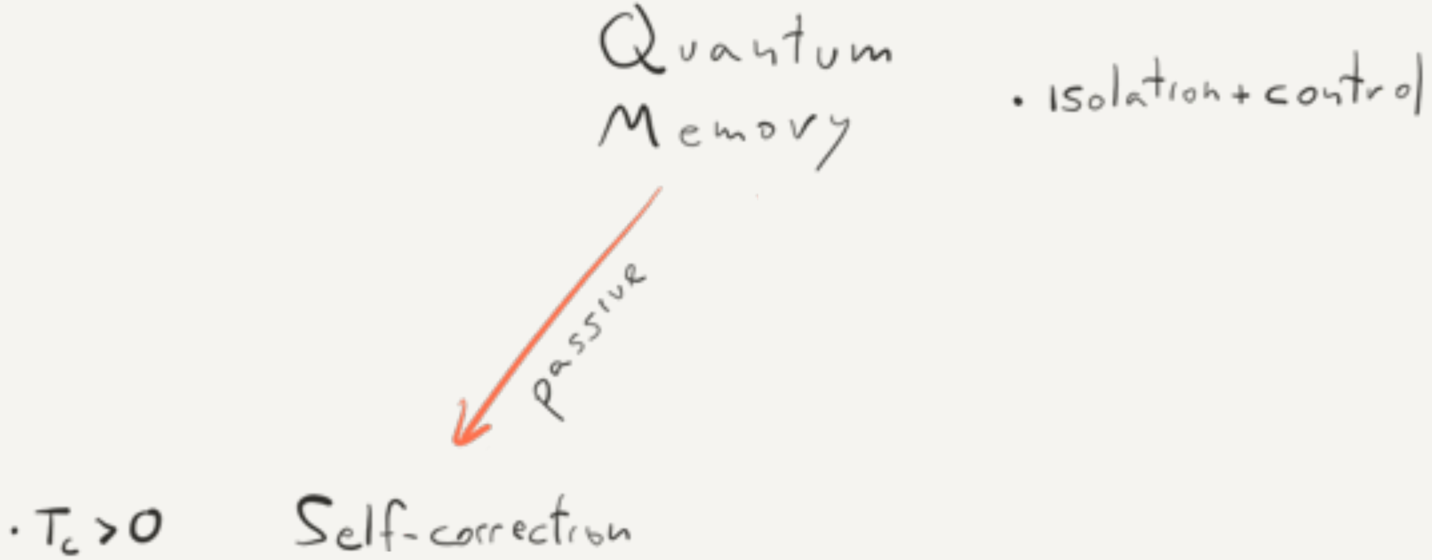
Time-correlated noise & confinement phenomena in quantum computation

