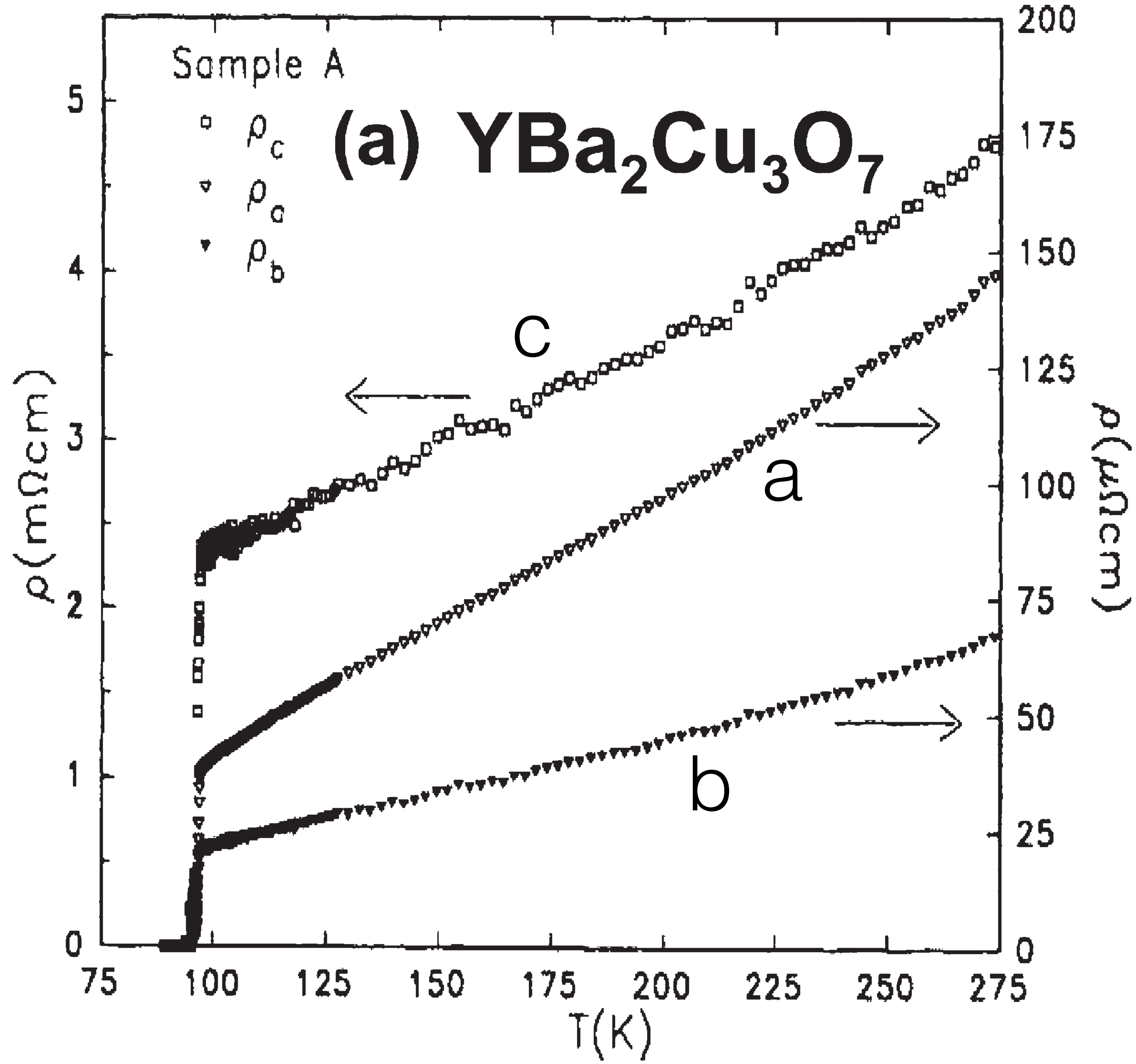
Superconductivity



$$\sigma_0 = \omega_p^2 \epsilon_0 \tau$$

$$\hbar\omega_{p,a} = 2.9 \text{ eV}$$
$$\hbar\omega_{p,b} = 4.4 \text{ eV}$$
$$\hbar\omega_{p,c} = 1.1 \text{ eV}$$

Quantum Hall Effect (fractional)

VOLUME 48, NUMBER 22 PHYSICAL REVIEW LETTERS 31 MAY 1982

Two-Dimensional Magnetotransport in the Extreme Quantum Limit

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(Received 5 March 1982)

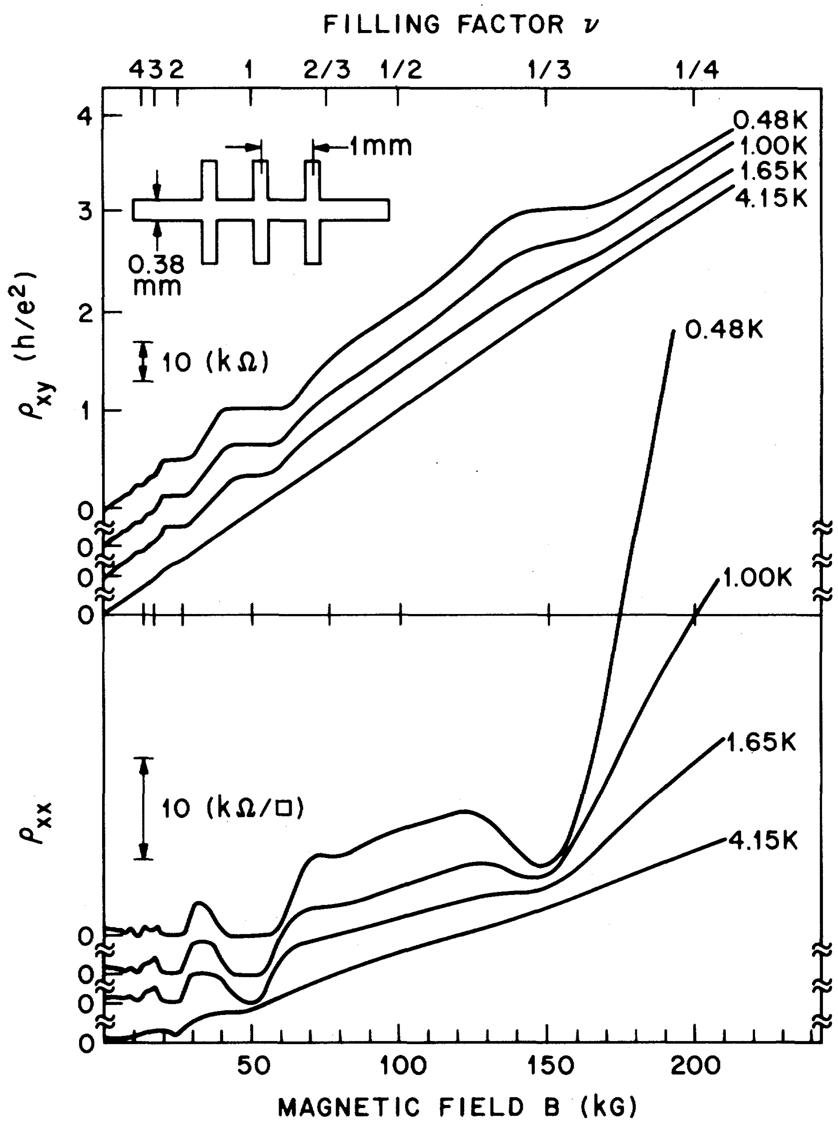
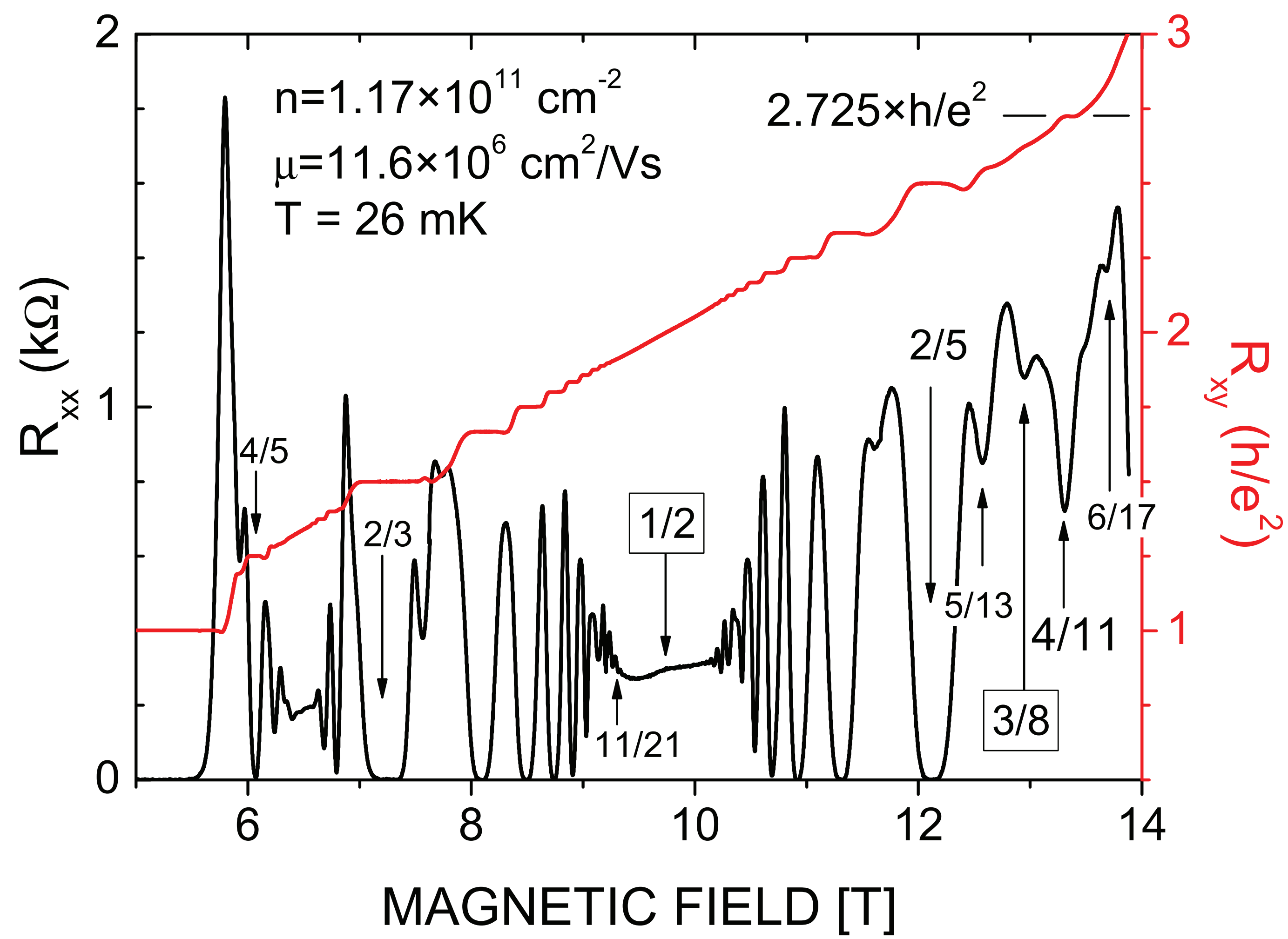
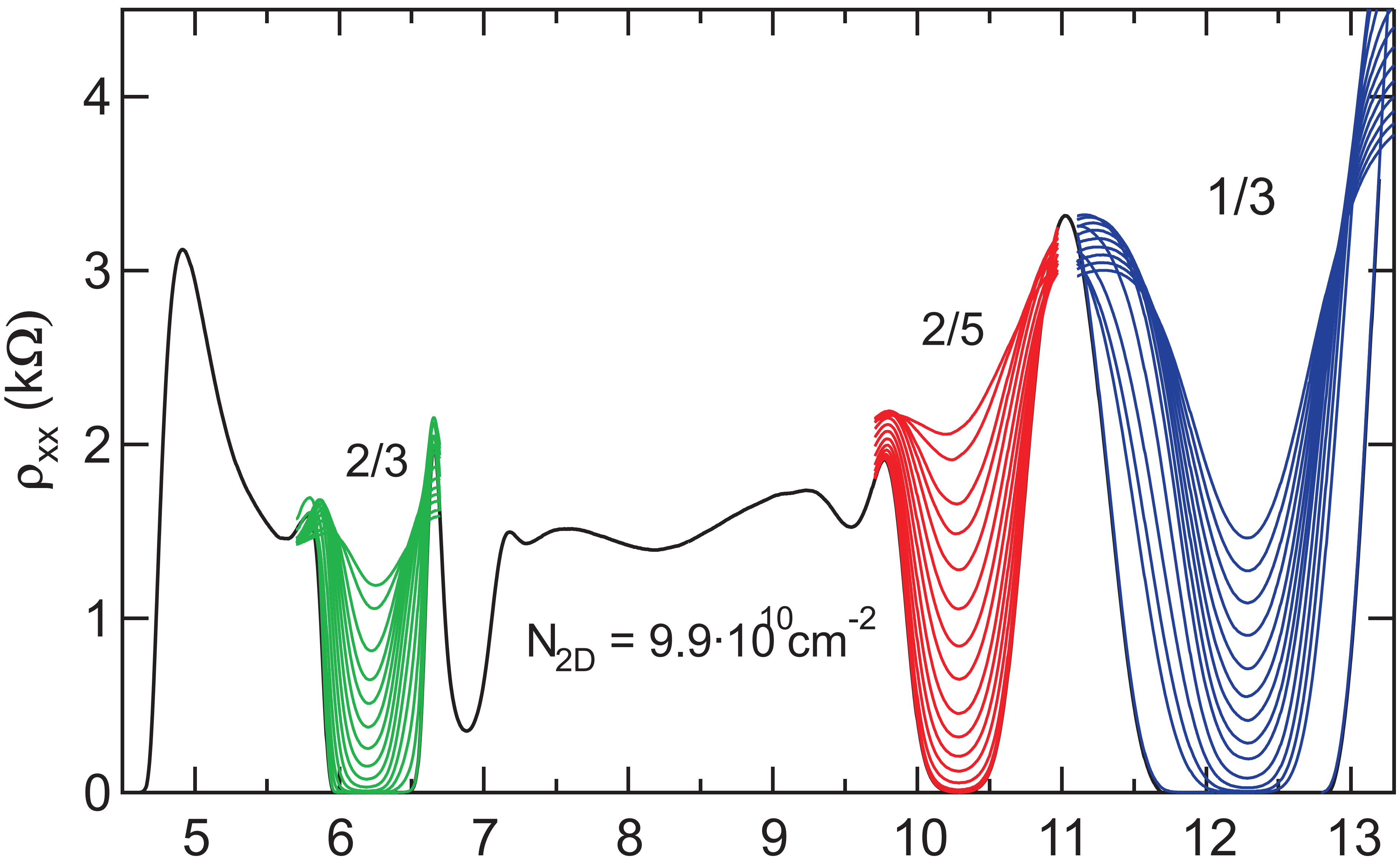


