Anisotropic Fermi Contours of Electron- and Hole-Flux Composite Fermions

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Sample growth: Loren Pfeiffer, Kenneth West, Kirk Baldwin, J. J. D. Lee
Theoretical calculations: Roland Winkler*

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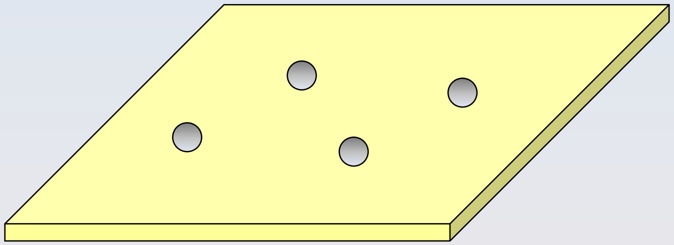
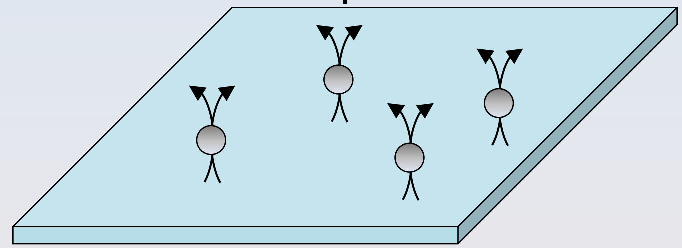
Composite fermions

Electrons

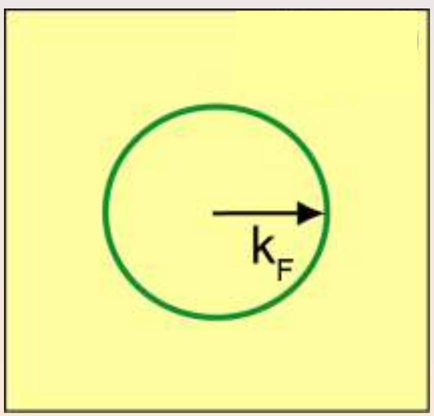


real space

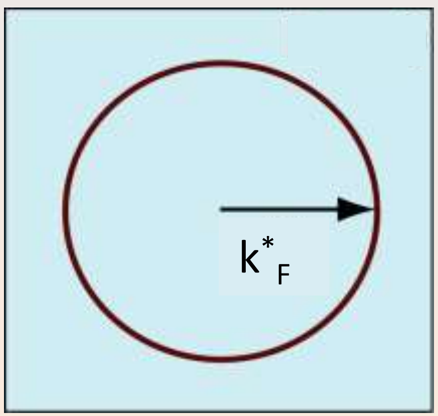
Composite fermions



$\nu = 1/2$, real space



reciprocal space

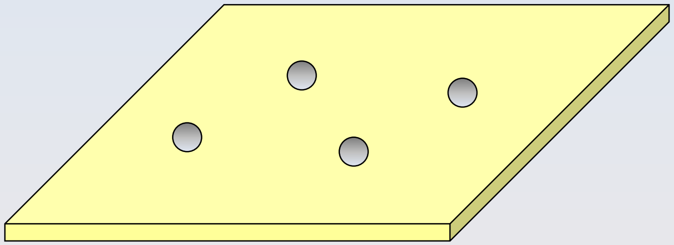


reciprocal space

T. Gokmen *et al.*, Nat. Phys. **6** : 621 - 624, 2010

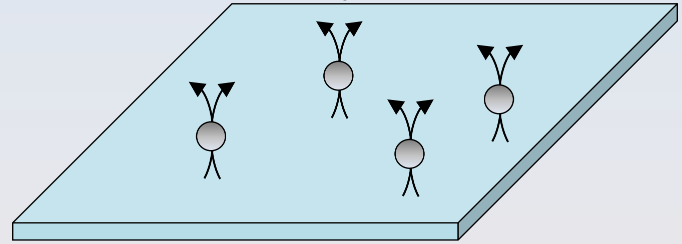
Composite fermions

Electrons



real space

Composite fermions



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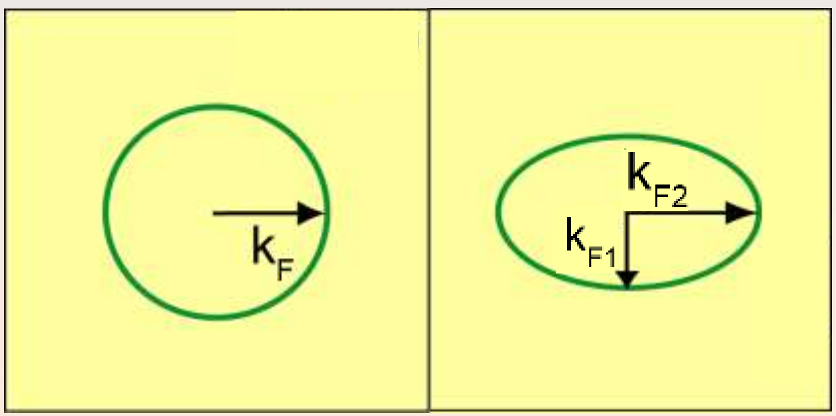
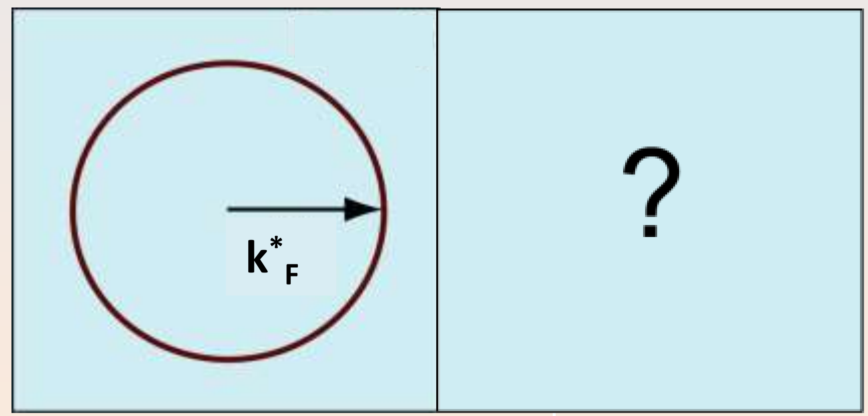


reciprocal space



reciprocal space

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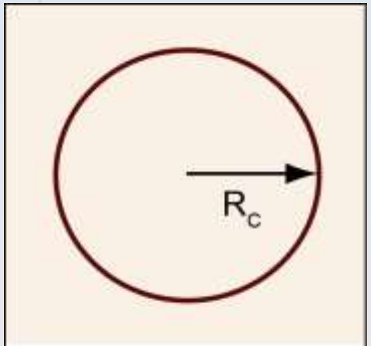
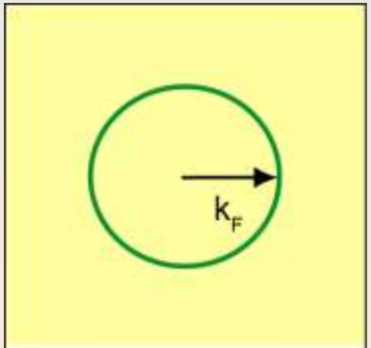
Princeton University

