# The EU Quantum Technology Flagship

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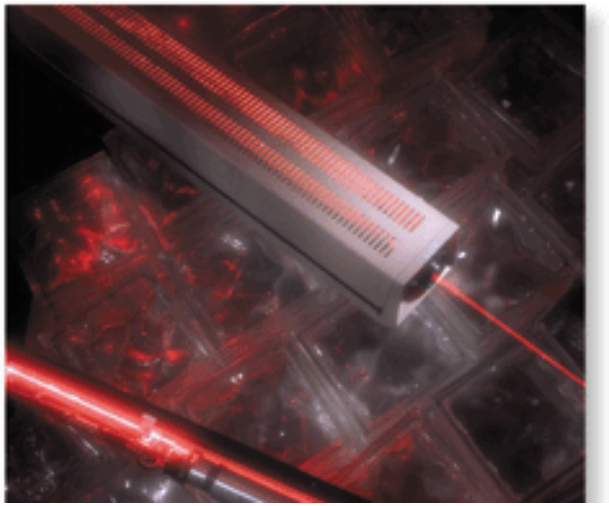
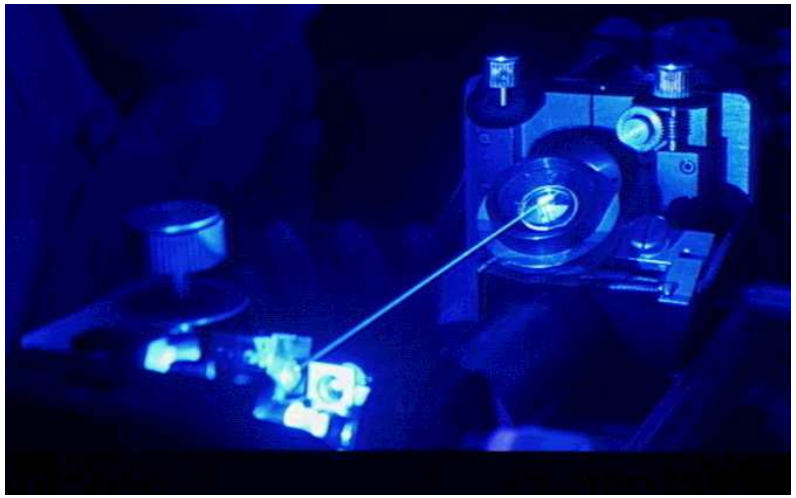
Collège de France, Ecole Normale Supérieure,

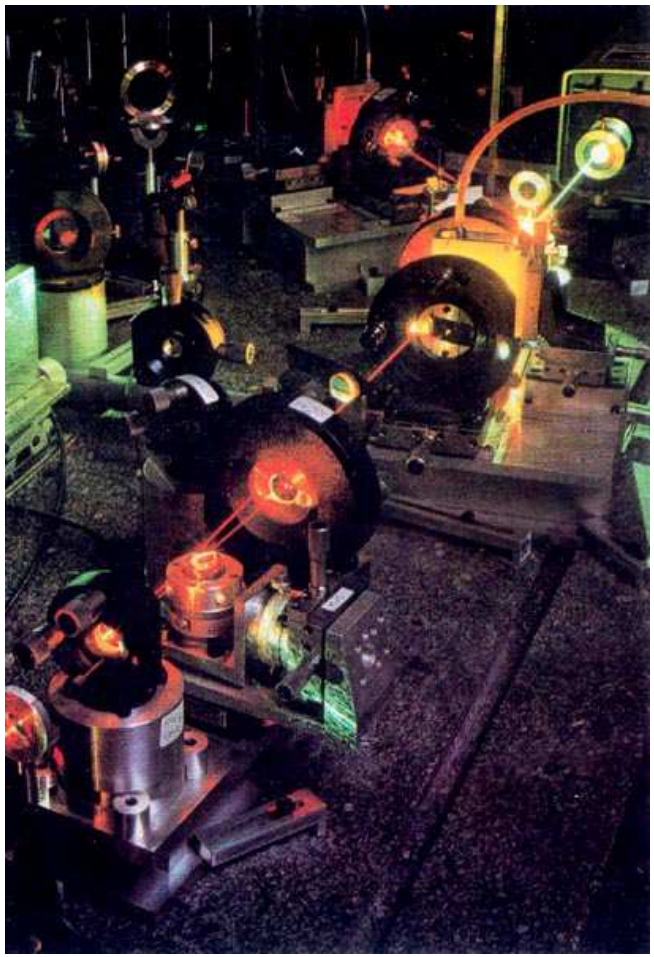
**Agence Nationale de la recherche**

Département Numérique et Mathématiques

# Fifty years ago: the invention of the laser

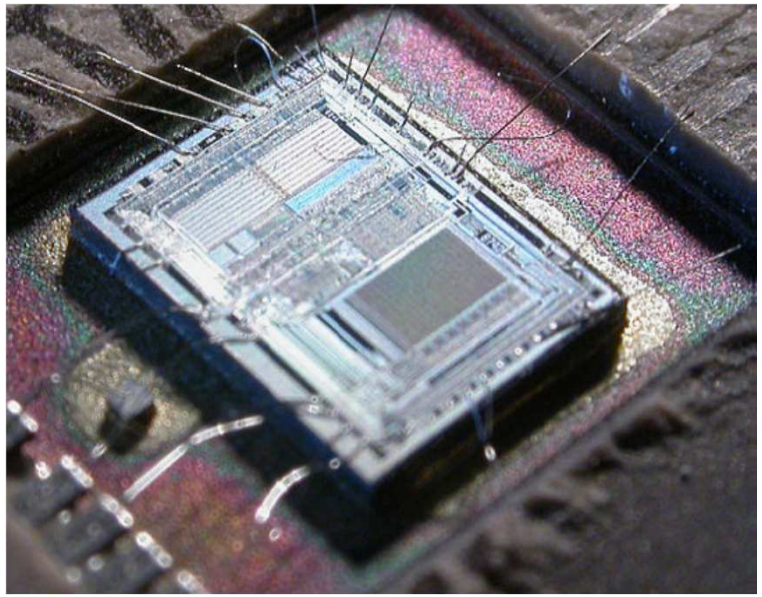






# Seventy years ago: the invention of the transistor


Replica of the first transistor invented at Bell Labs in 1947



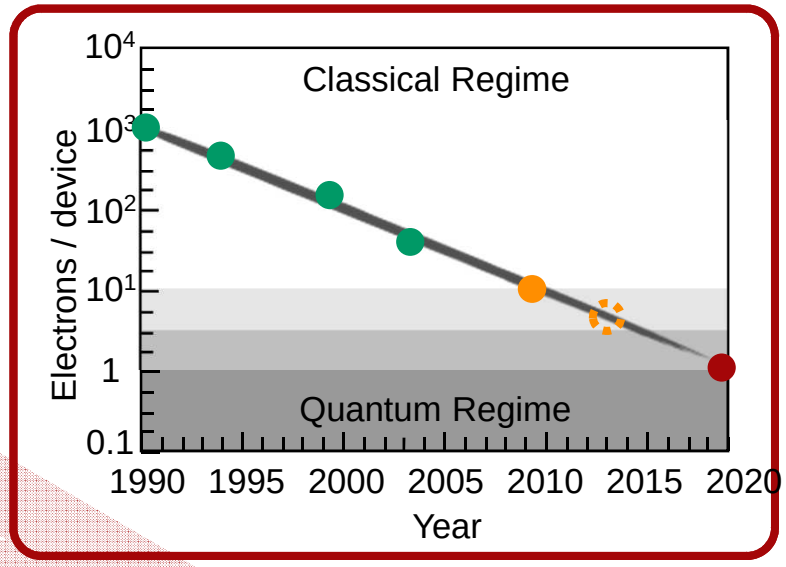
Integrated circuit (Intel)
It can contain billions of transitors

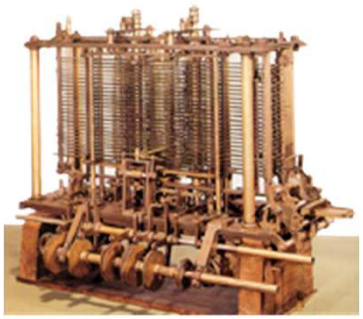
# The future is quantum

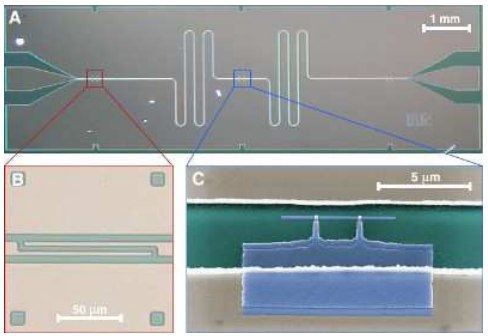
Moore's law: the number of transistors that can be placed inexpensively on an integrated circuit has doubled approximately every two years

Eventually the quantum wall will be hit

- ➢ push back the hitting time (more Moore)
- ➢ change completely the technology (more than Moore)
- ➢ and quantum technologies for **green IT**





# Quantum Technologies

Quantum technologies are already present :

- The first quantum revolution has allowed explaining and exploiting the structure and the interactions of atoms, light and matter, in order to design lasers or electronic chips.

