Electrons in 2D subject to perpendicular magnetic field

Landau levels: $$E_n = \hbar\omega_c(n + \tfrac{1}{2})$$

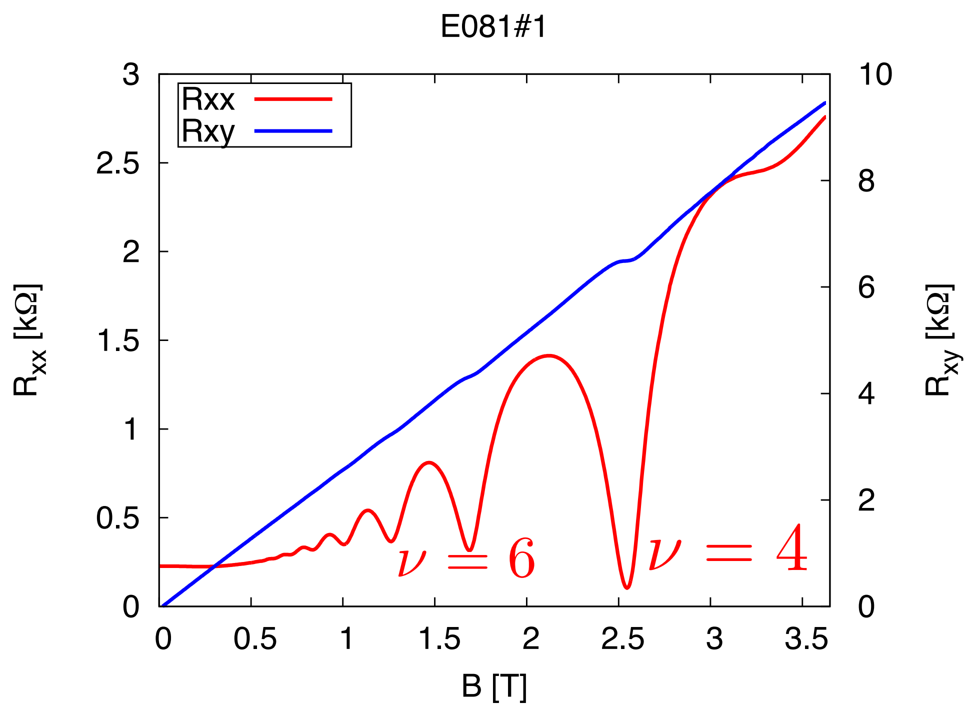
filling factor: $$\nu = \frac{n}{eB/h} = \frac{N_e}{N_q}$$

Extreme quantum limit

SdH $\xrightarrow[\nu \gg 1 \quad\quad \nu \approx 1]{}$ IQHE

$$\text{SdH} \quad \nu \gg 1 \longrightarrow \nu \approx 1 \quad \text{IQHE}$$

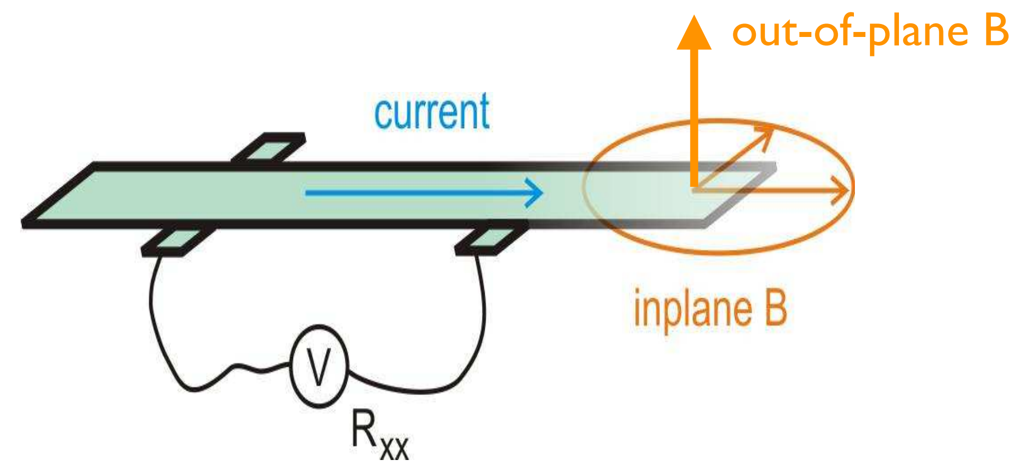
Plain 2DEG

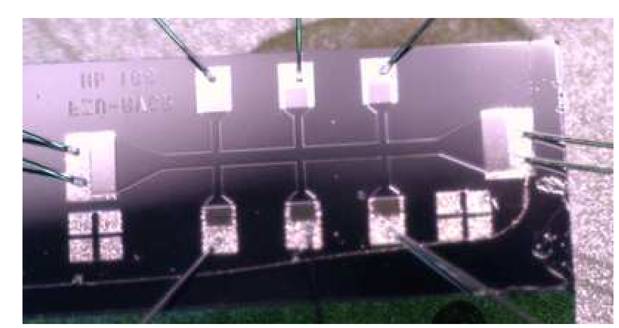


$$\hat{\rho} = \begin{pmatrix} 0 & \rho_n \\ -\rho_n & 0 \end{pmatrix}$$

$$\rho_{xy} = \frac{2\pi\hbar}{e^2\nu} \qquad \sigma_{xy} = 2n\frac{e^2}{2\pi\hbar}$$
$$\equiv 1/\rho_n$$

