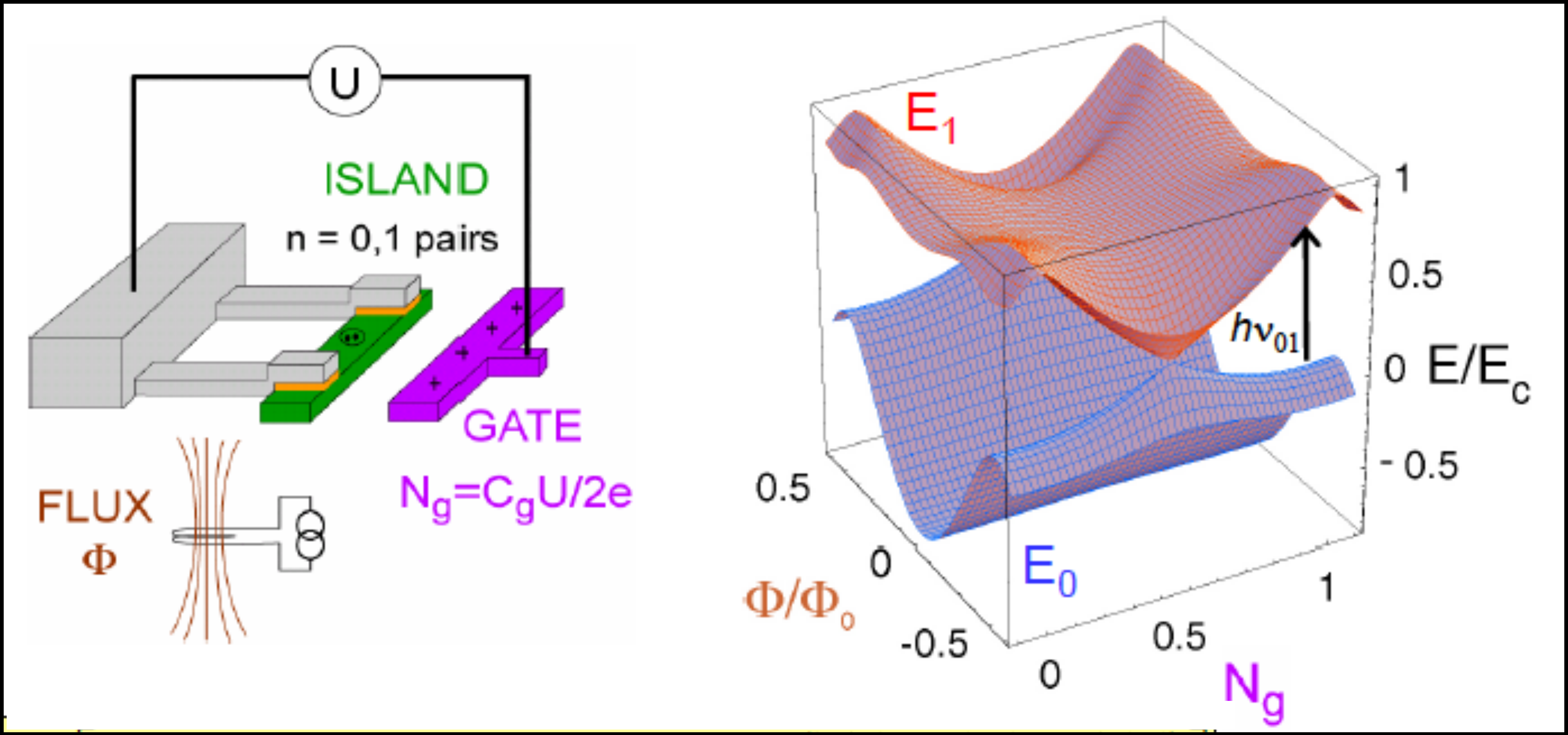
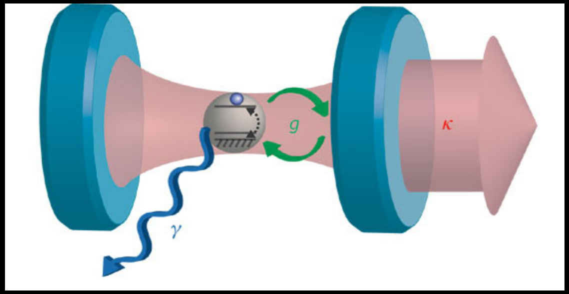
Split Cooper pair box qubit: the "artificial atom" with two control knobs



