Pasqal Defining the quantum reality

Quantum Computing with Neutral atoms – Loïc Henriet, Pasqal

November 13th, 2024

Pasqal Defining the quantum reality

2019
Pasqal Founded
Headquarters: France

2021
Pasqal raises €25 M
in Series A

2022
Pasqal merges with
Qu & Co.

2022
Pr. Alain Aspect, co-founder, is awarded the Nobel Prize in Physics

2022
First Neutral Atoms Quantum Computer available on the cloud

2023
Highlighted by BCG
company developing enterprise-grade ready offer

2023
Pasqal raises
€100 M in Series B

2024
Pasqal exceeds 1,000 atoms in quantum processor

2024
IBM collaboration

2024
First quantum computer
acquired by a private company (Aramco)

2024
First quantum computer delivered
to GENCI and CEA

2024
CMA CGM Group and Pasqal join forces

Quantum Processing Units (QPU) for Customers

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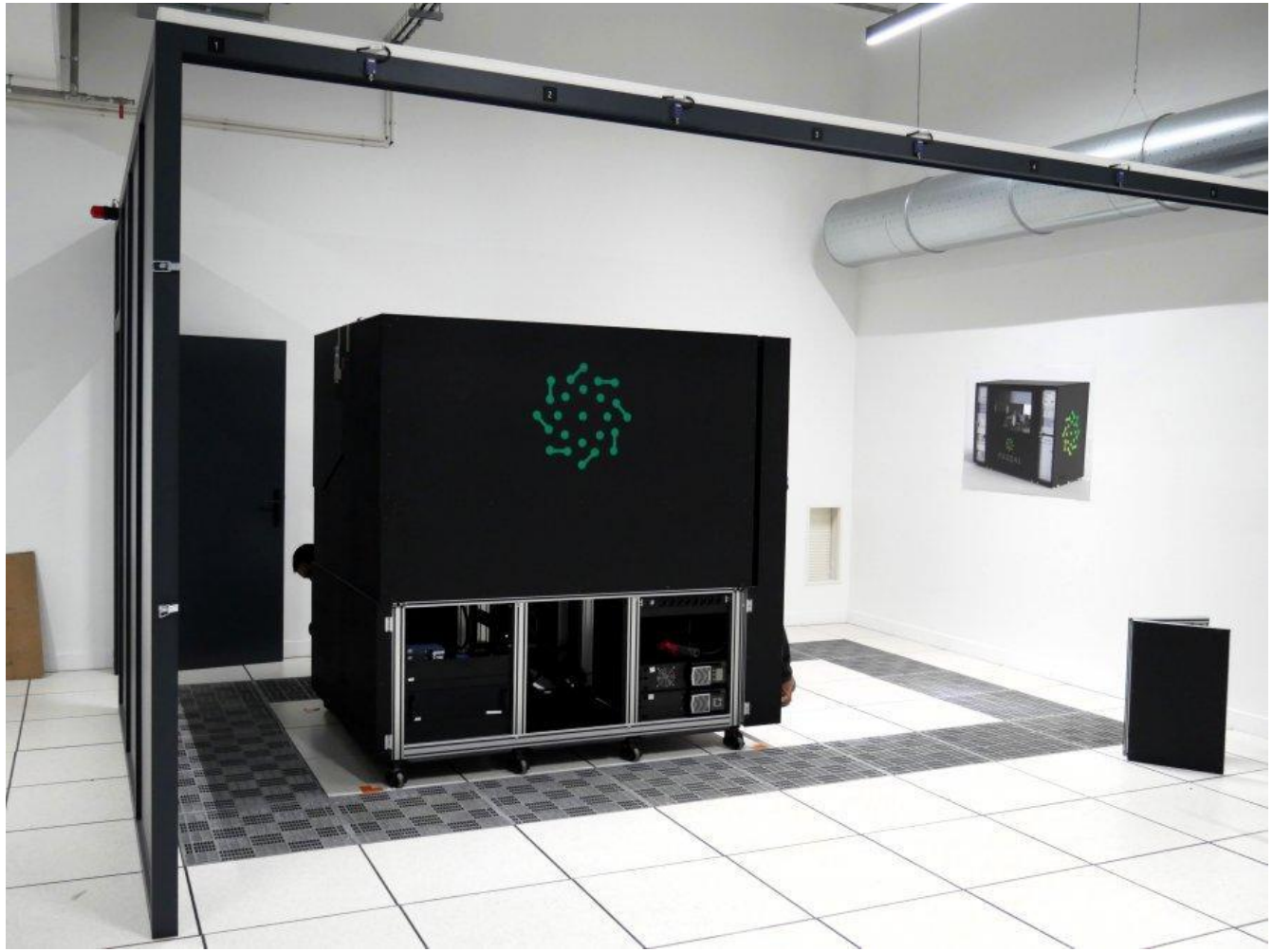

