Journal Club - Zumbühl Group

Universität Basel

Bulk Thermal Conductance of the 5/2 and 7/3 Fractional Quantum Hall States in the Corbino Geometry

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Outline

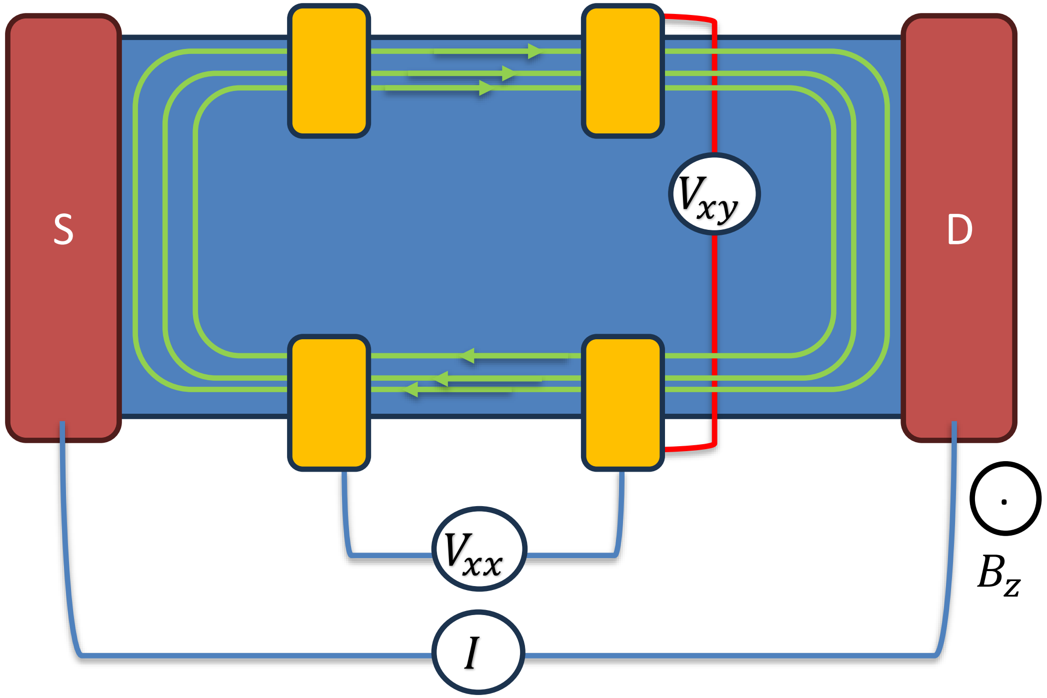
- Motivation & Basic concepts
- The Corbino Disc device
- Experimental procedure
- Result

