

Transport measurements of InSb nanowires with induced superconductivity

Hugh Churchill (Harvard, now MIT)

Valla Fatemi (MIT)

Kasper Grove-Rasmussen (NBI)

Vlad Manucharyan (Harvard)

Willy Chang (Harvard/NBI)

Charles Marcus (NBI)

wires: Mingtang Deng (Lund)

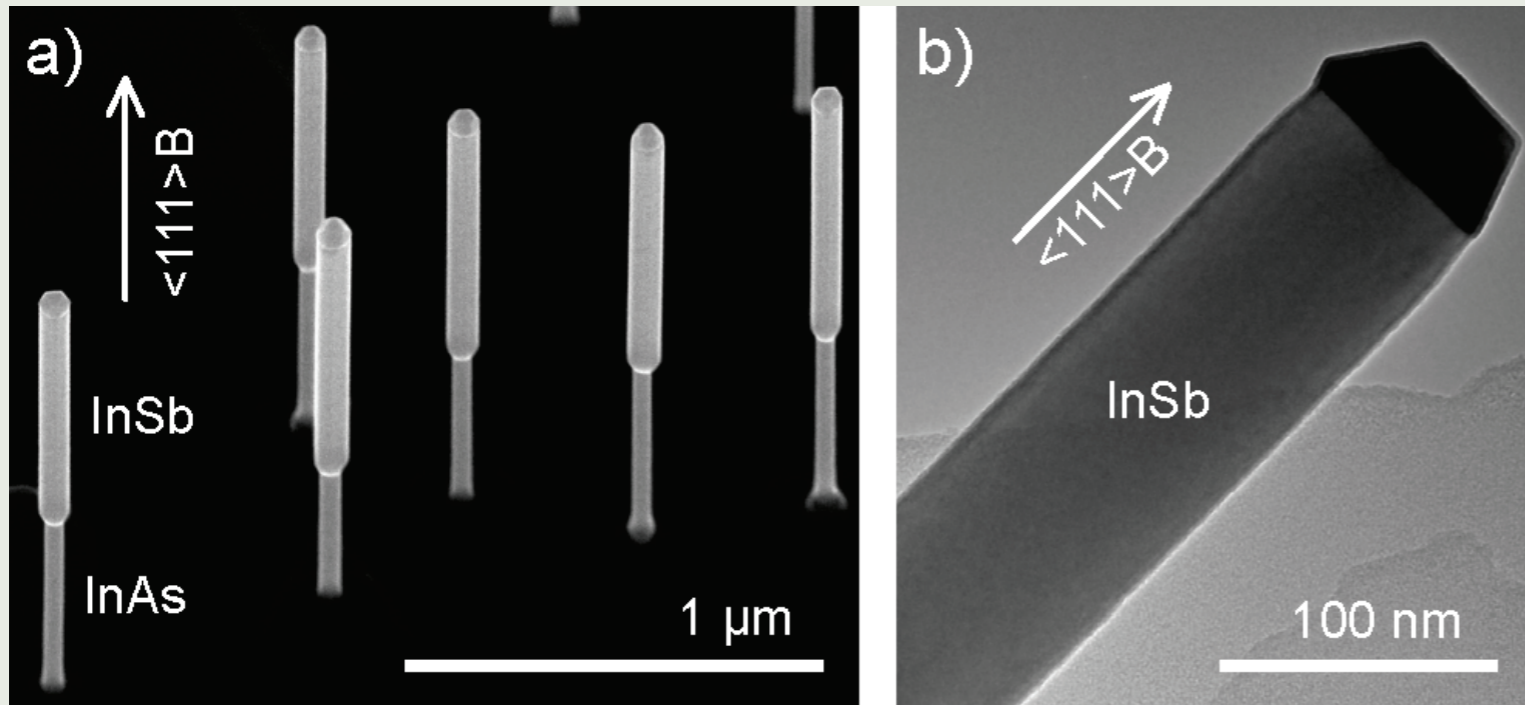
Hongqi Xu (Lund)



3 configurations:

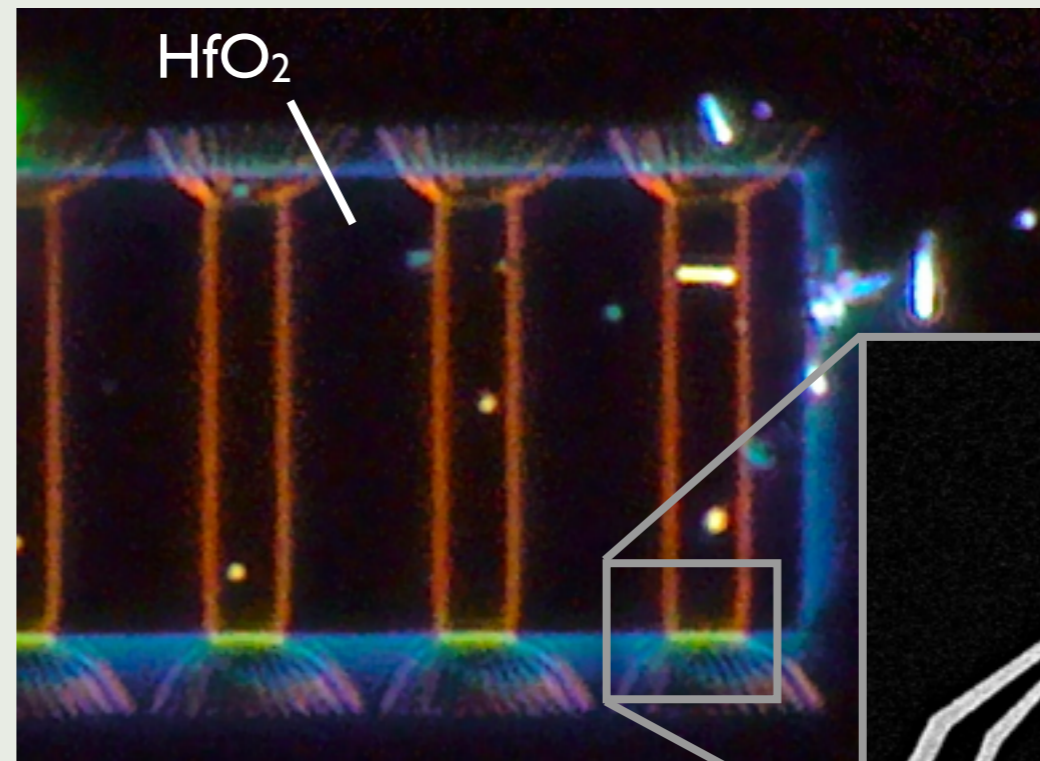
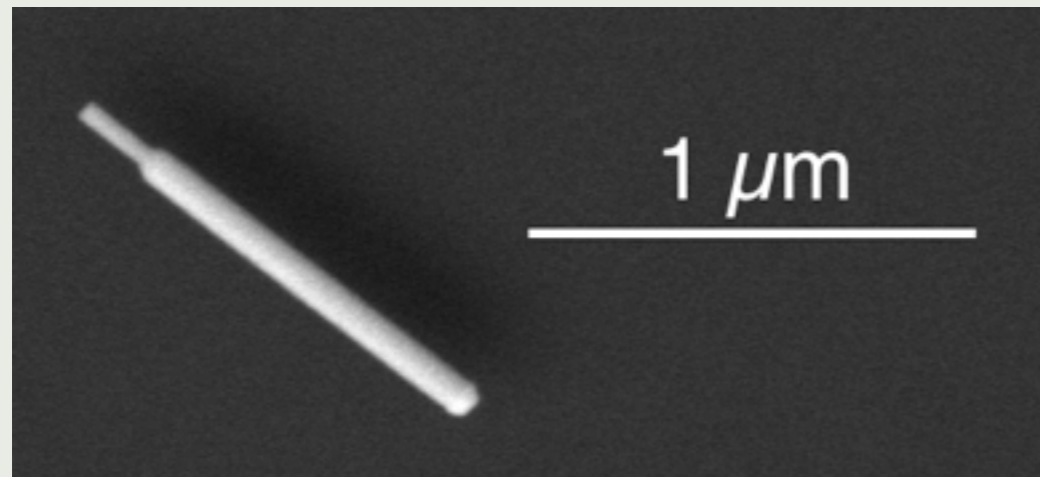
1. Quantum point contact
2. Andreev bound states
3. Quantum dot (weakly coupled to both sides)

InSb nanowires from Lund



Nilsson *et al.* Nano Lett. (2009)

Wires deposited on
bottom-gate substrates:



2 devices measured

Device #1: two-sided (N-wire-S-wire-N)

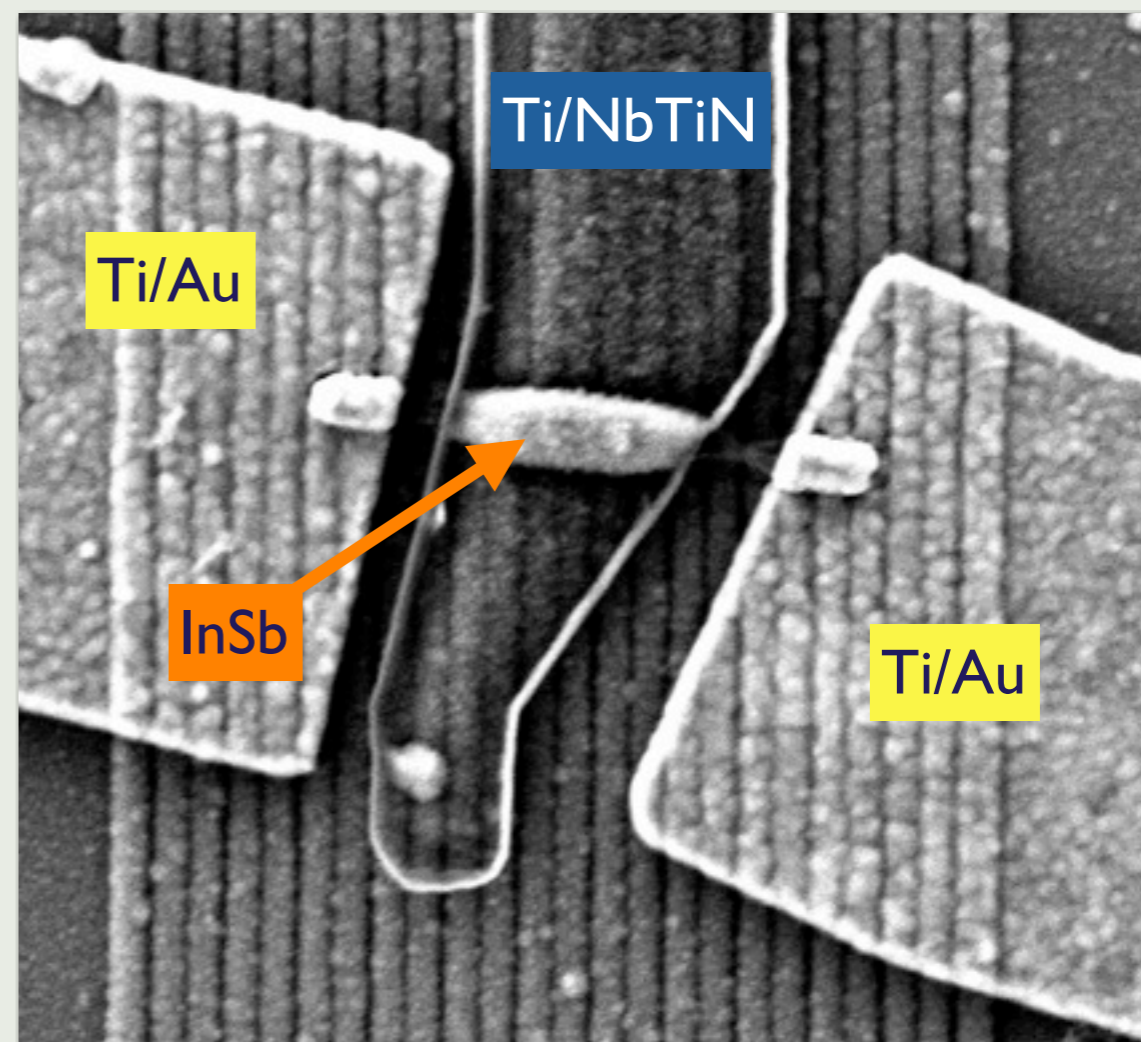
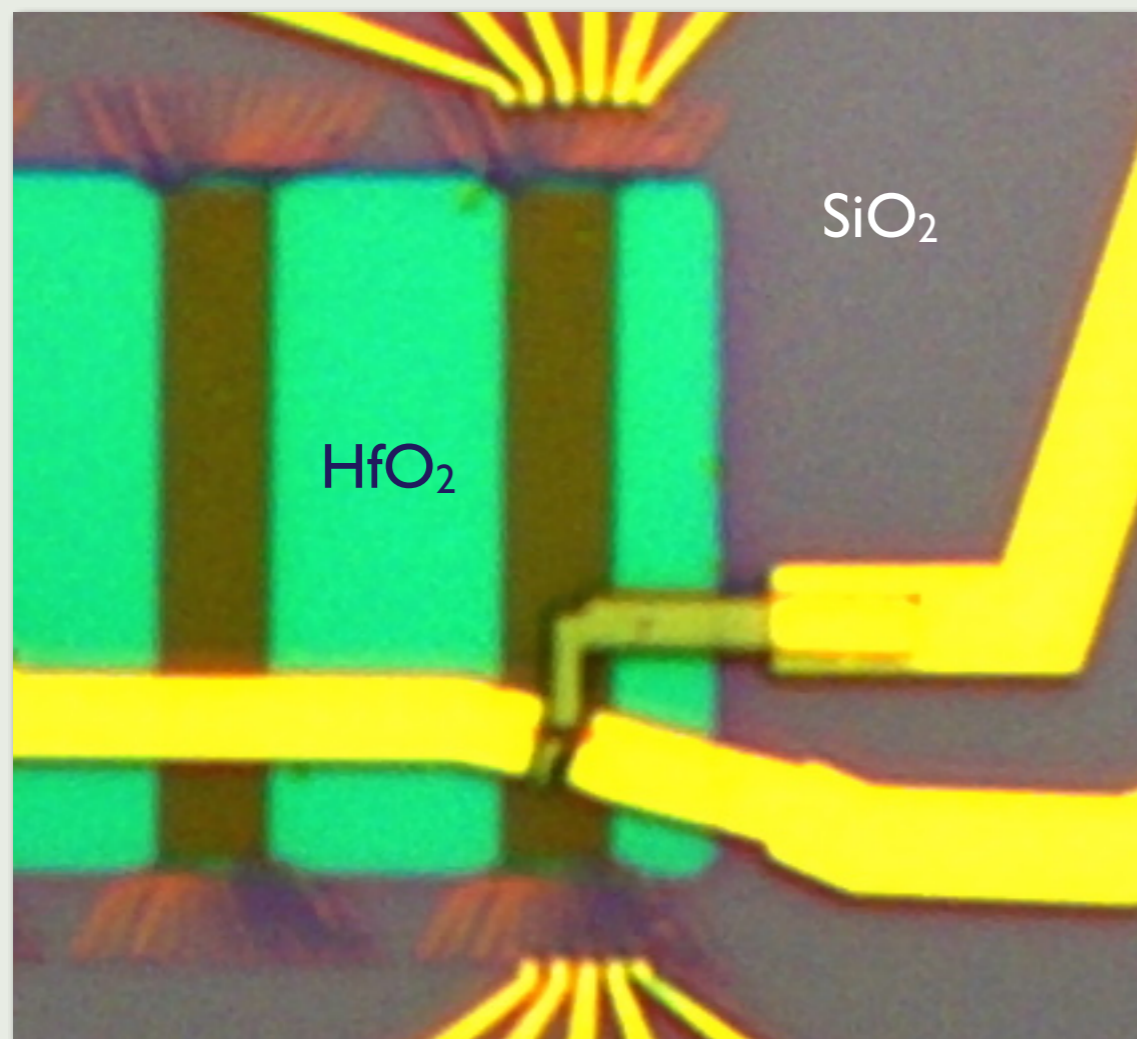
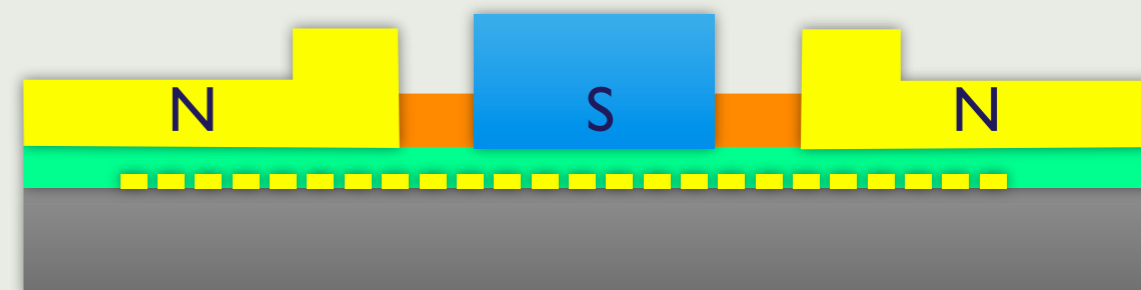
150 nm wide uncovered regions

300 nm wide superconducting contacts

Device #2: one-sided (N-wire-S)

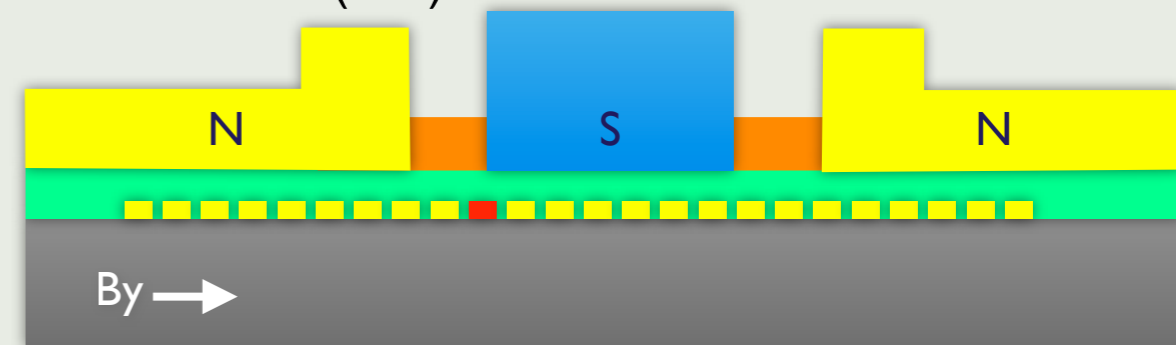
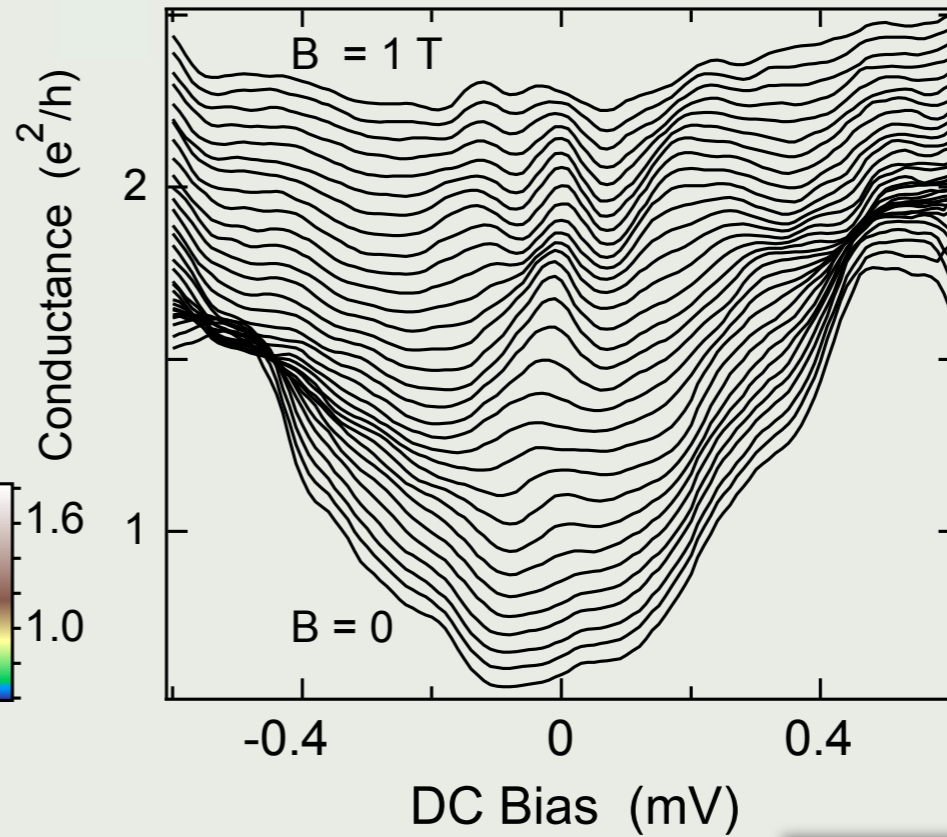
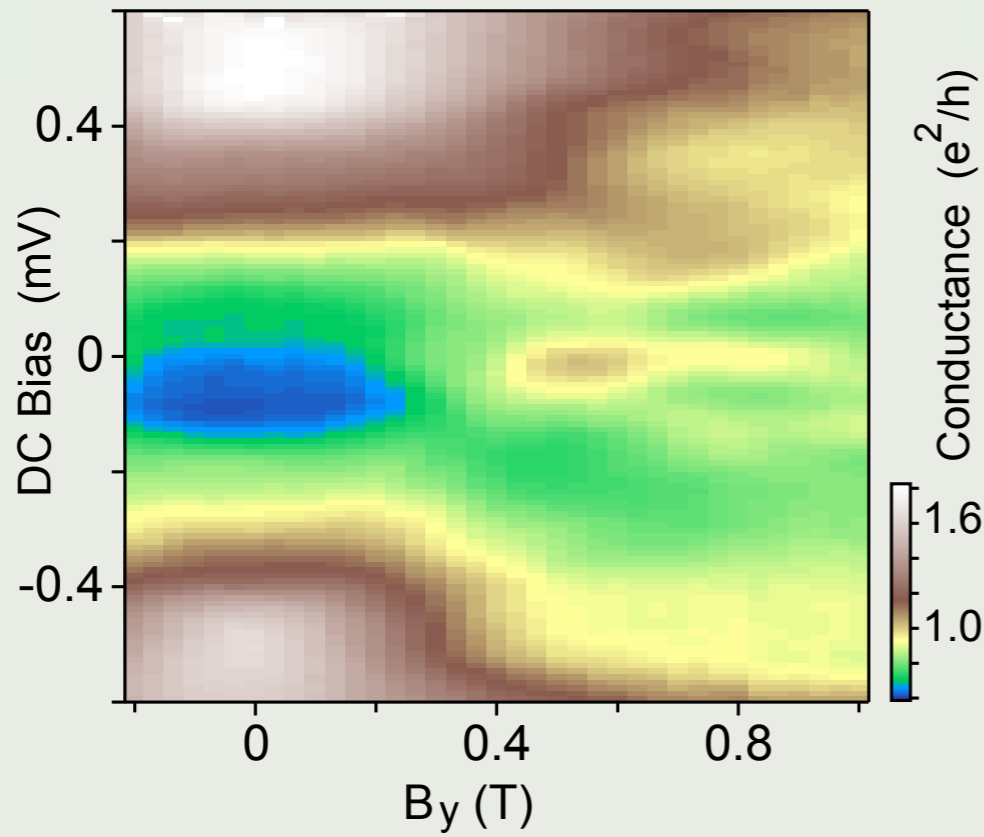
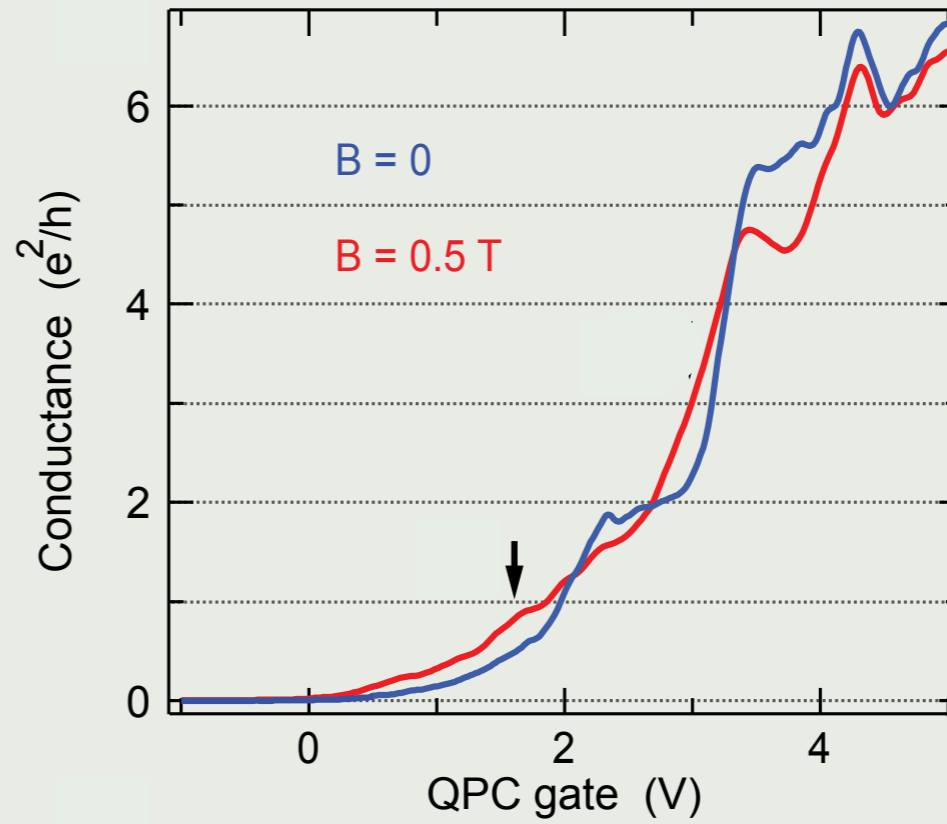
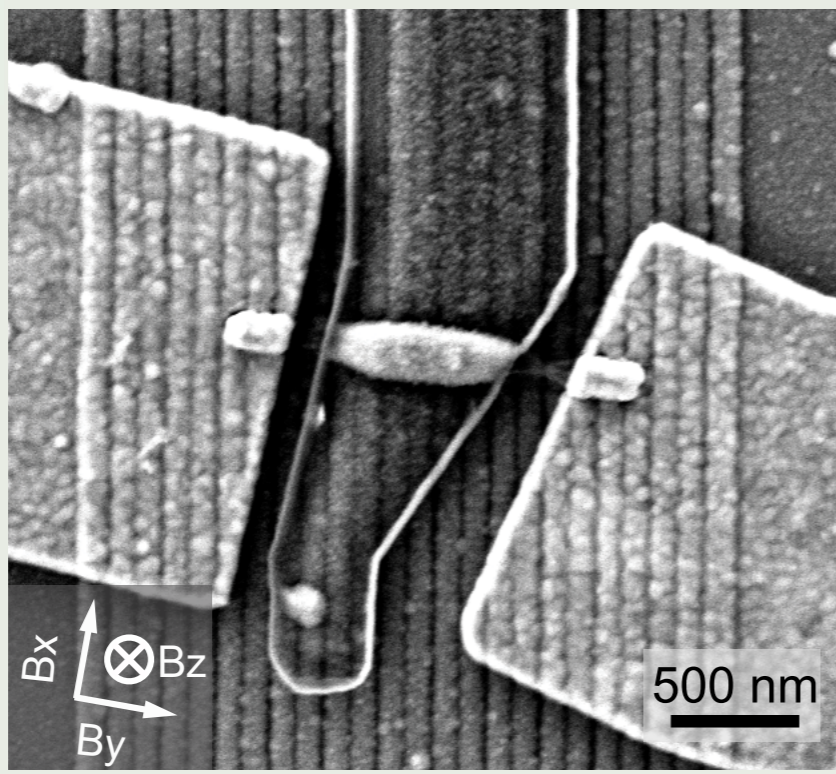
100 nm wide uncovered region

