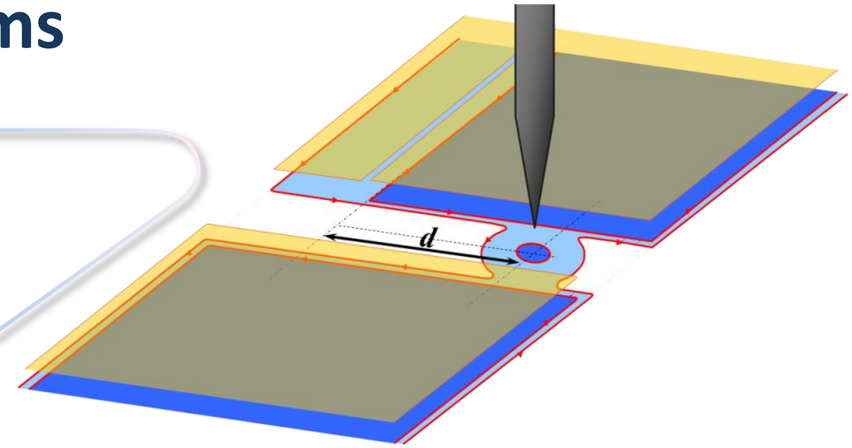
Imaging Fractional Incompressible Stripes in Integer Quantum Hall Systems



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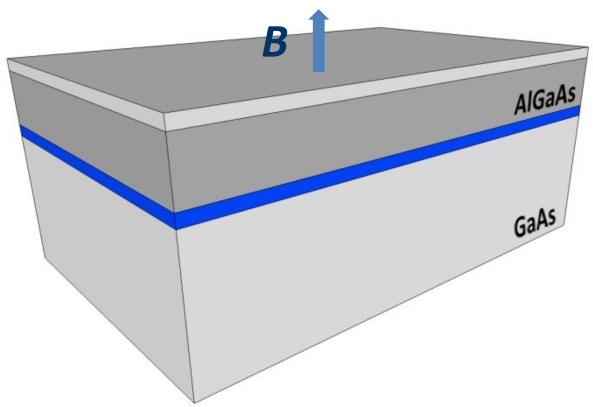
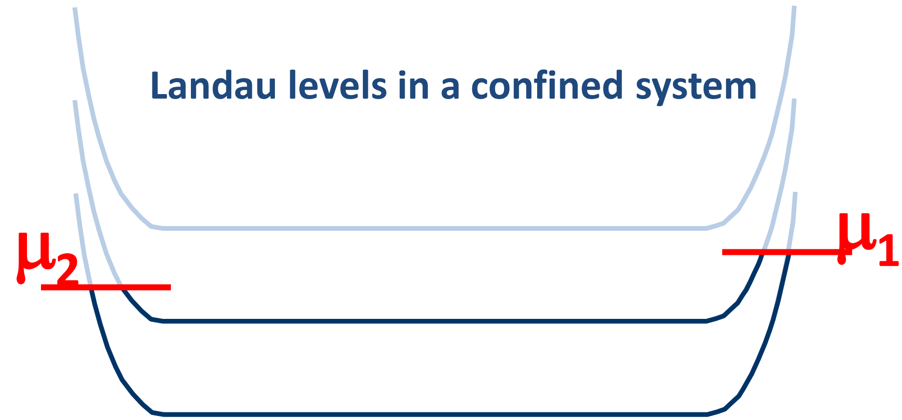
The non-interacting picture of the QH effect

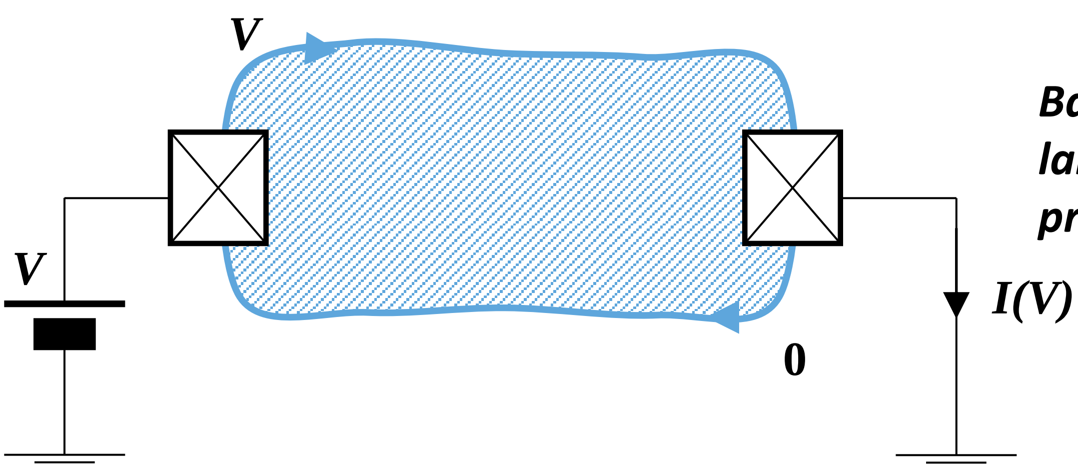


2DES
in high field



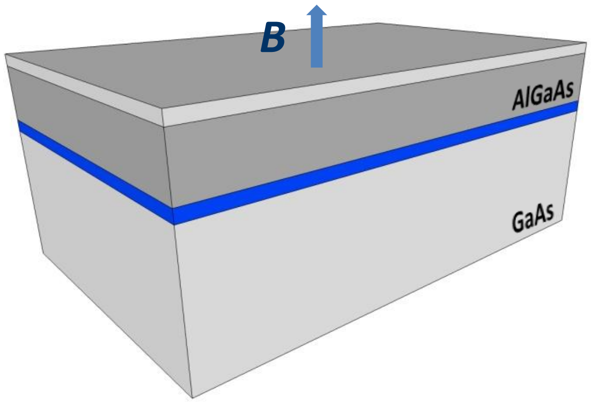
- Edge state picture:
  current is carried by chiral 1D channels

$$G \equiv \frac{dI}{dV} = \nu \frac{e^2}{h}$$



Backscattering is suppressed due to the large spatial separation between counter-propagating channels

The non-interacting picture of the QH effect



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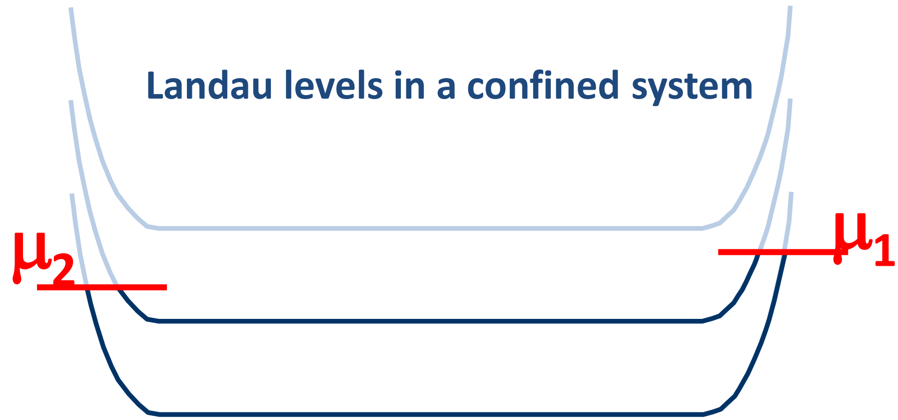

- Edge state picture:
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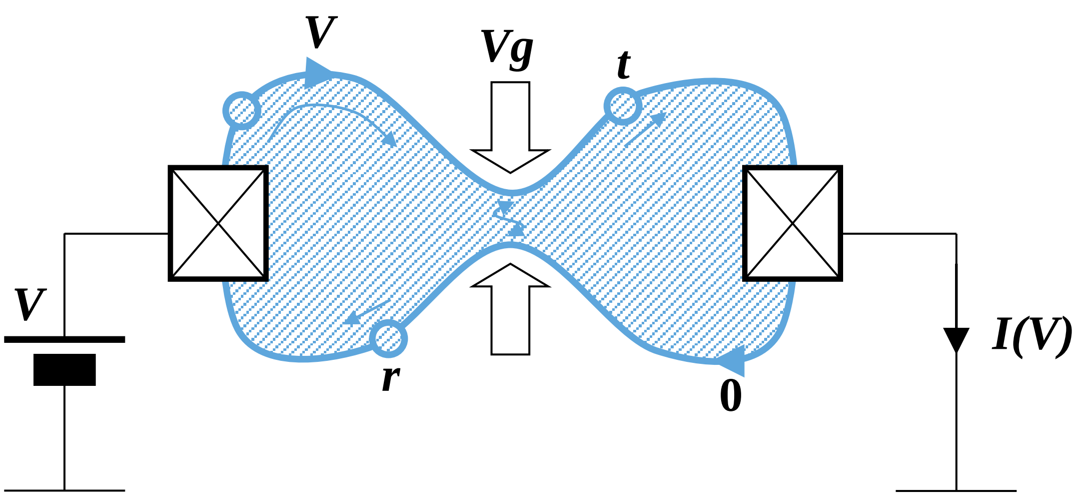


With a QPC we can intentionally induce backscattering, which provides us information about the edge properties

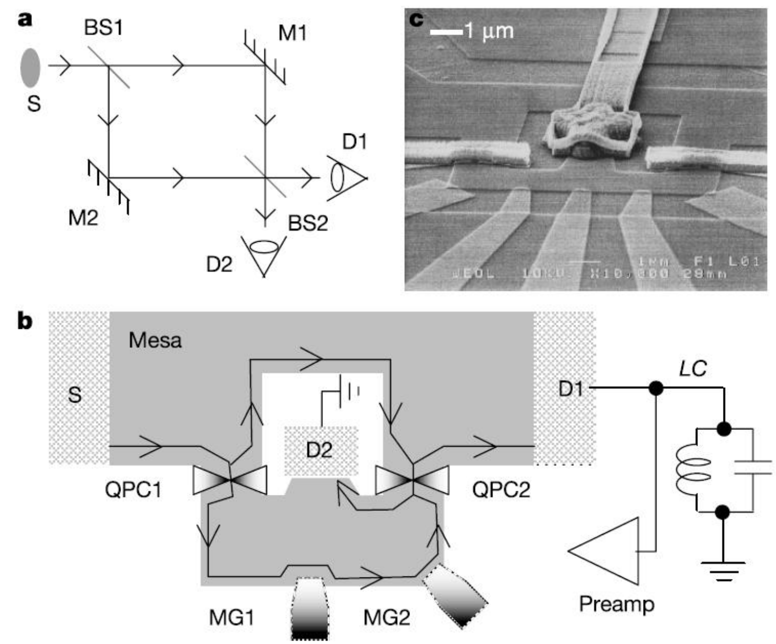
Roddaro et al.: PRL **90** (2003) 046805
Roddaro et al.: PRL **93** (2004) 046801
Roddaro et al.: PRL **95** (2005) 156804
Roddaro, Paradiso et al.: PRL **103** (2009) 016802

Edge channel-based interferometers

The very large coherence length has been exploited to implement complex interferometers as the electronic Mach-Zehnder.