Quantum Memory

- isolation + control



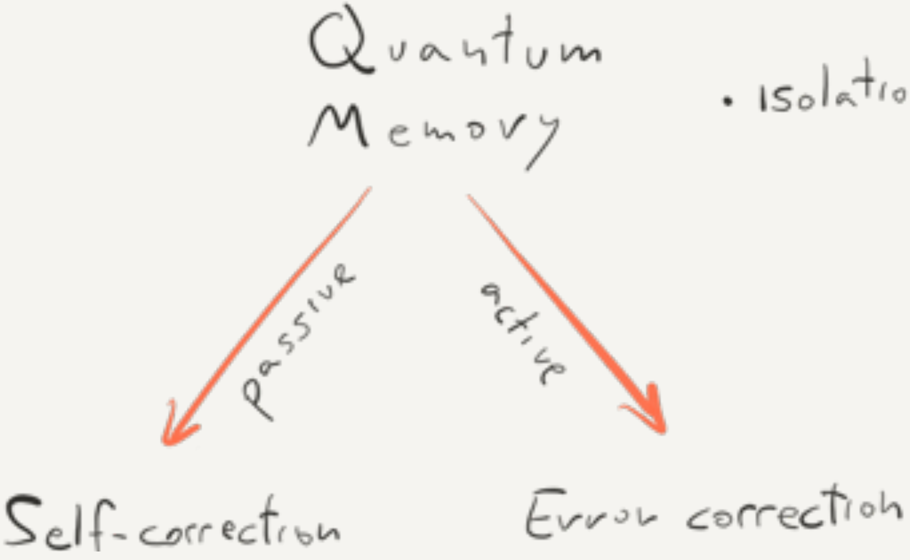
Quantum Memory

- Isolation + control

passive

- $T_c > 0$

Self-correction



Quantum Memory

- isolation + control

passive

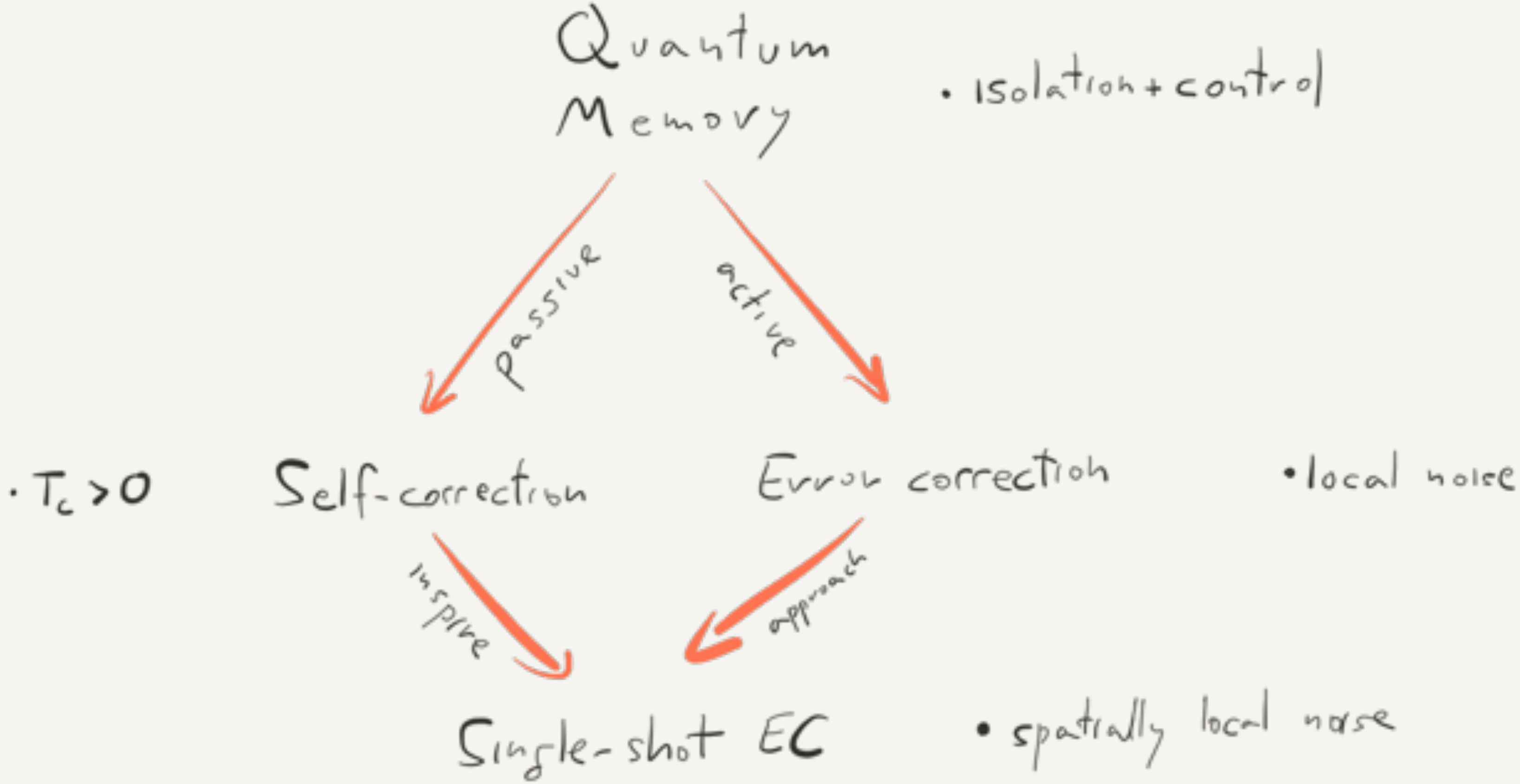
active

- $T_c > 0$

Self-correction

Error correction

- local noise


Quantum Memory
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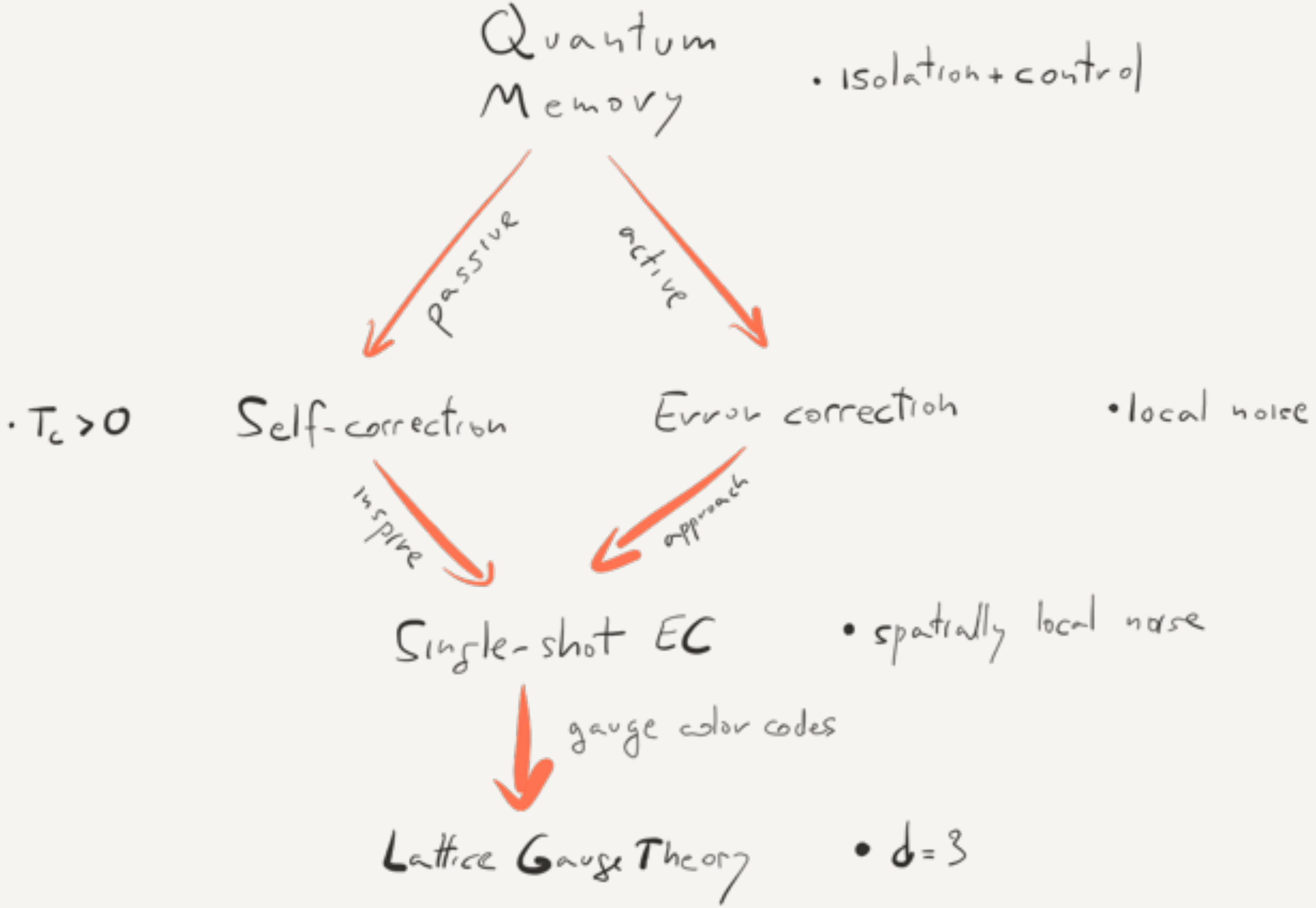
active
