Bloch ferromagnetism of composite fermions

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Journal club

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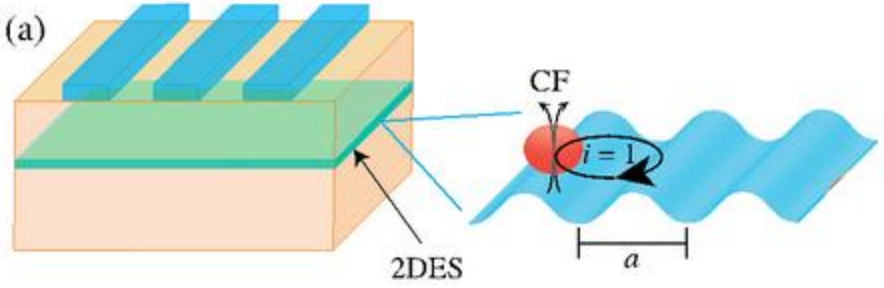
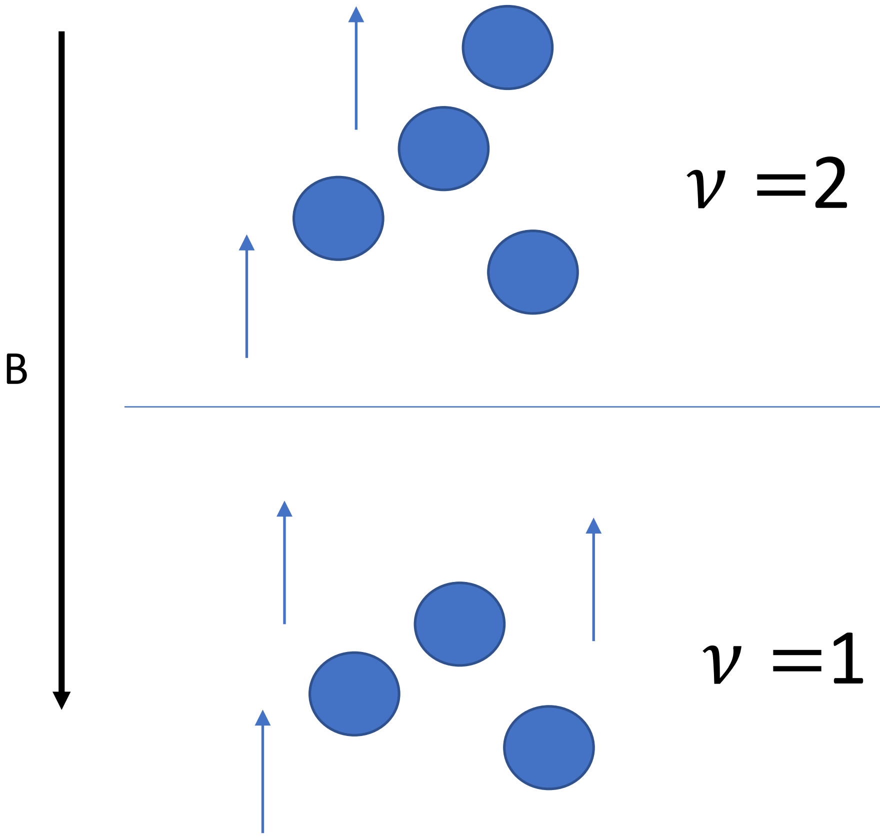


Introduction:

