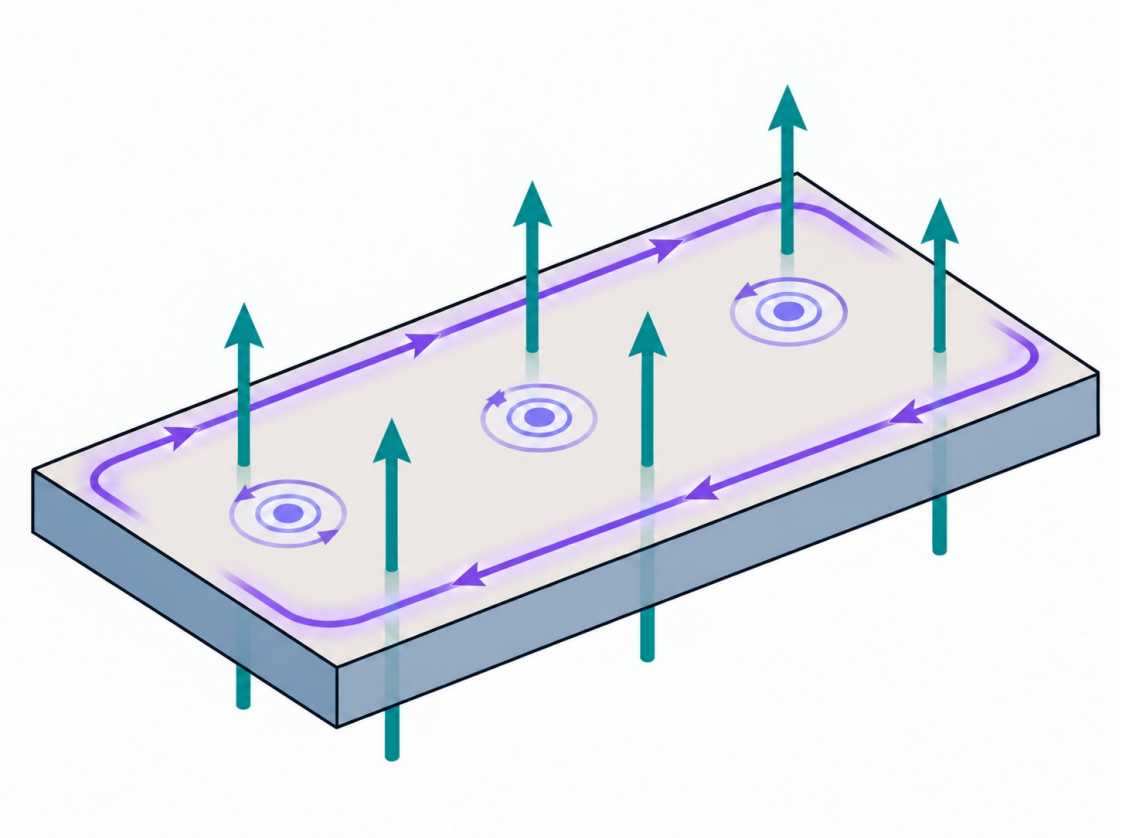
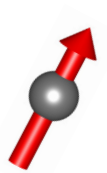
Quantization and conduction on the edge

chiral edge states

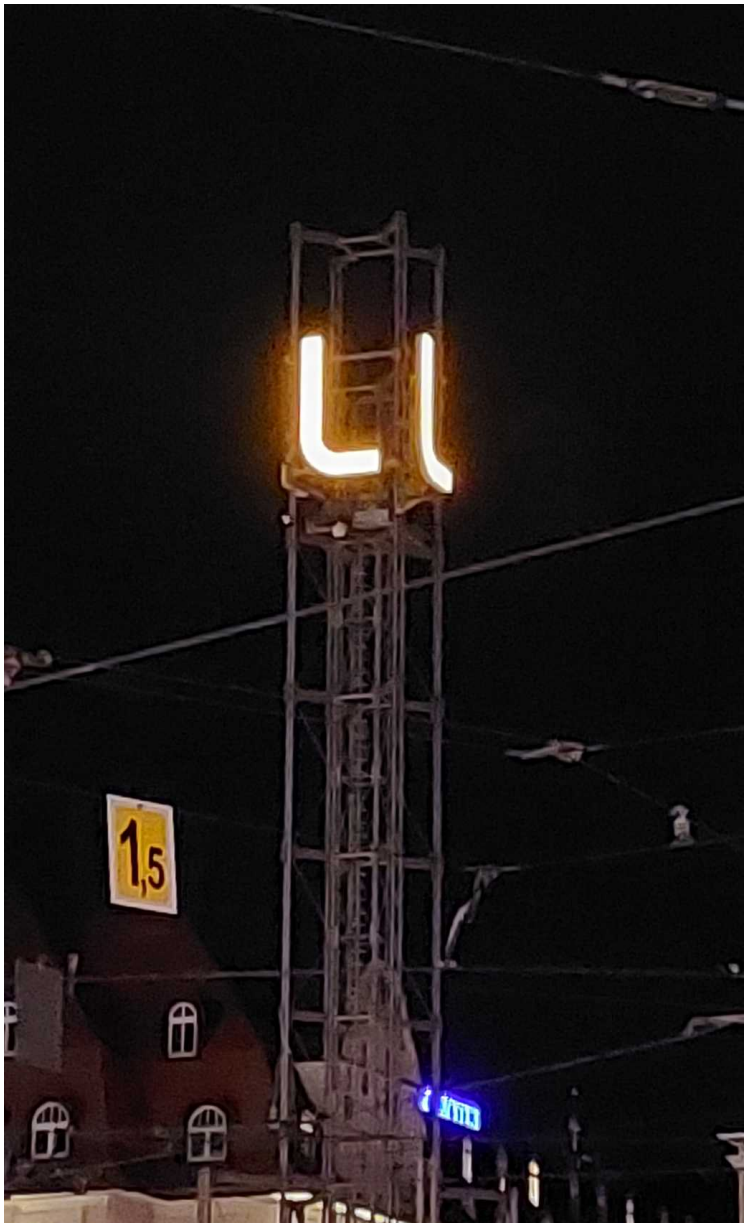




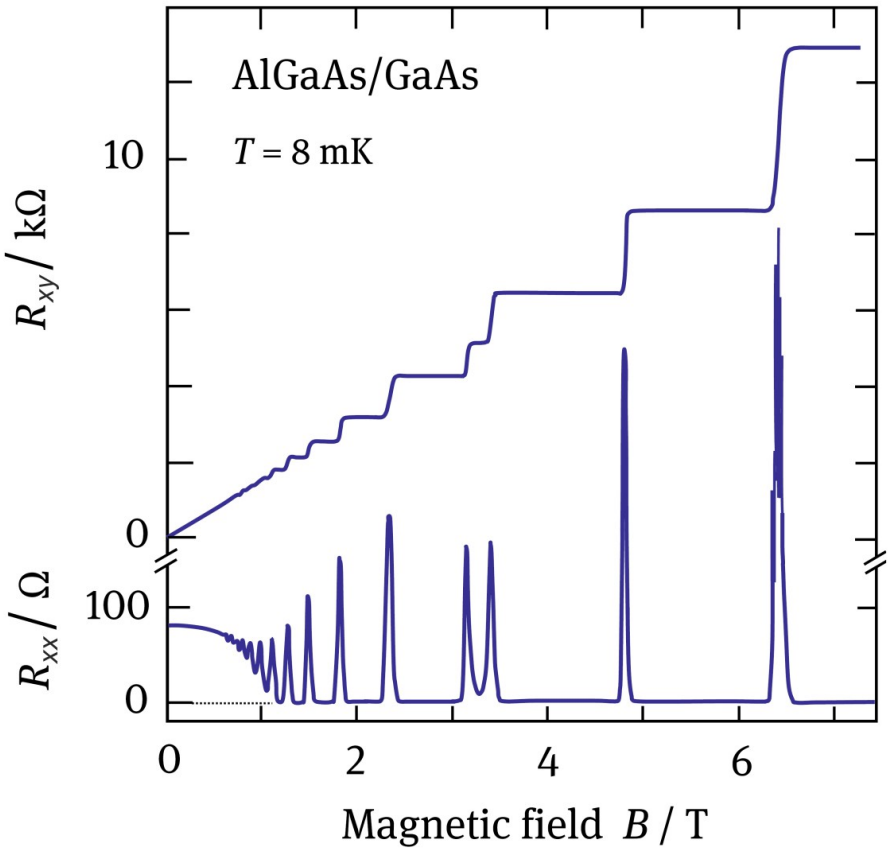
by Alexander Tsirlin, Leipzig University

