

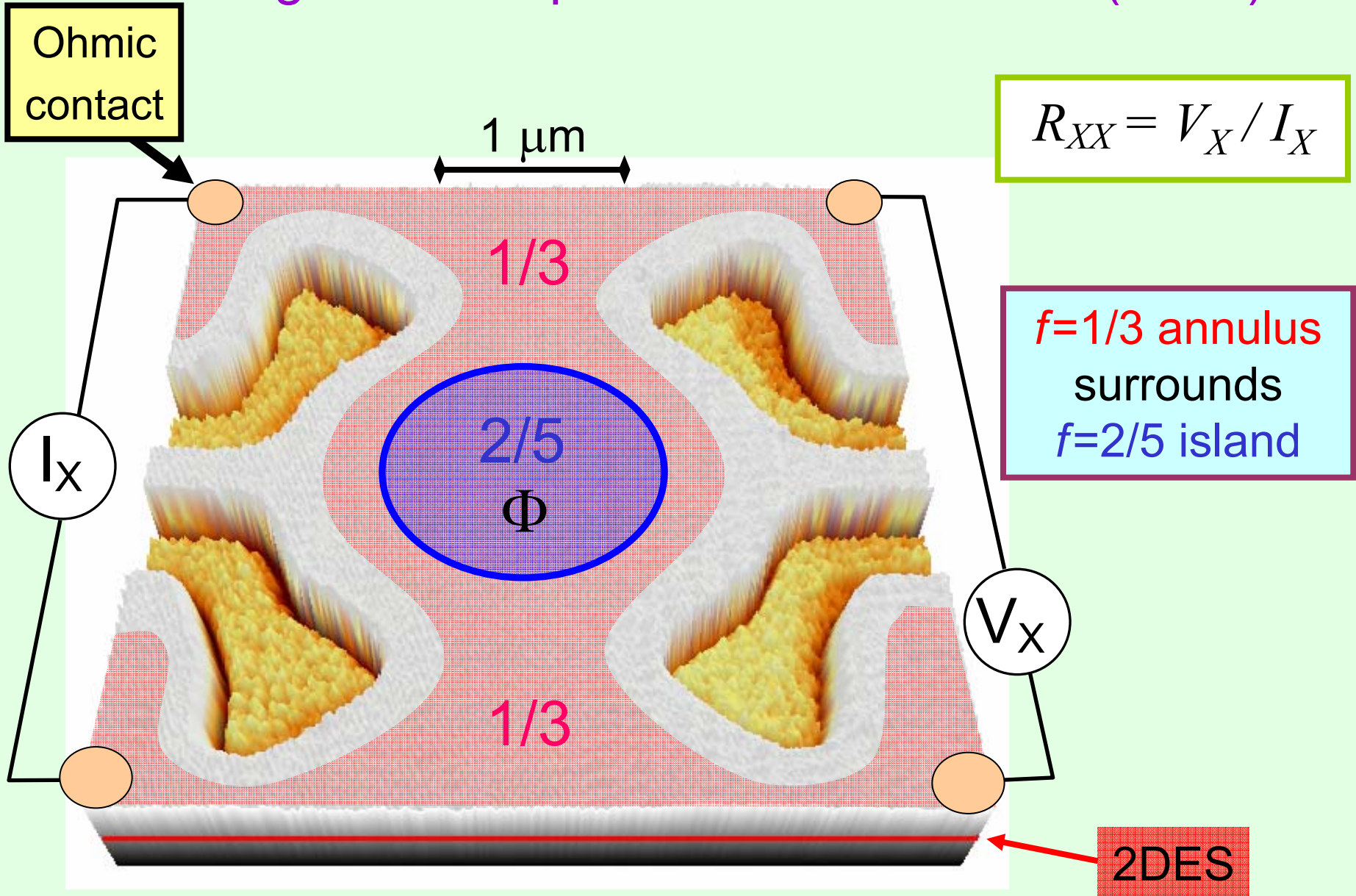


Thermal Dephasing in the Laughlin Quasiparticle Interferometer

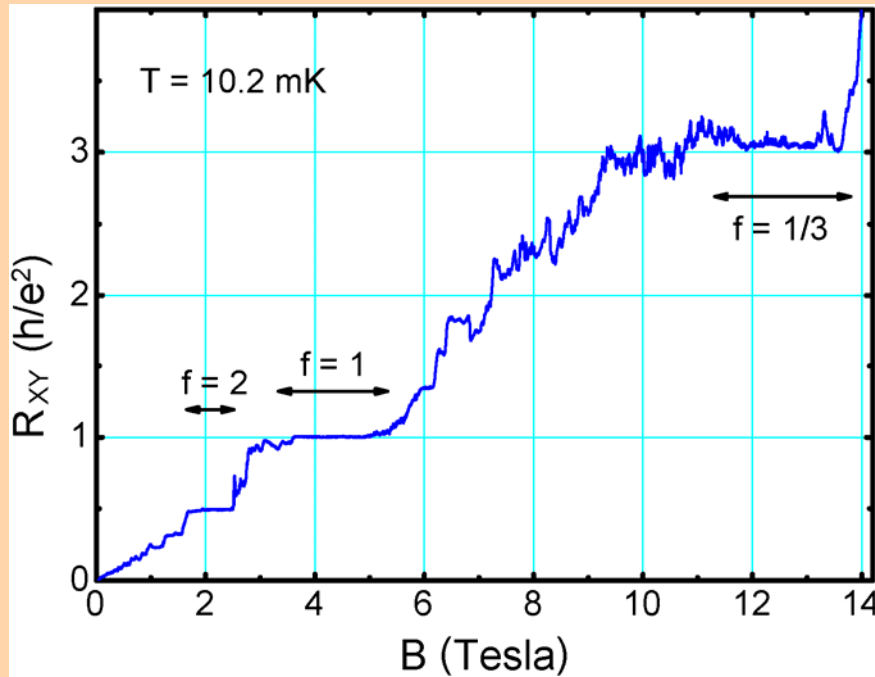
F. E. Camino, W. Zhou and V. J. Goldman

Stony Brook University

Laughlin Quasiparticle Interferometer (LQPI)