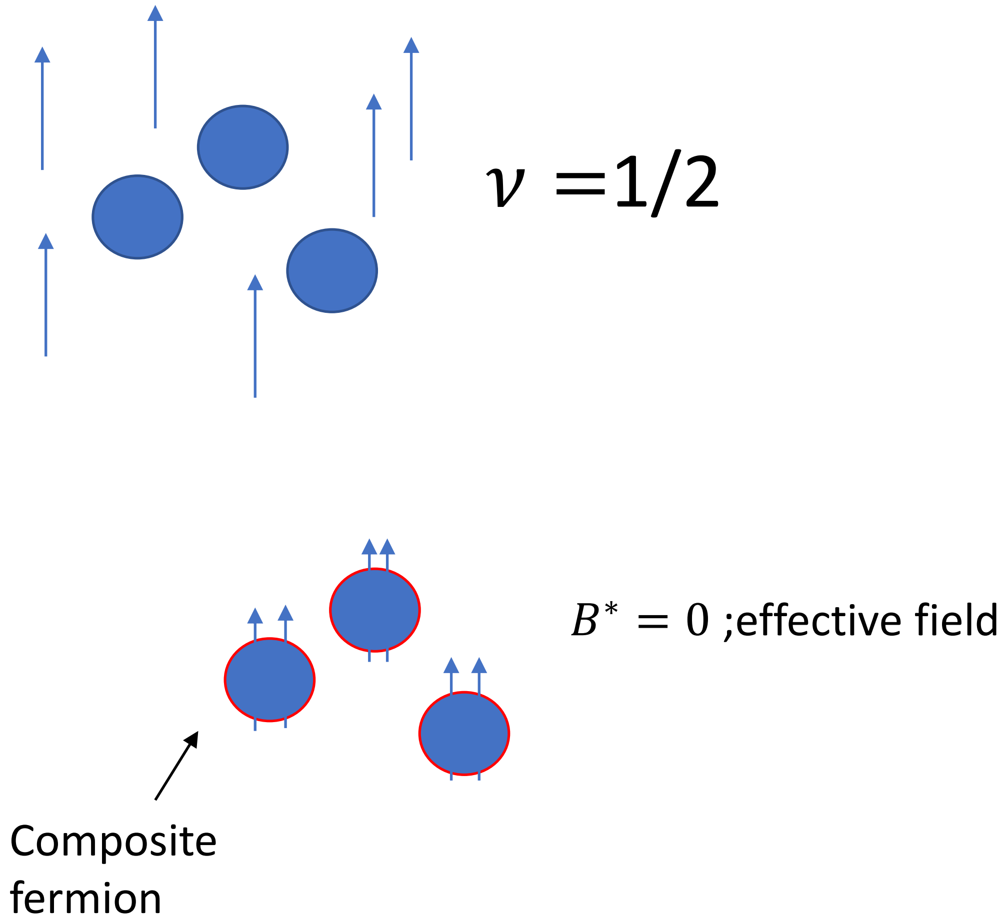
composite fermions
and
Bloch-ferromagnetism

Composite Fermions (CF)

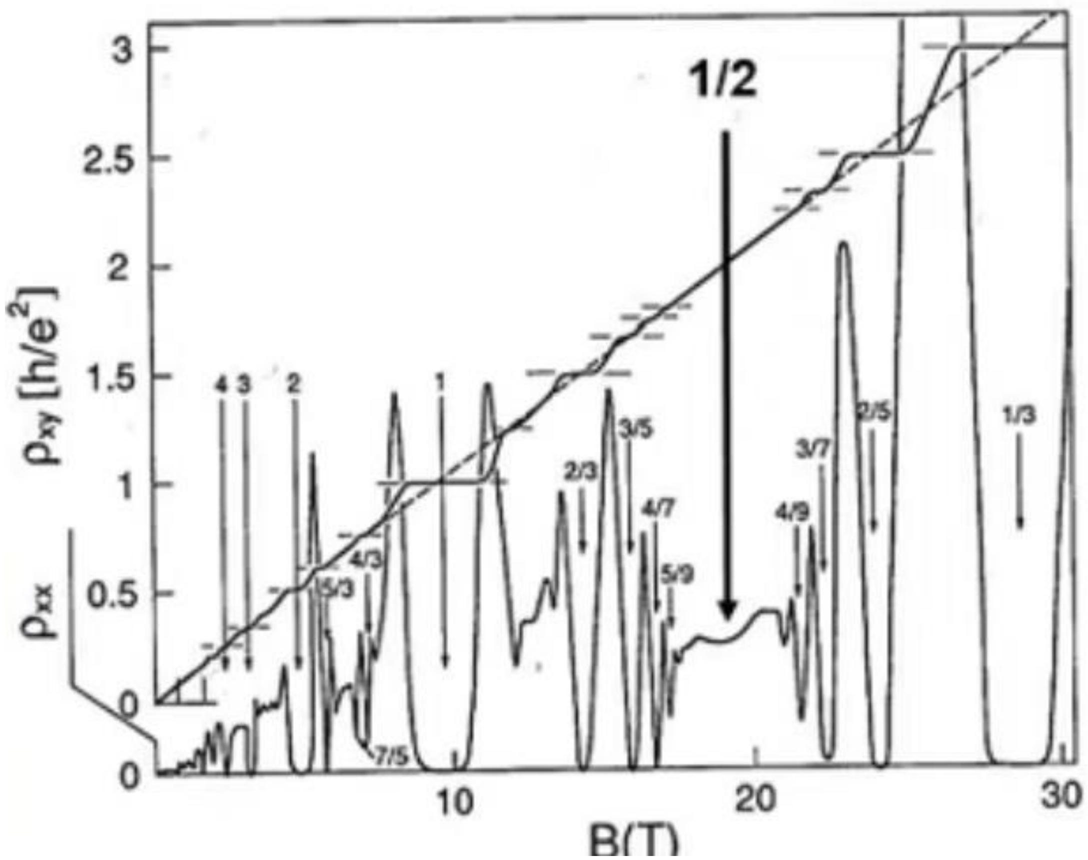
- Filling factor $\nu = \frac{N_e}{N_\phi}$