FIG. 1. ρ_{xy} and ρ_{xx} vs B, taken from a GaAs-$Al_{0.3}$-$Ga_{0.7}As$ sample with $n = 1.23\times10^{11}/cm^2$, $\mu = 90\,000$ cm^2/V sec, using $I = 1\ \mu A$. The Landau level filling factor is defined by $\nu = nh/eB$.



Activated transport (FQHE)



Excitation spectrum in the 1/3 Laughlin state

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

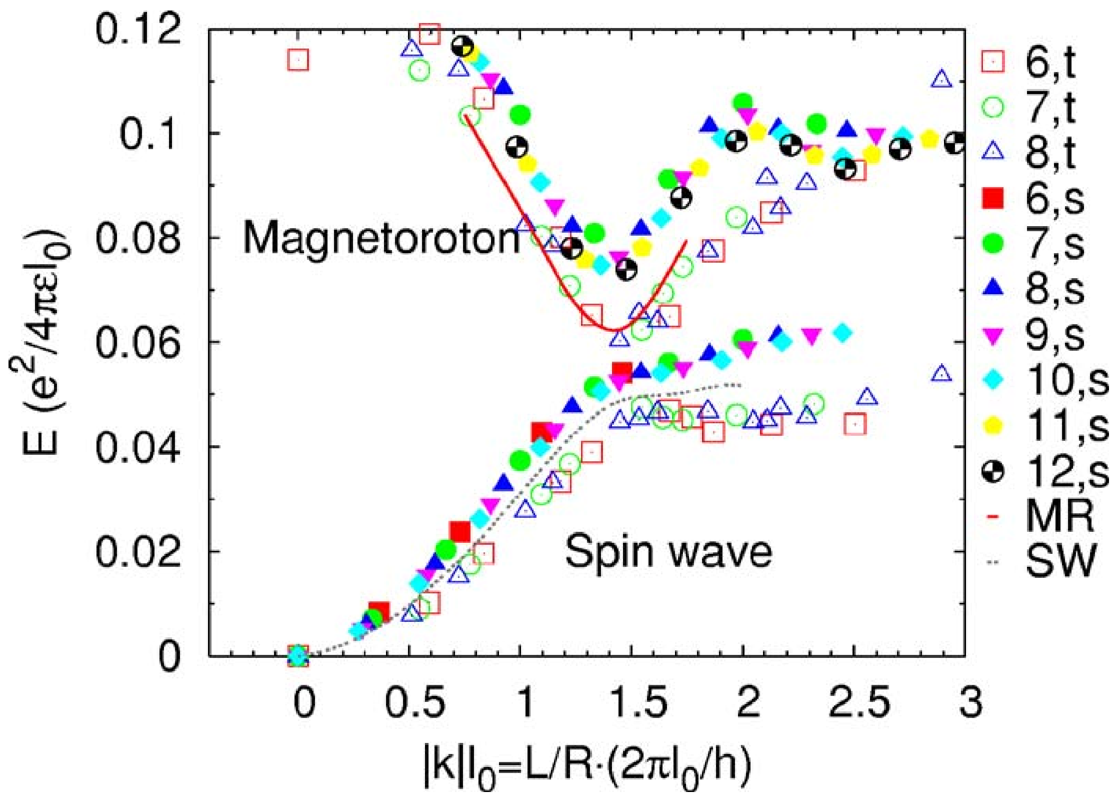


FIG. 5. (Color online) The spin wave (SW) and the magnetoroton branch (MR) seen in the ED spectra of ideal $\nu=1/3$ systems of different sizes and geometries. In the legend, *t* stands for torus, *s* for sphere, and the number indicates the number of electrons. The lines (solid and dotted) were obtained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

Single-mode approximation

superfluid He

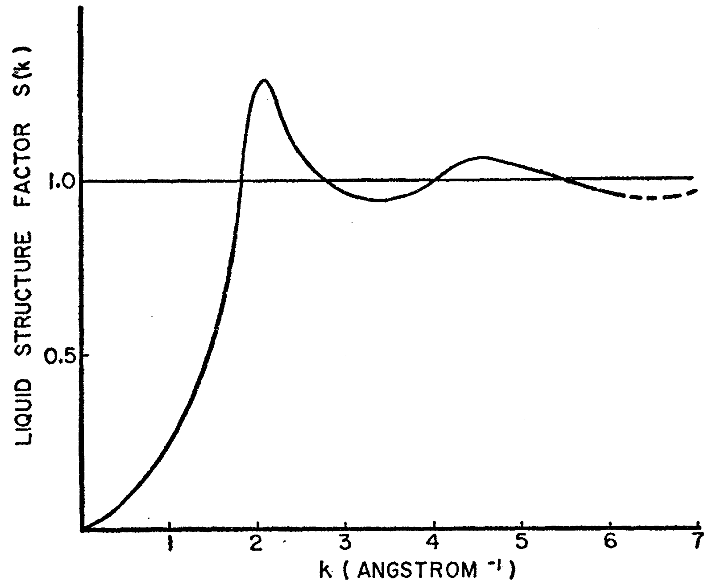
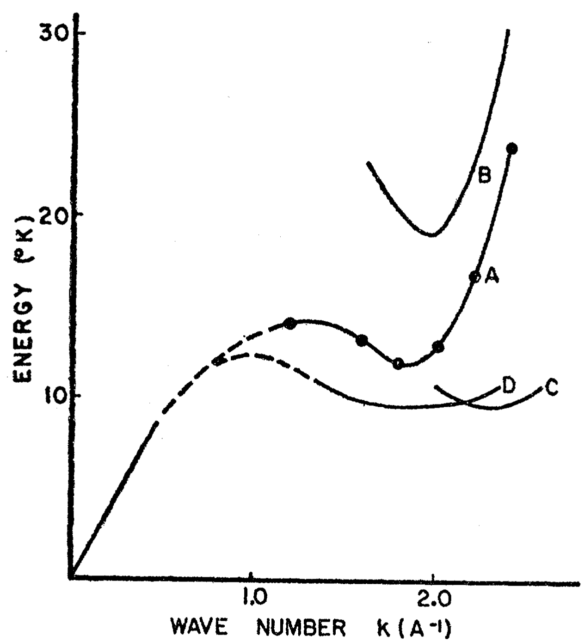


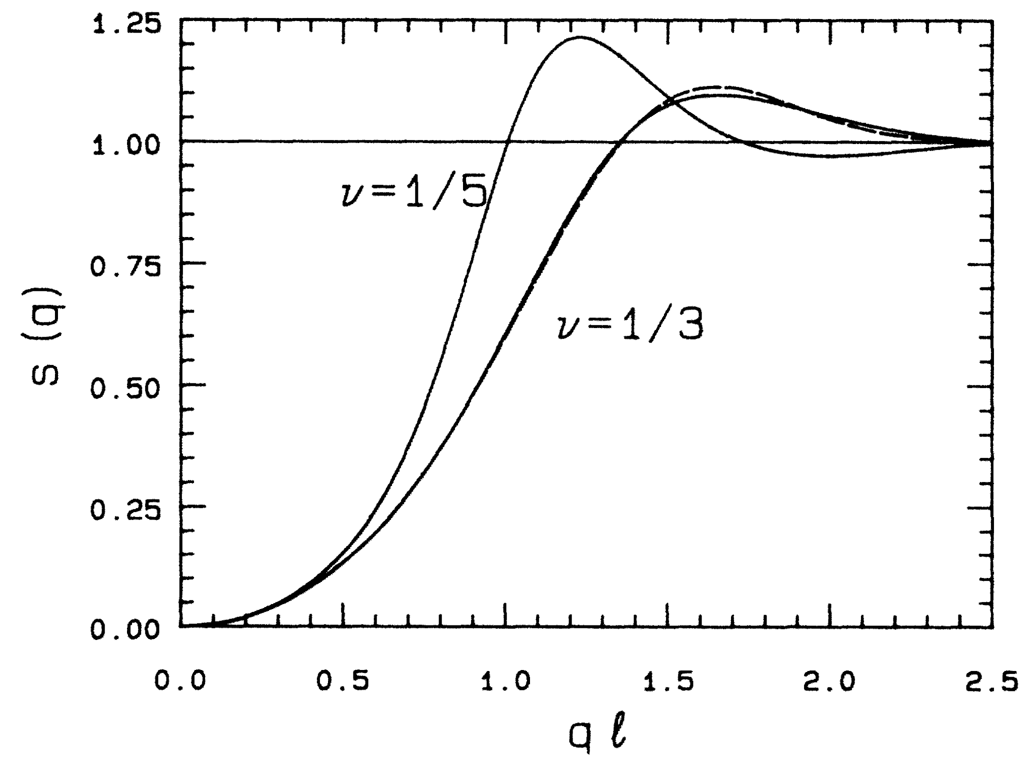
FIG. 1. The liquid structure factor $S(k)$, based on the x-ray scattering data of Reekie and Hutchison. The principal maximum corresponds to a wavelength equal to the nearest neighbor distance in helium. Appendix A describes modifications we have made in the data.

