



Introduction to Quantum Machine Learning

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DISCUSSION POINTS

Overview

Introduction to Quantum Systems

Qubits & Properties

Quantum Entanglement

Quantum Entanglement with Q#

ML Overview

QML Intuition

ML vs QML

Applications of QML

Demo of Classification using Q#

Summary

QUANTUM IN THE NEWS

- IBM promises 1000-qubit quantum computer—a milestone—by 2023

Source: newsroom.ibm.com

- Quantum Computer with Quantum Volume 64

Source: [Honeywell.com](https://www.honeywell.com)

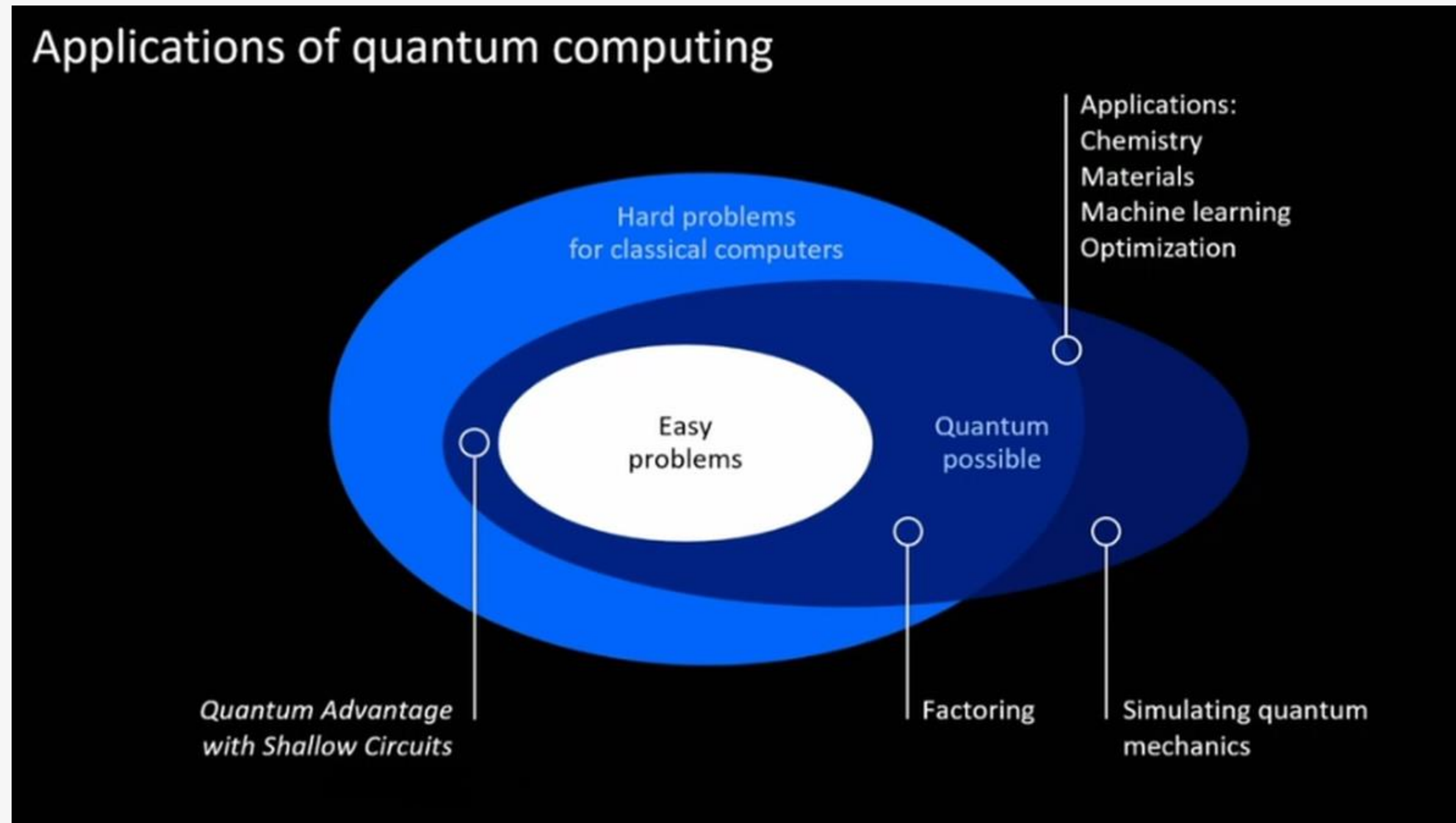
- 64 Quantum Volume Cloud Accessible Computer

