

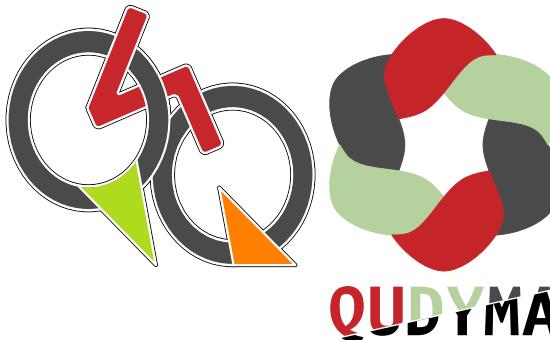
# Fluxoid valve effect in full-shell nanowire Josephson junctions

Carlos Payá

QTYR25 – July 8<sup>th</sup>, 2025



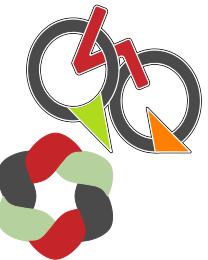
**CSIC**



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**icmm**

# About us



## Collaborators:

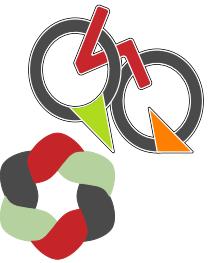


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### Fluxoid Valve Effect in Full-Shell Nanowire Josephson Junctions

Carlos Payá, F. J. Matute-Cañadas, A. Levy Yeyati, Ramón Aguado, Pablo San-Jose, Elsa Prada  
[arXiv:2504.16989 \(2025\)](https://arxiv.org/abs/2504.16989)

**Josephson effect and critical currents in trivial and topological full-shell hybrid nanowires**  
Carlos Payá, Ramón Aguado, Pablo San-Jose, Elsa Prada  
[Phys. Rev. B 111, 235420 \(2025\)](https://doi.org/10.1103/PhysRevB.111.235420)



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Full-shell nanowire junctions can work as  
**magnetic-field controlled supercurrent valves**

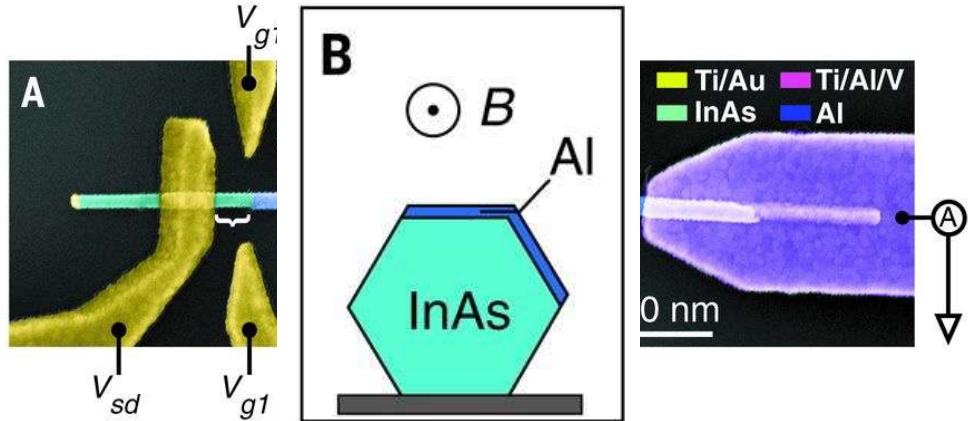
How does **radii mismatch** in a full-  
shell junction affect the  
supercurrent?

What about Majoranas?

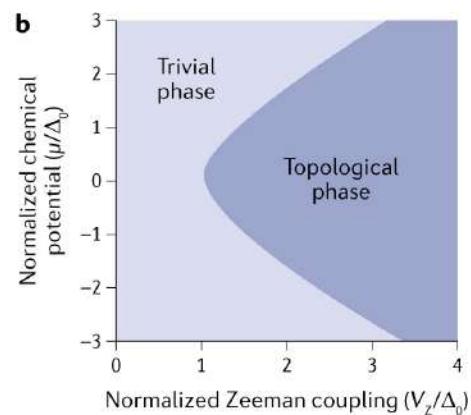
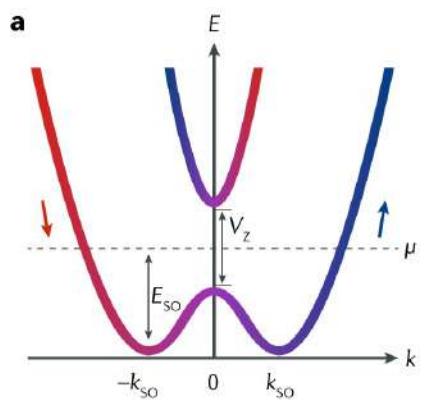
# Why do we care about full-shells?



