Absence of quasi-Majorana false positives in full-shell hybrid nanowires

Carlos Payá

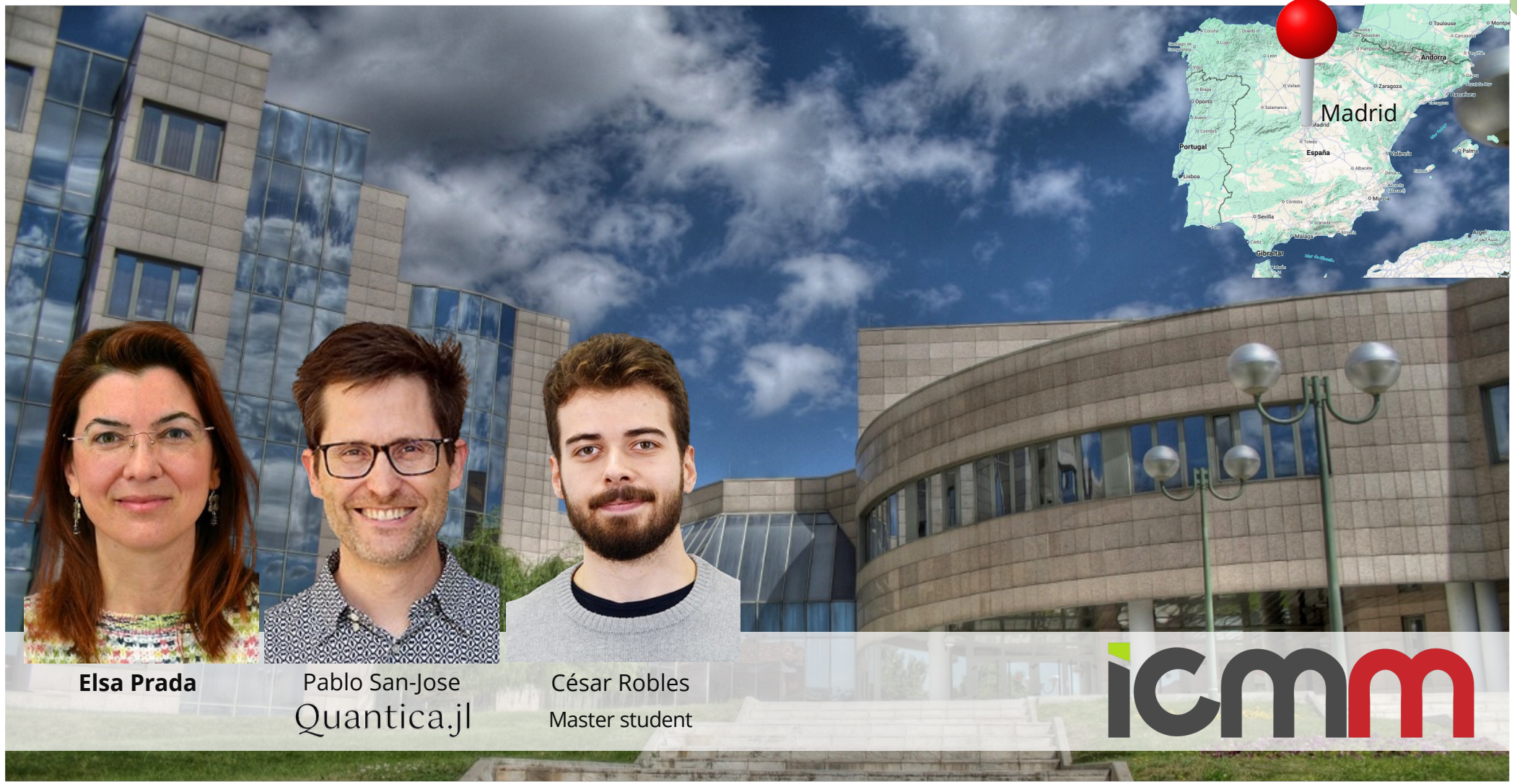
QTYR 2026 - Valencia, 26 June 2026

CSIC

QUDYMA

icmm

The team


Madrid
Portugal
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Toulouse
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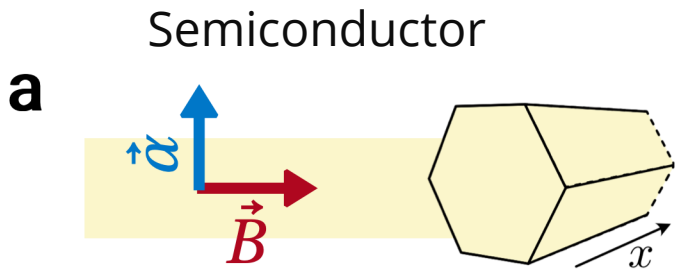
Lisboa
Sevilla
Gibraltar
Elsa Prada
Pablo San-Jose
Quantica.jl
César Robles
Master student
icmm

Majoranas 101 – Helical bands



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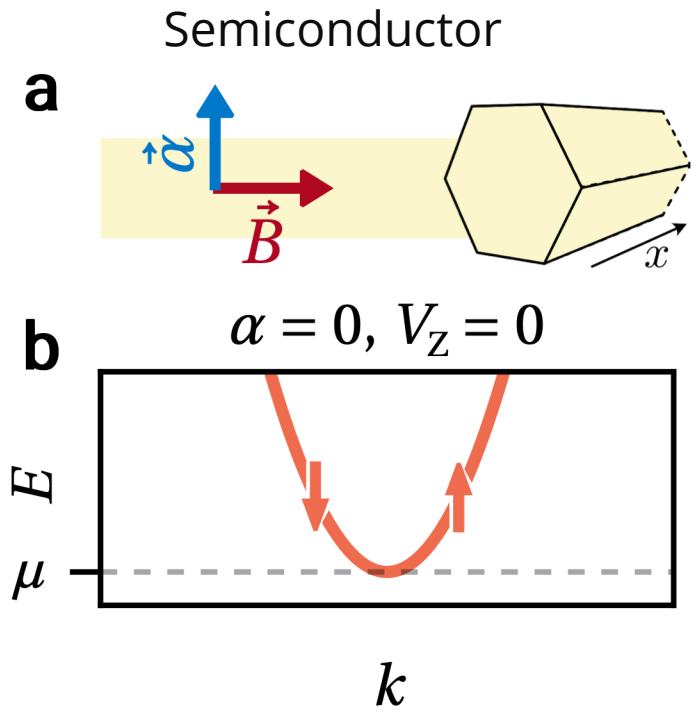

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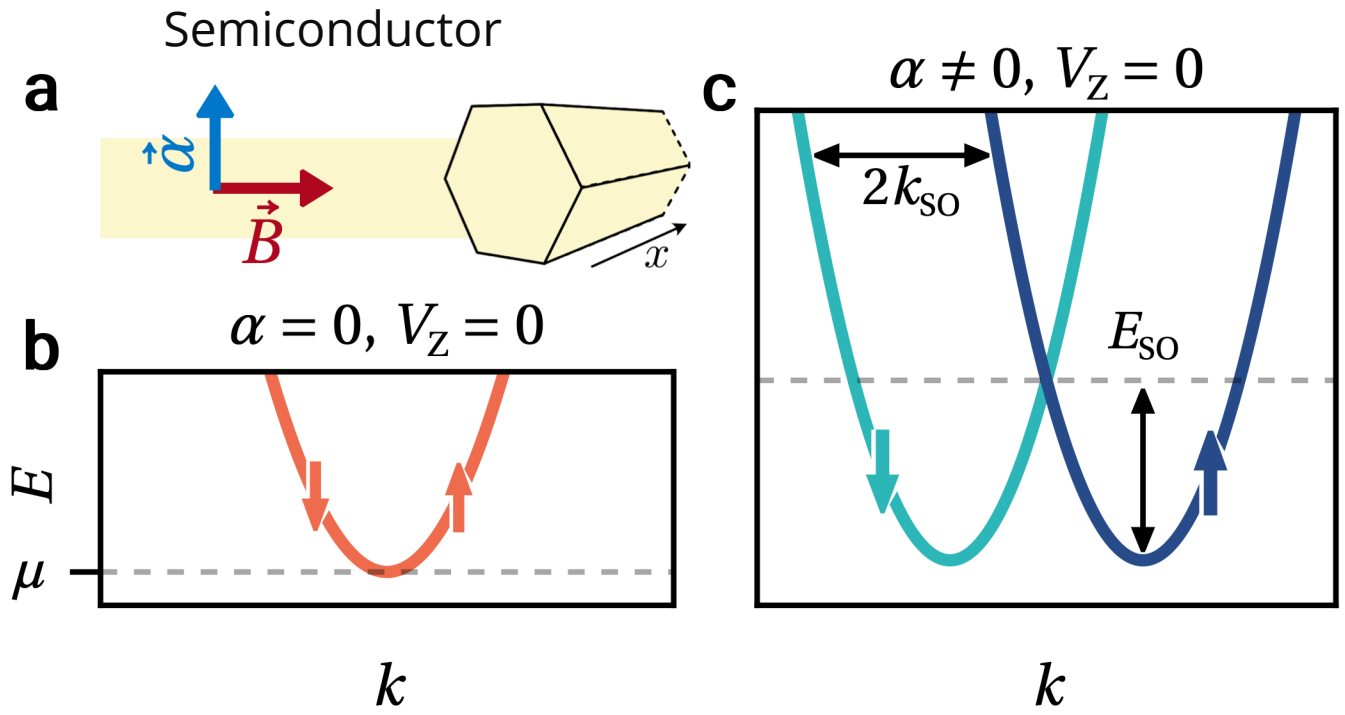

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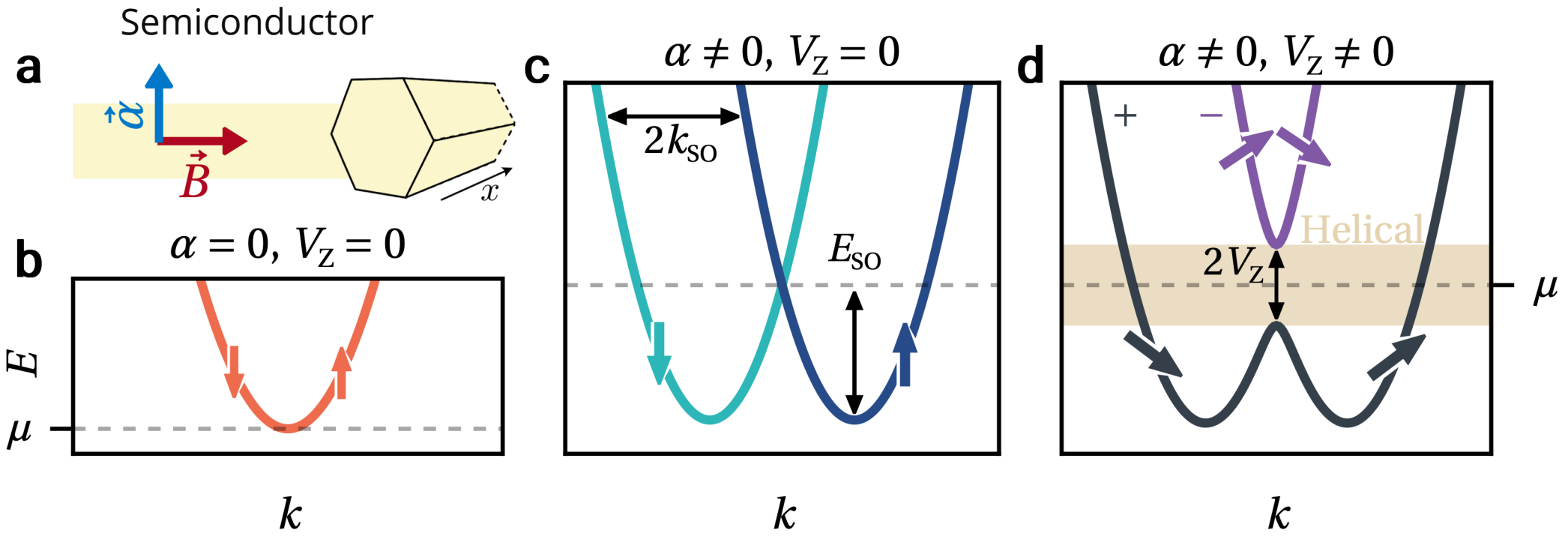
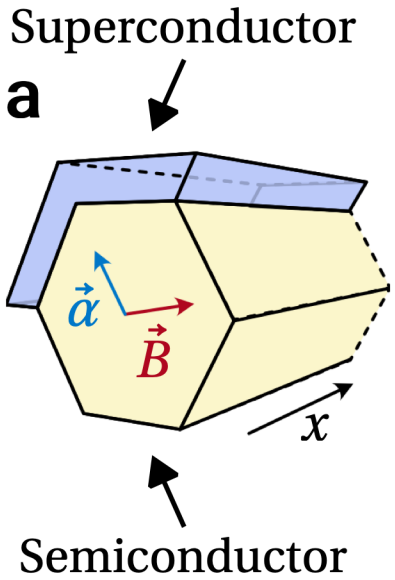


Majoranas 101 – p-wave superconductor



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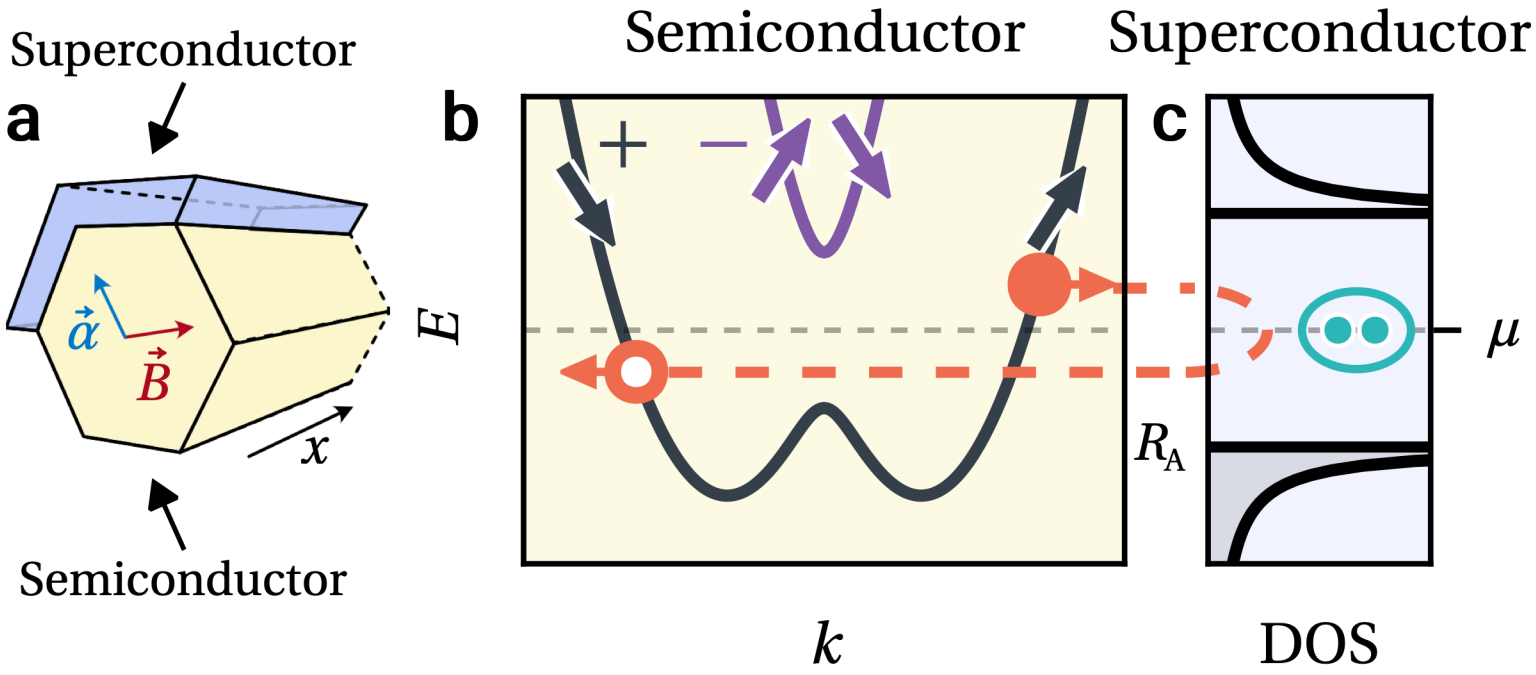
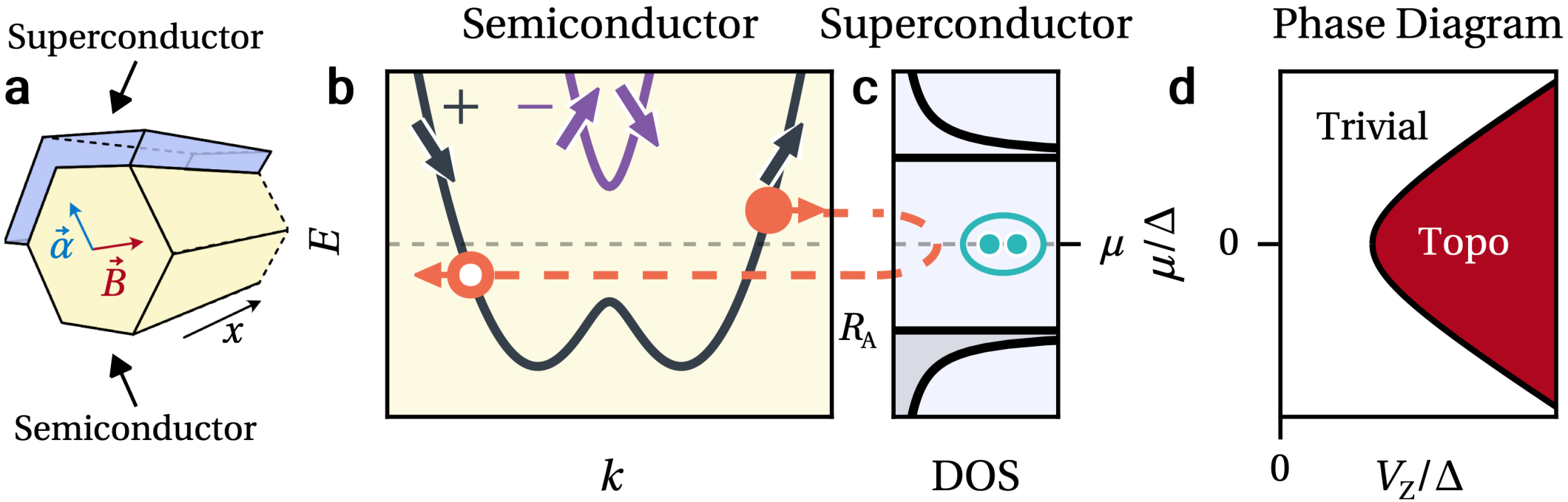
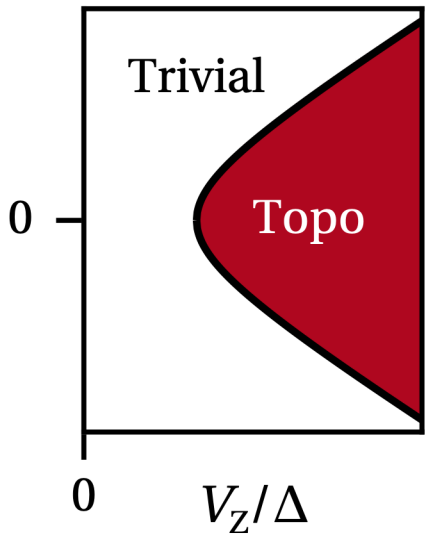
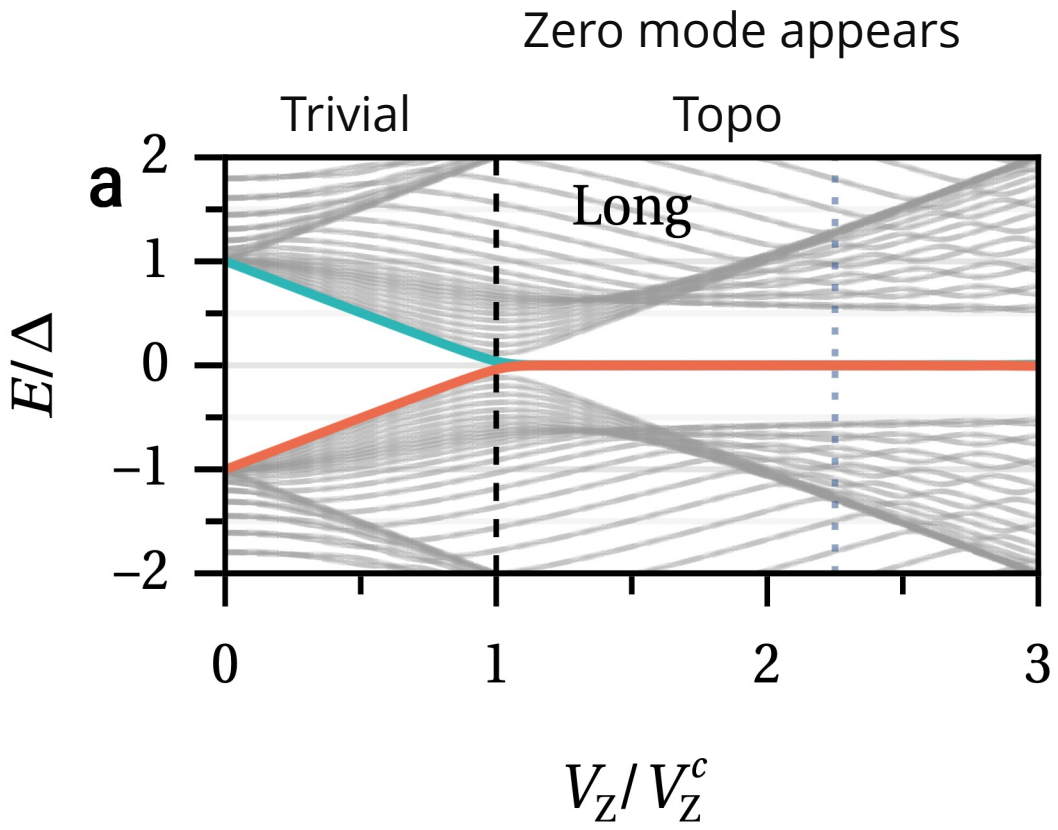


Majoranas 101 – p-wave superconductor



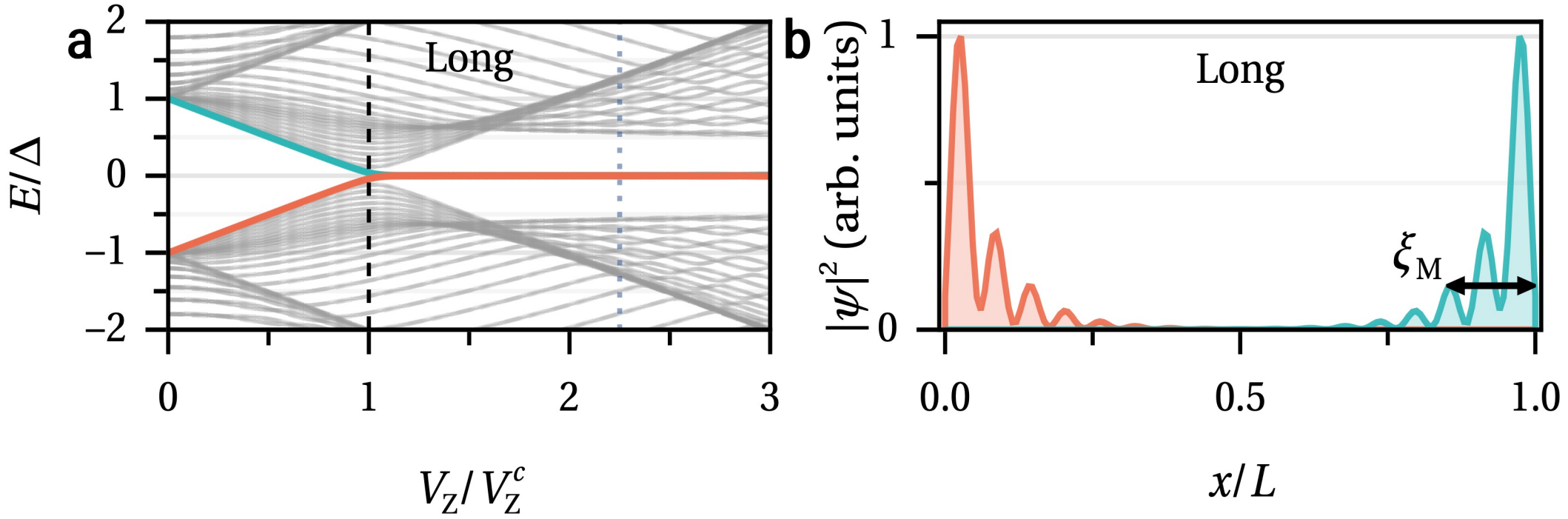
Majoranas 101 – The bulk-boundary correspondence





Majoranas 101 – Edge states

Zero mode is localized at
the ends of the wire



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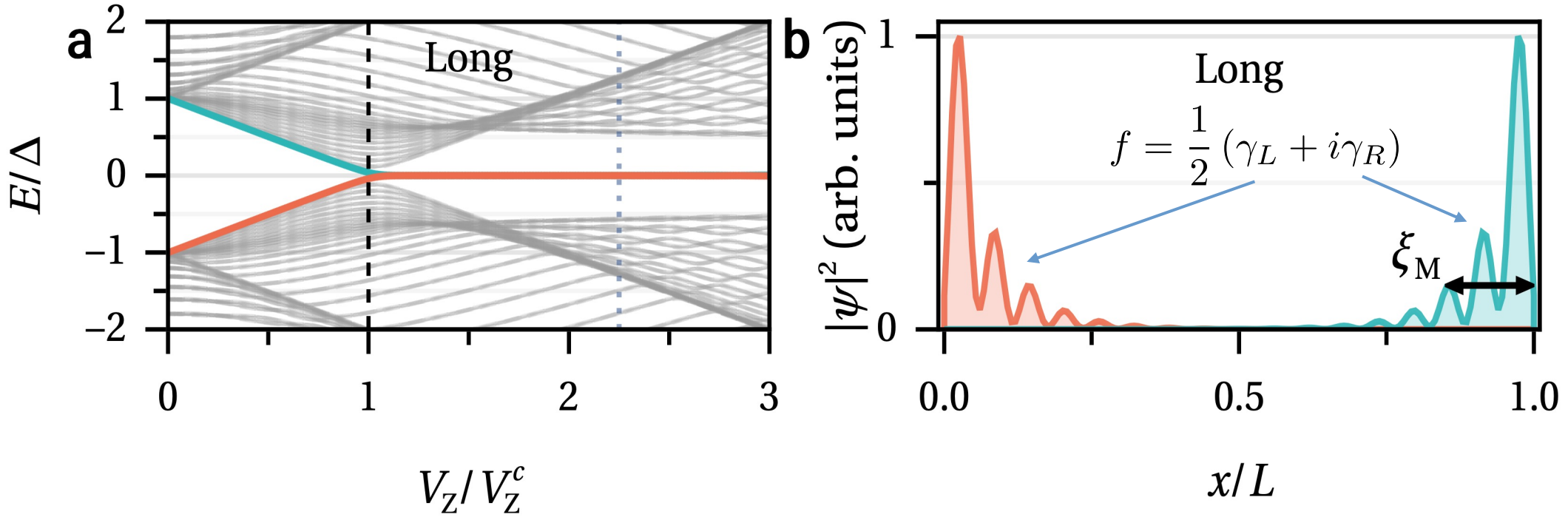
Zero mode is localized at the ends of the wire



