Majorana Box Qubits & Code Networks

Plugge, Rasmussen, Egger & Flensberg, NJP **19** 012001 (2017)

Karzig, Knapp, Lutchyn, Bonderson, Hastings, Nayak, Alicea, Flensberg, Plugge, Oreg, Marcus & Freedman, arXiv:1610.05289

Plugge, Landau, Sela, Altland, Flensberg & Egger, PRB **94**, 174514 (2016)

Landau, Plugge, Sela, Altland, Albrecht & Egger, PRL **116**, 050501 (2016)

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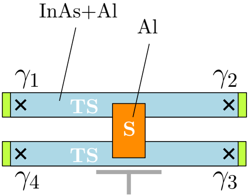
Capri Spring School, April 24th 2017

Topological Qubit on Majorana Island

- Two parallel, floating TS wires coupled by trivial SC
  → Box with 4 MZMs + charging energy



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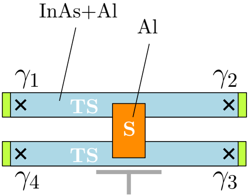

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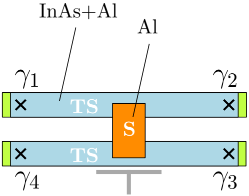

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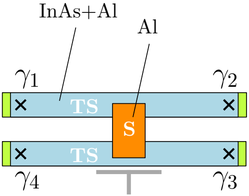

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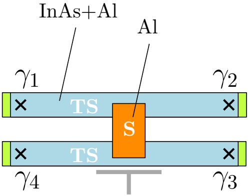

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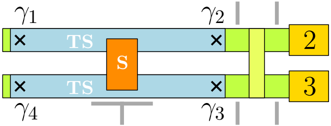

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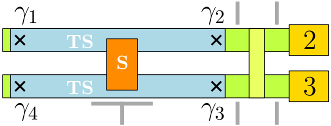

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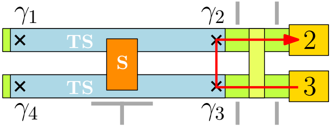

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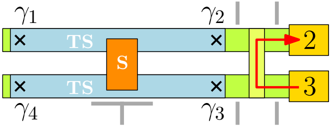

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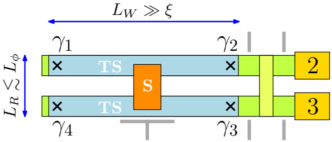

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- Dimensions of box: squeezed 'H': $L_W \gg \xi$, but $L_R \lesssim L_\phi$

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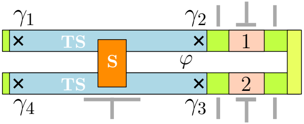

Frey et al., PRL (2012)/Liu et al., PRL (2014), Reilly et al., APL (2007), Colless et al., PRL (2013)
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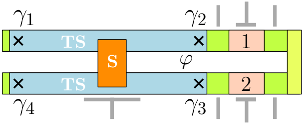

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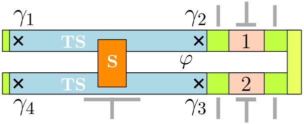

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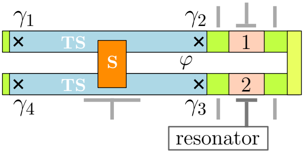

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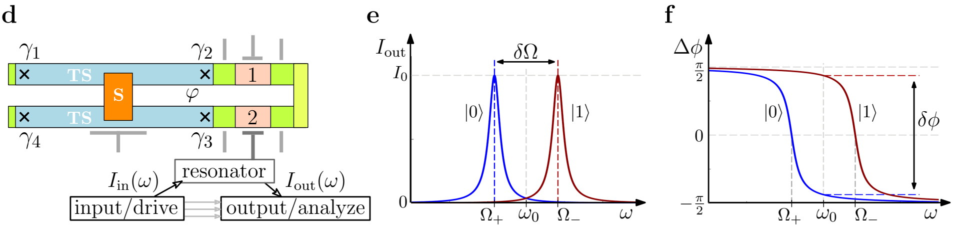

