SPIN AND MOMENTUM IN SEMICONDUCTOR NANOWIRES

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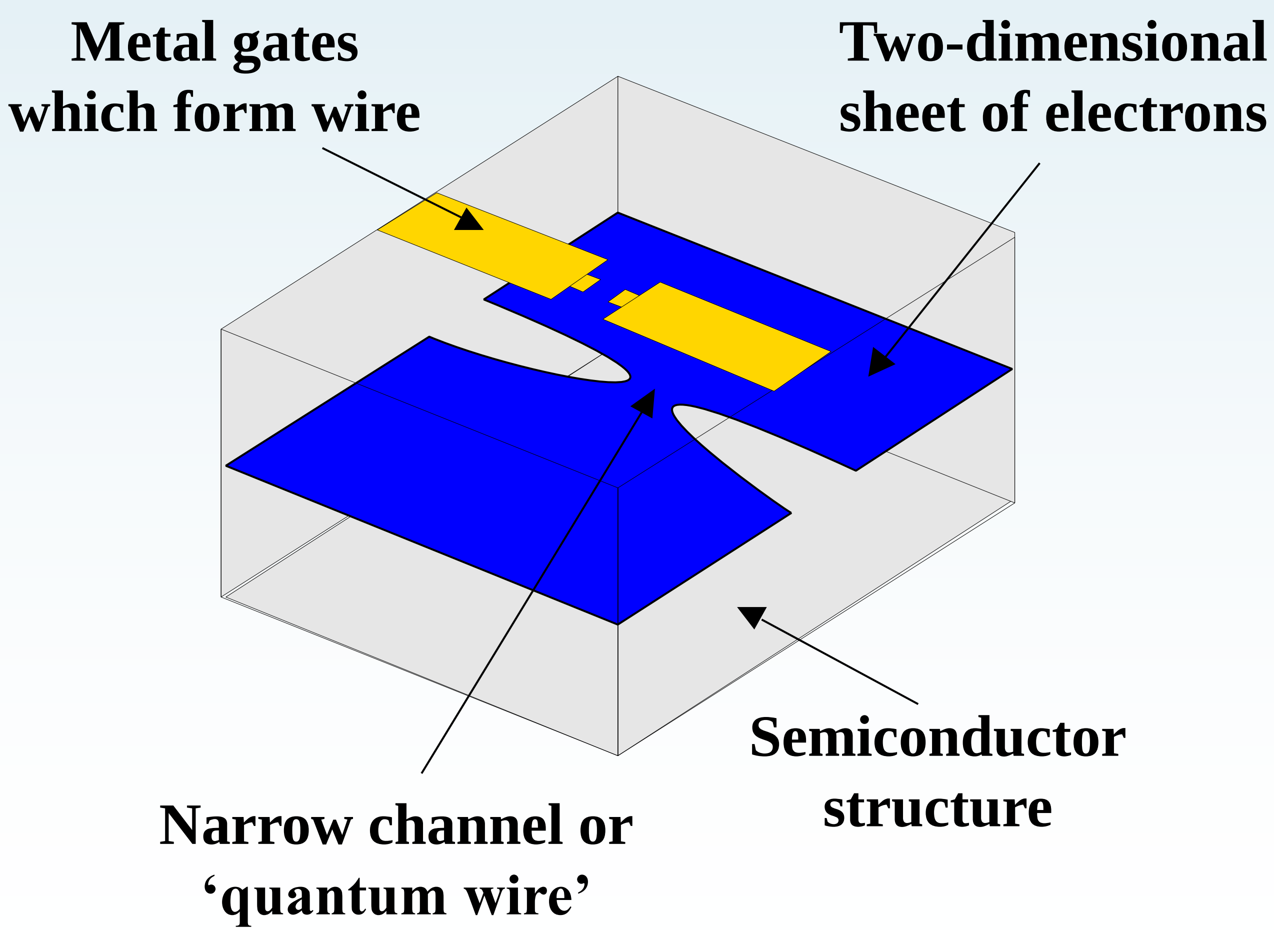
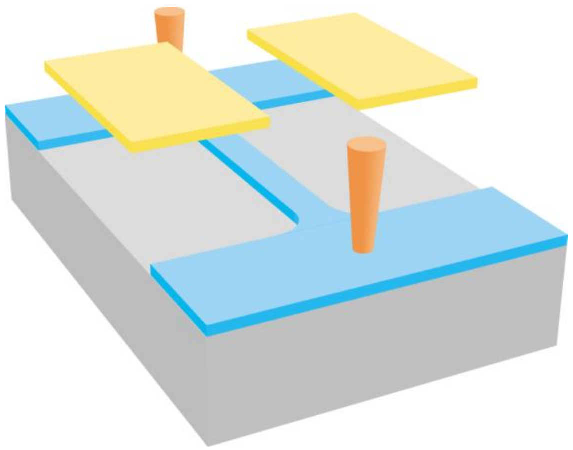
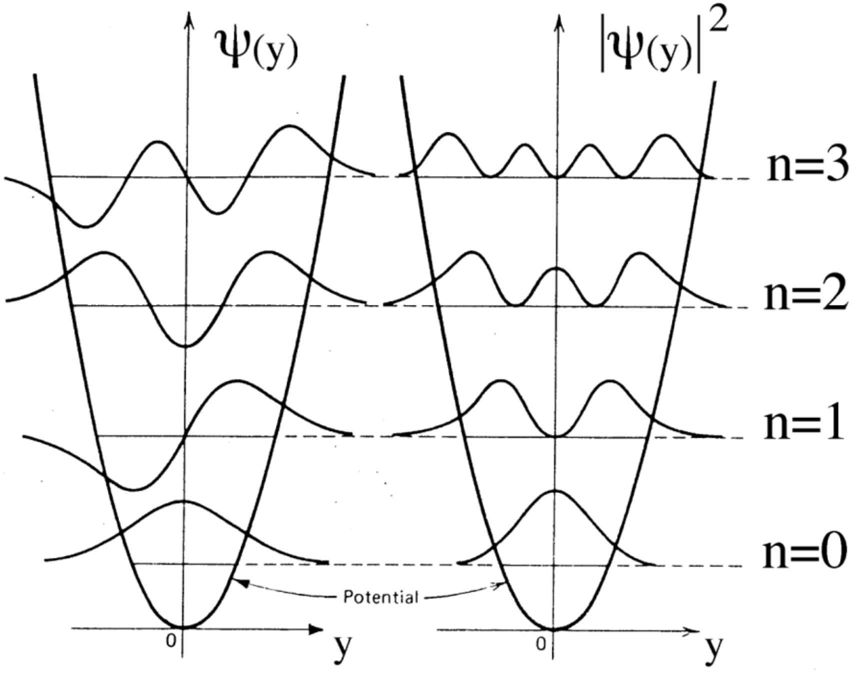
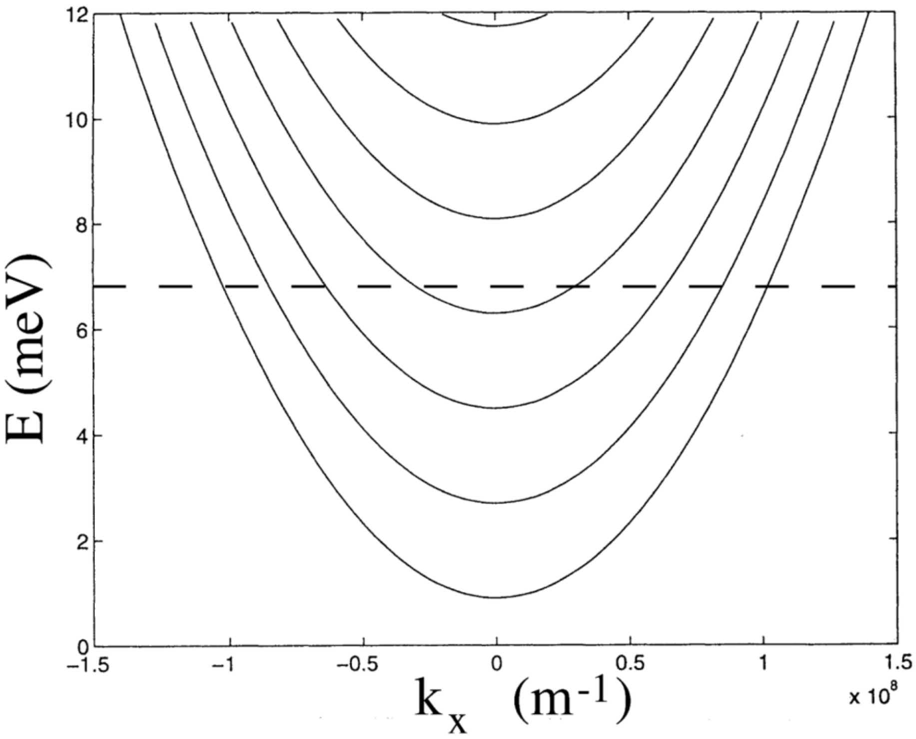
Forming the one-dimensional quantum wire



Quantum states in quasi-1D systems.



