



DE LA RECHERCHE À L'INDUSTRIE

High Performance Computing and Quantum Computing 2021 Fourth Edition

CINECA Workshop – 15 December 2021



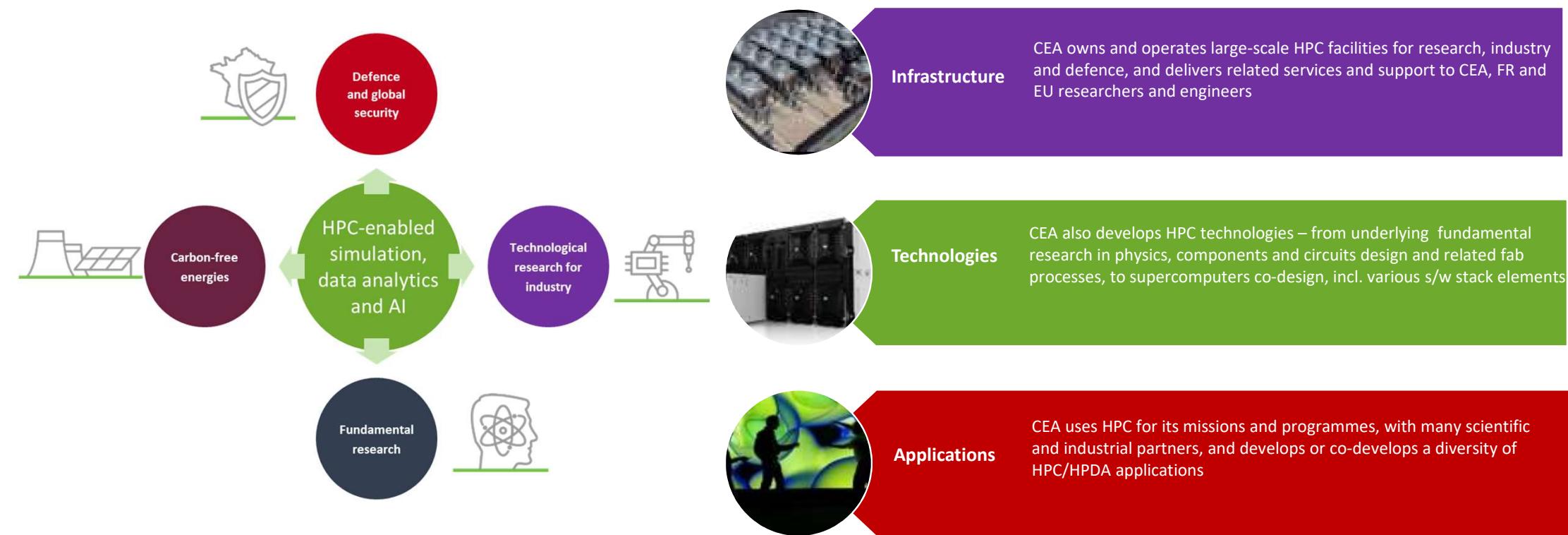
Quantum Computing and HPC perspective at CEA

Dr. Ing. Jean-Philippe Nominé

Dr. Ing. Guillaume Colin de Verdière

CEA: large RTO - 4 strategic axes – HPC player all along the value chain

<http://www-hpc.cea.fr/index-en.htm>



From Research to Industry – For Research and Industry

Quantum research for Quantum Computing at CEA – Main teams

► CEA/DRF – Fundamental Research Directorate

- **Iramis Institute: Quantronics Group (Pr. Daniel Estève)**
[Quantronics Group | Research Group in Quantum Electronics, CEA-Saclay, France](#)
<https://iramis.cea.fr/spec/Pres/Quantro/static/index.html>
- **IPhT Institute: Quantum Information Group (Nicolas Sangouard)**
[Research – Quantum Information Theory | IPhT](#)
<https://quantum.paris/research/>



