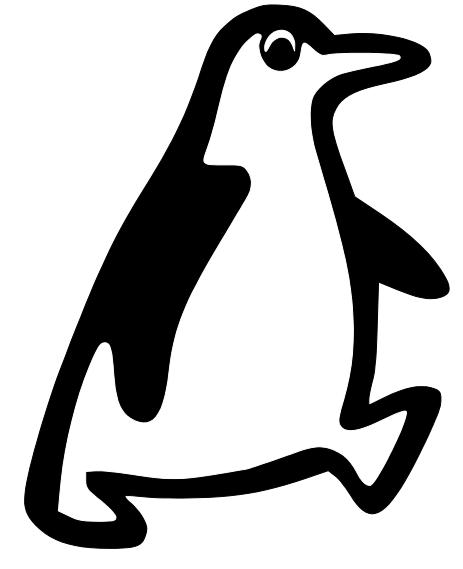# Andreev tunneling in NIS junctions and and SINIS turnstiles

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1. Introduction

• Aim: Create a current standard with relative accuracy of 10^{-7} with SINIS turnstiles
• Higher order tunneling processes ultimately limit the charge quantization.
• Here we focus on Andreev reflection, the dominant two electron process between a superconductor and a normal metal.
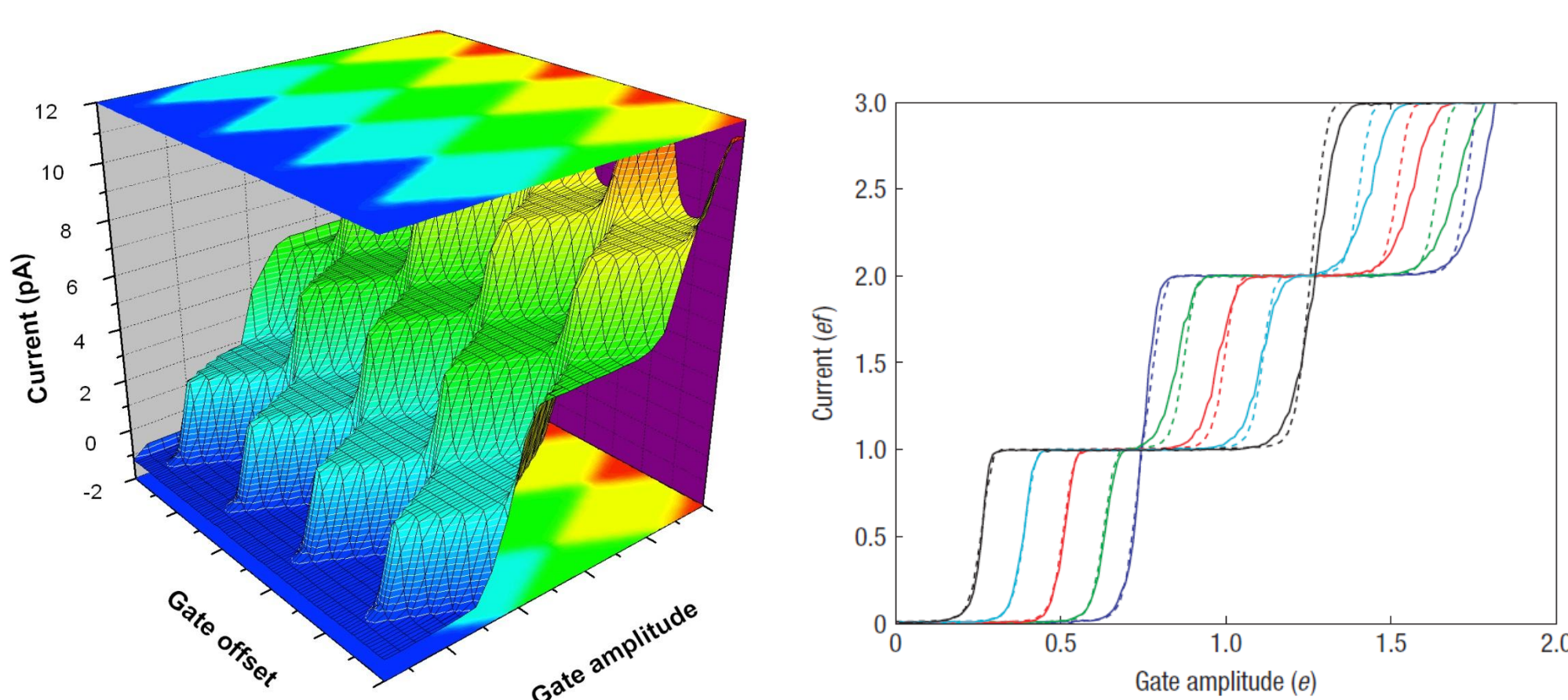
2. Basics

