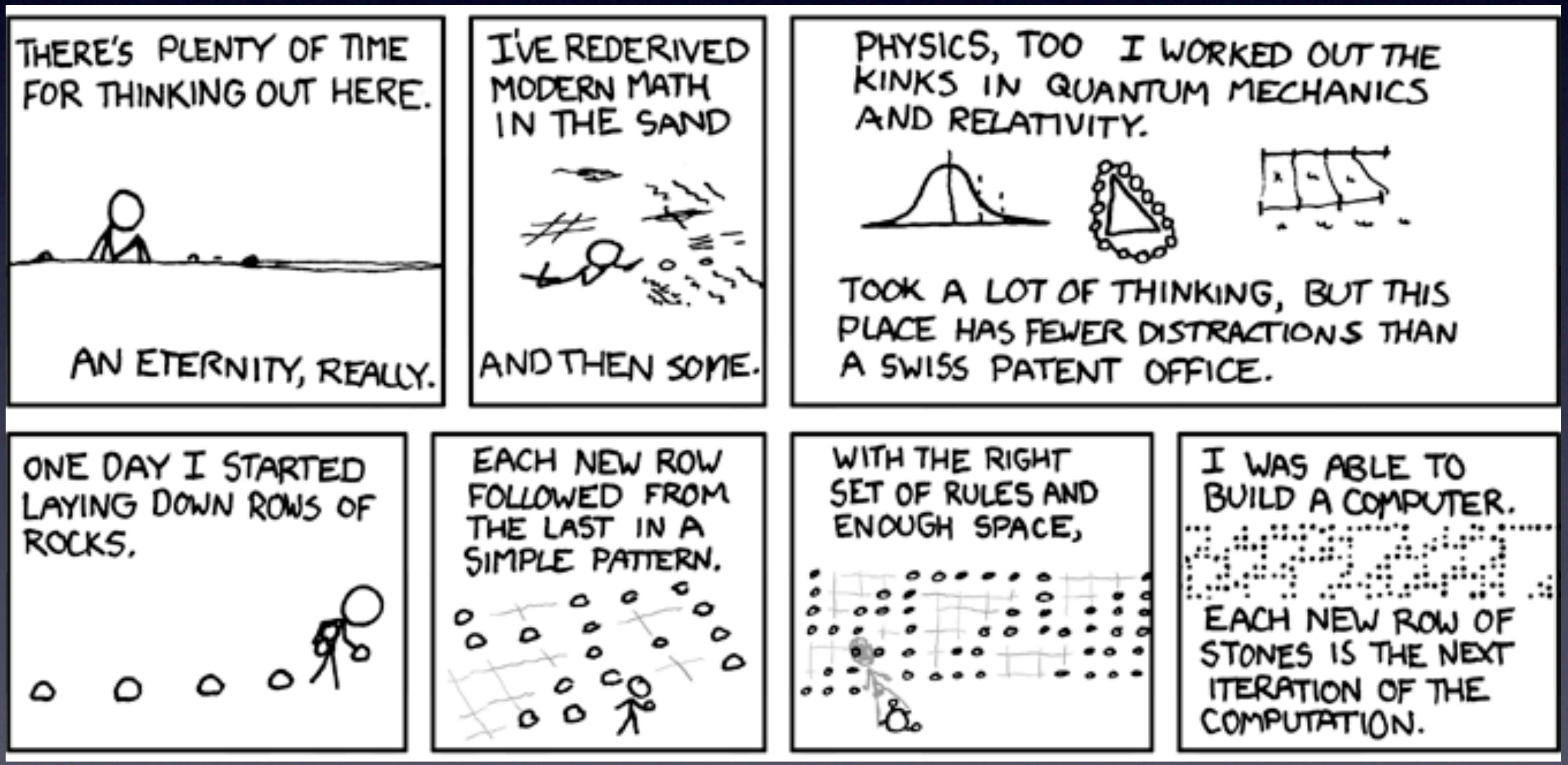
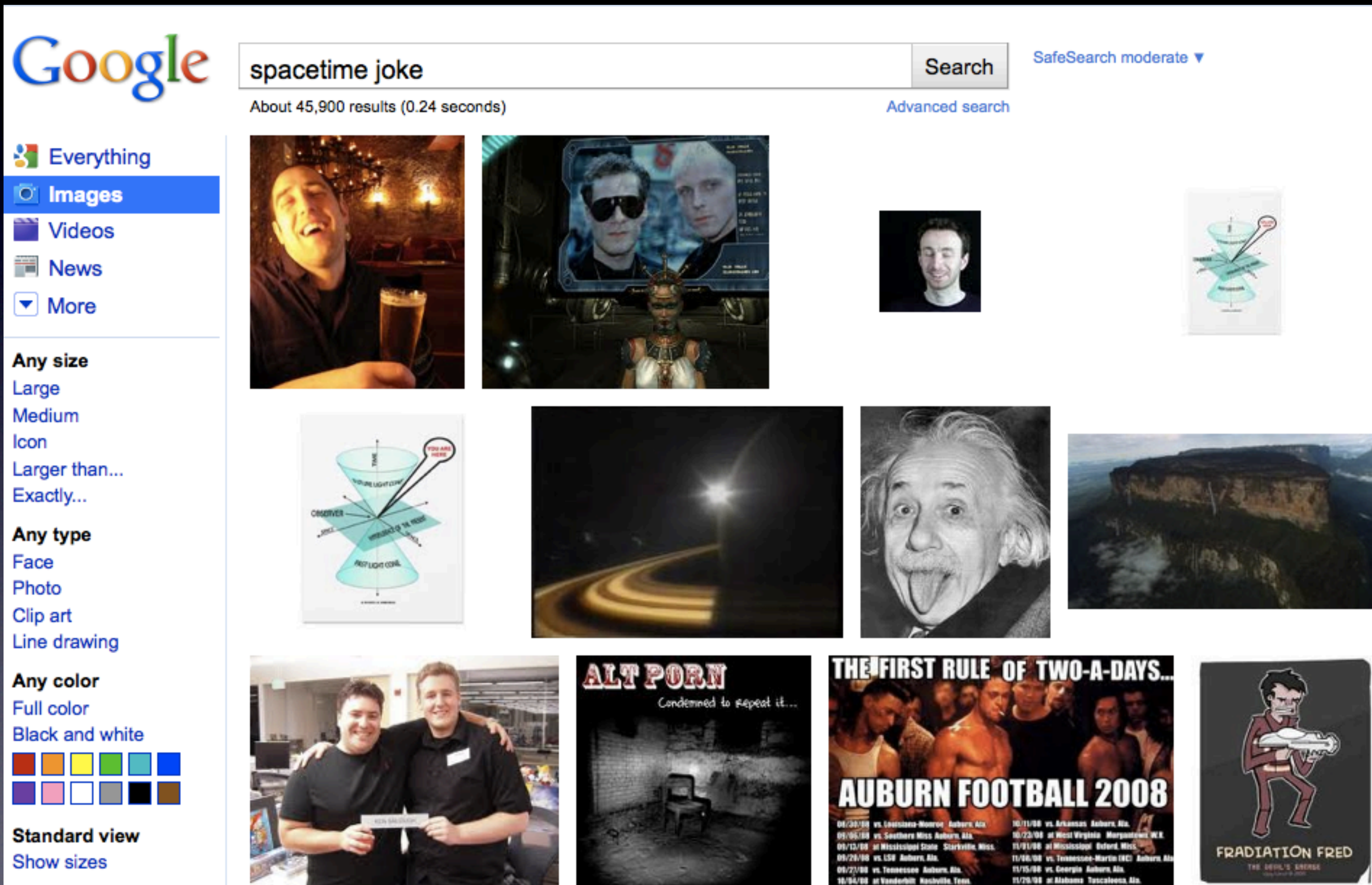
Turning Time Into Space for Codes and Profit*

Dave Bacon
University of Washington



*no warrantee, void where prohibited, not valid in WA, Australia, or anywhere else in this universe

Spacetime Joke



TQC 2011

6th Conference on Theory of Quantum Computation, Communication and Cryptography

24-26 May, Madrid, Spain

Menu

- General information
- Scope
- Program
  - Invited speakers
- Submissions
- Registration
- Location and travel info
- Submission policy
- Committees

Organizer

QUITEMAD

Quantum Information Technologies in Madrid

Contact via email

Sponsors

La Suma de Todos

General information

The sixth Conference on the Theory of Quantum Computation, Communication and Cryptography will be held at Madrid, Spain, from 24th - 26th May 2011. Download the poster!

Quantum computation, quantum communication, and quantum cryptography are topics of a new and interdisciplinary field in the intersection of computer science, information theory, and quantum mechanics. The aim of the TQC'11 conference is to allow deep coverage of new and original research on these topics and to raise important problems that can benefit from theoretical investigation and analysis.

As for previous TQC conferences, a post-conference proceedings volume will be published in Springer's Lecture Notes in Computer Science to which selected speakers will be invited to contribute.

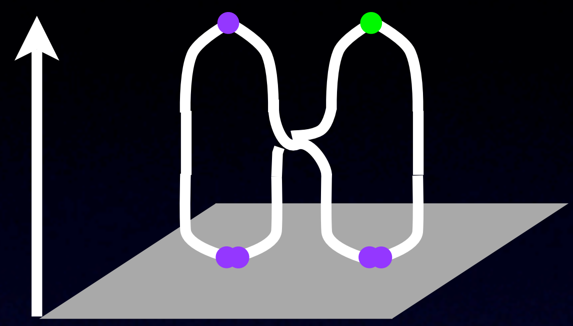
Lecture Notes in Computer Science

LNCS LNAI LNBI

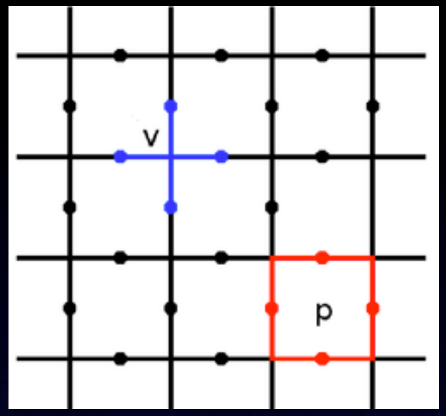
Important dates

- Submission deadline: **January 24, 2011 (23:59 CET local time)**
- Notification of acceptance/rejection: March 14, 2011
- Final version of extended abstracts: March 31, 2011
- Registration deadline: May 10, 2011
- Conference: May 24-26, 2011
- Post-proceedings submission deadline: End of June 2011
- Publication date: October 2011

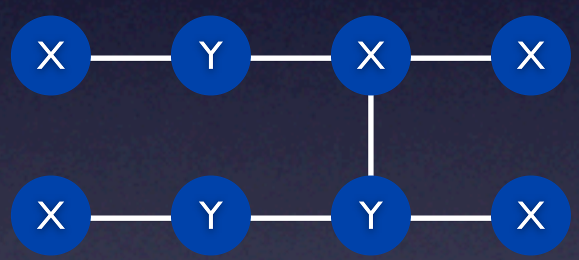
What Are We Doing?



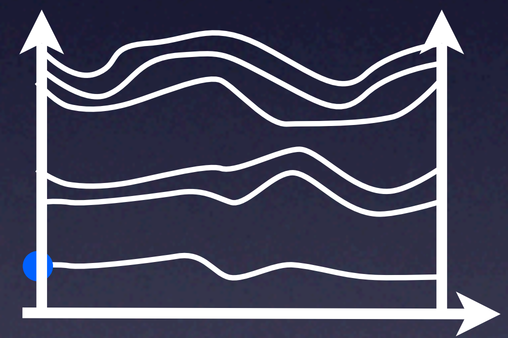
Topological QC



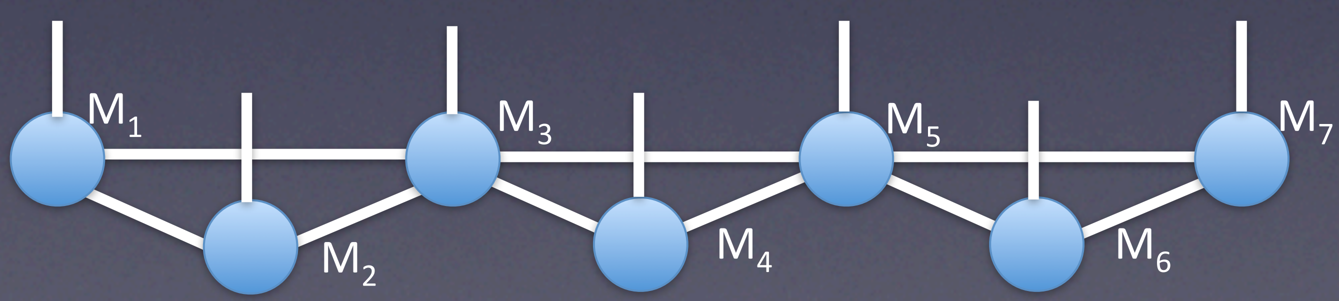
Local Fault-tolerant QC



Measurement-based QC



Adiabatic QC



Matrix Product States, PEPS, MERA, tensor networks

Quantum Computational Matter?

A focus on systems, states, models, phases where space-time locality is an important limiting constraint

Systems, states, models, phases where quantum information or quantum computational are front and center

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WE ARE PHYSICISTS, but for materials yet to be engineered?

Systems, states, models, phases where quantum information or quantum computational are front and center

Quantum Computational Matter?

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WE AREN'T SCARED BY INFORMATION?

Self-Correcting System

Physics of the device enacts quantum error correction and allows fault-tolerant quantum computing?