The modern Cooper pair box: Circuit QED

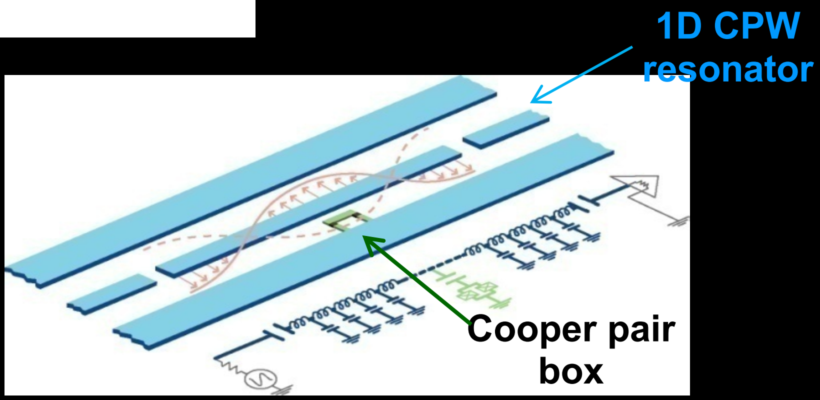
Inspired from cavity QED



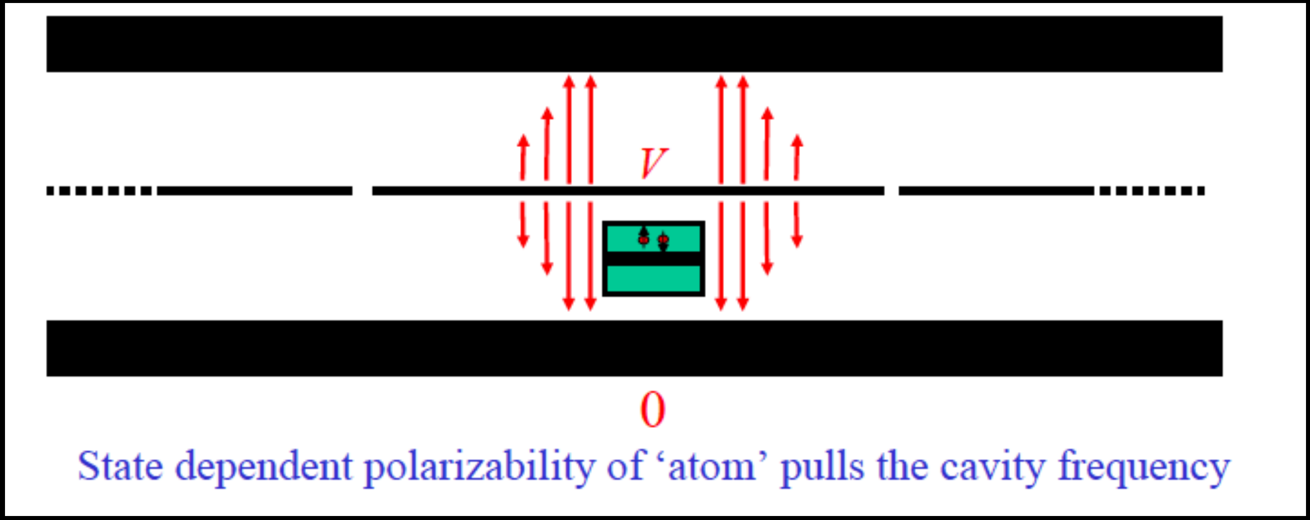
S. Haroche, JM Raimond, M. Brune
LKB- ENS Paris