Characterization of the Experimental Scenario

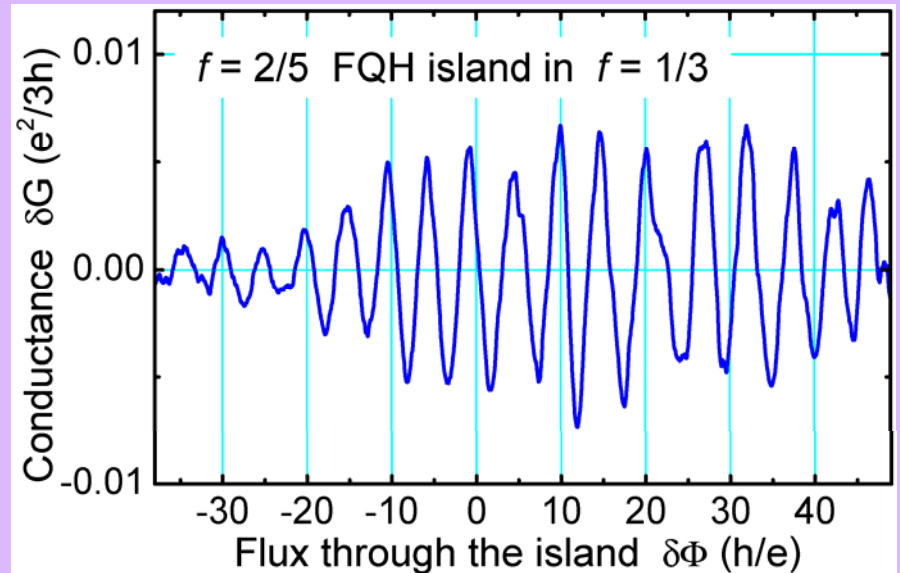


$R_{XY} = 3 h/e^2$, then
 current is transported by
 $f = 1/3$ fluid

Aharonov-Bohm conductance
 oscillations with flux period

$$\Delta\Phi = 5 h/e \quad (*)$$

(*) Camino *et al.*, PRB **72**, 075342 (2005);
 PRL **95**, 246802 (2005)
 Zhou *et al.*, cond-mat/0512329 (2005)

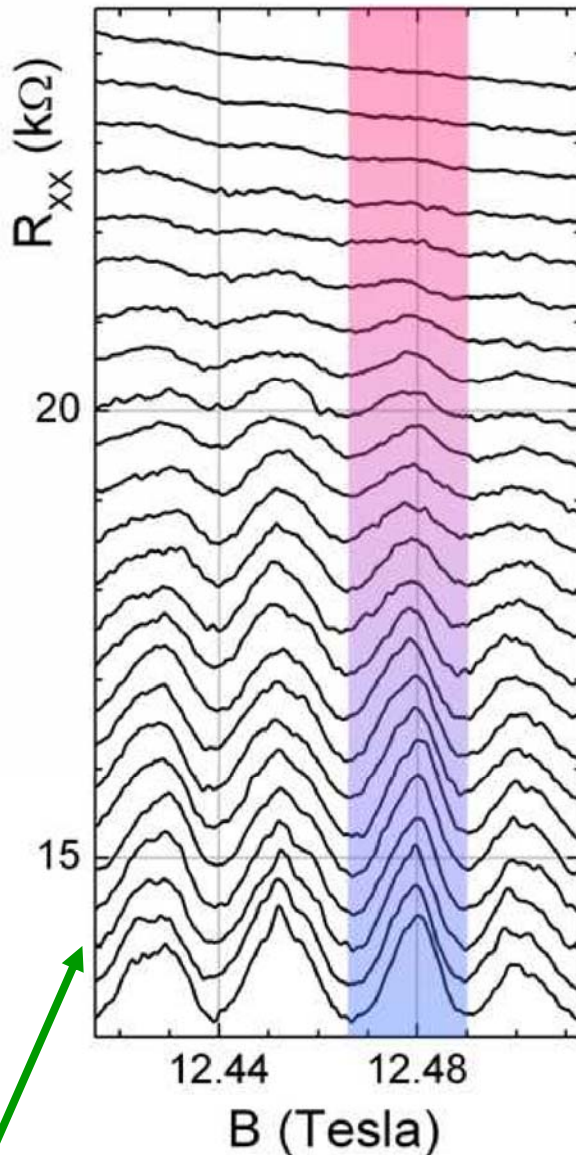


Temperature Dependence of Oscillations

141 mK

increasing temperature

10.2 mK



Analysis steps:

- 1) measure $\delta R_{XX}(T)$ for 6 regular oscillations
- 2) calculate δG using

