Edge channel tunneling spectroscopy of 5/2 fractional quantum Hall excitations in etch defined quantum point contacts

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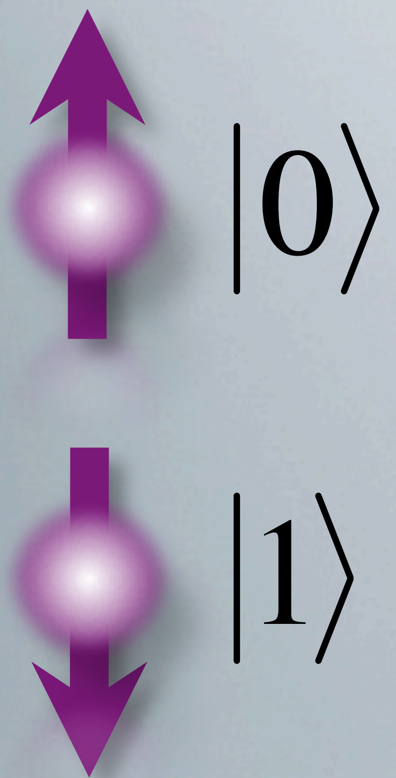
Quantum computers



Modern encryption is based on the assumption that it is impossible to prime-factorize a large digit number within a reasonable time frame.

Classical computer

A 200-digit number was prime-factorized after **170 CPU years**.

Quantum Computer

A 600-digit number can be prime-factorized **in 6 CPU days!**
(Shor's algorithm)

Examples: quantum computers are good for

- Quantum data base search
- Simulation of quantum physical process in chemistry and solid state physics

Solid state quantum computers: coherence times

- Superconducting circuits.

$T_1 = 1\text{-}10\ \mu s \quad T_2 = 0.1\text{-}1\ \mu s$

- Semiconductor impurities: contain electrons by using donor atoms in semiconductor material.

$T_1 > 1000\ s \quad T_2 \sim 60\ ms$ for electron spins

$T_2 = 1 s$ for electron spins

- Quantum dots: isolate single electrons in a semiconductor physically and/or electrostatically.

GaAs: $T_1 = 1 s \quad T_{2\ \text{spin-echo}}$ = few hundreds of μs

Si/SiO_2: $T_1 = 1 s \quad T_2 = 0.3\ \mu s$ for mobile electrons

Si/SiGe: T_1 = Few seconds $\quad T_2$ = No results so far

Topological Quantum computers: Advantages

Utilizes the edge state in a quantum Hall system, protected by an energy gap.

➡ Information is encoded in the single particle states.

➡ Superposition states of the qubits are very fragile.

➡ Any stray interaction with the environment including the imperfections in the host material can result in loss of information.

➡ Error correction schemes would be challenging beyond ONE error in every 10, 000 steps.

Information is encoded in the many-body/non-local states .

Topological properties are unaffected by small perturbations.

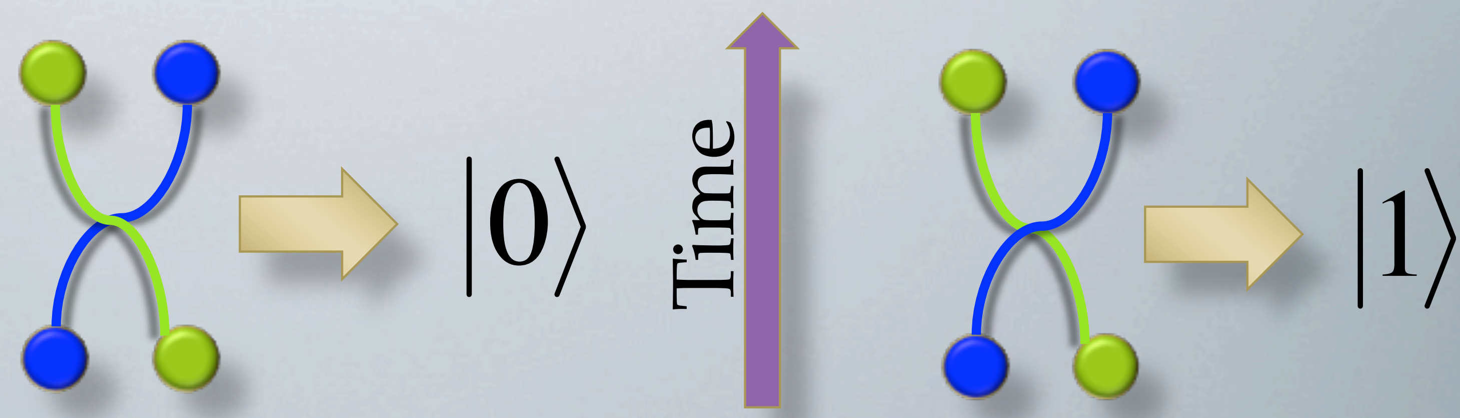
Built-in resistance to environmental decoherence.