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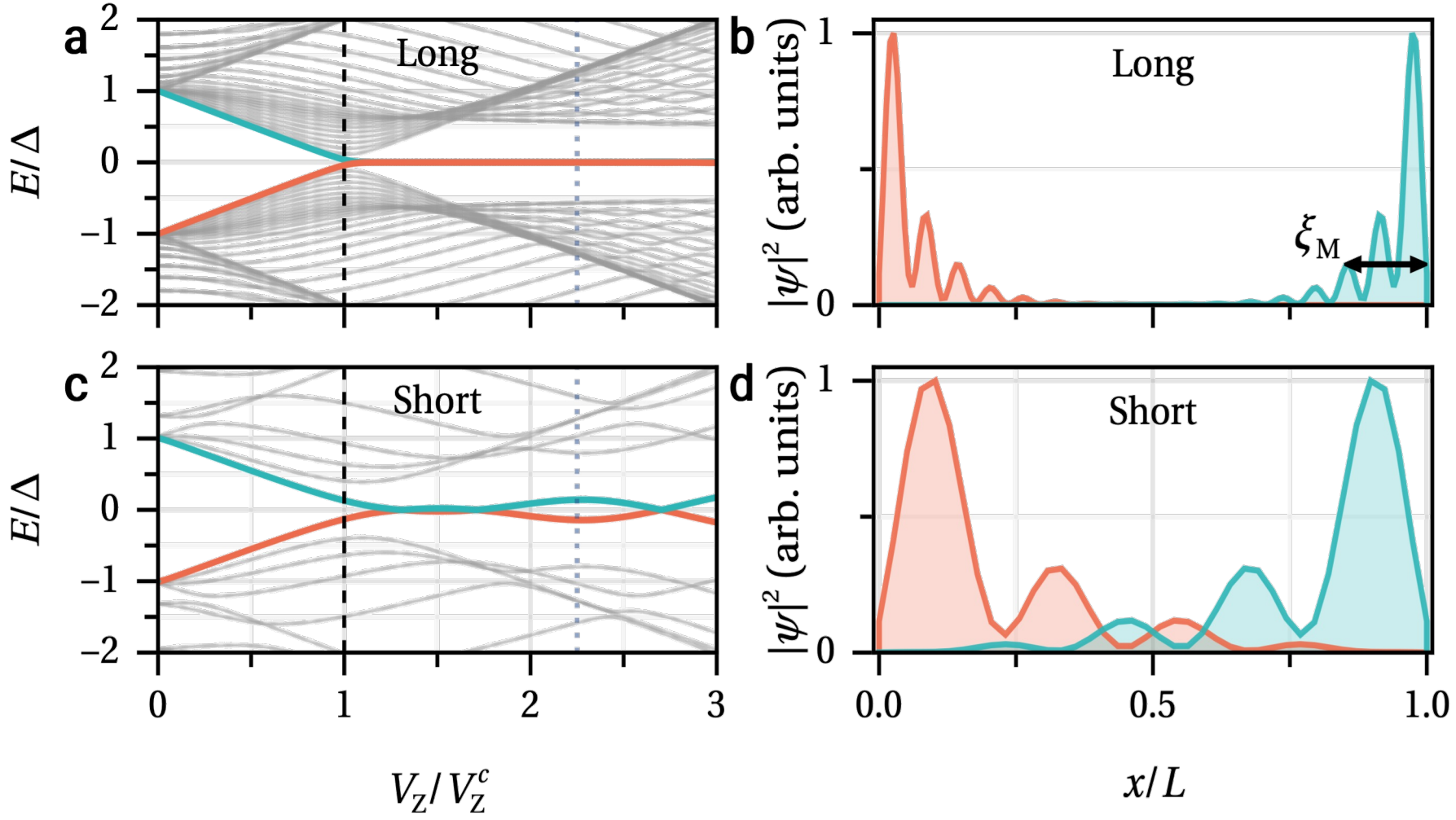
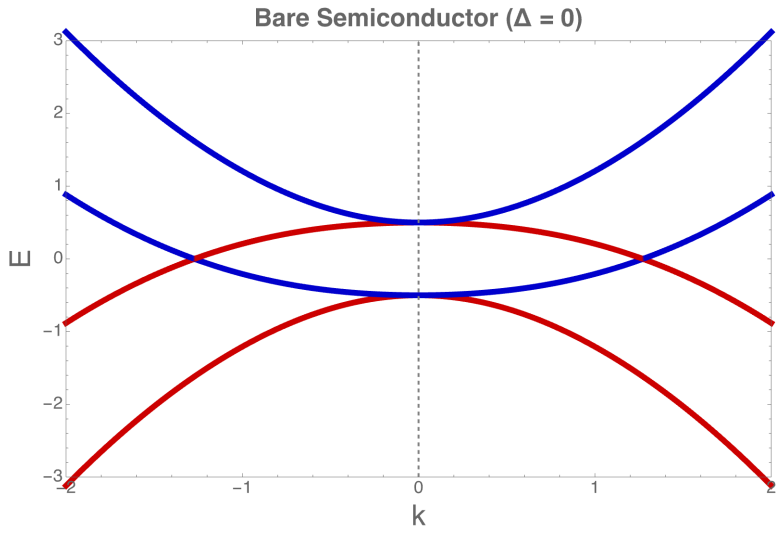
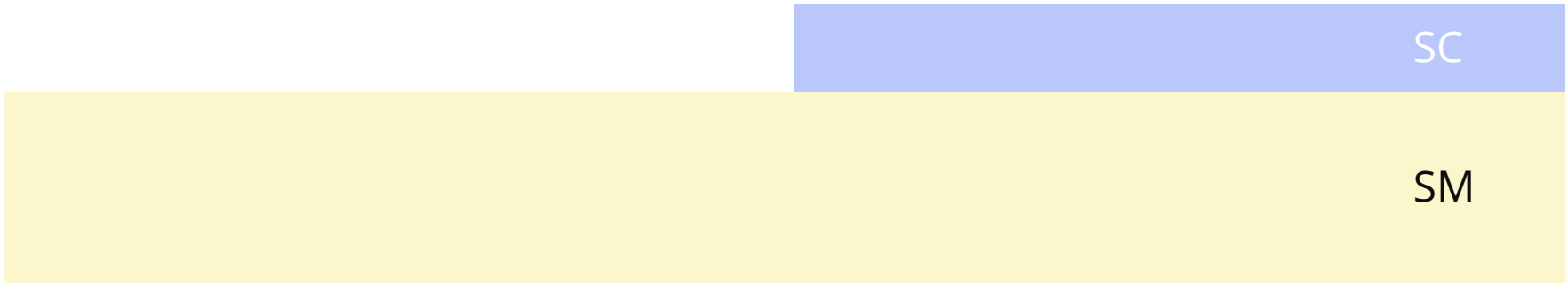


Majoranas 101 – Topological boundary





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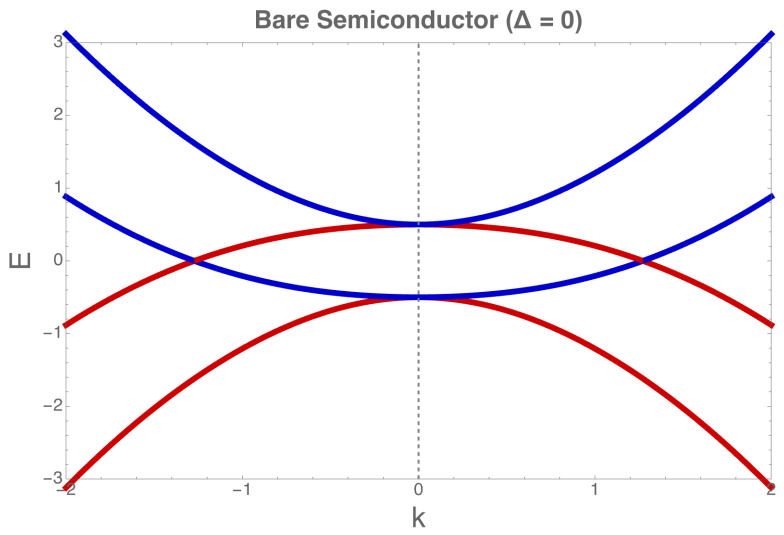
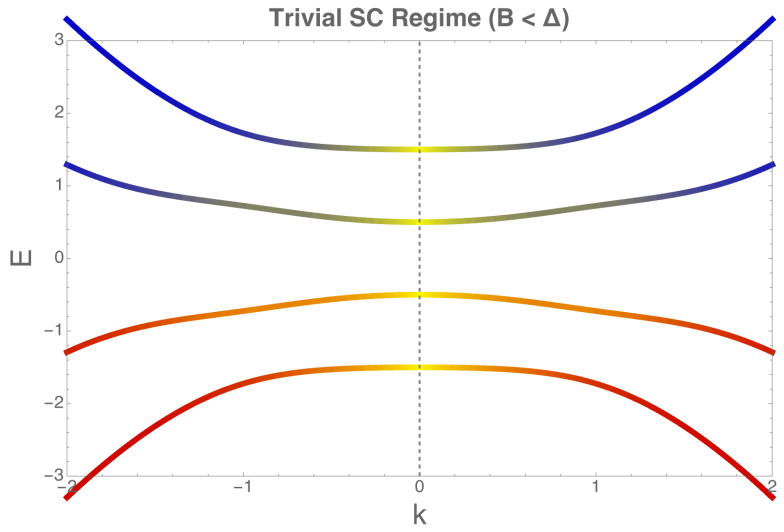
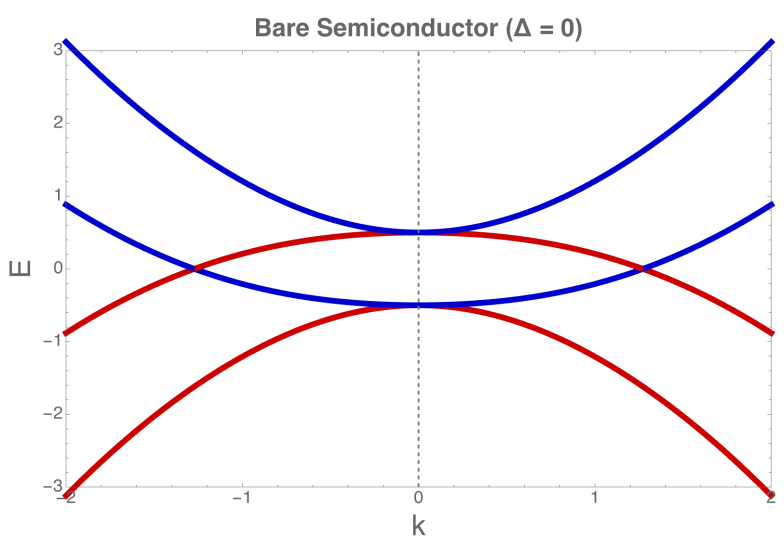


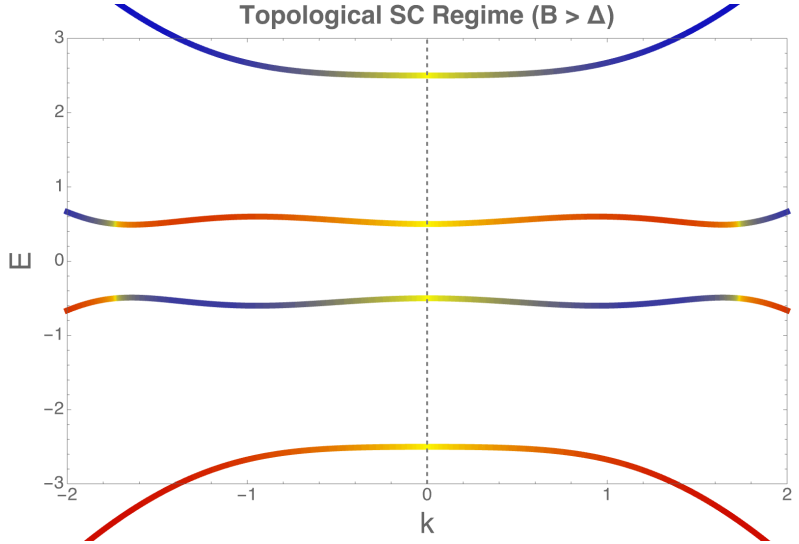


SC

SM

Majoranas 101 – Topological boundary





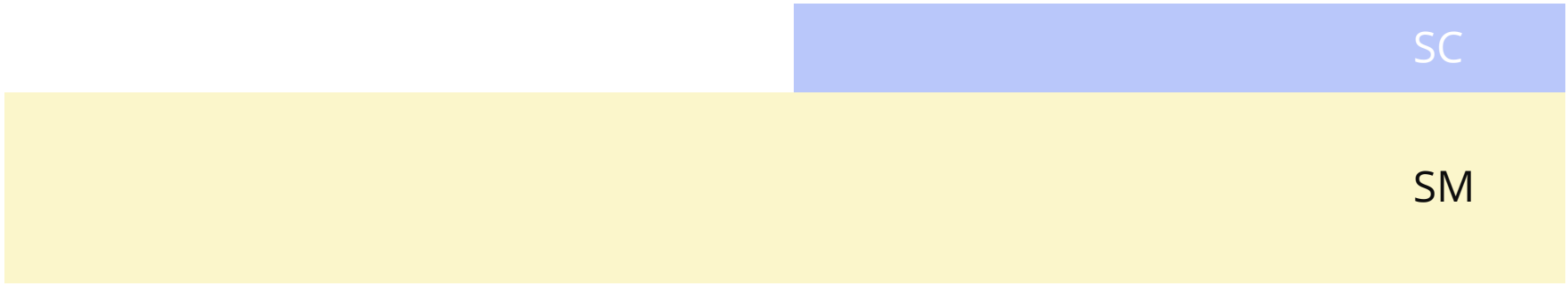
SC

SM

Majoranas 101 – Topological boundary

Band Inversion

$m > 0$ $m < 0$



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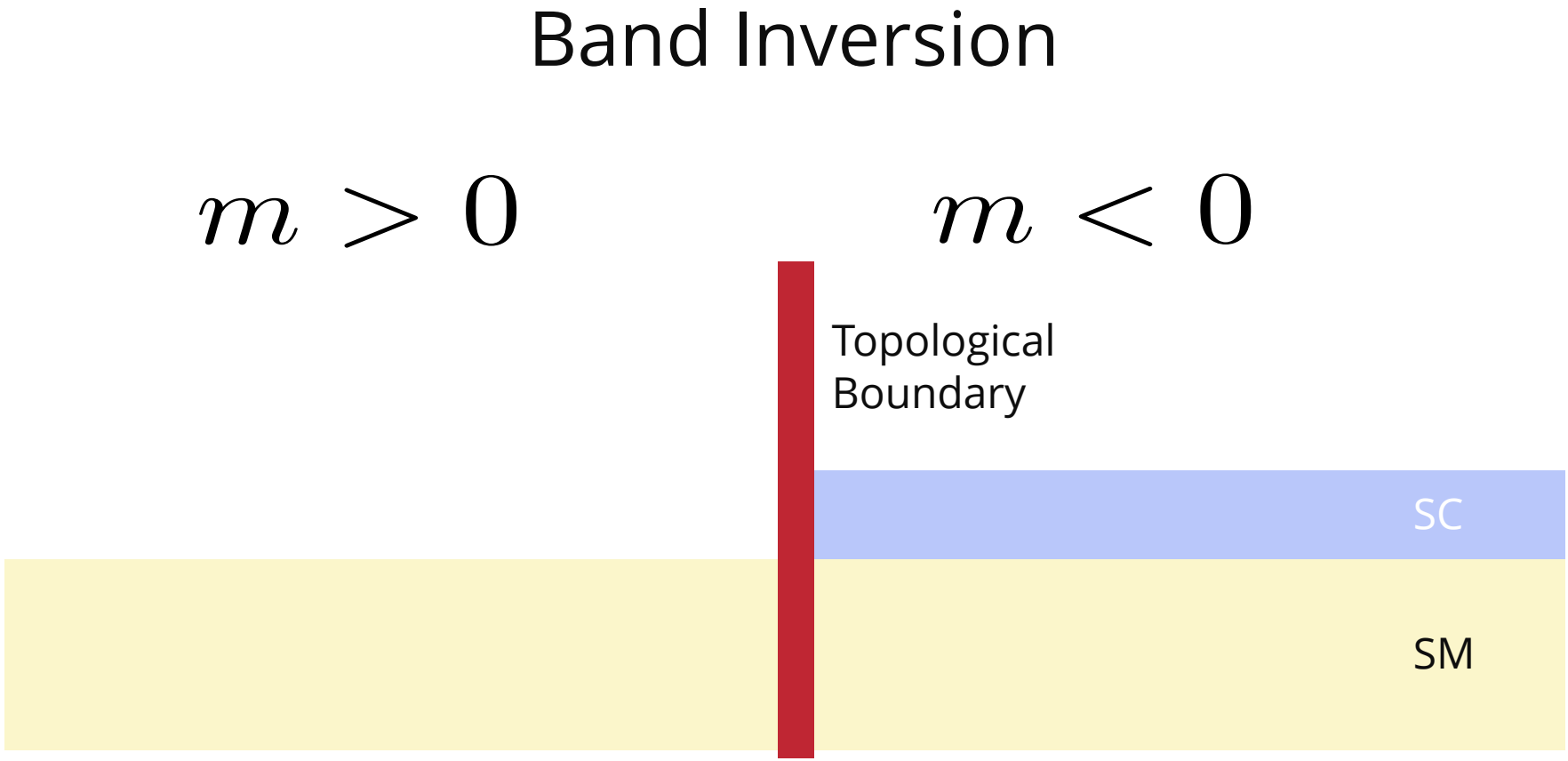

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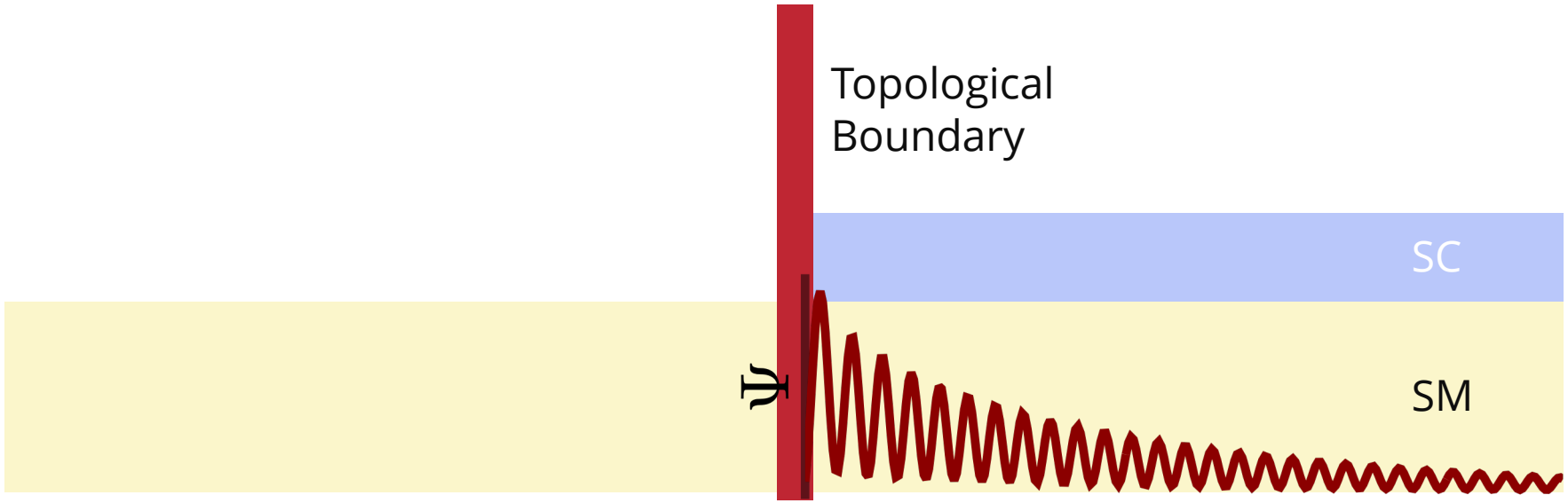
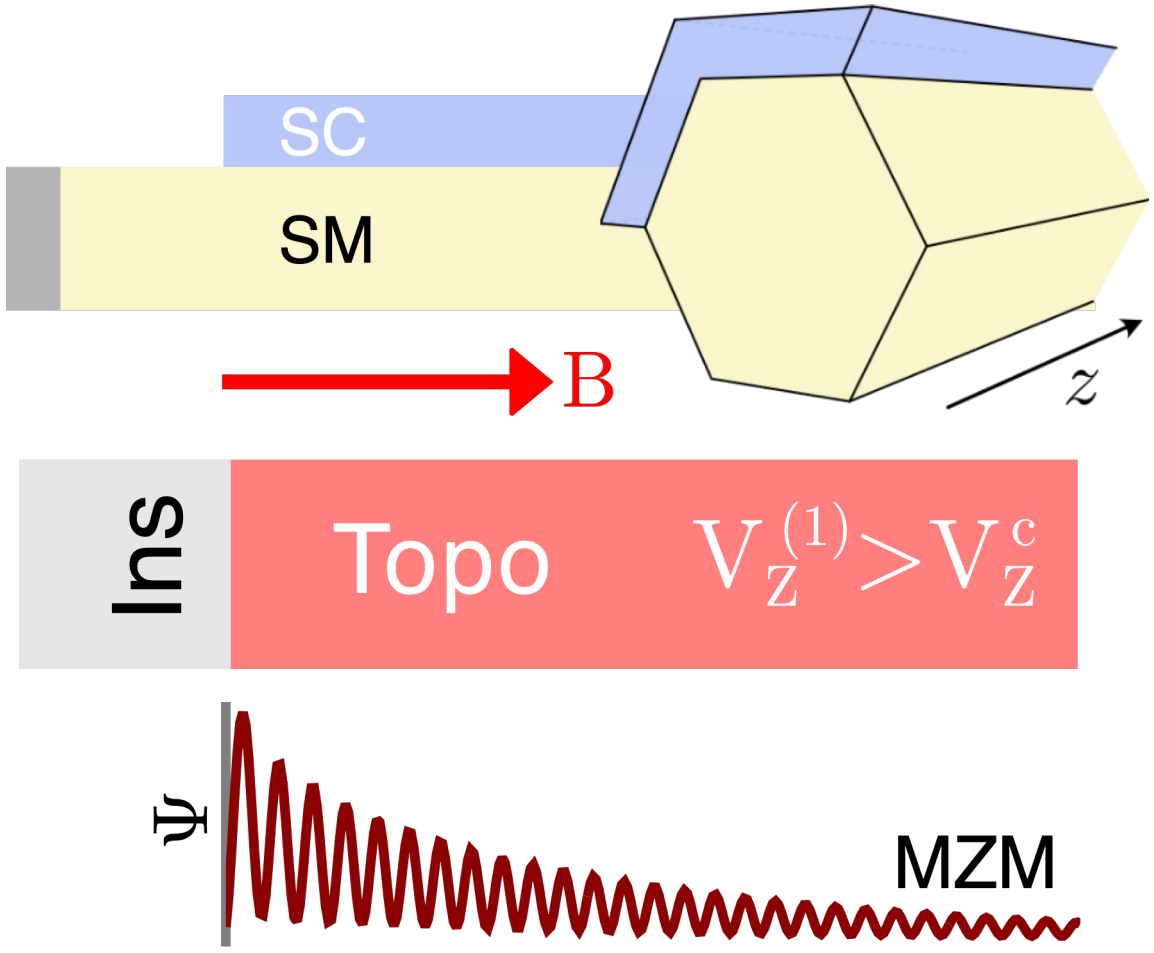
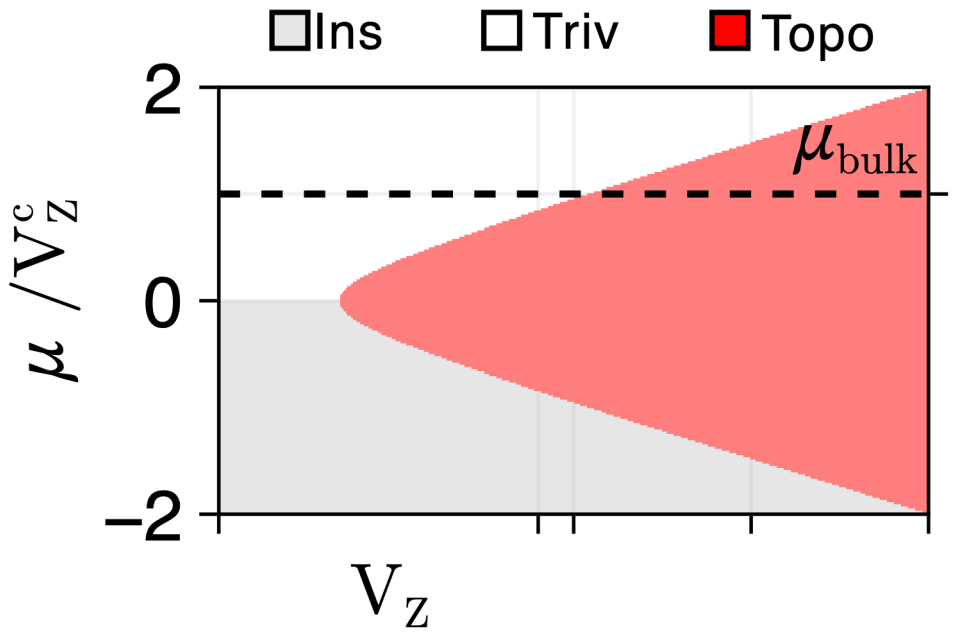


