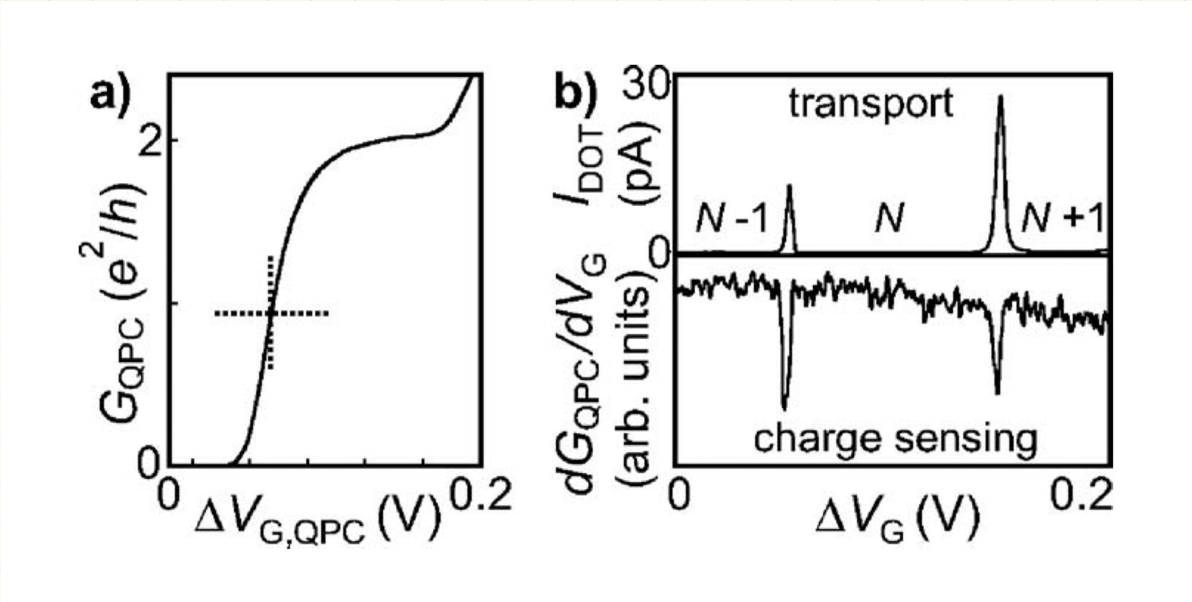
MARCH 30th, 2020

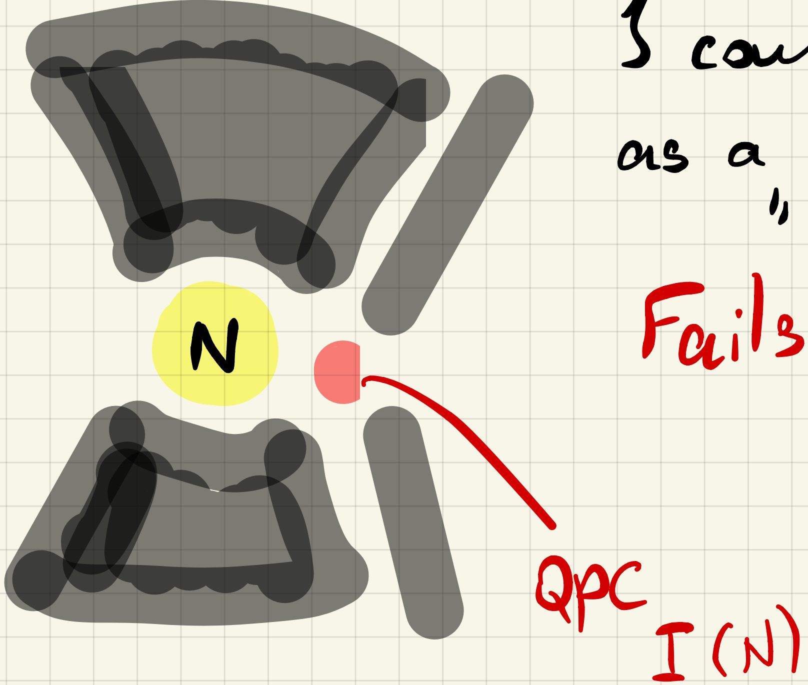
VIRTUAL-SPIN MEETING

M & C, HANSON et al.

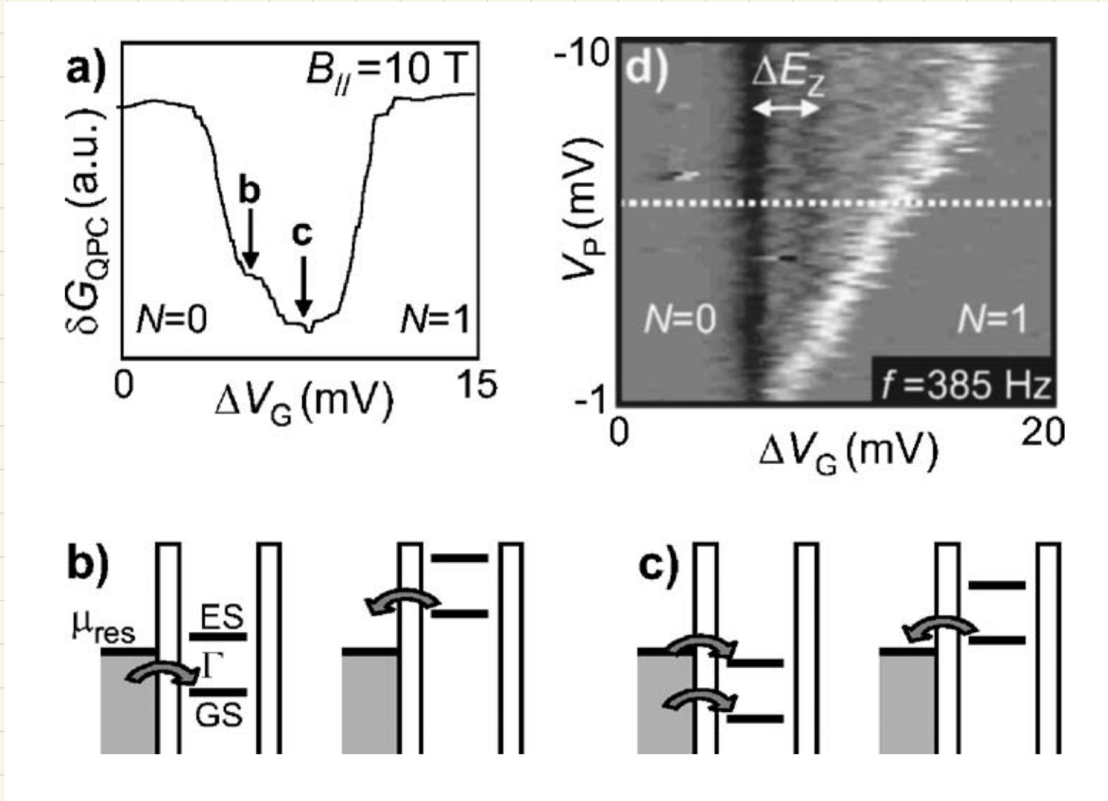
Charge sensing

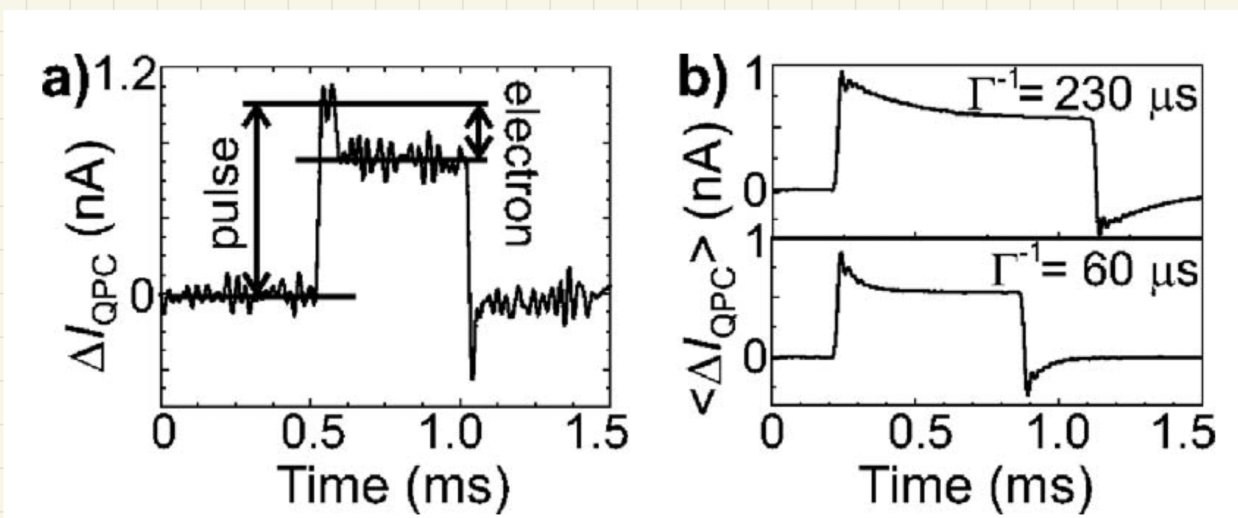


I could say that N acts as a „gate" on ● .



