SAND2015-3994C

Quantum Transport in InAs/GaSb

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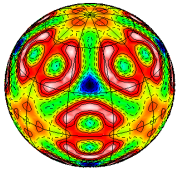

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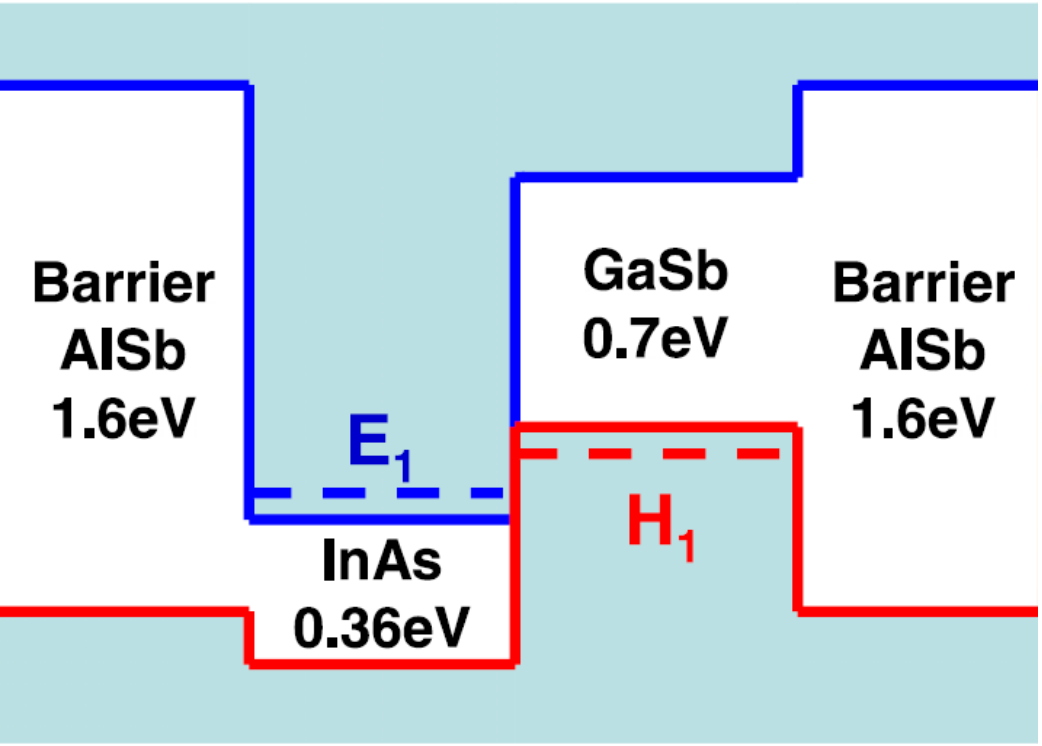
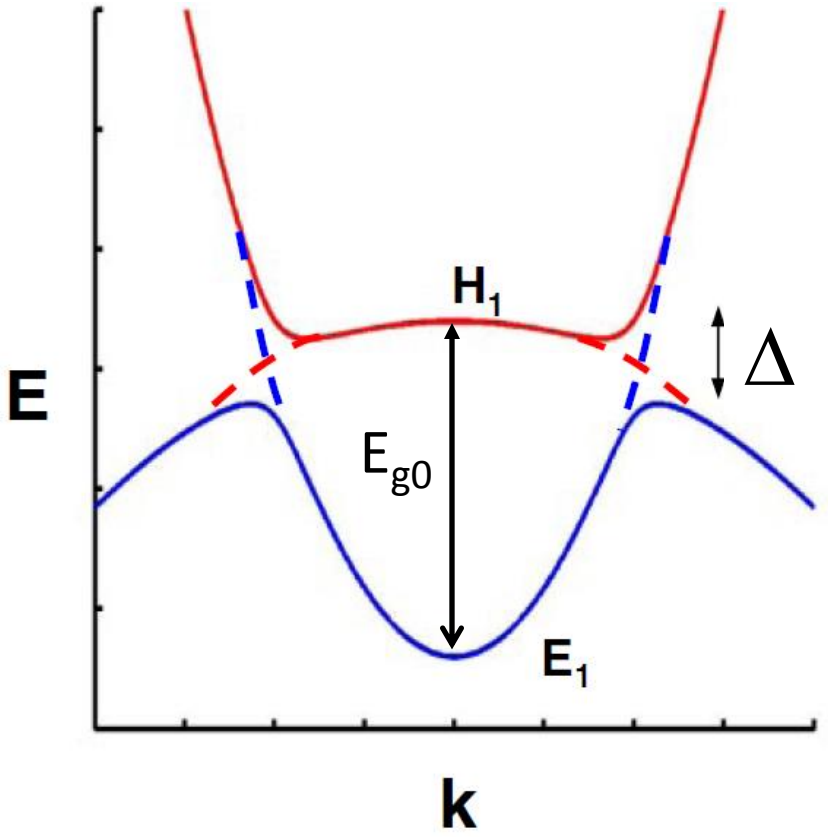
Outline

- The sample
- The experiment and results
  - Electron transport at zero magnetic field
  - Electron transport at low magnetic fields
  - Electron transport at very high magnetic fields
- Summary

The sample:





Quantum spin Hall effect

C.X. Liu, T.L. Hughes, X.L. Qi, K. Wang, and S.C. Zhang, Phys. Rev. Lett. **100**, 236601 (2008).

Growth structure:

air

InAs 20A (or GaSb 20A)

AlSb 500A

GaSb QW 50A

InAs QW 150A

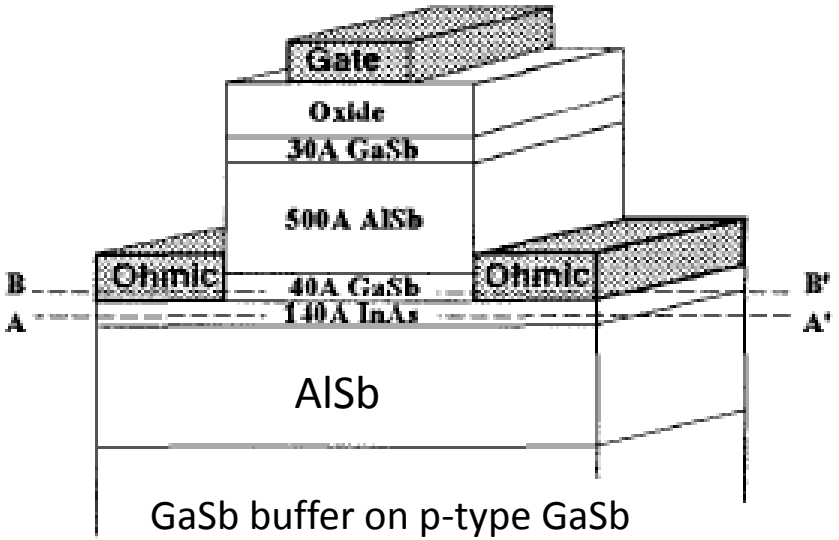
AlSb 1um

GaSb 1um

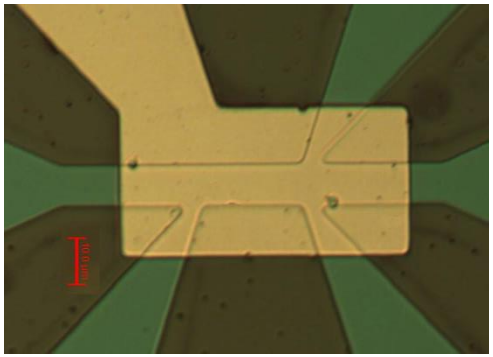
GaSb substrate (p-doped)

