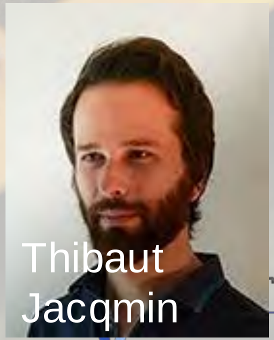
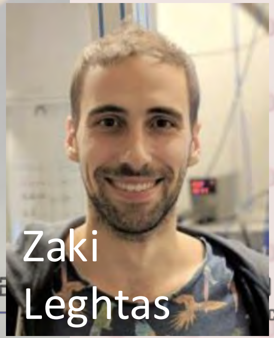
Probing the quantum motion of a MHz mechanical resonator with a resonant rf-fluxonium

S. Deléglise, K. Gerashchenko, R. Rousseau, L. Balembois, H. Patange, P. Manset, A. Riva, H. Le Sueur, P.-F. Cohadon, T. Briant, A. Heidmann, T. Jacqmin

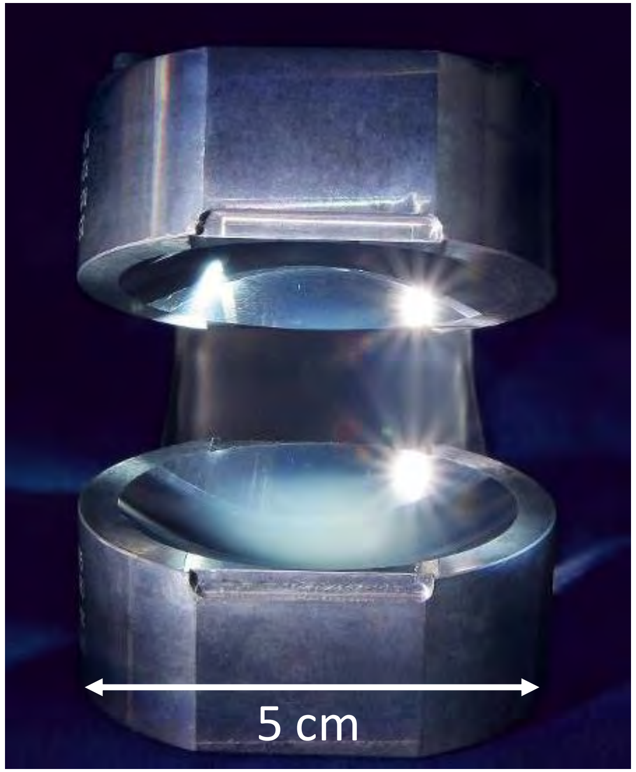
Collab: Z. Leghtas (LPENS), E. Flurin (CEA), A. Sarlette (Inria)





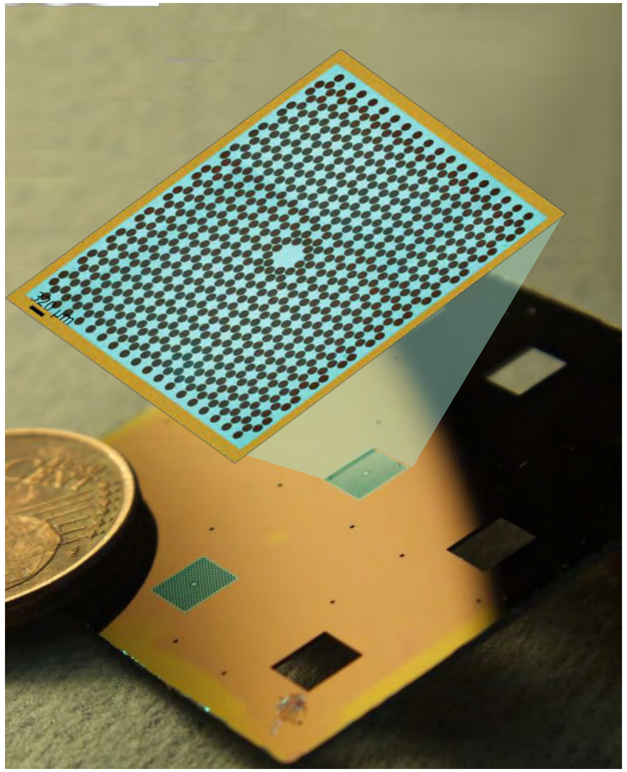
Qfeedback, June 5th 2026

from Cavity Quantum Electro Dynamics … …to circuit Quantum Acousto Dynamics



Photon box

- $\omega_{cav}/2\pi = 50$ GHz
- $T_1 = 130$ ms
- $Q = 4 \cdot 10^{10}$
- $n_{th} = 0.05$ @ 800 mK

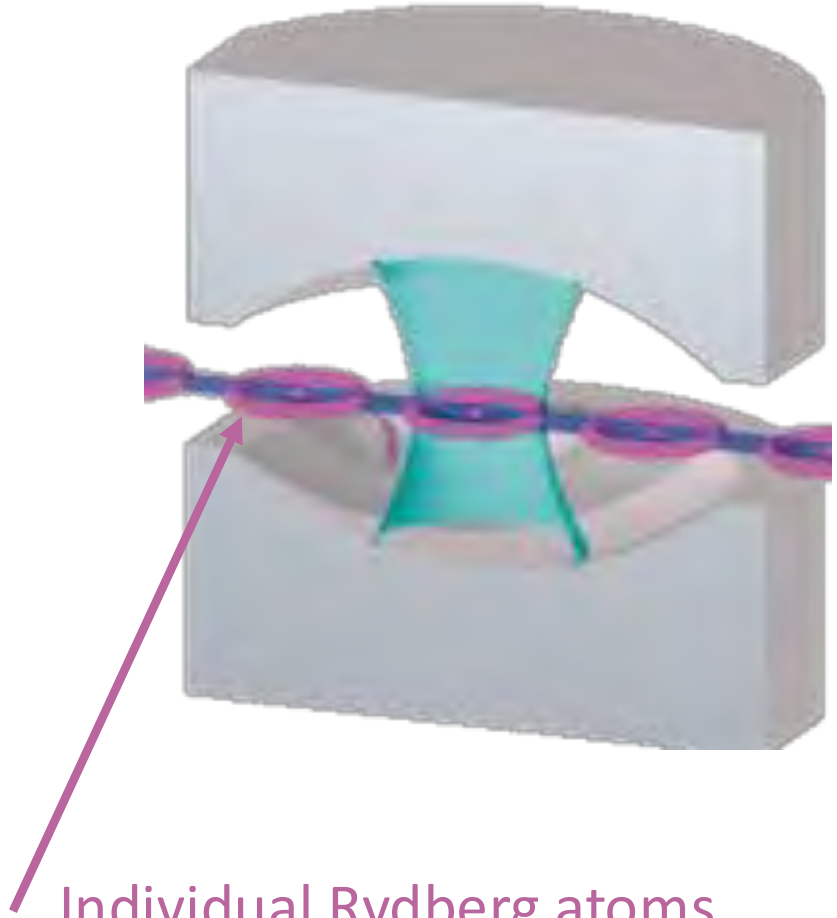


Phonon box

- $\omega_m/2\pi = 1$ MHz
- $T_1 = 2$ minutes
- $Q = 10^9$
- $n_{th} = 50$ @ 10 mK

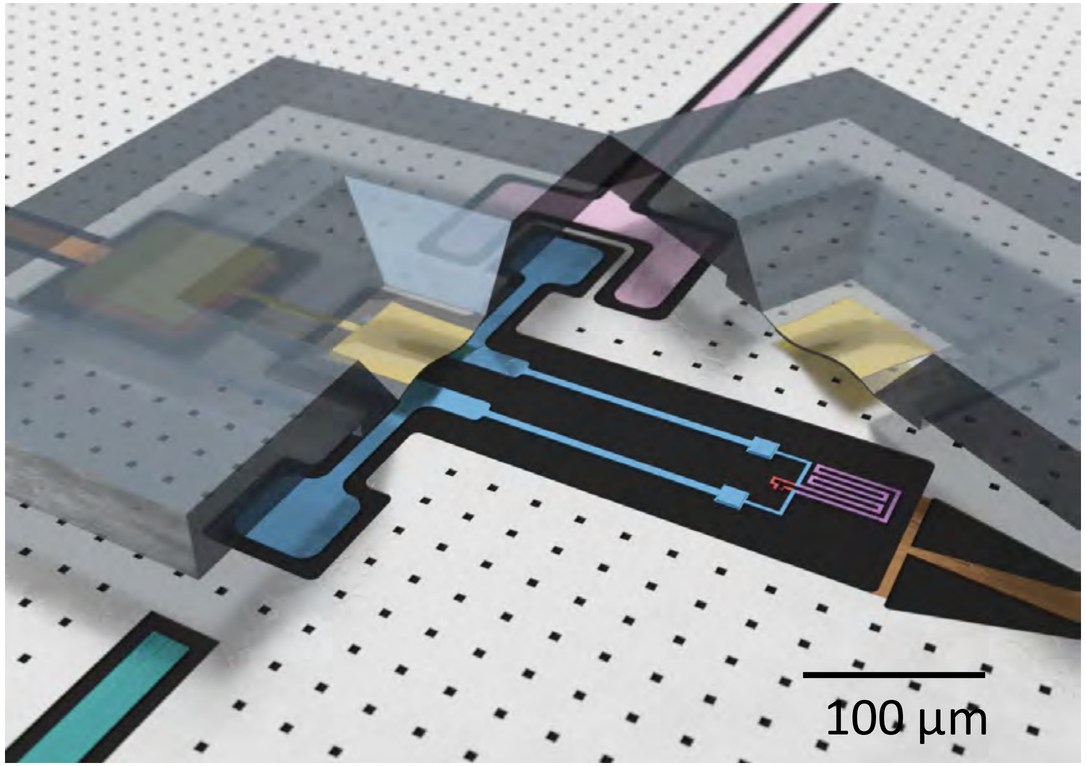
A Journey through quantum optics at LKB

from Cavity Quantum Electro Dynamics …



Individual Rydberg atoms

…to circuit Quantum Acousto Dynamics



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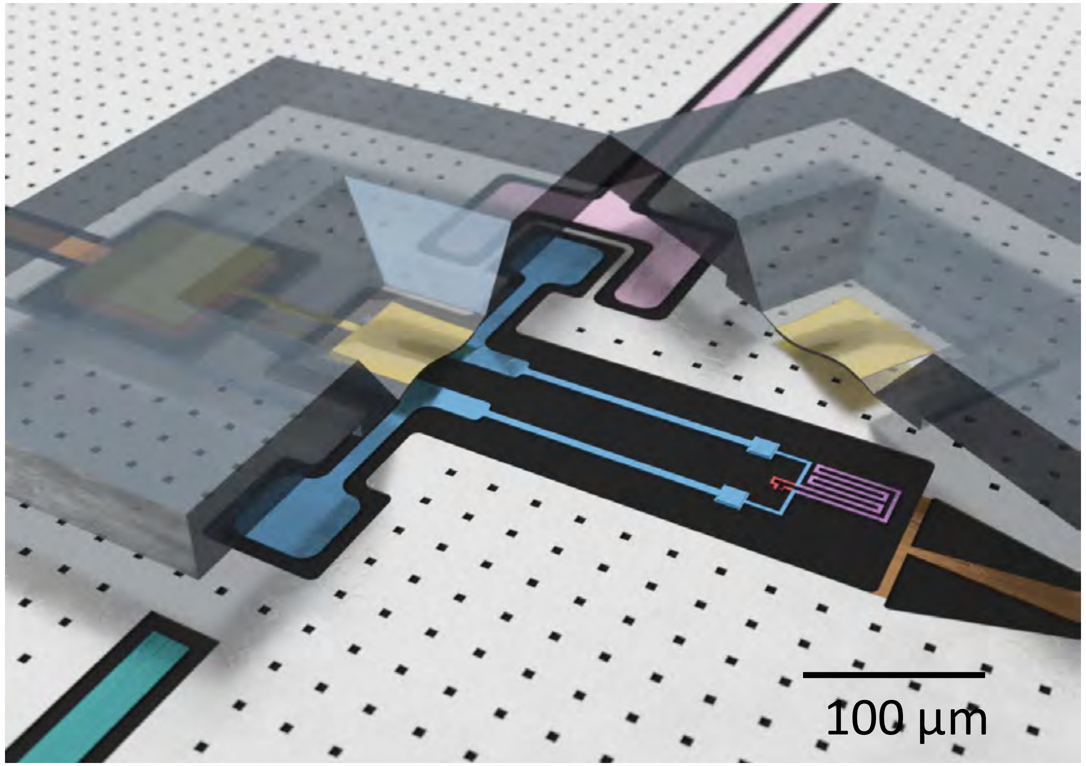

Individual Rydberg atoms

$\sim$ 120 atoms per T_1

- Strong coupling regime

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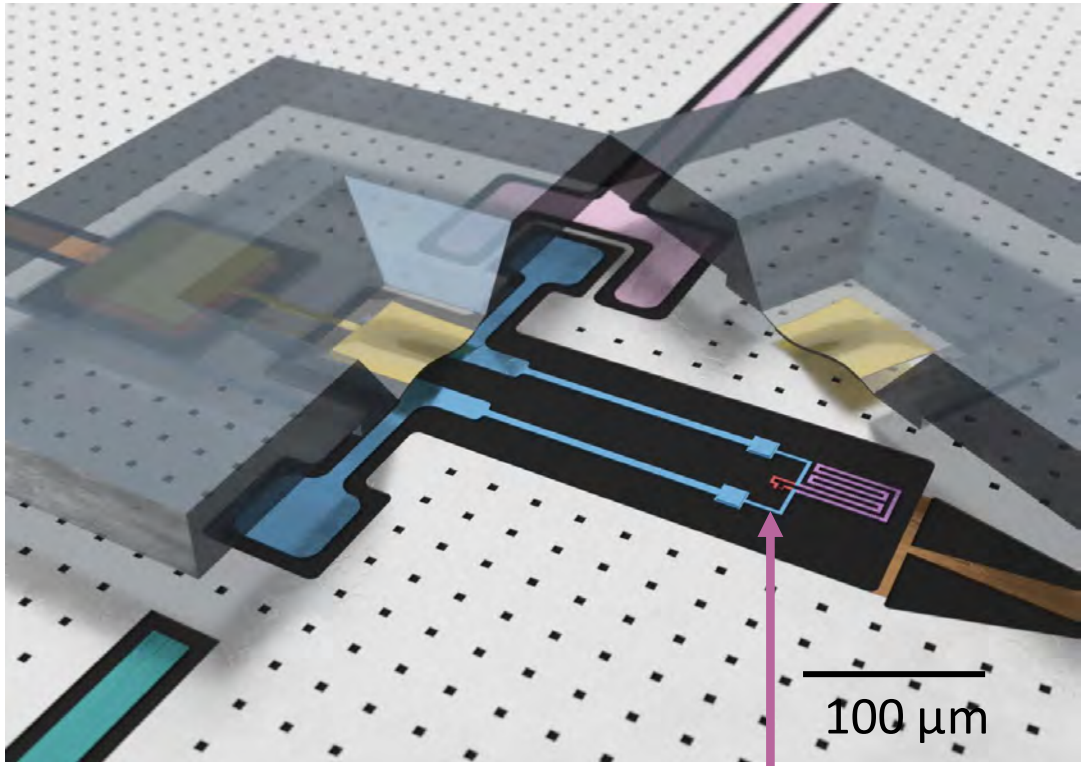

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Artificial atom (Fluxonium qubit)

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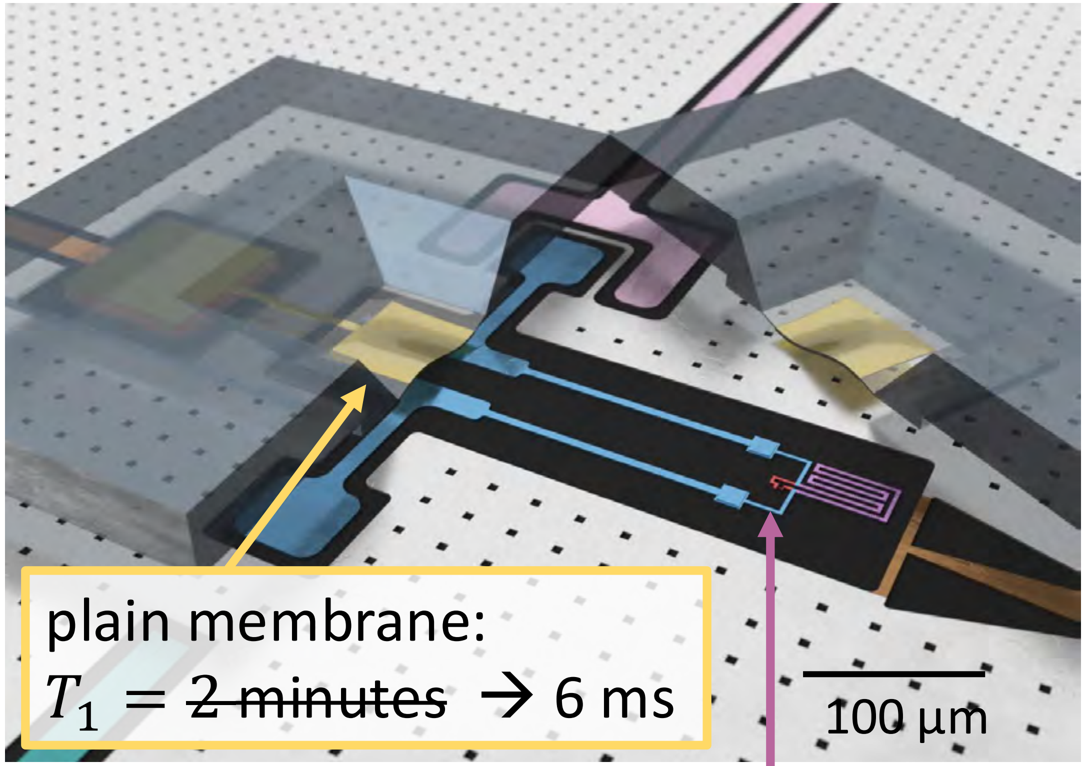

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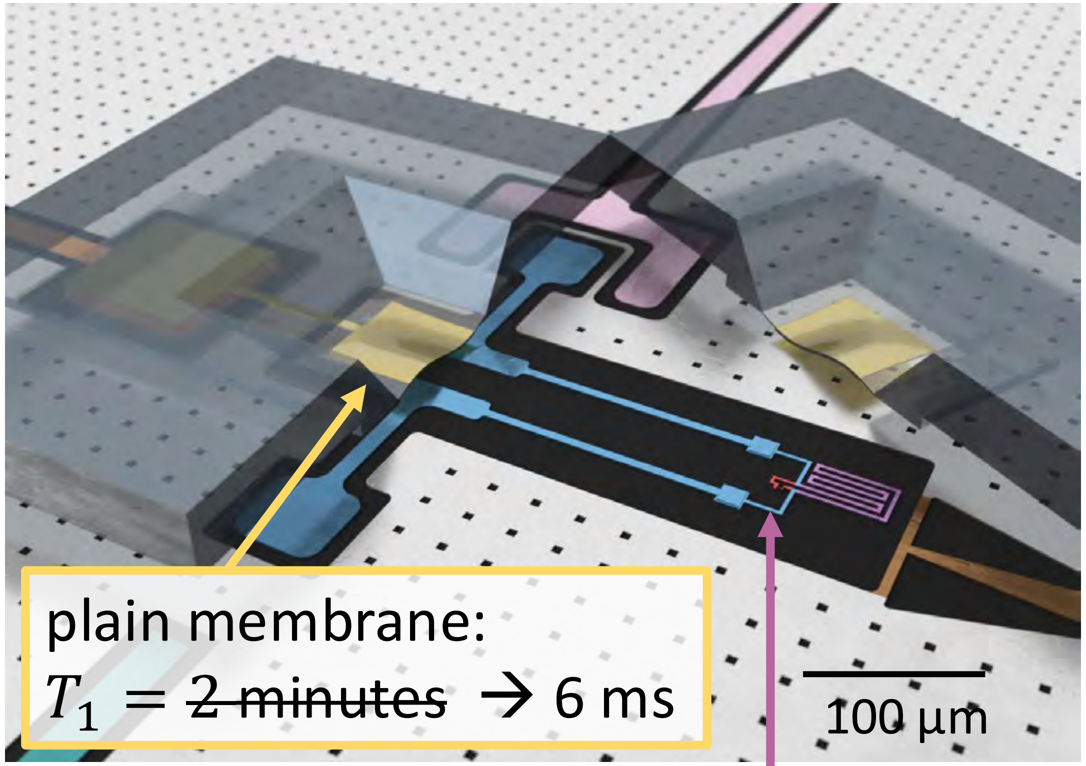

Artificial atom (Fluxonium qubit)

$\sim$ 400 qubit/membrane interactions per T_1

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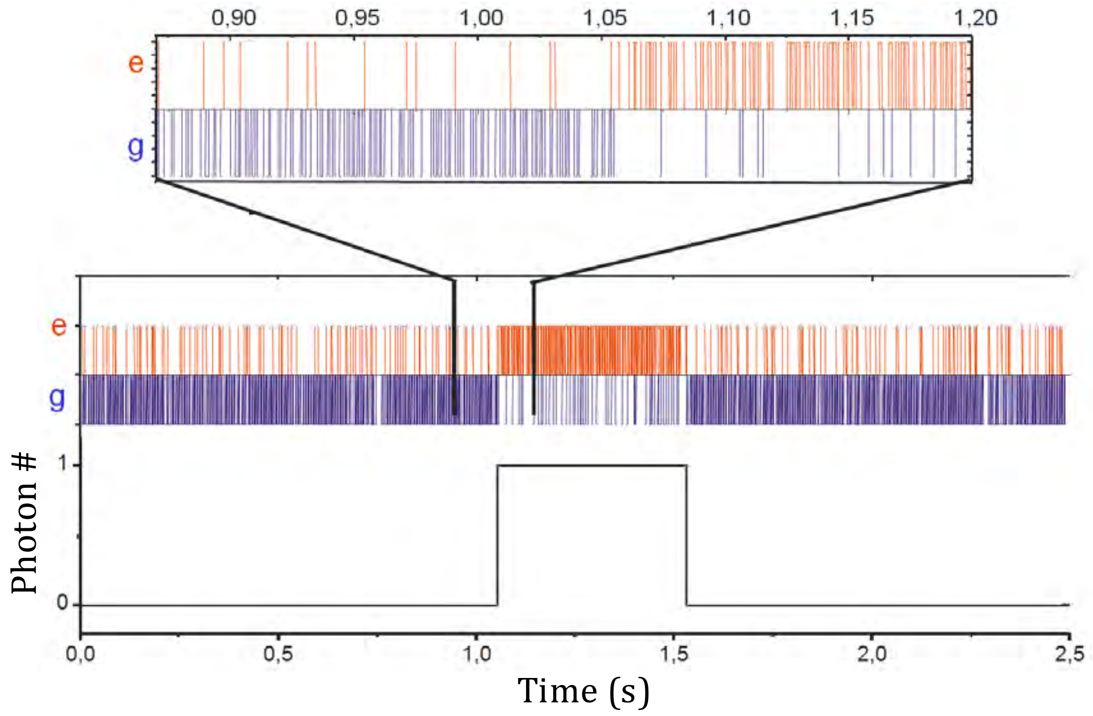
Each atom performs a strong measurement of the resonator state

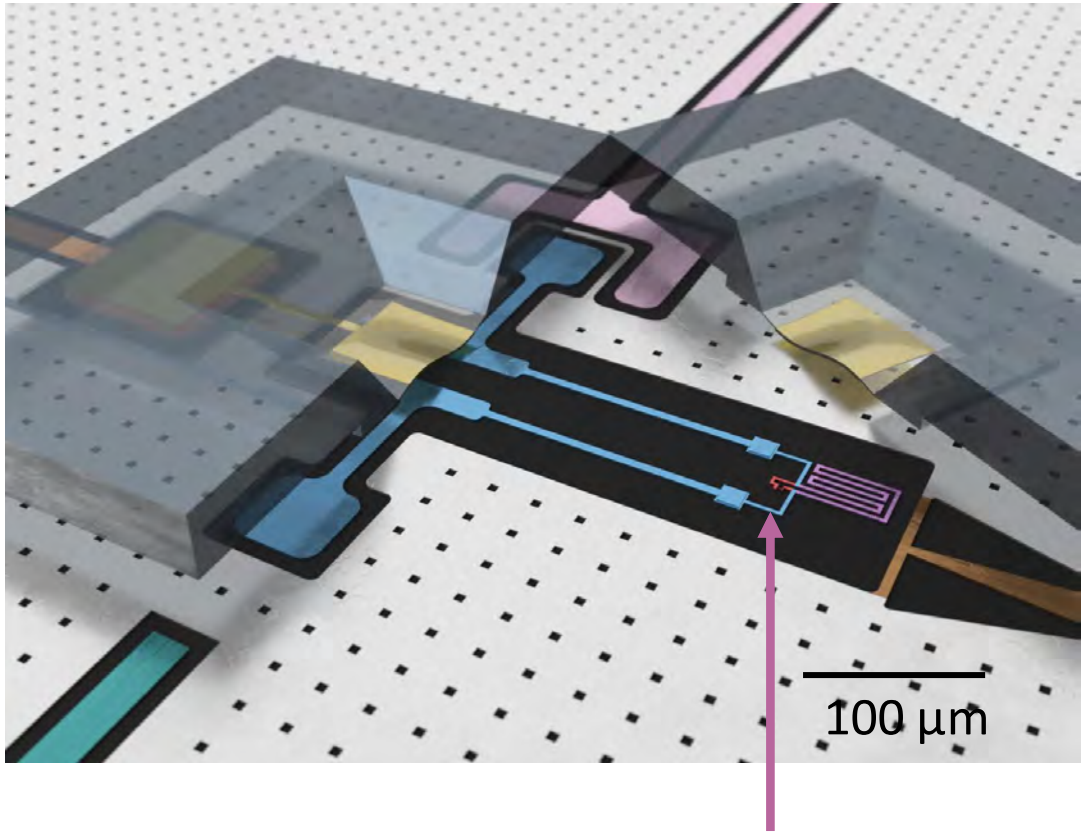


Birth and death of a photon in a cavity

Gleyzes *et al*. *Nature*, *446*(7133), 297-300 (2007).

- Strong coupling regime

…to circuit Quantum Acousto Dynamics



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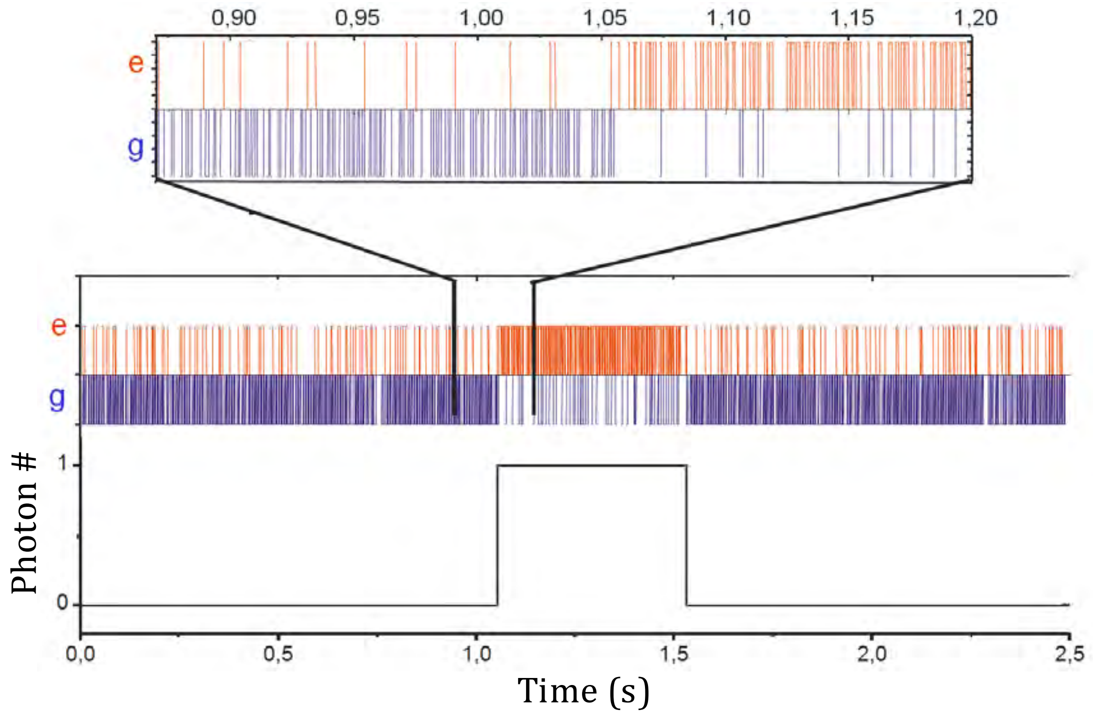

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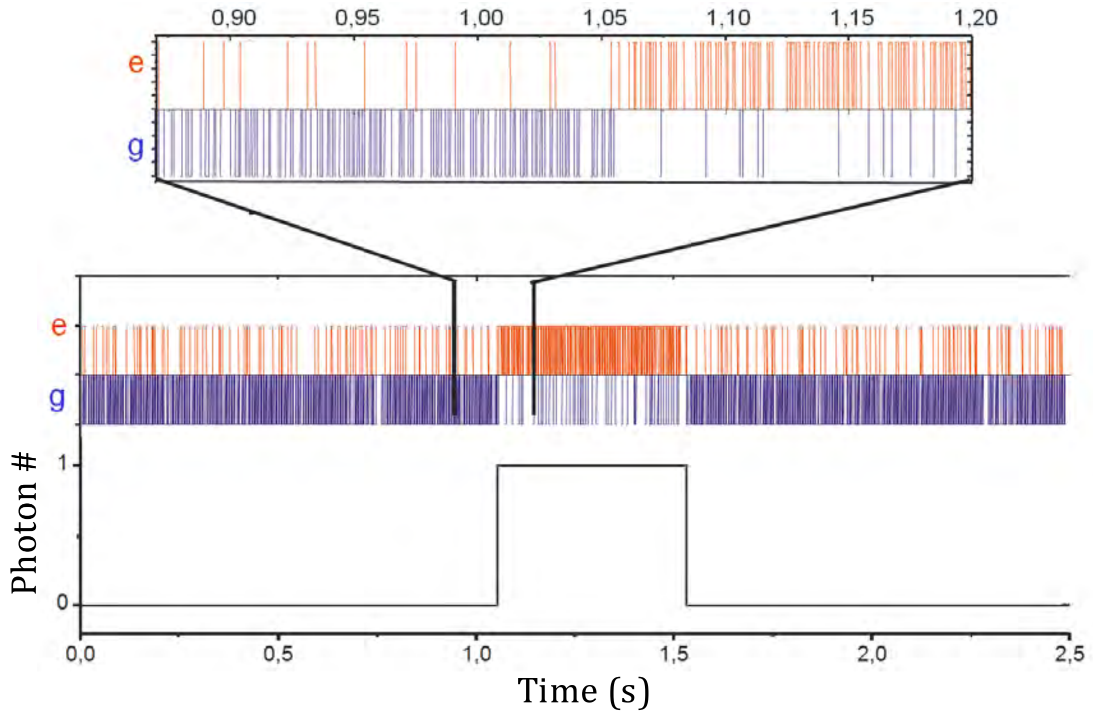

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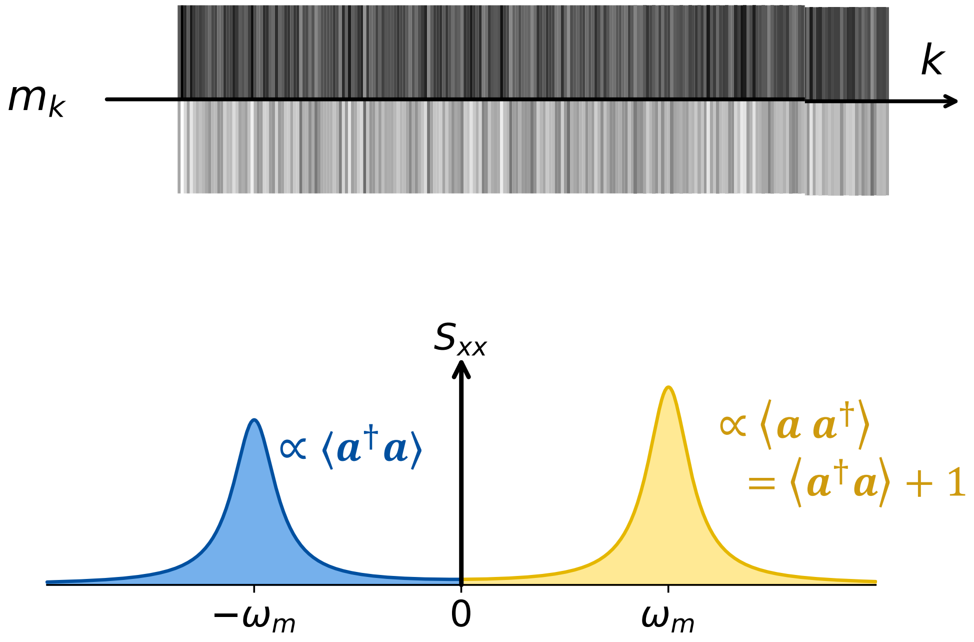

Quantum spectrum asymmetry

Gerashchenko *et al.*, arXiv 2505.21481 (2025).

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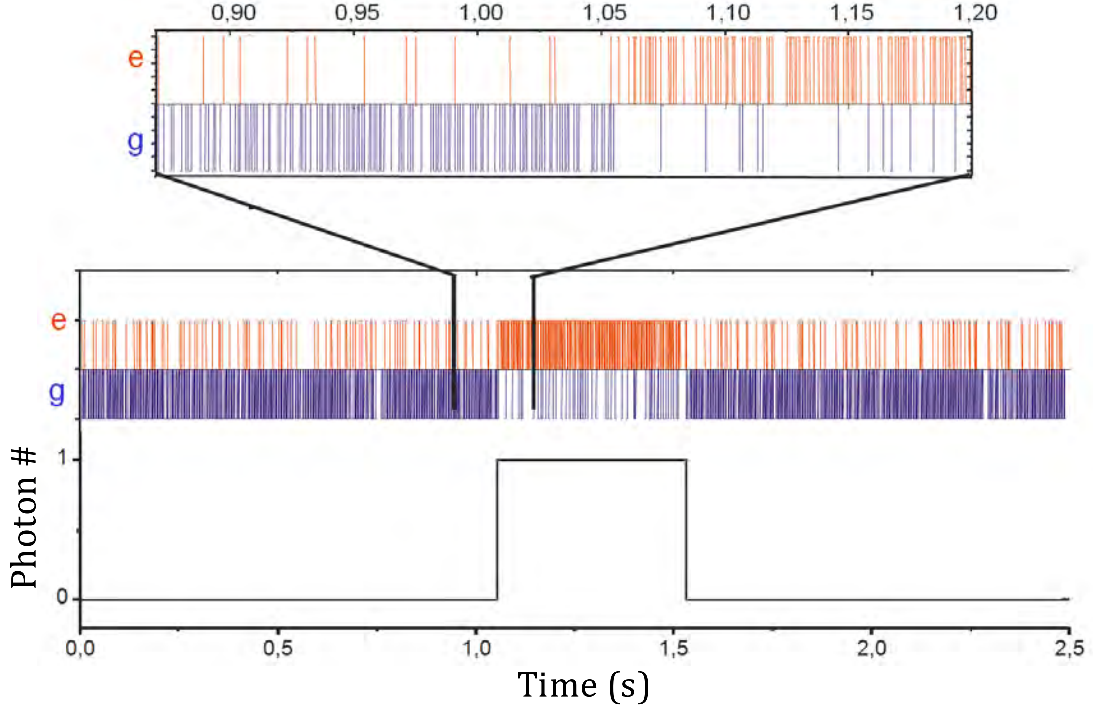

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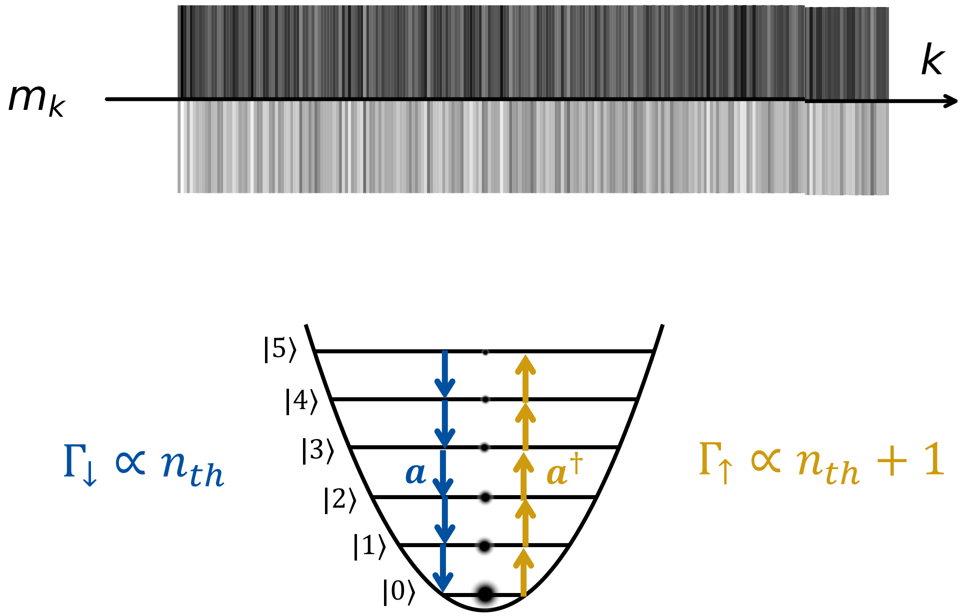

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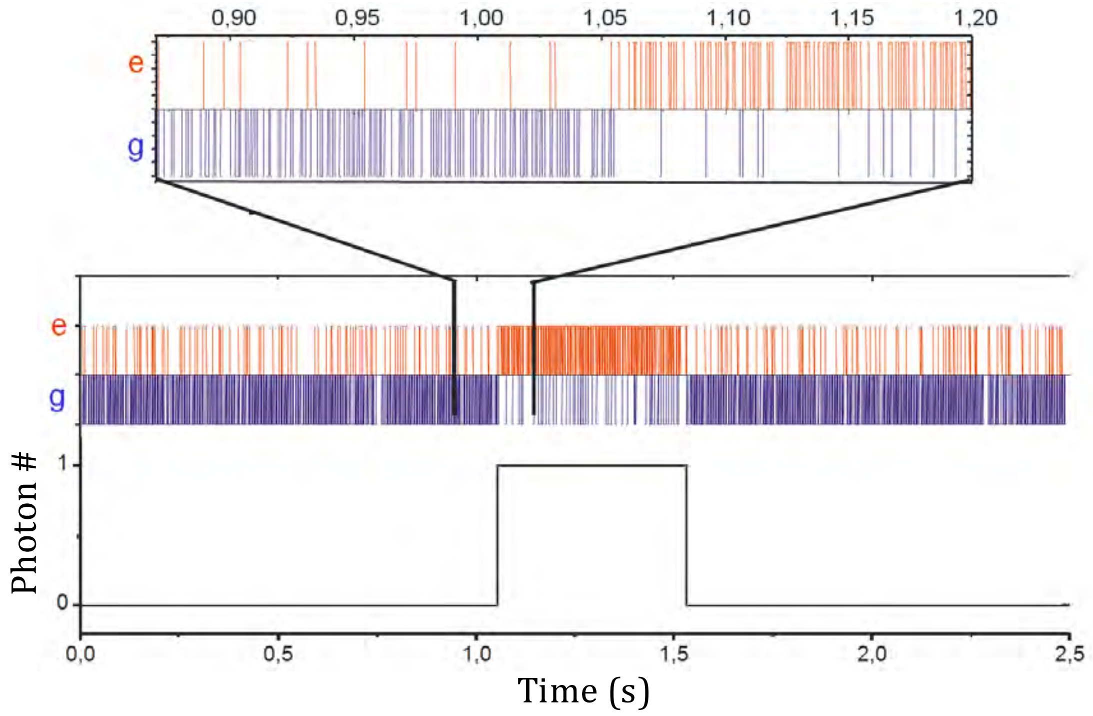

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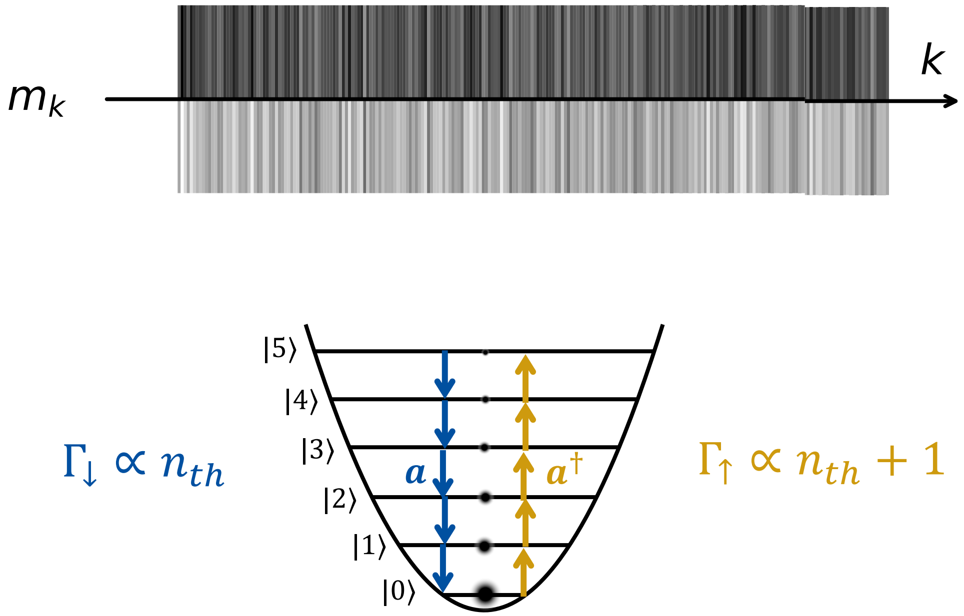

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Goal: experimental test of spontaneous collapse models

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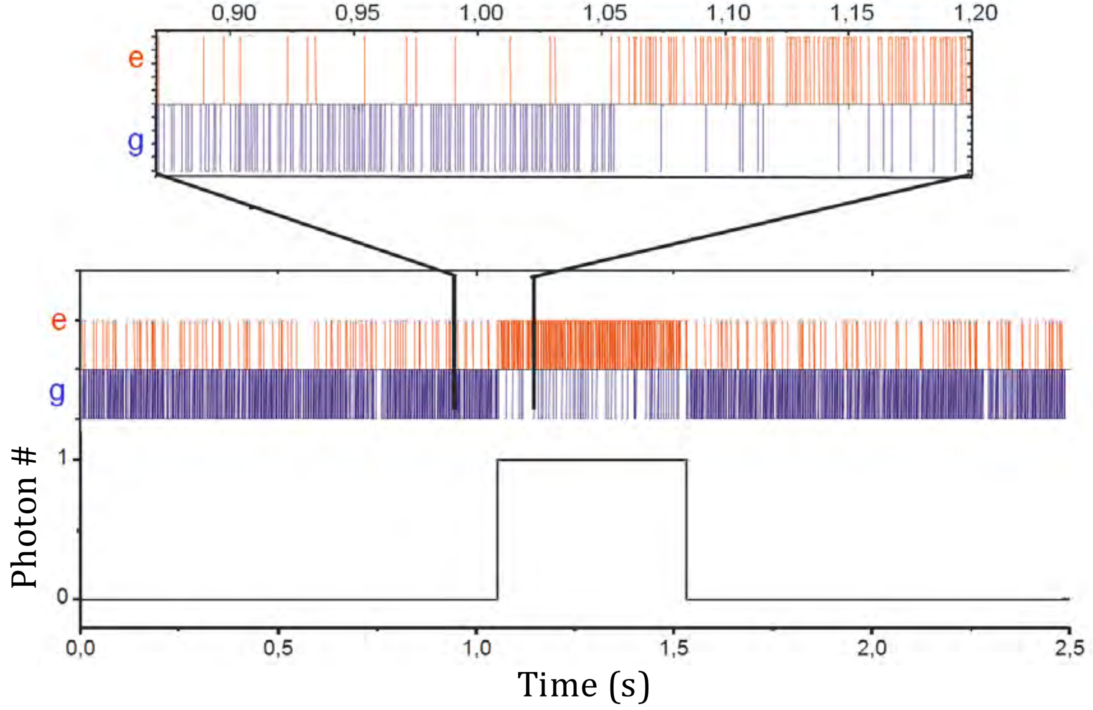

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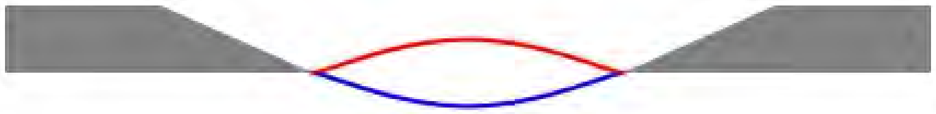
Gleyzes *et al*. *Nature*, *446*(7133), 297-300 (2007).

$$|\Psi\rangle = |\alpha\rangle + |-\alpha\rangle$$



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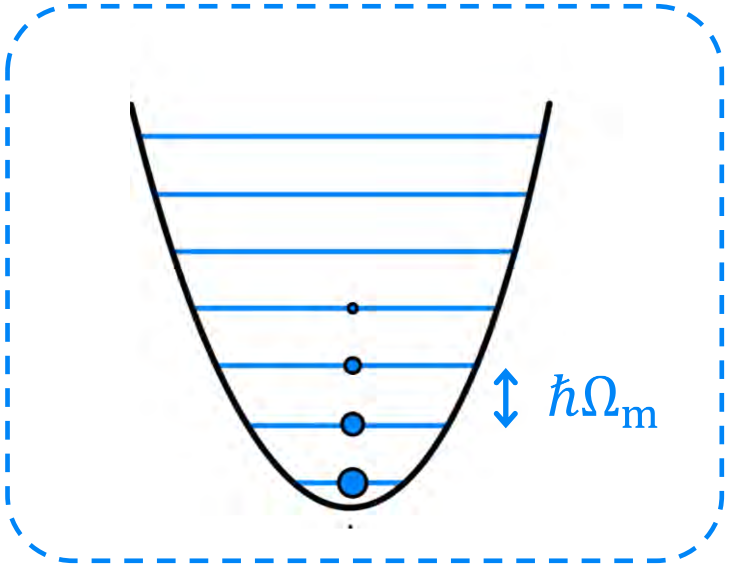
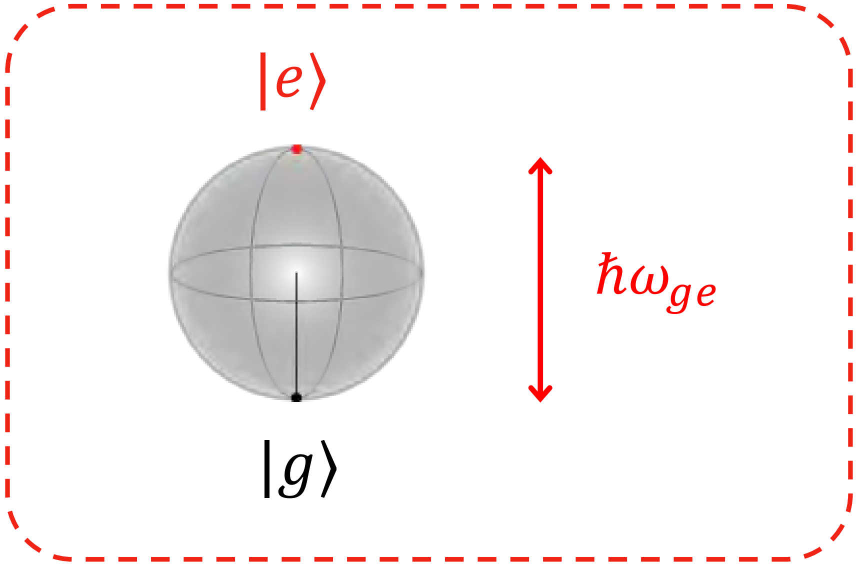
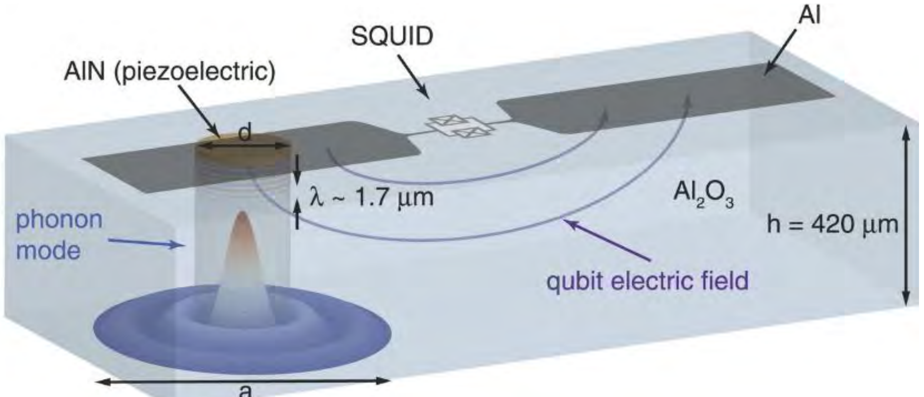
Circuit Quantum Acousto Dynamics



Bulk accoustic mode @ 6 GHz

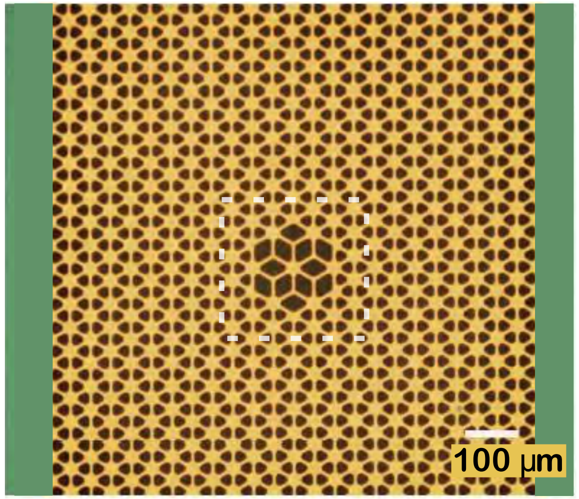


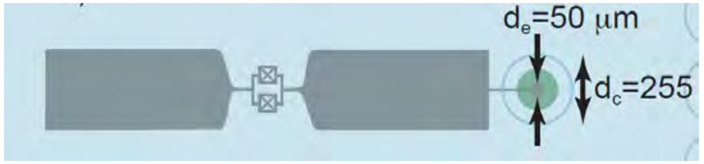
Superconducting qubit @ 6 GHz

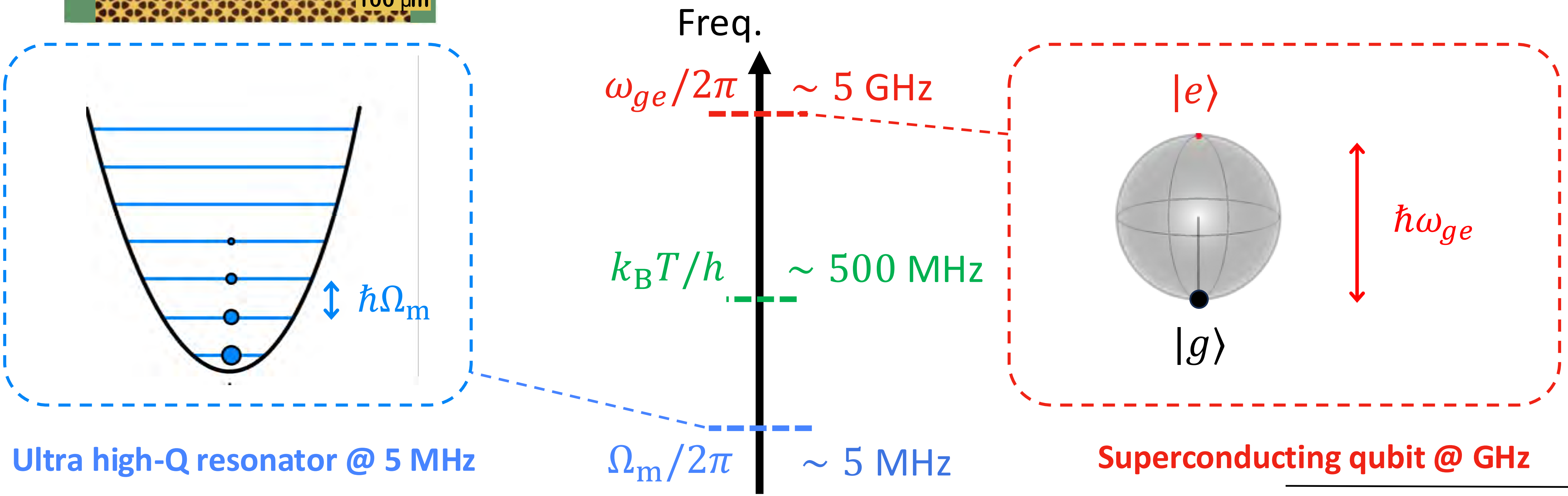


Schrödinger cat states of a 16-microgram mechanical oscillator
Bild et al, Vol 380, Issue 6642 pp. 274-278, Science 2023
Yiwen Chu group @ ETH

