

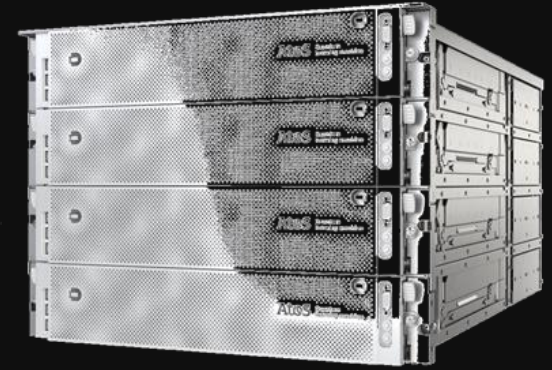
# Classical/quantum hybrid computing: What system architectures?

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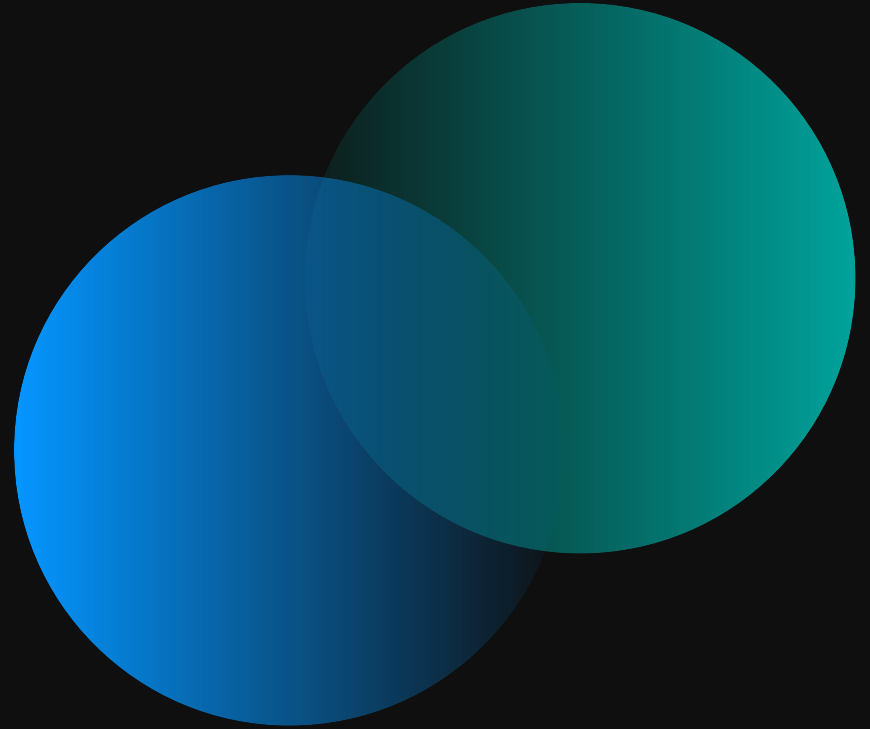


# Foreword: Atos in the Quantum landscape

- HPC manufacturer, #3 in the World
- Invested in quantum research since 2016
- Our focus : what can quantum technologies bring to HPC
- Our platform, QLM:
  - Built on an HPC fat node (up to 48 TB memory)
  - Complete quantum programming framework
  - Embeds high performance emulators (perfect, simulation of quantum physics noise)
  - Hardware-agnostic hybridization node for quantum devices
- Used by 30+ HPC centers in 4 continents
- **We already integrate quantum processors into supercomputers:**
  - IQM processor at LRZ (German BMBF project Q-Exa)
  - Pasqal analog simulator at GENCI and FZJ (EuroHPC project HPC-QS)
  - OpenSuperQ processor at FZJ (German BMBF project Q-Solid)