Partial-shell

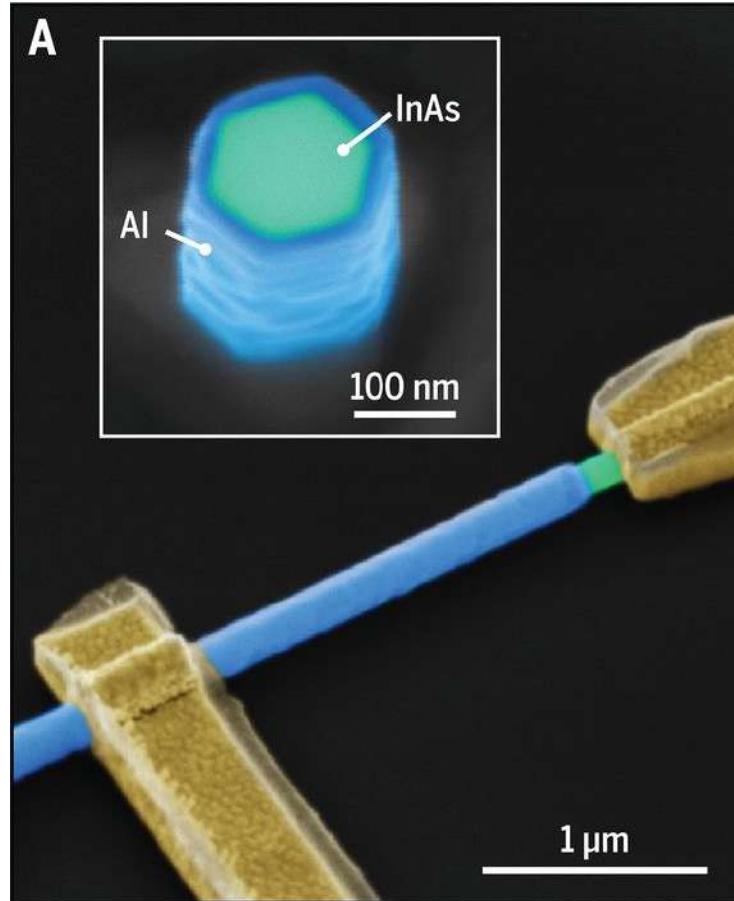


M. T. Deng et al. *Science* 354, 6319 (2016)



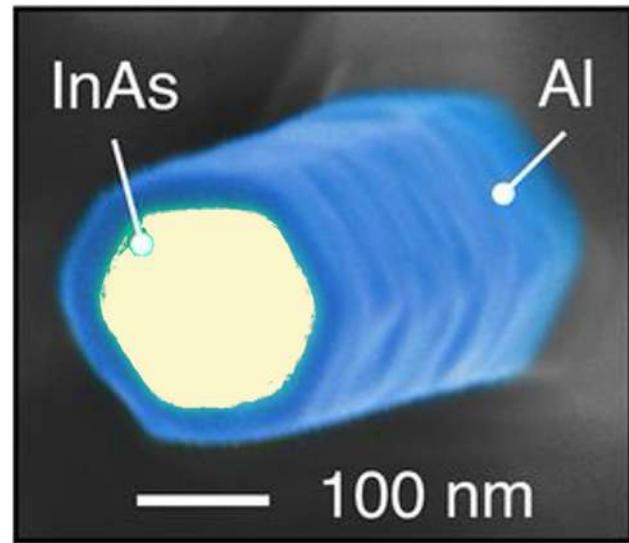
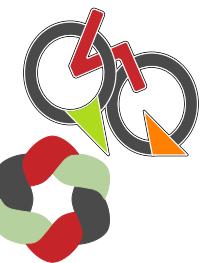
R. M. Lutchyn et al. *Nature Reviews Materials* 3, 52–68 (2018)