An electronic Mach–Zehnder interferometer

Yang Ji, Yunchul Chung, D. Sprinzak, M. Heiblum, D. Mahalu & Hadas Shtrikman



Ji *et al.*: Nature **422**, 415 (2003)

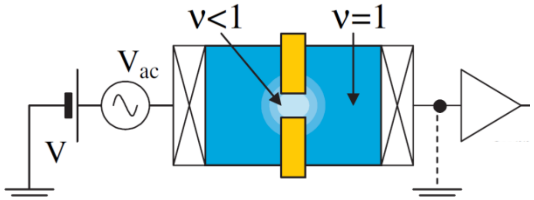
Edge channel-based interferometers

The very large coherence length has been exploited to implement complex interferometers as the electronic Mach-Zehnder.

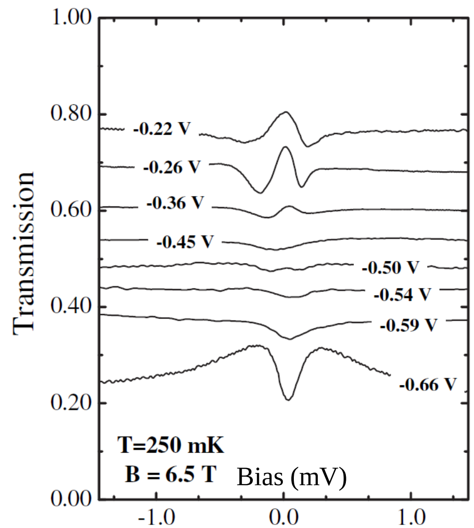
Puzzle: internal structure of edge seems to play no role here

Role of the inner edge structure?

Roddaro *et al.*: experiments on QPCs revealed signatures of **fractional components** in "simple" **integer channels**



PRL **95**, 156804 (2005)



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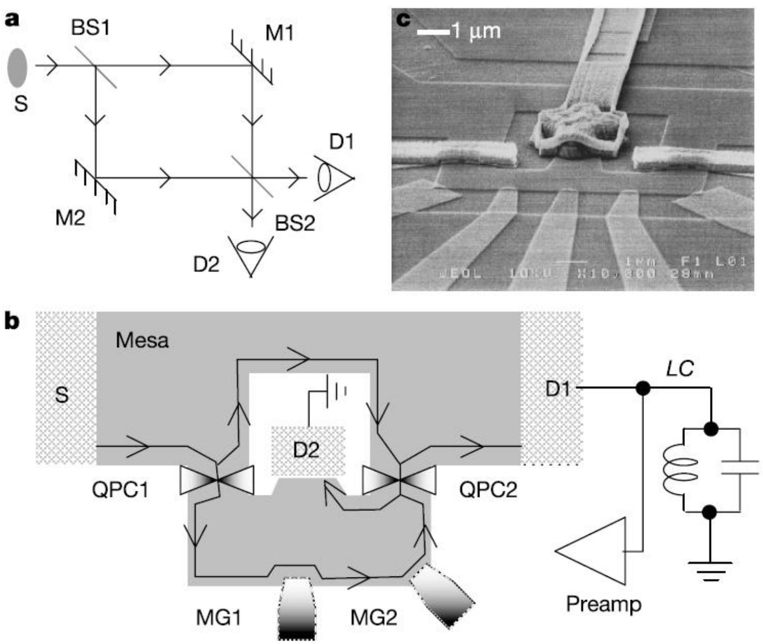


Ji *et al.*: Nature **422**, 415 (2003)

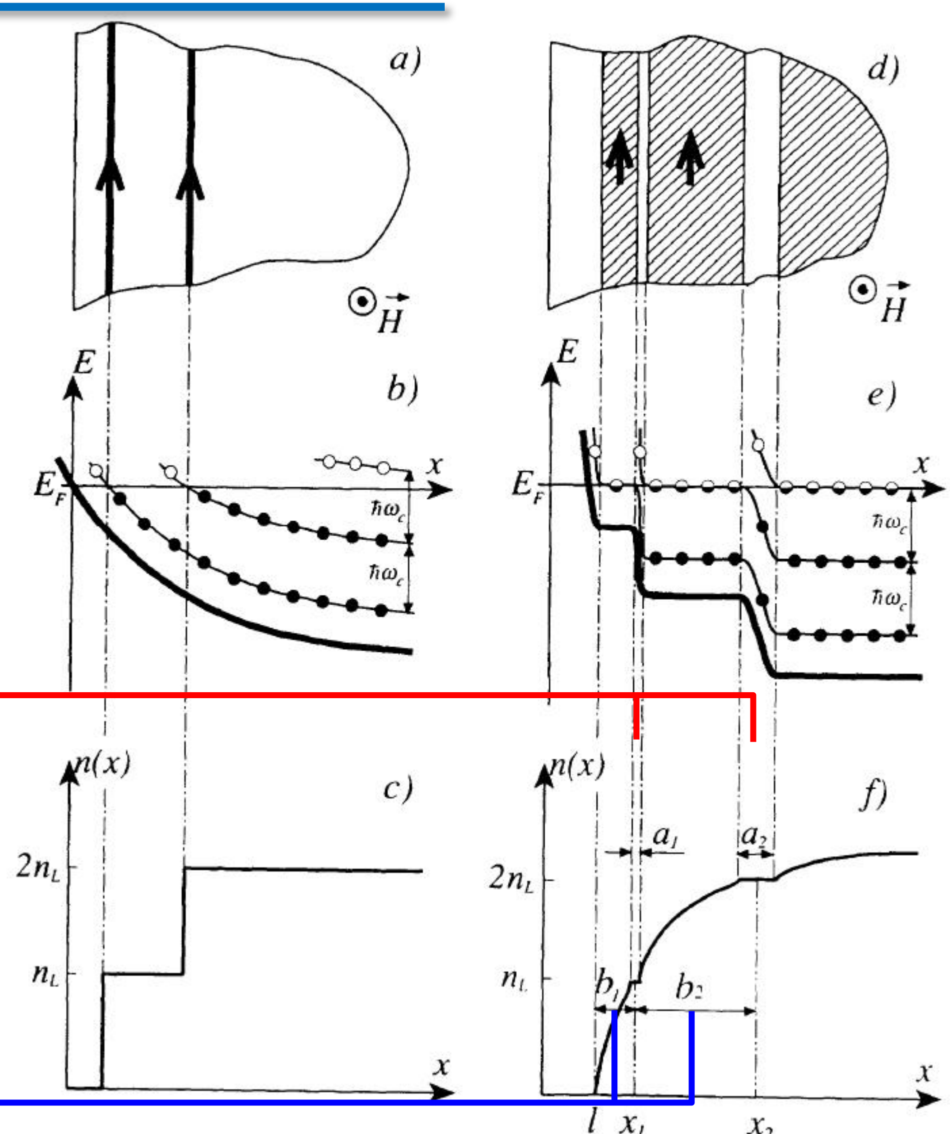
Need for spatially resolved measurements

Non-interacting VS interacting picture

• The self consistent potential due to e-e interactions modifies the edge structure

•For any realistic potential the density goes smoothly to zero.

•Alternating compressible and incompressible stripes arise at the sample edge



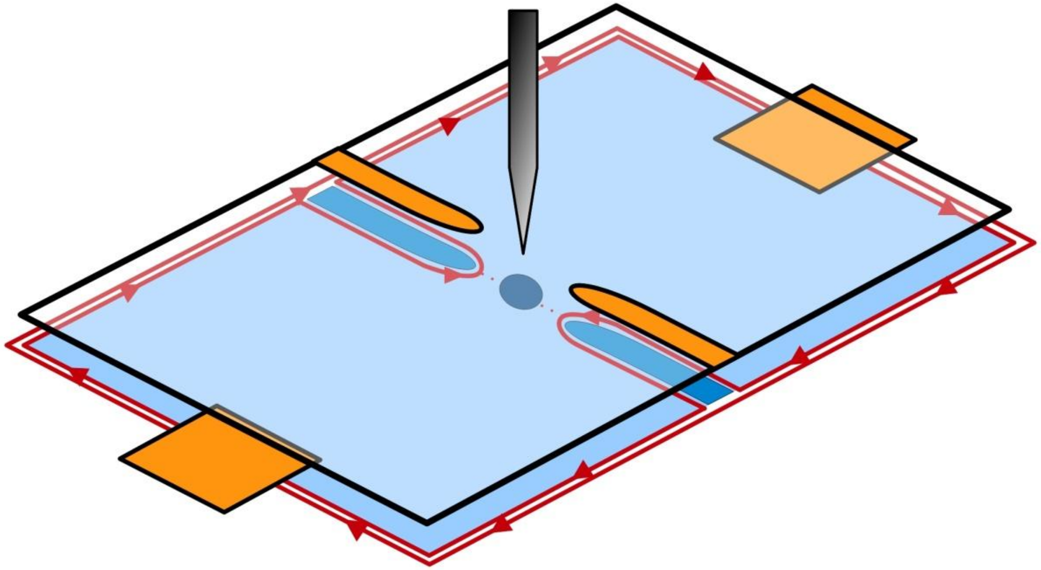
Incompressible stripes:
•The electron density is constant
•The potential has a jump

Compressible stripes:
•The electron density has a jump
•The potential is constant

D. B. Chklovskii *et al.*: PRB **46** (1992) 4026.

Edge channel tomography by SGM

SGM technique: we select individual channels from the edge of a quantized 2DEG, we send them to the constriction and make them backscatter with the biased SGM tip.