Lecture 4: October 20, 2026

Landau levels looming in the dark

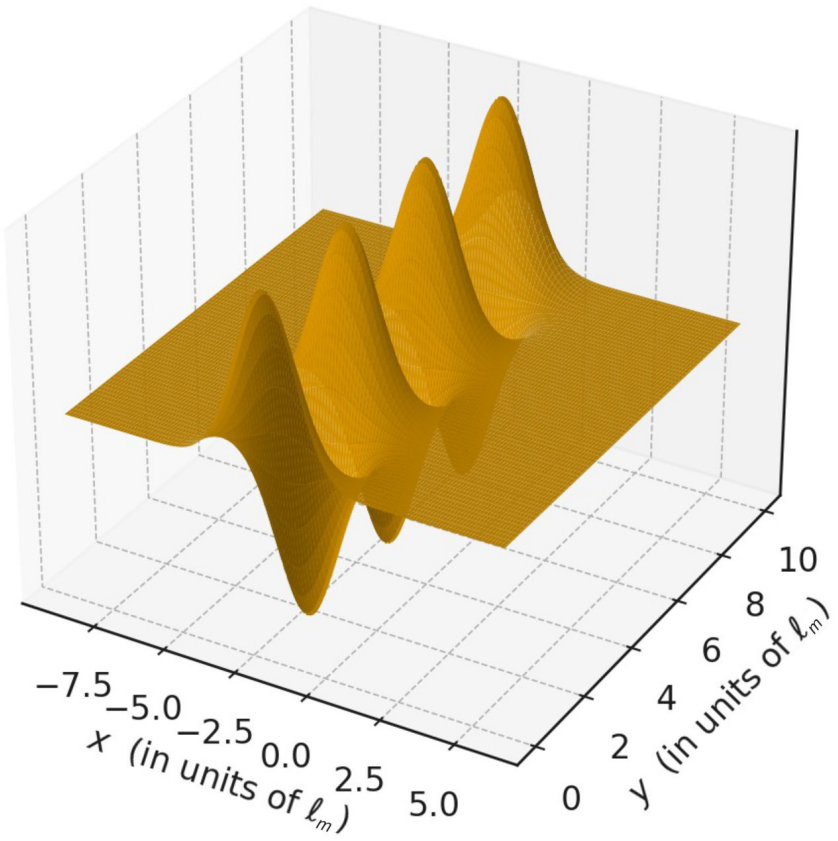


Landau levels are the key to understanding quantum Hall effect!