Fails if tunnel time > meas time



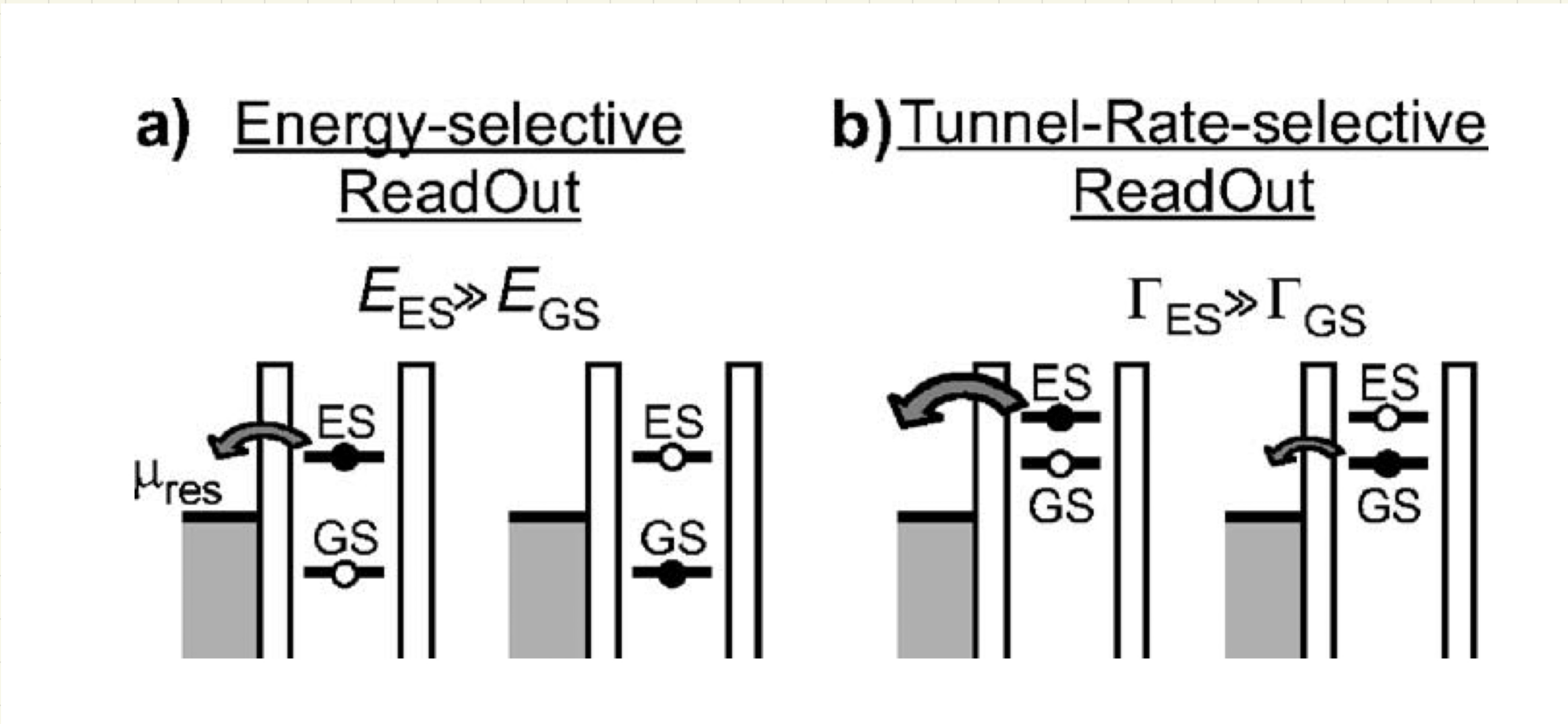


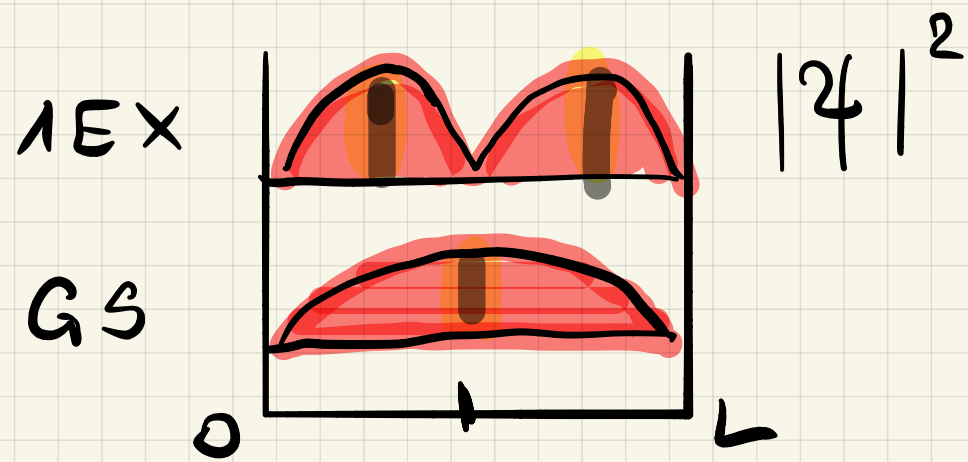
Different Gate Settings

Different Γ

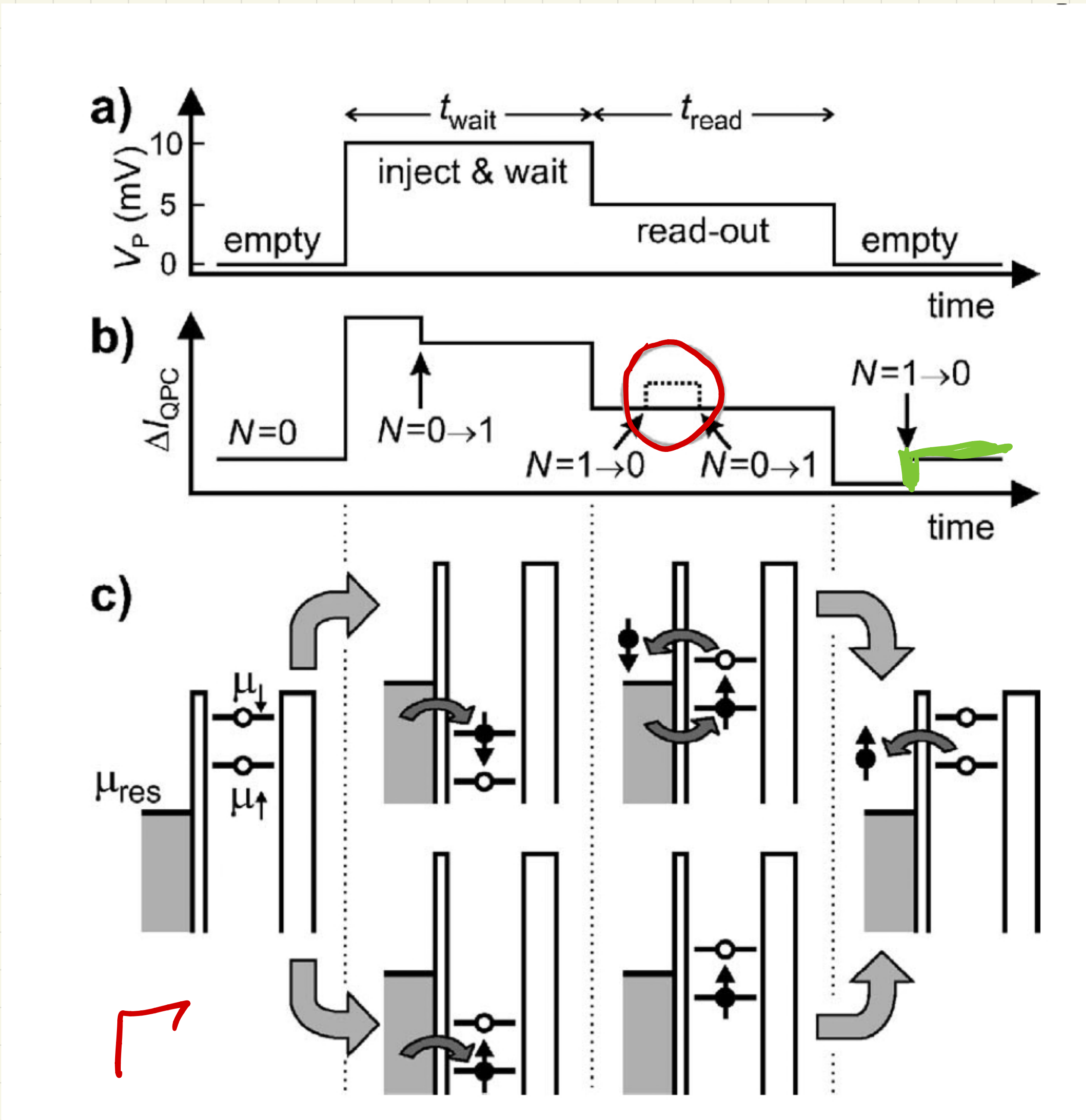
Single shot readout

Spin to charge conv. (destructive)





