Some aspects of magnetotransport in graphite

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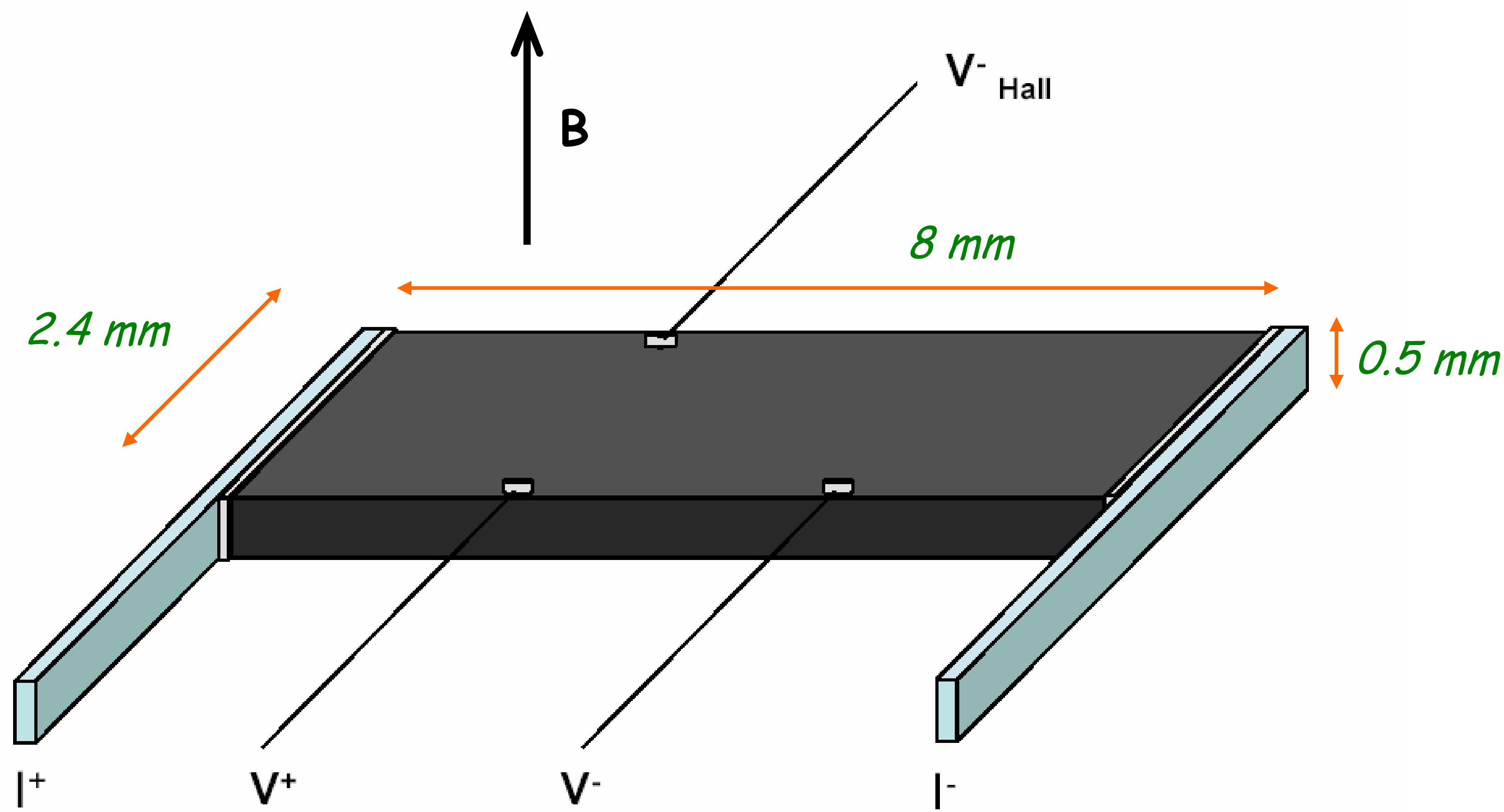
HOPG Graphite, sample geometry:



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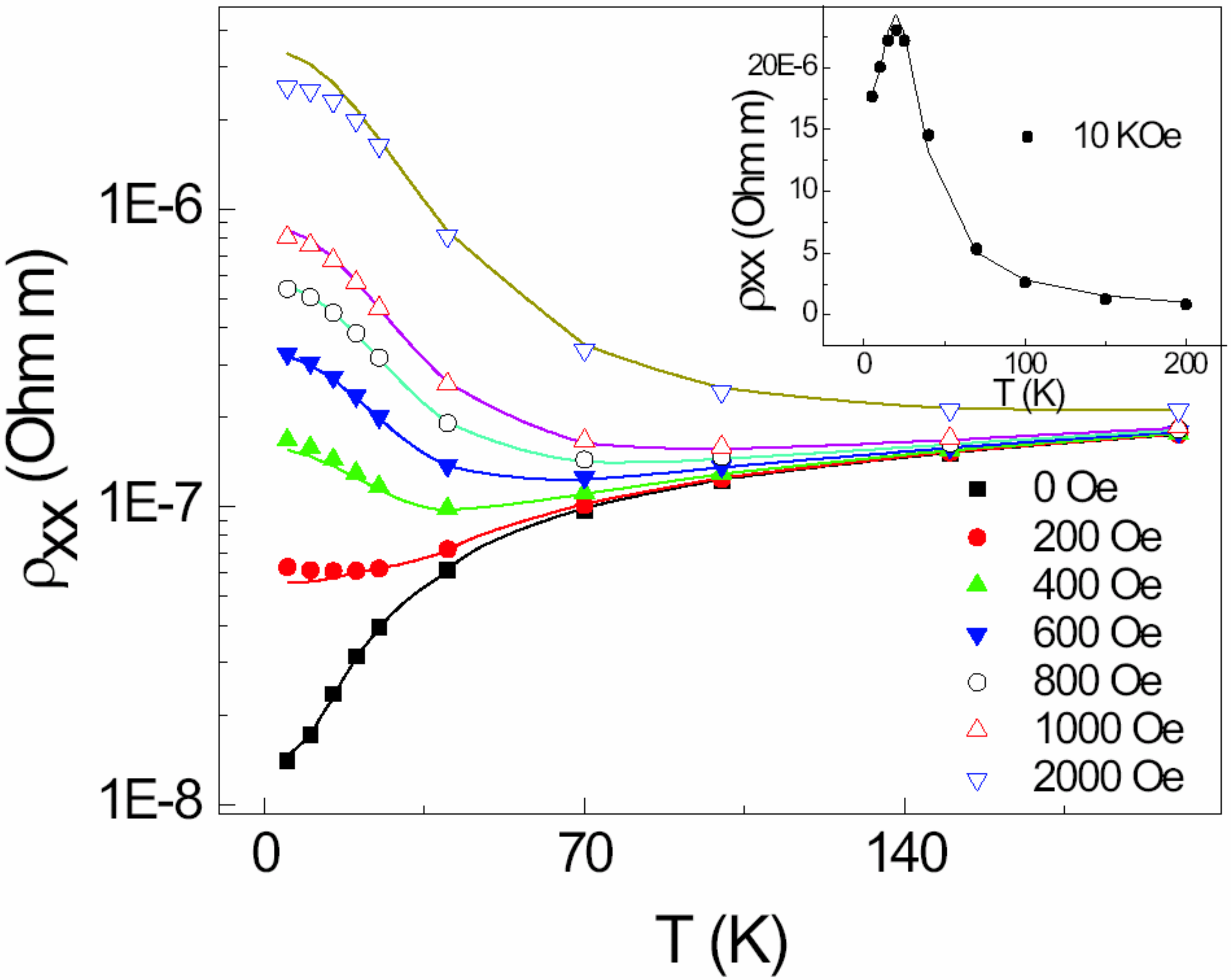
Magnetoresistance at low fields



Two-band model:

$$\rho_{xx} = \frac{\rho_1\rho_2(\rho_1+\rho_2) + (\rho_1 R_2^2 + \rho_2 R_1^2) B^2}{(\rho_1+\rho_2)^2 + (R_1+R_2)^2 B^2}$$