• $T_c > 0$
Self-correction
Error correction
• local noise
inspire
approach
Single-shot EC
• spatially local noise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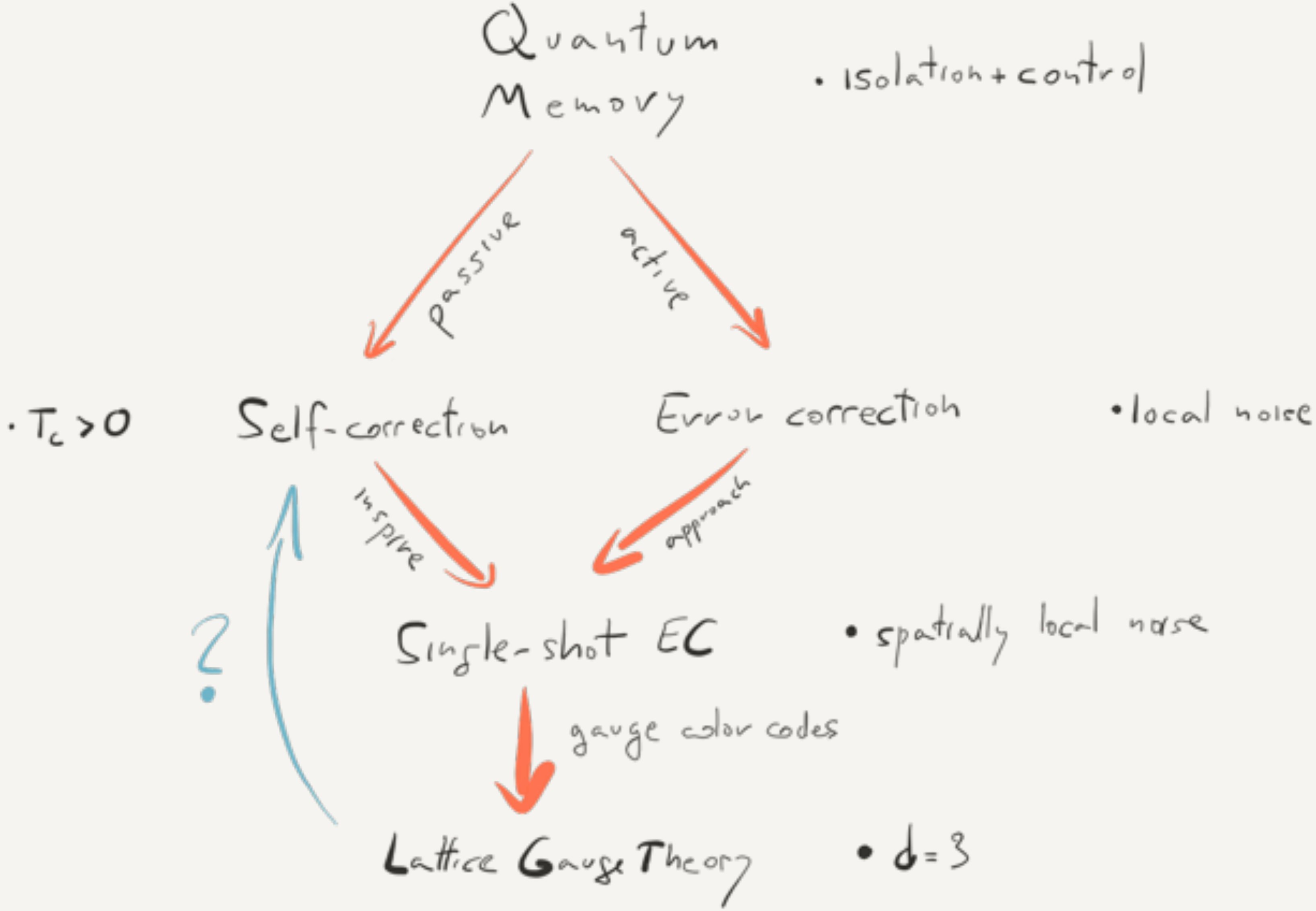
gauge color codes
Lattice Gauge Theory
• $d=3$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?
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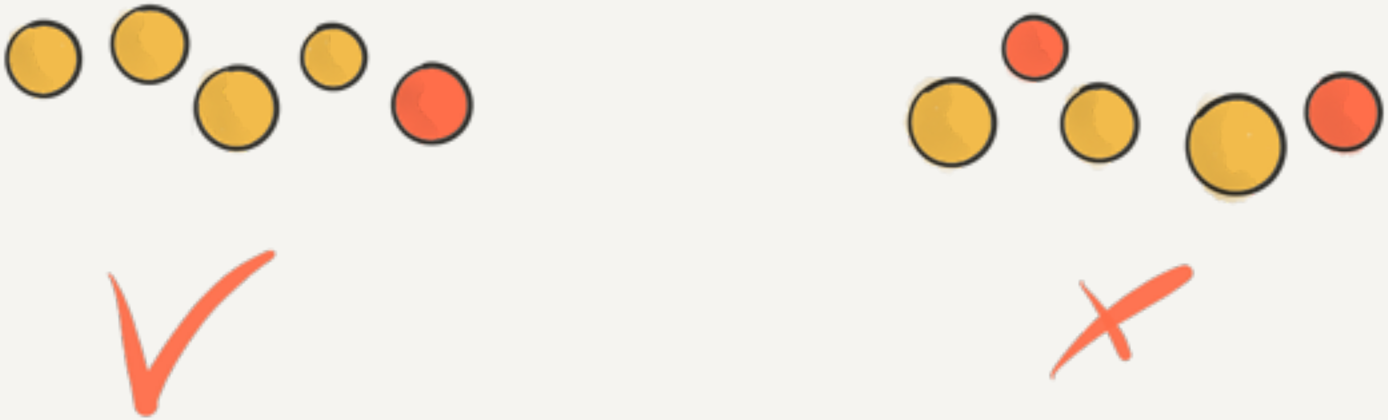
Lattice Gauge Theory
• $d = 3$

