SQA CONFERENCE

25 - 28 August

Delft, Netherlands

SUPERCONDUCTING QUBITS AND ALGORITHMS CONFERENCE

CONFERENCE GUIDE

information about the conference | schedule | abstracts

VERSION 2025.08.21

ABOUT THE CONFERENCE

Superconducting Qubits and Algorithms (SQA) Conference is a not-for-profit scientific conference with a focus on science, technology, and algorithms relevant for superconducting quantum computers. This year it is organized by QuTech, OrangeQS and IQM Quantum Computers and the scientific community.

Contents

Preface

Welcome to the third edition of the Superconducting Qubits and Algorithms (SQA) Conference!

From its debut as Europe's largest conference on superconducting qubits and algorithms, the SQA Conference has brought together leading scientists and successful companies from all over the world to exchange and discuss the rapid progress in the field. It our pleasure to welcome you to three days filled with exciting talks, excellent posters, exhibitions, and numerous networking opportunities.

The organising team is proud to welcome you to Delft, a city with a rich tradition in superconducting quantum computing. It was here that Europe's first superconducting setup was built. Today, at QuTech – the quantum technology research institute of Delft University of Technology – and within the surrounding ecosystem of companies such as OrangeQS, Qblox, QuantWare and Delft Circuits, several hundred researchers and industry professionals are advancing the technology.

SQA creates an independent discussion platform that brings together over 350 quantum enthusiasts in Delft, the Netherlands, and even more online. The conference facilitates the exchange of ideas on many cross-sectional topics, covering the entire spectrum of superconducting quantum computers from qubit design to high-fidelity operations to near-term algorithms.

In the past years we have seen a number of exciting announcements and unexpected discoveries in the field of superconducting quantum computing. Let's celebrate them together at the SQA Conference 2025.

We are looking forward to connecting with you and learning about all these fascinating insights at this unique conference.

Christian K. Andersen (Conference Host)
Vivek Sinha (Member of the Organising Committee)
Amber Van Hauwermeiren (Member of the Organising Committee)
Stefan Seegerer (Member of the Organising Committee)


Elements of the Surface Code
SQA CONFERENCE
Elements of the Surface Code

Details

The conference is held from **25 - 28 August, 2025** in Delft, the Netherlands.
We are excited to welcome over 350 researchers and experts from the field of superconducting qubits and algorithms to Delft.

The conference themes include the following:

A. Applications of superconducting qubits beyond computing
B. Benchmarking and enabling software
C. Near-term algorithms, applications, and co-design
D. Quantum error correction and mitigation
E. Supporting hardware
F. Fabrication and materials
G. Design and modeling
H. Scaling and modelling of superconducting qubits
I. Scaling superconducting quantum devices
J. Unconventional superconducting qubits
K. High-fidelity elementary operations

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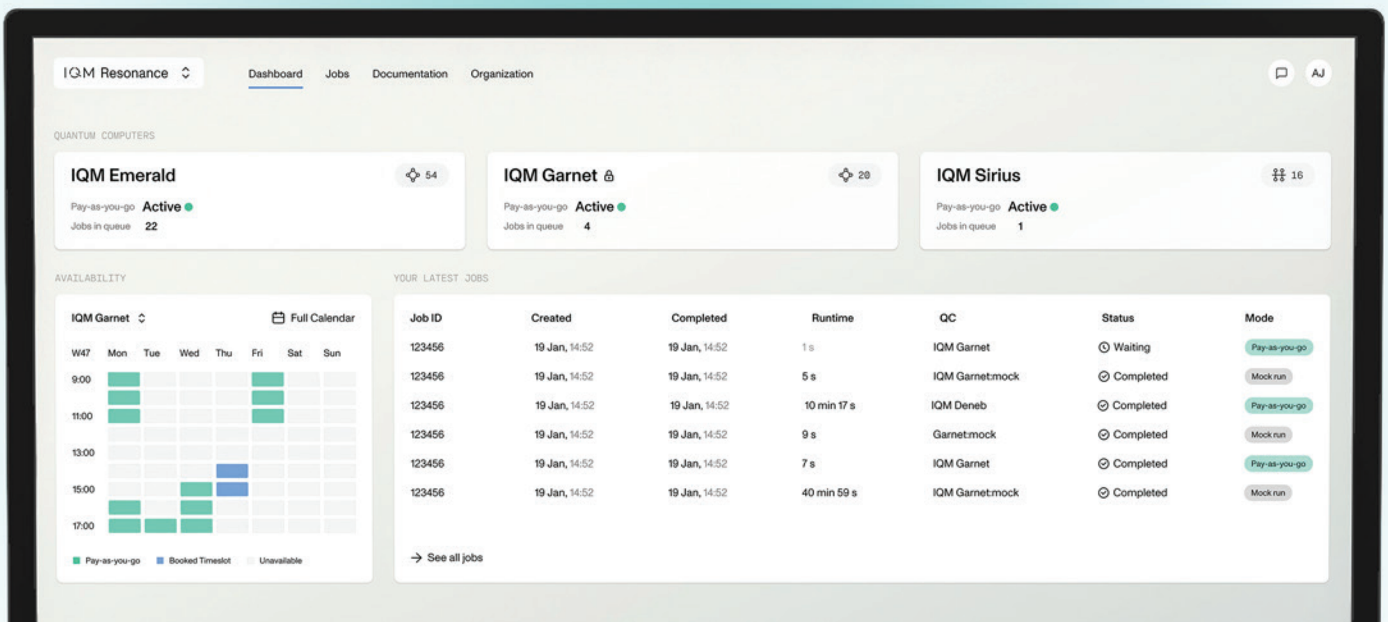


Conference Program

The event is a scientific conference structured around scientific talks and poster sessions. The conference program is outlined as follows (all times in CEST):

MONDAY, 25 AUGUST

13:30	Registration opens in Theater de Veste
15:00	Opening and Keynote by **Nathan Lacroix** (Google Quantum AI)
16:00	Scientific Session: *Quantum error correction*
17:00	Welcome reception, supported by Quantum Machines and QuTech
18:00	Ask Me Anything with DiVincenzo -- by Orange Quantum Systems

TUESDAY, 26 AUGUST

09:00	Opening Day 2 and Keynote by **Anna Grassellino** (Fermilab)
09:50	Scientific Session: *Materials, fabrication and devices*
10:45	Coffee break
11:30	Scientific Session: *Fluxonium and Error-Protected Qubits*
12:30	Lunch break
13:30	Poster Session 1
13:30	Workshop by Quantum Machines (location: Pathe, Cinema 5)
13:30	Workshop by Zurich Instruments and Riverlane (Pathe, Cinema 7)
14:30	Workshop by Qblox (Pathe, Cinema 5)
14:30	Workshop by IQM (Pathe, Cinema 6)
14:30	Workshop by Qruise (location: Pathe, Cinema 7)
15:00	Coffee break
15:45	Scientific Session: *Quantum Algorithms*
	Excursions & Delft Quantum Ecosystem tour

WEDNESDAY, 27 AUGUST

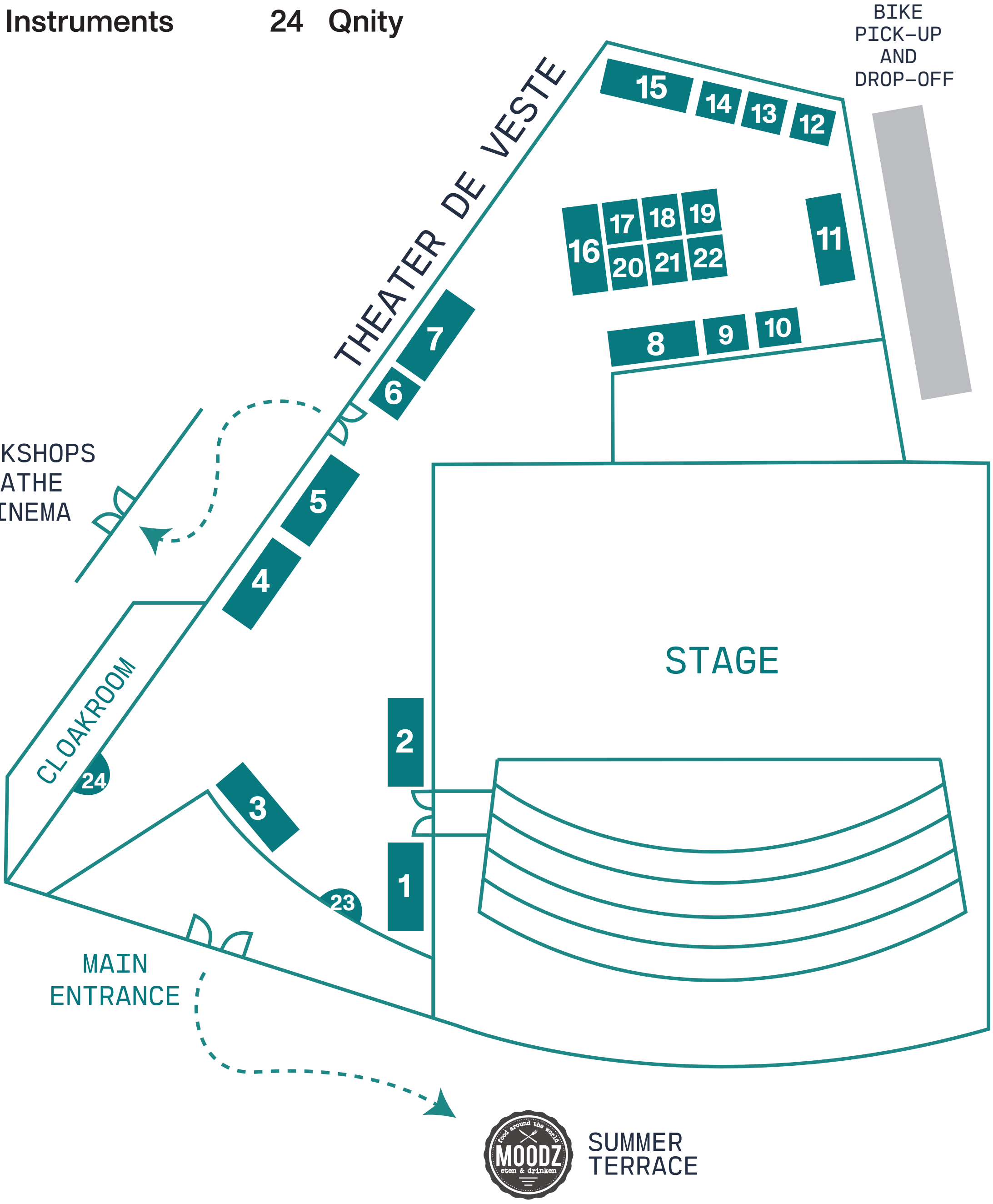
09:00	Opening Day 3
09:10	Scientific session: *Quantum benchmarking, calibration and standardization* Supported by OpenSuperQPlus
10:45	Coffee break
11:00	Scientific session: *Coupling and modelling of superconducting qubits*
12:30	Lunch break
13:30	Poster Session 2
13:30	Workshop by QT Indu (Pathe, Cinema 5)
14:30	Workshop by Orange Quantum Systems (Pathe, Cinema 7)
14:30	Workshop by QuantrolOx (Pathe, Cinema 5)
14:30	Workshop by QuantWare (Pathe, Cinema 7)
15:00	Coffee break
15:45	Keynote by Harry Putterman (Amazon Web Services)
16:30	Scientific session: *Bosonic and unconventional qubits*
19:00	Dinner in the Nieuwe Kerk

THURSDAY, 28 AUGUST

09:00	Opening Day 4
09:10	Scientific session: *Quantum control and enabling technologies*
10:45	Coffee break
11:30	Scientific Session: *Applications of superconducting qubits beyond computing*
12:20	Conference photo
12:30	Lunch break
13:45	Scientific session: *Full-stack systems, quantum gates and quantum readout*
15:15	Coffee break
16:00	Scientific session: *Scaling superconducting quantum devices* Supported by Orange Quantum Systems
18:00	Poster prize announcement Closing of Conference Excursion to Delft Circuits Conference after-party

Exhibition

1 QuantrolOx
2 QuTech
3 Quantum Machines
4 Qblox
5 QuantWare
6 Bluefors
7 Zurich Instruments
8 Qruise
9 Arctic Instruments
10 Vasta
11 OrangeQS
12 Oxford Instruments
13 AQSolotl
14 HQubit
15 QTIndu
16 MayBell Quantum
17 Keycom
18 YQuantum
19 Kiutra
20 Coax Co.
21 Intermodulation Products
22 Delft Circuits
23 ScalinQ
24 Qnity



OpenSuperQPlus

Just like its predecessor OpenSuperQ, the OpenSuperQPlus project (2023-2026) is part of the European Quantum Flagship Initiative, bringing together 28 partners from 10 countries under the leadership of Forschungszentrum Jülich. Structured into two distinct project phases of 3.5 years each, OpenSuperQPlus follows an ambitious agenda with the ultimate goal of developing a versatile 1,000-qubit quantum-computing system made in Europe.
During the current first phase, quantum computer demonstrators with the target of controlling a 100 qubits each are being developed at three partner sites in the Netherlands, Sweden, and Germany. These systems should lay the foundation for the final 1,000-qubit system and are intended to be made accessible to end users in science and industry via a cloud platform.
The large-scale consortium anticipates special use cases in quantum simulation for the chemical industry and materials science, as well as in solving optimisation problems, advancing machine learning and piloting quantum error correction.