One Code, Two Models

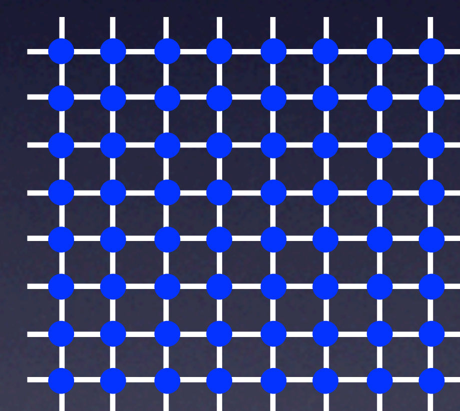
Redundancy code:
$$\begin{aligned} 0 &\rightarrow 000\cdots0 \\ 1 &\rightarrow 111\cdots1 \end{aligned}$$

Ising model: $$E = -J\sum_{\langle i,j\rangle} s_i s_j \qquad s_i \in \{+1,-1\}$$

1D

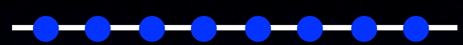
$$\cdots 0 \quad 0 \quad 0 \quad 1 \quad 1 \quad 0 \quad 0 \quad 0 \cdots$$
$$- \quad - \quad + \quad - \quad + \quad - \quad -$$

