Temperature dependence of Andreev spectra in a superconducting carbon nanotube quantum dot

A. Kumar, M. Gaim, D. Steininger, A. Levy Yeyati, A. Martín-Rodero, A. K. Hüttel, and C. Strunk

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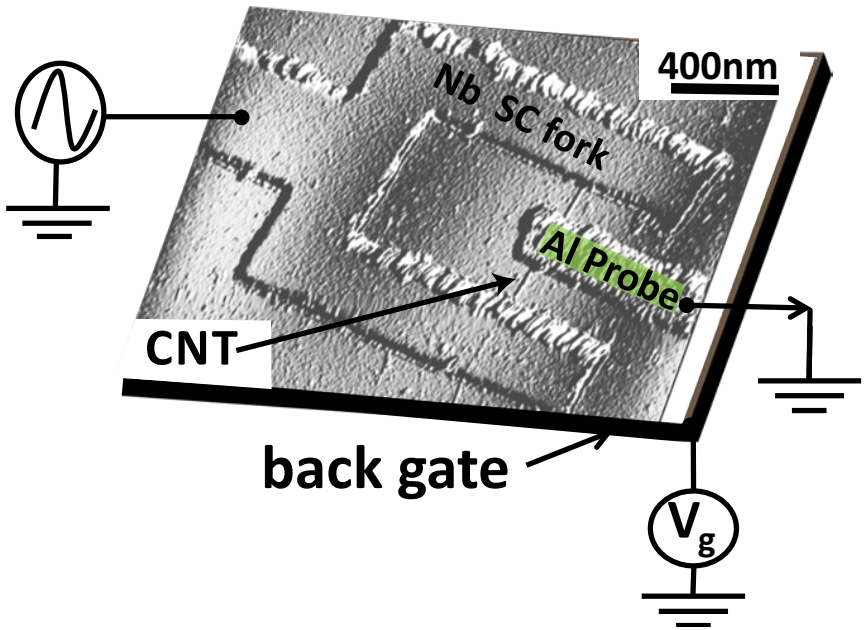
(TT 73.5), 2. April 2014, DPG Frühjahrstagung Dresden

the setup



- "traditional" nanotube device fabrication: metal on top
- 3nm Pd / 60nm Nb "fork" electrode
- 1nm Ti / 60nm Al tunnel probe, weakly coupled
- Andreev bound states form between branches of Nb fork
- tunnel probe "senses" local density of states

Niobium: B_{crit}, T_{crit}, Δ_{Nb}

$\longrightarrow$ much larger parameter space

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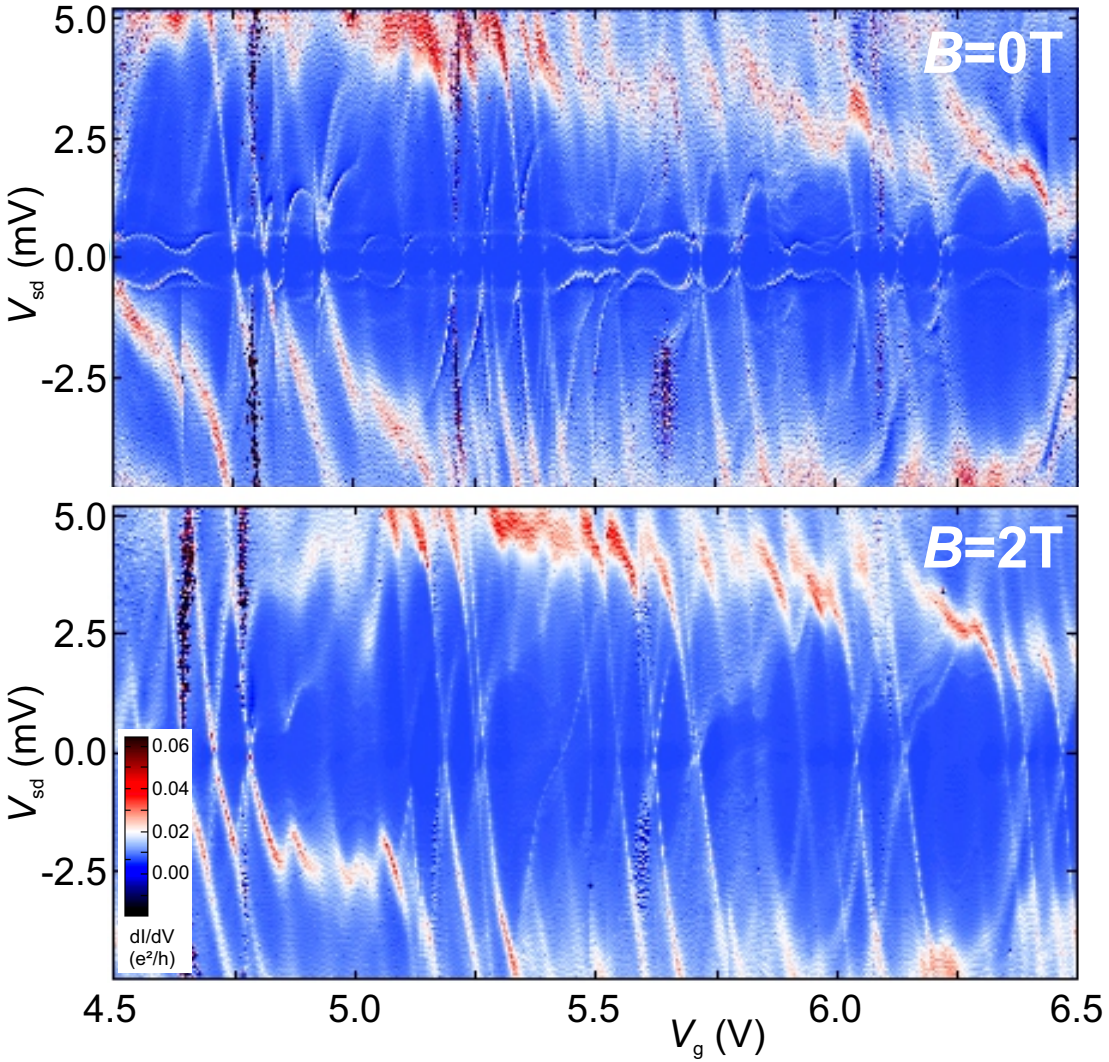
differential conductance — overview



