

Title: Cohort Project Presentation - Frustration-free Monitored Dynamics Beyond the Stabilizer Framework

Speakers:

Collection: PSI 15th Anniversary Reunion

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# Merging space and time for fault-tolerance

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# Repetition code

- Code words:

$$|0\rangle \mapsto |00 \cdots 0\rangle$$

$$|1\rangle \mapsto |11 \cdots 1\rangle$$

- Check operators:

$$\{Z_1 Z_2, \dots, Z_{L-1} Z_L\}$$

- Logical operators:

$$\bar{X} = X_1 X_2 \cdots X_L$$

$$\bar{Z} = Z_1$$



*problem:* measuring these checks is something that has to happen over time!

# Repetition code

- Code words:

$$|0\rangle \mapsto |00 \cdots 0\rangle$$

$$|1\rangle \mapsto |11 \cdots 1\rangle$$

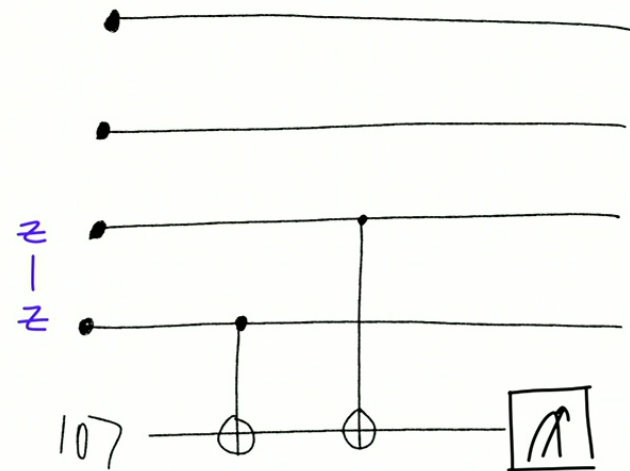
- Check operators:

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- Logical operators:

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errors can happen anywhere, and propagate.... it get's really complicated!

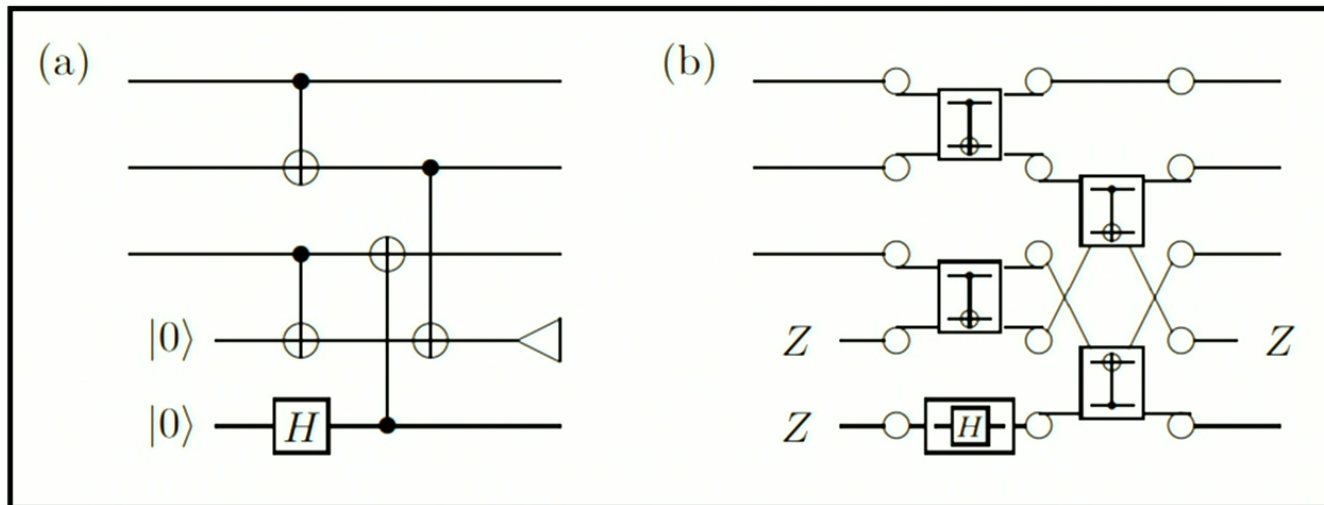
# Errors throughout space and time

- We generally think about codes on a single time-slice, but quantum error correction is fundamentally a *spacetime* process
  - may be simpler to treat space and time on equal footing!
- In fact, there are a lot of suggestive relationships between  $d$ - and  $(d+1)$ -dim quantum error correcting codes
  - measurement-based quantum computing
  - stat-mech models of  $d$  and  $(d+1)$  codes
- [Bacon et al '17] and [Gottesman '22] propose maps

