Shifting error thresholds

Using threshold surfaces to navigate multiple interacting imperfections.

QCDESIGN

Previously...

In previous carousels we saw that:

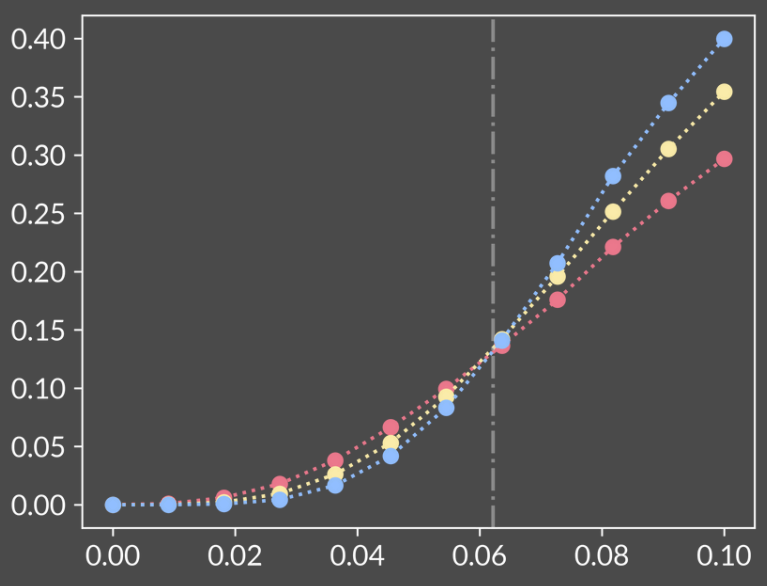
- An **error threshold** tells us how much error a system can handle before quantum error correction fails.

- **Staying below this threshold is essential** for scaling quantum computers.

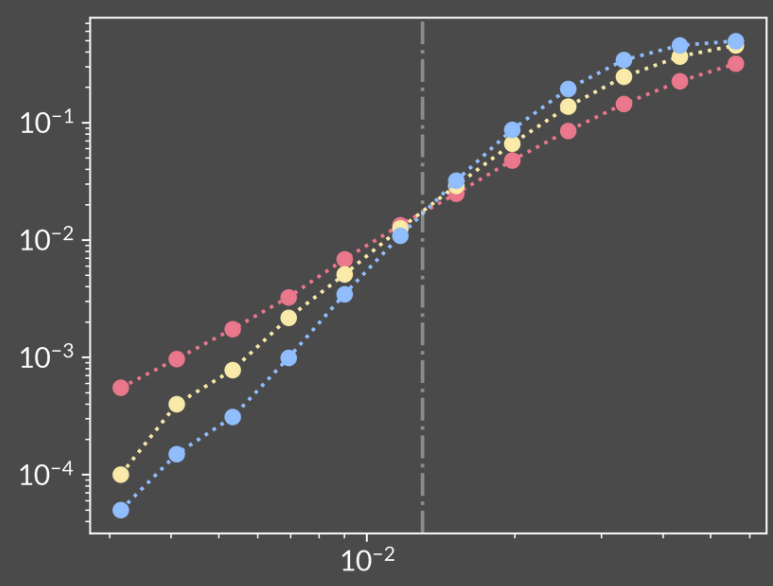
We also saw that:

Hardware has **many kinds of imperfections**, each with its own threshold plot.

