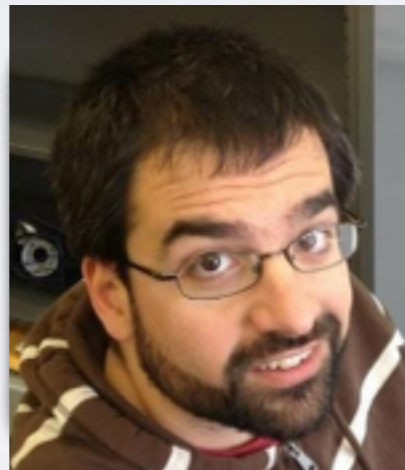


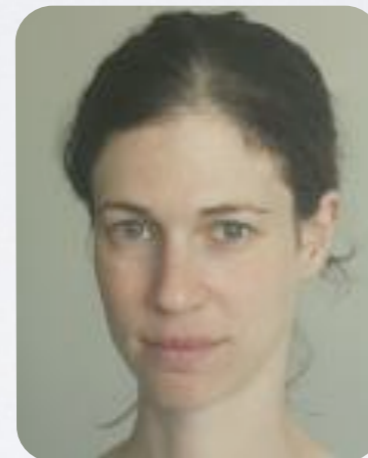
# TOPOLOGICAL INSULATOR NANOWIRES

**Jens Hjørleifur Bárðarson**

Max Planck Institute for the physics of complex systems — Dresden



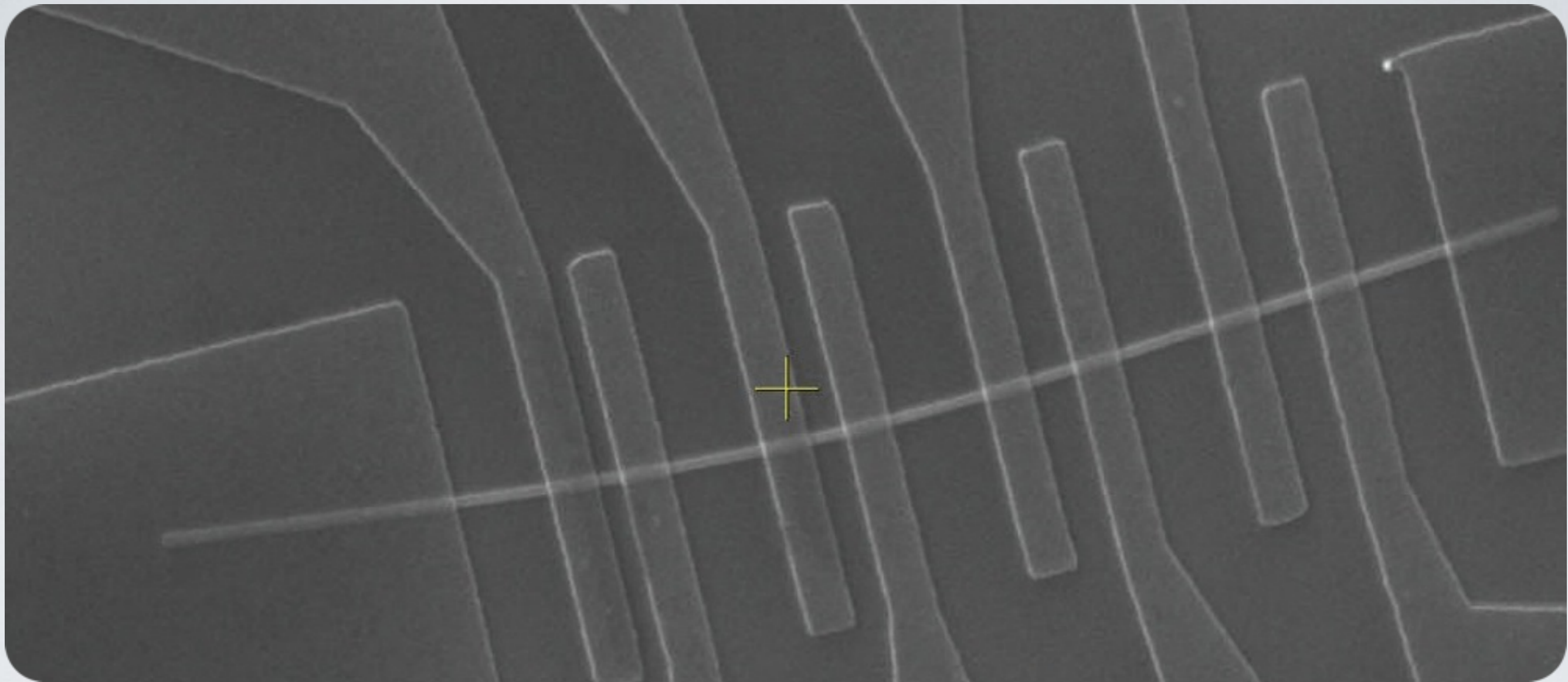
Fernando de Juan  
UC Berkeley

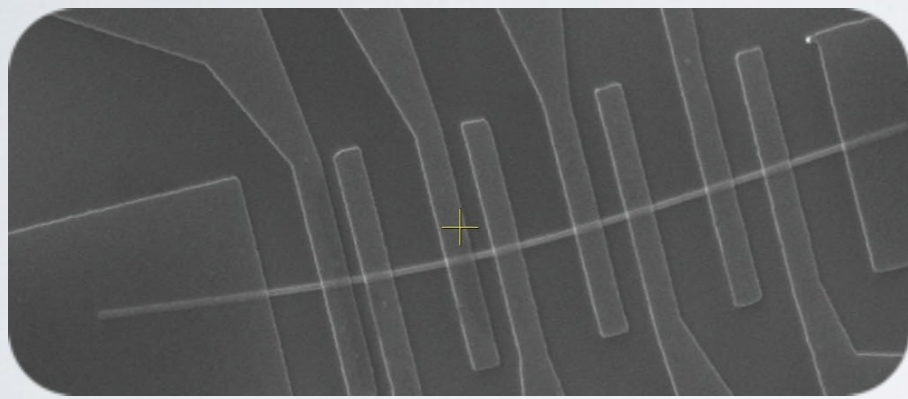


Roni Ilan  
UC Berkeley

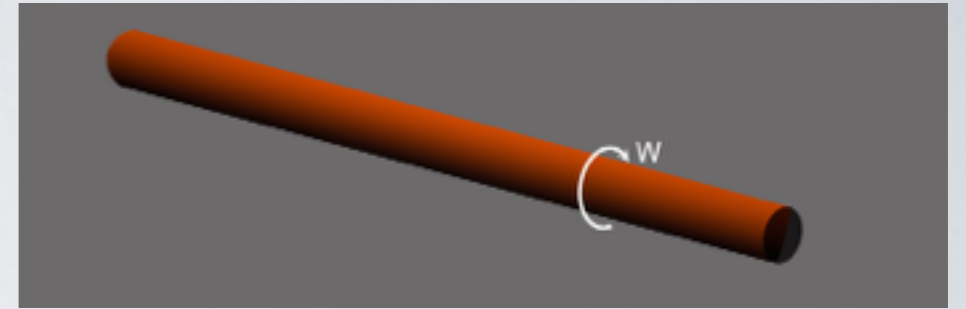
Main story: Robust Transport signatures of topological superconductivity in topological insulator nano wires

F. de Juan, R. Ilan, JHB — arXiv:1401.5832 (PRL in press)





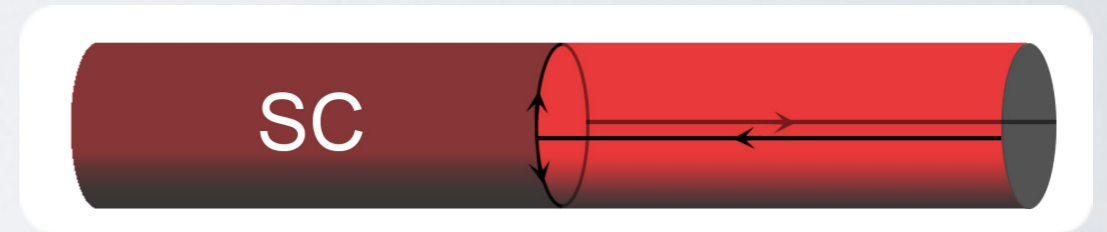
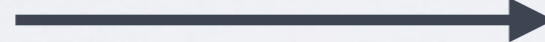
N - Ti - N



JHB, P.W. Brouwer, and J. E. Moore, PRL (2010)

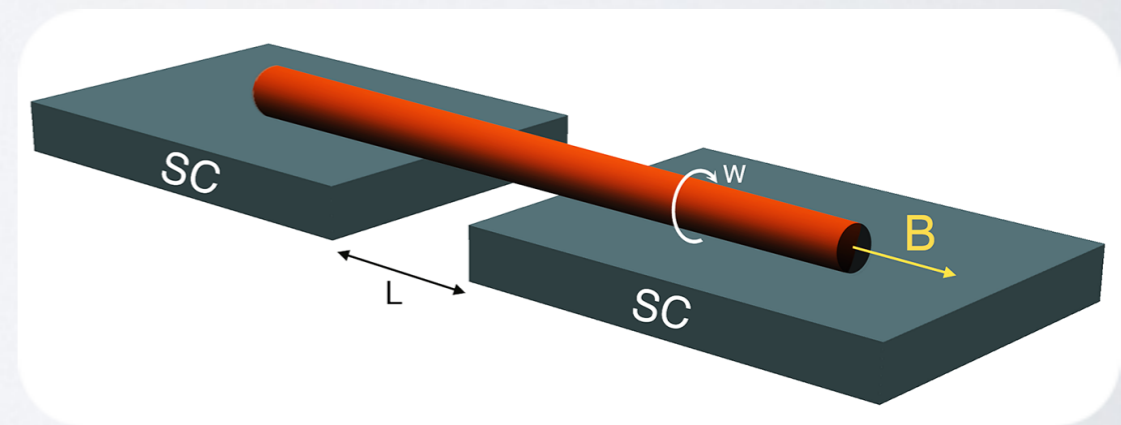
JHB and J. E. Moore, Rep. Prog. Phys (2013)

N - Ti - S



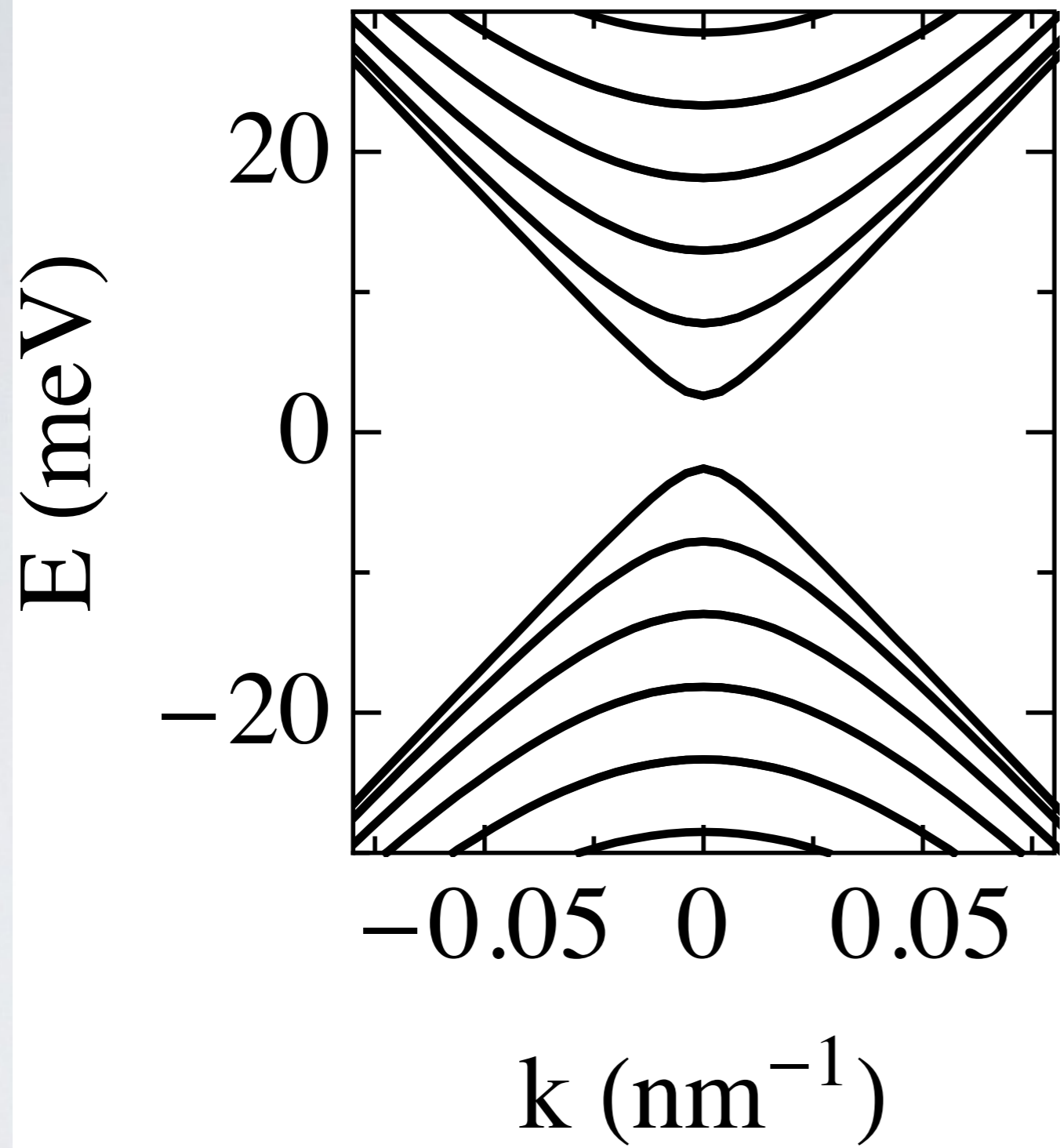
F. de Juan, R. Ilan and JHB PRL (2014)