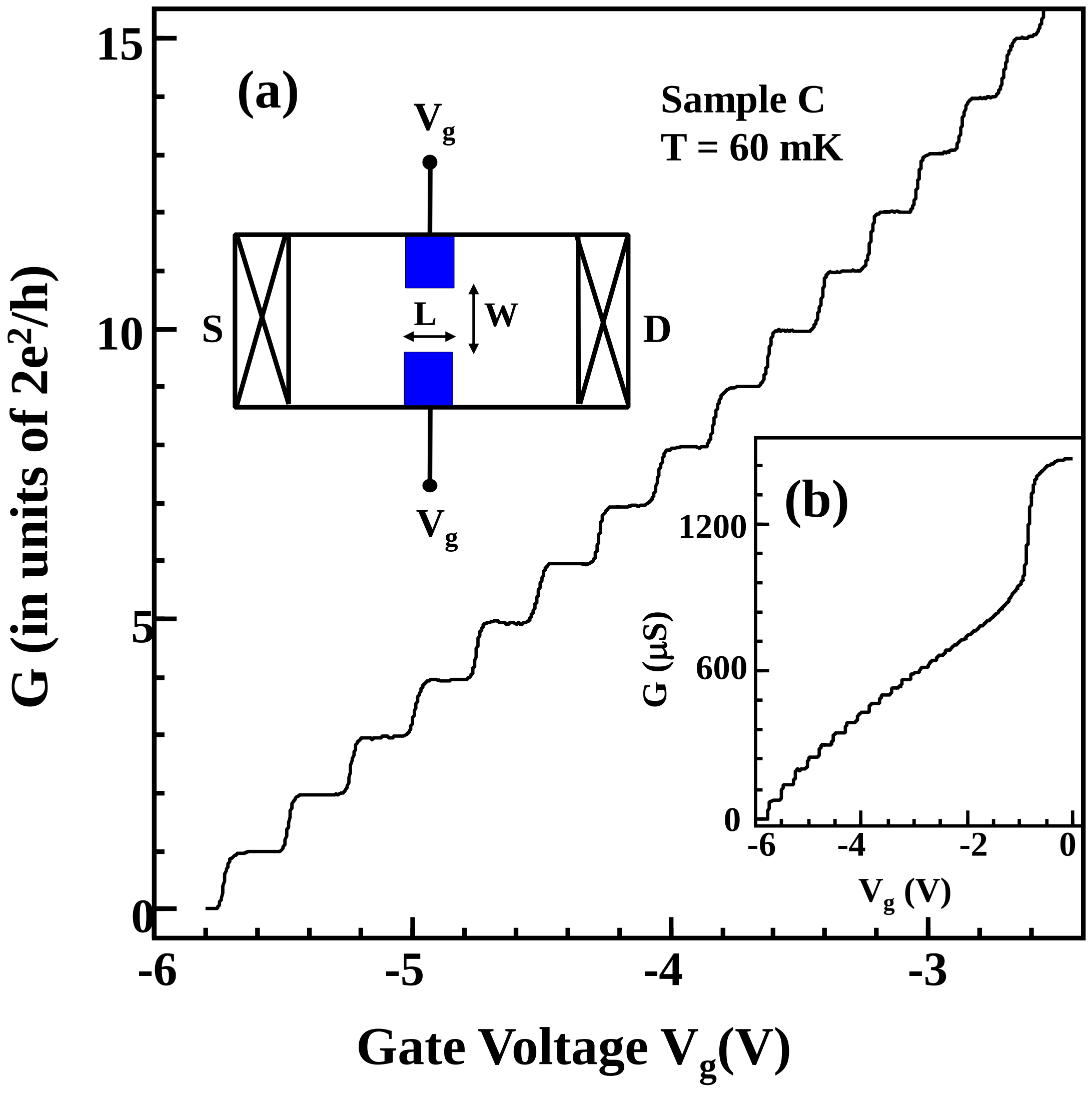




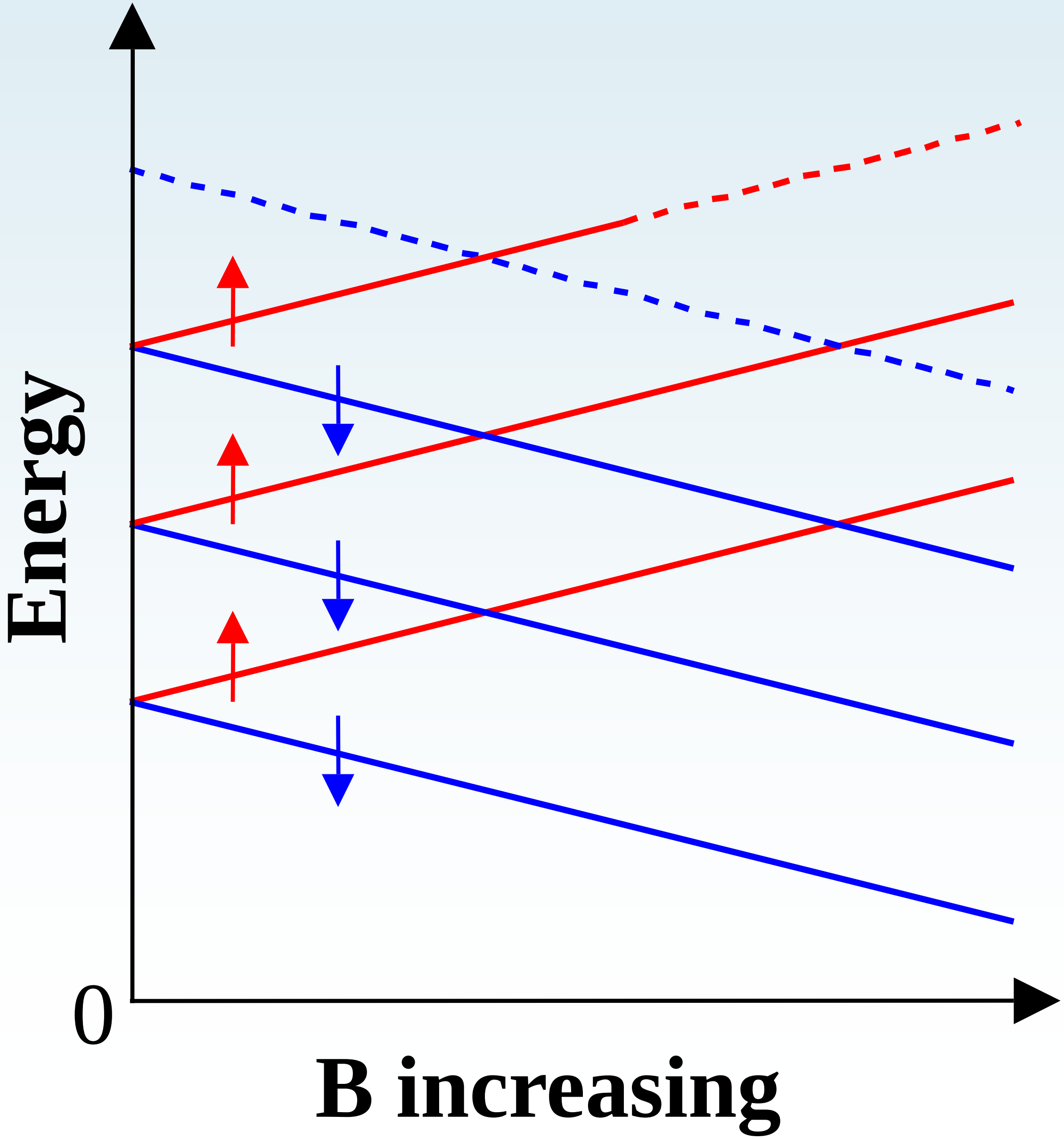
Dispersion:

$$E_i = \frac{\hbar^2 k^2}{2m^*} + E_{i,0}$$

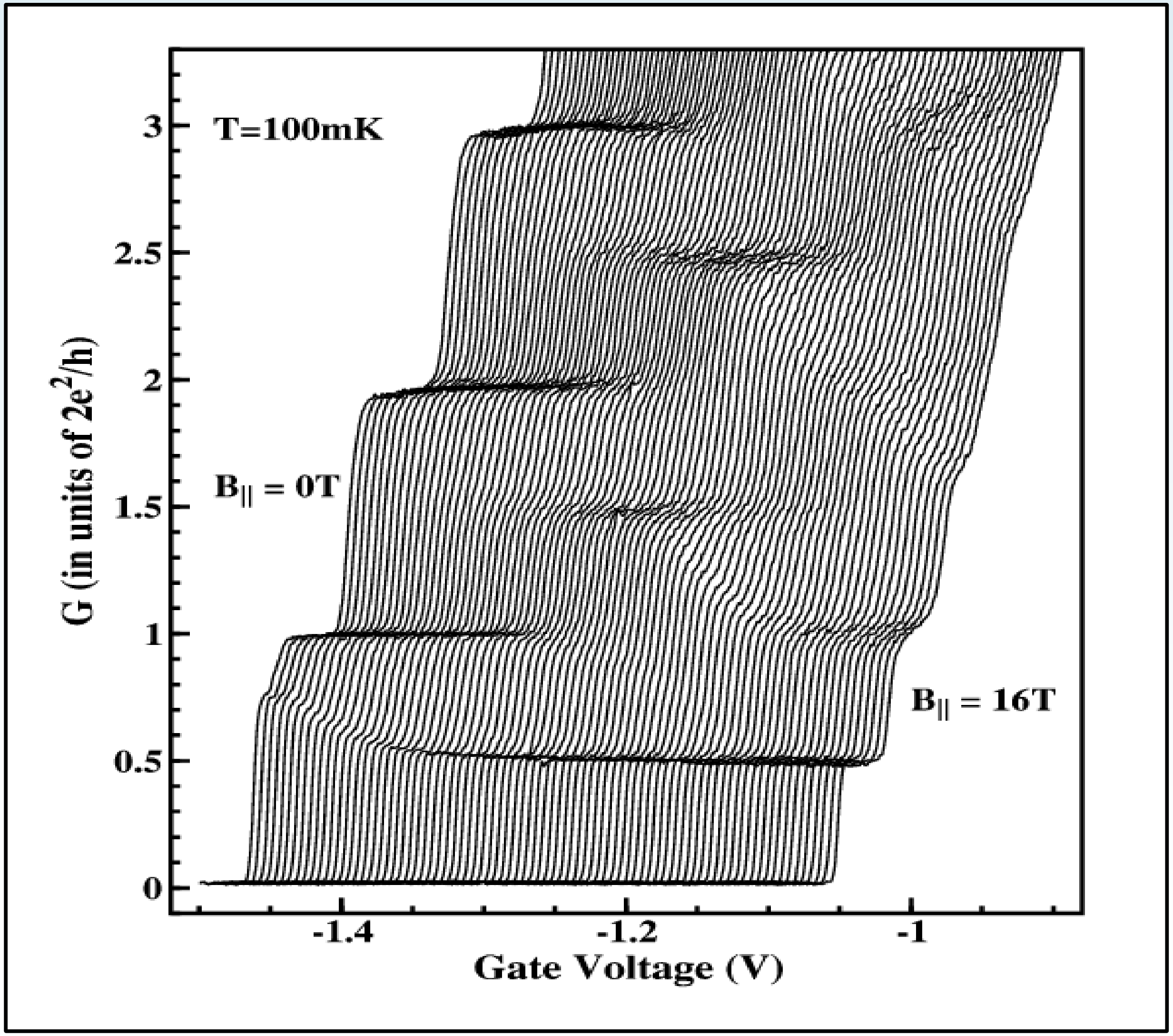
Ballistic Quantisation, Thomas et al



Energy of spin-polarised 1D 1D subbands



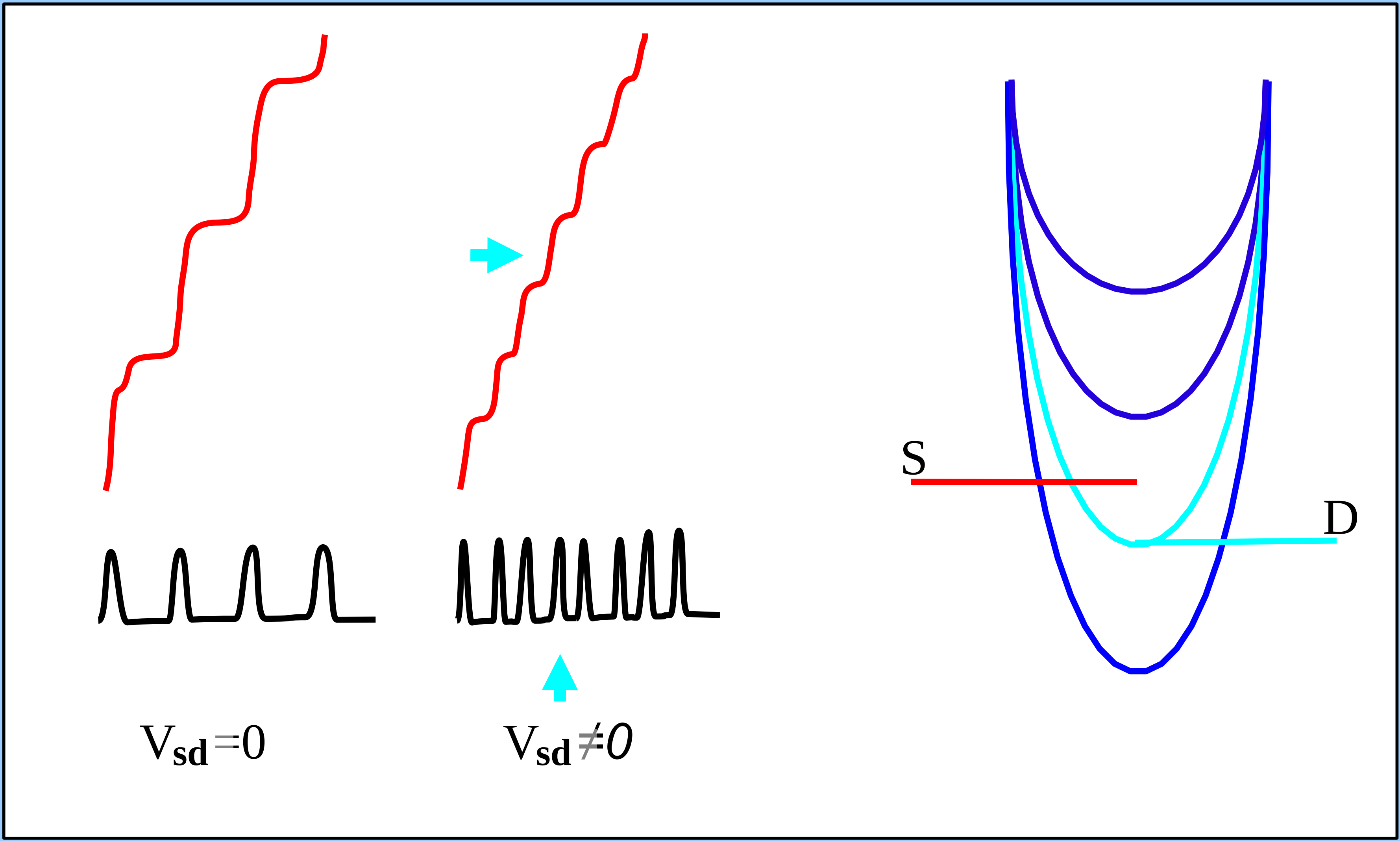
Conductance in an in-plane magnetic field, Thomas et al, Phys.Rev., B61,R13365, 2000