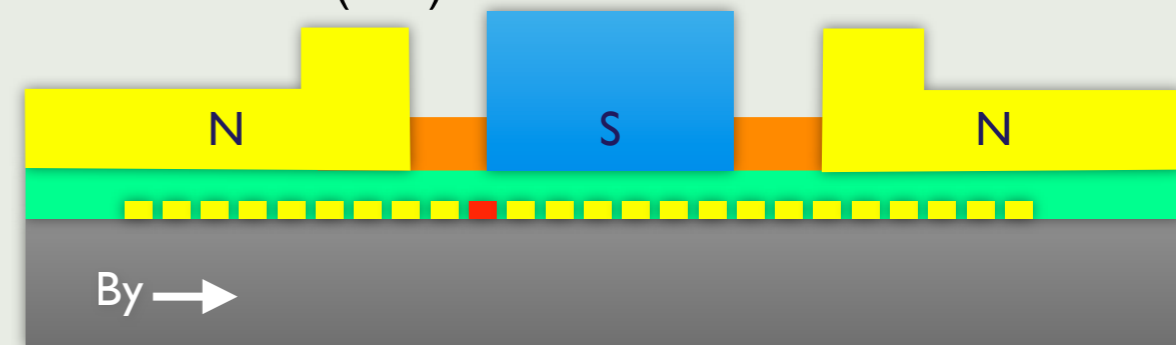
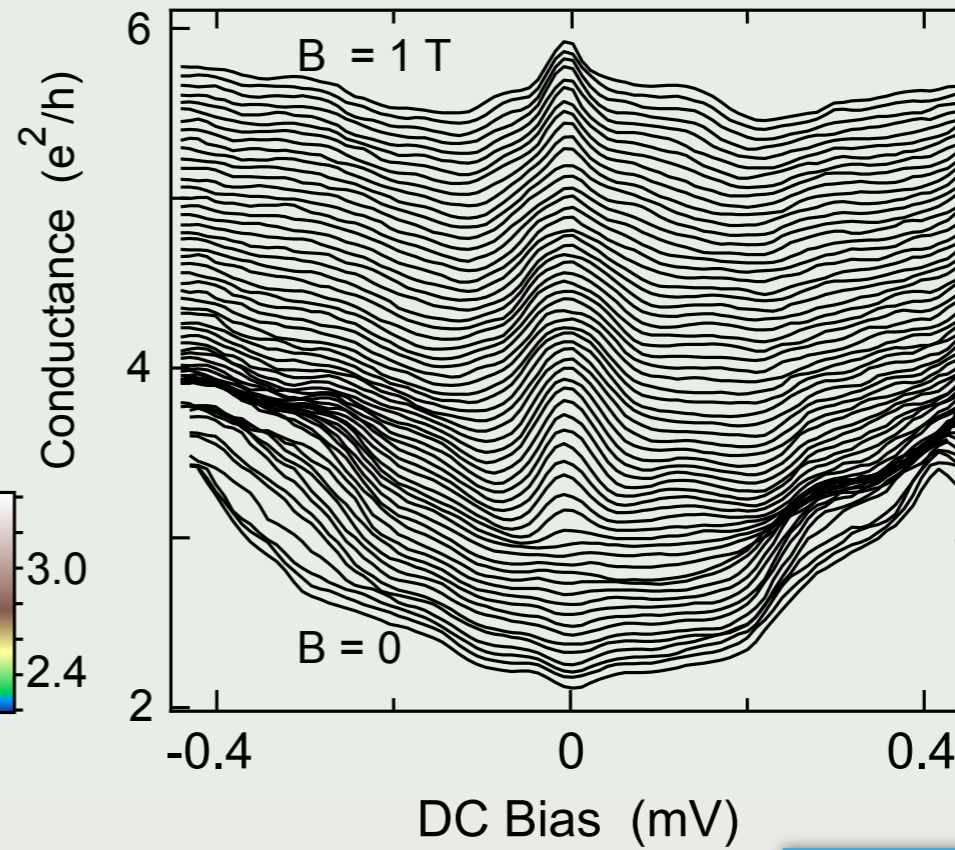
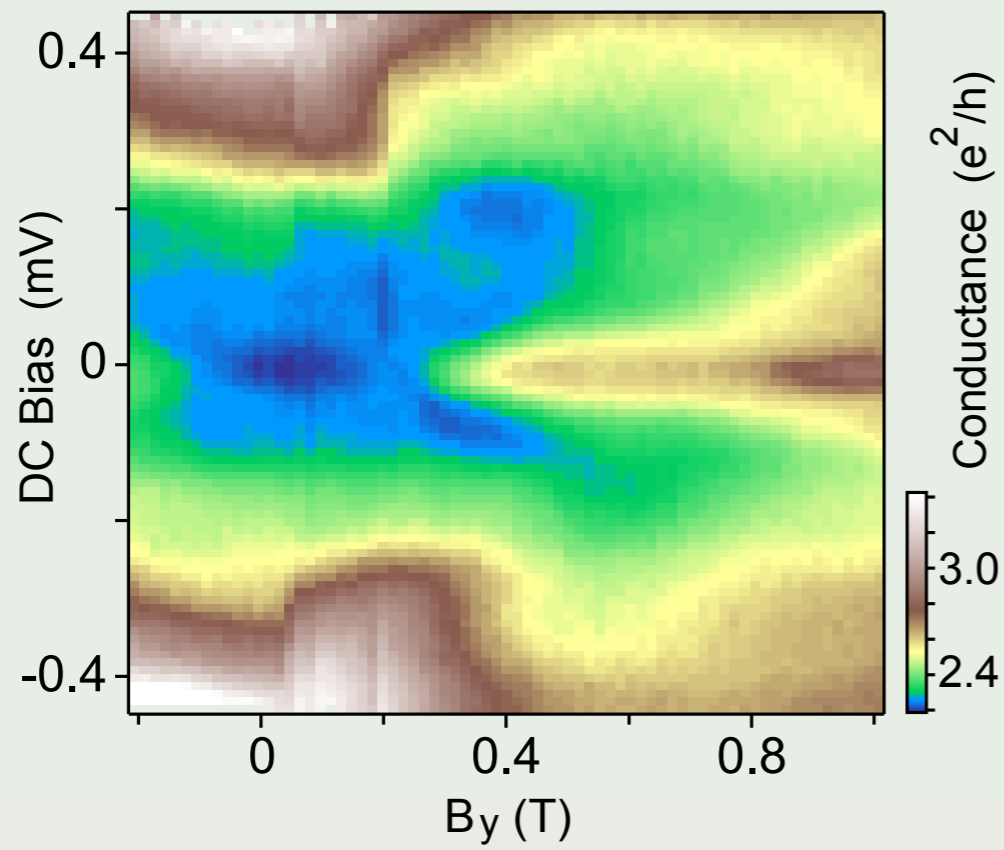
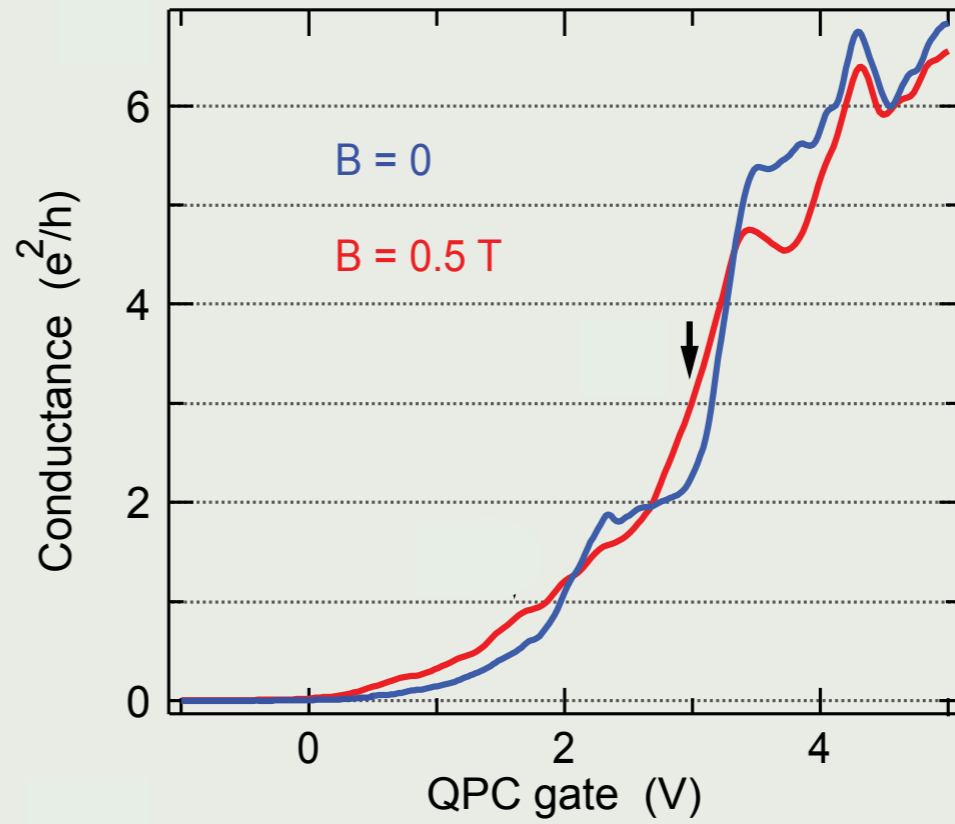
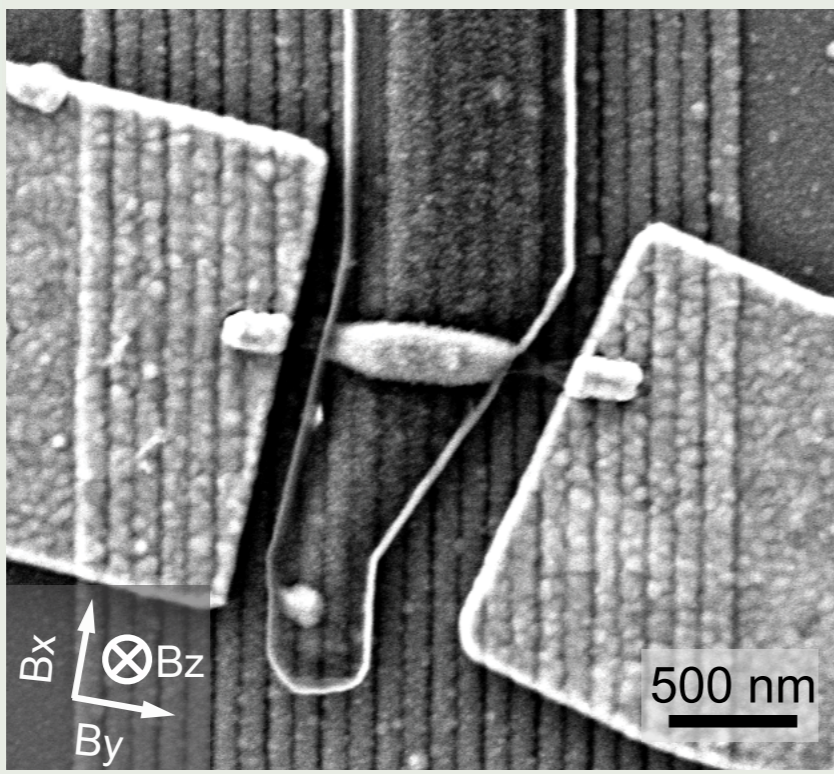
400 nm wide superconducting contact



