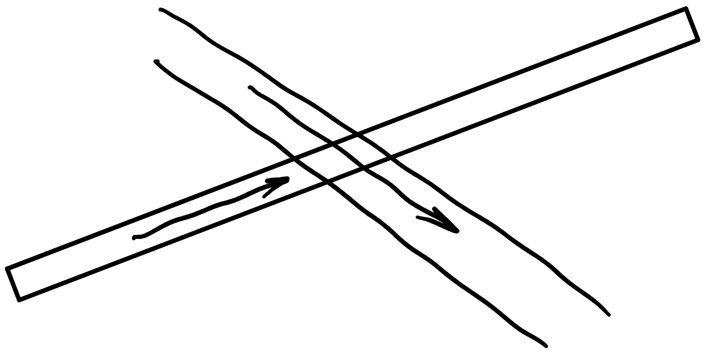
Interplay of interactions and disorder

If electrons propagate ballistically:

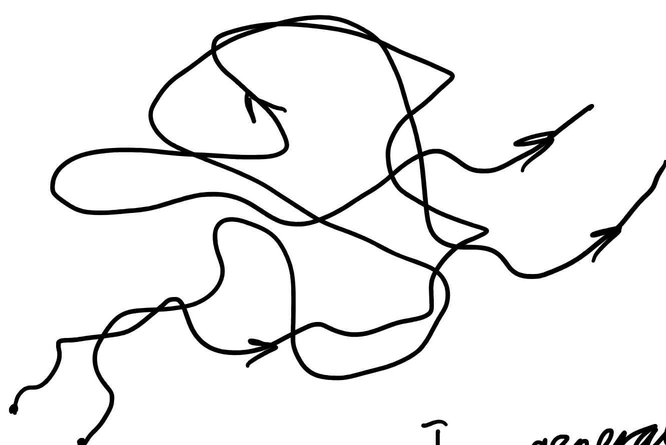


Typical interaction region $\sim \frac{1}{k_F}$

That's why in

$\frac{1}{\tau_T} \sim \frac{T^2}{\hbar \varepsilon_F}$ we have ε_F in the denominator!

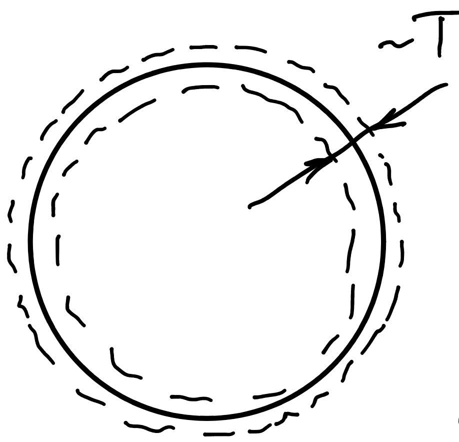
It strongly changes if there is electron diffusion:



In general, $\frac{1}{\tau} \neq \frac{1}{\tau_{imp}} + \frac{1}{\tau_{e-e}}$

Strong diffusion creates conditions for interference between different electrons.

How does interference happen?



Electrons pick up phases $\sim e^{i\frac{E_i}{\hbar}t}$

Typical energy difference between 2 electrons: $|E_i - E_j| \sim T$

After time $\boxed{t_{ee} \sim \frac{\hbar}{T}}$ coherence between different electrons is lost

If electrons move diffusively, this corresponds to the distance $L_{ee} \sim \ell\sqrt{\frac{t_{ee}}{\tau}} \sim$

$$\sim v_F \tau \left(\frac{\hbar}{T\tau}\right)^{\frac{1}{2}} \sim \left(\frac{v_F^2 \tau \hbar}{T}\right)^{\frac{1}{2}} \sim \left(\frac{\hbar D}{T}\right)^{\frac{1}{2}}$$

$\boxed{L_{ee} \sim \left(\frac{\hbar D}{T}\right)^{\frac{1}{2}}}$ is similar to the dephasing length L_φ that we had in single-particle problems

Effective size of the interaction region $= L_{ee}$

The characteristic momentum transfer $q \sim \frac{1}{L_{ee}}$

$\frac{1}{\tau_i} \propto L_{ee}^{-d}$ – collision frequency

$$\frac{1}{\tau_e} \propto L_{ee}^{\ldots} \quad \text{– collision frequency}$$

$$3D: \frac{1}{\tau_e} \propto T^{\frac{3}{2}} \varepsilon_F^{-2} \tau^{-\frac{3}{2}}$$

Note: $\frac{1}{\tau_e}$ is the electron collision frequency and not the scattering rate!

In order for electrons to interfere, they must meet again within time t_{ee}. The probability of that is

$$P \sim \int_{\tau}^{\tau_{ee}} \frac{v_F \lambda^2 dt}{(D t)^{\frac{3}{2}}}$$

leading to the „WL-like" correction

$$\Delta\sigma \approx - \text{const} + \frac{e^2}{\hbar} \frac{1}{L_{ee}} \qquad (3D)$$

$$\Delta\sigma \approx -2 \frac{e^2}{\hbar} \ln \frac{L_{ee}}{l} \qquad (2D)$$