Cooper Pair Box 'atom' in resonator
(Schoelkopf group , Yale, 2004)

Transmon Cooper pair box
E_J>>E_C insensitive to charge noise
Koch et al., Yale, 2007



Using the cavity
to measure
the state
of the "atom"



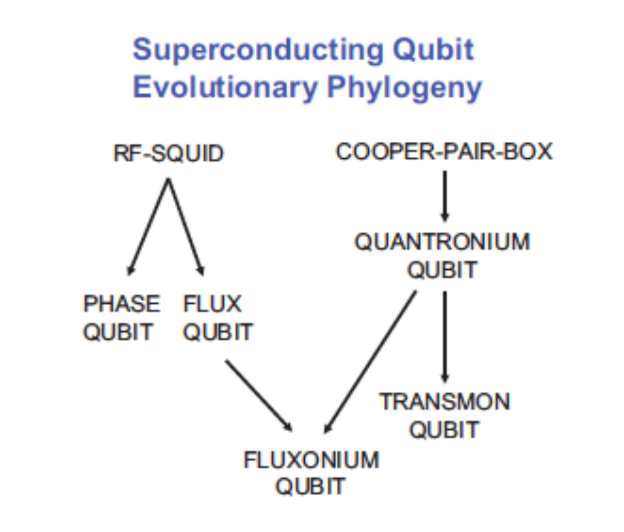
The artificial atom

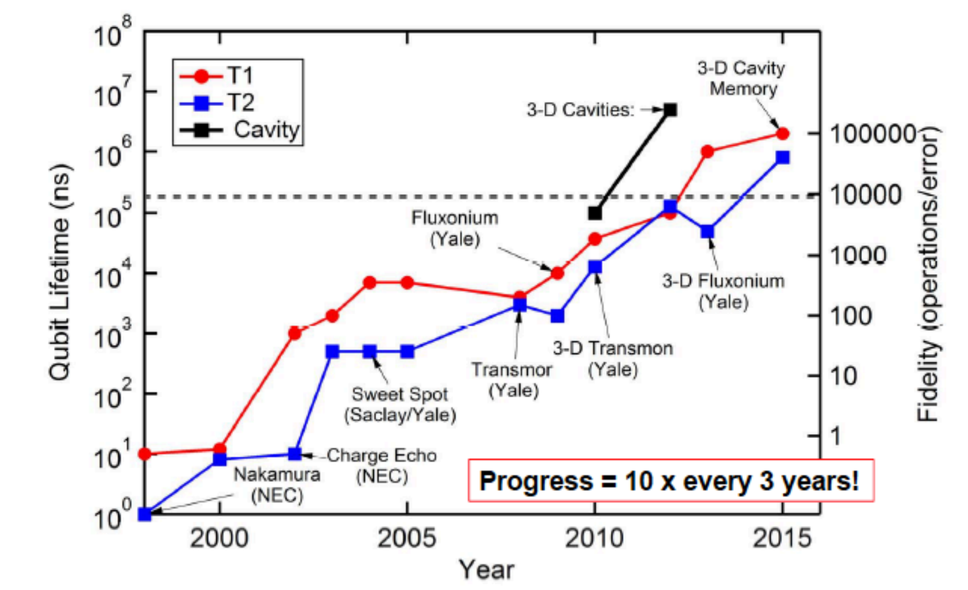
REVIEW SCIENCE VOL 339 8 MARCH 2013

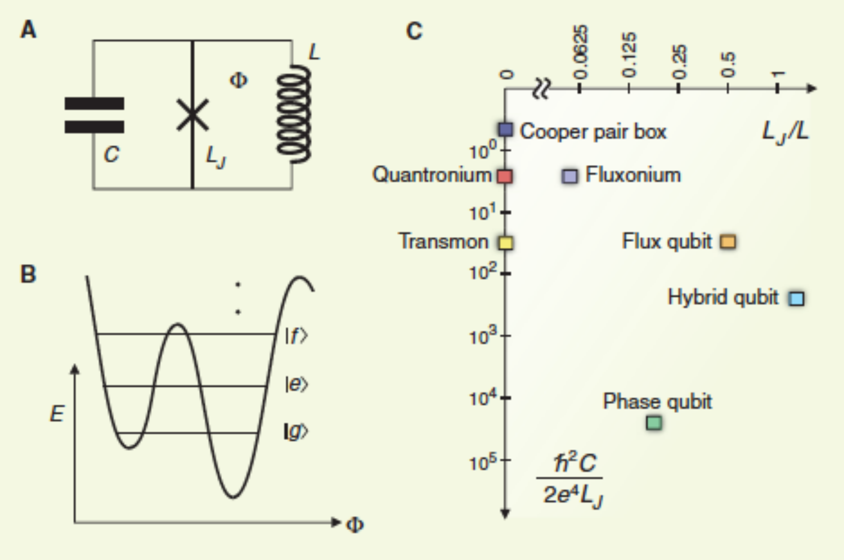
Superconducting Circuits for Quantum Information: An Outlook

M. H. Devoret[1,2] and R. J. Schoelkopf[1*]

The performance of superconducting qubits has improved by several orders of magnitude in the past decade. These circuits benefit from the robustness of superconductivity and the Josephson effect, and at present they have not encountered any