Thermal Relaxation Errors

Meeting with Professor Schnetzer and Rikab

August 17, 2020

Talking Points

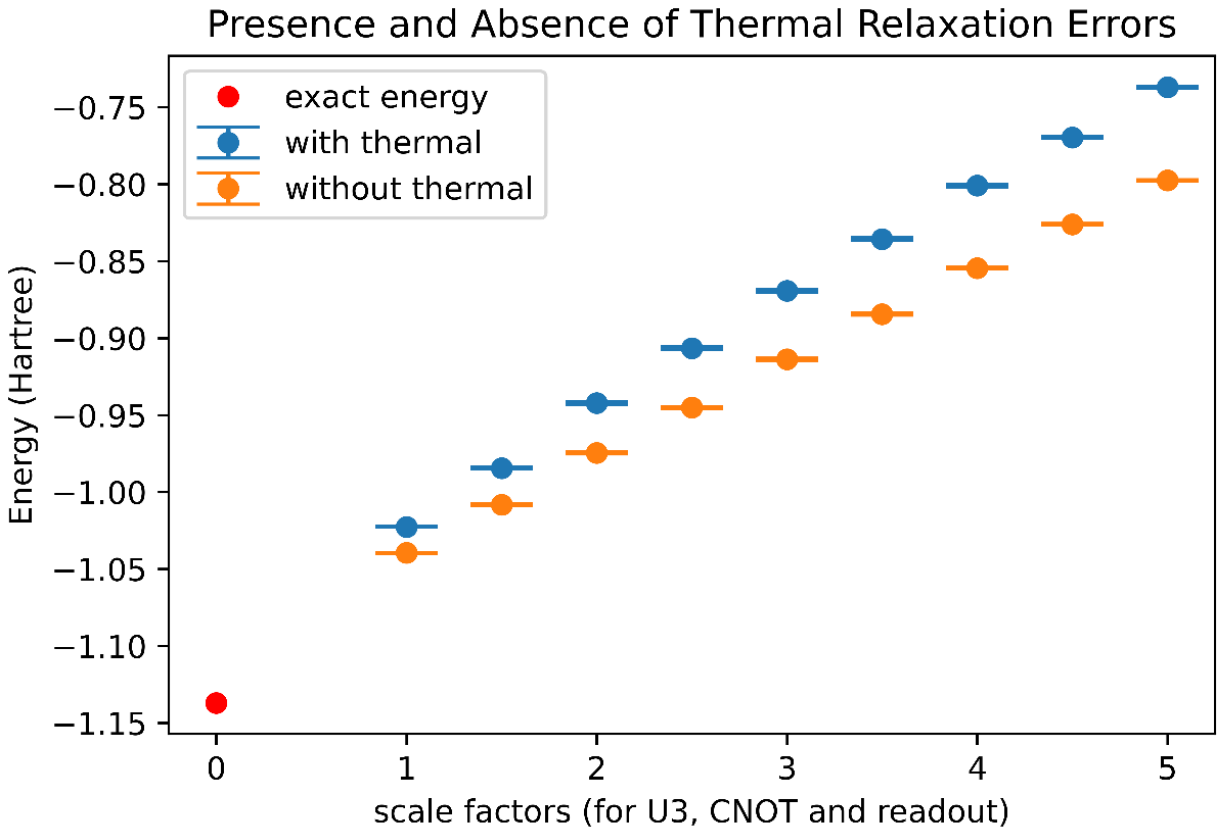
- Thermal Relaxation Errors are significant.
- In Qiskit device noise model,

  Gate Error = $\mathrm{E}_{depolar}(\epsilon)$ + $\mathrm{E}_{thermal}(t_1, t_2, gate\_time)$
- In **noise model**, we amplify $\mathrm{E}_{depolar}$ by adding in pairs of gates (1 CNOT -> 3 CNOTs). And, we amplify $\mathrm{E}_{thermal}$ by scaling t_1 and t_2.
- In **pulse stretching**, we are increasing $gate\_time$ and hence only amplifying $\mathrm{E}_{thermal}$. We don't do anything directly to amplify the $\mathrm{E}_{depolar}(\epsilon)$ term. How does then pulse stretching produce accurate results?

