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Sensitivity to electronics error in coupled double quantum dot qubits

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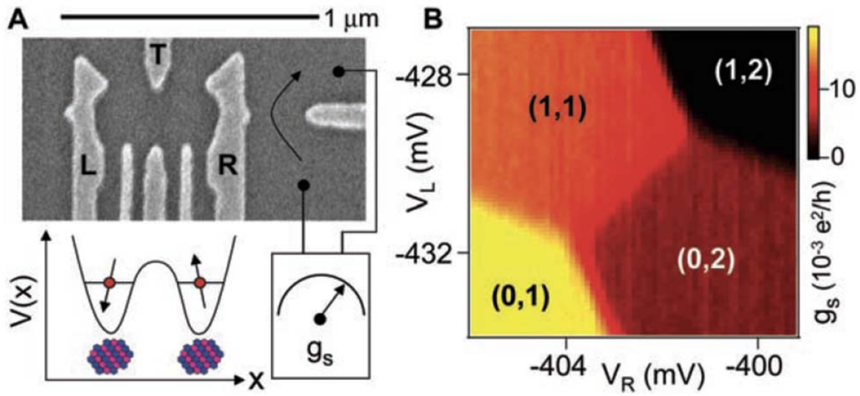
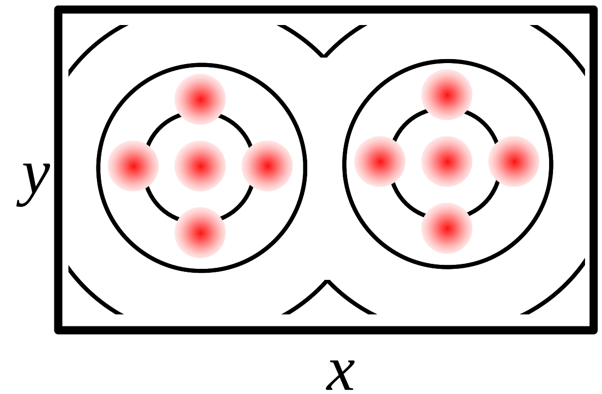
Controlled Phase / Coulomb gate

2-electron singlet & triplet encode quantum information

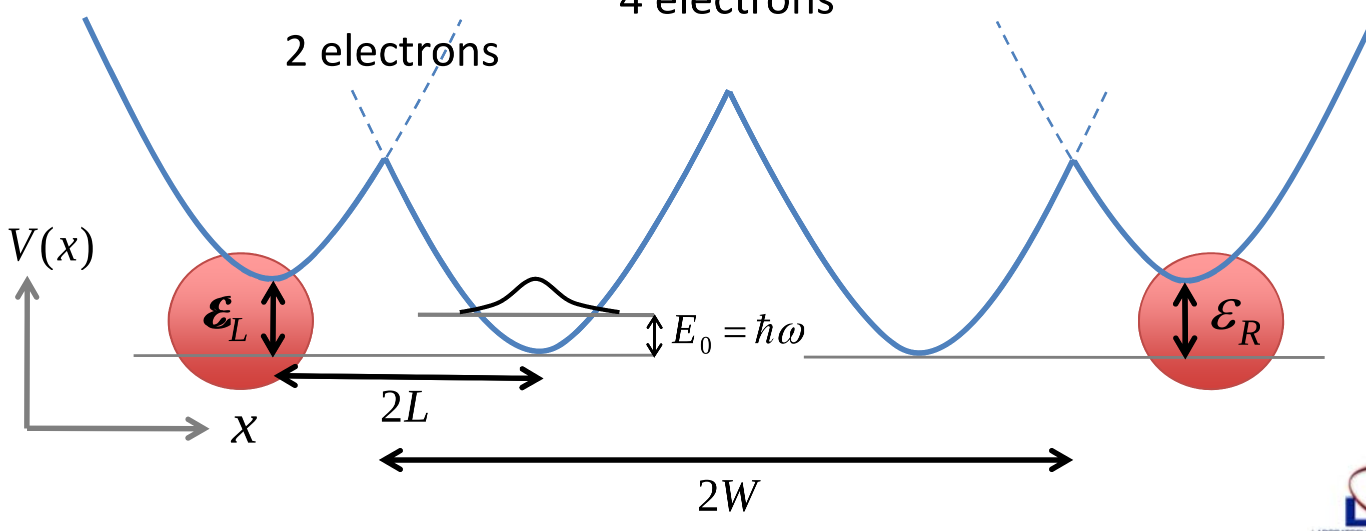
Petta et al., Science **309**, 2180 (2005)



