Crossed Andreev reflection in layered graphene structures

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Hungary
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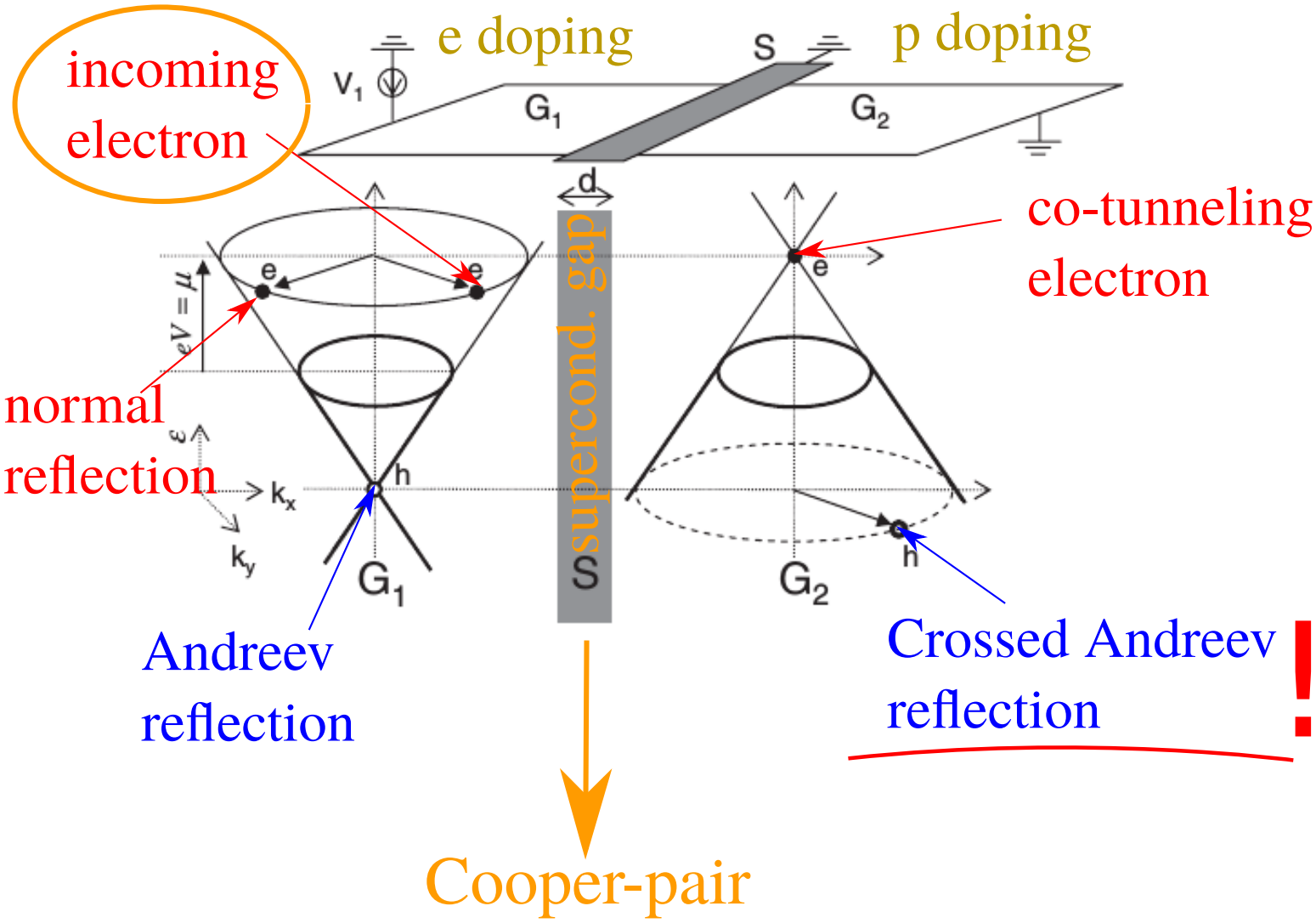
MOMENTUM OF INNOVATION

FLAG-ERA

Topograph meeting 2020.01.23.

Motivation

Proposal of J. Cayssol, PRL **100**, 147001 (2008):



"antisymmetric" gating:

Andreev reflection and electron co-tunneling **are suppressed** !

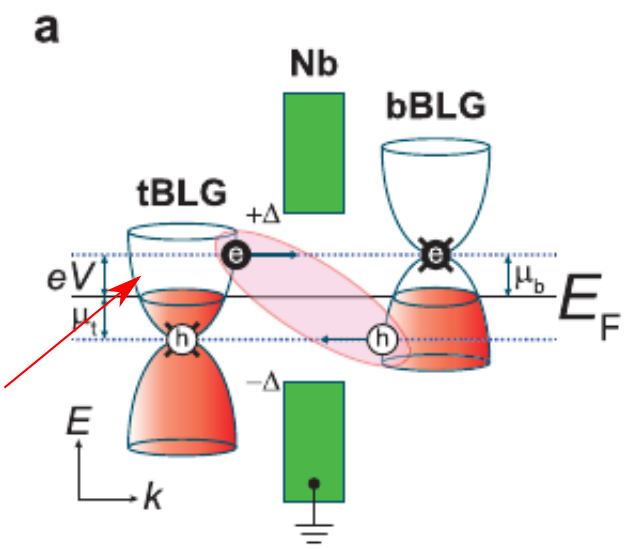
Drawback:

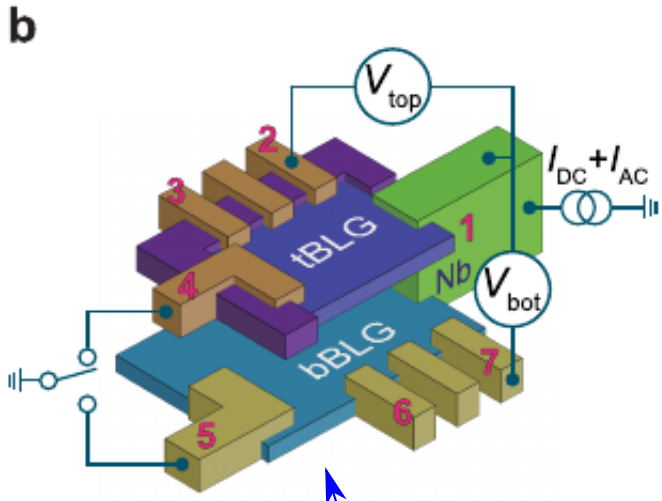
1) the Dirac points should be within the sup. gap

2) at arbitrary energy the Andreev reflection and electron co-tunneling would not be suppressed

