Quantum Technology Initiative

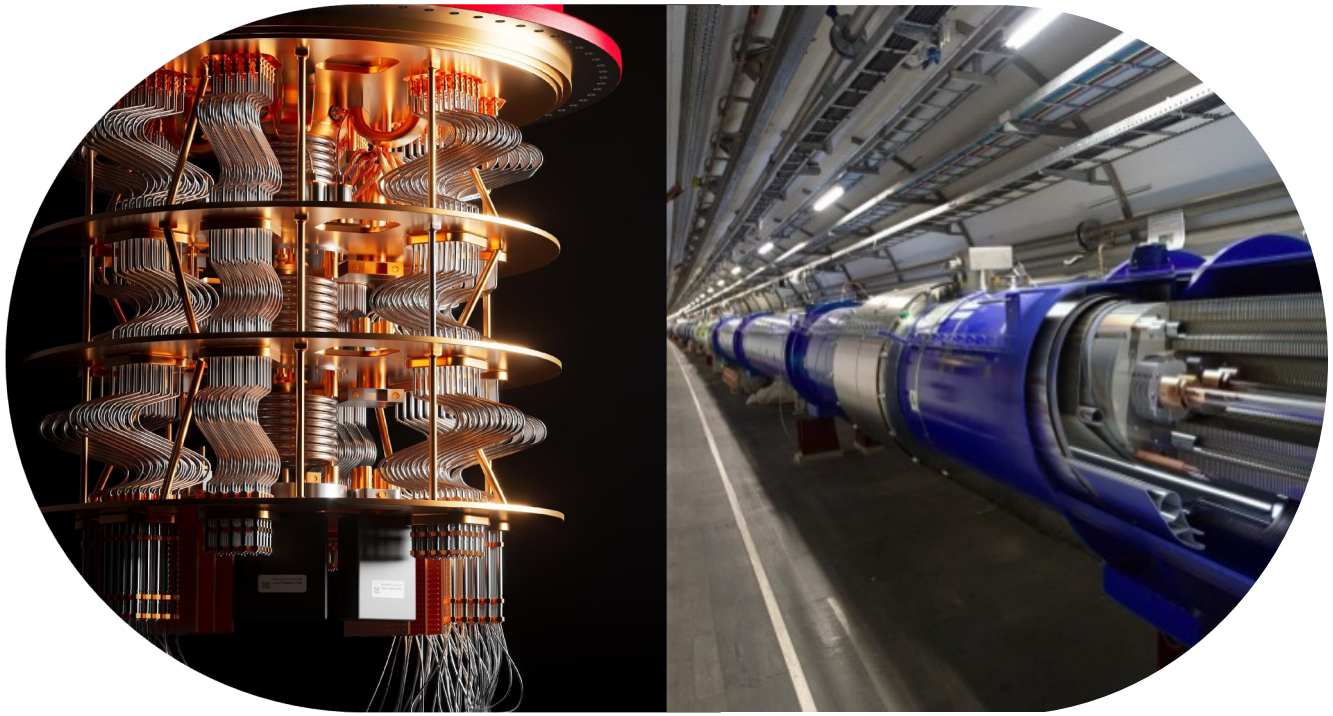
Phase 2

Planning the start of the activities

Michele Grossi, Sofia Vallecorsa

CERN | QUANTUM TECHNOLOGY INITIATIVE

How does CERN engage in Quantum Technologies?



