Enhancement of topological phase in long Josephson junctions

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Planar Josephson junctions are considered promising tools for creating Majorana bound states (MBS) due to the ability to control the topological transition by adjusting the superconducting phase difference [1]. The topological transition can arise even under weak magnetic fields; nevertheless, the region of the phase range where topological superconductivity occurs is small. Furthermore, this area cannot be directly observed when the superconducting phase difference is implied by an external magnetic flux [2]. In this study, we theoretically show that elongation of the junction leads to the amplification of the Zeeman effect, which in turn leads to the extension of the topological phase region. We demonstrate however that in long junctions the presence of transverse modes with effective momenta aligned parallel to the superconducting interfaces causes the reduction of the induced superconducting gap which can lead to the collapse of Majorana bound states [3]. To overcome this limitation, we introduce additional superconducting contacts that further proximitize the semiconductor region and reopen the superconducting gap. We demonstrate that in this suggested system, it is feasible to explore the topological transition by performing critical current measurements.

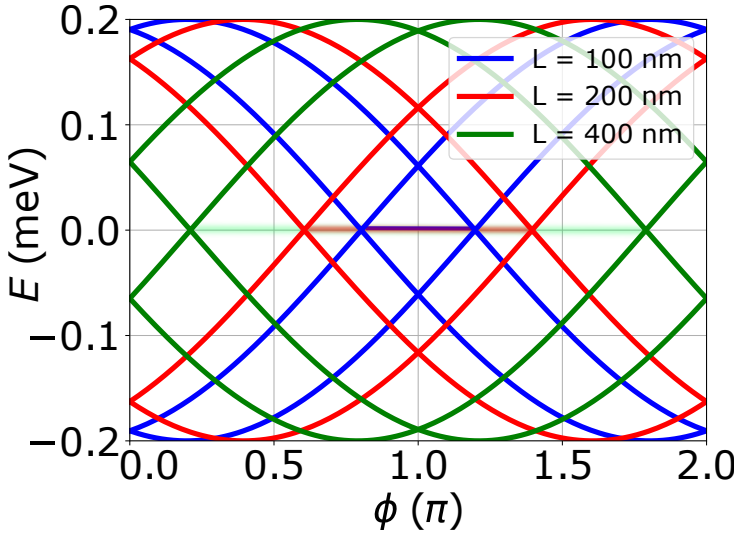

Figure 1: Schematic of an ABS structure. Three blurry lines at zero energy with blue, red, green denote the region where Majorana bound states appear for the junction length L = 100, 200, 400 nm respectively.

[1] F. Pientka, A. Keselman, E. Berg, A. Yacoby, A. Stern, and B. I. Halperin *Phys. Rev. X.* **7**, 021032 (2017).

[2] M. Hell, M. Leijnse, and K. Flensberg, *Phys. Rev. Lett.* **118**, 107701 (2017).

[3] C. M. Moehle, P. K. Rout, N. A. Jainandunsing, D. Kuiri, C. Ting Ke, D. Xiao, C. Thomas, M. J. Manfra, M. P. Nowak, S. Goswami, *Nano Lett.* **22**, 8601 (2022).