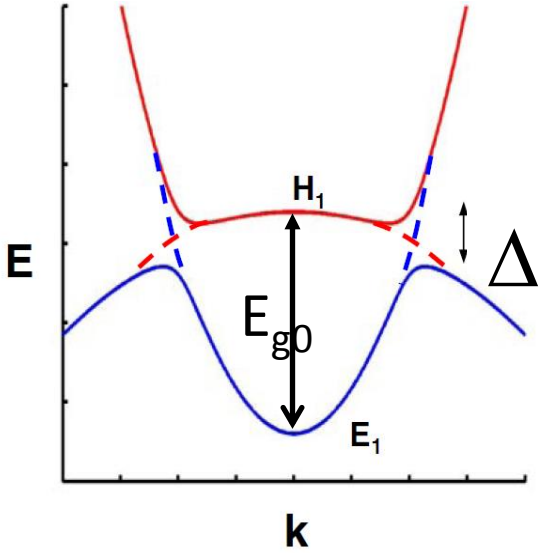
Field-effect transistor:

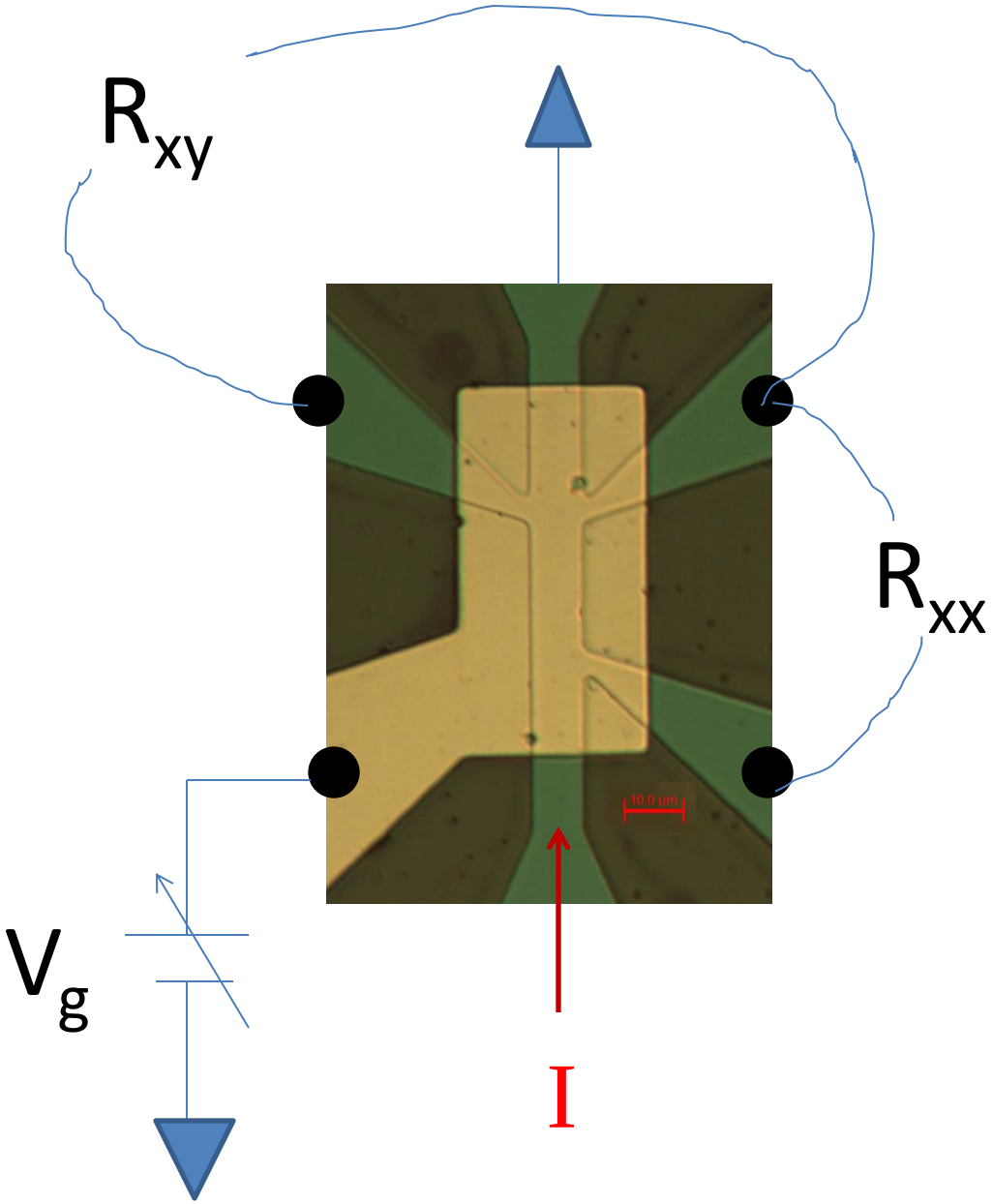
Yang et al, Appl. Phys. Lett. **69**, 85 (1996).