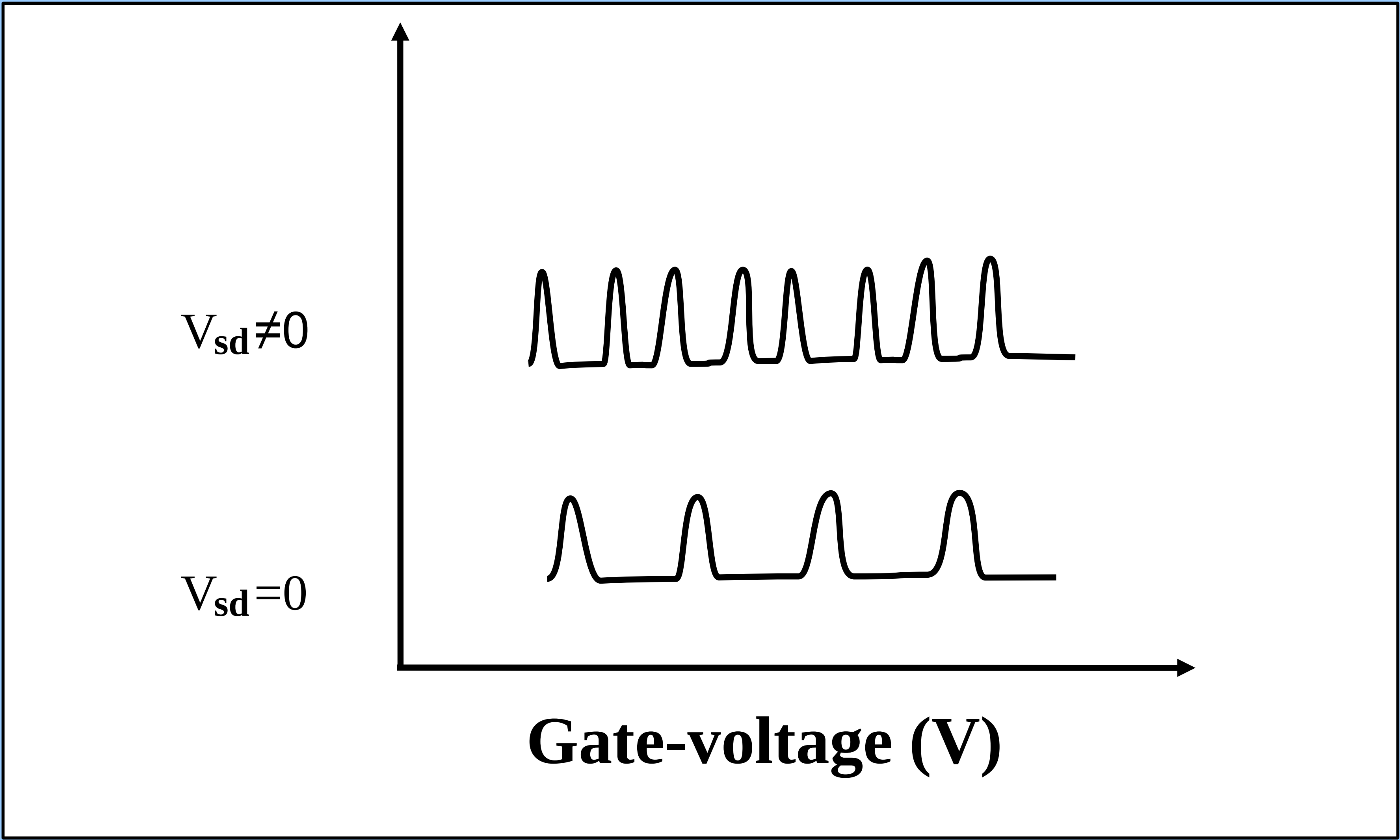
DC-bias measurements

- A powerful way of probing an energy spectrum by lifting the momentum degeneracy.
- Can give information about a subband when it is partially populated.
- Behaviour at crossings strongly deviates from a non-interacting picture.
- DC-bias spectroscopy will show that although plateaux are correctly quantised away from crossings, characteristics are still dramatically affected by interactions.

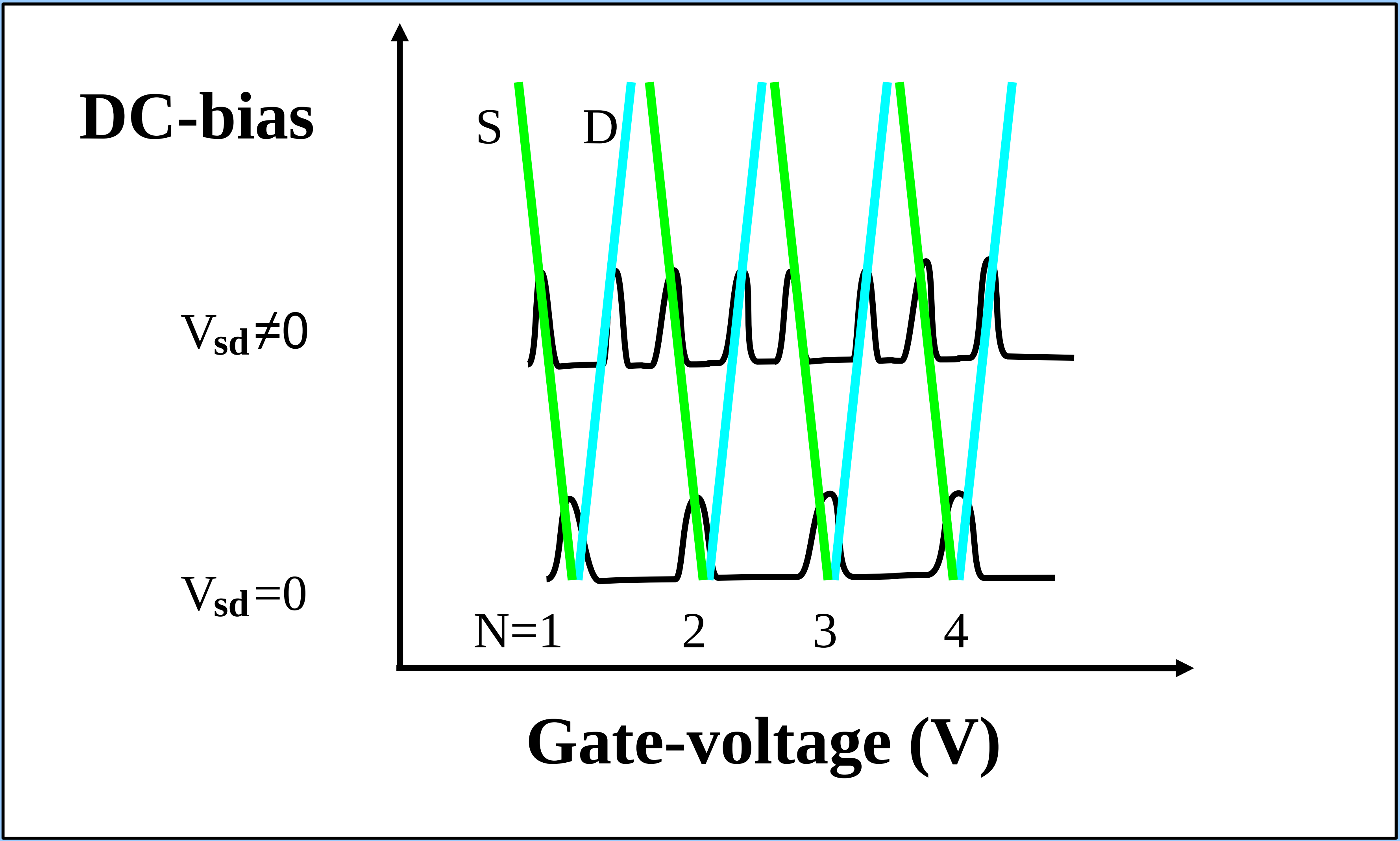
Transconductance peaks split in two by DC-bias



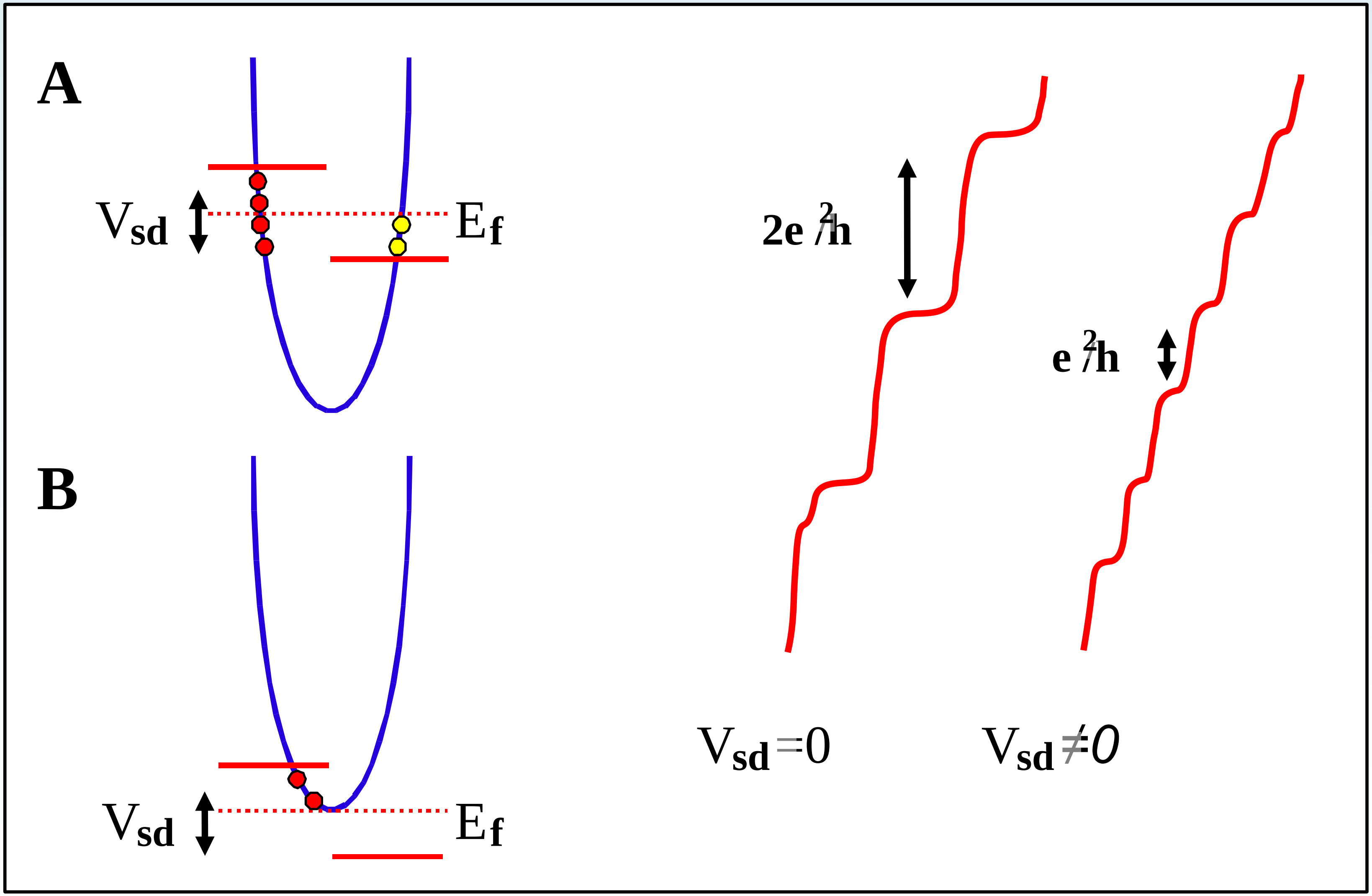
Plot dG/dVg as function of DC-bias and gate-voltage



Peaks for each subband split into two



“Half-plateaux” caused by DC-bias



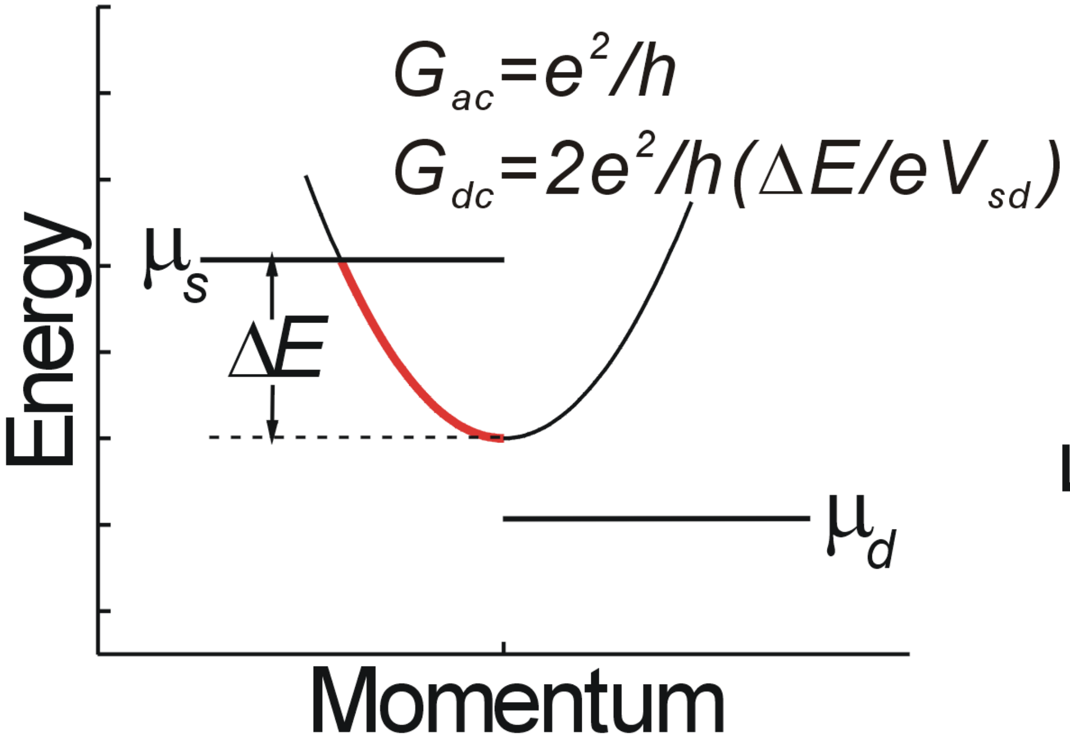
AC or DC Measurements ?