ϵ : Gate Error Rate; equal to 1-F where F is the average gate fidelity; F is computed through Randomized Benchmarking

Thermal Relaxation Errors

- T_1 : Time before state |1> decays to state |0>
- T_2 : *(Dephasing Time)* Time before |+> state decays into equal probabilistic mixture of |+> and |-> so you can no longer predict the initial state.
- Experiment: With and without thermal relaxation errors on Fake London noise simulator (1000 samples)
- Thermal Relaxation Errors are significant.



Gate Errors on Qiskit Noise Models

How implemented?

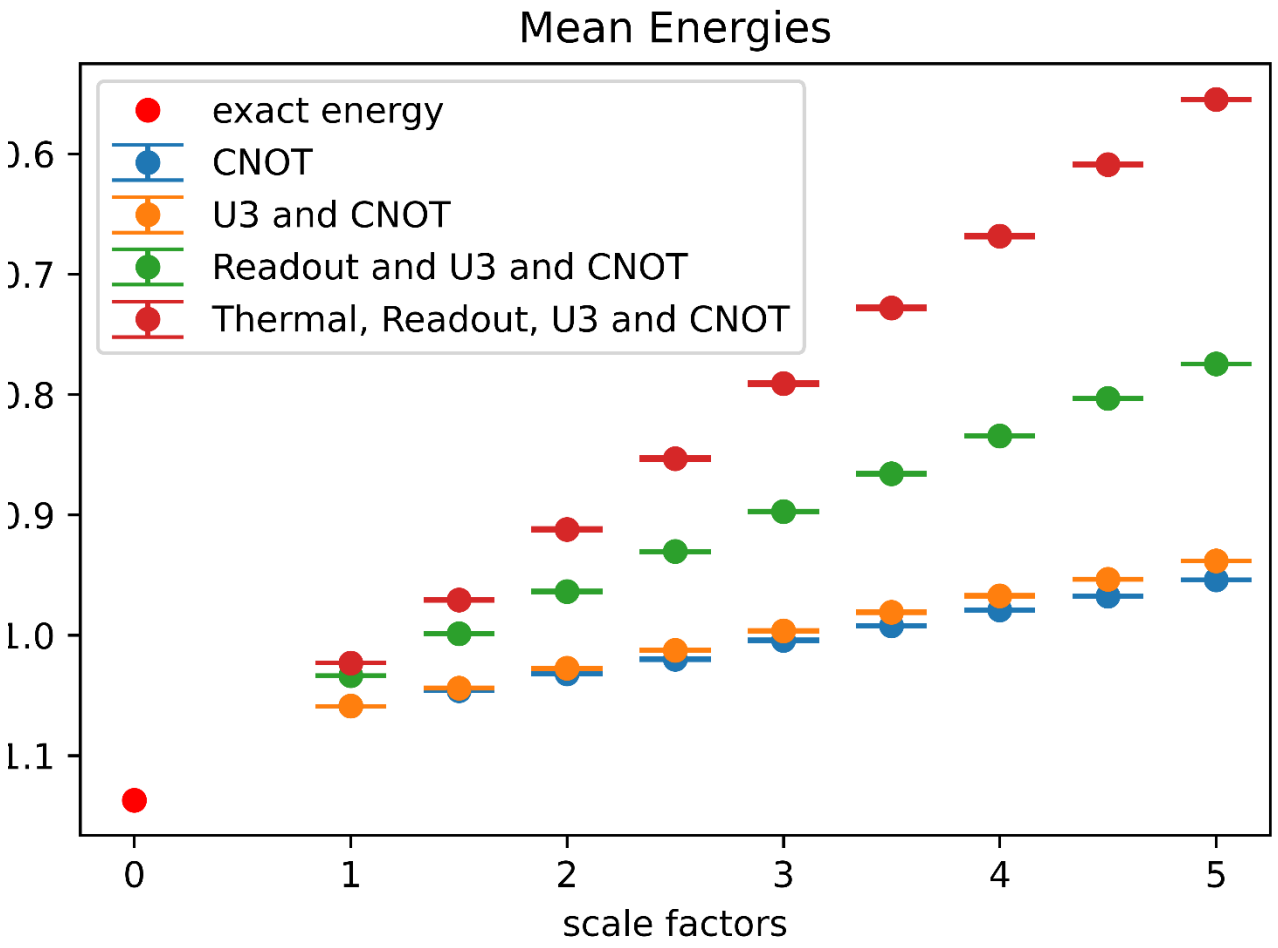
Gate Error = Depolarizing Error + Thermal Relaxation Error