$$\delta G = \delta R_{XX} / (R_{XY}^2 - \delta R_{XX} R_{XY})$$

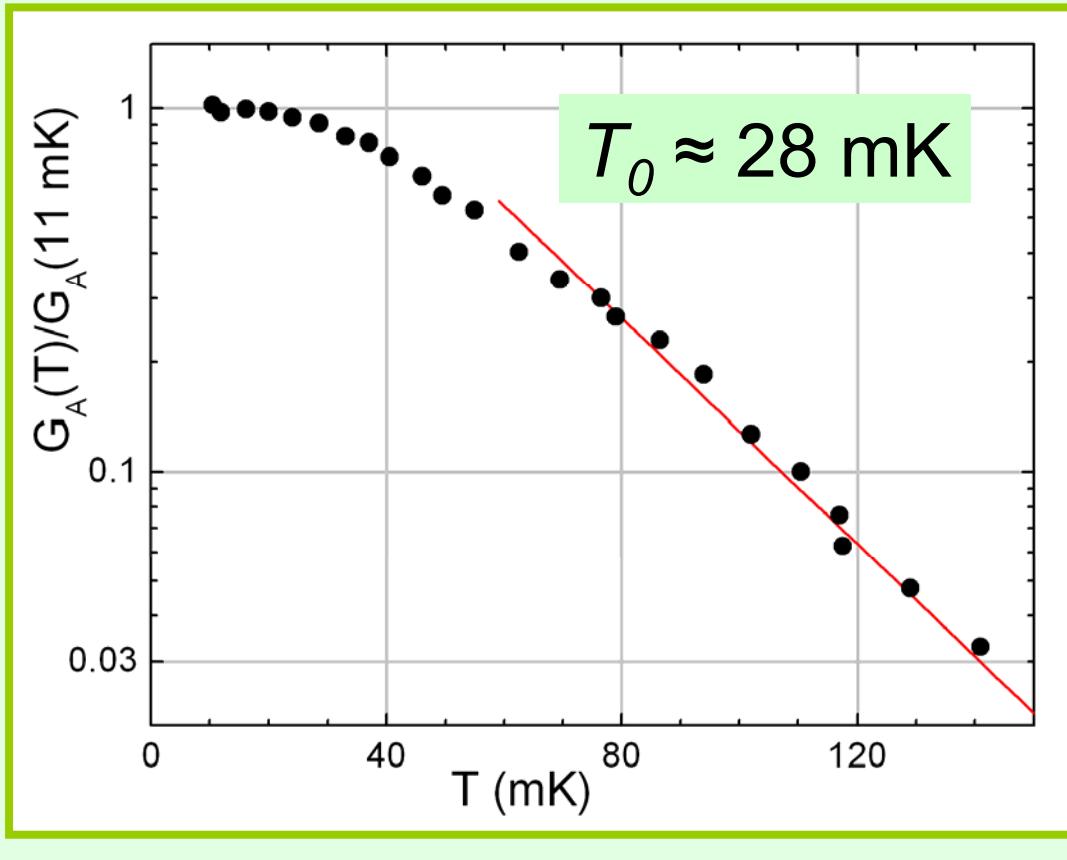
where $R_{XY} = 3h/e^2$

~12.9 kΩ background comes from R_{XX} quantization:

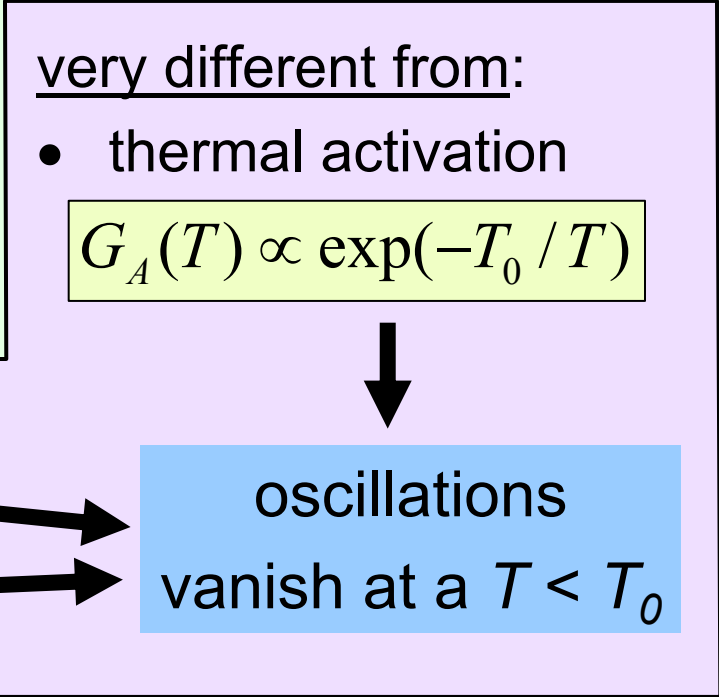
$$R_{XX} = R_{XY} \left(\frac{1}{3}\right) - R_{XY} \left(\frac{2}{5}\right) = \frac{1}{2} h/e^2$$