QT4HEP

Develop technologies required by the CERN scientific programme

Integrate CERN to future quantum infrastructures

HEP4QT

Extend and share technologies available at CERN

Boost development and adoption of QT beyond CERN

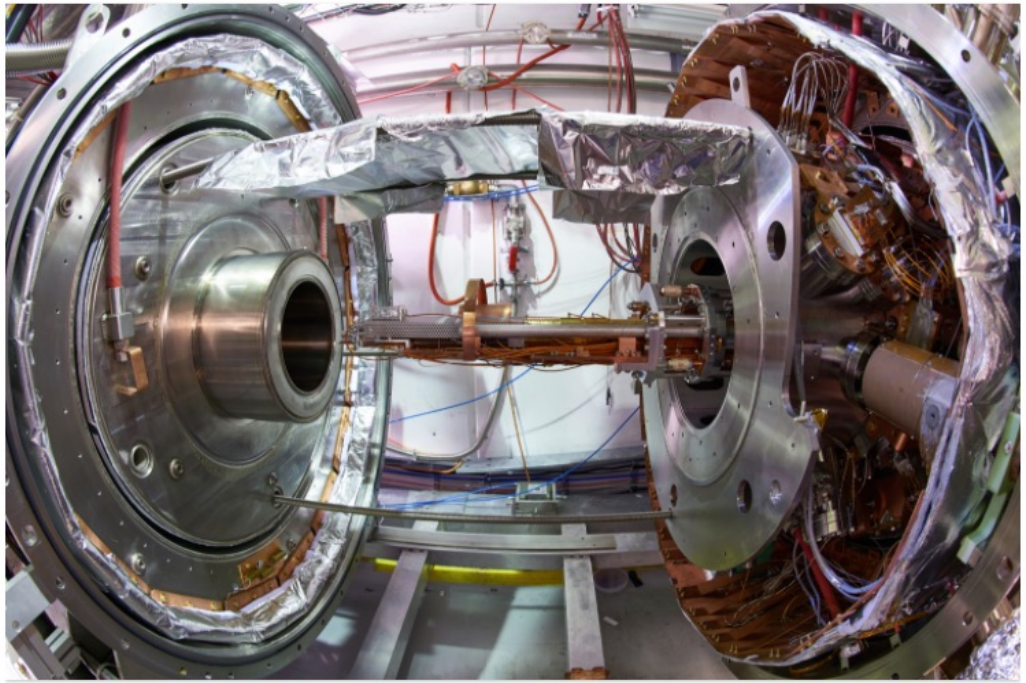
The CERN QTI launched in 2020

Voir en français

CERN meets quantum technology

The CERN Quantum Technology Initiative will explore the potential of devices harnessing perplexing quantum phenomena such as entanglement to enrich and expand its challenging research programme

30 SEPTEMBER, 2020 | By Matthew Chalmers



The AEgIS 1T antimatter trap stack. CERN's AEgIS experiment is able to explore the multi-particle entangled nature of photons from positronium annihilation, and is one of several examples of existing CERN research with relevance to quantum technologies. (Image: CERN)

Main objectives

- Identify areas where CERN can make an impact
- Understand impact of quantum technology on CERN programme
- Collaborate with quantum initiatives in the CERN Member States
- Facilitate the collaboration across the HEP community and between HEP and the QuantuM tech. community

QTI Roadmap: https://doi.org/10.5281/zenodo.5553774

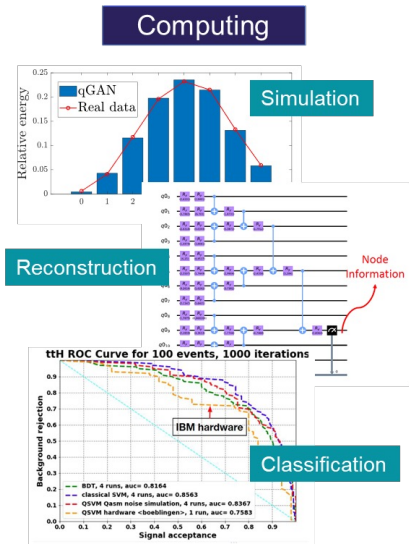
An exploratory initiative

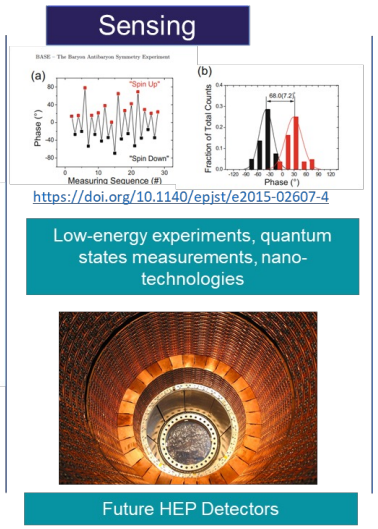
Quantum simulation and HEP theory applications