QBLOX

Qblox is a leading provider of scalable and modular quantum control stacks. Qblox operates at the frontier of the quantum revolution in supporting academic and industrial labs worldwide with quantum control electronics.

The Qblox control stack, known as the Cluster, combines key technologies for qubit control and readout with a modular solution supporting a wide variety of customers and qubit platforms.

The Qblox team is 150+ members strong and continues to innovate hardware and software that is qubit-type-agnostic, sophisticated, and scalable to support operations on thousands of qubits.
For more information, visit www.qblox.com.

QUANTUM MACHINES

Quantum Machines (QM) is a leading provider of quantum control solutions, driving the advancement of quantum computing with its Hybrid Control approach. By harmonizing quantum and classical operations, Hybrid Control eliminates friction and optimizes performance across hardware and software, enabling researchers and engineers to iterate at speed, resolve setbacks, and bring visionary ideas to life. Its platform supports any type of quantum processor, empowers the industry to scale systems, accelerates breakthroughs, and pushes the boundaries-previously impossible.

To learn more about Quantum Machines, visit www.quantum-machines.co or follow QM on LinkedIn and Bluesky.

QuTech

QuTech is the quantum technology research institute of Delft University of Technology in the Netherlands. At QuTech, around 350 people are working on this radically new technology with world-changing potential.

Our mission is to develop scalable prototypes of a quantum computer and an inherently secure quantum internet, based on the fundamental laws of quantum mechanics.

We take pride in our academic excellence—evidenced, among other things, by the high number of papers we publish in leading academic journals—as well as in our economic impact and focus on valorisation, as demonstrated by the thriving quantum ecosystem of quantum technology companies around the university, supported by Quantum Delta Delft.

QuantrolOx

QuantrolOx is an Anglo-Finnish company pioneering the development of automated qubit control software that brings sustained and stable gate performance to qubits. This enables scientists to focus on using quantum computers rather than constantly fixing them. The company achieved this by automating the tuning, stabilisation, and optimisation of qubits, thereby removing a key bottleneck in the scaling of quantum computers. With QuantrolOx, quantum scientists get a stable platform for sustained experimentation and get more out of their expensive quantum infrastructure. Their software is applicable across many types of quantum technologies.

Maybell

Maybell builds the tools you need to usher in the quantum future. Quantum technology is rapidly evolving, but the tools supporting the quantum revolution have to keep up. Maybell's redesigned dilution refrigerator enables more fridges per lab, more experiments per fridge, and unparalleled reliability, flexibility, and user experience. They employ cutting-edge science and human-centered engineering to deliver industry-leading performance and unrivaled user experience.

Zurich Instruments

Zurich Instruments makes cutting-edge instrumentation for scientists and technologists working in advanced laboratories and who are passionate about phenomena that are notoriously difficult to measure. The company's hardware offering includes lock-in amplifiers, quantum computing control systems, impedance analysers, and arbitrary waveform generators. They bring innovation to quantum control systems in the form of efficient workflows, tailored specifications and feature sets, and a high degree of reliability, allowing quantum researchers to focus on developing and scaling up quantum processors and other elements of the quantum stack.

qruise

Qruise develops software that helps scientists and researchers use Machine Learning tools in their day-to-day scientific workflows without having to worry about what's under the hood. ML has revolutionised how science is being done and taking advantage of this new numerical toolset should not require having a full time ML scientist on the team to design, develop and deploy systems. Qruise is developing ML for Science as a productised toolset making ML driven discovery accessible to all. Our first offerings address the growing pains of controlling current generation noisy quantum computers (NISQ devices) and provide improvements in operational fidelities through the use of ML & Quantum Optimal Control.

QUANTWARE

QuantWare is a leading provider of quantum hardware and creator of the VIO Quantum Processor Unit (QPU) scaling technology. Leading the Quantum Open Architecture paradigm, QuantWare powers the quantum computers of customers in 20 countries, spread over four continents. QuantWare's VIO provides a scaling platform to unlock the fastest path towards systems with more than 1 million qubits. VIO is available in Quantum Processors designed by QuantWare, via Foundry Services, and as Packaging Service.

QTIndu – Quantum Technology Courses for Industry is a project founded by the European Commission. QTIndu focuses on developing education and training programmes that prepare professionals for the rapidly evolving field of quantum technologies. By creating modular, hands-on courses tailored to the needs of industry, including SMEs and public sector organizations, QTIndu helps bridge the gap between academic research and practical applications in quantum computing, sensing, and communication.
The initiative brings together universities, research institutes, and industry partners to ensure that training is relevant, accessible, and future-oriented.

IQM is a global leader in superconducting quantum computers. IQM provides both on-premises full-stack quantum computers and a cloud platform to access its computers. IQM customers include the leading high-performance computing centers, research labs, universities, and enterprises that have full access to IQM's software and hardware. IQM has over 300 employees with headquarters in Finland and a global presence in France, Germany, Italy, Japan, Poland, Spain, Singapore, South Korea, and the United States.

KNOW YOUR QUANTUM CHIP
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OrangeQS delivers test solutions for better quantum chips. The OrangeQS MAX is the first utility-scale turn-key quantum chip test equipment for industry. For qubit R&D, test system building blocks are available in the OrangeQS FLEX product line. Consultancy and services are offered through Quantum Care.

Monday, August 25

KEYNOTE

SCALING AND LOGIC IN THE COLOR CODE ON A SUPERCONDUCTING QUANTUM PROCESSOR

Keynote by **Nathan Lacroix**, Google Quantum AI

Quantum error correction is essential for bridging the gap between the error rates of physical devices and the extremely low error rates required for quantum algorithms. Recent error-correction demonstrations on superconducting processors have focused primarily on the surface code, which offers a high error threshold but poses limitations for logical operations.

The color code enables more efficient logic, but it requires more complex stabilizer measurements and decoding strategies. Measuring these stabilizers in planar architectures like superconducting qubits is challenging, and realizations of color codes have not addressed performance scaling with code size on any platform.

In this talk, I present a comprehensive demonstration of the color code on a superconducting processor operated below threshold. We demonstrate transversal Clifford gates and prepare magic states, a key resource for universal computation, achieving fidelities exceeding 99% with post-selection. Finally, we teleport logical states between color codes using lattice surgery. Together, these experiments establish the color code as a compelling research direction to realize fault-tolerant quantum computation on superconducting processors in the near future.

Visit
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MONDAY 25 AUGUST, 2025 | 16:00 – 17:00

Scientific session: Quantum error correction

To reset, or not to reset -- that is the question

Ophelia Crawford, Riverlane

Whether to reset qubits, or not, during quantum error correction (QEC) is a question of both foundational and practical importance. Text-book QEC demands that qubits are reset after measurement. However, fast qubit reset has proven challenging to execute at high fidelity. Consequently, many cutting-edge QEC experiments are opting for alternative reset schemes which avoid physically resetting qubits and that seem, at first appearance, to be equivalent to physical reset. However, in this work, we reveal fundamental differences in the fault-tolerant properties of reset schemes previously thought to be similar.
There are three broad classes of reset strategy: (a) Unconditional reset: a non-unitary operation (RZ) maps all states into the |0rangle|0*rangle* state. This is the text-book approach. (b) Conditional reset: a conditional bit-flip gate is applied on the auxiliary qubit if and only if the previous measurement outcome was 1. (c) No-reset: like conditional reset, but the effect of the conditional bit-flip gate is tracked in software.
Several recent quantum memory experiments with superconducting qubits used the no-reset scheme, while others implemented unconditional reset, making it timely to investigate the differences between these approaches. On the one hand, we confirm the claim from that for quantum memory there is no significant impact on QEC performance.
On the other hand, we find dramatic consequences when we perform a logical operation. We find that unconditionally resetting qubits can reduce the duration of fault-tolerant logical operations by up to a factor of two as the number of measurement classification errors that can be tolerated is doubled. We use the stability experiment as a proxy for lattice surgery to complement our analytical insights with extensive numerical results for a range of superconducting-inspired circuit-level Pauli noise models.
Lastly, we propose and numerically compare two novel syndrome extraction circuits that can reduce the time overhead of no-reset approaches. The first works by spreading the auxiliary qubit measurement classification errors to the data qubits, thereby flipping more of the stabiliser measurement outcomes. The second uses two ancilla qubits per stabiliser and effectively obtains two measurement outcomes for each stabiliser in one QEC round. These alternative circuits can be tested in near-term experiments and could offer long-term solutions.

Parallelized CZ gates for parity check measurements

Stephan Tasler, Friedrich-Alexander-Universität Erlangen-Nürnberg

Quantum error correction (QEC) is one of the crucial building blocks for developing quantum computers that have potential for reaching a quantum advantage in applications. Prominent candidates for QEC are stabilizer codes.
The readout of stabilizer codes is repeated many times during calculation. Thus it is beneficial, to reduce the time and increase the fidelity of the stabilizer readout procedure. In this project we investigate stabilizer readout in superconducting circuits hardware formed by transmon qubits interacting via tunable couplers. We design a CZZ gate that maps the parity of two data qubits onto one measurement qubit in a single step. We find a CZZ gate with a fidelity of 99.97%. For the unrotated surface code we can implement the CZZ gate in a fault tolerant readout protocol. We find, that using the CZZ gate in any type of surface code improves the physical error threshold compared to the standard two-qubit readout.

MONDAY 25 AUGUST, 2025 | 16:00 – 17:00

Quantum error detection with star architecture QPU

Florian Vigneau, QM Quantum computers

The architecture of a QPU affects the performance of quantum error correction. The Star-configuration offers higher connectivity than the square-grid topology and thus enables more hardware efficient implementation of some error correction codes. We demonstrate error detection using a four-qubit code on a star-topology QPU. Our QPU features six superconducting transmon qubits coupled to a central resonator via tunable couplers. We apply two-qubit gates between pairs via the central resonator with a specific protocol based on qubit-resonator interaction. On this hardware, we characterize the lifetime, coherence time, and perform state tomography of the logical states.

OpenSuperQPlus

Building a European Ecosystem for Superconducting Quantum Computers

Full hardware and software stack

External access at demonstrator sites

Integration in high-performance computing infrastructures

Benchmark applications in chemistry, materials science, optimisation, machine learning

High-coherence systems with up to 1,000 qubits

28 partners from 10 countries - universities, companies, RTOs

Start Date
1 March 2023

Duration
42 Months

Budget
€ 20 Mil.