Source: newsroom.ibm.com



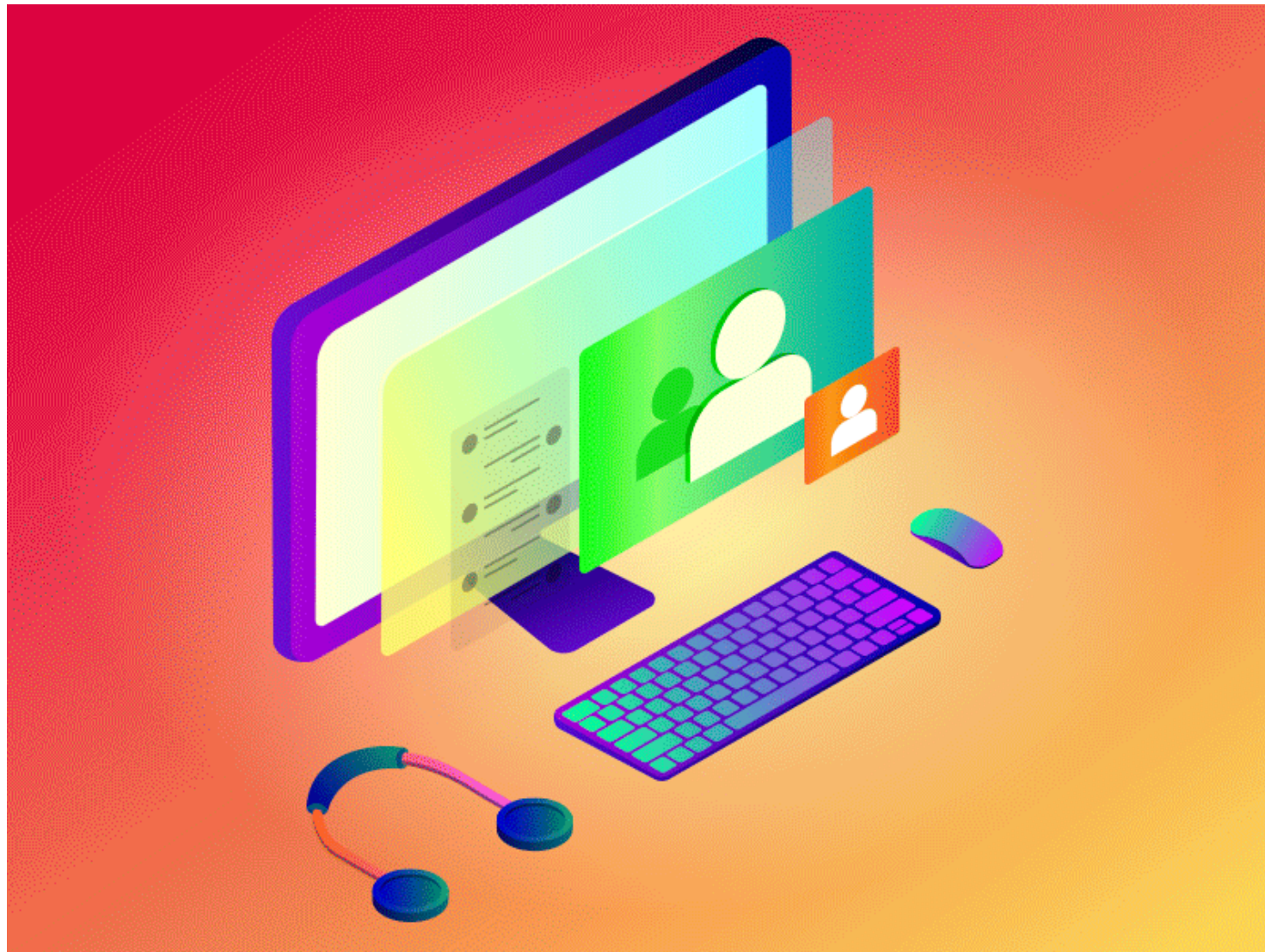
IBM Q System

APPLICATIONS OF QUANTUM COMPUTERS



Source: ibm.com

