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Edge reconstruction in fractional quantum Hall states

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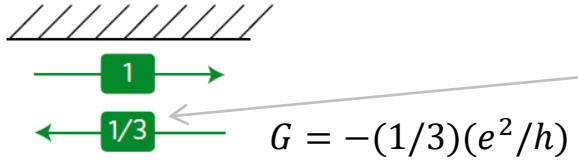
Motivation

- where the current flows in quantum Hall effect
- edge reconstruction
- open questions about edge states for $\nu = 2/3$ model

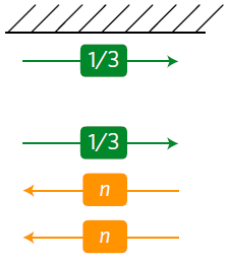
$\nu = 2/3$

Girvin and MacDonald [1, 2]



Kane *et al.* [3, 4]
includes inter channel
interactions and scattering

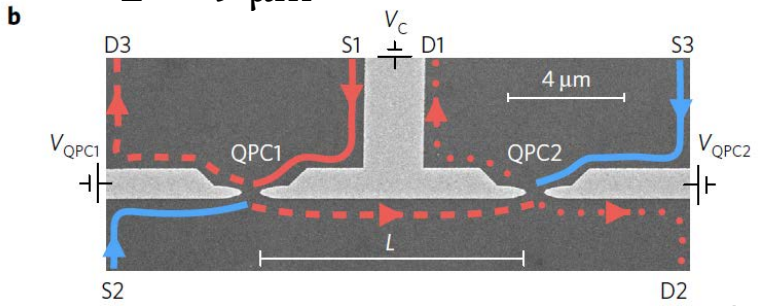
Meir [5]
Wang *et al.* [6]



[1] MacDonald, Phys. Rev. Lett. **64,** 220223 (1990)
[2] Girvin, Phys. Rev. B **29,** 60126014 (1984)
[3] Kane et al., Phys. Rev. Lett. **72,** 41294132 (1994)
[5] Kane et al., Phys. Rev. B **51,** 1344913466 (1995)
[5] Meir, Phys. Rev. Lett. **72,** 26242627 (1994)
[6] Wang et al., Phys. Rev. Lett. **111,** 246803 (2013)

