Majorana Fermion Induced Non-local Current Correlations in Spin-orbit Coupled Superconducting Wires

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Jornal Club

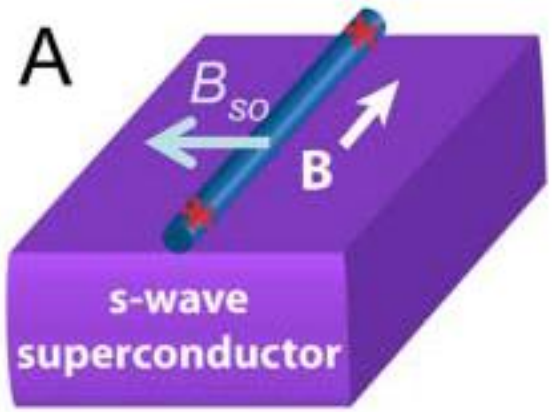
29th January, 2013

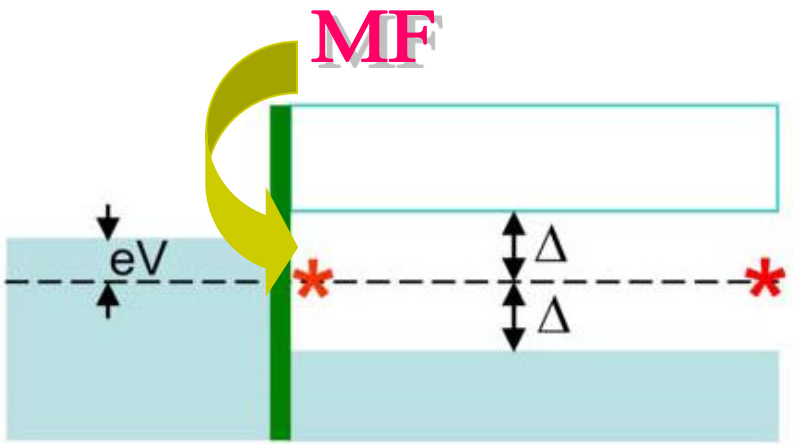
arxiv:1212.5879v2 [cond-mat.mes-hall]

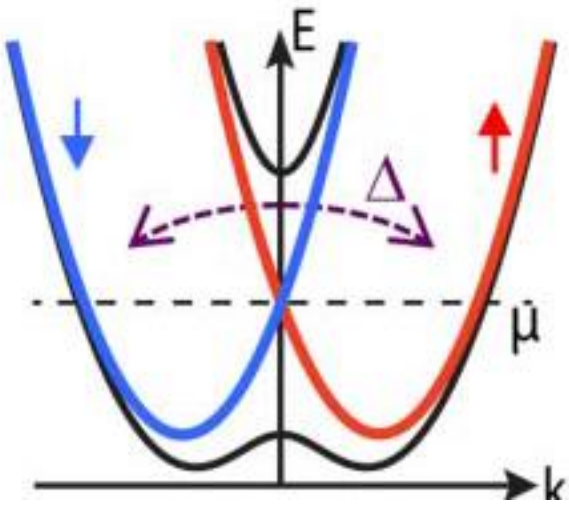
Outline of the talk

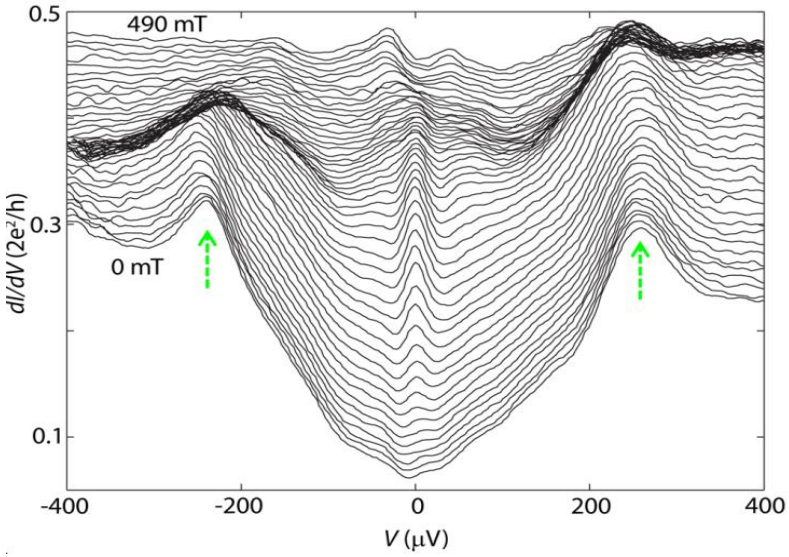
- Introduction and Motivation
- Model and Formalism
- Results: Current and Shot Noise
- Disorder effect
- Conclusion

