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Spin-dependent phase diagram in bilayer 2D electron systems

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Bilayer electron systems with total filling $\nu = 1$ involve rich physics arising from the interplay between the intralayer and interlayer interactions parameterized by the ratio between the interlayer distance d and the magnetic length ℓ_B. One key issue in this system is the nature of the phase transition that occurs when exploring the system between the two limits of weak and strong interlayer interactions, i.e., compressible Fermi-liquid states of composite fermions and an incompressible quantum Hall state. Here we report tilted-field experiments on a double quantum well with negligible tunneling that demonstrate that the spin degree of freedom plays a decisive role in the ground-state phase diagram of this system [1]. When the ratio η of the Zeeman to Coulomb energies is enhanced by tilting the sample in a field by an angle θ, we observe that the phase boundary located at $d/\ell_B = 1.90$ for $\theta = 0$ shifts to higher densities until it saturates at $d/\ell_B = 2.33$ for $\theta \geq 60$ degree. The data thus establish a spin-dependent phase diagram as a function of η and d/ℓ_B. We model the energies of the competing phases treating the compressible state as nearly independent Fermi liquids of composite fermions. The excellent agreement between the model and experiment indicates that at small θ the compressible state is only partially polarized and its Zeeman-dependent energy is responsible for the observed shift of the phase boundary, with the saturation at large θ signaling the full polarization. This in turn implies that the intrinsic transition, expected for the ideal system without spin and intensively studied in theory, is preempted by a transition to a partially polarized compressible state in the standard experimental conditions and can only be revealed by suppressing the spin degree of freedom. Our results thus shed new light on previous experiments and show a way to investigate the intrinsic properties of the system. [1] P. Giudici *et al.*, Phys. Rev. Lett. **100**, 106803 (2008).