Error rate < 10^{-30}

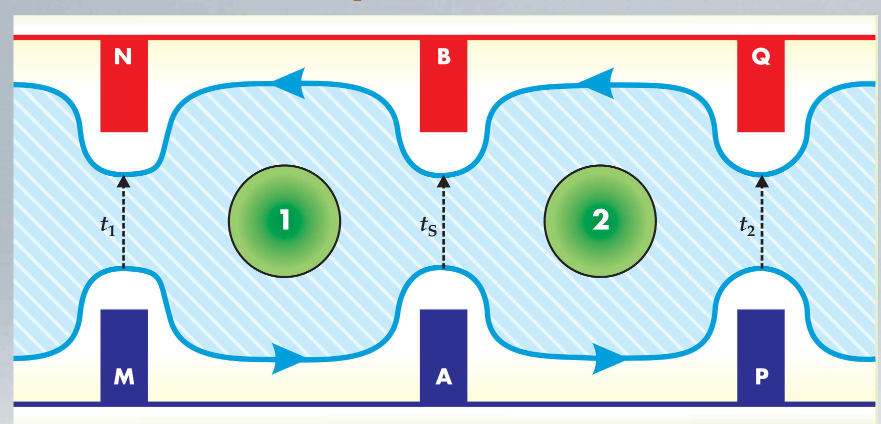
Sankar Das Sarma, Michael Freedman & Chetan Nayak, Phys. Rev. Lett. **94**, 166802 (2005)
Sankar Das Sarma, Michael Freedman & Chetan Nayak, Physic Today (2006)

Topological Quantum gates

- Anyon braiding
  forms the qubit states



- Trapping and manipulation of non-Abelian Anyons



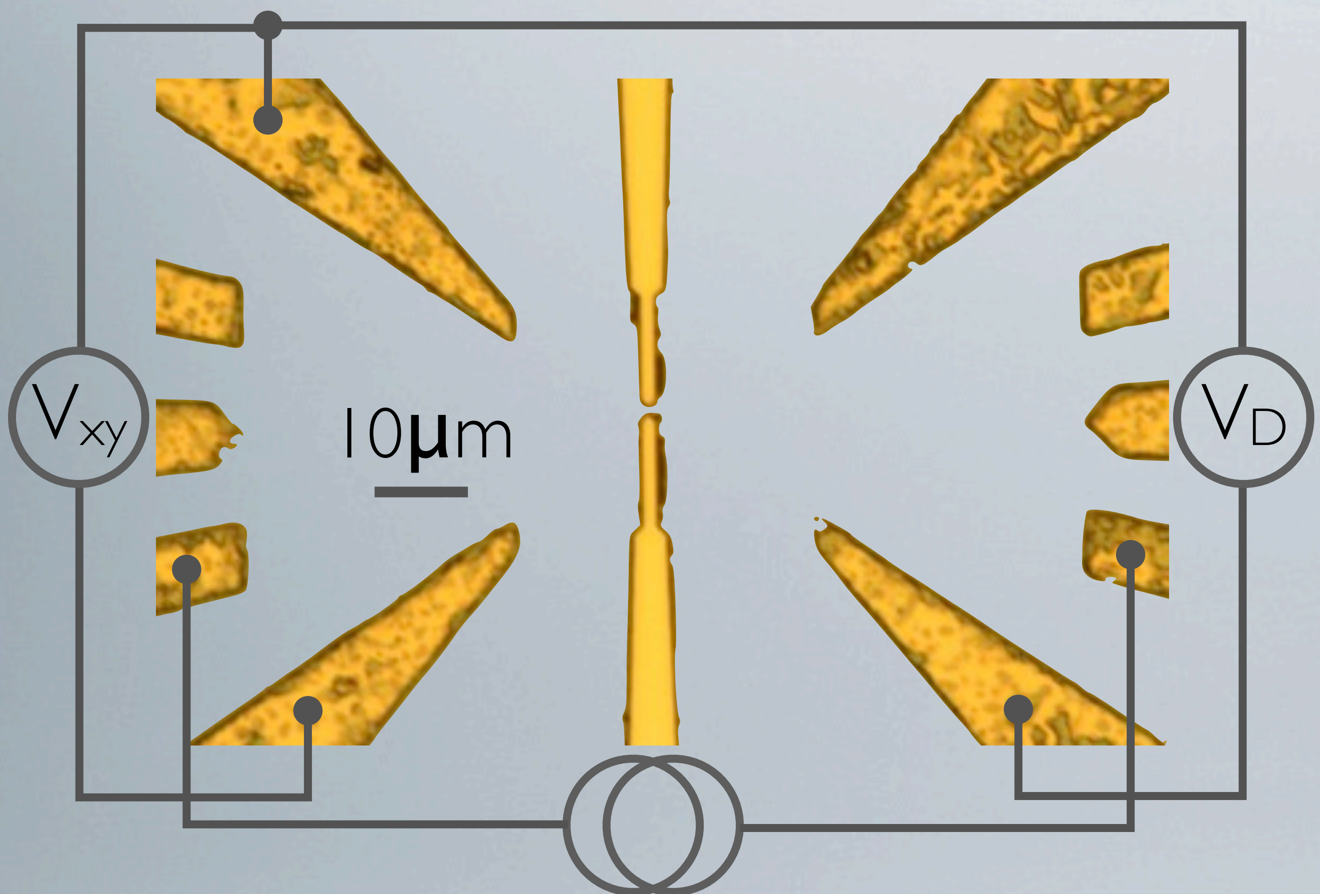
- ν = 5/2 fractional quantum Hall excitations are proposed to be non-Abelian with topological properties.