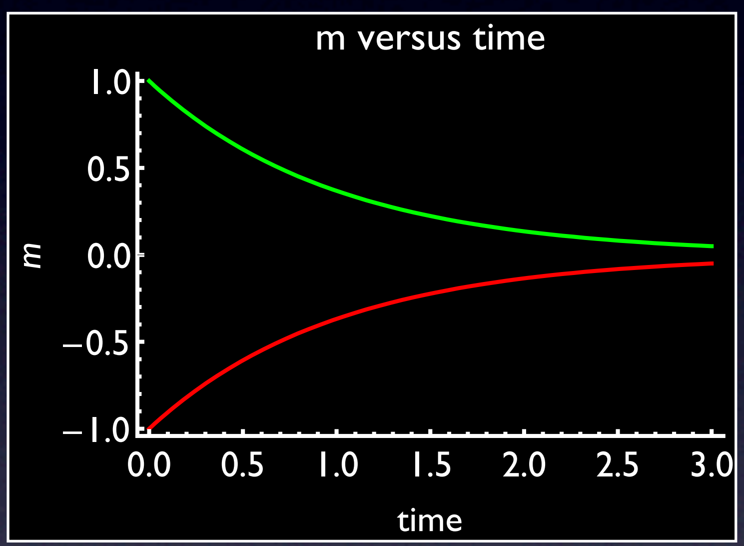
2D



Memory

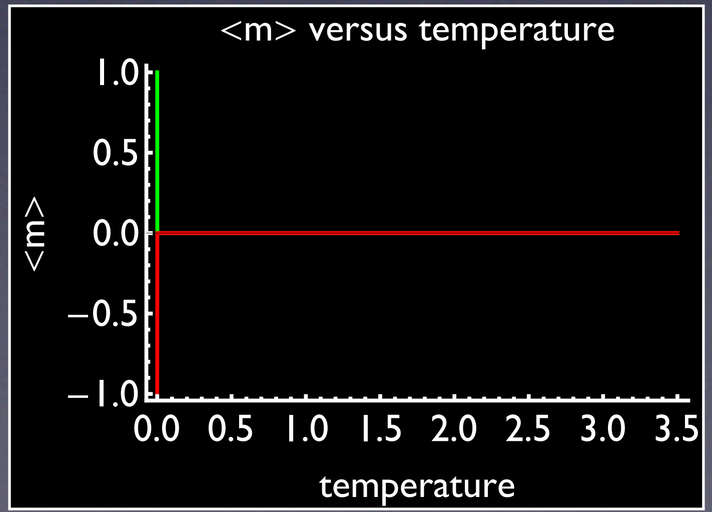
1D



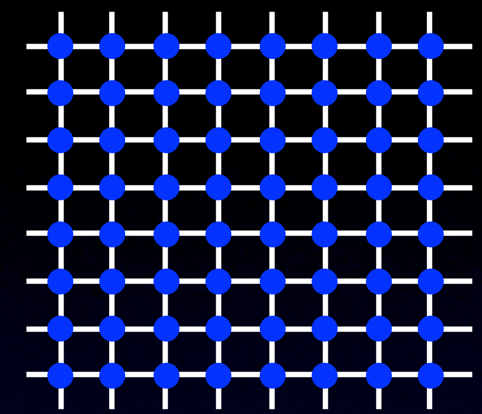


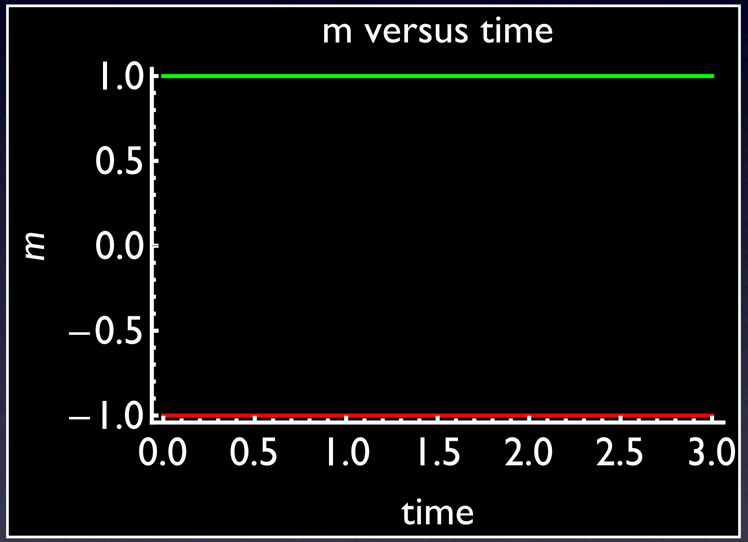
rate ~ $\exp(-c\beta J)$

$\beta = T^{-1}$

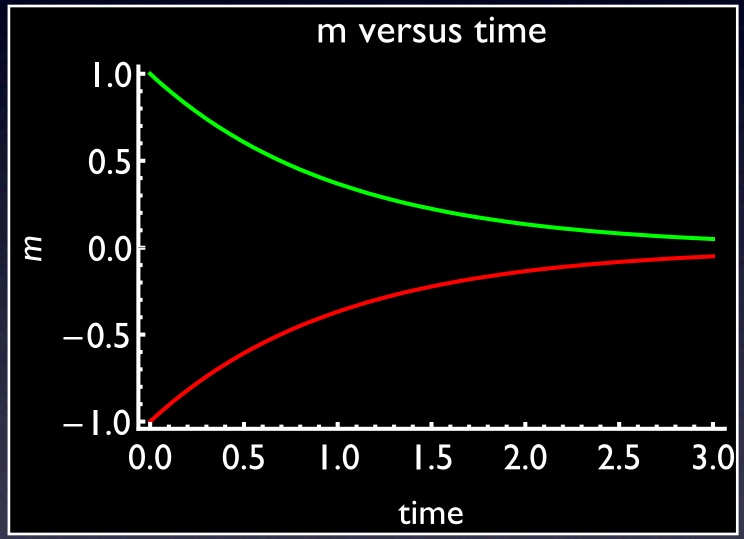


2D

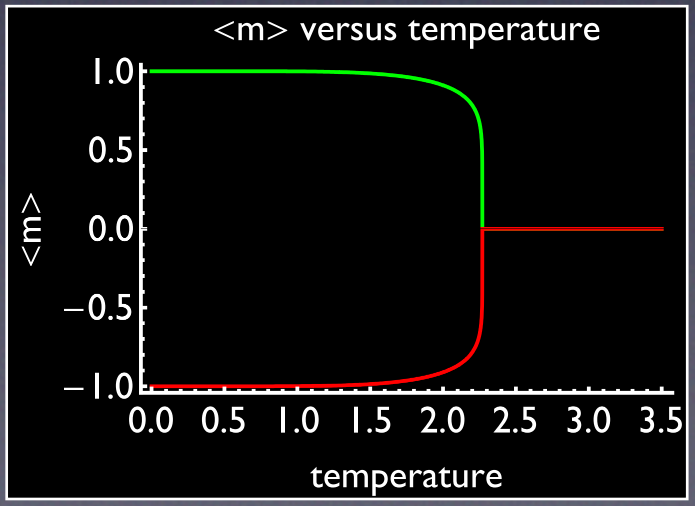




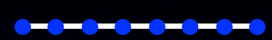
$T < T_C$

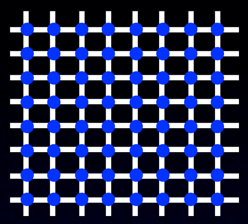


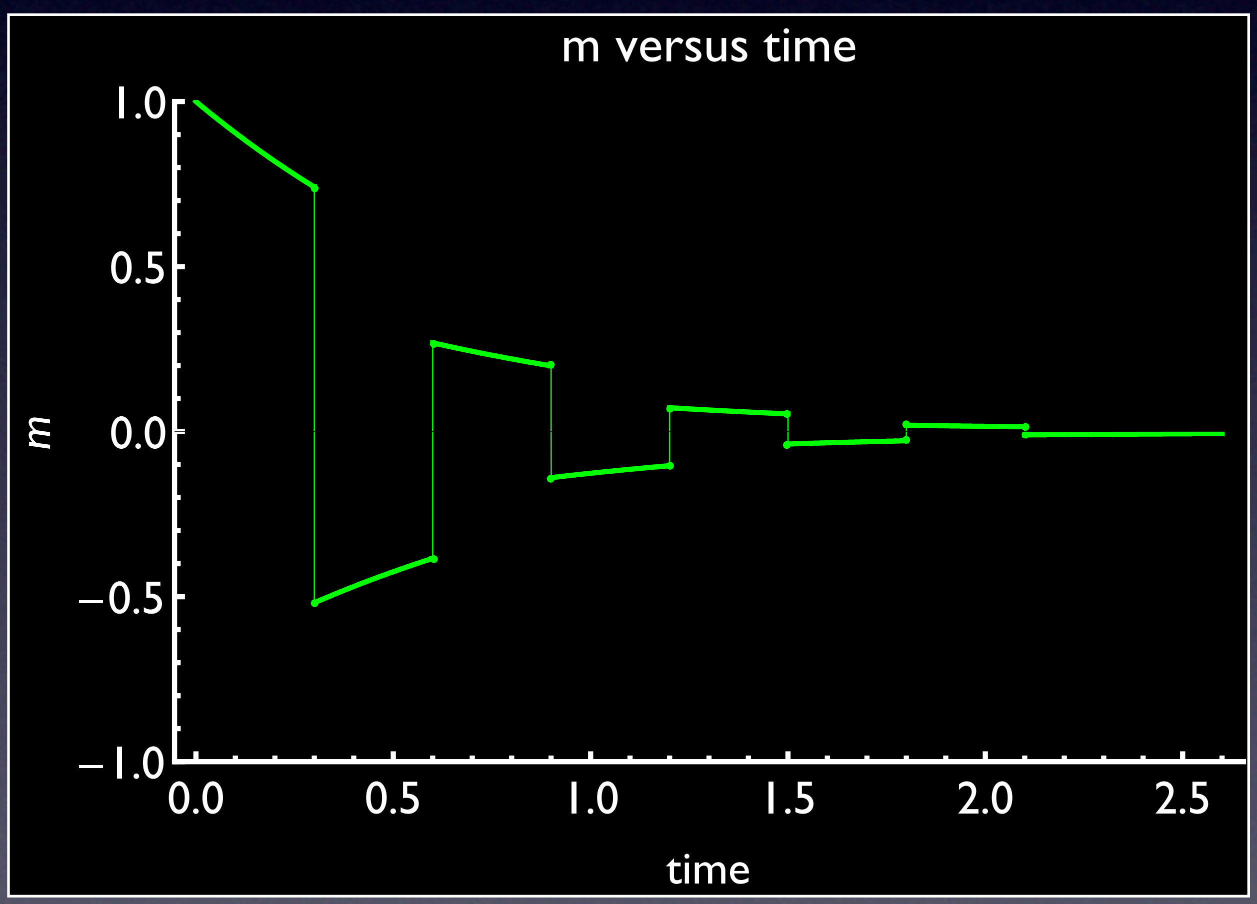
$T > T_C$

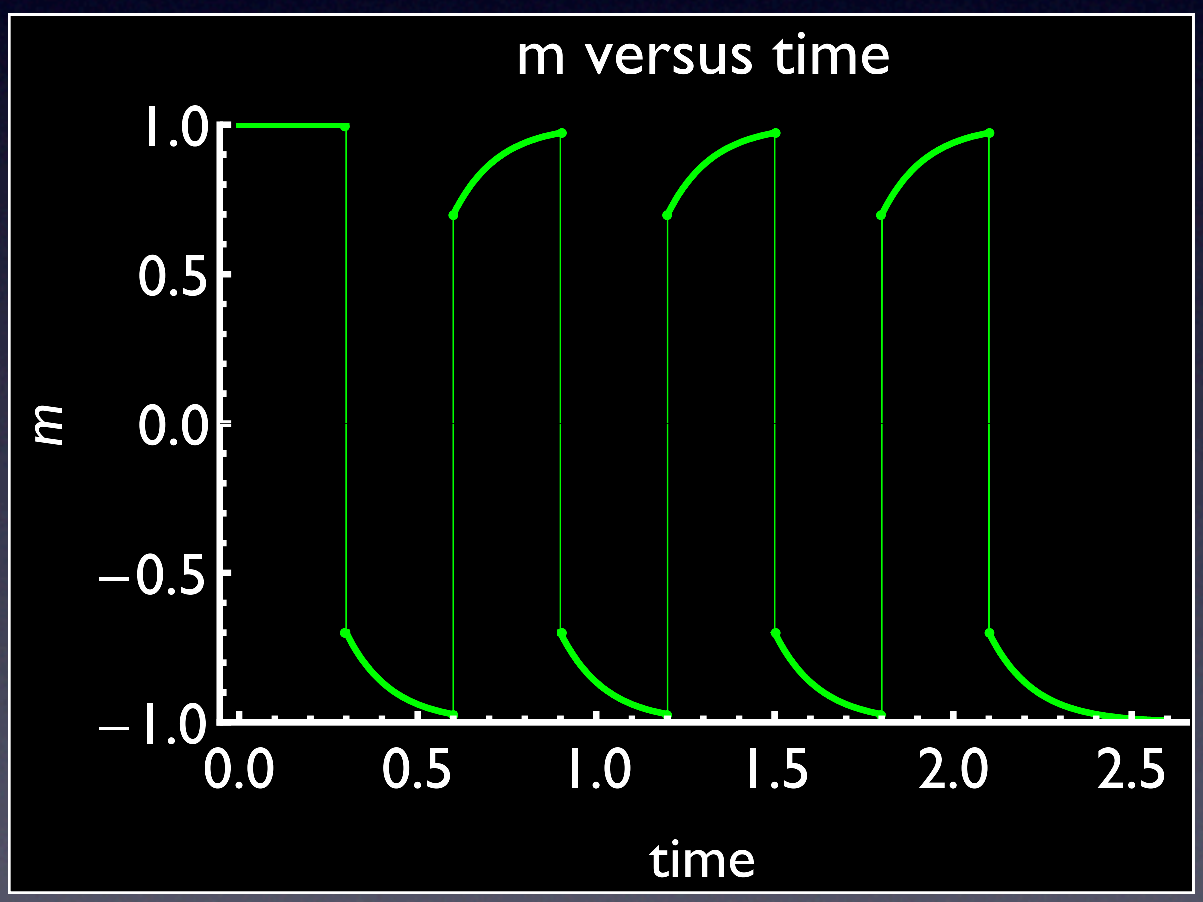


Fault-Tolerance

1D 

2D 





Resilience to "gate" of flipping spins: self-correcting

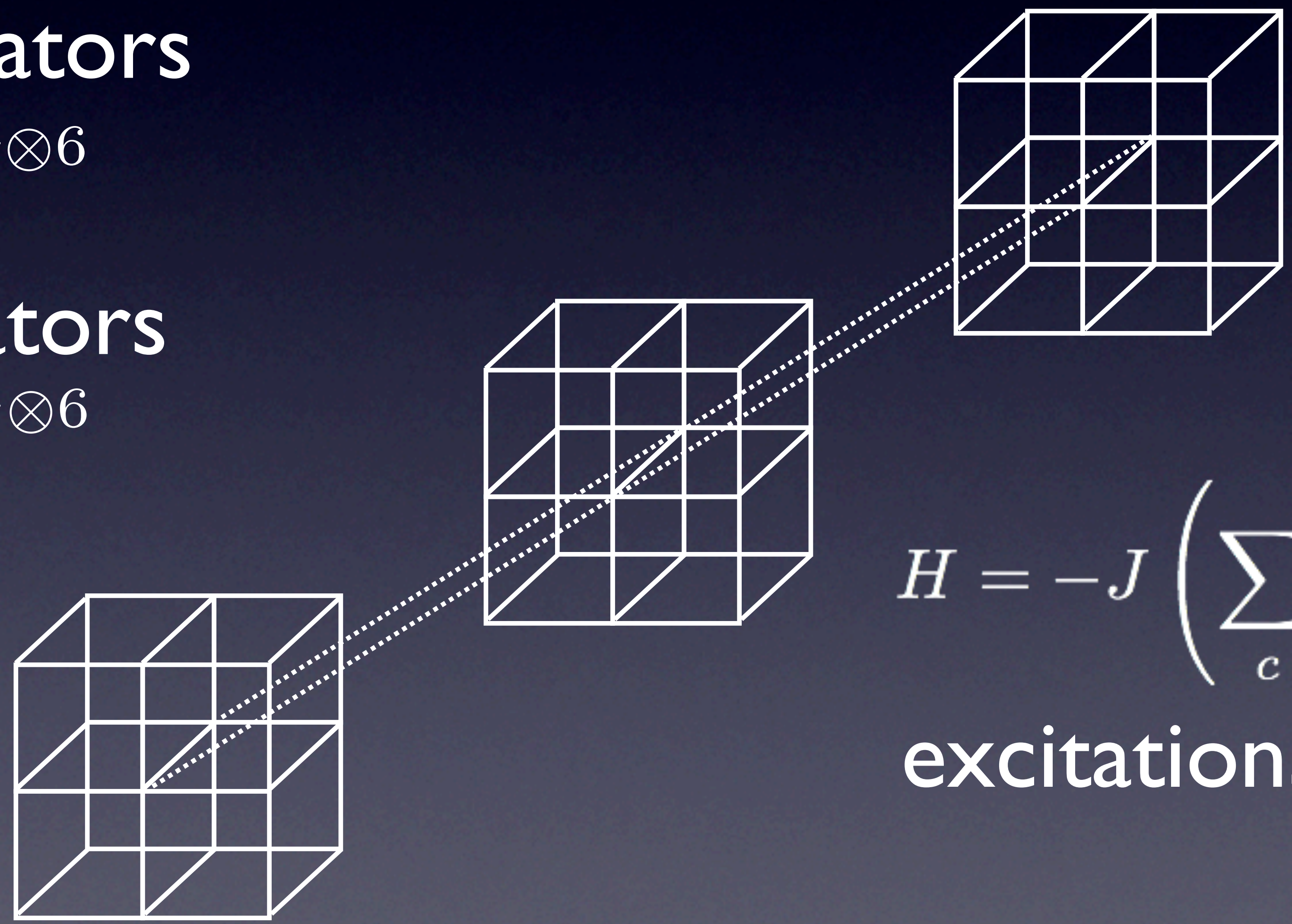
Self-Correcting Quantum Systems?

cube operators

$$S_c = Z^{\otimes 6}$$

link operators

$$S_l = X^{\otimes 6}$$



qubits on plaquettes

$$H = -J\left(\sum_c S_c + \sum_l S_l\right)$$

excitations = strings

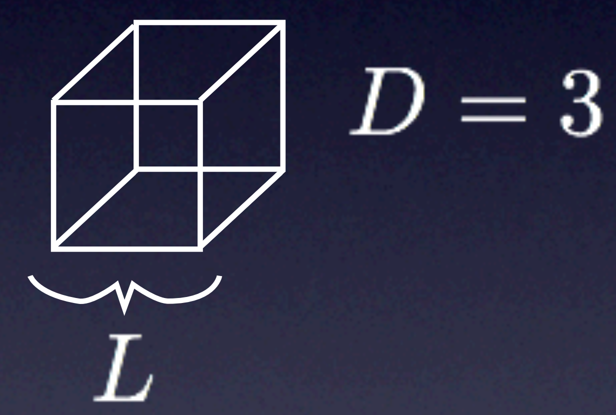
4D toric code is self-correcting

Bravyi-Terhal Bounds

[Bravyi-Terhal arXiv:0810.1983]

For k-local *D* dimensional stabilizer codes (subspace and subsystem) on an $\{1,..,L\}^D$ lattice, the distance of the code is bound by

$$d \leq cL^{D-1}$$



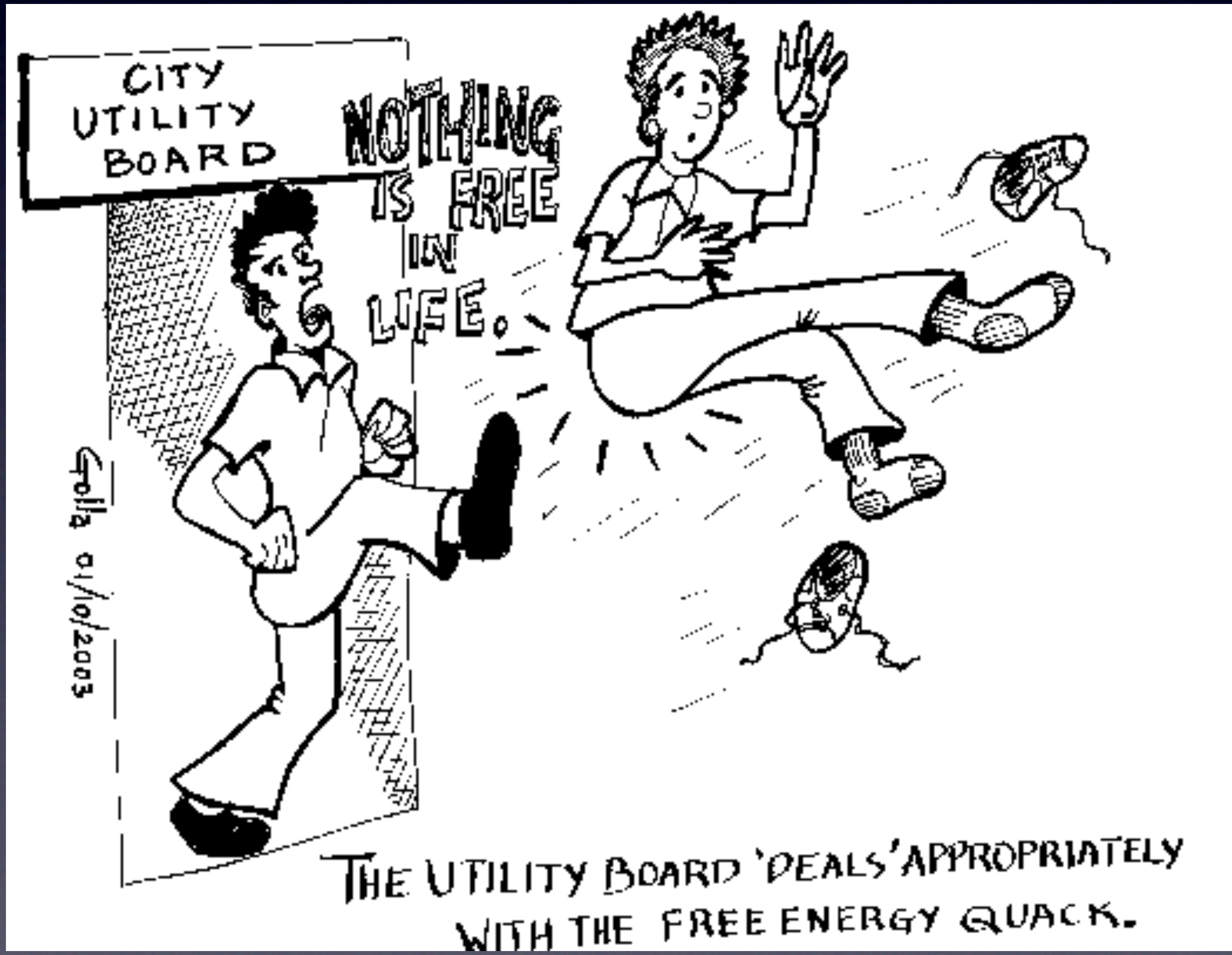
D	bound	best known
1	c	c, many
2	cL	toric, color codes, d=cL
3	cL^2	3D toric, color codes, d=cL
4	cL^3	4D toric, color code, $d=cL^2$

Without Spatial Locality

Classical	Quantum
distance = n	distance = n/2
redundancy code (works with bits)	polynomial code (uses qudits)

Looking For?

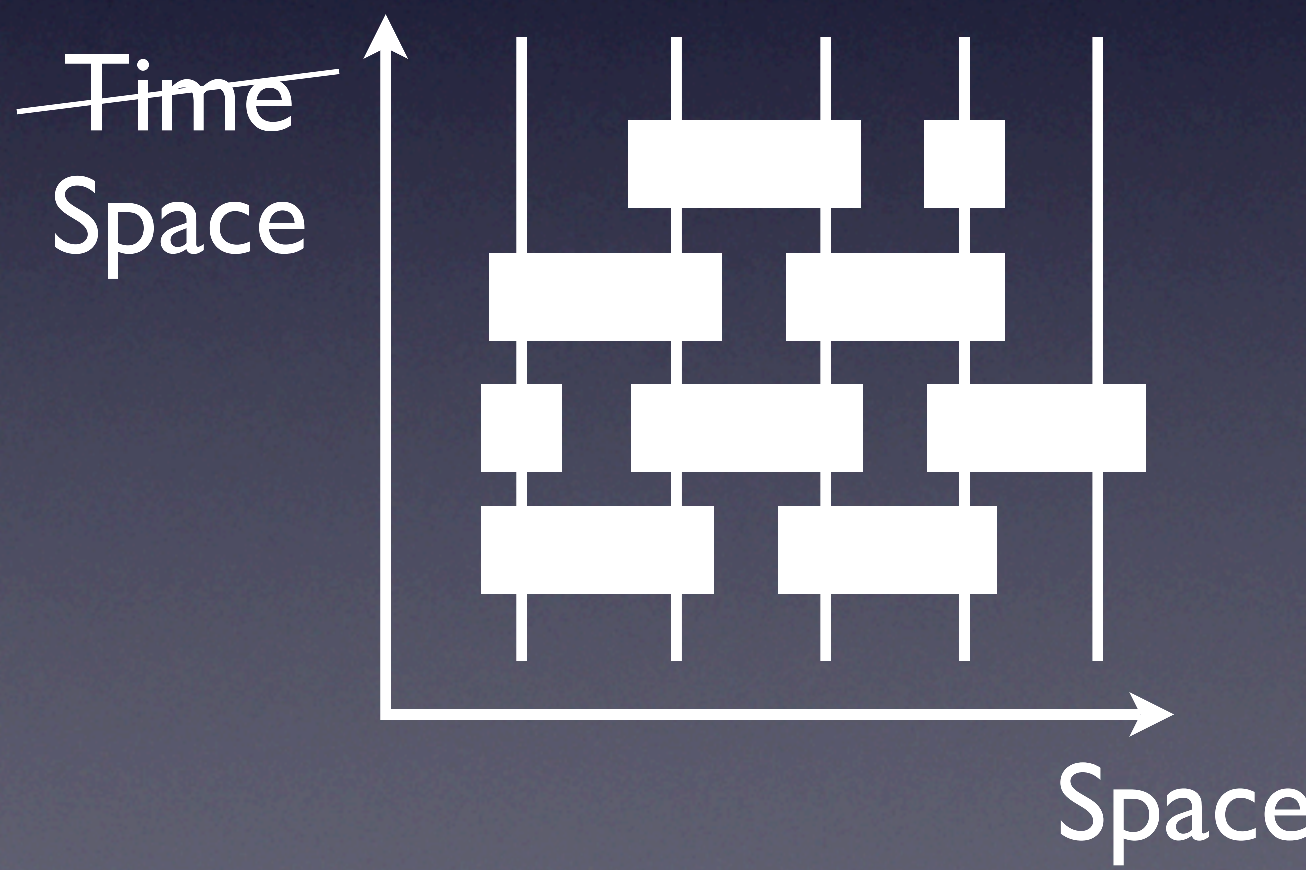
Competition between most likely errors and cost of these errors (energy versus entropy)



Codes with <u>local check operators</u>.....

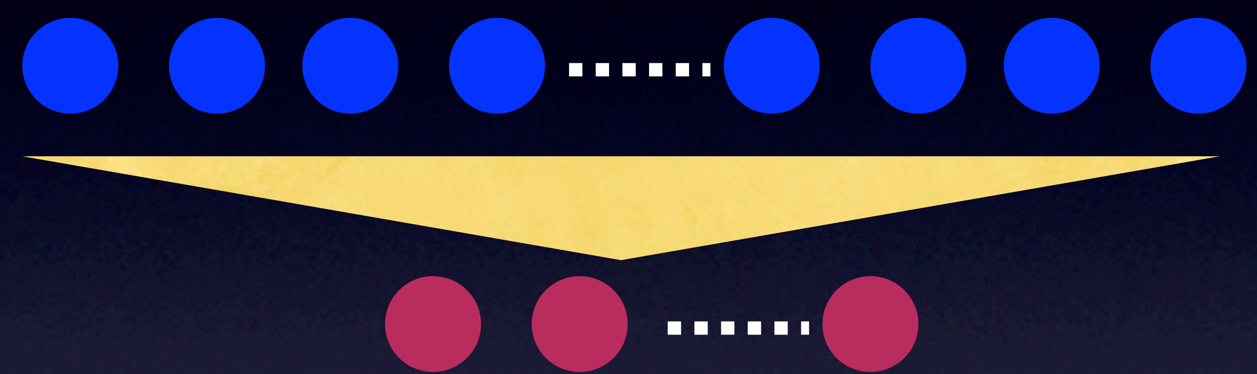
Turn Time to Space?

We know how to perform quantum error correction, locally in space-time. Can we leverage this to design codes that are local in space?