QPU compatible with **standard environment**

Setup at **room temperature**

Industrial **off-the-shelf** components

Low energy consumption (equivalent to 4 hair dryers)

Pushing Engineering for Neutral Atoms QPUs

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Engineering

A choice that enables us both to boost our technologies and develop products that can be used by the community

Boosting performance

NEAR-TERM QC

Qubit scaling

Increase # of qubits in same QPU

+

Addressability

Run and parallelize multiple qubit ops

+

Repetition rate

Increase the max # of calculations per second

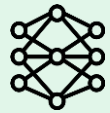
+

ERROR CORRECTED QC

Error Correction

Implement active error correction on logical qubits

+



Interconnect

Increase logical computational power

Mature Products & Community-driven application development

QPU generations

+

Increasing hours of QPU for users

+

Collaborative platform

+

Open-source software stack

From early advantage to full-scale FTQC **on the exact same hardware platform**

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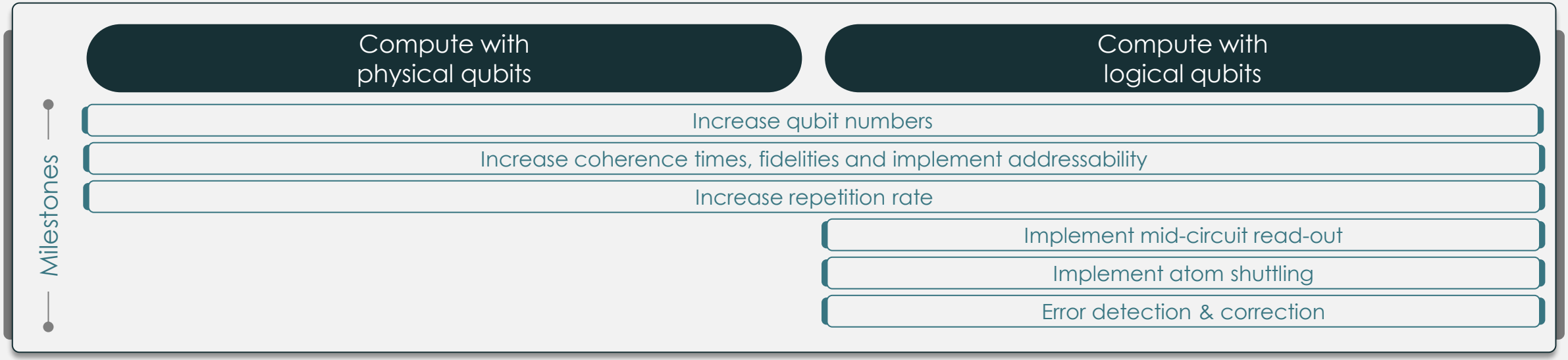