Full-shell

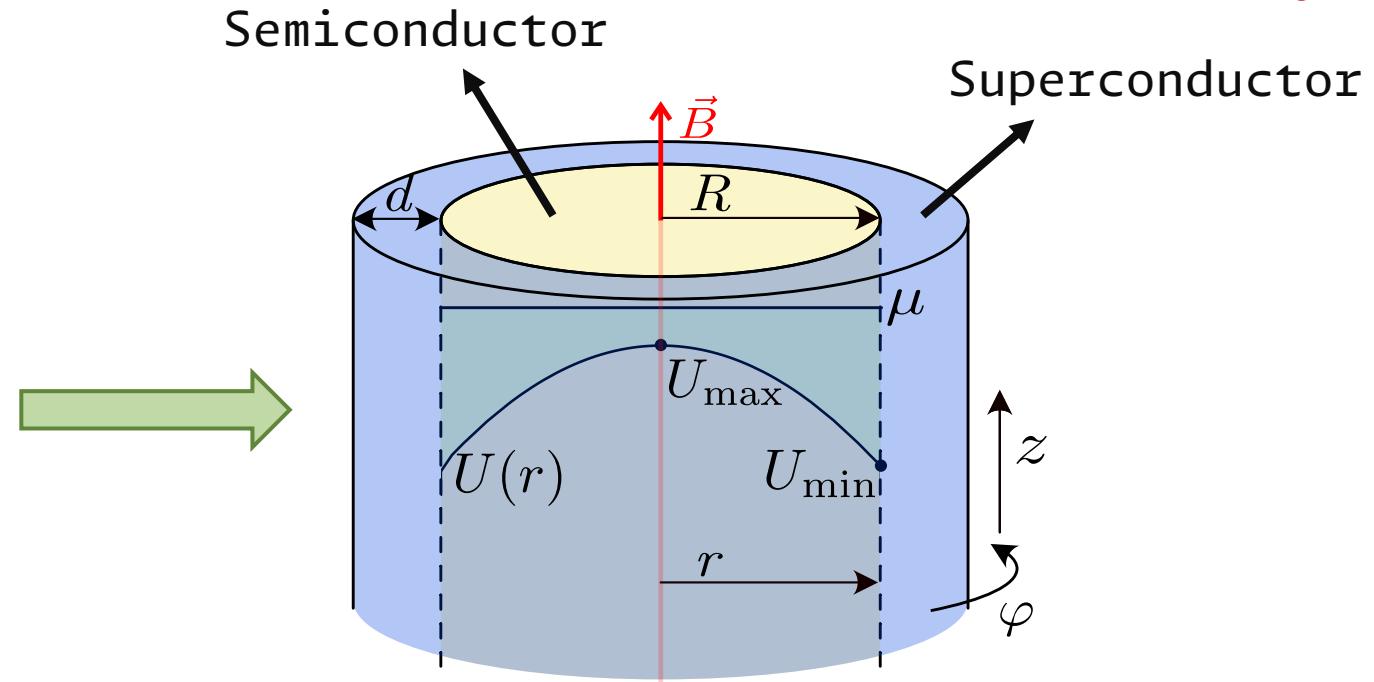


S. Vaitiekėnas et al. *Science* 367, 1442 (2020)

# A full-shell hybrid nanowire



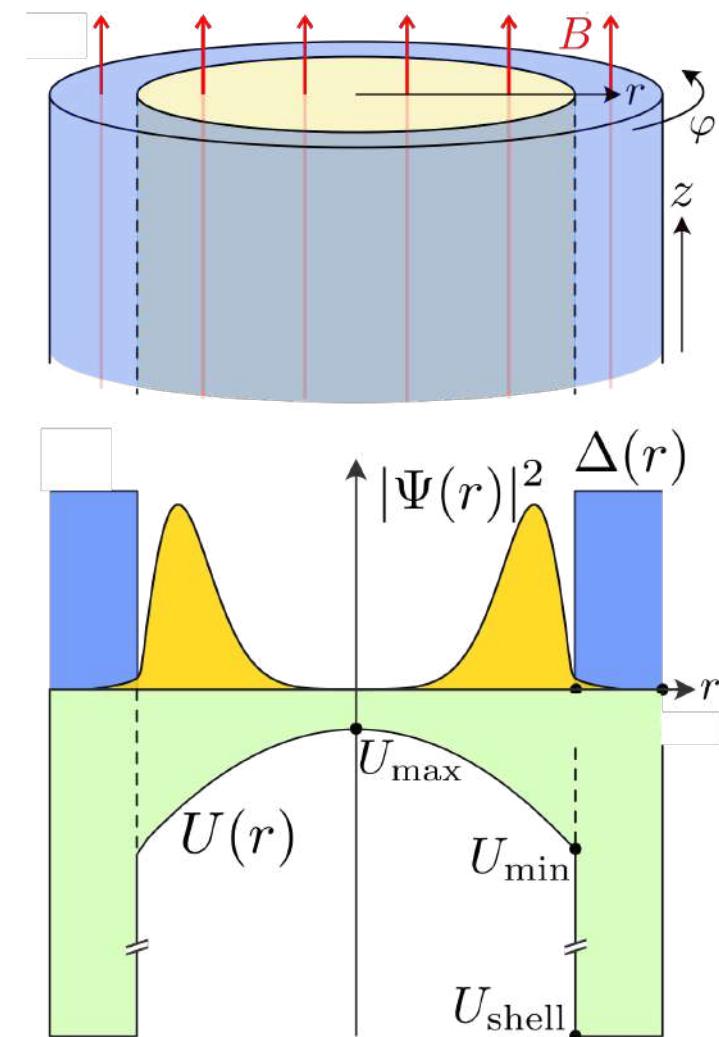
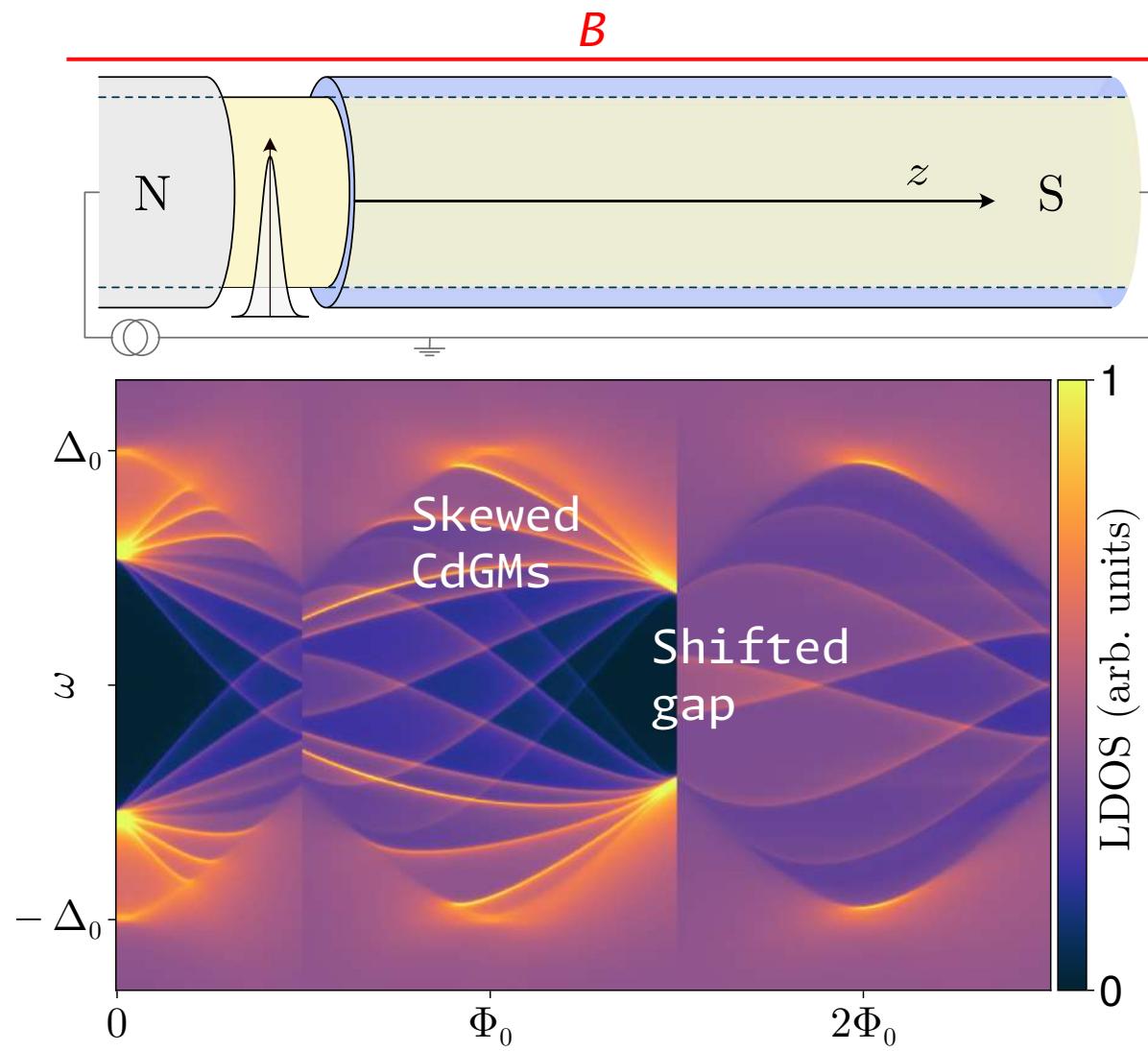
S. Vaitiekėnas et al., Science, 2020



