Review of Existing European Trainings

1. Introduction
2. Quantum Masters & PhDs
3. Quantum for Professionals
4. HR Perspectives

INTRODUCTION: OVERVIEW OF QUANTUM TRAINING COURSES

The importance of theory in France

- Students in France must study at least 3 to 4 years until they can study quantum physics
- Postgraduate students have an in-depth understanding

An experimental approach is much more common in English-speaking countries

The key role of laboratories

Laboratories physically next to the universities influence very much the courses taught

15: this is the most common average number of students per year group in French and Swiss universities

HR point of view

- When recruiting an engineer, you may not need to recruit a postgraduate who has studied quantum
- To be specialized in HPC, cryptography, chemistry, finance… may suffice to be a good fit for the job

In the UK, Netherlands and in the US the approach is different

Few students

FOCUS ON QUANTEDU FRANCE

QuanTEdu France is a skills and professions project, part of the France 2030 investment program

AMBITIONS

Develop quantum education in universities and grandes écoles

Create 16 000 employees directly and indirectly in quantum

21 universities are partners as well as industrial firms and innovation stakeholders

STAKES

1. **Raising students' awareness** of quantum-related technologies and professions
2. **Increase interest** among young people and the general public through public events (popularization)
3. **Training** students in quantum professions and technologies
4. **Strengthen expertise** through professional training and its expansion
5. **Awarded** the innovation prize at the CMA awards in December 2023

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QUANTUM FUNDAMENTAL PHYSICS ARE THE MOST COMMON TRAINING COURSES

Quantum fundamental physics refer to optics, nanophysics… Many a student will choose such training courses, as it give the possibility to specialize afterwards in PhD for instance

Content of quantum fundamental physics training courses

- Quantum **Mechanics**: Core principles like wave-particle duality and Schrödinger equation
- Quantum **Field Theory**: Basics of quantized fields and particle interactions
- Quantum **Information**: Qubits, entanglement, and quantum computing basics
- Quantum **Optics**: Light-matter interaction and photon statistics.
- Condensed **Matter**: Quantum solids, band theory, and superconductivity

Several European universities offer quantum fundamental physics training courses

UGA Université Grenoble Alpes

Humboldt-Universität zu Berlin

University of Cambridge

École Polytechnique – IP Paris

UCC Coláiste na hOllscoile Corcaigh University College Cork, Ireland

Université Côte d'Azur

Unité de formation Physique – université de Bordeaux

University of Oxford

CentraleSupélec

Research is the most usual offering

- Most postgraduate students choose to pursue their studies and do a PhD
- Such students may well have a leading role as physicist in a startup or in a leading firm
- To be more specific, experimental scientists, engineers, theorists, application researchers is the decreasing order in size of jobs occupied by students after a quantum physics education

Focus on one training course

- **Lille** offers some very classical quantum physics courses:
  - Advanced training in lasers, photonics, complex, and quantum systems
  - Two tracks: **Research** (Complex & Quantum Systems) and **Optics** (Lasers & Photonics)
  - Internships in research labs or photonics companies, leveraging expertise from PhLAM research teams

ICFP Master (ENS, X, Sorbonne, université de Paris/Saclay) is one of the most prestigious educational establishment

The ICFP Master is a prestigious program aimed at top-tier French and international students, offering comprehensive training in both theoretical and experimental fundamental physics

Program objective

Program structure

- Year 1 (M1):
  - 1st semester: coursework
  - 2nd semester: research internship in France or abroad
- Year 2 (M2):
  - 1st semester: coursework
  - 2nd semester: short research internship and optional courses

Key features

- **Broad Spectrum**: Covers a wide range of fundamental physics topics, from high-energy physics to condensed matter and astrophysics
- **Research Integration**: Strong emphasis on research, with internships and close collaboration with leading laboratories.