- Second quantum revolution : reaching the level of individual quantum objects to design novel devices

In research labs individual quantum objects have been studied for several decades, although it was not obvious in the beginning

Erwin Schrödinger, 1952

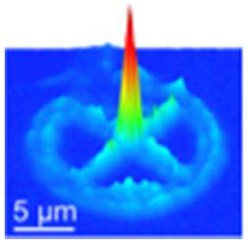
*«we never experiment with just one electron or atom or (small) molecule. In thought-experiments we sometimes assume that we do; this invariably entails ridiculous consequences…. »*

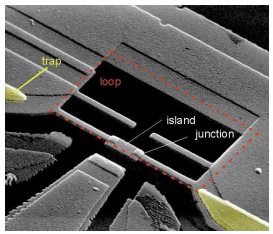
# 2nd quantum revolution

When reaching the level of individual quantum objects, the most surprising and far-reaching quantum properties, such as superpositions and entanglement, become experimental evidences.

**These quantum properties open the way to revolutionary methods to process and manipulate the information carried by such objects.**

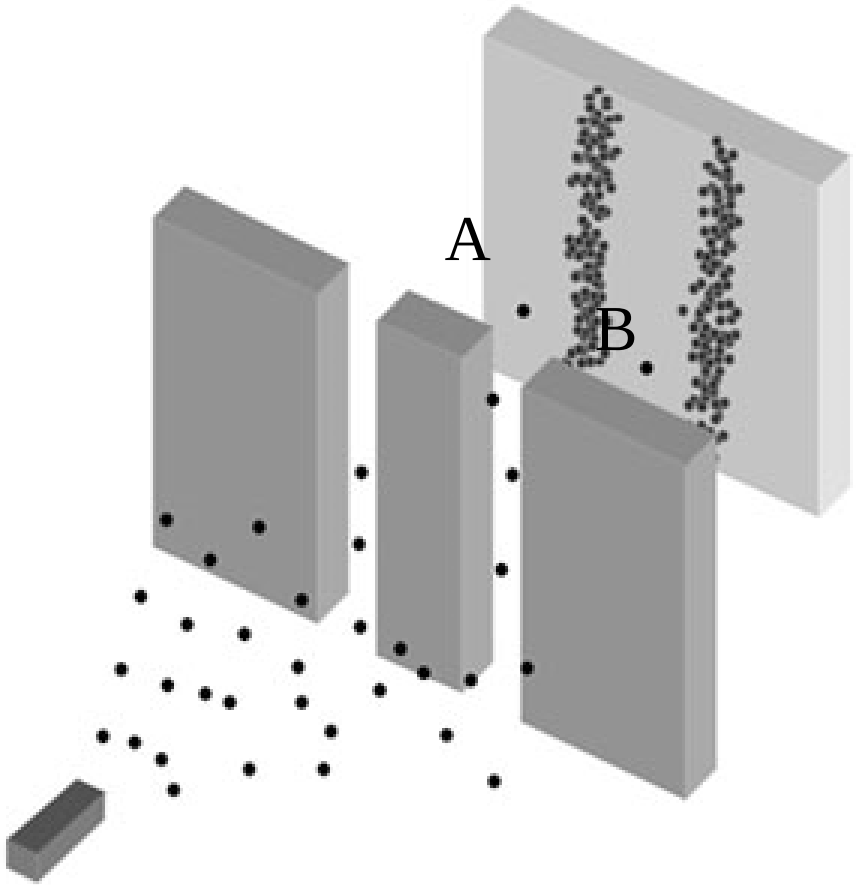
source of individual photons




Quantum bit (qubit) in superconductors

# The superposition principle



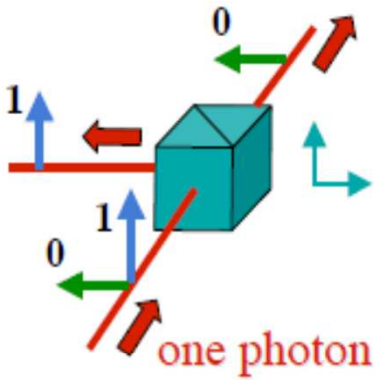

$$|\psi\rangle = \alpha\,|\psi_A\rangle + \beta\,|\psi_B\rangle$$

Nils Bohr

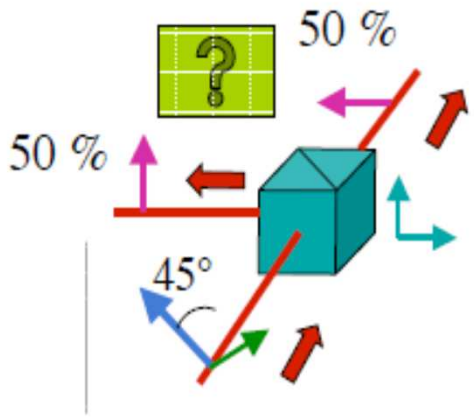
Erwin Schrödinger

# Quantum key distribution with a single photon

Coding a bit (0 or 1)
on the polarization
of one photon

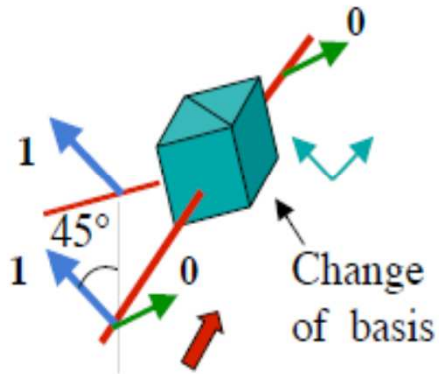



Deterministic result




Random result

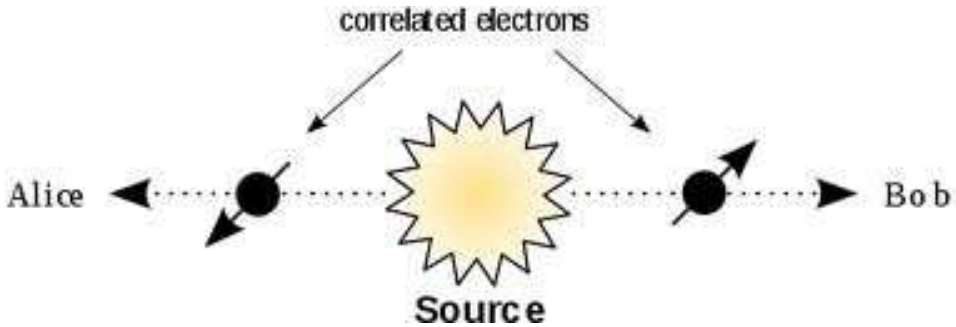
A useful information is extracted
if and only if the basis
used by the emitter (coding)
and by the receiver (detecting)
are the same !