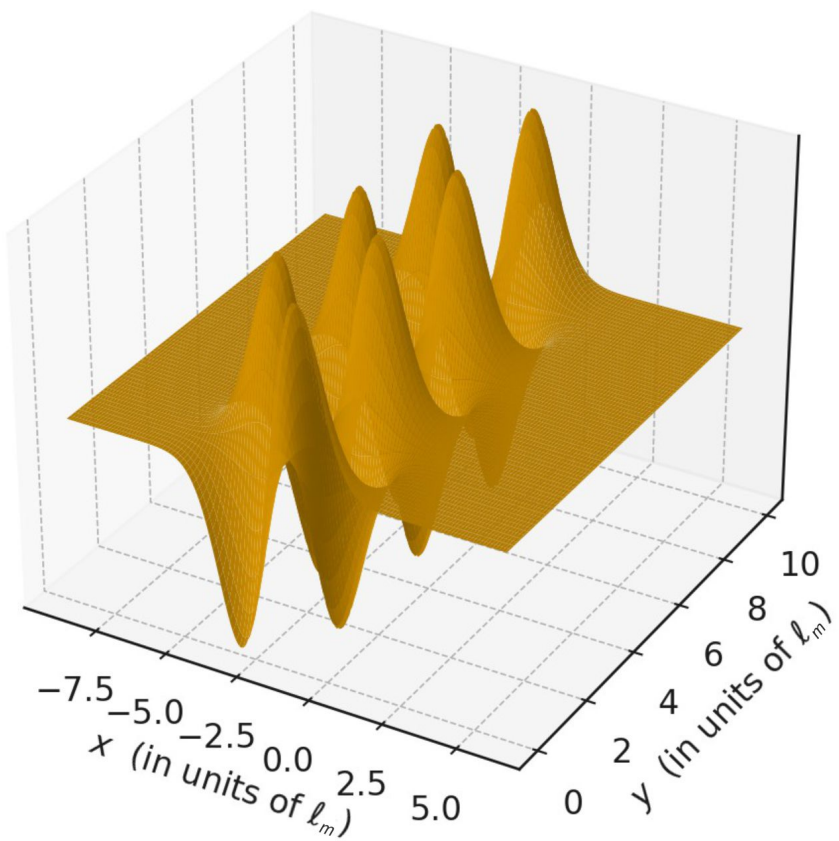


Wavefunctions of electrons in Landau levels

Landau gauge used



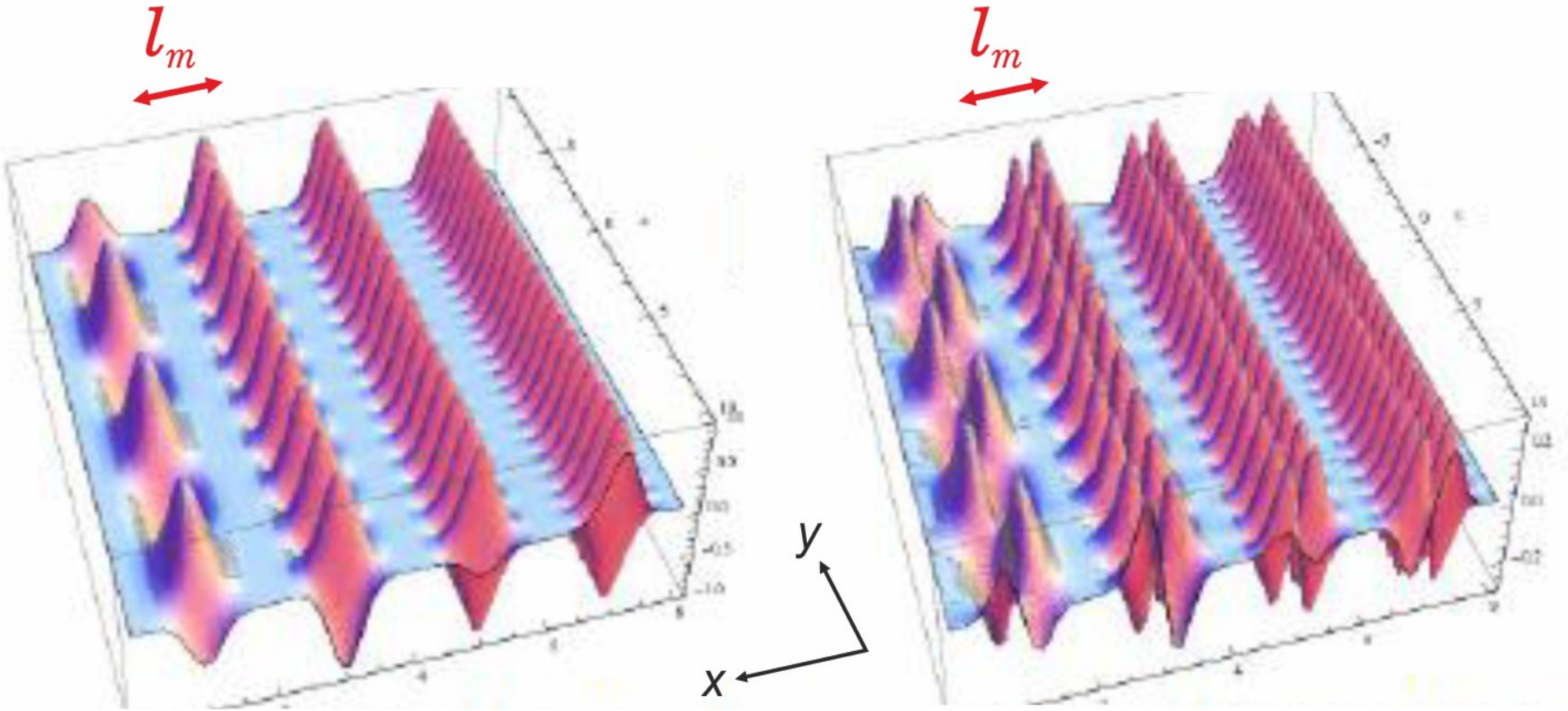
$n = 0$ Landau level



$n = 1$ Landau level

Wavefunctions of electrons in Landau levels

Landau gauge used

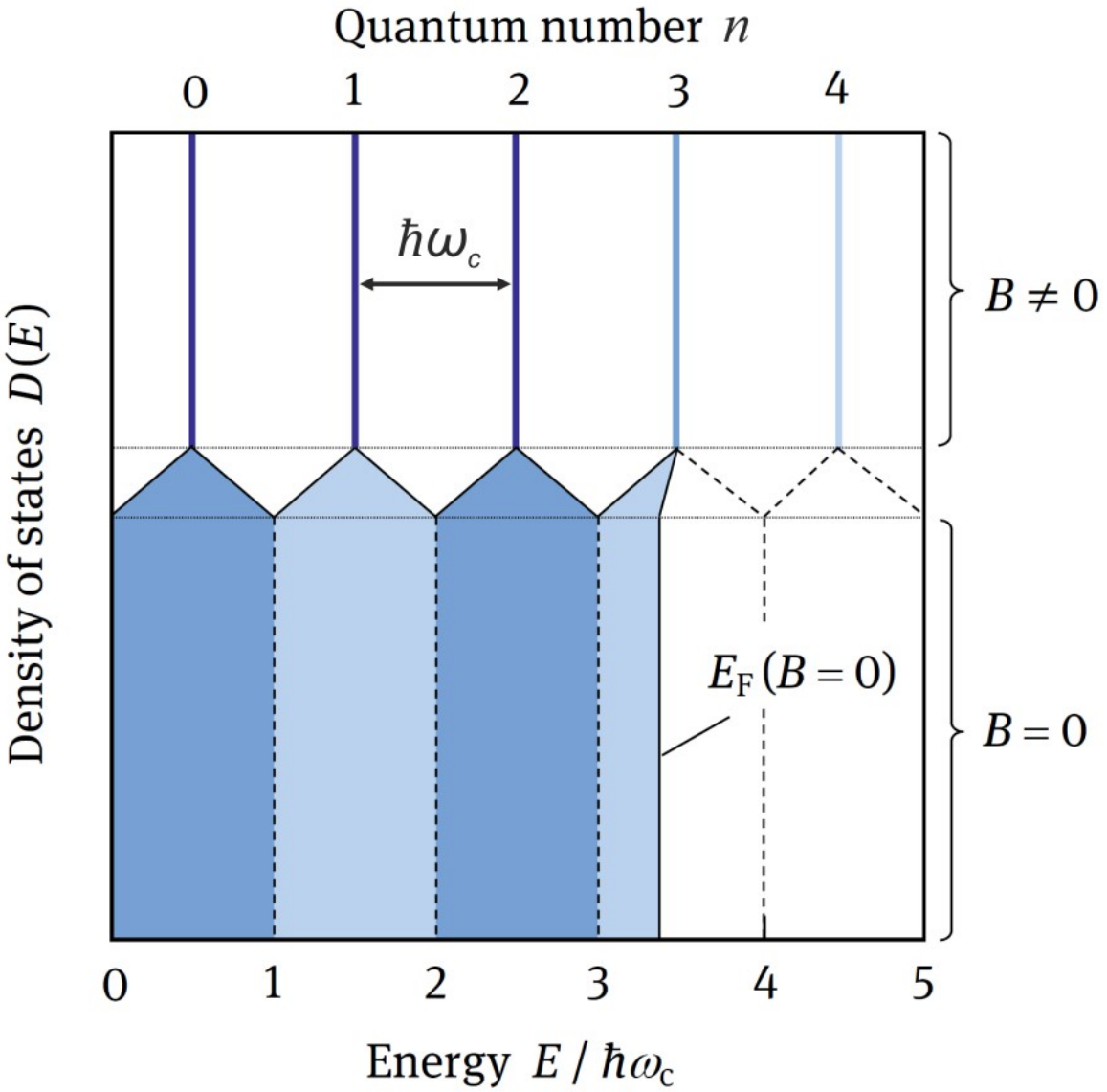


$n = 0$ Landau level

$n = 1$ Landau level

Image credit: Eva Andrei

Degeneracy of Landau levels



Increasing B:

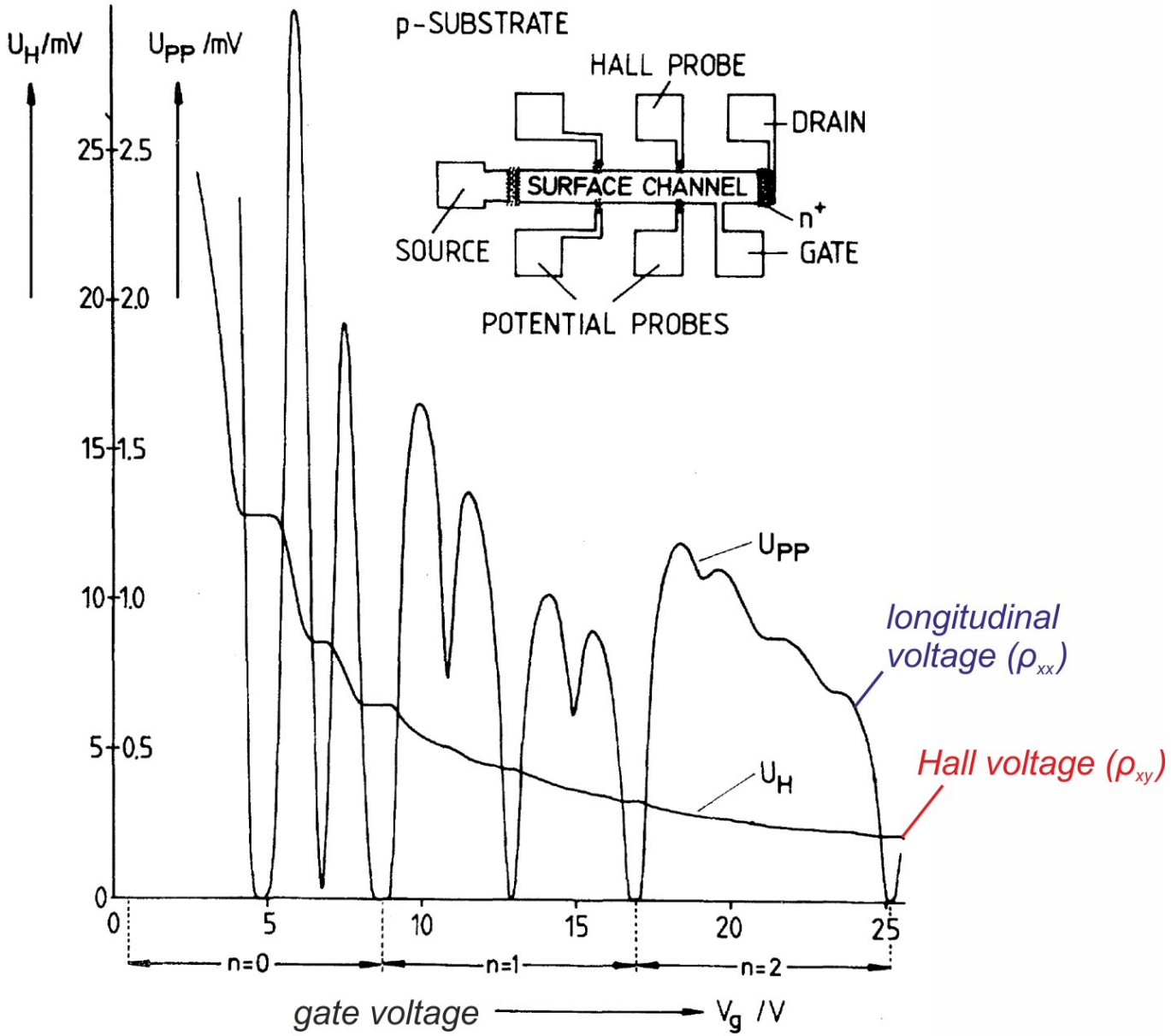
- increases spacing between LL's ($\hbar\omega_c$)
- squeezes more states into a single LL

Degeneracy $\sim B$

$(N = \Phi/\Phi_0)$

S. Hunklinger, Festkörperphysik

Earliest experimental data



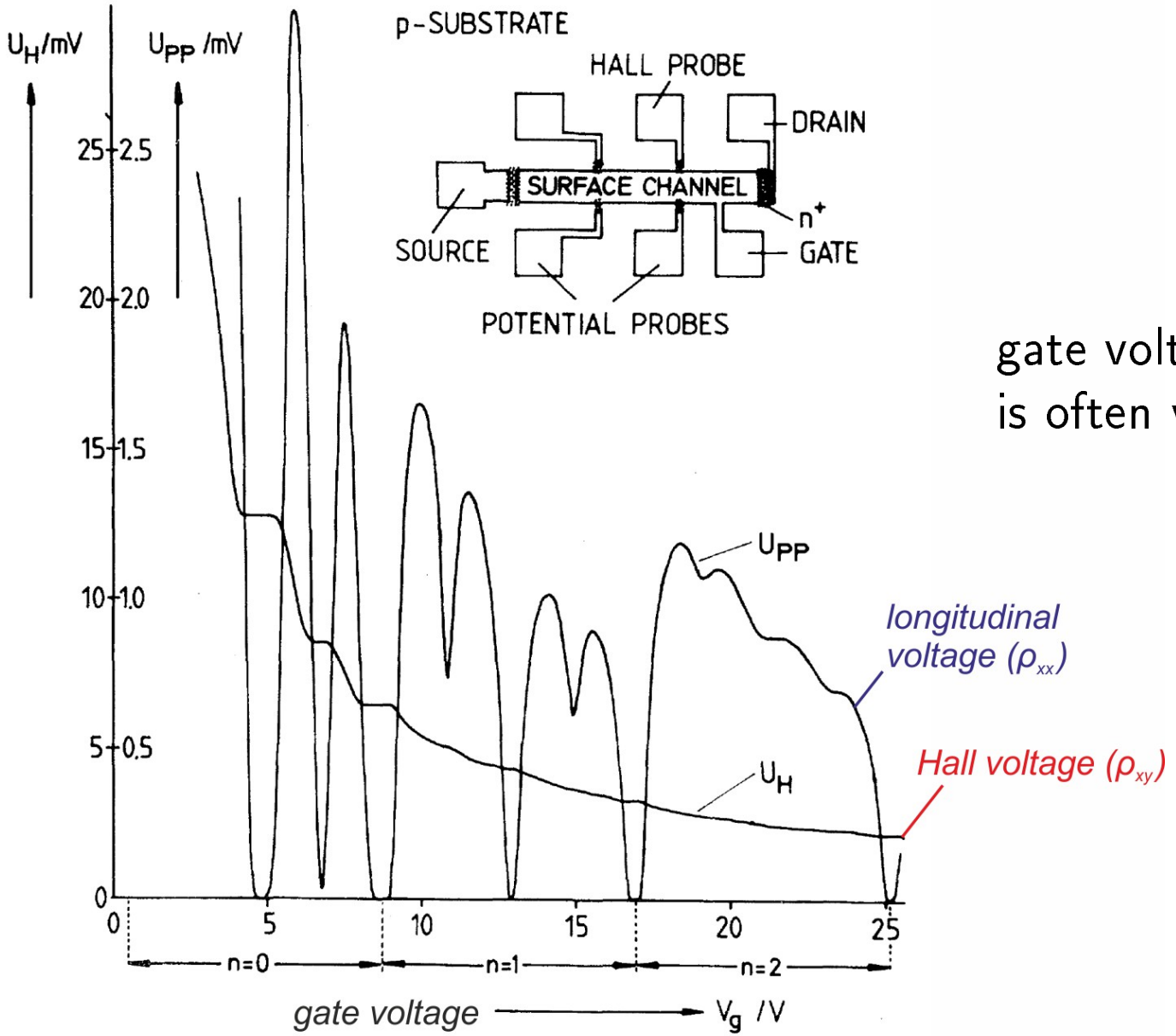
Si-MOSFET

$B = 18\,\mathrm{T}$

$T = 1.5\,\mathrm{K}$

Phys. Rev. Lett. 45, 494 (1980)