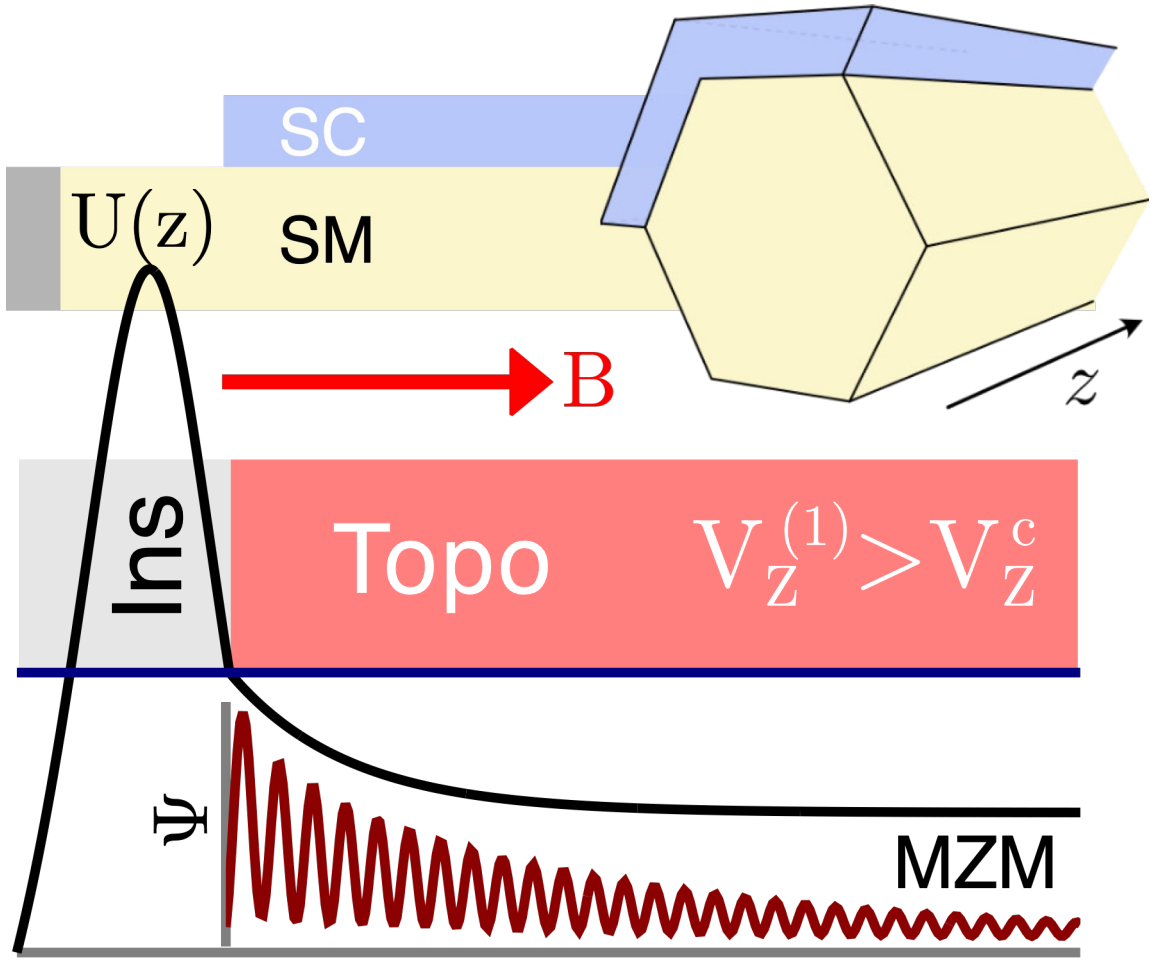
The Majorana nanowire

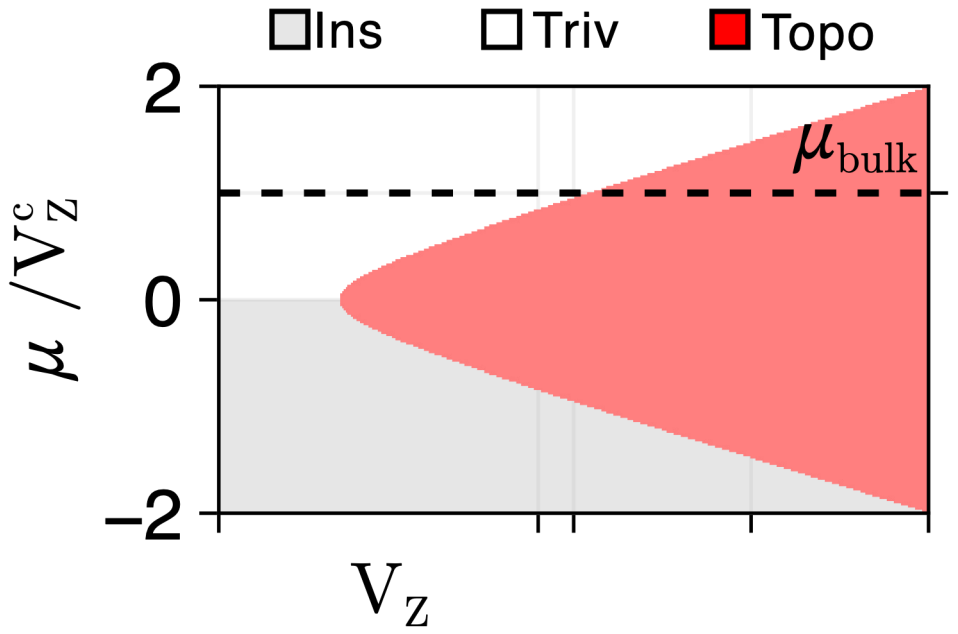




CP *et al.* arXiv:2604.24858 (2026)
PRB 86, 180503 (2012) | PRB 86, 100503 (2012) | SciPost Phys. 7, 061 (2019)

The Majorana nanowire





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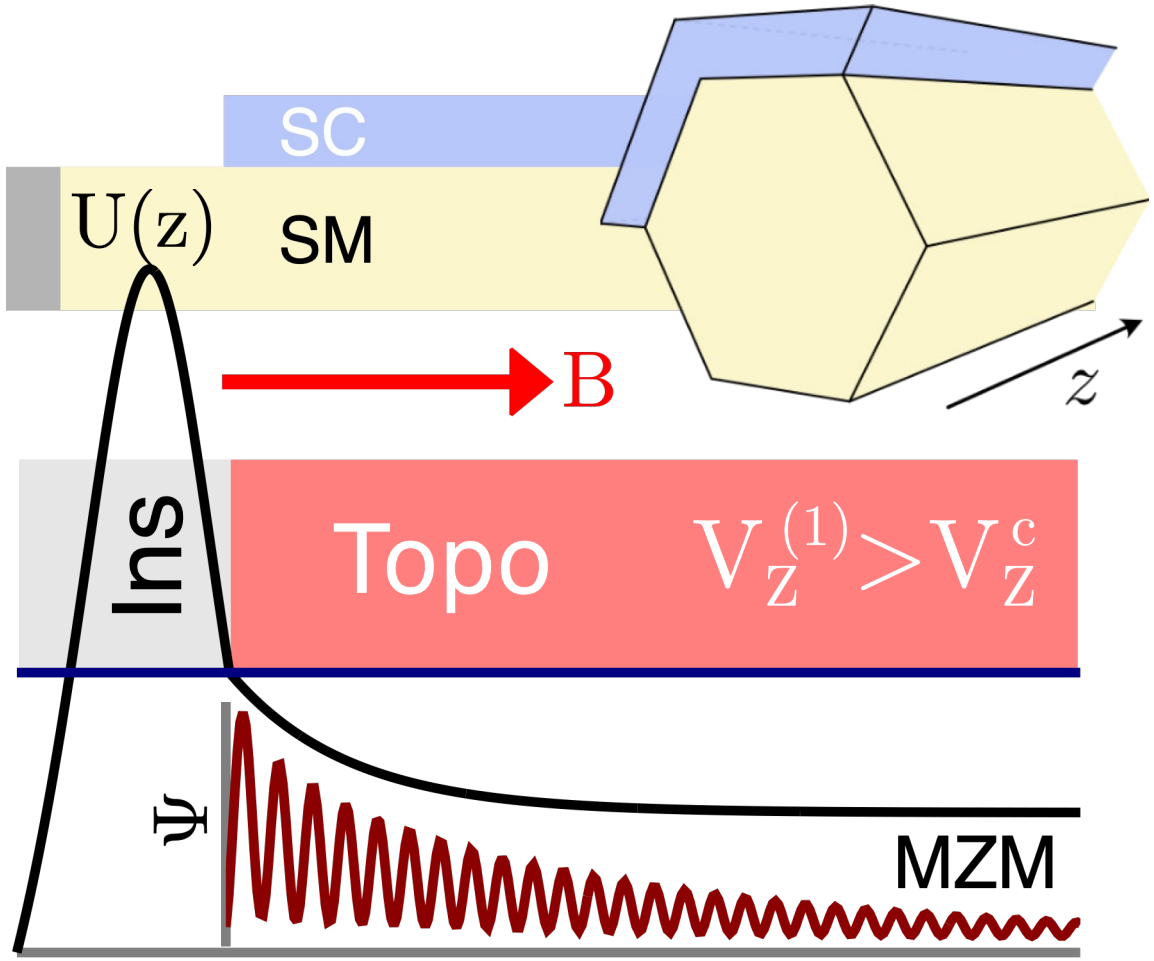

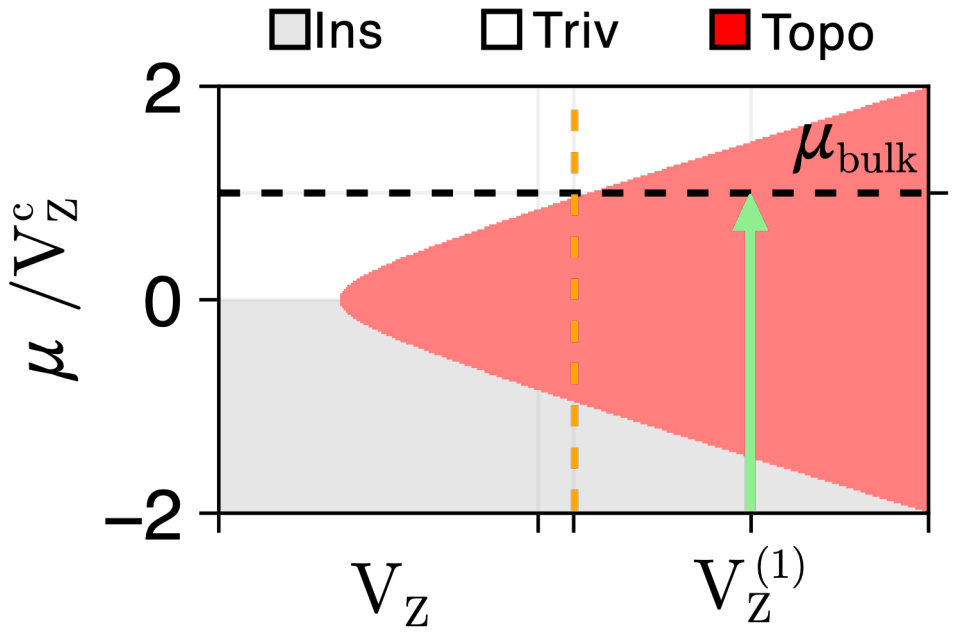

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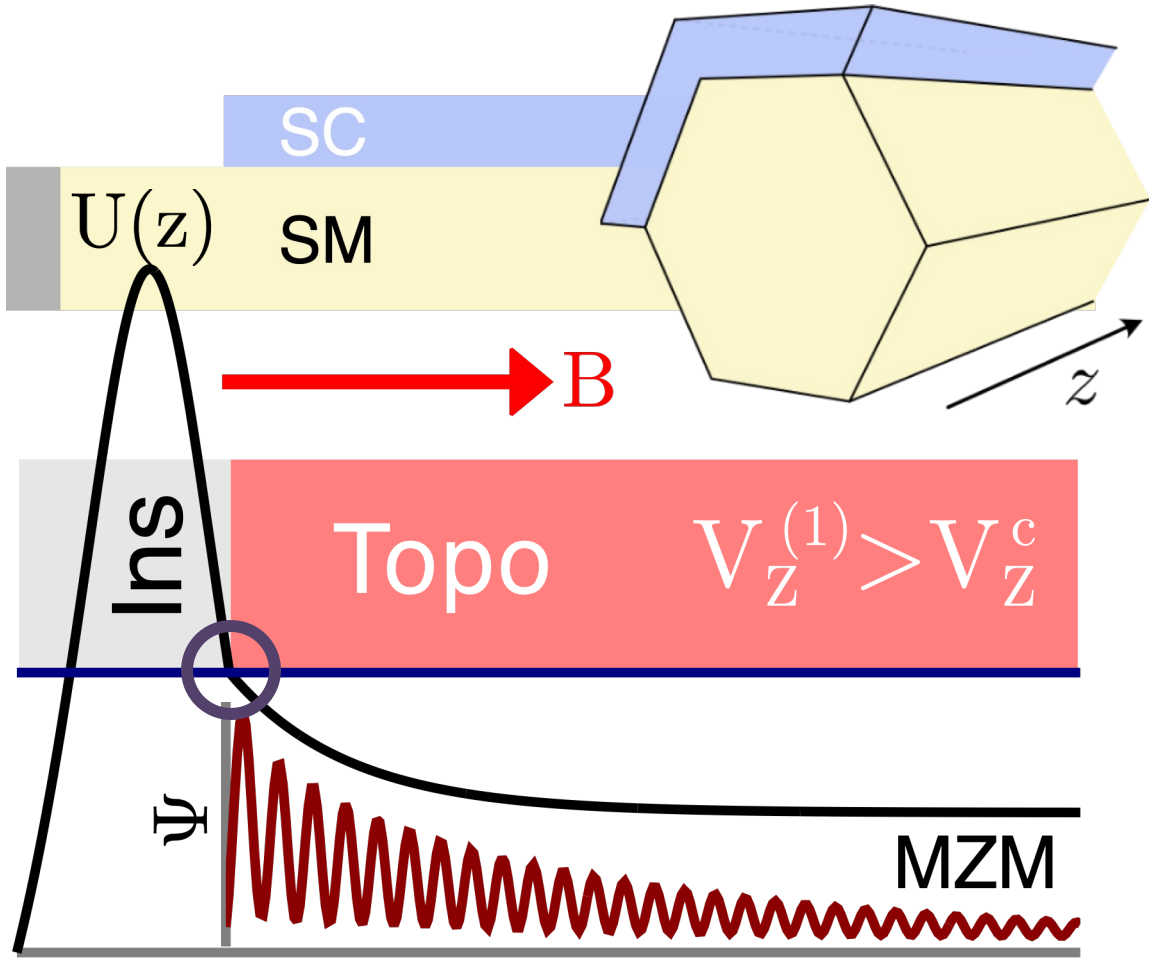

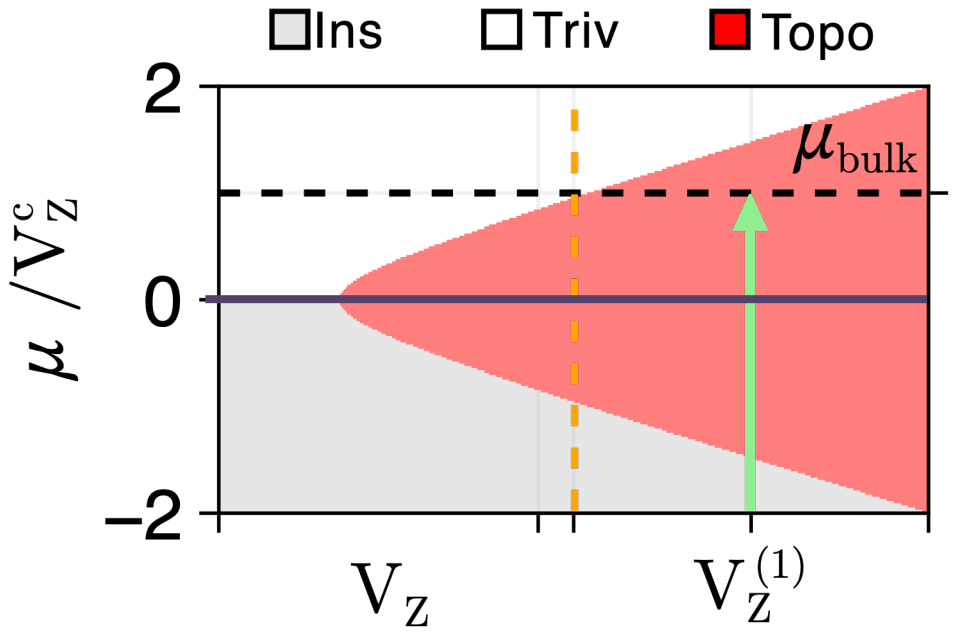

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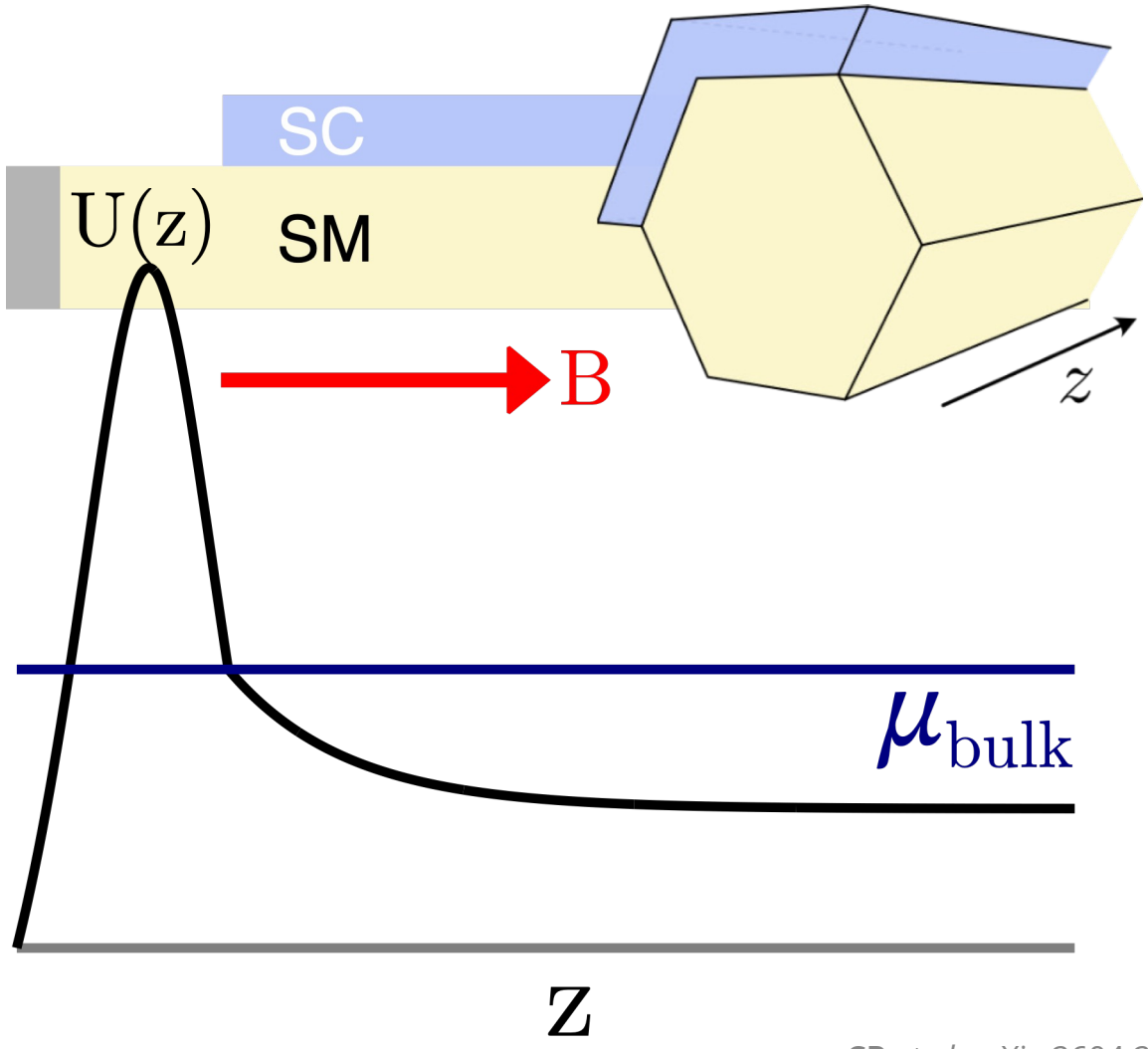
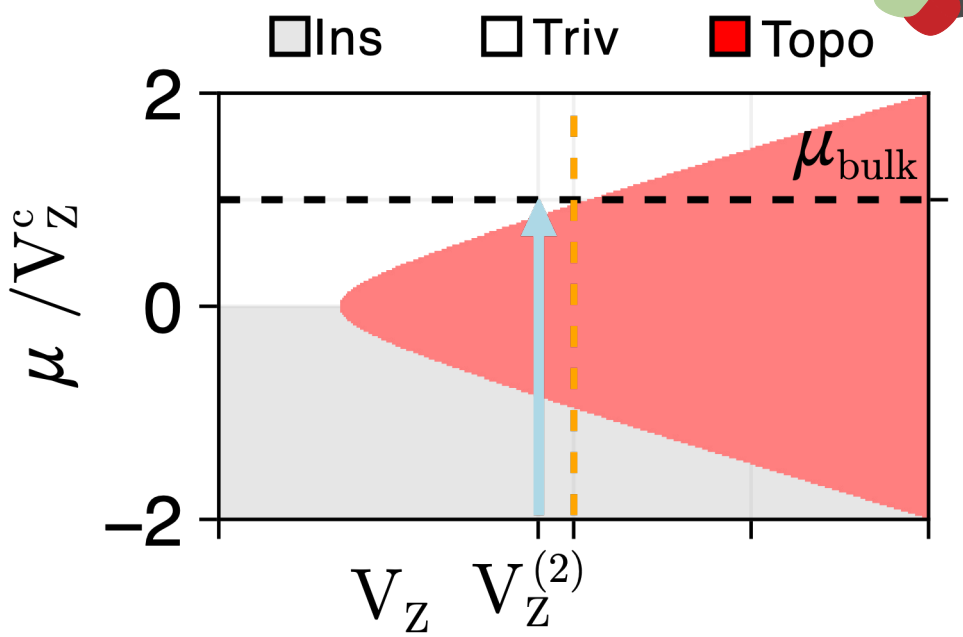
Quasi-Majoranas





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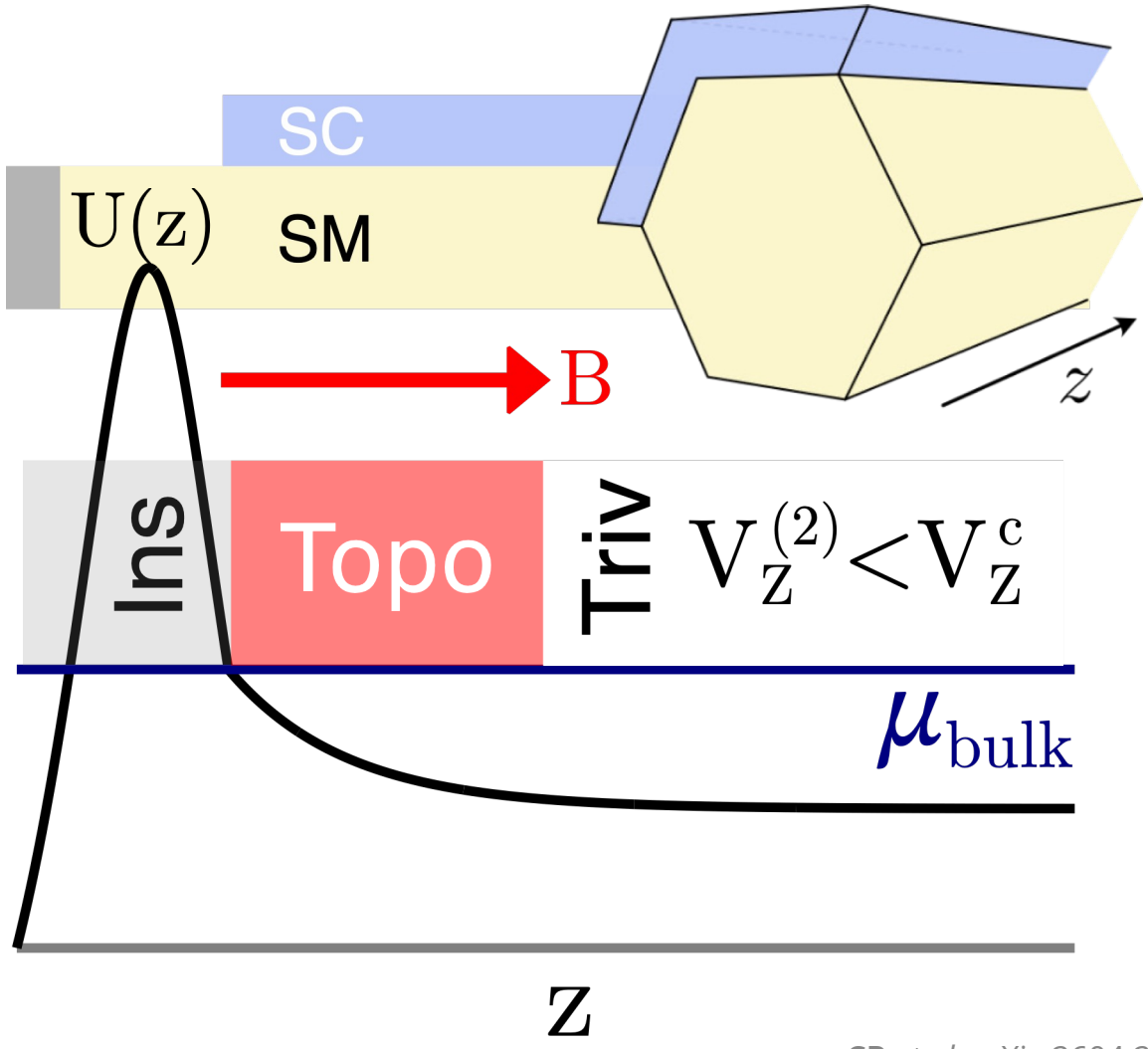

