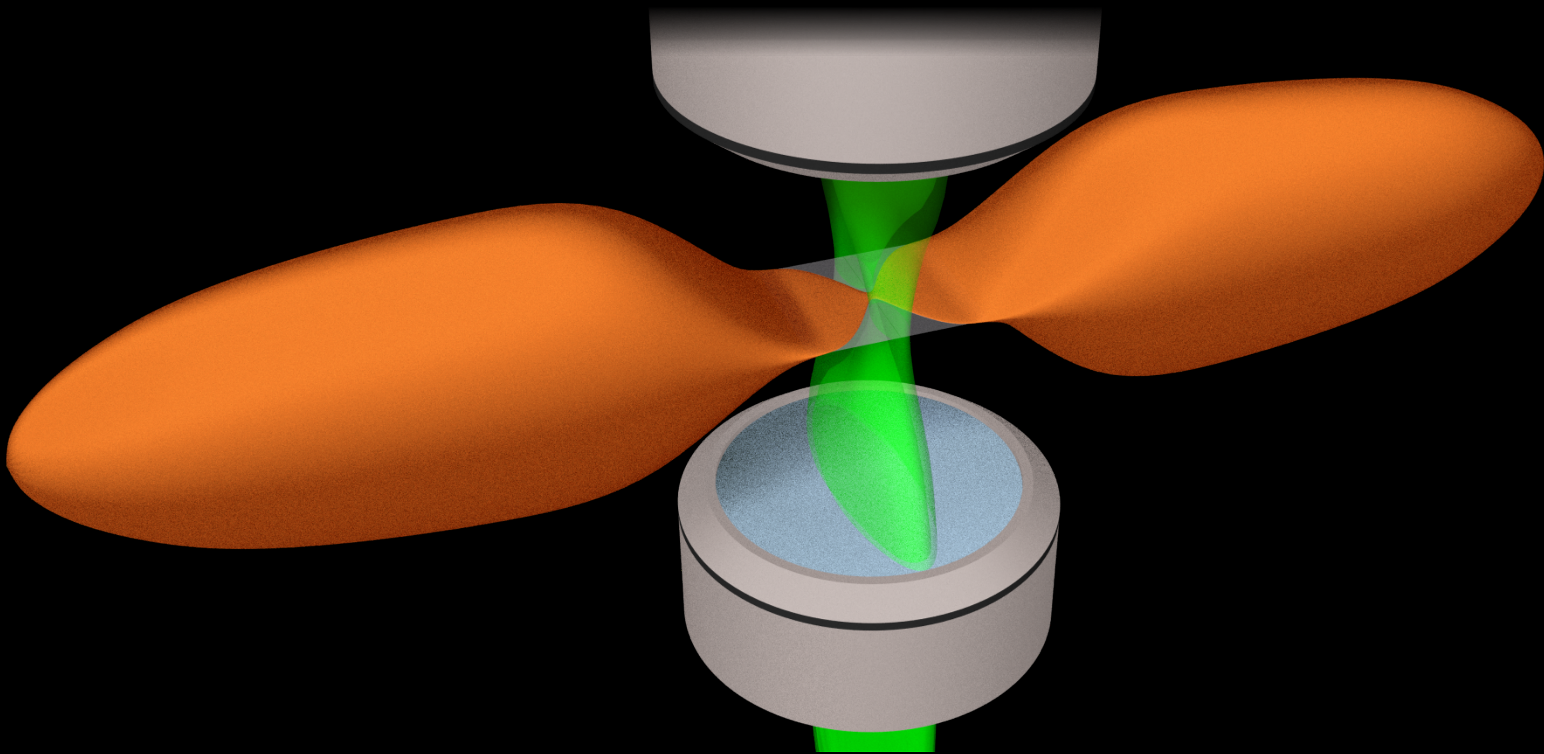
Quantized conductance for neutral matter



J.P. Brantut, S. Krinner, D. Stadler, D. Husmann, M. Lebrat and T. Esslinger

Institute for Quantum Electronics
ETH Zürich

Mesoscopic Devices

which size are comparable to the de Broglie wavelength of particles

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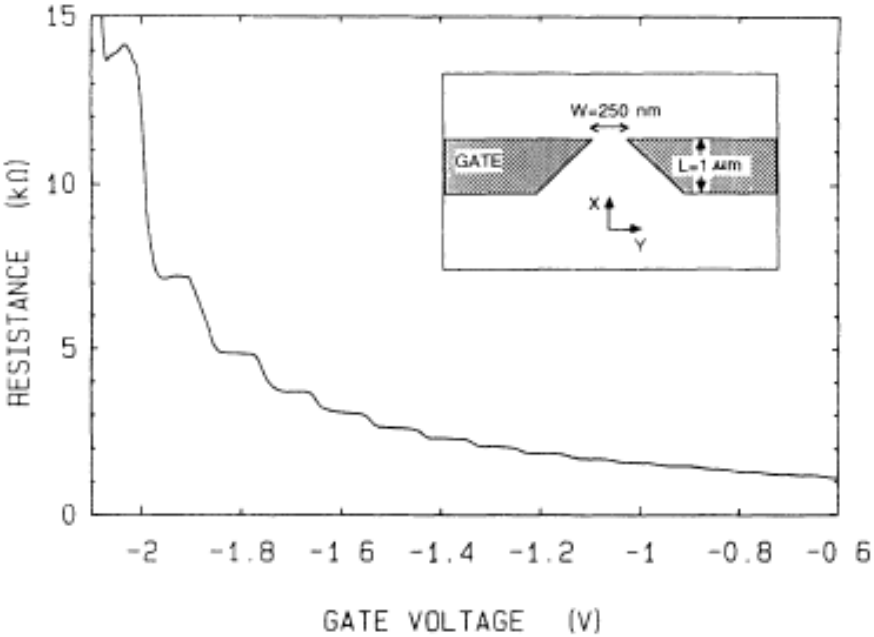
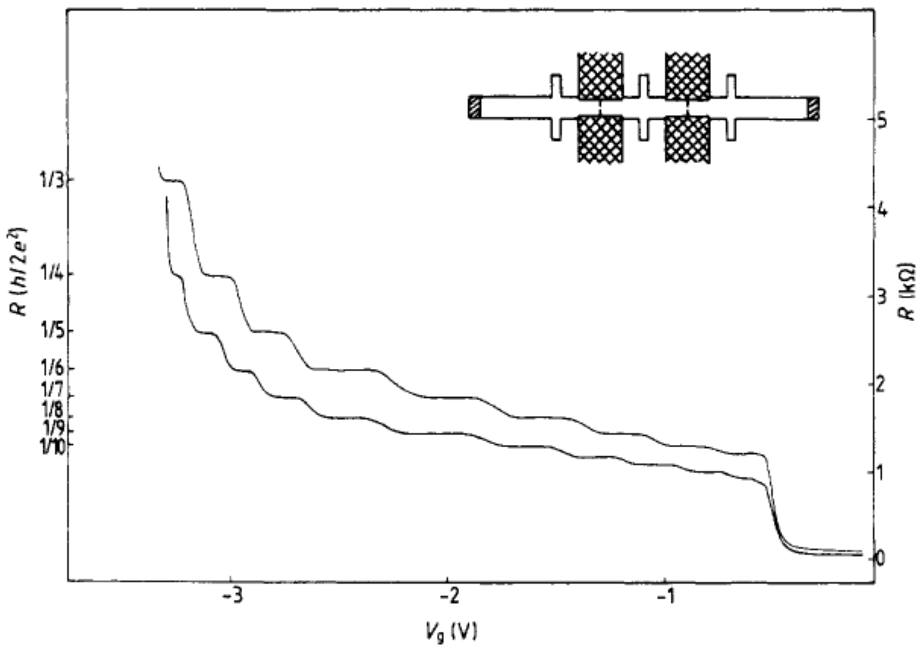


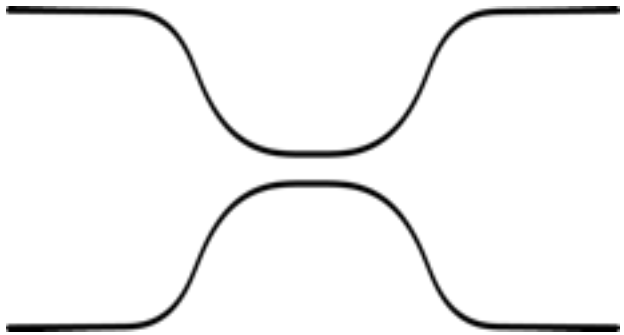
B. J. van Wees, H. van Houten, C. W. J. Beenakker, J. G. Williamson, L. P. Kouwenhoven, D. van der Marel, C. T. Foxon, Phys. Rev. Lett. **60**, 848 (1988)



D A Wharam, T J Thornton, R Newbury, M Pepper, H Ahmed, J E F Frost, D G Hasko, D C Peacock, D A Ritchie and G A C Jones, J. Phys. C: Solid State Phys. 21 L209