Tuning the Fermi contour shape



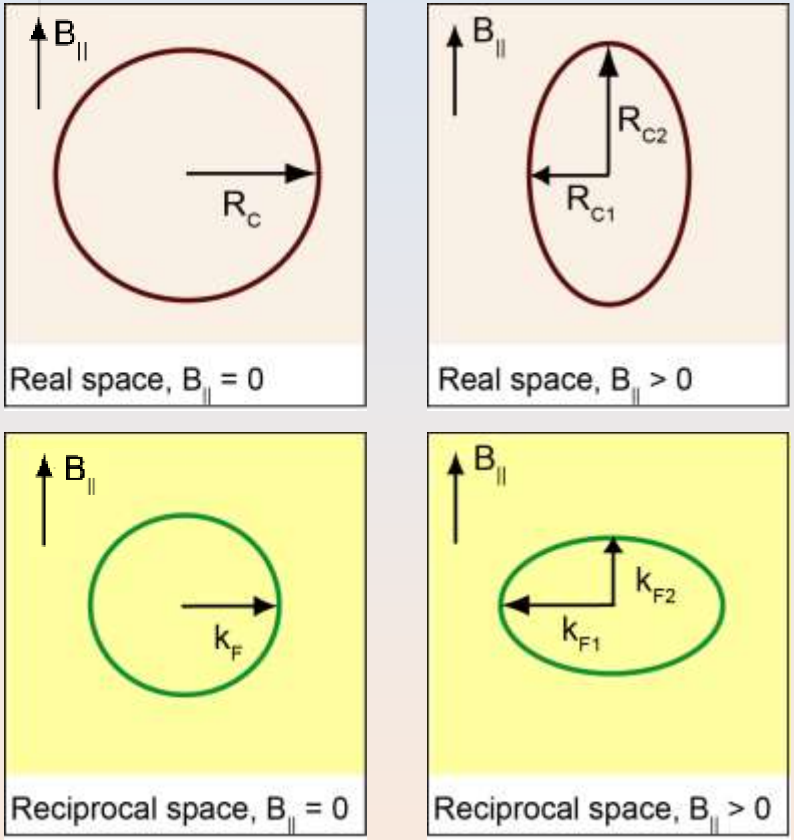
Real space, $B_{||} = 0$

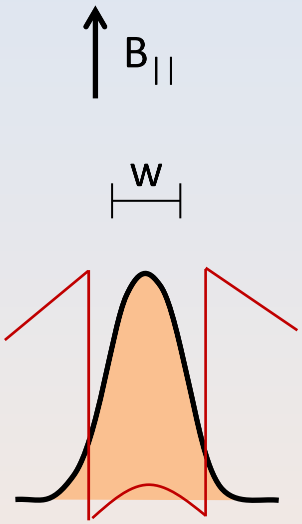


Reciprocal space, $B_{||} = 0$

Tuning the Fermi contour shape

zero thickness finite thickness

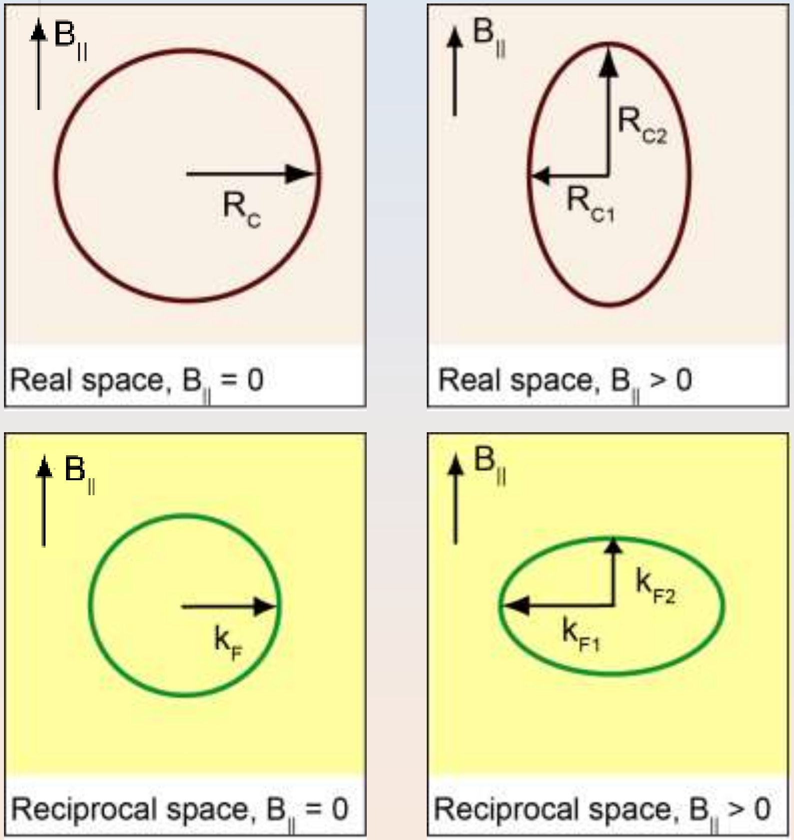


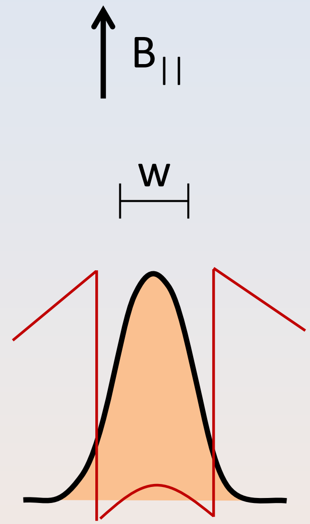


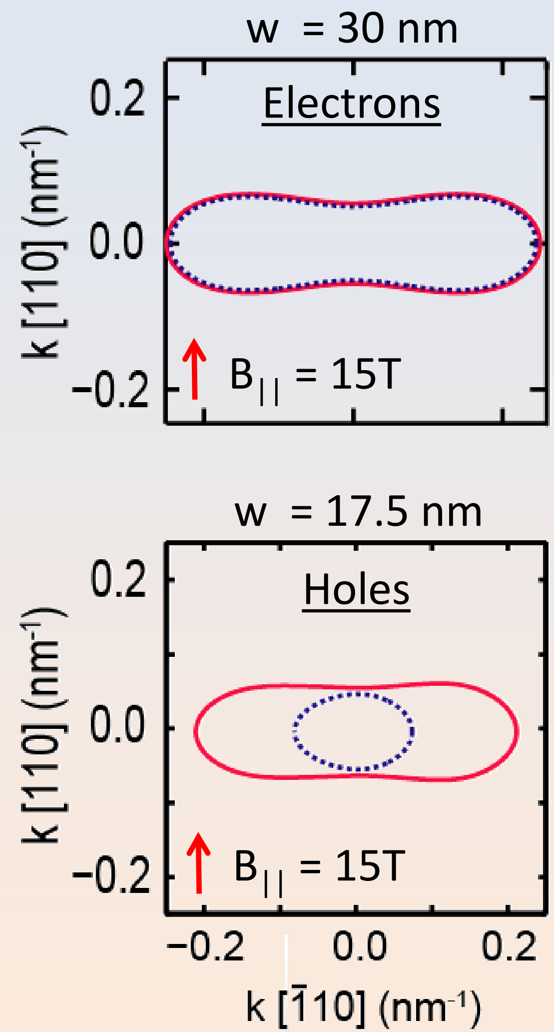
Fermi contour distortion in parallel field

zero thickness

finite thickness

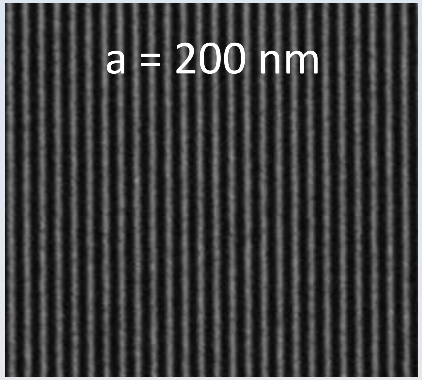


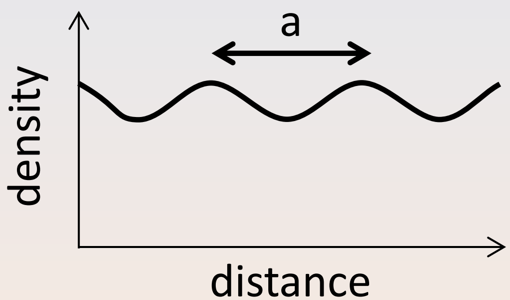


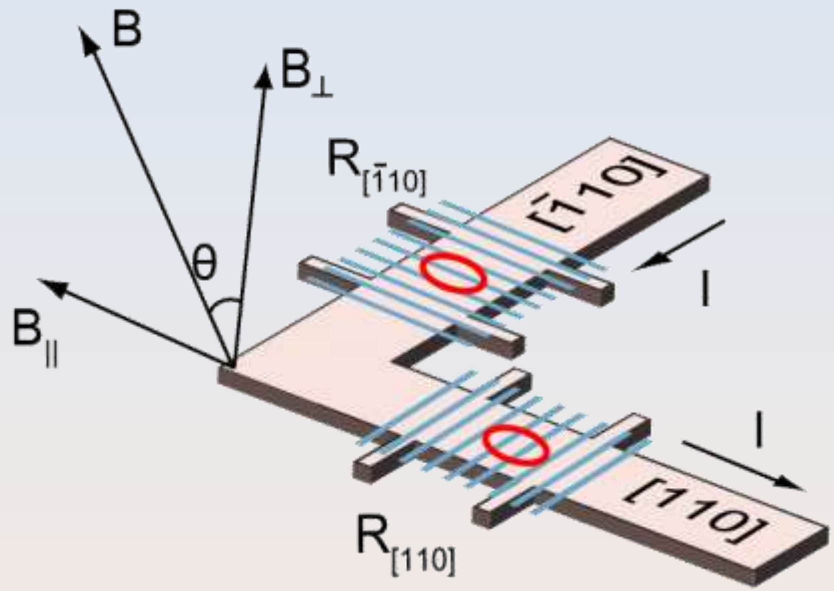


Kamburov *et al.*, arXiv:1306.3537; Phys. Rev. B 86, 241302 (2012)

Measuring Fermi contour shape: commensurability oscillations







- Negative e-beam resist
- Piezo-electric effect in GaAs
- Periodic density modulation

- Keep sample tilt fixed
- Sweep field & take data
- Simultaneously measure $R_{[110]}$ & $R_{[\bar{1}10]}$

Kamburov *et al.*, Phys. Rev. Lett. 109 (2012); Phys. Rev. B 85 (2012)