$\nu = 2/3$

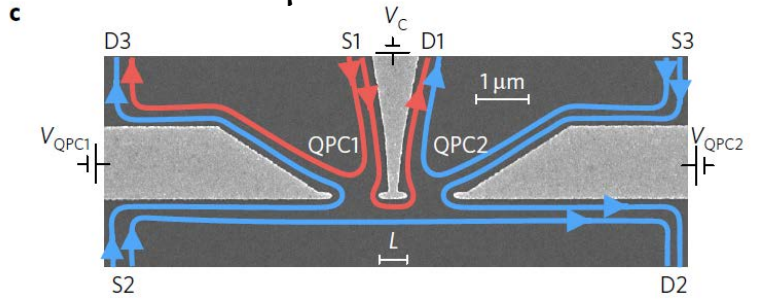
$L = 9\ \mu m$



$t_1 = t_1 = 1/2$

$t_{S1\to D2} = 1/4$

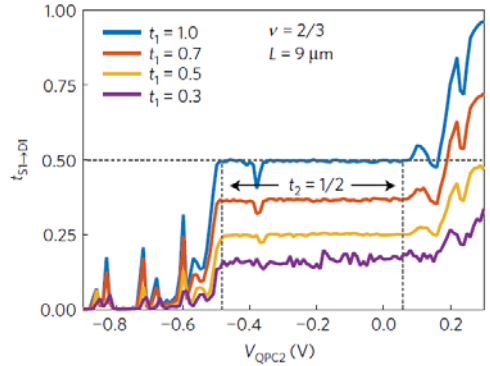
$L = 0.4\ \mu m$

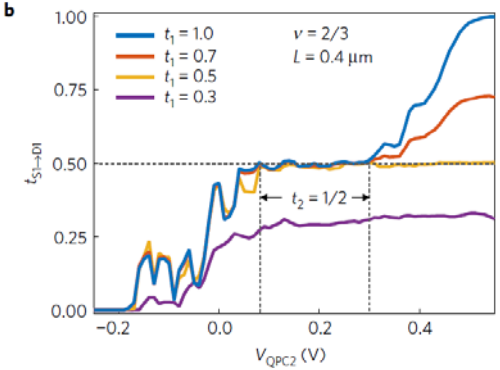


$t_1 = t_1 = 1/2$

$t_{S1\to D2} = 0$

GaAs-AlGaAs heterostructure
$(1.2–2.5) \times 10^{11}\ cm^{-2}$
$(3.9–5.1) \times 10^{6}\ cm^2\ V^{-1}\ s^{-1}$



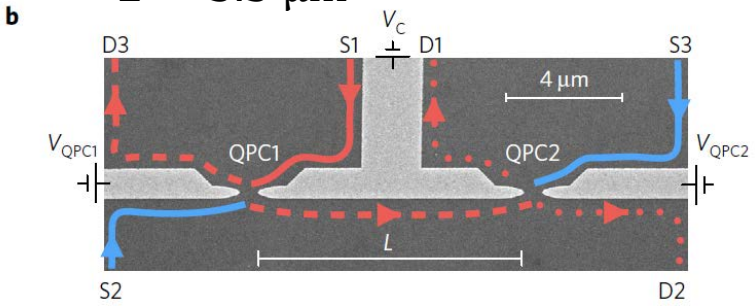


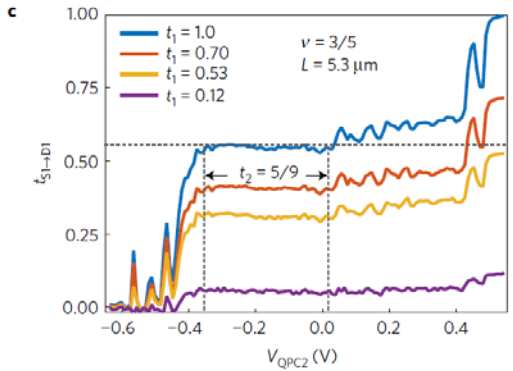
- $t_{S1\to D1}$
- $t_{S1\to D1} = t_1/2$
  for all t_1 once $t_2 = 1/2$
- $t_{S1\to D1} = t_1 \times t_2$
- single charge mode

- $t_{S1\to D1} = 1/2$
  for $t_1 \geq 1/2$ once $t_2 = 1/2$
- $t_{S1\to D1} \approx t_1$
  for $t_1 < \frac{1}{2}$ once $t_2 = 1/2$
- two charge channels
- few micrometers equilibration length