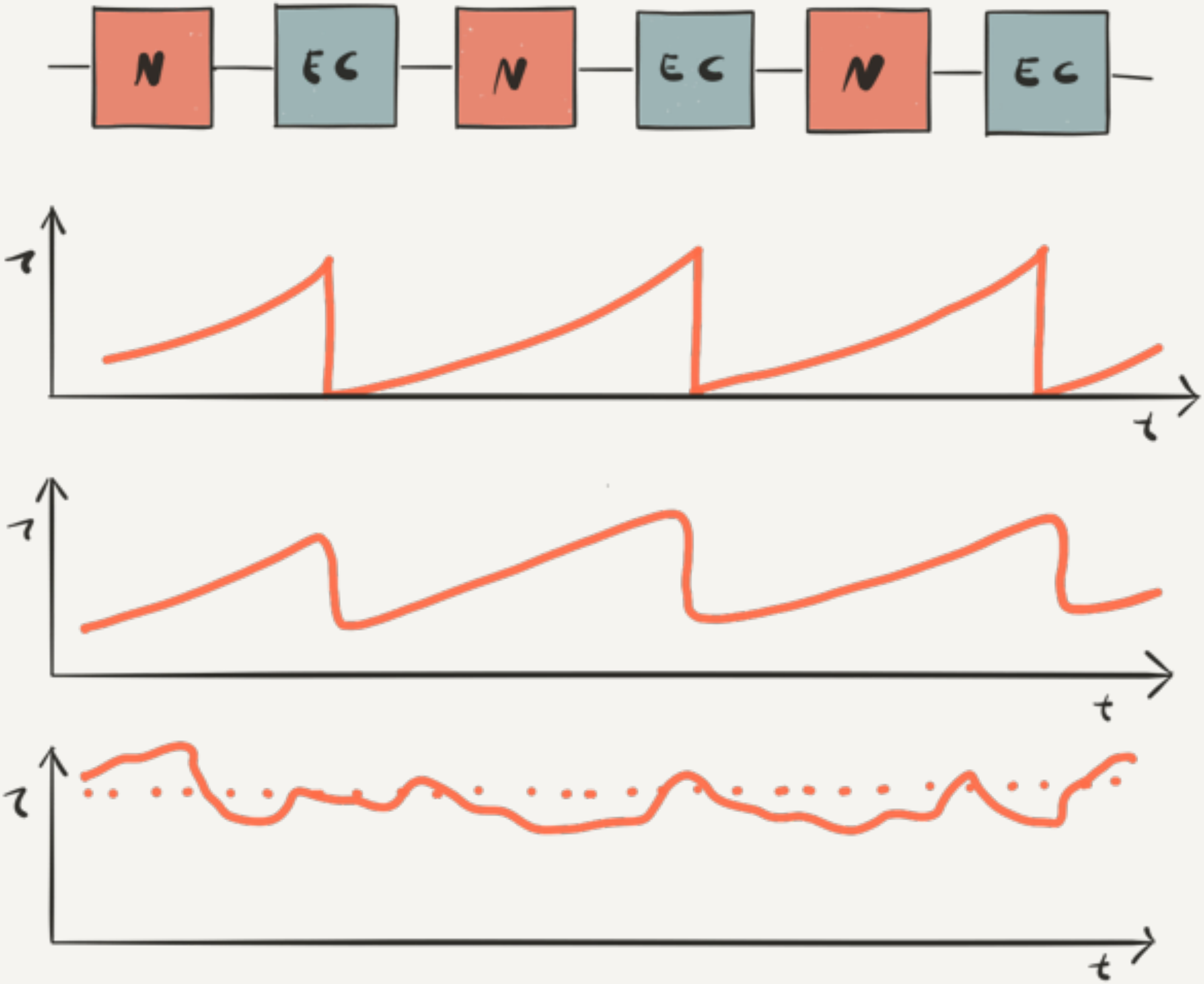
Quantum error correction

logical
qubit

physical
qubits

Quantum error correction




N
EC
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EC
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EC
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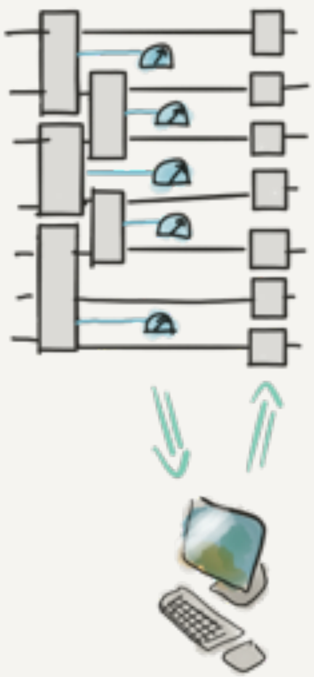
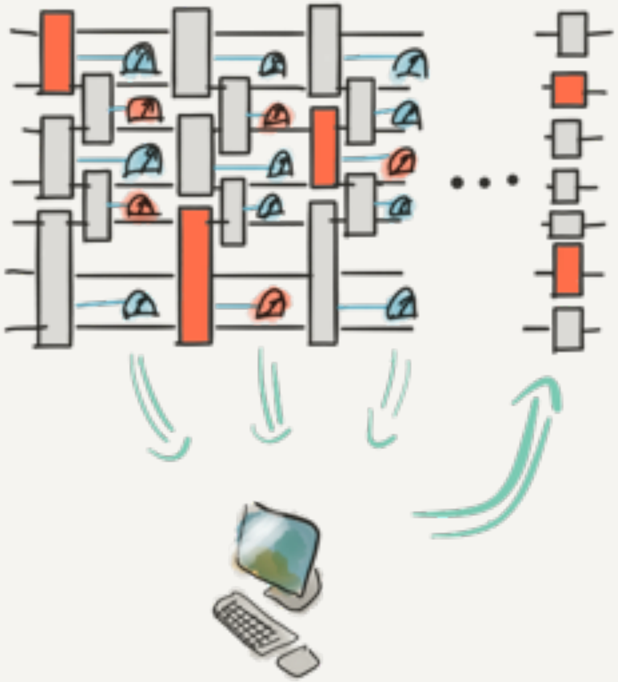
Quantum error correction