Composite fermion commensurability oscillations

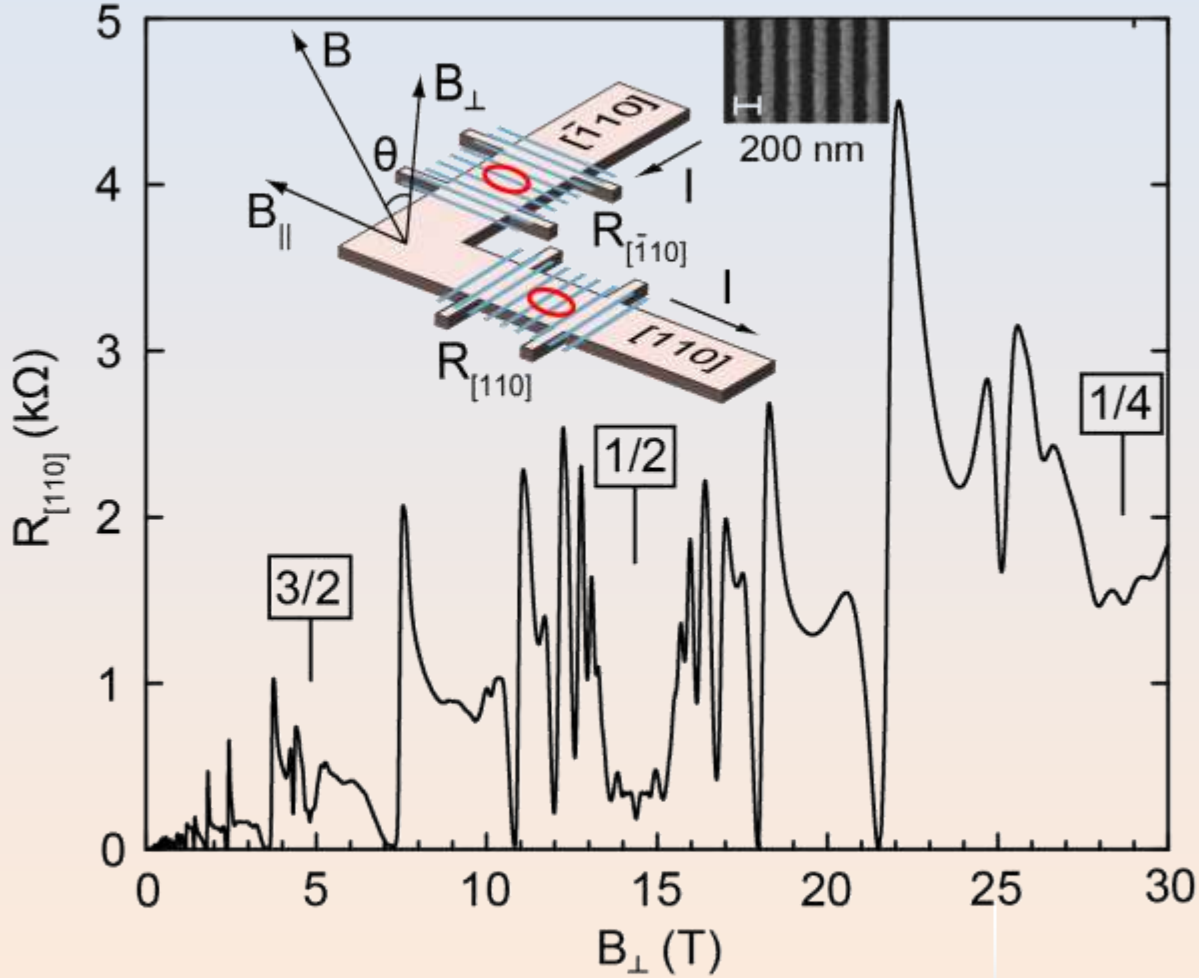
T = 300 mK

n = 1.8 x 10^{11} cm^{-2}

cap layer 95 nm
$Al_xGa_{1-x}As$ 95 nm
GaAs, W = 40 nm
$Al_xGa_{1-x}As$ 95 nm
(100) GaAs substrate

Si δ (between cap layer and upper $Al_xGa_{1-x}As$)

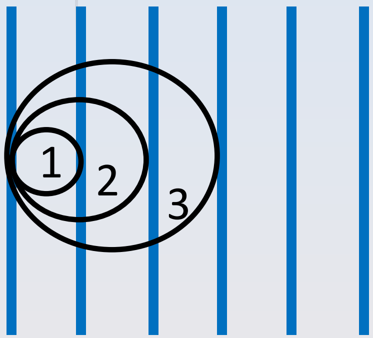
Si δ (between lower $Al_xGa_{1-x}As$ and substrate)

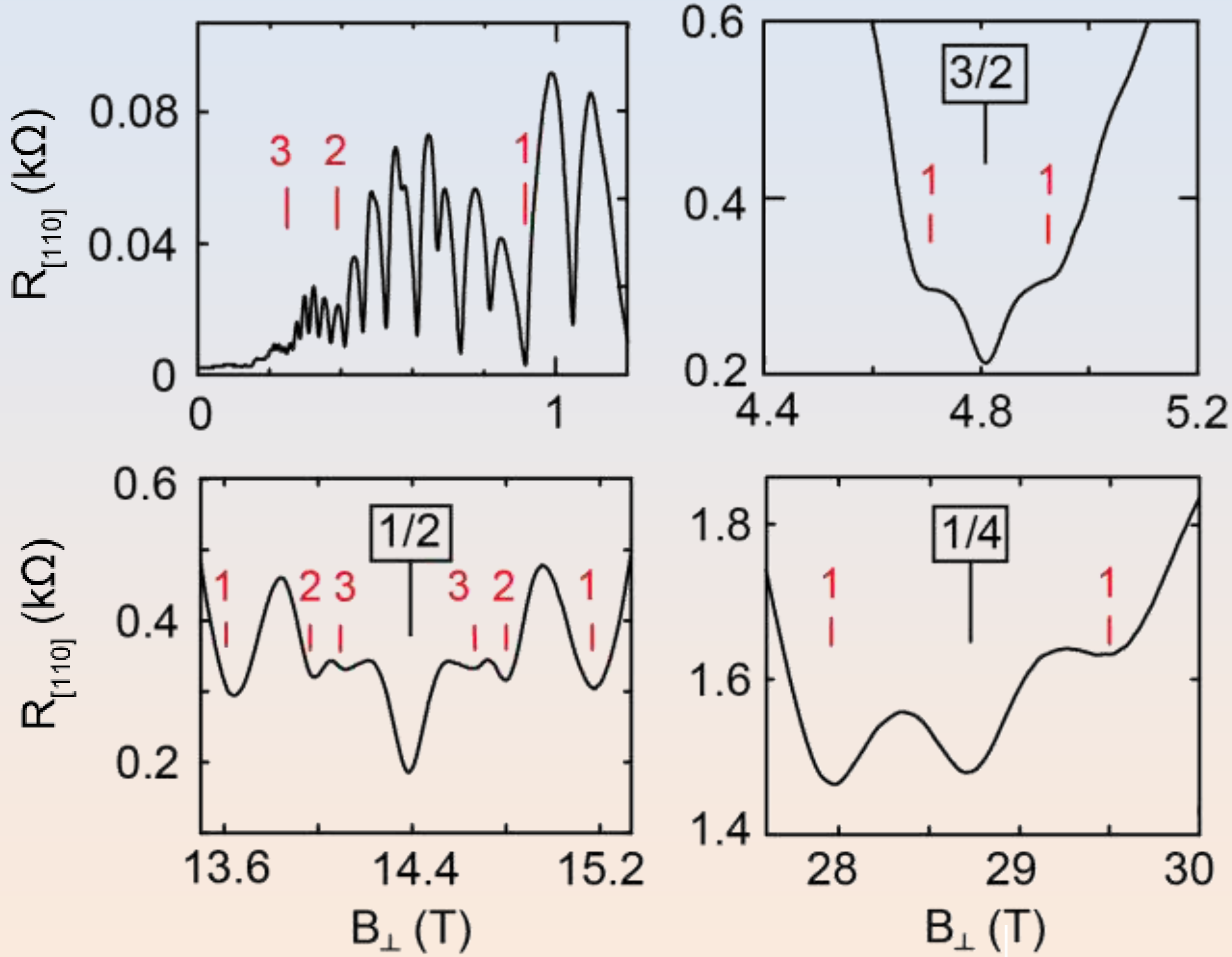


Smet *et al*., Phys. Rev. Lett. 80, 4538–4541 (1998)

