A Journey through Hybrid Normal–Quantum Dot–Superconducting Systems

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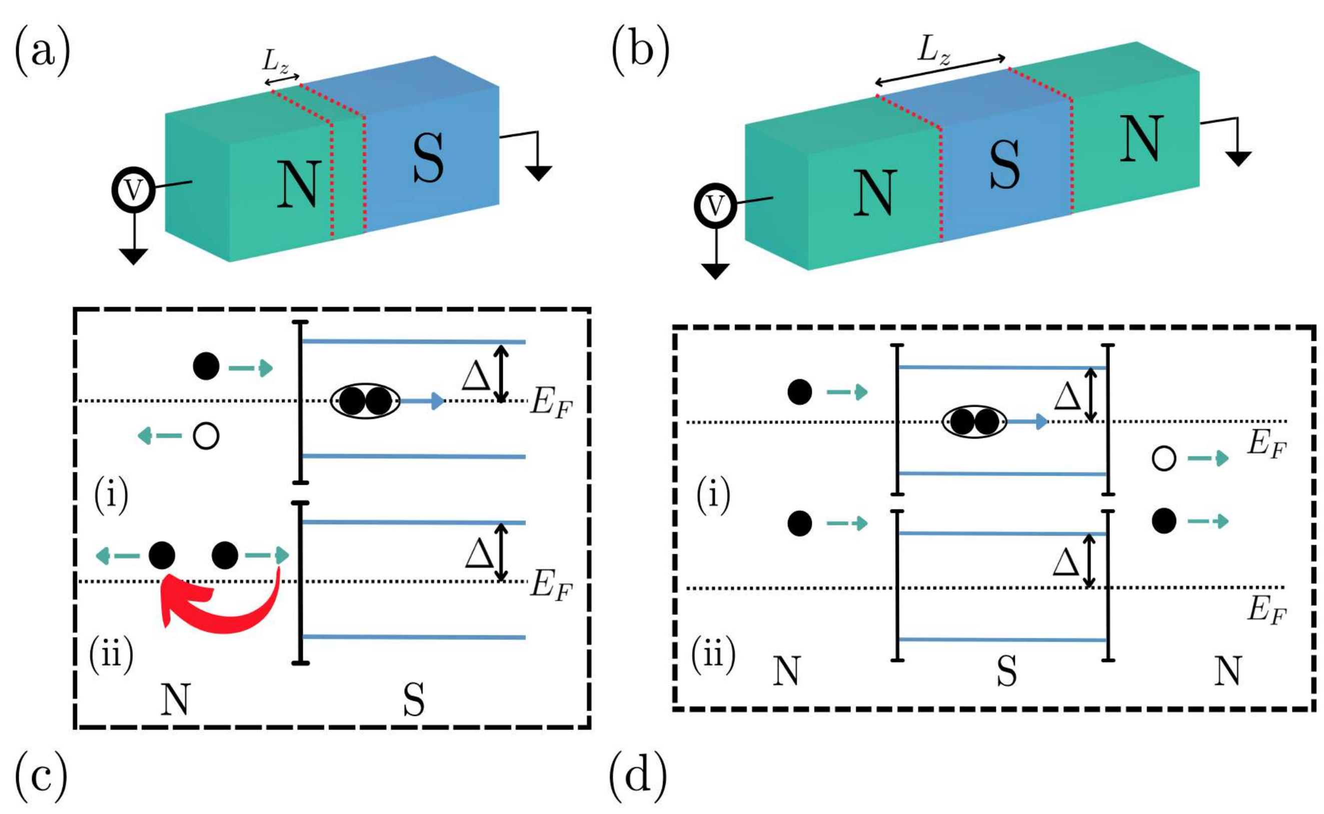
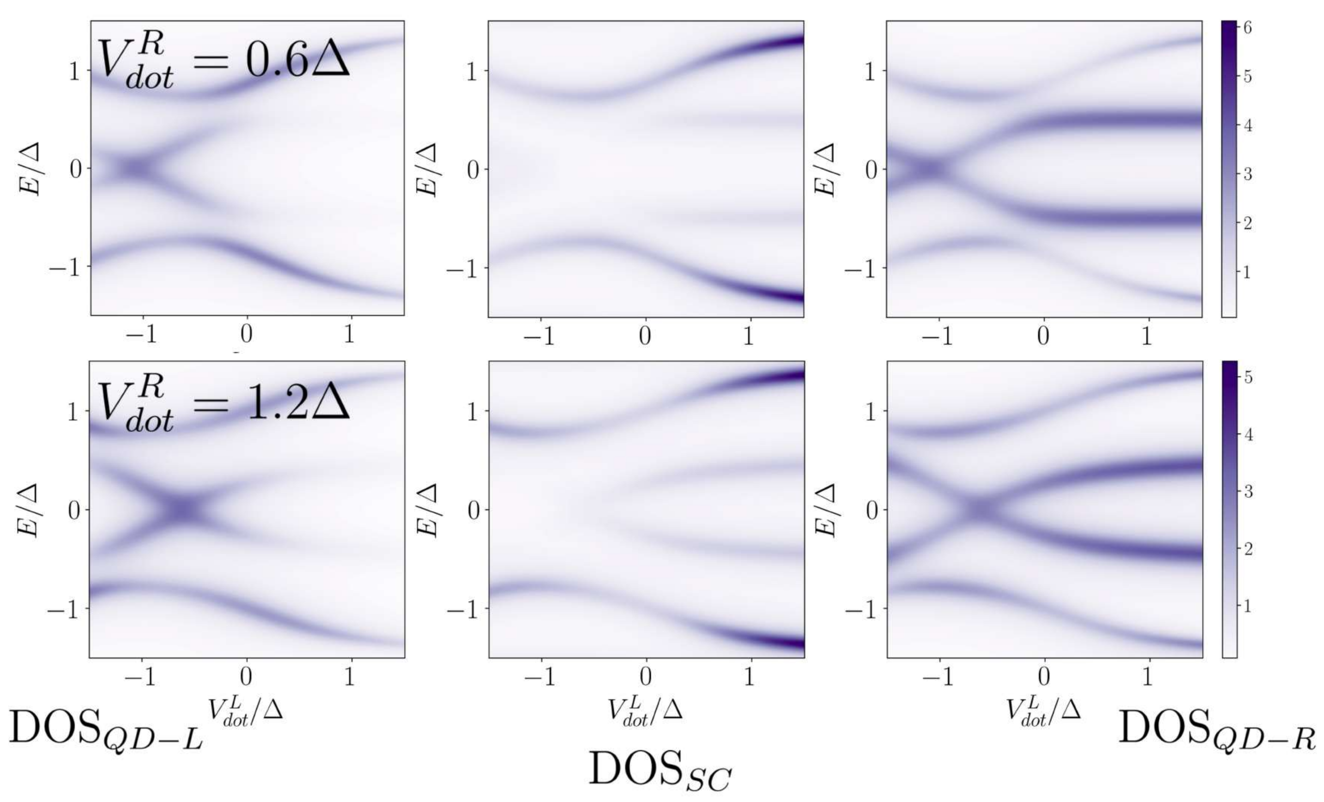
Introduction: Hybrid NS Physics