Stabilizer Subsystem Codes

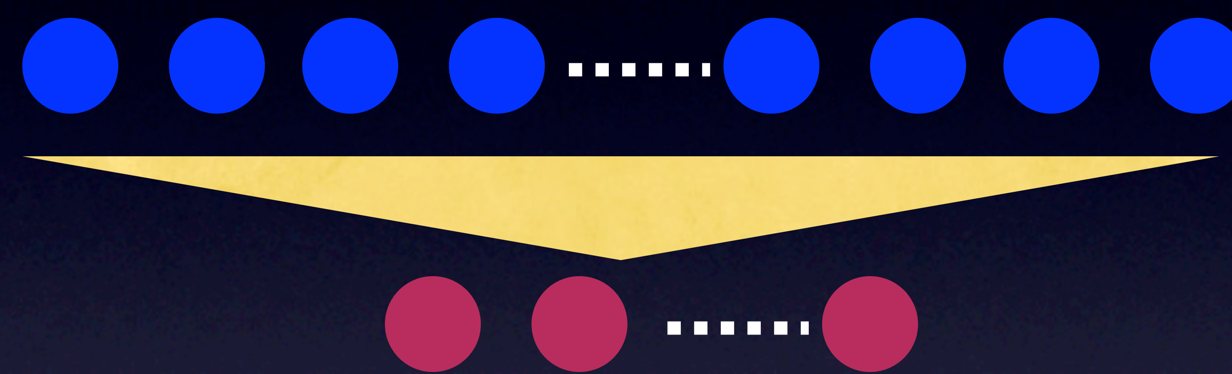
[Poulin, arXiv:quant-ph/0508131]



Stabilizer Subsystem Codes

[Poulin, arXiv:quant-ph/0508131]

n physical qubits



[n,k,d] subspace code

k encoded qubits

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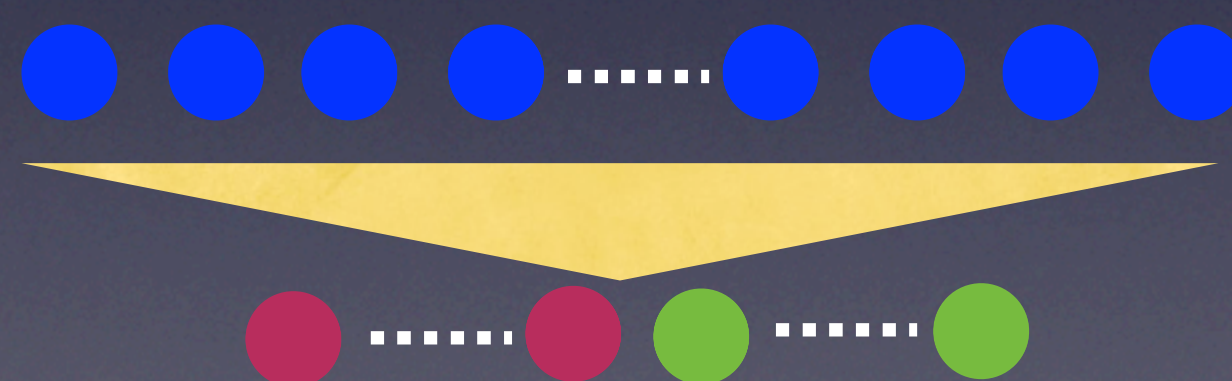
n physical qubits



[n,r,k,d] subsystem code

k encoded qubits

k gauge qubits

Baloney Sandwich Example

Gauge

$$\tilde{X}_1 = \begin{matrix} X & X & I \\ I & I & I \\ I & I & I \end{matrix} \quad \tilde{X}_2 = \begin{matrix} I & X & X \\ I & I & I \\ I & I & I \end{matrix} \quad \tilde{X}_3 = \begin{matrix} I & I & I \\ I & I & I \\ X & X & I \end{matrix} \quad \tilde{X}_4 = \begin{matrix} I & I & I \\ I & I & I \\ I & X & X \end{matrix}$$

$$\tilde{Z}_1 = \begin{matrix} Z & I & I \\ Z & I & I \\ I & I & I \end{matrix} \quad \tilde{Z}_2 = \begin{matrix} I & I & Z \\ I & I & Z \\ I & I & I \end{matrix} \quad \tilde{Z}_3 = \begin{matrix} I & I & I \\ Z & I & I \\ Z & I & I \end{matrix} \quad \tilde{Z}_4 = \begin{matrix} I & I & I \\ I & I & Z \\ I & I & Z \end{matrix}$$

Stabilizer

$$S_1 = \begin{matrix} X & X & I \\ X & X & I \\ X & X & I \end{matrix} \quad S_2 = \begin{matrix} I & X & X \\ I & X & X \\ I & X & X \end{matrix} \quad S_3 = \begin{matrix} Z & Z & Z \\ Z & Z & Z \\ I & I & I \end{matrix} \quad S_4 = \begin{matrix} I & I & I \\ Z & Z & Z \\ Z & Z & Z \end{matrix}$$

Baloney Sandwich Example

Gauge

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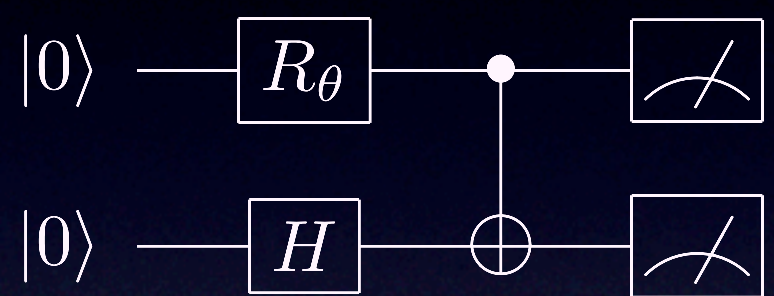
$$S_1 = \begin{matrix} X & X & I \\ X & X & I \\ X & X & I \end{matrix} \quad S_2 = \begin{matrix} I & X & X \\ I & X & X \\ I & X & X \end{matrix} \quad S_3 = \begin{matrix} Z & Z & Z \\ Z & Z & Z \\ I & I & I \end{matrix} \quad S_4 = \begin{matrix} I & I & I \\ Z & Z & Z \\ Z & Z & Z \end{matrix}$$

Measure large stabilizer using only 2-qubit measurements

$$\tilde{X}_1, \tilde{X}_3, \tilde{X}_1\tilde{X}_3 S_1 \quad \tilde{X}_2, \tilde{X}_4, \tilde{X}_2\tilde{X}_4 S_2 \quad \tilde{Z}_1, \tilde{Z}_2, \tilde{Z}_1\tilde{Z}_2 S_3 \quad \tilde{Z}_3, \tilde{Z}_4, \tilde{Z}_3\tilde{Z}_4 S_4$$

One Way QC

[Raussendorf and Briegel, Phys. Rev. Lett. 86, 5188 (2001)]



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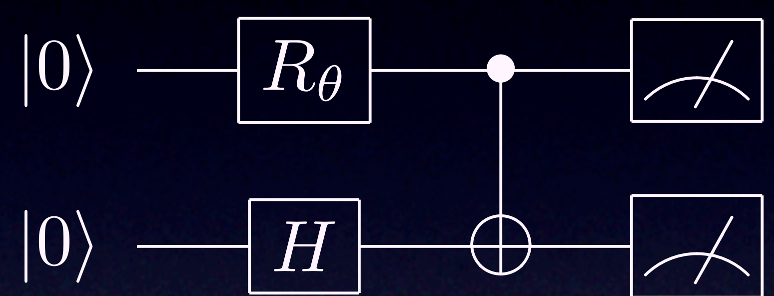
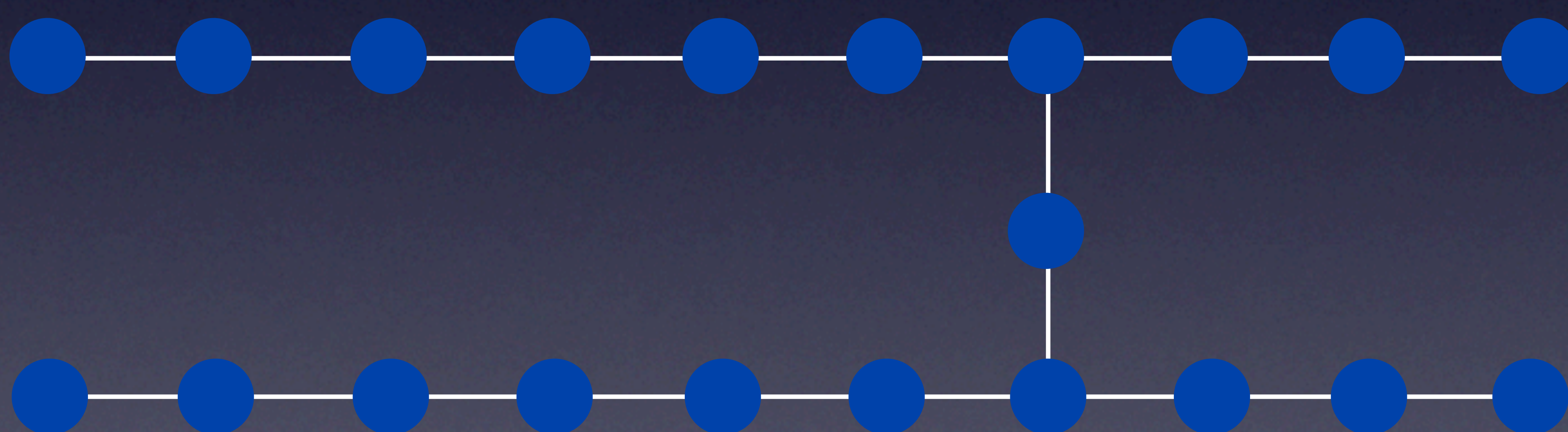
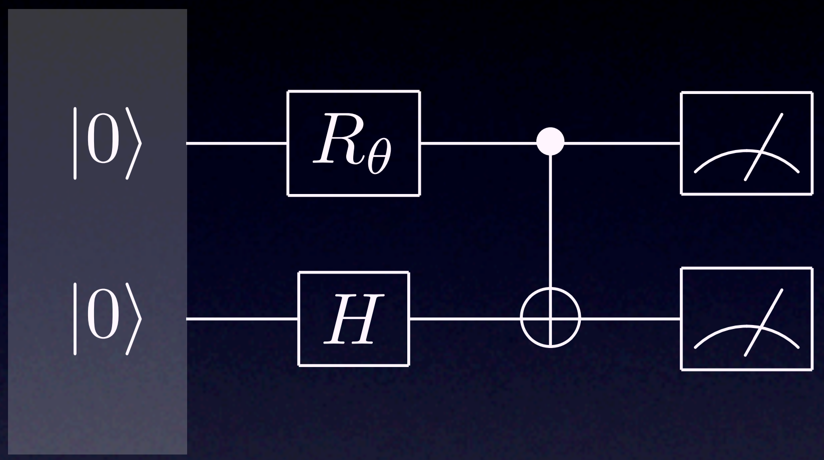


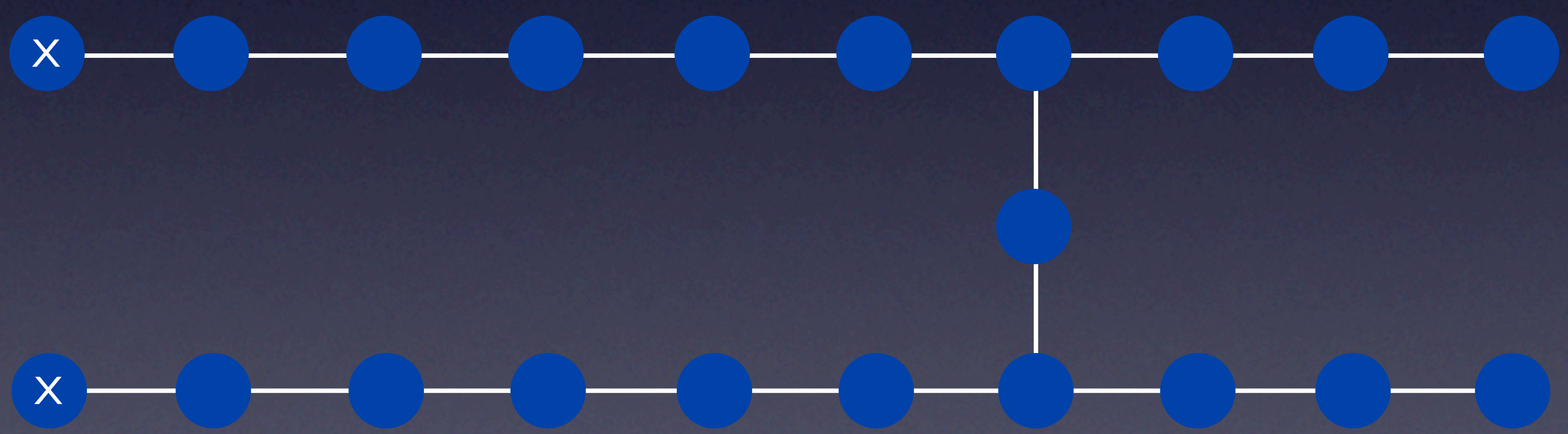


Create Entangled State

One Way QC

[Raussendorf and Briegel, Phys. Rev. Lett. 86, 5188 (2001)]