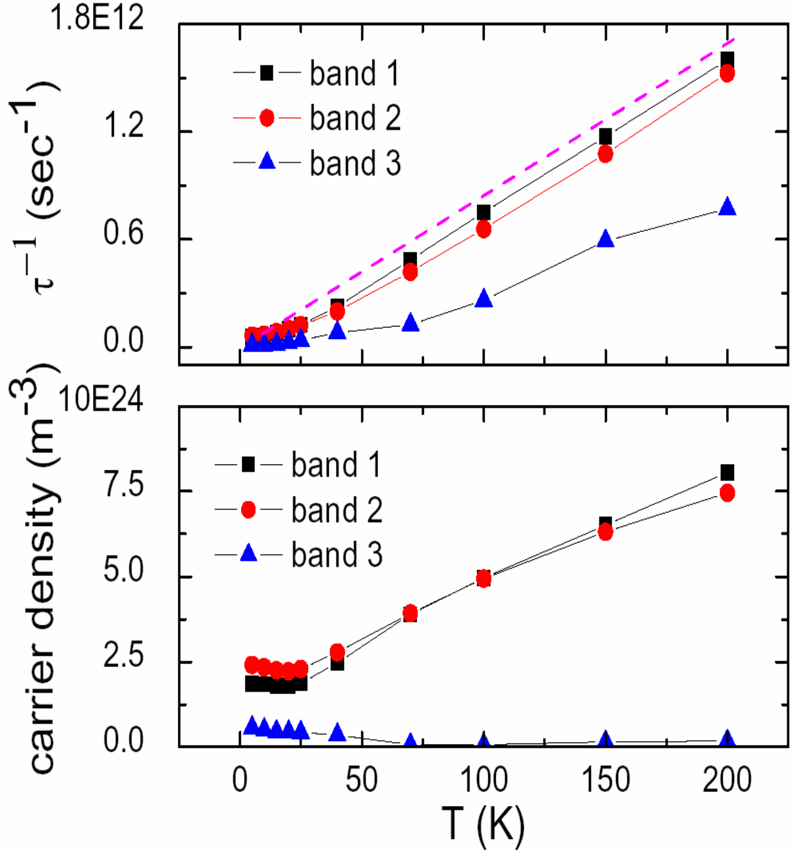
$\rho_i = m_i / n_i e^2 \tau_i$

$R_i = 1 / q_i n_i$

If $\rho_{1,2} \sim T^a$ **and** $R_1 = -R_2 = R$

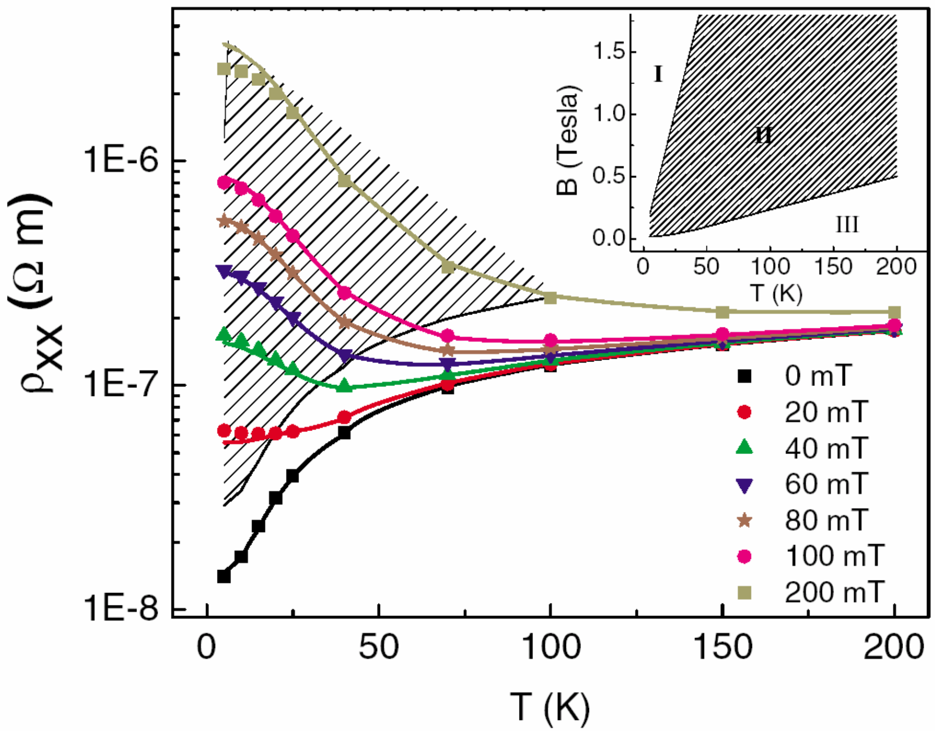
$\rho_{xx} = C_0 T^a + C_1 R^2 B^2 / T^a$