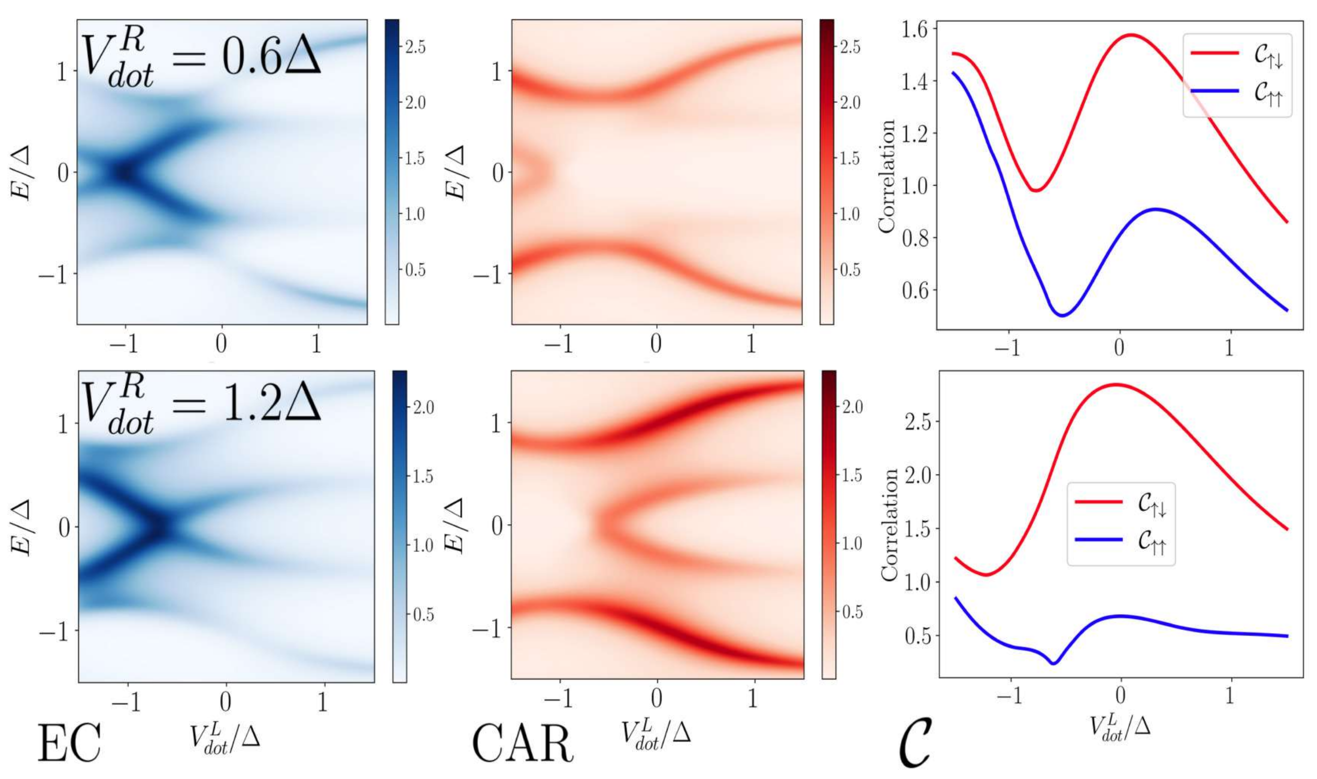
- Nanoscale hybrid superconducting (S) – normal (N) structures, give rise to a plethora of intriguing physics probed easily through standard conductance transport measurements.
- The key player is the exotic form of interaction of the superconducting Cooper pair condensate with the electron sea in the normal metal, mediated by various **Andreev reflections** (AR).
- This can be seen as AR in N-S structures along with Crossed AR (CAR) in N-S-N structures.



