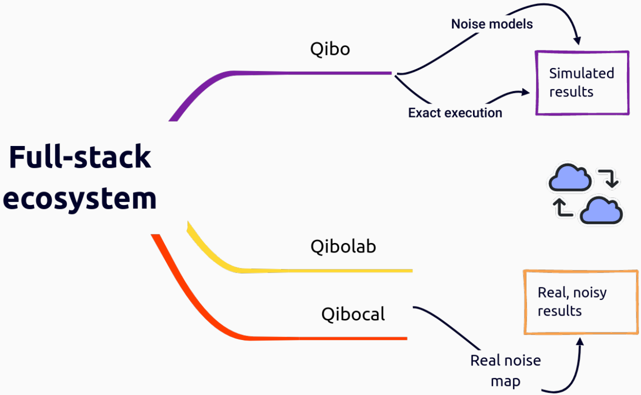
>_ qibo covers all quantum computation areas, thus we can implement and test **full-stack** quantum algorithms.



Full-stack gradient descent

>_ `WORK 1:` hardware-compatible **quantum gradient descent** (QGD)[1]:

- implementing parameter-shift rules to evaluate gradients on hardware;
- successfully fitting $y = \sin 2x$ on TII QPUs.
- results comparable to a genetic optimization.

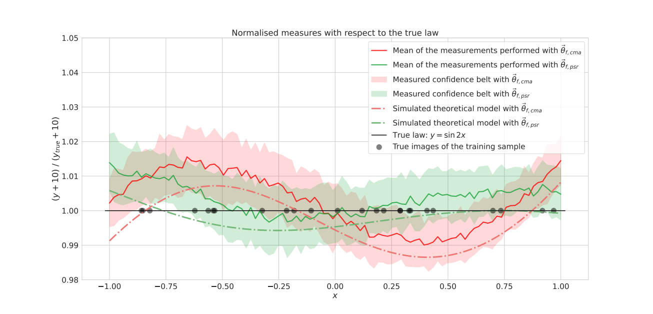


Figure 1: Normalised fit of $y = \sin 2x$ through a full-stack Adam descent performed using `qibo`.

[1] arXiv:2210.10787

Error mitigation impact on QGD algorithms

>_ `WORK 2:` error mitigation impact during QGD steps:

- combine error mitigation with derivation methods we have in `qibo`;
- successfully fitting High Energy Physics (HEP) quarks parton density functions in simulation using mitigated-noisy circuits;
- we are going to run the algorithm on the hardware.

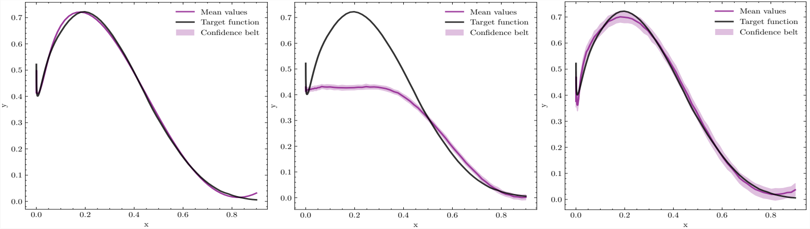
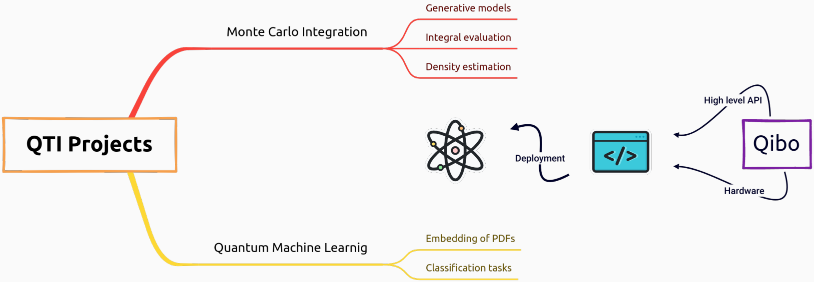


Figure 2: PDF fit performed with different levels of noisy simulation. From left to right, exact simulation, noisy simulation, noisy simulation applying error mitigation to the predictions.

Quantum technologies for High Energy Physics (HEP)

>_ We cooperate with the Quantum Techonolgy Initiative (QTI) at CERN, where Matteo is spending the Doctoral program.



>_ The qibo ecosystem has been presented[2] and used[3] during the QTI-TH forum.

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[2] QTI-TH Forum 2023-01-12
[3] QTI-TH Forum 2023-01-26

>_ WORK 3: we used qibo for testing a new Quantum Adiabatic Machine Learning (QAML) strategy[4]:

- we embed a Cumulative Density Function (CDF) into ad adiabatic evolution;
- we translate the adiabatic hamiltonians into circuits;
- we derivate this circuits with hardware-compatible techniques for estimating the Probability Density Function (PDF).

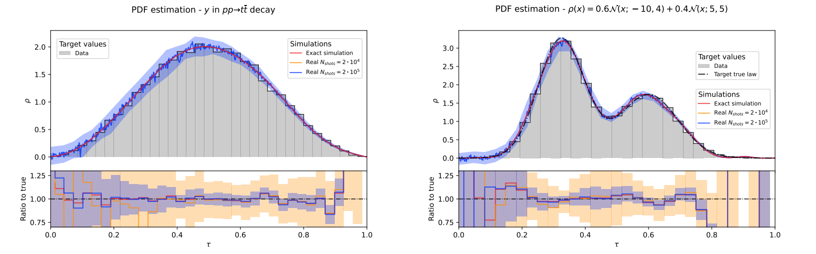

Figure 3: QAML results. On the right PDF fit of rapidity in a $pp \to t\bar{t}$ HEP decay, on the left we fit a gaussian mixture.

[4] arXiv:2303.11346

Upcoming

>_ `WORK 4:` Quantum Analytical integration using the parameter shift rule.

Given the integral:

$$I = \int_a^b g(x)\,\mathrm{d}x, \tag{1}$$

we can use the expectation value of an observable $\hat{B}$ to fit $g(x)$;

$$\hat{g}(x) \equiv \langle \mathcal{C}(x) \rangle \equiv \langle \psi_i | \mathcal{C}^\dagger(x) | \hat{B}\, \mathcal{C}(x) | \psi_i \rangle\,, \tag{2}$$

this makes the original circuit $\mathcal{C}$ a good estimator of the integral function as $I = \langle \mathcal{C}(b) \rangle - \langle \mathcal{C}(a) \rangle$ due to the fundamental theorem of integral calculus.

>_ `WORK 5:` How to classify HEP event topology using a quantum annealer?

We had an interesting discussion during the QTI-TH Forum[a] about the topic and we are thinking to use `qibo` for approaching this task.

[a] QTI-TH Forum 2023-03-30