Quick Quantum Hall effect

2DEG with out-of-plane field B_z

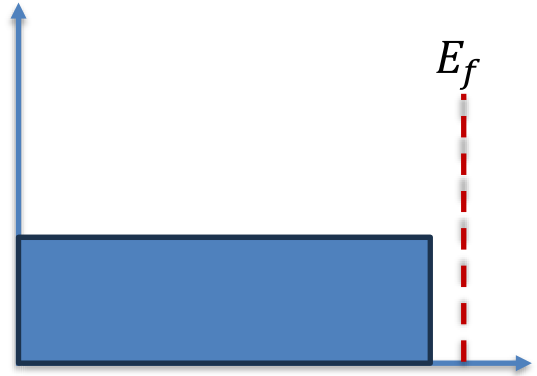
Landau quantisation

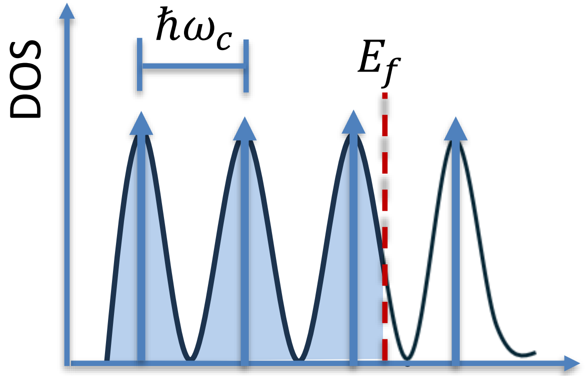
→ chiral edge states



$$\omega_c = \frac{eB}{m_e}$$

$$B_z \neq 0 \quad E = \hbar\omega_c(1/\,2 + n)$$



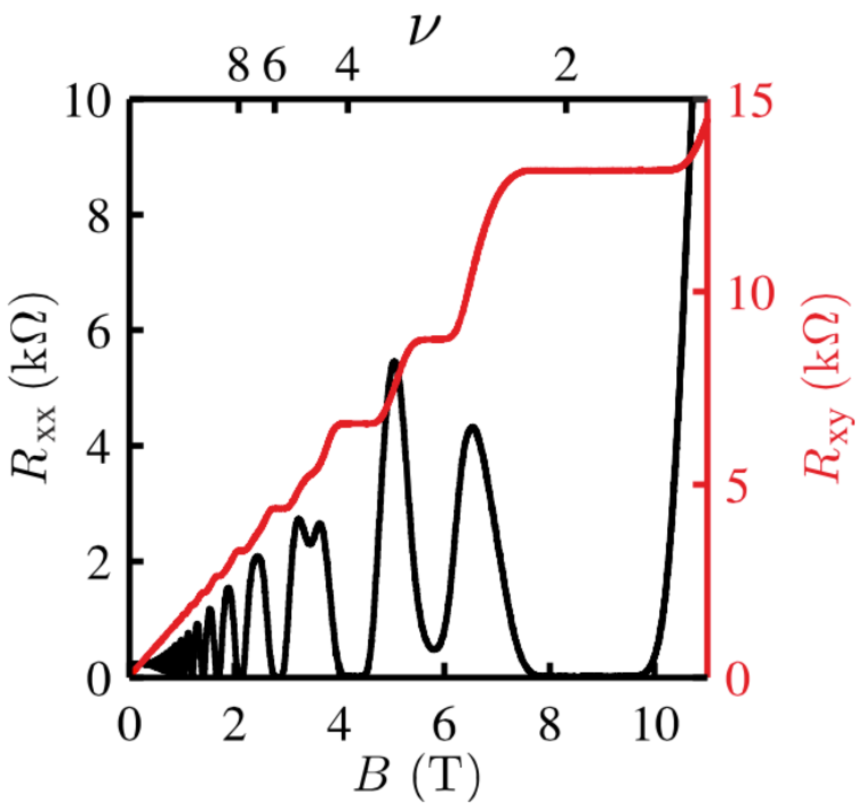


