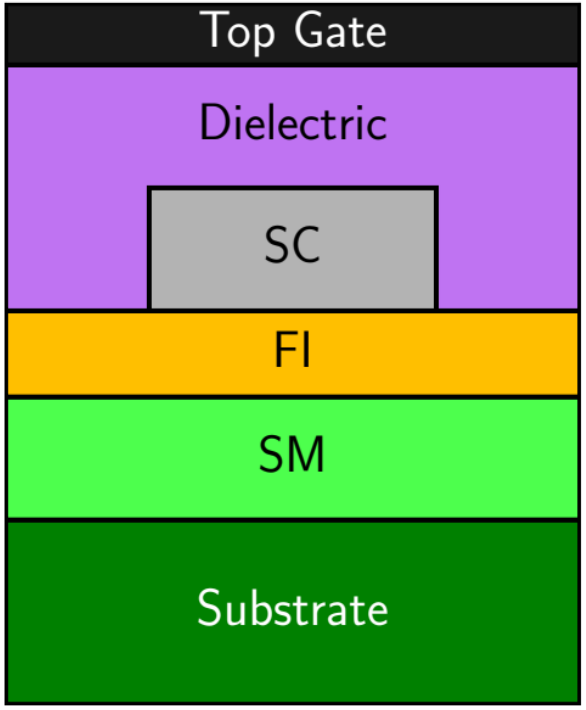
SEMICONDUCTOR-FERROMAGNET-SUPERCONDUCTOR PLANAR HETEROSTRUCTURES FOR 1D TOPOLOGICAL SUPERCONDUCTIVITY

npj Quantum Materials 7, 81 (2022)

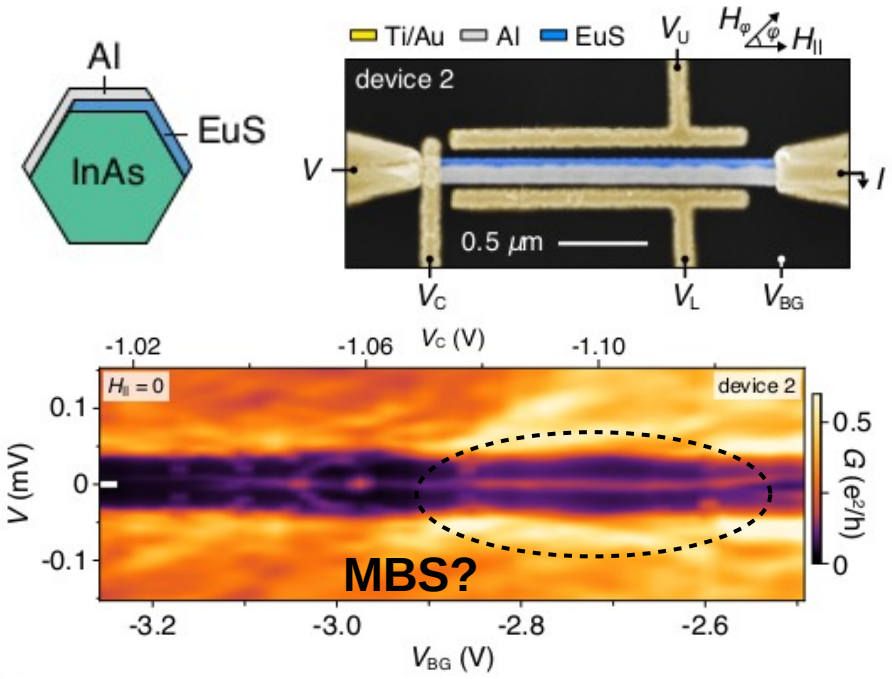
Samuel D. Escribano



SM-SC-FI planar wires

Early theoretical works proposed that topological superconductivity could be achieved in heterostructures mixing three materials