PHYSICAL REVIEW LETTERS

Highlights Recent Accepted Collections Authors Referees Search Press About S

Featured in Physics Editors' Suggestion

Factoring 2048-bit RSA Integers in 177 Days with 13 436 Qubits and a Multimode Memory

Élie Gouzien and Nicolas Sangouard
Phys. Rev. Lett. **127**, 140503 – Published 28 September 2021

https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.127.140503

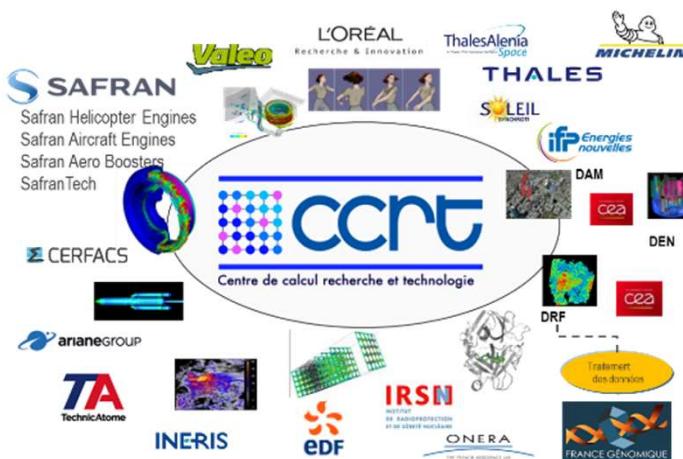
► CEA/DRT/LETI – Technological Research Directorate

- CMOS qubits : Silicon-based Quantum Computing - Maud Vinet Leti (CEA), IRIG Institute (CEA/U. Grenoble), Institut Néel (CNRS)
- QLSI Quantum Flagship project, QuCube ERC Synergy Grant
<http://h2020-qlsi.eu/>
- [CEA-Leti Details Silicon-based Quantum Computing Roadmap - EE Times Europe](#)
<https://www.eetimes.eu/cea-leti-details-silicon-based-quantum-computing-roadmap/>
- [The Knowledge Factory - Cryo-CMOS electronics for quantum applications \(cea.fr\)](#)
<https://www.cea.fr/drft/english/Pages/News/Scientific-results/2021/cryo-cmos-electronics-for-quantum-applications.aspx>



HPC infrastructures at CEA

- ▶ We co-design and operate large HPC infrastructures and systems
Incl. operations of GENCI's Joliot-Curie tier0 system
- ▶ CCRT is another component oriented towards industrial uses
Computing Centre for Research and Technology is cofunded by industrial partners
Specific access/data management for industrial confidentiality
Exploiting a 31 qbits ATOS QML since 2018
(early use case exploration by industrial partners)



CEA in figures (2019)