Deterministic result

# Entanglement

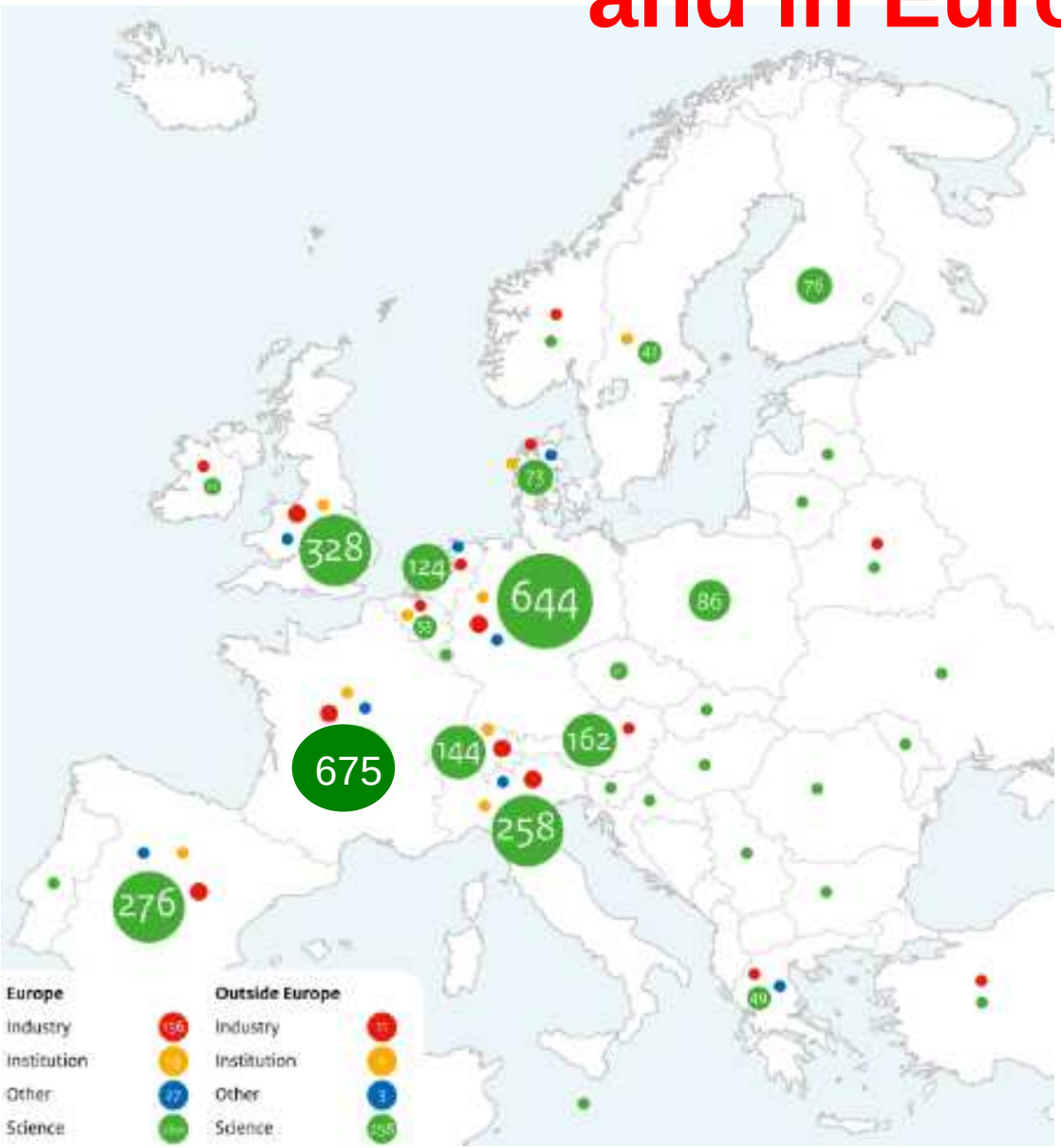
$$|\psi\rangle = |\uparrow_A\rangle|\downarrow_B\rangle + |\downarrow_A\rangle|\uparrow_B\rangle$$




A. Einstein B. Podolsky N. Rosen

**Also a resource for QKD**

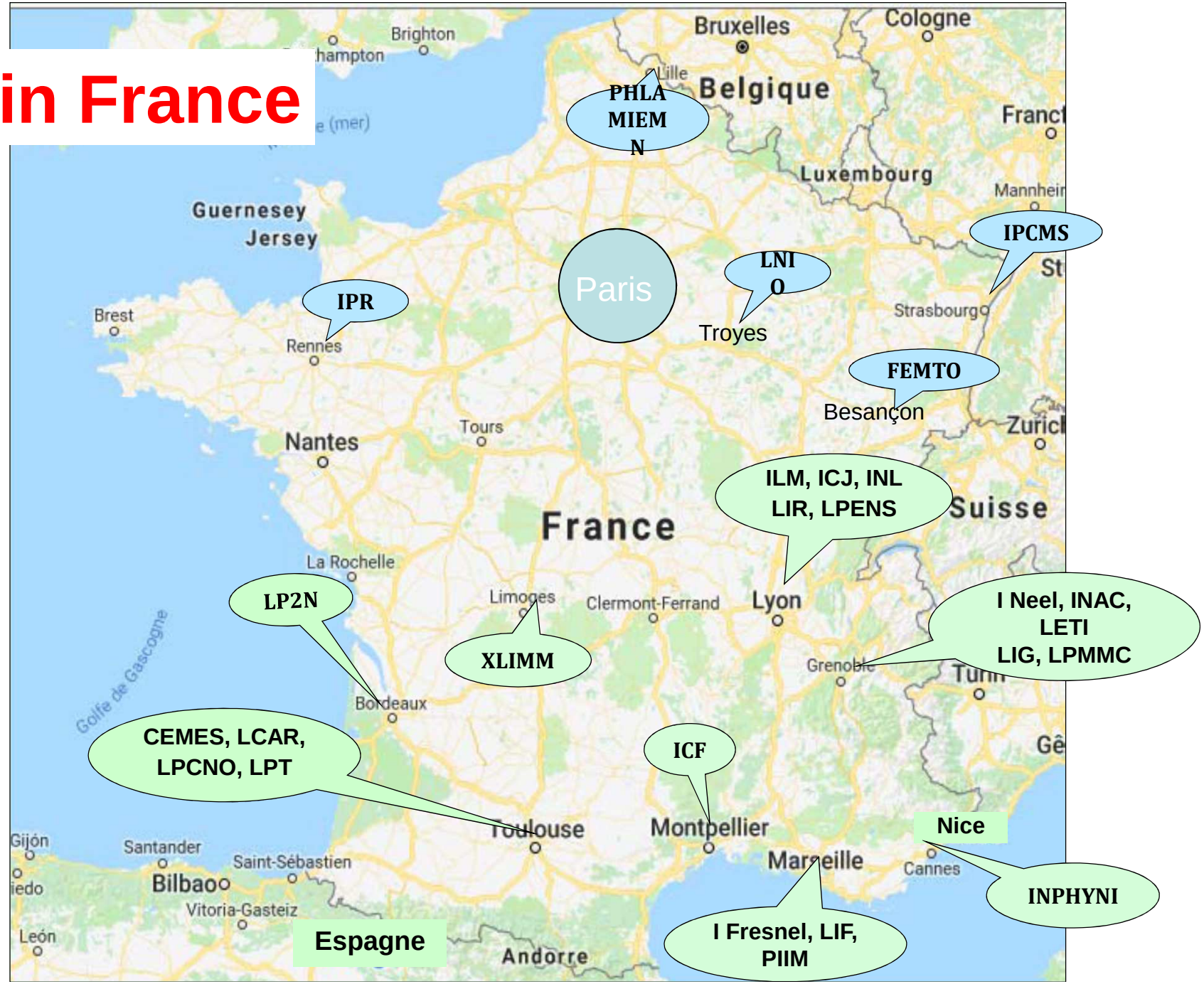
# Quantum technologies in France and in Europe