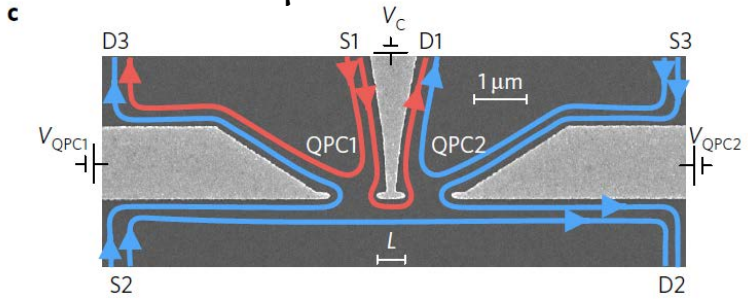
$\nu = 3/5$

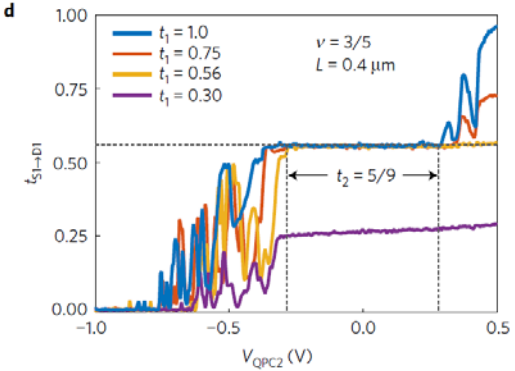
$L = 5.3\ \mu m$





$L = 0.4\ \mu m$



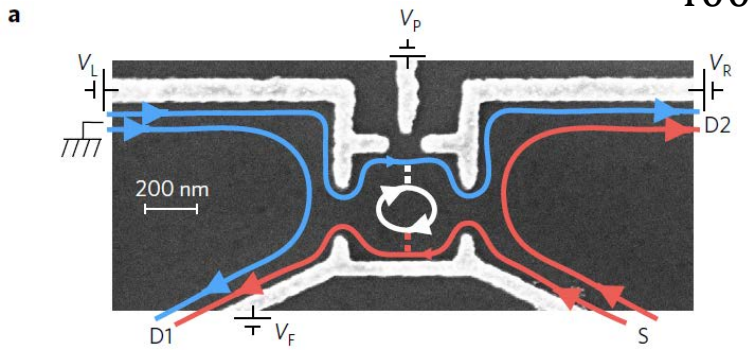


Qualitatively similar to $\nu = 2/3$

GaAs-AlGaAs heterostructure
$(1.2–2.5) \times 10^{11}\ cm^{-2}$
$(3.9–5.1) \times 10^{6}\ cm^2\ V^{-1}\ s^{-1}$

