# Amplifying Readout Errors in VQE Optimized Circuit (1)

Meeting with Professor Schnetzer and Rikab

August 13, 2020

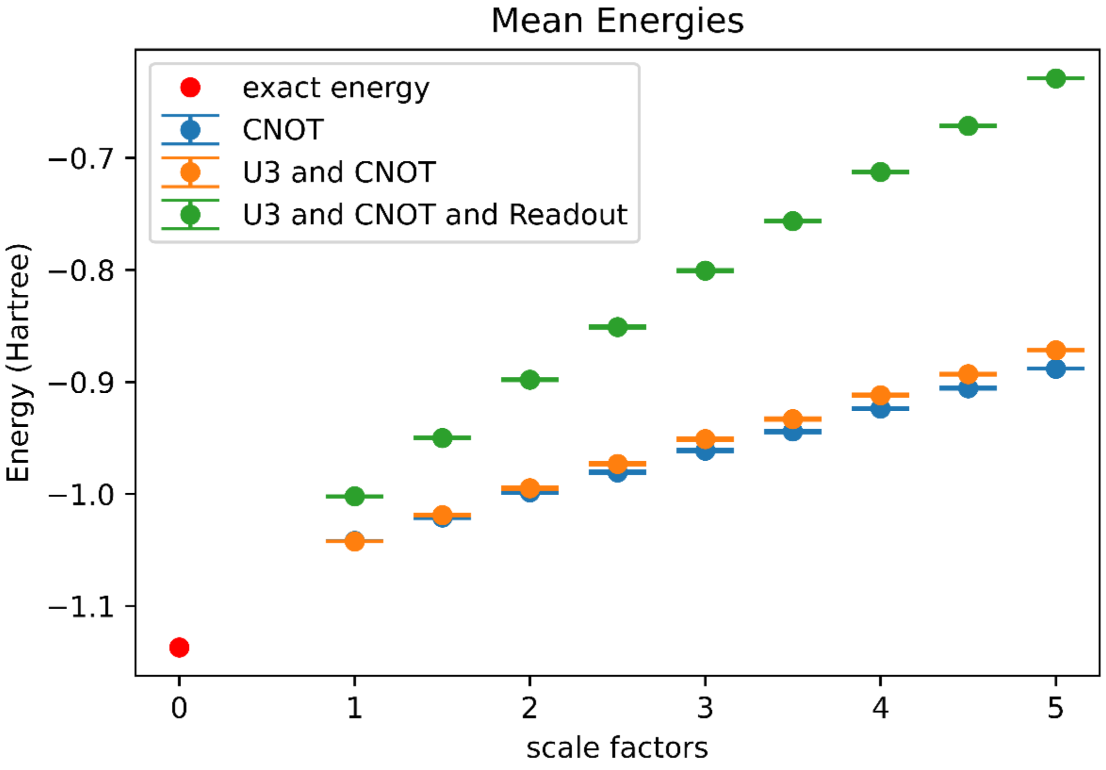
# Talking Points

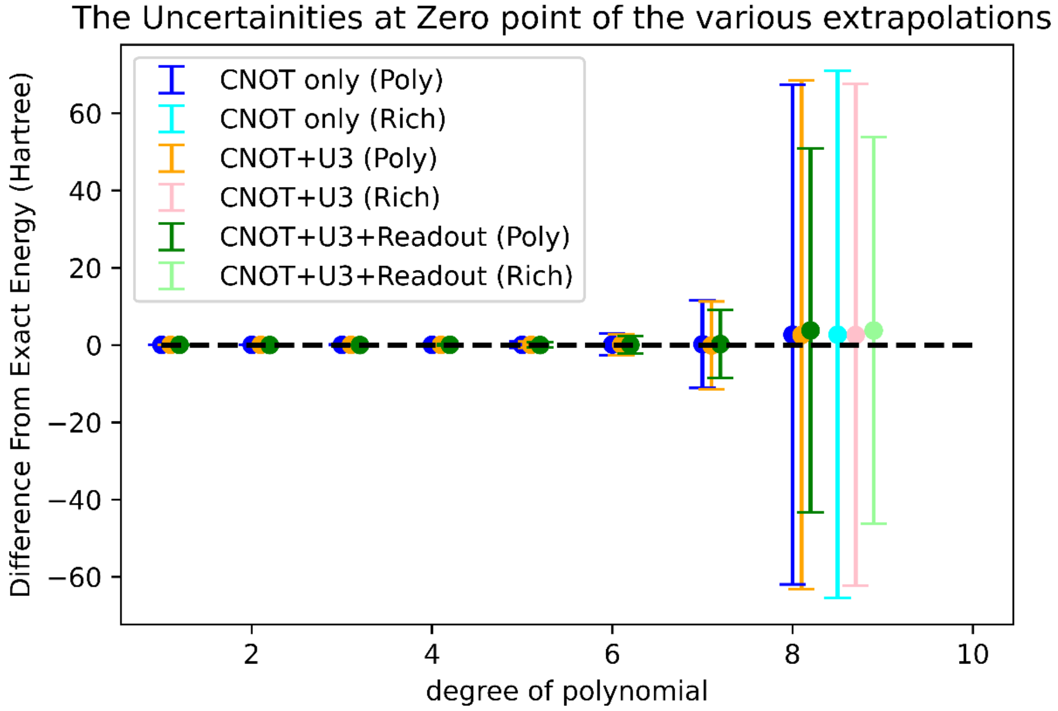
- Amplifying Readout Errors does improve the extrapolated zero noise energy, but not enough to bring it within chemical accuracy. (On the London Noise model)
- Still missing a noise source outside of U3, CNOT and readout errors
  - Could be thermal relaxation error (t1, t2 times of qubits)