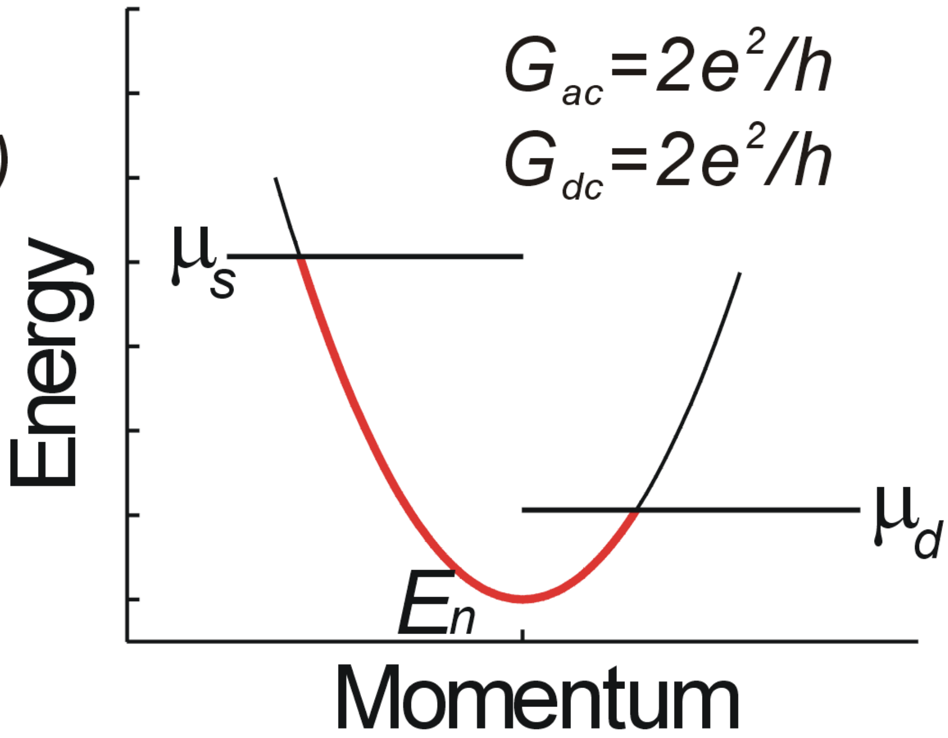
By analogy with tunnelling and related measurements the field started by looking at the differential.

However allied to DC is the most effective combination.

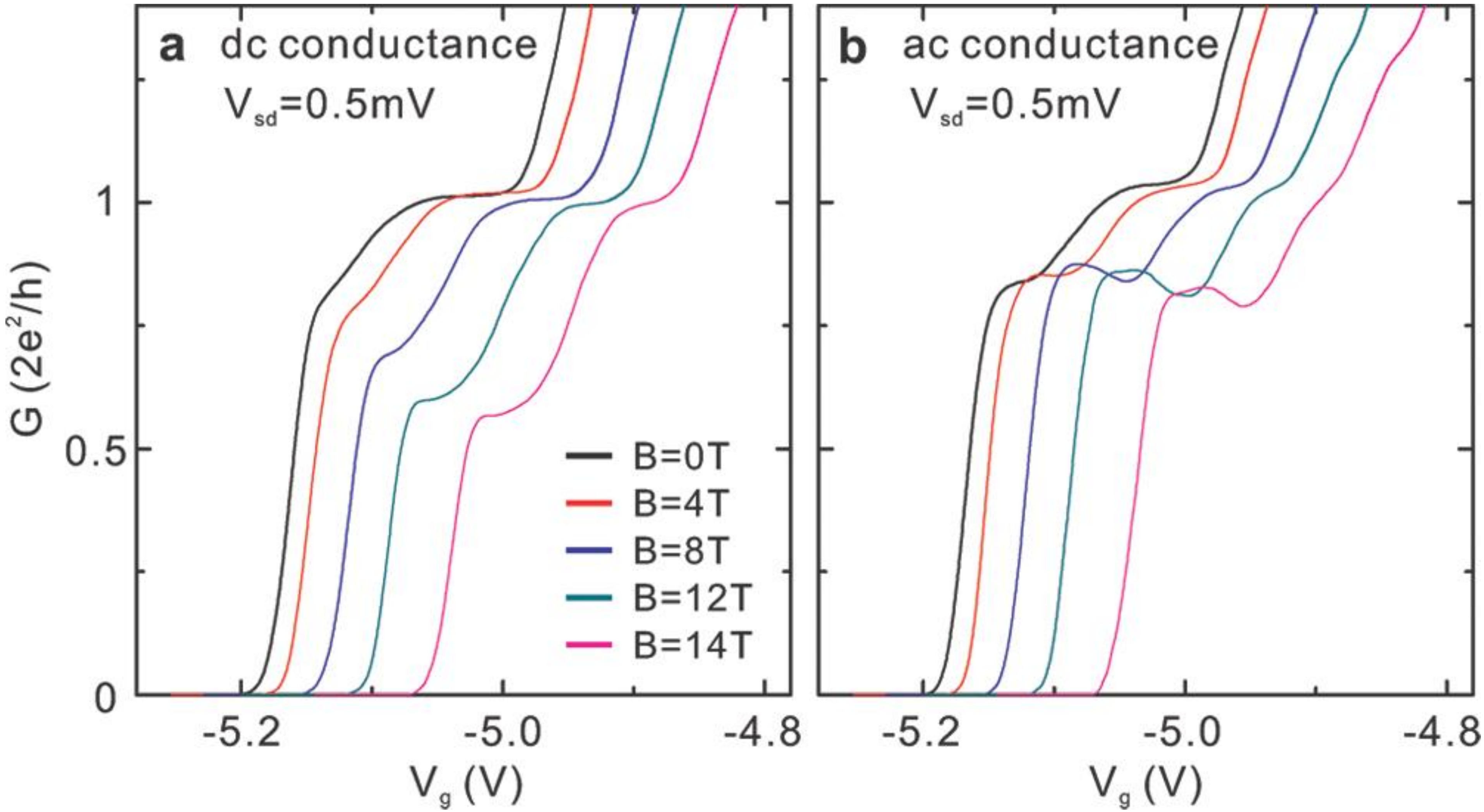
Allows unique information to be obtained, the filling of a subband, g value and related phenomena.

DC Conductance allied to Differential Conductance G_{ac}

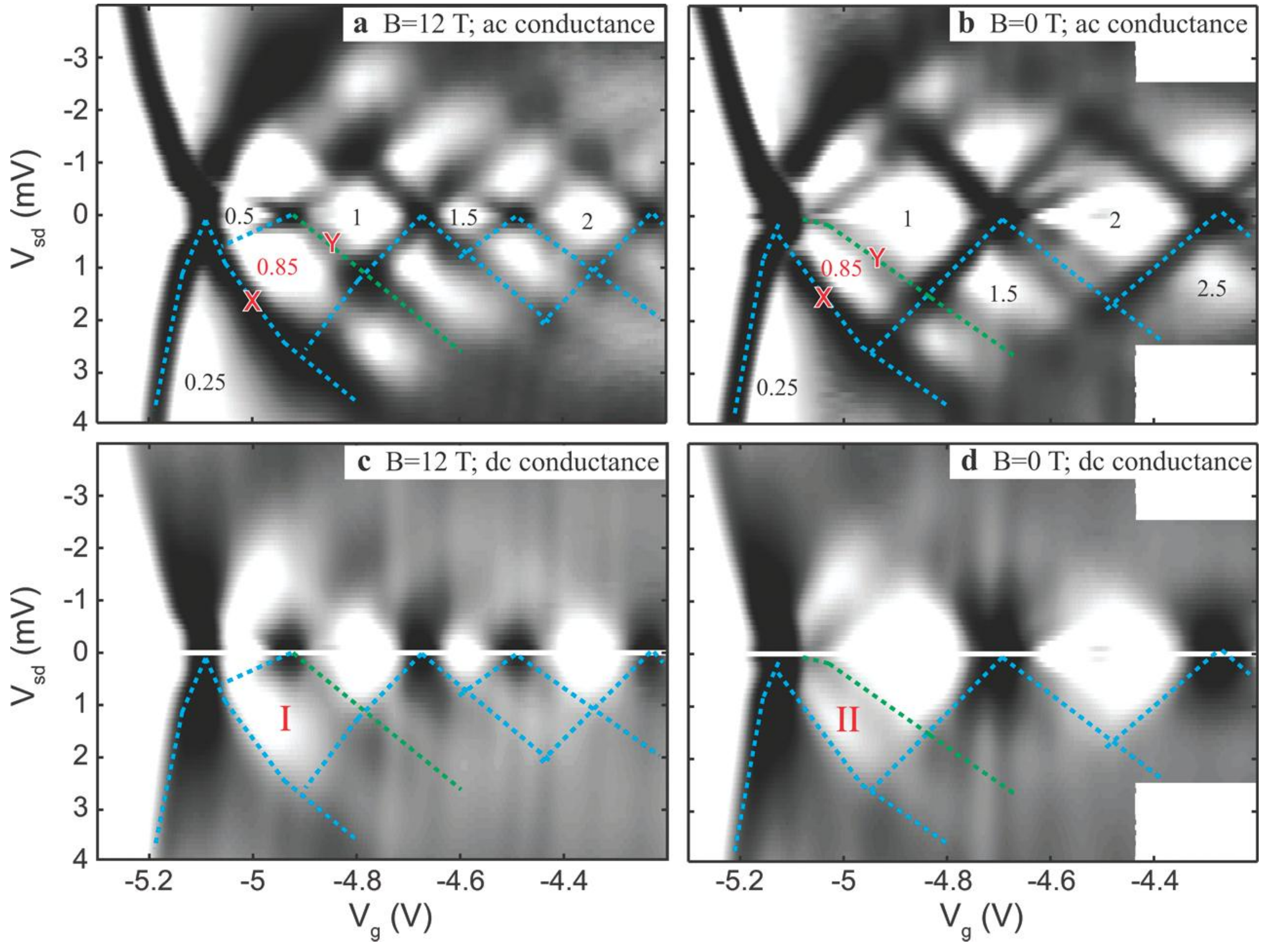




SIMULATANEOUS MEASUREMENTS OF DC AND DIFFERENTIAL SHOWING INCREASING SPIN POLARISATION OF 0.7 AND 0.85 INDEPENDENT OF B, CHEN et al, NANO LETT., 10, 2330, 2010



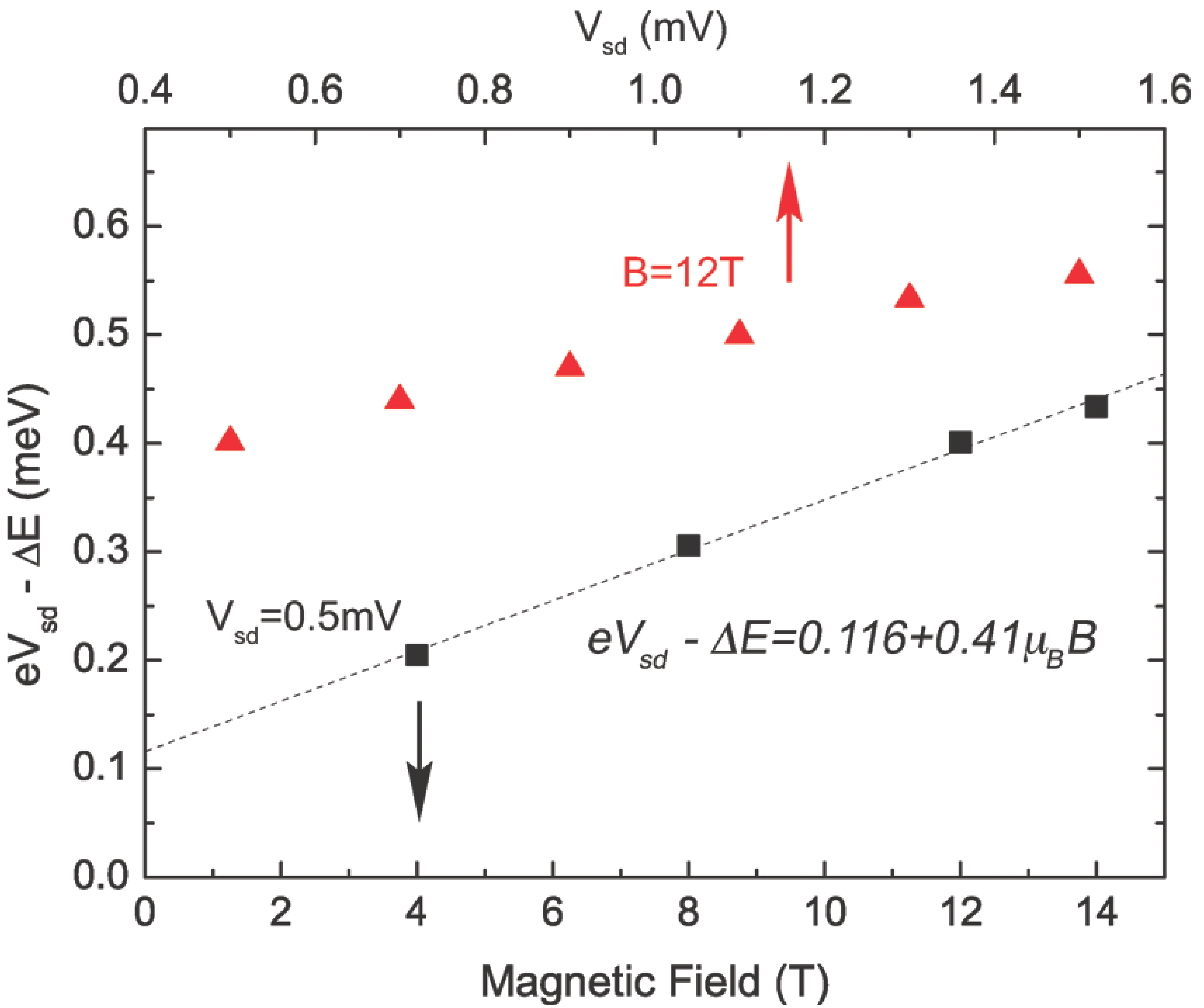
Grey-Scale Showing Polarisation, Chen et al Nano Lett, 10, 2330-2334, 2010



