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Majorana fermions in carbon nanotubes

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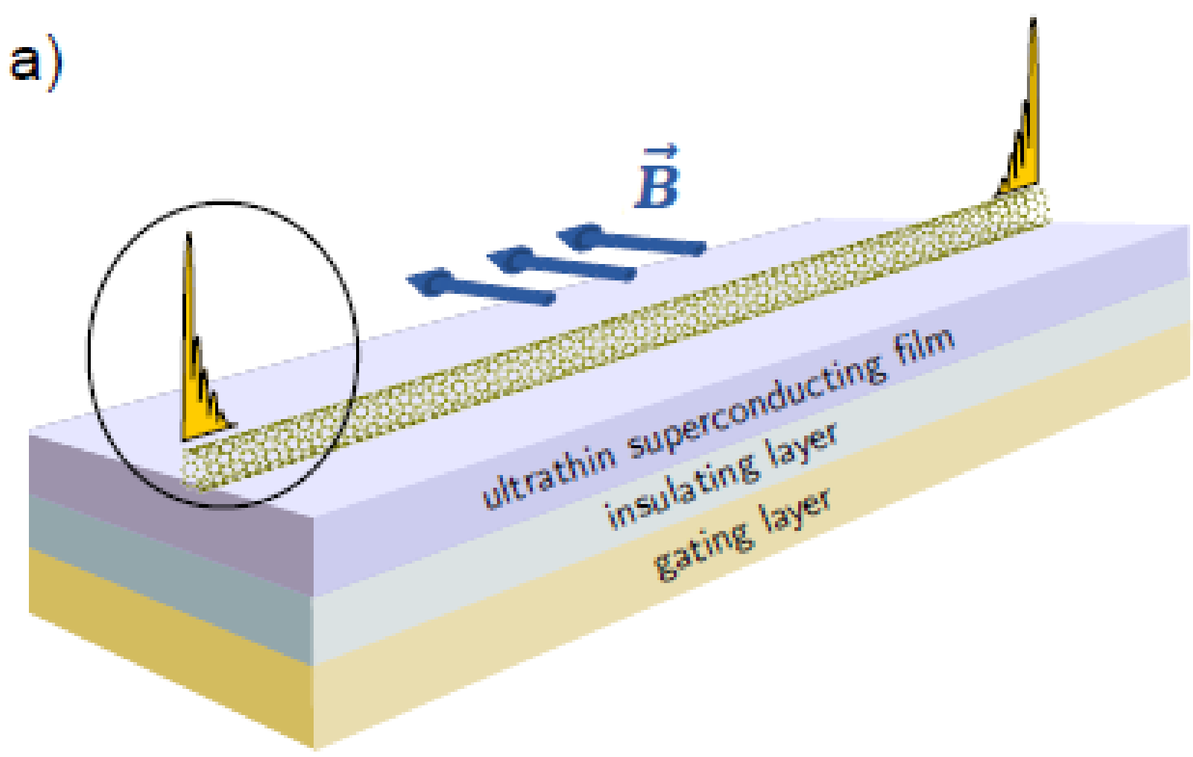
Abstract: Engineering effective p-wave superconductors hosting Majorana quasiparticles (MQPs) is of particular interest for fundamental research as well as for applications in fault-tolerant topological quantum computation.
In quasi one-dimensional systems, the parameter space for topological superconductivity is significantly reduced by the coupling between transverse modes.
Together with the requirement of achieving the topological phase under experimentally feasible conditions, this strongly restricts in practice the
choice of systems which can host MQPs.
Here we demonstrate that semiconducting carbon nanotubes (CNTs) in proximity with ultrathin s-wave superconductors, e.g. exfoliated NbSe2, and in perpendicular magnetic field satisfy these needs. By precise numerical tight-binding calculations in the real space we show the emergence of localized zero-energy states at the CNT end of which we determine the full 3D spatial profile. We show that the chiral nature of the CNT lattice is imprinted in the MBS wave function which has a helical structure, anisotropic in the transverse direction. The local spin canting angle displays a similar spiral pattern, varying around the CNTs circumference. The experimental state of the art is discussed.

Caption: **Majorana bound states in carbon nanotubes.** a) A carbon nanotube in proximity with a thin superconductor can support Majorana bound states at its edges. b) Spin canting angle of a Majorana function in a carbon nanotube.



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