University of Basel

Negative spin exchange in a multielectron quantum dot

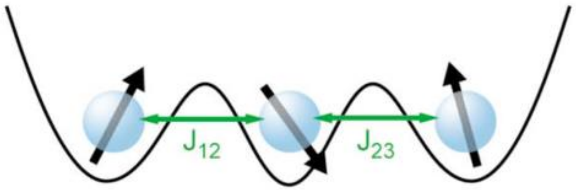
Frederico Martins, Filip K. Malinowski, Peter D. Nissen, Saeed Fallahi, Georey C. Gardner, Michael J. Manfra, Charles M. Marcus, Ferdinand Kuemmeth

Liuqi Yu
13.10.2017

Introduction

exchange-only qubit

Exchange interaction suffices for the qubit operations, which removes the implementation of oscillating magnetic fields.



E. Laired et al., Phys. Rev. B **82**, 075403 (2010)

exchange interaction →

Large multielectron quantum dot

- fast spin interaction
- better flexibility of spatial control

Searching knobs for tuning the exchange interaction

motivation

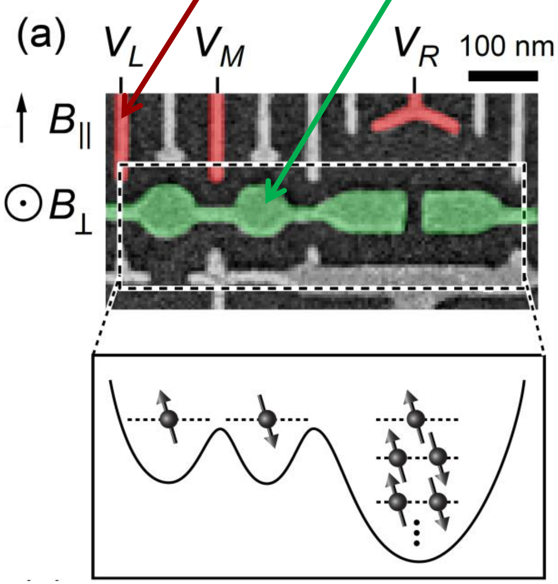
How does the overall dot potential landscape (dot shape) affect the spin on such dot array structure.

