Exploiting Symmetries in Quantum Machine Learning

IQM CHALLENGE

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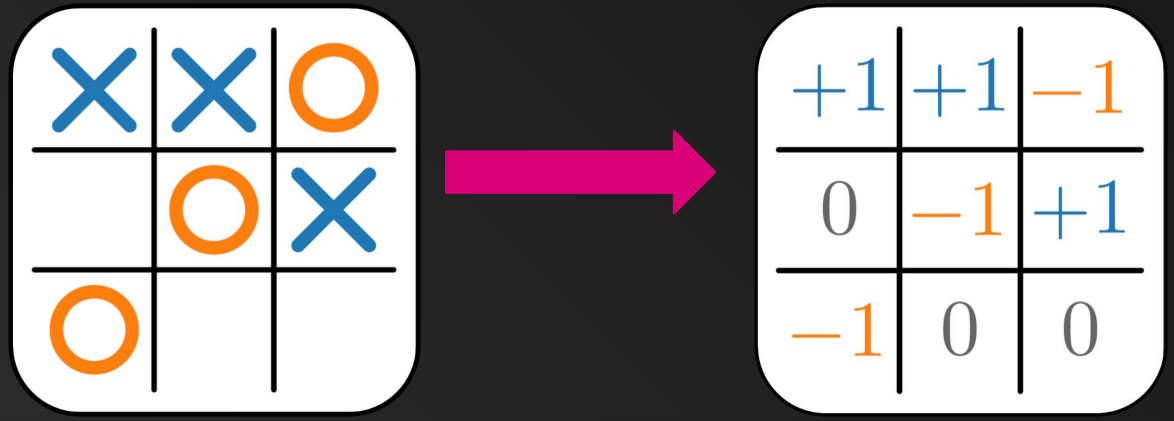
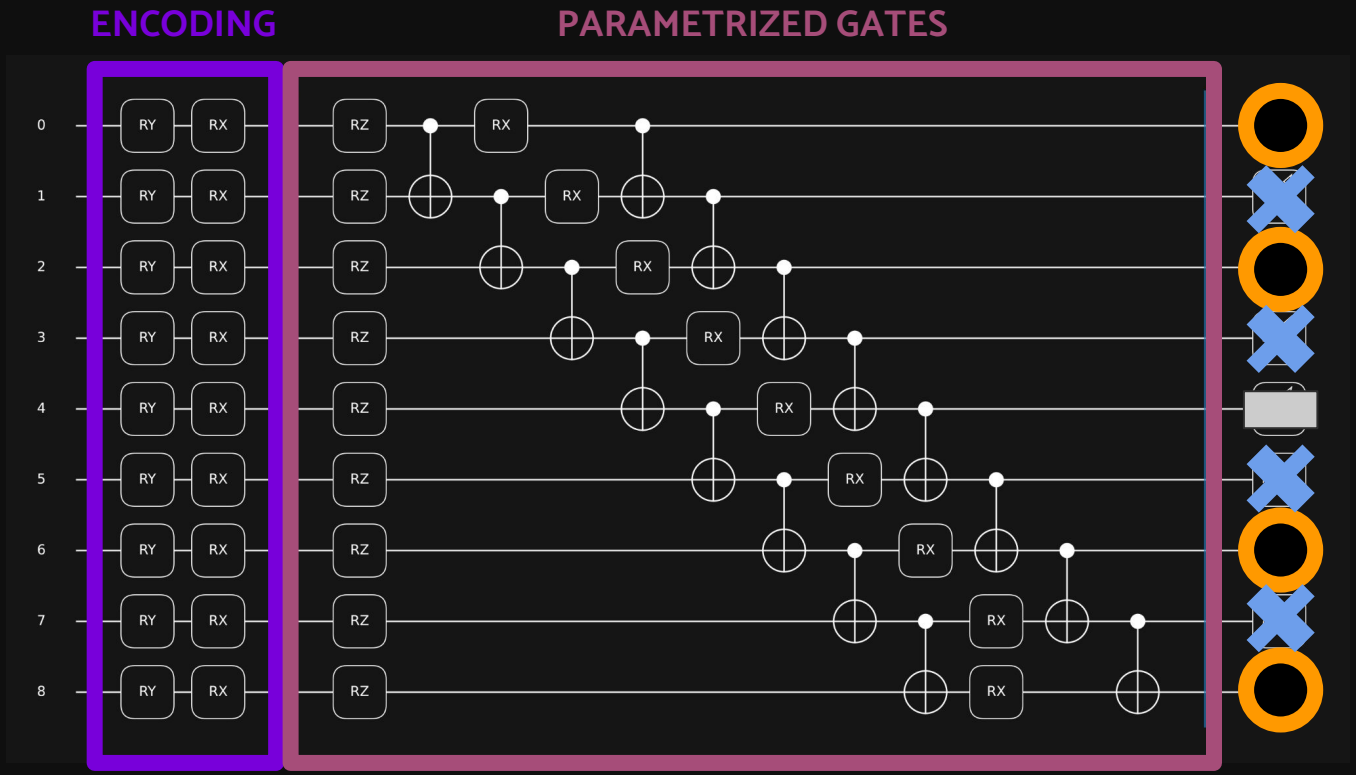
Chiara Ballotta, Davide Cugini, Francesco Ghisoni, Francesco Scala

01
Tic tac toe

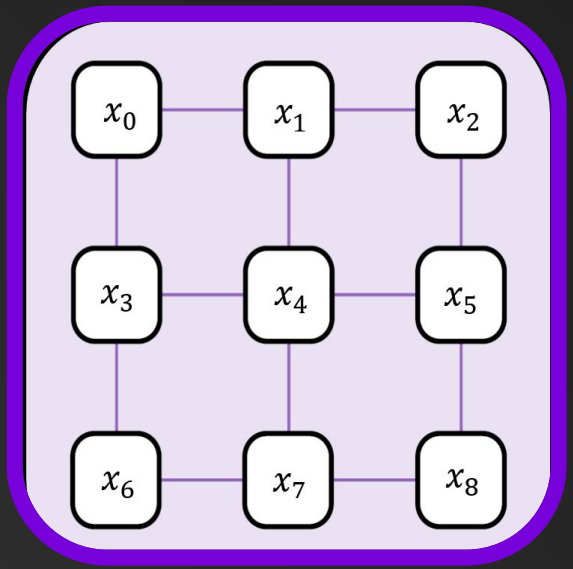
1. Generic QNN
2. Partially symmetric
3. Symmetric