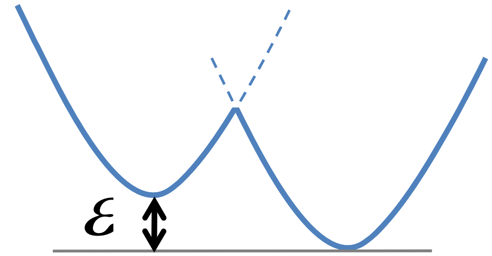
Method: Full-CI with Gaussian basis.
Spatial layout of basis elements:

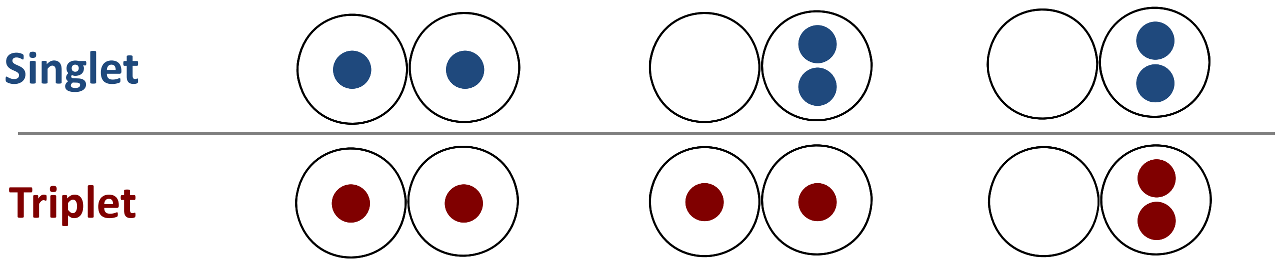


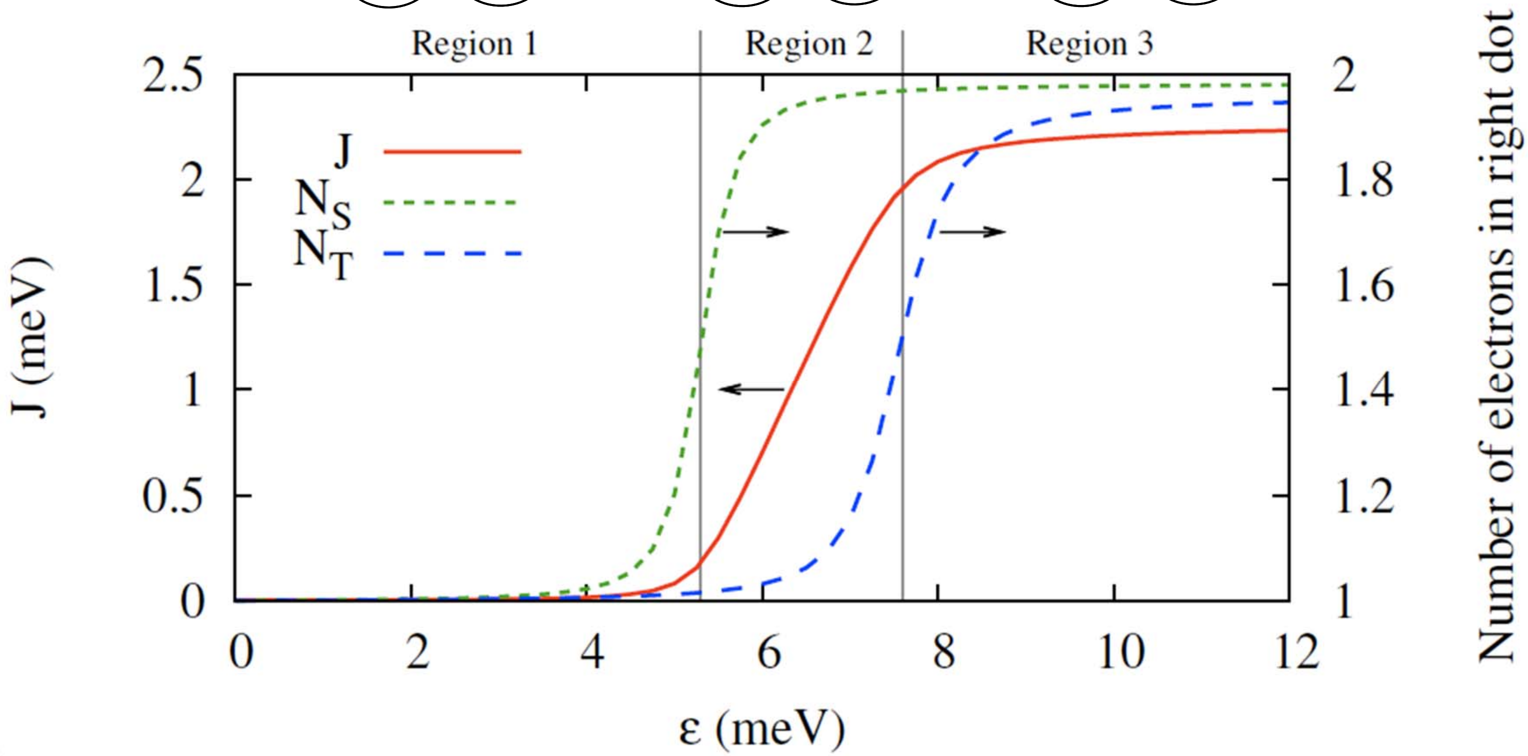
Potential:



Single DQD Physics







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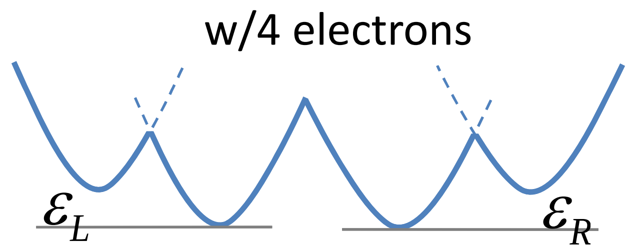
Two DQDs: Entanglement metric

Double DQD Hamiltonian in the singlet-triplet basis:

$$
\begin{array}{cc}
 & \begin{array}{cccc} |SS\rangle & |ST\rangle & |TS\rangle & |TT\rangle \end{array} \\
H = & \begin{pmatrix} E_{SS} & & & \\ & E_{ST} & & \\ & & E_{TS} & \\ & & & E_{TT} \end{pmatrix}
\end{array}
$$

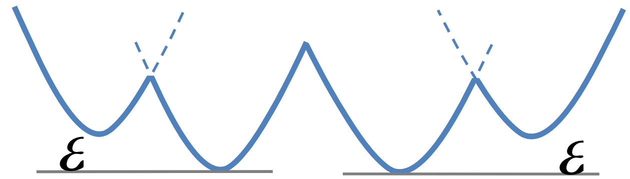


Exchange energy of right DQD = $\begin{cases} J_R(|S\rangle) = E_{ST} - E_{SS} & \text{when left dot is singlet} \\ J_R(|T\rangle) = E_{TT} - E_{TS} & \text{when left dot is triplet} \end{cases}$

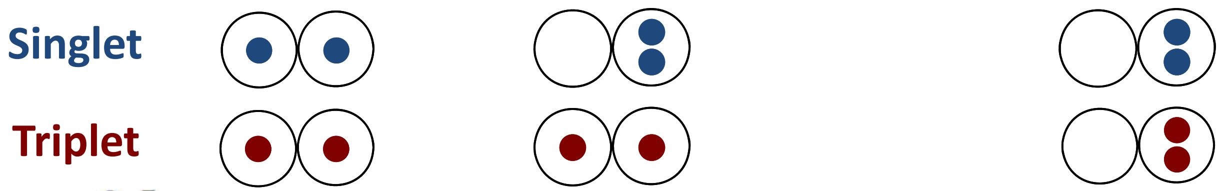
Two-qubit coupling energy $\Delta = J_R(T) - J_R(S) = (E_{TT} - E_{ST}) - (E_{TS} - E_{SS})$

