# Poor’s man Majorana with superconducting phase control

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Majorana modes, topologically protected edge states arising in 1D systems, demonstrate non-abelian anyonic properties, rendering them promising candidates as fundamental components for fault-tolerant quantum computers [1]. Despite extensive efforts spanning two decades to generate and manipulate these states in nanowires, their definitive existence remains elusive [2]. Recent proposals have shifted focus towards engineering chains of quantum dots (QDs) to emulate the Kitaev chain [3, 4]. While it is feasible to achieve a rudimentary version of Majorana modes with only two QDs, called Poor’s Majorana modes (PMMs), they often exhibit a limited topological minigap for fined tunned parameters. This is primarily due to the substantial magnetic fields required, which is significantly detrimental for such short chains.

We present a novel approach to engineer a magnetic field-free Kitaev chain utilizing superconducting phase differences. Our strategy involves coupling each QD to three superconductors, see Fig. 1. By tuning the coupling between the two QDs and three (out of six) superconducting phases, we find PMMs without the need for magnetic fields. Through analytical calculations of a minimal model and numerical simulations of a more realistic description, we demonstrate the robustness of our approach, yielding PMMs across a broad parameter range. Notably, these modes exhibit measurable topological minigaps unaffected by magnetic field-induced smearing. Furthermore, our scheme facilitates the emergence of PMM in the strong coupling regime with the superconductors, thereby mitigating certain sources of noise.

## References

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## Figures

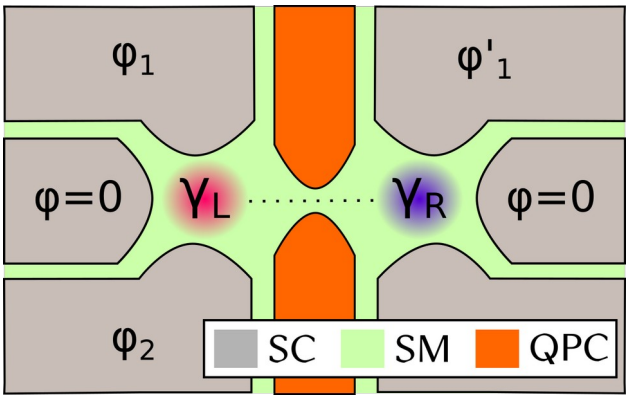


**Figure 1:** Sketch of the system analyzed in our work: a double quantum dot (QD) electrostatically defined in a semiconductor (SM), represented in red/blue colors. Each QD is coupled to three different superconductors (SCs). By tunning the coupling between the QDs (with the gates in orange) and controlling three out of six superconducting phases, one can obtain Poor’s Majorana modes (PMM) on each QD, the so-called left $\gamma_L$ and right $\gamma_R$ Majoranas.