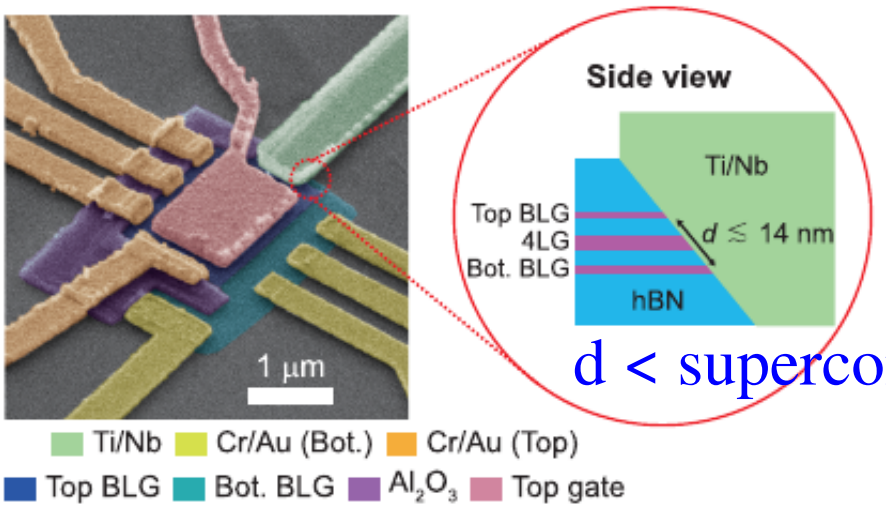
Experimental realization

Geon-Hyoung Park et. al., Nano Lett. 2019, 19, 9002–9007:





two sheets of bilayer graphenes



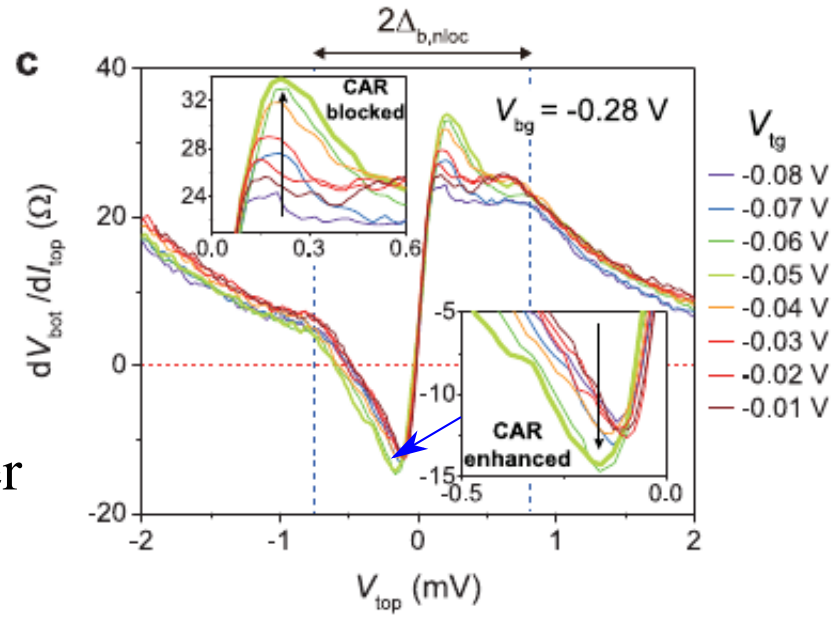
d < superconducting coherece length

evidence for the crossed Andreev reflection (CAR) in the non-local differential resistance:

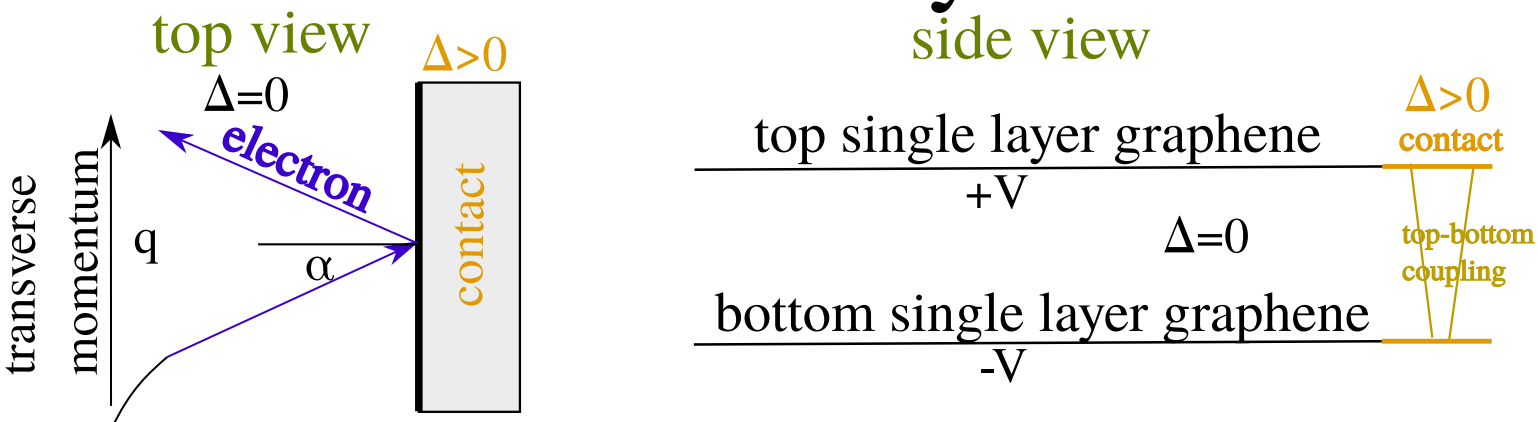
$$\frac{dV_{top}}{dI_{bot}}$$

top layer

bottom layer



Geometry

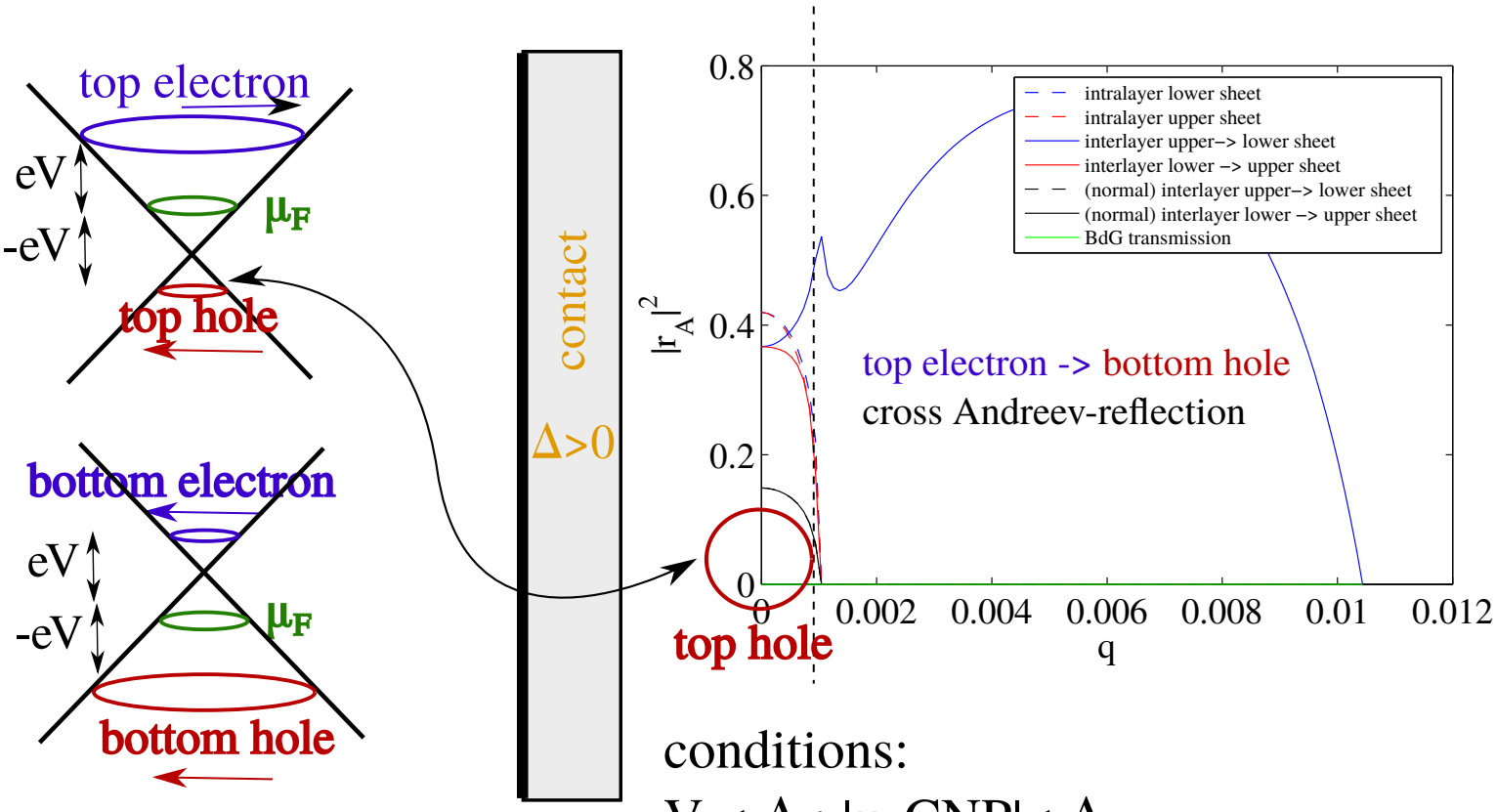


highly doped superconducting contact ($T<T_c$)

top-bottom coupling: single tight binding parameter for the "distance" between the layers

q can be translated into the incident angle α

Andreev Reflection Amplitude



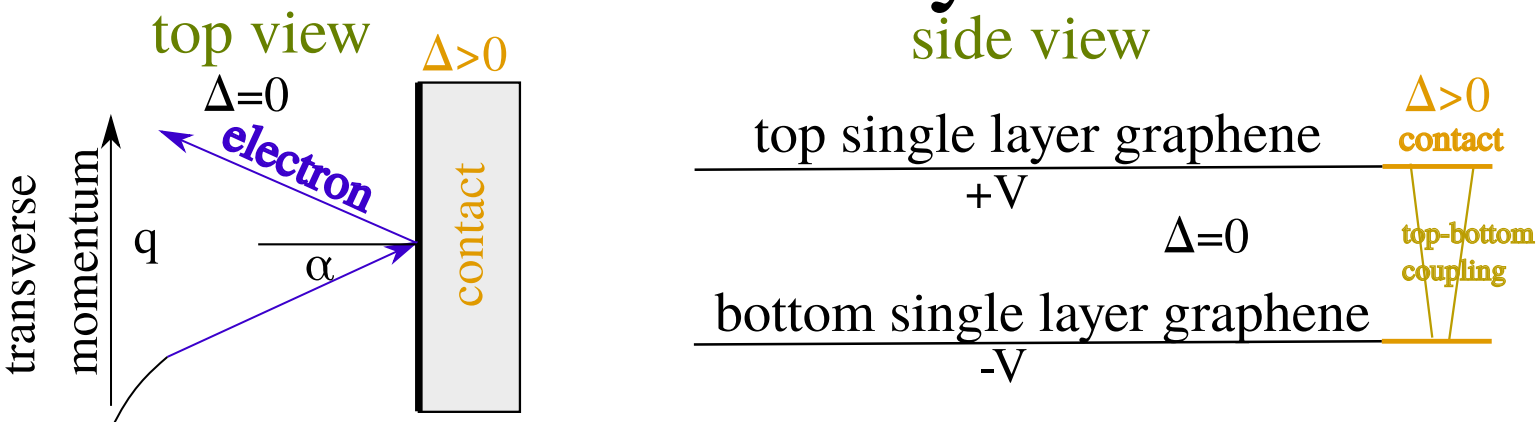
conditions:

$V < \Delta$; $|\mu\text{-CNP}| < \Delta$

chemical potential

charge neutrality point

Geometry



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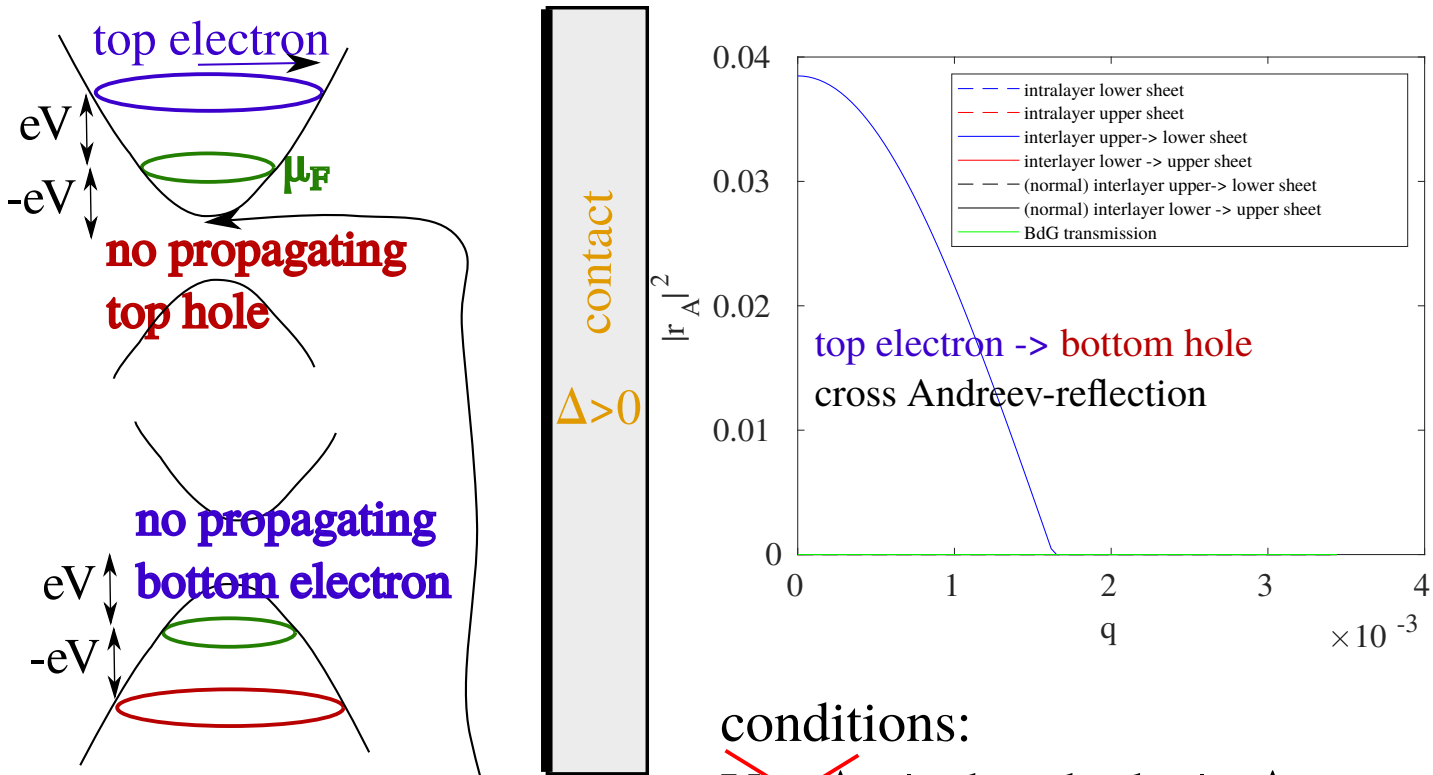
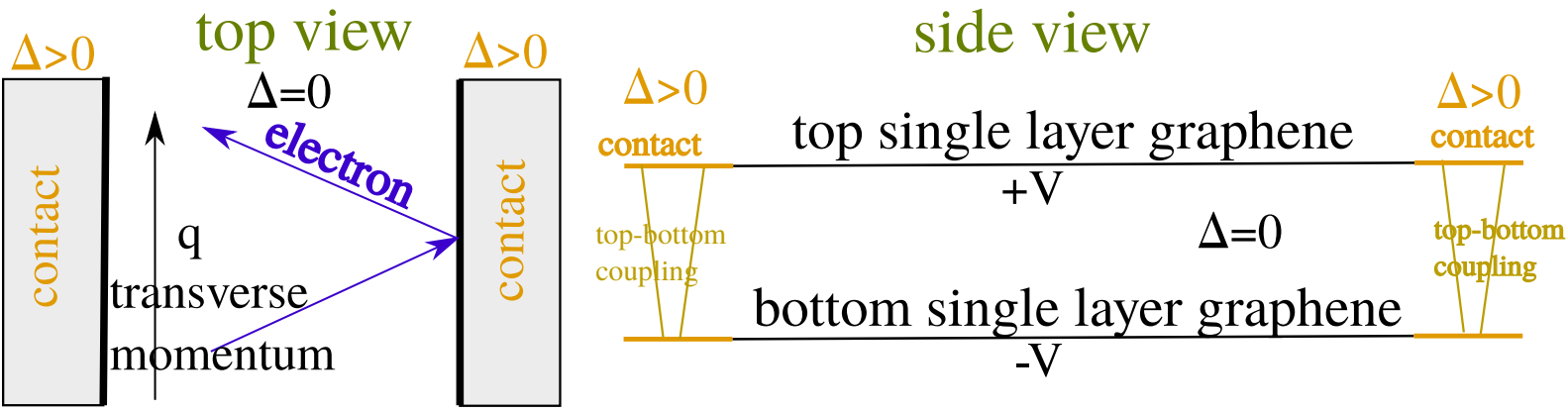