  - I also have to be more specific in defining the simple noise model. As of now, I am assuming single qubit and 2 qubit gates on all qubits have the same error rate.

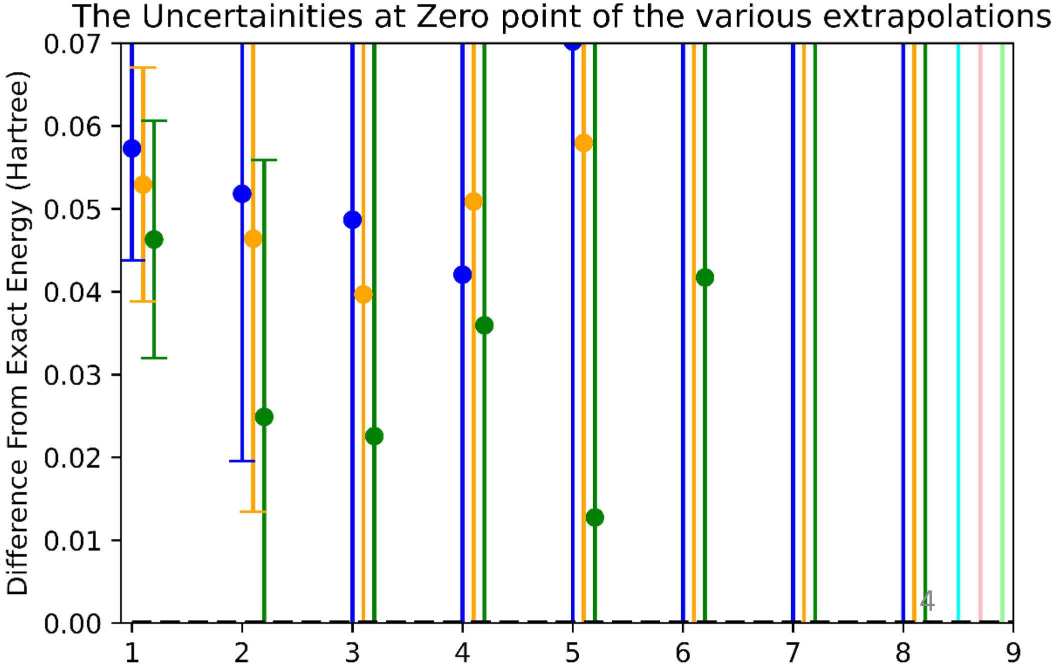
# Experiment 1

- Earlier we amplified both U3 and CNOT error rates by adding in more gates. But the computed zero noise extrapolated energy was still >50 times off chemical accuracy.
- Question: Does amplifying readout errors make a difference?