- Flux attachment



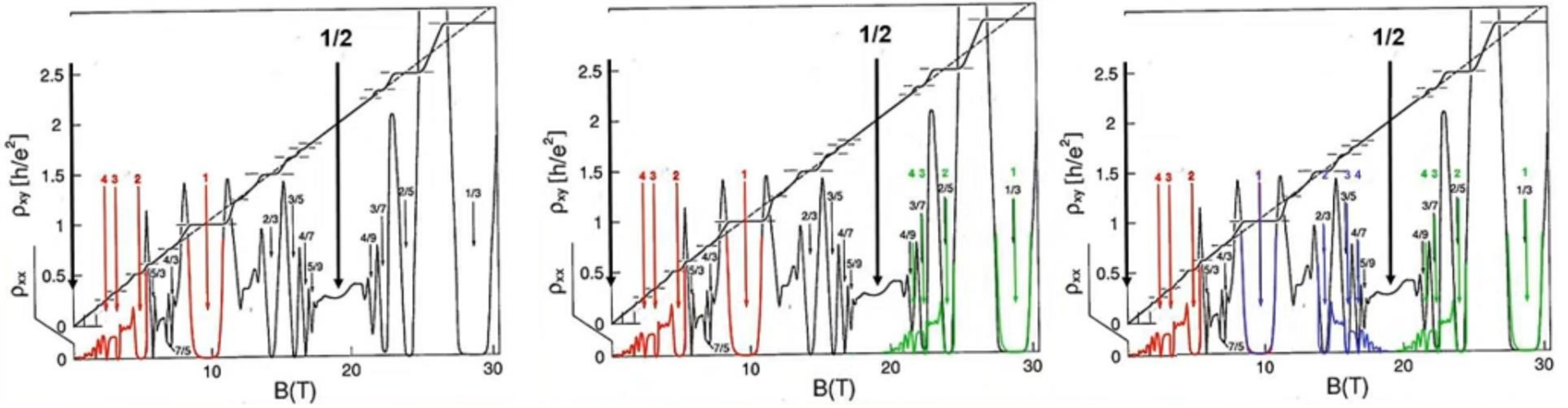
Composite Fermions



- Collective particle that describes some fractional states
- Flux attachement electron bind to 2m Fluxqunata
- Composite fermions see reduced field B*
- Bulk nu=1/2 == B*=0
  - Nu=1/2 for Cf is like B=0 for Electrons!

Composit Fermions

- The fractions can be explained as integer QHE of composite fermions!



Bloch Ferromagnetism

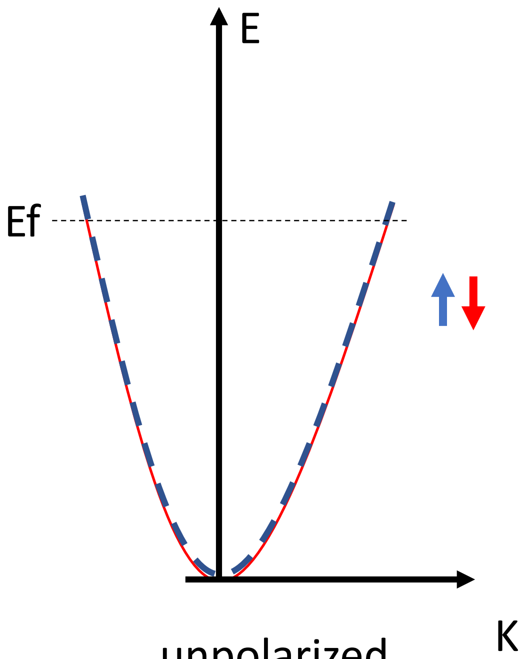
Bemerkung zur Elektronentheorie des Ferromagnetismus und der elektrischen Leitfähigkeit.