Earliest experimental data



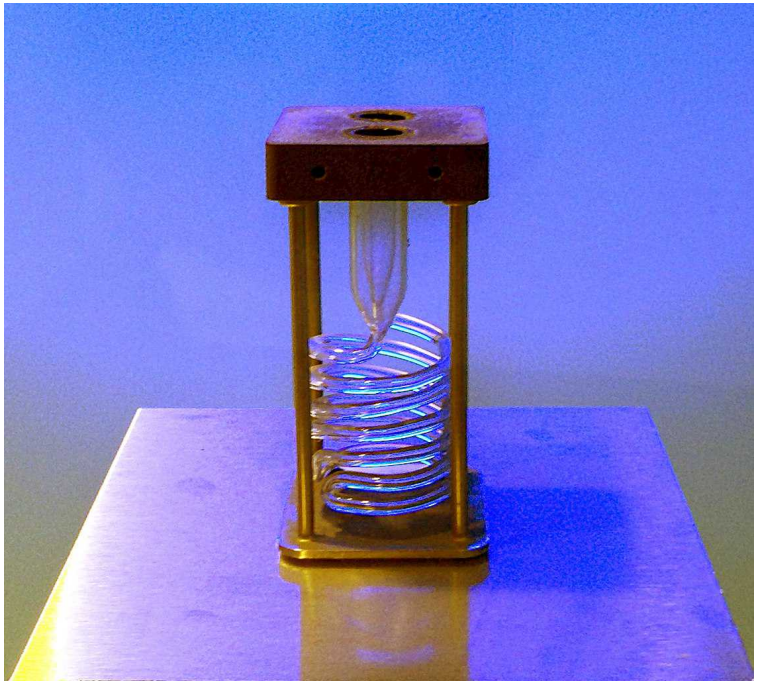
Si-MOSFET

$B = 18\,\mathrm{T}$

$T = 1.5\,\mathrm{K}$

gate voltage ($\Rightarrow n_e$)
is often varied instead of B

Phys. Rev. Lett. 45, 494 (1980)

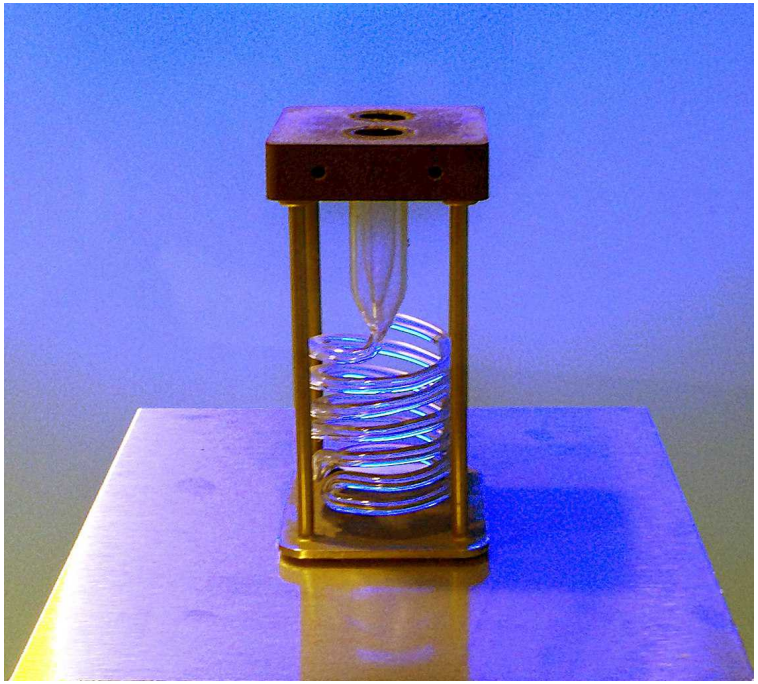


1860: Siemens mercury unit
1 m of Hg with 1 mm^2 cross-section

1863: coil made of German silver
(Maxwell, Joule *et al.*)

1893: international mercury standard
106 cm of Hg with fixed mass

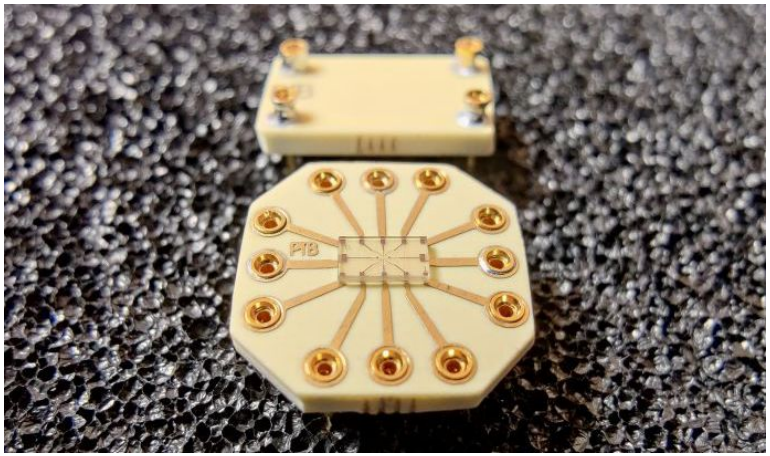
Image credits: Reinraum (CC-BY-SA)



1860: Siemens mercury unit
1 m of Hg with 1 mm^2 cross-section

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(Maxwell, Joule *et al.*)

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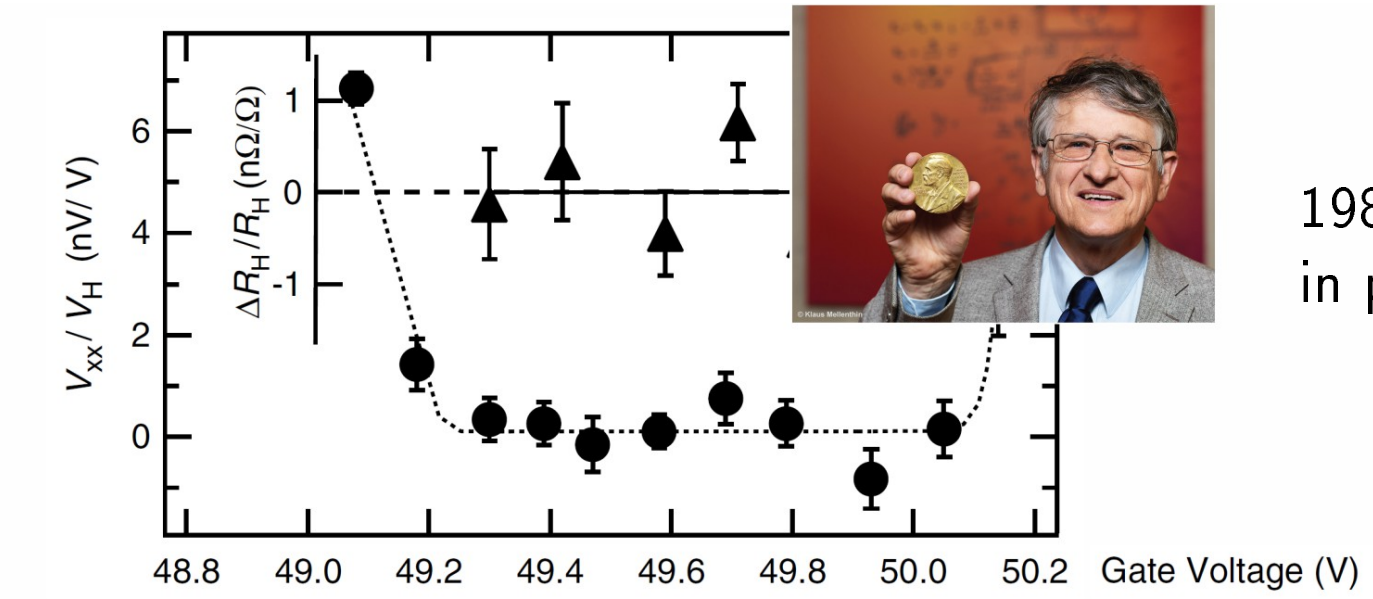
1990: QHE standards

(GaAs/AlGaAs heterostructures
or graphene)