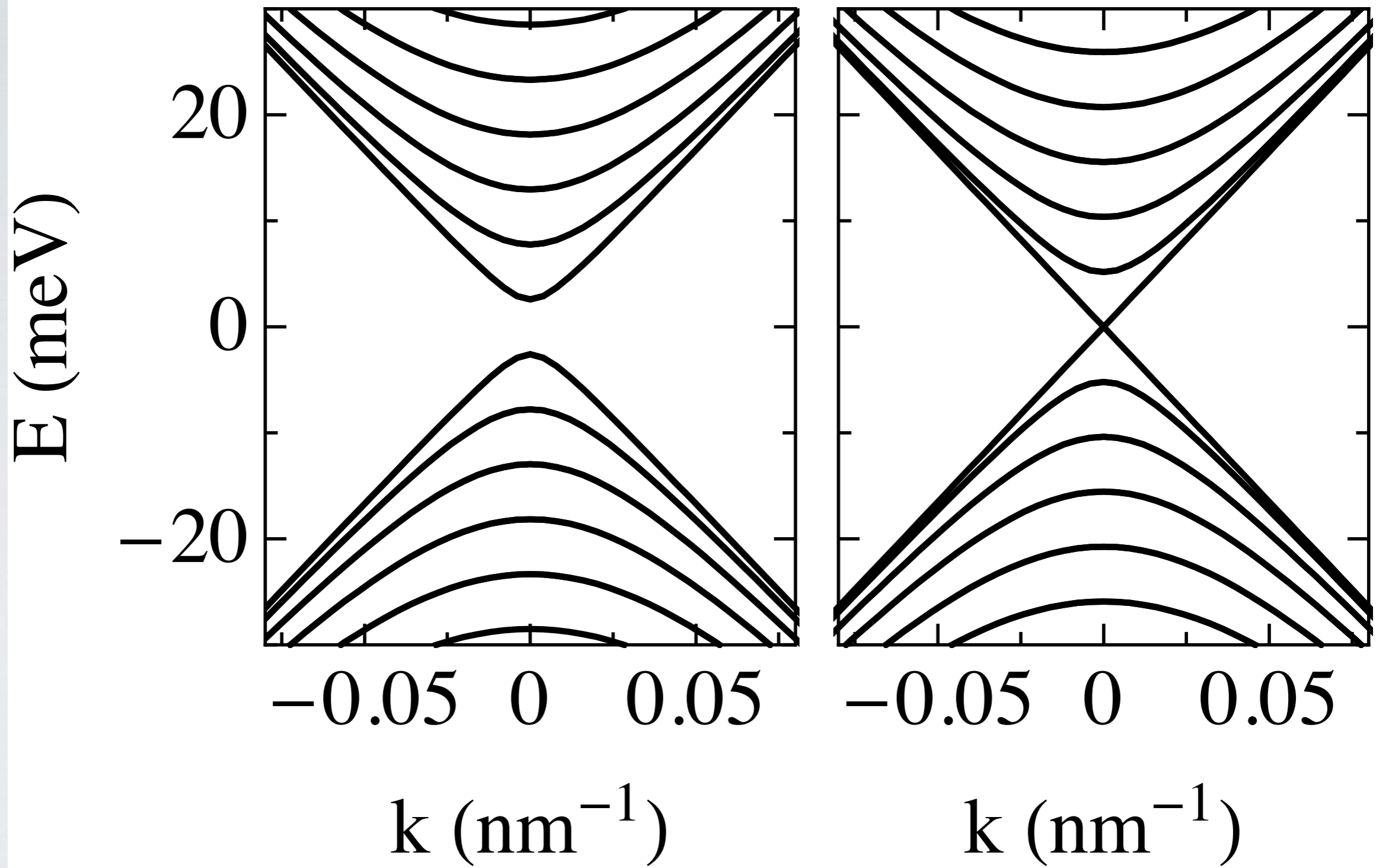
S - Ti - S

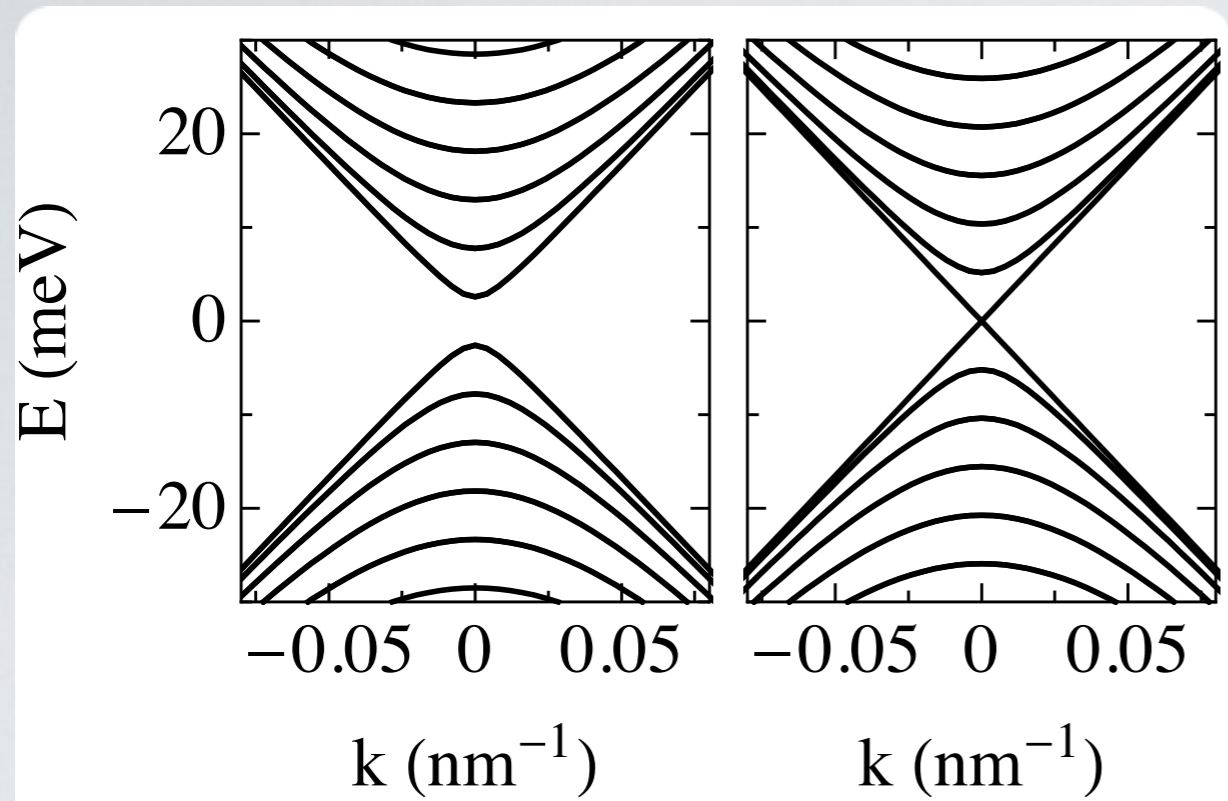


R. Ilan, JHB, H-S Sim, J. E. Moore, New J. Phys. (2014)



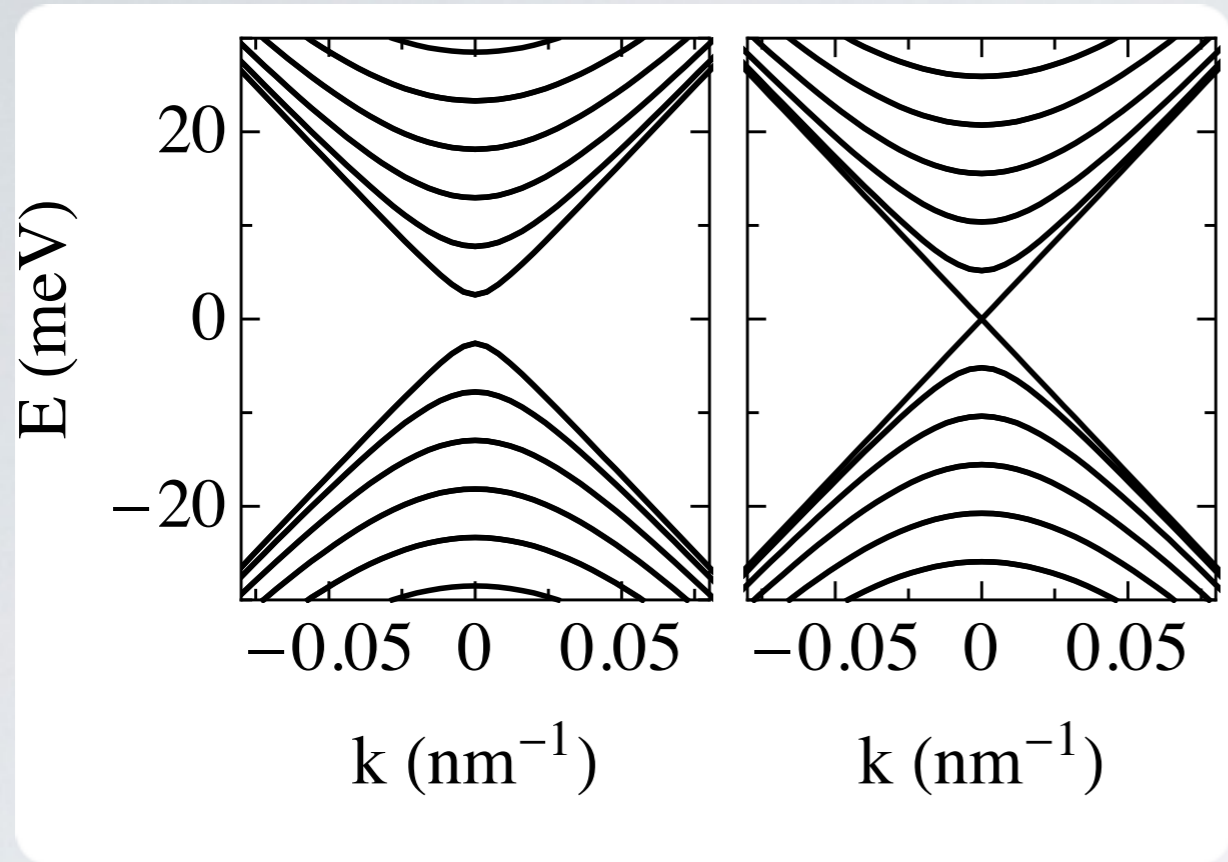






$$\mathcal{T}H\mathcal{T}^{-1} = H \quad \mathcal{T}^2 = -1$$

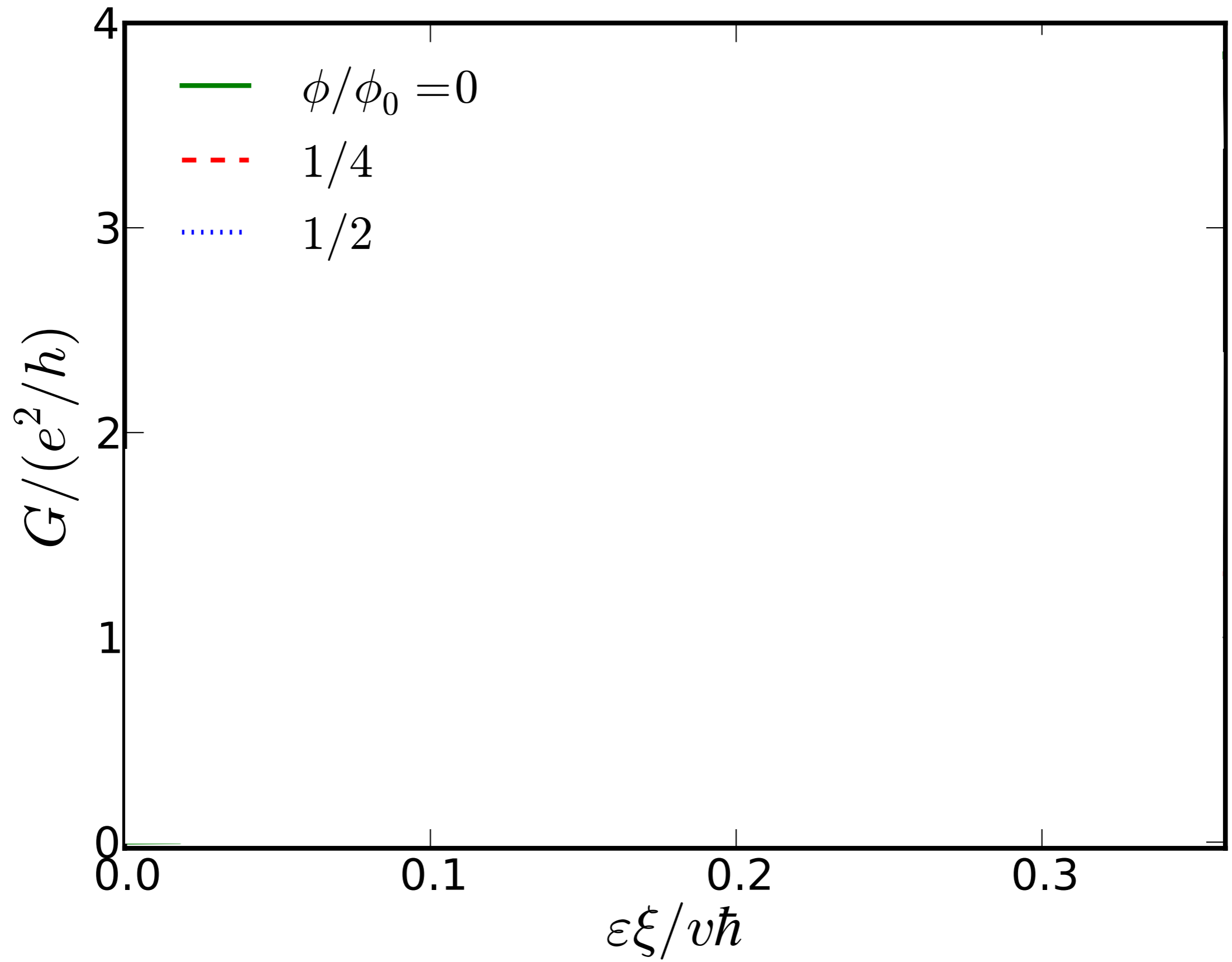
$$S^T = -S$$