Von **F. Bloch** in Zürich.

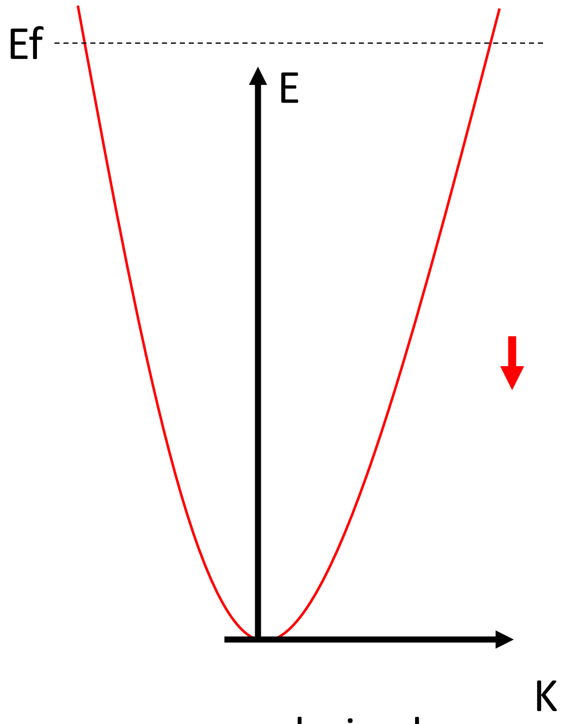
(Eingegangen am 21. Juni 1929.)

Es wird auf die Möglichkeit hingewiesen, den Ferromagnetismus auf die Leitungselektronen zurückzuführen. Für sein Eintreten ist dann u. a. deren Nullpunktsenergie wesentlich. Bei dieser Gelegenheit wird eine elementare Ableitung der Formeln für Energieschwerpunkt und Multiplizität der verschiedenen Termsysteme bei beliebiger Ausgangsbesetzung der Zellen angegeben.

- Prediction:
  conduction electrons polarize if energeticaly favorable
  - Competition betweent kinetic and potential energy (coulomb)
- GaAs expected for r_s >26
  ($n \simeq 4.6 \times 10^8\ \mathrm{cm}^{-2}$)
  - r_s = distance in units of bohrradius
- Fermi wavevector increases
  - Can be measured!



unpolarized



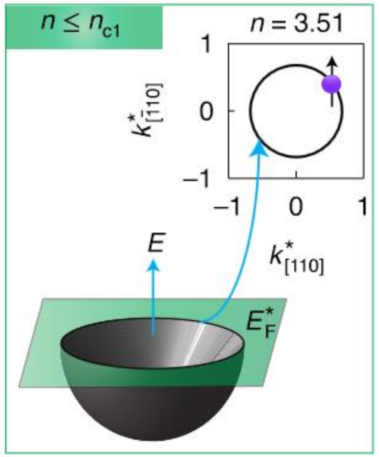
polarized

Bloch, F. *Z. Physik* **57,** 545–555 (1929)

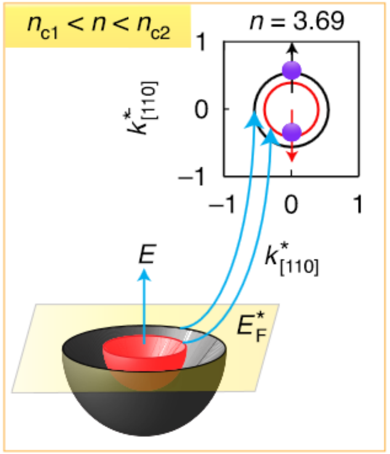
Measurement (What?)

- Bloch Transition changes Fermi surface
  - Decrease from two to one fermi-surfaces (only on spin)
  - Fermi wave vector bigger after transiton (higher density for one spin)
- In this article:
  measure spin polarized densities $n_{\uparrow}^{*}$ and $n_{\downarrow}^{*}$
  for different total densities / magnetic fields

Polarized



Partially polarized



Measurement (What?)