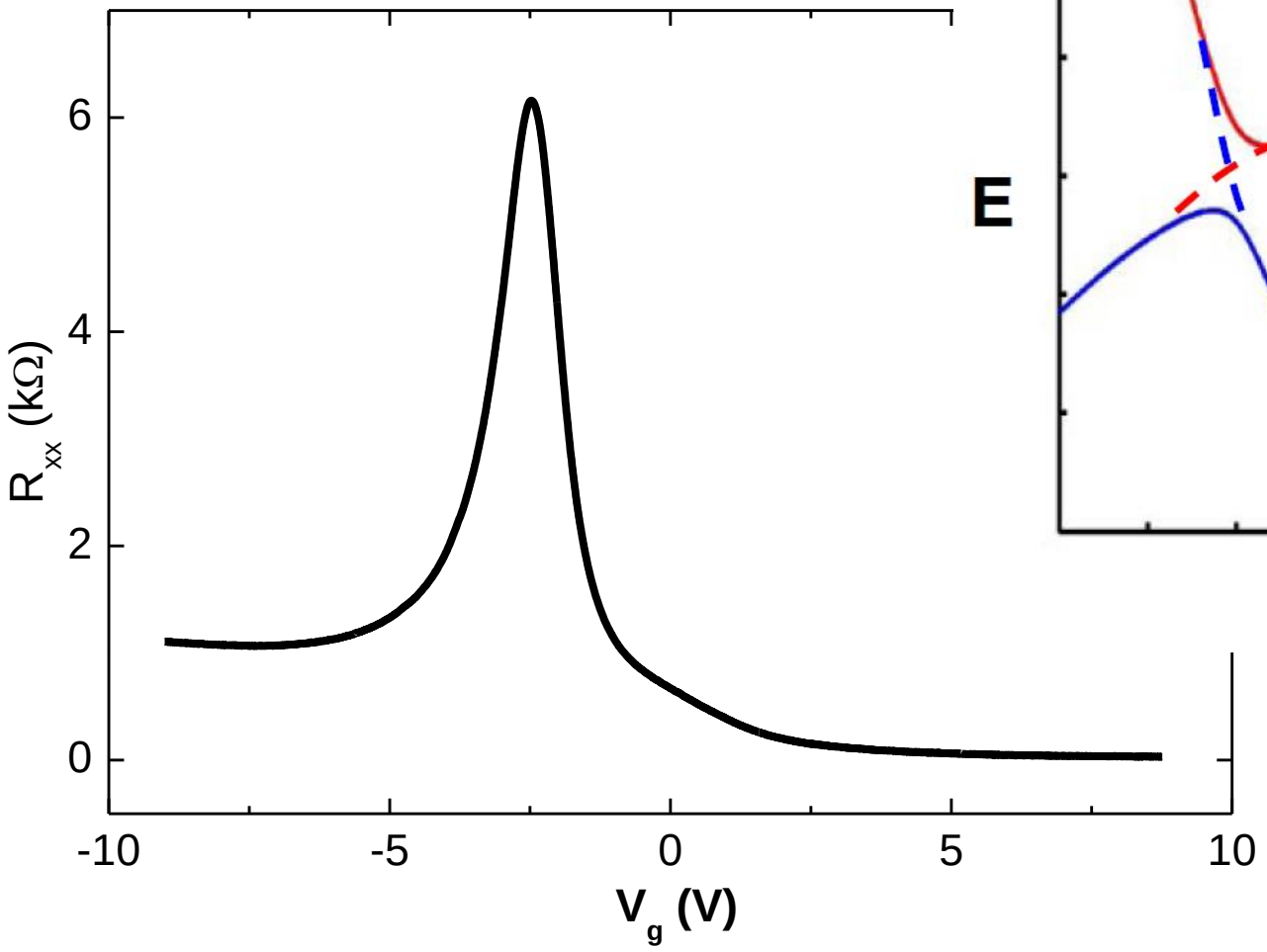
GaSb buffer on p-type GaSb

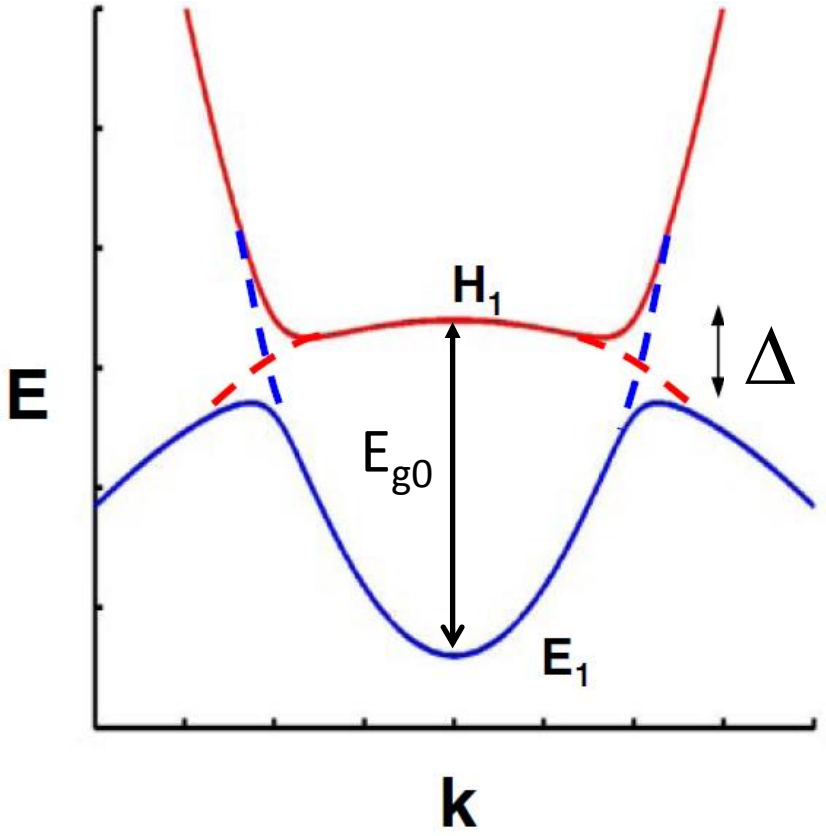


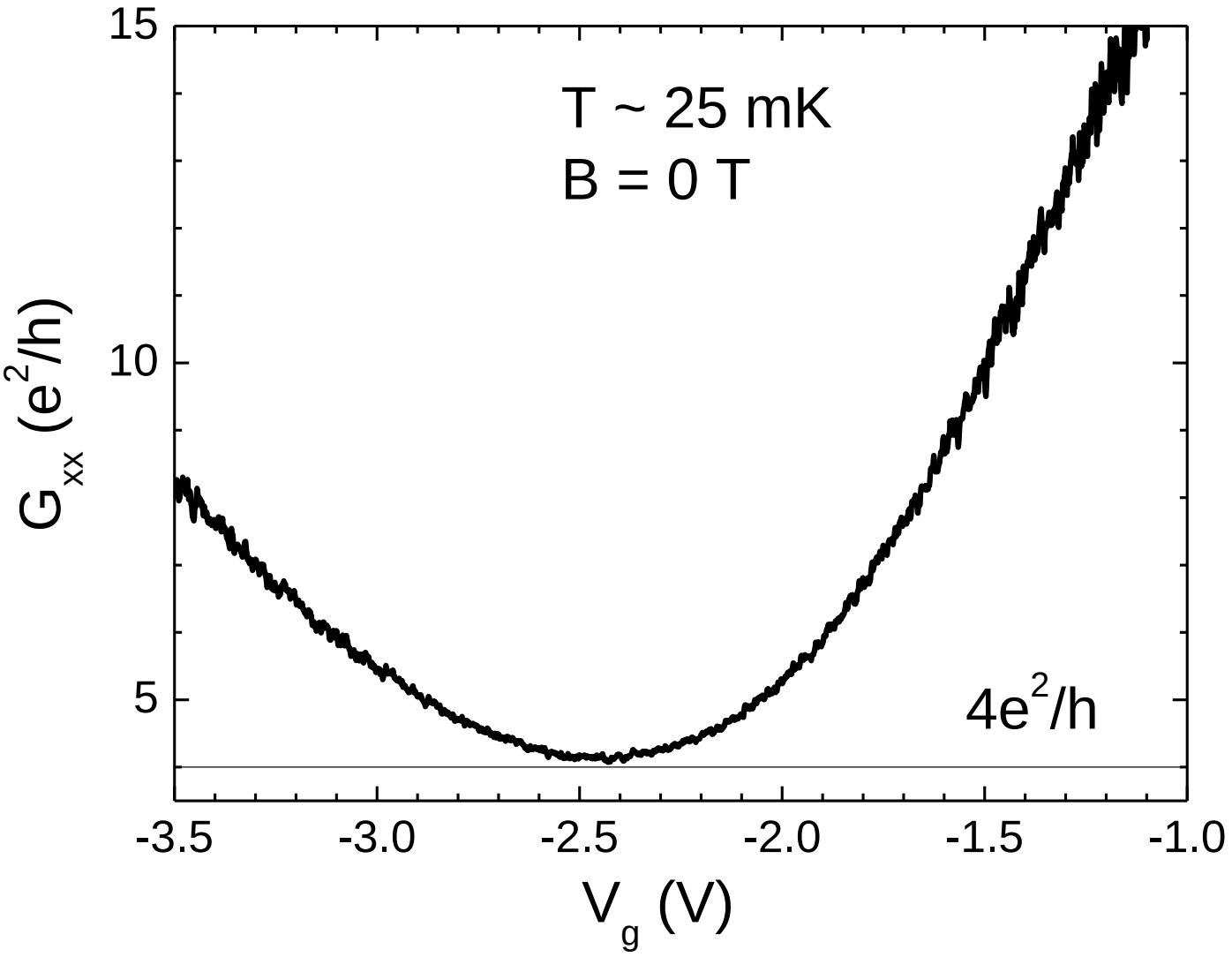



R_{xy}
R_{xx}
V_g
I
10.0 µm

Electron transport at zero magnetic field:






T ~ 25 mK
B = 0 T
4e²/h
G_xx (e²/h)
V_g (V)
15
10
5
-3.5
-3.0
-2.5
-2.0
-1.5
-1.0

$$\sigma^{th}_{xx} \approx e^2/h \times E_{g0}/\Delta$$

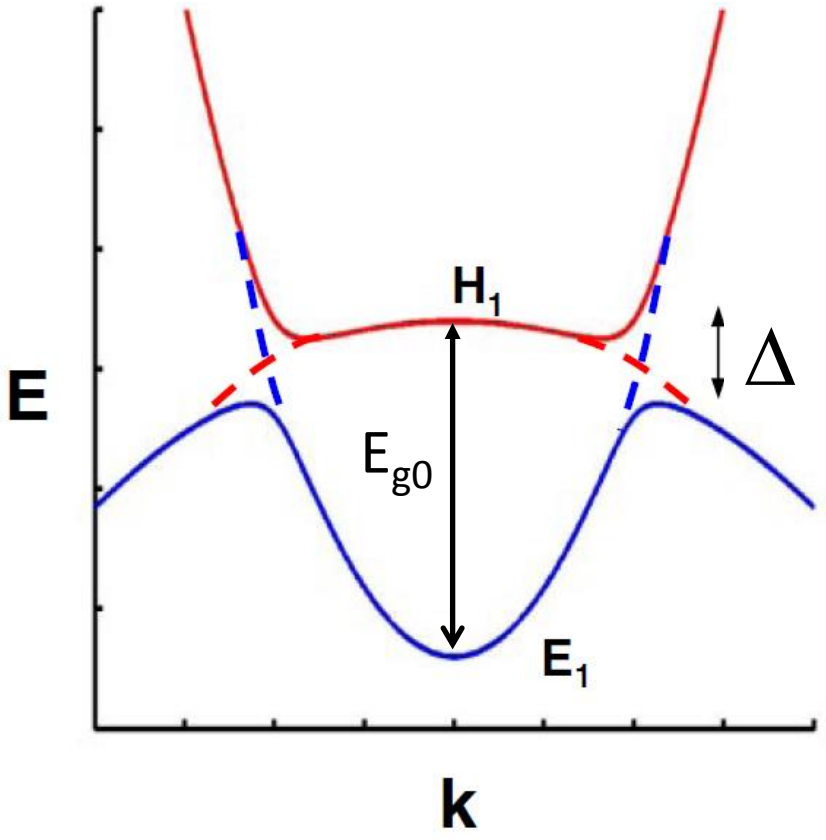
Y. Naveh and B. Laikhtman, Europhys. Lett. **55**, 545 (2001).