hard physical limits. However, building an error-corrected information processor with many such qubits will require solving specific architecture problems that constitute a new field of research. For the first time, physicists will have to master quantum error correction to design and operate complex active systems that are dissipative in nature, yet remain coherent indefinitely. We offer a view on some directions for the field and speculate on its future.







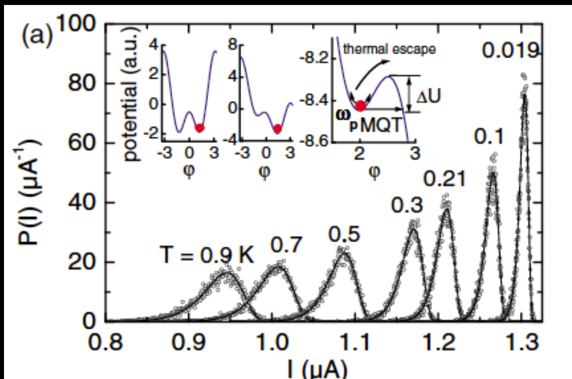
Napoli Expertise

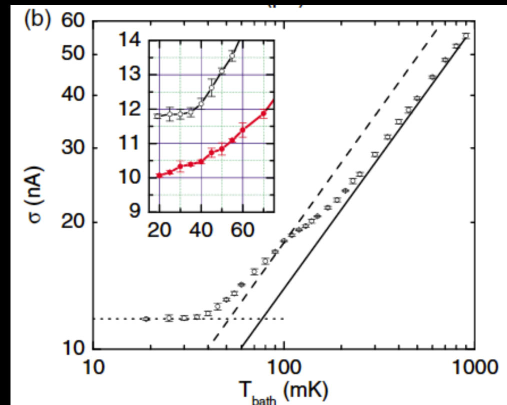
Quantum - Josephson

PRL 94, 087003 (2005) PHYSICAL REVIEW LETTERS week ending 4 MARCH 2005

Macroscopic Quantum Tunneling in d-Wave $YBa_2Cu_3O_{7-\delta}$ Josephson Junctions