Princeton University

Composite fermion commensurability oscillations





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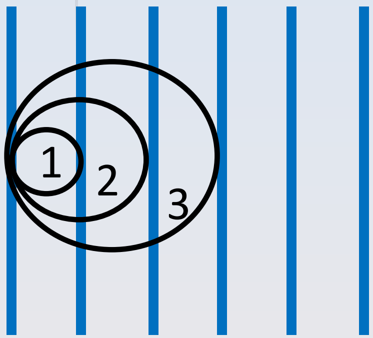
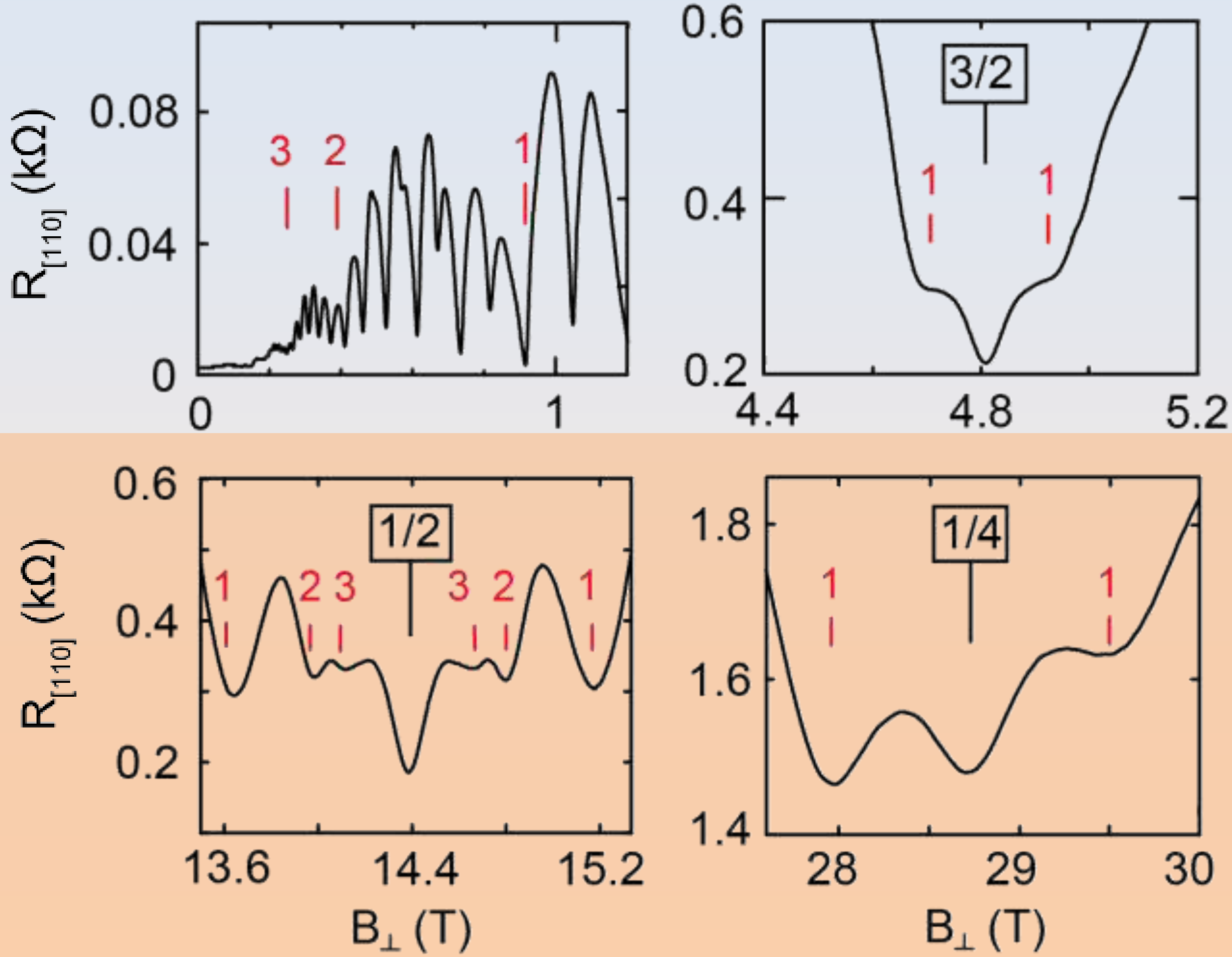


$$\frac{2R_C}{a} = i + \frac{1}{4}$$

$$i = 1, 2, 3 \ldots$$

$$2R_C = \frac{2\hbar k_F}{eB}$$

$$k_F = \sqrt{4\pi n}$$



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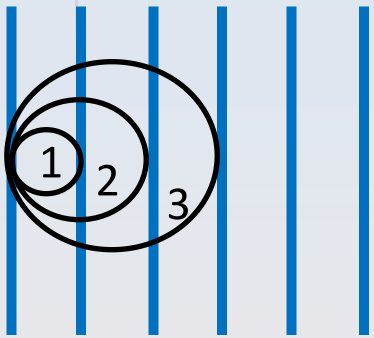

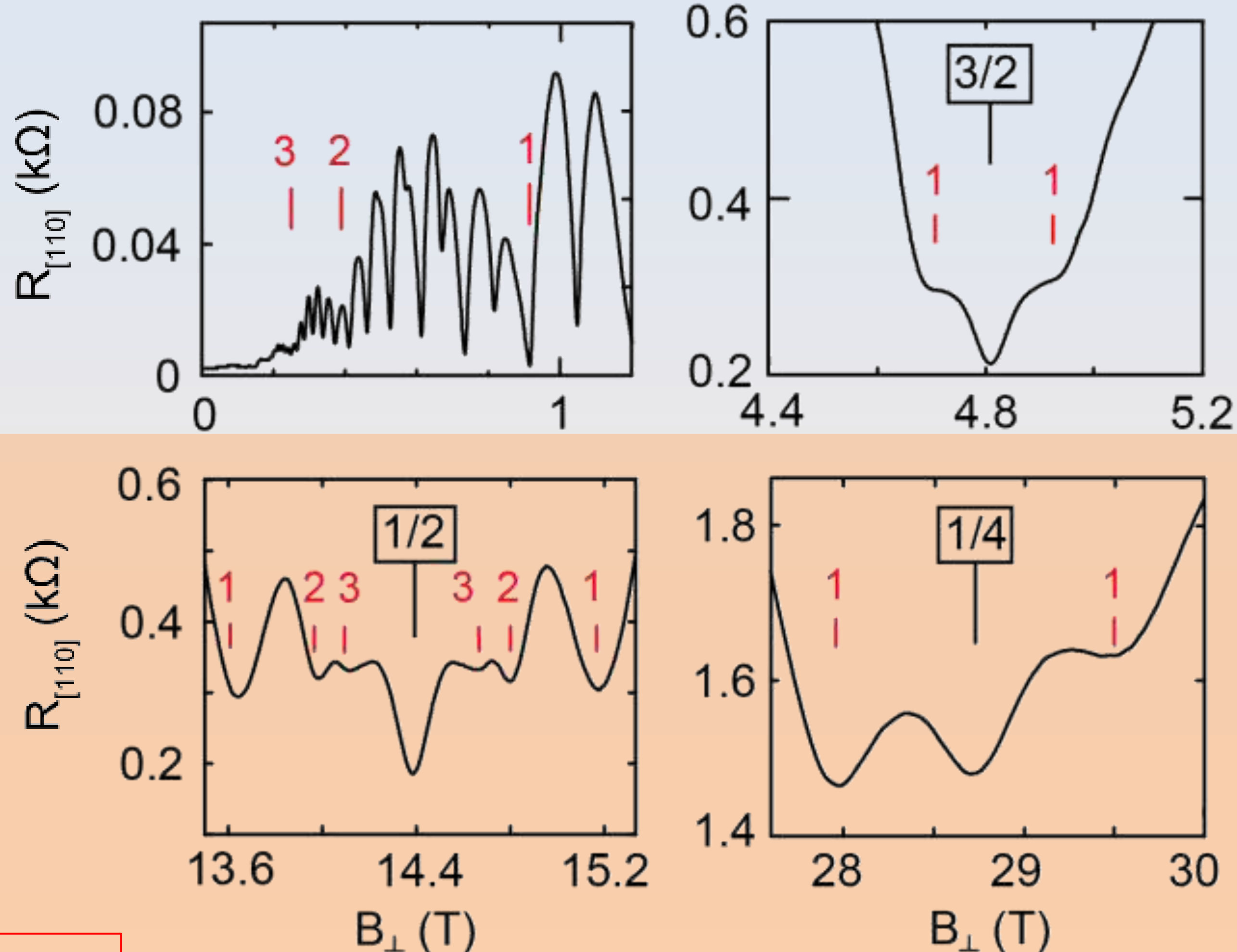

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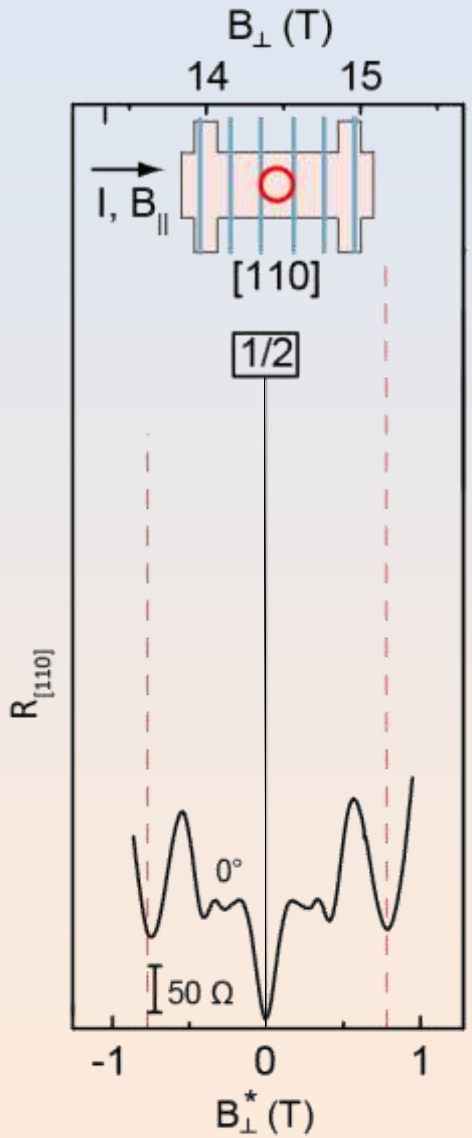
$$\boxed{k^*{}_F = \frac{5}{8}\frac{eaB^*{}_{i=1}}{\hbar}}$$

