Towards a hybrid quantum operating system

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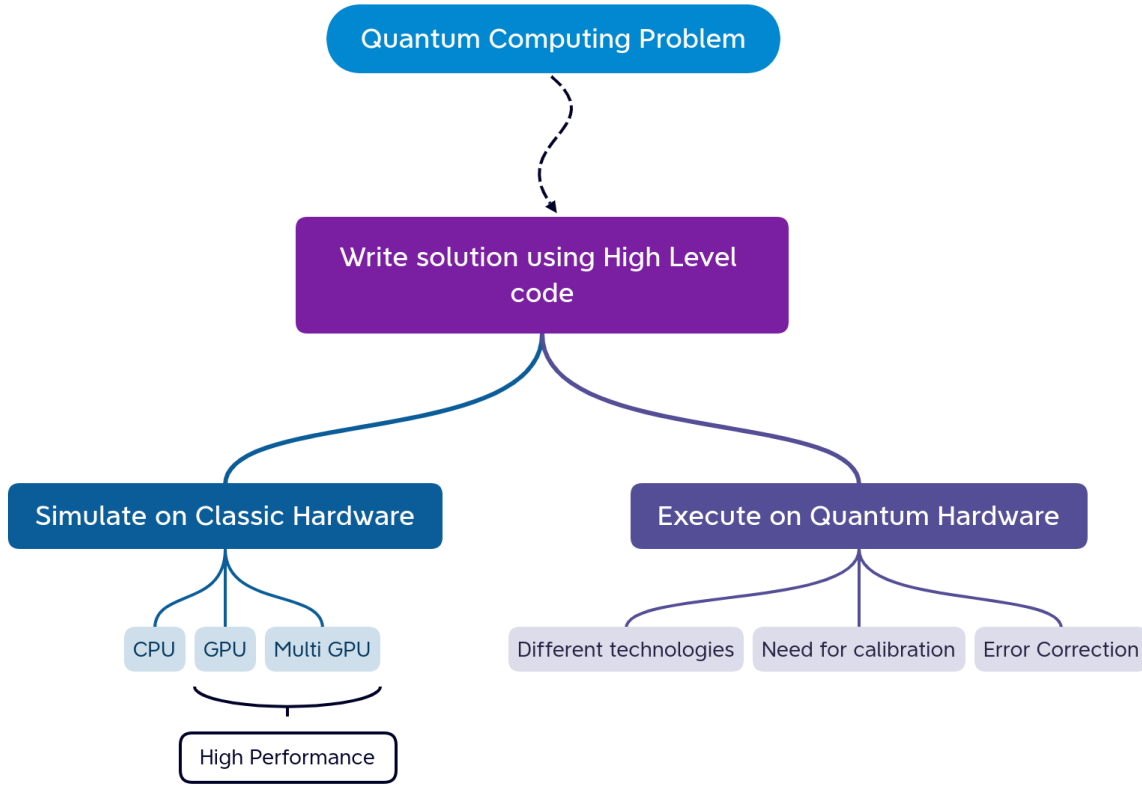
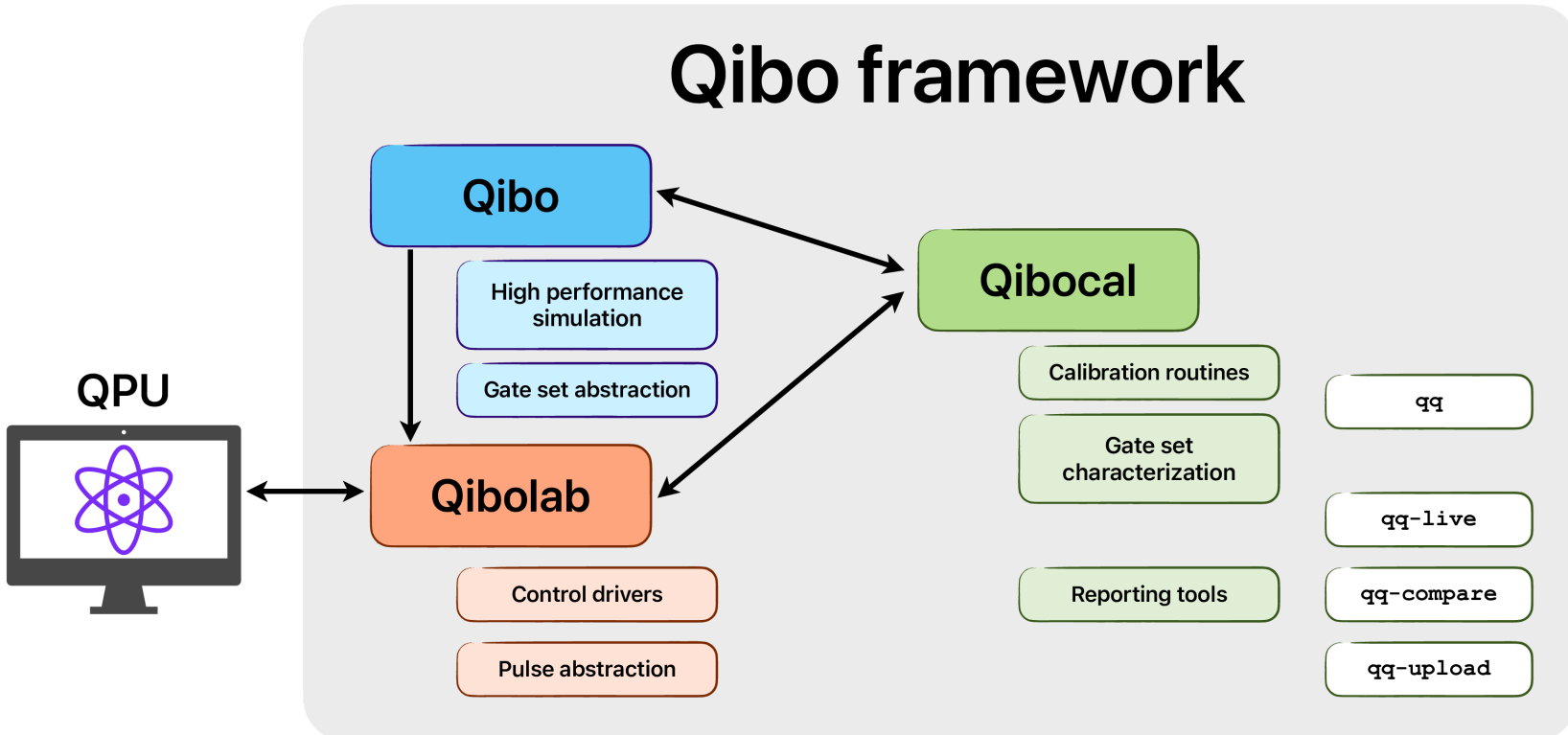
What is the challenge?