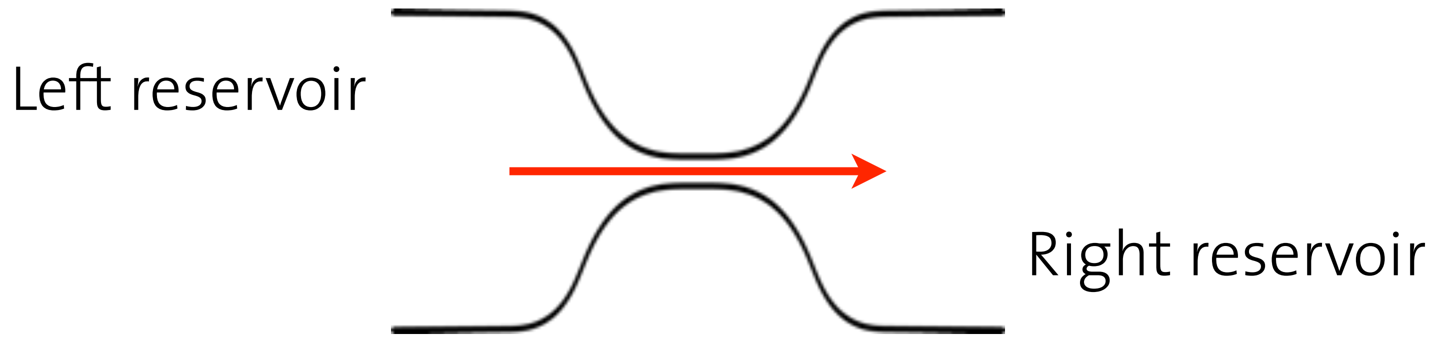
Conductance Quantization : Landauer theory

Left reservoir

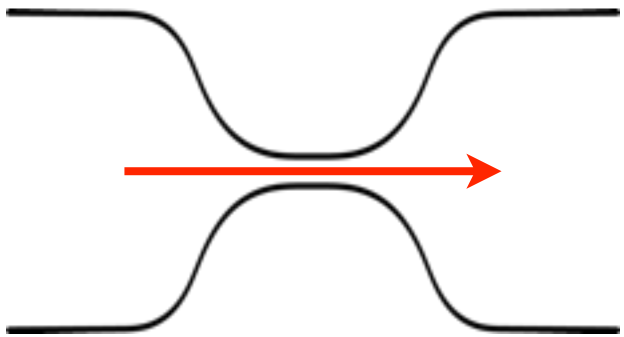


Right reservoir

Conductance Quantization : Landauer theory



Conductance Quantization : Landauer theory

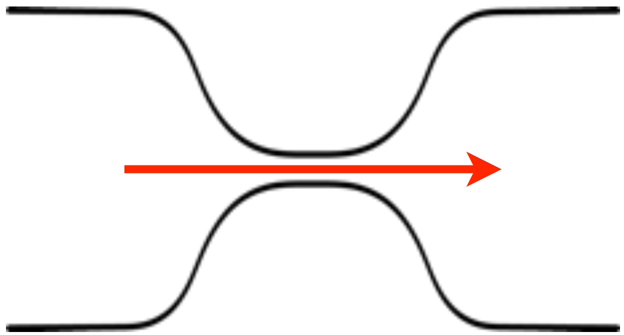


Group velocity $$v_g(\epsilon) = \sqrt{2\epsilon/m}$$

Density of states $$g_{1D}(\epsilon) = \frac{1}{2\pi\hbar v_g(\epsilon)}$$

Conductance Quantization : Landauer theory

Left reservoir



Right reservoir

Group velocity $$v_g(\epsilon) = \sqrt{2\epsilon/m}$$

Density of states $$g_{1D}(\epsilon) = \frac{1}{2\pi\hbar v_g(\epsilon)}$$

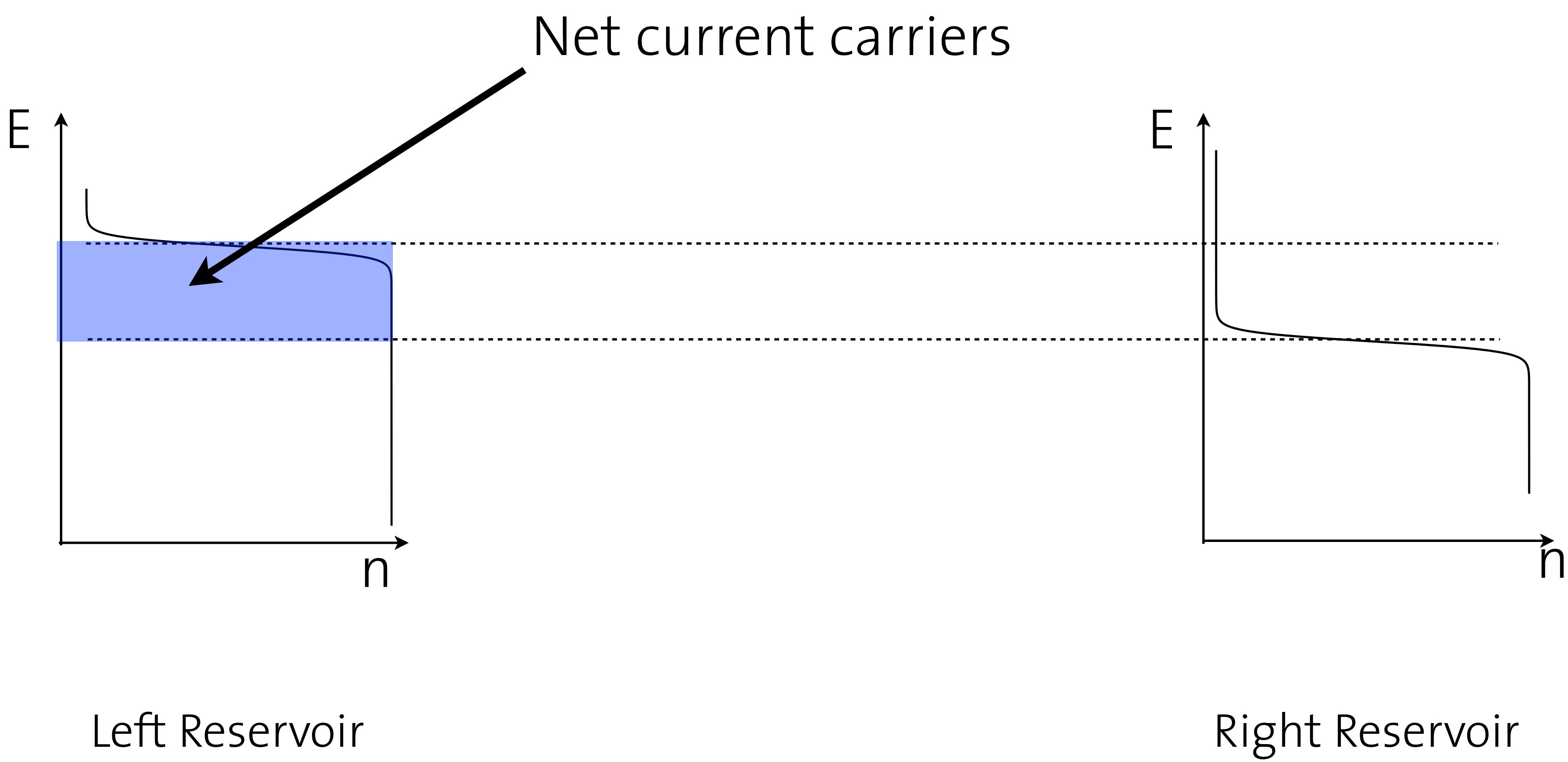
Current $$I = \int_{E_F}^{E_F+\Delta\mu} g_{1D}(\epsilon) v_g(\epsilon) d\epsilon = \frac{\Delta\mu}{h}$$

