A Q_ϕ=25000 SUPERCONDUCTING CHARGE QUBIT

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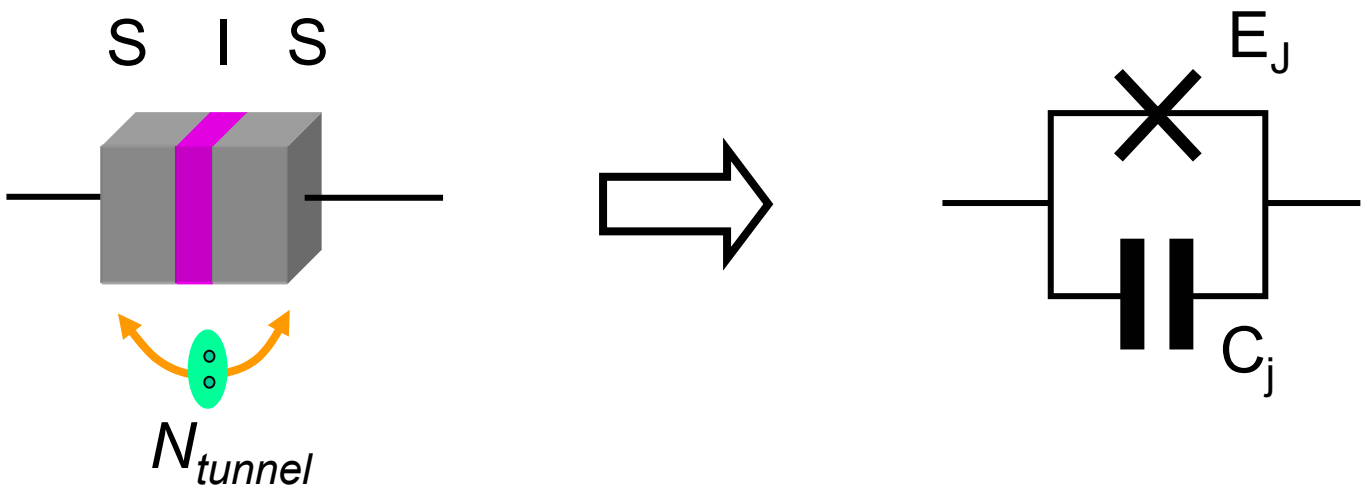
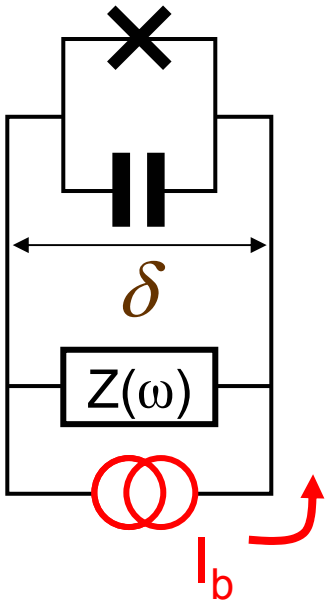
Stony Brook, May 2003

THE JOSEPHSON TUNNEL JUNCTION: AN ATOM-LIKE SYSTEM TO WHICH YOU CAN ATTACH WIRES ...



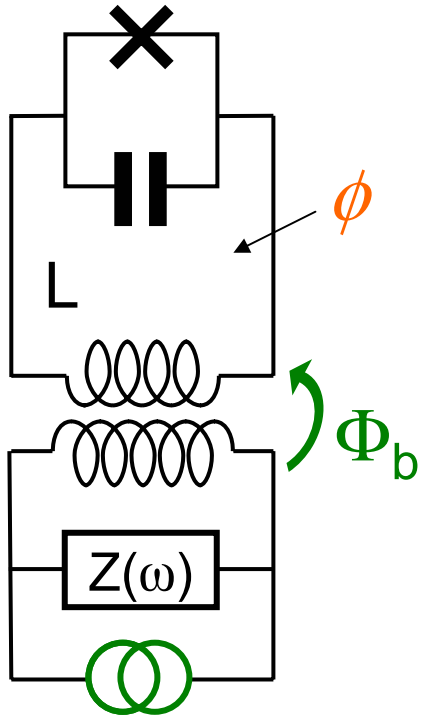
.... IN 3 DIFFERENT WAYS

"CURRENT-BIASED JUNCTION"



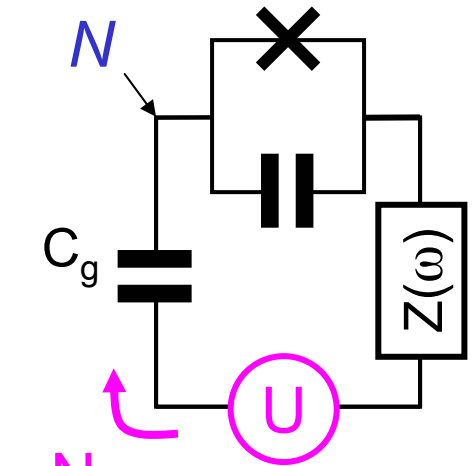
phase across junction

"RF-SQUID"



flux thru loop

"COOPER-PAIR BOX"