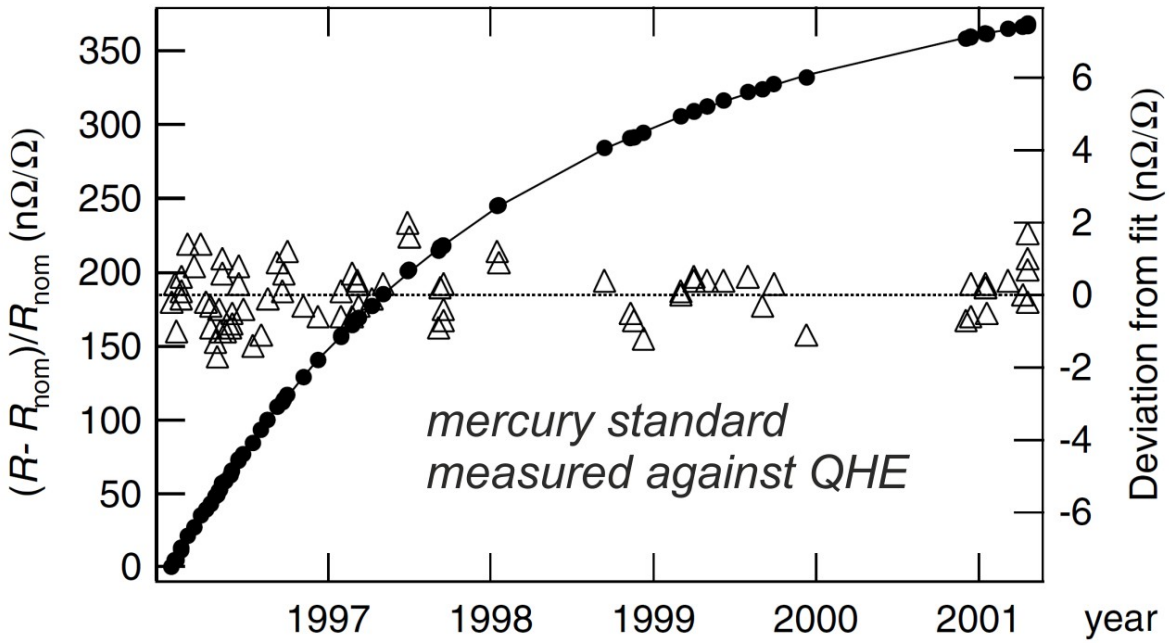
Image credits: Reinraum (CC-BY-SA) and PTB

New resistance standard

Rep. Prog. Phys. 64, 1603 (2001)

