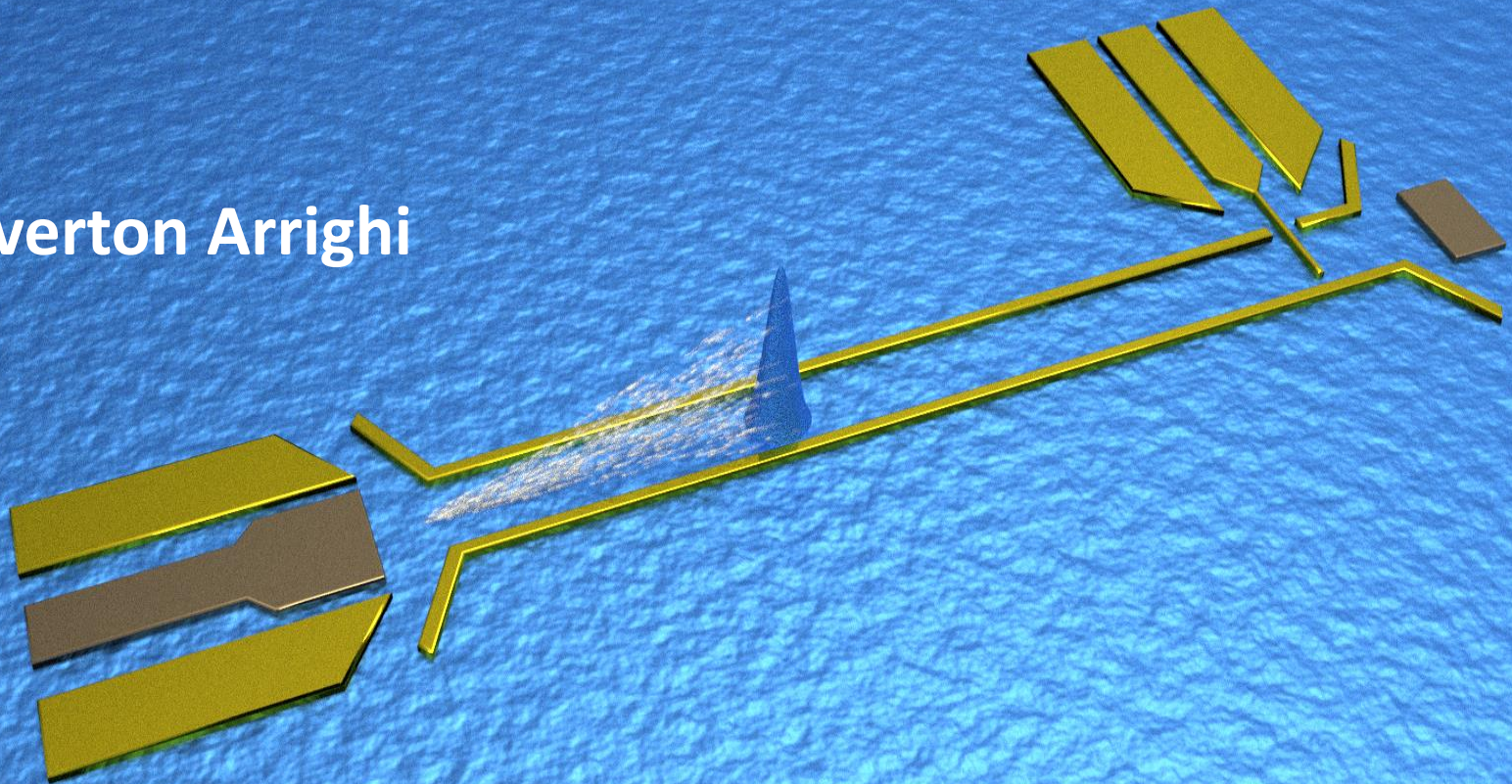


Unveiling the bosonic nature in an ultrafast single-electron pulse

Everton Arrighi



Collaborators

Gregoire Roussely,

Shintaro Takada, Giorgos Georgiou, Martin Schalk

Tristan Meunier, Matias Urdampilleta, **Christopher Bäuerle**



Arne Ludwig

Andreas Wieck

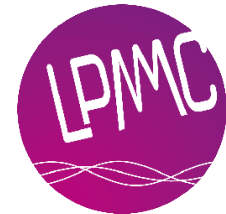
University of Bochum

RUHR
UNIVERSITÄT
BOCHUM

RUB

Franck Hekking

LPMMC Grenoble



Pacôme Armagnat,

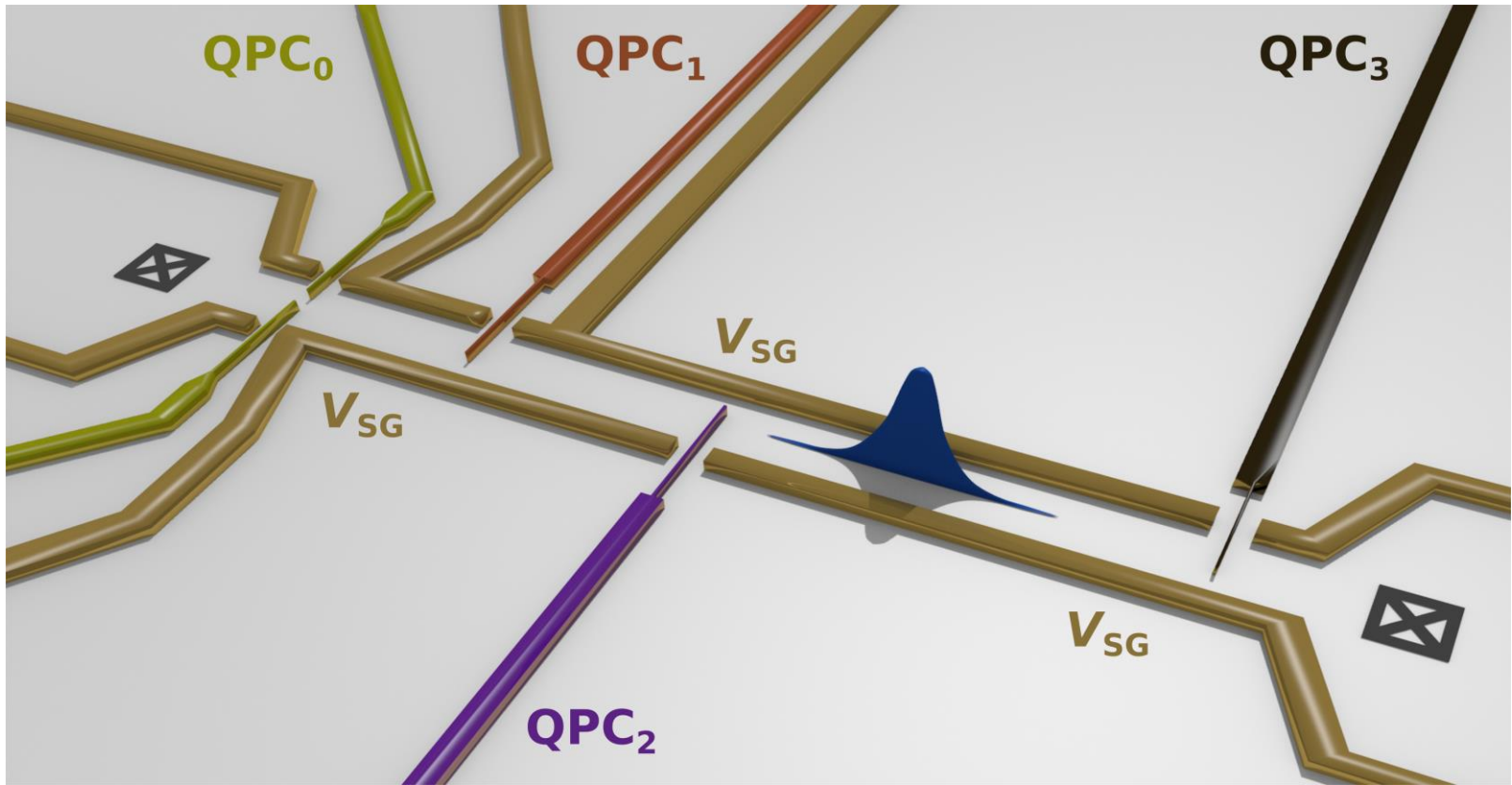
Thomas Kloss,

Xavier Waintal

INAC, CEA Grenoble



Motivation



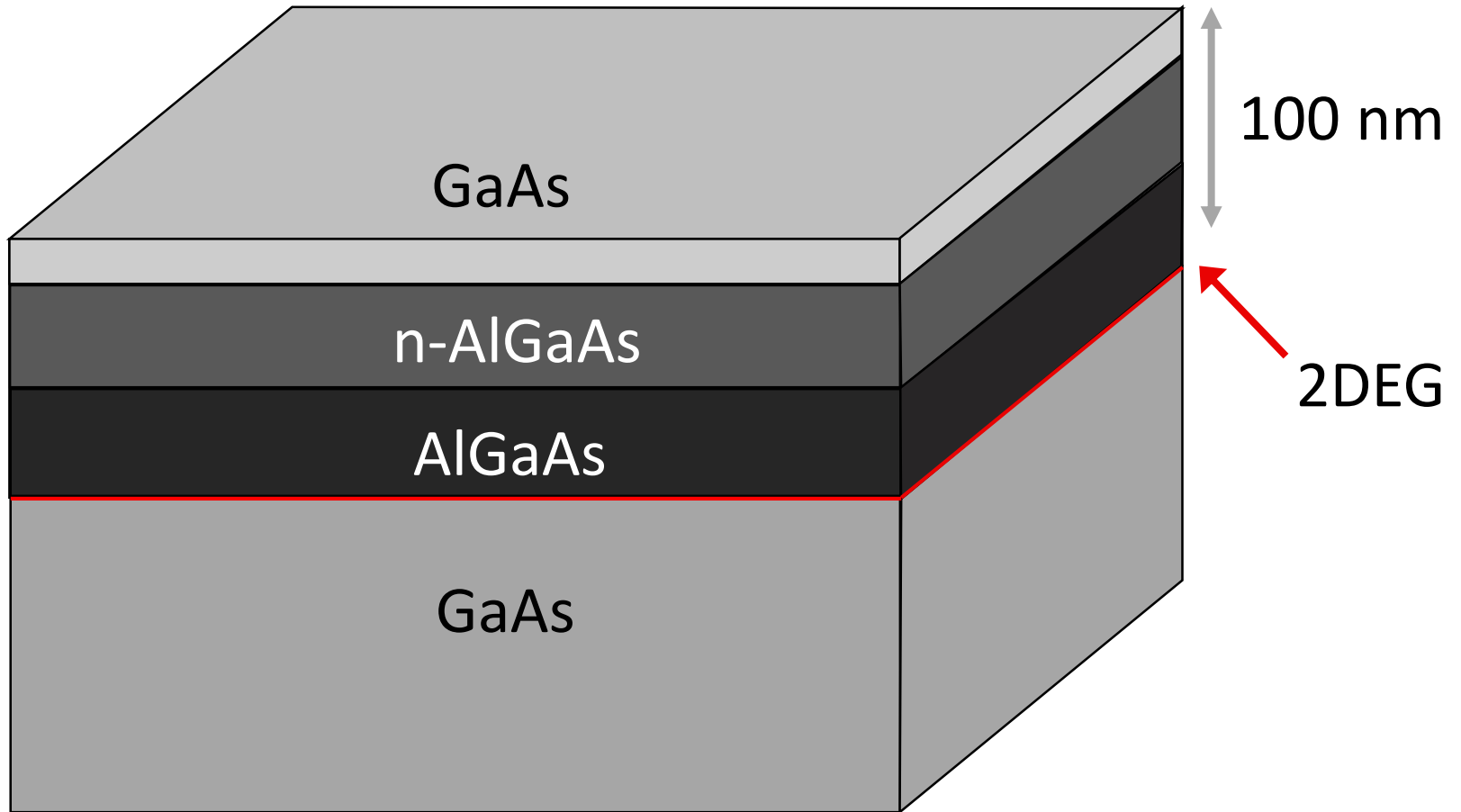
Probe the internal dynamics of a quantum conductor