Composite fermion commensurability oscillations

T = 300 mK
w = 40 nm
n = 1.8 x 10^{11} cm^{-2}
a = 200 nm

$$k_F = \sqrt{4\pi n}$$



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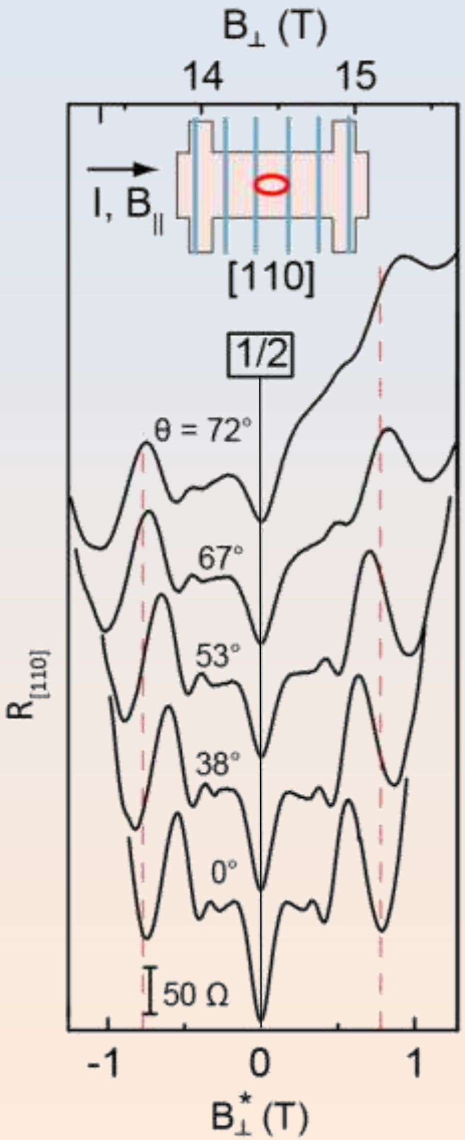

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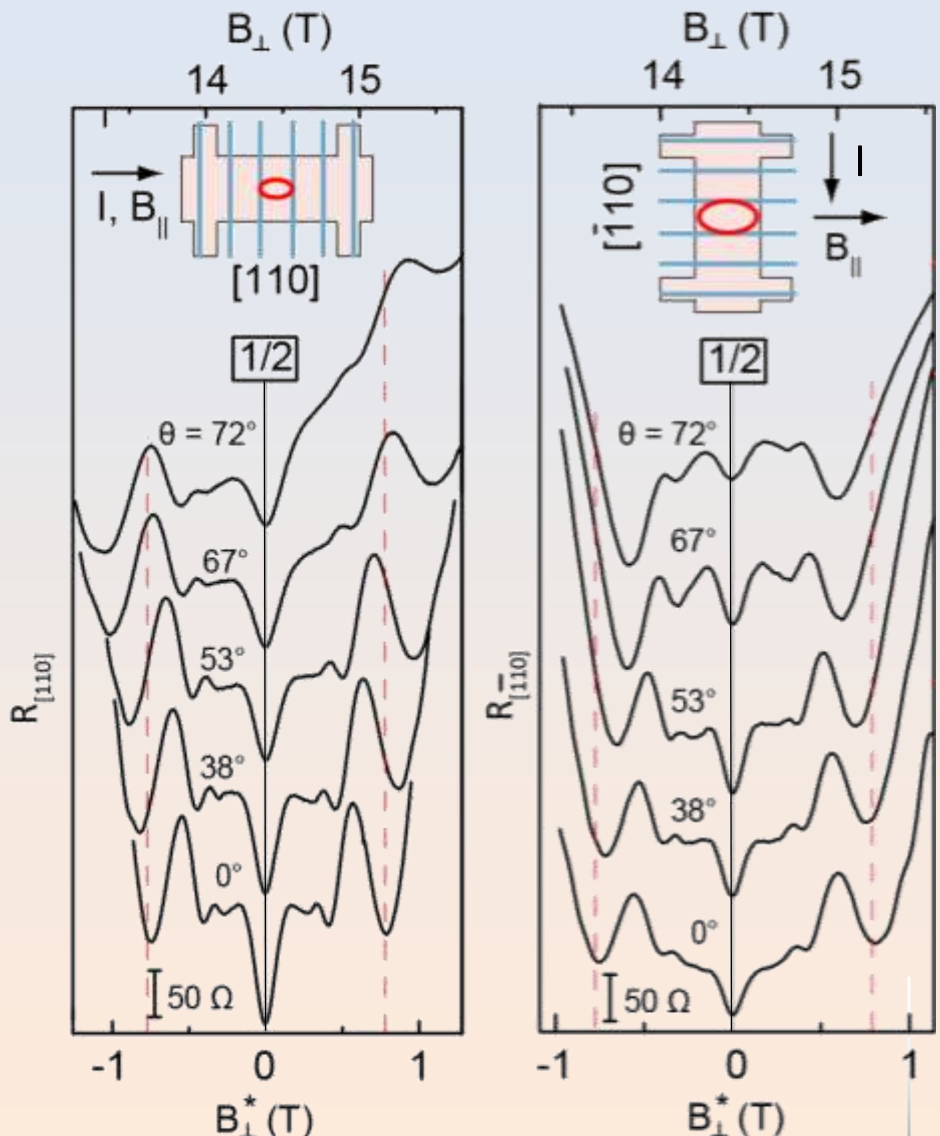

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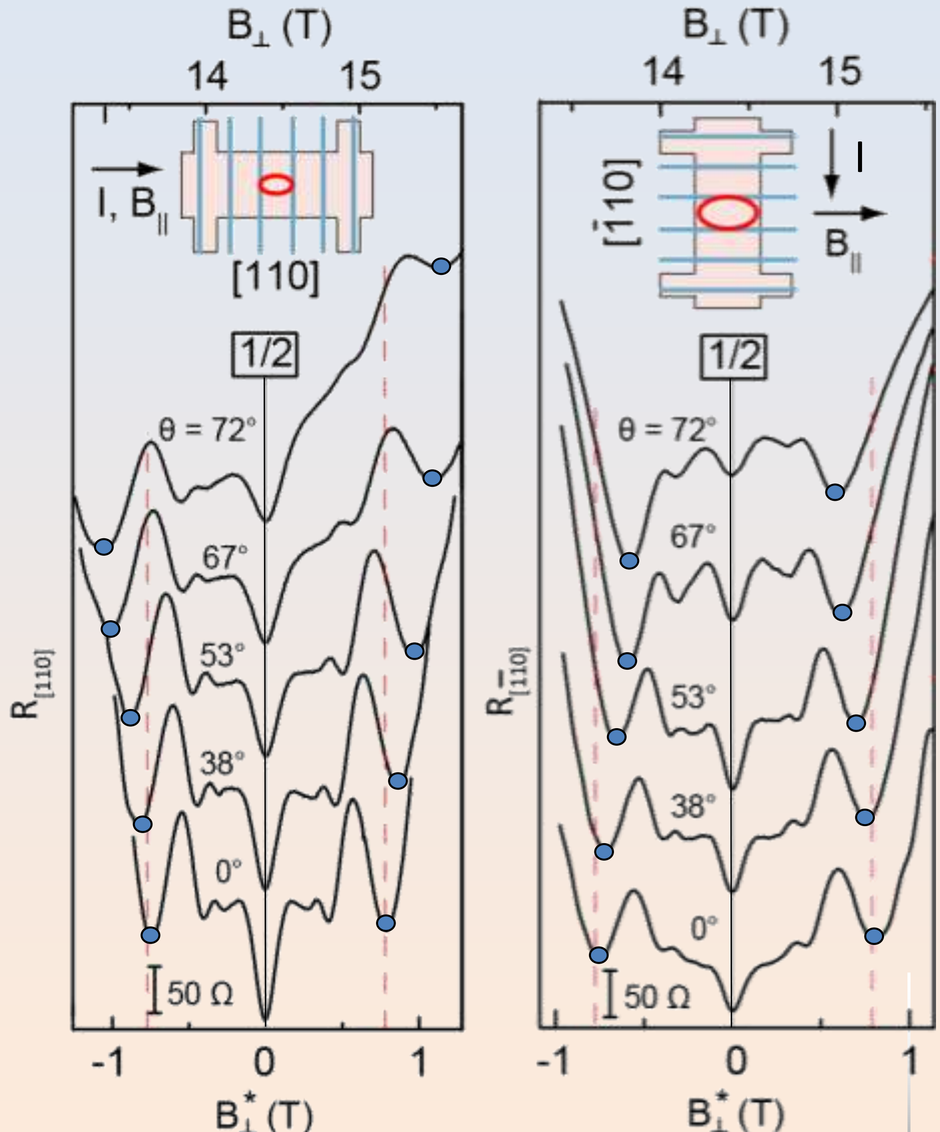