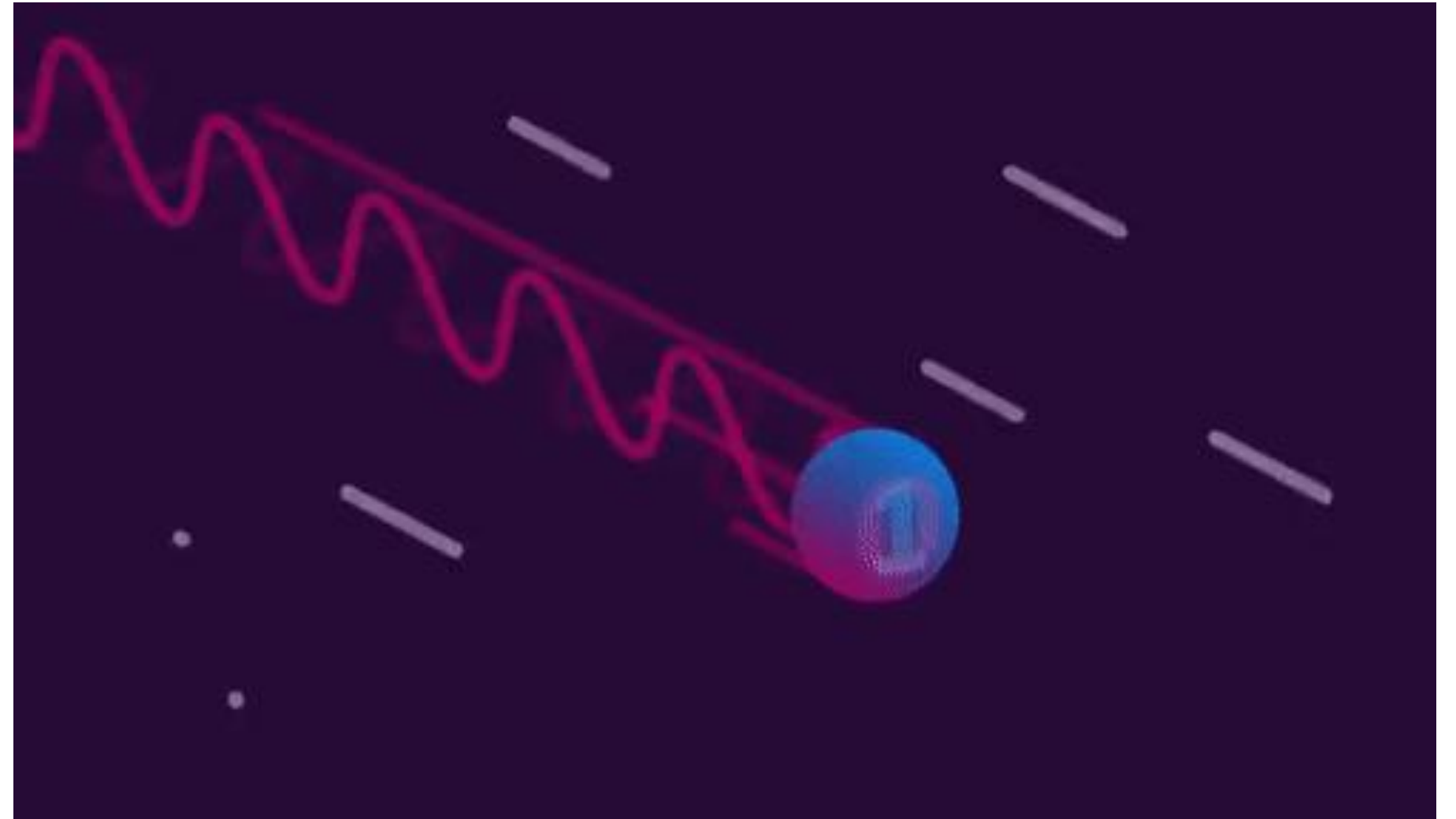
CLASSICAL COMPUTERS



QUBITS



IBM Q System

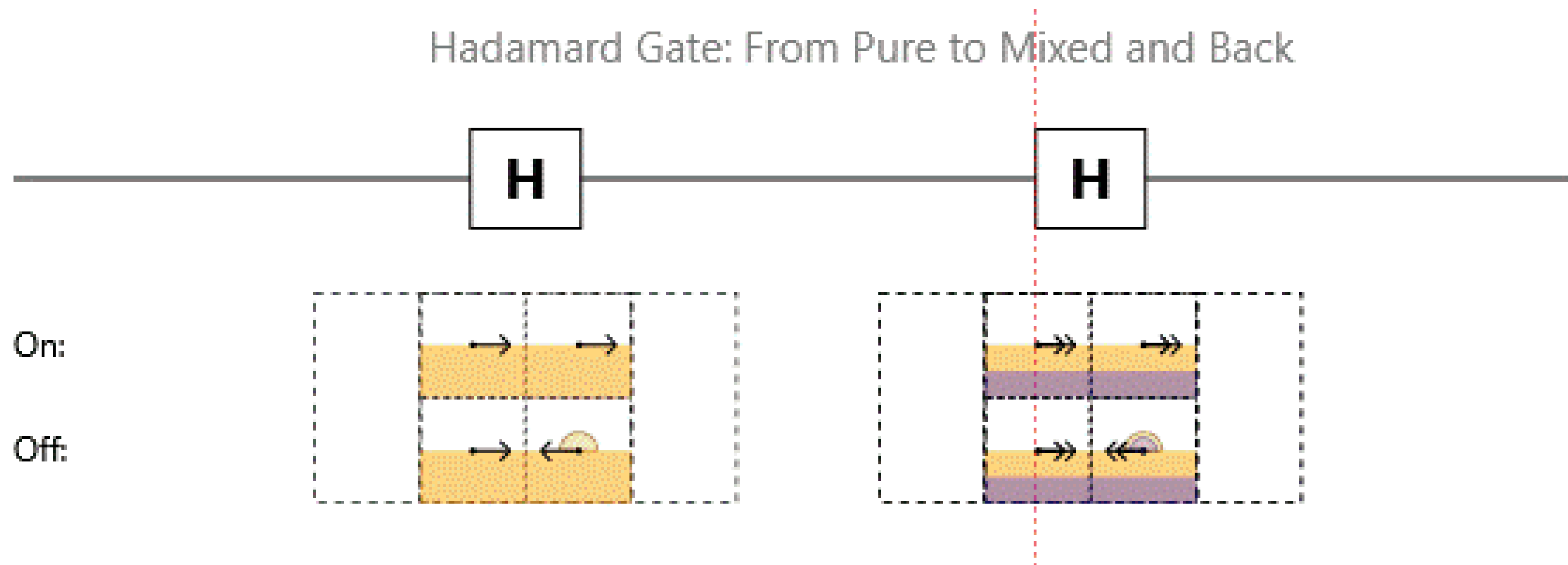


Superposition