$$L = 10 \mu\text{m}$$
$$v_F \sim 10^5 \text{ m/s}$$

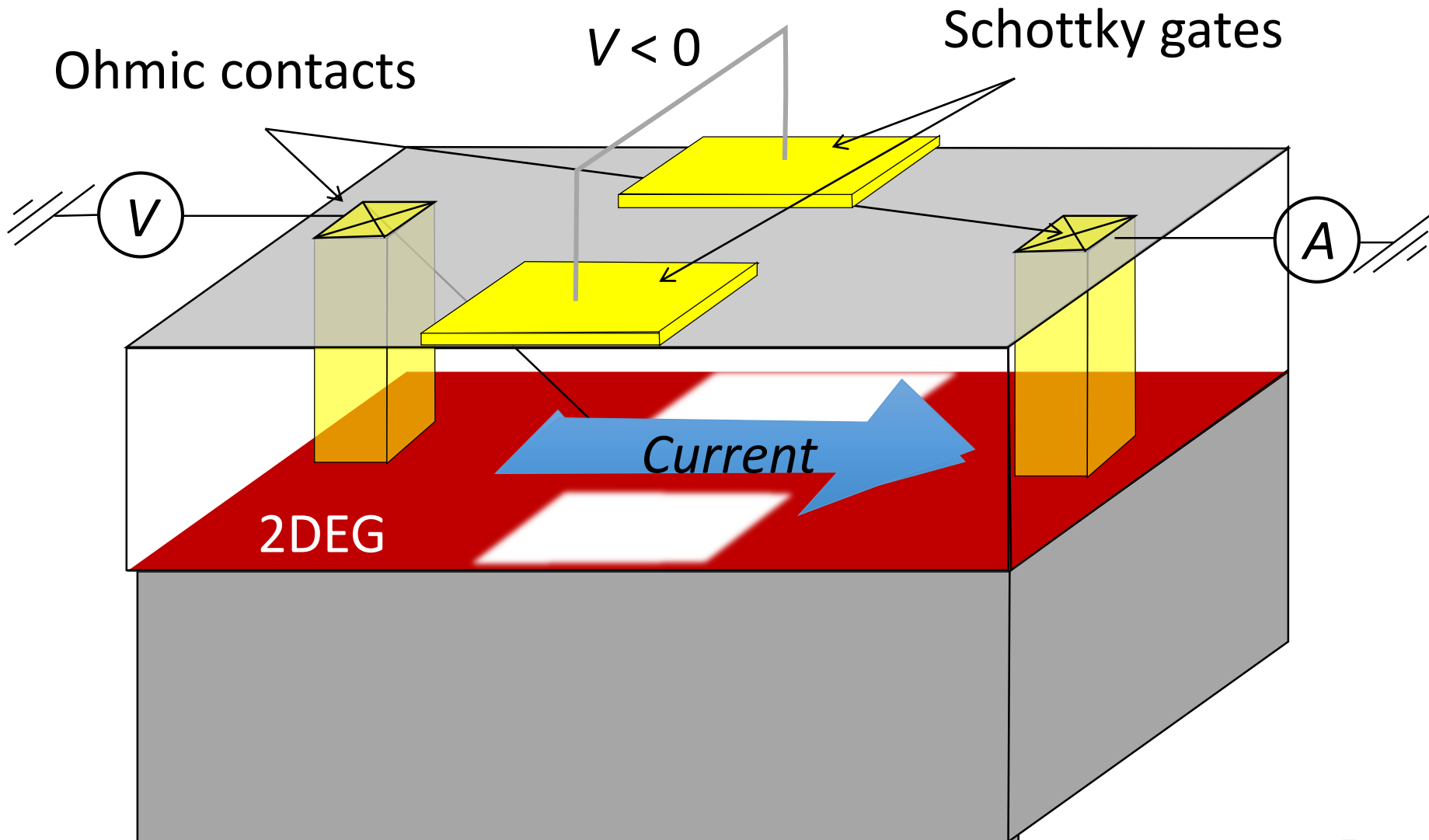


$$\Delta\tau < 100 \text{ ps}$$

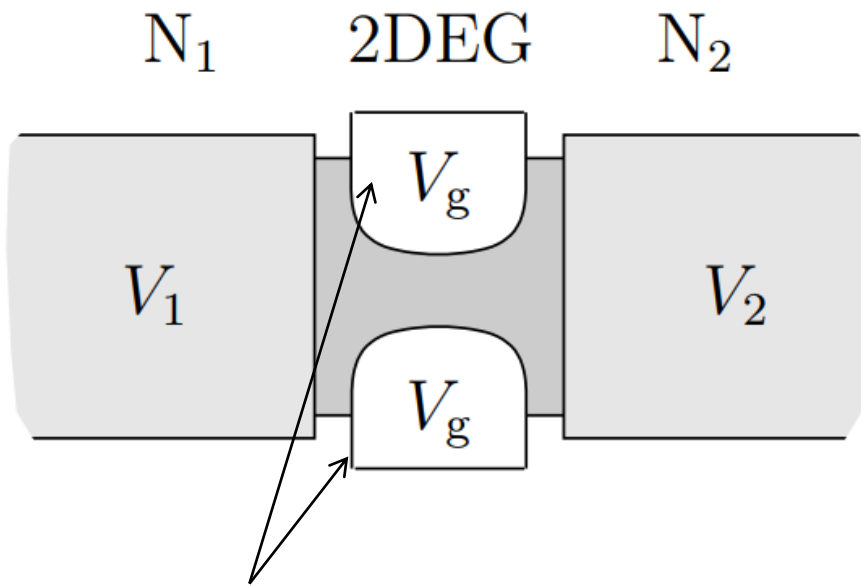
GaAs/AlGaAs 2DEG



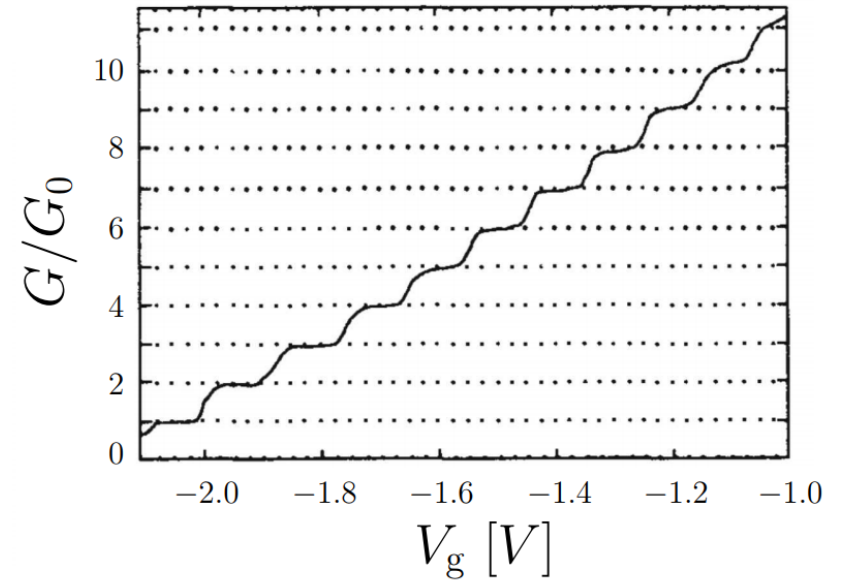
GaAs/AlGaAs 2DEG



QPC



Schottky gates

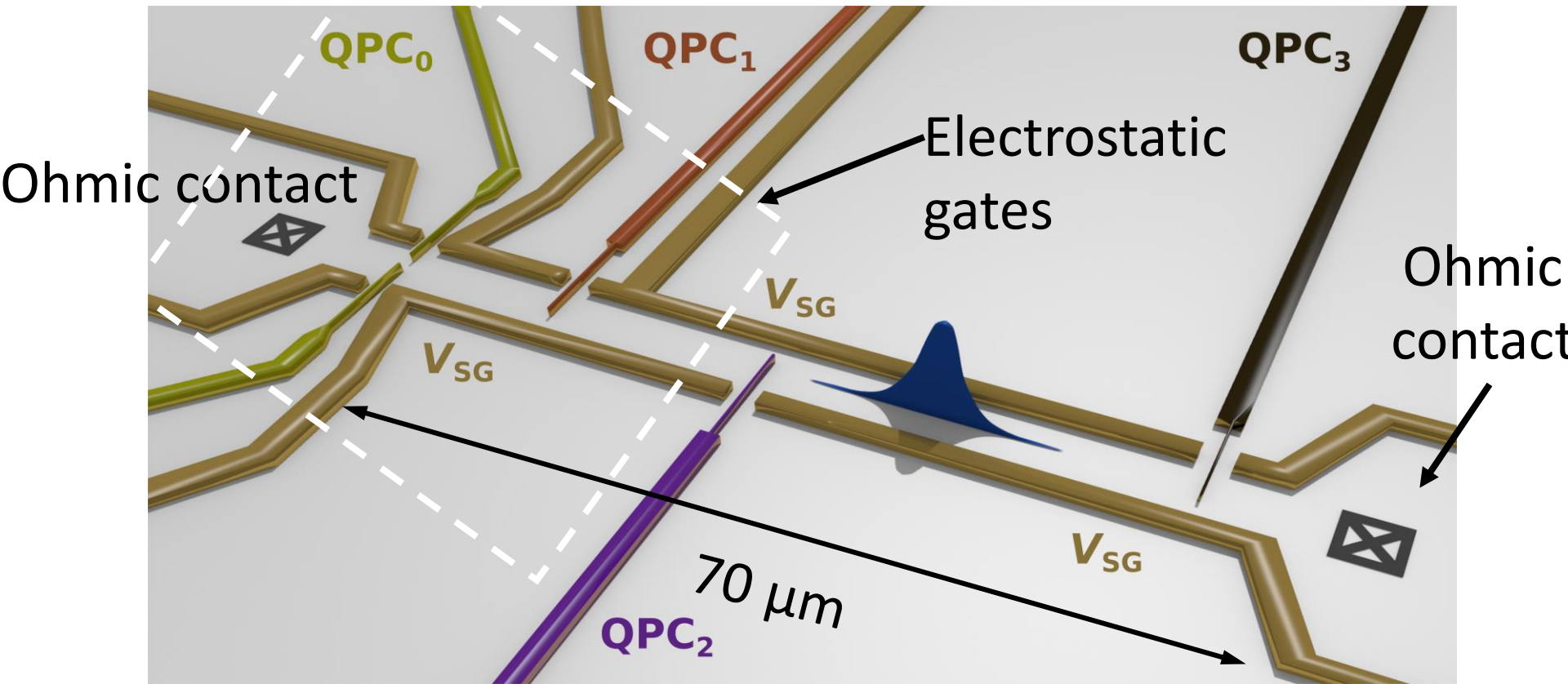


Lesovik and Sadovskyy, PHYS-USP, (2011)

Outline

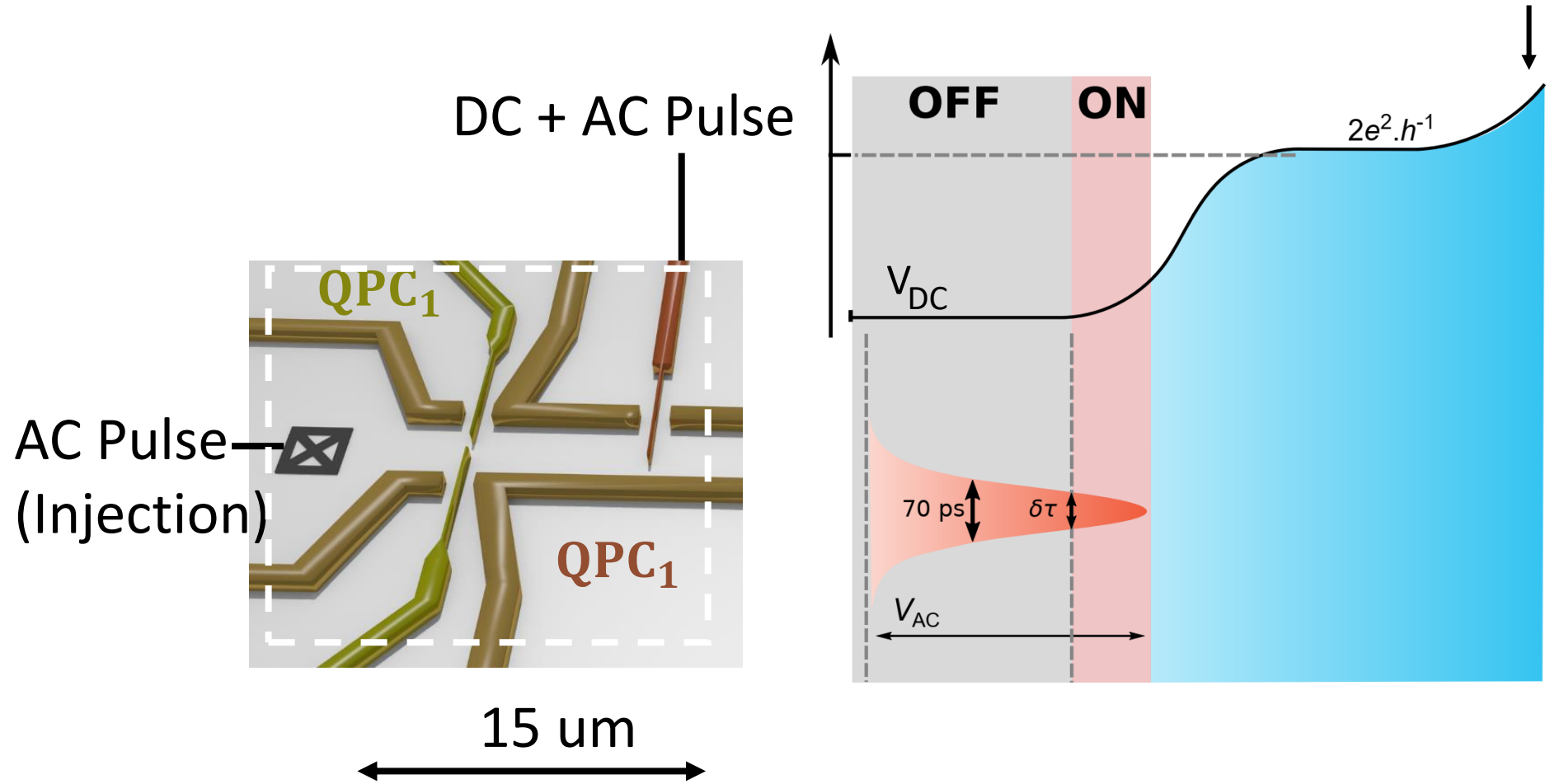
- ✓ Measure the time of flight
- ✓ Control of the velocity: Confinement
- ✓ Control of the velocity: QPC selection