Extracting $n_i(T)$ and $\tau_i(T)$ from measurement of $\rho_{xx}(T,B)$ and $\rho_{xy}(T,B)$:



"Metal-insulator-like" behavior in semimetals

due to existence of the interval:



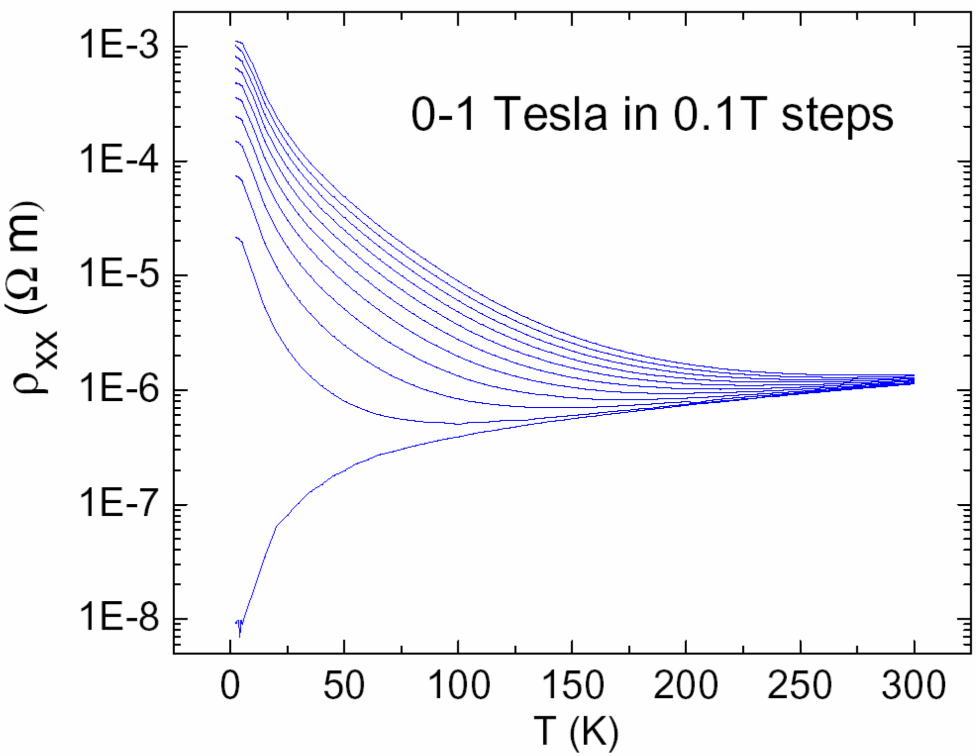
$$\hbar/\tau < \hbar\omega_c \ll k_B T$$

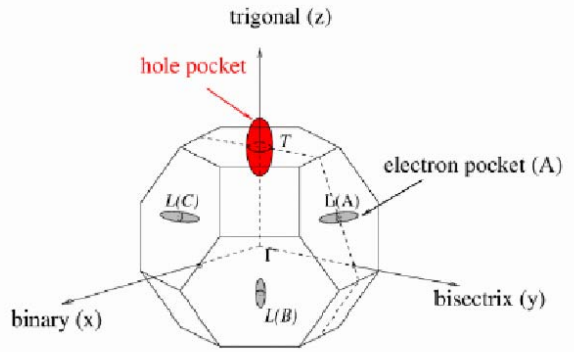
- clean
- small cycloton mass
- low carrier density

electron-phonon: $$\tau^{-1} \simeq (k_F a_0)(m^*/m_0)\, k_B T/\hbar$$

X. Du, SWT, D. L. Maslov, A. F. Hebard, PRL (2005)

Similar behavior in bismuth:



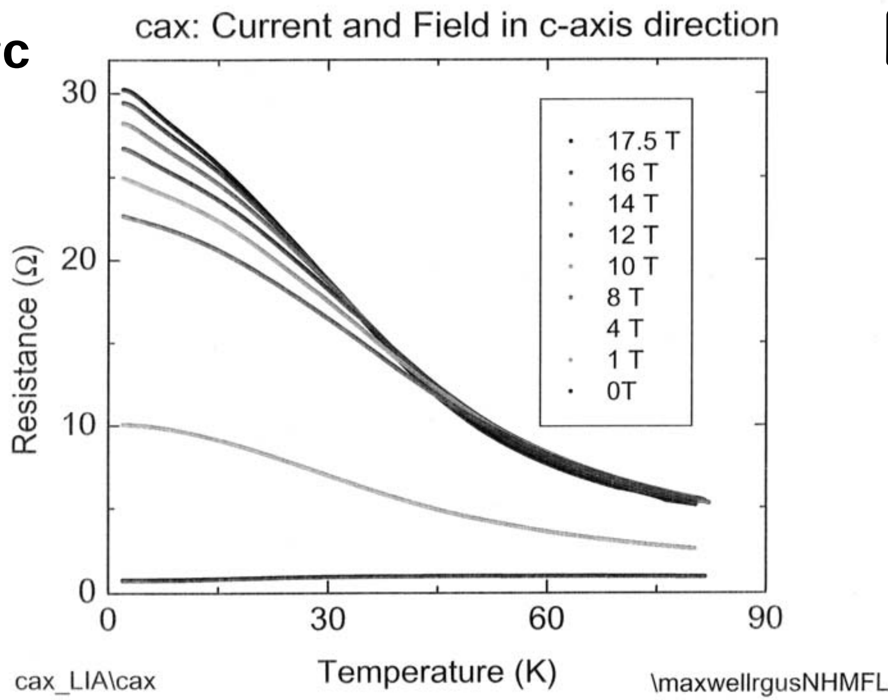


Brillouin zone of Bi

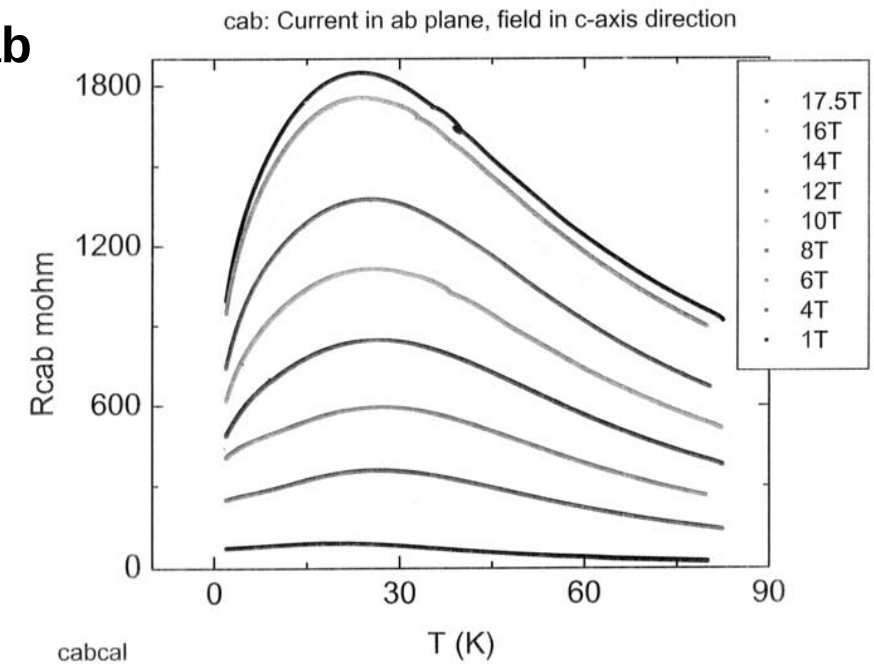
X. Du, SWT, D. L. Maslov, A. F. Hebard, PRL (2005)

