Unconventional features in transport and noise in the second Landau level

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Outline

- Introduction
  - Quantum Hall effect (QHE)
  - Fractional quantum Hall effect
  - Charge density wave (CDW) in the QHE
  - The second Landau level
  - Hall bar and Corbino geometry

- Low frequency noise measurement
  - Noise and transport measurement in the FQHE and CDW
  - The second Landau level

Quantum Hall effect in conventional 2DEG

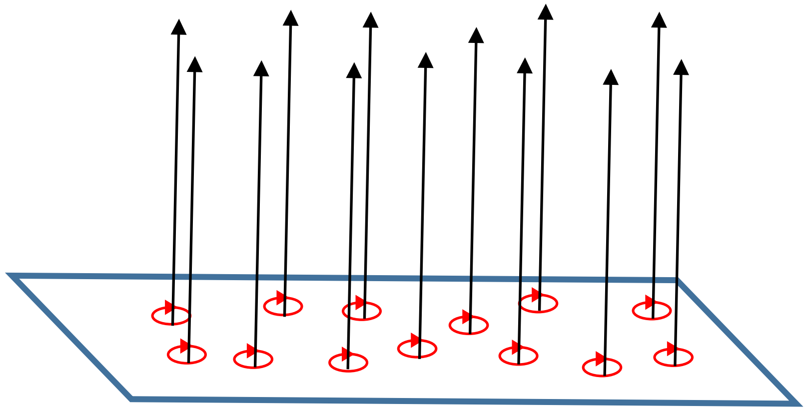
Landau level (LL) for Schrödinger electrons:

$$E_N = \hbar\omega_C\left(n + \frac{1}{2}\right)$$

$$\omega_C = eB/m$$

Landau level filled when there is one electron per flux quanta: $\phi_0 = h/e \ (\phi = B.S)$

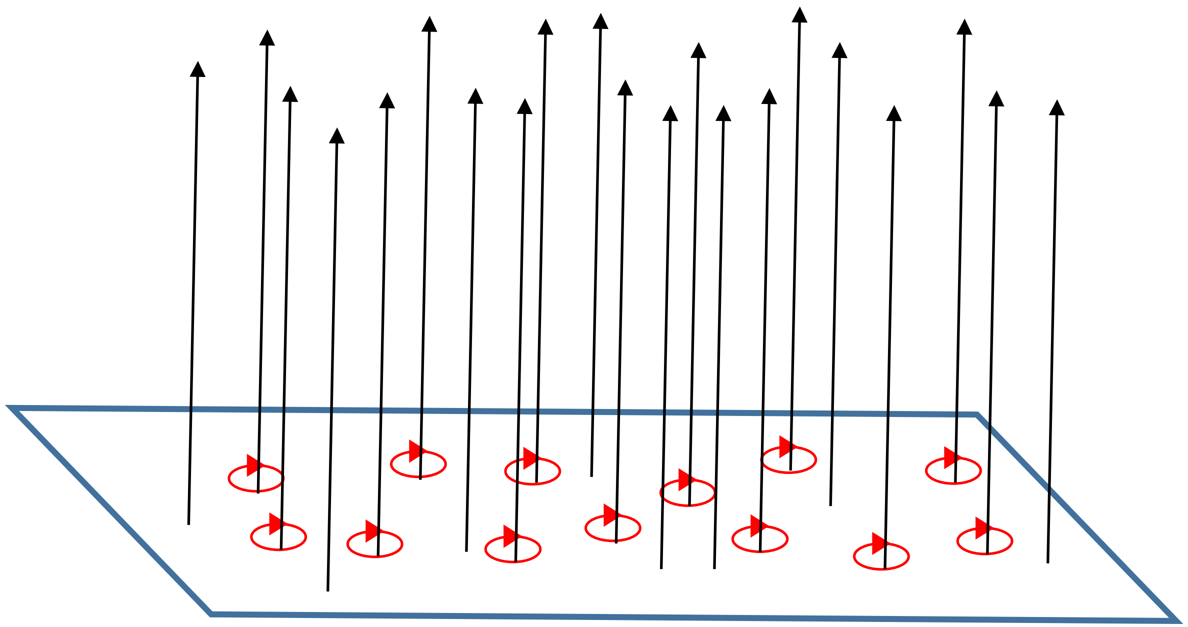
$\nu = 1$



ν represents the filling factor: the number of filled Landau Level

Fractional quantum Hall effect: the composite fermion picture

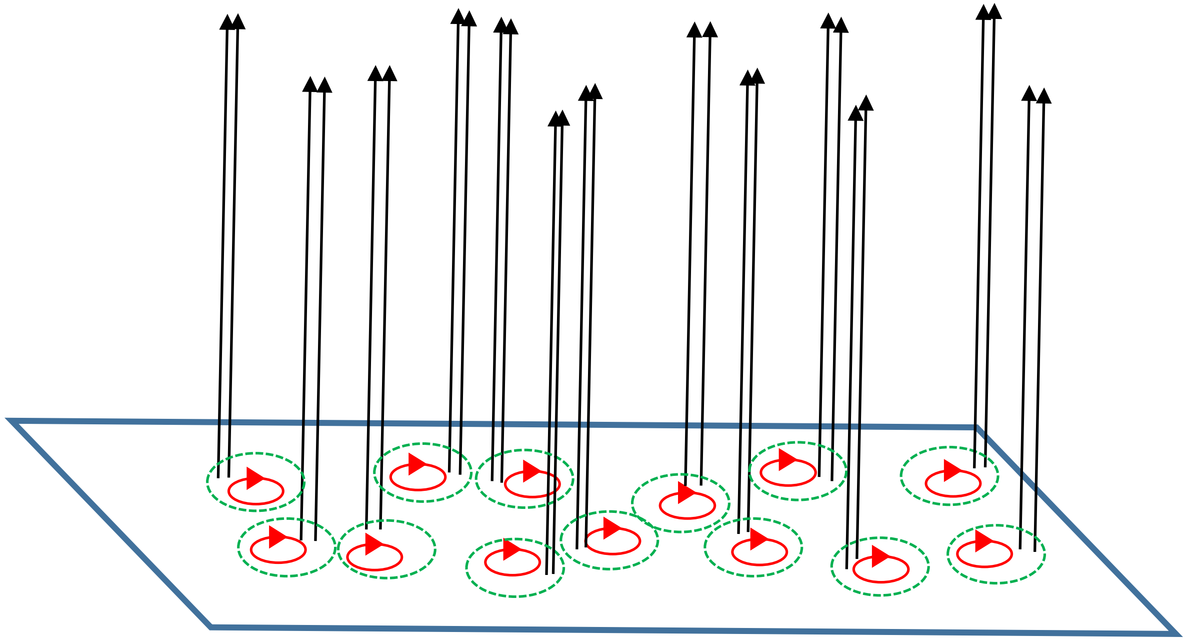
$\nu < 1$



Fractional quantum Hall effect: the composite fermion picture

Composite Fermions

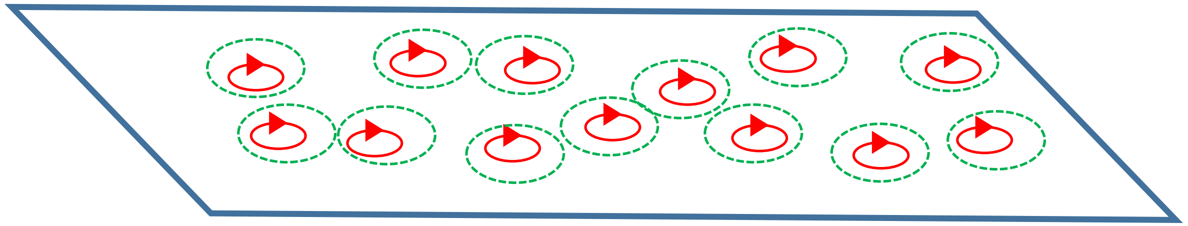
$\nu = 1/2$

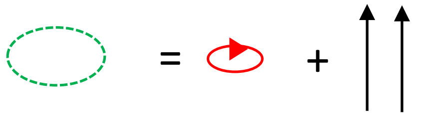


Fractional quantum Hall effect: the composite particle picture

Composite Fermions

$\nu = 1/2$





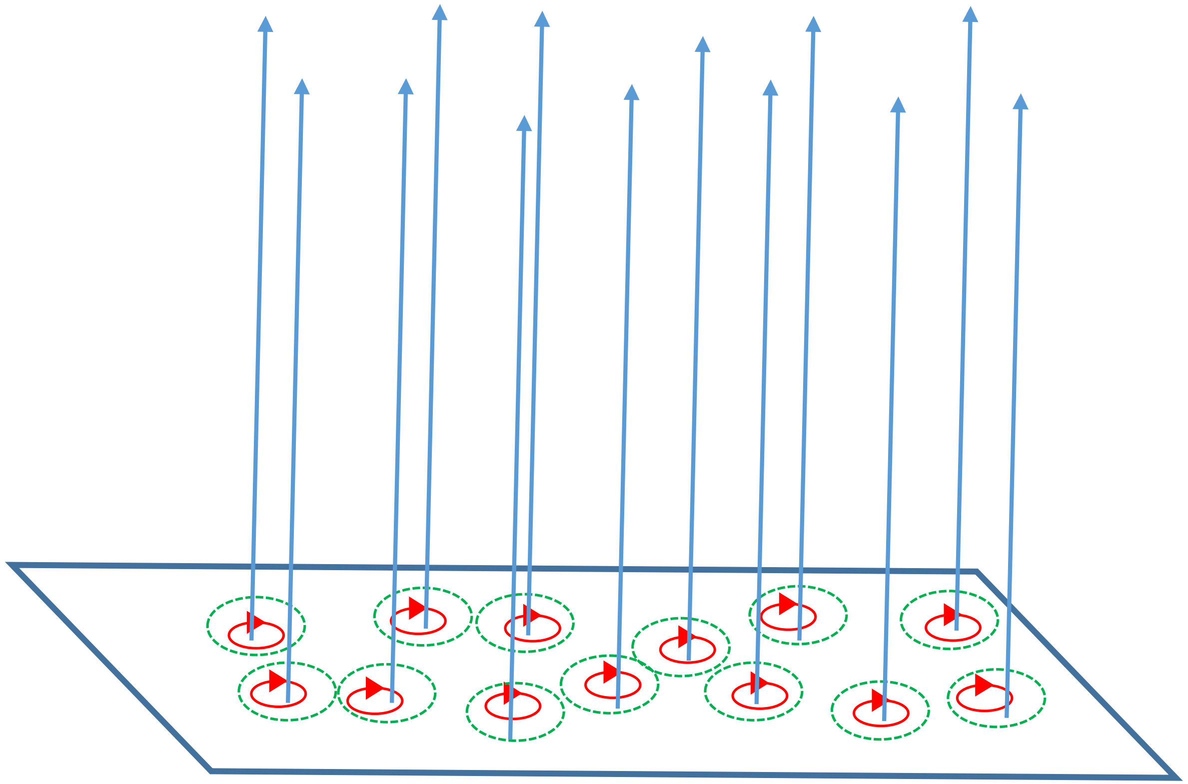
1 CF $= 1\ e^{-} + 2\ \phi_0$

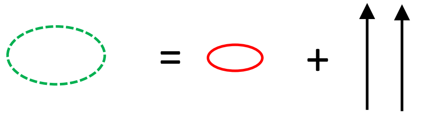
Fractional quantum Hall effect: the composite fermion picture