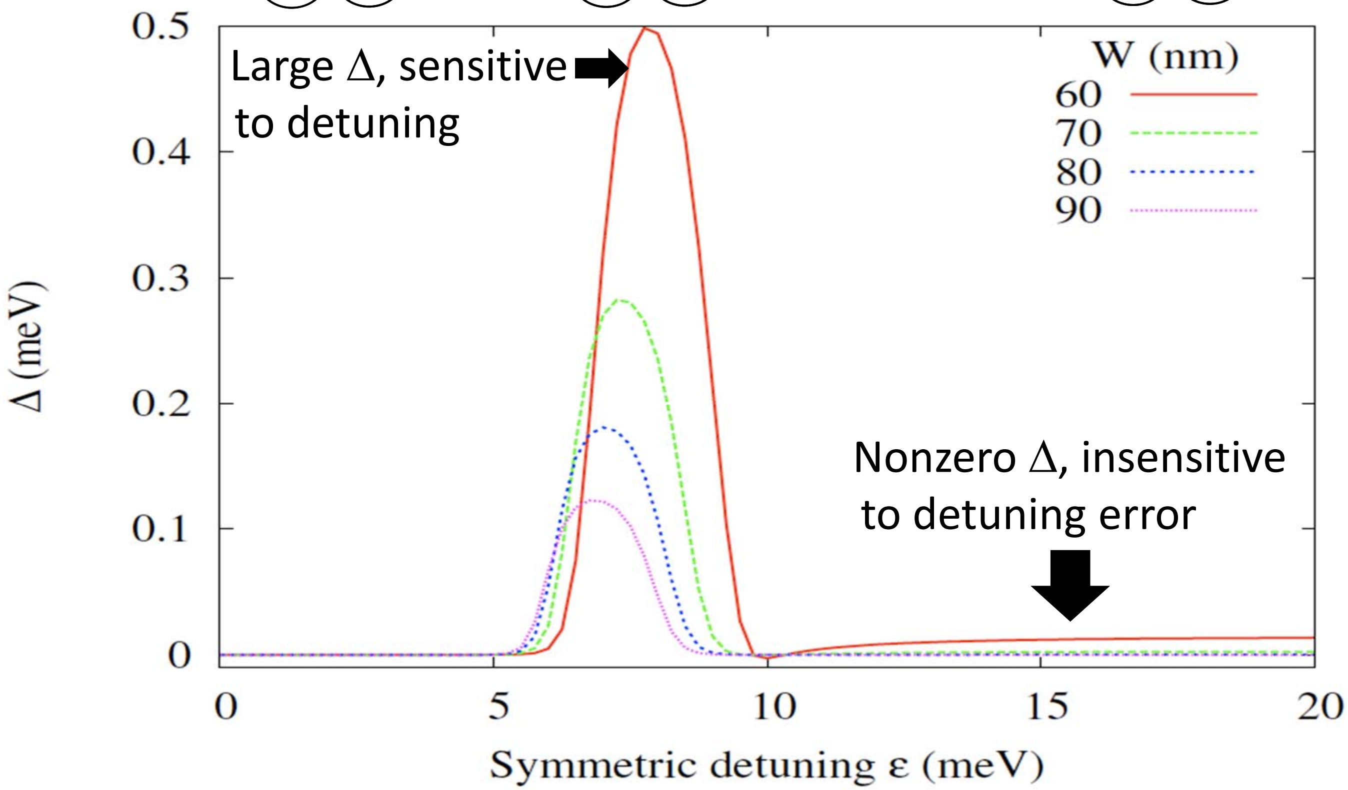
- Analogous to the exchange energy in a single-qubit rotation gate
- $\Delta / \hbar$ proportional to the speed of *controlled* rotation (Cphase)
- Nonzero Δ means qubits are entangled