Assumptions:

- All non-relaxation errors are depolarizing
- Now thermal relaxation errors should occur if the qubits are “idle” i.e. while no gates are acting on the qubits. However, in the device noise models generated by Qiskit, relaxation errors ***only*** occur while qubits are being acted upon by gates.
- Ignores non-local errors such as ‘cross-talk’. *(This includes readout error correlation between qubits)*

Amplifying one error at a time (1)

FakeLondon Noise Model (1000 samples)

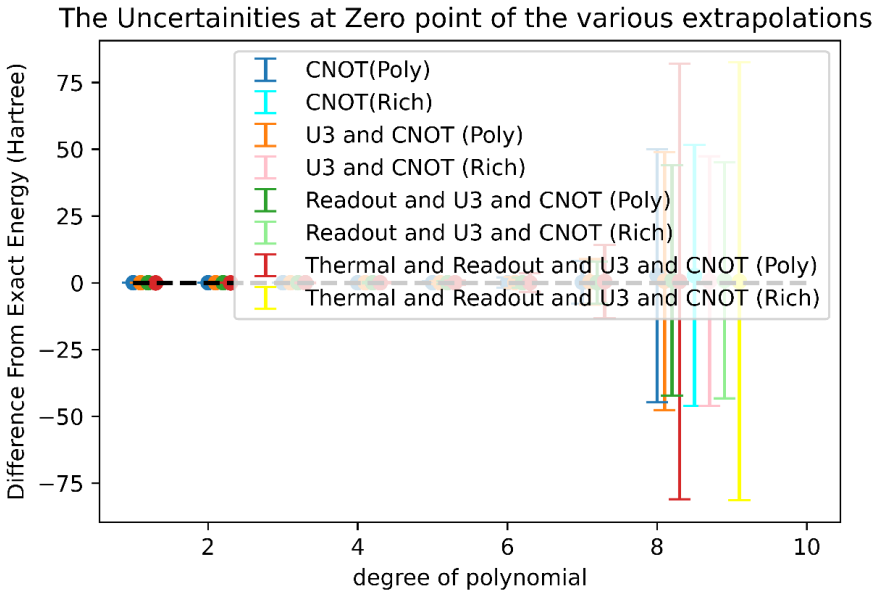


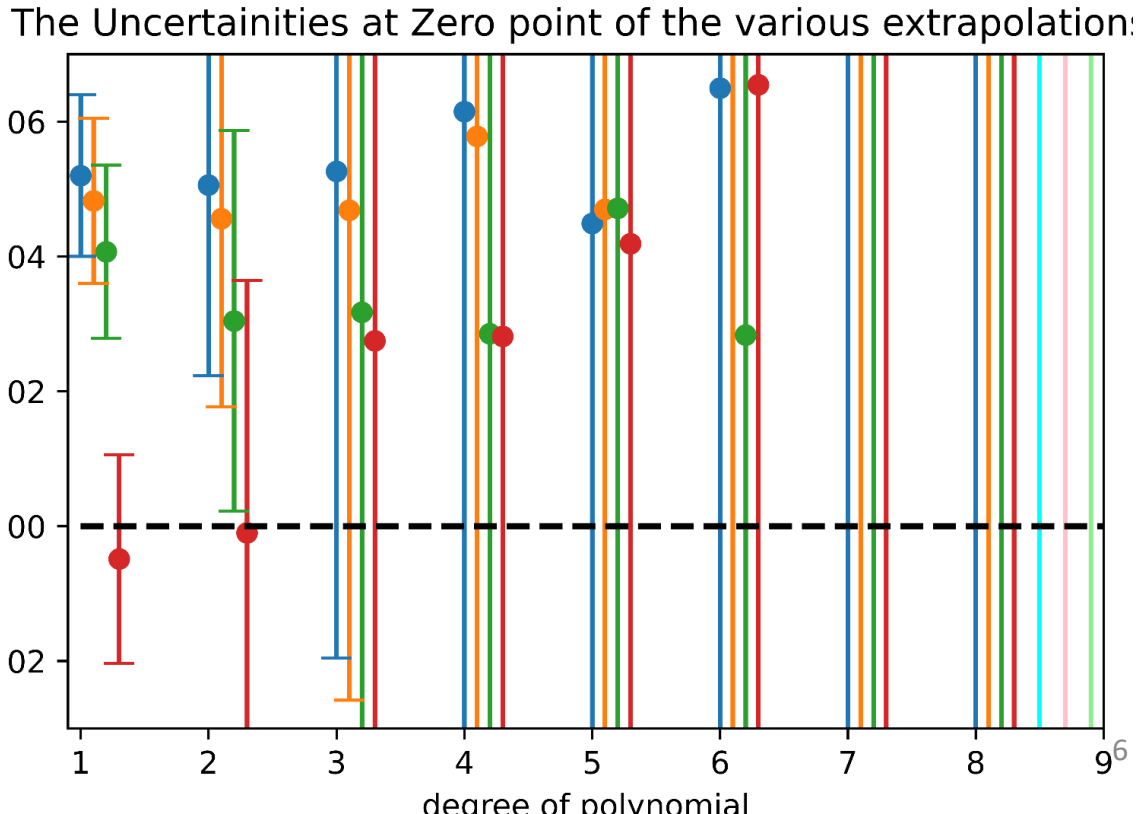
Amplifying one error at a time (2)

FakeLondon Noise Model (1000 samples)

Bottom Plot

(On the Y axis, '-0.' is cut out)