Expectation:

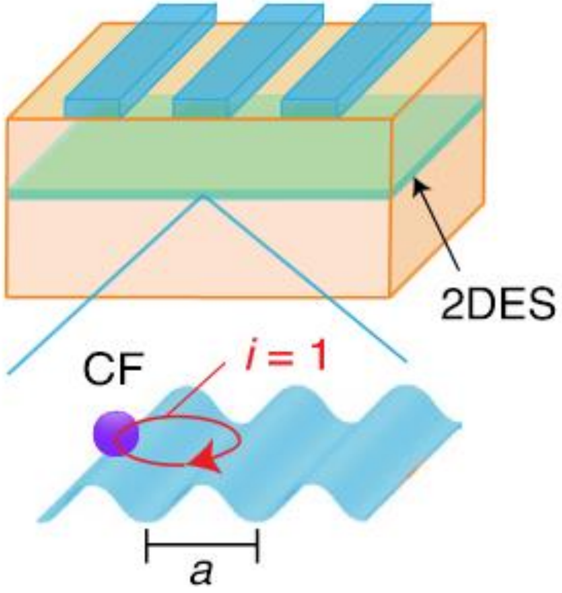
- $E_z = g\ \mu_B B$ and $E_c = e^2/4\pi\epsilon\epsilon_0 l_b$; $l_b = \sqrt{(\hbar/eB)}$; $E_c \propto \sqrt{(B)}$
- Ratio $\alpha = E_z/E_c \propto \sqrt{B} \propto \sqrt{n}$ for $\nu = const$
- Polarization determined by α (polarized if $\alpha > \alpha_c$)

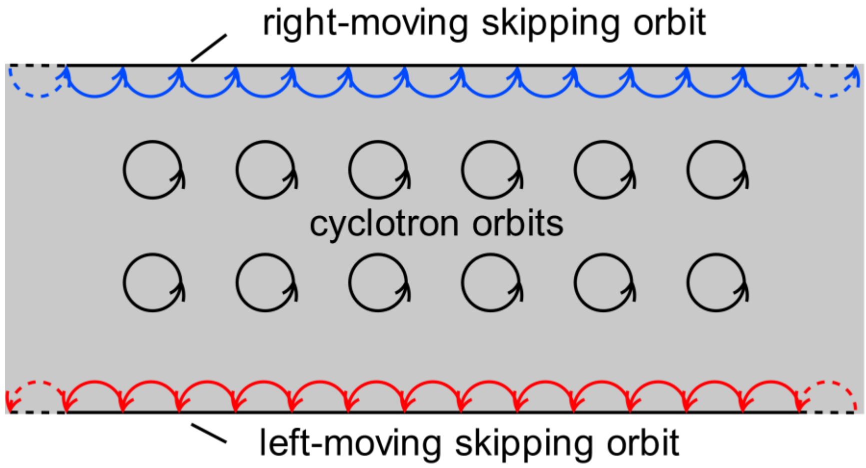
- Expect polarized phase for high density
- Polarization decays at low desities

Measurement Technique(How?)

Geometric resonance

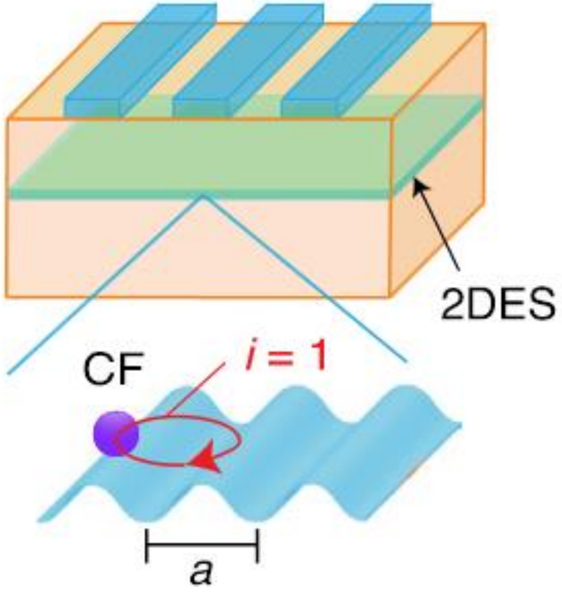
- Straine inducing superlattice (Period 190-220nm)
- Density modulated by ~0.5%
- Resonance if cyclotron orbit comensurate with modulation period





