Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

(One page maximum)

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Thesis possibility after internship: YES
Funding: YES If YES, which type of funding:

Fractional statistics of anyons

In three-dimensional space, elementary excitations fall into two categories depending on the phase ϕ accumulated by the many-body wave function while exchanging two particles. This phase governs the statistics of an ensemble of particles: bosonic particles, for which $\phi = 0$, tend to bunch together, whereas fermions ($\phi = \pi$) antibunch and follow Pauli's exclusion principle. In two-dimensional systems, other values of ϕ can be realized, defining types of elementary excitations called anyons that obey fractional or anyonic statistics with intermediate levels of bunching or exclusion. Anyons are currently the subject of intensive research both for their fundamental properties but also for the possibility to encode robust quantum information by braiding specific types of anyons in topological quantum computing schemes. Their existence has been predicted 40 years ago, in particular in strongly correlated topological materials, such as the fractional quantum Hall effect. However, direct evidences of their peculiar properties have only been obtained this year: in our group, by implementing a collision between anyons in a microscopic collider [1] (see Figure) and at Purdue University by using a Fabry-Perot interferometer for anyons [2].

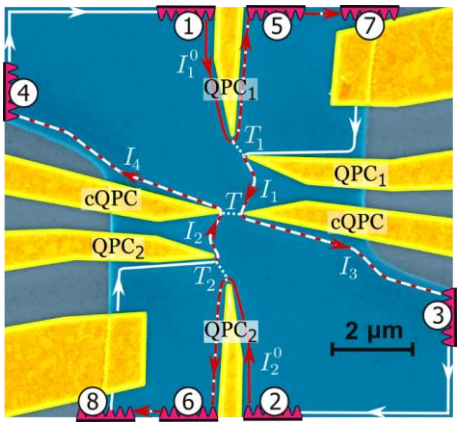

Figure: Scanning electron microscope picture of an anyon collider realized in a two-dimensional electron gas (in blue). Under a strong magnetic field, current propagates along the edge channels (red lines). Anyons are randomly emitted by partitioning the input currents I_1^0 and I_2^0 using metallic split gates (in gold) called quantum point contacts (QPC1 and QPC2). They collide on the central quantum point contact cQPC used as a beam splitter. By measuring the cross-correlations between the output current I_3 and I_4, one can measure the tendency of particles to bunch to form larger packets of charge or on the contrary to exclude each other and exit in different outputs.

The purpose of this project is to explore the fractional statistics of anyons in different fractional quantum Hall states using the geometries of colliders or interferometers. At different filling factors, different types of anyons obeying different statistics can be obtained. For example anyons in the Laughlin states (for filling factors 1/3 and 1/5) are closer to bosons whereas anyons in the Jain sequence (such as filling factor 2/5) are predicted to be closer to fermions. In addition, the role of relaxation and decoherence will be investigated to understand how they affect the peculiar properties of anyons.

[1] H. Bartolomei *et al.*, *Science* **368**, 173–177 (2020).
[2] J. Nakamura et al., *Nat. Phys.* **16**, 931–936 (2020).

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: NO