Circuit acting on  $d$ -dim QEC  $\mapsto$   $(d+1)$ -dim QEC

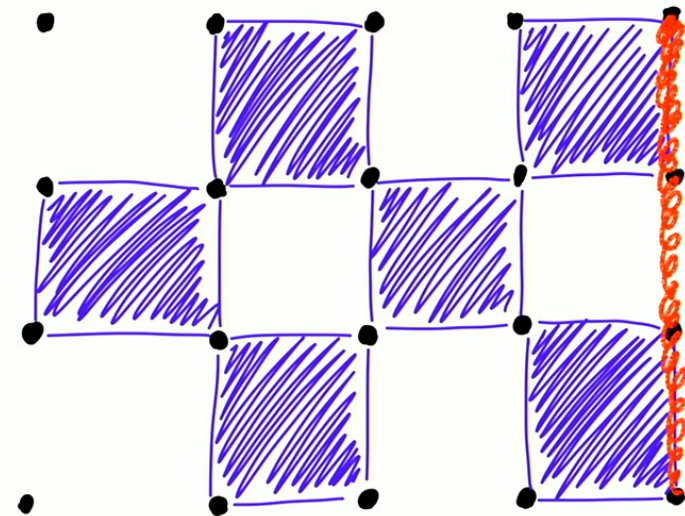
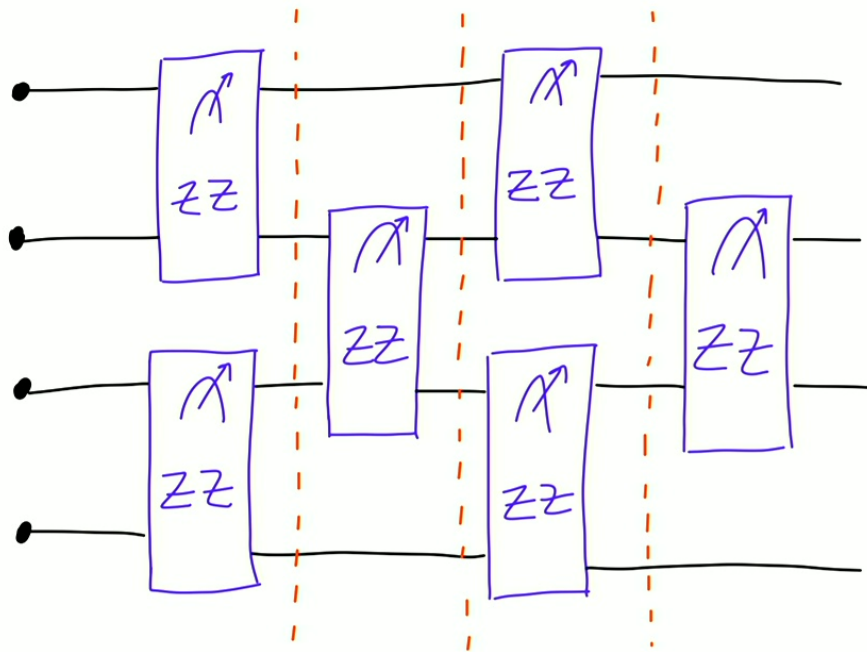
# Mapping between Circuit and Codes

- There is a mapping between circuit elements and the generators of a *subsystem* code