traces shifted vertically by 0.4 kΩ

T-dependence of Oscillation Amplitude $G_A(T)$

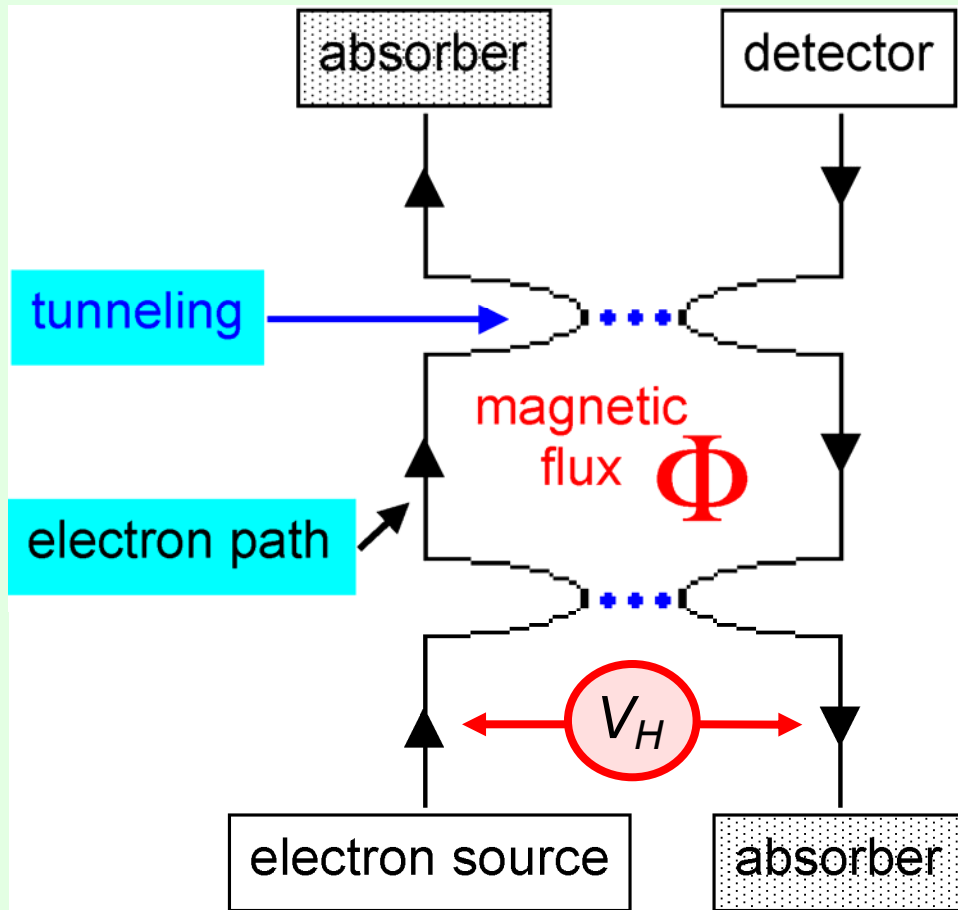


- high- T asymptotics:
 $G_A(T) \propto \exp(-T / T_0)$
- Aharonov-Bohm oscillations persist for $T > T_0$



- Fermi liquid behavior in:
 - resonant tunneling in quantum dots
 - Coulomb blockade devices

Theoretical Model of a Quantum Interferometer (*)



(*) Chamon *et al.*, PRB **55**, 2331 (1997)

- interferometer formed by χ LL edge channels
- single QH filling in device

- amplitude of oscillations:

$$G_A(T) \propto H_g \left(\frac{2\pi\omega_J}{\omega_0}, \frac{\omega_J}{2\pi T} \right)$$