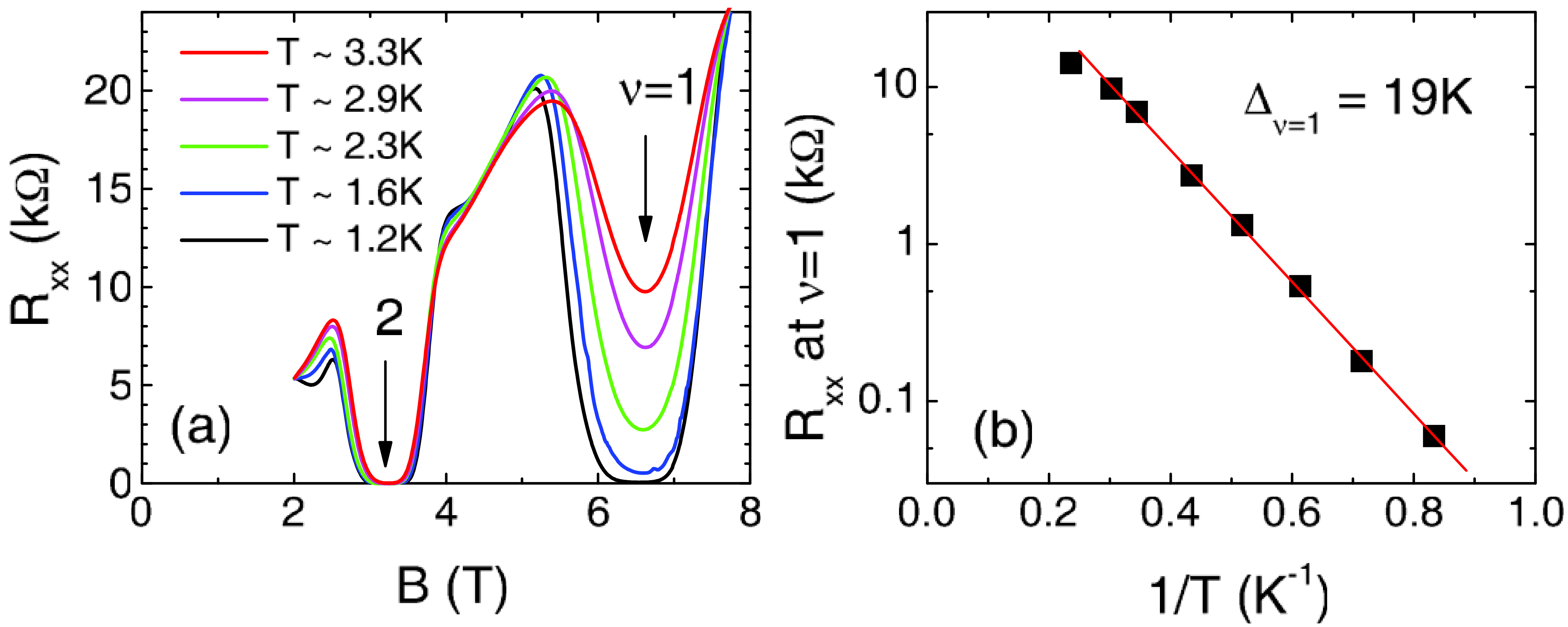
Hall bar geometry

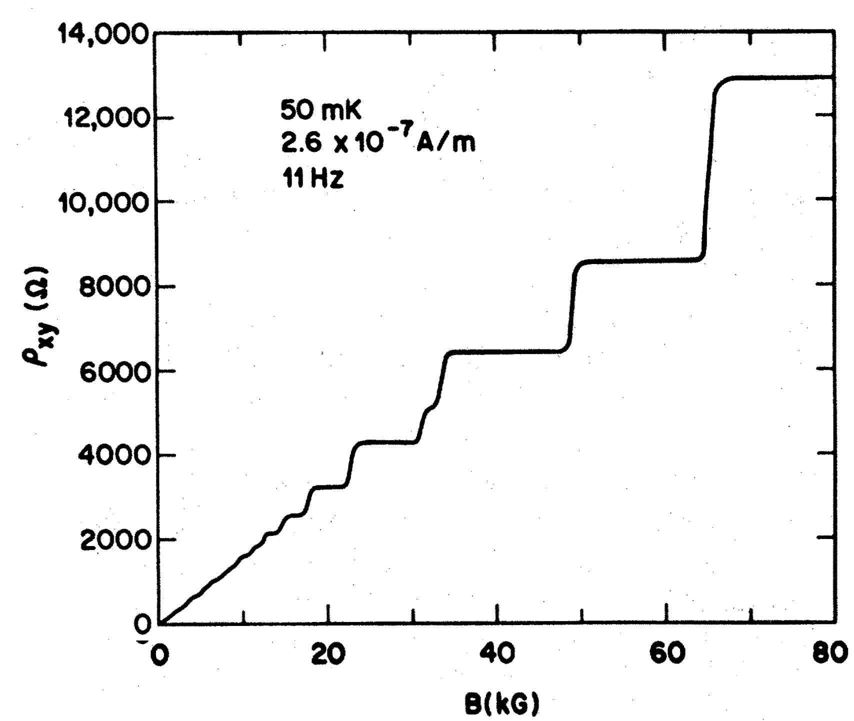


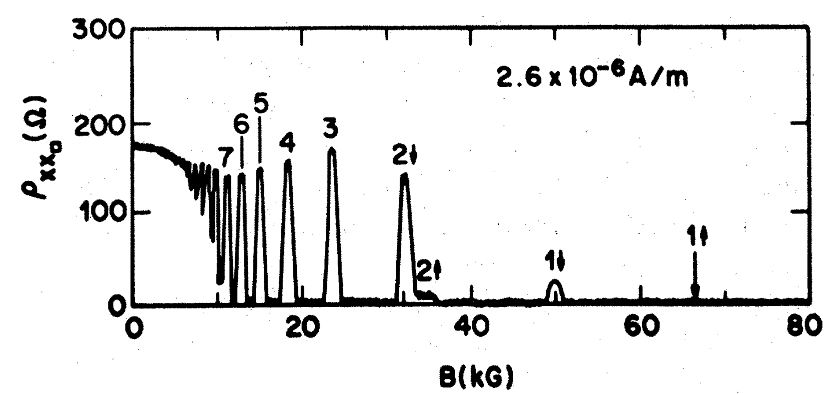


Courtesy of L. Nádvorník (MFF/FZU AV)

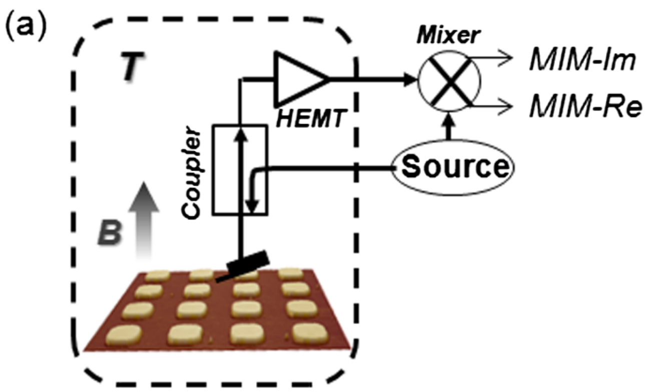
Activated transport (IQHE)

