Furious Five

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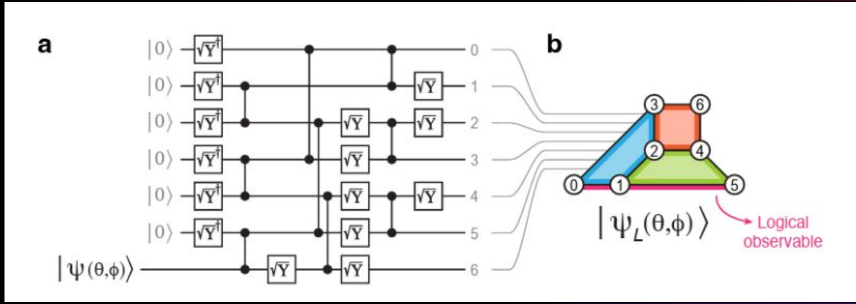
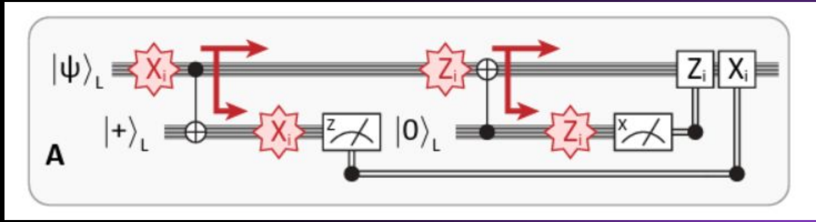
QuEra Technical Challenge

iQuHack 2026

Step 1: Initial Exploration





Programmed in stim

```
SQRT_Y_DAG 0 1 2 3 4 5
CZ 1 2 3 4 5 6
SQRT_Y 6
CZ 0 3 2 5 4 6
SQRT_Y 2 3 4 5 6
CZ 0 1 2 3 4 5
SQRT_Y 1 2 4

H 13
SQRT_Y_DAG 7 8 9 10 11 12
CZ 8 9 10 11 12 13
SQRT_Y 13
CZ 7 10 9 12 11 13
SQRT_Y 9 10 11 12 13
CZ 7 8 9 10 11 12
SQRT_Y 8 9 11

CX 0 7 1 8 2 9 3 10 4 11 5 12 6 13
MZ 7 8 9 10 11 12 13

<more gates>

CZ rec[-7] 0 rec[-6] 1 rec[-5] 2 rec[-4] 3 rec[-3] 4 rec[-2] 5 rec[-1] 6
CX rec[-14] 0 rec[-13] 1 rec[-12] 2 rec[-11] 3 rec[-10] 4 rec[-9] 5 rec[-8] 6

SQRT_Y_DAG 1 2 4
CZ 0 1 2 3 4 5
SQRT_Y_DAG 2 3 4 5 6
CZ 0 3 2 5 4 6
SQRT_Y_DAG 6
CZ 1 2 3 4 5 6
SQRT_Y 0 1 2 3 4 5

MZ 0 1 2 3 4 5 6
```

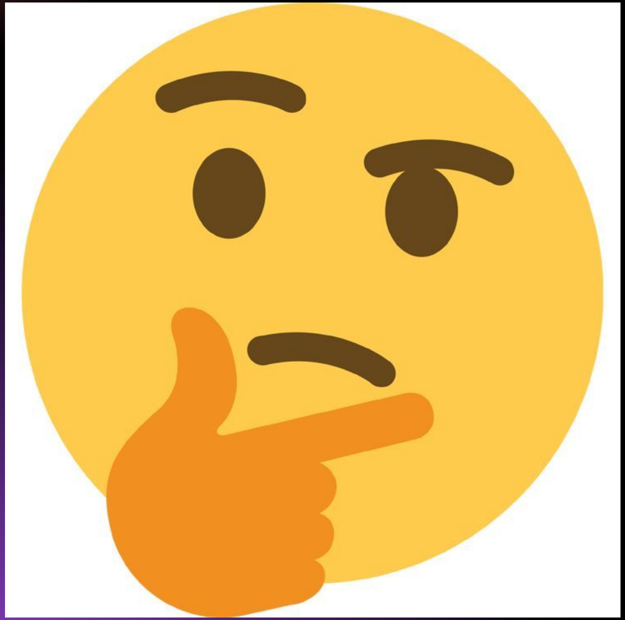
Step 1: Initial Exploration (Cont.)