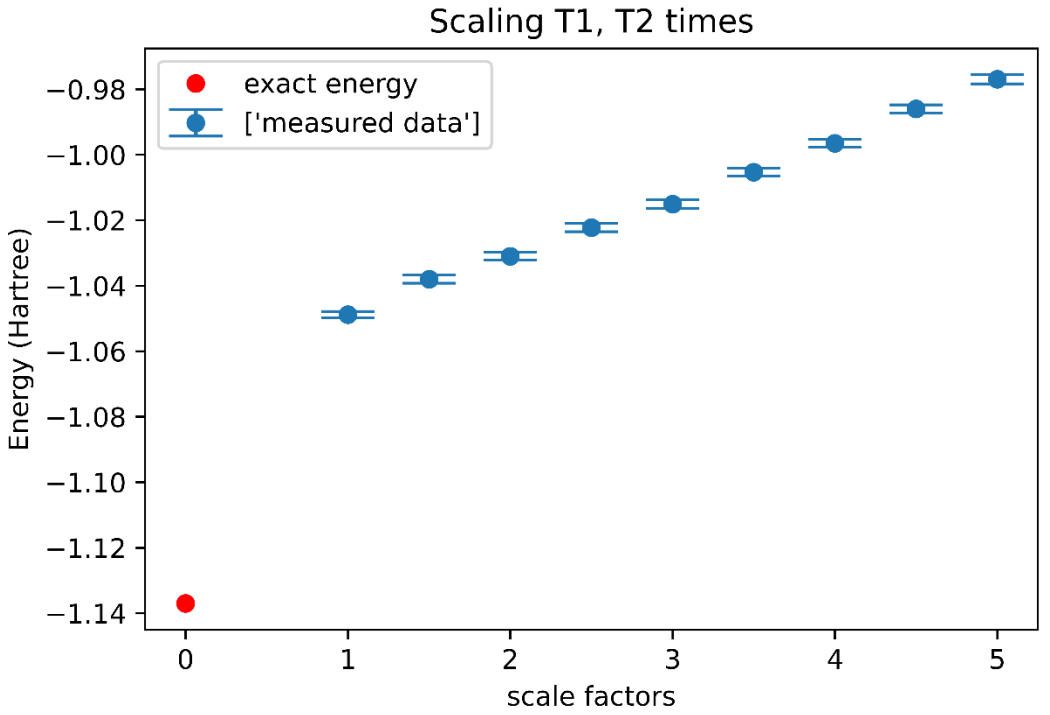




Amplifying only Thermal Relaxation Errors

- Ignoring amplification of U3, CNOT and readout errors
- Since only thermal relaxation errors are amplified, this experiment is similar to stretching gate pulses on the noise model (not actual quantum computer)
- Result: Just amplifying thermal relaxation errors does not amplify the overall error rate on the noise model.