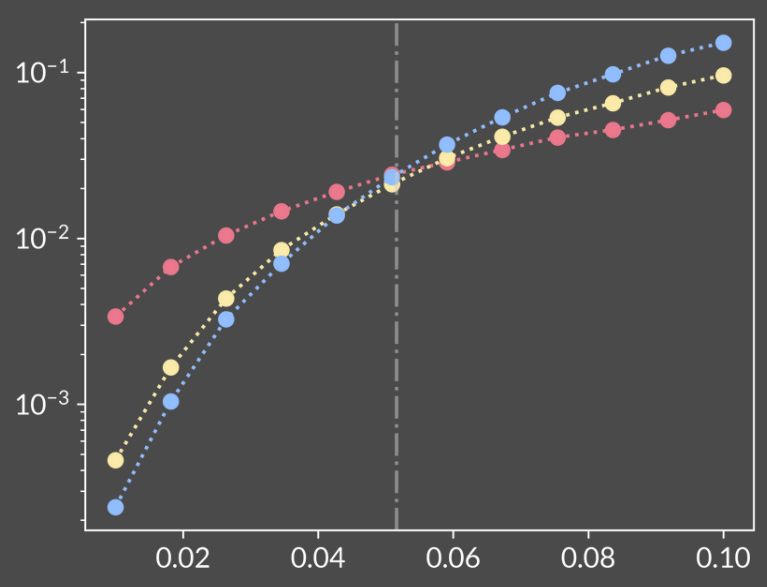
Depolarizing noise



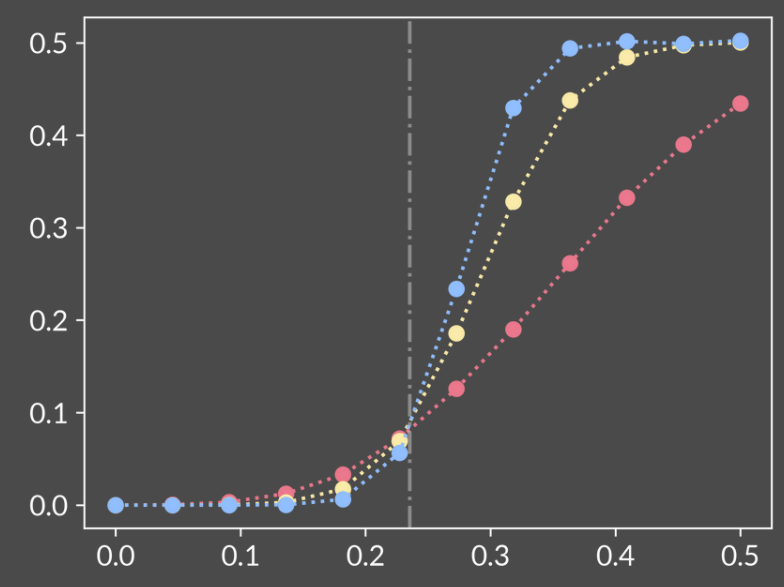
Mitigated leakage



Scattering



Optical loss



...and others as well!

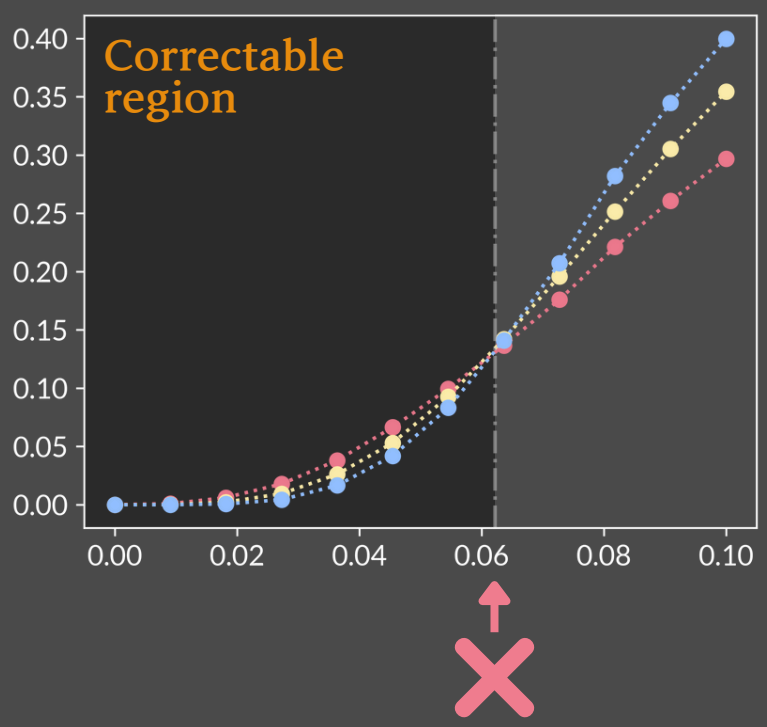
But thresholds —and threshold plots— for different imperfections are not independent.

Multiple imperfections

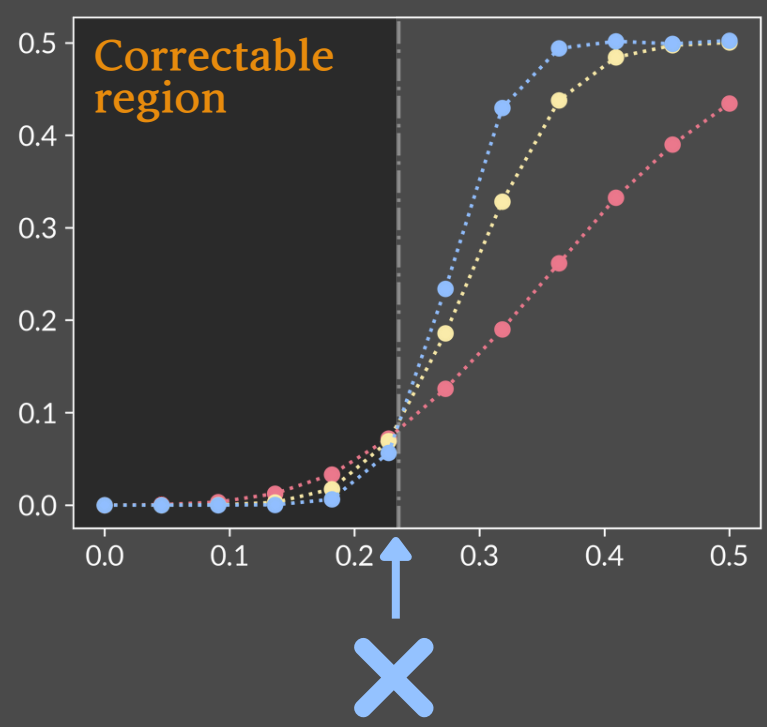
To account for how thresholds for one error depend on other errors in the system, error correction codes must handle multiple imperfections simultaneously.