T. Bauch,[1] F. Lombardi,[1] F. Tafuri,[2] A. Barone,[3] G. Rotoli,[4] P. Delsing,[1] and T. Claeson[1]



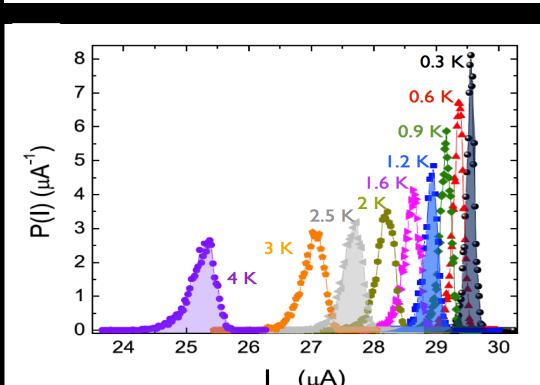


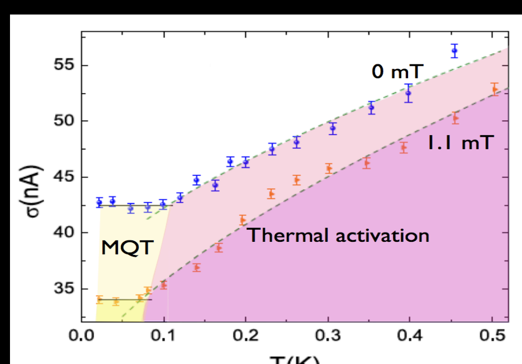
nature COMMUNICATIONS

Received 12 Dec 2014 | Accepted 1 May 2015 | Published 9 Jun 2015 DOI: 10.1038/ncomms8376 OPEN