Composite Fermions

$1e^{-} + 2\,\phi_0$

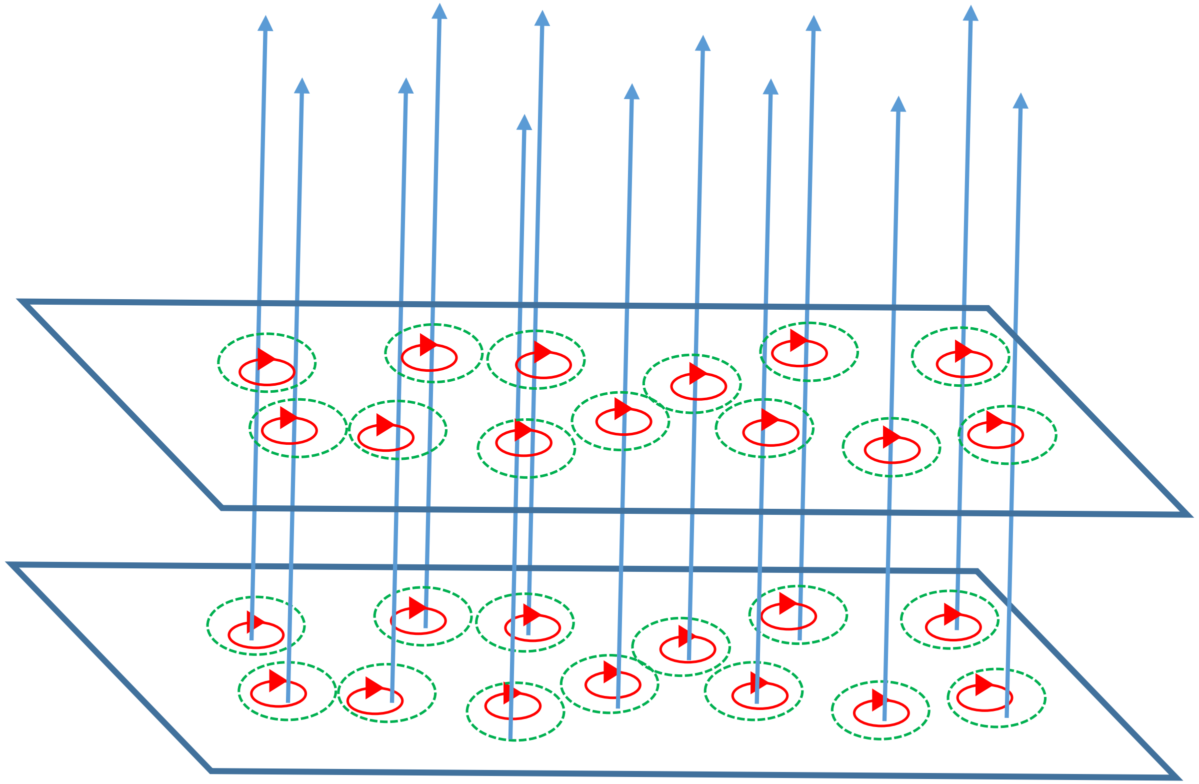
$\nu^* = 1 \Rightarrow \nu = 1/3$





1 CF $= 1\ e^{-} + 2\,\phi_0$

Fractional quantum Hall effect: the composite fermion picture



Composite Fermions

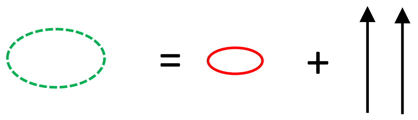
$1e^{-} + 2\,\phi_0$

$\nu^{*} = 2 \Rightarrow \nu = 2/5$

In general:

$$\nu = \frac{p}{2mp \pm 1}$$

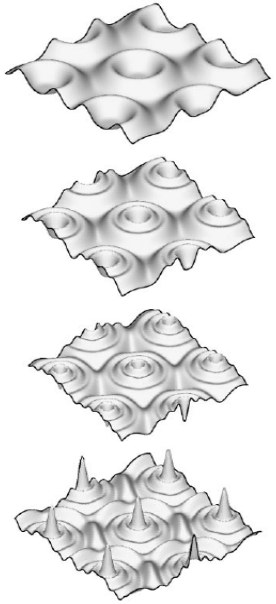
m, p are integer



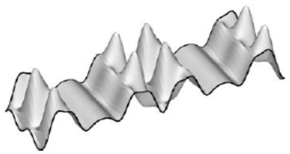
1 CF $= 1\ e^{-} + 2\ \phi_0$

Charge density wave at higher Landau Level

R. Côté, et al
PRB 68, 155327



Bubble phase
$\nu^* = 1/4 \;\&\; 3/4$



Stripe phase
$\nu^* = 1/2$

VOLUME 76, NUMBER 3 PHYSICAL REVIEW LETTERS 15 JANUARY 1996

Charge Density Wave in Two-Dimensional Electron Liquid in Weak Magnetic Field

A. A. Koulakov, M. M. Fogler, and B. I. Shklovskii

Landau Level mixing:

$$\kappa = \frac{e^2/\epsilon l}{\hbar\omega_C}$$

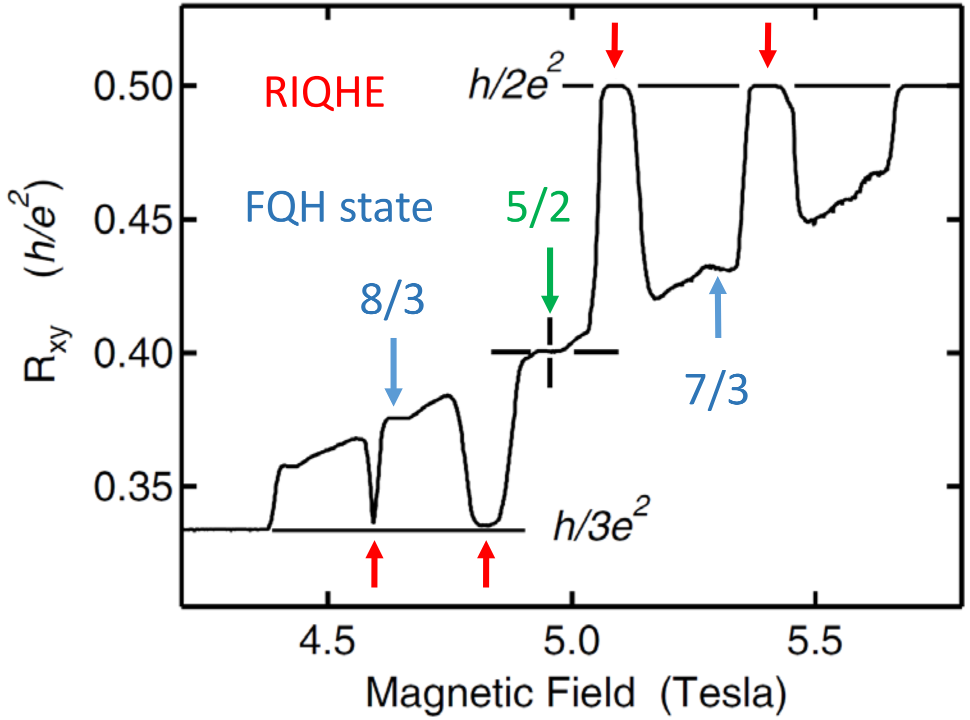
(l is the distance between electron and $\omega_C = eB/m$)

Ratio of the Coulomb interaction to the cyclotron energy

Charge density wave (CDW) measured in stripe and bubble phases

Stripe phase observed in anisotropy of transport

The second Landau Level: competition between phases



VOLUME 88, NUMBER 7 PHYSICAL REVIEW LETTERS 18 FEBRUARY 2002

Insulating and Fractional Quantum Hall States in the First Excited Landau Level

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(Received 24 September 2001; published 30 January 2002)

nature physics ARTICLES

PUBLISHED ONLINE: 26 OCTOBER 2015 | DOI: 10.1038/NPHYS3523

Observation of a transition from a topologically ordered to a spontaneously broken symmetry phase

N. Samkharadze[1†‡], K. A. Schreiber[1†], G. C. Gardner[2,3], M. J. Manfra[1,2,3,4], E. Fradkin[5] and G. A. Csáthy[1,3★]

PRL 116, 016801 (2016) PHYSICAL REVIEW LETTERS week ending 8 JANUARY 2016

Optical Emission Spectroscopy Study of Competing Phases of Electrons in the Second Landau Level

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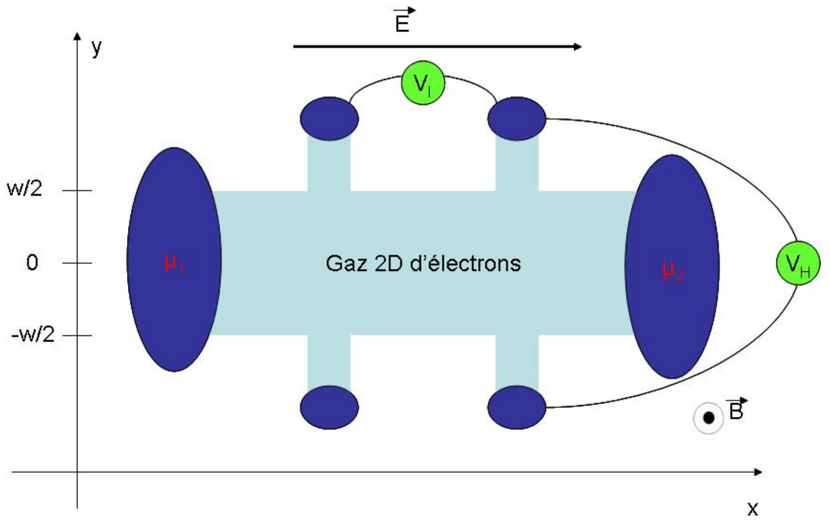
Hall Bar vs Corbino

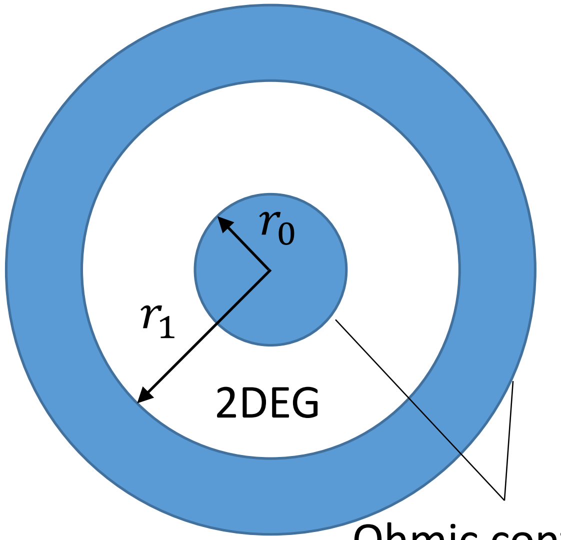


Access to R_{xx} *and* $R_{xy} = R_{Hall}$

Giving access to conductivities:

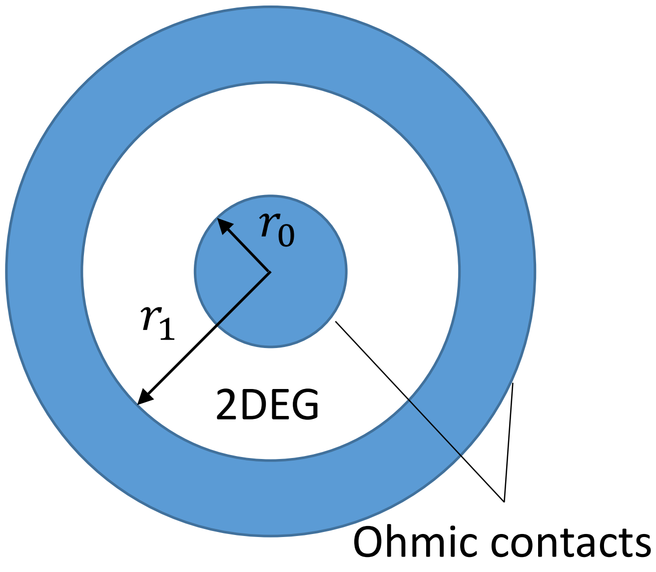
$$\sigma_{xx} = \frac{\rho_{xx}}{\rho_{xx}^2+\rho_{xy}^2} \qquad \sigma_{xy} = \frac{\rho_{xy}}{\rho_{xx}^2+\rho_{xy}^2}$$