Universal conductance quantum 1/h

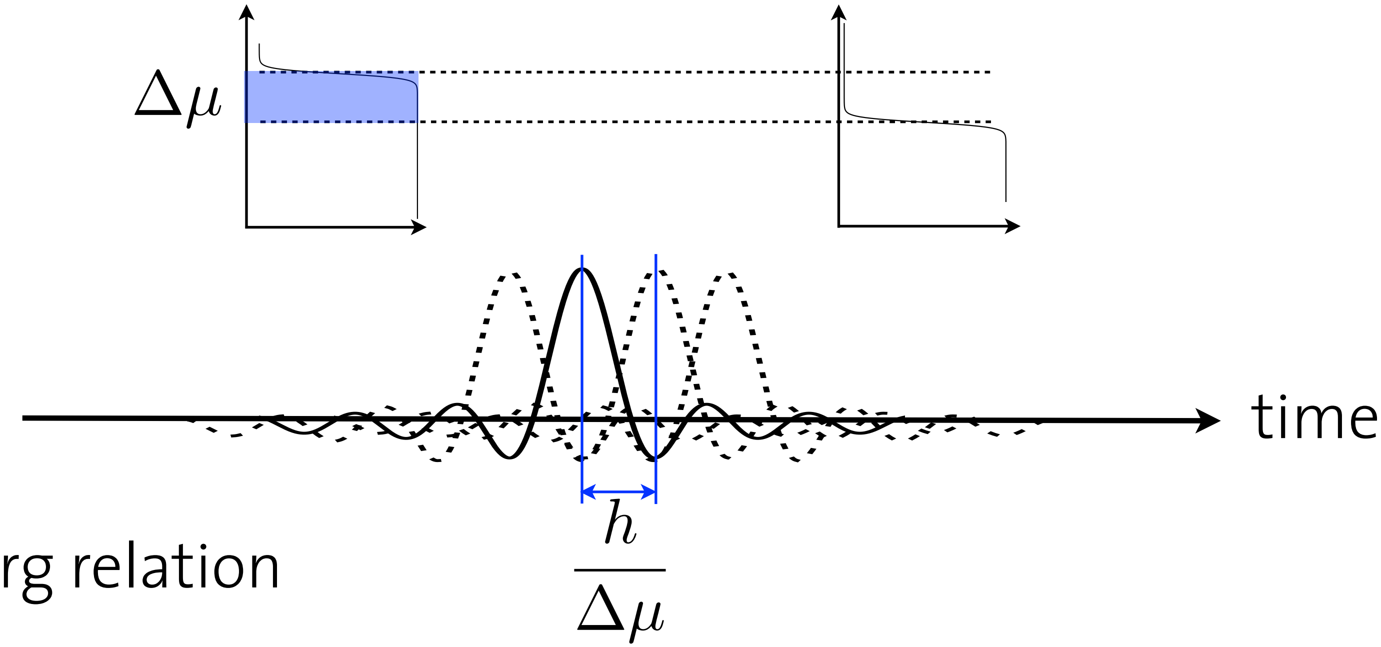
Left Reservoir

Right Reservoir

Universal conductance quantum 1/h

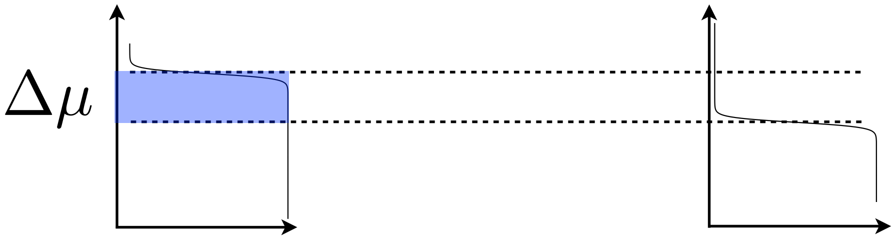


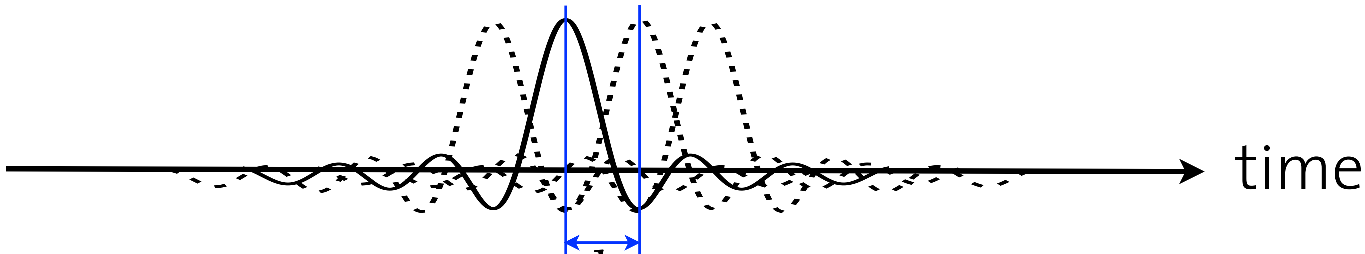
Universal conductance quantum 1/h



Heisenberg relation

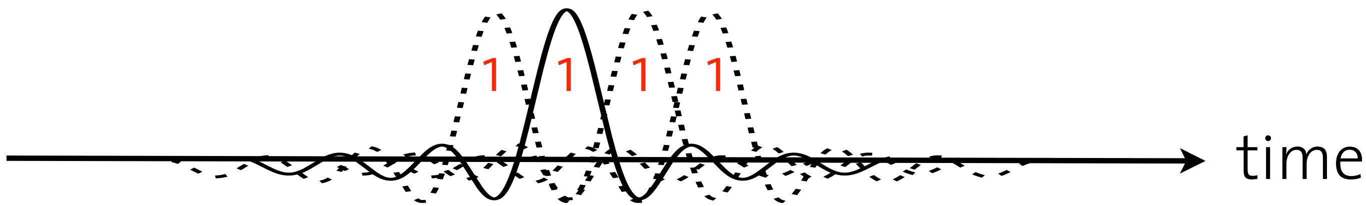
Universal conductance quantum 1/h





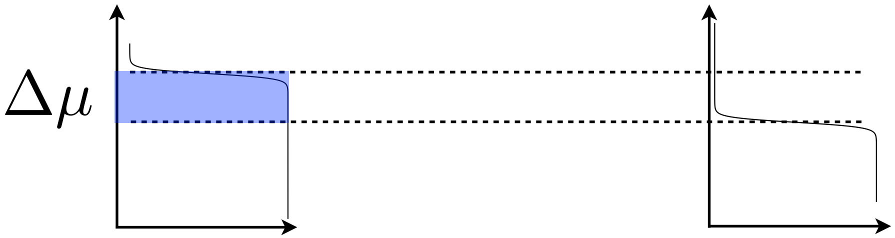
Heisenberg relation

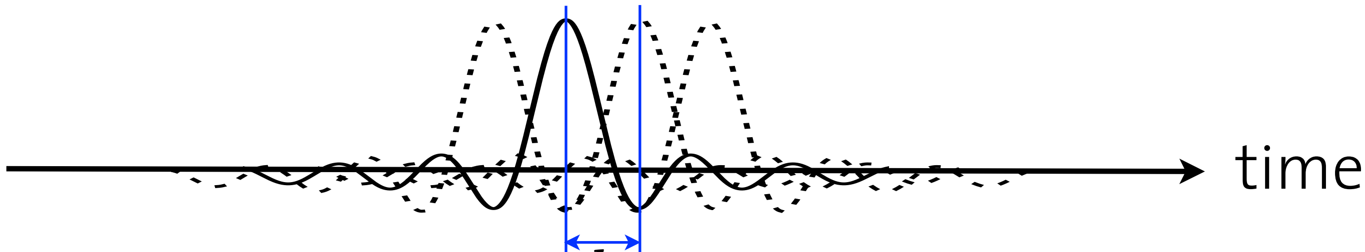
$$\frac{h}{\Delta\mu}$$



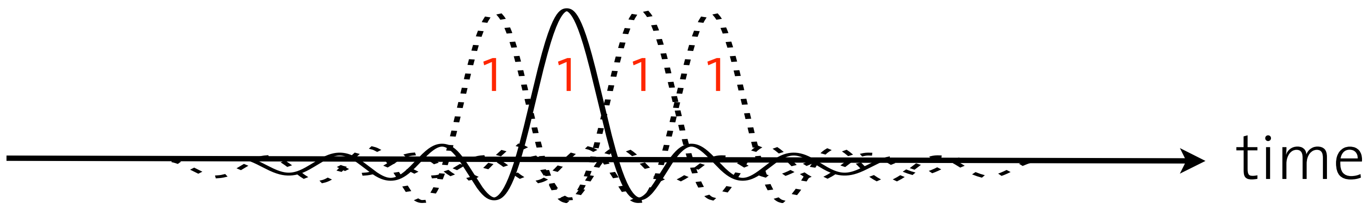
Pauli principle

Universal conductance quantum 1/h





Heisenberg relation $\frac{h}{\Delta\mu}$



Pauli principle

$$I = \frac{\Delta\mu}{h}$$

Universal conductance quantum 1/h

No reference whatsoever to electric charges, fields etc

Universal conductance quantum 1/h

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DOI: 10.1007/s10909-005-8223-3

On the Feasibility of Detecting Quantized Conductance in Neutral Matter

Yuki Sato, Byeong-Ho Eom, and Richard Packard

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(Received May 18, 2005; revised July 18, 2005)

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Quantum Point Contacts for Neutral Atoms

J. H. Thywissen,* R. M. Westervelt,† and M. Prentiss
Department of Physics, Harvard University, Cambridge, Massachusetts 02138
(Received 19 July 1999)

LOW TEMPERATURE PHYSICS VOLUME 34, NUMBERS 4–5 APRIL-MAY 2008

LIQUID HELIUM

Quantum-limited mass flow of liquid ^{3}He

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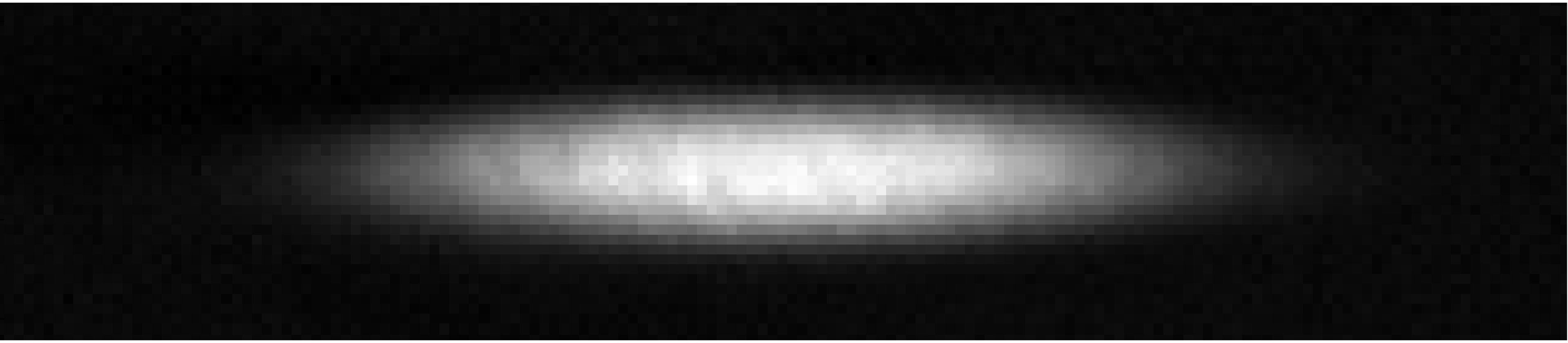
Department of Physics, McGill University, 3600 rue Université, Montréal, Qc, Canada