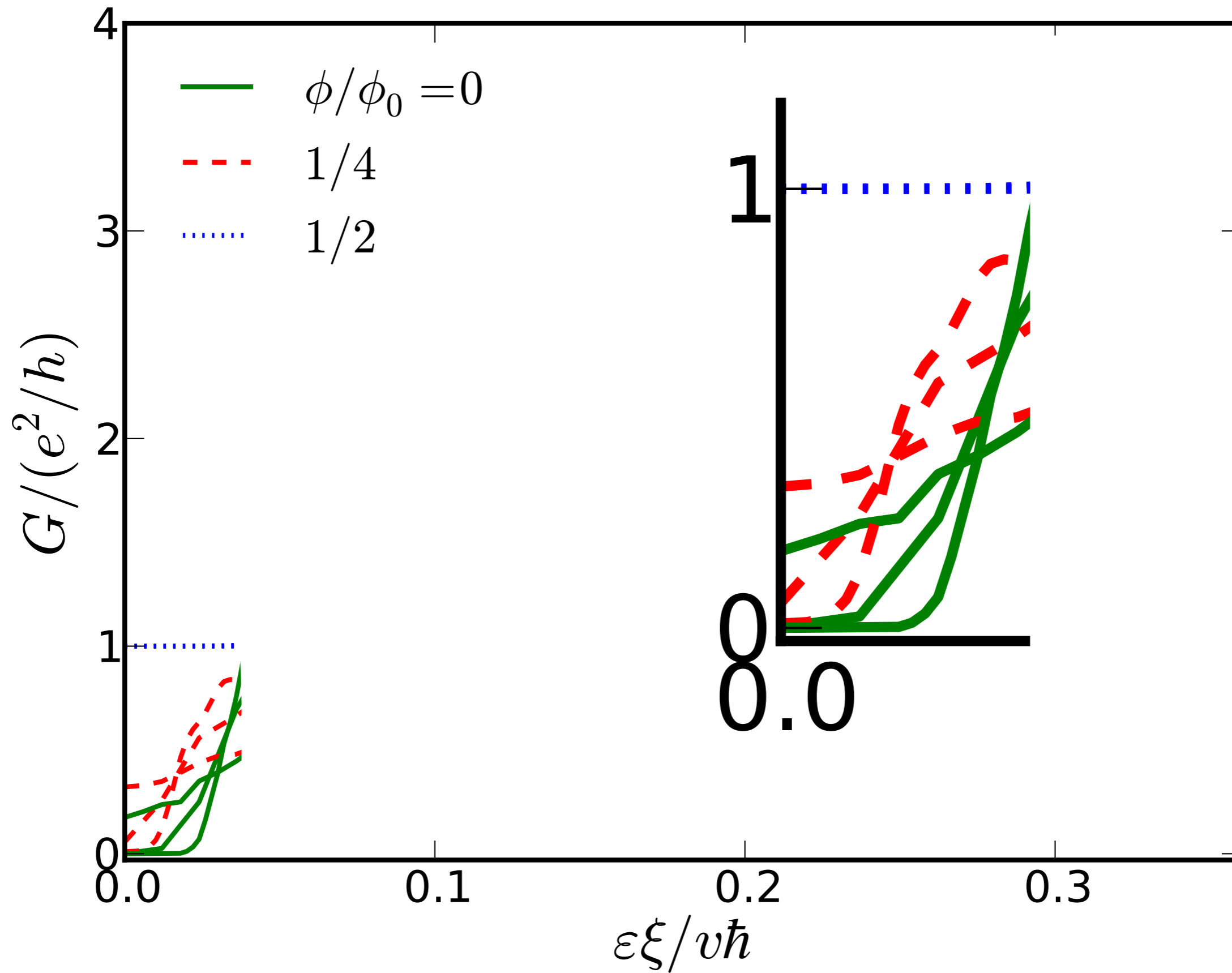


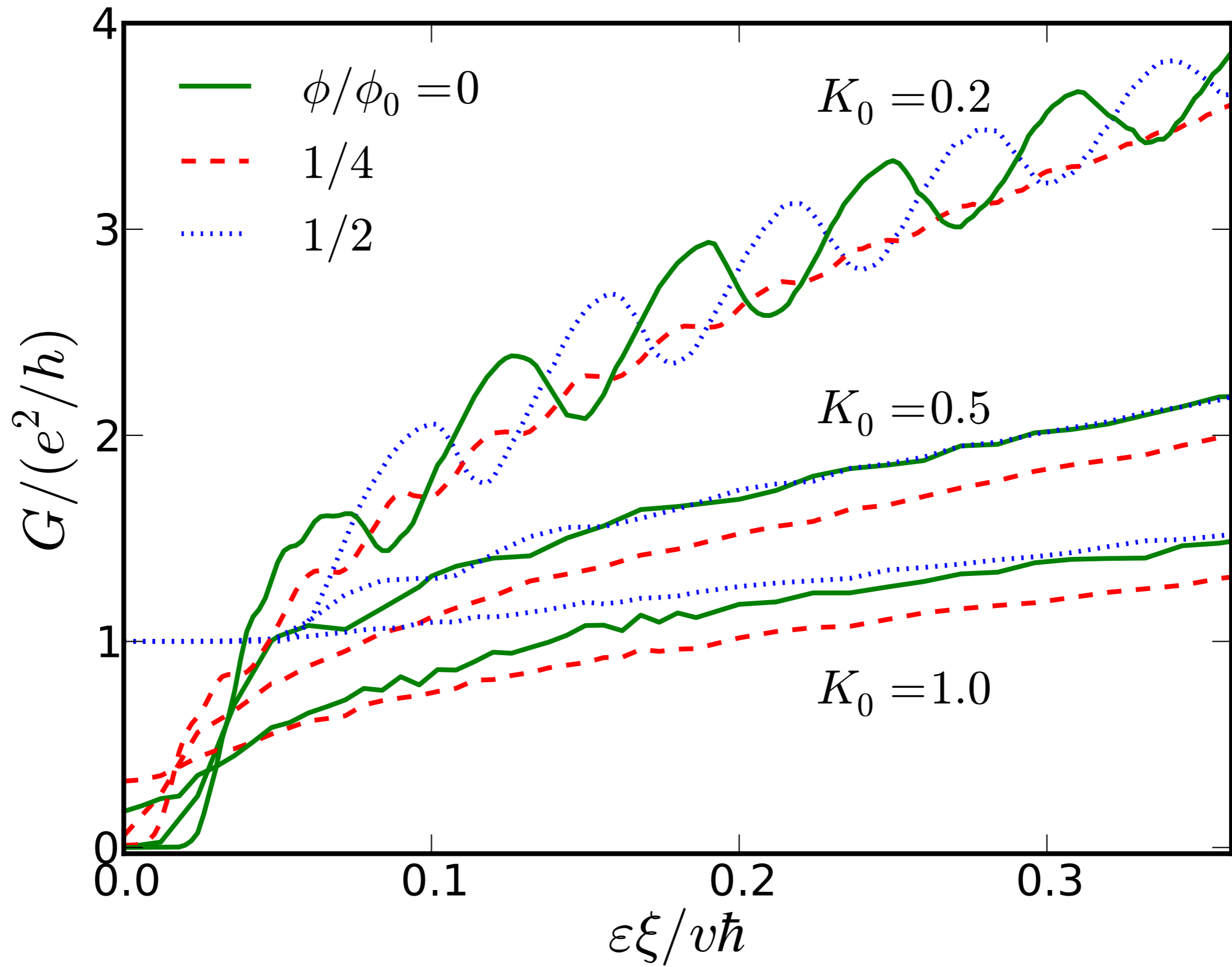
$$\mathcal{T}H\mathcal{T}^{-1} = H \quad \mathcal{T}^2 = -1$$

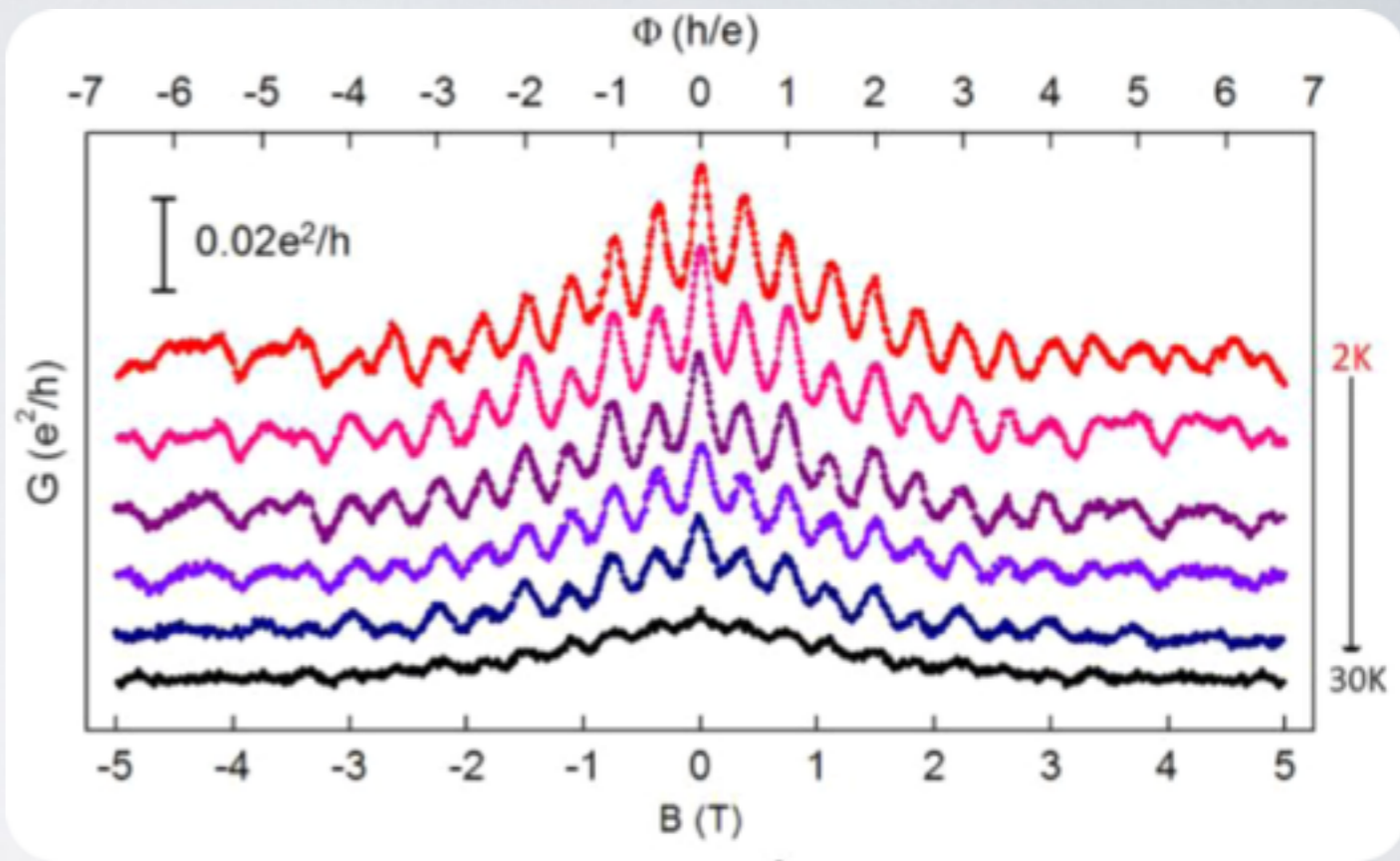
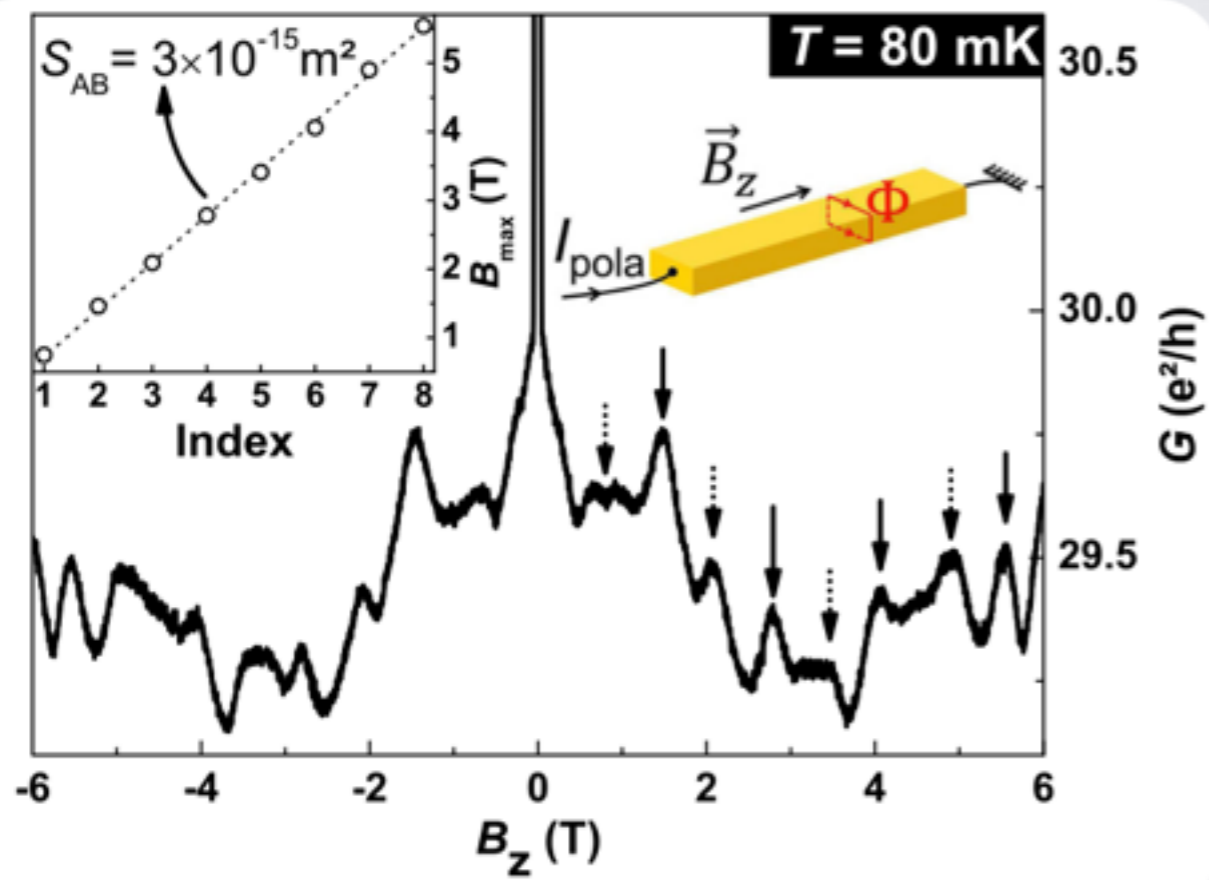
$$S^T = -S$$

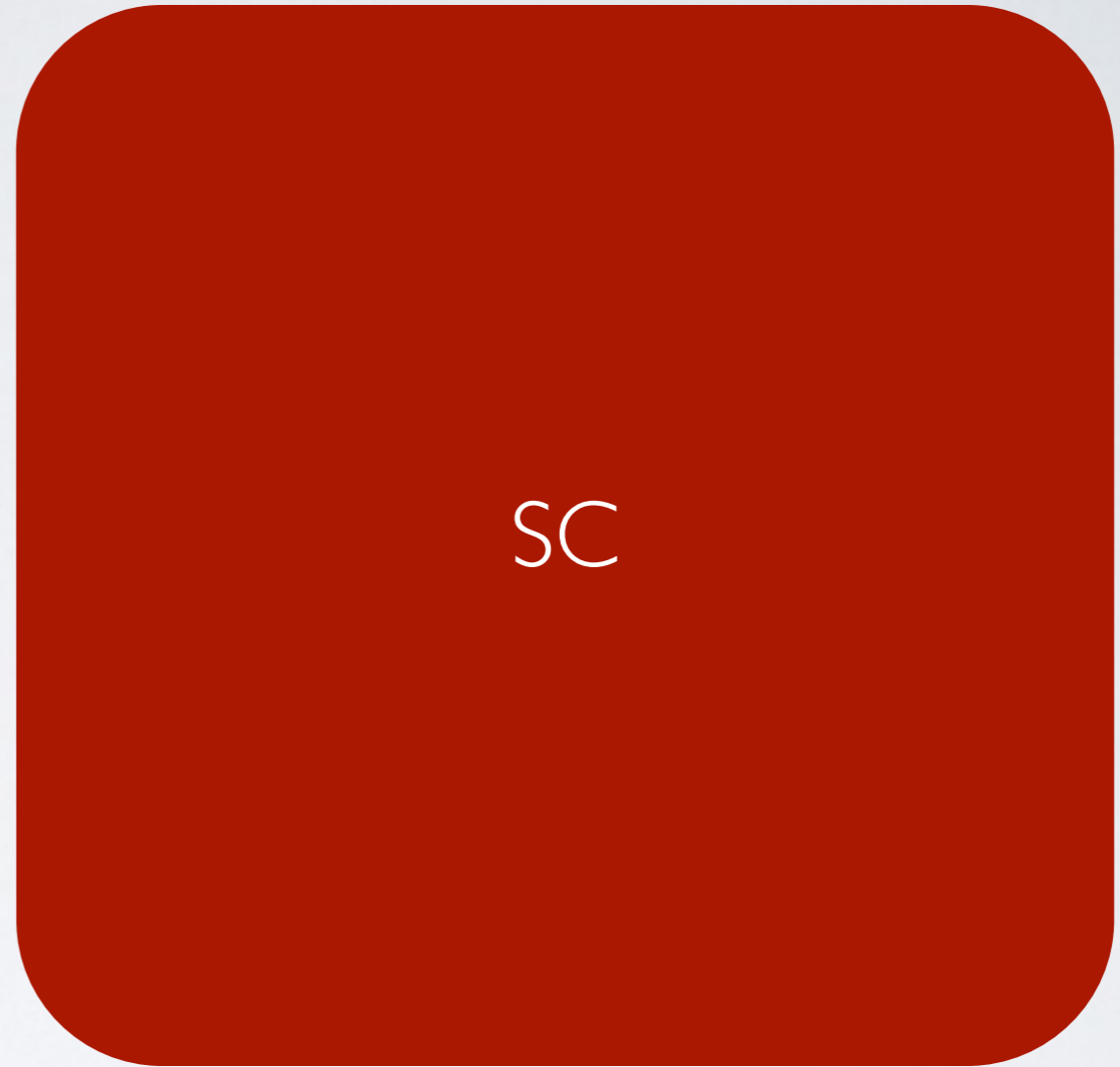
Kramers degeneracy  
&  
perfectly transmitted mode