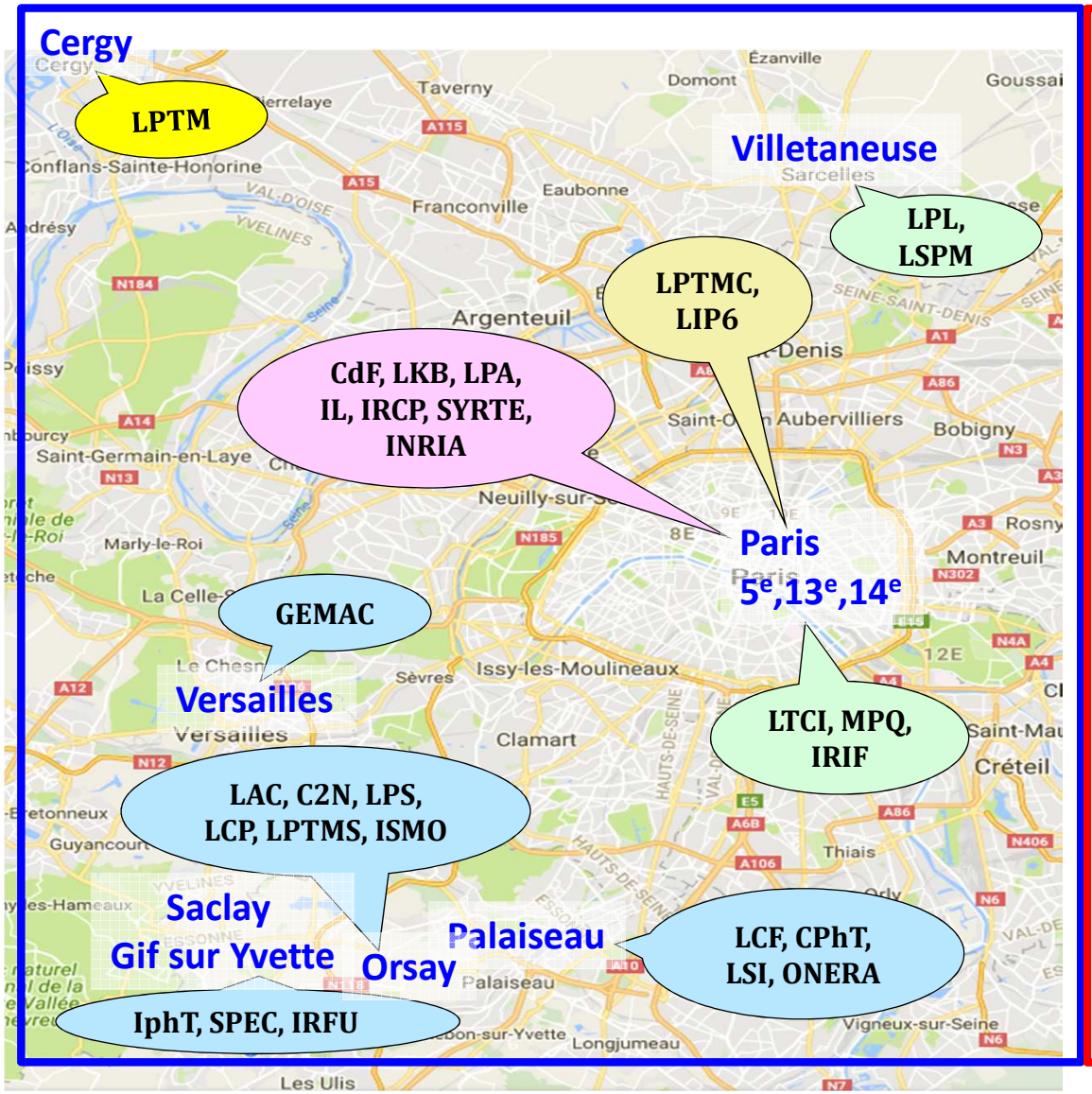

Companies

Atos
ASML
SAFRAN
AEROSPACE · DEFENCE · SECURITY
HUAWEI
IBM
intel
BOSCH
e2v
Alcatel·Lucent
TOSHIBA
imec
THALES
SINGLE QUANTUM
IDQ
SIEMENS
NOKIA
Microsoft

# QT in France


Brighton
Bruxelles
Cologne
Lille
Belgique
PHLA
MIEM
N
Luxembourg
Guernesey
Jersey
IPCMS
Paris
LNI
O
Troyes
Strasbourg
IPR
Brest
Rennes
FEMTO
Besançon
Tours
Nantes
ILM, ICJ, INL
LIR, LPENS
Suisse
France
La Rochelle
LP2N
Limoges
Clermont-Ferrand
Lyon
I Neel, INAC,
LETI
LIG, LPMMC
XLIMM
Grenoble
Golfe de Gascogne
Bordeaux
CEMES, LCAR,
LPCNO, LPT
ICF
Toulouse
Montpellier
Nice
Gijón
Santander
Saint-Sébastien
Bilbao
Marseille
Cannes
INPHYNI
Vitoria-Gasteiz
León
Espagne
Andorre
I Fresnel, LIF,
PIIM

# Network in the Ile de France Region SIRTEQ




**Some numbers:**

* 300 CNRS, CEA or Univ. staff,
* 250 doctoral students
* 100 post-doctoral students,
* **650 researchers total**
* **>100 teams, 30 laboratories**
* **gathers computer scientists and physicists from condensed matter, cold atoms, quantum optics, metrology, material science...**

# National and regional initiatives for Quantum Technologies

- 2 GDR National networks concerning quantum science and technology

**Ingénierie Quantique, des aspects Fondamentaux aux Applications**

**GDR Atomes froids**

- Paris Center for Quantum Computing (PCQC)
- 6 national fabrication platforms
- 4 Excellence Initiative (IDEX)
- 5 LABEX (Laboratory of Excellence) coordinated in the framework of the national network IQFA
- Several regional Initiatives

# ANR: National Research Agency

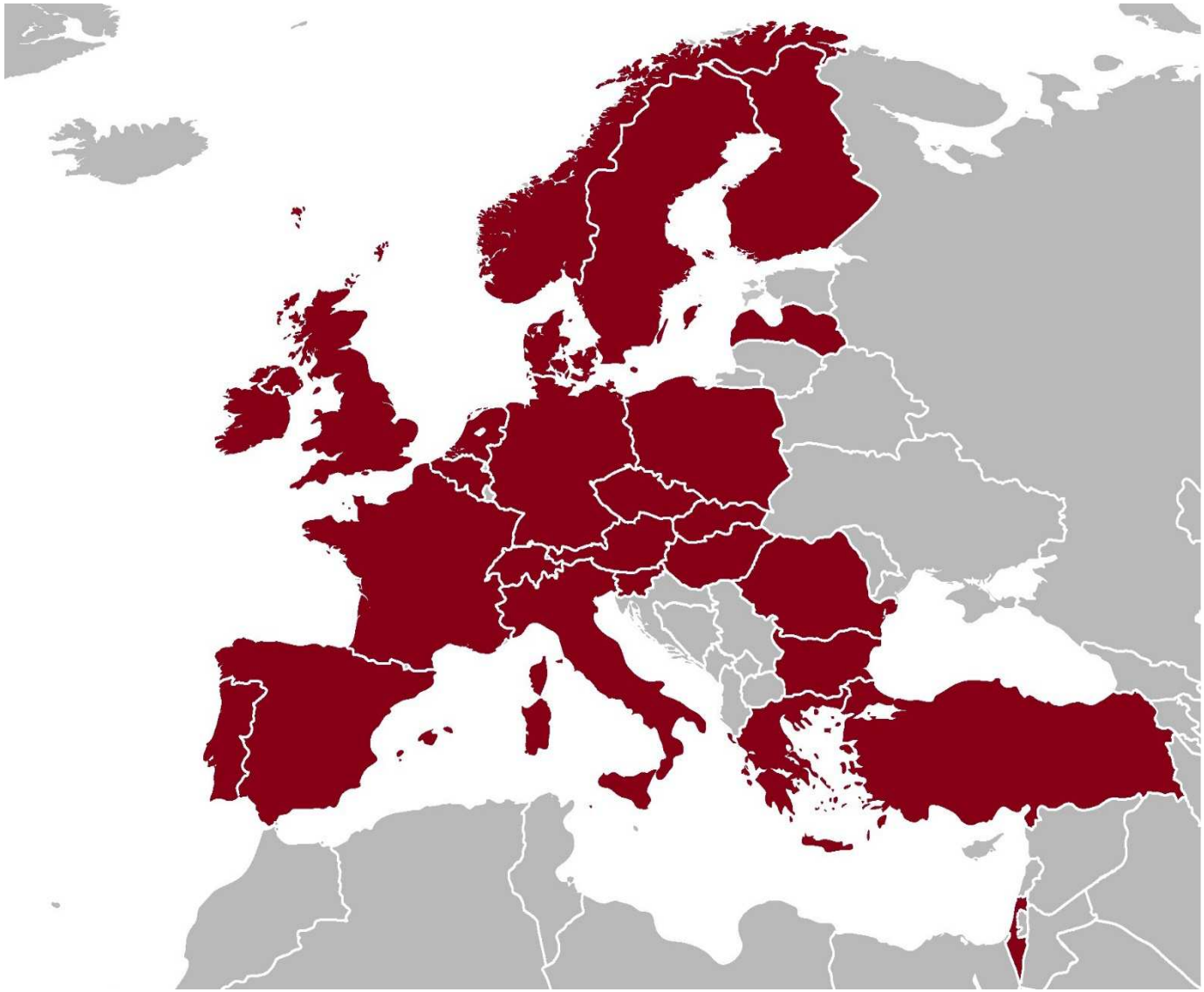
- Specific budgets for Quantum Technologies defined by the Ministery, starting in 2018 : 10M€/year
- Direct participation to European financing : 3 M€ contribution to the QuanERA (Eranet Cofund) call
- Next QuantERA call (not Cofund) 2 M€ end 2018 or beginning 2019