Professional network

Thanks to world-renowned researchers and a vide community of international students, postgraduates and PhDs can build a strong professional network both in public and private sectors

SCIENCES SORBONNE UNIVERSITÉ

université PARIS-SACLAY

Université Paris Cité

ENS

QUANTUM TECHNOLOGIES AND ENGINEERING EDUCATION

Many educational establishments offer quantum technologies masters, which are the most practical courses students may expect to experiment quantum engineering

Key points to bear in mind

Content

- **Quantum Computing and Algorithms**: study of quantum algorithms (e.g., Shor's and Grover's algorithms), quantum error correction, and quantum information theory.
- **Quantum Hardware**: design and operation of quantum systems, including qubits, quantum gates, and quantum sensors.
- **Advanced Laboratory Work**: hands-on training in quantum experiments, device fabrication, and the practical application of quantum technologies.

Relevant universities

- Bordeaux
- Bourgogne / Aarhus and Kaiserslautern universities
- Rhône Alpes University
- PSL Quantum engineering
- ETH
- EPITA

Job openings

- Engineer
- Experimental researcher
- Technicians

EPITA HAS BUILT AN ORIGINAL ENGINEERING QUANTUM MASTER

1. The educational input of French Startups

- French startups teach at EPITA and educate thereby their future employees: students know very well the architecture of Alice & Bob, Pasqal and Quandela at the end of their master
- This hands-on education make these students ready to work
- Visits are organized to experiment the environment of such startups

2. Close connection with leading firms

- EPITA has close ties with firms like:
  - EDF
  - Microsoft
  - IBM
  - Thales
  - French startups

3. The emphasis is put on computing and cryptography

- Courses on computing and software: mastering quantum computer architectures, software development and quantum algorithm, hybrid HPC/QPU environments
- Trainings on Post-quantum cryptography, quantum cryptography, quantum communication, quantum sensors

QUANTUM INFORMATION AND COMMUNICATION

Educational Content

- **Quantum Circuits and Algorithms:** Basics of quantum circuits, logic gates, and quantum algorithms.
- **Quantum Cryptography:** Advanced techniques in quantum key distribution and other quantum cryptographic protocols.
- **Quantum Information Theory:** Study of quantum entanglement, communication, and complexity theories.

Quant. Information masters

As the main topics taught are somewhat narrow and specic, just a **few universities** offer quantum information and cryptography masters:

SCIENCES SORBONNE UNIVERSITÉ

TELECOM Paris

IP PARIS

UNIVERSITY OF OXFORD

universität wien

TU Delft
Delft University of Technology

EPFL

Focus on TU Delft Master

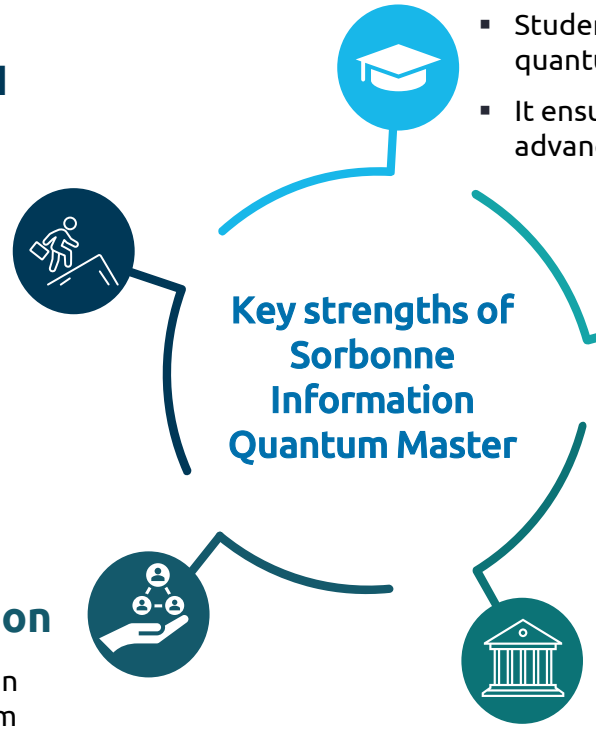
- The program allows specialization in quantum computing, communication, or sensing.
- It also offers access to advanced facilities, including cleanrooms and high-performance computing labs.
- Emphasizing both technical and soft skills, the curriculum includes training in the societal and ethical implications of quantum technology, preparing graduates for leadership roles in the field.