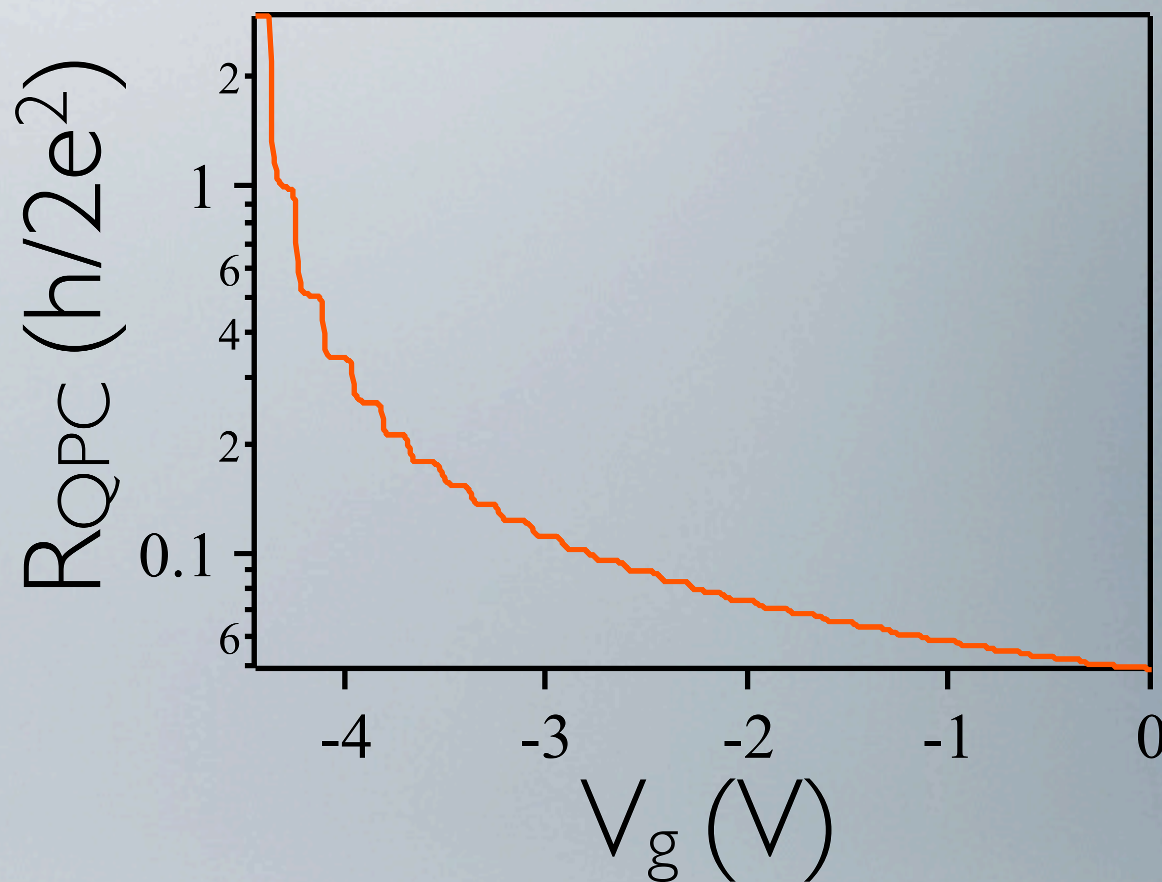
- Not many studies on ν = 5/2 excitations in reduced dimensions

Outline

- Device
- Quasiparticle tunneling experiments
- Temperature dependance
- Conclusions