https://topocondmat.org/w3_pump_QHE/QHEedgestates.html

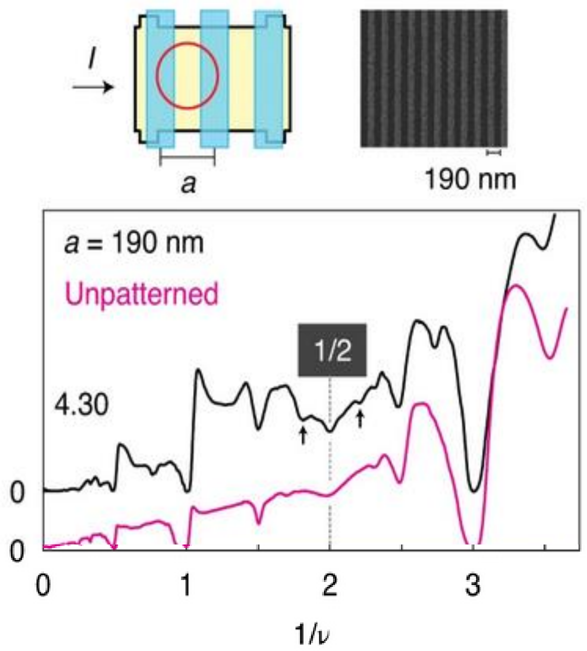
Measurement Technique (How?)
Geometric resonance



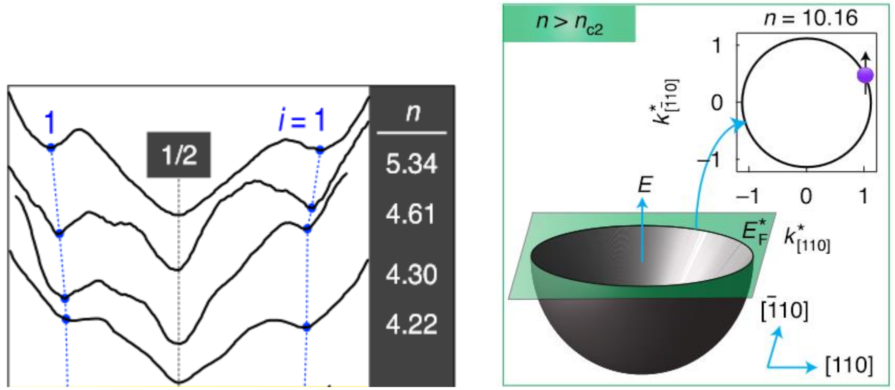
- Resonance if cyclotron orbit comensurate with modulation period
- $R_c^* = \frac{\hbar k_F^*}{eB^*}$
- Resonanz condition $2\mathrm{R}_\mathrm{c}^*/\mathrm{a} = i + 1/4; i = (1,2,3, \dots)$
- Cyclotron resonance at some effective field B^* gives k_F
- $\rightarrow n^* = {k_F^*}^2/4\pi$