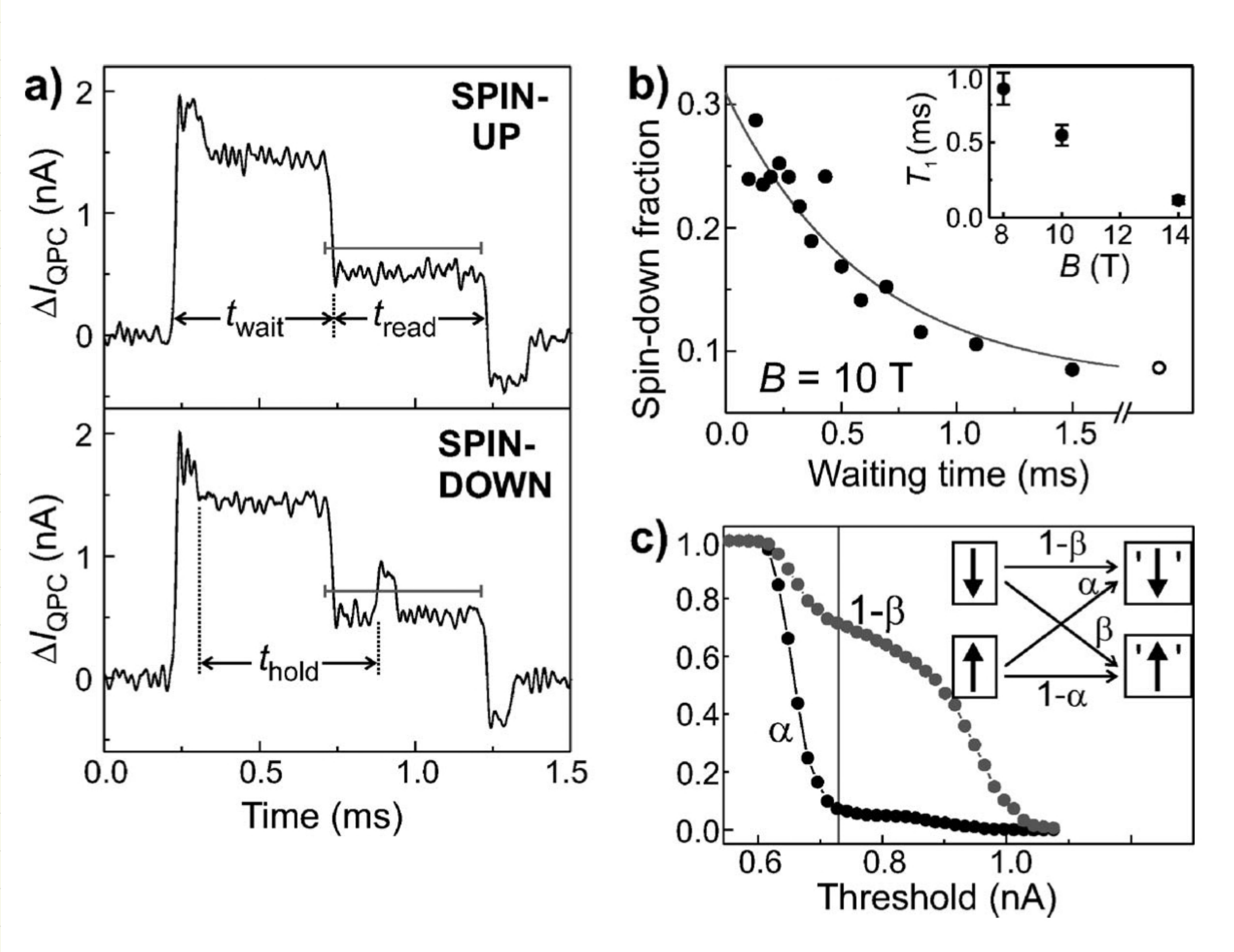
ERO (Elzerman)



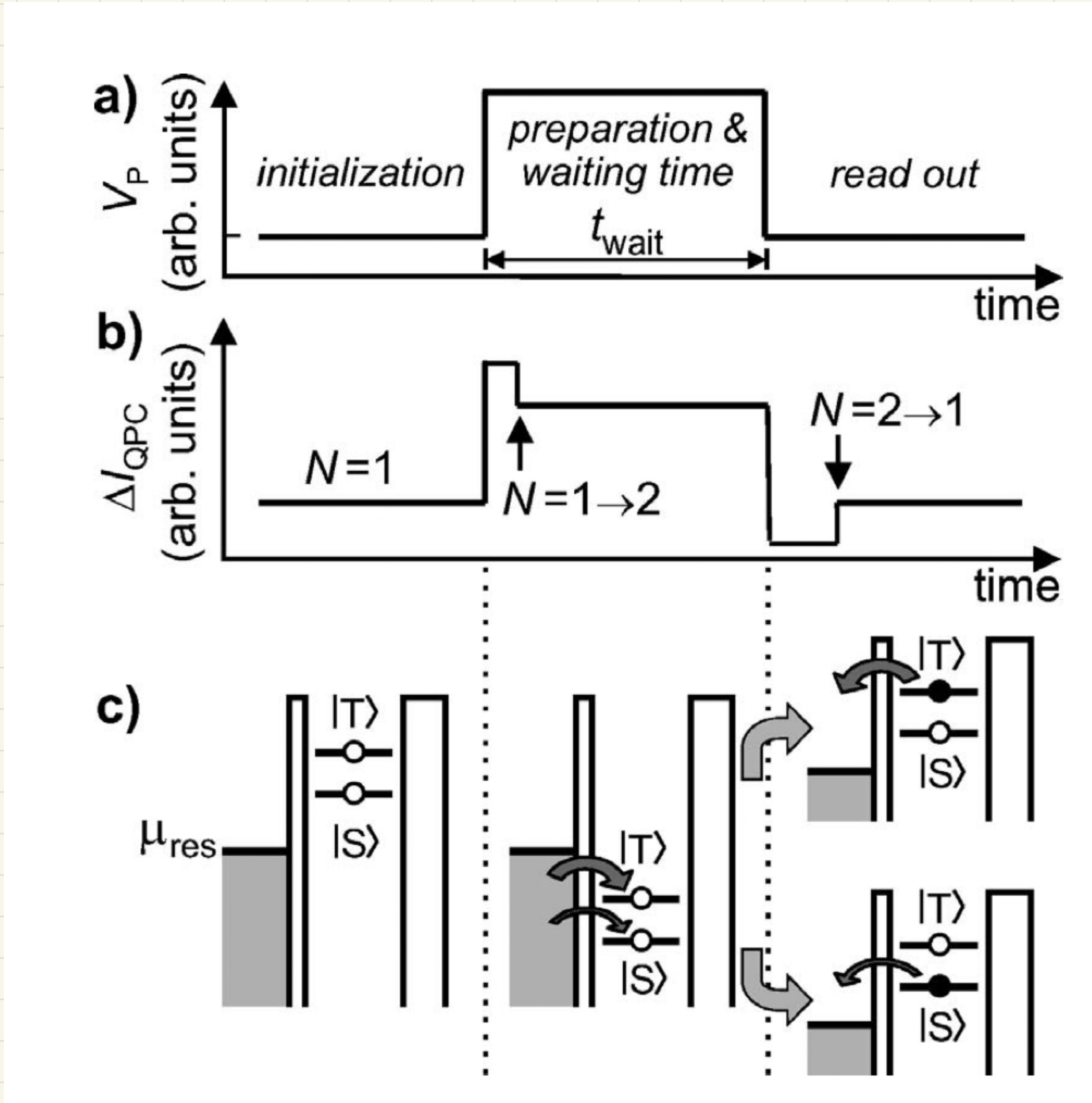
if the bump is missing → GS which is seen by the step in the end

(Also good for re-initialization)

more likely to exchange with lead if wait long



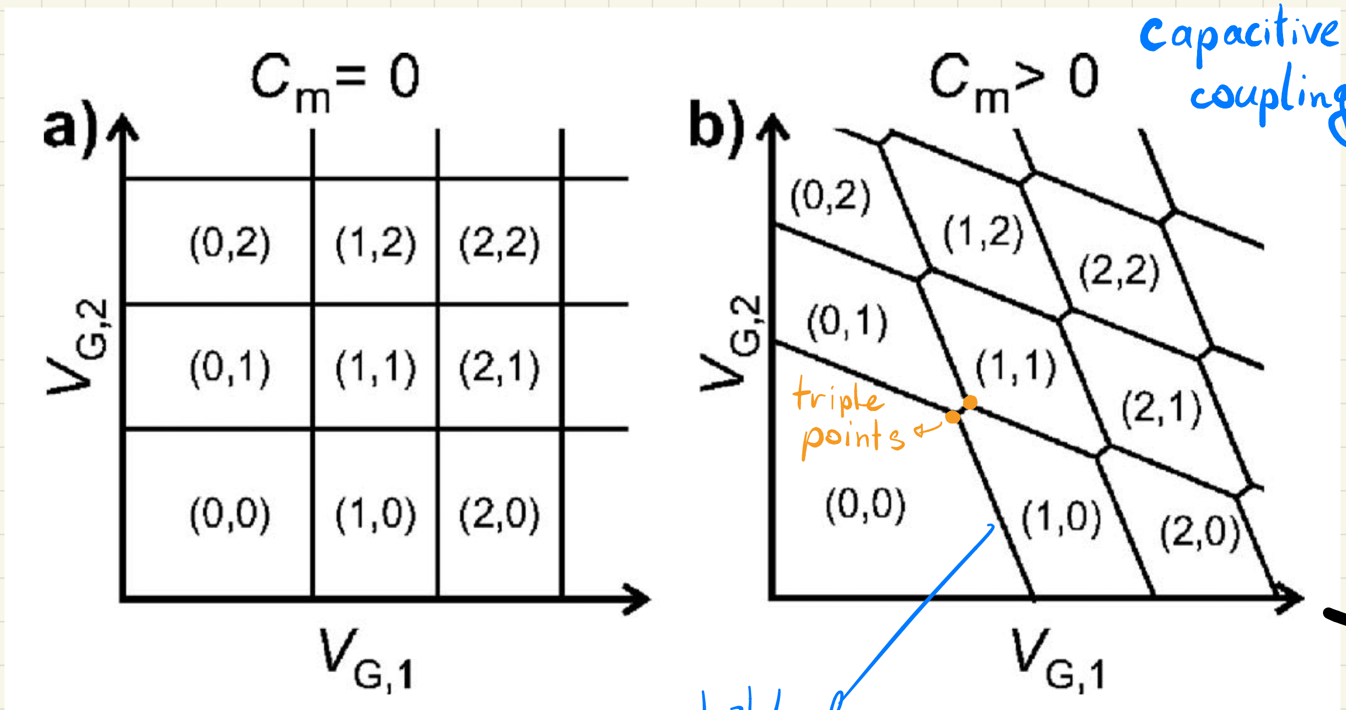
TR - RO



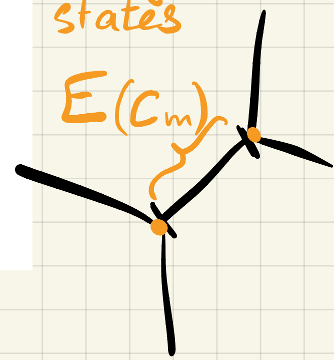
a)
V_P (arb. units)
initialization
preparation & waiting time
read out
t_{wait}
time
b)
ΔI_{QPC} (arb. units)
$N=1$
$N=1\rightarrow2$
$N=2\rightarrow1$
time
c)
μ_{res}
|T⟩
|S⟩