QPCs defined by etching and side-gating





Advantages

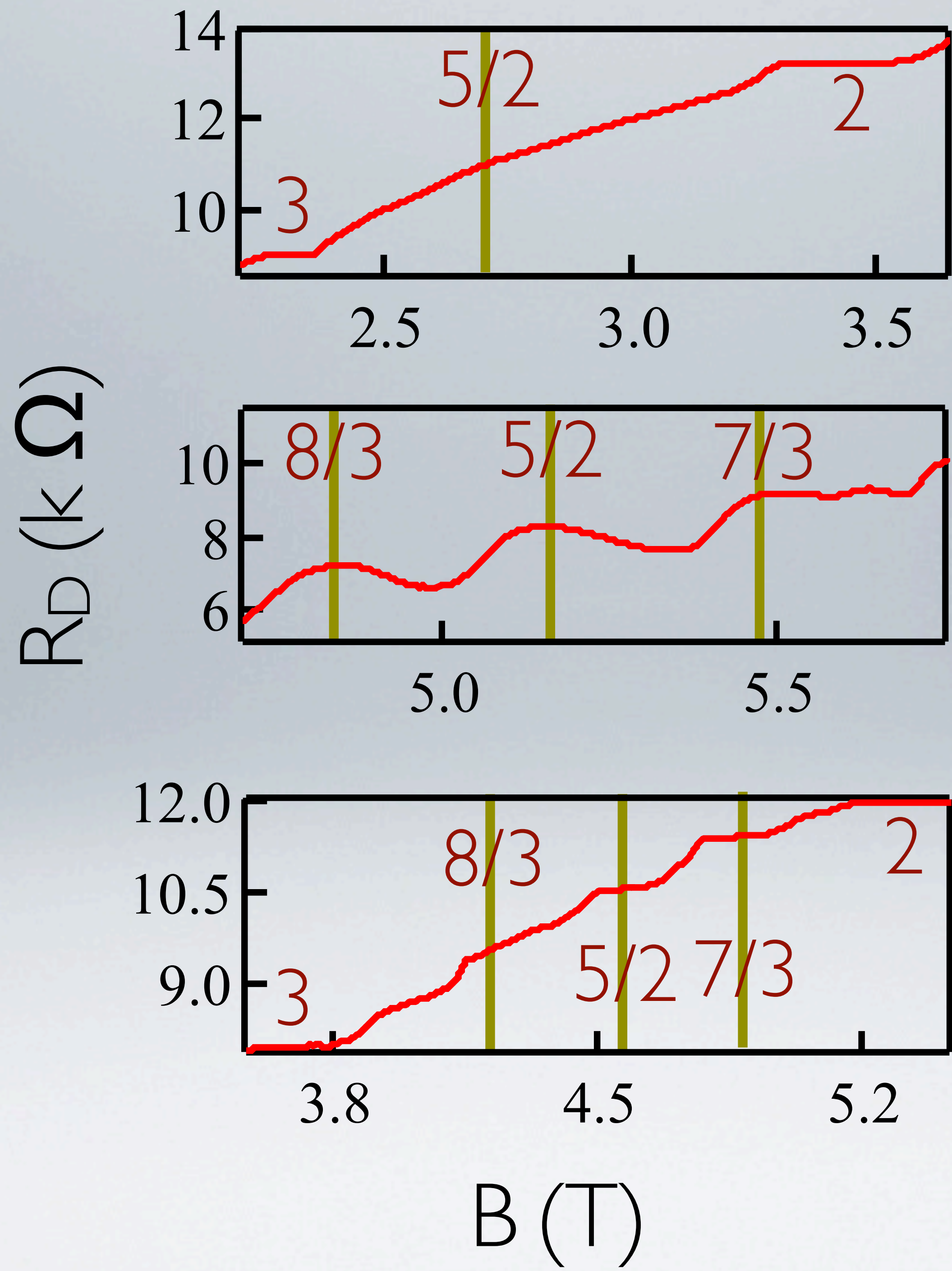
- All optical lithography, preserves the material quality, ideal for scaling.
- Etching defines the channel without gate voltage
- Proximity ohmic contacts reduce the path length travelled by the electrons, improves SNR

Fractional quantum Hall effect in QPCs

Device 1 — $n_s \sim 1.65 \times 10^{11}\ cm^{-2}$

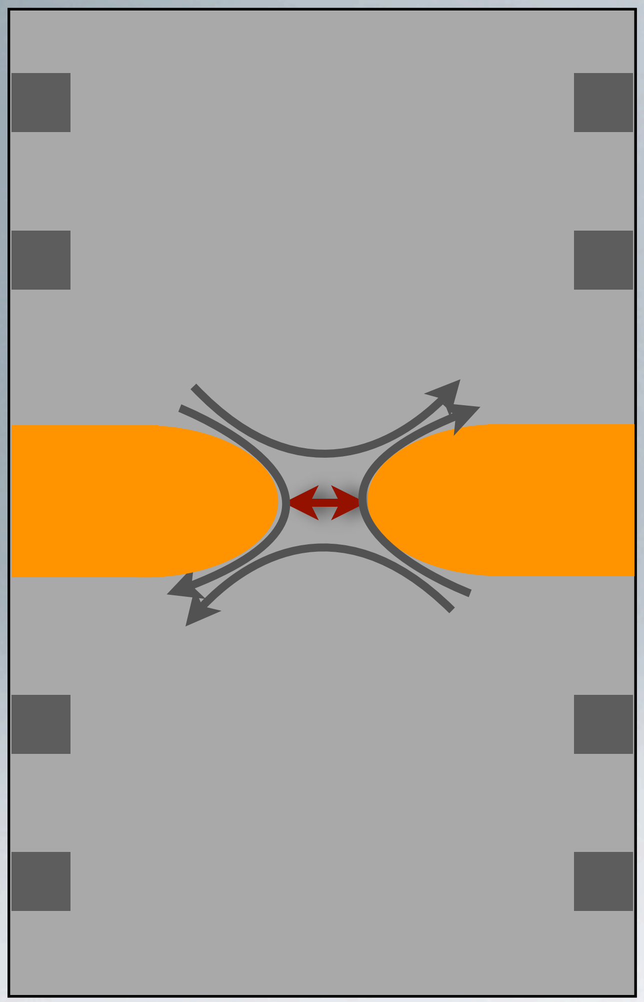
Device 2 — $n_s \sim 3.0 \times 10^{11}\ cm^{-2}$

