Investigating the performance of distance 2 heavy-hexagon codes on IBM devices

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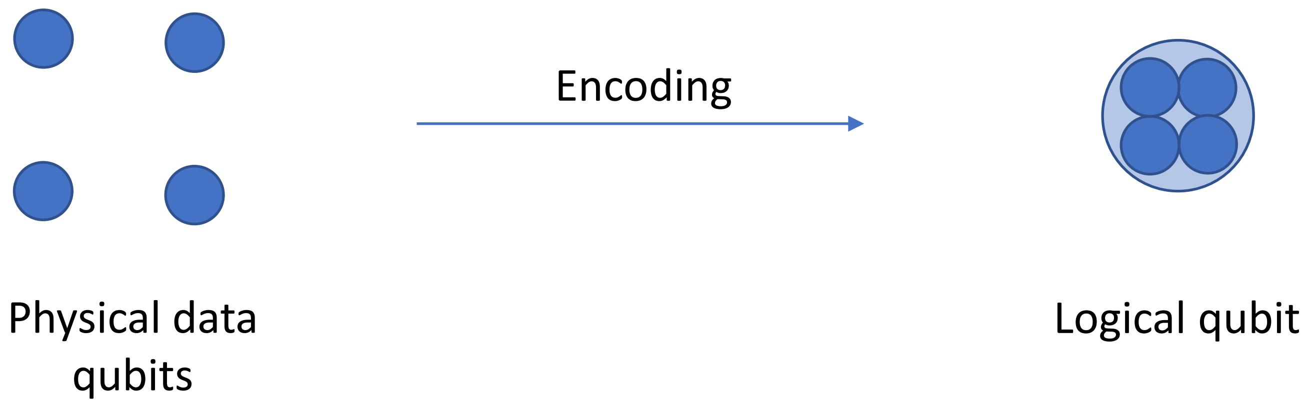
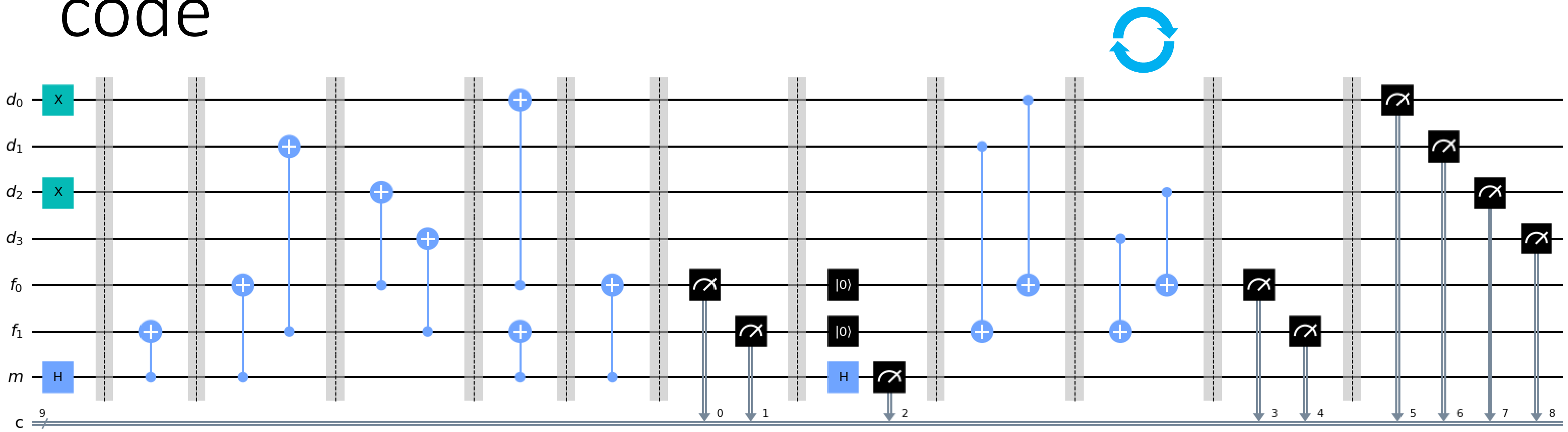
What is quantum error correction?

Quantum error correction encodes logical qubits within multiple physical qubits.



Encoded quantum information is protected from logical errors via measurements of the code stabilizers. These measurements inform us about possible physical qubit errors without revealing encoded logical information.