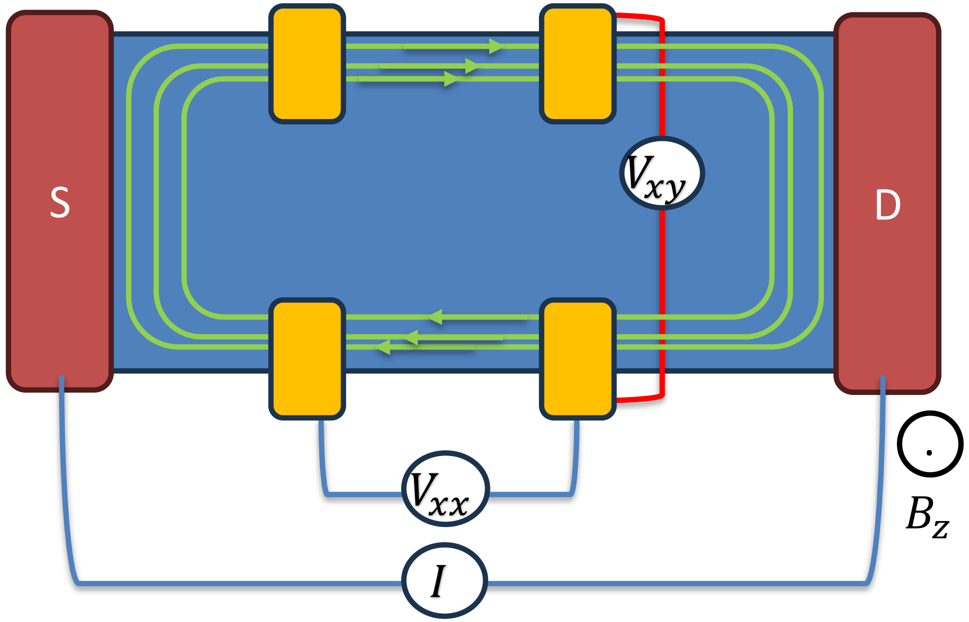
Quick Quantum Hall effect

On a QHE Plateau

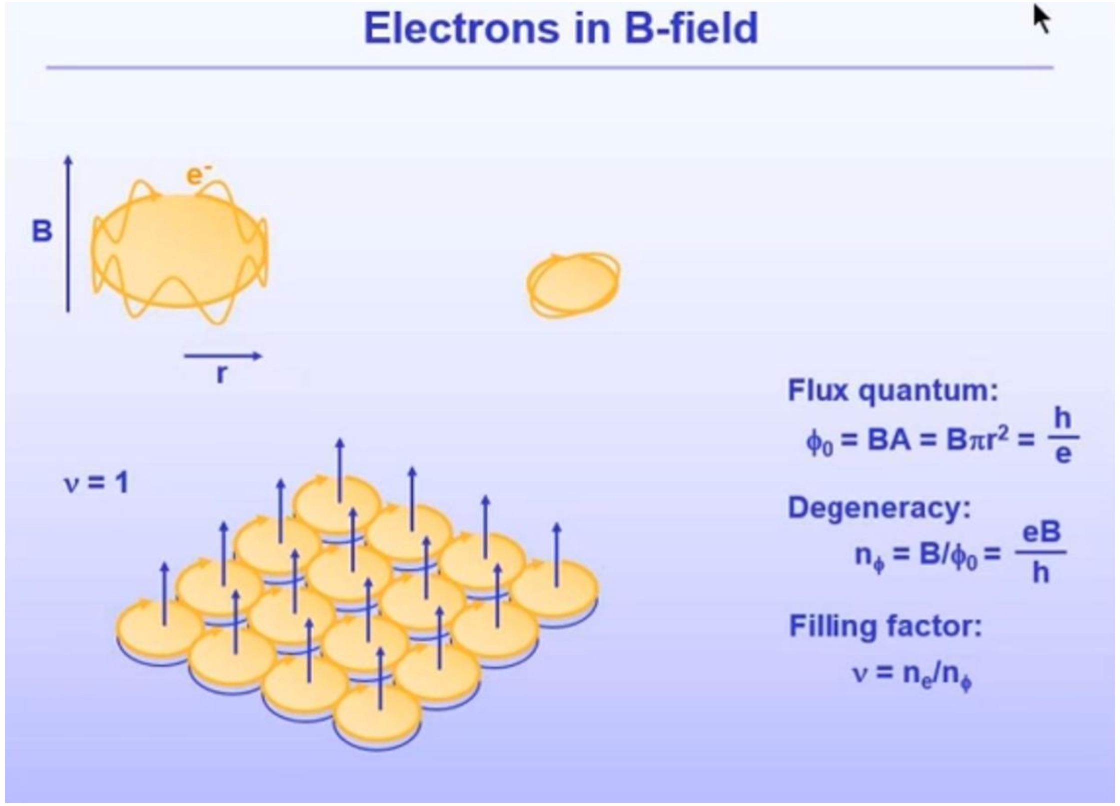
$Rxy\ /\ G_{xy}$ Quantized

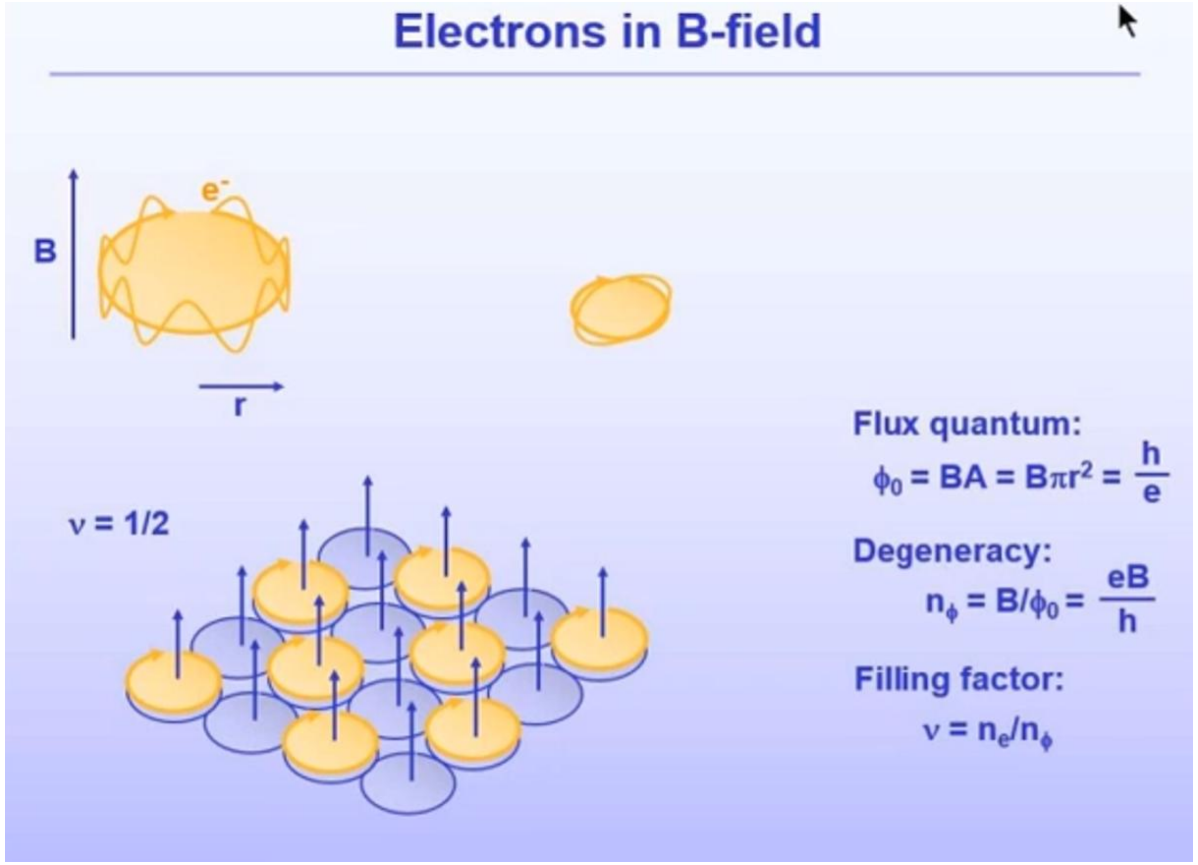
$R_{xx}/\ G_{xx} = 0$





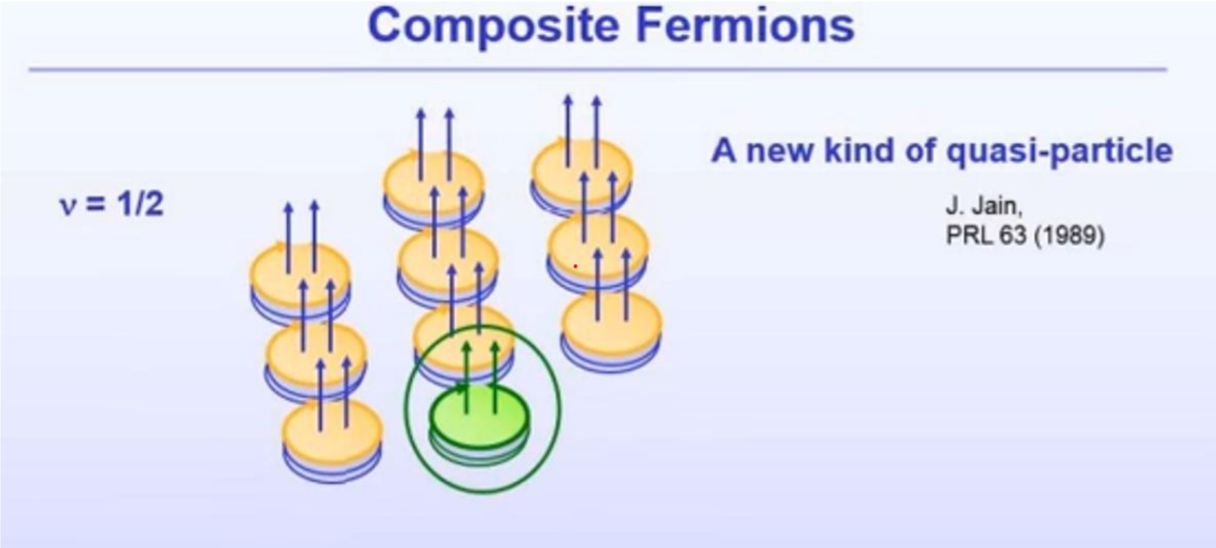
Quick Fractional Quantum Hall effect