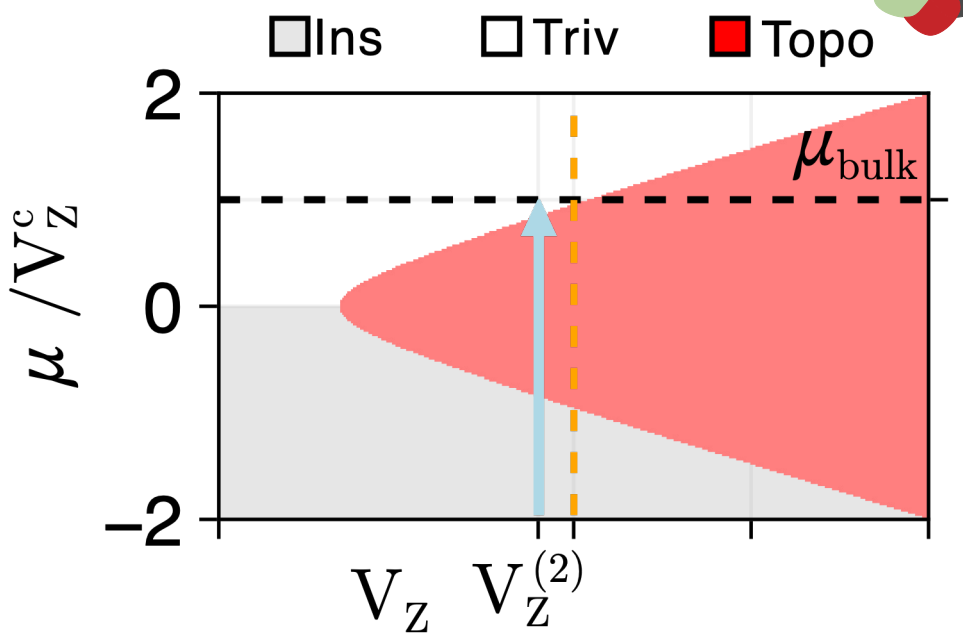

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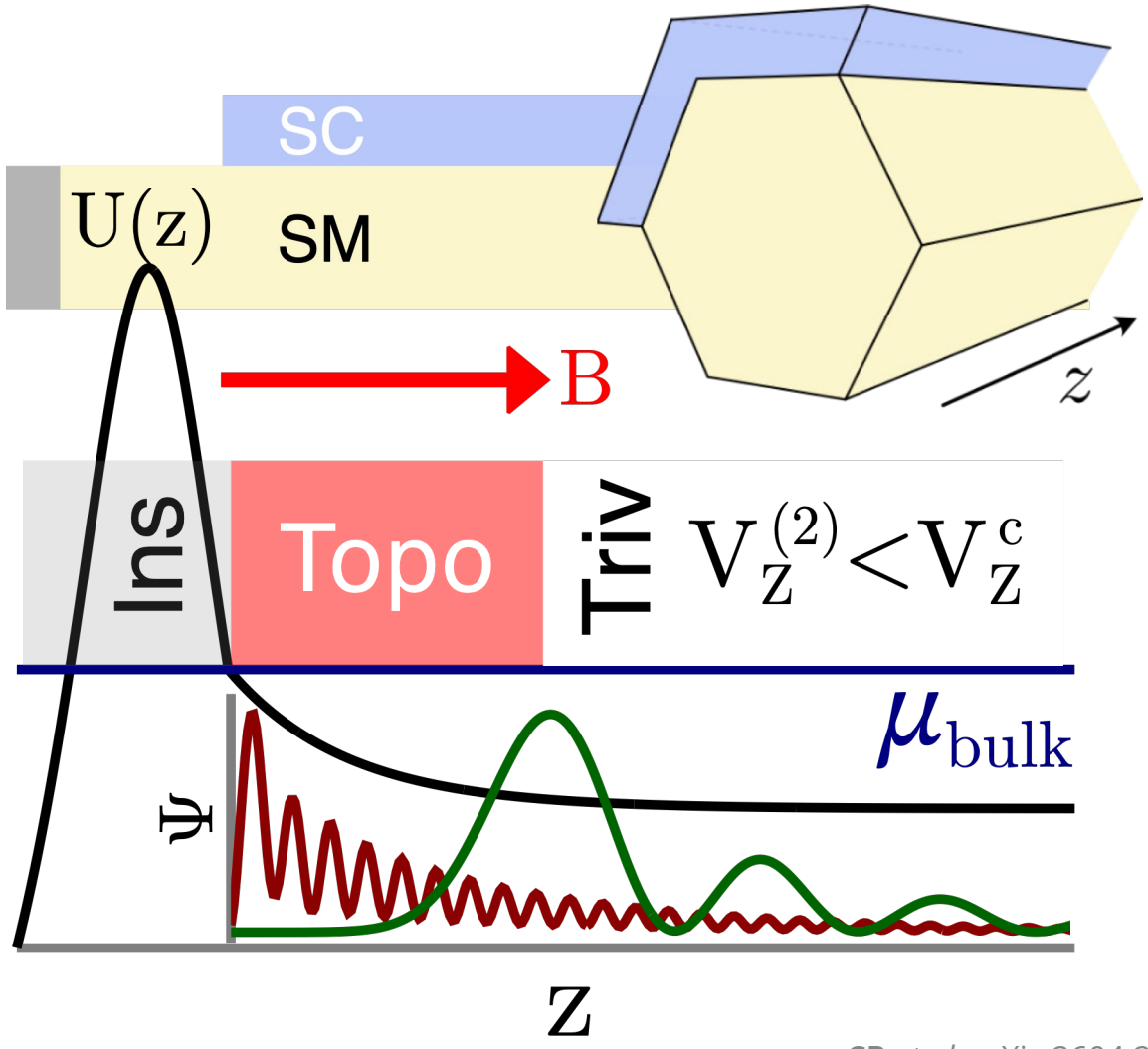

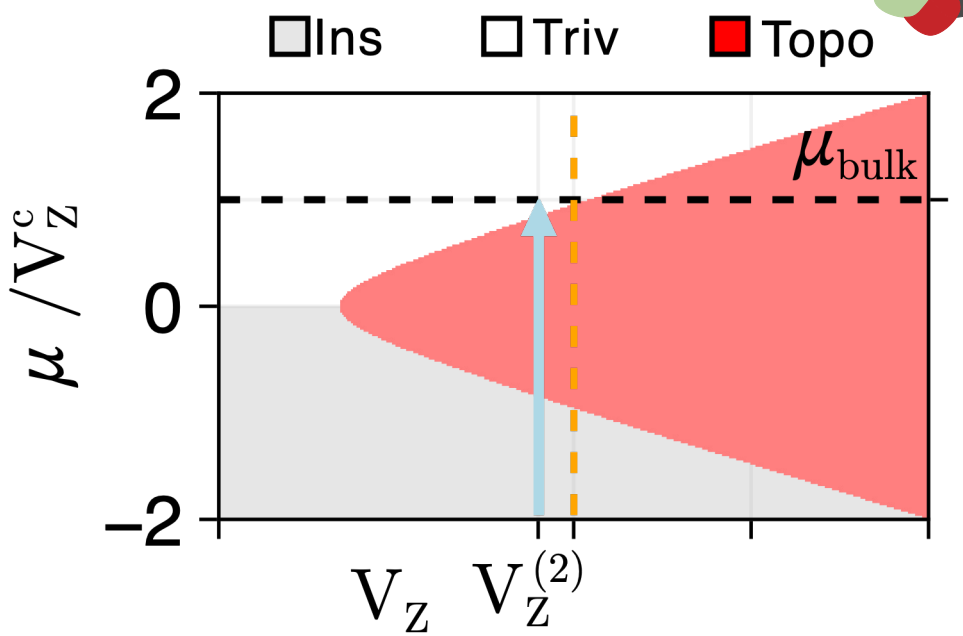

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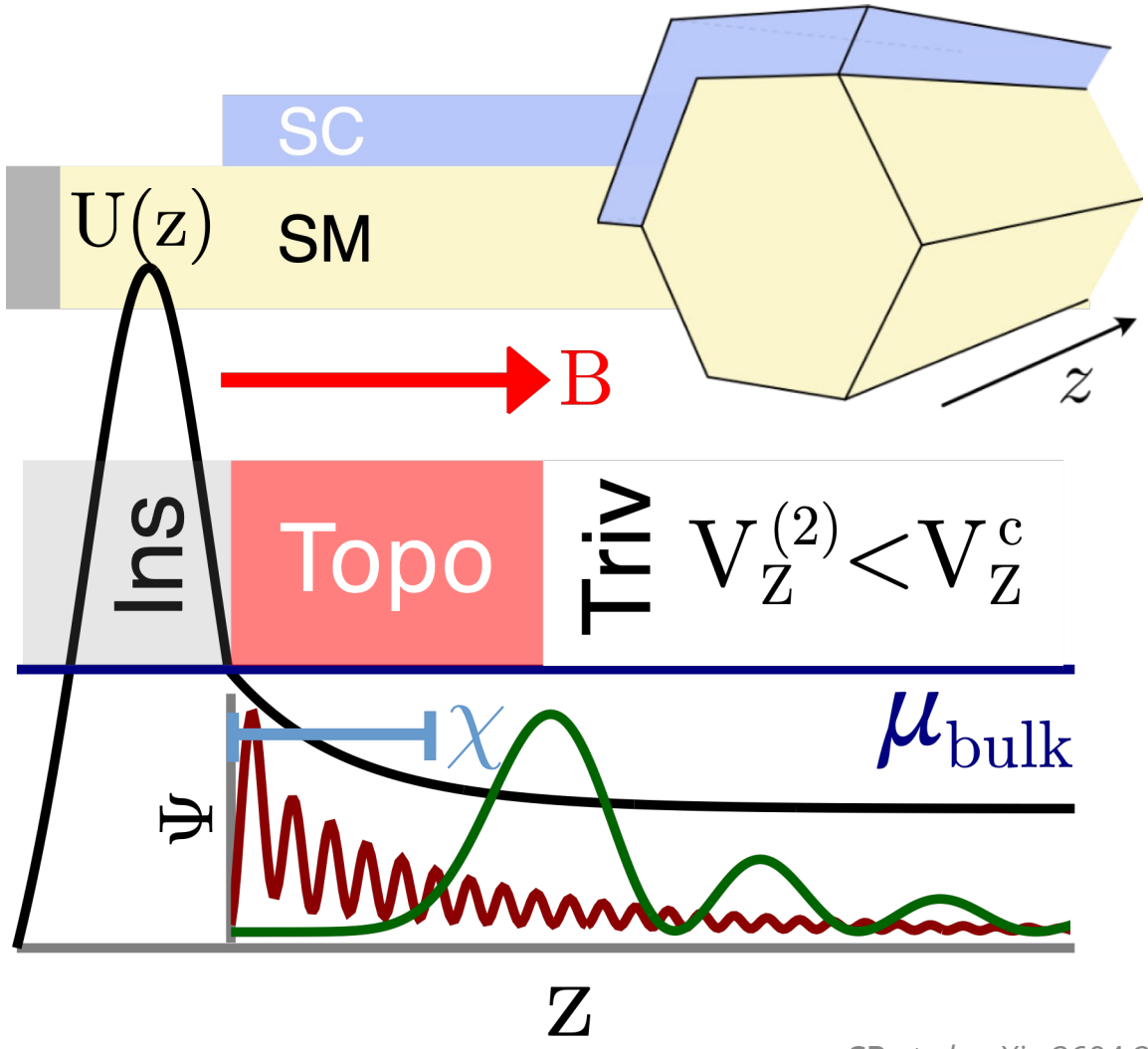

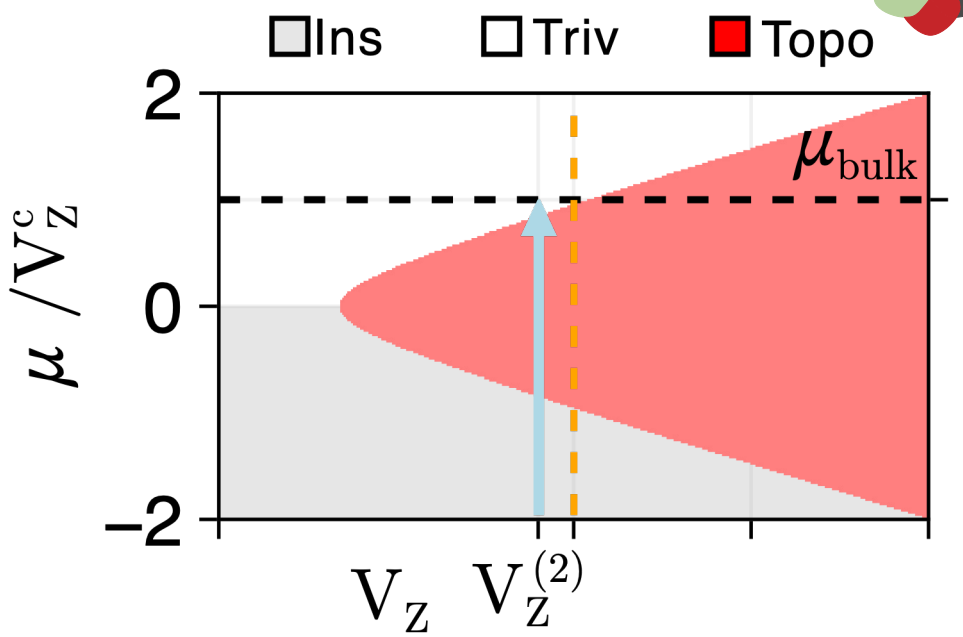

$$\chi >> \frac{\hbar \alpha \mu_{bulk}}{V_Z \Delta}$$

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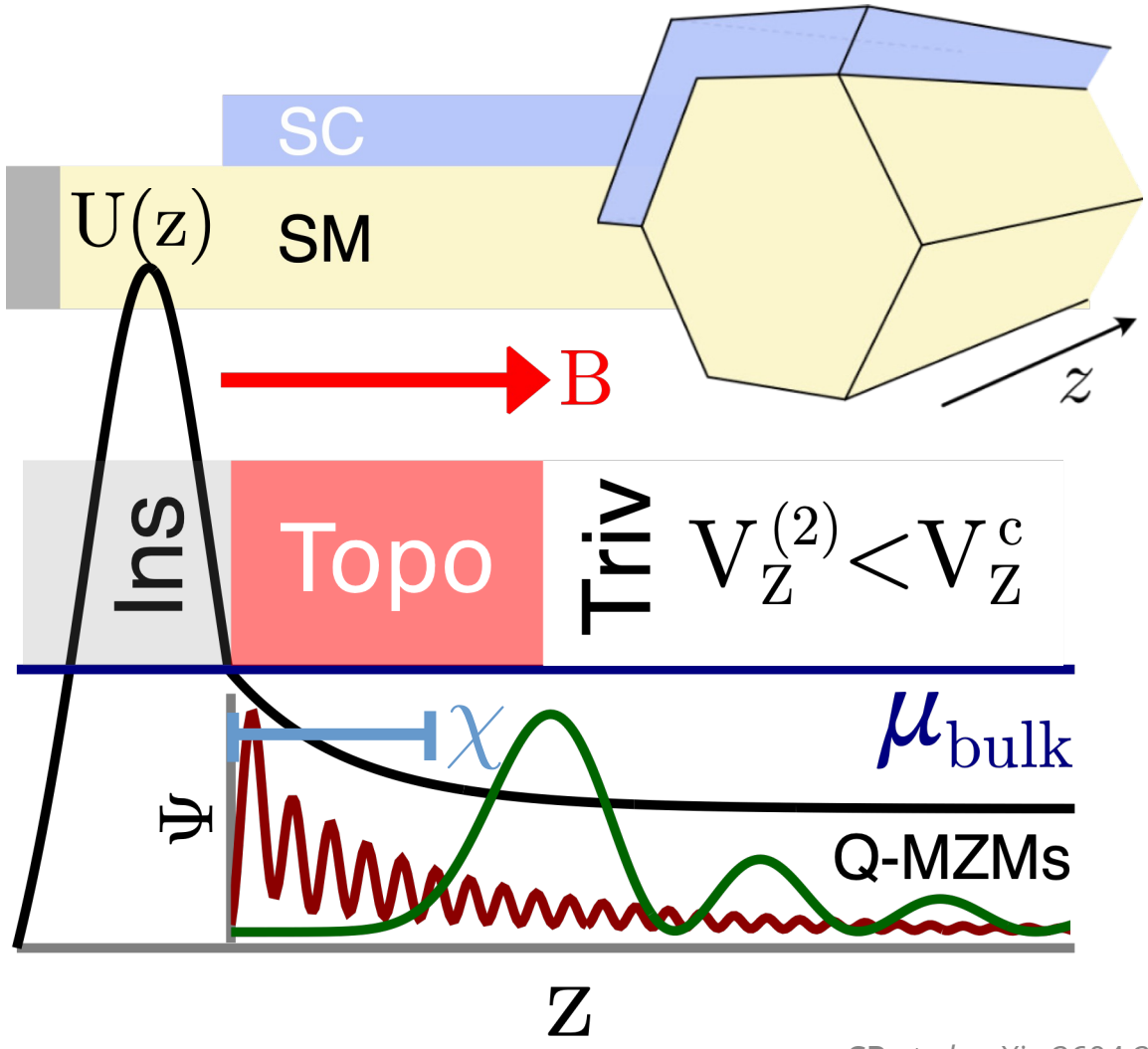
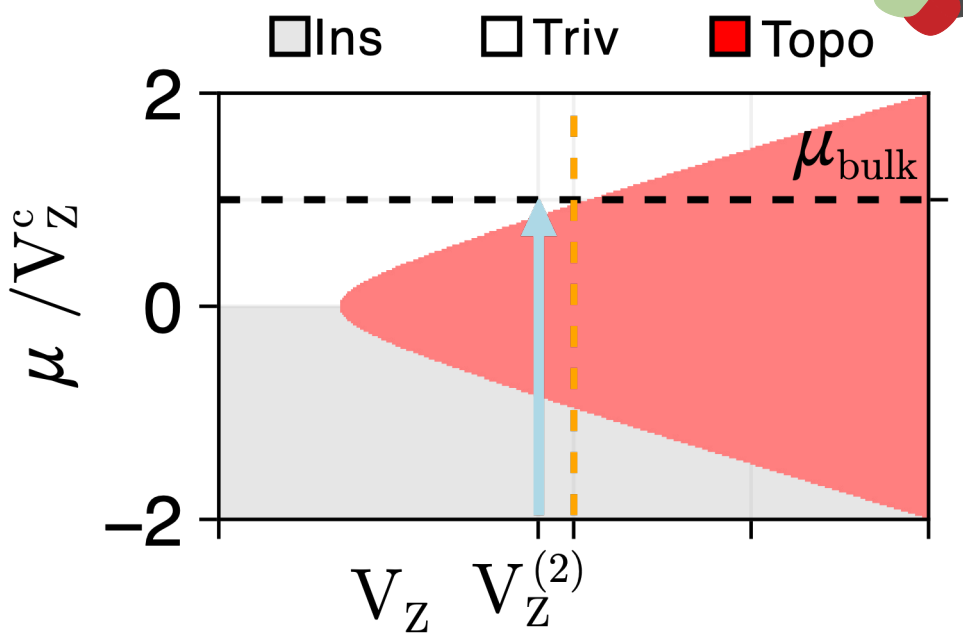
Quasi-Majoranas





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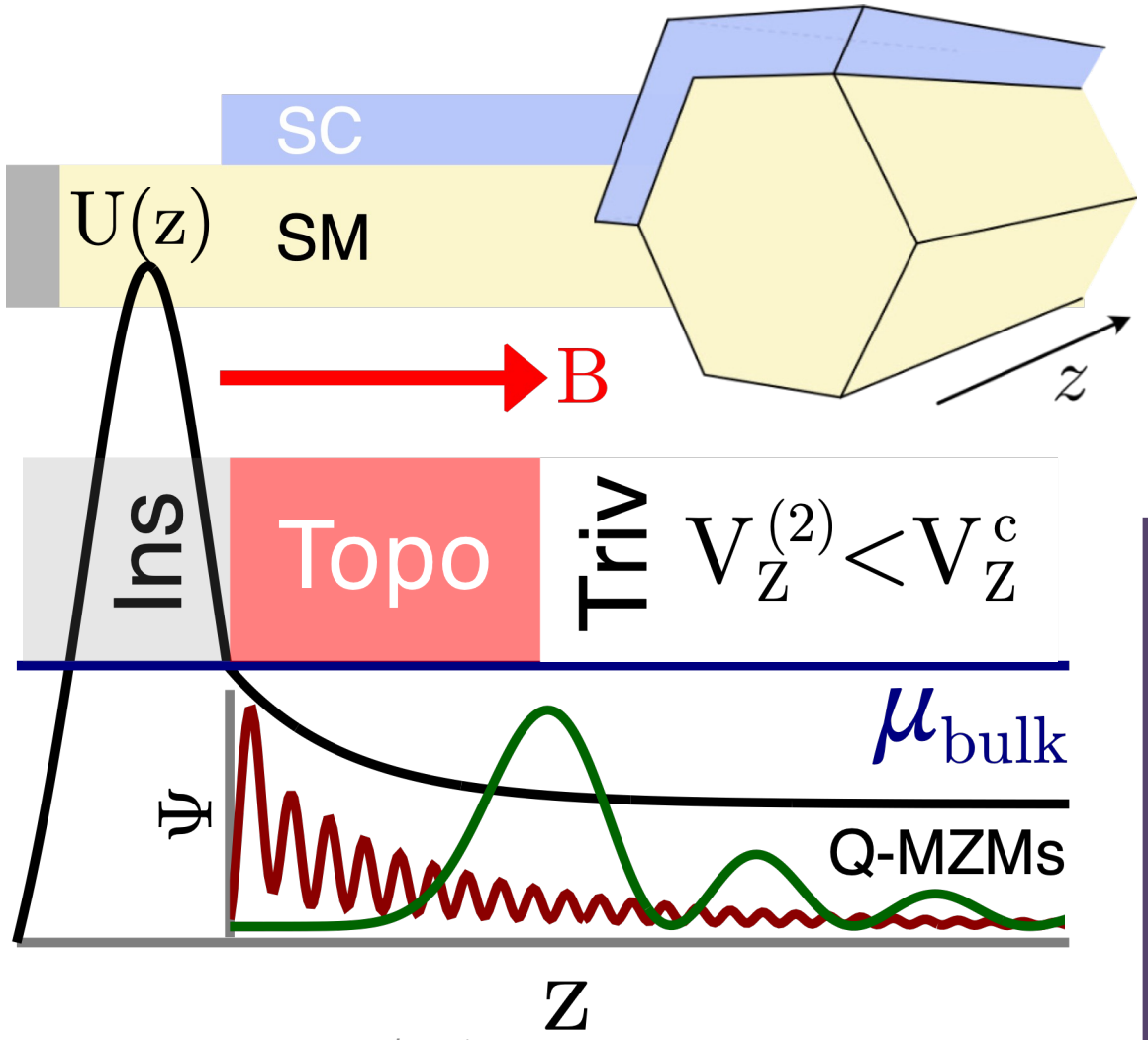