Consider threshold plots for two imperfections:

Imperfection A

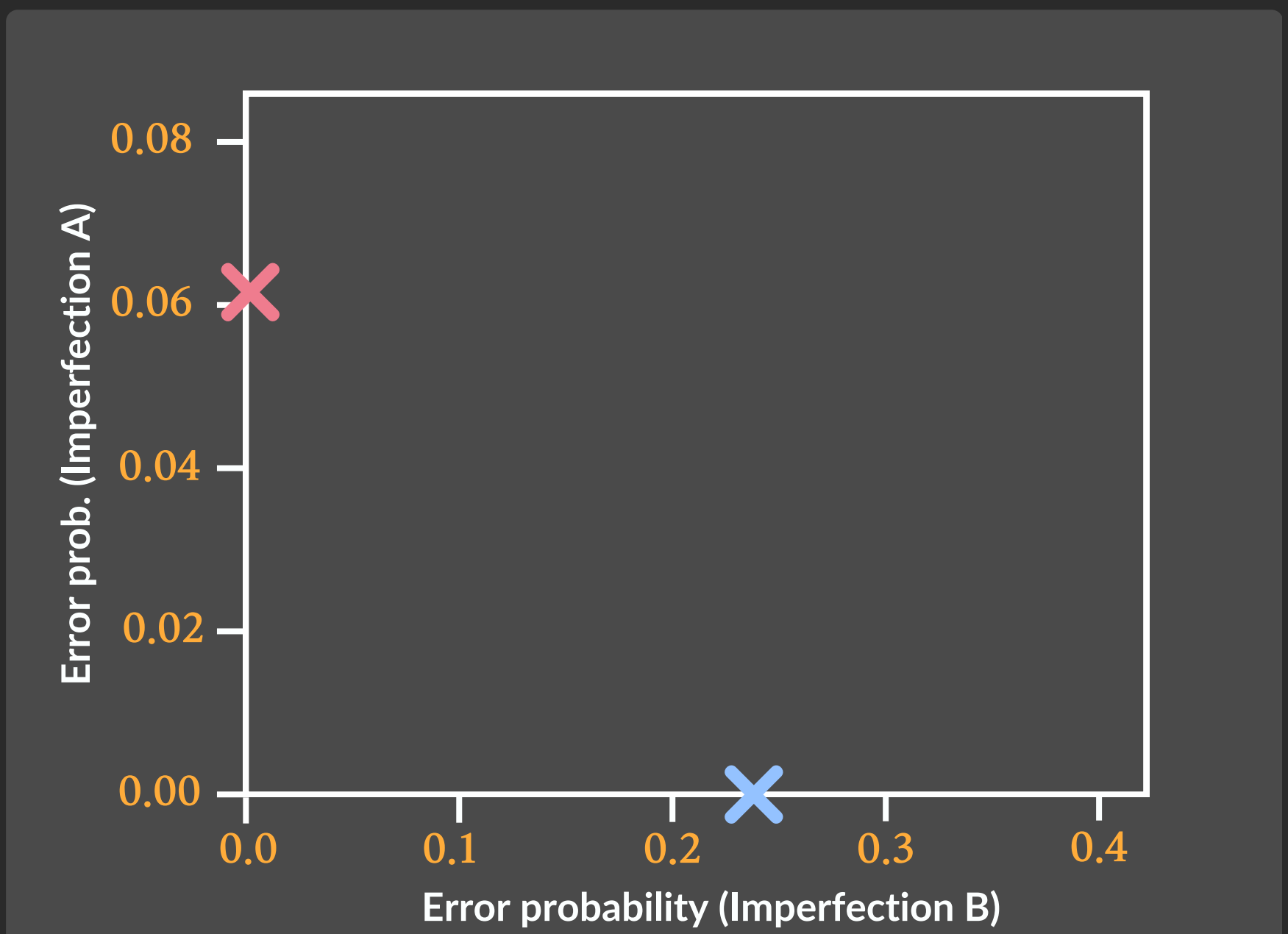


Imperfection B



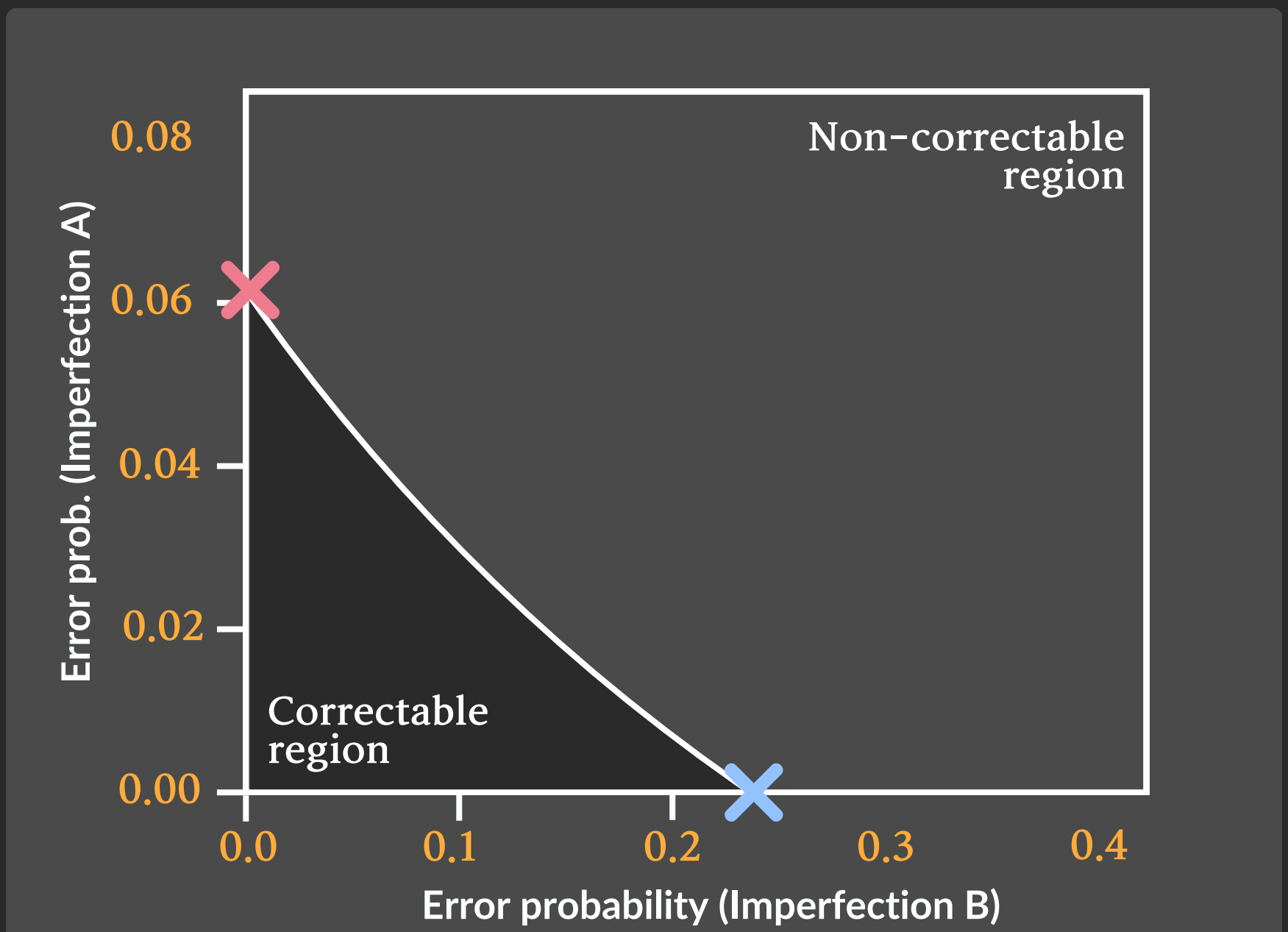
To the left of the thresholds ✕ and ✕ are the correctable regions for each imperfection.

If either imperfection A or B is present (but not both simultaneously), we can mark the threshold for each imprefection on a 2D plot as follows:



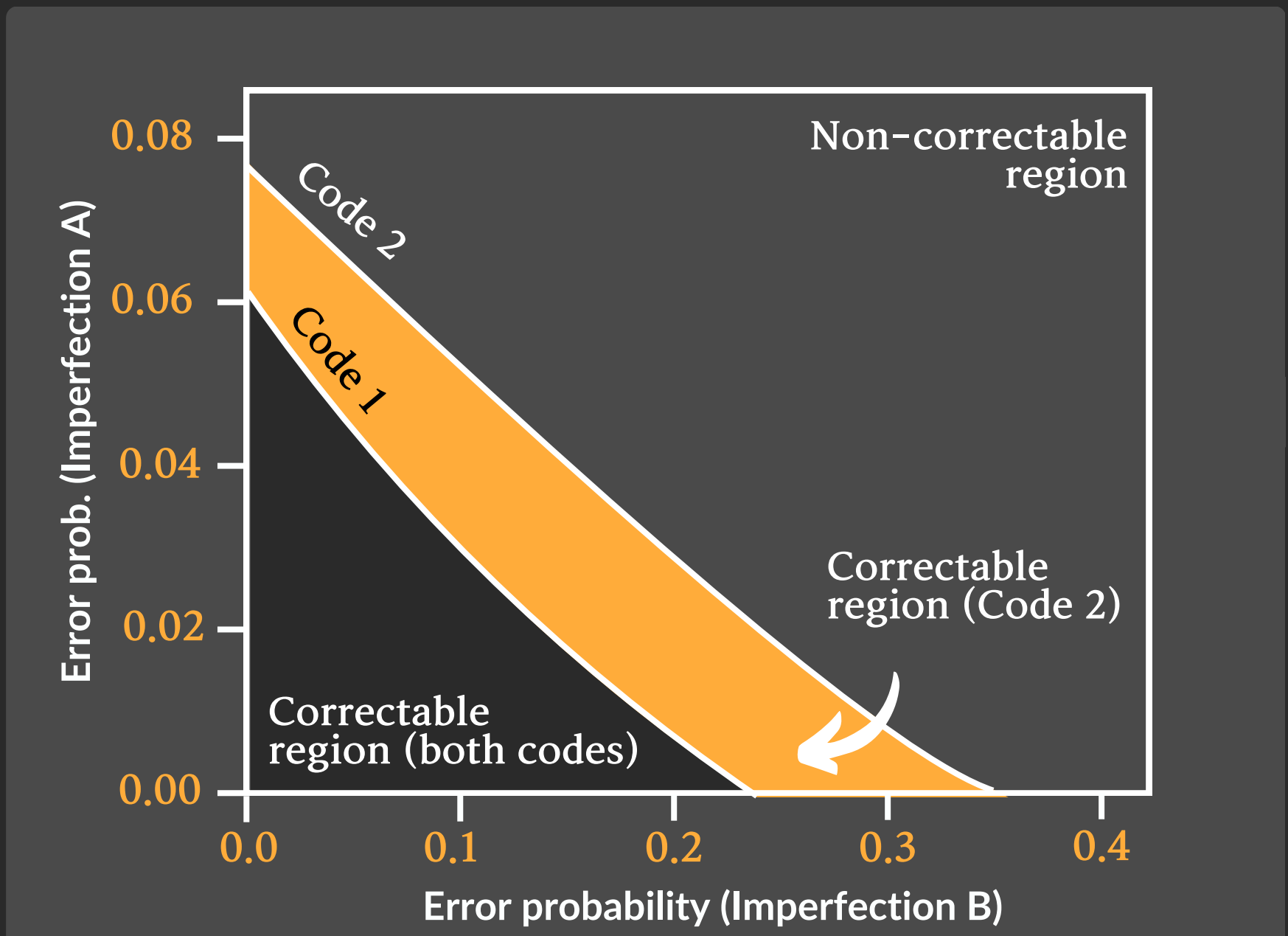
But if both imperfections are present, thresholds form a curve on a surface.

Correctable errors are on the bottom-left of this curve. **Non-correctable errors** are on the top right.