28 Partners
10 Countries

QUANTUM

OpenSuperQPlus is part of the Quantum Flagship initiative of the European Union.

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Tuesday, August 26

KEYNOTE

ADVANCING COHERENCE OF SUPERCONDUCTING QUANTUM SYSTEMS AT THE SQMS CENTER

Keynote by **Anna Grassellino**
Fermilab

In this talk I will discuss the results of materials and devices studies, both for transmon qubits and 3D cavities, to understand sources of decoherence in superconducting quantum devices, including two-level system losses, quasiparticles and other noise sources. A systematic study of microwave loss of various materials including niobium, tantalum, aluminum and related oxides, and substrate loss for silicon and sapphire will be presented, using both cavities and qubits to disentangle subsystem losses and build a hierarchy of losses and mitigation strategies in these devices. We will present how we have achieved coherence values in transmons in excess of a millisecond.

Detailed material characterization studies of qubit fragments with advanced surface and superconducting characterization techniques across many SQMS partner institutions will be presented, highlighting new findings on nanoscopic origins of decoherence. We will also present device studies of quasiparticle bursts with comparison of qubits measured above and underground at Gran Sasso, temperature studies to disentangle TLS vs quasiparticle losses and novel studies showing that applying a magnetic field can reduce temporal T1 fluctuations in transmon qubits.

Combining these high coherence cavities and qubits, we will present the latest results on a record coherence cavity-qudit two-cell system, with coherence in excess of 20 milliseconds. Leveraging sideband interactions and novel error-resilient protocols, including measurement-based correction and post-selection, we achieve high-fidelity control over quantum states. This enables the preparation of Fock states up to N = 20 with fidelities exceeding 95%, the highest reported to date to the authors' knowledge, as well as two-mode entanglement with coherence-limited fidelities reaching up to 99.9% after post-selection. These results establish our SQMS platform as a robust foundation for quantum information processing, allowing for future extensions to high-dimensional qudit encodings.

Finally we will discuss important scalability issues SQMS is addressing such as large scale cryogenics and interconnects.

TUESDAY 26 AUGUST, 2025 | 09:50 – 10:45

Scientific session: Materials, fabrication and devices

Native-oxide-passivated trilayer junctions for superconducting qubits

Joonas Govenius, Arctic Instruments

Superconducting qubits in today's quantum processing units are typically fabricated with angle-evaporated aluminum--aluminum-oxide--aluminum Josephson junctions. However, there is an urgent need to overcome the limited reproducibility of this approach when scaling up the number of qubits and junctions. Fabrication methods based on subtractive patterning of superconductor--insulator--superconductor trilayers, used for more classical large-scale Josephson junction circuits, could provide the solution but they in turn often suffer from lossy dielectrics incompatible with high qubit coherence. In this work, we utilize native aluminum oxide as a sidewall passivation layer for junctions based on aluminum--aluminum-oxide--niobium trilayers, and use such junctions in qubits. We design the fabrication process such that the few-nanometer-thin native oxide is not exposed to oxide removal steps that could increase its defect density or hinder its ability to prevent shorting between the leads of the junction. With these junctions, we design and fabricate transmon-like qubits and measure time-averaged coherence times up to 30 μs at a qubit frequency of 5 GHz, corresponding to a qubit quality factor of one million. Our process uses subtractive patterning and optical lithography on wafer scale, enabling high throughput in patterning. This approach provides a scalable path toward fabrication of superconducting qubits on industry-standard platforms.

TUESDAY 26 AUGUST, 2025 | 09:50 – 10:45

Self-aligning hard stops for a flip-chip architecture

Matvey Finkel, TU Delft

In recent years, the scaling of superconducting quantum processors has motivated the transition from monolithic to flip-chip device architectures. Flip-chip allows the assembly of a large quantum processor from smaller modules that are easier to fabricate. It also allows for the separation of qubits from control circuits, protecting fragile Josephson junctions from the harsh fabrication steps required for optimal control circuitry. Qubit control and readout are primarily done through inter-chip capacitance and thus require a well-controlled chip-to-chip separation, achieved by use of hard stops – stiff bumps on the chip surface which define the separation. We present new self-aligning hard stops that provide micrometer accuracy for both vertical and lateral placement without any sticky layers or indium bumps, making the chips easily reusable without compromising performance. We present a proof-of-principle demonstration of this reusability by interchanging qubit and control chips over several cooldowns, with average coupling rates varying 5.2%. Our measurements of resonator quality factors and initial transmon characterization prove the feasibility of this approach for creating superconducting quantum processors.
We acknowledge funding from Intel corporation, the Allowance for Top Consortia for Knowledge and Innovation (TKIs) of the Dutch Ministry of Economic Affairs, the Dutch National Growth Fund (KAT-1), and the Netherlands Organization for Scientific Research (NWA.1292.19.194).

Scaffold-Assisted Window Junctions for Superconducting Qubit Fabrication

Chung-Ting Ke, Academia Sinica

Realizing fault-tolerant quantum computing (FTQC) requires many high-quality superconducting qubits. It is desirable to leverage modern semiconductor industry technology to ensure quality, uniformity, and reproducibility. Unlike conventional Josephson junction fabrication relies mainly on resist-assisted double-angle evaporation, posing integration challenges. In this talk, we demonstrate a liftoff-free qubit fabrication that integrates seamlessly with existing industrial technologies. This method employs a silicon oxide (SiO2scaffold to define an etched window with a well-controlled size to form a Josephson junction. The SiO2, which has a large dielectric loss, is etched away in the final step using vapor HF, leaving little residue. This Window junction (WJ) process mitigates the degradation of qubit quality during fabrication and allows clean removal of the scaffold.

The WJ process is validated by inspection and Josephson junction measurement. The scaffold removal process is verified by comparing the quality factor of the resonators with and without SiO2 coating/removing, showing minimum impact. Furthermore, compared to scaffolds fabricated by plasma-enhanced chemical vapor deposition (PECVD), qubits made by WJ through physical vapor deposition (PVD) achieve relaxation time up to 57mumus. The choice of SiO2 indicates the impact on the qubit quality due to the cleanness of the removal of SiO2. Our results pave the way for a lift-off-free qubit fabrication process, designed to be compatible with modern foundry tools and capable of minimizing damage to the substrate and material surfaces.

TUESDAY 26 AUGUST, 2025 | 11:30 – 12:30

Scientific session: Fluxonium and Error-Protected Qubits

Architectural Considerations for Scaling a Fluxonium Processor

Chunqing Deng, Quantum Science Center of Guangdong-Hong Kong-Macau Greater Bay Area

The fluxonium qubit is a compelling candidate for quantum processors due to its long coherence times and strong anharmonicity. These properties have enabled high-fidelity quantum operations in small-scale systems. A key challenge now is to determine whether a multi-qubit fluxonium processor can maintain similar performance at scale. We examine architectural strategies for scaling up a fluxonium processor. Specifically, we compare capacitive and inductive coupling for implementing two-qubit gates. Capacitive coupling leverages strong interactions between noncomputational states, enabling microwave-activated gates; however, this approach may suffer from short lifetimes of the involved excited states and increased leakage. In contrast, inductive coupling enables strong interactions within the computational subspace, preserving coherence and suppressing leakage during gate operations. Despite these advantages, inductive coupling can introduce significant flux crosstalk when scaling up, whereas capacitive coupling offers a more straightforward path to low-crosstalk, low-stray-interaction networks. In the end, we propose a scalable fluxonium processor architecture that incorporates tunable transmon couplers, and we present supporting experimental results.

A Compact Planar Multi-Modal Device for Efficient Error Suppression Encoding

Vivek Maurya, University of Southern California, USA

One of the major challenges in achieving fault-tolerant quantum computing has been the fidelity of two-qubit entangling gates. Traditional two-qubit gates typically rely on transverse coupling, which, in the weak coupling limit, introduces unwanted ZZ interaction terms. These parasitic terms often lead to spectator errors and contribute to qubit dephasing. Although weak ZZ coupling can introduce errors that require external drives to correct, strong ZZ coupling can be advantageous. In this work, we present a planar version of a multimodal device, commonly called a Trimon, which features three qubit-like modes A, B, and C, with strong, all-to-all longitudinal coupling. Our planar implementation uses two quarter-wave readout resonators to dispersively couple to modes A and C, and B and C, respectively, enabling more efficient readout, along with a charge line that improves control speeds compared to its 3D counterpart. We also discuss how this compact design of longitudinally coupled three-qubit modes can enable fast and high fidelity multi-qubit gates allowing us to construct decoherence-free subspaces and thereby improving the system's robustness against offset-charge errors.

TUESDAY 26 AUGUST, 2025 | 11:30 – 12:30

Single-Qubit Gates Beyond the Rotating-Wave Approximation for Strongly Anharmonic Low-Frequency Qubits

Martijn Zwanenburg, TU Delft

Single-qubit gates are in many quantum platforms applied using a linear drive resonant with the qubit transition frequency which is often theoretically described within the rotating-wave approximation (RWA). However, for fast gates on low-frequency qubits, the RWA may not hold and we need to consider the contribution from counter-rotating terms to the qubit dynamics. The inclusion of counter-rotating terms into the theoretical description gives rise to two challenges. Firstly, it becomes challenging to analytically calculate the time evolution as the Hamiltonian is no longer self-commuting. Moreover, the time evolution now depends on the carrier phase such that, in general, every operation in a sequence of gates is different. In this work, we derive and verify a correction to the drive pulses that minimizes the effect of these counter-rotating terms in a two-level system. We then derive a second correction term that arises from non-computational levels for a strongly anharmonic system. We experimentally implement these correction terms on a fluxonium superconducting qubit, which is an example of a strongly anharmonic, low-frequency qubit for which the RWA may not hold, and demonstrate how fast, high-fidelity single-qubit gates can be achieved without the need for additional hardware complexities.

TUESDAY 26 AUGUST, 2025 | 13:30 – 15:00

Poster session 1

Please visit
abstracts.sqa-conference.org
to see the abstracts

TUESDAY 26 AUGUST, 2025 | 13:30 – 15:00

Workshops

13:30
Mastering Qubit Calibration with QUAlibrate
Quantum Machines

Location: Pathe, Cinema 5

13:30
From QPU Characterization to QEC experiments: An End-to-End Workflow with LabOne Q and Deltakit
Zurich Instruments and Riverlane

Location: Pathe, Cinema 7

14:30
More capabilities, fewer lines of code
Qblox

Location: Pathe, Cinema 5

14:30
Accelerating Quantum Computing Research with IQM Resonance
IQM

Location: Pathe, Cinema 6

14:30
ML calibration and continuous operation of superconducting QPU
Qruise

Location: Pathe, Cinema 7

TUESDAY 26 AUGUST, 2025 | 15:45 – END OF DAY PROGRAM

Scientific session: Quantum Algorithms

Quantum-HPC integration: challenges and opportunities

Alba Cervera Lierta, Barcelona Supercomputing Center

In the last decade, the quantum computing field has advanced from theory and university-lab experiments to operational computing machines developed by several companies and startups. To control and operate quantum devices one needs traditional computation: the quantum operations instructions and the quantum processing unit (QPU) readout are orchestrated by a "classical" computer. On top of that, there are no purely-quantum algorithms, since several pre and post-processing algorithmic subroutines require traditional computation. All these facts lead us to integrate quantum computers with classical computers, extending the supercomputer's capabilities by enabling a new chip technology. In this talk, I will address the quantum-HPC integration roadmap: the motivation, methods, challenges, and opportunities. In particular, I will focus on the Barcelona Supercomputing Center experience with the installation, operation, and integration of two superconducting circuit-based quantum computers on-premises. I will also review examples of applications that superconducting circuits quantum computers can tackle: high-dimensional quantum computation and the generation of highly entangled states.