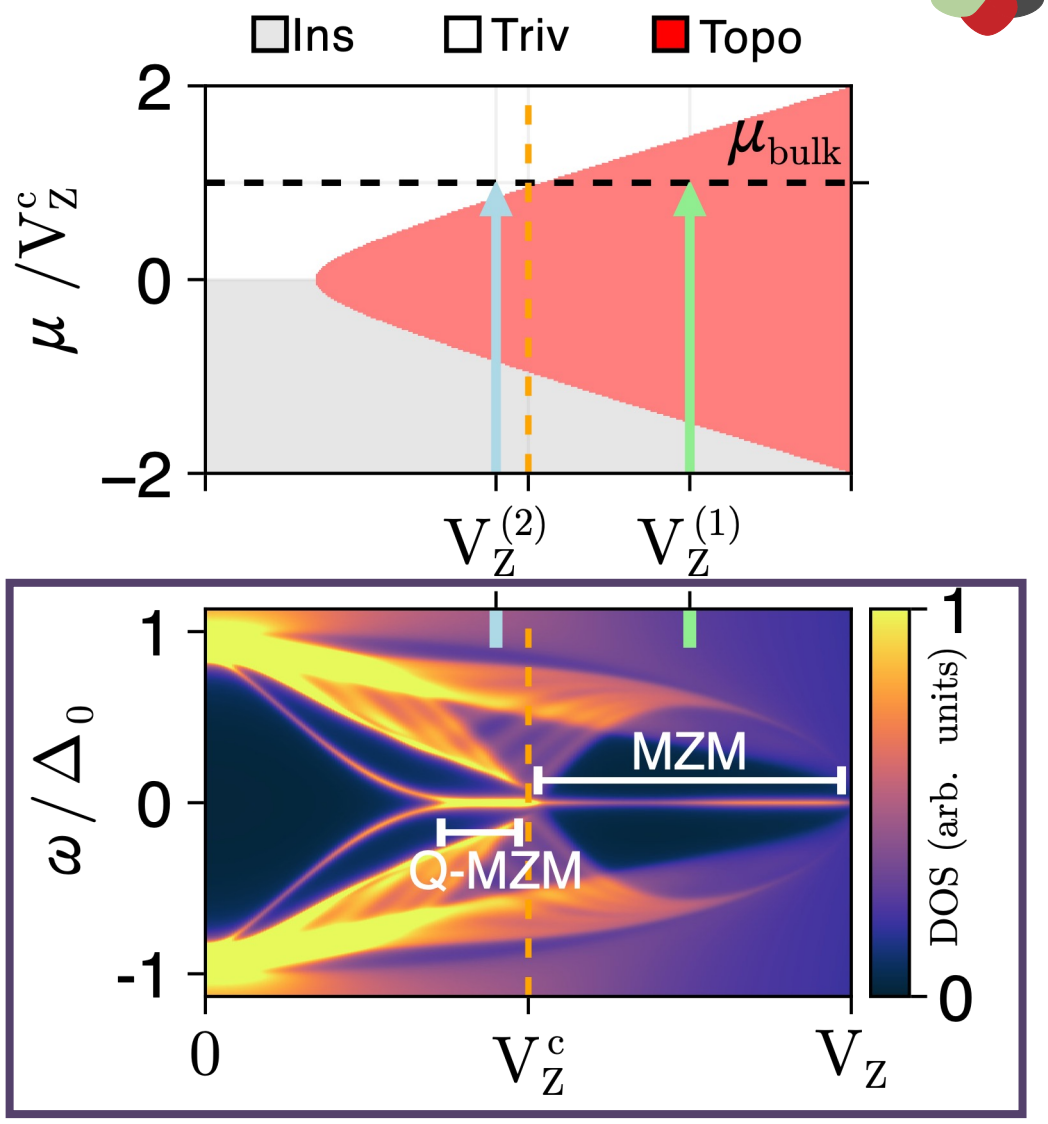

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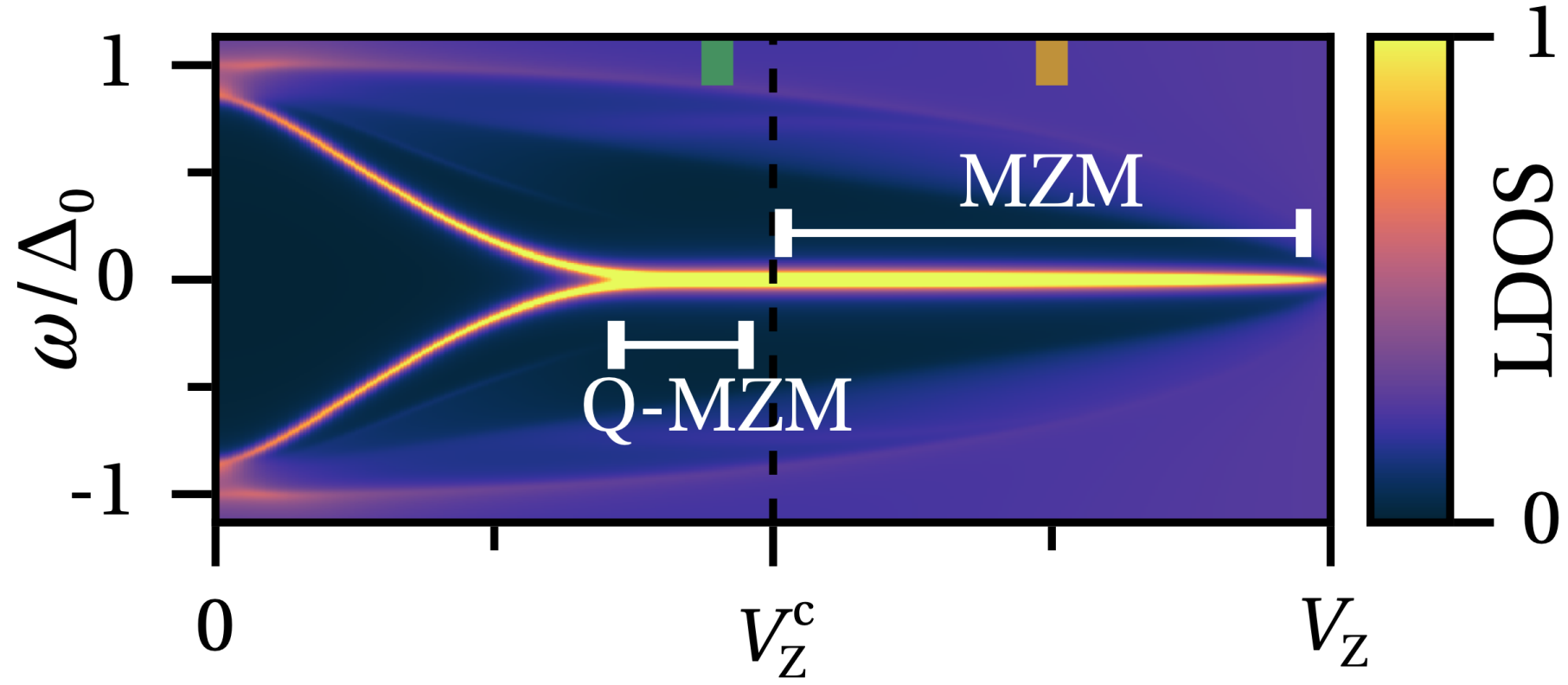
(Quasi-)Majoranas in tunneling spectroscopy



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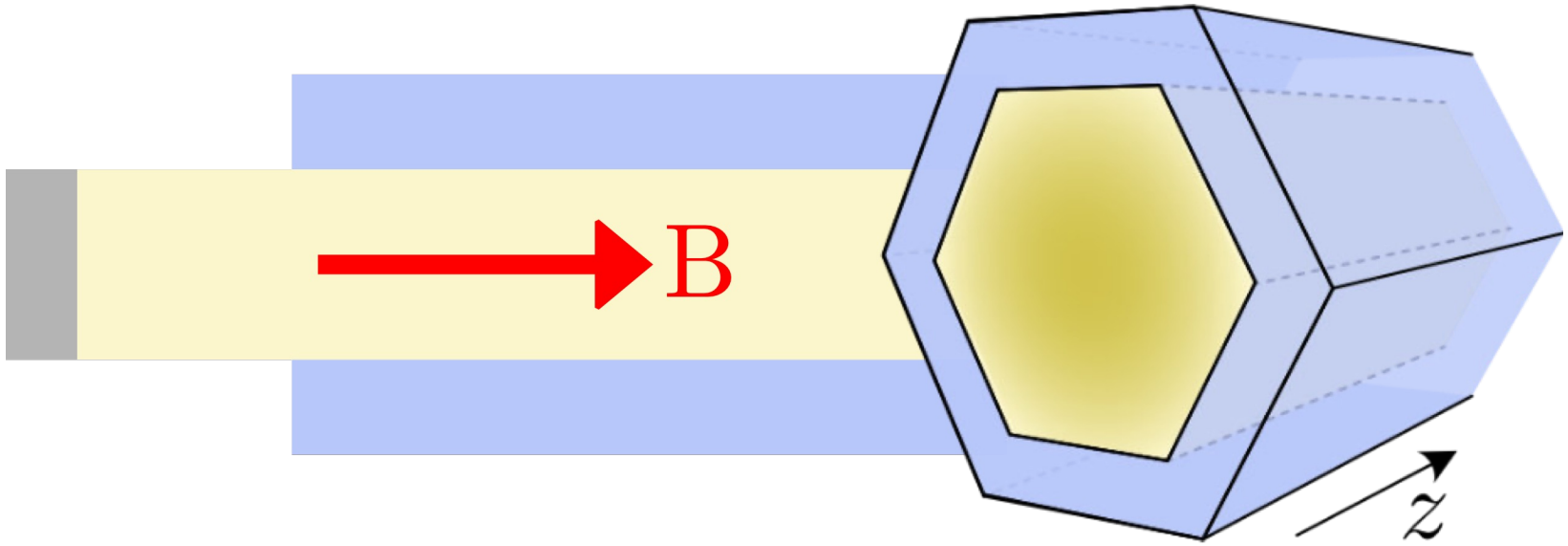
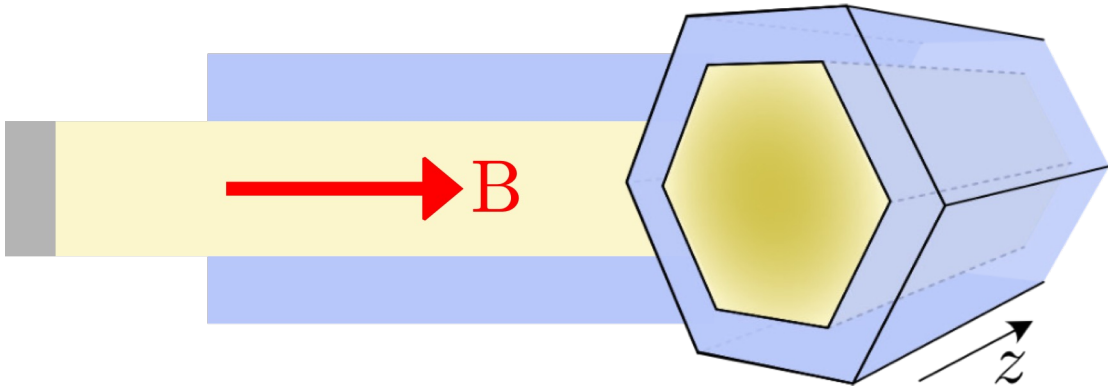
Full-shells 101



Not all angular modes have Majoranas



~cylindrical symmetry:

$$[H_{FS}, J_z] = 0$$

$$J = \underbrace{-i\partial_\varphi}_{\text{angular}} + \underbrace{\frac{1}{2}\sigma_z}_{\text{spin}} + \underbrace{\frac{1}{2}n\tau_z}_{\text{electron-hole}}$$

$$n \in \mathbb{Z}$$

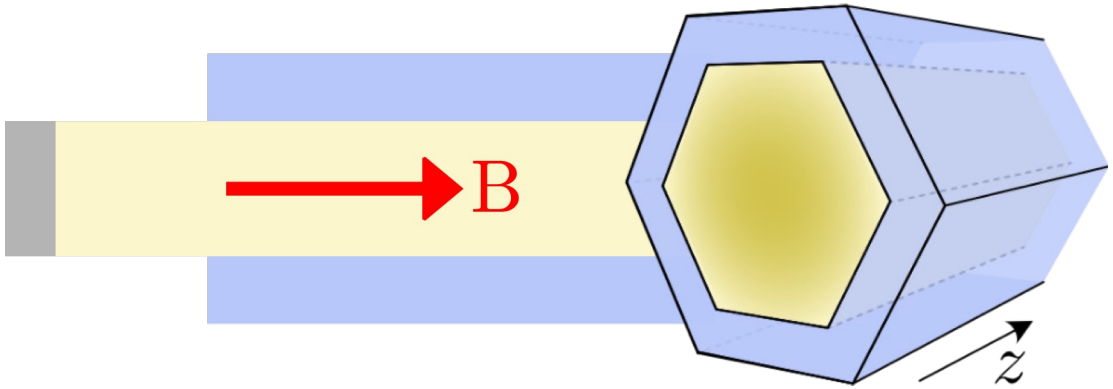
Majorana condition:

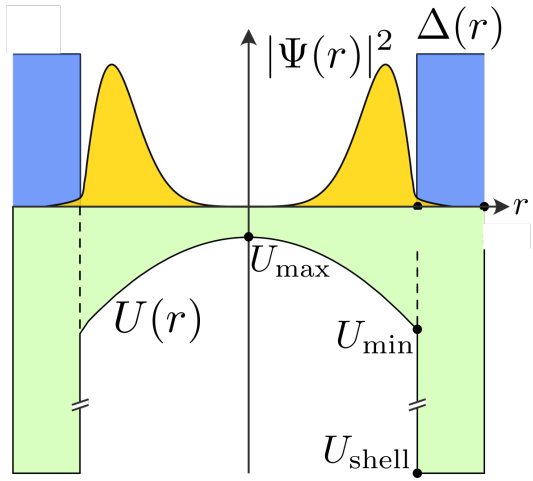
$$\mathcal{P}\Psi_{m_J}(E) = \Psi_{-m_J}(-E)$$

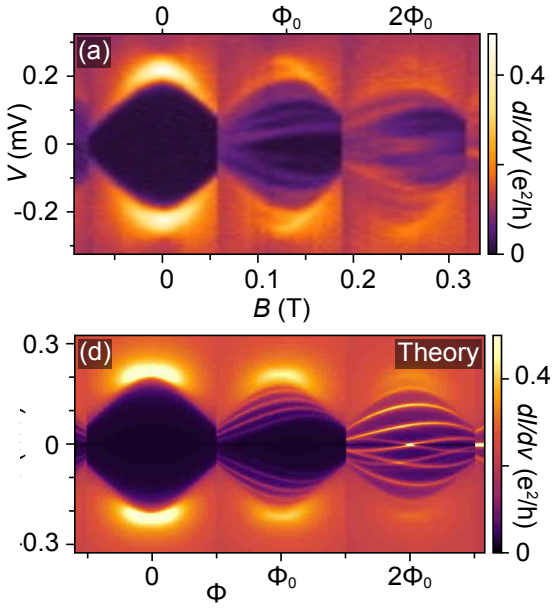
$\mathcal{P}$ particle-hole

$$m_J = 0$$

Not all angular modes have Majoranas







~cylindrical symmetry:

$$[H_{FS}, J_z] = 0$$

$$J = -i\partial_\varphi + \frac{1}{2}\sigma_z + \frac{1}{2}n\tau_z$$

angular — spin — electron-hole

$$n \in \mathbb{Z}$$

Majorana condition:

$$\mathcal{P}\Psi_{m_J}(E) = \Psi_{-m_J}(-E)$$

$\mathcal{P}$ particle-hole

$$m_J = 0$$

Non-0 angular modes: Trivial Skin

$$J = -i\partial_\varphi + \frac{1}{2}\sigma_z + \frac{1}{2}n\tau_z$$

Topology:

$$m_J = 0 \Rightarrow n \text{ odd}$$

Just the semiconductor:

$$L = -i\partial_\varphi + \frac{1}{2}\sigma_z \quad m_J = 0 \Rightarrow m_L = \pm\frac{1}{2}$$

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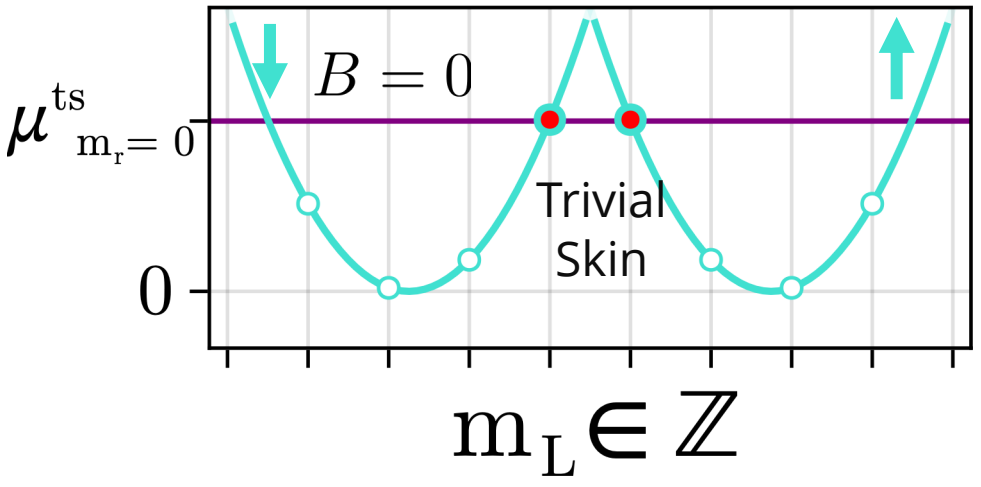
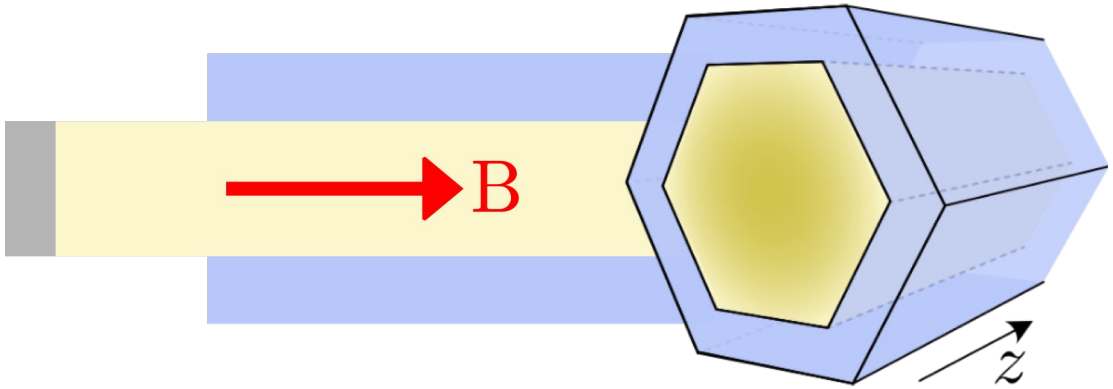
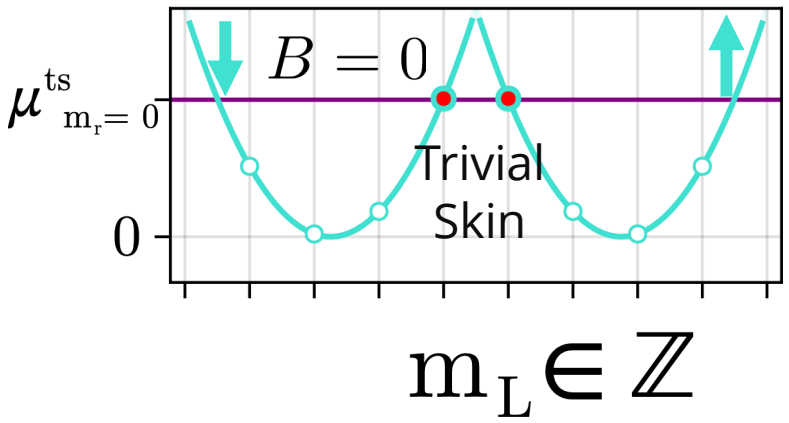
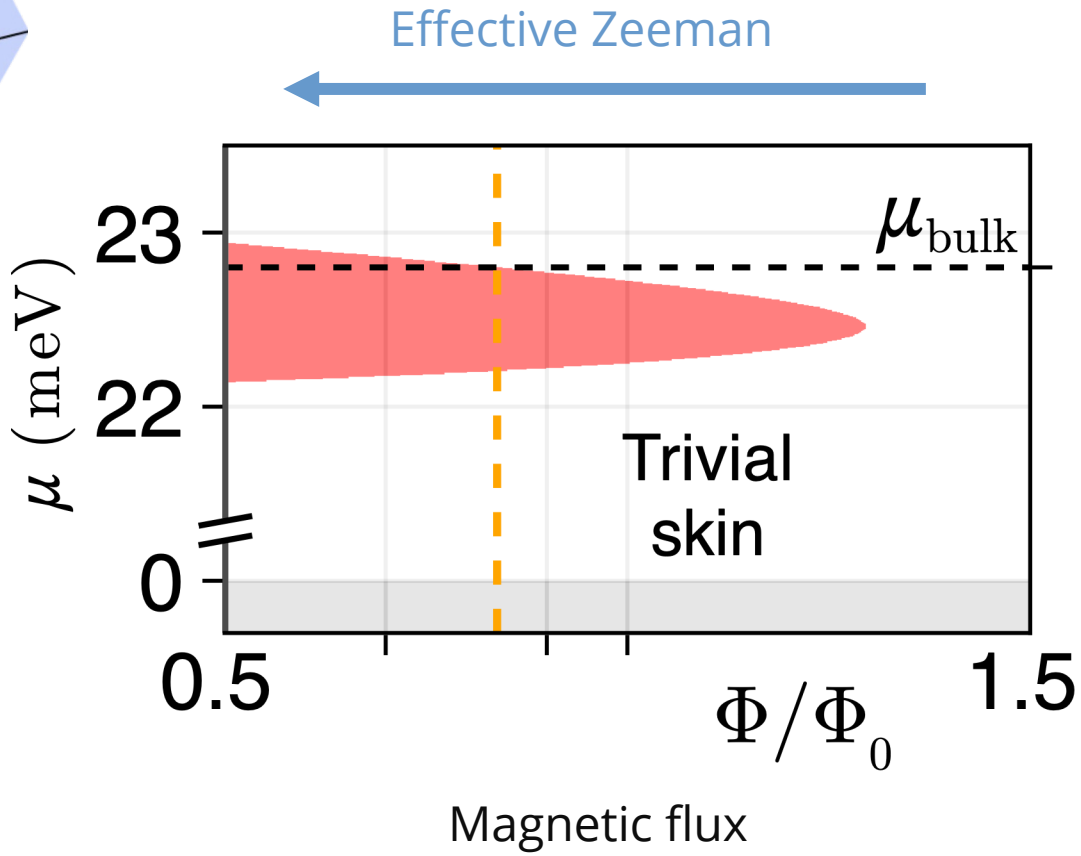
Decoupled semiconductor
Angular Rashba bands



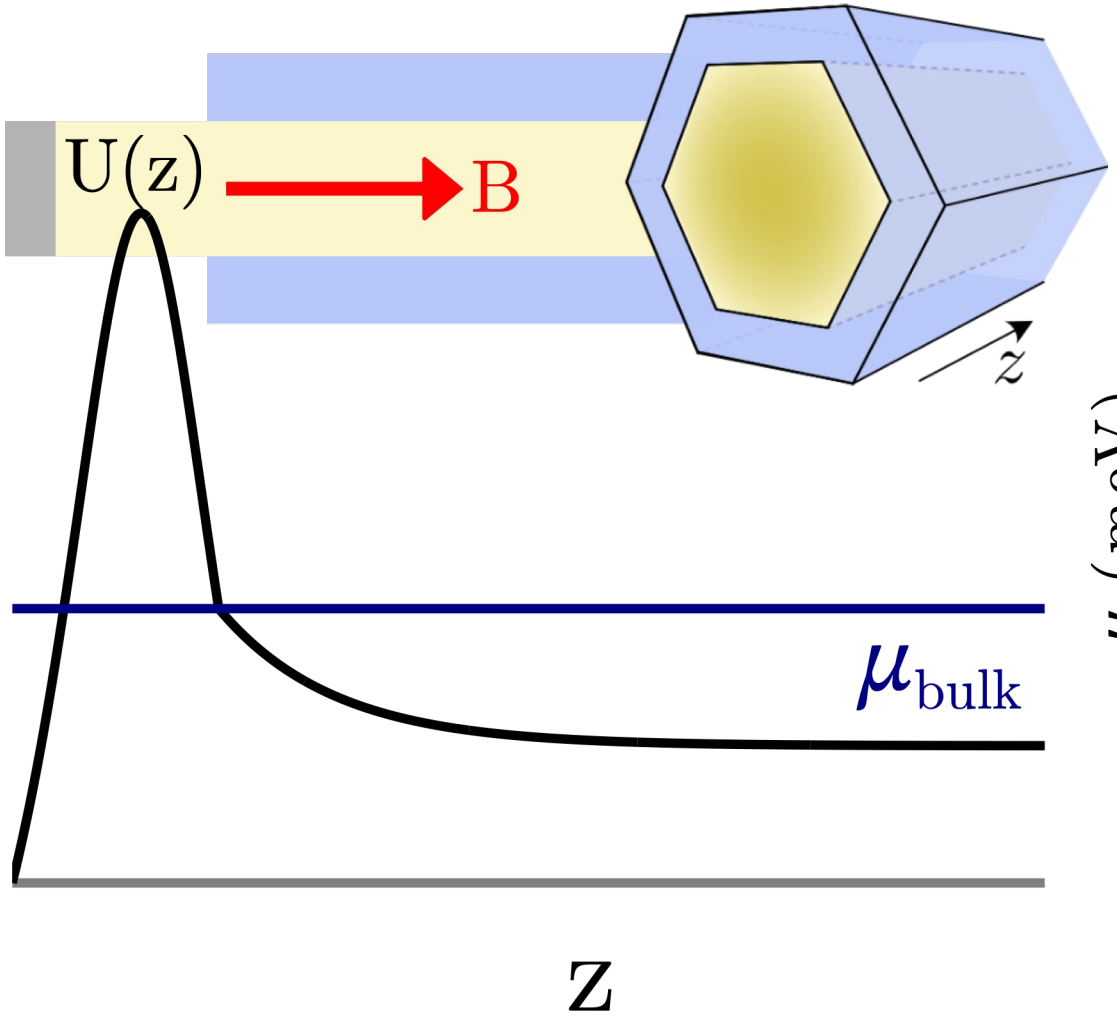
Full-shell electrostatics

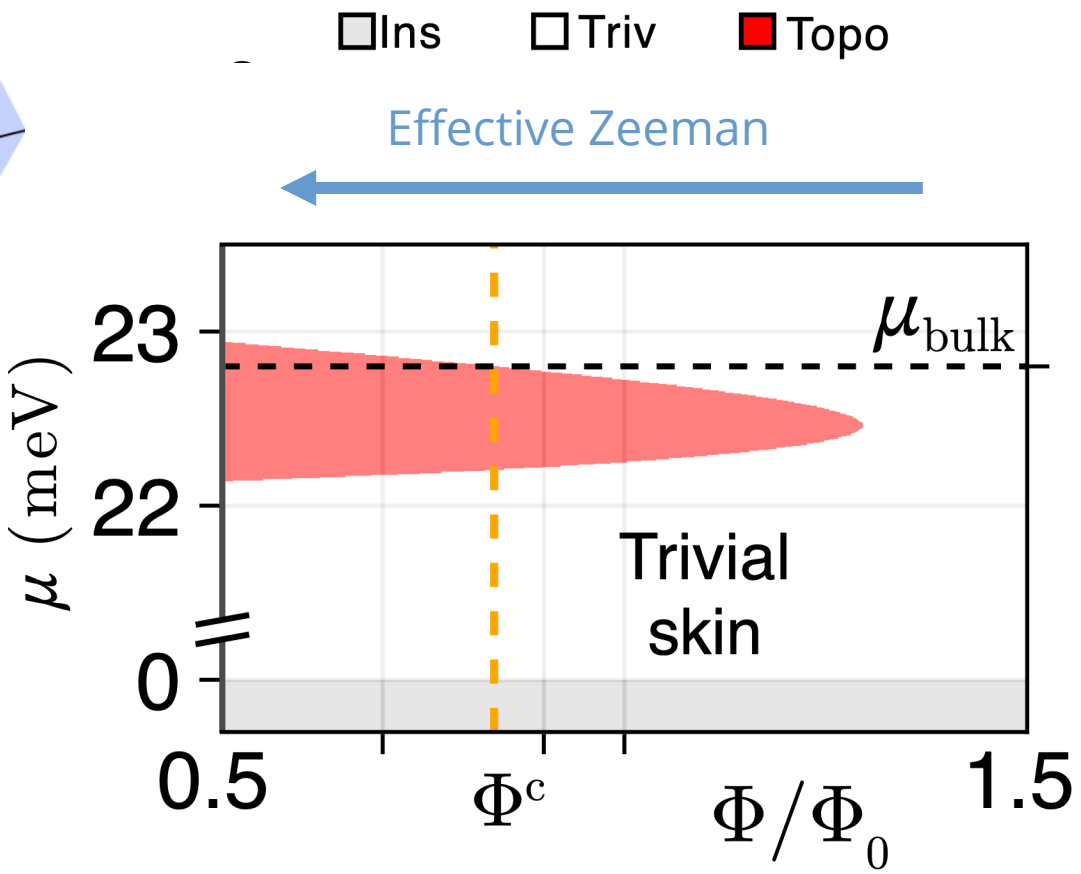






Majoranas *not* at the wire end





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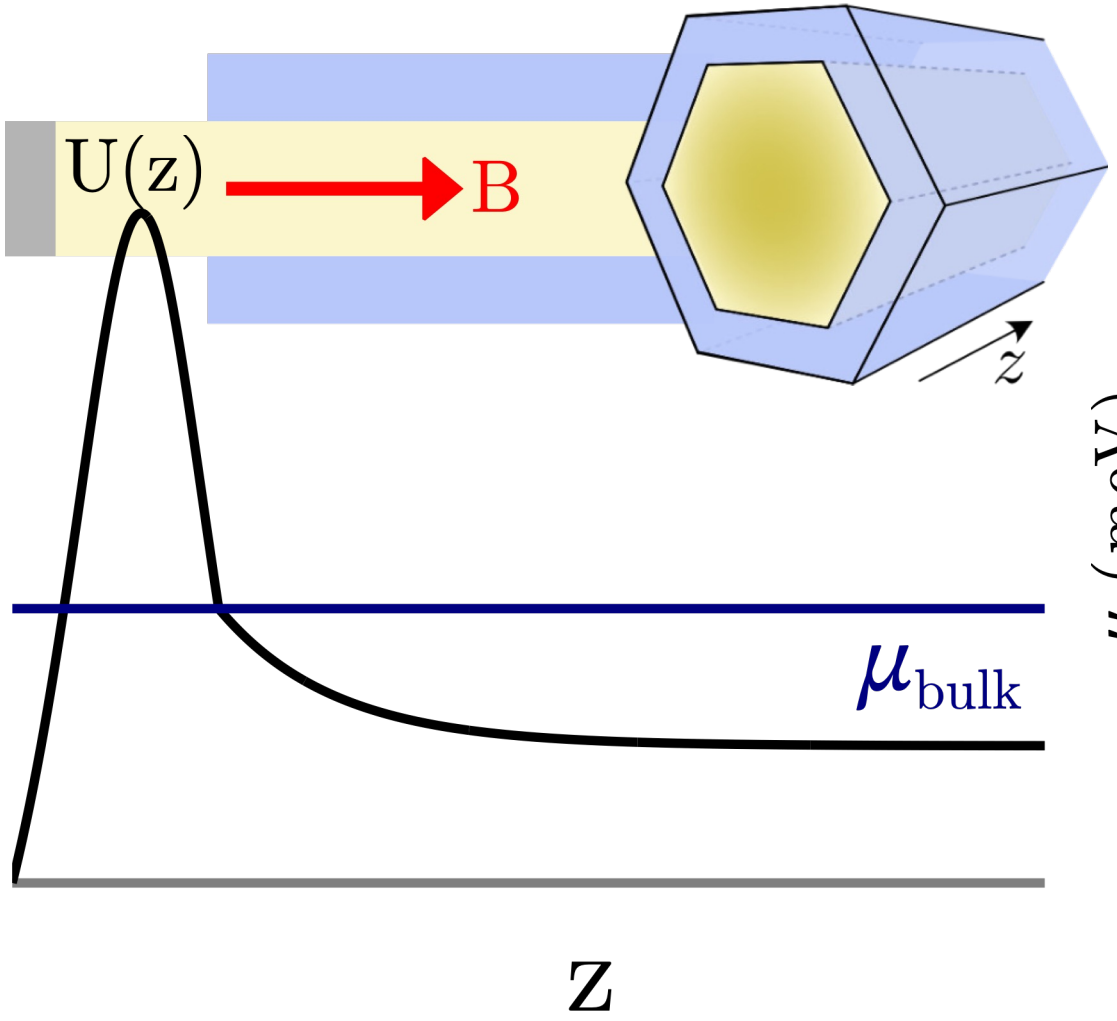