• Single electron transistor with superconducting leads and normal metallic island: (SINIS = SET with NIS junctions)
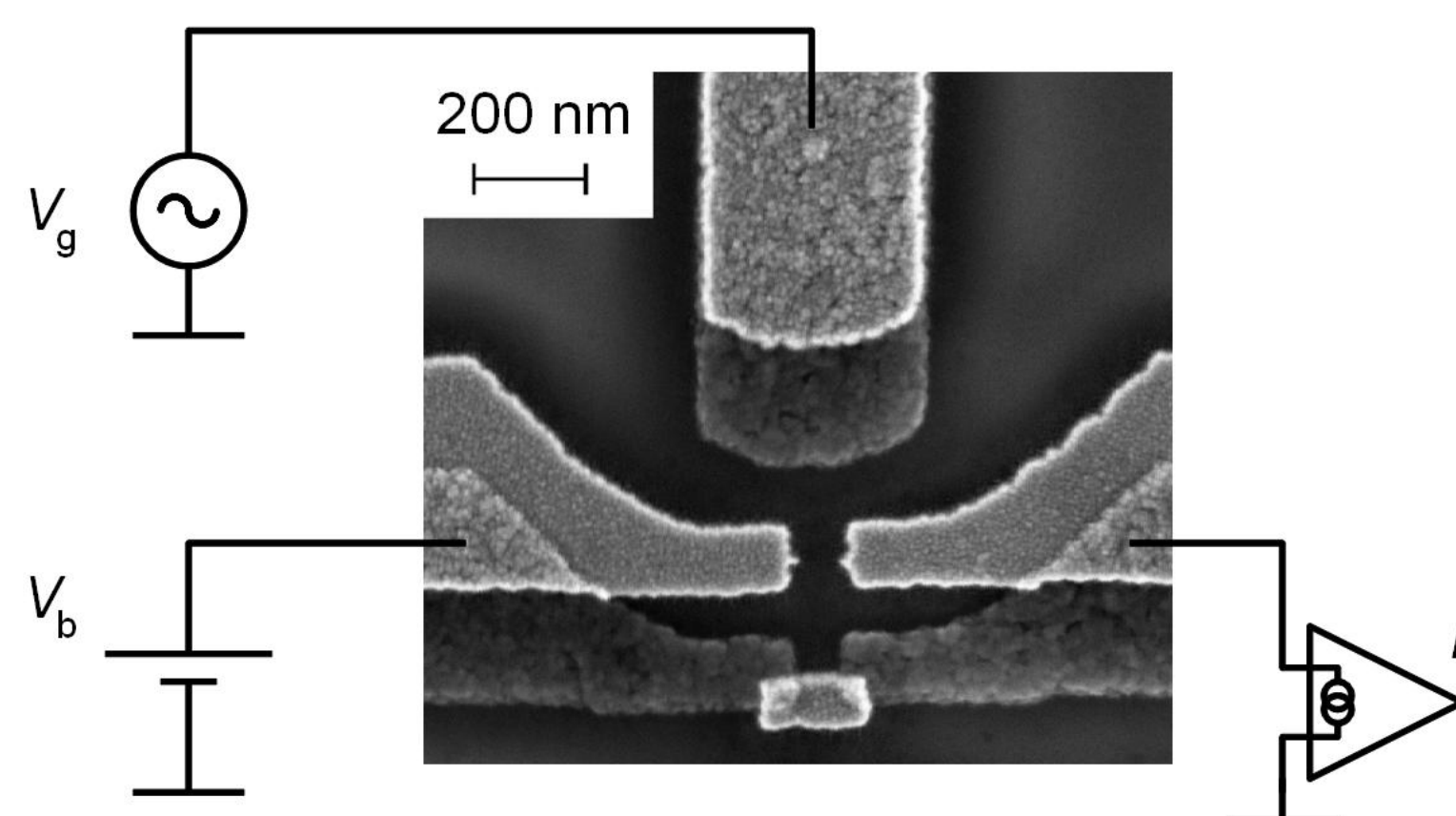