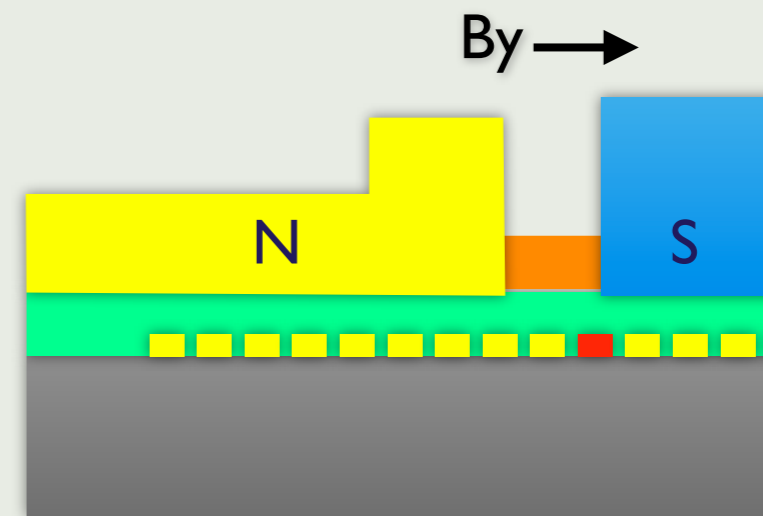
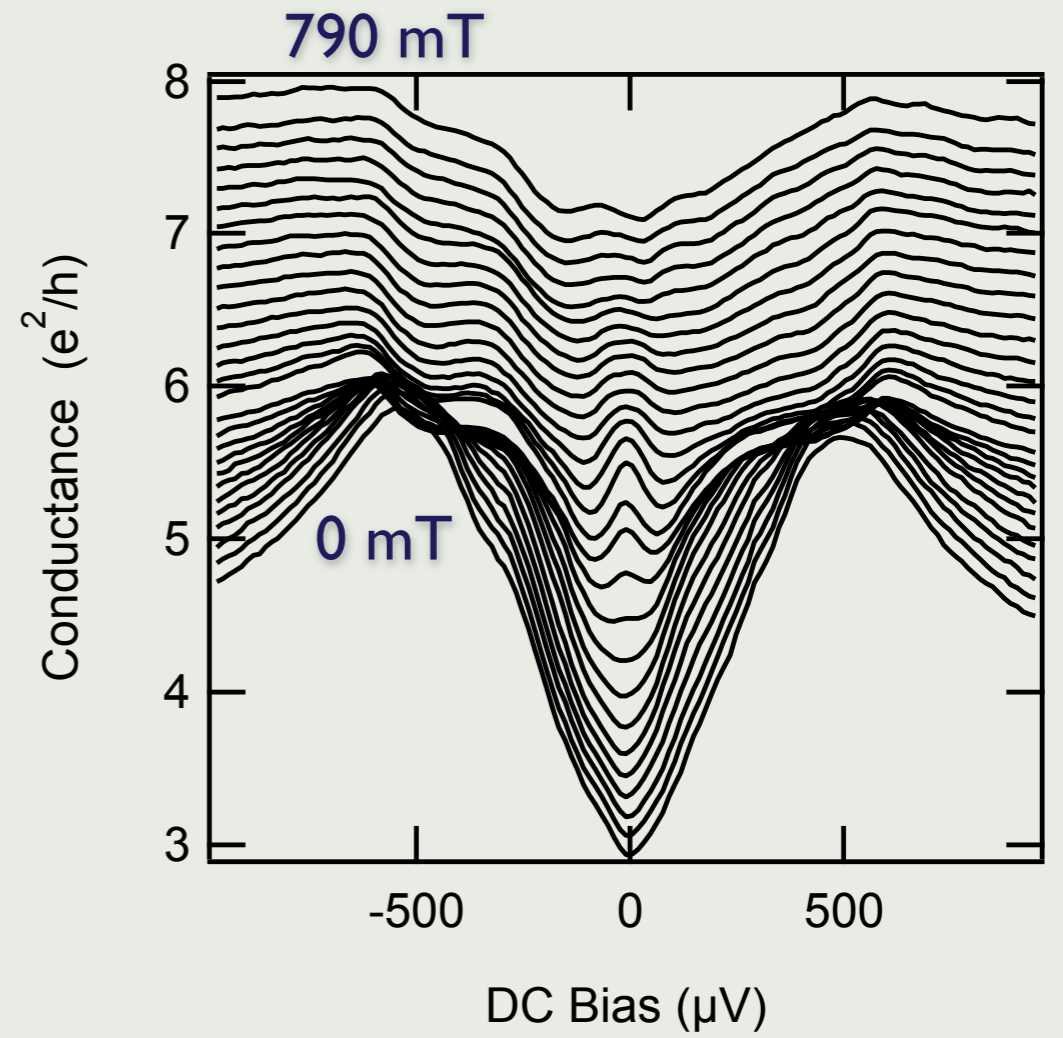
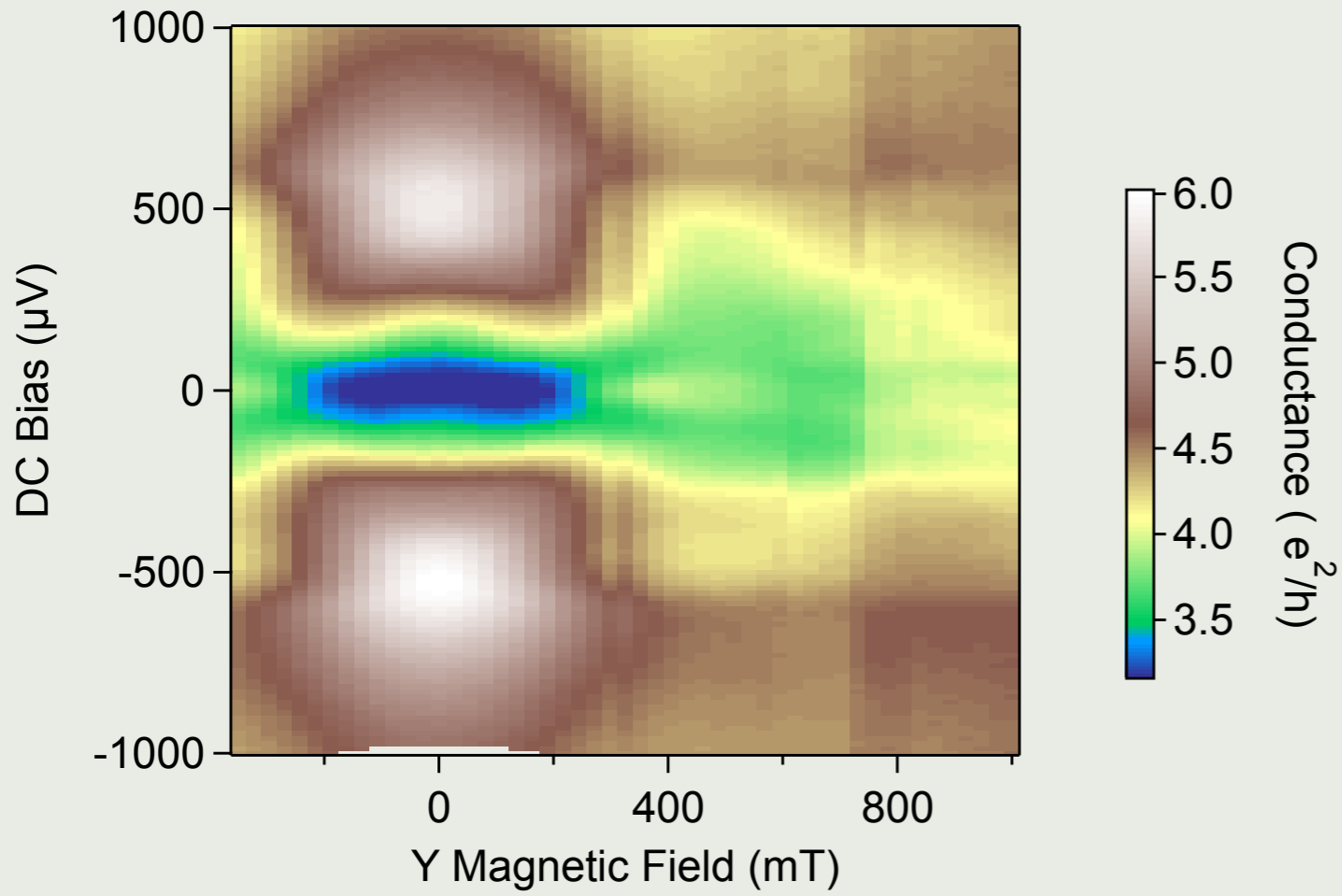
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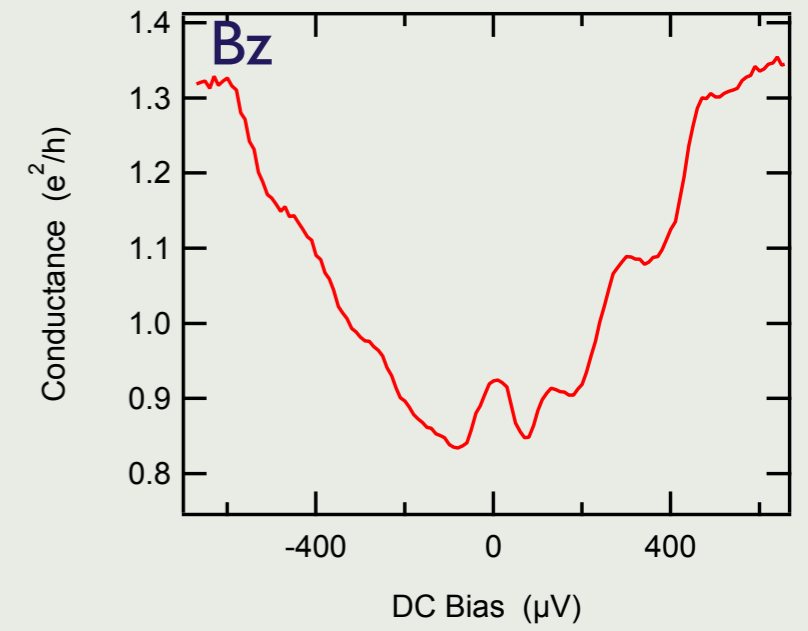
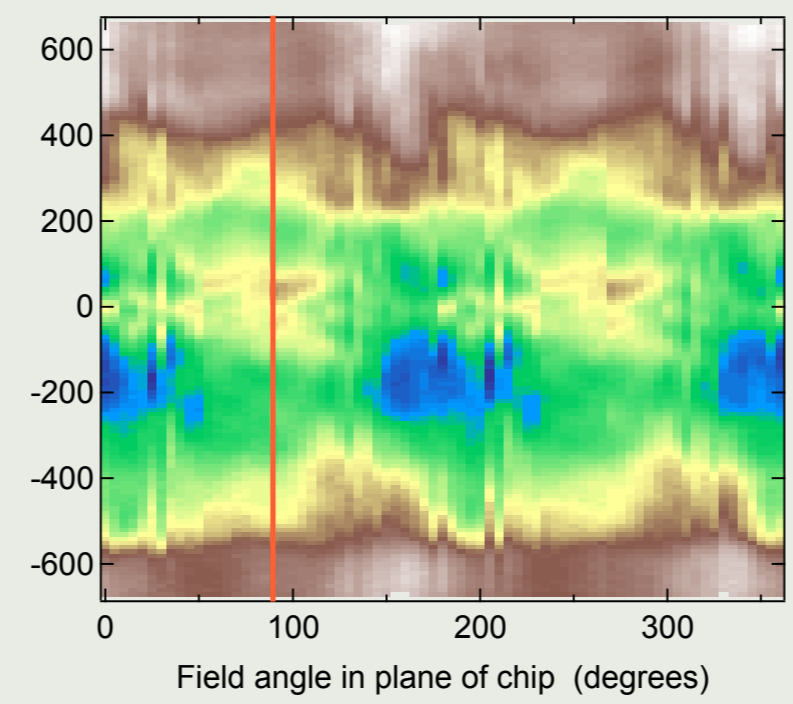
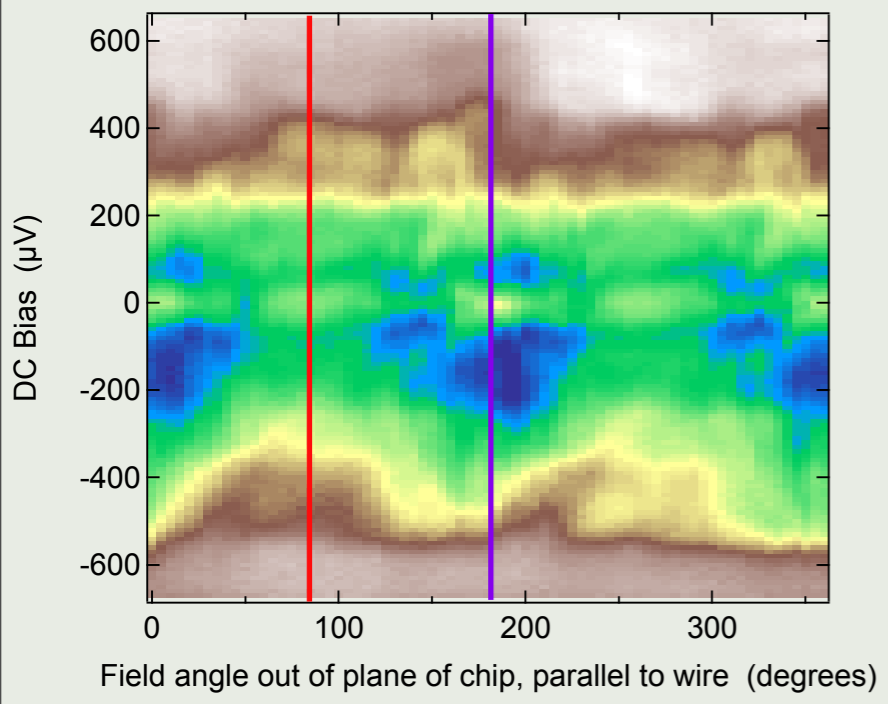
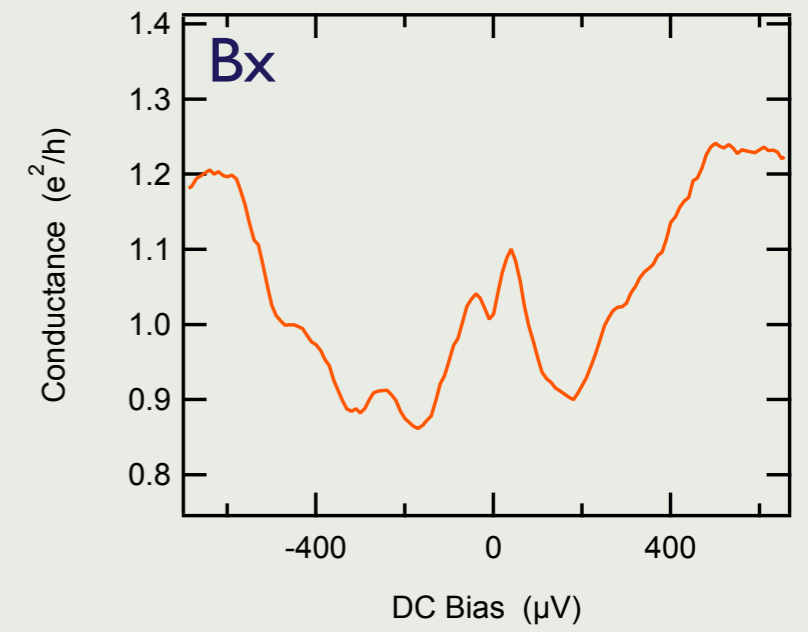
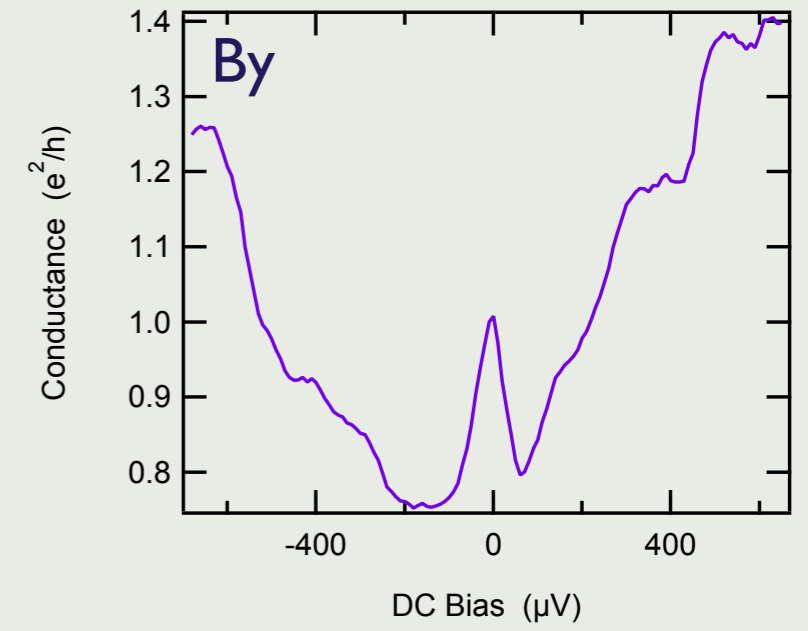
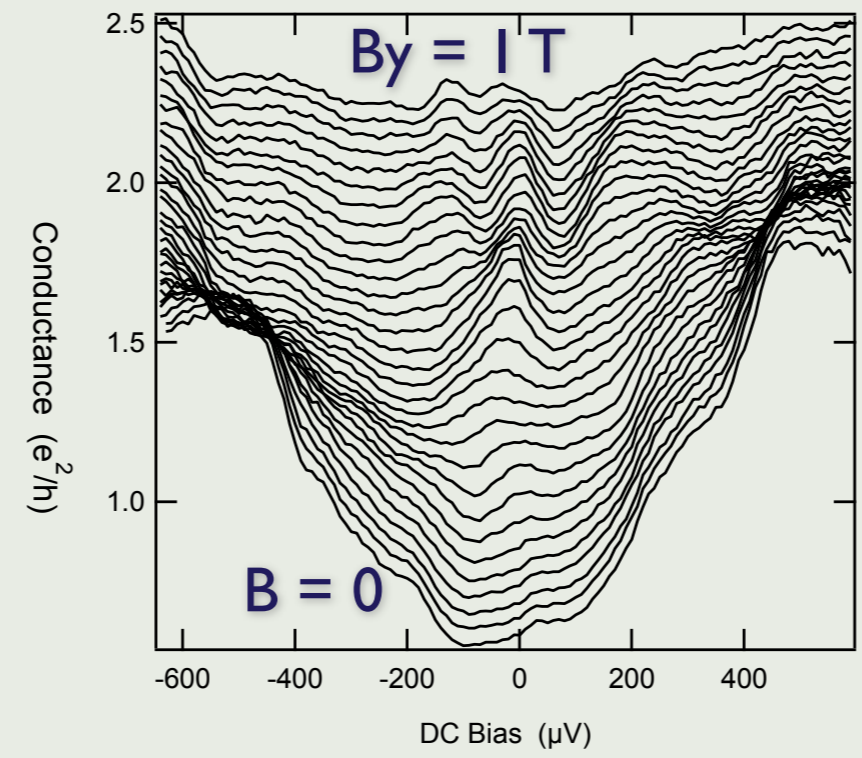
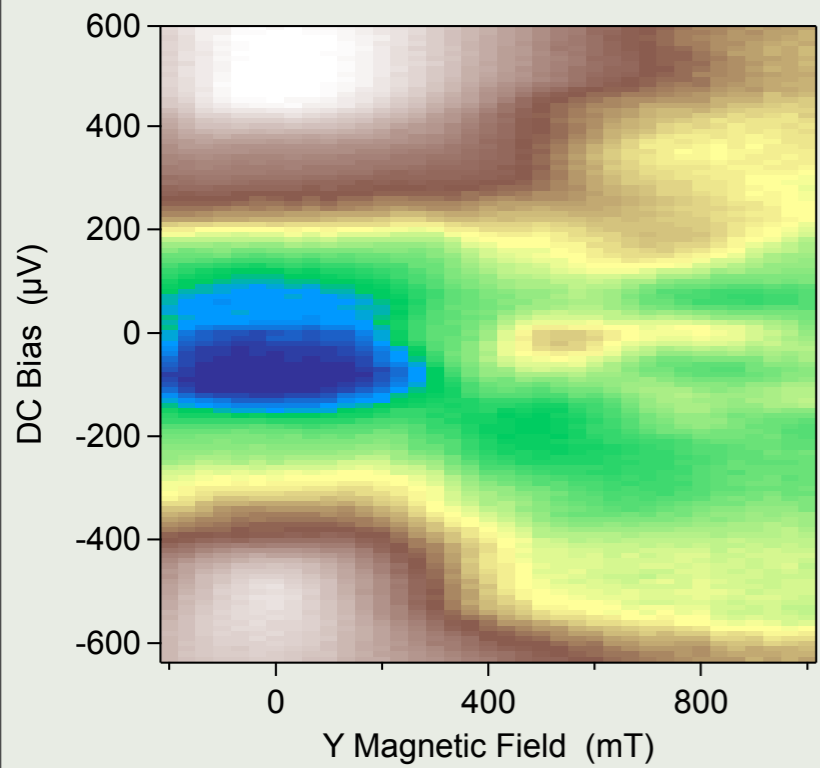




QPC, second device

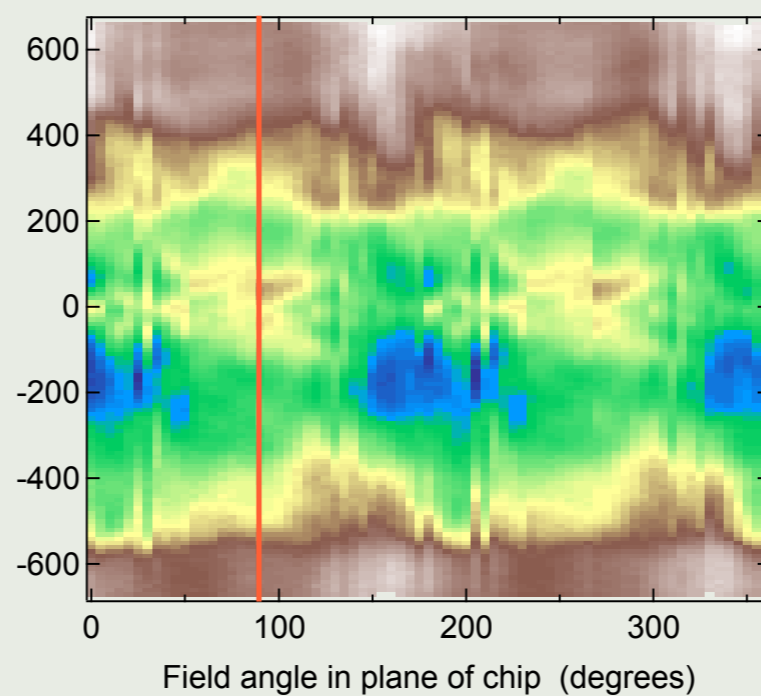
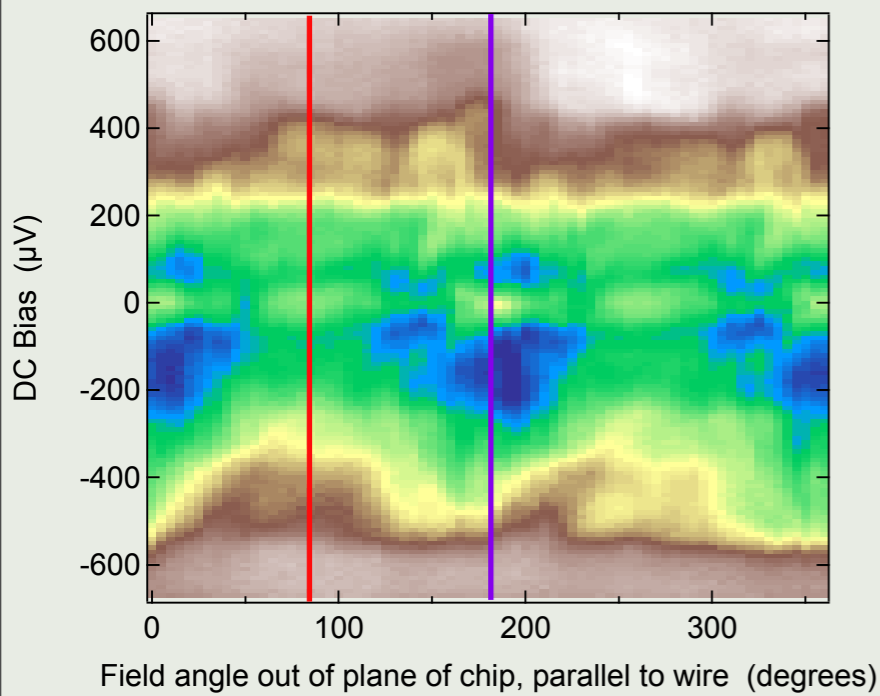
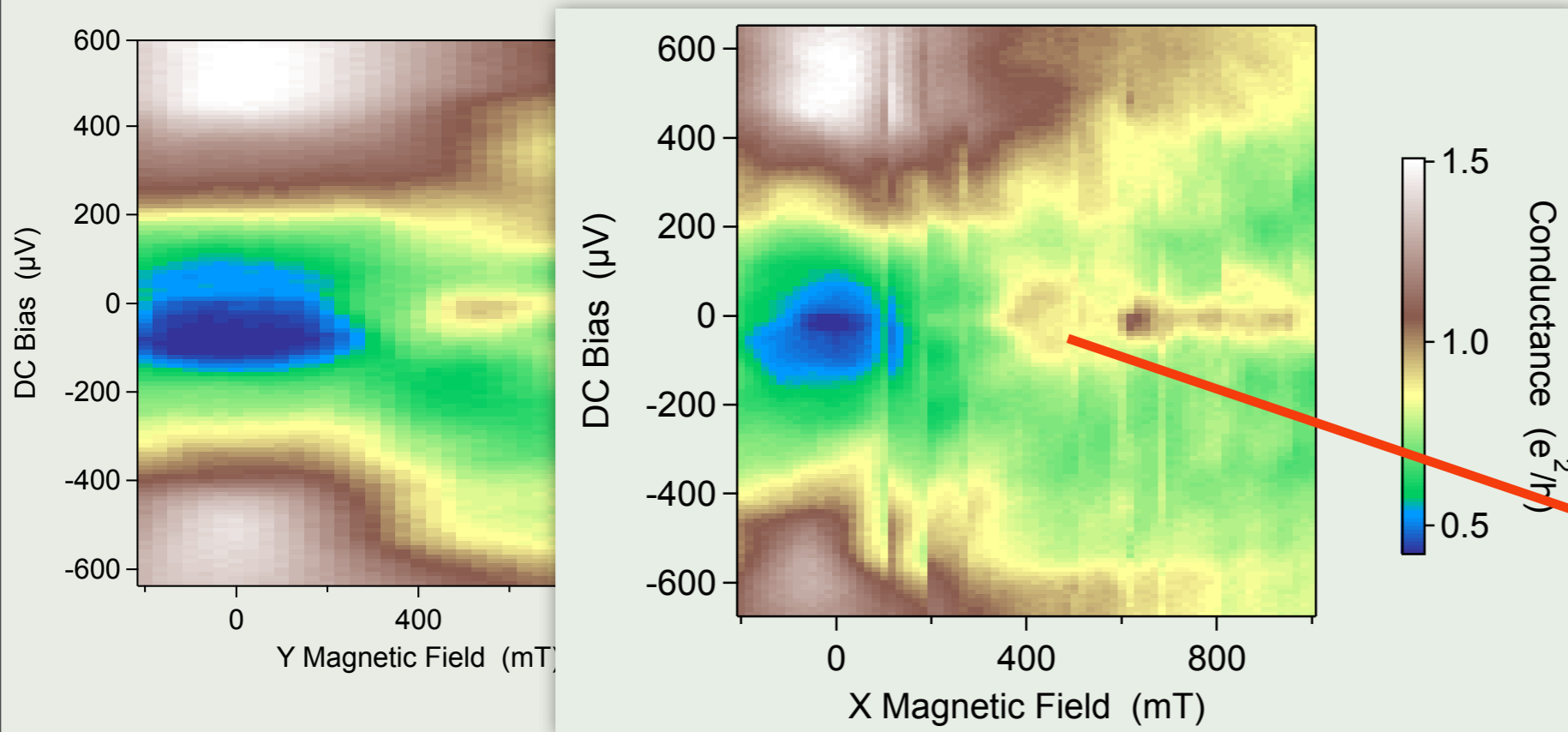


Field-angle dependence

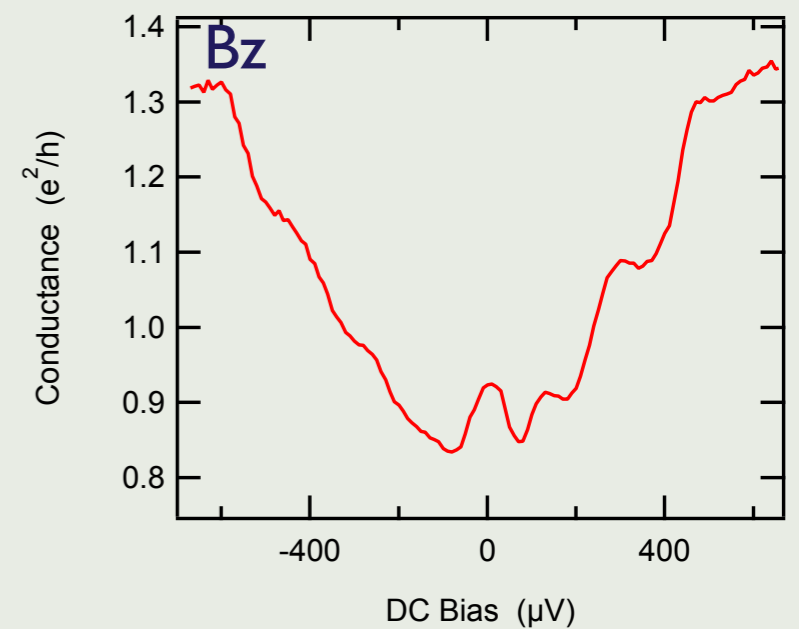
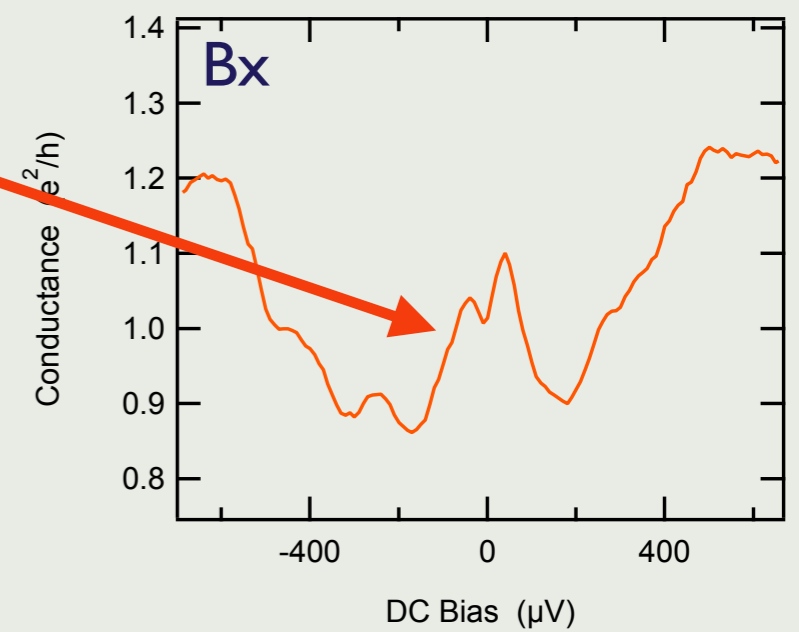
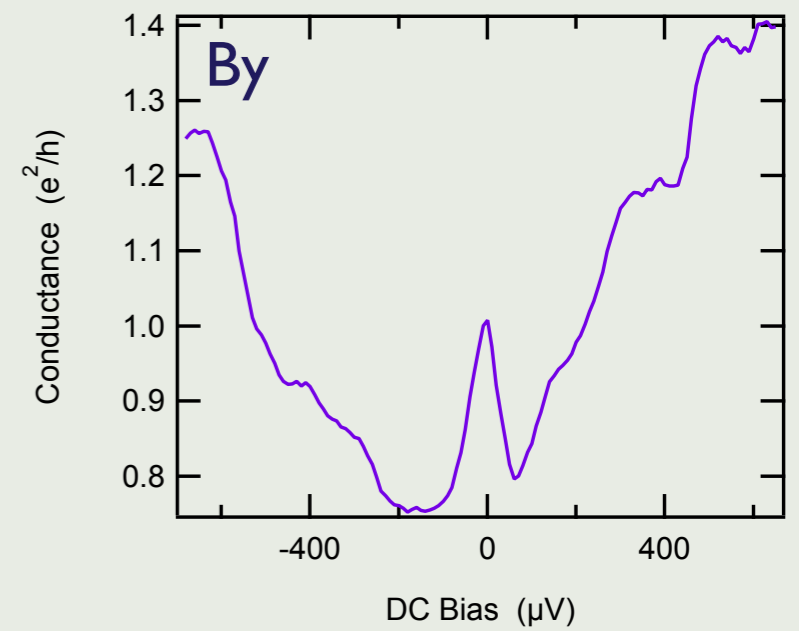