FOCUS ON SORBONNE

The Sorbonne Master's in Quantum Information excels in combining cutting-edge research with practical application, offering top-tier courses and strong industry connections for outstanding career prospects in quantum technologies

GLOBAL APPROACH

The program blends insights from computer science, physics, and mathematics, offering a holistic understanding of quantum information science



CUTTING-EDGE CURRICULUM

- Students are exposed to the **latest developments** in quantum algorithms, cryptography, and computing
- It ensures that they are at the forefront of technological advancements

RESEARCH-ORIENTED PROJECTS

- Emphasis on collaborative projects and **hands-on experimentation** allows students to apply theoretical knowledge to real-world quantum problems
- These projects prepare students for a possible PhD

International Reputation

With instruction in English and a curriculum designed for an international audience, the program attracts students from around the world. This diversity enriches classroom discussions and fosters **global perspectives on quantum technologies**

EXPERT FACULTY

Courses are taught by **leading researchers** from renowned institutions like **LIP6, LKB, and INRIA**, providing students with valuable academic and professional networks.

INTERDISCIPLINARY QUANTUM EDUCATION

Interdisciplinary quantum education gives a comprehensive approach to quantum technologies and namely attract chemistry students

Comprehensive Curriculum

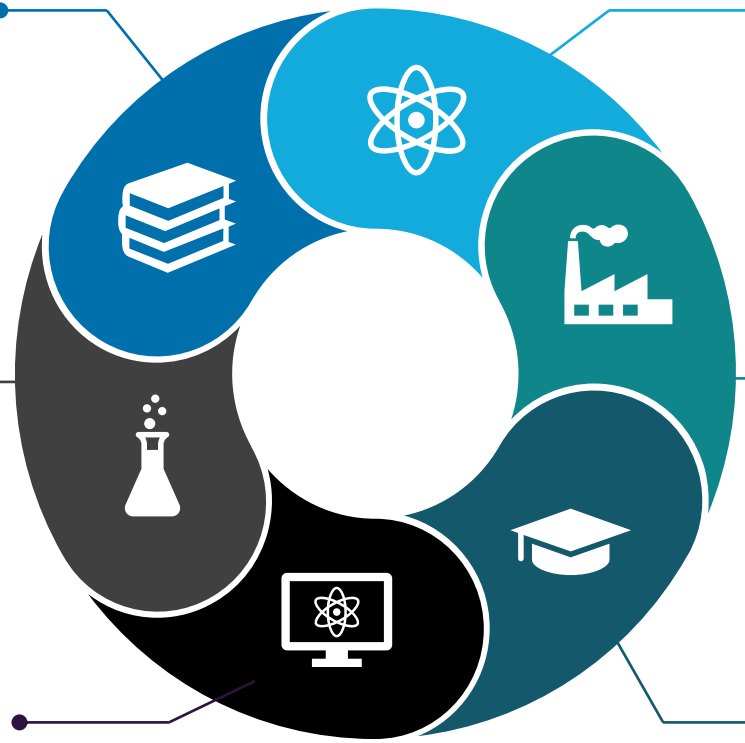
The program offers an integrated approach covering physics, chemistry, mathematics, and engineering to provide a broad understanding of quantum technologies

Specialization Options

The flexibility to choose between experimental and theoretical tracks allows students to tailor their studies to specific interests and career goals

Access to Advanced Facilities

State-of-the-art laboratories and equipment are available, supporting both experimental and computational aspects of quantum research