Is it possible to create from scratch a framework for all of this?

Introducing Qibo

Open-source full stack API for quantum simulation, hardware control and calibration


Qibo framework
Qibo
High performance simulation
Gate set abstraction
Qibocal
Calibration routines
Gate set characterization
Reporting tools
qq
qq-live
qq-compare
qq-upload
QPU
Qibolab
Control drivers
Pulse abstraction

Simulation

Gate set abstraction

```python
import numpy as np
from qibo.models import Circuit
from qibo import gates, set_backend

# Set driver engine
set_backend("numpy")

c = Circuit(2)
c.add(gates.X(0))

# Add a measurement register on both qubits
c.add(gates.M(0, 1))

# Execute the circuit with the default initial state |00>.
result = c(nshots=100)
```

```python
# Change backend
set_backend("qibojit")

# Circuit execution with new driver
result = c(nshots=100)
```

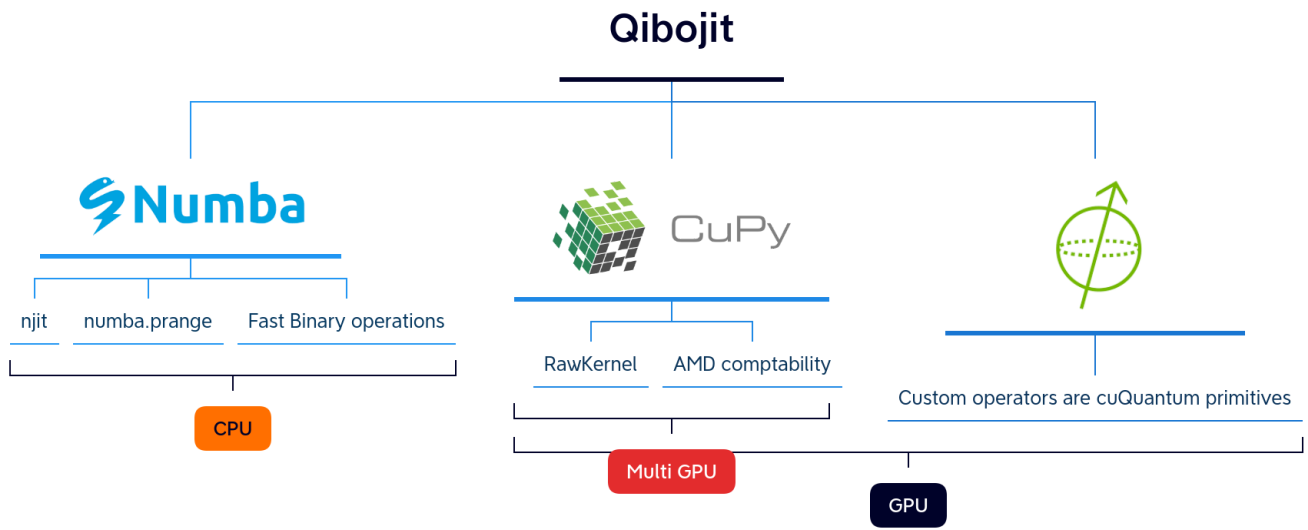
Qibo features

- Definition of a standard language for the construction and execution of quantum circuits with device agnostic approach to simulation and quantum hardware control based on plug and play backend drivers.
- A continuously growing code-base of quantum algorithms applications presented with examples and tutorials.
- Efficient simulation backends with GPU, multi-GPU and CPU with multi-threading support.
- A Simple mechanism for the implementation of new simulation and hardware backend drivers.