conditions:

~~V < Δ~~ ; |μ-band edge|< Δ

chemical potential

Geometry



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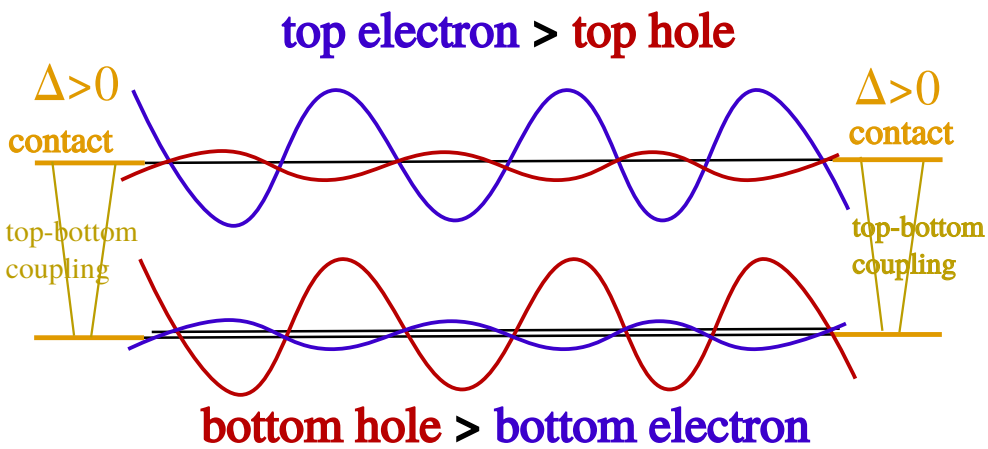
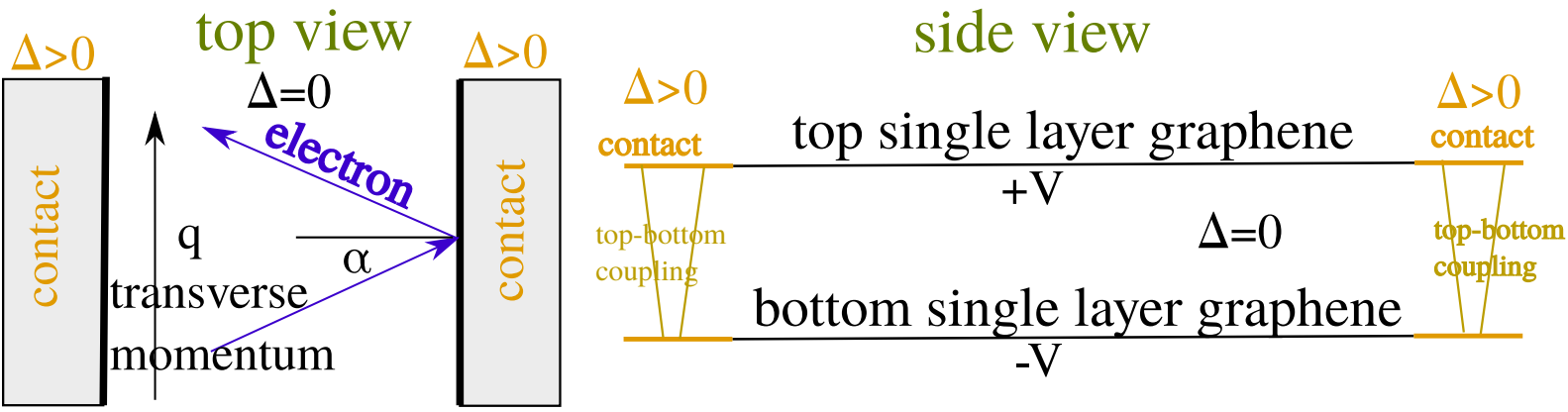
Expectation



resonantly enhanced spillting of the electron and hole wave function?