Composite fermion Fermi wave vectors

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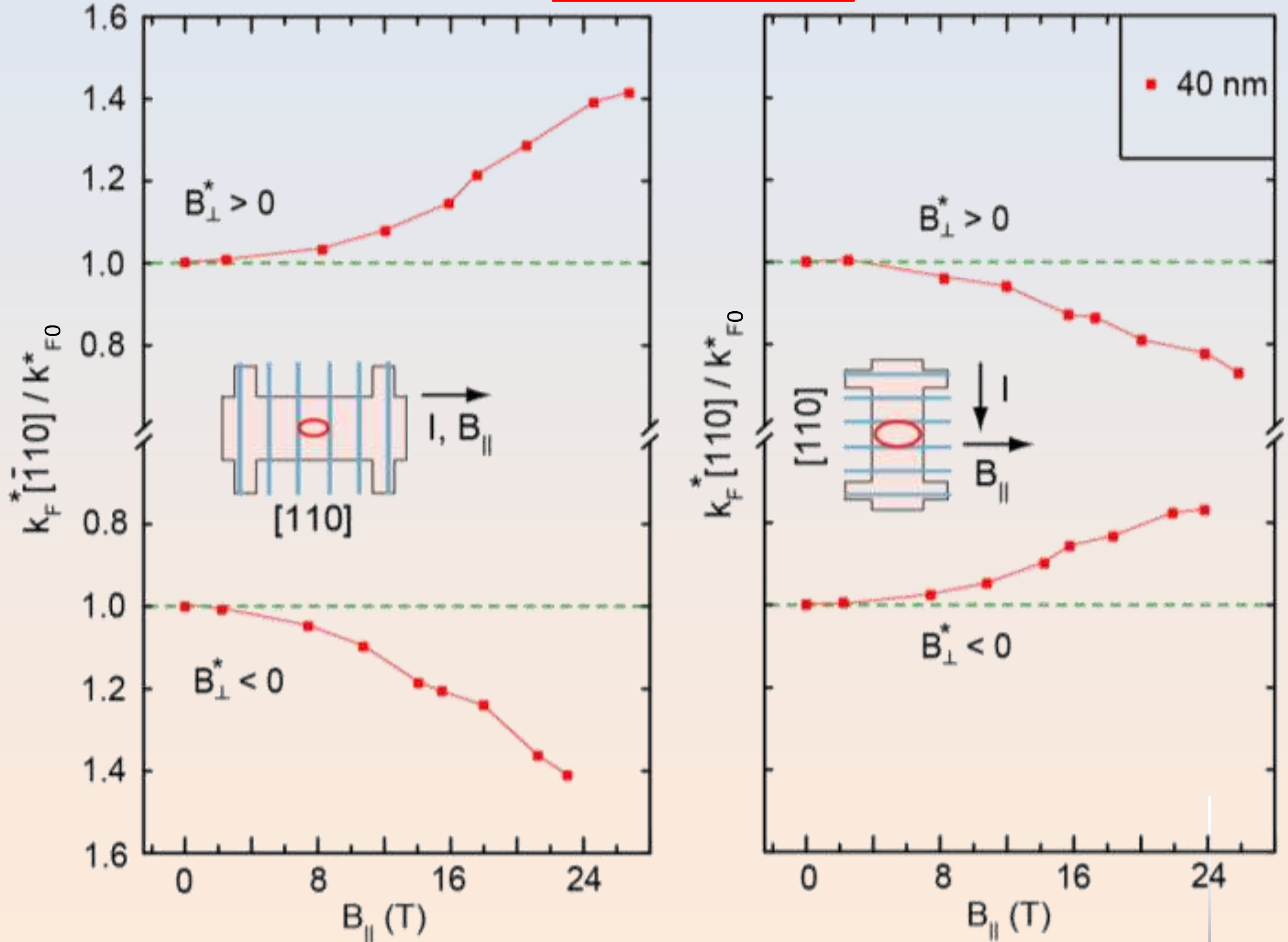

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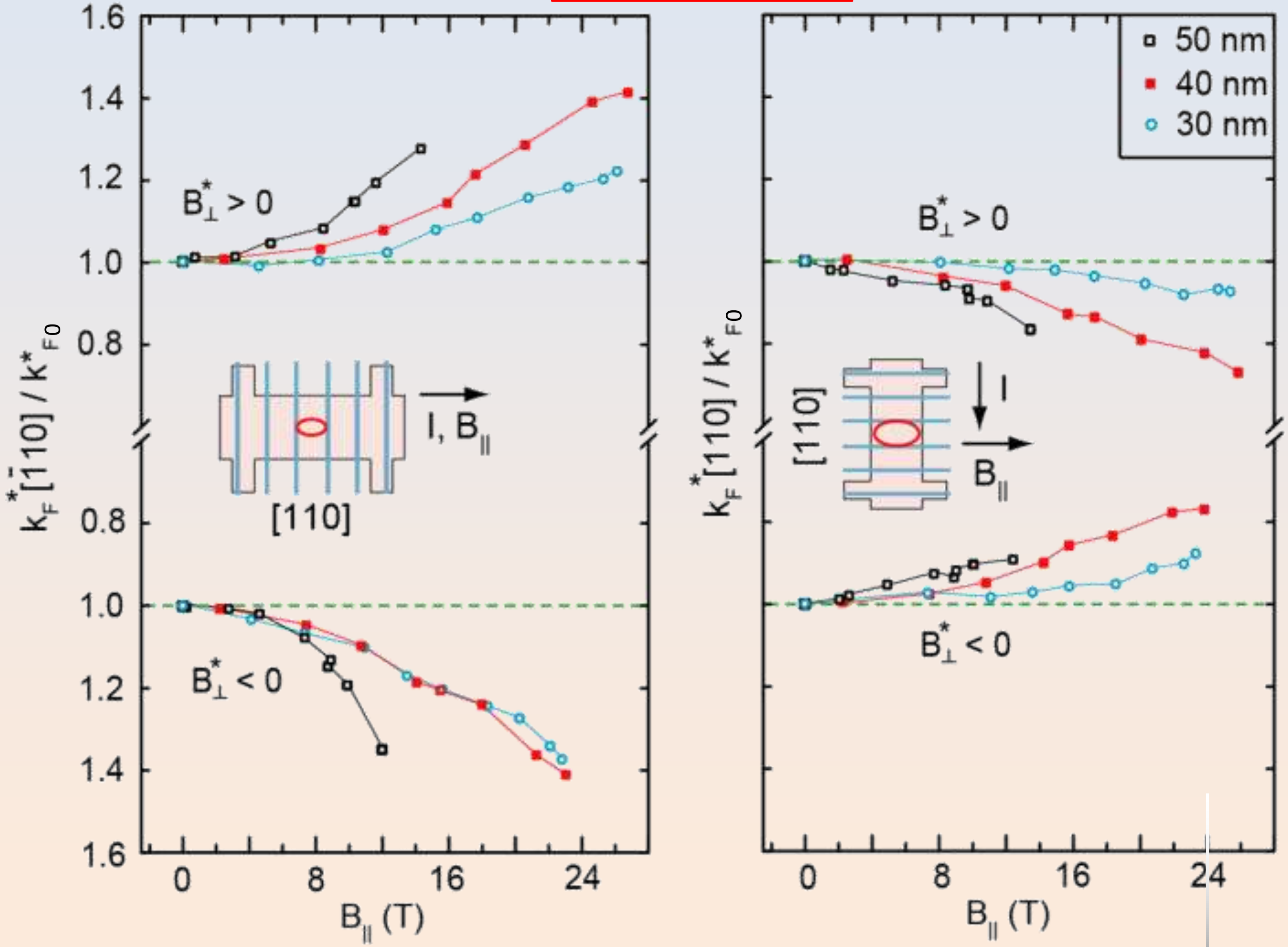
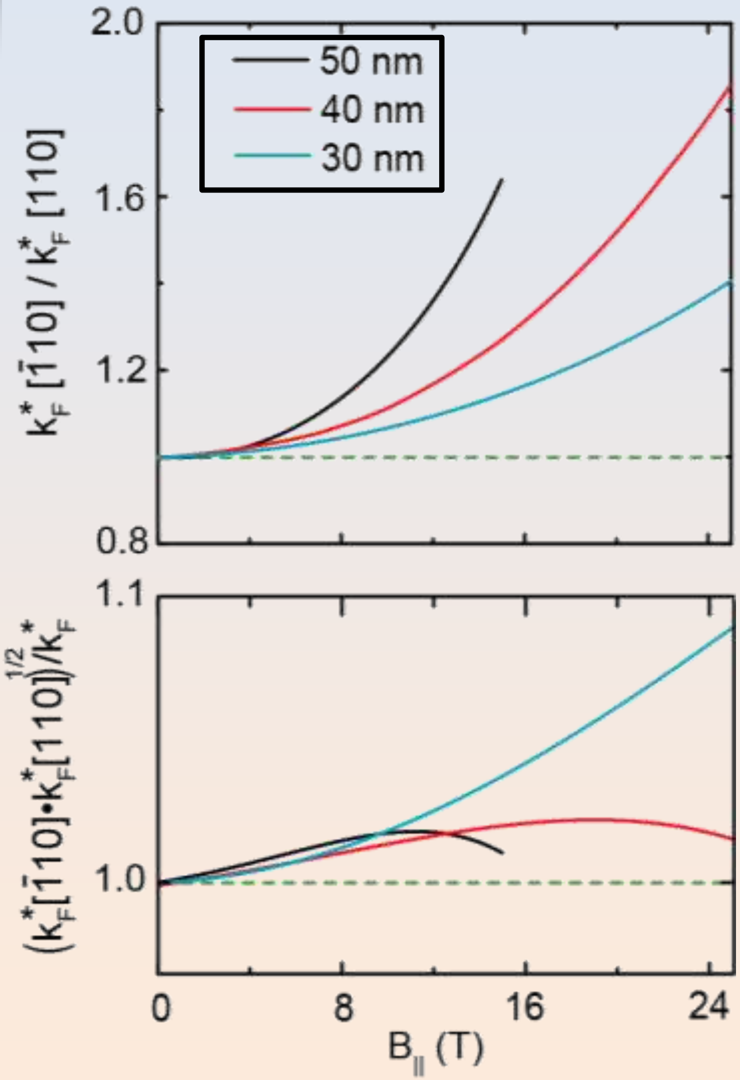
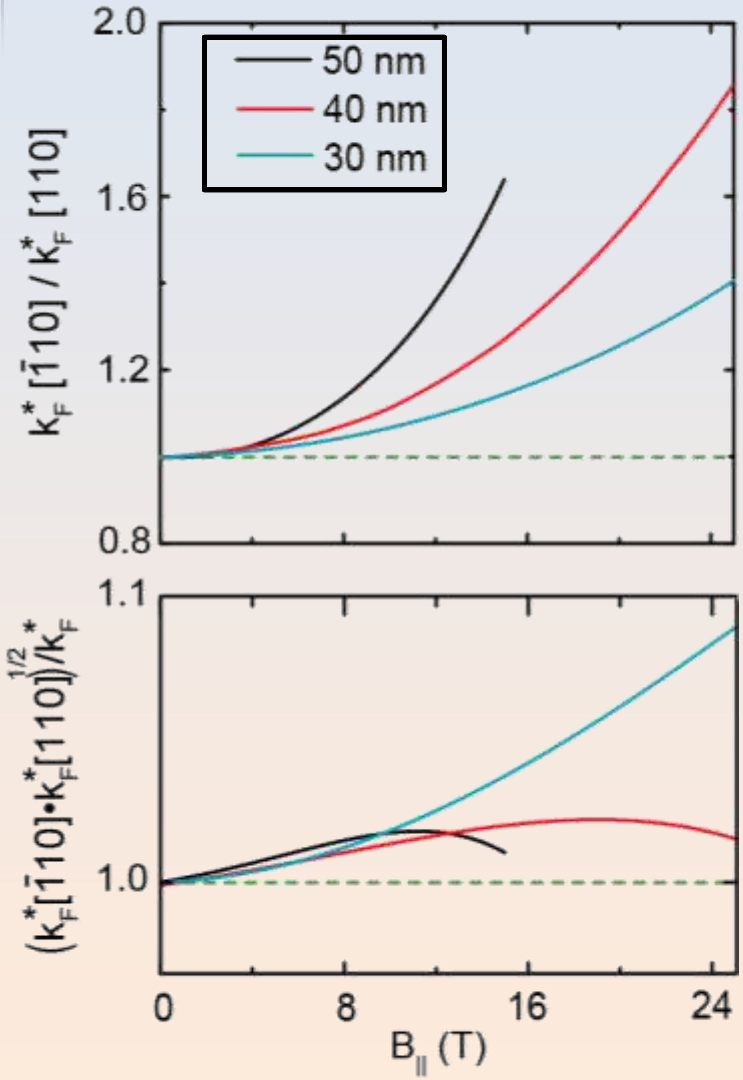