01. Some structuring  
properties of  
quantum computing



# Quantum acceleration is not universal

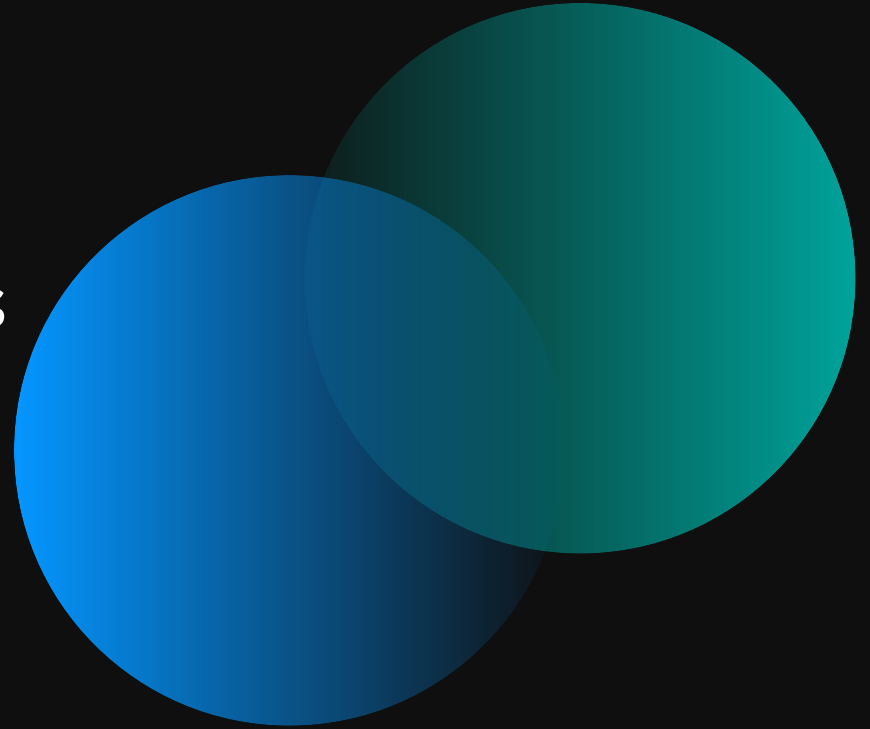
- A classical algorithm is NEVER accelerated on a quantum computer
- The class of known quantum algorithms with exponential gain is thin:
- Example 1: Shor
- Example 2: HHL
- <https://quantumalgorithmzoo.org/>



# Quantum data movements

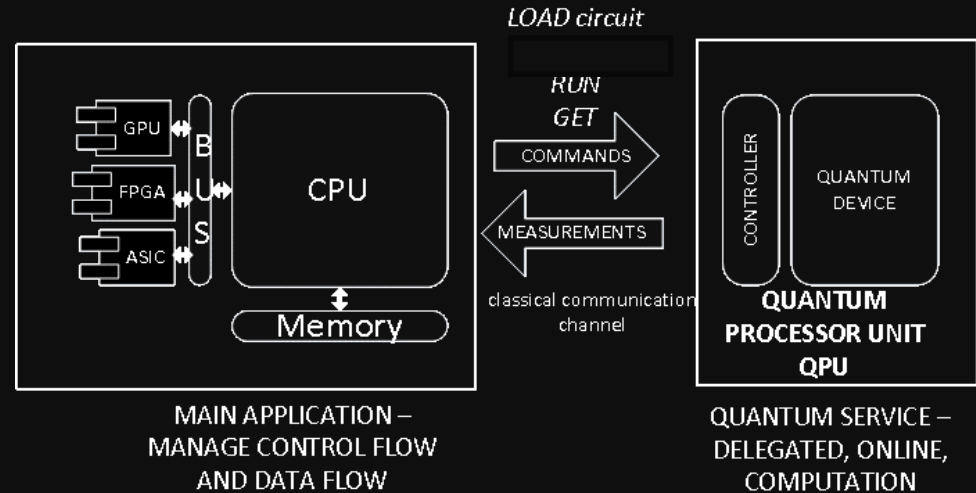
- Copy : no cloning theorem !
- Test: the measurement destroys the superposition!
- Data loading: the creation of a given quantum state has an exponential cost in number of gates!
- Communicating with a QPU:
  - IN: Circuit + parameters – no quantum state!
  - OUT - measure (bitstring)