- $B = 0\,\mathrm{T}$: supercond. energy gap and ABS features clearly visible around zero bias
- $B = 2\,\mathrm{T}$: return to regular Coulomb blockade behaviour
- disordered system, no clear indications of shell filling

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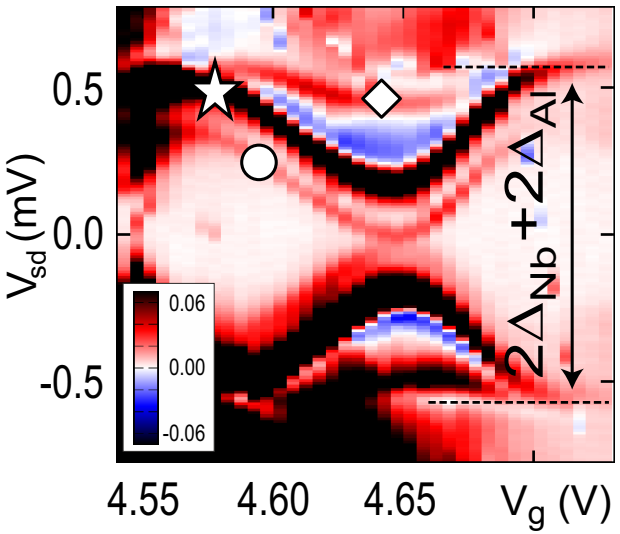
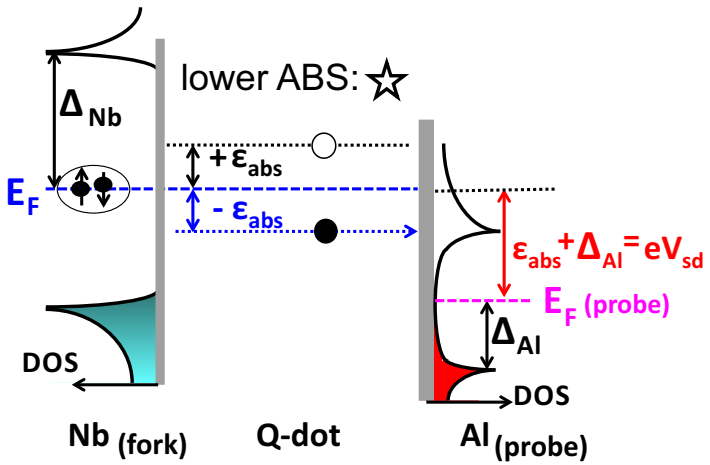
detail analysis of ABS features (I)





- "non-crossing" ABS $\varepsilon_{abs}(V_g) \geq 0$
- main resonance (☆): ABS aligned with BCS edge in Al tunnel probe
- weak replica (○): ABS at Fermi edge of probe electrode
  [note: needs finite DOS in BCS gap of probe electrode]
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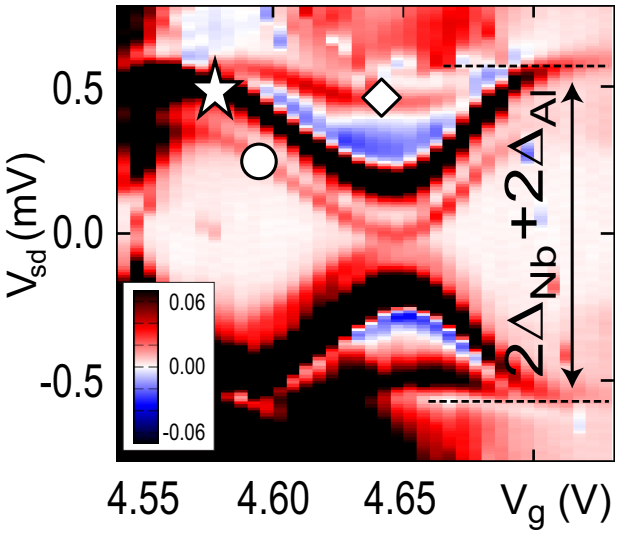