Mesurements

a



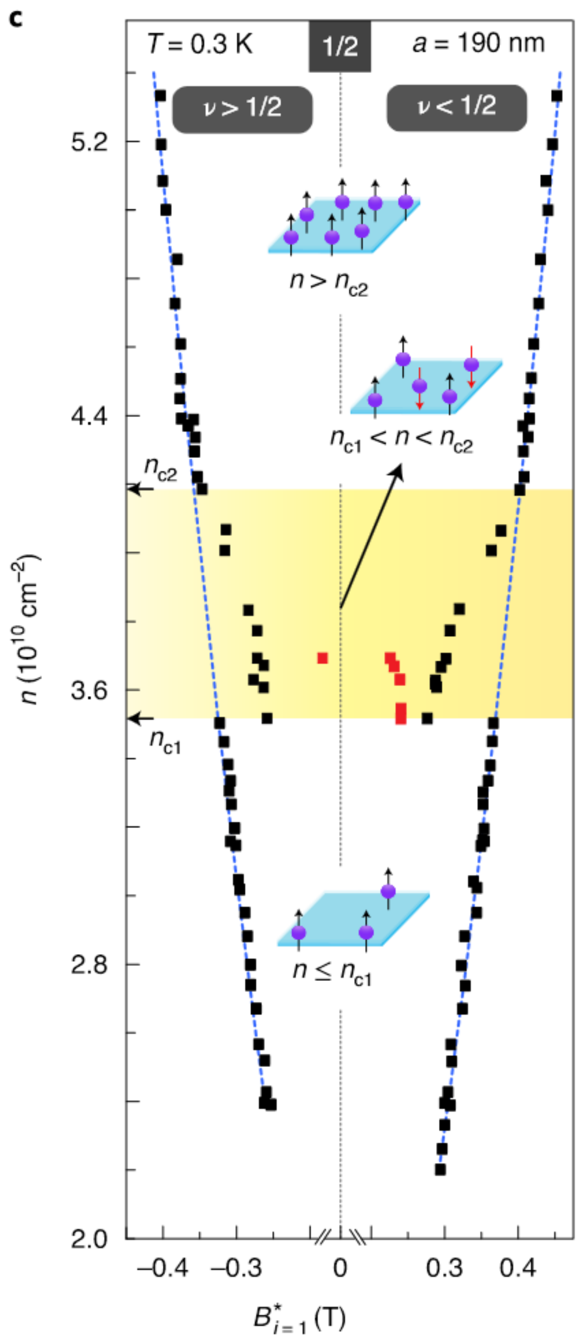
b



Modulation gives extra dips in ρ_{xx}

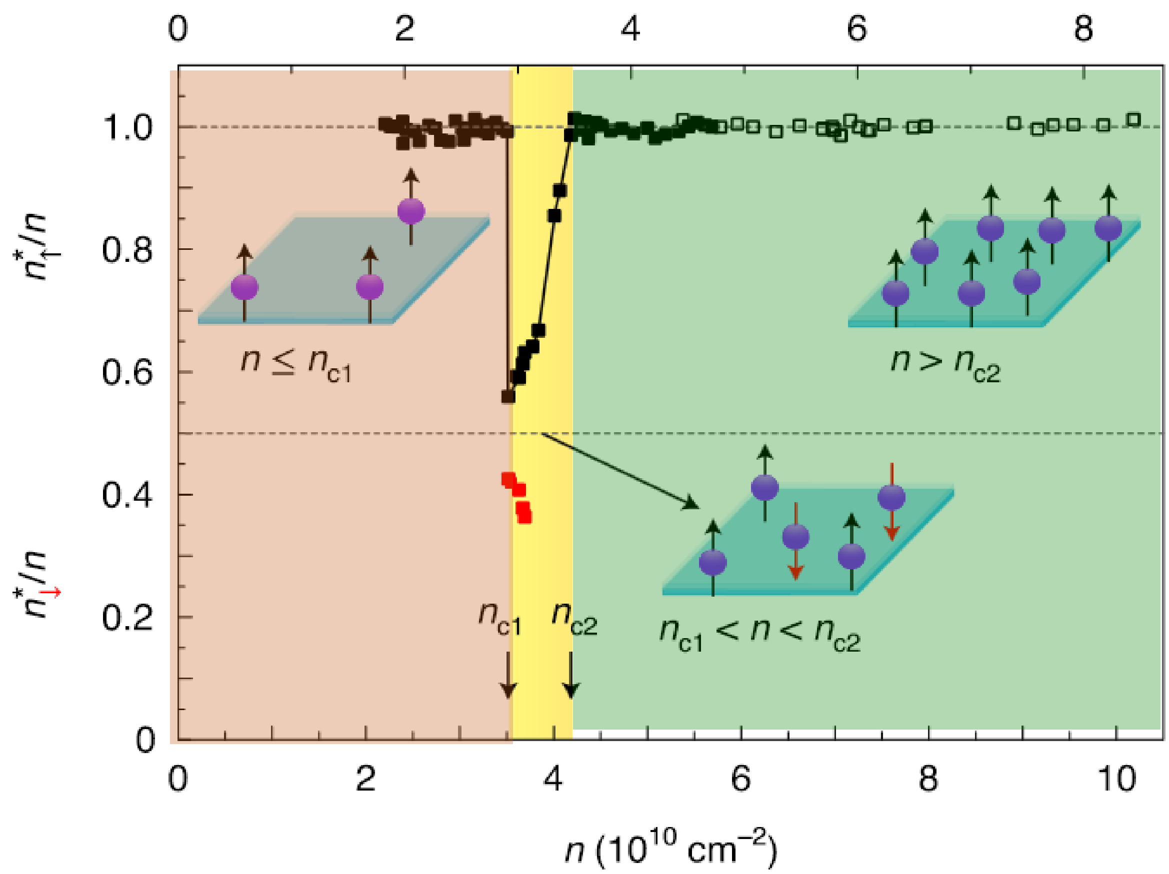
measurements

- Extracted „fermi wavevectors „ for different densities
  - Yellow region shows deviation from expected behavior for simple densitie reduction
  - Also second dip means other spin polarization available