Motivation



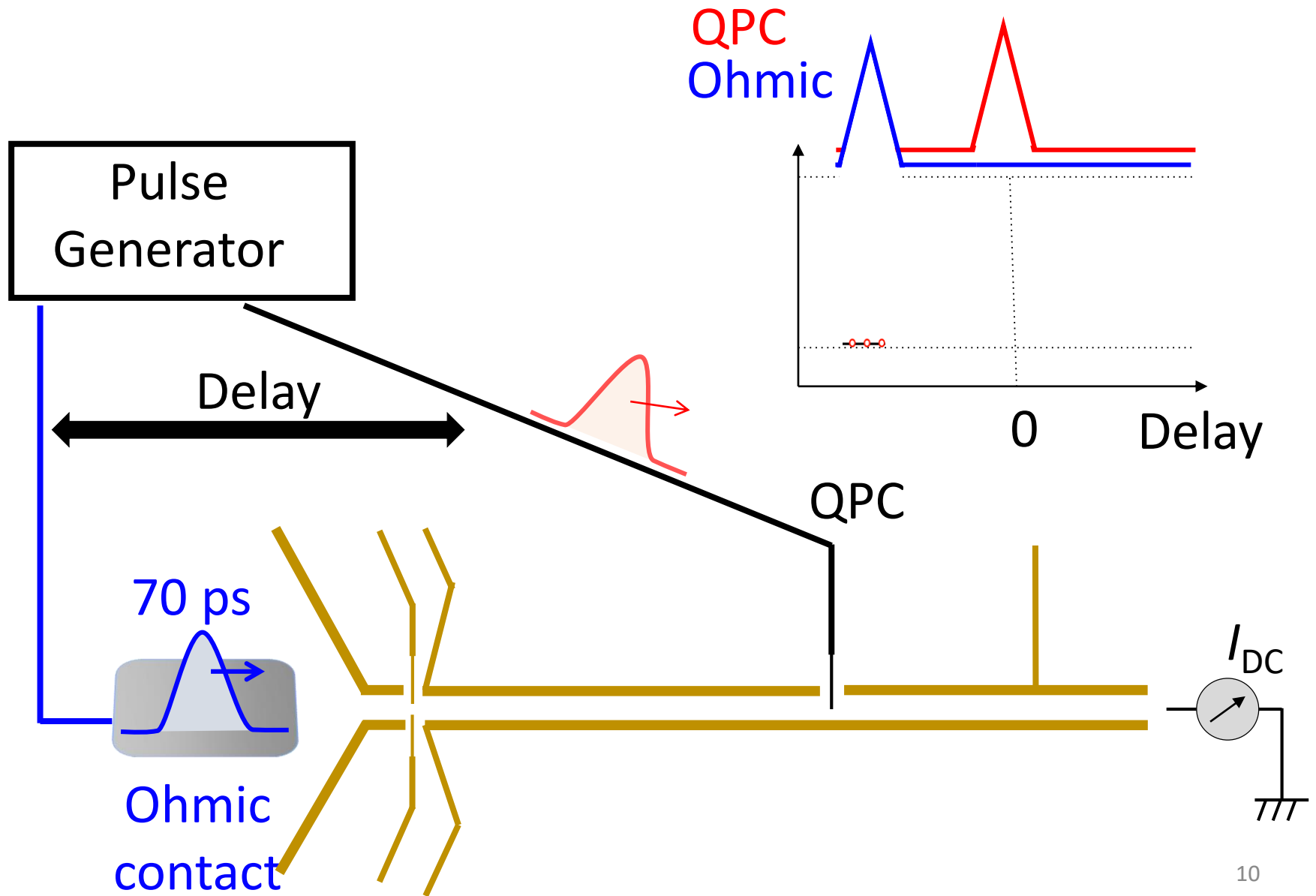
Probe the internal dynamics of a quantum conductor

QPC as a Fast-Switch

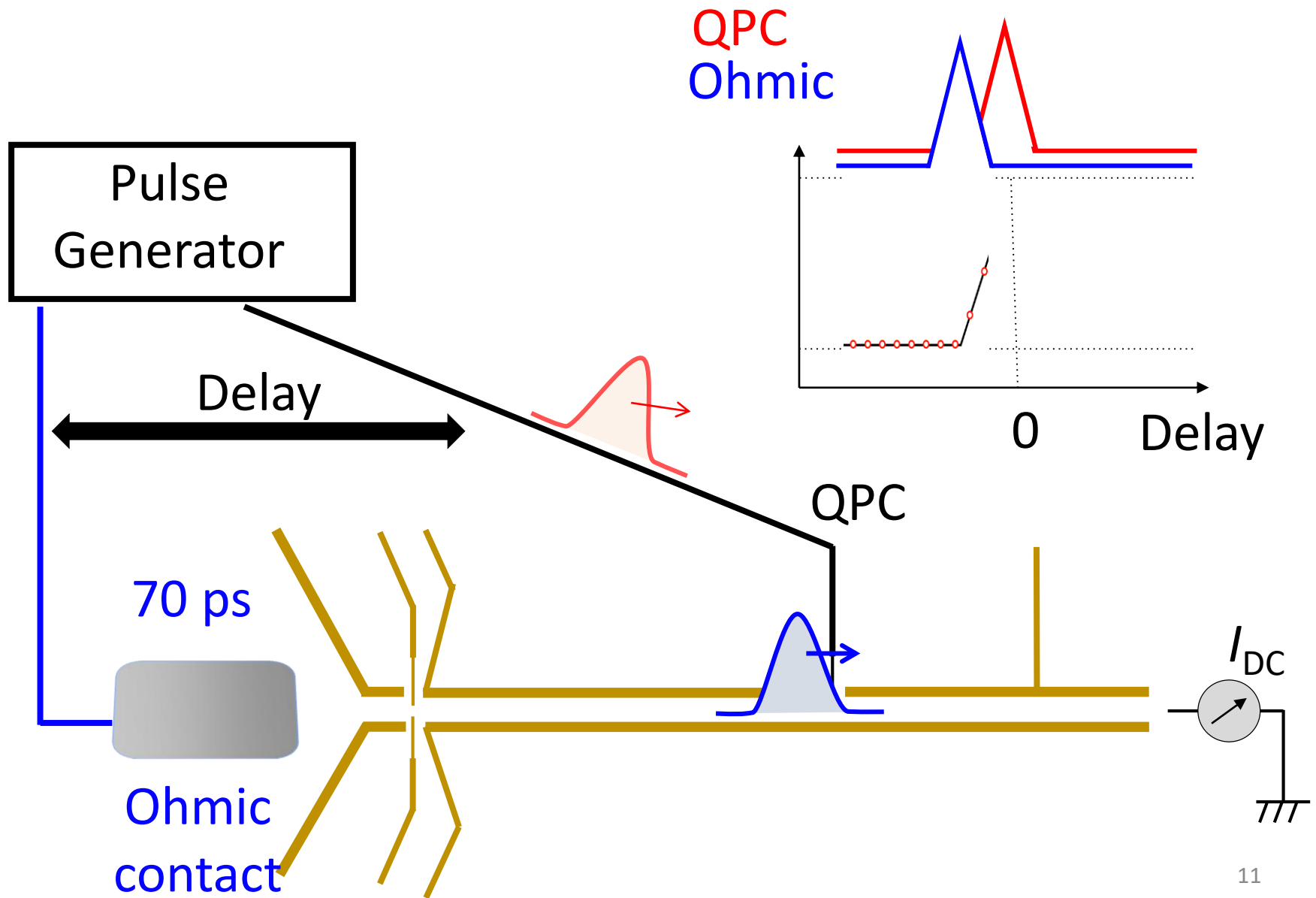


Nature Communications **9**, 2811 (2018)