Coupling a MHz mechanics to a superconducting qubit

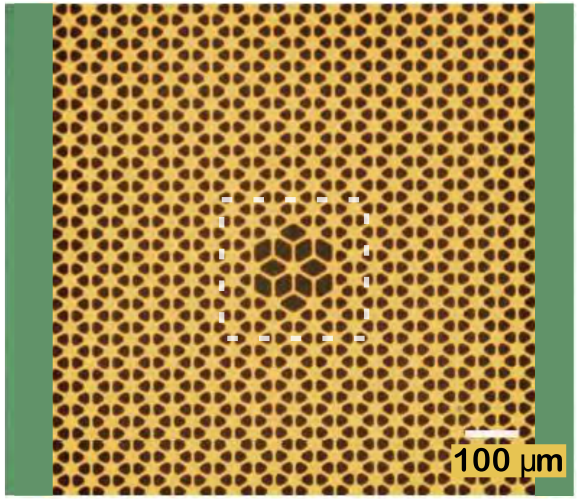


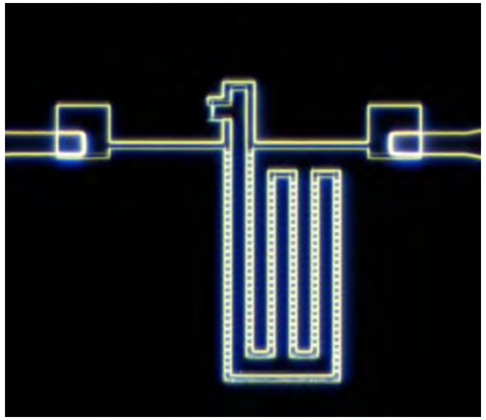


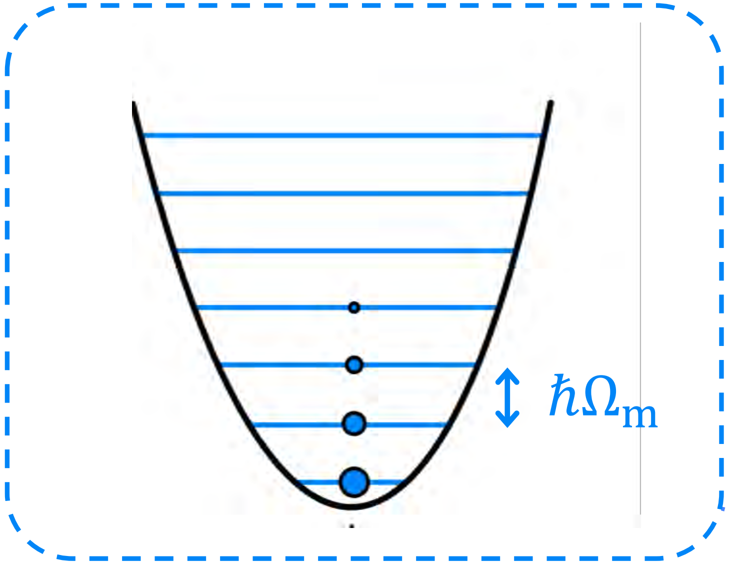


Viennot *et al*, PRL **121** (2018)

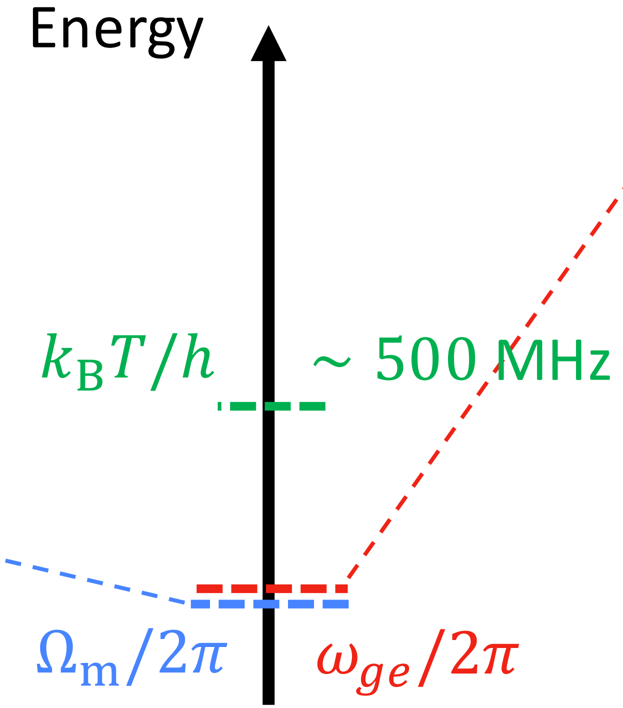
Our approach

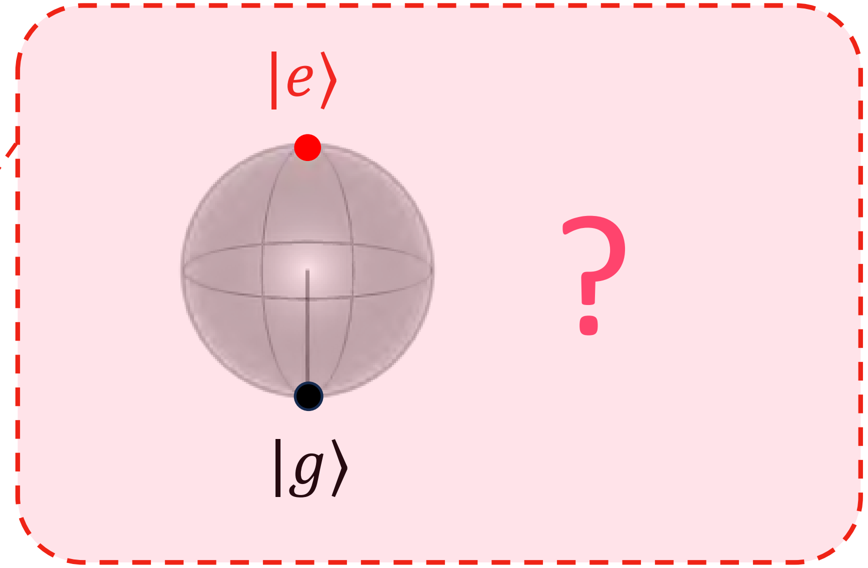






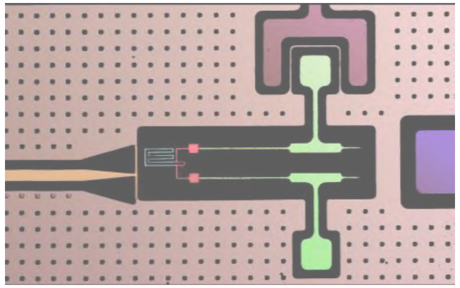
Ultra high-Q resonator @ 5 MHz



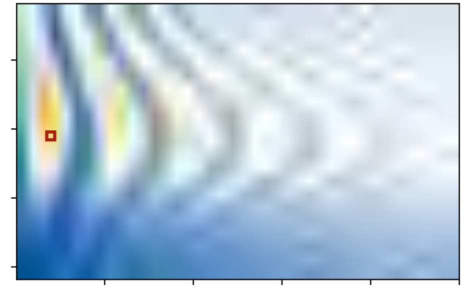


Superconducting qubit @ 5 MHz

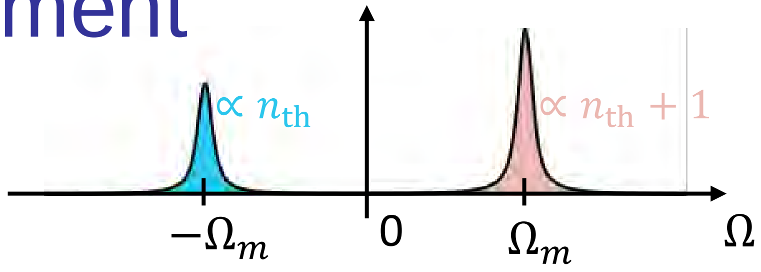
- Radio-frequency fluxonium qubits



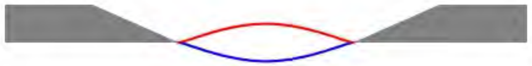
- Hybrid qubit/mechanical system: MecaFlux



- Quantum asymmetry measurement

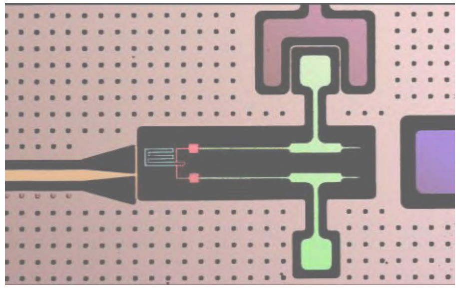


- Perspectives



Outline

- Radio-frequency fluxonium qubits



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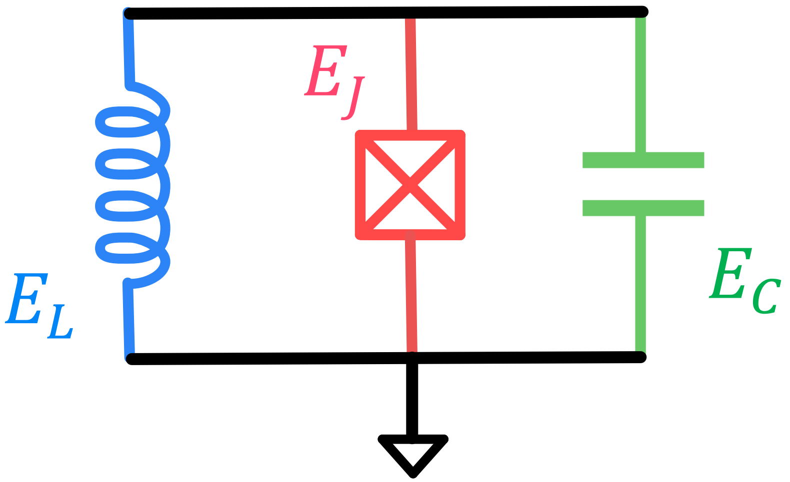
The (heavy) fluxonium



Universal Fast-Flux Control of a Coherent, Low-Frequency Qubit, Zhang, … Schuster Phys. Rev. X 11, 011010 (2021)

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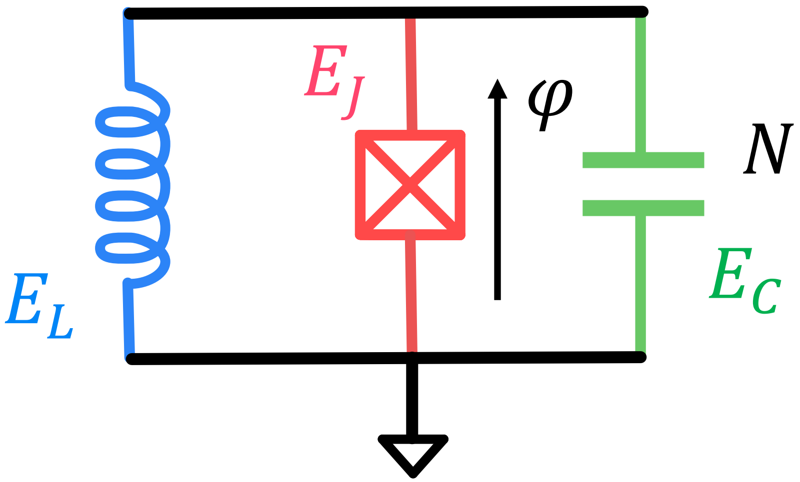

Superconducting phase difference across the junction:

$$\varphi = \frac{\phi}{\Phi_0}$$

(position-like)

Displacement charge between junction electrodes:

$$N = \frac{Q}{2e}$$

(momentum-like)

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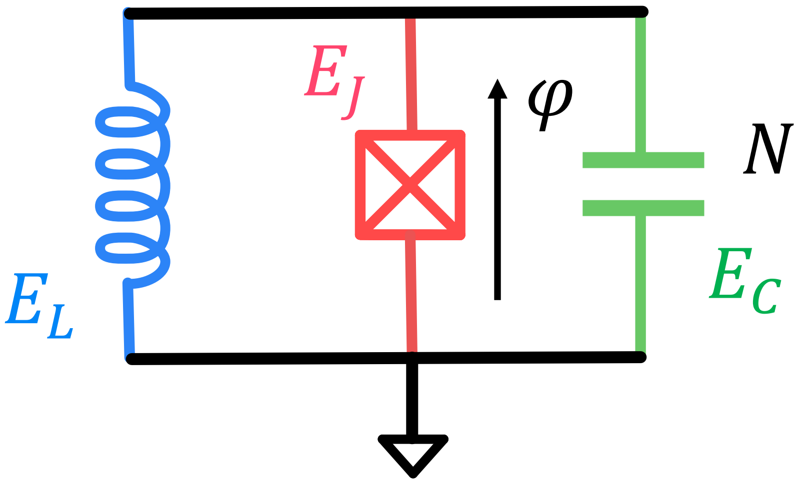
The (heavy) fluxonium

$$\hat{H} = \frac{1}{2}E_L\hat{\varphi}^2 - E_J\cos(\hat{\varphi} - \varphi_{\text{ext}}) + 4E_C\hat{N}^2$$

Potential energy



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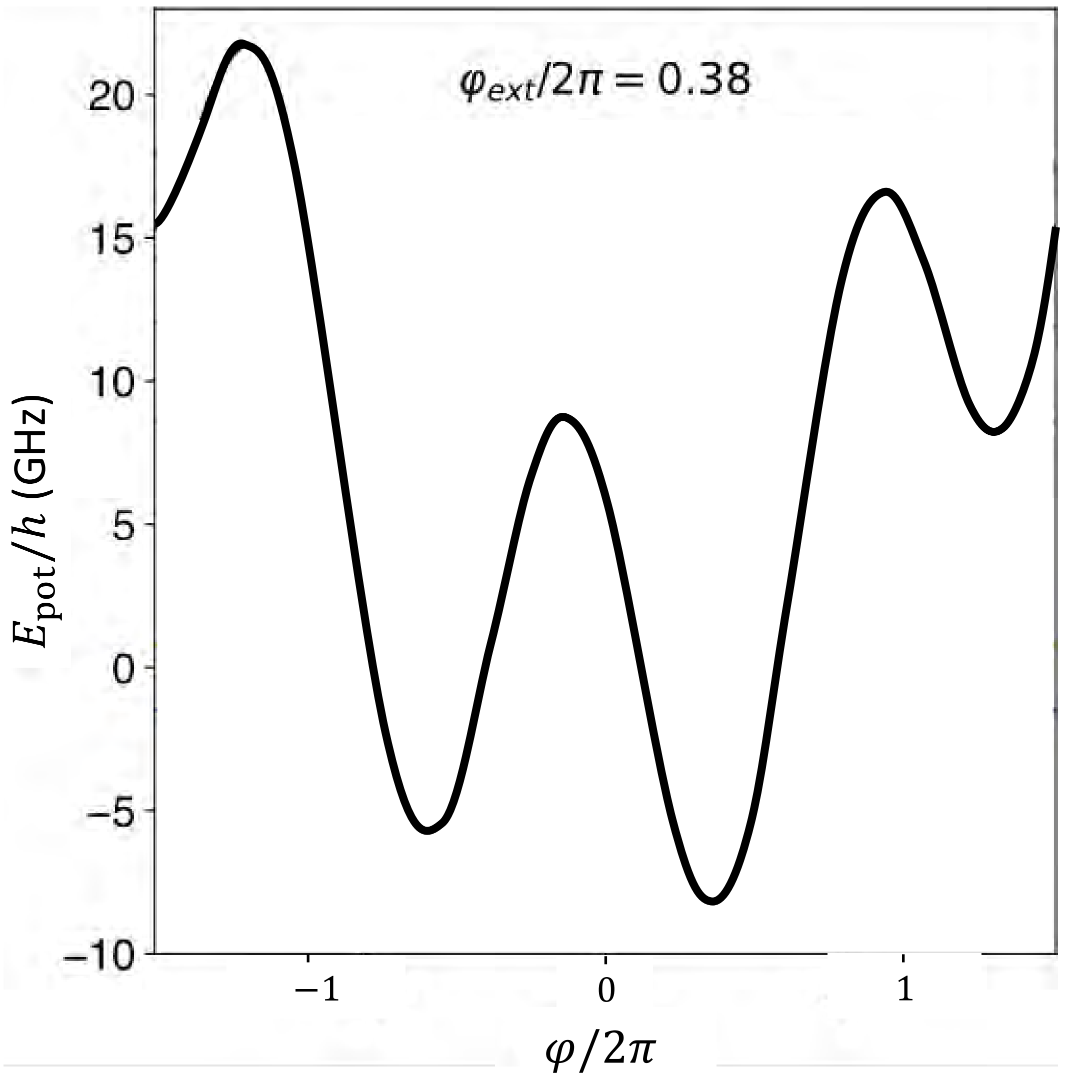

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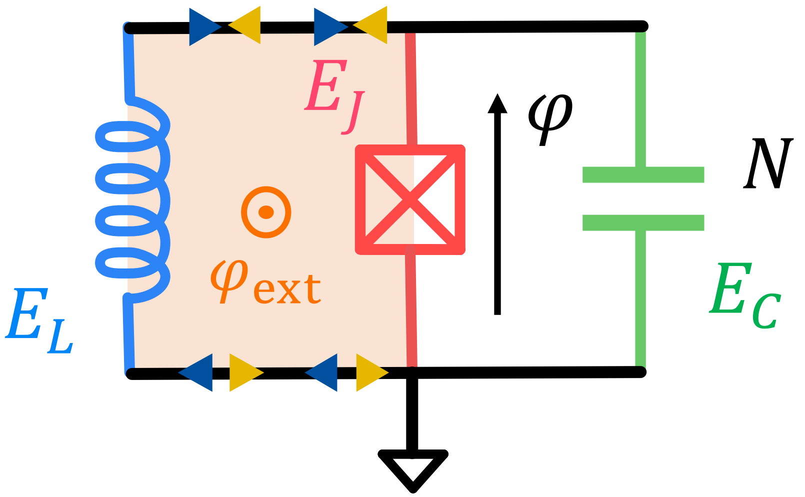

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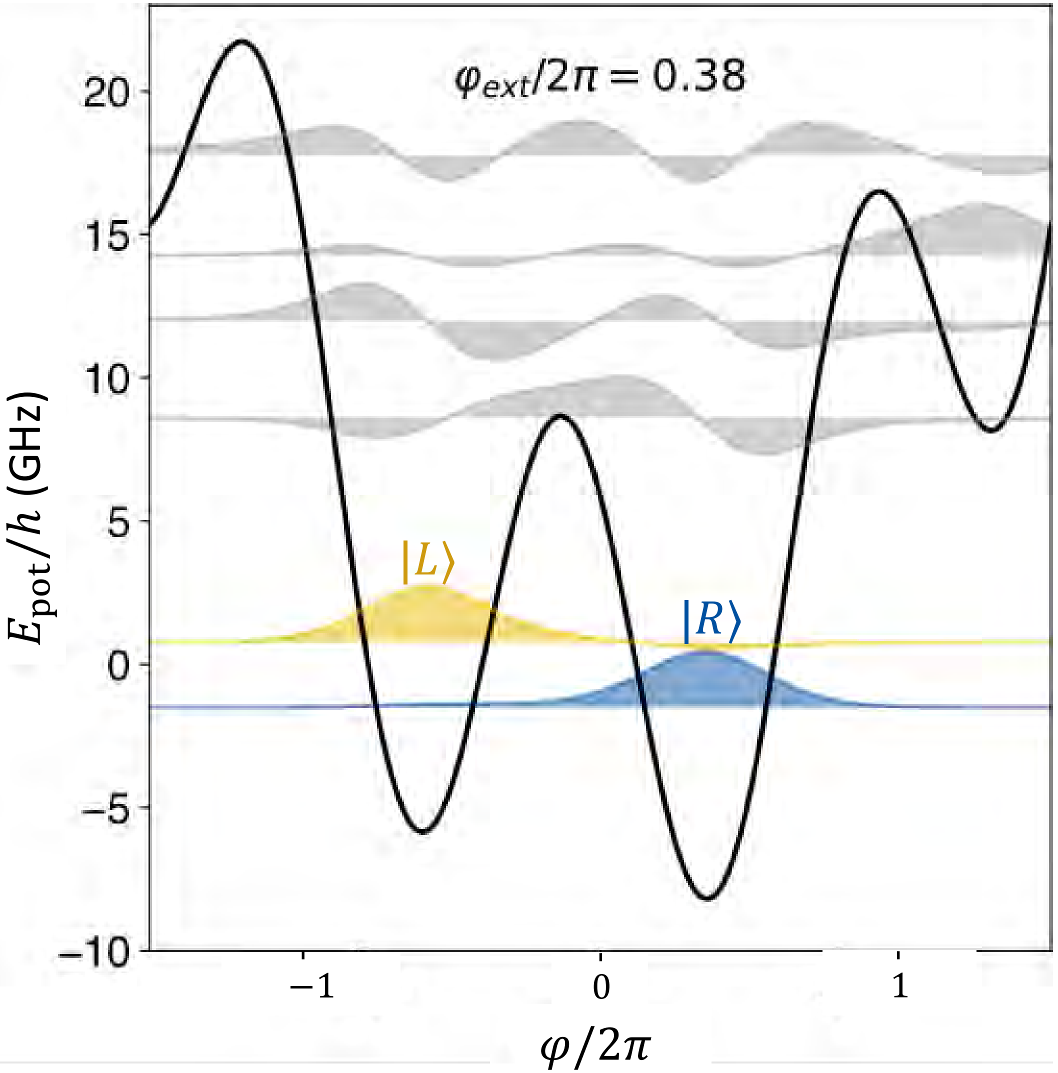

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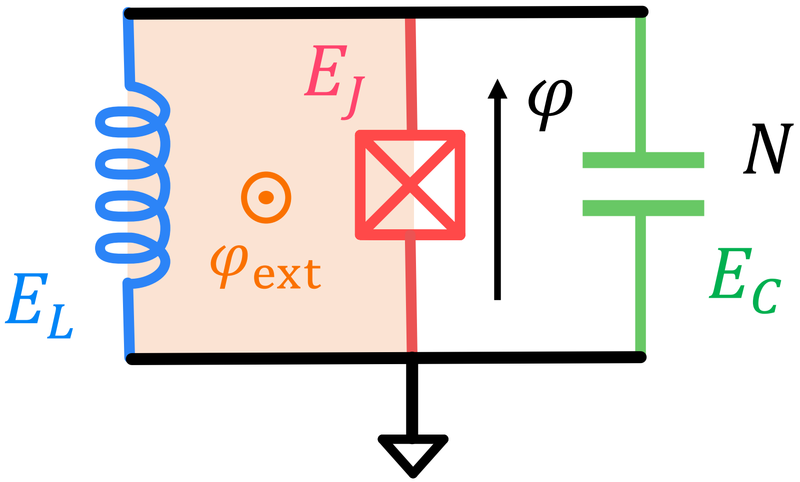
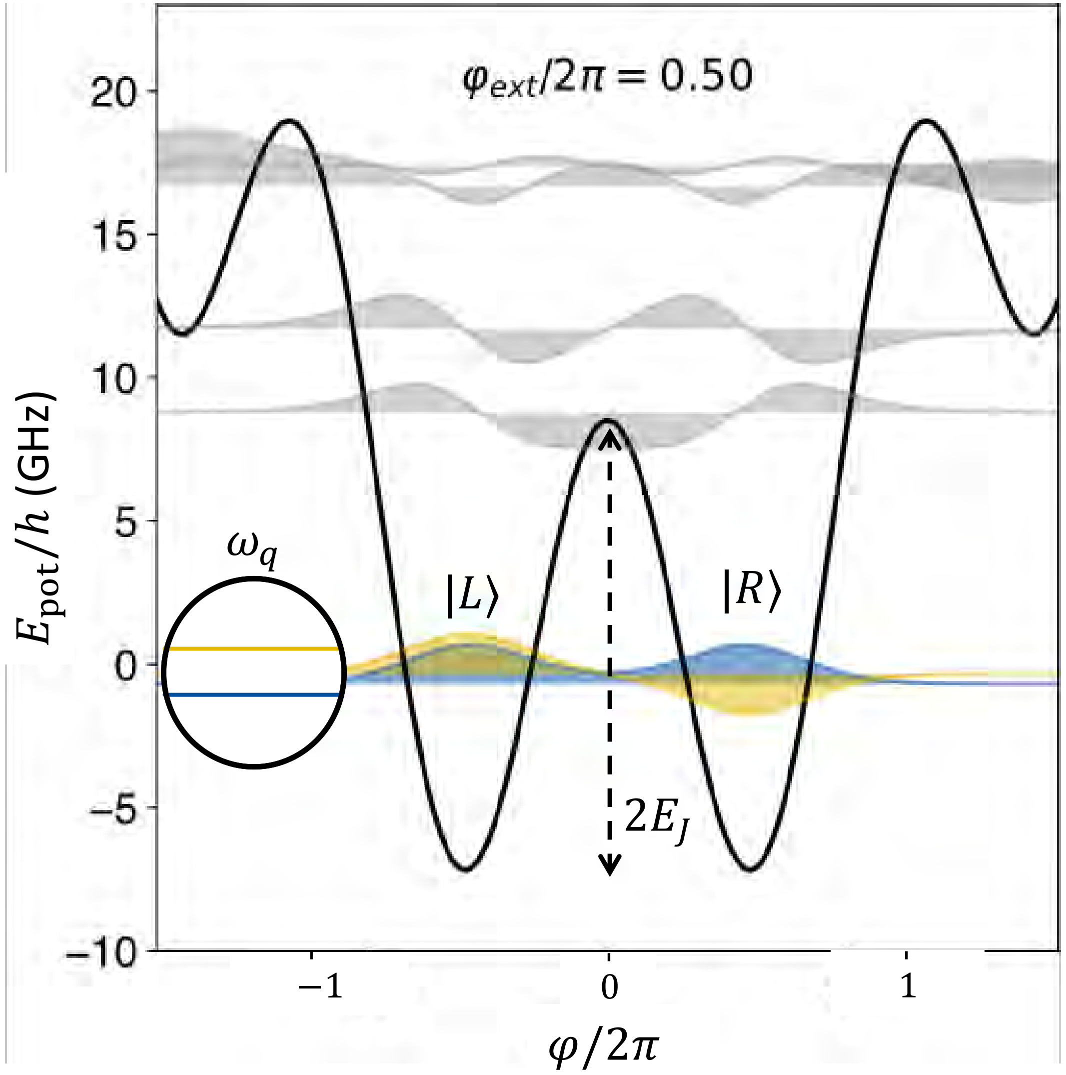


Flux frustration point ($\varphi_{\text{ext}}/2\pi = 0.5$) :

The localized states hybridize:

$|e\rangle \rightarrow |L\rangle - |R\rangle$

$|g\rangle \rightarrow |L\rangle + |R\rangle$



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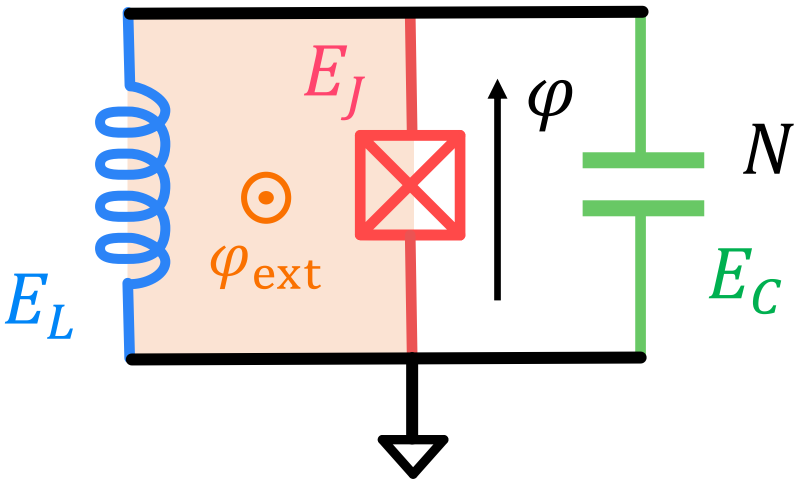
Potential energy　　Kinetic energy



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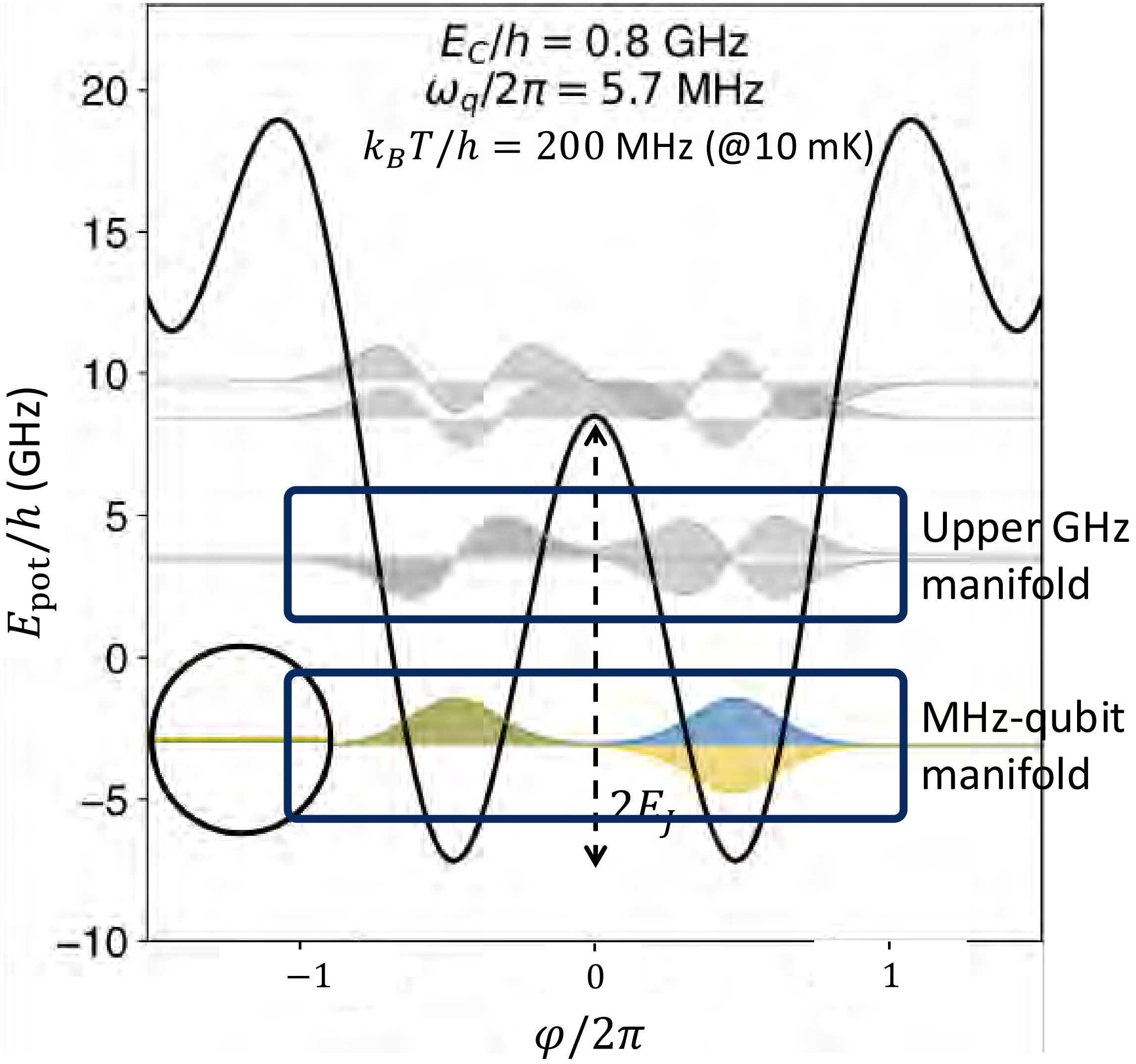
The tunnel splitting decreases exponentially with: E_J/E_C



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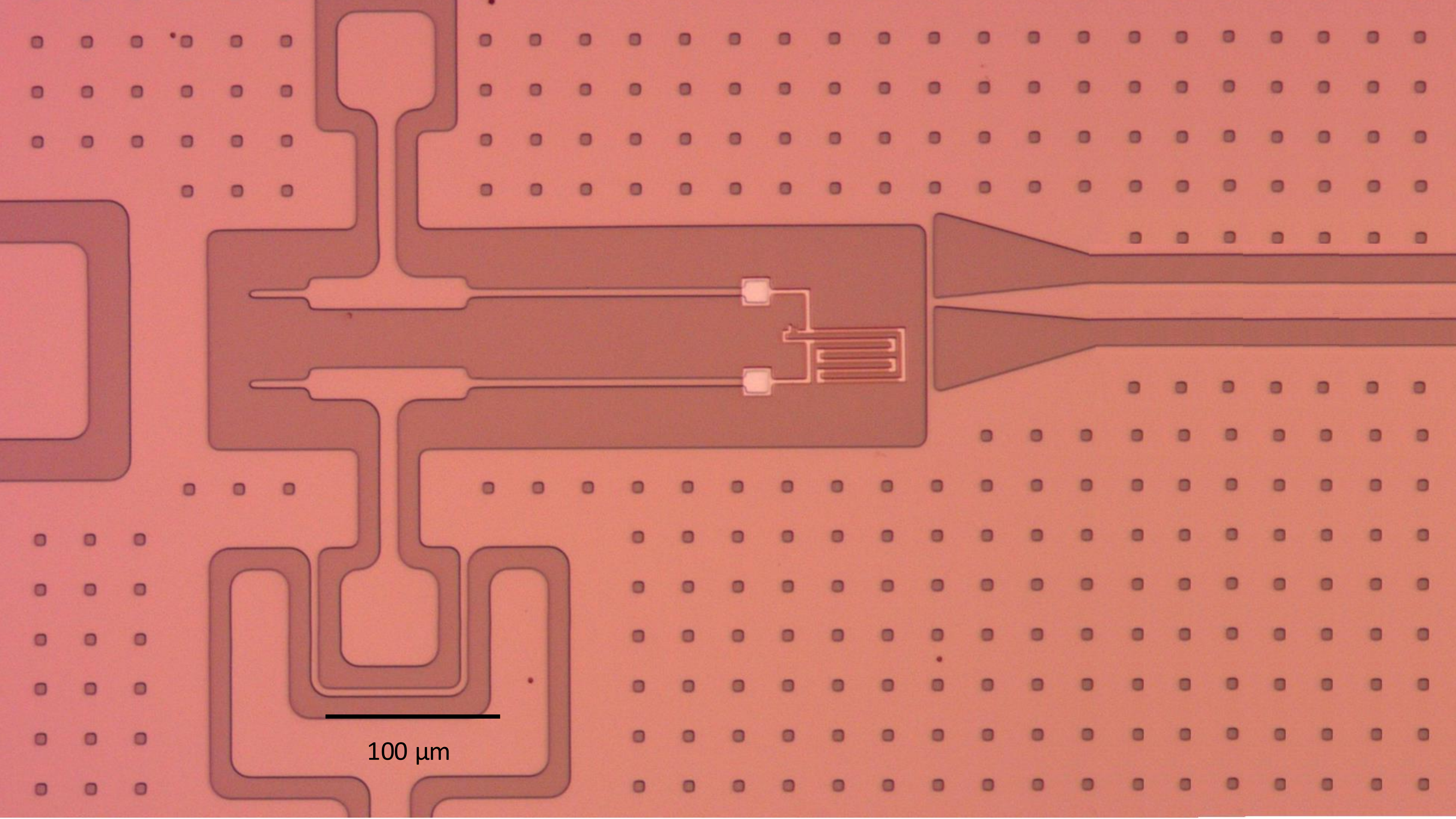
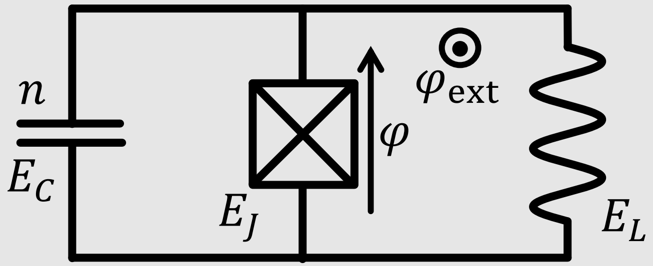
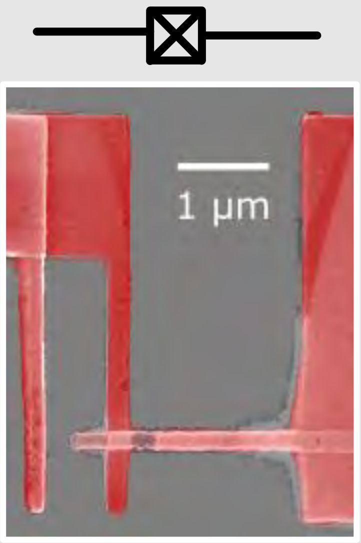