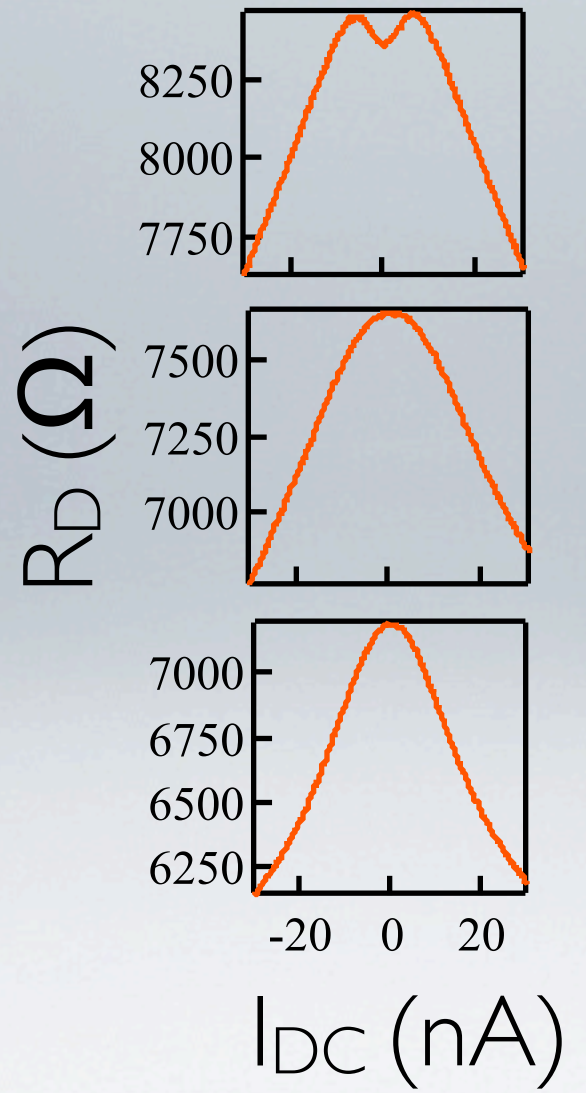
Device 3 — $n_s \sim 2.8 \times 10^{11}\ cm^{-2}$

