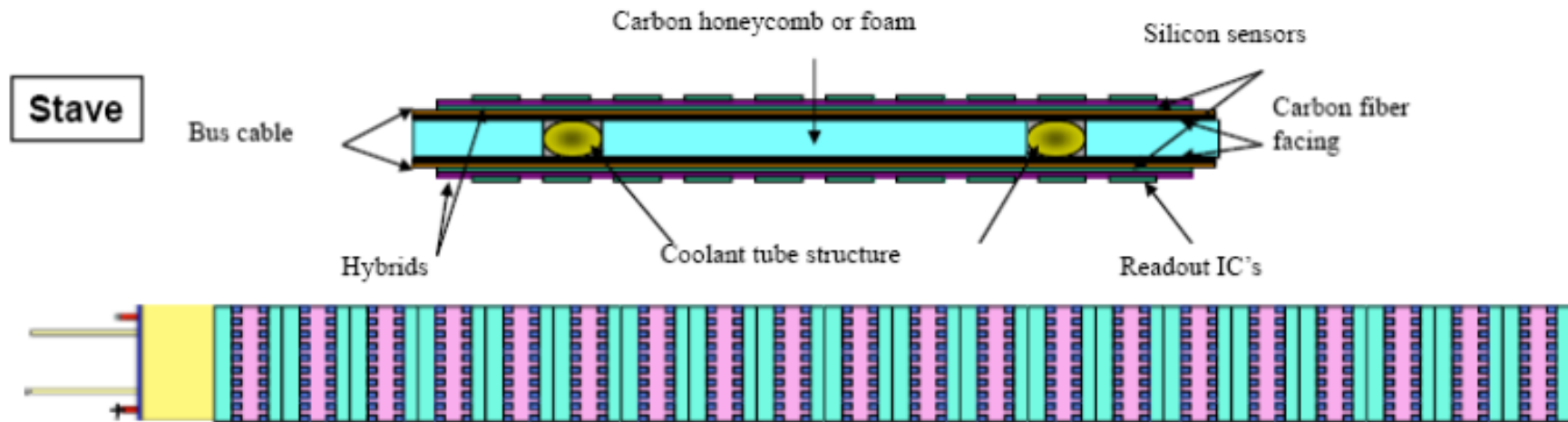


Quantum Machine Learning Models detect flaws in the thermal profile of the Stave Cores for the ATLAS ITk