• DC current - voltage characteristics with extended stability regions for the charge states:
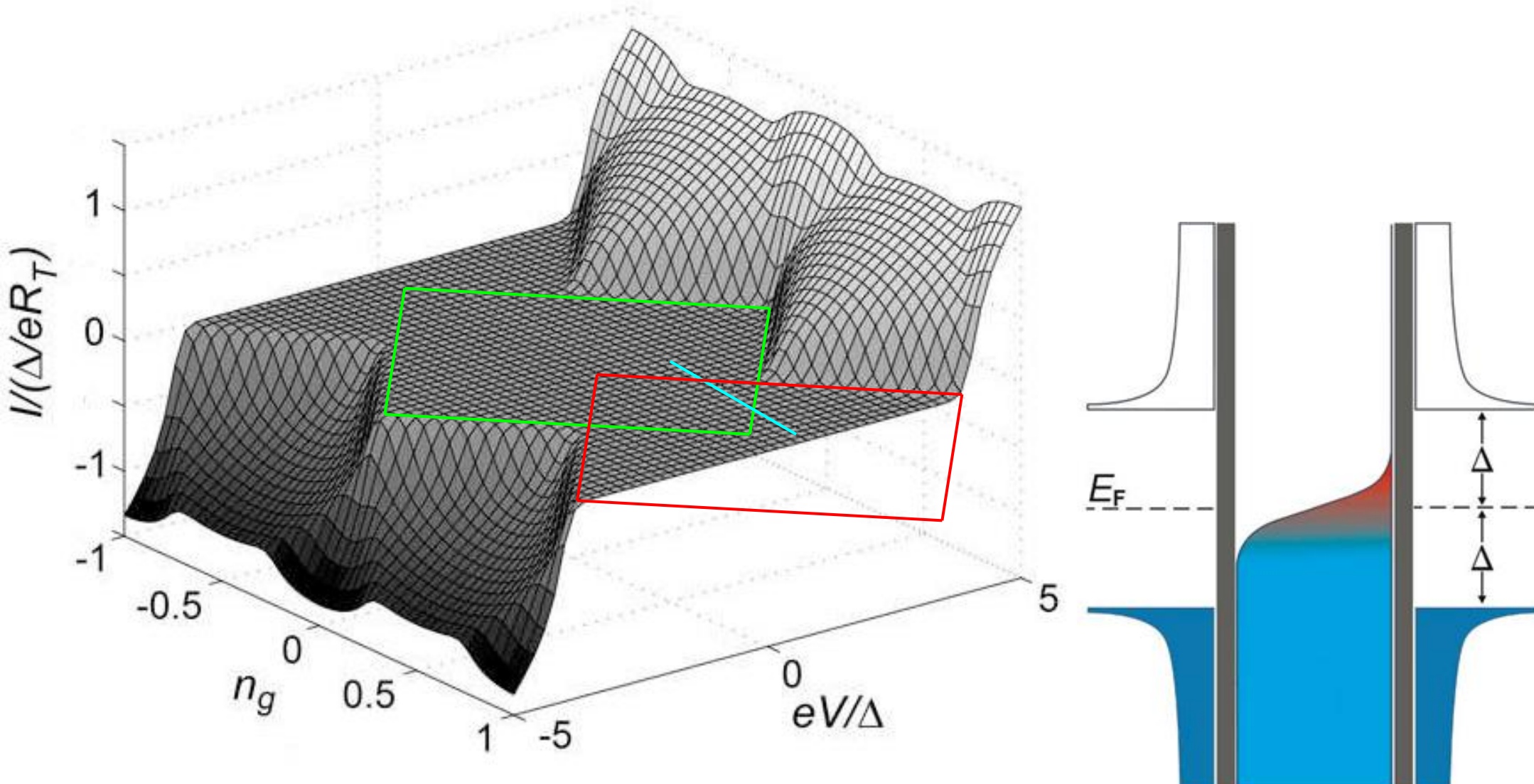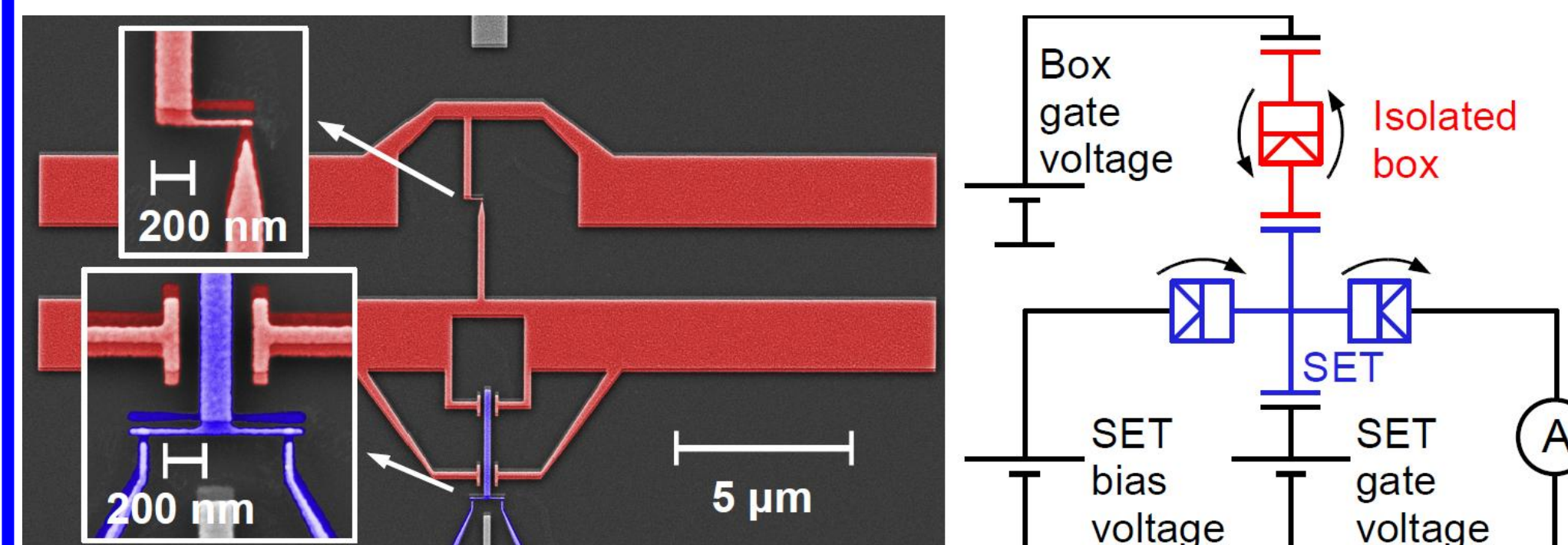