# QuantERA Co-funded Call

## QuantERA: FET ERA-NET Cofund Action in Quantum Technologies

- Broad Scope: Quantum (« Q ») communication, Q simulation, Q computation, Q information sciences, Q metrology sensing and imaging, Novel ideas and applications in quantum science and technologies
- Low TRLs targeted, FET-like: Long-term vision, Breakthrough S&T target, Novelty, Foundational, High-risk, Interdisciplinary
- Project size: 1 to 2 M€, at least 3 partners from 3 countries, 2 to 3 years

# QuantERA Consortium



# QuantERA Consortium coordinated by NCN (Poland)

## 26 countries, 31 organizations

- Poland – NCN, NCBR
- Austria – FWF, FFG
- Belgium – FNRS, FWO
- Bulgaria – NBSF
- Czech Republic – MSMT
- Denmark – IFD
- Finland – AKA
- France – ANR
- Germany, BMBF, VDI-TZ
- Greece – GSRT
- Hungary – NKFIH
- Ireland – SFI
- Israel - MATIMOP
- Italy – MIUR, CNR
- Latvia – VIAA
- Netherlands – FOM
- Norway - RCN
- Portugal – FCT
- Romania – UEFISCDI
- Slovakia – SAS
- Slovenia – MIZS
- Spain – MINECO
- Sweden – VR
- Switzerland – SNSF
- Turkey – TUBITAK
- United Kingdom – EPSRC, IUK

**Contributions of the Member States and associated countries, together with the EC : 38 M€**

**Call budget 34 M€**

# QuantERA
# Strategic Advisory Board

**Peter L. Knight**, Imperial College

**Alain Aspect**
Institut d'Optique

**Hans Mooij**
Technische Universiteit Delft

**Tommaso Calarco**
Universität Ulm

**Kelly Richdale**
Vice President Quantum Safe Security
idQuantique

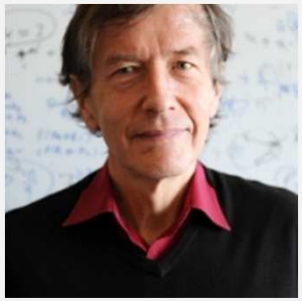
**Anna Sanpera**
Universitat Autònoma Barcelona

**Bruno Desruelle**
Muquans

**Francesca Ferlaino**
Universität Innsbruck

**Andrew Shields**
Toshiba Research Labs Europe

**Ataç İmamoğlu**
ETH Zürich



**Marek Żukowski**
Uniwersytet Gdański

# QuantERA Co-funded Call

- Launch of the call: **January 2017**
- Deadline for pre-proposals: **15 March 2017**

  **220 pre-proposals submitted**
- Notification of accepted pre-proposals**: May 2017**

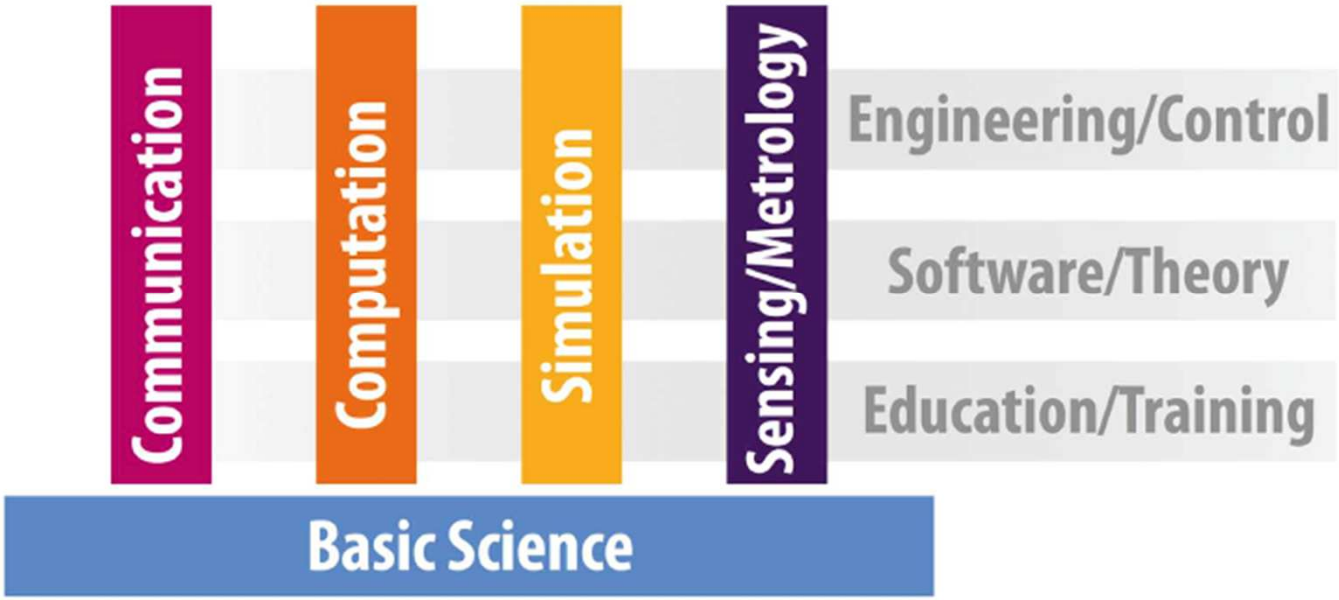
  **92 pre-proposals accepted**
- Deadline for full proposals: **10 July 2017**
- Rebuttal stage: **September 2017**
- Notification of accepted proposals: **October 2017**

  **26 proposals accepted**
- Projects start: **early 2018**

# European Quantum Technologies Flagship

# Amsterdam 17 May 2016
# Presentation of Quantum Manifesto

# European Quantum Technologies Flagship

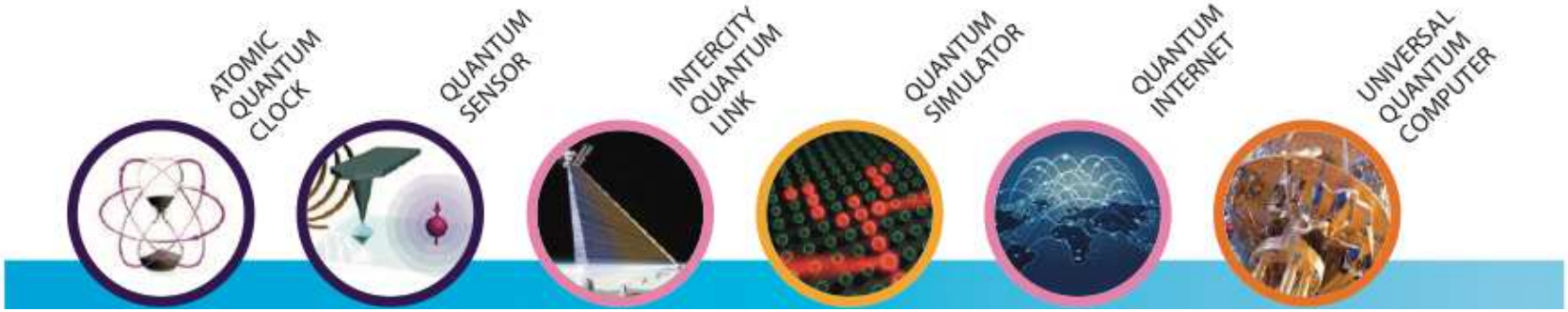



Report handed over to the European Commission Nov 2017

1 billion euros over 10 years
1st call for proposals is open (dead line end of February): 148 M€

https://ec.europa.eu/digital-single-market/en/news/intermediate-report-quantum-flagship-high-level-expert-group