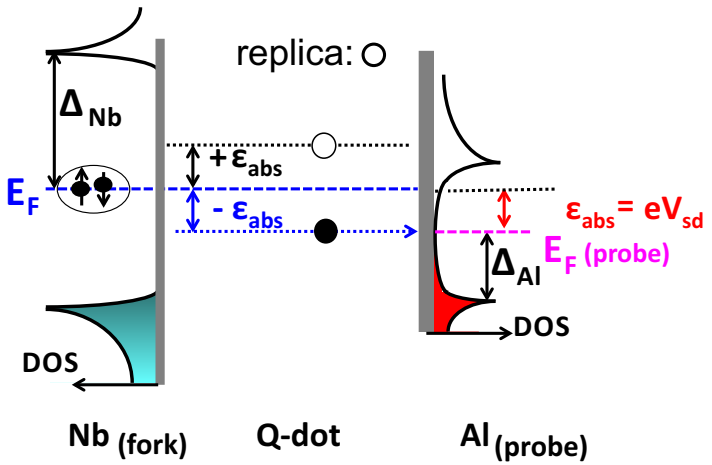

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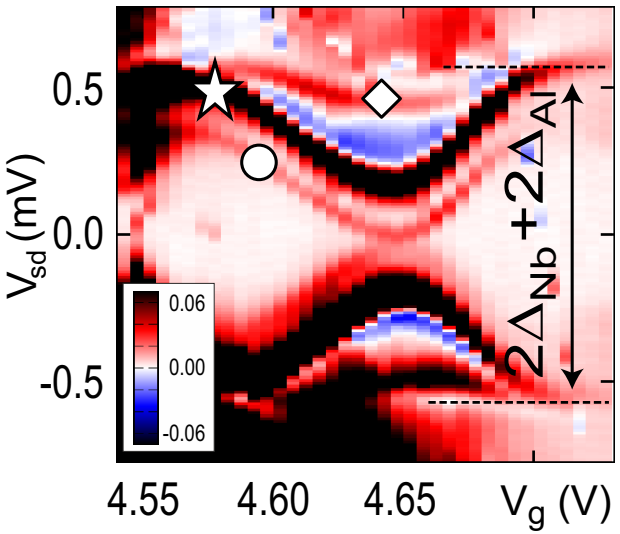

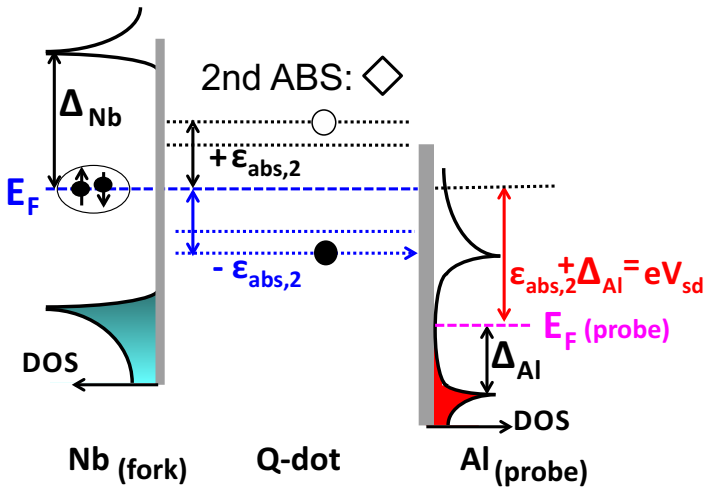

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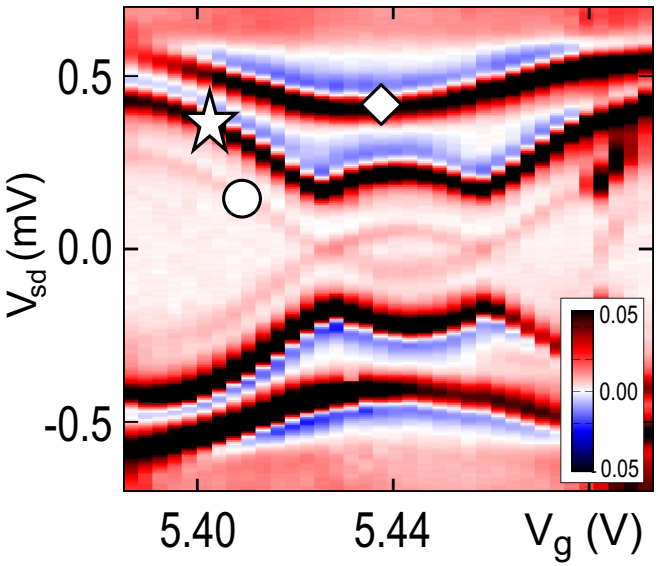