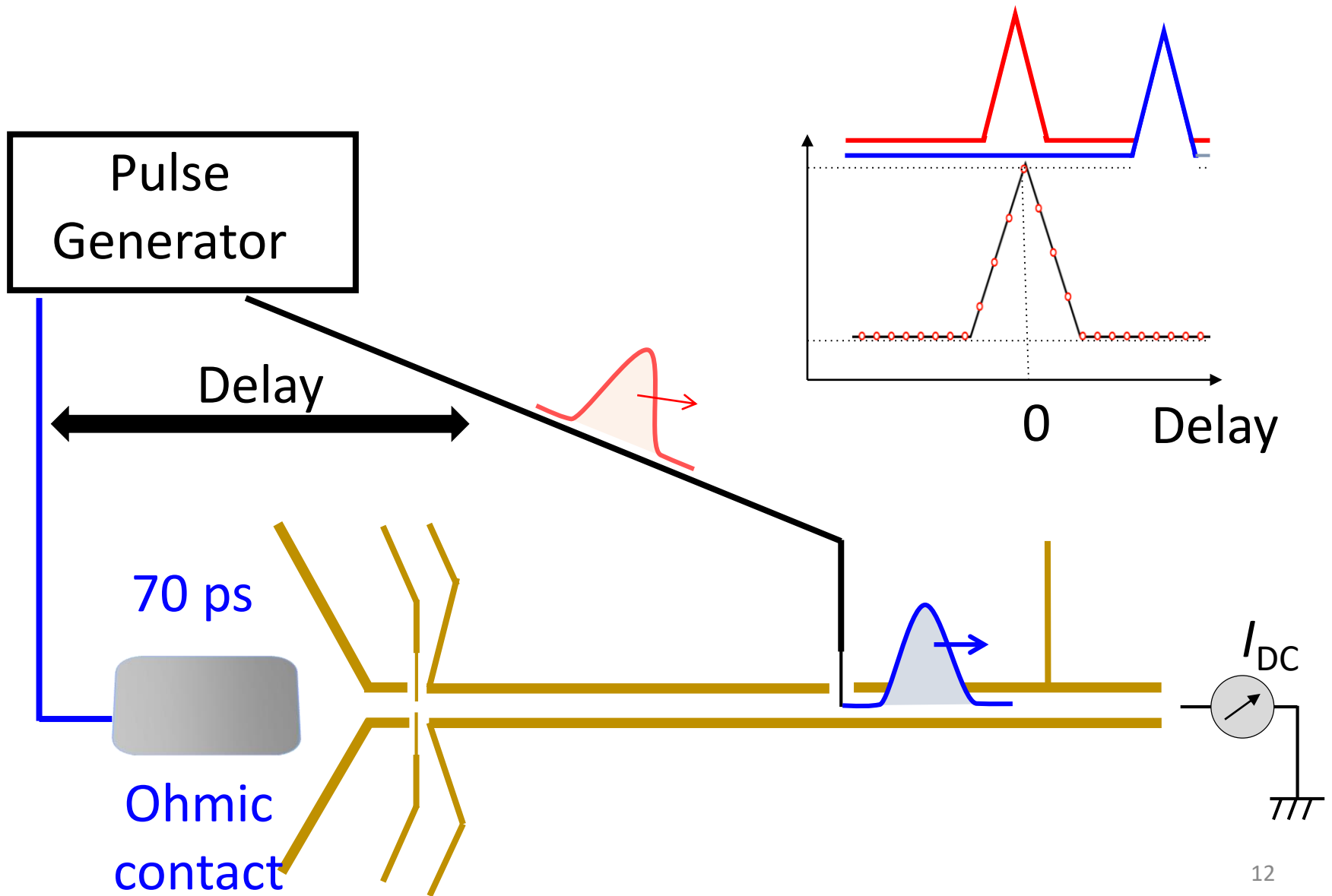
Time resolved measurements



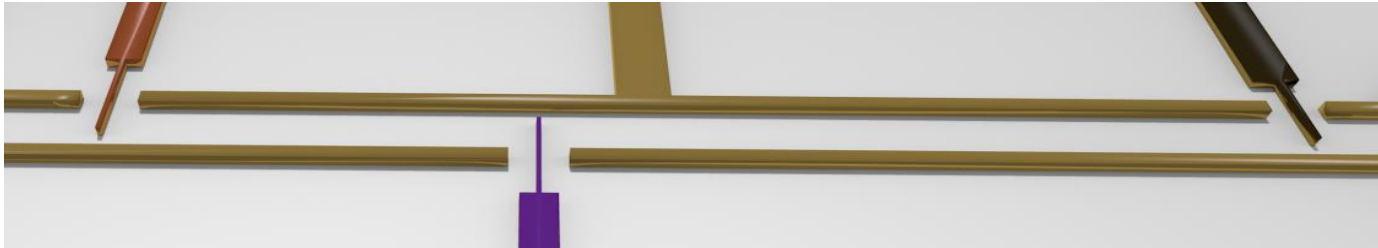
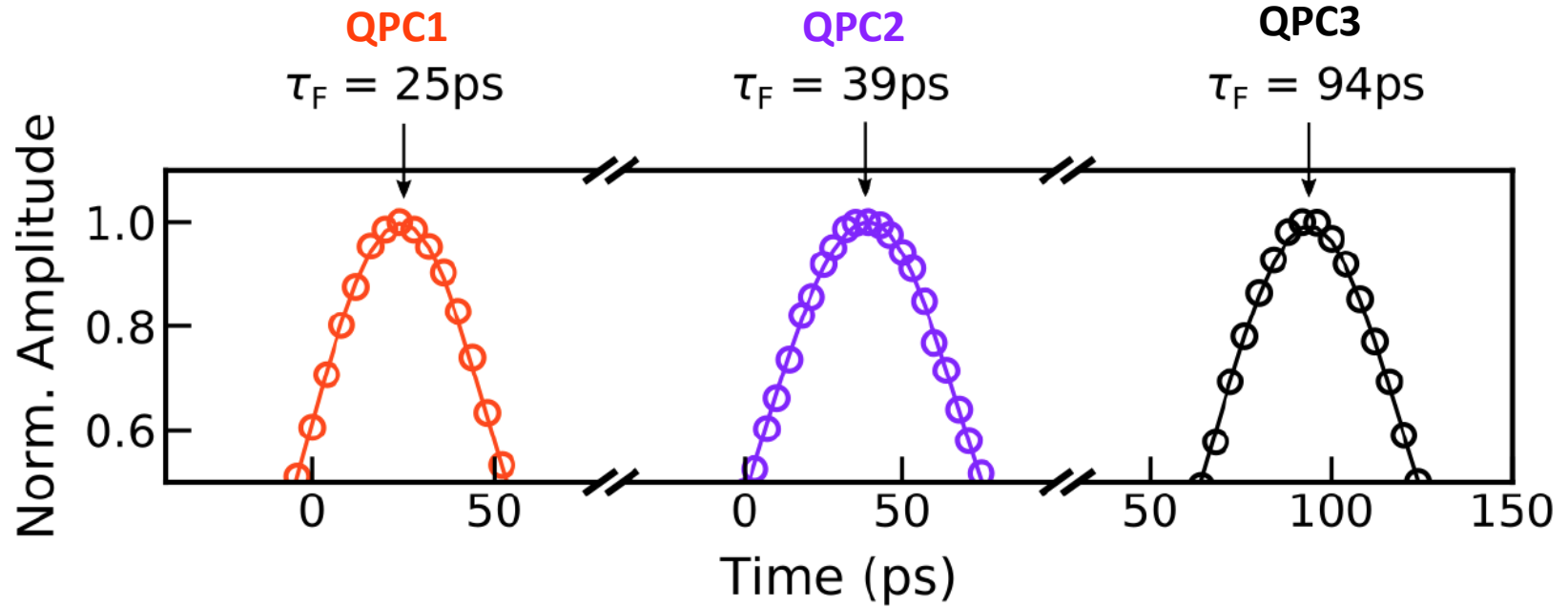
Time resolved measurements



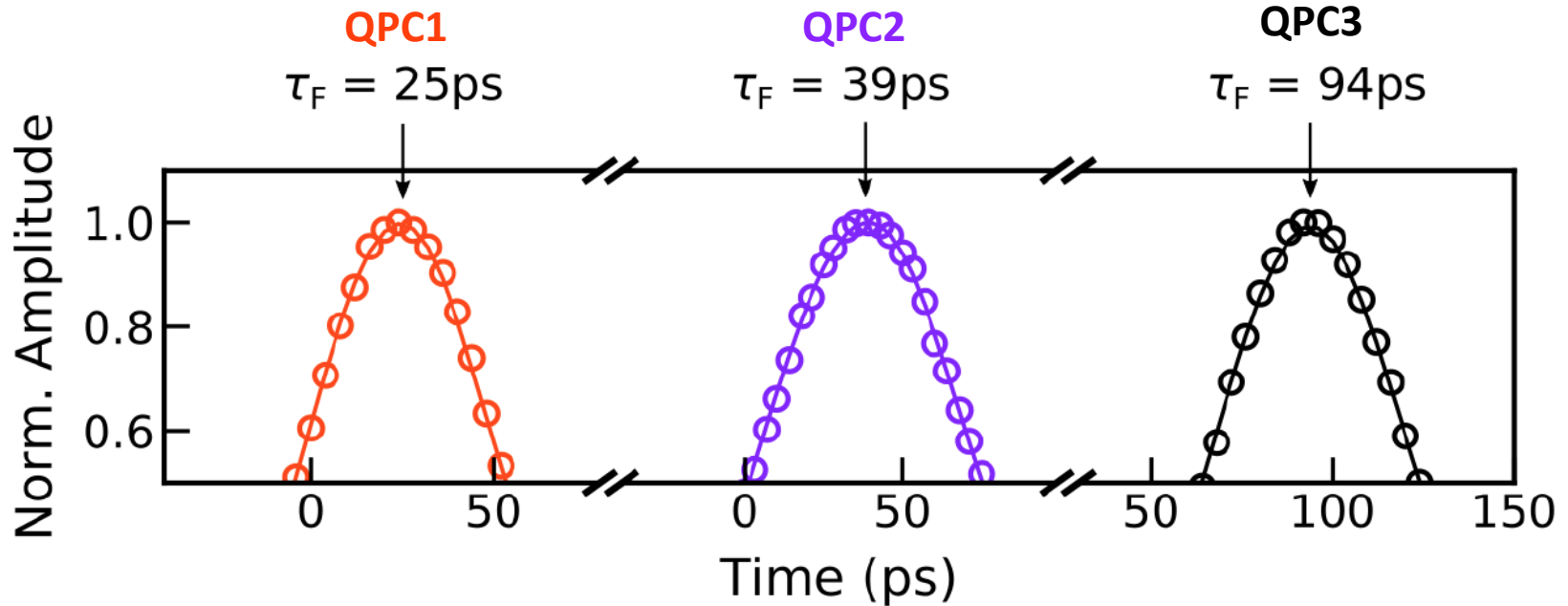
Time resolved measurements



Propagation velocity of wave packet



Propagation velocity of wave packet



Velocity of pulse

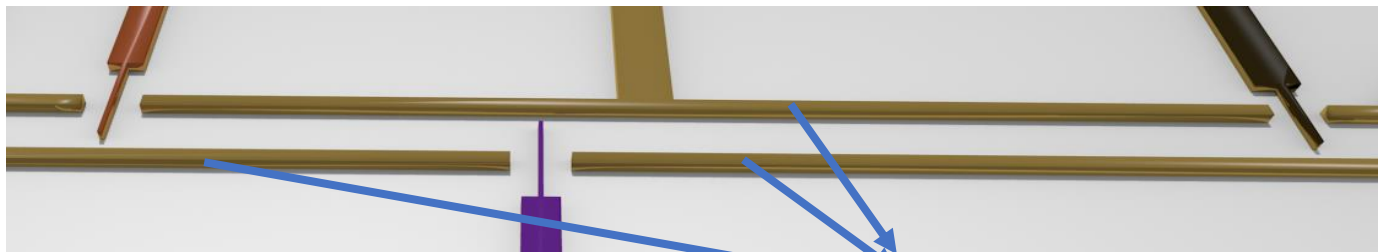
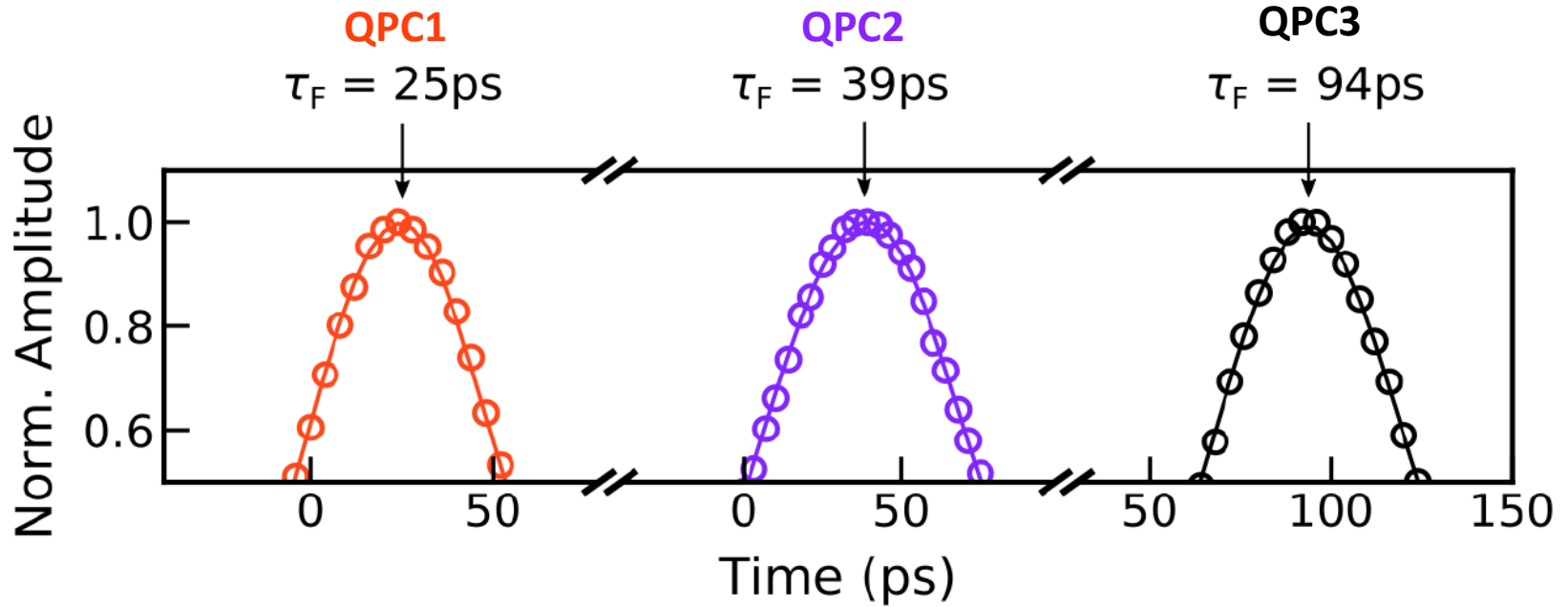
$$\approx 10 \cdot 10^5 \text{ m/s}$$

$$v_P \approx 5 \cdot v_F$$

**Take home
message**

Voltage pulse propagates $v_P \gg v_F$!!