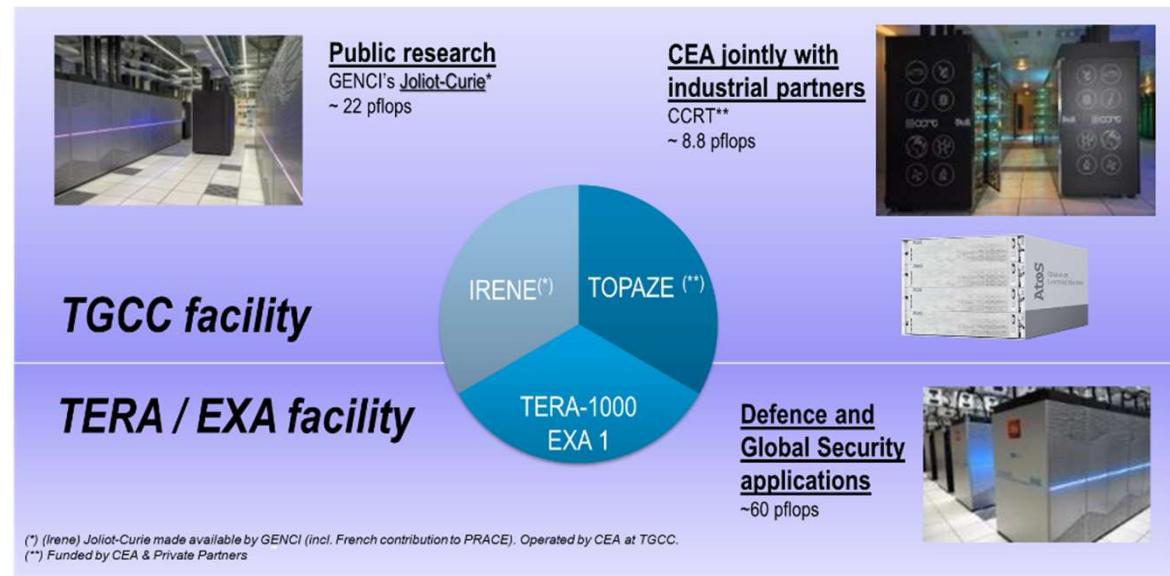
- ▶ 9 research centres
- ▶ 20 181 employees
- ▶ 39 joint research units (JMR)
- ▶ 670 priority patents filed in 2019
- ▶ 216 start-ups since 1972
- ▶ 5 billion euros budget



CEA supercomputing Complex

Bruyères-le-Châtel
Near Paris

TERA/EXA, TGCC
facilities





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CEA Supercomputing Complex HPC+QC Standpoint

Commissariat à l'énergie atomique et aux énergies alternatives - www.cea.fr

French National Quantum Plan => PNCQH

- Global plan announcement in January 2021
- Incl. Quantum computing
 - PNCQH Hybrid Quantum Computing Platform



Les Echos

La France va consacrer 1,8 milliard d'euros aux technologies quantiques

Le montant promis par Emmanuel Macron dépasse les attentes du secteur mais reste inférieur aux moyens chinois et américains. Avec ses plateformes de renom, ses industriels et ses start-up, la France a des atouts - mais aussi des faiblesses - pour la construction d'un écosystème quantique de classe mondiale.

A screenshot of a news article from the website of the newspaper "Les Echos". The headline is "La France va consacrer 1,8 milliard d'euros aux technologies quantiques". Below the headline is a short text summary. At the bottom of the screenshot, there is a small image showing two people working in a laboratory or industrial setting, surrounded by complex equipment.

PNCQH Hybrid Quantum Computing Platform

- Develop usage of collaborative quantum/HPC computing
- Offer a testbed for research + a full environment for end-users
- Hybrid (HPC/Q) agnostic platform @ TGCC based on
 - Quantum Emulator (Atos QLM)
 - Multiple QPUs (Pasqal + other FR/EU technologies...)
 - TGCC- GENCI supercomputers
 - An agnostic software ecosystem
- 4 axes
 - Acquisition of QPUs
 - Research (academic & industrial) to develop a full software for the platform
 - Develop hybrid use cases
 - Dissemination, training, setup of competence centres
- A 5 year programme (88 M€) – starting end of 2021
 - Led by CEA Inria Genci, with CNRS, Atos, OVH, French Universities ...
 - Coordinated with EuroHPC HPCQS project (started Dec. 1, 2021)
 - First step of PNCQH is the French contribution to HPCQS