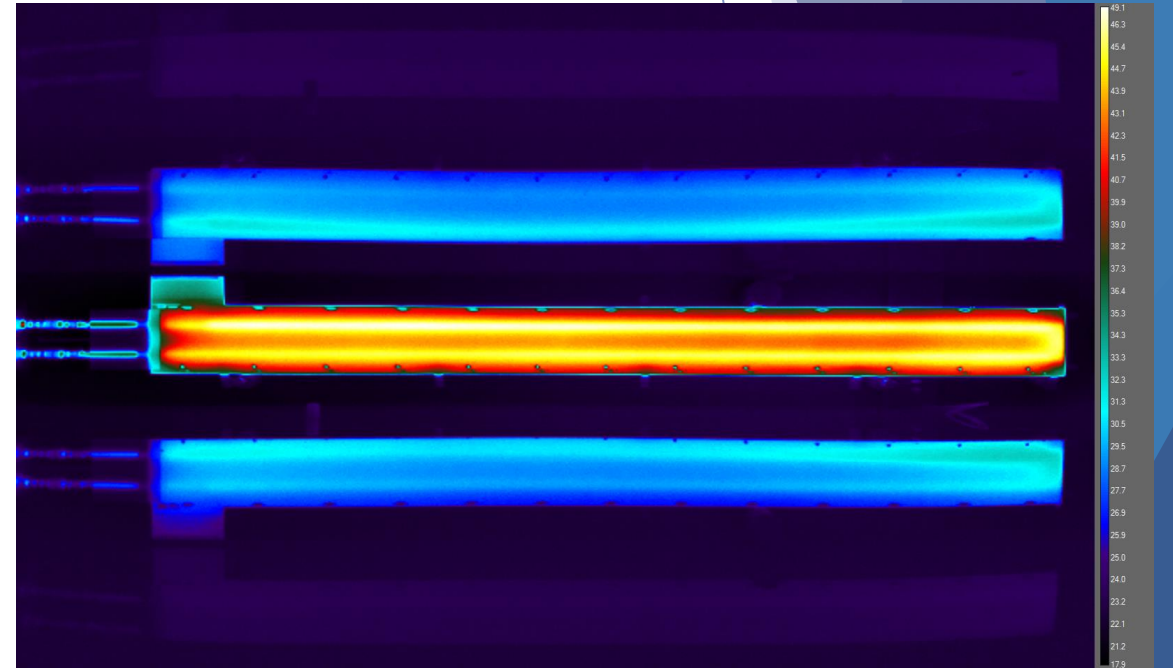
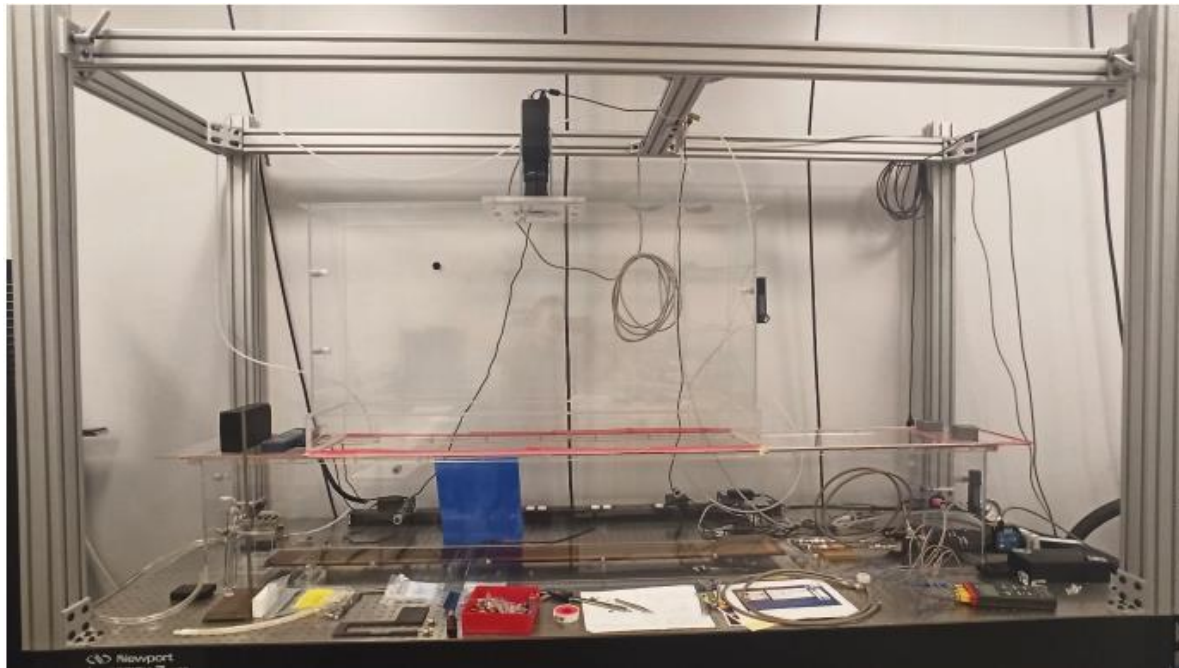
Argyris Giannisis Manes
Professor Oliver Keith Baker
Yale University