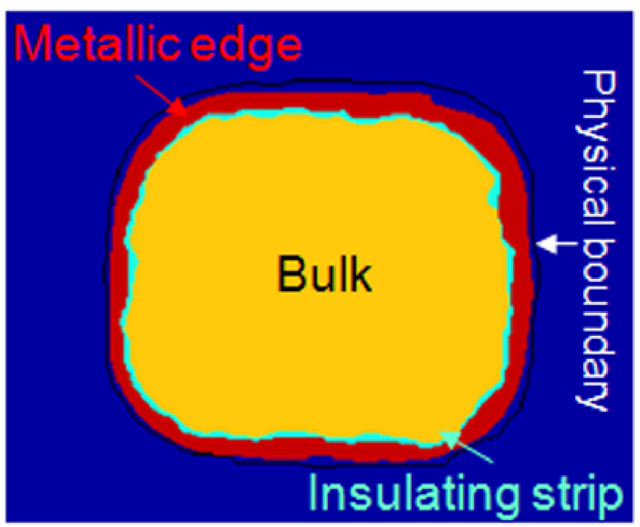


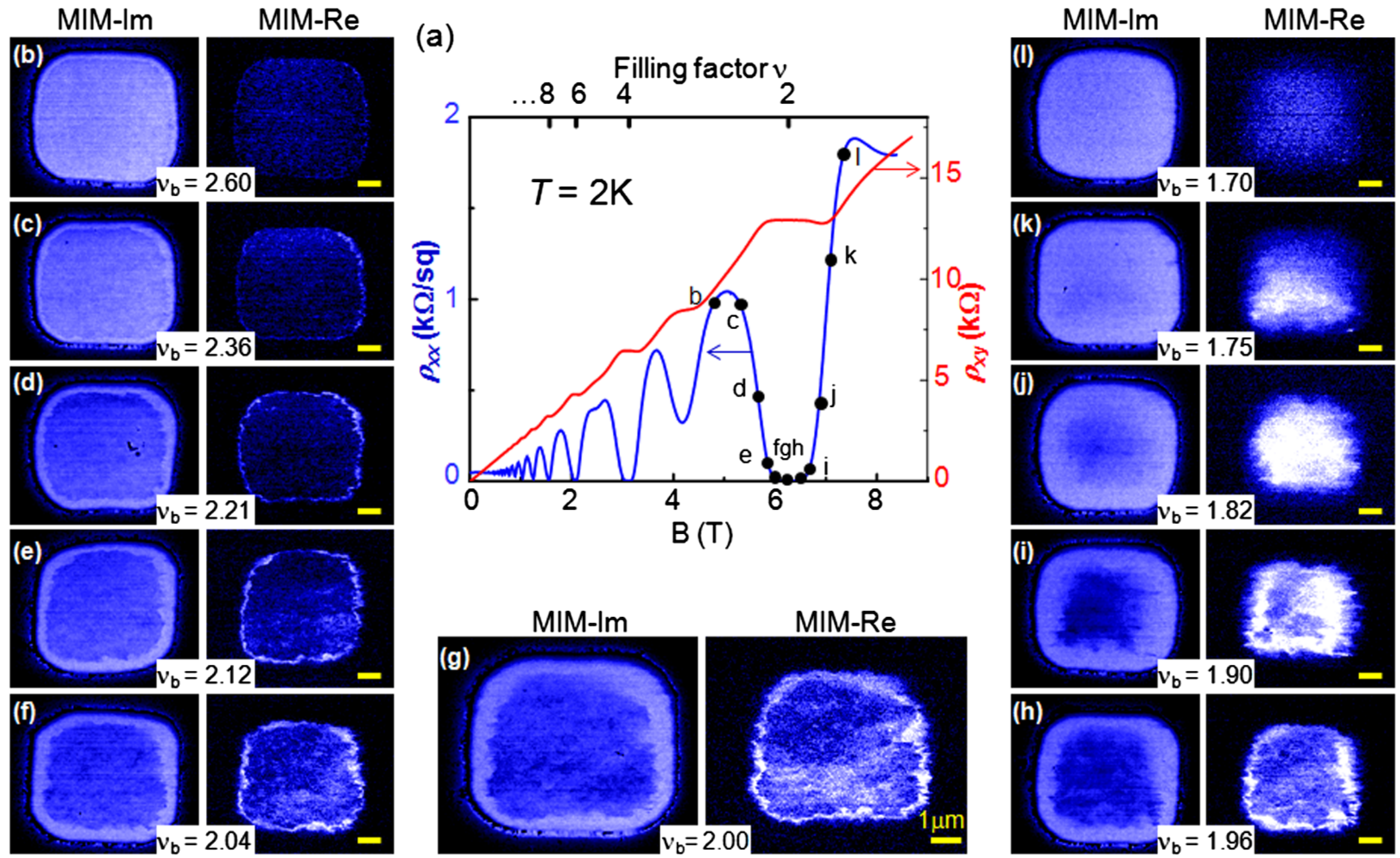




Edge states

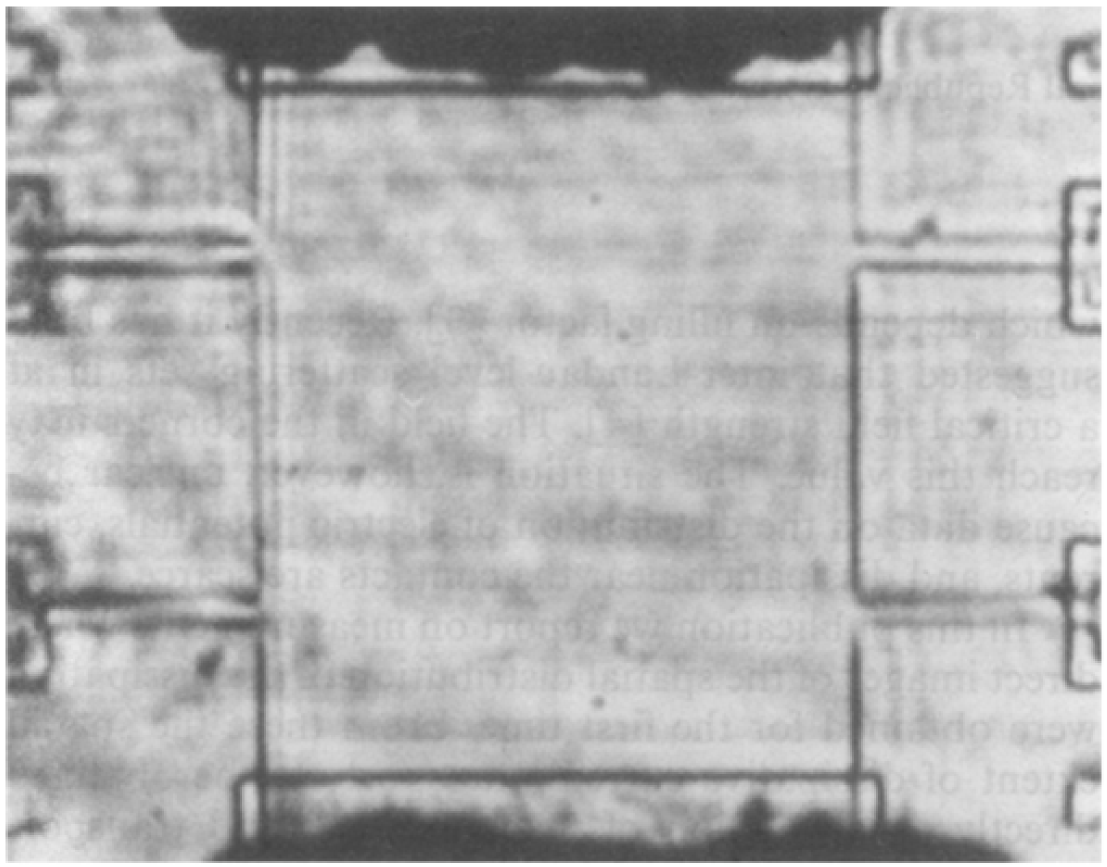

(a)
T
Mixer
MIM-Im
MIM-Re
HEMT
Coupler
Source
B


Metallic edge
Physical boundary
Bulk
Insulating strip

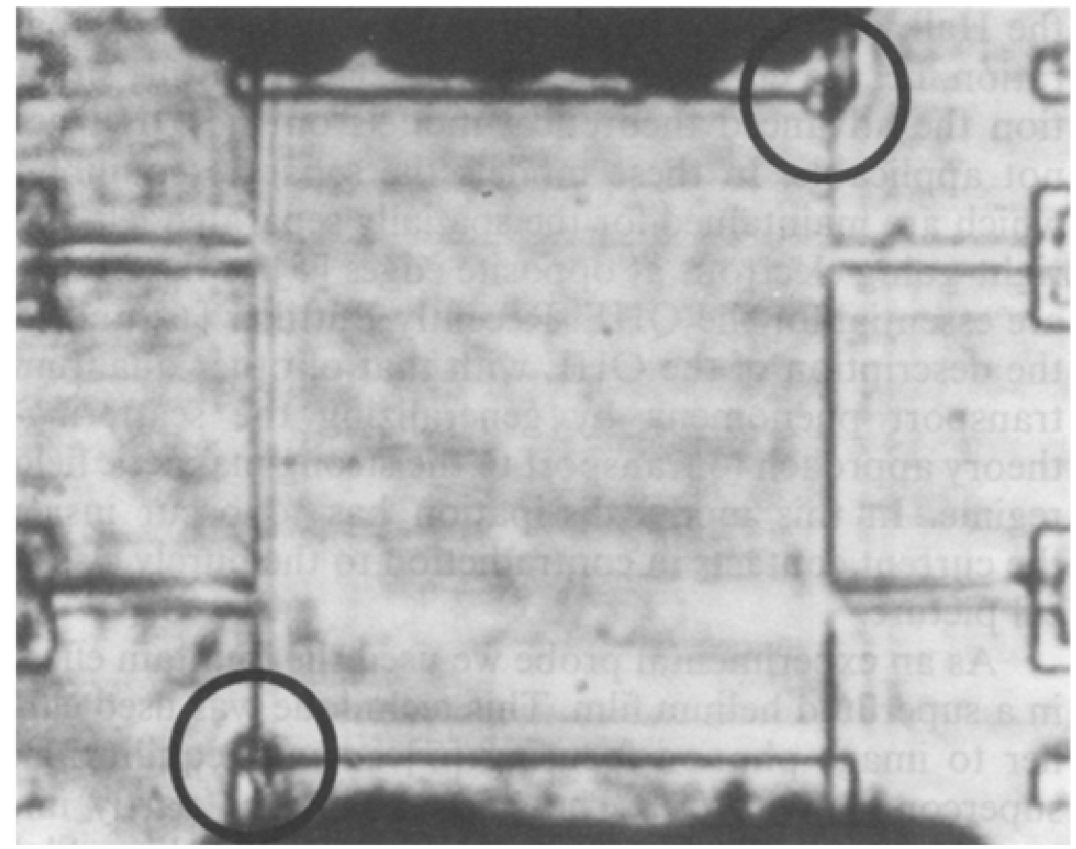

MIM-Im
MIM-Re
(b) ν_b = 2.60
(c) ν_b = 2.36
(d) ν_b = 2.21
(e) ν_b = 2.12
(f) ν_b = 2.04
(a)
Filling factor ν
...8 6 4 2
T = 2K
ρ_{xx} (kΩ/sq)
ρ_{xy} (kΩ)
B (T)
b c d e fgh i j k l
(g) ν_b = 2.00
1μm
(l) ν_b = 1.70
(k) ν_b = 1.75
(j) ν_b = 1.82
(i) ν_b = 1.90
(h) ν_b = 1.96

Dissipation of energy in a Hall bar (IQHE)