100 µm

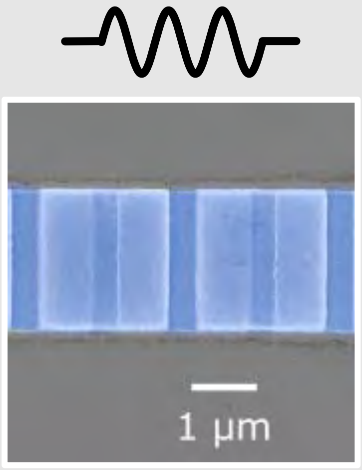
Fluxonium design



Single small junction



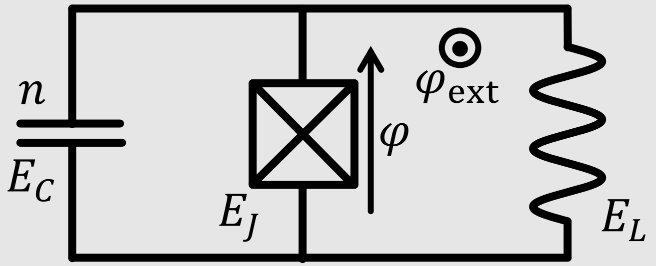
360 large junctions

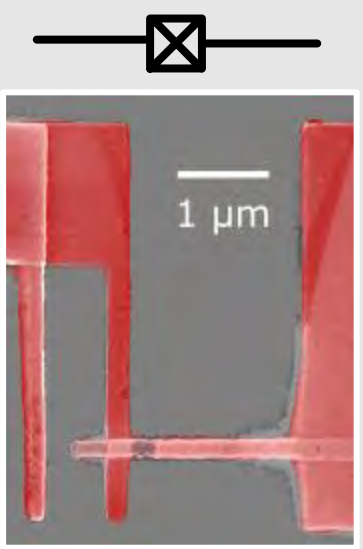


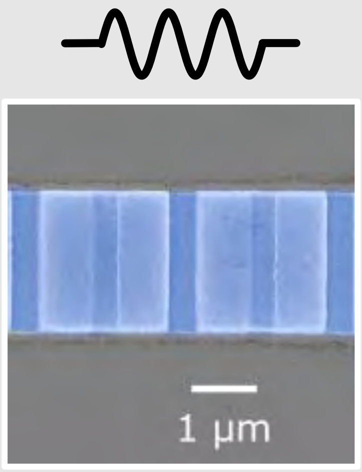
Al
Si
Nb

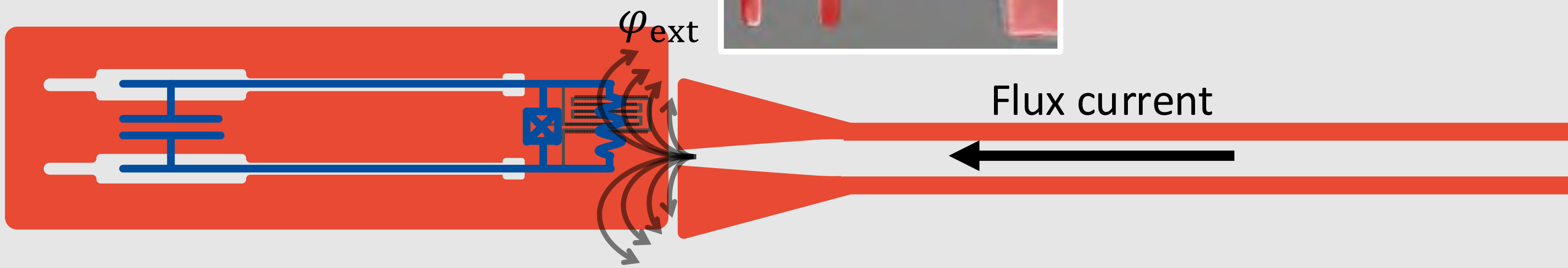
100 µm

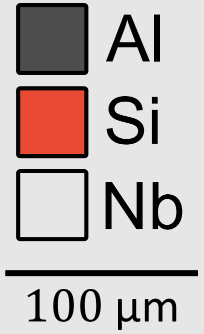
Fluxonium design



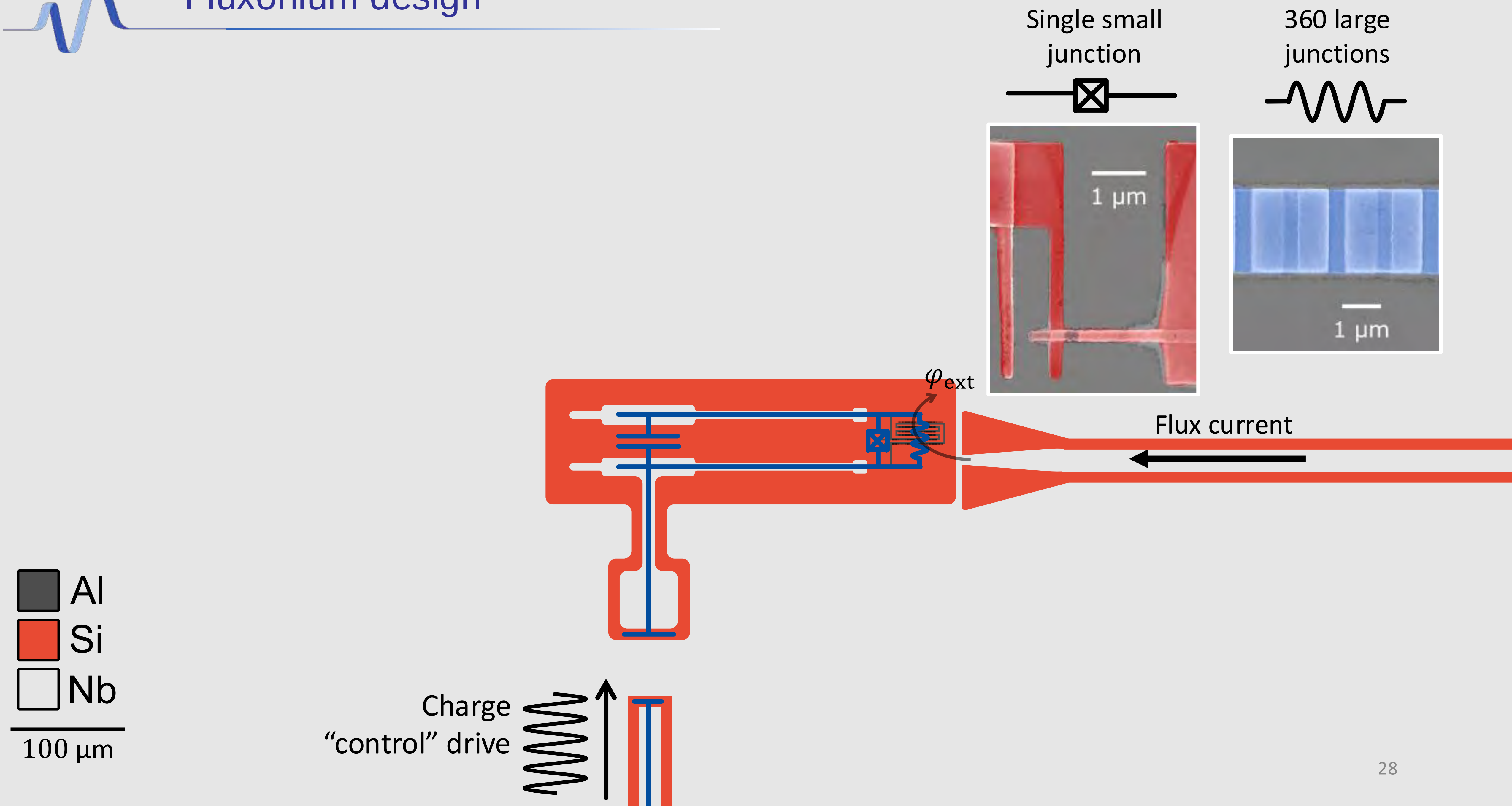




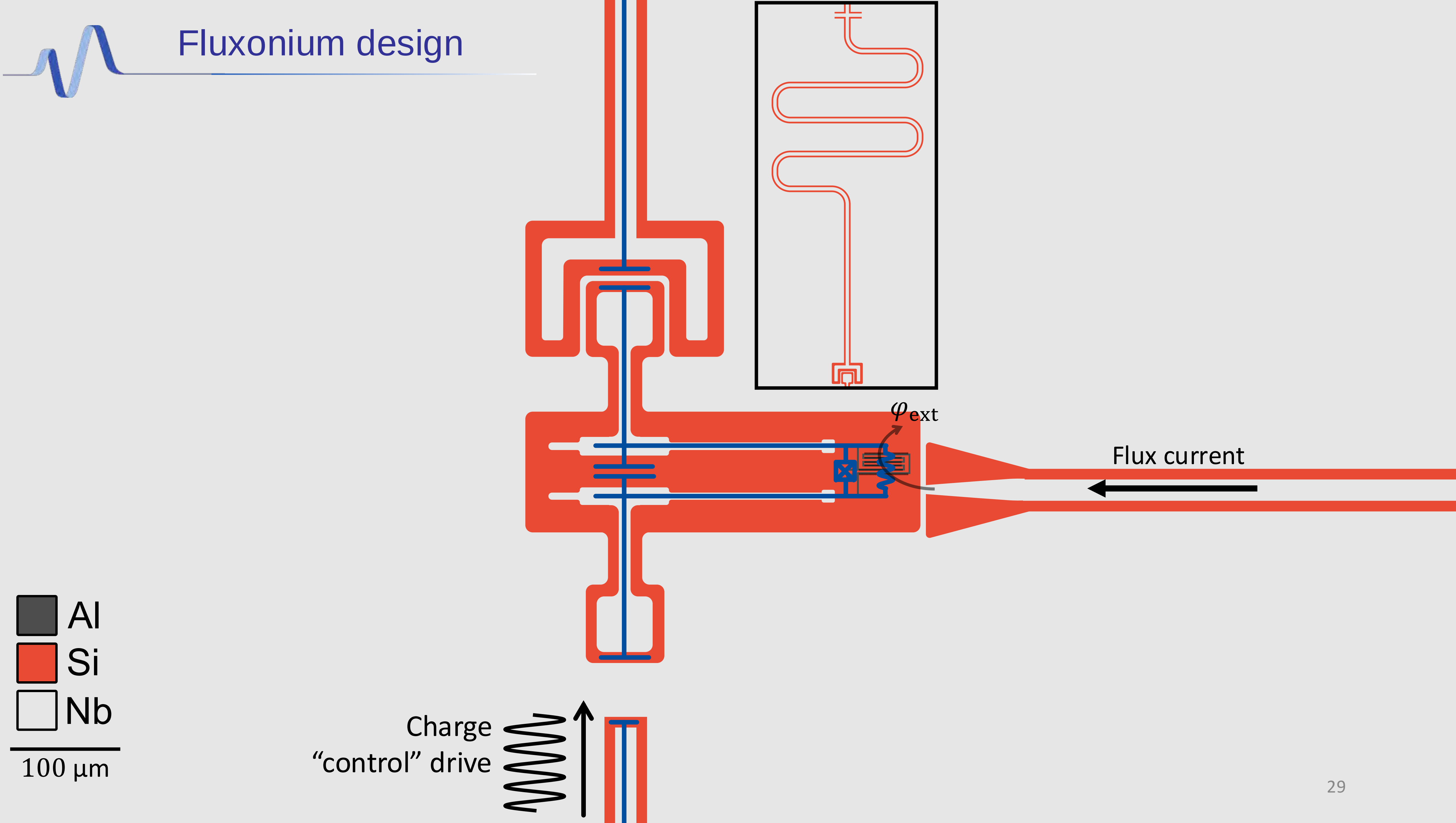




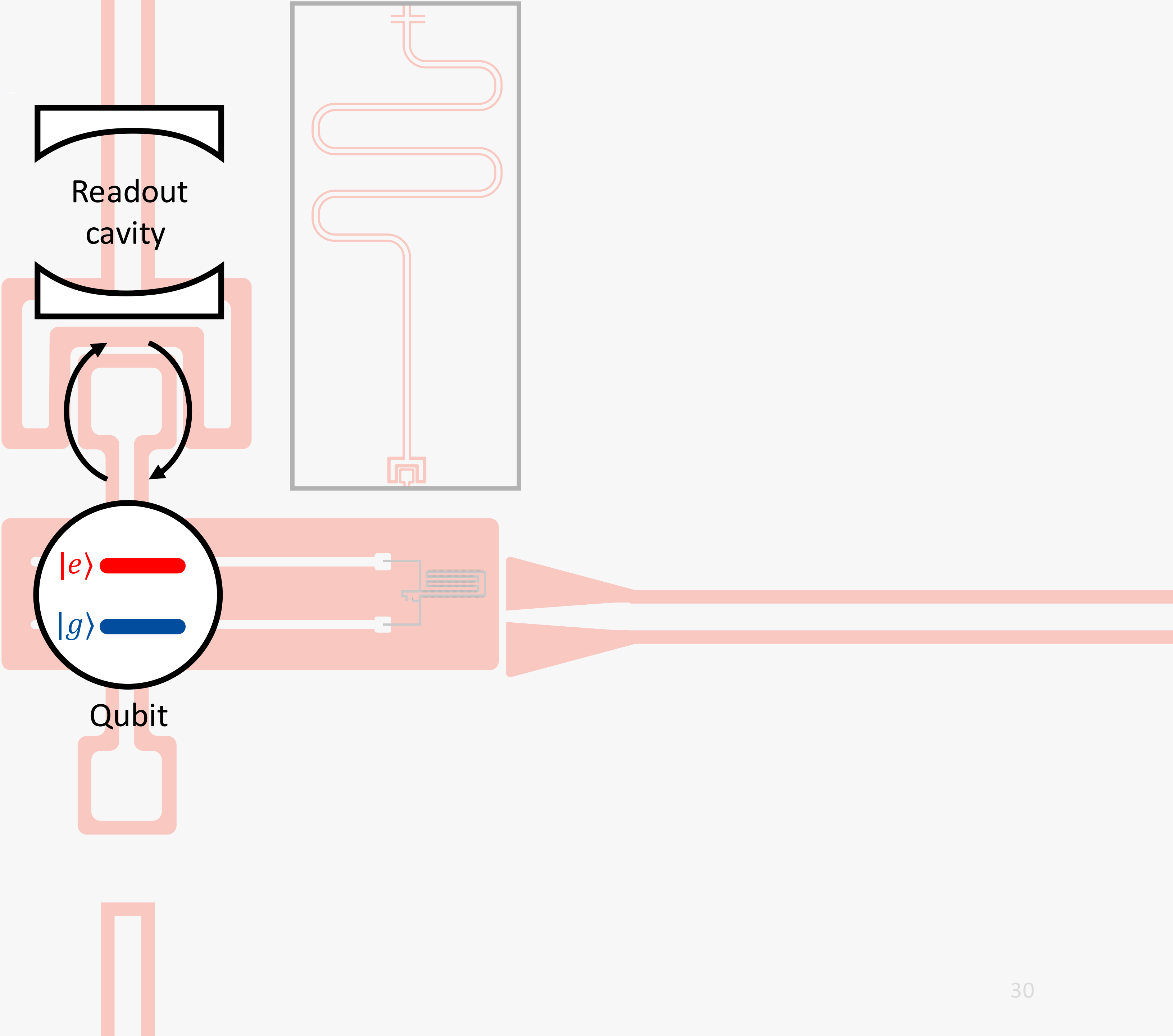
Fluxonium design



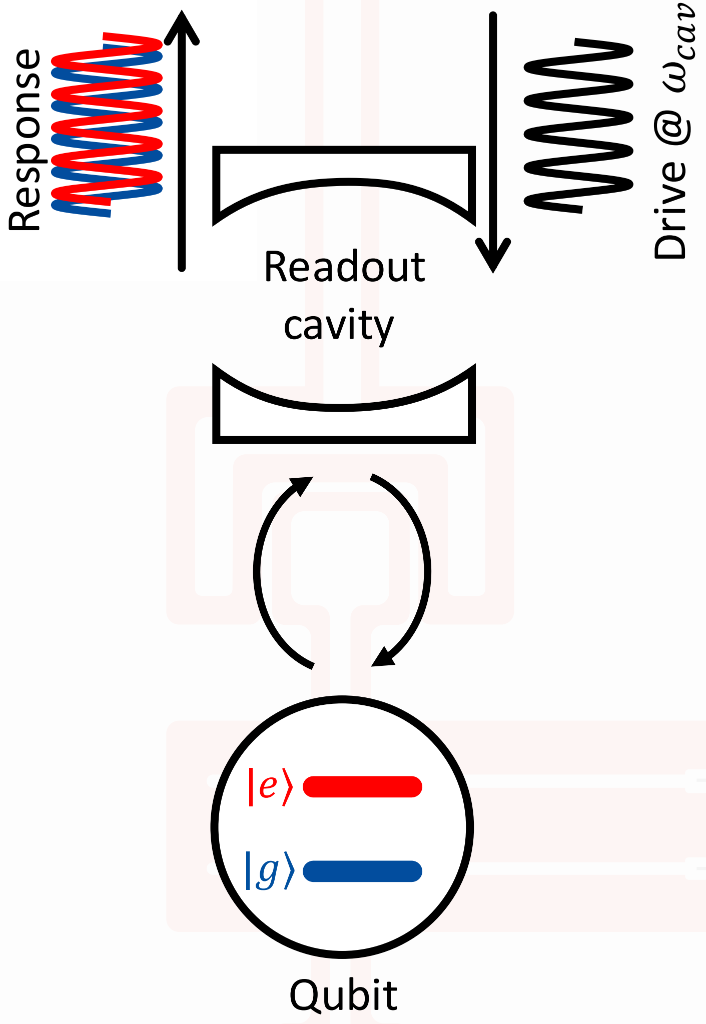
Fluxonium design



Fluxonium readout

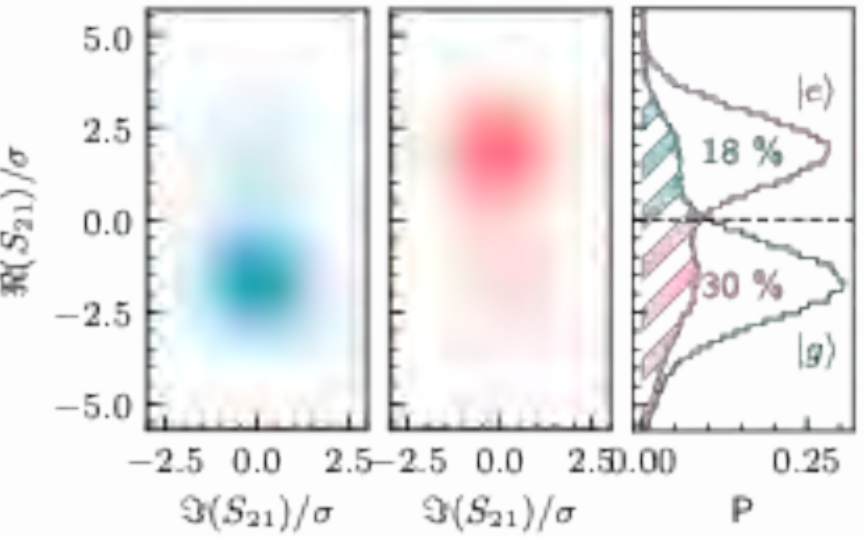


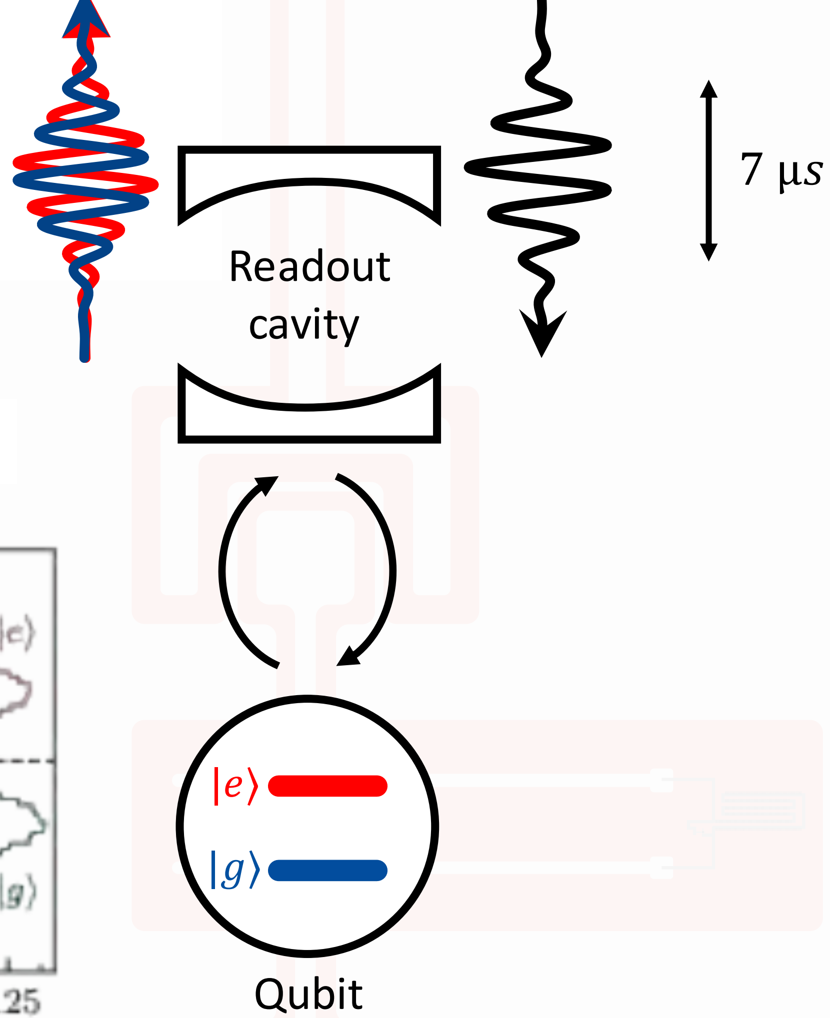
Readout response depends on the qubit state



Readout response depends on the qubit state

Complex reflection coefficient



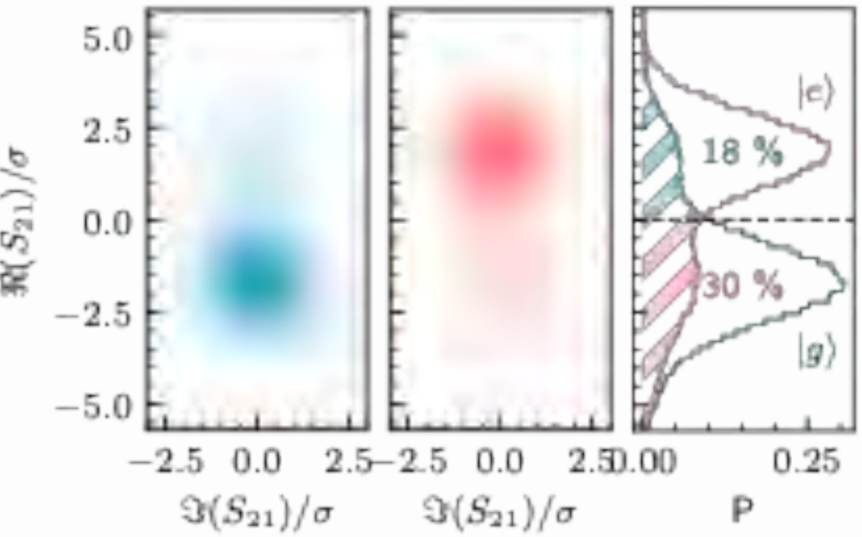


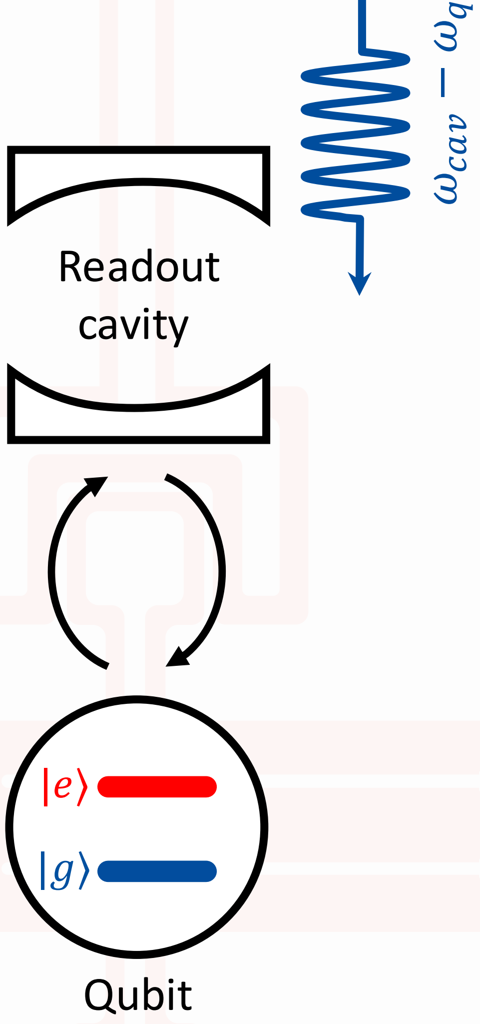
Single-shot readout with 77 % fidelity

Sideband preparation

Readout response depends on the qubit state

Complex reflection coefficient

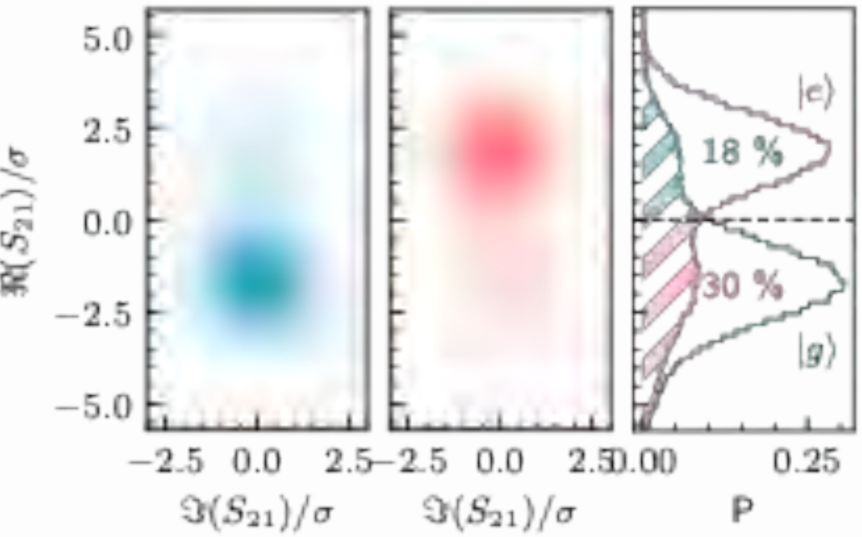


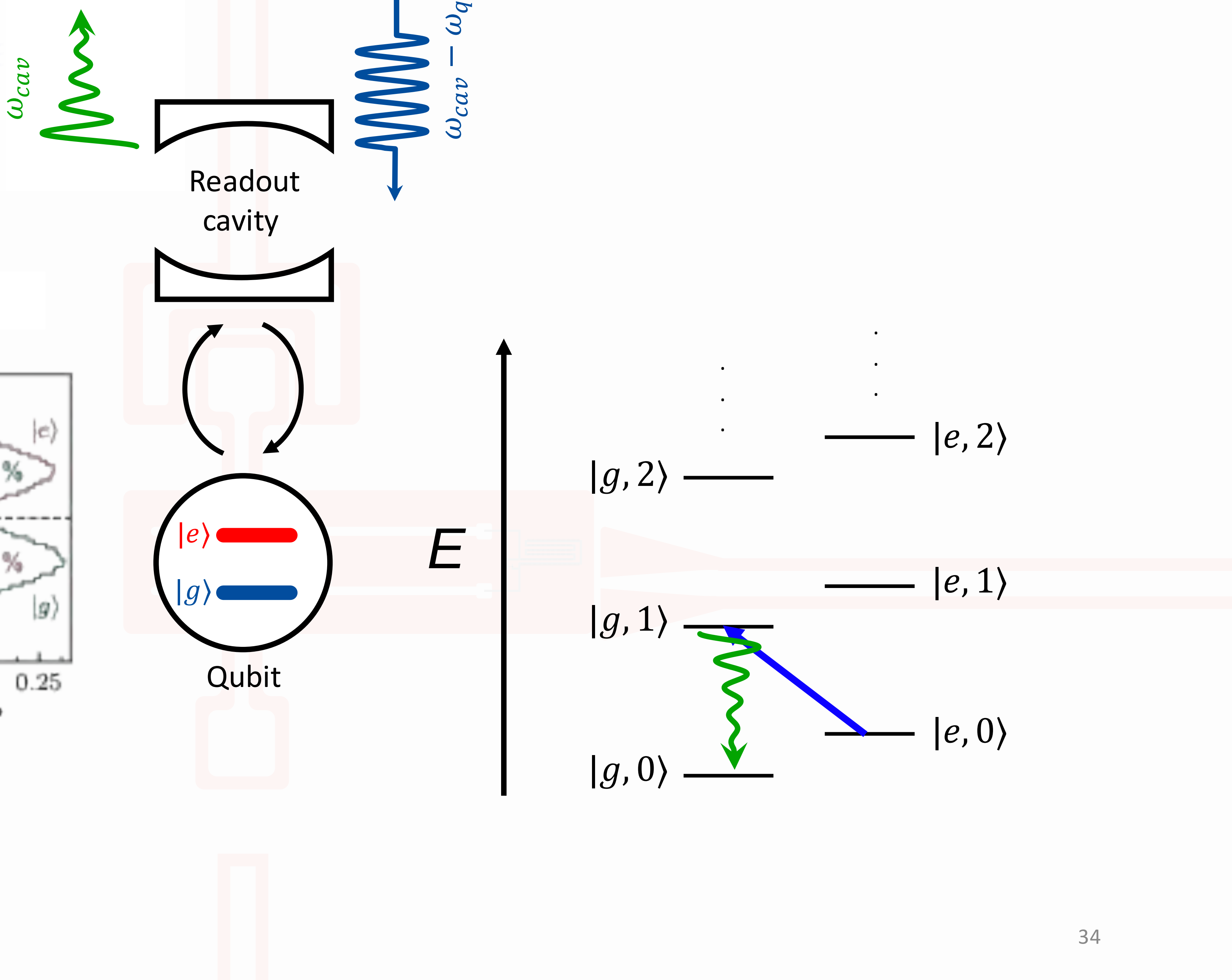


Single-shot readout with 77 % fidelity

Readout response depends on the qubit state

Complex reflection coefficient



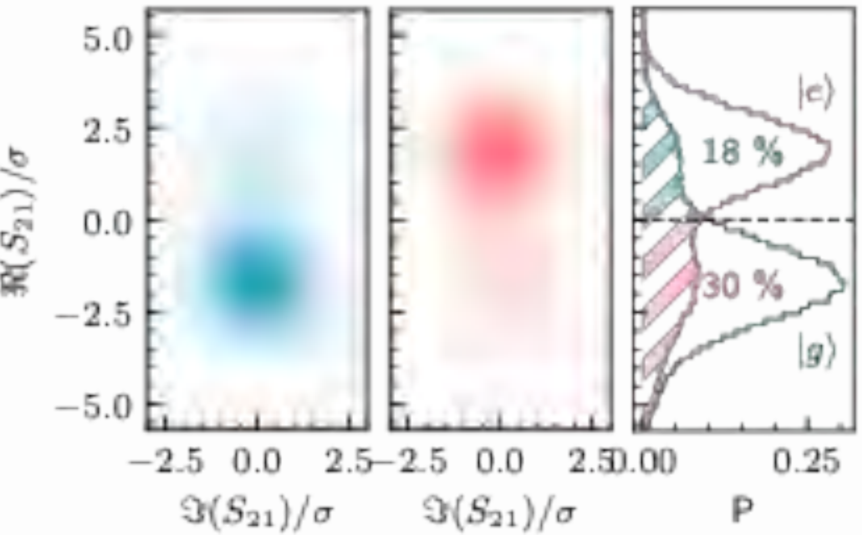


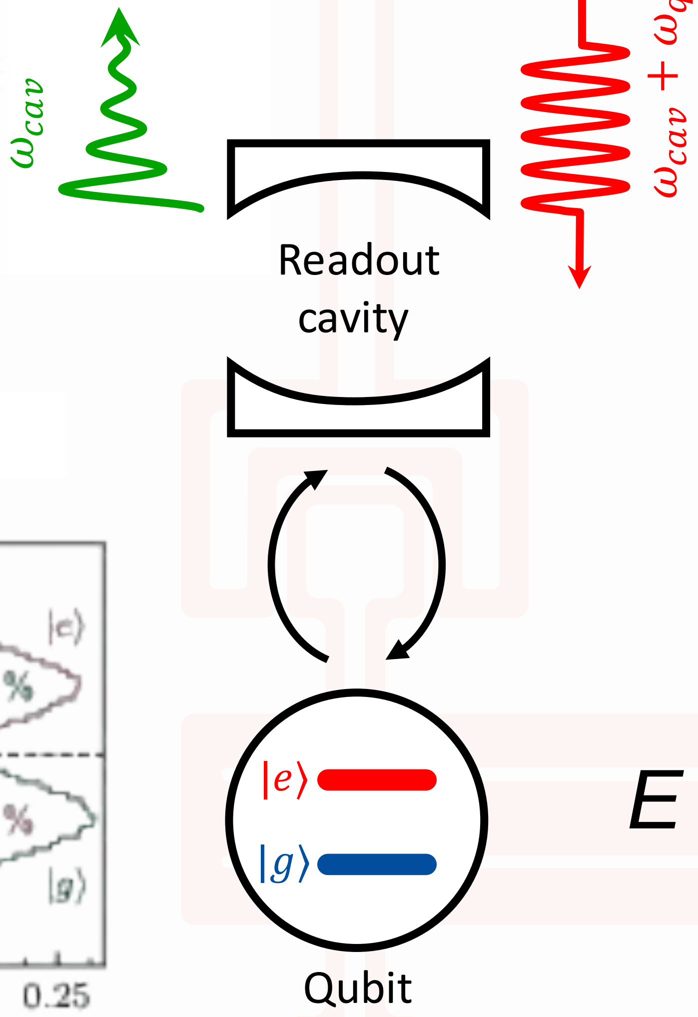
Single-shot readout with 77 % fidelity

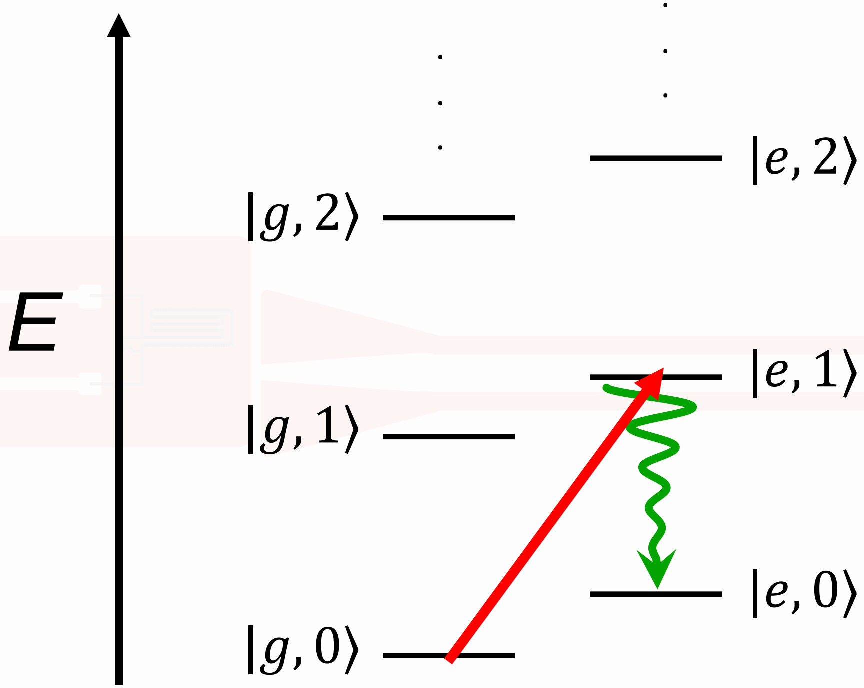
Sideband prepa…

Readout response depends on the qubit state

Complex reflection coefficient





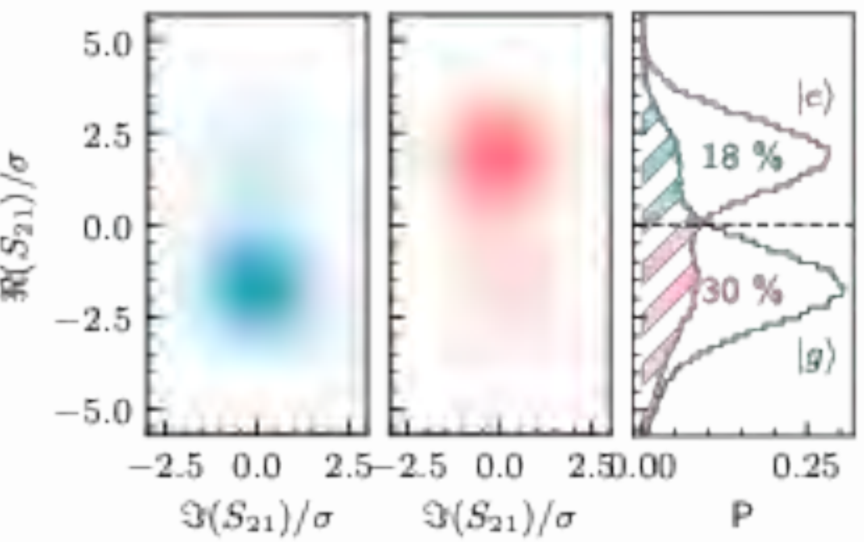


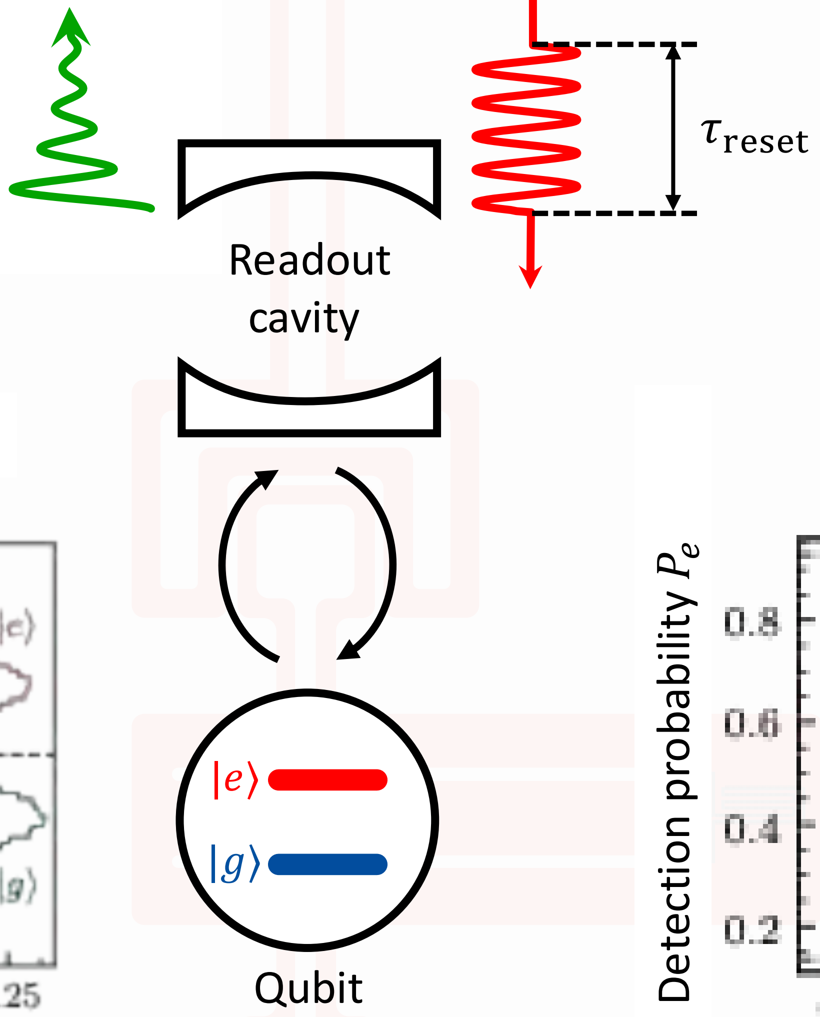
Single-shot readout with 77 % fidelity

Sideband prepa

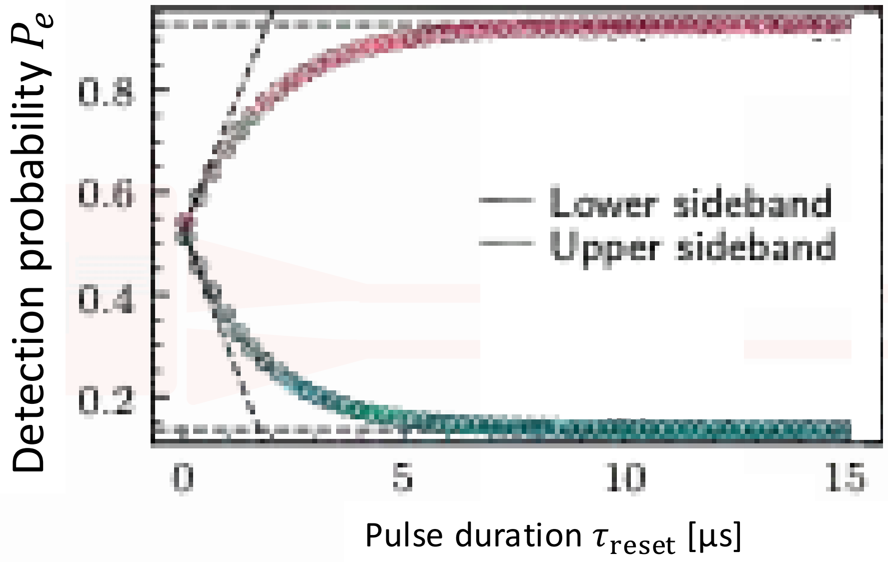
Readout response depends on the qubit state

Complex reflection coefficient





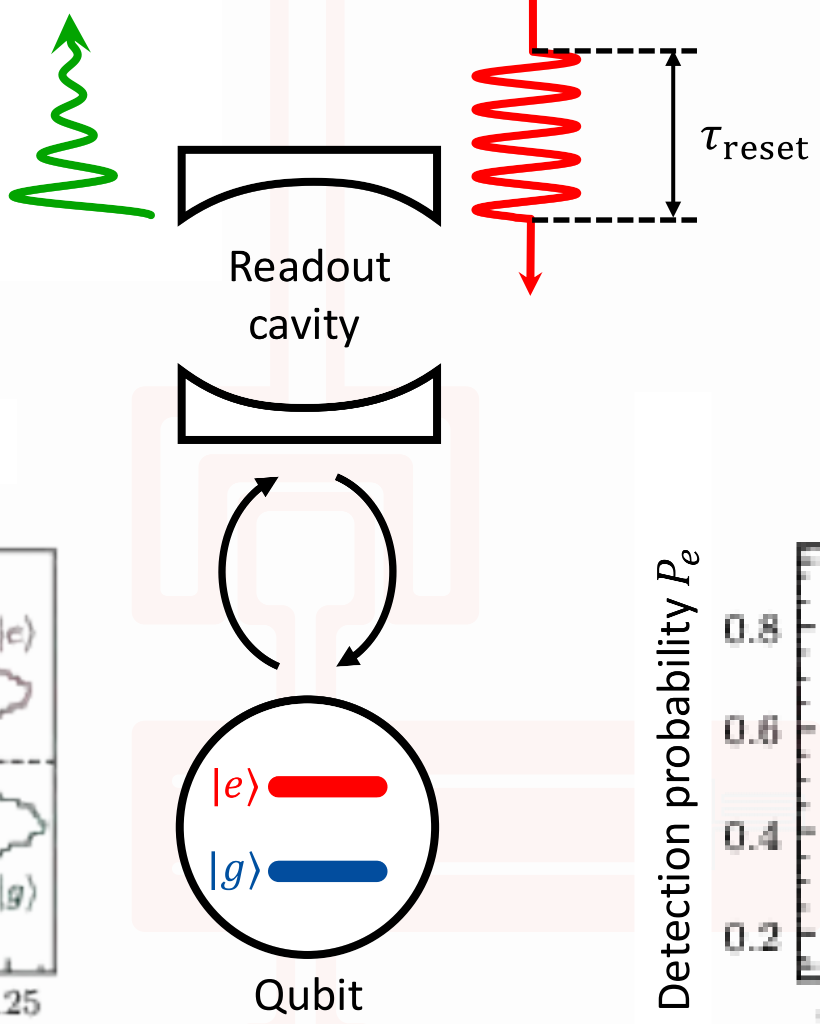
Preparation fidelity



Single-shot readout with 77 % fidelity

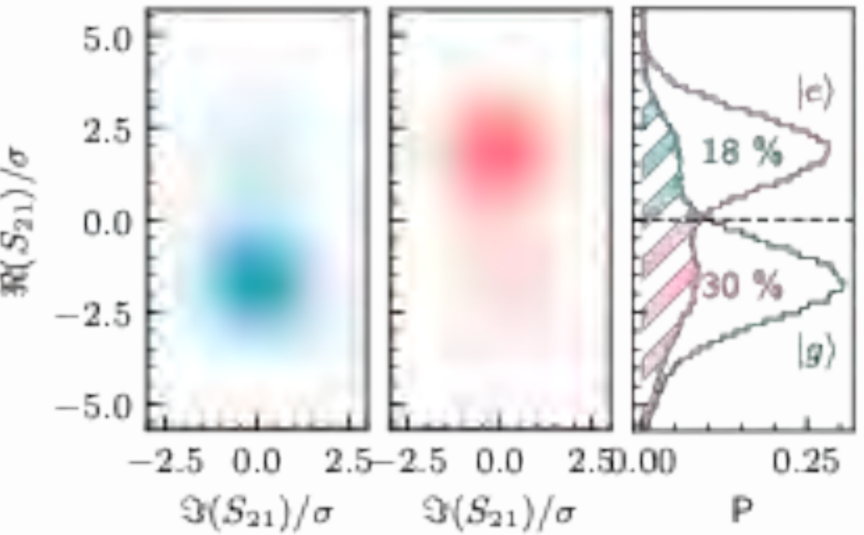
B.-L. Najera-Santos *et al.*… , **High-Sensitivity ac-Charge Detection with a MHz-Frequency Fluxonium Qubit**, PRX (2024)

Sideband prepa

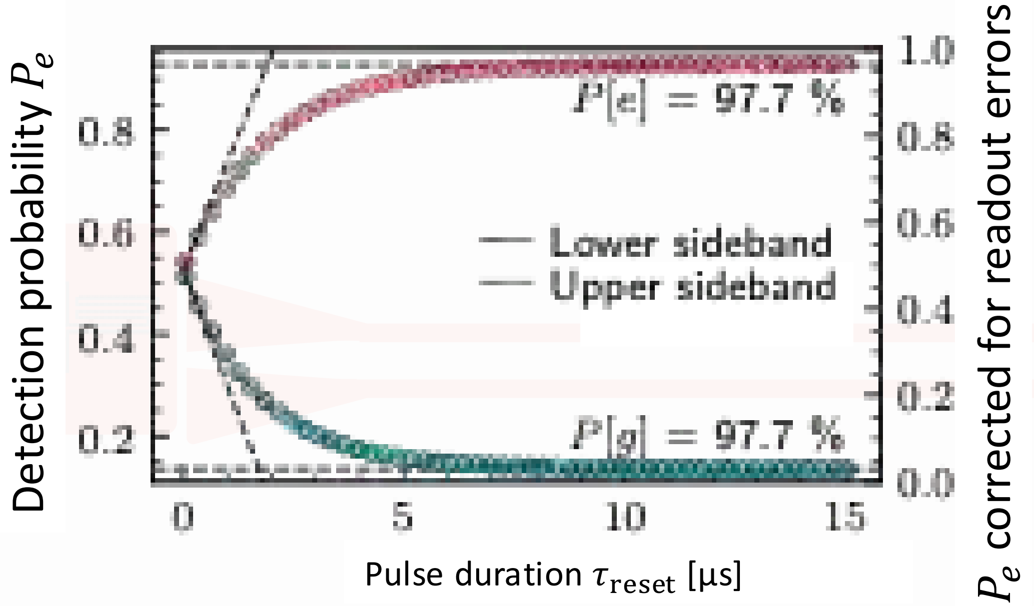


Readout response depends on the qubit state

Complex reflection coefficient



Preparation fidelity



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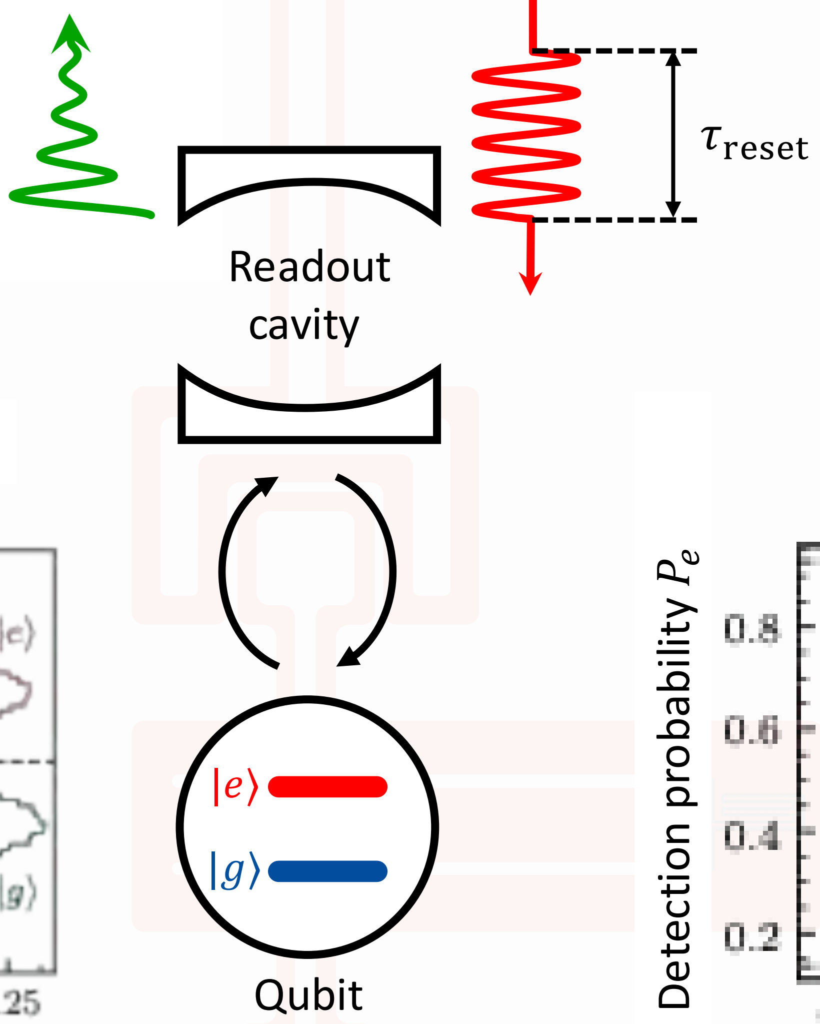
Sideband prepa



Readout response depends on the qubit state

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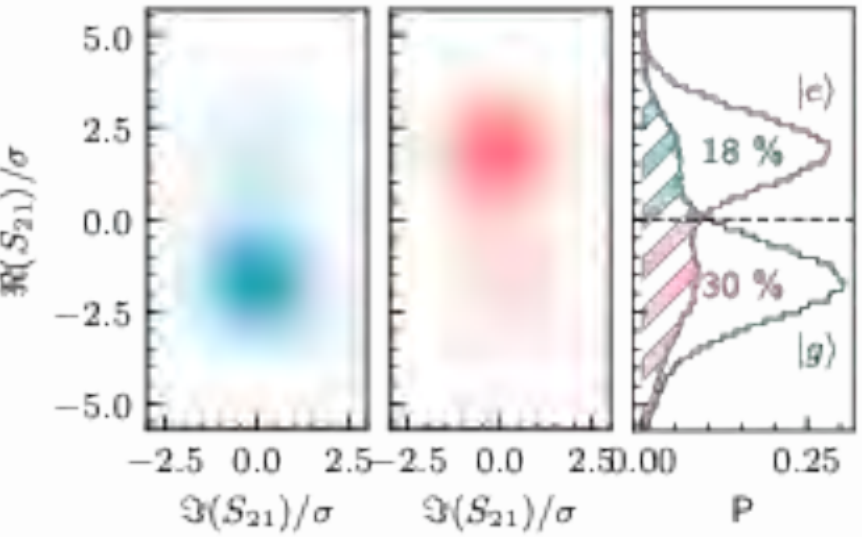
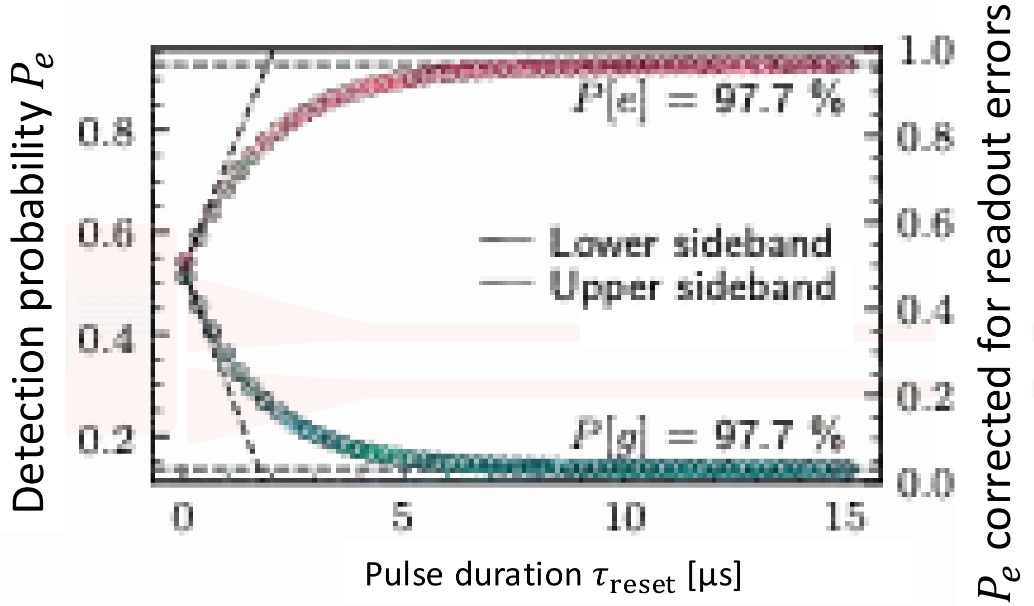


Preparation fidelity

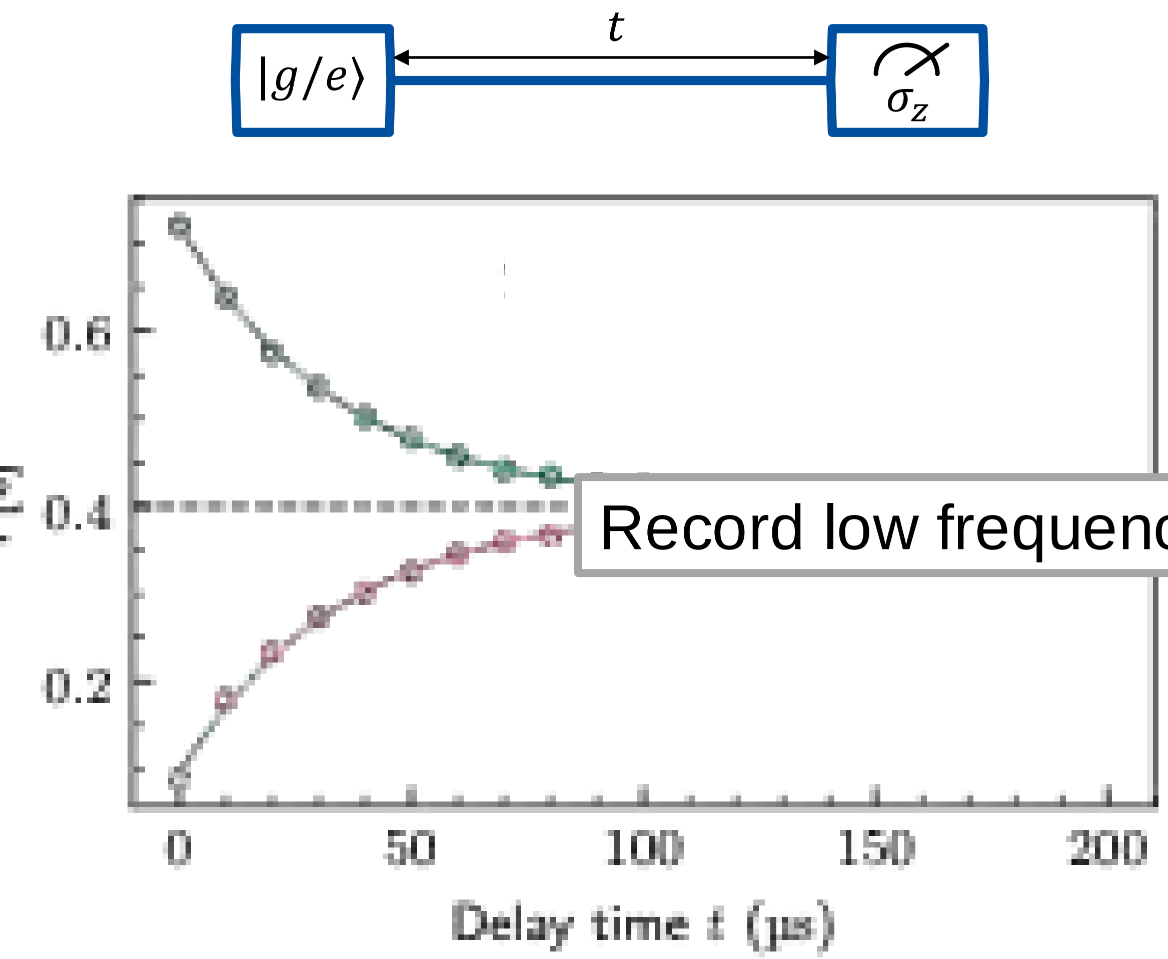


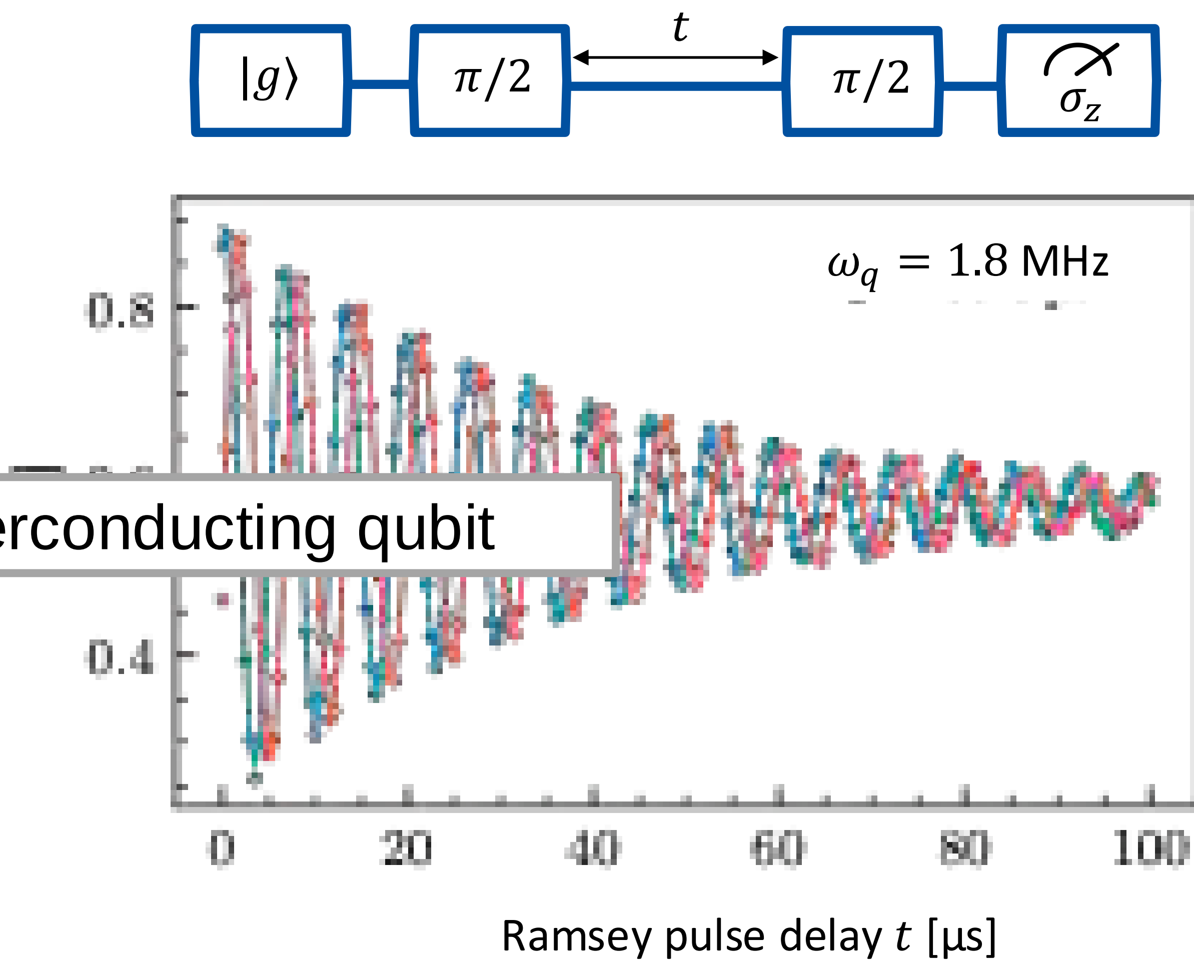
Single-shot readout with 77 % fidelity

Effective temperature: $T_{\text{eff}} = 23\ \mu\text{K}$

B.-L. Najera-Santos *et al.*... , **High-Sensitivity ac-Charge Detection with a MHz-Frequency Fluxonium Qubit**, PRX (2024)

Lifetime measurements





Record low frequency superconducting qubit

Energy relaxation time
$T_1 = 34$ μs

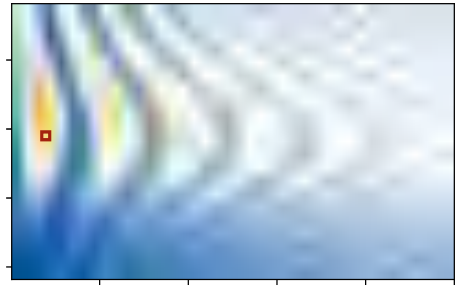
Ramsey decay time
$T_2^* = 38.6$ μs

B.-L. Najera-Santos *et al.*… , **High-Sensitivity ac-Charge Detection with a MHz-Frequency Fluxonium Qubit**, PRX (2024)