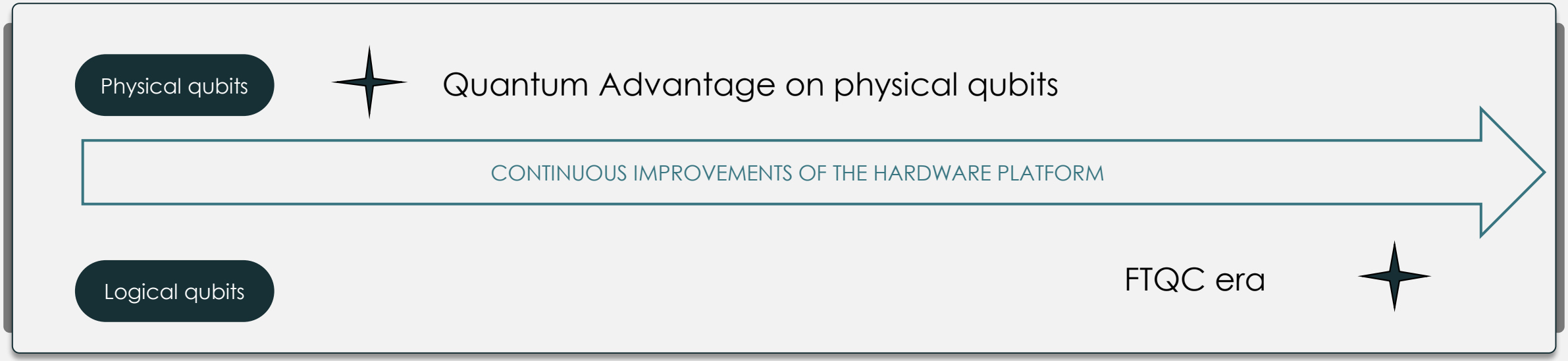

4 Main Algorithmic Pillars

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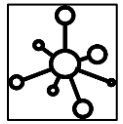
Quantum Simulation

- Spin model dynamics (Ising/XY). In 2021, IOGS/CNRS lab implemented quantum Ising model beyond what could be simulated classically [1].
- Chemistry & Material Science Applications

Graph Machine Learning



- HW-native Quantum Evolution Kernel (QEK) [2], Quantum Graph transformers [3]
- Extensions to state-of-art graph ML models (*graph transformers, shortest path*, …)

Optimization

- Graph-based optimization problems (*MIS, MaxCut,* …)
- Network optimization, scheduling, mission planning, …

Differential Equations

- Differentiable Quantum Circuit (DQC) proposal [4].
- Many extensions including *stochastic* differential equations.

[1] Scholl, et al., Nature volume 595, pages 233–238 (2021)
[2] Henry, et al., Phys. Rev. A 104, 032416 (2021)
[3] Thabet et al., 41st International Conference on Machine Learning
[4] Kyriienko, et al., Phys. Rev. A 103, 052416 (2021)

