Strained HgTe: Magnetotransport and magnetocapacitance

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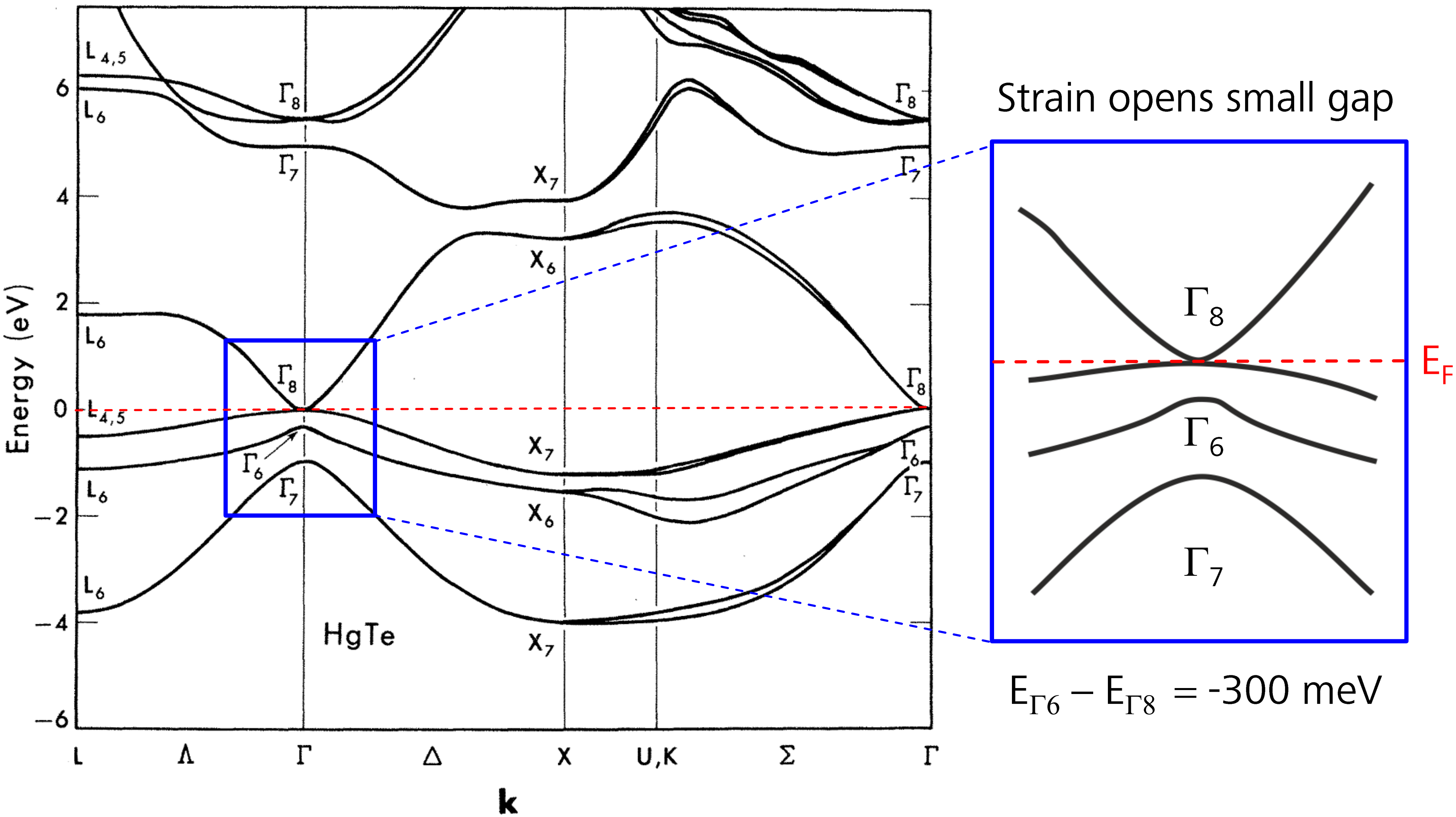
& close cooperation with S. Ganichev's group