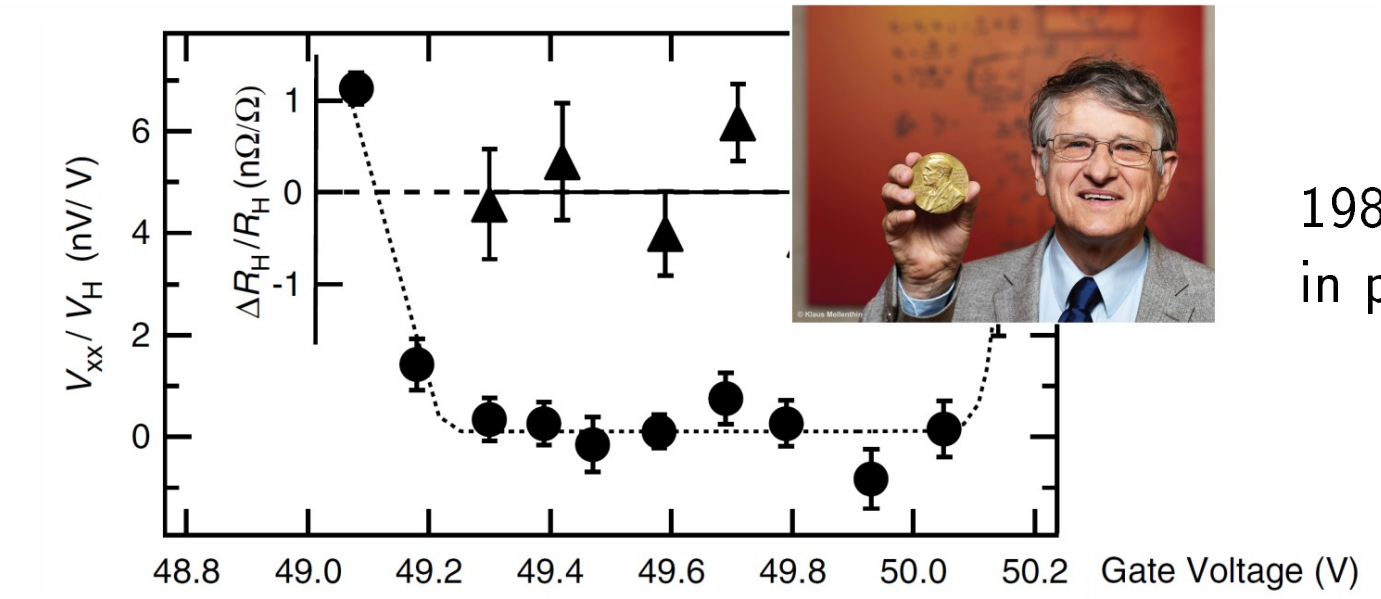


1985 Nobel prize in physics

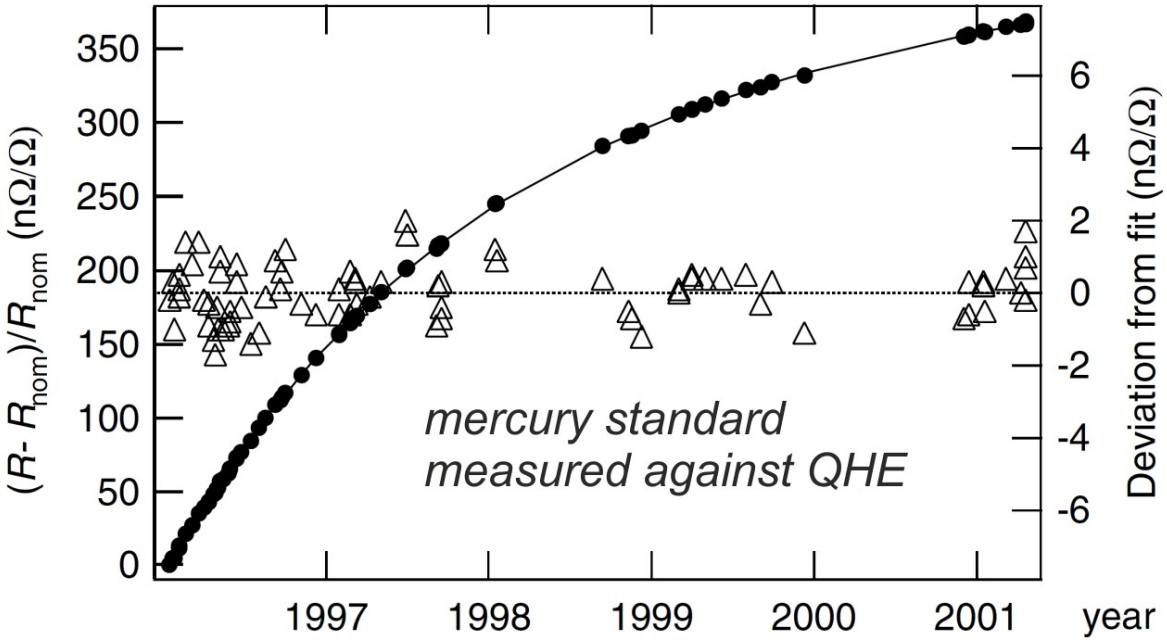


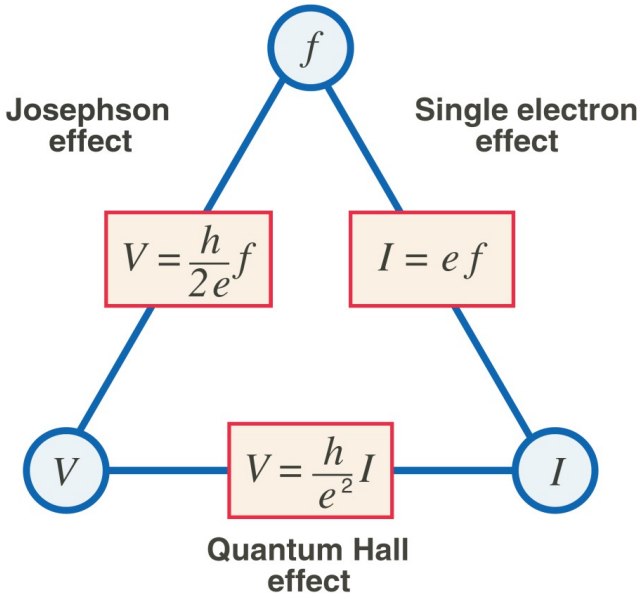
New resistance standard

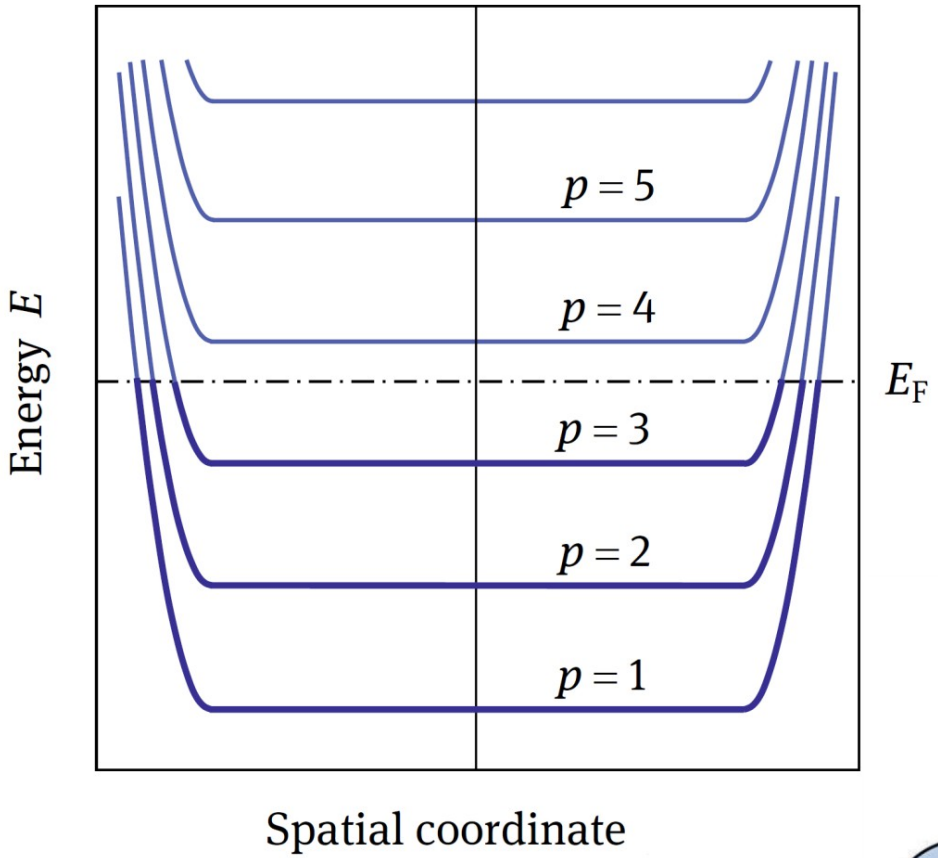
Rep. Prog. Phys. 64, 1603 (2001)



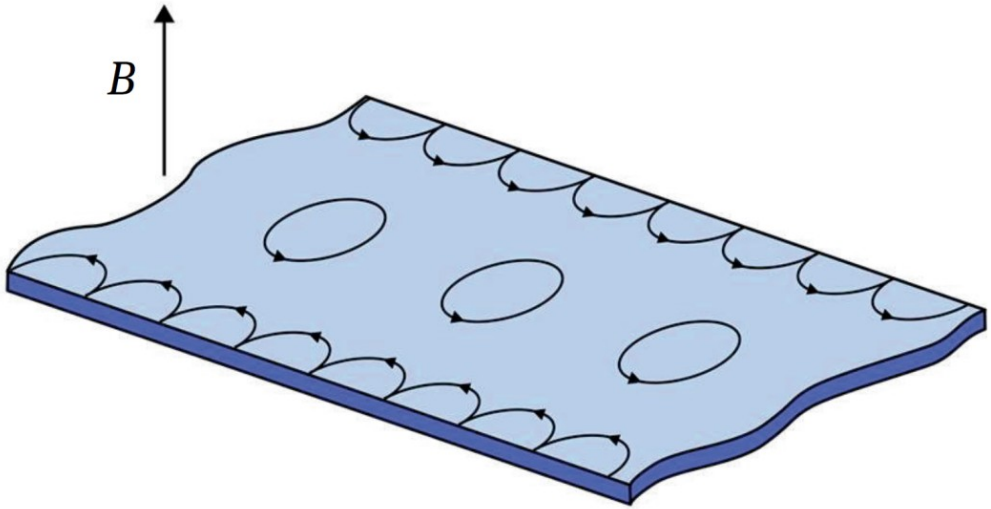
1985 Nobel prize in physics







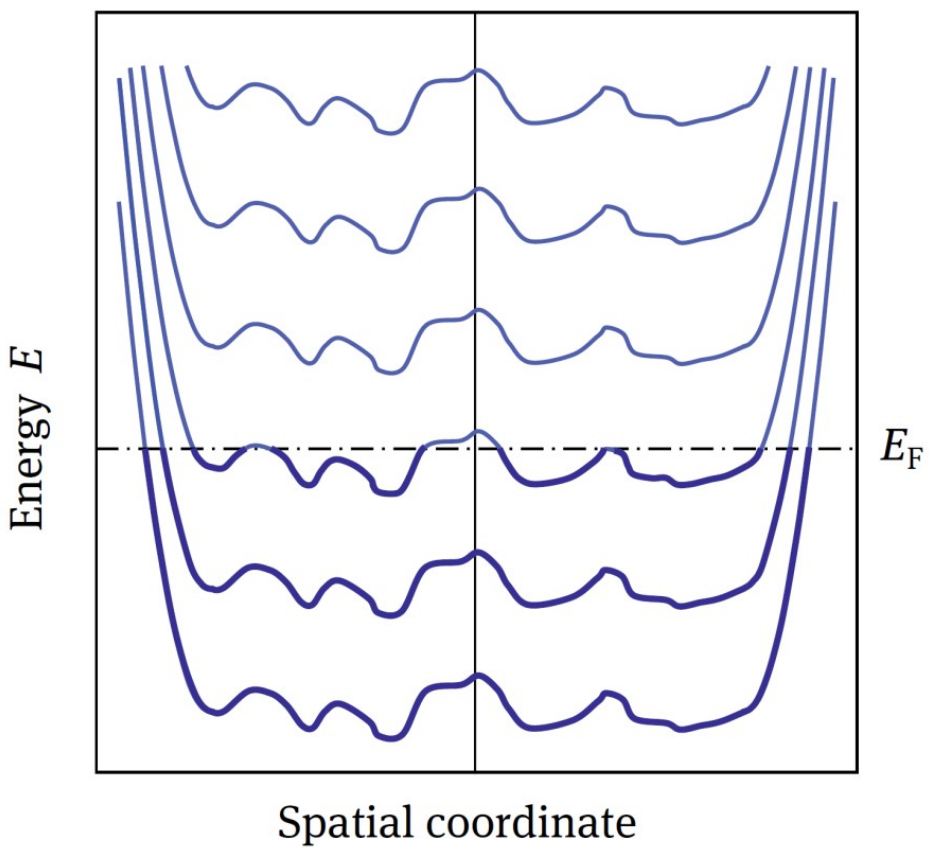
These modes are **chiral**
(propagate in one direction only)