• Charge pumping: DC voltage bias and a RF gate drive produces electron pumping with current $I = nef$

3. Counting single Andreev tunneling events

• SET electrometry is used to detect individual tunneling events between two metallic islands connected with an NIS junction:
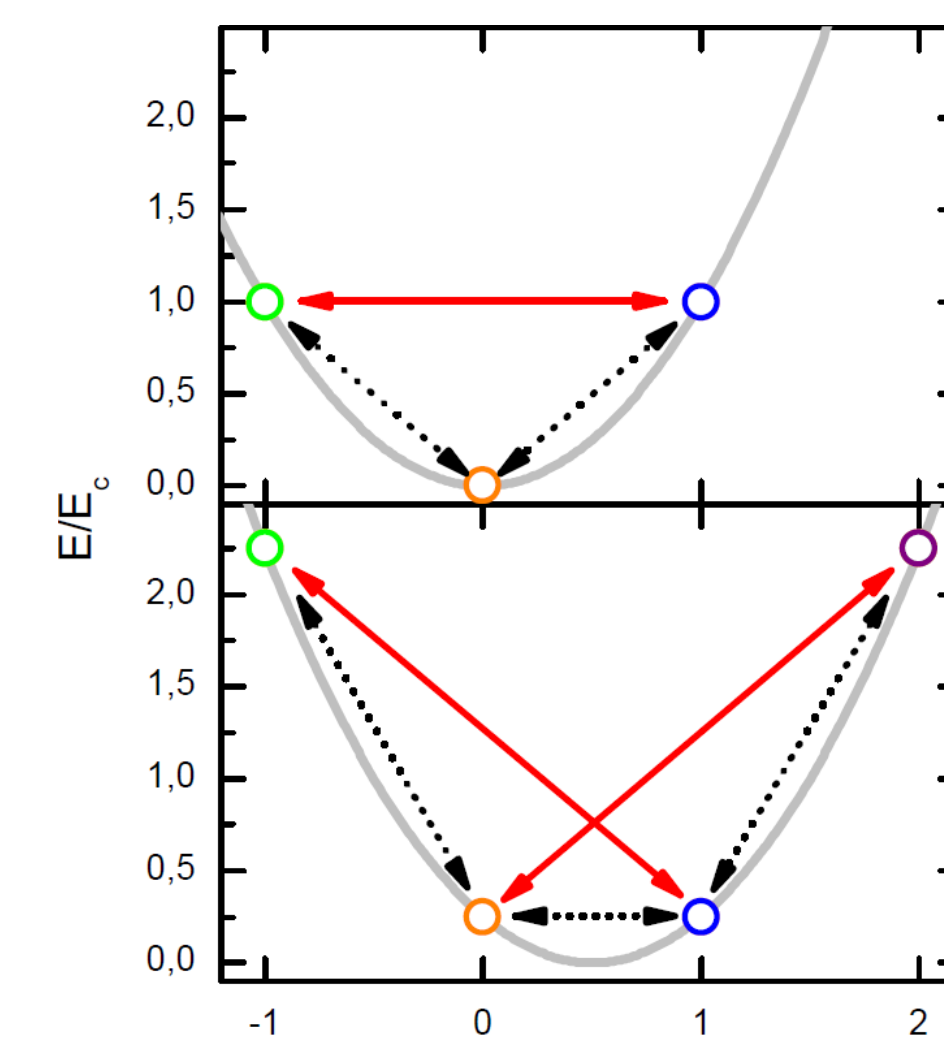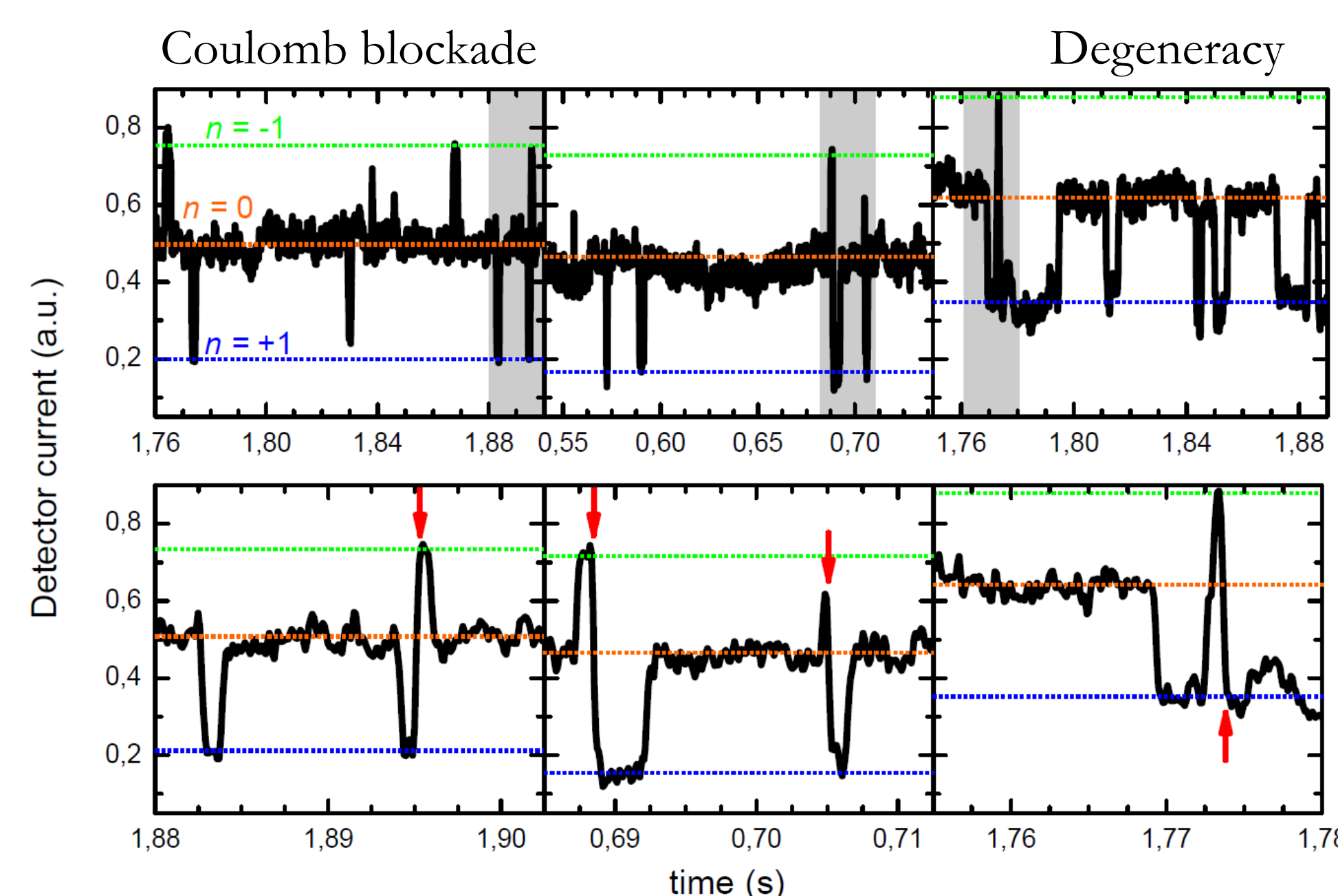