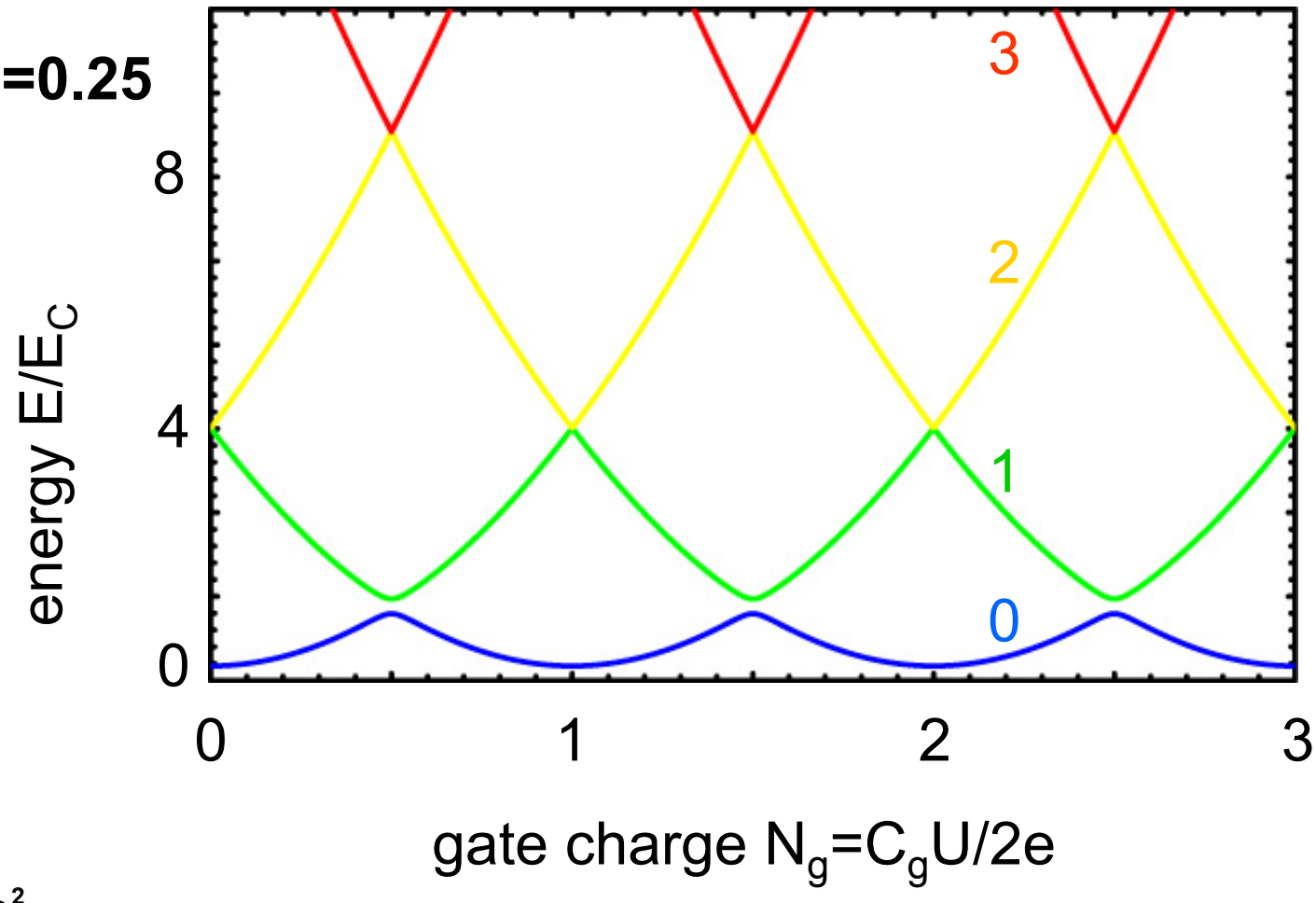


island charge

$$Z(\omega) \sim Z_{vac} = 377\Omega$$

ENERGY LEVELS OF THE COOPER PAIR BOX IN THE CHARGE REGIME

$E_J/E_C = 0.25$



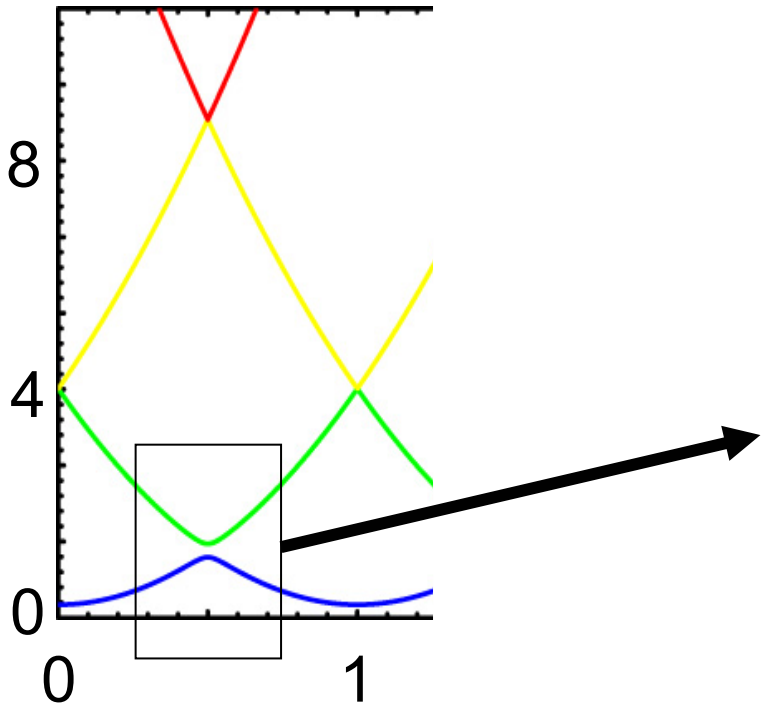
$$E_c = \frac{e^2}{2\left(C_g + C_j\right)}$$

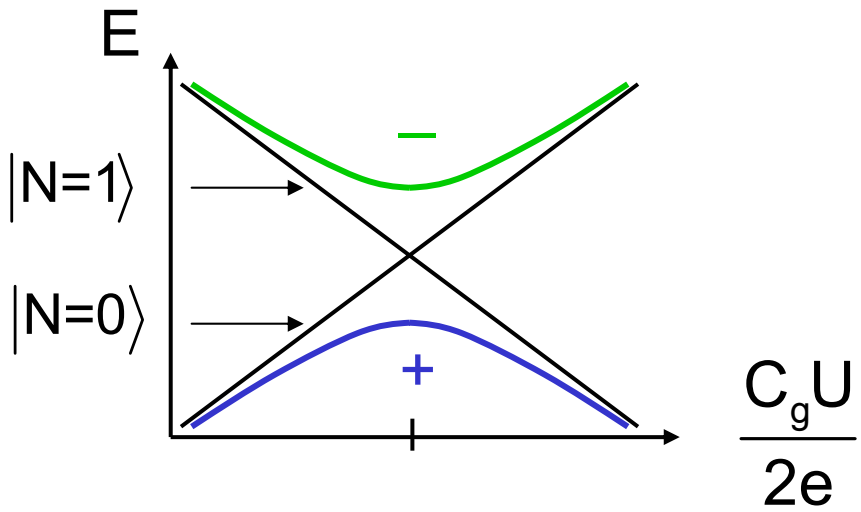
Zorin, Averin & Likharev '85

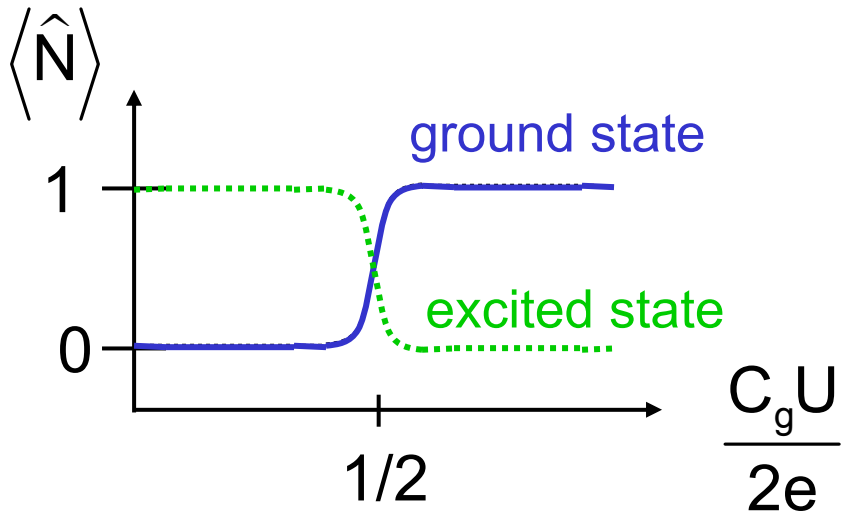
EXP^{TAL} IMPLEMENTATIONS OF SQUBITS

CONTROL / MEASURE	CHARGE	FLUX	PHASE
CHARGE	Saclay, SUNY Stony Brook, NEC, Yale, Chalmers, LPS, JPL, …	_____	_____
FLUX	_____	SUNY Stony Brook, TU-Delft, UC Berkeley, NTT, Rome …	NIST
PHASE	**Saclay** **Yale/Saclay**	IBM TU-Delft …	NIST U. Kansas U. Maryland …

BOX AS SPIN 1/2





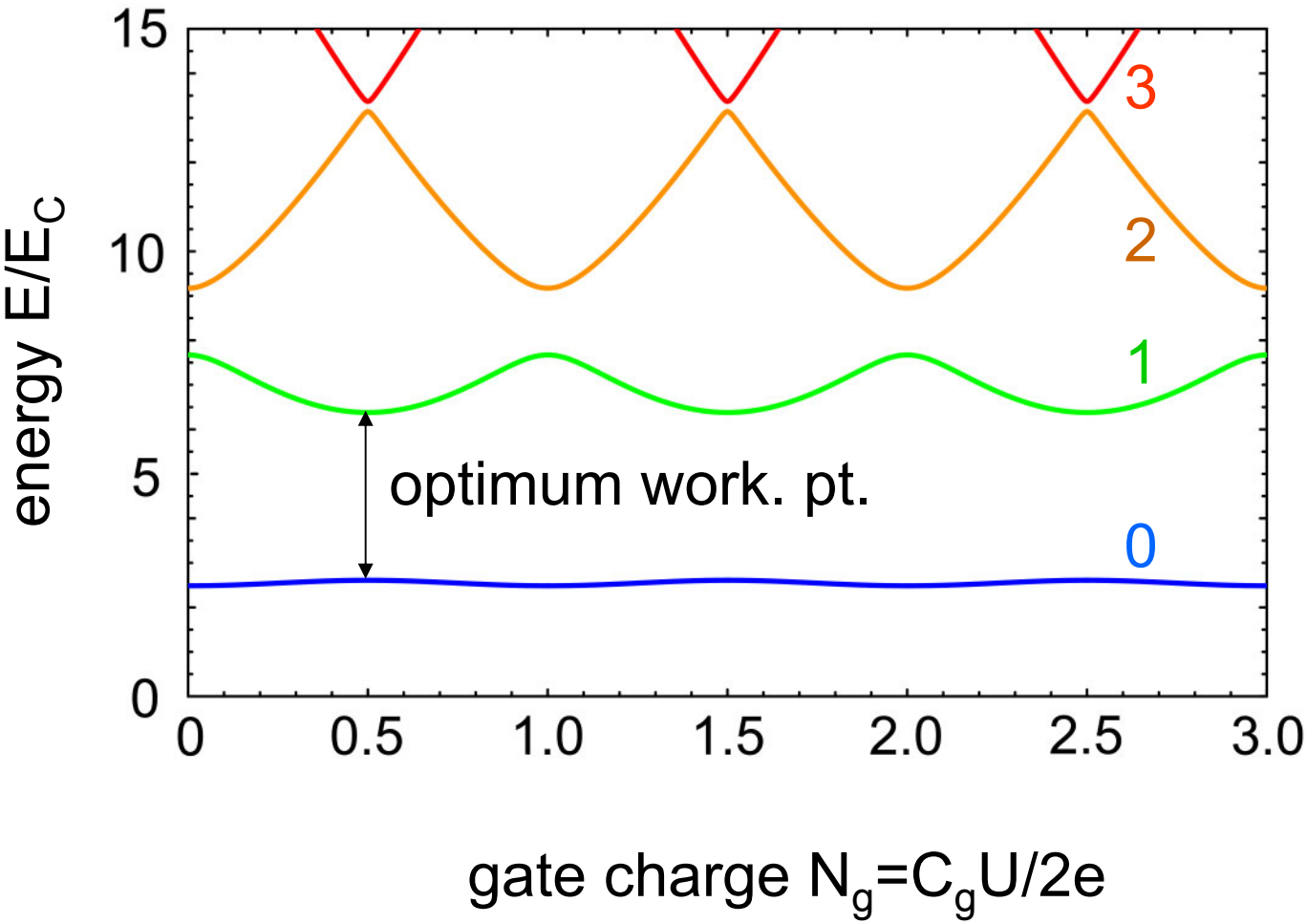


Saclay
NEC
Yale / Chalmers

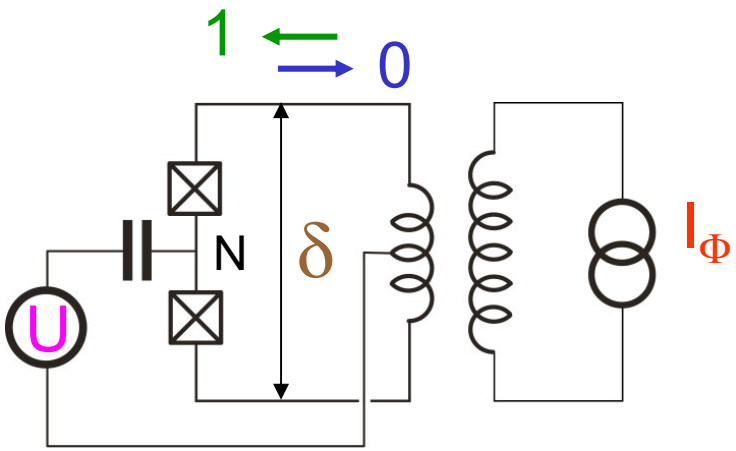
OFFSET CHARGE !