Fabry-Perot interferometer

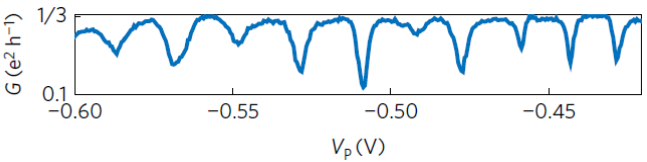
$400 \times 400\ \mathrm{nm}^2$



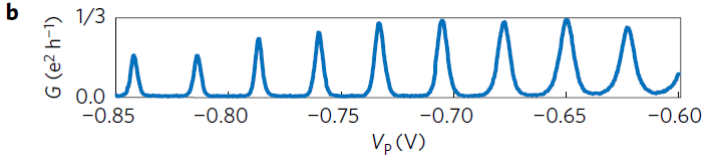
$t_{QPC1} = t_{QPC2} = 1/2$

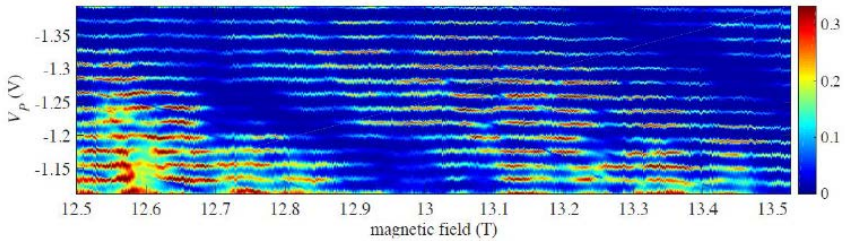
$t_{FPI} = 1/2$

$G_{FPI} = 1/3\ e^2/h$

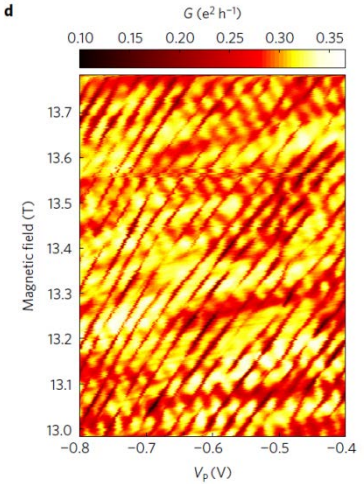


$t_{QPC1}, t_{QPC2} \ll 1$ Coulomb blockade peaks



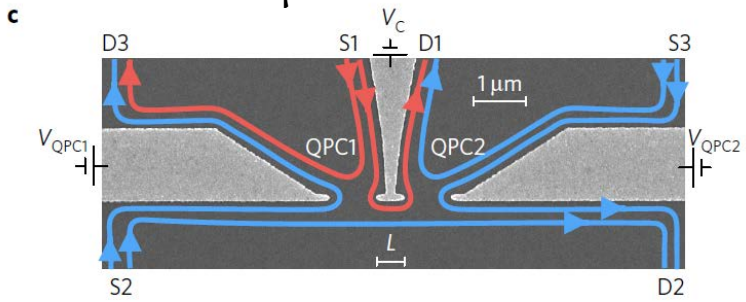


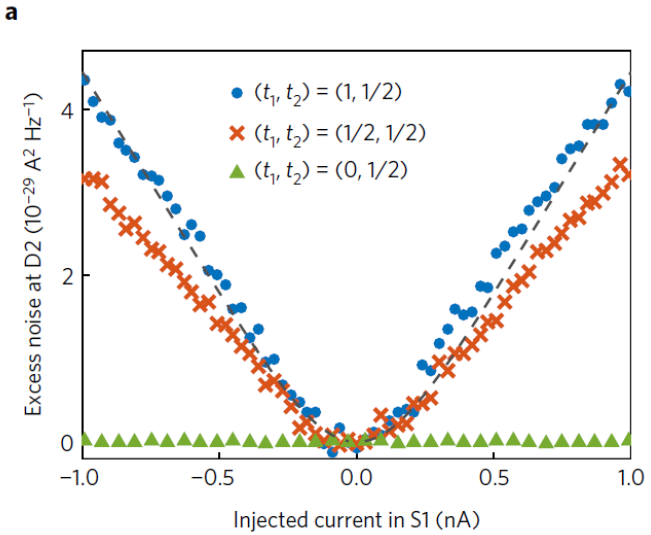
- white channel is quantized
- energy aligned with the Fermi energy → backscattering via resonant tunneling
- Coulomb dominated “inner dot”



Noise measurements

$L = 0.4\ \mu m$





$t_1 = t_1 = 1/2$
$t_{S1 \to D2} = 0$

$\nu = 2/3$

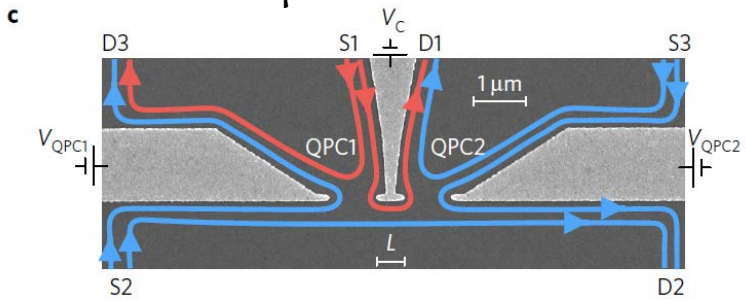
- current did not arrive at D2
- current fluctuations measured in D2 (red crosses)
- noise plots with and without current are similar

- current fluctuations are never observed in integer or particle-like fractional states

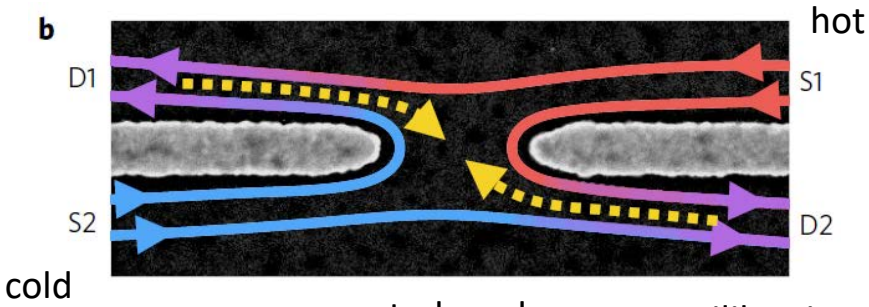
- currentless-noise must result from upstream neutral mode(s)