Scaling enhancement of quantum algorithms on superconducting qubit hardware

Philipp Auma, ParityQC

We present and demonstrate Parity Twine, a general method for the implementation of quantum algorithms that optimizes both gate count and circuit depth. This SWAP-less circuit synthesis uses connectivity-adapted CNOT-based building blocks to outperform known state-of-the art methods for implementing prominent quantum algorithms such as the quantum Fourier transform or the Quantum Approximate Optimization Algorithm, effectively generating algorithmic all-to-all connectivity on sparsely connected physical devices. Parity Twine is well suited for a wide range of superconducting quantum hardware, including linear, square-grid, hexagonal, ladder and all-to-all connected devices. Here, we demonstrate a significant improvement in the process fidelity of the quantum Fourier transform run on an IQM Crystal device accessed via IQM resonance when compared to alternative approaches. We discuss the scaling for larger systems indicating a fidelity improvement of multiple orders of magnitude.

Visit
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TUESDAY 26 AUGUST, 2025 | 15:45 – END OF DAY PROGRAM

Universal gate-based quantum reservoir computing for sequential data process

Francesco Monzani, University of Milan

Analysis of time series for predicting complex behaviors, including chaotic processes and anomaly detection, arises in several fields. Reservoir computing represents a consolidated computational paradigm in sequential information analysis and signal processing, theoretically founded on its universal approximation property. In particular, we investigate here the computational power of a gate-based quantum echo state network architecture for the online processing of temporal data, already implementable on currently available superconducting quantum computers. Firstly, we demonstrate its universality by fulfilling sufficient conditions that secure the universality of quantum reservoir computers. These sufficient conditions are encompassed in a formal setting, which serves as a general framework, regardless of the particular implementation of the reservoir. Notably, the universality of the gate-based echo state network is ensured by the essential action of a non-unital and strictly contractive quantum channel, which allows for the separability of the inputs and naturally ensures the fading memory of the network, respectively. Informed by this theoretical result, we show that it is possible to leverage quantum dissipation as a computational resource. Indeed, the amplitude damping can be exploited as an intrinsic non-unital and contractive channel, making computation effective. Moreover, we discuss a new algorithm that allows for the tunability of damping, making gate-based quantum reservoir computing more adaptable to a variety of quantum hardware. Eventually, we demonstrate the learning capabilities of the network by testing it on typical benchmark tasks for reservoir computing, quantifying its short-term memory, its ability to reconstruct nonlinear time-dependent functionals, and its predicting capacity, by both numerical simulationss and experiments on superconducting qubits. These results establish the computational power of this architecture on a solid theoretical foundation, ensuring potential applications for real-world applications of gate-based quantum reservoir computing for sequential signal processing.

Simulating gauge-invariant SU(2) Yang-Mills Theory with near-term quantum computers

Klaus Liegener, Walther-Meissner-Institute

Quantum Simulation of the Lattice Gauge Theories is a prime candidate for useful applications on near-term quantum devices. Some abelian gauge groups have already been simulated with great success, however, non-abelian groups have seen less progress due to challenges in implementing the Gauss constraint. In this talk, we propose going directly to the gauge-invariant Hilbert space by implementing the constraint prior to simulations. While the resulting Hamiltonian is of greater complexity, it also provides an inherent robustness of the system with respect to gauge-transformation and a reduction in the number of qubits required for the simulation. We showcase the advantages of this method explicitly for a toy-model of coarse-grained SU(2) Yang-Mills theory in 3D and develop a variational algorithm to obtain the energy levels of the system with high accuracy even on NISQ devices.

TUESDAY 26 AUGUST, 2025 | 15:45 – END OF DAY PROGRAM

Parallelizing commercial quantum hardware for feature encoding optimization in neutrino physic

Roberto Moretti, University of Milan-Bicocca

Machine Learning (ML) techniques for background event rejection in Liquid Argon Time Projection Chamber (LArTPC) detectors have been extensively studied for various physics channels, yielding promising results. In this contribution, we highlight the performance of Quantum Machine Learning (QML)-based background mitigation strategies to enhance the sensitivity of kton-scale LArTPCs for rare event searches in the few-MeV energy range. We emphasize their potential in the search for neutrinoless double beta decay ($0\nu\beta\beta$) of the 136Xe isotope, which is a low-energy event, generating very short, undersampled tracks in LArTPCs that are difficult to analyze with traditional methods. We present the application of QML algorithms, particularly Quantum Support Vector Machines (QSVMs). QSVMs exploit quantum computation to map original features into a higher-dimensional vector space so that the resulting hyperplane would allow better separation within classes. The choice of this transformation called feature map is critical, and results in a positive, semidefinite scalar function called kernel. QSVMs exhibit competitive performance but require careful design of their kernel functions, as optimizing a quantum kernel for specific classification tasks remains an open challenge in QML. We address this problem by employing powerful meta heuristic genetic optimization algorithms, which allow for the discovery of quantum kernel functions tailored to both the dataset and, crucially, the quantum hardware in use. We evaluate the impact of noise through experiments conducted on different IBM quantum backends with over 100 qubits. We further explore the feasibility of partitioning quantum devices to compute multiple independent quantum kernels in parallel, achieving significant acceleration in the genetic optimization process. This approach demonstrates that genetic optimization on modern quantum hardware is feasible under certain conditions, leading to a substantial speed-up and contributing to the pioneering of quantum hardware parallelization.

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Wednesday, August 27

09:10 – 10:45

Scientific session: Quantum benchmarking, calibration and standardization

Supported by OpenSuperQPlus

Benchmarking of quantum coherence dynamics at the observational limit

Morten Kjaergaard, Niels Bohr Institute, University of Copenhagen

The field of advanced control and calibration of superconducting qubits have evolved dramatically over the last couple of years. In this presentation I will discuss recent results from our lab on developing an exceedingly tight loop between rapid FPGA-based advanced logic deployed for qubit characterization, optimisation and parameter validation. In particular I'll discuss new techniques for estimating T1 in just a few ms and some surprising physics we found at these very rapid obersvational speeds. In addition, I'll show new work from our software suite that can estimate optimal parameters for readout, single-qubit parameters, coherence and gate benchmarking on sub-second timescales. I'll end by discussing the impact of our results on fundamental physics and advanced control of superconducting qubits.

Benchmarking Quantum Computers

Kristel Michielsen, University of Cologne and Forschungszentrum Jülich

Quantum computing promises unprecedented possibilities for important computing tasks such as quantum simulations in chemistry and materials science or optimization and machine learning.
In order to evaluate quantum computing as a new compute technology, profound test models and benchmarks are needed to compare quantum computing, quantum simulating and quantum annealing devices with trustworthy emulations on digital supercomputers. These emulations provide essential insight into the operation of those quantum devices, enable benchmarking and contribute to their design.
We present cross-platform benchmarking outcomes for various quantum computing devices and quantum algorithms. Among other examples, we present benchmarking results for the quantum approximate optimization algorithm (QAOA) emulated on a supercomputer and for the D-Wave quantum annealers for the tail assignment problem, a planning problem from aircraft industry.

WEDNESDAY 27 AUGUST, 2025 | 09:10 – 10:45

Reinforcement Learning for real-time context-aware gate calibration with DGX Quantum

Arthur Strauss, NU Singapore

Quantum gates on state-of-the-art devices are approaching limits where traditional quantum optimal control methods struggle to further reduce error rates below thresholds required for fault tolerance. A key bottleneck lies in the context-agnostic nature of current physical gate characterization. Methods such as randomized benchmarking provide global figures of merit like average gate fidelity, averaged over a broad range of scenarios, thereby obscuring context-specific correlations tied to the particular quantum circuit where the gate is deployed. Recent research has addressed noise from both spatially and temporally correlated sources, but definitions of context-awareness often remain static—focused on fixed device characteristics such as coupling-induced crosstalk or frequency collisions.
In contrast, our work introduces a gate calibration protocol that adapts dynamically to the specific quantum circuit being executed, targeting residual noise like microwave crosstalk and gate bleedthrough, whose effects depend heavily on circuit structure. Building on model-free reinforcement learning (RL) for quantum control, and extending it to context-aware fidelity estimation and real-time parameter inference, we present a novel paradigm for gate-based quantum computing: each gate is calibrated with pulse parameters tailored to its context within the circuit.
While context-specific calibration traditionally incurs prohibitive overhead due to compilation and communication delays, we leverage the DGX Quantum platform from Quantum Machines to demonstrate a low-latency, high-efficiency implementation. This enables the training and deployment of a classical RL agent that suppresses coherent noise effects, such as pulse distortions dependent on rotation angles. We further simulate the suppression of classical microwave crosstalk in quantum circuits involving six qubits with non-trivial interactions, recovering high-fidelity entangling gates (beyond 4 9s). Our approach paves the way for maintaining physical error rates below fault-tolerance thresholds in systems where spatial and temporal error correlations vary with circuit structure. This establishes a new avenue for leveraging advanced control systems to close the gap between circuit-level considerations and pulse-level optimization—critical for scalable, fault-tolerant quantum computing.

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WEDNESDAY 27 AUGUST, 2025 | 09:10 – 10:45

Characterization of Superconducting Qubits in a Low Data Regime

Alexandra Ramôa, Iberian Nanotechnology Lab

Characterizing quantum systems is crucial for quantum science, underpinning processes such as calibration, certification, and sensing. Bayesian inference is one of the most promising approaches, as a framework capable of optimal use of the quantum resources, which has been applied to an extensive range of practical problems. Examples include state or process tomography, Hamiltonian learning, noise model estimation, and others.

We apply Bayesian inference with advanced statistical methods to the calibration of superconducting qubits from IBMQ, achieving better results than Qiskit's default tools, especially in low data regimes. In Ramsey experiments, we reduce the uncertainty in resonance frequency estimation by a factor of 10 without increasing the number of measurements. For coherence time estimation, we achieve similar uncertainty to standard methods using only 6.6\% of the data. The proposed algorithms excel in experimental characterization in the low data regime, and when the measurements have degrees of freedom. We additionally investigate adaptivity, dataset ordering, and other heuristic methods as resources for quantum characterization, discuss scenarios where standard methods fail, and propose alternatives.

We also develop algorithms for the characterization of other open quantum systems, to further optimize the inference and control. While Bayesian inference has often been applied to the characterization of quantum systems, these instances often target unidimensional estimation problems where simple statistical tools suffice. We demonstrate the shortcomings of these tools through numerical simulations and propose more robust alternatives.

In particular, we report and compare results from different techniques, such as sequential importance resampling with the Liu-West filter and with Markov Chain Monte Carlo kernels, Hamiltonian Monte Carlo (HMC), stochastic gradient HMC with and without friction, HMC with energy conserving subsampling, random walk Metropolis-Hastings (RWM), tempered likelihood estimation, block pseudo-marginal Metropolis-Hastings with subsampling, hybrid approaches that adaptively switch between HMC and RWM, and Gaussian rejection filtering.

We propose heuristics for the experimental design, assess the impact of often neglected factors such as the dataset ordering, and explore how commonly used strategies fail in different contexts.

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WEDNESDAY 27 AUGUST, 2025 | 09:10 – 10:45

A charge-basis tomographic protocol for superconducting qubits

Elena Lupo, Forschungszentrum Jülich

Understanding and controlling quantum states of superconducting circuits relies on the use of accurate models and parameters. In this regard, traditional spectroscopic techniques are employed to extract excited state populations, transition frequencies, and rates. However, crucial information about quantum coherence can only be obtained through phase-sensitive methods such as quantum state tomography, which is usually performed in the system's energy basis. In this work, we introduce a complementary method for reconstructing the ground state of a transmon in the basis of its relative charge across the junction - a representation that can provide new insights into the quantum circuits and can assist in validating its Hamiltonian model. Inspired by methods from cavity state tomography, our approach combines the flux-tuning of a split Josephson junction and adiabatic evolution to achieve the desired density matrix reconstruction. Further possible applications of this method include the study of hybrid superconductor-semiconductor junctions.