# Quantum Manifesto




## 1. Communication

**0 – 5 years**

- A Core technology of quantum repeaters
- B Secure point-to-point quantum links

**5 – 10 years**

- C Quantum networks between distant cities
- D Quantum credit cards

**> 10 years**

- E Quantum repeaters with cryptography and eavesdropping detection
- F Secure Europe-wide internet merging quantum and classical communication

## 2. Simulators

**0 – 5 years**

- A Simulator of motion of electrons in materials
- B New algorithms for quantum simulators and networks

**5 – 10 years**

- C Development and design of new complex materials
- D Versatile simulator of quantum magnetism and electricity

**> 10 years**

- E Simulators of quantum dynamics and chemical reaction mechanisms to support drug design

## 3. Sensors

**0 – 5 years**

- A Quantum sensors for niche applications (incl. gravity and magnetic sensors for health care, geosurvey and security)
- B More precise atomic clocks for synchronisation of future smart networks, incl. energy grids

**5 – 10 years**

- C Quantum sensors for larger volume applications including automotive, construction
- D Handheld quantum navigation devices

**> 10 years**

- E Gravity imaging devices based on gravity sensors
- F Integrate quantum sensors with consumer applications including mobile devices

## 4. Computers

**0 – 5 years**

- A Operation of a logical qubit protected by error correction or topologically
- B New algorithms for quantum computers
- C Small quantum processor executing technologically relevant algorithms

**5 – 10 years**

- D Solving chemistry and materials science problems with special purpose quantum computer > 100 physical qubit

**> 10 years**

- E Integration of quantum circuit and cryogenic classical control hardware
- F General purpose quantum computers exceed computational power of classical computers

# Members of the High Level Steering Committee

## Academic Members

- Prof. Dr. Jürgen Mlynek, *Chairman*
- Prof. Dr. Rainer Blatt, *Academic Member (AM)*
- Prof. Dr. Vladimir Buzek, *AM*
- Prof. Dr. Tommaso Calarco, *AM*
- Prof. Dr. Per Delsing, *AM*
- Prof. Dr. Elisabeth Giacobino, *AM*
- Prof. Dr. hab. Marek Kus, *AM*
- Prof. Dr. Eugene Simon Polzik, *AM*
- Dr. Maria Luisa Rastello, *AM*
- Prof. Dr. ir. Wim Van Saarloos, *AM*
- Prof. Dr. Lluis Torner, *AM*
- Prof. Ian Walmsley, AM

- Prof. Dr. Maria Chiara Carrozza, Observer
- Dr. Gustav Kalbe, European Commission (EC)
- Beatrice Marquez-Garrido, EC
- Matyas Kovacs, Assistant to the Chairman
- Dr. Marco Wedel, Assistant to the Chairman

# Industrial members

| | |
|---|---|
| **Mr. Paolo Bianco** | Airbus Defense & Space UK |
| **Dr. Markus Matthes** | ASML |
| **Dr. Cyril Allouche** | Atos SE |
| **Dr. Fabio Cavaliere** | Ericsson |
| **Dr. Grégoire Ribordy** | ID Quantique |
| **Ms. Jaya Baloo** | KPN |
| **Dr Graeme Malcolm** | M2 Lasers |
| **Dr. Michael Bolle** | Robert Bosch |
| **Dr. Norbert Lütke-Entrup** | Siemens AG |
| **Dr. Guido Chiaretti** | ST Micro |
| **Mr. Daniel Dolfi** | Thales |
| **Dr. Iñigo Artundo Martinez** | VLC Photonics |

# Tasks of the High Level Steering Committee

to deliver advice to the DG CONNECT on

**(1) a Strategic Research Agenda**, taking into account industrial aspects, with

- a **long term roadmap** for the flagship and
- a detailed agenda for the H2020 **ramp-up phase** that should start in 2018

(2) **an Implementation Model**, it should propose a **concrete** implementation approach both for the short term ramp-up phase within H2020 as well as for the longer term beyond H2020;

(3) **a Governance Model**,

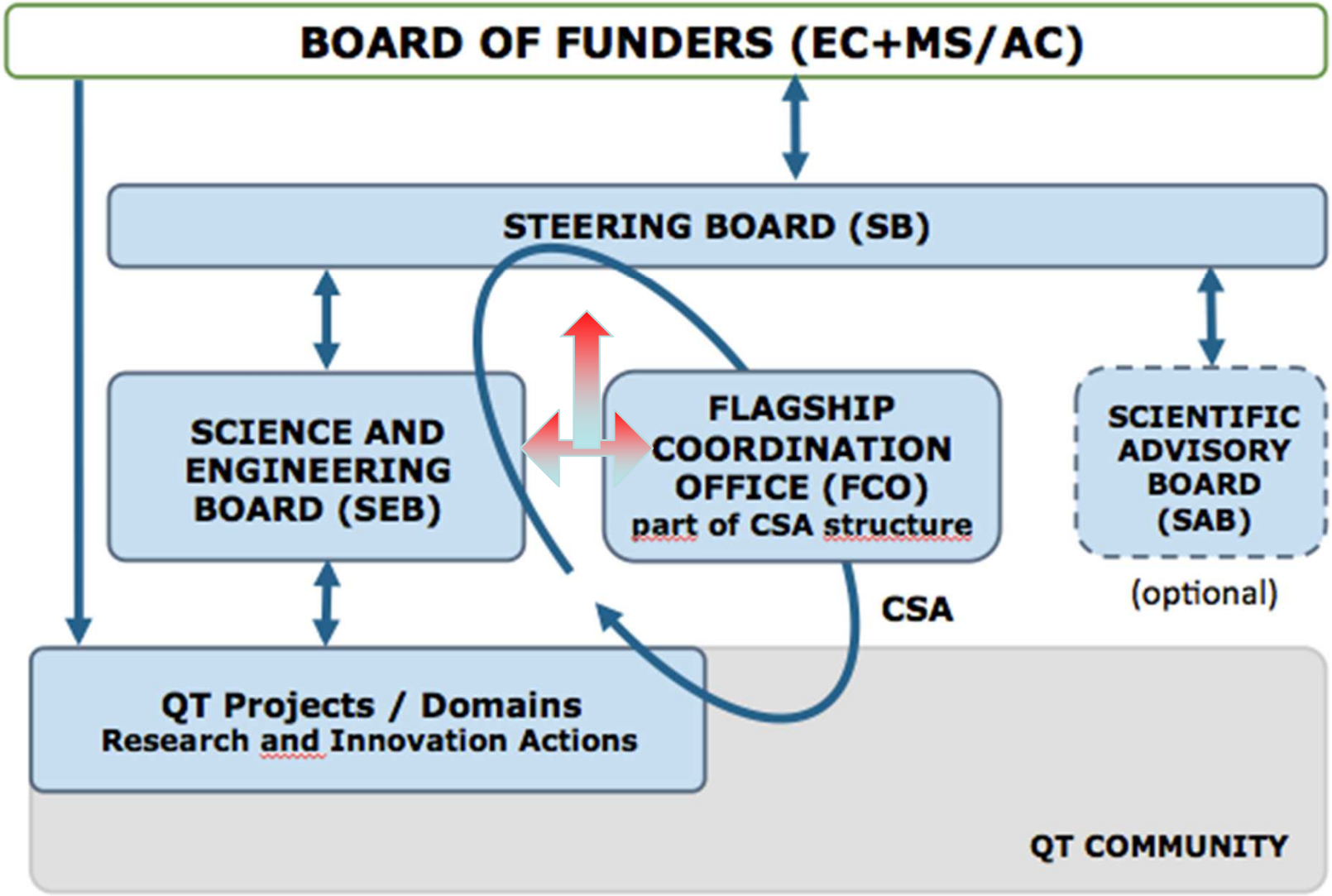
- internal governance of the flagship
- relations with Member States, with the Commission and with the relevant funding agencies.