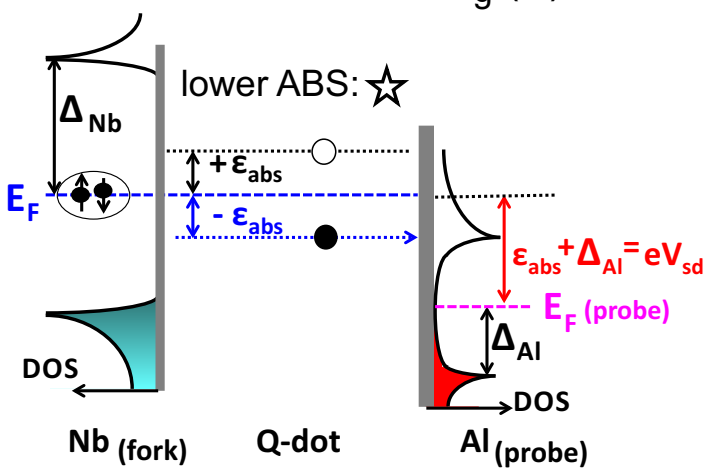

- "crossing" ABS: 0-π phase transition
  $\varepsilon_{abs}(V_g)$ passes through zero
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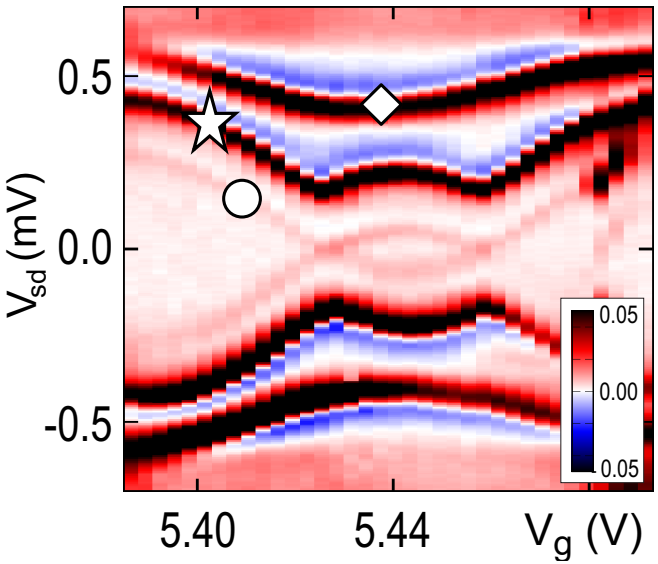

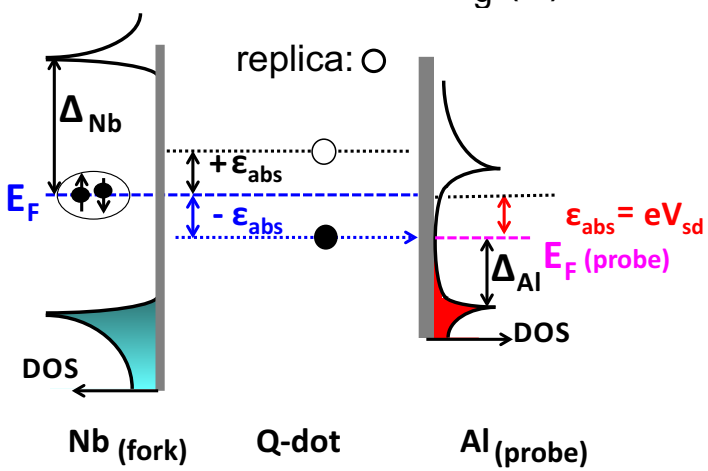

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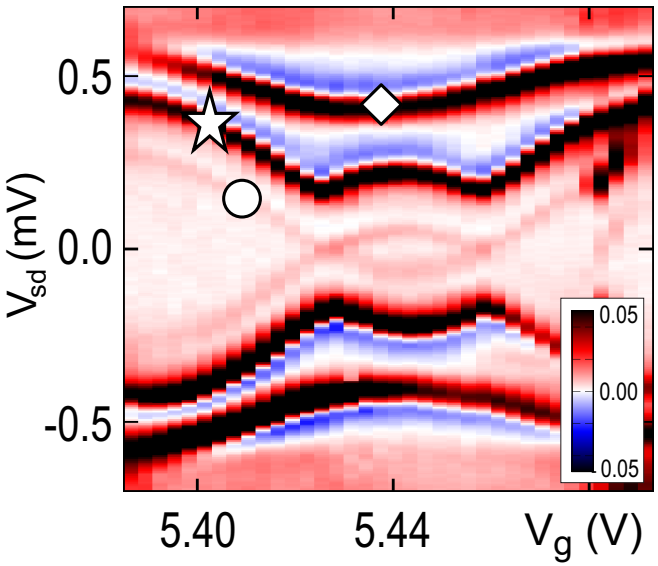