Propagation velocity of wave packet

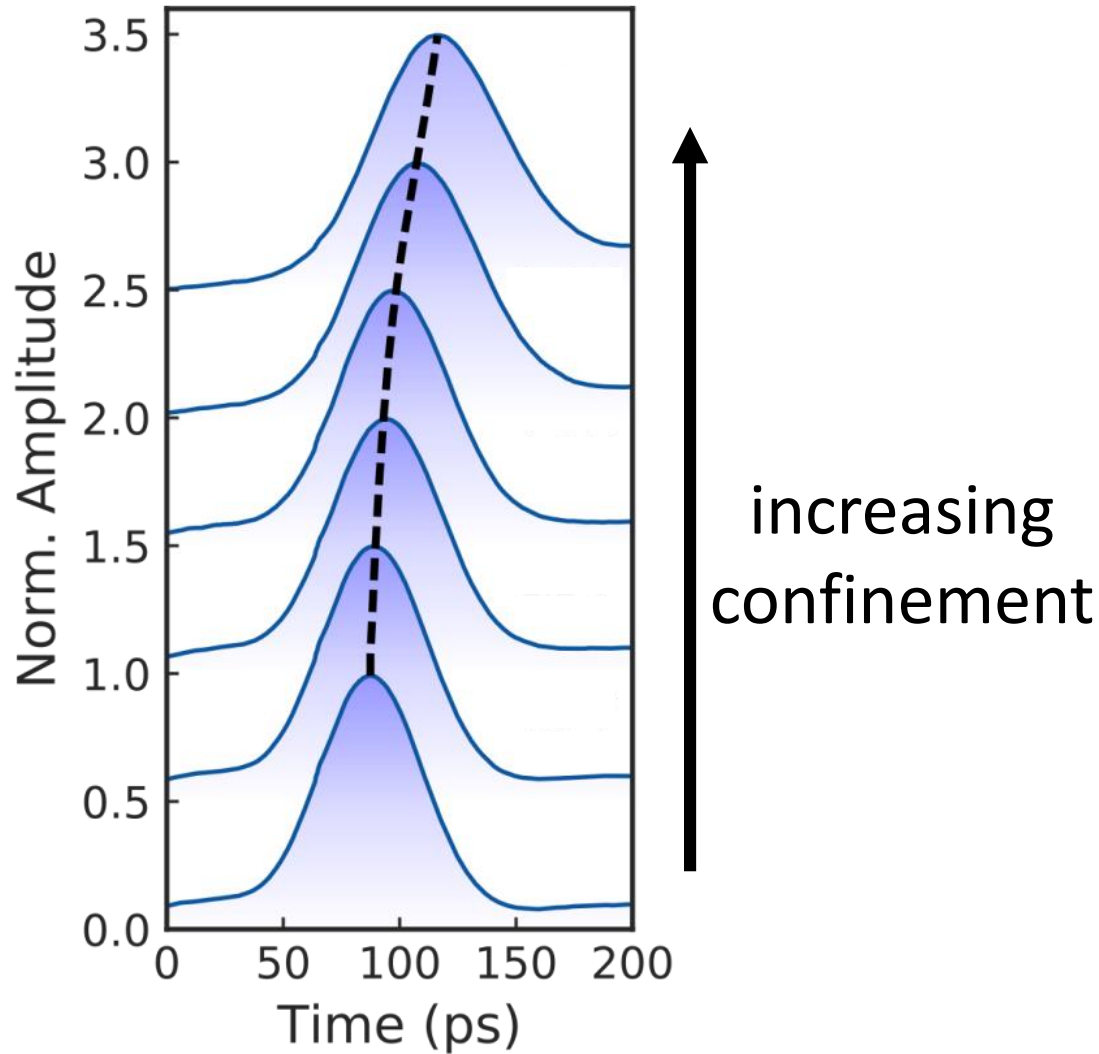


Confinement

Outline

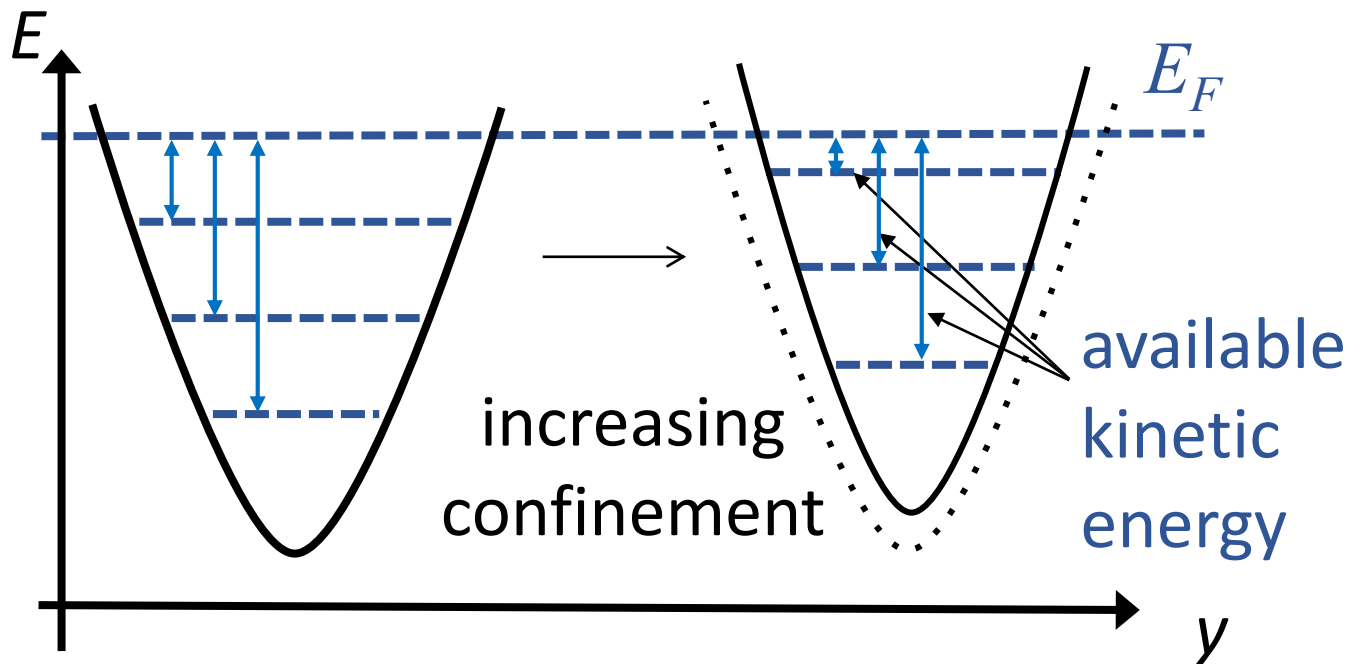
- ✓ Measure the time of flight
- ✓ Control of the velocity: Confinement
- ✓ Control of the velocity: QPC selection

Changing the confinement



Changing the confinement

$$E_F = E_{Kinetic} + E_{Potential}$$



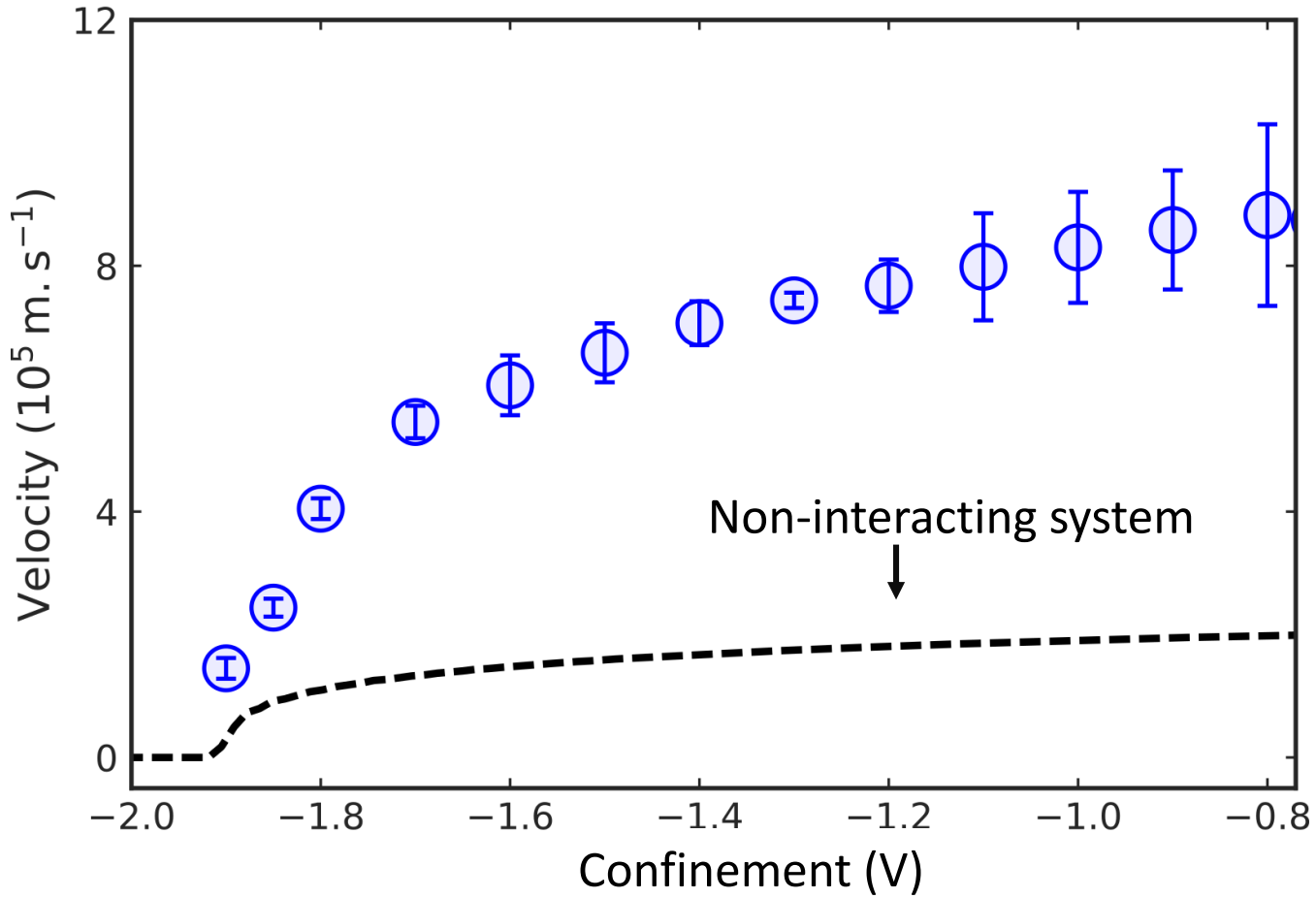
**Take home
message**

Stronger confinement



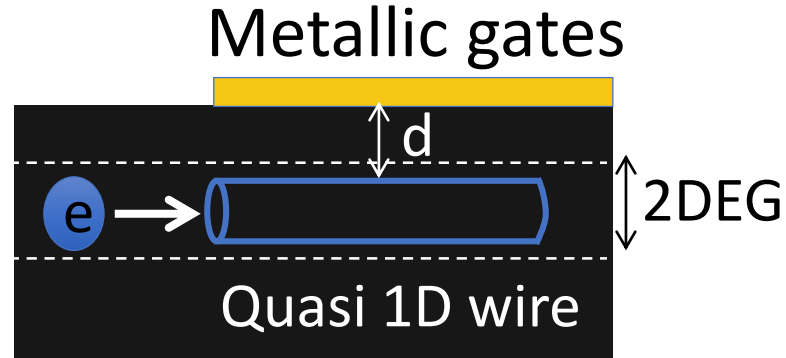
Lower velocity

Changing the confinement

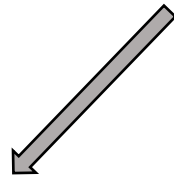


Changing the confinement

Matveev and Glazman PRL (1993): Quasi-1D wire containing N channels

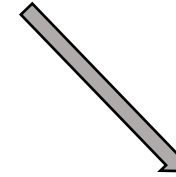


Velocity renormalized by Coulomb interaction



N-1 slow charge mode

$$v \approx v_{fermi}$$

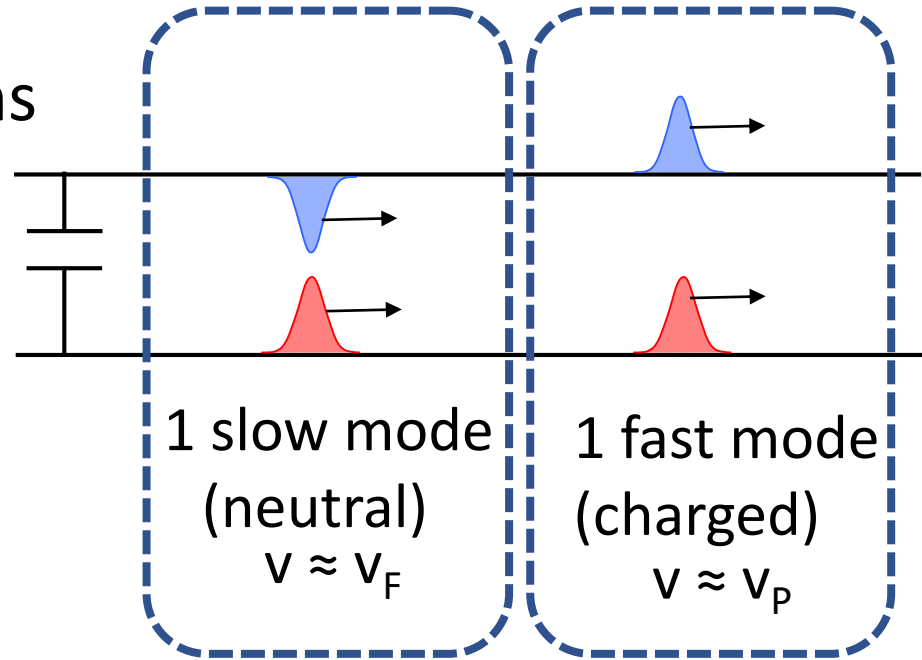
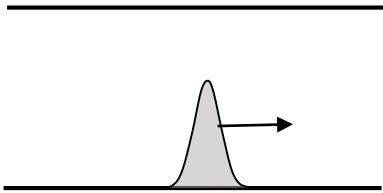