Macroscopic quantum tunnelling in spin filter ferromagnetic Josephson junctions

D. Massarotti[1,2], A. Pal[3], G. Rotoli[4], L. Longobardi[4,5], M.G. Blamire[3] & F. Tafuri[2,4]

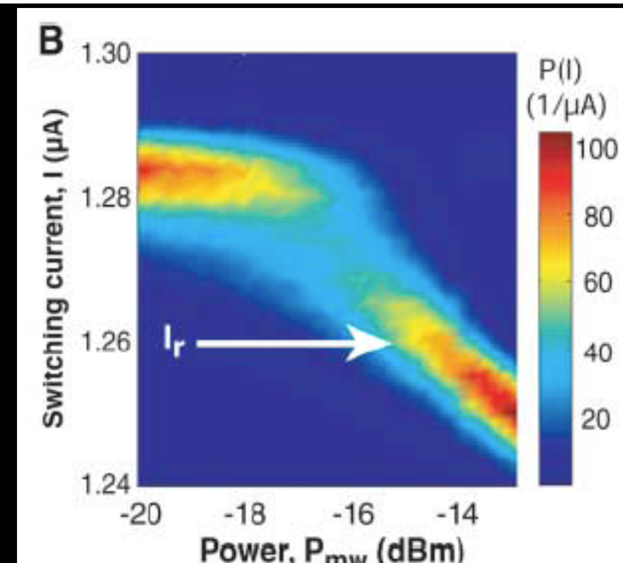




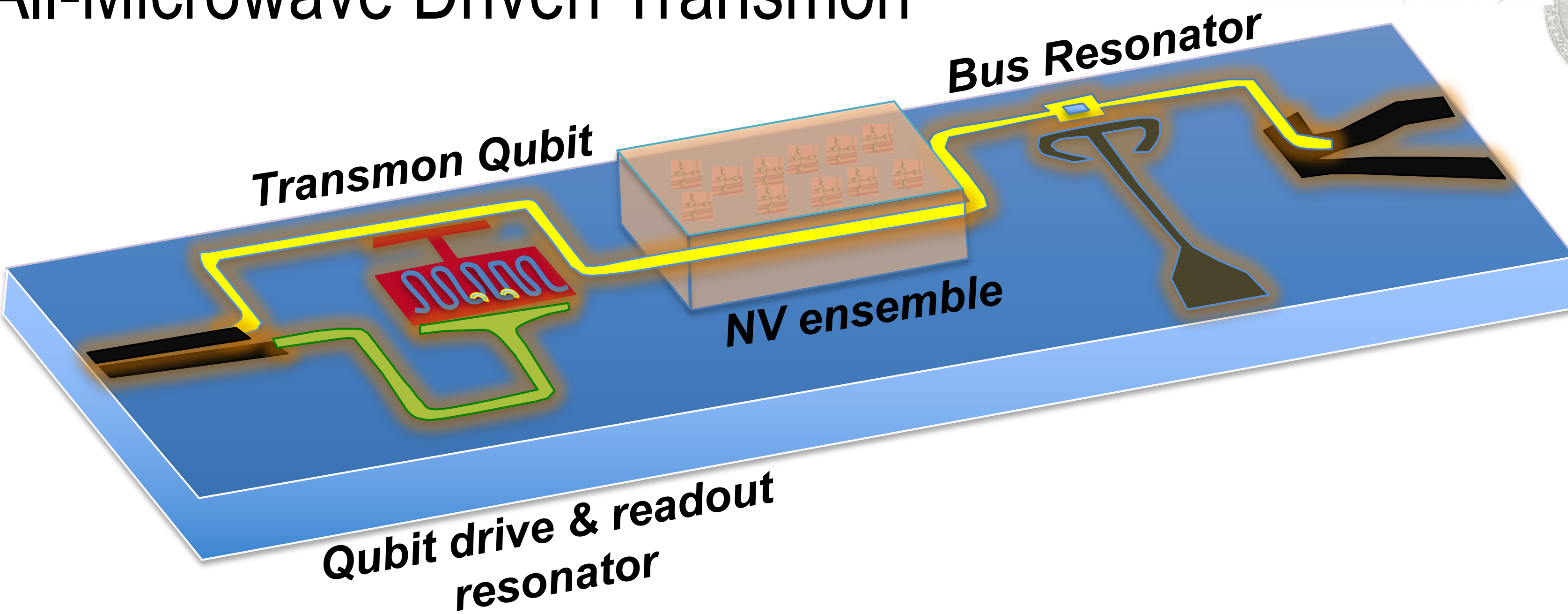
SCIENCE VOL 311 6 JANUARY 2006

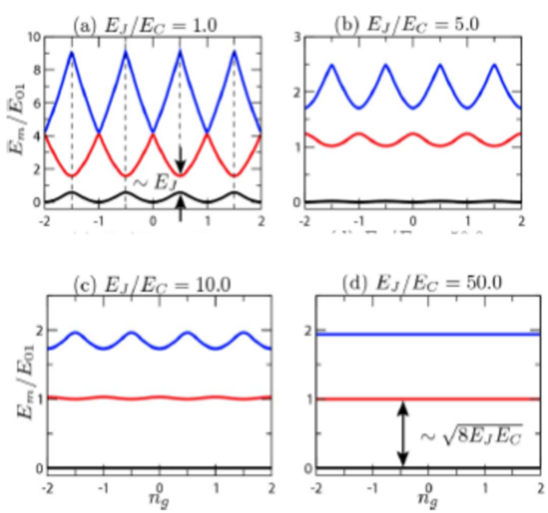
Quantum Dynamics of a d-Wave Josephson Junction

Thilo Bauch,[1] Tobias Lindström,[1] Francesco Tafuri,[2] Giacomo Rotoli,[3] Per Delsing,[1] Tord Claeson,[1] Floriana Lombardi[1*]



All-Microwave Driven Transmon





Interfacing S-Qubits with cryogenic logic

IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 29, NO. 5, AUGUST 2019

Interfacing Superconducting Qubits With Cryogenic Logic: Readout

Caleb Howington, Alex Opremcak, Robert McDermott, Alex Kirichenko, Oleg A. Mukhanov, and Britton L. T. Plourde

Replacing room temperature analog components with cryogenic digital components

An alternative method for measuring qubits involves mapping the qubit state onto the photon occupation in a microwave cavity, followed by subsequent photon detection using a Josephson photomultiplier (JPM). The JPM measures the qubit and stores the result in a classical circulating current.

Existing single flux quantum (SFQ) circuitry. An underdamped Josephson transmission line (JTL) can be coupled to the JPM and fluxons traveling along the JTL are accelerated or delayed, depending on the circulating current state of the JPM. This fluxon delay can then be converted to an SFQ logic signal resulting in a digital qubit readout paving the way for cryogenic digital feedback necessary for error-correcting codes.