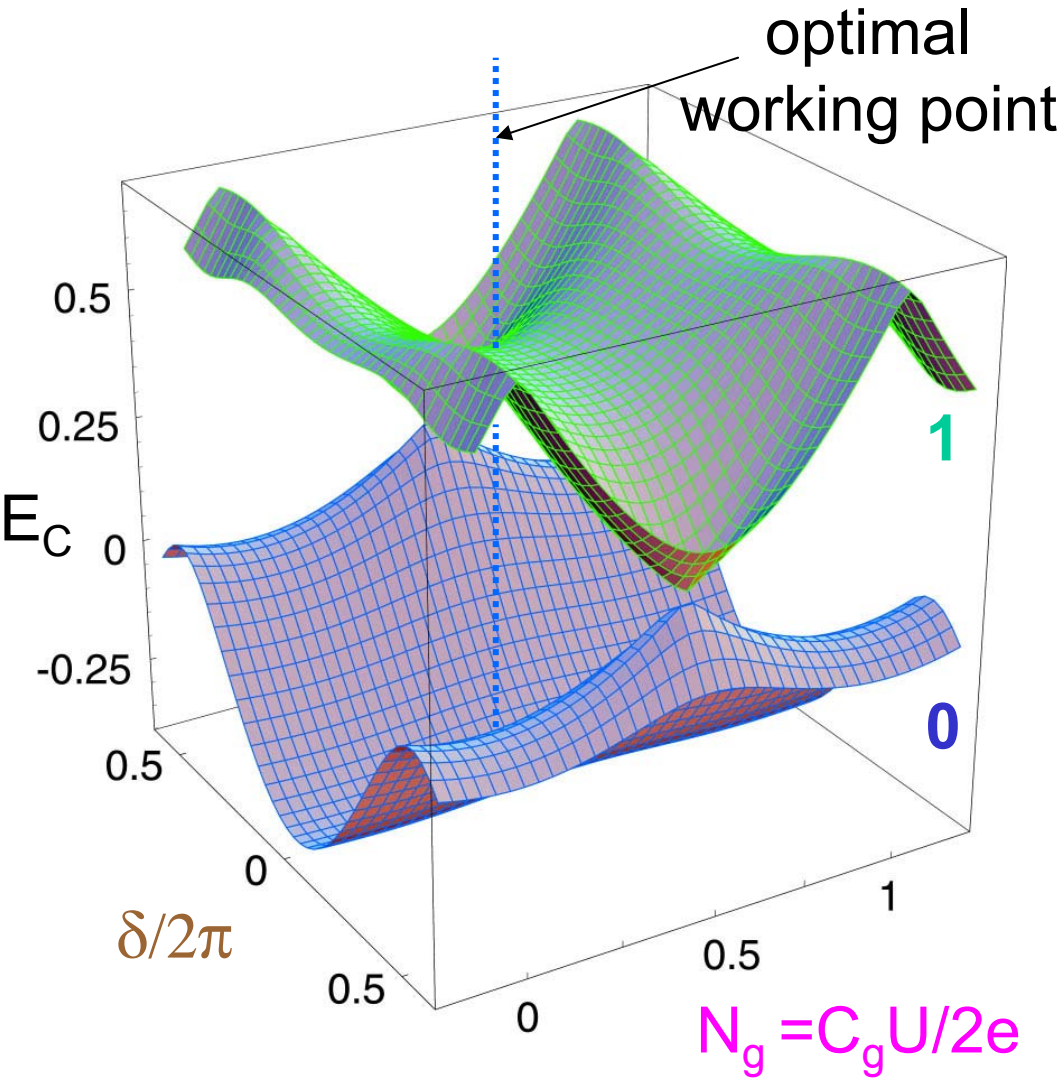
ENERGY LEVELS IN THE INTERMEDIATE REGIME

$E_J/E_C = 4$



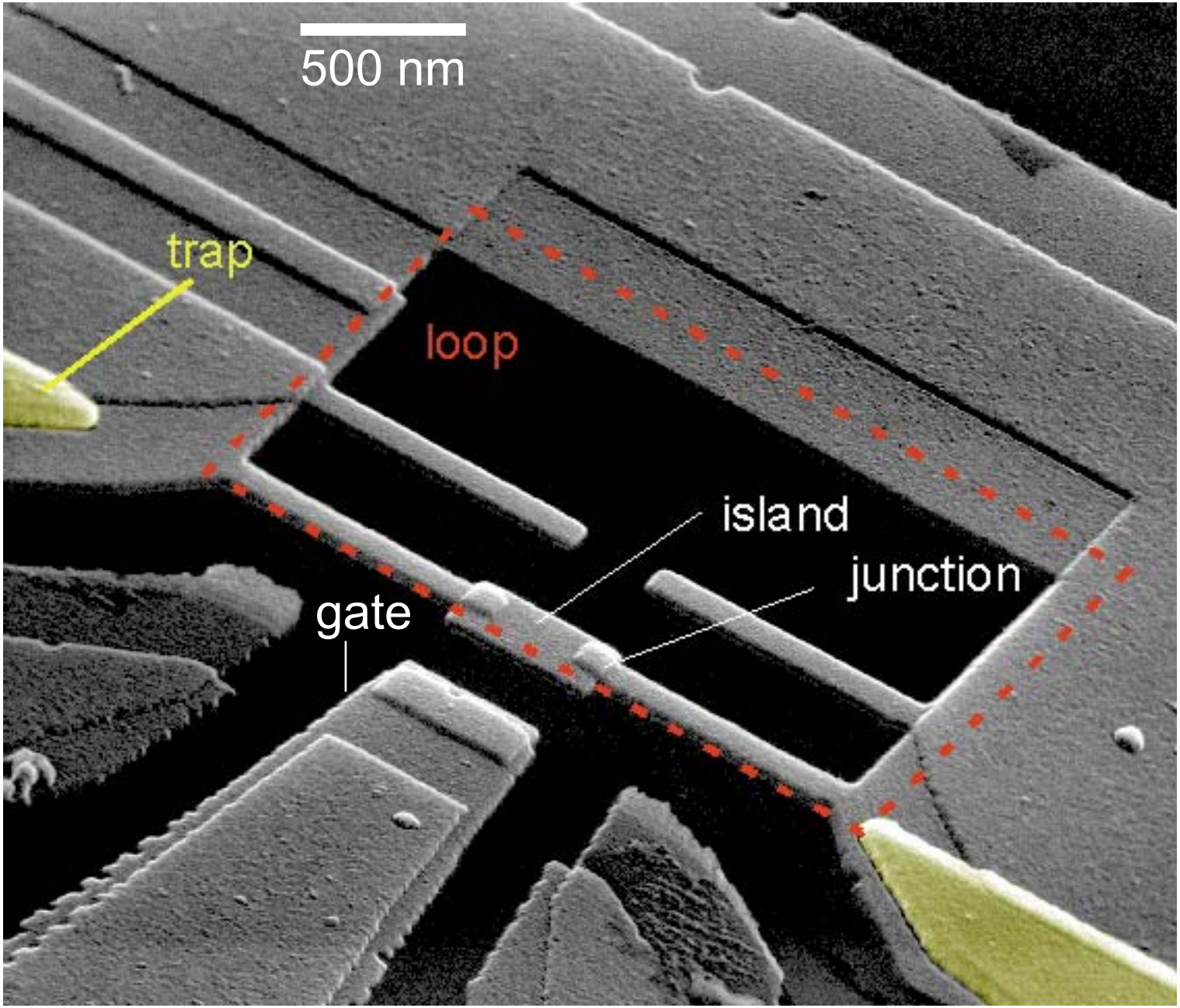
KEY IDEA : WRITE WITH CHARGE, READ WITH PHASE