## 02. Programming models and architectures



# Hybrid compute model

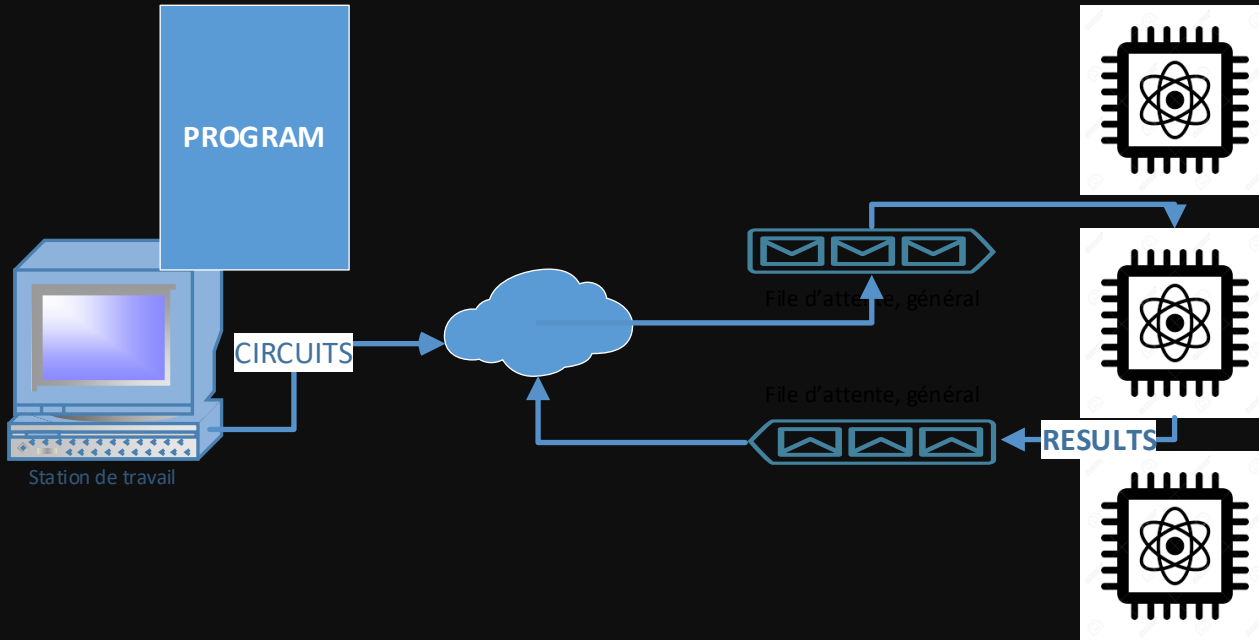
- Quantum Processor Unit (QPU) as a (very) specialized co-processor
- Execution control remains with the CPU
- QPU as synchronous slave of CPU



The CPU builds the circuits on the fly, submits them to the QPU, and retrieves measurements

# What architecture for HPC and cloud?

1<sup>st</sup> option : QPU aaS – ex IBM Q v1, AWS, ..