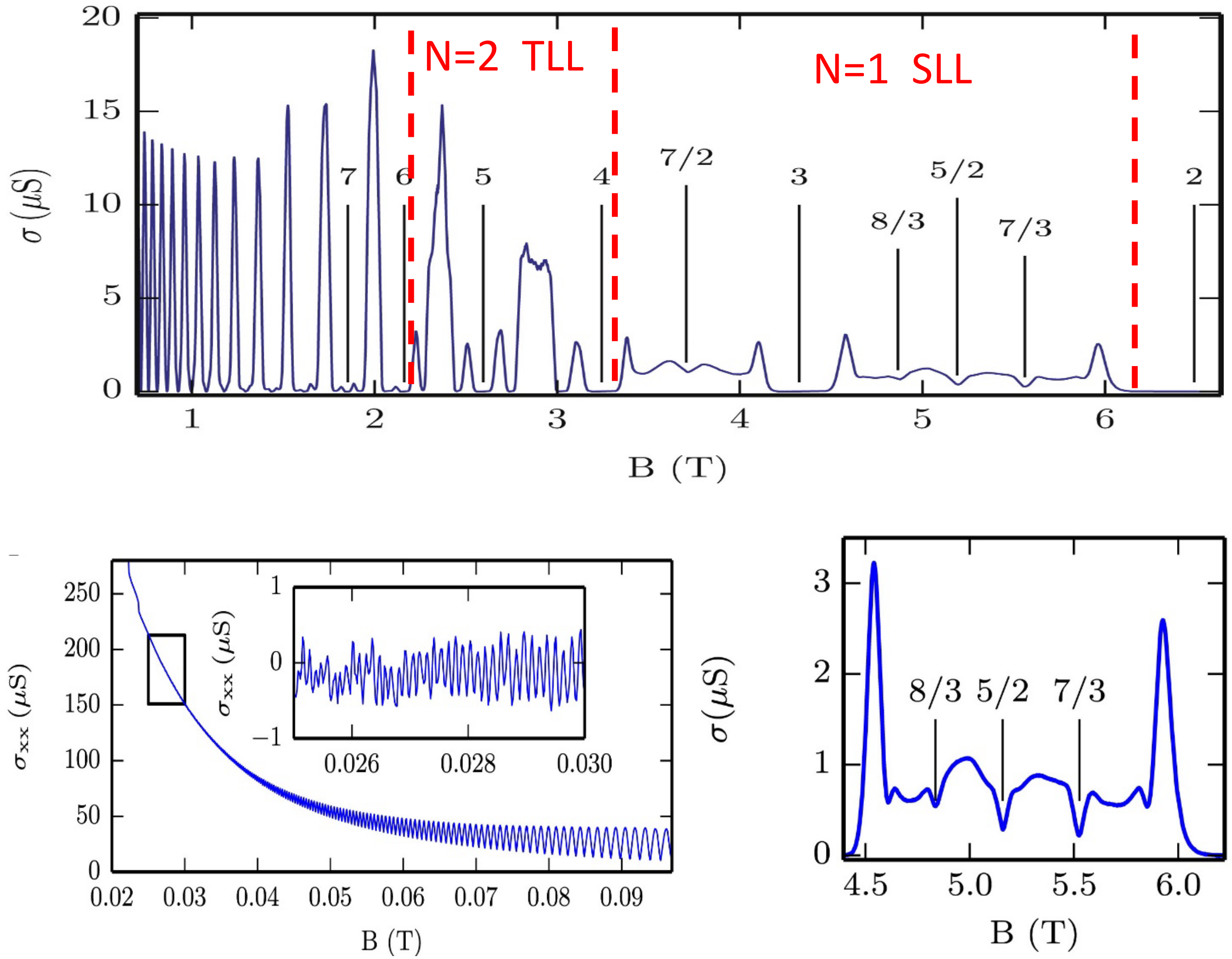
$$V = \frac{I}{2\pi\sigma_{xx}} \ln\frac{r_0}{r_1}$$



- Acces to σ_{xx} without aspect ratio factor
- Bulk measurement, edges states don't participate to transport.

Quantum Hall effect in Corbino geometry

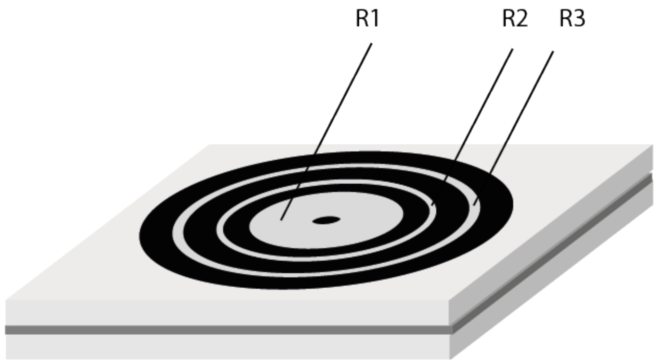


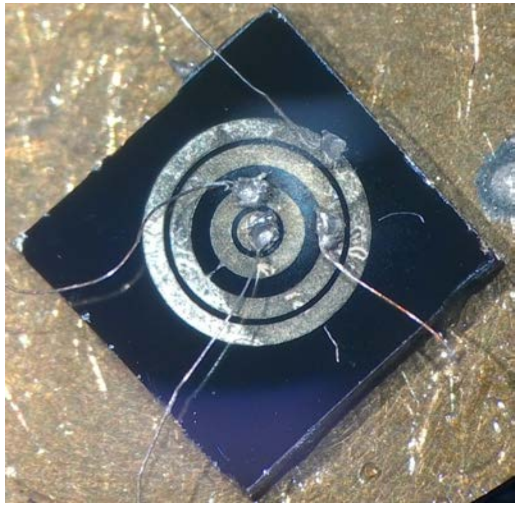


B.A Schmidt, K. Bennaceur, S. Bilodeau, G. Gervais, L. N. Pfeiffer, K. W. West, Solid state Comm 217 (2015)

Noise and transport measurements in Corbino

3 Corbinos in a sample with distance between contact:
$\Delta R1=550\ \mu m$
$\Delta R2=40\ \mu m$
$\Delta R3=100\ \mu m$

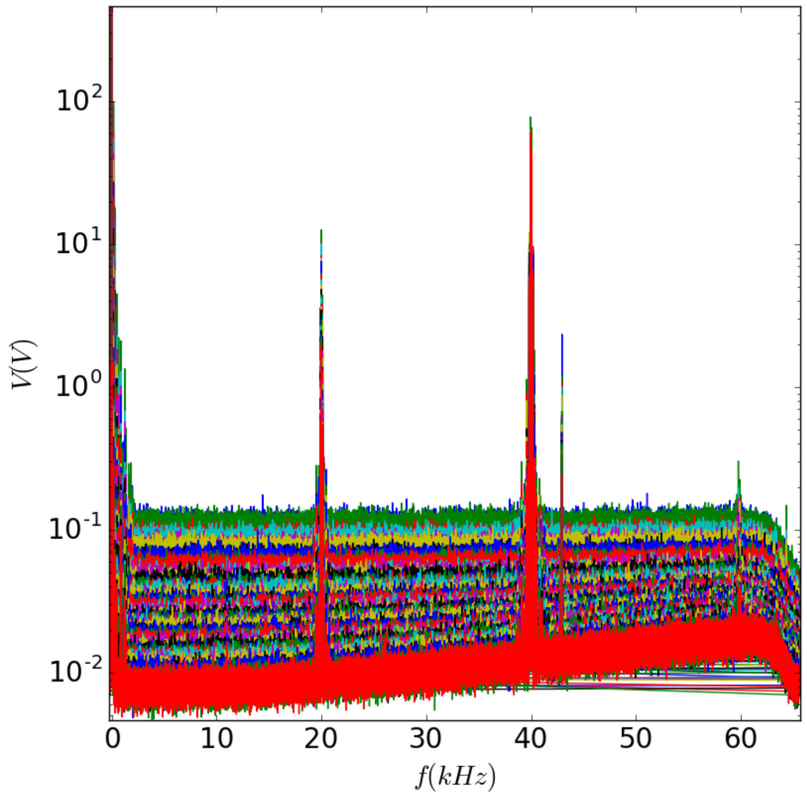


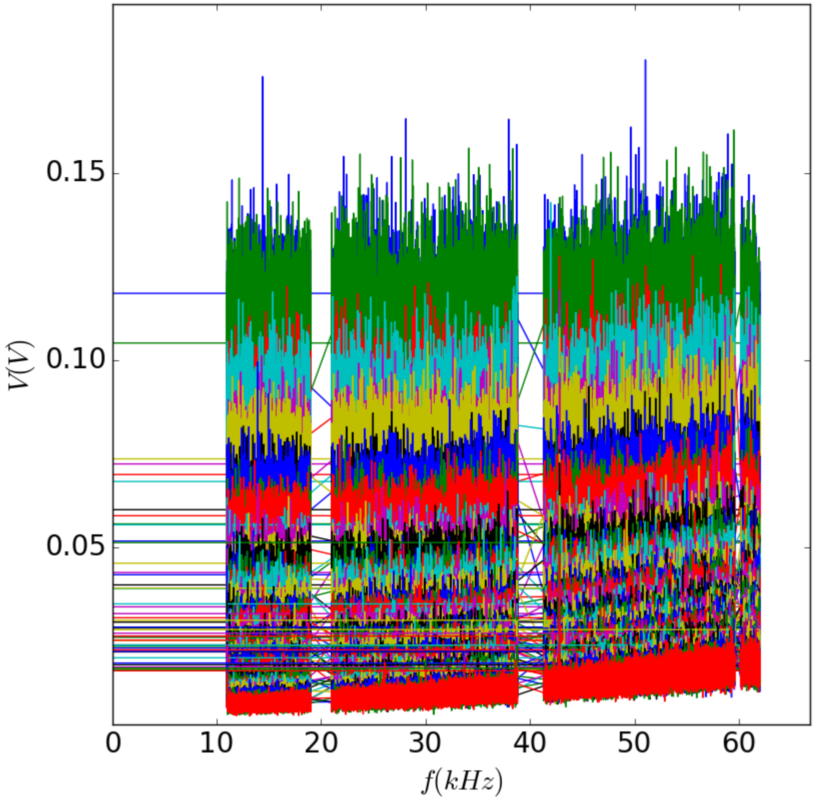


Base T= 7mK
Electron T~15-20mK

Current noise

$$S_I(\omega) = \langle \delta I(\omega)^2 \rangle = \langle \delta I(\omega)^2 \rangle_{sample} + \frac{\langle \delta V(\omega)^2 \rangle_{amp}}{\left(Z(\omega) + R_{amp}\right)^2} + \langle \delta I(\omega)^2 \rangle_{\mathrm{amp}}$$





$$Z(\omega) = R_{ech} // C_{coax}$$

Ampli NF, gain 1^{e7}

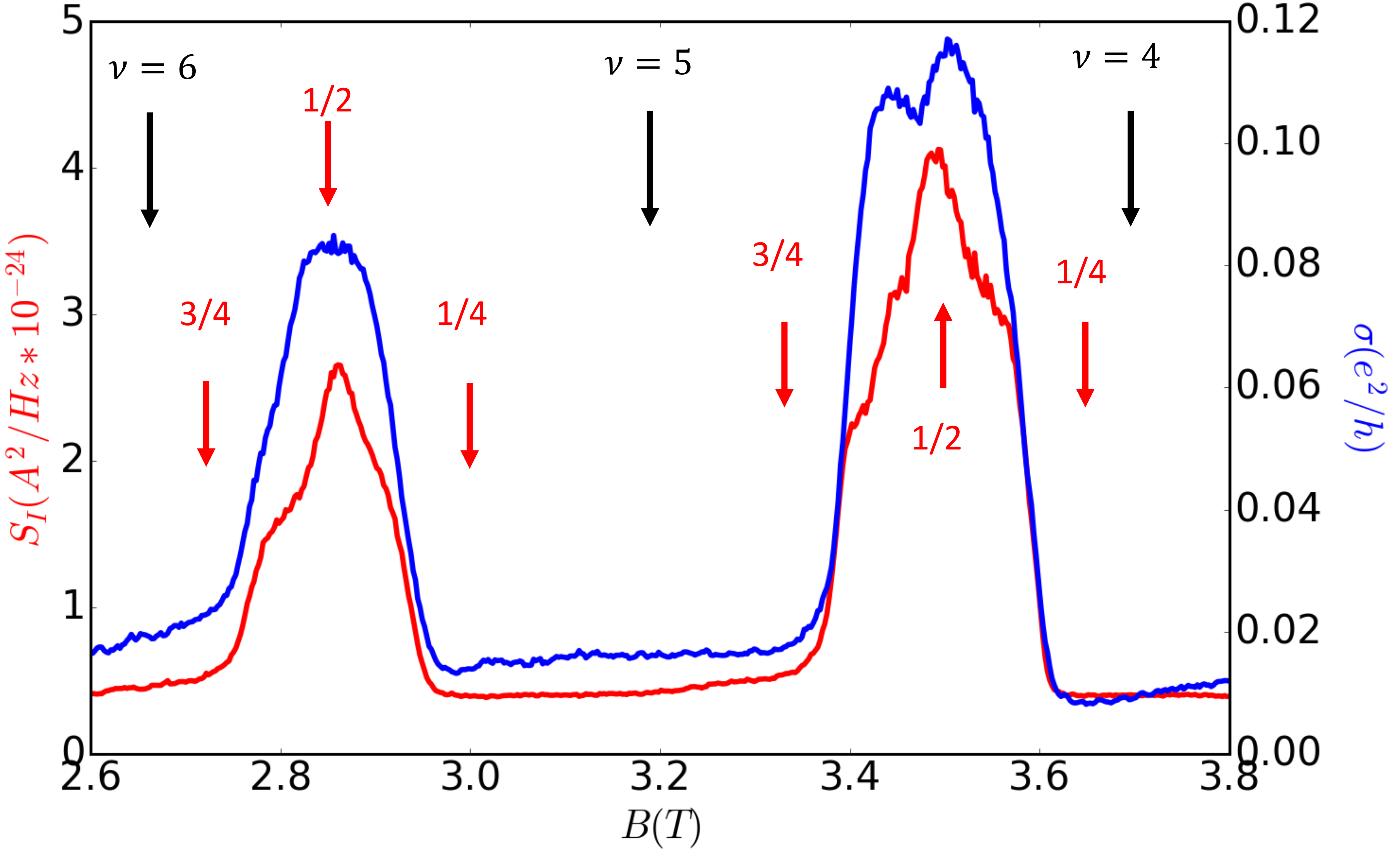
$$\sqrt{\langle \delta V^2 \rangle} \approx 2.6\, nV/\sqrt{Hz}$$

