Calcul Québec

Calcul Québec’s HPC and Quantum Computing Infrastructures

ISC’25 - Quantum Resources for Unified Computing Hub

Mission

Calcul Québec is devoted to providing academic and research communities with **state-of-the-art computing infrastructure and expertise**. This contributes to the advancement of knowledge in all branches of learning and to the training of highly qualified personnel capable of efficiently operating modern computing systems.

Members and Partners

Partenaires connectivité

Partenaires financiers

Our services

Computing clusters

Cloud computing

Quantum computing

Personalized support

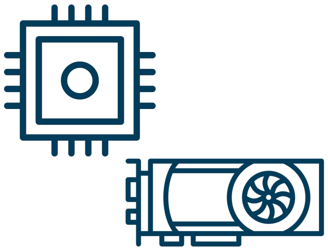
Data Storage

Notebooks

Documentation

Training Workshops

Existing infrastructure



HPC clusters

- Béluga
  - 32,080 CPUs, 688 V100
- Narval
  - 83,216 CPUs, 636 A100
- Rorqual (coming soon)
  - 131,712 CPUs, 324 H100

Universal gate-based quantum computer

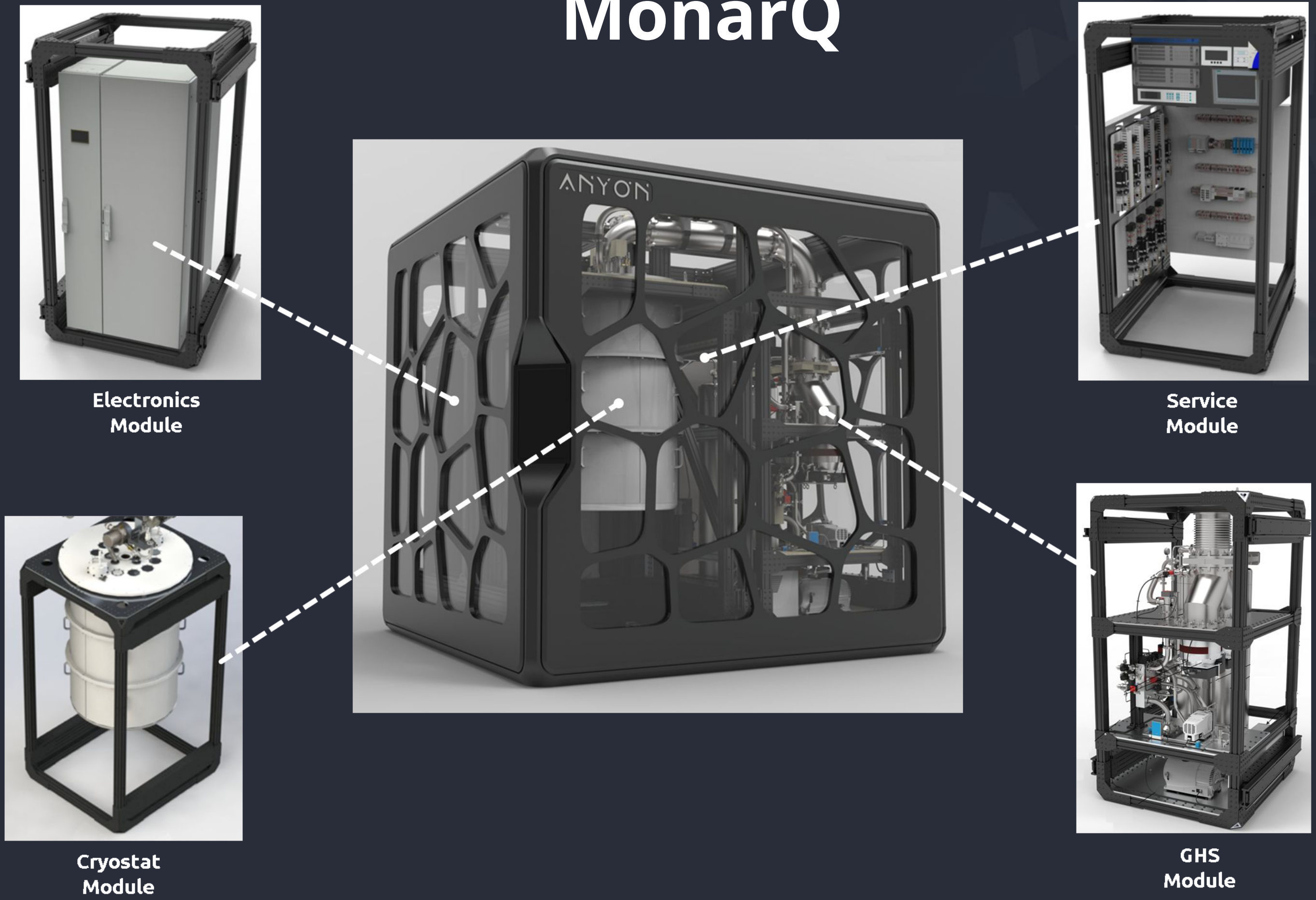
- MonarQ
  - 24 superconducting qubits

Future desirable state

A framework to make it possible to use **quantum computers as accelerators** in addition to the resources provided by a classical HPC cluster

→ make things **easy** for researchers
→ make things **efficient**

MonarQ



ANYON

Challenges with quantum devices

→ Sensitive to noise
→ Requires extreme environments

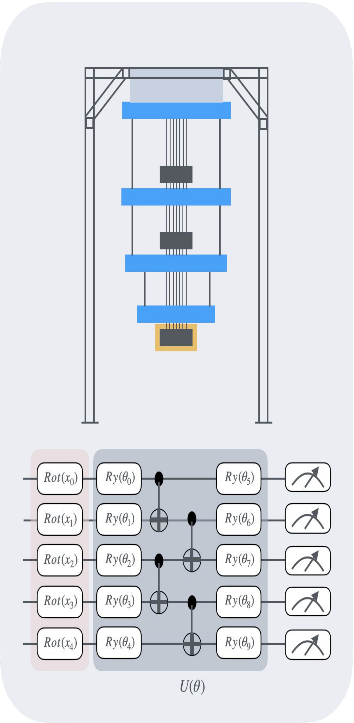
- Maintenance and calibration
- Specialized skills
- Training the user community
- Custom software solutions

Maintenance and Calibration

- Challenges of experimental technology
