The quest for logical qubits

Many top QC teams are working on building logical qubits. Why?

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To understand what makes logical qubits so important in quantum computing, let’s take a look at some applications where quantum computers are expected to really shine.

The table below lists some promising applications along with typical numbers of gates needed to run those applications.

Application	Gate counts
Scientific breakthrough	10,000,000+
Fertilizer manufacture	1,000,000,000+
Drug discovery	1,000,000,000+
Battery materials	10,000,000,000,000+

As you can see, these applications need **very large** numbers of gates!

Why does this matter?

More gates

More computation time

More errors accumulate

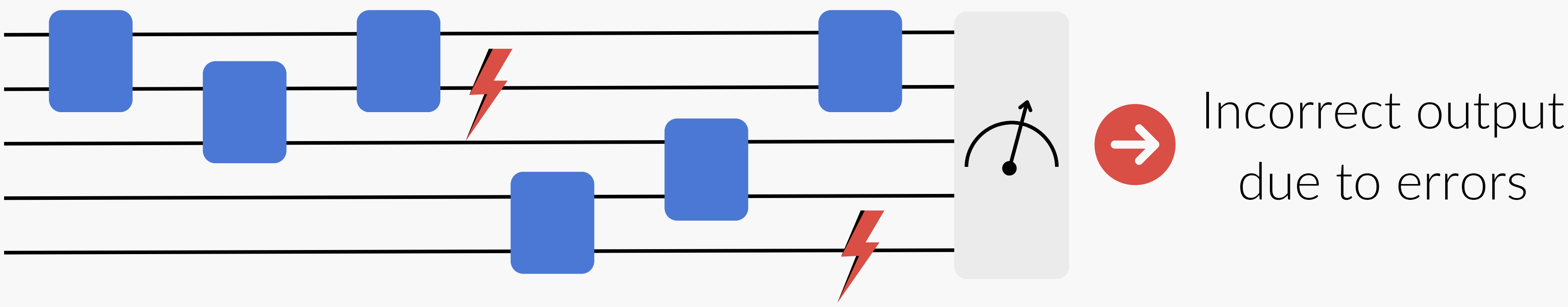
We need to get the error probability **really low**!

But how low?

Let's consider two examples:

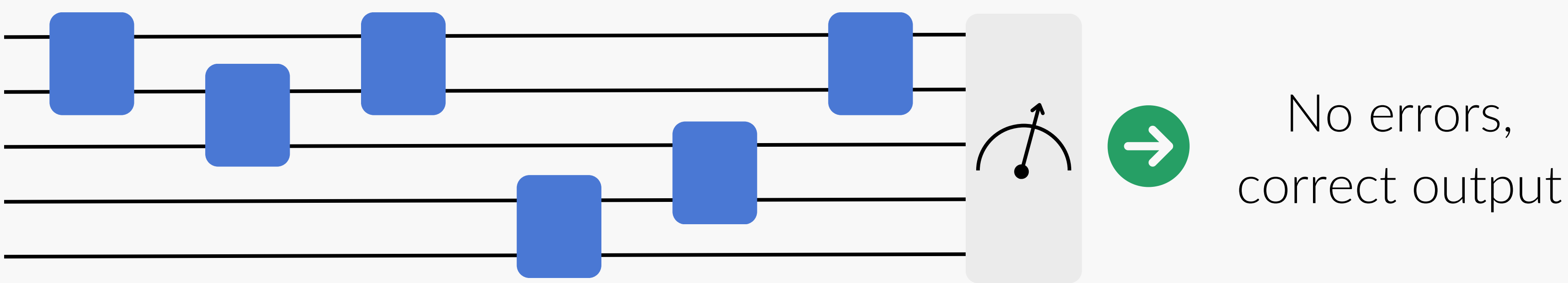
High error rate → algorithm fails

If we apply **100 gates** in sequence, and an **error** can occur once **every 10 gates**, the algorithm is likely to fail.



Low error rate → algorithm succeeds

If we apply **100 gates** in sequence, and an **error** can occur once **every 1000 gates**, the algorithm is likely to succeed.



In practice, some gates can be applied at the same time, but we can still use the following rule of thumb to estimate the error rate.

For **reliable computation**, the error rate must be lower than the inverse of the number of gates:

$$\text{error rate} < \frac{1}{\text{number of gates}}$$

Big problems need low error rates

From this rule of thumb, we can see that for big applications, the required error rates are extraordinarily low:

Application	Error rates
Scientific breakthrough	<1/10,000,000
Fertilizer manufacture	<1/1,000,000,000
Drug discovery	<1/1,000,000,000
Battery materials	<1/10,000,000,000,000

So how do today's quantum computers fare?

Requirement: <1/10,000,000

Reality: >1/1,000 (i.e. not great!)

To run these applications, we need qubits with **much lower** errors.