WEDNESDAY 27 AUGUST, 2025 | 11:30 – 12:30

Scientific session: Coupling and modelling of superconducting qubits

The P-Mon -- A Protected Three-Mode Qubit

Max Werninghaus, Walther-Meissner-Institut

To control and measure the state of a quantum system, it must necessarily be coupled to external degrees of freedom. This inevitably leads to spontaneous emission via the Purcell effect, photon-induced dephasing from measurement back-action, and errors caused by unwanted interactions with nearby quantum systems. To tackle this fundamental challenge, we make use of the design flexibility of superconducting quantum circuits to form a multimode element—an artificial molecule—with symmetry-protected modes. The proposed qubit design consists of three superconducting islands coupled to a central island via Josephson junctions. It exhibits two essential nonlinear modes, one of which is flux insensitive and used as the protected qubit mode. The second mode is flux tunable and serves via a cross-Kerr-type coupling as a mediator to control the dispersive coupling of the qubit mode to the readout resonator. We demonstrate the Purcell protection of the qubit mode by measuring relaxation times that are independent of the mediated dispersive coupling. We show that the coherence of the qubit is not limited by photon-induced dephasing when detuning the mediator mode from the readout resonator and thereby reducing the dispersive coupling. Furthermore, we outline our approach to two-qubit gate operations towards a scalable architecture based on our qubit design

Scalable and non-perturbative effective models for superconducting-qubit processors

Simon Pettersson Fors, Chalmers

Superconducting quantum processors are experimentally progressing towards 100+ qubits. To model these many-qubit systems, it is often required to integrate out weakly coupled degrees of freedom resulting in effective descriptions. In this talk, we present a scalable and non-perturbative approach for deriving effective Hamiltonians from a renormalization procedure and flow equations. We showcase our approach on a two-dimensional array of transmons coupled with tunable couplers and compare against exact numerical diagonalization for few-qubit systems. By integrating out high-energy degrees of freedom, we infer how ZZ-like couplings scale in the two-dimensional array. Our approach is a scalable method to accurately model long-range couplings in superconducting quantum simulators and quantum processors.

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WEDNESDAY 27 AUGUST, 2025 | 11:30 – 12:30

Multi-qubit couplers and multi-qubit gates

Verena Feulner, Friedrich-Alexander-Universität Erlangen-Nürnberg

A key challenge in quantum computing is the implementation of multi-qubit gates that operate significantly faster than the qubit decoherence time, while still achieving the high fidelity required for practical applications. Traditional approaches decompose multi-qubit interactions into sequences of two-qubit gates, increasing execution time and susceptibility to decoherence.
Additionally, simulating interactions between non-neighboring (diagonal) qubits on rectangular lattice architectures is inefficient, as it typically requires multiple gate operations, leading to increased error rates.
We propose a circuit architecture that enables direct diagonal coupling between qubits and supports the simultaneous execution of iSWAP gates between two qubit pairs.
To evaluate performance, we take the full five-element fidelity into account, providing a comprehensive measure of gate quality in the presence of realistic interactions.
Our setup involves four transmon qubits coupled via either a dc-SQUID or a SNAIL (Superconducting Nonlinear Asymmetric Inductive eLement), and aims to reduce gate count and improve execution speed. We investigate the feasibility of this design for realizing efficient multi-qubit gate operations in superconducting quantum systems.

WEDNESDAY 27 AUGUST, 2025 | 13:30 – 15:00

Poster session 2

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WEDNESDAY 27 AUGUST, 2025 | 13:30 – 15:00

Workshops

13:30
Introduction to Quantum Inspire and Quantum Network Explorer Demonstrators
QTIndu

Location: Pathe, Cinema 5

13:30
OrangeQS Juice & Quantify
Orange Quantum Systems

Location: Pathe, Cinema 7

14:30
Accelerating qubit calibration using Quantum EDGE
QuantrolOx

Location: Pathe, Cinema 5

14:30
Contralto-A: Calibrating State-of-the-Art Quantum Processors for QEC
QuantWare

Location: Pathe, Cinema 7

WEDNESDAY 27 AUGUST, 2025 | 14:45 – 16:30

KEYNOTE

HARDWARE-EFFICIENT QUANTUM ERROR CORRECTION USING CONCATENATED BOSONIC

Keynote by **Harry Putterman**
Amazon Web Services

To solve problems of practical importance, quantum computers will likely need to incorporate quantum error correction, where a logical qubit is redundantly encoded in many noisy physical qubits. The large physical-qubit overhead typically associated with error correction motivates the search for more hardware-efficient approaches. In this talk we will present and characterize a superconducting circuit which realizes a logical qubit memory formed from the concatenation of encoded bosonic cat qubits with an outer repetition code of distance d=5. The bosonic cat qubits are passively protected against bit flips by two photon dissipation. The phase-flip correcting repetition code operates below threshold, with logical phase-flip error decreasing with code distance from d=3 to d=5. Concurrently, the logical bit-flip error is suppressed with increasing cat-qubit mean photon number. The minimum measured logical error per cycle is on average 1.75(2)% for the distance-3 code sections, and 1.65(3)% for the longer distance-5 code. We will tie our results to the longer term opportunities for reaching computationally relevant error rates with concatenated bosonic qubits.

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WEDNESDAY 27 AUGUST, 2025 | 16:30 – END OF DAY PROGRAM

Scientific session: Bosonic and unconventional qubits

Control and measurement of Schrödinger cat states in bosonic cQED

Yvonne Gao, National University of Singapore

Cat states, with their distinctive phase-space interference features, are promising candidates for a wide range of quantum information processing tasks. In this talk, I will present our recent work on manipulating the non-Gaussian characteristics of bosonic cat states residing in superconducting cavities to enhance their resilience against photon loss. I will also discuss our implementation of a practical and resource-efficient measurement scheme that enables noise-resilient tomography of these bosonic states. These demonstrations are carried out using small bosonic cQED devices consisting of only a single cavity coupled to a nonlinear ancillary transmon. Our results provide a useful set of tools for quantum information processing using cat states in bosonic cQED systems.

Enhancing the Kerr-cat qubit with auto-parametric dissipation

Sergey Hazanov, Weizmann Institute of Science

Stabilized cat qubits are a promising candidate for realizing hardware-efficient quantum error corrected qubits. While dissipative cat qubits offer long coherence via engineered two-photon loss, they require complex circuitry and operate at slow gate speeds. Kerr-cat qubits simplify the hardware by using Kerr nonlinearity for stabilization, but suffer from limited coherence and slow readout.
We propose the auto-parametric Kerr-cat qubit, a hybrid approach that enhances Kerr-based stabilization with auto-parametric engineered dissipation. A small two-photon loss channel can improve bit-flip lifetimes by over an order of magnitude, while a three-photon loss channel enables fast, high-fidelity readout. Both dissipation processes are implemented through a single tunable buffer mode, minimizing hardware overhead. This strategy improves performance without significant added hardware complexity, pointing toward practical and scalable implementations of stabilized cat qubits.

WEDNESDAY 27 AUGUST, 2025 | 16:30 – END OF DAY PROGRAM

Uncovering intrinsic loss mechanisms in super-semi nanowire gatemons

Zhenhai Sun, University of Copenhagen

The exotic current-phase relation and electrostatic gate-tunability provided by the hybrid superconductor-semiconductor Josephson junctions make gatemons an appealing platform to study condensed matter physics and build novel superconducting circuits. However, multiple experiments across several material platforms have not been able to reproduce high-coherence gatemons on par with current transmons, suggesting intrinsic loss mechanisms in proximitized super-semi Josepshon junctions yet to be understood. To investigate potential undetermined loss channels, we fabricated and measured three types of qubits: high-coherence transmons, transmons augmented with gatemon-style gate lines, and nanowire-based gatemons. By using the two types of transmons as references, we were able to isolate relaxation mechanisms from the Purcell effect, internal loss, and spontaneous emission to the gate line. Our result suggests that the gatemons have intrinsic loss channels originating from the proximitized super-semi Josephson junctions.

Spin circuit QED in the time domain

Tobias Bonsen, TU Delft

Circuit quantum electrodynamics (circuit QED) has been an enabling factor in the scaling of superconducting quantum processors over the past decades. In recent years, circuit QED with semiconductor spins (spin circuit QED) has emerged as a promising avenue for scaling spin qubit processors. In spin circuit QED, superconducting resonators are patterned on top of the semiconductor heterostructure and can mediate long-range interactions between spin qubits, opening up possibilities for quantum processors consisting of distributed spin registers with on-chip classical control electronics.

We present our realization of long-range spin-spin interactions using an on-chip superconducting resonator in two regimes. First with two spins detuned from the resonator frequency, allowing the demonstration of two-qubit iSWAP logic via virtual photons. Next, we tune the two spin frequencies to match the resonator frequency. Here, we show coherent spin-photon oscillations (vacuum Rabi oscillations) and utilize this to demonstrate spin-state transfer in this resonant spin-photon regime. Finally, we observe a speedup in the oscillations when populating the resonator before turning on the interaction. We fit simulations to the data in this resonant regime and comment on ways to improve the cooperativity of the system.

Thursday, August 28

09:10 – 10:45

Scientific session: Quantum control and enabling technologies

Dynamic circuits for efficient quantum computation: logarithmic-depth approximate quantum Rourier transform on a line

Elisa Baumer, IBM Quantum

Dynamic quantum circuits—those that incorporate mid-circuit measurements and feed-forward operations—offer significant advantages for entanglement distribution and circuit depth reduction. In this talk, we illustrate these benefits through introductory examples and then focus on a major application: implementing the Approximate Quantum Fourier Transform (AQFT) in logarithmic depth using only 4n qubits arranged on a line with nearest-neighbor connectivity. For certain input states, we further reduce the qubit count to 2n. A key contribution of our construction is a new implementation of an adder with logarithmic depth under linear connectivity constraints, enabling the more efficient AQFT realization and broader applications in quantum algorithm design.

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THURSDAY 28 AUGUST, 2025 | 09:10 – 10:45

Tightly integrating a GPU and a QPU for fast calibration of multi-qubit circuits

Michaela Eichinger, Quantum Machines

As quantum processing units (QPUs) scale to dozens of qubits, the seamless integration of classical and quantum computing through hybrid control architectures becomes essential. Increasing QPU sizes, coupled with advancements in gate and readout fidelities, are paving the way for fault-tolerant quantum computation via quantum error correction (QEC). However, achieving this requires real-time decoding of logical qubit states from ancilla measurements, necessitating a hybrid approach that tightly merges classical and quantum processing.

Quantum system characterisation and error budgeting using differentiable digital twins

Anurag Saha Roy, Qruise

In-depth characterisation of quantum devices is crucial not just for the optimal operation of high fidelity gates but more importantly, to identify true system parameters for creating an accurate model of the QPU and its control stack. Such an accurate digital twin of the system is critical for generating an error budget – a quantitative breakdown of the contribution of different error generating factors to the bottomline benchmarks of a QPU's performance. We use modern Machine Learning tools to combine a differentiable physics accurate digital twin with data from a broad set of characterisation experiments to build a model with a high predictive power that accurately predicts the outcome of experiments even outside the training dataset. This predictive model is then used to extrapolate the error contributions from different system and environmental factors. We test these tools on superconducting QPUs and discuss various demonstrative results.

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THURSDAY 28 AUGUST, 2025 | 09:10 – 10:45

Automated QPU Characterization and Calibration Workflows: From Bring-Up to Gate Optimization

Jelena Trbovic, QuantrolOx

Developing high-quality quantum processing units (QPUs) requires fast and accurate calibration, whether for fabrication feedback, iterative design, or pre-scaling evaluation. Accelerating this process requires tools that not only automate qubit characterization, such as coherence times, coupling strengths, and crosstalk, but also maintain optimal working points to ensure high-fidelity control and readout.