Science **361**, 1239–1242 (2018)   21 September 2018

RESEARCH

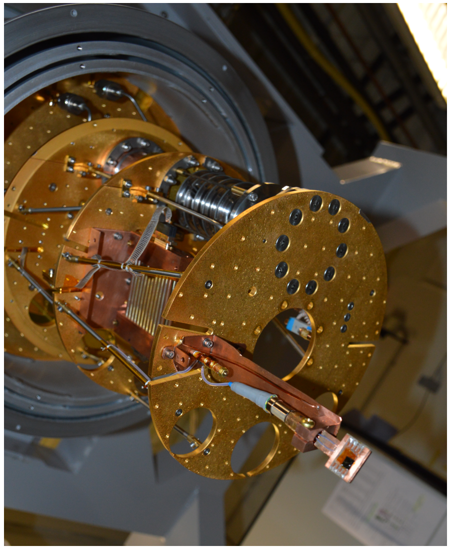
QUANTUM ELECTRONICS

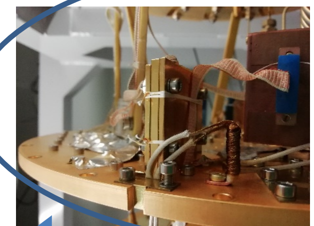
Measurement of a superconducting qubit with a microwave photon counter

A. Opremcak[1]*, I. V. Pechenezhskiy[1]*†, C. Howington[2], B. G. Christensen[1], M. A. Beck[1], E. Leonard Jr.[1], J. Suttle[1], C. Wilen[1], K. N. Nesterov[1], G. J. Ribeill[1]‡, T. Thorbeck[1]§, F. Schlenker[1], M. G. Vavilov[1], B. L. T. Plourde[2], R. McDermott[1]||

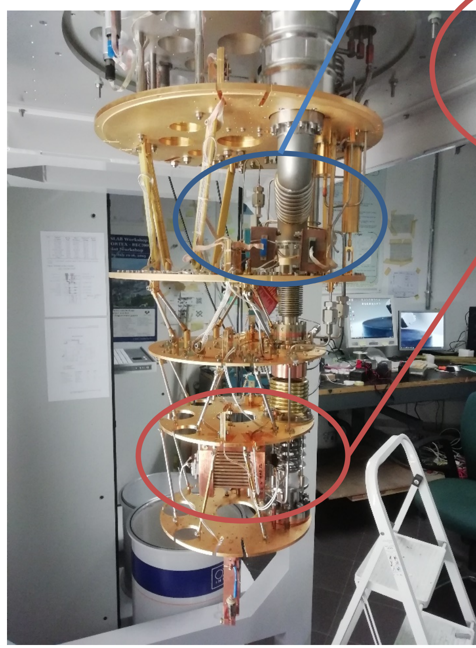
Fast, high-fidelity measurement is a key ingredient for quantum error correction. Conventional approaches to the measurement of superconducting qubits, involving linear amplification of a microwave probe tone followed by heterodyne detection at room temperature, do not scale well to large system sizes. We introduce an approach to measurement based on a microwave photon counter demonstrating raw single-shot measurement fidelity of 92%. Moreover, the intrinsic damping of the photon counter is used to extract the energy released by the measurement process, allowing repeated high-fidelity quantum nondemolition measurements. Our scheme provides access to the classical outcome of projective quantum measurement at the millikelvin stage and could form the basis for a scalable quantum-to-classical interface.