Outline

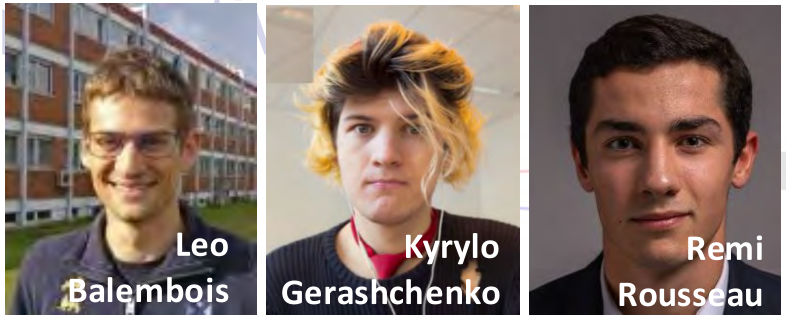
- Radio-frequency fluxonium qubits

- Hybrid qubit/mechanical system: MecaFlux

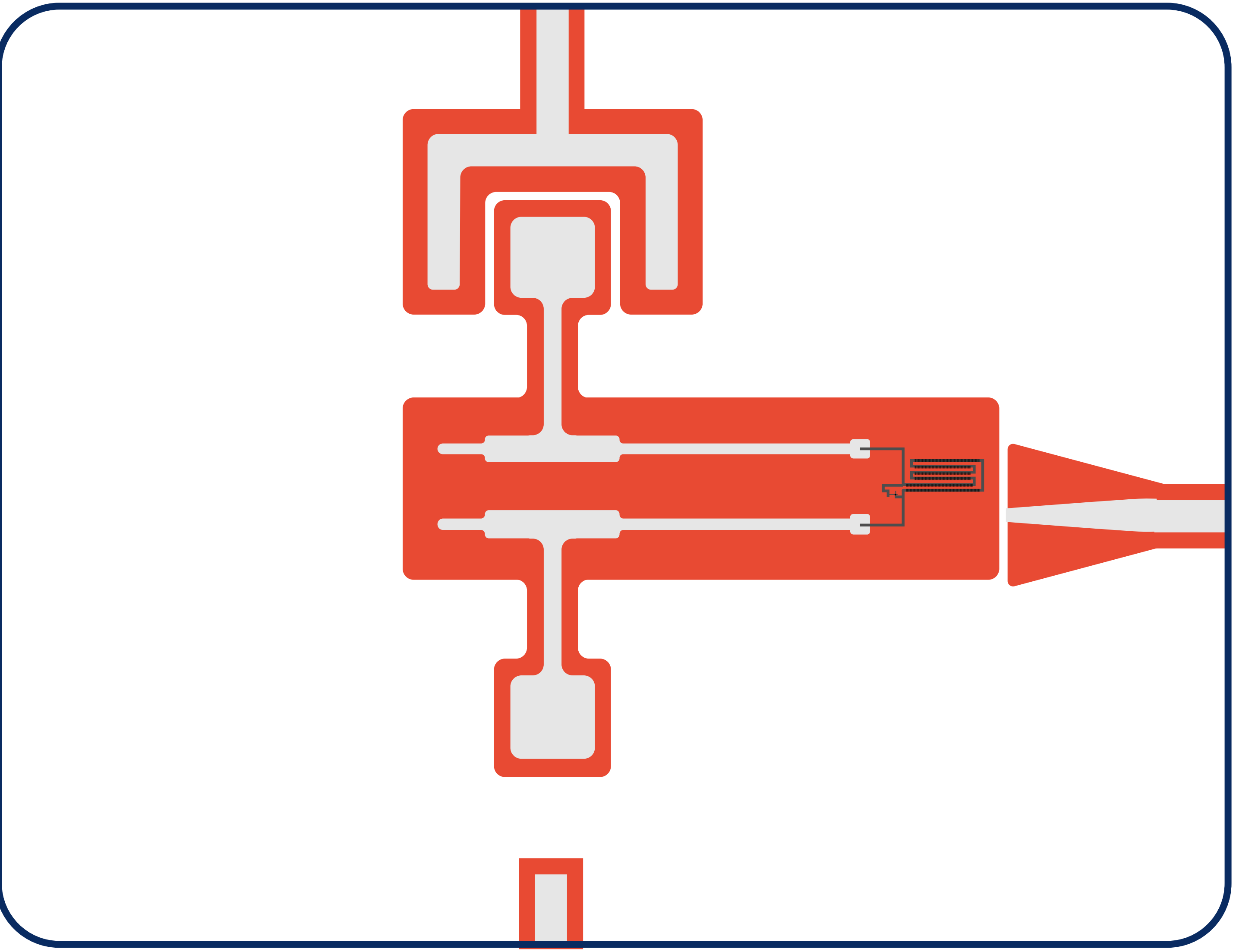


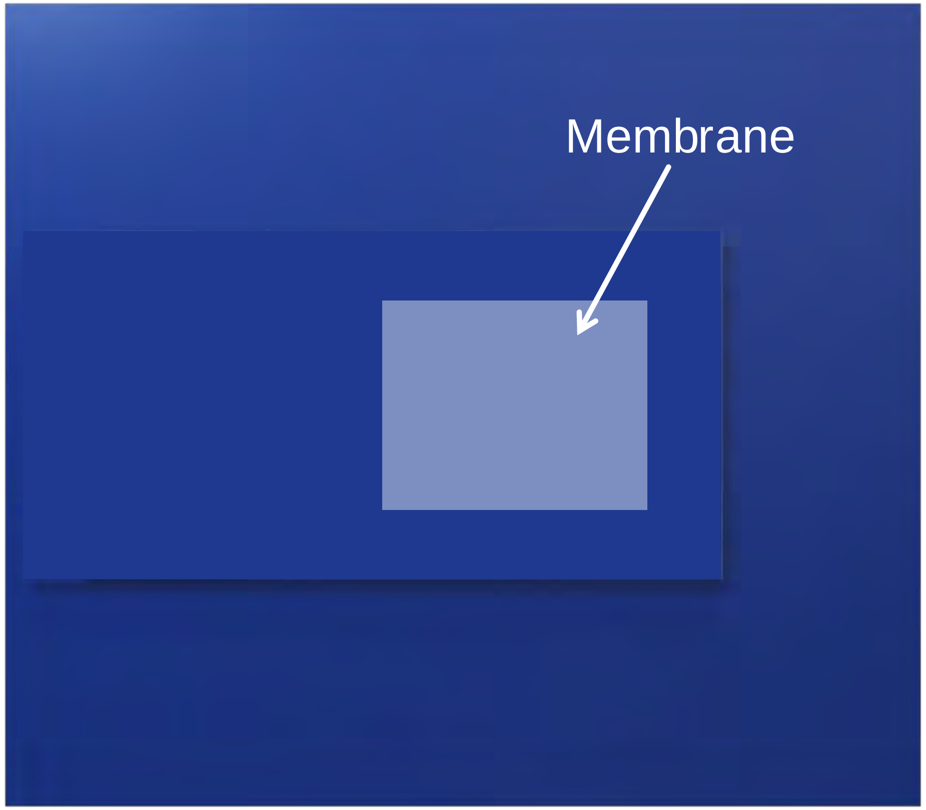
- Quantum asymmetry measurement

- Pe

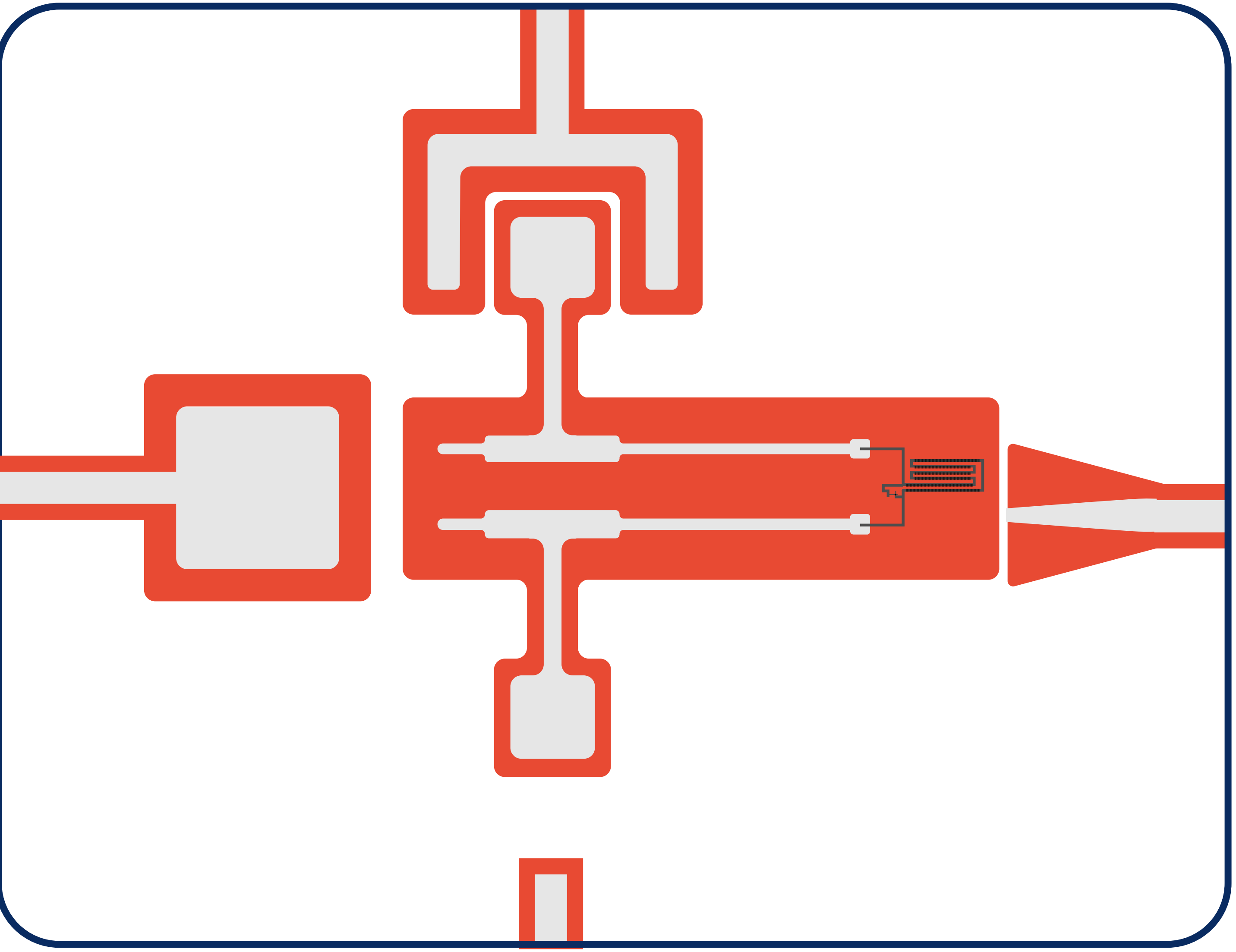


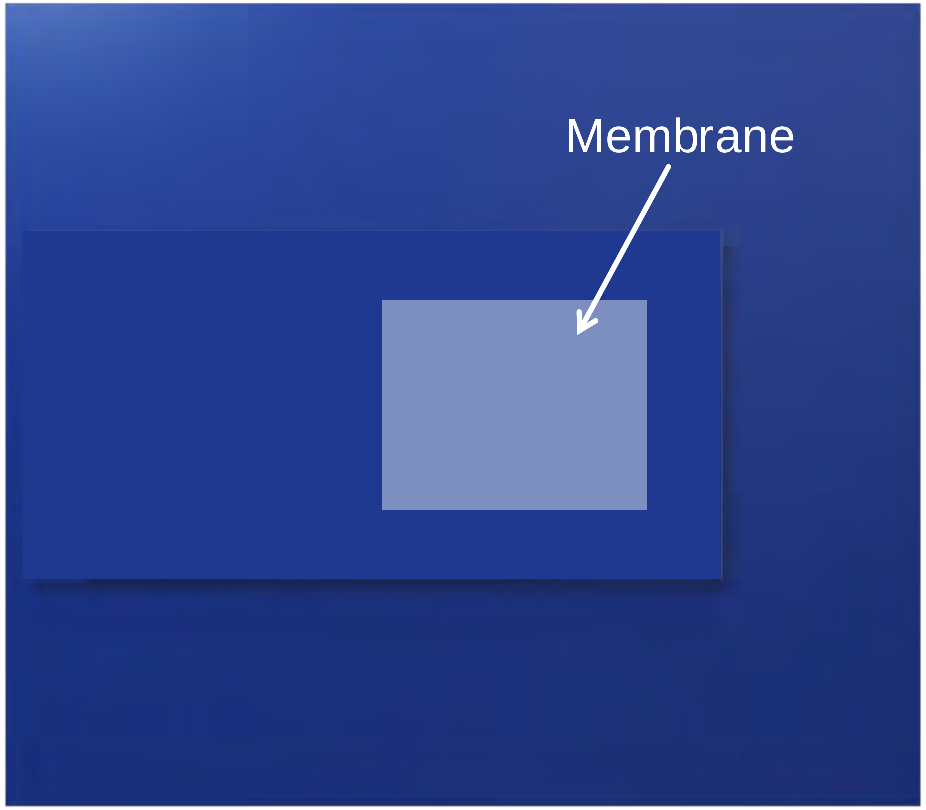
Qubit-membrane coupling



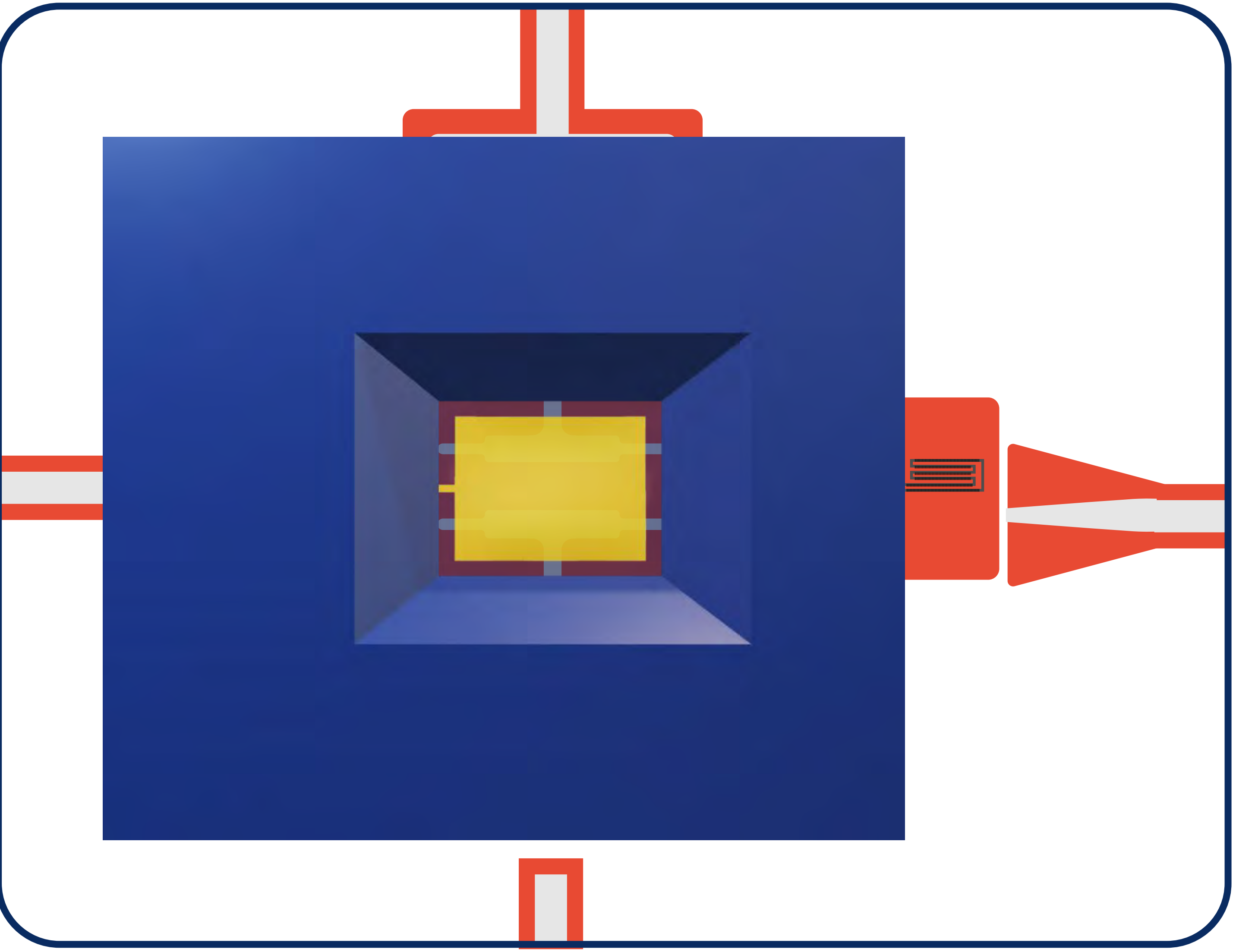


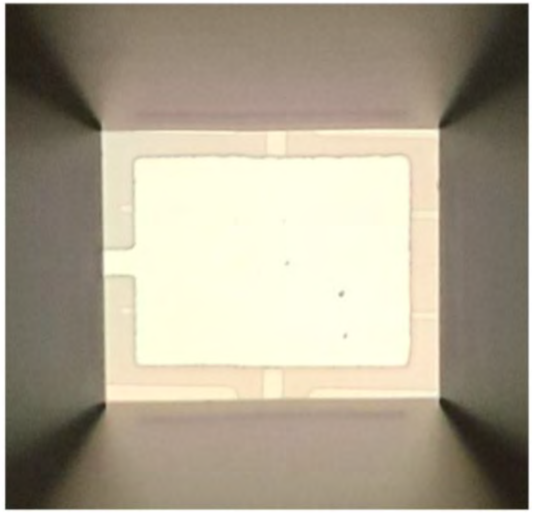
Qubit-membrane coupling

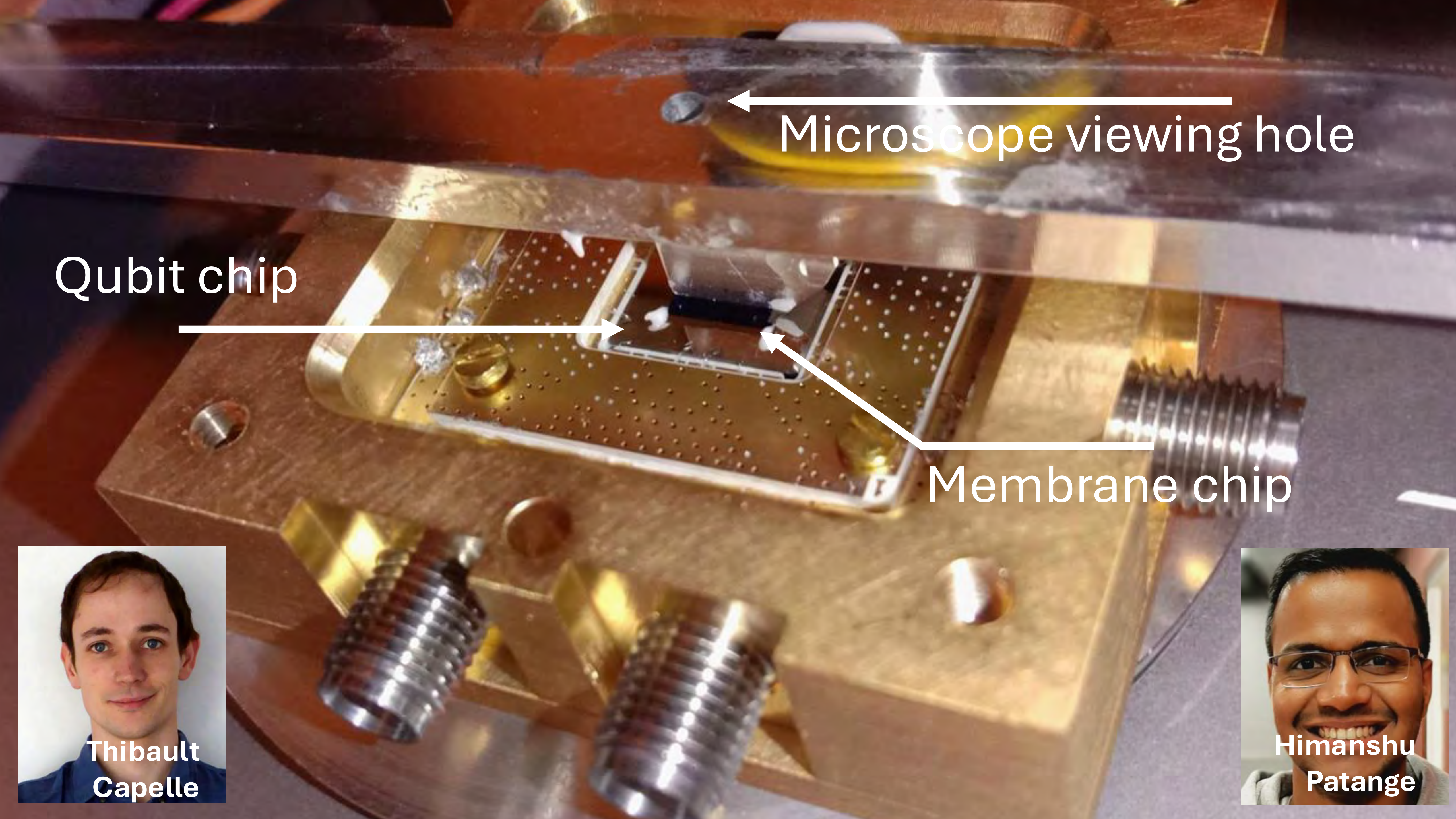


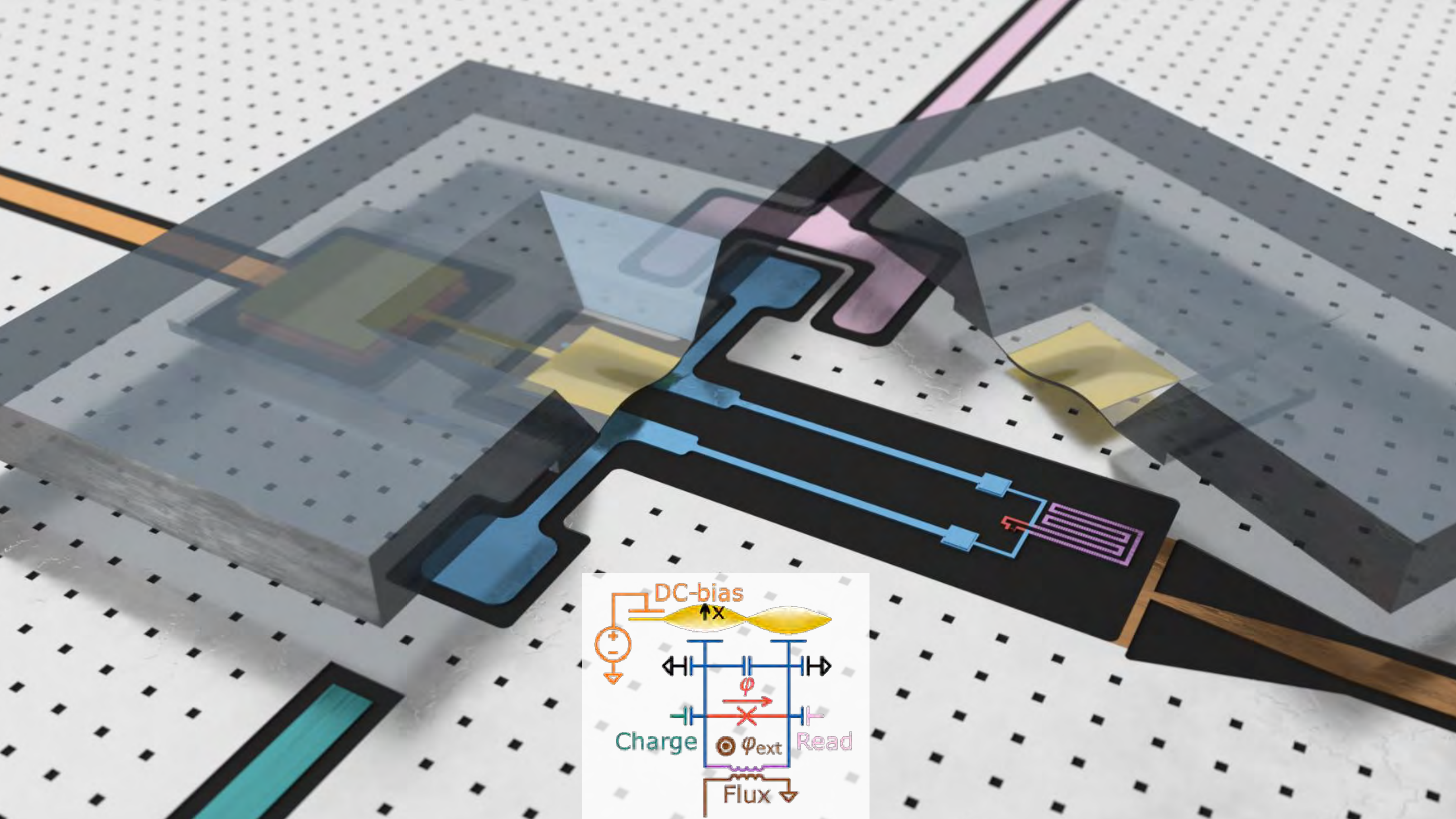


Qubit-membrane coupling





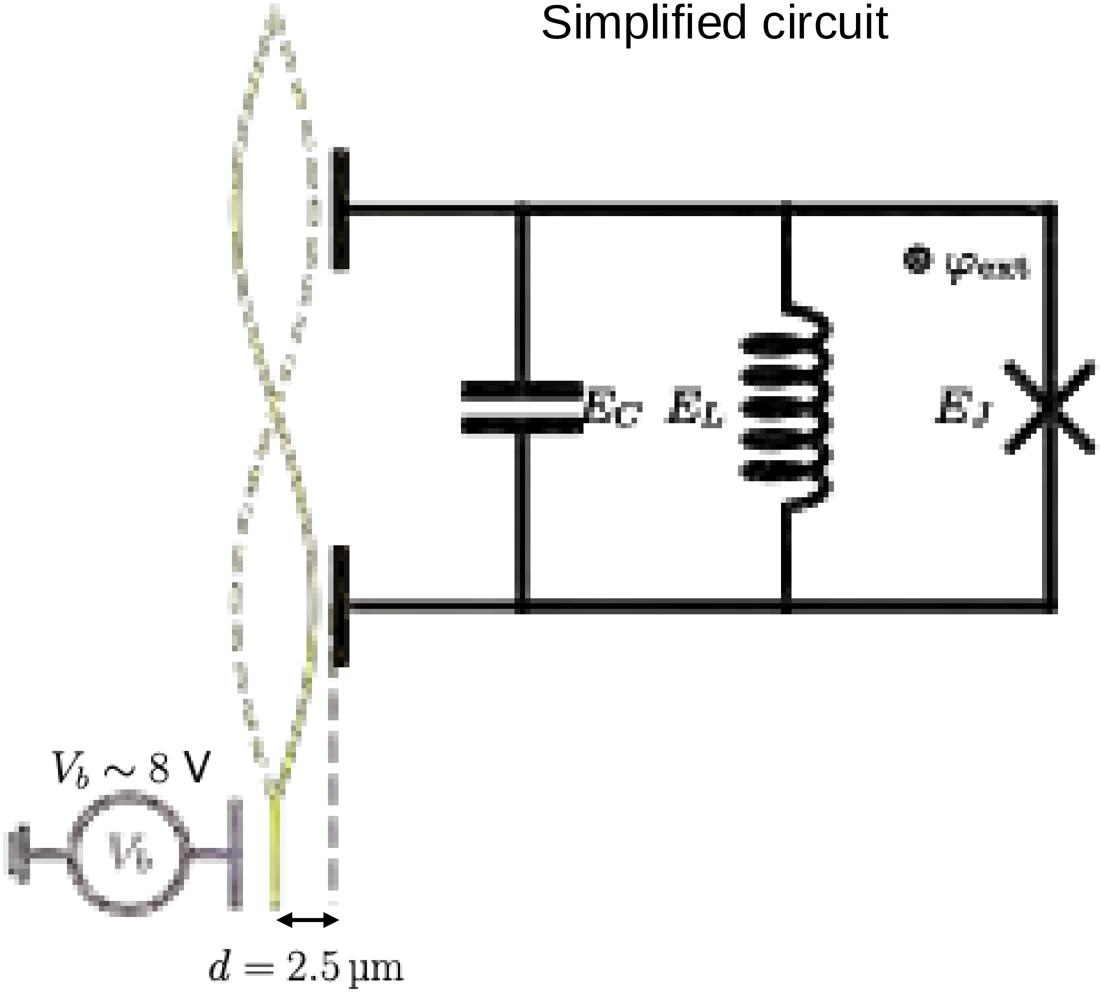

Microscope viewing hole
Qubit chip
Membrane chip
Thibault Capelle
Himanshu Patange



DC-bias
x
φ
Charge
φ_{ext}
Read
Flux

Coupling description

Simplified circuit



System Hamiltonian

$$\boldsymbol{H} = \tfrac{1}{2}E_L\,\boldsymbol{\varphi}^2 \;-\; E_J\cos(\boldsymbol{\varphi} - \varphi_{\rm ext}) \;+\; 4E_C\,(\boldsymbol{n} - n_g(\boldsymbol{x}))^2$$

Position-dependent offset charge :

$$n_g(\boldsymbol{x}) = n_{\rm zpf}\;\boldsymbol{x} \propto V_b\;\boldsymbol{x}/d^2$$

Linear coupling :

$$\boldsymbol{H}_{\rm int} \propto \boldsymbol{n}\cdot\boldsymbol{x}$$

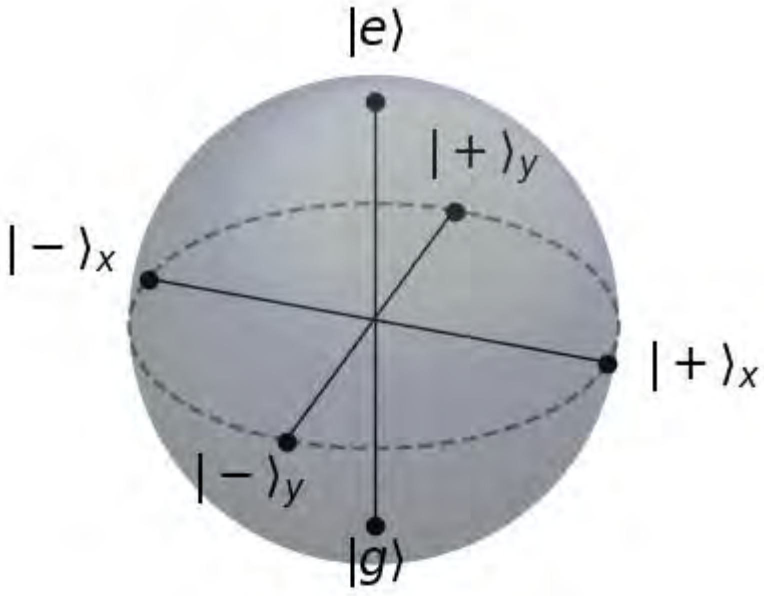
Jaynes-Cummings interaction :

$$\boldsymbol{H}_{\rm int}/\hbar = i\frac{\Omega}{2}\left(\boldsymbol{a}^\dagger\boldsymbol{\sigma}_- - \boldsymbol{a}\boldsymbol{\sigma}_+\right)$$

Membrane spectroscopy (via Ramsey)

$\Omega_m/2\pi = 4.4$ MHz

Dispersive interaction



$\omega_{eg}/2\pi = 2.2$ MHz

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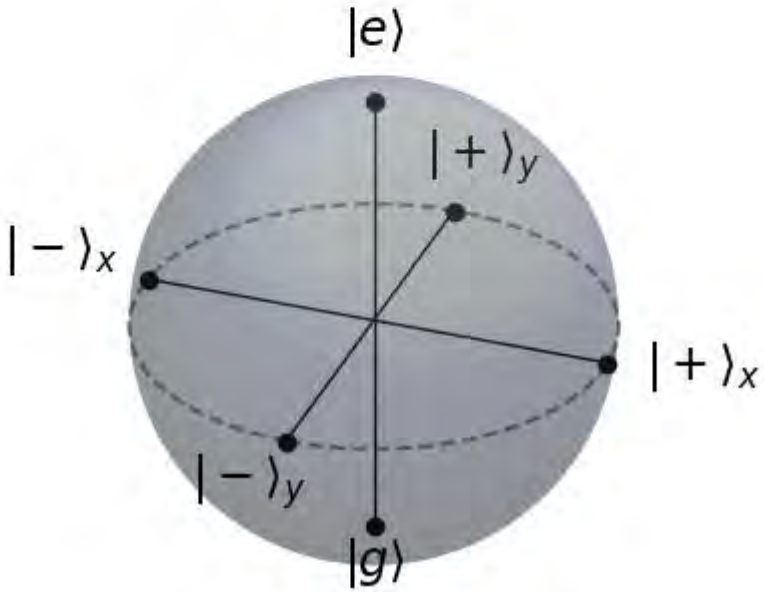
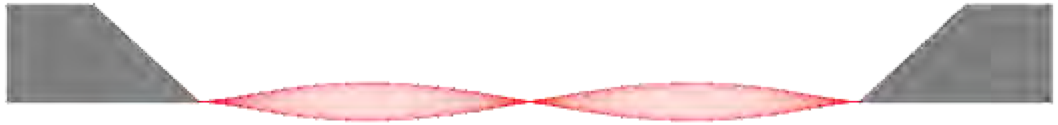


$\omega_{eg}/2\pi = 2.2$ MHz

1. Continuously drive the membrane in a coherent state of mean phonon number $\bar{n}$

Membrane spectroscopy (via Ramsey)



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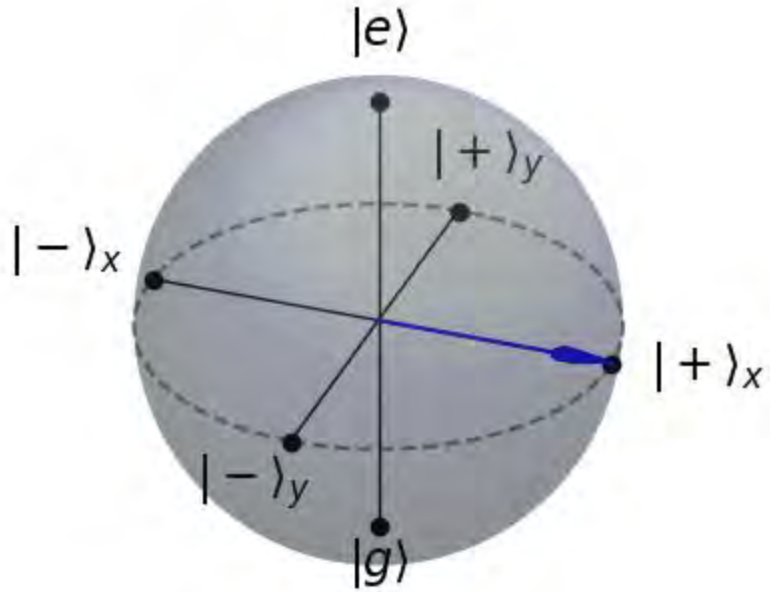
Dispersive interaction

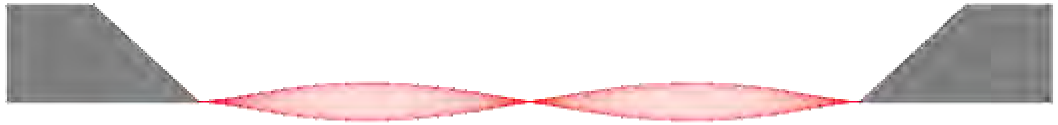


$\omega_{eg}/2\pi = 2.2$ MHz

1. Continuously drive the membrane in a coherent state of mean phonon number $\bar{n}$

2. Detect the mechanically induced AC-Stark shift with a Ramsey sequence

Membrane spectroscopy (via Ramsey)



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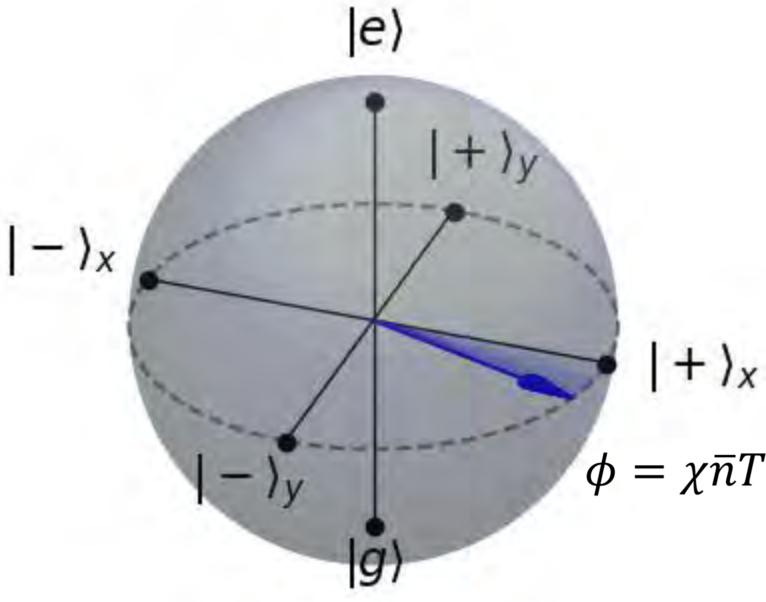

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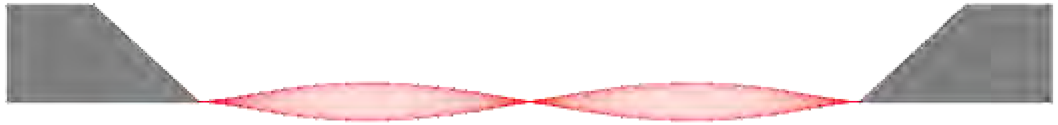
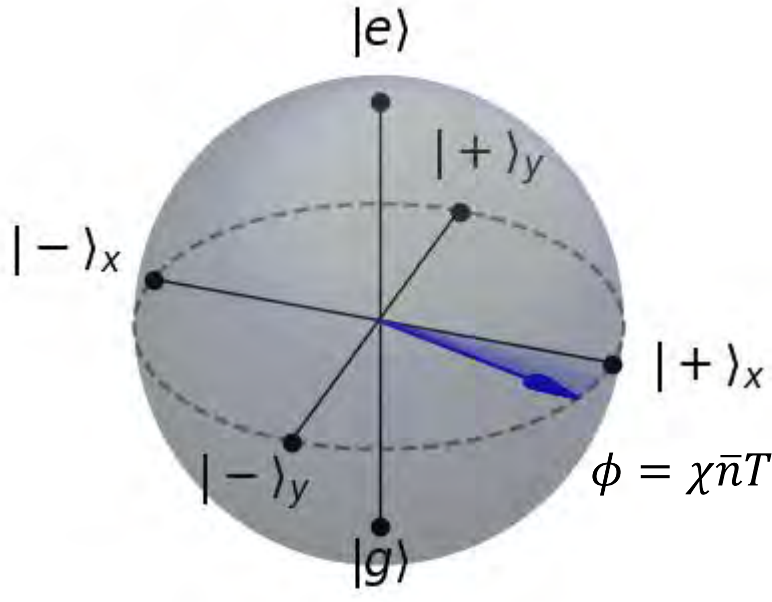


$\Omega_m/2\pi = 4.4$ MHz

Dispersive interaction



$\omega_{eg}/2\pi = 2.2$ MHz

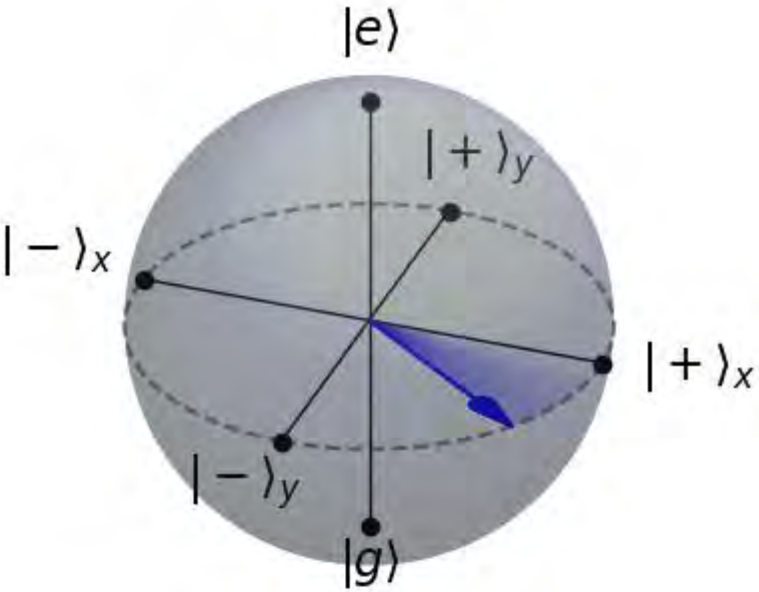
1. Continuously drive the membrane in a coherent state of mean phonon number $\bar{n}$

2. Detect the mechanically induced AC-Stark shift with a Ramsey sequence

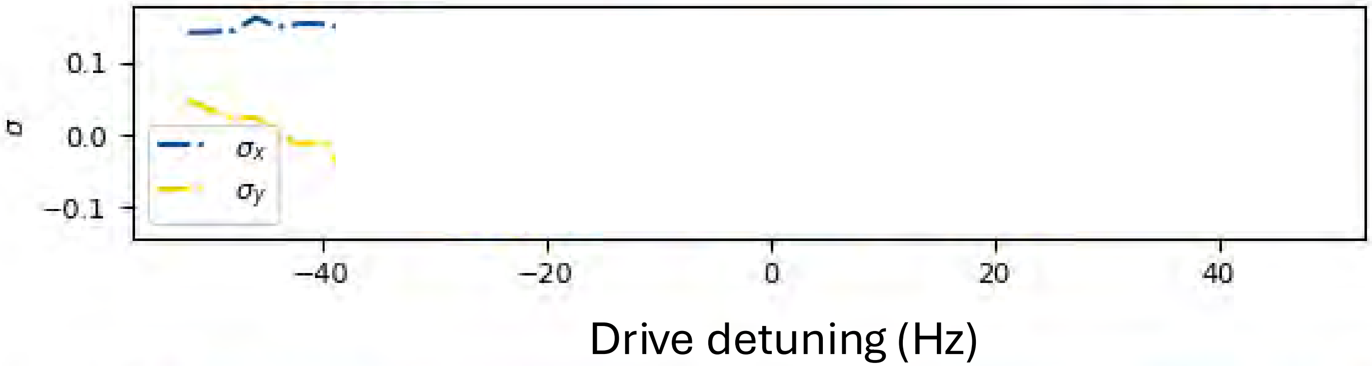
3. Repeat as a function of drive frequency

Membrane spectroscopy (via Ramsey)

Dispersive interaction

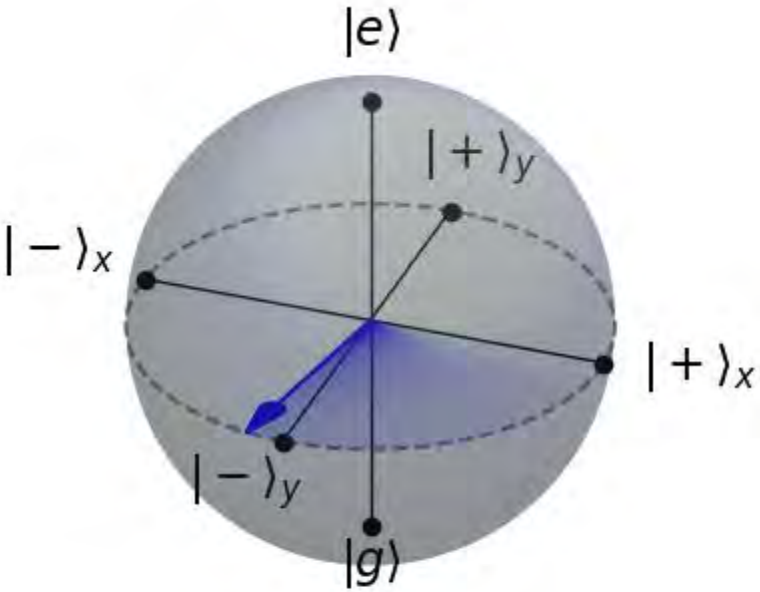


$$\omega_{eg}/2\pi = 2.2 \text{ MHz}$$



Membrane spectroscopy (via Ramsey)

Dispersive interaction



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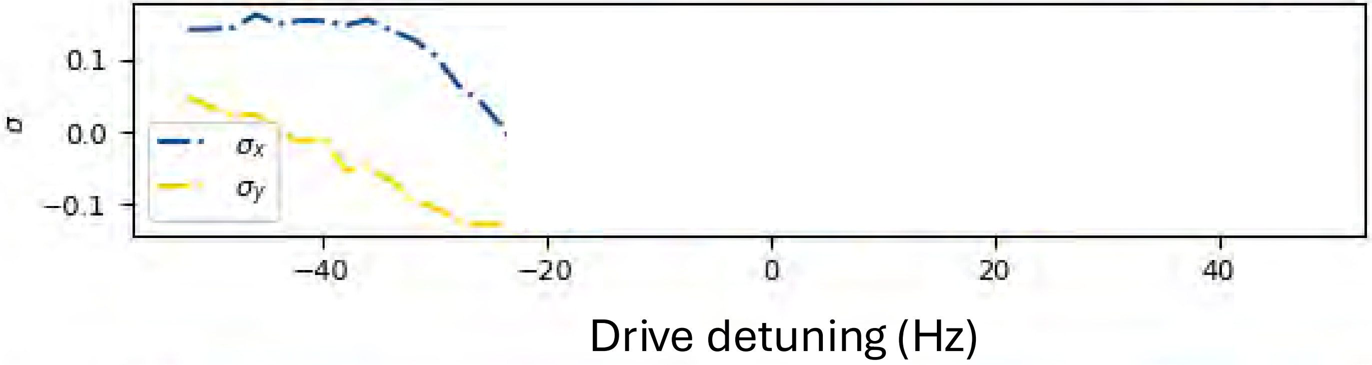
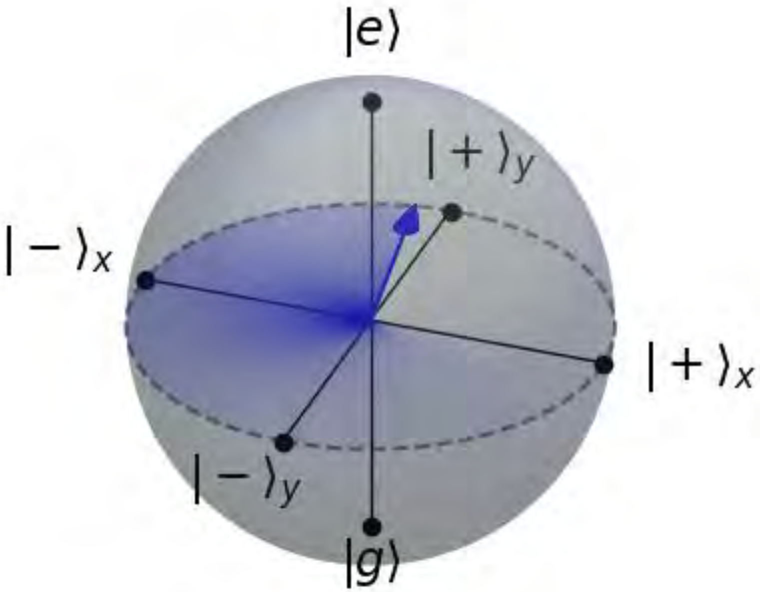


Membrane spectroscopy (via Ramsey)

Dispersive interaction



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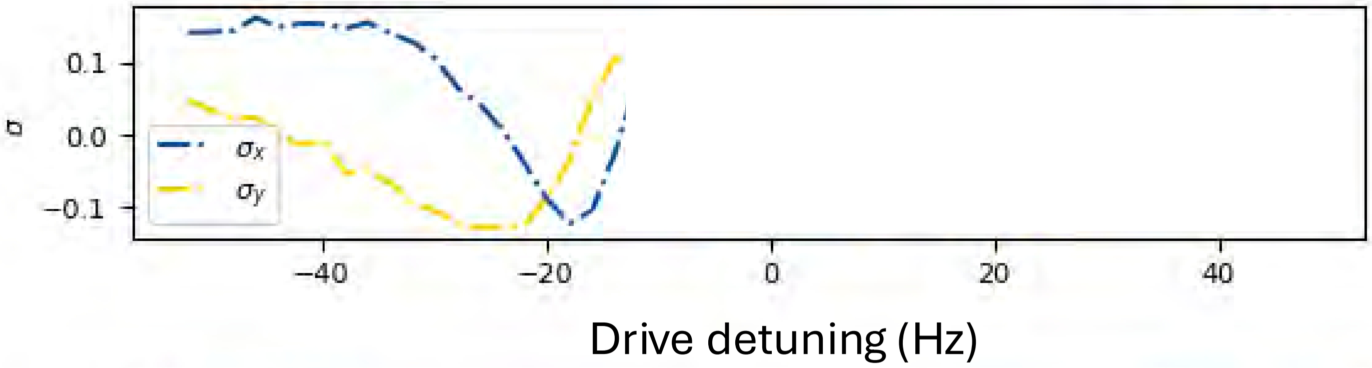
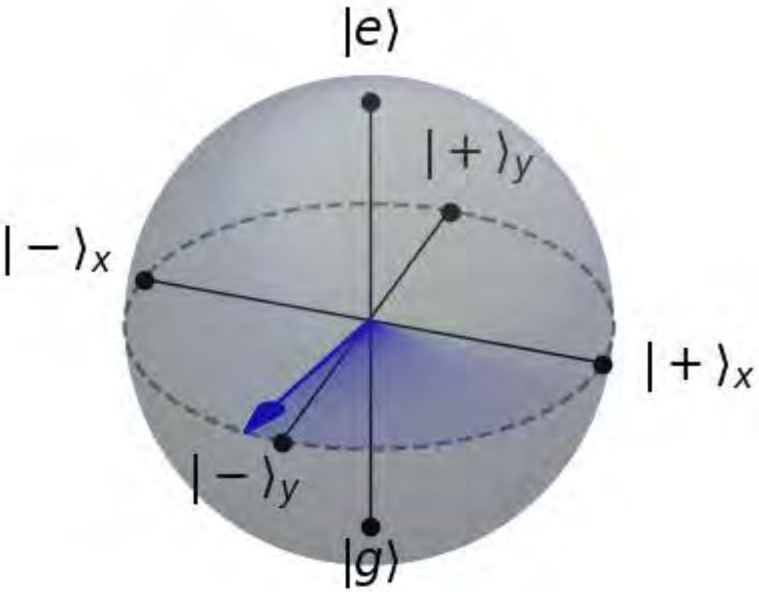


Membrane spectroscopy (via Ramsey)

Dispersive interaction



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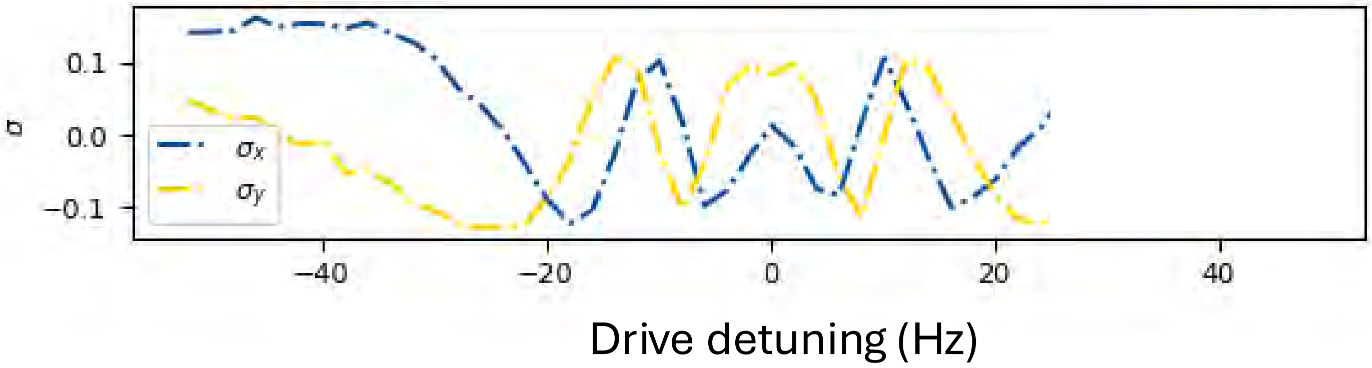
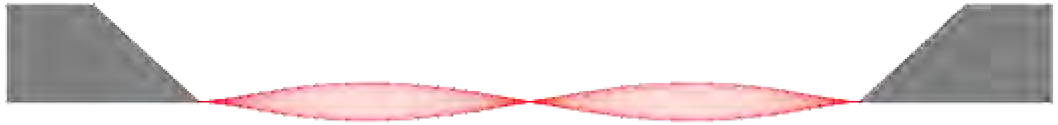


Membrane spectroscopy (via Ramsey)



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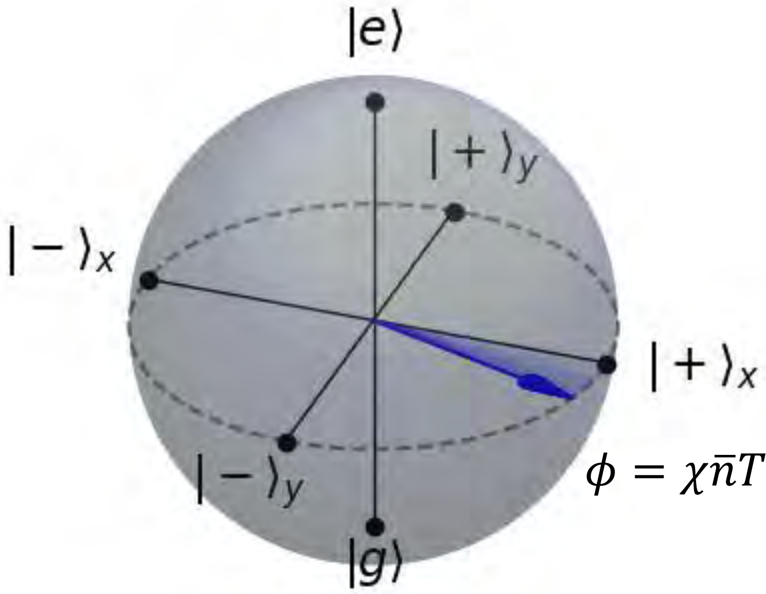