W. J. Mullin[a)]

Department of Physics, University of Massachusetts, Amherst, Massachusetts 01003, USA
(Submitted October 29, 2007)
Fiz. Nizk. Temp. **34**, 321–325 (April–May 2008)

Experimental setup

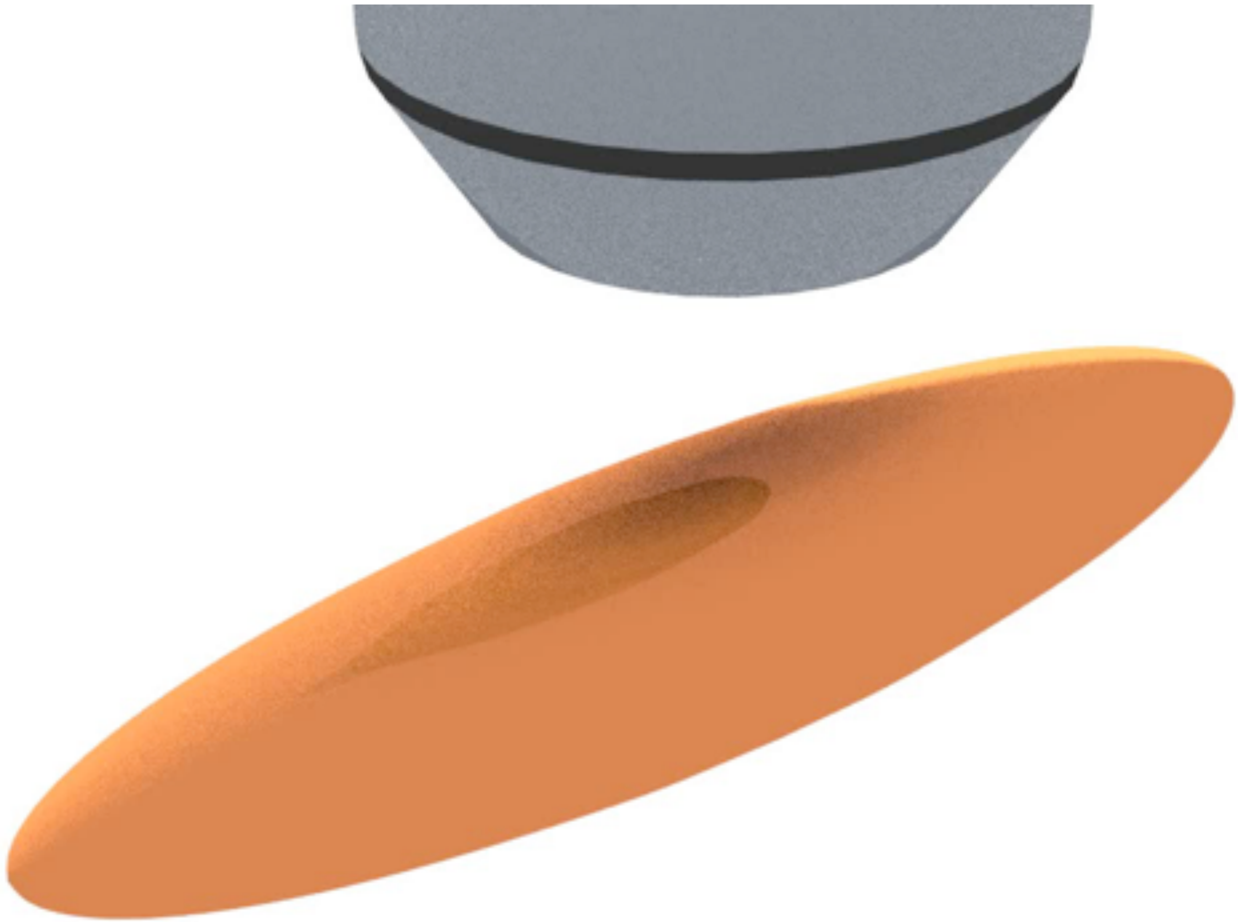


7.5 10^4 ^{6}Li atoms

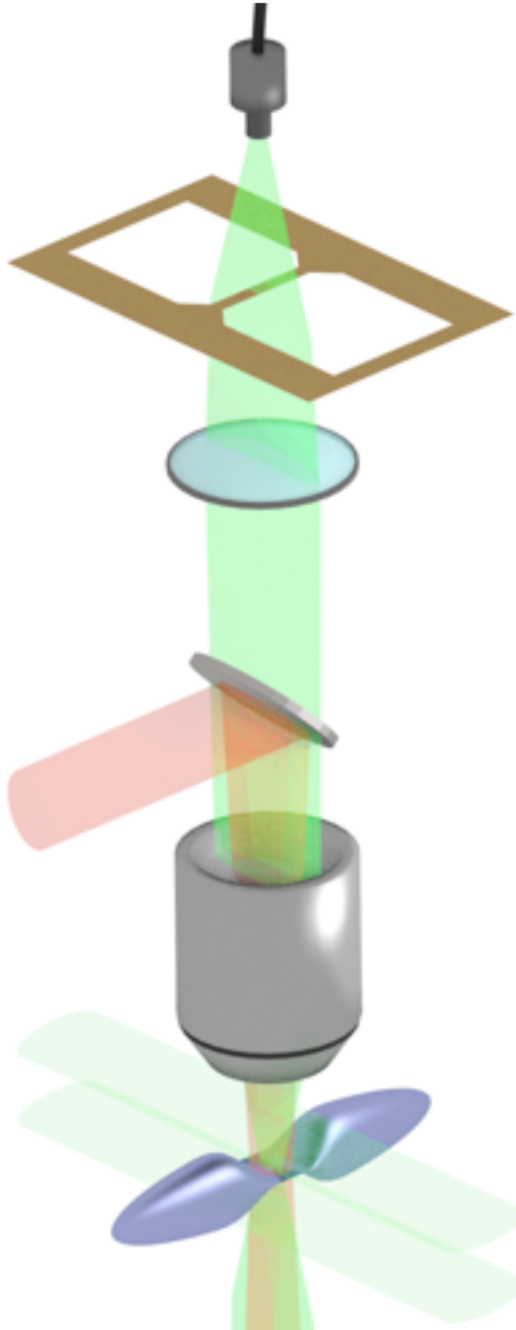
T ~ 0.11 T_F

T_F = 352 nK

Experimental setup : cloud shaping



Experimental setup : cloud shaping



Experimental setup : cloud shaping

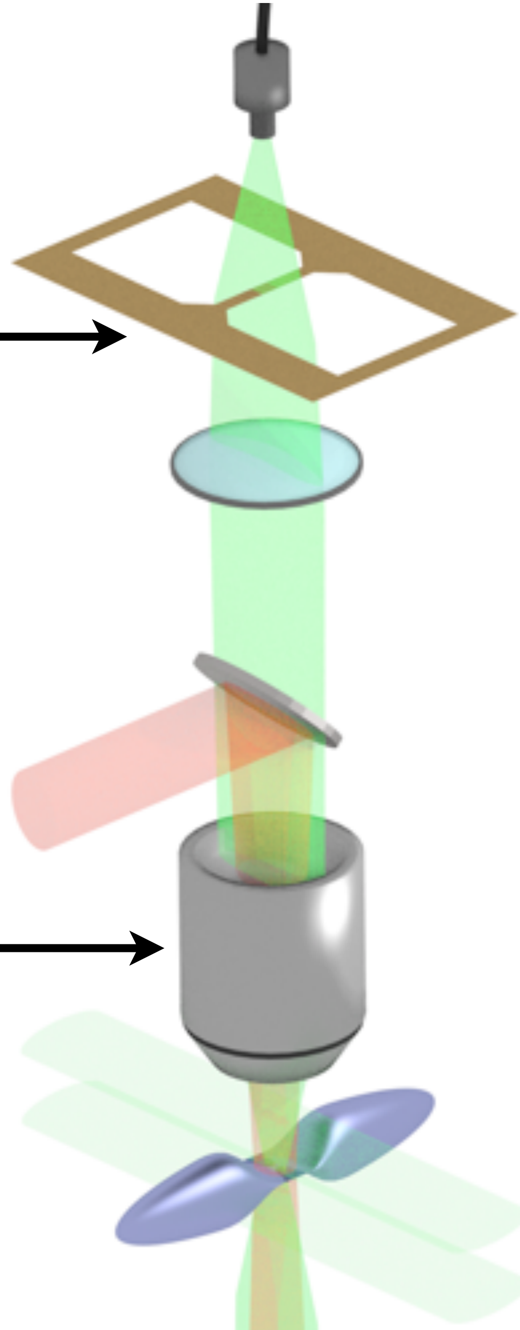
Binary mask

Gaussian beam (@ 532 nm)