- **Bulk filling factor ν=4**
- **B = 3.04 T**
- **2 spin-degenerate edge channels**
- **gate-region filling factors $g_1 = g_2 = 0$**

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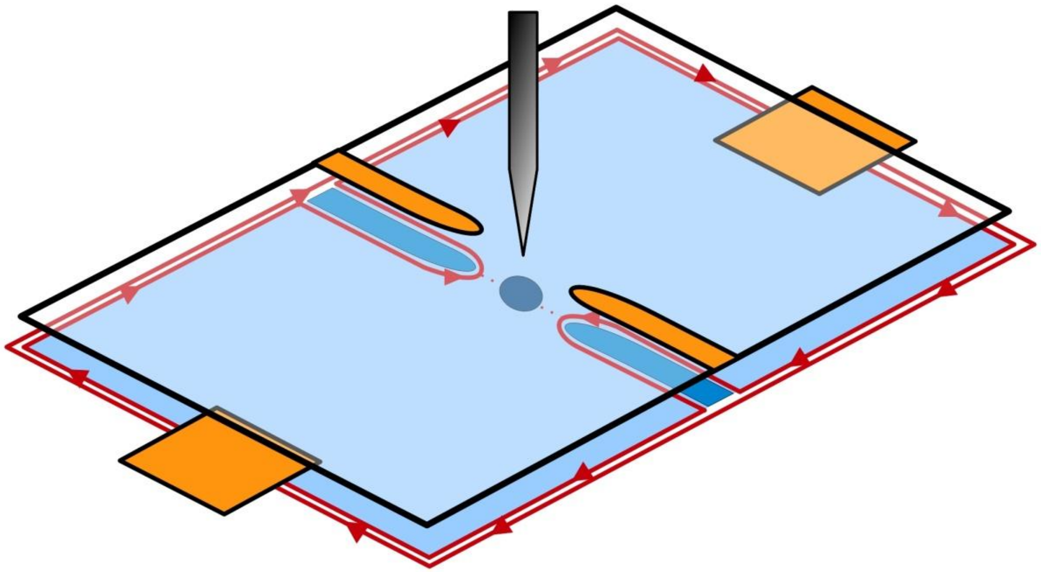

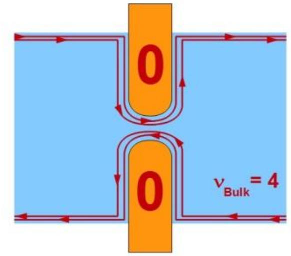

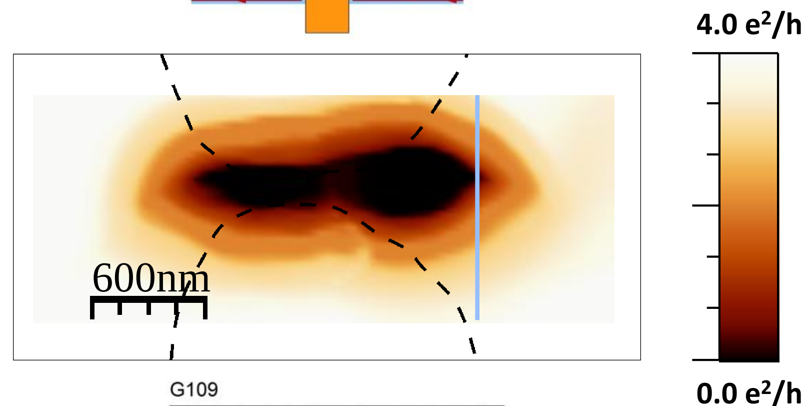

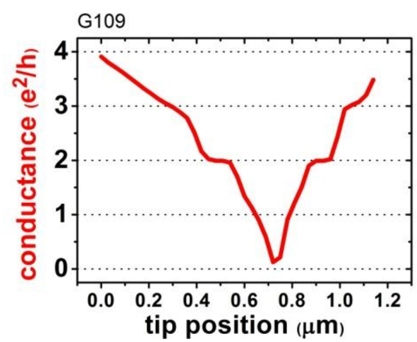

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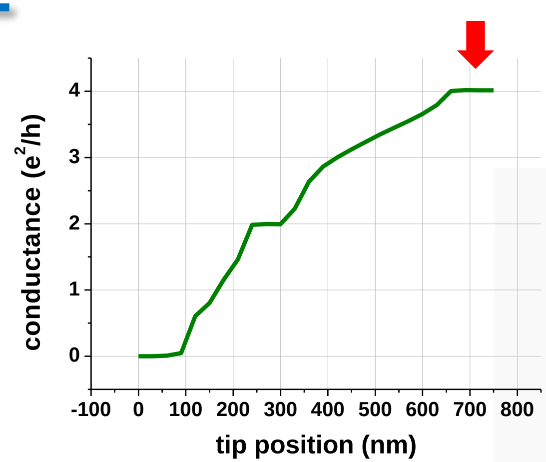
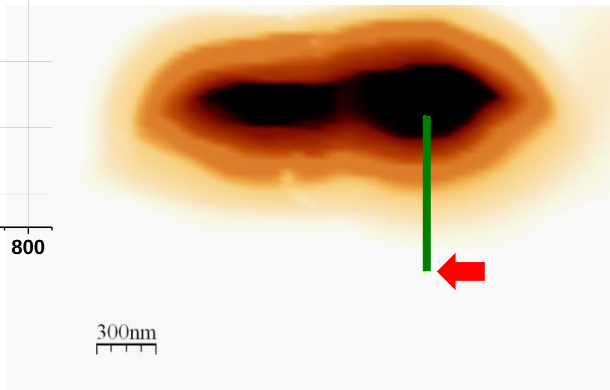
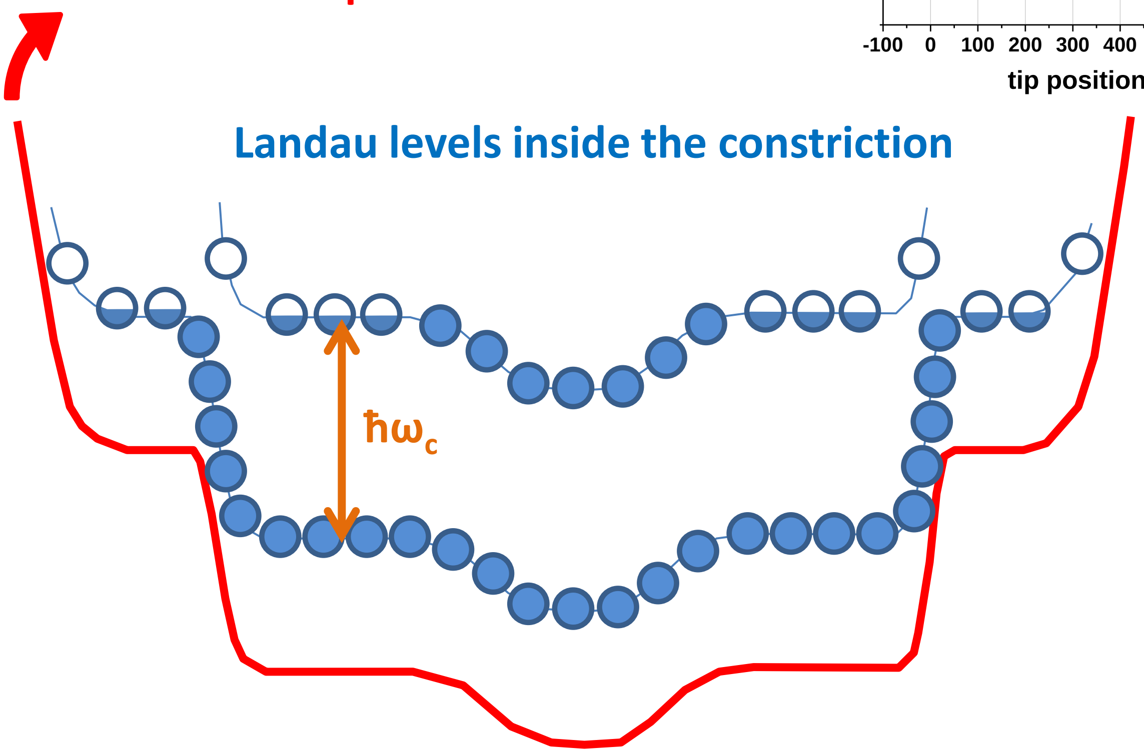
N. Paradiso *et al., Physica E 42 (2010) 1038.*