In this joint work with Academia Sinica, we demonstrate how Quantum EDGE software enables automated workflows that provide both rapid single-qubit bring-up and nuanced optimization of two-qubit gate performance. Beyond conventional routines, it supports customized procedures to extract physical parameters of interest, offering deeper insight into QPU behavior. The software automates standard procedures such as DRAG tuning and readout optimization, enabling fast and reproducible qubit bring-up with minimal manual intervention. For high-fidelity two-qubit gates, the system addresses deeper challenges: leakage suppression, precise pulse shaping, and mitigation of residual interactions such as ZZ coupling.

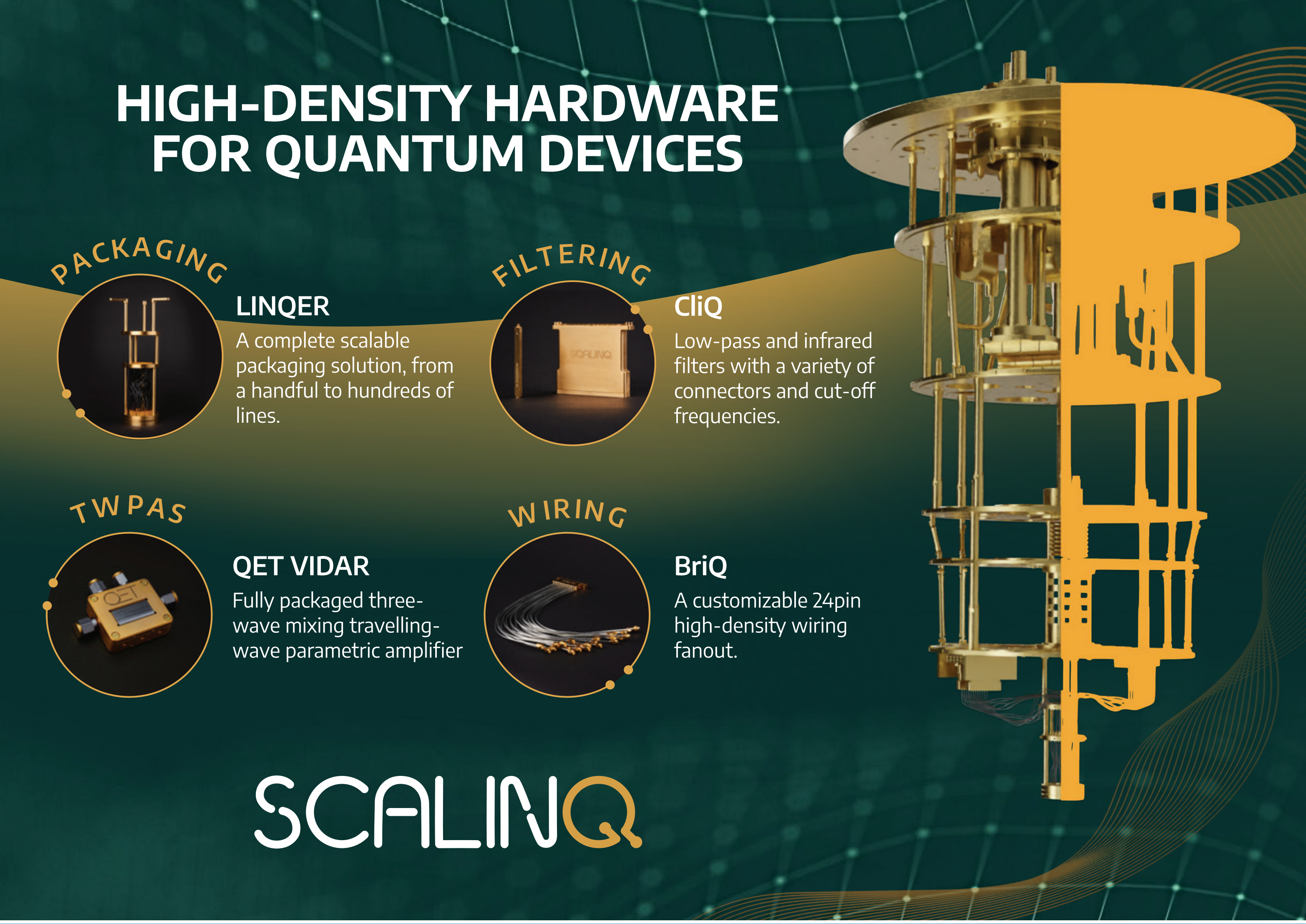
We present automated procedures that tune working points by identifying the optimal qubit and coupler bias configurations. These routines are complemented by cryoscope-based pulse predistortion, which compensates for flux line distortions and ensures accurate control of qubit frequency trajectories during gate execution.

In this talk, we will highlight results from automated calibrations performed on Academia Sinica's QPU using Quantum EDGE. We demonstrate how a combination of automated workflows and fine-tuned control protocols enables stable, high-fidelity quantum operation across multiple qubits laying the foundation for scalable, algorithm ready quantum systems.

Scalable Quantum Computing with Optical Links

Taryn Stefanski, QPhox

Superconducting qubit-based processors are currently one of the leading architectures for quantum computing. Despite the rapid advancement of the field, scaling these systems will inevitably be limited by hardware constraints, namely the finite space and cooling power available within the required cryogenic infrastructure. Overcoming this limitation could be feasibly achieved with the incorporation of optical interconnects between physically separated processing modules. While optical frequency links offer the advantage of low loss and low noise propagation, an intermediary is required to enable the conversion between the microwave and optical frequency domains. Here, we discuss a number of protocols that would enable on-demand, high fidelity entanglement between remote superconducting qubit-based processors and the corresponding performance metrics and requirements of the transducer hardware. Furthermore, we highlight the utility of current or near-term transducers and describe the advantages of multiple parallel transduction channels and integration with auxiliary hardware, such as microwave or optical quantum memories. This technology will enable computational capabilities that surpass what is achievable with a single processing unit and provides a path towards attaining utility scale quantum computation.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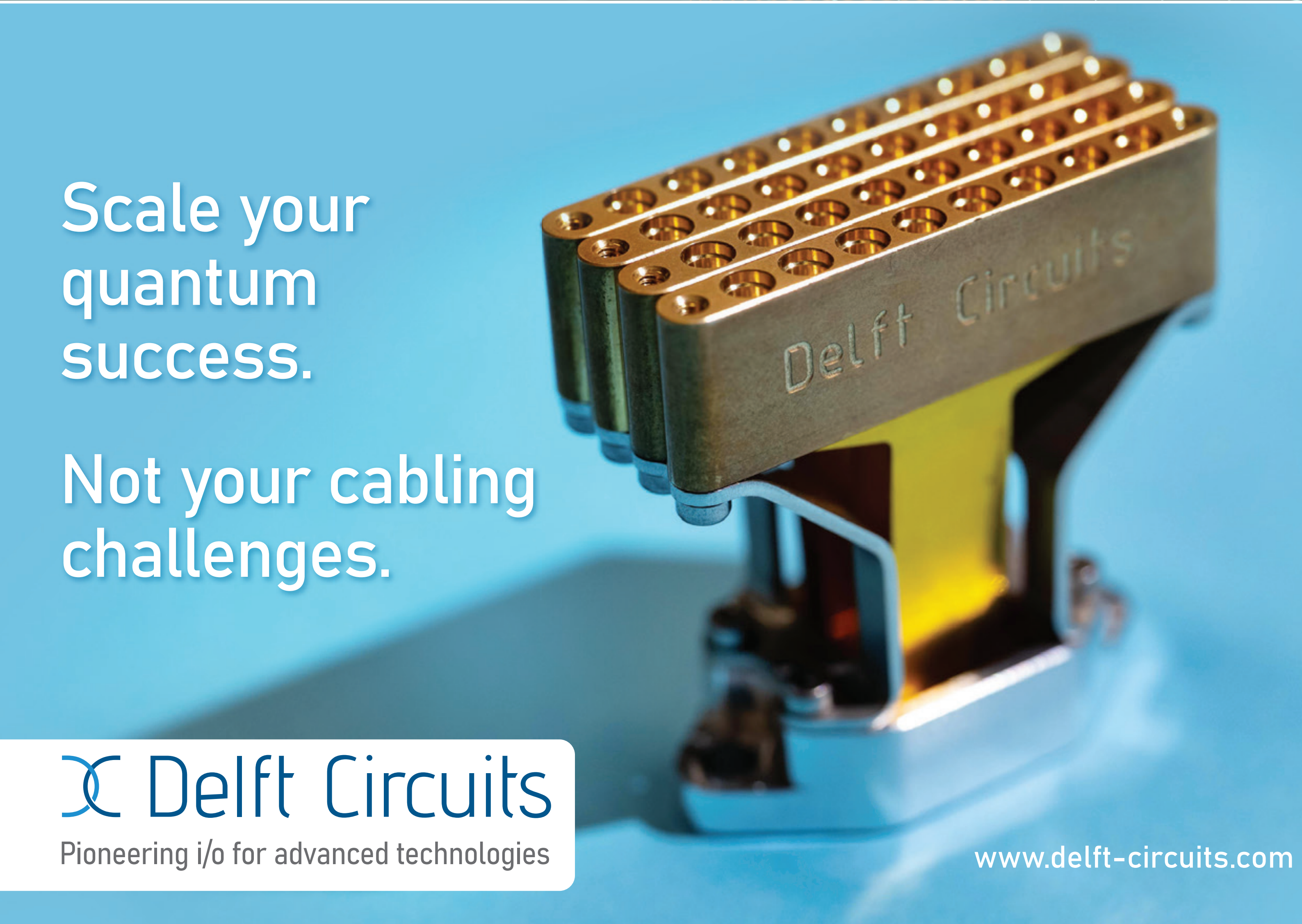
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THURSDAY 28 AUGUST, 2025 | 11:30 – 12:20

Scientific session: Applications of superconducting qubits beyond computing

Quantum thermodynamics with superconducting circuits: fundamental insights and applications

Simone Gasparinetti, Chalmers University of Technology

I will describe our efforts in developing quantum thermal machines based on superconducting circuits, as well as the methodology needed to appreciate tiny photonic heat currents and their fluctuations. Our interest here is twofold. On one hand, we'd like to establish quantum thermodynamics as an enabling technology. In this direction, we demonstrated the autonomous reset of a superconducting qubit to an effective temperature of 22 mK, driven by a quantum absorption refrigerator. On the other hand, we'd like to investigate how genuinely quantum resources can be harnessed to perform thermodynamic tasks. In this direction, we have recently demonstrated quantum refrigeration driven by pure dephasing. We expect this line of work to ultimately lead to "quantum advantages" in thermodynamics. While the existence and extent of such advantages remain active areas of research, our collaborators and we have obtained encouraging theoretical results regarding the thermodynamics of precision. I will therefore conclude by discussing our experimental activities in this area, more specifically, in relation to thermodynamic uncertainty relations and quantum clocks.

Generation of frequency-bin microwave photons enabled by a broadband resonator

Takeaki Miyamura, University of Tokyo

An itinerant microwave photon enables quantum communication between remote superconducting qubits in distributed quantum computing architectures. However, photon loss during propagation leads to a significant source of error. Frequency-bin encoding of microwave photons provides a method to detect such photon loss events. In this work, we demonstrate the generation of frequency-bin microwave photons enabled by a broadband resonator coupled to a fixed-frequency transmon. By applying two microwave drives whose frequencies are appropriately tuned, we encode the qubit state into two distinct frequencies of the emitted photon. Our method only needs one drive line to emit such a frequency-encoded photon, making it readily compatible with current superconducting qubit integration schemes.