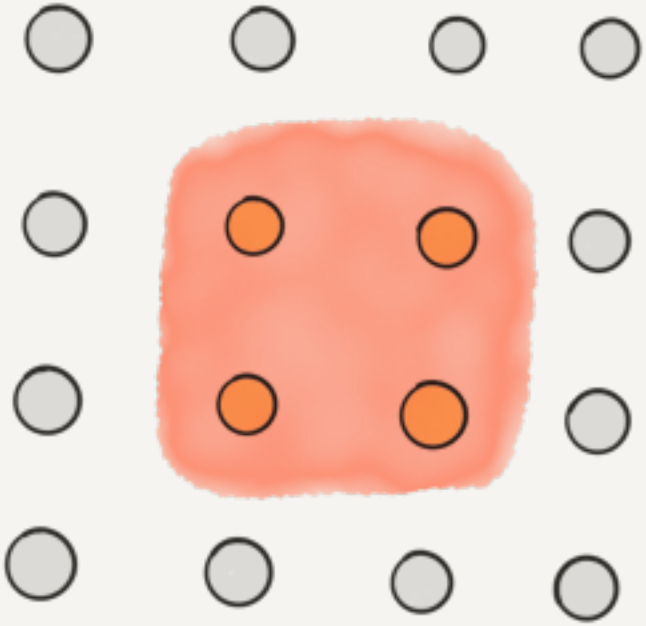


ideal



noisy

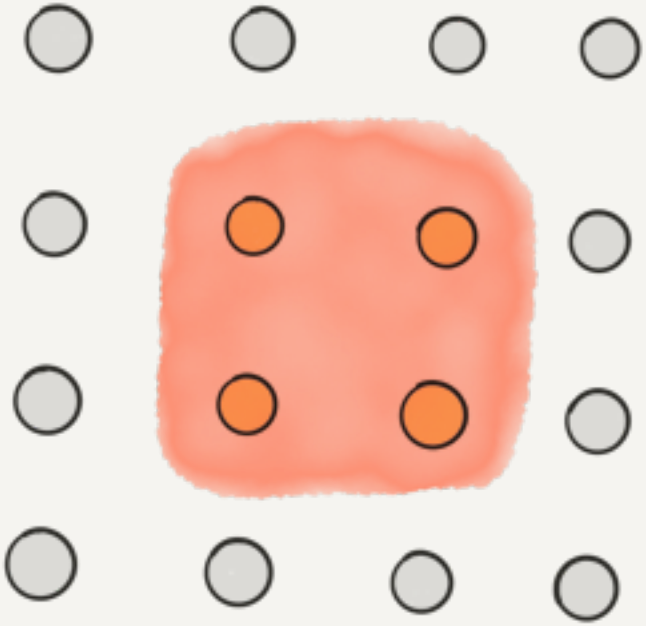
Topological codes



local check operators

local indistinguishability

Topological codes



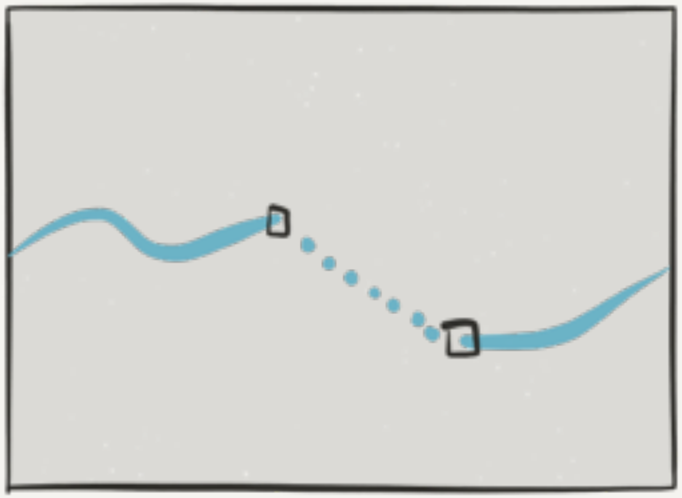
$H = \sum$ 

code = ground state

syndrome = excitations

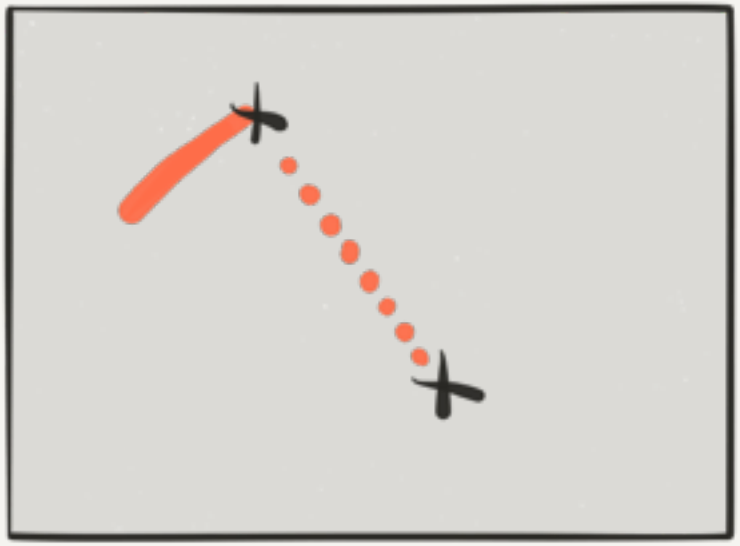
$d = 2$

✓

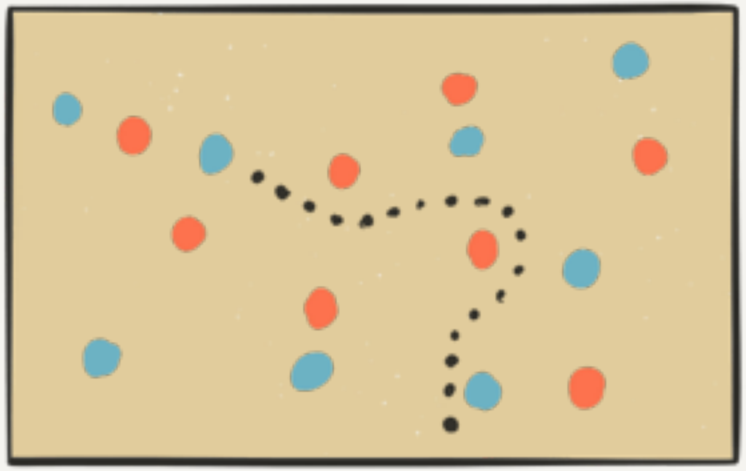


✗

$d = 2$



$d = 2$

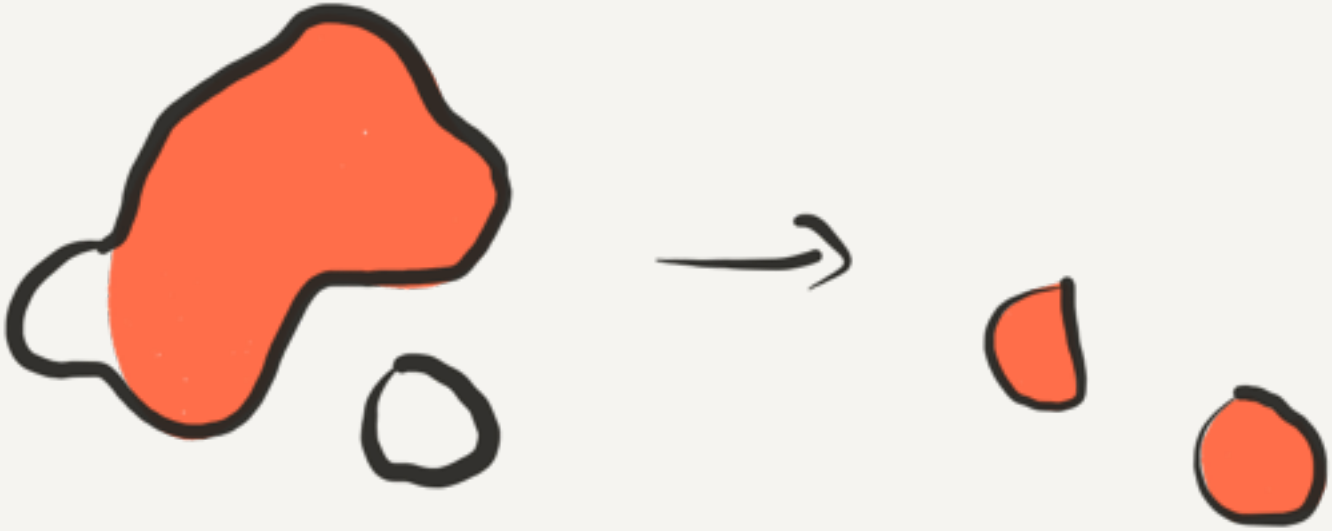


$T_c = 0$

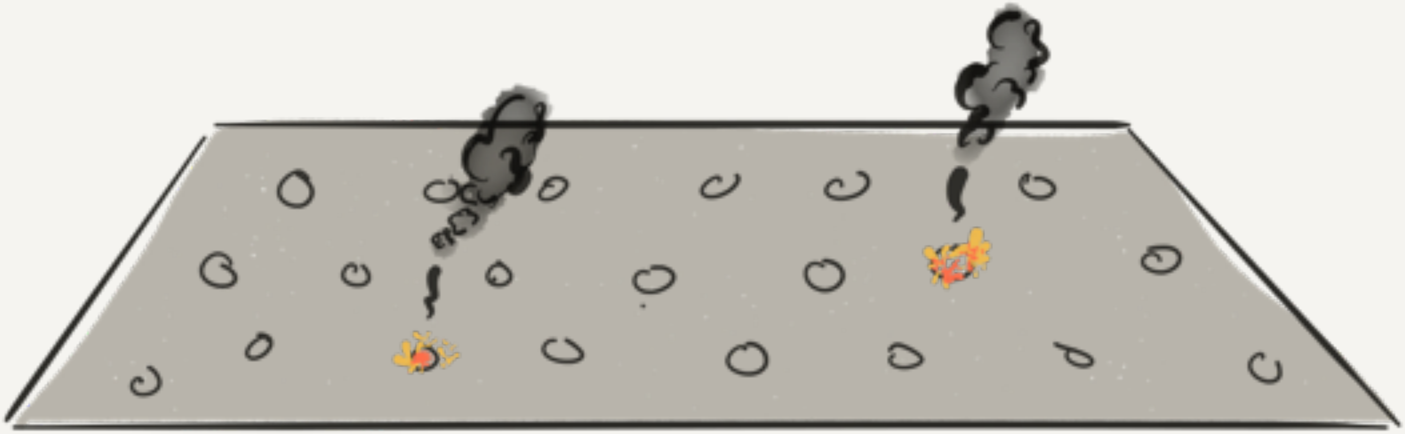
$d = 4$

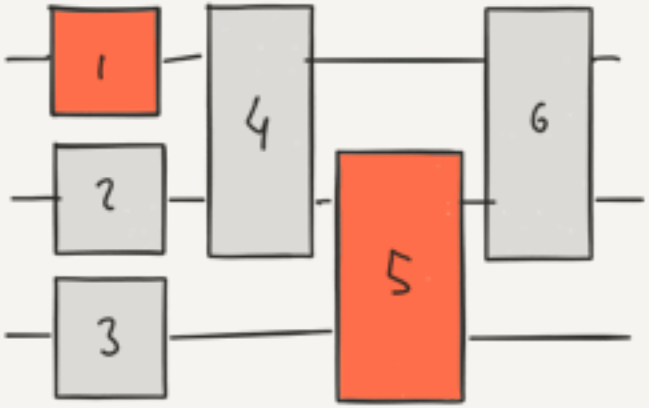
$T_c > 0$

$d = 4$

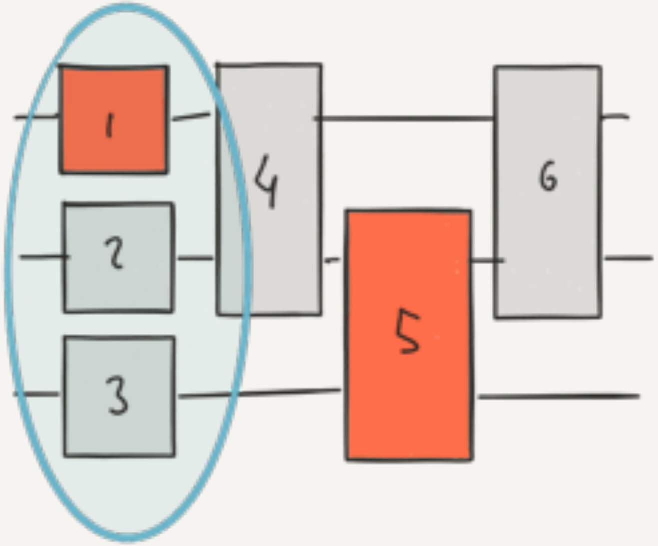


Localized measurement errors yield