Introduction and Motivation



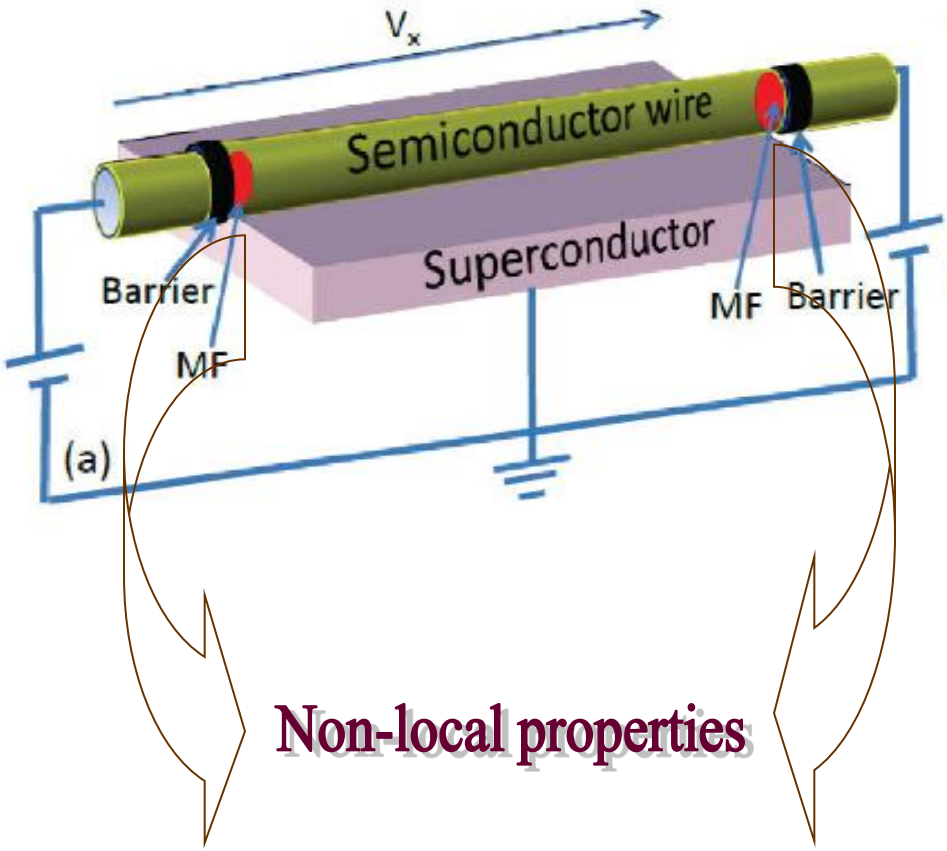


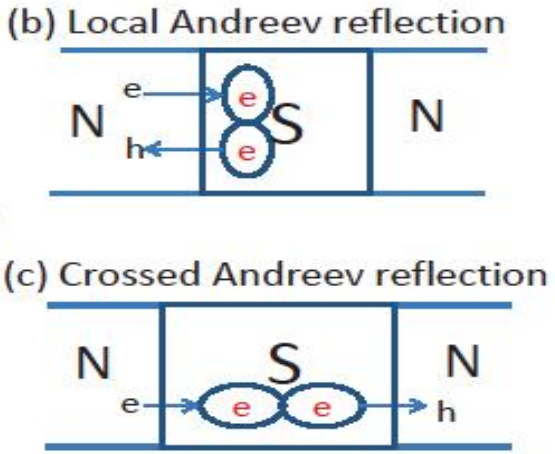




Science 336, 1003 (2012)