Geometry



highly doped superconducting contacts ($T<T_c$)

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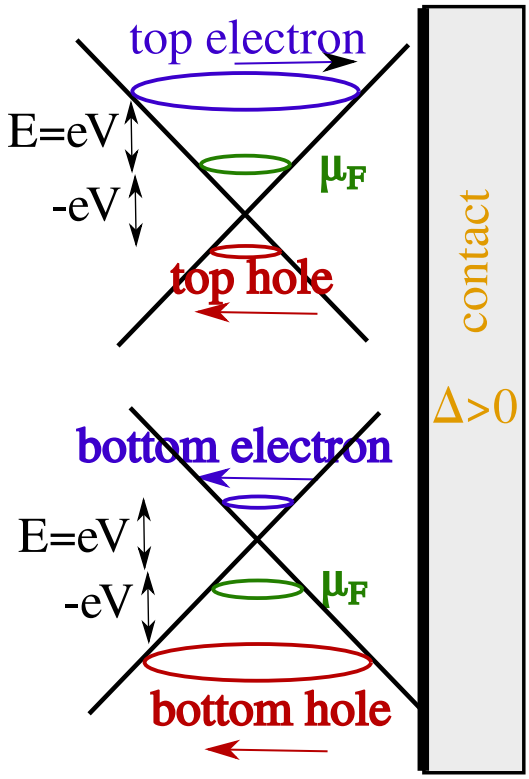
Density of States

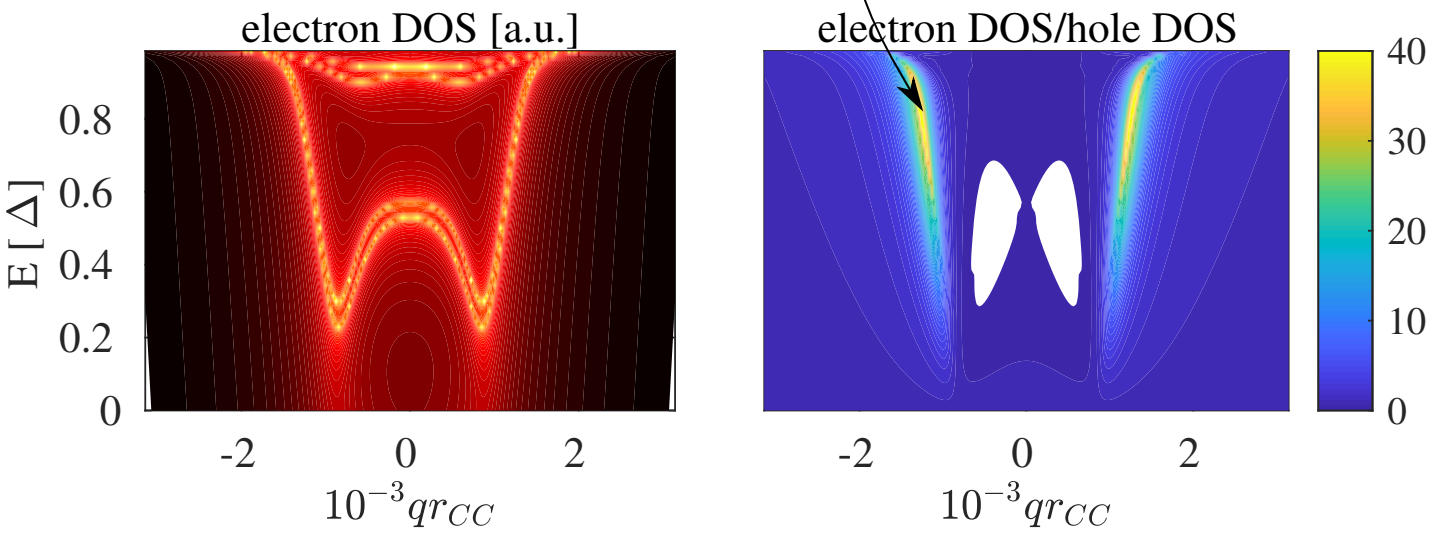
at the center of the central region
on the upper sheet



$DOS_{electron} > DOS_{hole}$

only at higher incident angles α
where there is no propagating hole state

$\Delta\varphi = \pi/3$ (phase difference)
junction length = 500 nm



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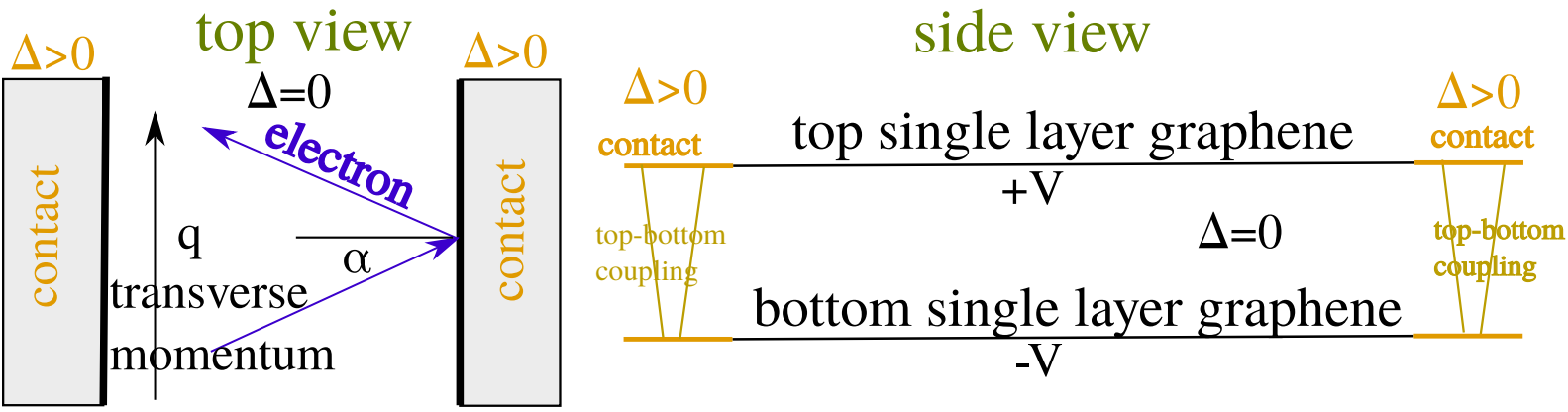

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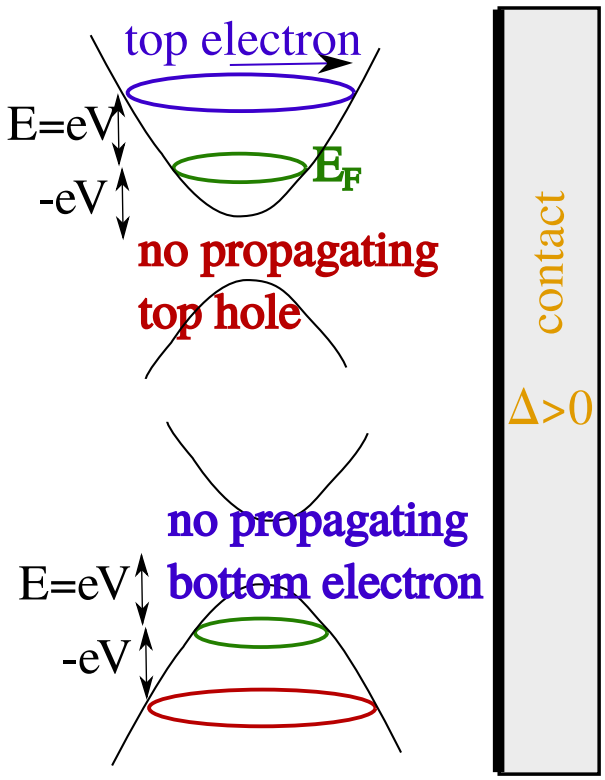

$DOS_{electron} > DOS_{hole}$

for almost all incident angles except for (α=) q=0.