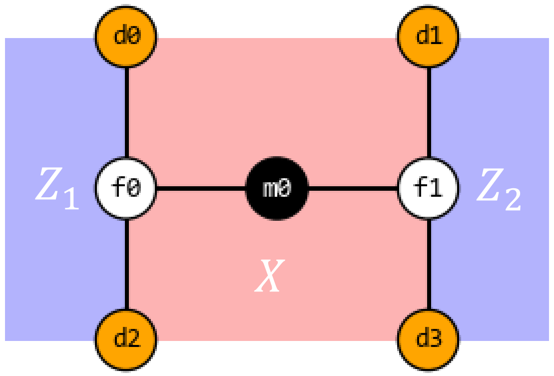
Circuit implementation of the heavy-hexagon code



State Initialisation

Stabilizer Measurement

Readout



Data Qubits

Flag Qubits

Measure Qubits

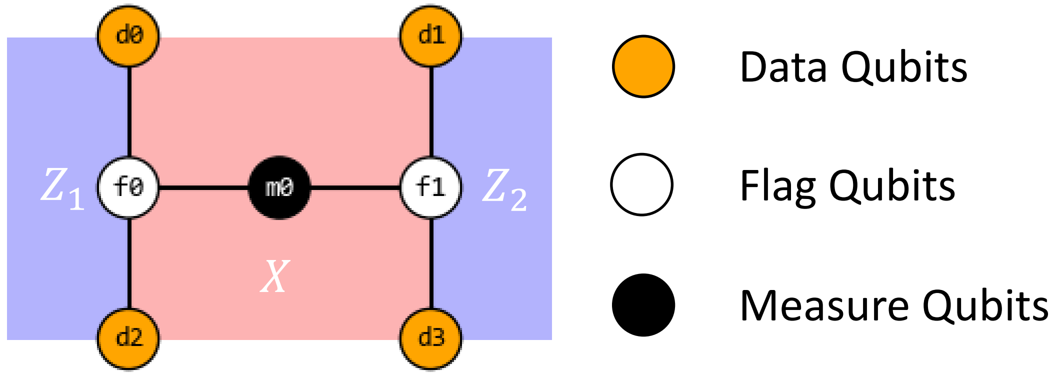
Measurement String:

f0,f1,m2,(z3,z4,…),d5,d6,d7,d8

Aims

- Implement heavy-hexagon codewords within a IBM device and perform Z stabilizer measurements

$$|0_L\rangle = \frac{1}{\sqrt{2}}(|0000\rangle + |1111\rangle)$$
$$|1_L\rangle = \frac{1}{\sqrt{2}}(|0101\rangle + |1010\rangle)$$



- Compare the performance of two machines with different noise characteristics over repeated Z stabilizer measurements

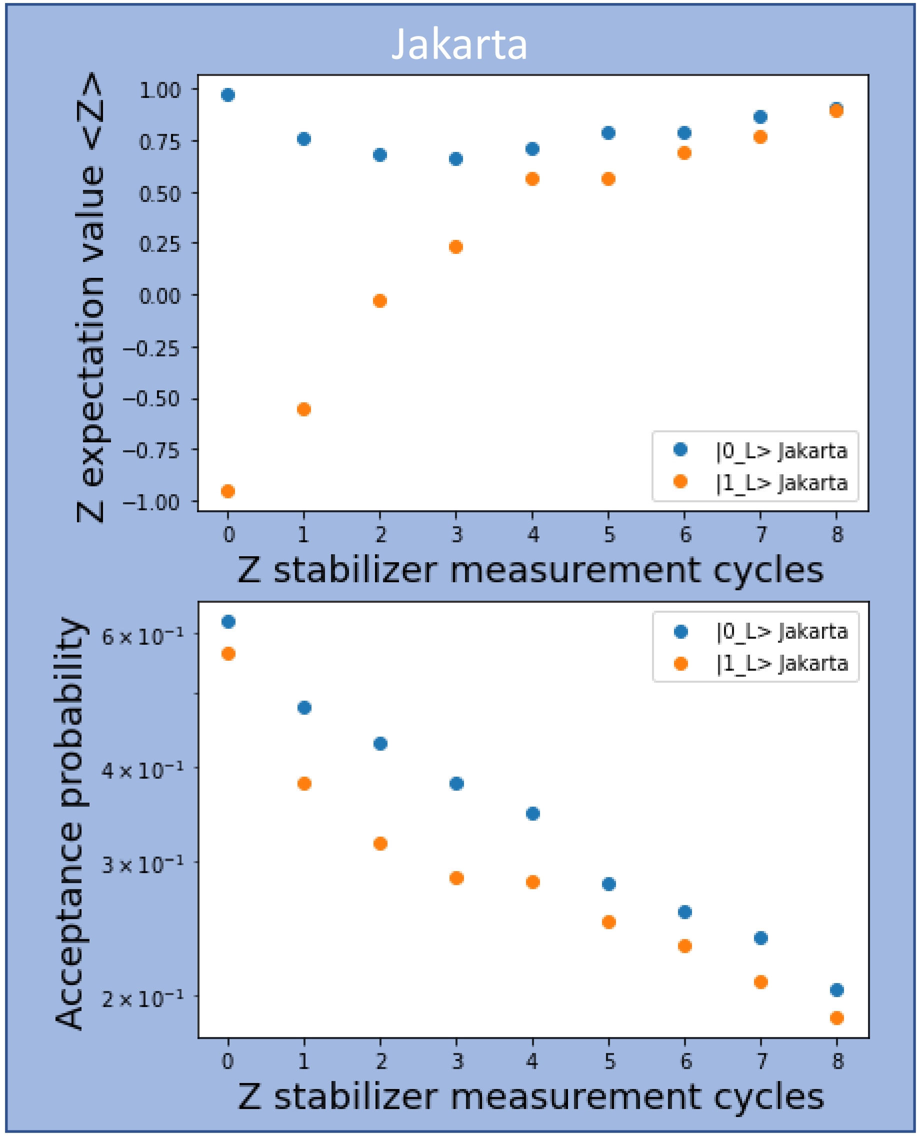
Heavy-hexagon codewords within different IBM devices