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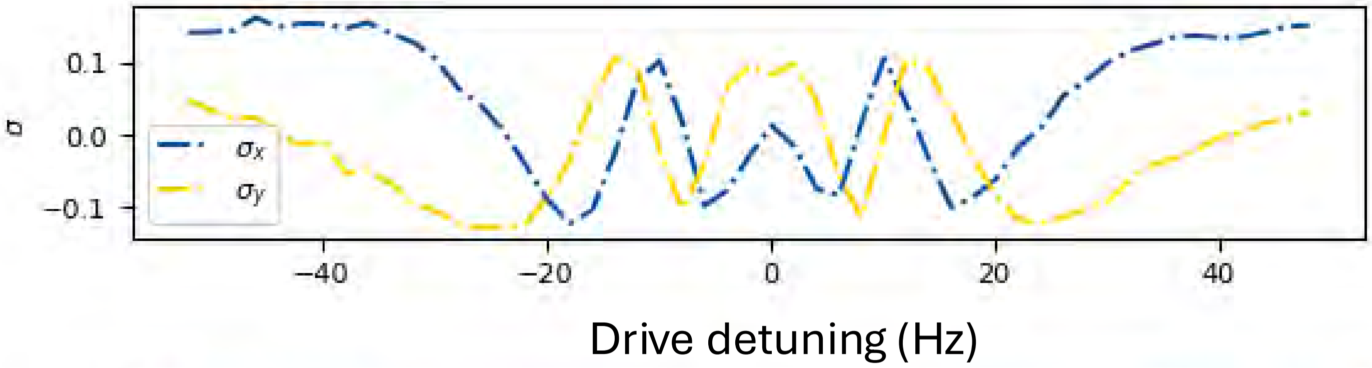
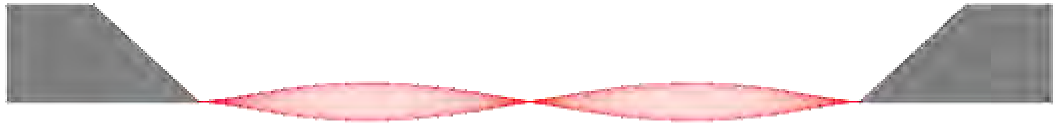


Membrane spectroscopy (via Ramsey)



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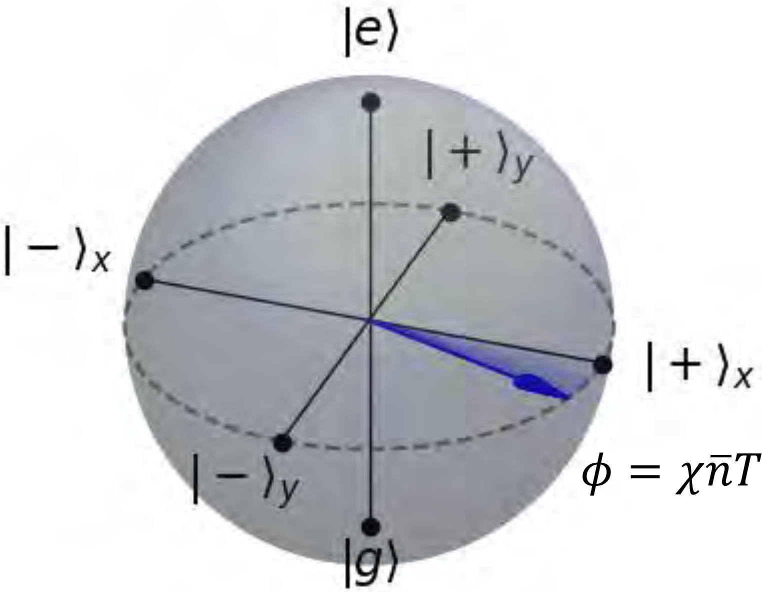

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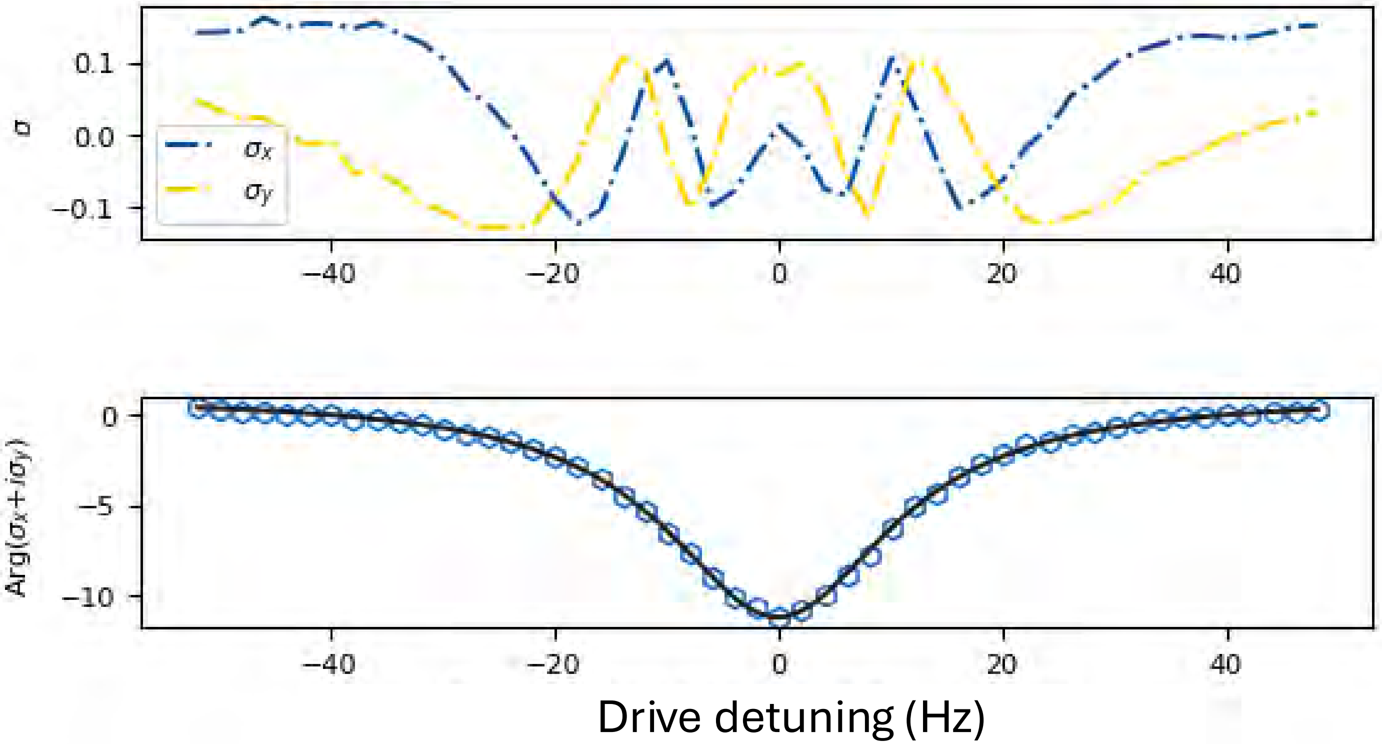
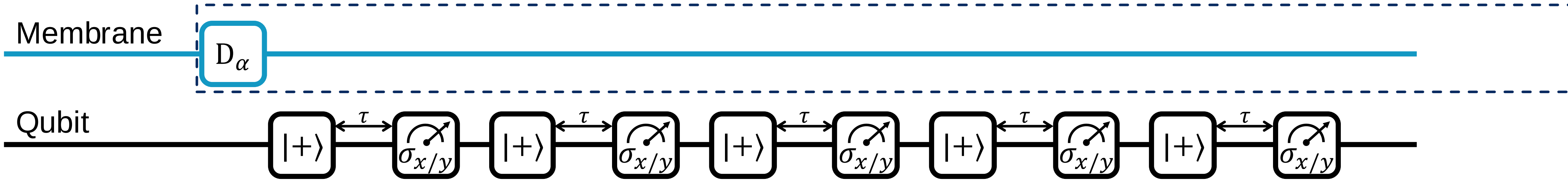
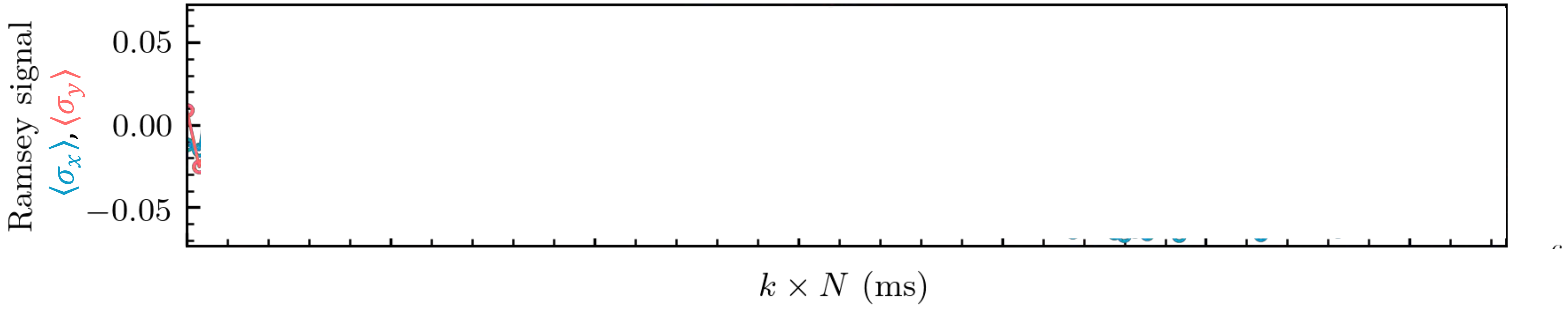


Mechanical lifetime

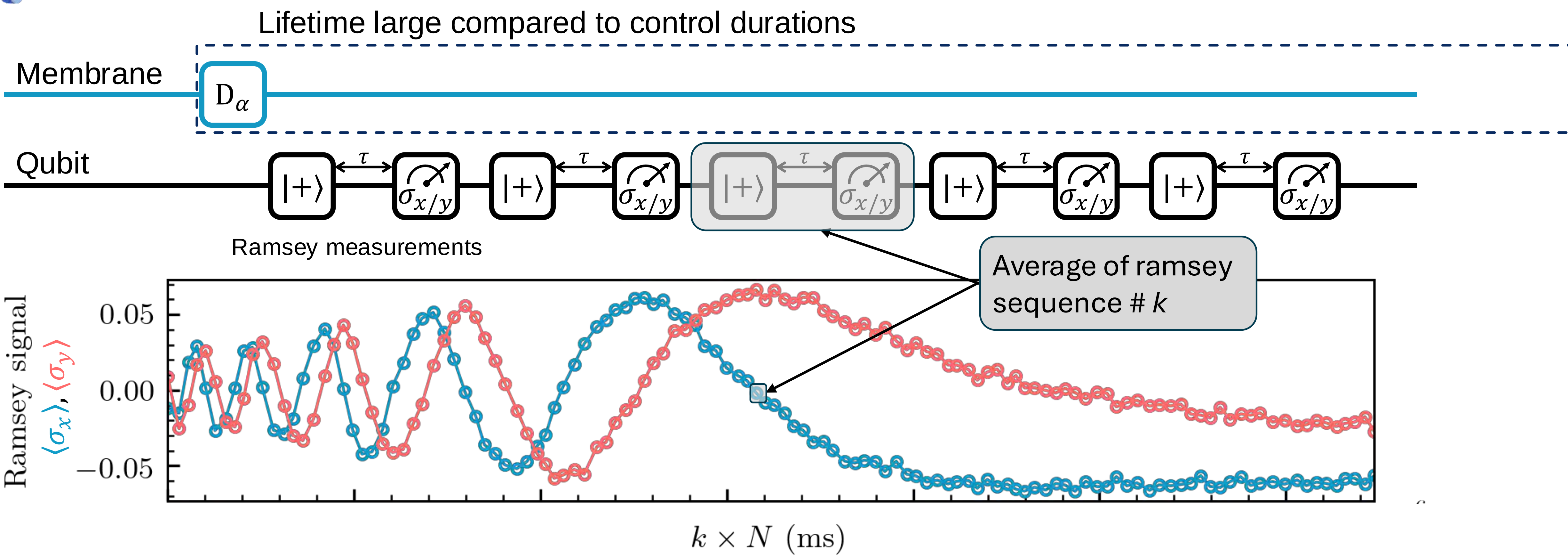
Lifetime large compared to control durations



Ramsey measurements



Mechanical lifetime



Mechanical lifetime

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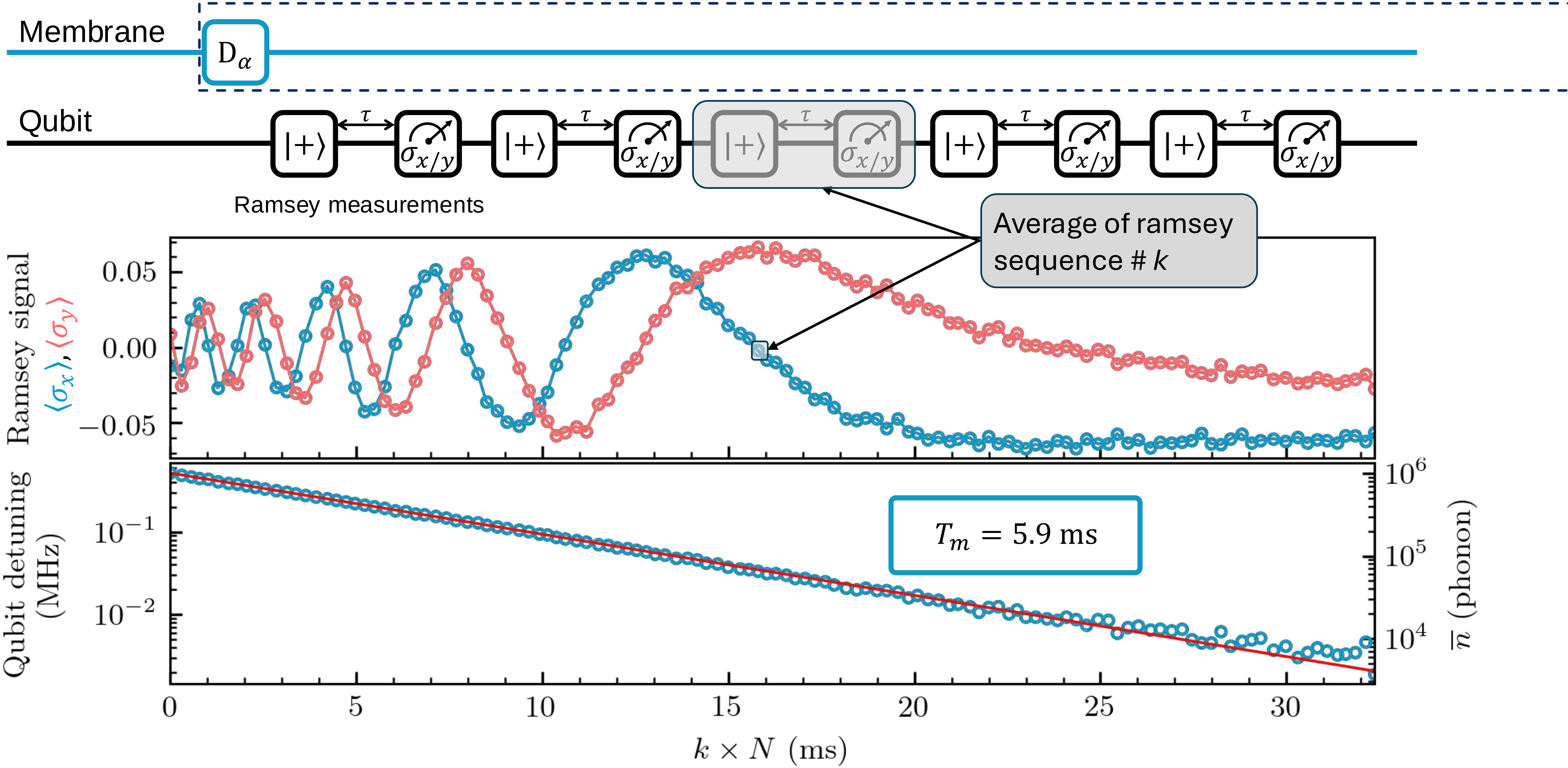
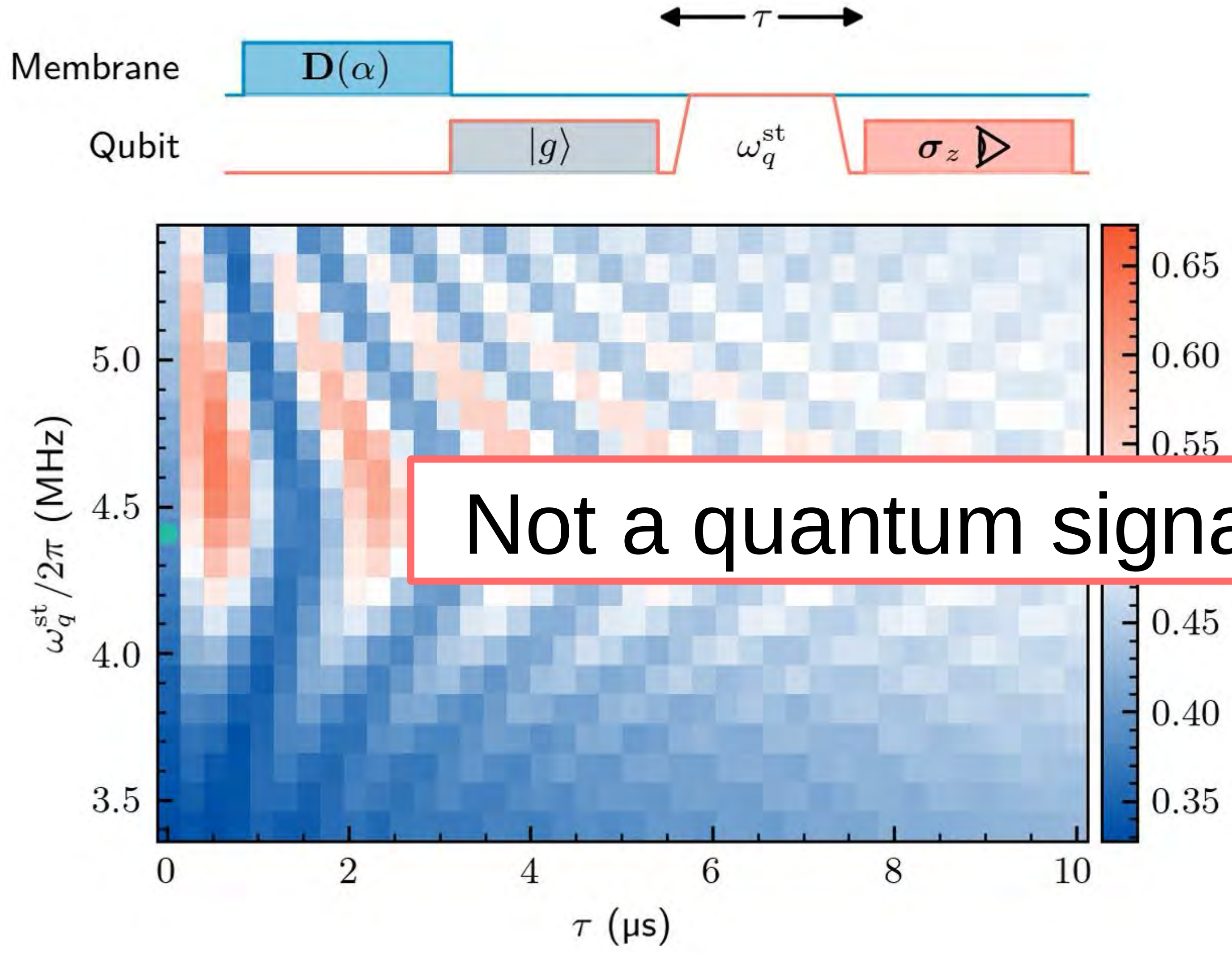
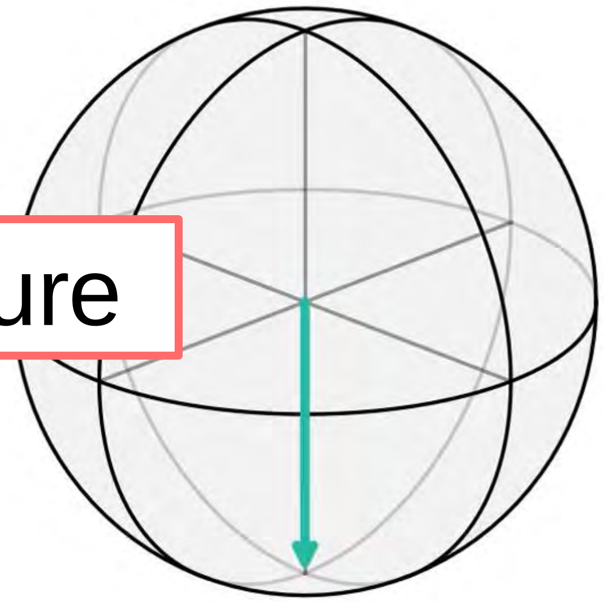


Mechanically induced Rabi oscillations

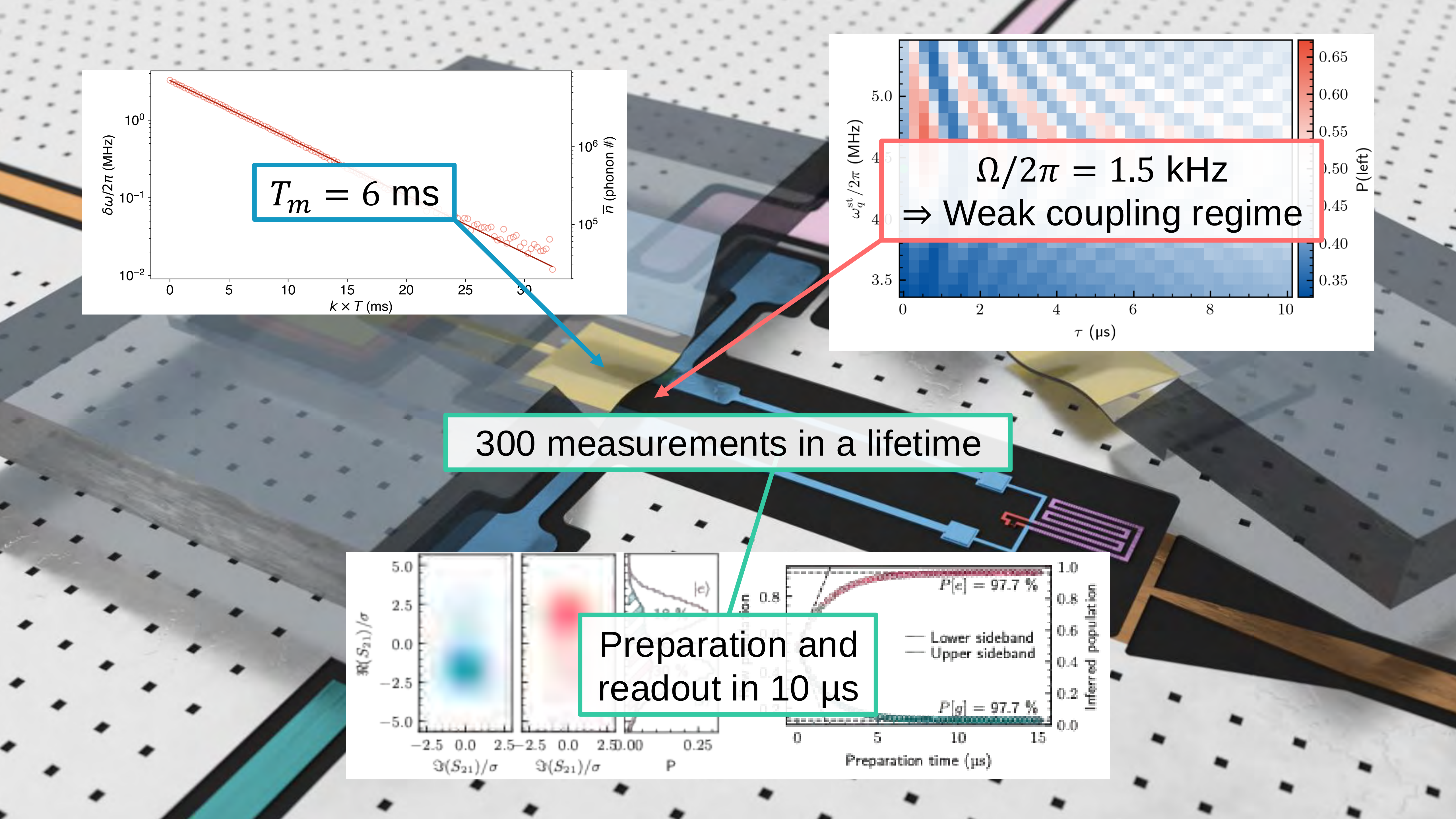


$\theta = \Omega|\alpha|\tau$

$|\alpha|^2 \sim 10^5$ phonons



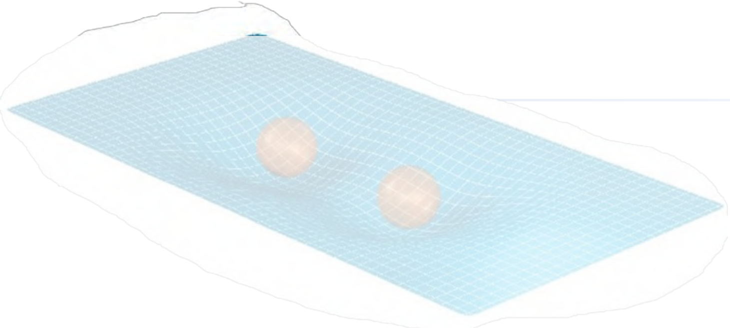
Not a quantum signature



$T_m = 6$ ms
$\Omega/2\pi = 1.5$ kHz
⇒ Weak coupling regime
300 measurements in a lifetime
Preparation and readout in 10 μs
$\delta\omega/2\pi$ (MHz)
$k \times T$ (ms)
$\bar{n}$ (phonon #)
$\omega_q^{st}/2\pi$ (MHz)
τ (μs)
P(left)
$\Re(S_{21})/\sigma$
$\Im(S_{21})/\sigma$
P
$P[e] = 97.7$ %
$P[g] = 97.7$ %
Lower sideband
Upper sideband
Inferred population
Preparation time (μs)

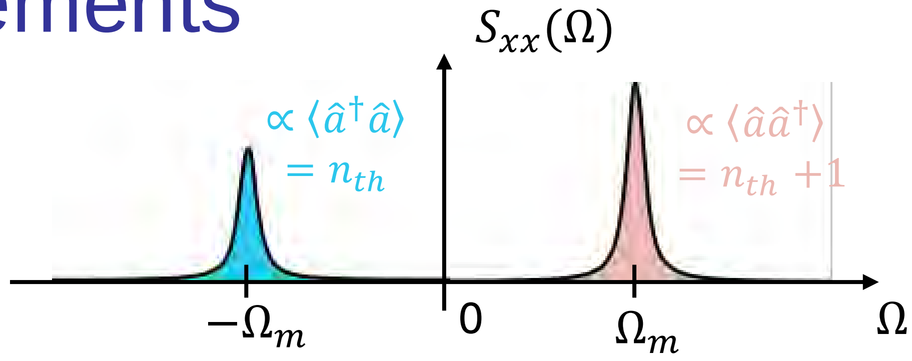
Outline

- Introduction/Motivation



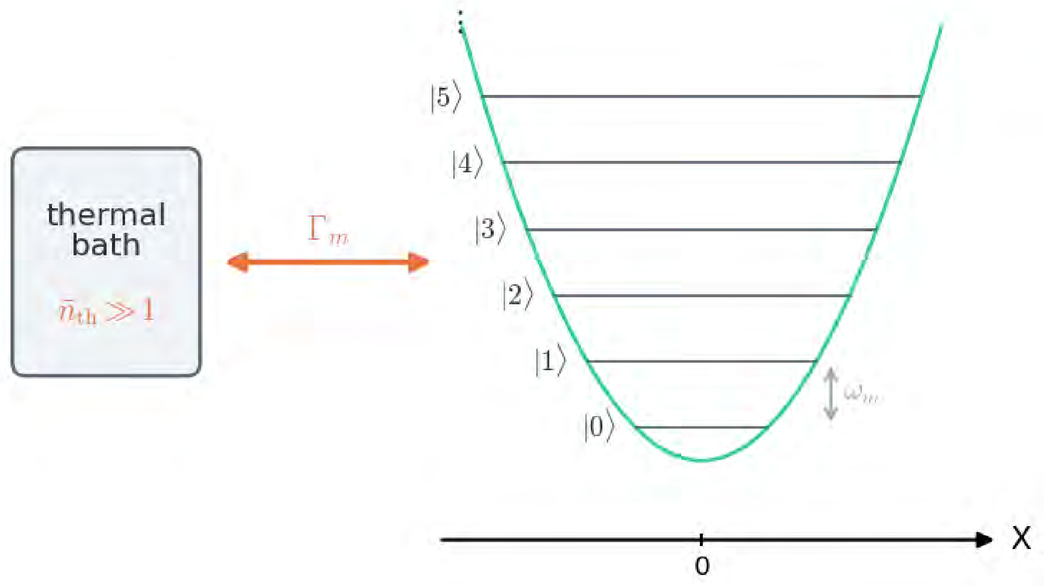
- Radio-frequency fluxonium qubits
- Hybrid qubit/mechanical system: MecaFlux

- **Quantum asymmetry measurements**



- Perspectives

A thought experiment …



A. A. Clerk, M. H. Devoret, S. M. Girvin, F. Marquardt & R. J. Schoelkopf, Rev. Mod. Phys. 82, 1155 (2010)

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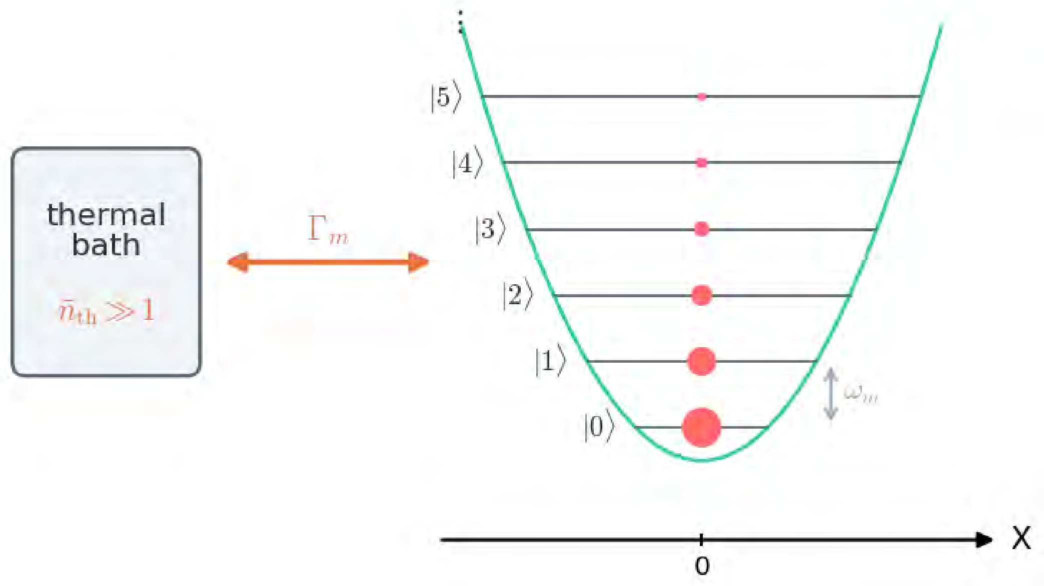

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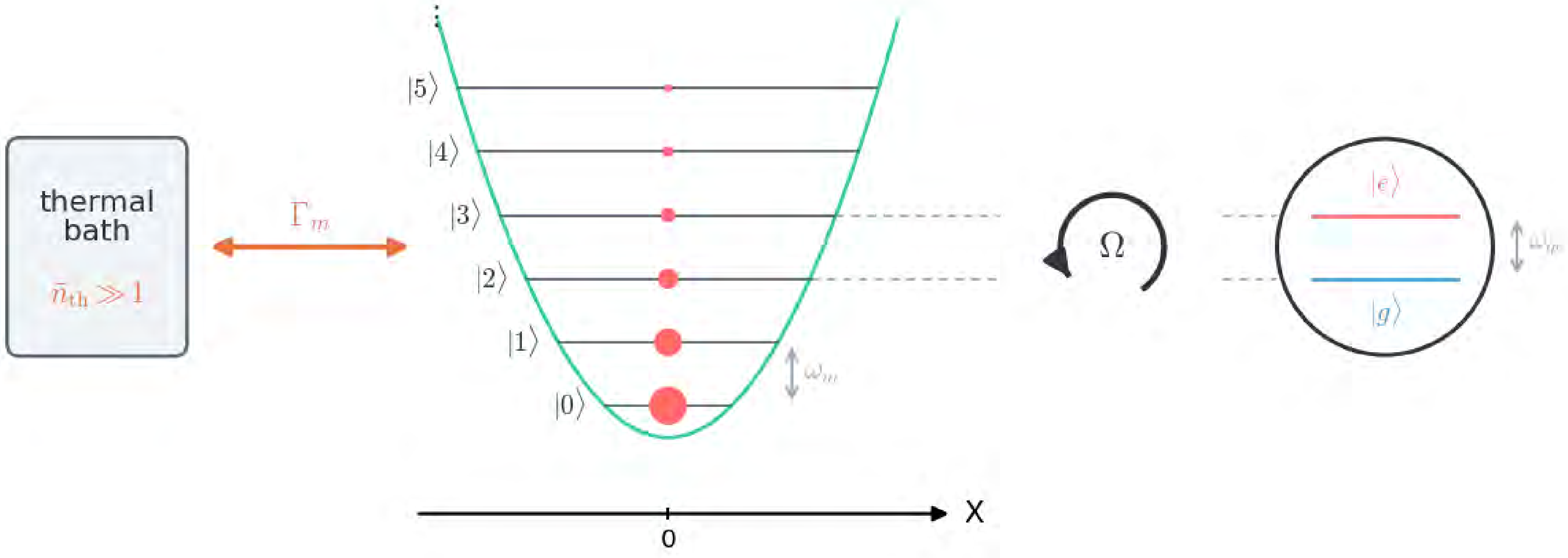

A qubit as a quantum spectrum analyzer :

- linearly couple the system observable to a qubit : $H = \hbar\Omega\,\hat{X} \otimes \hat{\sigma}_x$

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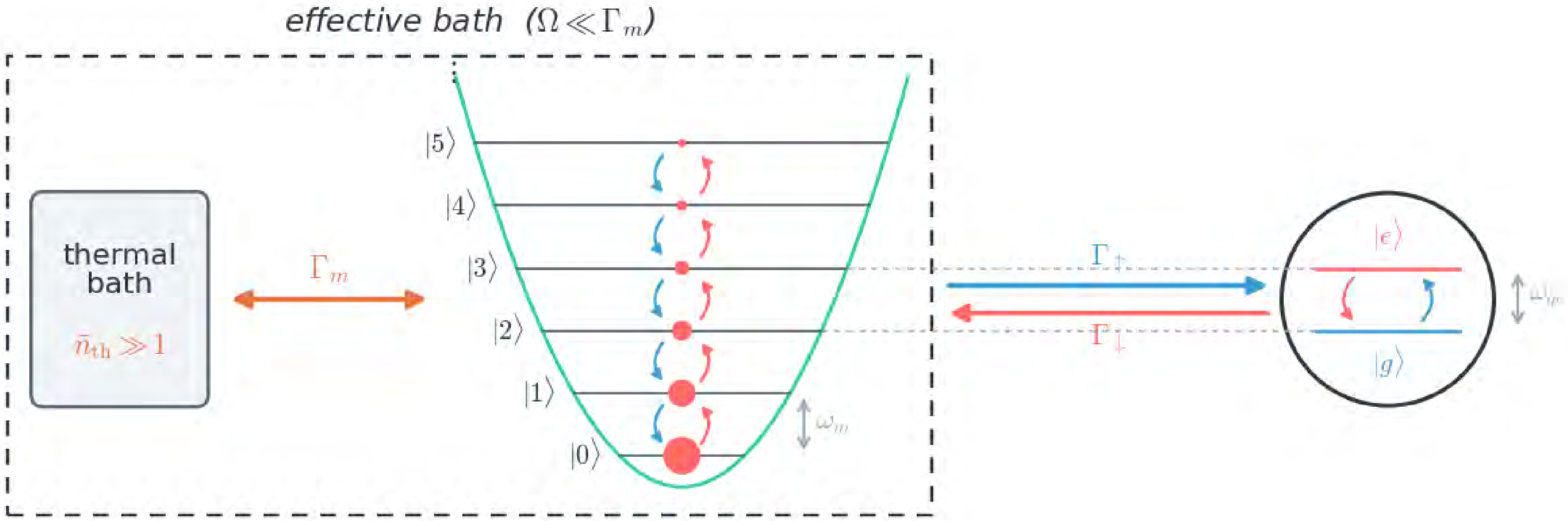

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- in the weak-coupling regime, the system acts as an effective bath

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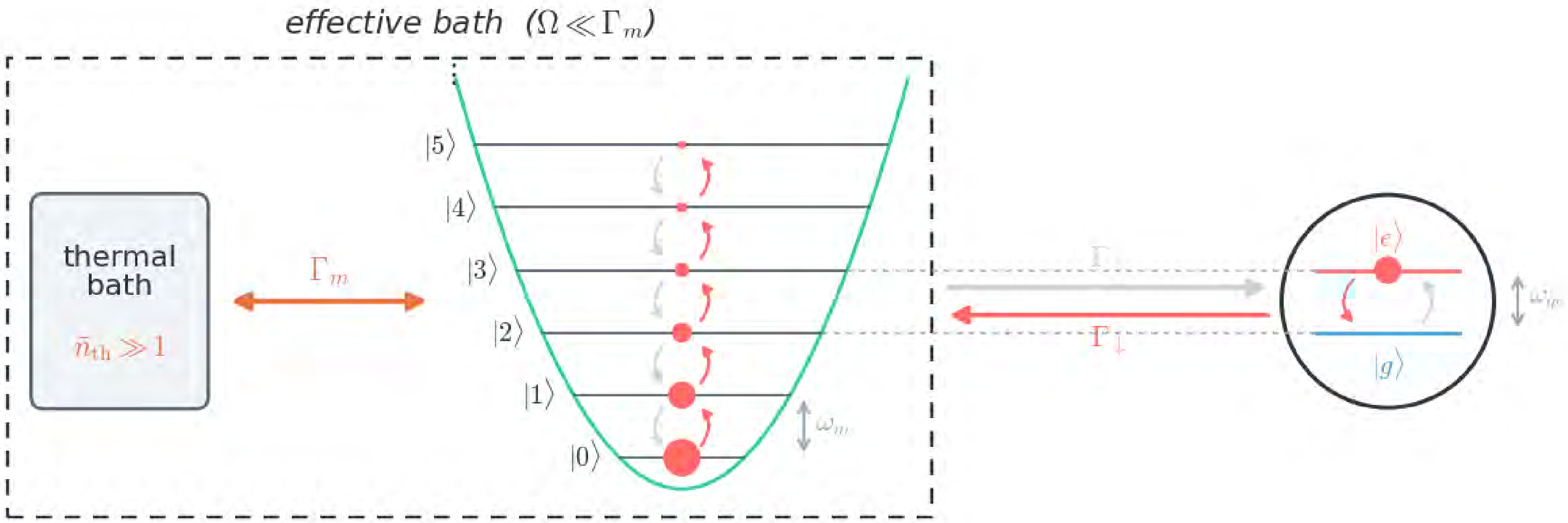

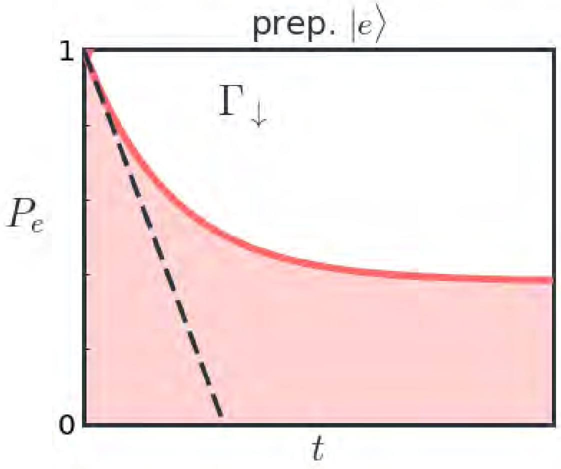

A qubit as a quantum spectrum analyzer :

- linearly couple the system observable to a qubit : $H = \hbar\Omega\,\hat{X}\otimes\hat{\sigma}_x$
- in the weak-coupling regime, the system acts as an effective bath
- the rates $\Gamma_\downarrow \propto S_{XX}(\omega_{ge})$ and $\Gamma_\uparrow \propto S_{XX}(-\omega_{ge})$

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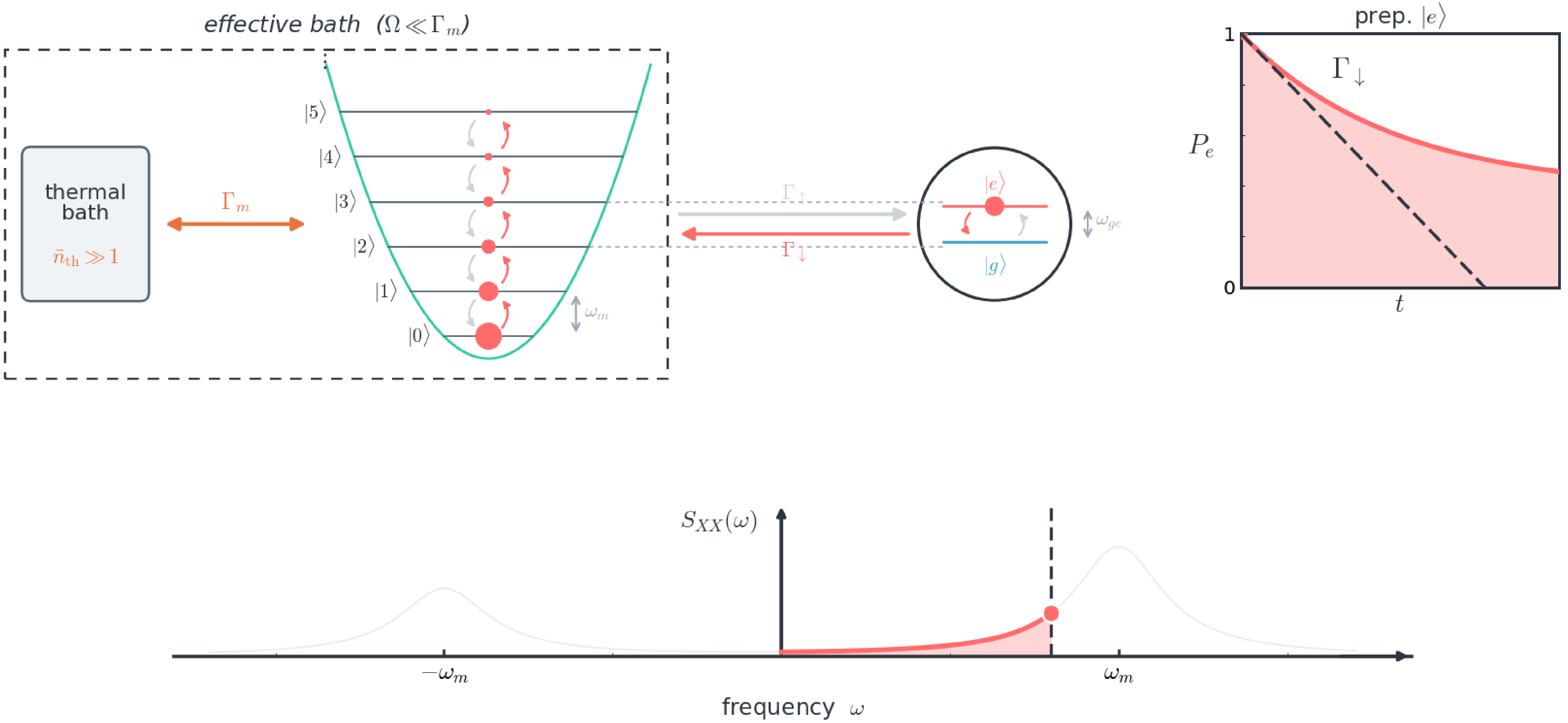
A thought experiment …



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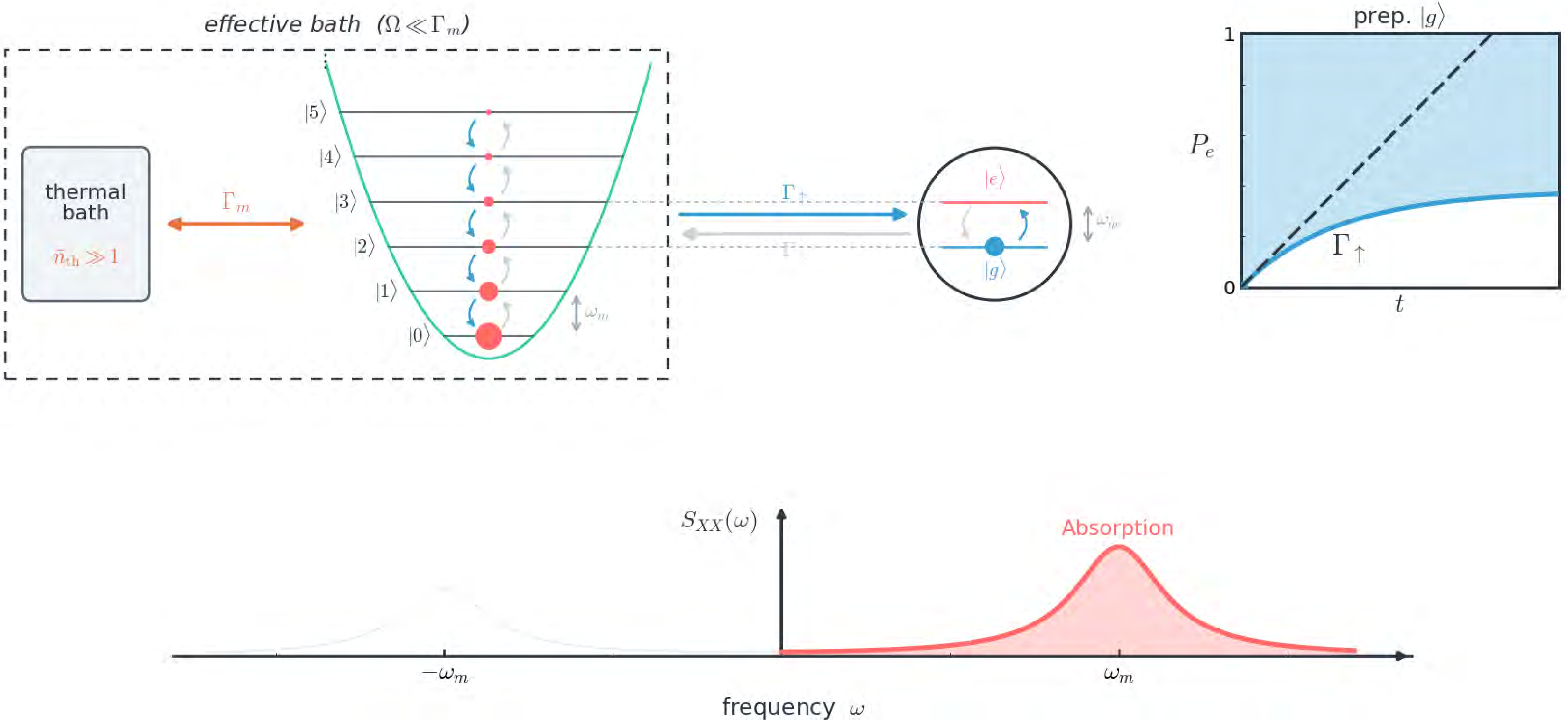

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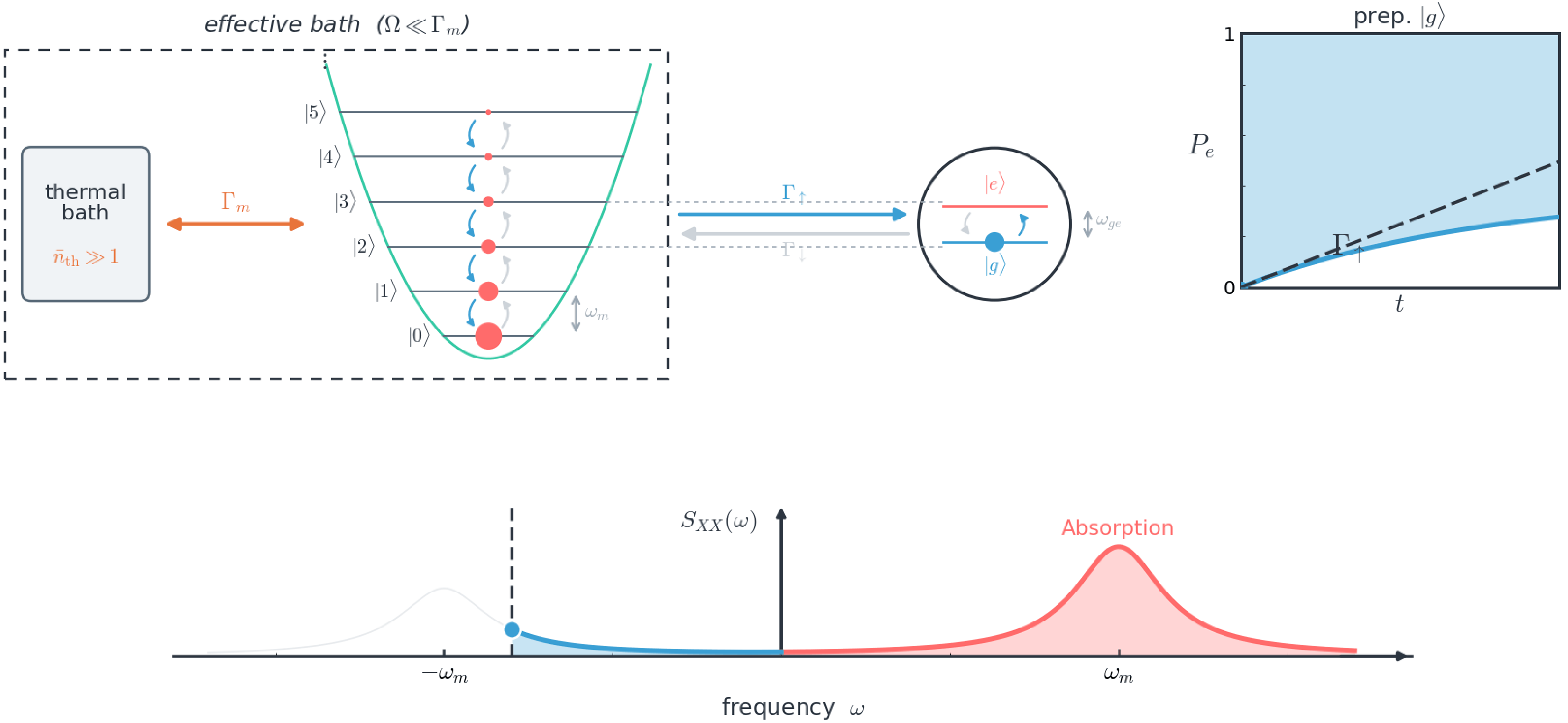

