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Finite-Layer Thickness Stabilizes the Pfaffian State for the 5/2 Fractional Quantum Hall Effect: Wave Function Overlap and Topological Degeneracy

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The fractional quantum Hall effect (FQHE) in the second orbital Landau level at even-denominator filling factor 5/2 remains mysterious and is currently motivating many scientists not only because of its connection to a possible implementation of a fault tolerant topological quantum computer (Das Sarma et al., PRL 94, 166802(2005)). In this work, we theoretically consider the effect of the quasi-two-dimensional nature of the experimental fractional quantum Hall systems on a number of FQHE states in the lowest three orbital Landau levels. Our primary result is that the finite width of the quasi-two-dimensional systems produce a physical environment sufficient to stabilize the Moore-Read Pfaffian state thought to describe the FQHE at filling factor 5/2. This conclusion is based on exact calculations performed in the spherical and torus geometries, studying wave function overlap and ground state degeneracy. Furthermore, our results open the possibility of creating optimal experimental systems where the 5/2 FQHE state would more likely be described by the Moore-Read Pfaffian. We also discuss the role of the three-body interaction Hamiltonian that produces the Moore-Read Pfaffian as an exact ground state and particle-hole symmetry in the FQHE at 5/2. We acknowledge support from Microsoft Project Q. Work done in collaboration with Sankar Das Sarma, Thierry Jolicoeur, and Kwon Park.