Noise generation

$L = 0.4\ \mu\text{m}$

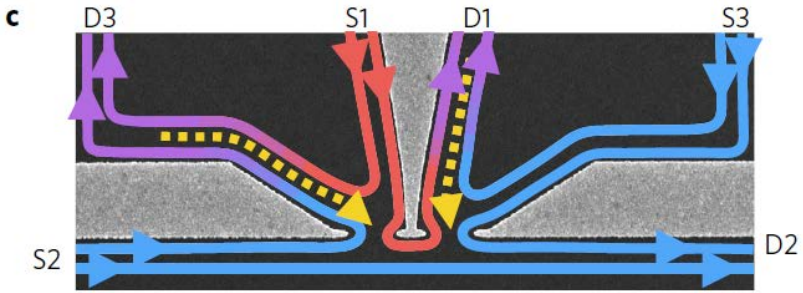


equilibration



Noise-generating mechanism:

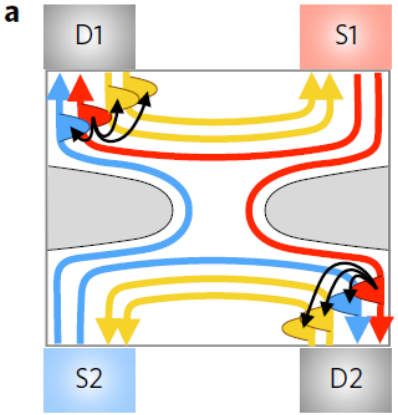
- charge equilibration with generation of neutral excitations (‘neutralons’)
- fragmentation with stochastic creation of quasi-particle/quasi-hole pairs