Phys Rev 102, 1189

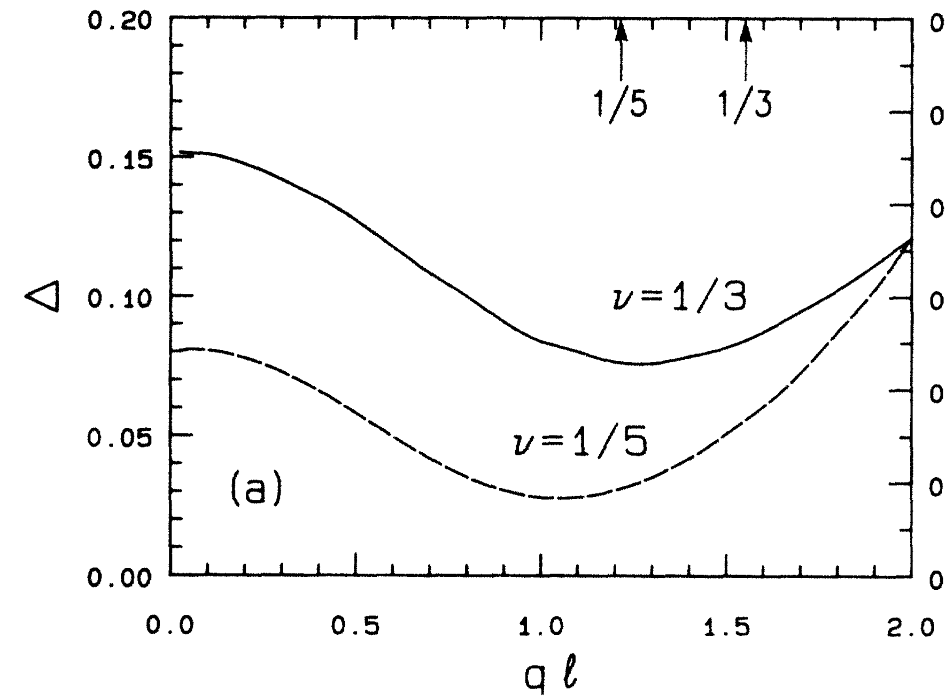
FIG. 6. The energy spectrum of excitations. Curve A is the spectrum $E_2(k)$ computed from Eq. (61). Curve B is the spectrum $E_1(k)$ computed with the simpler wave function (5). Curve C is the Landau-type spectrum used by de-Klerk *et al.*[4] to fit the second sound and specific heat data. Curve D is a Landau-type spectrum with p_0 taken the same as in A, and μ and Δ chosen to fit the specific heat data. For small k, all curves are asymptotic to the line $E=\hbar ck$.



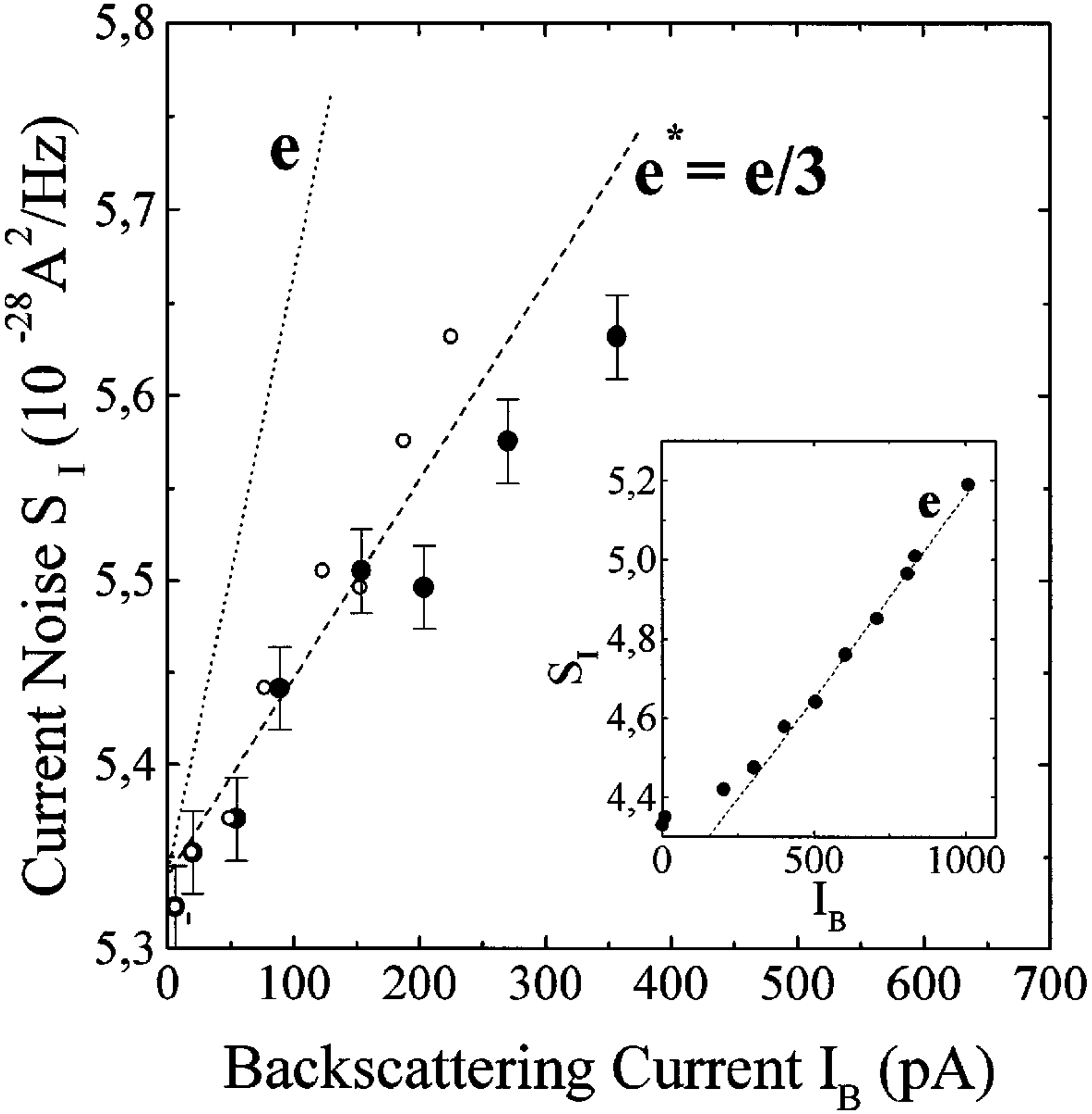
FQHE liquid



Phys Rev B 33, 2481



Shot noise in FQHE regime



$$S_I = e \cdot I$$

$$\nu = 1/3$$

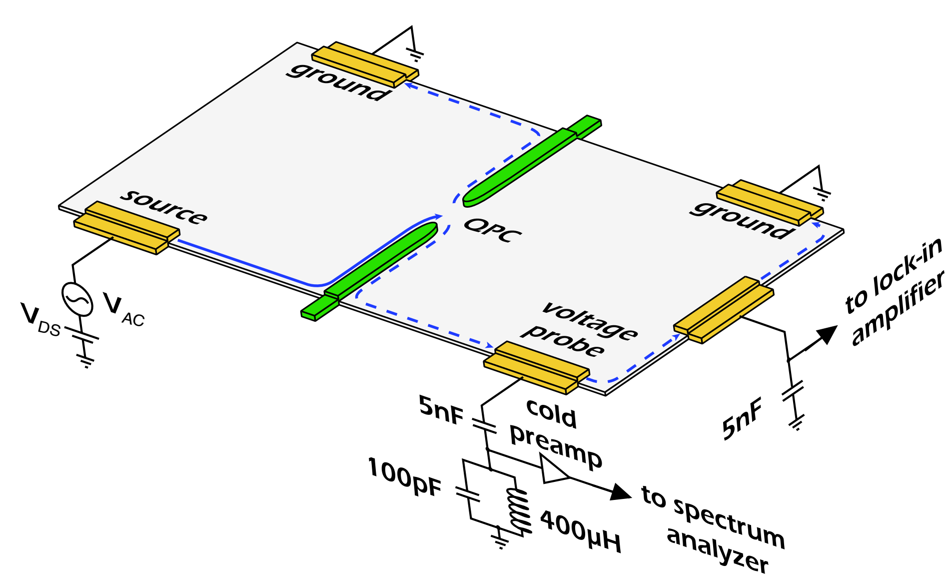
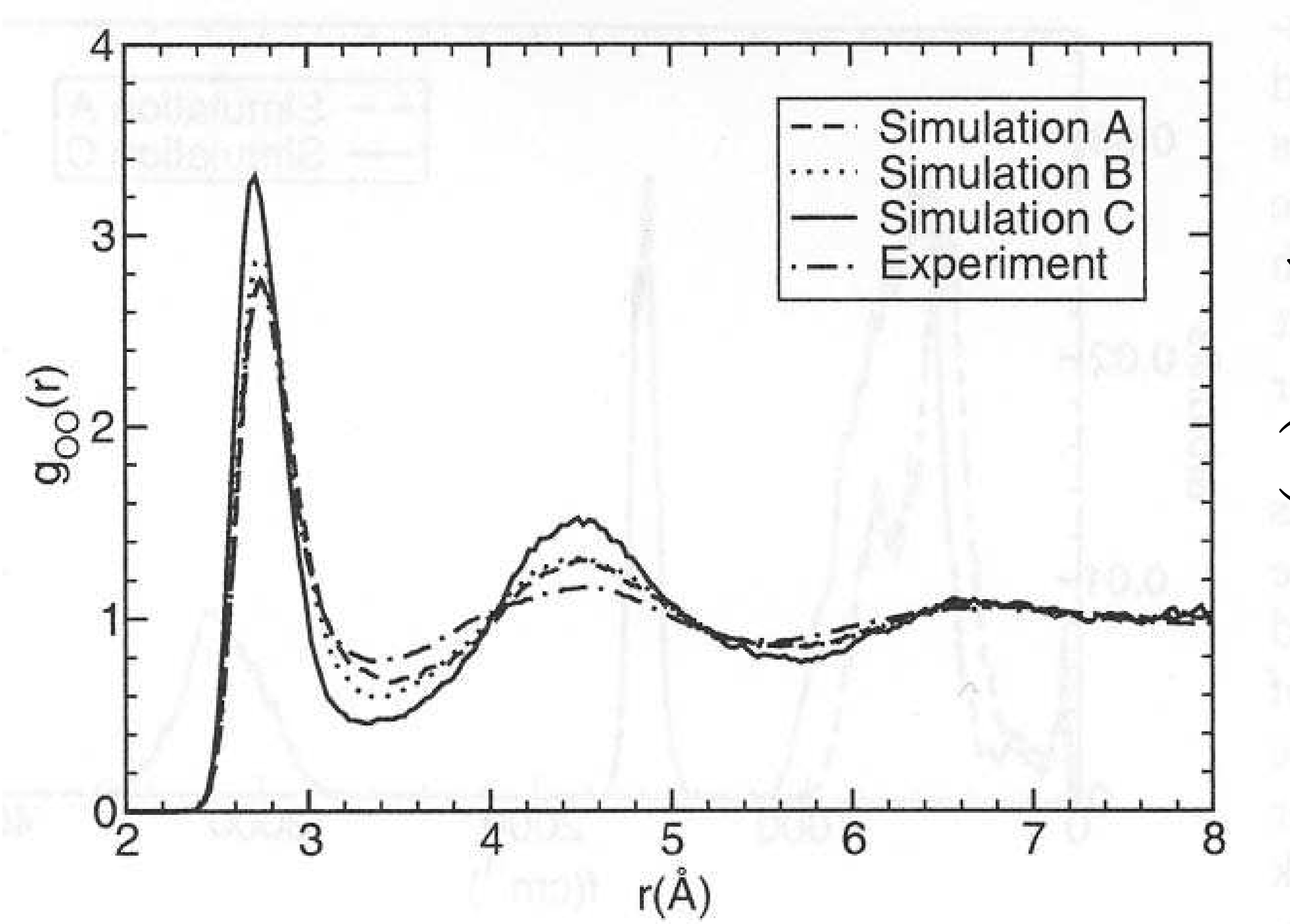