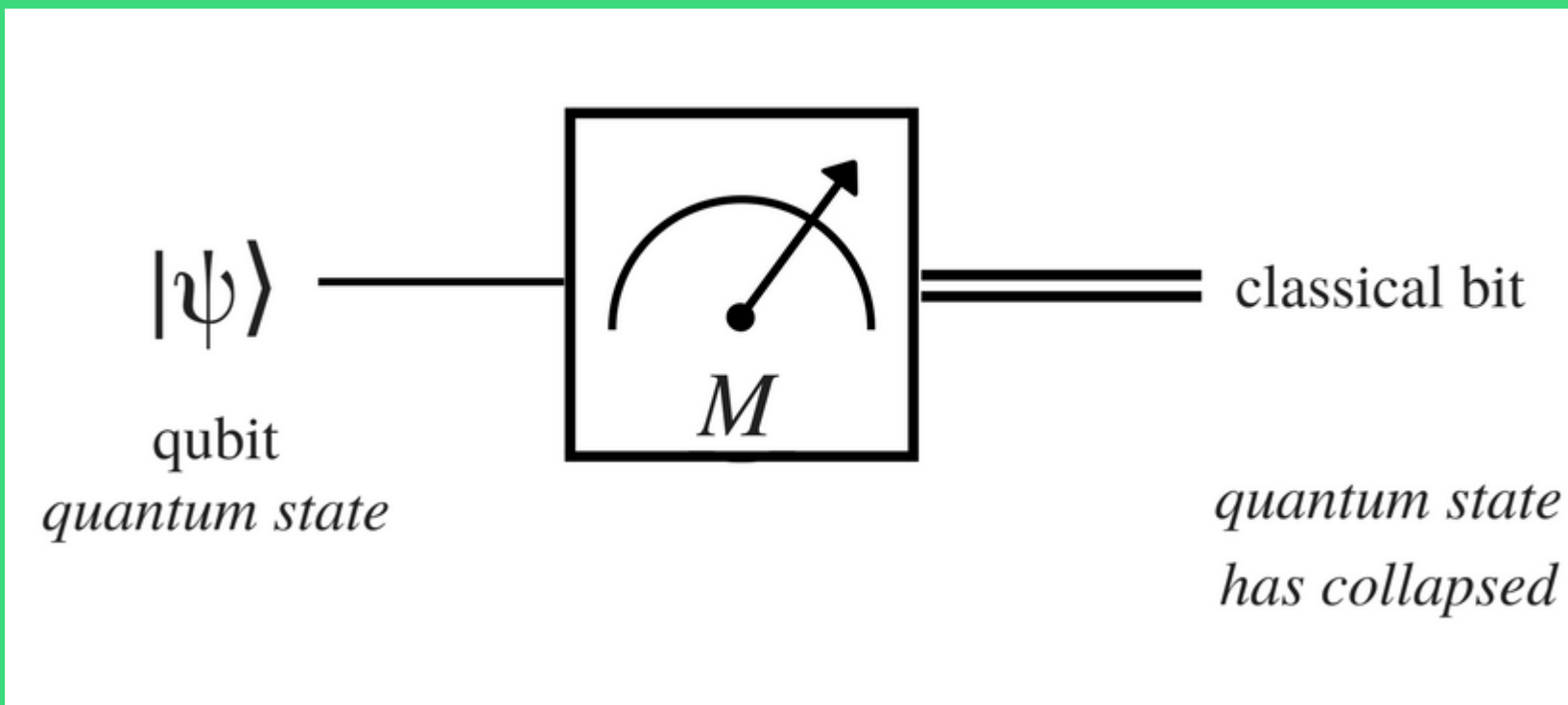
HADAMARD GATE

$$H = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$$

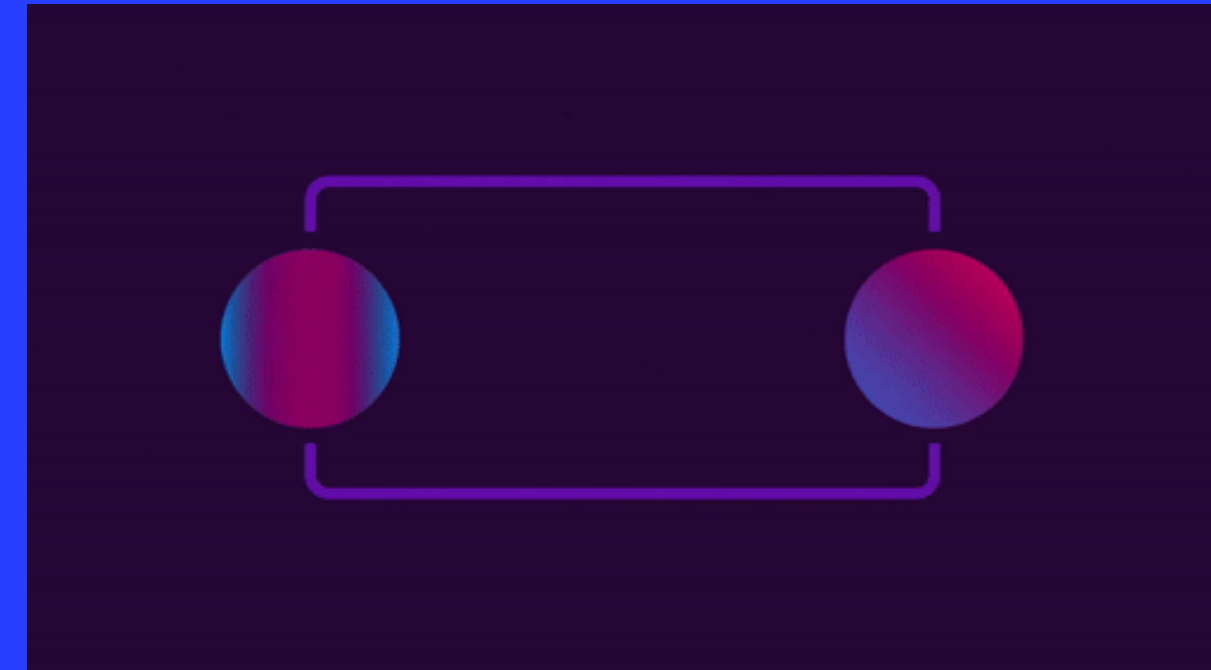