Spin States in Double QDs

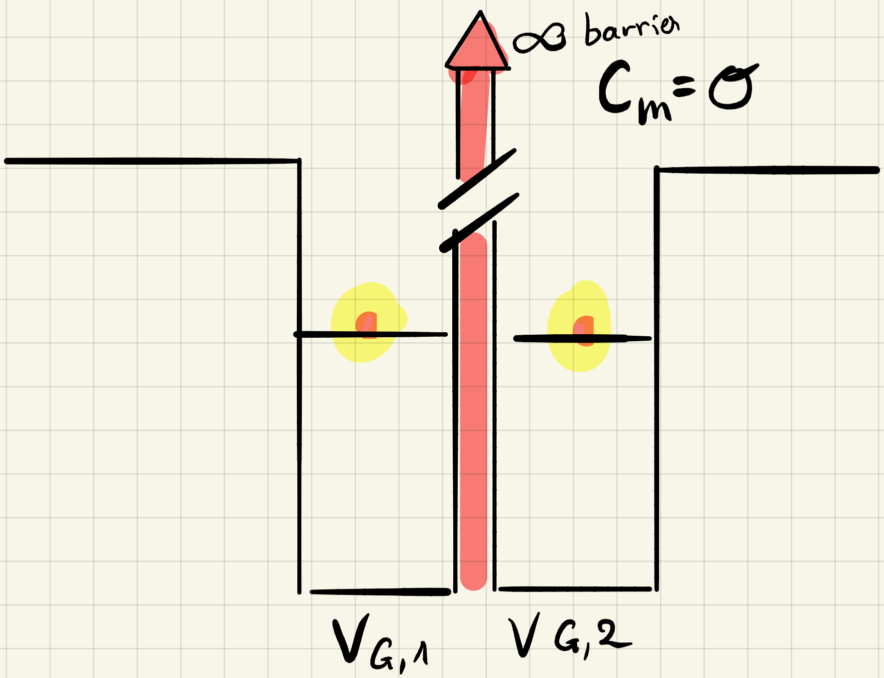
μ on either dot is indep. of charge on other dot →

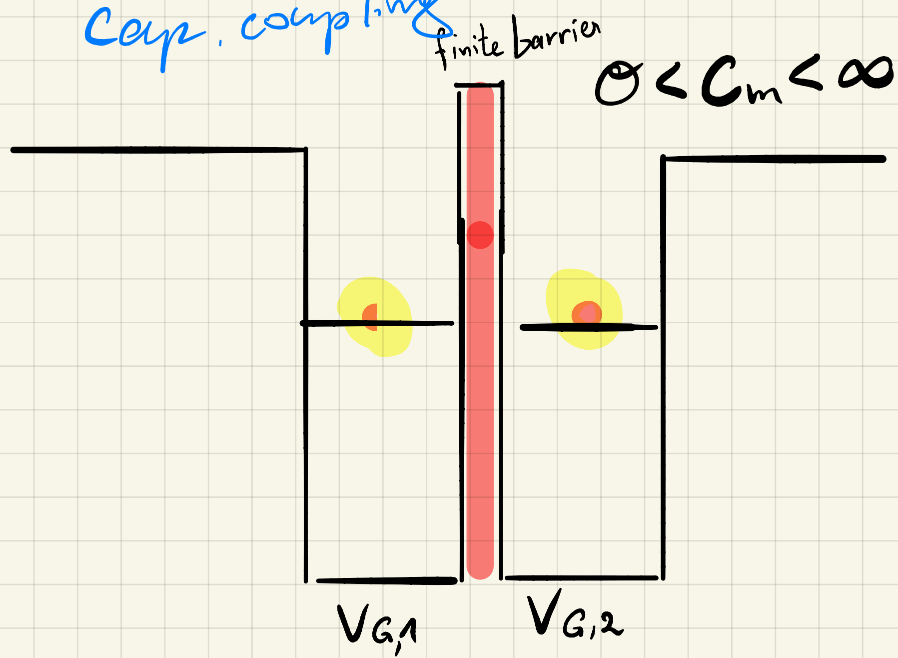


degenerate charge states

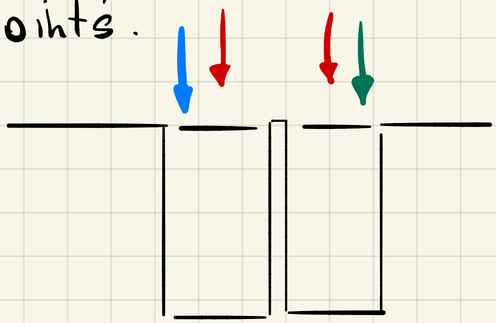


tilt from cap. coupling

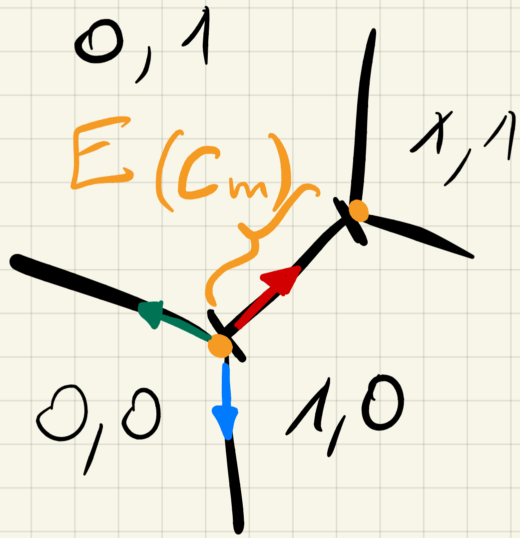




- @ low V_{SD}, transport is only possible in triple points.

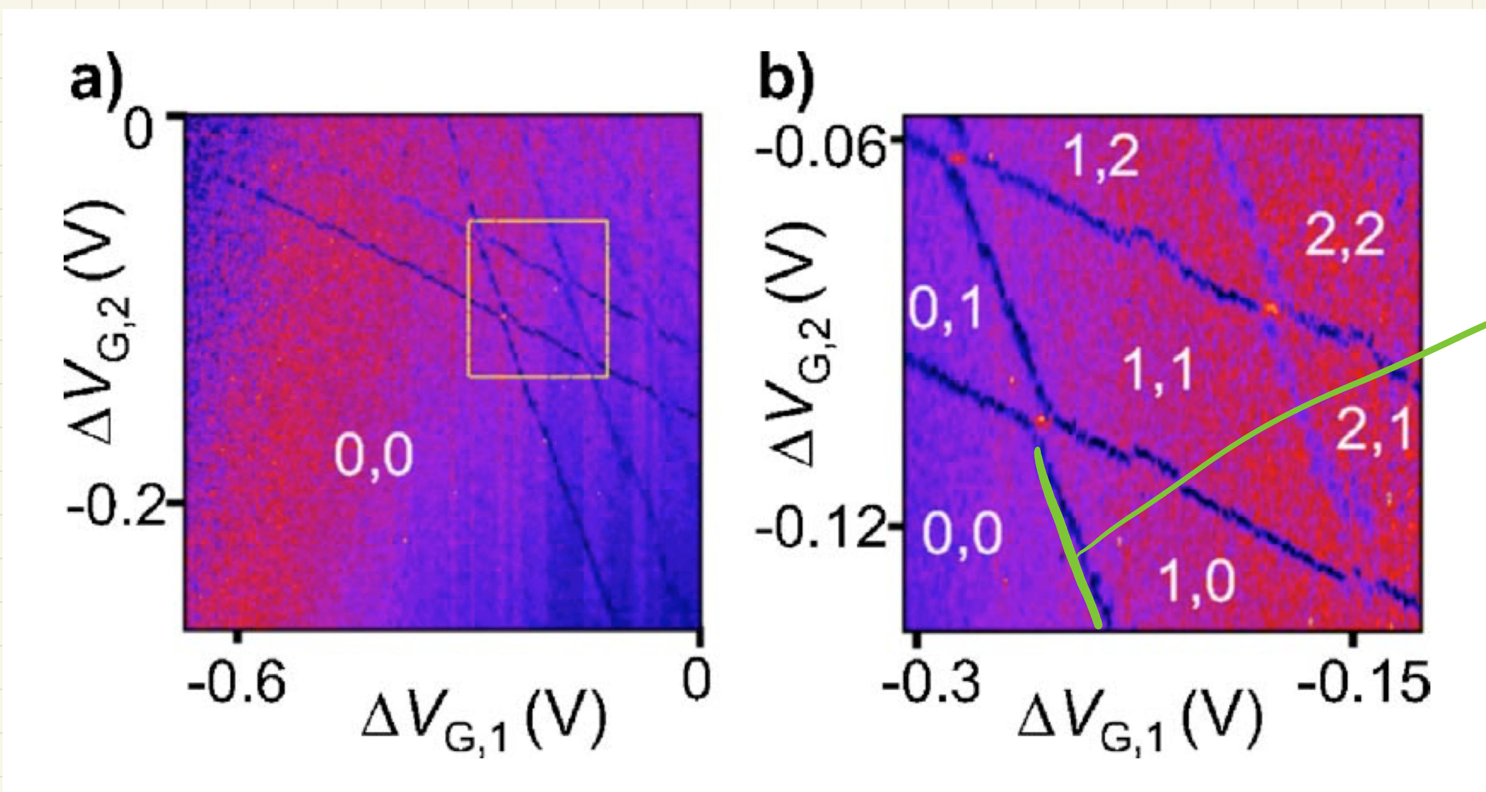


(consider elastic tunneling only)