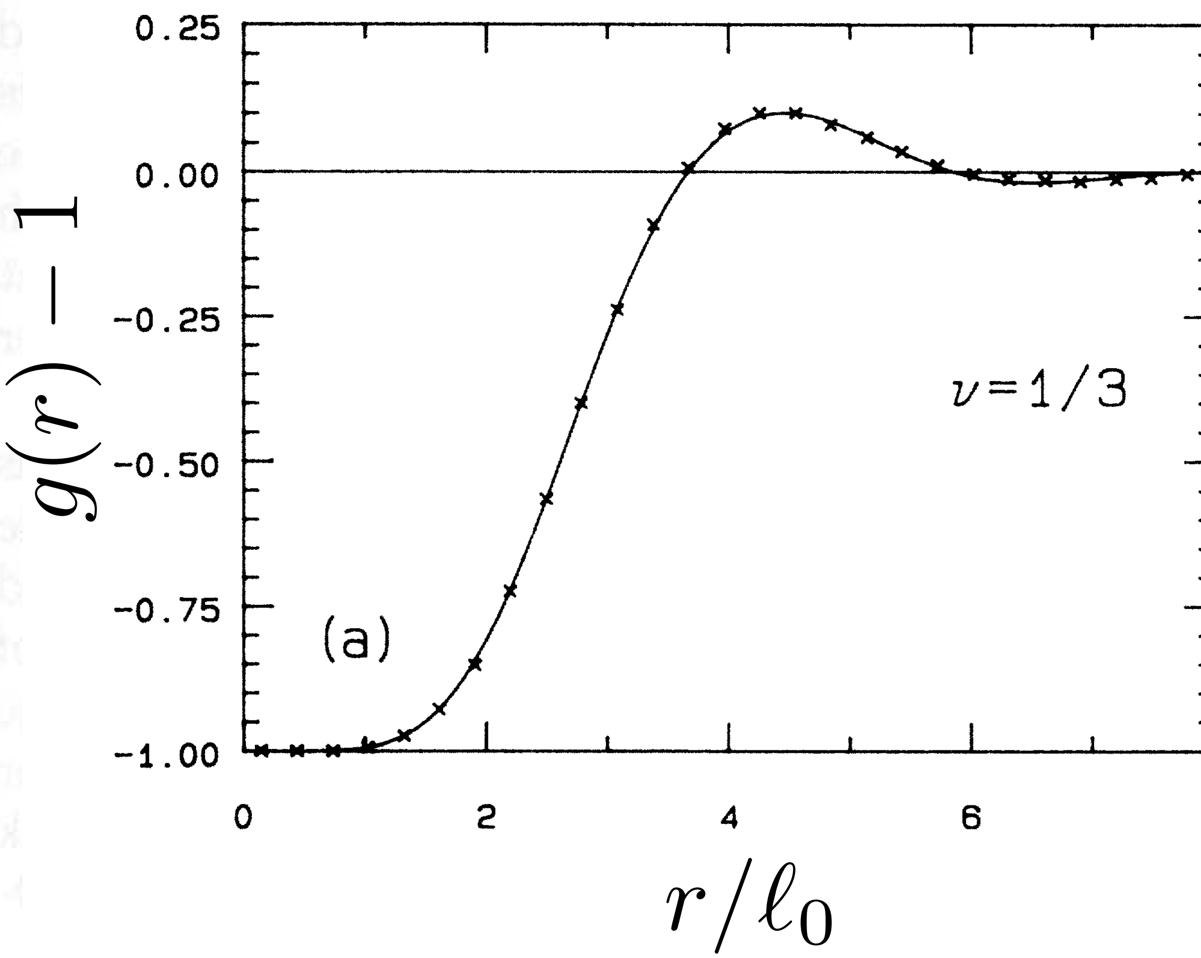
FIG. 1 (color online). Schematic of the noise measurement setup (see text for details).

Liquids: density-density correlation

water



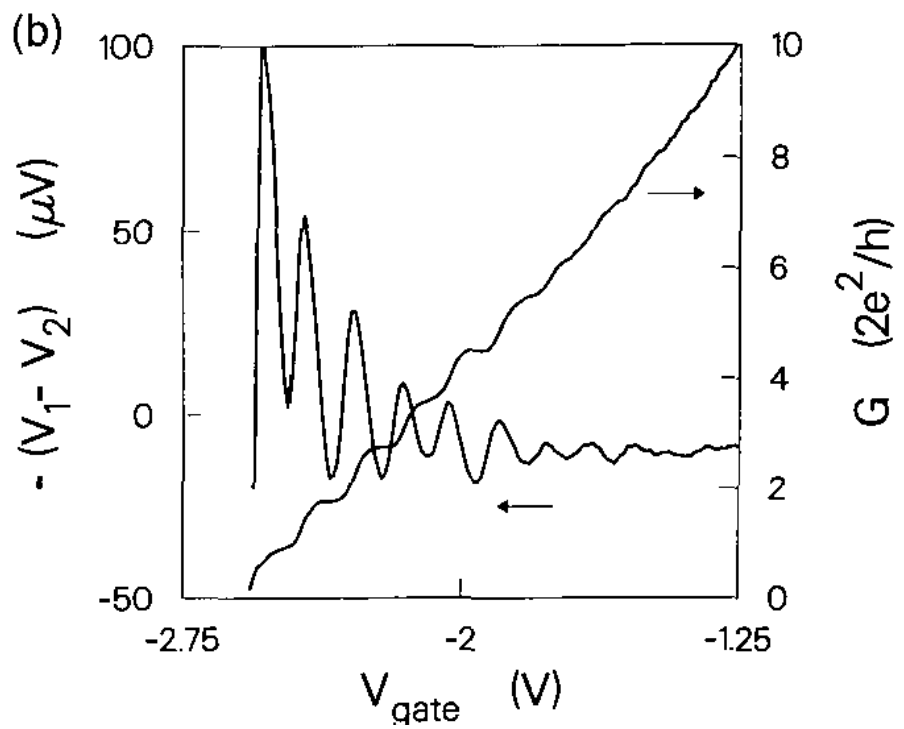
FQHE at 1/3

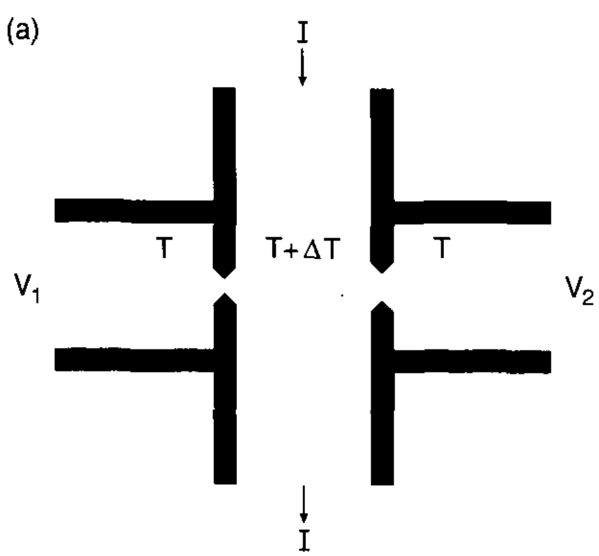


$$g(\vec{r}) \propto \left\langle \sum_{i\neq j} \delta(\vec{r}_i - \vec{r}_j - \vec{r}) \right\rangle$$

Other "types of transport"