Microscope objective

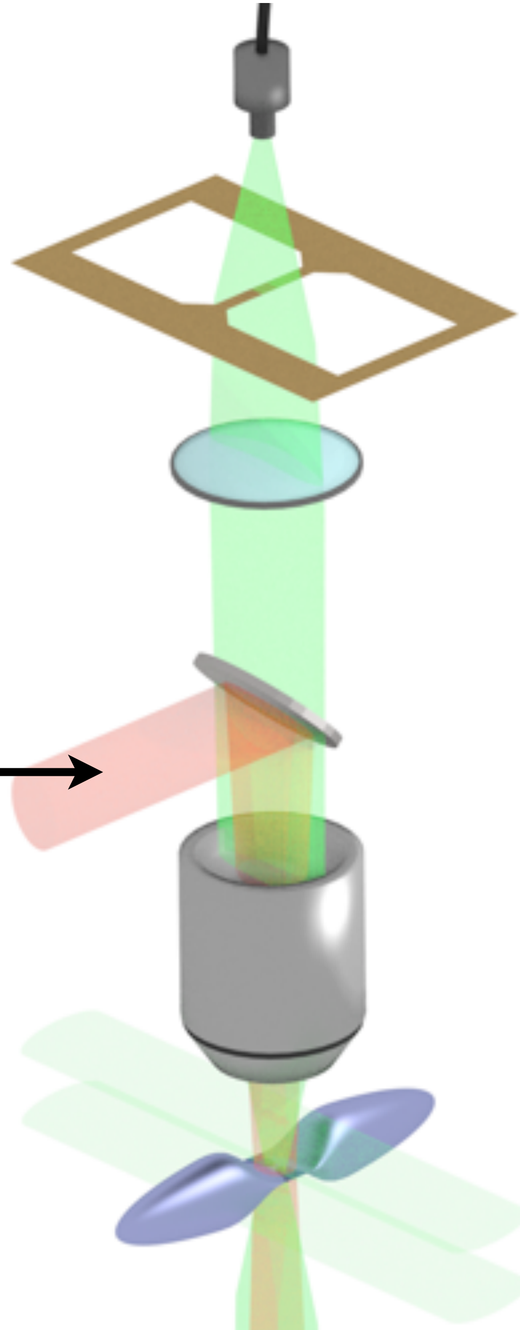
Demagnification x11

Images a "split gate" onto the atoms



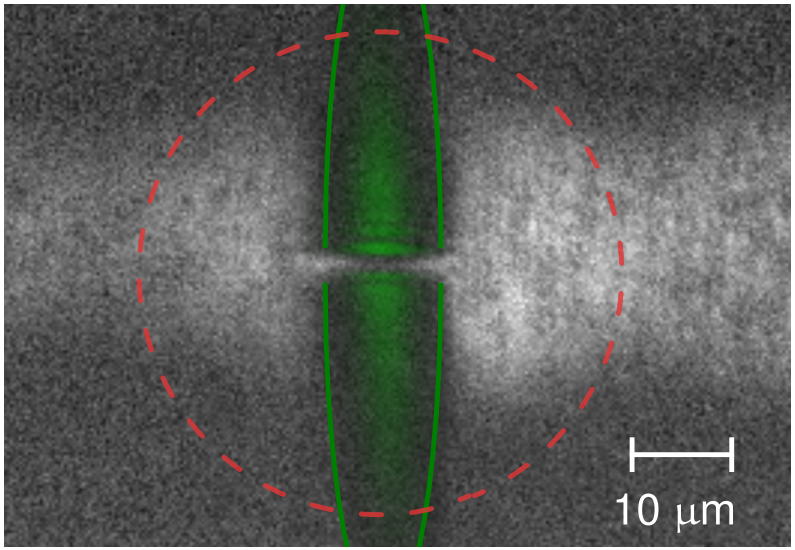
Experimental setup : cloud shaping

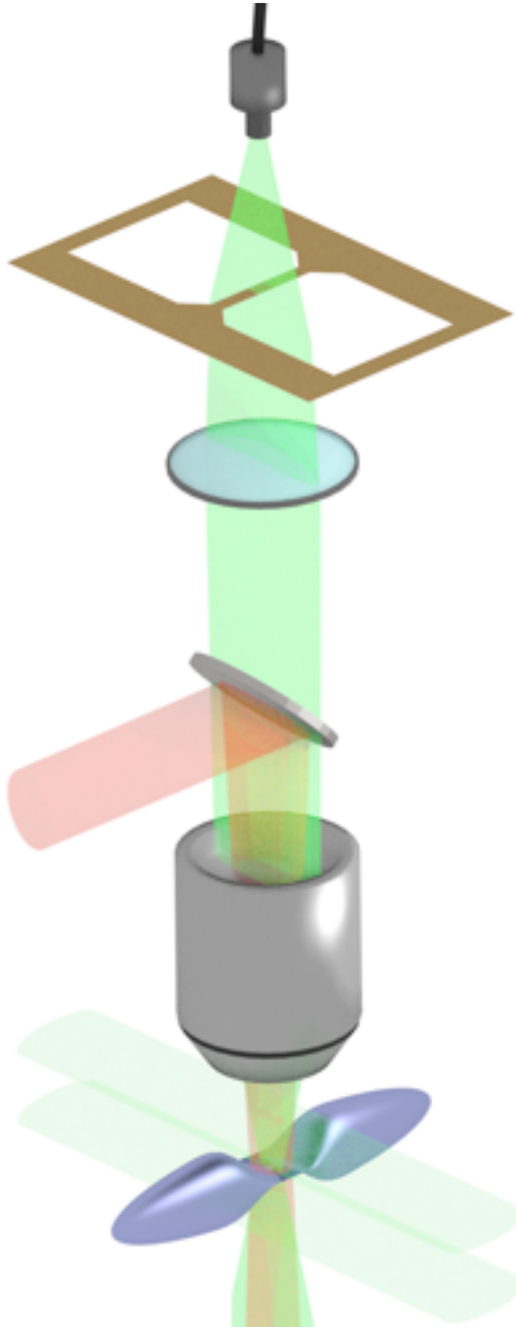
Attractive “Gate” potential
Gaussian envelope (@ 767 nm)



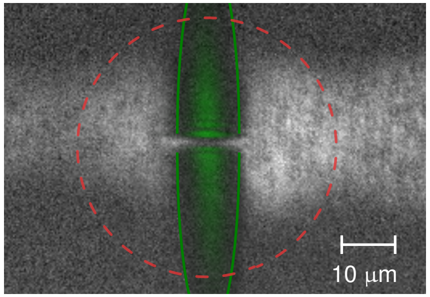
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Experimental setup : cloud shaping



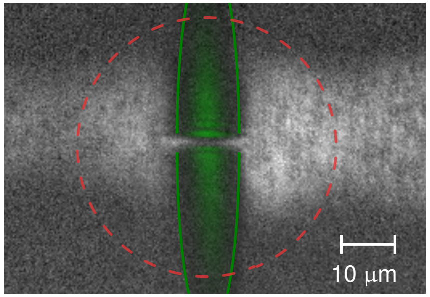


Experimental setup : cloud shaping



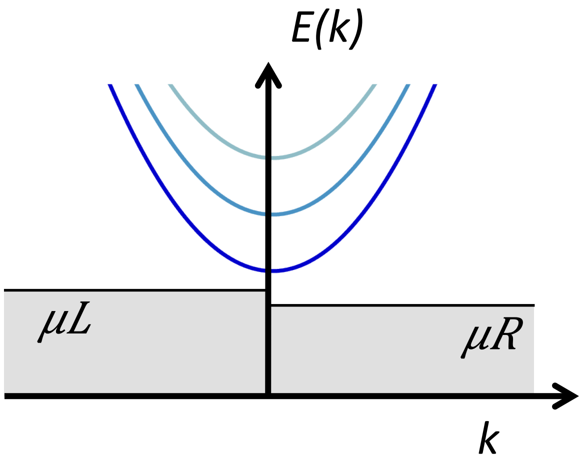
x-frequency	30 kHz
z-frequency	10 kHz
Channel ground state	1 µK

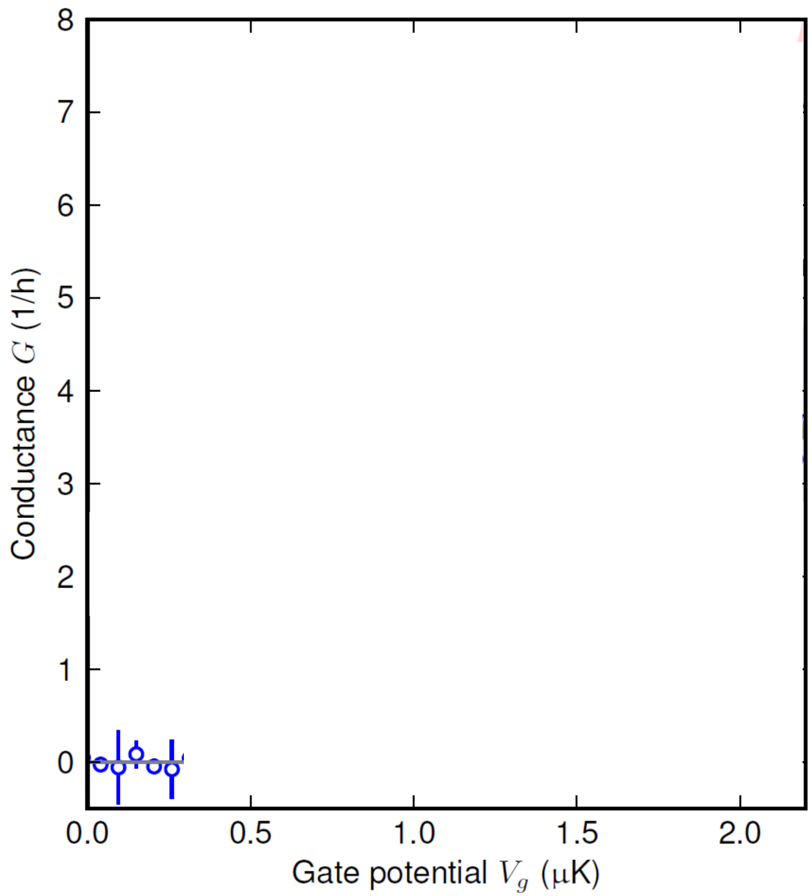
Experimental setup : cloud shaping



x-frequency	30 kHz
z-frequency	10 kHz
Contact ground state	1 µK
Chemical potential	0.352 µK
Temperature	42 nK
Gate Potential	0 - 3 µK