Research Integration

Students engage in research from early on, gaining practical experience and insights into advanced quantum science

Industry Connections

Strong ties with industry partners facilitate internships and real-world experience, enhancing career readiness in quantum technology fields

Focus on ARTEQ

ARTEQ offers the opportunity to students after the M1 to discover quantum through both a theoretical and a hands-on approach (internship). Quantum physics, computer science, information hardware, neuromorphic engineering & quantum machine learning, quantum matter are taught

THE BAVARIAN UNIVERSITIES LMU AND TUM PROVIDE ONE OF THE MOST PRESTIGIOUS QUANTUM MASTER

The Master's Degree Program in Quantum Science and Technology, jointly offered by Technical University of Munich (TUM) and Ludwig-Maximilians-University Munich (LMU), provides an interdisciplinary and research-oriented education in quantum technologies.

Flexibility	Students can tailor their studies by specializing in either Experimental or Theoretical Quantum Science & Technology, aligning their education with their career goals in research or industry	Dual University Advantage provides access to a diverse array of classes, research opportunities, and academic resources across two leading institutions	**TUM/LMU**
World-Class Research	The Munich Center for Quantum Science and Technology (MCQST) enables student to gain exposure to innovative quantum technologies	Ferenc Krausz has generated and measured the first attosecond light pulse and used it for capturing electrons' motion inside atoms, marking the birth of attophysics	**2023 Nobel Prize**
Quantum Applications	The curriculum is designed to translate quantum theory into practical technologies, such as quantum computing, quantum sensing, and quantum cryptography	The quantum ecosystem in Munich gathers several laboratories (Max Planck) and industries involved in quantum	**Hub**

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Technical University of Munich

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QUANTUM FOR PROFESSIONALS

TRAININGS FOR ENGINEERING

- **Fundamentals of Quantum Information**: Understand the basics of quantum computing and its abstract principles.
- **Quantum Internet & Quantum Computers**: Explore potential global impacts of quantum technology.
- **The Hardware of a Quantum Computer**: Learn about quantum computer components and operations.
- **Architecture, Algorithms, and Protocols**: Study the layers and algorithms of quantum systems.
- **Machine Learning for Semiconductor Quantum Devices**: Discover AI applications in quantum chip control.

CERN

Since 2020, **CERN** Openlab and the CERN Quantum Technology Initiative offered free, open lectures on quantum computing. CERN utilizes quantum simulators and real quantum computers, such as IBM Quantum Experience and D-Wave Leap.

- The course introduces basic quantum computing concepts and practical implementation of algorithms.
- Topics include:
- Quantum key distribution
- Quantum teleportation and superdense coding
- Quantum algorithms for combinatorial optimization
- Quantum variational algorithms and quantum machine learning

QURECA'S TRAININGS

Support for Businesses and Educational Partners: Provides resources to understand and expand knowledge in quantum technologies

Online Training: Offers CPD-certified courses globally for developing quantum technology skills

Qureka! Box: A tool designed to introduce quantum computing to high school students, undergraduates, professionals, and enthusiasts

Custom Training: Develops tailored training programs in collaboration with experts to prepare businesses for the quantum era

