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Direct capacitive probe of valley order in a bilayer graphene quantum Hall ferromagnet

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Bilayer graphene is a highly tunable quantum Hall system: both the spin and valley splitting can be manipulated independently of the electron density. Recently, a number of studies have revealed a rich phase diagram of gapped ground states corresponding to diverse spin/valley isospin polarizations; however, all of these studies are indirect, relying on the dependence of features associated with gapped states on electric or magnetic field to infer the isospin ordering of these states. In this talk, I will describe a capacitive technique capable of directly detecting the valley component of the isospin order. By sensitively measuring the difference in capacitance between top and bottom gates of a dual-gated bilayer graphene device, we extract layer-charge response–the tendency of the layer polarization to change in response to a change in chemical potential of the entire bilayer. The asymmetric capacitance reflects the ground state layer polarization, and thus, in the zero Landau level (zLL), the valley polarization. In agreement with theoretical expectations, we find that the phase diagram of the octet zLL is, for the most part, characterized by the filling of pairs of degenerate sublevels with different orbital quantum numbers. Surprisingly, however, we also observe numerous additional states at intermediate electric fields, associated with an "odd" layer occupation. Finally, we find that phase transitions between states with different layer polarization are characterized by large anomalies in the asymmetric capacitance, which persist well into the compressible center of the Landau level.