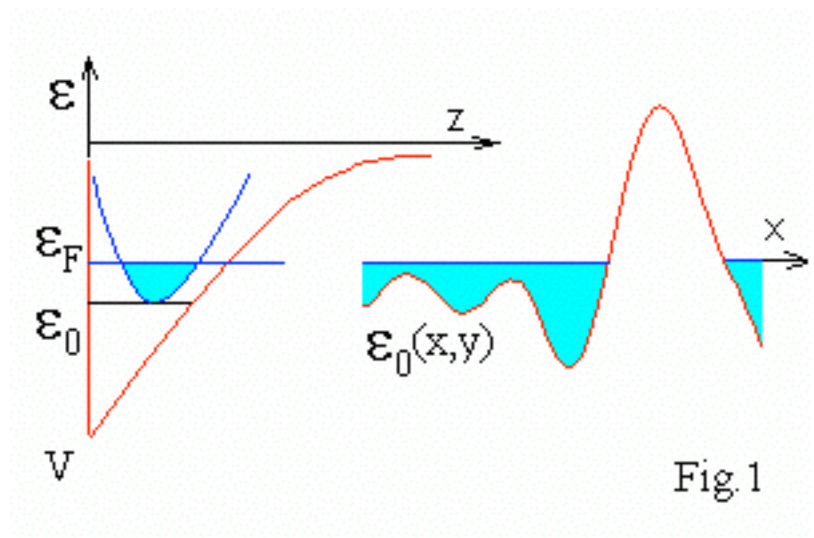
current off

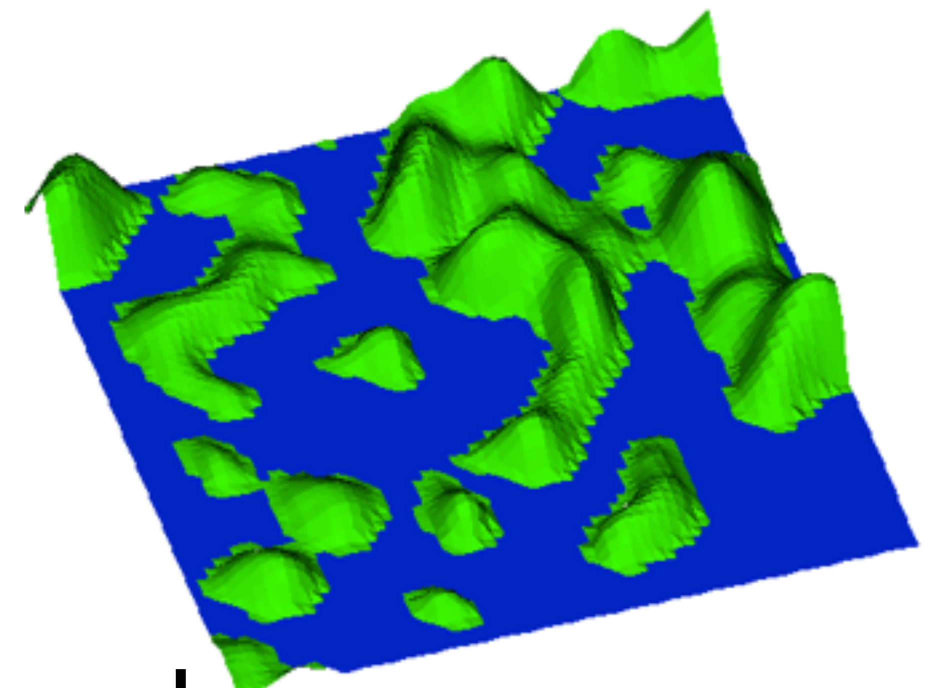


current on

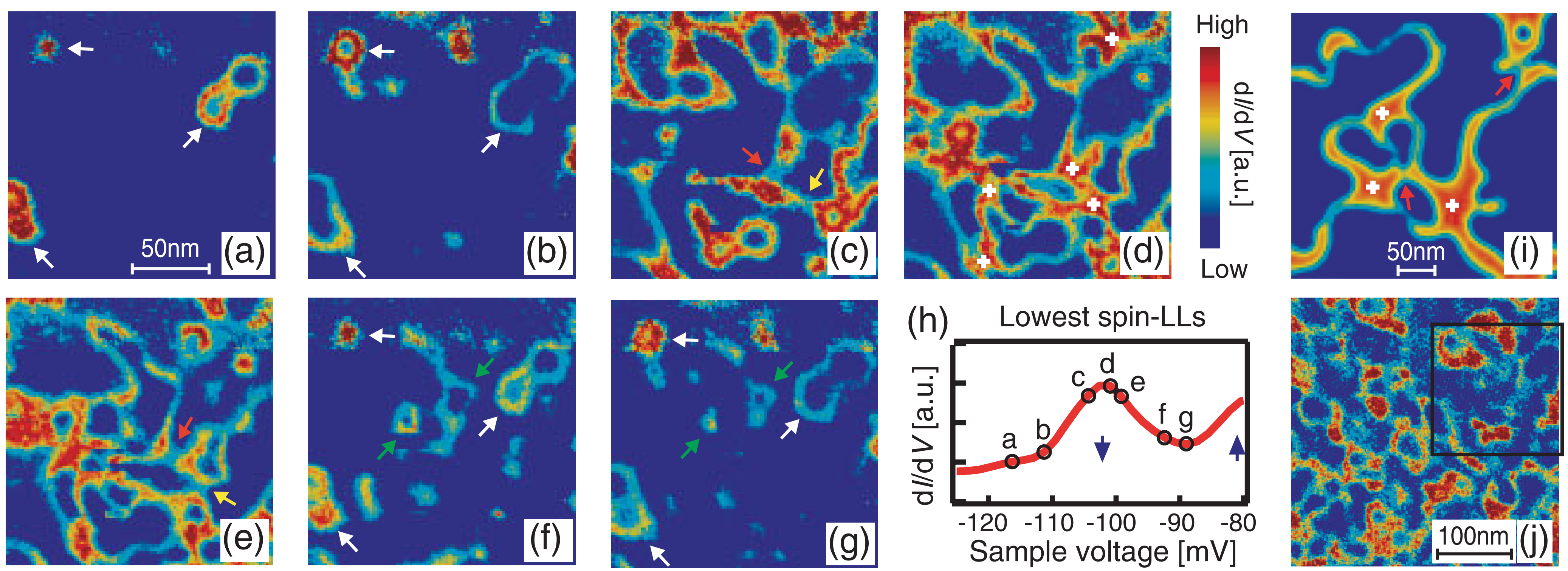


Percolation picture of IQHE



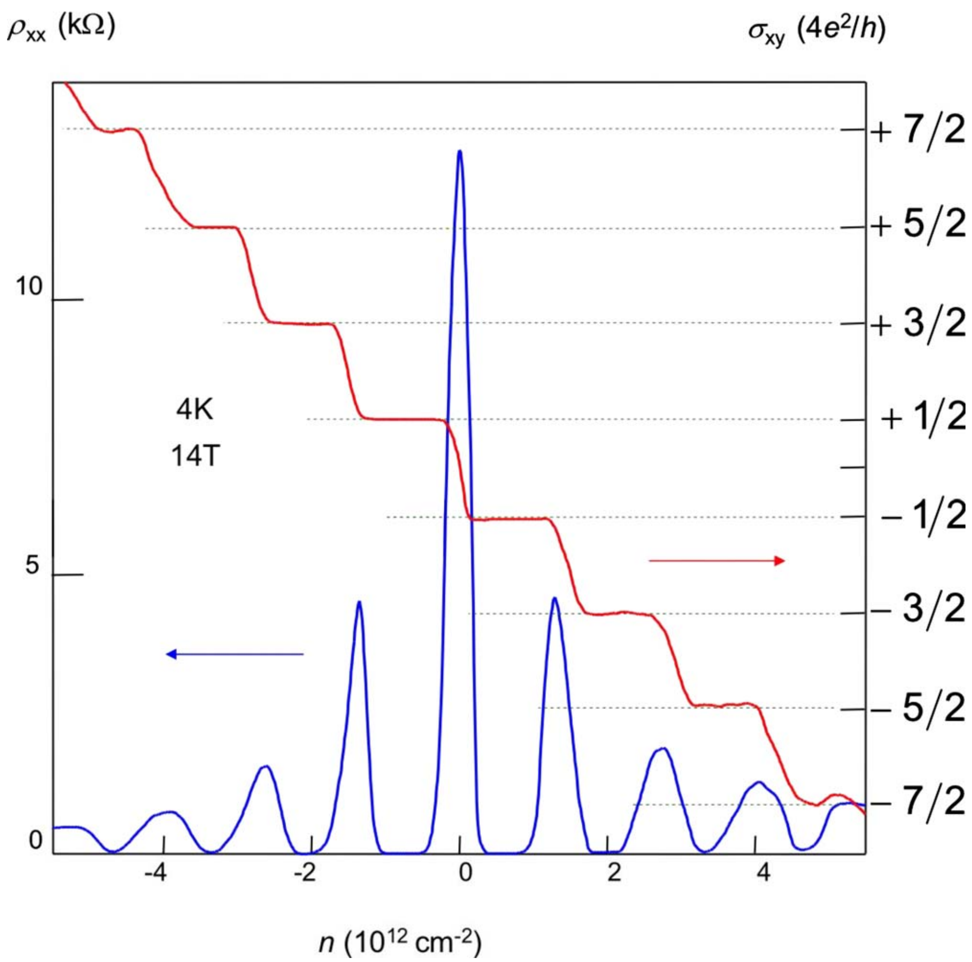


LDOS measured



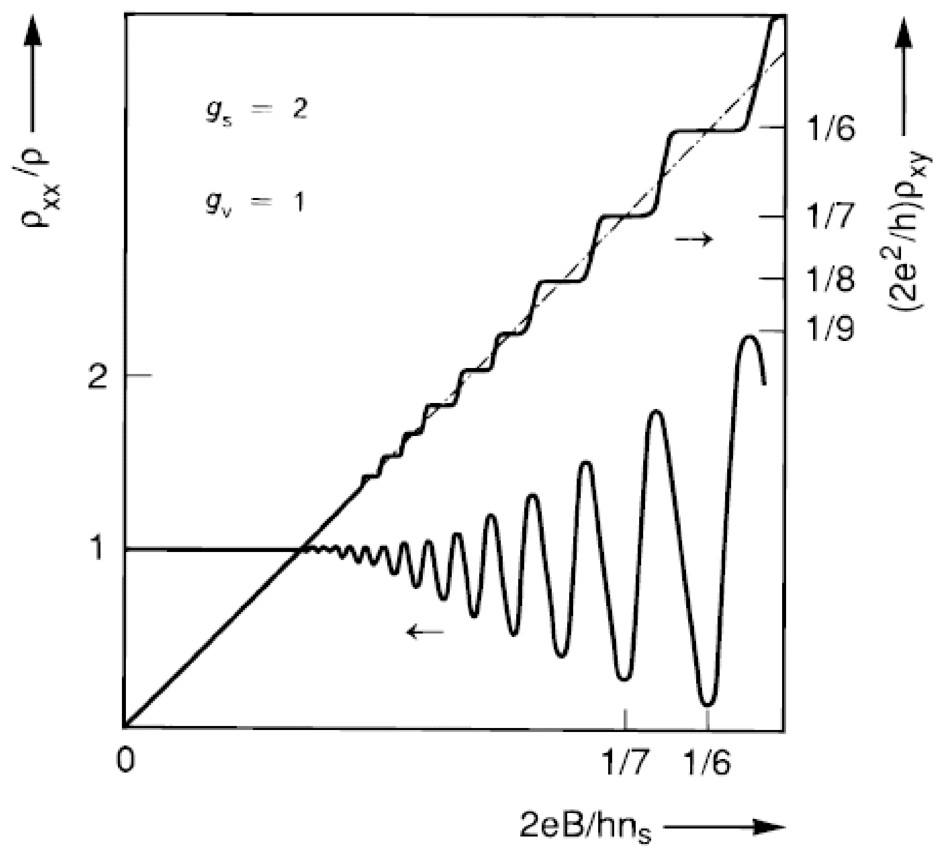
Berry phase manifestation in Landau level offset

graphene



- 'half-integer' IQHE
- Berry phase = π

2DEG



- true IQHE
- Berry phase = 0

Quantum Hall Effect (fractional)

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Two-Dimensional Magnetotransport in the Extreme Quantum Limit

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Bell Laboratories, Murray Hill, New Jersey 07974
(Received 5 March 1982)