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QUANTUM FIRMS WILL DIVERSIFY THEIR RECRUITMENTS TO MEET THEIR NEEDS

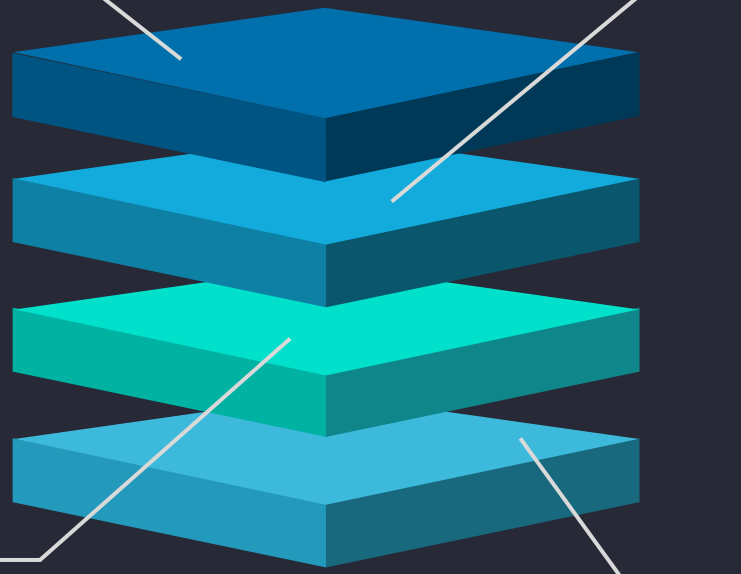
Against the background of a higher hardware maturity the demand in software engineers is bound to increase in the next years

THEORISTS AND RESEARCHERS

They have a leading role to ensure the reputation of the firm on both national and international scopes

TECHNICIANS

They have the experience to make hardware operational



SOFTWARE ENGINEERS

These engineers will become more and more needed, as the maturity of hardware becomes mature

RECRUITING HARDWARE ENGINEERS (ELECTRICAL, MECHANICS, OPTICS)