- Need realistic uptime expectations

* image used from https://www.gettyimages.com/, credit filo

Specialized skills



Hardware		Engineer	Hardware provider
Compiler → microwave pulses	Signal digitization	Experimental Physicist	
Transpiler → native gate set, placement on physical qubits, optimization...			
Quantum Circuit representing the problem	Output Analytics	Quantum Information Scientist	Programmer (quantum algorithm)
Mathematical approximation of the problem	Quantum solution	Quantum Developer	
		User	

* Inspired by Challenges and Opportunities of Near-Term Quantum Computing Systems, A. Córcoles et al.

Sharing Knowledge

- Consultation and support for researchers and their teams
- Workshops on theory and programming
- Presentations at conferences
- Online documentation and resources
- **Summer research program for Québec postsecondary and graduate students**

quantum@calculquebec.ca

Software Development Projects

Developing Custom Software

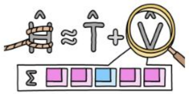
- An in-house transpiler built from scratch
- Plugin development
    - PennyLane
    - Qiskit
- A benchmarking suite to stress-test MonarQ
- Scheduling and optimization of QPU usage
- Integrating with classical compute systems

PennyLane's quantum device partners

XANADU | aws | AQT | Google | IBM Quantum

IONQ | Microsoft | Quantum Inspire | rigetti | Unitary Fund

And now ANYON



Demo

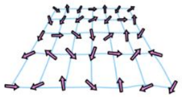
How to build compressed double-factorized Hamiltonians

Learn how to build compressed double-factorized Hamiltonians with PennyLane.