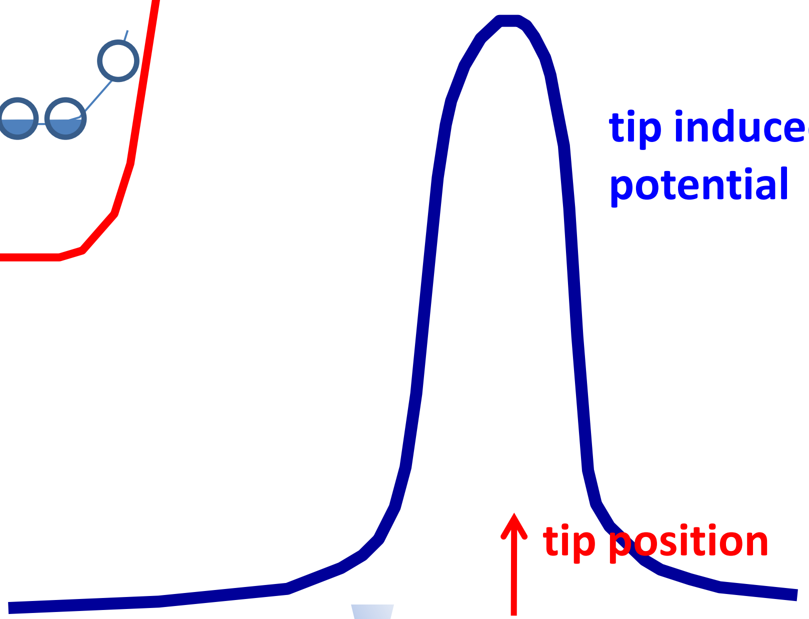
How we probe incompressible stripes





Self-consistent potential





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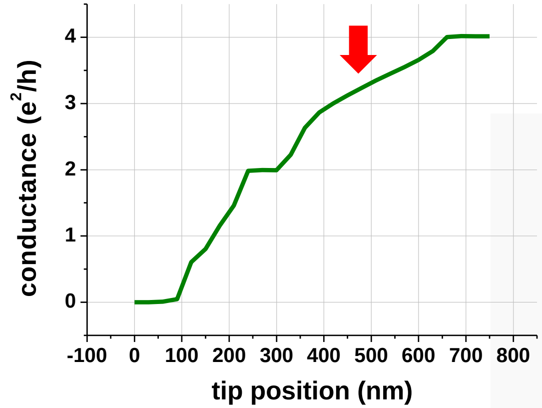

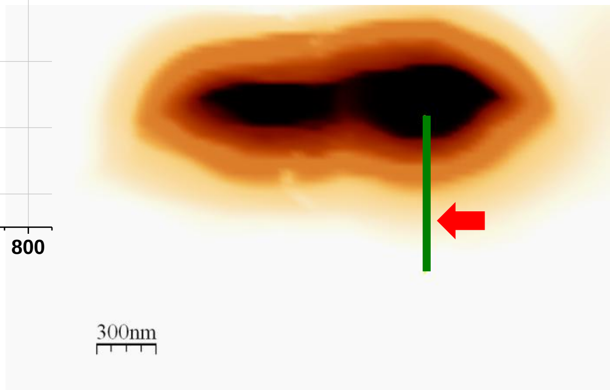

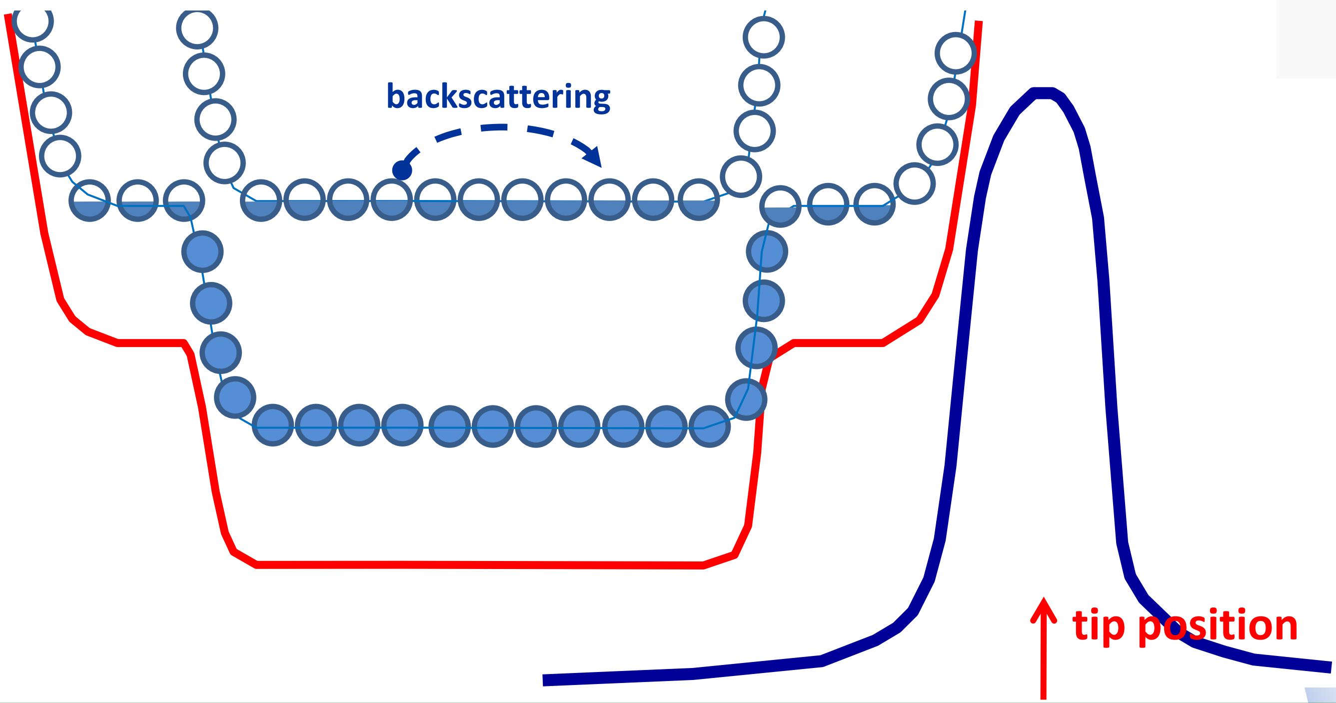

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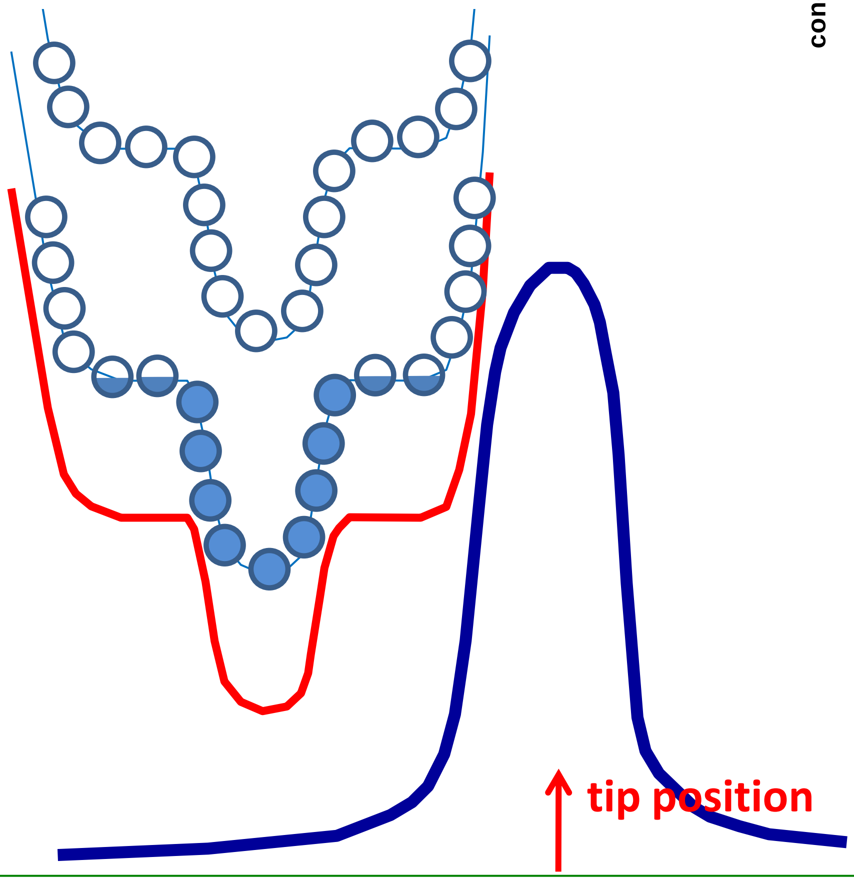
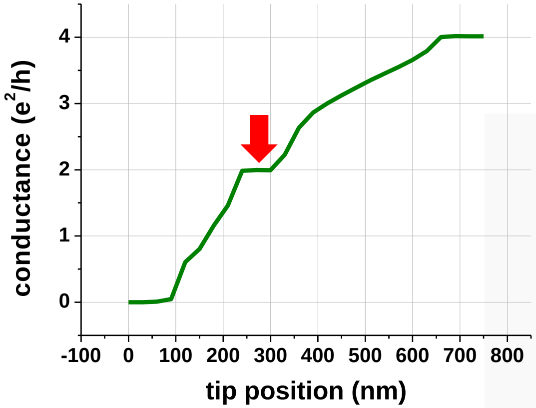
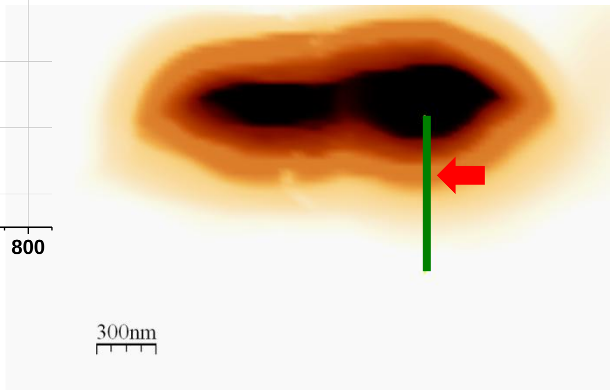
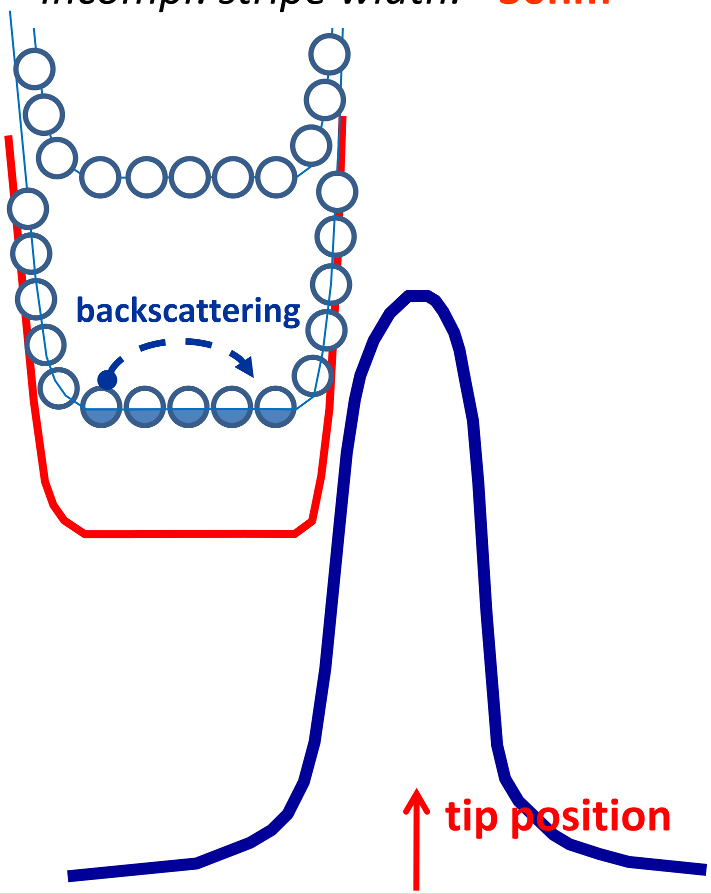