Measurement





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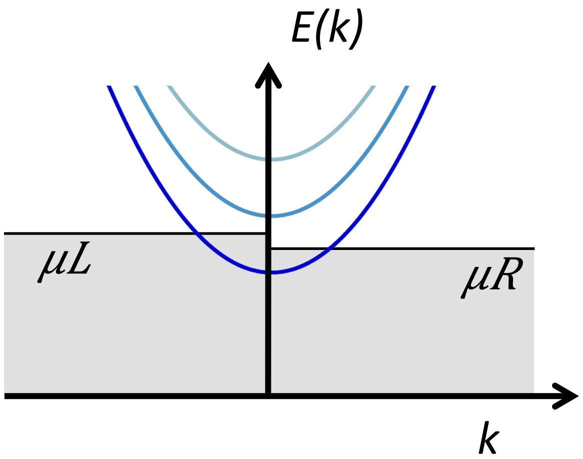

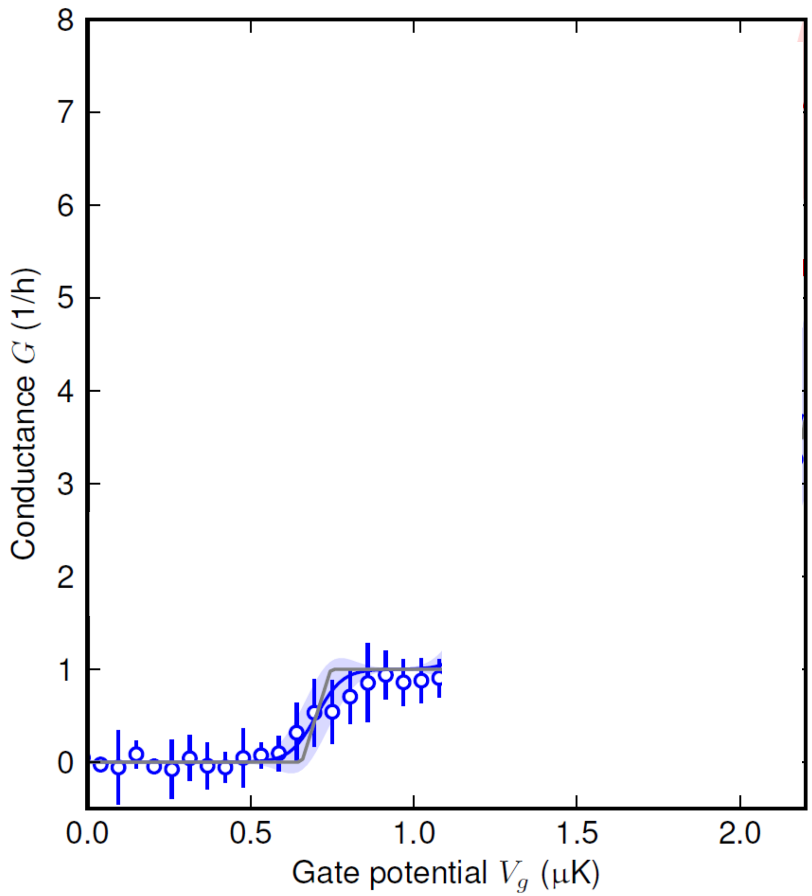

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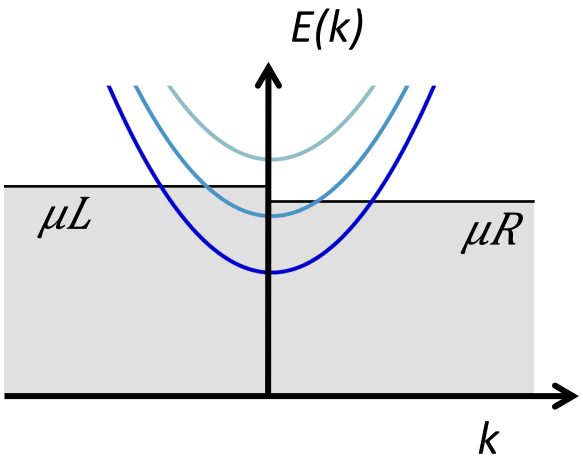
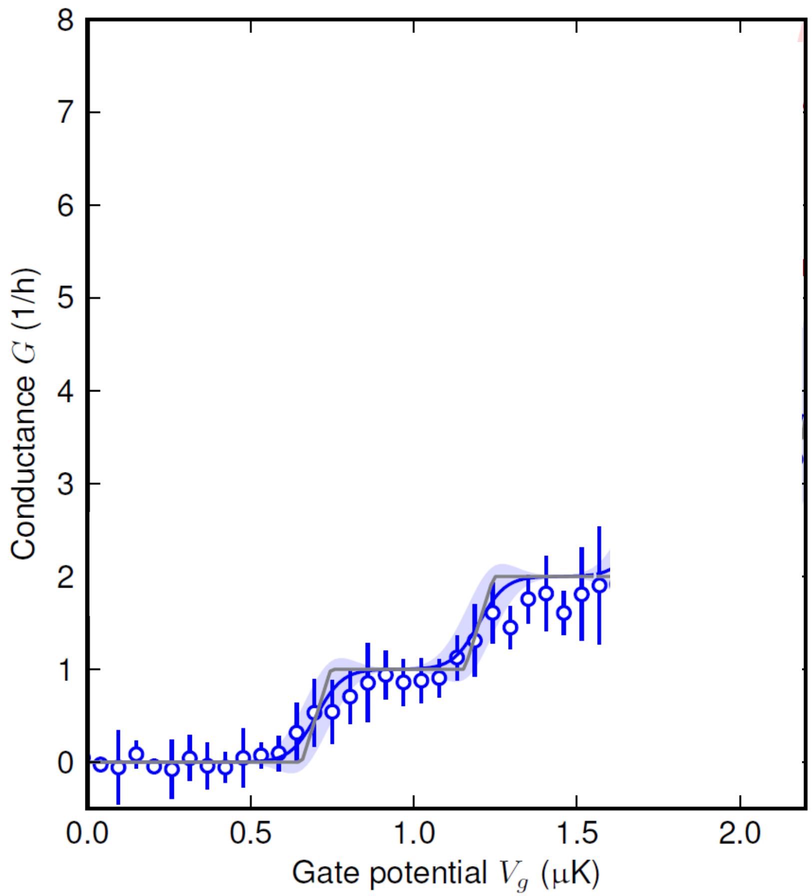
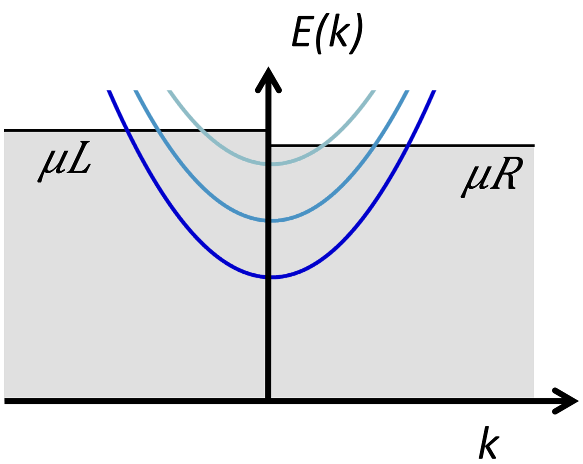