$$\sqrt{\langle \delta I^2 \rangle} \approx 335\, fA/\sqrt{Hz}$$

Noise in Crystal phase

1/2 = stripe phase
1/4 = bubble phase

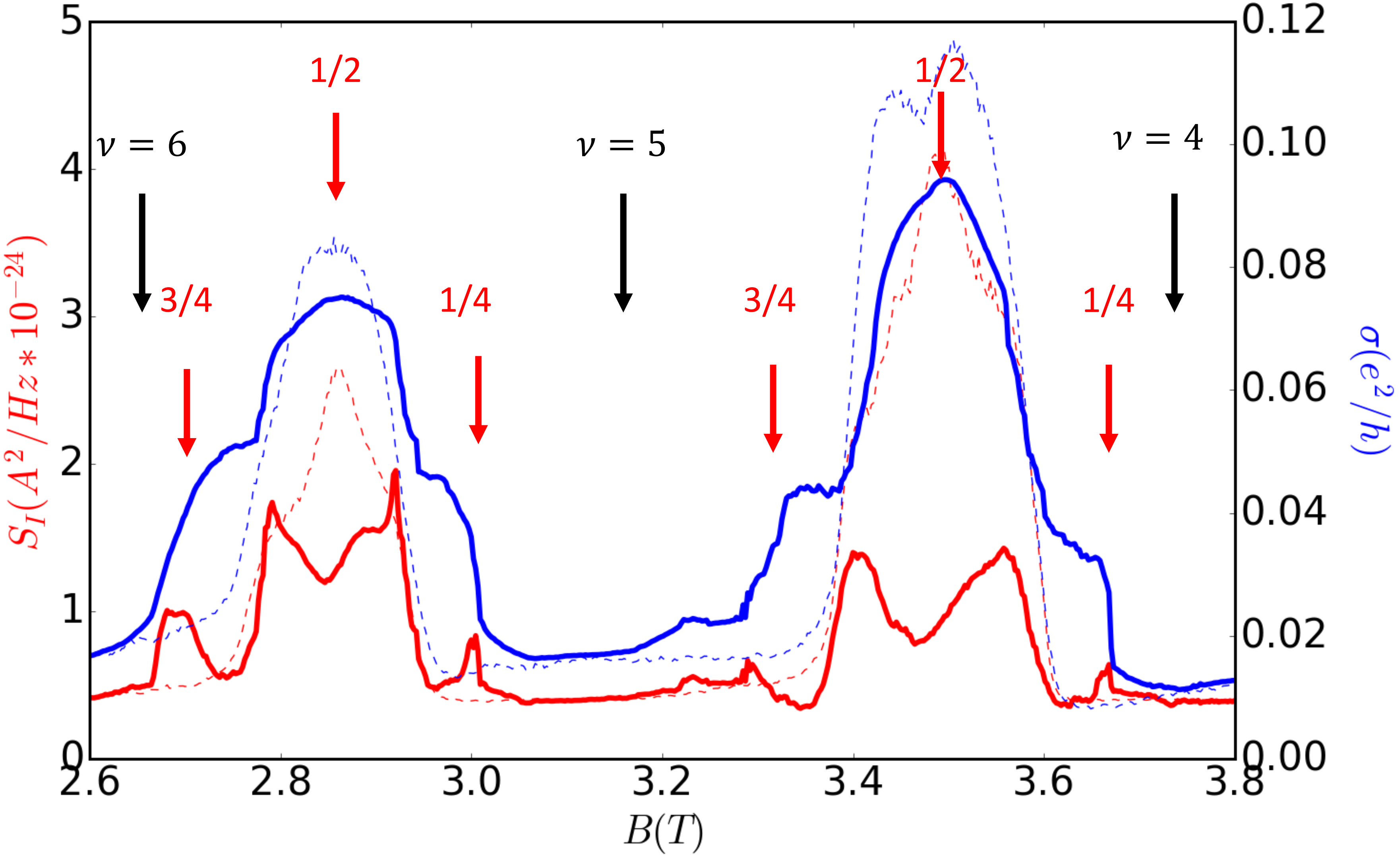
$V_{bias} = 40\ \mu V$



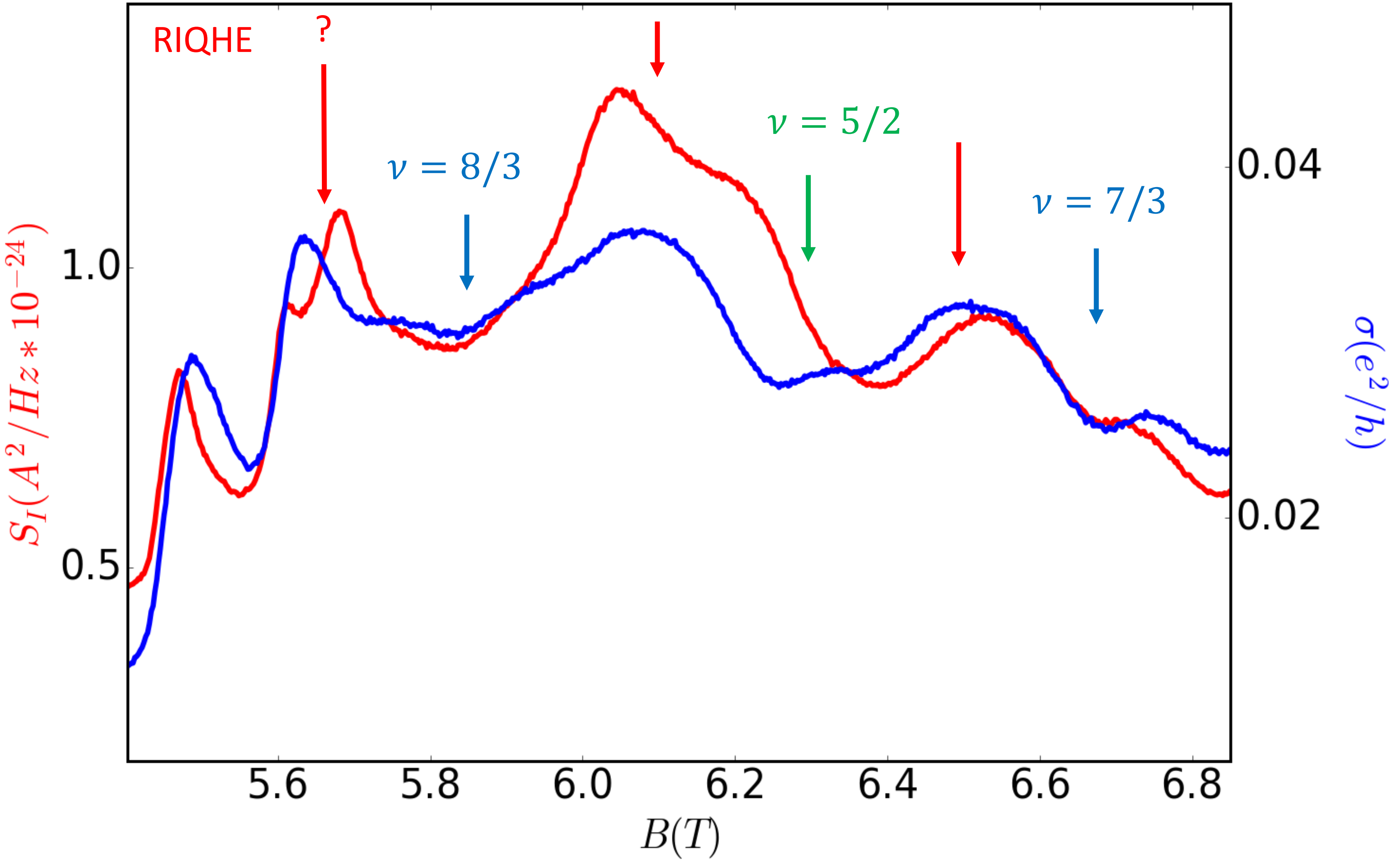
Noise in Crystal phase

1/2 = stripe phase
1/4 = bubble phase

$V_{bias} = 220\ \mu V$
$V_{bias} = 40\ \mu V$

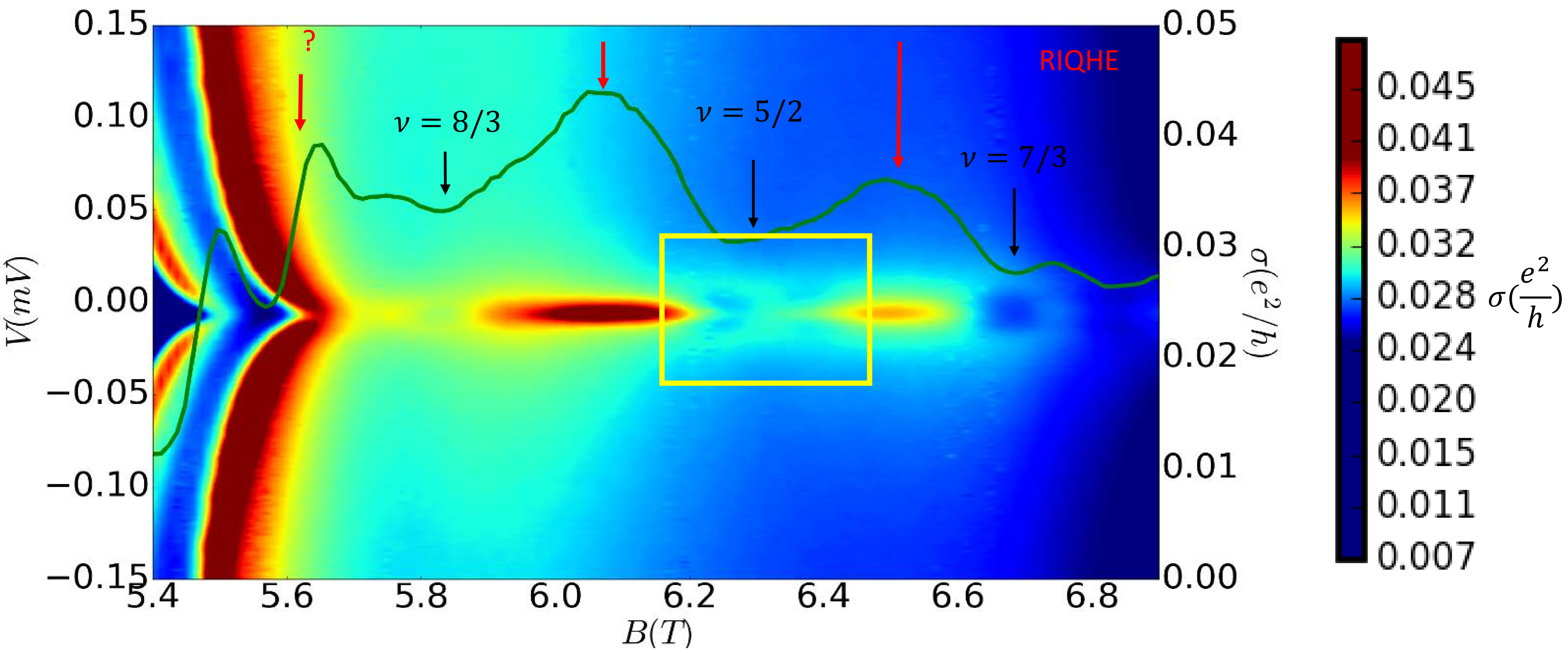


Transport and noise in the second Landau level



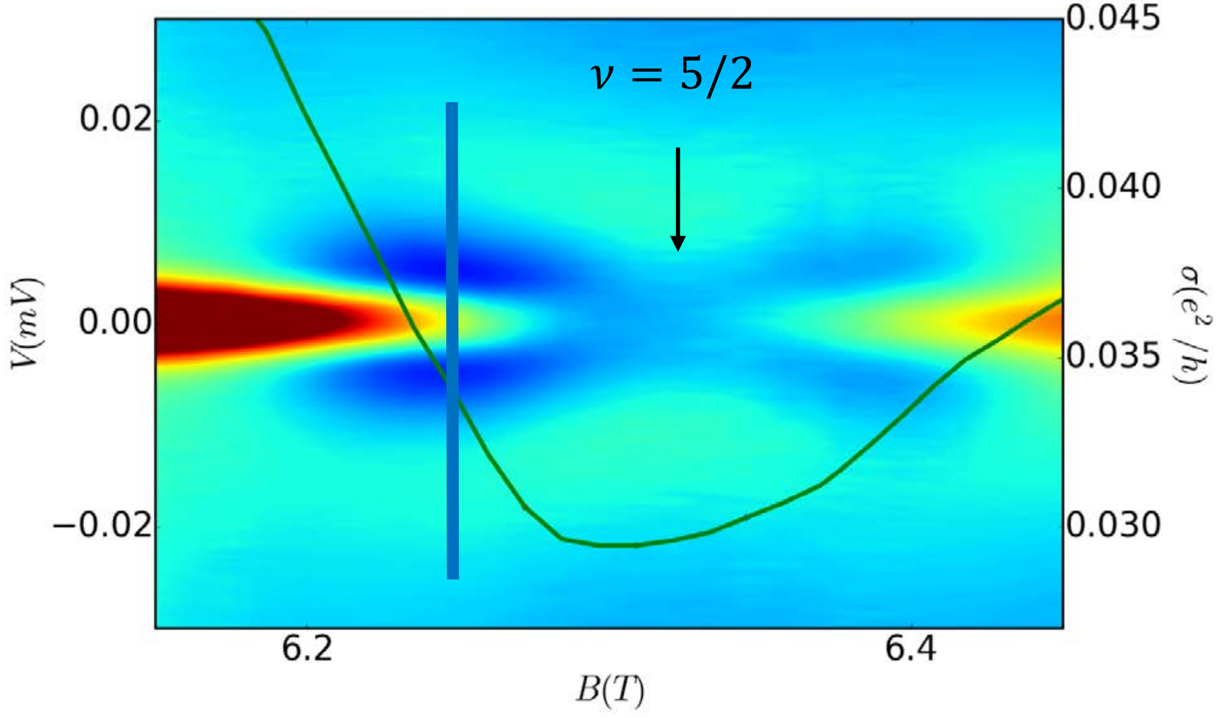