Composite fermion Fermi contour anisotropy



- $B_{||}$-induced anisotropy
- Well-width dependence
- Consistent with elliptical shape

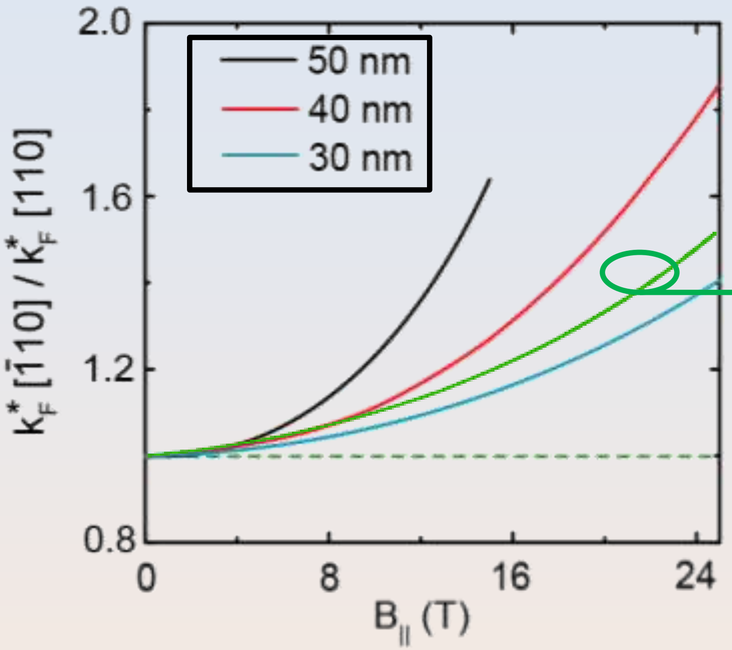
Composite fermion Fermi contour anisotropy



- $B_{||}$-induced anisotropy
- Well-width dependence
- Consistent with elliptical shape

- Lack of theoretical calculations

Composite fermion Fermi contour anisotropy



- $B_{||}$-induced anisotropy
- Well-width dependence

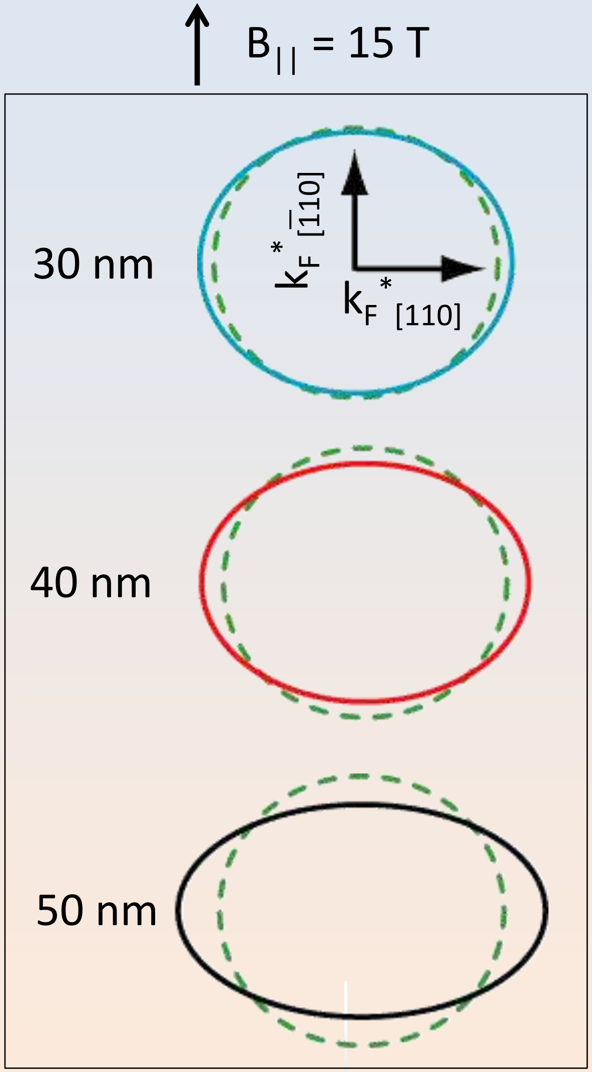
Hole-flux CFs
w = 17.5 nm

- Importance of band structure

Kamburov *et al.*, Phys. Rev. Lett. 110, 206801 (2013)

Summary

- Direct evidence of composite fermion Fermi contour anisotropy
- Tunability with parallel field
- Strong dependence on carrier layer thickness
- Dependence on band structure



Summary

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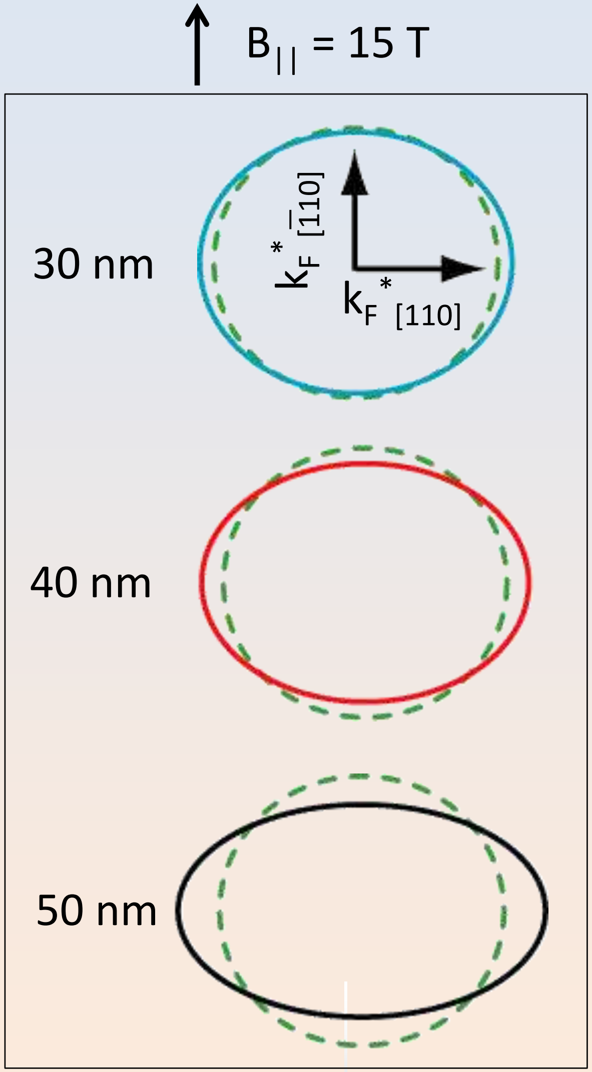
- Very different from 2D electrons