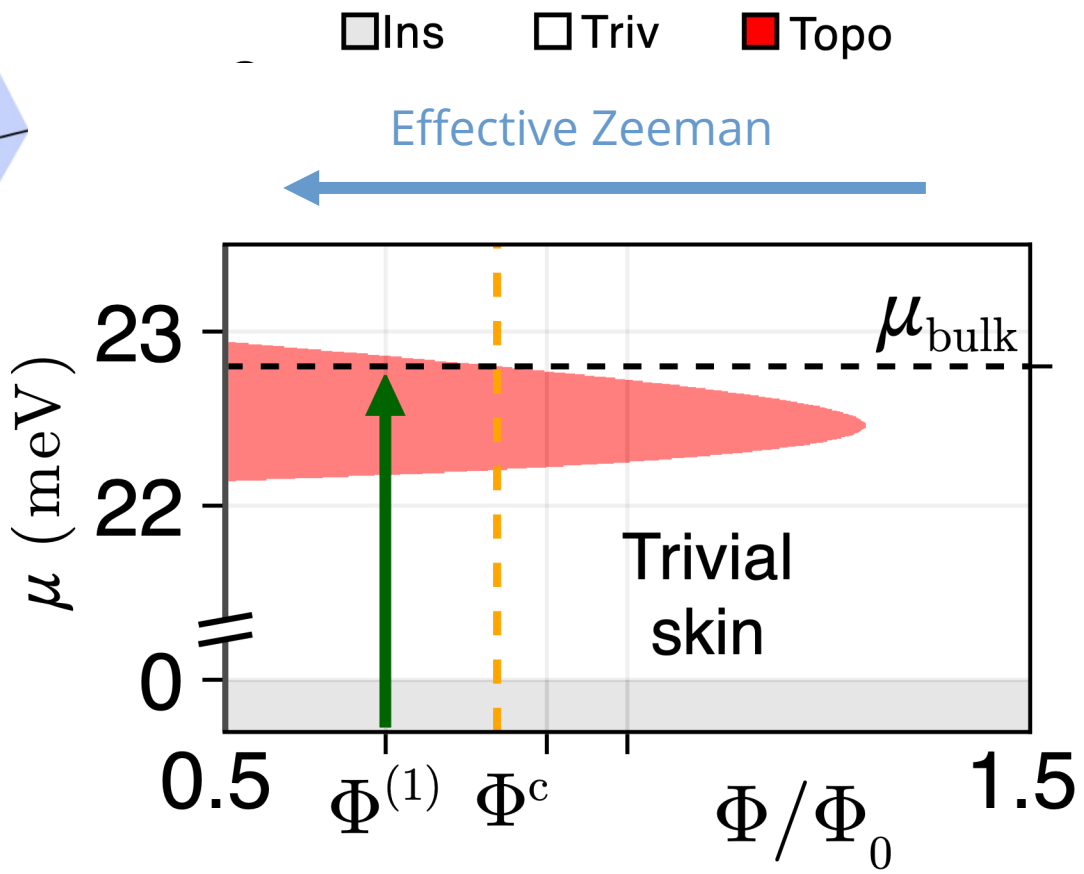

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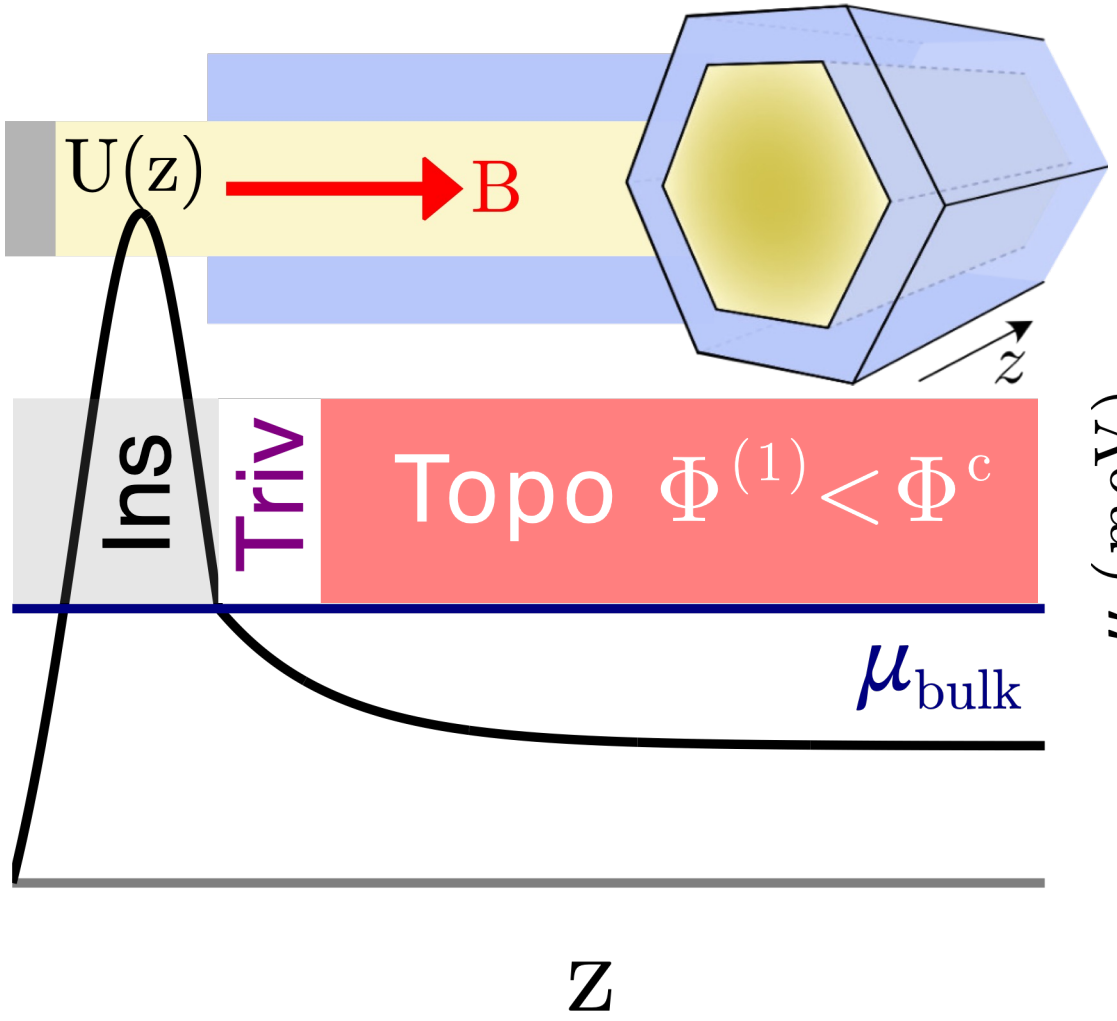

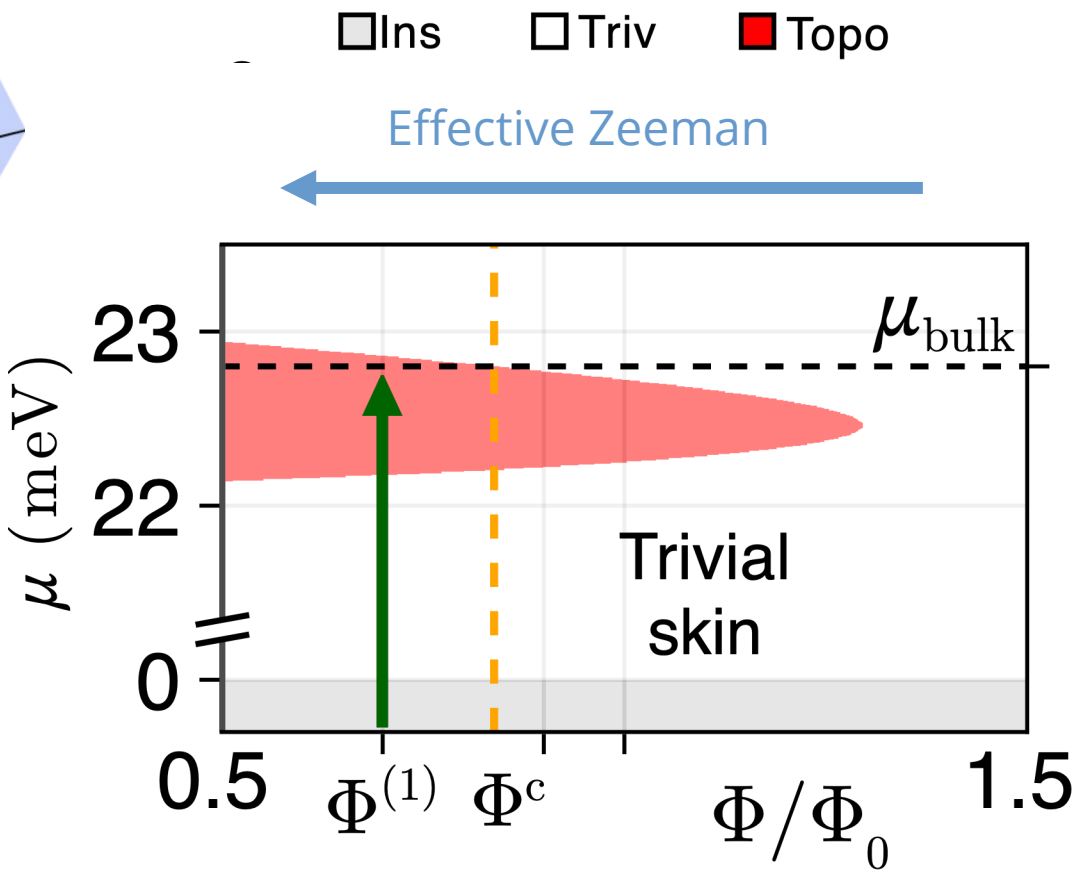

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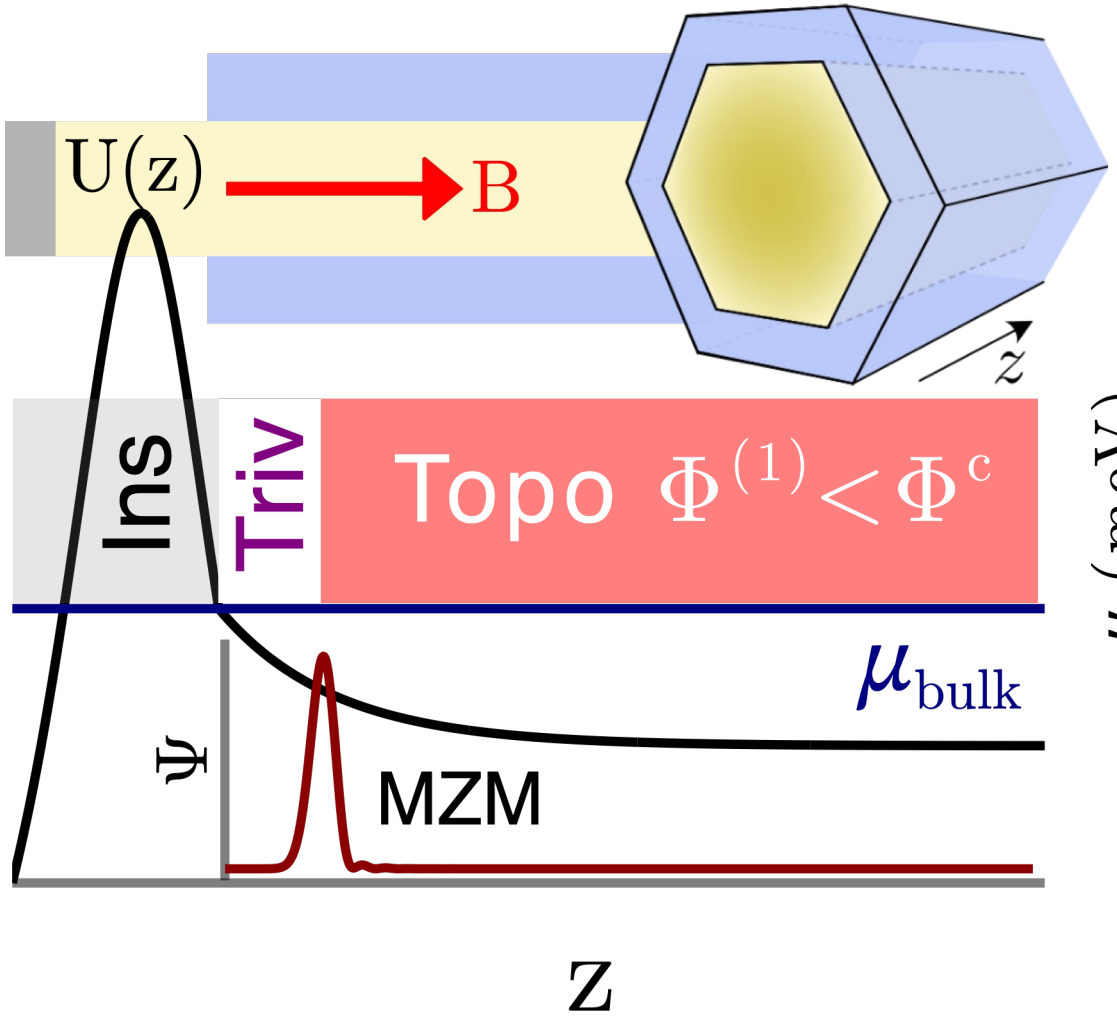
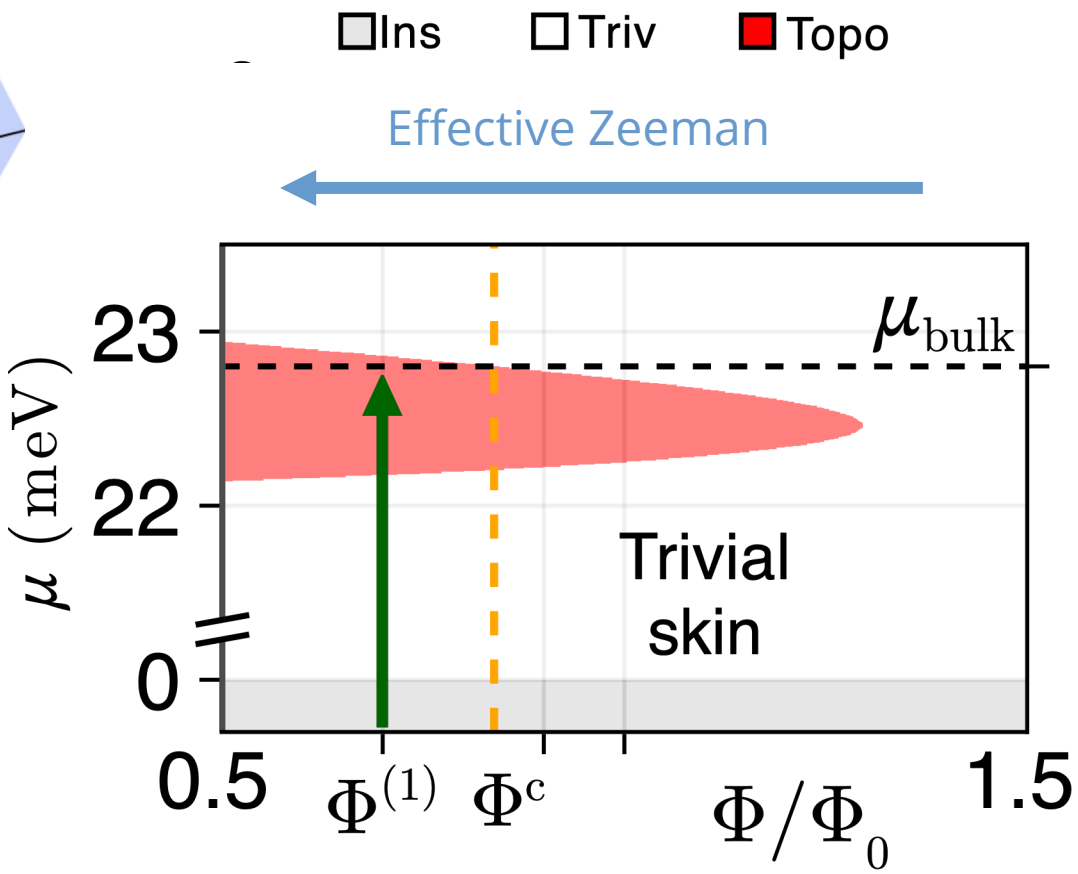
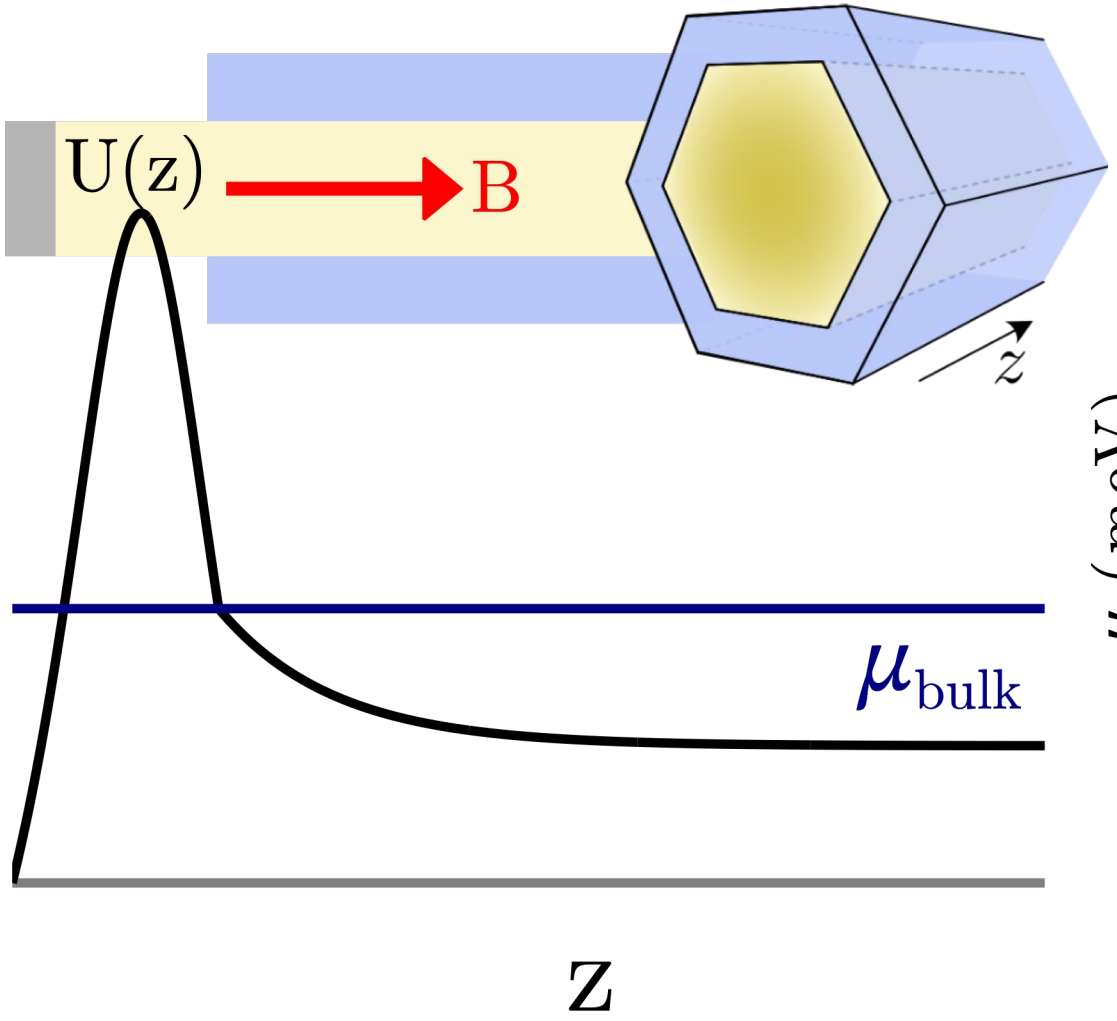
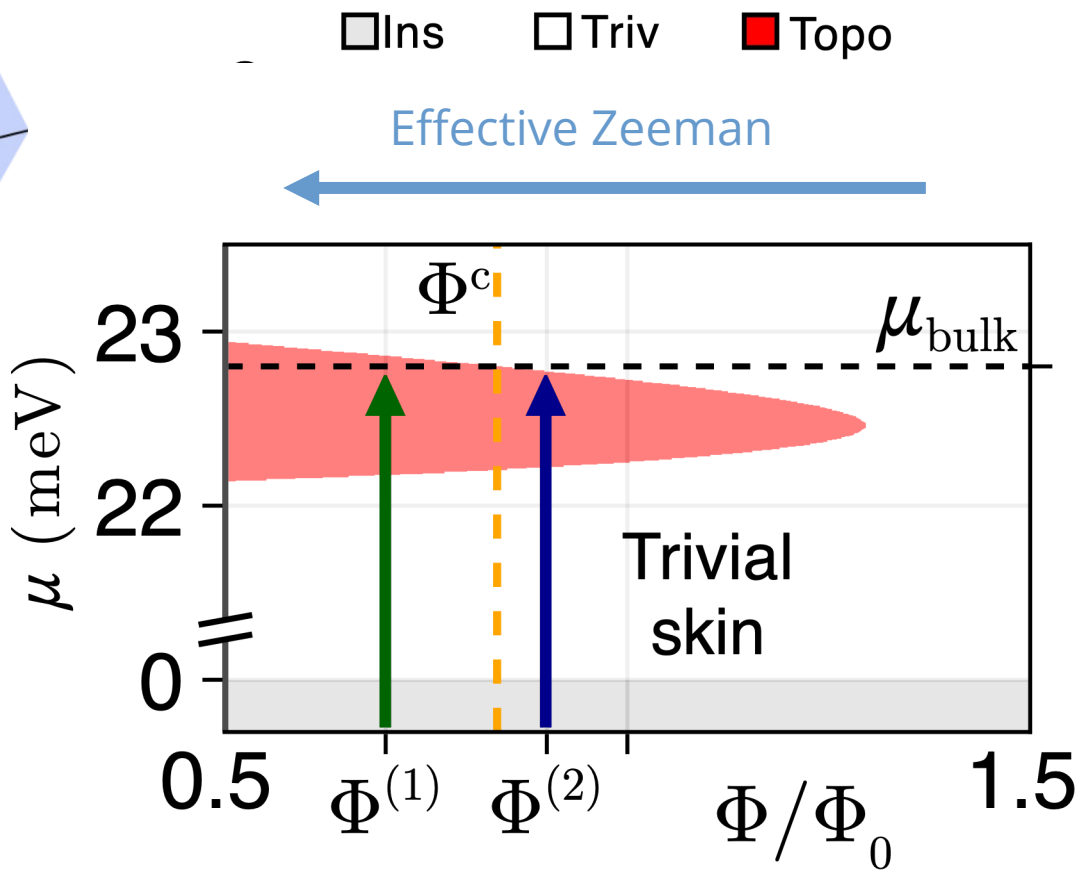