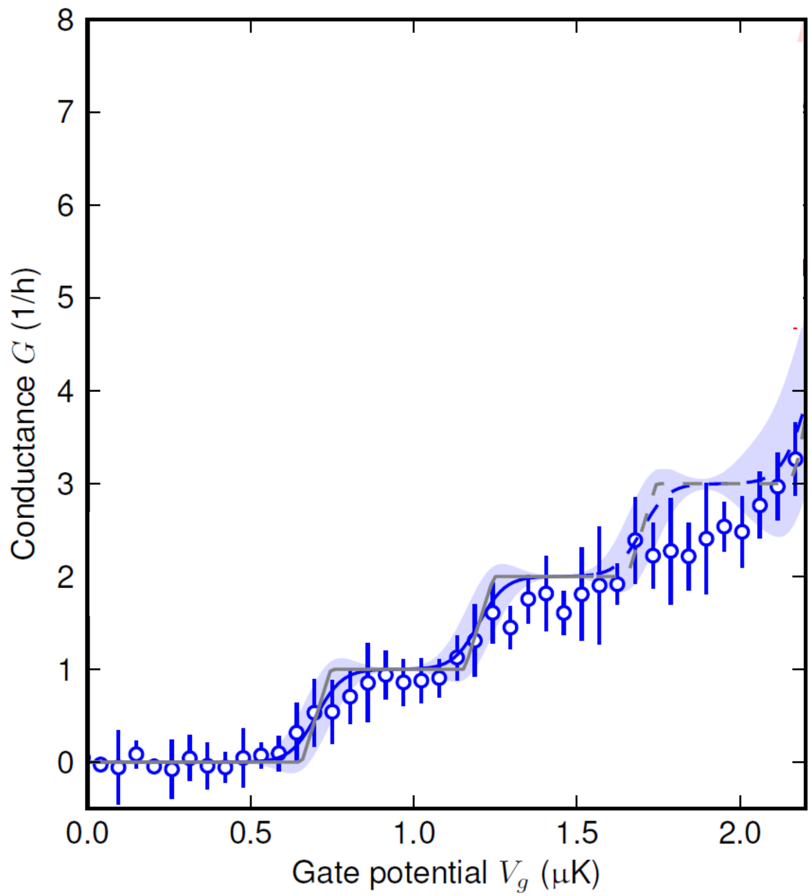


Sunday, June 29, 14

Measurement



Landauer theory
No free parameter



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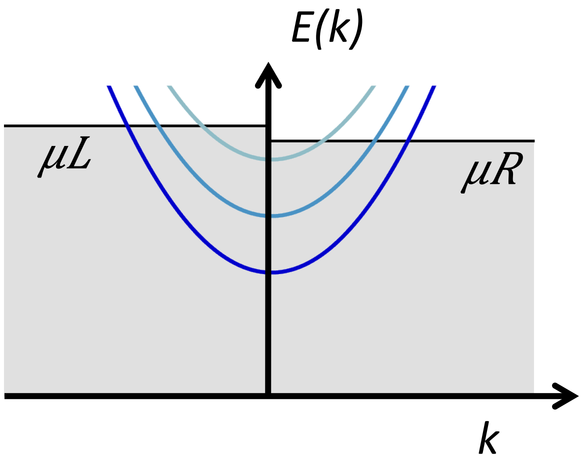
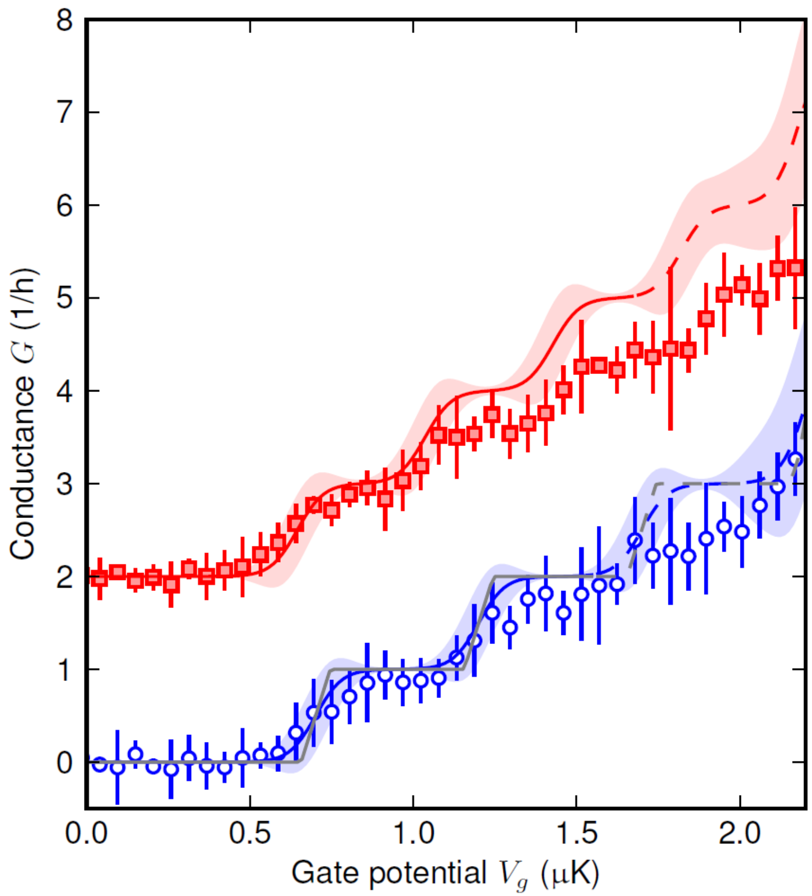


$$\nu_z = 10.4\,\mathrm{kHz}$$
$$\nu_z = 8.2\,\mathrm{kHz}$$



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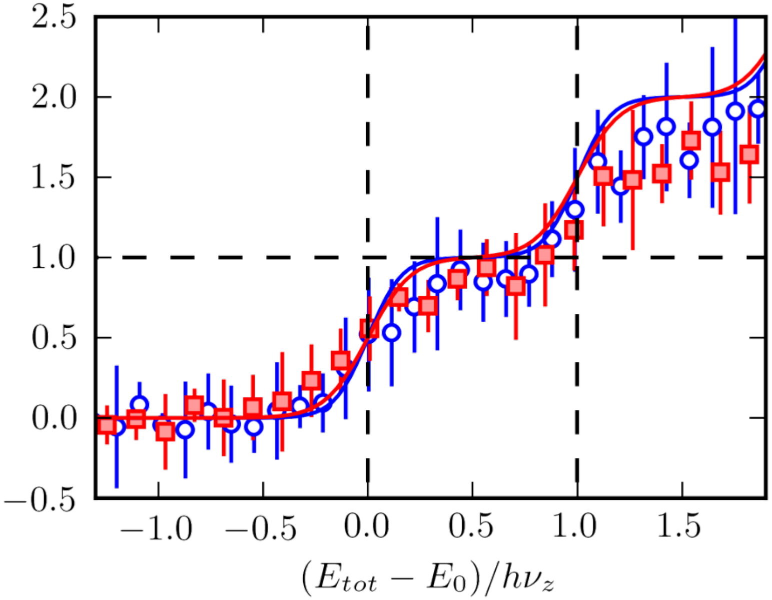

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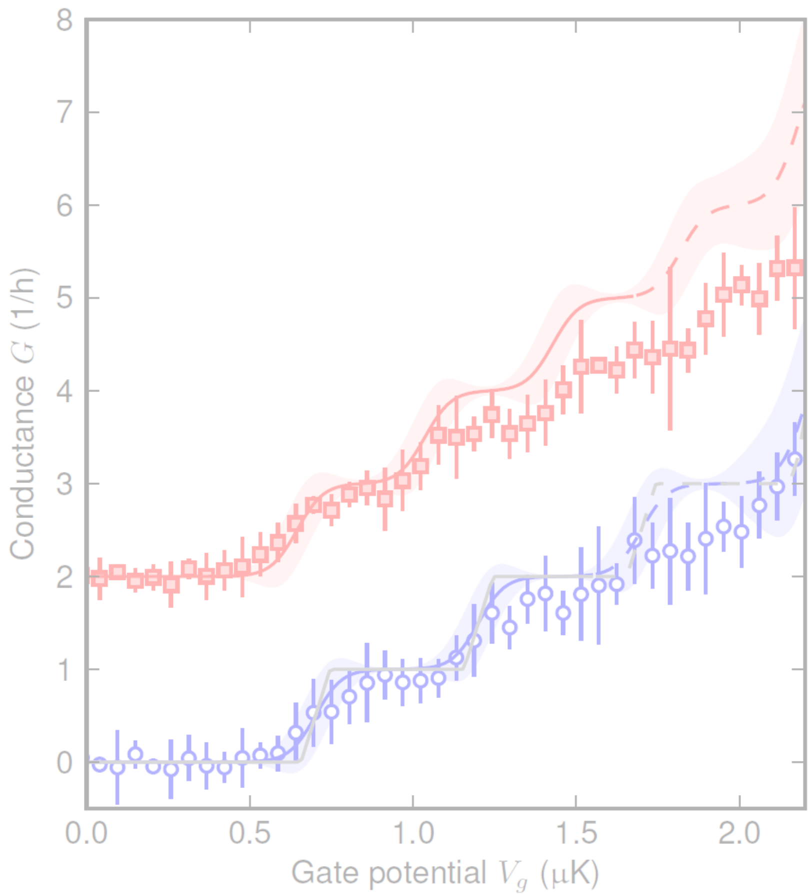
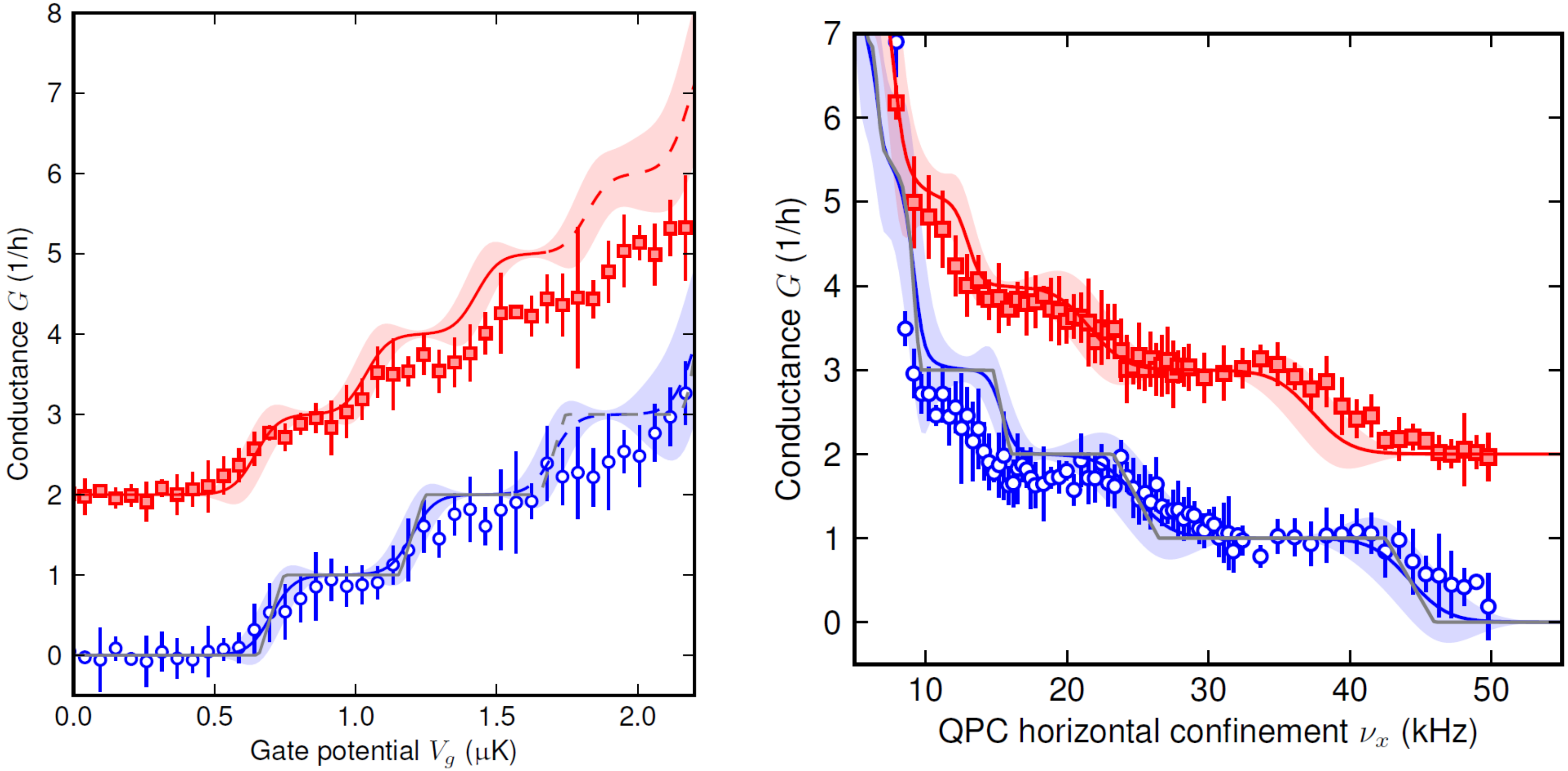