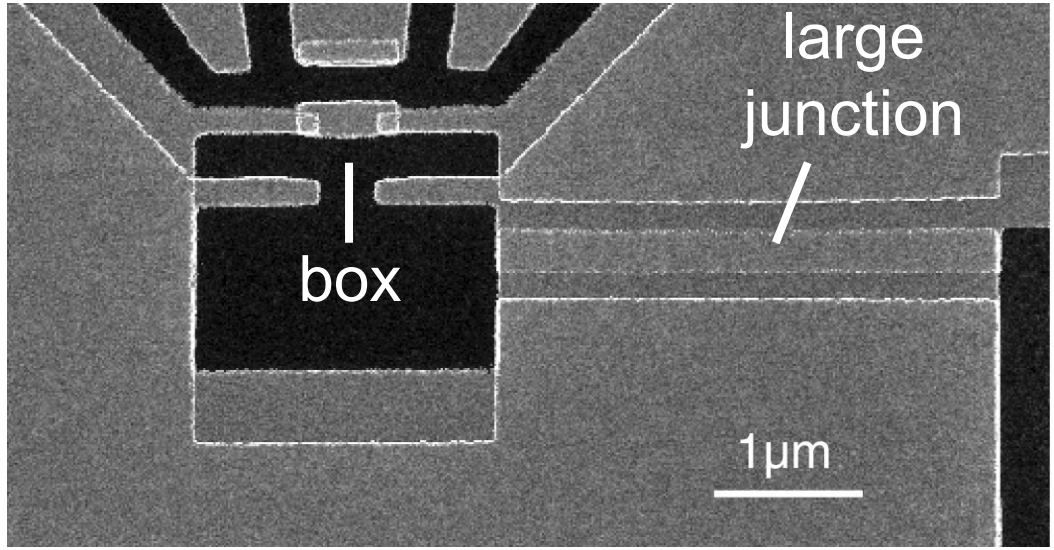


readout measures current
response to applied phase δ
instead of island charge N

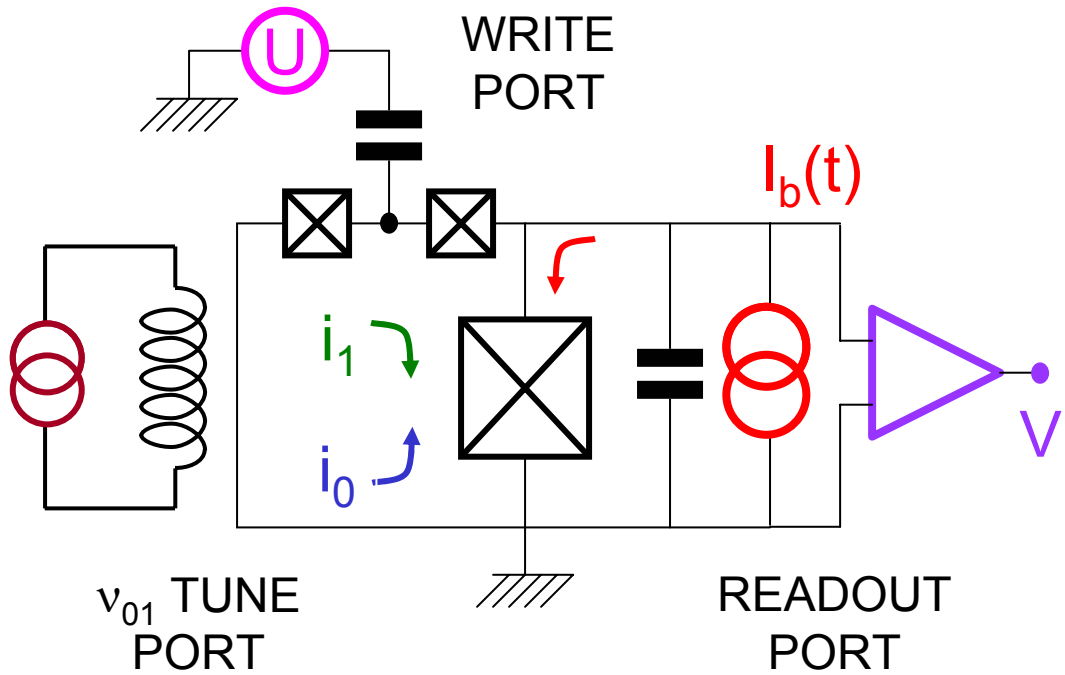
Cottet et al. 2002
Friedman & Averin, Zorin, Buisson et al.