But making qubits with errors that are over 10,000 times better than today is a tough engineering challenge!

The good news is that we can get around that!

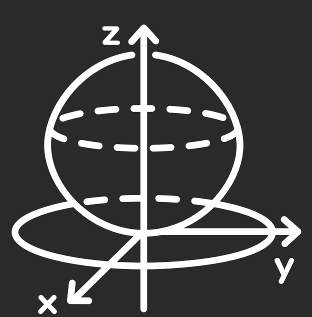
Enter logical qubits

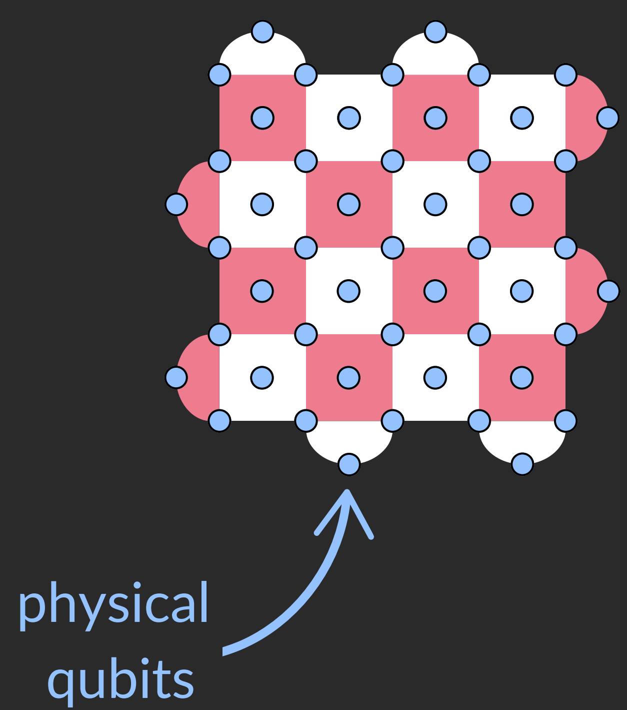
What if, instead of trying to make qubits with drastically lower errors, we could just use **more of them** to solve the same problem?

That's exactly the idea behind logical qubits!

Logical qubits protect information from one qubit by spreading it over many qubits.

1 qubit of information — encoded into → many physical qubits: **a logical qubit**





Logical qubits can run deep circuits

Using logical qubits composed of 1000s of physical qubits keeps the overall error levels low, enabling the realization of big circuits with billions of logical gates or more!

That's exactly what's needed for building **reliable** and **useful** quantum computers.

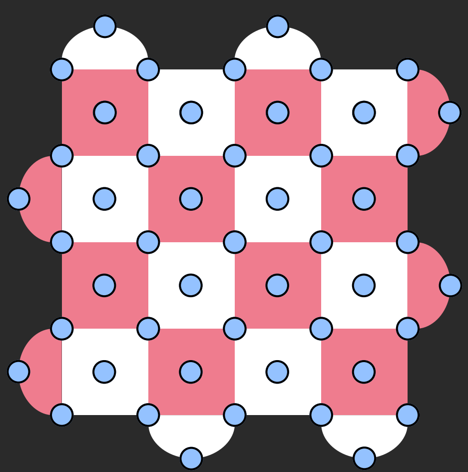
Which is why many teams are focused on developing logical qubits.

How Plaquette™ helps

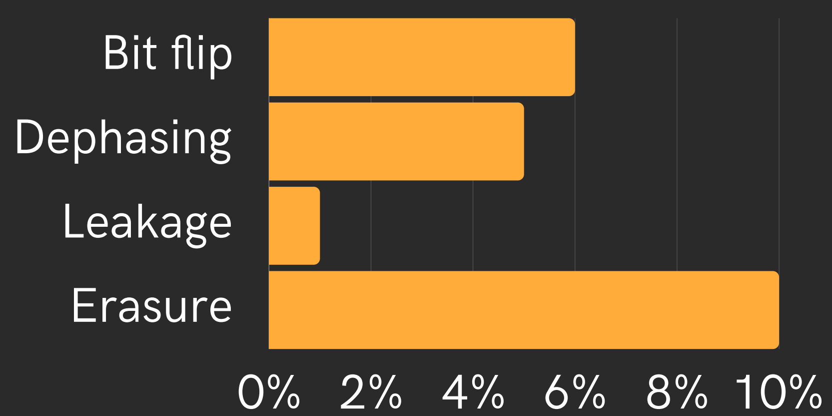
Building logical qubits is a complex process that requires understanding how errors behave across thousands of physical qubits.

Plaquette provides insights into error thresholds to guide the design of logical qubits.

Plaquette



Threshold for different hardware imperfections



Learn more about Plaquette™

If you’re interested to learn how to use Plaquette to plan out your hardware roadmap, we’re happy to chat.

Contact us here on LinkedIn™, or head on over to the website at qc.design.

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