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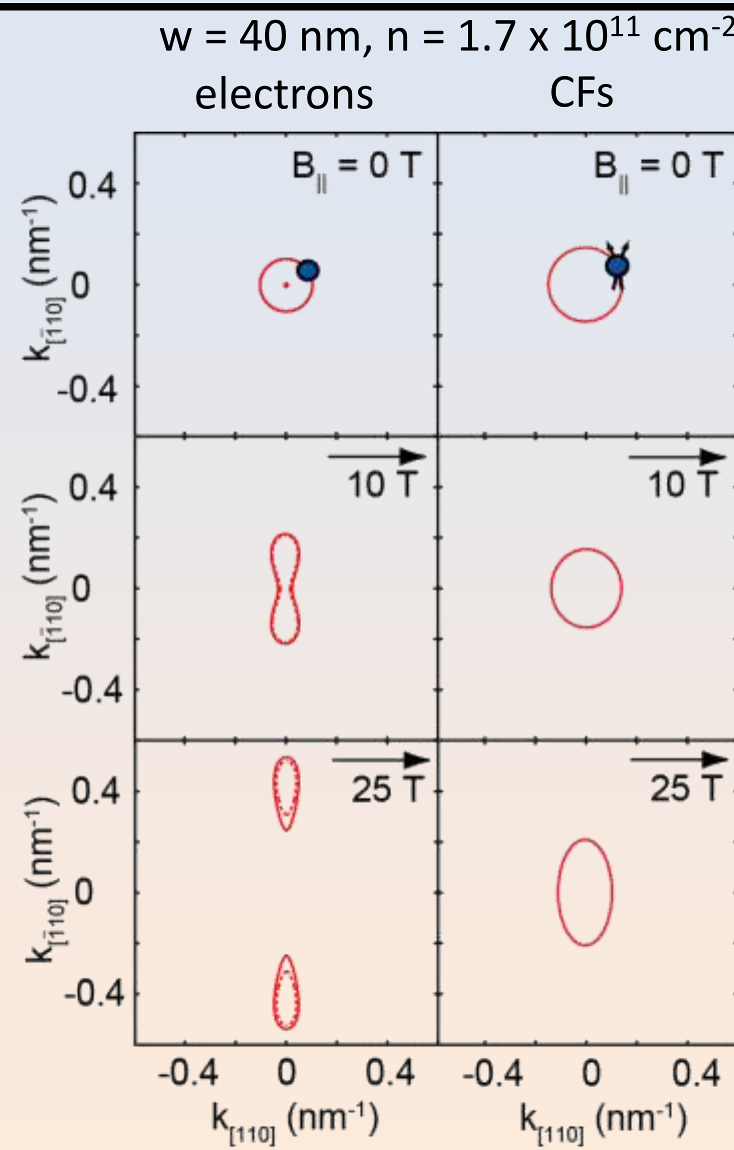
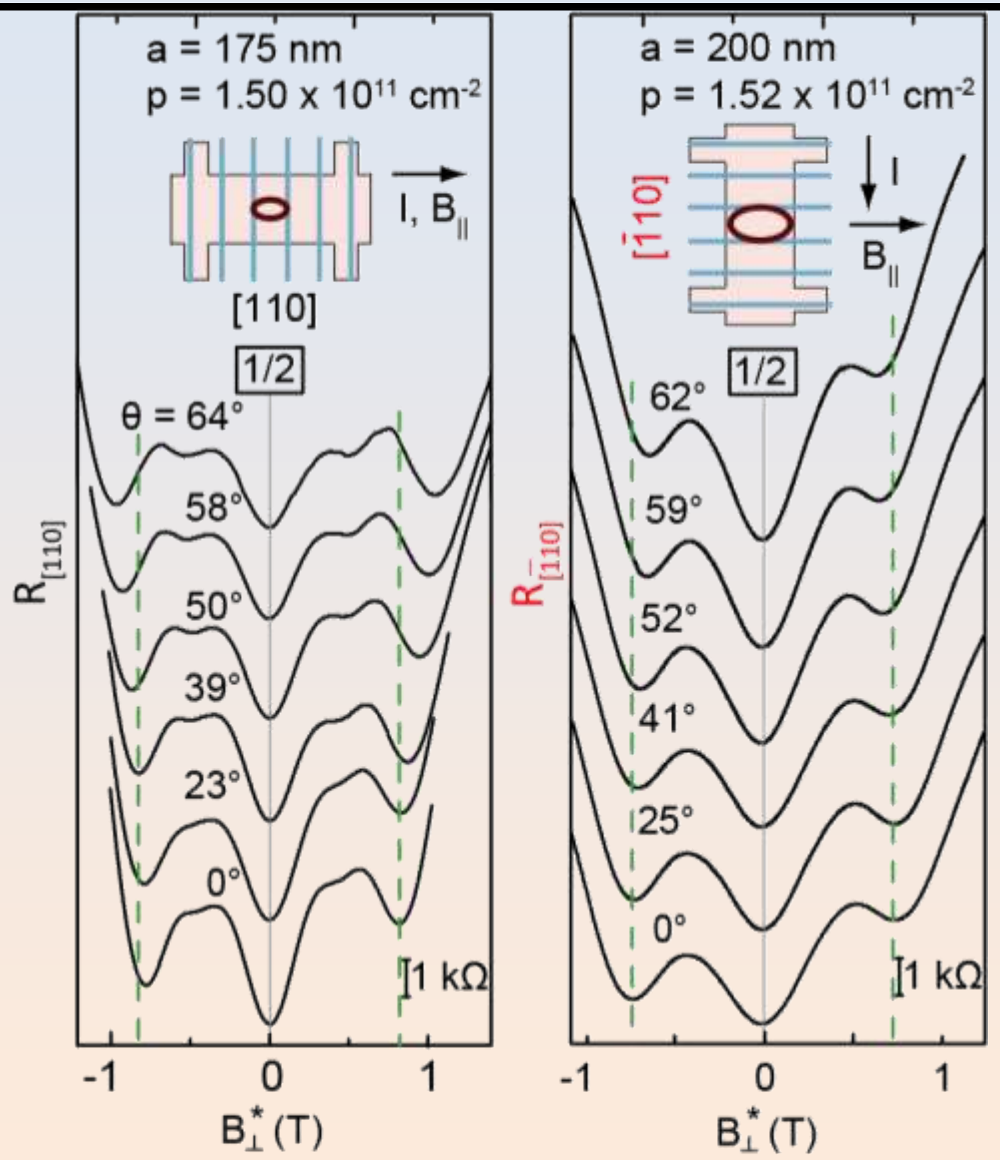


Hole-flux composite fermion Fermi contour size



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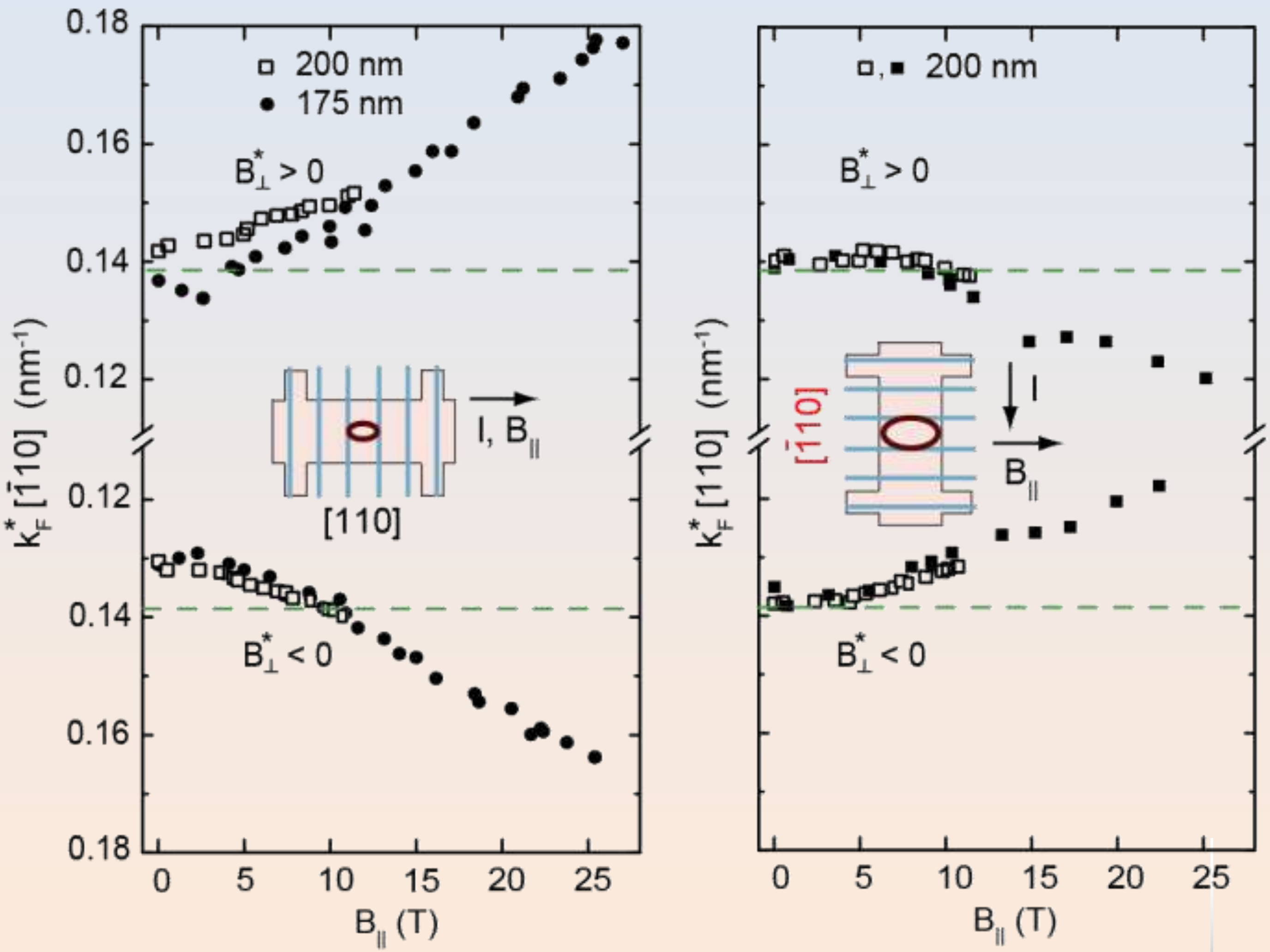

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