- $g = 1/3$ for $f = 1/3$ FQH fluid

Josephson: $\omega_J = qV_H / \hbar$

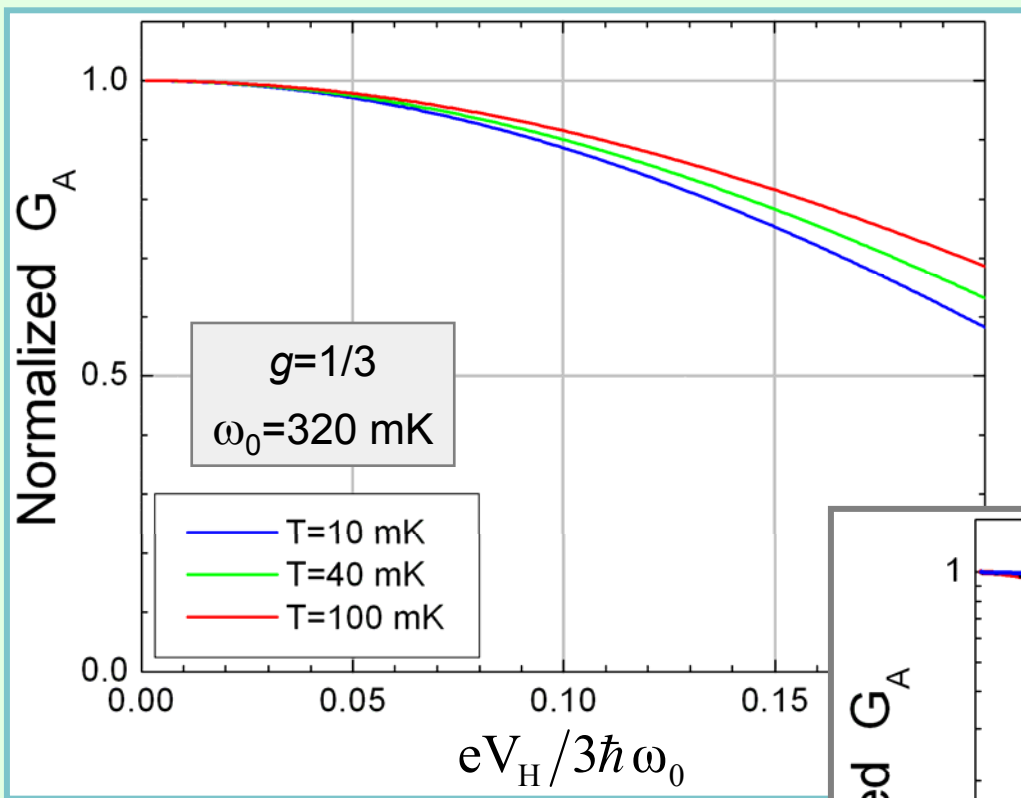
$q = e/3$ is the quasiparticle charge

oscillatory: $\omega_0 = 4\pi u / C$

u is the edge velocity

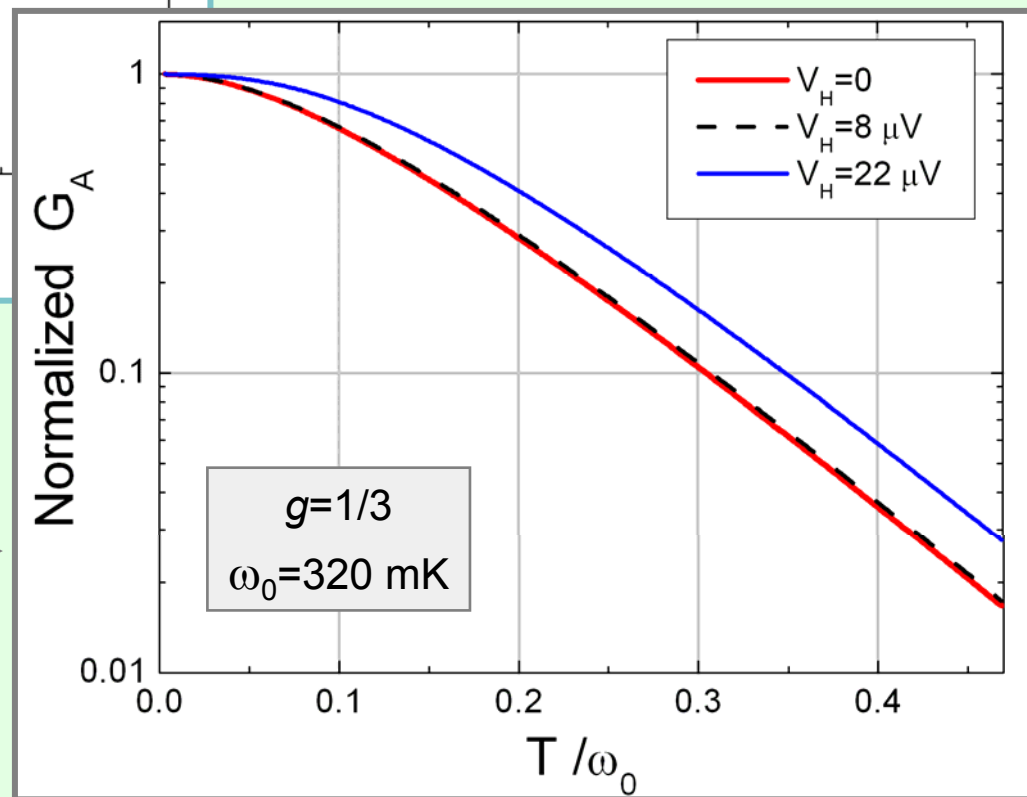
C is the closed path circumference

Chamon et al. Model Predictions

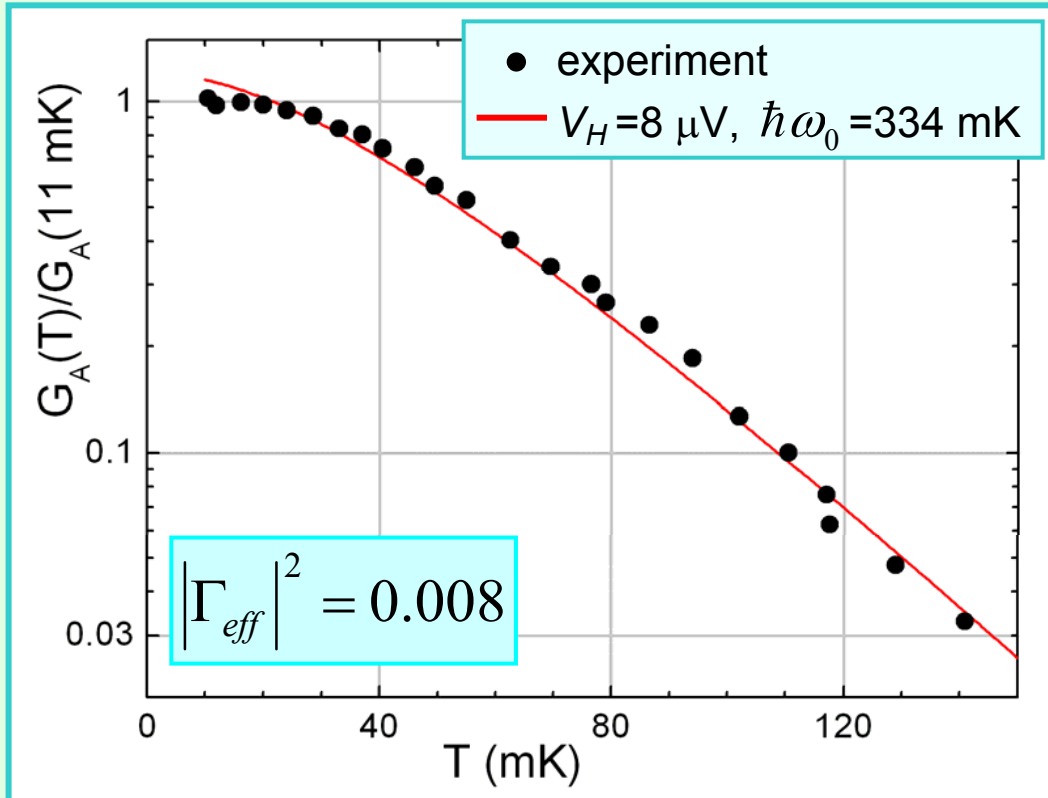


fixed temperature
variable bias V_H

fixed bias V_H
variable temperature



Comparison with Quantum Interferometer Model



- fit is very good!
- $V_H = 8 \mu\text{V}$ from experiment

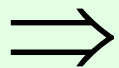
$$V_H = \sqrt{7.2^2 + 2^2} = 7.5 \mu\text{V}$$