1 fast charge mode

$$v \approx v_{plasmon}$$

Slow and Fast modes

+ interactions



1 slow mode
(neutral)
 $v \approx v_F$

1 fast mode
(charged)
 $v \approx v_p$

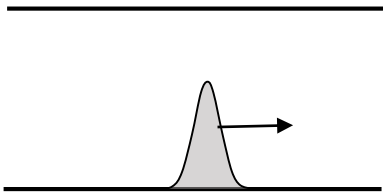
Bocquillon et al., Nat. Com. (2013)

Inoue et al., PRL (2014)

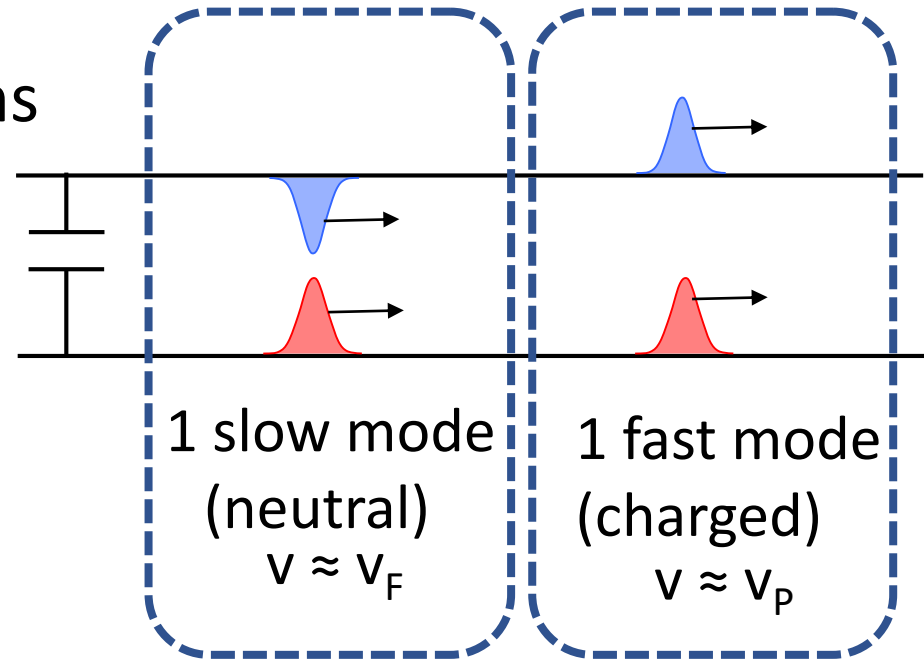
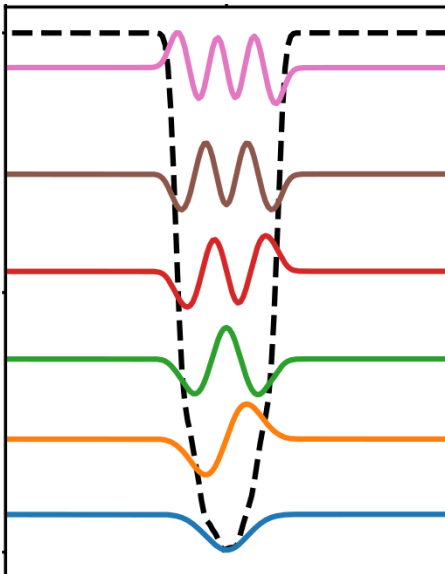
Hashisaka et al., Nature Phys. (2017)

Slow and Fast modes

+ interactions



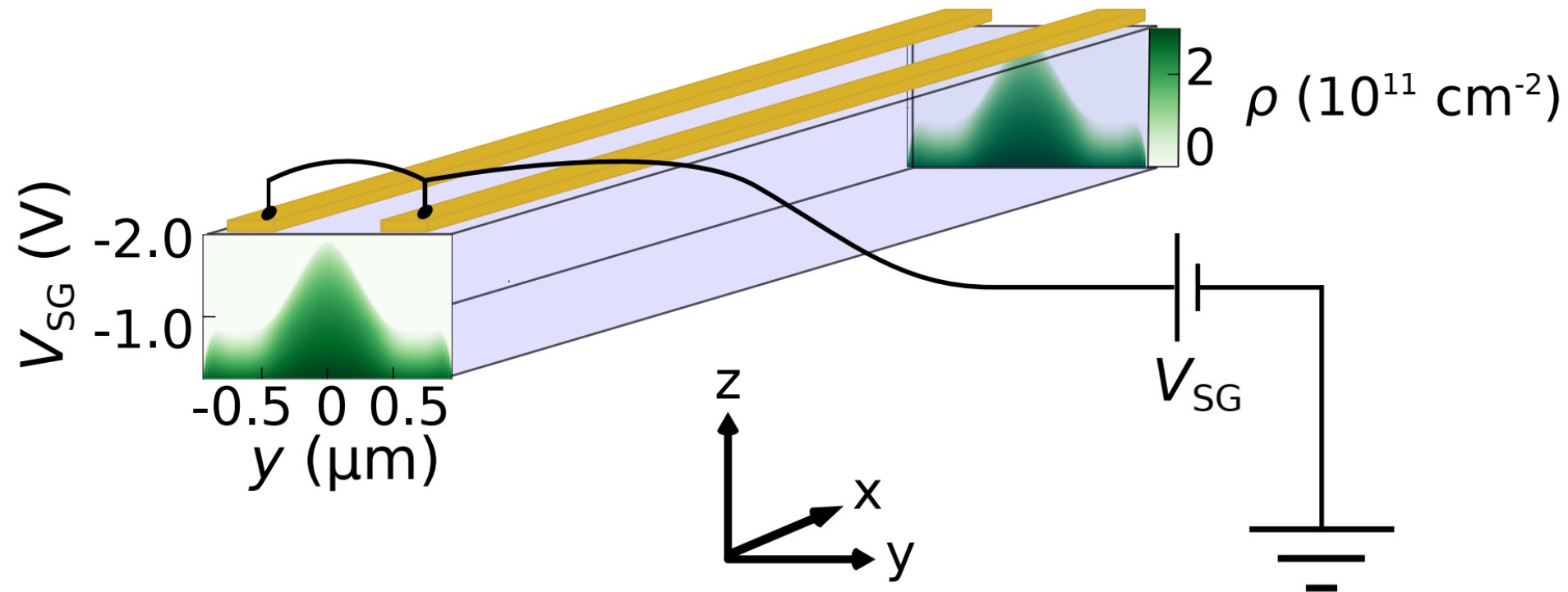
$N \approx 1-40$ (in our case)
(separated in energy)



N-1 SLOW modes
(almost neutral)

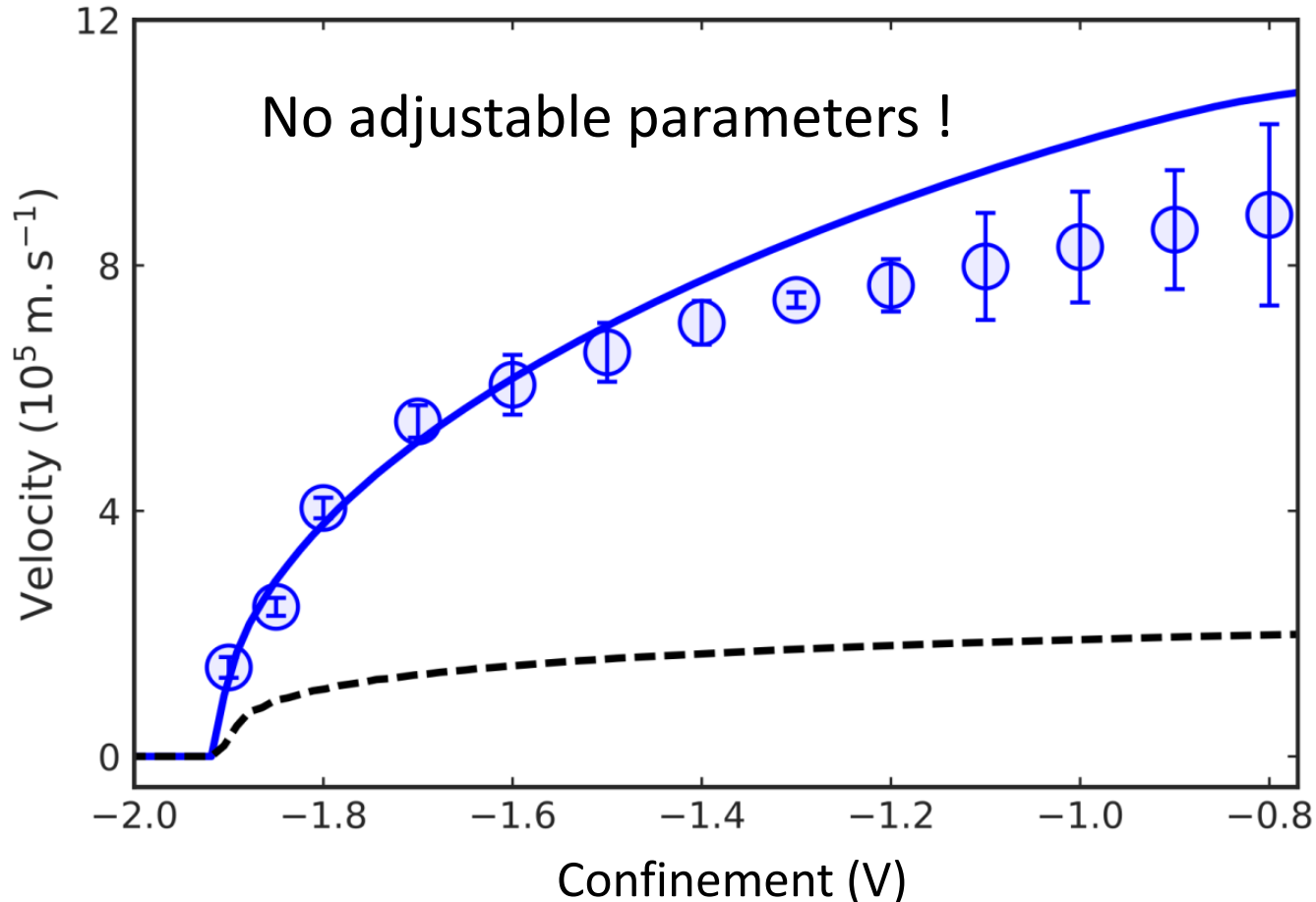
1 FAST mode
(charged)

Parameter free calculation of velocities



Further details in Pacôme Armagnat's Poster
Self-Consistent Quantum Electrostatics

Controlling the velocity of WP



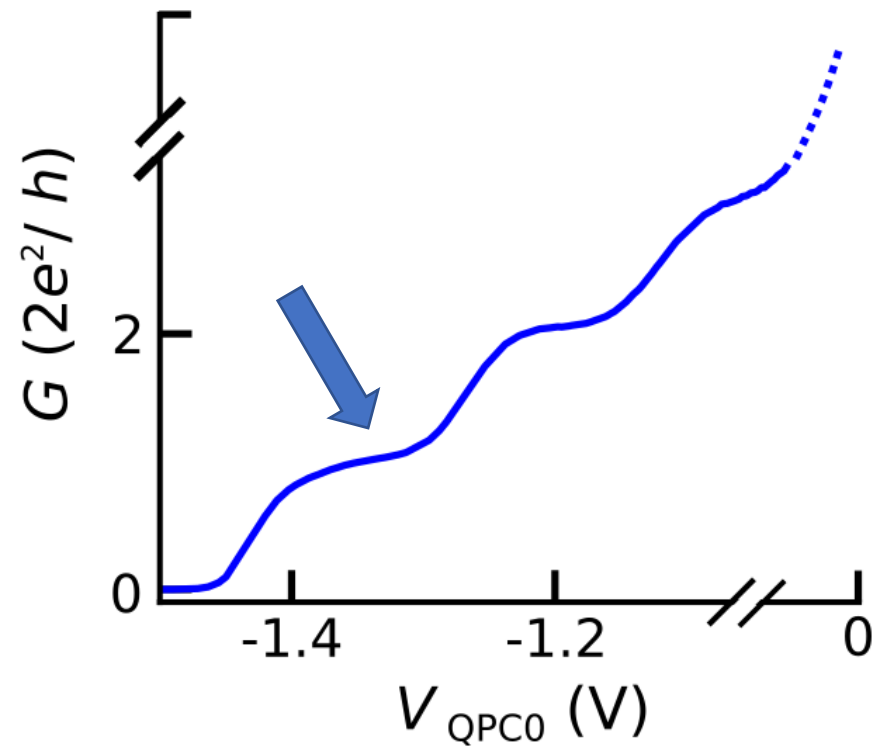
- Very good agreement with theory
- Velocity is **increased** by Coulomb interactions