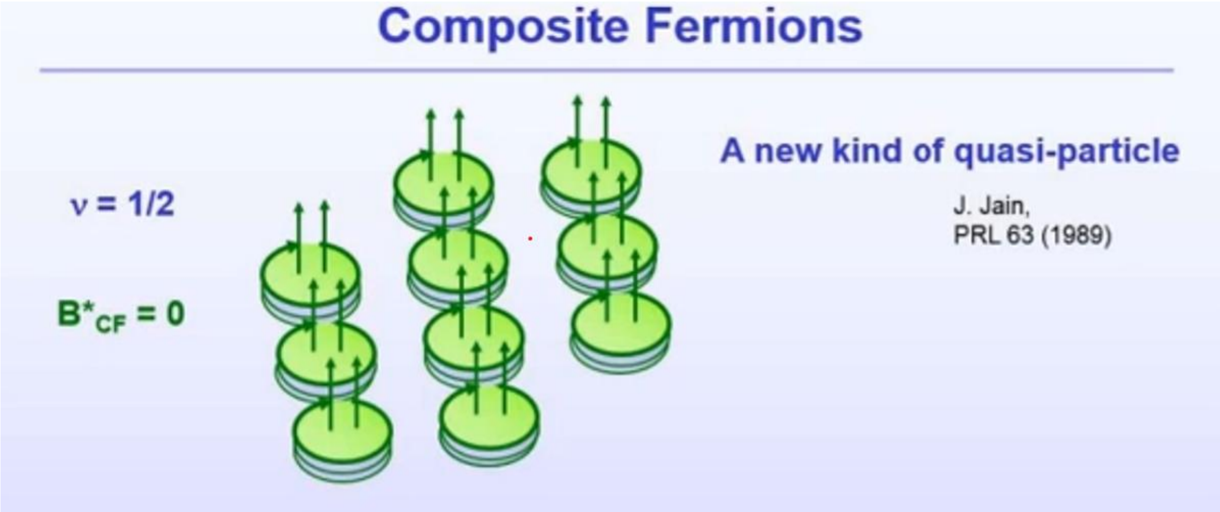


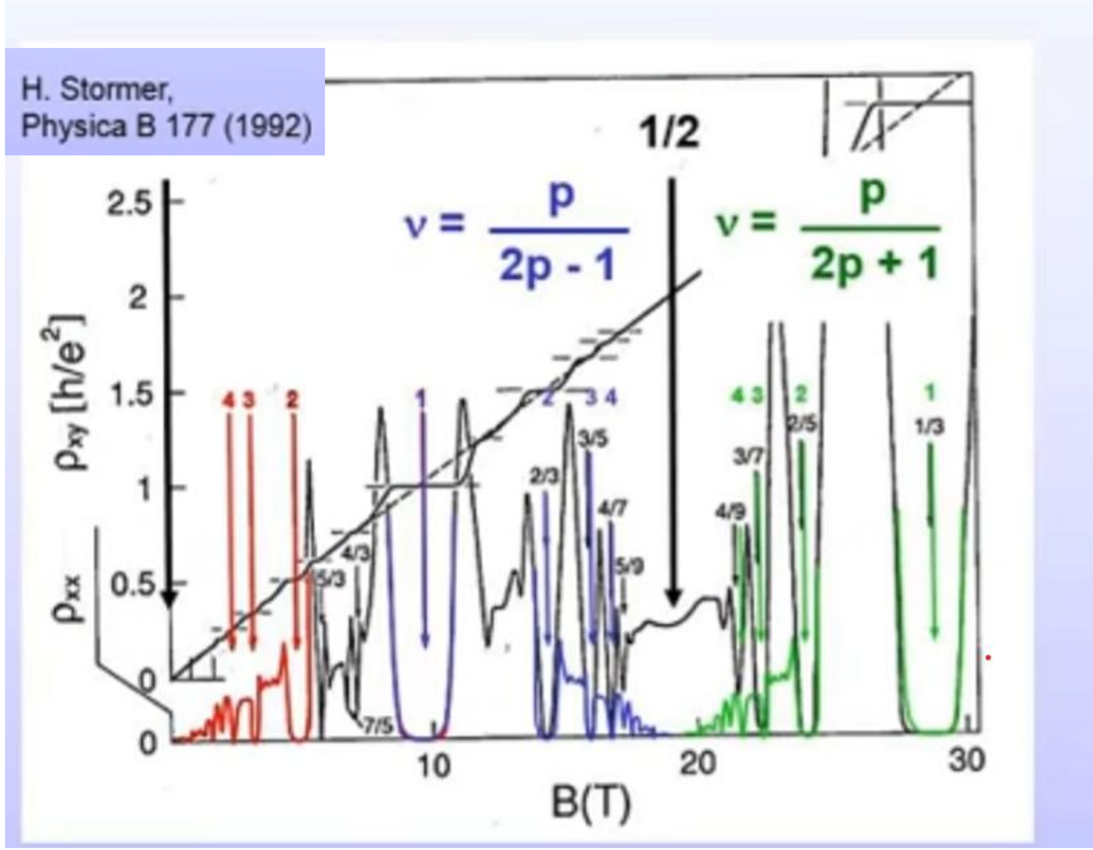


Speaker: Matthew A. Grayson (EECS, NU)
"The workshop on Semiconductors, Electronic Materials, Thin Films and Photonic Materials"
Tel Aviv University February 22-25, 2015
https://www.youtube.com/watch?v=UNyNjZeG1wc