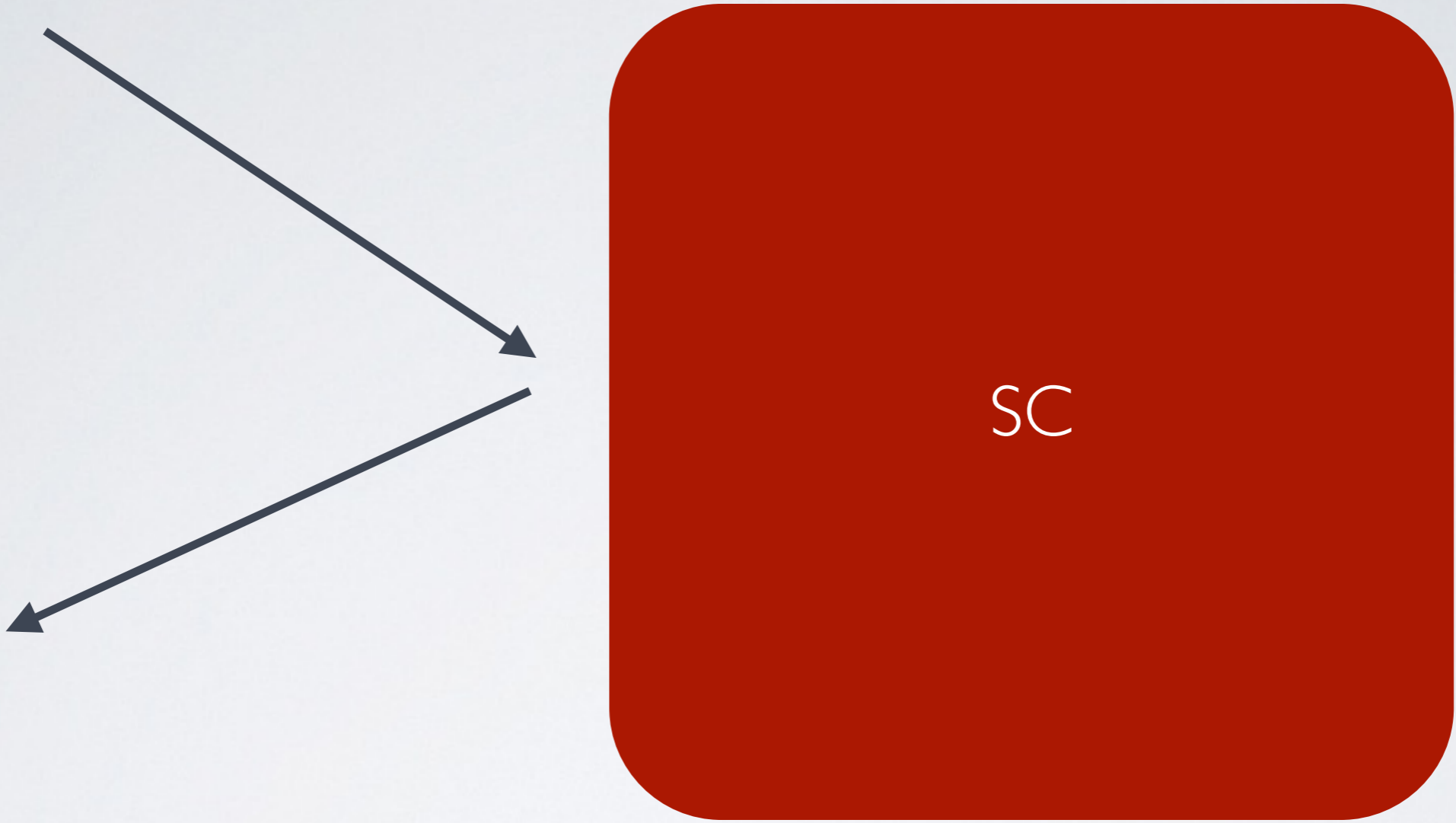


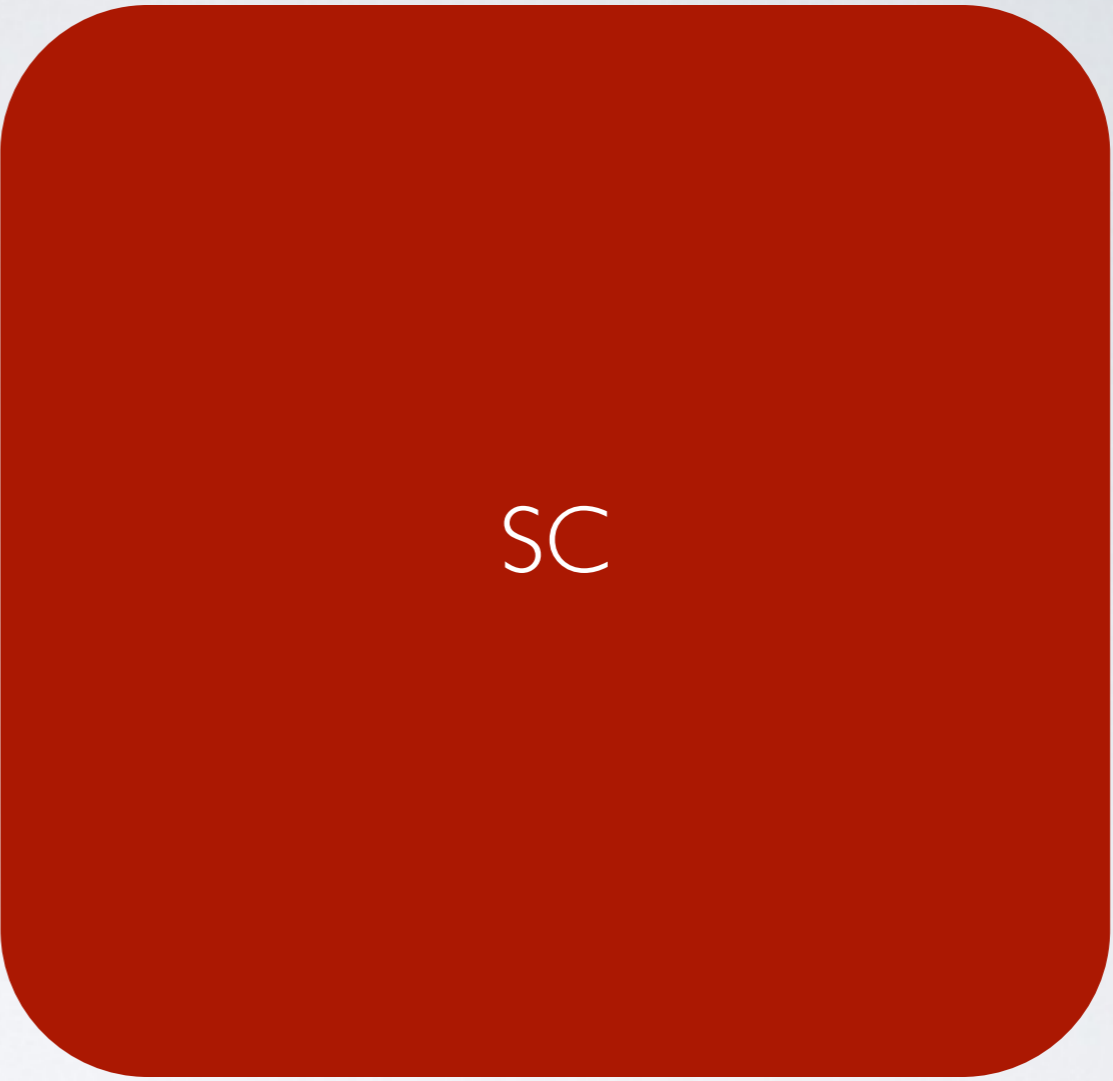
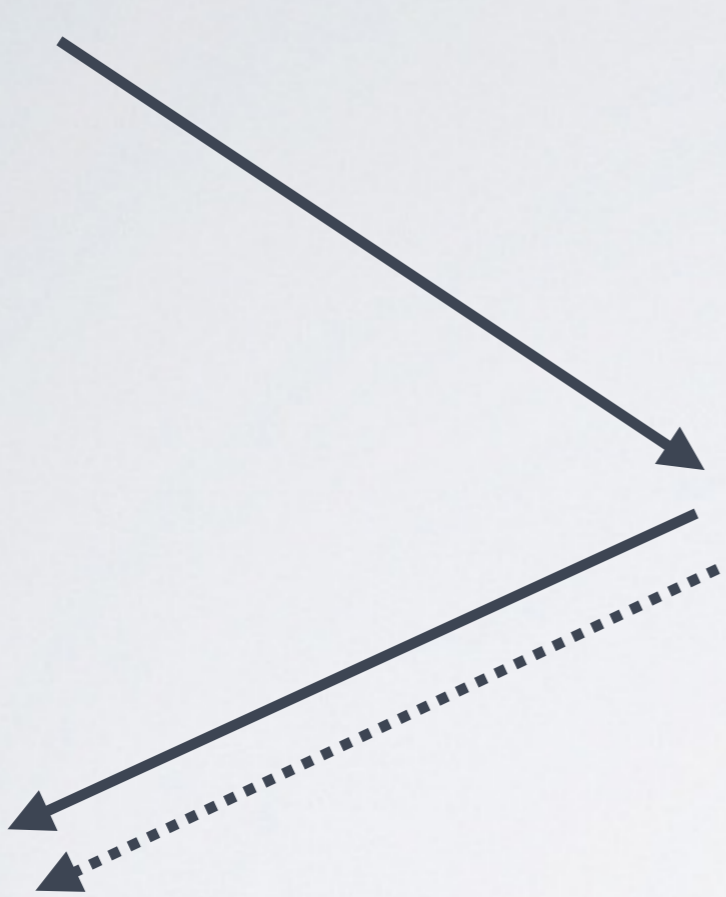


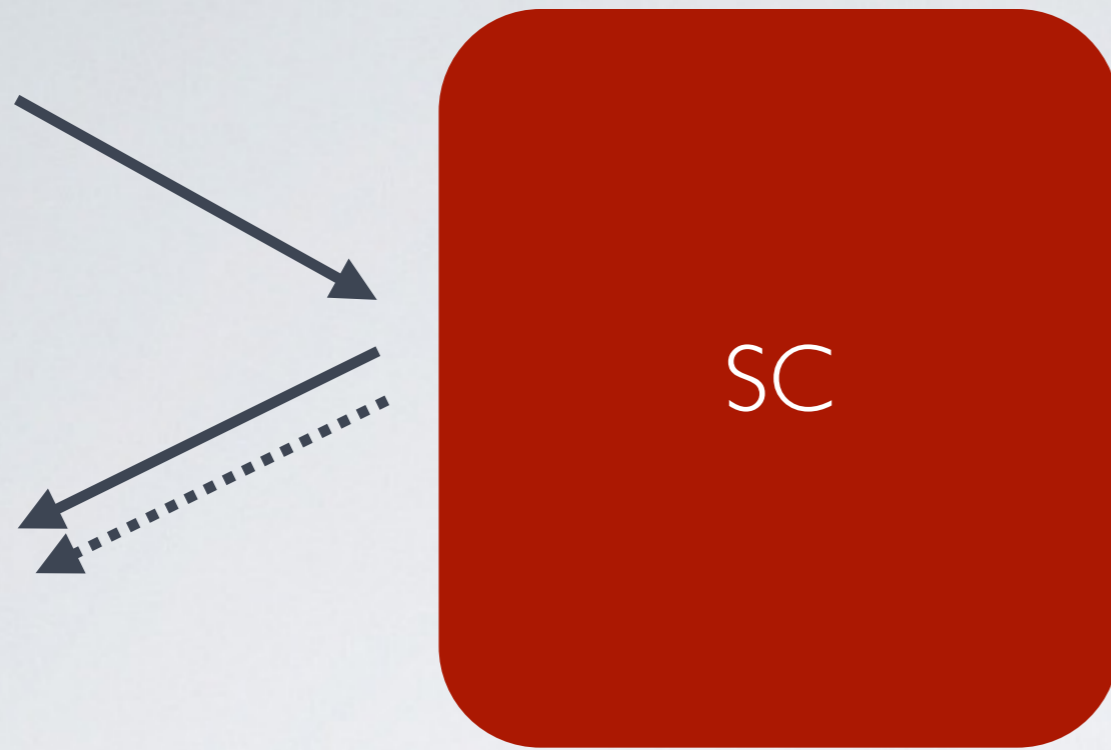








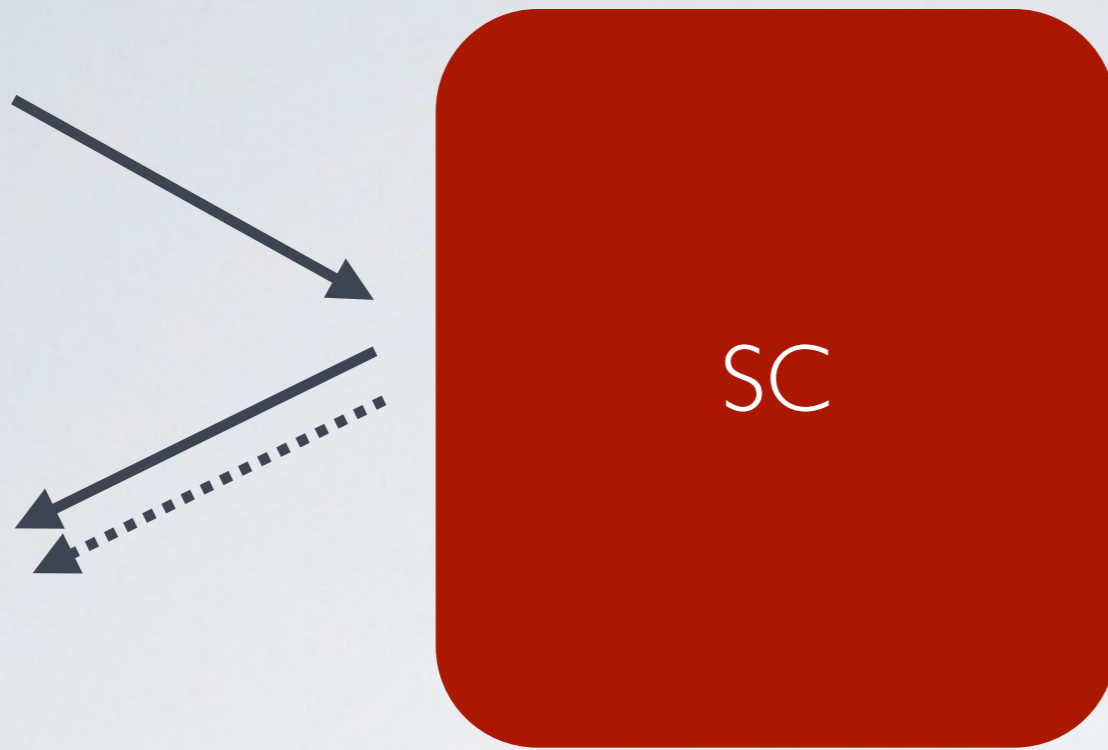




$$r = \begin{pmatrix} r_{ee} & r_{eh} \\ r_{he} & r_{hh} \end{pmatrix}$$

B. Béri PRB (2009);

Wimmer, Akhmerov, Dahlhaus, Beenakker NJP (2011)

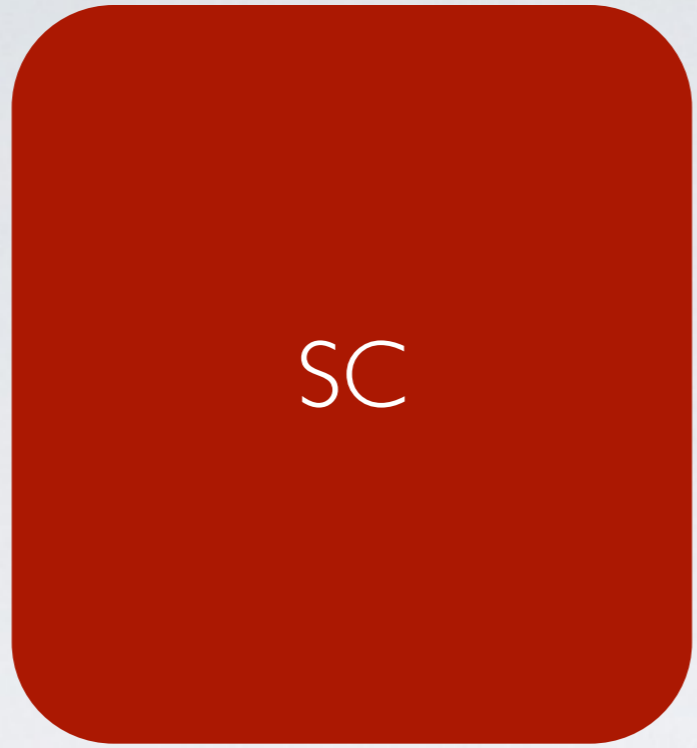
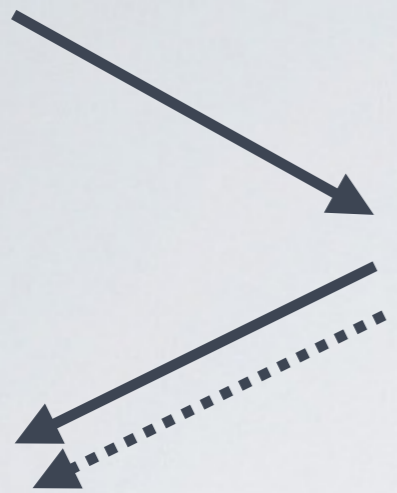


$$r = \begin{pmatrix} r_{ee} & r_{eh} \\ r_{he} & r_{hh} \end{pmatrix}$$

$$\sigma_x H^* \sigma_x = -H$$

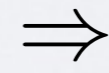
$$\sigma_x r(\varepsilon)^* \sigma_x = r(-\varepsilon)$$

$$r^\dagger r = 1$$

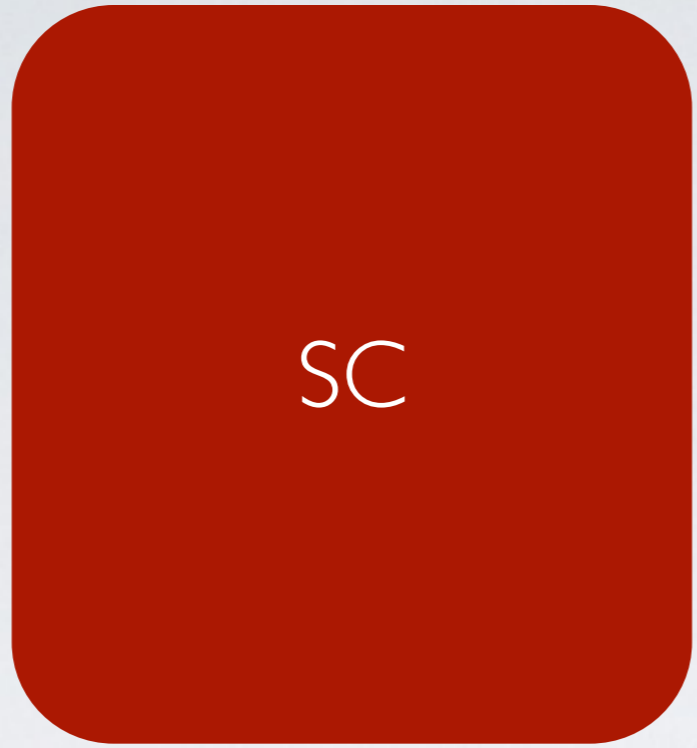
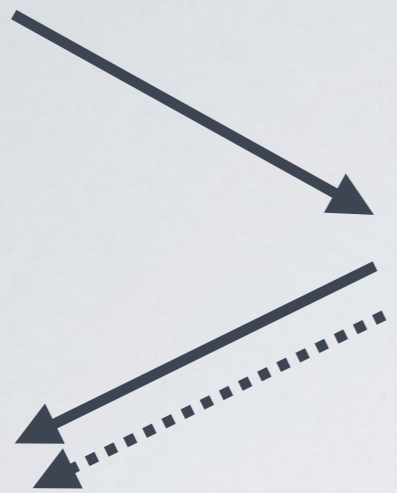


$$r = \begin{pmatrix} r_{ee} & r_{eh} \\ r_{he} & r_{hh} \end{pmatrix}$$

$$\begin{aligned} \sigma_x H^* \sigma_x &= -H \\ \sigma_x r(\varepsilon)^* \sigma_x &= r(-\varepsilon) \\ r^\dagger r &= 1 \end{aligned}$$