Outline

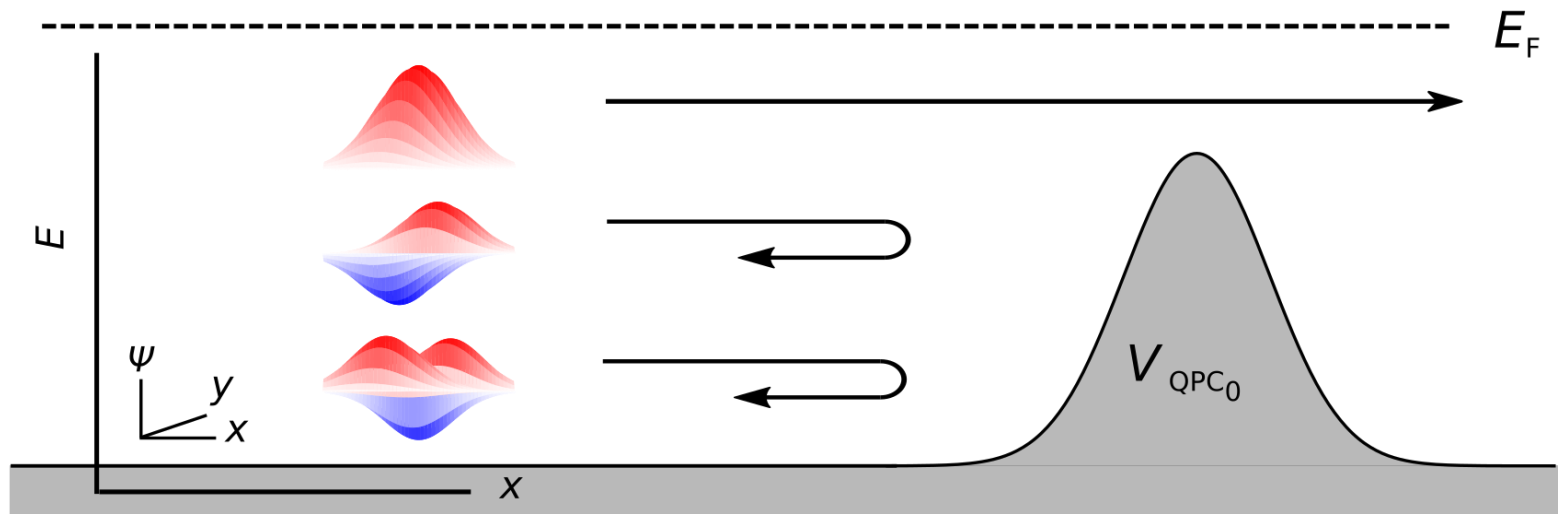
- ✓ Measure the time of flight
- ✓ Control of the velocity: Confinement
- ✓ Control of the velocity: QPC selection

Selecting Channels

QPC₀



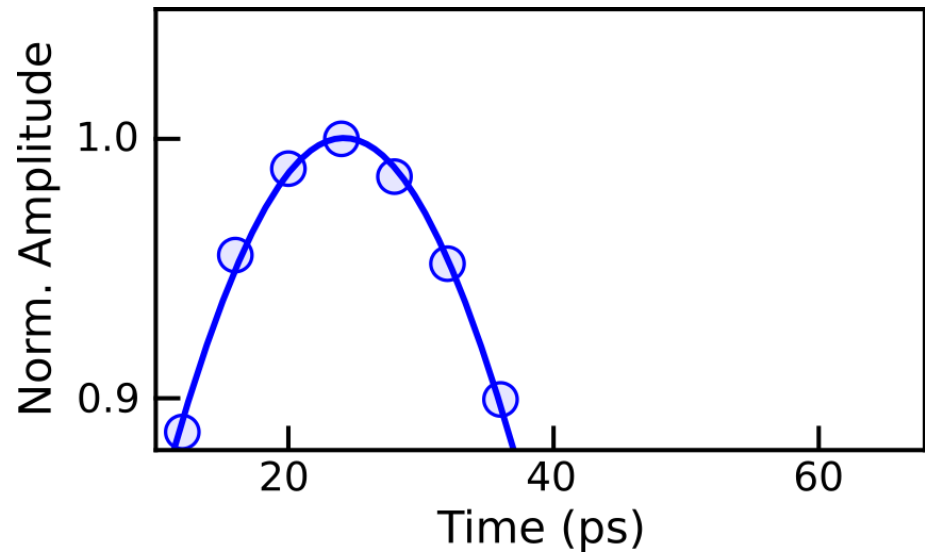
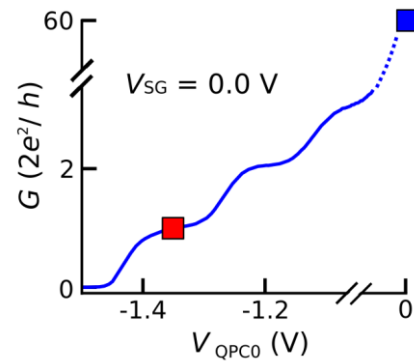
Selecting Channels



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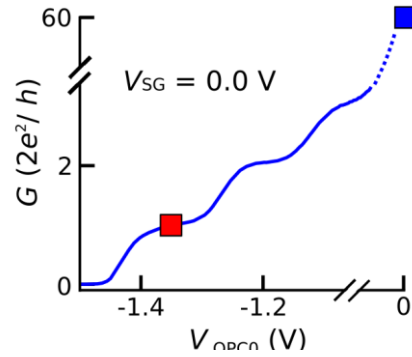
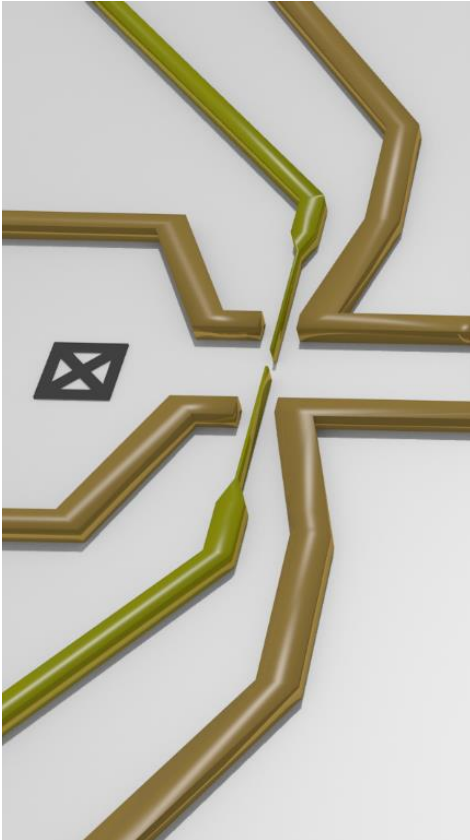
Selecting Channels