500 nm
trap
loop
island
junction
gate

ELECTRON MICROGRAPH OF SAMPLE

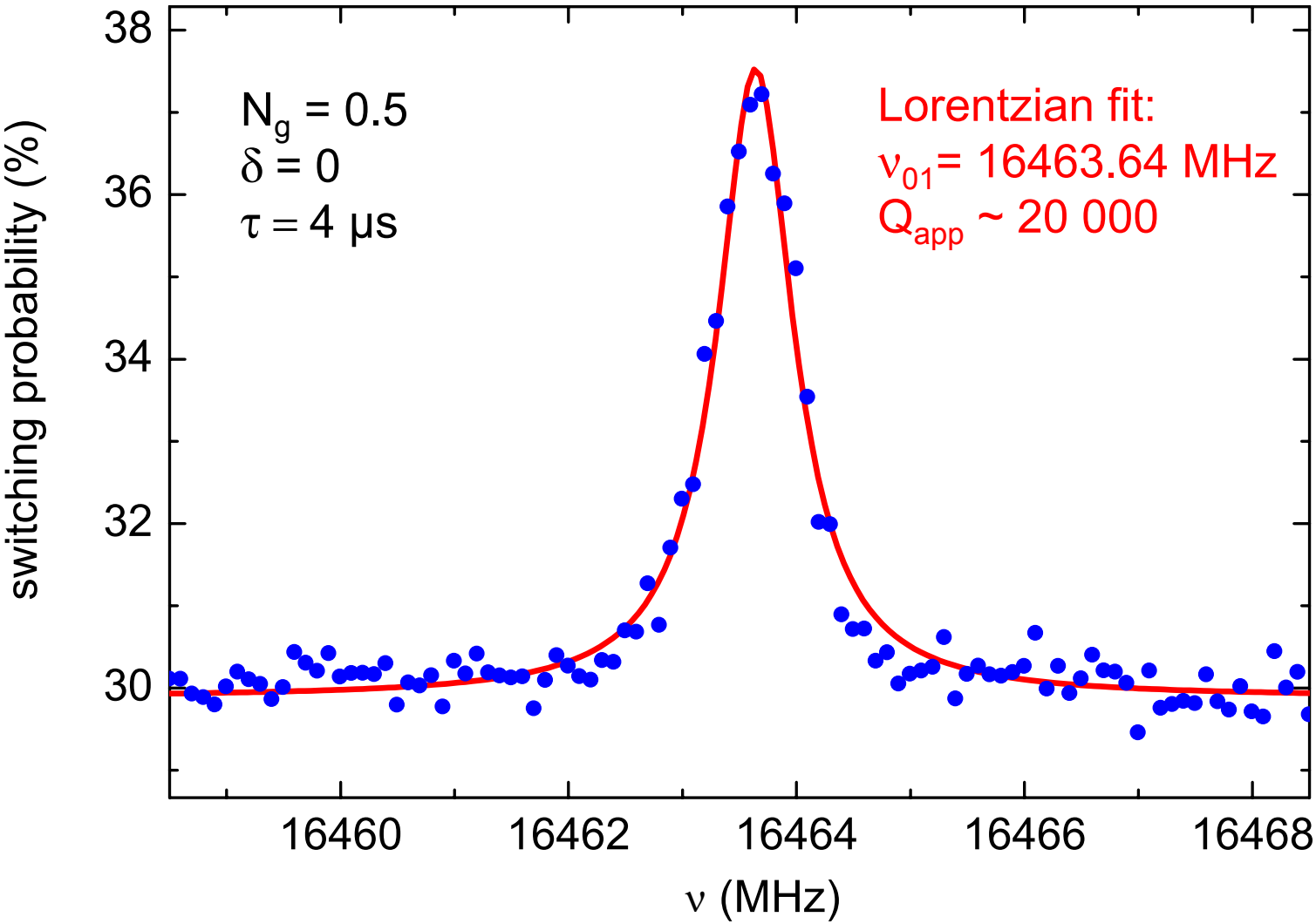


EXPERIMENTAL SETUP

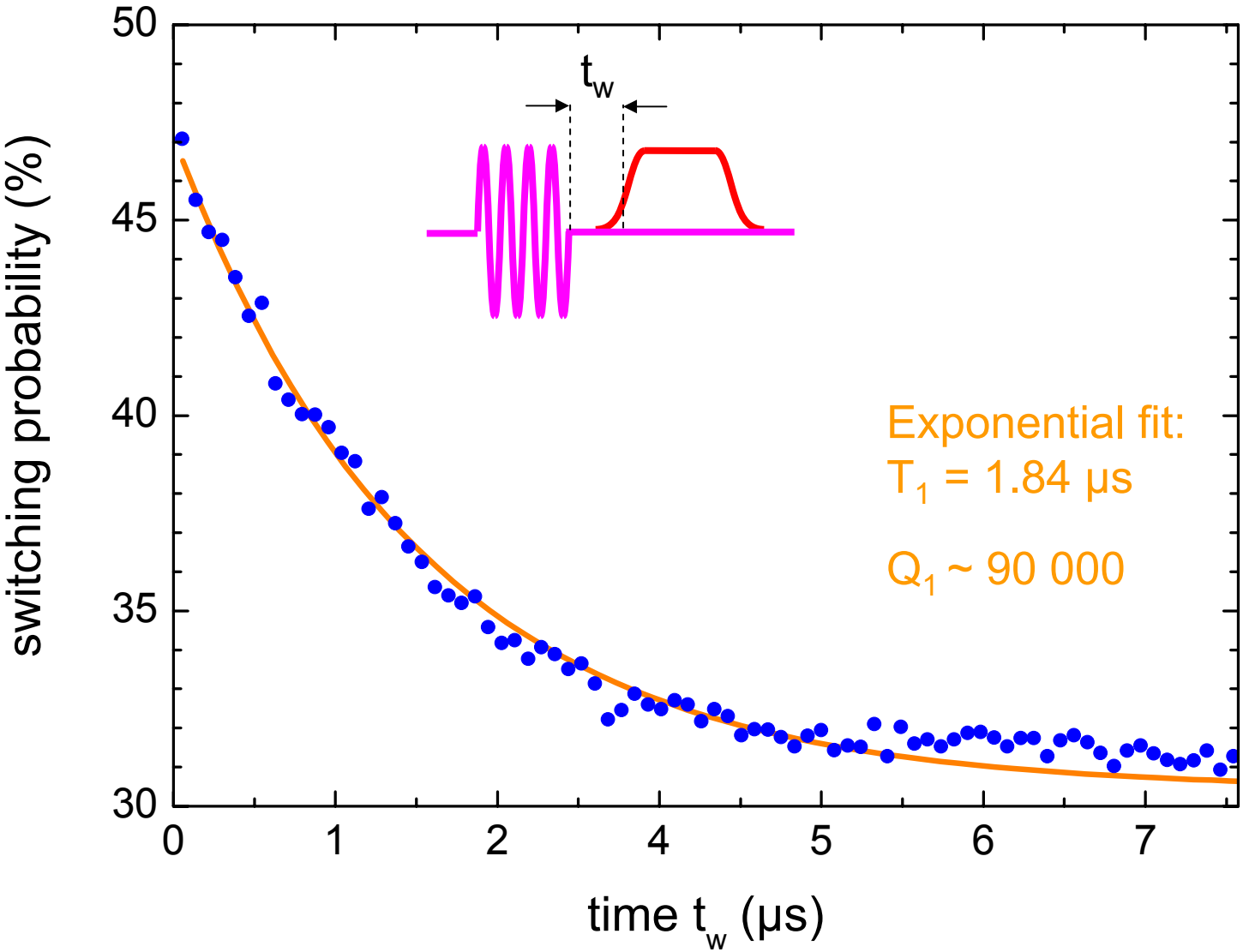


Vion *et al.*, Science **296** (2002), 286

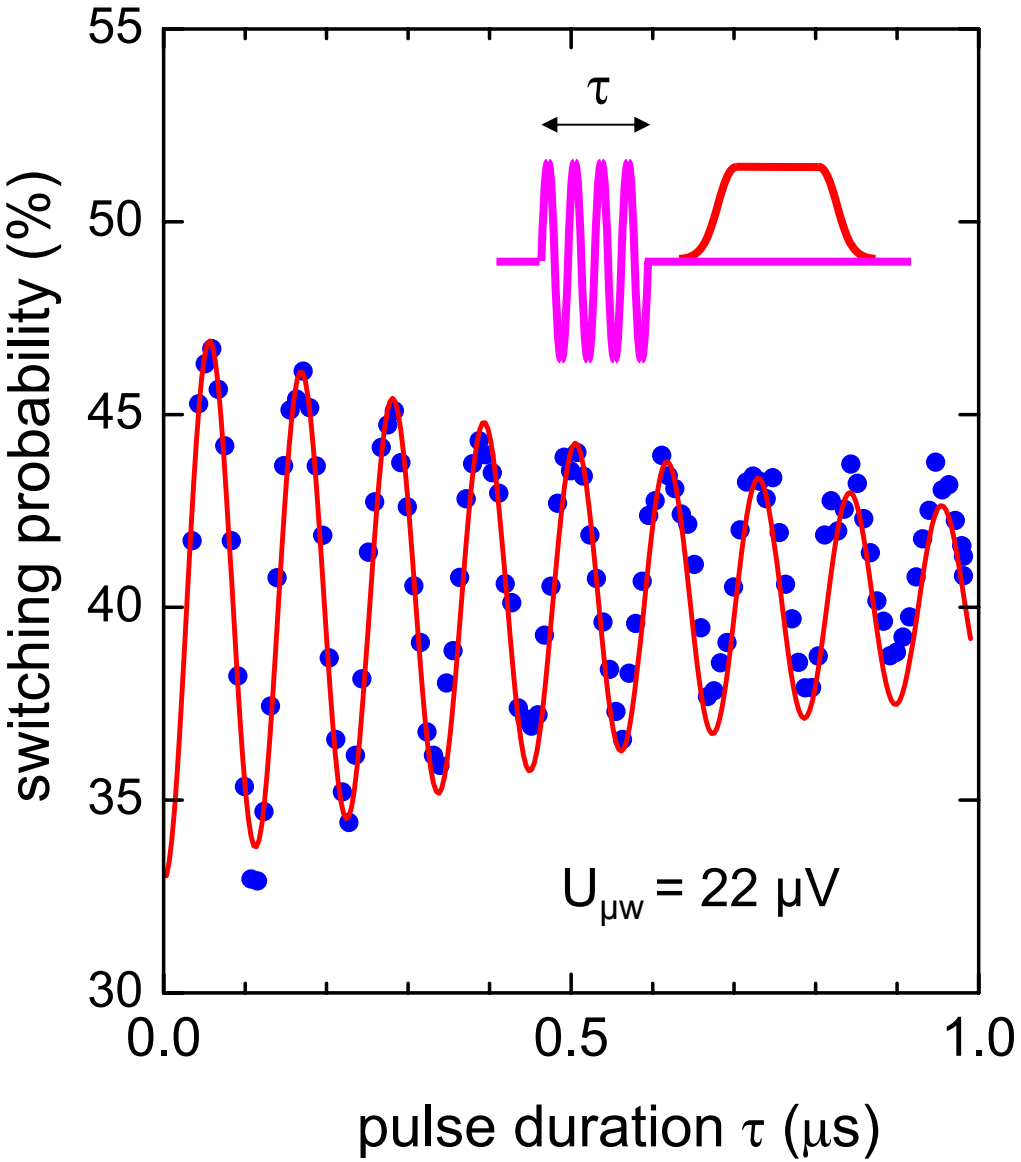
CW ABSORPTION LINESHAPE AT OPTIMAL POINT