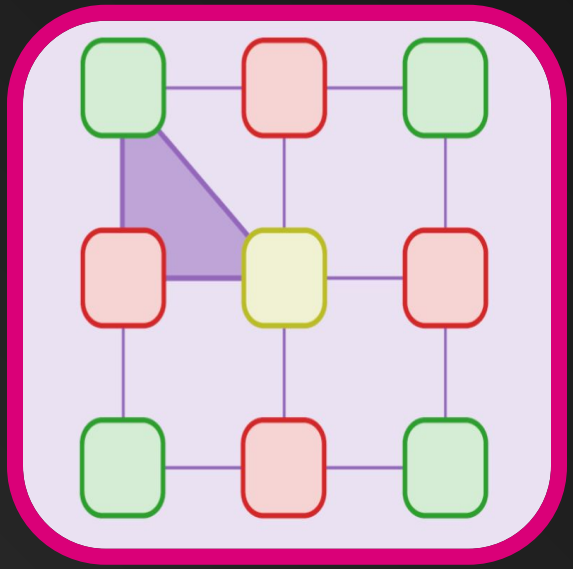


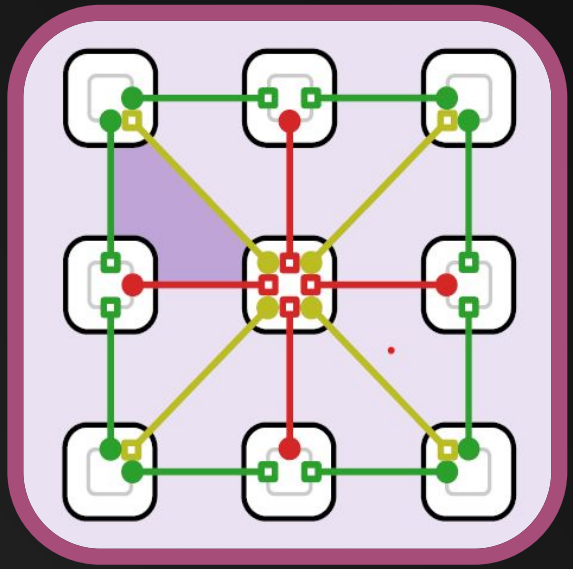
GENERIC QNN



SYMMETRIZATION

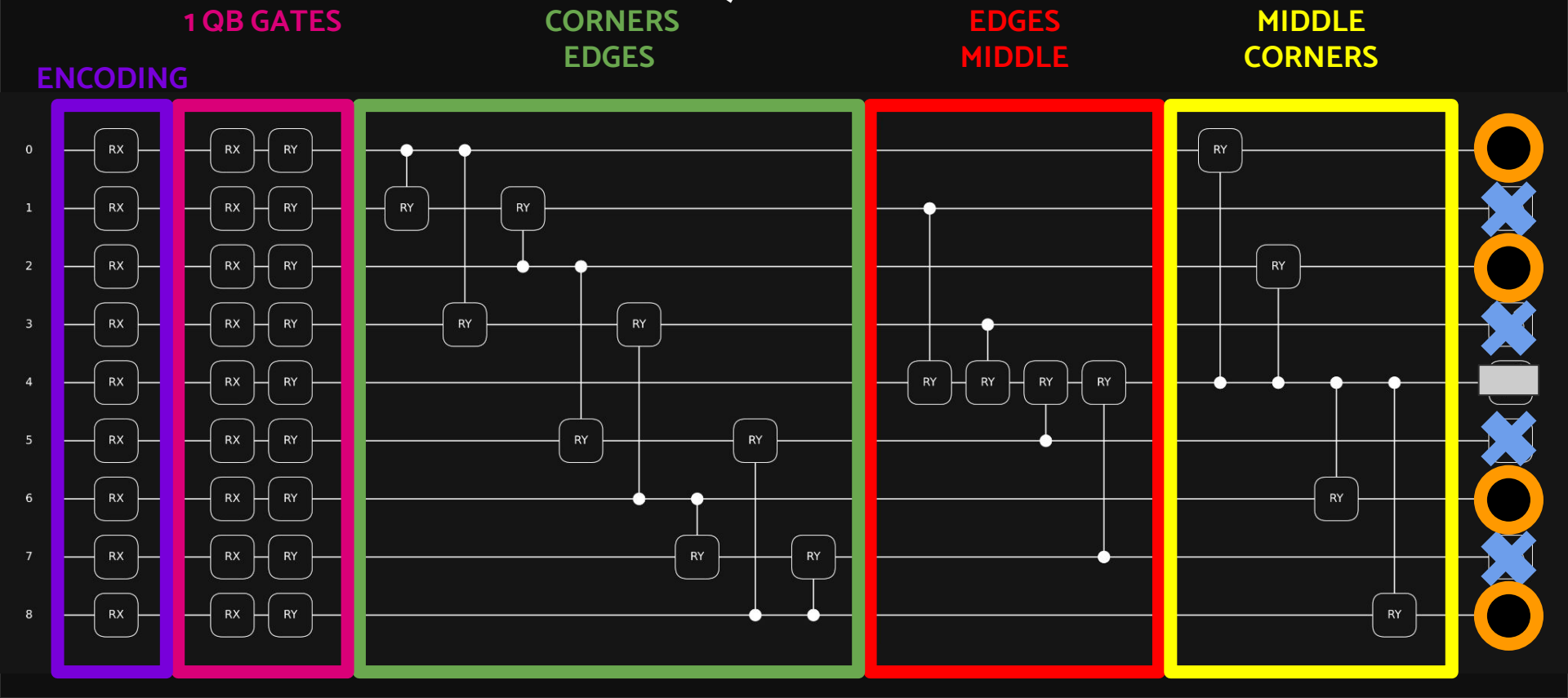




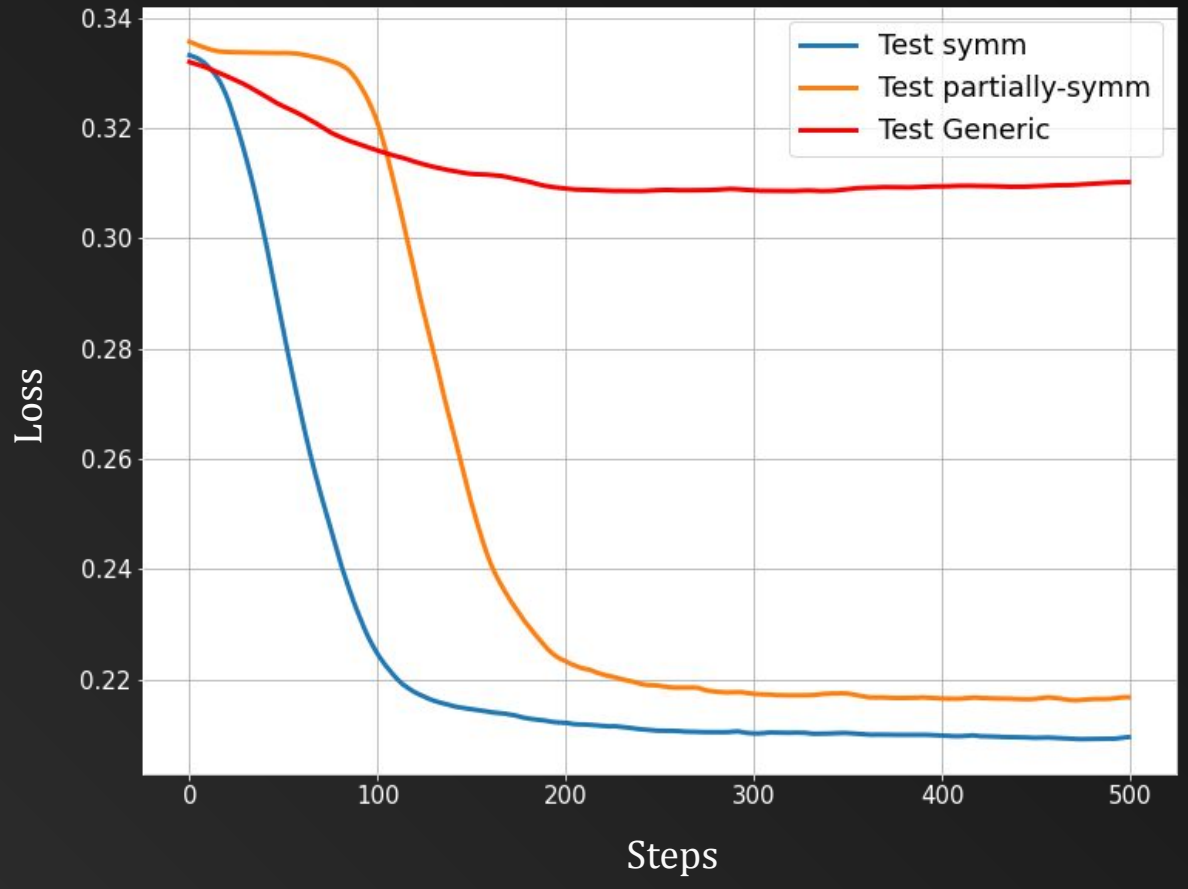


Exploiting Symmetry in Variational Quantum Machine Learning, J.J. Meyer et al.