Device and characterization

GaAs quantum dots

pulsing gates

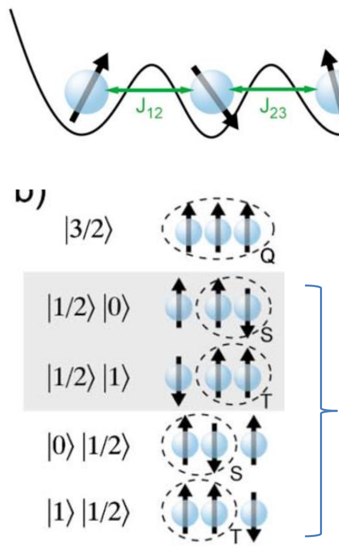
accumulation gates



$$n = 2.5 \times 10^{15}\, m^{-2}$$

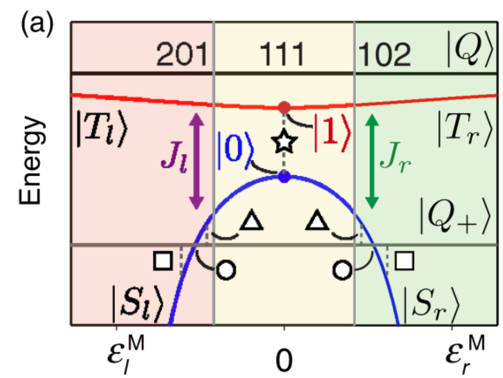
$$\mu = 230\, m^2/Vs$$

triple quantum dots

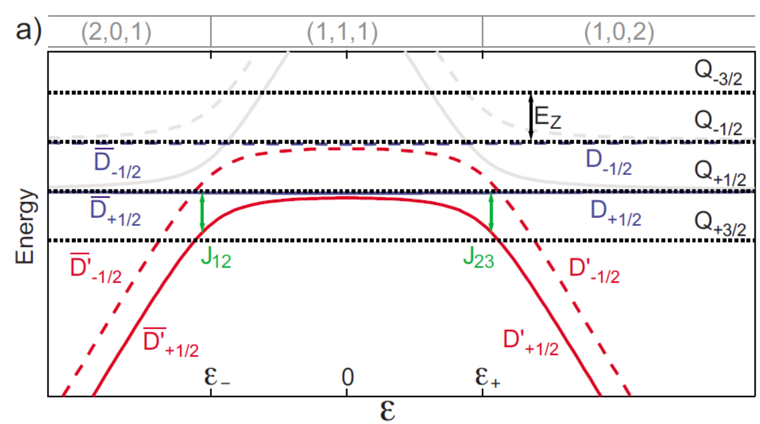


quadruplet

doublet

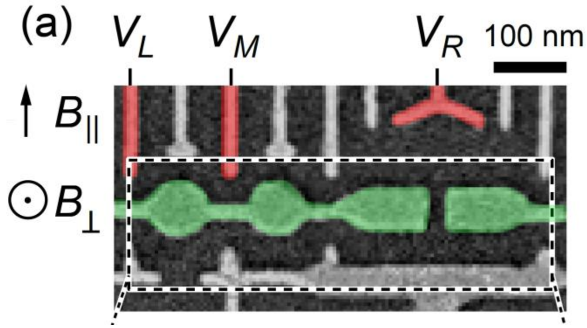


J. Medford et al., PRL **111**, 050501 (2013)



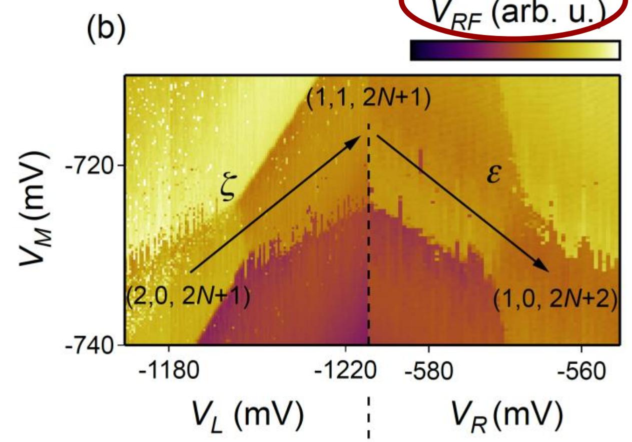
E. Laired et al., Phys. Rev. B **82**, 075403 (2010)

Measurement scheme



sensor reflectometry signal

charge diagram



three relevant states:

(2,0,2N+1) (1,1,2N+1) (1,0,2N+2)

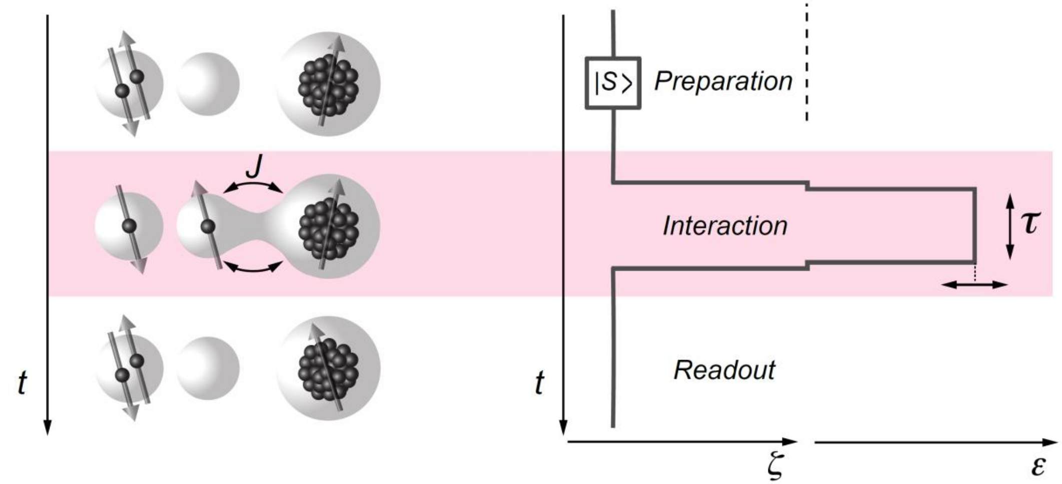
singlet outcome:

no interaction

non-singlet outcome:

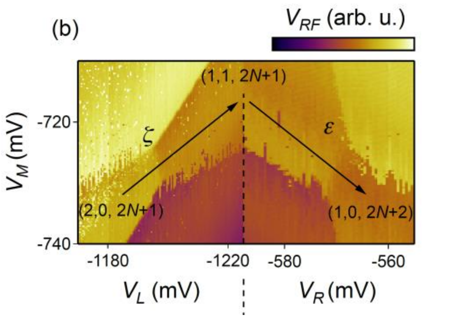
with interaction

P_S: fraction of singlet outcomes



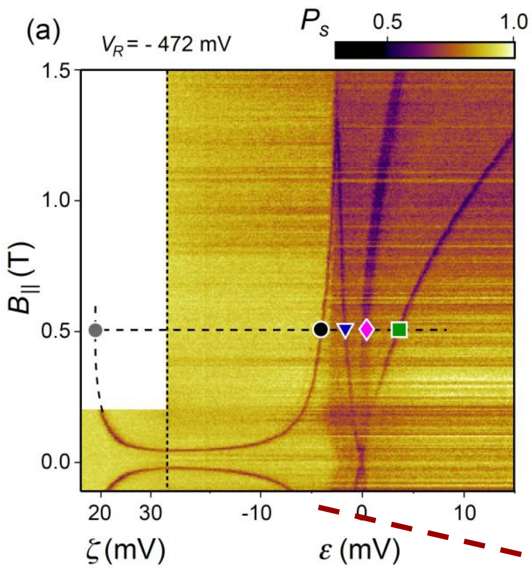
Varying τ and ζ, ε

Spin leakage spectroscopy



$\tau = 150ns$

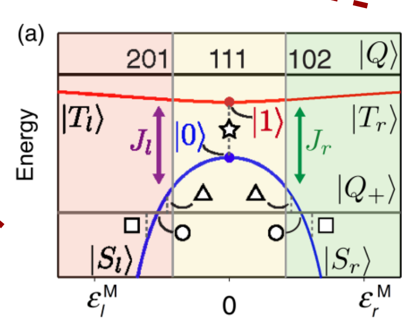
incoherent spin mixing



spin leakage:
suppression of P_S

The relative Zeeman shift of Q^+ will map out J

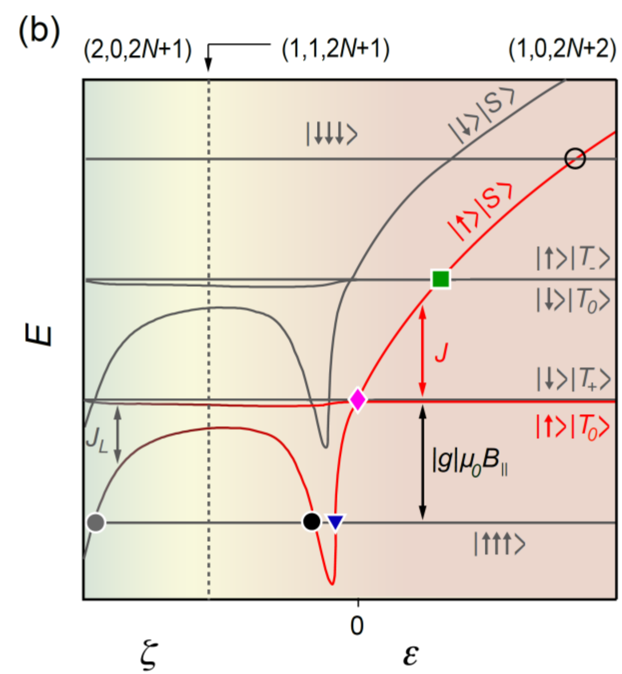
$$J = g\mu_B B$$



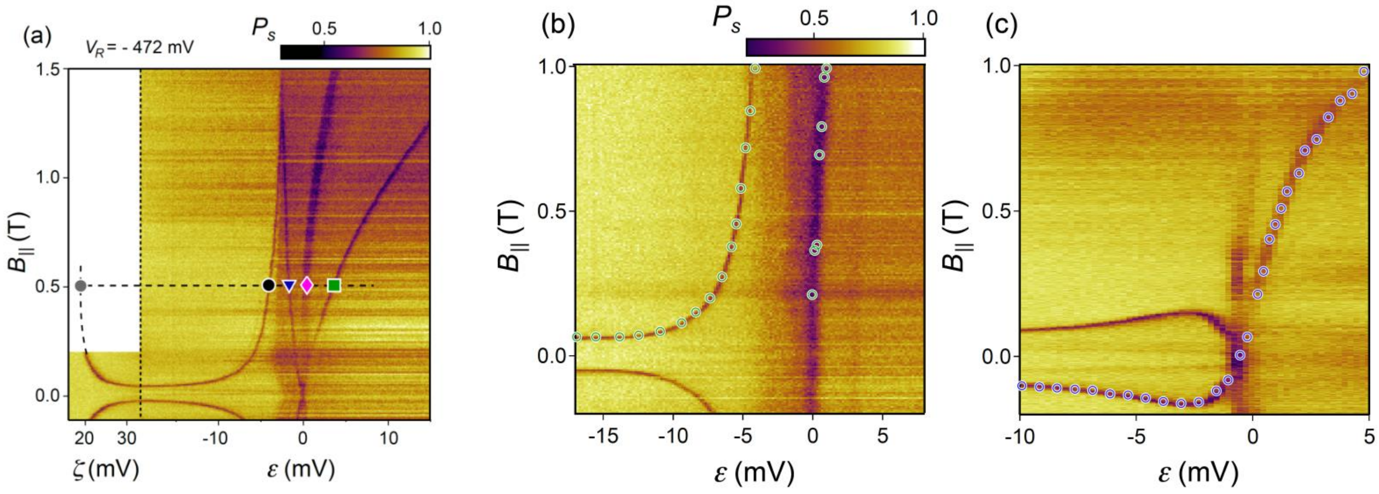