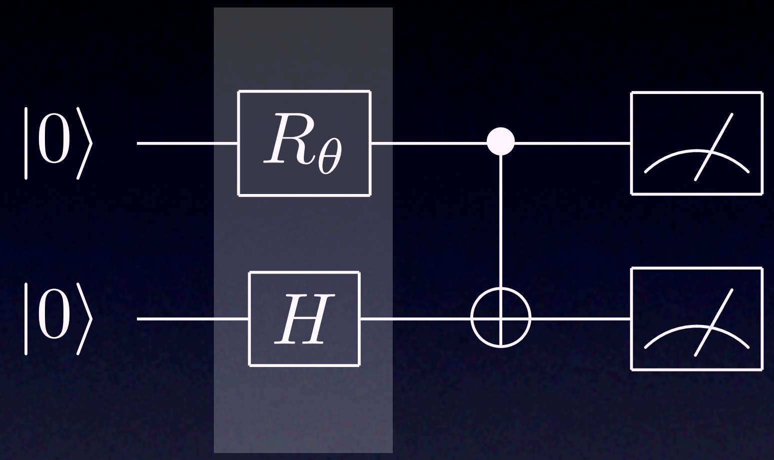


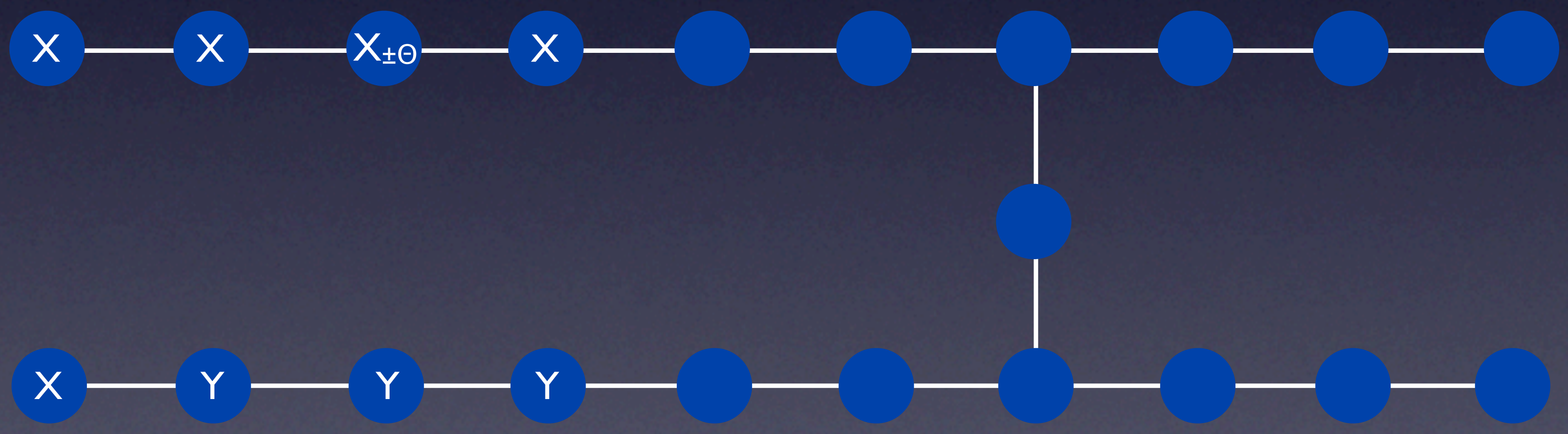


Adaptively measure to enact circuit

One Way QC

[Raussendorf and Briegel, Phys. Rev. Lett. 86, 5188 (2001)]





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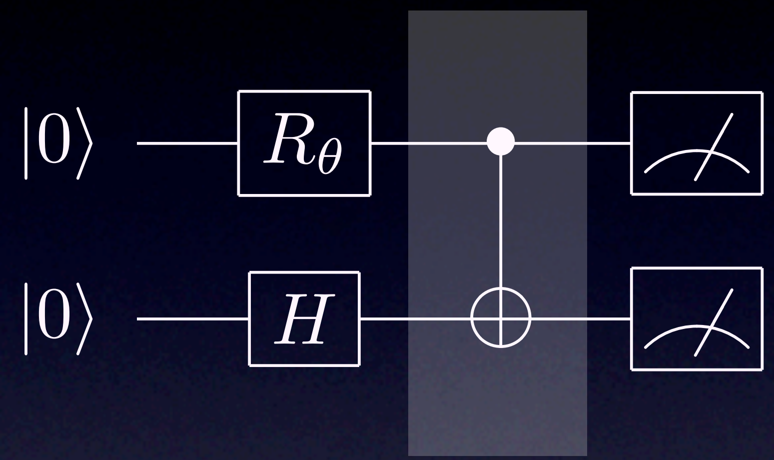

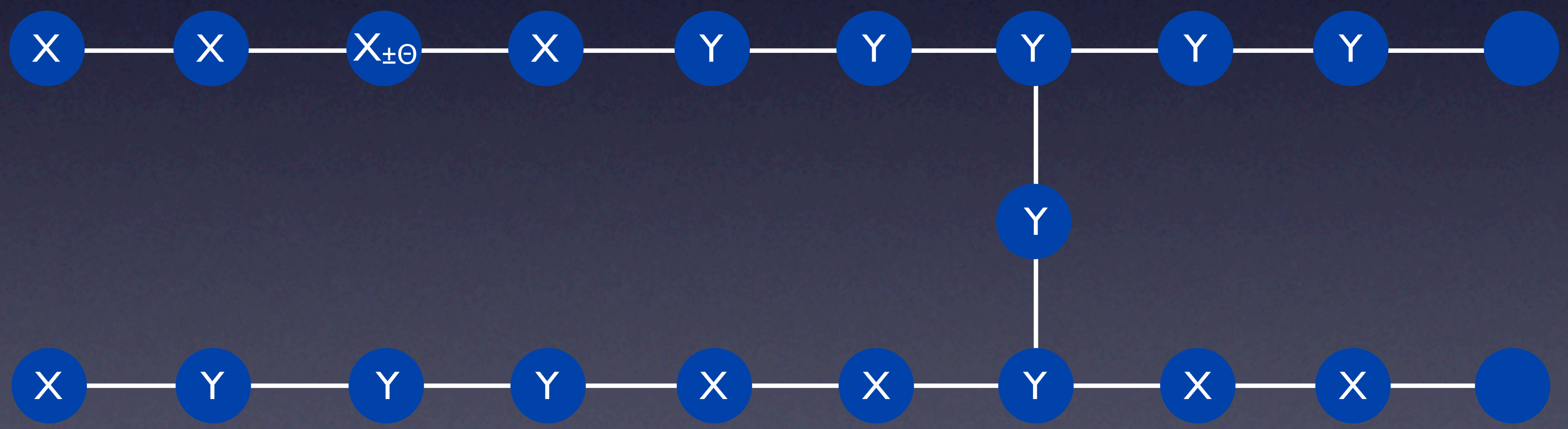

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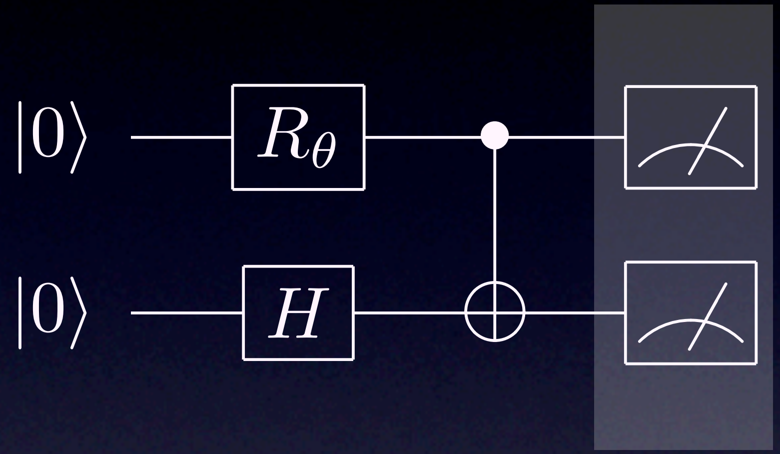
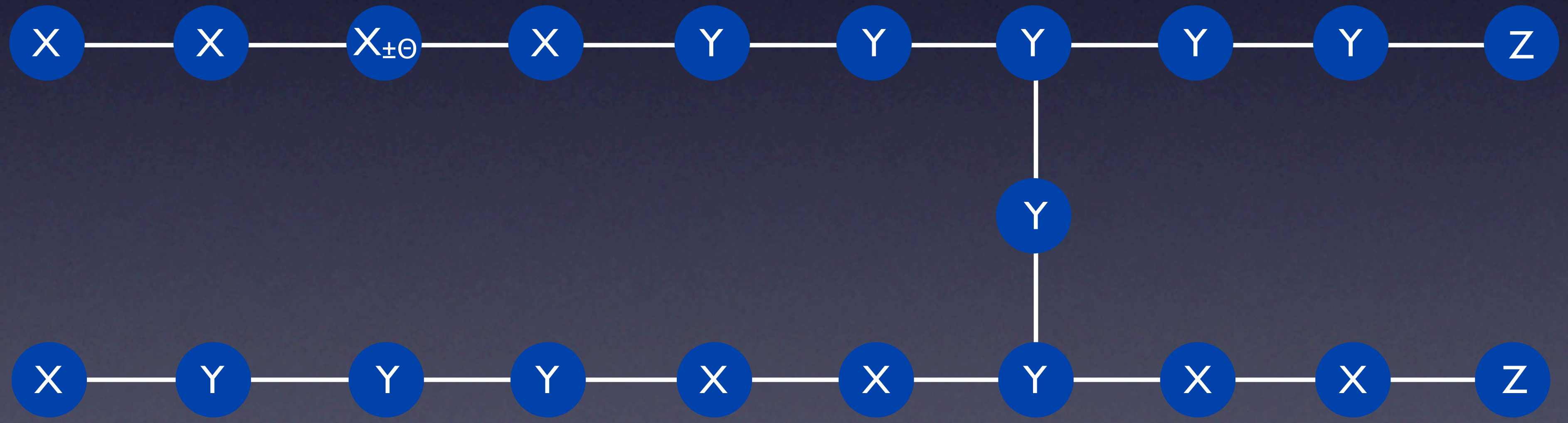




Adaptively measure to enact circuit

Initial state described locally + measurements are all local

There's a Code in My Wire

Vertex operators at v: $X_v \prod_{(w,v)\in E} Z_w$

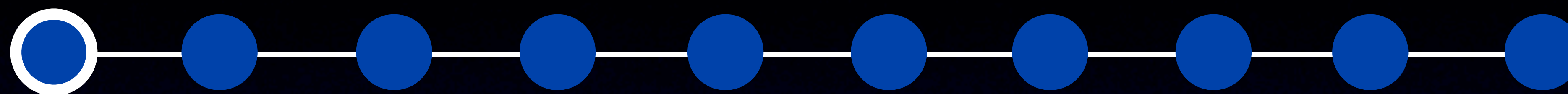
Consider stabilizer code with stabilizer generators all vertices in a line except first one:

$$S_i = [Z]_i[X]_{i+1}[Z]_{i+2} \qquad 2 \le i \le n-2$$

$$S_{n-1} = [Z]_{n-1}[X]_n$$

n-1 independent stabilizers = one encoded qubit

There's a Code in My Wire



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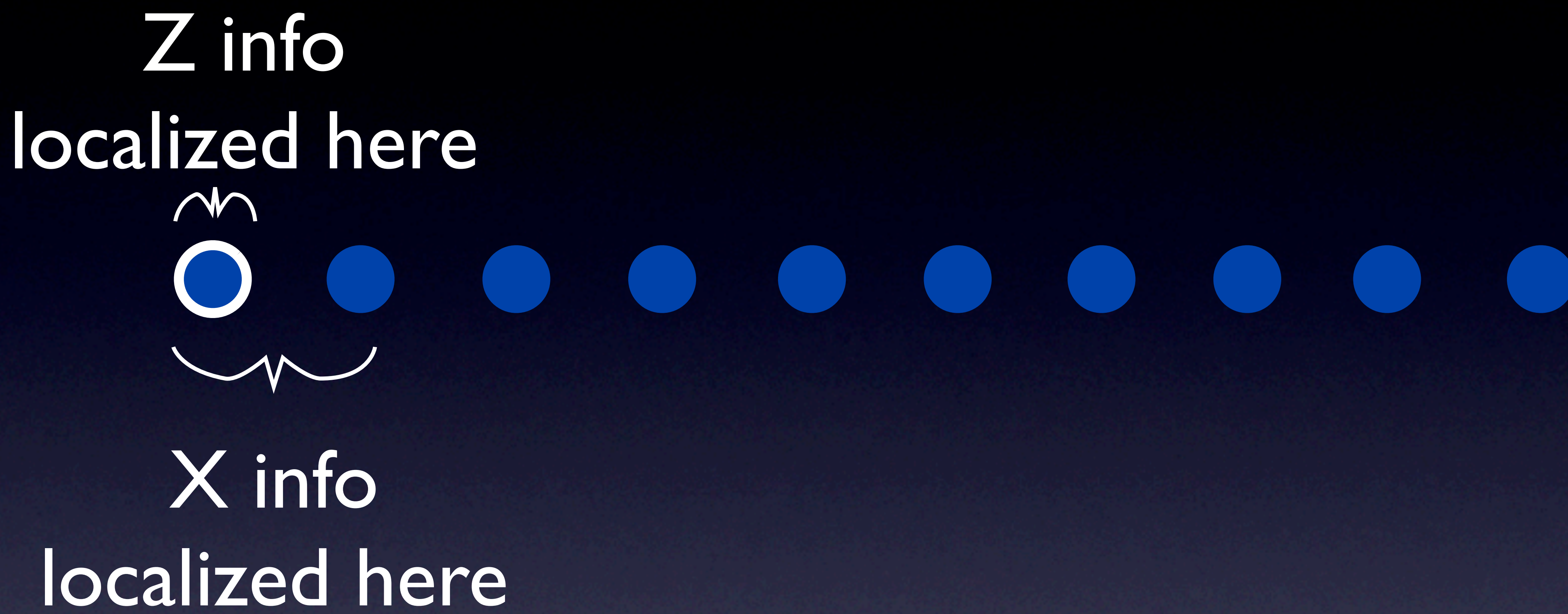


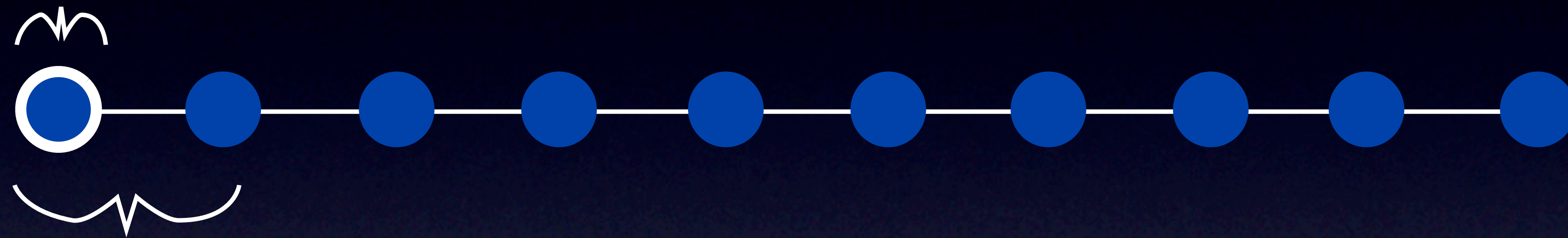
$$S_i = [Z]_i [X]_{i+1} [Z]_{i+2} \quad 2 \leq i \leq n-2$$

$$S_{n-1} = [Z]_{n-1} [X]_n$$

logical qubit: $\bar{X} = [X]_1 [Z]_2, \bar{Z} = [Z]_1$

There's a Code in My Wire

Z info
localized here



X info
localized here

$$S_i = [Z]_i [X]_{i+1} [Z]_{i+2} \quad 2 \leq i \leq n-2$$

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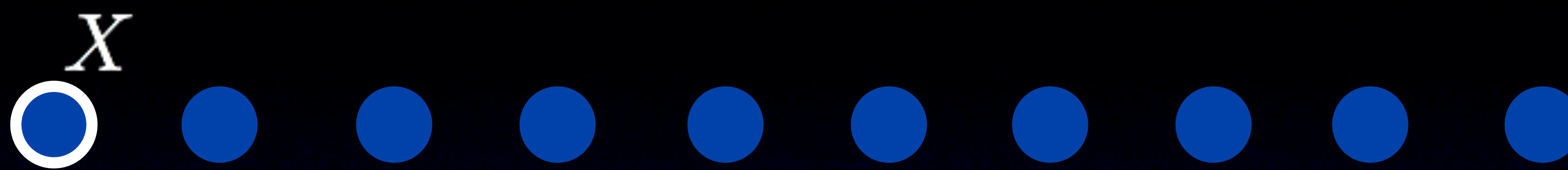


Add a gauge qubit:

$$S_i = [Z]_i[X]_{i+1}[Z]_{i+2} \quad 3 \leq i \leq n-2$$

$$S_{n-1} = [Z]_{n-1}[X]_n$$

$$\tilde{X}_1 = [X]_1, \tilde{Z} = [Z]_1[X]_2[Z]_3$$

logical qubits?