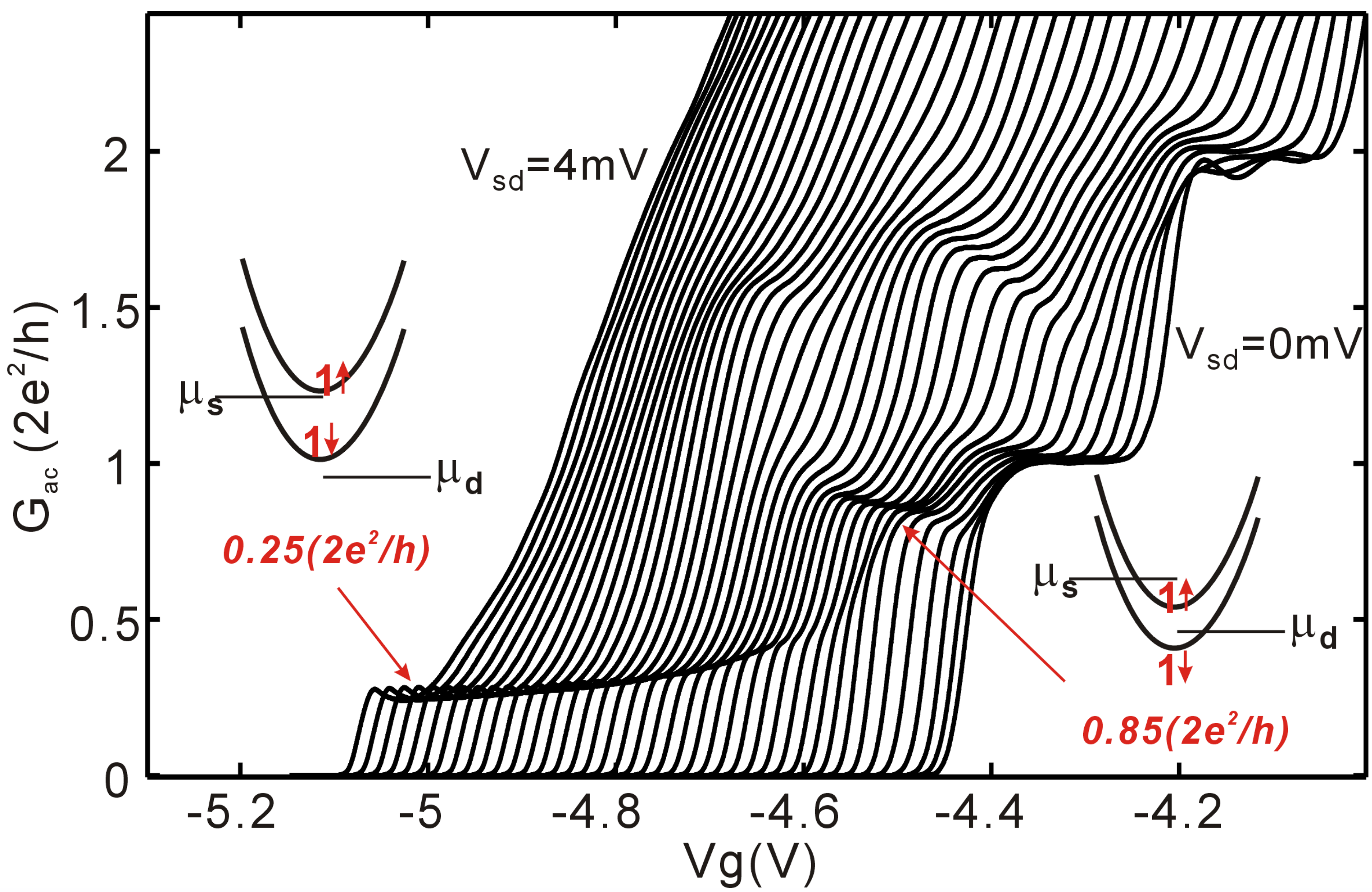
The 0.85

- The DC measurement allied to the ac shows that the minority spin (up) level fills very slowly giving this quasi plateau
- By analogy the 0.7 would be the minority spin level pinned just above or at the source. The repulsion arising from the spin-spin interaction.

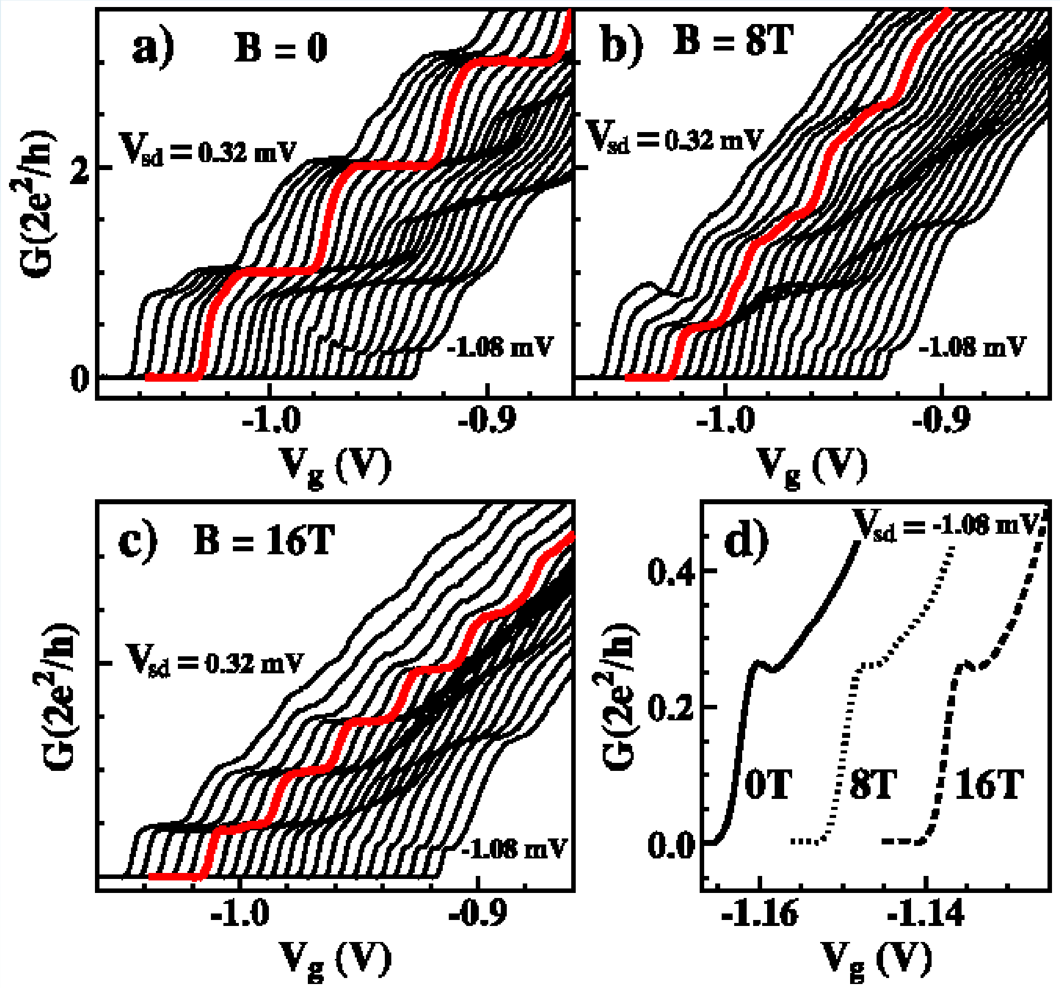
ENERGY DIFFERENCE BETWEEN FIRST ANTI-PARALLEL SUBBAND AND DRAIN, SHOWING VARIATION IN g VALUE.
CHEN *ET AL*, NANO LETT, 10, 2330-2334, 2010



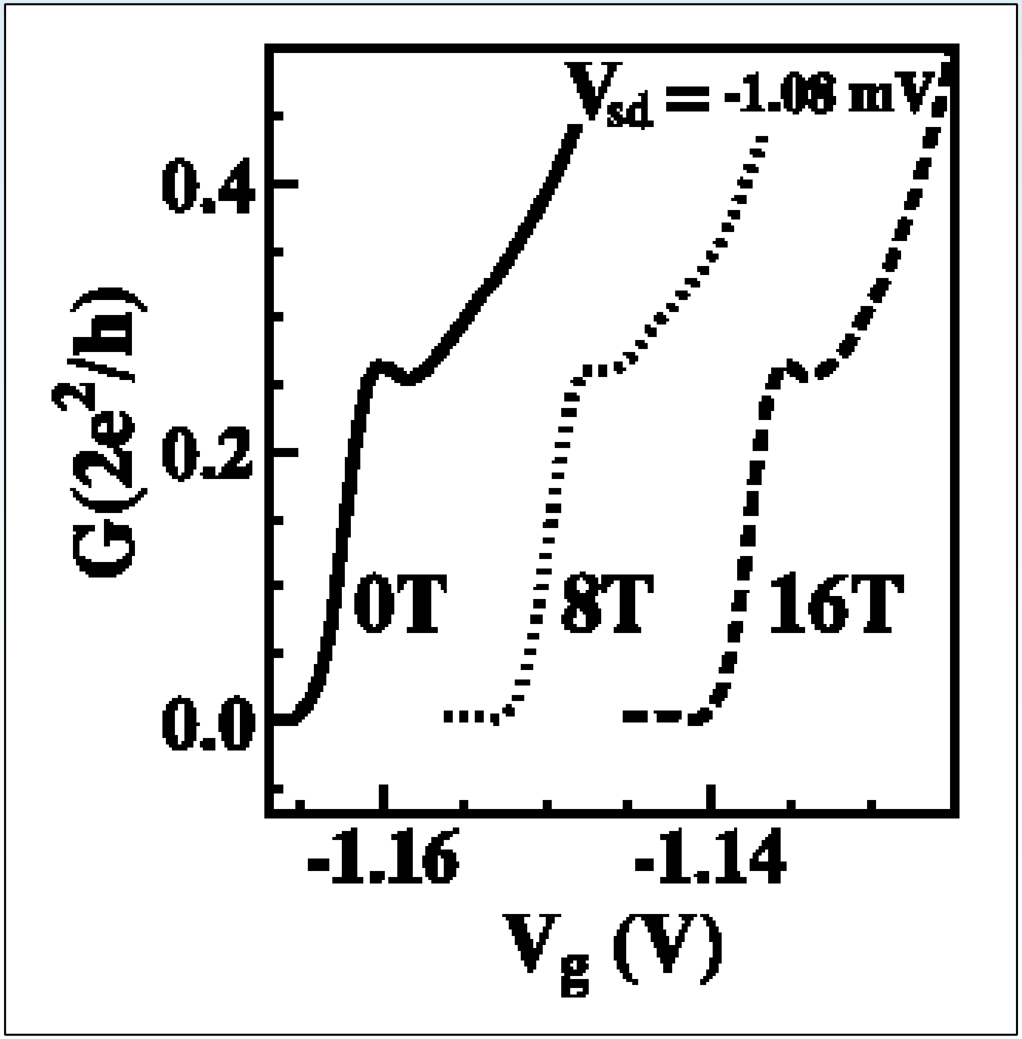
FORMATION OF 0.25, CHEN et al, APL, 93, 032102, 2008