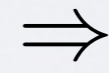


Béri degeneracy



$$r = \begin{pmatrix} r_{ee} & r_{eh} \\ r_{he} & r_{hh} \end{pmatrix}$$

$$\begin{aligned} \sigma_x H^* \sigma_x &= -H \\ \sigma_x r(\varepsilon)^* \sigma_x &= r(-\varepsilon) \\ r^\dagger r &= 1 \end{aligned}$$

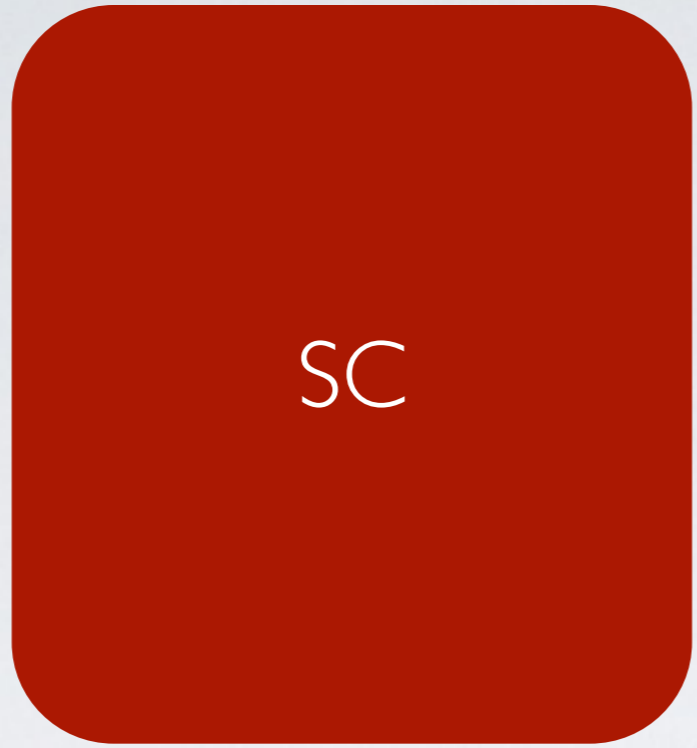
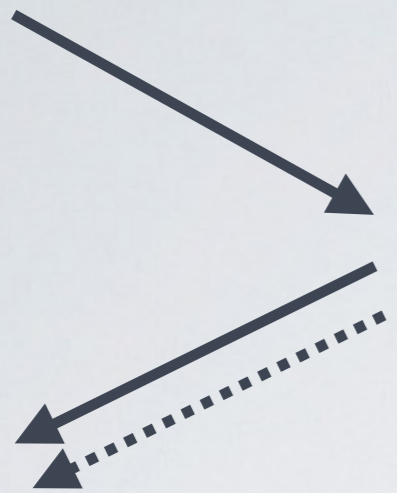


Béri degeneracy

Single mode:  $r_{ee} r_{he}^* = 0$

B. Béri PRB (2009);

Wimmer, Akhmerov, Dahlhaus, Beenakker NJP (2011)



$$r = \begin{pmatrix} r_{ee} & r_{eh} \\ r_{he} & r_{hh} \end{pmatrix}$$

$$\begin{aligned} \sigma_x H^* \sigma_x &= -H \\ \sigma_x r(\varepsilon)^* \sigma_x &= r(-\varepsilon) \\ r^\dagger r &= 1 \end{aligned}$$

$\Rightarrow$

Béri degeneracy

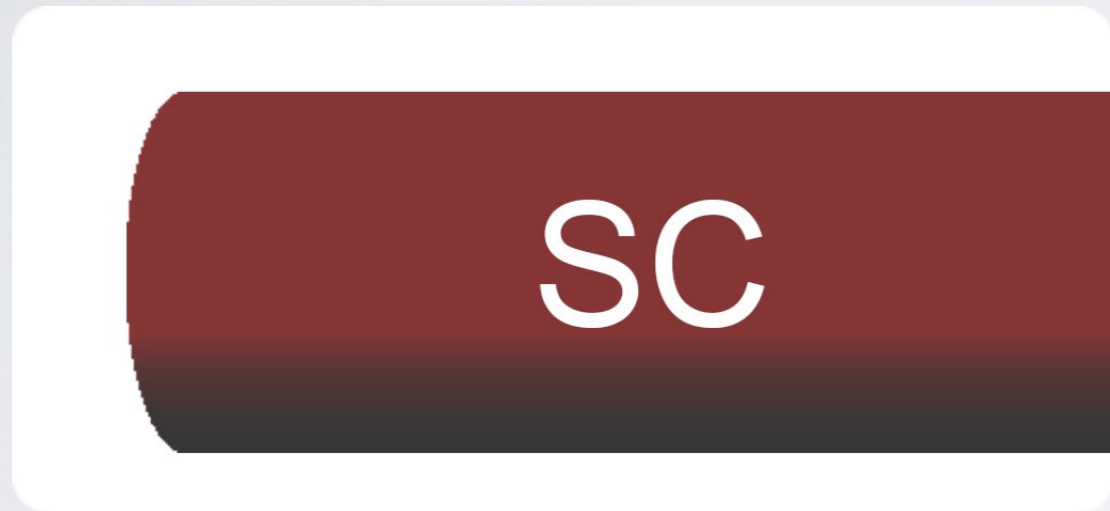
Single mode:  $r_{ee} r_{he}^* = 0 \Rightarrow$

$$\begin{aligned} |r_{ee}| = 1, r_{he} = 0 & \quad \det r = 1 \\ r_{ee} = 0, |r_{he}| = 1 & \quad \det r = -1 \end{aligned}$$

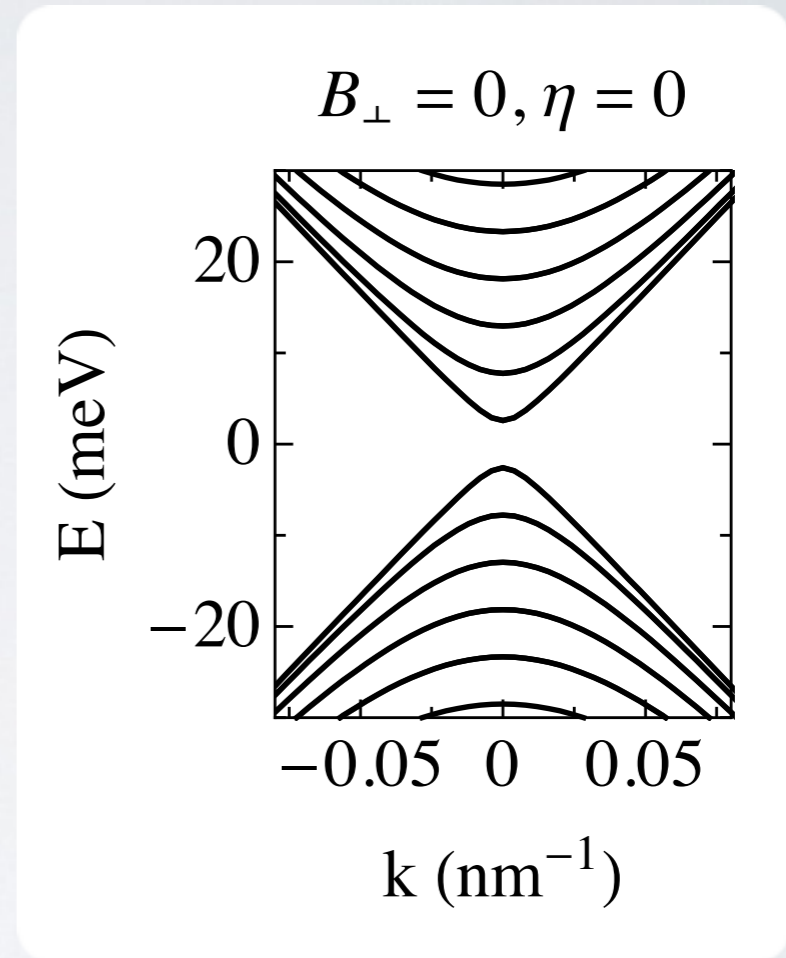
B. Béri PRB (2009);

Wimmer, Akhmerov, Dahlhaus, Beenakker NJP (2011)