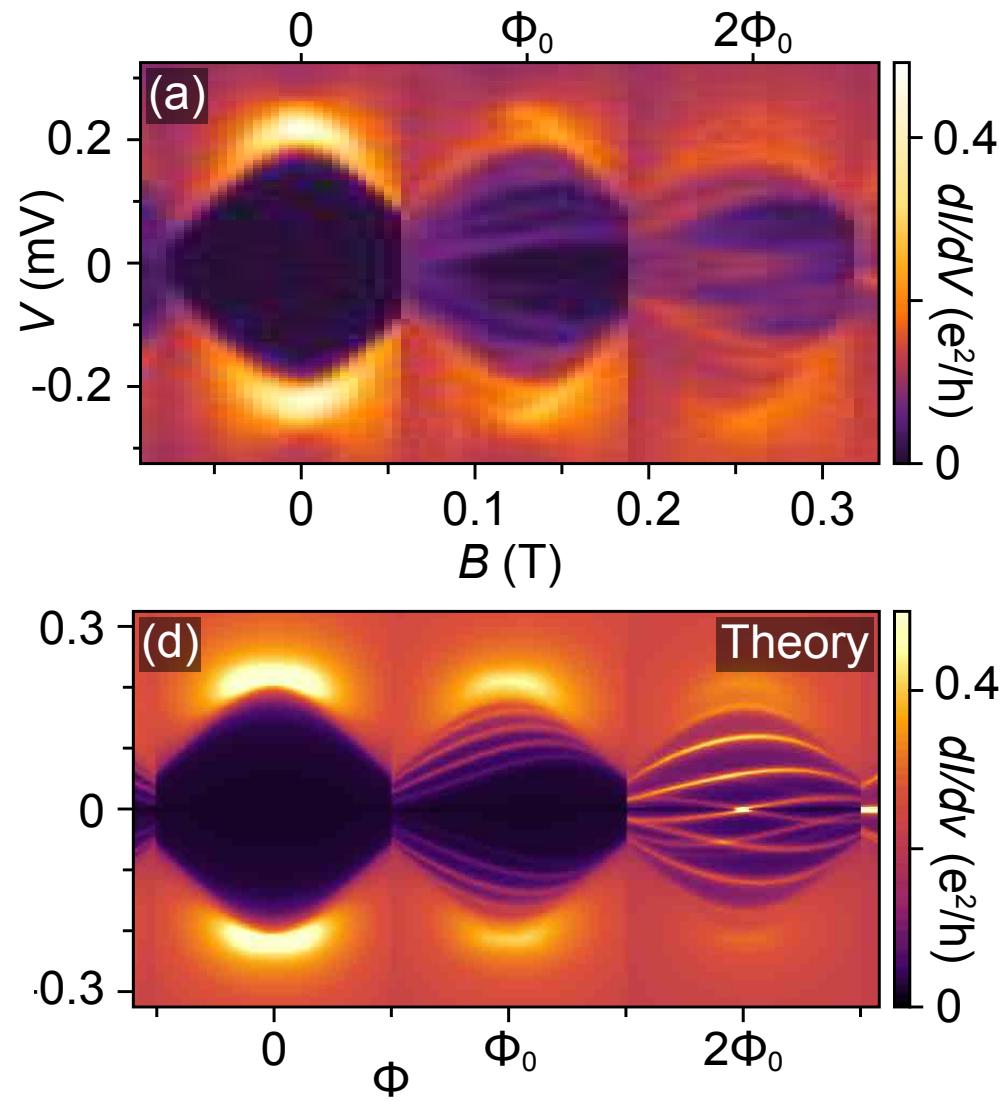
- Topological at lower magnetic fields
- Protected from charge noise