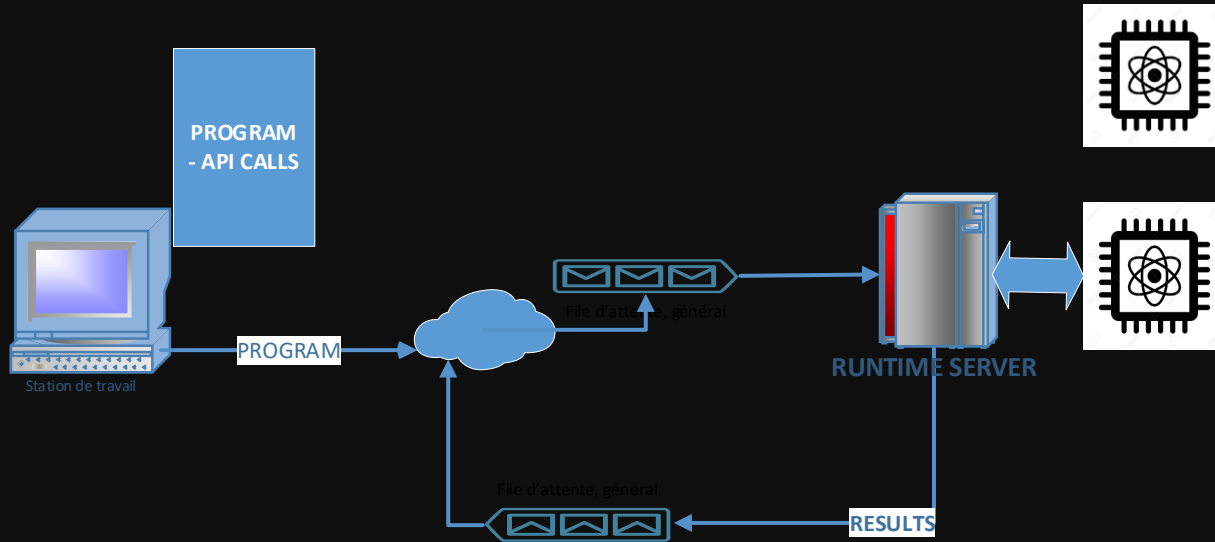


Trouble:  
User latency  
Underutilization of QPU  
(98% idle!)



# What architecture for HPC and cloud?

2<sup>nd</sup> option : Runtime aaS – ex IBM Q OpenQASM3



## Flaws:

- Loss of user control
- Loss of added value for the user code
- Not scalable – monolithic pattern

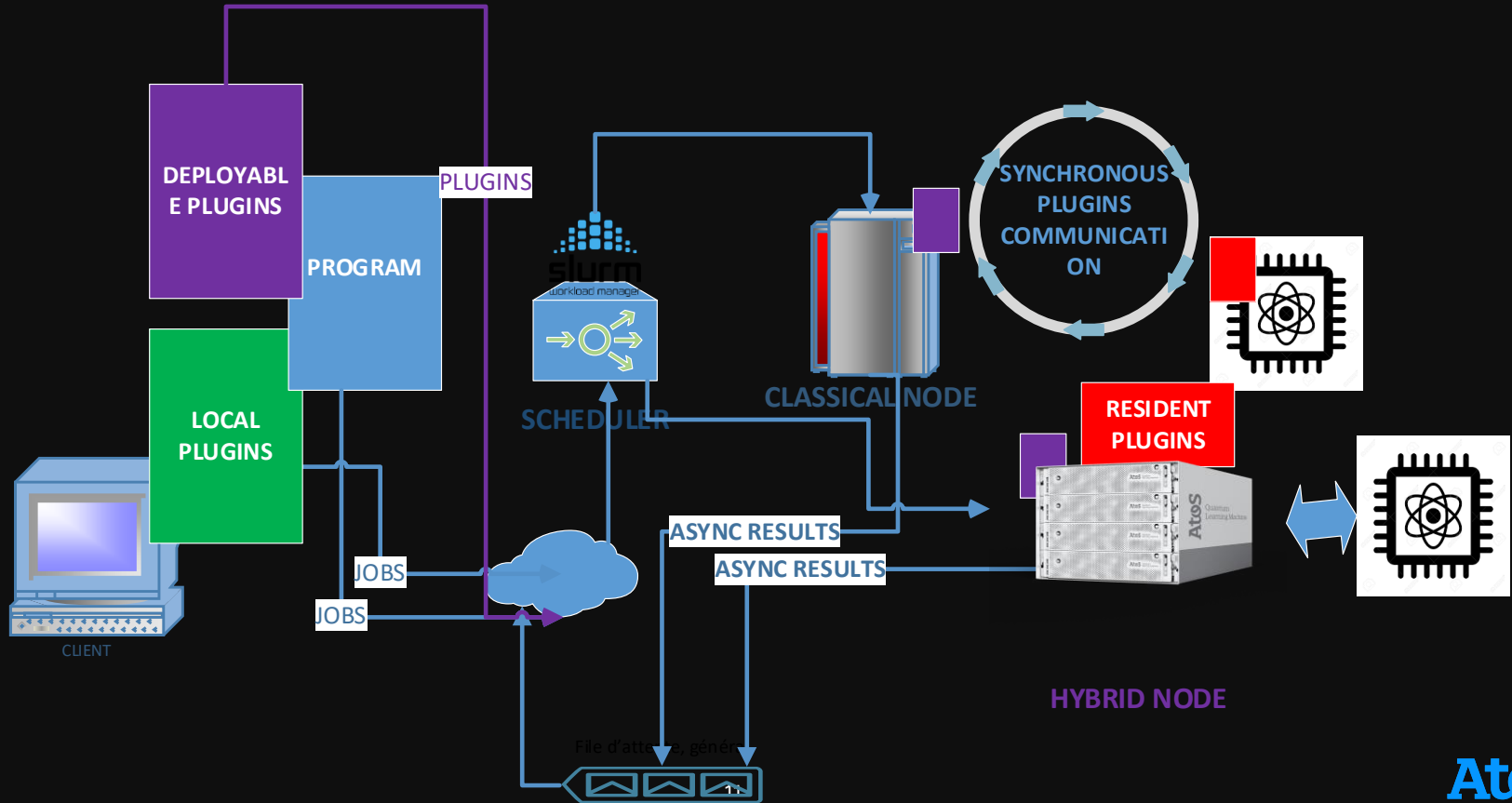
# What architecture for HPC and cloud?