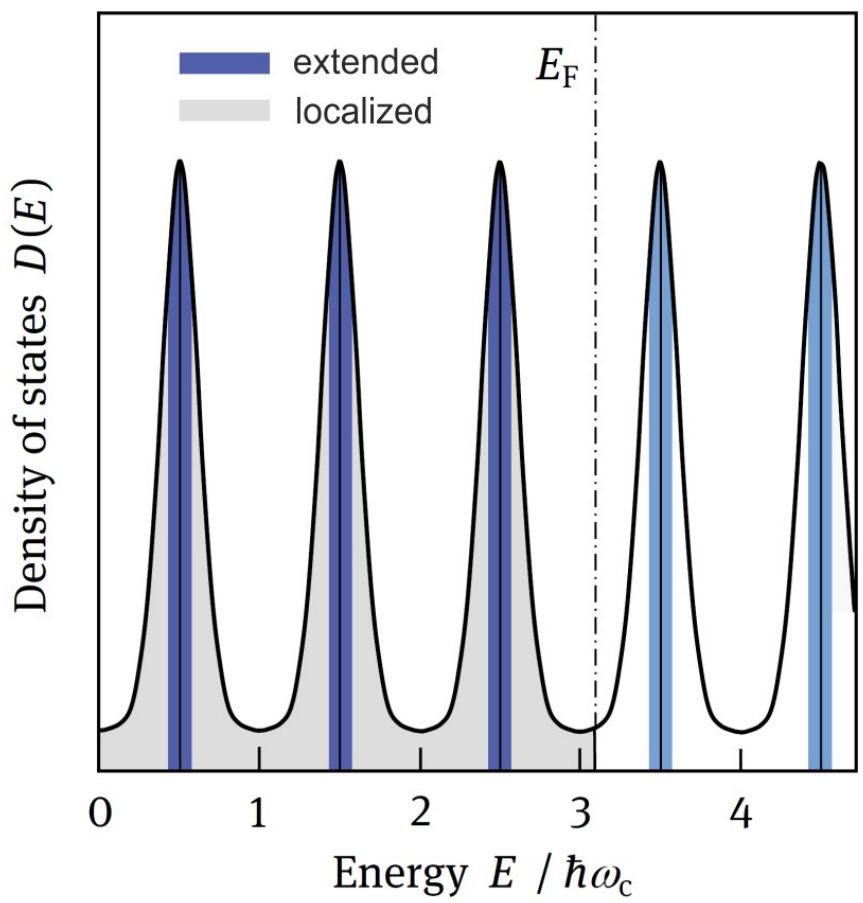


One chiral mode
for each Landau level

S. Hunklinger, Festkörperphysik

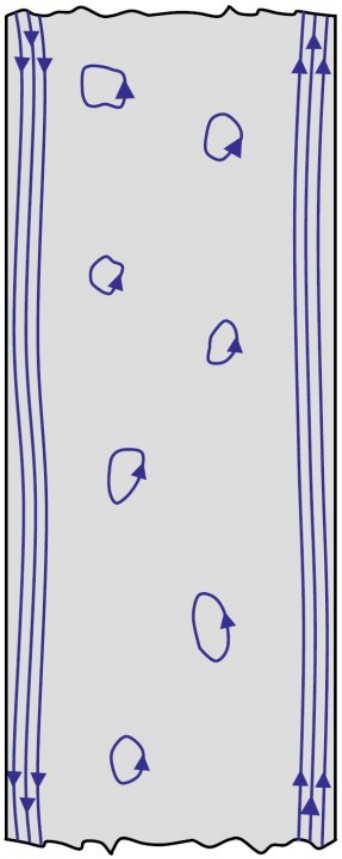
Effect of disorder



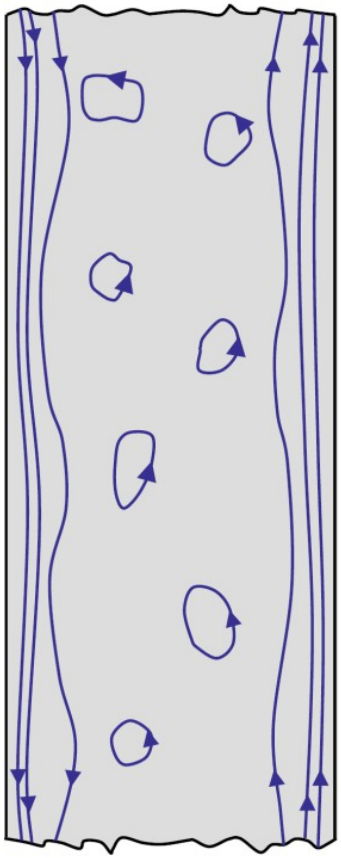


S. Hunklinger, Festkörperphysik

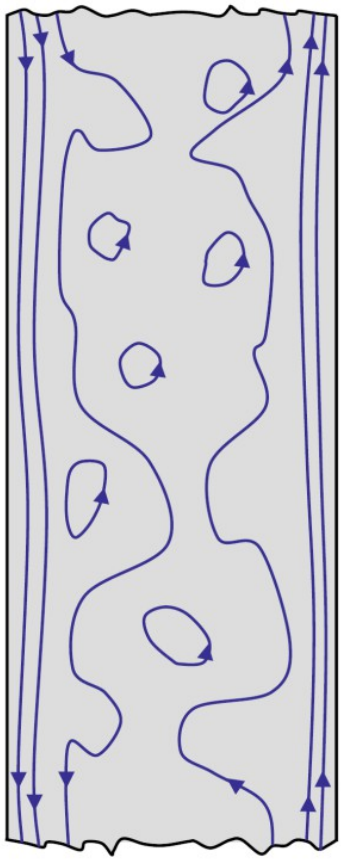
Effect of disorder

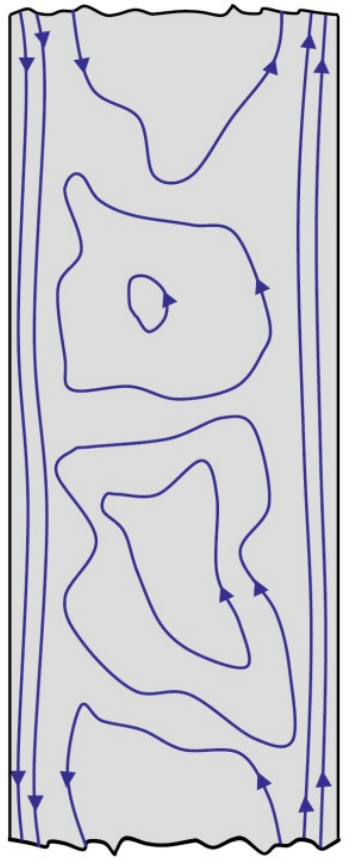


$n = 3$



crossover between two plateaux,
one conducting mode
separates from the edge





$n = 2$