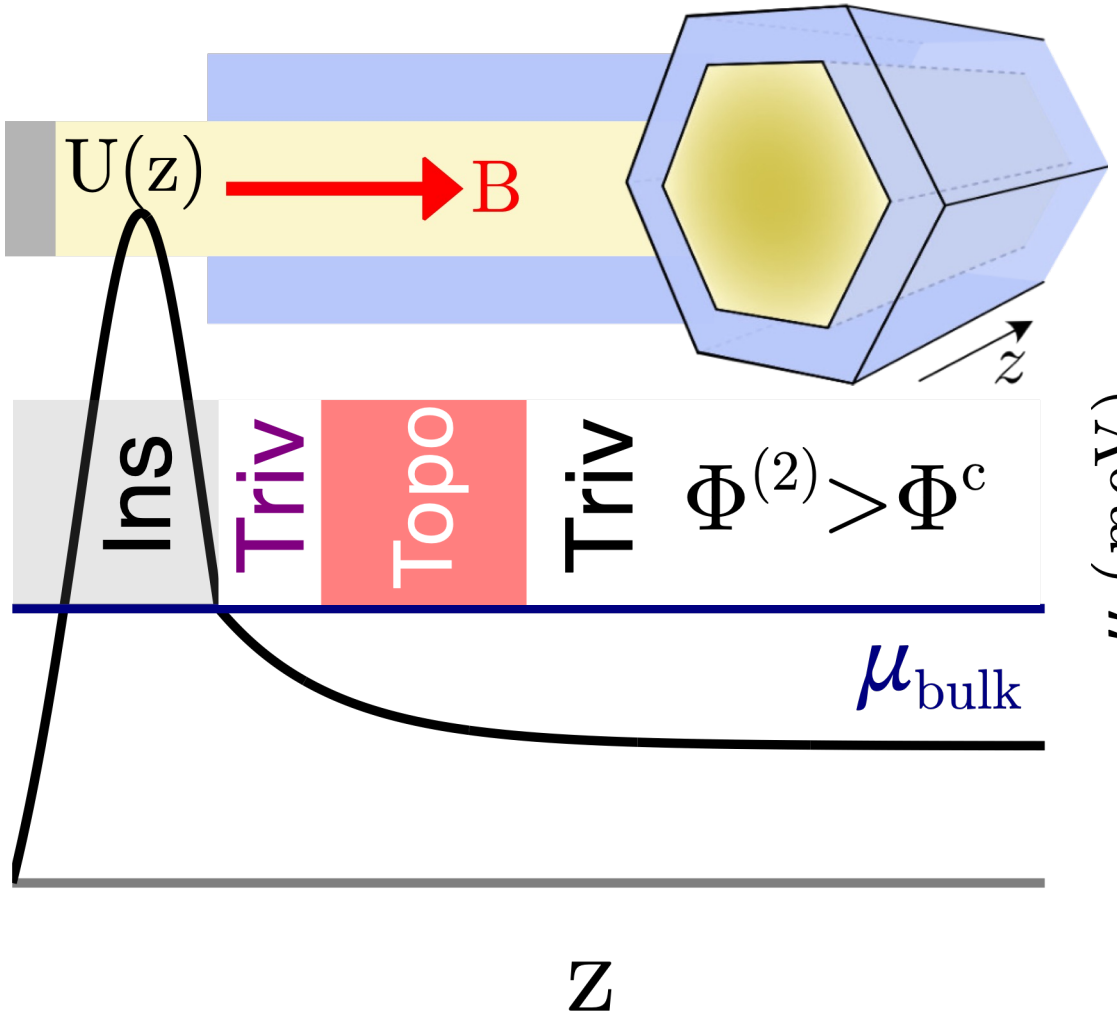


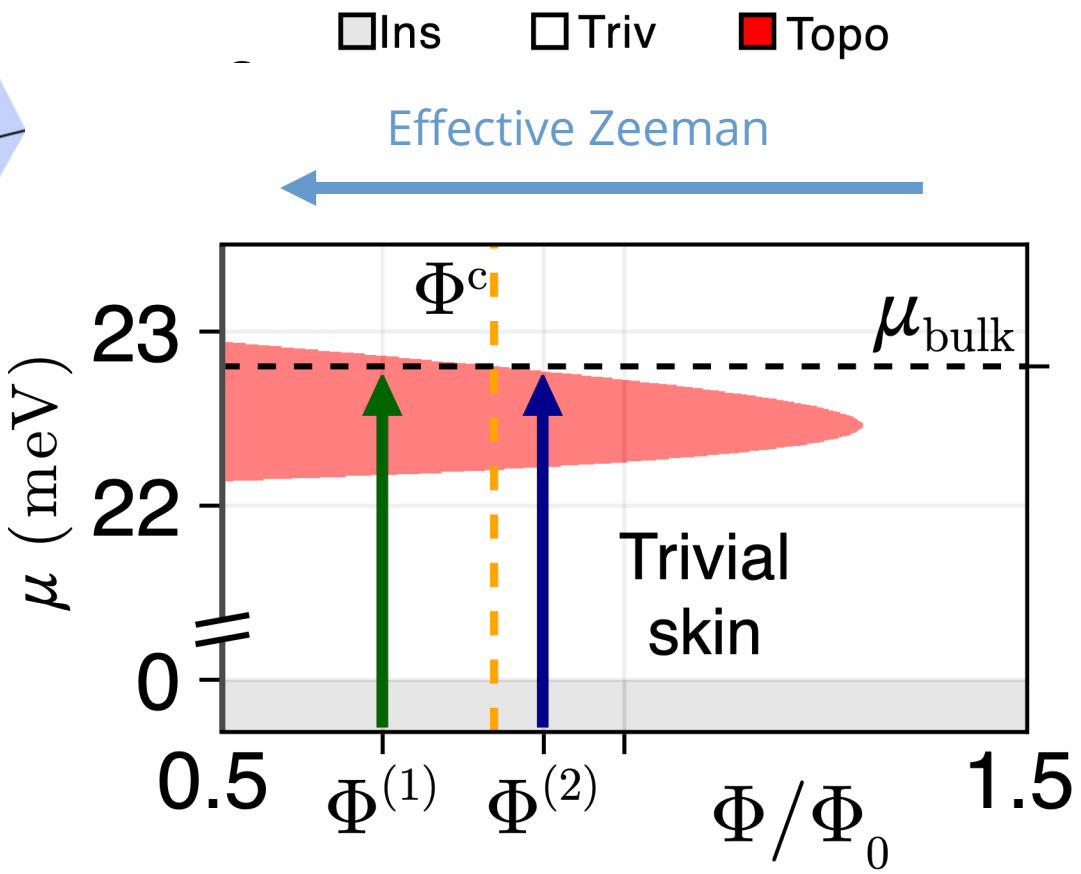
Quasi-Majoranas *not* at the wire end





Quasi-Majoranas *not* at the wire end





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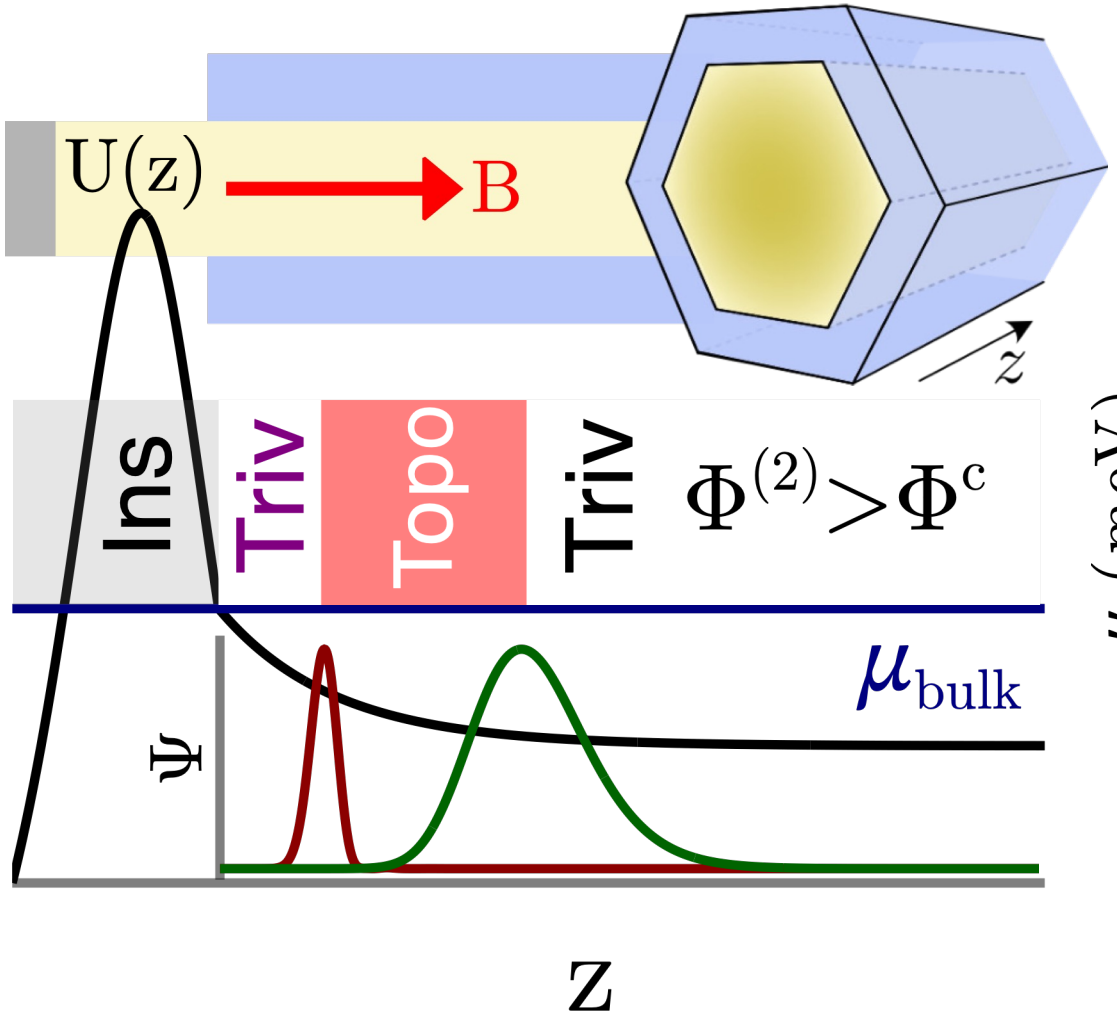

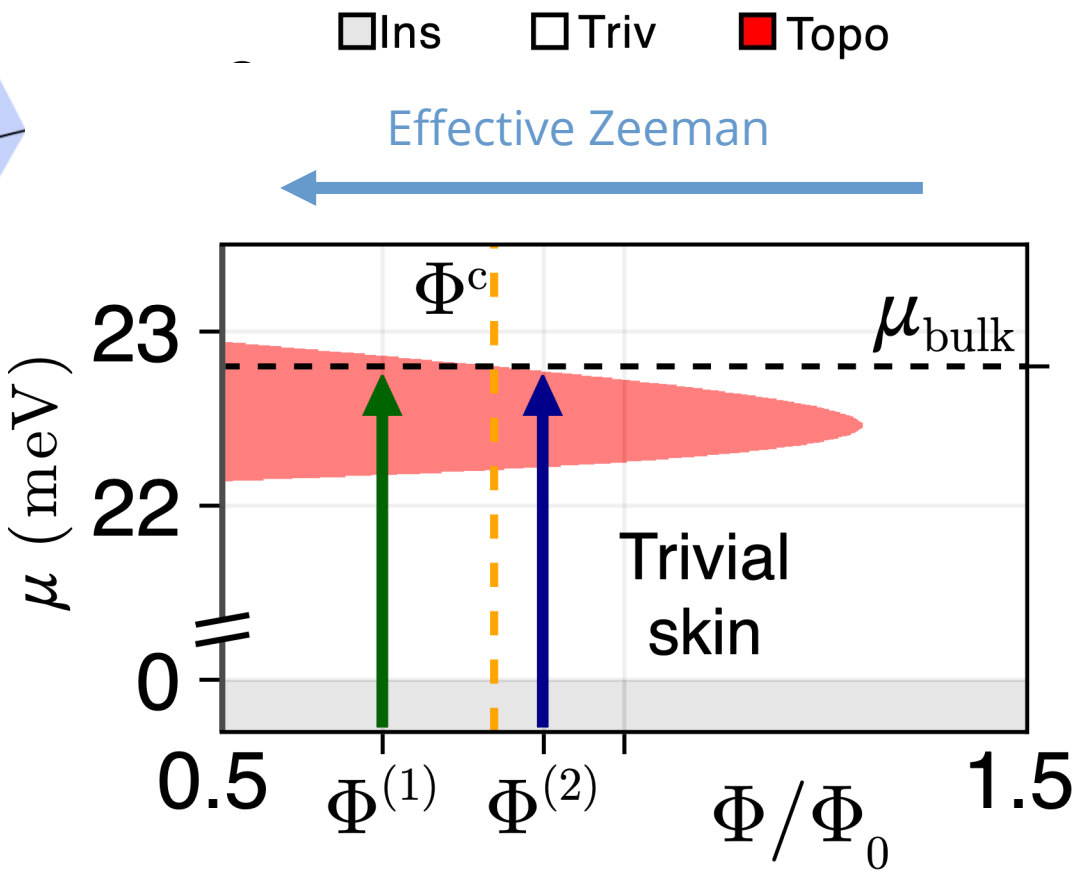

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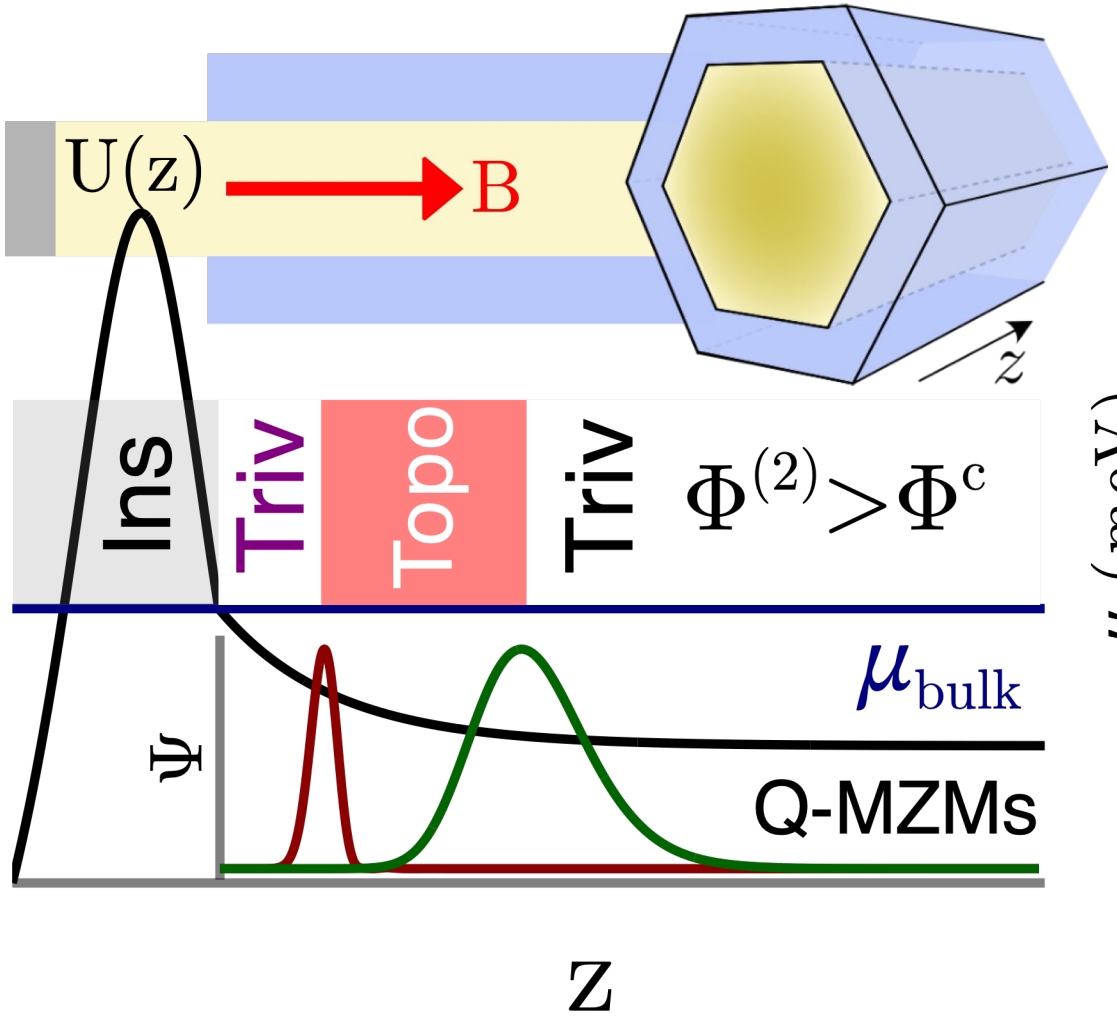
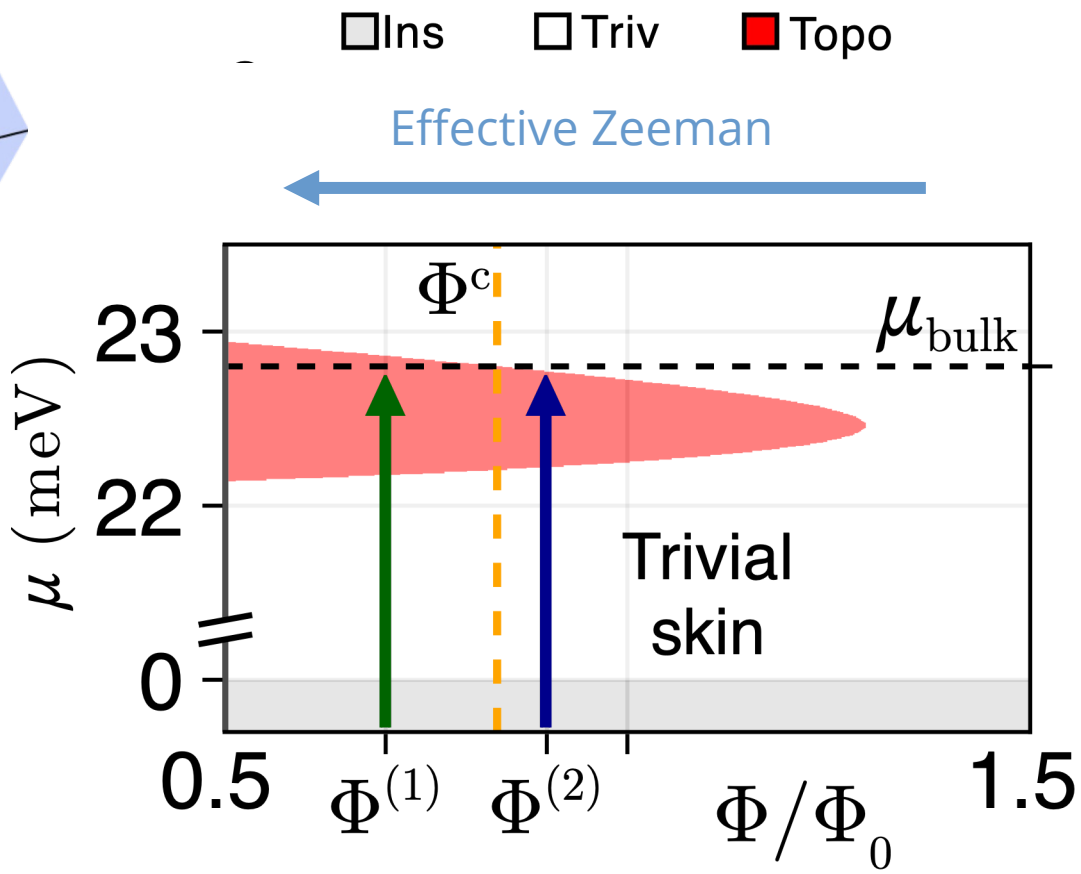
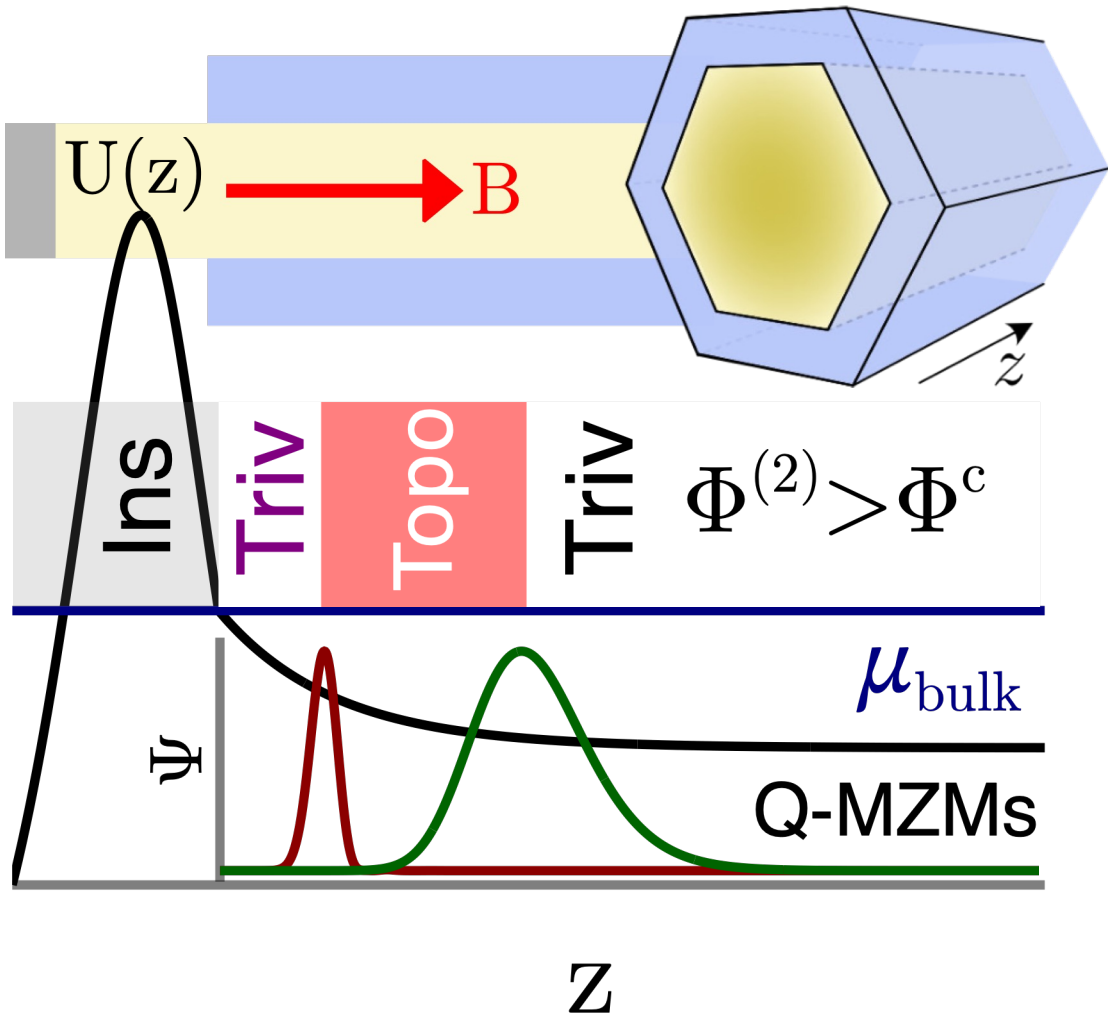
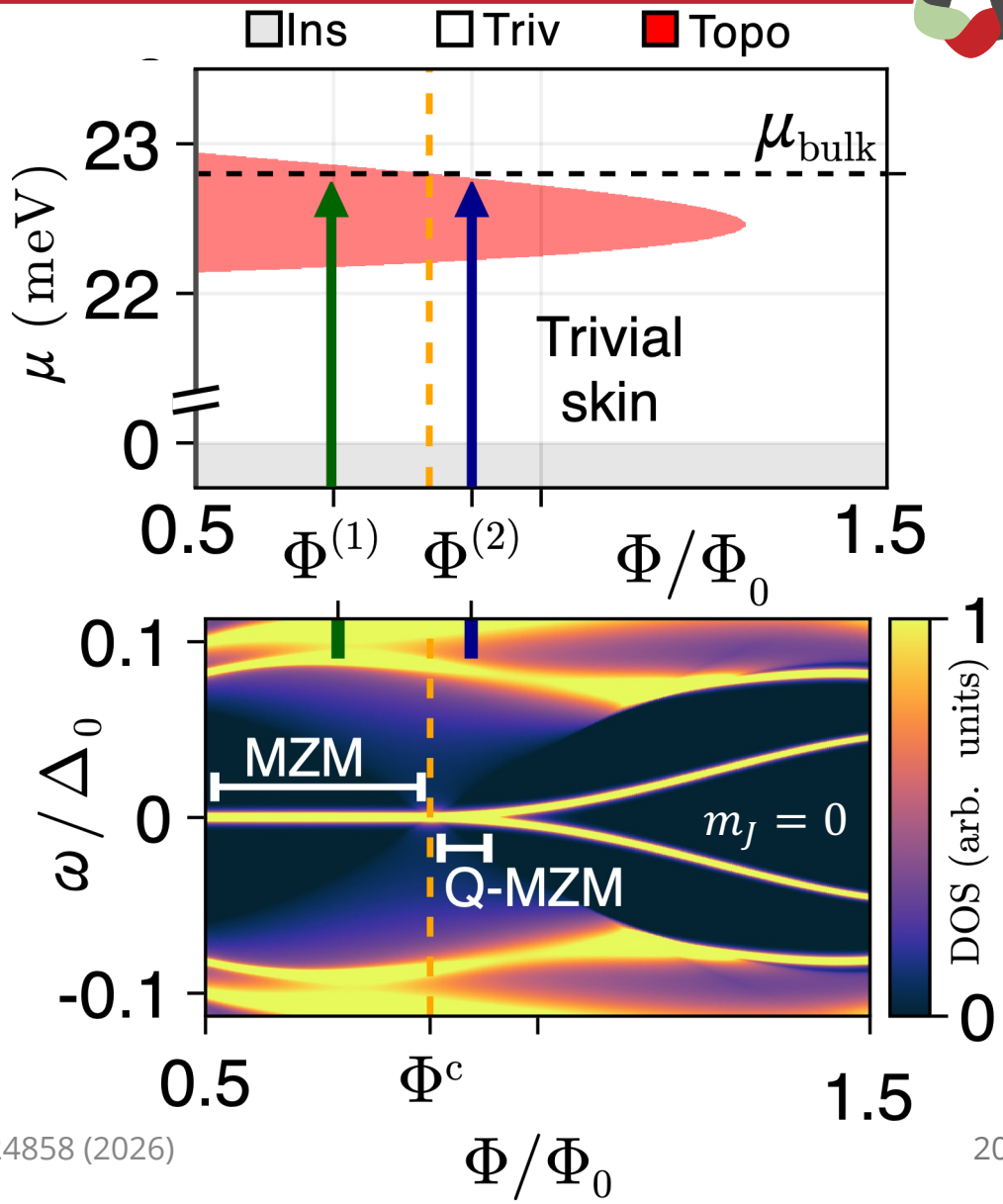