It fosters the performance of the machines

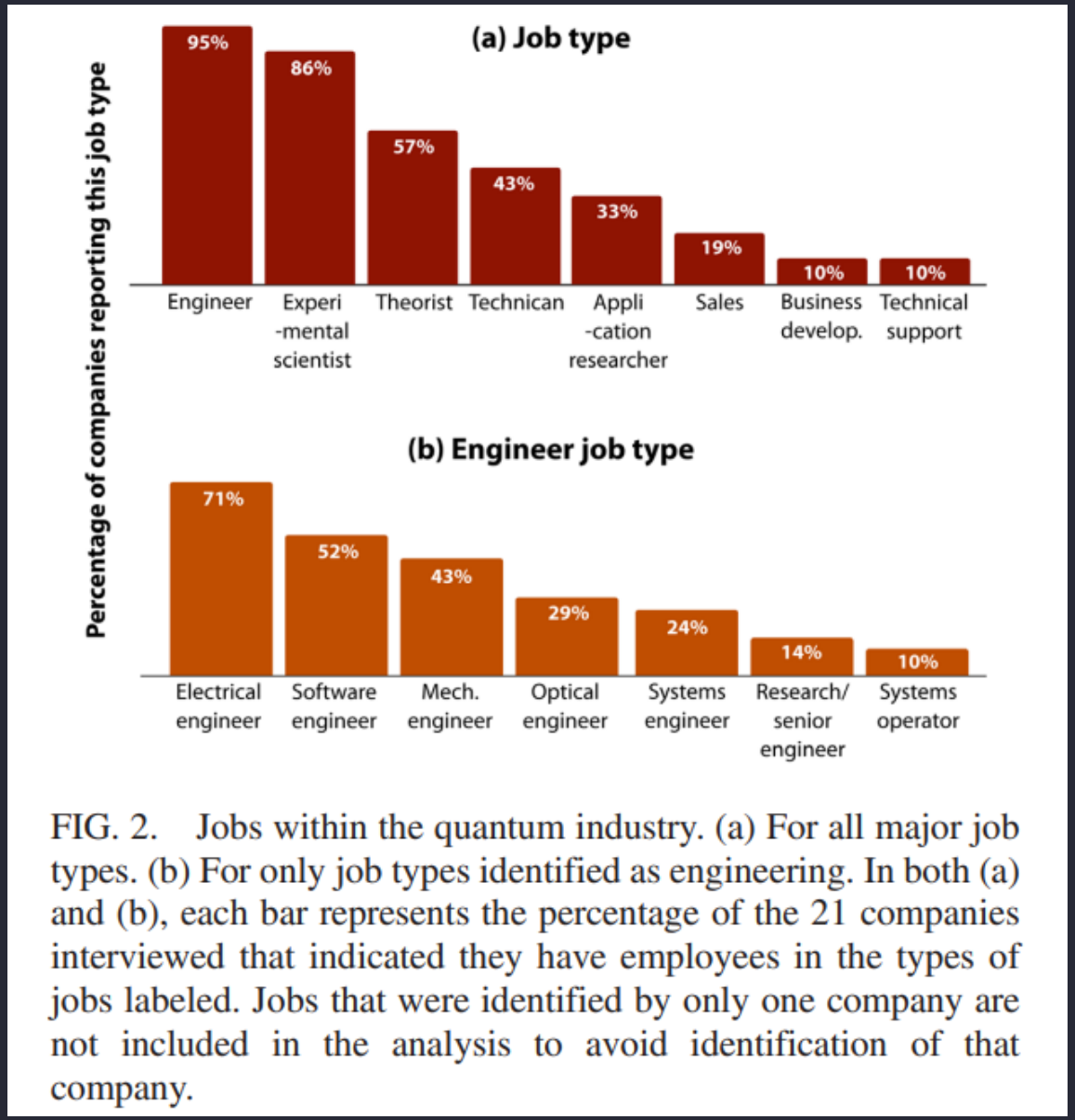


FIG. 2. Jobs within the quantum industry. (a) For all major job types. (b) For only job types identified as engineering. In both (a) and (b), each bar represents the percentage of the 21 companies interviewed that indicated they have employees in the types of jobs labeled. Jobs that were identified by only one company are not included in the analysis to avoid identification of that company.

Preparing for the quantum revolution: What is the role of higher education?

Michael F. J. Fox, Benjamin M. Zwickl, and H. J. Lewandowski

2020

FURTHERMORE, FIRMS NEED TO BETTER UNDERSTAND THE UPCOMING MARKET NEEDS

As the use cases are very diverse, firms are bound to engage experts from diverse sectors

