Robust probes of the anyonic braiding phase

Inès Safi

Laboratoire de Physique des Solides, CNRS-Université Paris-Saclay, Orsay Cédex-France.

ines.safi@universite-paris-saclay.fr

Two-dimensional electronic systems in the fractional quantum Hall (FQH) regime host anyons, quasiparticles characterized by fractional charge and statistics beyond the conventional boson-fermion dichotomy [1]. While experimental techniques, such as quantum point contact (QPC) measurements and noise spectroscopy, have successfully probed the fractional charge of these excitations, accessing their statistical phase θ remains a significant challenge. Recent pioneering experiments [2] have made progress but still face complexities, particularly at hierarchical filling factors due to inter-mode interactions and edge reconstruction.

In this talk, we tackle this challenge by investigating hierarchical quantum Hall edges comprising N co-propagating modes and a local QPC. Our analysis [3] reveals that an injected anyon fractionalizes into N nonuniversal charge components, each associated with an effective phase $\pi\delta_m$ that depends on inter-mode interactions. Crucially, only the sum of these phases, defining the local scaling dimension $\delta = \theta/\pi \pmod{\pi}$, remains protected, contrary to the widespread assumption that θ and δ are generically independent. We further demonstrate that time-domain braiding with phase θ [4] can only be achieved under stringent conditions: either noninteracting modes of equal velocities or a spatially local injection at the QPC.

To isolate θ as a genuine statistical phase, distinct from its role as a scaling dimension, we introduce two minimal single-QPC protocols [3] leveraging an exchange link between anyons and quasiholes at the QPC protected from inter-mode interactions. Two nonequilibrium fluctuation-dissipation relations enable direct probing of θ by connecting DC backscattering noise to either an integral over the DC current or the admittance phase accessible even at low frequencies. For thermalized edges, the unique solution for the integral equation exhibits Tomonaga-Luttinger liquid behavior without imposing free chiral modes [5]. Then the admittance phase directly yields θ in the quantum regime for $\delta > 1/2$. This brings new insights into Hong-Ou-Mandel setups [6,7].

References

[1] Feldman, D. E. and Halperin, Bertrand I., Rep. Prog. Phys. 84, 076501 (2021).
[2] J. Nakamura *et al*, Nat. Phys. 16, 931 (2020). H. Bartolomei *et al*, Science 368, 173 (2020).
[3] I. Safi, arXiv:2510.10525 (2025).
[4] C. Han *et al*, Nat. Comm. 7, 11131 (2016)
[5] A. Latyshev and I. Safi, arXiv:2510.20592.
[6] M. Ruelle *et al.*, Science 389, eadm7695 (2025).
[7] A. Latyshev *et al* arxiv: 2509.07875.

Figures

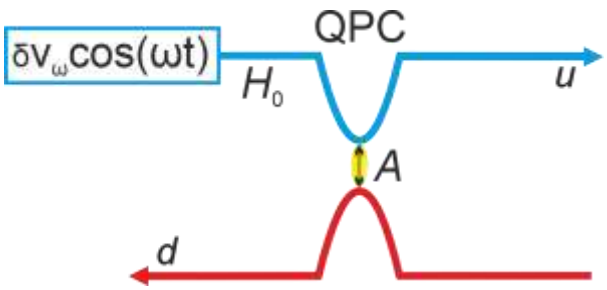

Figure: A local QPC with backscattering operator A between upper (u) and lower (d) edges with Hamiltonian H_0. The admittance protocol is valid at small AC voltage and frequencies and applies to QPC sources.