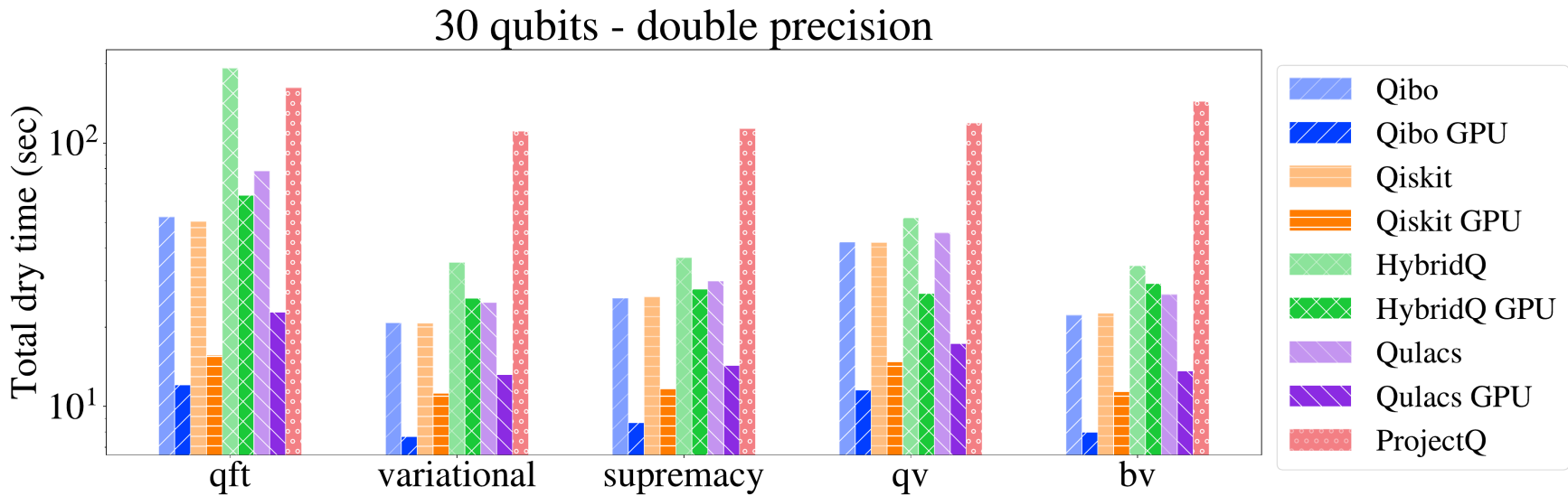
High performance simulation

❌ Long computational times using naive approach (`Numpy` or `TensorFlow`) for circuits with large number of qubits.

✅ We need more sophisticated tools to be able to simulate a quantum circuits with more qubits!



BENCHMARK



All the benchmarks are available in qibojit-benchmarks.

QIBOLAB

Automatic deployment of quantum circuits on quantum hardware

Motivation

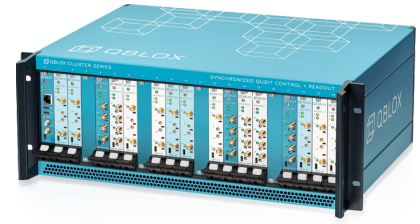
How are gates implemented on a quantum computer?

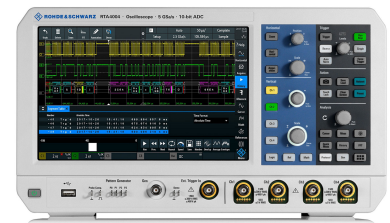
By sending microwave pulses.

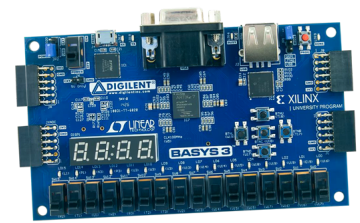
How do we control them?

Using FPGAs

→ We need both a pulse level API + drivers to interface Qibo with different instruments.







Pulse API example

```python
from qibolab import Platform
from qibolab.pulses import ReadoutPulse, PulseSequence

# Define PulseSequence
sequence = PulseSequence()
# Add some pulses to the pulse sequence
sequence.add(ReadoutPulse(start=0,
                  amplitude=0.3,
                  duration=4000,
                  frequency=200_000_000,
                  shape='Gaussian(5)'))

# Define platform
platform = Platform("tii1q_b1")
# Platform setup
platform.connect()
platform.setup()
platform.start()
# Executes a pulse sequence.
results = platform.execute_pulse_sequence()
platform.stop()
platform.disconnect()
```

Drivers implemented

Currently Qibolab supports the following drivers:

- Qblox
- Quantum Machines
- Zurich Instruments
- RFSoC
- ZCU11 (under development)