localized residual noise



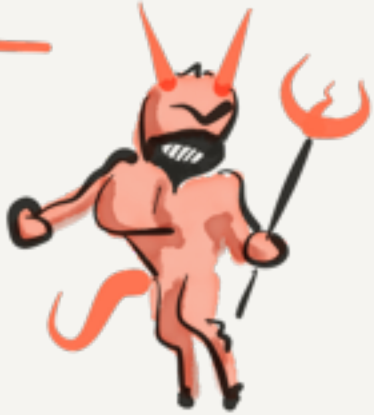


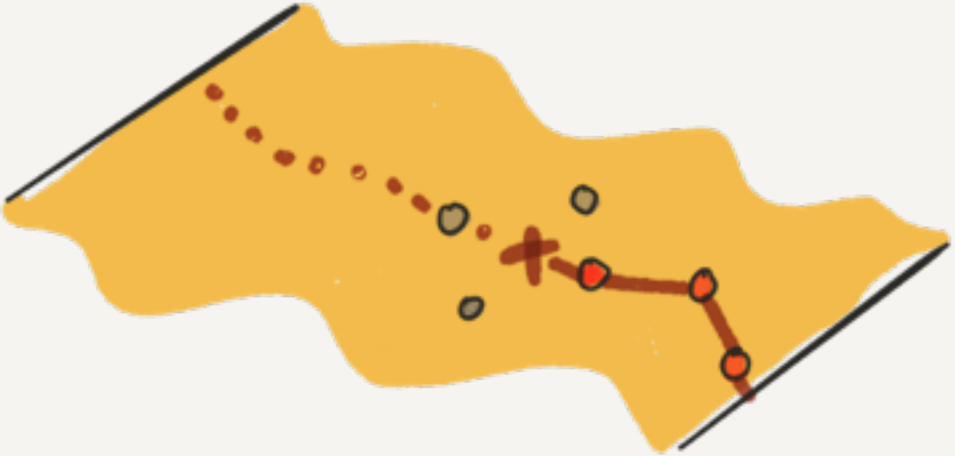
$$P\left(\boxed{1} \wedge \boxed{5}\right) \leq \lambda^2$$

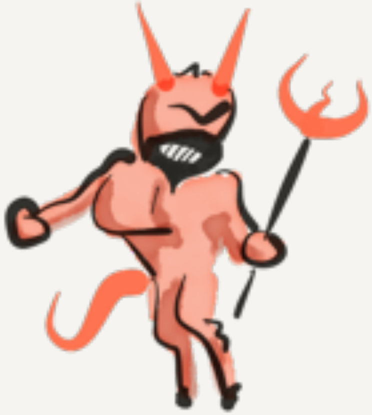


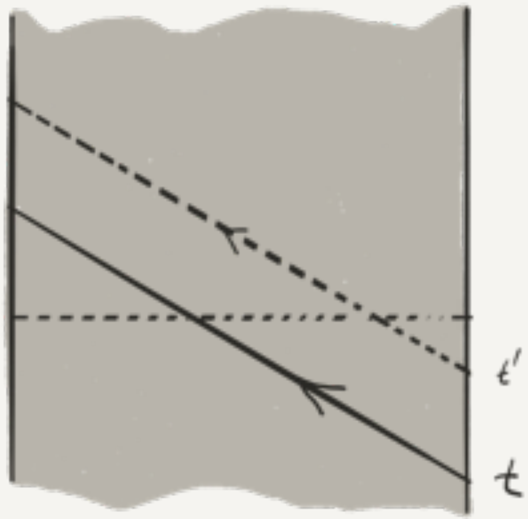
~~$P(\boxed{1} \wedge \boxed{5}) \leq$~~

$P(\boxed{1} \wedge \boxed{3}) \leq \lambda^2$

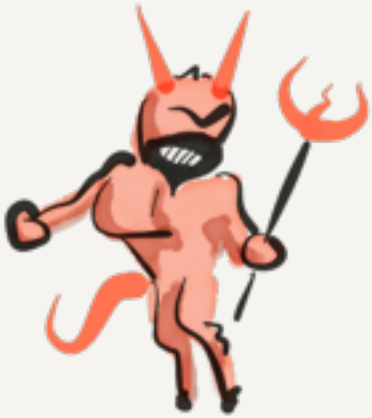


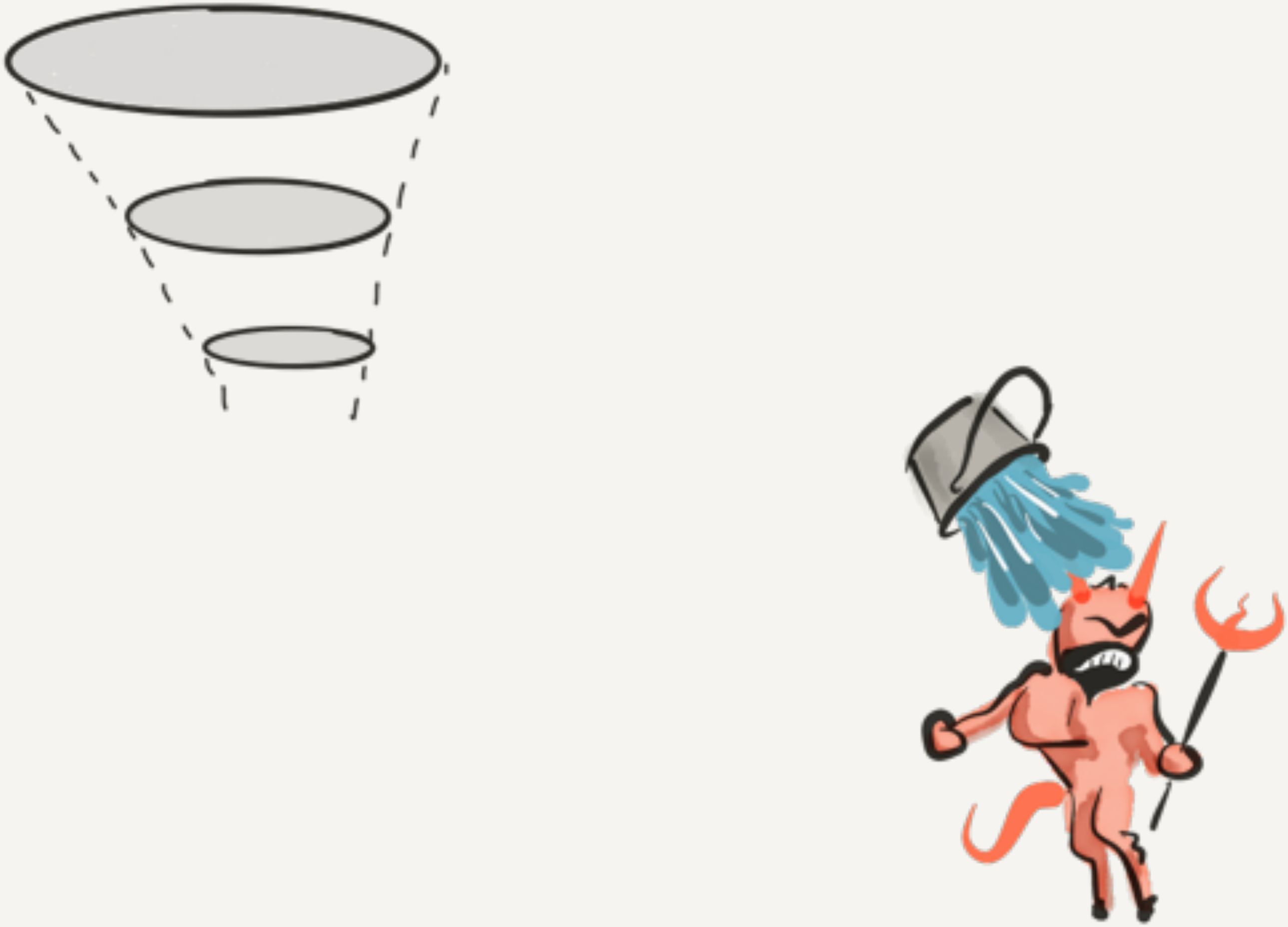






t'
t

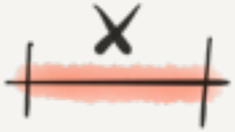




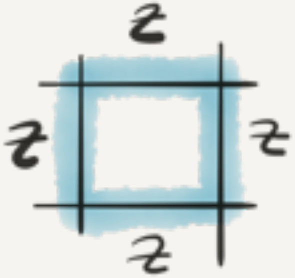
Quantum memories based on single-shot error correction exhibit an error threshold under spatially local noise