Non linear transport in the second Landau level

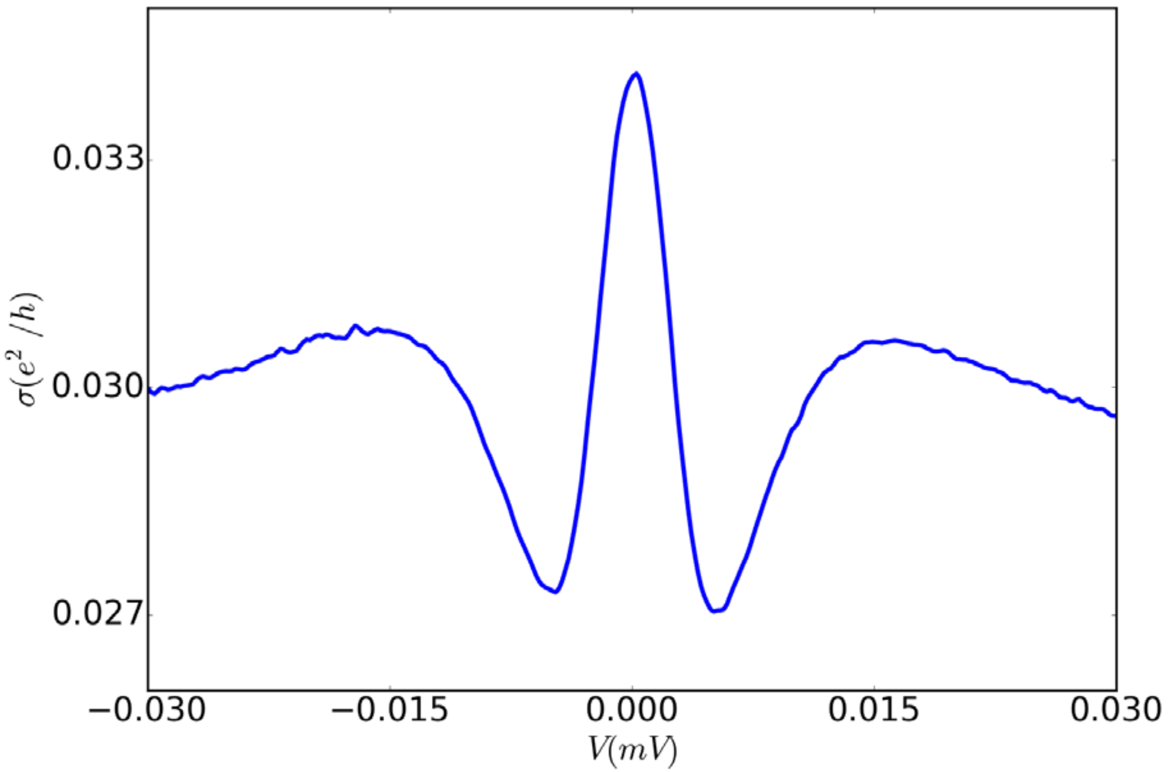
Differential conductance $(\partial I / \partial V)$



Non linear transport in the 5/2 state

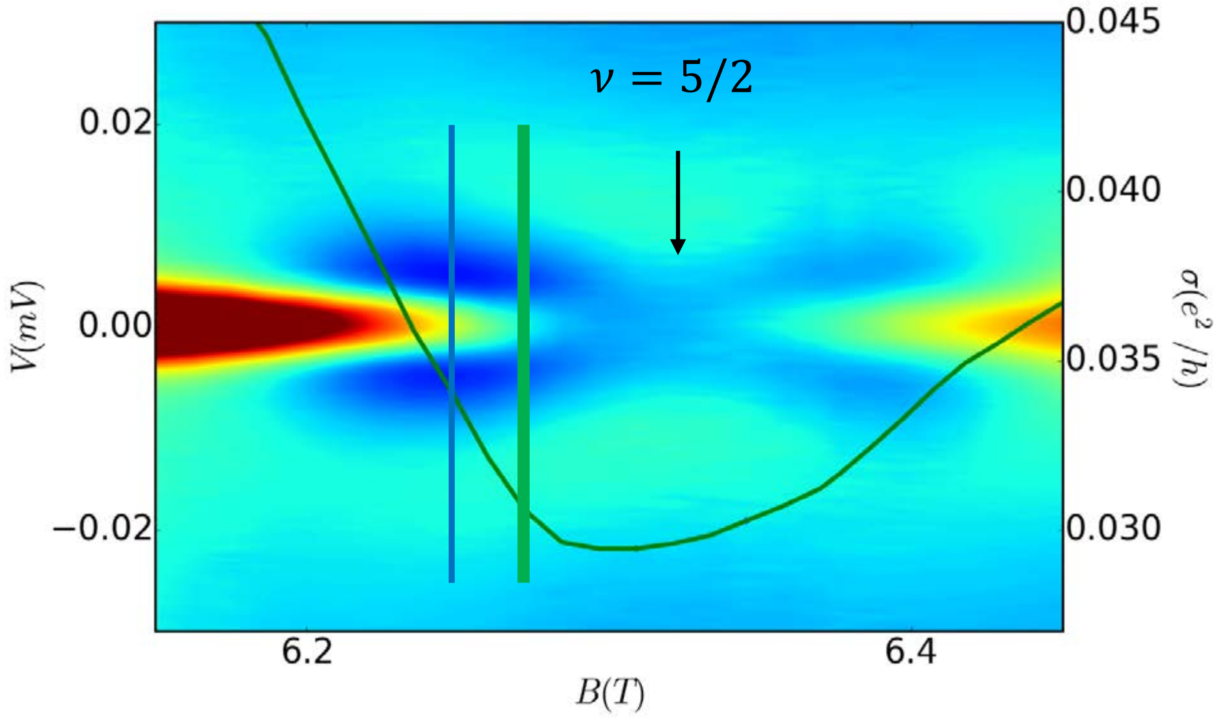
Differential conductance ($\partial I / \partial V$)

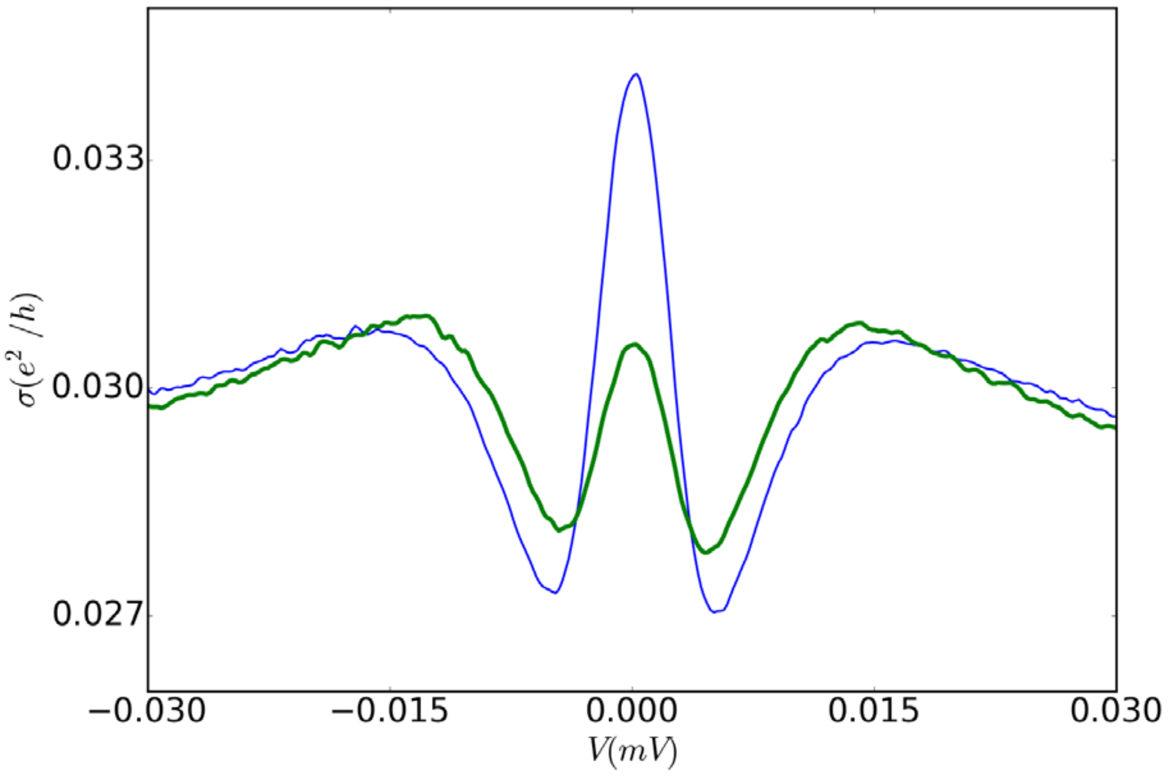




Non linear transport in the 5/2 state

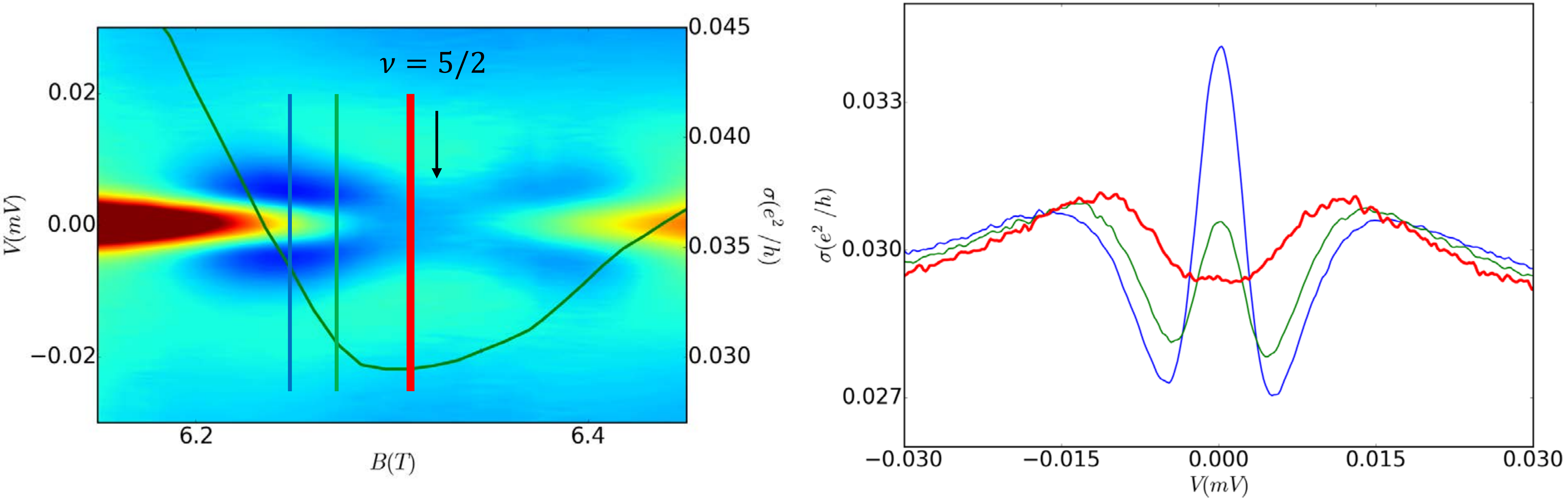
Differential conductance ($\partial I / \partial V$)