We also supports local oscillators

- RohdeSchwarz SGS100A
- ERASynth

Introducing Qibocal

A reporting tool for calibration using Qibo

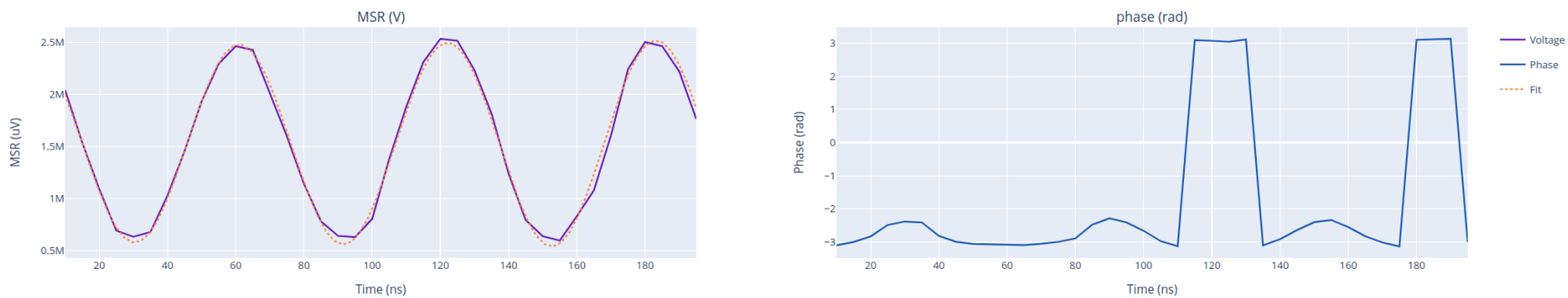
Motivation

Let's suppose the following:

1. We have a QPU (self-hosted).
2. We have control over what we send to the QPU.
3. We know how to convert Pulses to Circuits.

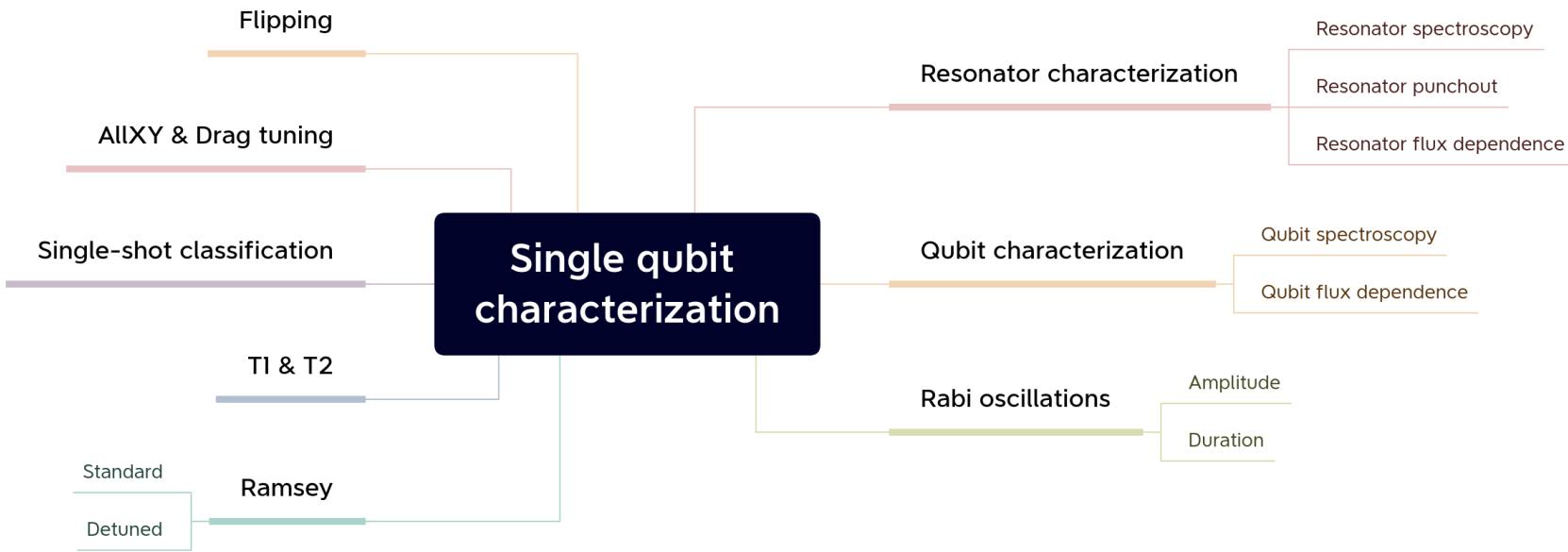
Can I trust my results? NO!