The group should consolidate contributions from the wider community of relevant stakeholders from academia, industry and Member States.

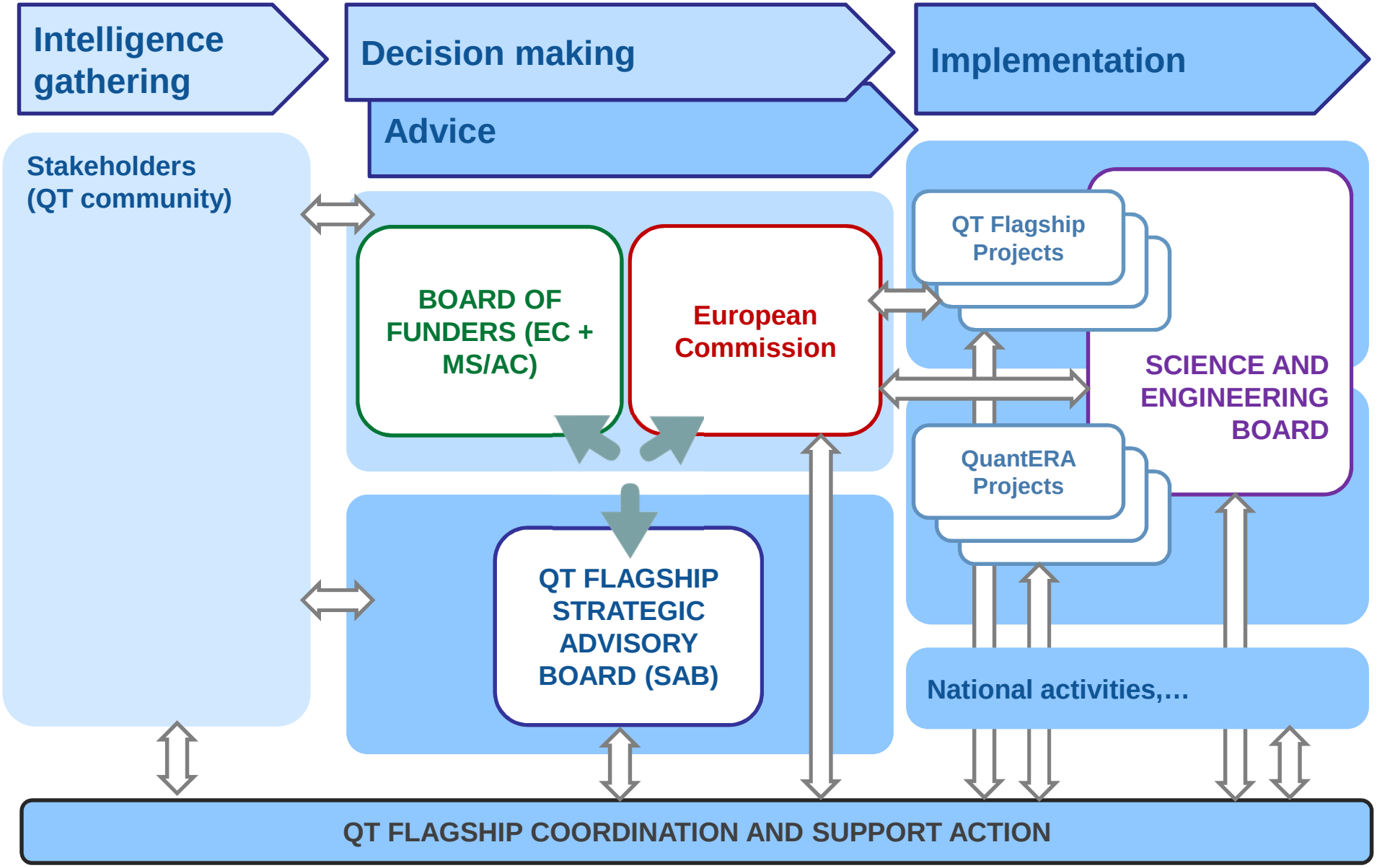
# Strategic research agenda

- **four QT pillars** :Simulation; Communication; Computing; Metrology and Sensing and Enabling Science
- and a **transverse cross-cutting domain**
- Inclusiveness should be rooted on excellence, together with industrial perspective
- Breakthroughs resulting in **disruptive technologies** are expected. For this high-risk projects should be supported
- Place Europe at the forefront of second quantum revolution

# Governance model for the QT Flagship



# QT Flagship Governance



# Strategic level

***Decision making** by public authorities*

**Board of Funders:**

- Discussion forum
- Alignment of initiatives
- Overall follow-up

**European Commission:**

- Planning of financial support
- Project selection and funding decision
- Project follow-up

***Strategic advice** by quantum community*

**Strategic Advisory Board:**

- Monitors the progress of the Flagship towards its goals
- Proposes updates of Strategic Research Agenda
- Works with the EC and reports progress to the BoF
- Gets inputs from networking & coordination level (CSA, SEB)

# QT Flagship
# Strategic Advisory Board

**Composition:**

- 6-8 academic members (including RTOs)
- 6-8 industrial members (including SMEs)
- from MS/AC
- appointed by the EC
- 1 chairperson + 1 vice-chair
- not involved in activities funded by the QT Flagship

**Rules of procedure:**

- Meeting up to 4x/year
- 2-year mandate

Transition from QT-HLSC:
~10 former QT-HLSC members appointed with an initial 1-year mandate

# QT Flagship
# Science & Engineering Board

Composition:
- QT Flagship project coordinators
- Representatives of QuantERA projects

Tasks:
- **Coordination** of QT Flagship R&I activities
- Identify **collaboration** opportunities, joint developments, sharing of infrastructures among projects
- Interacts with the **Strategic Advisory Board and reports to the EC**

# QT Flagship
# Coordination and Support Action

- Networking of **stakeholders**
- Liaison with **QT initiatives at national/regional level**
- Management the **information repository** (databases,…)
- Organisation of **workshops, conferences**
- Organisation of the **benchmarking** of QT projects

- **Promotes, disseminates**, maximises outreach
- Facilitates **International cooperation**
- Collects **progress indicators**
- Identifies **education and training** offers/needs
- Identifies **standardisation** needs
- **Supports** the SEB and SAB

# Present coordination action
# (16 months, 2018-2019) :
# Quantum Coordination and Support Action
# QSA

## Partners

| | |
|---|---|
| 1 Universität Ulm | DE |
| 2 Robert Bosch GmbH | DE |
| 3 Thales SA | FR |
| 4 Université de Genève | CH |
| 5 Universität des Saarlandes | DE |

Contact (French partner): Thierry Debuisschert (Thalès)