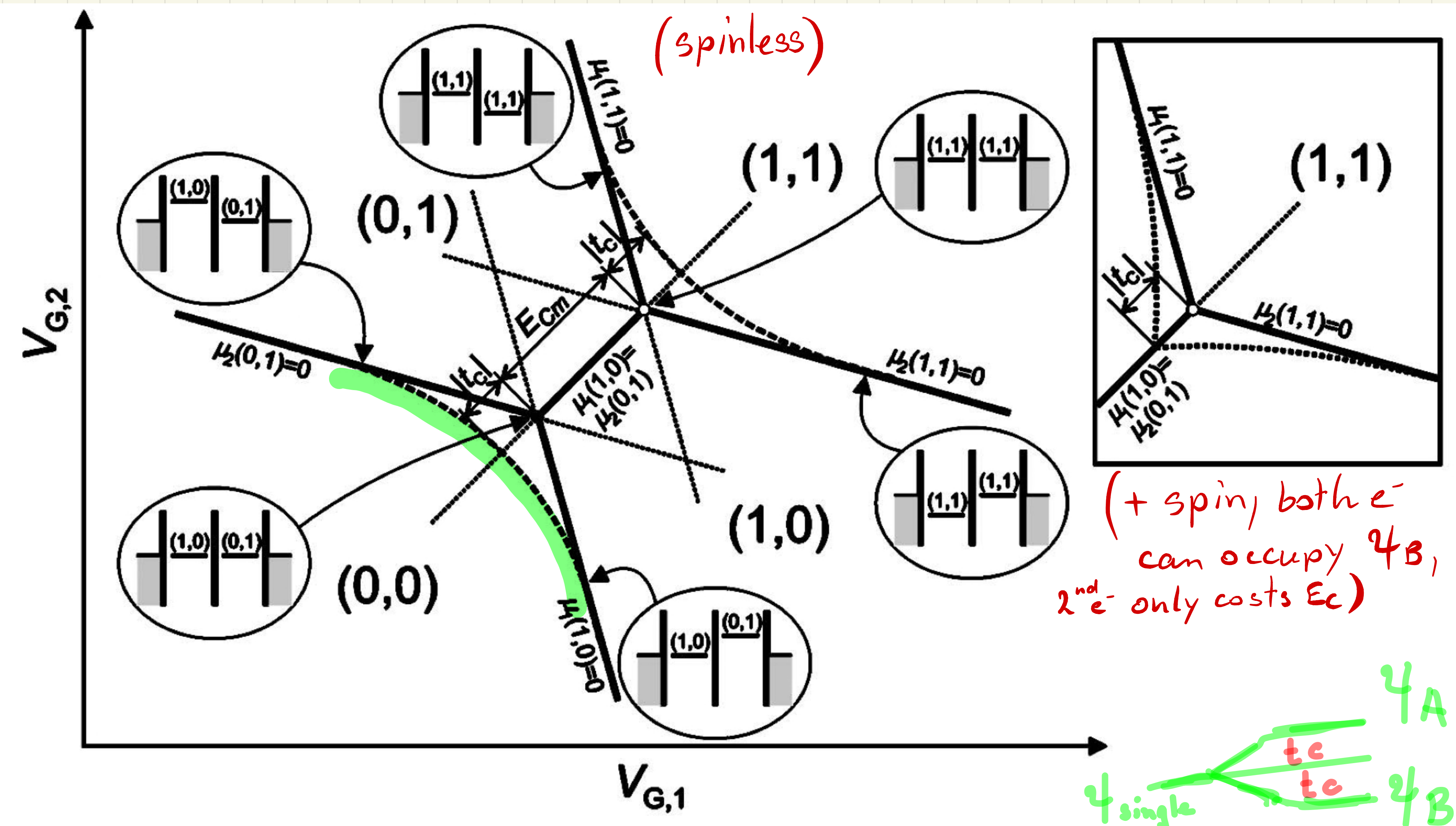


- But a charge sensing measurement will detect any change in e^--config.

↓ we can map out all transitions.



brighter, bc. an e^- is travelling from L ⇄ R small tunnel coupling t_c → negligible w/ respect to electrostatic coupling



- very strong t_c, WF overlaps accross both dots, hybridisation

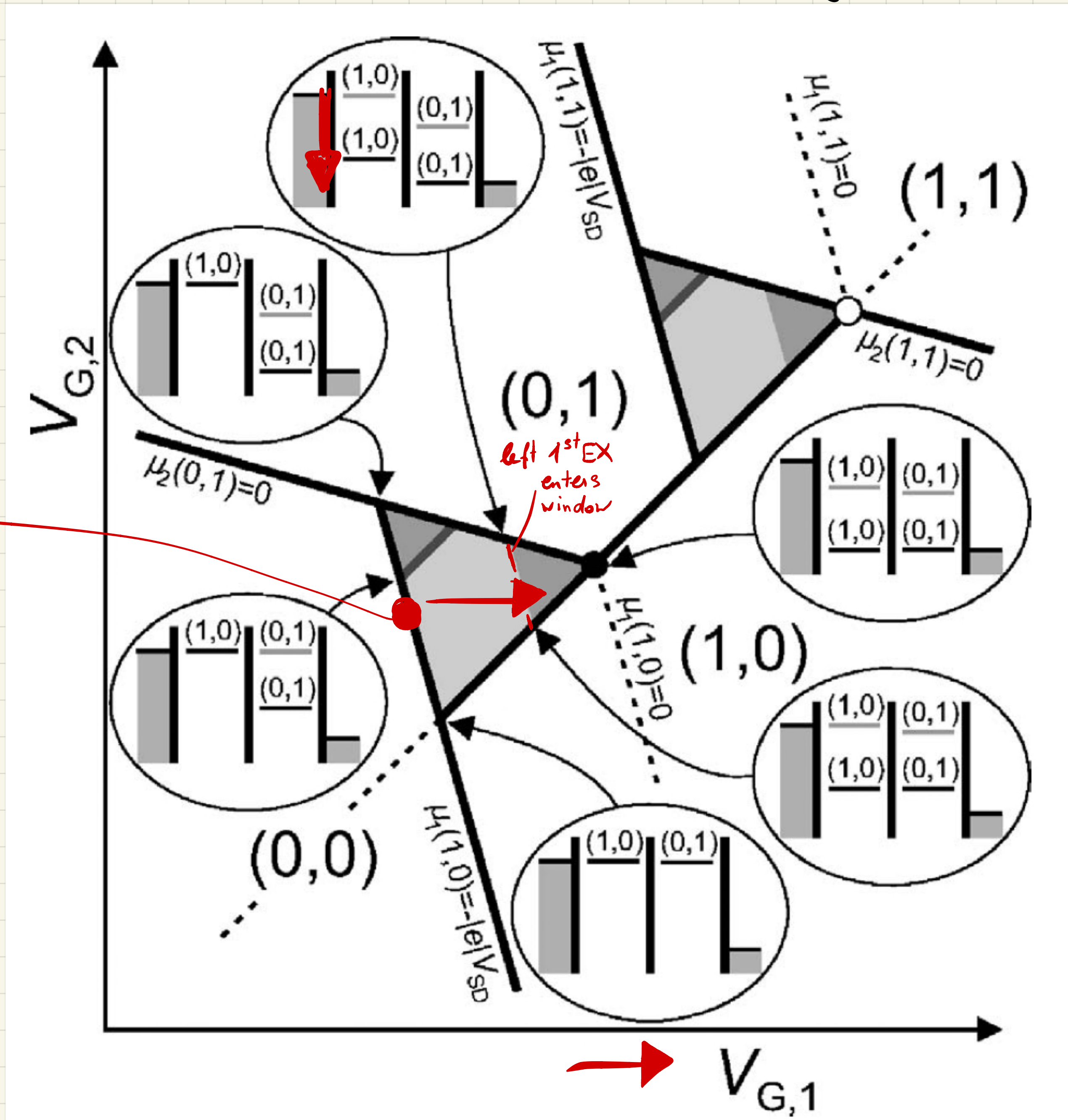
Q: How about large t_c ?