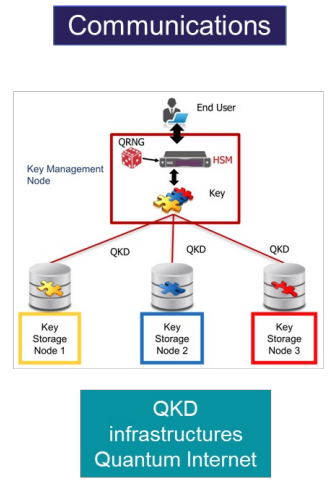
Quantum Computing

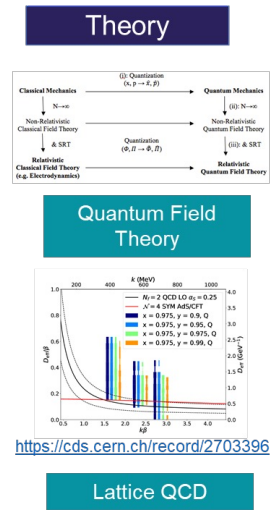
Quantum Sensing

Quantum Communication



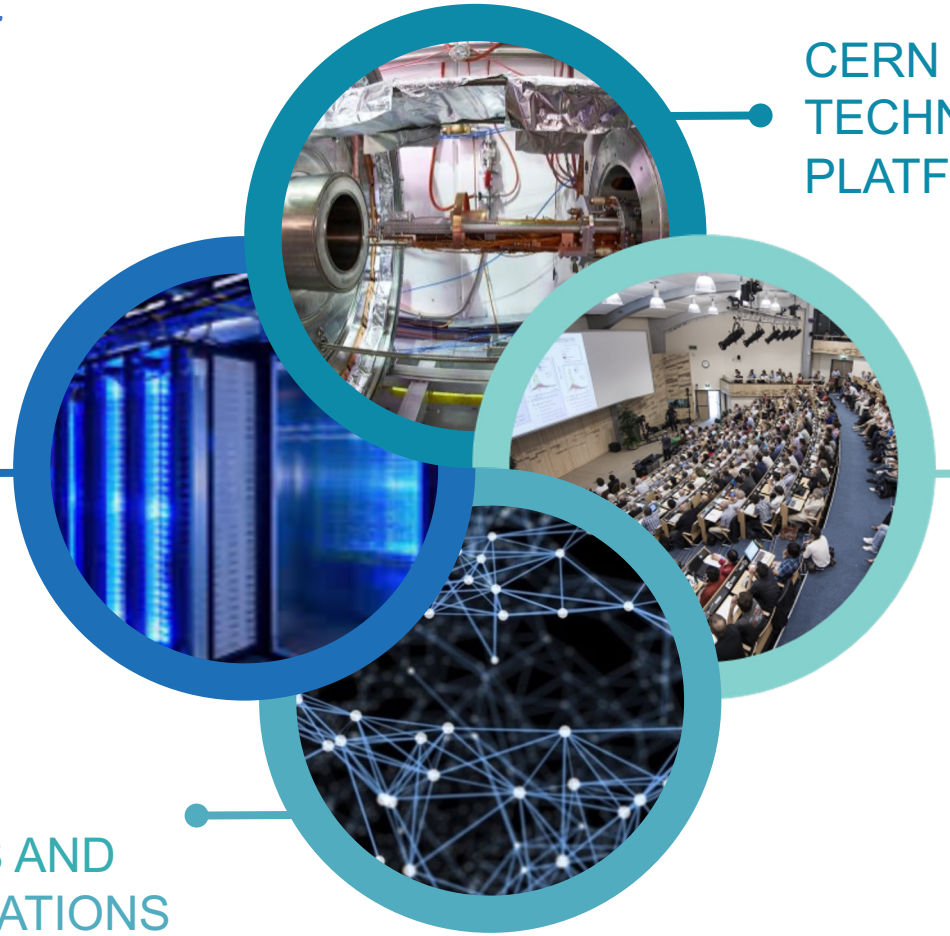






CERN QTI Phase 2

Launched January 2024



CERN QUANTUM TECHNOLOGY PLATFORMS

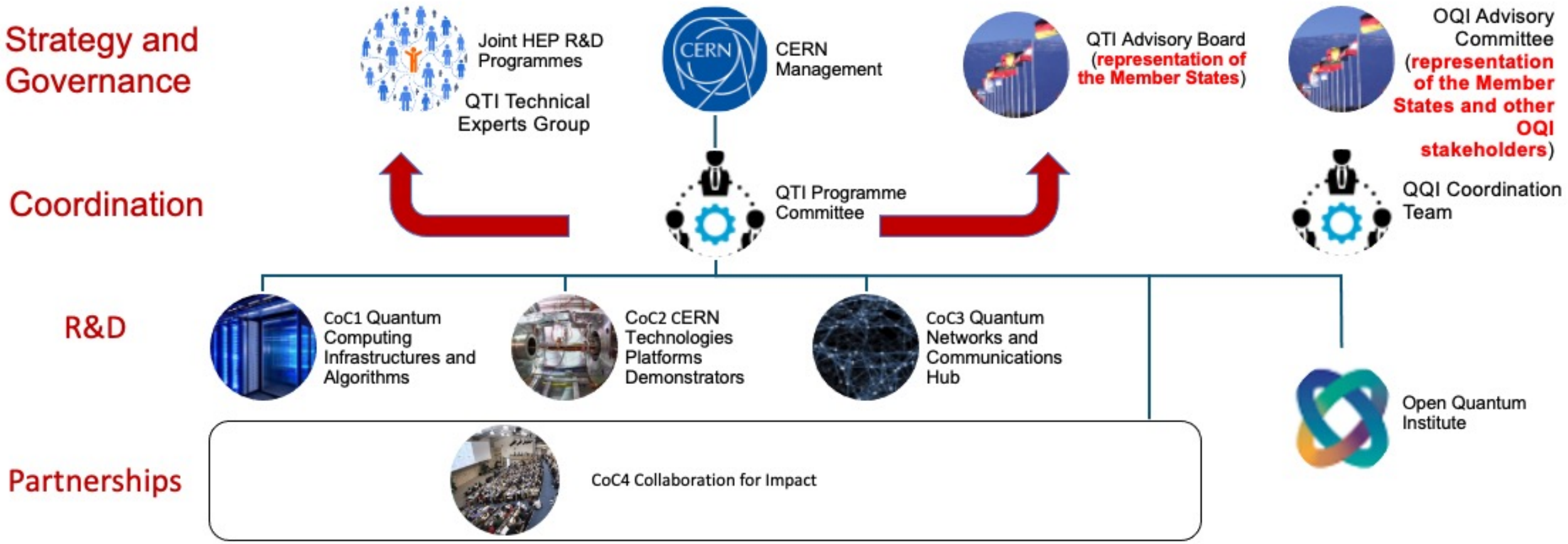
HYBRID QUANTUM COMPUTING AND ALGORITHMS

COLLABORATION FOR IMPACT

QUANTUM NETWORKS AND COMMUNICATIONS

CERN | QUANTUM TECHNOLOGY INITIATIVE

A 5 years research plan


Strategy and Governance
Joint HEP R&D Programmes
QTI Technical Experts Group
CERN
CERN Management
QTI Advisory Board (representation of the Member States)
OQI Advisory Committee (representation of the Member States and other OQI stakeholders)
Coordination
QTI Programme Committee
QQI Coordination Team
R&D
CoC1 Quantum Computing Infrastructures and Algorithms
CoC2 cERN Technologies Platforms Demonstrators
CoC3 Quantum Networks and Communications Hub
Open Quantum Institute
Partnerships
CoC4 Collaboration for Impact

Research Program in IT

With BE and some contribution by TH

COC1: HYBRID QUANTUM COMPUTING AND ALGORITHMS

Prioritisation and expected impact	Objectives
Core objectives required for QTI 2 to be of impact	• **Objective 1.1a**: Simulation of high dimensional classical or quantum system on hybrid infrastructures • **Objective 1.2a**: Theoretical foundation of quantum machine learning algorithms • **Objective 1.2b**: Quantum algorithms for theory applications • **Objective 1.2c**: Quantum advantage modelling
Objectives that extend the reach and impact of the core	• **Objective 1.3**: Software development for control and calibration of qubits systems
Longer-term objectives that require additional resources	• **Objective 1.1b**: Distributed quantum quantum internet development • **Objective 1.2c**: Resource optimisation and green computing