Future market needs

#finance

#logistics

#chemistry

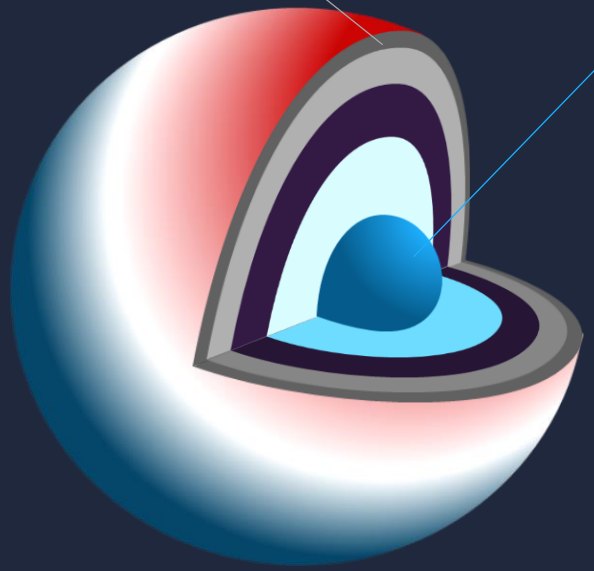
#military

Impact on application development

Slight increase in consulting / business

Increased diversity of the software engineers

Prioritizing by value



Quantum specialists

#Theorists

#Electrical engineers

#Software engineers

Impact on the firm

Lead the research and innovation development

Knowledge-management

Reputation and influence of the firm

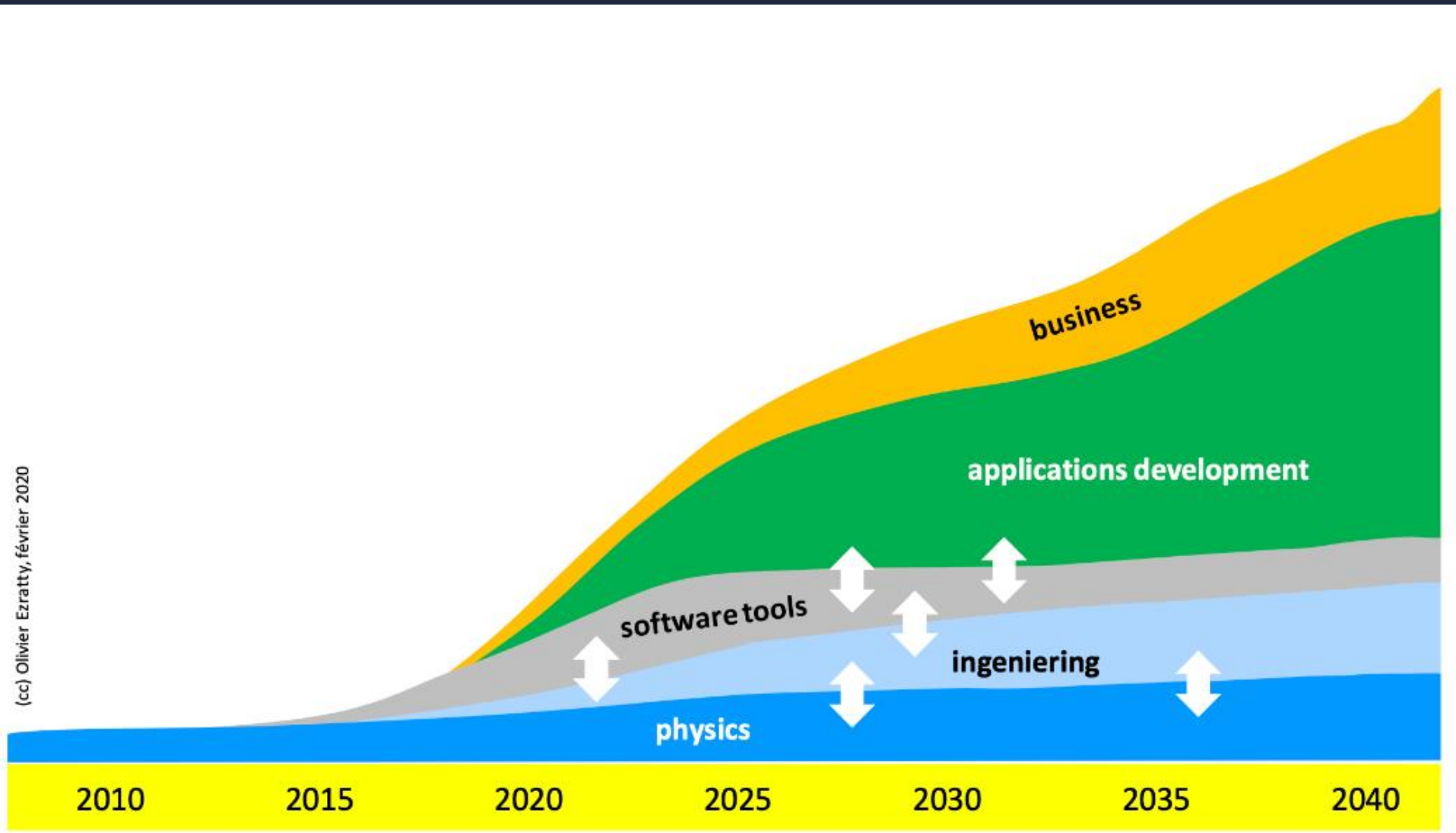


Figure 967: how quantum tech skills need will evolve over time. More engineering and then more software and more business skills. (cc) Olivier Ezratty, 2020.

DON’T MISS OUT OUR QUANTUM JOB FAIR ON DECEMBER 11TH

Registrations are open!

Siméon Valdman
simeon@lelabquantique.com

le lab quantique