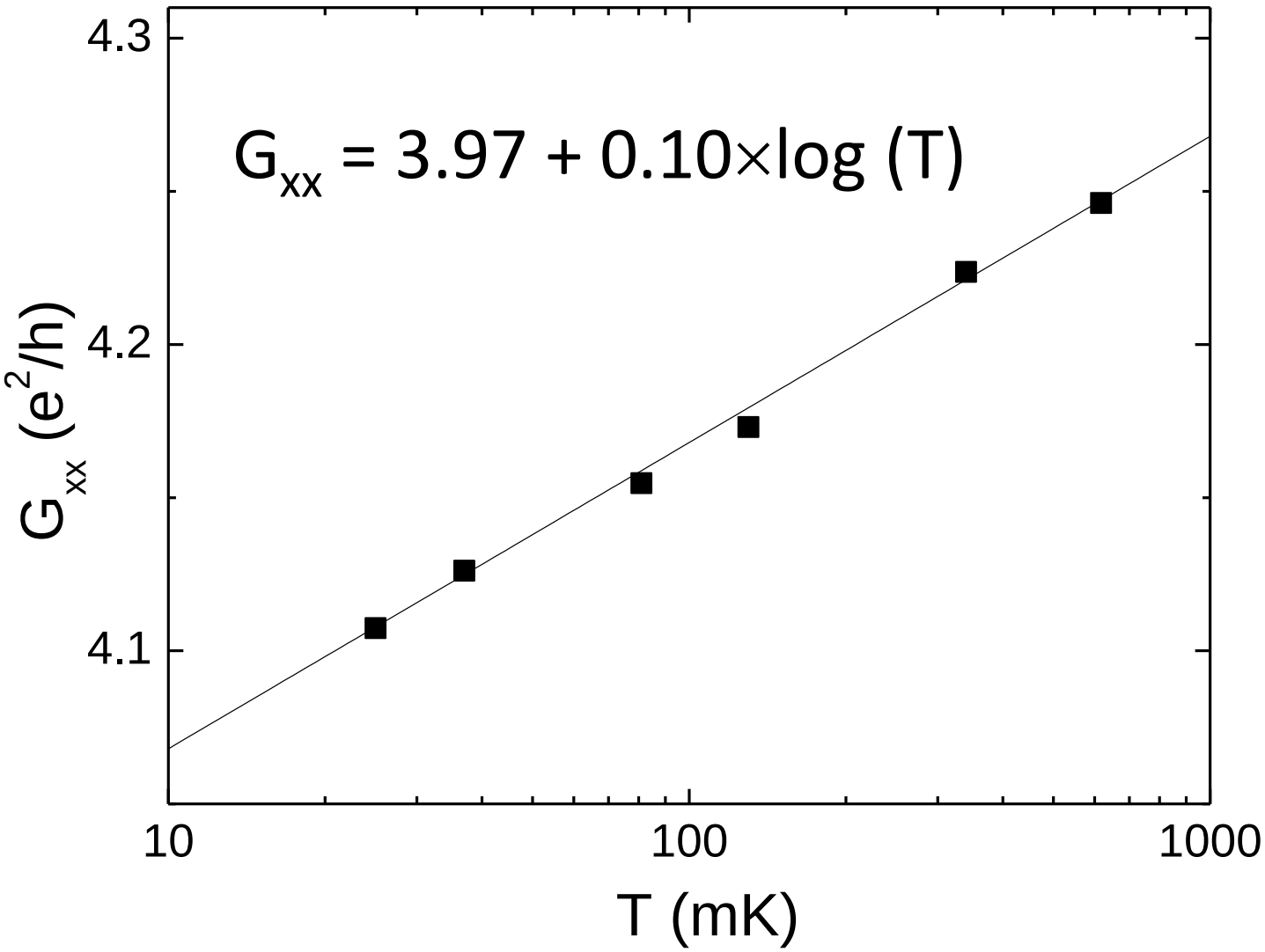
E_{g0} ~ 15 meV

Δ~ 1 meV

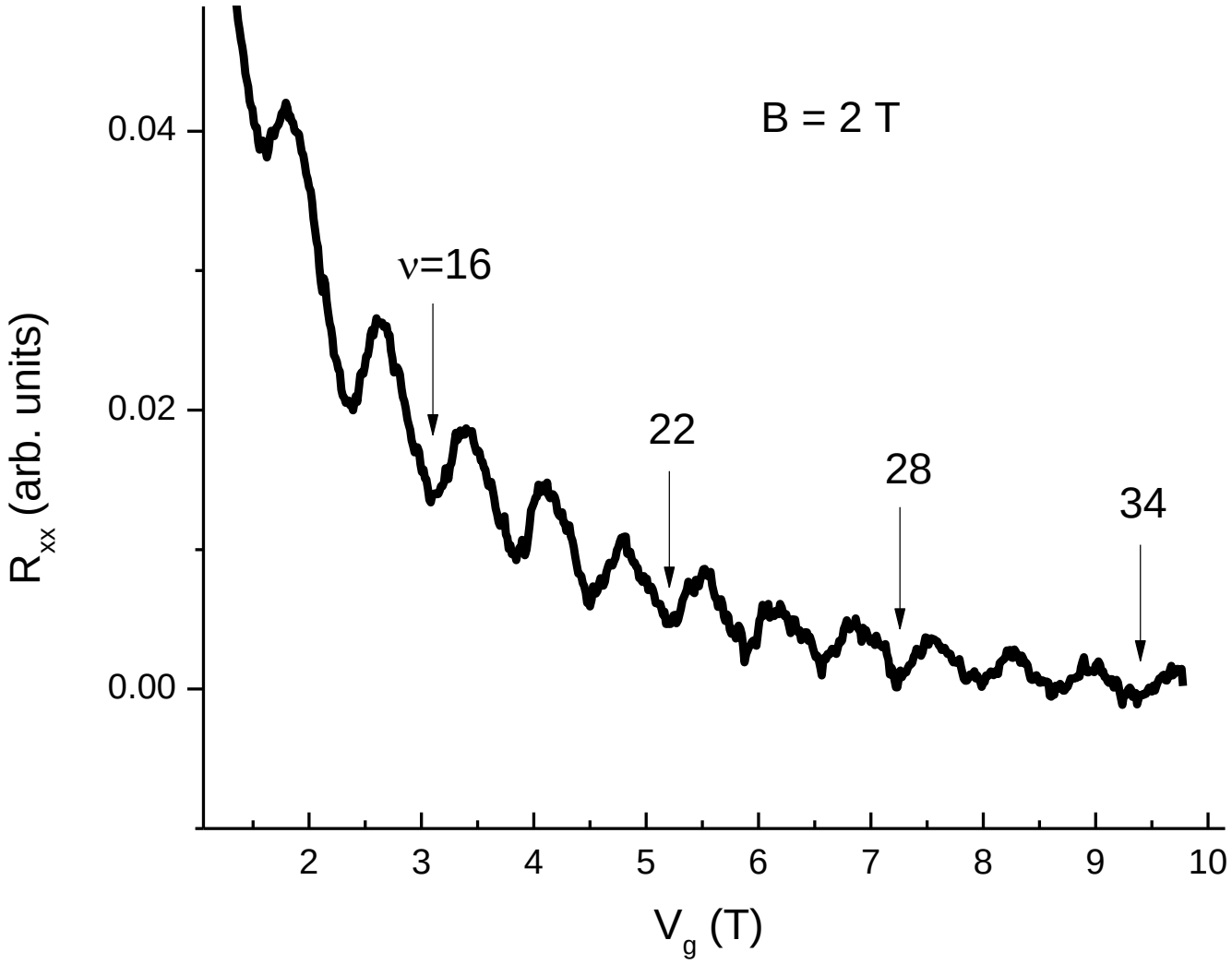
$\sigma^{th}_{xx} \approx 15\ e^2/h$

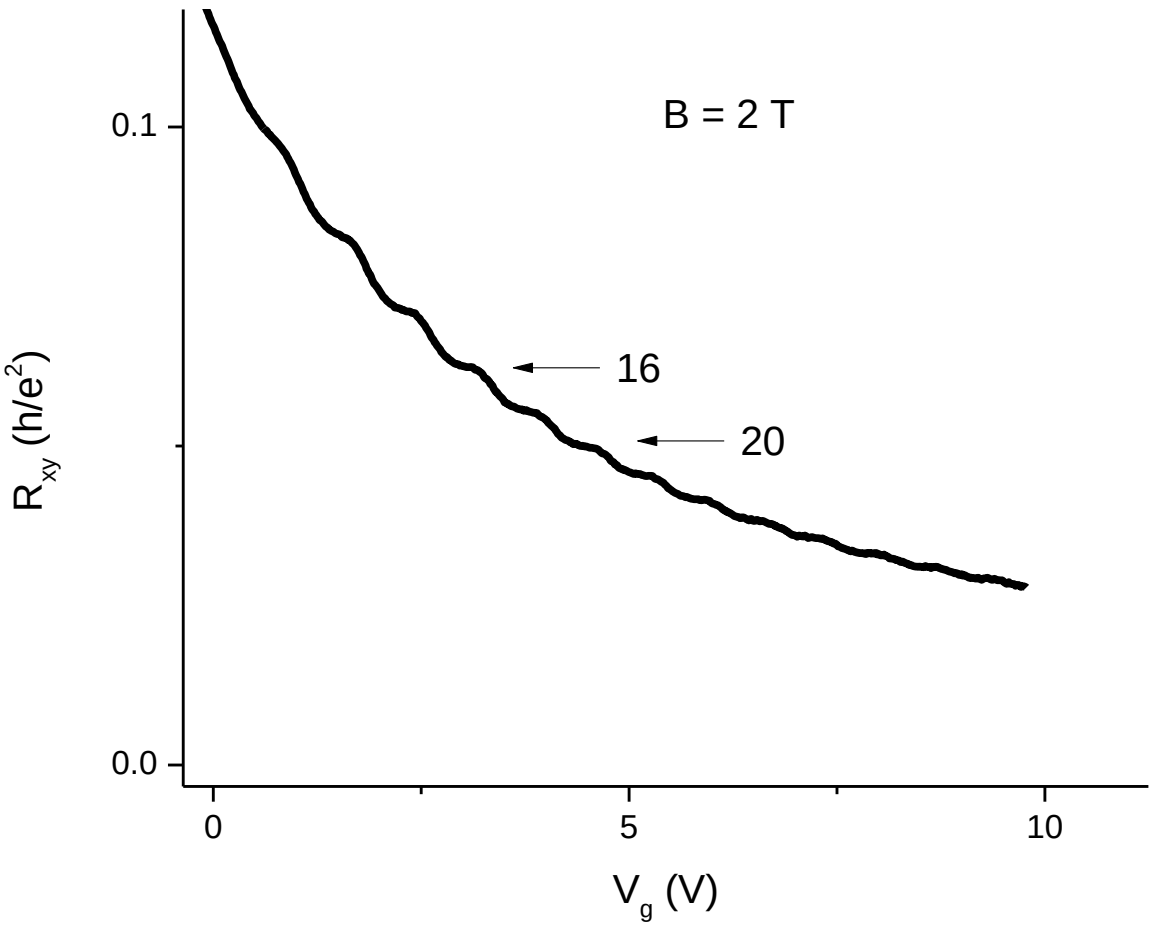
