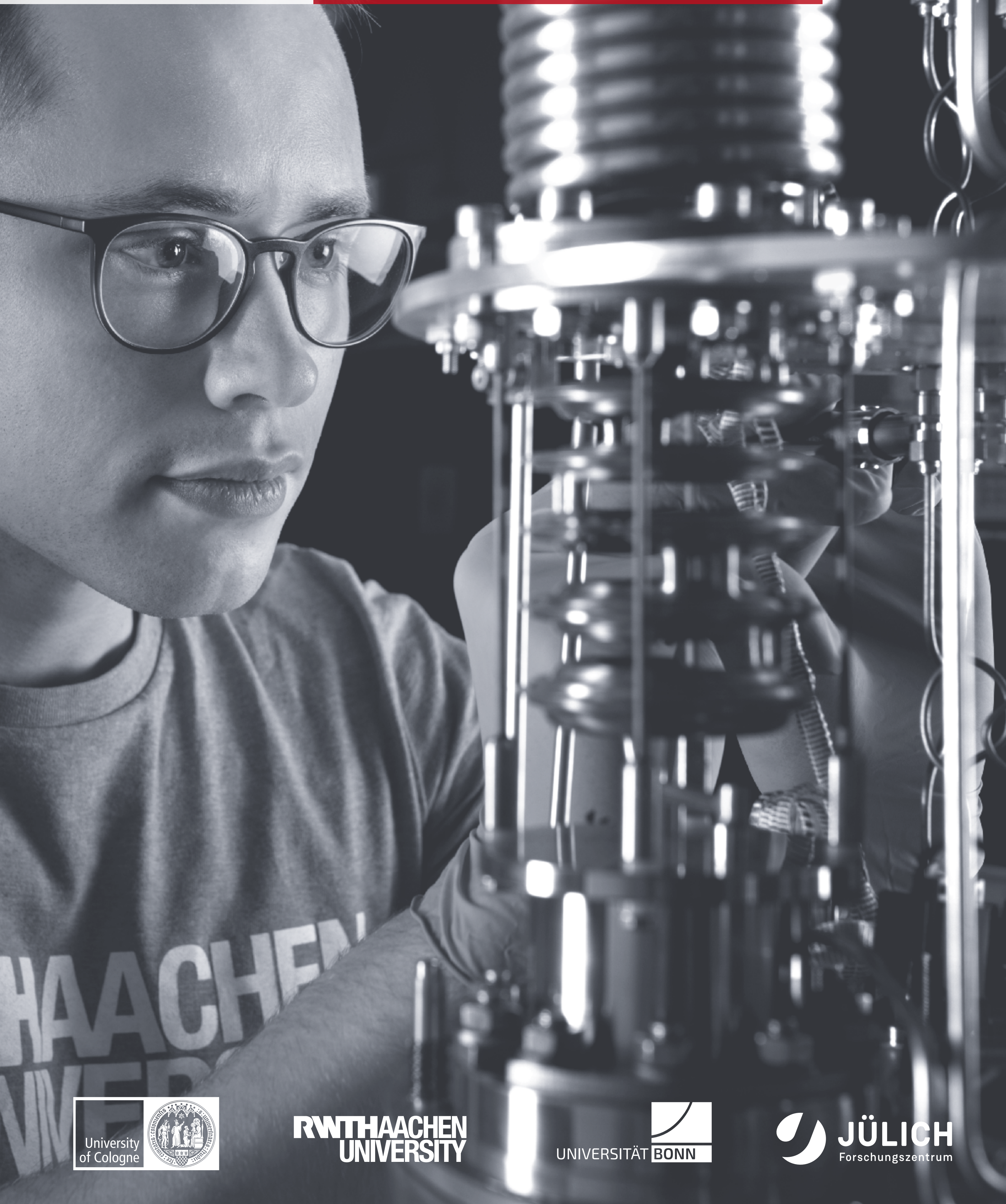
ML4Q
MATTER AND LIGHT FOR QUANTUM COMPUTING

AT A GLANCE



University of Cologne

RWTH AACHEN UNIVERSITY

UNIVERSITÄT BONN

JÜLICH Forschungszentrum

ML4Q
AT A GLANCE

ML4Q stands for Matter and Light for Quantum Computing. The Cluster of Excellence set off in 2019 for a long collaborative journey in order to develop new computing and networking architectures using new findings in the fundamental research in solid-state physics, quantum optics, and quantum information science.

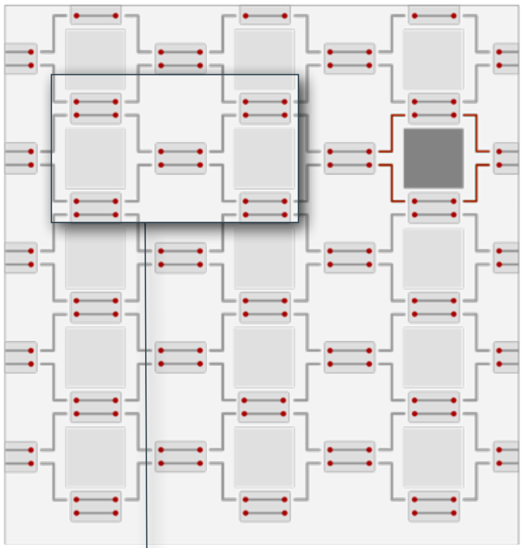
THE CLUSTER'S MISSION

Using the principles of quantum mechanics, it is the long-term goal of ML4Q to develop new computing and networking architectures with a power beyond anything classically imaginable. Quantum computers could be powerful tools in key areas such as materials design, pharmaceutics, or artificial intelligence. Quantum communication could be made effectively secure. ML4Q builds on the complementary expertise in the three key research fields of solid-state physics, quantum optics, and quantum information science to develop the best hardware platform for quantum information technology, and provide comprehensive blueprints for a functional quantum information network.

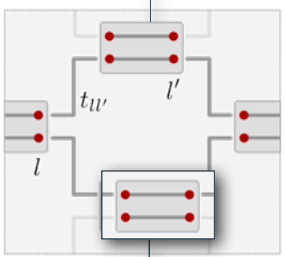
The long-term goal of the cluster is to realize network and processing architectures protected by error-correction protocols and eventually connected to a quantum version of the internet.
This goal defines a hierarchy of challenges, both in fundamental science and in technology, which must be overcome at early and intermediate stages.

qubits	processing	connectivity
for information storage	quantum information	through quantum links

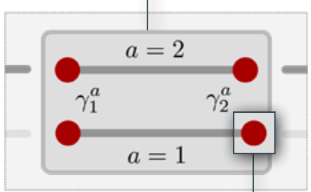
THE VISION



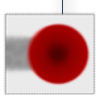
The processor units of a network comprise arrays of qubits whose implementation requires scalable designs. We envision to realize these units by the end of the second funding period.



The ML4Q core projects are dedicated to the development of both spin qubit platforms as well as topologically protected Majorana qubits as an alternative platform with the prospect of superior performance in the long term.



As Majorana-based quantum information hardware is still in its infancy, major intermediate challenges need to be overcome. These include the actual engineering of Majorana qubits.



On an even more fundamental level, first significant achievements in the realization and optimization of quantum materials harboring Majorana states were subject of the first two years of the running period (see Focus Area 1 and Focus Area 2 reports).

THE SCIENTIFIC APPROACH

The scientific structure of ML4Q spans four Focus Areas, each addressing a specific set of problems relevant to the cluster's mission. All Focus Areas include theoretical as well as experimental components and transcend the boundaries of disciplines and institutions.

- **Focus Area 1** aims to identify and explore novel topological hardware platforms for quantum information processing, including hybrid structures of topological insulators and superconductors as well as the ways to realize parafermions.

- **Focus Area 2** aims to realize Majorana qubits as a promising alternative to superconducting qubits or spin qubits. In parallel, protocols for readout, manipulation, and error correction are designed.

- **Focus Area 3** designs novel schemes of quantum control, error correction and mitigation. It investigates the operation of quantum devices under realistic noisy environmental conditions and explores topological and computational quantum matter subject to external driving.

- **Focus Area 4** focuses on the linkage of quantum processing units. Specifically, it takes steps towards realizing integrated atomic/optical and solid-state platforms and implementing quantum links between heterogeneous qubit setups.

OPPORTUNITIES FOR YOUNG SCIENTISTS

Attracting and retaining the best young talents in the field by offering competitive career opportunities is a top priority for ML4Q. Current offers include:

- Undergraduate grants
- Independence grants for postdoctoral researchers
- New tenure-track professorships
- ML4Q Research School with cluster-specific courses, e.g. “Platforms for Quantum Technologies” for Master students
- Master program for Quantum Technology in Aachen as well as specialized lectures on quantum technologies in Bonn and Cologne

PARTICIPATING INSTITUTIONS

ML4Q is a cooperation by the University of Cologne, University of Bonn, RWTH Aachen University as well as the Forschungszentrum Jülich. Partner institutions are the Heinrich Heine University Düsseldorf, the Fraunhofer Institute for Laser Technology ILT and the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR.

FUNDING

ML4Q has been funded within the Excellence Strategy by the German Research Foundation (DFG) since January 2019. The first funding period ends in 2025.

ML4Q **IN NUMBERS**

194

MEMBERS AND ASSOCIATES

46

PROFESSORS

64

INTERNATIONAL SCIENTISTS

70

PHD STUDENTS

35

FEMALE SCIENTISTS

37

ADMINISTRATIVE & TECHNICAL STAFF

7

RESEARCH INSTITUTIONS

92

PUBLICATIONS IN 2020

41

POSTDOCS

14

OPEN CALL PROJECTS AND INDEPENDENCE GRANTS

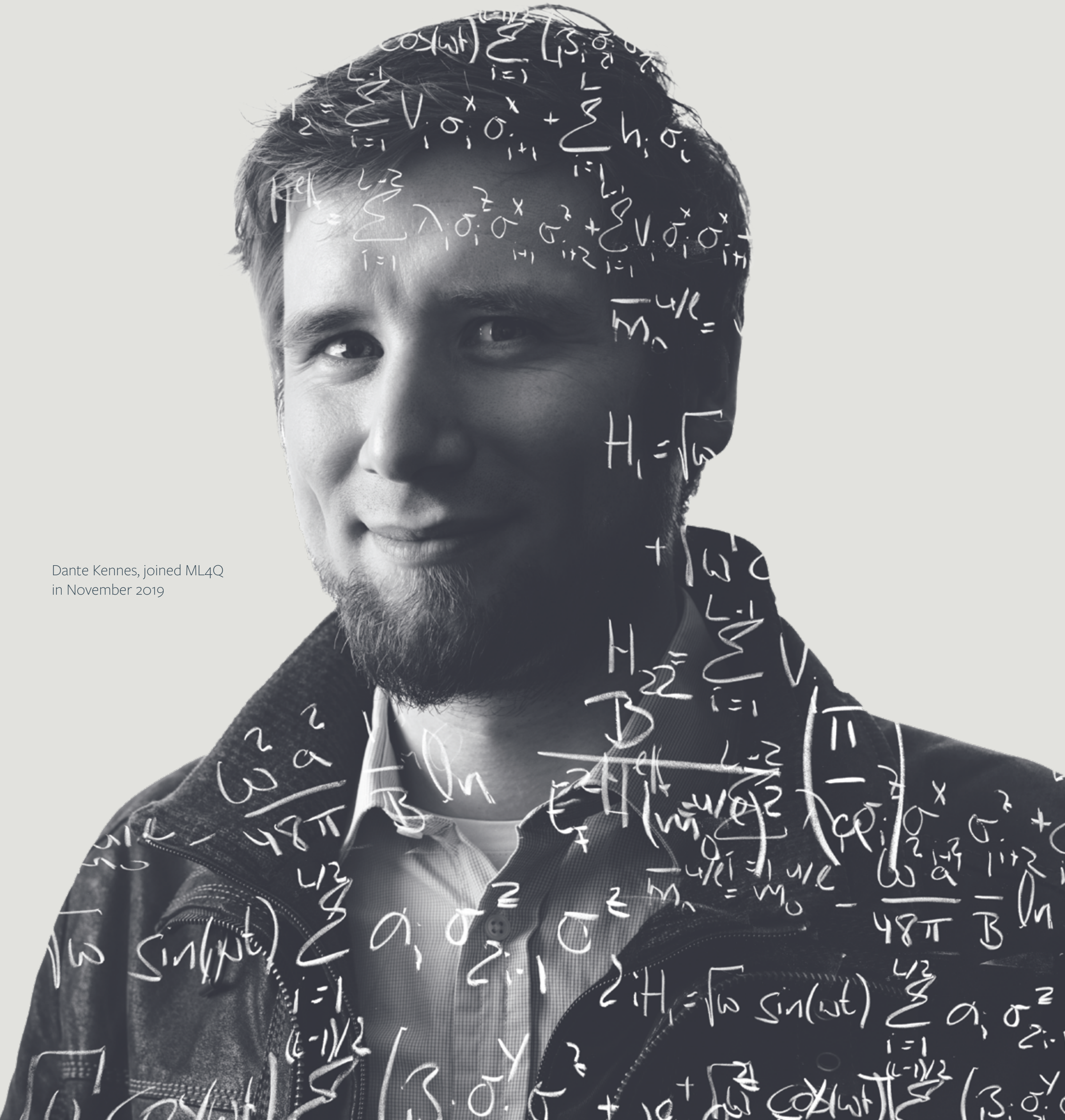
24

PUBLICATIONS IN 2020

WITH TWO OR MORE ML4Q GROUPS INVOLVED
(13 CROSS-SITE PUBLICATIONS)

DANTE KENNES

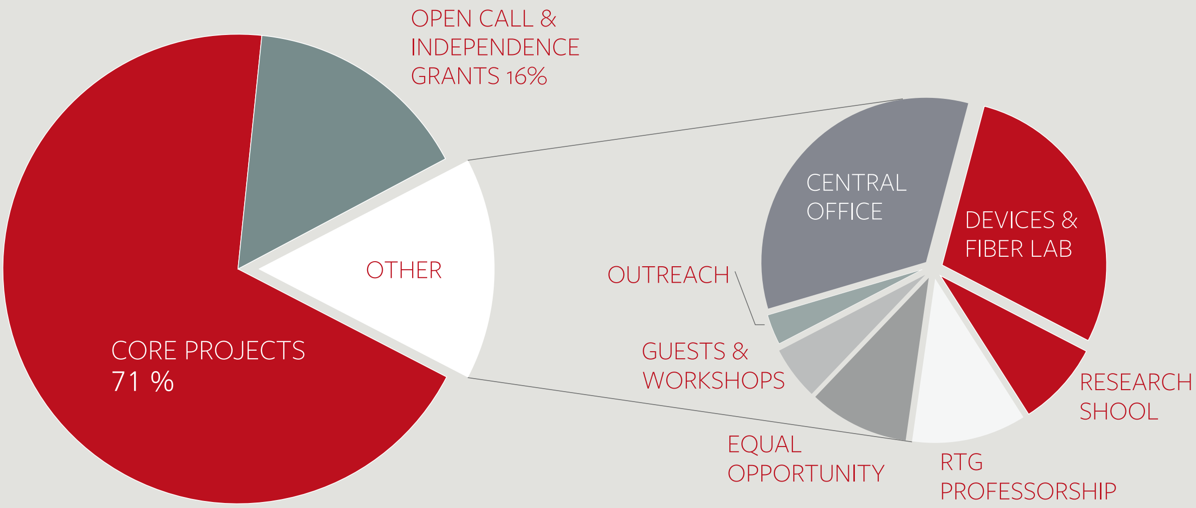
“The vibrant scientific environment within ML4Q as well as critical efforts being spent on connecting different geographic and scientific communities within the cluster allow younger scientists to enter the field of quantum computing with ease.



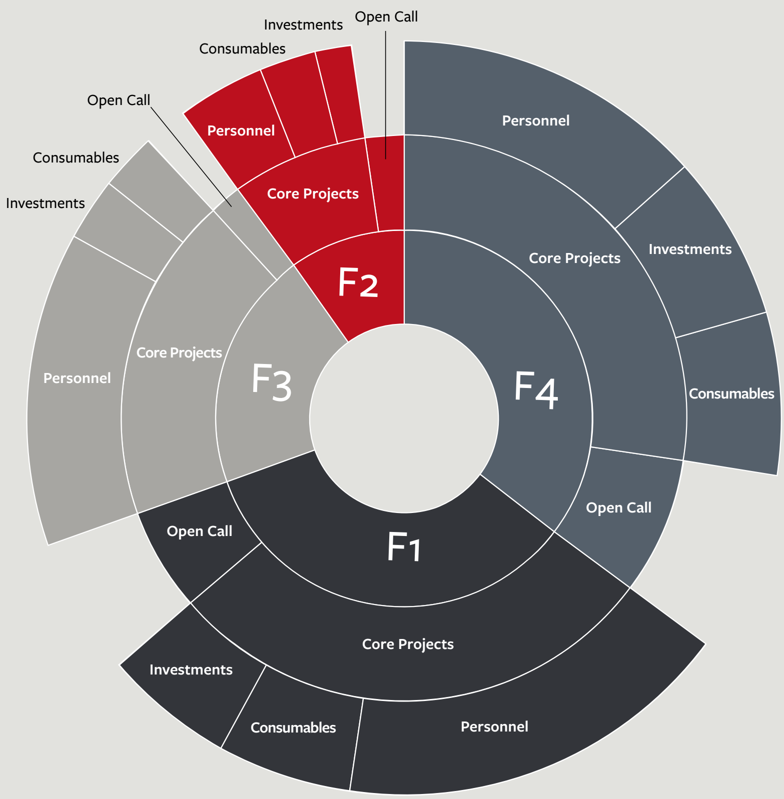
Dante Kennes, joined ML4Q in November 2019

ML4Q **IN NUMBERS**

CORE PROJECTS & CENTRAL MEASURES



In 2020, 71% of the expenses were dedicated to personnel, instrumentation and consumables in the core projects. While funds allocated to Open Call projects made up only 2% of the expenses in 2019, two calls in 2020 led to the allocation of 16% of the expenses to Open Call projects as well as Independence Grants. Expenses for supporting measures (research school, equal opportunity, workshops and outreach) as well as the Fiber Lab, ML4Q Devices and the central office made up about one-tenth of the annual budget.



All Focus Areas include theoretical as well as experimental components bringing different needs for personnel, consumables and instrumentation. Here is an overview of the allocation of core project funds in 2020 broken down by Focus Area and type of funding. Most Focus Areas experienced additional growth in 2020 through the Open Call projects.

INTERNATIONALIZATION

All academic groups experienced growth in 2020 on both a national and an international level. 32% of ML4Q members are international scientists coming from over 20 countries (see map below). As in 2019, postdoctoral scientists still show the highest level of internationalization.

AUSTRIA
BELGIUM
BOSNIA & HERZEGOVINA
BRAZIL
CANADA
CHINA
FRANCE
GEORGIA
GREECE
INDIA
IRAN
ISRAEL
ITALY
JAPAN
LIECHTENSTEIN
NETHERLANDS
POLAND
ROMANIA
RUSSIA
SPAIN
SWEDEN
UKRAINE
UNITED KINGDOM
USA

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