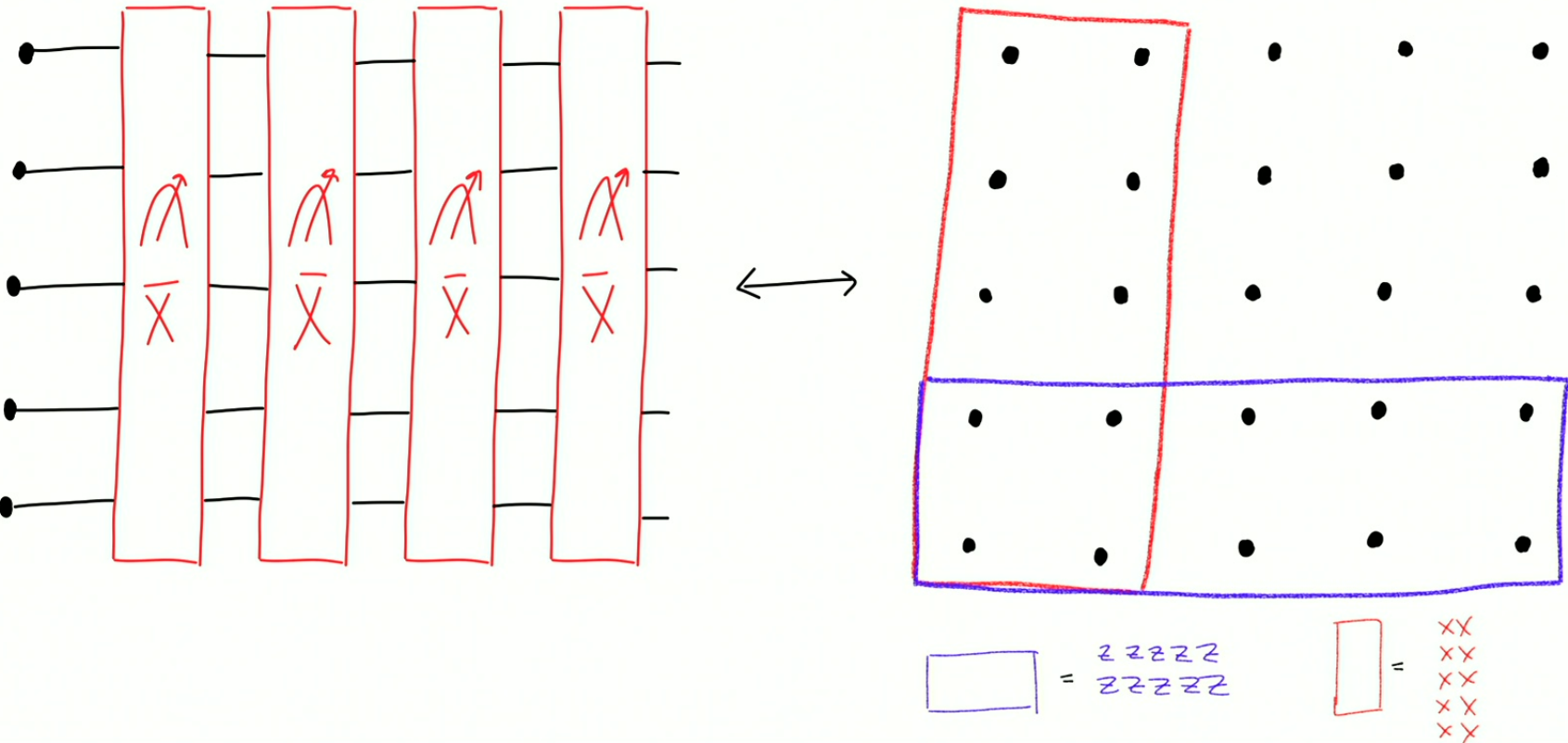
	$ZZ, XX$
	$ZX, XZ$
	$XX, II, ZZ, IZ$ $IX, XI, II, ZZ$
	$Z$
	$ 0\rangle$ $Z$

# Circuit 1: repetition code check measurements





# Circuit 2: repetition code logical measurements





# Summary

- Quantum error correction is fundamentally a spacetime process!
- We explore instances of a mapping from [Bacon et al '17], [Gottesman '22]  
Circuit acting on  $d$ -dim QEC  $\mapsto$   $(d+1)$ -dim QEC
- In these examples, we're able to relate error detection in the circuits to the error detection capabilities of the corresponding spacetime code

Thank you!

# Super extra bonus toric code slide??