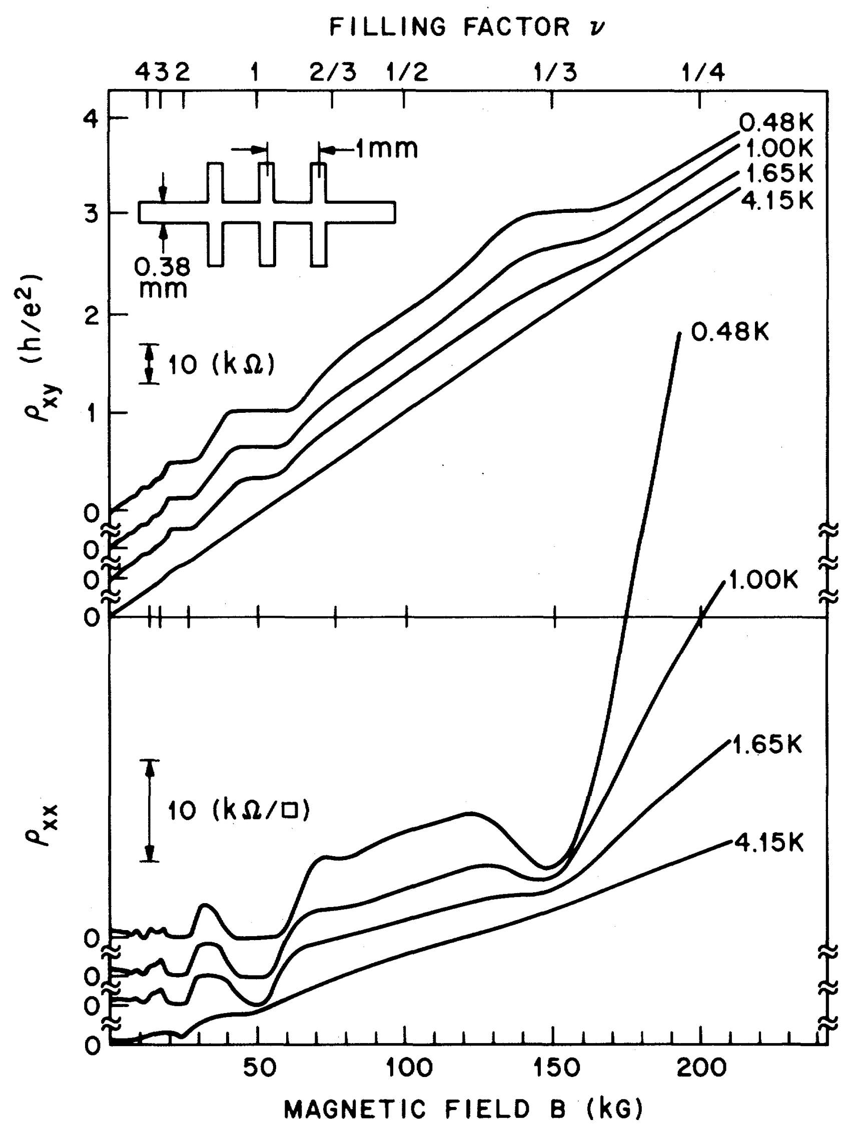
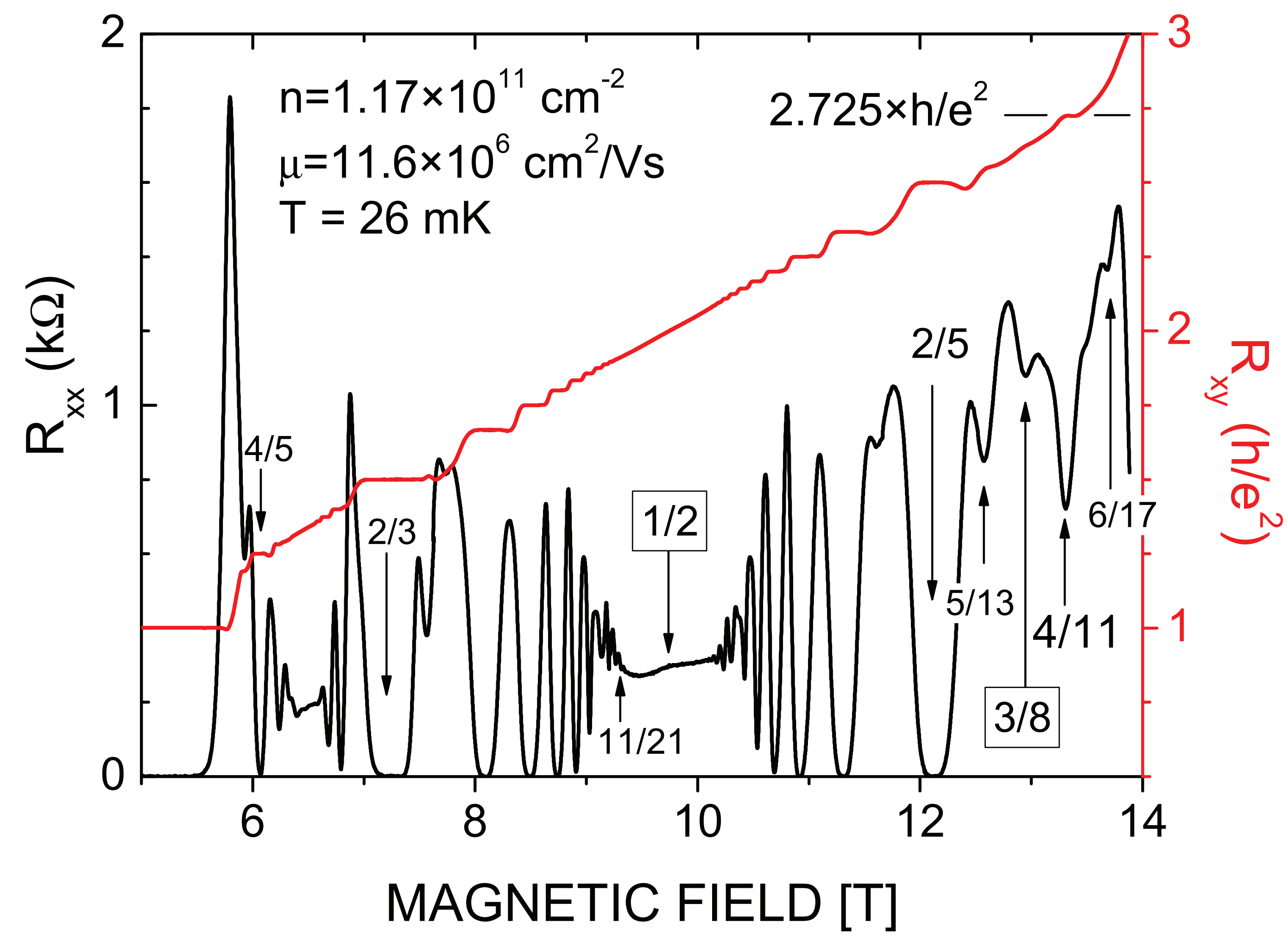
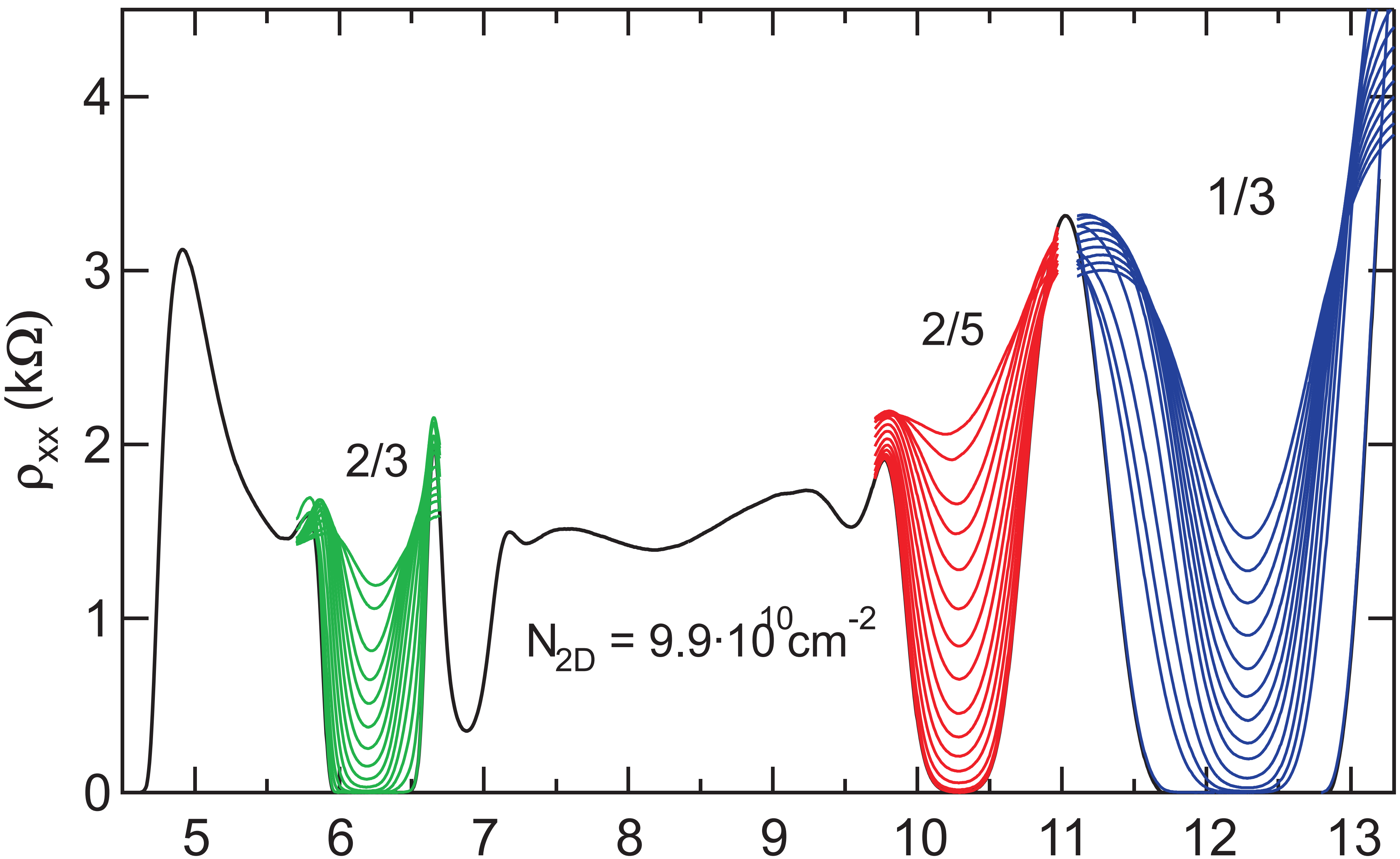


FIG. 1. ρ_{xy} and ρ_{xx} vs B, taken from a GaAs-$Al_{0.3}$-$Ga_{0.7}As$ sample with $n = 1.23\times10^{11}/cm^2$, $\mu = 90\,000\ cm^2/V$ sec, using $I = 1\ \mu A$. The Landau level filling factor is defined by $\nu = nh/eB$.