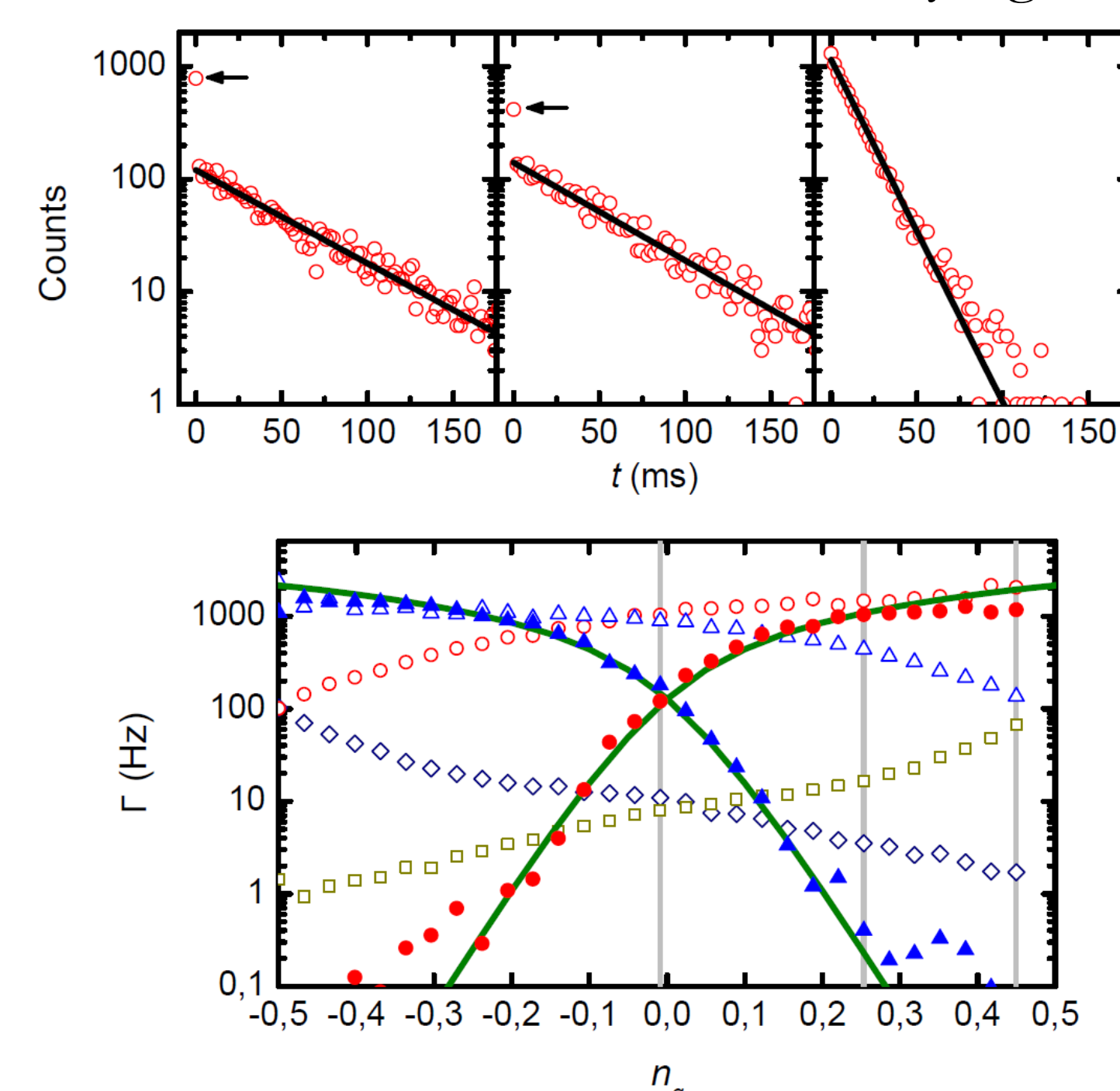• Sample parameter values:
$E_c = 0.2 \Delta$
$\Delta = 216 \ \mu eV$
$R_T = 2 \ M\Omega$