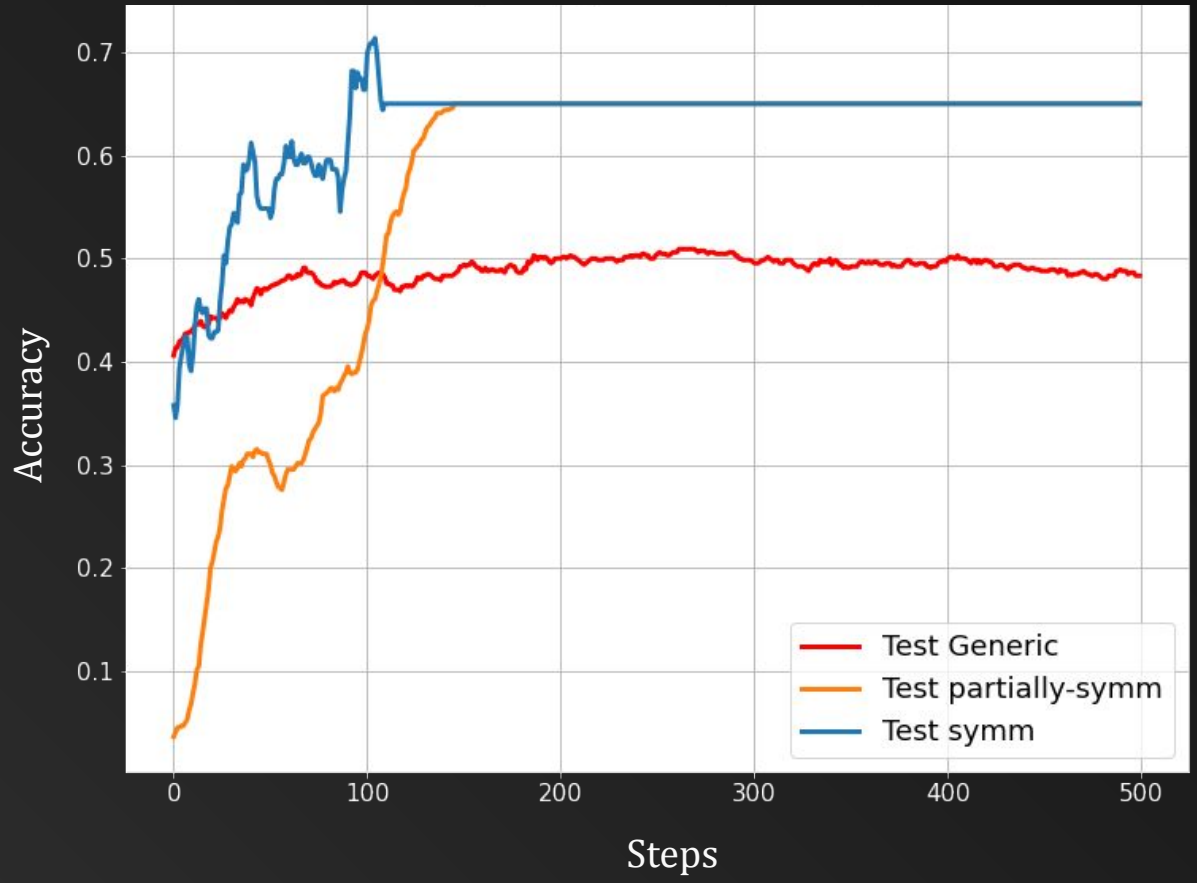
SYMMETRIC QNN



Loss - 3 layers



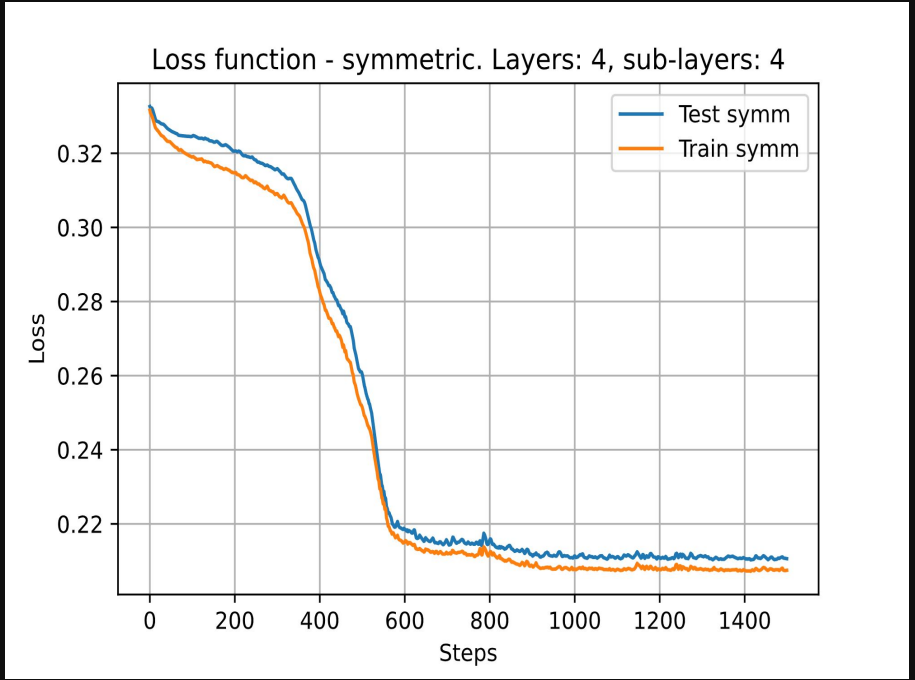
Accuracy- 3 layers



HIGHLIGHT

“Not simulated are circuits for the values (4,4), (4,5), (5,3), (5,4) and (5,5) due to their growing computational demand.”

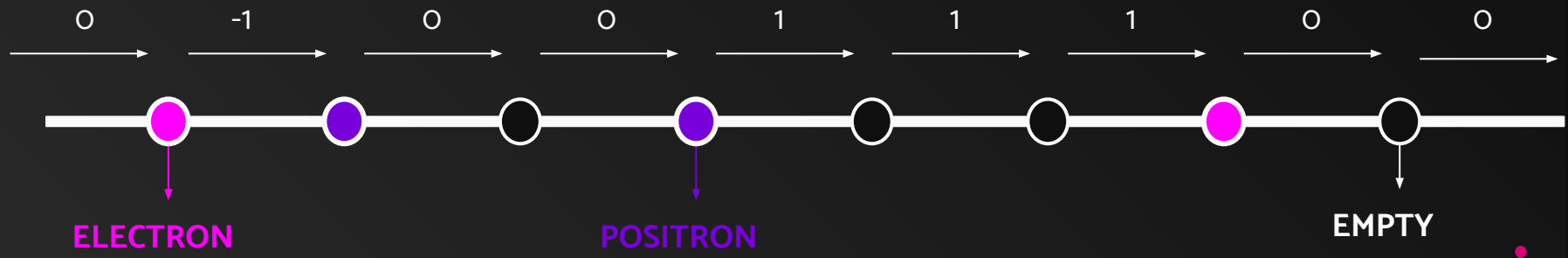
Exploiting Symmetry in Variational Quantum Machine Learning, J.J. Meyer et al.



02
Schwinger model

-Inherently symmetric problem
-Toy model of the Standard Model (1+1 dimensions)
-Spacetime discretized: Lattice formulation