# Results
London Noise Model



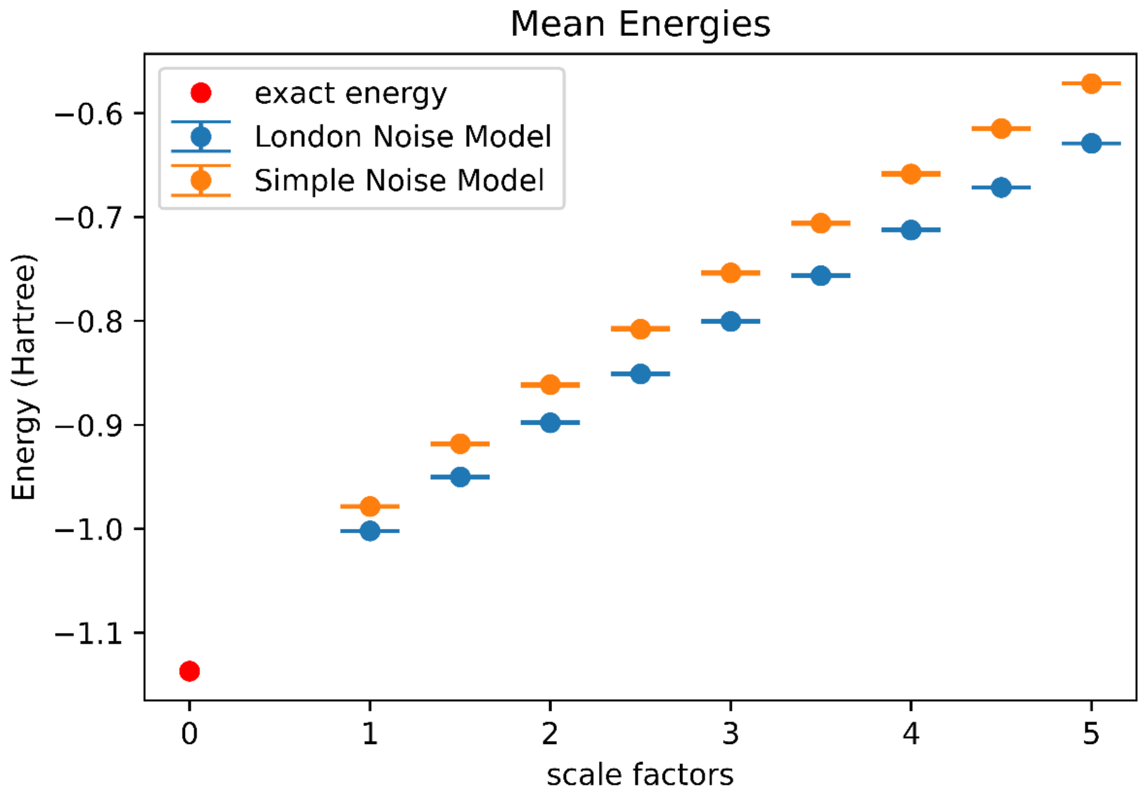
# Experiment 2

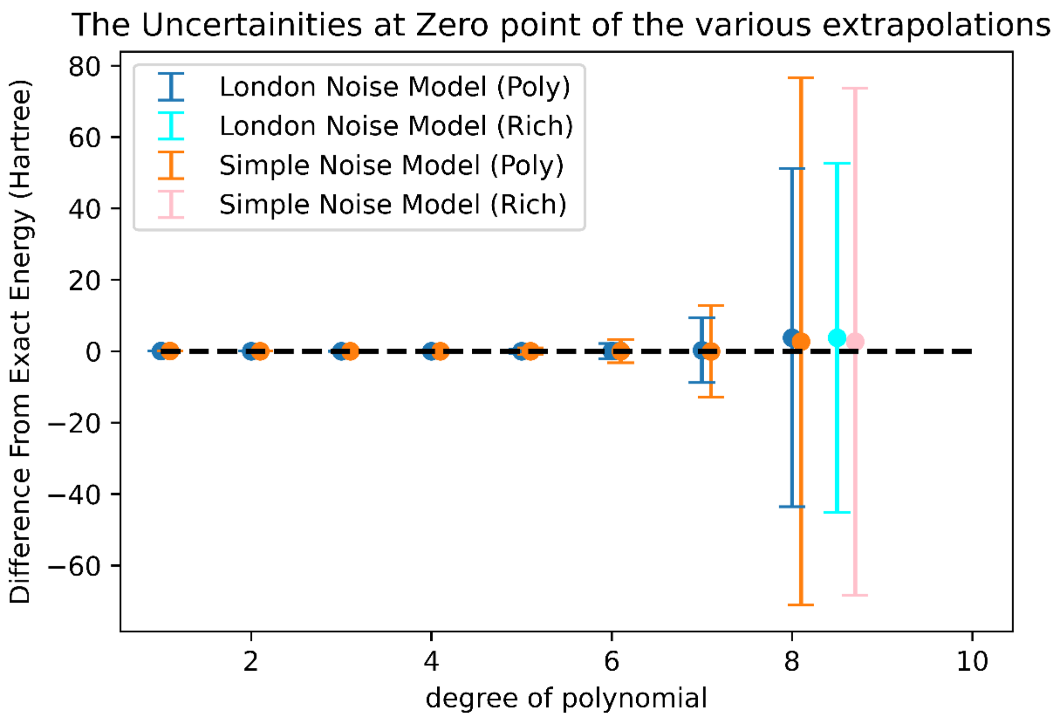
- Earlier, we concluded that there may be other errors besides the U3 and CNOT gate errors affecting results in the London Noise Model. We want to find what other error sources are there that may account for that ‘jump’ between 0 and 1 noise scaling points.
- Here I construct a simple noise model (details outlined in slide 8)
- Question: Are there other noise sources besides readout, single qubit and 2 qubit gate errors?