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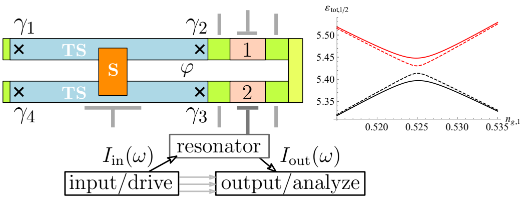

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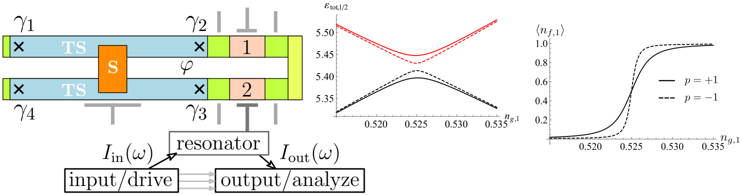

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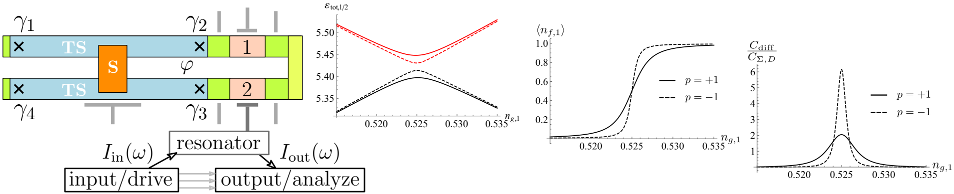

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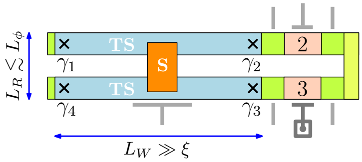

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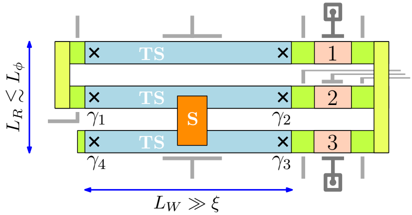

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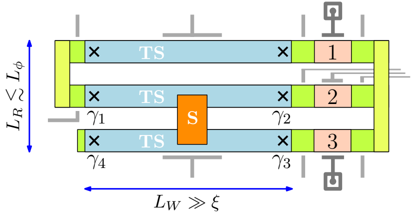

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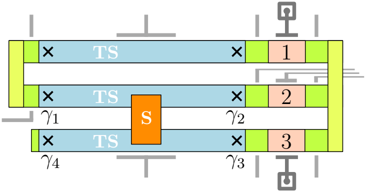

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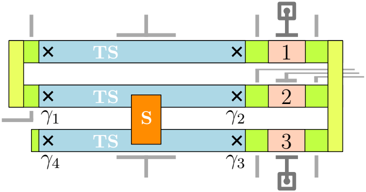

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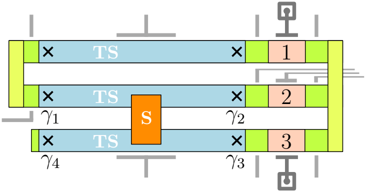

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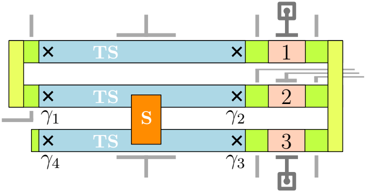
    fine-tune: $\mathrm{Re}(t_0^* t_1) = 0 \rightarrow$ no dynamical phase on MBQ
    $\rightarrow$ geometric phase $\theta = \mathrm{Im}(t_1/t_0) \rightarrow$ gate $\hat{P}_z(\theta) = e^{i\theta\hat{z}}$



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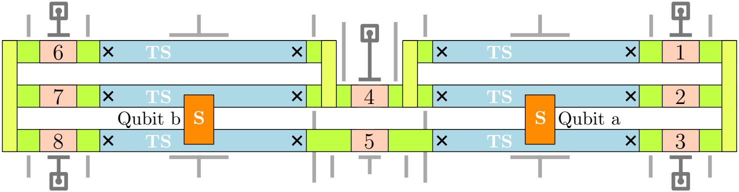
Joint-Parity Readout of MBQs