Case1: Symmetric detuning



$$\varepsilon \equiv \varepsilon_L = \varepsilon_R$$





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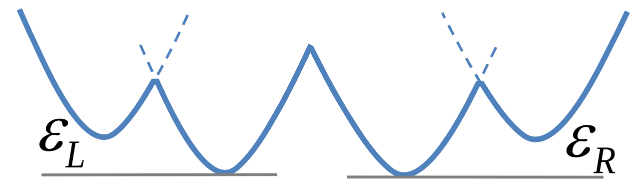
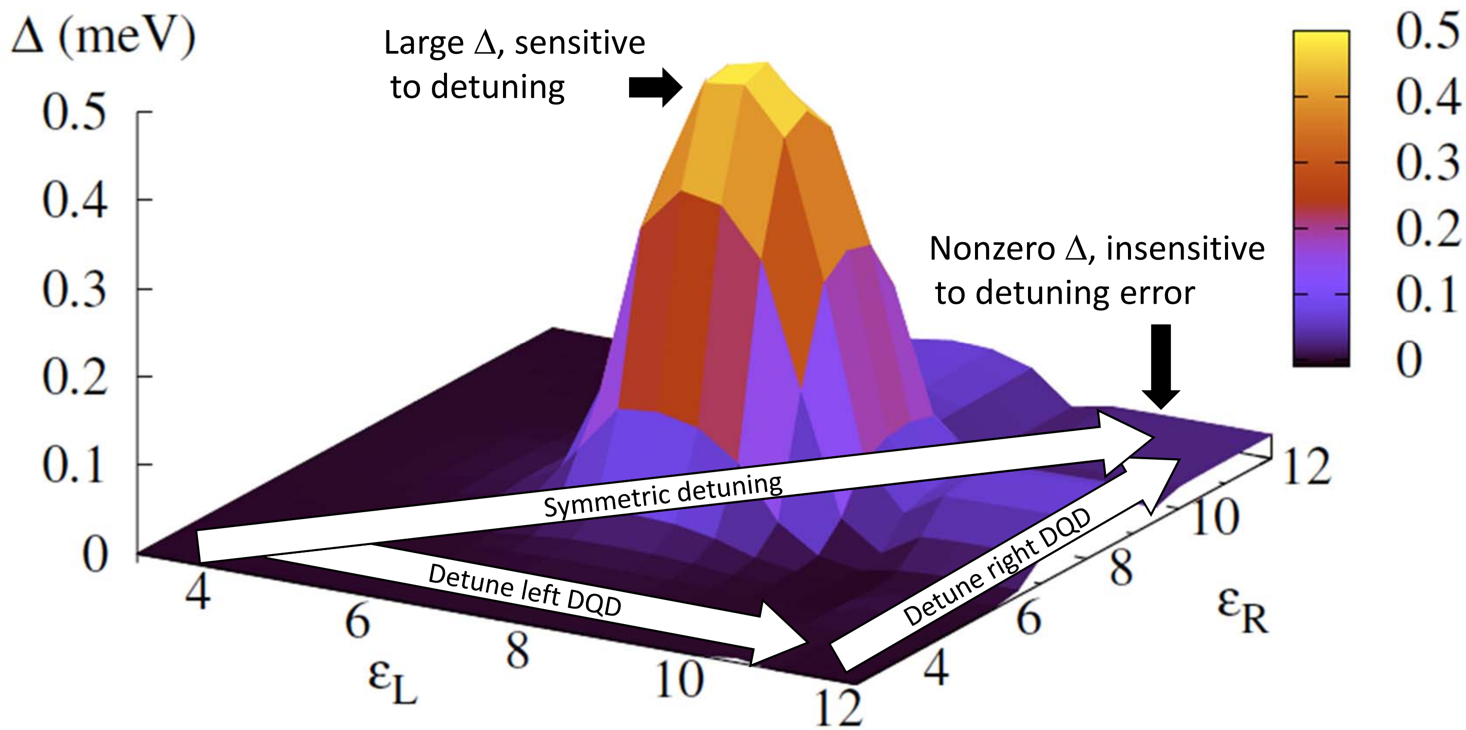
Case2: Asymmetric detuning