PERIODIC BOUNDARY CONDITIONS

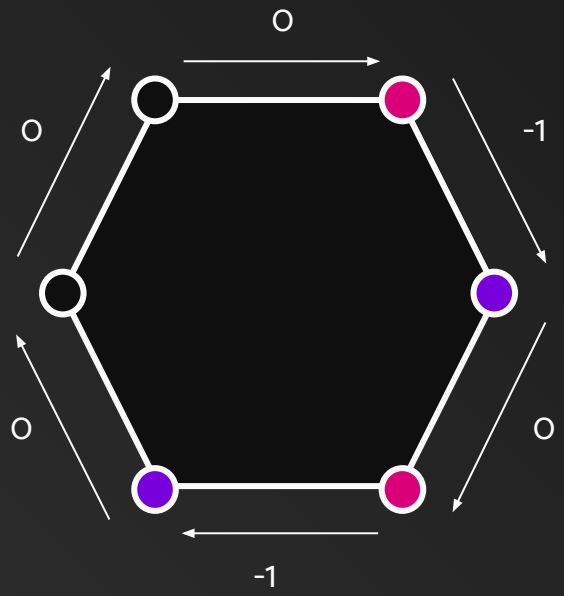


THE HAMILTONIAN

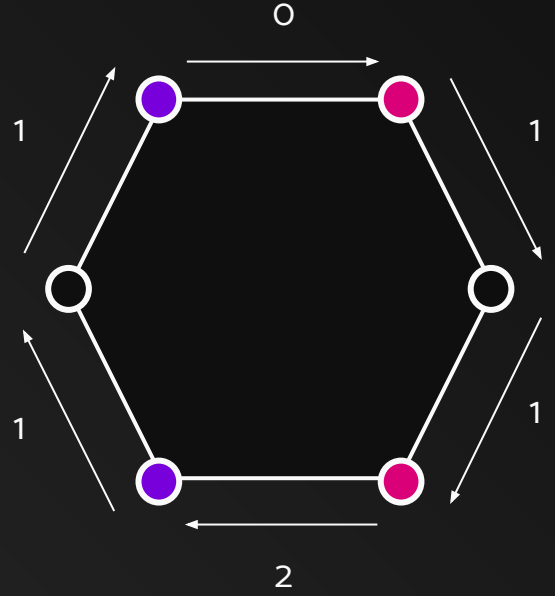
$$\mathrm{H} \propto \Sigma_i E_i^2$$

THE PROBLEM

TRUNCATION: Electric field allowed to vary in an interval ΔE

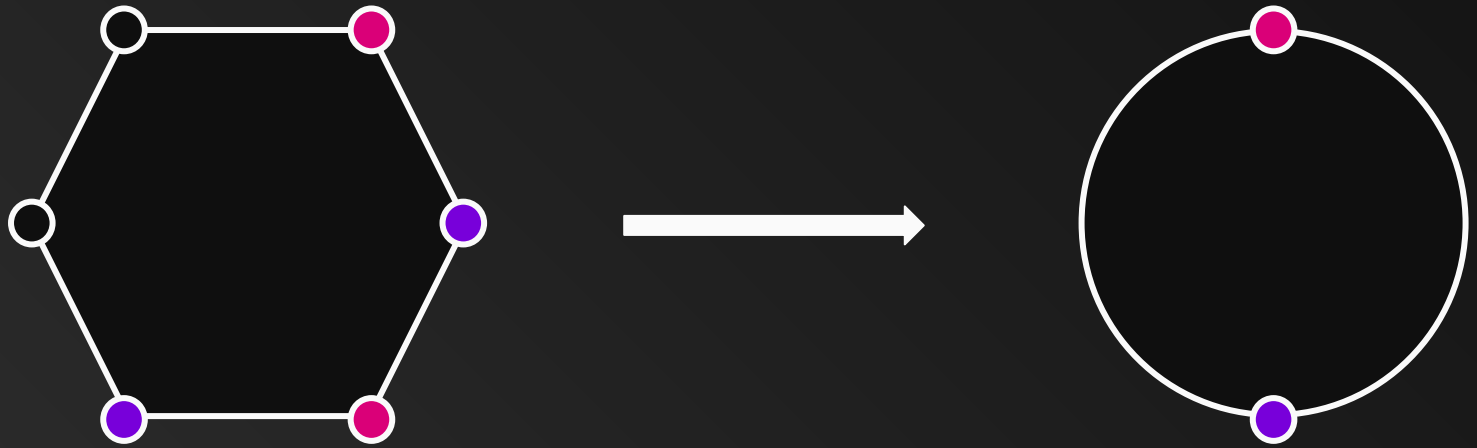


$\Delta E = 1$



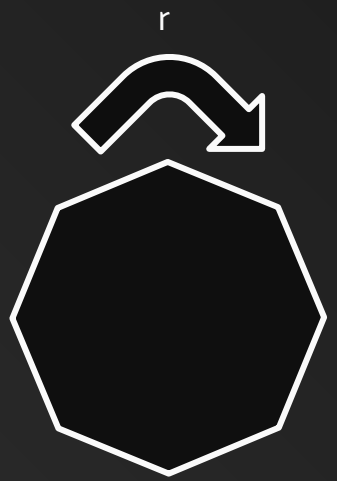
$\Delta E = 2$

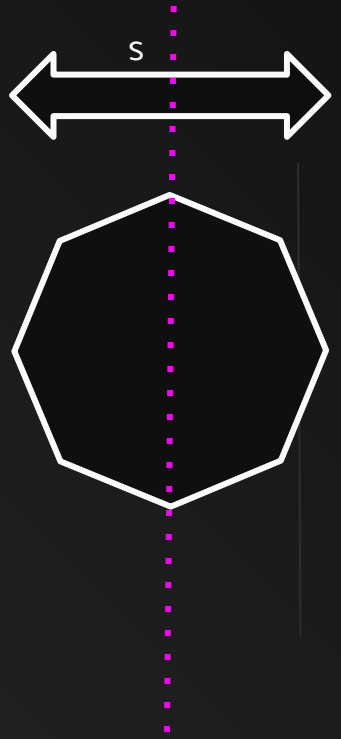
LATTICE REDUCTION



ΔE Is preserved!

