Local and nonlocal transport signatures of spin polarization in first- and second-order topological superconductors

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Spin-dependent transport offers a powerful tool for probing topological phases in hybrid semiconductor-superconductor structures. In this presentation, we theoretically explore the spin and quantum transport signatures of both 1D first-order and 2D second-order topological superconductors using spin-polarized probes.

In the 1D regime, we focus on proximitized Rashba nanowires [1]. We establish an exact correspondence between the sign of nonlocal conductance and the sign of the quasiparticle spin density. We demonstrate that this effect can be used to effectively detect the spin inversion associated with the topological phase transition [2] and allows for controlled switching between cross Andreev reflection (CAR) and elastic cotunneling (ECT) processes.

Considering 2D second-order topological superconductors, we show numerically that in certain systems Majorana corner states (MCS) exhibit characteristic electronic spin textures that enable an unambiguous labeling of individual MCS within each pair [3]. We introduce a detection scheme in which local and nonlocal conductance features are directly tied to the electronic spin density of the zero-energy MCS and of higher-energy spin-polarized edge modes. Moreover, we show that these characteristics can be exploited to confirm the spatial exchange of MCS, an essential operation for topological quantum computation.

Finally, we show that in both systems these transport signatures remain stable under moderate static disorder, thereby providing a clear pathway for experimental verification.

Acknowledgments *We gratefully acknowledge Polish high-performance computing infrastructure PLGrid (HPC Center: ACK Cyfronet AGH) for providing computer facilities and support within computational grant no. PLG/2025/018062*

References

[1] P. Szumniak, D. Loss, and J. Klinovaja, Phys. Rev. B 110, 115413 (2024).

[2] P. Szumniak, D. Chevallier, D. Loss, and J. Klinovaja, Phys. Rev. B 96, 041401(R) (2017).

[3] P. Szumniak, D. Loss, and J. Klinovaja, arXiv:2606.26992 (2026).