# Topological superconductivity



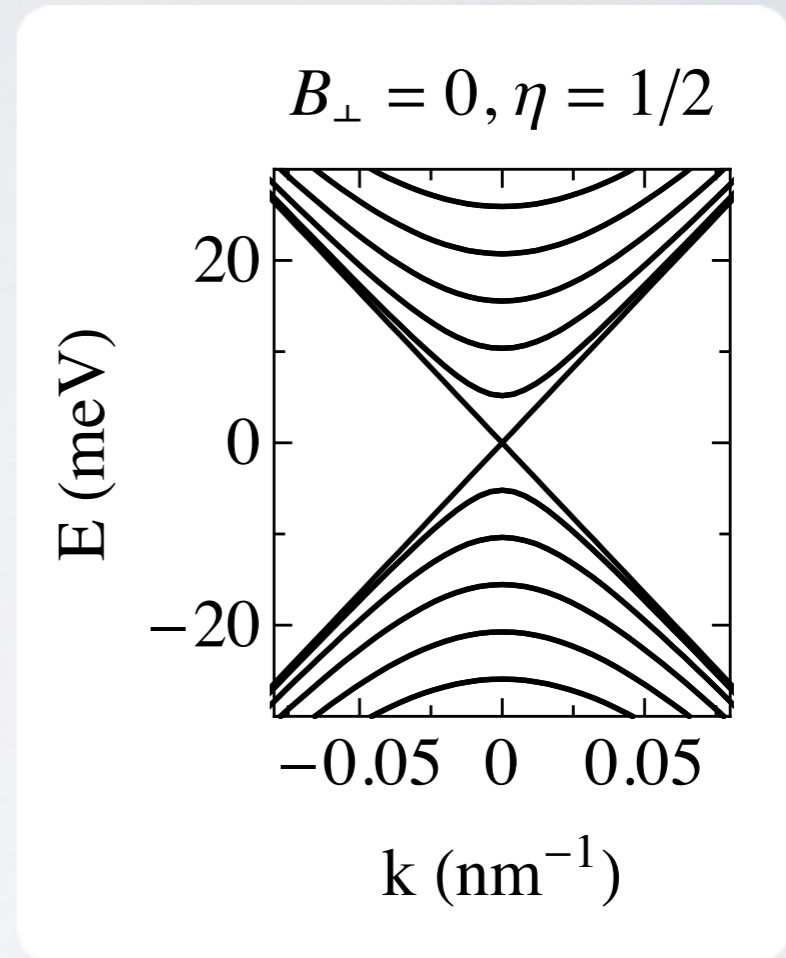
Single mode:  $G_{NS} = 0$

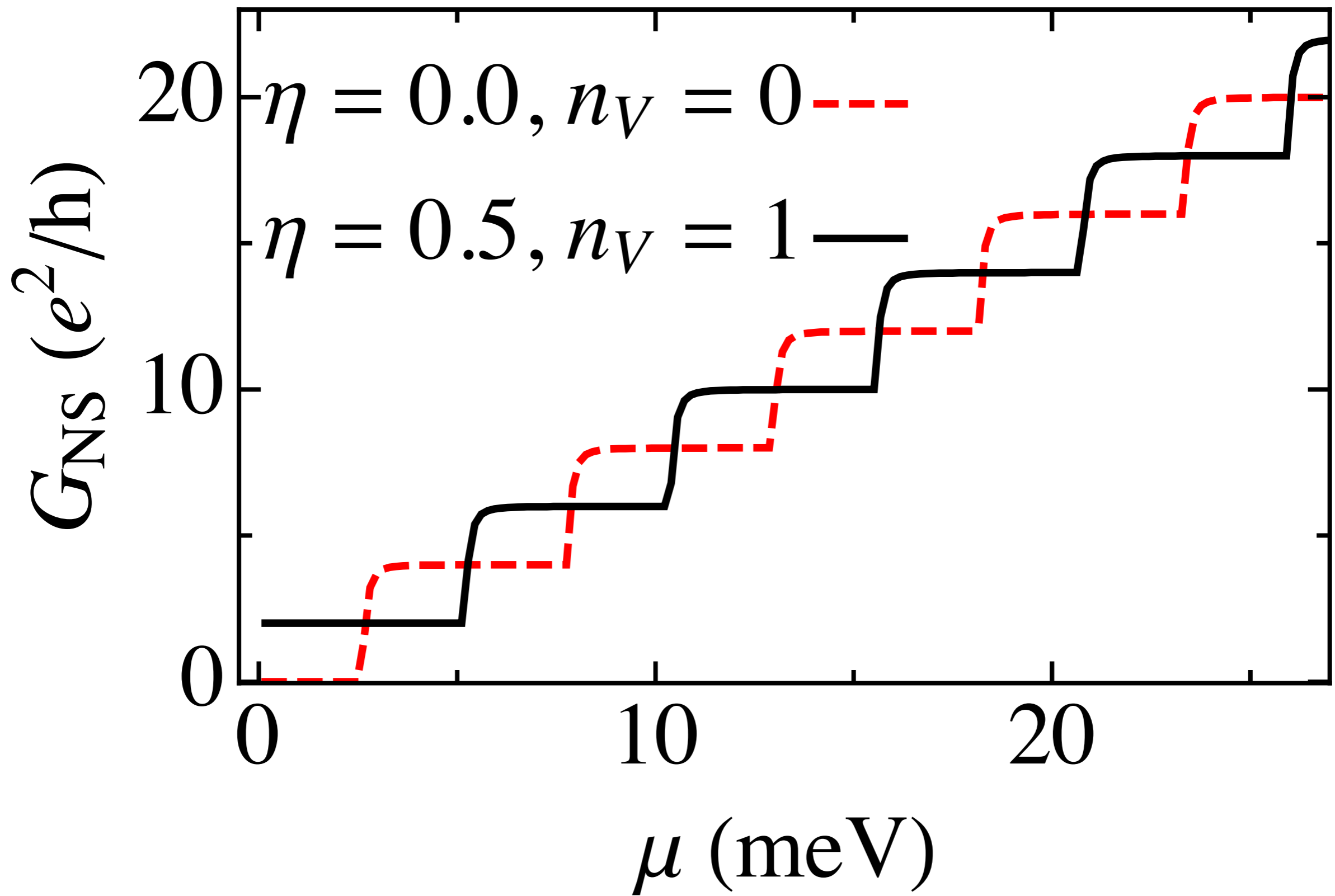


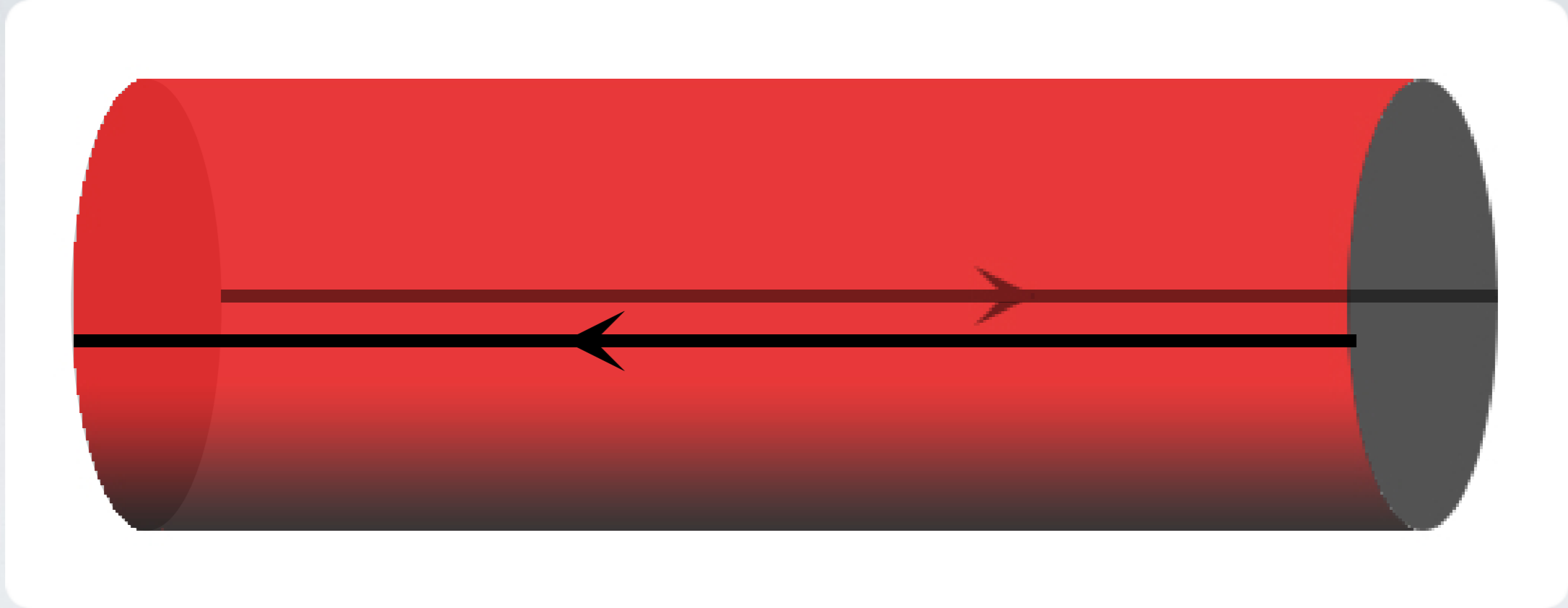
# Topological superconductivity

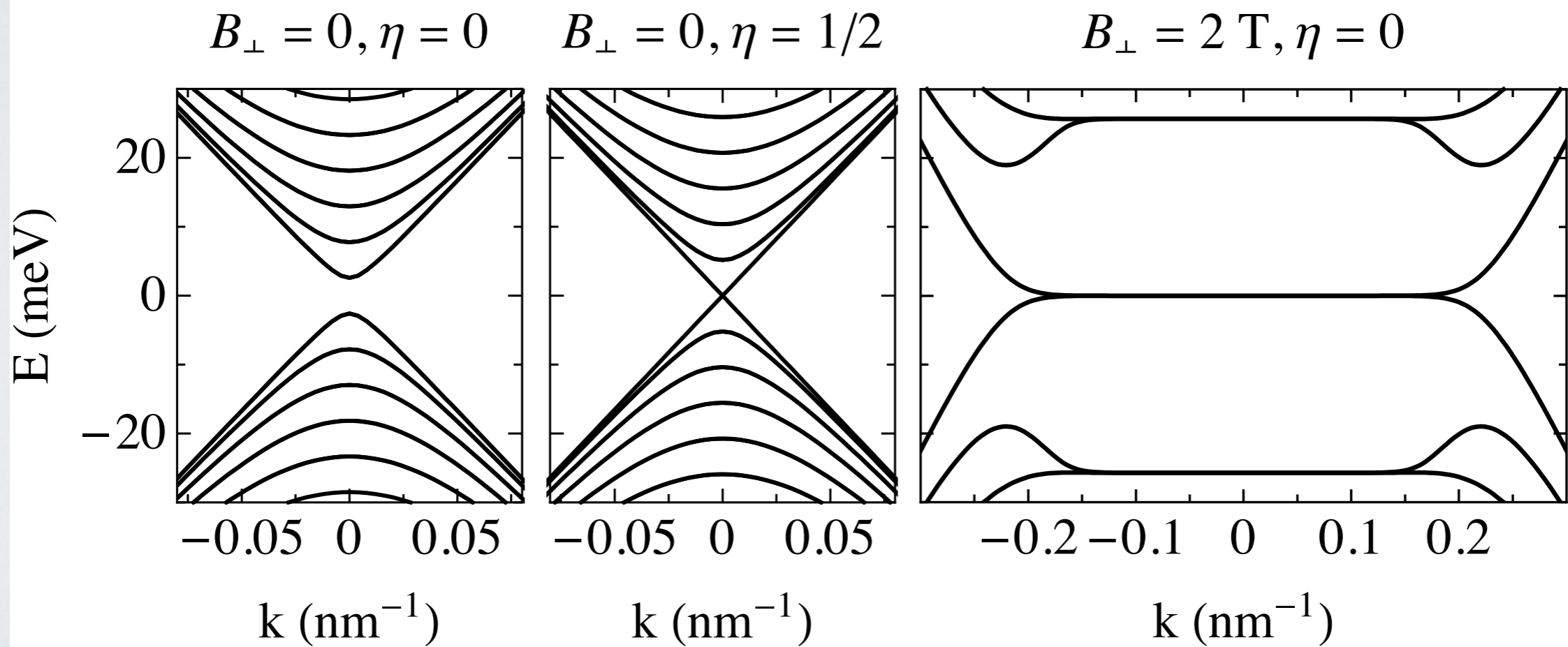
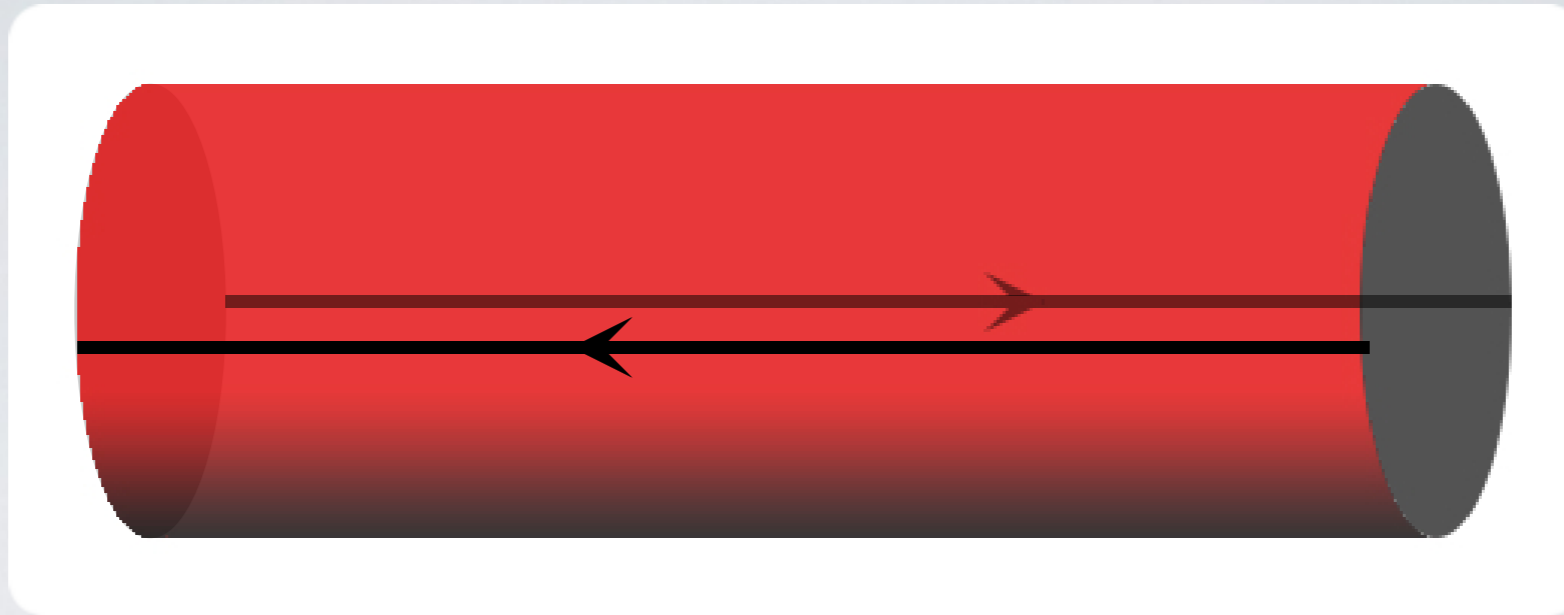