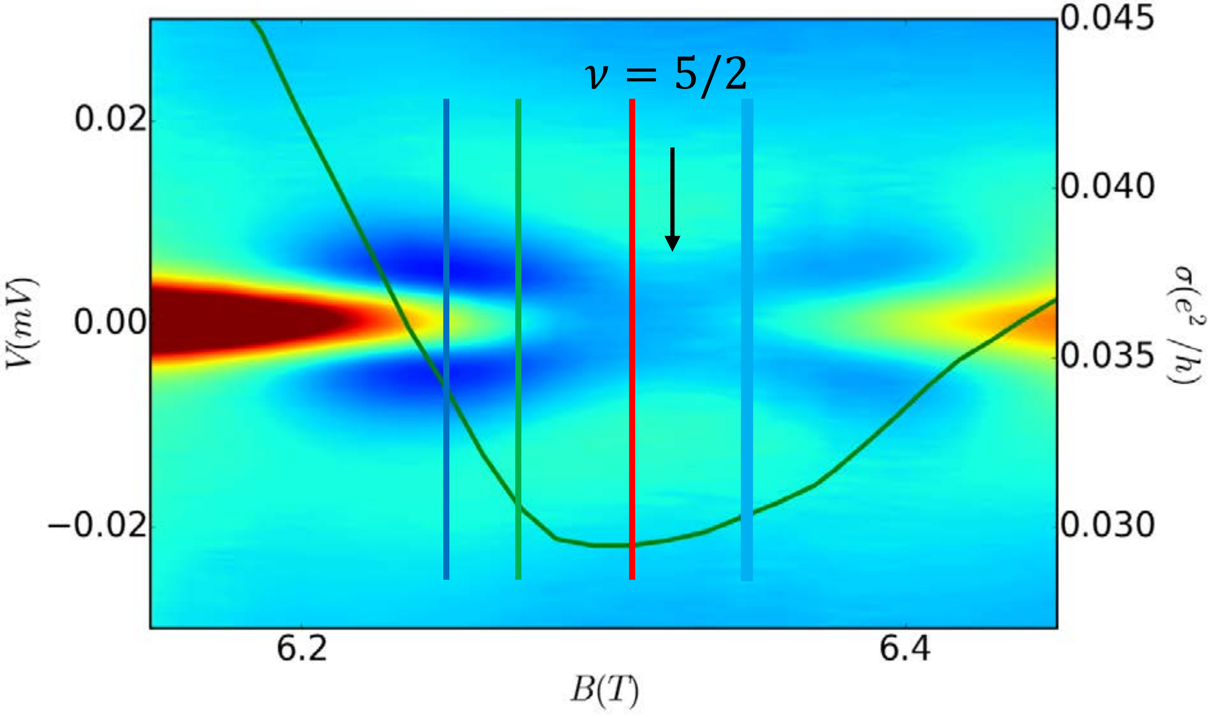
Non linear transport in the 5/2 state

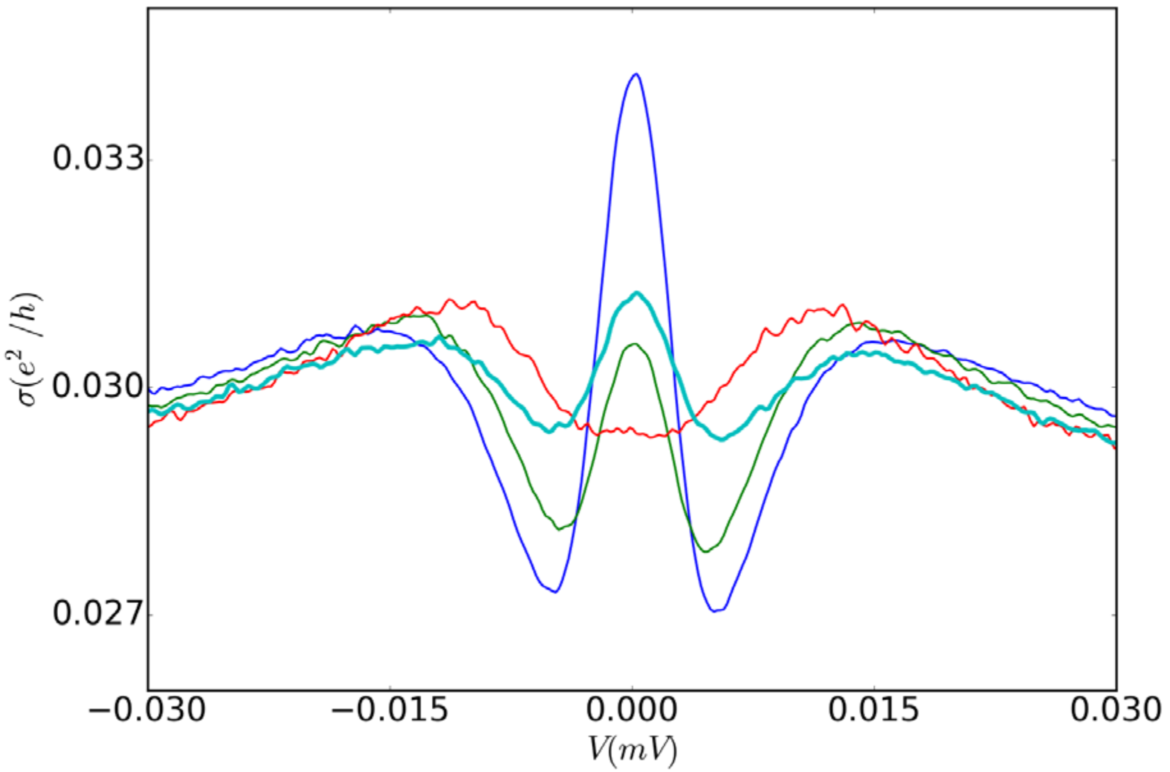
Differential conductance ($\partial I / \partial V$)



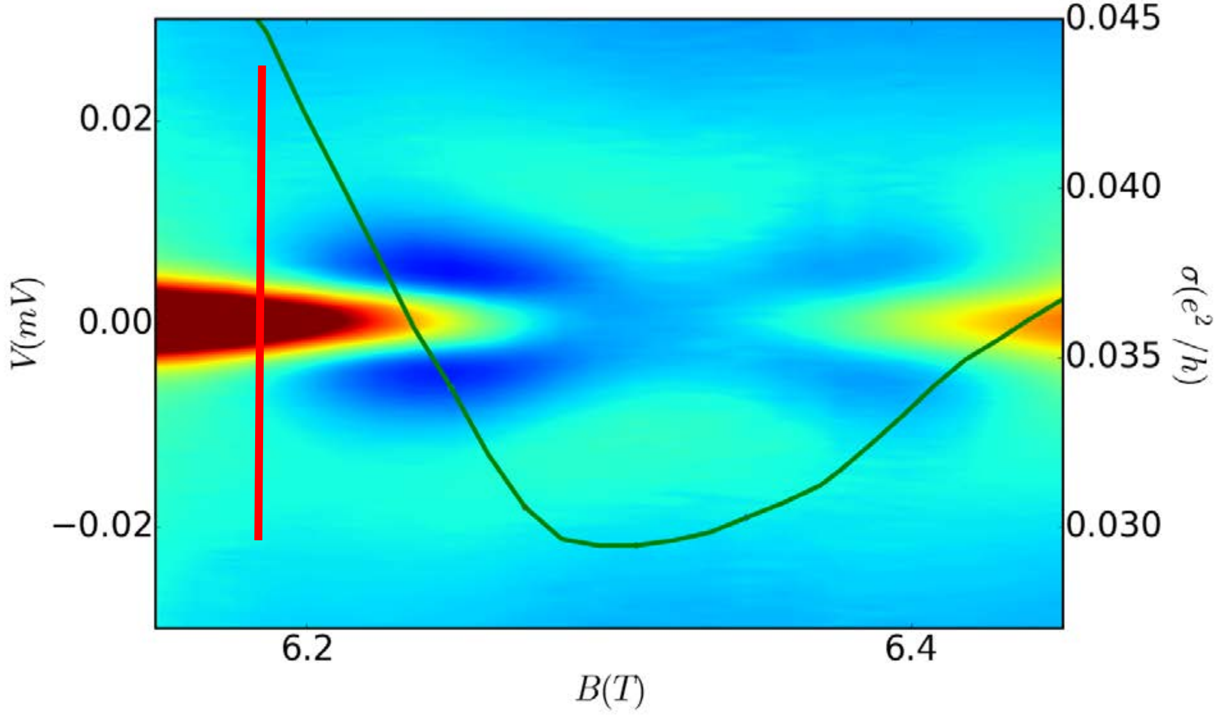
Non linear transport in the 5/2 state

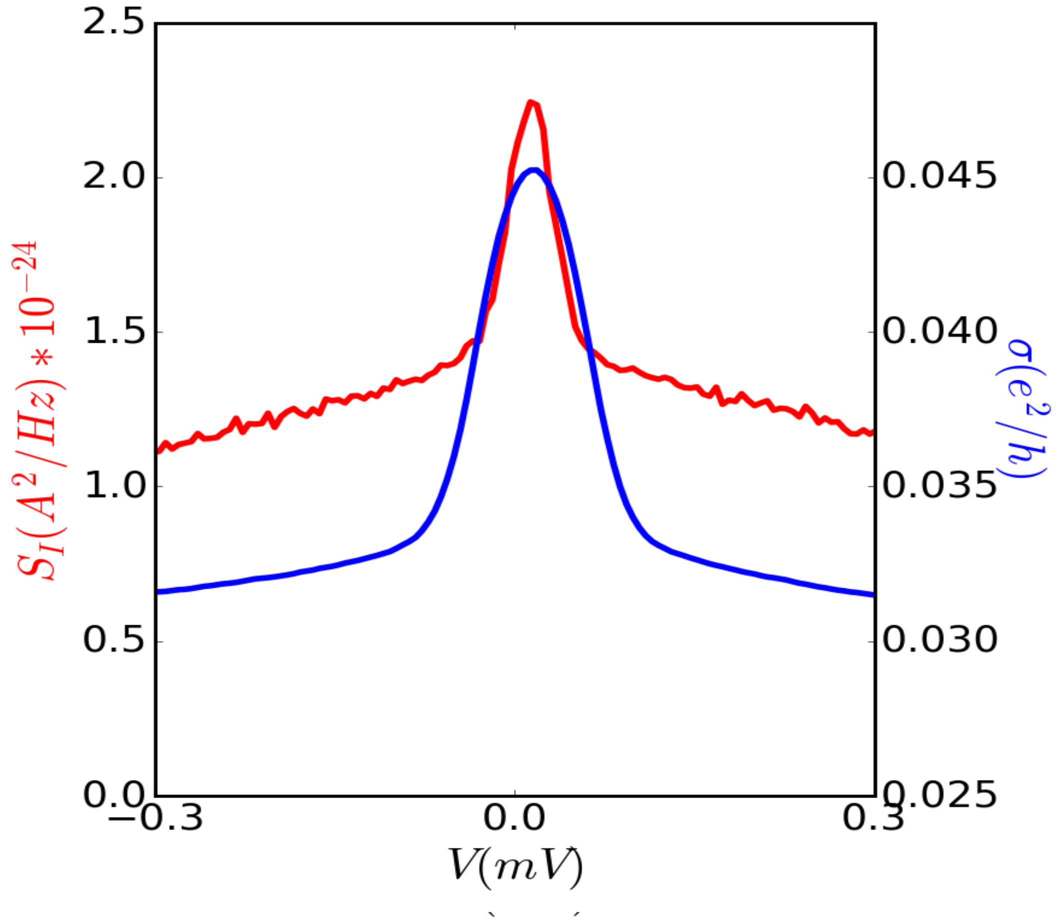
Differential conductance ($\partial I / \partial V$)