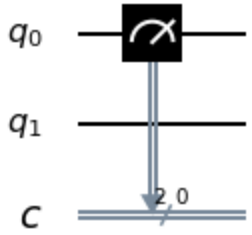
Data From FakeLondon Noise Model (100 samples)

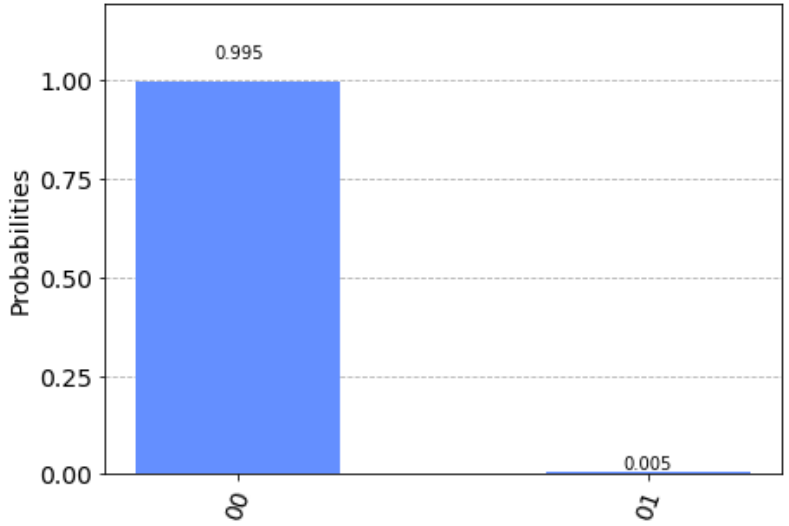


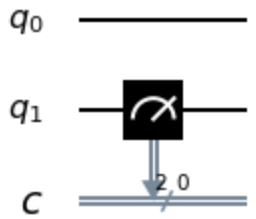
Loose Ends from Readout Error Experiments

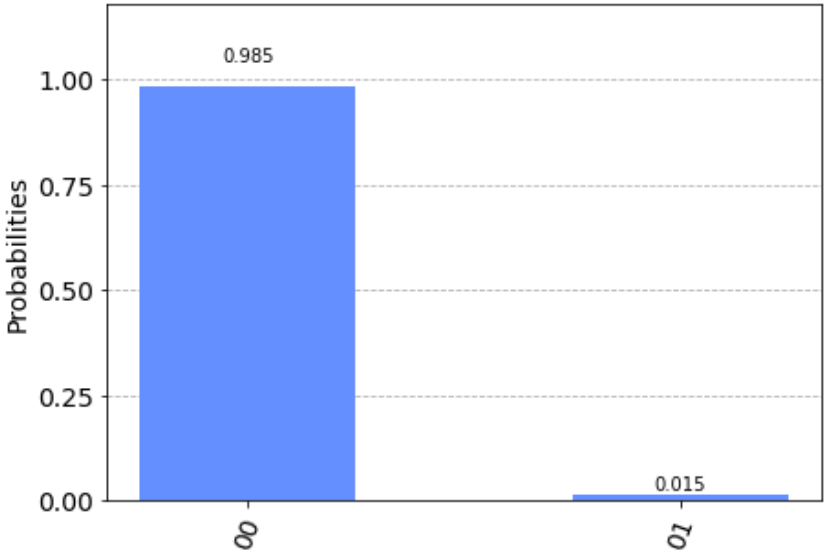
Looking at Correlation between Qubits, Doing the experiments from last week on real device