Quick Fractional Quantum Hall effect







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Ground state degeneracy and entropy

Interactions between Quasi particles give new feature

Bosons : $\psi(r_1, r_2, r_i) = \psi(r_2, r_1, r_i)$

Fermions : $\psi(r_1, r_2, r_i) = -\psi(r_2, r_1, r_i)$

Anyons (2D) : $\psi(r_1, r_2, r_i) = e^{i\theta}\psi(r_2, r_1, r_i)$

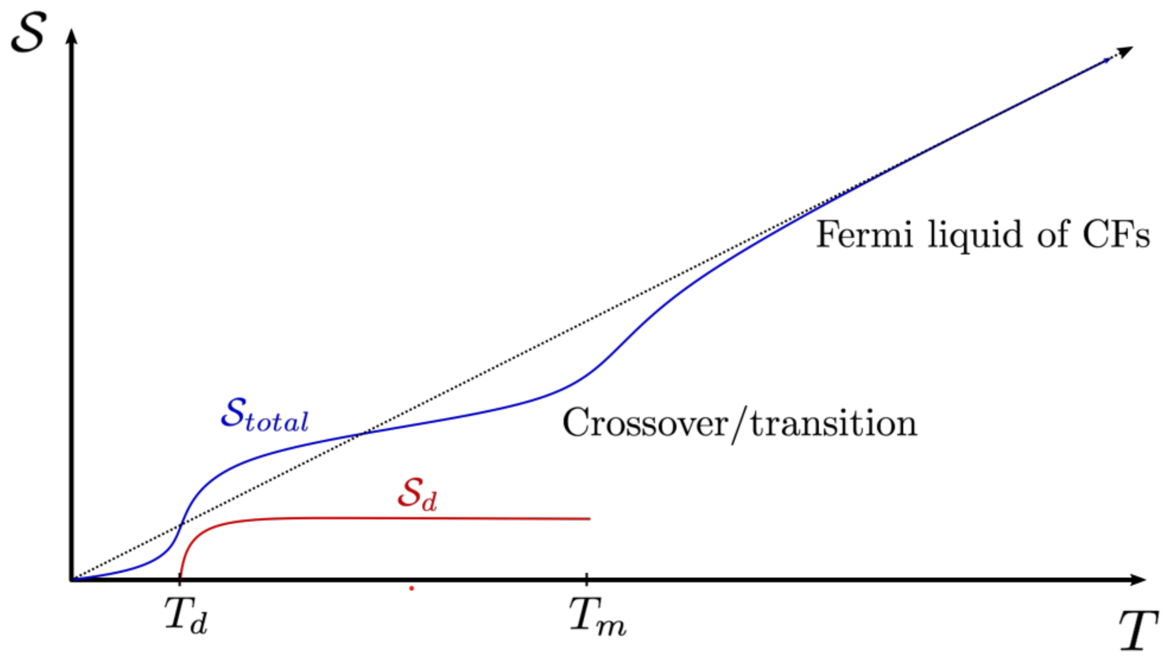
Non-Abelian Anyons(2D): $\boxed{\psi_j(r_1, r_2, r_i) = M_{jk}\psi_k(r_2, r_1, r_i)}$

# of degenerate ground states $D = d^{N_{qp}}$

Entropy $\mathcal{S}_D = k_B \log D = k_B N_{qp} \log d$

$$\mathcal{S}_{total} = \mathcal{S}_D + \mathcal{S}_n$$

To measure the non-Abelian entropy



$T_d = 67$ mK (assuming the 150 nm size estimate)

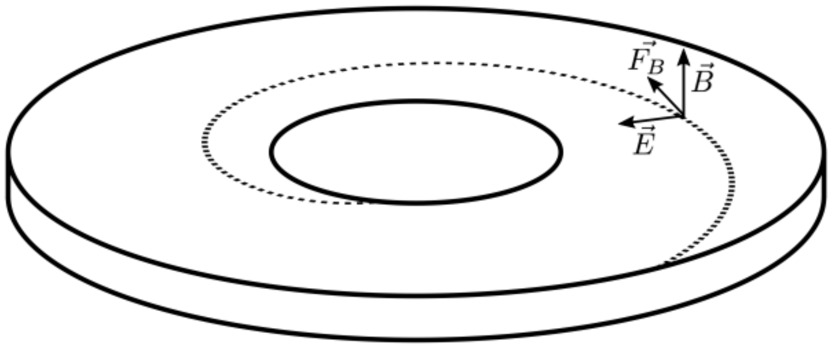
$$\mathcal{S}(T) = \mathcal{S}(T_0) + \int_{T_0}^{T} \frac{C}{T'} dT'$$

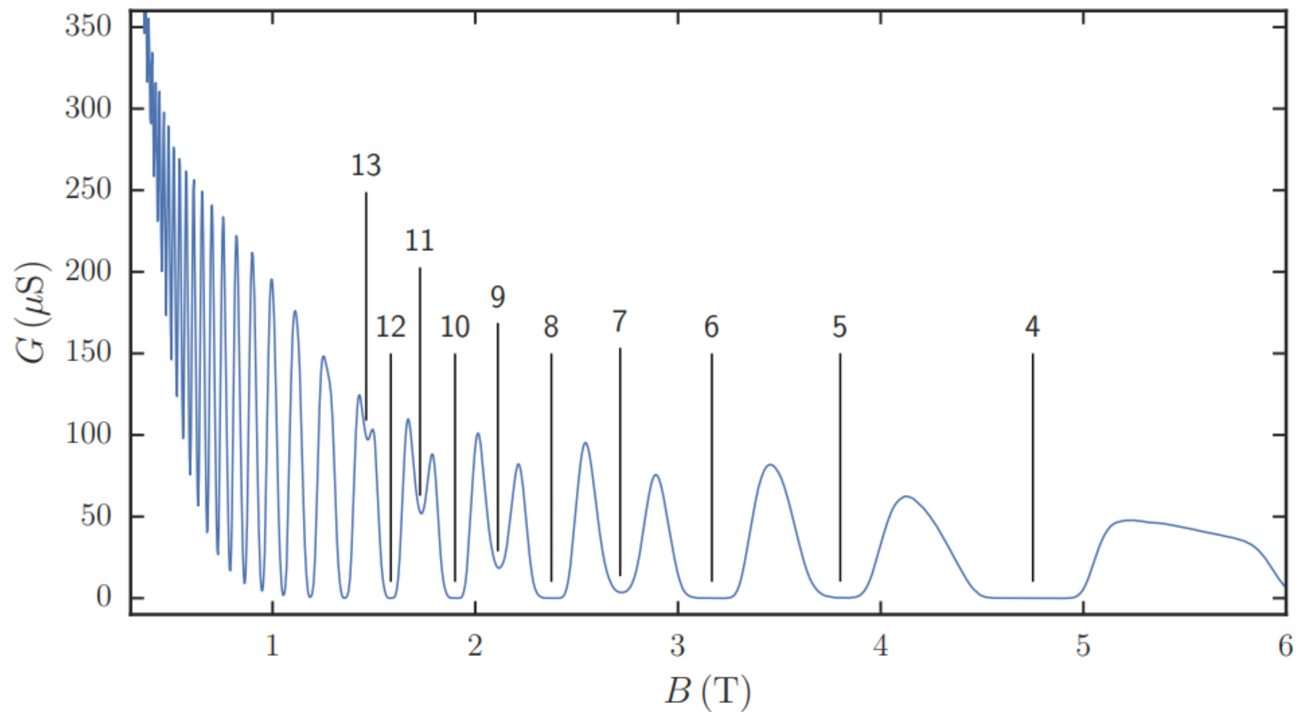
$\mathcal{S}(T)$ is negligible. Finally, it may be possible to find $\mathcal{S}$ in absolute units at high temperature, when the CF's form a Fermi liquid. The entropy of a Fermi liquid is known to be linear with an intercept of zero, as illustrated in Figure 3.2. Linear behaviour over a wide range of T could therefore be used to determine $\mathcal{S}$. This latter approach has been successfully used in studies of superfluid Helium-3 [49].

