

INTERNSHIP PROPOSAL

Master 2 ICFP

Laboratory name: Centre de Physique Théorique (CPHT)
CNRS identification code: UMR 7644
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Internship location: CPHT, Ecole Polytechnique, Palaiseau

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

Poor man's Majorana bound states coupled to photons

The Kitaev chain is the canonical model for the appearance of Majorana bound states (MBS) [1]. In a two-site Kitaev chain "poor man's MBS" emerge when the parameters are fine-tuned to a sweet spot, such that the chemical potential is tuned to zero and the hopping equals the superconducting pairing [2]. In its simplest form, the coherent single particle tunneling is externally controlled by the gate voltages between dots, while the tunneling of Cooper pairs happens via virtual states in the superconductor, when electrons or holes are simultaneously created or annihilated in pairs. Hence, in realizations involving quantum dots, tuning to the sweet spot can be achieved by controlling the tunneling with gate voltages, while the pairing will typically be fixed microscopically from the superconductor properties. On the experimental side, a minimal Kitaev chain of two-sites has been realized in a platform based on quantum dots [3]. The effect of electron-electron interactions in quantum dots-based platforms is important as they can lead to the hybridization between MBS, deteriorating their quality. In our work [4], we show that coupling a two-site interacting Kitaev chain to cavity photons offers a new and largely tunable platform to control poor man's MBS.

The goal of this internship is to study how to use photon coupling to realize good quality poor man's Majorana bound states in three-sites (and longer) interacting Kitaev chains. This project relies on state-of-the-art analytical and numerical techniques of quantum many-body physics to solve the electron-photon Hamiltonian.

After successful completion of the internship there is a possibility to go on with a PhD and work on the ERC Project "Q-Light-Topo".

[1] A. Y. Kitaev, Unpaired Majorana fermions in quantum wires, *Physics-Uspekhi* 44, 131 (2001).

[2] M. Leijnse and K. Flensberg, Parity qubits and poor man's Majorana bound states in double quantum dots, *Phys. Rev. B* 86, 134528 (2012).

[3] T. Dvir et al., Realization of a minimal Kitaev chain in coupled quantum dots, *Nature* 614, 445 (2023).

[4] Á. Gómez-León, M. Schiró, and O. Dmytruk, High-quality poor man's Majorana bound states from cavity embedding, *arXiv preprint arXiv:2407.12088* (2024).

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: YES