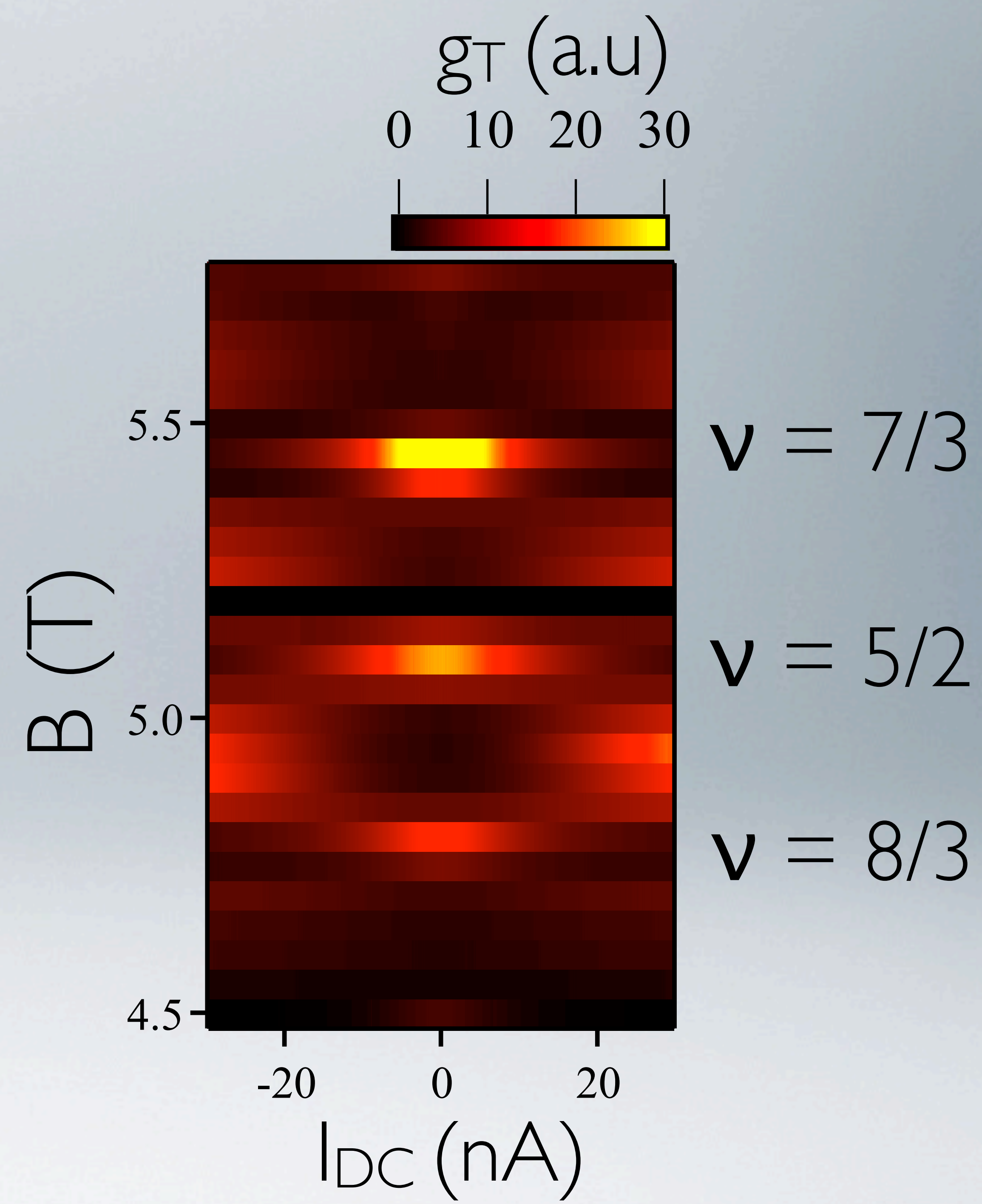


Well formed 5/2 state in the channel

Quasiparticle tunneling in the 2^{nd} Landau level







Tunneling I-V curves can provide useful information about the quasiparticles

Temperature dependance of 5/2 state

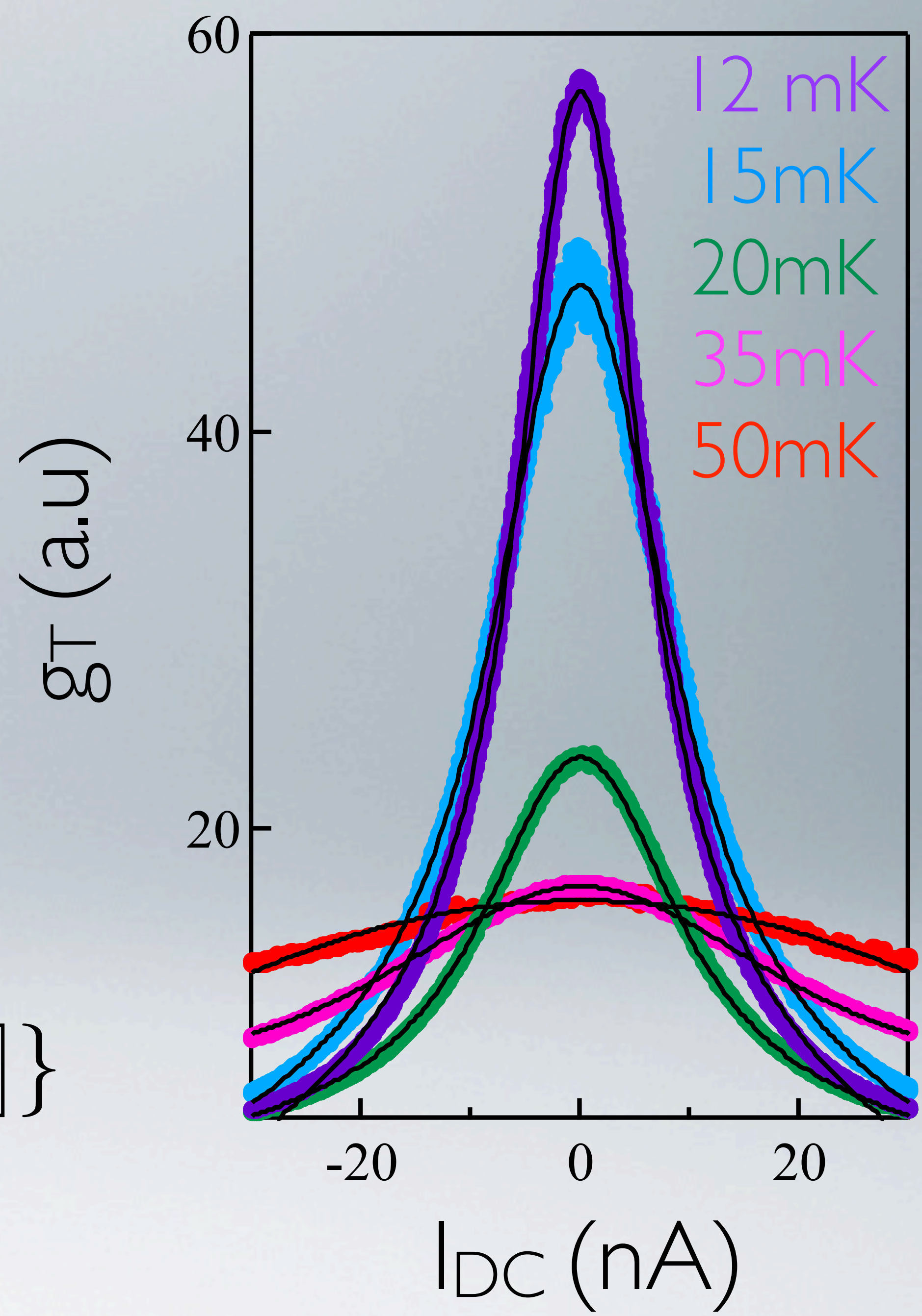
Weak tunneling of quasiparticles