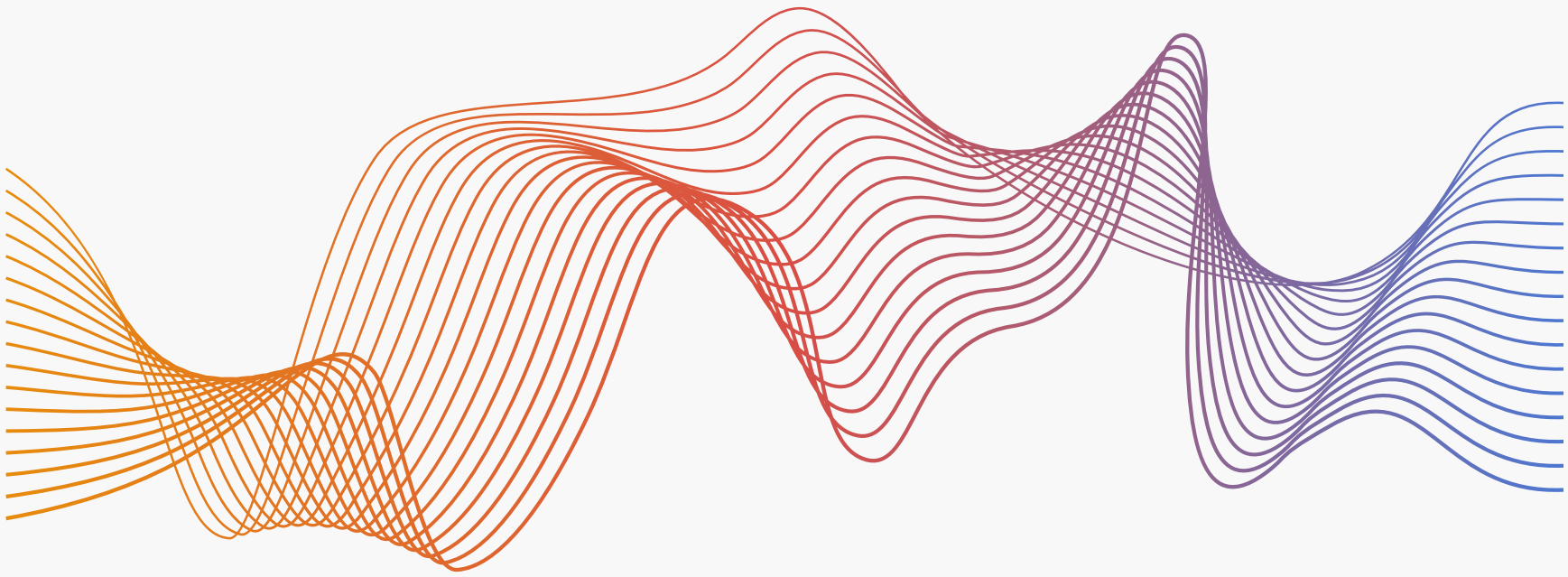


We can also have different codes, which form different curves on the surface.

Some codes have larger correctable regions than others.



For more than two imperfections, thresholds form hyper-surfaces in higher dimensions.



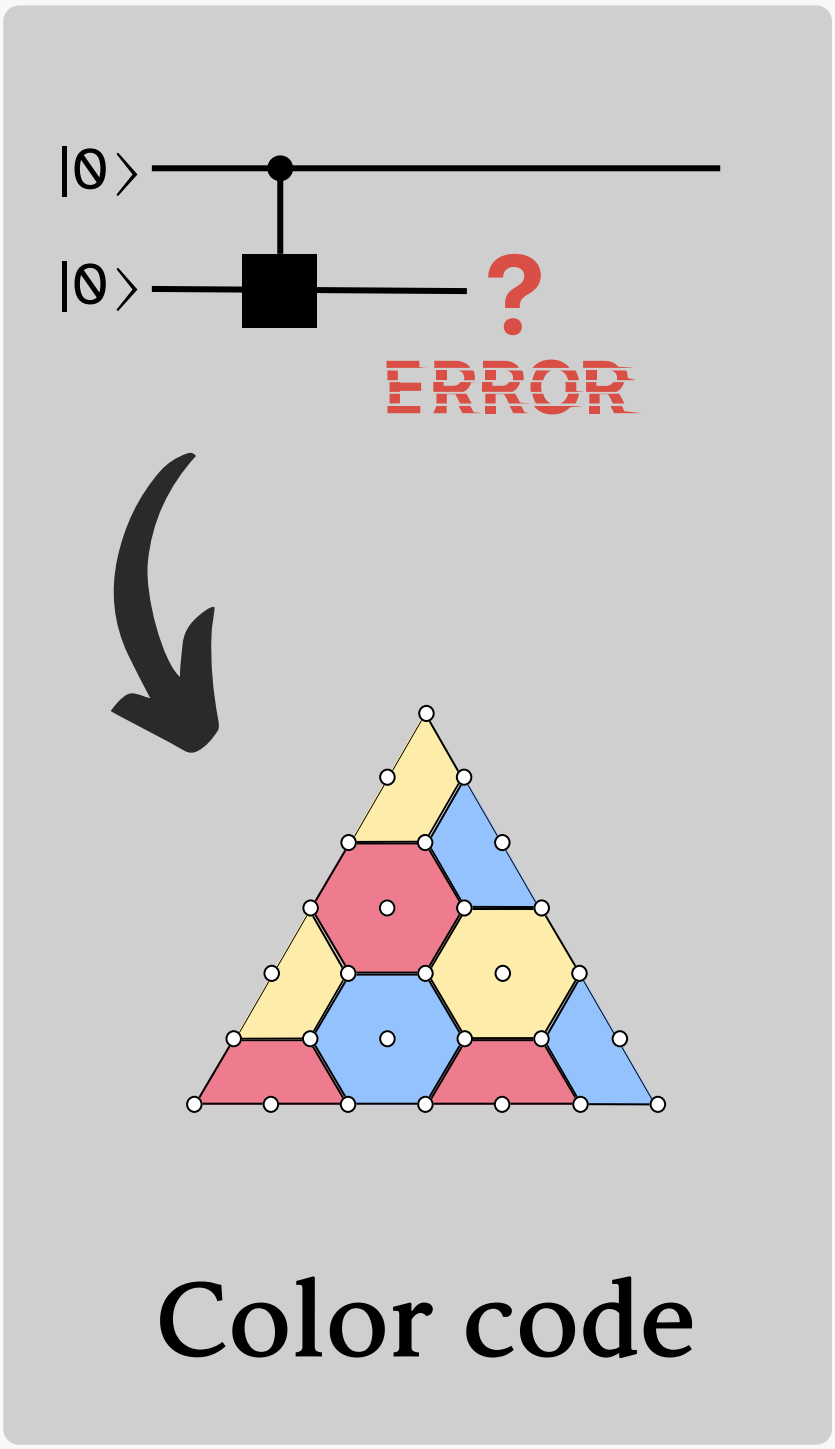
To design **robust systems**, we have to **account for all possible imperfections.**

What does this mean?