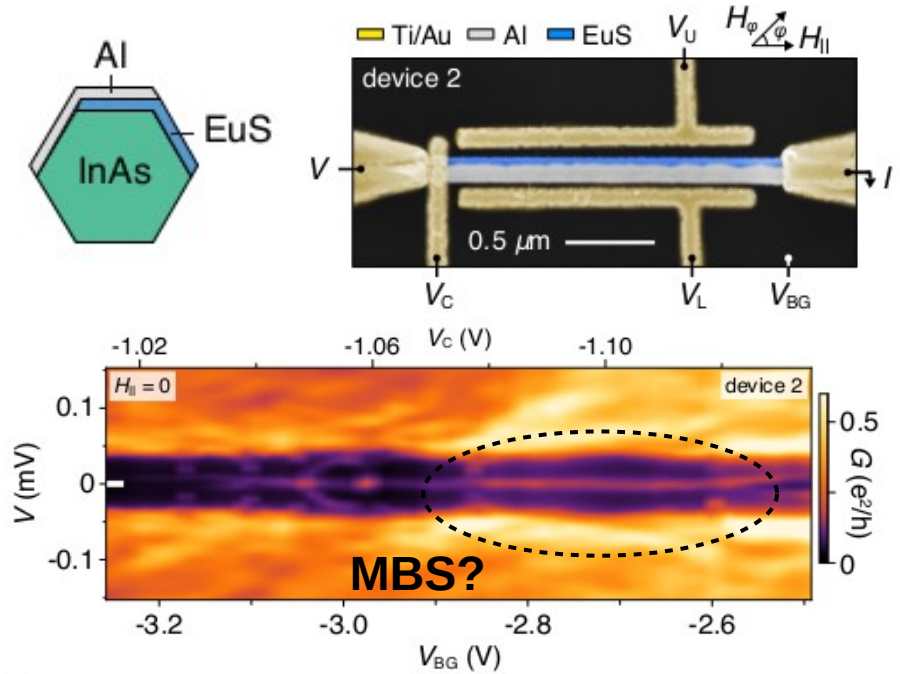
Semiconductor with SO coupling + Superconductor + **Magnetic insulator**



J. D. Sau *et al.*, PRL **104**, 040502 (2010).

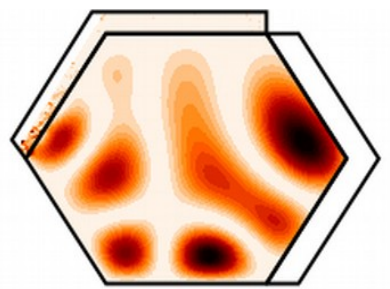
SM-SC-FI planar wires

Overlapping geometry
Shows ZBP compatible with MBSs



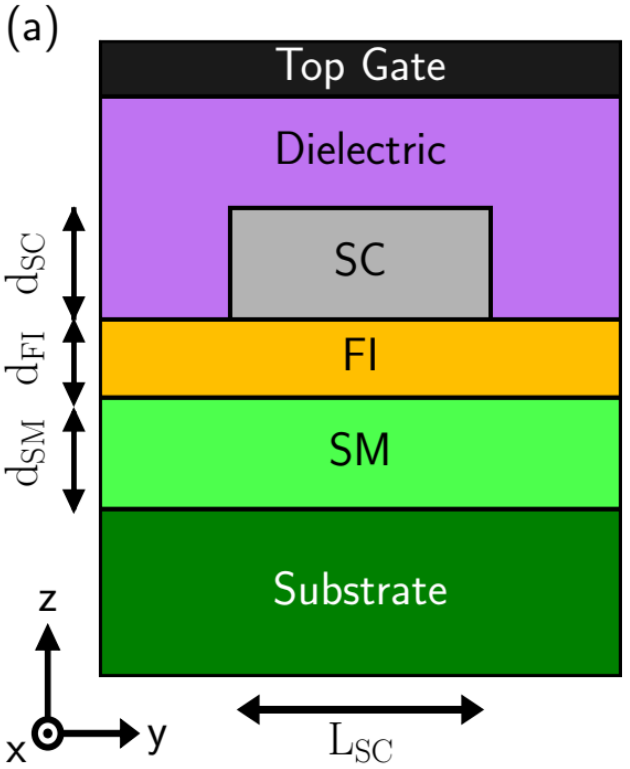
Nanowire-based platforms:

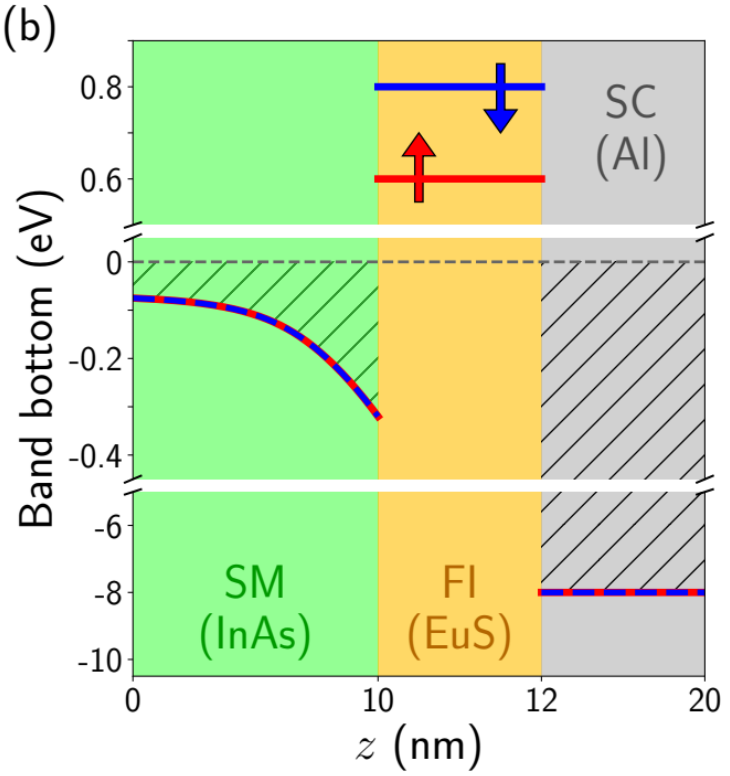
- The wavefunction in nanowires spreads all across the section (weak proximity effects).
- Difficult to manipulate and escalate.
- Moreover, wires usually present high degree of disorder.



S. Vaitiekenas *et al.*, Nat. Phys. **17**, 43 (2021).

SM-SC-FI planar wires





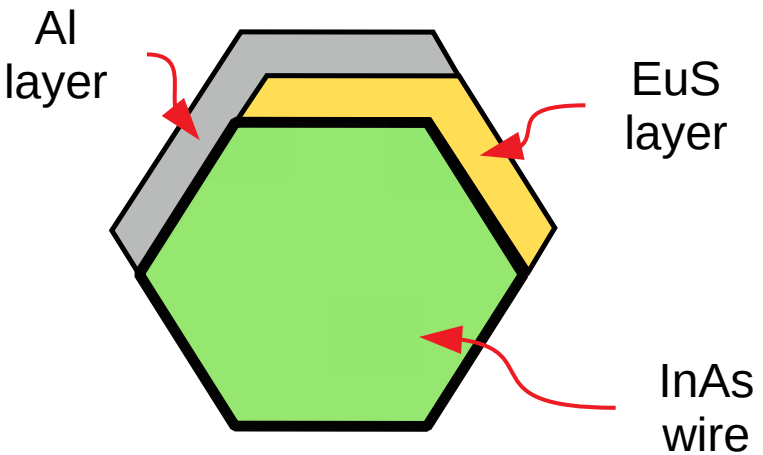
The insulator should be thin enough to allow electrons to tunnel through

But thick enough to induce a strong magnetization

Optimal FI thickness?