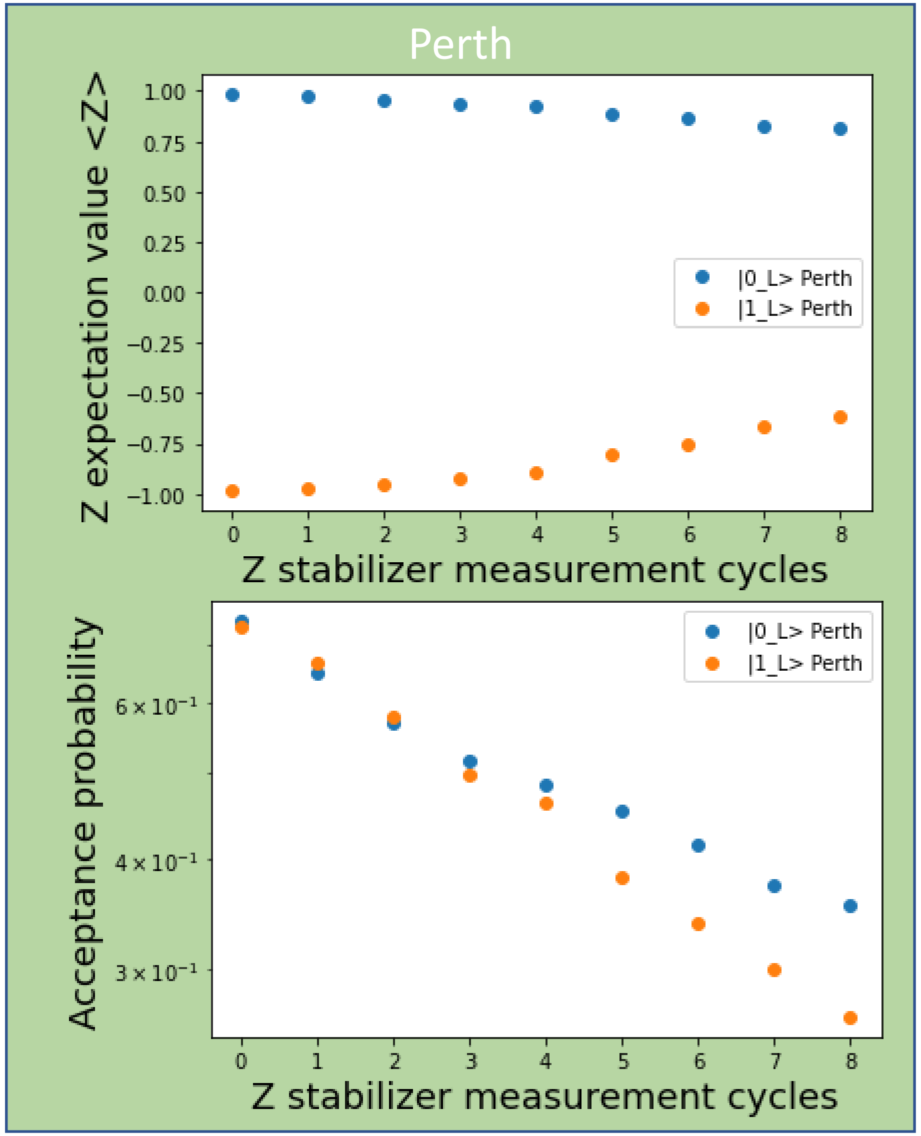
We considered the performance of the encoding on two IBM devices with different noise characteristics