Graphite in the Ultra Quantum Limit

R_c



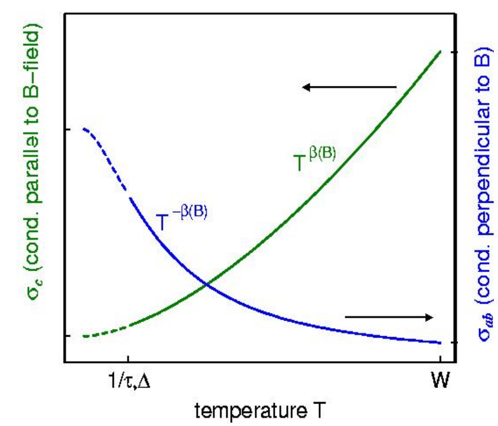
R_{ab}



Xu Du (Rutgers), A. F. Hebard (UF)

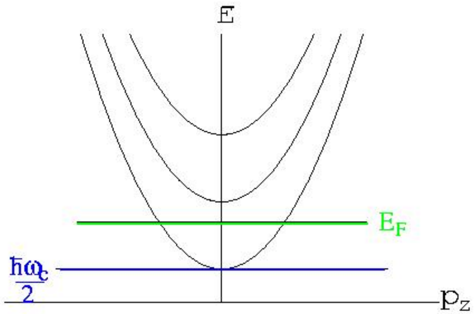
$$\sigma_c = \frac{ne^2\tau}{m_{||}} \sim \tau \sim T^{\beta(B)}$$

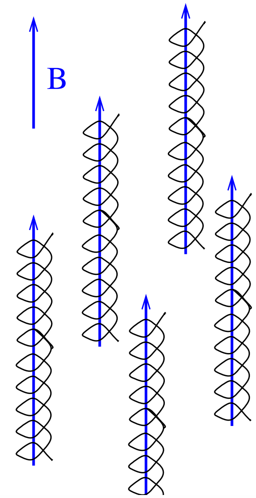
$$\sigma_{ab} = \nu_F e^2 D_\perp \sim \frac{1}{\tau} \sim T^{-\beta(B)}$$



SWT, D. L. Maslov, L. I. Glazman, PRB (2002)

The Ultra-Quantum Limit (UQL):





(Brazovsky 71)
(Yoshioka + Fukuyama 81
(Yakovenko 93)

$$\frac{\partial \gamma(\mathbf{r}_\perp, \xi)}{\partial \xi} = \int d^2 r'_\perp \gamma(\mathbf{r}'_\perp, \xi)\gamma(\mathbf{r}_\perp - \mathbf{r}'_\perp, \xi)[1 - e^{i(\mathbf{r}_\perp \wedge \mathbf{r}'_\perp)}]$$

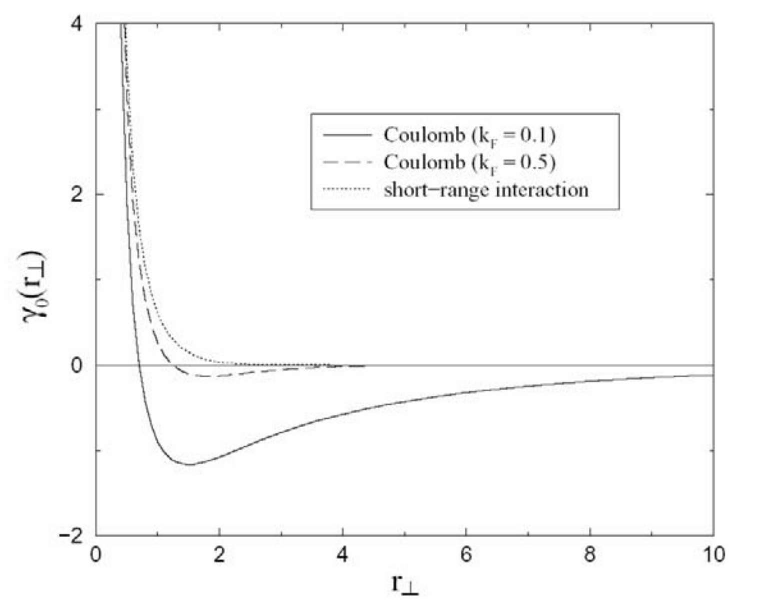
$$\frac{\partial \Gamma(\mathbf{k}_\perp, \xi)}{\partial \xi} = \Gamma^2(\mathbf{k}_\perp, \xi) - \int \frac{d^2 q_1 d^2 q_2}{(2\pi)^2} \Gamma(\mathbf{q}_1, \xi)\Gamma(\mathbf{q}_2, \xi) e^{i(\mathbf{q}_2 \wedge \mathbf{k}_\perp + \mathbf{k}_\perp \wedge \mathbf{q}_1 + \mathbf{q}_1 \wedge \mathbf{q}_2)}$$