- Cylindrical symmetry
- Charge at interface
- SOC induced by band bending

# Sub-gap levels skewness at the edge



# CdGMs experimental demonstration



## Caroli-de Gennes-Matricon Analogs in Full-Shell Hybrid Nanowires

M. T. Deng, Carlos Payá, Pablo San-Jose, Elsa Prada, C. M. Marcus, S. Vaitiekėnas  
Phys. Rev. Lett. 134, 206302 (2025)



PRL



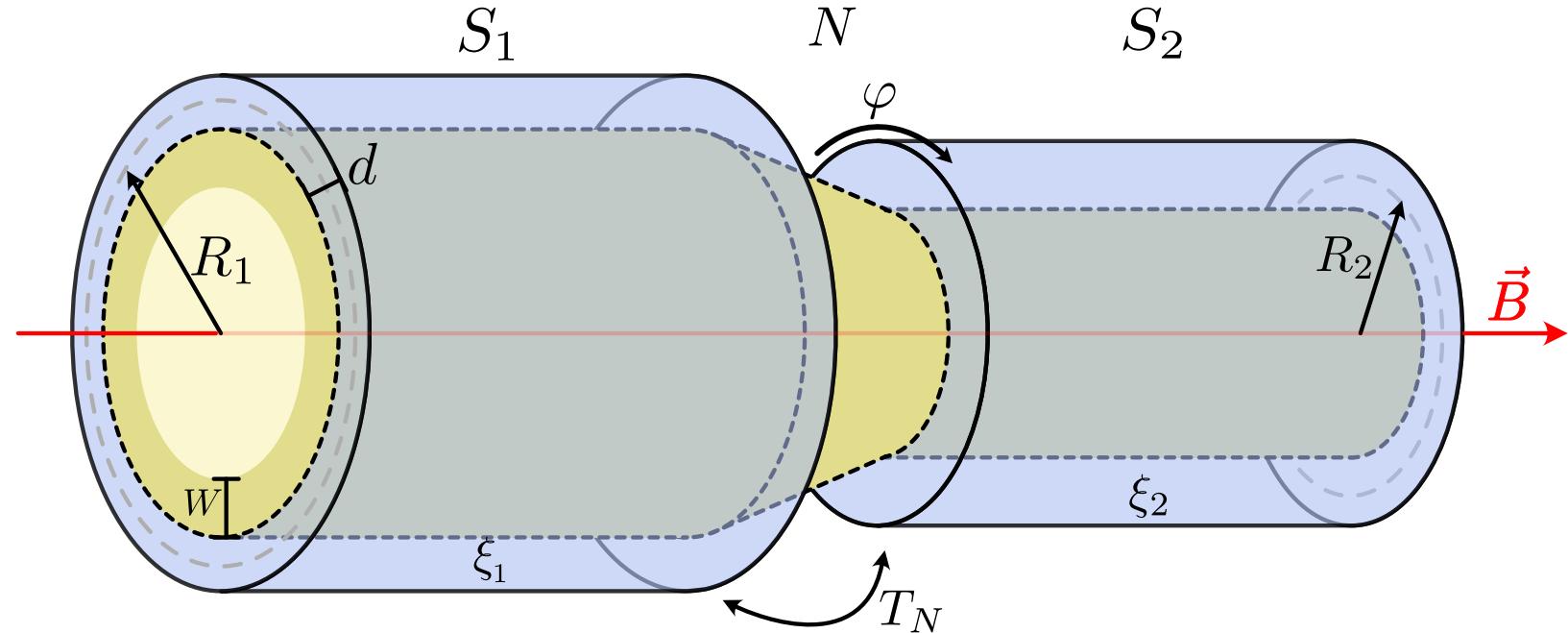
UNIVERSITY OF  
COPENHAGEN



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**What happens in a Josephson junction  
with different radii?**

# A full-shell Josephson junction

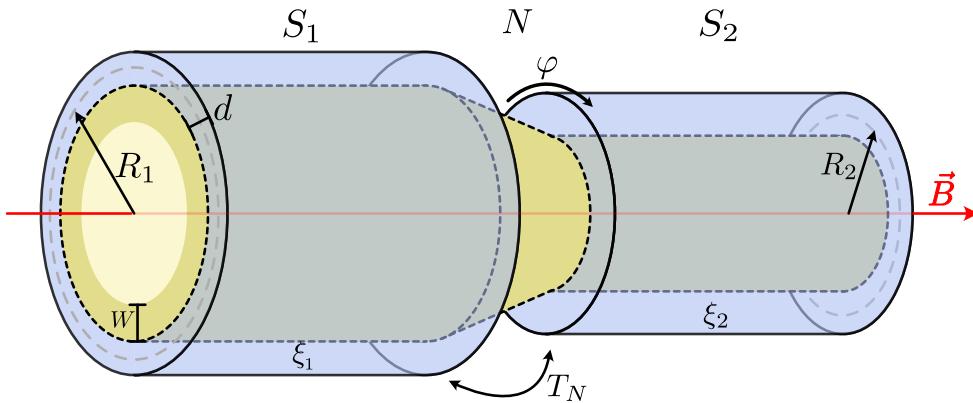


- Short junction,  $L_N \ll \xi_{SC}$
- Controlled transparency  $T_N$
- No voltage bias  $\Rightarrow$  dc Josephson

# Fluxoid mismatch blocks current



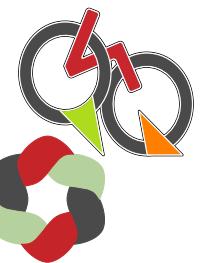
$$n_1 = \left\lfloor \frac{\pi R_1^2 B}{\Phi_0} \right\rfloor$$