CEA POC : Jacques-Charles Lafoucrière, HPC Programme Director at CEA

Région Île de France

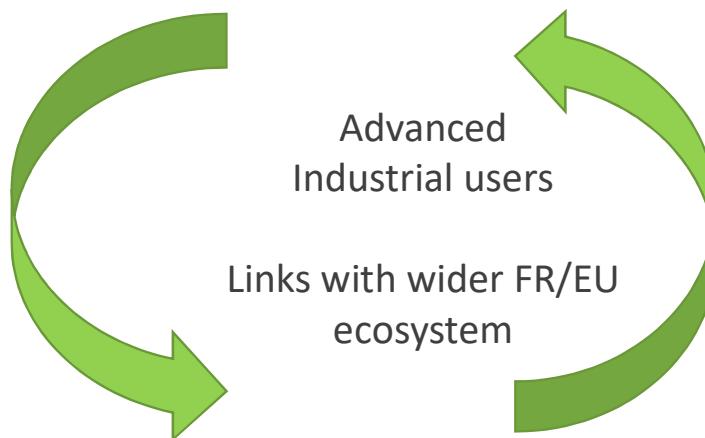
le lab quantique

GENCI Le calcul intensif au service de la connaissance

PAck Quantique (PAQ)

Support industries to assess quantum computing on real use cases thanks to french academic consortia and Quantum startups

SIR TEQ, PCQC, quantum PARIS-SACLAY, PASQAL, QCWARE, THALES, Air Liquide, EDF, Qubit, TOTAL



Teratec Quantum Computing Initiative (TQCI)

Press release, June 2020

The aim of the TQCI (initiative) is to create a Center of Competence in Quantum Computing, "cementing" the ecosystem and bringing together future users, technology providers and research centers, in order to rapidly build up skills and develop know-how in the field of quantum computing.

Our initiative is based on three axis:

- ➔ Development of action-research in mathematical formulation, algorithms and numerical methods
- ➔ Realization of use cases and experimentation
- ➔ Training, information and community management

Following the presentation of the FORTEZA Report last January, the Government asked the four ministries concerned to draw up a Quantum Development Plan for France. This plan should give priority for France to gain capacity to design and build computers and accelerators using quantum technology on the national territory. Building on its key asset for co-design enabling industrial technology suppliers and future users to share the same project, TERATEC proposes that this Plan should simultaneously manage hardware and software developments and applications, while implementing its roadmap for TQCI.

As in 2019, TERATEC plans to organize two seminars in 2020, one devoted primarily to hardware developments and the second to Applications. This will be an opportunity for member partners to take ownership of the Government Plan and determine first concrete actions to be carried out as part of its application in the industrial world.

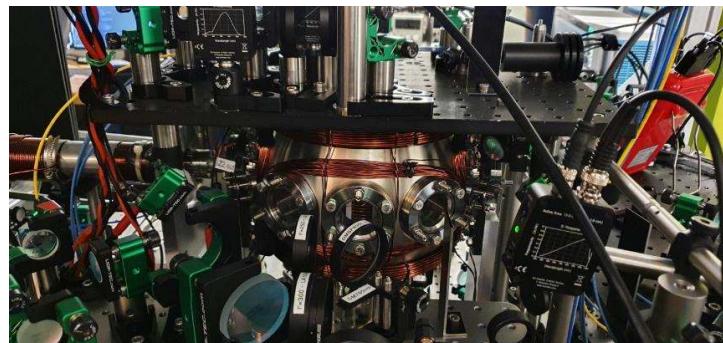
<https://www.lelabquantique.com/wp-content/uploads/2020/11/CP-PAQ-v2.0.pdf>

http://www.teratec.eu/actu/calcul/2020_06_TQCI_UK.pdf

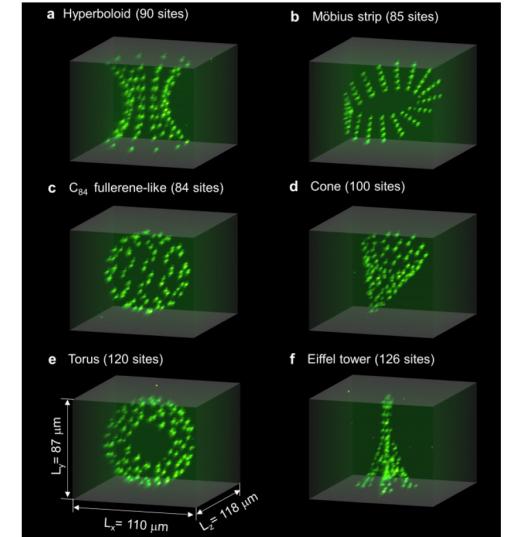
First technology of interest: the Pasqal machine