QD-S-QD: Strong Coupling

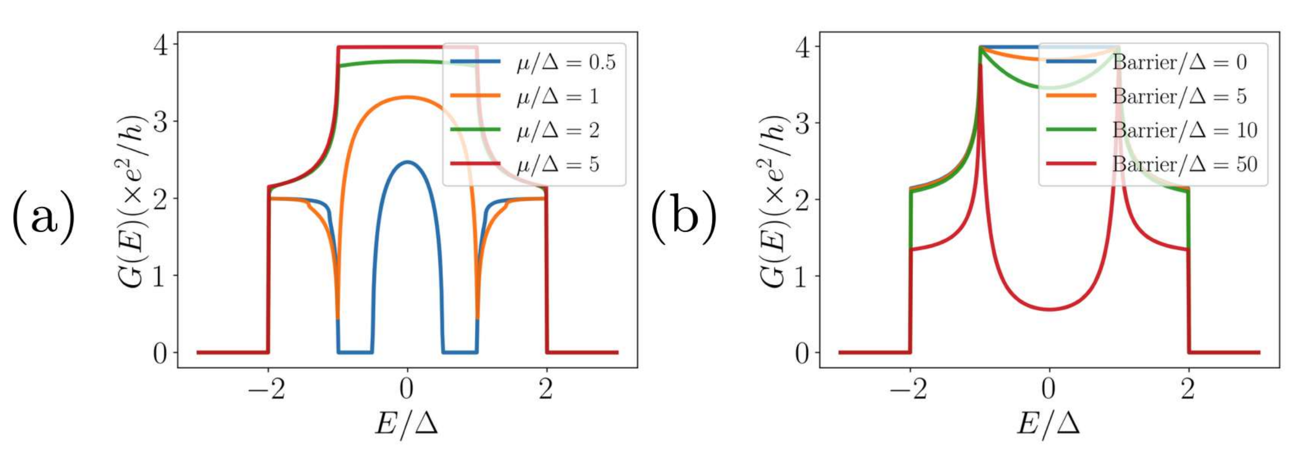
- We model the Andreev (CAR)–related to Cooper pair splitting–and elastic co-tunneling (EC) transport in QD-S-QD systems using the **non-equilibrium Green's function** (NEGF) method.
- We have a SC of $100nm$, QD coupling of $\mathcal{O}(10^{-2}t_0)$, where $t_0 = \hbar^2/(2ma^2)$ is the lattice hopping and $a = 5nm$ is the discretization with V^L_{dot} varying and V^R_{dot} fixed in or outside the gap.
- For the case $\Delta = 1meV$, the density of states (DOS) and the CAR and EC currents are shown.
- We discover a **peak** in the $\uparrow - \downarrow$ fermionic **correlations** between the dots at the CAR point.





Rekapitulieren: NS transport

We recap the basics of Andreev reflections in NS structures. Within the gap, both AR and normal reflection can occur. The **Andreev approximation** deals with the $\mu >> \Delta$ regime wherein normal reflections are suppressed. Moreover, **barriers** at the N-S interface **suppress AR** as well – to be noted as untuned QDs are similar to barriers.