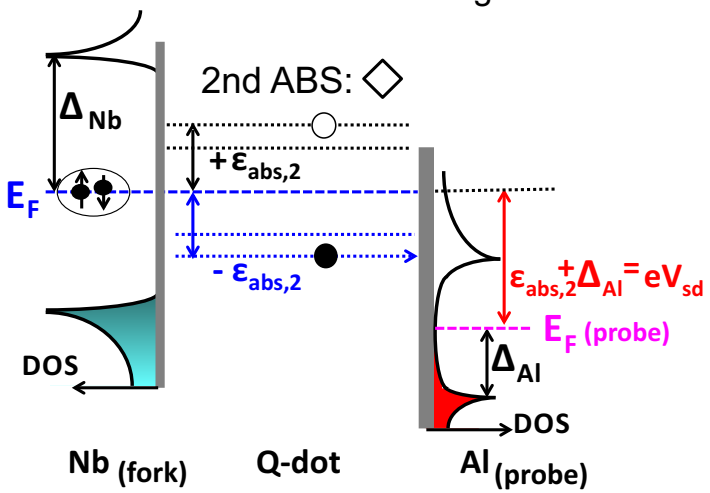

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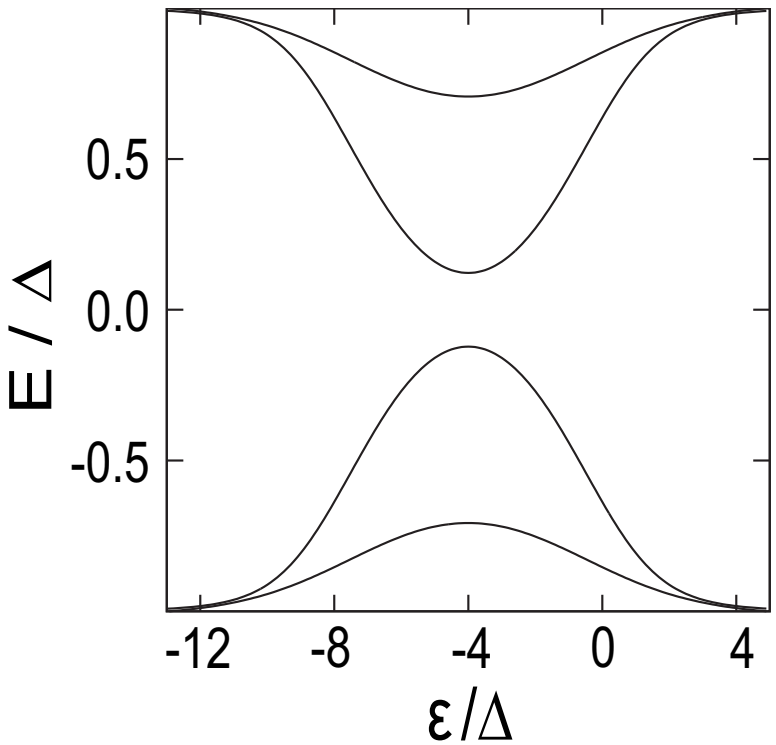
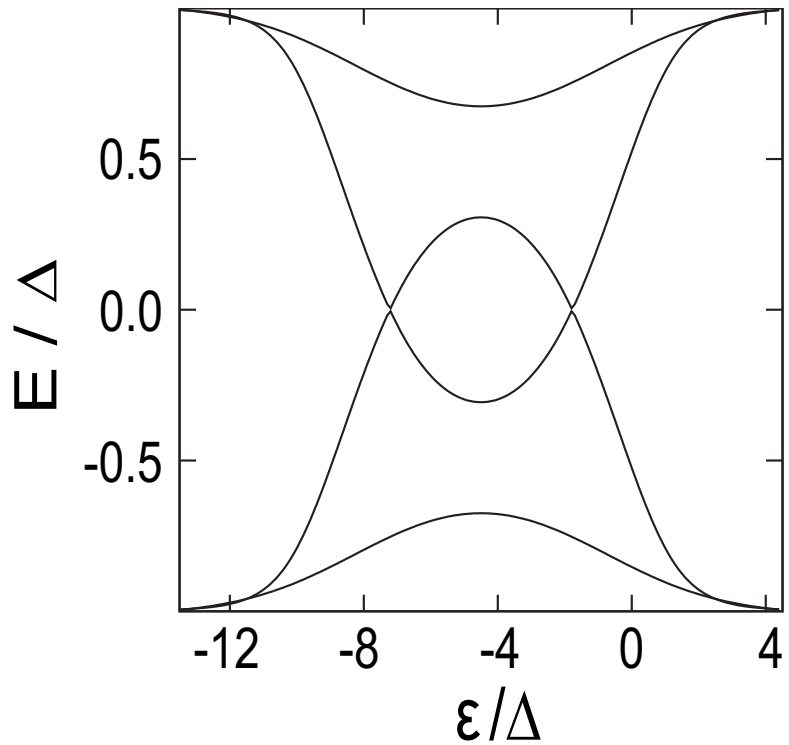
gate voltage dependence of the bare $\varepsilon_{\mathrm{abs}}(V_{\mathrm{g}})$





- NRG calculations for a two-channel superconducting Anderson model
- two local levels couple via two channels to the superconductor
- crossing / non-crossing controlled by ratio $T_K(E_C, \Gamma)/\Delta$

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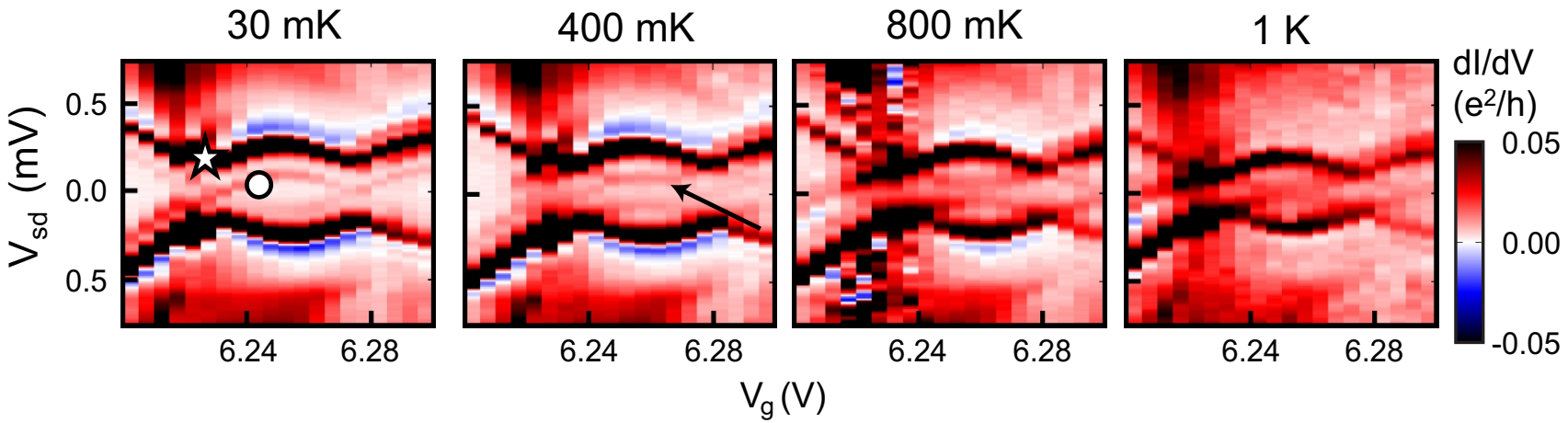
temperature evolution — experiment



- measurement: distinct change of satellite curvature above 400 mK
- thermal excitation?