Neutralon-induced noise

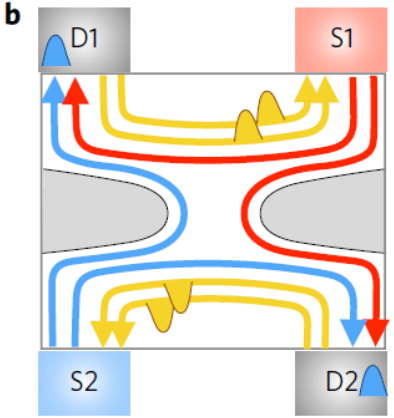
neutralon generation

hot

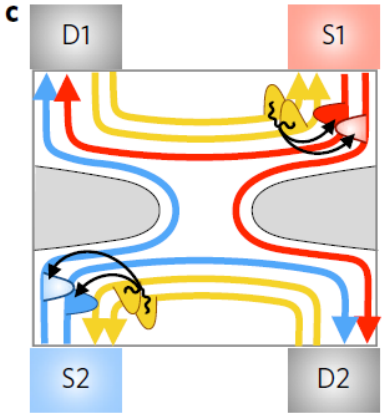


cold

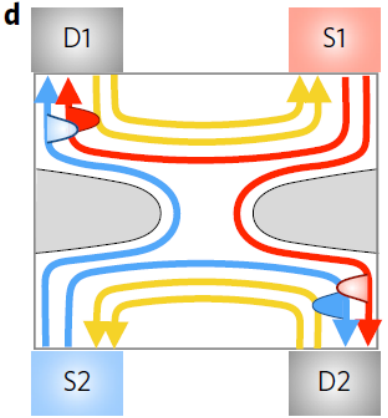
neutralon flow



neutralon pair decays into qp/qh pair



current noise

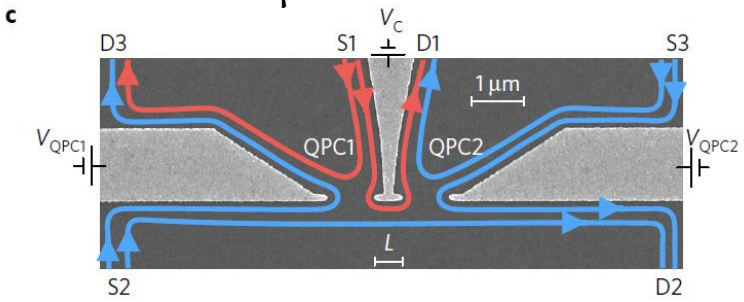


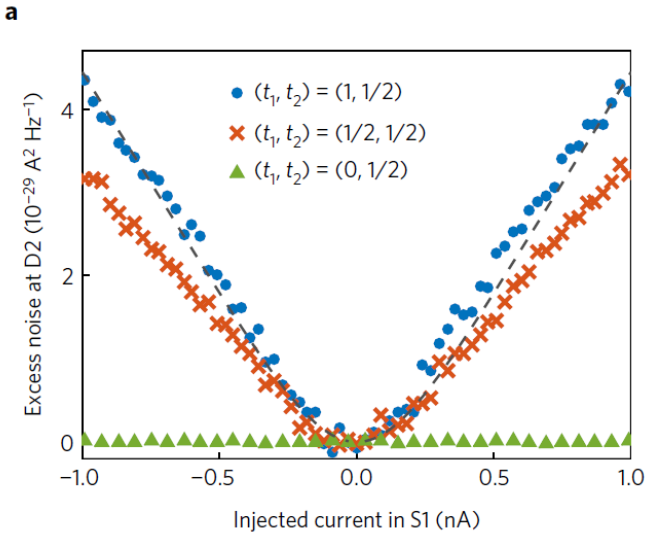
Conclusion

- model for $\nu = 2/3$: two $1/3\ e^2/h$ downstream co-propagating edge channels
- equilibrate on a few micrometer length scale
- shot-noise-like fluctuations due to interplay between charge and neutral modes