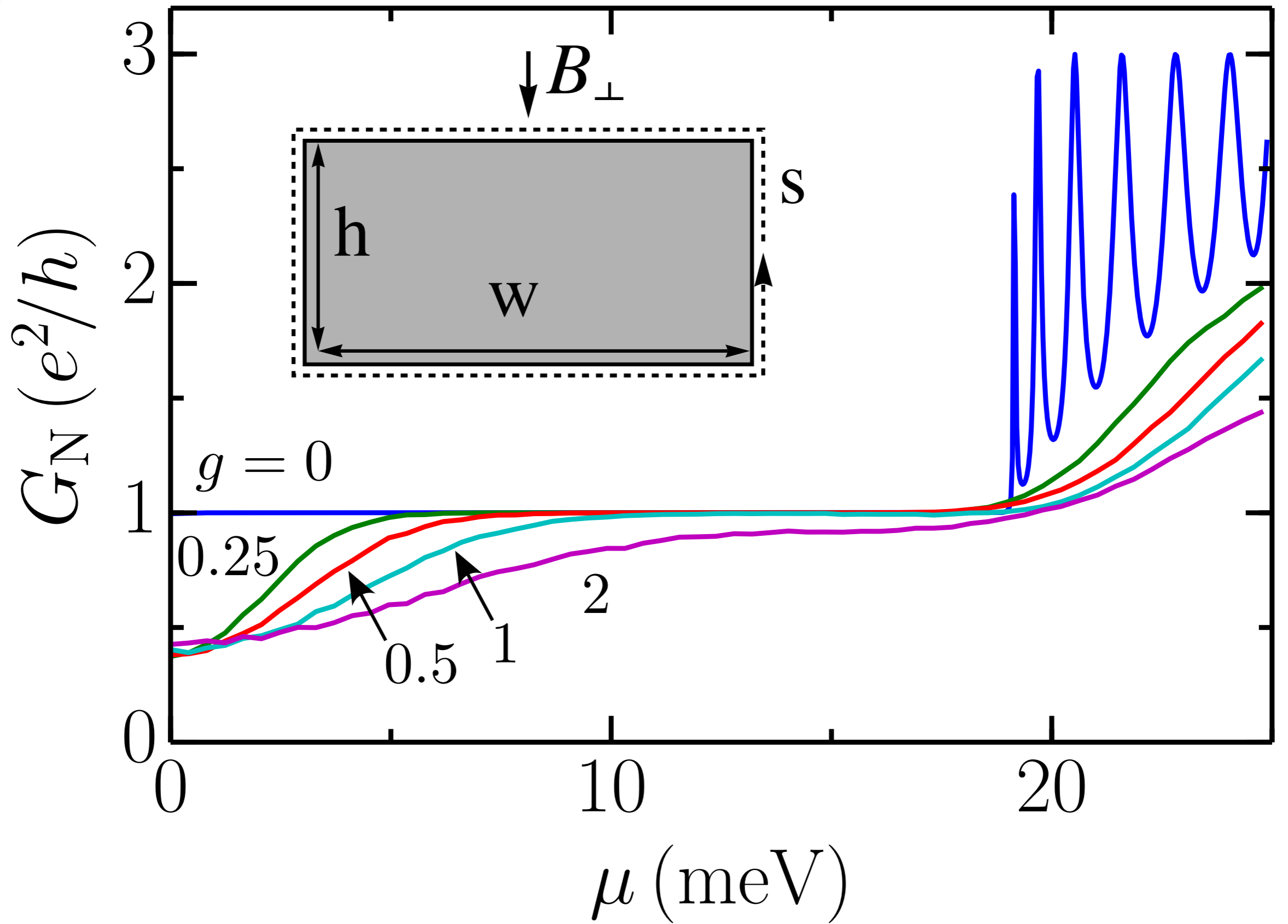
Single mode:  $G_{\text{NS}} = 2e^2/h$

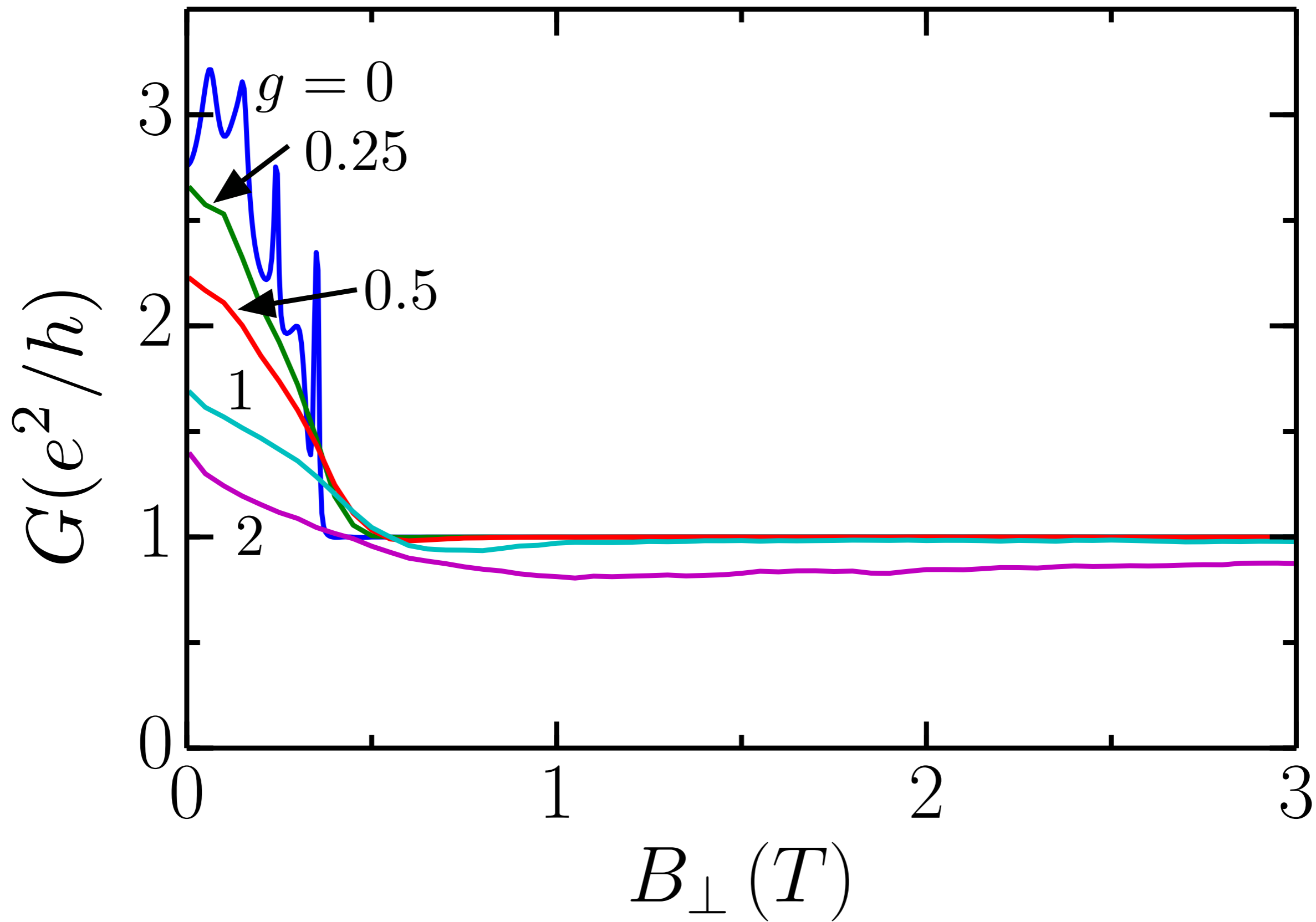


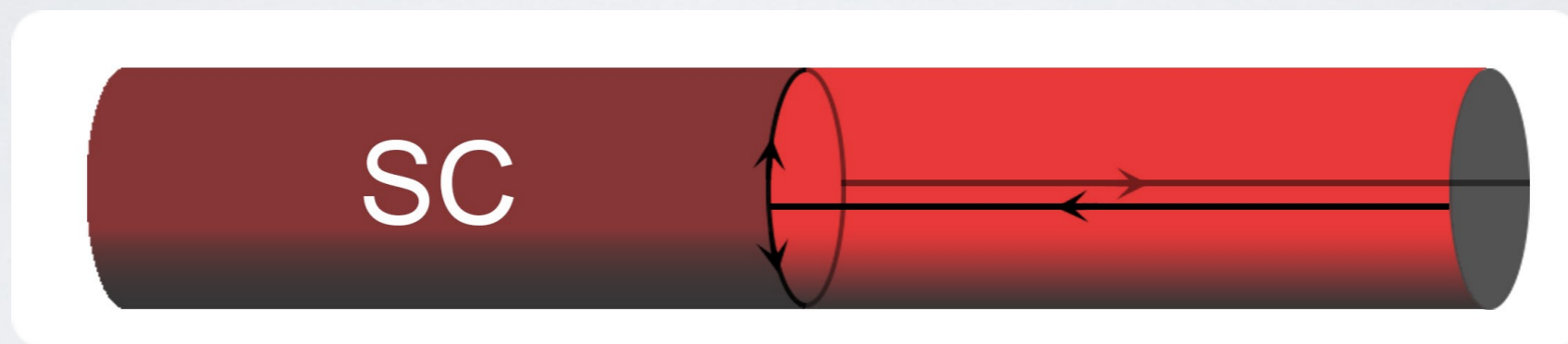




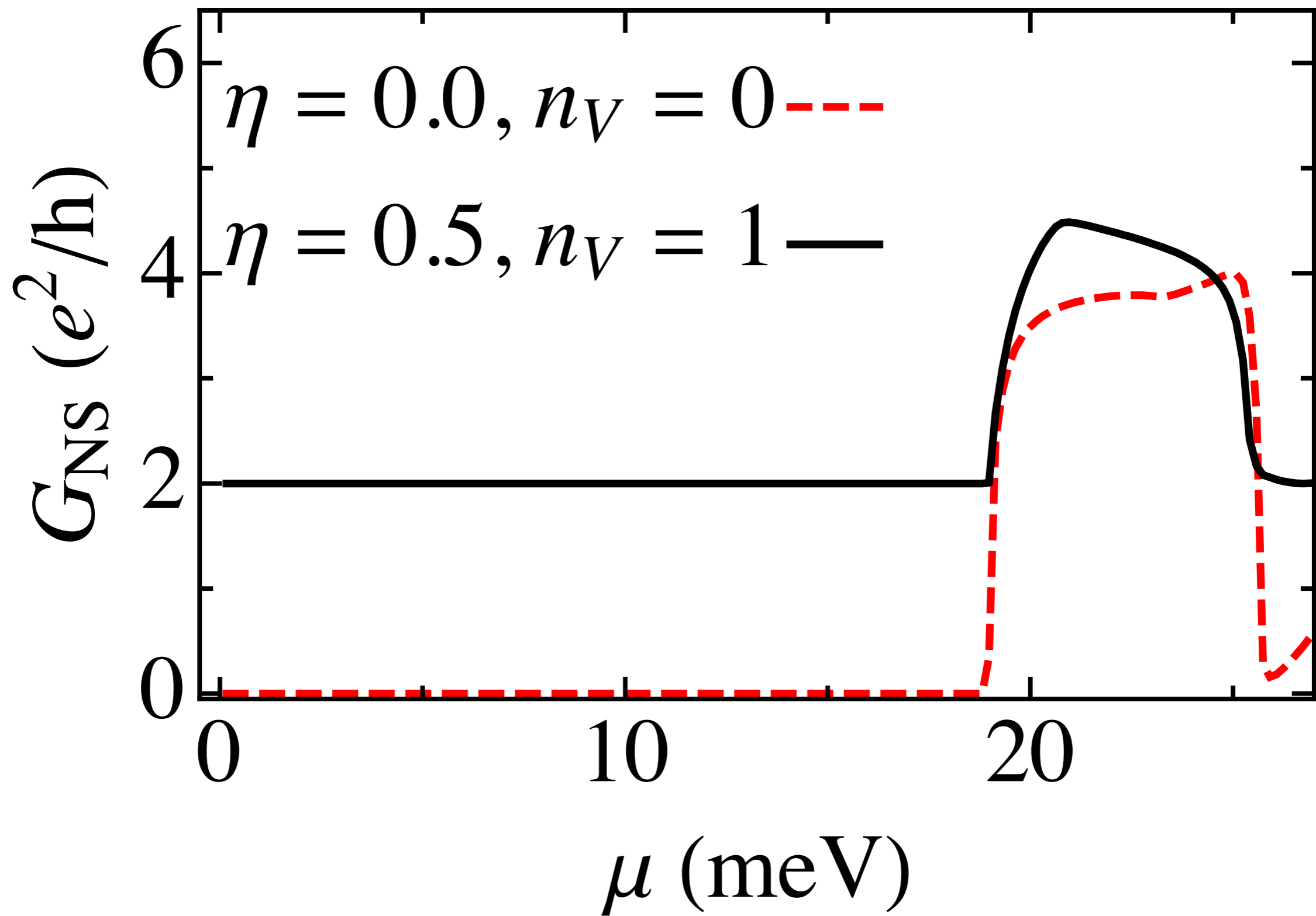




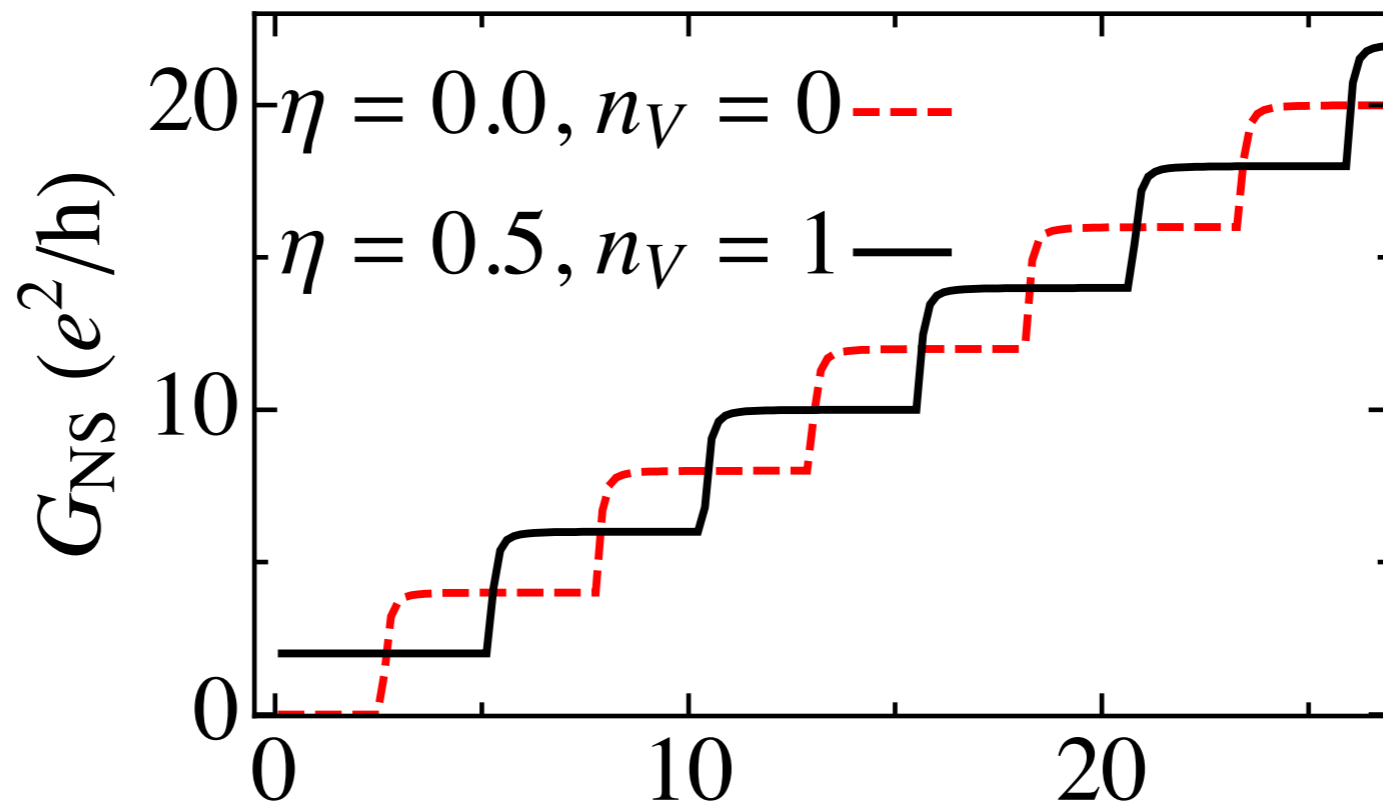




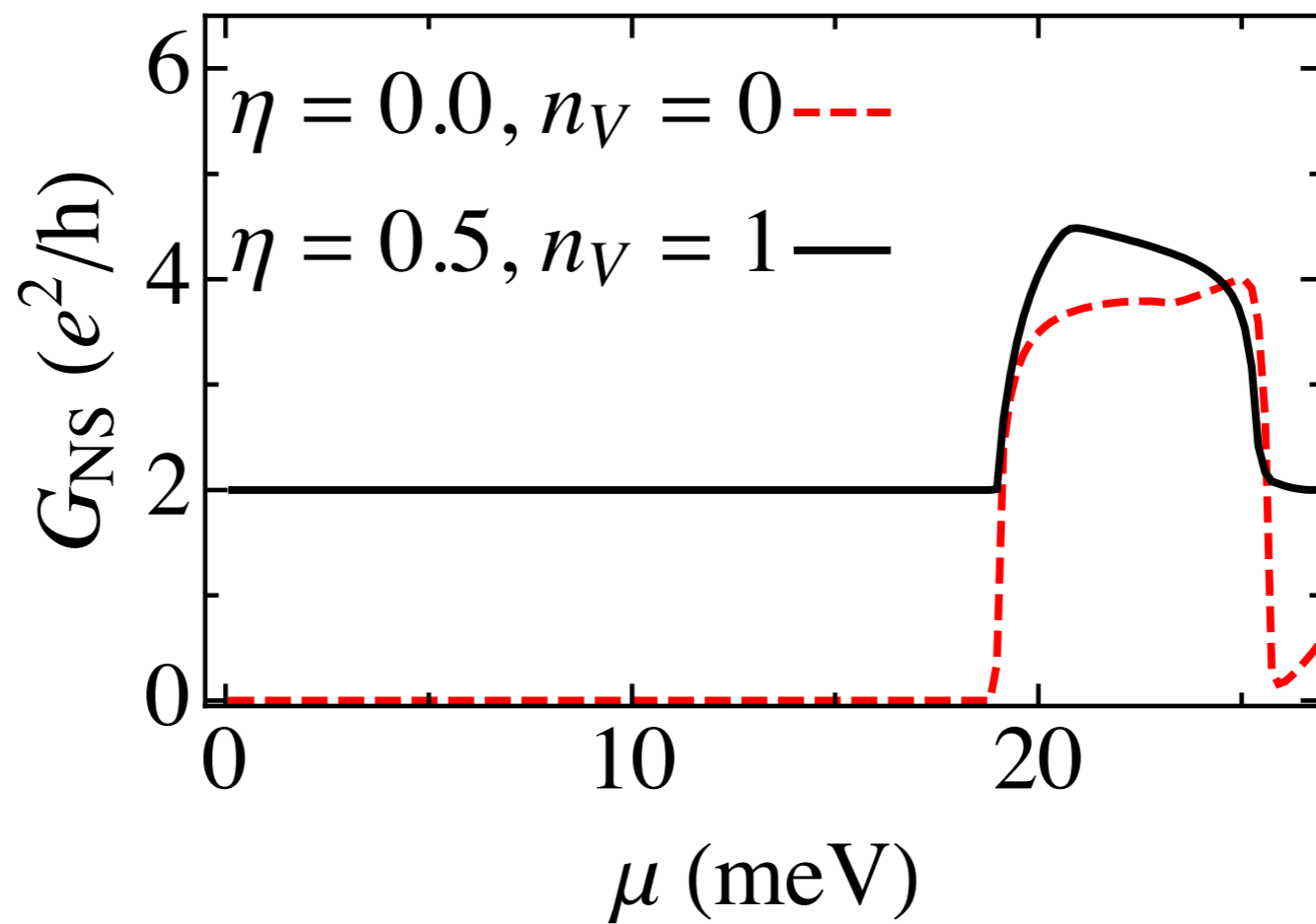
$$B_{\perp} = 2 \text{ T}$$

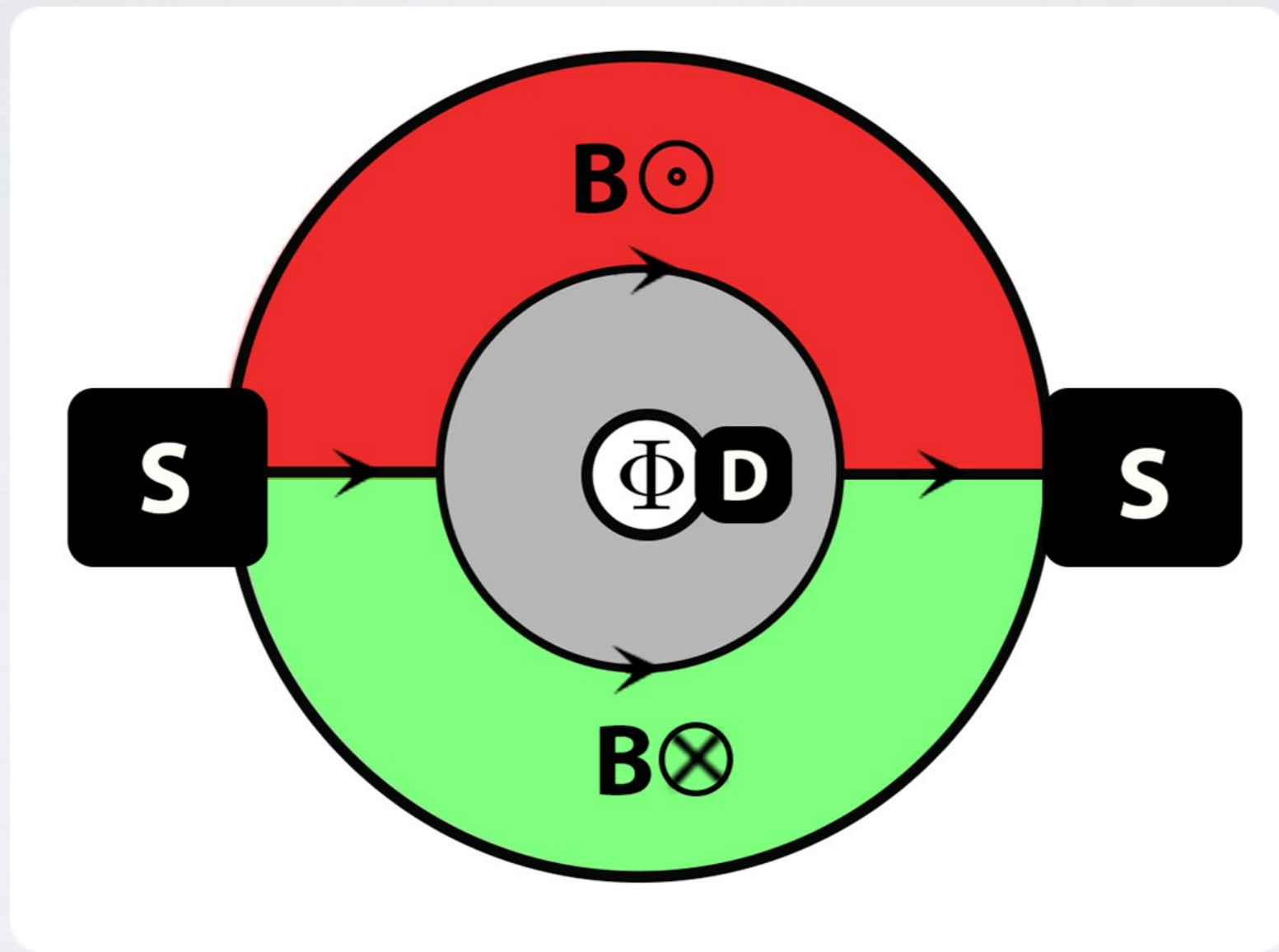
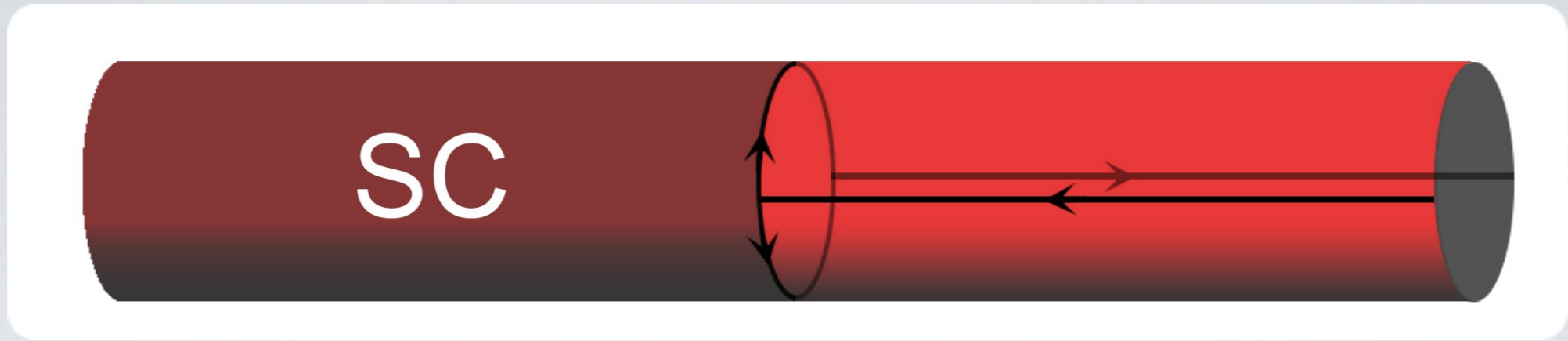