Acknowledgements

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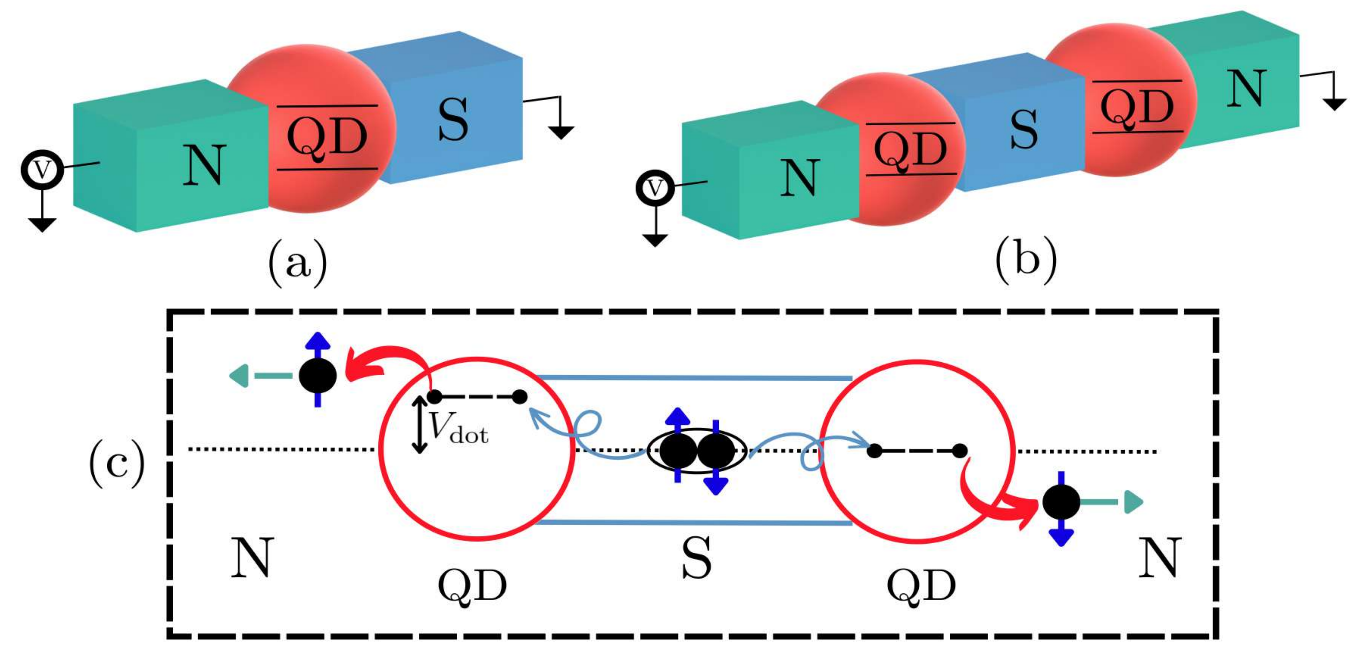
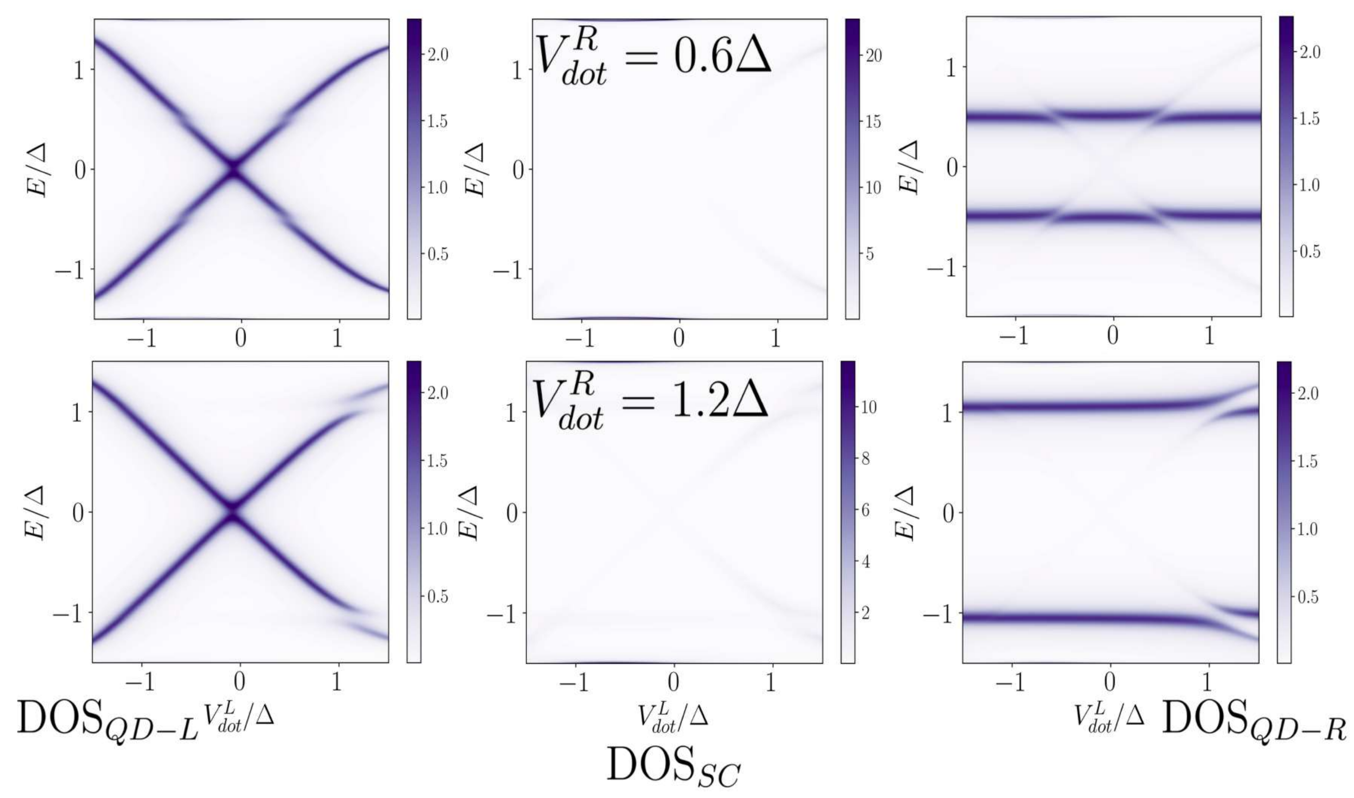
Connecting the *dot*(s)