Model and Formalism





Hamiltonian

$$
\begin{aligned}
H_{q1D} &= \sum_{\mathbf{R},\mathbf{d},\alpha} -t(\psi^{\dagger}_{\mathbf{R}+\mathbf{d},\alpha}\psi_{R,\alpha} + h.c.) - \mu\psi^{\dagger}_{\mathbf{R},\alpha}\psi_{\mathbf{R},\alpha} \\
&+ \sum_{\mathbf{R},\mathbf{d},\alpha,\beta} -iU_R\psi^{\dagger}_{\mathbf{R}+\mathbf{d},\alpha}\hat{z}\cdot(\vec{\sigma}\times\mathbf{d})_{\alpha\beta}\psi_{\mathbf{R},\beta} + h.c. \\
&+ \sum_{\mathbf{R},\alpha,\beta} \psi^{\dagger}_{\mathbf{R},\alpha}[(V_x\sigma_x)_{\alpha\beta} + V_{\mathrm{imp}}(\mathbf{R})\delta_{\alpha\beta}]\psi_{\mathbf{R},\beta} \\
&+ \sum_{\mathbf{R},\alpha} \Delta\psi^{\dagger}_{\mathbf{R},\alpha}\psi^{\dagger}_{\mathbf{R},-\alpha} + h.c.
\end{aligned}
$$

Chosen Parameters

$$\Delta = 250\mu eV$$
$$t \approx 6.25meV$$
$$\alpha \approx 0.25eV\cdot\mathring{A}$$
$$a \approx 10nm$$
$$N_x a \approx 1\mu m$$
$$N_y a \approx 100nm$$
$$t_{LC} = 0.3t$$
$$t_{RC} = 0.3t$$

$V_x = 2\Delta$ → Topological regime → MF

Recursive Green's Function

$$S_{ij}^{\alpha\beta} = -\delta_{i,j}\delta_{\alpha,\beta} + i[\Gamma_i^{\alpha}]^{1/2} * G^r * [\Gamma_j^{\beta}]^{1/2}$$

Formula

$$\bar{I}_i = \frac{\mathrm{e}}{h}\int_0^{\mathrm{e}V} \sum_{j,\alpha} \mathrm{Tr}[I - \mathrm{sgn}(\alpha) S_{ij}^{e\alpha}(E)^{\dagger} S_{ij}^{e\alpha}(E)]dE,$$

$$P_{ij} = \sum_{\alpha,k\beta\neq l\beta'} \mathrm{sgn}(\alpha)\mathrm{Tr}[S_{il}^{e\beta'}(E)^{\dagger} S_{ik}^{e\beta}(E) S_{jk}^{\alpha\beta}(E)^{\dagger} S_{jl}^{\alpha\beta'}(E)],$$

$$C_{ij} = \frac{2\mathrm{e}^2}{h}\int_0^{eV} P_{ij}(E)dE,$$

M. P. Anantram and S. Datta, PRB 53,16390 (1996)

$$C_{ij} = \int_{-\infty}^{+\infty} \overline{\delta I_i(0)\delta I_j(t)}dt \qquad \delta I_i = I_i(t) - \bar{I}_i$$

Naive Expectation →

$$F = S/I$$

(a) Topological Regime:

Presence of Majoranas

Fano factor $F \approx e$

CAR dominates

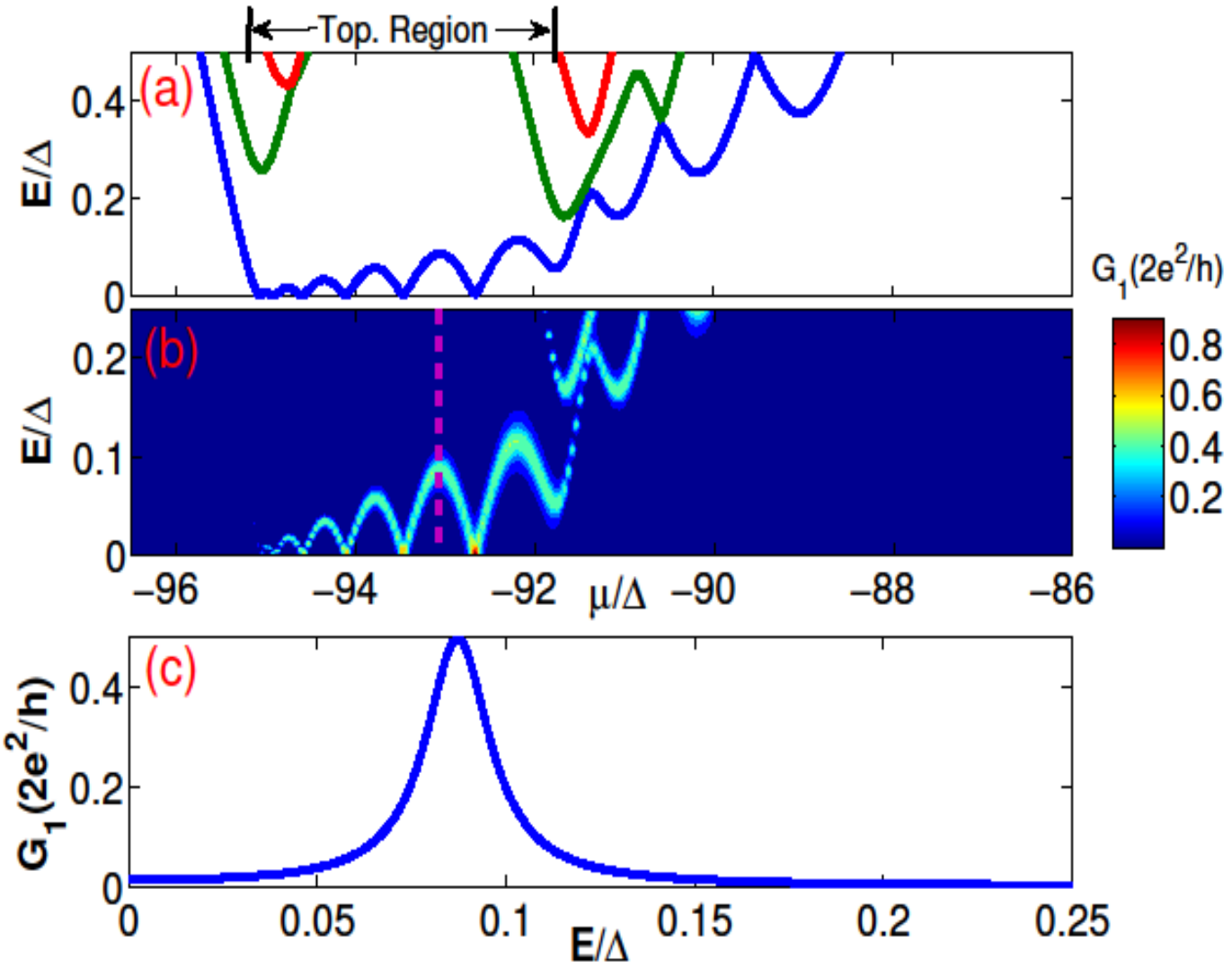
(b) Non-Topological Regime:

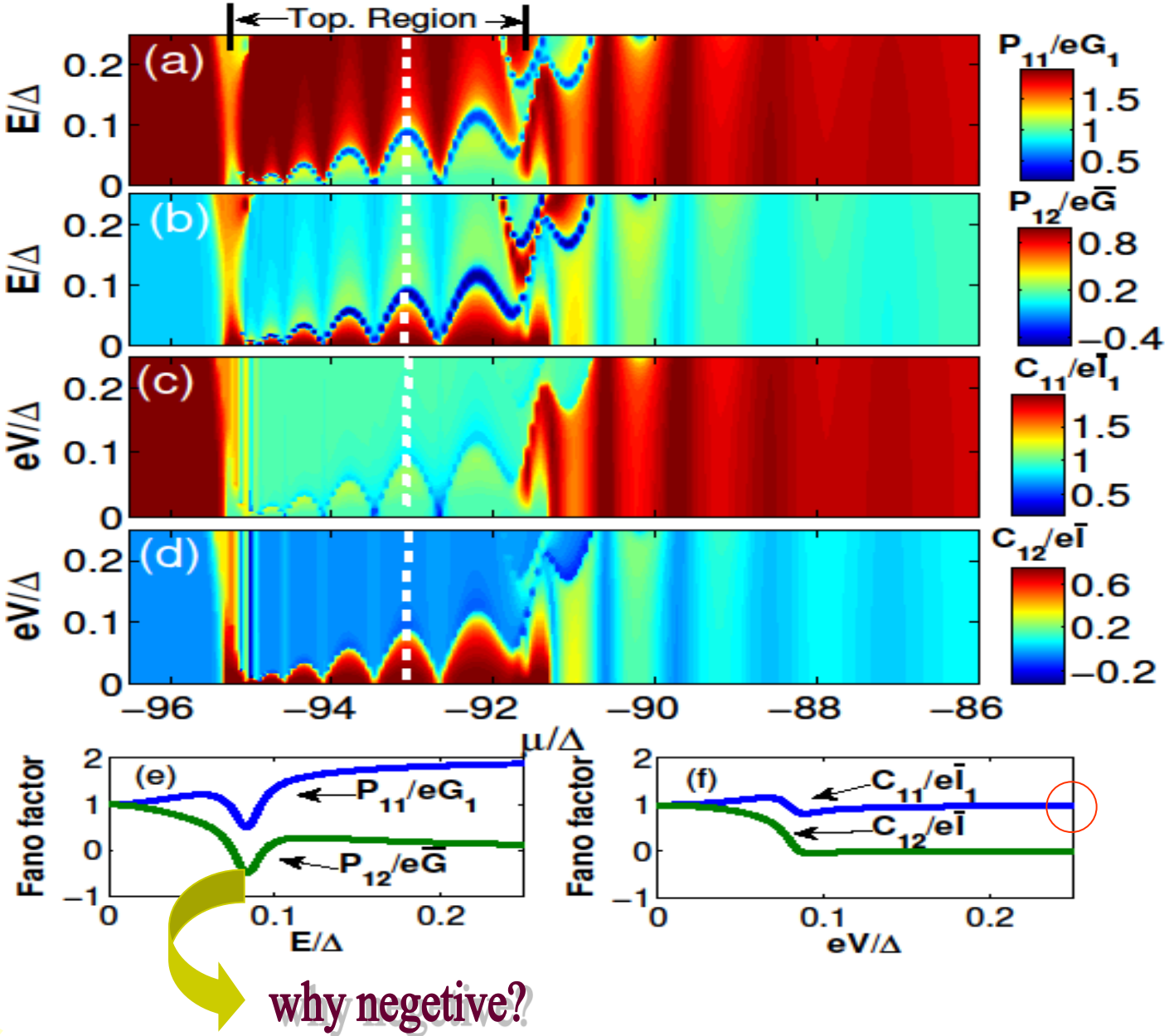
No Majoranas

Fano factor $F \approx 2e$

AR dominates

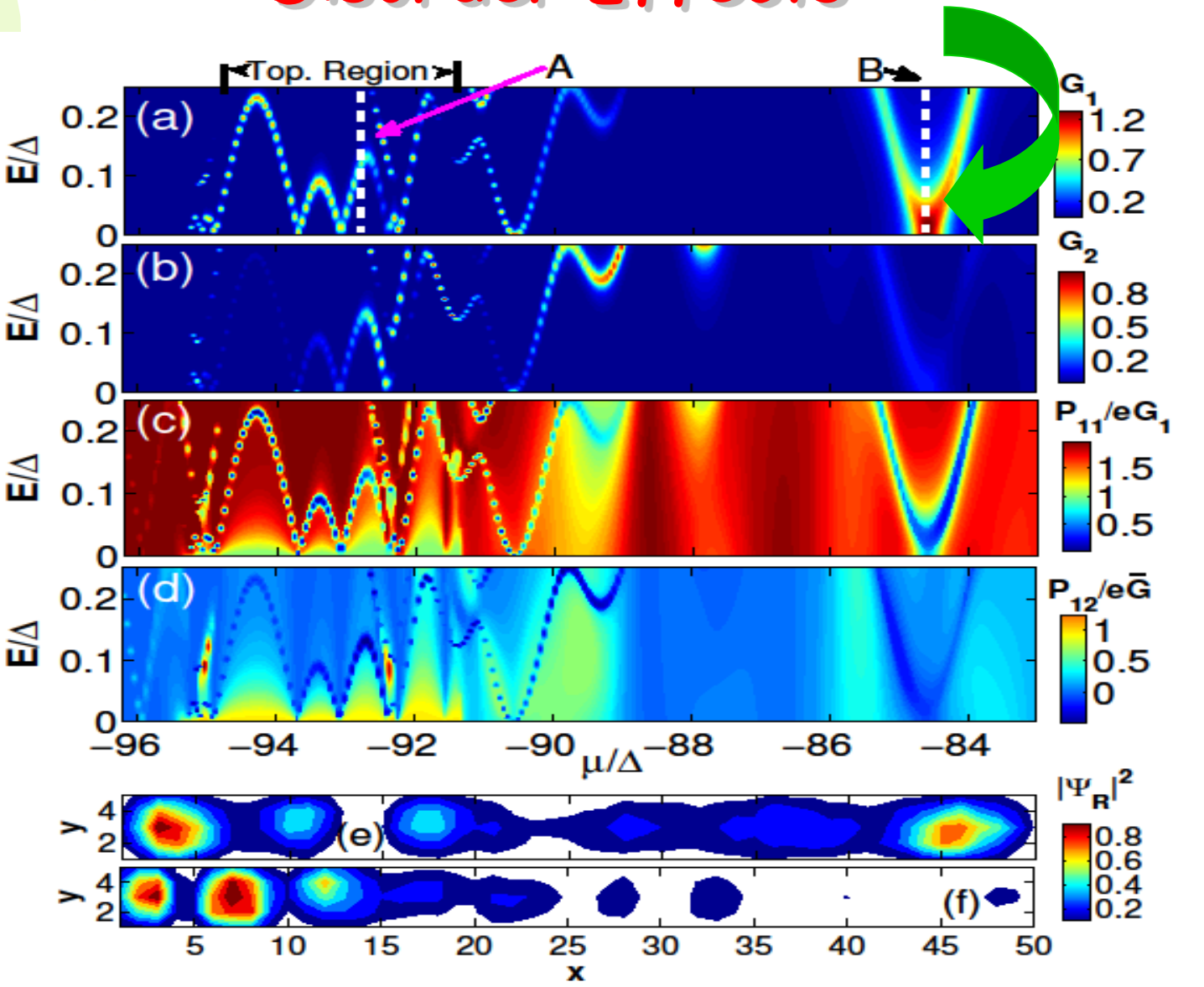
Numerical Results




Top. Region
(a)
(b)
(c)
(d)
E/Δ
eV/Δ
0.2
0.1
0
−96
−94
−92
−90
−88
−86
P_{11}/eG_1
1.5
1
0.5
$P_{12}/e\bar{G}$
0.8
0.2
−0.4
$C_{11}/e\bar{I}_1$
$C_{12}/e\bar{I}$
0.6
−0.2
μ/Δ
(e)
(f)
Fano factor
P_{11}/eG_1
$P_{12}/e\bar{G}$
$C_{11}/e\bar{I}_1$
$C_{12}/e\bar{I}$
E/Δ
eV/Δ
why negetive?

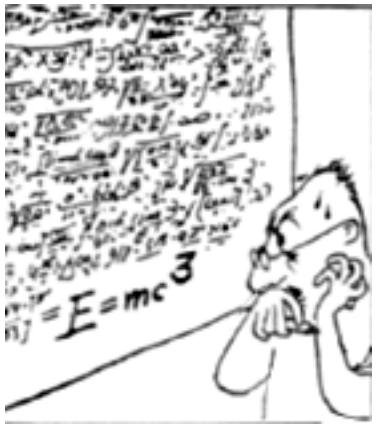
Disorder Effects

PRL 109, 267002 (2012)
PRB 87, 024515 (2013)



$w = 20\Delta$ → Strong disorder

Conclusions



- Shot noise can be another probe to determine MF????

- "Particularly, the shot noise can be used to distinguish the fermionic end states from true MF end states even in the presence of disorder".


THANKS
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