Statistics-induced entanglement from Andreev-like tunnelling in anyonic colliders

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We investigate how fractional quasiparticle statistics generate entanglement in an anyonic Hong–Ou–Mandel (HOM) collider at filling factor $\nu < 1/2$. Even when two anyonic subsystems are coupled solely through electron tunneling, we demonstrate that fractional-statistics–induced entanglement emerges between them. Our platform consists of fractional quantum Hall edges linked by a quantum point contact that transmits fermions exclusively, making it analogous to Andreev tunneling. Each fermionic tunneling event triggers an Andreev reflection of anyonic quasi-holes, which braid with incoming anyons from non-equilibrium beams supplied by diluters—a process we term ”anyon–quasihole braiding.”

The Andreev-like tunneling in an anyonic collider is ”halfway” between the integer case (where both tunneling and dynamics along the arms are fermionic) and a purely anyonic collider (both tunneling and dynamics are anyonic). Detecting statistics-induced entanglement in transport experiments is challenging already for fermions; for anyons, this challenge is compounded by the limited physical intuition regarding the mechanisms that generate entanglement (such as bunching and antibunching in bosonic and fermionic systems). Moreover, quasiparticle collisions—expected to directly encode anyonic statistics through entanglement—are commonly believed to play a negligible role in noise measurements of anyonic HOM colliders. In the dilute-beam regime, such collisions are typically masked by time-domain braiding, in which an incoming anyon braids with spontaneously generated quasiparticle–quasihole pairs.

The Andreev-like setup overcomes this obstacle: because conventional time-domain braiding is absent under fermionic tunneling, the Andreev–HOM geometry enables a direct probe of true anyon–anyon collisions. The exchange of electrons—carrying only ”trivial” fermionic statistics—is nonetheless sufficient to make two anyonic subsystems mutually aware of each other's fractional statistics, producing measurable statistical entanglement. We quantify this effect through current-noise cross-correlations, which serve as an entanglement pointer. The theory is verified in the experiment [1]; the measured data agree remarkably well with the theoretical predictions for both the current cross-correlations and the entanglement pointer.

Our results establish two-particle collisions as the key mechanism behind fractional-statistics–induced entanglement in anyonic colliders. Our work opens new directions for studying emergent phenomena governed by anyonic statistics and prospectively paves the way to the exploration of entanglement induced by non-Abelian statistics. Generating and quantifying the statistics-induced entanglement through transport experiments is expected to allow both the identification of non-Abelian states and the manipulation of entanglement in topological quantum platforms.

Reference:

[1] Gu Zhang, Pierre Glidic, Frederic Pierre, Igor Gornyi, and Yuval Gefen, Nature Commun. 16, 6558 (2025)