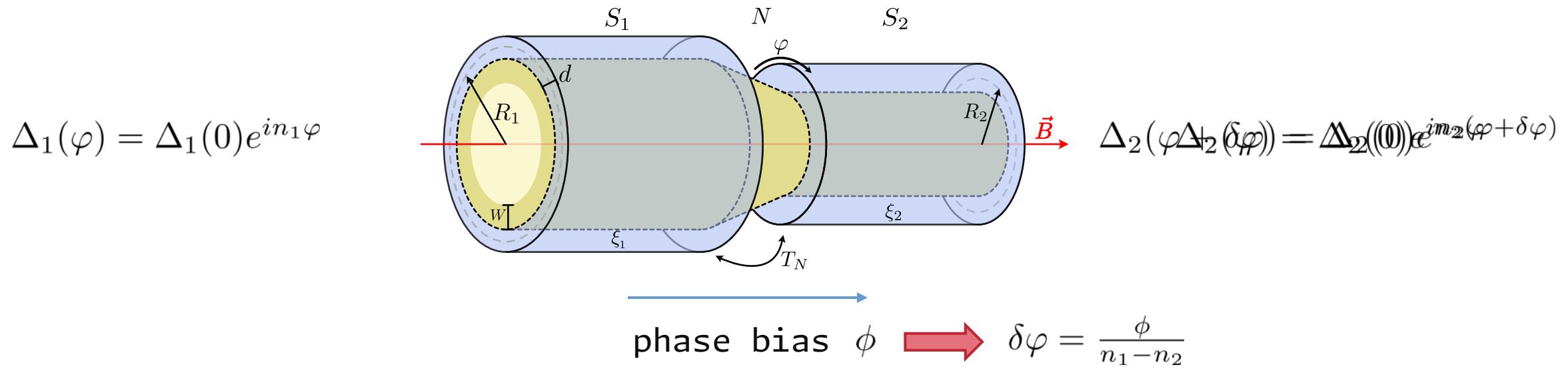
$$n_2 = \left\lfloor \frac{\pi R_2^2 B}{\Phi_0} \right\rfloor$$

No current flow if  $n_1 \neq n_2$

# Fluxoid mismatch blocks current



No current flow if  $n_1 \neq n_2$



But there is cylindrical symmetry!  $\rightarrow \delta\varphi$  cannot change the free energy

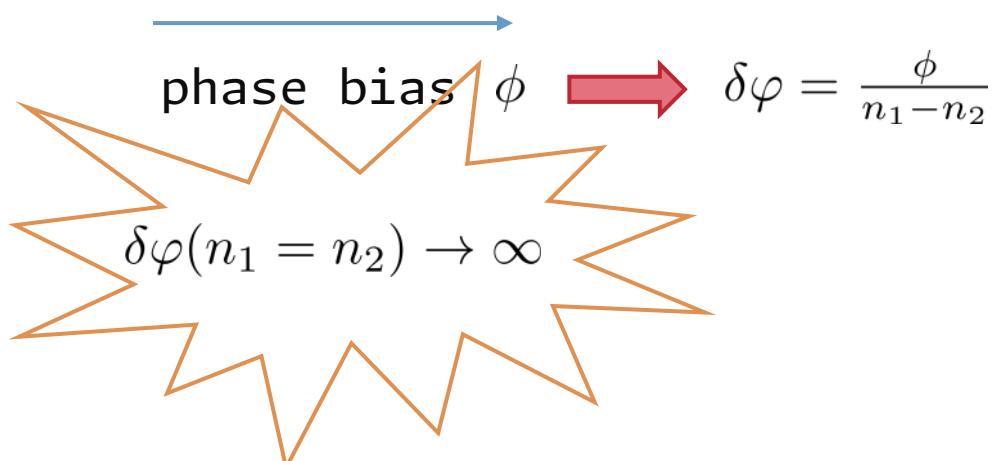
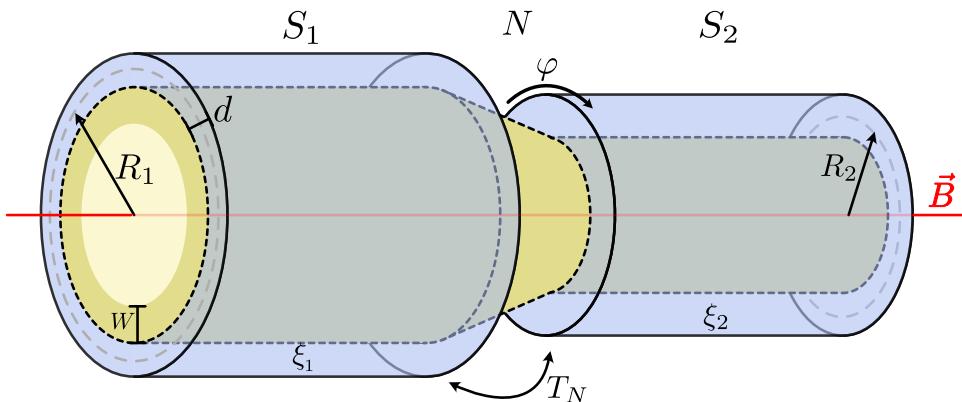
$$\partial_\phi F(\phi) = 0 \Rightarrow J = 0$$