Characterization and calibration are an essential step to properly operate emerging quantum devices.

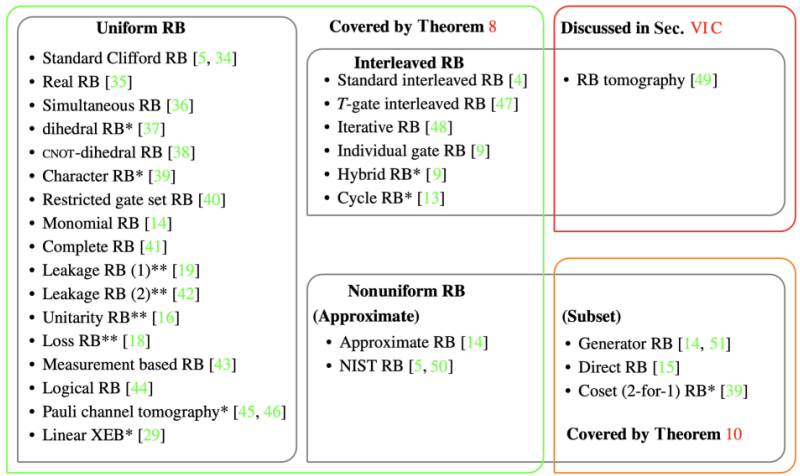


Calibration of RX pulse amplitude through a Rabi experiment through Qibocal.

Single Qubit Characterization: Pulse Level



Single Qubit Characterization: Circuit Level

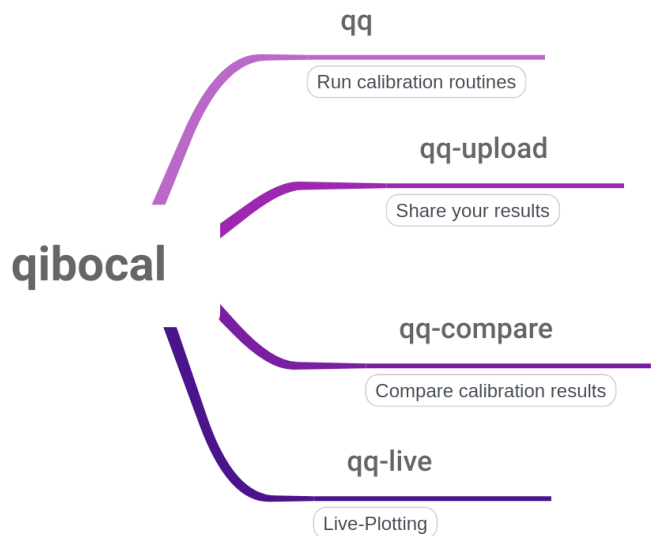


Currently in Qibocal the following protocols are implemented:

- Standard RB
- Simulataneous Filtered RB
- XId RB

We are currently developing a suite for the development of the latest quantum benchmarking protocols available in the literature.

Reporting tools



- Platform agnostic approach
- Launch calibration routines easily
- Live-plotting tools
- Autocalibration (under development)