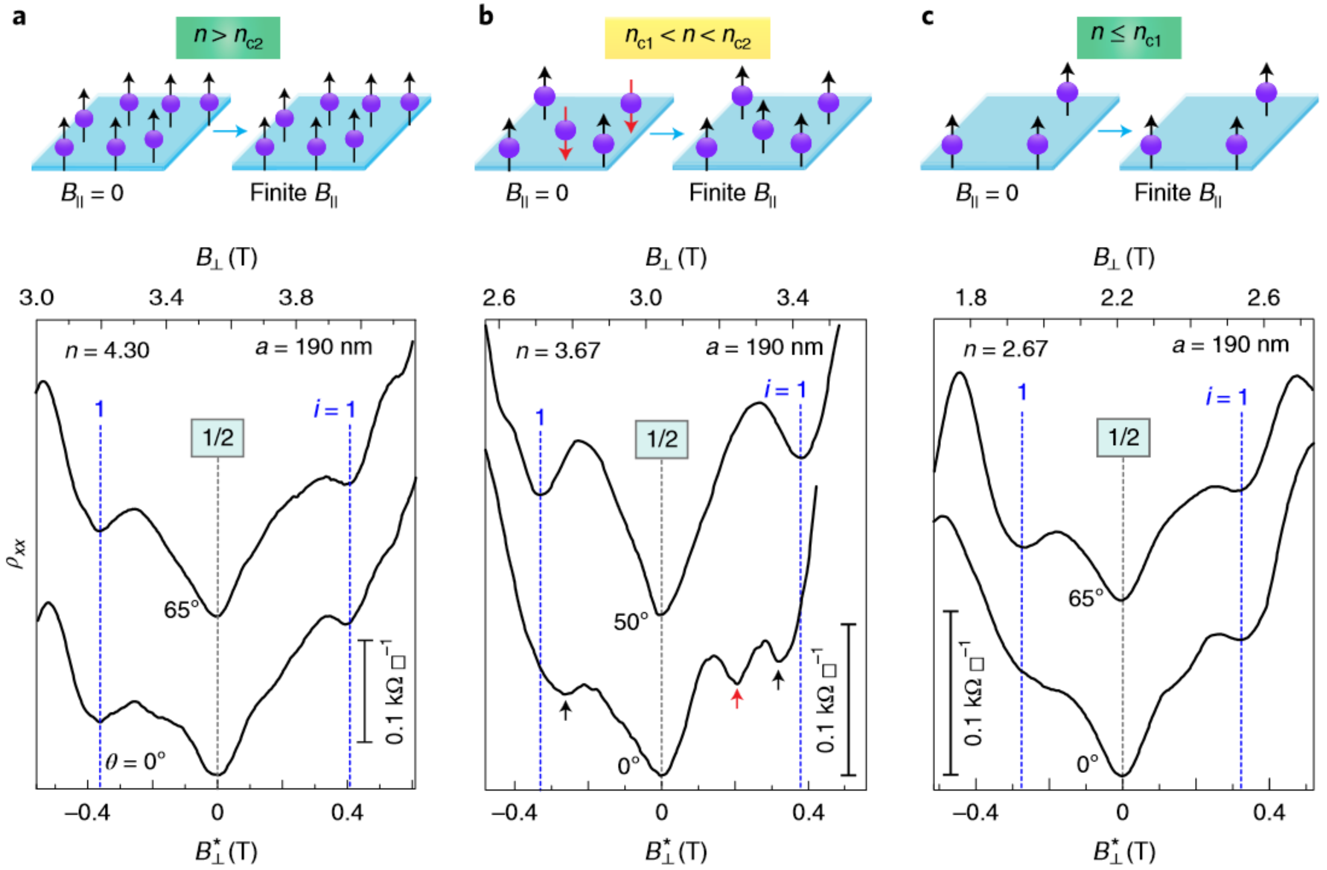
Results : extracted spinpolarized density

- „Trivial“ Spin polarized regime at high density
  - $\alpha = \frac{E_Z}{E_C} > 0.01 \propto \sqrt{B}$
- Intermediat spin unpolarized regime
- Bloch ferromagnet
  - $r_s < 4$ compared to
    predicted 26 for electrons
  - Landau level mixing may
    alter inter CF –interactions…



Tilted field

- E_C depends on perpendicular field only
- E_z scales with Total field
- Using tilted field measurement α can be tuned
- In-plane field recovers spin polarization in intermediate regime



Summary

- Observed ferromagnetic transition in composit fermions
  - At high densities expected
  - At low densities possibly bloch transition