applied bias

noise voltage

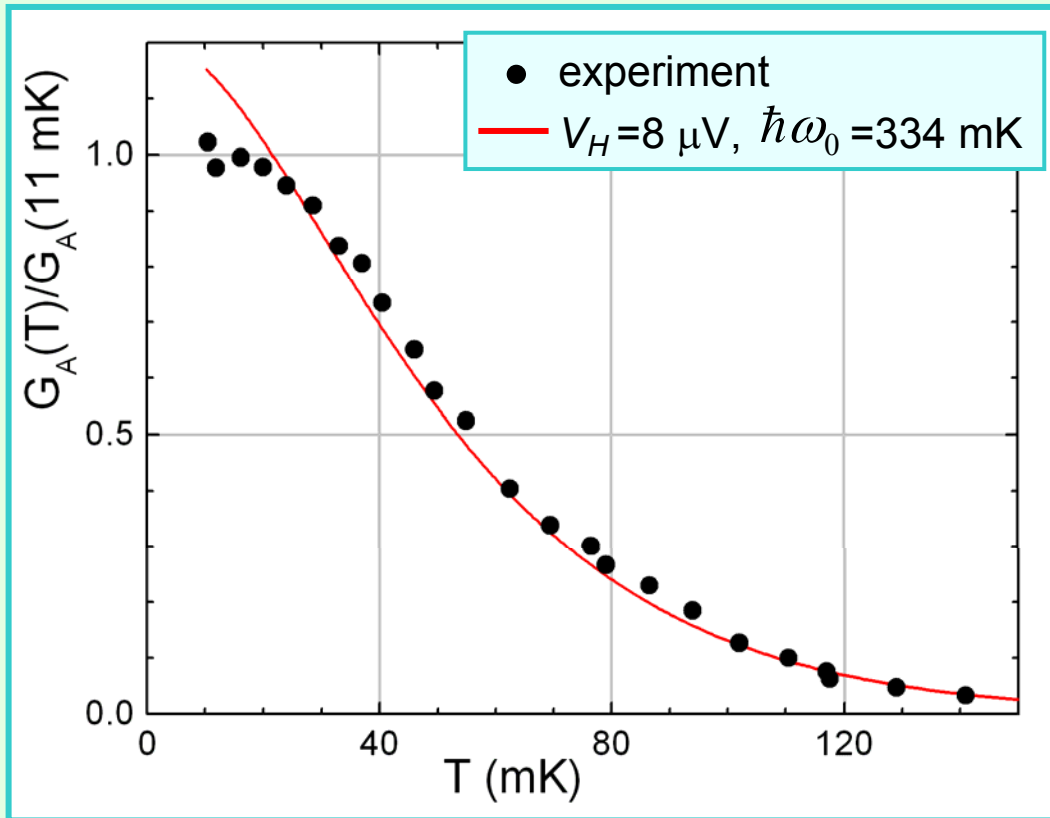
- fit is very similar for $V_H \rightarrow 0$
- Chamon et al. theory is first order in Γ
- experimental $\Gamma_{eff} \ll 1$

Using $\omega_0 = 4\pi u / C$ from fit ($C = 4.0 \mu\text{m}$): $u = 1.4 \times 10^4 \text{ m/s}$



confining electric field
(at chemical potential) $= u B = 1.7 \times 10^5 \text{ V/m}$

Effective Electron Temperature (T_e)



a) No saturation of oscillation amplitude down to lowest T 's

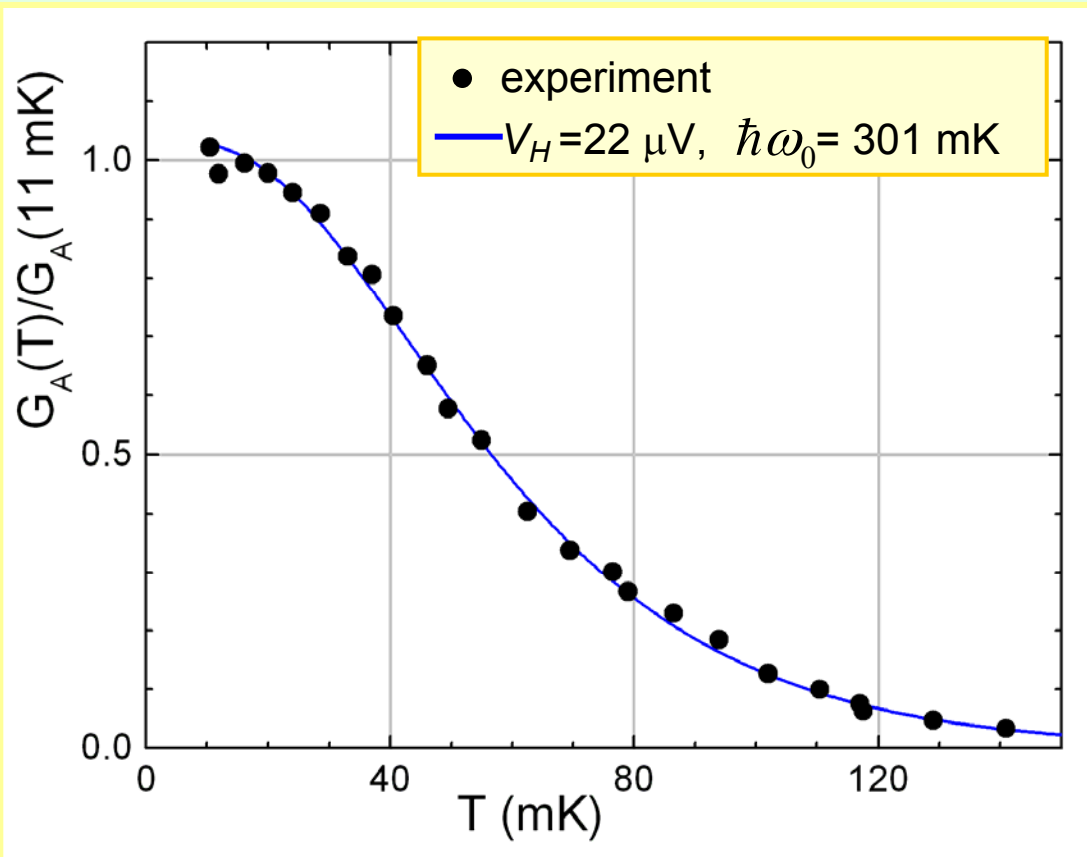
- amplitude changes by:
40% from 40 to 10 mK
5% from 20 to 10 mK

b) noise voltage $2 \mu\text{V}$ and $T_e = 18 \text{ mK}$ obtained from QAD experiments using almost **identical experimental conditions**

- we expect less heating in LQPI, since LQPI (2000 e) is larger than QAD (300 e). Also, tunneling amplitude Γ is less in LQPI

\Rightarrow in LQPI, T_e should be less than 18 mK observed in QAD

Adding V_H as a fitting parameter



$V_H = 22 \mu\text{V}$
fit is extremely good!
however, $22 \mu\text{V}$ is
not likely in our set-up!