Demo

How to use Catalyst with Lightning-GPU

Learn how to use Catalyst with Lightning-GPU to boost the runtime performance of your quantum programs.



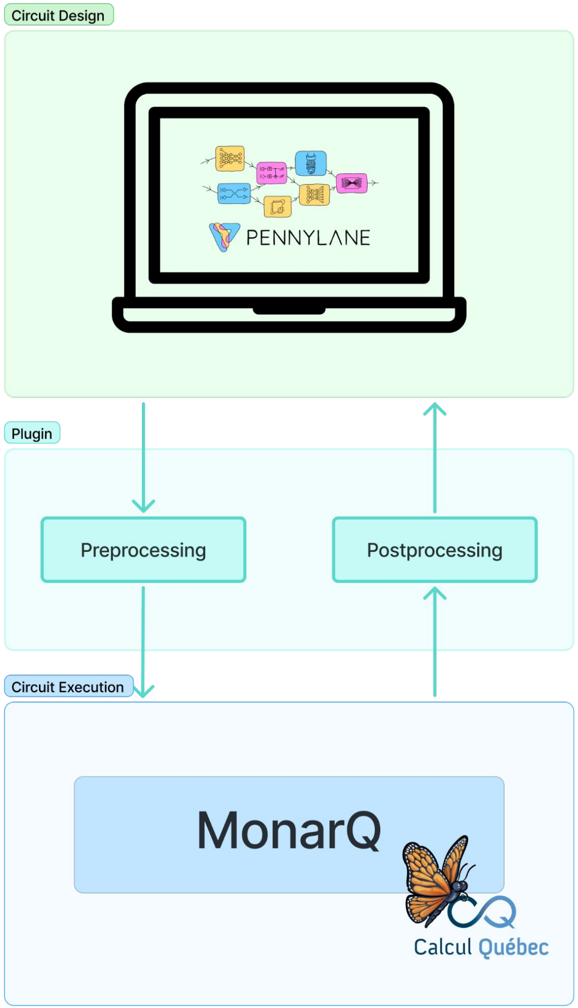
Demo

How to build spin Hamiltonians

Learn how to build spin Hamiltonians with PennyLane.