For $\varepsilon < -5mV$
consistent with previous spin leakage measurements

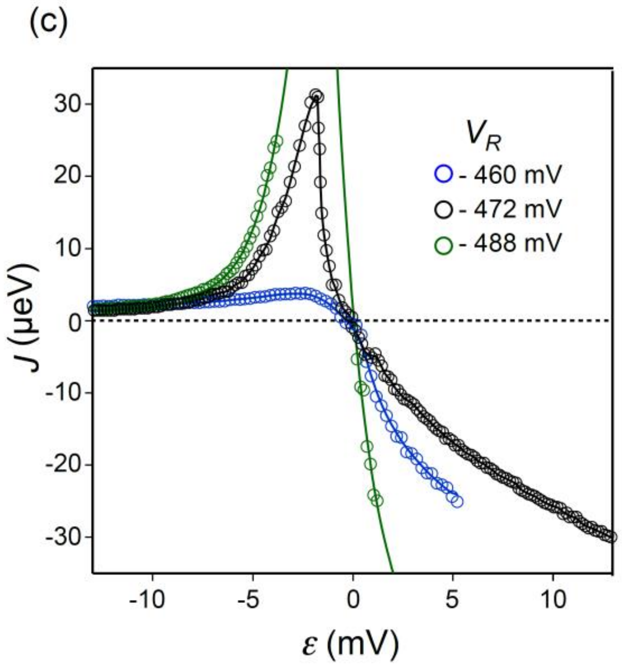
For $\varepsilon > -5mV$
Non-trivial magnetic field dependence

- overall drop in the background of P_S
- J has a maximum
- J reaches zero around $\varepsilon = 0$



Confinement dependence

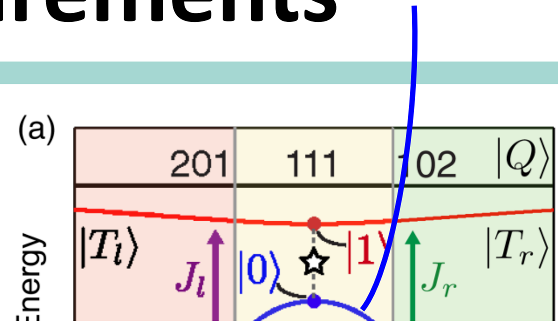




$J(\varepsilon)$ shows the same behavior for different confinement potentials.