# Fluxoid mismatch blocks current

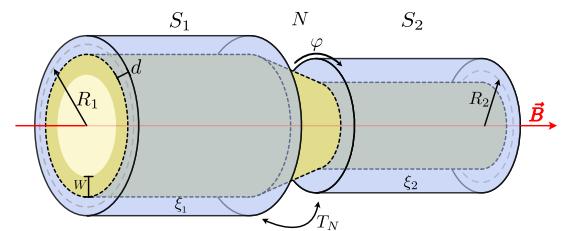
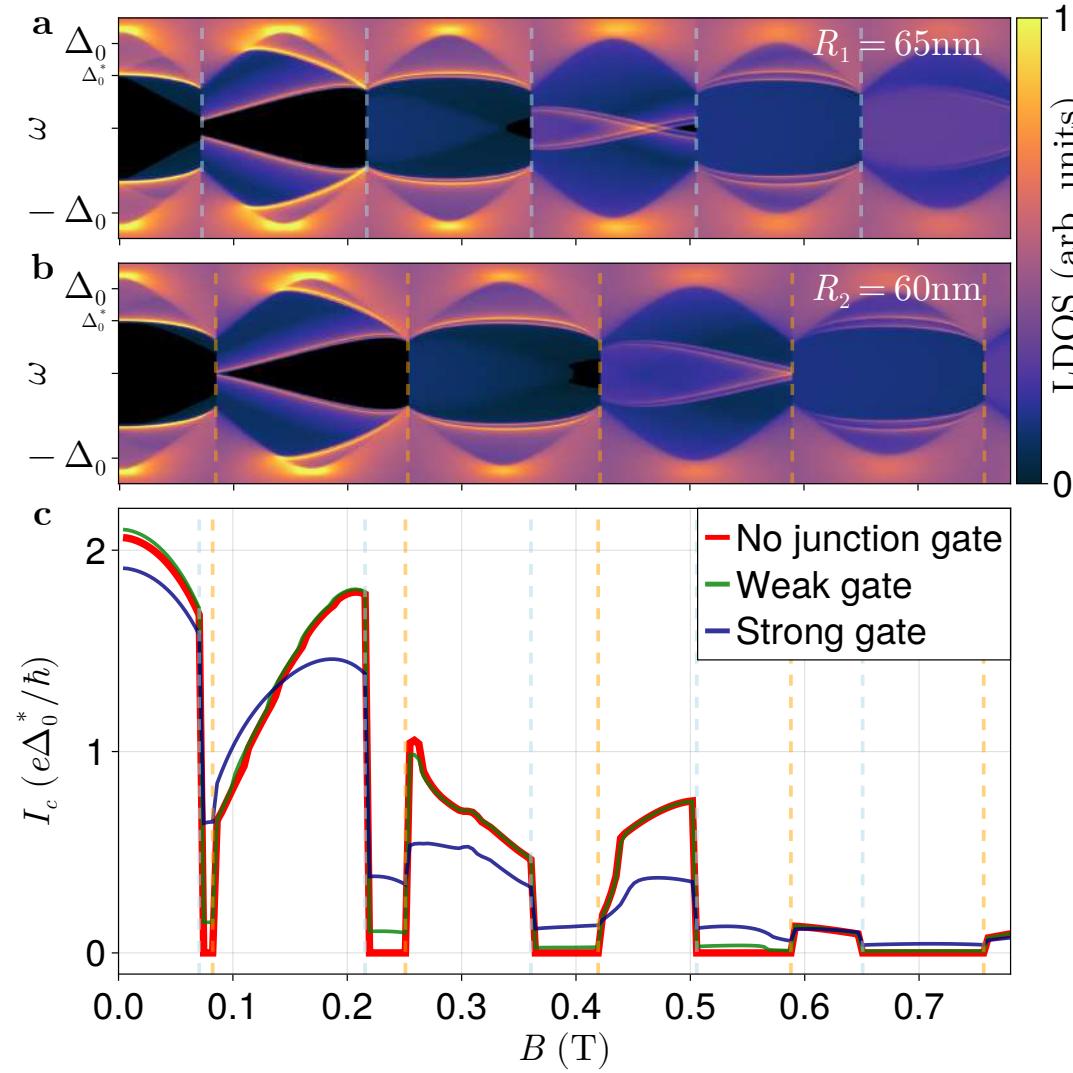


Current flows if  $n_1 = n_2$

$$\Delta_1(\varphi) = \Delta_1(0)e^{in_1\varphi} \quad \text{and} \quad \Delta_2(\varphi + \delta\varphi) = \Delta_2(0)e^{n_2(\varphi + \delta\varphi)}$$