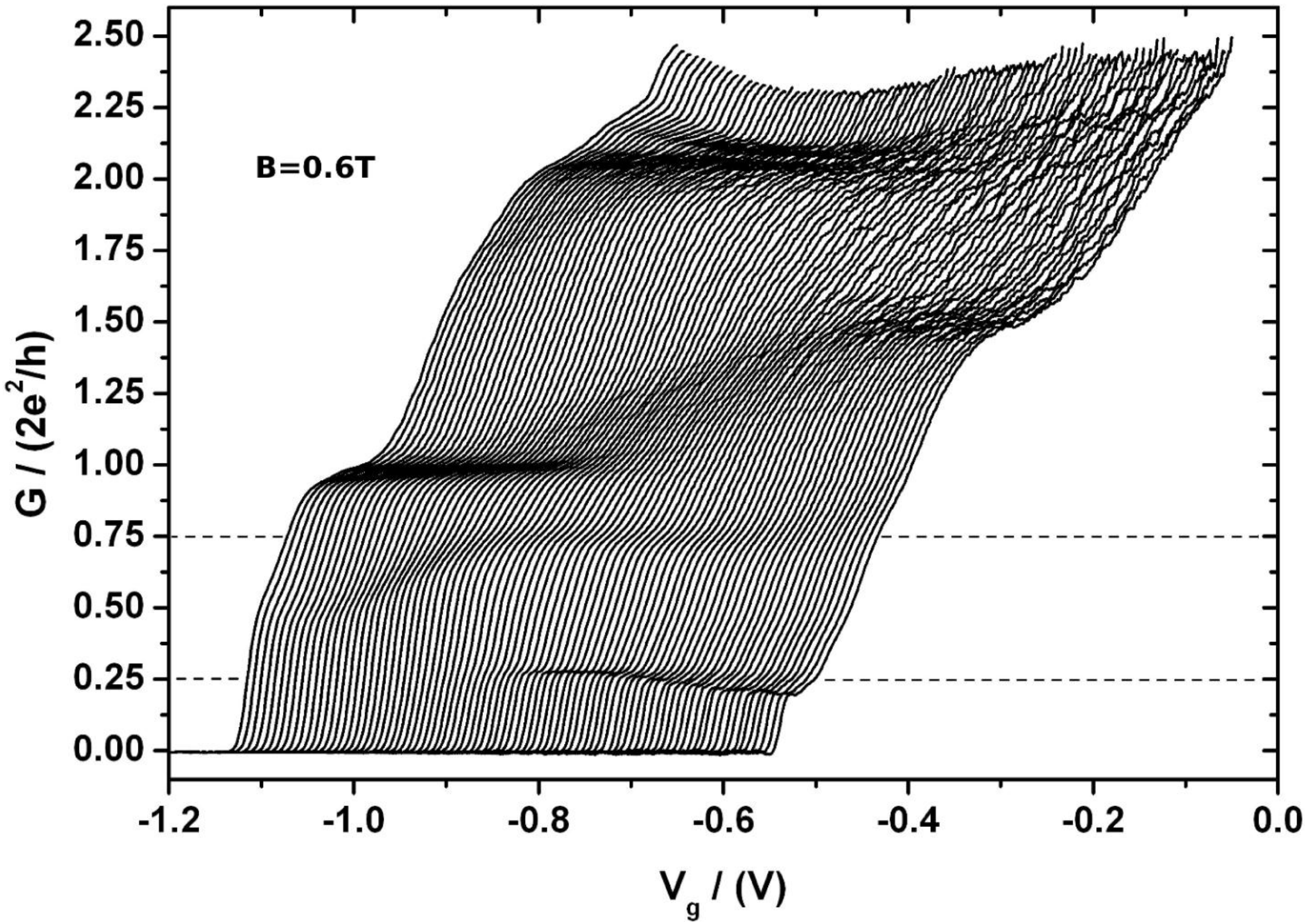
DC-bias data at B=0,8 and 16T



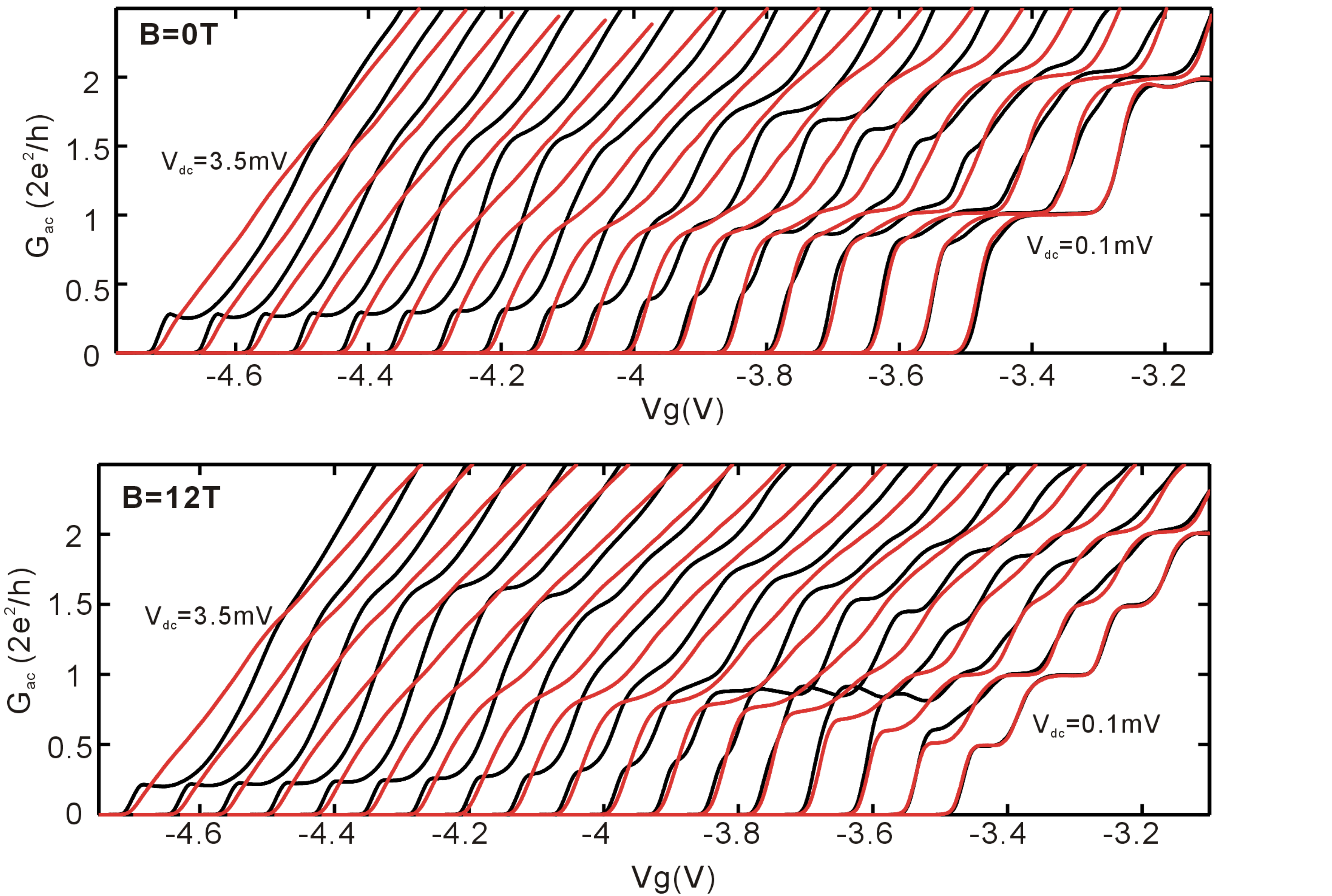
DC-bias '0.25' structure at B=0, 8 and 16T

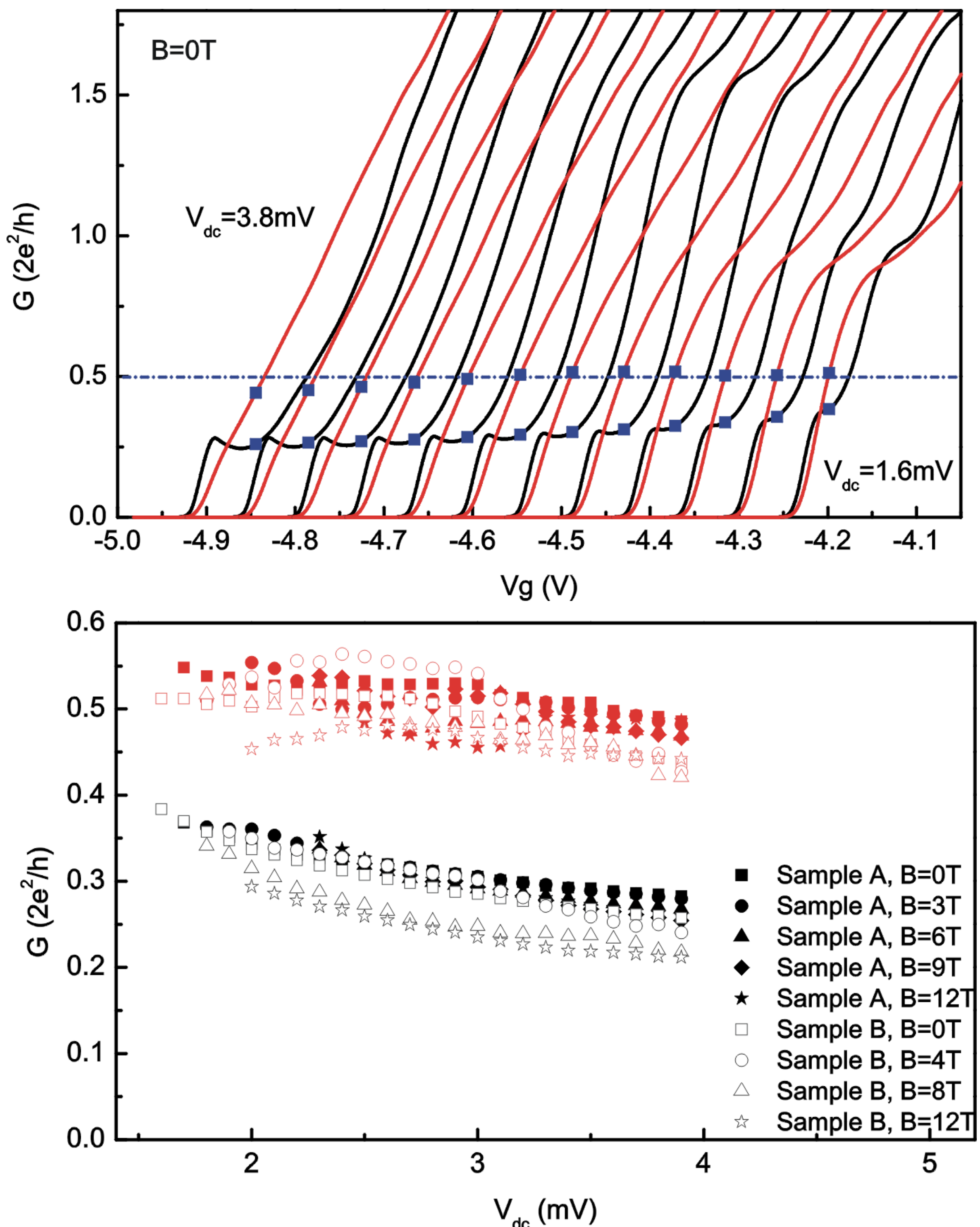


InGaAs with In 0.25,Ga 0.75, Vsd increased from 0 to 4mV showing jump from 0.25 to 0.75 with 1.5 appearing. Simmonds et al, App.Phys.Lett, 92, 152108, 2008



Comparison of dc and differential conductances, Chen et al Nano.Lett, 10, 2330, 2010





B=0T
V$_{dc}$=3.8mV
V$_{dc}$=1.6mV
G (2e^2/h)
Vg (V)
G (2e^2/h)
V$_{dc}$ (mV)
Sample A, B=0T
Sample A, B=3T
Sample A, B=6T
Sample A, B=9T
Sample A, B=12T
Sample B, B=0T
Sample B, B=4T
Sample B, B=8T
Sample B, B=12T

WHAT DOES SOURCE-DRAIN VOLTAGE DEPENDENCE SHOW

Confirms zero bias measurements and gives quantitative data on how the two spin directions repel each other.

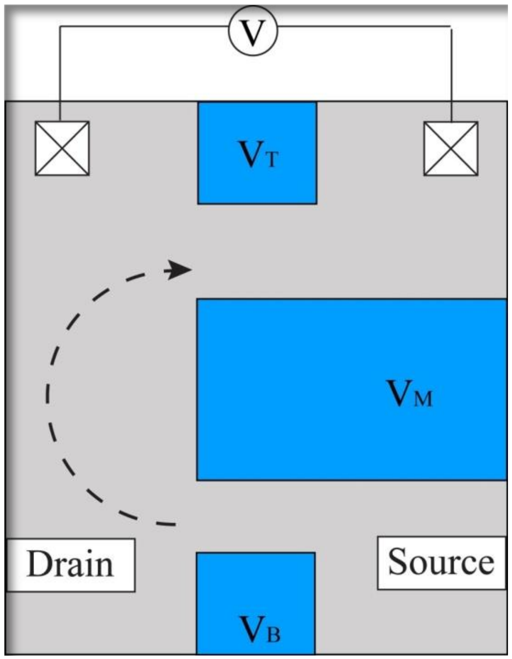
Shows that the spin down (lowest energy) slowly fills with electrons while initially repelling the spin up level at the source potential.