Stave Cores

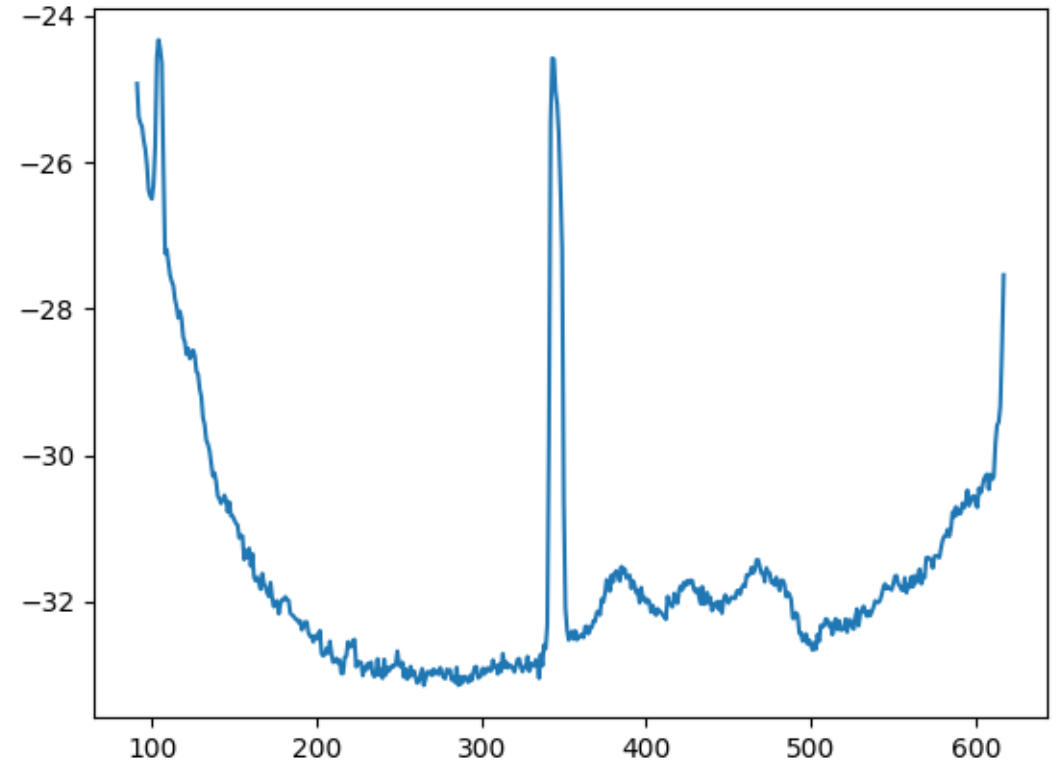
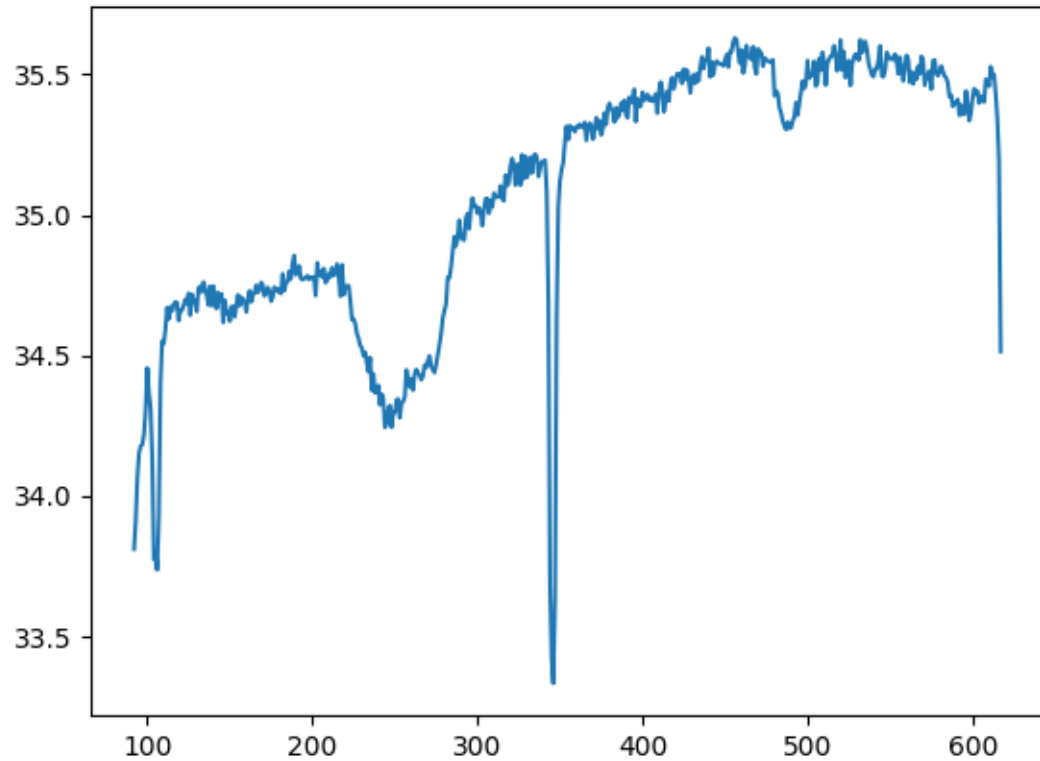
- ▶ Component of the ATLAS Detector Inner Tracker (ITk)
- ▶ Rectangular Structures that provide electrical services, mechanical support, and cooling to the ATLAS Silicon Strip Detectors