- QDs 4 & 5 , coupled via MBQs a & b → ring exchange
  detuning $\sim \varepsilon$, tunneling $\sim (t_a \hat{z}_a + t_b \hat{z}_b)$



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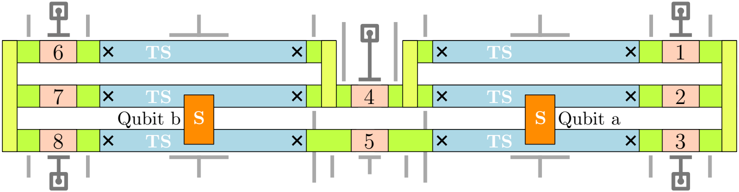

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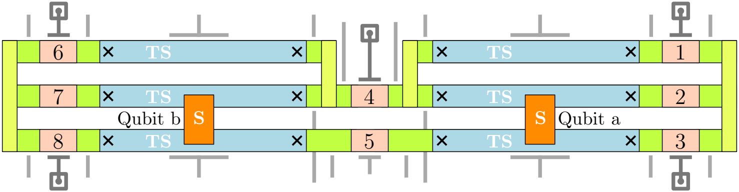
- QD choice identifies participating MBQs & Pauli ops.



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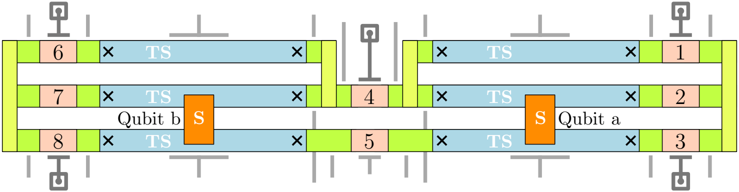
$\rightarrow$ Resilient decoherence-free subspaces $z_a z_b = +(-)$



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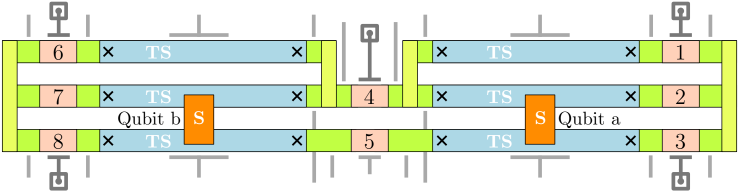
- Simple Bell test experiments to verify MBQ operation
  Prepare $x_{a,b} = \pm$, Measure $z_a z_b = \pm$, Check z_a/x_a, z_b/x_b



Two-Qubit QC & Measurement-based Cliffords

- 2×2 array of MBQs: 2 data qubits, 2 ancilla* qubits
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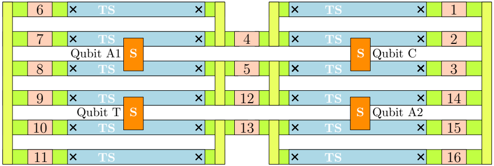

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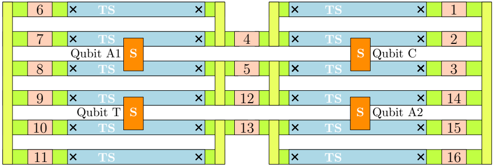

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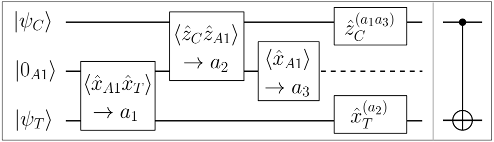
a



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Flip T iff C in $|1\rangle_C$

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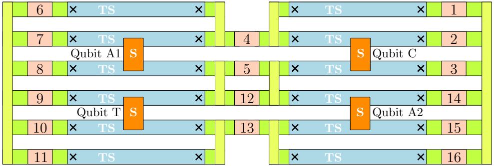