How can we verify the error correction works?

"Mirror Fidelity" Approach!

Step 1: Initial Exploration (Cont.)

How can we exactly do the mirror fidelity approach?

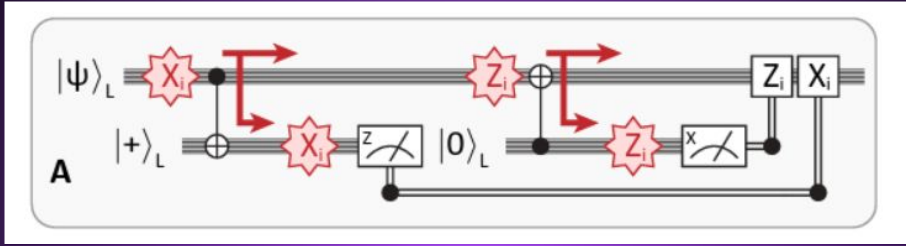


We didn’t know how do take that route, so we consulted QuEra staff!

Step 1: Initial Exploration (Cont.)

Our takeaways From QuEra Staff:

1. Use parity of physical qubits instead
2. Use `squin` for code instead of `stim`.
3. Use `stim` ONLY for simulation
4. The QEC circuit is meant to not collapse the original logical qubit



Step 2: Finding the Solution

> "
>
> Our solution to the challenge is exploratory in nature. We will explain each individual part as we demonstrate the corresponding code.

Step 2: Finding the Solution

Phase A: MSD Encode

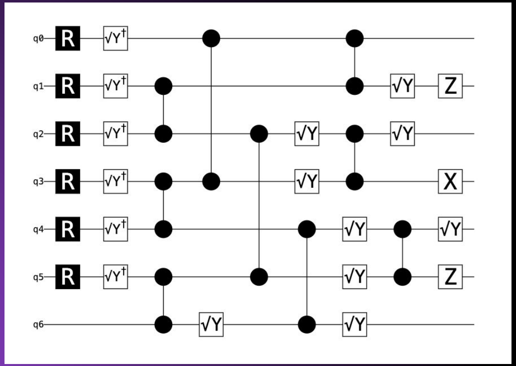
1. We made the MSD encode circuit in **`squin`** & simulated it using **`stim`**.
2. Considered both the cases of noise and no noise.
3. Calculated the syndromes as well as the logical observable after measuring the qubits.

Step 2: Finding the Solution

Phase A: MSD Encode

4. We noticed that while the physical observable is consistent with the input state `|0>`, two of the syndromes are consistent of the opposite polarity (-1 instead of 1).
5. While we were unable to understand why this is the case, we applied an **`X`** gate to the third qubit which flips all three syndromes back to 1.

```
q0: -SQRT_Y_DAG---@---------------@--------------------
                  |               |
q1: -SQRT_Y_DAG-@-|---------------@------SQRT_Y--------
                | |
q2: -SQRT_Y_DAG-@-|------@-SQRT_Y-@------SQRT_Y--------
                  |      |        |
q3: -SQRT_Y_DAG-@-@------|-SQRT_Y-@--------------------
                |        |
q4: -SQRT_Y_DAG-@--------|-@------SQRT_Y-@------SQRT_Y-
                         | |             |
q5: -SQRT_Y_DAG-@--------@-|------SQRT_Y-@-------------
                |          |
q6: ------------@-SQRT_Y---@------SQRT_Y---------------
```