Thermopower

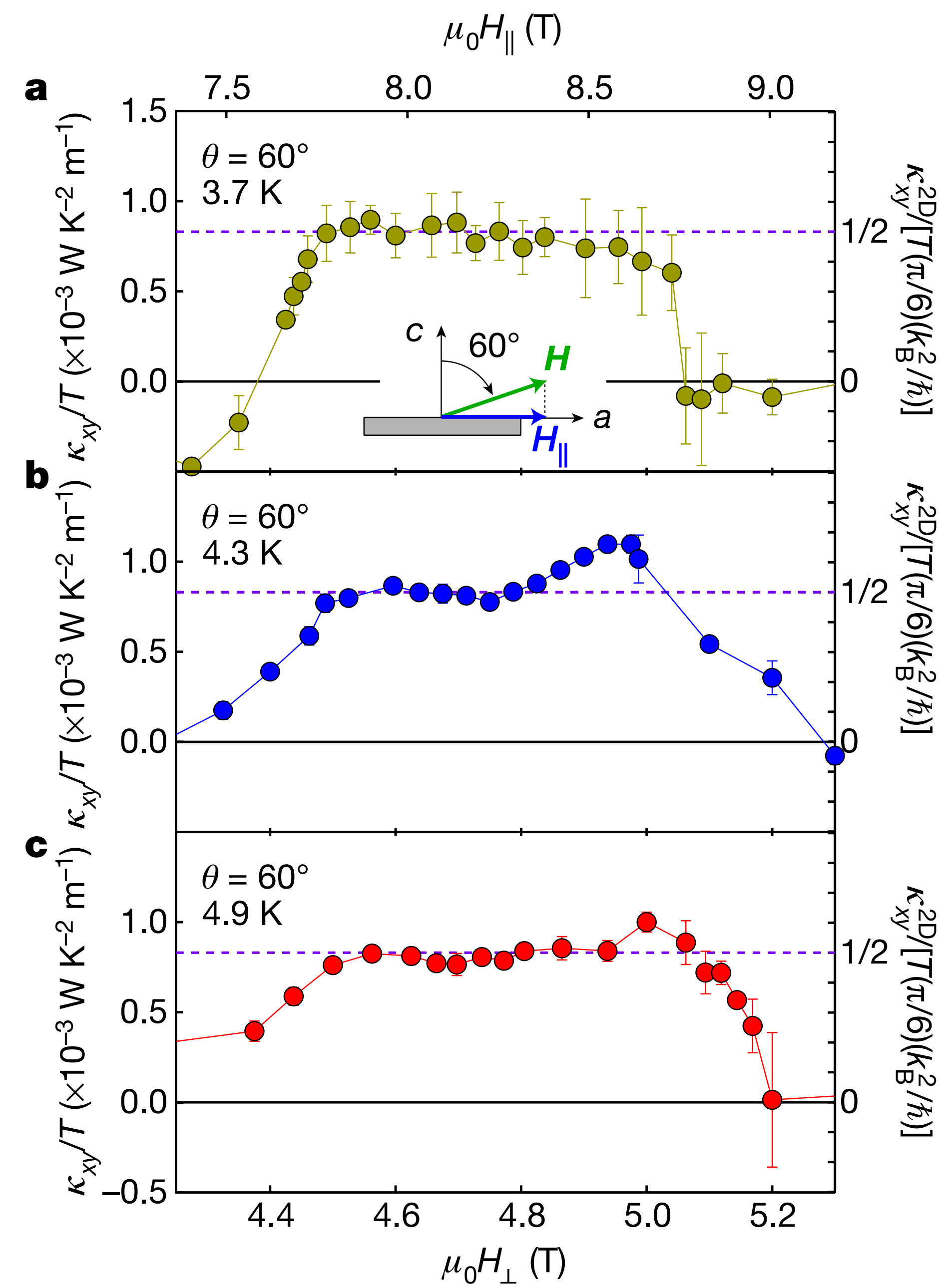




$$S = -\frac{k_B}{e}\frac{\ln 2}{N-\frac{1}{2}}$$

$$S = V/\Delta T$$

Thermal conductivity



Back to edge states

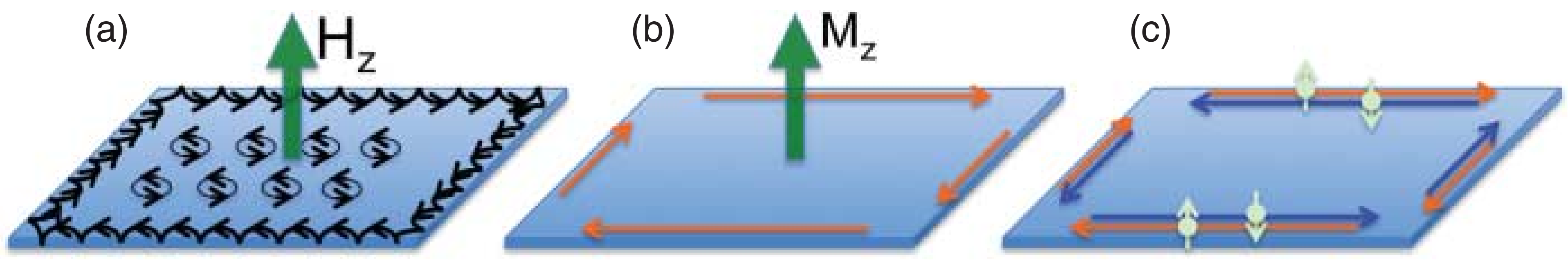
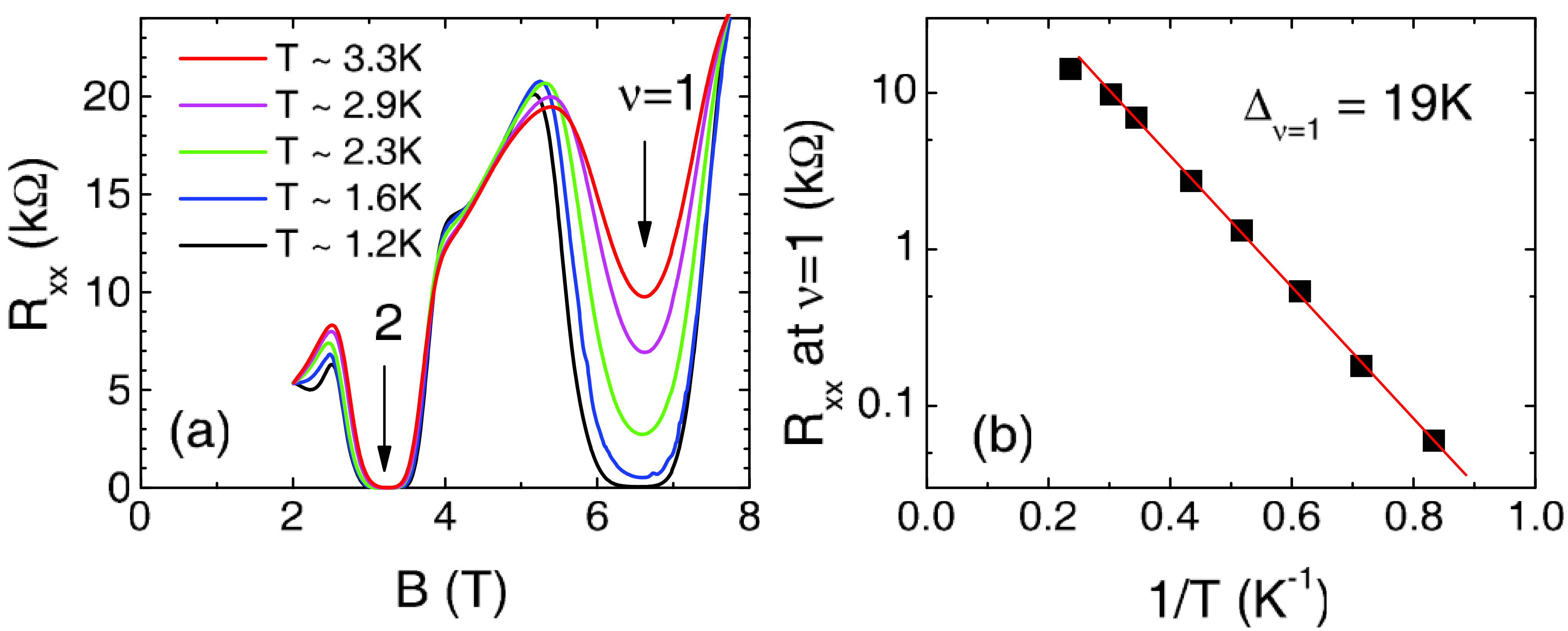
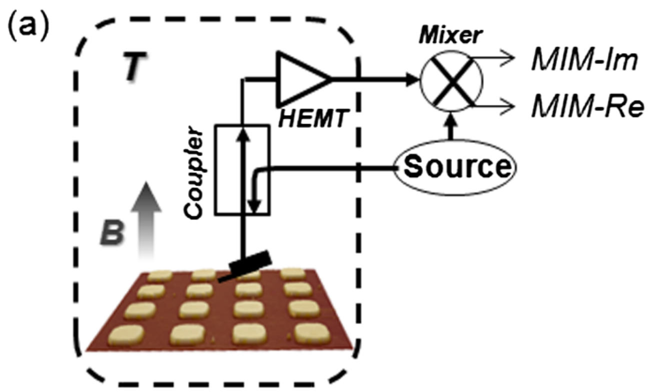
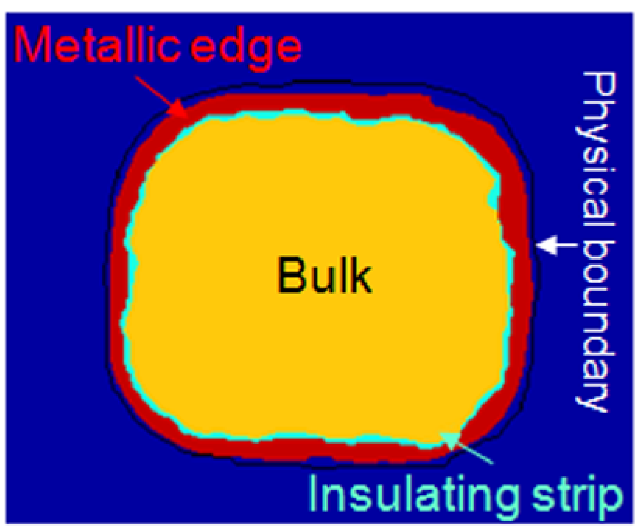


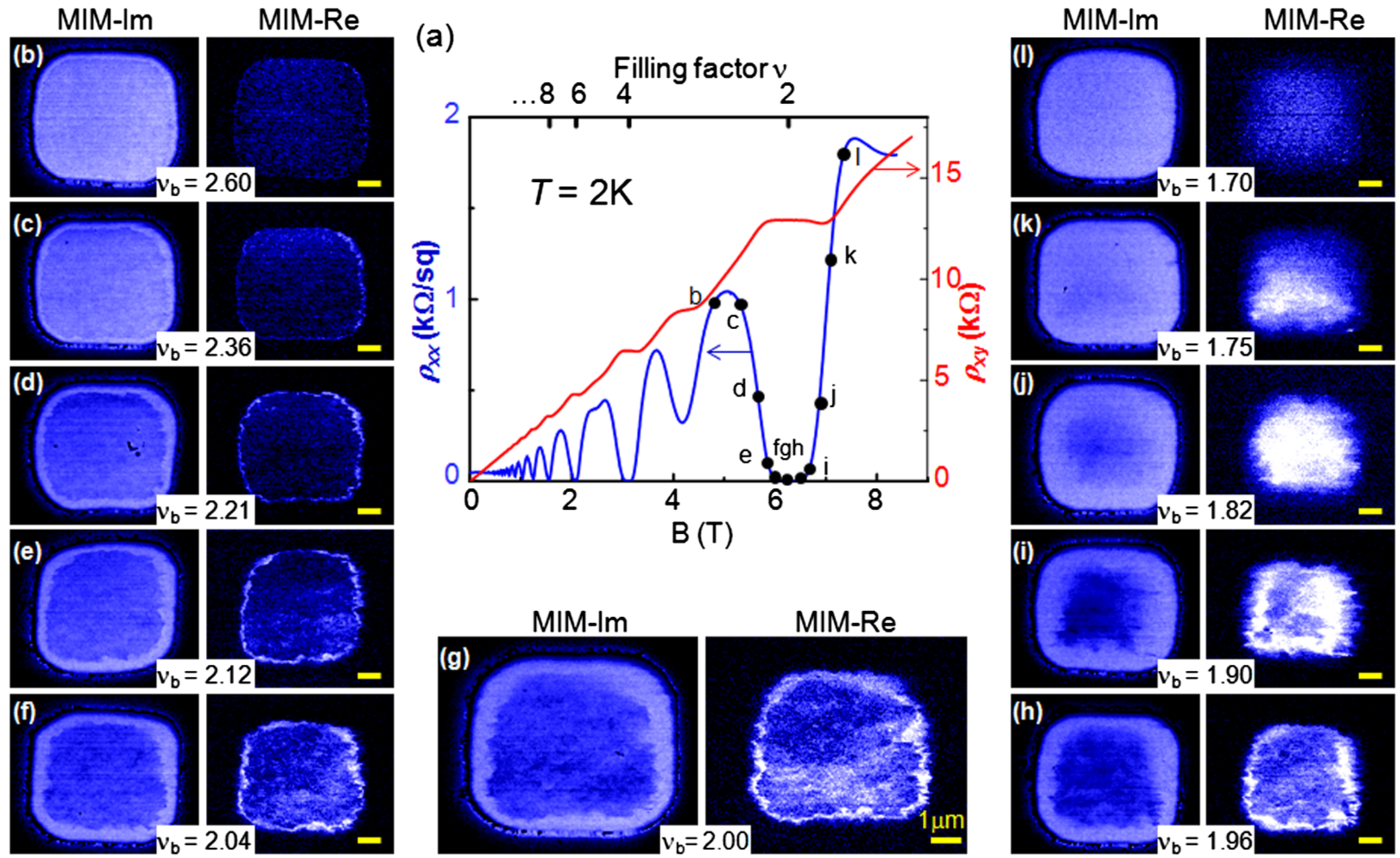
Figure 4. Schematic illustrations of the edge states in (a) QHE, (b) QAHE and (c) QSHE.