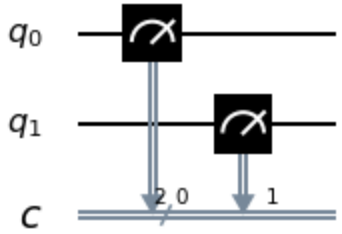
Correlation between Readout Error Rates of Qubits

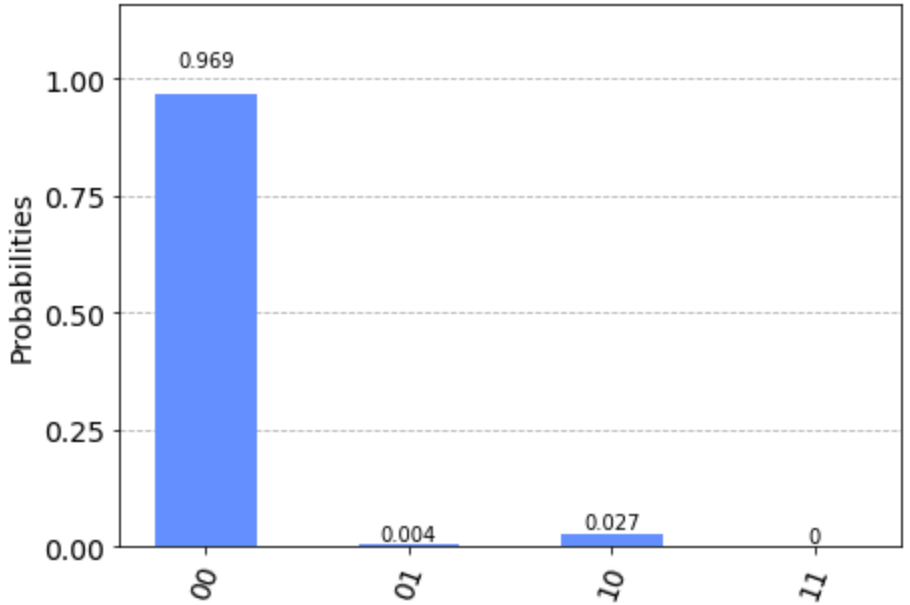






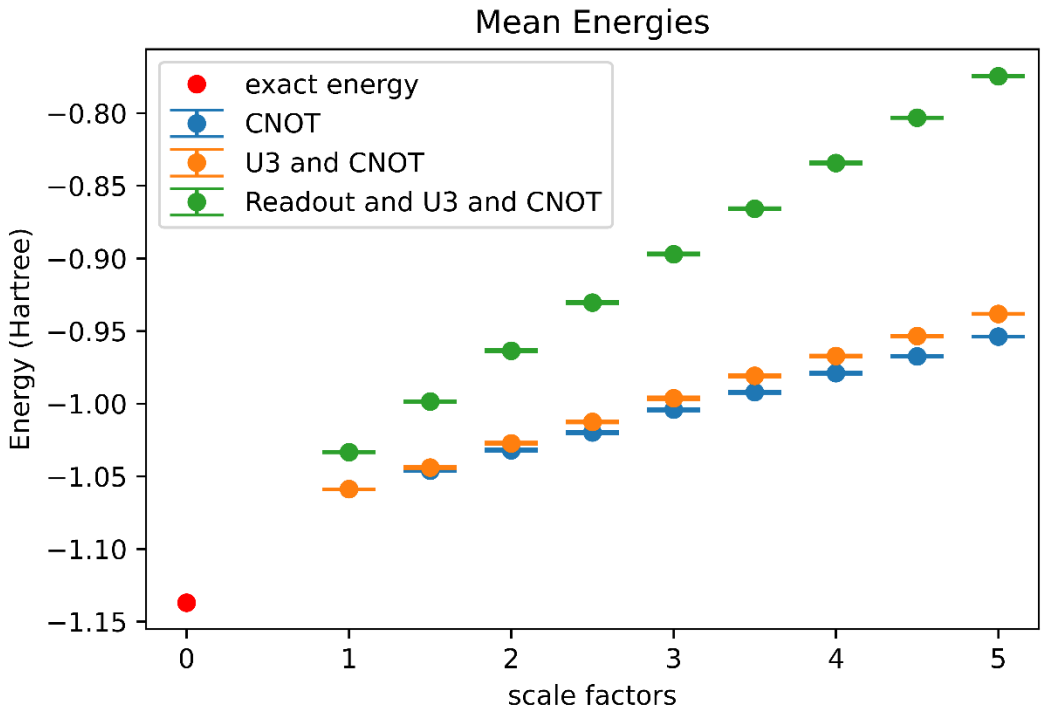