Smart-charging optimization with neutral-atom QPU

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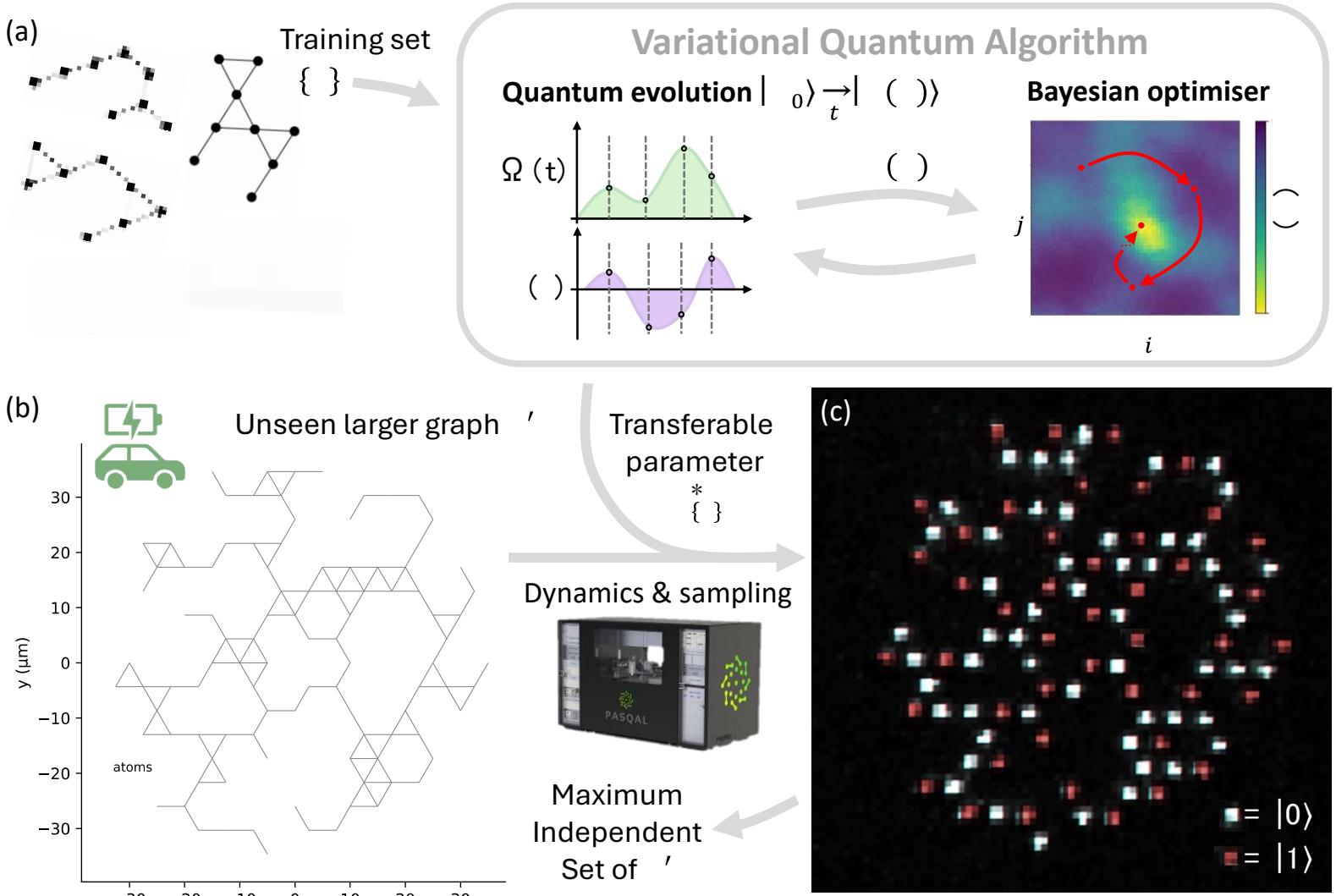
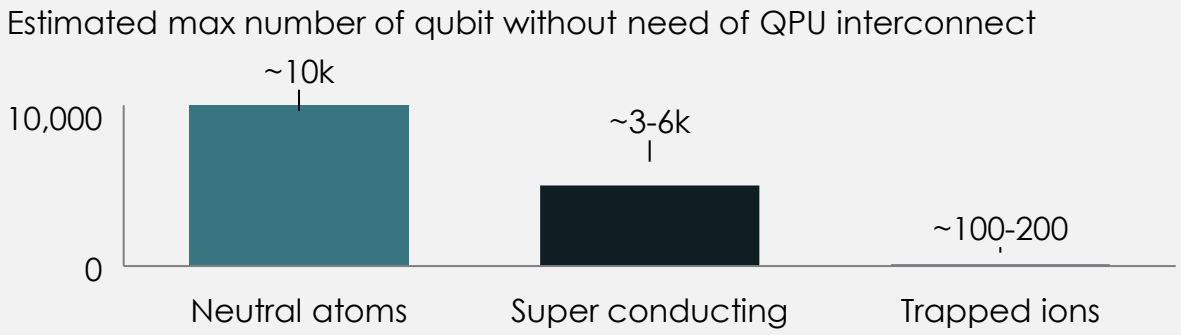
EDF