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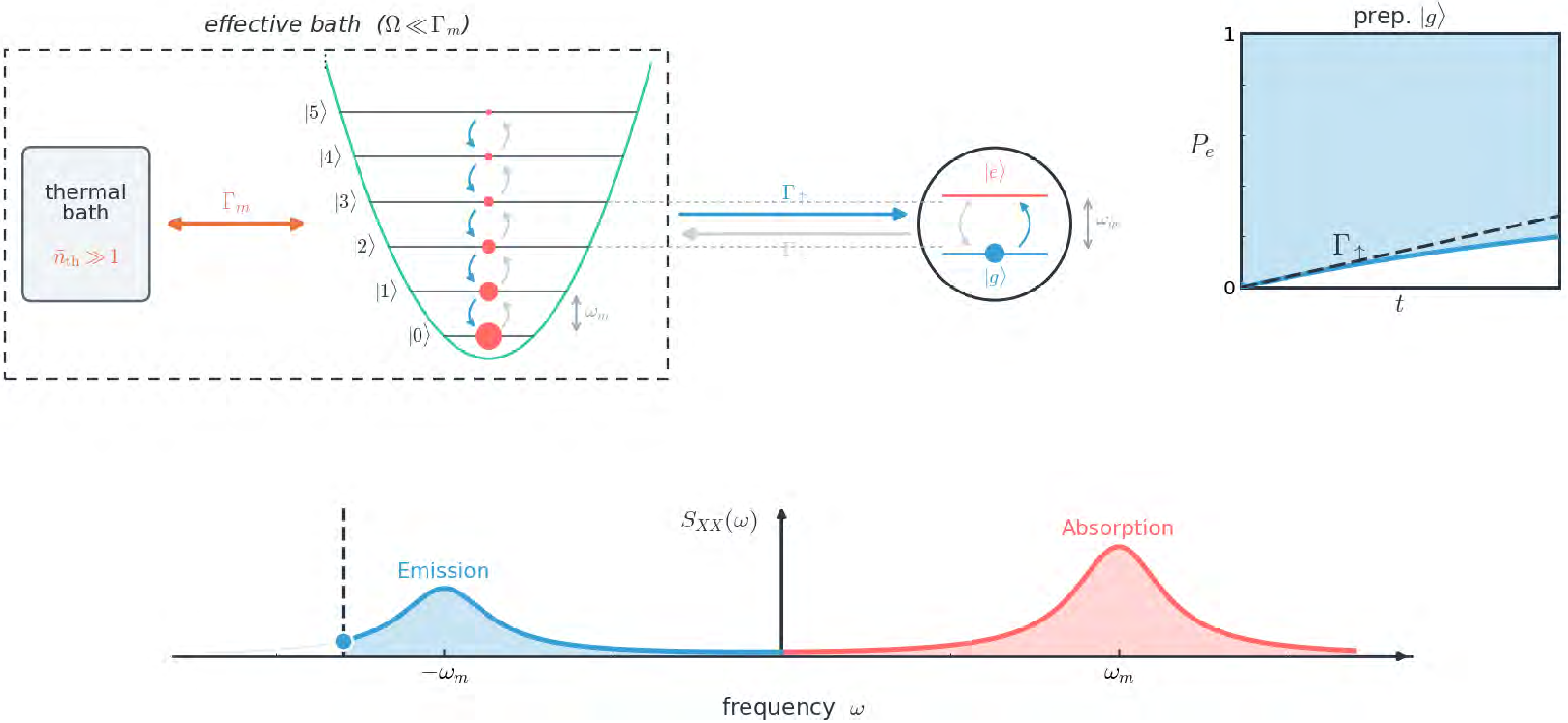

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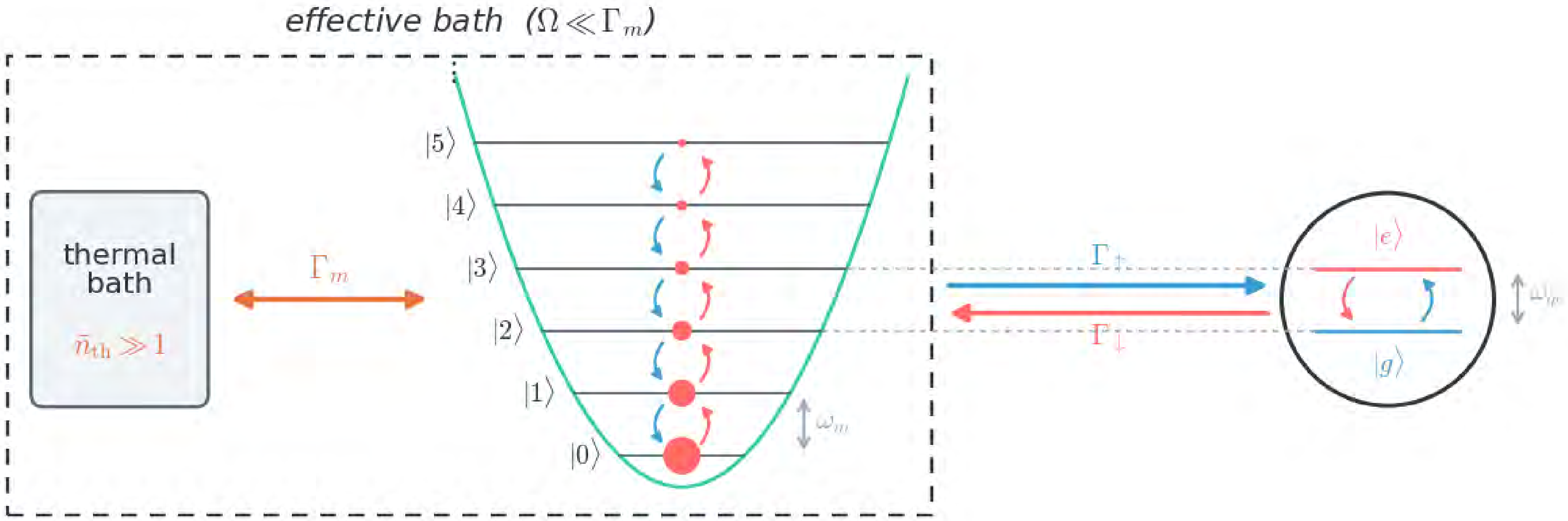

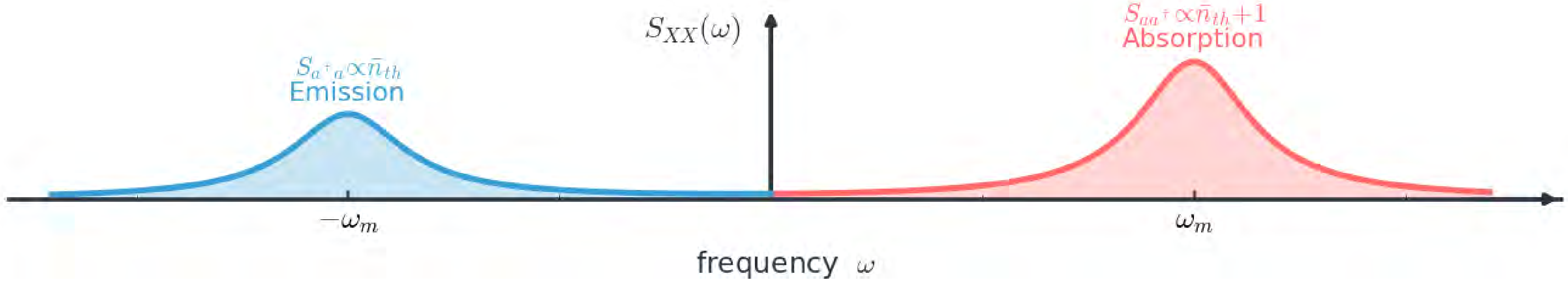

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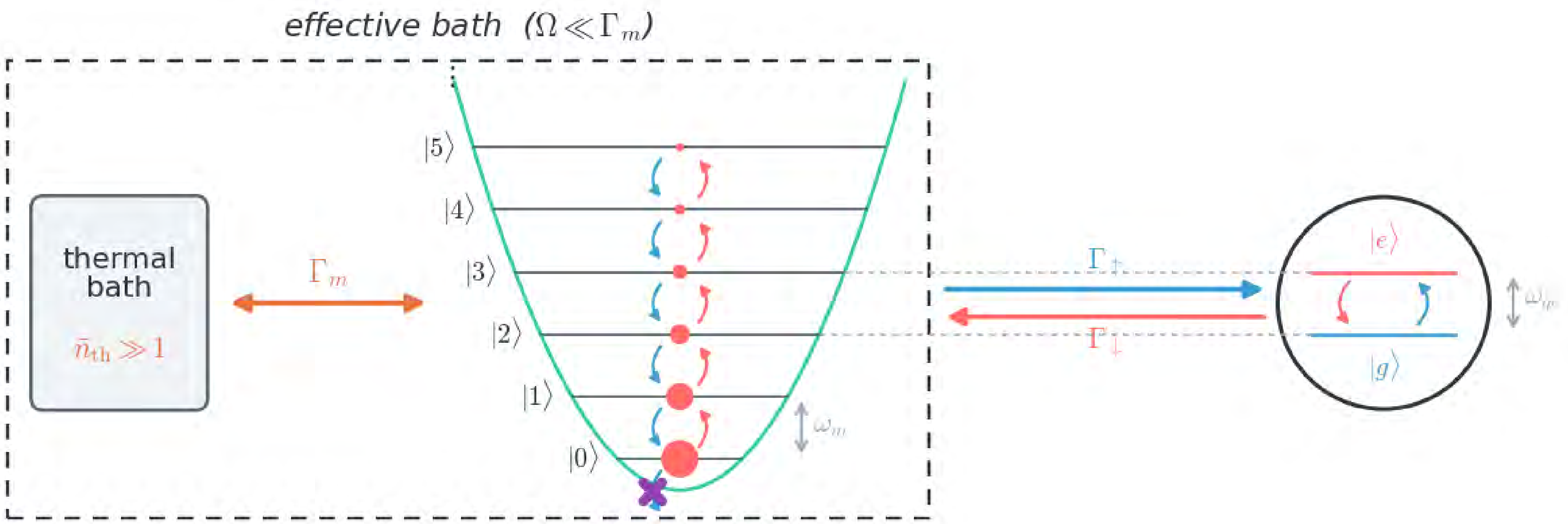

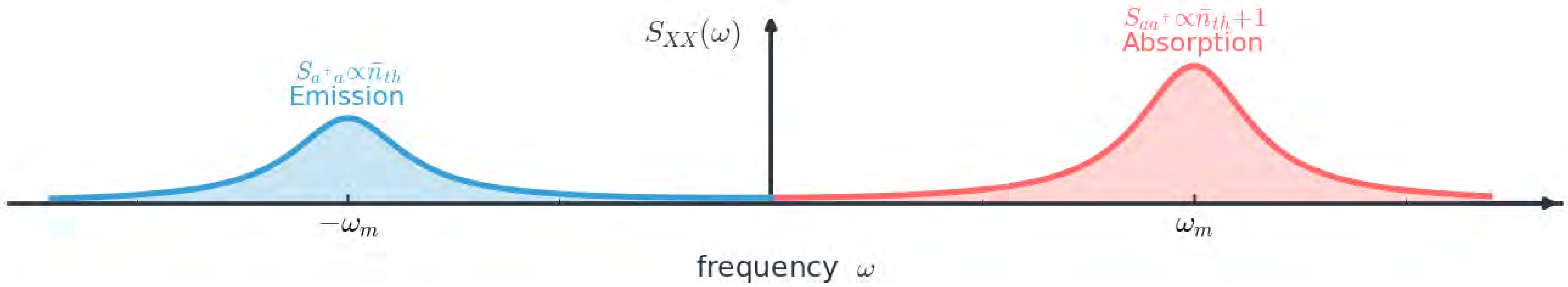

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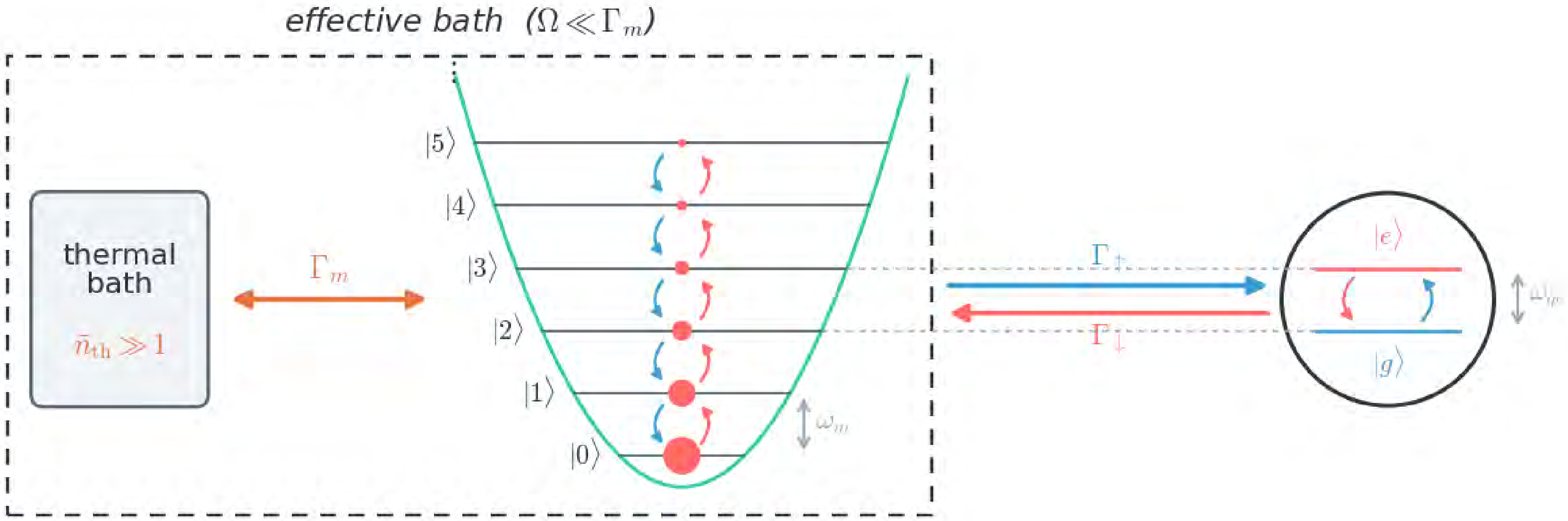
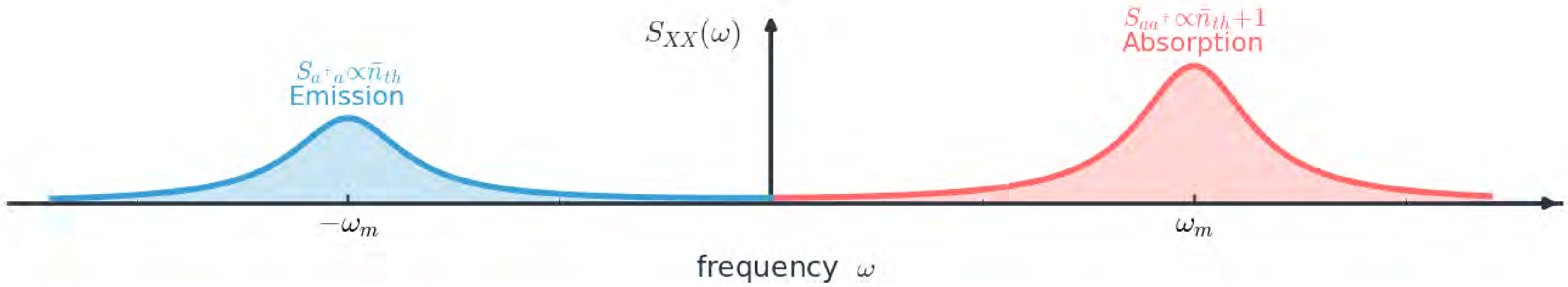


Quantum signature

$[a, a^\dagger] = 1$



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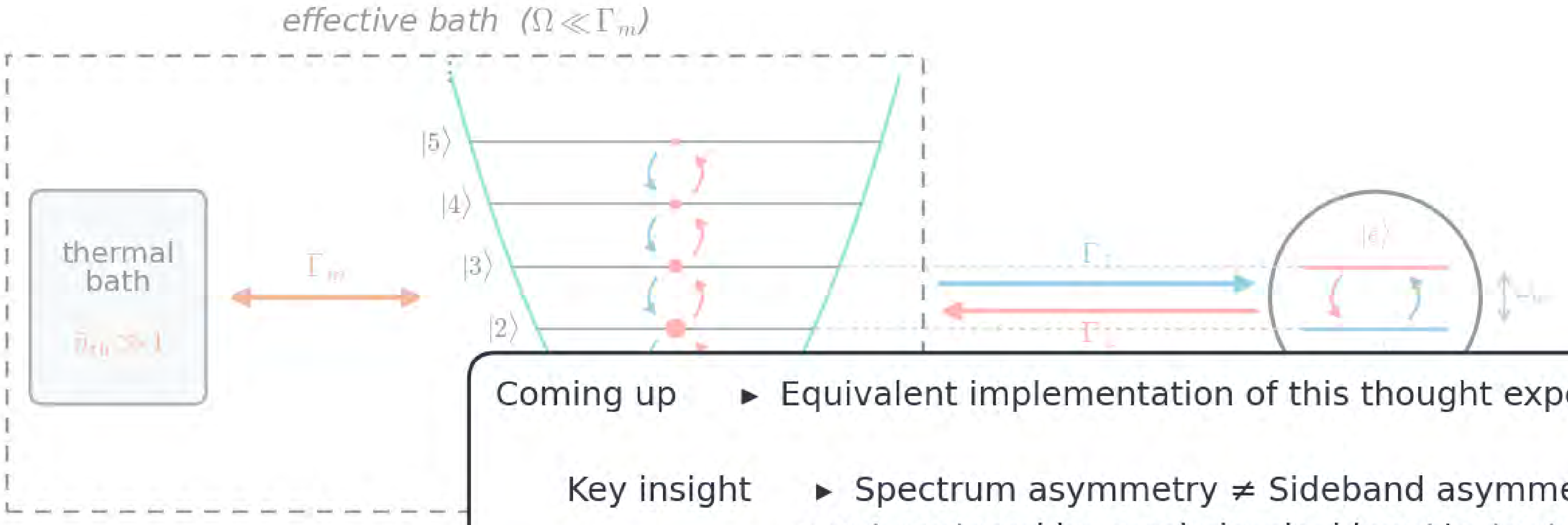
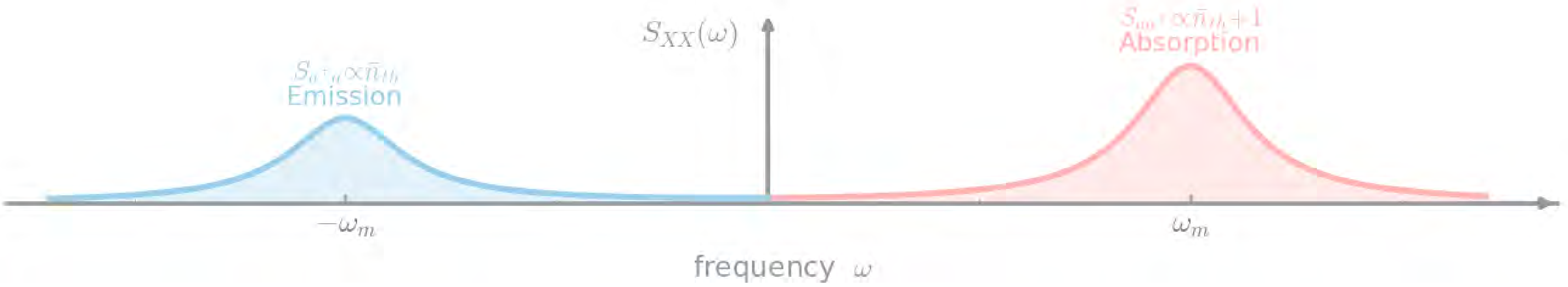


Coming up ▸ Equivalent implementation of this thought experiment

Key insight ▸ Spectrum asymmetry ≠ Sideband asymmetry
⇒ not captured by semi-classical input/output theory



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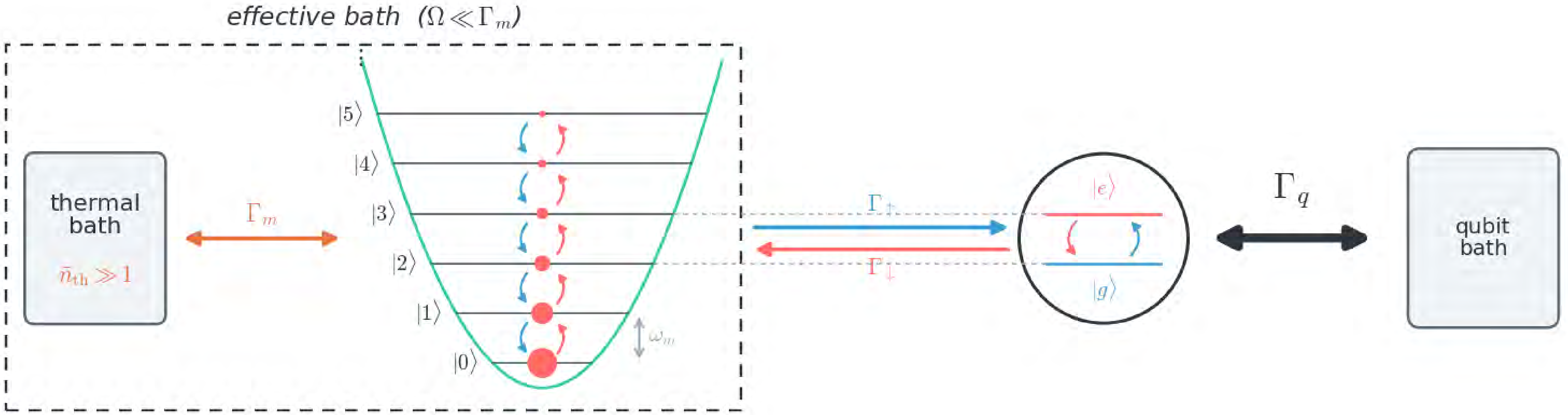

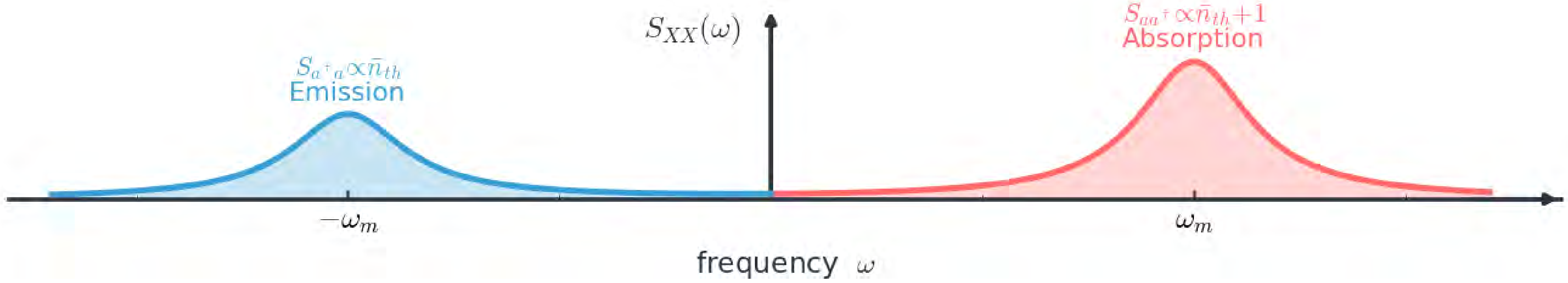

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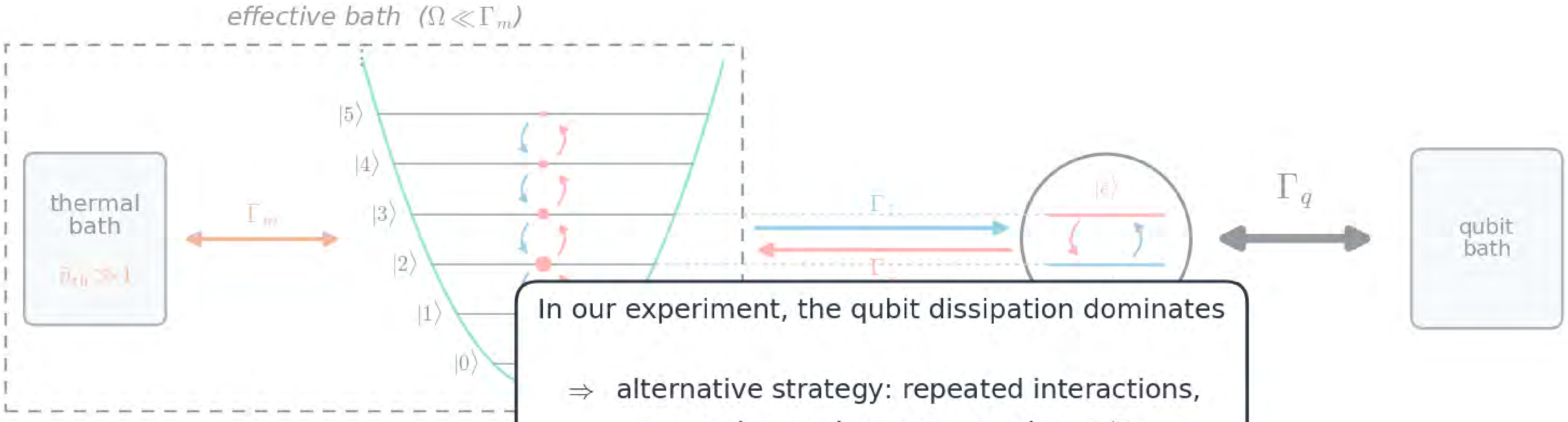
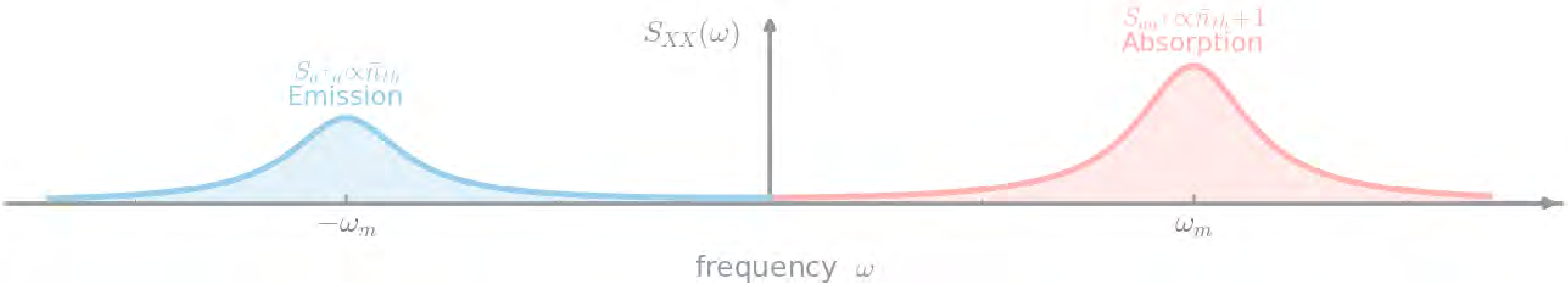


In our experiment, the qubit dissipation dominates

$\Rightarrow$ alternative strategy: repeated interactions, each one short compared to $1/\Gamma_q$



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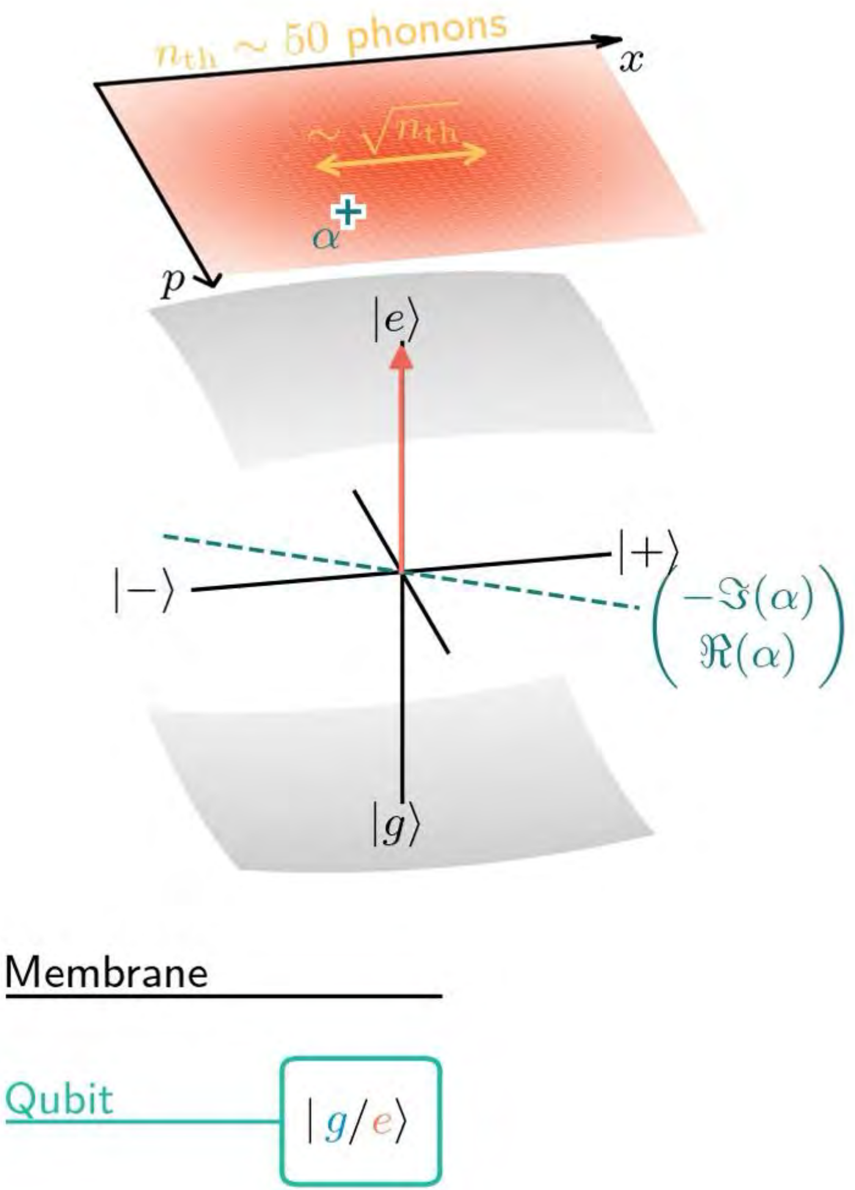
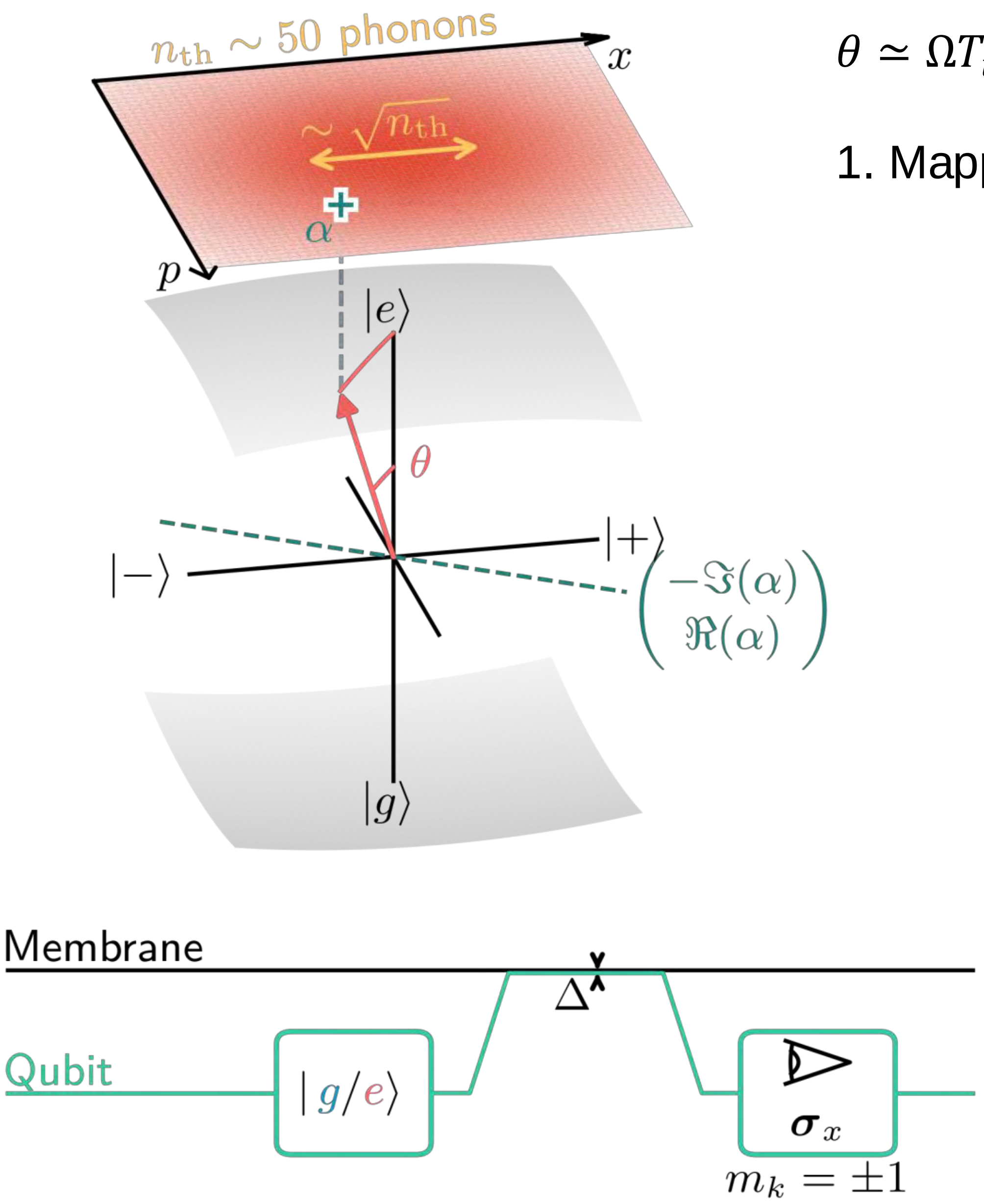
Spectrum analyzer measurement



$\theta \simeq \Omega T_{int}\sqrt{n_{th}} \approx 0.2 \text{ rad} \ll 1$

1. Mapping: $x \leftrightarrow \sigma_x$

Spectrum analyzer measurement



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2. Measure qubit σ_x projection

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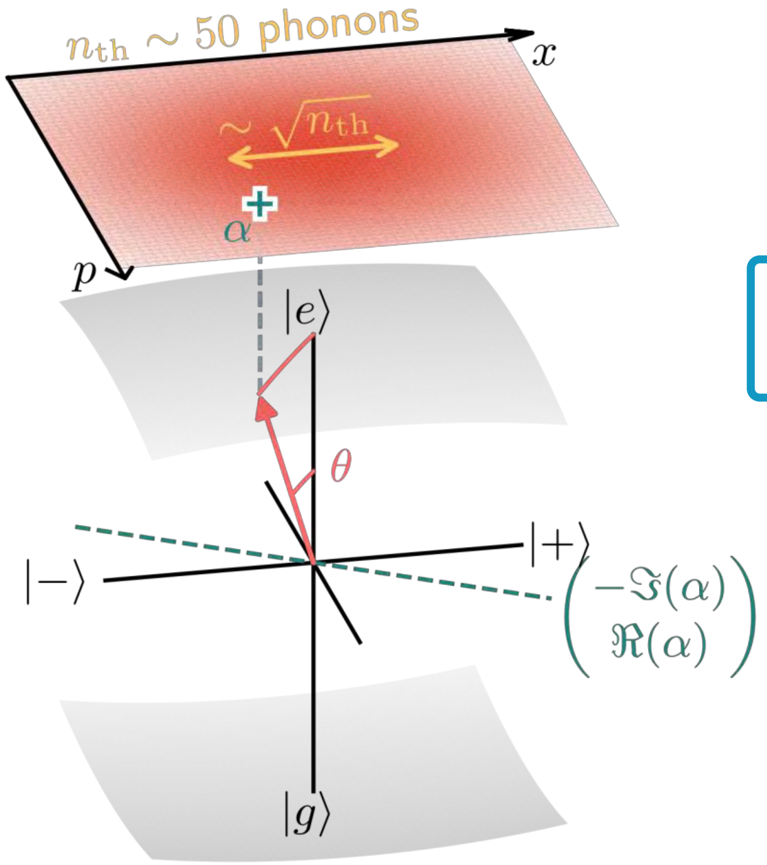

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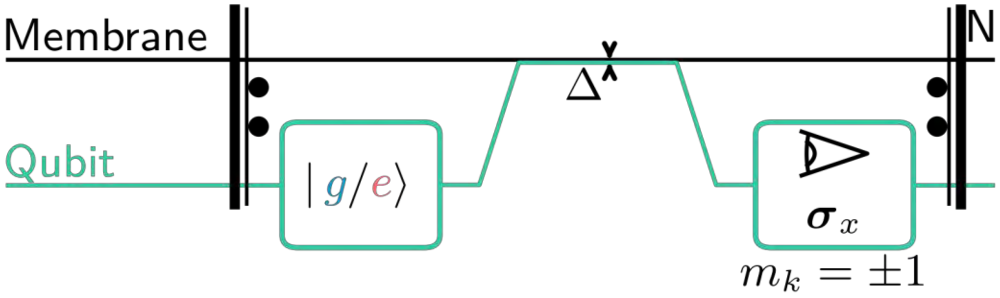
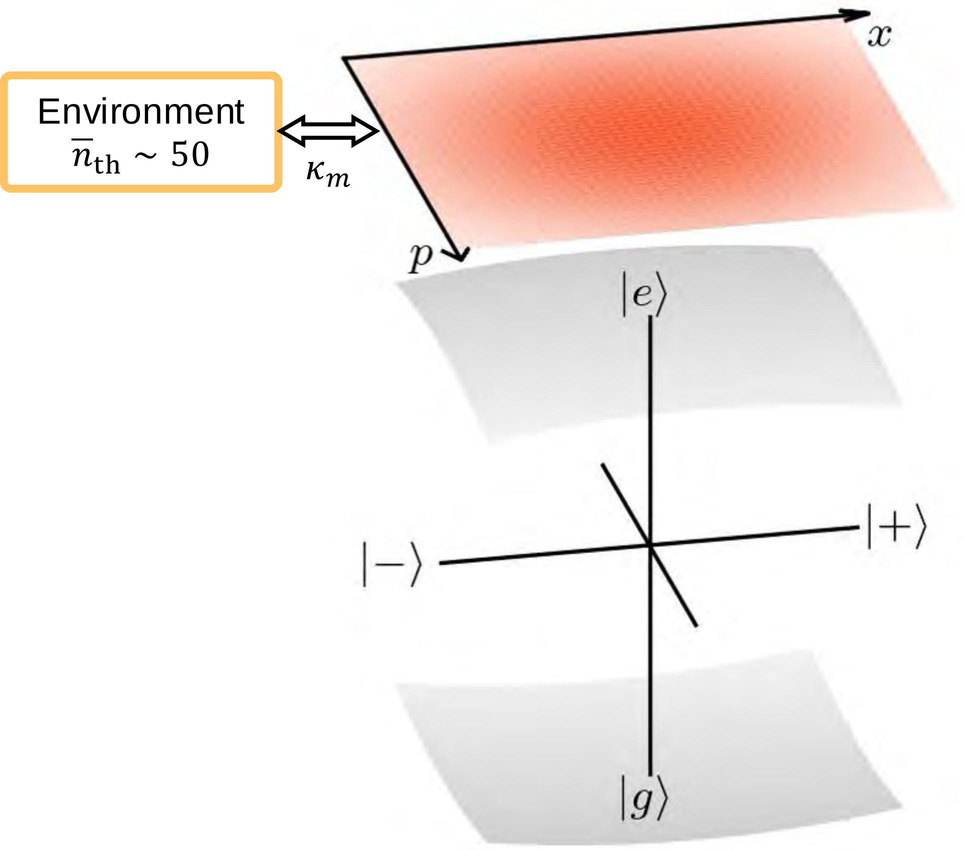
Each measurements yields **one bit** carrying **weak information**; however, we can accumulate **many detections** during $T_{1,m}$



Spectrum analyzer measurement



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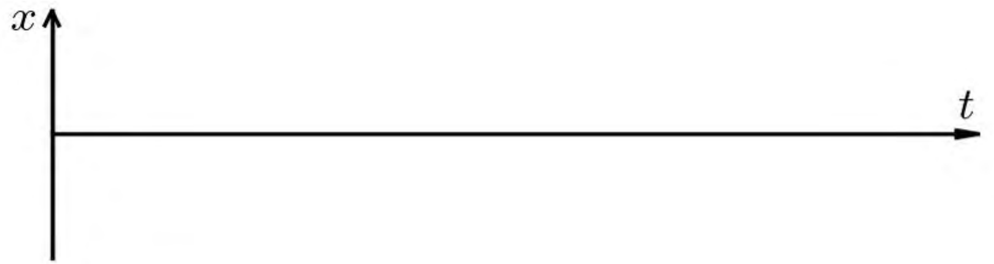
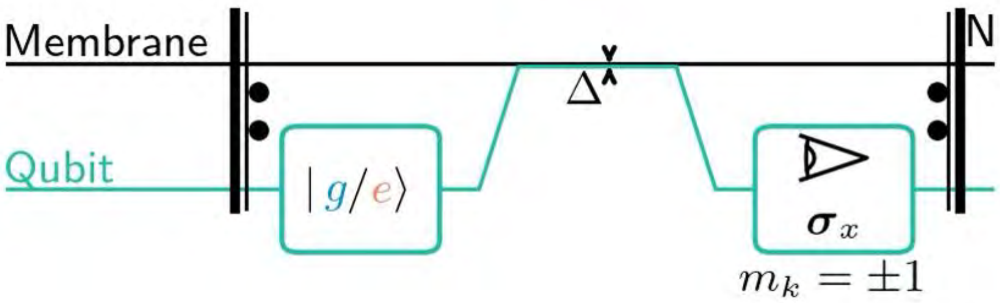
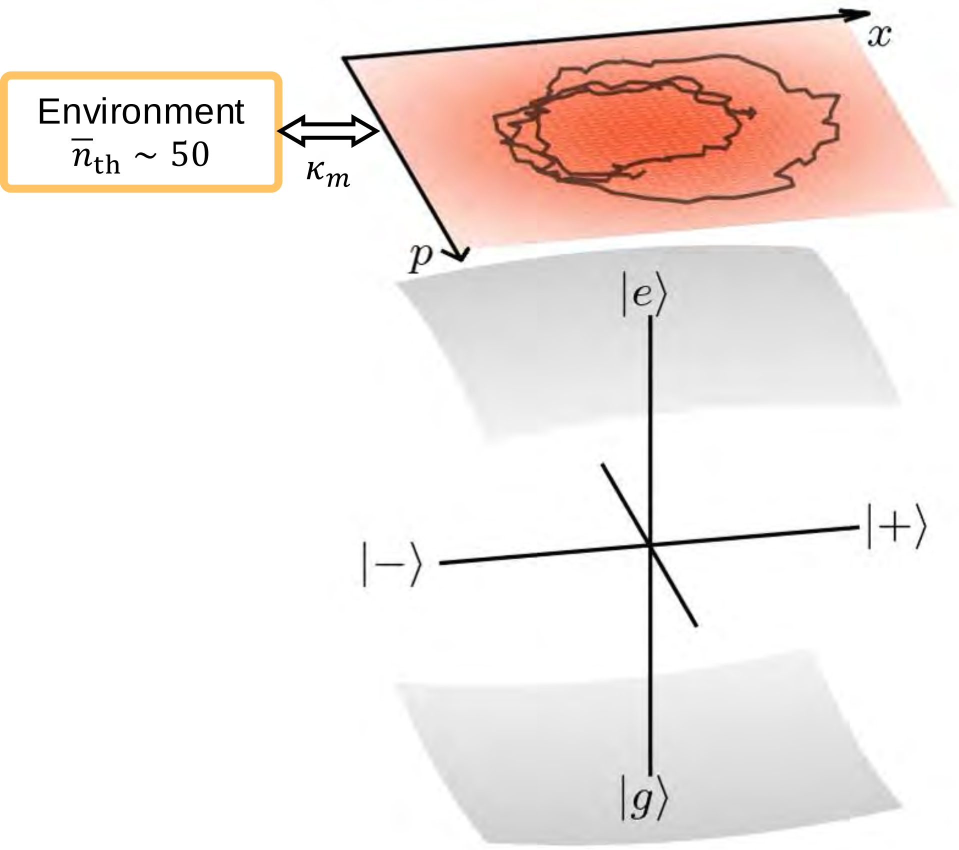




Spectrum analyzer measurement



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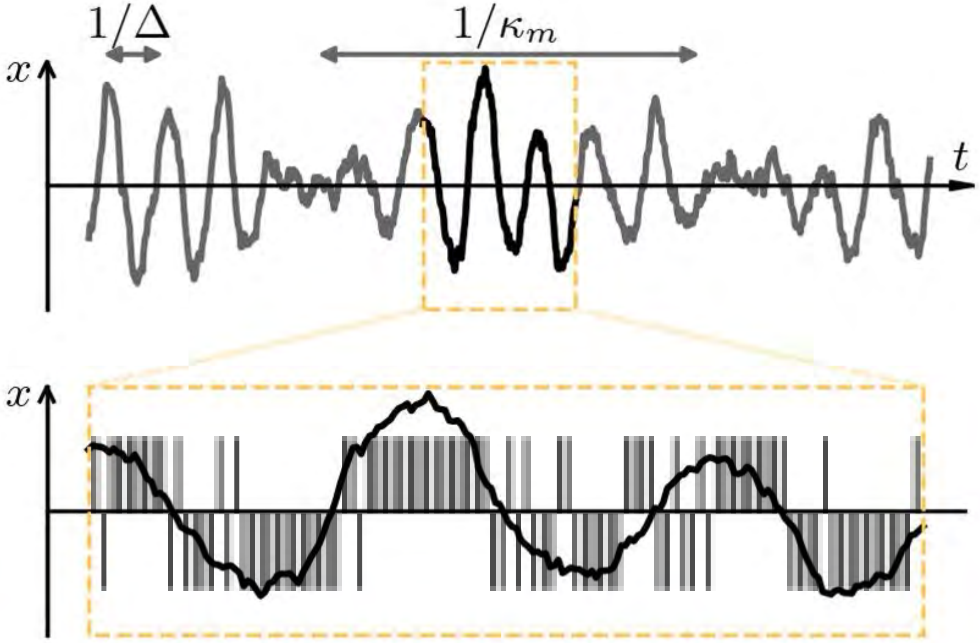

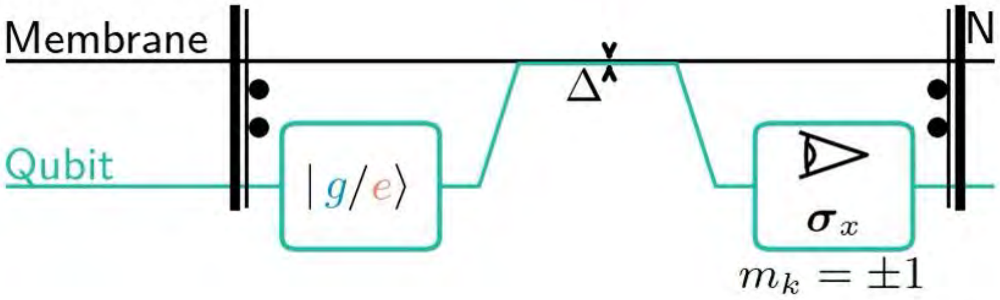

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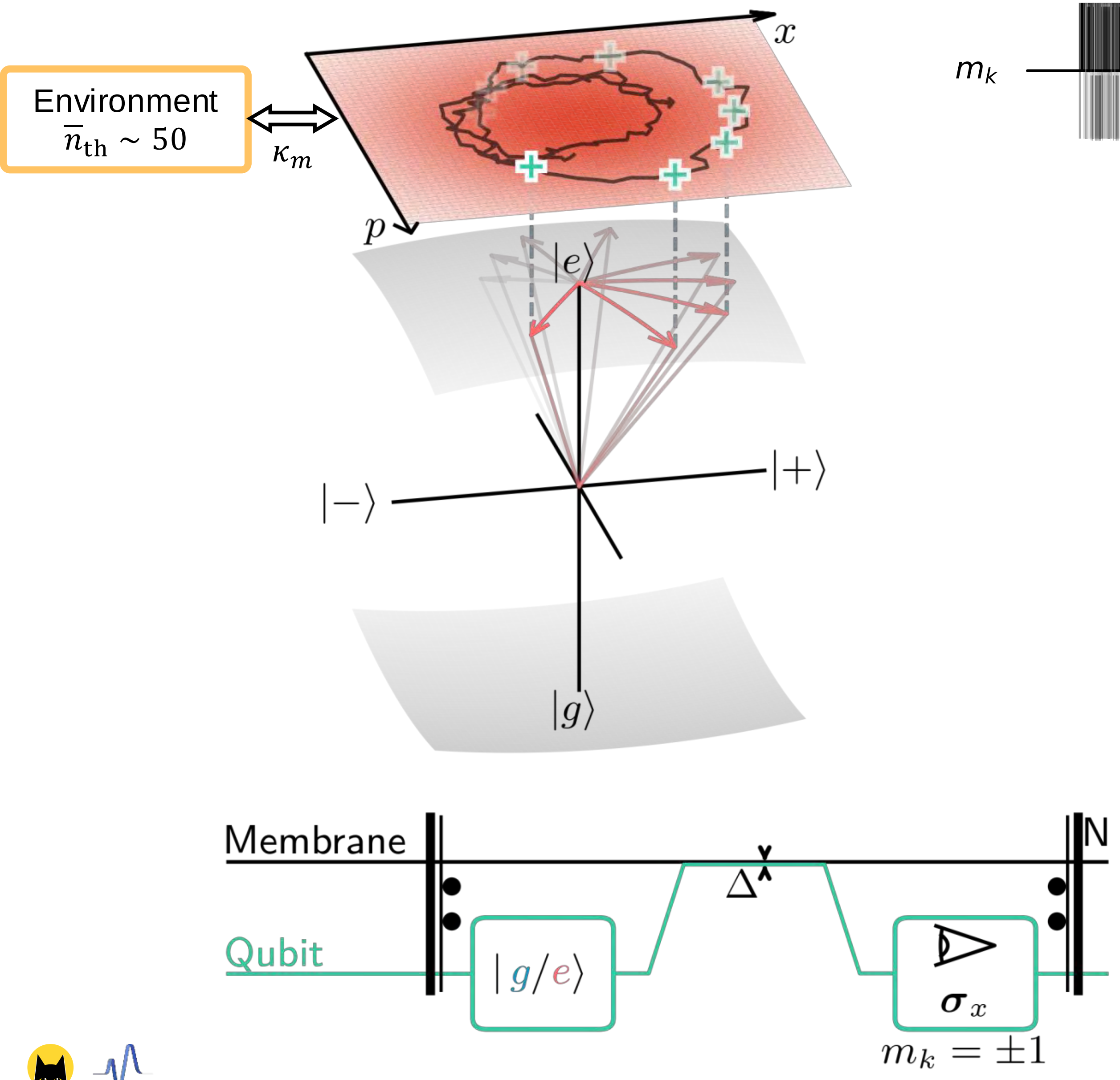