# Submitted (20 February 2018) Coordination Action 36 months, 2018-2021

# Quantum Flagship Coordination and Support Action (QFlag)

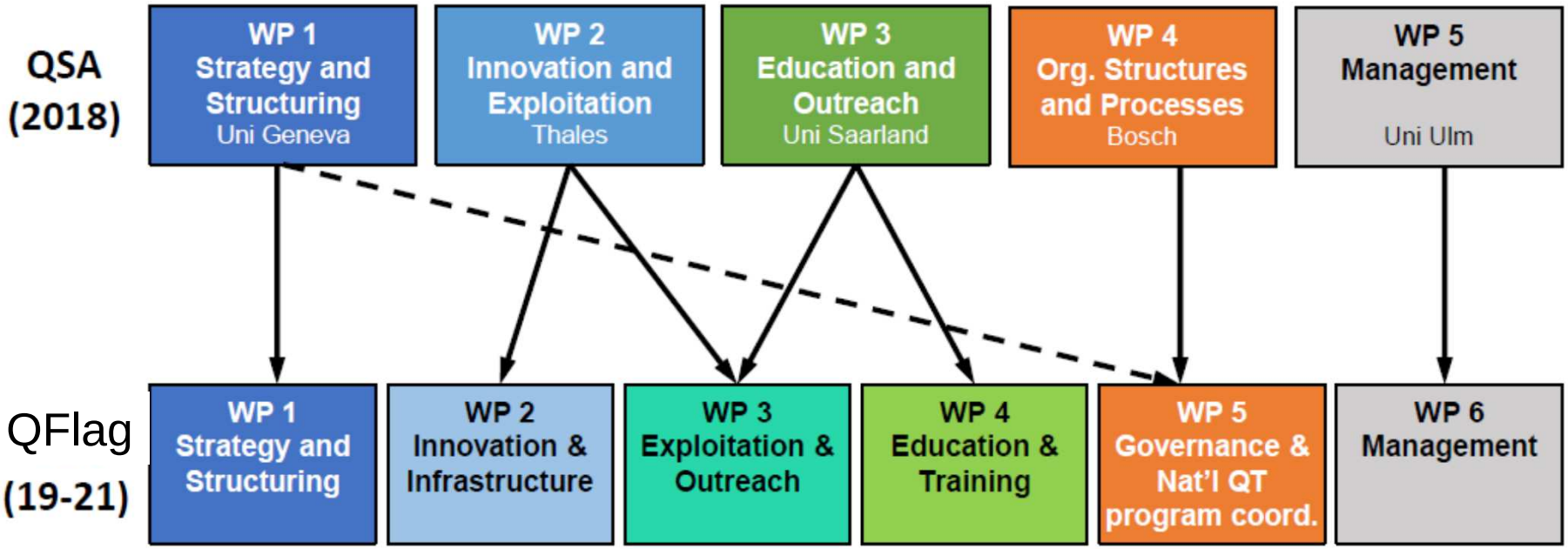
## Partners

| | | |
|---|---|---|
| 1 | VDI Technologiezentrum GmbH | DE |
| 2 | Université de Genève | CH |
| 3 | Nederlandse Organisatie voor Toegepast natuurweten-schappelijk onderzoek TNO | NL |
| 4 | Commissariat à l'energie atomique et aux energies alternatives | FR |
| 5 | Robert Bosch GmbH | DE |
| 6 | Consiglio Nazionale delle Ricerche | IT |
| 7 | Fundació Institut de Ciències Fotòniques | ES |

Contacts (French partners): Philippe Chomaz, Yves Samson (CEA)

# Coordination and Support Actions

QSA and proposed CSA work packages and partners




**CSA consortium partners:**

- Bosch
- CEA
- Uni Geneva
- Uni Ulm
- TNO
- VDI Technologiezentrum

# Work Programme 2018-2020

QT Flagship = 10+ year duration

QT Flagship ramp-up phase in H2020 (2017-2020)

- QuantERA (33 M€) in 2017 (started)
- CSA in 2017 (WP update)

} **Transition period**
+ MS initiatives (?)

- RIA in 2018
- CSA in 2018
- ERANET 2020

} **WP18-20** **130 M€**

**=> Project start: 1/1/2019**

QT Flagship "full" deployment in FP9 (2020 & beyond)

# WP 2018-2010 : funding

- **a. Quantum Communication**
- **b. Quantum Computing Systems**
- **c. Quantum Simulation**
- **d. Quantum Metrology and Sensing**
- **e. Fundamental science**

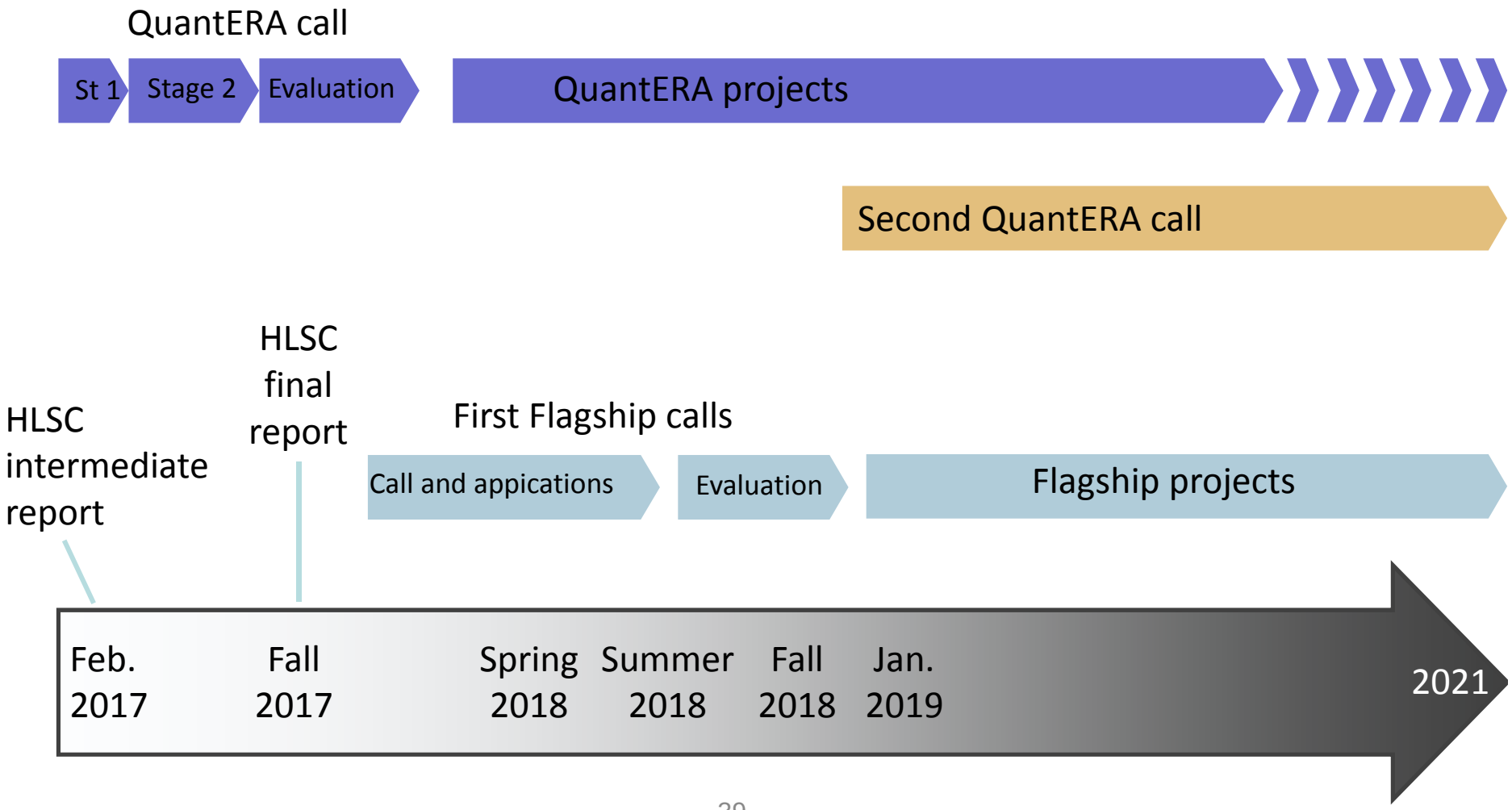
• For areas a. to d., proposals should be based on a **close cooperation between academia and industry**

• The Commission considers that proposals for Research and Innovation Actions requesting a contribution from the EU **up to EUR 10 million would allow the areas a. to d.** to be addressed appropriately;

• proposals requesting a contribution from the EU between **EUR 2 and 3 million would allow the area e.** to be addressed appropriately.

# Timeline : 1st Flagship Call

## Opening : 31 Oct 2017, Deadline : 20 Feb 2018



# Quantum Computing milestones

- **In 3 years**, fault tolerant routes will be demonstrated for making quantum processors with eventually more than 50 qubits
- **In 6 years**, quantum processor fitted with quantum error correction or robust qubits will be realized, outperforming physical qubits;
- **In 10 years**, quantum algorithms demonstrating quantum speed-up and outperforming classical computers will be operated.

Thank you for your attention