$|B| = 500\text{ mT}$

Field-angle dependence



$|B| = 500 \text{ mT}$



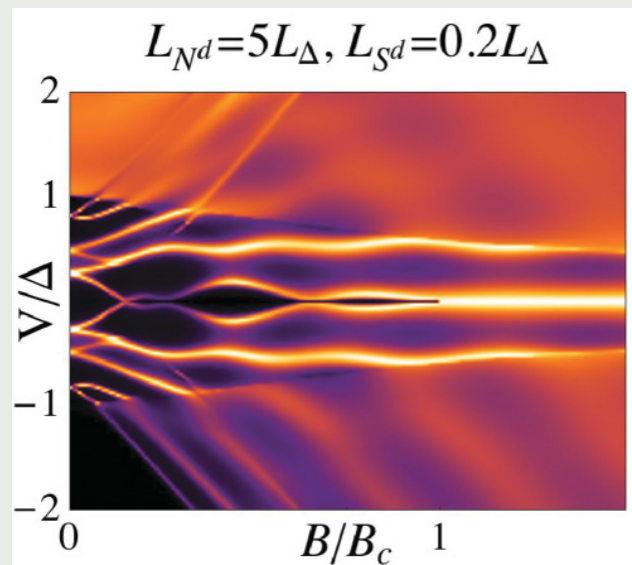
Oscillations

PHYSICAL REVIEW B **86**, 180503(R) (2012)



Transport spectroscopy of NS nanowire junctions with Majorana fermions

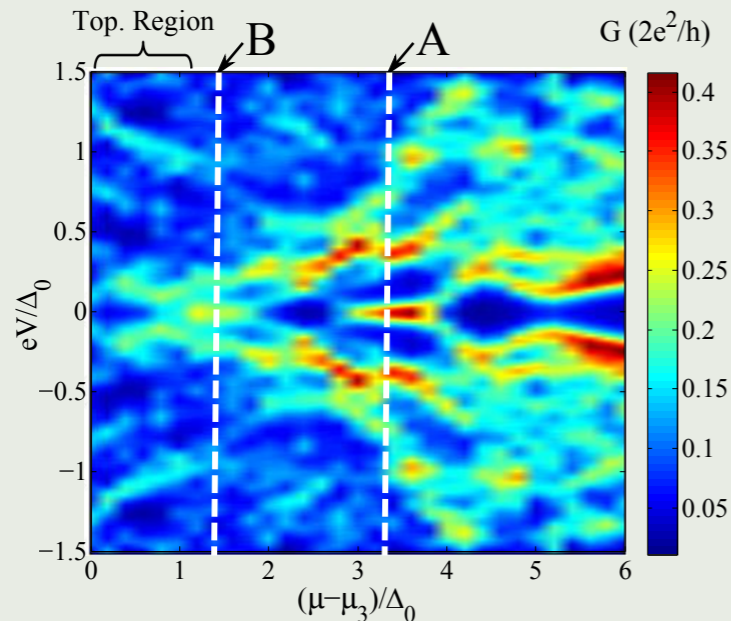
Elsa Prada,¹ Pablo San-Jose,² and Ramón Aguado¹



Zero-bias peaks in spin-orbit coupled superconducting wires with and without Majorana end-states

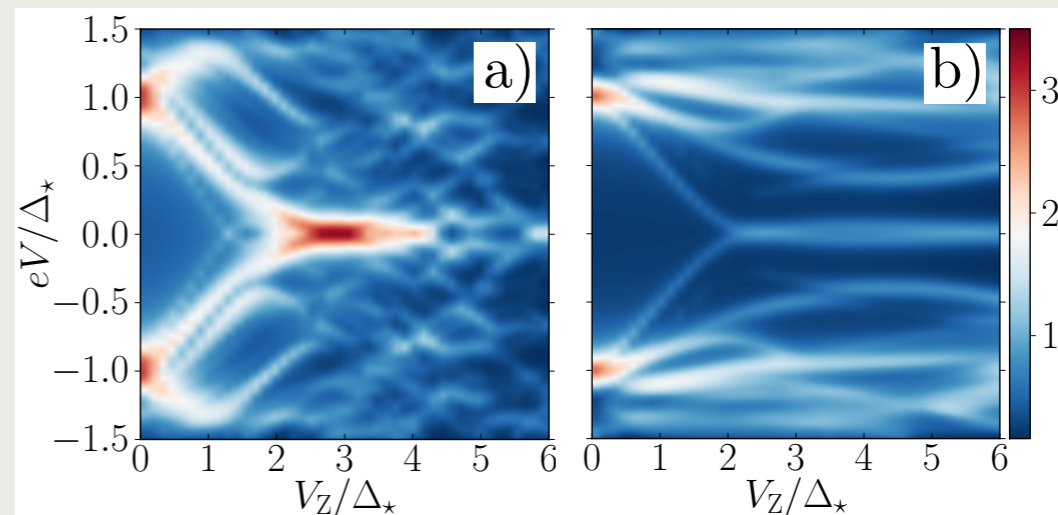
Jie Liu^{1,*}, Andrew C. Potter^{2,*}, K.T. Law¹, and Patrick A. Lee²

¹Department of Physics, Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong, China and
²Massachusetts Institute of Technology 77 Massachusetts Ave. Cambridge, MA 02139



Realistic transport modeling for a superconducting nanowire with Majorana fermions

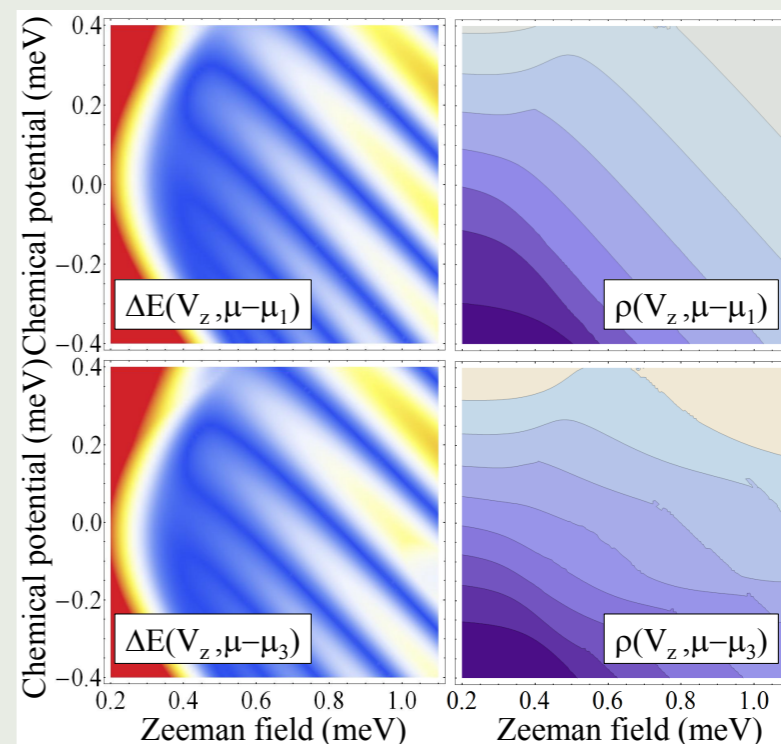
Diego Rainis, Luka Trifunovic, Jelena Klinovaja, and Daniel Loss
 Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland
 (Dated: July 26, 2012)



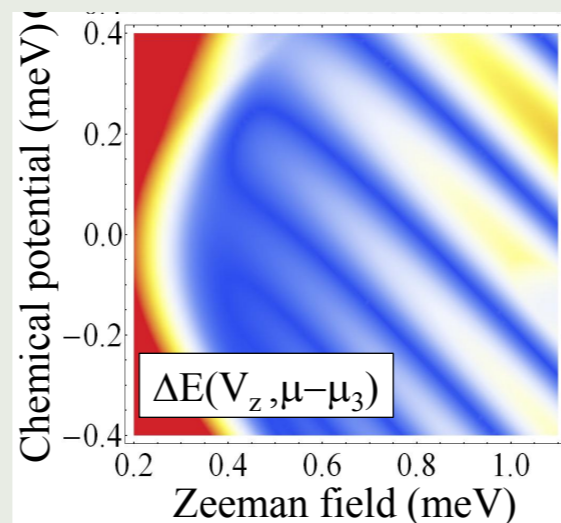
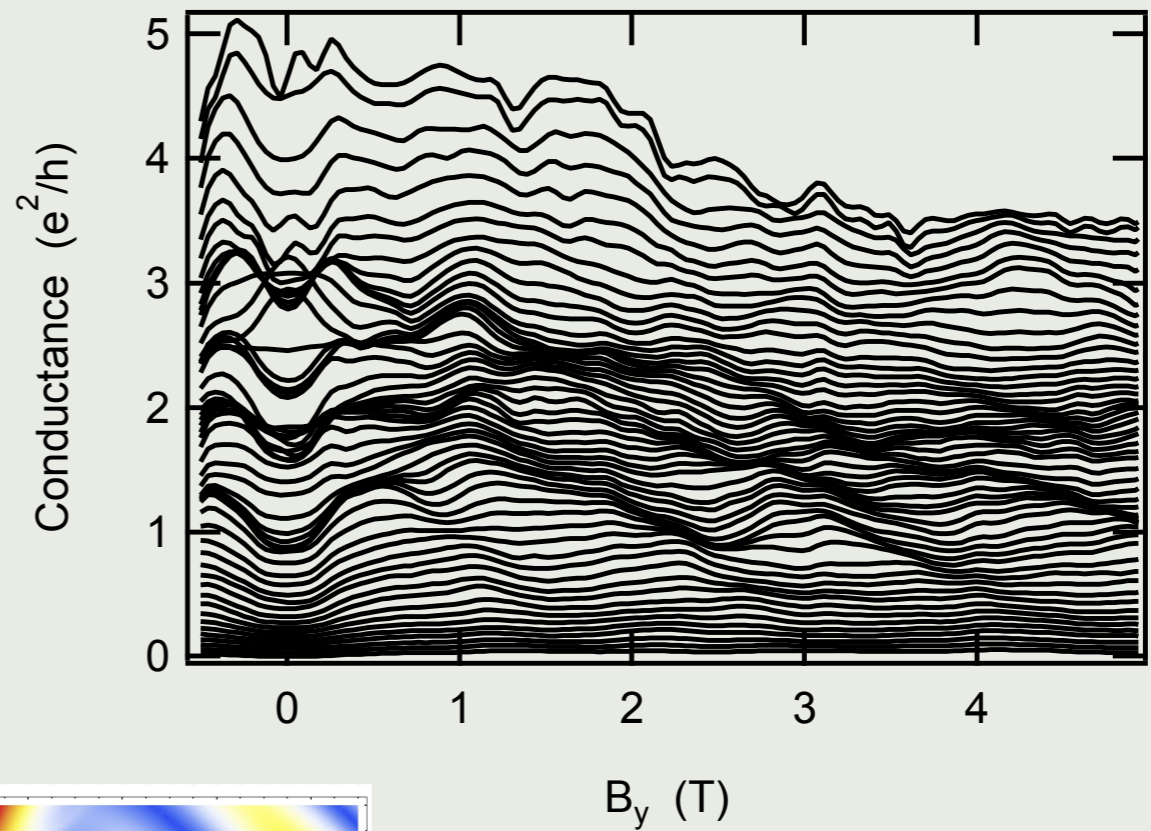
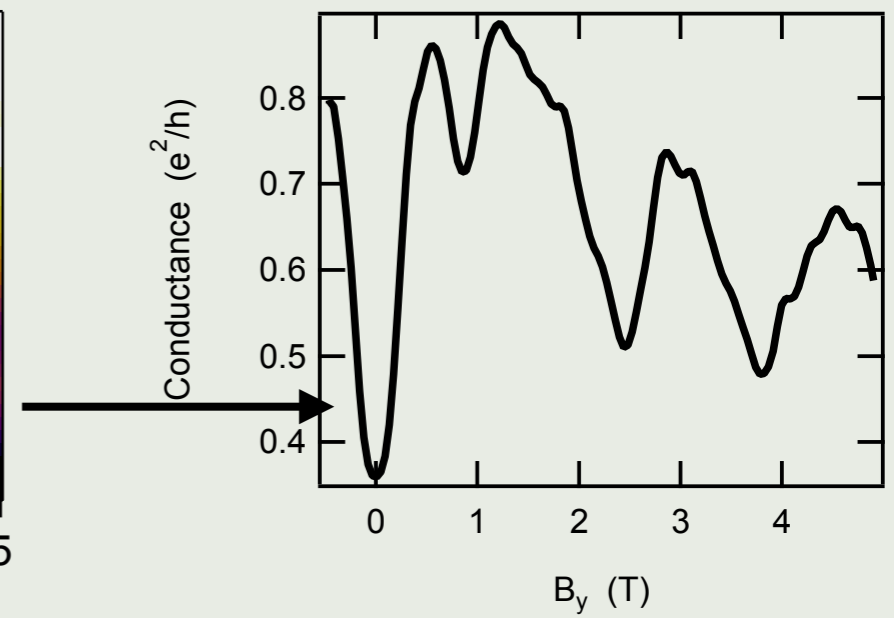
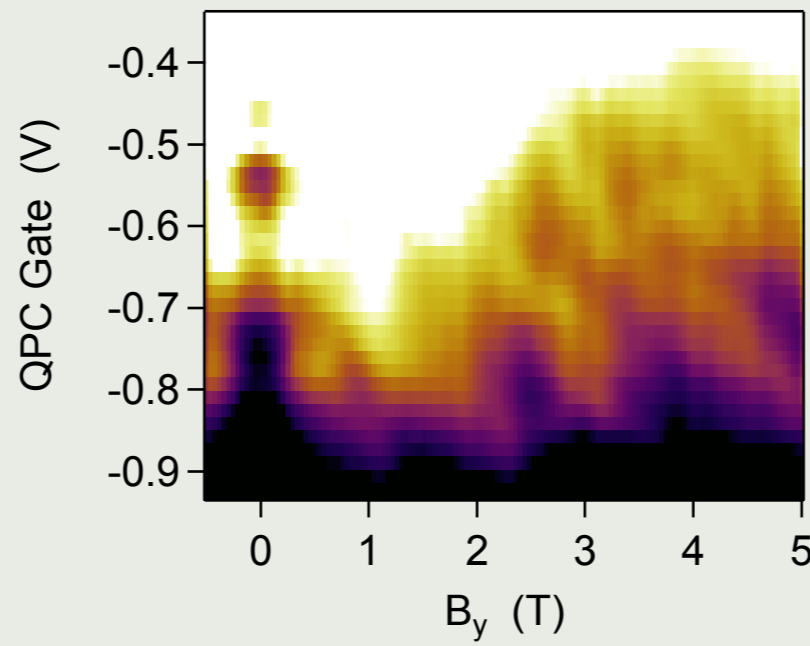
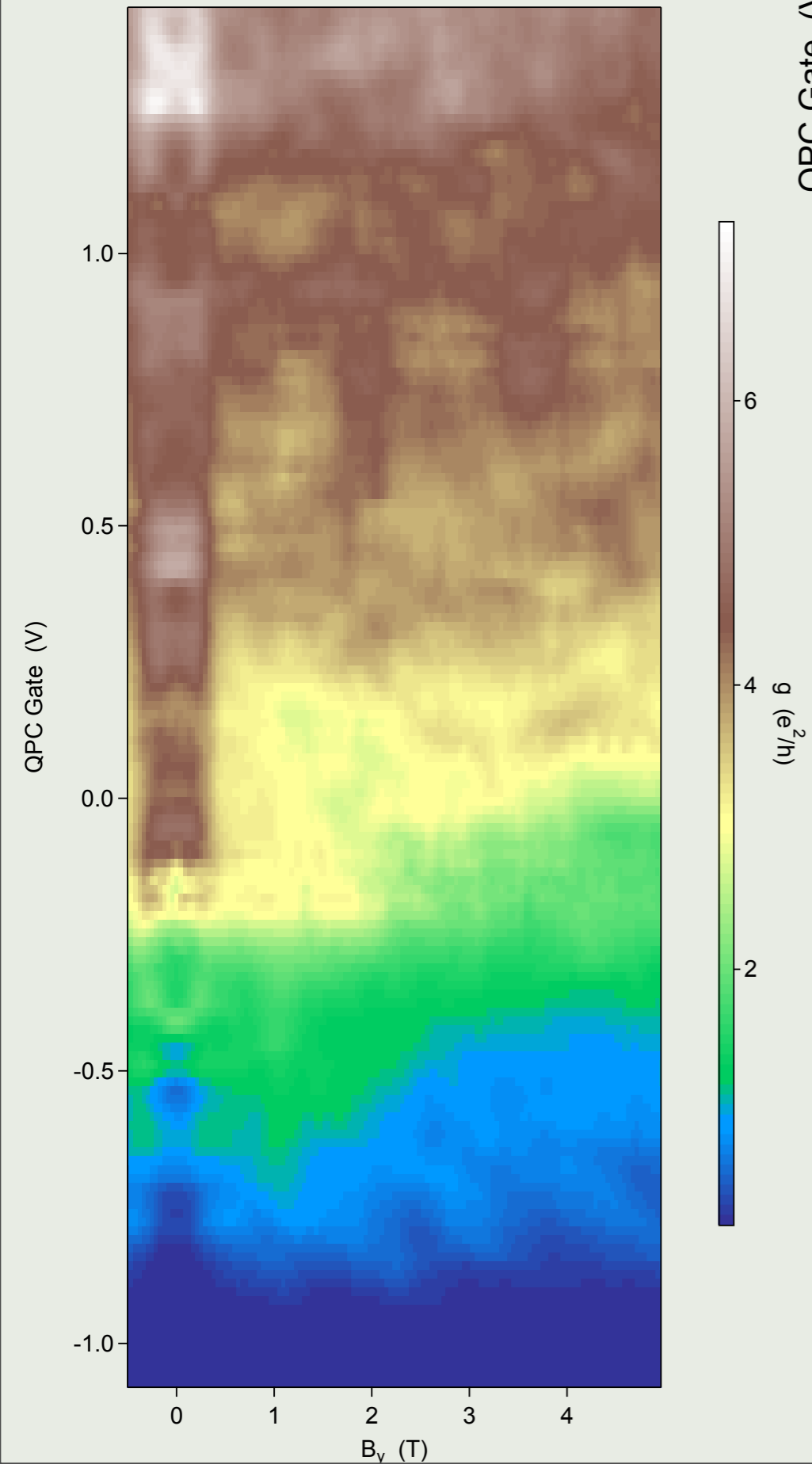
A Majorana smoking gun for the superconductor-semiconductor hybrid topological system

S. Das Sarma¹, Jay D. Sau², and Tudor D. Stanescu³

¹Condensed Matter Theory Center, Department of Physics, University of Maryland, College Park, Maryland 20742-4111, USA
²Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA
³Department of Physics, West Virginia University, Morgantown, WV 26506, USA