Strict 1D (Luttinger-liquid): $$\frac{\partial \Gamma(\xi)}{\partial \xi} = 0$$

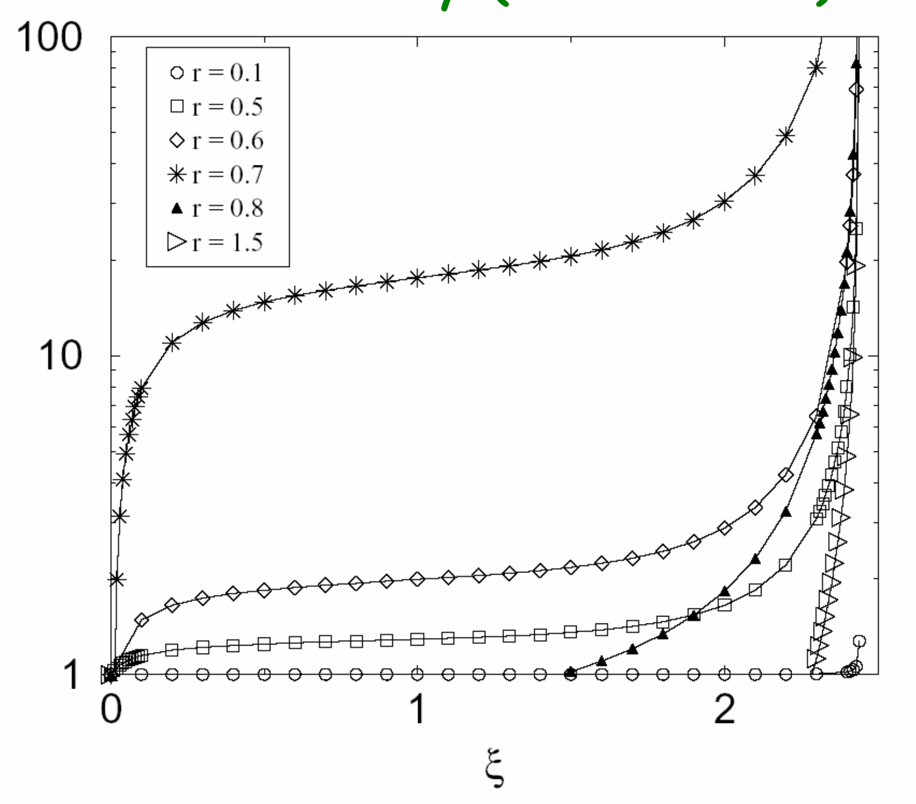
3D + B, infinite-range interaction: $$\frac{\partial \Gamma(0, \xi)}{\partial \xi} = 0$$

Initial condition for the RG flow:

$$\gamma_0(\mathbf{r}_\perp) = \frac{1}{(2\pi)^3 v_F}\left[e^{-r_\perp^2/2}U(0,\mathbf{r}_\perp) - (2\pi\ell_B^2)\int \frac{d^2q_\perp}{(2\pi)^2} e^{i\mathbf{r}_\perp\cdot\mathbf{r}_\perp - q_\perp^2\ell_B^2/2}U_0(2k_F,\mathbf{r}_\perp)\right]$$

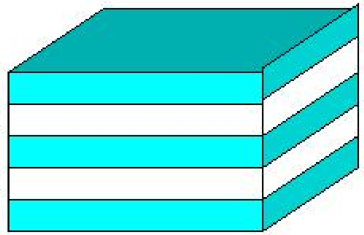


Instability (for κ = 0.1):

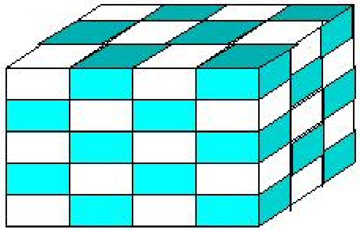


Instability at high magnetic fields:

Short-range interaction: "1D" Charge-density-wave
($2k_F$ charge modulation along the magnetic field direction)



Long-range interaction: "3D" Charge-density wave
($2k_F$ charge modulation along the magnetic field direction and κ modulation in the transverse direction)



expmts:

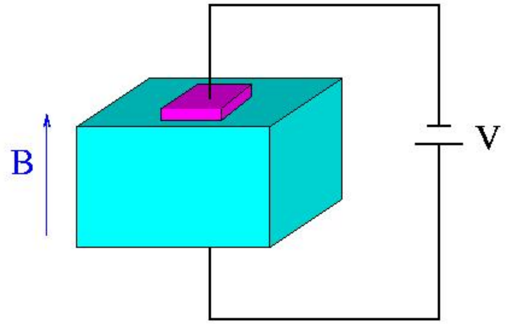
Y.Iye et al. 1982

Y.Iye and G.Dresselhaus 1985

H.Ochimizu et al. 1992

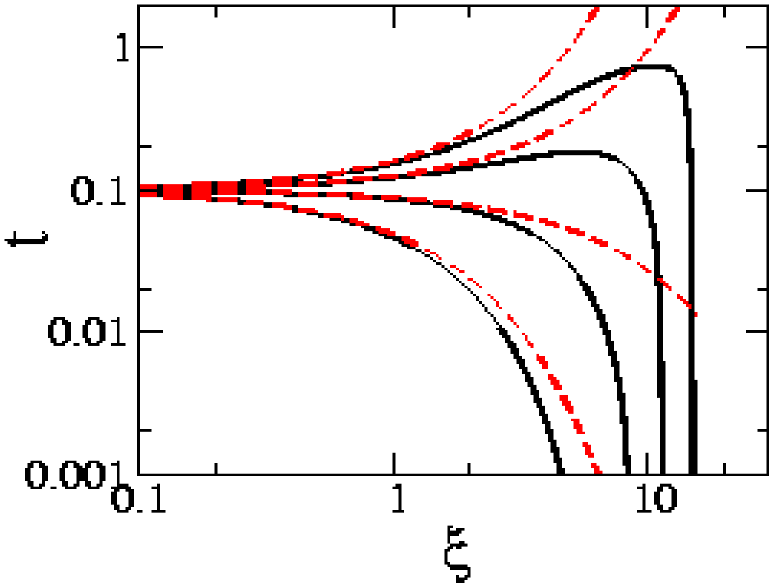
H.Yaguchi and J.Singleton 1998

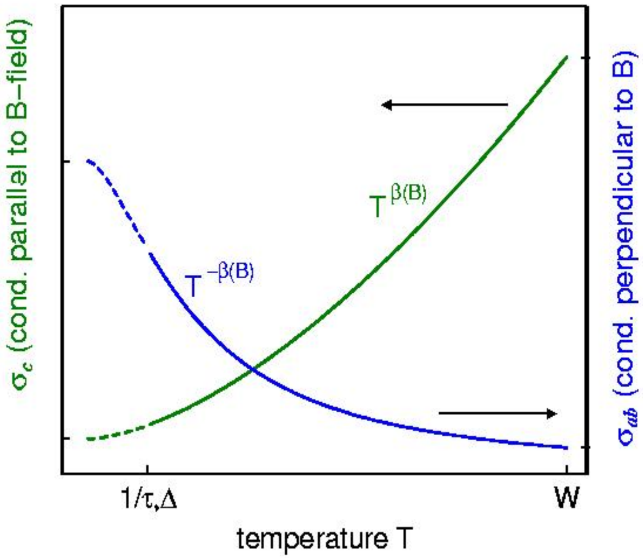
Tunneling density of states (B + e-e interaction)



$$dt/d\ln\varepsilon = (\Gamma_0/2)\, t\, (1 - |t|^2)$$

$$t \sim |E-E_F|^{\Gamma_0/2}$$





$$\Delta = W \exp(-a v_F / e^2)$$

$$E_{PL} \simeq E \exp(-\pi v_F / e^2 |\ln \kappa|)$$