Activated transport (FQHE)



Excitation spectrum in the 1/3 Laughlin state

$$H = \frac{1}{2m} \sum_{i=1}^{N_e} \left(\vec{p}_i - q\vec{A}(\vec{r}_i) \right)^2 + \frac{e^2}{4\pi\varepsilon} \sum_{i<j} \frac{1}{|\vec{r}_i - \vec{r}_j|}$$

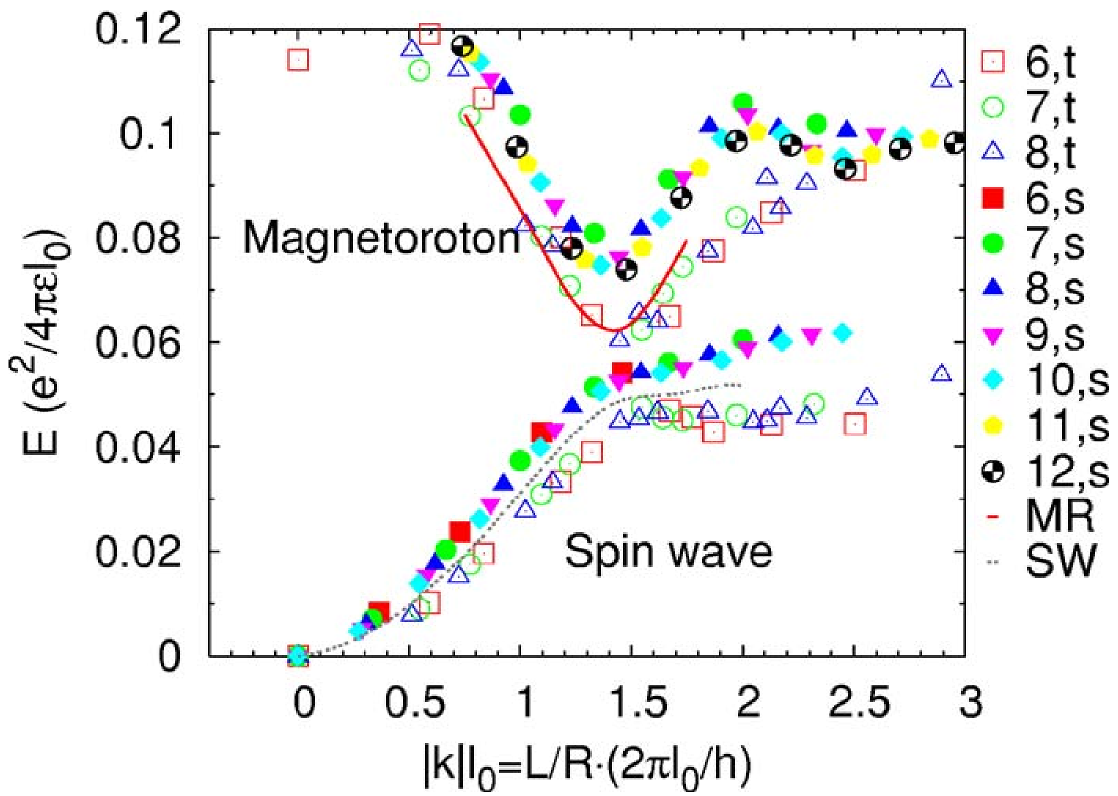
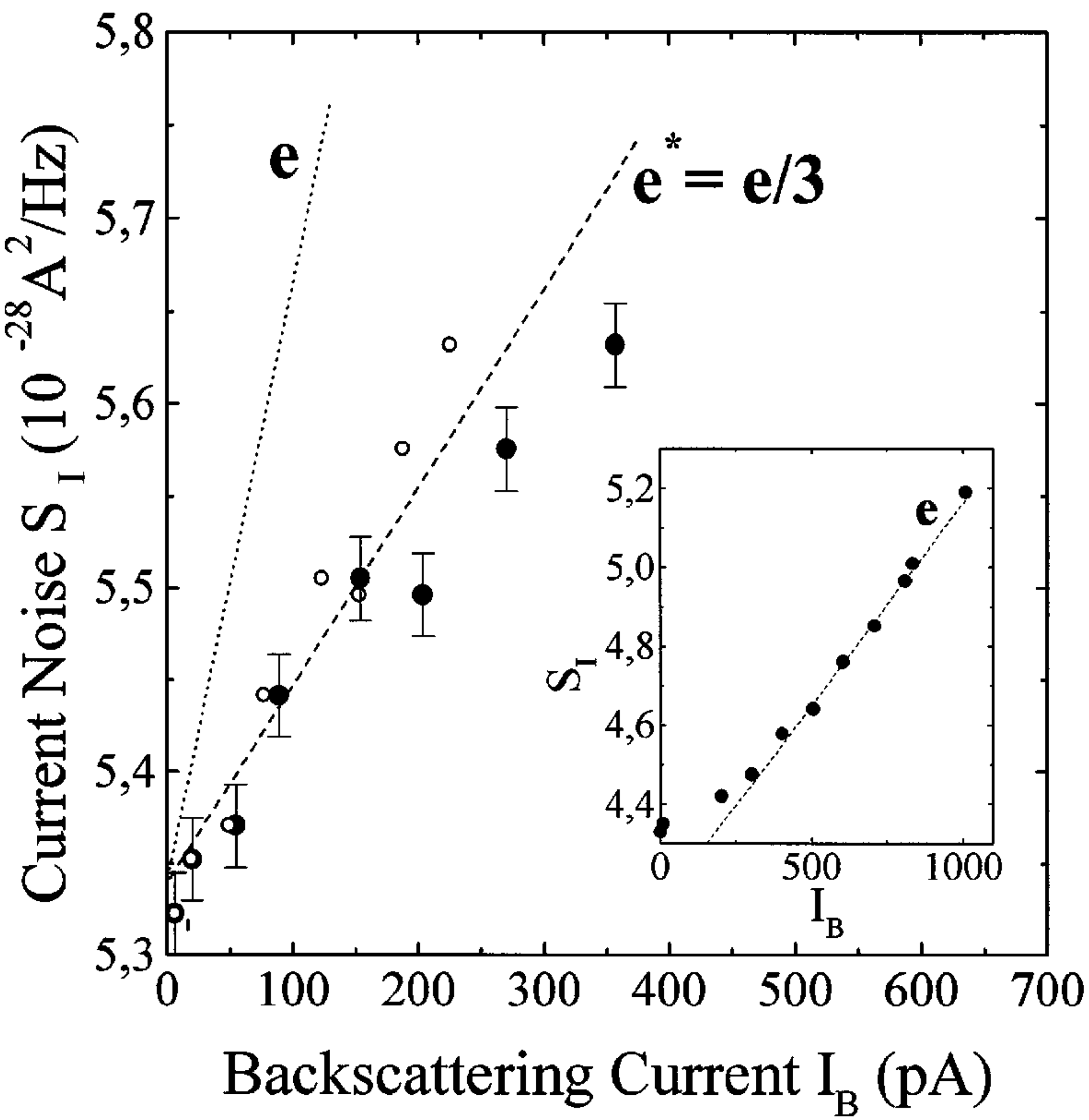


FIG. 5. (Color online) The spin wave (SW) and the magnetoroton branch (MR) seen in the ED spectra of ideal $\nu=1/3$ systems of different sizes and geometries. In the legend, *t* stands for torus, *s* for sphere, and the number indicates the number of electrons. The lines (solid and dotted) were obtained from the $1/N\rightarrow 0$ extrapolation of the data (MR and SW) on the sphere.