## Atos' approach

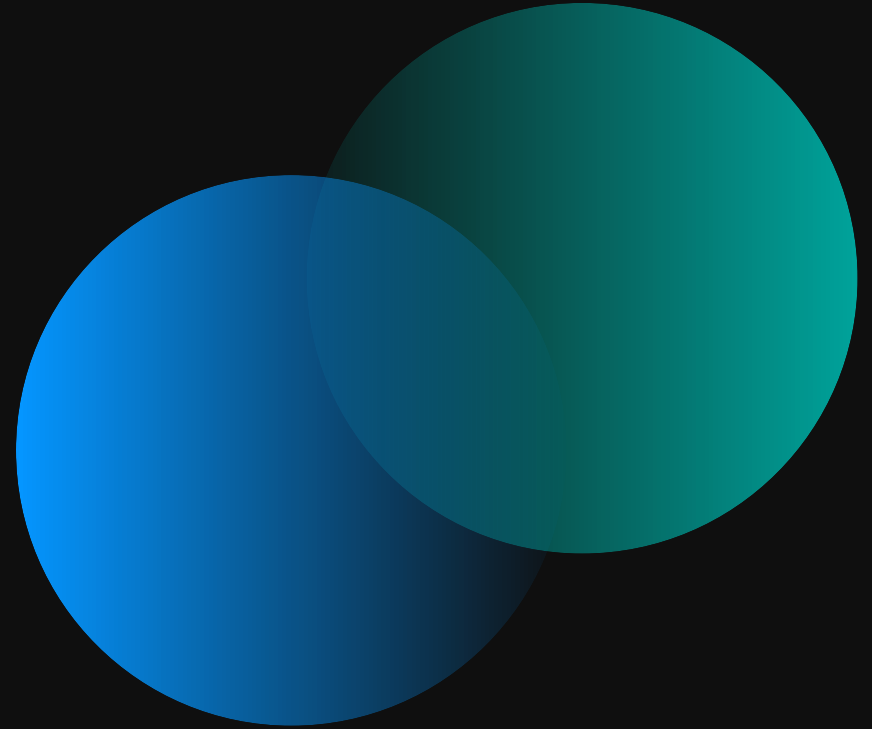
- Hybrid programming framework based on micro-services
- Microservices deployable on client / server / QPU ; synchronous / asynchronous
- Communication between microservices transparent for the user
- Tight integration with the resource manager

# What architecture for HPC and cloud?

Atos myQLM PowerAccess



## 03. Post-NISQ Architecture Issues



- Distributed quantum programming
- Classical Interconnect ?
- Quantum Interconnect?
- Distributed heterogeneous programming
- LSQ programming: pre-compiled static circuits

A photograph of a server rack containing four AtoS Quantum Learning Machine units. The units are stacked vertically and have a perforated metal front panel. The AtoS logo is visible on each unit. To the right of the rack is a large box with the AtoS logo and the text 'Quantum Learning Machine'. The entire scene is dimly lit with a blue tint.

Questions?

# Thank you!

Bonus: try myQLM!



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