THURSDAY 28 AUGUST, 2025 | 11:30 – 12:20

Single-atom maser in bosonic circuit QED through flux-activated parametric dissipation

Fernando Valadares, National University of Singapore

Beyond coherent interactions, the full control of a light-matter system requires harnessing from dissipative dynamics. The irreversibility of dissipation finds use in several elementary tasks such as leakage reduction, unconditional state preparation and stabilization. We study the on-demand control over coherent and dissipative dynamics of a high-Q superconducting cavity coupled to a flux-tunable transmon. In the first part of the talk, based on recently published results, we demonstrate how changing the cavity-transmon coupling regime within coherence times has several use cases in bosonic quantum information, such as fast state preparation, suppression of nonlinearities and flexible choice in cavity tomography. In the second half, we expand the system to include tunable dissipation, implementing a single-atom maser as proof-of-principle. The transmon population inversion is achieved through parametric resonance the environment, and the resulting energy is loaded into the high-Q cavity to create masing. The control over parametric resonances allows the investigation of different threshold regimes and the optimization of the steady state. With high on-off dissipation ratio, the masing can be interrupted to allow tomography of the light field to measure the photon statistics. These results aim to expand the manipulation of light-matter dynamics in bosonic circuit QED, which is of profound interest for quantum computation, sensing, and fundamental research on quantum phases of matter.

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THURSDAY 28 AUGUST, 2025 | 13:45 – 15:15

Scientific session: Full-stack systems, quantum gates and quantum readout

Mitigating spectator effects and leakage in the Delft demonstrator

Leo DiCarlo, QuTech and Kavli Institute of Nanoscience, Delft University of Technology

I will present the open, full-stack architecture for superconducting quantum computing developed for both research in quantum error correction and public access in collaboration with companies from the Delft ecosystem. Two recent experiments will be featured. The first investigates the optimal frequency positioning of tunable couplers, focusing on minimizing the impact of spectator qubits on single-qubit gates, two-qubit gates and readout. The second presents the realization of a signalling leakage reduction unit built into readout operations without extra time cost. We demonstrate the benefits of signalling leakage over just seeping it using memory and stability experiments on repetition codes. This research is funded by the Dutch National Growth Funds (KAT-1), the European Flagship (OpenSuperQPlus), and Intel corporation.

Efficient Implementation of Arbitrary Two-Qubit Gates via Unified Control

Fei Yan, Beijing Academy of Quantum Information Science

The native gate set is fundamental to the performance of quantum devices, as it governs the accuracy of basic quantum operations and dictates the complexity of implementing quantum algorithms. Traditional approaches to extending gate sets often require accessing multiple transitions within an extended Hilbert space, leading to increased control complexity while offering only a limited set of gates. Here, we experimentally demonstrate a unified and highly versatile gate scheme capable of natively generating arbitrary two-qubit gates using only exchange interaction and qubit driving on a superconducting quantum processor, achieving maximum expressivity. Using a state-of-the-art transmon-coupler-transmon architecture, we achieve high fidelities averaging $99.37 \pm 0.07\%$ across a wide range of commonly used two-qubit unitaries. This outstanding performance, combined with reduced complexity, enables precise multipartite entangled state preparation, as demonstrated. To further enhance its applicability, we also show the high-fidelity realization of the unique B gate, which efficiently synthesizes the entire family of two-qubit gates. Our results highlight that fully exploiting the capabilities of a single interaction can yield a comprehensive and highly accurate gate set. With maximum expressivity, gate-time optimality, demonstrated high fidelity, and easy adaptability to other quantum platforms, our unified control scheme paves the way for optimal performance in quantum devices, offering exciting prospects for advancing quantum hardware and algorithm development.

THURSDAY 28 AUGUST, 2025 | 13:45 – 15:15

Heisenberg-limited calibration of quantum gates

Akel Hashim, Lawrence Berkeley National Lab

The calibration of high-quality single- and two-qubit gates is an essential component in engineering large-scale quantum computers. However, many standard calibration techniques based on bootstrapped sweeps or randomized circuits may not be sensitive to certain calibration errors in a gate. As a result, these approaches are inefficient, requiring many experimental shots to achieve acceptable performance. Moreover, the calibration of quantum gates is the largest overhead in experimental implementations of quantum applications. This calibration overhead scales linearly in the number of qubits if gates are calibrated serially, and at worse scales combinatorially in the number of possible two-qubit gates, depending on the underlying hardware platform. Thus, it is necessary to improve calibration routines and reduce the overall calibration overhead for scalable quantum computing.
In this work, we demonstrate that an efficient characterization method known as robust phase estimation (RPE) can enable high-precision, Heisenberg-limited estimates of coherent errors in native gates. Using RPE, the calibration problem may now be reduced to a simple optimization loop that minimizes the estimated coherent error. We experimentally demonstrate our calibration protocols for both single- and two-qubit gates, and under different contexts (e.g., simultaneous gate calibration). We validate the improved performance with gate set tomography.
Finally, we argue that for quantum computing to be scalable, it will be necessary to parallelize gate calibration. This overhead can be made constant in the number of qubits if (1) all single-qubit gates are calibrated in parallel, and (2) the number of possible combinations of two-qubit gates are restricted and are calibrated in parallel for each combination. Methods such as RPE enable (1) more rapid and precise calibration of simultaneous native gates via closed-loop optimization, and (2) rapid characterization of context-dependent errors that may occur under different combinations of parallel gates. For some context-dependent errors, we show how RPE enables us to account for them using flexible compilation tools, without the need for recalibration. Our results demonstrate that the costly overhead of calibrating gates under different contexts can be replaced with cheap characterization methods paired with flexible compilers. Therefore, we argue that it is more scalable to do less calibration, and instead do more characterization.

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THURSDAY 28 AUGUST, 2025 | 13:45 – 15:15

Fundamental speedup of the controlled-Z gate in superconducting qubits using a triple-state degeneracy

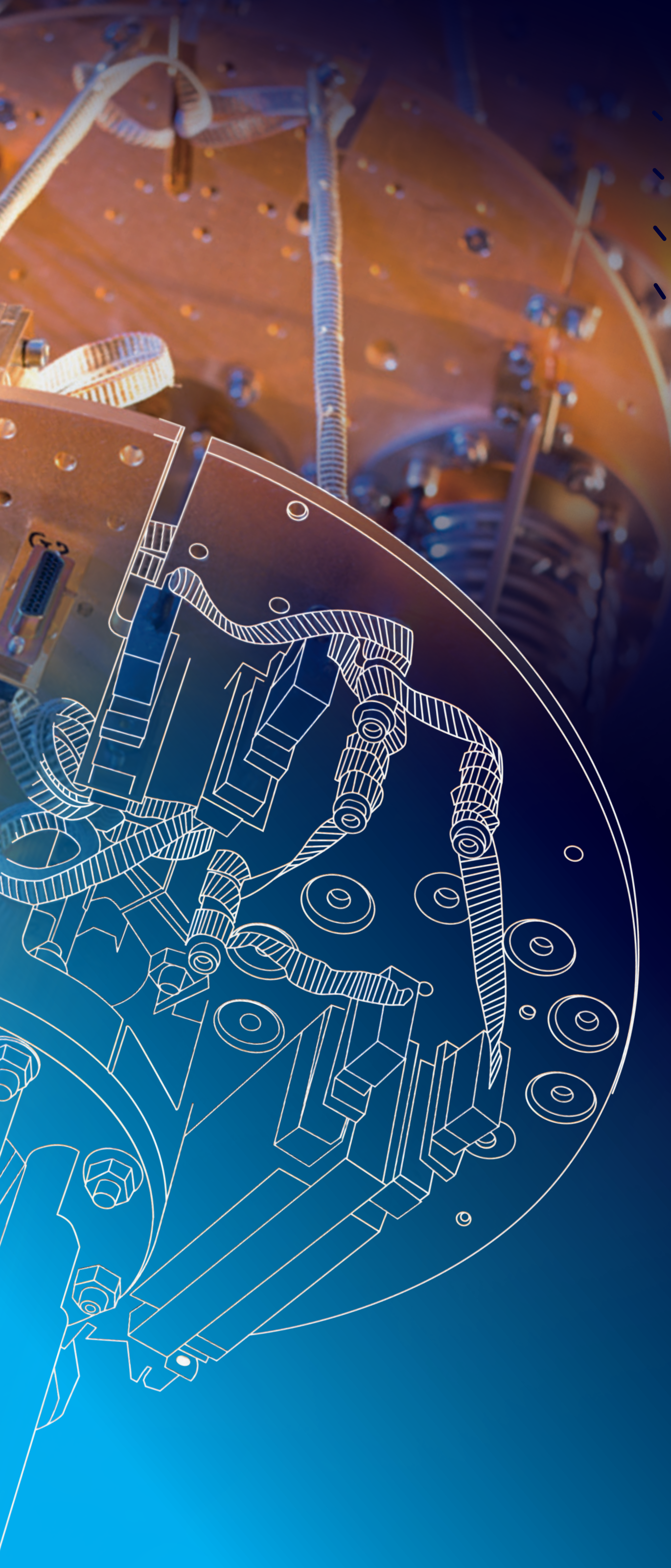
Simone D Fasciati, University of Oxford

Useful quantum computation requires fast and high-fidelity entangling gates between qubits. In superconducting quantum circuits, many common realizations of the two-qubit controlled-Z (CZ) gate involve an interaction between a pair of states in the two-excitation subspace. It has been proposed theoretically that increasing the number of involved states from two to three would yield a CZ gate faster by a factor of $\sqrt{2}$. This scheme requires two qubits with exactly opposite anharmonicities. Here, we experimentally demonstrate such a system using a transmon coupled capacitively to an inductively shunted transmon (IST). We observe that the dynamics of the triple-state degeneracy in the two-excitation subspace closely match theoretical predictions, including the $\sqrt{2}$ interaction speedup. This allows us to execute a CZ gate in 25 ns using fast flux control, while also maintaining low levels of coherent (ZZ) error during idling thanks to the opposite anharmonicities. We obtain a CZ gate fidelity of 99.80(2) % from interleaved randomized benchmarking, stable over a period of 12 hours without recalibration. Crucially, this gate scheme does not require tunable coupling between qubits, minimizing hardware complexity.

Fast multiplexed superconducting qubit readout with intrinsic Purcell filtering

Peter Spring, Riken Center for Quantum Computing

The measurement of superconducting qubits now constitutes a major component of the error budget and execution time for algorithms requiring detection and feedback. This talk presents advances in achieving fast, high-fidelity qubit readout via the dispersive interaction between a qubit and a readout resonator. We begin by demonstrating a compact Purcell filter formed by capacitively and inductively coupling the readout resonator to a filter resonator. By engineering readout mode linewidths up to 42 MHz, we realize simultaneous readout of four qubits within a 56 ns integration window, achieving assignment fidelities between 99.65% and 99.91%. Furthermore, we show that using the “Path Signature” of the measurement record—rather than the weighted integral—can enhance this readout fidelity further.
In the second part of the talk, we introduce a “MIST benchmarking” pulse sequence to characterize measurement-induced relaxation and measurement-induced leakage. We use this sequence to experimentally show that fast, high-fidelity dispersive readout can be performed with minimal leakage from the computational subspace. Finally, we present simulations of Transmon ionization to explain the observed absence of significant leakage.



THURSDAY 28 AUGUST, 2025 | 16:00 – 18:00

Scientific session: Scaling superconducting quantum devices

Supported by Orange Quantum Systems

Elements for high performance quantum error correction

Johannes Heinsoo, IQM

High performance quantum error correction benefits from, among other things, high fidelity and low leakage gates, fast calibration, highly connected architecture and a resource efficient code. We present low leakage single qubit gates achieved using FAST DRAG pulses, 1e-3 two-qubit gates error achieved by finetuning coupling strengths and 1e-3 state assignment error in the same device. Fast calibration is achieved using a novel error amplification method and pipelining of calibration tasks and hardware instructions. For increased connectivity, we introduce a novel qubit-star constellation architecture and report the present performance of the necessary gates. We have demonstrated the use of a unit cell of such a constellation in a quantum error detection experiment with two logical qubits [4]. Finally, we propose tile codes as a good compromise between qubit-count efficiency and hardware complexity.