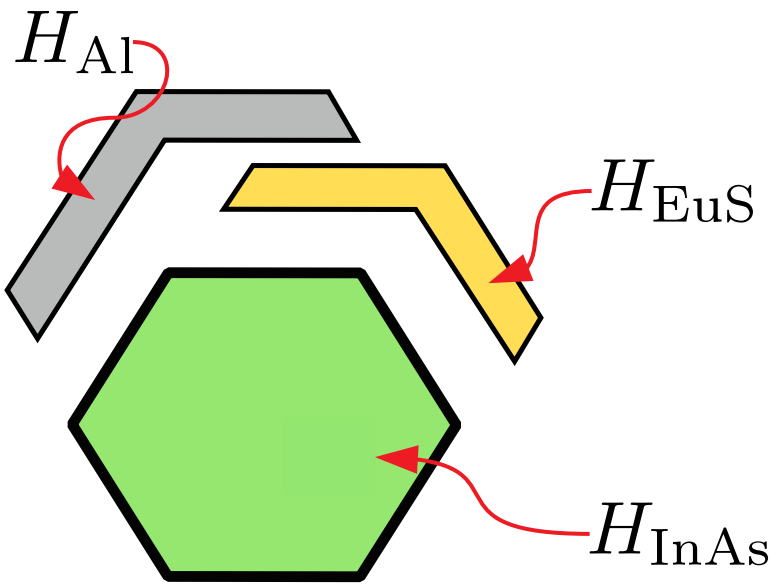
SM-SC-FI planar wires

We describe each material separately. When joined together, we describe the system with a single Hamiltonian with spatial dependent parameters.



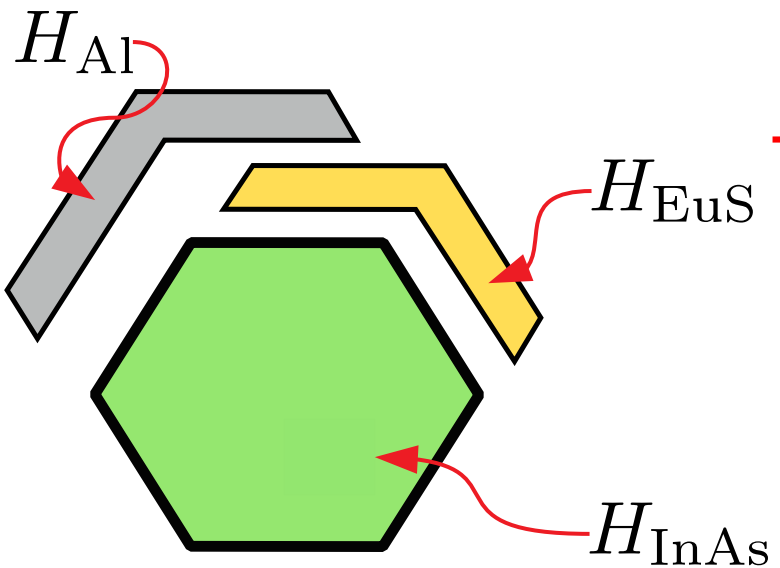
SM-SC-FI planar wires

We describe each material separately. When joined together, we describe the system with a single Hamiltonian with spatial dependent parameters.



SM-SC-FI planar wires

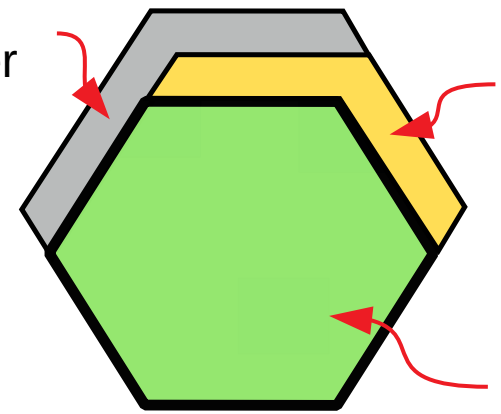
We describe each material separately. When joined together, we describe the system with a single Hamiltonian with spatial dependent parameters.



$$\rightarrow H = H_{\mathrm{InAs}} \oplus H_{\mathrm{Al}} \oplus H_{\mathrm{EuS}}$$

SM-SC-FI planar wires

We describe each material separately. When joined together, we describe the system with a single Hamiltonian with spatial dependent parameters.