Anyway we need to measure C

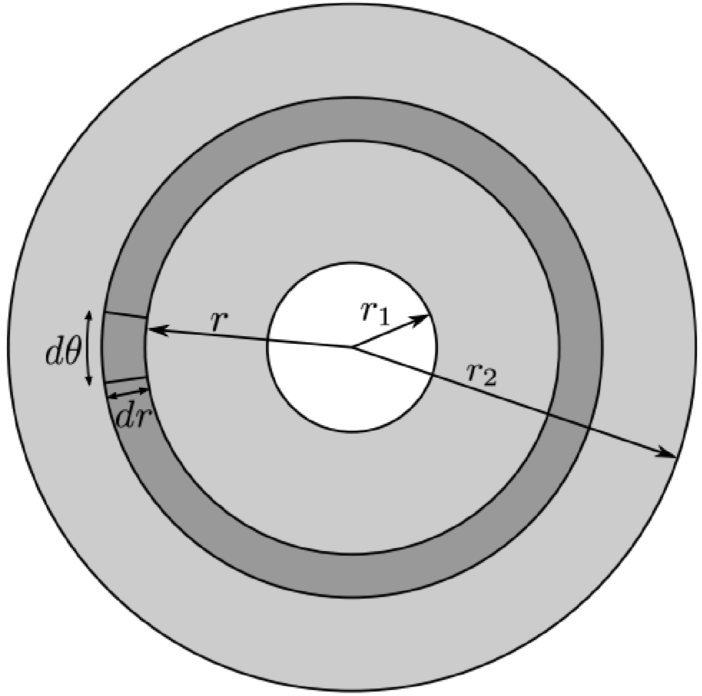
$$C = K\tau$$

The Corbino disc device

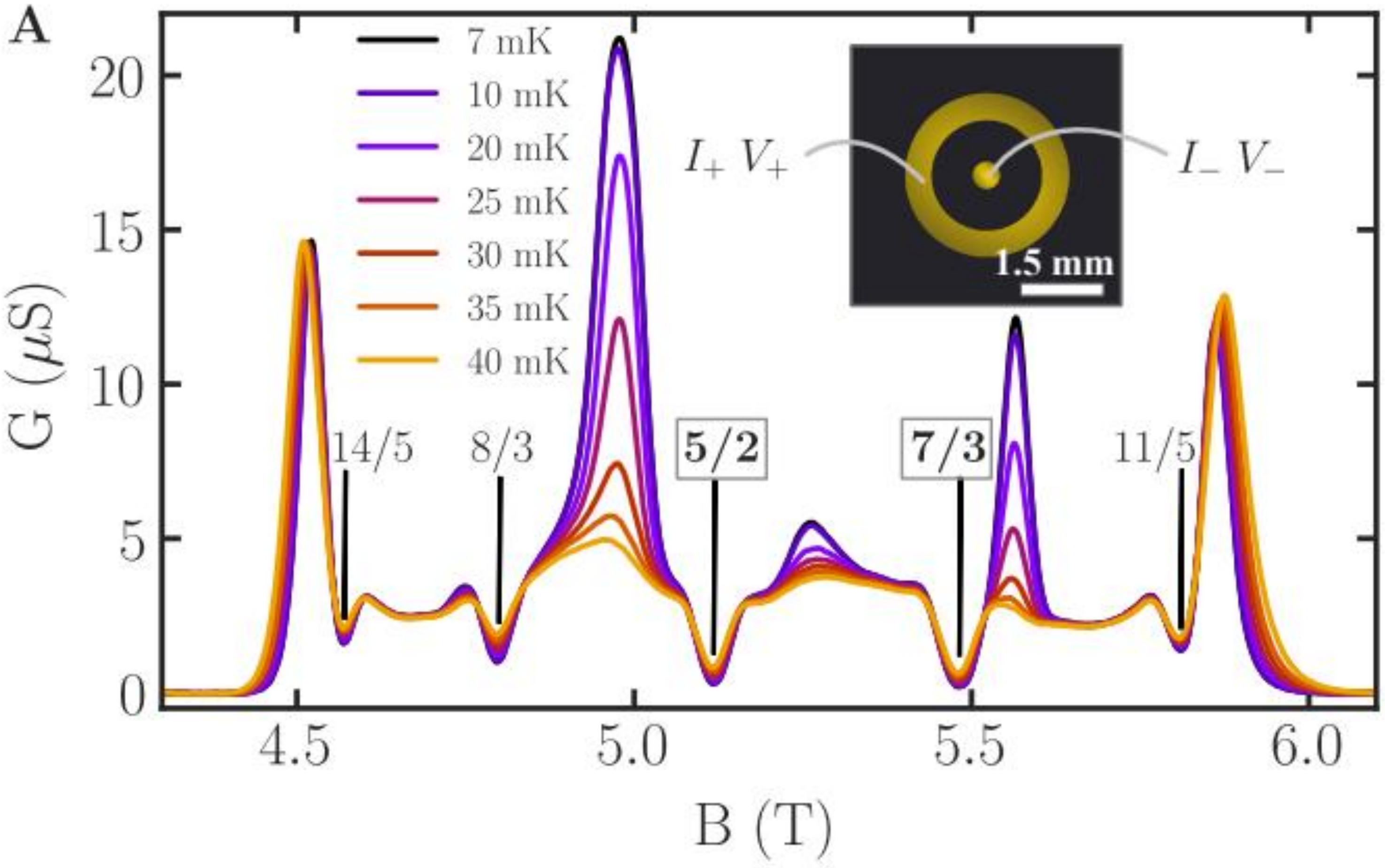




$$2\pi\sigma_{xx} = G\log\left(r_2/r_1\right)$$



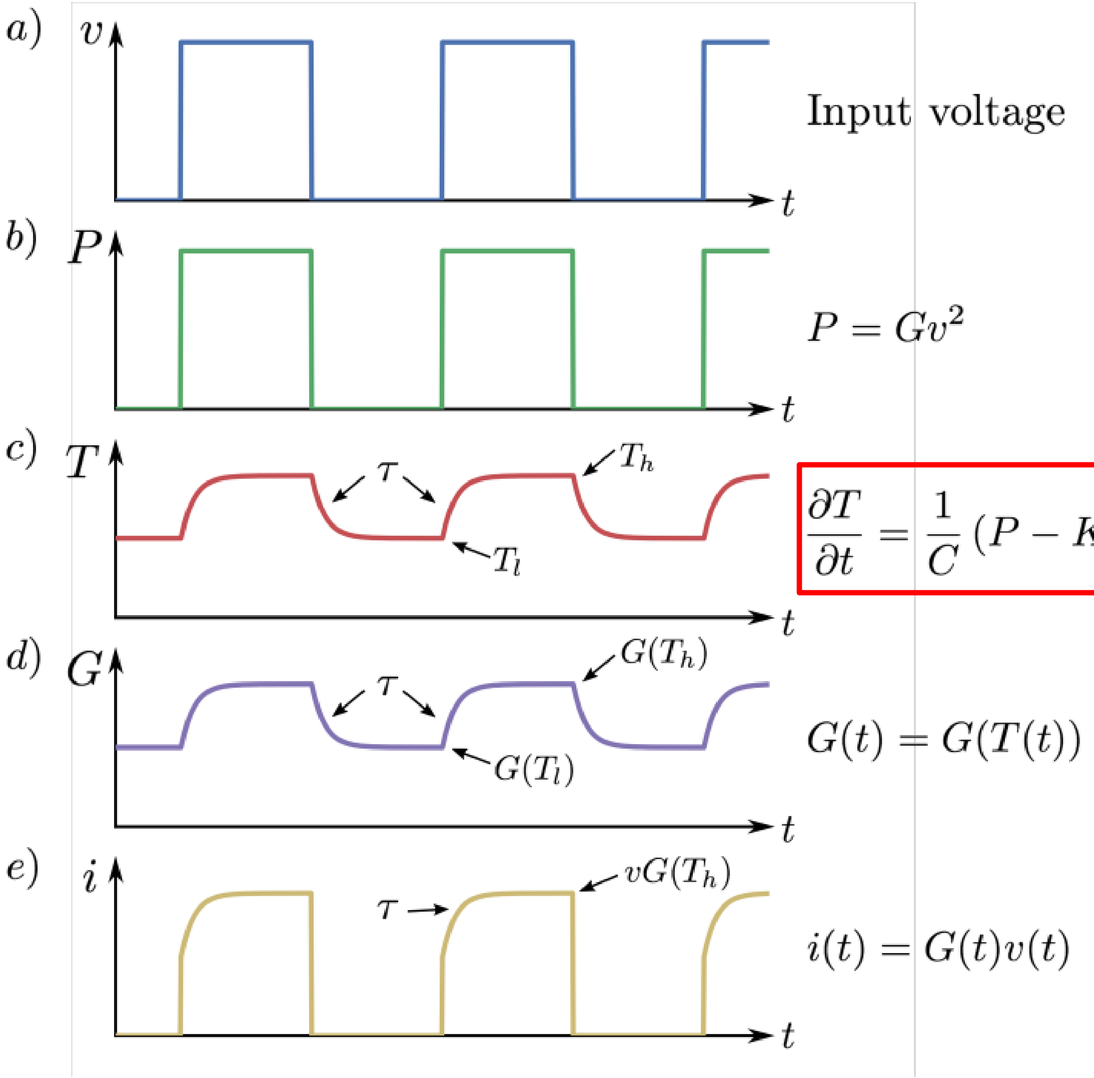
Method: Corbino Disc Thermometry (?)