$\Delta\varphi = \pi/3$ (phase difference)
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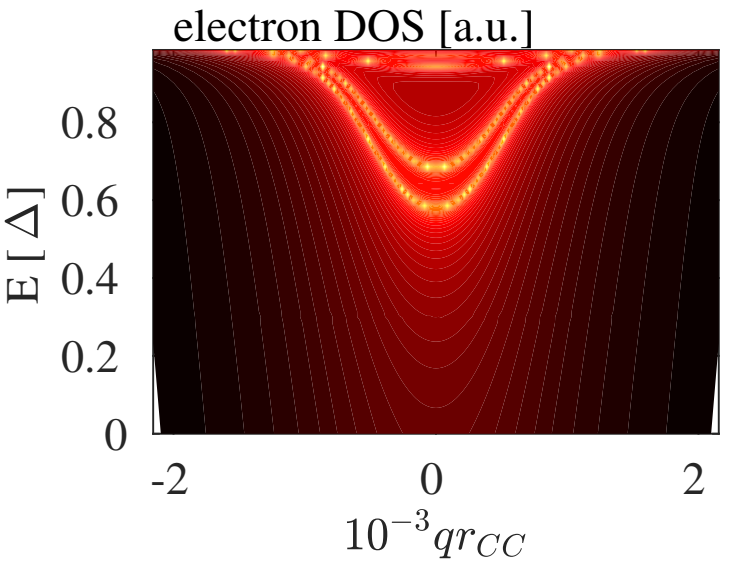

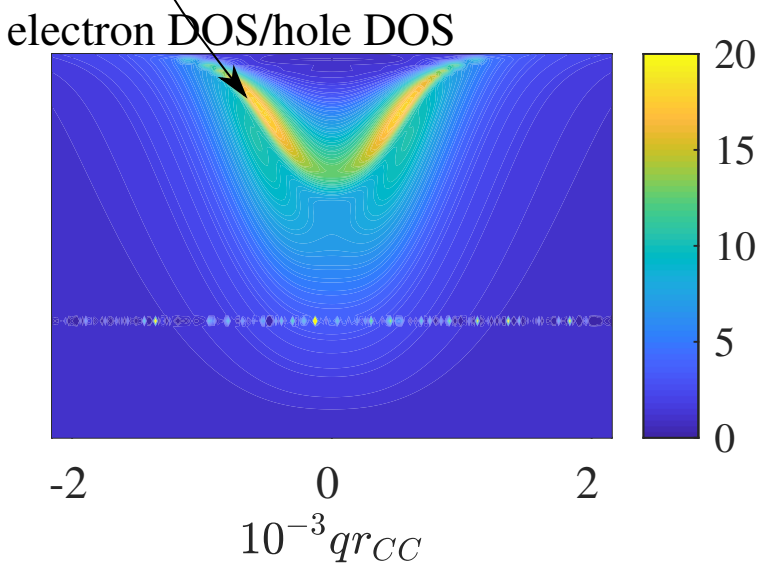

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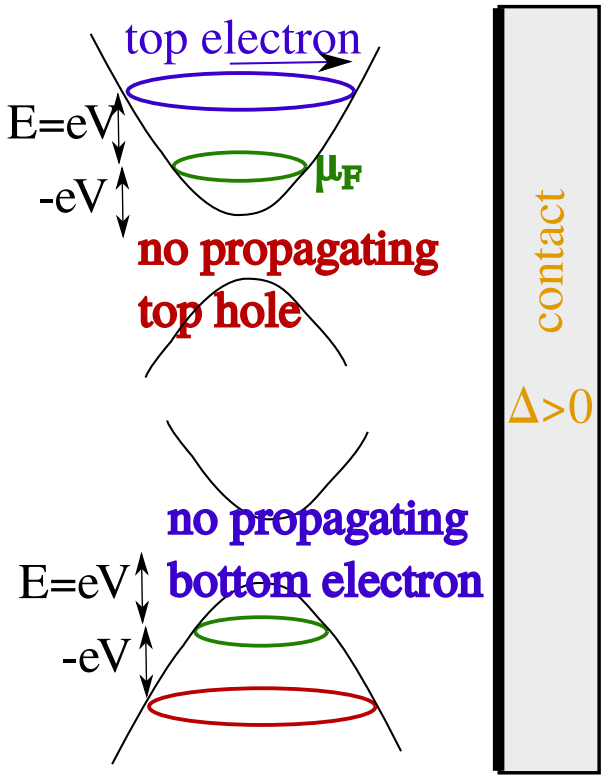

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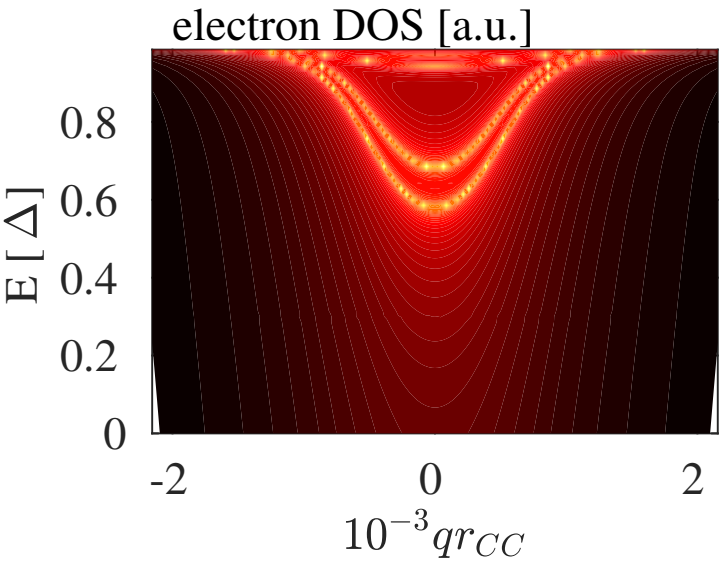
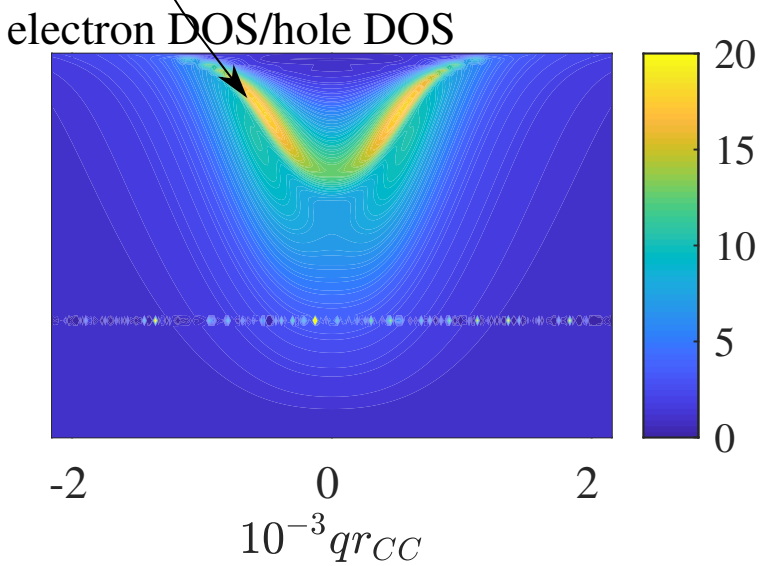
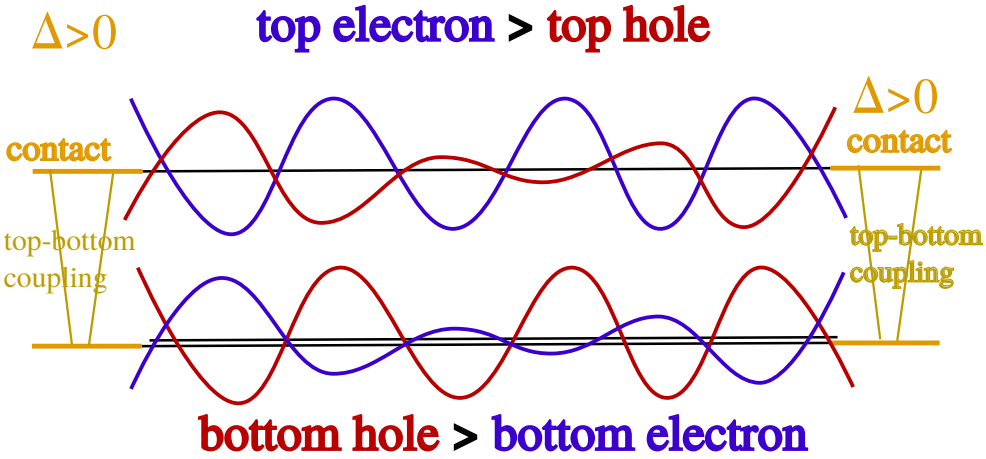