Step 2: Finding the Solution

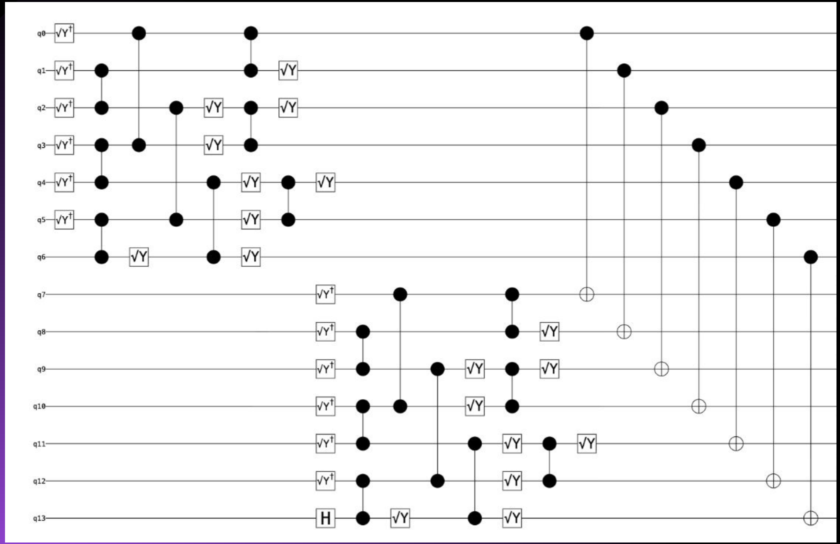
Phase A: MSD Encode

6. We sampled the circuit and dropped the shots where the syndromes indicate an error.
7. Calculated the corresponding logical and physical errors and noticed a significant decrease in error rate after the syndrome-filtering mechanism.

Step 2: Finding the Solution

Phase B: Implementing QEC

- Measuring the qubits and collapsing them is not useful
- Instead, we implemented QEC
- This allowed us to transfer syndromes to the auxiliary logical qubit |+>



Step 2: Finding the Solution

Phase B: Implementing QEC

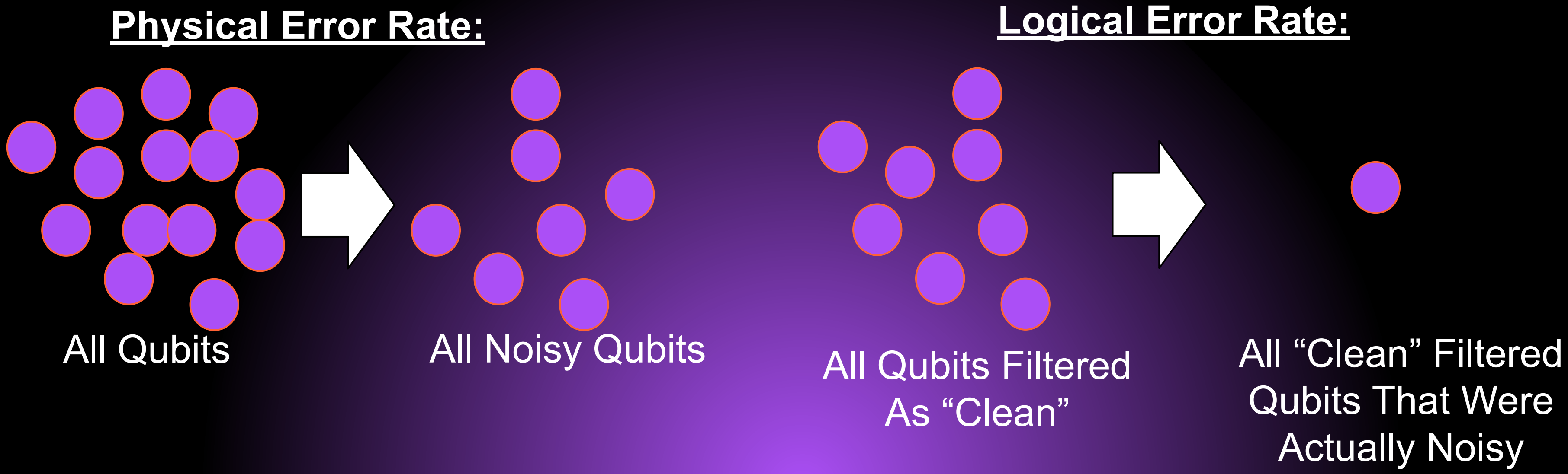
- By measuring the auxiliary qubit we're able to extract quantum information without collapsing the original qubit
- We then added loops that allow us to run this over multiple iterations

```
Values (no noise):  [ 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1 -1  1  1  1]
Logical error rate:  0.014925373134328358
```