Varying the split gate strength



What do we learn ?

It works...

... with neutral particles: no forces are applied to the atoms

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... with closed, microcanonical reservoirs: only elastic processes take place in the reservoirs, no dissipative dynamics

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... with neutral particles: no forces are applied to the atoms

... with closed, microcanonical reservoirs: only elastic processes take place in the reservoirs, no dissipative dynamics

... with very little interparticle scattering in the reservoirs: mean free path much larger than the cloud size

Wide control over the reservoirs dynamics

Wide tunability of the geometry

Using “optical lithography”, any geometry can be implemented

Wide tunability of the geometry

Using "optical lithography", any geometry can be implemented

Example: quantum wire with sharper edges

In-situ picture of the potential shape

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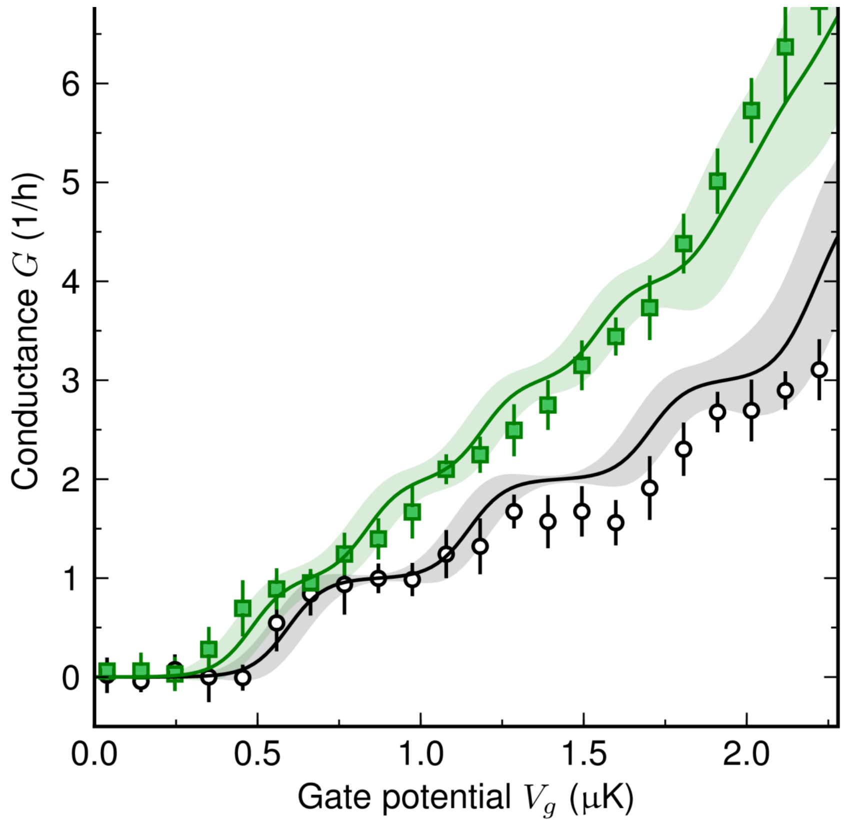

Sunday, June 29, 14

Conclusions and perspectives

Strongly interacting gases: BEC-BCS crossover

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Engineering reservoirs: non thermal, coherent, small size

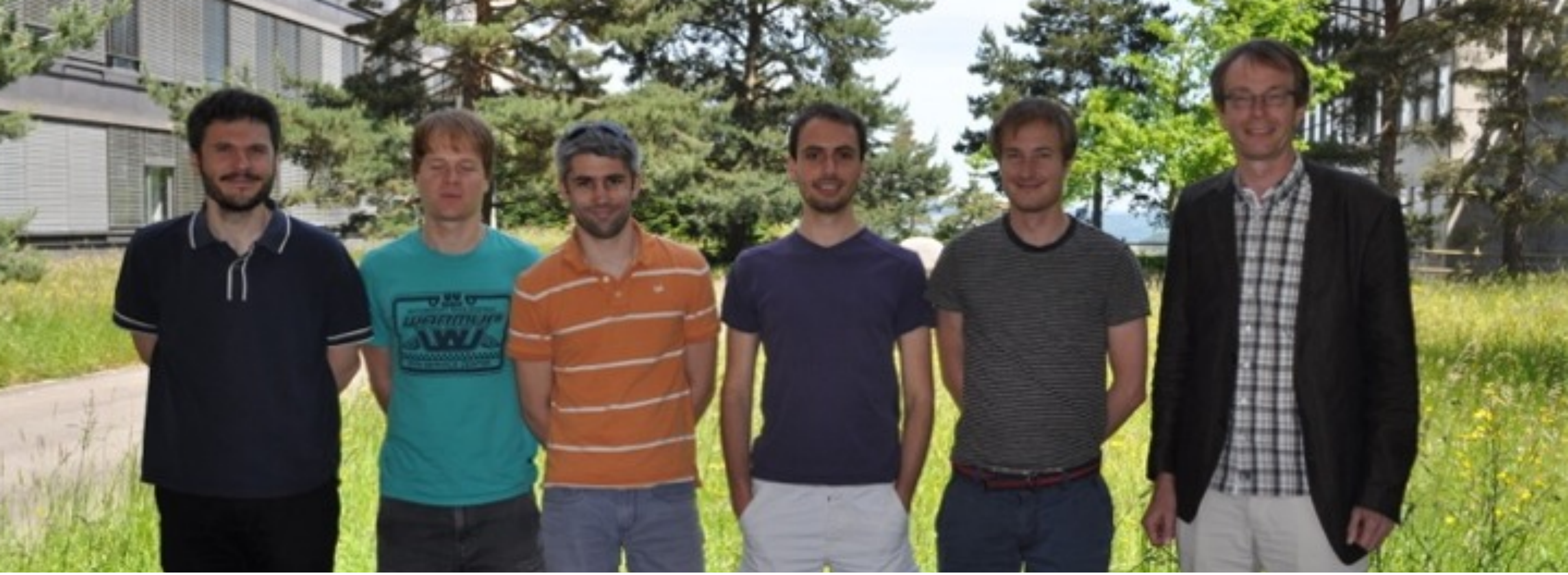
Conclusions and perspectives

Strongly interacting gases: BEC-BCS crossover

Engineering reservoirs: non thermal, coherent, small size

Other transport coefficients: heat conductance, thermopower

J.P. Brantut *et al*, Science **342**, 713 (2013)



Charles Grenier JPB Dominik Husmann
Sebastian Krinner Martin Lebrat Tilman Esslinger

arXiv:1404.6400

Discussions: C. Chin, W. Zwerger, T. Ihn, K. Ensslin, Y. Imry, G. Blatter, A. Georges, T. Giamarchi

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erc European Research Council Established by the European Commission
ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich
FNSNF Swiss National Science Foundation
QSIT Quantum Science and Technology National Centre of Competence in Research