QUANTUM LAB

Quantum Information Lab
Dipartimento di Fisica, Università di Roma La Sapienza

SAPIENZA
UNIVERSITÀ DI ROMA

Coordination of projects in the field of the Pillar "Innovative Europe": the "life" of two projects

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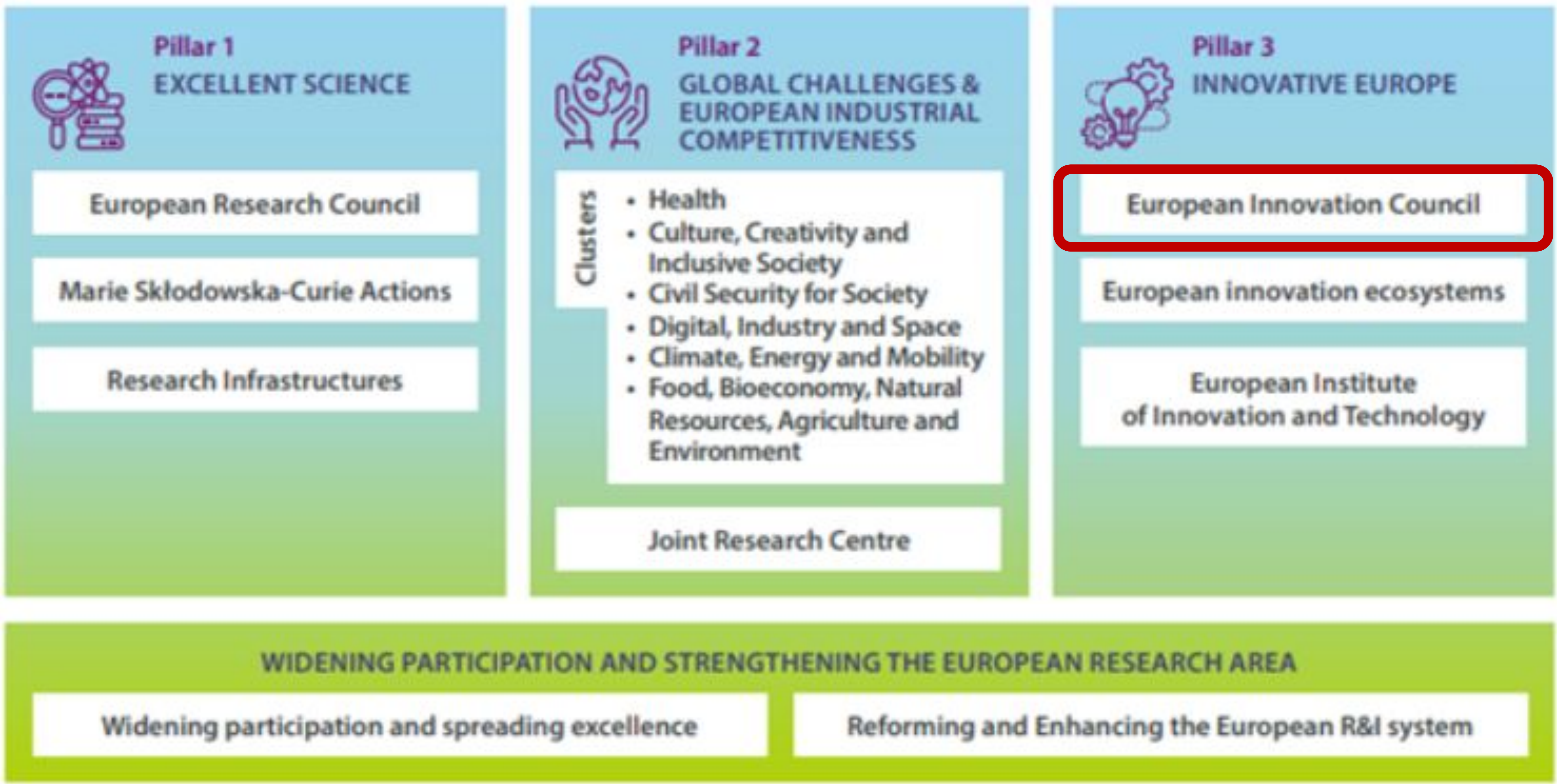
www.quantumlab.it

OUTLOOK

- EIC: European Innovation Council
- Coordination of PHOQUSING Project
- Coordination of QUCHIP Project
- Experience of PhD students in my research group

Widening participation and strengthening the European Research Area"



European Innovation Council - EIC

eic European INNOVATION Council

The European Innovation Council (EIC) is the main tool in support of innovation promoted by the European Commission under Horizon Europe, the new Framework Program for Research and Innovation of the EU for the period 2021-2027.

The EIC, in particular, is the most relevant initiative within Pillar 3 - Innovative Europe and aims to identify, develop and implement high-risk innovations of various kinds, with **a main focus on pioneering innovations, disruptive, with a high impact on society and potentially market-creating.**

QUCHIP

1. Coordinator of a FET: FUTURE AND EMERGING TECHNOLOGIES - PROACTIVE

QUCHIP
Quantum Simulation on a Photonic Chip

QUCHIP-Quantum Simulation on a Photonic Chip

Funding programme:
FETPROACT-3-2014: Quantum simulation
Overall funding: € 2,681,714
Funding to Quantum Information Lab: € 431,250
Grant agreement no: 641039
Period: 1 March 2015-28 February 2018

QUCHIP will address four main objectives:

QUCHIP objectives

Objective 1. Multiphoton quantum walk

Objective 2. Boson sampling

Objective 3. Photonics quantum technologies

Objective 4. Simulated quantum phenomena

Partner n.	Partner short name	Institution full name
1	**UNIROMA1**	**Università di Roma "La Sapienza"**
2	UOB	University of Bristol
3	UOXF	The Chancellor, Masters and Scholars of the University of Oxford
4	CNR	Consiglio Nazionale delle Ricerche
5	UNIVIE	Universitaet Wien
6	UPB	Universitaet Paderborn
7	UULM	Universitaet Ulm
8	ULB	Université Libre de Bruxelles
9	SOUTH	University of Southampton

CALL FET-PROACT-3-2014

Call budget overview

TOPIC : Quantum simulation

Topic identifier: FETPROACT-3-2014
Publication date: 11-12-2013

Types of action: RIA Research and Innovation action
DeadlineModel: single-stage
Opening date: 11-12-2013
Deadline: 01-04-2014 17:00:00

Scope:

Specific challenge: Devices that exploit quantum phenomena such as superposition and entanglement have the potential to enable radically new technologies. Several promising directions are now well known, for instance in quantum computation and simulation, quantum communication, quantum metrology and sensing. However, overcoming basic scientific challenges as well as bridging from the scientific results to concrete engineering technologies has proved difficult. This objective challenges the research community to develop solutions using quantum technologies that will ultimately address real world problem, with a potential for disruptive change.

Scope: Proposals shall address research and development for quantum simulation to address a class of problems that is beyond the reach of classical computing, and that can contribute to answering questions in fundamental or applied sciences, e.g. in quantum materials science or the life sciences.

Criteria for selection

Subcriteria for evaluation criterion 1 "Excellence":

* Clarity of targeted breakthrough and its specific science and technology contributions towards a long-term vision.
* Novelty, level of ambition and foundational character.
* Range and added value from interdisciplinarity.
* Appropriatness of the research methods.

Threshold for this criterion: 4/5

Weight for this criterion: 60%

Subcriteria for evaluation criterion 2 "Impact":

* Importance of the new technological outcome with regards to its transformational impact on technology and/or society.
* Quality of measures for achieving impact on science, technology and/or society.
* Impact from empowerment of new and high potential actors towards future technological leadership.

Threshold for this criterion: 3.5/5

Weight for this criterion: 20%

Subcriteria for evaluation criterion 3 "Quality and efficiency of the implementation":

* Quality of the workplan and clarity of intermediate targets.
* Relevant expertise in the consortium.
* Appropriate allocation and justification of resources (person-months, equipment, budget).

Threshold for this criterion: 3/5

Weight for this criterion: 20%

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QUCHIP

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Project Information

QUCHIP

Grant agreement ID: 641039

Closed project

Start date 1 March 2015

End date 28 February 2018

Funded under
H2020-EU.1.2.2.

Overall budget
€ 2 681 713,75

EU contribution
€ 2 681 713,75

Coordinated by
UNIVERSITA DEGLI STUDI DI ROMA LA SAPIENZA

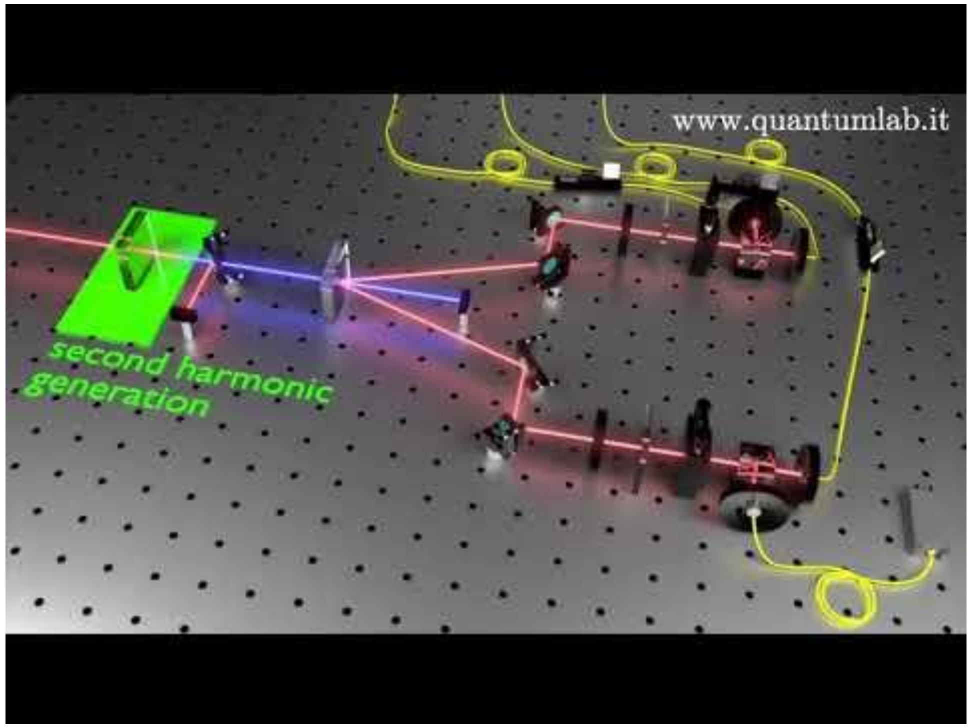
Italy

QUCHIP

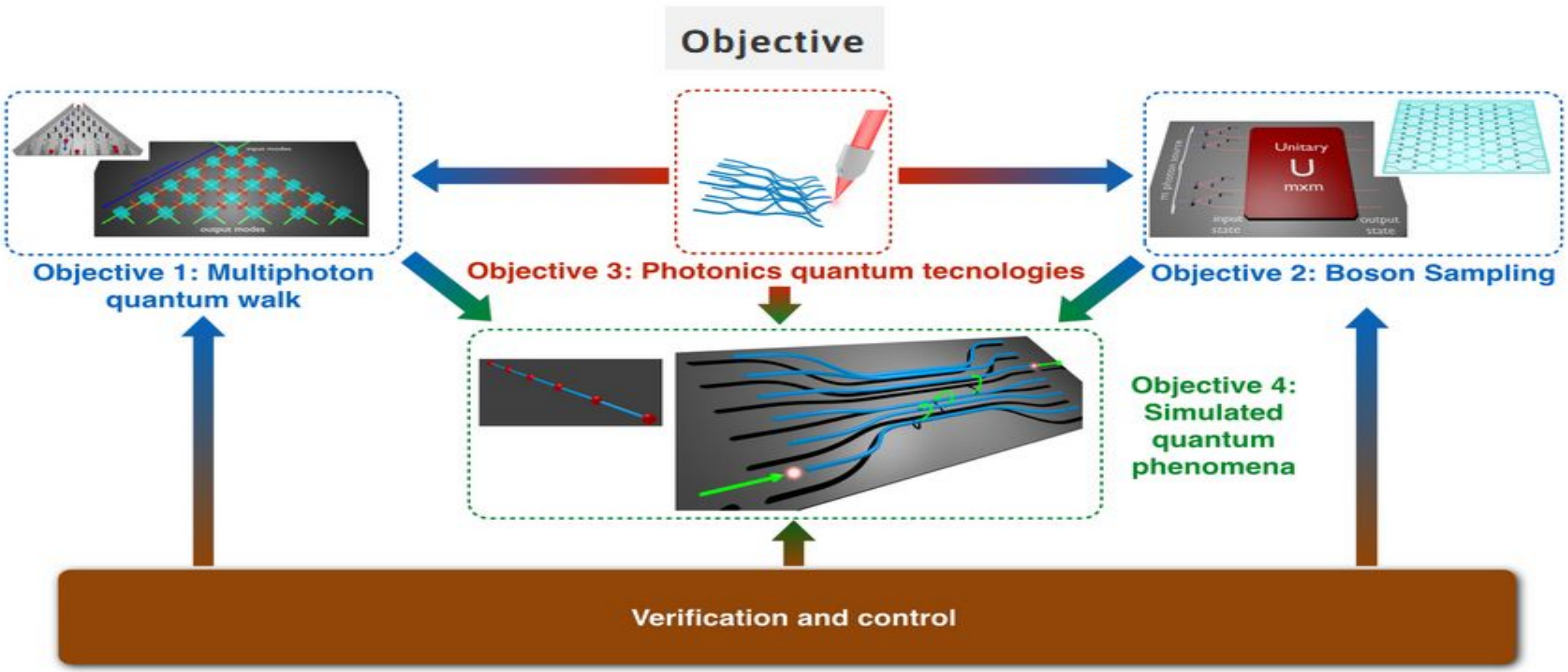
Quantum Simulation on a Photonic Chip

Objective

Simulation is a fundamental computational tool for modern science with applications ranging from drug design to materials science. Quantum simulators have the potential to revolutionize the way simulations are performed by accessing system sizes that are untractable in classical machines. As a result, they will become a suite of powerful and precise instruments enabling the investigation of relevant phenomena in the dynamics of complex quantum systems, such as quantum transport and energy transfer, as well as implementing quantum improved computation - tasks hard to simulate classically. QUCHIP aims at implementing quantum simulation on integrated photonic processors. Photons present unique advantages deriving from their mobility and the immunity to decoherence: these two features make them substantially different from any other quantum system. Moreover integrated quantum photonics capitalizes on the multi-billion dollar investment already placed into photonics development and commercialization. QUCHIP will exploit these advantages to implement quantum walk experiments in which several photons propagate over complex circuit architectures "jumping" between different waveguides. This platform represents the most resource-efficient quantum computation scheme to date: Boson Sampling.

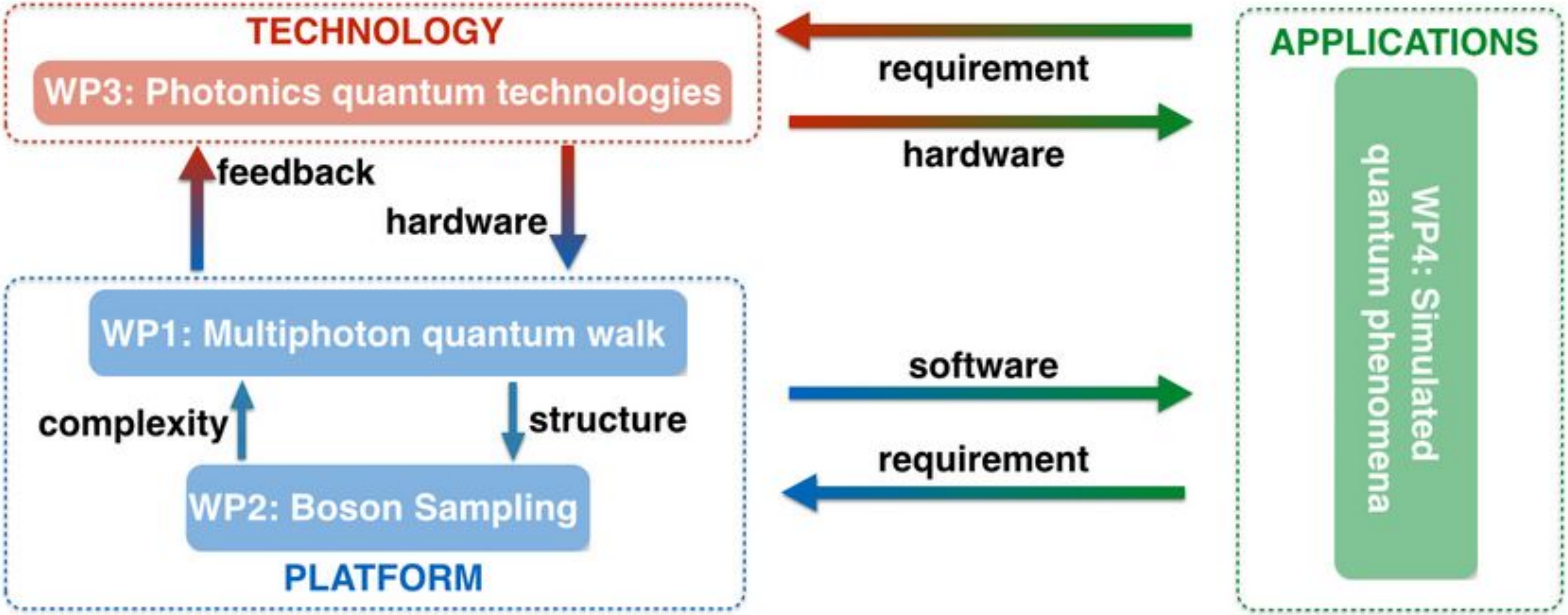


The project

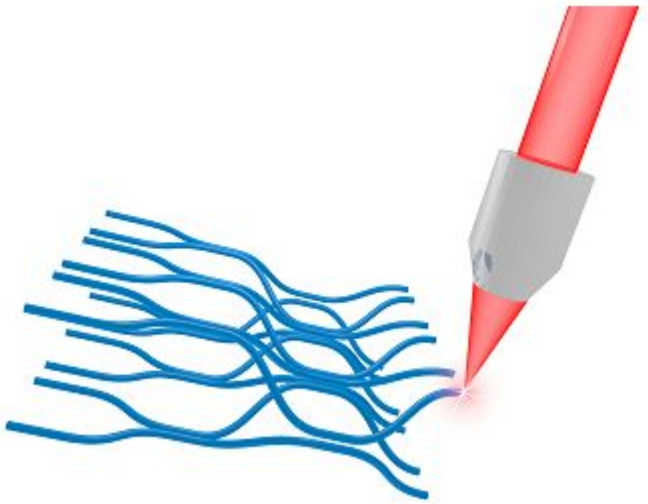


Simulation is a fundamental computational tool for modern science with applications ranging from drug design to materials science. Quantum simulators have the potential to revolutionize the way simulations are performed by accessing system sizes that are untractable in classical machines. As a result, they will become a suite of powerful and precise instruments enabling the investigation of relevant phenomena in the dynamics of complex quantum systems, such as quantum transport and energy transfer, as well as implementing quantum improved computation – tasks hard to simulate classically. QUCHIP aims at implementing quantum simulation on integrated photonic processors.

Methodology of the project



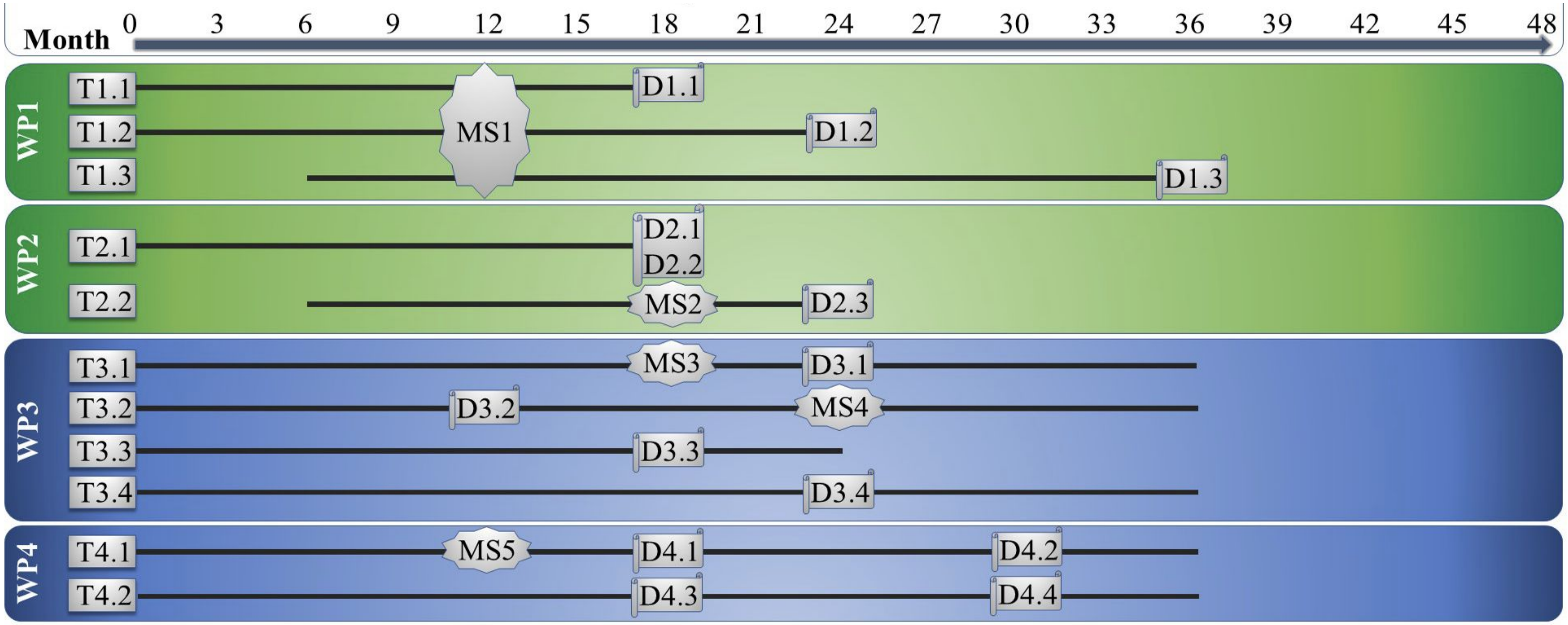
WP1 – Quantum walks
WP2 – Boson Sampling
WP3 – Photonic quantum technologies
WP4 – Simulated quantum phenomena



WP: workpackages

Project timeline
Gantt chart

A **Gantt chart** is a type of bar chart that illustrates a project schedule.



1. **Working package (WP):** is a building block of the work breakdown structure that allows the project management to define the steps necessary for completion of the work
2. **Deliverable (D):** Describe the quantifiable goods or services that must be provided upon the completion of a project. Deliverables can be tangible or intangible in nature.
3. **Milestone (MS):** A project milestone is a management tool that is used to delineate a point in a project schedule. These points can note the start and finish of a project, and mark the completion of a major phase of work.

OUTREACH

Video interview with University of Southampton QnP Laboratory leader, Dr Alberto Politi, and PhD student, Robert Cernansky on the EU collaboration QUCHIP
http://www.quchip.eu/

QUCHIP involves 9 European Universities and Research Centres from 5 different European countries.

The Consortium QUCHIP consists of many of the leading experimental groups in Europe currently working on optical quantum simulation.

Deliverables

- Documents, reports (17)
- Demonstrators, pilots, prototypes (3)
- Websites, patent fillings, videos etc. (4)

Publications

- Peer reviewed articles (76)

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Roadmap

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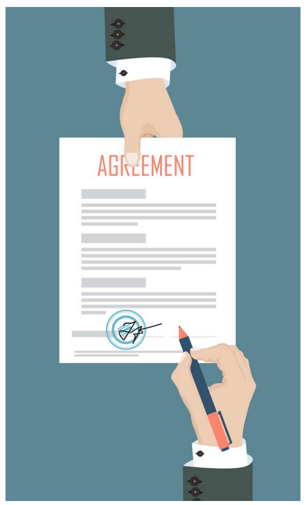
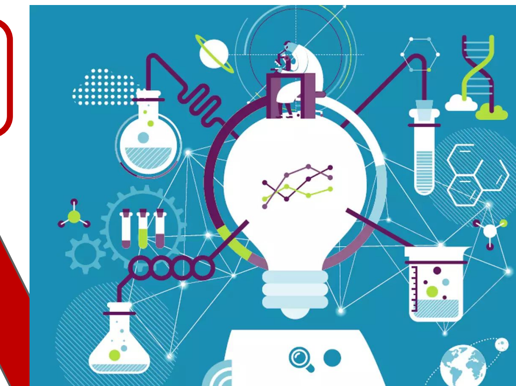
Grant Agreement



Kick-off Meeting

Main objectives

Research



Outputs **Deliverables** **Milestones**

Conferences

Outreach

Schools and workshops

Review Meeting

Final Outcome

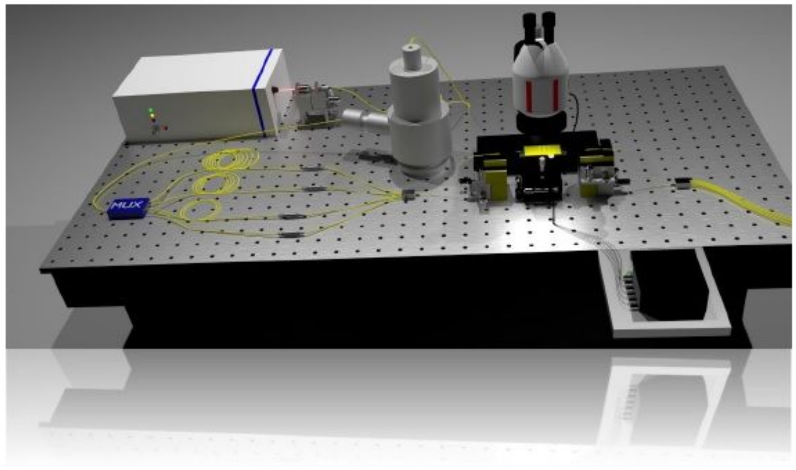
PHOQUSING

Phoqusing
Photonics Quantum Sampling Machine

PHOQUSING Project in brief…

- Funding programme:H2020-FETOPEN-2018-2020/H2020-FETOPEN-2018-2019-2020-01
- Overall funding: 3,305,955.00 €
- Period: 1 September 2020 – 31 August 2024

	Beneficiary	Country	PI
	Sapienza Università di Roma (CO)	Italy	Fabio Sciarrino
	IFN-CNR	Italy	Roberto Osellame
	LIN INL	Portugal	Ernesto F. Galvão
	CNRS	France	Pascale Senellart
	Quix	The Netherlands	Jelmer Renema
	Sorbonne Université	France	Elham Kashefi
	Veriqloud	France	Marc Kaplan



www.phoqusing.eu

What we supposed to do with that money?

Quantum sampling machines are novel devices capable of producing and manipulating randomness in a quantum way, for advantage in algorithms implemented in a hybrid quantum/classical fashion.

PHOQUSING aims to build working photonic quantum sampling machines.

The project

PHOQUSING in brief

The PHOQUSING (PHOtonic Quantum SamplING machine) project is funded by the FET- Future Emerging Technologies, a programme that supports ambitious interdisciplinary research at early stages of development with radical vision, with breakthrough technological targets.

PHOQUSING aims at realising the potential of quantum computing in a photonics computational hybrid device.

PHOQUSING 1st year results

PHOQUSING results are published in the most outstanding international peer-review journals in physics and photonics.

PHYSICAL REVIEW LETTERS

Bright Polarized Single-Photon Source Based on a Linear Dipole

S. E. Thomas, M. Billard, N. Coste, S. C. Wein, Priya, H. Ollivier, O. Krebs, L. Tazaïrt, A. Harouri, A. Lemaître, I. Sagnes, C. Anton, L. Lanco, N. Somaschi, J. C. Loredo, and P. Senellart
Phys. Rev. Lett. **126**, 233601 – Published 11 June 2021

PHYSICAL REVIEW APPLIED

Calibration of Multiparameter Sensors via Machine Learning at the Single-Photon Level

Valeria Cimini, Emanuele Polino, Mauro Valeri, Ilaria Gianani, Nicolò Spagnolo, Giacomo Corrielli, Andrea Crespi, Roberto Osellame, Marco Barbieri, and Fabio Sciarrino
Phys. Rev. Applied **15**, 044003 – Published 1 April 2021

PHOQUSING overview

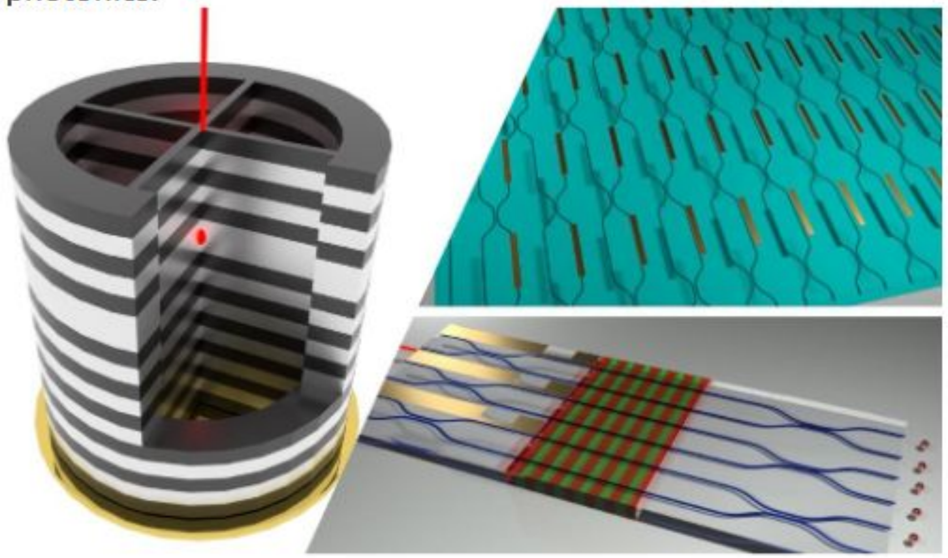
What is quantum computation?

Quantum computers exploit the incredible possibilities of quantum mechanics to significantly enhance computing power, compared with the computers currently available based on a conventional approach. In this context, it is essential to experimentally demonstrate the potential of quantum computers.

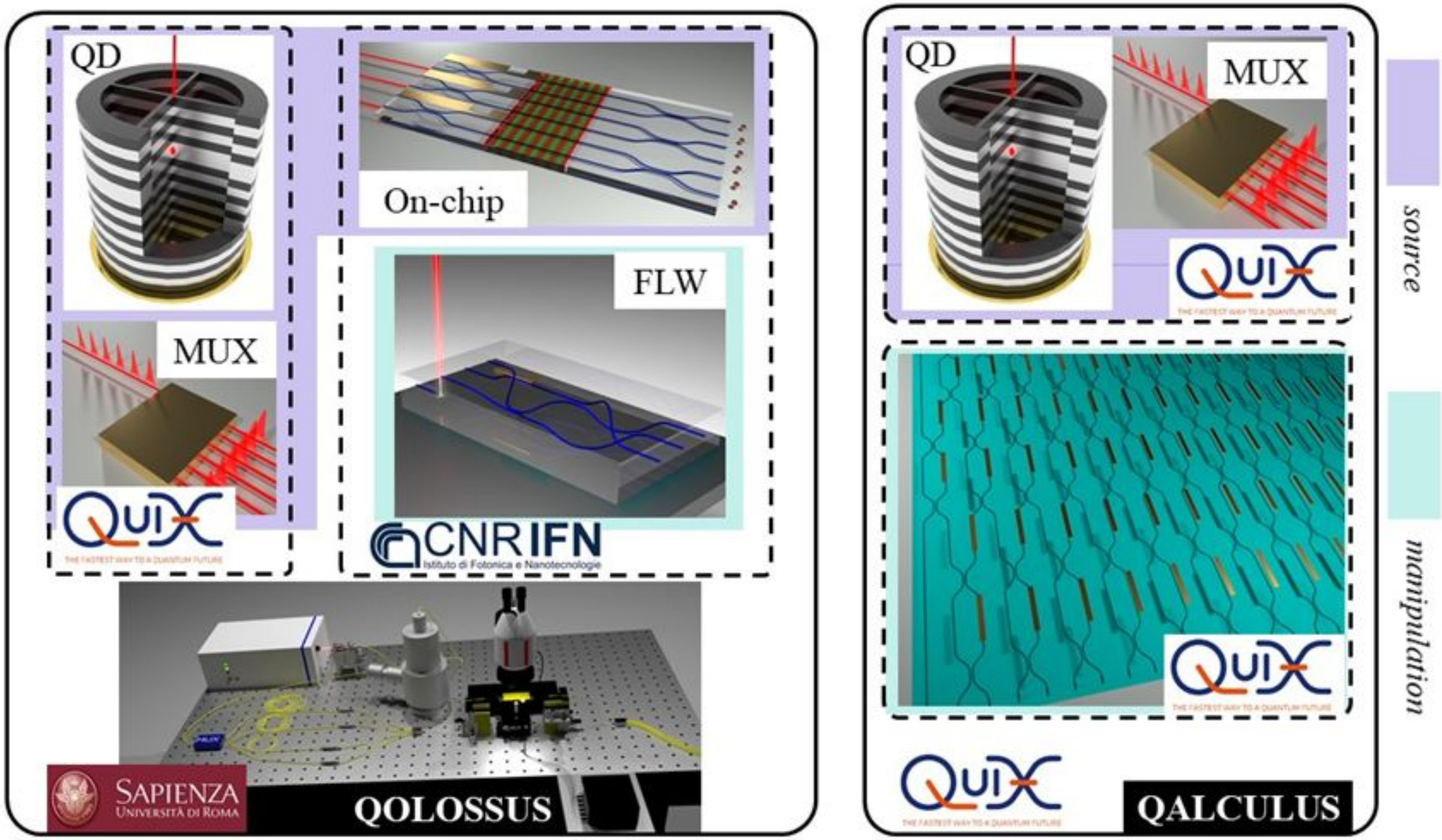
Recently, the study of computational problems that produce samples from probability distributions (quantum sampling problems or random circuit sampling) has highlighted a path forward to demonstrate quantum supremacy, corresponding to a scenario where a quantum device solves a specific problem faster than any classical system, as well as first applications.

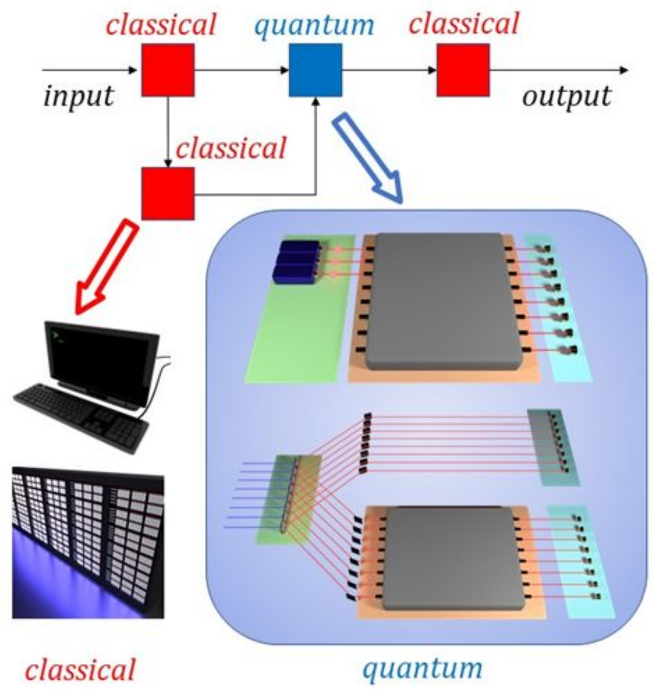
PHOQUSING and hybrid technology

The partners of the PHOQUSING project are trying to develop useful quantum computation by using a hybrid computational model combining classical and quantum processes. The aim is to implement such a hybrid computational system based on integrated cutting-edge photonics.



The Sampling machines

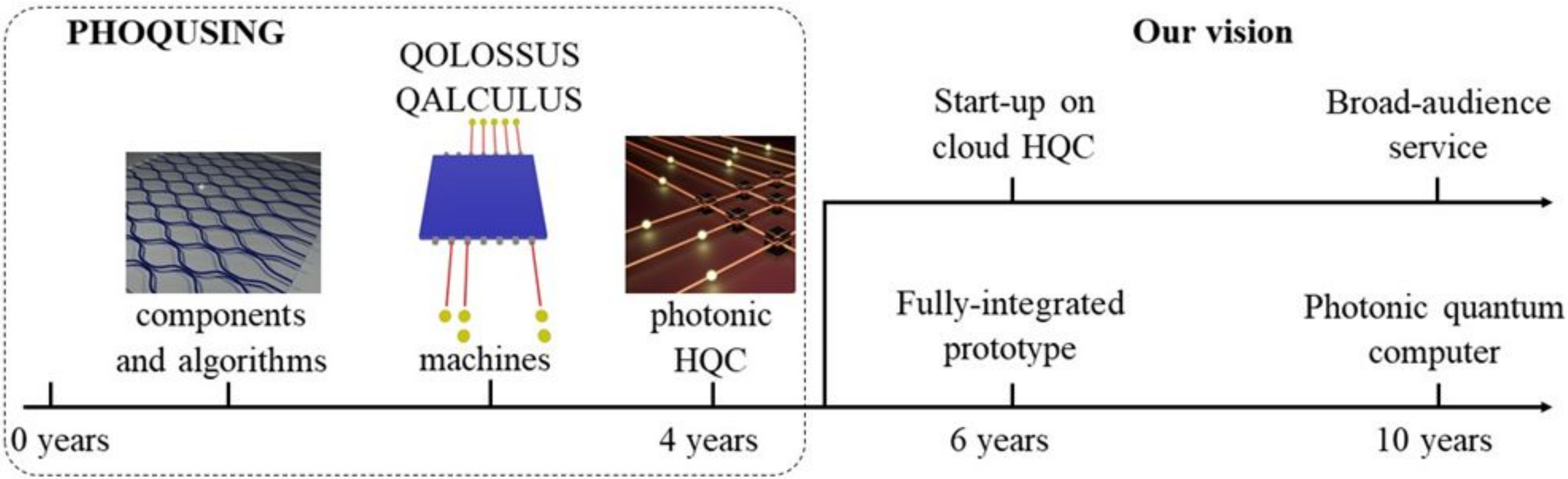




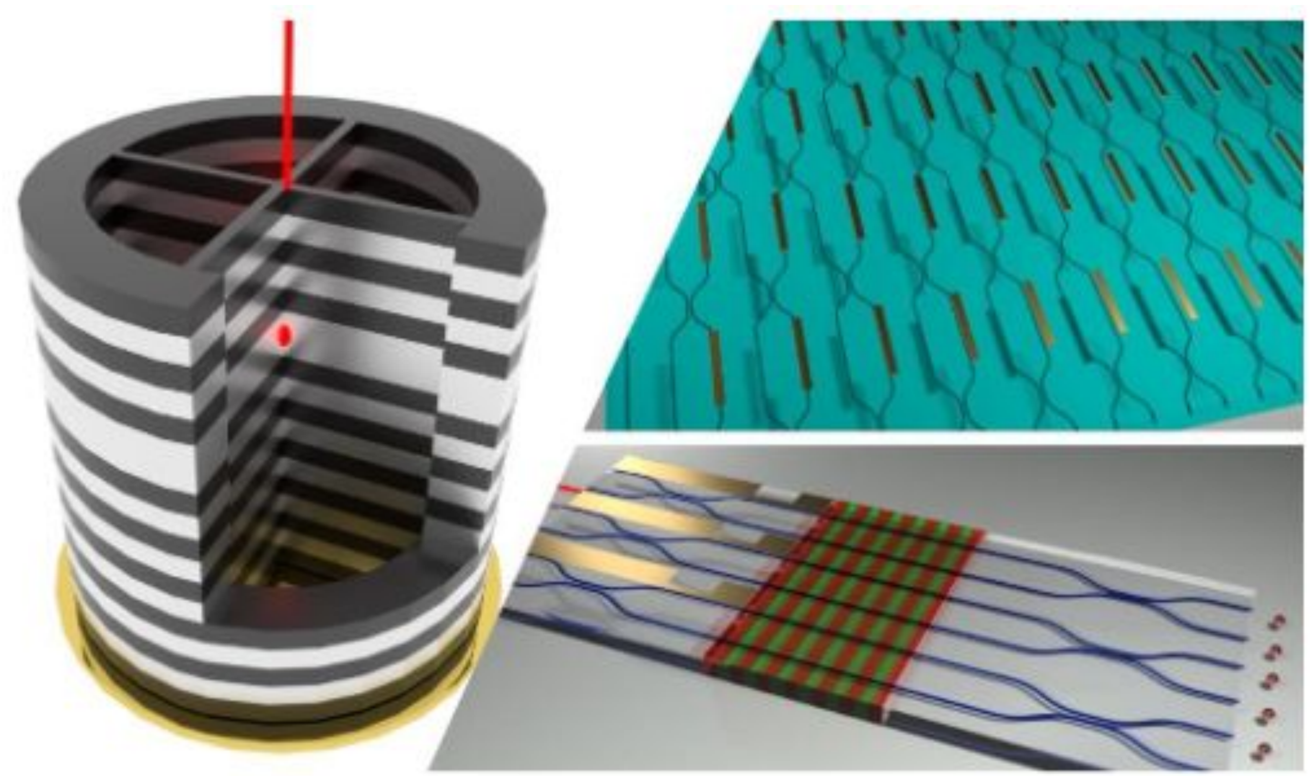
Sampling	Fixed Fock	Gaussian/ Scattershot	Driven	Number superposition	Adaptive	Bernoulli	Nonlinear
QOLOSSUS	✗	✓	✓	✗	✓	✓	✓
QALCULUS	✓	✗	✗	✓	✓	✗	✗

Technology	QD source	On-chip source	Reconfigurability	Large # modes	3D	Polarization
QOLOSSUS	✓	✓	✓	✗	✓	✓
QALCULUS	✓	✗	✓	✓	✗	✗

Expected impact



1st Annual meeting



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OUTREACH

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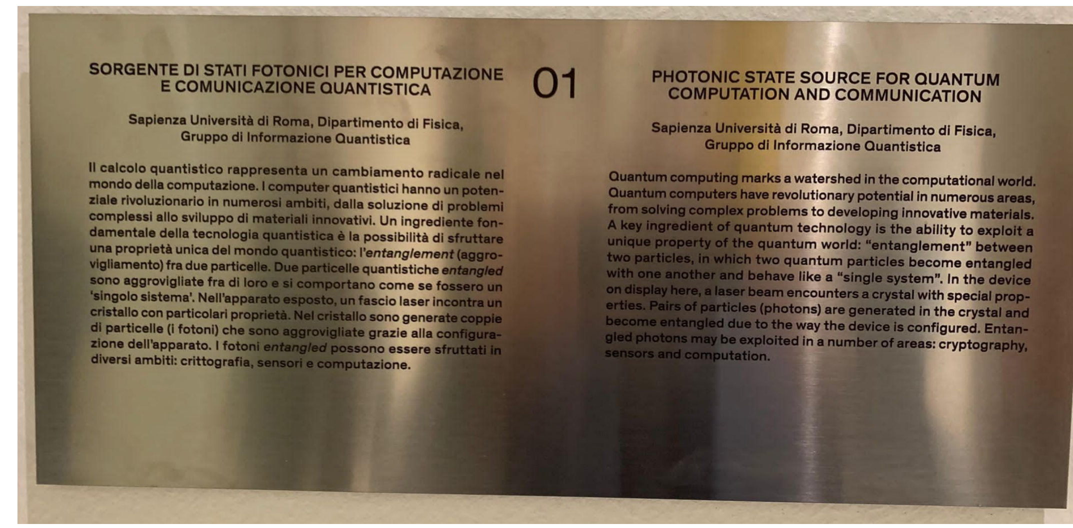
Pd palazzo delle esposizioni

VISITA GUIDATA ALLE MOSTRE TI CON ZERO, LA SCIENZA DI ROMA E INCERTEZZA

Team:
Prof. Fabio Sciarrino
Dr. Emanuele Polino
Dr. Gonzalo Carvacho
PhD Alessia Suprano



SORGENTE DI STATI FOTONICI PER COMPUTAZIONE E COMUNICAZIONE QUANTISTICA

01

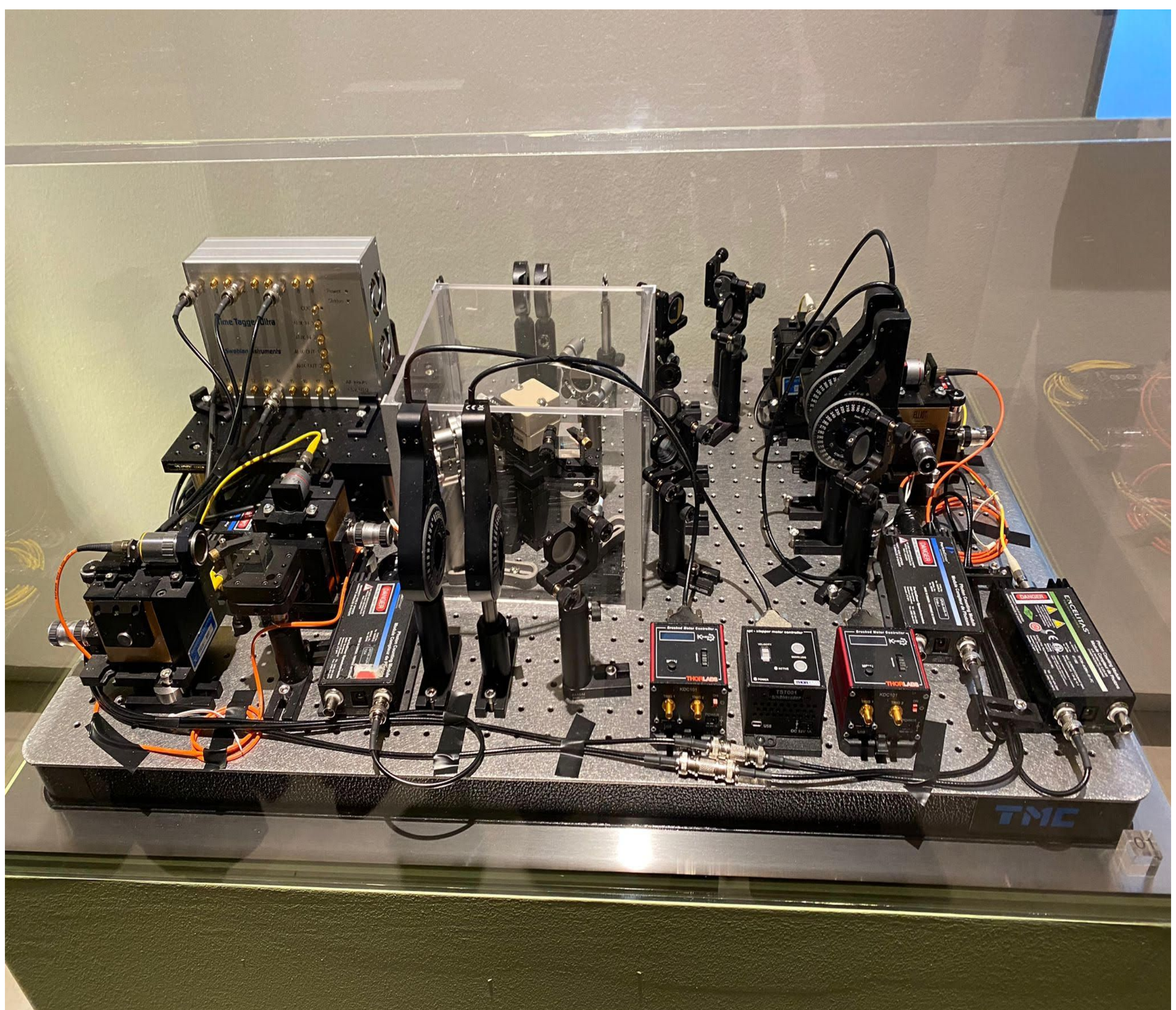
Sapienza Università di Roma, Dipartimento di Fisica, Gruppo di Informazione Quantistica

Il calcolo quantistico rappresenta un cambiamento radicale nel mondo della computazione. I computer quantistici hanno un potenziale rivoluzionario in numerosi ambiti, dalla soluzione di problemi complessi allo sviluppo di materiali innovativi. Un ingrediente fondamentale della tecnologia quantistica è la possibilità di sfruttare una proprietà unica del mondo quantistico: l'*entanglement* (aggrovigliamento) fra due particelle. Due particelle quantistiche *entangled* sono aggrovigliate fra di loro e si comportano come se fossero un 'singolo sistema'. Nell'apparato esposto, un fascio laser incontra un cristallo con particolari proprietà. Nel cristallo sono generate coppie di particelle (i fotoni) che sono aggrovigliate grazie alla configurazione dell'apparato. I fotoni *entangled* possono essere sfruttati in diversi ambiti: crittografia, sensori e computazione.

PHOTONIC STATE SOURCE FOR QUANTUM COMPUTATION AND COMMUNICATION

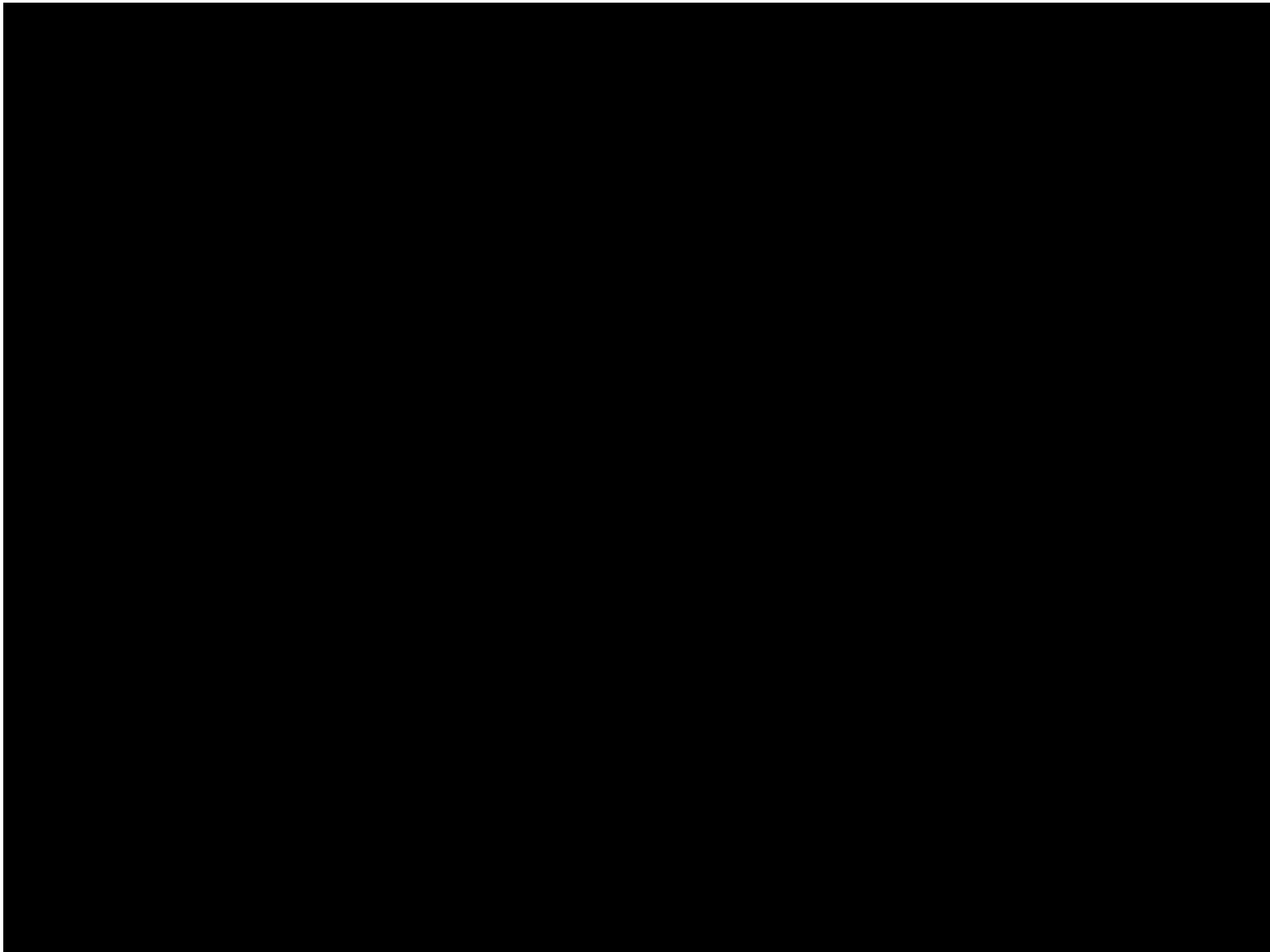
Sapienza Università di Roma, Dipartimento di Fisica, Gruppo di Informazione Quantistica

Quantum computing marks a watershed in the computational world. Quantum computers have revolutionary potential in numerous areas, from solving complex problems to developing innovative materials. A key ingredient of quantum technology is the ability to exploit a unique property of the quantum world: "entanglement" between two particles, in which two quantum particles become entangled with one another and behave like a "single system". In the device on display here, a laser beam encounters a crystal with special properties. Pairs of particles (photons) are generated in the crystal and become entangled due to the way the device is configured. Entangled photons may be exploited in a number of areas: cryptography, sensors and computation.



Photon entangled source

Alessia Suprano
3rd year PhD student



Opportunities for a PhD student involved in a project!

PhD students






1. **Do carry out research and publish scientific articles**

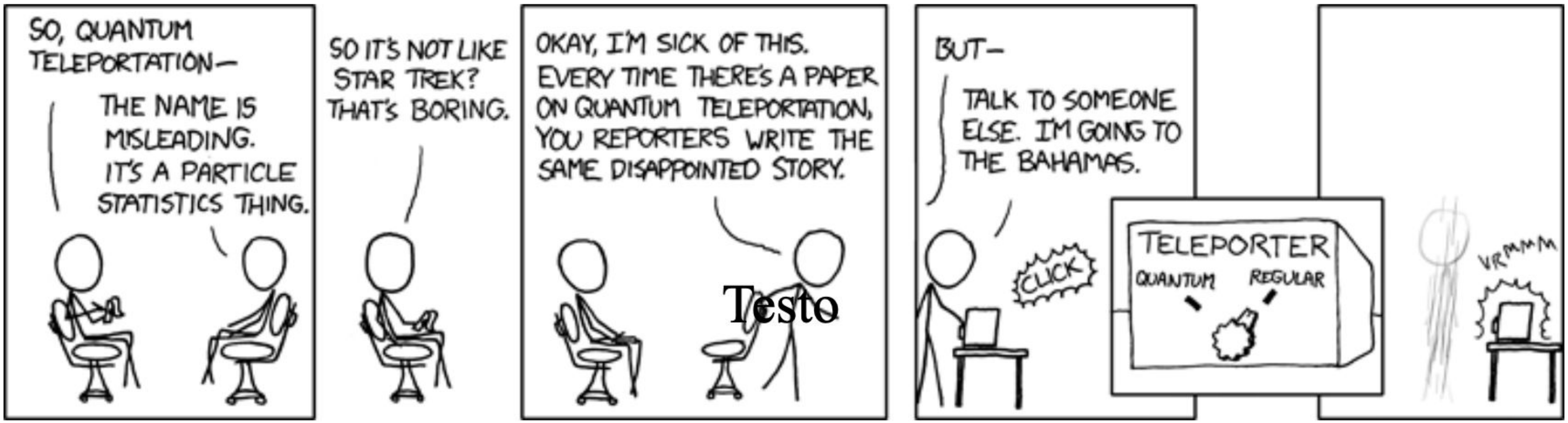
2. **Travel outside to present their work and participate in outreach activities**

3. **Visit other research groups and perform internships**

4. **Enjoy science!!**

"Working on a project is a very interesting experience for PhD students. First of all, it is very helpful to develop organization skills as the work scheduling and complying with the deadline. Moreover, it promotes the connection with researchers from different laboratories and universities, allowing to enlarge the student contact network. It can reveal very useful at the beginning of a career in research".

Thank you!



PICQUE

MARIE CURIE ACTIONS

erc

3D-QUEST

FUTURO IN RICERCA

F I R B

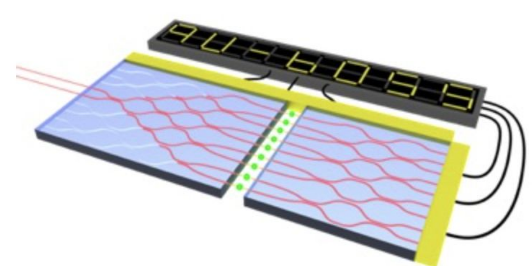
Fondo per gli investimenti della Ricerca di Base

THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION

HORIZON 2020

QUCHIP

Quantum Simulation on a Photonic Chip



Phoqusing

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Enjoy life, enjoy quantum!