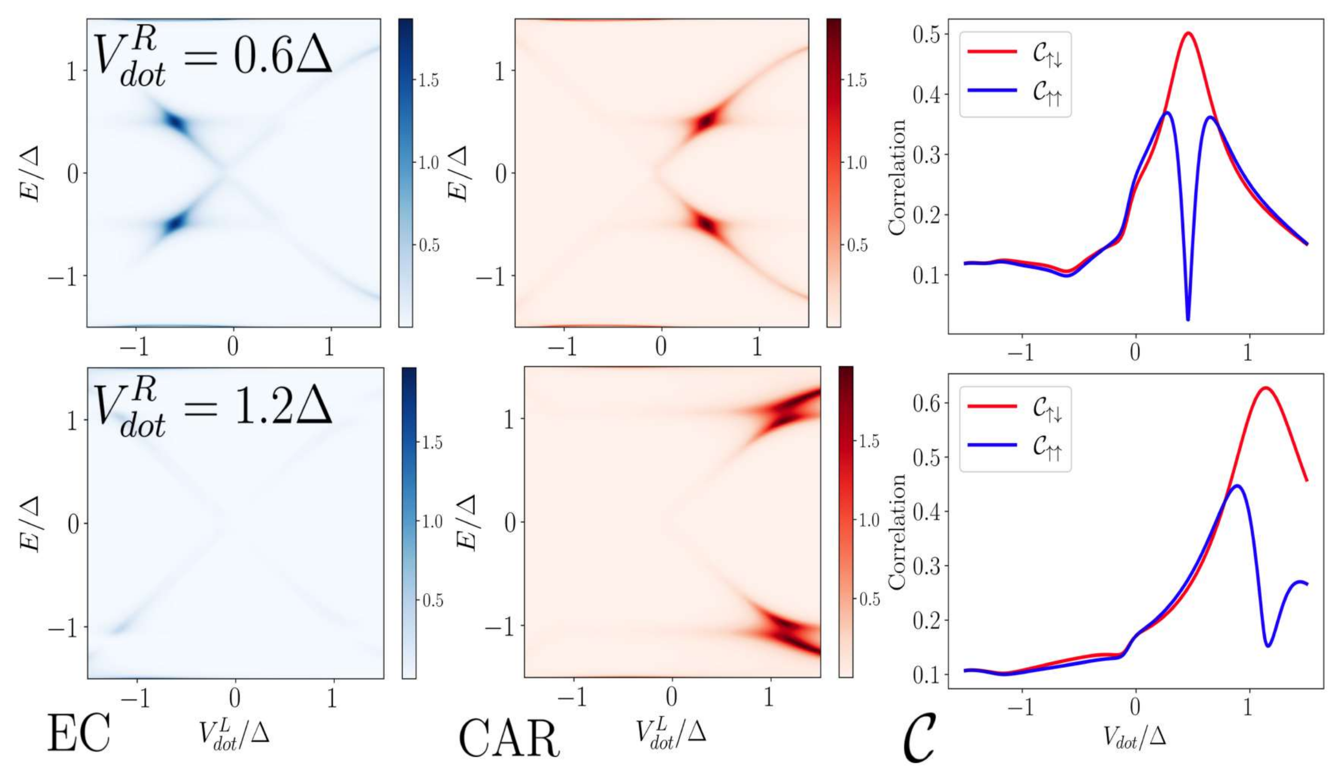
- More interesting situations can arise if the various Andreev phenomenon can be *controlled*.
- **Quantum dots** (QDs) fabricated in such structures enable such control by tuning the dot voltage!
- Primary application of interest: QD mediated **Cooper Pair Splitting** in QD-S-QD systems [1].