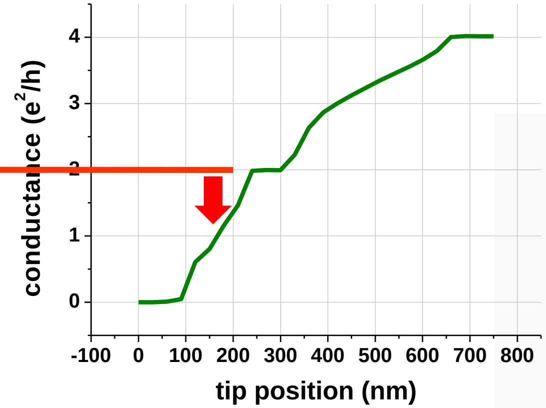


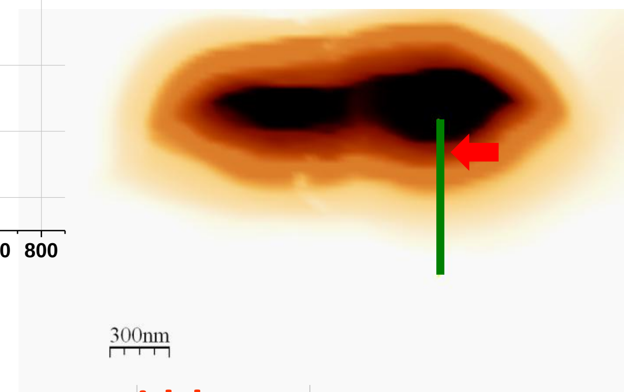


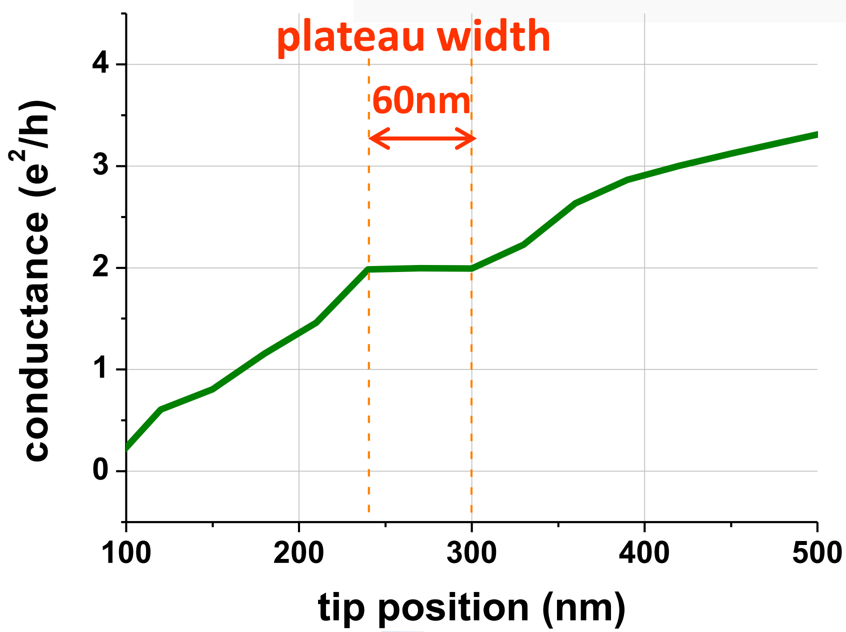
How we probe incompressible stripes

Energy gap: **ħω=5.7 meV**
Plateau width: **60 nm**
Incompr. stripe width: **≈30nm**