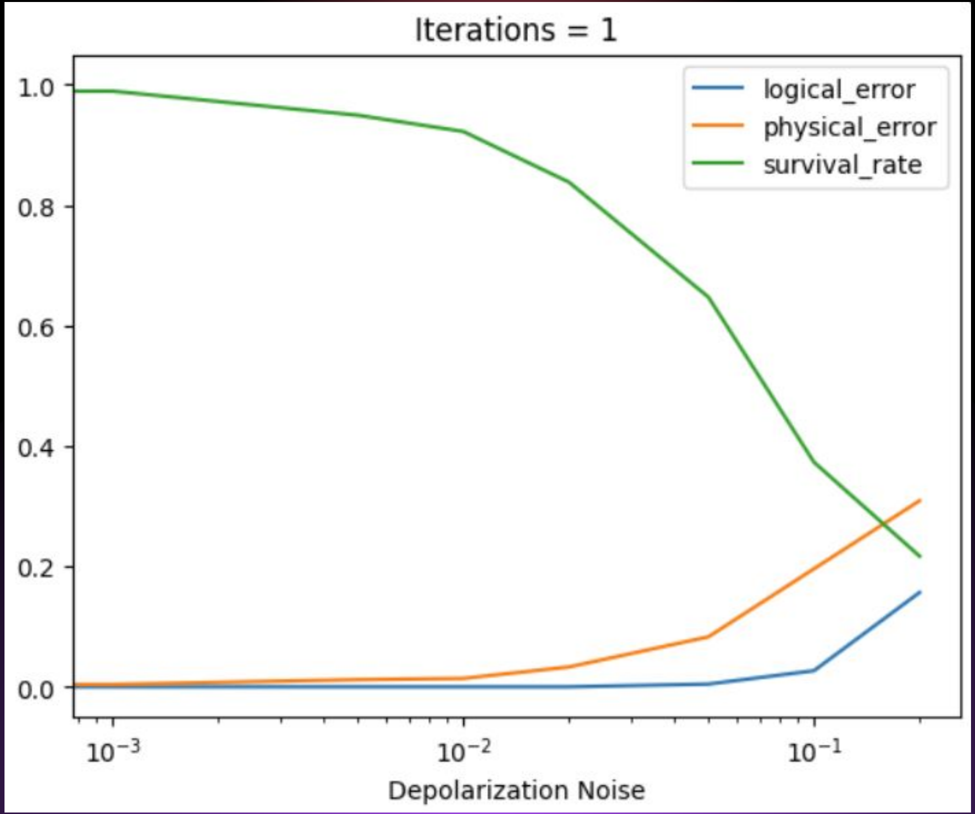
Step 2: Finding the Solution

Phase C: Post Selection

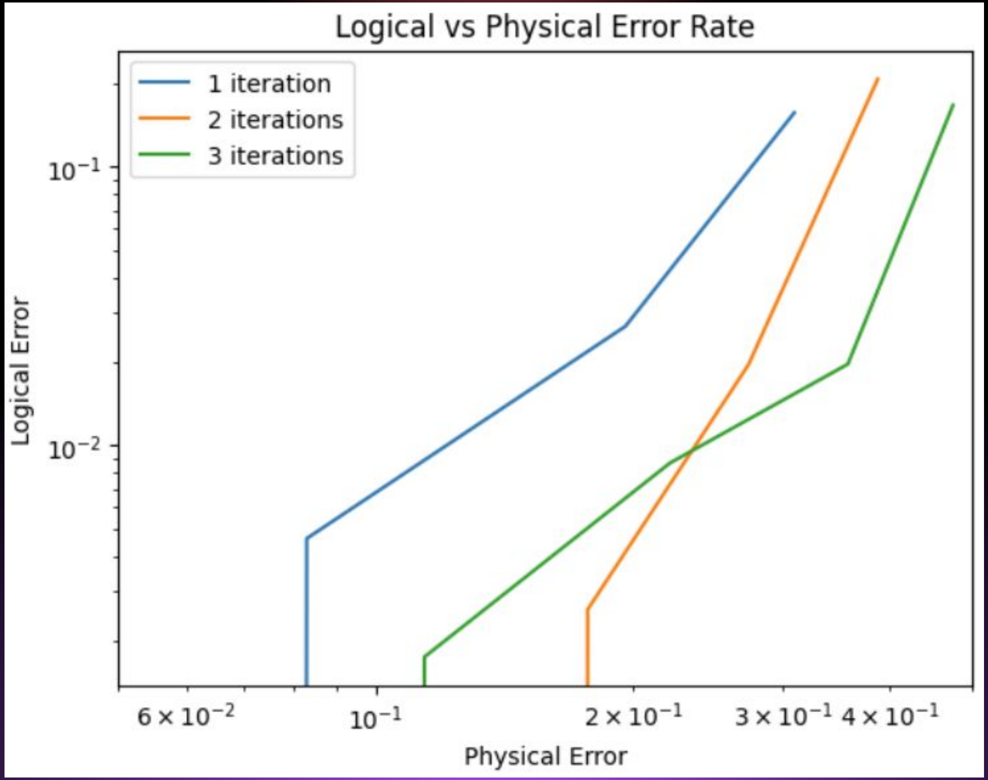
- We implemented post selection by analyzing the measurement data from the QEC circuit.