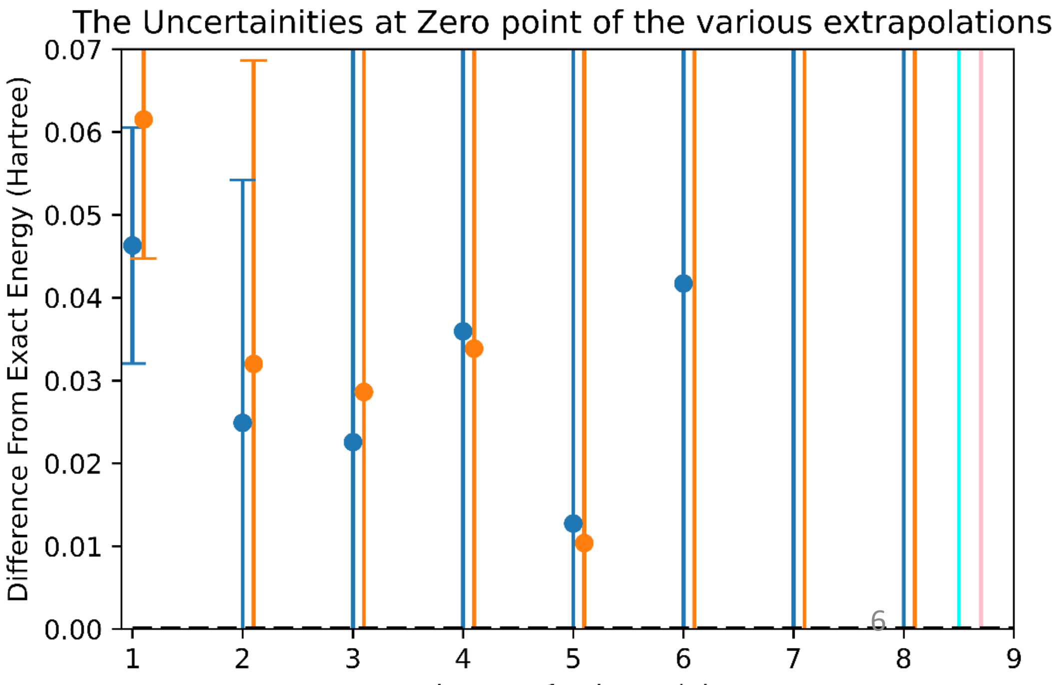
# Results

London Noise Model and Simple Noise Model

***Amplifying U3, CNOT, and readout errors in both!***



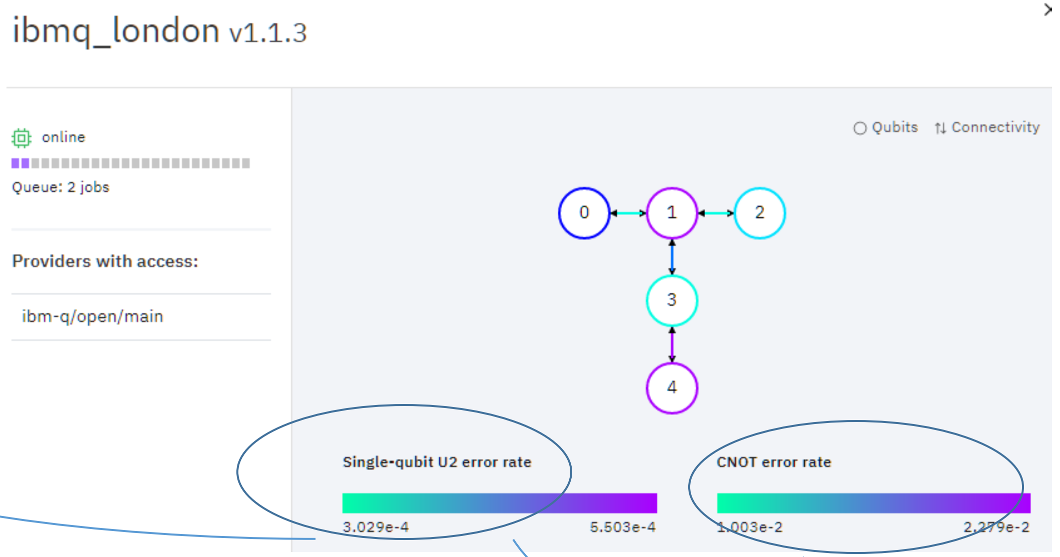
# Methods

Simple Noise Model and Amplifying Readout Errors

# Simple Noise Model

- Gate Errors:
  - Using information here, I add in depolarizing errors (just like the London Noise Model)

  *I assume that all single qubit and 2 qubit gates on all qubits have the same error rate (not assumed by London Noise Model)*




- Readout errors
  - Using information from here, I add in readout errors to the noise model.

| Qubit | T1 (Âµs) | T2 (Âµs) | Frequenc | Readout error | Singl |
|---|---|---|---|---|---|
| Q0 | 53.70296 | 73.43838 | 5.253997 | 2.00E-02 | |
| Q1 | 40.5309 | 71.17946 | 5.048845 | 3.50E-02 | |
| Q2 | 69.59602 | 26.70285 | 5.230339 | 1.43E-01 | |
| Q3 | 64.53714 | 78.41965 | 5.201325 | 3.00E-02 | |
| Q4 | 89.05166 | 19.48939 | 5.065943 | 2.50E-02 | |

# How to Amplify Read out Errors

Information obtained from London Device

$$\begin{array}{ll} q_0: & [\ 0.04 \quad 0.033\ ] \\ q_1: & [\ 0.06 \quad 0.077\ ] \\ \vdots & \\ q_5: & [\ \underbrace{\sim}_{P(0|1)} \quad \underbrace{\sim}_{P(1|0)}\ ] \end{array}$$

Since our VQE circuit only contains 2 qubits, we have to amplify errors in the first 2 qubits — $q_0$ and $q_1$