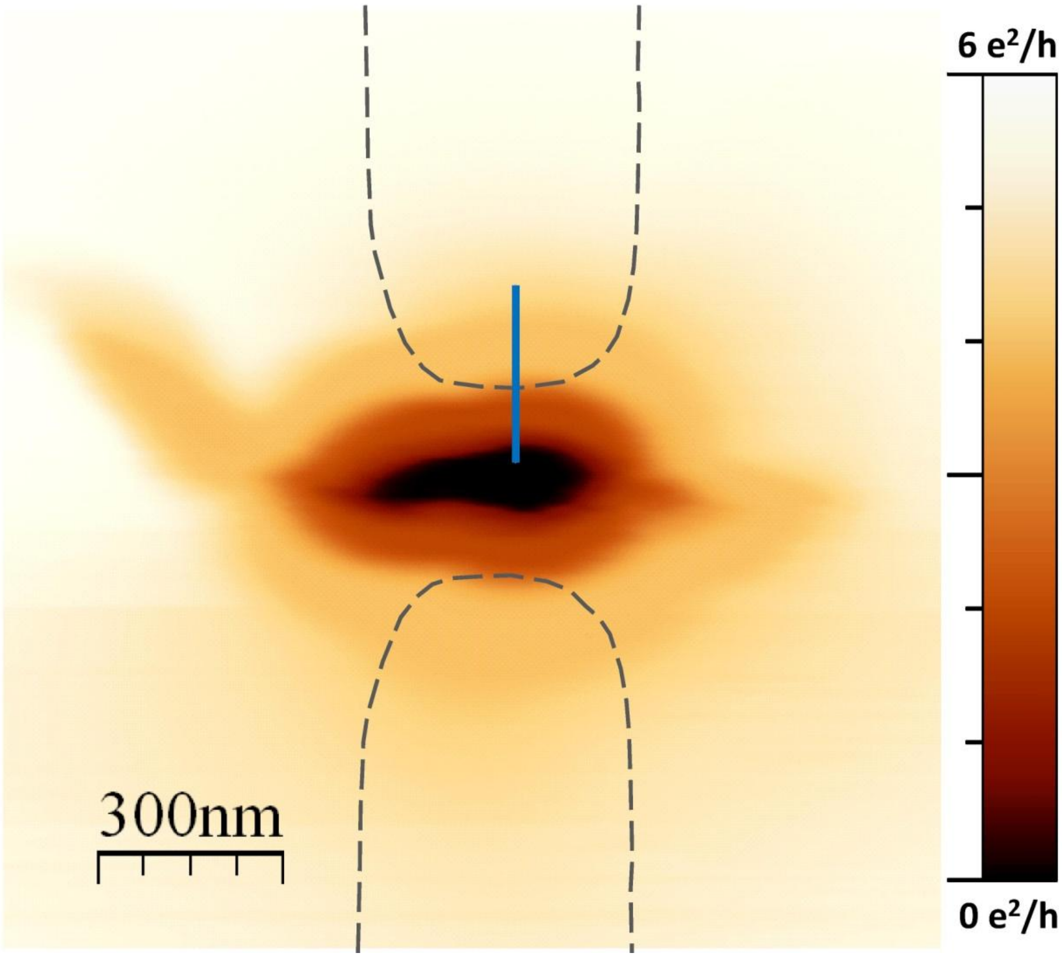


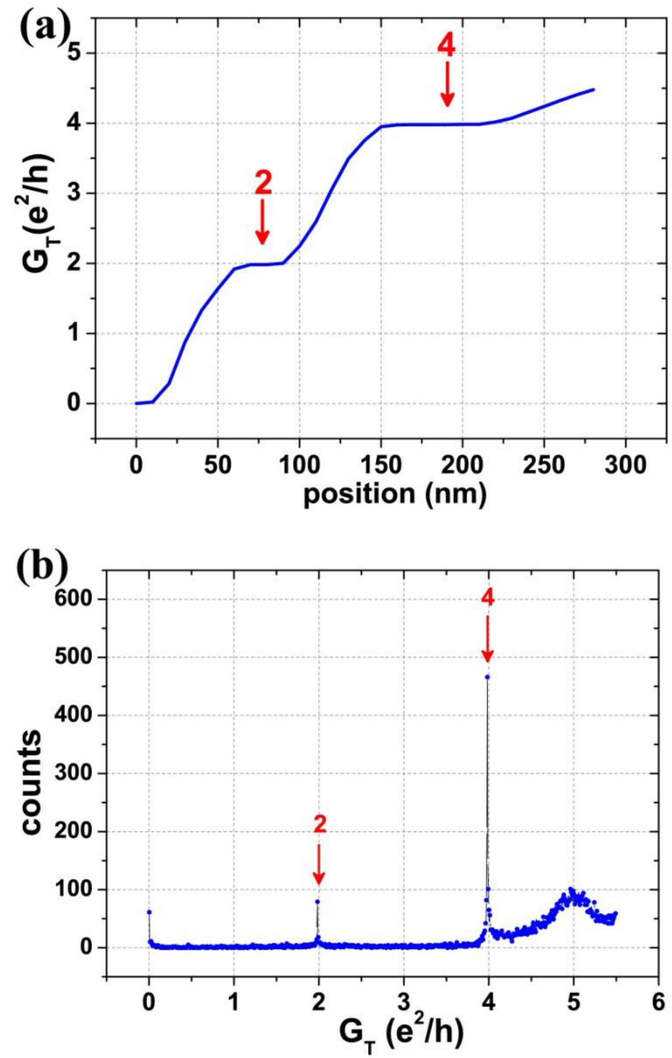






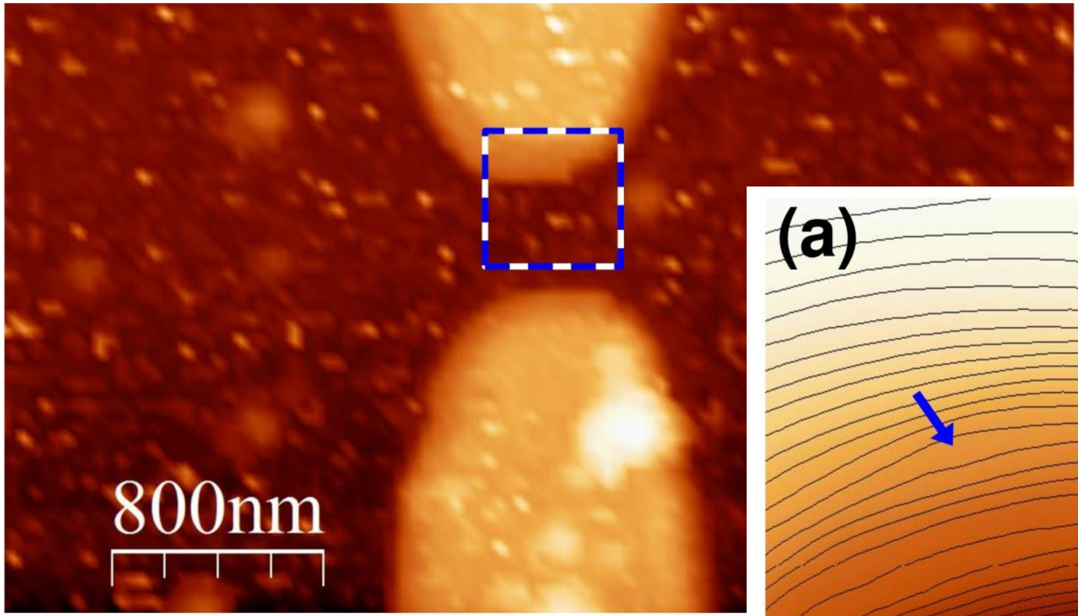
Histogram analysis

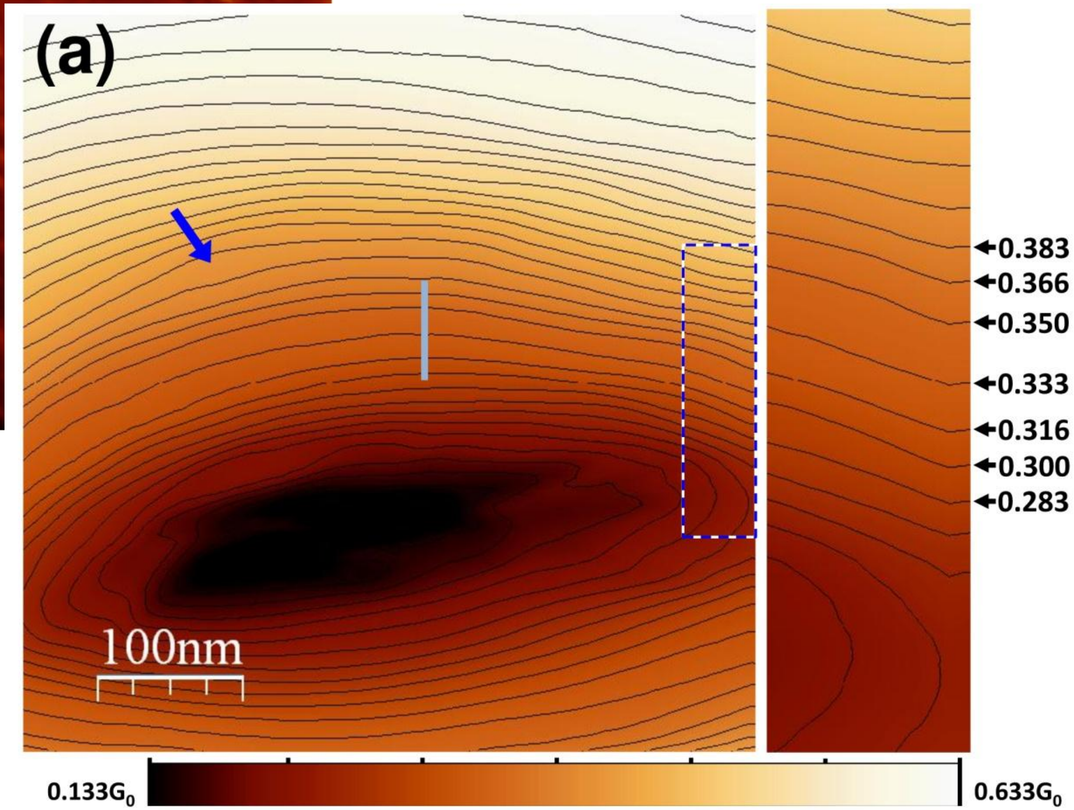




ν=6

Imaging fractional structures in integer channels (ν=1)





N. Paradiso *et al.* Phys. Rev. Lett. **108**, 246801 (2012)

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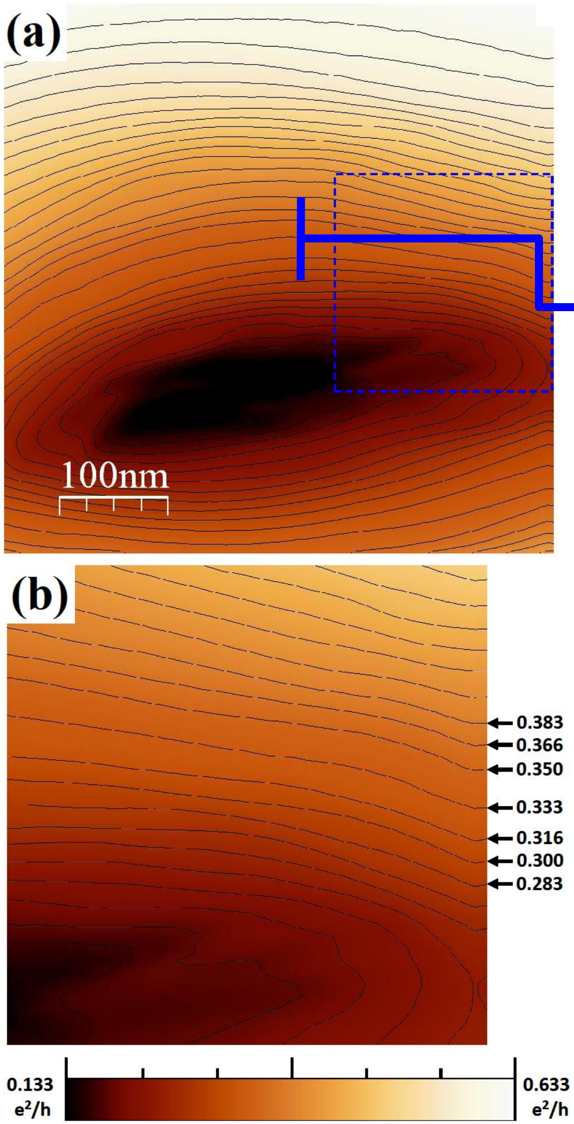
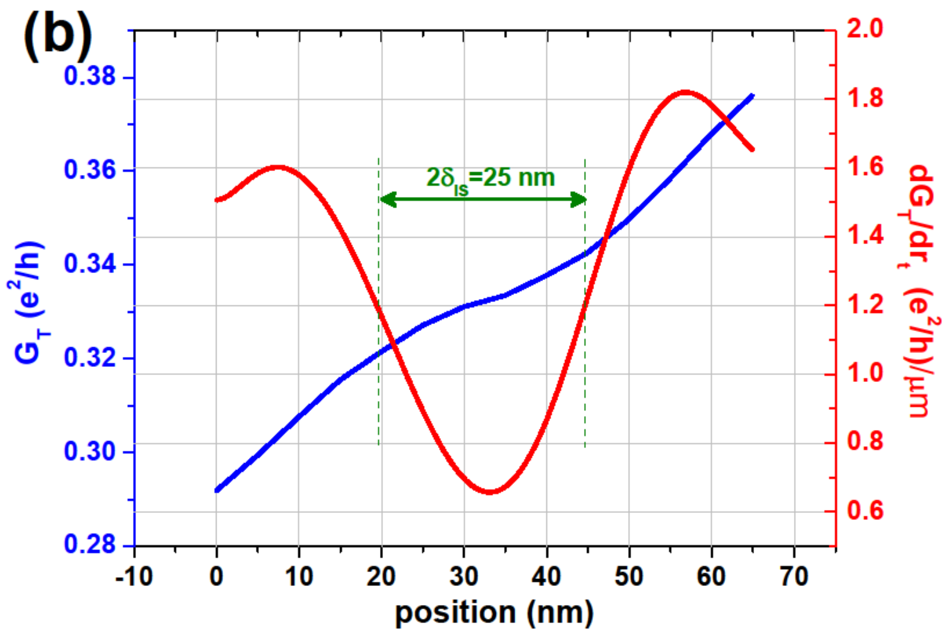