→ Reproduces left part of before seen Fig,

- Coulomb int is ~ $\mathcal{O}(1-2)$ higher than t_c

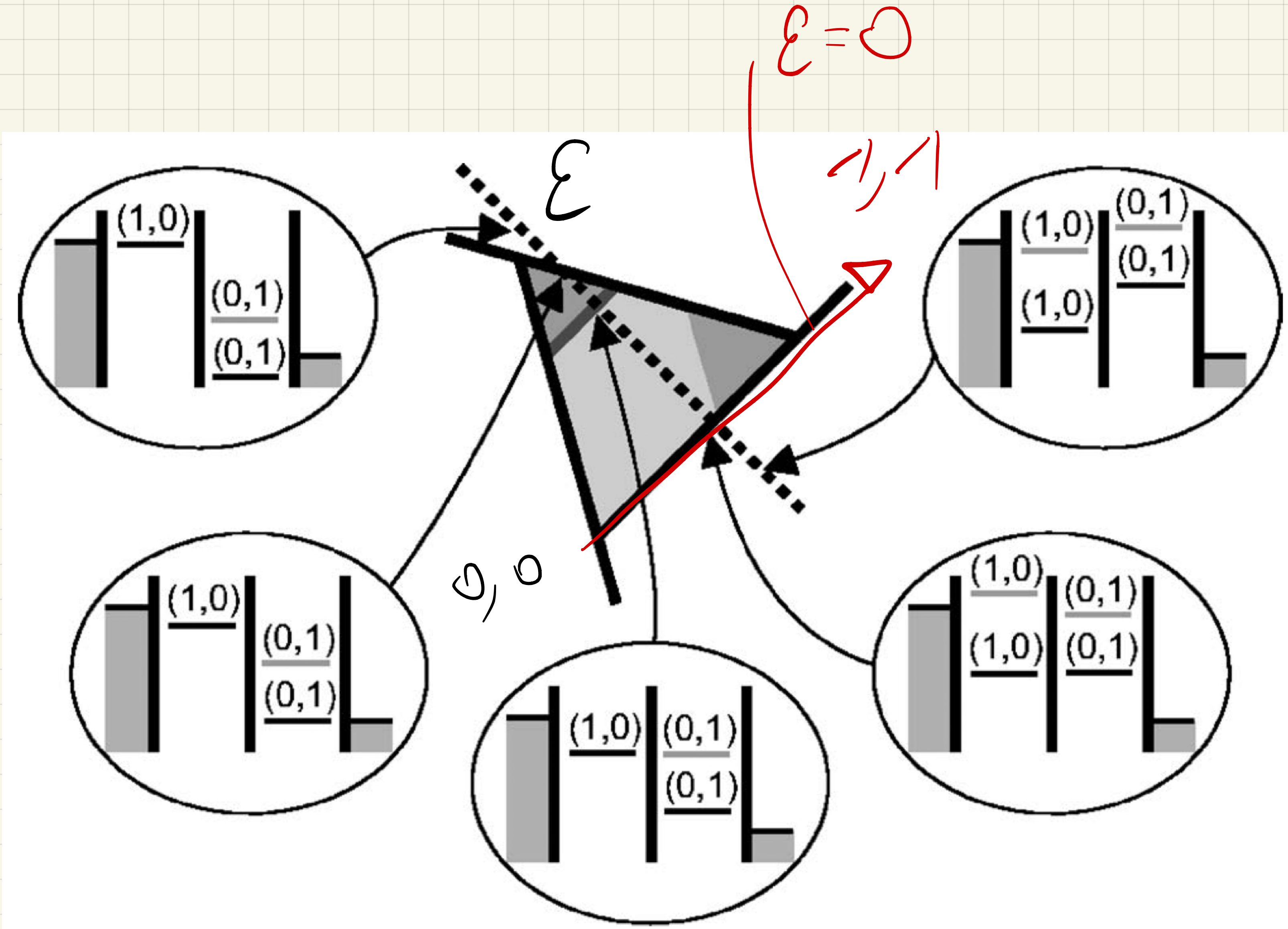
⇒ e^- are strongly localized

High Bias Regime
(consider inelastic tunneling)



kick out left e^-

- Introduce detuning (ε-axis): levels inside dots are detuned w/ respect to eachother.



Spins in 2-e^- DQDs

E_{ST}

Δ_z

Δ_z

$$S(0,2) = (|\uparrow_2\downarrow_2\rangle - |\downarrow_2\uparrow_2\rangle)/\sqrt{2},$$

$$T_+(0,2) = |\uparrow_2\uparrow_2\rangle,$$

$$T_0(0,2) = (|\uparrow_2\downarrow_2\rangle + |\downarrow_2\uparrow_2\rangle)/\sqrt{2},$$

$$T_-(0,2) = |\downarrow_2\downarrow_2\rangle,$$

$J = 4t_c^2/E_c$

(Hubbard approx.)

$$S(1,1) = (|\uparrow_1\downarrow_2\rangle - |\downarrow_1\uparrow_2\rangle)/\sqrt{2},$$

$$T_+(1,1) = |\uparrow_1\uparrow_2\rangle,$$

$$T_0(1,1) = (|\uparrow_1\downarrow_2\rangle + |\downarrow_1\uparrow_2\rangle)/\sqrt{2},$$

$$T_-(1,1) = |\downarrow_1\downarrow_2\rangle.$$

---

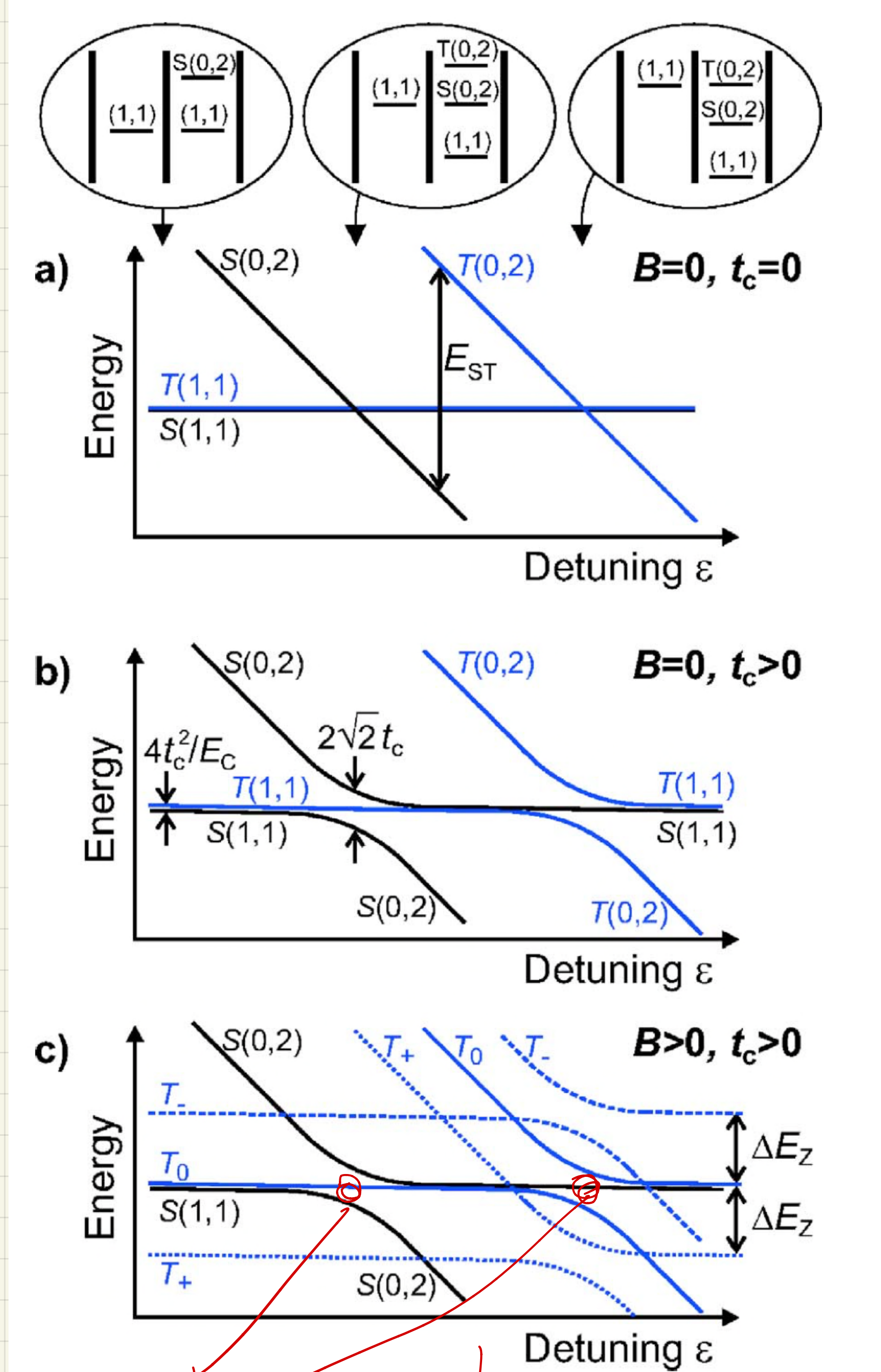
consider small t_c, for three values of ε:

b) $(1,1)$ & $(0,2)$ hybridize, split $2\sqrt{2}t_c$

→ while preserving spin! $\underset{(T)}{S(1,1)} \rightleftarrows \underset{(T)}{S(0,2)}$