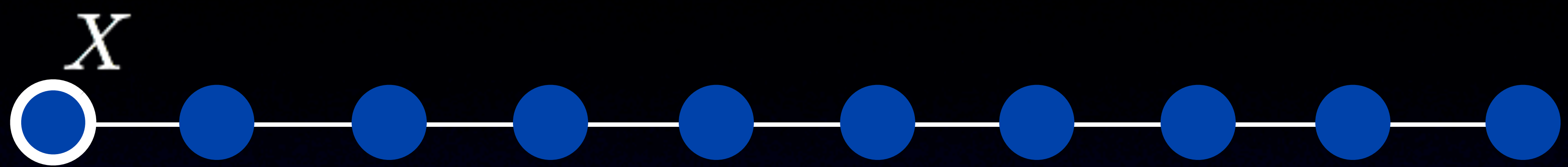
$$\bar{X} = [X]_1[Z]_2, \bar{Z} = [Z]_1$$

does <u>not</u> commute with new gauge qubits

$$\bar{X} = [X]_1[Z]_2, \bar{Z} = [X]_2[Z]_3$$

commutes with new gauge qubits

There's a Code in My Wire



Add a gauge qubit:

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logical qubits?

$$\bar{X} = [X]_1 [Z]_2, \bar{Z} = [Z]_1$$

does <u>not</u> commute with new gauge qubits

$$\bar{X} = [X]_1 [Z]_2, \bar{Z} = [X]_2 [Z]_3$$

commutes with new gauge qubits

There's a Code in My Wire

Z info localized here $\bar{X} = [X]_1[Z]_2, \bar{Z} = [X]_2[Z]_3$

X info localized here

modulo the gauge qubits: $\tilde{X}_1 = [X]_1, \tilde{Z} = [Z]_1[X]_2[Z]_3$

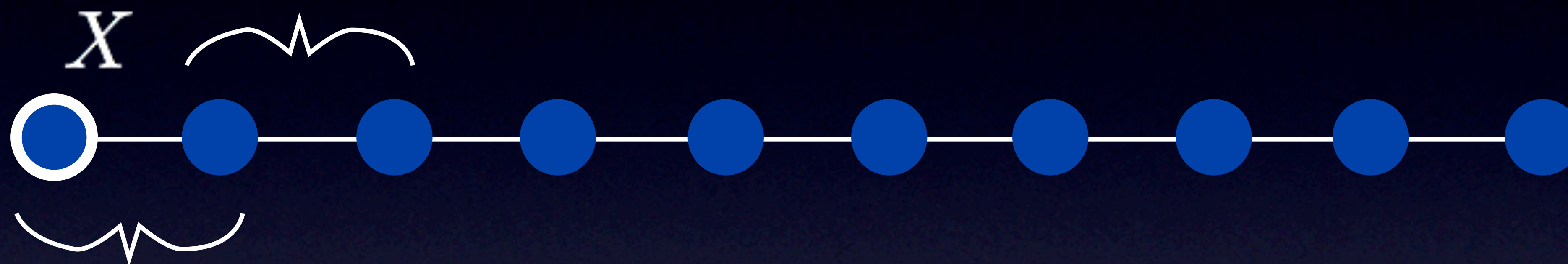
Z info localized here

X info localized here $\bar{X}\tilde{X}_1 = [Z]_2$

q-info has propagated down the wire with Hadamard

There's a Code in My Wire

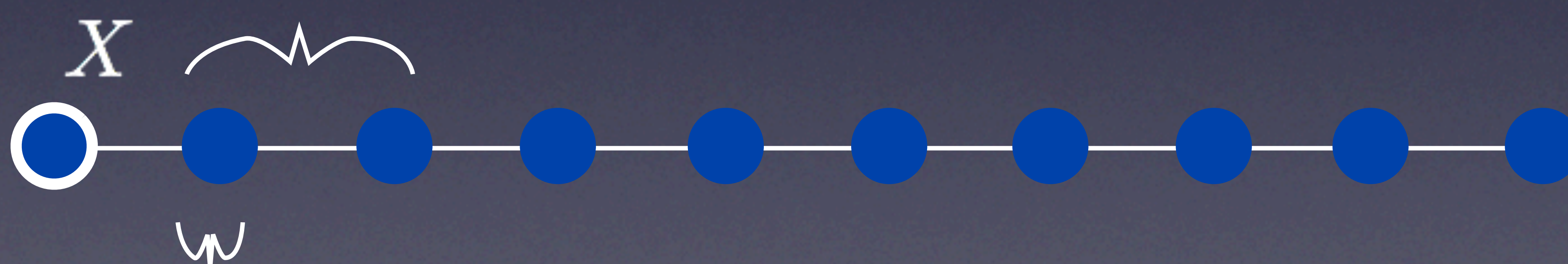
Z info localized here $\bar{X} = [X]_1[Z]_2, \bar{Z} = [X]_2[Z]_3$



X info localized here

modulo the gauge qubits: $\tilde{X}_1 = [X]_1, \tilde{Z} = [Z]_1[X]_2[Z]_3$

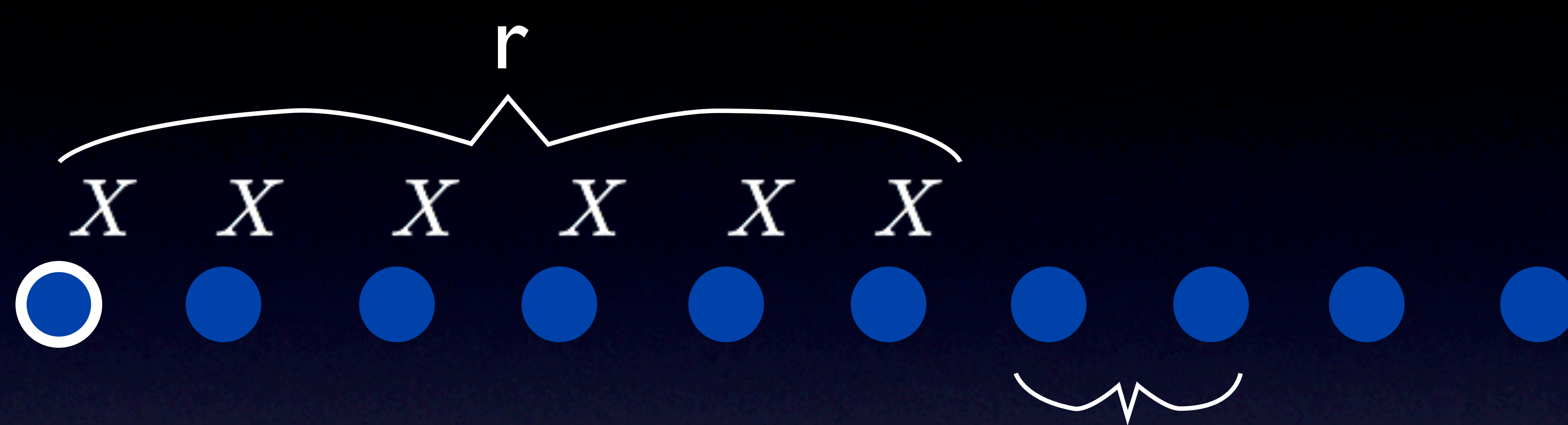
Z info localized here



X info localized here $\bar{X}\tilde{X}_1 = [Z]_2$

q-info has propagated down the wire with Hadamard

There's a Code in My Wire



[n,1,r,1] subsystem code

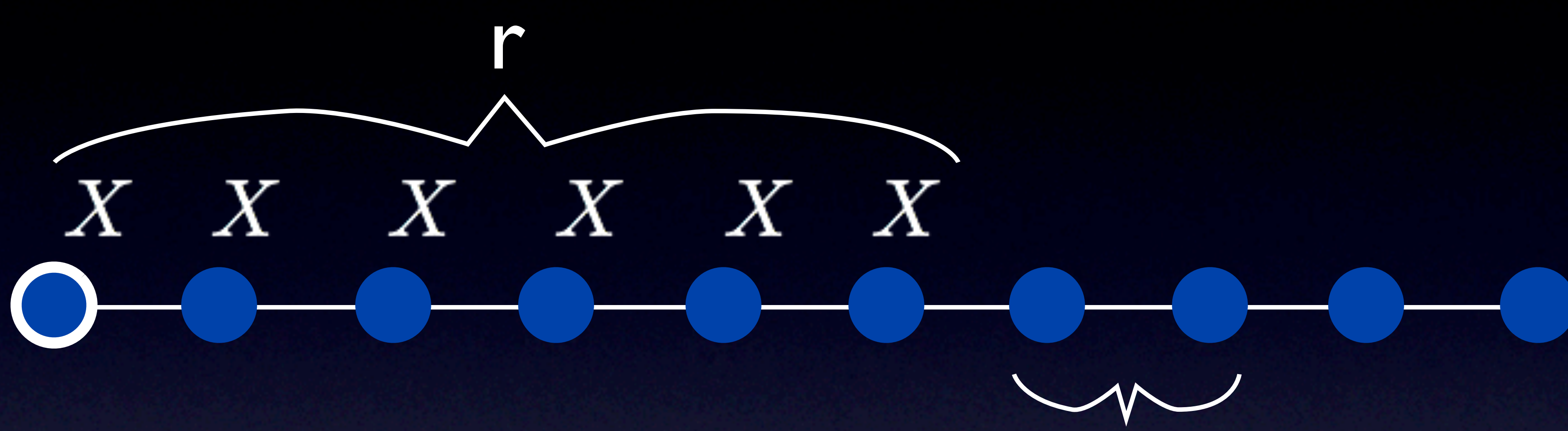
Modulo gauge, information can be localized here

$$\bar{X} = [X]_1[X]_3[X]_5[X]_7[Z]_8$$

$$\bar{Z} = [X]_2[X]_4[X]_6[Z]_7$$

MBQC from a coding perspective

There's a Code in My Wire



[n,1,r,1] subsystem code

Modulo gauge, information can be localized here

$$\bar{X} = [X]_1[X]_3[X]_5[X]_7[Z]_8$$
$$\bar{Z} = [X]_2[X]_4[X]_6[Z]_7$$

MBQC from a coding perspective

Dave WTH Are You Doing?

Take: set of n-qubit Pauli operators
These: generate a group
This: group = r qubit Pauli group + abelian group
Elements: gauge operators and stabilizer operators

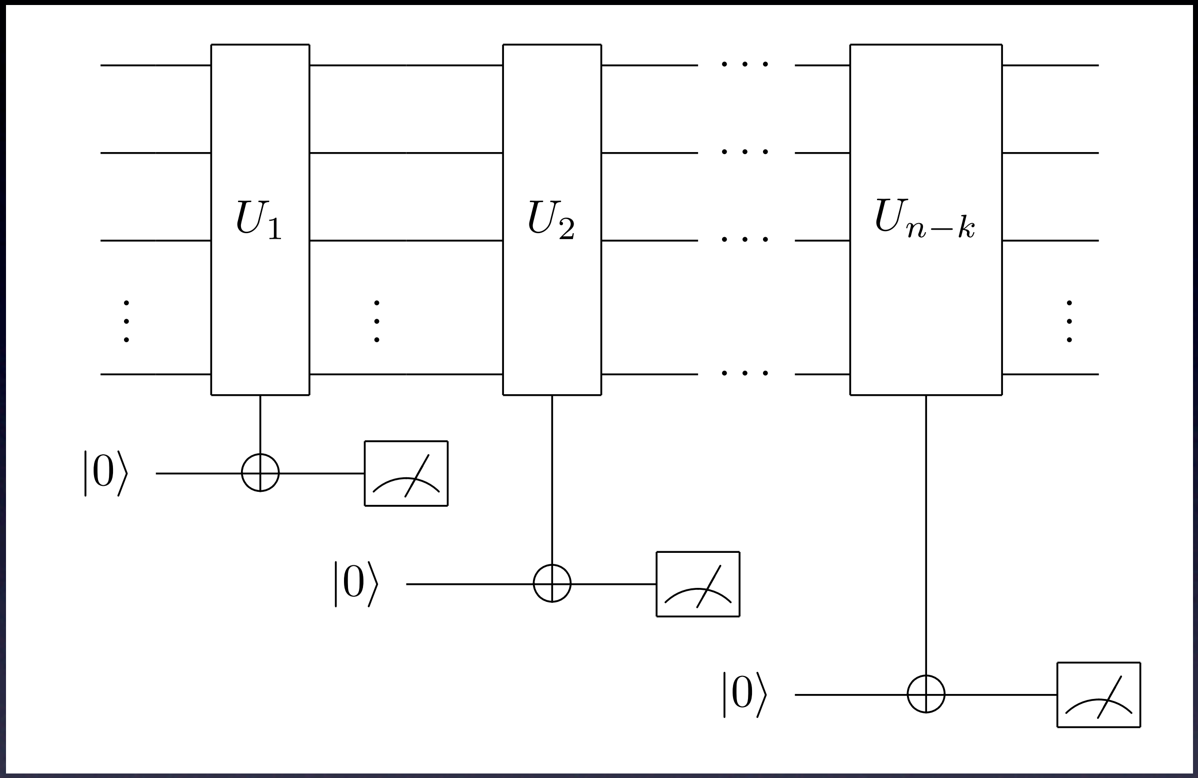
$$\mathcal{T} = \langle T_1, \ldots, T_m \rangle \qquad \mathcal{T} = \mathcal{G} \otimes \mathcal{S}$$