Pennylane-Calculquebec Plugin

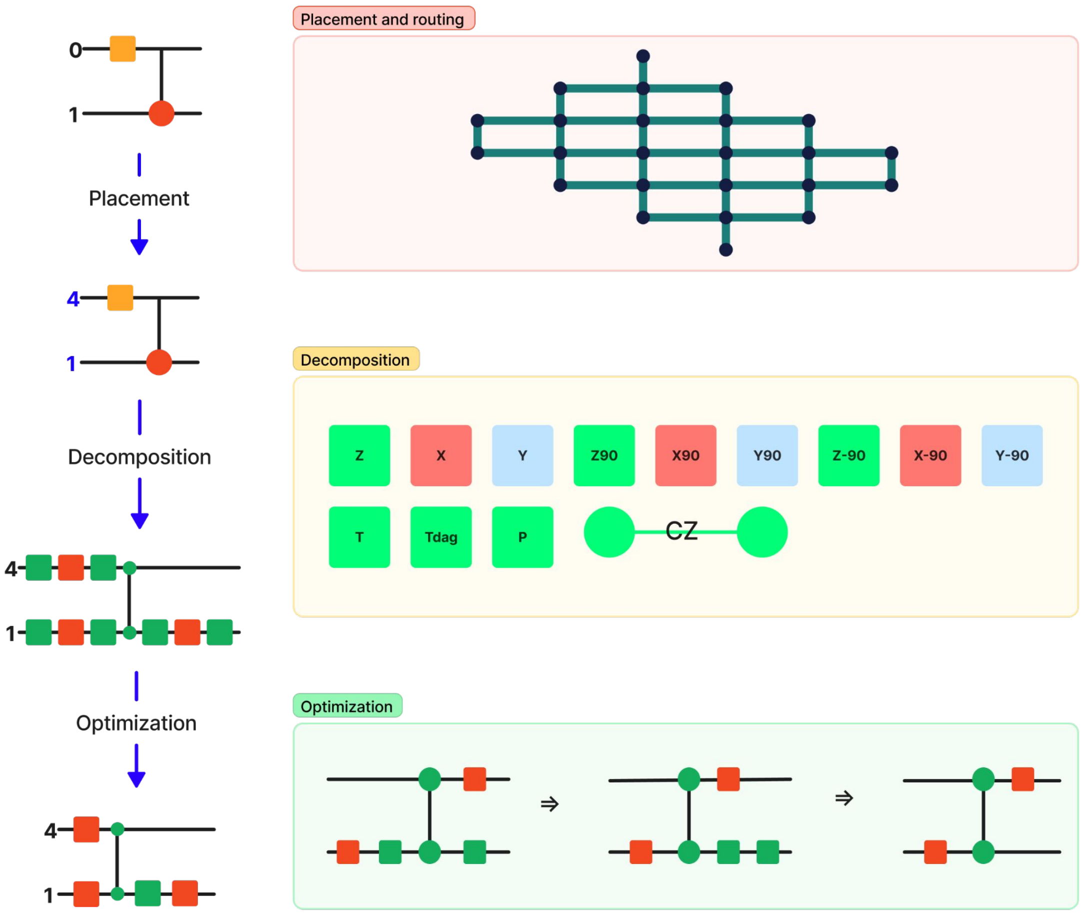
A plugin that sits at both ends of the execution in the form of classical preprocessing and postprocessing functions.



Preprocessing circuits

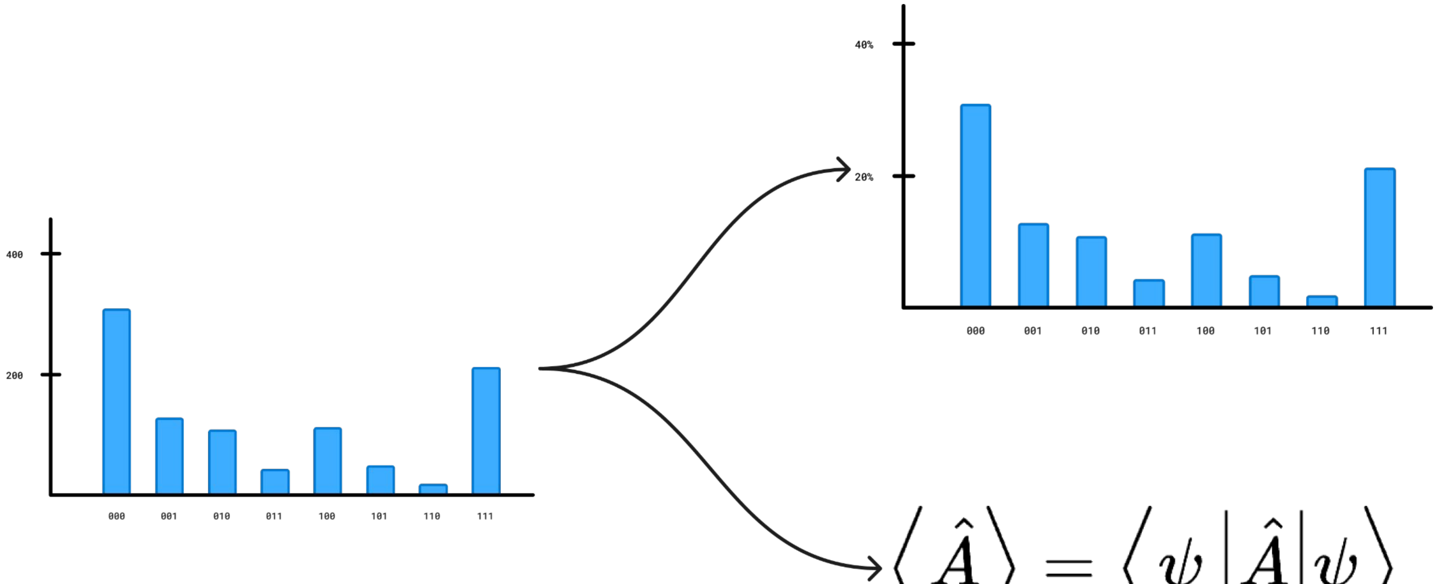
To achieve a certain level of of abstraction, a circuit or an algorithm would ideally not be altered.