δ_{IS} ~ 12 nm



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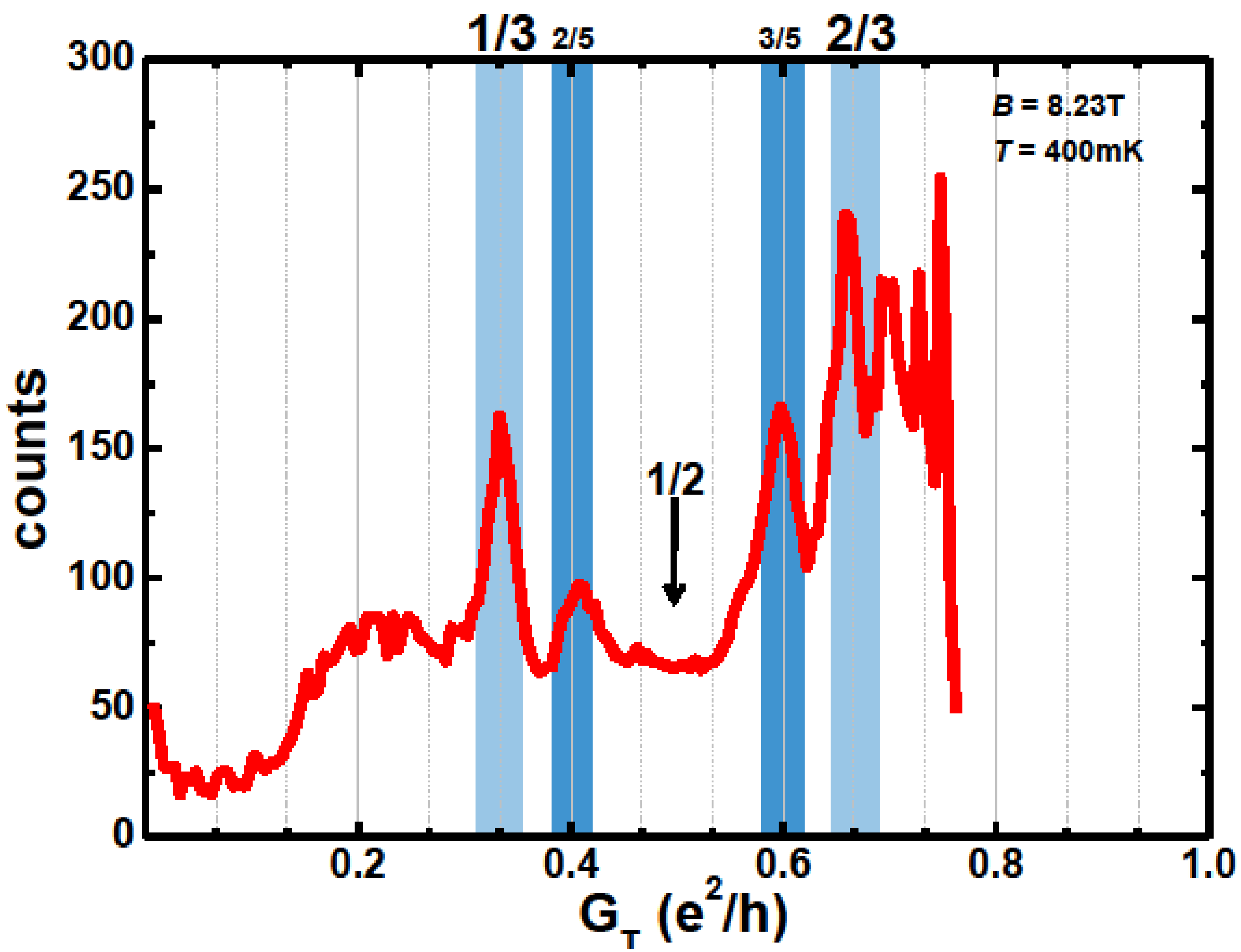

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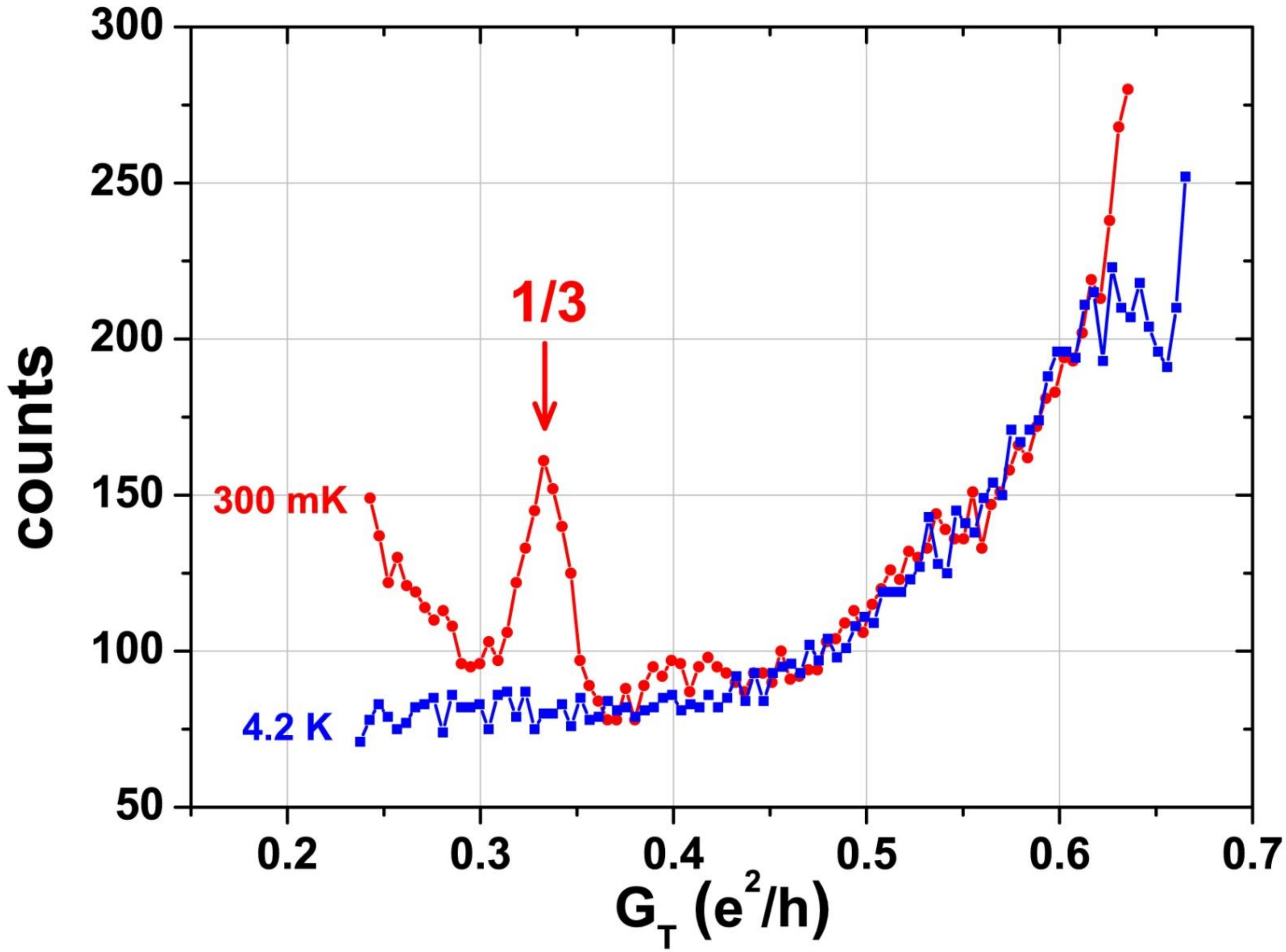
Temperature dependence of 1/3 peak in histogram



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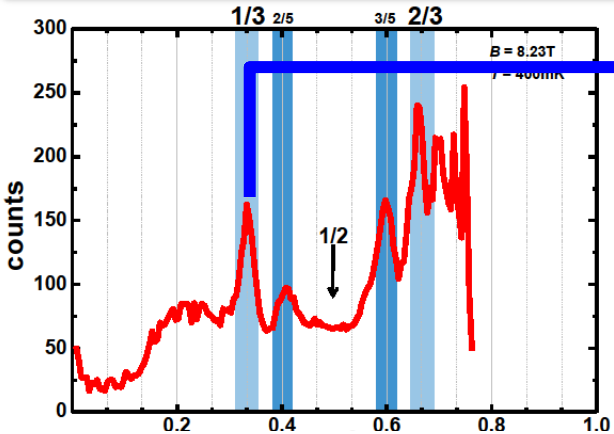
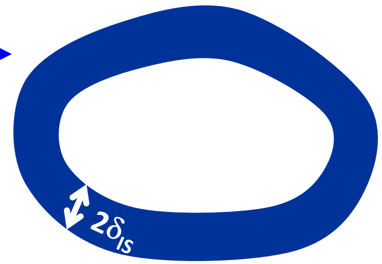
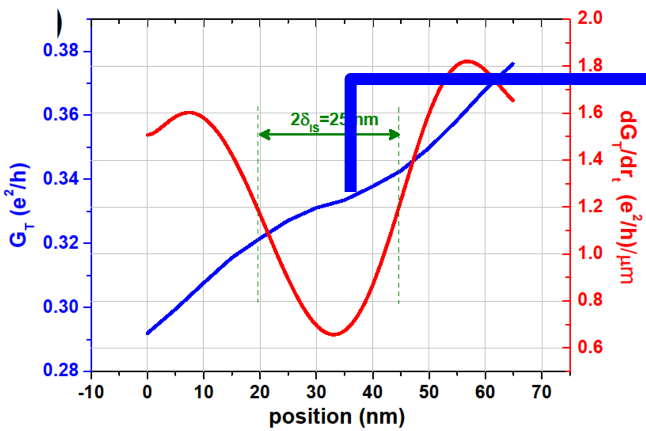
Fractional edge reconstruction