$G^{th}_{xx} = 5\ e^2/h \sim 4\ e^2/h$

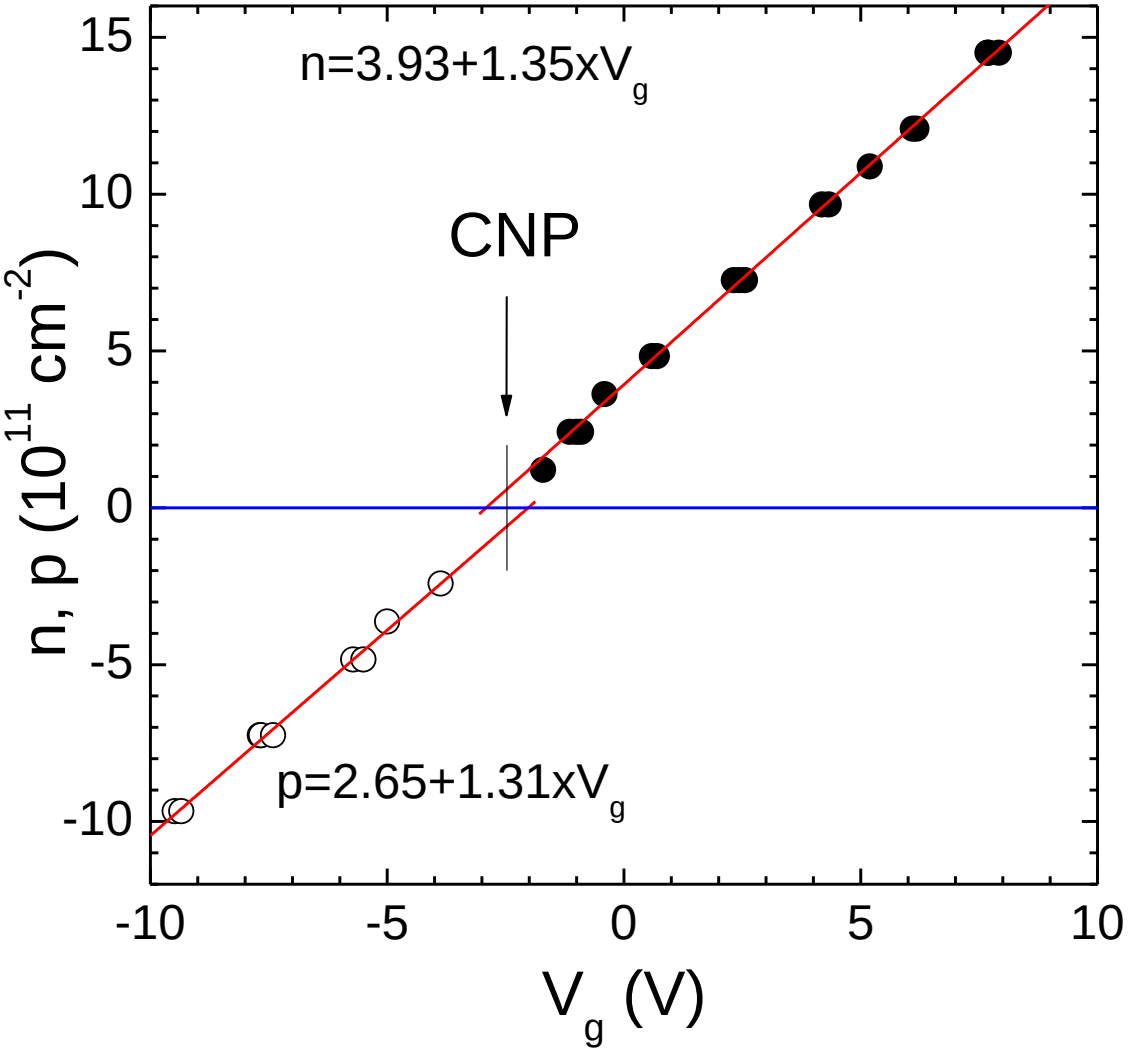



$G_{xx} = 3.97 + 0.10 \times \log(T)$
G_{xx} (e^2/h)
4.3
4.2
4.1
10
100
1000
T (mK)

Electron transport at low magnetic fields:

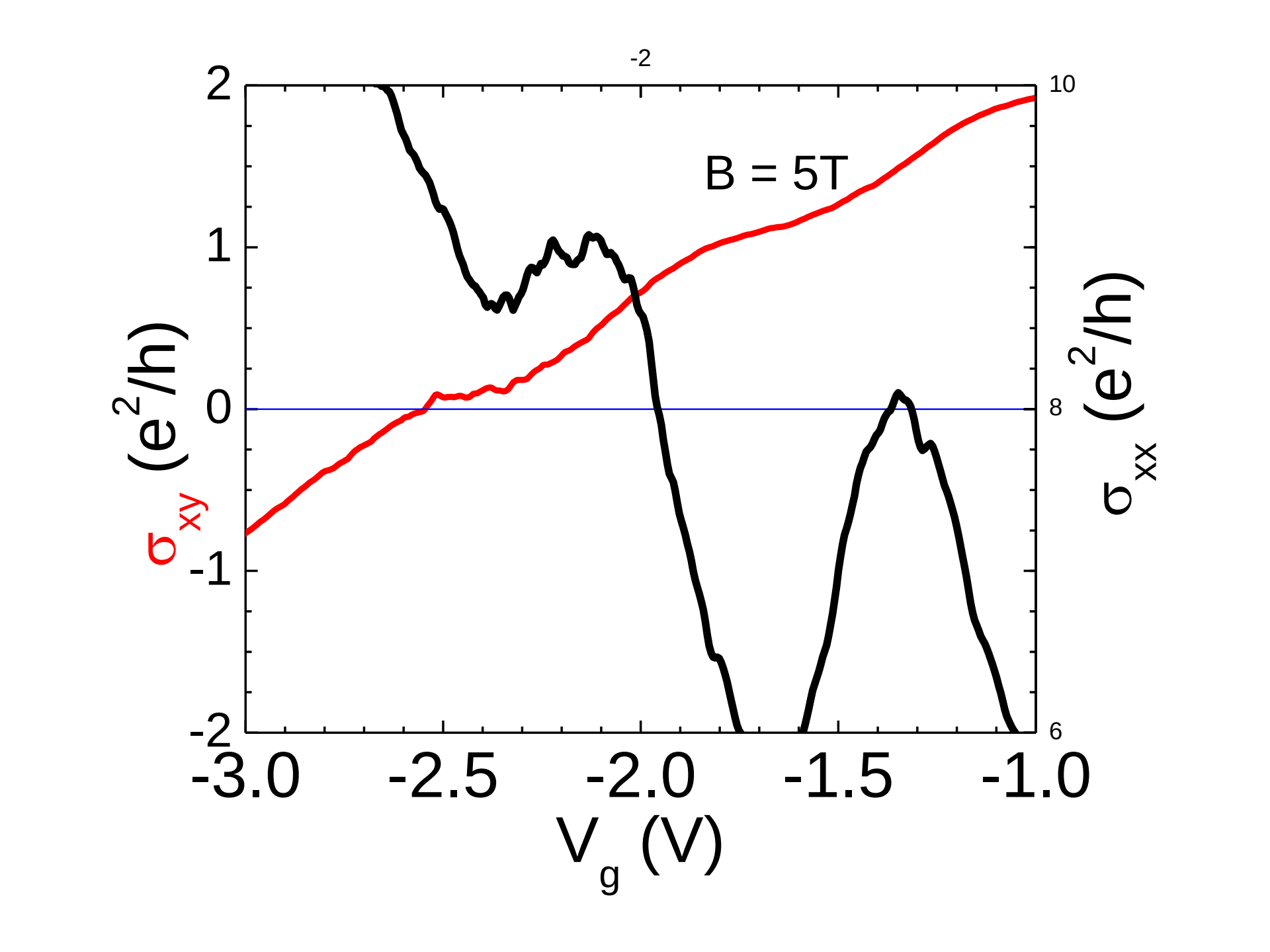



B = 2 T
0.1
0.0
16
20
0
5
10
R_{xy} (h/e^2)
V_g (V)