From our experimental set-up
we determine

$$V_H = \sqrt{7.2^2 + 2^2} = 7.5 \mu\text{V}$$

applied bias noise voltage

Tests that rule out $V_H = 22 \mu\text{V}$ from Heating

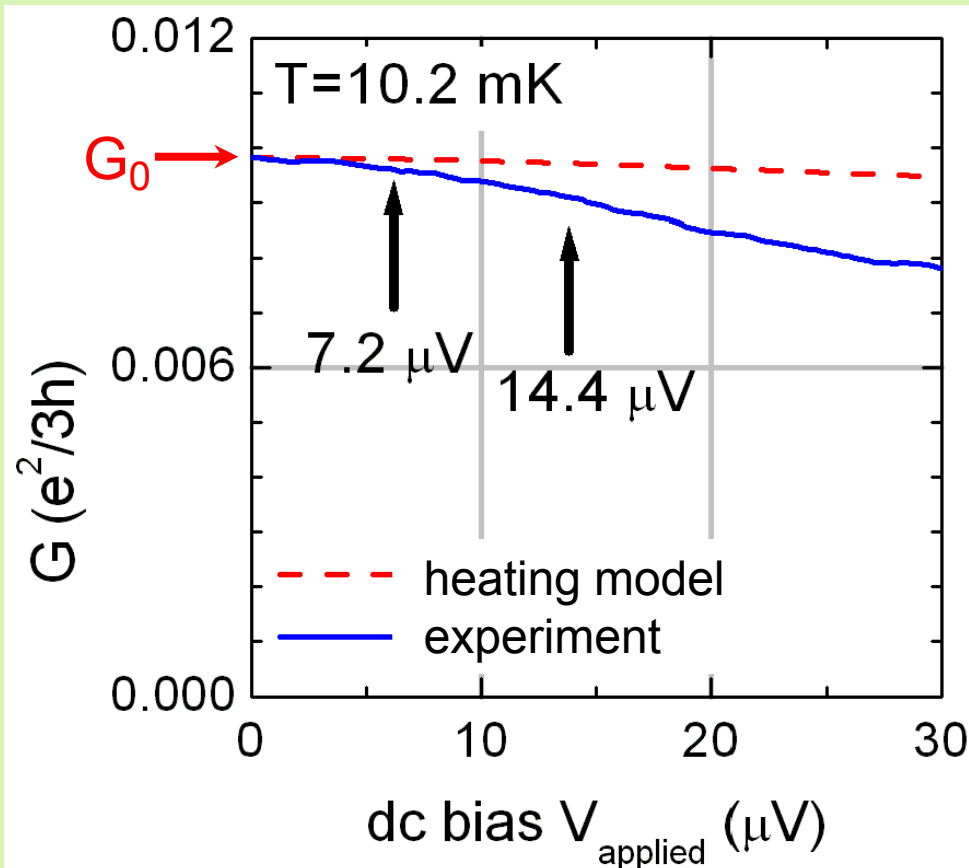
- electron heating model:

a) $P \propto V_H^2 = V_{\text{applied}}^2 + V_{\text{noise}}^2$

b) $T_e^5 - T_{\text{bath}}^5 \propto V_H^2$

c) $\frac{\delta G}{\delta T_e} = G_0 \frac{\partial H_g}{\partial T}$

- experiment vs. heating model (assuming $V_{\text{noise}} = 21 \mu\text{V}$ **WRONG!**)



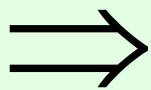
V_{applied}		$\delta G / G_0$	
		heating model	exp.
ac	$\times 0.5$	0.25%	2-3%
dc	7.2 μV	- 0.3%	- 3%
	14.4 μV	- 1%	- 8%

Conclusions

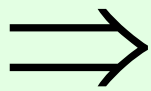
- T-dependence of the amplitude of conductance oscillations shows **thermal dephasing**, expected for an electron interferometer
- data fit very well the χ LL theory of Chamon et al. for a two point-contact **LQPI**
- Topological nature of fractional statistics ($\Delta_{\Phi}=5h/e$):

$f = 2/5$ island quasiparticles determine the period, but do not affect T-dependence of the oscillation amplitude:

$\Delta_{\Phi}=5h/e$ persists to the highest T

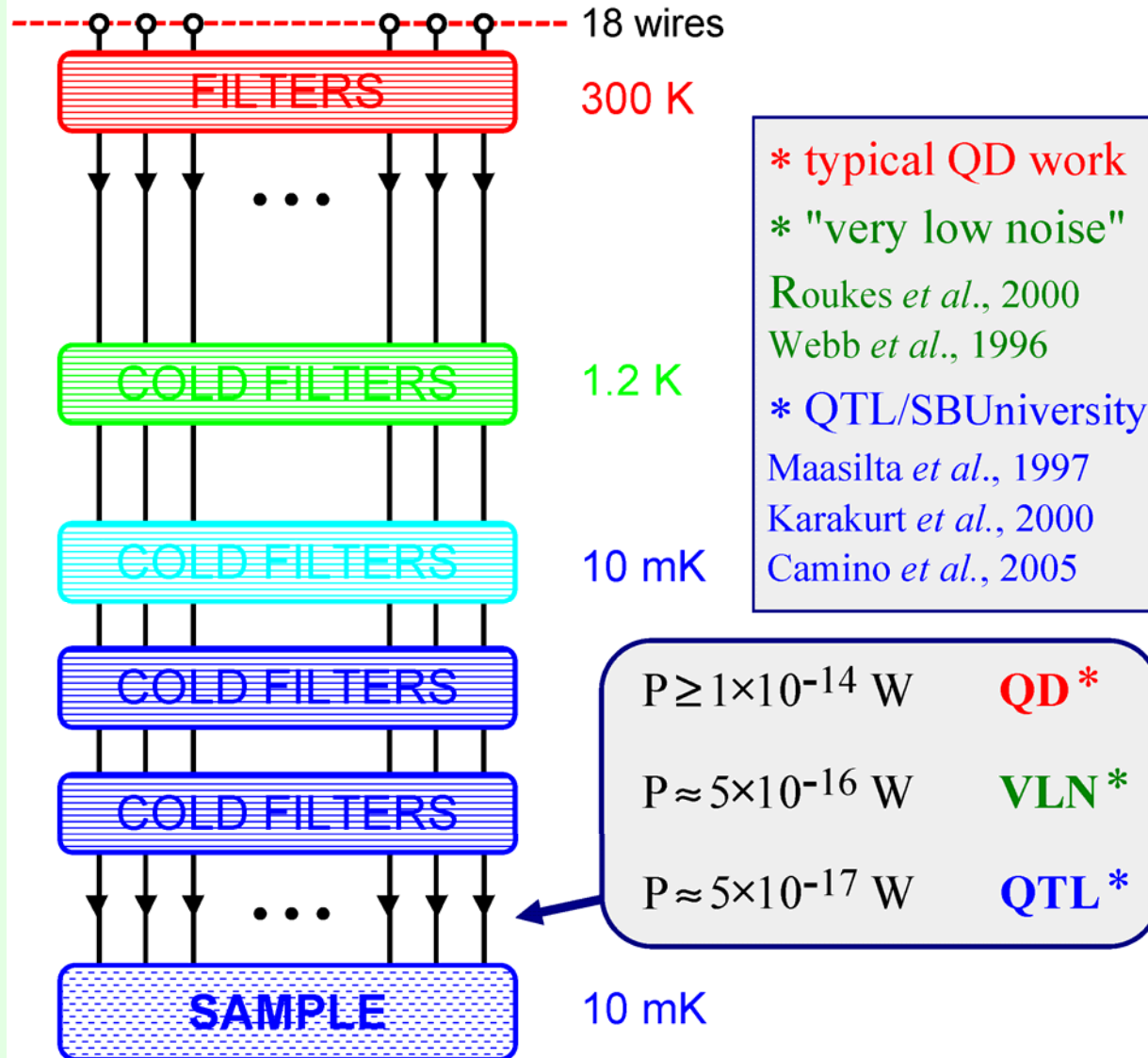


reveals robustness of statistical interaction due to its topological nature

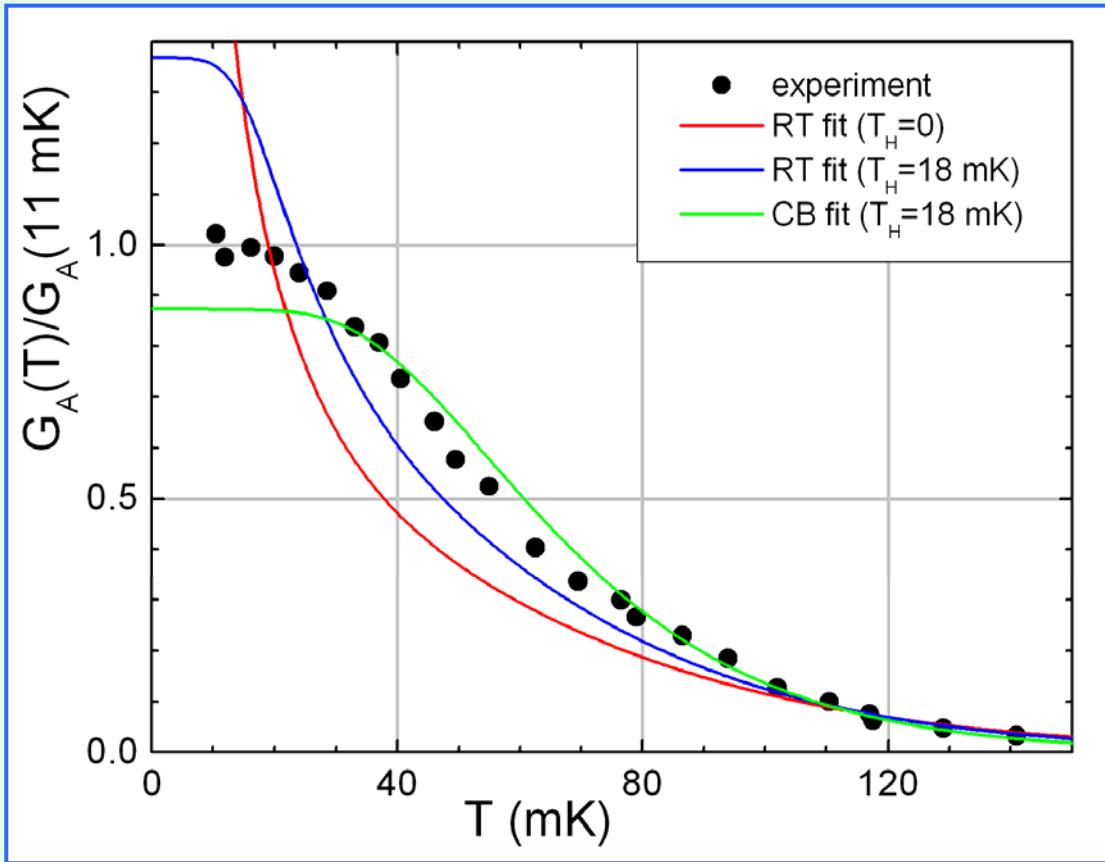


potential application for implementing topological quantum computation

Electromagnetic "Noise" Filtration



Comparison with Resonant Tunneling and Coulomb Blockade Models



1) resonant tunneling (RT):

$$G(T) = G_0 / T \cosh^2(X/T)$$

no realistic T_H fits data

2) Coulomb blockade (CB):

$$G(T) = G_0 X / T \sinh(X/T)$$

- fit does not depend on T_H at this scale

- fit saturates at ~32 mK, while experiment still rises
- if CB, minima should rise while maxima remain const. as T is increased. This is not observed in experiment