$$g_{\mathrm{T}} = AT^{(2g-2)}F\left(g, \frac{e^{*}I_{\mathrm{dc}}R_{xy}}{kT}\right)$$

$$g_{\mathrm{T}} = \frac{R_{\mathrm{D}} - R_{xy}}{R_{xy}^{2}}$$

$$F(g,x) = B(g + i\frac{x}{2\pi}, g - i\frac{x}{2\pi})$$

$$\{\pi\cosh(x/2) - 2\sinh(x/2)\boldsymbol{Im}[\Psi(g + \boldsymbol{i}\frac{x}{2\pi})]\}$$

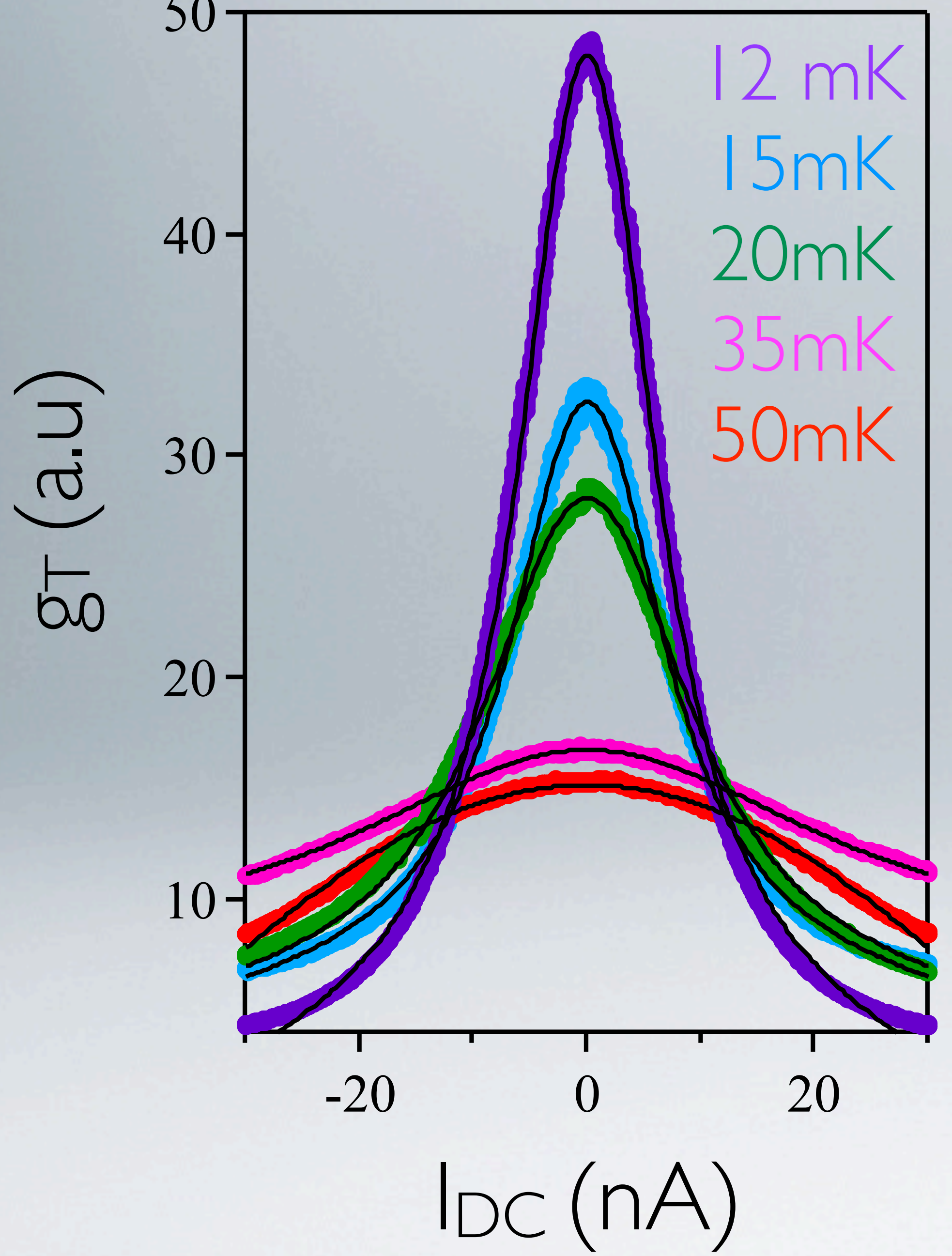


g = 0.8 e* = 0.25 (held)