c) $\Delta_z \gg t_c$, Zeeman splitting of

T_+, T_0, T_-



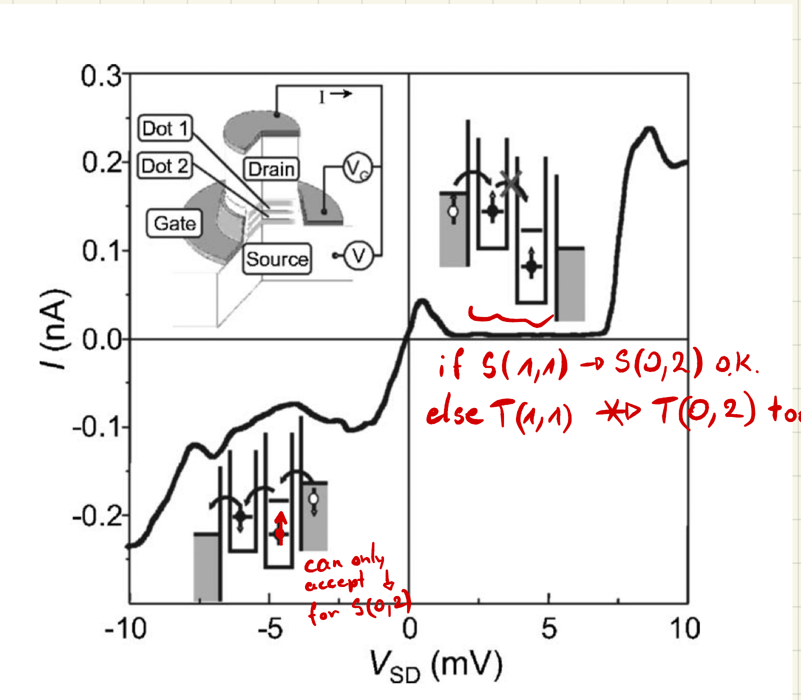
see transport

PSB

Idea: @ $V_{SD} < 0$, $(0,1) \to (0,2) \to (1,1) \to (0,1)$

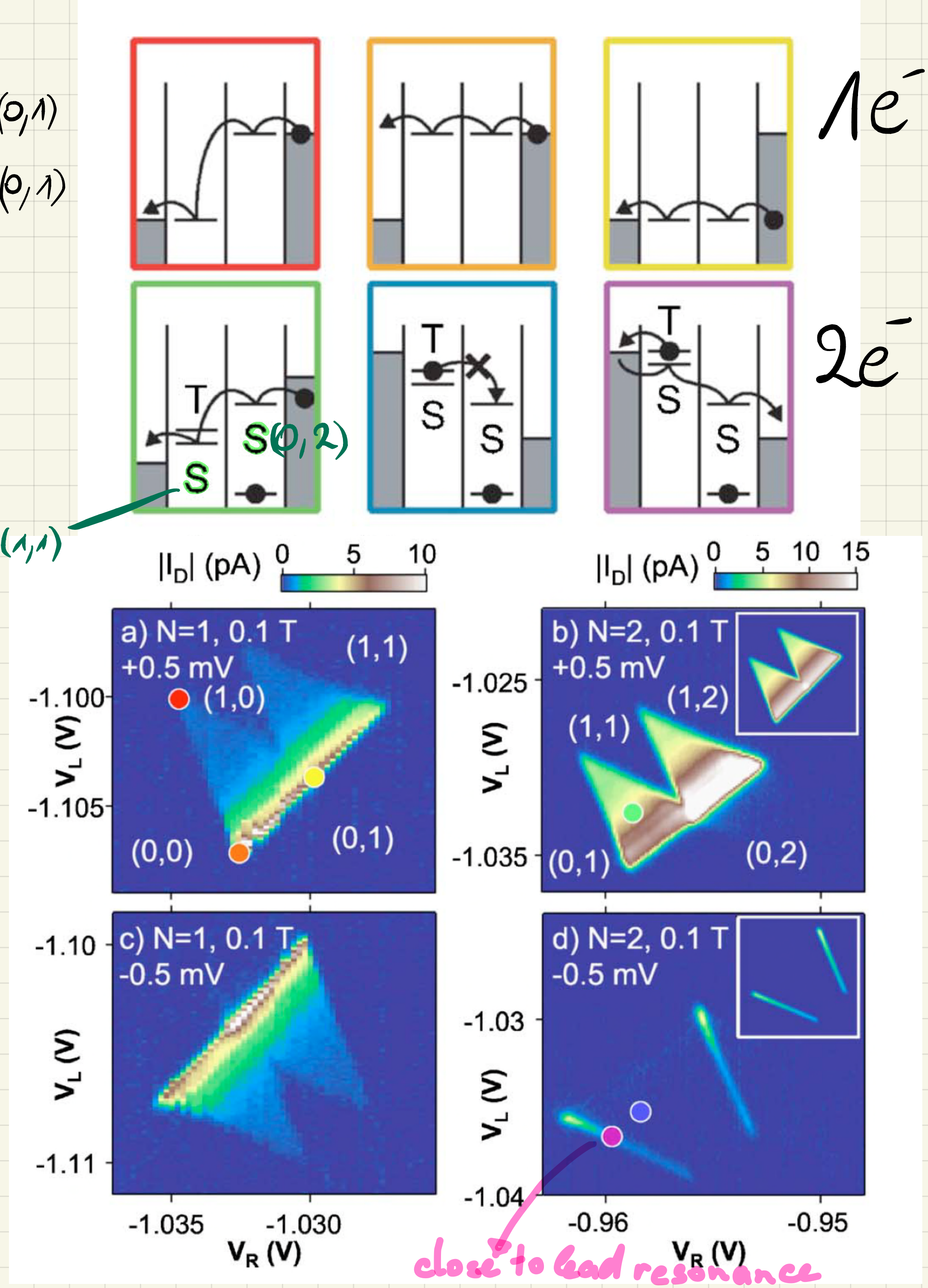
@ $V_{SD} > 0$, $(0,1) \to (1,1) \to (0,2) \to (0,1)$

(V_{SD} doesn't exceed E_{ST}!)



if $S(1,1) \to S(0,2)$ o.k.
else $T(1,1) \not\to T(0,2)$ too high

can only accept ↓ for $S(0,2)$



$1e^-$

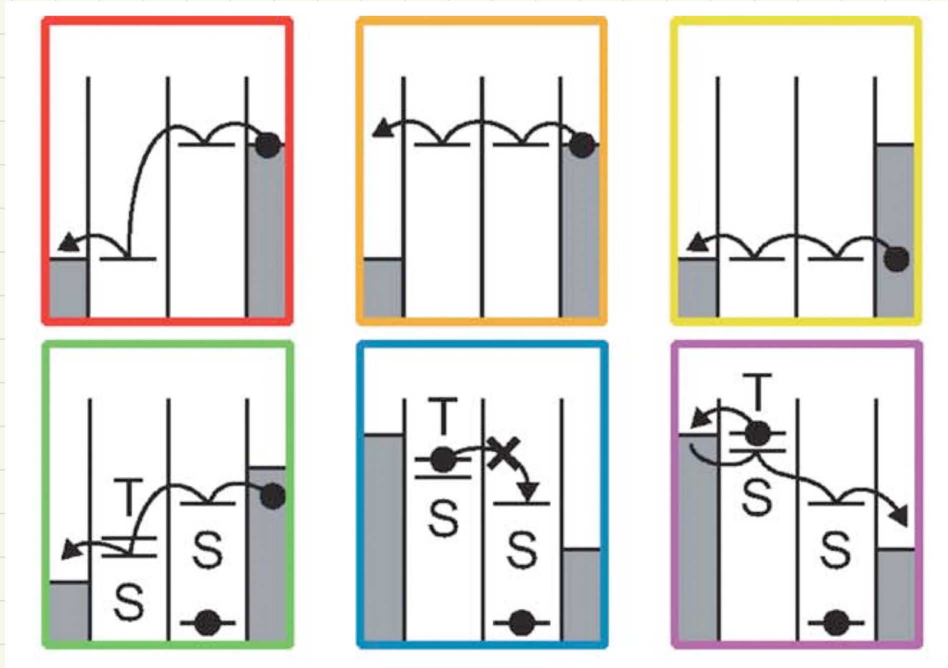
$2e^-$

$S(0,2)$

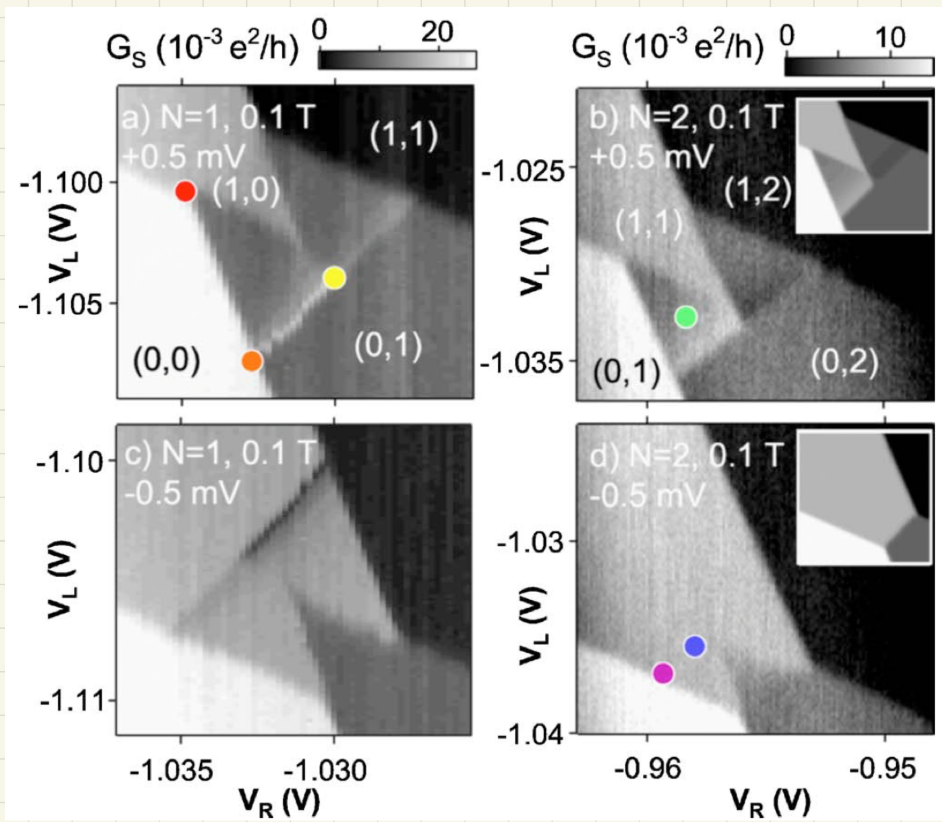
$S(1,1)$

close to lead resonance

(Don't consider spin flip mechanisms & assume spin relaxation time T_1 has not passed)