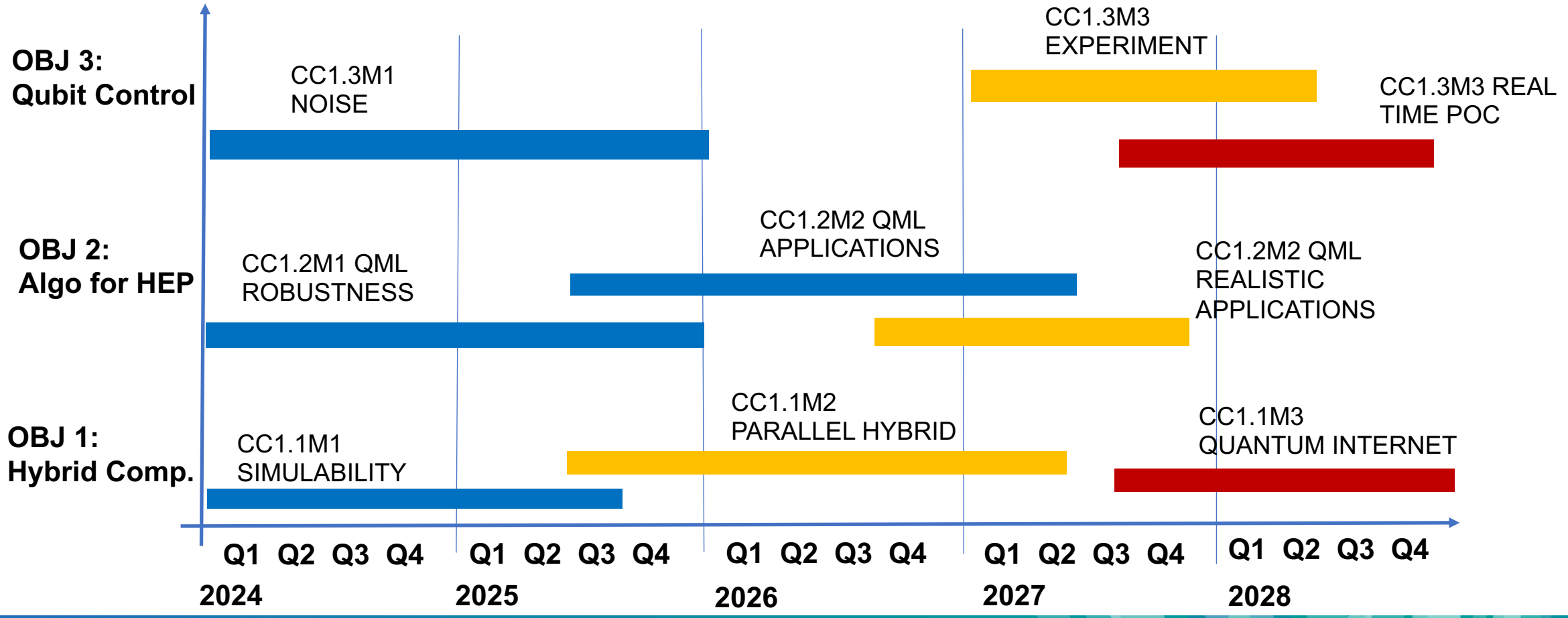
Table 2: Centre of Competence 1 High-Level Objectives and Priorities

COC3: QUANTUM NETWORKS AND COMMUNICATION

Prioritisation and expected impact	Objectives
Core objectives required for QTI 2 to be of impact	• **Objective 31a**: Setup of time, frequency and QKD infrastructure using White Rabbit • **Objective 3.1b**: Network interconnections with European partners for quantum communication and time dissemination • **Objective 3.2a**: deployment of time and frequency distribution service
Objectives that extend the reach and impact of the core	• **Obejective 3.1c:** contribute to the standardisation of quantum communication protocols • **Objective 3.1d**: stretching the reach of quantum entanglement over longer distances • **Objective 3.1e:** demonstrate feasibility of reliable quantum entanglement communication together with traditional optical network communications over Internet communication fibres • **Objective 3.2c:** time and frequency synchronisation with national time services of neighbouring countries
Longer-term objectives that require additional resources	• **Objective 3.1f**: experiments with quantum repeaters

Table 13: Centre of Competence 3 High-Level Objectives

CoC1: MILESTONES TIMELINE



Simulation of high dimensional classical or quantum system on hybrid infrastructures 1.1a

Milestone	Topic
	Entanglement Forging
1.1M1	Simulability/stabilizer state
	Tensor Networks
1.1M2	Hybrid QML – classic preprocess (HPC)
1.1M3	quantum internet

Theoretical foundation of quantum machine learning algorithms 1.2 a

Milestone	Topic
1.2M2 QML applications	Generative model universality + HEP applic
1.3M1 Noise	Barren Plateau vs Noise
	Physics and Symmetry (non-Hermitian)
1.2M1 QML robustness	Trainability and generalization QML
	Topological Data (hep)
1.2M3 QML HEP application on HW	

Quantum algorithms for theory applications 1.2 b

Milestone	Topic
1.2M2 QML applications	Event generation (QML - HEP)
	Anomaly detection (NF)
	Feynman diagram
	Quantum HEP tool (Pythia etc)

Quantum advantage modelling 1.2 c

Milestone	Task
Quantum advantage modelling	Performance across multiple Q HW
	Noise vs Symmetry
	Geometric ML and application (i.e. tracking)
Quantum advantage modelling	Resource optimization – green computing

Software development for control and calibration of qubits systems 1.3

Milestone	Task
1.3M1 Noise on real HW	Validation of selected noise models on real hardware
1.3M2	Initial verification of theoretical results using the experimental infrastructure foreseen in CC2
1.3M3	Initial prototype demonstrating real time processing pipeline