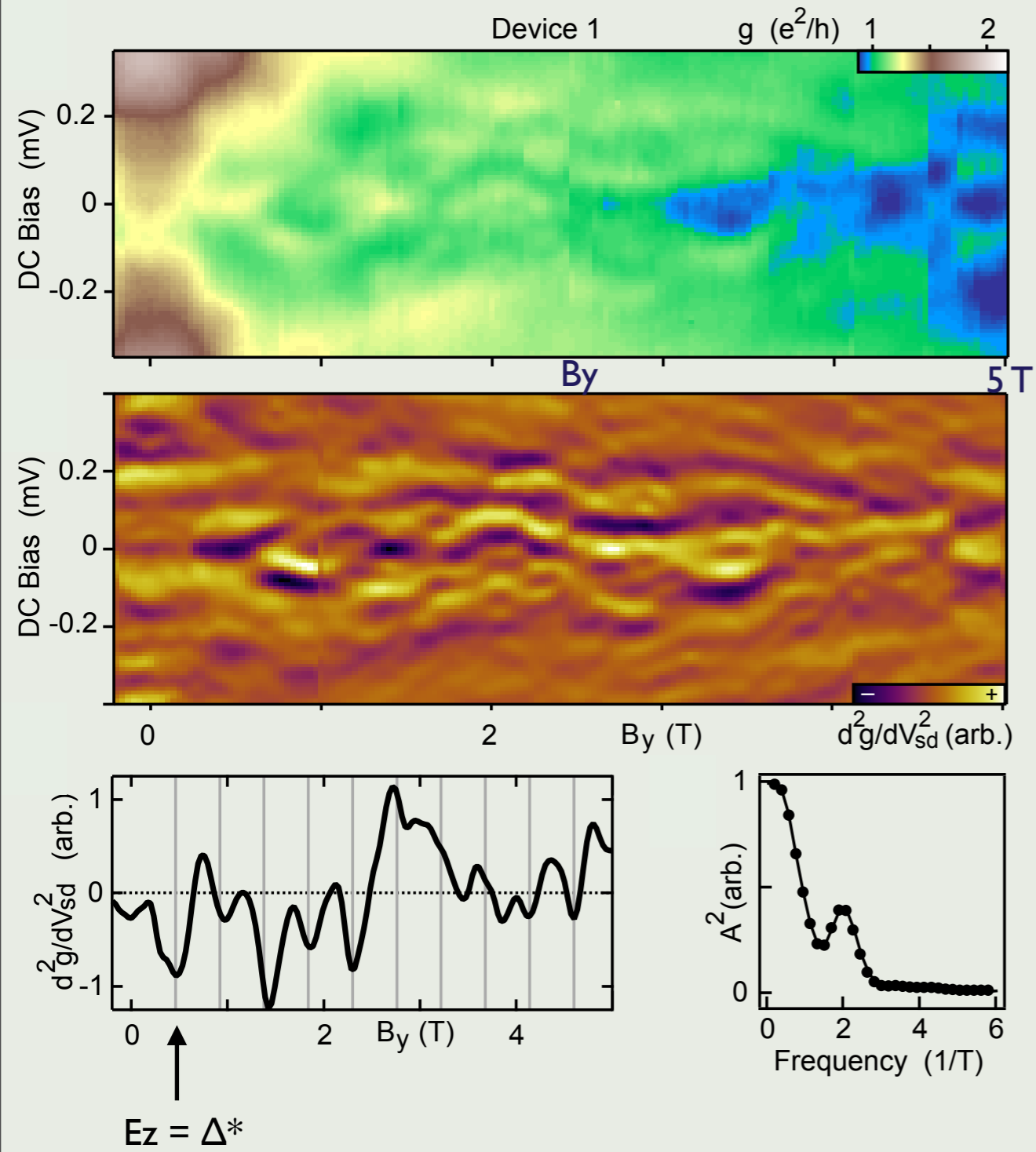
Oscillations



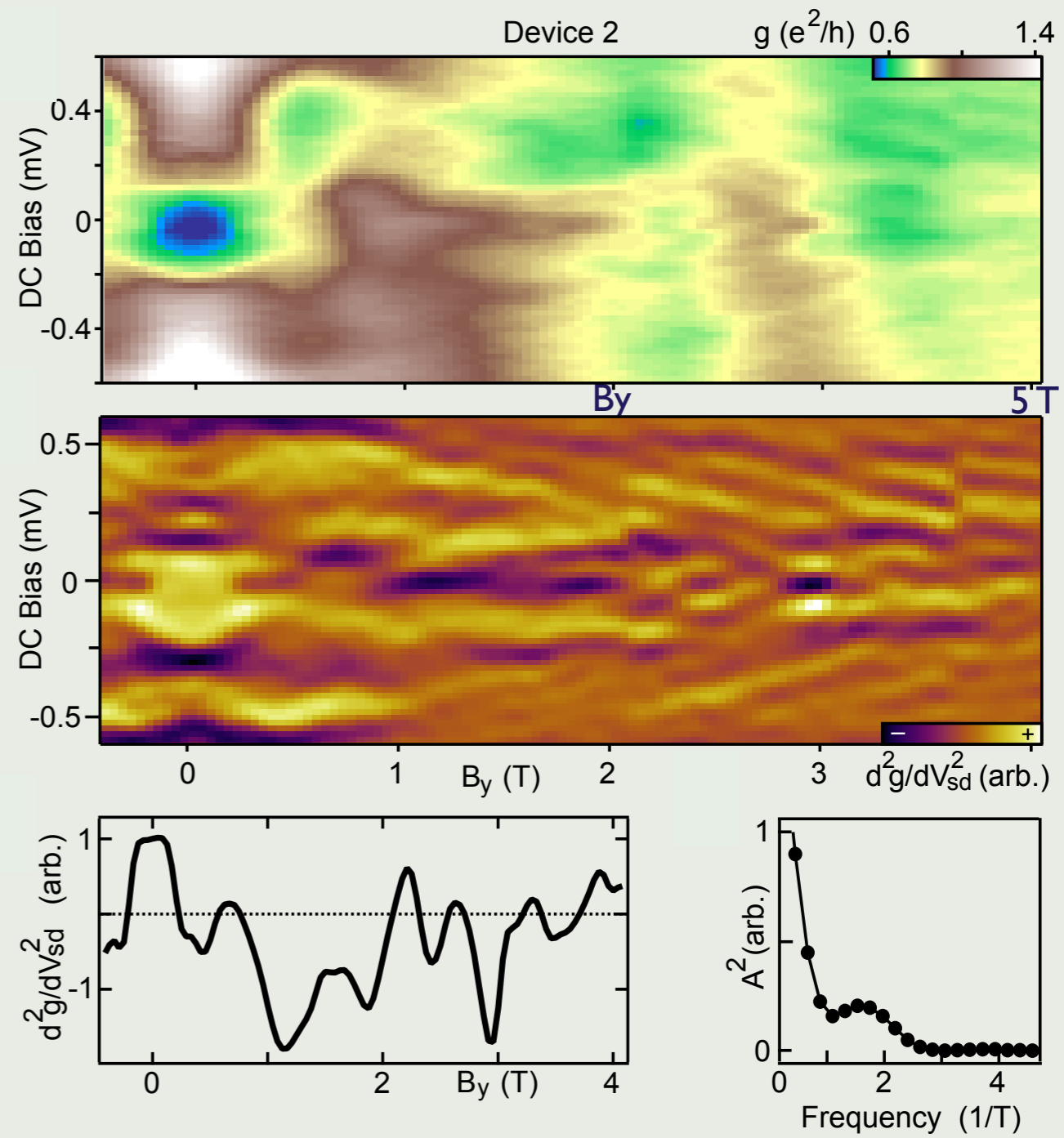
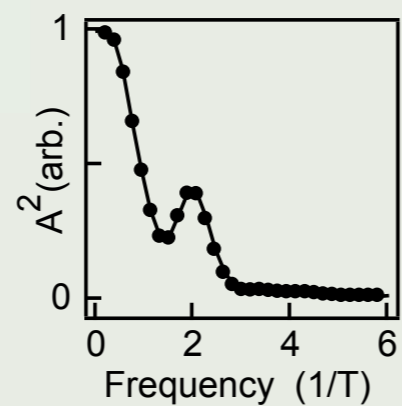
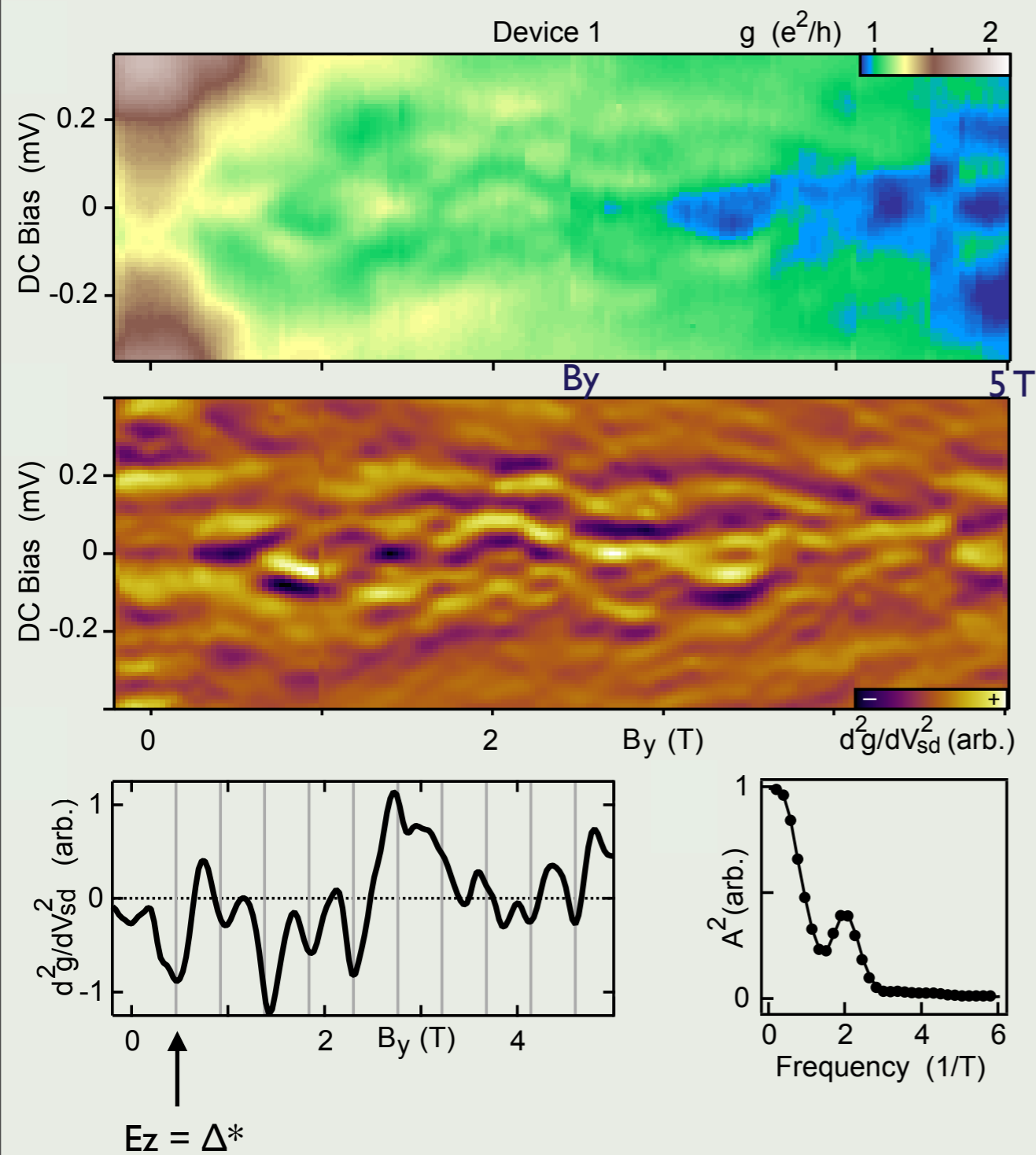
Das Sarma *et al.*
arXiv:1211.0539

constant chemical potential
or constant density?

Oscillations, cont.



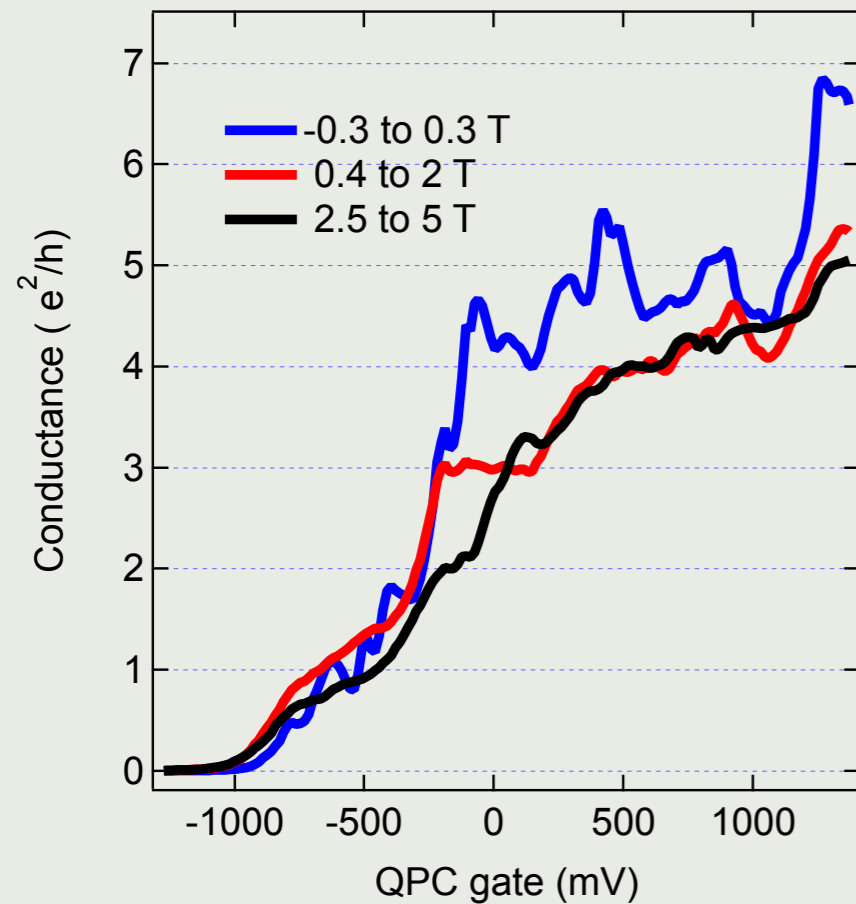
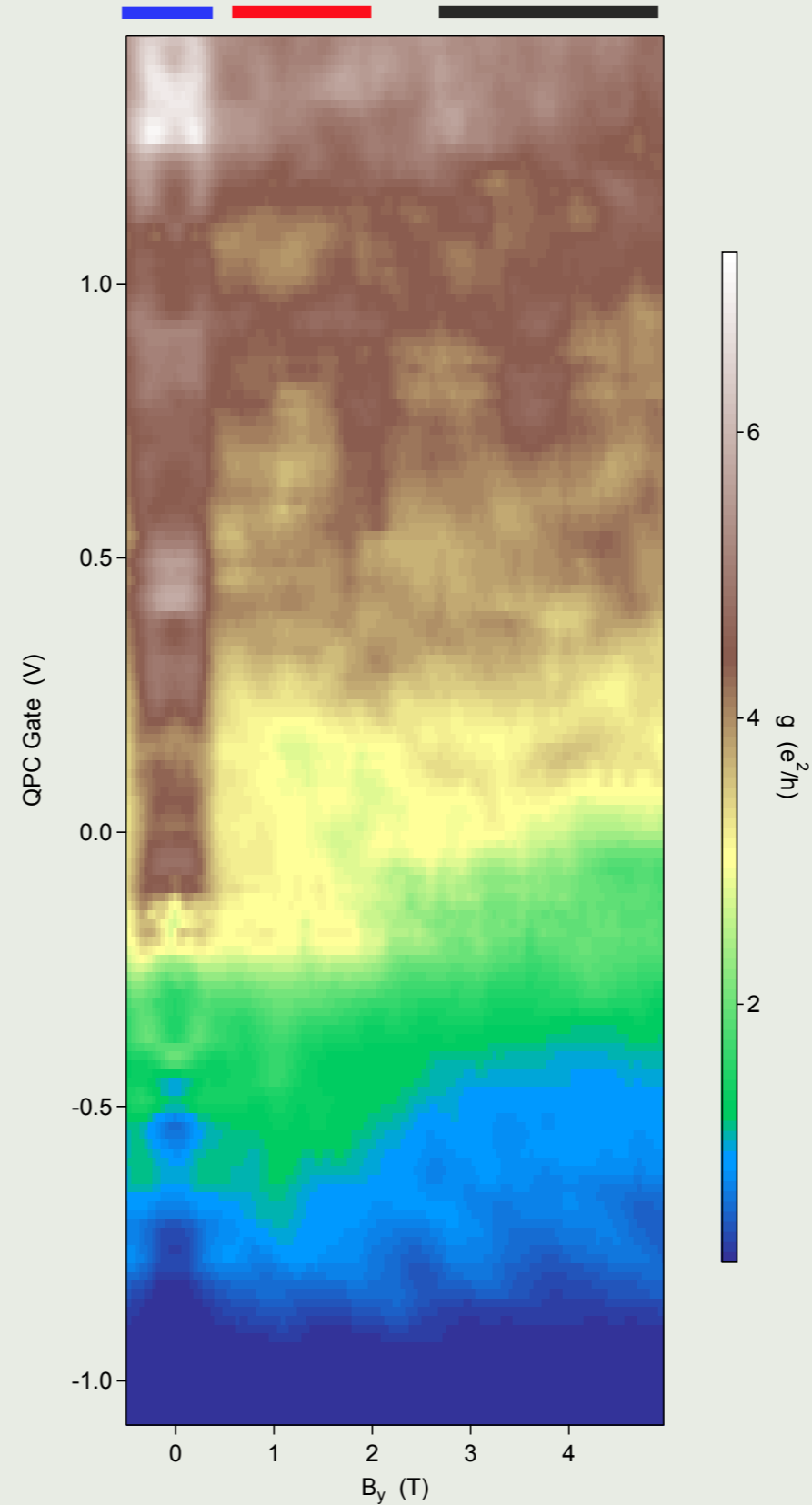
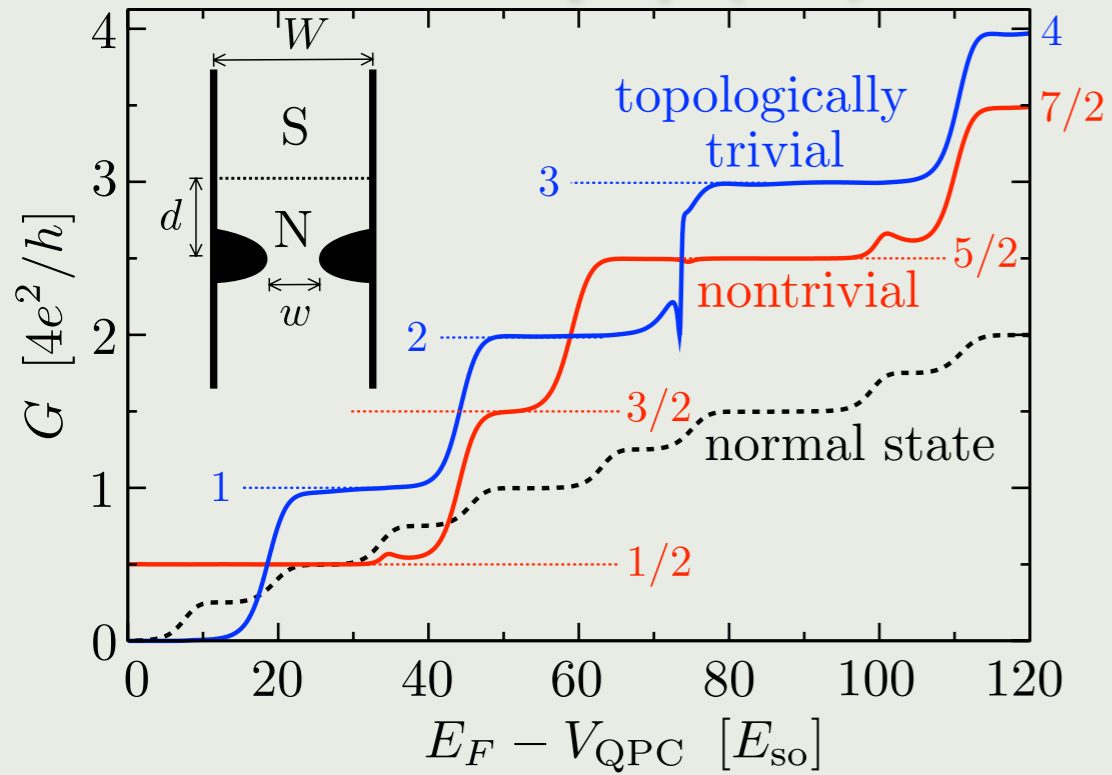
Oscillations, cont.



These oscillations are too fast given expected $kF * L$,
and the period does not change significantly with B

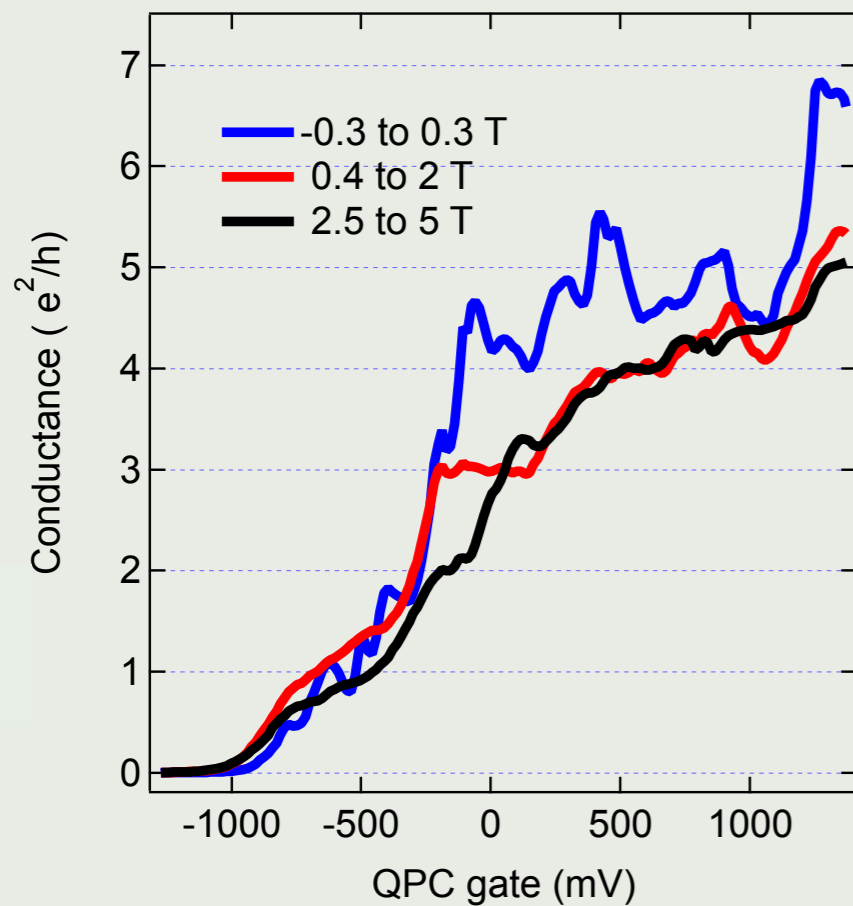
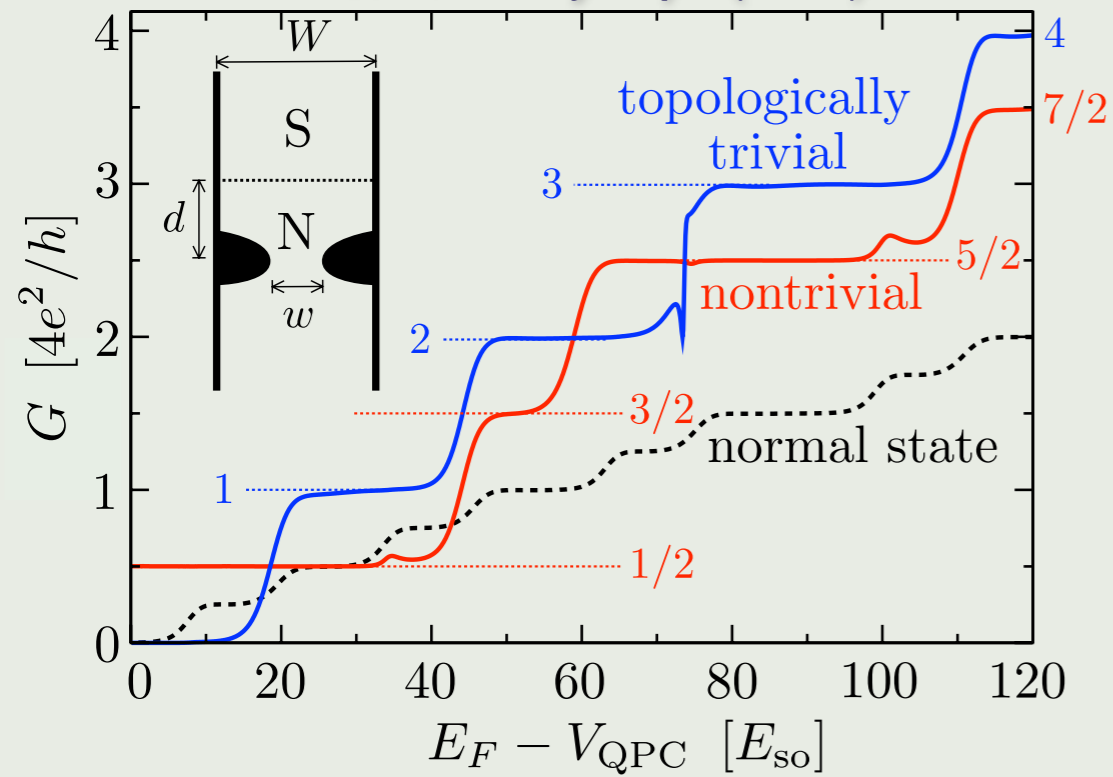
QPC, field dependence of plateaus

Wimmer et al. New J. Phys. (2011)

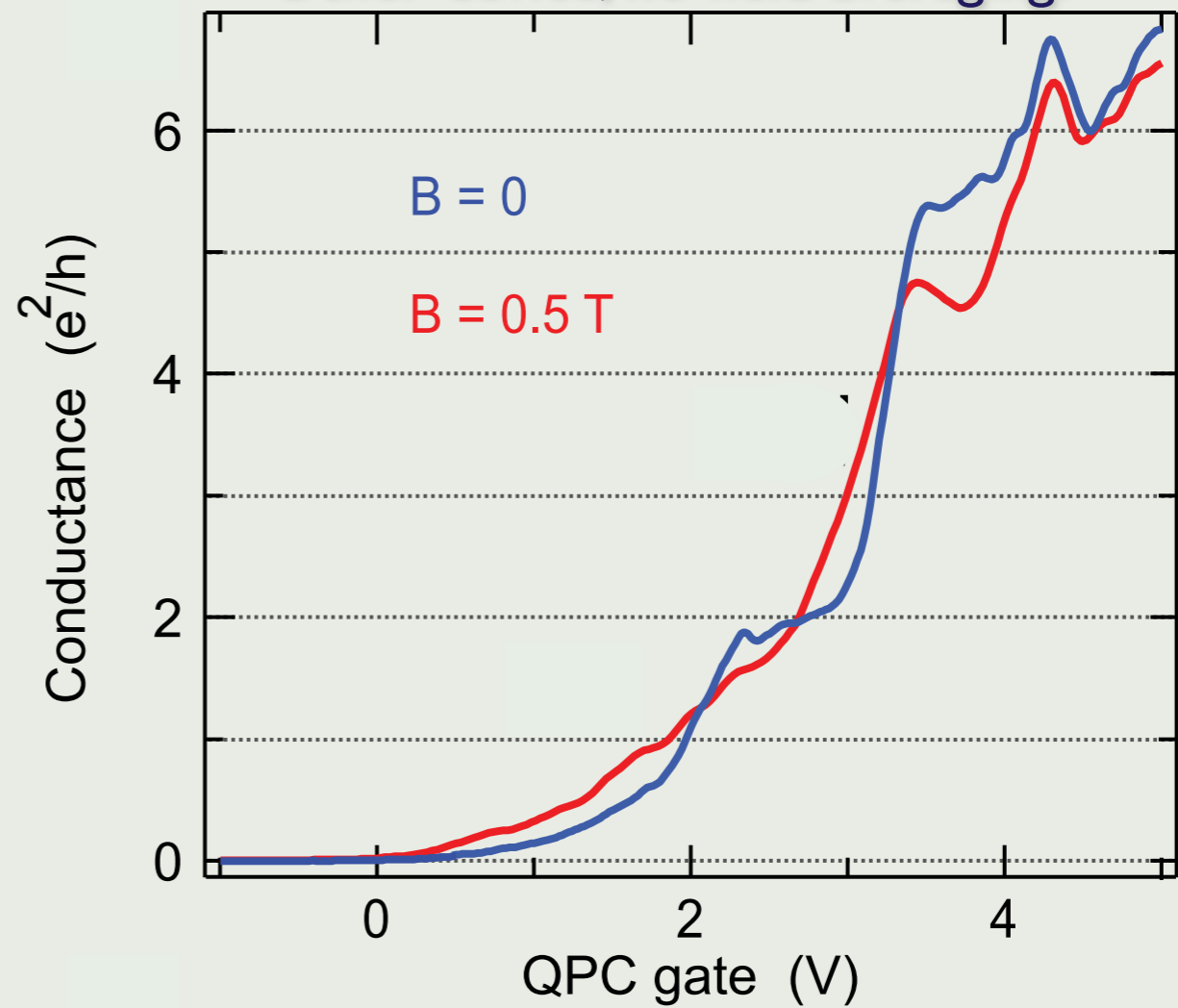


QPC, field dependence of plateaus

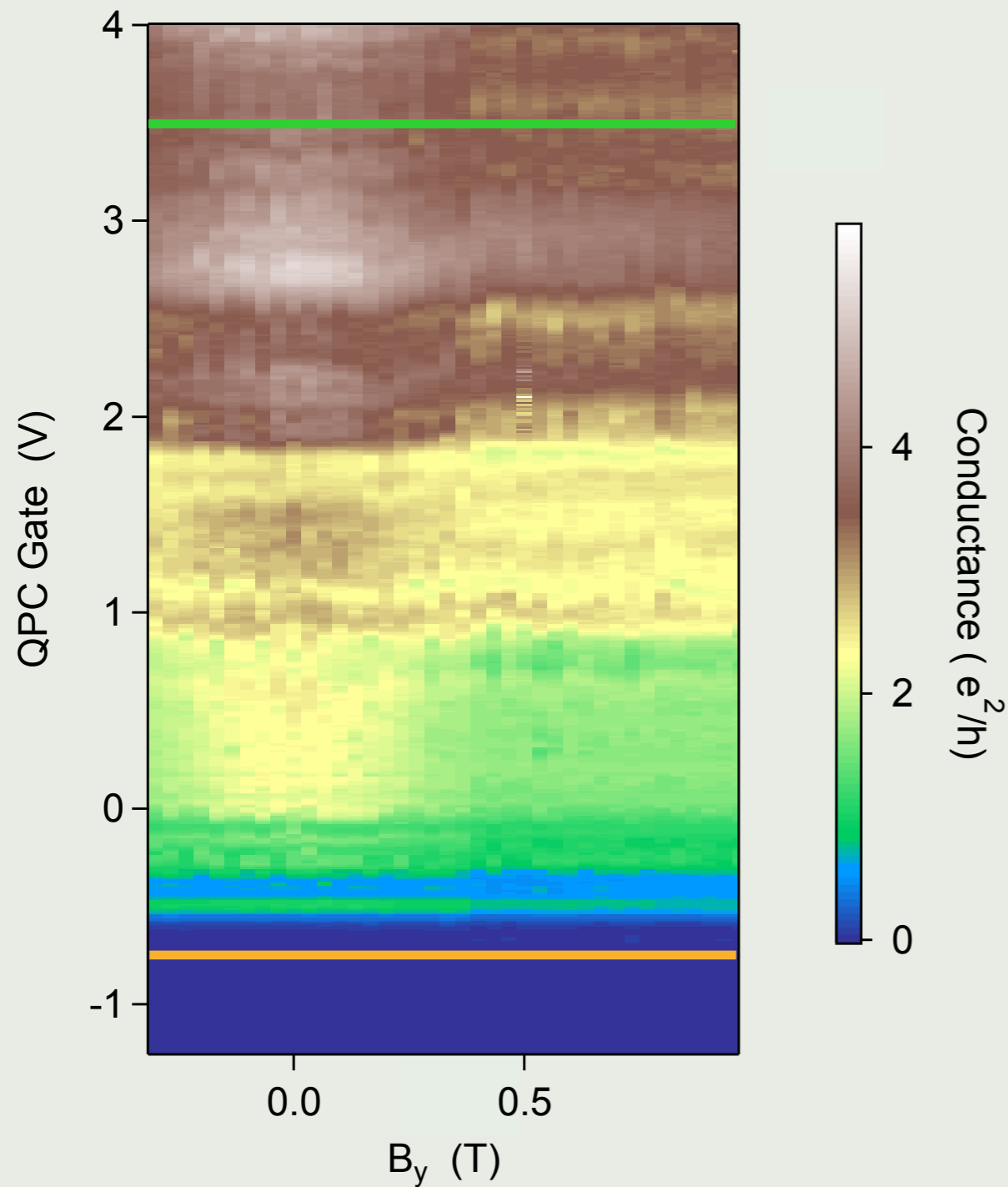
Wimmer et al. New J. Phys. (2011)