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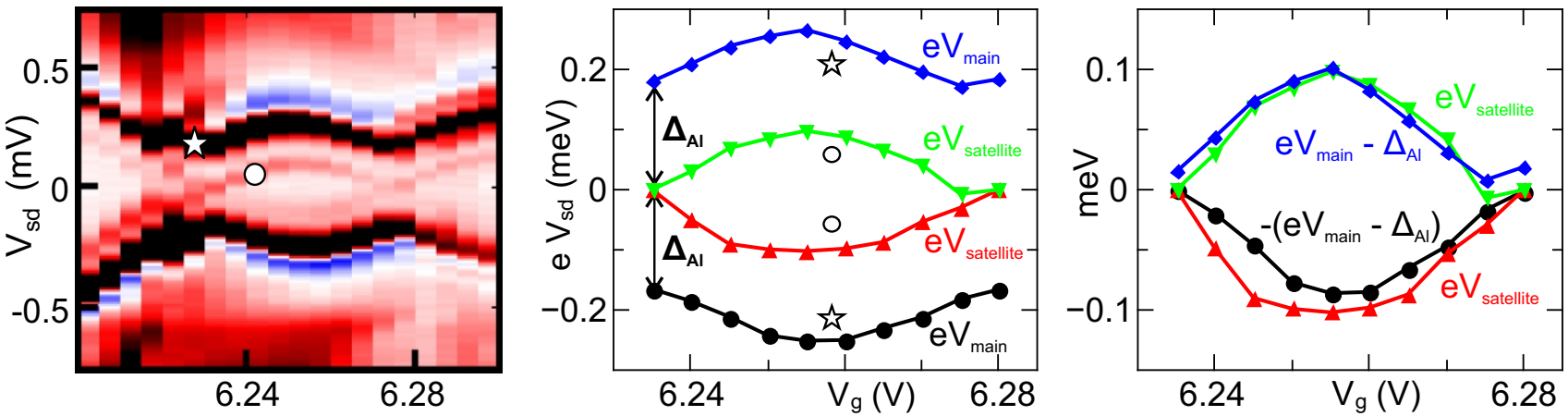
30mK, low-temperature replica



- distance between main resonance and satellite constant, $\sim \Delta_{Al}$
- "shift" $\longrightarrow$ peak positions coincide
- $eV_{main} - \Delta_{Al} = eV_{satellite}$
- this reduces all gate dependence to $\varepsilon_{abs}(V_g)$

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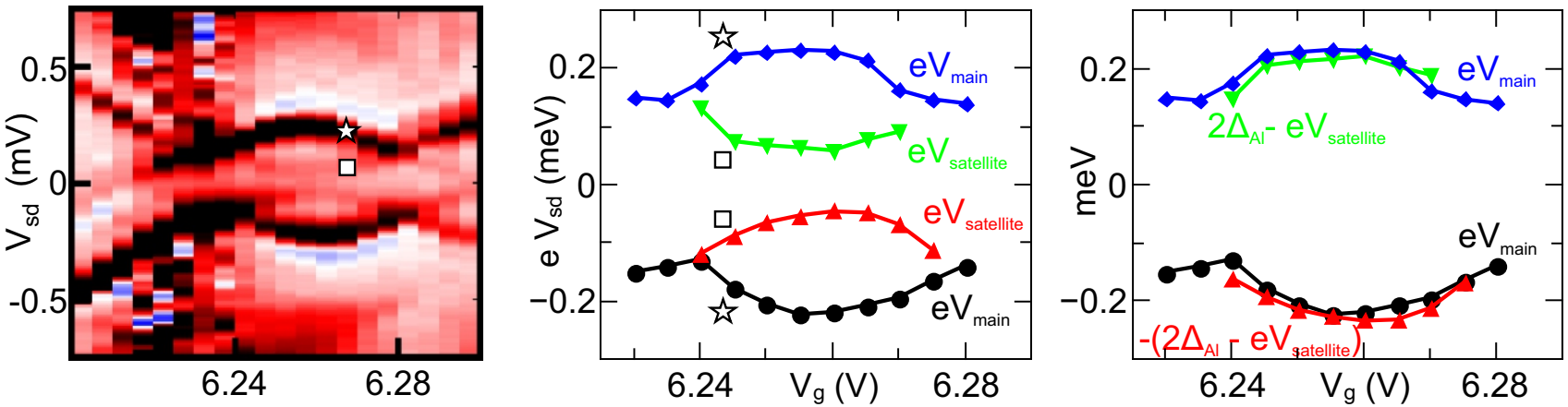
800mK, high-temperature replica



- "flip and shift" $\longrightarrow$ again, peak positions coincide
- need a minus sign from somewhere!
- $2\Delta_{Al} - eV_{satellite} = eV_{main}$
- this reduces all gate dependence to $\varepsilon_{abs}(V_g)$
- why? ...