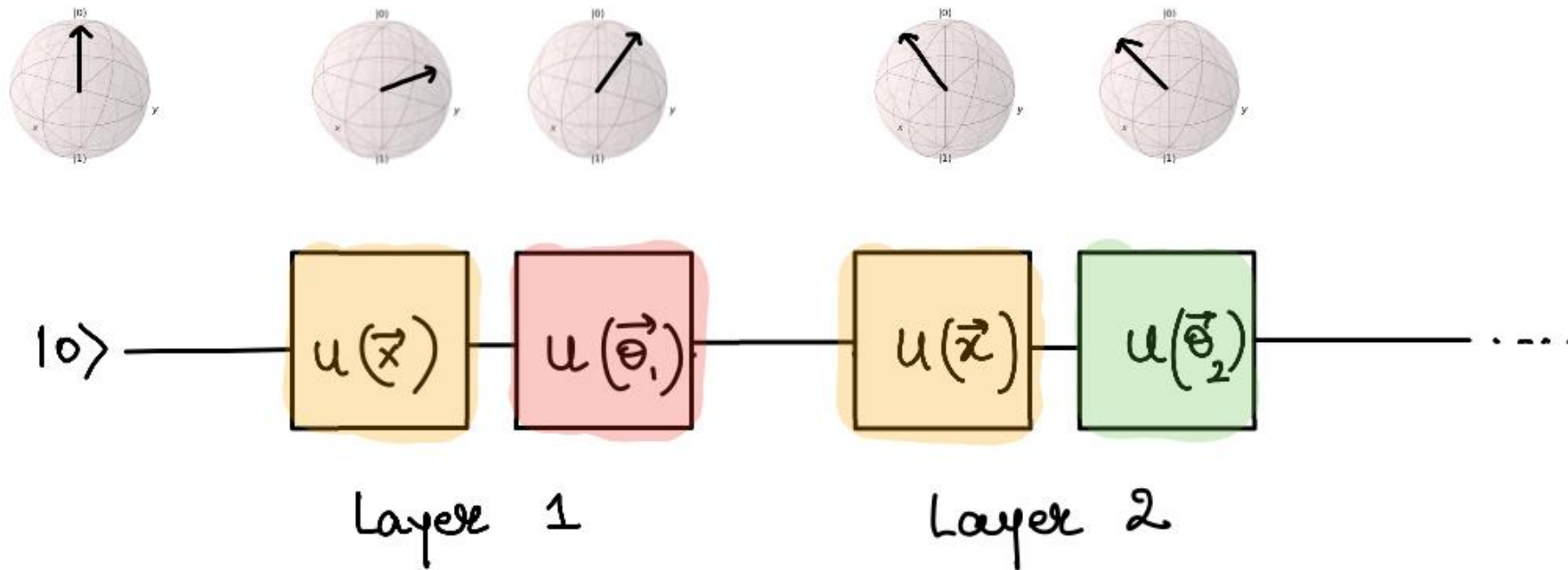
Stave Cores- Thermal Profiles



Thermal Profile of Cooling Pipe



Quantum Data Re-uploading Classifier



$$Cost = \sum_{i \in \text{data points}} 1 - \text{fidelity}(i)$$

1-Qubit Quantum Re-uploading Classifier applied to Stave Thermal Data

Cost: 0.030324 | Train accuracy 0.980713 | Test Accuracy : 0.981283

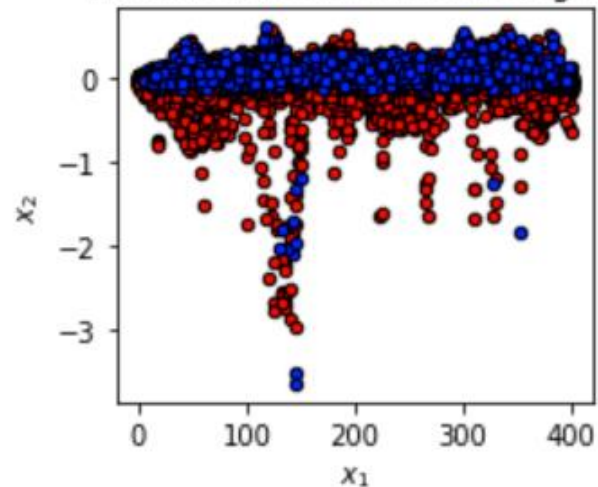
Learned weights

Layer 0: [3.10171031 0.33721596 0.10065511]