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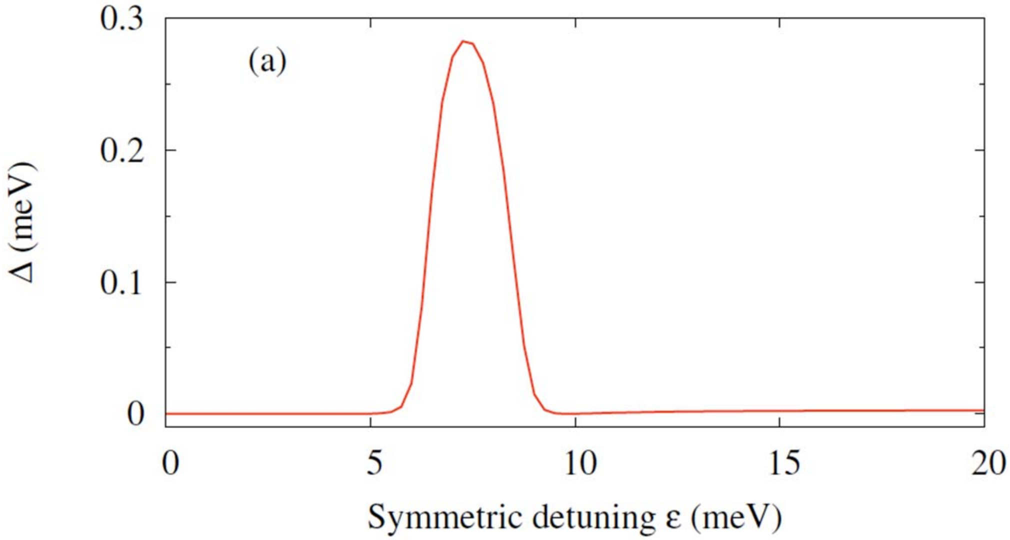
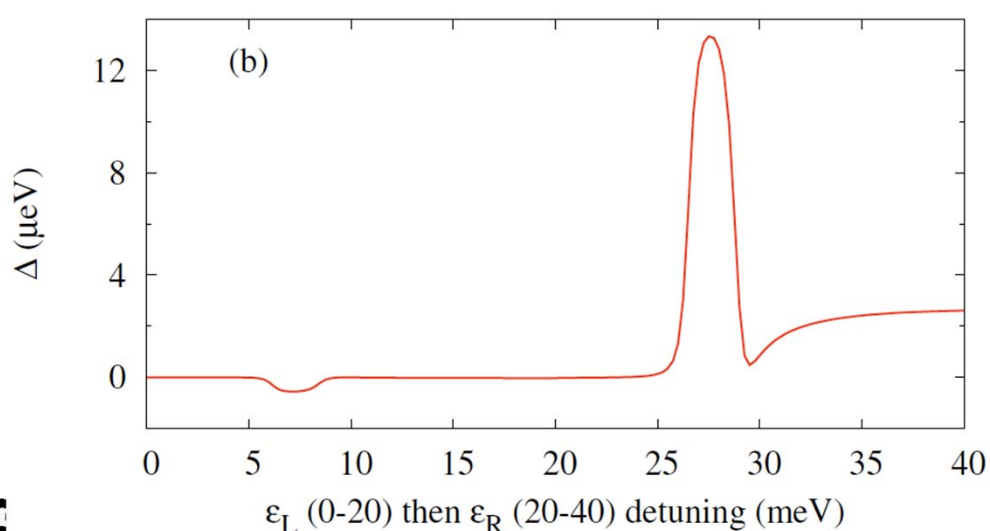
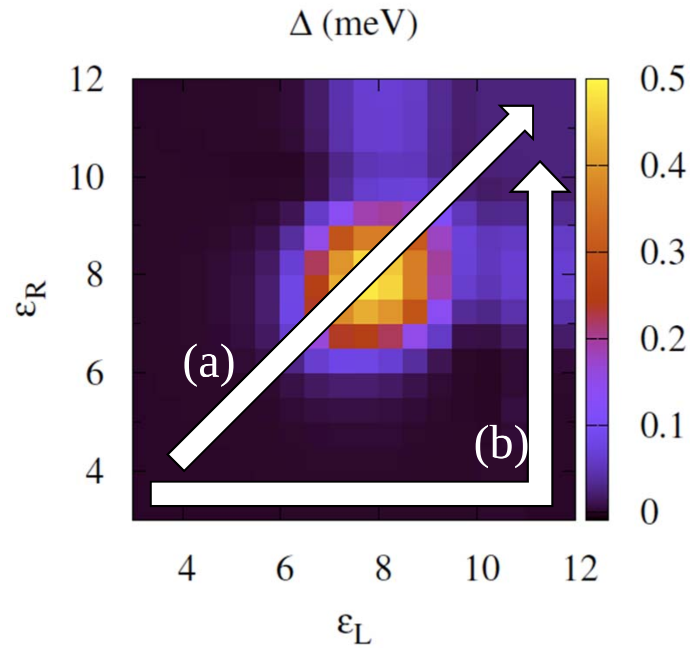
Gate operation: btwn. on and off







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Summary / Conclusions

- Capacitive coupling between two singlet-triplet DQDs results in 2-qubit "Coulomb" gate ~ Cphase
- Coulomb gate can be operated in different regimes, with tradeoff between speed and detuning insensitivity
- Non-symmetric biasing opens up new possible operation regimes, and would be advantageous for operating in the high-detuning regime which is less sensitive to detuning noise.