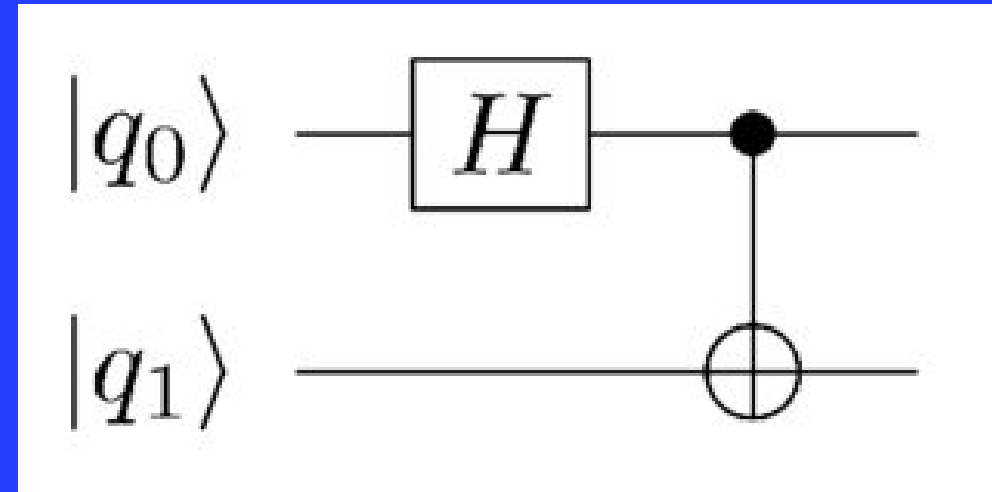
Hadamard Gate: From Pure to Mixed and Back



MEASUREMENT



QUANTUM ENTANGLEMENT



"Spooky Action at a distance"