SYMMETRY GROUP

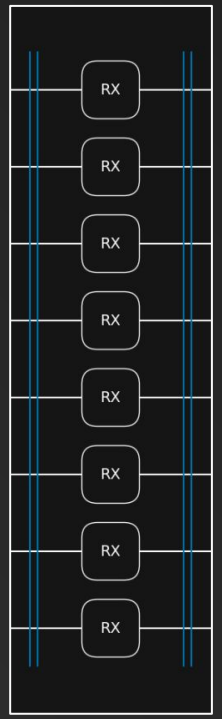


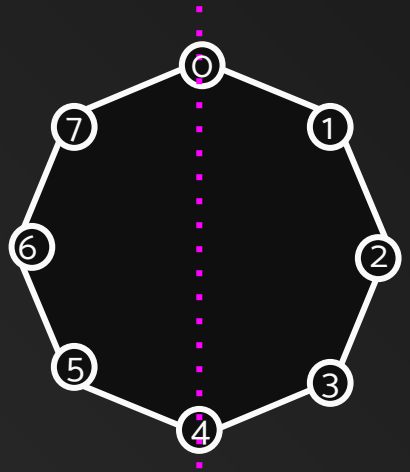


$$\Delta E < 2$$

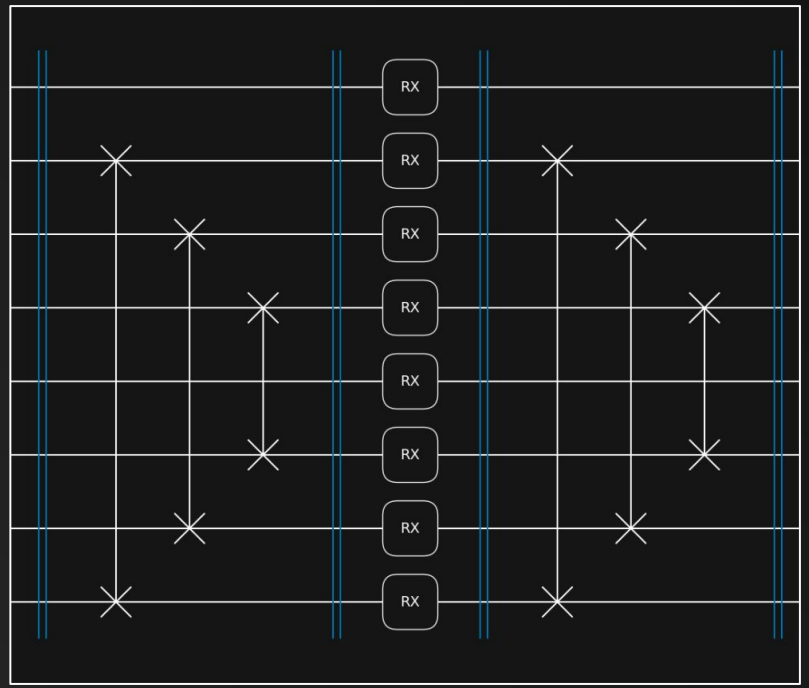
$$N\ sites = 8$$

ENCODING CIRCUIT

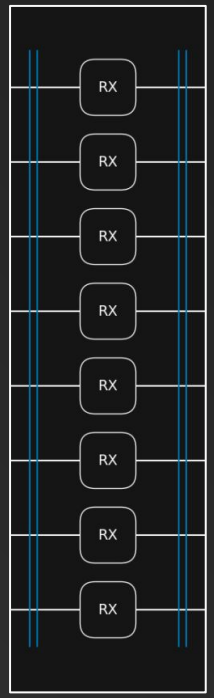


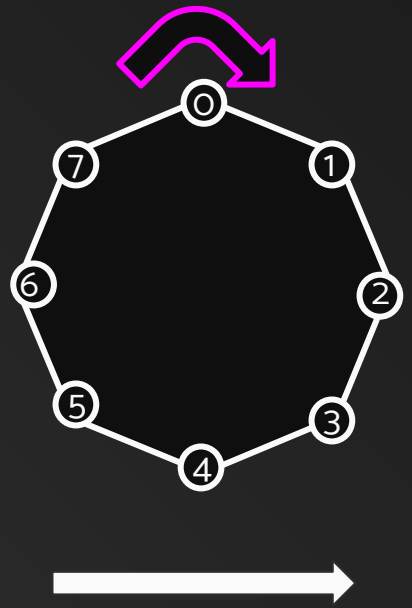


REFLECTION