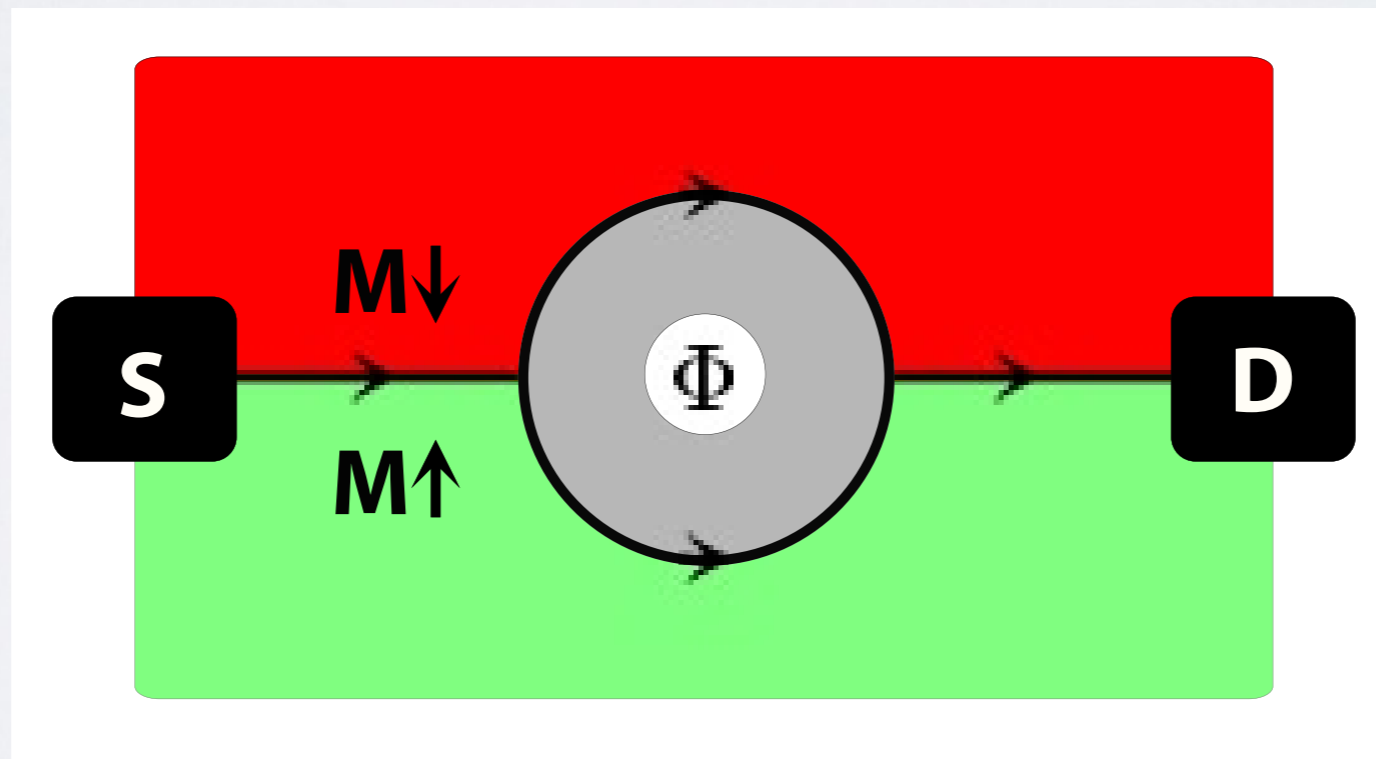
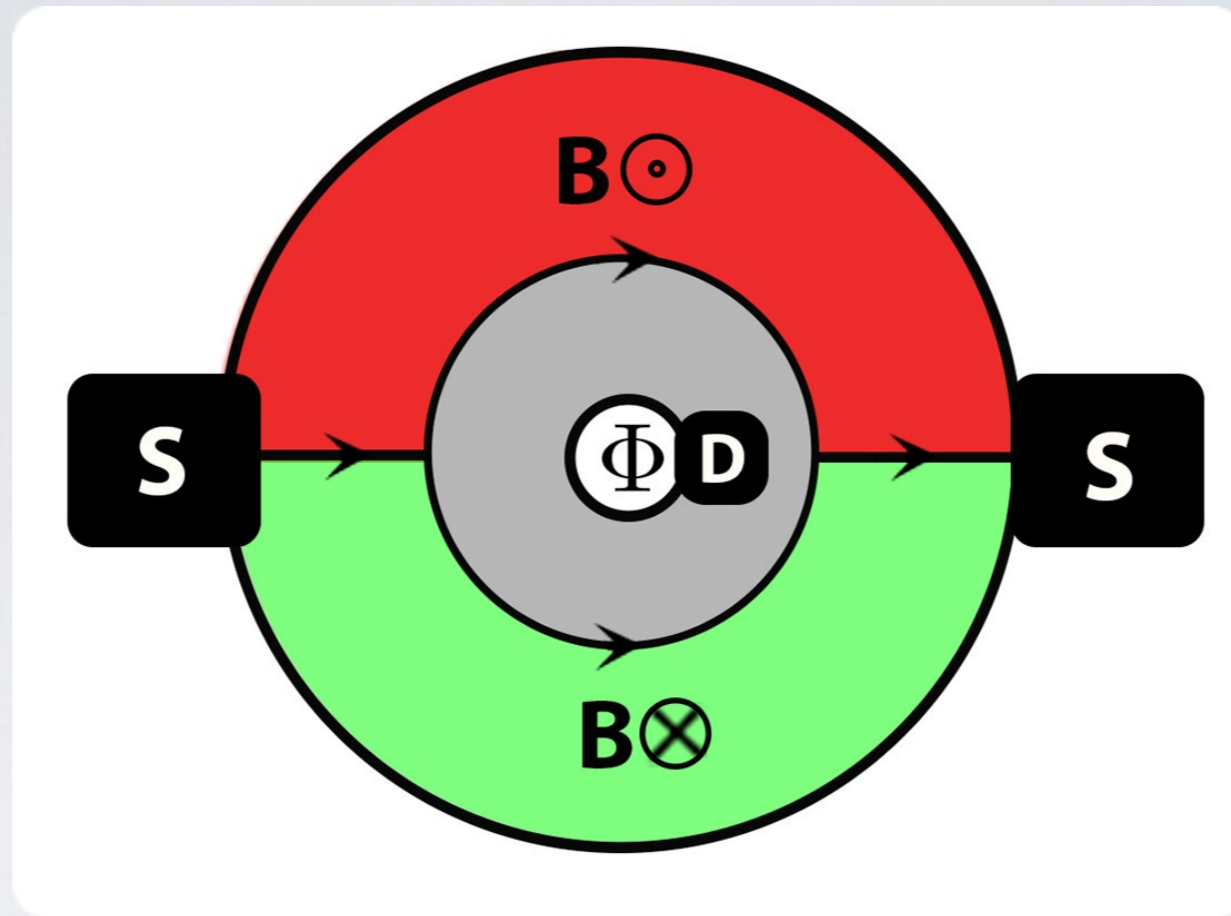
$$B_{\perp} = 0$$



$$B_{\perp} = 2 \text{ T}$$





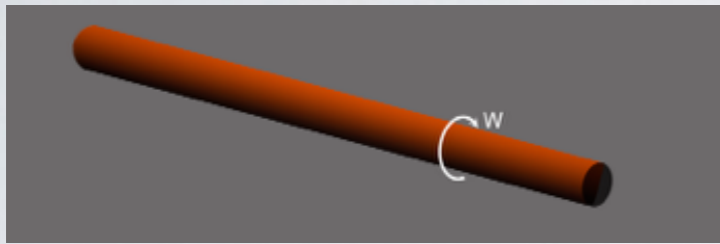


F. de Juan, R. Ilan and **JHB** PRL (2014)

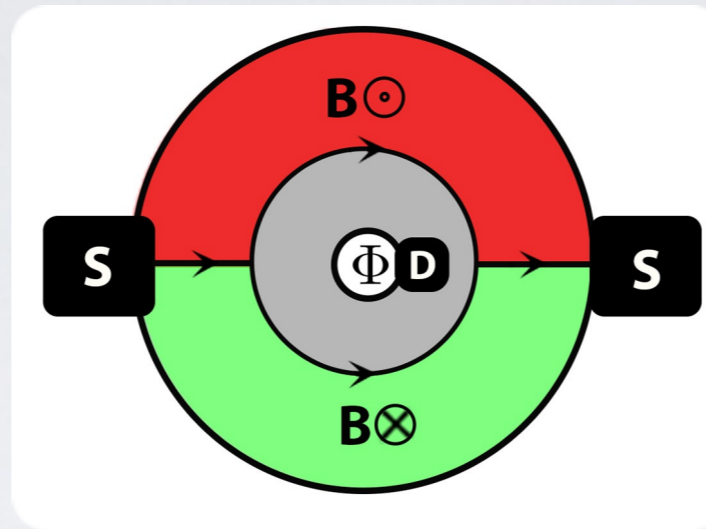
Fu and Kane, PRL (2009), Akhmerov, Nilsson, and Beenakker PRL (2009)

# Summary: TI nanowires a rich playground of fundamental physics

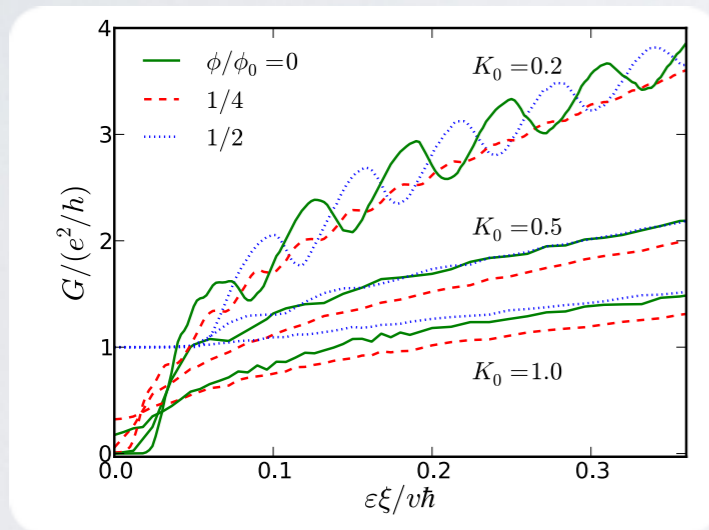
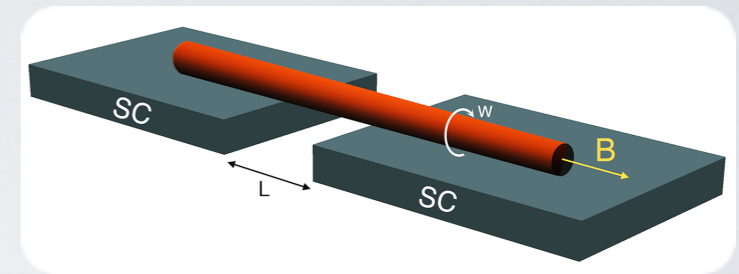
**N**



**NS**

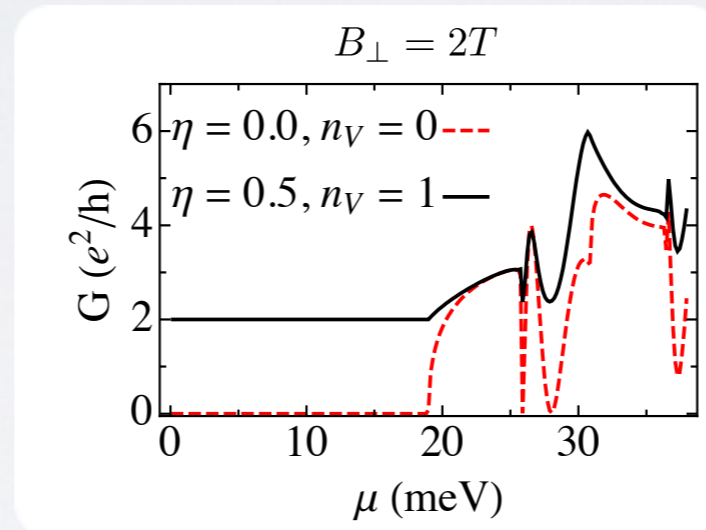


**SNS**



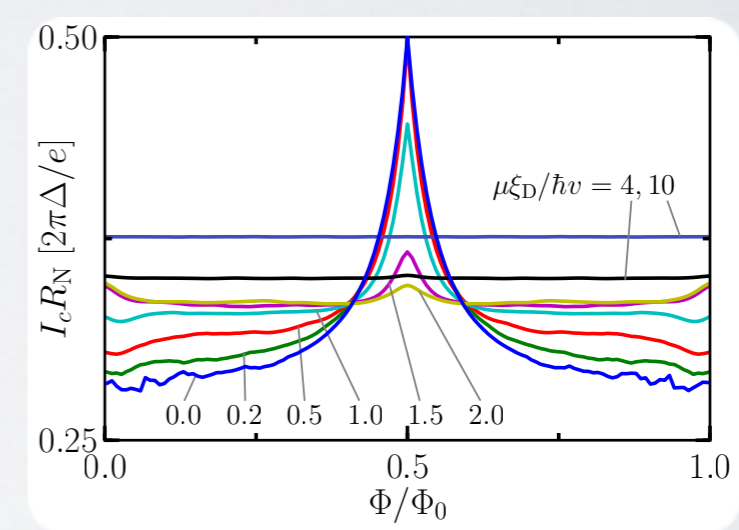
Aharonov - Bohm oscillations

JHB, Brouwer, Moore PRL (2010)



Majorana interferometry

de Juan, Ilan, JHB, arXiv:1401.5832 (PRL in press)



Perfectly transmitted mode

Ilan, JHB, Sim, Moore NJP (2014)

See also review: JHB and J. E. Moore, Rep. Prog. Phys. (2013)