$\mathcal{G}$ ← $\mathcal{P}_r$

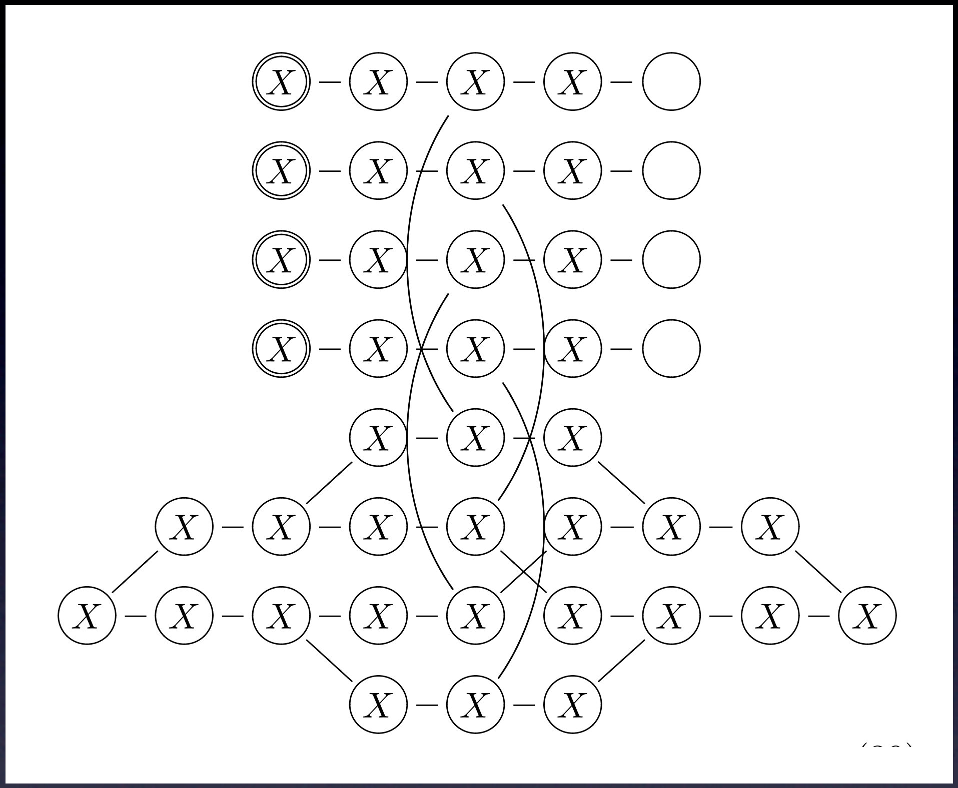
Left over: Pauli operators that commute with the group, but not in the group generate logical

$$\mathcal{L} = \mathcal{P}_k$$

Main Idea (WAKE UP)



Circuit for measuring syndrome of a [n,k,d] stabilizer code



MBQC scheme for circuit, convert to subsystem code on N qubits

Claim: RHS code is [N,k,d] code*

* = subject to circuit having a particular FT like criteria

Dictionary:

circuit to labeled graph

labeled graph describes group

$$\mathcal{T} = \langle T_1, \ldots, T_m \rangle$$

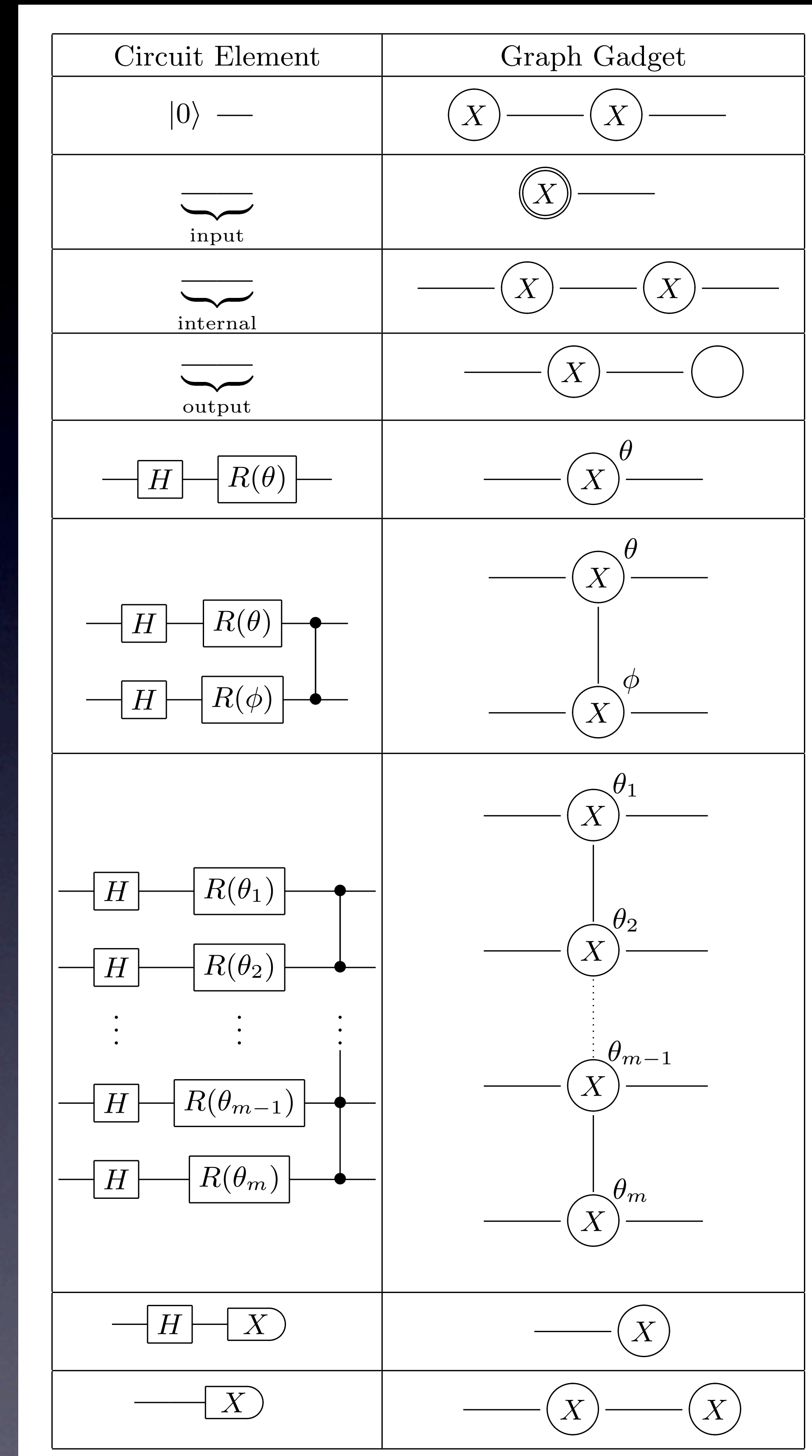
include: vertex operators for non-double framed vertices

$$X_v \prod_{(w,v)\in E} Z_w$$

include: single qubit for each X labeled vertex

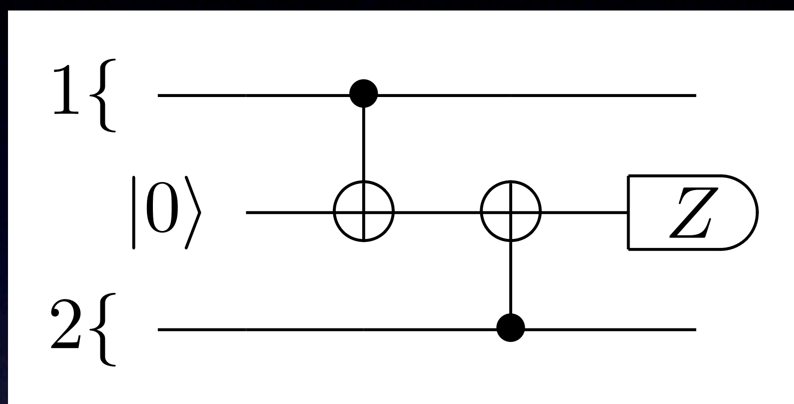
$$\cos\theta X_v + \sin\theta Y_v$$

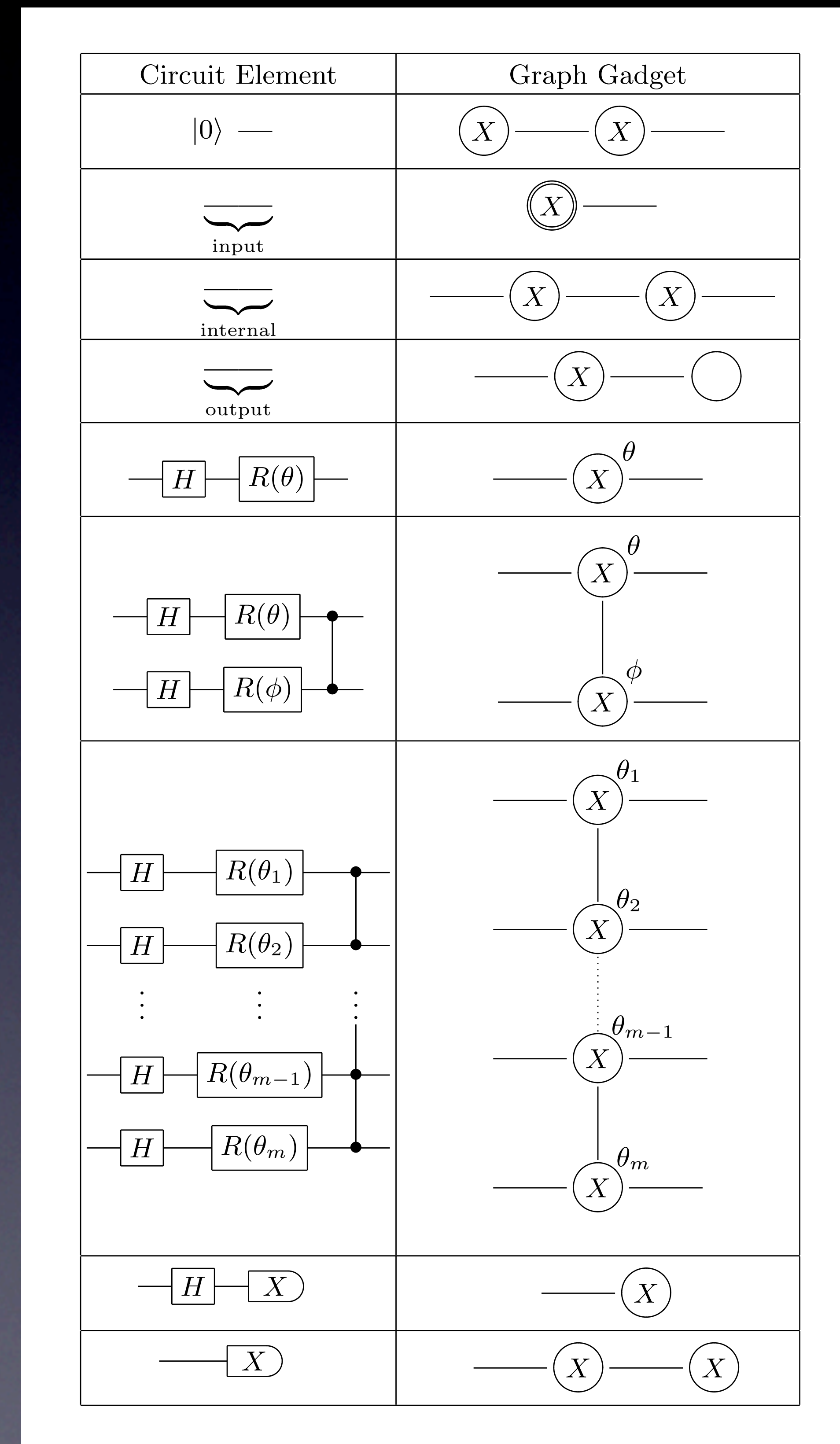
$\theta = 0$ for no θ label



Circuit, Circuit, Graph

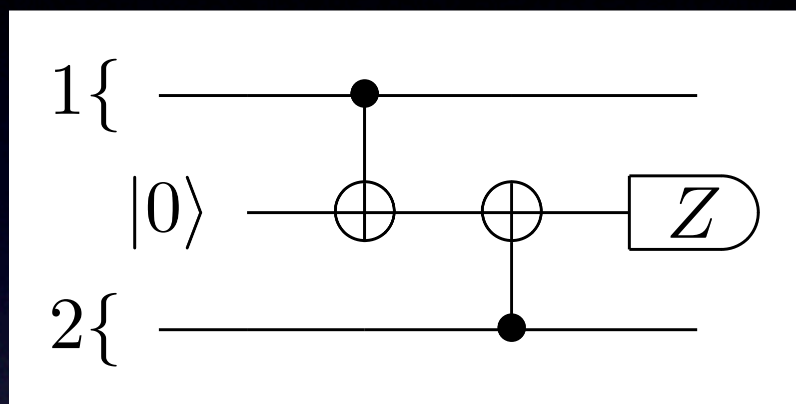
Simplest stabilizer code: $S = Z \otimes Z$