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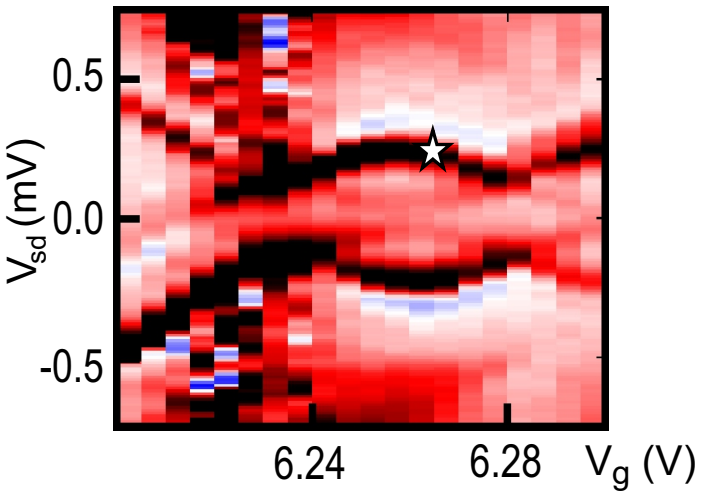
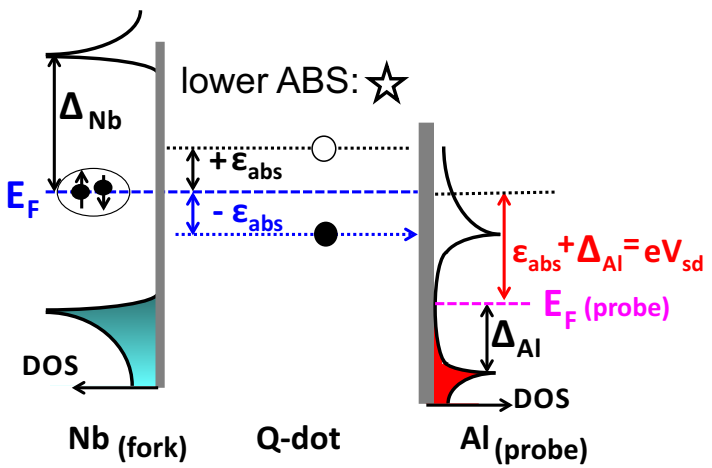
detail analysis of ABS features (III)





- main resonance (☆): ABS aligned with BCS edge in Al tunnel probe (same as before)
- weak replica, high temperature (□): excited ABS aligned at BCS edge in Al tunnel probe
- indeed, $2\Delta_{Al} - eV_{satellite} = eV_{main}$

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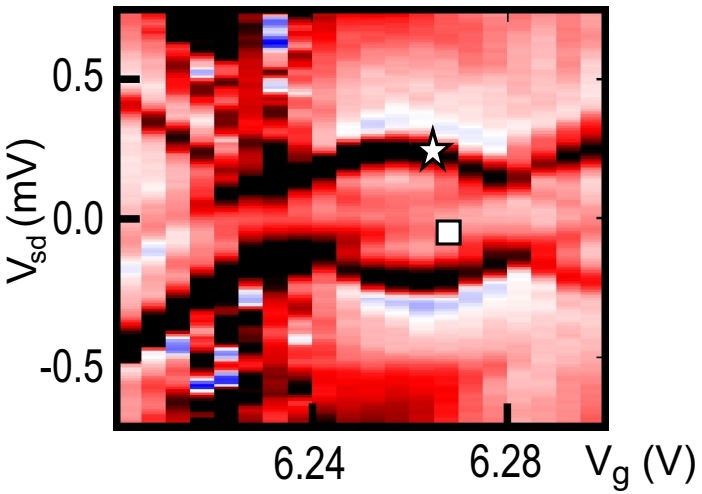