δ_{IS} determined from SGM measurements

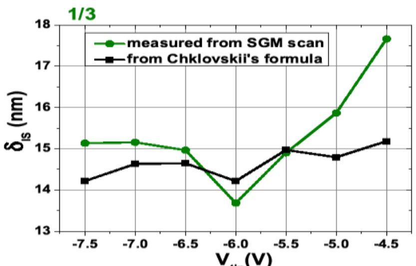
the finite range in GT defines a stripe in the SGM map

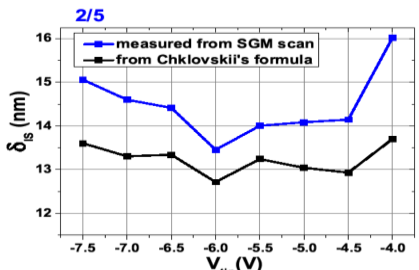


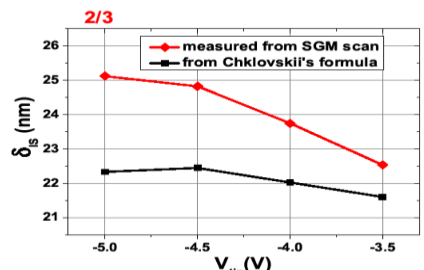
$$\frac{dn}{dr}$$

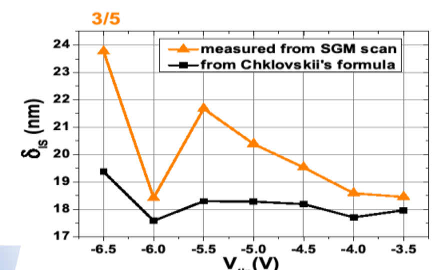
δ_{IS} determined from Chklovskii's formula

$$\delta_{IS}^2 = \frac{4\Delta\mu_f\varepsilon}{\pi^2 e^2 dn/dr|_{r=r_f}}$$



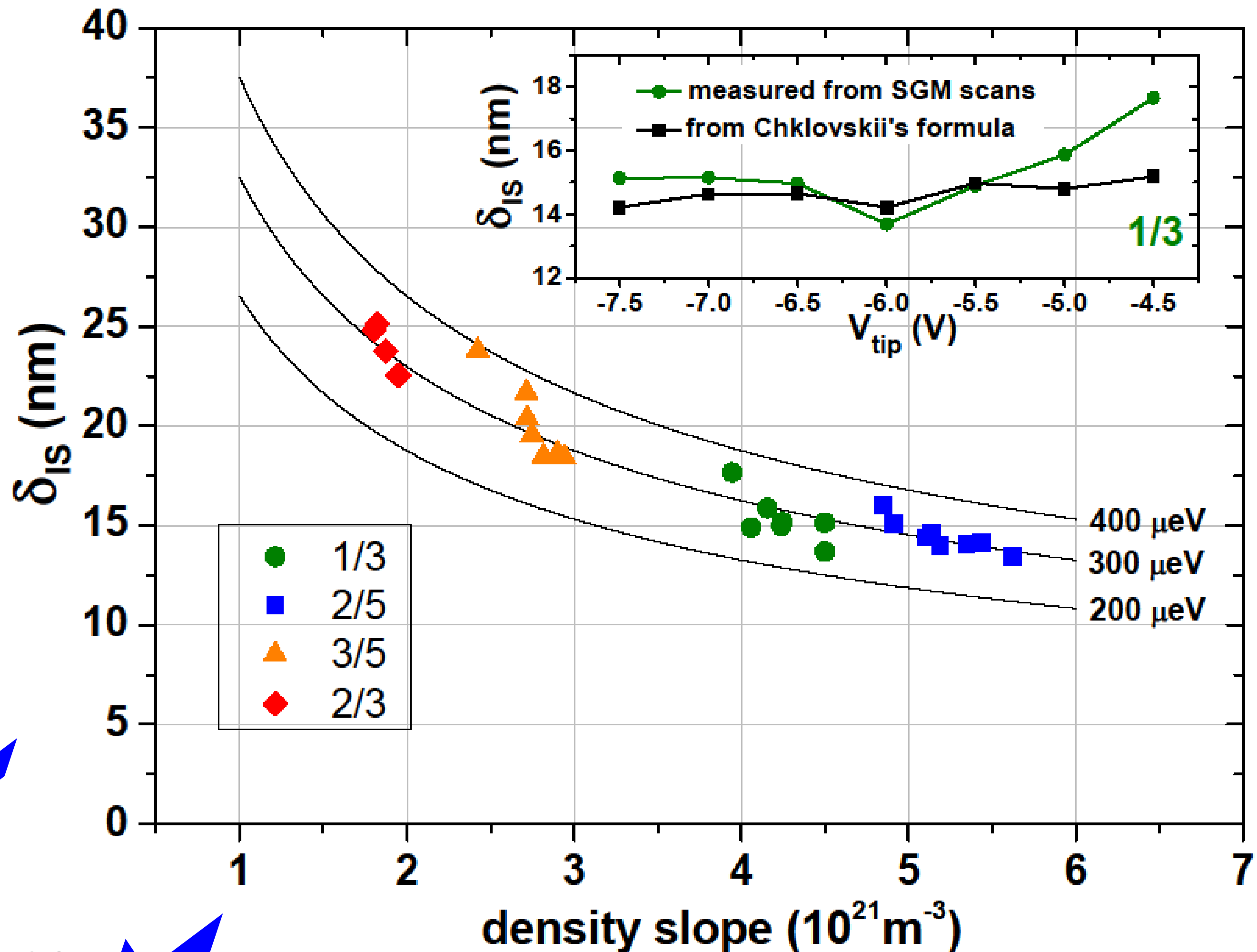






Fractional edge reconstruction

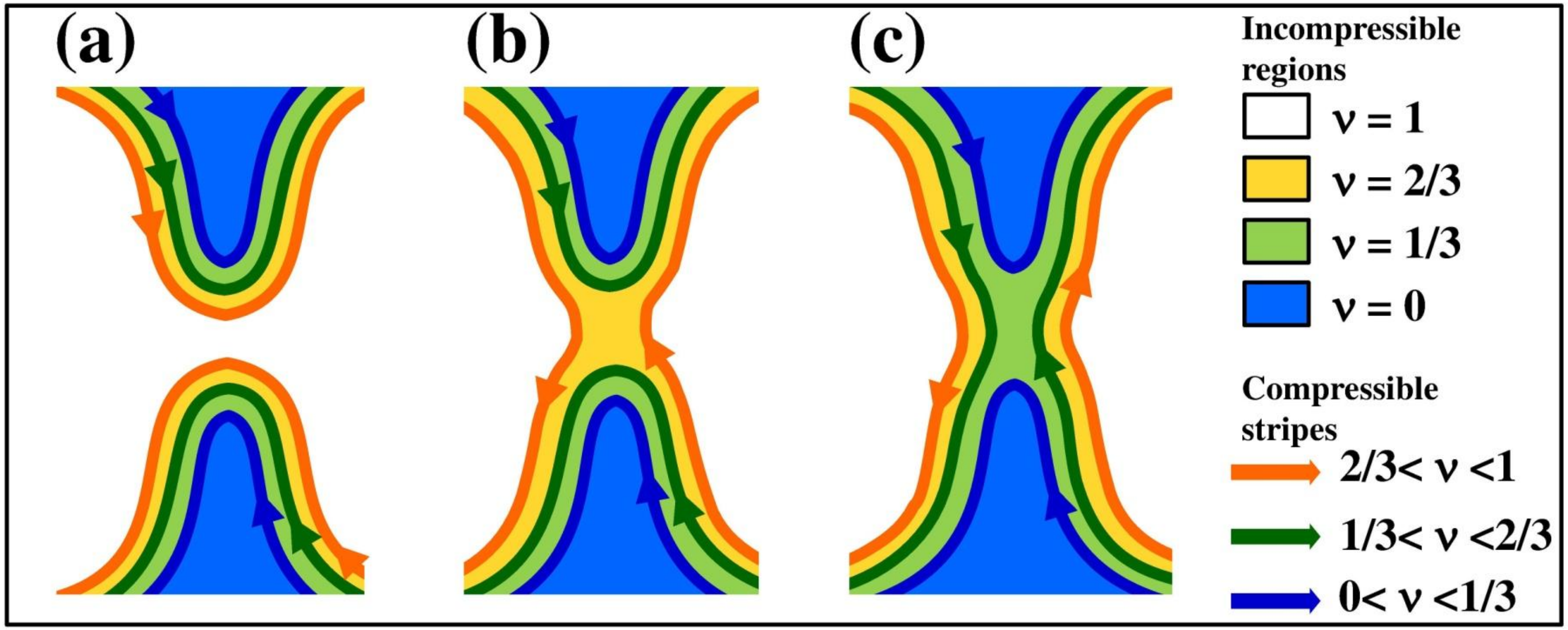
The IS width values (colored dots) obtained from SGM images compare well with the reconstruction picture predictions (black lines)



Inner edge structure ***demonstrated*** *and* ***imaged***

Quantitative test *of the IS width dependence on the density slope*

Summary



- Fractional incompressible stripes observed in integer edge channels
- Estimate width of these stripes
- Comparison with edge reconstruction theory