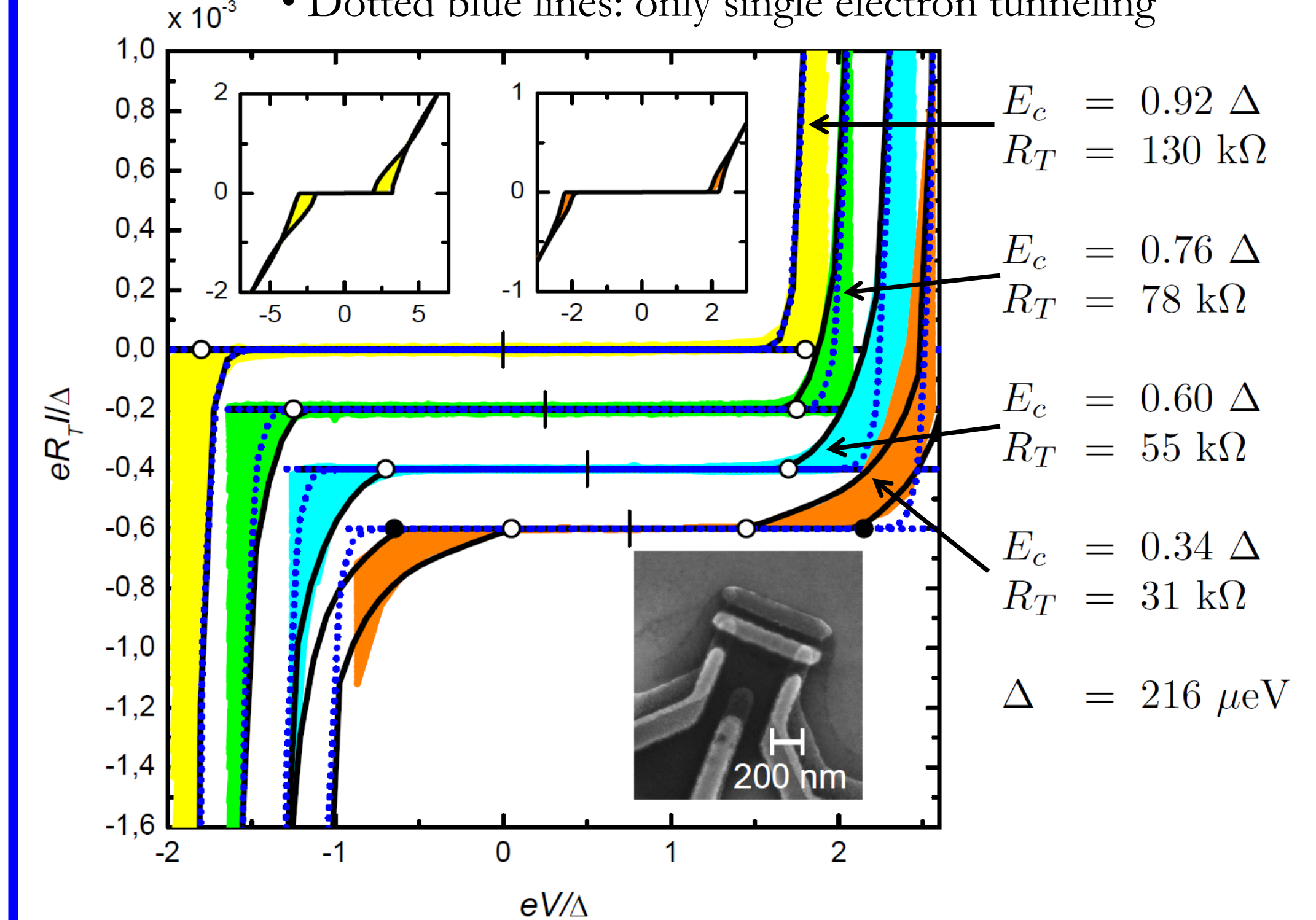• Time traces of the electrometer current::