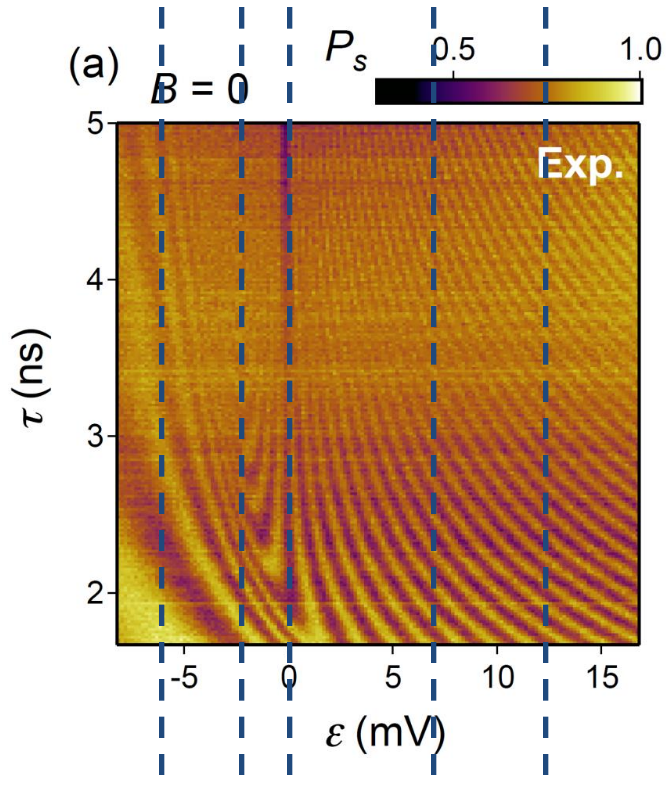
→ triplet-preferring ground state for (1,0,2N+2) charge state