Qibocal Reports

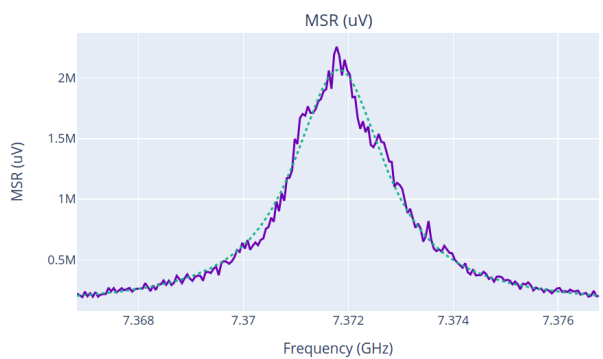
Actions

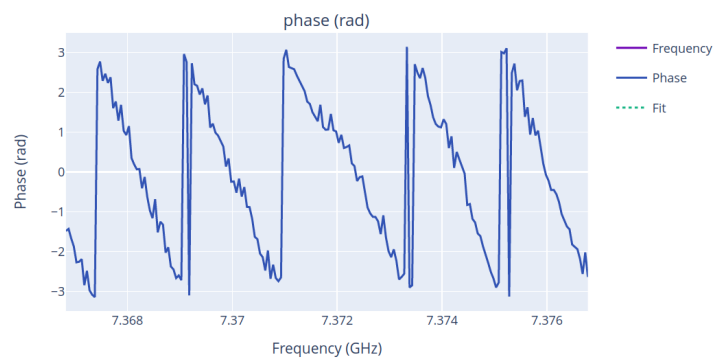
Please find below data generated by actions:

Resonator Spectroscopy Low Power - 0

- Qubit 0

qubit	Fitting Parameter	Value
0	readout frequency	7,371,823,304 Hz
0	amplitude	0.022