Coulomb blockade | Degeneracy
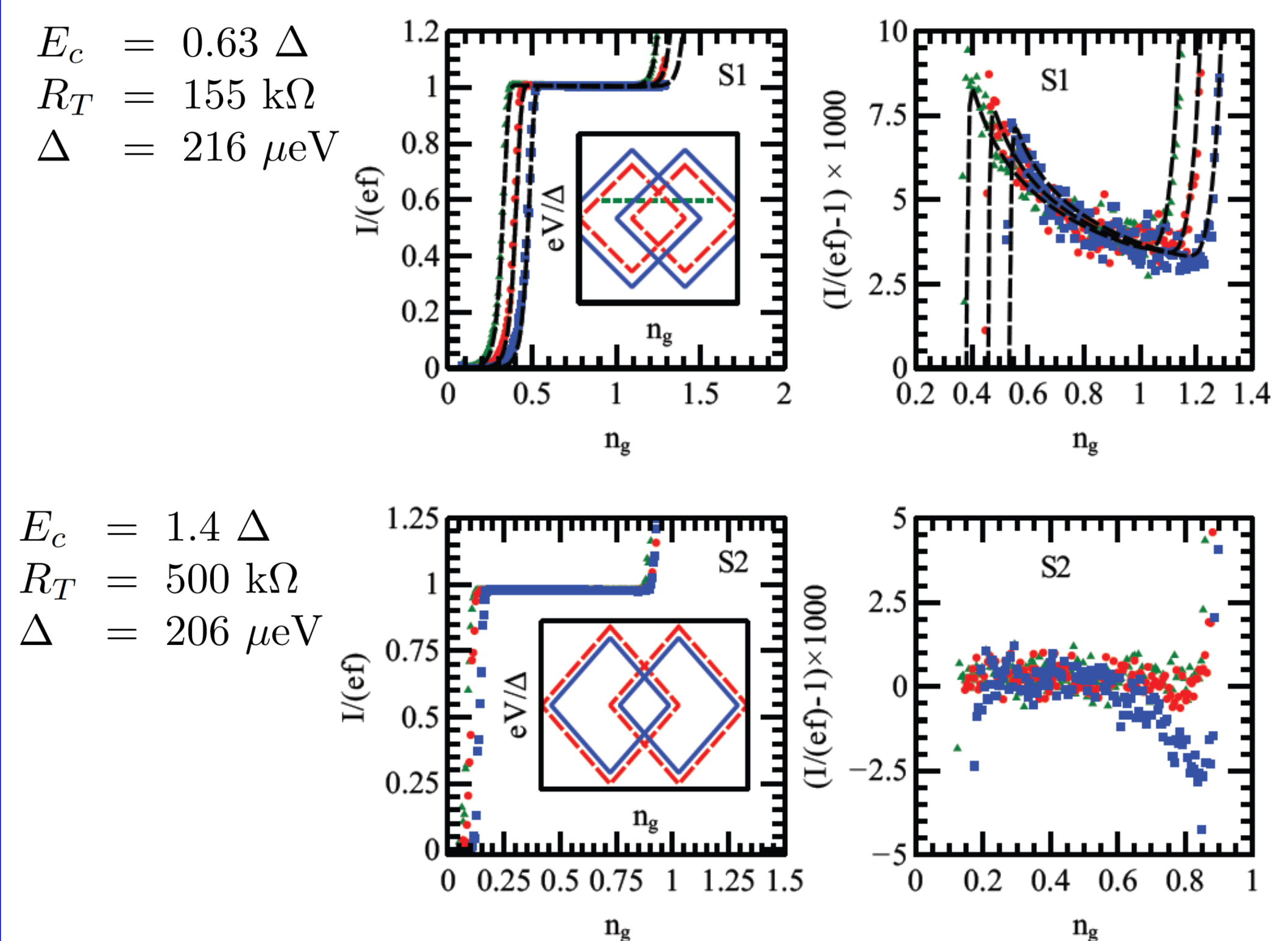
• Lifetime distribution of the lowest lying state:

Effective size of a conduction channel:
$A_{ch} = 30 \ nm^2$

4. Andreev tunneling in SINIS turnstiles
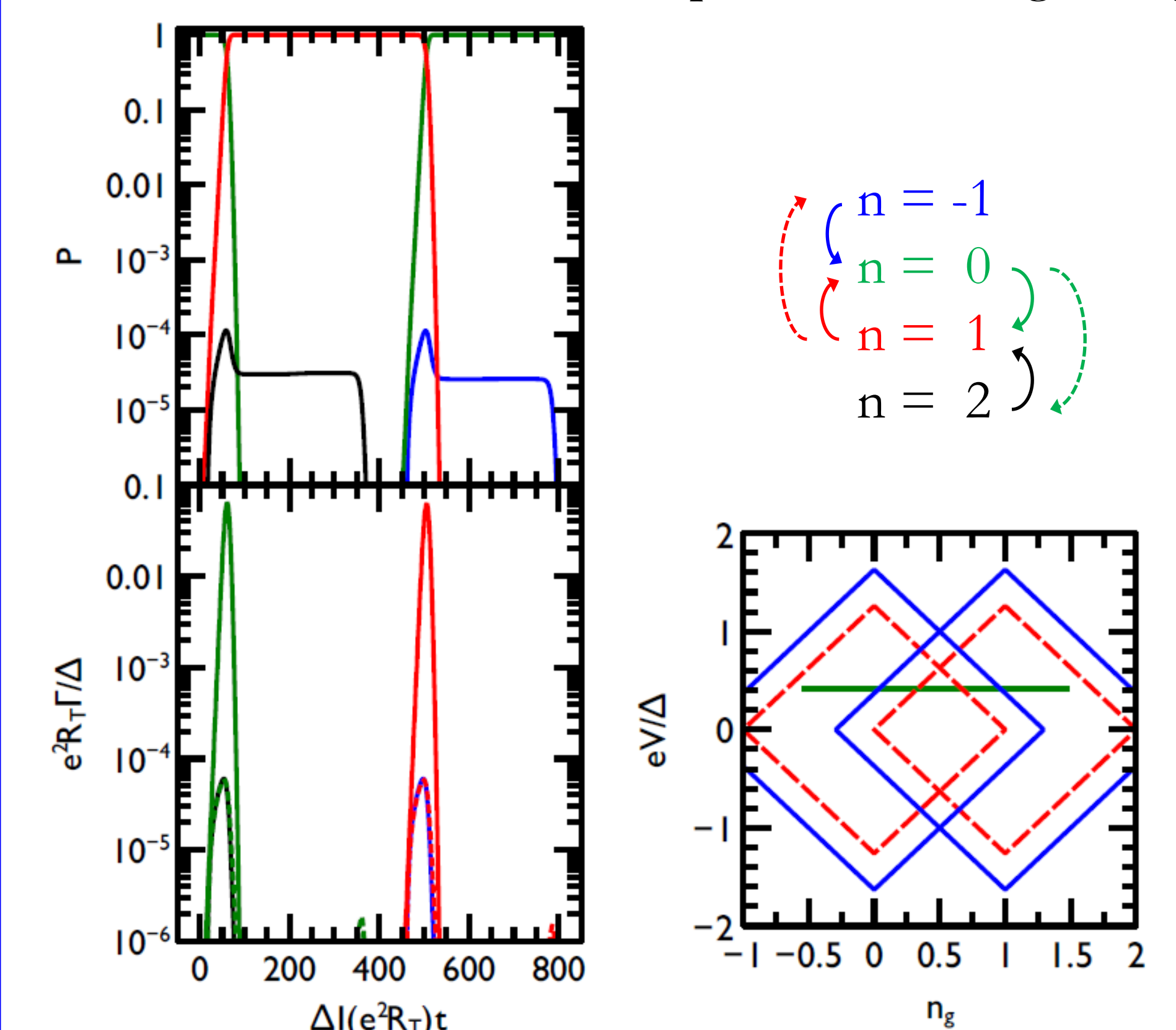
• Colored regions: measured current
• Solid black lines: Andreev tunneling taken into account
• Dotted blue lines: only single electron tunneling

$E_c = 0.92 \Delta$, $R_T = 130 \ k\Omega$
$E_c = 0.76 \Delta$, $R_T = 78 \ k\Omega$
$E_c = 0.60 \Delta$, $R_T = 55 \ k\Omega$
$E_c = 0.34 \Delta$, $R_T = 31 \ k\Omega$
$\Delta = 216 \ \mu eV$

• Presence of Andreev tunneling during electron pumping:
$f = 10 \ MHz$

$E_c = 0.63 \Delta$
$R_T = 155 \ k\Omega$
$\Delta = 216 \ \mu eV$

$E_c = 1.4 \Delta$
$R_T = 500 \ k\Omega$
$\Delta = 206 \ \mu eV$

• Simulations of the different processes during the cycle:

$n = -1$
$n = 0$
$n = 1$
$n = 2$

References

Pekola et al. Nature Phys. **4**, 120 (2008)
Averin, Pekola, PRL **101**, 066801(2008)

Saira et al. PRB **82**, 155443(2010)
Maisi et al. arXiv:1012.5750 (2010)