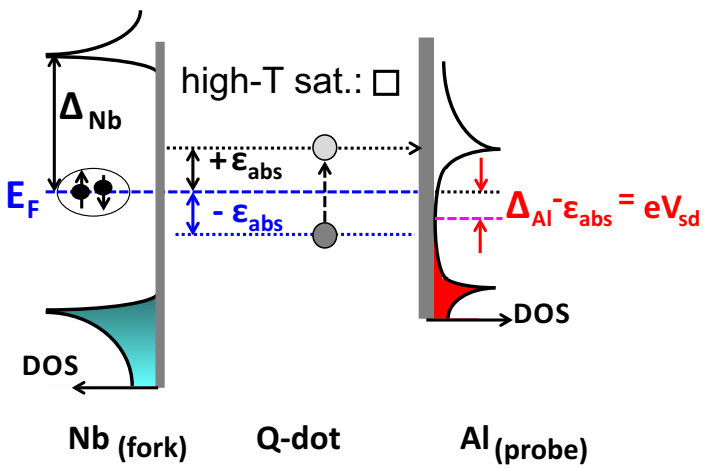

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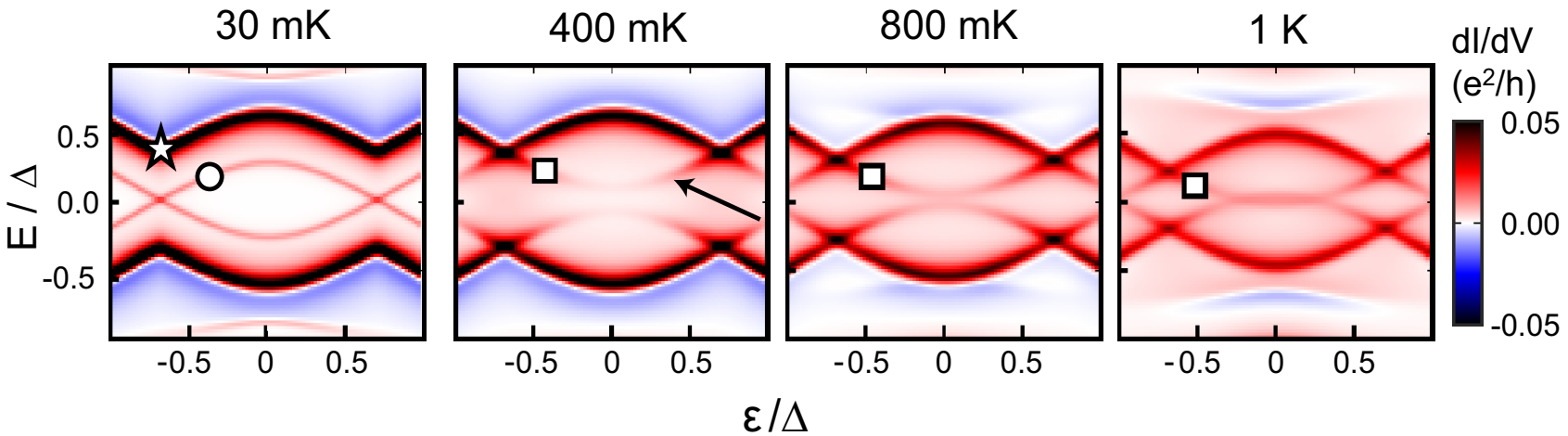
temperature evolution — model calculation



- mean field description of the superconducting Anderson model
- two superconducting leads with two different gap parameters
- only temperature-dependent parameter: $\Delta_{\mathrm{Al}}(T)$
- change of satellite curvature above 400 mK nicely reproduced

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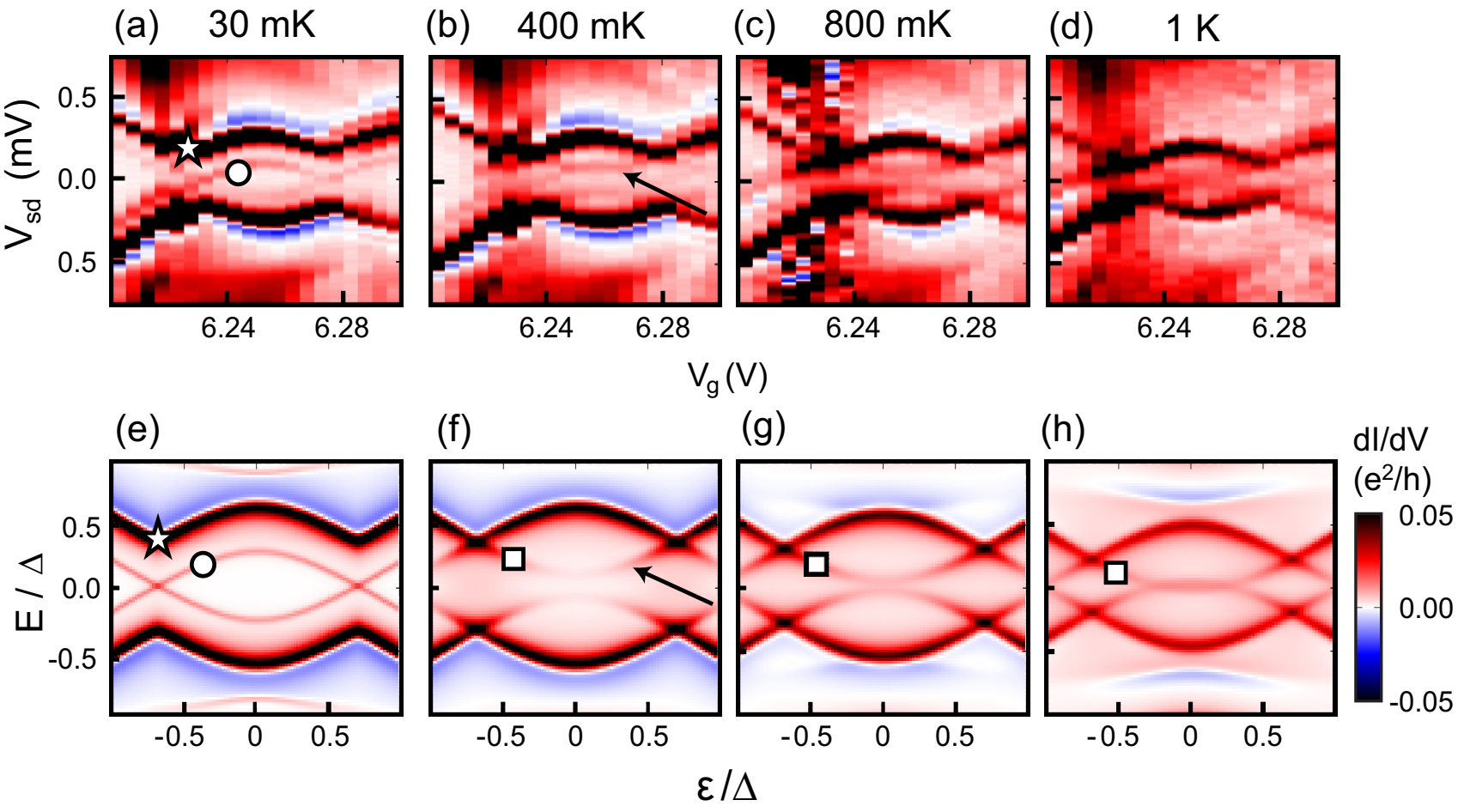
Thank you! — Questions?



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