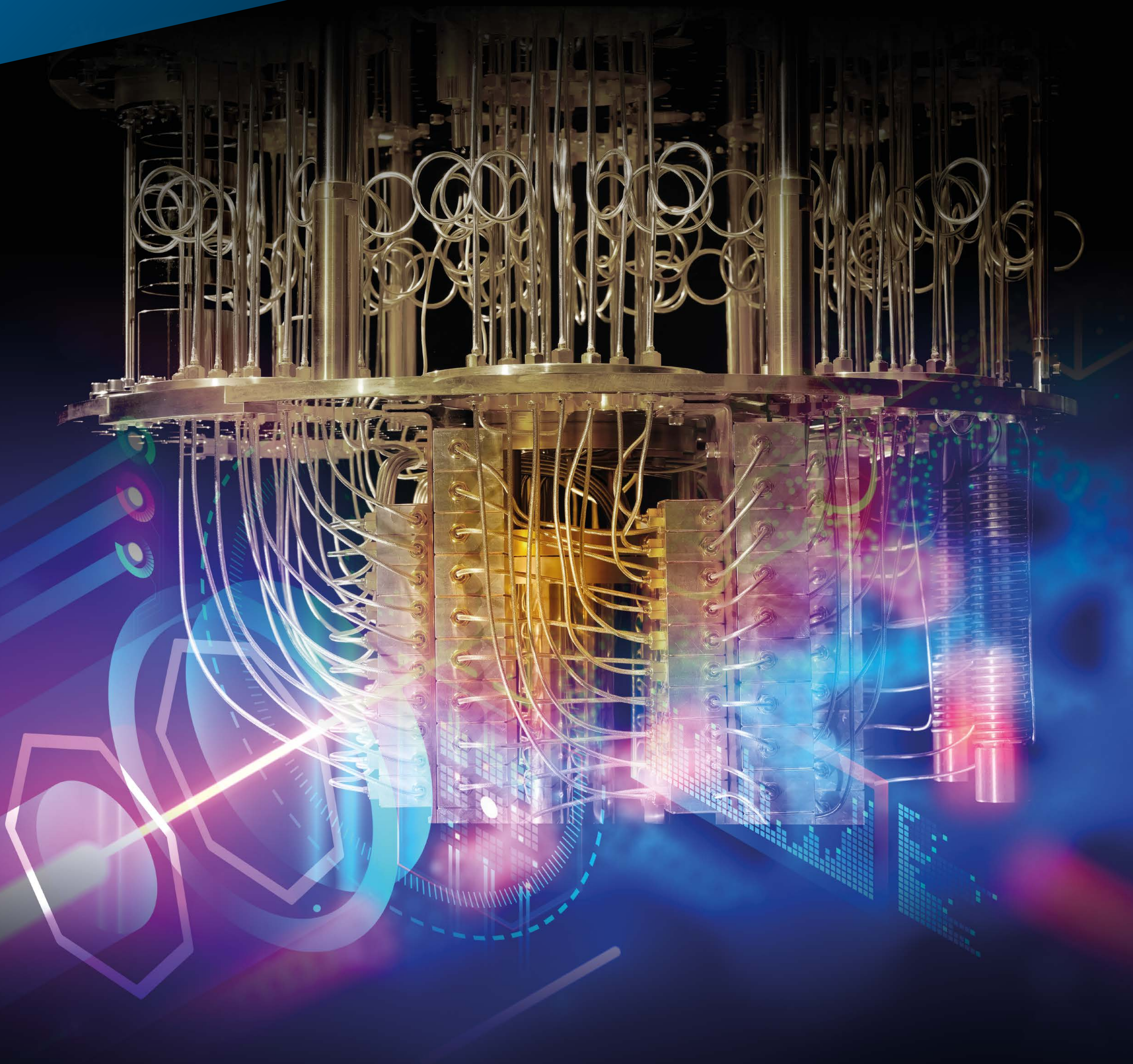
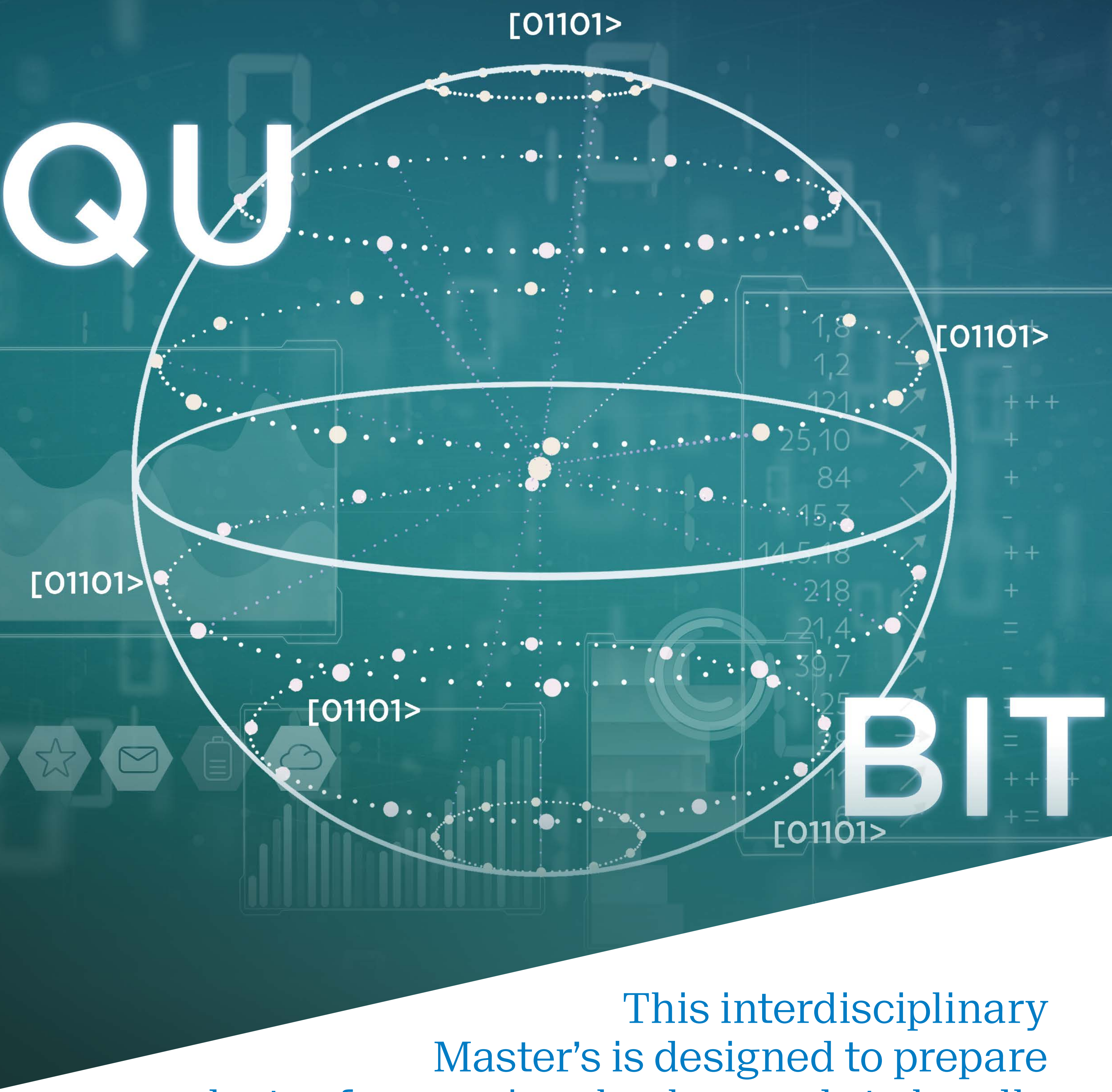
MASTER

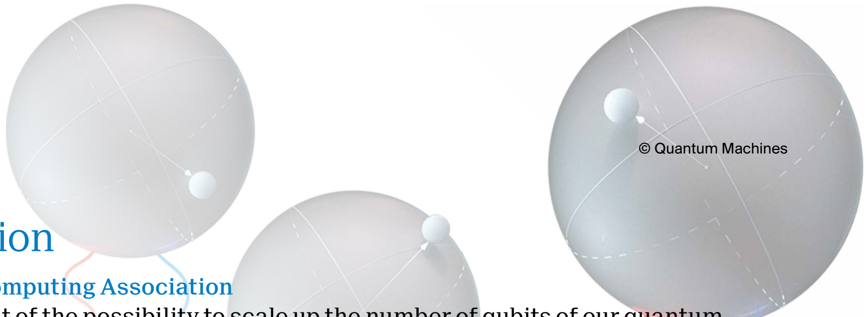
QUANTUM SCIENCE AND ENGINEERING



EPFL



This interdisciplinary Master's is designed to prepare graduates from various backgrounds to handle the new paradigm shift brought by Quantum science and technology in the way we treat data, communicate, measure and compute. Thanks to their broad vision of diverse aspects of the field, they will have the ability to thrive in this new technology frontier which has the disruptive potential to revolutionize our society.



Paving the way towards fault tolerant quantum computation

Arthur Strauss, former president of EPFL's Quantum Computing Association

Perspectives of quantum advantage are highly dependent of the possibility to scale up the number of qubits of our quantum processors. This goes hand in hand with the need to scale up and improve the quality of classical tools enabling interaction between qubits and user. The Quantum Orchestration Platform (QOP) created by Quantum Machines (a global leader in control systems for quantum computing) sets the grounds for a unified vision of quantum control, embedding in its architecture key features that will gain critical importance with the advent of scalable quantum hardware. In this master thesis we selected quantum computing applications representative of the technology and showed how the QOP inserts itself as a bridge between different abstraction layers that usually compose a full quantum computing stack. We envision the QOP as an enabler for running more complex protocols on near-term quantum devices such as hybrid classical-quantum algorithms, but also in the way towards fault-tolerance by proposing capabilities suitable for Quantum Error Correcting Codes.

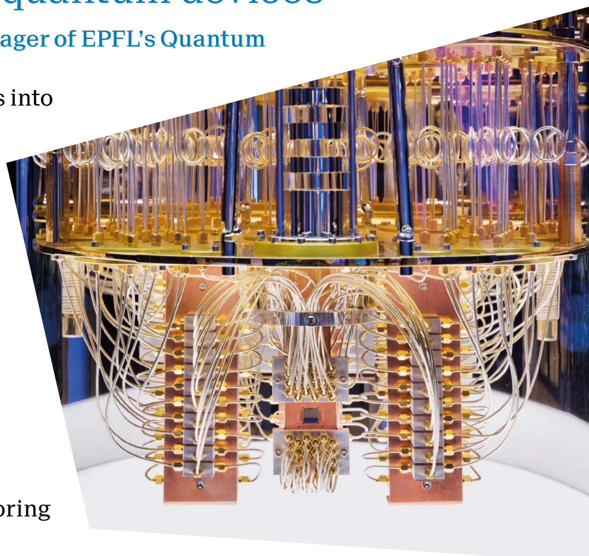
Sara Santos: "Quantum Computing is an incredibly dynamic and interdisciplinary field at the intersection of physics and computer science. The outstanding education I received at EPFL along with the network I built here was invaluable while looking for future master or PhD positions in top tier companies like IBM."

Variational quantum algorithms on noisy intermediate scale quantum devices

Sara Santos, Master's student and Manager of EPFL's Quantum Computing Association

Quantum time evolution provides deep insights into physical dynamics, but also holds promises for optimization tasks. However, simulation on a classical computer generally requires an exponential amount of resources. Storing the wave function of only 125 spins would require a memory with more bits than there are atoms in the observable universe!

A quantum computer, on the other hand, offers a natural representation of such an enormous space with only 125 qubits to encode the full wave function. Moreover, with the recent astonishing technological advances, we now have the first functional quantum computers with over 100 qubits. In a joint effort with IBM Research (Zurich) and EPFL, our goal is to demonstrate quantum time evolution on present day quantum devices, by exploring variational algorithms which trade-off resource requirements against accuracy.



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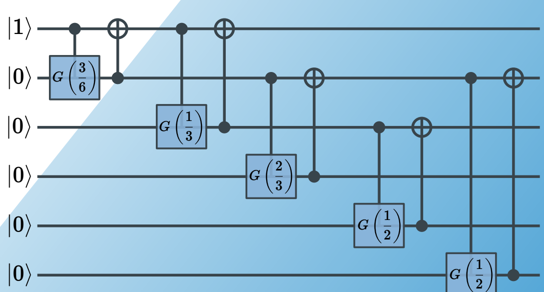
Clément Javerzac-Galy: "It is fascinating to be amongst the first generation to use real quantum computers. It is an opportunity to speed up learning and to contribute to a great research endeavor. It is also a perfect jumpstart to applying quantum technologies in industry."

Efficient quantum circuits for GHZ and W states

Clément Javerzac-Galy, co-founder of MIRAEX startup

Entanglement is a fundamental concept in quantum information and entangled states constitute powerful resources in distributed information processing. For example, Greenberger–Horne–Zeilinger (GHZ) states are important for quantum secret sharing, while so-called W states are central to quantum memories or multiparty network protocols. In this project students from physics and communication systems, joined forces to investigate efficient new algorithms to create N-qubit GHZ and W states with time-complexity scaling linearly and logarithmically in N. Quantum circuits implemented on experimental IBM quantum computers up to $N = 16$, demonstrate entanglement through tomography and other methods. While the fidelity decreases with increasing N, it does so much more slowly for logarithmic depth algorithms, and these constitute interesting primitives for other quantum information tasks.




```
qr = QuantumRegister(6)
cr = ClassicalRegister(6)
circuit = QuantumCircuit(qr)
circuit.cg36(qr[0],qr[1])
circuit.cx(qr[1],qr[0])
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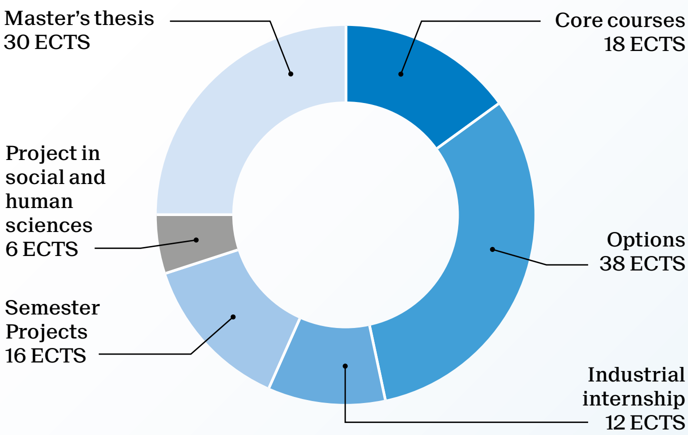
Master of Science in

QUANTUM SCIENCE AND ENGINEERING

2-year program - 120 ECTS



	Credits
Core courses	**18**
Computational complexity	6
Fundamentals of solid-state materials	4
Introduction to quantum computation	5
Introduction to quantum information processing	5
Introduction to quantum science and technology	5
Quantum and nanocomputing	6
Quantum physics I	5
Semiconductor devices I	4
Solid state systems for quantum information	4

Options			38
Advanced cryptography	A		6
Advanced machine learning		B	4
Algorithms II	A		8
Artificial neural networks/reinforcement learning	A		6
Atomistic and quantum simulations of materials		B	4
Classical and quantum photonic transducers		B	3
Computational methods in molecular quantum mechanics	A	B	4
Computational quantum physics	A		4
Cryptography and security	A		8
Deep learning		B	4
Distributed algorithms	A		8
Foundations of data science	A	B	8
Fundamentals of integrated photonic components		B	4
Information theory and coding	A		8
Interacting Quantum Matter	A		4
Introduction to crystal growth by epitaxy		B	2
Introduction to electronic structure methods	A	B	4
Lab in nanoelectronics		B	4
Low rank approximation techniques	A		5
Machine learning	A	B	8
Machine learning for physicists	A		4
Mathematics of data: from theory to computation		B	6
Metrology		B	3
Metrology praticals		B	2
Molecular dynamics and monte carlo simulations	A	B	2
Molecular quantum dynamics	A	B	3
Nanoelectronics		B	2
Nanotechnology		B	3
Nonlinear optics for quantum technologies	A	B	4
Optimization for machine learning	A		8
Photonic systems and technology		B	4
Physics of photonic semiconductor devices	A	B	4
Physique quantique II	A	B	5
Properties of semiconductors and related nanostructures		B	5
Quantum electrodynamics and quantum optics	A	B	6
Quantum information and quantum computing	A	B	4
Quantum information theory	A	B	4
Quantum optics and quantum information	A	B	6
Quantum transport in mesoscopic systems	A	B	4
Semiconductor devices II		B	4
Semiconductor physics and light-matter interaction	A	B	4
Solid state physics III	A		6
Statistical mechanics	A	B	4
Statistical physics IV	A	B	6

Students choose their option classes within one specialization:

A. Quantum information and computation

B. Quantum hardware and engineering

It is possible to take up to 8 credits within the other specialization or outside this study plan (upon validation by the program's committee).

Career prospects

Given the wide range of topics covered by this Master's program, graduates acquire a comprehensive set of skills enabling them to become the main actors of the next "quantum revolution" as many companies are increasingly embracing quantum information technology, both at the level of research and development, and within a proactive implementation strategy at the level of advanced services. Besides pursuing careers in quantum science, their interdisciplinary profile also enables graduates to thrive in the information technology sector and in the industry at large.

Schools of Basic Sciences,
Engineering, Computer and Communication Sciences
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