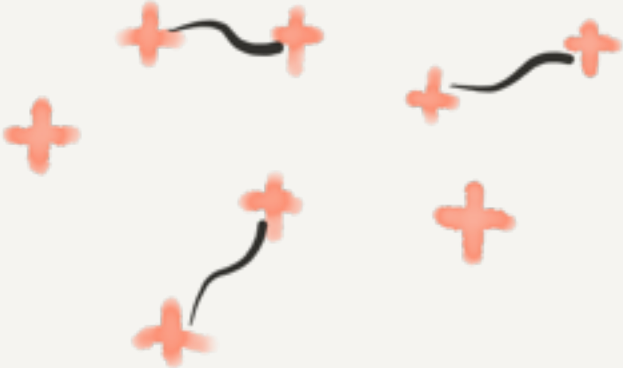
Gauss

e



m





Subsystem codes

$$\mathcal{H}_0 = \mathcal{H}_{\text{logical}} \otimes \mathcal{H}_{\text{gauge}}$$

logical qubits

“gauge” qubits

Subsystem codes

$$\mathcal{H}_0 = \mathcal{H}_{\text{logical}} \otimes \mathcal{H}_{\text{gauge}}$$

logical qubits “gauge” qubits

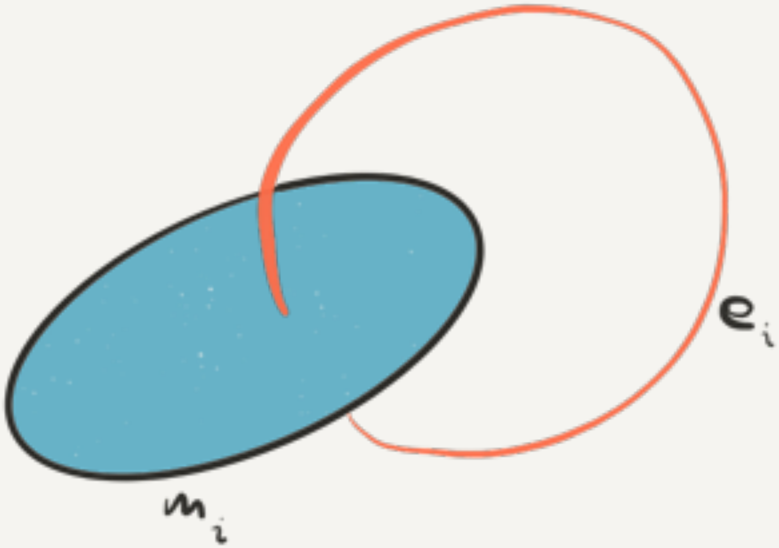
Gauge color codes

gauge qubits = gauge field (lattice)

syndrome = sources

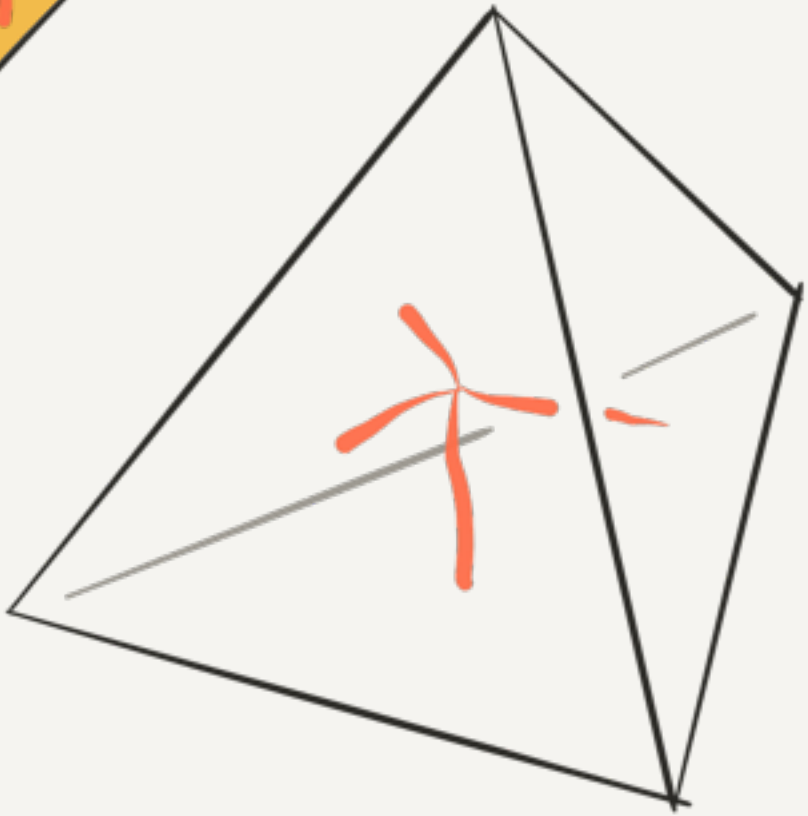
logical qubits = “hidden” topological d.o.f.