Edge states

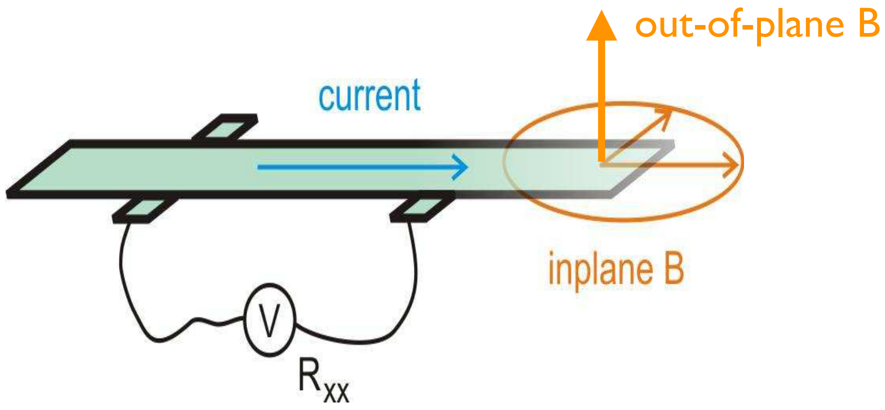


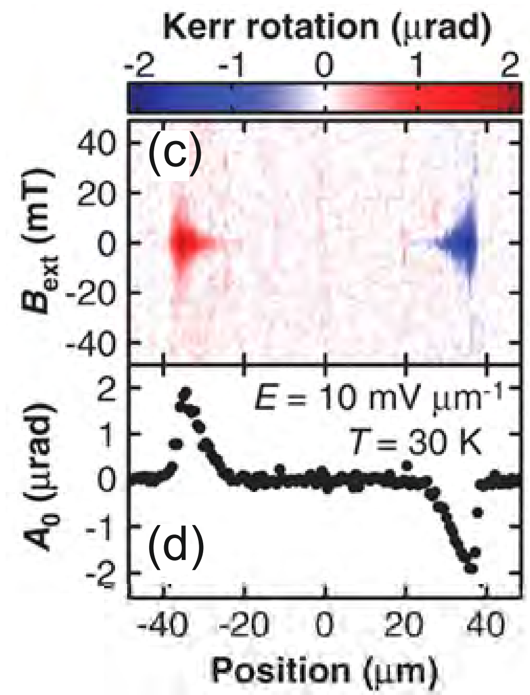


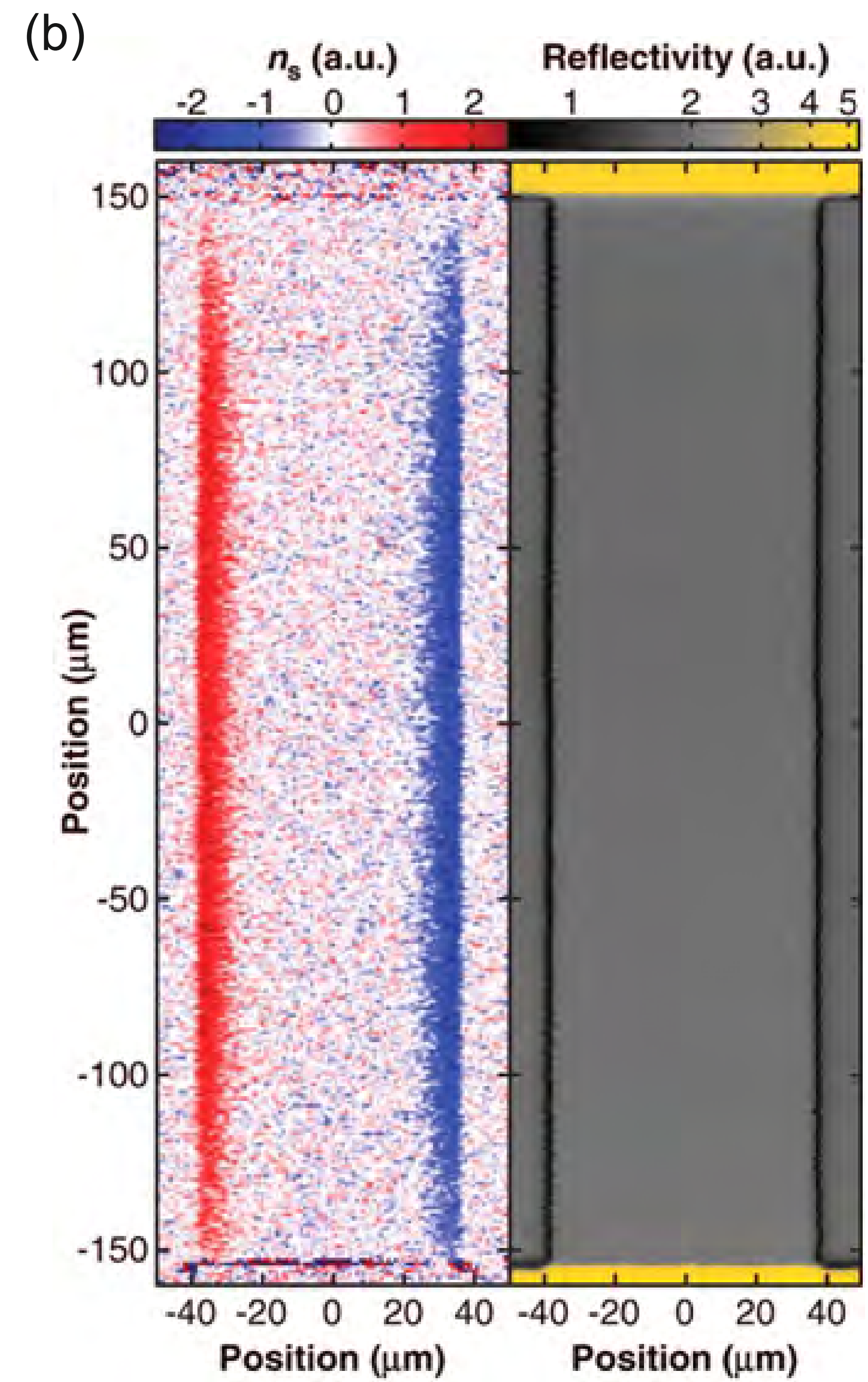


$$\sigma_{yx} = \frac{ie^2}{\hbar} \sum_n \int \frac{d^2k}{(2\pi)^2} f(\vec{k}, n) \left[\left\langle \frac{\partial u_n}{\partial k_y} \middle| \frac{\partial u_n}{\partial k_x} \right\rangle - \left\langle \frac{\partial u_n}{\partial k_x} \middle| \frac{\partial u_n}{\partial k_y} \right\rangle \right]$$

Spin Hall effect







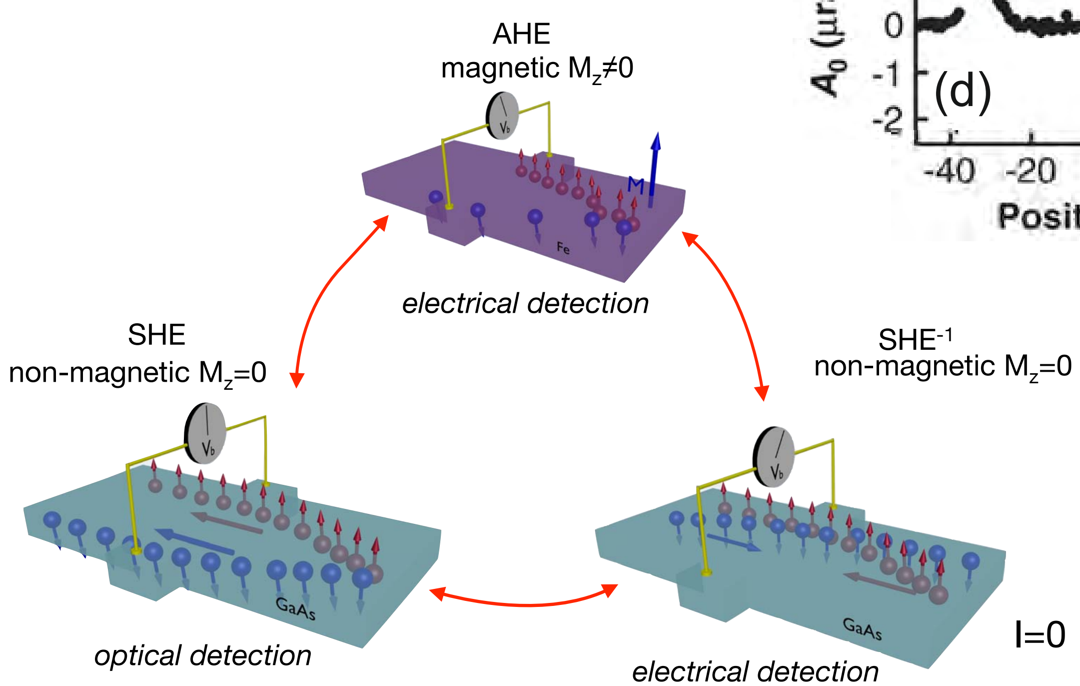
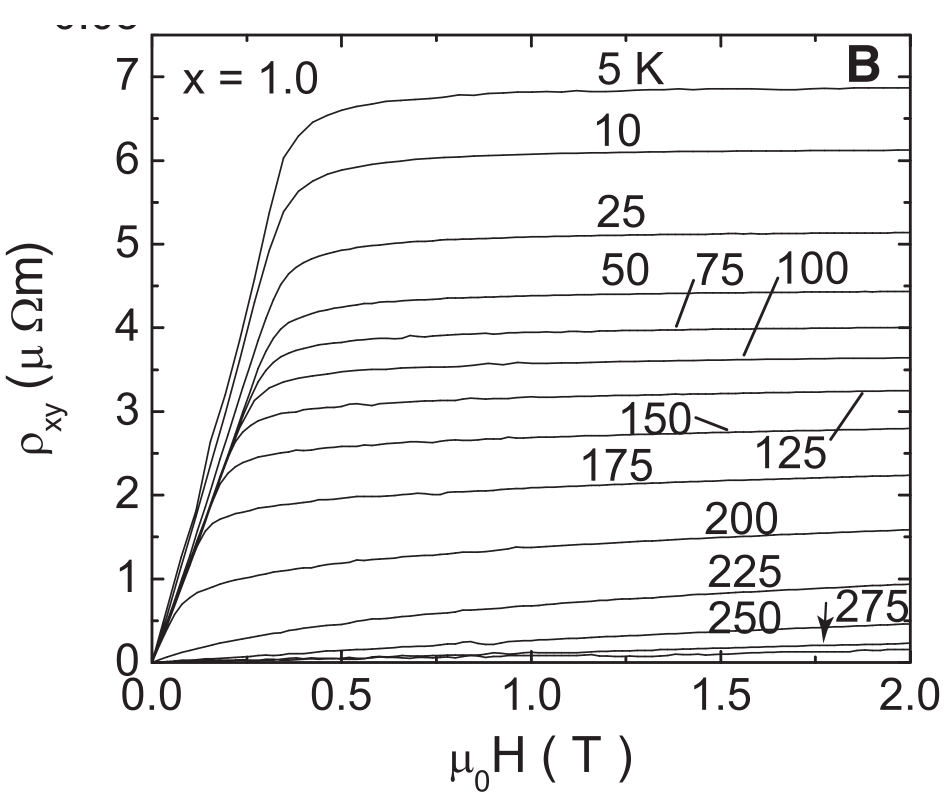


FIG. 1 An illustration of the connected family of the spin-dependent Hall effects. In the AHE, a charge current generates a polarized transverse charge current. In the SHE an unpolarized charge current generates a transverse pure spin-current. In the ISHE a pure spin-current generates a transverse charge current.

More spin-orbit driven effects:

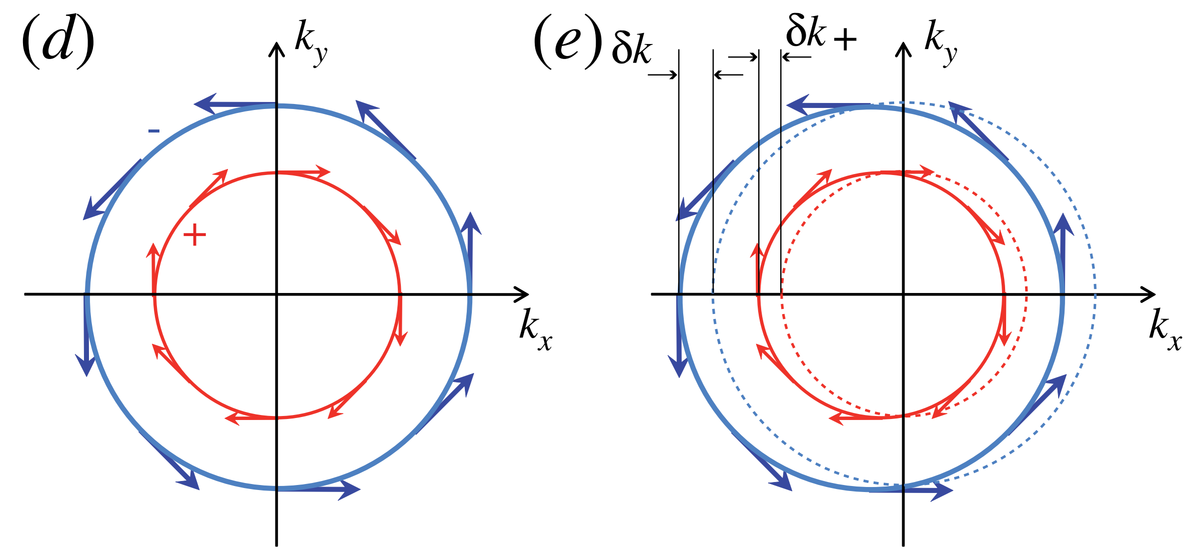
AHE (anomalous Hall effect)