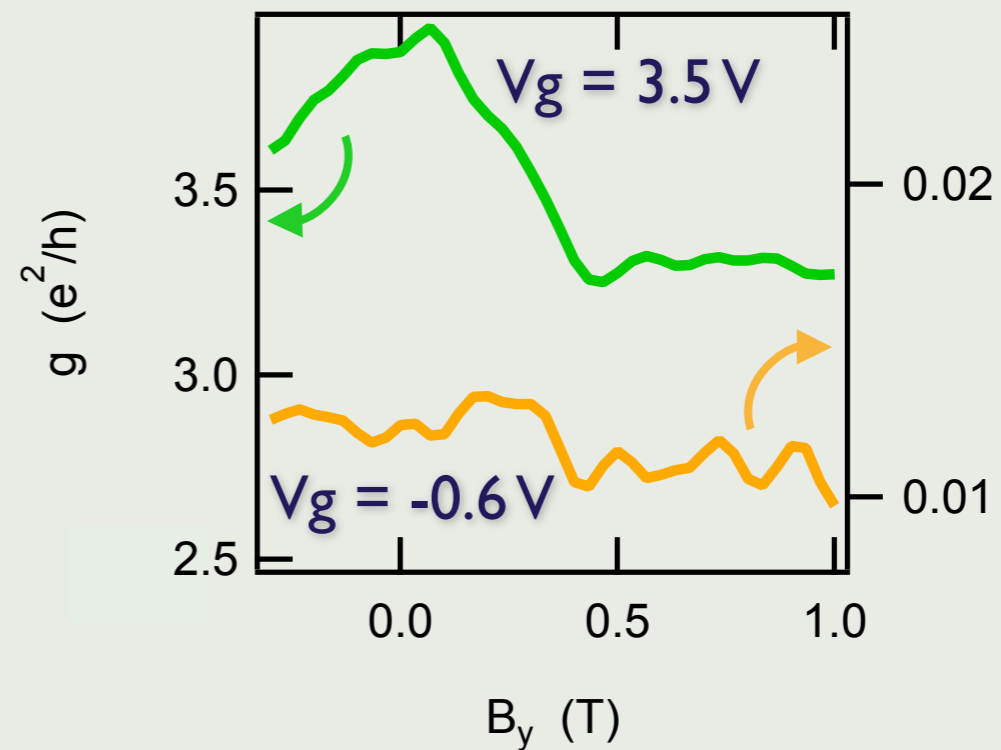
Other device, no field averaging:



QPC field dependence at 4 K



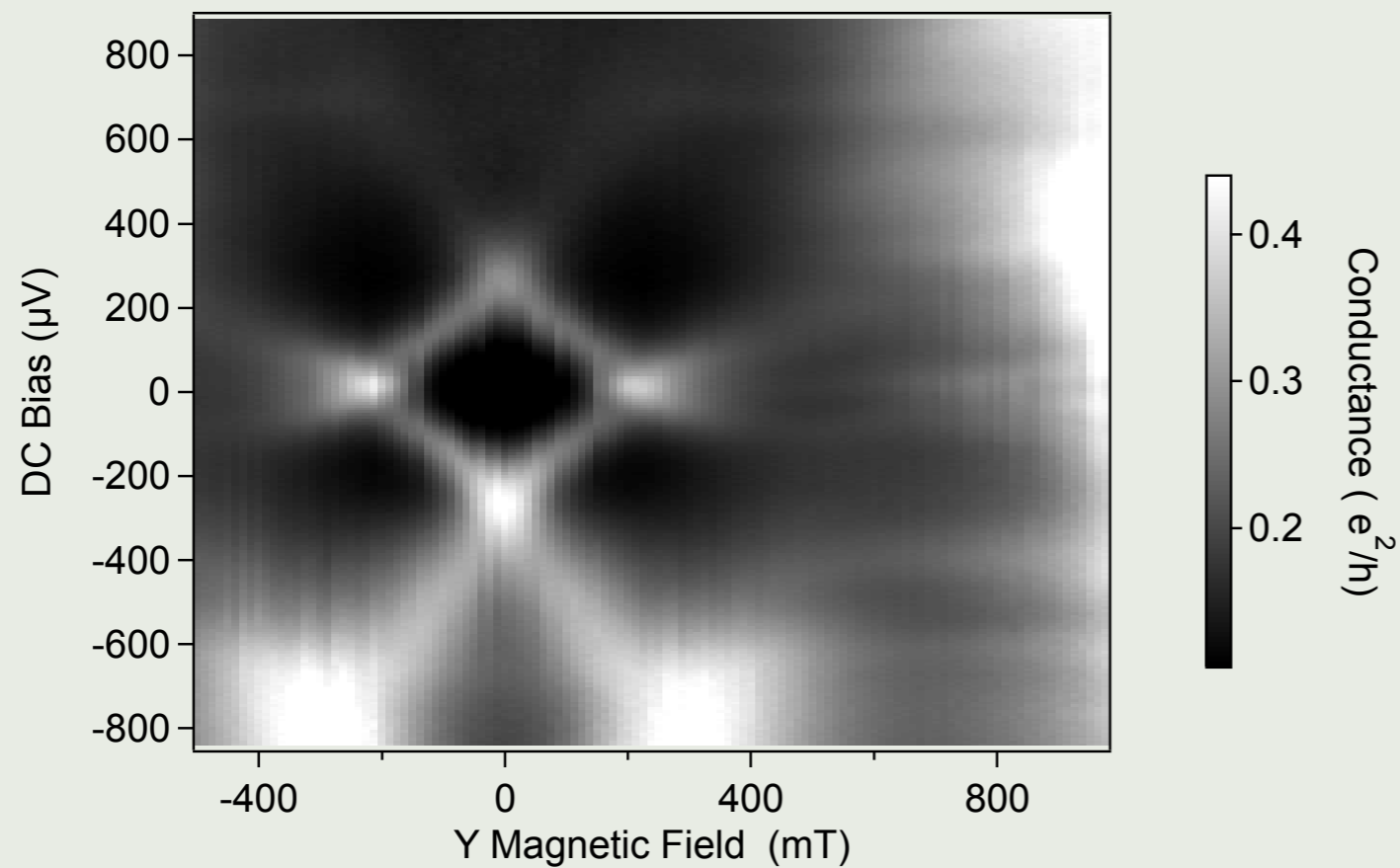
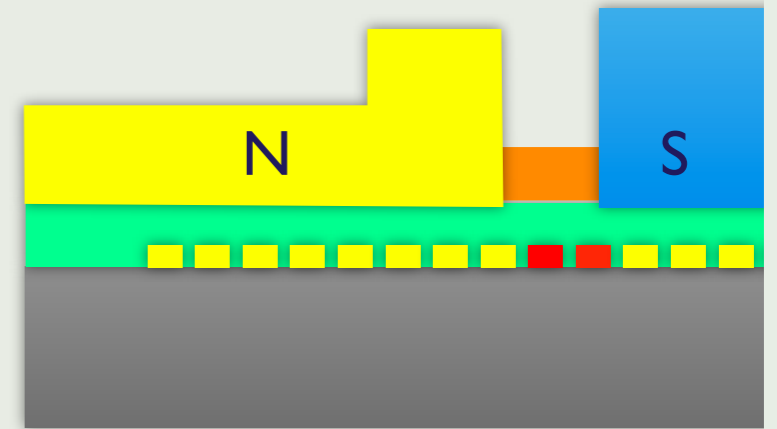
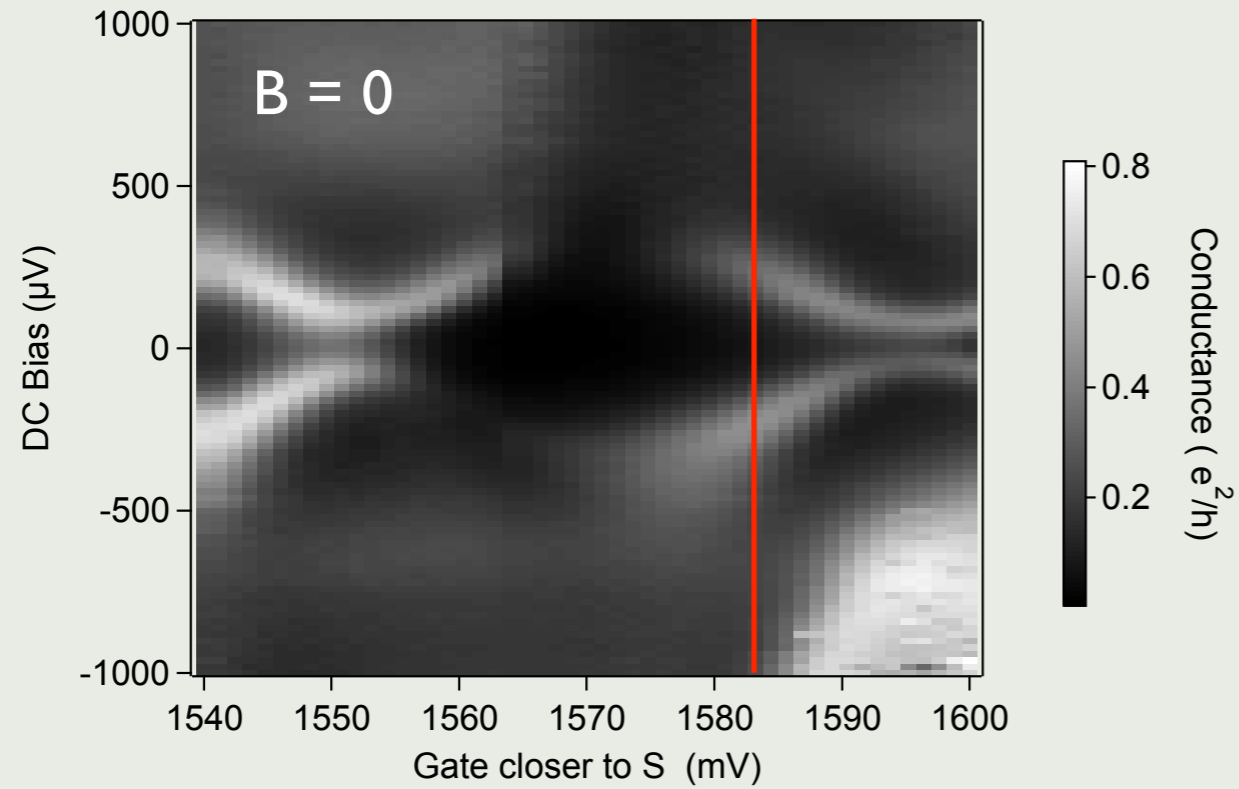
Conductance increase near pinch-off is gone by 4 K, Andreev enhancement at higher conductance is still present



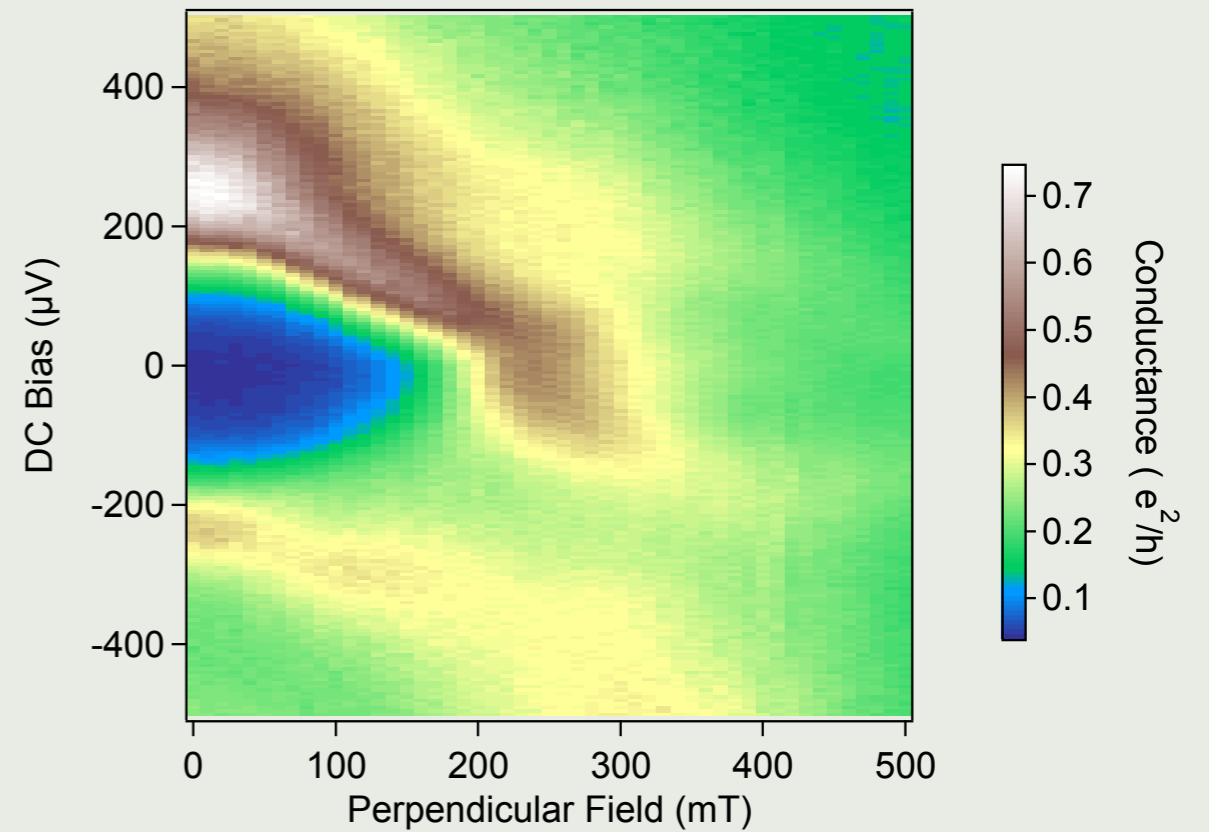
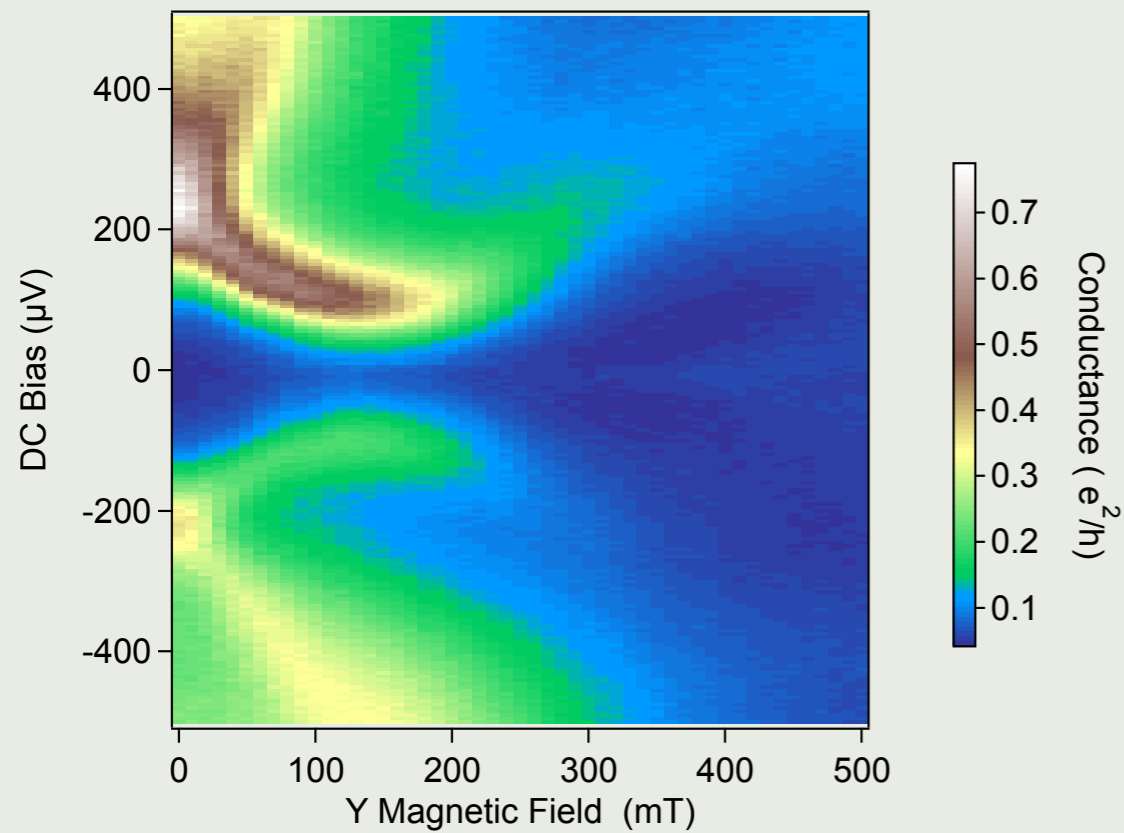
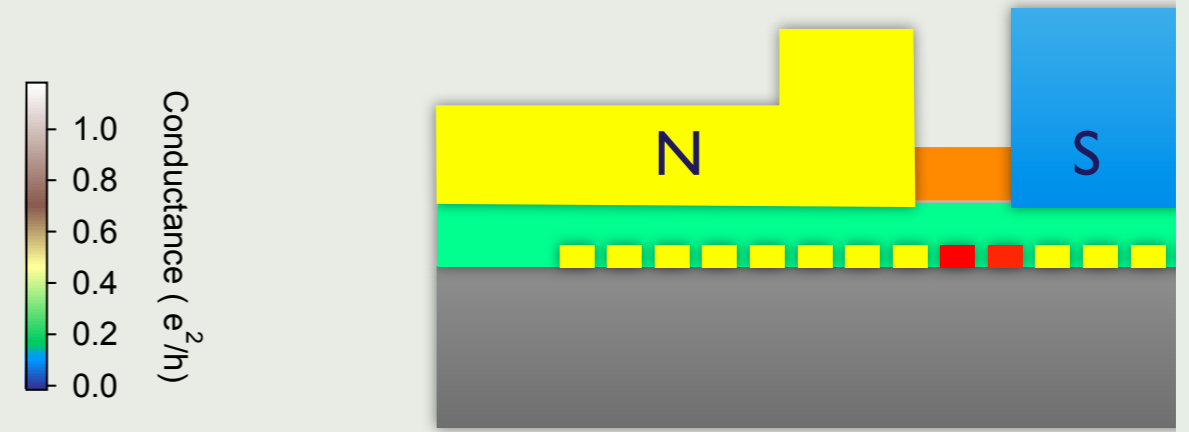
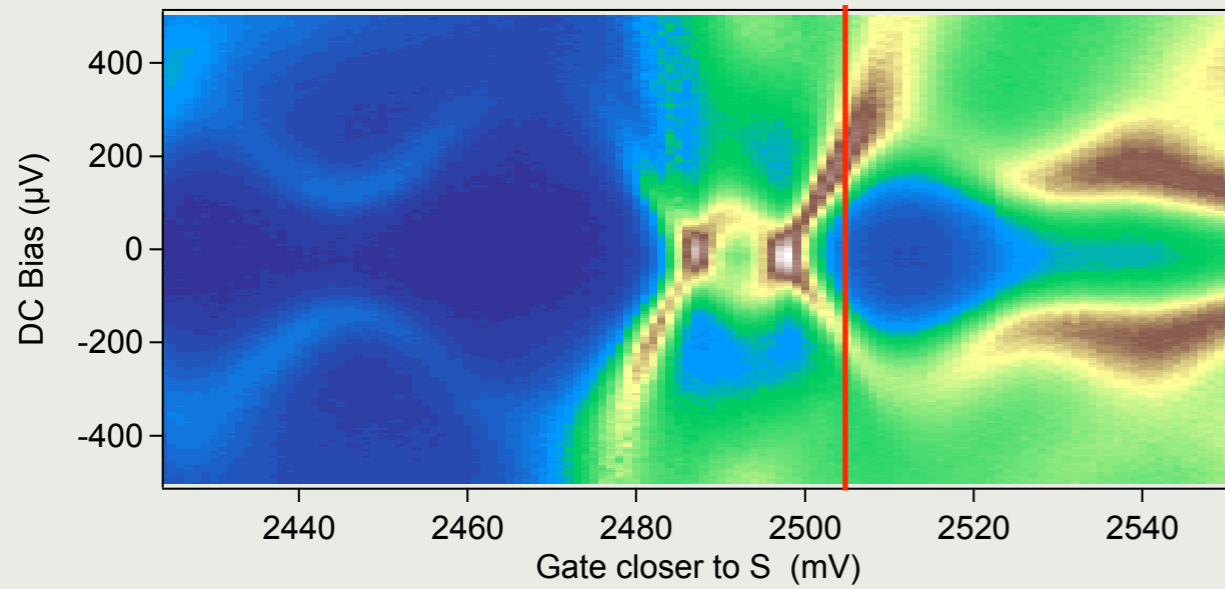
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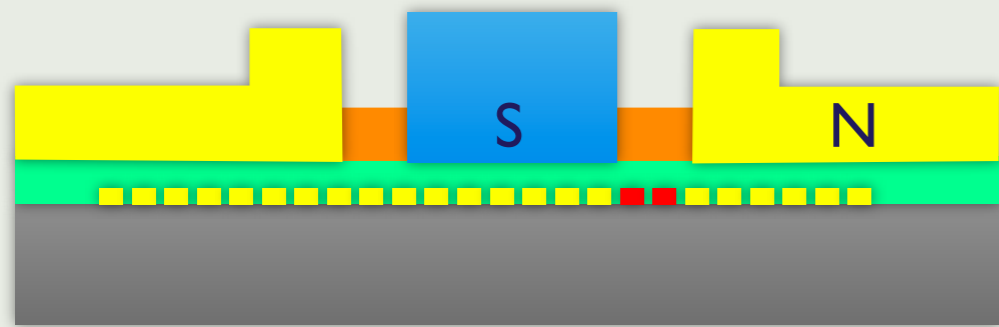
ABS, Zeeman splitting