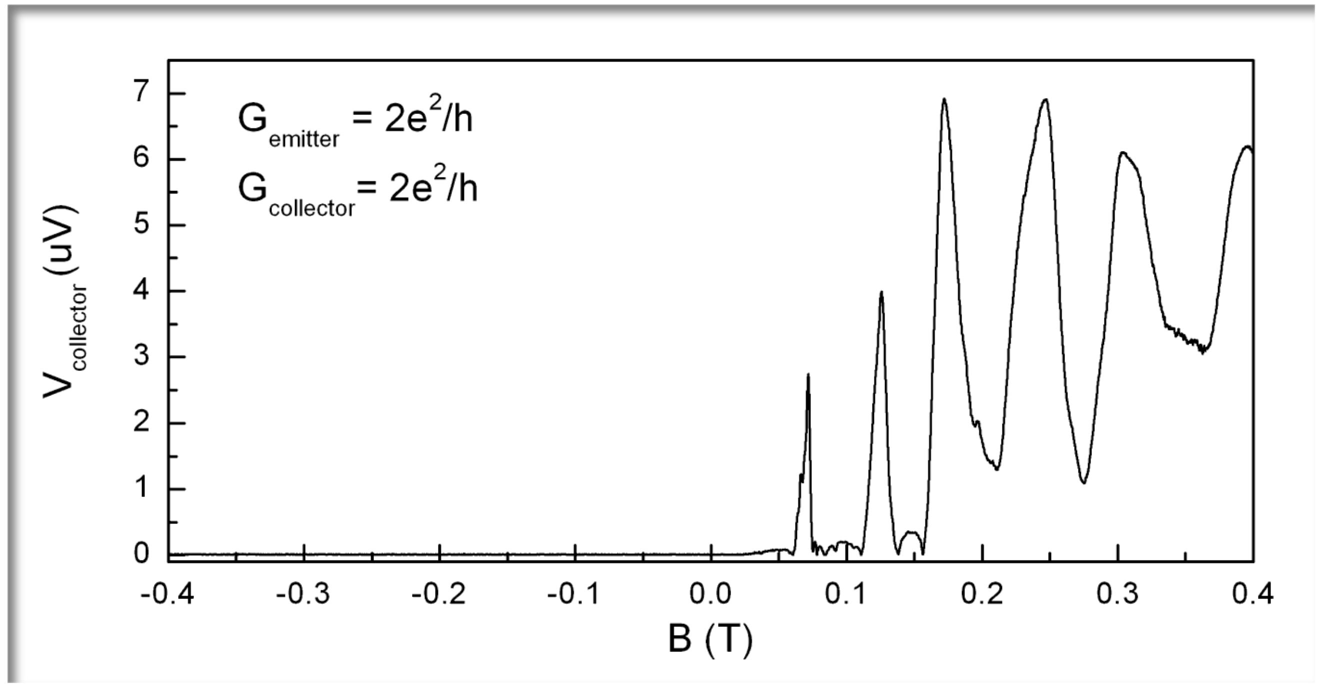
When the opposite momentum spin down electrons enter so do the spin up electrons

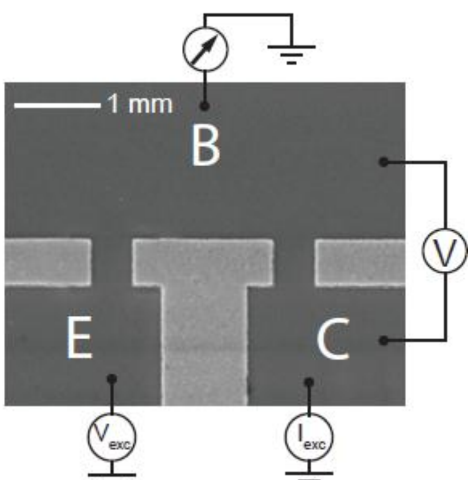
Indicates the 0.7 is due to the same effect – dynamic spin gap.

Consider the 0.25 in more detail, if a spin polarised single momentum stream of electrons could be useful in quantum logic.

Electron focusing experiment



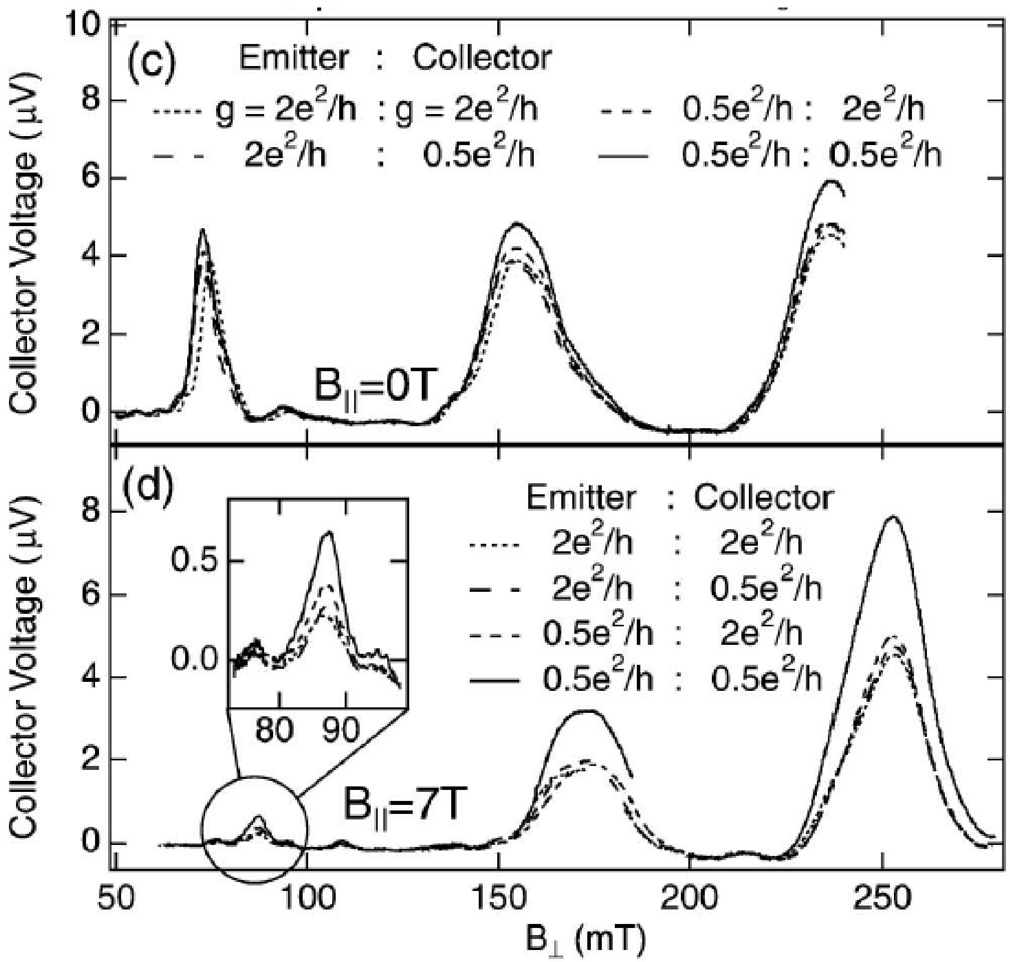




- Cyclotron motion of electrons under a perpendicular field.
- The field of the focusing peaks, B_f, is given by