Shot noise in FQHE regime



$$S_I = e \cdot I$$

$$\nu = 1/3$$

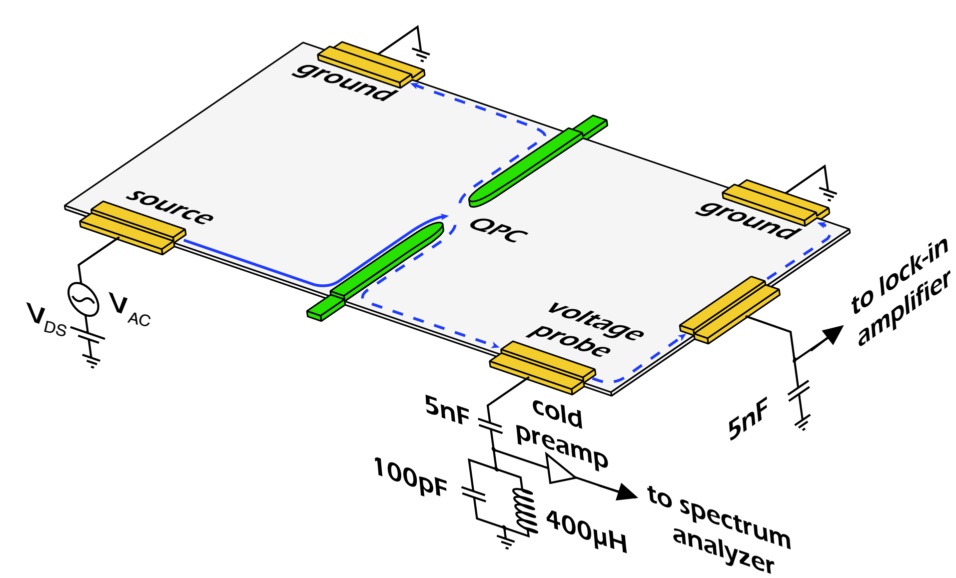
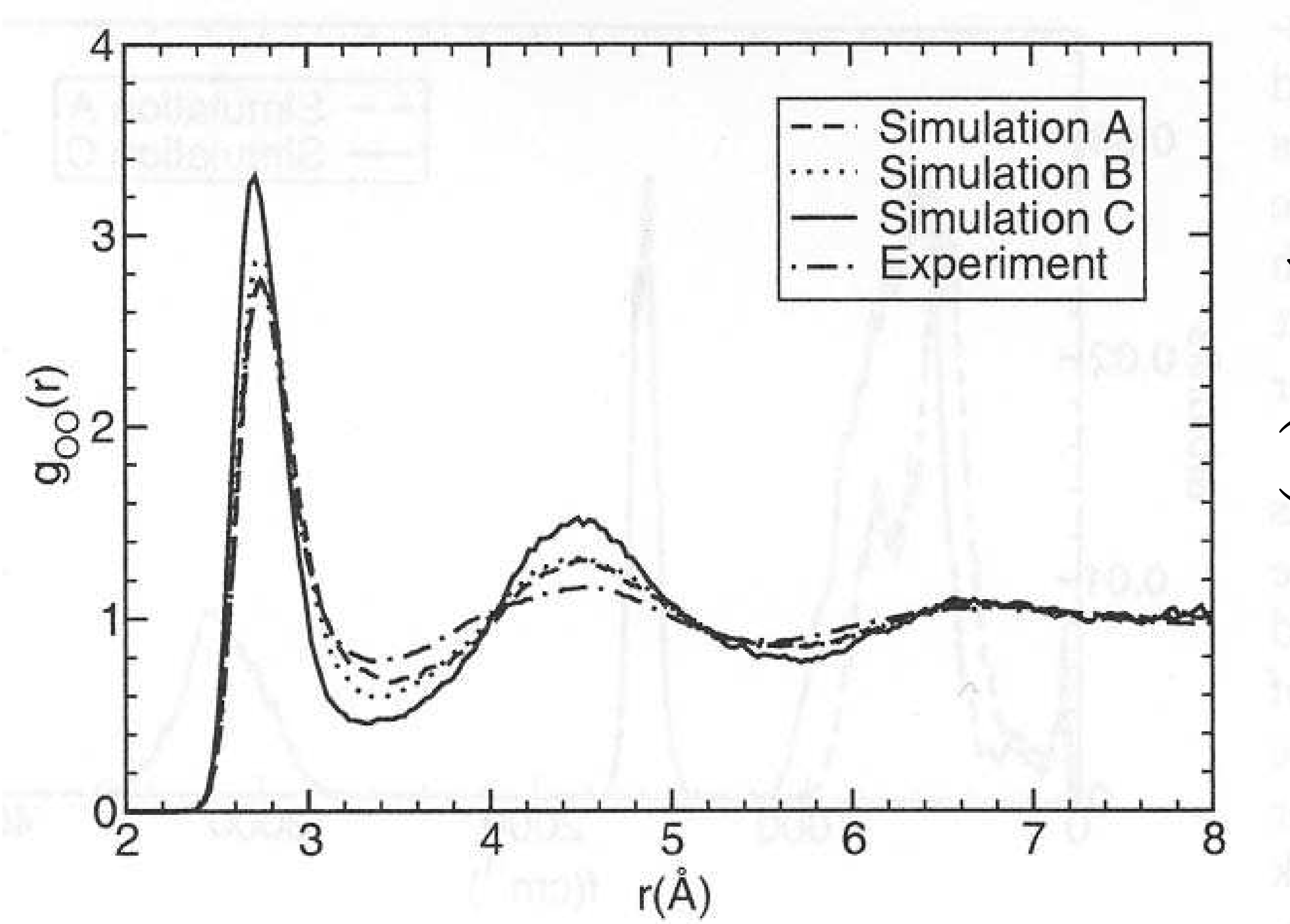


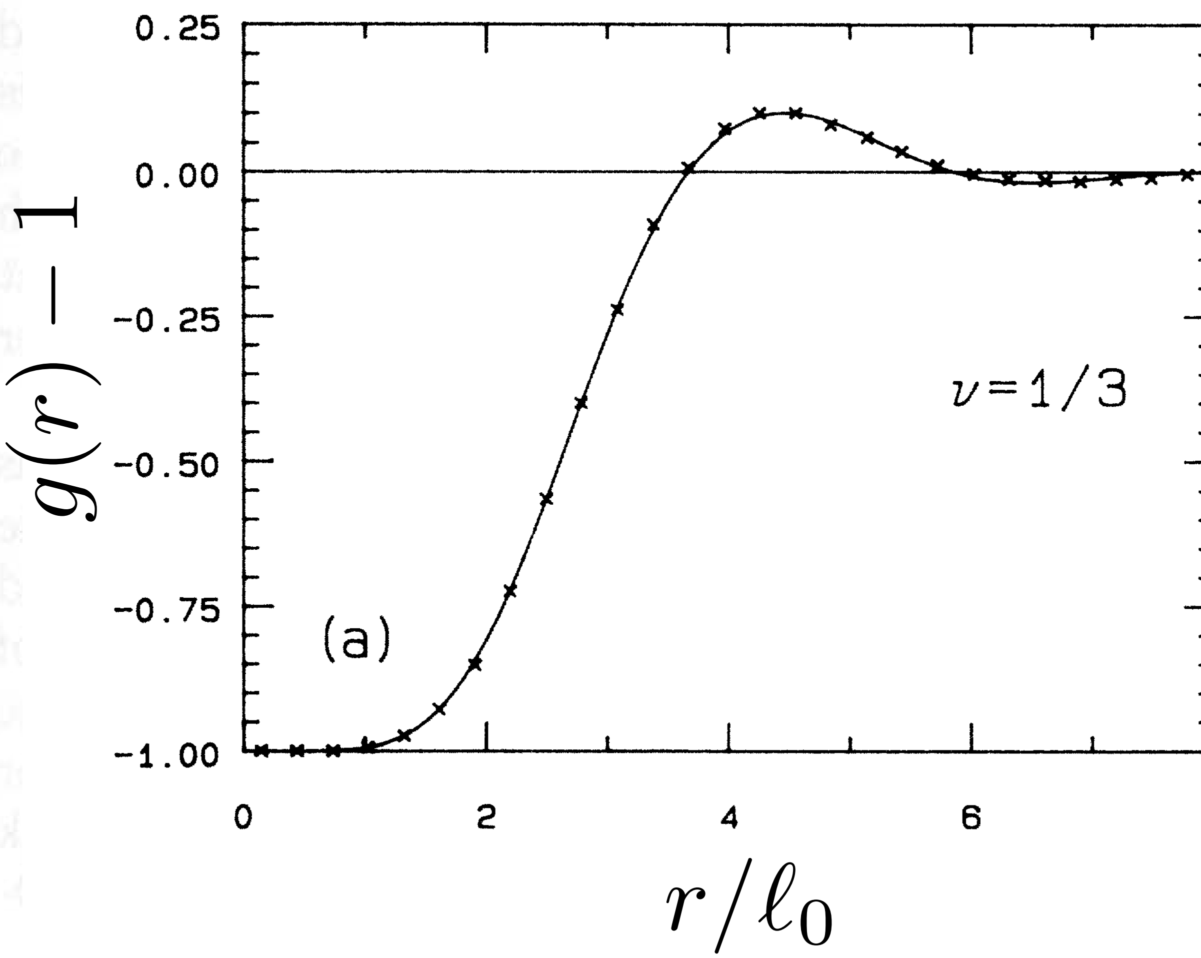
FIG. 1 (color online). Schematic of the noise measurement setup (see text for details).

Liquids: density-density correlation

water



FQHE at 1/3



$$g(\vec{r}) \propto \left\langle \sum_{i \neq j} \delta(\vec{r}_i - \vec{r}_j - \vec{r}) \right\rangle$$