Step ①: Amplify each qubit's $P(0|1)$ and $P(1|0)$ by some factor c.

$q_0$: $[\, c\,A(0|1)\ ,\ c\,A(1|0)\, ]$ $\qquad$ $q_1$: $[\, c\,B(0|1)\ ,\ c\,B(1|0)\, ]$

* suppose $c=1$

Step ②: Compute the readout error matrix for each qubit

$$A = \begin{bmatrix} A(0|0) & A(0|1) \\ A(1|0) & A(1|1) \end{bmatrix} \qquad B = \begin{bmatrix} B(0|0) & B(0|1) \\ B(1|0) & B(1|1) \end{bmatrix}$$

Step ③: Combine the 2 matrices

$$B \otimes A = \begin{bmatrix} B(0|0) \otimes A & B(0|1) \otimes A \\ B(1|0) \otimes A & B(1|1) \otimes A \end{bmatrix}$$

$$\underbrace{R_{-1}}_{\text{2 qubit readout error matrix with amplification factor of 1}} = B \otimes A$$

Step 4: Compute $R_{-c}$ by repeating steps 1-3

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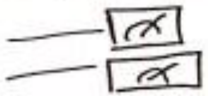
Note: Once you have measured your circuit , you will get counts which look like

$$\{ '00': 100,\ '01': 100,\ '10': 100,\ '11' \ 100 \}$$

↑ shots

These counts already have readout errors i.e. they have gone through $R_{-1}$. Our goal is to apply additional readout errors such that the counts effectively go throug $R_{-c}$ (readout errors scaled by factor c).

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Step 5 : Compute X in equation $X R\_1 = R\_C$

$$X = R\_C \cdot (R\_1)^{-1}$$

Step 6 : Apply X to counts.