# Fluxoid valve effect



Worsens if symmetry is broken

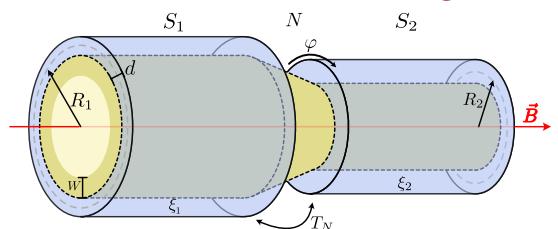
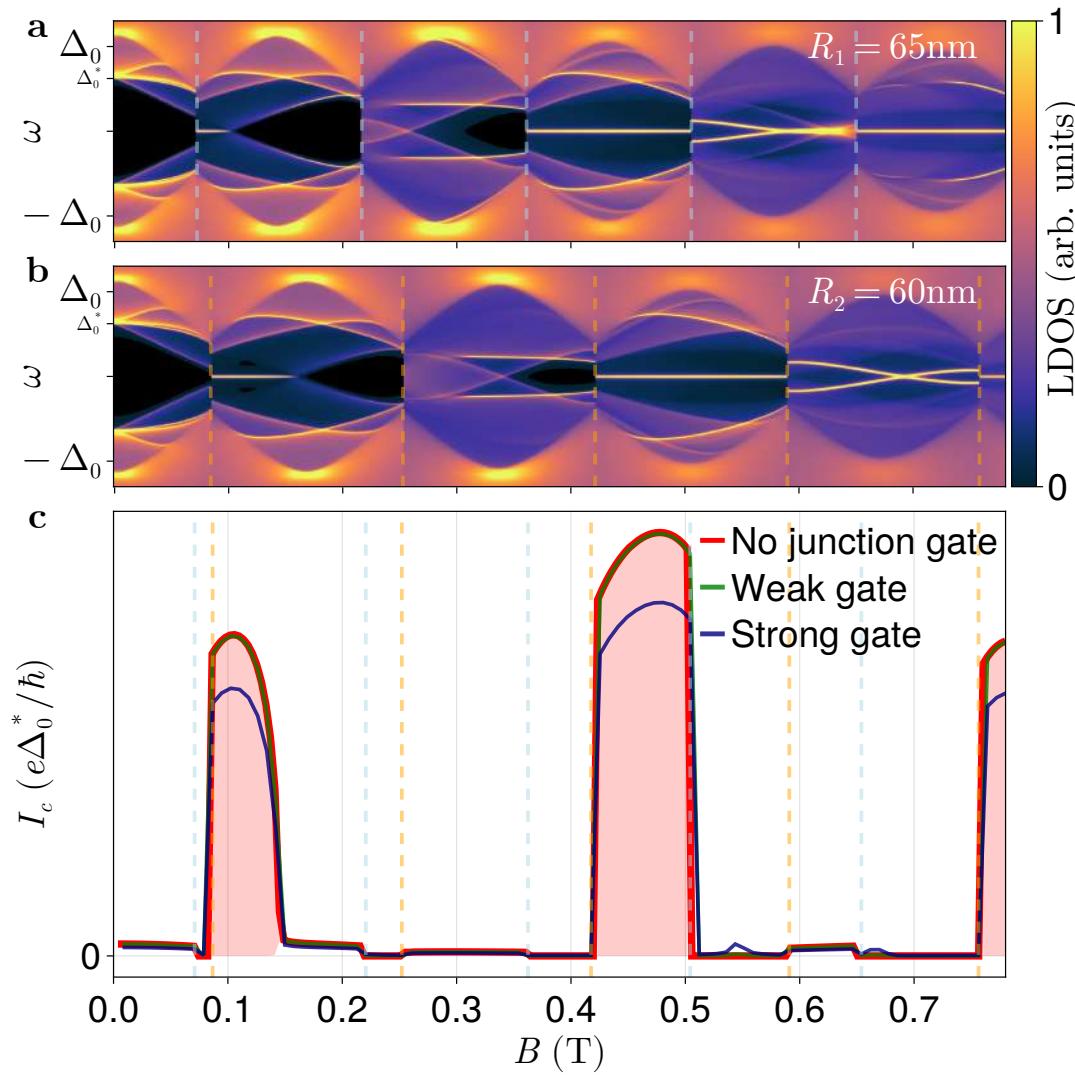


# What if there are Majoranas?

# Majoranas improve valve

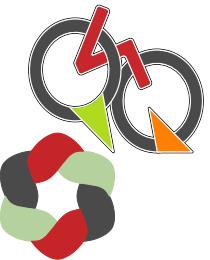


$T_N \rightarrow 0$



Majorana  
conductance  
goes with

$$\sqrt{T_N}$$



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## Full story here!

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arXiv:2504.16989 (2025)



Jesper Nygård



Eduardo Lee

## Experiments ongoing by



J. Nygård group,  
NBI, Copenhagen

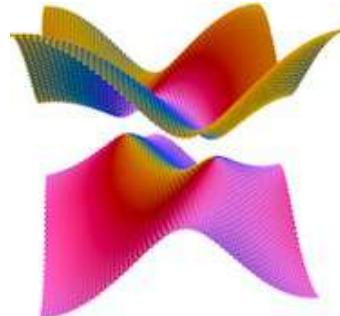
E. Lee group,  
IFIMAC, Madrid

**IfiMAC**  
Condensed Matter Physics Center

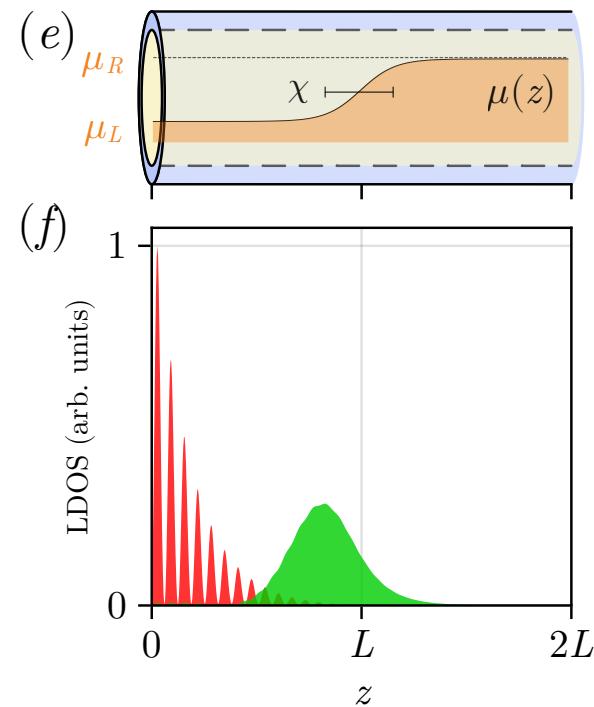
# SPAM!



**Chemical potential  
inhomogeneities...  
Fake Majoranas?!?**



Quantica.jl



Check poster!



[github.com/pablosanjose/Quantica.jl](https://github.com/pablosanjose/Quantica.jl)

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PID2021-125343NB-I00  
PRE2022-101362