QPC₀ 1st plateau



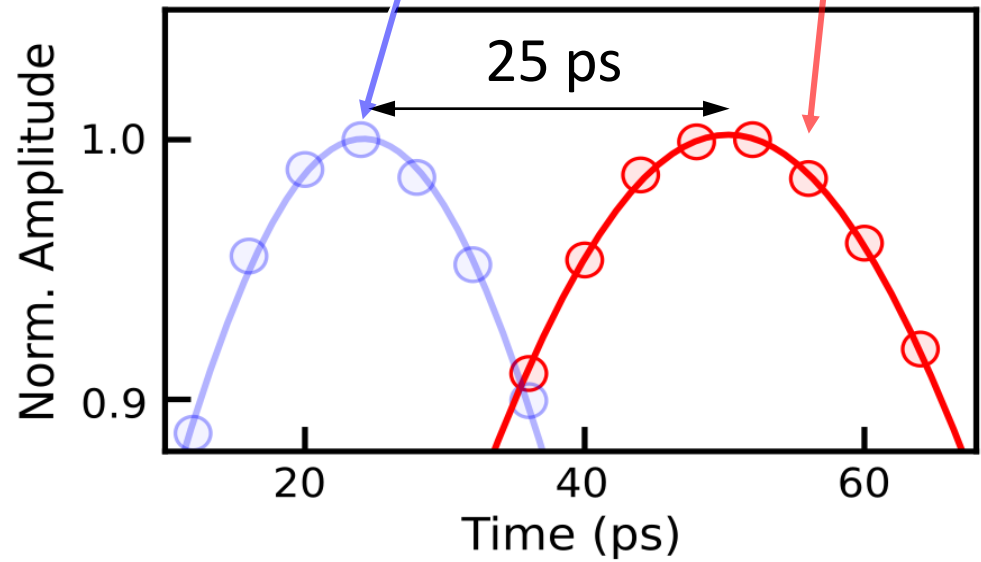
Selecting Channels

QPC₀ 1st plateau

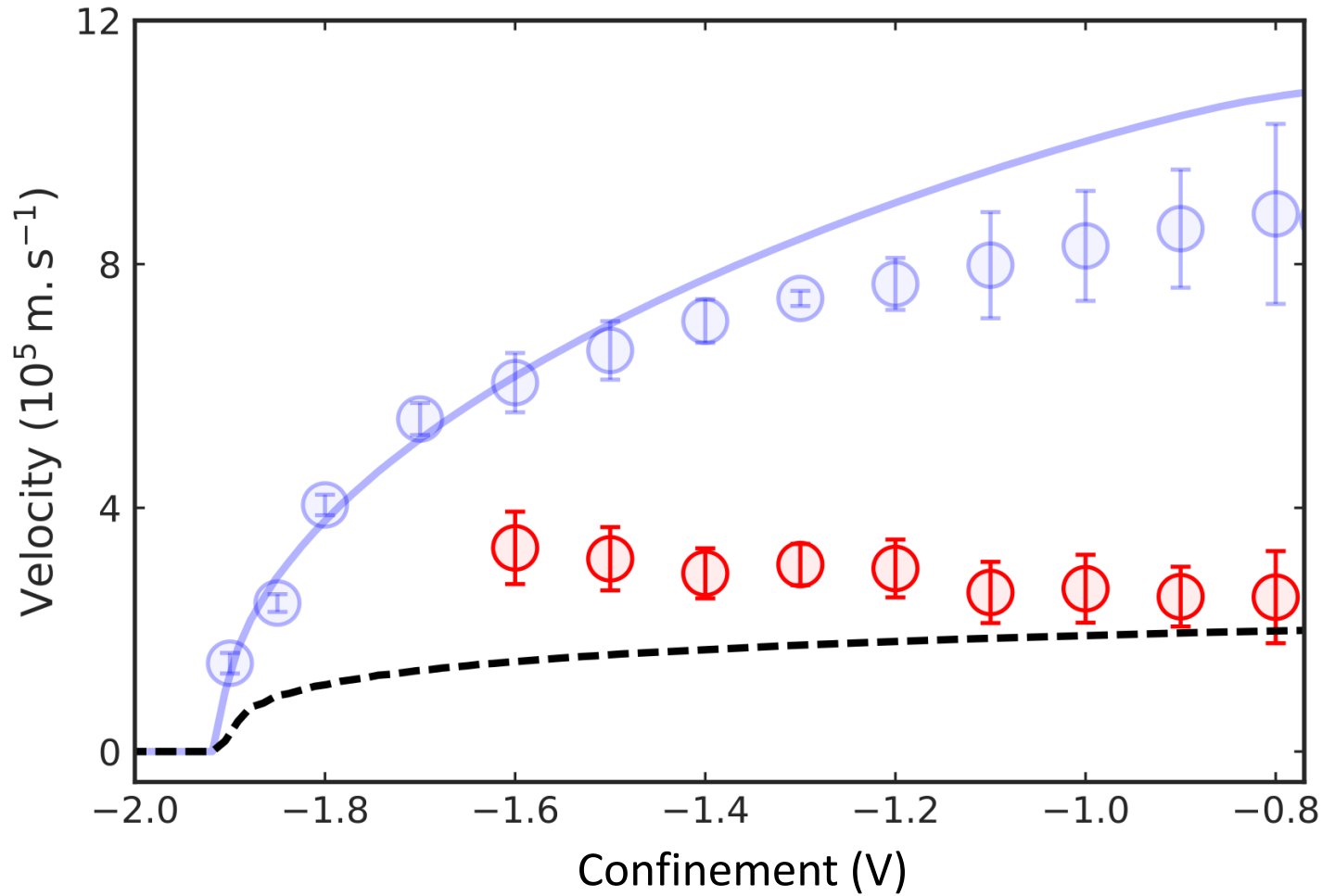


OPC₀ unpolarized

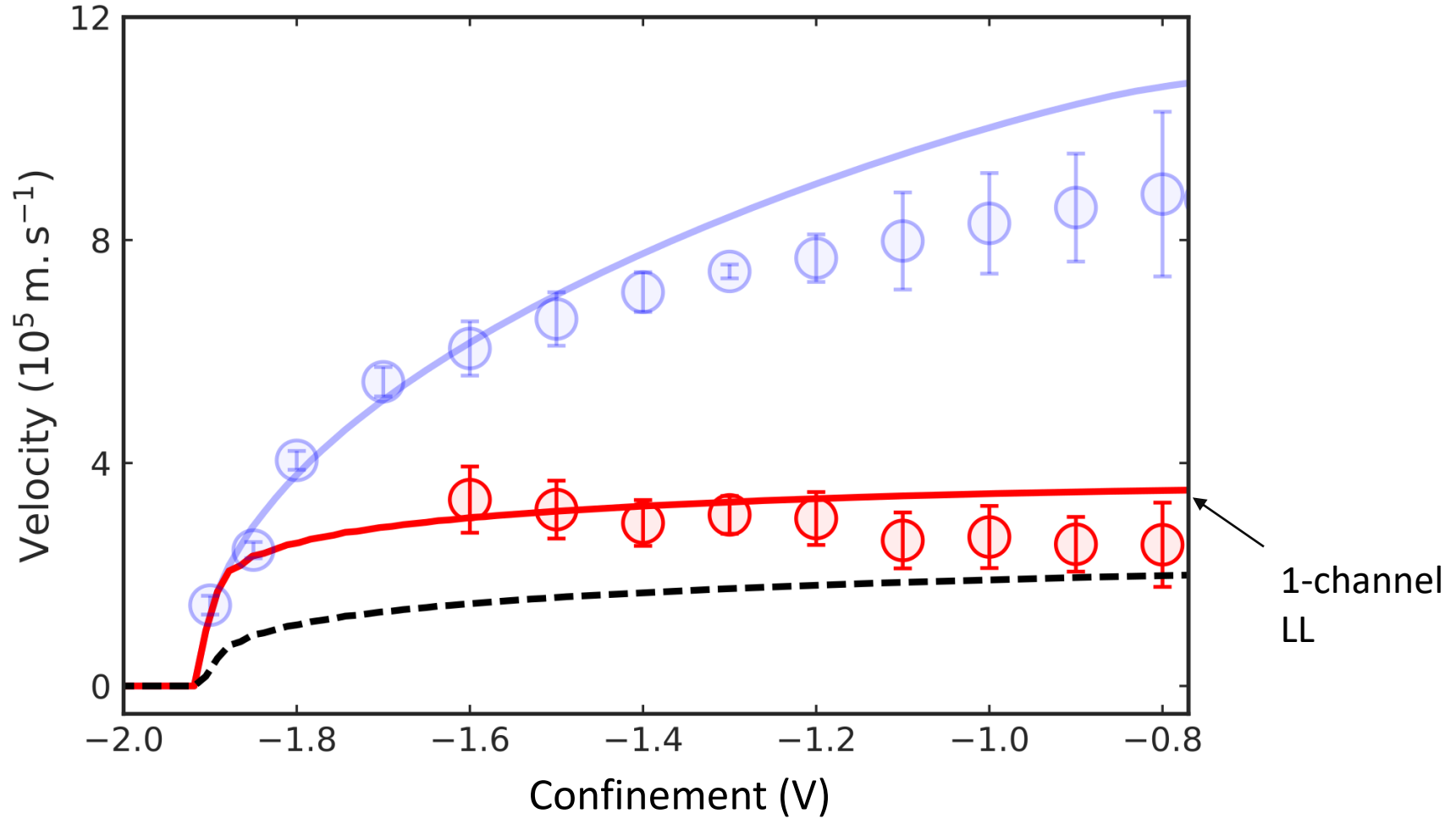
$G_{QPC_0} = 1^{\text{st}}$ plateau



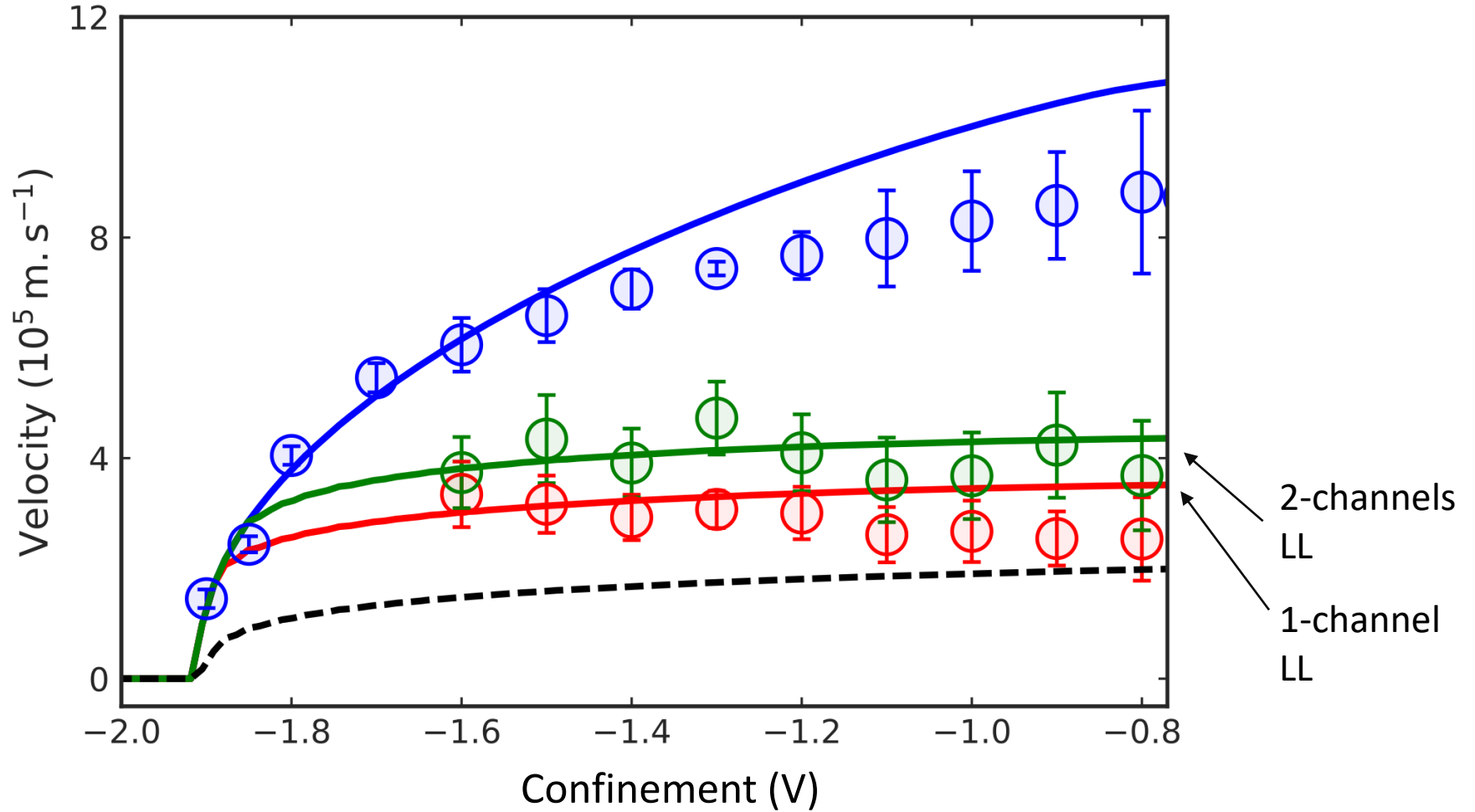
Selecting Channels



Selecting Channels



Selecting Channels



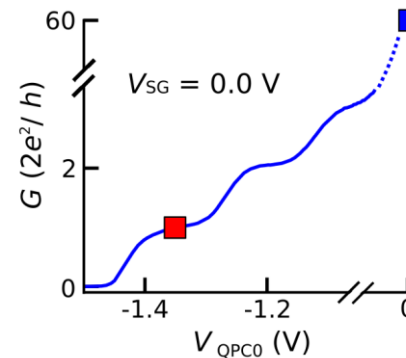
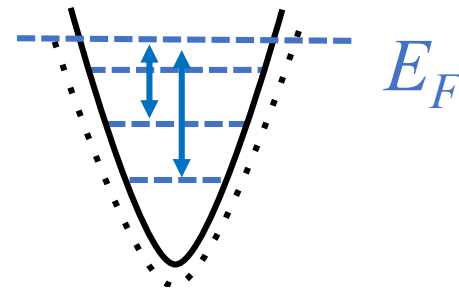
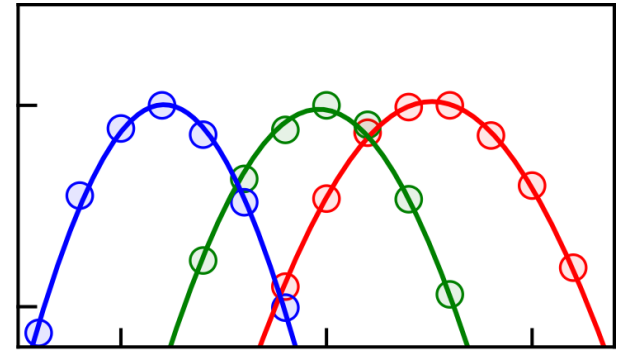
Results

✓ Measure the time of flight

✓ Control of the velocity

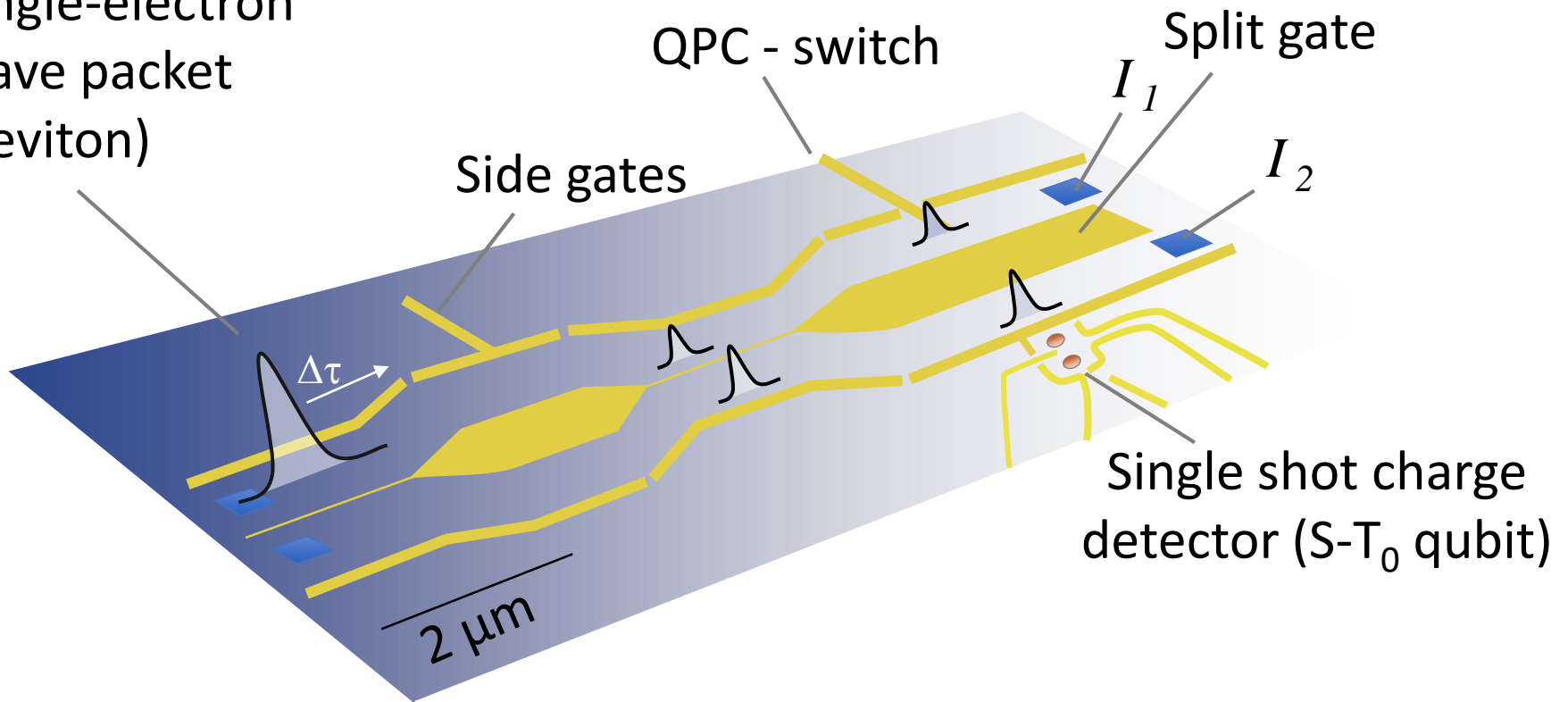
Confinement

QPC selection



Further Perspectives

Single-electron
wave packet
(Leviton)



Gaury et al., Nature Comm. (2014)

Bäuerle et al., Rep. Prog. Phys (2018)

Yamamoto et al., Nature Nanotech. (2012)