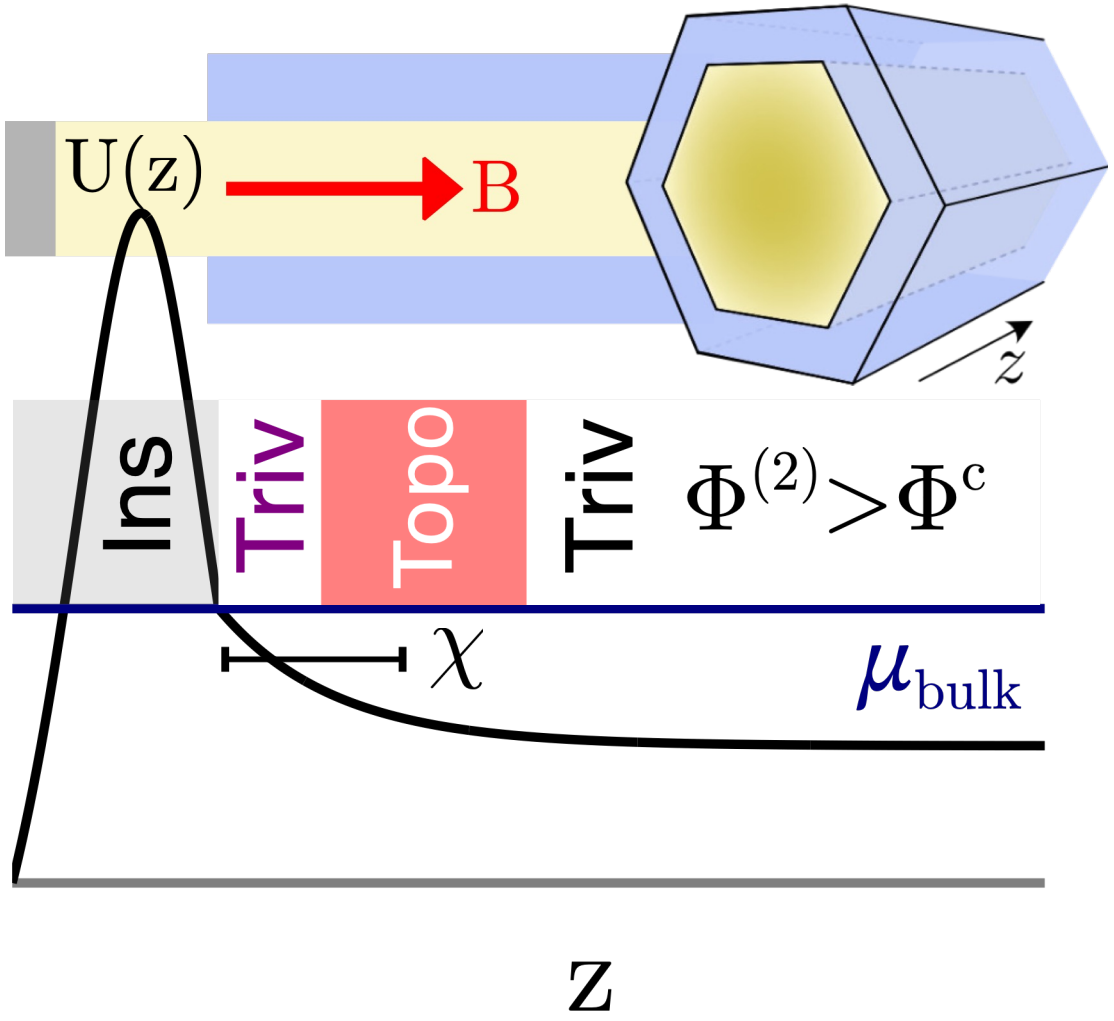


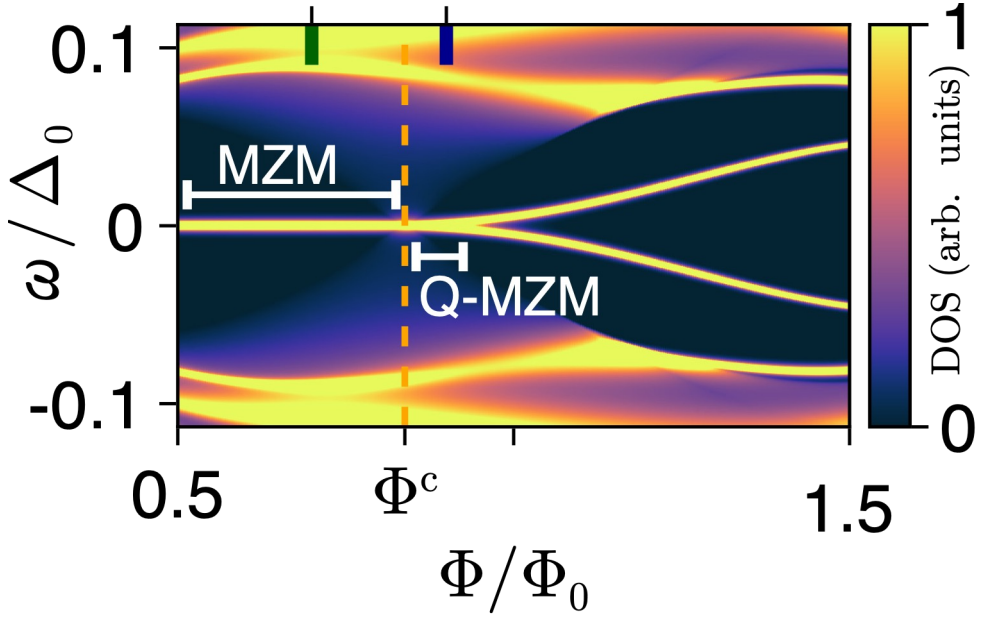
Zero bias peaks in full-shells





Barrier smoothness: the key factor





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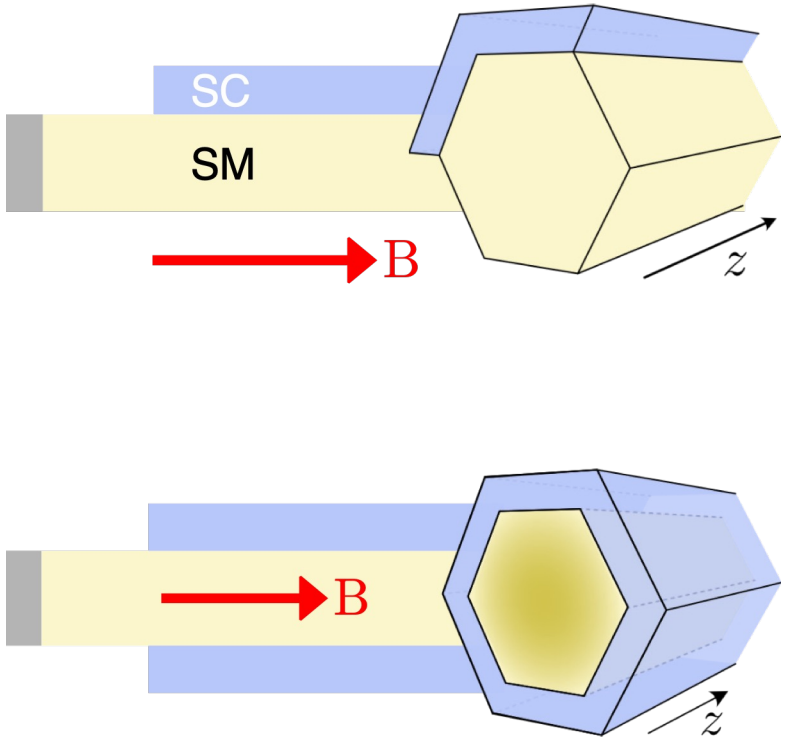
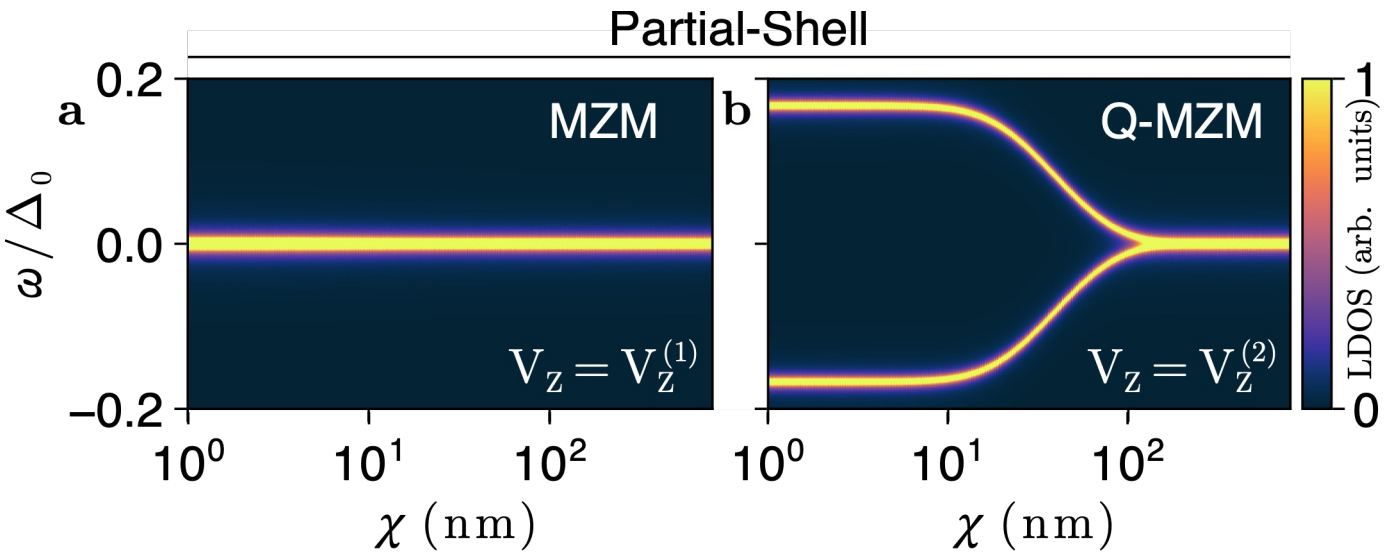
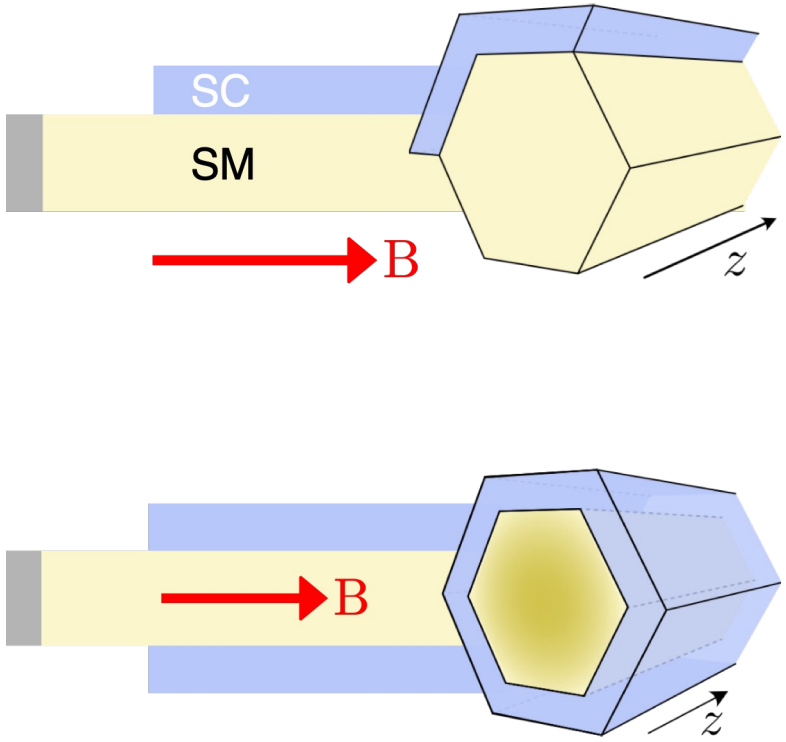
- Where is the topo transition
- Formation of Q-MZM ZBP

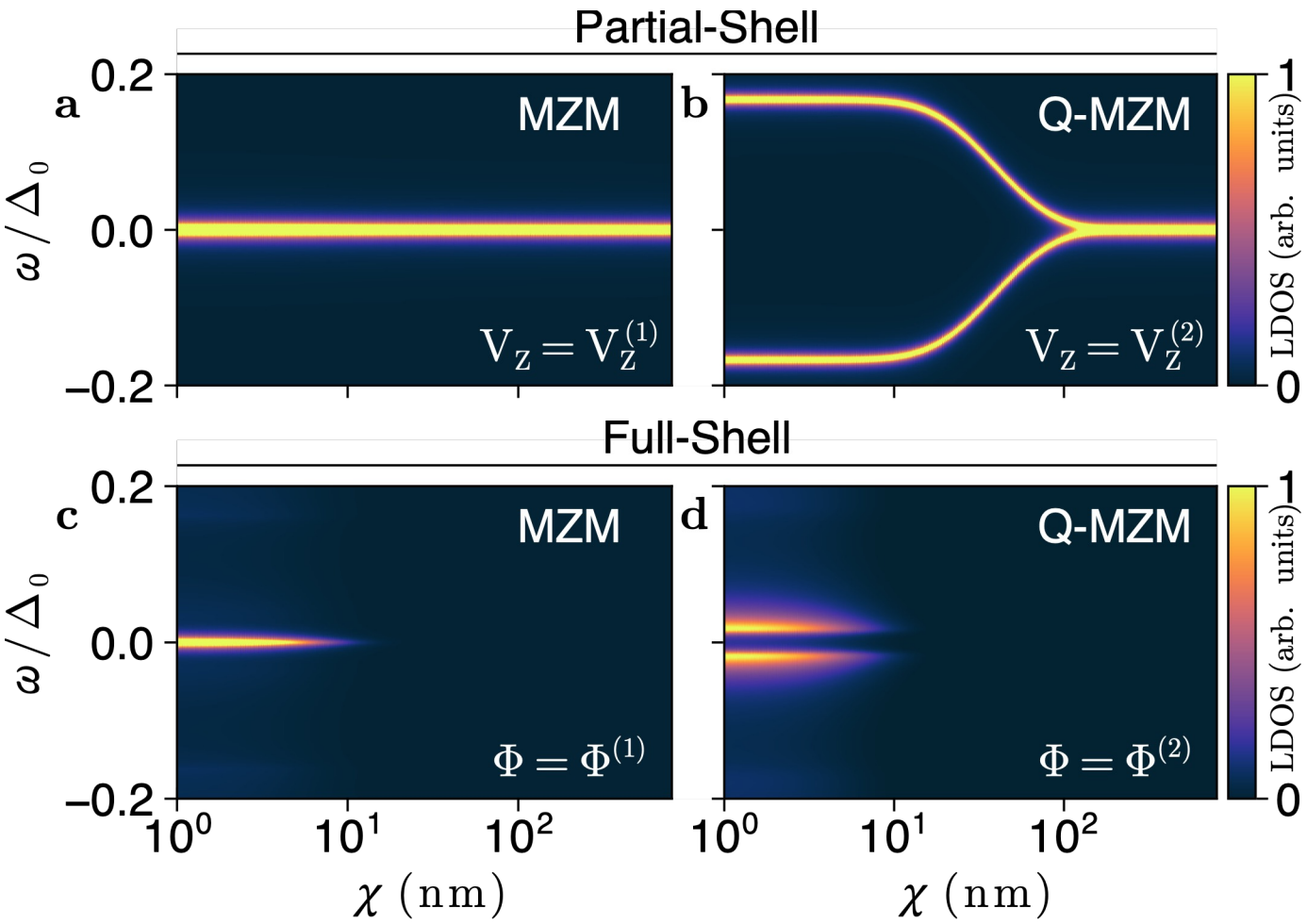
False-positives in partial-shells



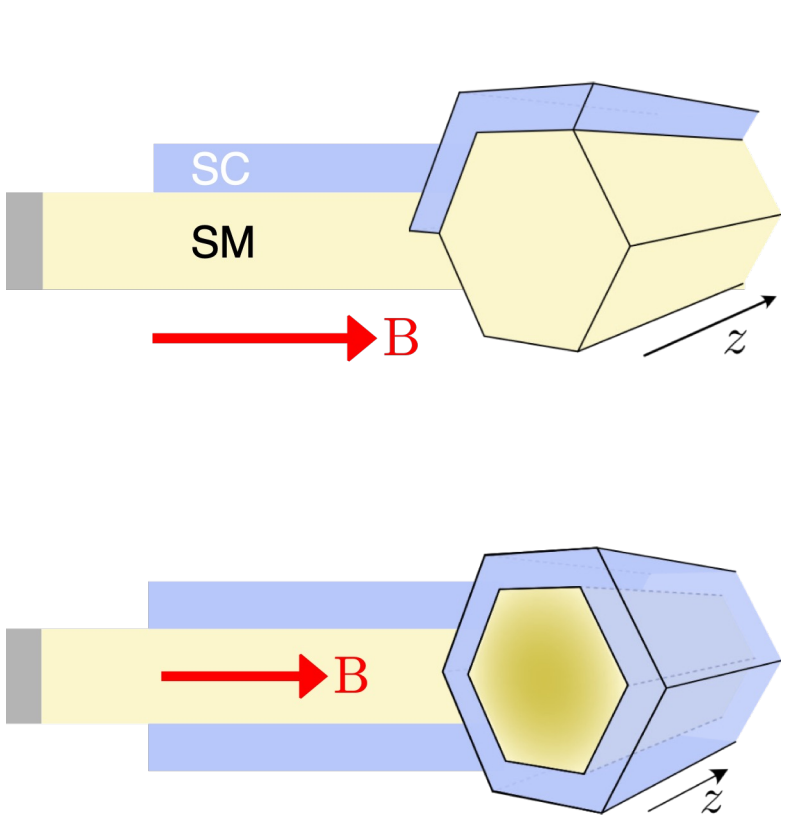


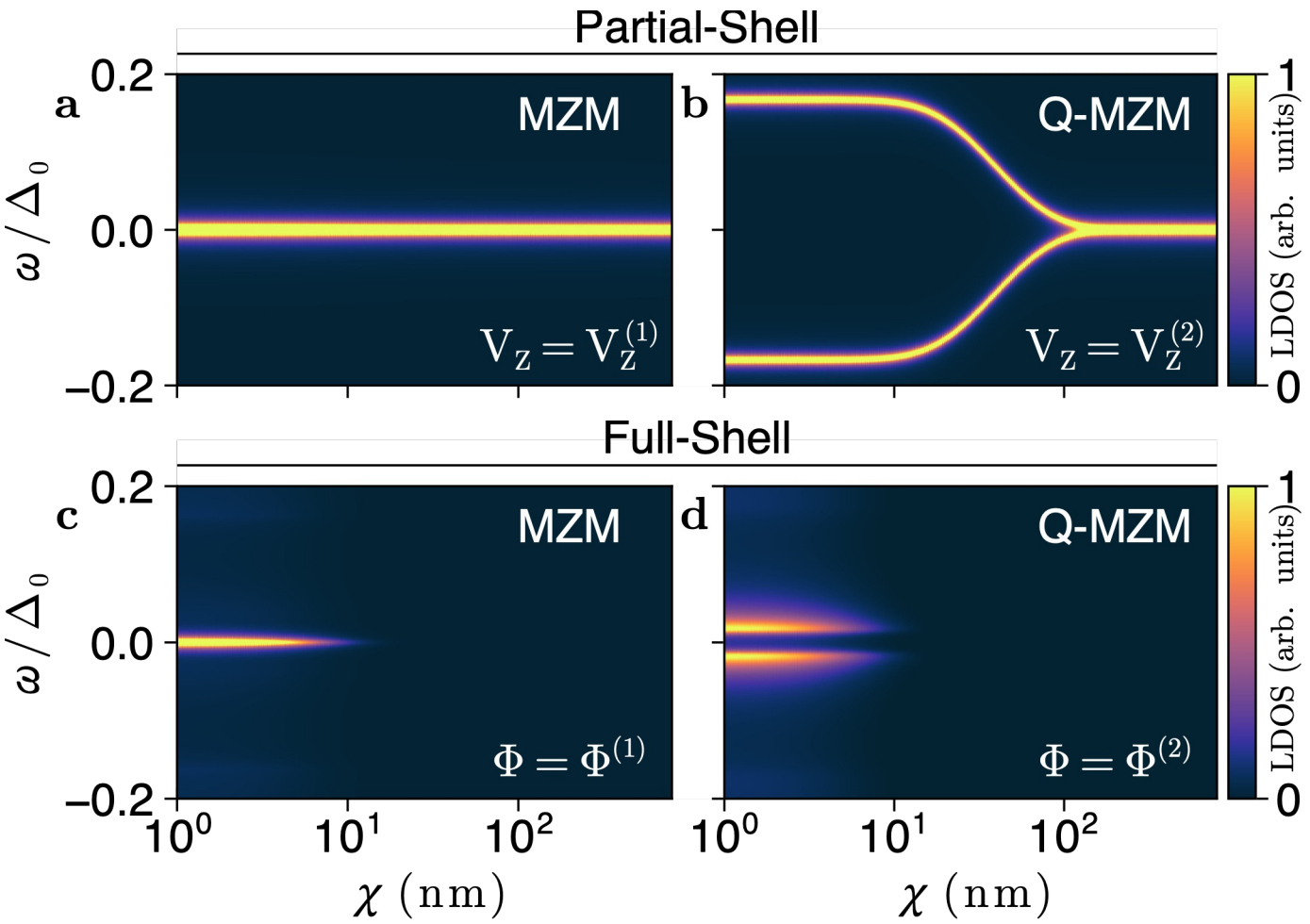
False-positives in full-shells????





Absence of false-positives in full-shells





Absence of false-positives in full-shells

1. Full-shell hybrid nanowires act as synthetic vortices that enclose CdGM analog states

2. When a magnetic flux induces a topological superconducting state, (quasi-) Majorana Zero Modes at the wire's ends coexist with these CdGM analogs.

3. Smooth electrostatic potentials generate Quasi-Majorana Zero Modes that mimic true MZMs by pinning to zero energy.

4. Unlike partial-shell devices, full-shell nanowires naturally create a "trivial skin" at the wire's ends due to non-topological modes (CdGMs)

5. This trivial skin physically prevents local probes from detecting impostor Q-MZMs.

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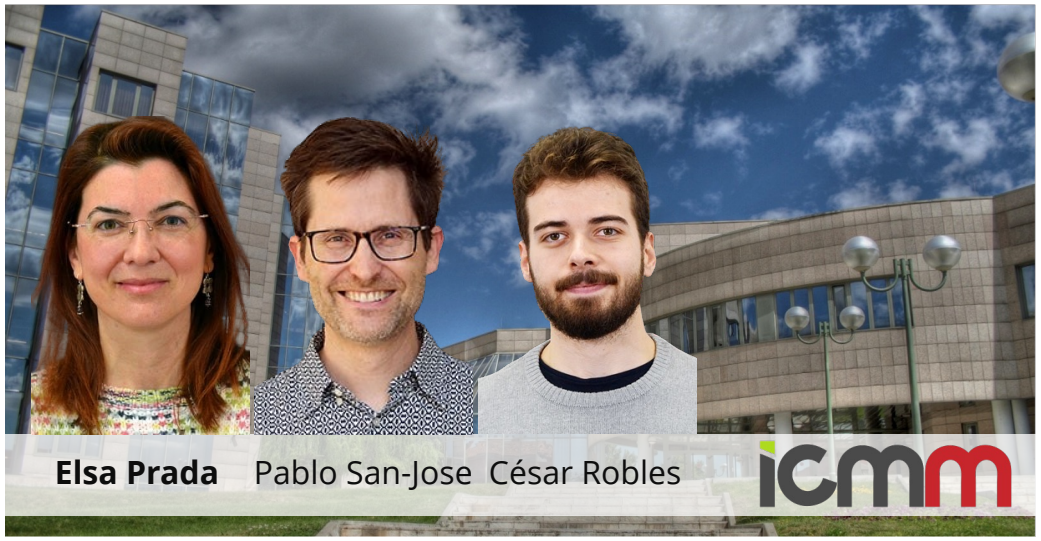
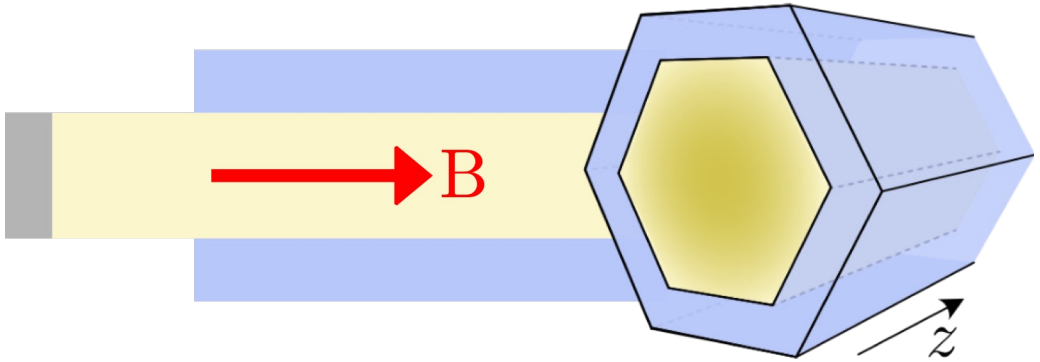
When interpreting pinned Zero-Energy Peaks (ZEPs) in the tunneling spectroscopy of full-shell nanowires, the presence of CdGM analogs guarantees the absence of Q-MZM false positives.





Absence of quasi-Majorana false positives in full-shell hybrid nanowires

Carlos Payá

Super-Semi Meeting, NBI – June 4th 2026

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