THURSDAY 28 AUGUST, 2025 | 16:00 – 18:00

Hardware efficient quantum computing using cat qubits

Nicolas Didier, Alice and Bob

Dissipative cat qubits implemented in a superconducting circuit architecture are an example of highly biased noise qubits, where the noise acting on the qubit is extremely polarised along a single direction of the Bloch sphere. It has recently been realised that this noise bias was particularly useful to reduce the resources required to perform fault-tolerant quantum computations on such qubits.

In this talk, I will review two key advantages provided by this noise bias. First, on the memory side, cat qubits can be used in high-rate phase-flip LDPC codes that are compatible with a local implementation in 2D, which is in general not possible with regular qubits. Second, on the compute side, cat qubits can be used to build very efficient magic state distillation factories by performing distillation directly at the physical level.

Rigetti's scalable quantum processor architecture with chiplets and inter-modular tunable couplers

Andrew Bestwick, Rigetti Computing

We propose approaching challenges to superconducting qubit chip scaling with a chiplet-based architecture. This involves interconnecting high-fidelity, small-scale quantum devices via a modular intra-chip tunable coupler to enable interactions between qubits across separate chips without degrading performance. In this talk, I will review Rigetti's progress in building and integrating large-scale devices using this architecture. I will start with operational procedures and performance measurements of our 9-qubit chiplet device, discuss results from recent intermediate-scale chiplet systems, and conclude with Rigetti's roadmap toward fault-tolerance with this architecture.

THURSDAY 28 AUGUST, 2025 | 16:00 – 18:00

Building a QPU tune-up framework for scalable quantum computing

Kent R. Shirer, Zurich Instruments

To build a fault-tolerant quantum computer, we first must master the challenge of building long-lived logical qubits, necessitating an increased size and complexity of superconducting quantum processing units (QPUs). With larger QPU size, the ability to quickly tune-up and maintain high-fidelity operations becomes increasingly important.
The quantum computing control system and its control software are critical to streamlining the tune-up procedure. Furthermore, software must represent the physics of the QPU and leverage the capabilities of the control hardware to complete tune-up procedures with minimal overhead, thereby maximizing the available computing time.
In this talk, we focus on the essential building blocks of our open-source software framework. This framework enables automated and semi-automated tune-up procedures that include data analysis, data storage, and qubit parameter updating, paving the way for future large-scale automated calibration routines. We discuss implementations of fast tune-up and characterization experiments and show how the framework, together with our scalable hardware system architecture, make our control system ideally suited for quantum error correction research aimed at developing logical qubits with algorithmically relevant error rates.

Scaling quantum optimization to the utility scale - solving nontrivial binary optimization problems with SC quantum computers

Yuval Baum, Q-CTRL

Quantum computing holds promise for revolutionizing how we solve complex optimization problems that are ubiquitous in various fields like logistics and networking. However, current noisy quantum hardware limits the applicability of hybrid quantum-classical algorithms that are theorized to perform well in ideal conditions. This study showcases how a novel hybrid algorithm combined with a comprehensive error suppression pipeline can efficiently solve large-scale binary optimization problems, pushing the boundaries of what is currently possible with existing quantum hardware and bringing us closer to an era where quantum computers can solve relevant real-world problems. Our novel implementation demonstrates exceptional performance in solving binary-optimization problems on a 156-qubit SC gate-model IBM quantum computer by leveraging the device scale and operation speed of contemporary superconducting devices, while employing advanced error suppression techniques to overcome the limited connectivity challenge that solid state devices pose. We demonstrate the performance of the solver on a variety of combinatorial optimization problems: Max-Cut, finding the ground state of a cubic Ising spin glass, Maximum Independent Set, Max-Sat, Max-k-Cut and more. For most problems investigated, graph topologies are not matched to device connectivity and demonstrate the ability to find the optimal solution with MaxCut on regular graphs with density up to 15%. For the problems presented, the Q-CTRL solver outperforms a heuristic local solver used to indicate the relative difficulty of the problems pursued.

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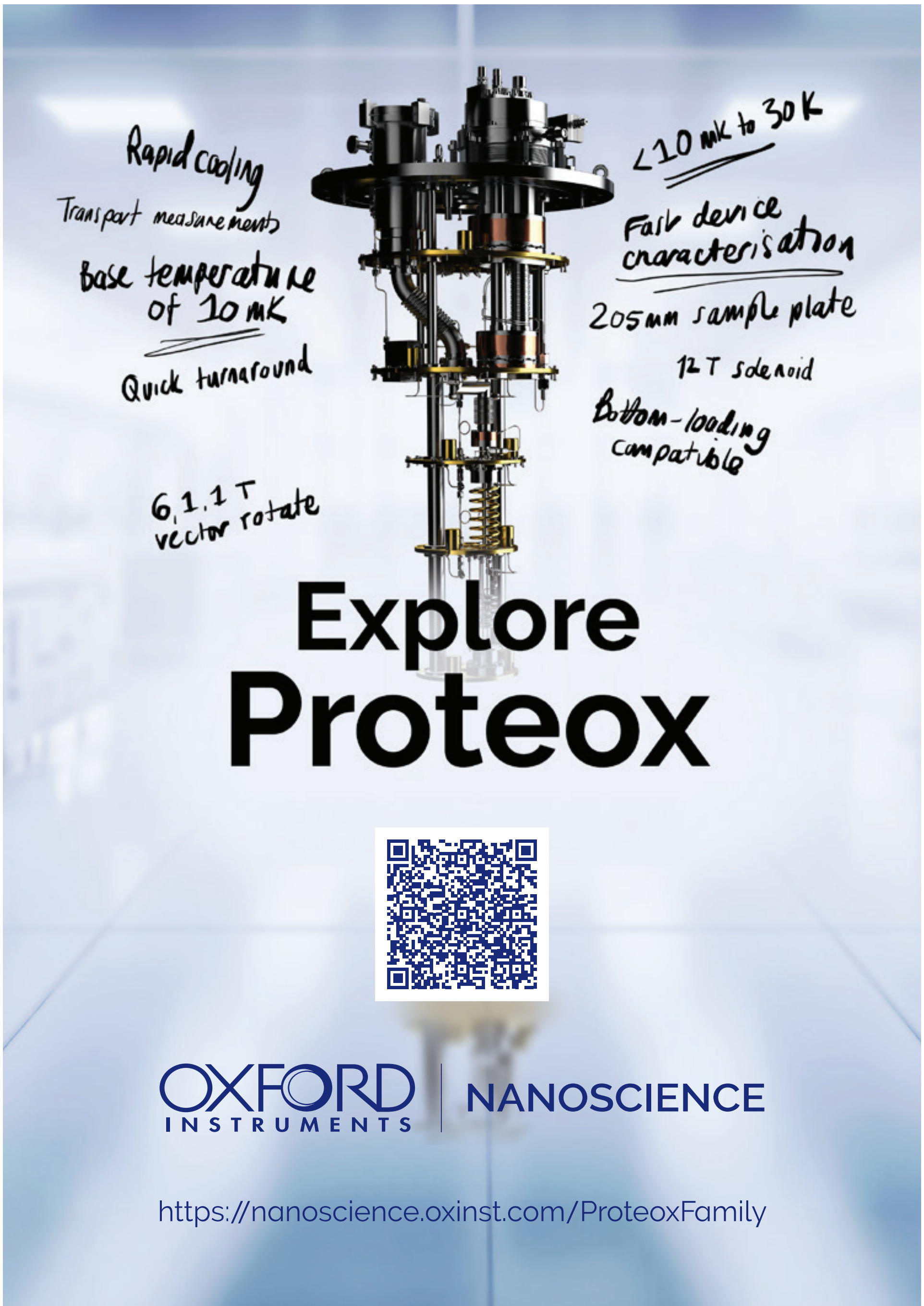

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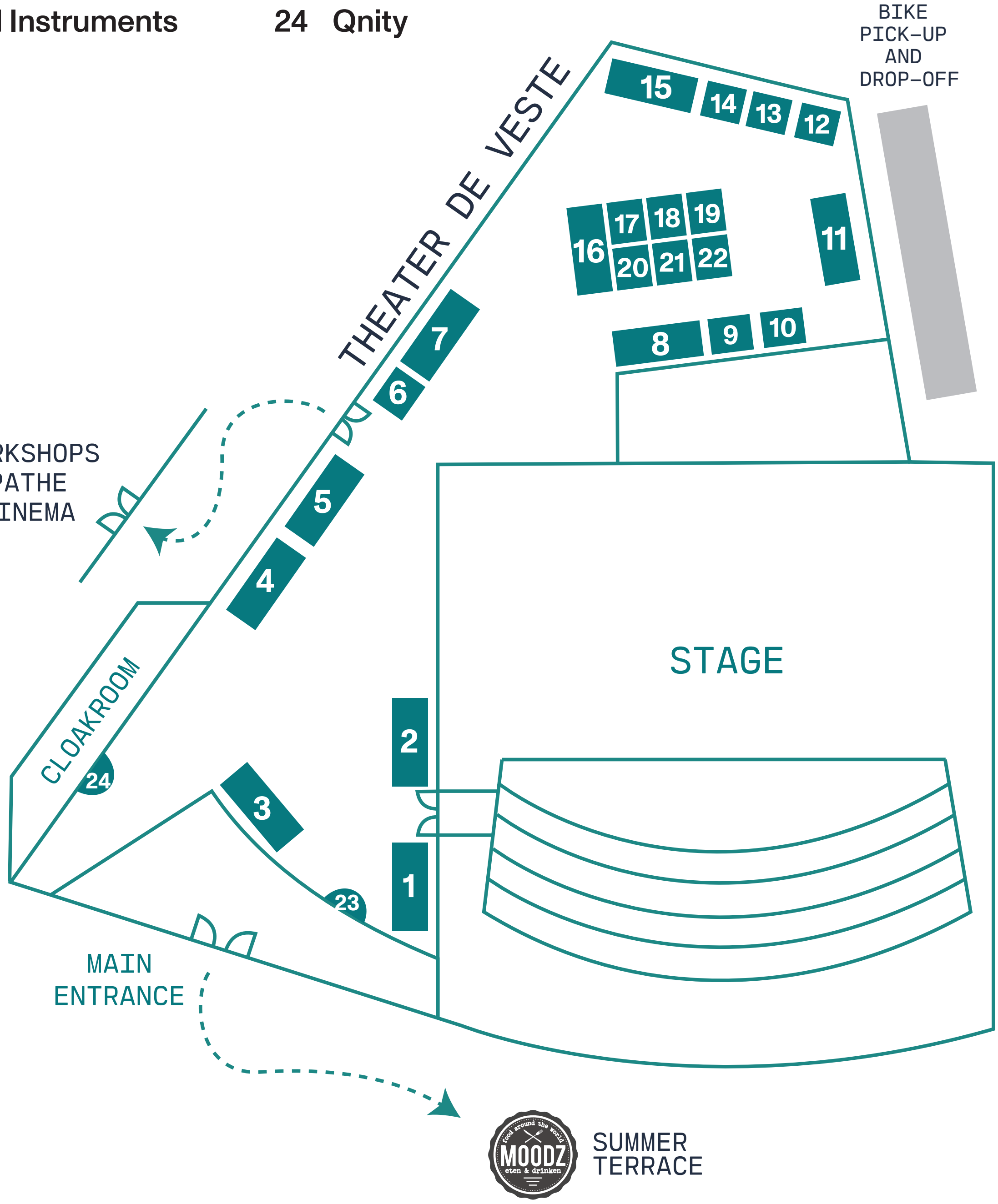

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