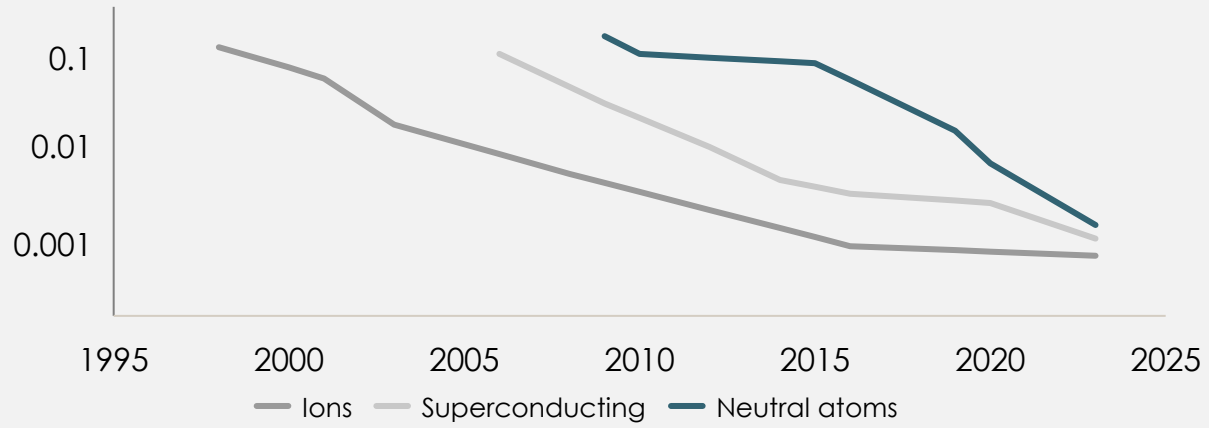
Neutral atoms technology is well positioned in the FTQC race and Pasqal R&D already exhibited promising results

Neutral atoms are best-suited to reach broad quantum advantage and FTQC at scale …

Neutral atoms are well fitted for scaling up



Fidelities are closing the gap with competing technologies



… with Pasqal in a leading position

1,100 The number of atoms Pasqal is able to put in a register

99.85 The 1-qubit gate fidelity reached by Pasqal

1. INRIA, FUB, DGA, IOGS

Digital Computing – Existing Analyses, Data and Results

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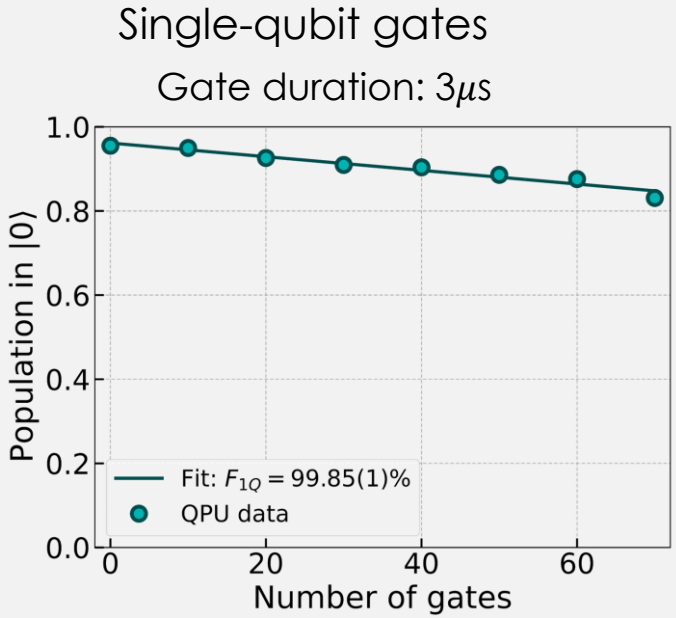
Preliminary results on 1-qubit gate fidelity measurement for Digital quantum computing

Quantity	Measured value
State lifetime	~20 s
Bare coherence time	3.4(1) ms
Coherence under dynamical decoupling (echo)	~4 s
Initialization efficiency	99.4(1)%