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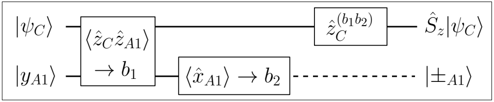

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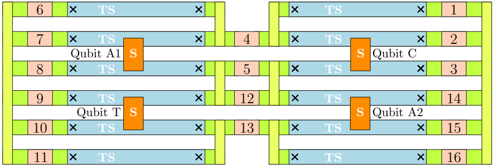

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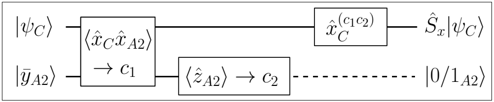

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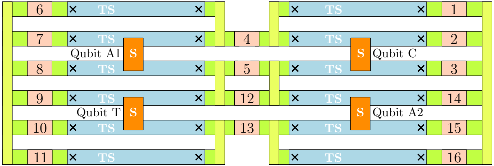

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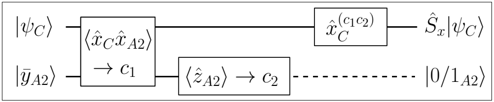

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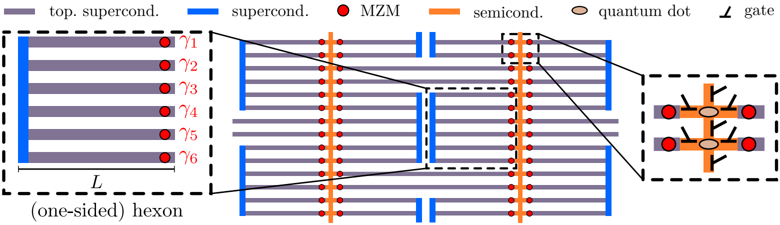
Extensions: Larger Islands & Networks

- Qubits: 4-MF or 6-MF islands, two-sided or comb/linear



Bonderson, Freedman, Nayak, PRL (2008) [arXiv:1610.05289, Plugge et al., PRB (2016)]

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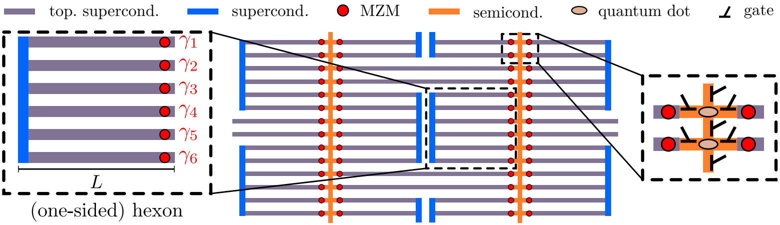

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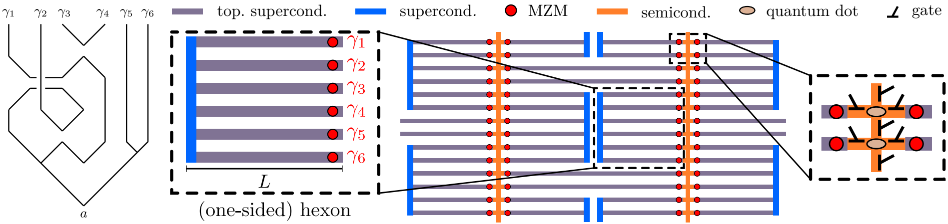

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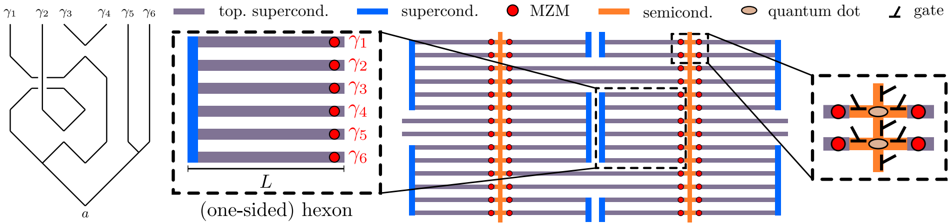