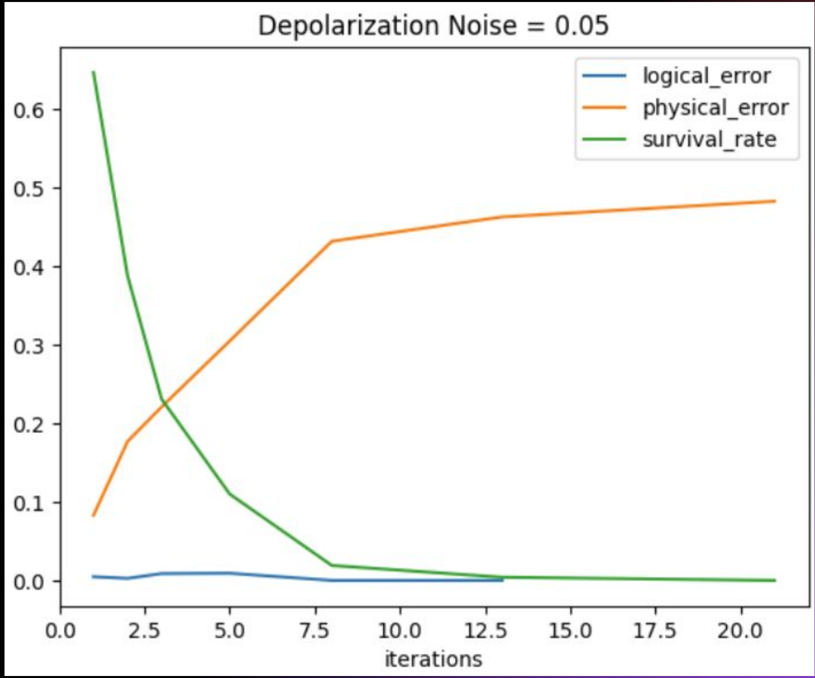
Step 3: Results/Data Analysis

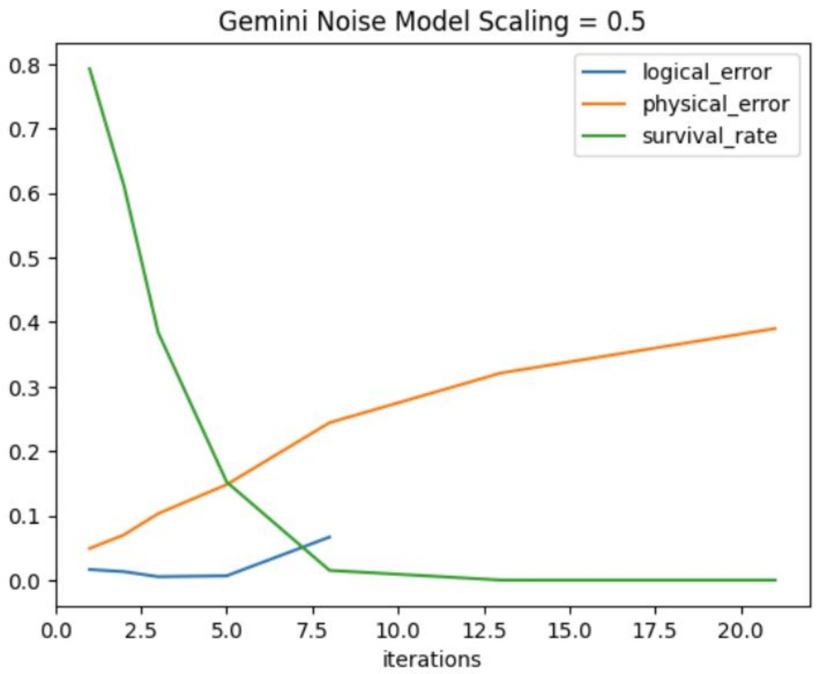


Step 3: Results/Data Analysis (Cont.)



Step 3: Results/Data Analysis (Cont.)





THANK YOU

Any questions?