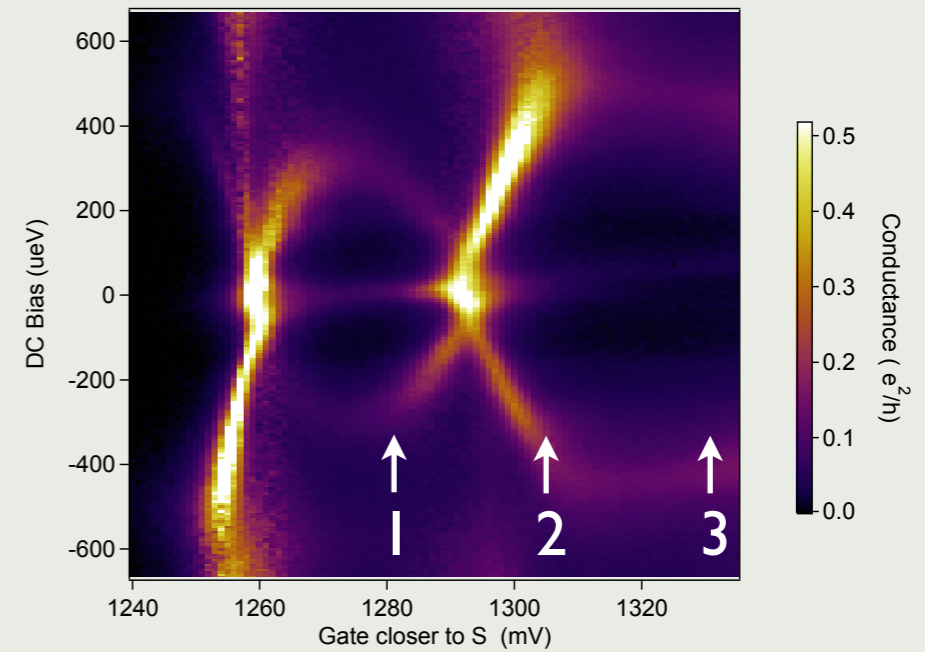
ABS, Zeeman splitting



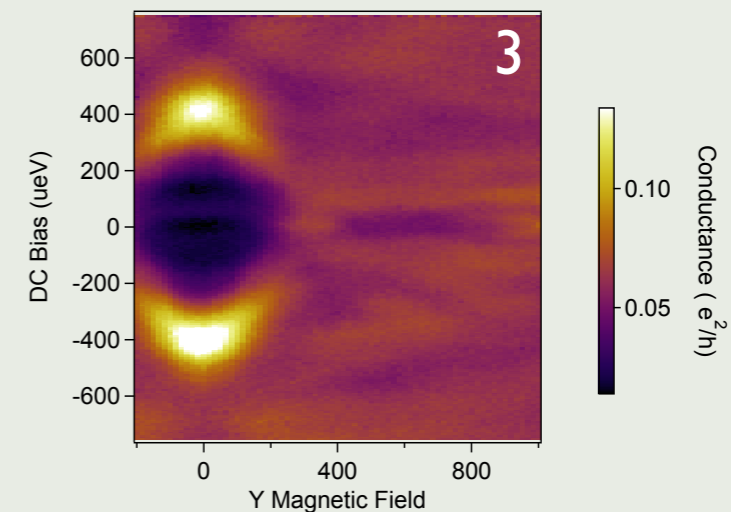
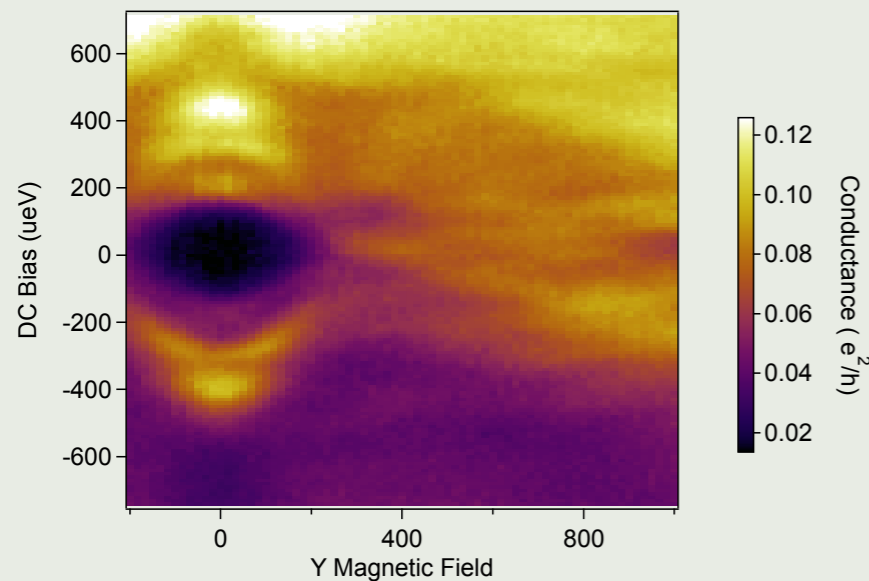
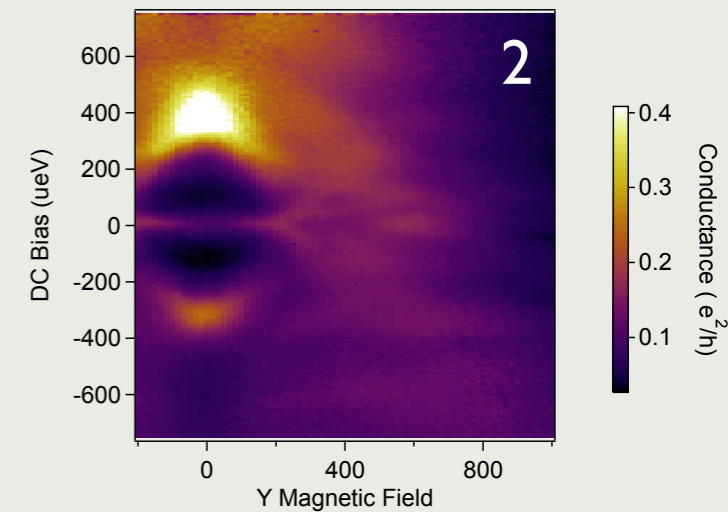
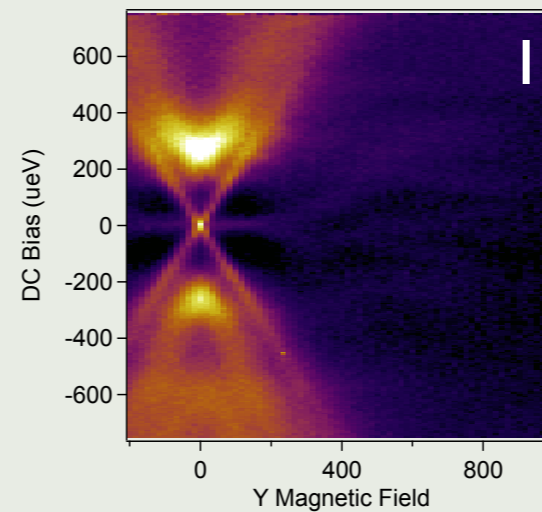
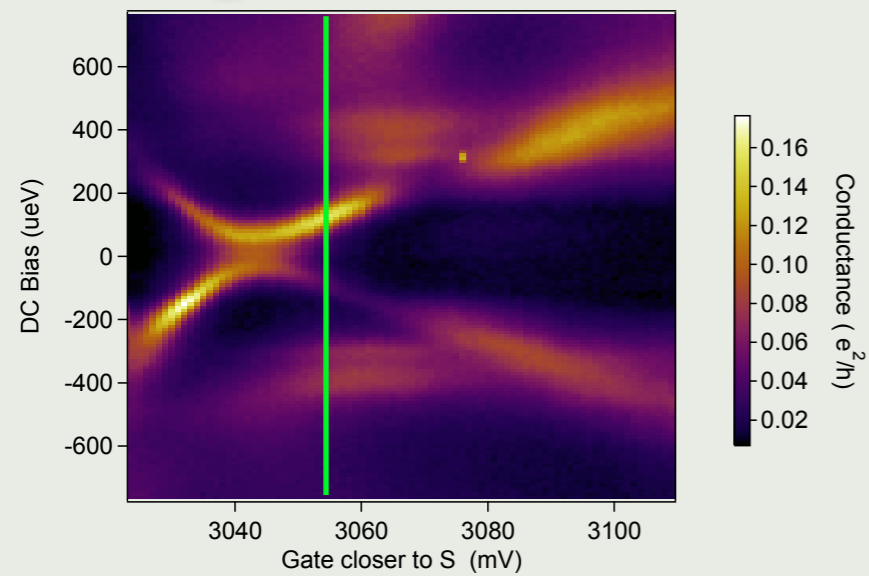
ABS, vary coupling to N and S



stronger N, weaker S



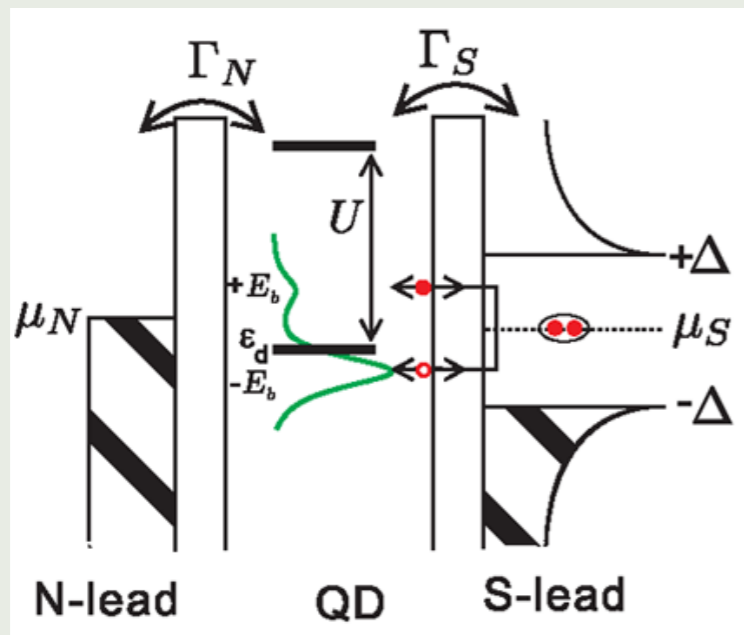
stronger S, weaker N



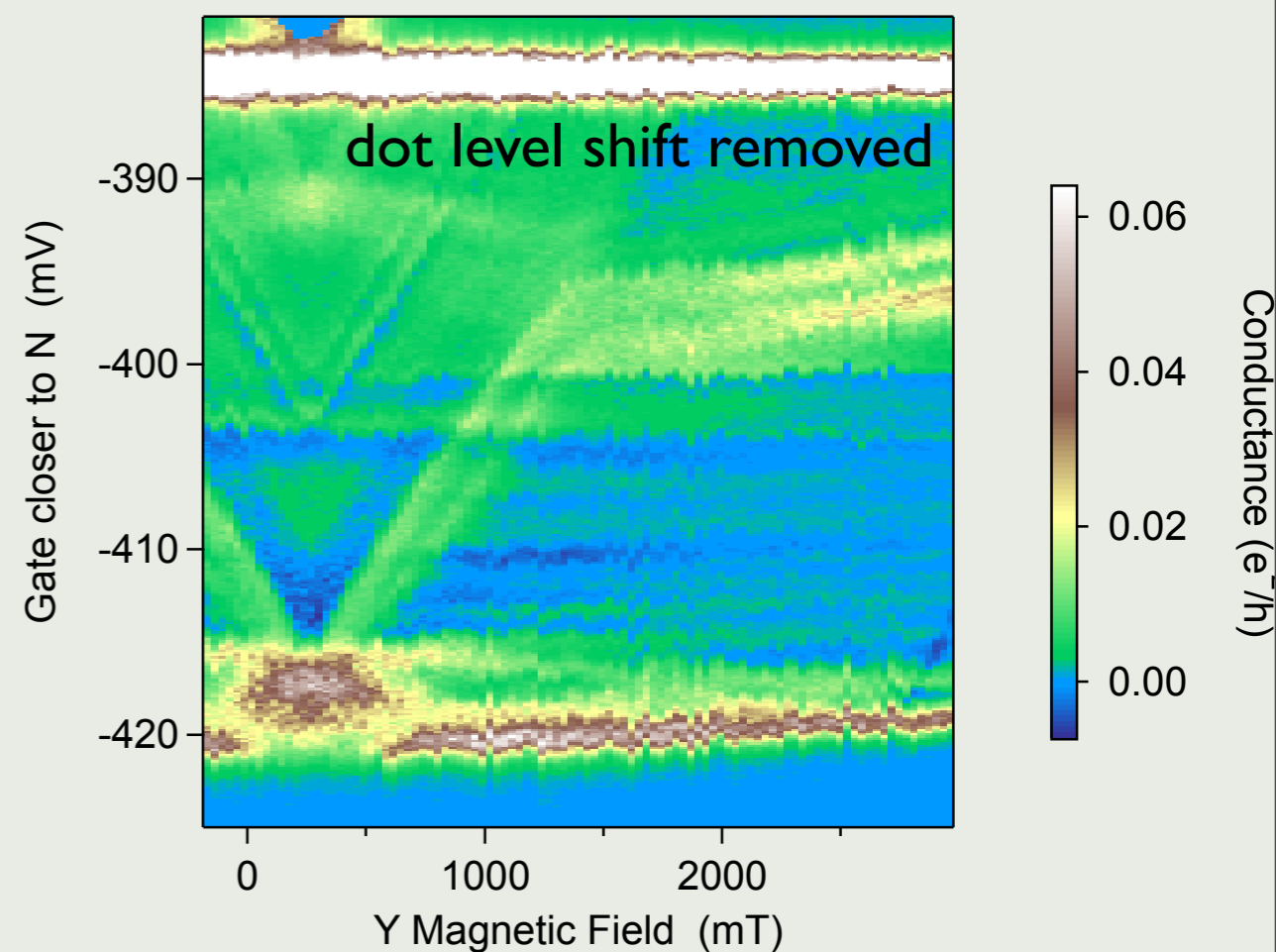
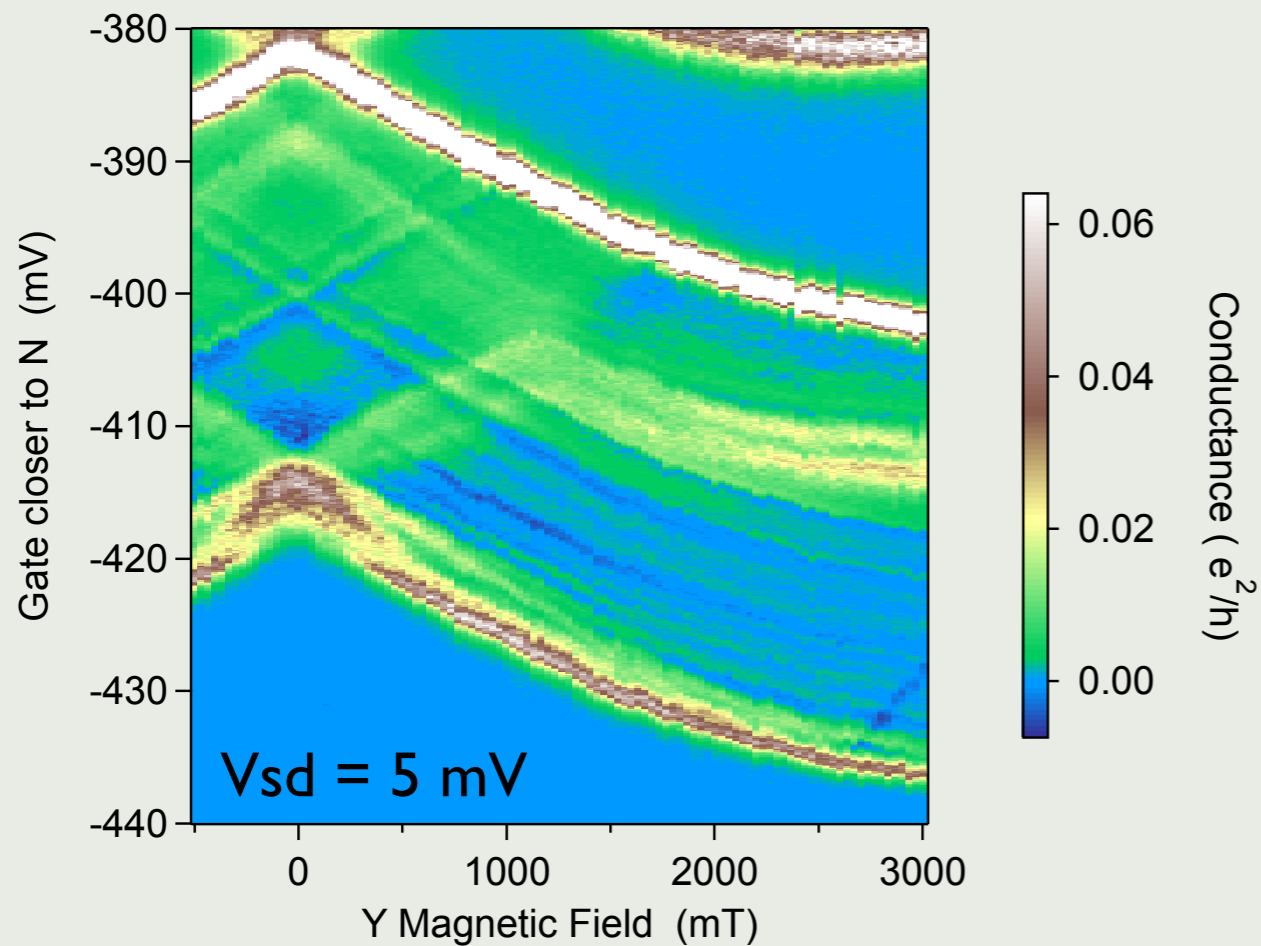
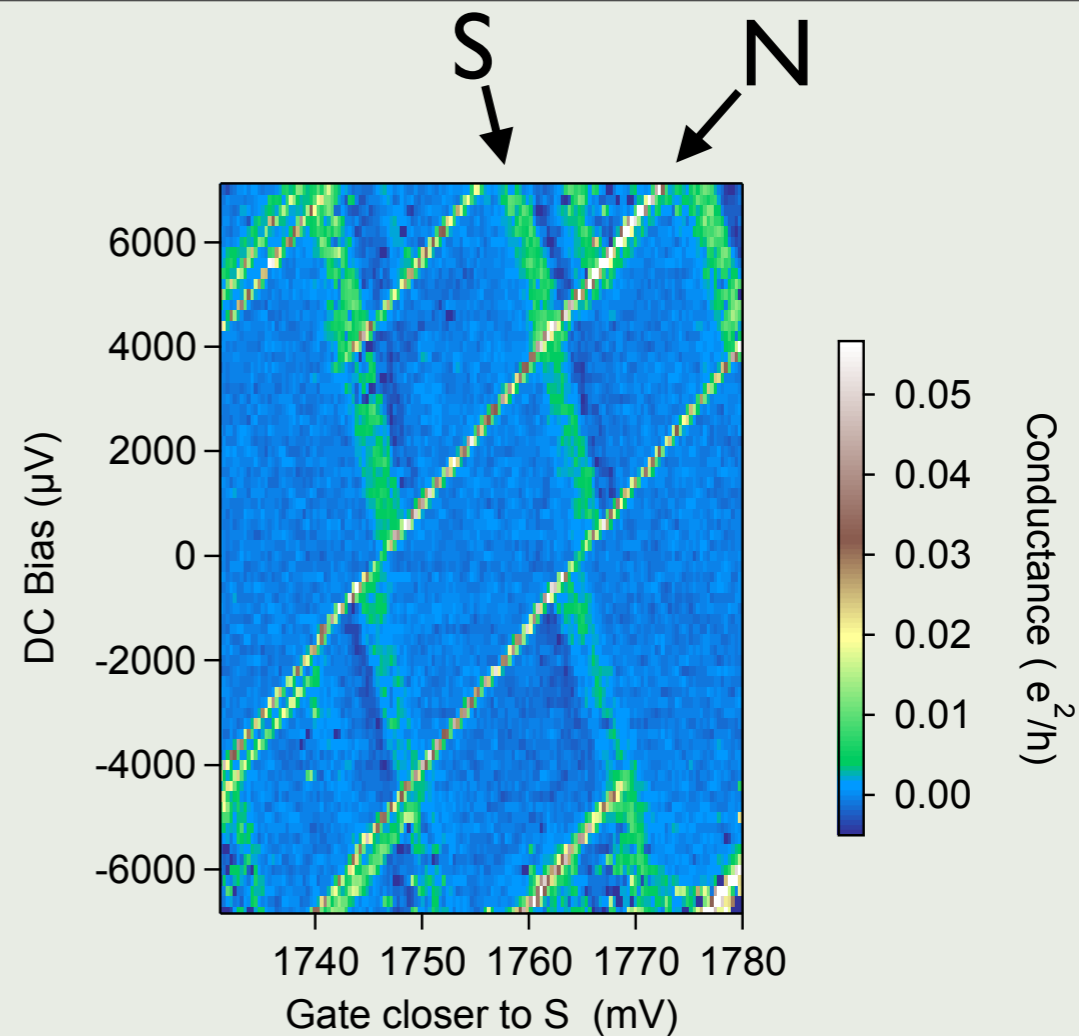
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N-dot-S



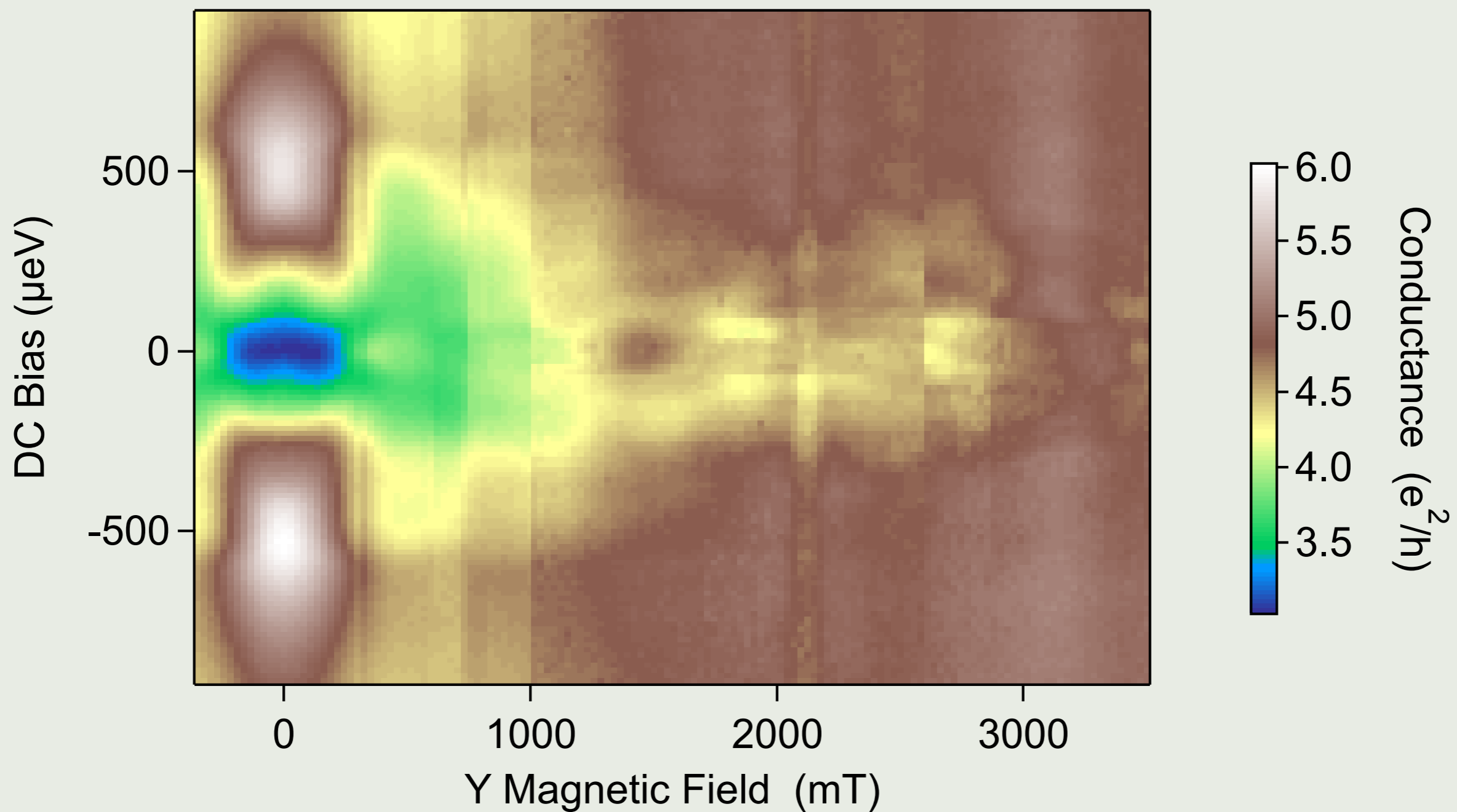
Deacon *et al.* PRL (2010)