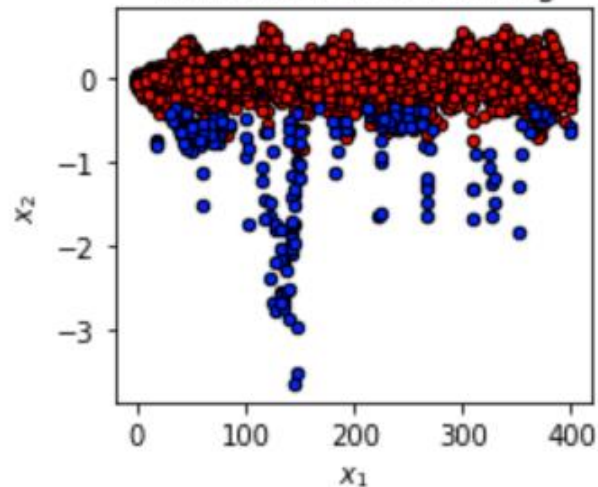
Layer 1: [0.01102998 -0.46293487 0.15022896]

Layer 2: [-0.08787595 -0.39129663 0.60111501]

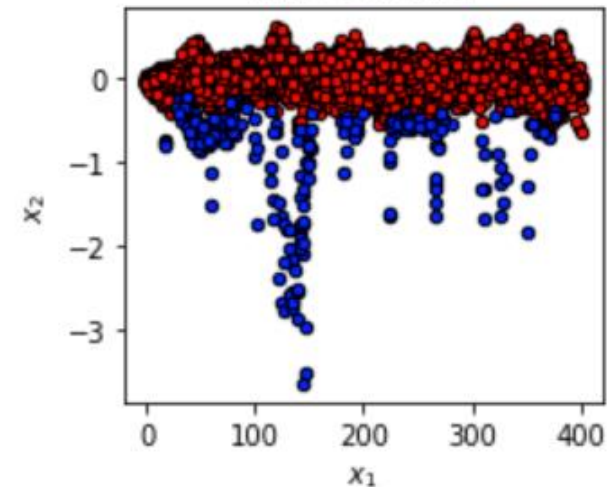
Predictions with random weights



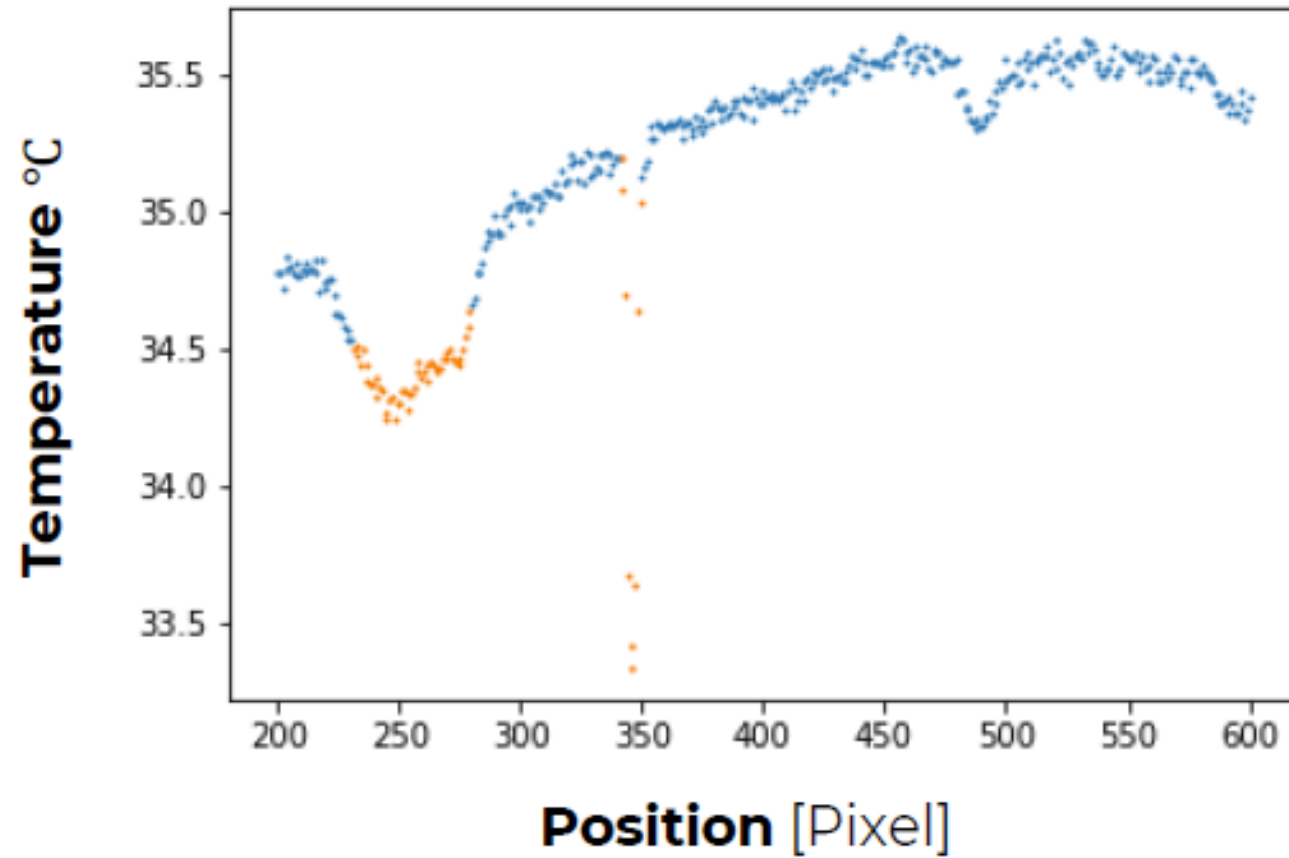