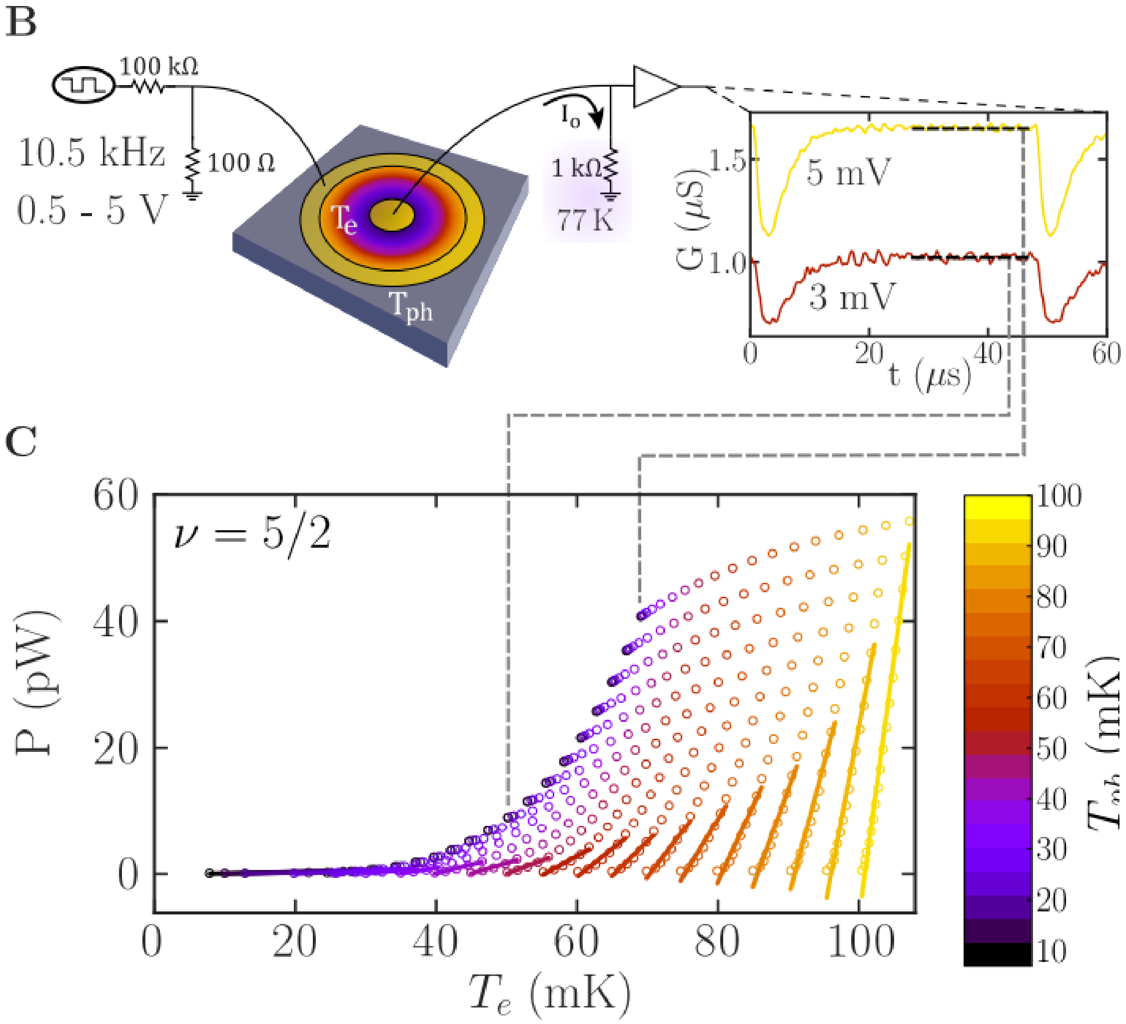
Te acquired by Intrapolation

Only T>20mK used

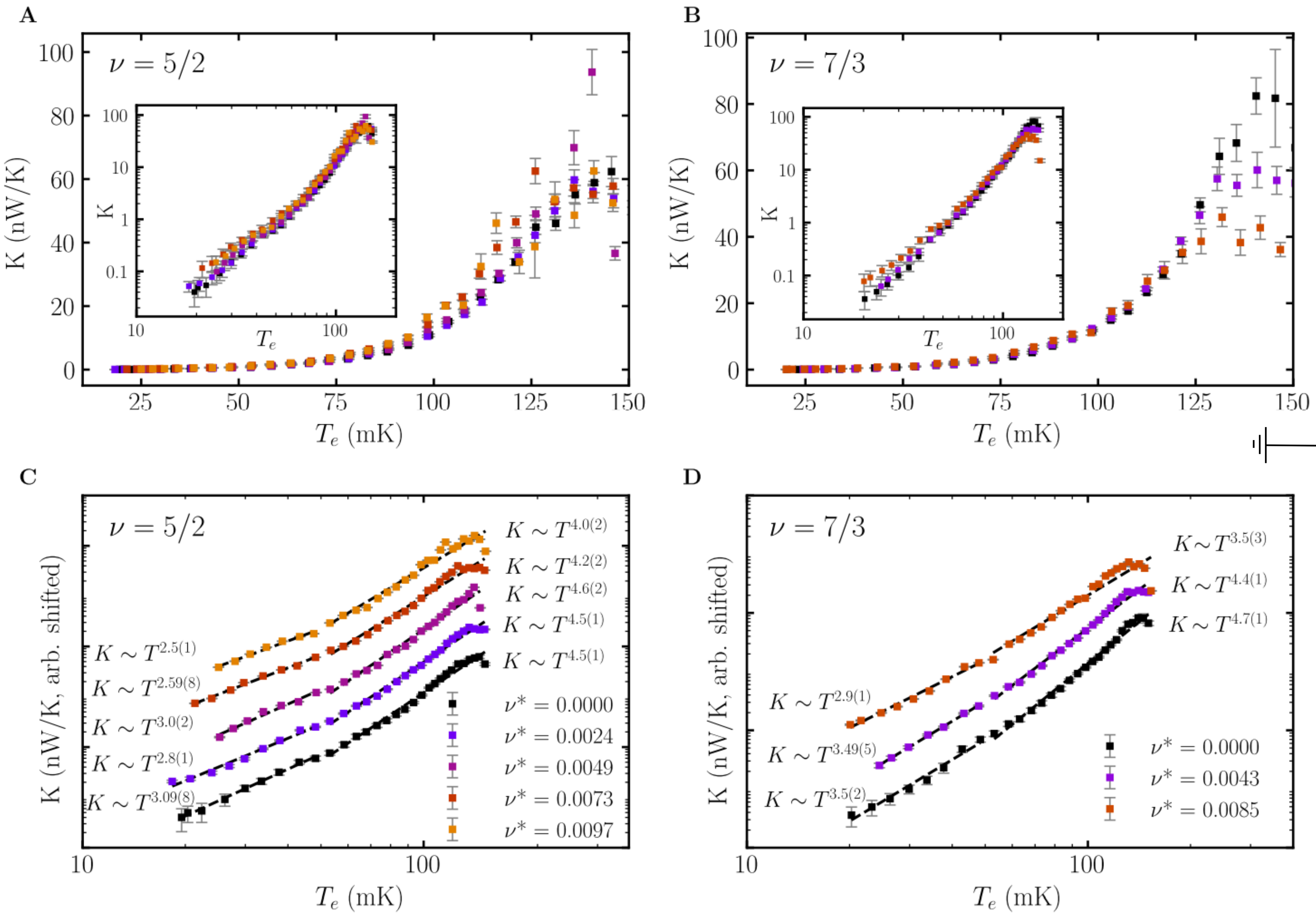
Method: Pause Heating and relaxing time

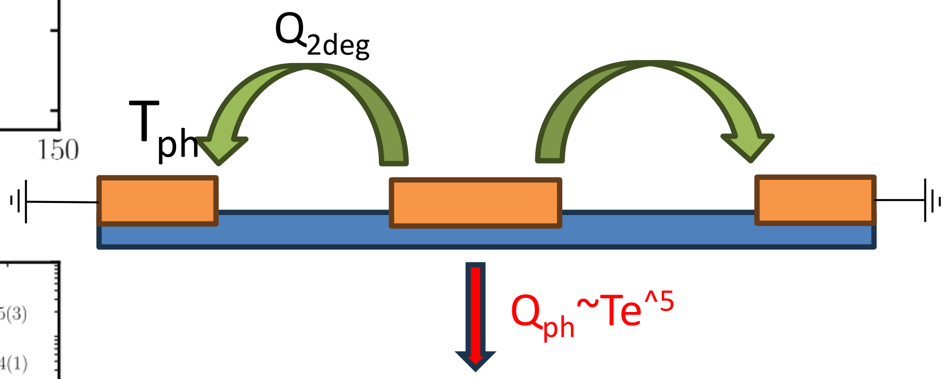


$$\frac{\partial T}{\partial t} = \frac{1}{C}(P - K\Delta T)$$



Result: 5/2 & 7/3 Heat Conductivity





Result: Violation of W-F law

$$\kappa_{WF} = \sigma_{xx} L_0 T$$

$$L_0 = \frac{\pi^2 k_B^2}{3e^2}$$

$$(K/T_e)/G_{xx} \sim 2.8 \times 10^5 \; L_0$$

Conclusion & Discussion

- Joel Heating pulse can be used to measure thermal conductance of Corbino Disc
- Electron-Phonon cooling dominates at high temperature
- Heat transfer through 2DEG is non-trivial