Summary

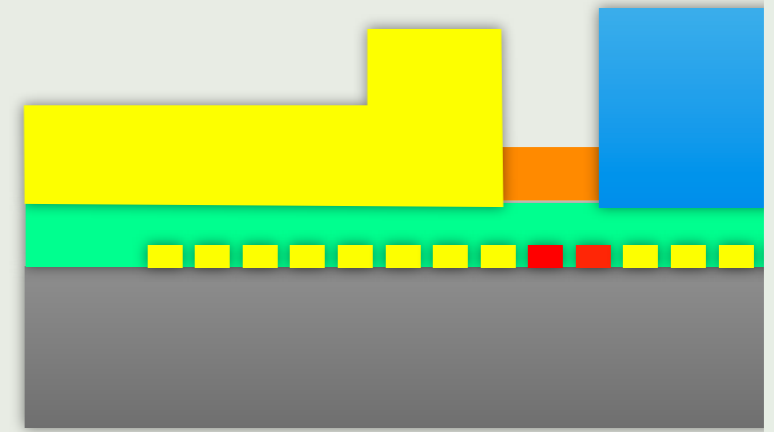
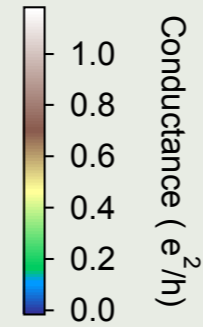
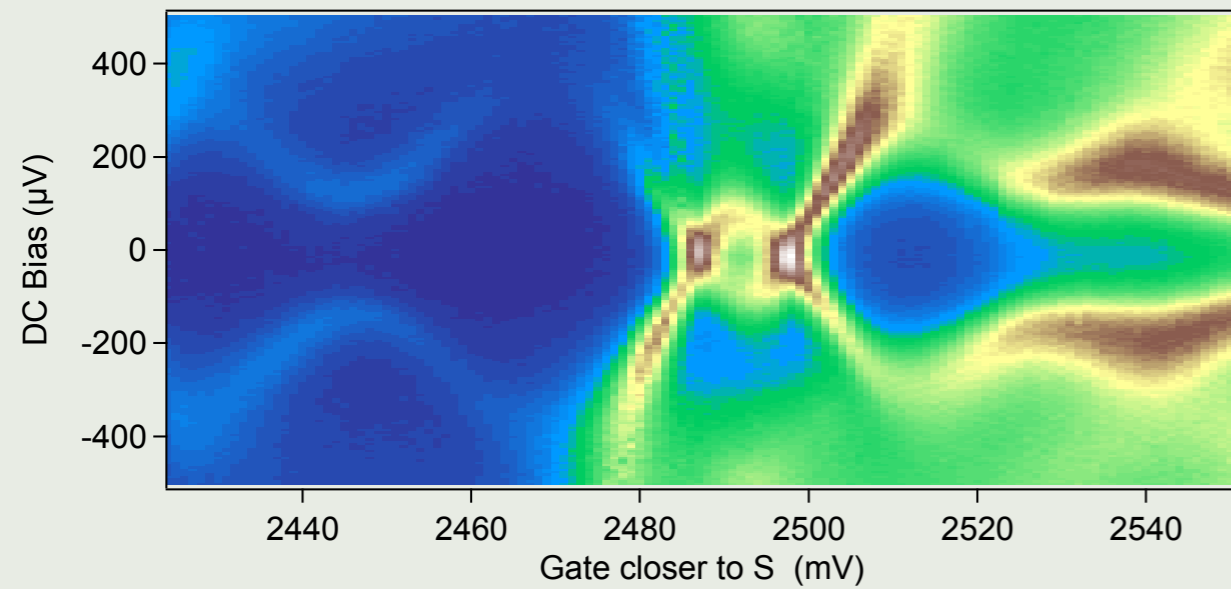
- QPC ZBPs are ubiquitous. Oscillations as function of gate and field, but quantitative disagreement with Majorana models
- B-dependence of QPC zero-bias conductance *qualitatively* similar to Wimmer *et al.*
- Zeeman-split ABS show SO splitting
- ABS zero-bias peaks appear at finite B and B = 0, depending on couplings to N and S
- Quantum dot at finite bias allows spectroscopy of dot and superconducting-wire DOS

QPC

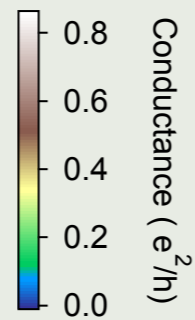
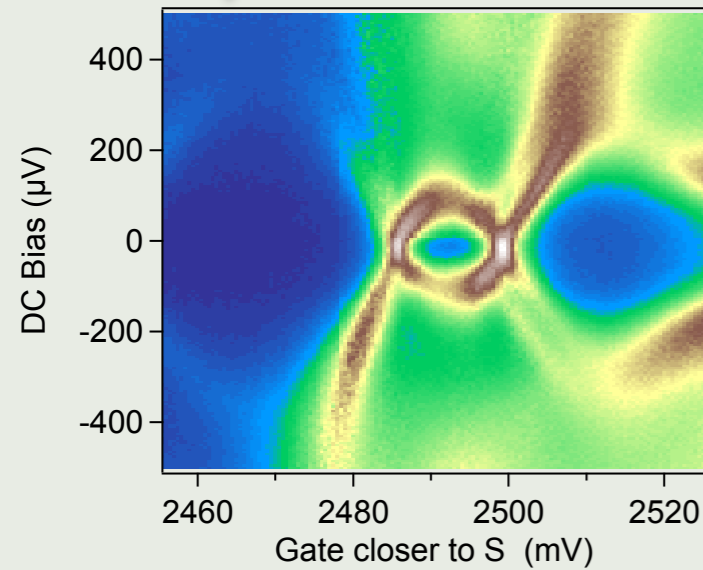


ABS, Zeeman splitting

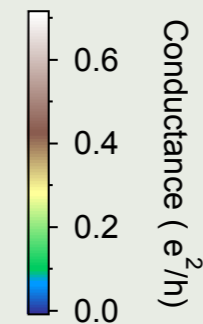
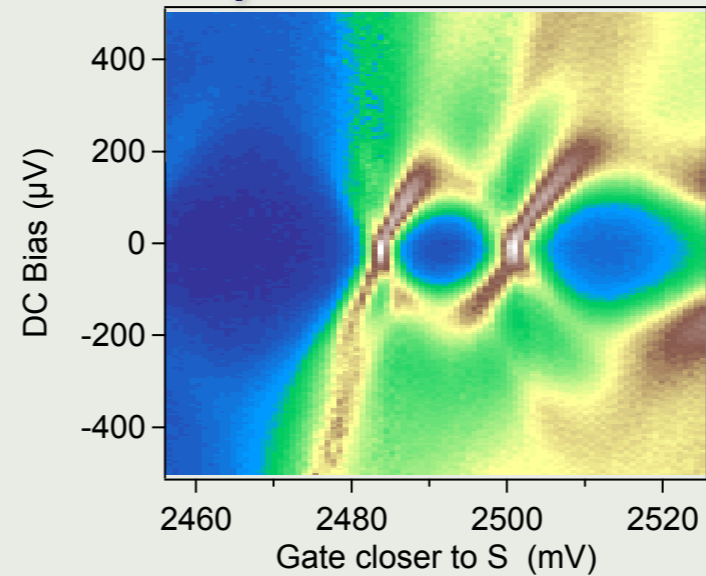
$B = 0$



$B_y = 30 \text{ mT}$

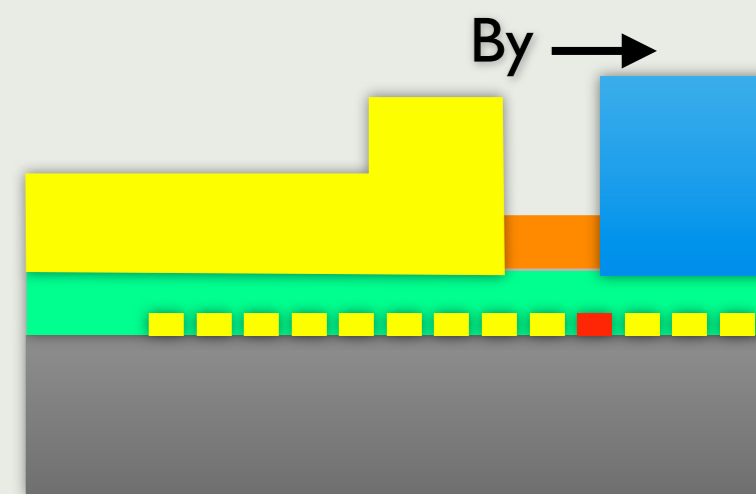
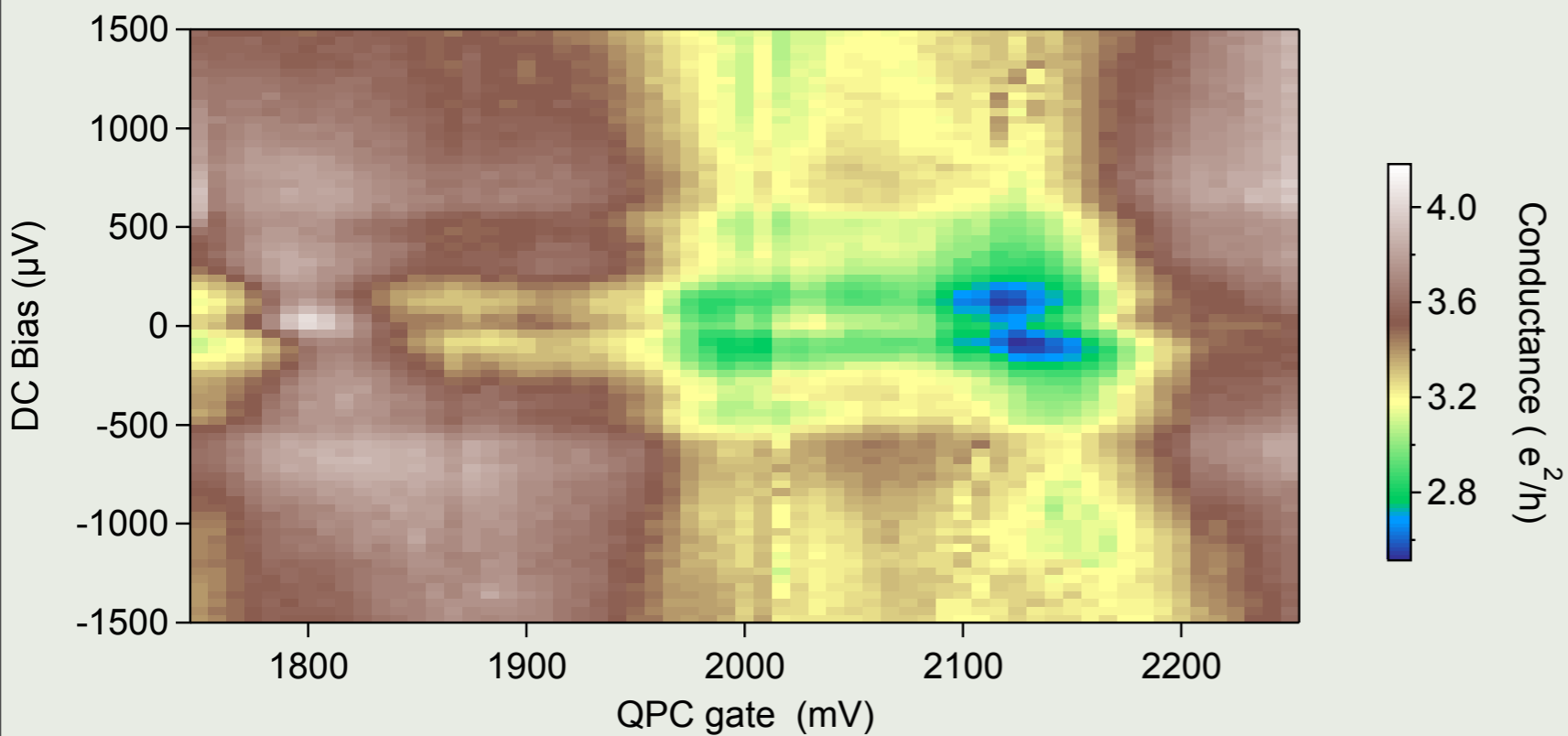


$B_y = 75 \text{ mT}$



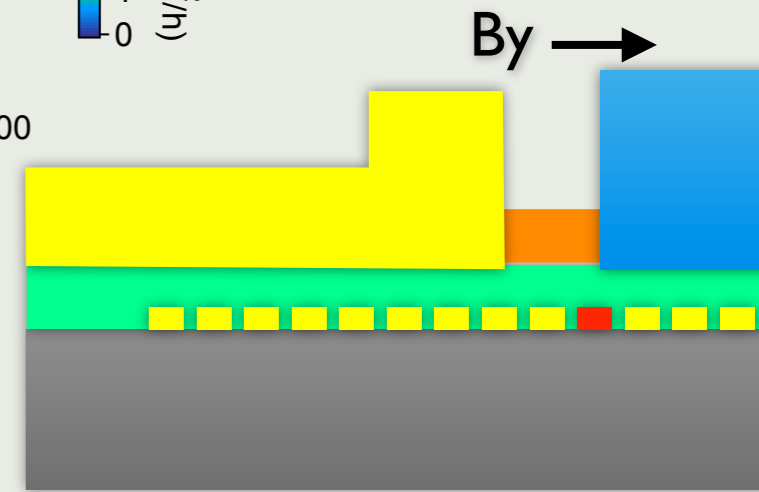
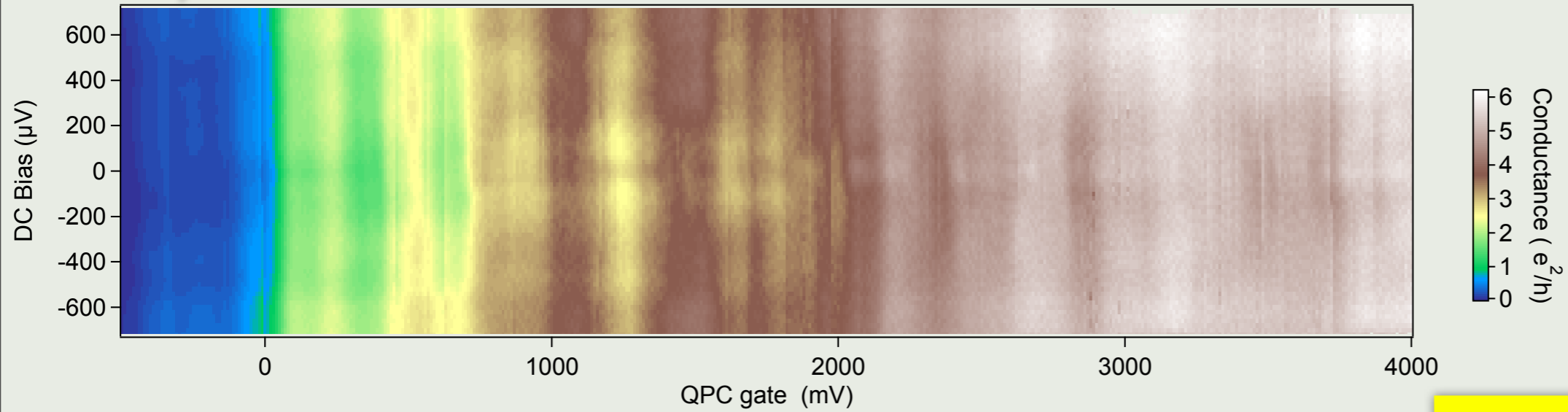
QPC, vary conductance

$B_y = 500$ mT

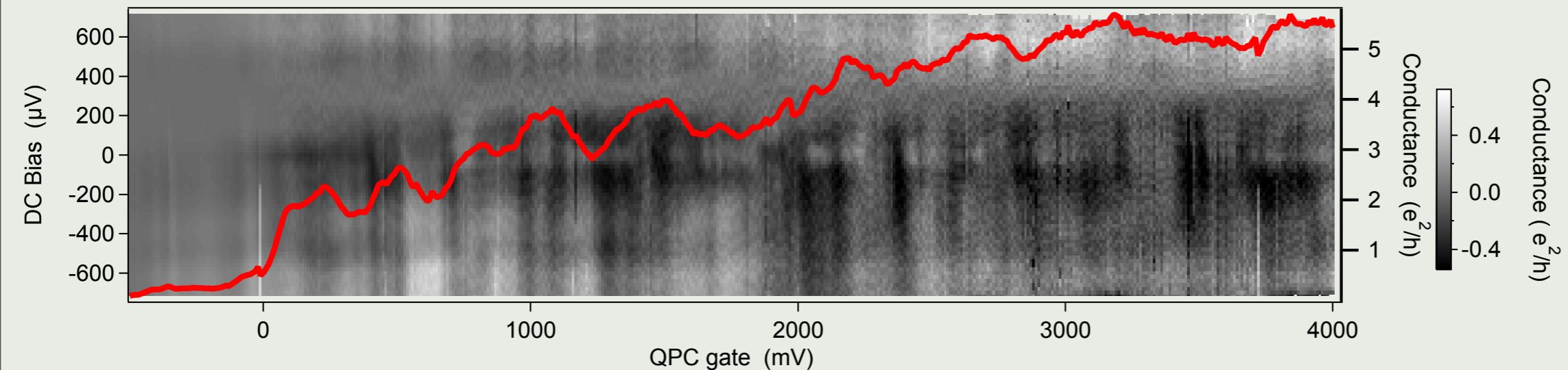


QPC, vary conductance

$B_y = 500$ mT

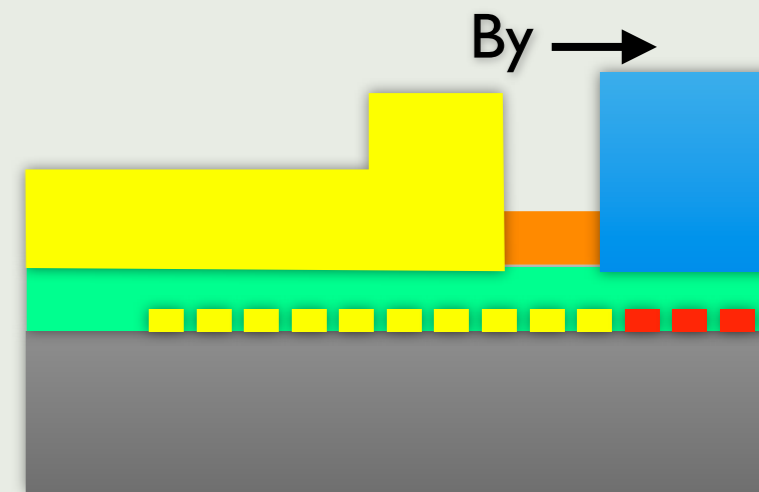
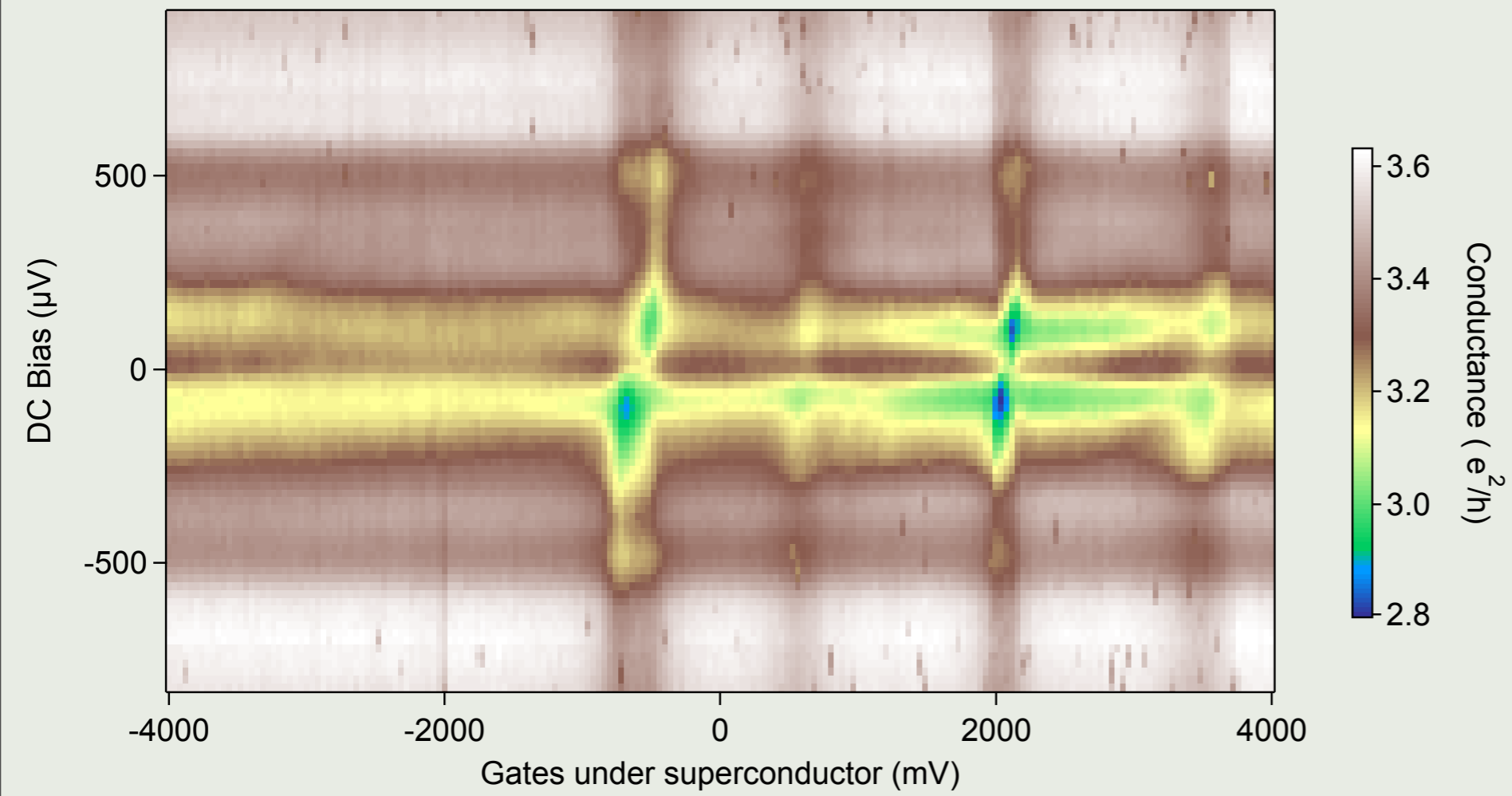


same as above with conductance at $300 \mu\text{V}$ (red line) subtracted from each column



QPC, vary gates under S

$B_y = 500$ mT



N-dot-S: at 1 T, is lineshape thermal?