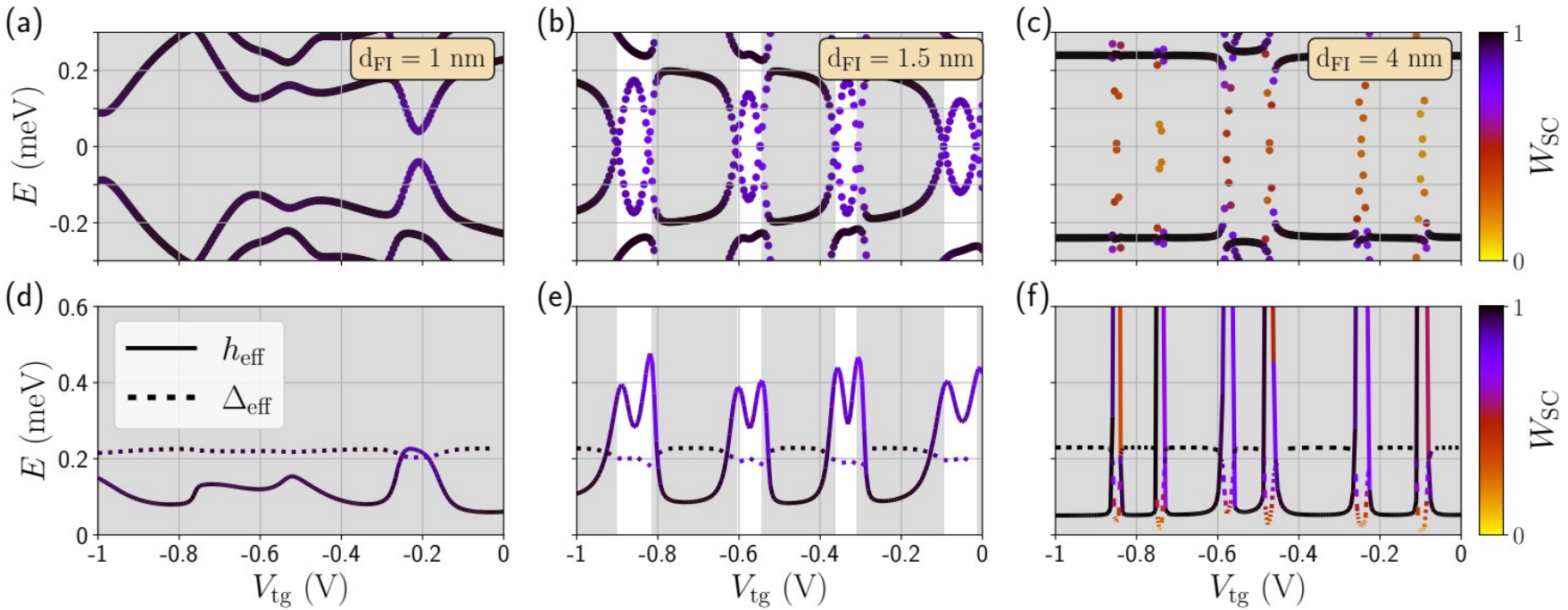


$$\mathrm{H}=\left[\vec{k}\frac{\hbar^2}{2m_{\mathrm{eff}}(\vec{r})}\vec{k}-E_F(\vec{r})+e\phi(\vec{r})+h_{ex}(\vec{r})\right]\tau_z + \frac{1}{2}\left[\vec{\alpha}(\vec{r})\cdot\left(\vec{\sigma}\times\vec{k}\right)+\left(\vec{\sigma}\times\vec{k}\right)\cdot\vec{\alpha}(\vec{r})\right]\tau_z + \Delta(\vec{r})\sigma_y\tau_y$$

$$\vec{\nabla}\cdot\left(\epsilon(\vec{r})\vec{\nabla}\phi(\vec{r})\right)=-\rho(\vec{r})$$