<https://pasqal.io>

- ▶ Quantum Simulation system (with possibility of implementing universal gates)
- ▶ Neutral Rydberg atoms, optically controlled



- Industrialisation/productisation on-going





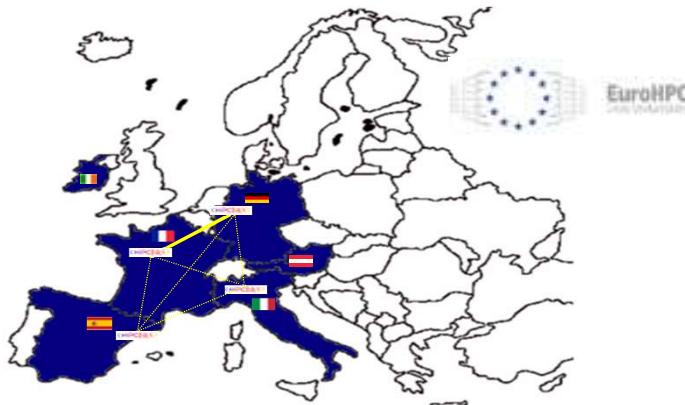
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CEA in HPCQS

Commissariat à l'énergie atomique et aux énergies alternatives - www.cea.fr

HPCQS

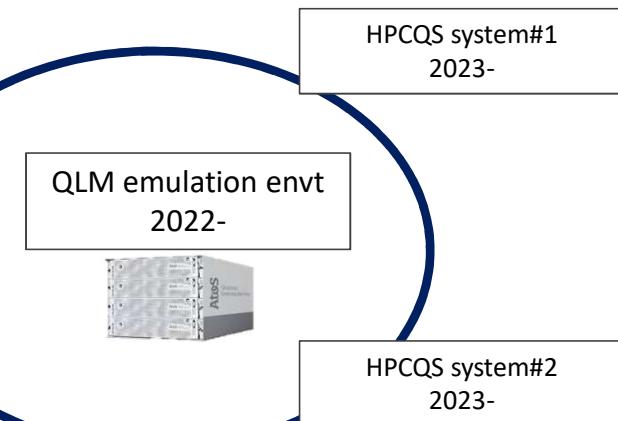


HPCQS brings together leading quantum and supercomputer experts from science and industry from six European countries.
Copyright : HPCQS

<HPC|QS>

**Foundations of a hybrid Quantum-HPC
European Infrastructure
2x100+ qubits**

Started Dec. 1, 2021 - Coord. FZJ/JSC K. Michielsen



- CEA/DSSI: integration, deployment of an emulation environment (QLM) then a quantum system at TGCC (Joliot-Curie Tier0)
- CEA/IPhT: benchmarks and applications



► General CEA coordination, technology watch

- Dr. Ing. G. Colin de Verdière
- Dr. Ing. J-Ph. Nominé

► Computing infrastructure related issues

- Frédéric Souques et al.

► Integration and System Admin Team

- Matthieu Hautreux et al.

► Operational Management Team

- Xavier Delaruelle et al.

► Coordination support

- Maike Gilliot

► Algorithms, benchmarks and applicatons

- Prof. N. Sangouard et al.