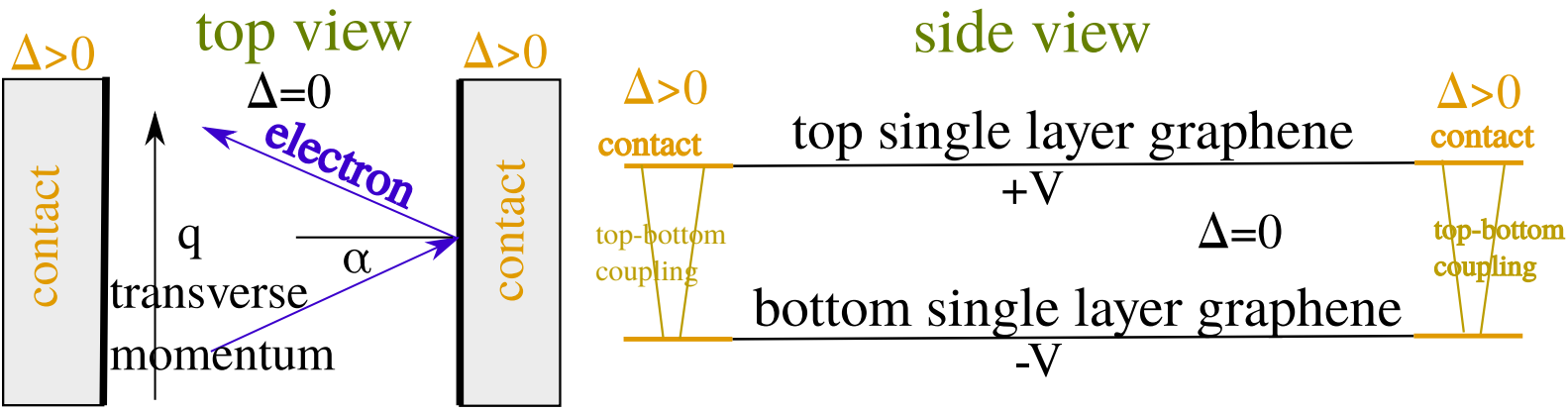
The decaying length of the hole states for gap |eV-band edge| = 1 meV at incident angle α=0

L~1/imag(k_0) hbar.$v_F k_0$ ~ |eV-band edge|

L ~ 600 nm



Geometry



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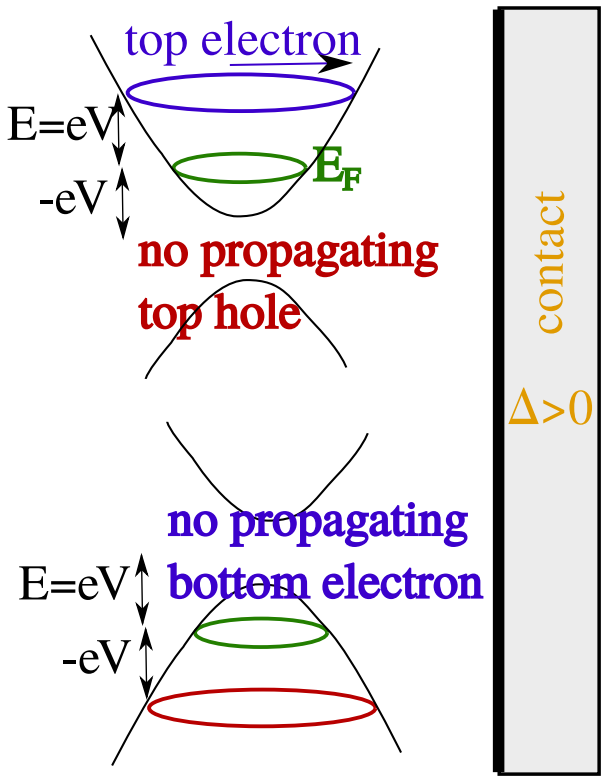
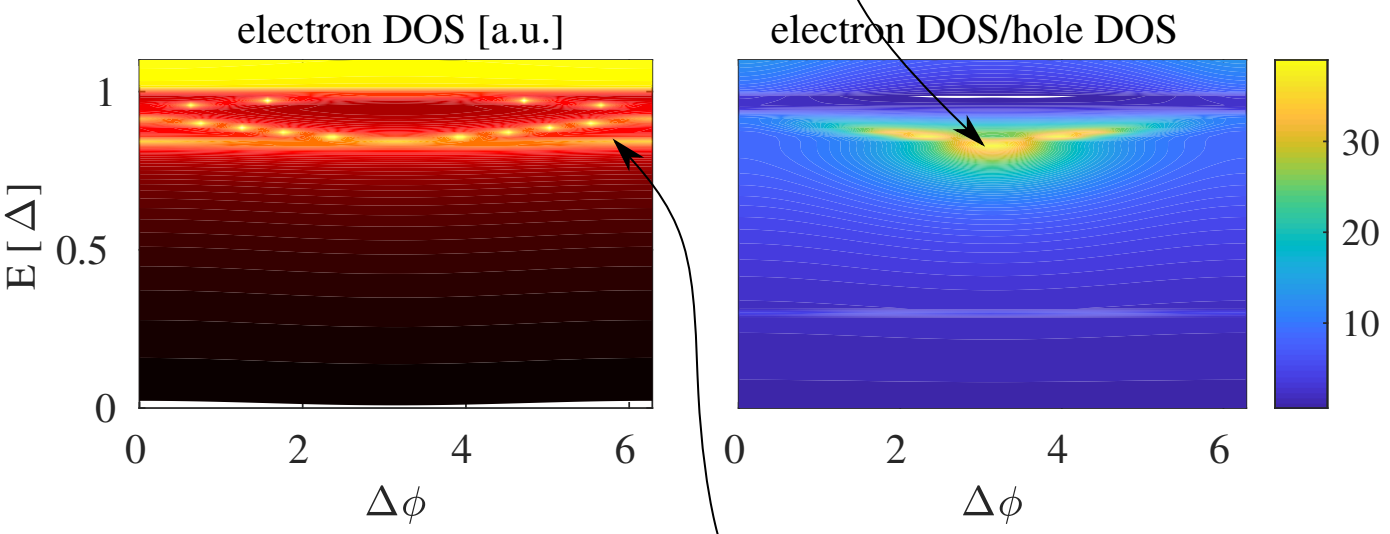