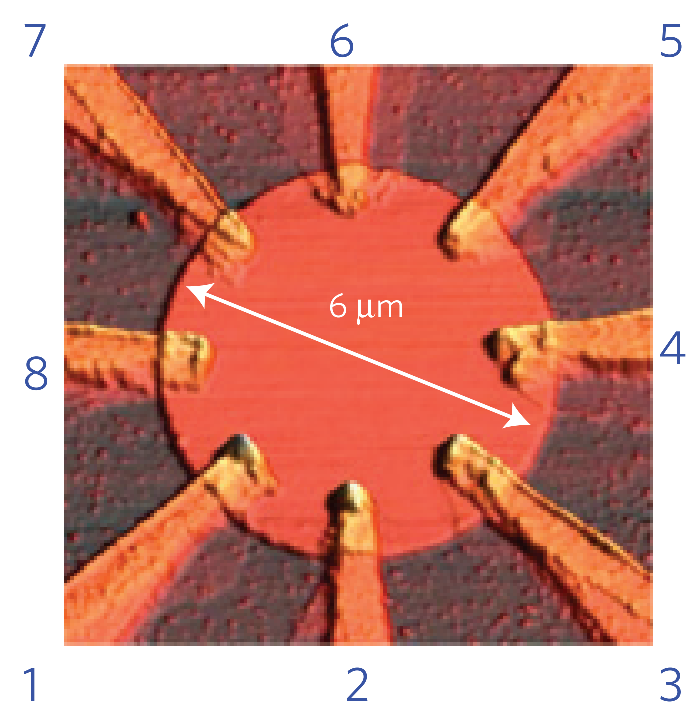
$CuCr_2Se_3Br$

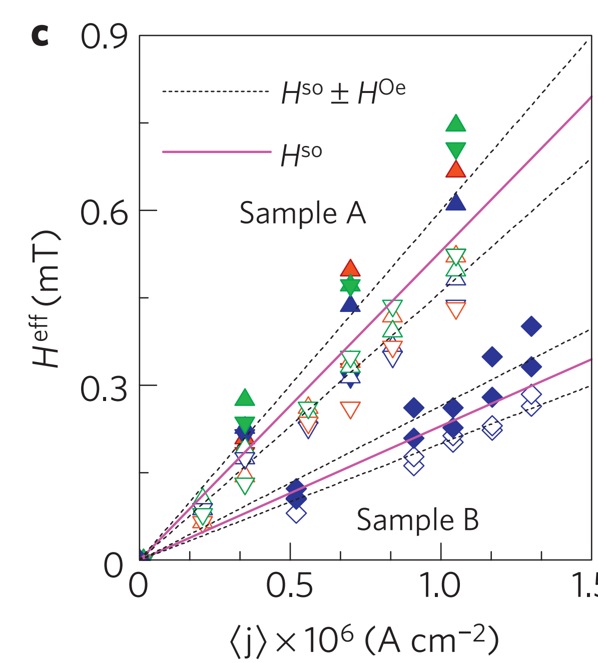


$$R_H = B \cdot (1/ne) + M \cdot \mathrm{const}$$

SOT (Edelstein effect)

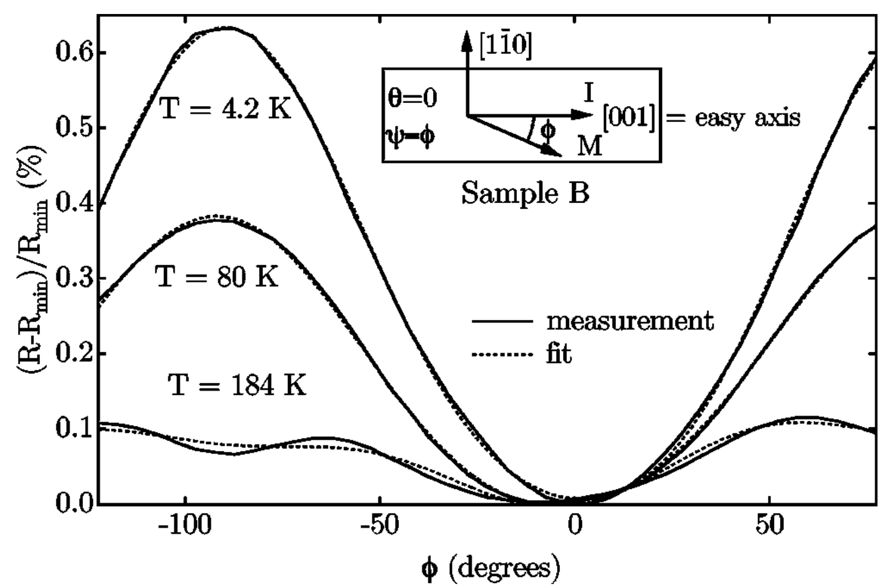






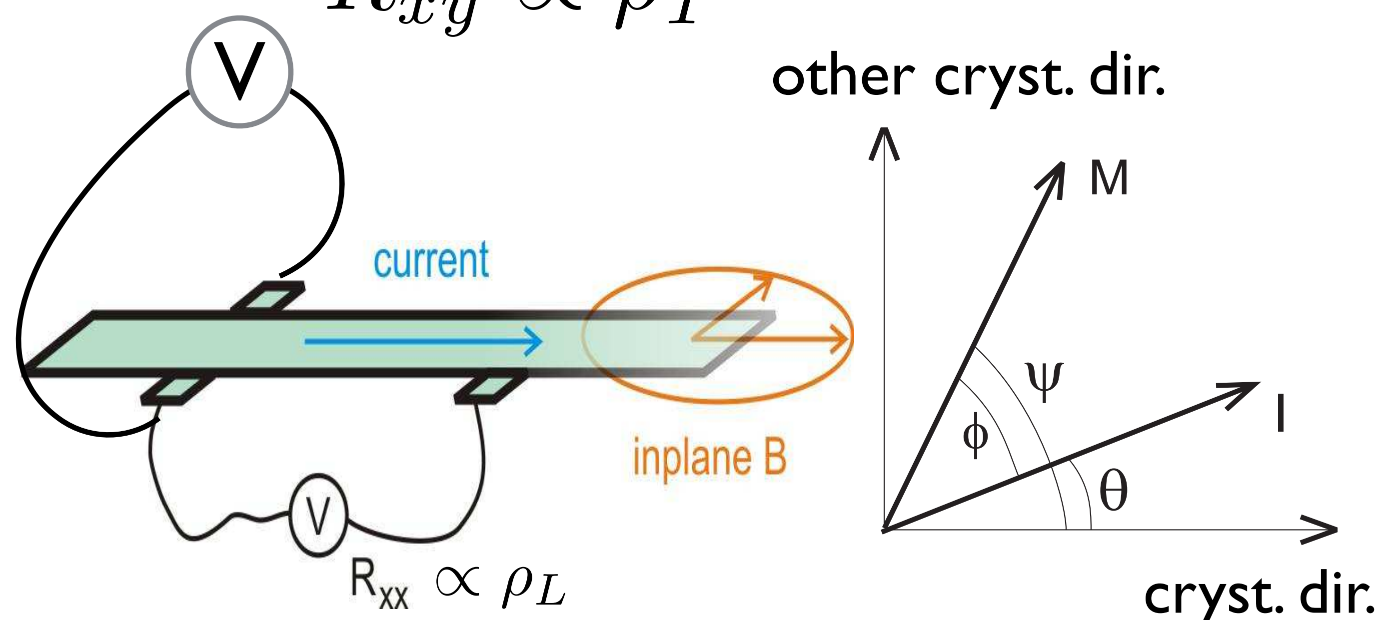
More spin-orbit driven effects:
AMR (anisotropic magnetoresistance)

Epitaxial Fe layer



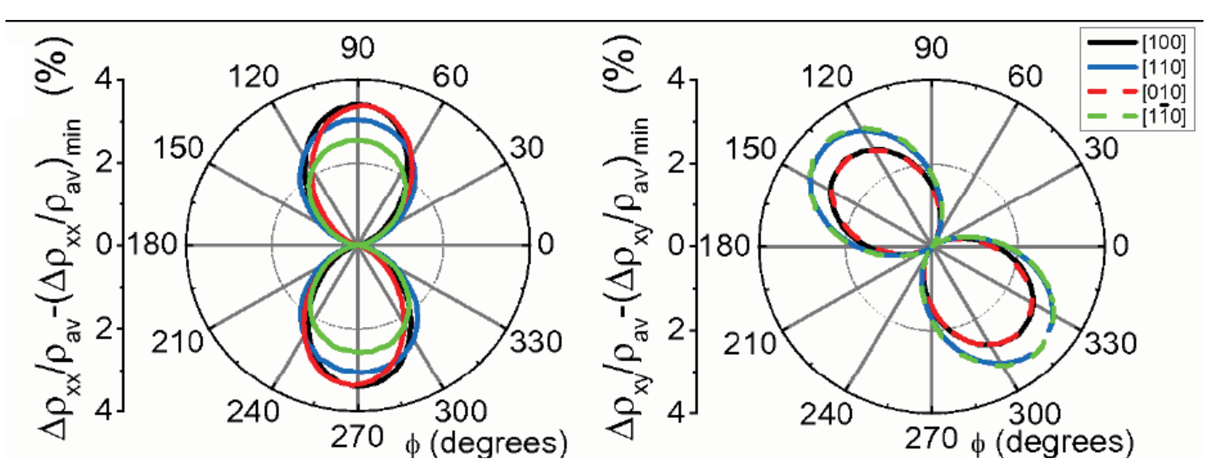
Phys Rev B 63, 134432

$R_{xy} \propto \rho_T$



$$\Delta\rho_L/\rho_{av} = C_I \cos 2\phi + C_{I,C}\cos(2\phi + 4\theta) + {}+ C_C\cos(4\phi + 4\theta) + C_U\cos(2\phi + 2\theta)$$