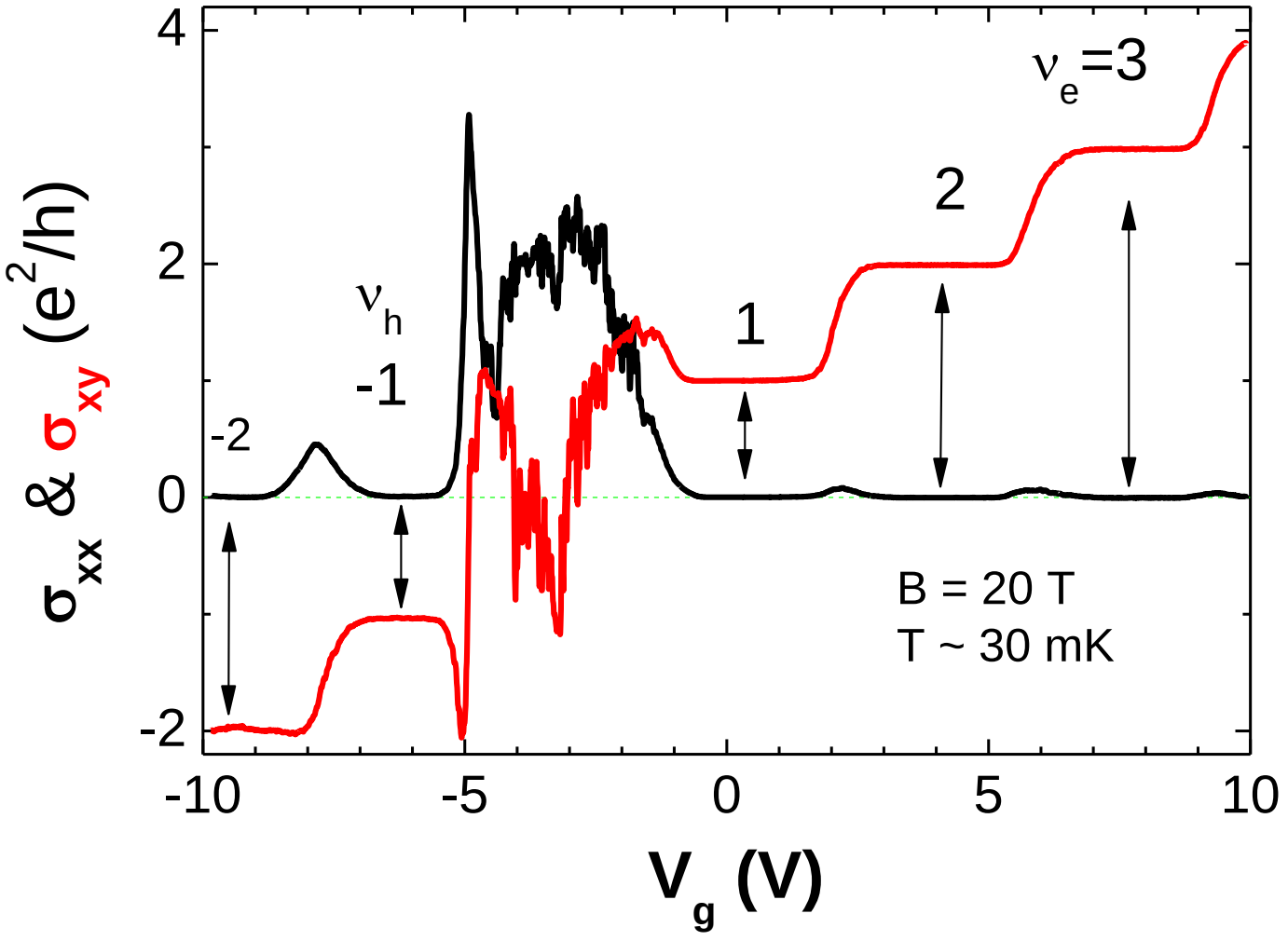


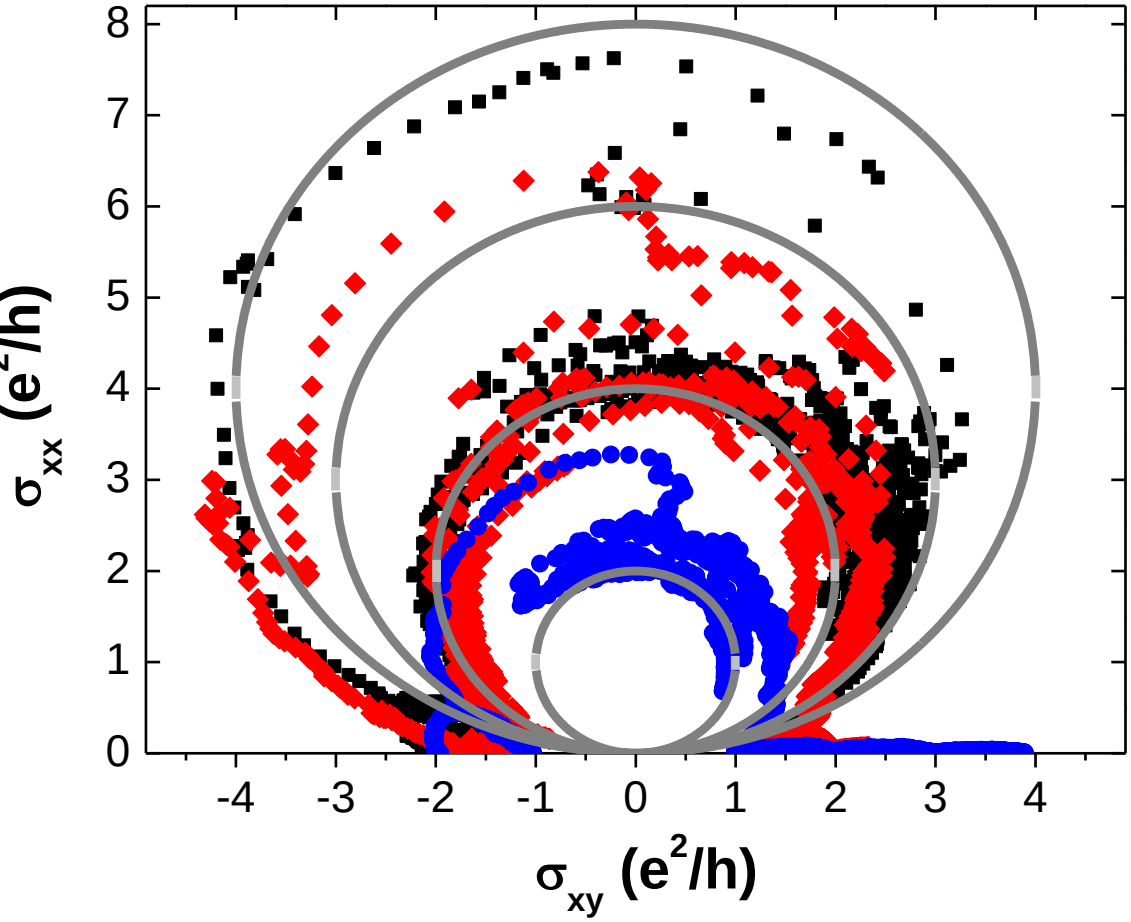
At CNP (n + p =0)

$|n| = |p| \sim 0.6\times10^{11}$ cm^{-2}


-2
2
1
0
-1
-2
10
8
6
B = 5T
σxy (e2/h)
σxx (e2/h)
-3.0
-2.5
-2.0
-1.5
-1.0
Vg (V)

Electron transport at high magnetic fields:

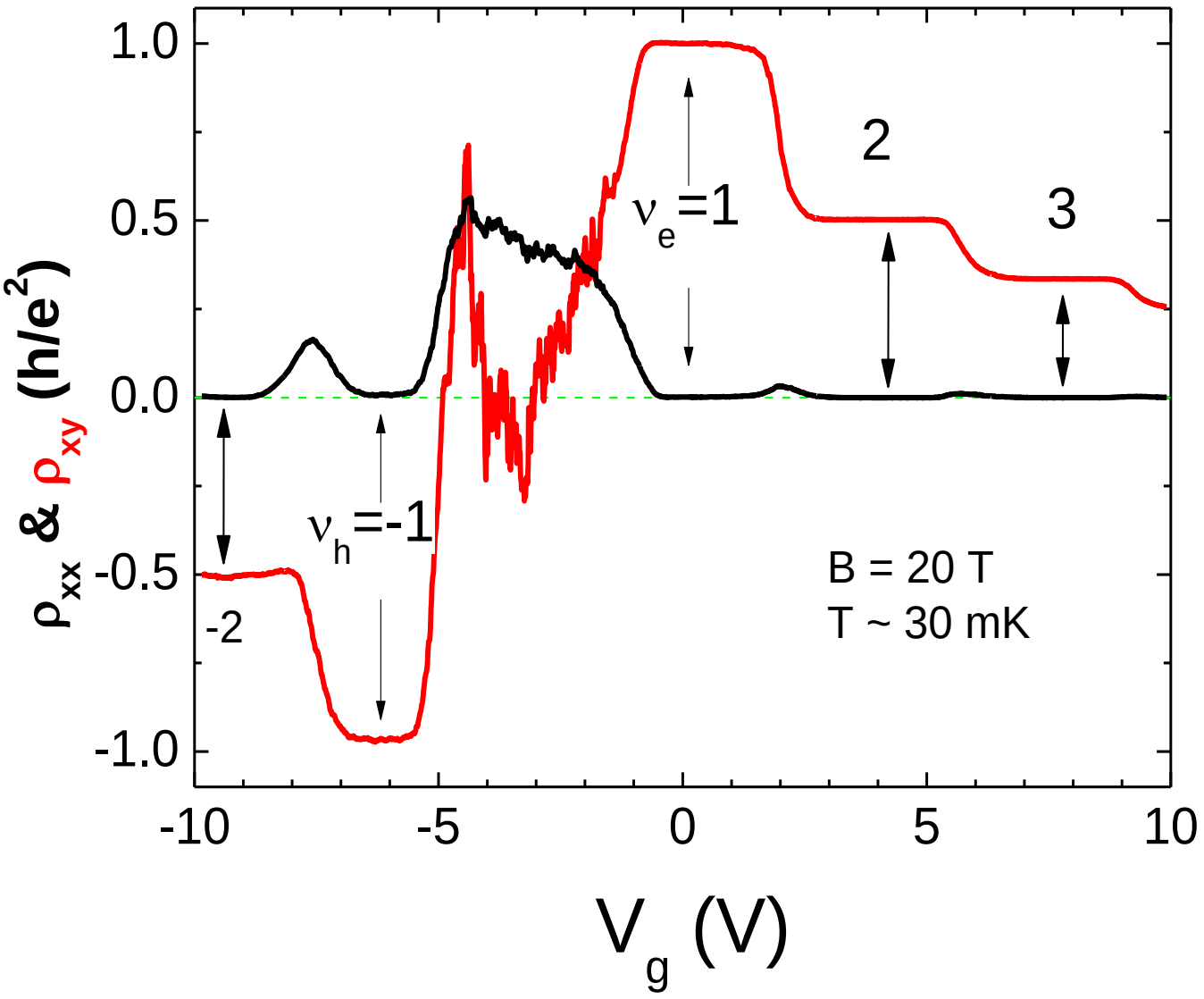




$$(\sigma_{xx} - N)^2 + \sigma_{xy}^2 = N^2$$

$$(\sigma_{xx} - N)^2 + \sigma_{xy}^2 = N^2$$

$$\rho_{xx} = h/e^2/(2N)$$


1.0
0.5
0.0
-0.5
-1.0
-10
-5
0
5
10
ρ_{xx} & ρ_{xy} (h/e^2)
V_g (V)
ν_e=1
ν_h=-1
2
3
-2
B = 20 T
T ~ 30 mK

$$(\sigma_{xx} - N)^2 + \sigma_{xy}^2 = N^2$$

$$\rho_{xx} = h/e^2/(2N)$$

Due to quantum spin Hall effect?

C.X. Liu, T.L. Hughes, X.L. Qi, K. Wang, and S.C. Zhang, Phys. Rev. Lett. **100**, 236601 (2008).
I. Knez, R.R. Du, and G. Sullivan, Phys. Rev. Lett. **107**, 136603 (2011).

Summary:

(1) well-developed integer quantum Hall effect states at Landau level fillings ν=1, 2 in the hole regime and ν=1, 2, 3… in the electron regime.

(2) a chaotic quantum transport behavior at extremely high magnetic fields around the charge neutrality point (CNP).

(3) a circular conductivity law in σ_{xx} versus σ_{xy}.