- A primary thermometry is necessary to have Te at low temperature

Appendix: Correction of T and K

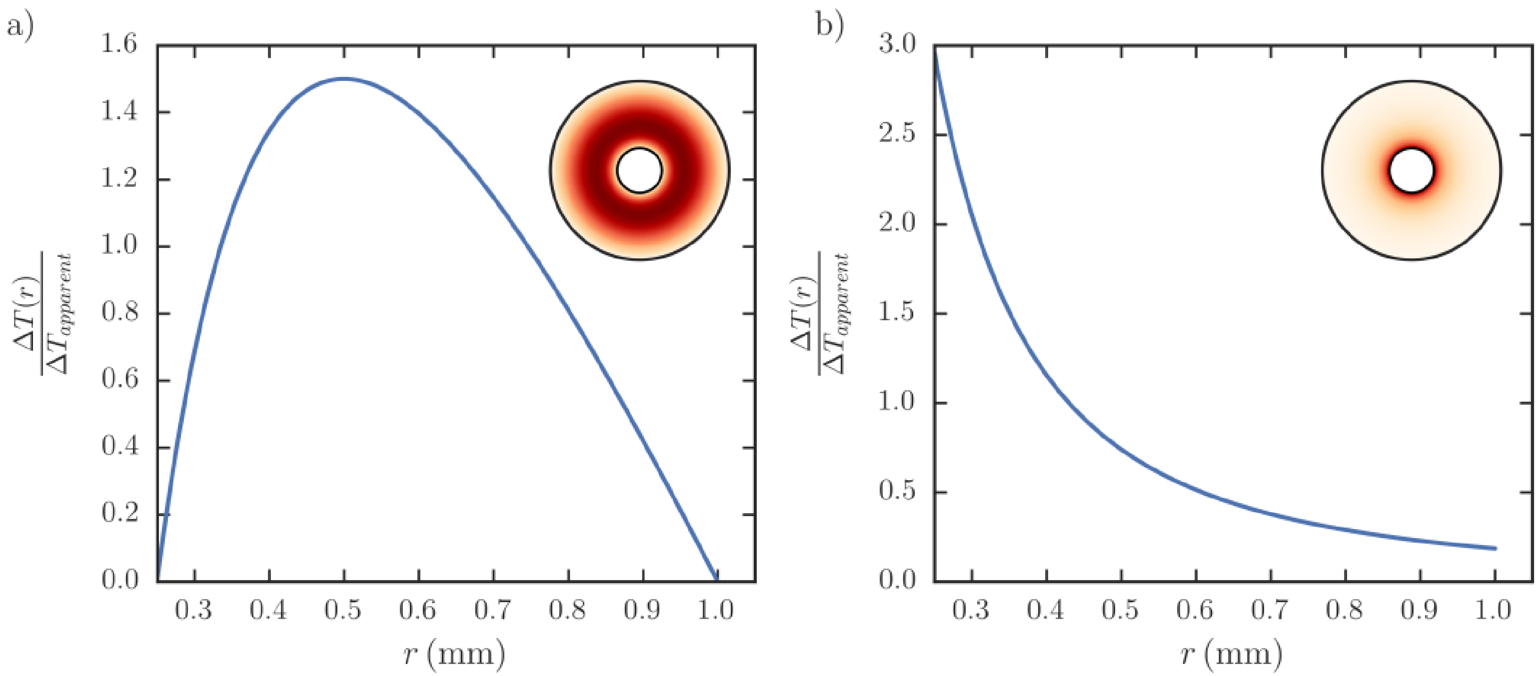


Figure 6.5: Analytical solutions for the temperature profile in our Corbino device under constant voltage bias. (a) Cooling through the contacts via electron diffusion. (b) Cooling through the electron-phonon interaction. Insets show the same data as 2D radial color plots.

II. *IN SITU* THERMOMETER CALIBRATION OF THE 2DEG

To obtain the temperature T_e of the two-dimensional electron gas (2DEG) when subjected to a heating power P, we make use of the temperature dependence of the conductance $G(T_e)$ at the 5/2 FQH state. As can be inferred from Fig. 1A of the manuscript, this temperature dependence is sharp enough to allow us to extract an electron temperature T_e from the conductance $G(T_e)$ making use of a univariate spline interpolation. This procedure was applied throughout all the non-exact filling factors $\nu^* \neq 0$. However, it is important to note that this procedure is limited to ~ 20 mK because the temperature dependence gets progressively weaker as the temperature falls below that range, and thus the thermal conductance could only be extracted for temperatures above 20 mK.

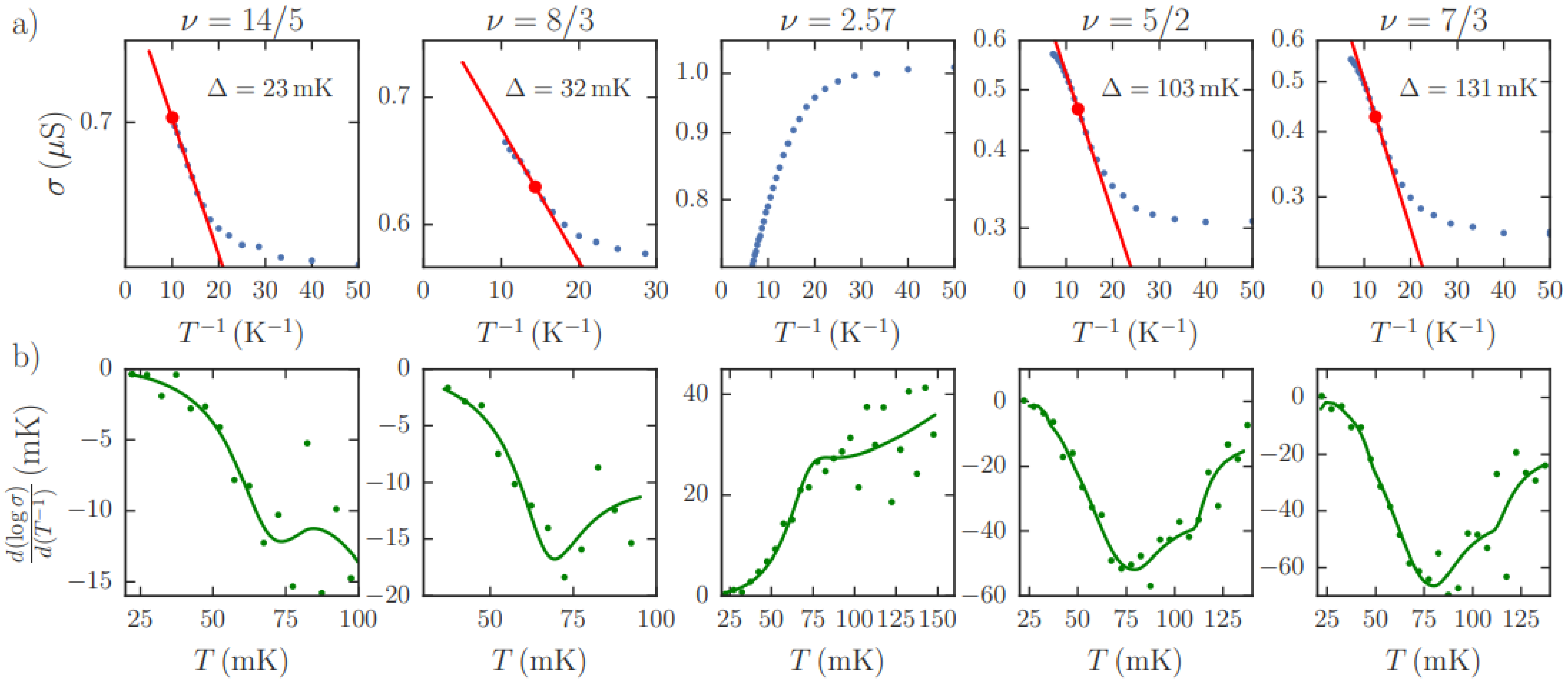


Figure 7.12: (a) Arrhenius fits to the conductivity at each indicated filling factor, with data in blue and linear fit to the activated region in red. The inflection point is marked by a red circle. (b) Corresponding plots of the Arrhenius slope vs. temperature, with data as points and a smoothed spline interpolation in green. The minima give $-\Delta/2$, and their locations in temperature give T_i.