Single-qubit gate fidelity of 99.85%

R&D Setups

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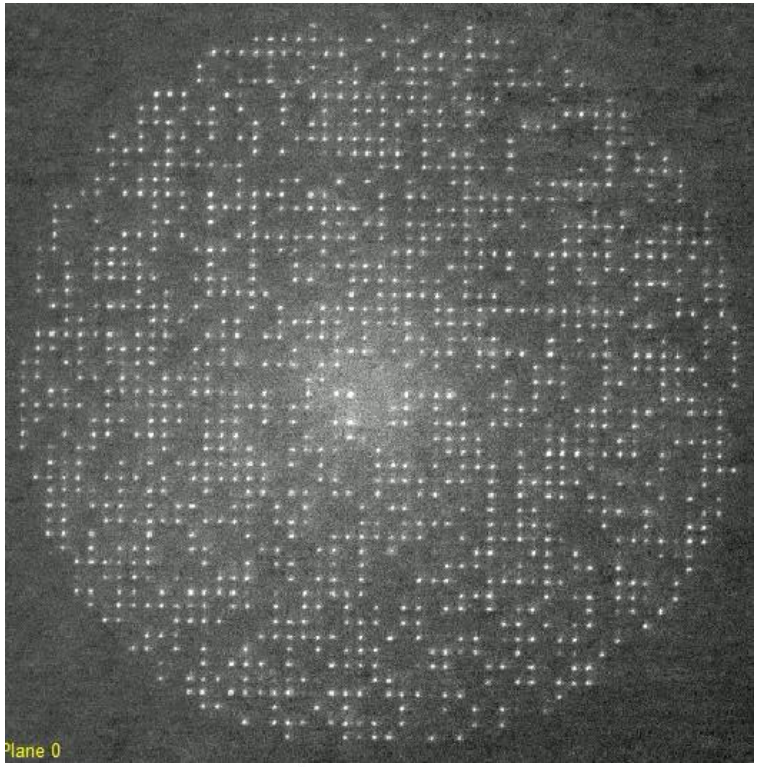
Large array generation (Humber) [7]

- Push limits of register scalability**; 2088 traps generated**
- Atom-by-atom rearrangement of an **828-atom target array** (95% occupancy)
- Future improvements to obtain defect-free arrays with several thousands of atoms
- **Not available for client calculations**



[7] G. Pichard Et al. "Rearrangement of single atoms in a 2000-site optical tweezers array at cryogenic temperatures", Arxiv. 2405.19503 (2024)

FTQC roadmap is bolstered by a comprehensive full-stack strategy designed to create a modular platform

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		2022-2023	2024-2025		2026-2027		2028-2029
Technology Pasqal & affiliated ecosystem	**HARDWARE PLATFORM**						
	Max qubits	200	1,000		10,000		
	Addressability	Z add	Z+X add	Addressable 1Q and 2Q gates			
	Base repetition rate	1 Hz	3 Hz		10 Hz		100 Hz
	FTQC Program		Atom shuttling	Ultra High - Fidelity Gates	Scalable logical qubits architecture		Full-scale FTQC
	HARDWARE ACCELERATED LIBRARIES						
	Quantum Matter & Quantum AI	Algorithm Blueprint	Algorithm Development		Production		
Products	**QUANTUM PROCESSORS**						
	Generation	**Orion Alpha** ~3M gates	**Orion Beta** ~5M gates On premise delivery	**Orion Gamma** ~10M gates On premise delivery	**Vela** ~40M gates	**Pegasus** ~200M gates	**Centaurus FTQC QPU** 200 Logical qubits 200M+ gates
	Total hours of QPU for users	500	5-10,000	20-30,000	60-70,000	200-250,000	500-550,000
	Factories	France	Canada	Factory 3			
	COMMUNITY						
	Platform		Learn	Interact	Collaborate		
	Open-source Software Stack	Pulser	Qadence	Solvers & Emulation			

Note:
[1] Webinar to discover Pasqal's roadmap to Quantum Readiness with a Full-Stack Approach & Transformative Use Cases - https://lnkd.in/evejEWUc