$$B_f = \frac{\sqrt{8m^* E_f}}{eL}$$

Detecting spin polarization

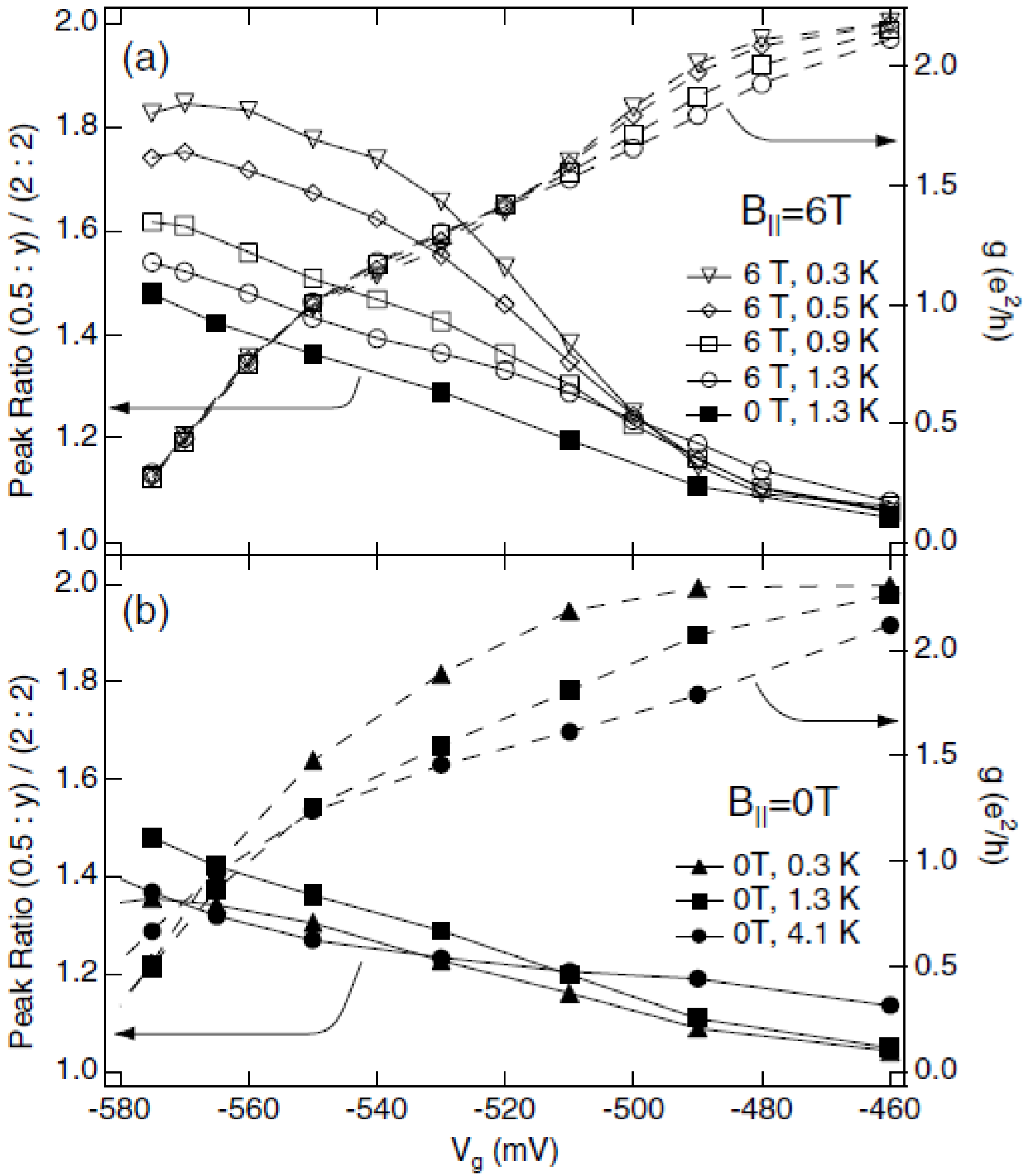


$$V_c = \alpha \frac{h}{2e^2} I_e (1 + P_e P_c)$$

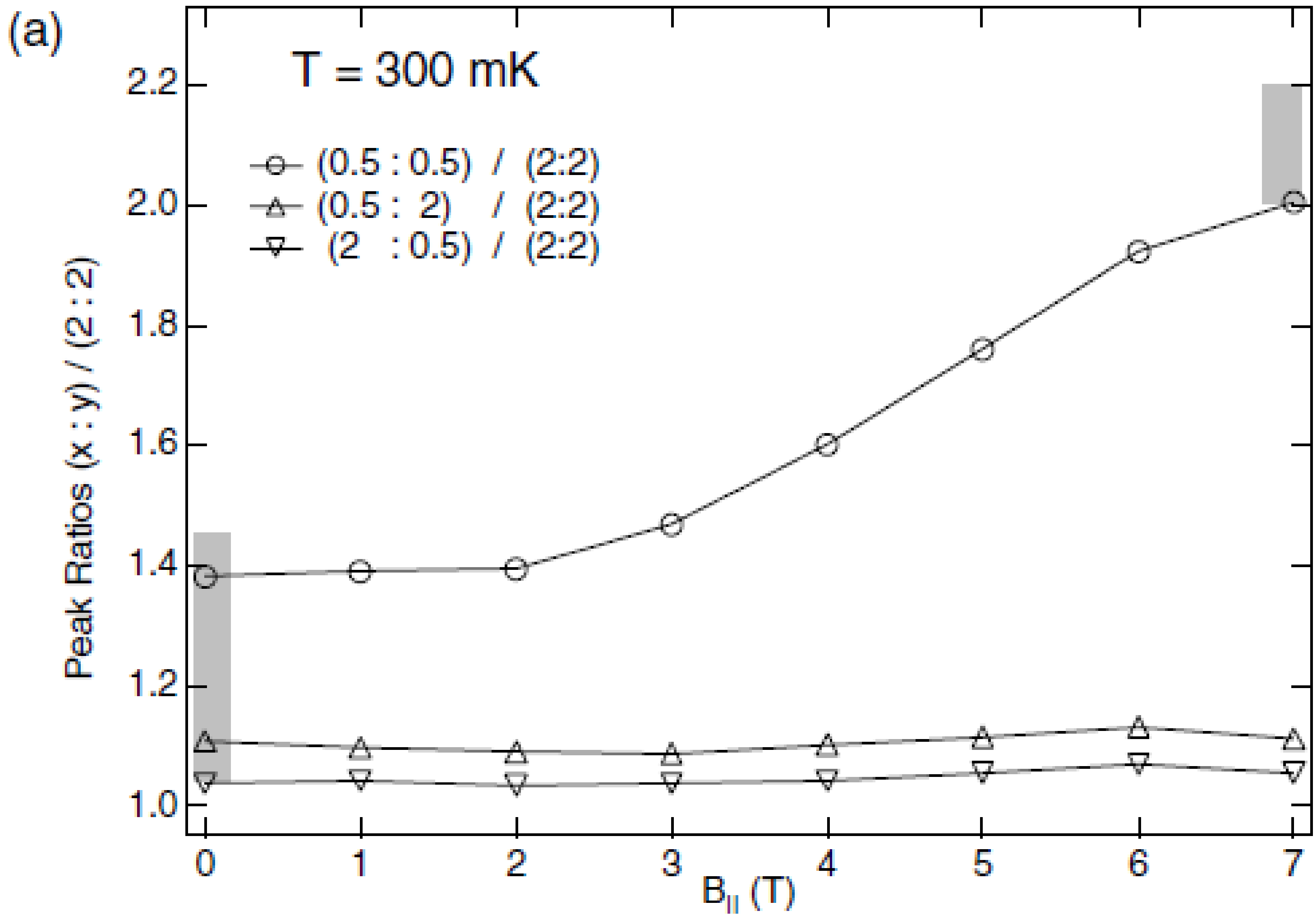
where $P=(T_{\downarrow}-T_{\uparrow})/(T_{\downarrow}+T_{\uparrow})$

This method was proposed by R. M. Potok *et al*., PRL,89, 266602, 2002 & Science 299, 679 (2003).

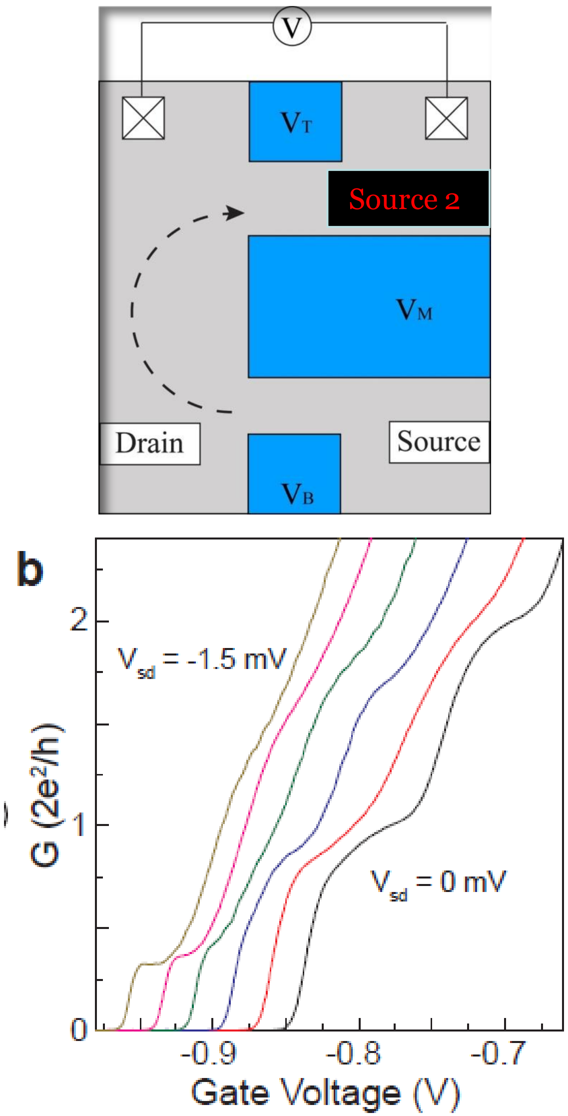
Growth of Spin Detection –R. M. Potok *et al*., PRL,89, 266602, 2002 & Science 299, 679 (2003)

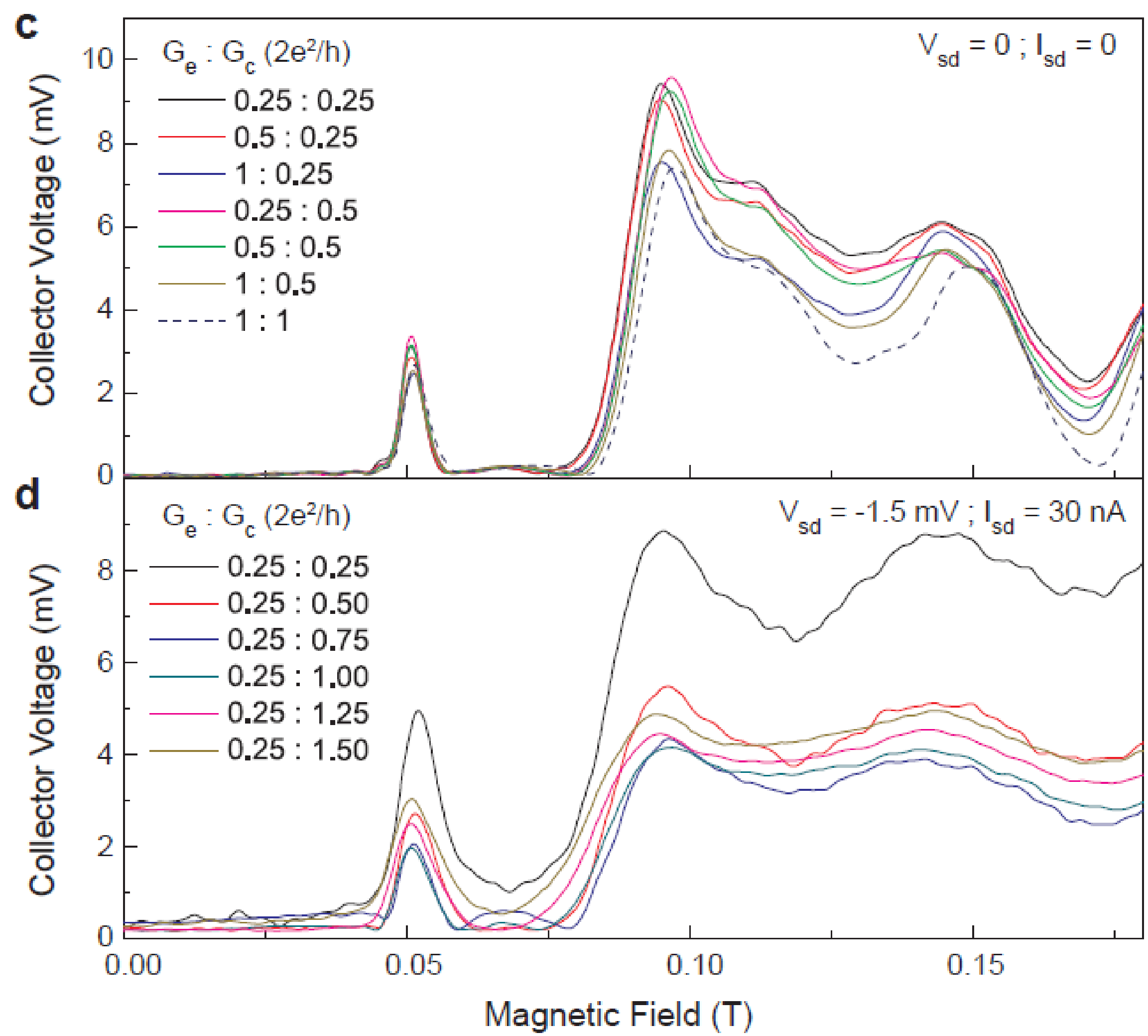


Spin Detection –R. M. Potok *et al*., PRL,89, 266602, 2002 & Science 299, 679 (2003)



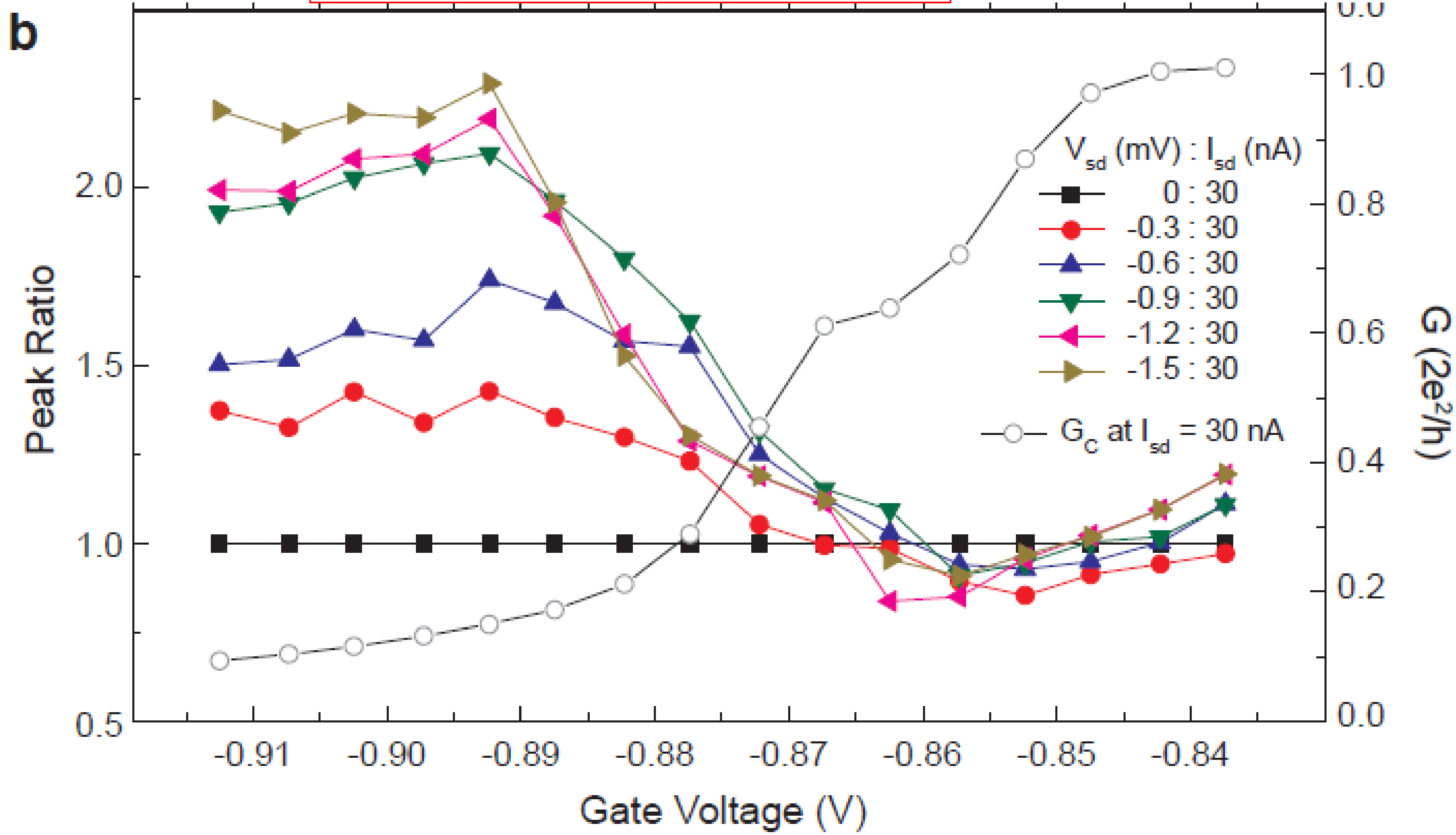
Detecting spin polarization under a source-drain bias, Chen et al, PRL in the press, arXiv:1202.5606





ELECTRICALLY INDUCED SPIN POLARISATION, Chen et al, PRL in the press, arXiv:1202.5606

$$V_c = \alpha \frac{h}{2e^2} I_e \left(1 + P_e P_c\right)$$



Spin Polarisation, B=0, , Chen et al, PRL in the press, arXiv:1202.5606