Jakarta		Perth
Avg. CNOT Error: 8.412e-3		Avg. CNOT Error: 1.091e-2
Avg. Readout Error: 4.390e-2	VS	Avg. Readout Error: 1.960e-2
Avg. T1: 153.22 us		Avg. T1: 160.7 us
Avg. T2: 40.69 us		Avg. T2: 122.91 us

Note that these noise characteristics are **averaged over all qubits** in the device, and **vary over regular calibrations**.

Performance of different IBM machines under repeated stabilizer measurements

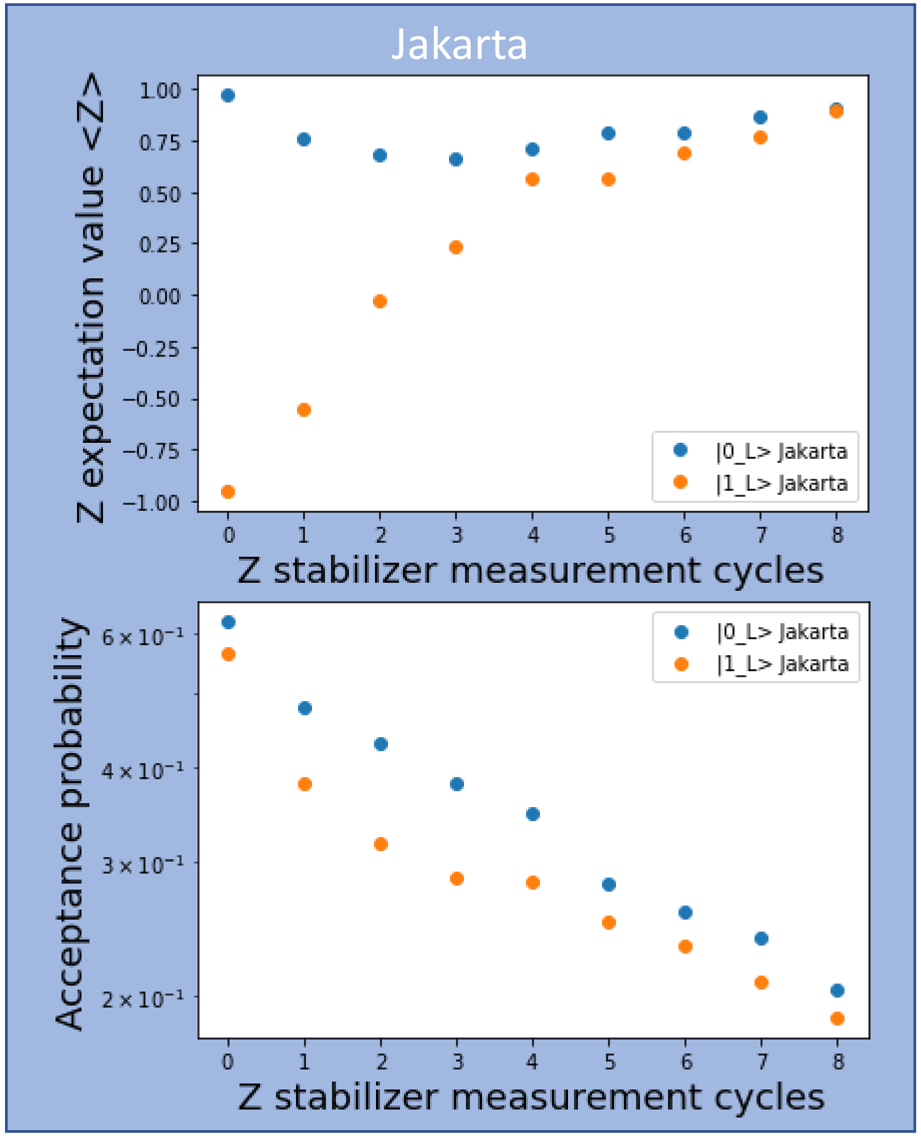


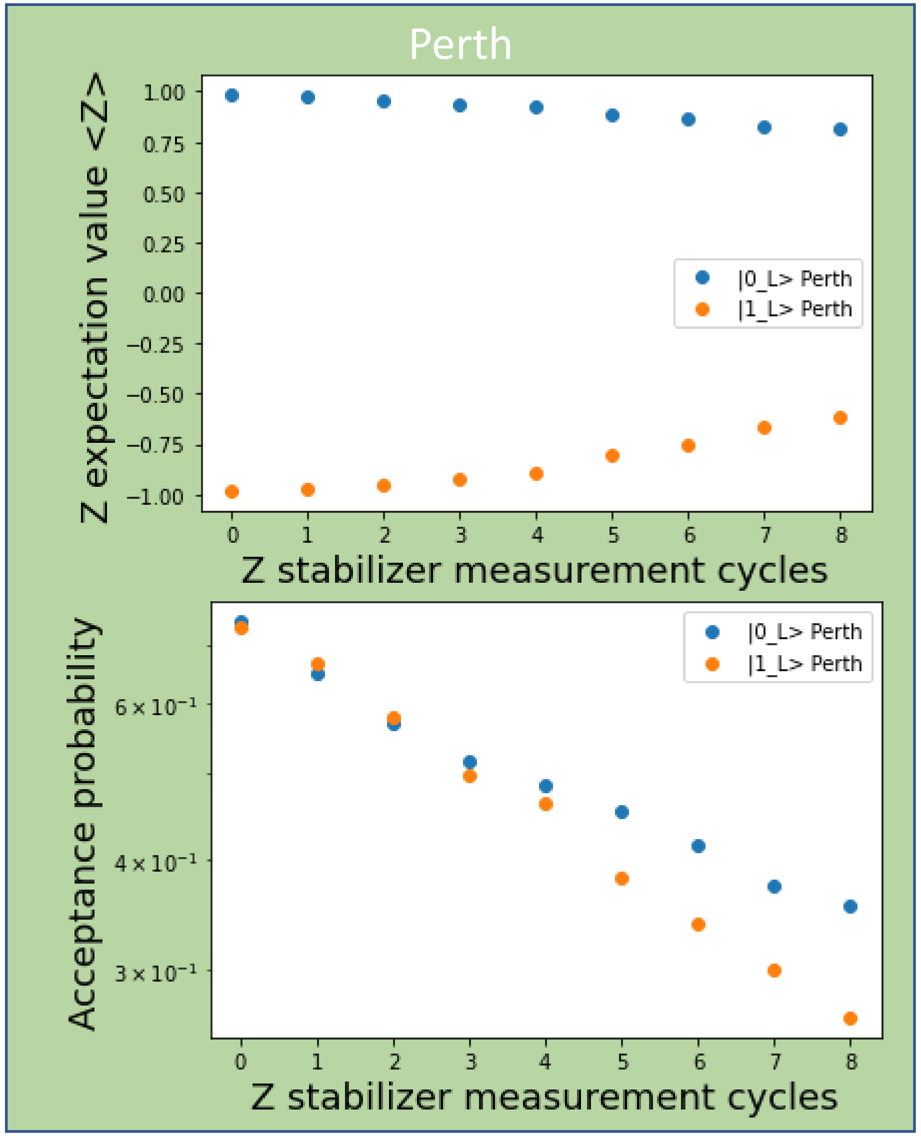


Discussion and Conclusion

We have demonstrated the distance-2 heavy-hexagon code within a pair of IBM devices.

Differences in the number of stabilizer measurements, the choice of codewords, the choice of stabilizers, and the individual noise characteristics of the device all lead to differences in the encoded error rate.


Jakarta
Z expectation value <Z>
Z stabilizer measurement cycles
|0_L> Jakarta
|1_L> Jakarta
Acceptance probability
Z stabilizer measurement cycles
|0_L> Jakarta
|1_L> Jakarta


Perth
Z expectation value <Z>
Z stabilizer measurement cycles
|0_L> Perth
|1_L> Perth
Acceptance probability
Z stabilizer measurement cycles
|0_L> Perth
|1_L> Perth