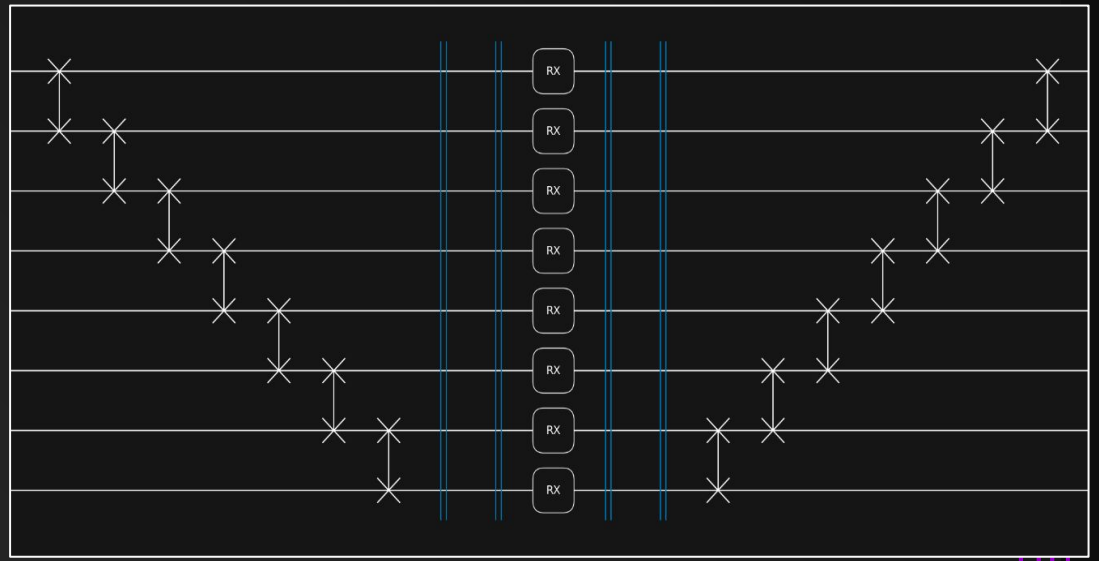


ENCODING CIRCUIT





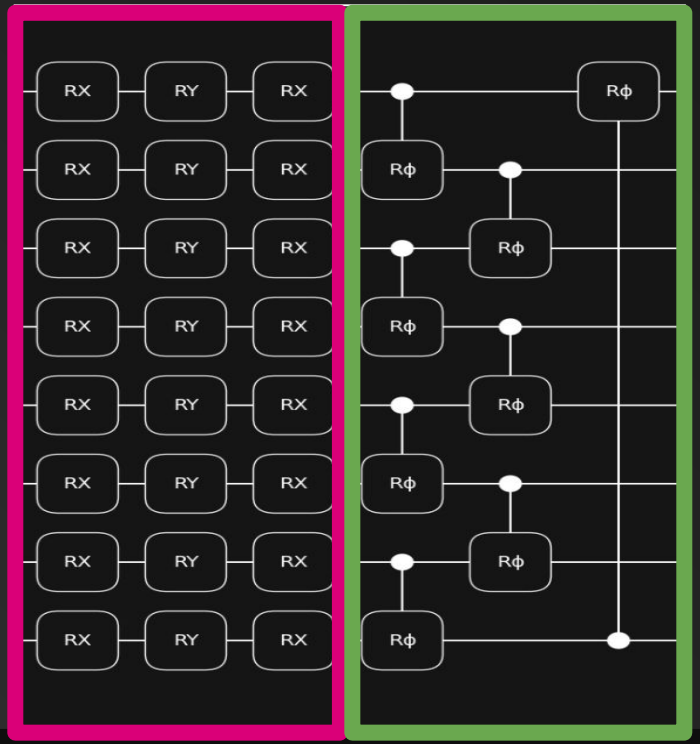
ROTATION



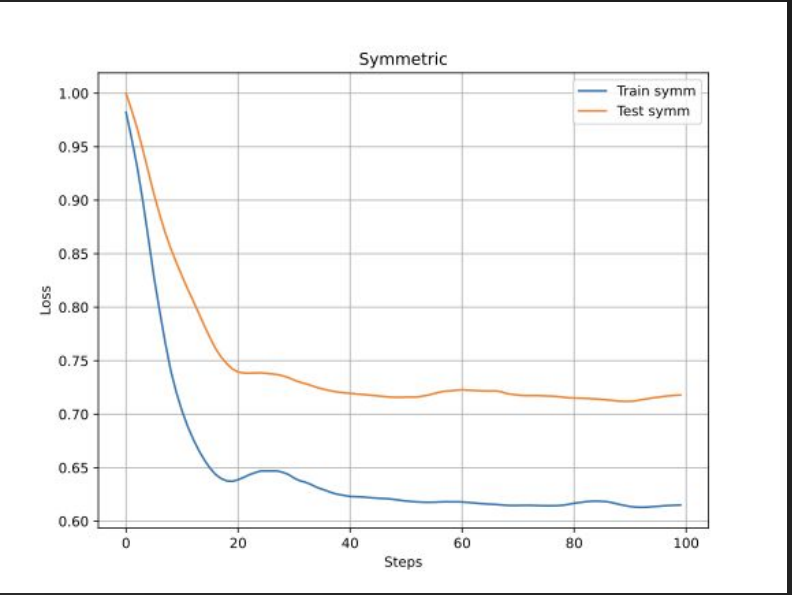
PARAMETRIZED CIRCUIT

1 QB GATES

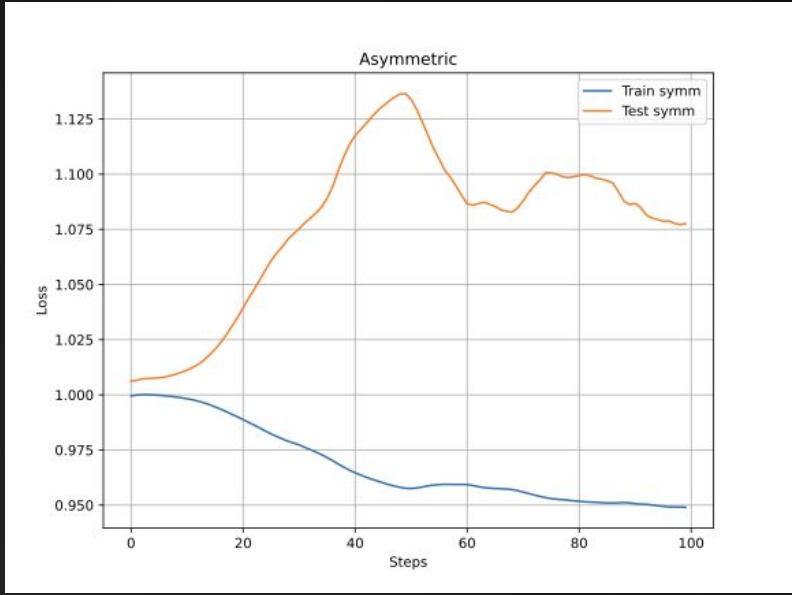
2 QB GATES



RESULTS



Test accuracy ~58%



Test accuracy ~30%

Thank you for your attention!

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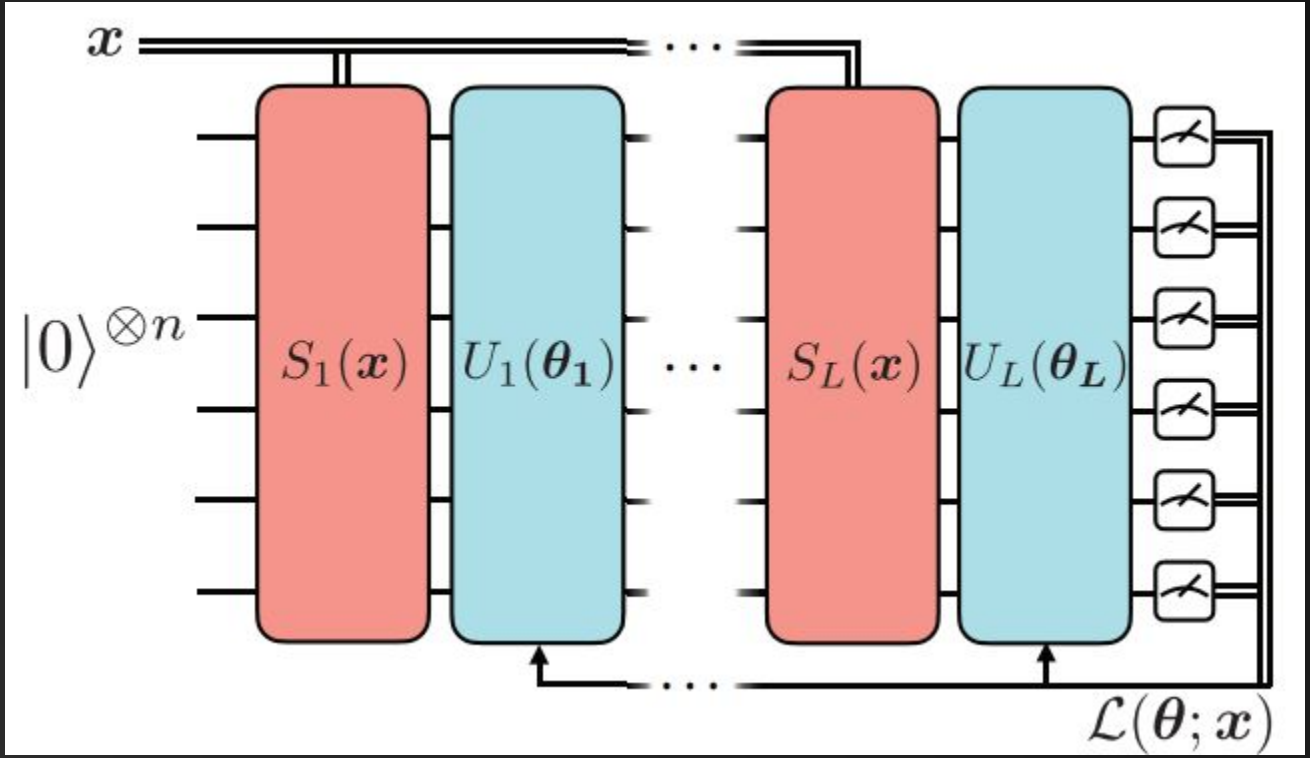
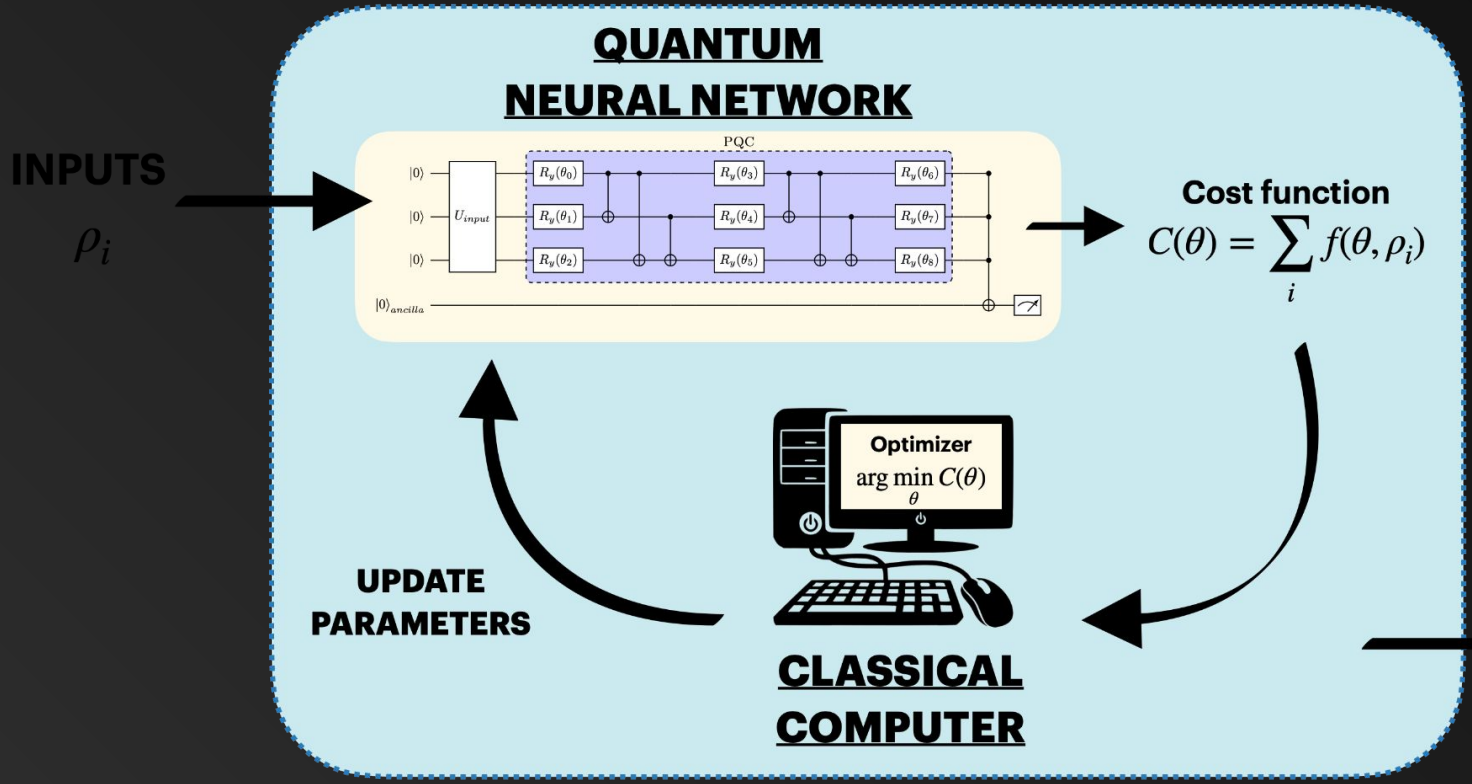
Variational Quantum Algorithms

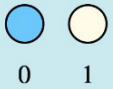



QUANTUM
NEURAL NETWORK
INPUTS
ρ_i
PQC
$|0\rangle$
$|0\rangle$
$|0\rangle$
$|0\rangle_{ancilla}$
U_{input}
$R_y(\theta_0)$
$R_y(\theta_1)$
$R_y(\theta_2)$
$R_y(\theta_3)$
$R_y(\theta_4)$
$R_y(\theta_5)$
$R_y(\theta_6)$
$R_y(\theta_7)$
$R_y(\theta_8)$
Cost function
$C(\theta) = \sum_i f(\theta, \rho_i)$
Optimizer
$\arg\min_\theta C(\theta)$
UPDATE
PARAMETERS
CLASSICAL
COMPUTER
GOAL

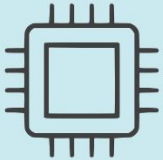
CLASSICAL MACHINE LEARNING (CML)

Classical Computing

BIT

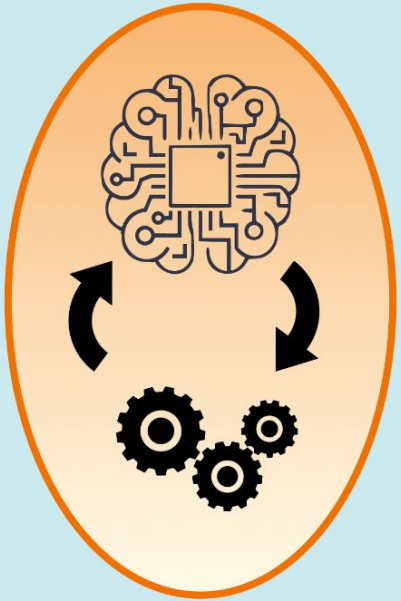


Algorithm



CPU/GPU processing

ML TASK



QUANTUM MACHINE LEARNING (QML)

Quantum Computing

QUBIT

Algorithm

QPU processing

ML TASK

02
Schwinger model

-Toy model of the Standard Model (1+1 dimensions)
-Spacetime discretized: Lattice formulation*

WHY ON A LATTICE? QCD can’t be treated perturbatively at low energies

WHY ON A QUANTUM DEVICE? Real time evolution + avoid sign problem

BARREN PLATEU