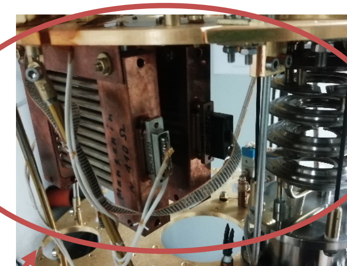
Cryogenic set up for qubit measurement





2019

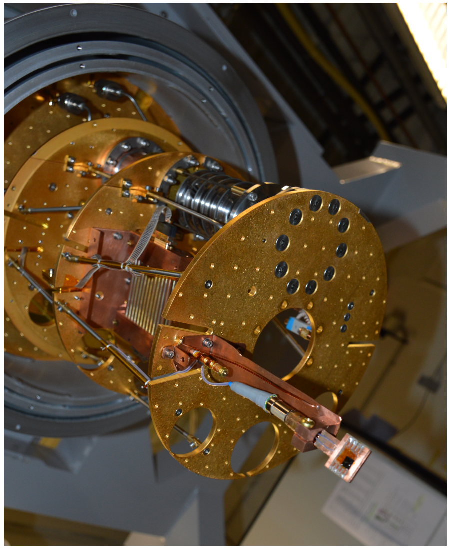


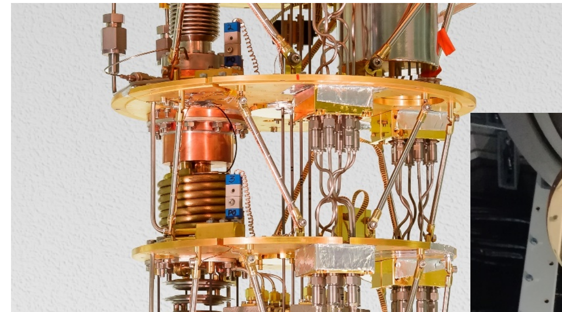


TRITON-Cryogen-dilution refrigerator

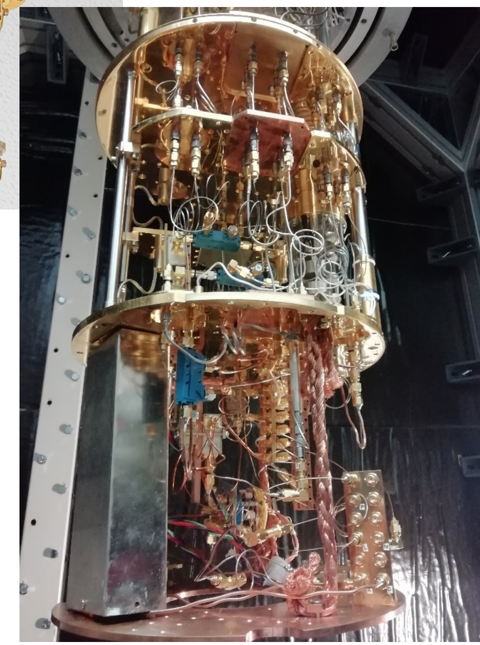
Now: 24 thermalized filtered DC-lines + 24 thermalized unfiltered DC-lines

Cryogenic set up for qubit measurement





2020



RF-lines for qubits measurements

Conclusions

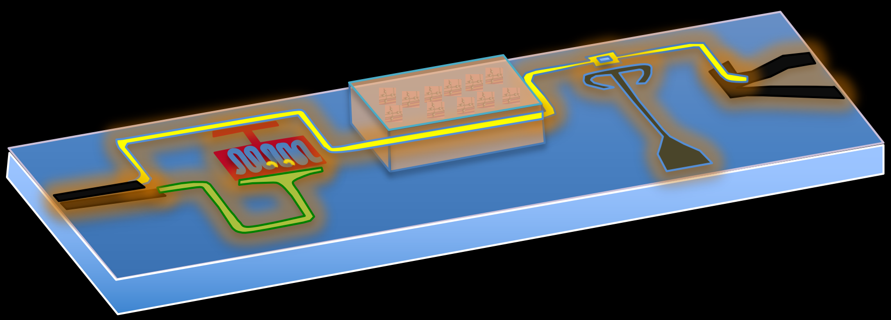
-Interesting use-cases of quantum computing identified
but >100 logical (error corrected) qubits needed …

-Low depth processors investigated at Google, IBM, Rigetti
Target: **quantum advantage**

-gate-based processors with quantum error correction
Scalable fab. mandatory.

-Other routes: hybrids, other types of junctions, RSFQ

any space for alternative systems
other than SIS?



hybrid quantum systems
quantum interfaces and couplers

unconventional systems
for alternative layout?
SFS and digital modules RSFQ