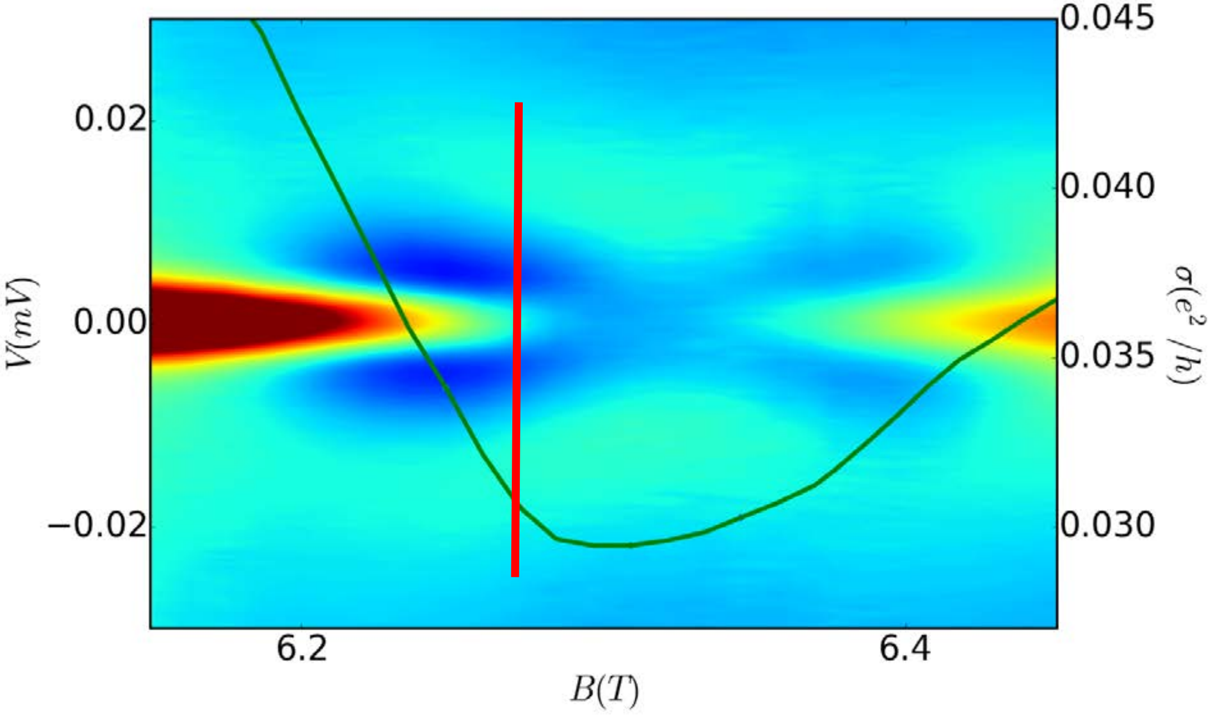


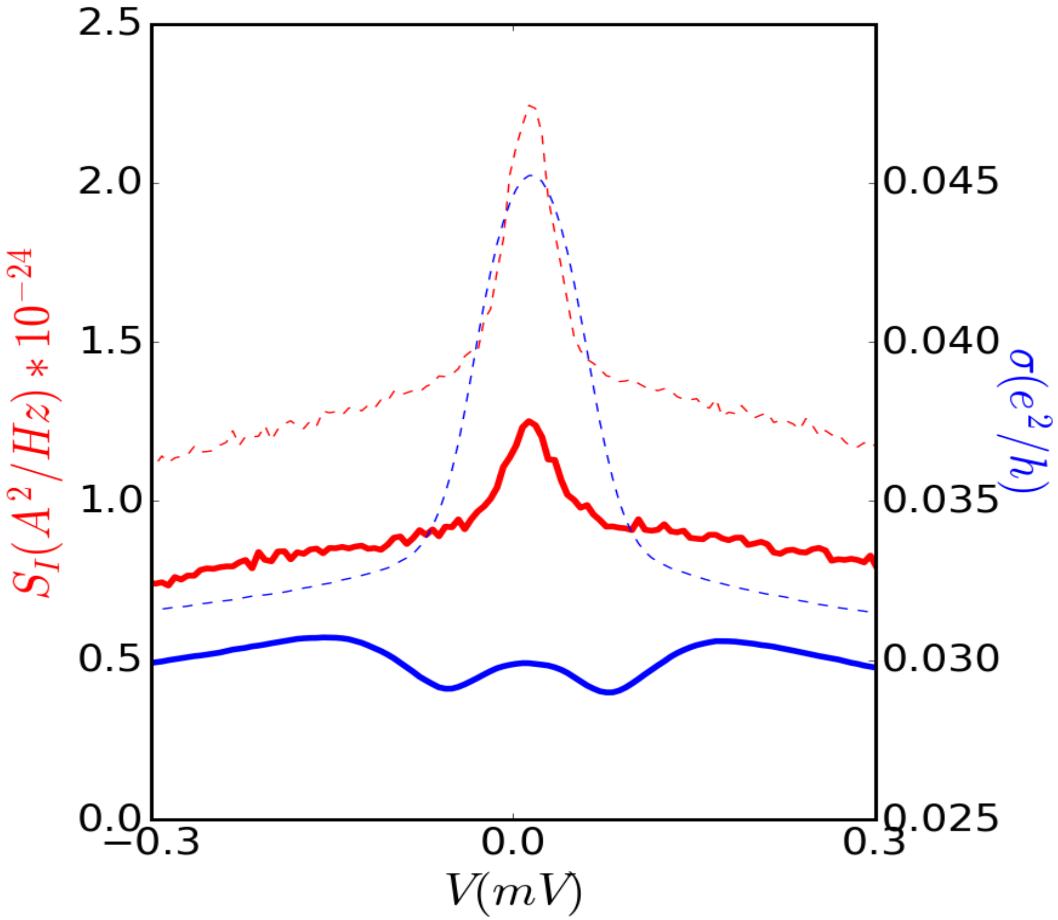
Noise in the 5/2 state



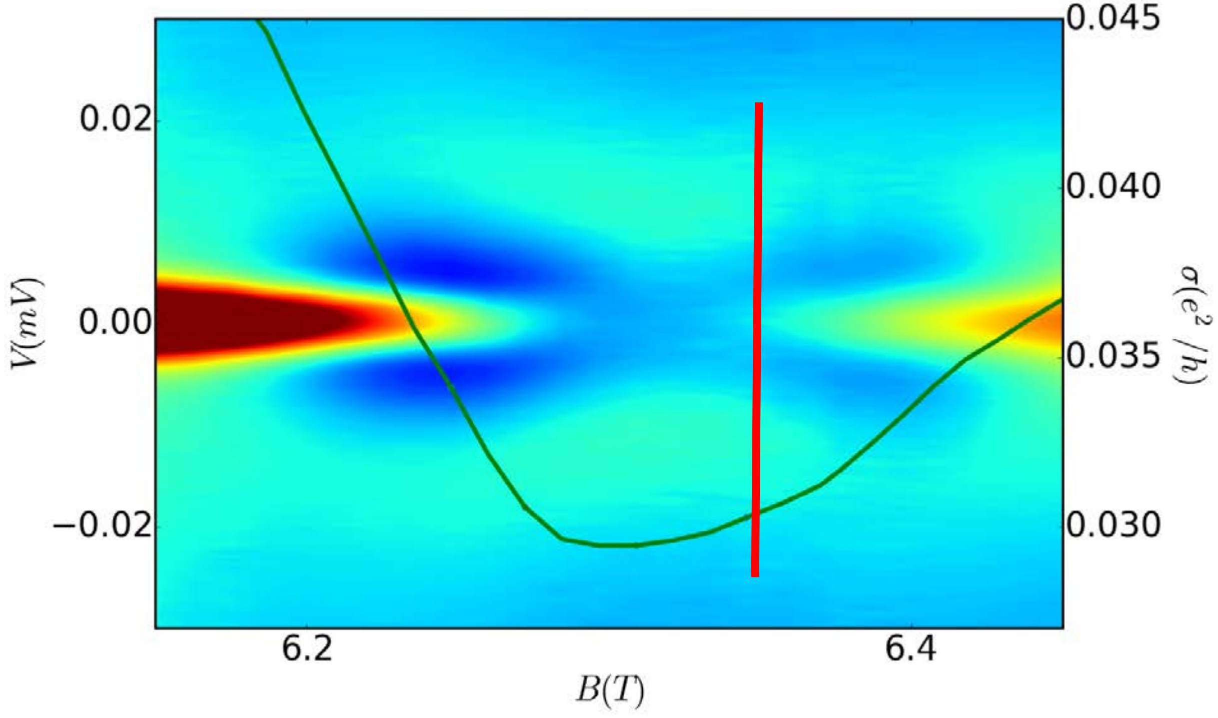


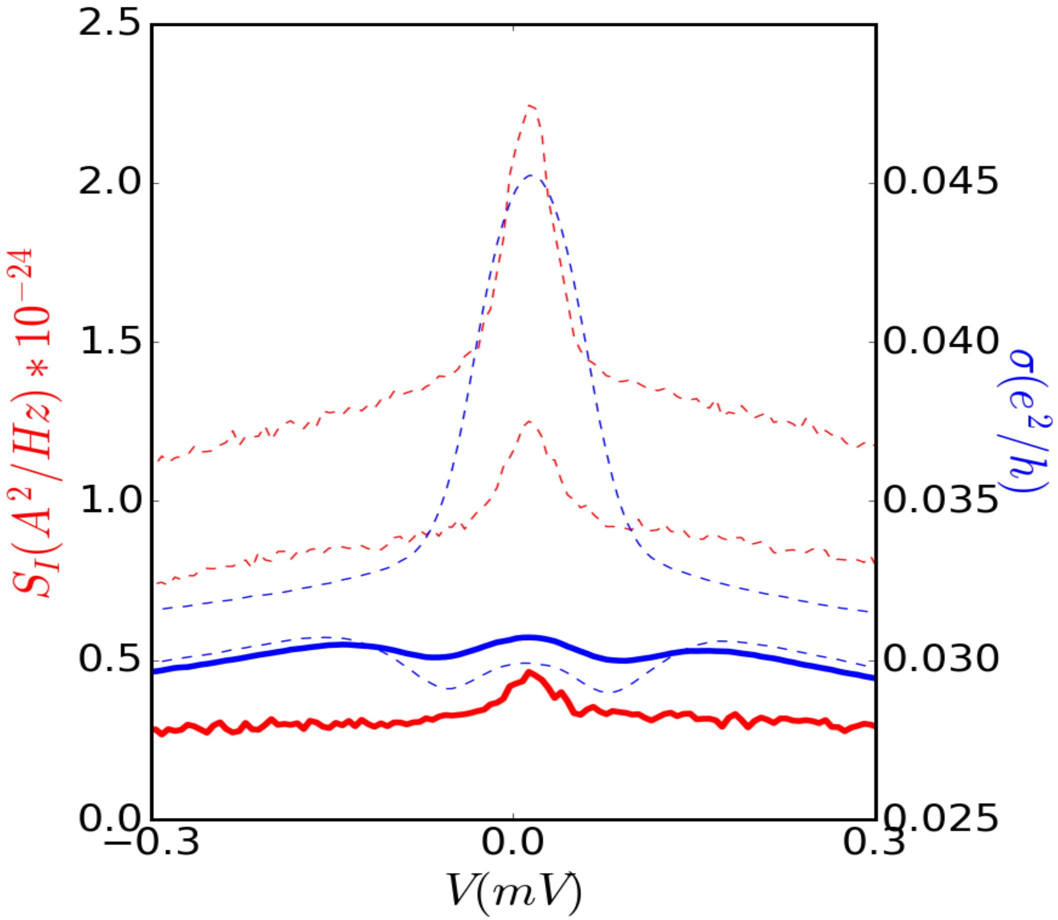
Noise in the 5/2 state





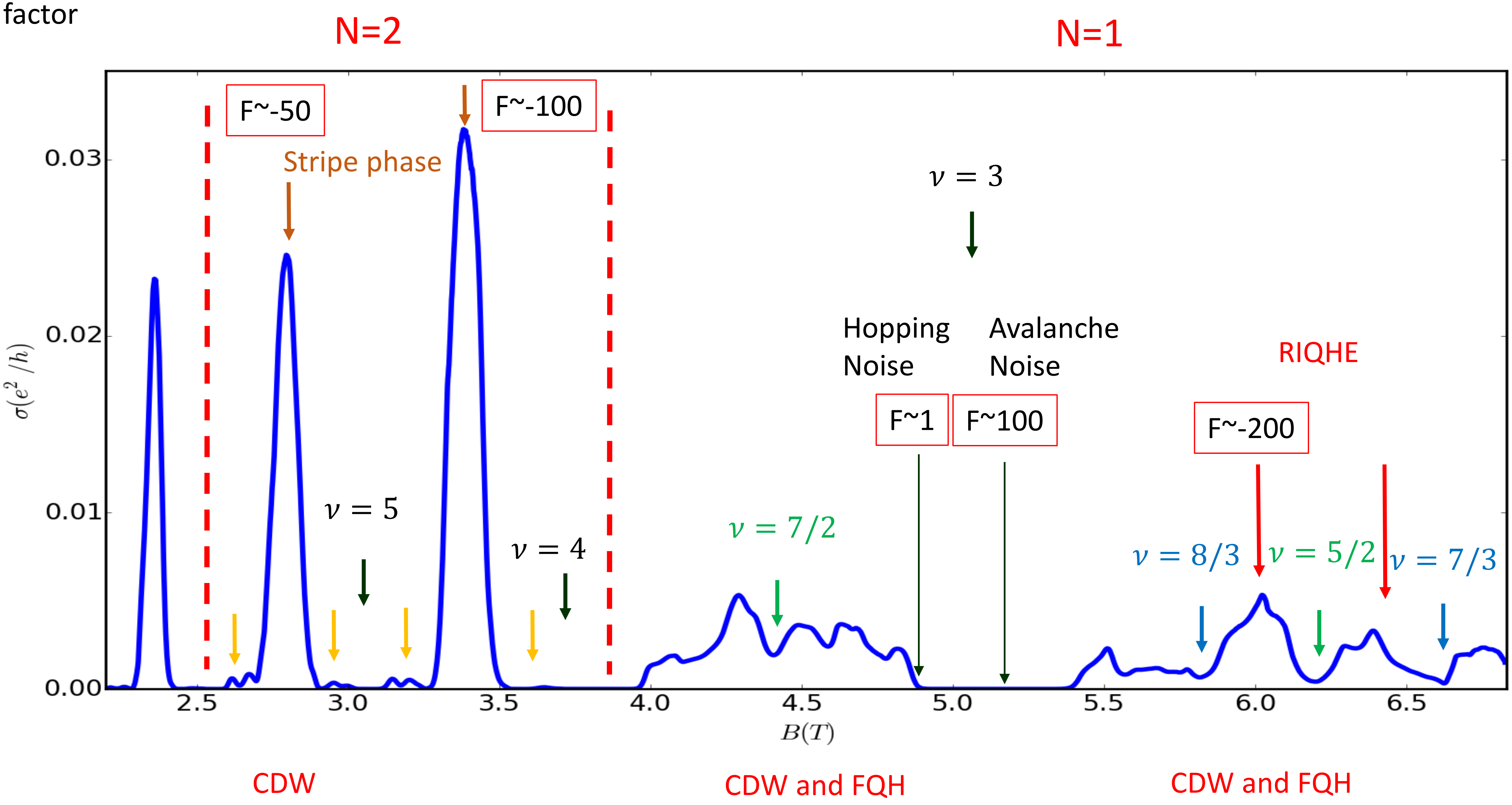
Noise in the 5/2 state





Summary

F=fano factor

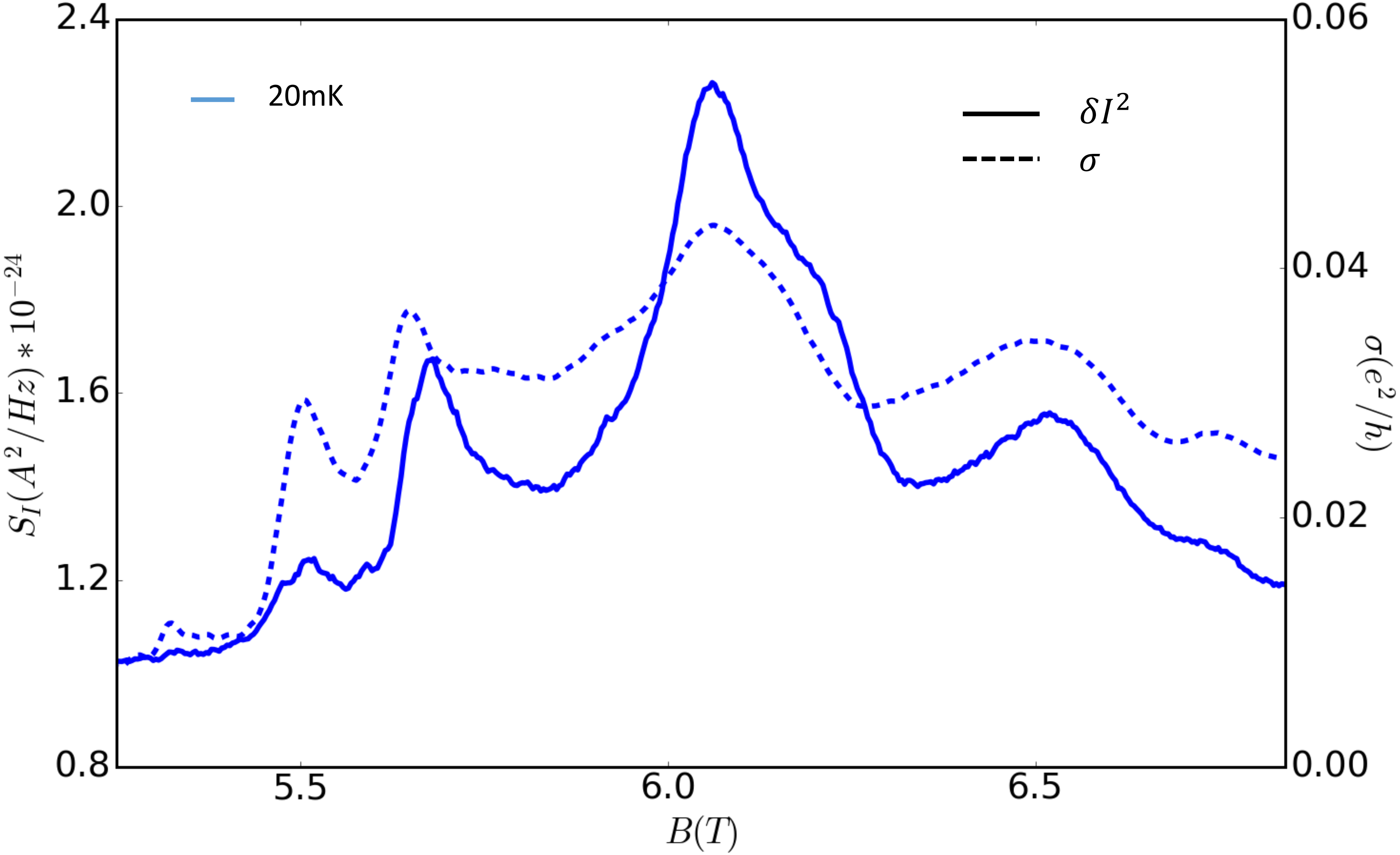


Conclusion

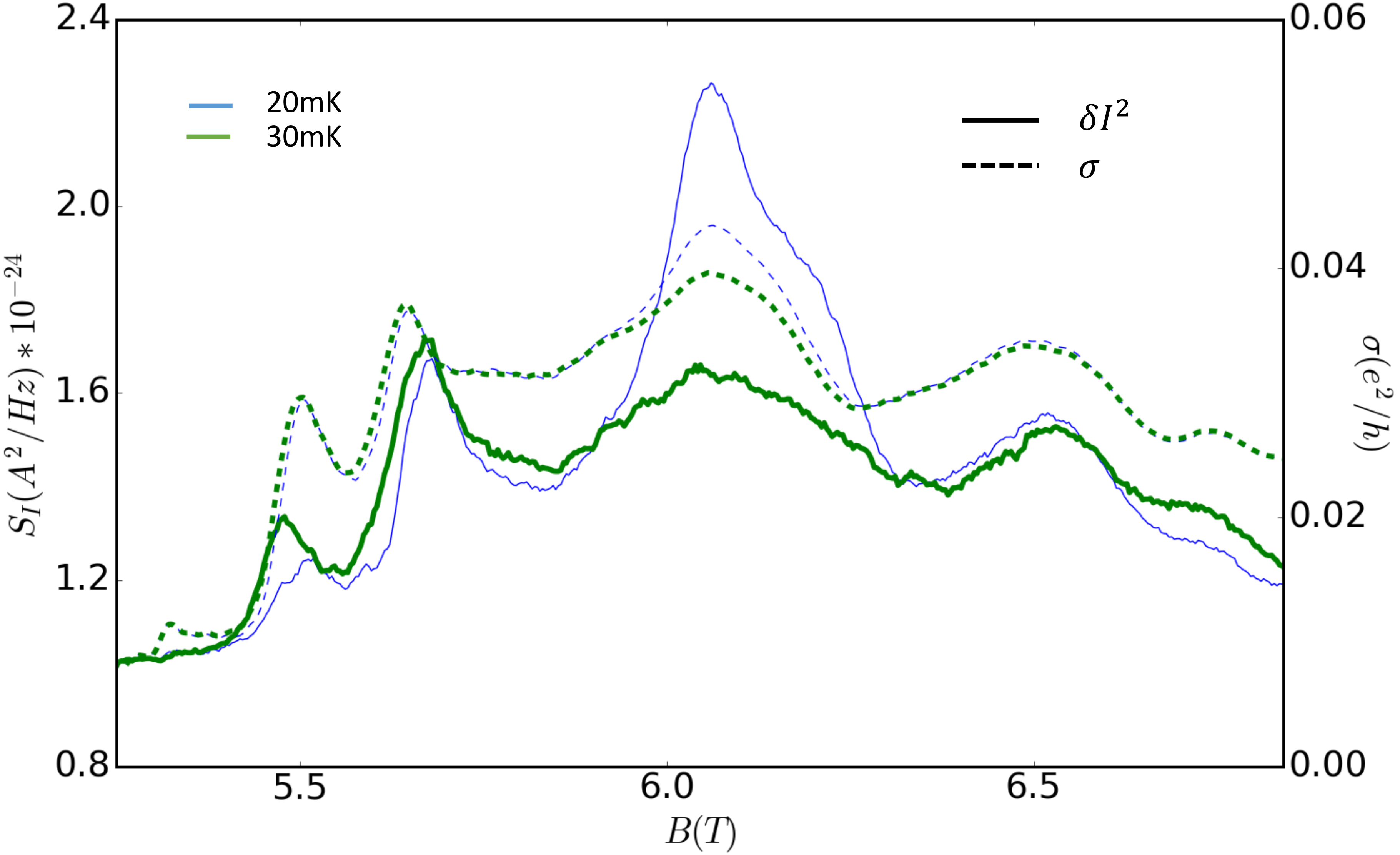
- First differential conductance and noise measured in FQHE in Corbino geometry
- crystal phases have a special signature in noise
- Evidence that there is a cohabitation between crystal phases and fractional phases in the SLL from the differential conductance and noise measurements

Thank you for your attention!

Second Landau level at different temperatures



Second Landau level at different temperatures



Second Landau level at different temperatures