SM-SC-FI planar wires

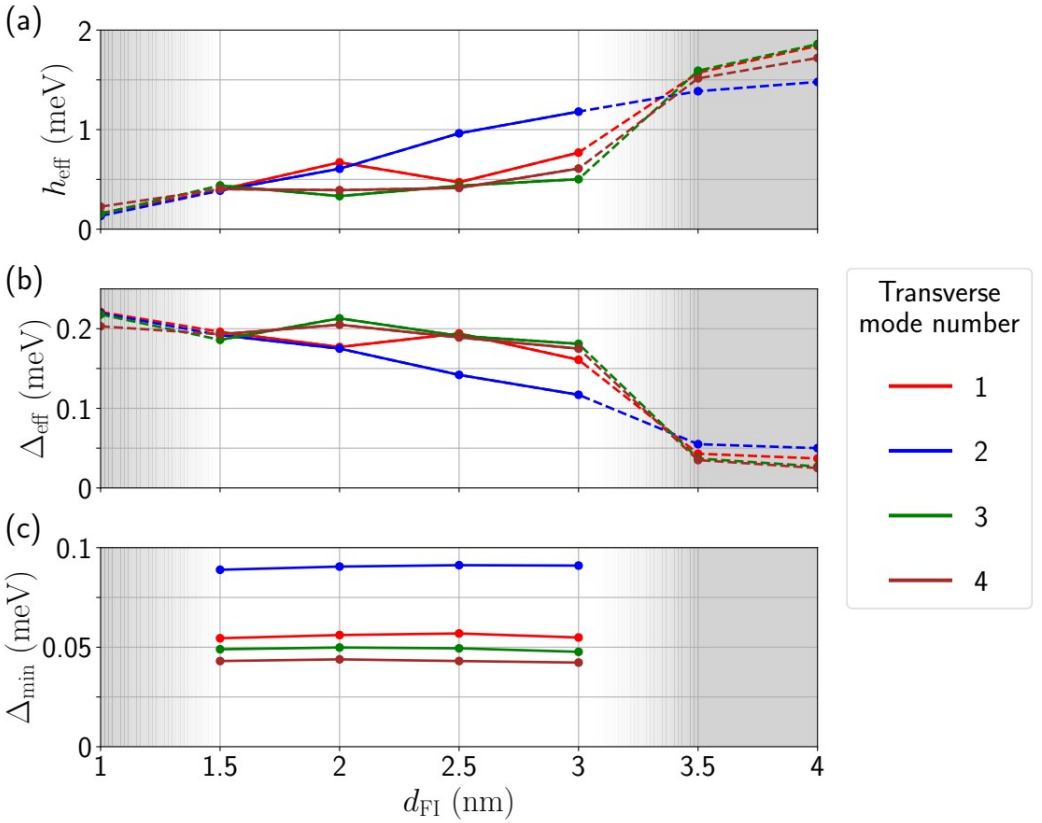
Spectrum (at k_x=0) for different FI thicknesses



SM-SC-FI planar wires

We analyze the evolution of different subbands for different FI thicknesses

We find that around 1.5 to 3 nm, InAs-EuS-Al heterostructures can support a topological superconducting phase



SM-SC-FI planar wires

Planar-based heterostructures show stronger confinement, leading to:

- Stronger proximity effects
- More regular and larger topological phases (predictability)
- Larger minigaps