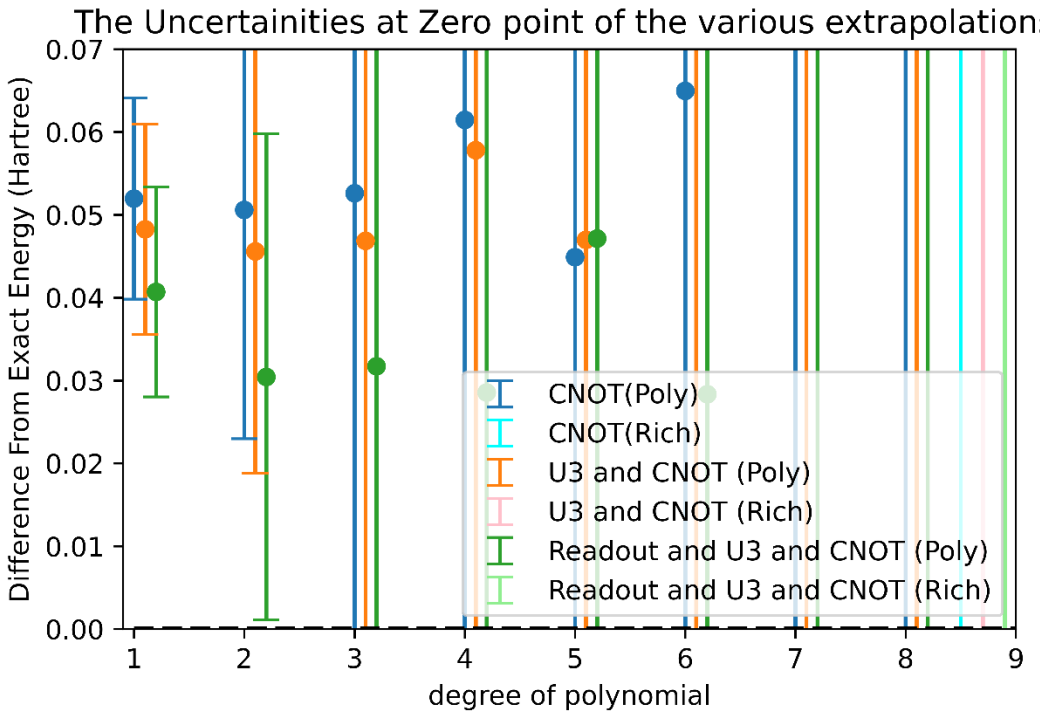




Data from London Device (8096 shots)

FakeLondon
Noise Model
1000 samples





London Device
25 samples