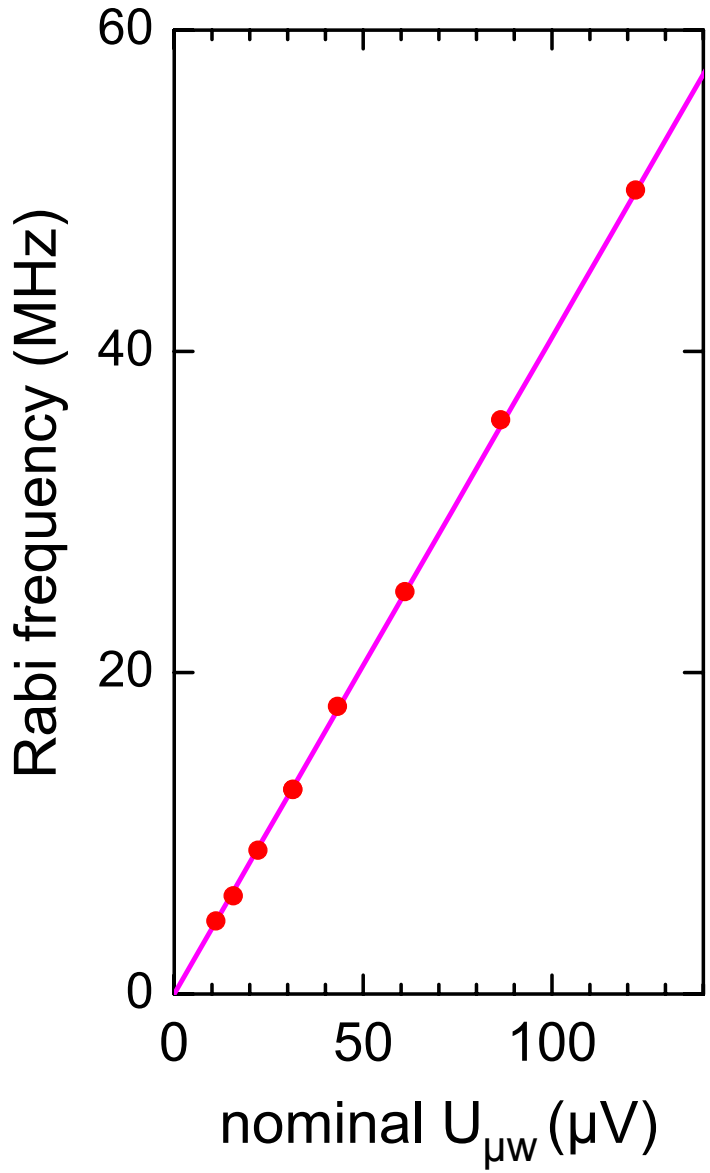


RELAXATION TIME AT OPTIMAL POINT

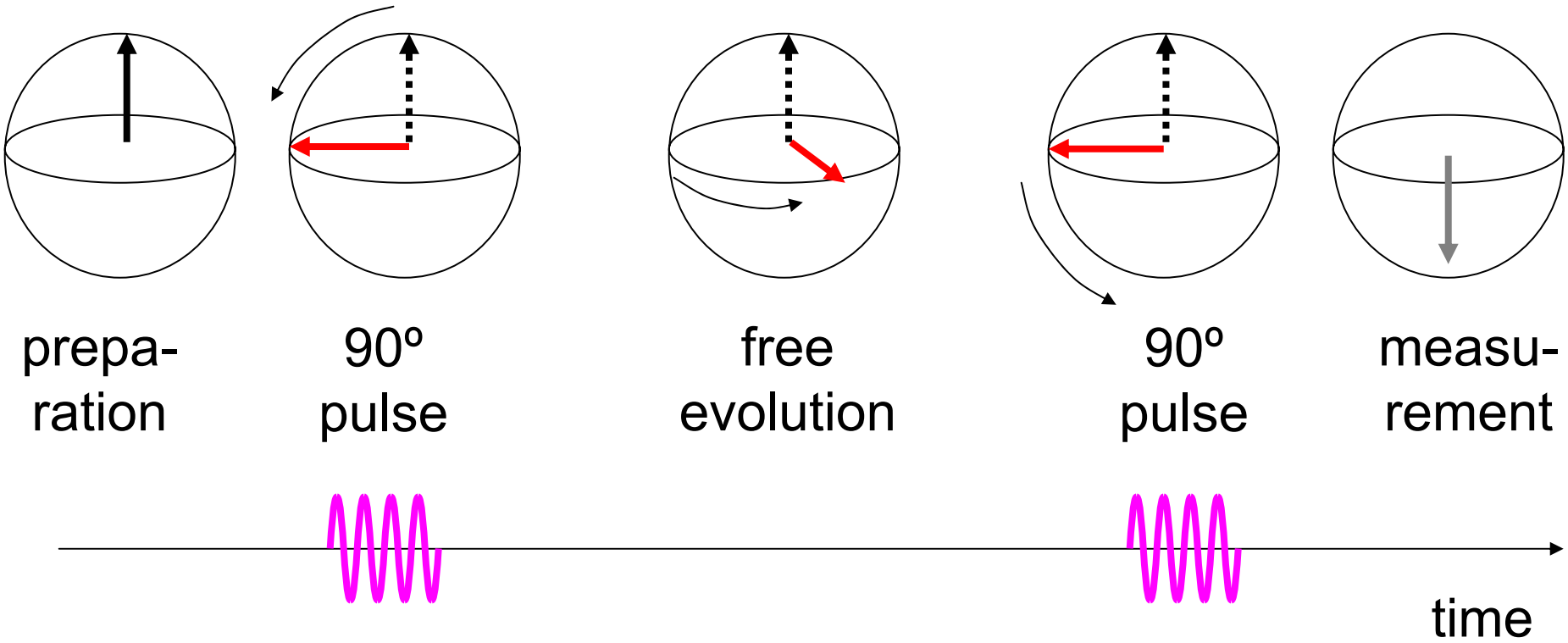


RABI OSCILLATIONS



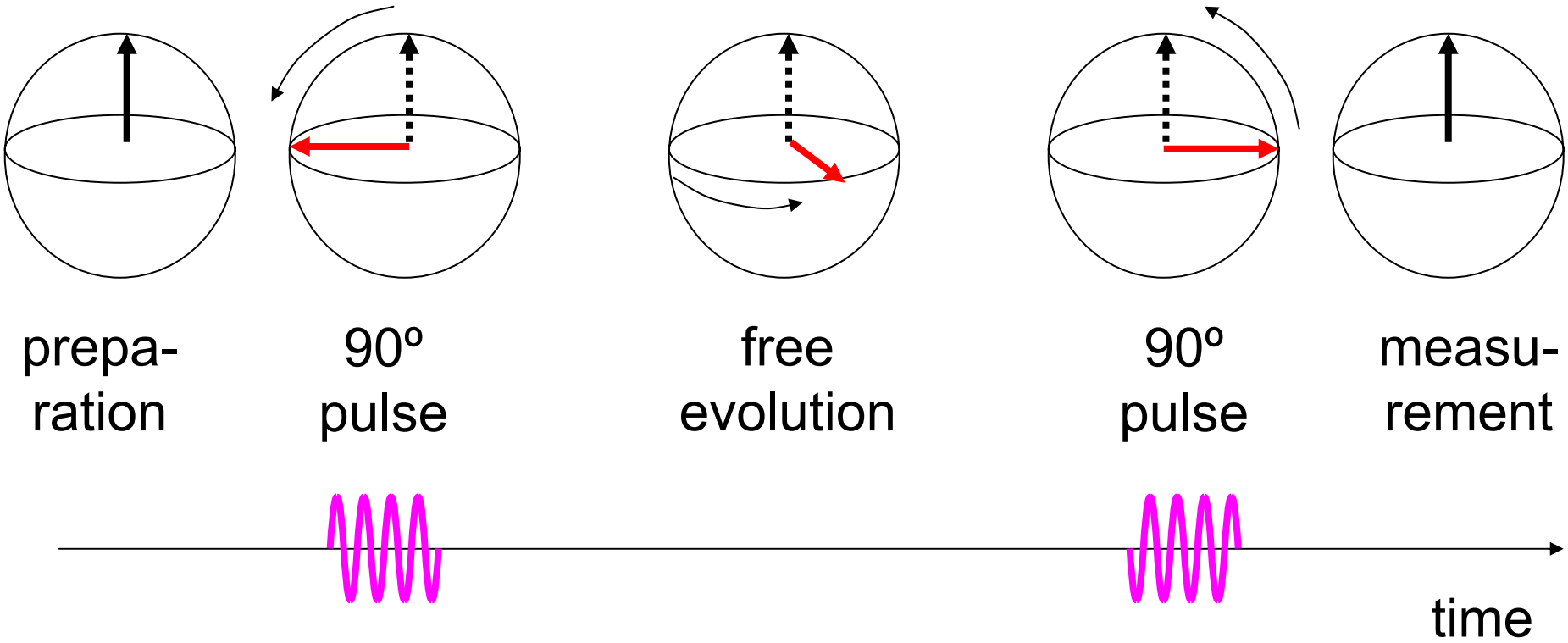


MEASURING QUANTUM COHERENCE LIFETIME (1)



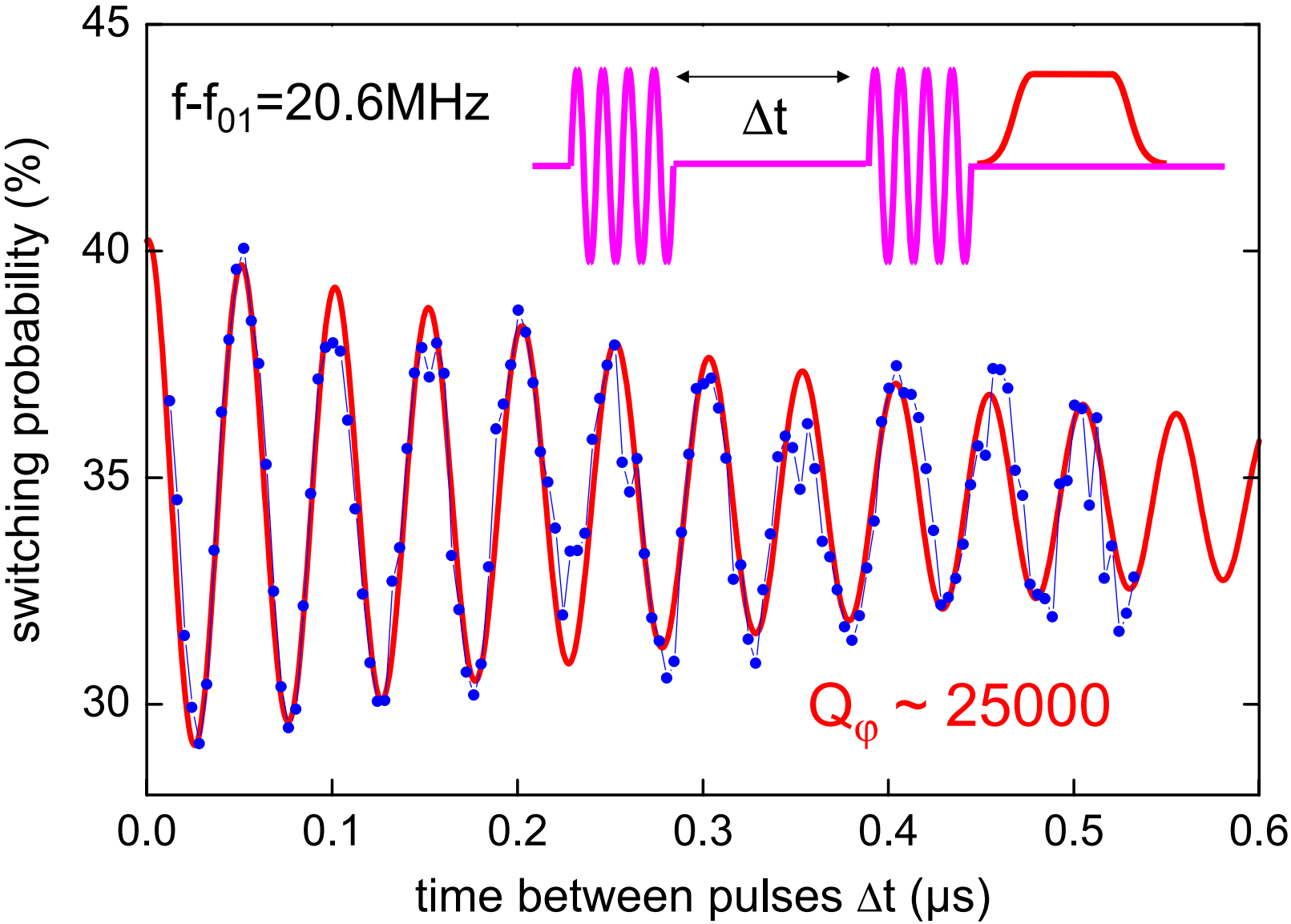
Ramsey fringe experiment, principle of atomic clocks

MEASURING QUANTUM COHERENCE LIFETIME (2)