Noise measurements

$L = 0.4\ \mu m$

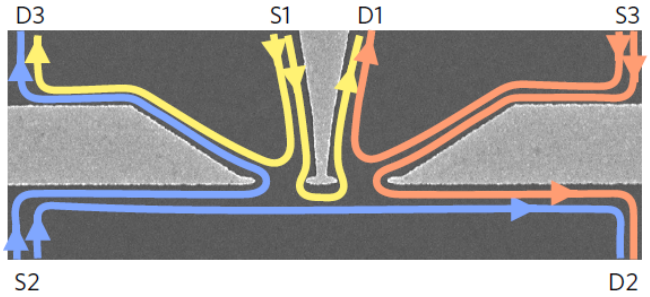




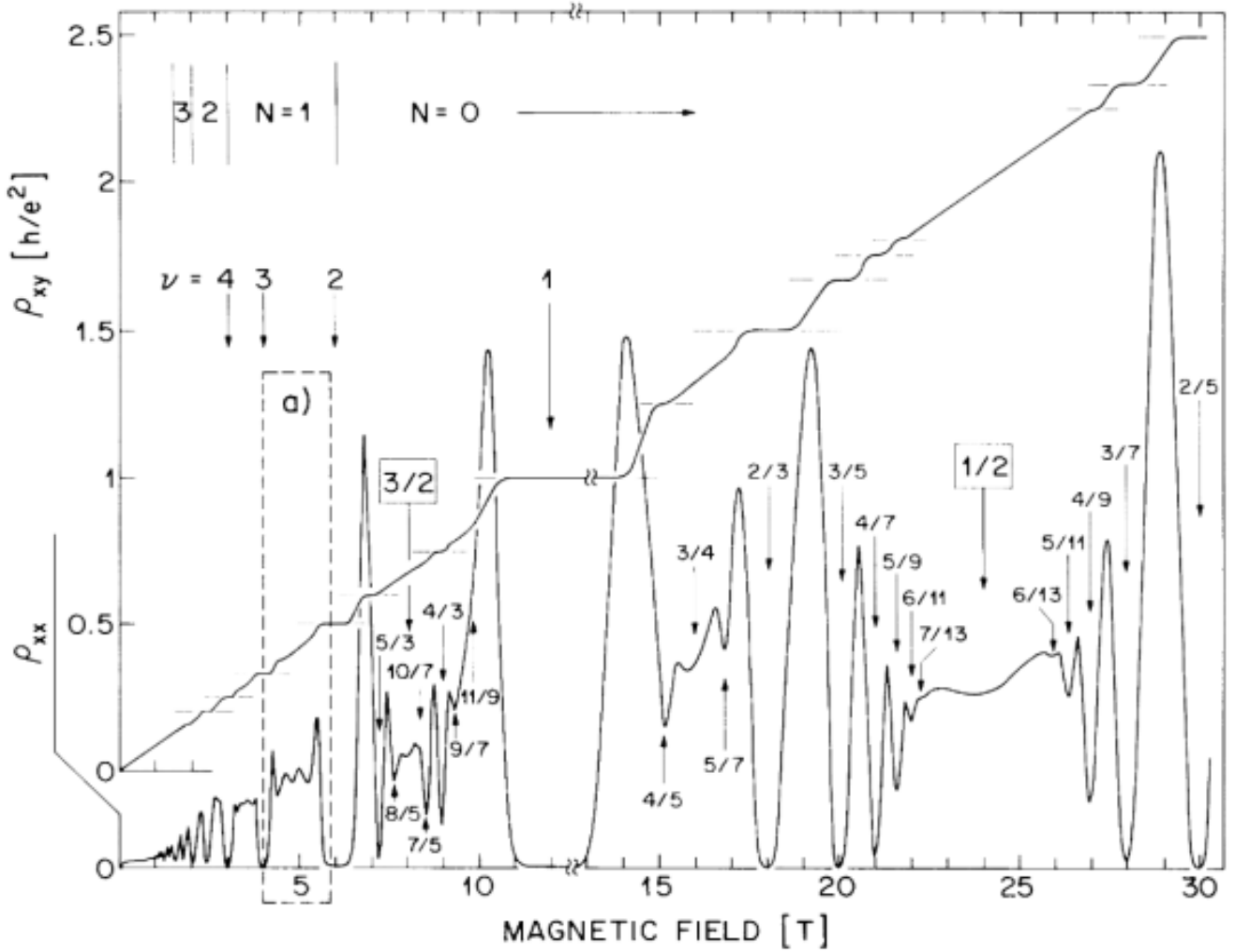
$S = 2qIt(1-t)\alpha(T)$ - spectral density

$F = S/2eIt(1-t)\alpha(T) = q/e$ - Fano factor

q - partitioned charge



	S1				S2				S3			
	t	F_{exp}	$F_{th}^{(1)}$	$F_{th}^{(2)}$	t	F_{exp}	$F_{th}^{(1)}$	$F_{th}^{(2)}$	t	F_{exp}	$F_{th}^{(1)}$	$F_{th}^{(2)}$
D1	0.5	0.76	2/3	2/3	0.0	0.54	1/3	1/2	0.5	0.51	1/3	1/2
D2	0.0	0.48	1/3	1/2	0.5	0.50	1/3	1/2	0.5	0.66	2/3	2/3
D3	0.5	0.49	1/3	1/2	0.5	0.68	2/3	2/3	0.0	0.40	1/3	1/2


3 2
N = 1
N = 0
ν = 4 3 2 1
a)
3/2
1/2
2/5
3/7
4/9
5/11
6/13
7/13
6/11
5/9
4/7
3/5
2/3
3/4
4/5
5/7
4/3
5/3
10/7
11/9
9/7
8/5
7/5
ρ_{xy} [h/e^2]
ρ_{xx}
MAGNETIC FIELD [T]
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30