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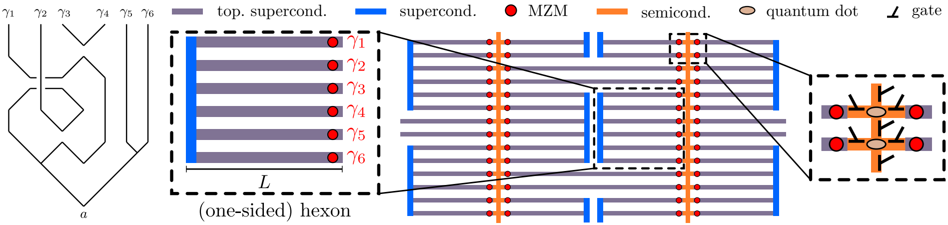

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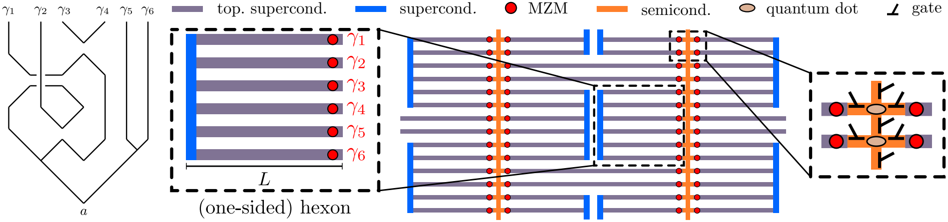
⇒ Choice: "Clifford-complete" network + code software [Vijay&Fu, Hastings]

or: hardware/network tailored towards specific code [DL talk]



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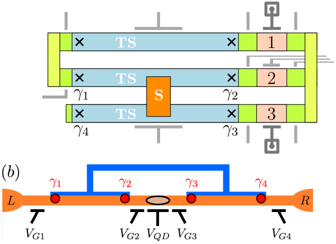

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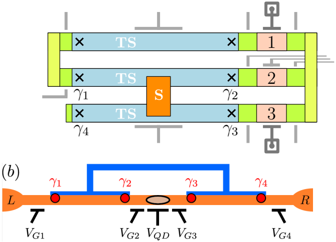

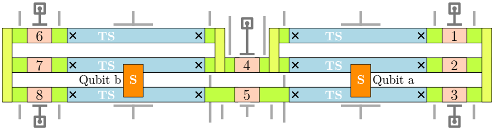

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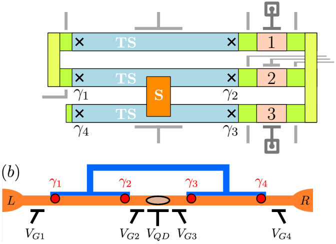

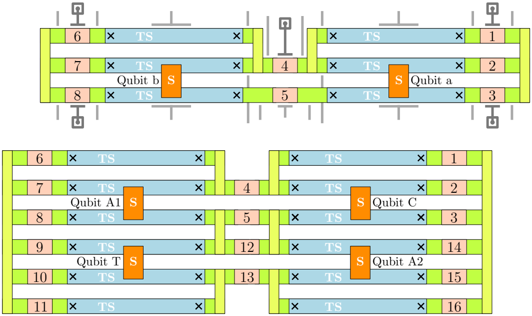

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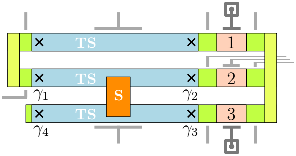

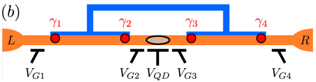

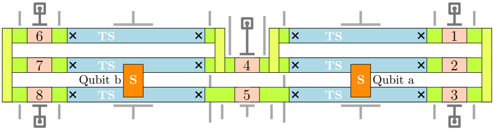

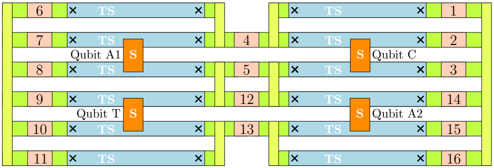

Thank you for your attention!