The process described here can be called “**Transpilation**”



Post-processing – Types of measurements

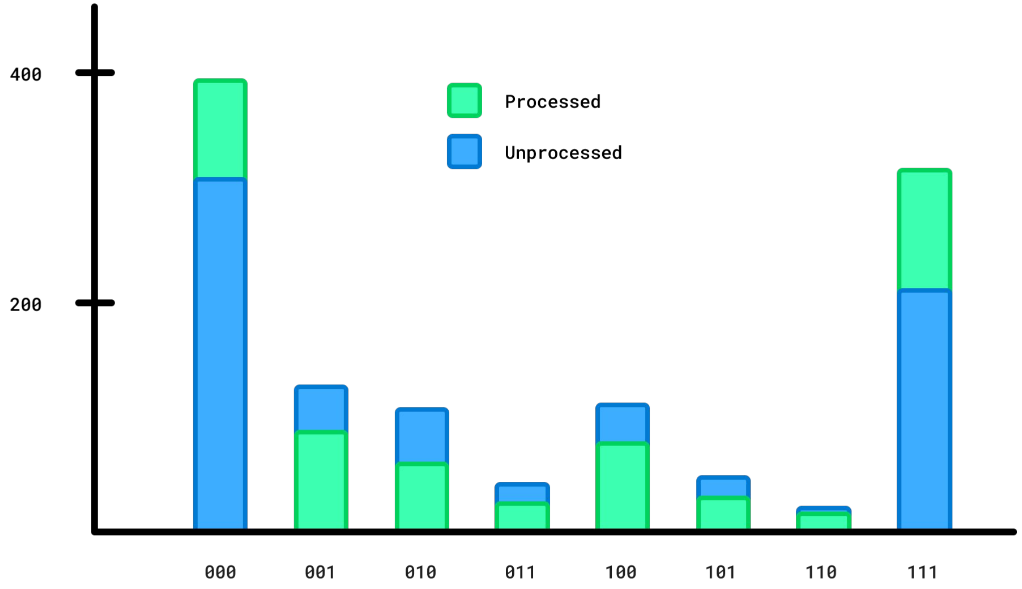
Results retrieved from MonarQ are a dictionary of counts. But in PennyLane and even in other frameworks, there are other ways to interpret the results.



$$\langle \hat{A} \rangle = \langle \psi | \hat{A} | \psi \rangle$$

Post-processing – Error mitigation

Post-processing techniques designed to reduce the impact of noise on quantum computations by transforming the measured outcomes to more closely reflect ideal, noise-free results — often without discarding data.



Testing and improving MonarQ

- MonarQ is a “NISQ” machine
- Collaborating with Anyon to continuously improve the performance
- Benchmarking
- Extraction of a complete noise model of MonarQ (decoherence, depolarizing noise, crosstalk, state tomography…)

Conclusions

Building Knowledge

Working with a quantum computer on a daily basis is an invaluable experience

- Innovate to overcome the constraints of a “NISQ” quantum computer
- Error mitigation expertise
- Characterization of a quantum computer (performance, noise properties, reliability)
- Software and tools development
- Integration with HPC
- Involvement of interns and students

Anticipated obstacles

Software

Network and Security

Resource Management

Latency

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