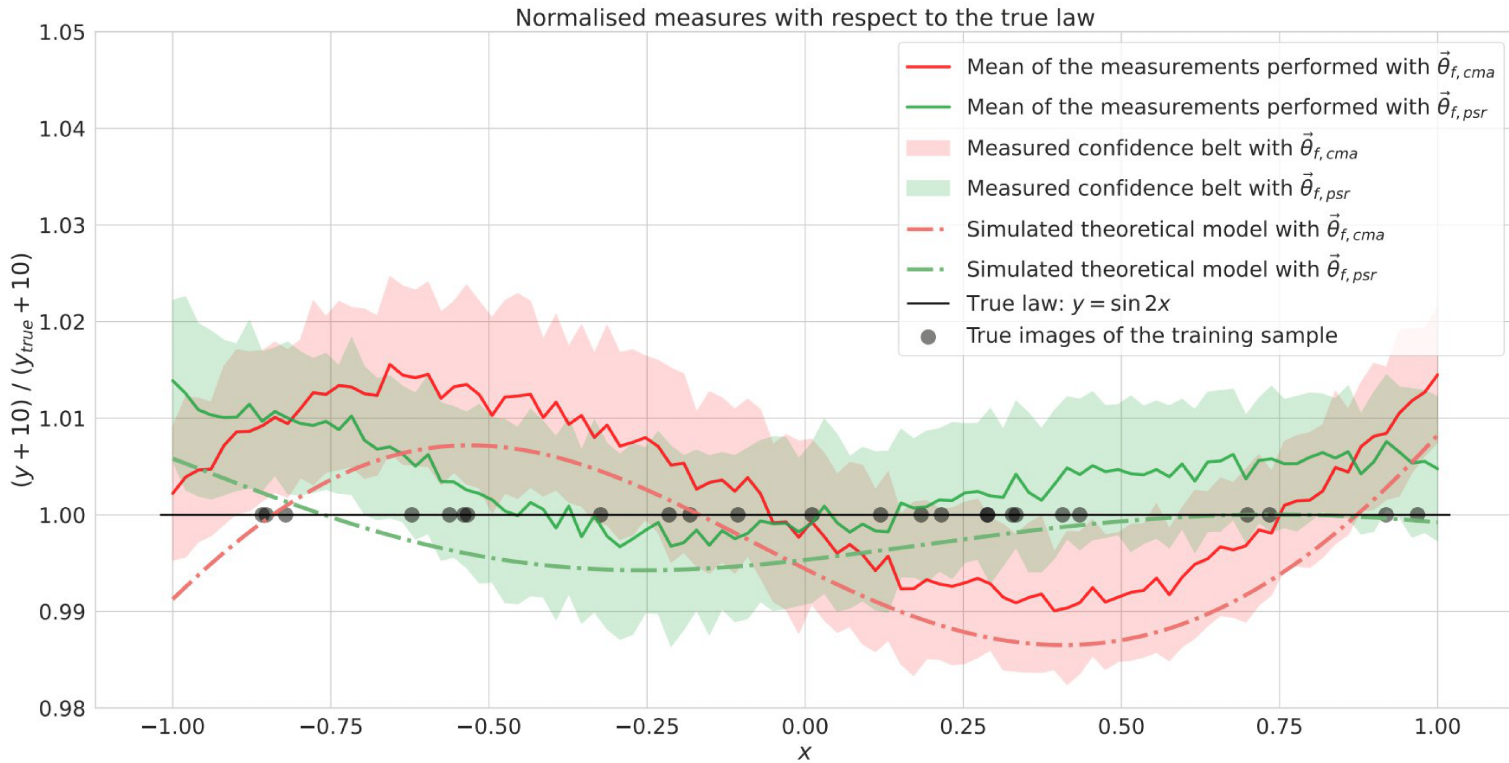


Applications

Paramater Shift Rule on Hardware

What can we achieve using `Qibo` + `Qibolab` + `Qibocal`?

Successfully performed a gradient descent on a QPU with a single using Parameter Shift Rule algorithm.



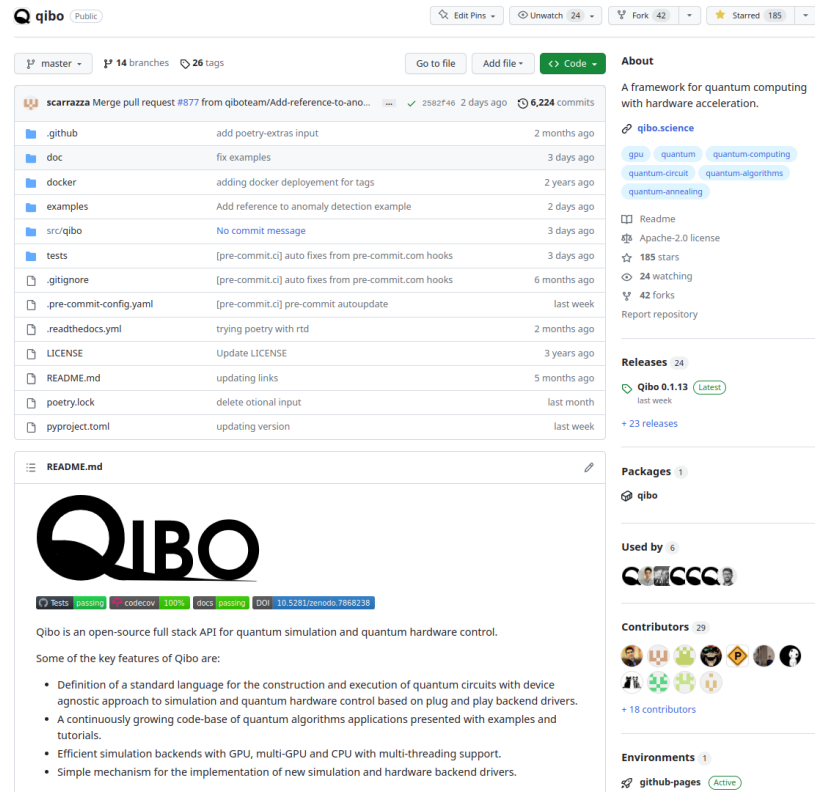
Outlook

Qibo is growing to accomodate different tasks:

- High performance quantum simulation: qibojit
- Hardware control: qibolab
- Hardware calibration: qibocal

Why should you choose Qibo?

- Publicly available as an open source project
- Modular layout design with the possibility of adding
  - a new backend for simulation
  - a new platform for hardware control
- Community driven effort



Thanks for listening!