Radu et al., Science **320**, 899 (2008), X. G. Wen, Phys. Rev. B **44** 5708 (191)

Tunneling on ν = 8/3 & 7/3

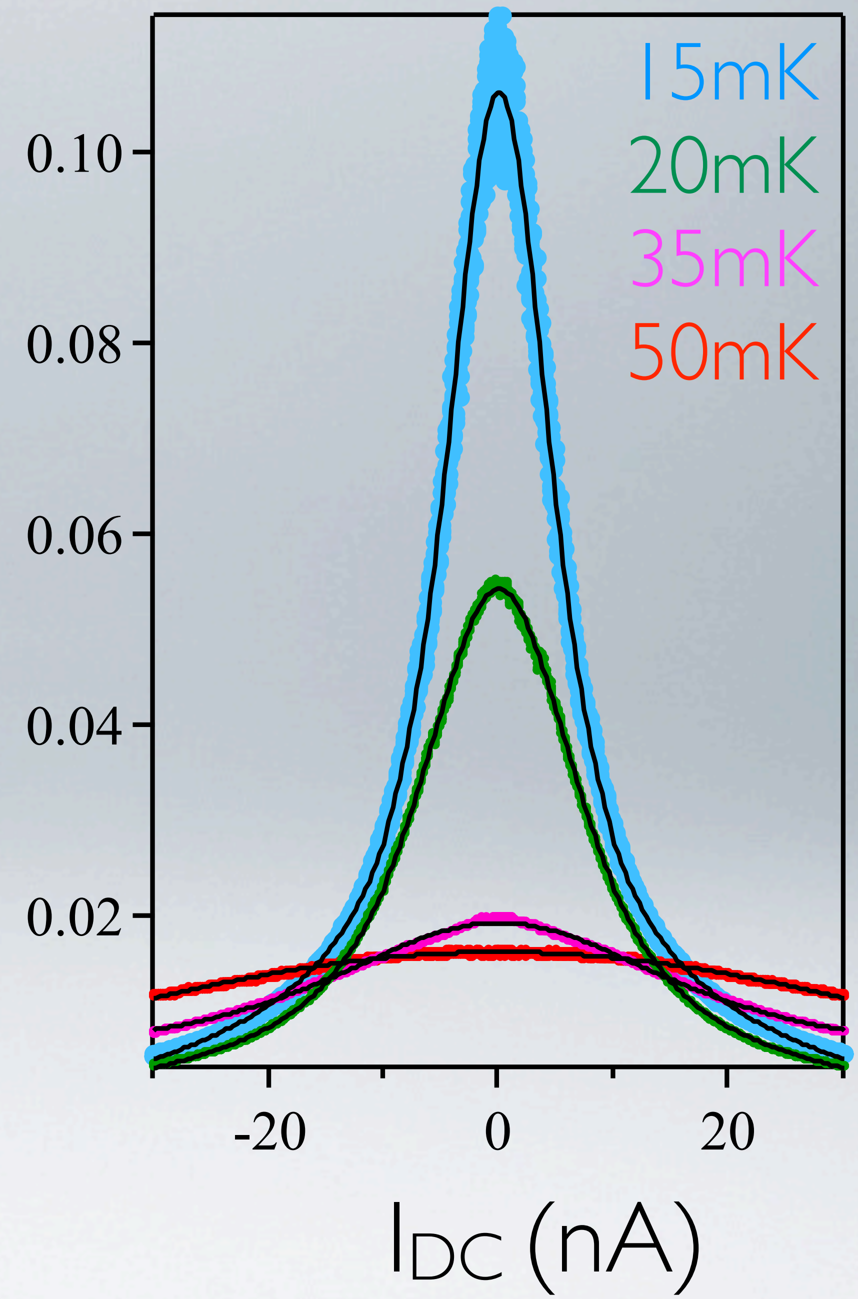
ν = 8/3



g = 0.8

e* = 0.33 (held)

ν = 7/3



g = 0.73

e* = 0.33 (held)

Conclusions

- All optical lithographed QPCs
- Well formed 7/3, 5/2 & 8/3 FQH states
- Tunneling experiments of quasiparticle conducted
- Effective charge and Coulomb interaction parameters extracted from tunneling I-V curves