Time domain measurements

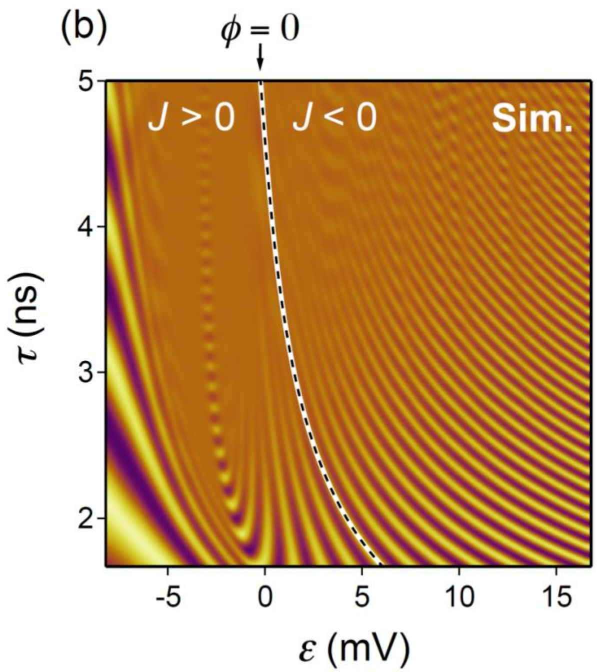


coherent oscillations by varying τ

Direct evidence for the sign reversal in J



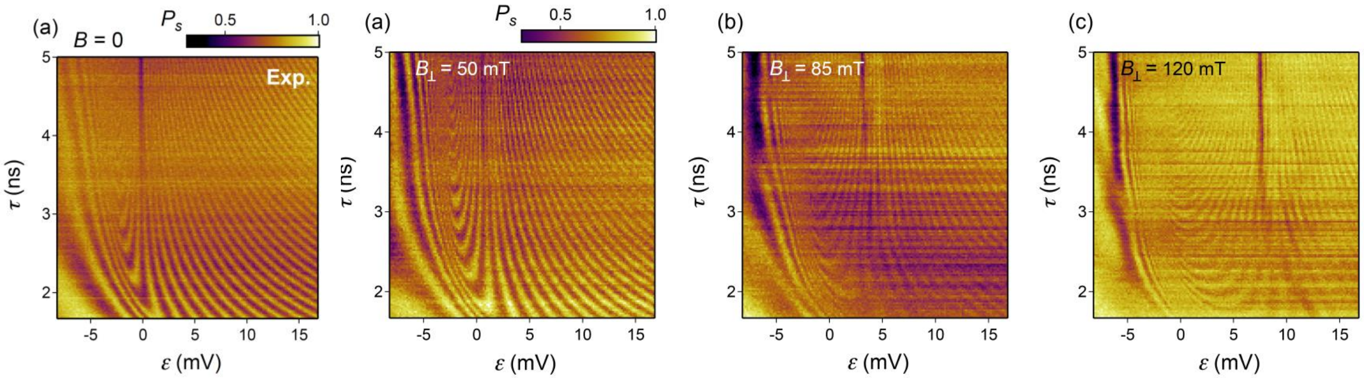
local maximum of $J(\varepsilon)$

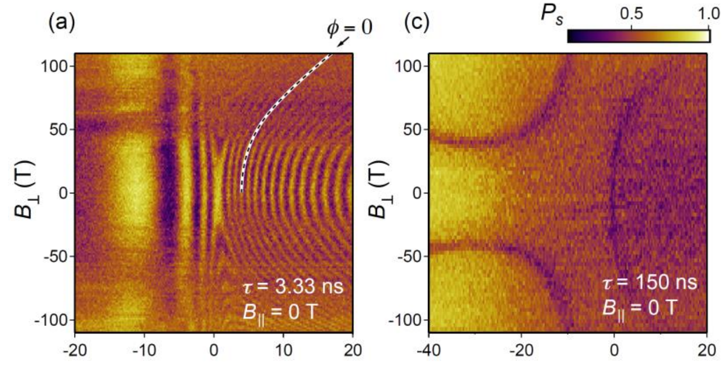


Following contours of equal phase (ϕ) around this "sweet spot", we note that $\phi(\tau)$ has opposite sign for large and small ε, implying a sign reversal in $J(\varepsilon)$.

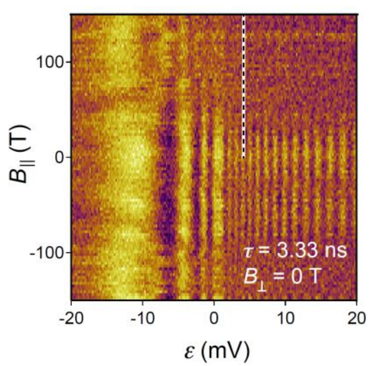
Perpendicular field dependence

increasing fields

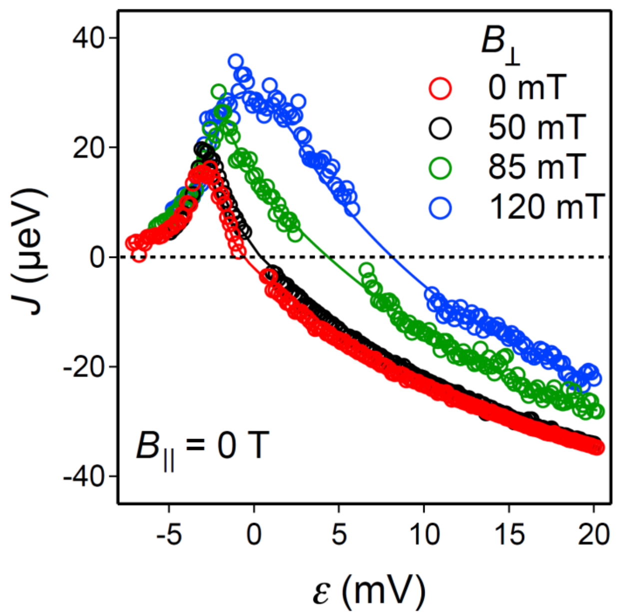




Out-of-plane magnetic field moves the sign reversal of J towards higher detuning.



Out-of-plane field dependence points to the sensitivity of the exchange profile on the electronic orbitals.



Summary

Study of the exchange interaction between a two-electron double quantum dot and a multielectron quantum dot through spin leakage measurements.

- A non-monotonic exchange interaction between the multielectron dot and its neighboring dot is found.
- The exchange interaction reverses sign, indicating a transition from a singlet-preferring to a triplet-preferring ground state.
- The exhange profile can be tuned by either confinement potential or perpendicular magnetic field.

University of Basel

Thank you