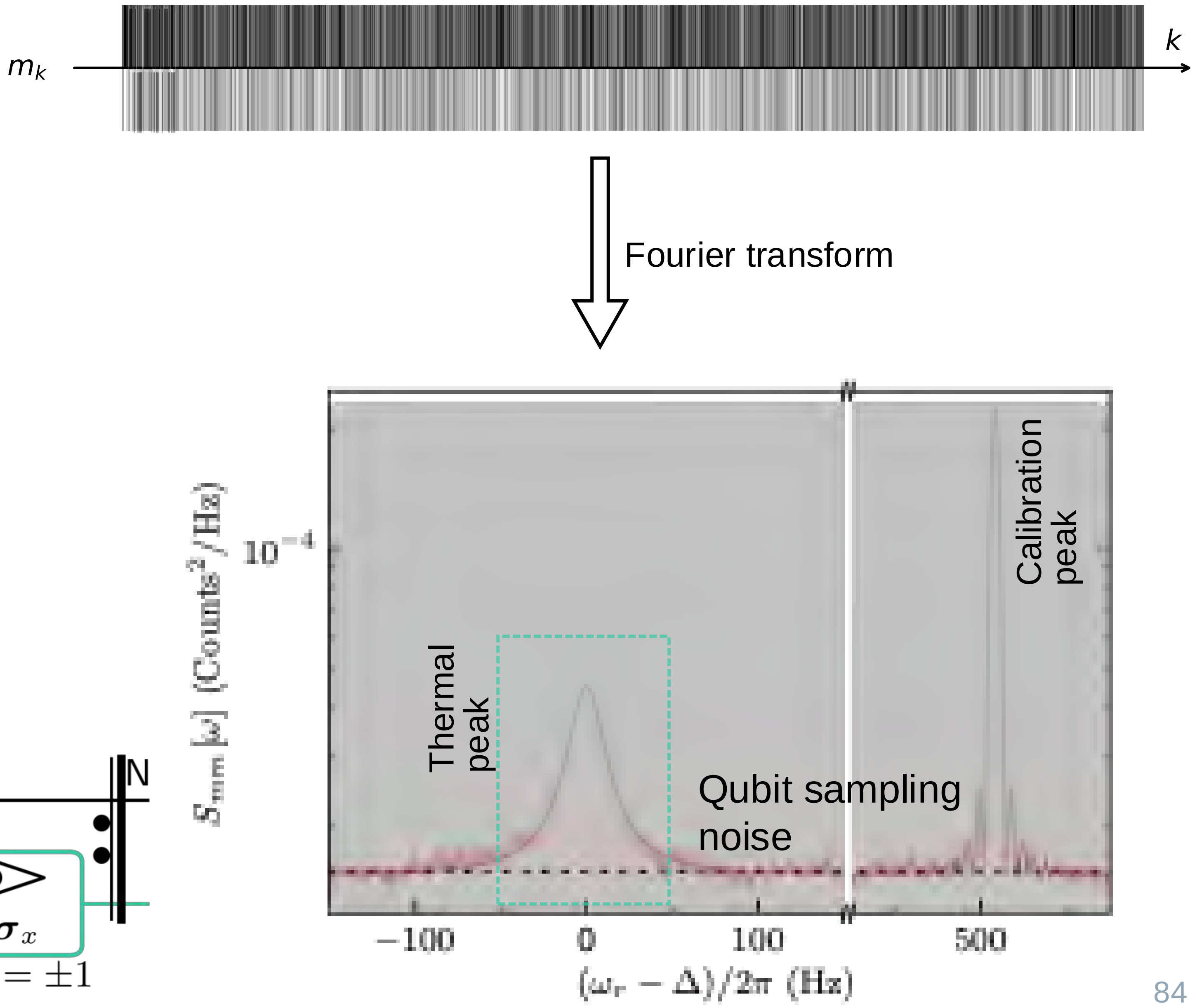

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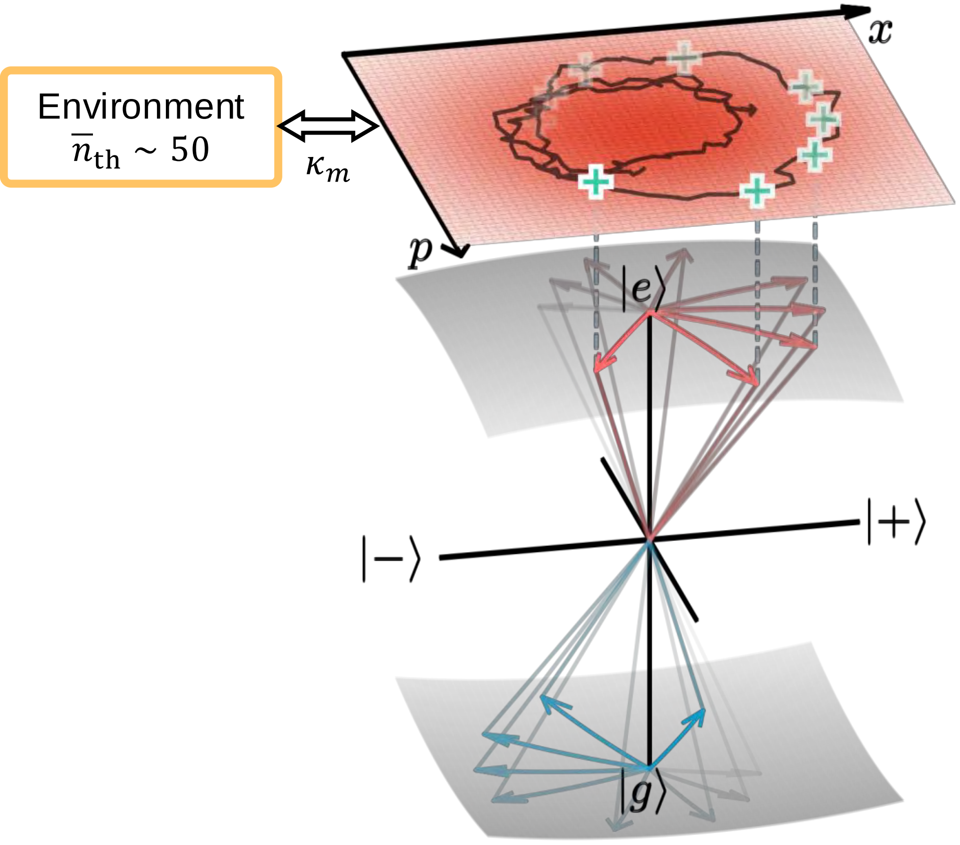

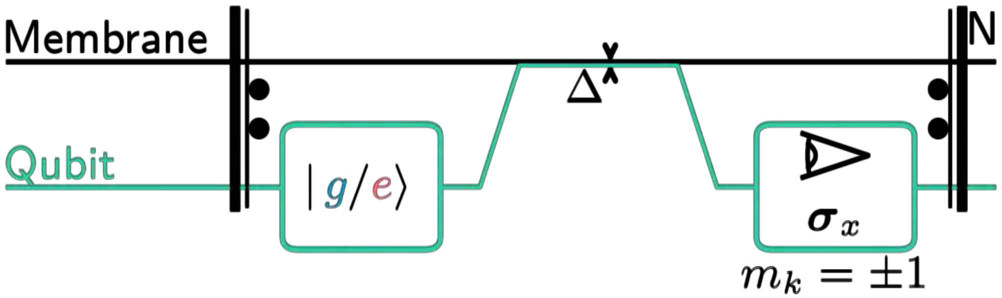

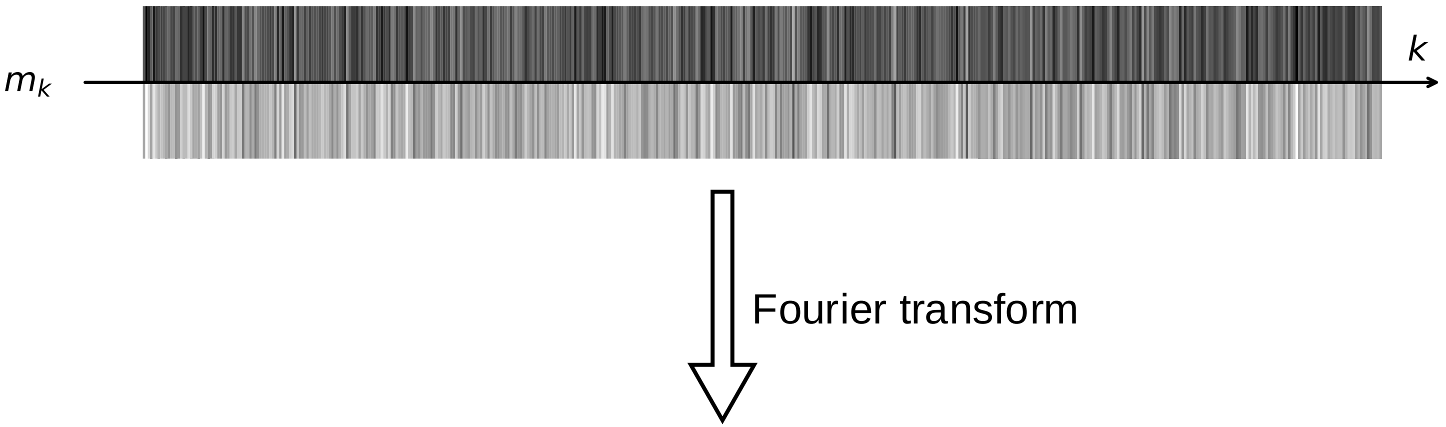

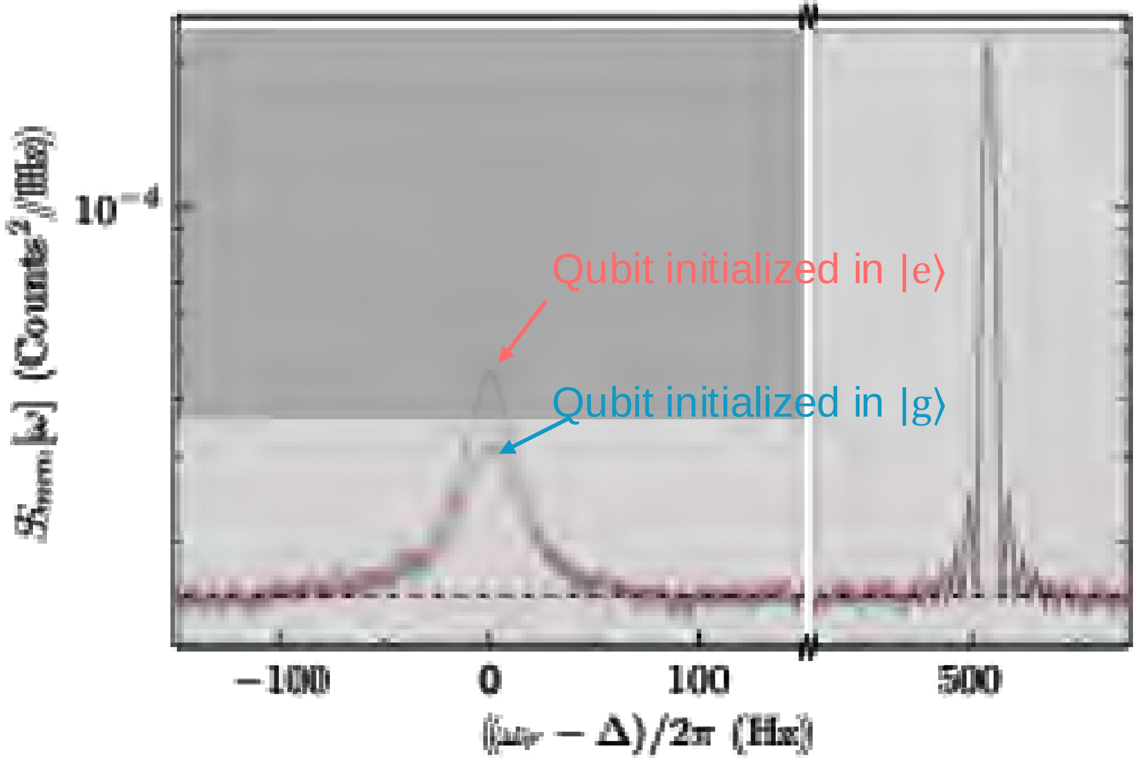

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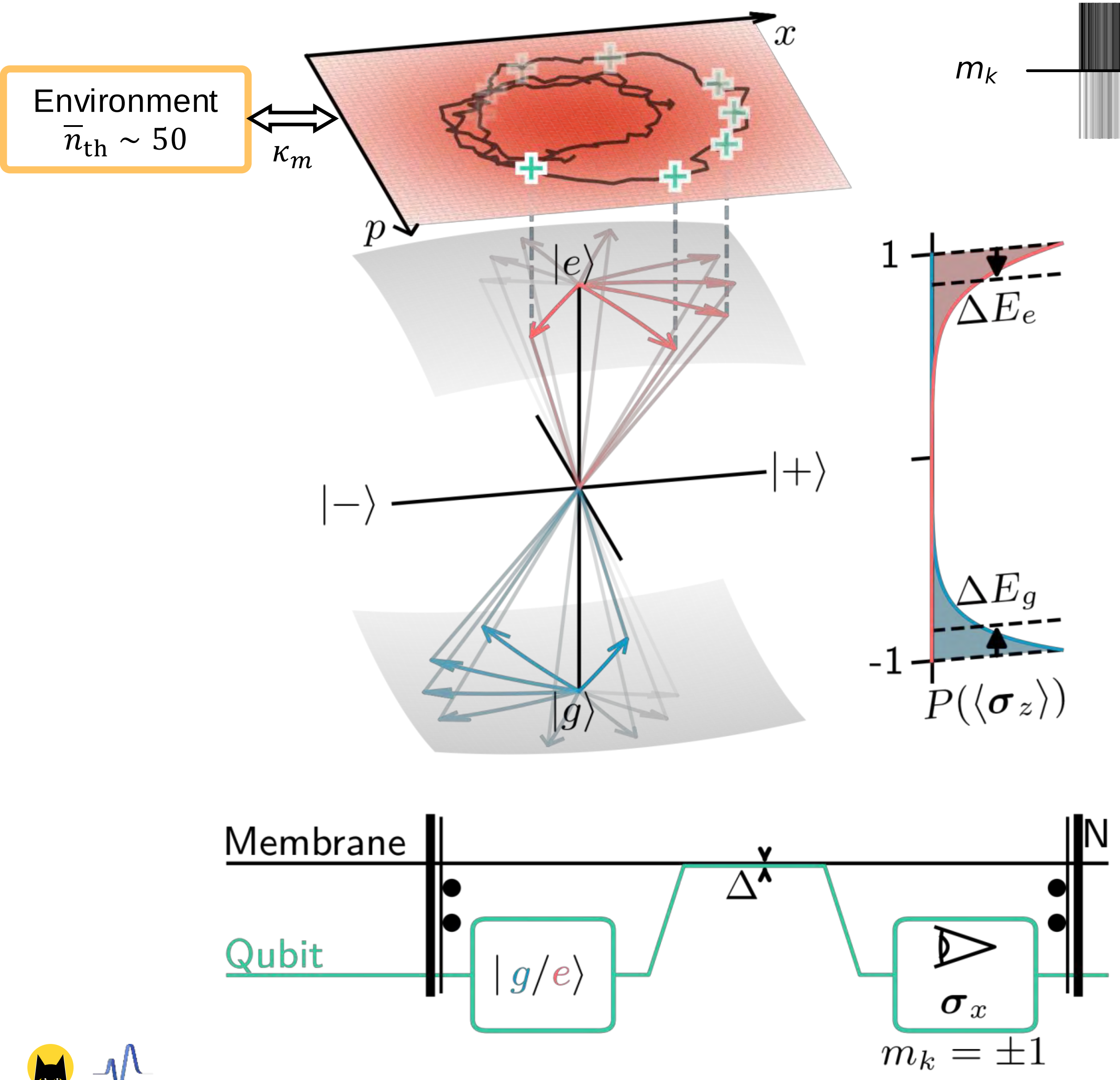

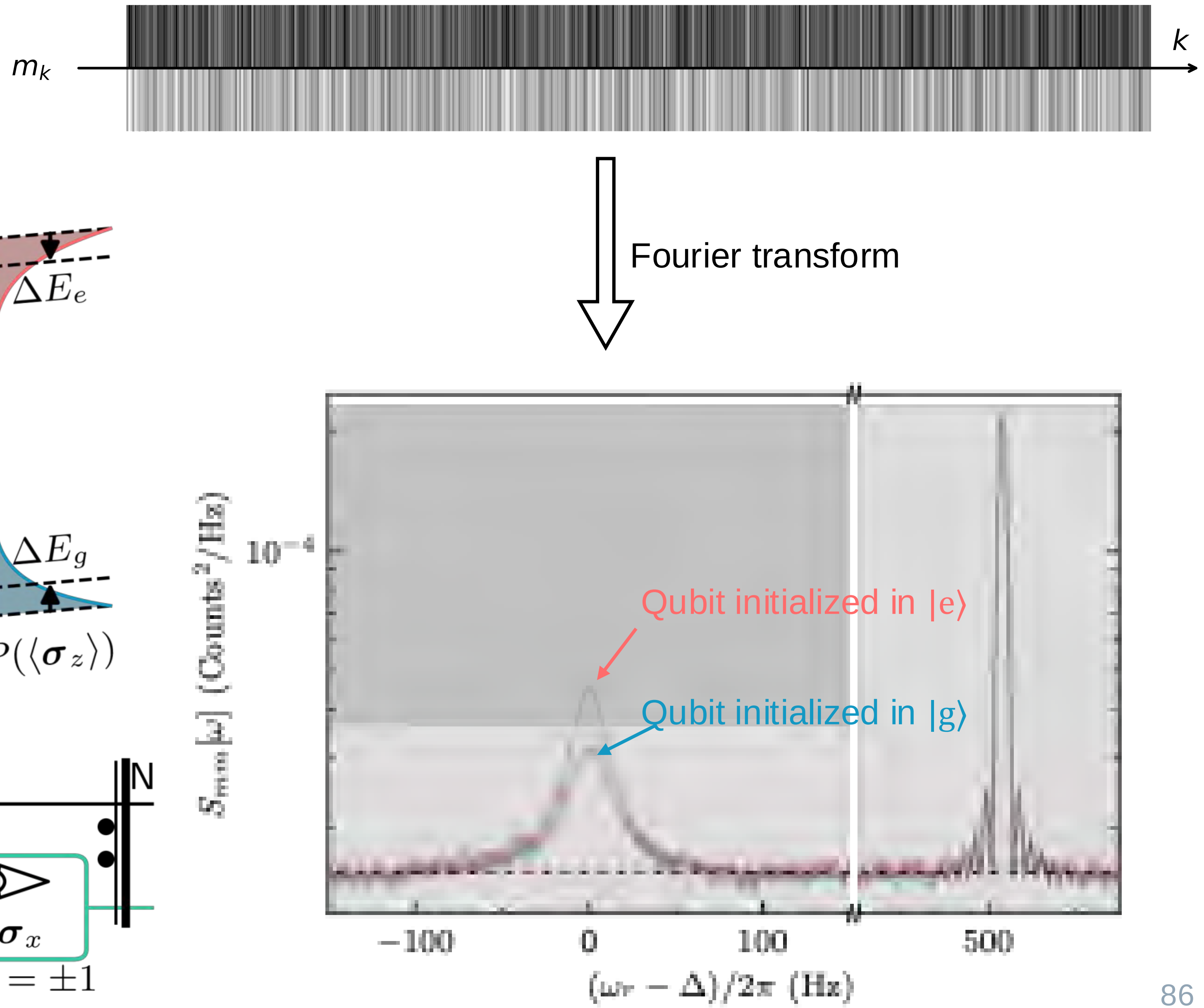

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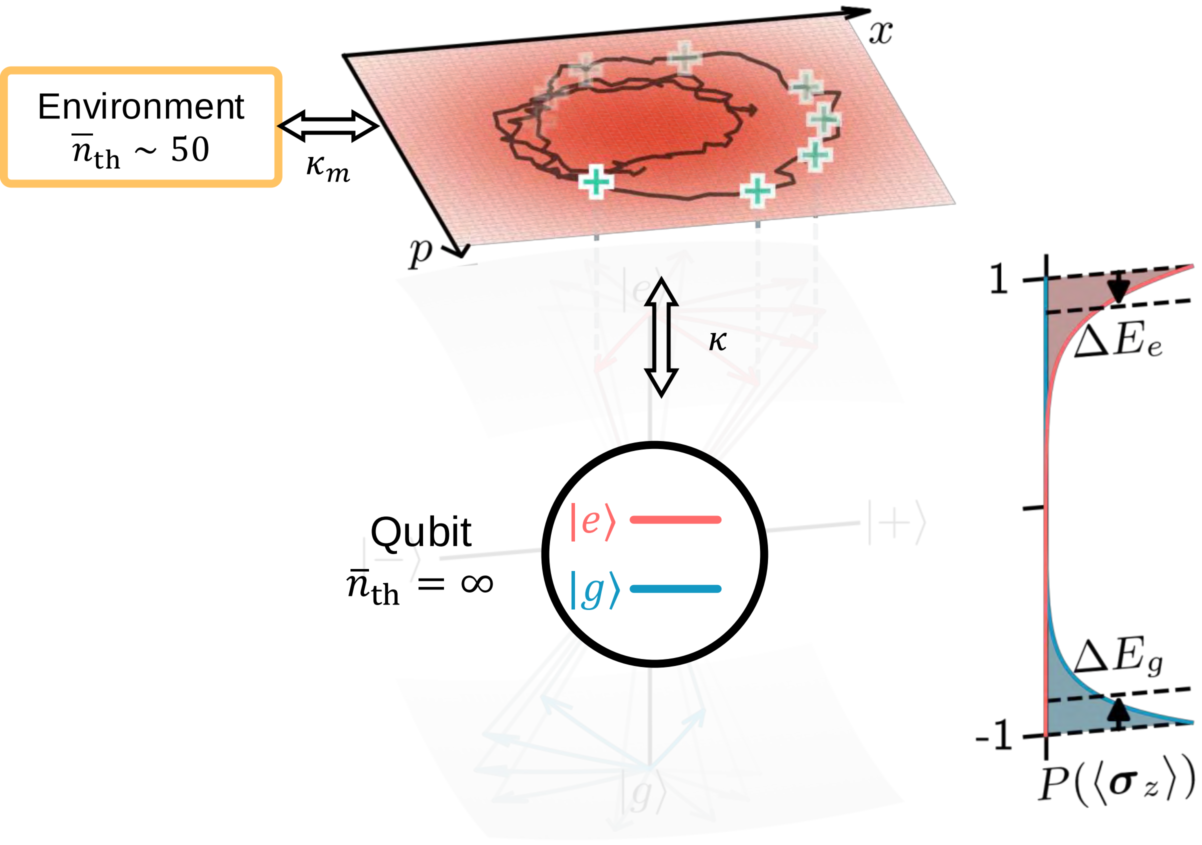
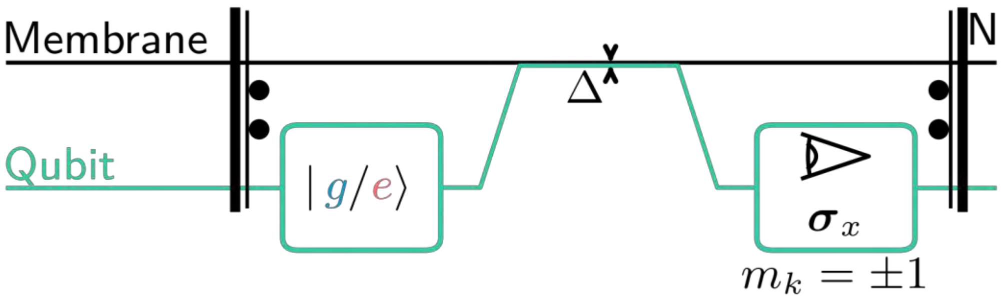




Mean energy exchange per cycle :

$$\Delta E_{g/e} = \pm n_{\text{th}} (\Omega T_{\text{int}})^2$$

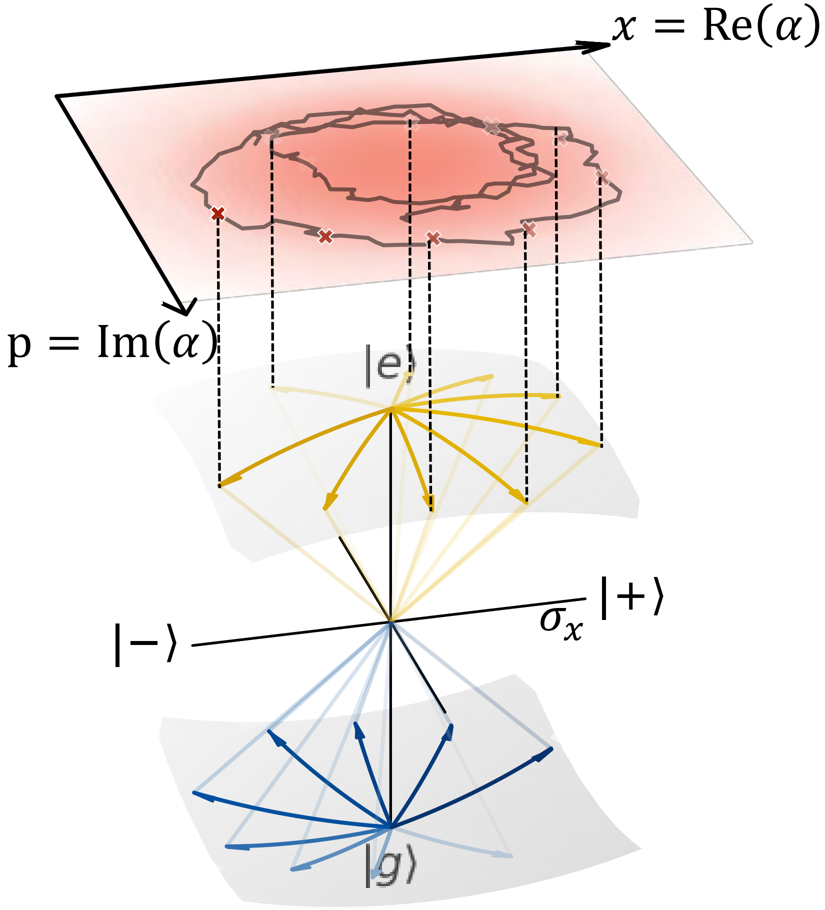
Qubit induced damping/amplification at rate :

$$\kappa = \pm (\Omega T_{\text{int}})^2 / T_{\text{cycle}}$$

Similar to dynamical back action in optomechanics

Semi-classical model

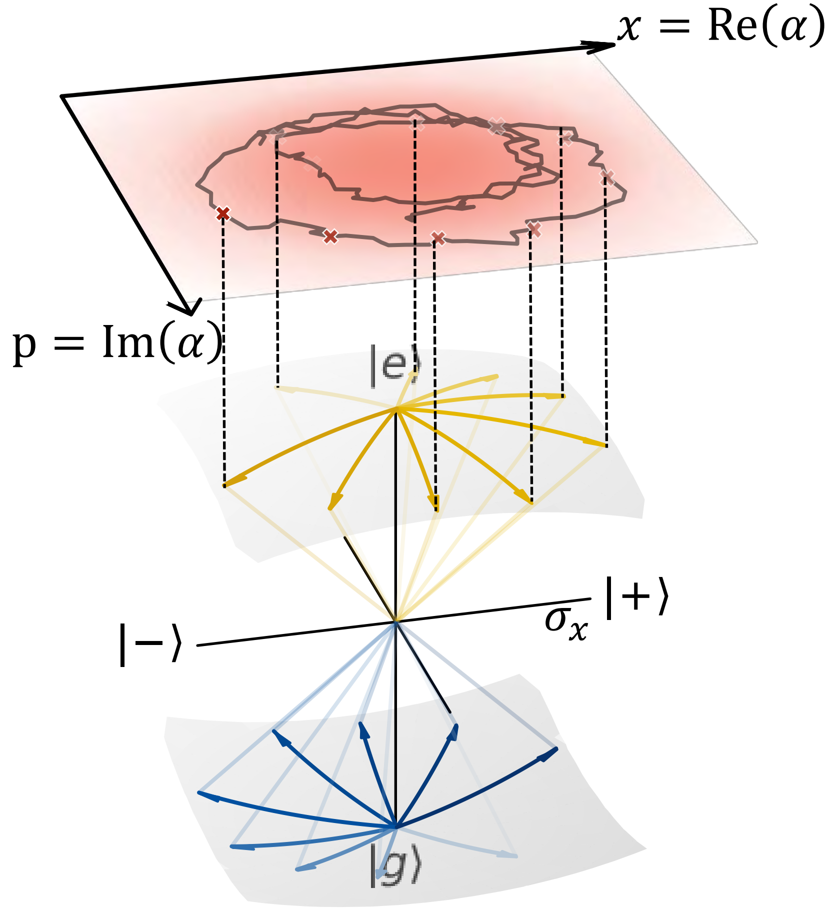
$$\boldsymbol{H}/\hbar = i\frac{\Omega}{2}(\alpha^* \boldsymbol{\sigma}_- - \alpha\, \boldsymbol{\sigma}_+)$$



Beyond the semi-classical model

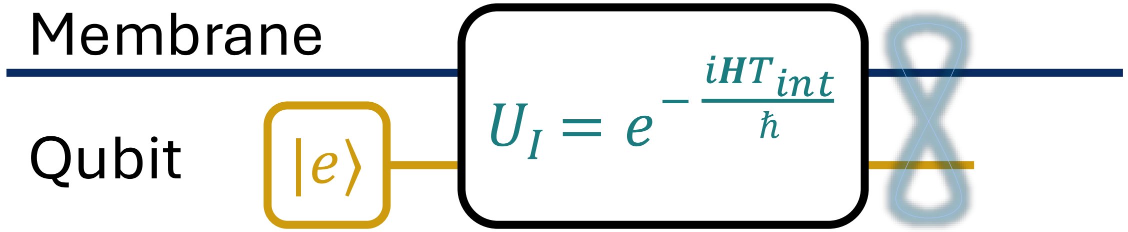
Semi-classical model

$$\boldsymbol{H}/\hbar = i\frac{\Omega}{2}(\alpha^{*}\boldsymbol{\sigma}_{-} - \alpha\,\boldsymbol{\sigma}_{+})$$



Quantum model

$$H/\hbar = i\frac{\Omega}{2}(\boldsymbol{a}^{\dagger}\boldsymbol{\sigma}_{-} - \boldsymbol{a}\,\boldsymbol{\sigma}_{+})$$



- Some (small amount) of entanglement is generated by the interaction

Beyond the semi-classical model

Semi-classical model

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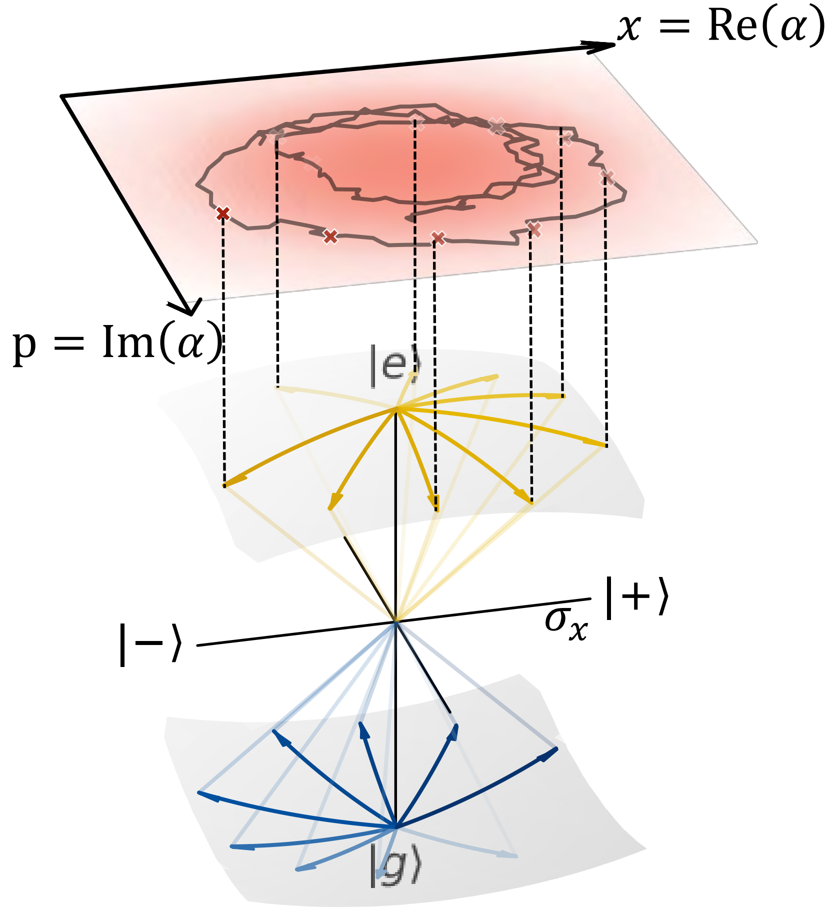

Quantum model

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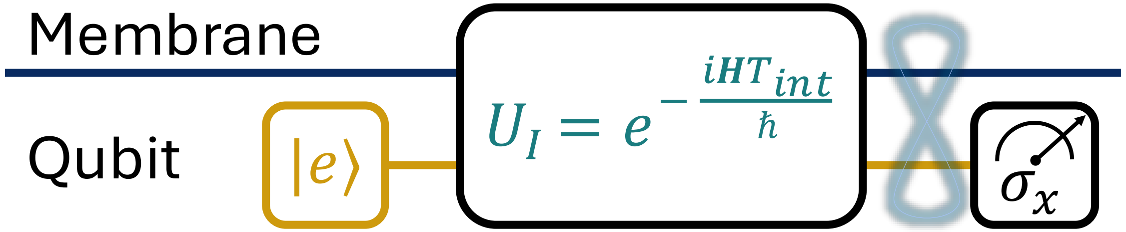


- Some (small amount) of entanglement is generated by the interaction

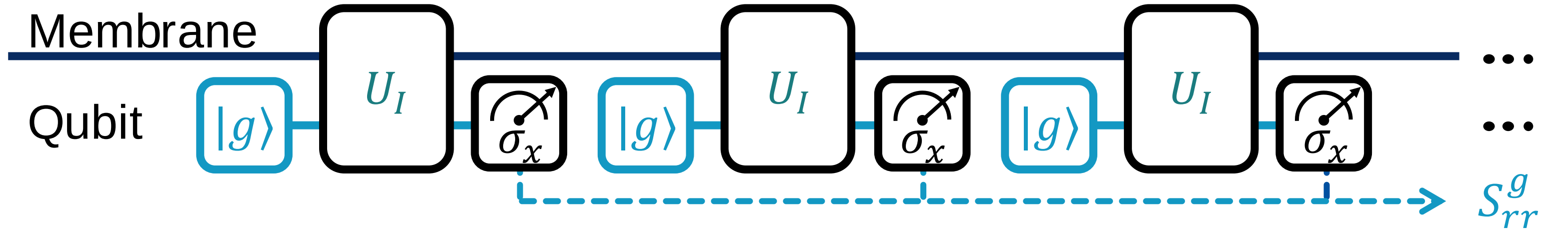
- The qubit projective measurement steers the membrane state in a conditional state that depends on the measurement outcome ($|+\rangle_x$ or $|-\rangle_x$)

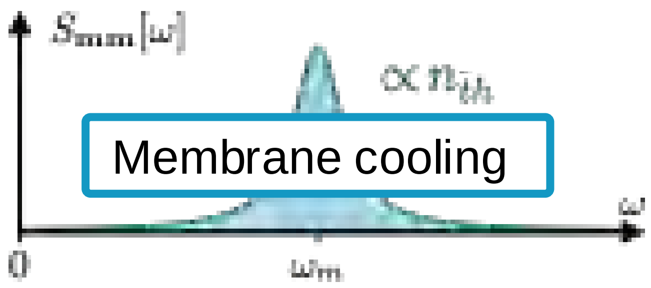
→ Quantum backaction

P. Rouchon A tutorial introduction to quantum stochastic master equations based on the qubit/photon system. Annual Reviews in Control ***54****, 2022, P. 252-261*

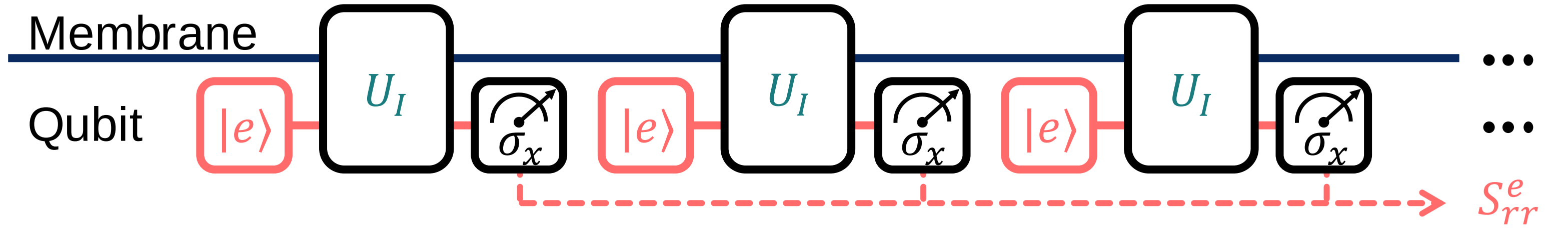
Mitigating dynamical backaction

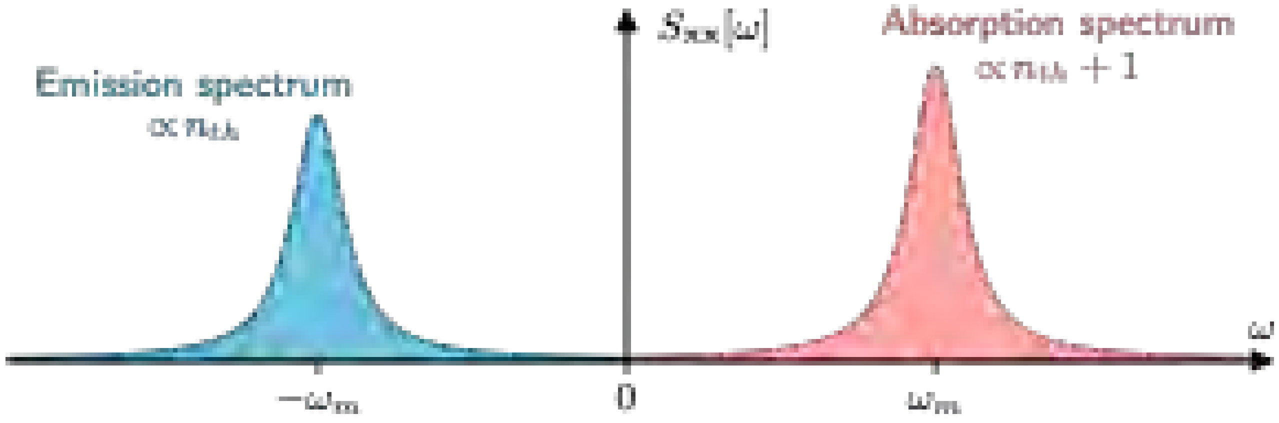
Preparation in $|g\rangle$:





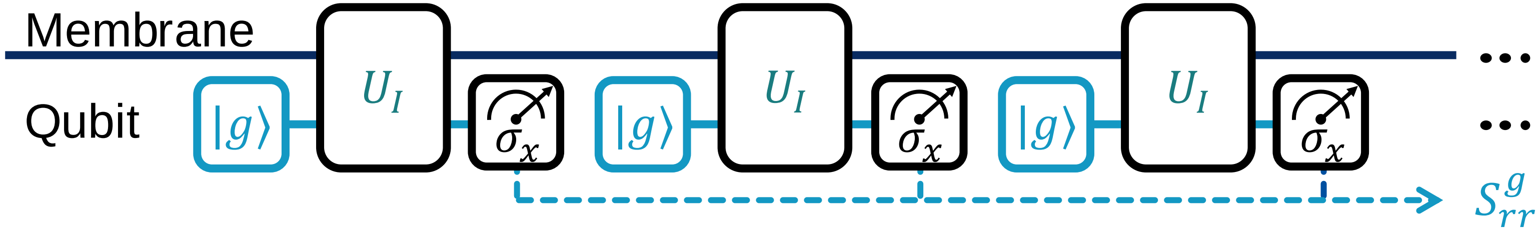
Preparation in $|e\rangle$:



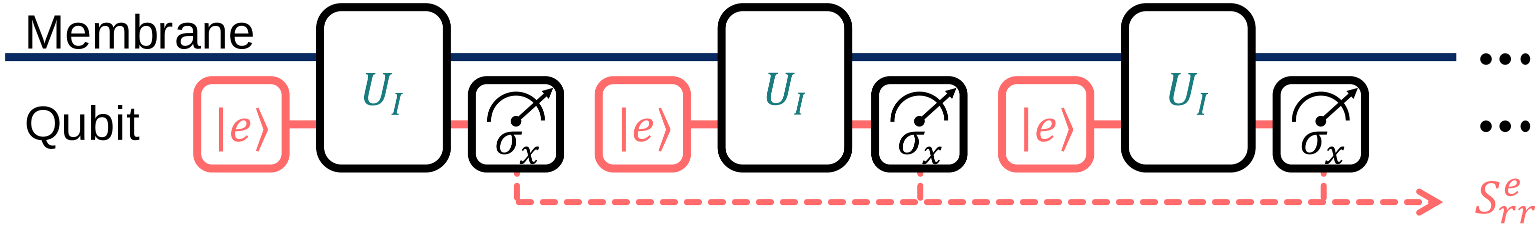


Mitigating dynamical backaction

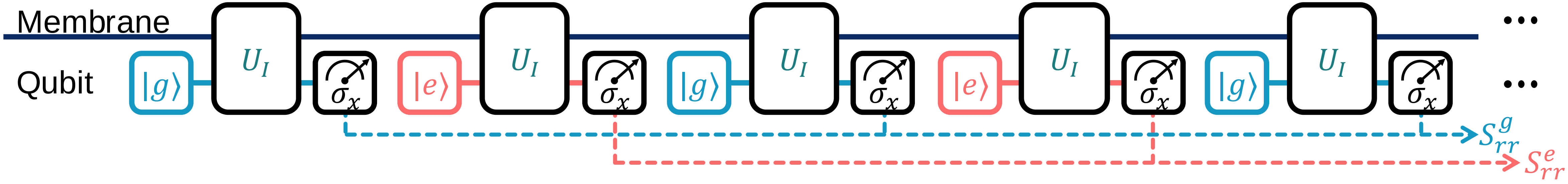
Preparation in $|g\rangle$:



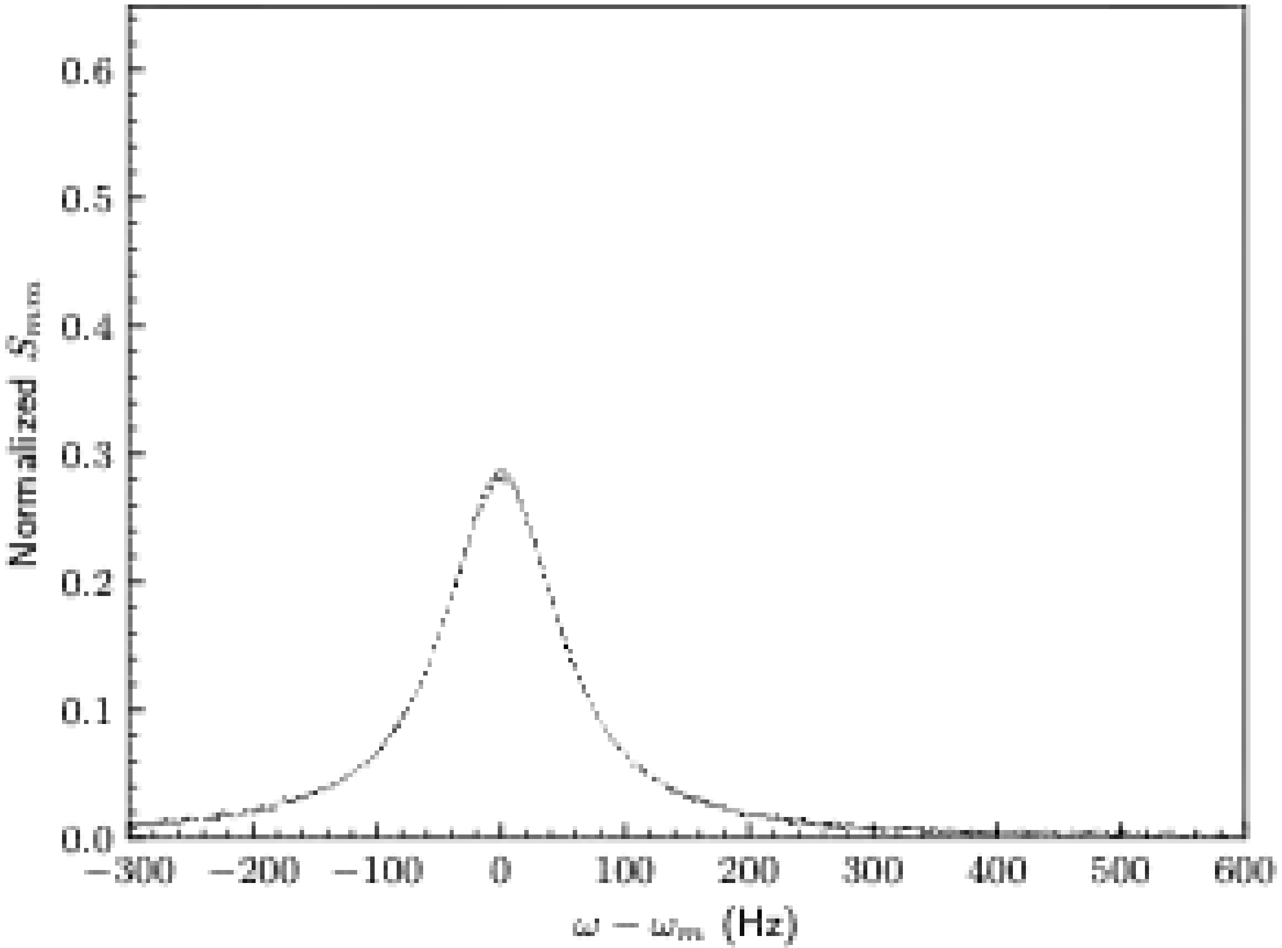
Preparation in $|e\rangle$:

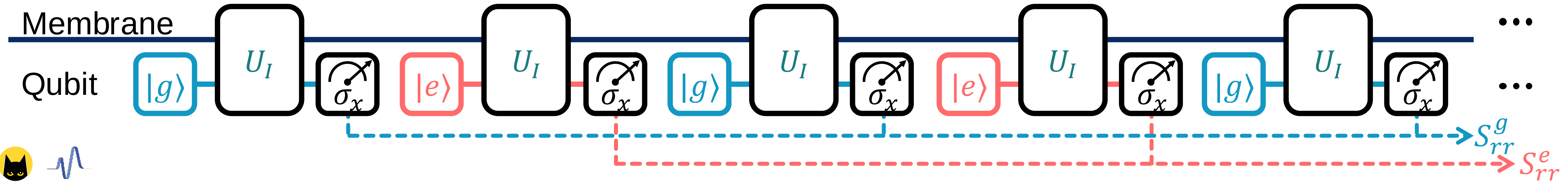


Alternating qubit state preparation:

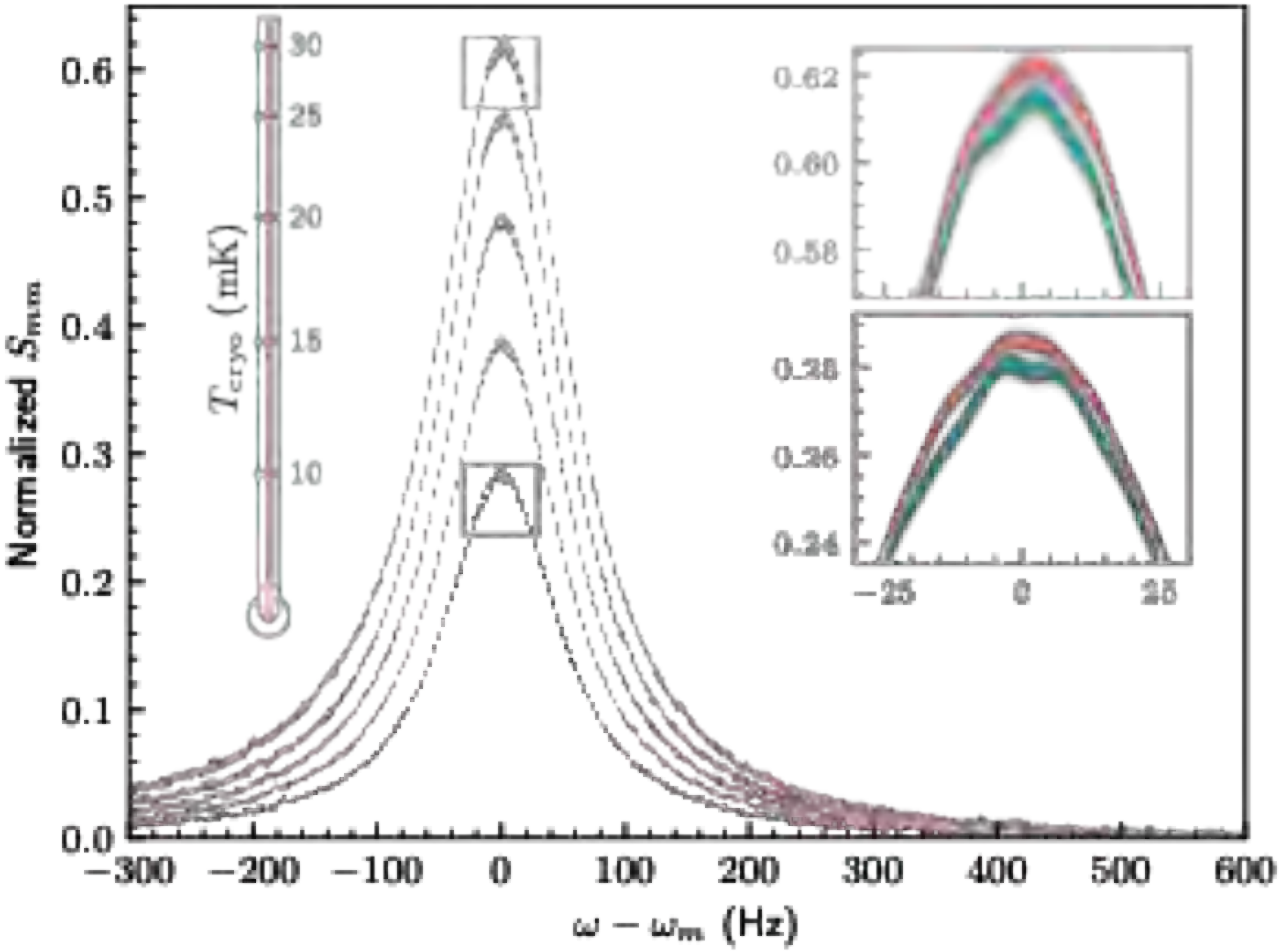


Spectrum asymmetry





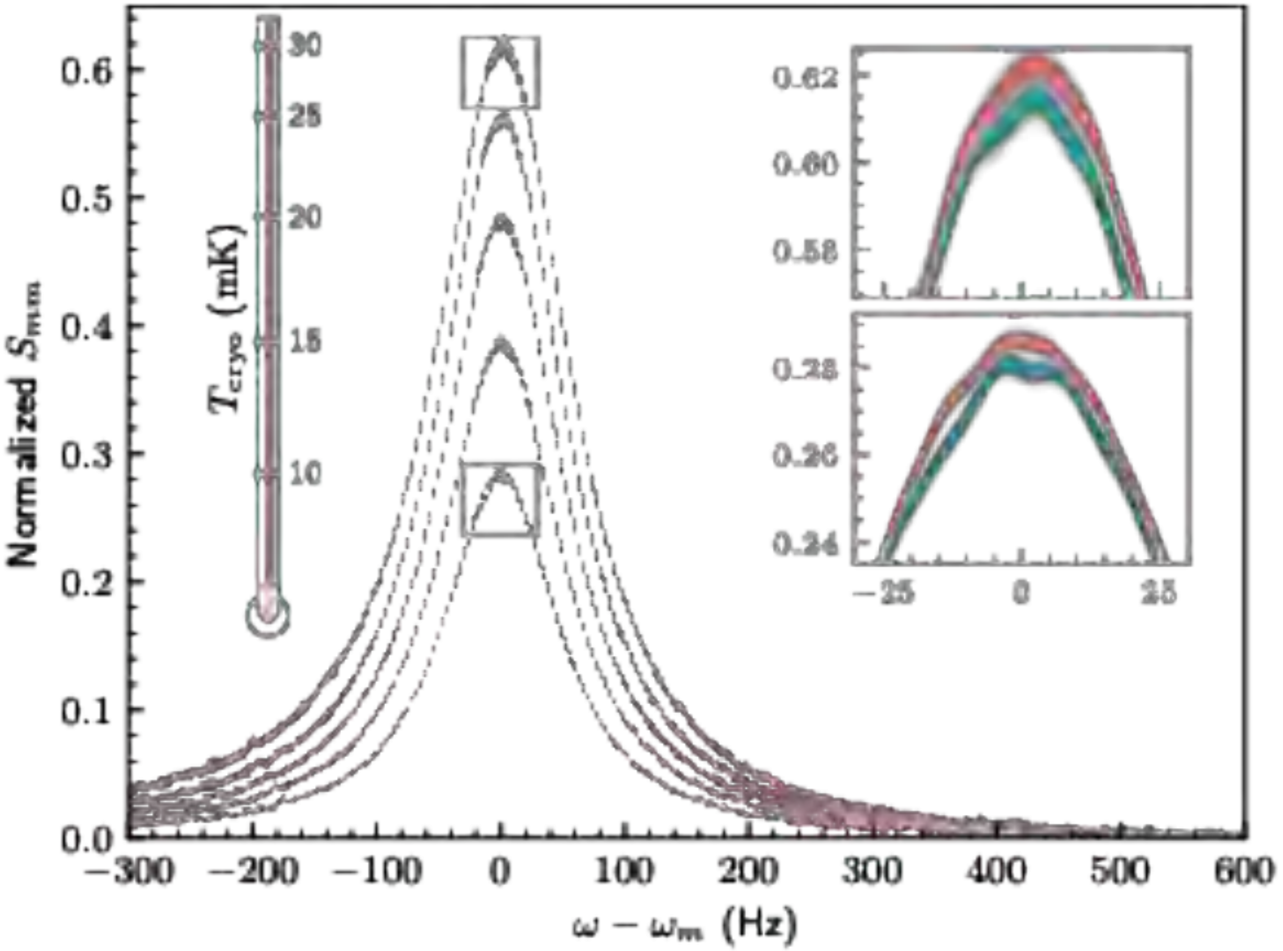
Spectrum asymmetry

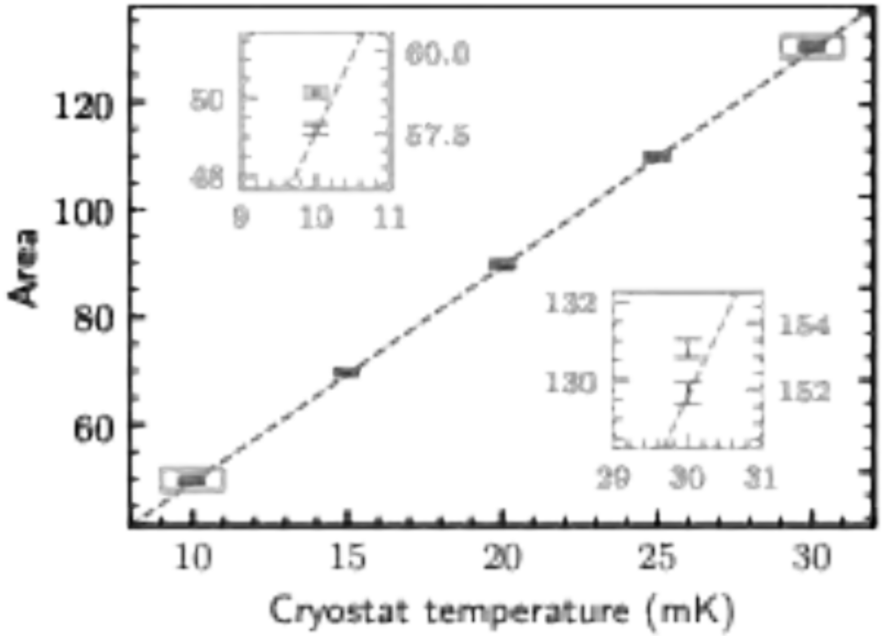


50 phonons at 10 mK
⇒ **2 %** difference

K. Gerashchenko*, R. Rousseau*, L. Balembois*, *et al.*, **Probing the quantum motion of a macroscopic mechanical oscillator with a radio-frequency superconducting qubit**, arXiv:2505.21481 (2025)