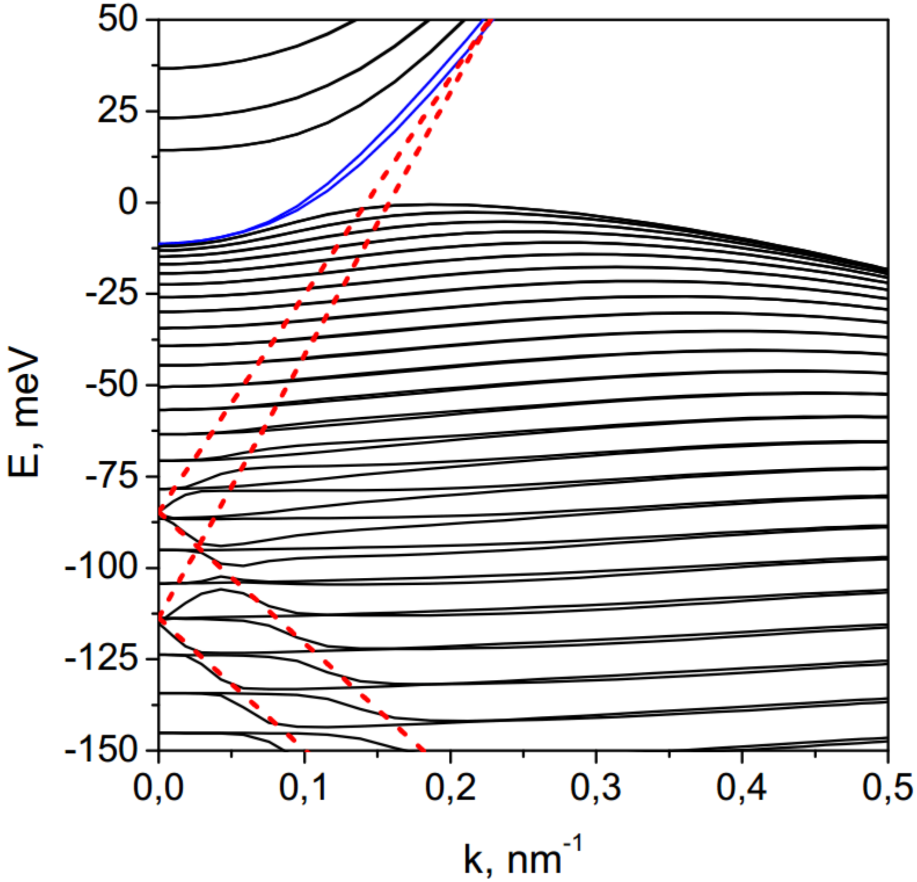
HgTe: Inverted band structure

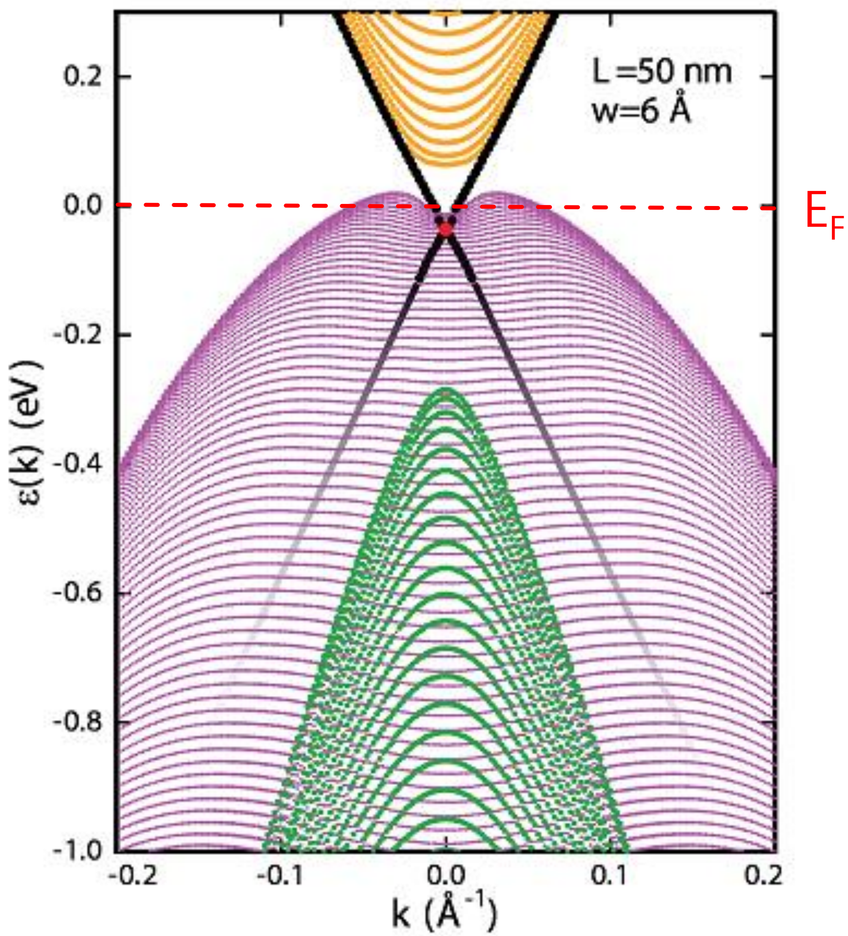


$E_{\Gamma 6} - E_{\Gamma 8} = -300\ \text{meV}$

D. J. Chadi et al., PRB **5** 3058 (1972)

Band structure of strained HgTe (001)

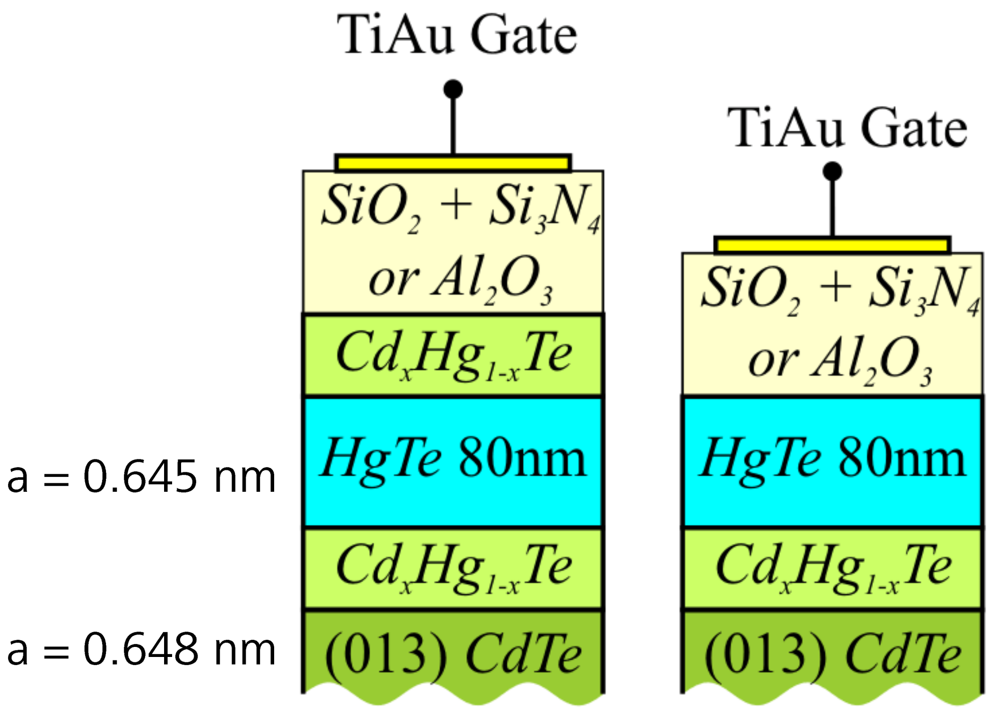


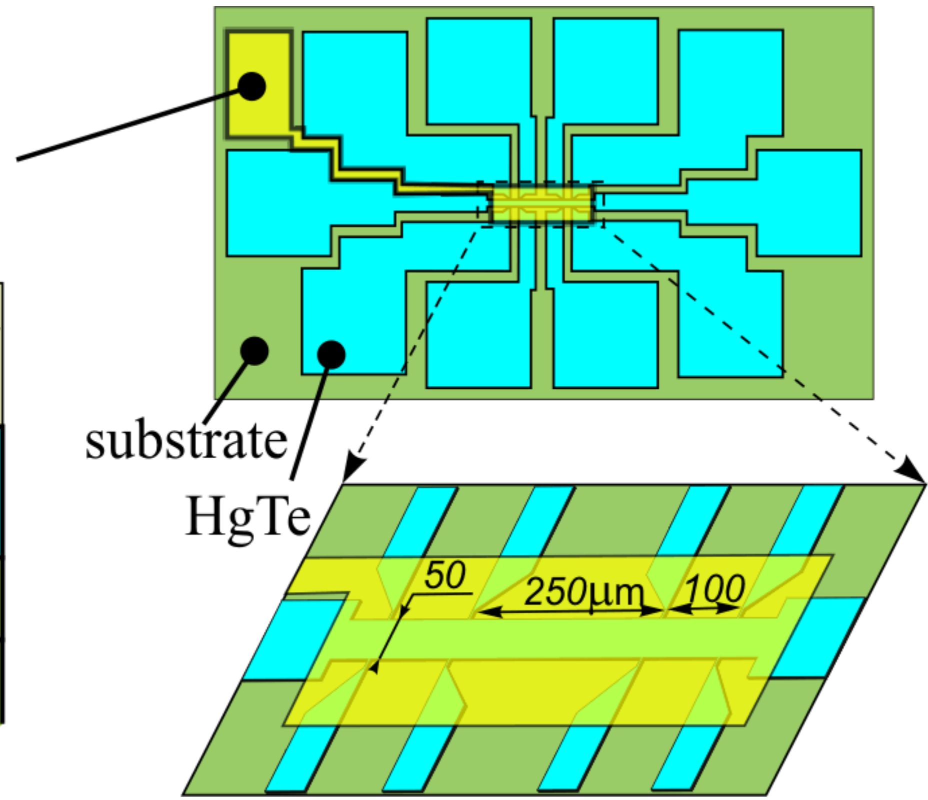


C. Brüne et al., PRL **106**,126803 (2011)

O. Crauste et al.,arXiv:1307.2008v1

Devices





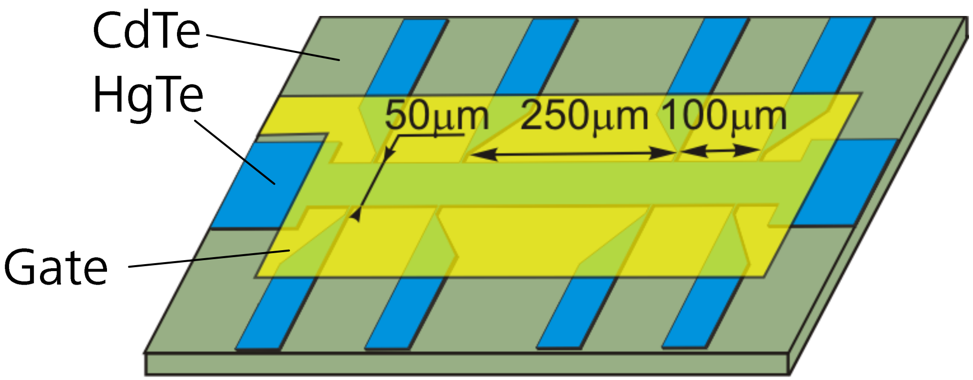
HgTe tensile strained

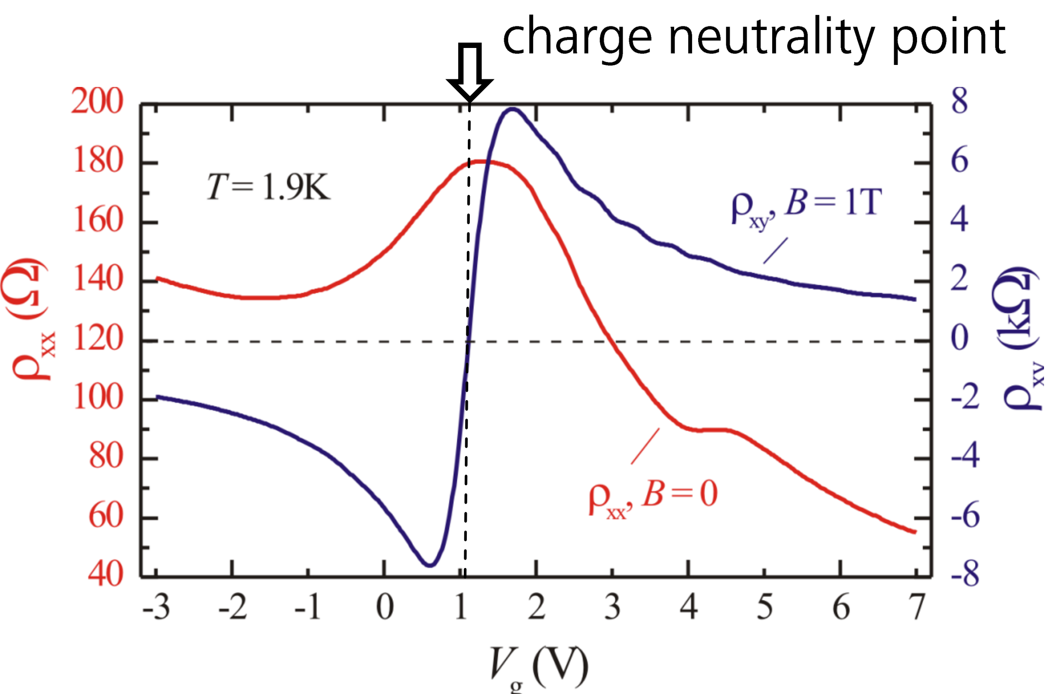
high mobility: up to $4 \cdot 10^5$ cm^2/Vs

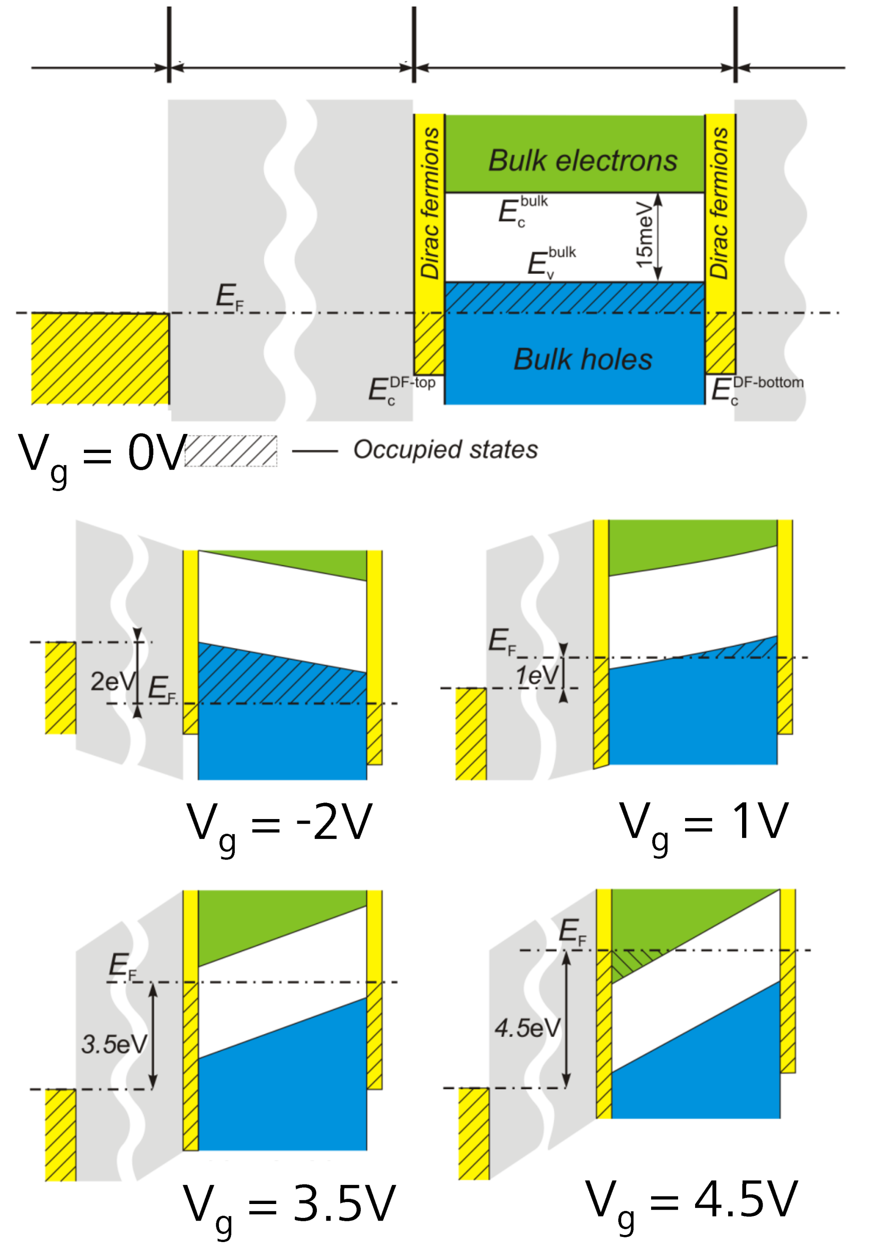
HgTe material:

Nikolai Mikhailov, Sergey Dvoretsky, Novosibirsk

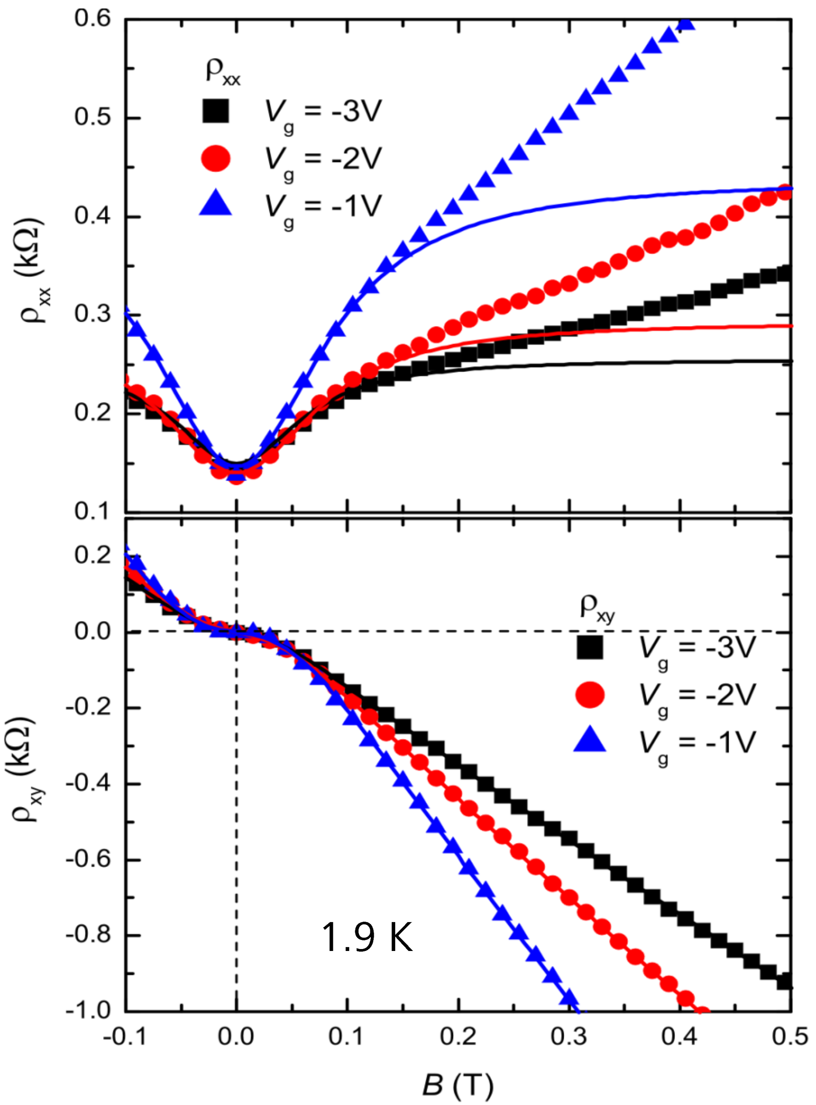
The system


CdTe
HgTe
Gate
50µm
250µm
100µm


charge neutrality point
T = 1.9K
ρxy, B = 1T
ρxx, B = 0
ρxx (Ω)
ρxy (kΩ)
Vg (V)


Bulk electrons
Bulk holes
Dirac fermions
15meV
EF
Vg = 0V
Occupied states
2eV
Vg = -2V
1eV
Vg = 1V
3.5eV
Vg = 3.5V
4.5eV
Vg = 4.5V

N and P from 2-carrier Drude model

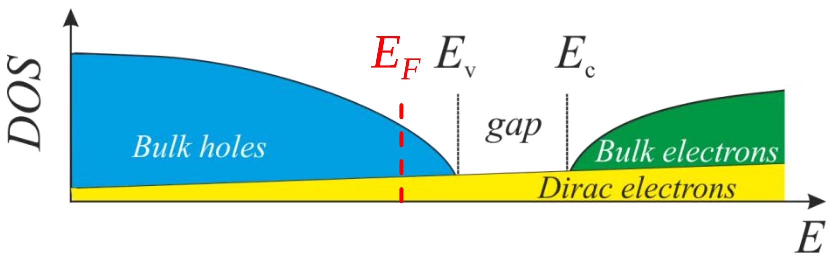


$$\sigma_{xx} = \sigma_{xx}^{(N)} + \sigma_{xx}^{(P)}$$
$$\sigma_{xy} = \sigma_{xy}^{(N)} + \sigma_{xy}^{(P)}$$

with

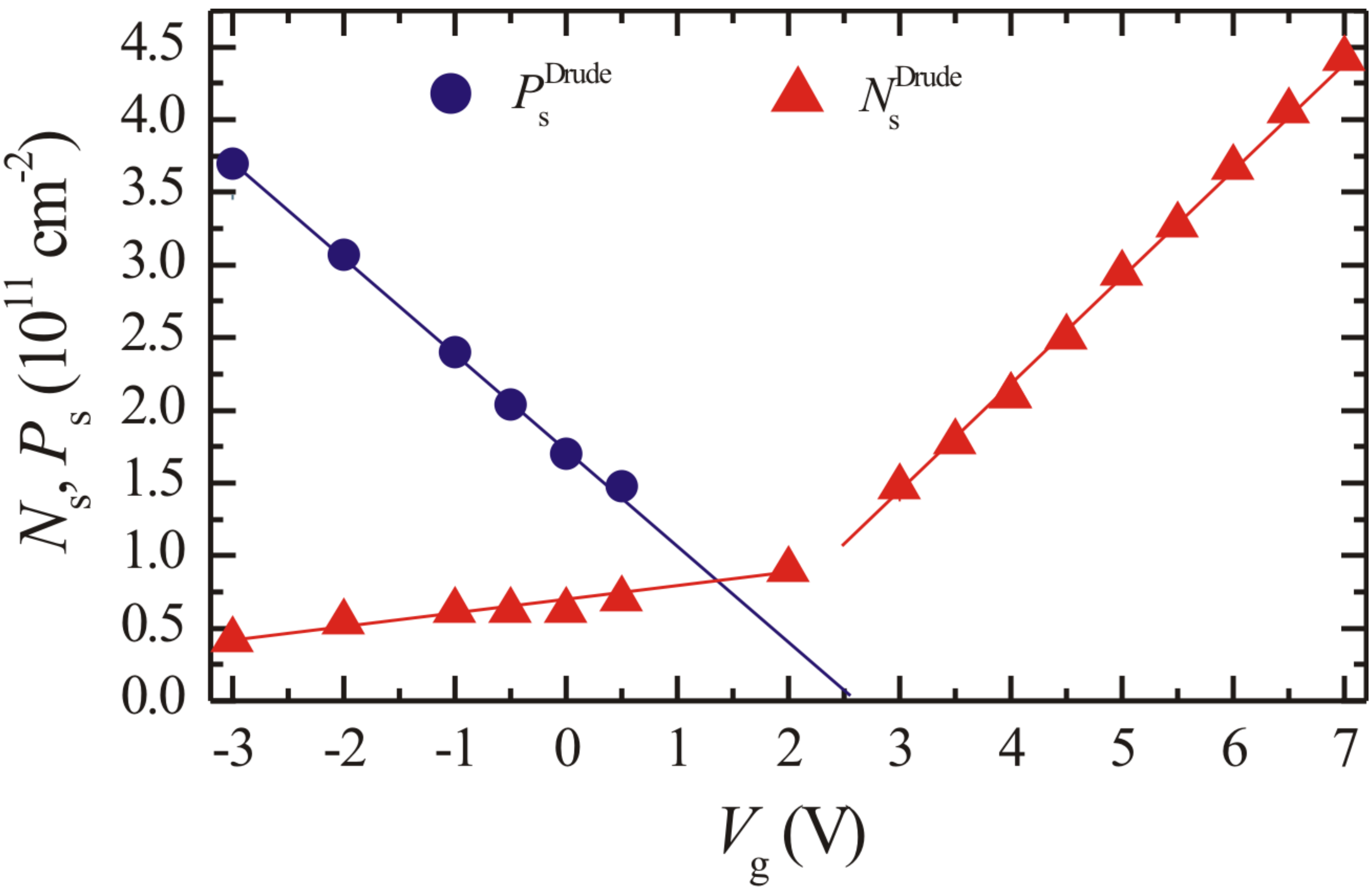
$$\sigma_{xx}^{(N)} = e\frac{N\mu_N}{1+(\mu_N B)^2};\ \sigma_{xx}^{(P)} = e\frac{P\mu_P}{1+(\mu_P B)^2};$$
$$\sigma_{xy}^{(N)} = e\frac{N\mu_N^2 B}{1+(\mu_N B)^2};\ \sigma_{xy}^{(P)} = e\frac{P\mu_P^2 B}{1+(\mu_P B)^2}$$

ρ_{xx} and ρ_{xy} from tensor inversion



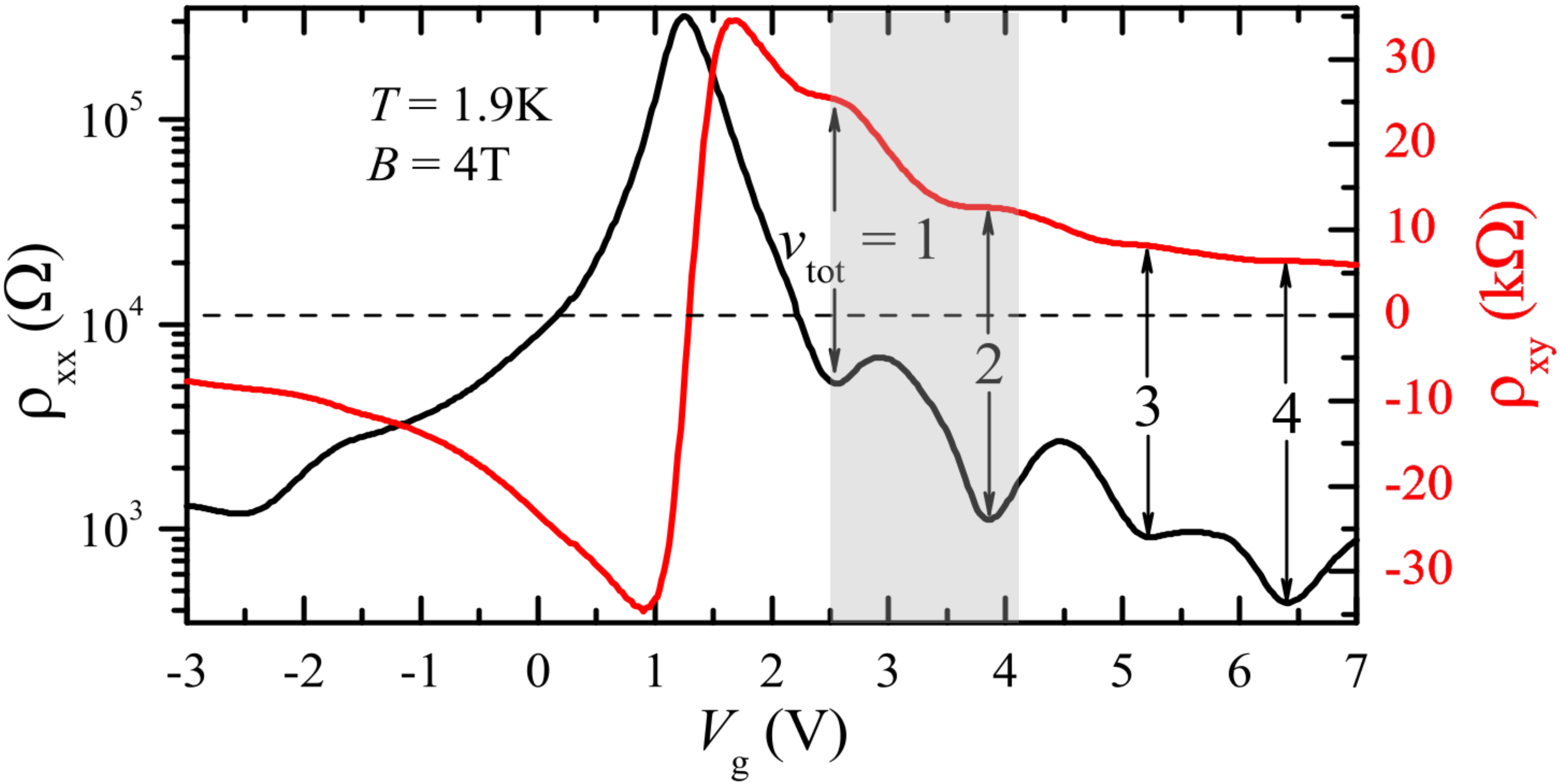
D. Kozlov et al., PRL **112**,196801 (2014)

From Drude model: $P(V_g)$ and $N(V_g)$



D. Kozlov et al., PRL **112**,196801 (2014)

$\rho_{xx}(V_g)$ and $\rho_{xy}(V_g)$ in quantizing B - fields

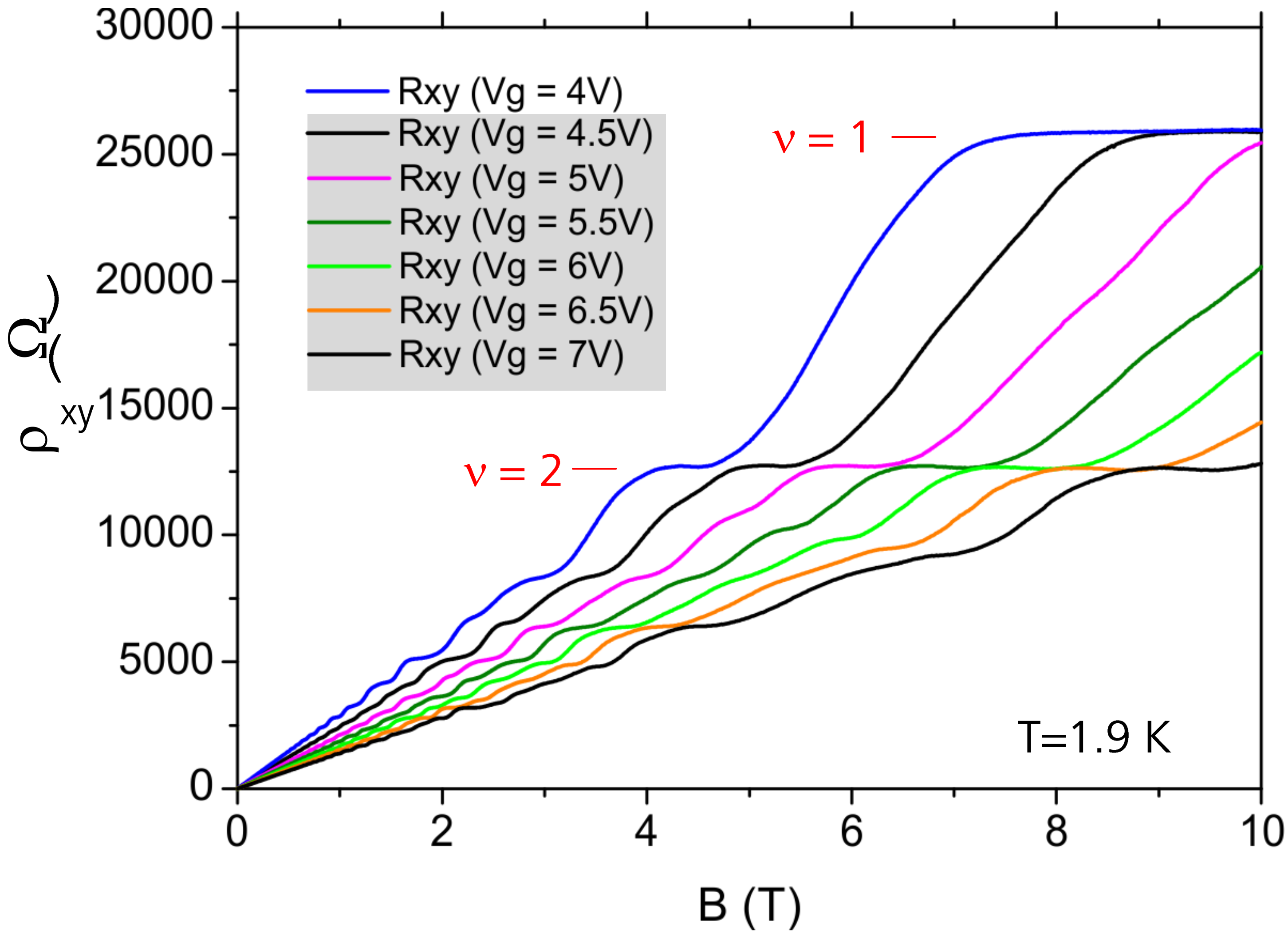


Quantized ρ_{xx} values and SdH oscillations occur for E_F in the gap and in the conduction band

D. Kozlov et al., PRL **112**,196801 (2014)

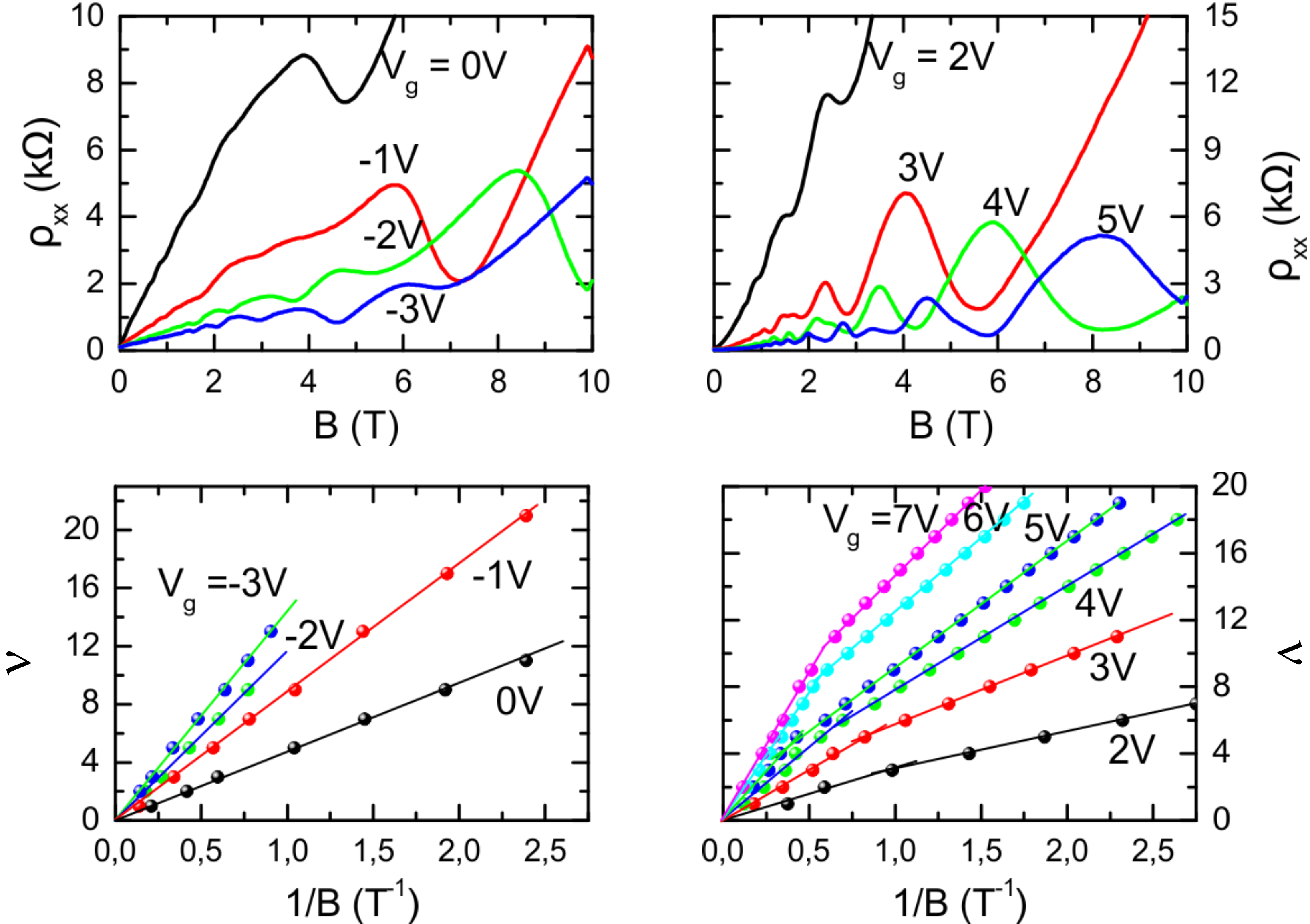
ρ_{xy} at different V_g

QHE also observed when E_F is located in CB ($V_g > 4V$)

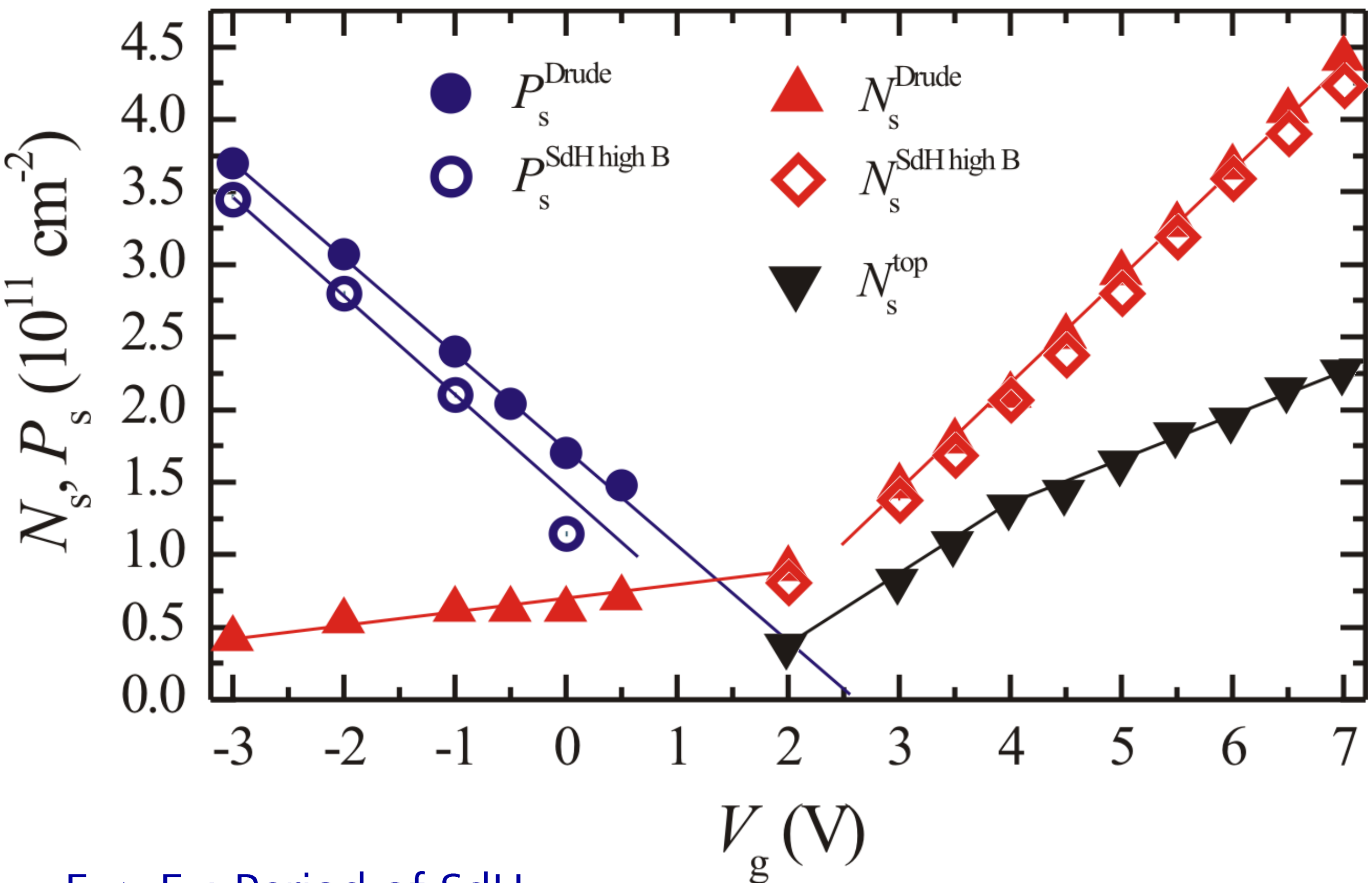


ρ_{xx} at different V_g

p-side **n-side**



N, P obtained from Drude and SdH (QHE)



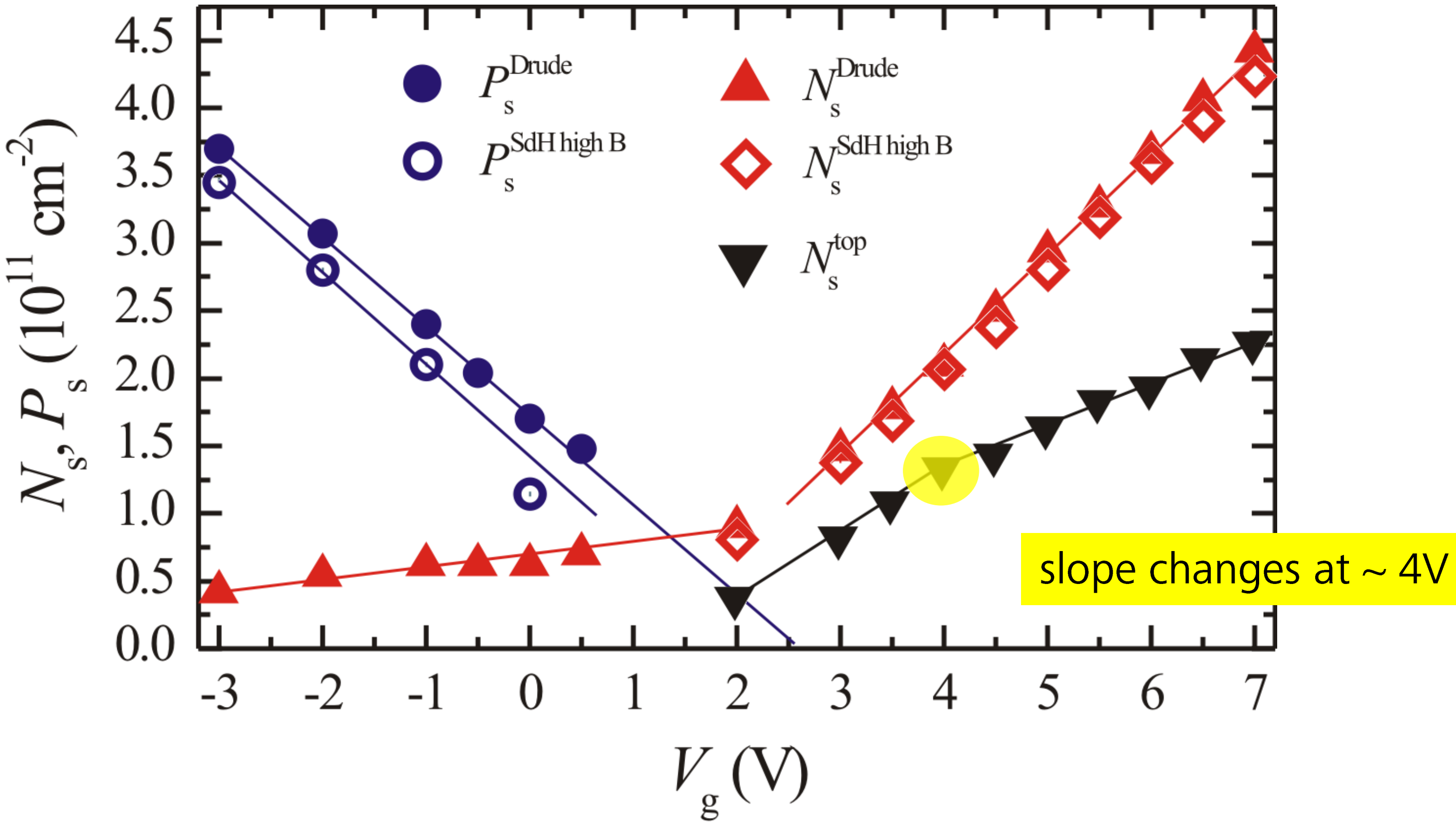
$E_F > E_V$: Period of SdH oscillations approximately given by $P_s^{Drude} - N_s^{Drude}$

$E_F > E_V$: Period of SdH oscillations determined by total electron density

K. Suzuki et al., PRL **93**, 016803 (2004)

D. Kozlov et al., PRL **112**,196801 (2014)

Slope change of $N_s^{top}(V_g)$

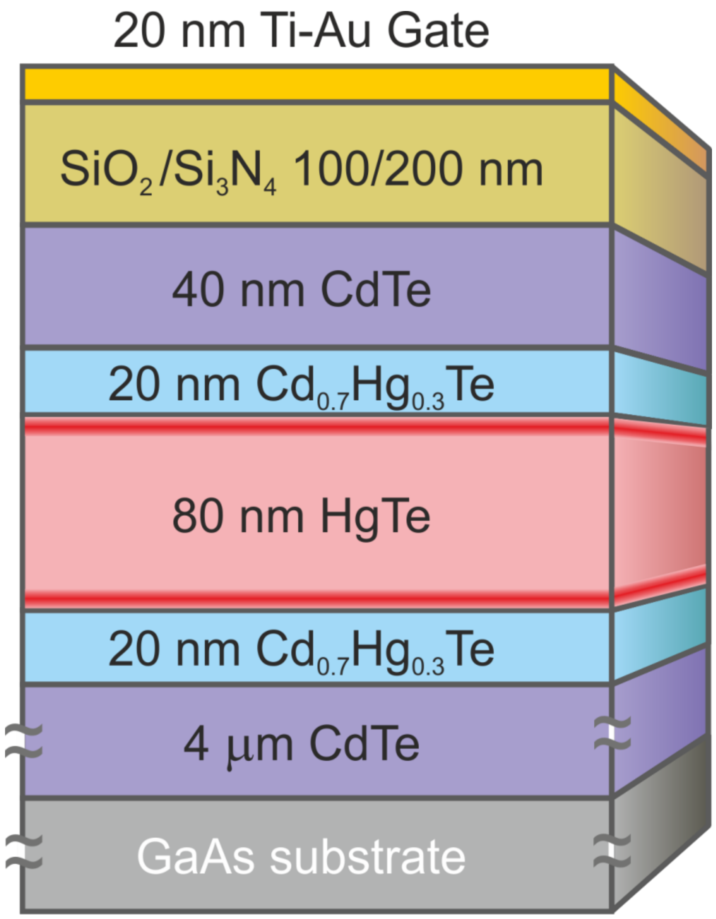


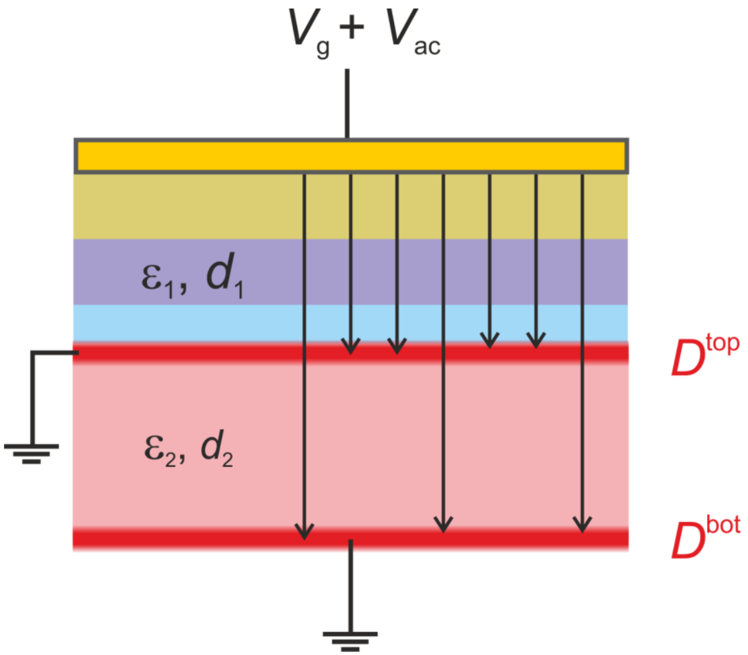
$$\frac{dn_s}{dV_G} = \frac{dn_s^{top}}{dV_G} + \frac{dn_s^{bulk}}{dV_G} + \frac{dn_s^{bot}}{dV_G} \propto C \approx \text{constant} \Rightarrow$$

Reduced slope dn_s^{top} / dV_g reflects E_F entering the conduction band

D. Kozlov et al., PRL **112**, 196801 (2014)

Magnetocapacitance measurements



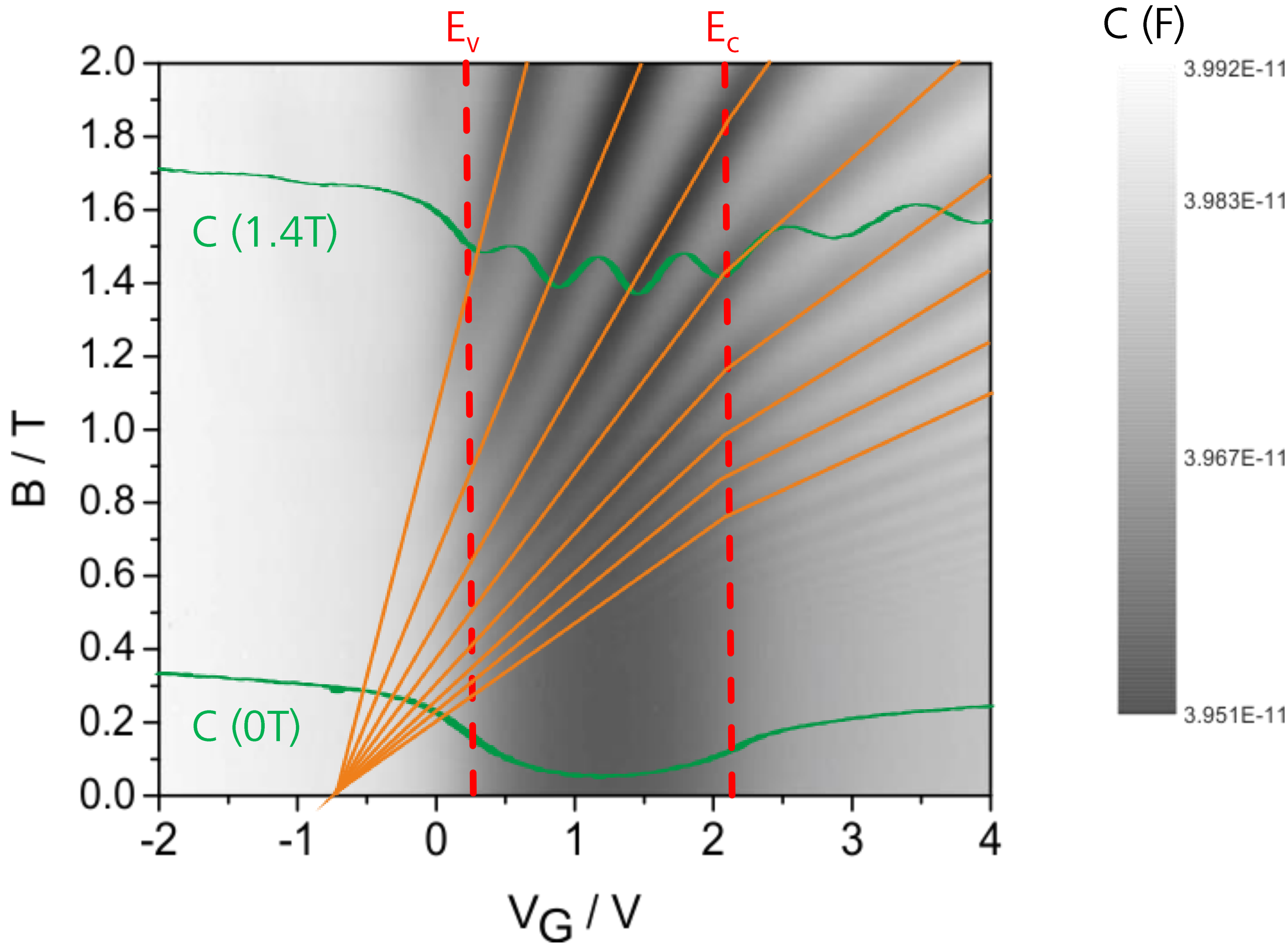


Total capacitance depends also on quantum capacitance e^2D in series to the geometrical capacitance $\varepsilon\varepsilon_0 A / d$

S. Luryi, APL **52**, 501 (1988)

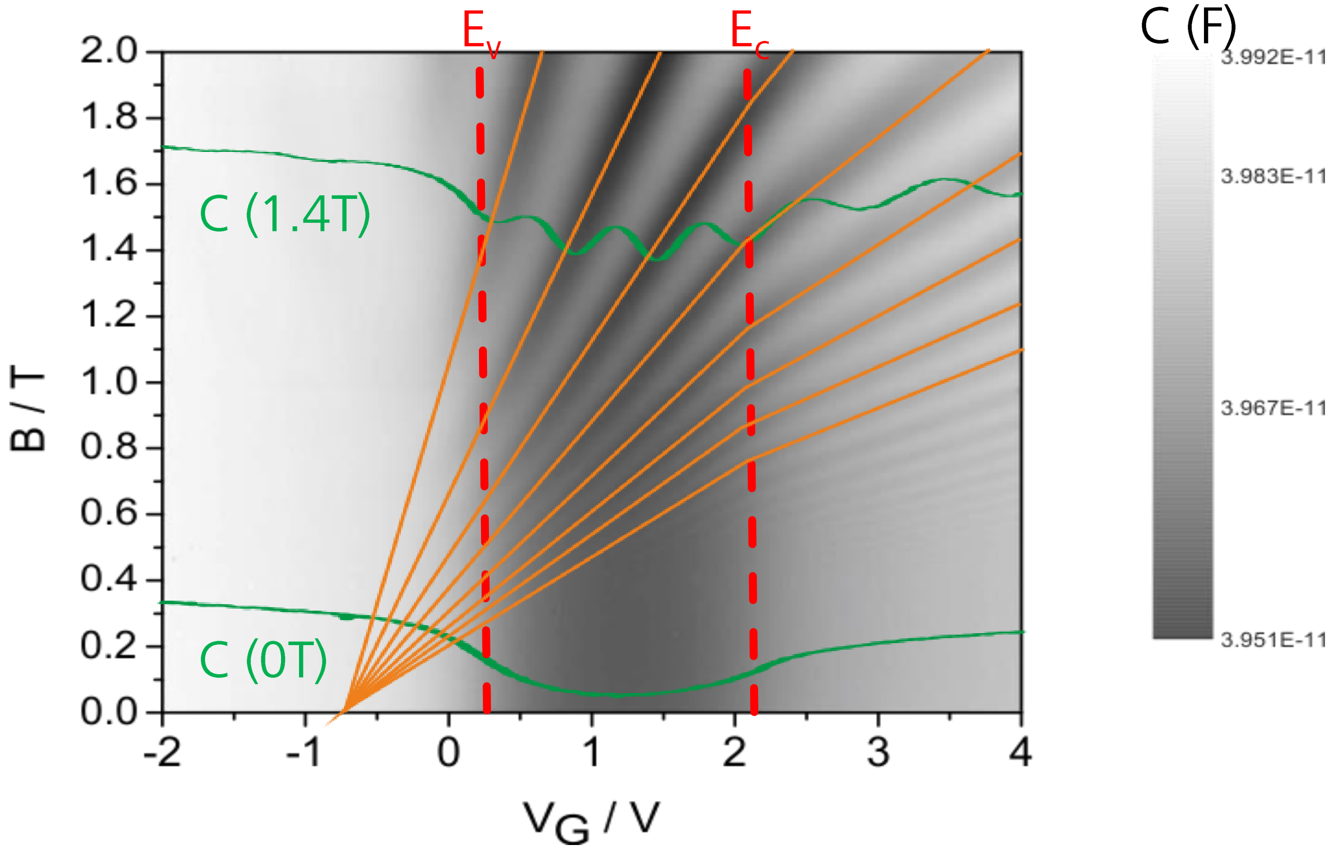
Magnetocapacitance

D. Bauer, unpublished



Magnetocapacitance

D. Bauer, unpublished



From $n_s = \nu n_L \Rightarrow \frac{dB_\nu}{dV_G} = \frac{2\pi\hbar}{e\nu}\frac{dn_s}{dV_G}$; $\frac{dn_s}{dV_G}$ = filling rate

$$\frac{dn_s}{dV_G} = \frac{dn_s^{top}}{dV_G} + \frac{dn_s^{bulk}}{dV_G} + \frac{dn_s^{bottom}}{dV_G} \propto C \approx \text{constant} \Rightarrow$$

Reduced slope dB/dV_G reflects E_F entering the conduction band

Summary

We studied transport and capacitance in high-mobility 3D-HgTe layers

E_F can be tuned from conduction band via gap into valence band

Quantum-Hall-effect and SdH-oscillations in gap and CB

Capacitance probes preferentially top surface $\rightarrow$ quantum capacitance

Topological Electronics

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Thank you very much for your attention