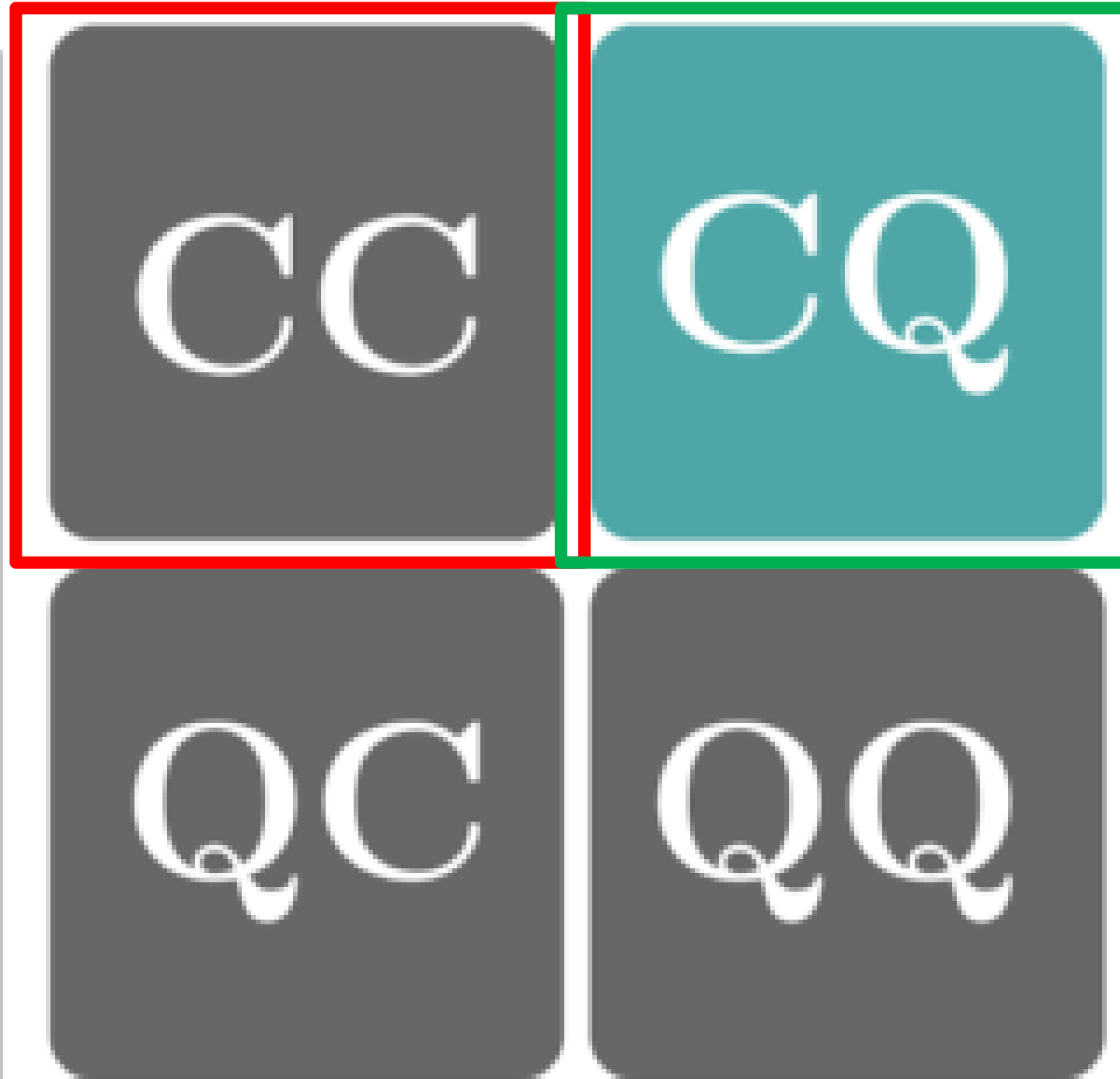
Albert Einstein

Bell Circuit With Microsoft Q#

```
operation TestBellState(count : Int, initial : Result) : (Int, Int) {  
  
    mutable numOnes = 0;  
    using ((q0, q1) = (Qubit(), Qubit())) {  
        for (test in 1..count) {  
            SetQubitState(initial, q0);  
            SetQubitState(Zero, q1);  
  
            H(q0);  
            CNOT(q0, q1);  
            let res = M(q0);  
  
            // Count the number of ones we saw:  
            if (res == One) {  
                set numOnes += 1;  
            }  
        }  
  
        SetQubitState(Zero, q0);  
        SetQubitState(Zero, q1);  
    }  
  
    // Return number of times we saw a |0> and number of times we saw a |1>  
    return (count-numOnes, numOnes);  
}
```