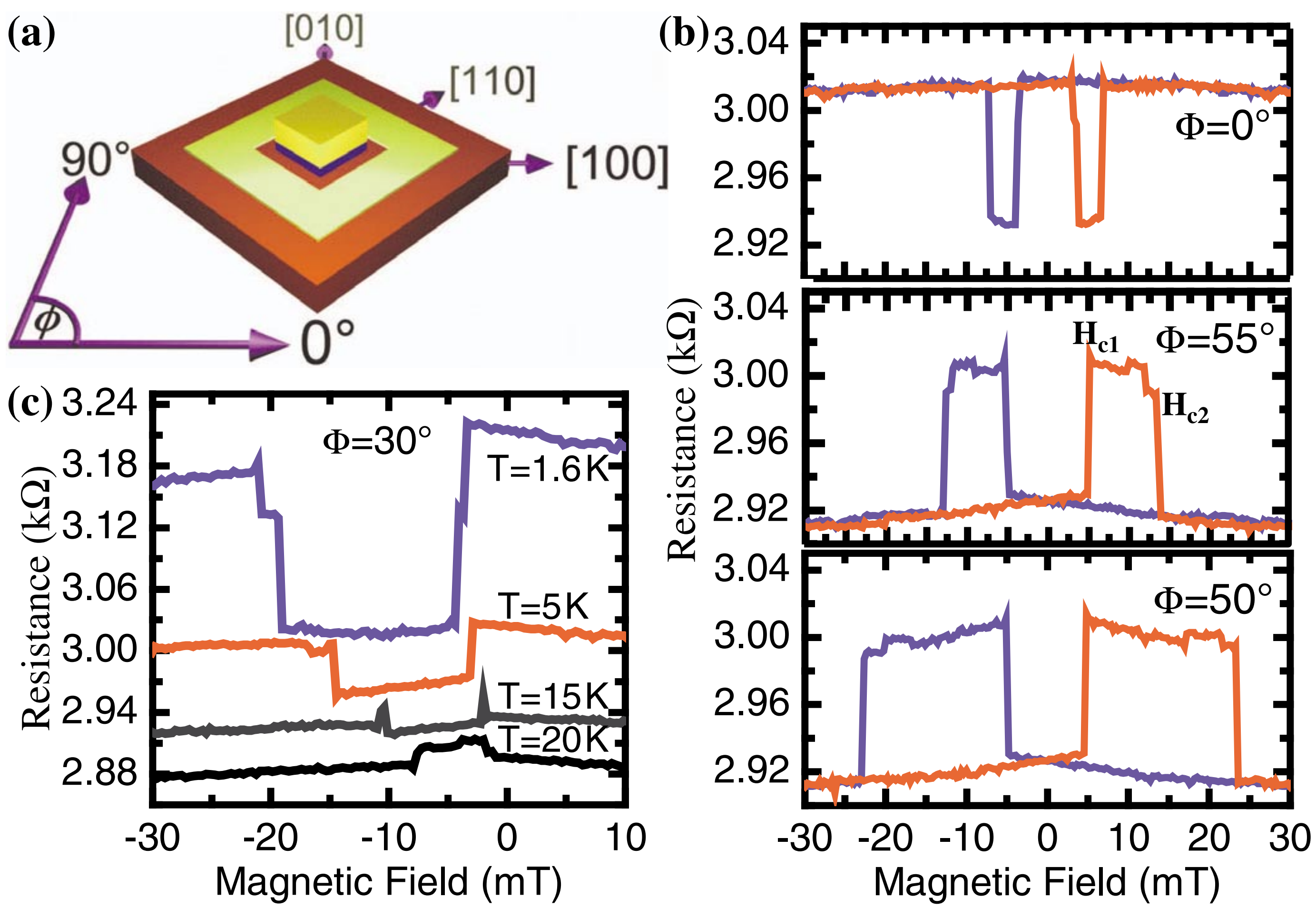
Epitaxial (Ga,Mn)As layer



$$\Delta\rho_T/\rho_{av} = C_I \sin 2\phi - C_{I,C}\sin(2\phi + 4\theta)$$

Phys Rev Lett 99, 147207

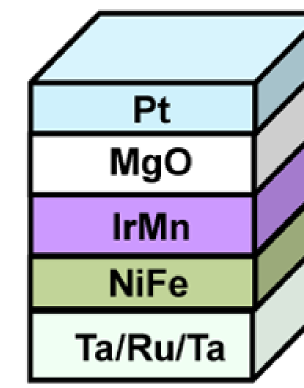
Spin-orbit driven effects: TAMR (tunneling anisotropic magnetoresistance)

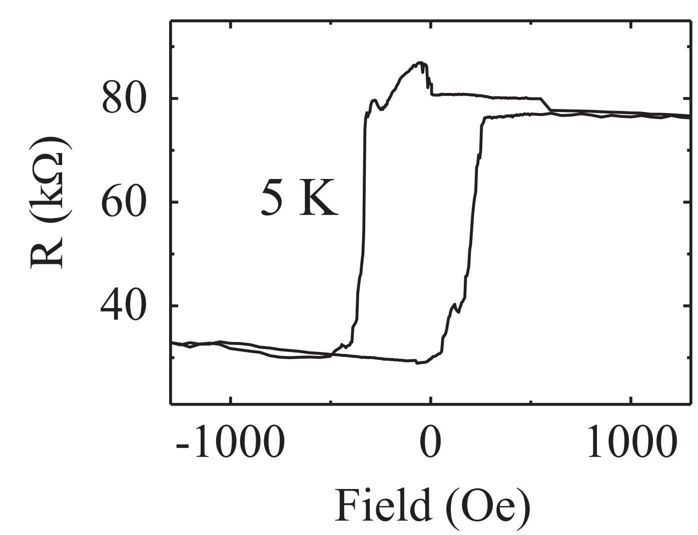


Phys Rev Lett 93, 117203 (2004)

tunneling structure:
(Ga,Mn)As/AlOx/Au
FM / I / NM

tunneling structure:
NiFe/IrMn/MgO/Pt
FM / AFM / I / NM

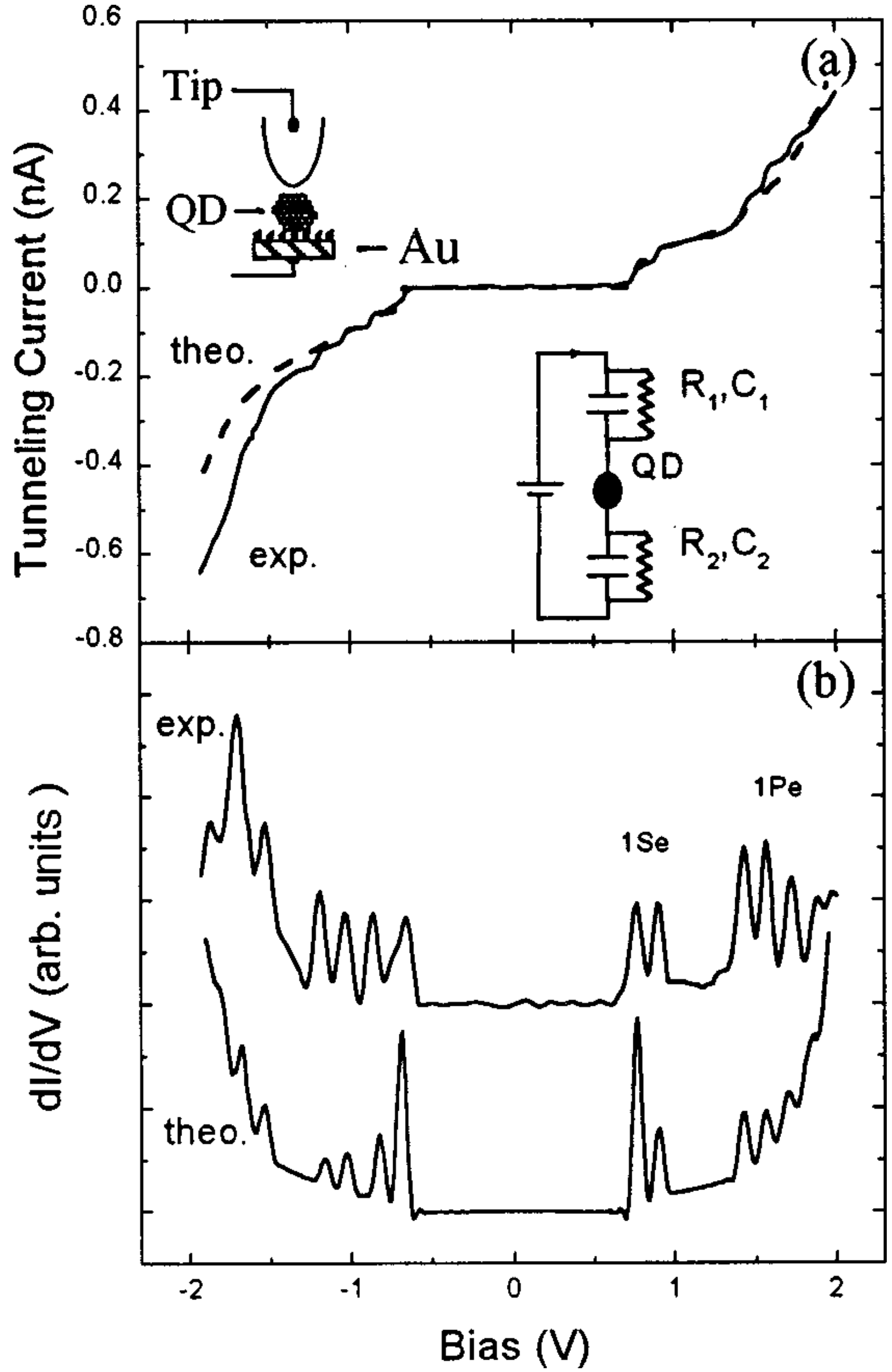




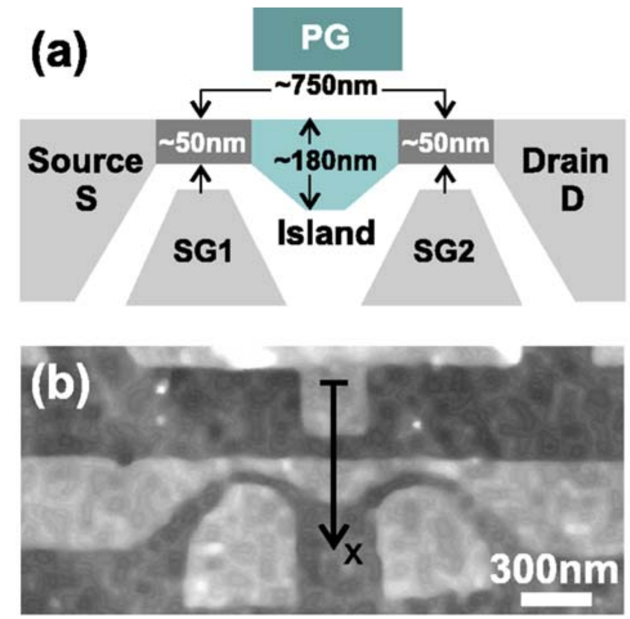
Phys Rev Lett 108, 017201 (2012)

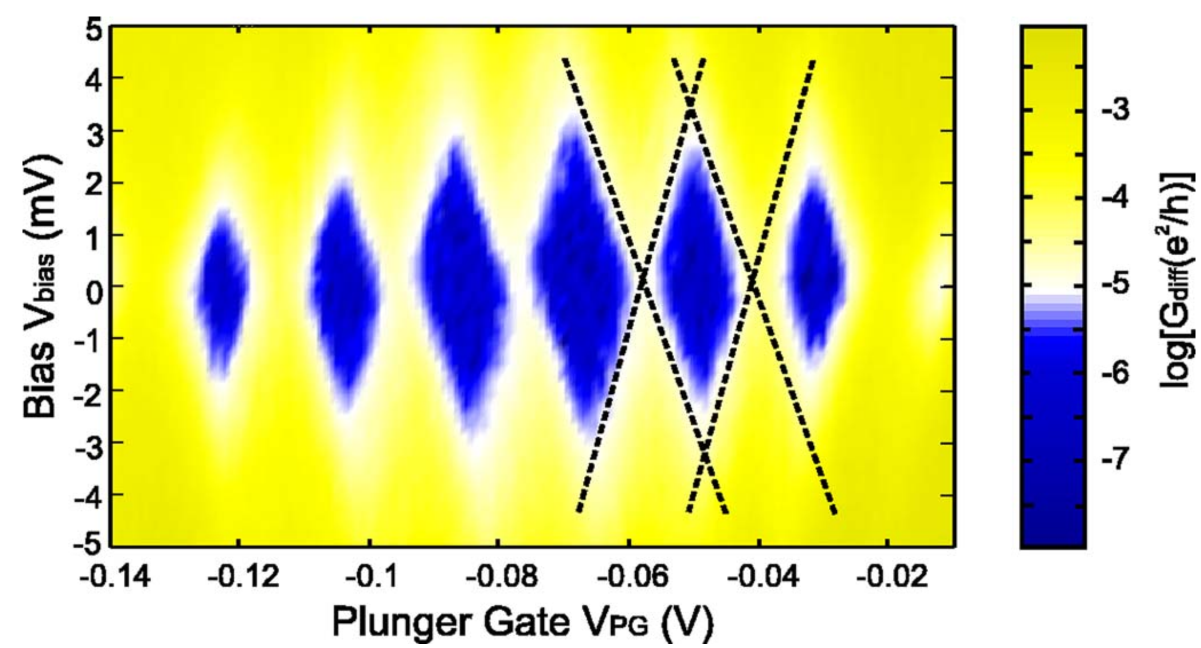
Tunneling through quantum dots

small dots - resonant tunneling



larger dots - Coulomb blockade





CMOS-based SET