$DOS_{electron} > DOS_{hole}$

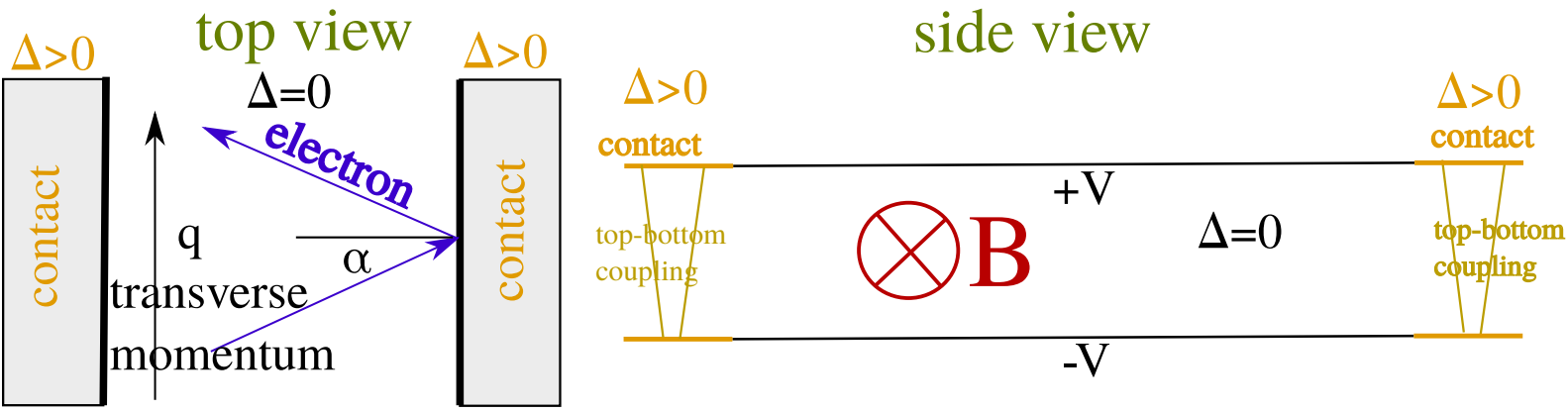
at $\Delta\varphi$ close to π

calculated for specific q > 0 (α>0)
junction length = 500 nm



non-dispersive state is localized to one of the S-G interfaces

Geometry



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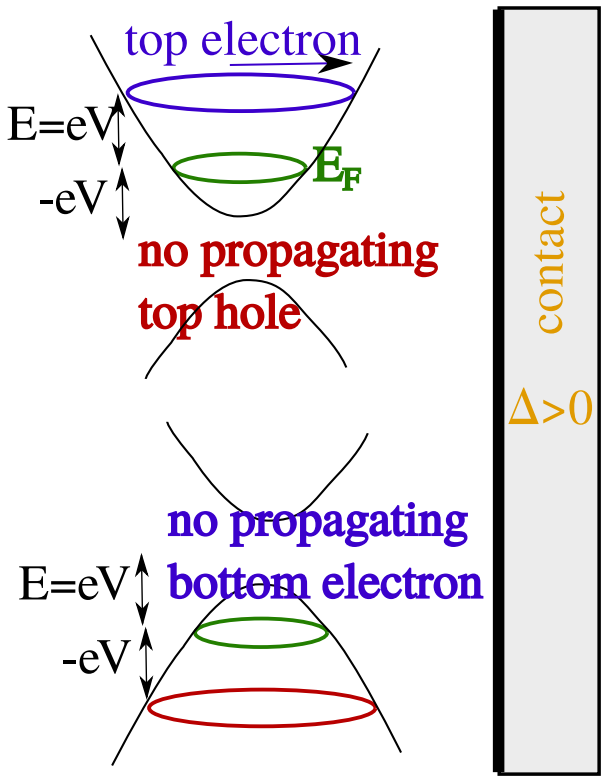
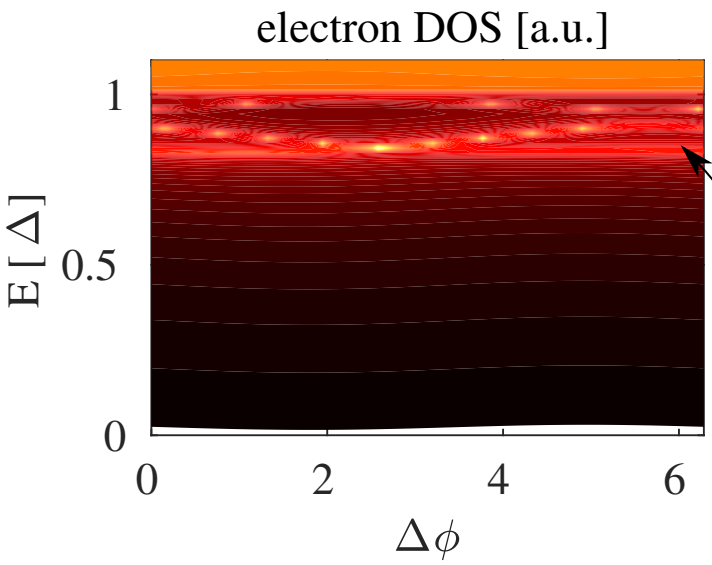
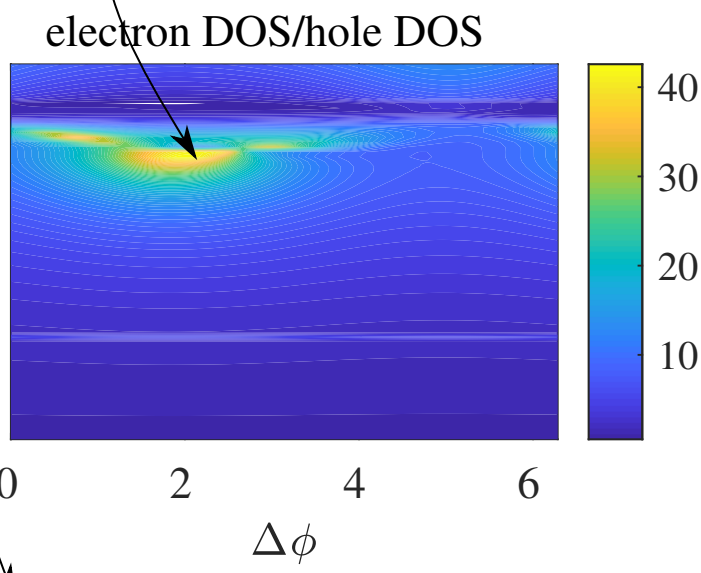


$DOS_{electron} > DOS_{hole}$

the maximum is shifted due to the magnetic flux

calculated for specific q > 0 (α>0)
and for a specific magnetic flux





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Acknowledgement

- NKFIH within the Quantum Technology National Excellence Program (Project No. 2017-1.2.1-NKP-2017-00001),
- ELTE Institutional Excellence Program (1783-3/2018/FEKUTSRAT) supported by the Hungarian Ministry of Human Capacities
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