QD-S-QD: Weaker Coupling

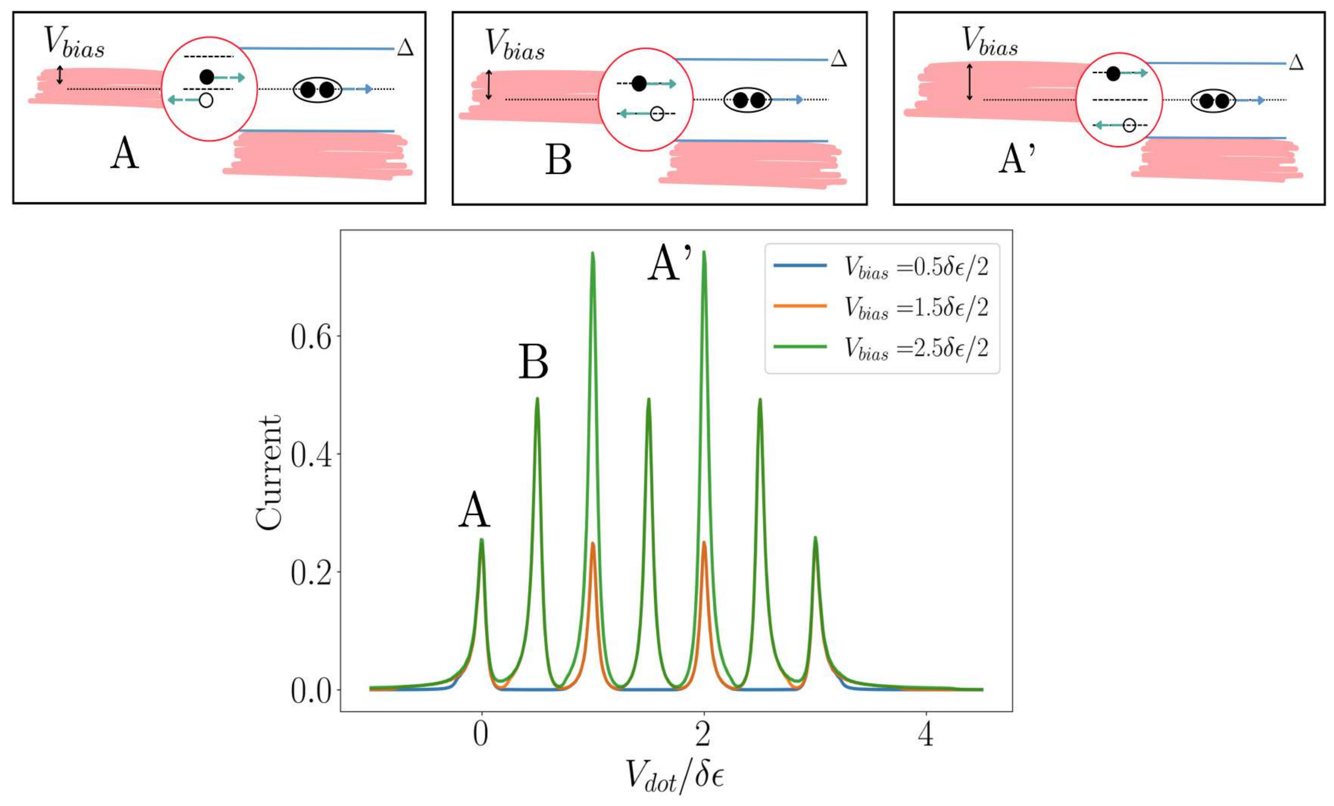
- The relevant **energy scale** in our setup is the **SC gap**. If the gap is increased, the coupling, with respect to the gap is **weaker**. What changes? We plot the results for $\Delta = 5meV$ below.
- Thus, stronger coupling leads to strong **hybridization** between the dots (right column), and weaker coupling shown more pronounced correlation peaks at CAR (this column)!
- In [2], QD-S-QD was analyzed using a classical master equation – hybridization was observed. Our analysis self-consistently differentiates between the hybrdized and uncoupled regimes.





N-QD-S Transport

To elucidate the control over Andreev processes and to establish consistency of our approach, we reproduce results from [3] explaining the different Andreev processes possible just with a single dot!



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