level.

However, it is known that the Laughlin wavefunction has little overlap with the ground state wavefunction at $\nu = 7/3$ in the second Landau level. The ground states at $\nu = 7/3$ and $8/3$ are still unknown. To determine the ground states at these fillings, we use the exact diagonalization method and density-matrix renormalization group (DMRG) method. We calculate overlaps between the ground state and the trial wavefunctions, the ground state energies, and the ground-state pair-correlation functions with finite thickness effect.

Without thickness effect, we find that the ground state wavefunction at $\nu = 8/3$ have very high overlap between the parafermion state, and the ground state energy of the parafermion state is lower than that of the Laughlin state. Further, the short-range structures of pair-correlation functions are significantly different from that of the Laughlin state. From these results, we consider that the parafermion state is a strong candidate of the ground state at $\nu = 7/3$ and $\nu = 8/3$.

In the finite thickness systems, the pair-correlations show Laughlin-like power low behavior and energy gaps of the Laughlin state are scaled by system sizes.

We will discuss about phase transition between the parafermion state and Laughlin state.