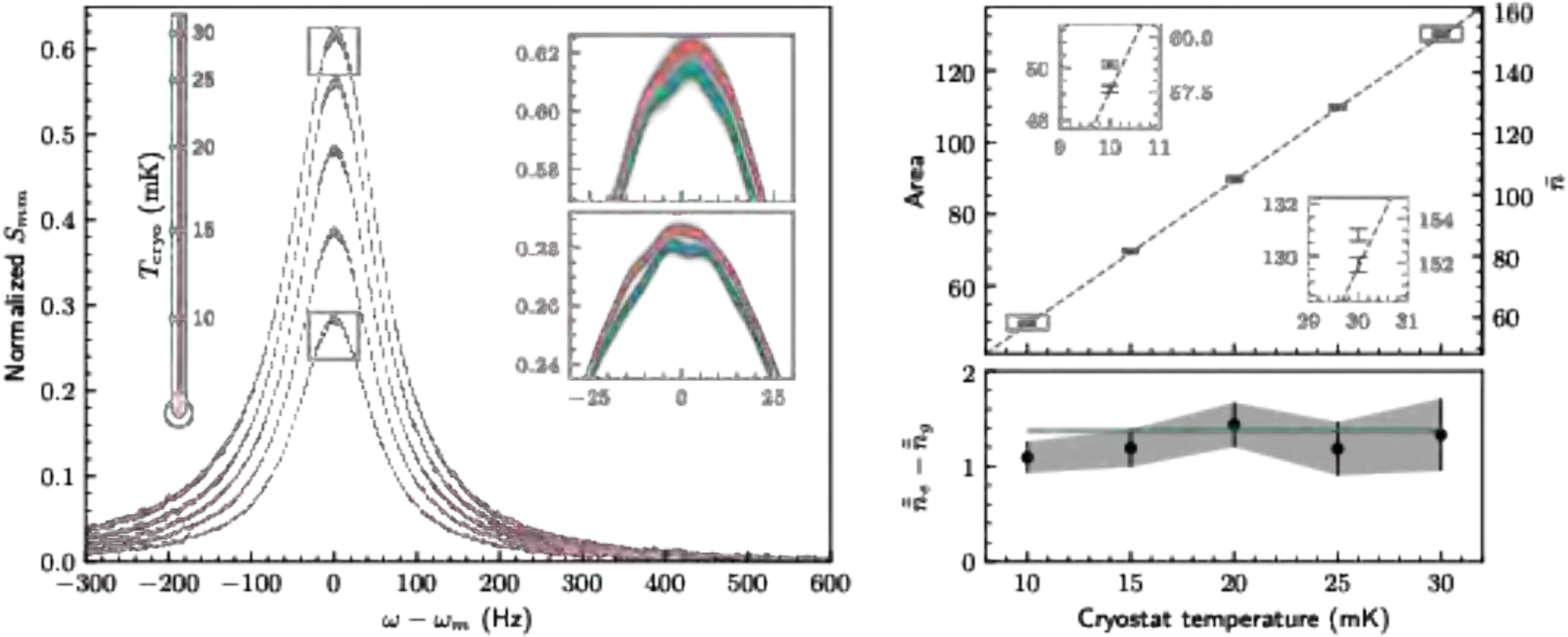
Spectrum asymmetry

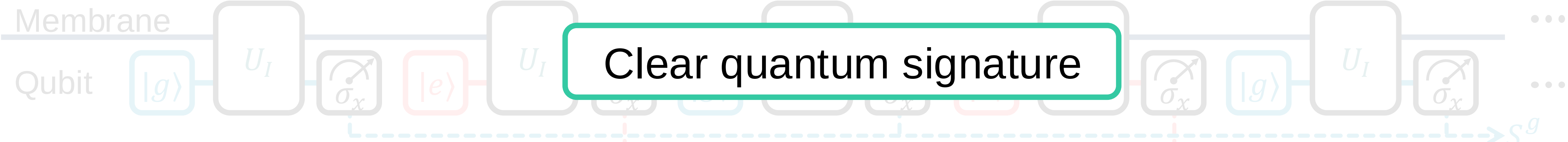




K. Gerashchenko*, R. Rousseau*, L. Balembois*, *et al.*, **Probing the quantum motion of a macroscopic mechanical oscillator with a radio-frequency superconducting qubit**, arXiv:2505.21481 (2025)

Spectrum asymmetry



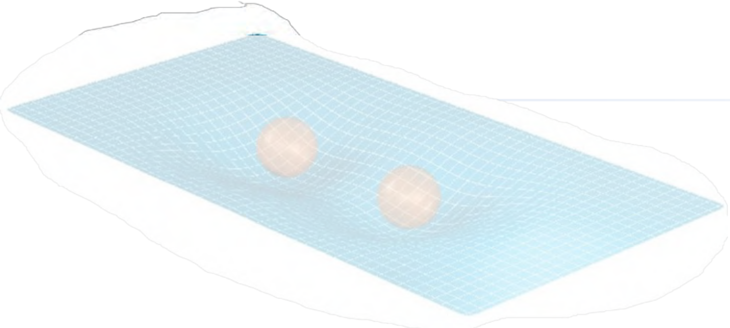


Clear quantum signature

K. Gerashchenko*, R. Rousseau*, L. Balembois*, *et al.*, **Probing the quantum motion of a macroscopic mechanical oscillator with a radio-frequency superconducting qubit**, arXiv:2505.21481 (2025)

Outline

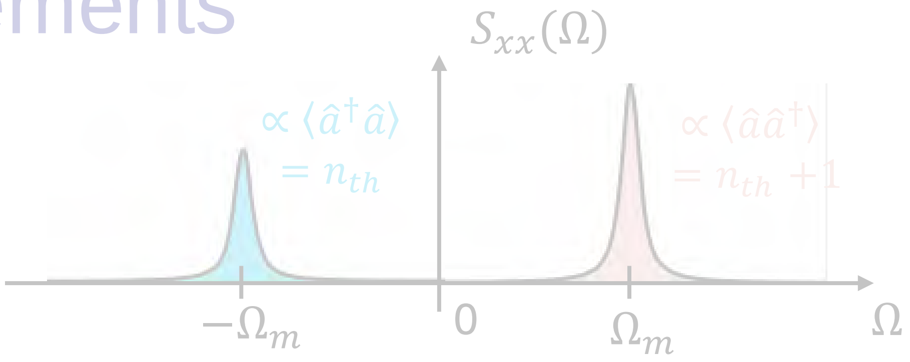
- Introduction/Motivation



- Radio-frequency fluxonium qubits

- Hybrid qubit/mechanical system: MecaFlux

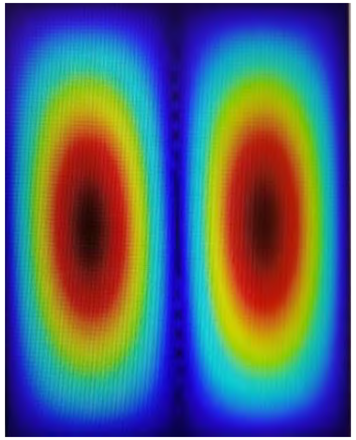
- Quantum asymmetry measurements

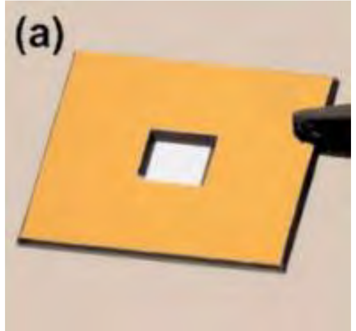


- **Perspectives**

From Rectangular to Torsional Membrane

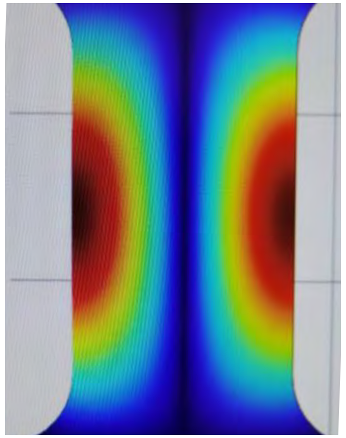
BEFORE

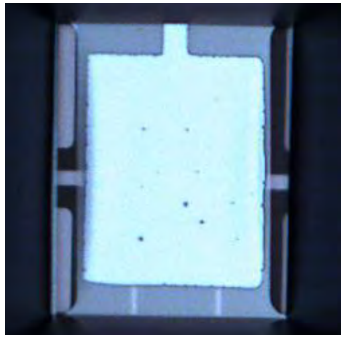




Rectangular
Membrane
5 ms @ 4 MHz

AFTER

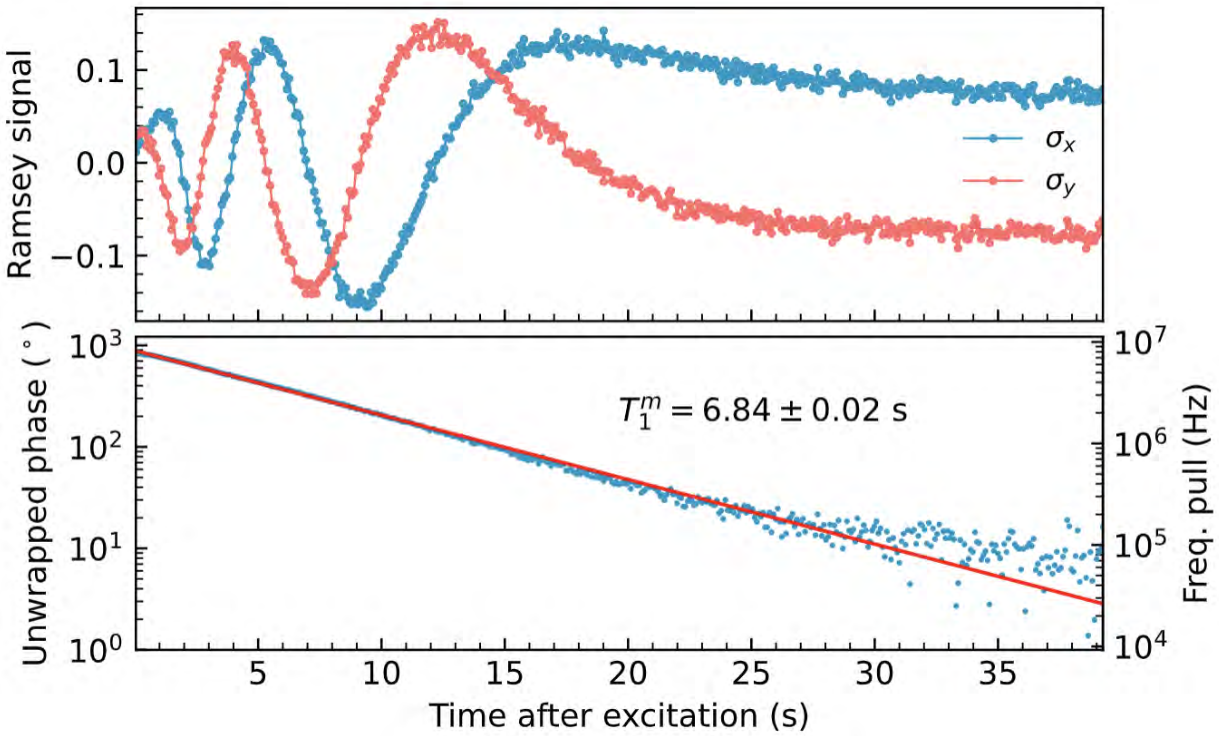


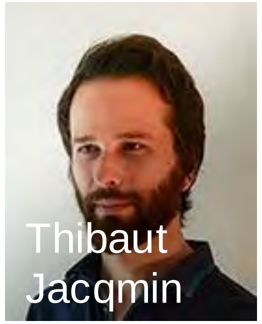


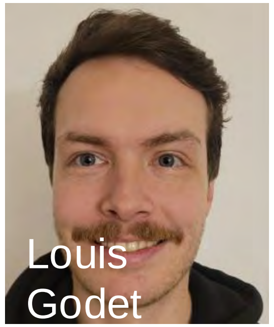
Torsional
Membrane
6.84 s @ 2 MHz

1,000× improvment!

Ringdown measurement



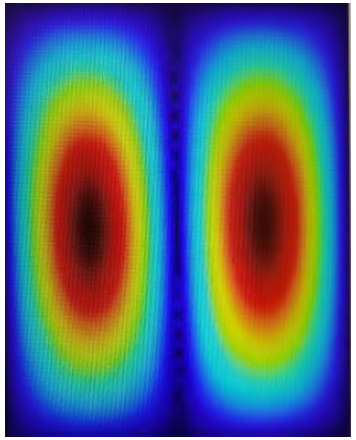


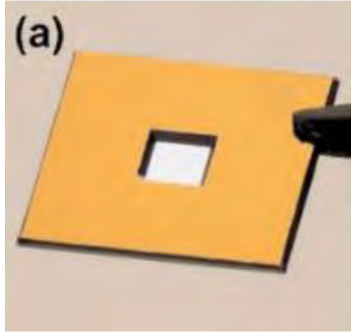


From Rectangular to Torsional Membrane

single shot average of 1000 consecutive ramsey measurements

BEFORE





Rectangular
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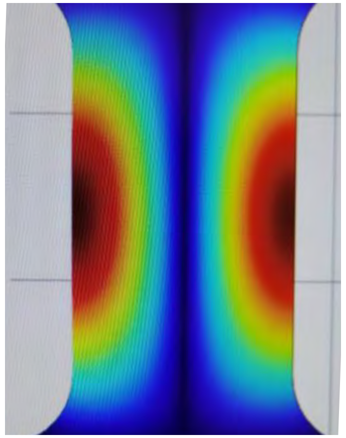
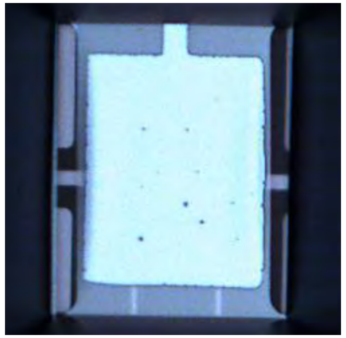
5 ms @ 4 MHz

AFTER





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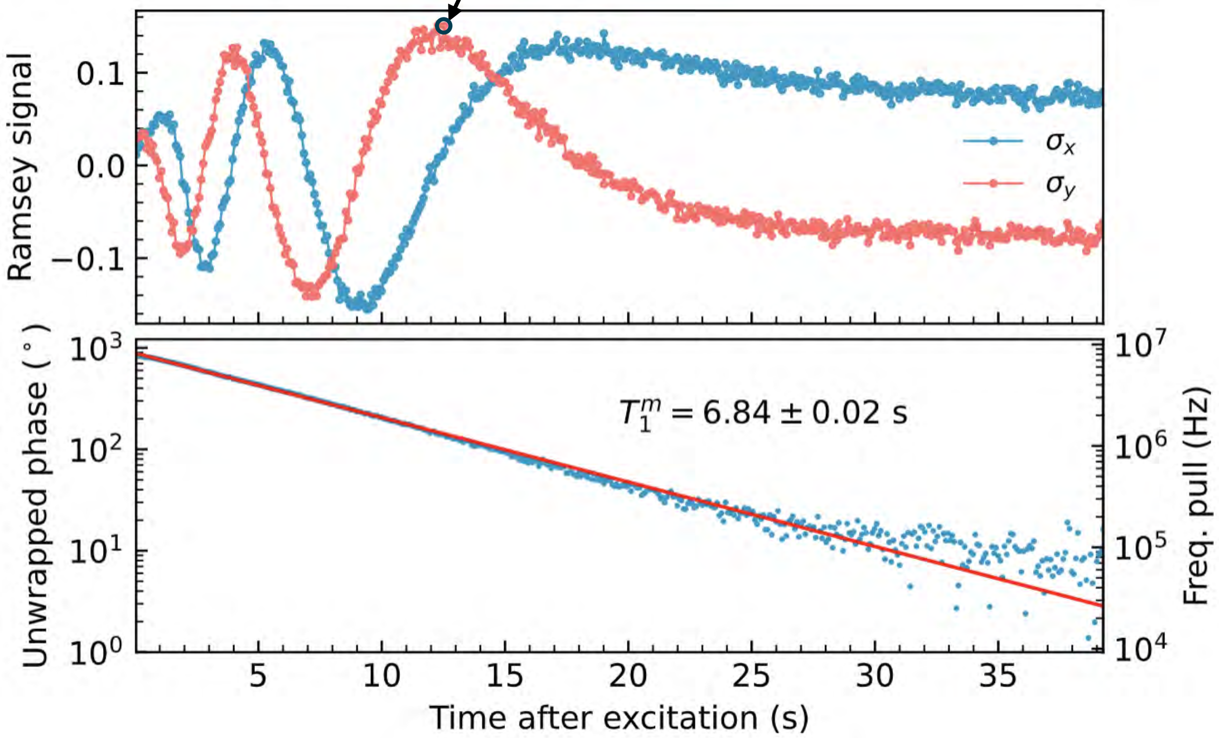
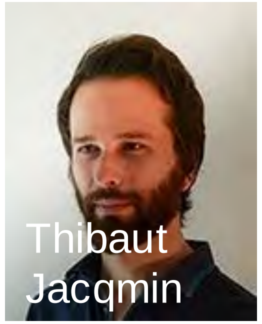
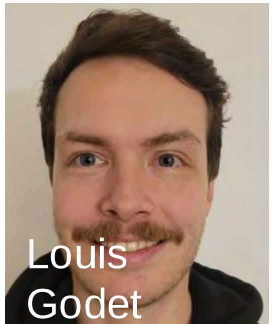
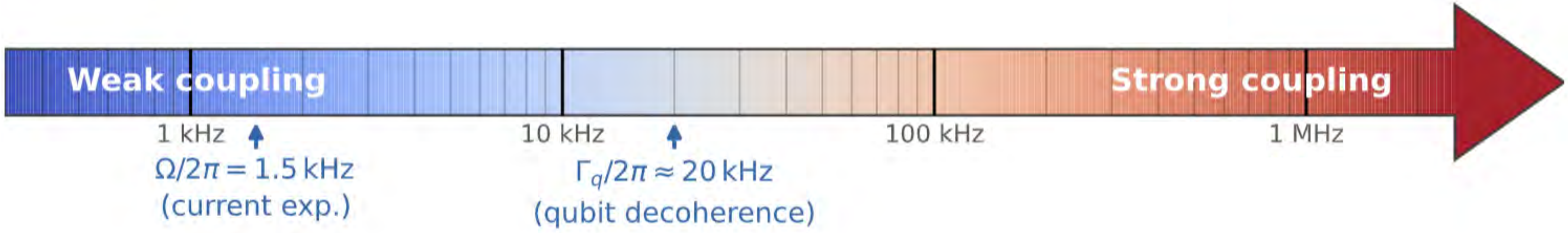






Perspectives: path to strong coupling

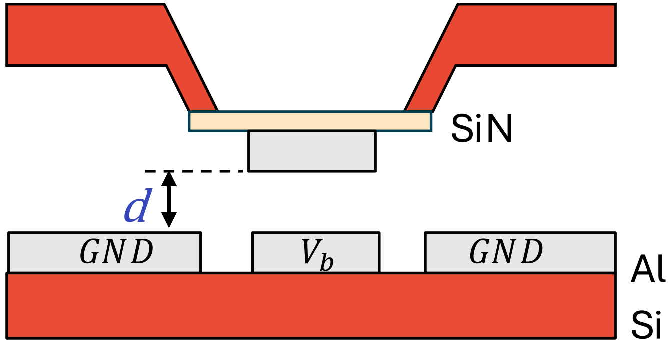
Coupling: $\Omega \propto V_b/d^2$

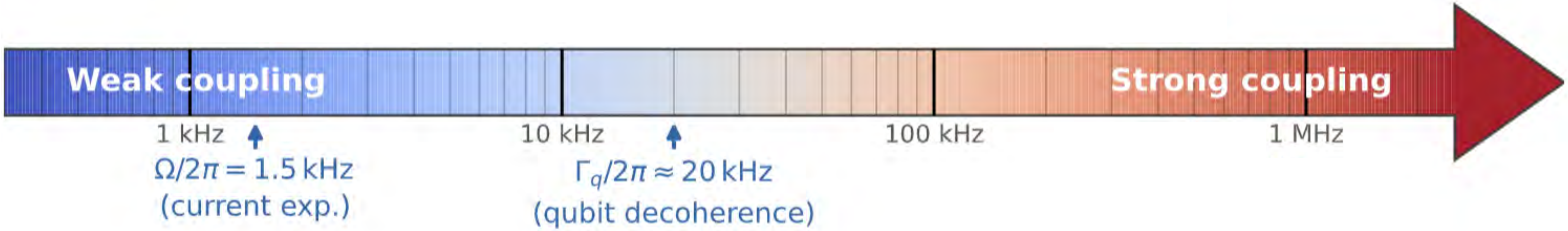


Perspectives: path to strong coupling

Coupling: $\Omega \propto V_b/d^2$

→ **Reduce gap** (WIP)
Objective: $d = 2.5\ \mu m$ → 500 nm ($\Omega \times 25$)





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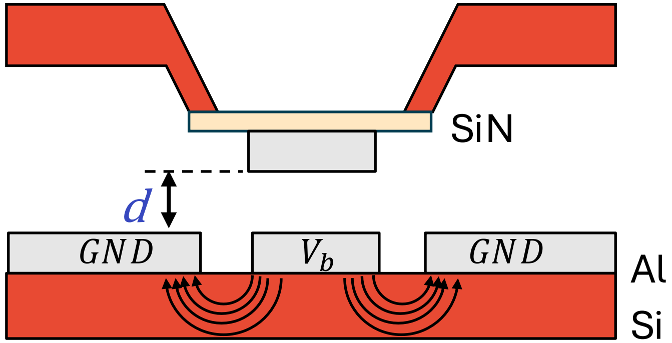
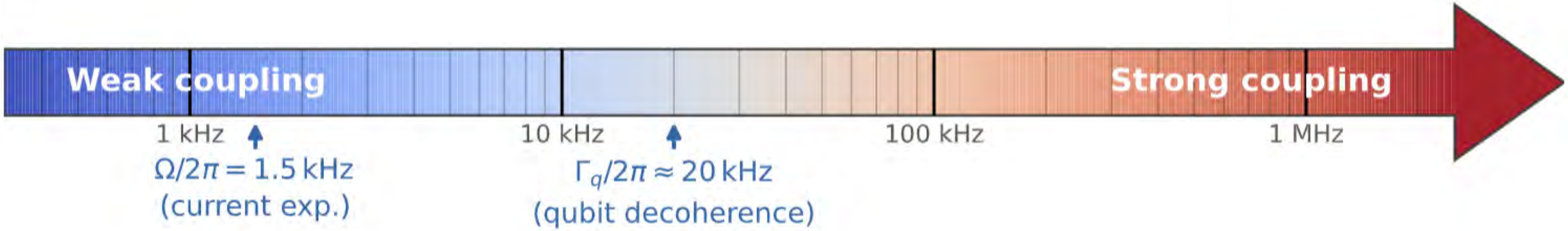


Avalanche ionization in Si
$|V_b| \lesssim 10\ \mathrm{V}$



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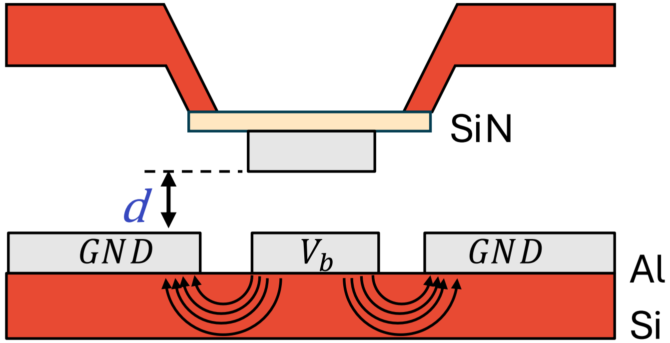
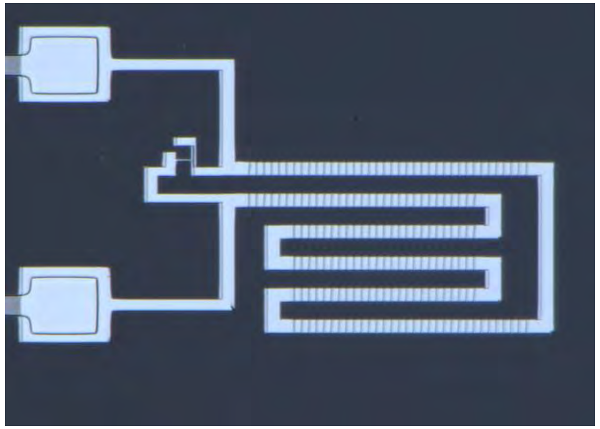
→ **Reduce gap** (WIP)
Objective: $\mathrm{d} = 2.5\ \mu\mathrm{m}$ → 500 nm ($\boldsymbol{\Omega} \times \mathbf{25}$)

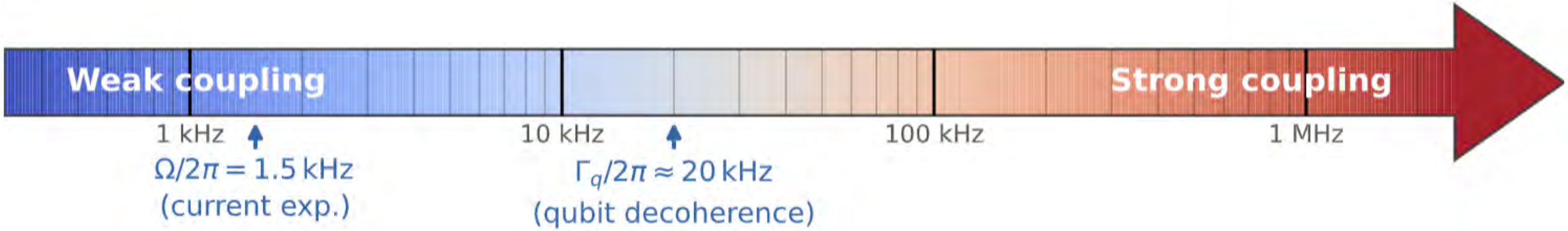
→ **Increase bias voltage**
Demonstrated: $V_b = 9\ \mathrm{V} \rightarrow 150\ \mathrm{V}$ ($\boldsymbol{\Omega} \times \mathbf{13}$)



Avalanche ionization in Si



Fluxonium on Saphhire



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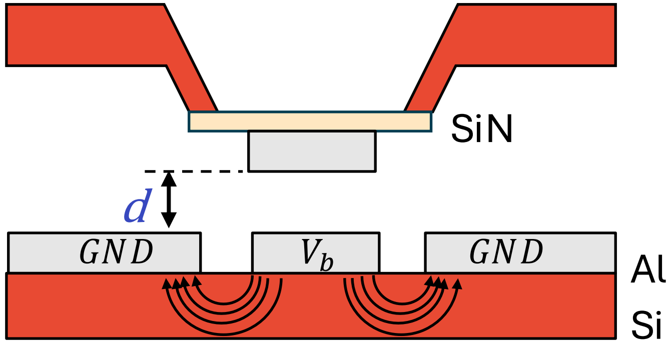
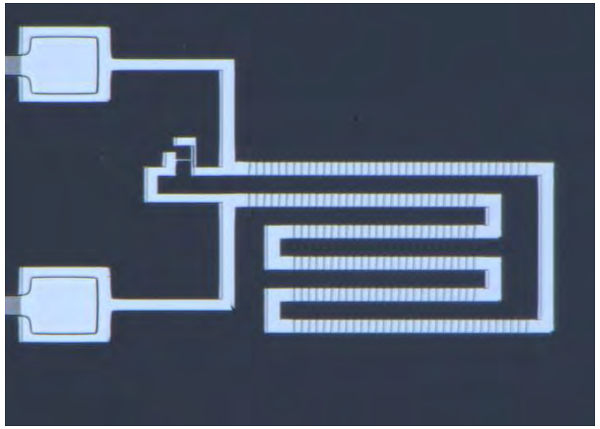
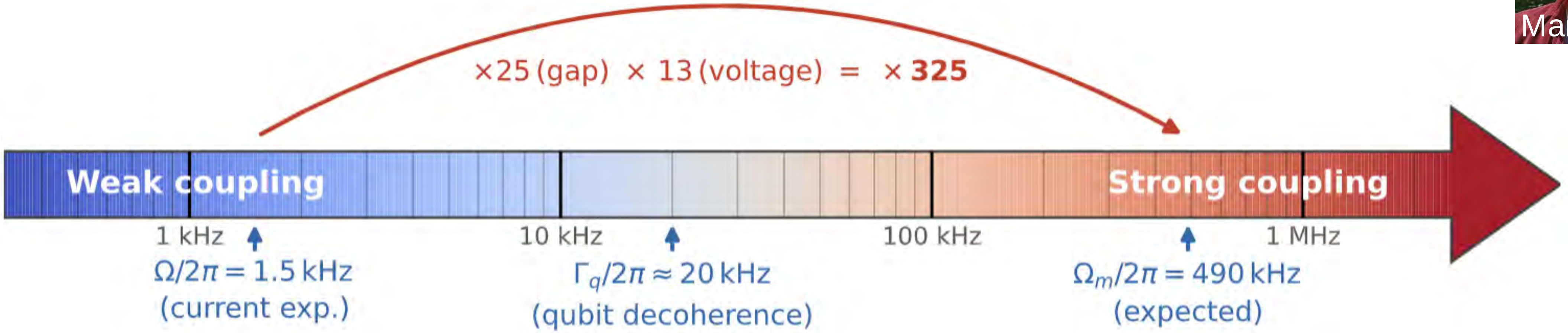


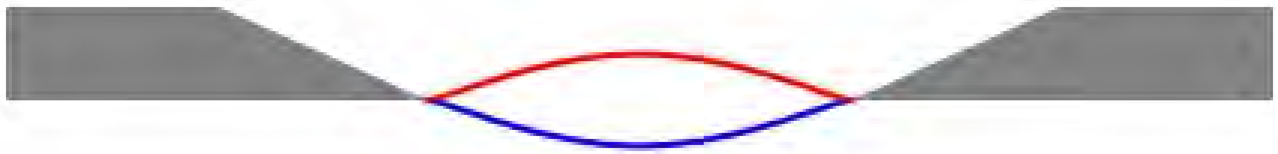
Avalanche ionization in Si



Fluxonium on Saphhire

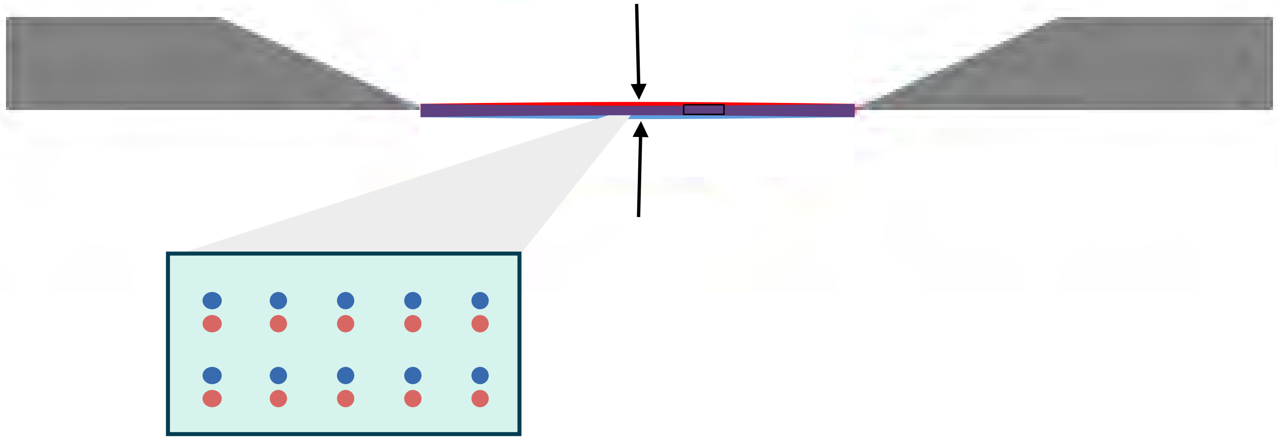


Testing Penrose model with low-frequency mechanical systems



$$|\Psi\rangle = \frac{1}{\mathcal{N}}\left(|\alpha\rangle + |-\alpha\rangle\right)$$

Testing Penrose model with low-frequency mechanical systems



$$|\Psi\rangle = \frac{1}{\mathcal{N}}\left(|\alpha\rangle + |-\alpha\rangle\right)$$

Necessary conditions:

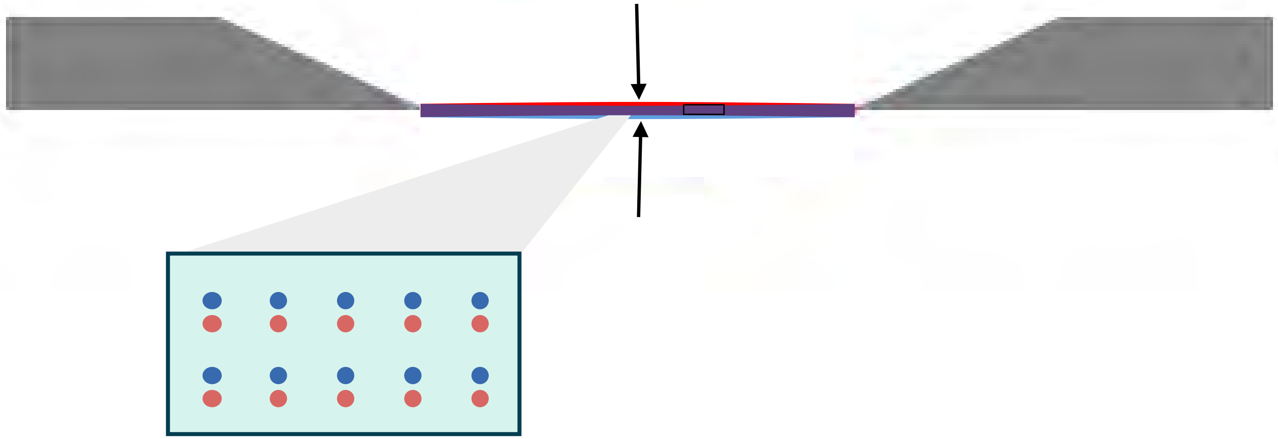
- spatial separation of the cat components

$x_{zpf}|\alpha| \geq$ Atomic nucleus diameter $\simeq 5$ fm

$$x_{zpf} = \sqrt{\frac{\hbar}{2m\Omega}}$$

M. Gely, G. Steele, AVS Quantum Sci. **3**, 035601 (2021)

Testing Penrose model with low-frequency mechanical systems



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$$x_{zpf} = \sqrt{\frac{\hbar}{2m\Omega}}$$

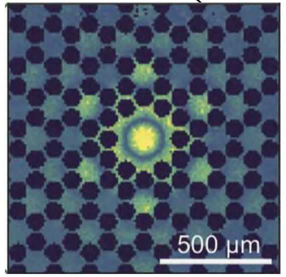
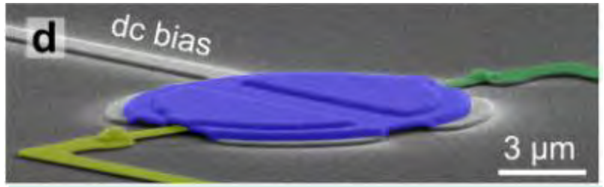
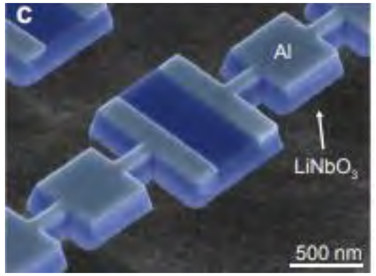
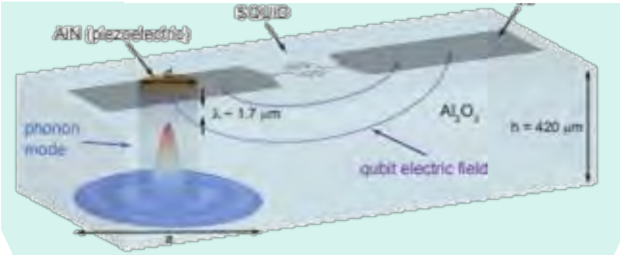
- Gravitational decoherence time

$\tau_g \ll$ Decoherence time due to mechanical losses

$$\tau_g \approx 3 \times 10^{-15}\left(\frac{1\text{kg}}{m}\right)\text{s}$$

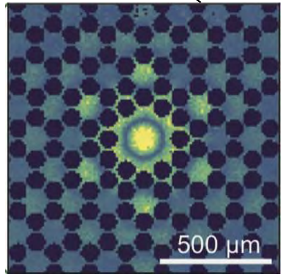
M. Gely, G. Steele, AVS Quantum Sci. **3**, 035601 (2021)

Mechanical systems in the Quantum Regime

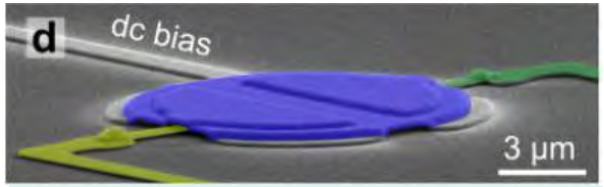
	Tsaturyan… Schliesser (2017)	Viennot… Lehnert (2018)	Arrangoiz-Arriola… Safavi-Naeini (2019)	Chu… Schoelkopf (2017)
				
Resonator frequency $\Omega_m/2\pi$	1 MHz	25 MHz	2.4 GHz	6.6 GHz
Motional mass m	2 ng	50 pg	2 pg	50 µg
Zero-point fluctuations x_{zpf}	2 fm	4 fm	1.3 fm	150 zm

Mechanical systems in the Quantum Regime

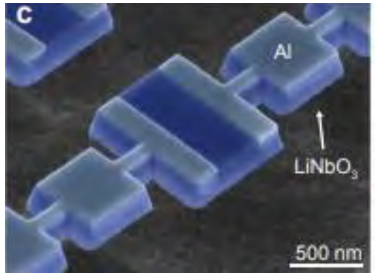
Tsaturyan… Schliesser (2017)



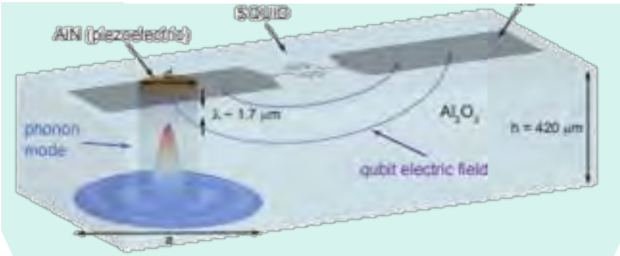
Viennot… Lehnert (2018)



Arrangoiz-Arriola… Safavi-Naeini (2019)



Chu… Schoelkopf (2017)



	Tsaturyan… Schliesser (2017)	Viennot… Lehnert (2018)	Arrangoiz-Arriola… Safavi-Naeini (2019)	Chu… Schoelkopf (2017)
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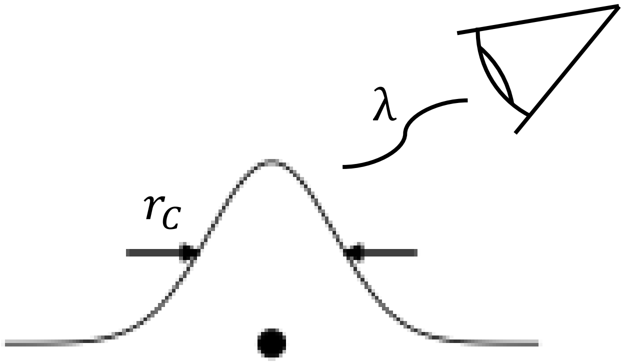
Motional mass m	2 ng	50 pg	2 pg	50 µg
Zero-point fluctuations x_{zpf}	2 fm	4 fm	1.3 fm	150 zm
Q-factor	10^9	10^5	10^4	10^6
Decoherence time of a 5-fm cat τ_d	100 ms	100 µs	100 ns	150 fs
	$\geq$	$\leq$	$\ll$	$\ll$
Gravitational de-coherence time τ_g	1 ms	60 ms	1.5 s	60 ns

Perspectives – collapse models

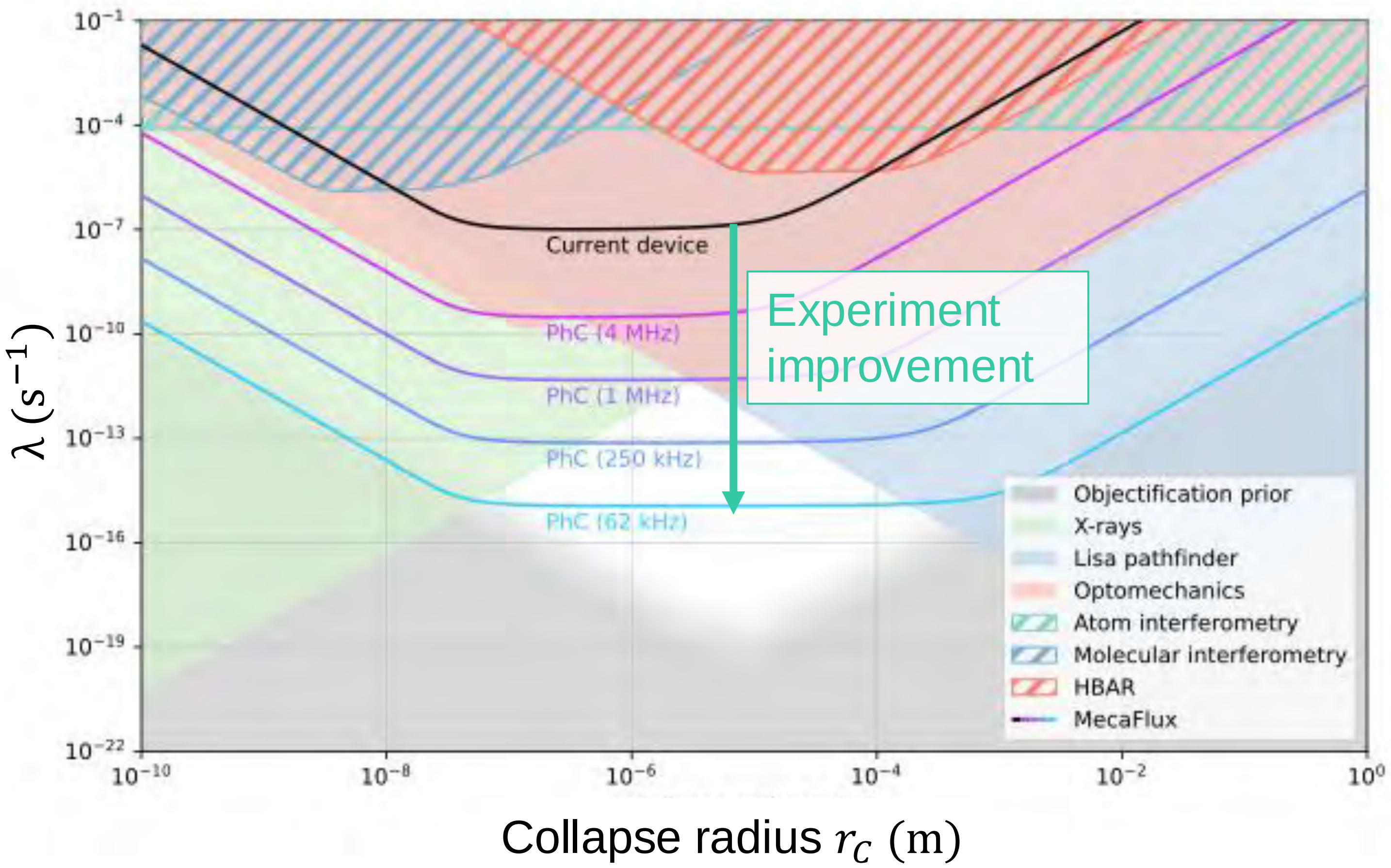
Collapse models resolve the **quantum measurement paradox** by introducing small modifications to the Schrodinger's equation

Continuous spontaneous localization model



r_C : measurement radius

λ : measurement rate



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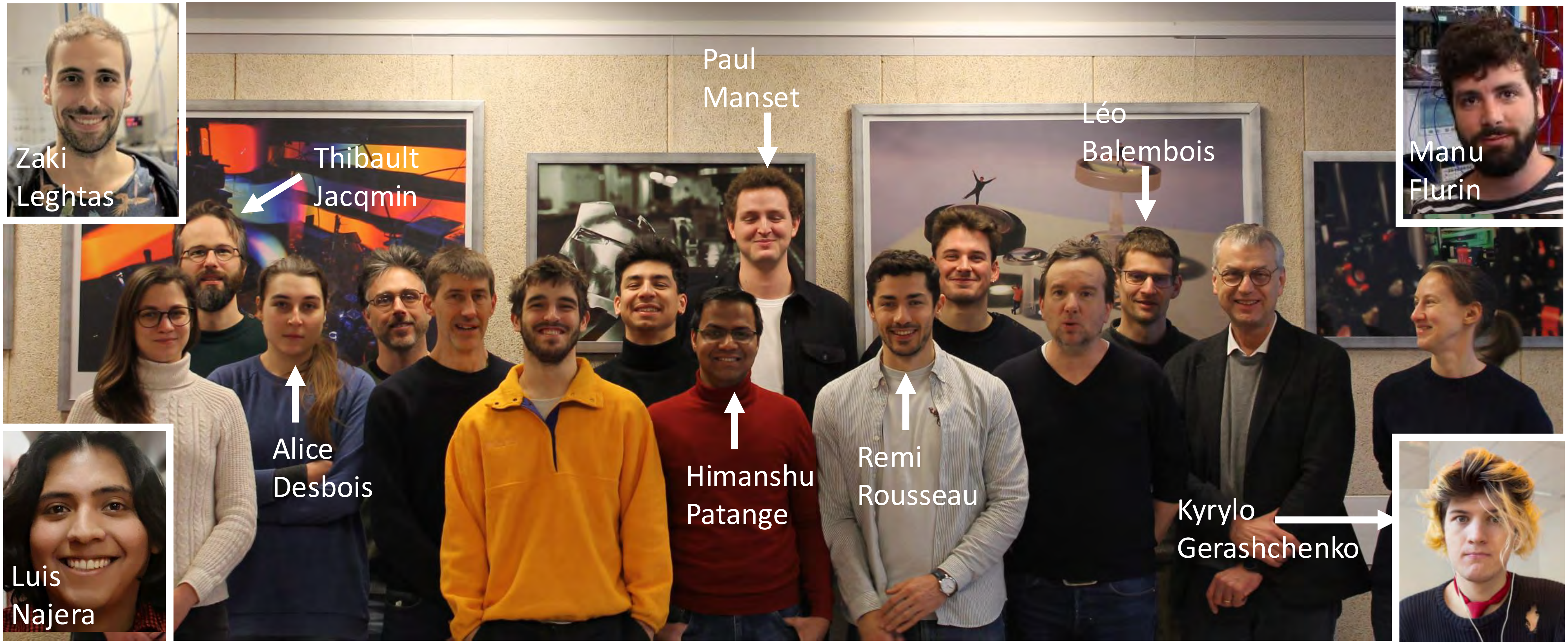
Optomechanics and quantum measurements group of LKB

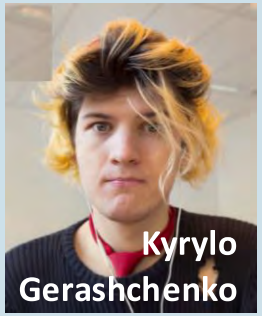


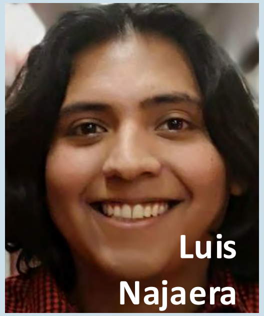
Thanks !!

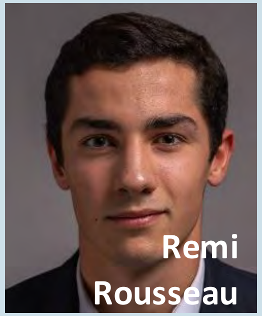
The team @ LKB

PhD students | Post doc | Permanent

This project

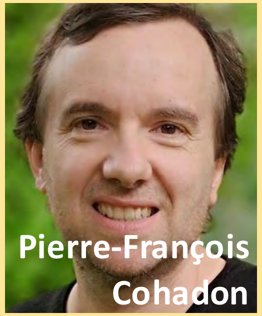






Cifre LKB/Alice & Bob

Optomechanical thermometry



Quantum limits

Collab.: