QUANTINUUM

QCC MTY IE

Ángel Reyna

Edgar Hernández

Justin Hou

Nana Marie Werther

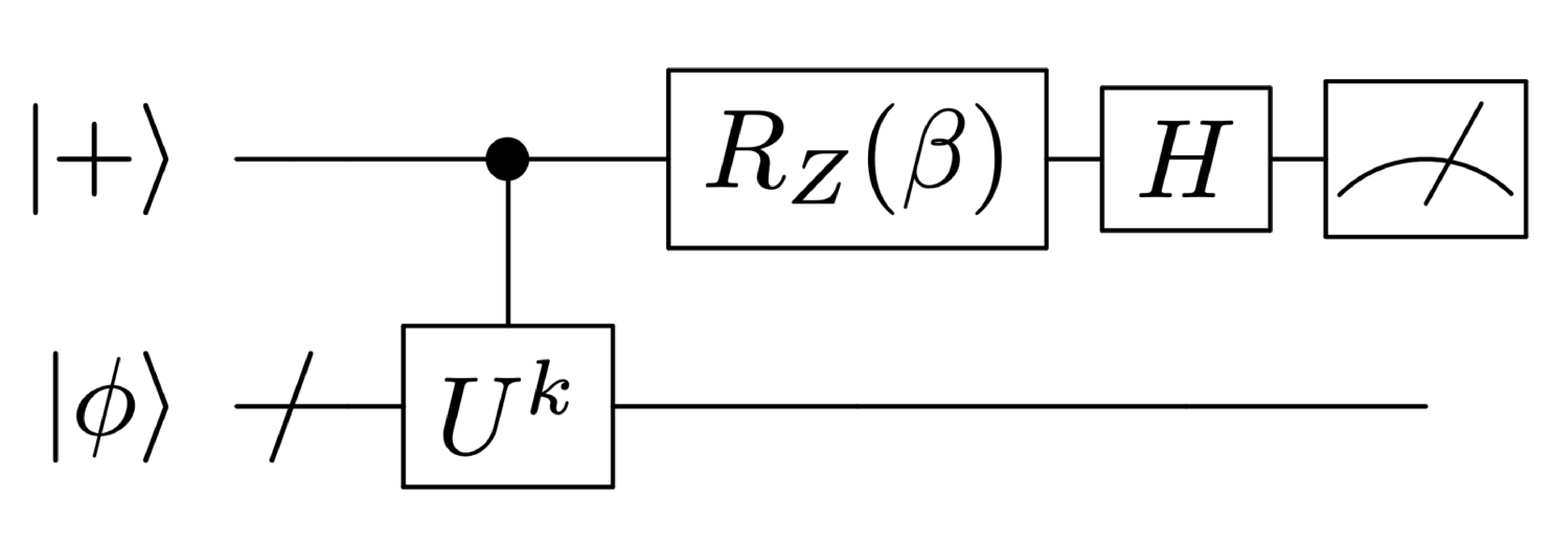
Santiago Copado

Quantum Phase Estimation

4th Feb 2024

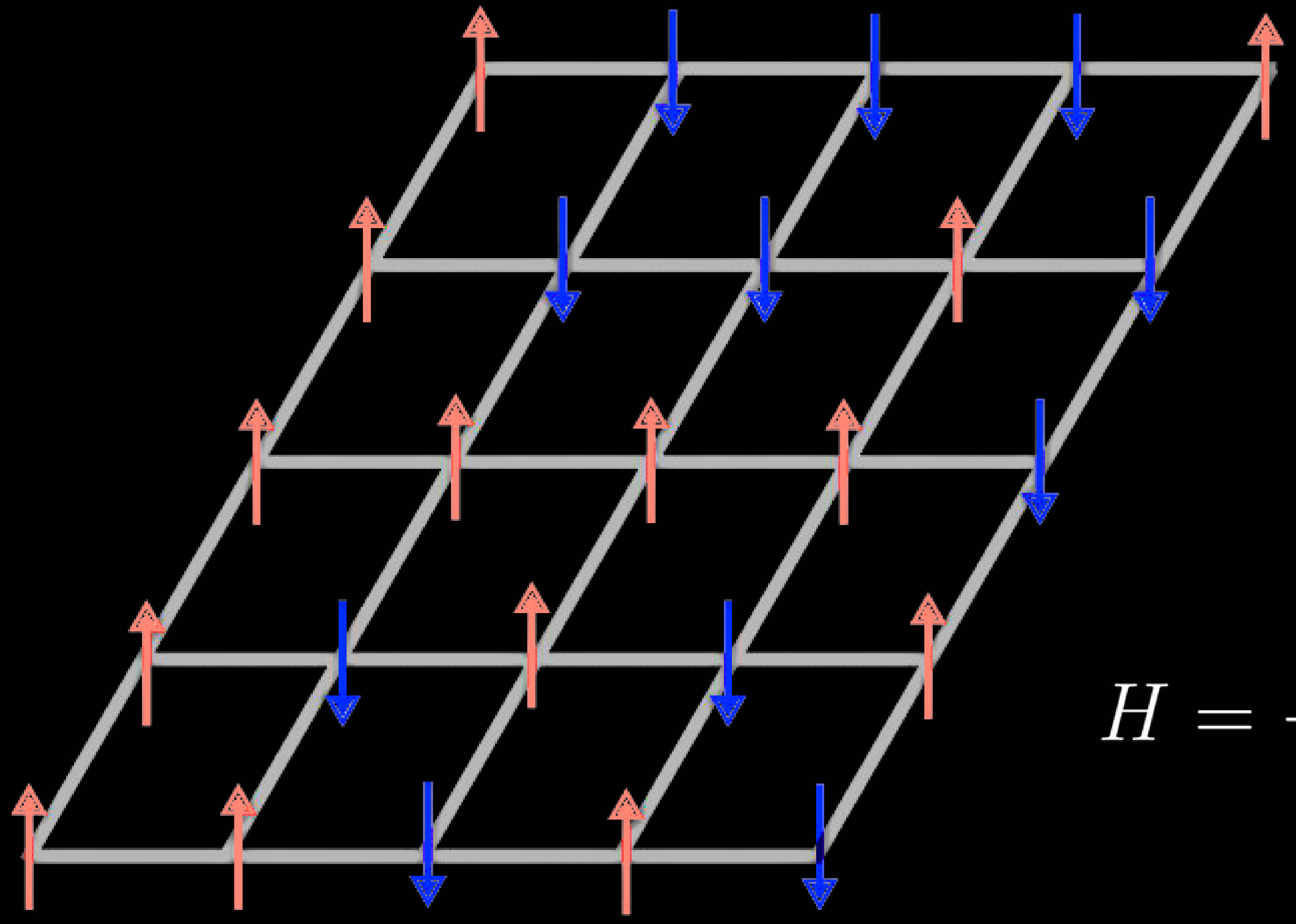
iQuHACK 2024

Background



Classic and Bayesian QPE

2D ISING Model



Finding the true global ground state!

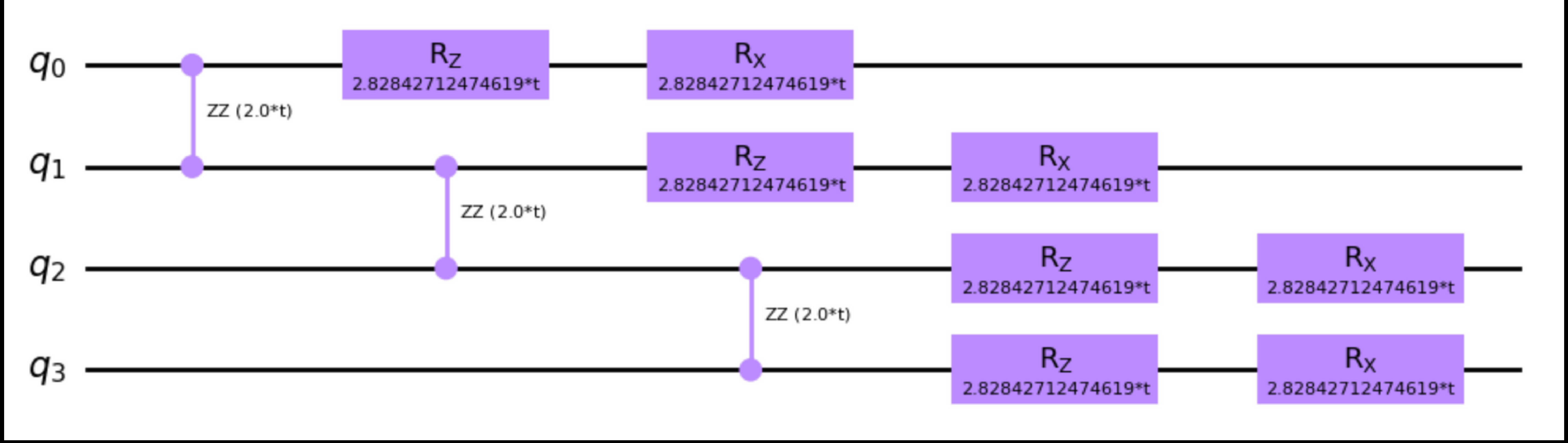
$$H = -J \sum_{i=0}^{L-2} \sigma_i \sigma_{i+1} - h \sum_{i=0}^{L-1} \sigma_i$$

$$H = -J \sum_{i=0}^{L-2} Z_i Z_{i+1} - h \sum_{i=0}^{L-1} (\sin\alpha Z_i + \cos\alpha X_i)$$

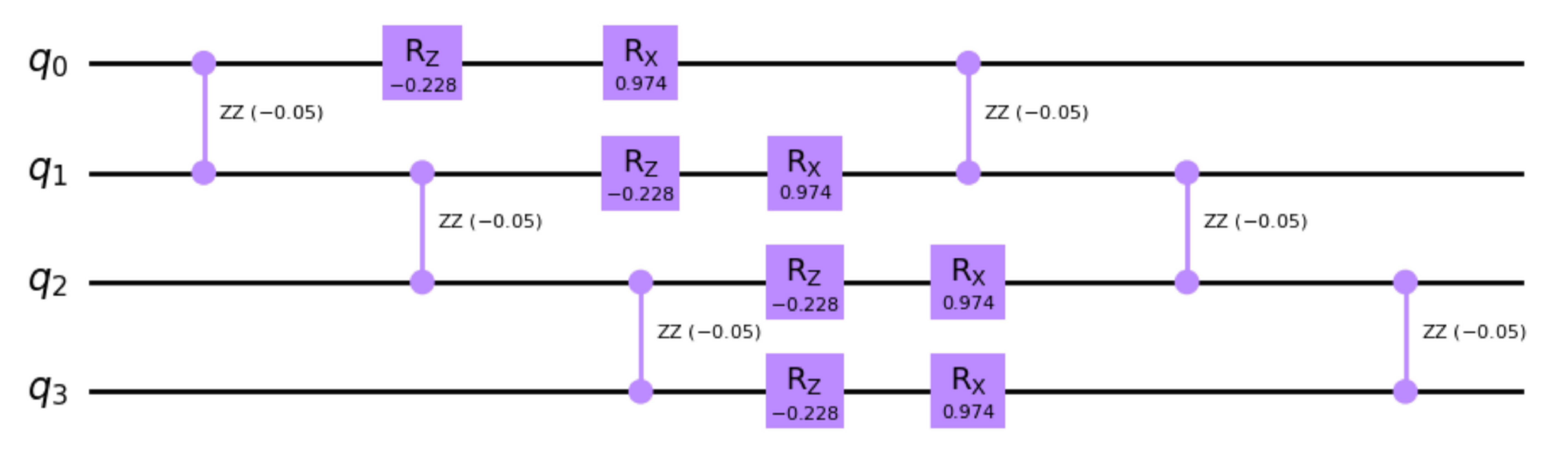
QUANTINUUM

iQuHACK 2024

Trotter step with Lie-Trotter



Trotter step with Suzuki Trotter (2nd order)



QUANTINUUM

iQuHACK 2024

Evidence

Optimizing quantum phase estimation for the simulation of Hamiltonian eigenstates

P. M. Q. Cruz[1,2,*], G. Catarina[1], R. Gautier[1,3], J. Fernández-Rossier[1,†]

[1] *QuantaLab, International Iberian Nanotechnology Laboratory (INL), Av. Mestre José Veiga, 4715-330 Braga, Portugal*

[2] *Departamento de Física e Astronomia, Faculdade de Ciências da Universidade do Porto, 4169-007 Porto, Portugal*

[3] *CentraleSupélec, Université Paris-Saclay, 91190 Gif-Sur-Yvette, France*

(Dated: August 3, 2020)

We revisit quantum phase estimation algorithms for the purpose of obtaining the energy levels of many-body Hamiltonians and pay particular attention to the statistical analysis of their outputs. We introduce the mean phase direction of the parent distribution associated with eigenstate inputs as a new post-processing tool. By connecting it with the unknown phase, we find that if used as its direct estimator, it exceeds the accuracy of the standard majority rule using one less bit of resolution, making evident that it can also be inverted to provide unbiased estimation. Moreover, we show how to directly use this quantity to accurately find the energy levels when the initialized state is an eigenstate of the simulated propagator during the whole time evolution, which allows for shallower algorithms. We then use IBM Q hardware to carry out the digital quantum simulation of three toy models: a two-level system, a two-spin Ising model and a two-site Hubbard model at half-filling. Methodologies are provided to implement Trotterization and reduce the variability of results in noisy intermediate scale quantum computers.

Exact Ising model simulation on a quantum computer

Alba Cervera-Lierta[1,2]

[1] Barcelona Supercomputing Center (BSC), Barcelona, Spain

[2] Institut de Ciències del Cosmos, Universitat de Barcelona, Barcelona, Spain

December 20, 2018

Completeness of the classical 2D Ising model and universal quantum computation

M. Van den Nest[1], W. Dür[1,2], and H. J. Briegel[1,2]

[1] *Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Innsbruck, Austria*

[2] *Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck, Austria*

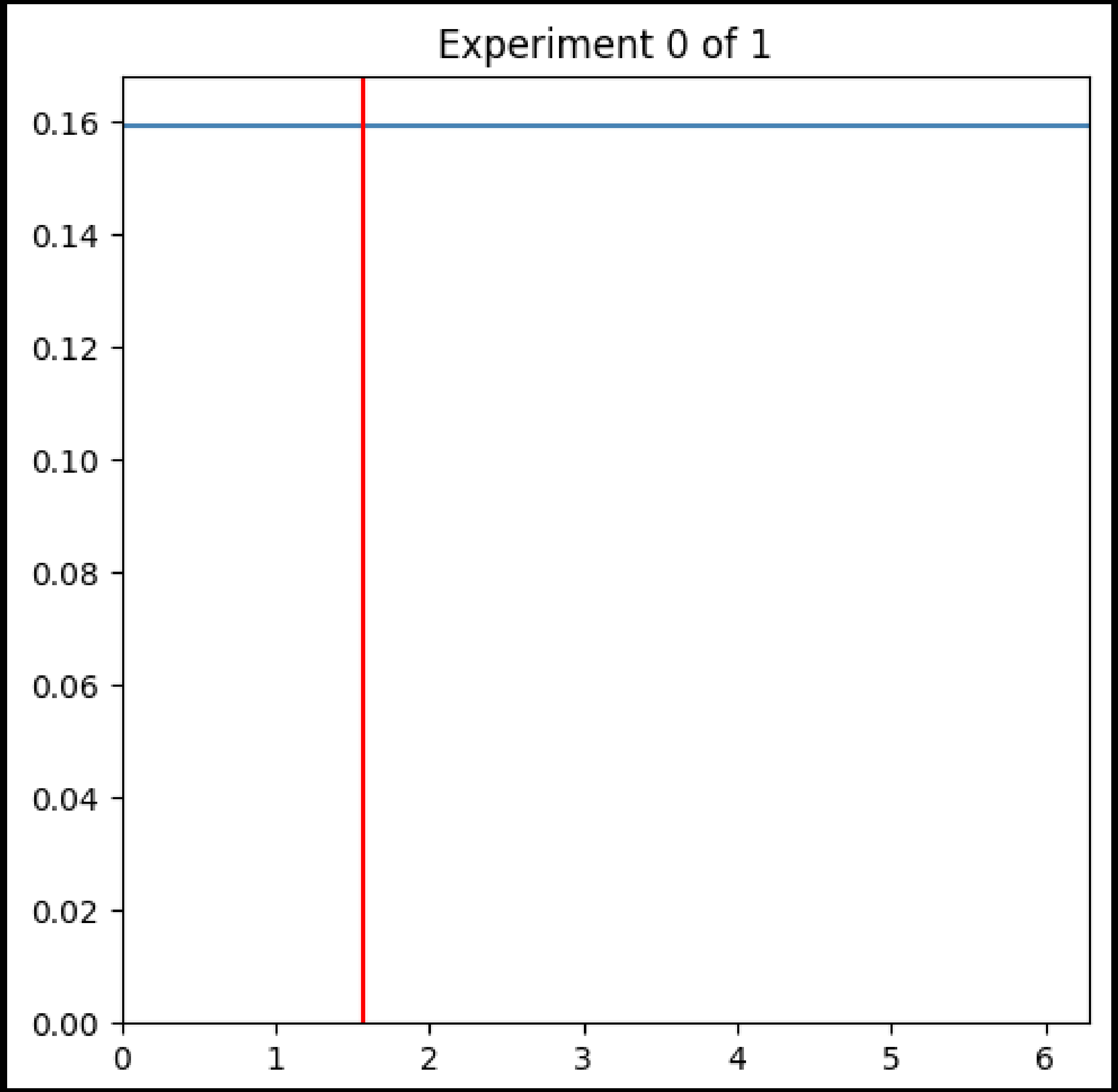
(Dated: October 22, 2018)

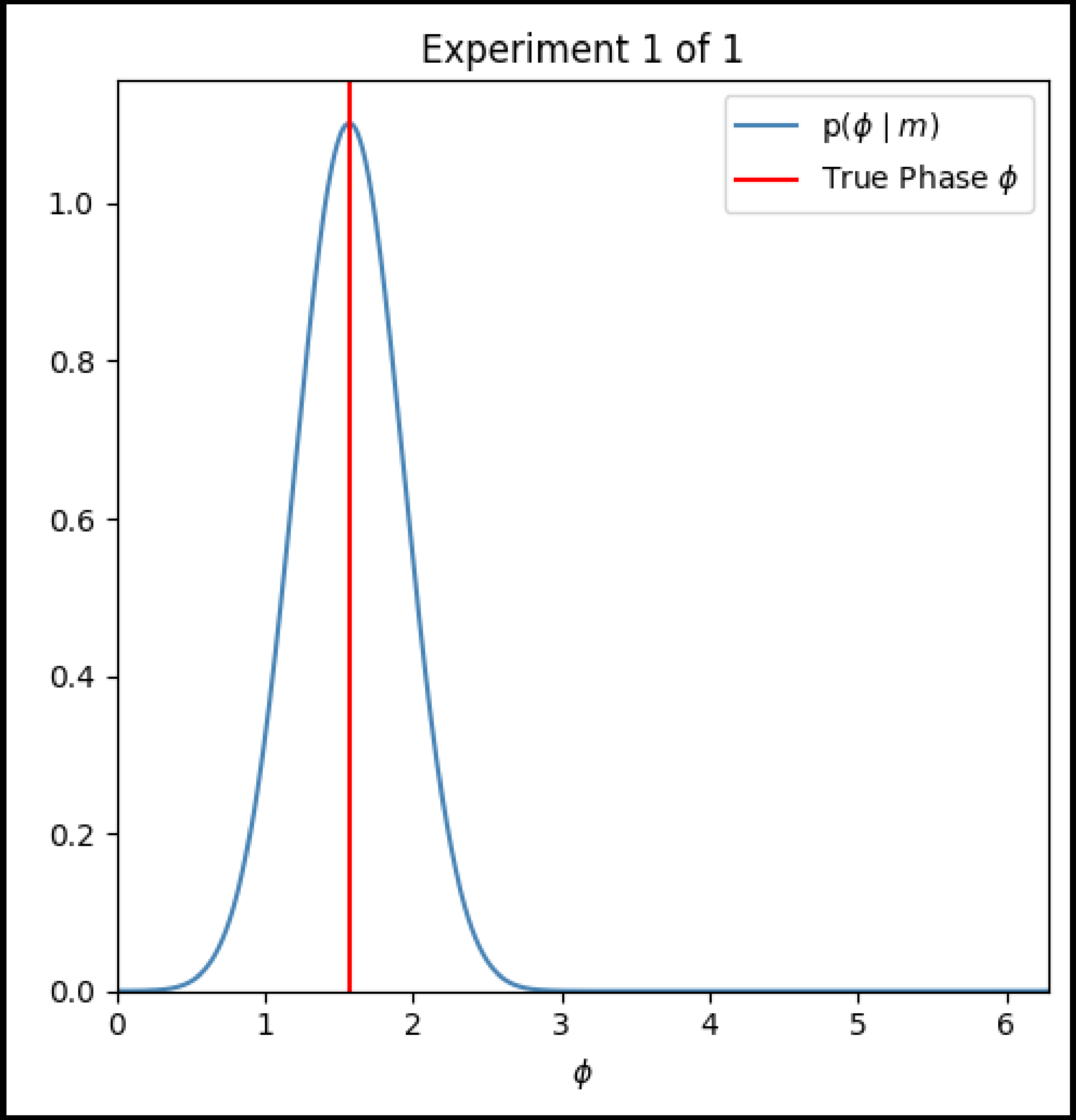
We prove that the 2D Ising model is *complete* in the sense that the partition function of any classical q-state spin model (on an arbitrary graph) can be expressed as a special instance of the partition function of a 2D Ising model with complex inhomogeneous couplings and external fields. In the case where the original model is an Ising or Potts-type model, we find that the corresponding 2D square lattice requires only polynomially more spins w.r.t the original one, and we give a constructive method to map such models to the 2D Ising model. For more general models the overhead in system size may be exponential. The results are established by connecting classical spin models with measurement-based quantum computation and invoking the universality of the 2D cluster states.

PACS numbers: 03.67.-a, 03.67.Lx, 75.10.Hk, 75.10.Pq, 02.70.-c

Results

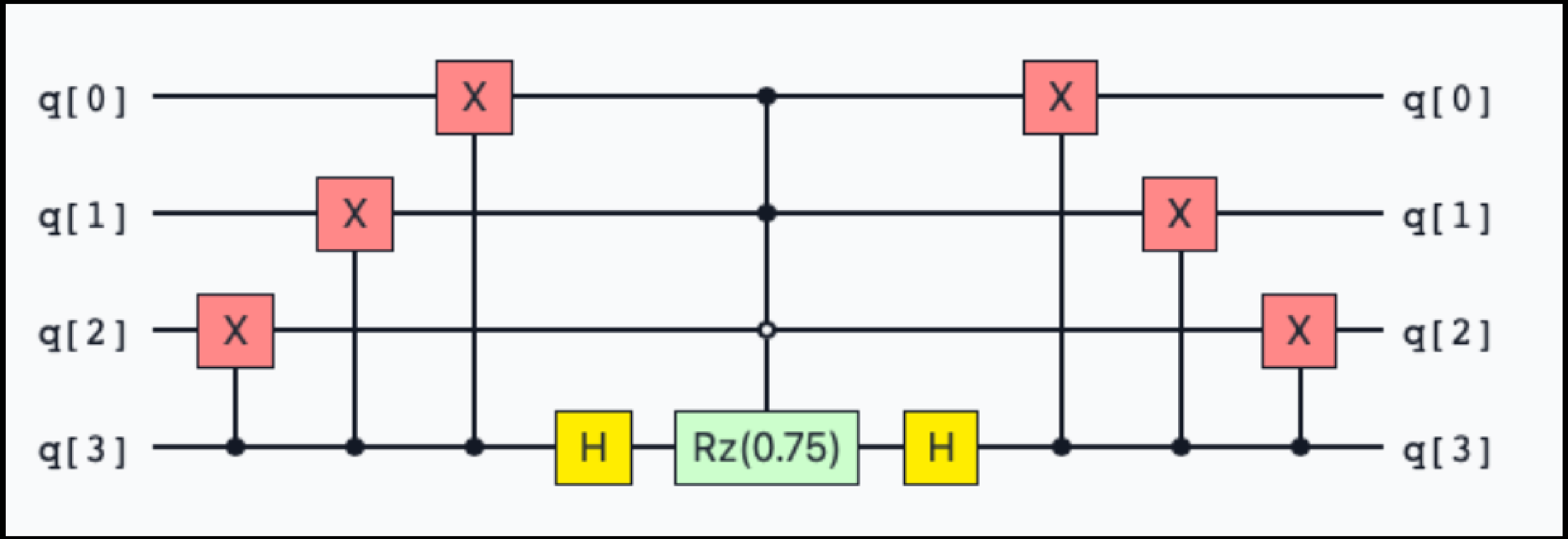
Bayesian Model

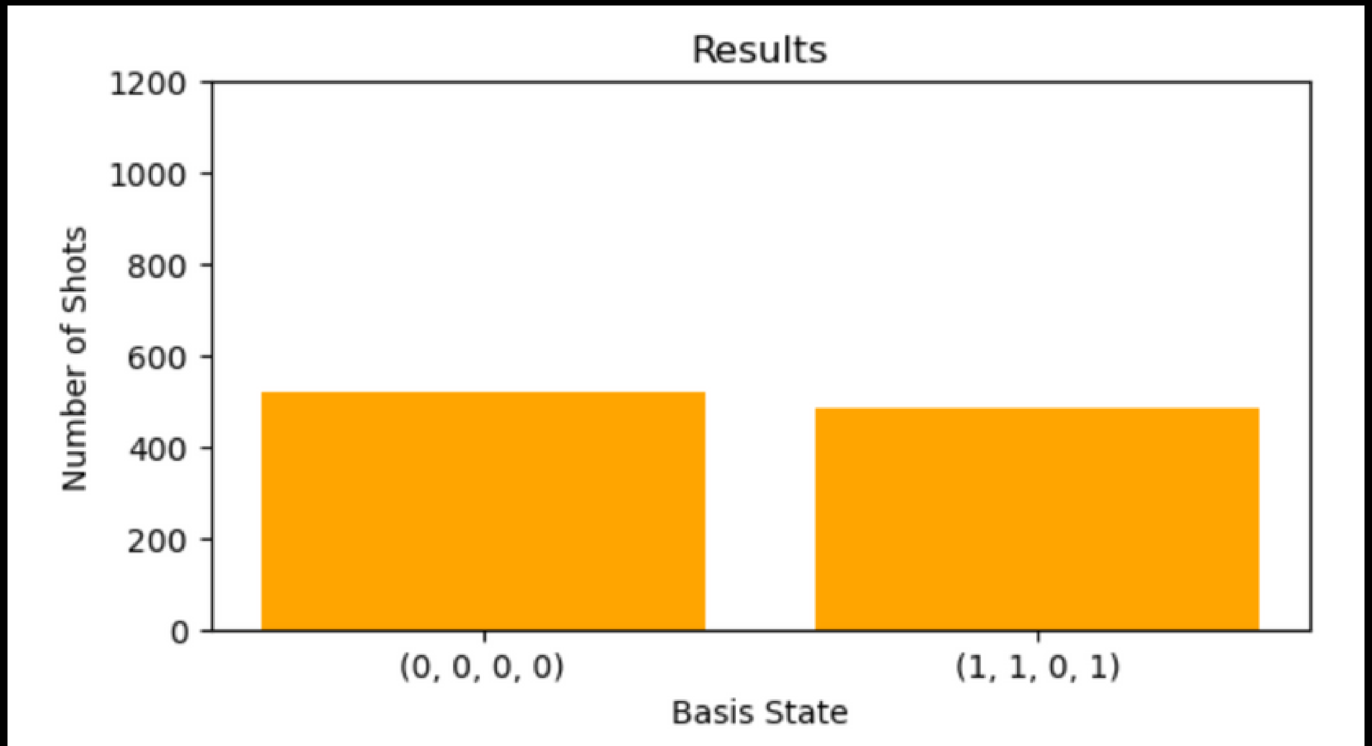


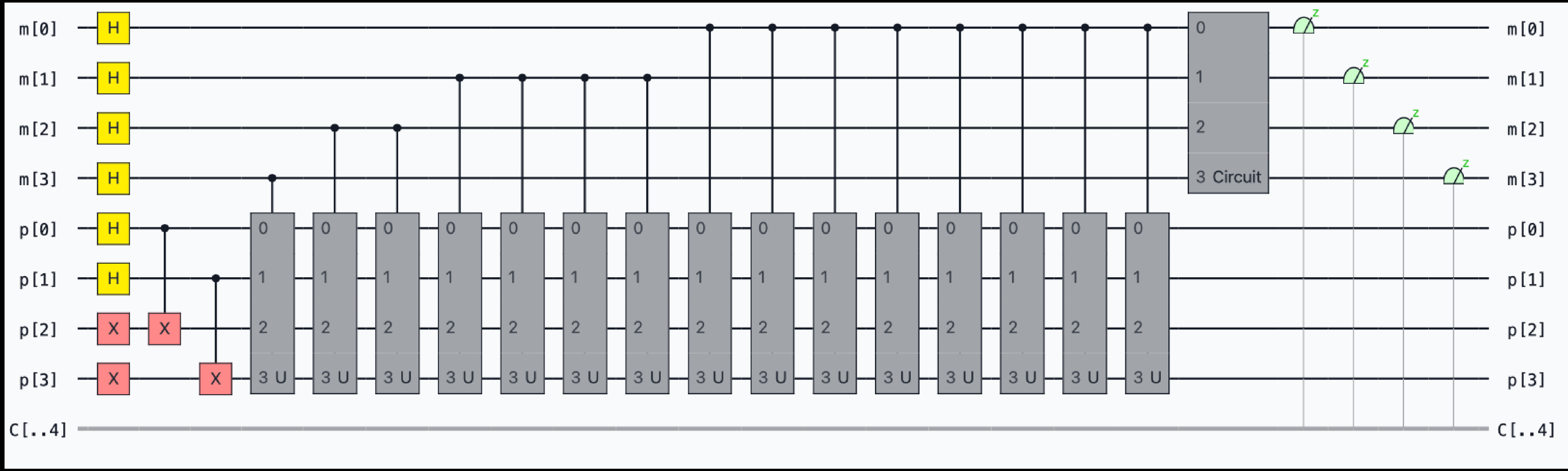


QUANTINUUM

iQuHACK 2024


q[0]
q[1]
q[2]
q[3]
X
H
Rz(0.75)
H


Results
Number of Shots
0
200
400
600
800
1000
1200
(0, 0, 0, 0)
(1, 1, 0, 1)
Basis State


m[0]
m[1]
m[2]
m[3]
p[0]
p[1]
p[2]
p[3]
C[..4]
H
X
U
3 Circuit
z