T
S
S
T
S
S
T
S
S



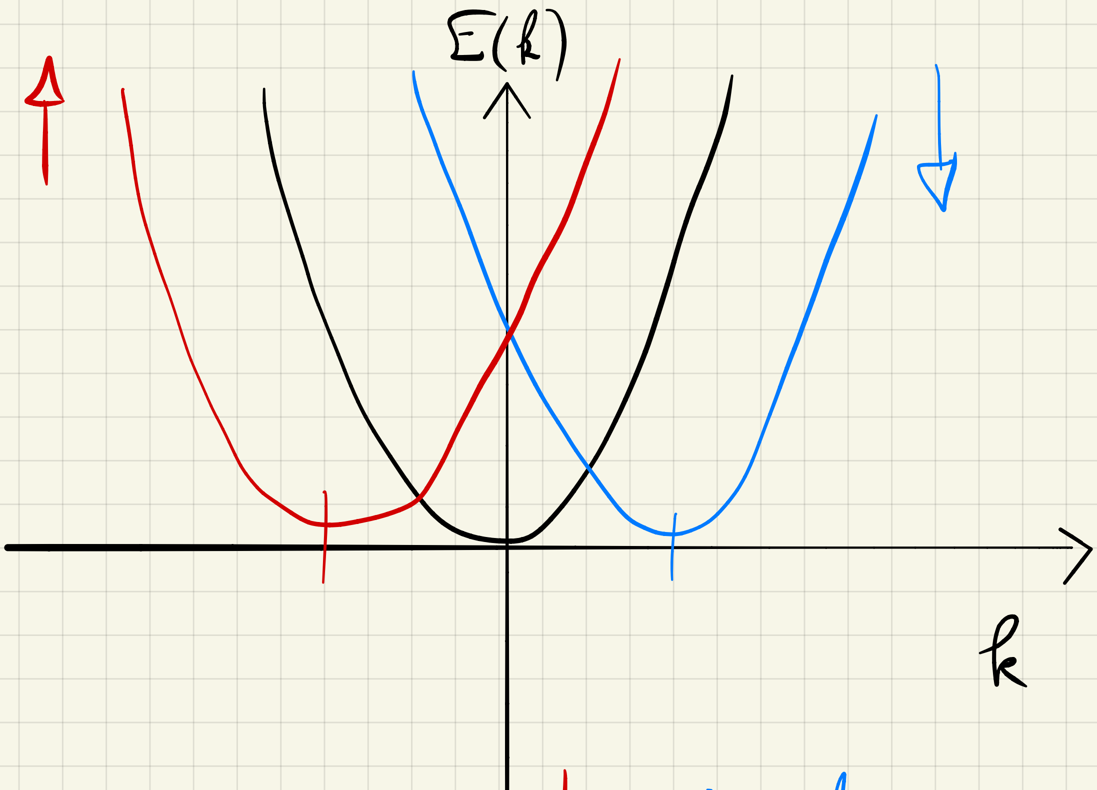
G_S (10^{-3} e^2/h)
0
20
a) N=1, 0.1 T
+0.5 mV
(1,1)
(1,0)
(0,1)
(0,0)
-1.100
-1.105
V_L (V)
G_S (10^{-3} e^2/h)
0
10
b) N=2, 0.1 T
+0.5 mV
(1,2)
(1,1)
(0,1)
(0,2)
-1.025
-1.035
V_L (V)
c) N=1, 0.1 T
-0.5 mV
-1.10
-1.11
V_L (V)
-1.035
-1.030
V_R (V)
d) N=2, 0.1 T
-0.5 mV
-1.03
-1.04
V_L (V)
-0.96
-0.95
V_R (V)

SOI

generally sth. $\propto \gamma \, k_i \, \sigma_j$

γ: material, k_i: momentum, σ_j: spin

1D:



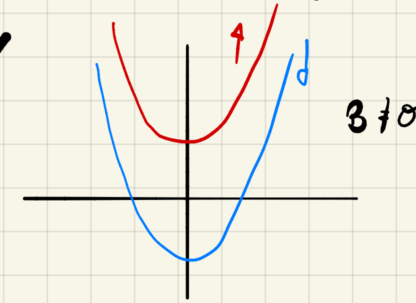
spins are polarised

spatial inv. sym

$$E_\sigma(k) = E_\sigma(-k)$$

time rev. sym.

$$E_\sigma(k) = E_{-\sigma}(-k)$$



But where does it all come from?

- Relativistic effect originating from charge carriers moving in an electric field. Hence the mat. param γ corresponds in some way to an E-field.
- The question which remains, is where the E-field originates from. $\longrightarrow$ SIA
  $\hookrightarrow$ BIA

When the potential through which the charge carriers move is inv-asym., the spin degeneracy is lifted even @ $B=0$.

- Can be the consequence of bulk inv. asym. of the underlying crystal, e.g. Zinc-blende structure. (BIA)

- Or a structure inversion asymmetry of the confinement potential e.g. domain boundaries, interfaces, dangling bonds, (strain fields) (SIA)

BIA

Independent of any macroscopic E-fields. Only microscopic.

Common Dresselhaus-Hamiltonian:

$$H_D = \beta\left(\{k_x, k_y^2 - k_z^2\}\sigma_x + c.p.\right)$$

Strong dependence on main crystallographic axis &, in 1D, on the symmetry of the shape of the radial confinement potential. If $k_i \to k_i'$ expressions prop. to $\langle k_x^2\rangle - \langle k_y^2\rangle$ can arise which vanish in ○-potential.

SIA

The Bloch part „feels" the atomic fields & the slowly varying envelope func. „feels" the macroscopic environment. SIA spin splitting arises when we have:

macro. E + micro. E (from cores)

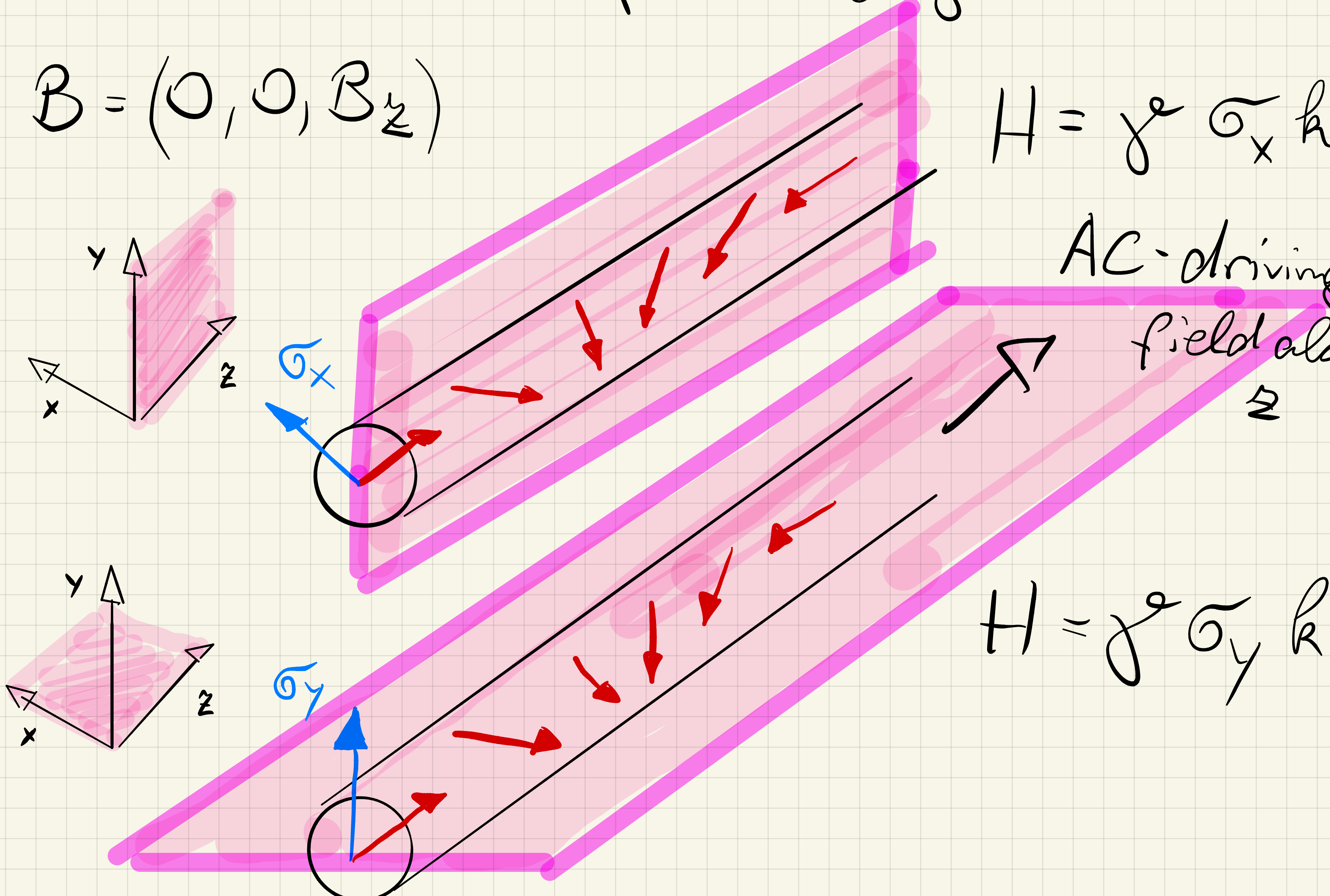
(lacks in semi-classical derivation w Lorentz force)

To first order (in $\mathcal{E}$ & k, using k·p theo.) the Rashba-Hamiltonian is: (1D along z)

$$H_R = \alpha(\sigma \times k)\,\hat{e}_z$$

Use of SOI for us:

$$B = (0, 0, B_z)$$



$$H = \gamma \sigma_x k_z$$

$$H = \gamma \sigma_y k_z$$

$$H\text{-flip} = \frac{\hbar^2 \hat{k}^2}{2m_{eff}} + \frac{1}{2} m_{eff}\,\omega_0^2 z^2 + \frac{1}{2} g \mu_B B_z \tilde{\sigma}_z + \gamma \tilde{\sigma}_{x,y} \hat{k}_z + eE_{\parallel} \cos(\omega_{ac} t)\, z$$

free particle H.O. Zeeman SOI AC-driving field

Our Direct Rashba SOI

1) find eigenstates in Luttinger-Kohn Hamiltonian (2 classes of bands: (HH, LH, Spl.off) x 2 for spin) & rest)

2) HH vs LH difference is whether spin is parallel or anti parallel to motion inside NW & of course mass

3) Energy gap $\Delta = \frac{const}{L_z^2}\left(\frac{1}{m_{LH}} - \frac{1}{m_{HH}}\right)$ fairly large

4) Under strong radial confinement & strong static strain an (electric) strain field is induced, which taken into account in the Bir-Pikus Hamiltonian, math. resembles a Rashba-esque SOI which is higly tunable $\frac{const'}{\Delta} E_x \sigma_y k_z$, $const'(C,U)$

5) further the HH & LH states mix, when coupling to this strain field.