Predictions after training



True test data

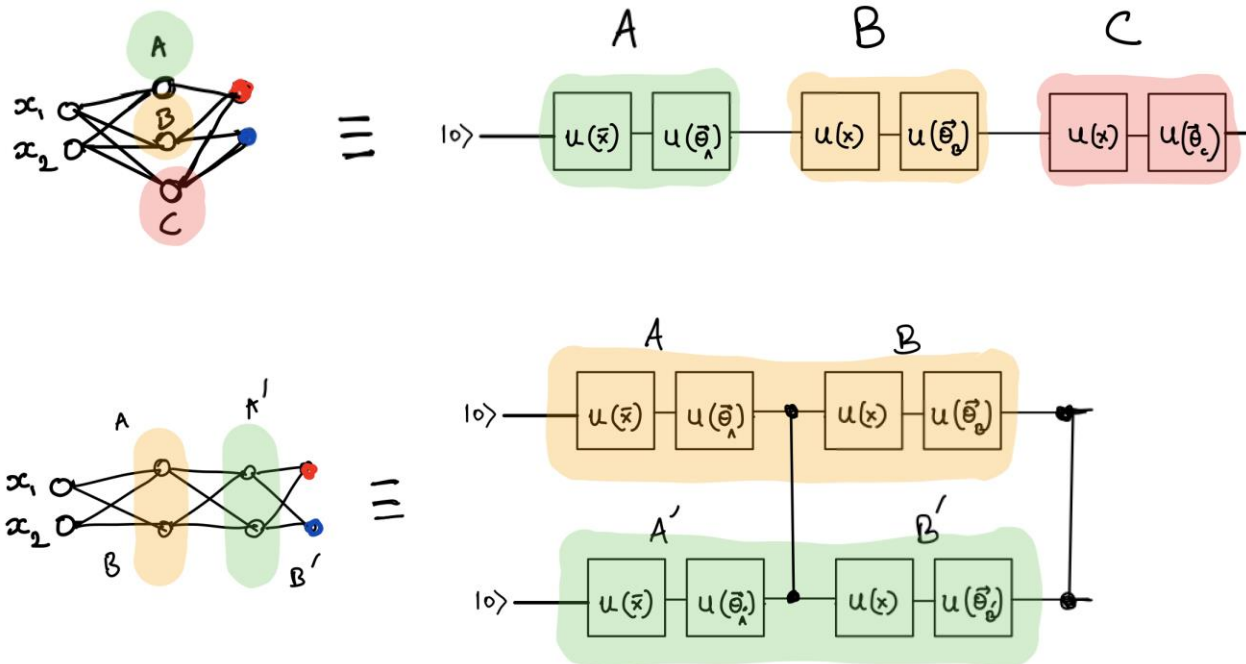


Classification Result



Multi-qubit Data-Reuploading Classifiers

- ▶ Introduce entanglement between the qubits
- ▶ Reduce the circuit depth
- ▶ Potential for Quantum Advantage