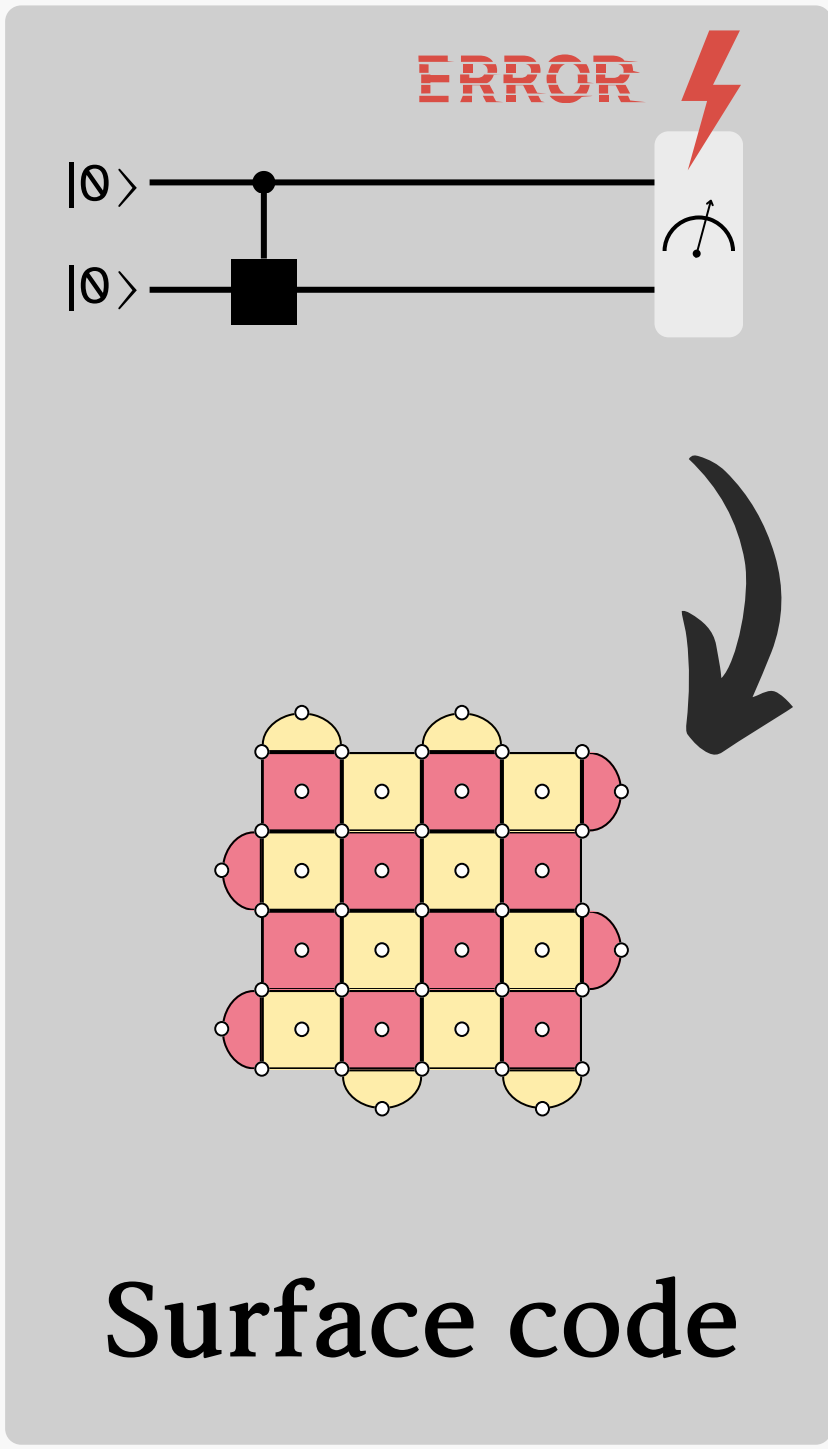
Staying within the correctable region requires **minimizing all error types simultaneously**.

Error correction codes must be tailored to the unique error landscape of each hardware platform.

