Coulomb interactions and effective quantum inertia of charge carriers in a macroscopic conductor

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Abstract: On one hand, electrical transport across macroscopic conductors can be described in terms of lumped circuit elements, including inductances and capacitances. On the other hand, the linear response of ballistic quantum conductors can also be described in terms of inductances and capacitances of quantum origin reflecting the fermionic nature of charge carriers which leads to characteristic RC or LC time scales associated with ballistic times of flights (ref 1,2). In the present work, we demonstrate that macroscopic conductors involving a small number of conducting channels also exhibit linear response properties of quantum origin, even if their size is much larger than the electronic coherence length.

As a paradigmatic example, we study the low-frequency admittance of a quantum Hall bar of a size much larger than the electronic coherence length(ref 3). We find that this macroscopic conductor behaves as an ideal quantum conductor with vanishing longitudinal resistance and purely inductive behavior up to 1 MHz. We study the dependence of this inductance on the length of the edge channel and on the filling factor. The experimental data are well described by a scattering model for edge magneto-plasmons taking into account the effective long range Coulomb interactions within the sample. We find that the inductance's dependence on the filling factor arises predominantly from the effective quantum inertia of charge carriers induced by Coulomb interactions.

References

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Figures

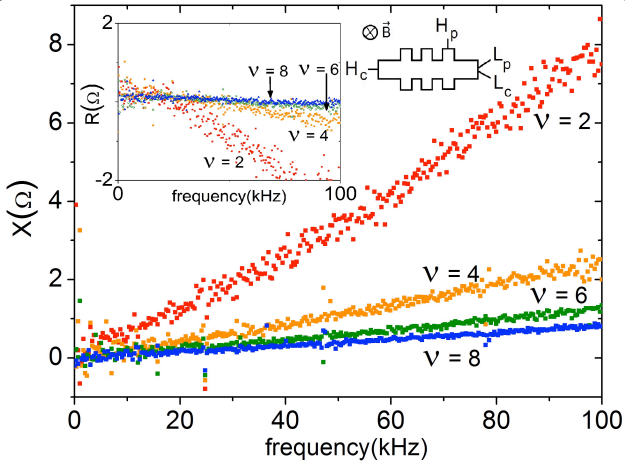

Figure 1: The reactance *X of an edge channel* as a function of the frequency *f* for different ν . Inset: The longitudinal resistance *R*(*f*) vanishes quadratically for integer filling factors

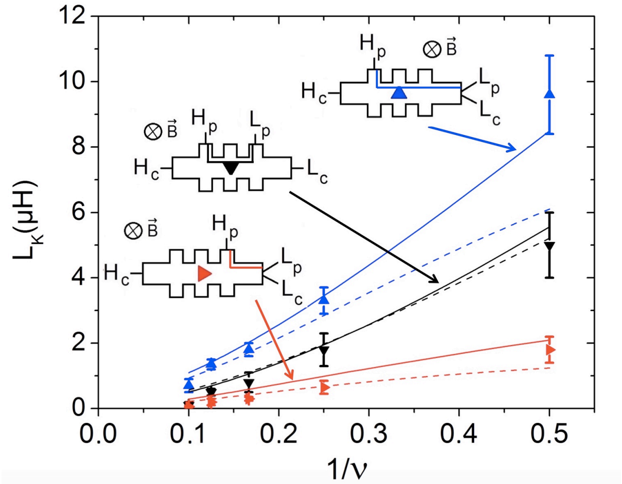

Figure 2: Quantum Inductance is proportional to the inverse of filling factor and to the length of edge channels.