2-Qubit Quantum Re-uploading Classifier Results

Cost: 0.027695 | Train accuracy 0.981856 | Test Accuracy : 0.982140

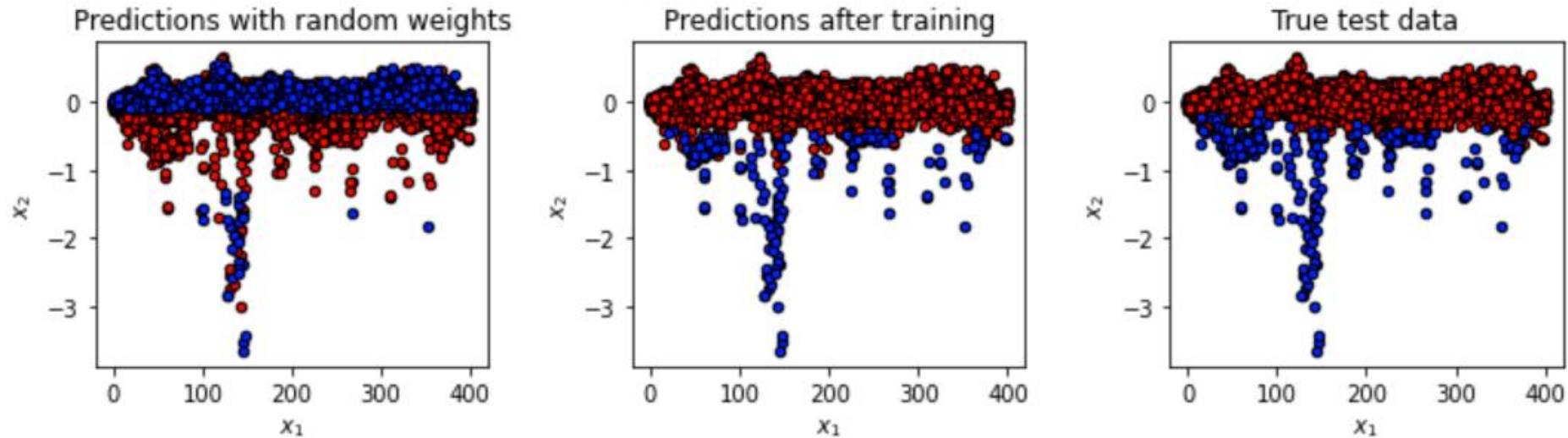
Learned weights

Layer 0: [-0.00708821 -0.47951861 1.2312937]

Layer 1: [0.51574435 -0.32071833 -0.21393055]