data processing device

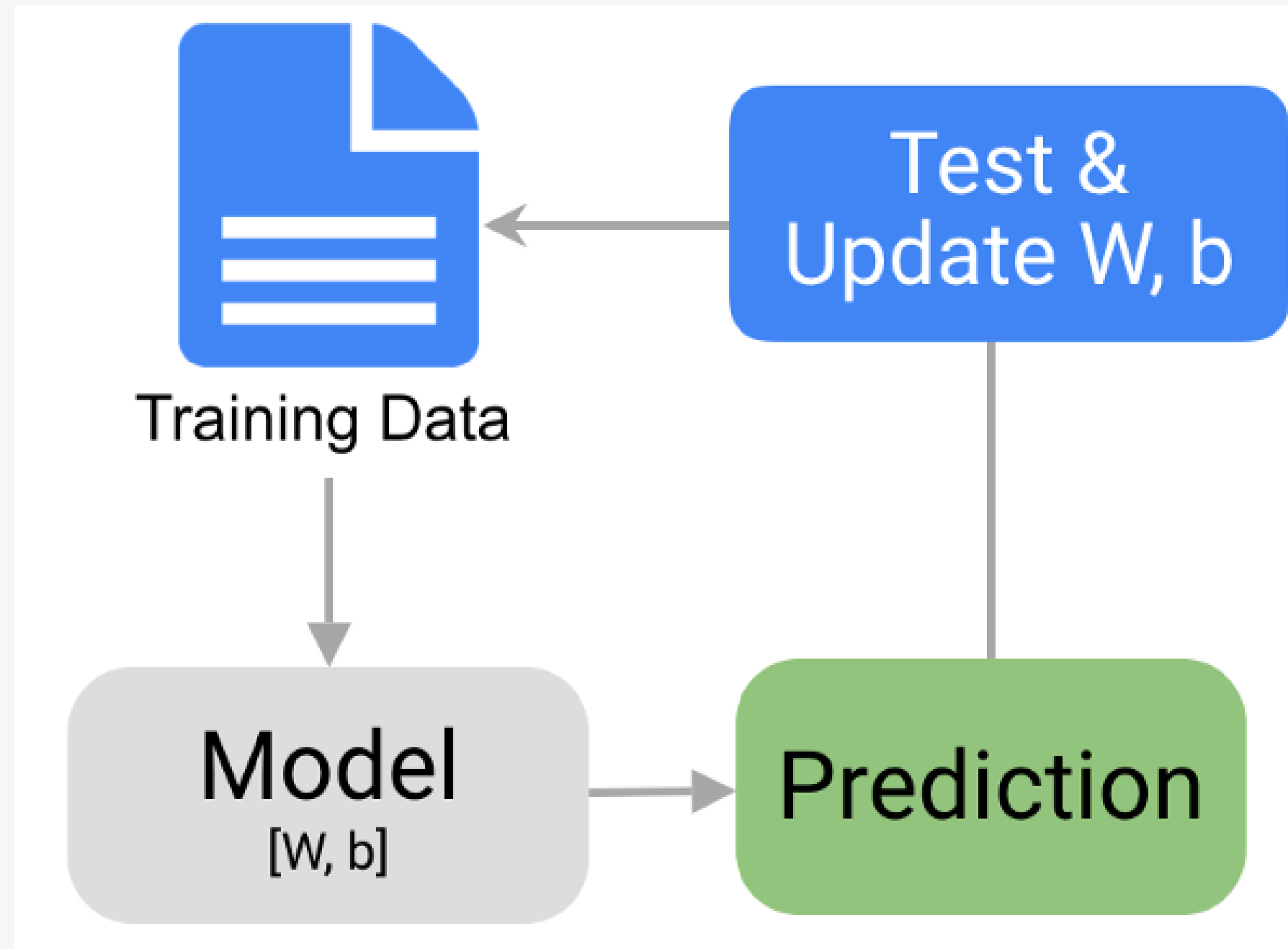
data generating system



C - classical, Q - quantum

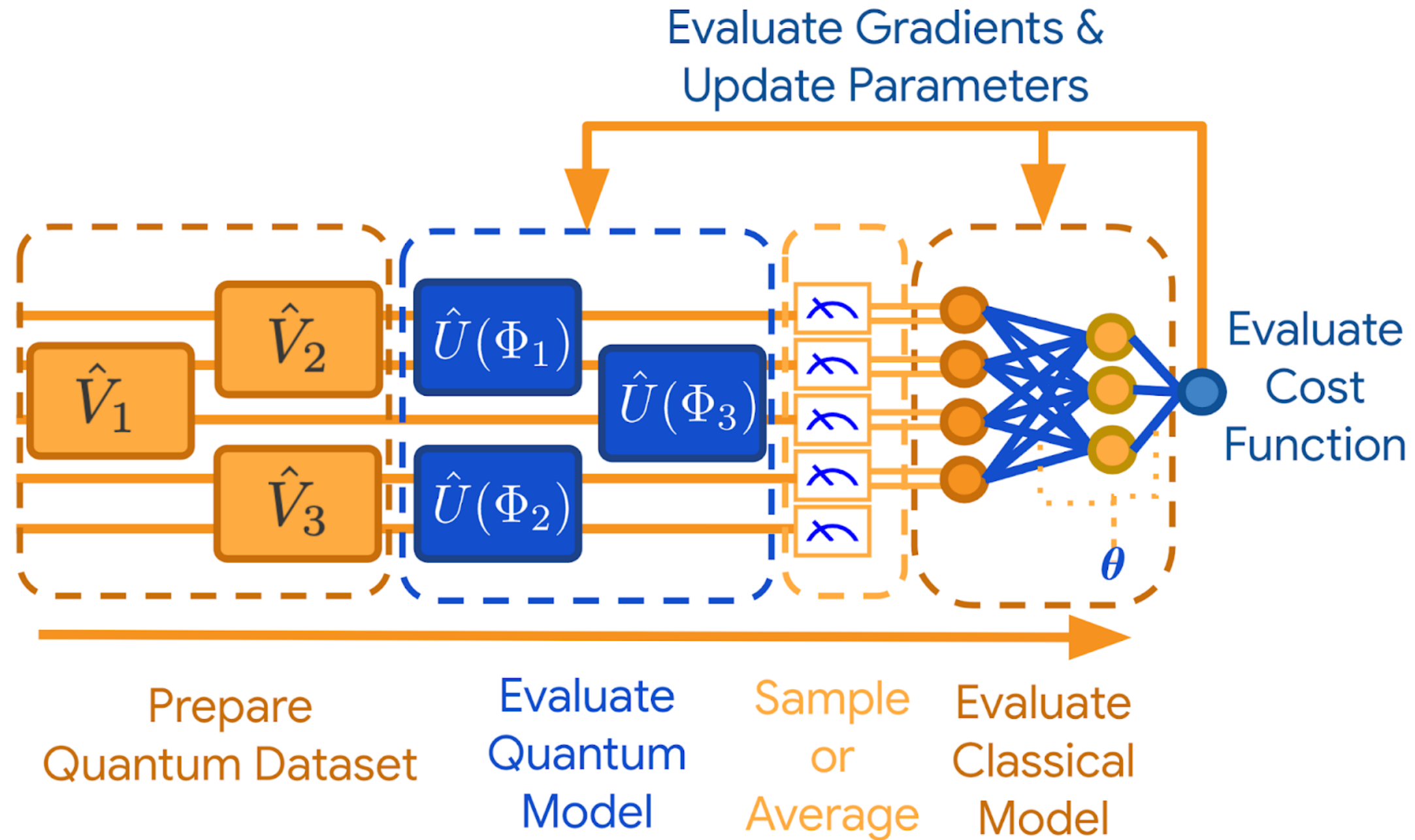
Approaches to Machine Learning

CC Overview



Hybrid Quantum-Classical: Steps for QML

1. Quantum Embeddings



2. Quantum Variational Circuit

3. Classical Optimizer

WHERE CAN QML BE USED?