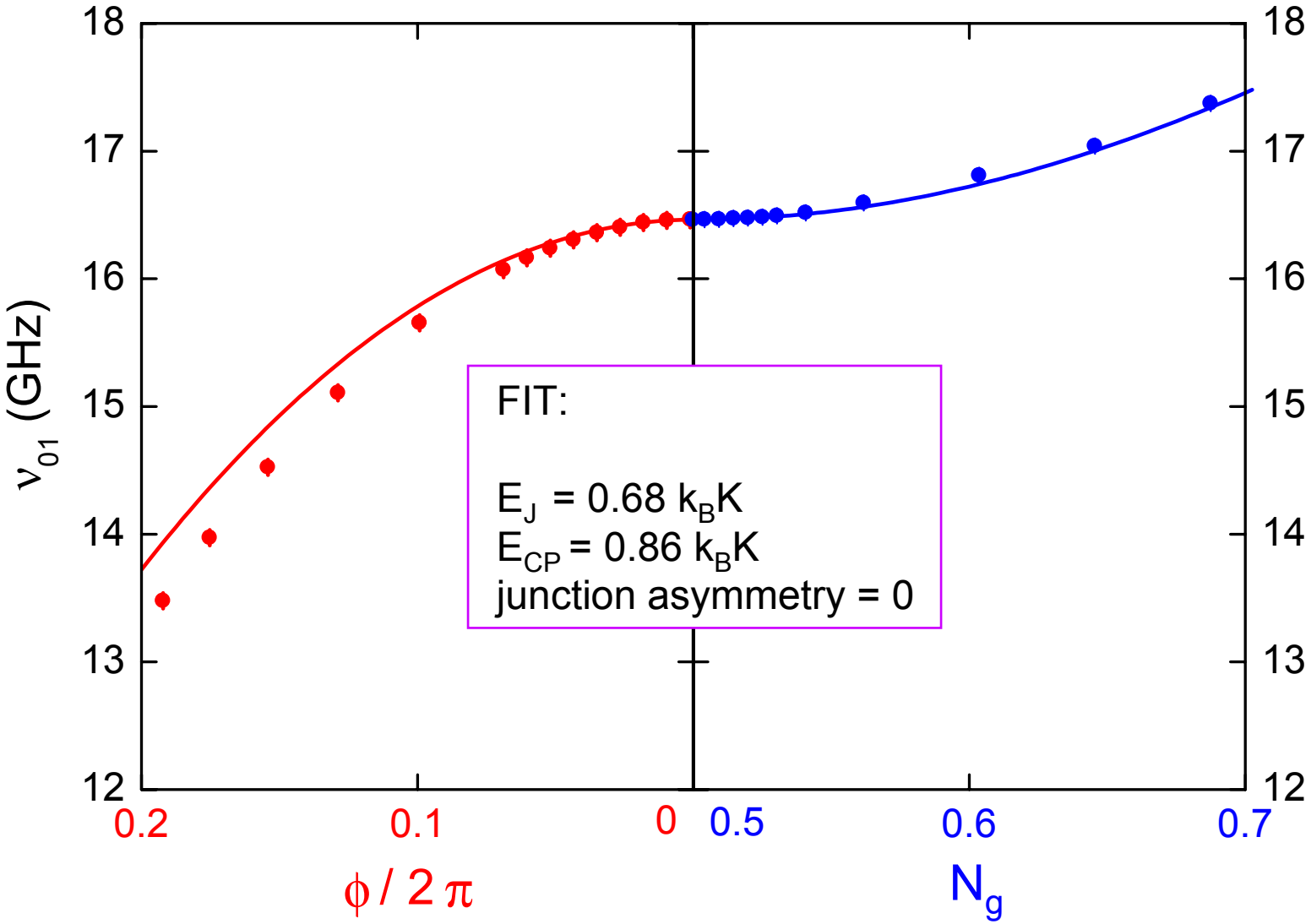


Ramsey fringe experiment, principle of atomic clocks

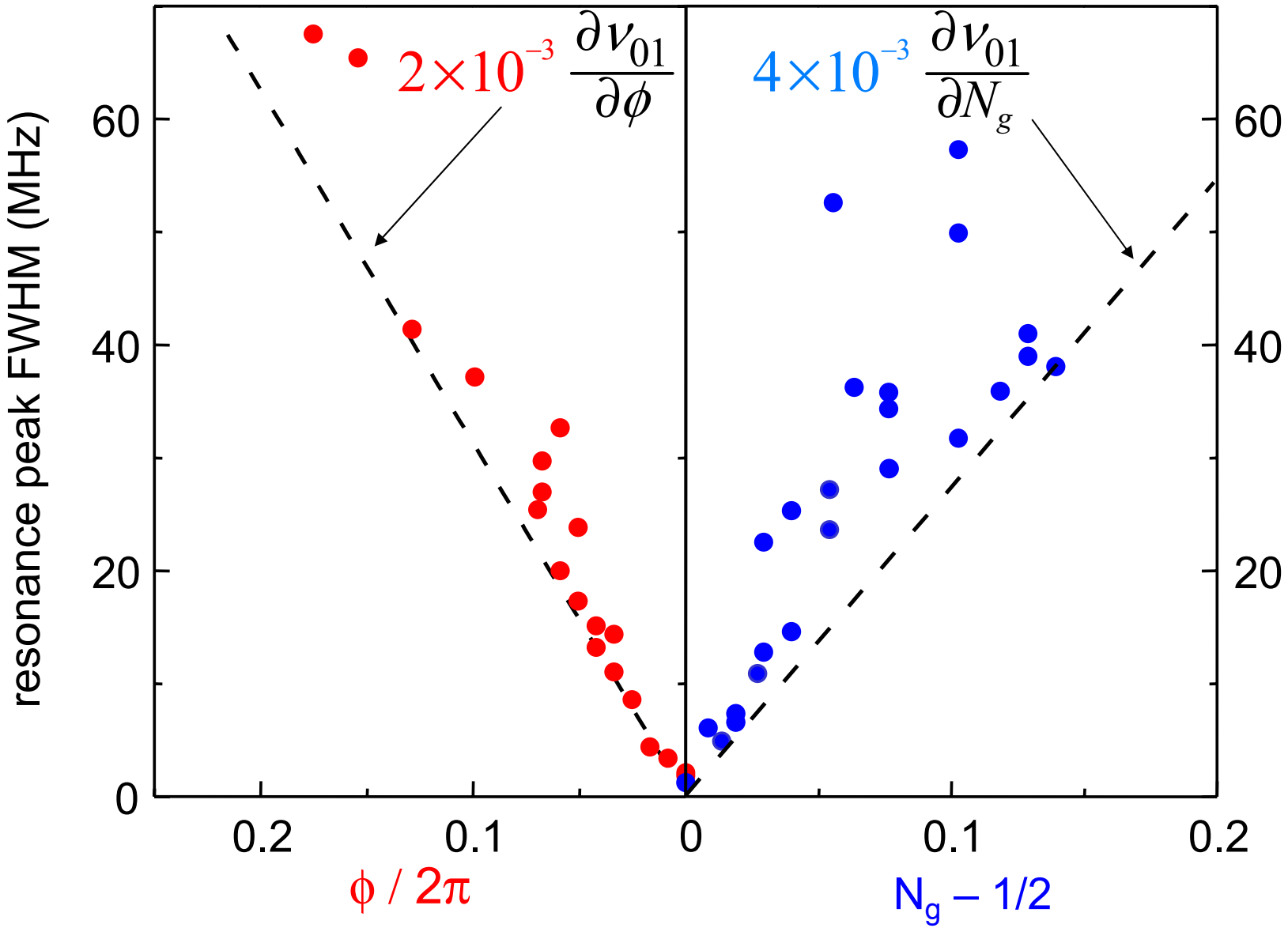
RAMSEY FRINGES MEASUREMENT



TRANSITION FREQUENCY vs BIAS

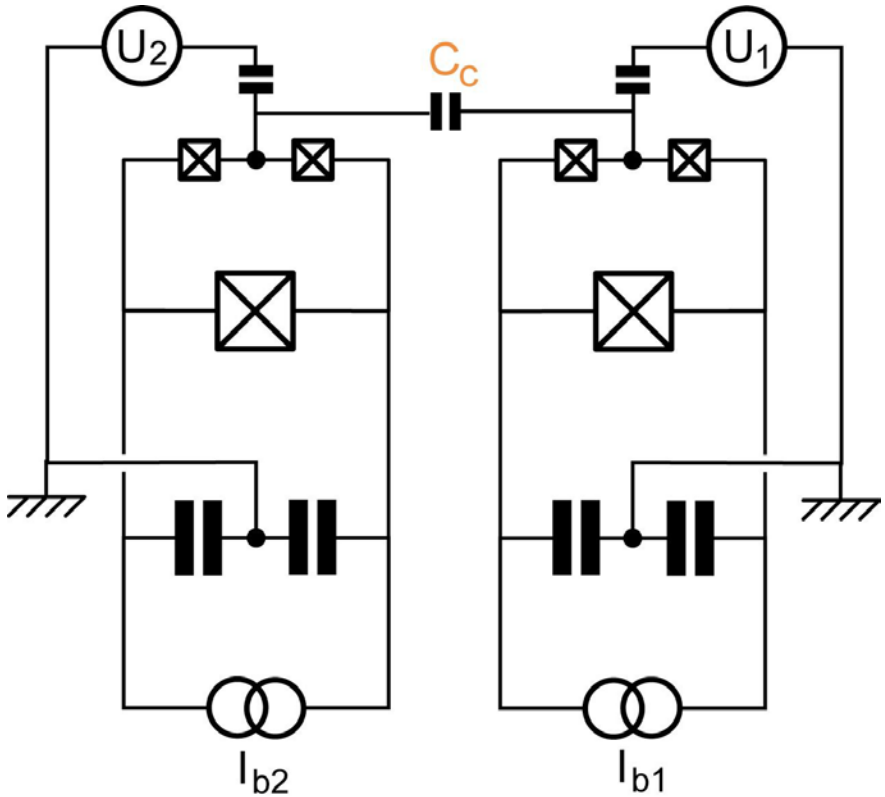


LINEWIDTH CLOSE TO THE OPTIMAL POINT



2-QUBIT GATE

qubit # 1 qubit # 2



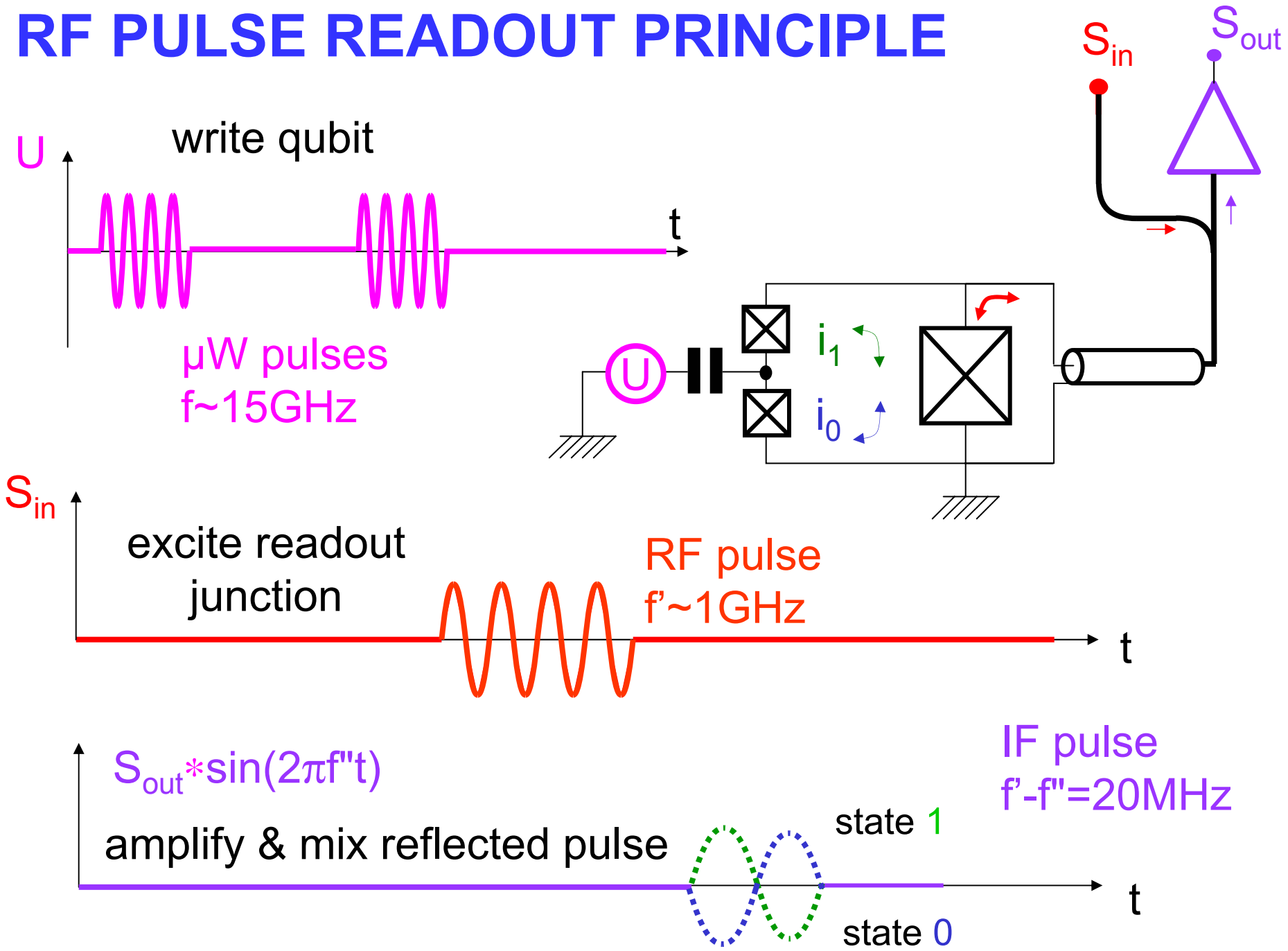
will prepare

$$\frac{|01\rangle - |10\rangle}{\sqrt{2}}$$

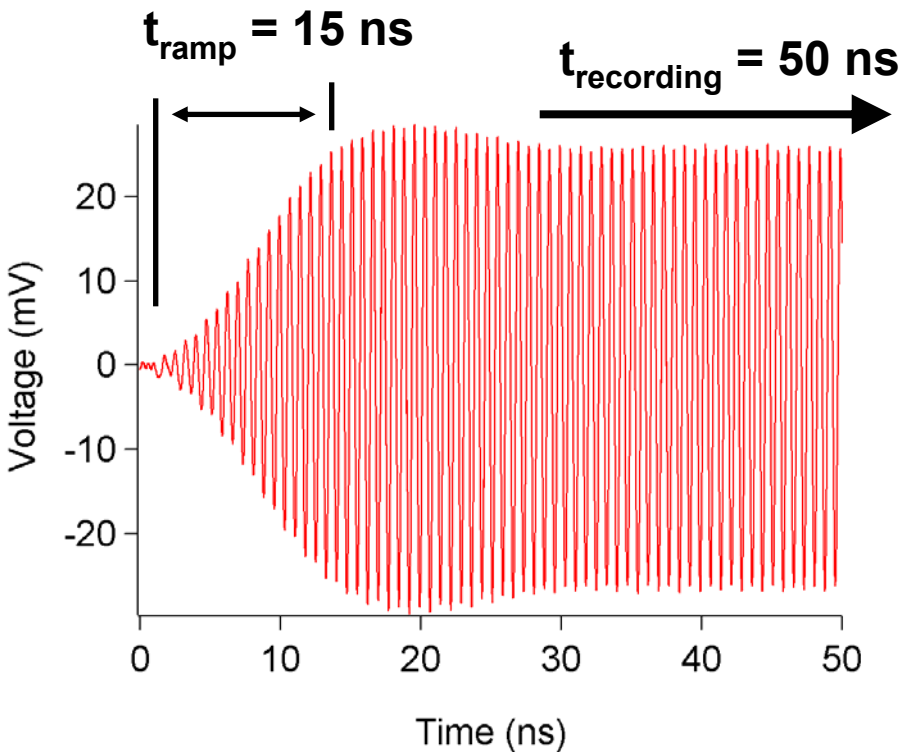
QUANTUM vs CLASSICAL SPIN-SPIN CORRELATIONS FOR 2 QUBITS

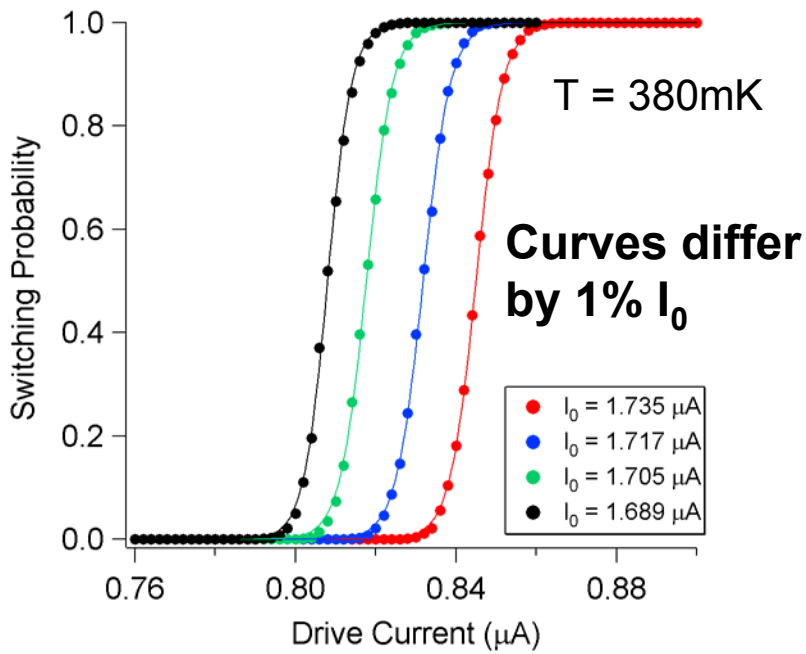
Qubit2 \ Qubit1	X	Y	Z
X	-1	**0.5** *(<0.33)*	**0.5** *(<0.33)*
Y	**0.5** *(<0.33)*	-1	**0.5** *(<0.33)*
Z	**0.5** *(<0.33)*	**0.5** *(<0.33)*	-1

RF PULSE READOUT PRINCIPLE



PRELIMARY RESULTS ON QUBIT READOUT PERFORMCE





- Measurement time is <15 ns! (<< T_1)
- Single-shot qubit state readout recorded in < 100 ns
- Discriminating power = 76% for 1% change in I_0 @ T=380 mK

CONCLUSIONS AND PERSPECTIVES

- EXISTENCE PROOF OF COHERENCE QUALITY FACTORS OF Q_φ~25 000 FOR CHARGE-PHASE QUBITS
- GATES BASED ON SIMPLE CAPACITORS
- RF-PULSE READOUT SHOULD BE QUASIPARTICLE-FREE; SHOULD IMPROVE CONTRAST, EFFICIENCY AND REPETITION RATE
- PROTECTION FROM 1/f CHARGE NOISE AND FLUX NOISE CAN BE IMPROVED FURTHER WITHIN PRESENT TECHNOLOGY