For example, hardware with high **erasure errors** might need an entirely different optimization than one prone to **measurement errors.**



Color code

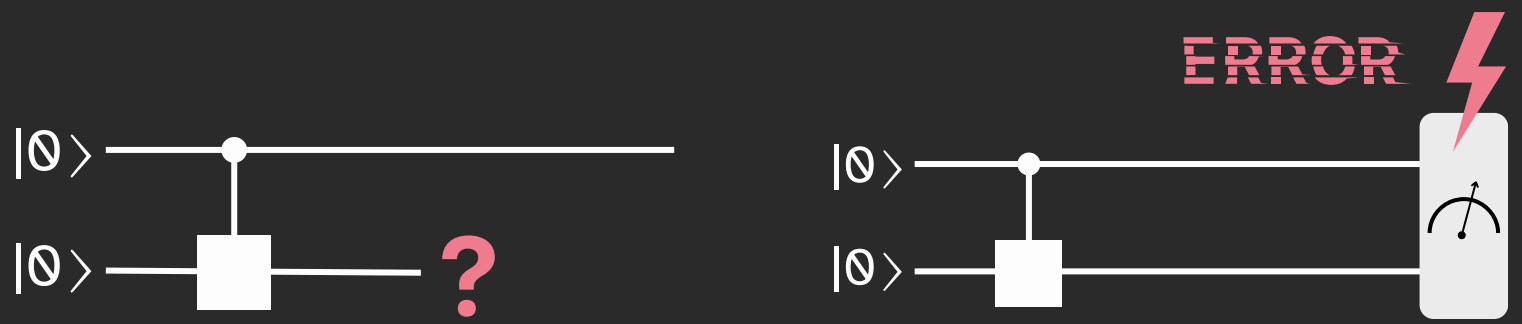


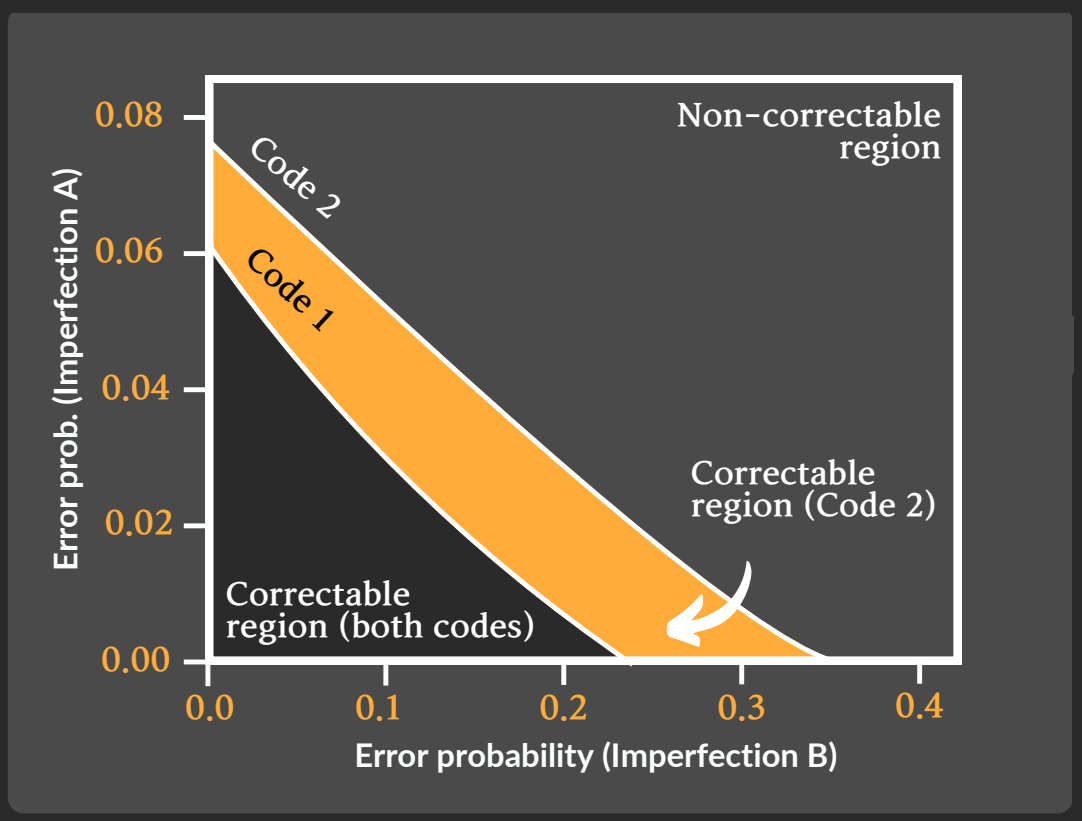
Surface code

Understanding how thresholds shift under **multiple imperfections** is key to designing fault-tolerant quantum systems.

That's why we built Plaquette™!

Plaquette simplifies threshold calculations, making it easier to account for multiple error types and combinations.





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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