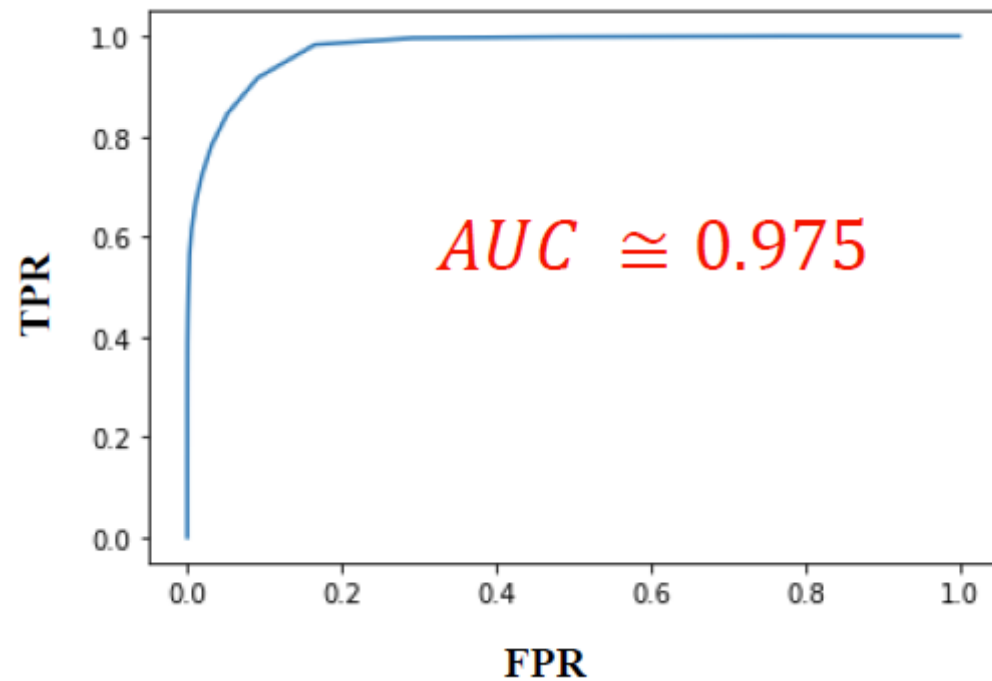
Layer 2: [0.14795977 -0.33775536 0.60111501]

Layer 3: [2.82785078 0.32958833 0.96990985]

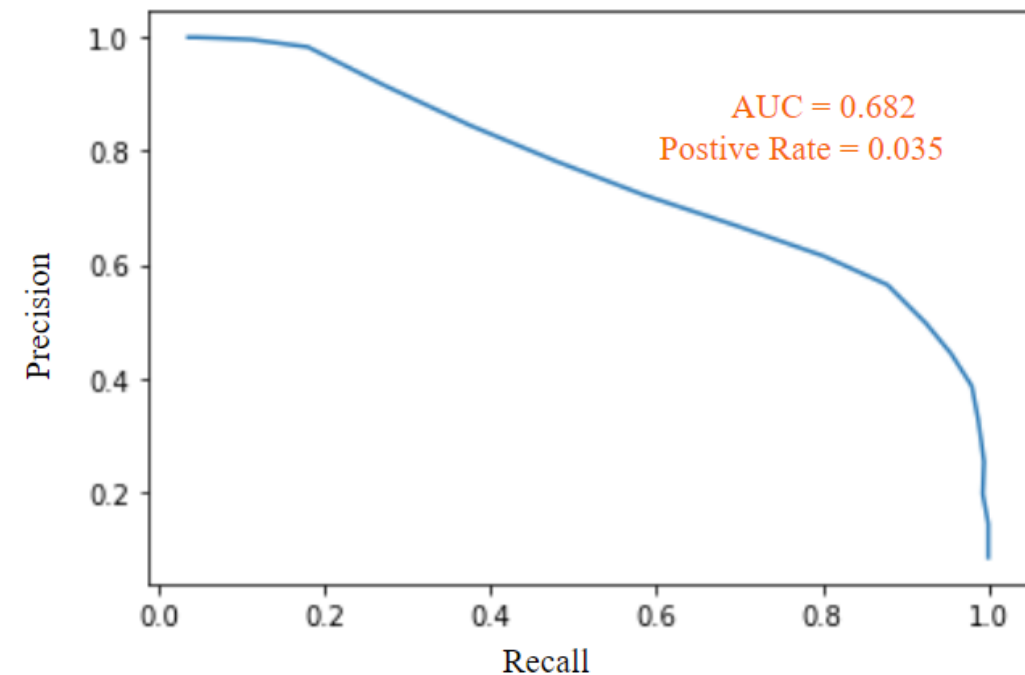


Receiver Operating Characteristic, Precision Recall Curve

Receiver Operating Curve



Precision Recall Curve



Next steps

- ▶ Running on Quantum Hardware
- ▶ Comparing with Classical Equivalents (Neural Networks)
- ▶ Future Applications?

Sources

- ▶ https://pennylane.ai/qml/demos/tutorial_data_reuploading_classifier.html
- ▶ Miñano, M. (2009, December 13). *ATLAS Strips Upgrade*. CORE Reader.

Thank you!