Finance

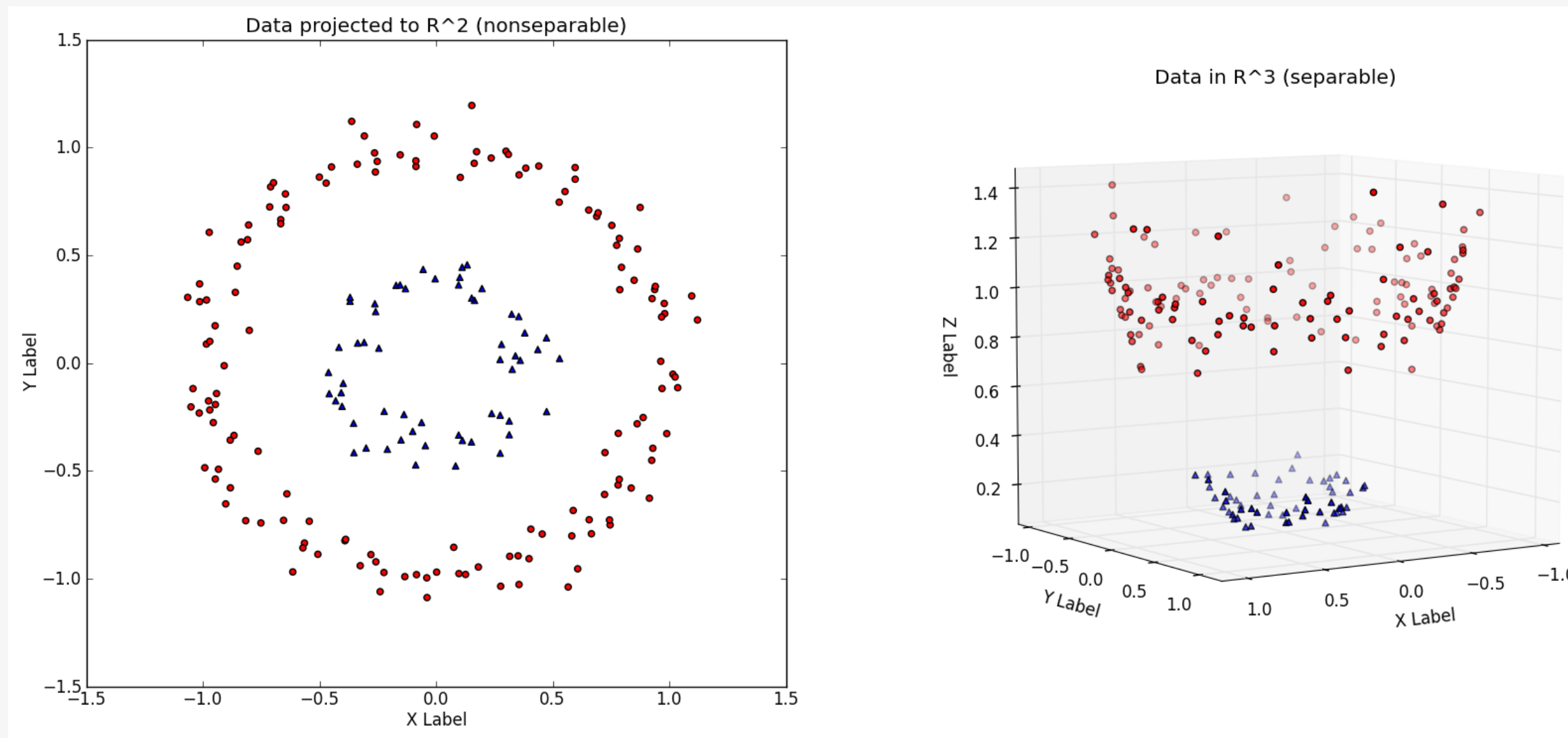
Portfolio Analysis in Finance

Classification Problems

Possibility of classifying very large and complex datasets, such as whether cells are cancerous based on several factors, at a higher speed and lower computation cost.

Topological Analysis

Hybrid implementations of small-scale quantum computing and powerful classical computing for very large datasets



SUMMARY

1. QML is all about uplifting the features of Quantum Computing to do Machine Learning
2. It's not about speedup, but looking at something different entirely
3. We can expect Hybrid Quantum-Classical Architectures in the future



Simple Classifier with Microsoft Q#



THANKS FOR ATTENDING!

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Feel free to reach out for any questions

Email: farhan.tuba@gmail.com for comments or questions.



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