$\mathbb{Z}_2^6$

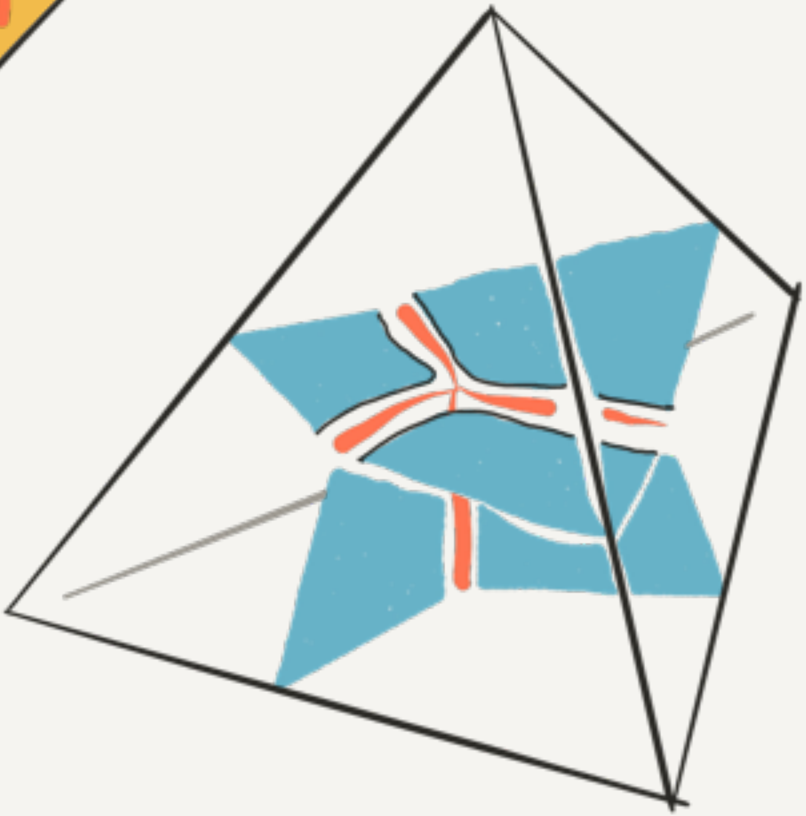



e, m


e, m




e, m

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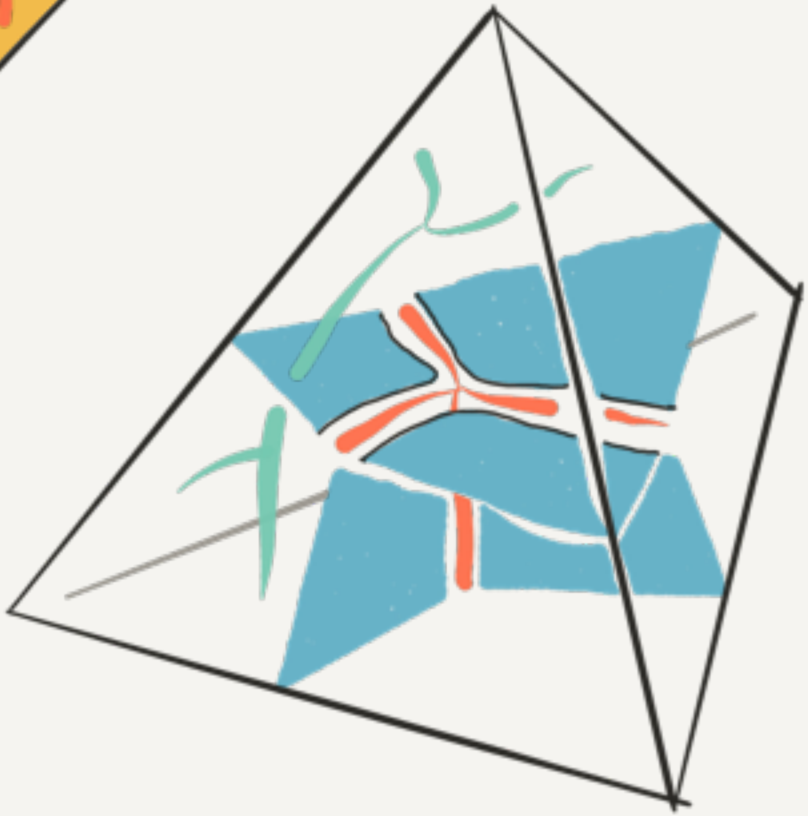
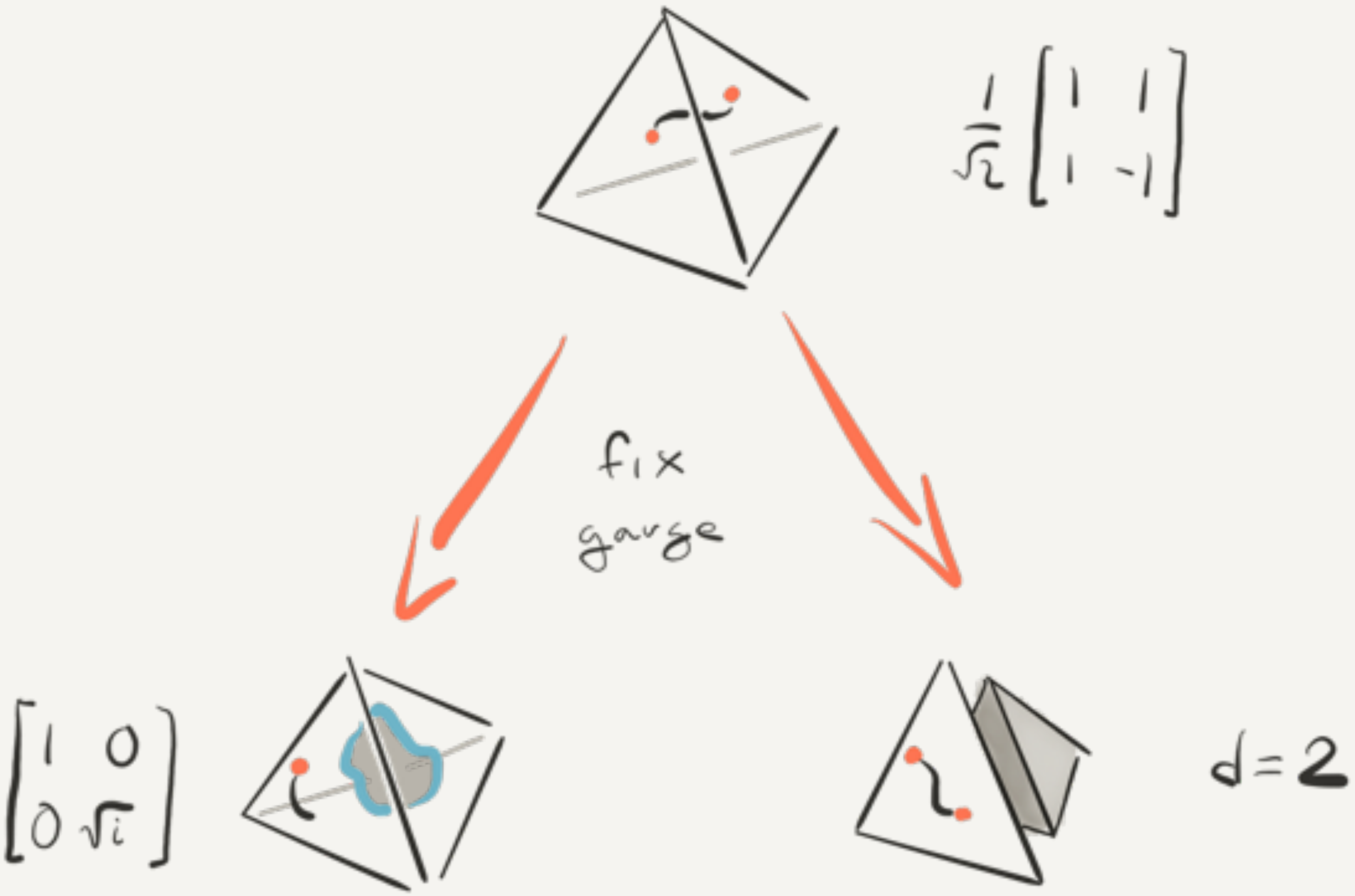
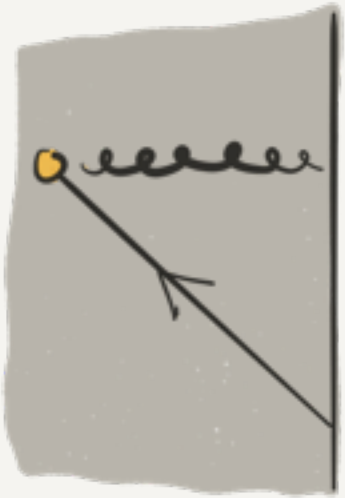




$$\frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & \sqrt{i} \end{bmatrix}$$

$d=2$



DISCUSSION

- $d = 1$ is a clear-cut no-go for time correlated noise. What about $d = 2$?
- What are the physics of gauge codes? Gapless phases, confinement…
- What is the physics behind the computational power of color codes?