► CEA/DIF/DSSI

- Département des Sciences de la Simulation et de l'Information
Bruyères-le-Châtel
F-91297 Arpajon Cedex

► CEA/DRF/IPhT

- Institut de Physique Théorique - Orme des Merisiers
CEA/DRF/IPhT, CEA/Saclay
F-91191 Gif-sur-Yvette Cedex

- ▶ **UC1. Certification/Performance Analysis for Quantum Simulators will provide a set of tools to certify the quantum features and accurately evaluate the performance of QSSs.**
 - CEA and CNRS will develop witness-based, device independent and analog randomised benchmarking and performance analysis schemes
- ▶ **UC3. Quantum Approximate Optimisation Algorithm (QAOA) :**
 - CEA will study and demonstrate the application of QAOA for factorisation.
- ▶ **UC4. Variational Quantum Eigensolver (VQE) will leverage the VQE algorithm to target the following applications in chemistry, solving wave equation and phase-estimation quantum Eigensolver:**
 - CEA will work on designing catalysts relevant for nitrogen fixation
- ▶ **Beyond using the machines for the partners use cases, HPCQS intends to open resources to the European scientific and industrial communities as soon as possible**

TERATEC Forum Quantum Computing Workshop series

TERATEC 2018 Forum
Workshop 3 - Wednesday, June 20 from 9h00 to 12h30

QUANTUM REVOLUTION IS HERE

Chaired by Guillaume COLIN DE VERDIÈRE, CEA



Forum TERATEC 2020
Mardi 13 octobre - Ateliers techniques

Atelier 3 - de 16h00 à 17h30

Calcul quantique : Quoi de neuf chez les QuBits ?
Présenté par Philippe OLLIER, CNET TECHNOLOGIES ORGANIC

Premiers processeurs quantiques passant à l'échelle et leurs applications

Par Georges MELONCHON, CEA, Paris



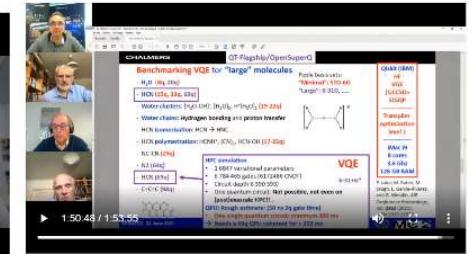
Forum Teratec 2021
Tuesday June 22 - Technical workshop

Europe is on its way towards "Hybrid Qomputing"



Forum Teratec 2021
Tuesday June 22 - Technical workshop

Europe is on Its way towards "Hybrid Qomputing"



**Pasqal, IQM, Quandela, AQT, C12,
Alice&Bob, and more...
POCs G. Colin de Verdière, JP Nominé**

under construction (June 14-15, 2022)

https://teratec.eu/gb/forum_2021/atelier_1.html

https://teratec.eu/gb/forum_2020/atelier_3.html

https://teratec.eu/gb/forum_2019/atelier_2.html

https://teratec.eu/gb/forum_2018/atelier_3.html

https://teratec.eu/gb/forum_2016/atelier_4.html

- ▶ 2022 An updated tour of European QuBits technologies
- ▶ 2021 Europe is on its way towards "Hybrid Qomputing"
- ▶ 2020 Quantum computing: what's new in QuBits?
- ▶ 2019 Quantum computing : which applications will benefit ?
- ▶ 2018 Quantum revolution is here
- ▶ 2016 Specialised computing architectures : helpers or challengers ?



Dr. Valeria Bartsch, Dr.-Ing Guillaume Colin de Verdière,
Dr.-Ing Jean-Philippe Nominé, Dr. Daniele Ottaviani, Dr. Daniele Dragoni,
Dr. Chayma Bouazza, Fabrizio Magugliani, David Bowden,
Dr. Cyril Allouche, Dr. Mikael Johansson, Dr. Olivier Terzo,
Dr. Andrea Scarabosio, Giacomo Vitali, Dr. Farida Shagieva,
Prof. Dr. Kristel Michielsen

05/10/2021

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TECHNOLOGY
PLATFORM
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https://www.etp4hpc.eu/pujades/files/ETP4HPC_WP_Quantum4HPC_FINAL.pdf

https://issuu.com/etp4hpc/docs/etp4hpc_wp_quantum4hpc_final



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Thank you for your attention!