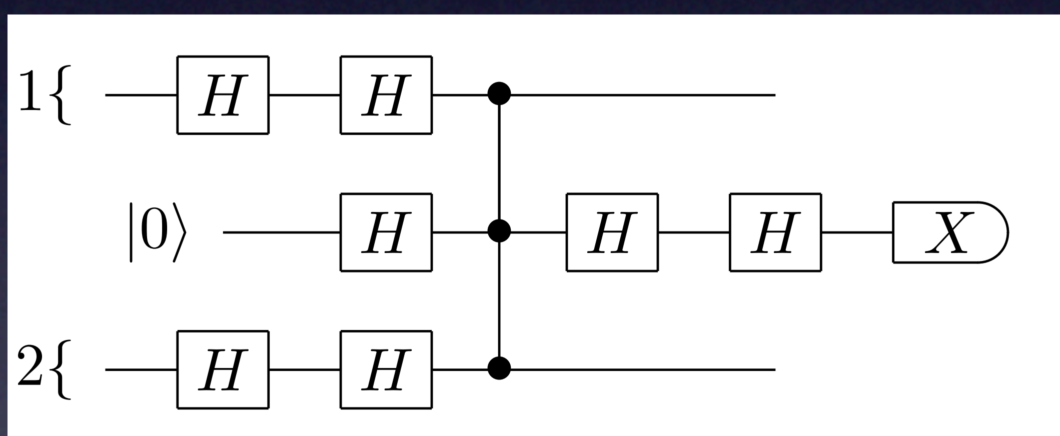


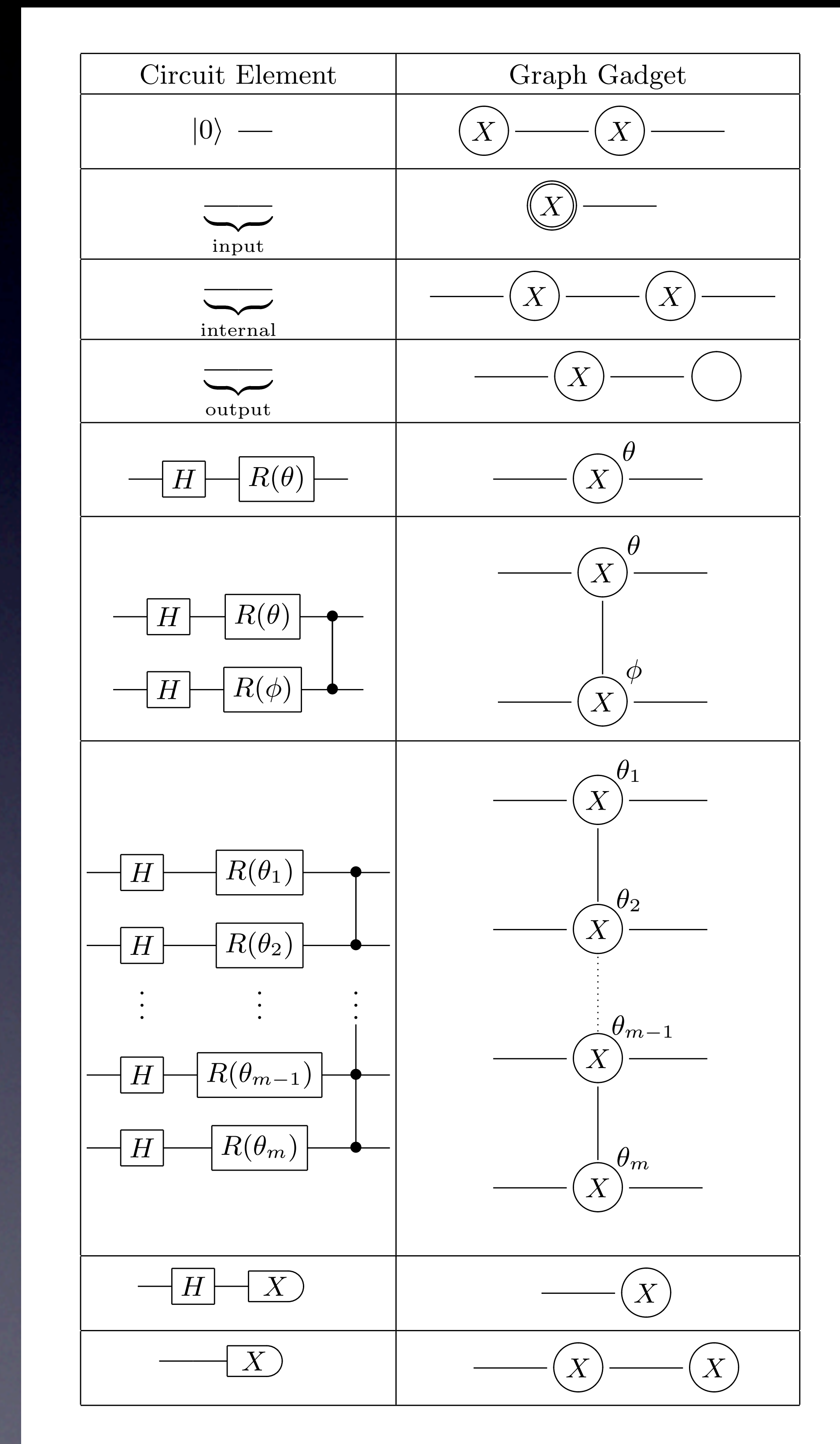


Circuit, Circuit, Graph

Simplest stabilizer code: $S = Z \otimes Z$

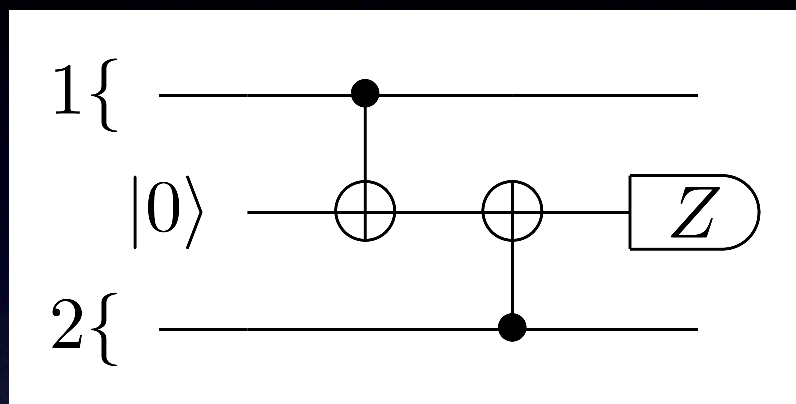


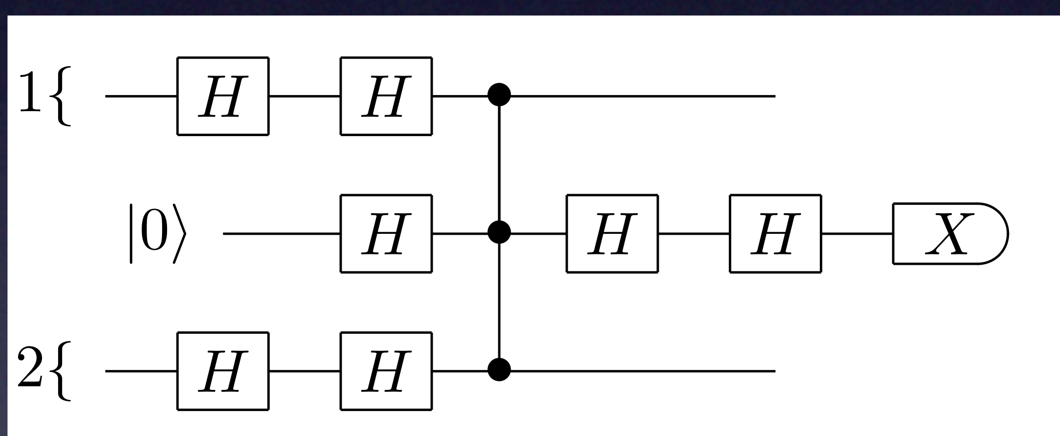


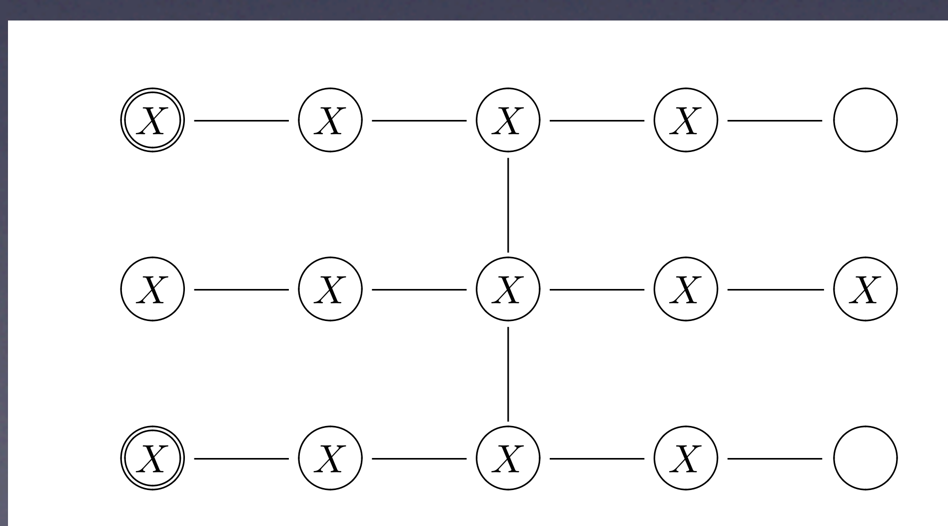


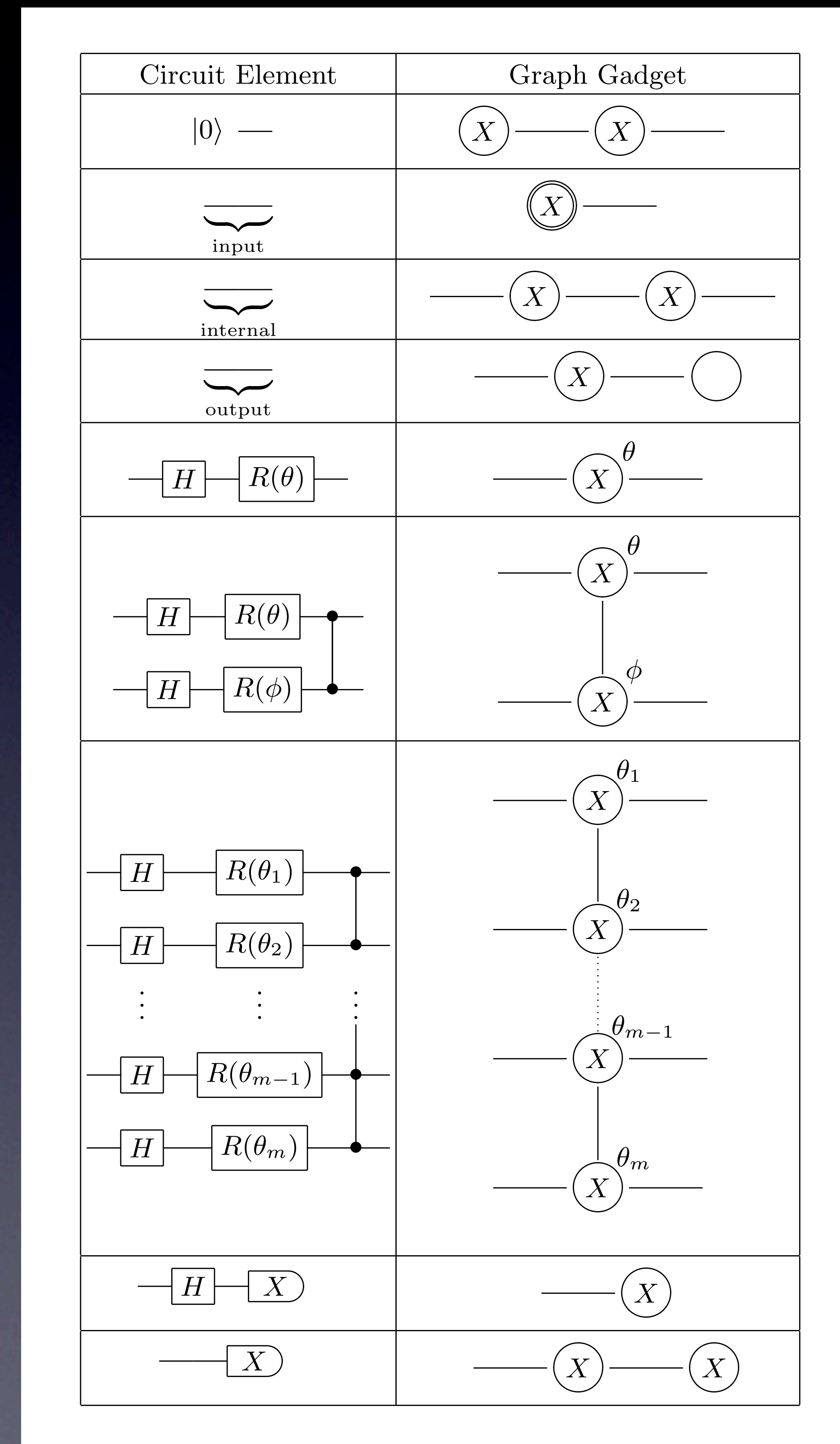
Circuit, Circuit, Graph

Simplest stabilizer code: $S = Z \otimes Z$





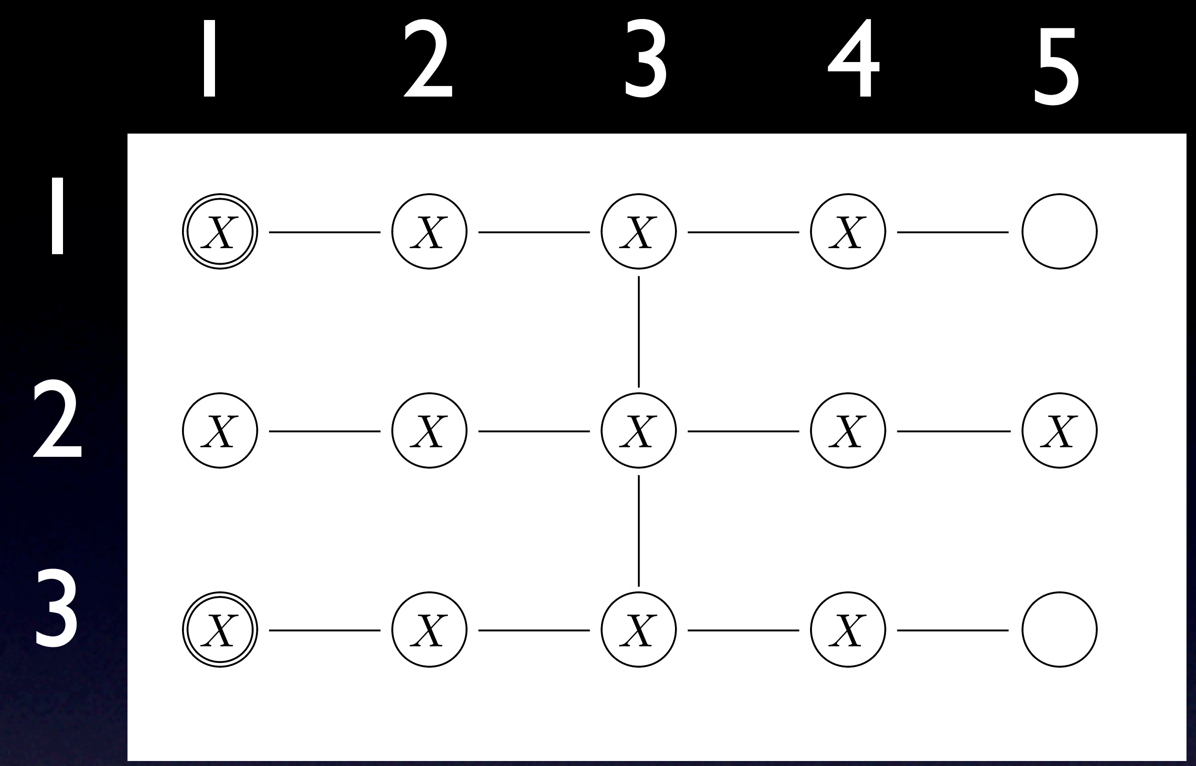




12 Gauge Qubits

$$\bar{X}_1 = X_{(1,1)}, \bar{Z}_1 = S_{(1,2)}$$
$$\bar{X}_2 = X_{(2,1)}, \bar{Z}_2 = S_{(2,2)}$$
$$\bar{X}_3 = X_{(a,1)}, \bar{Z}_3 = S_{(a,2)}$$
$$\bar{X}_4 = X_{(1,2)}, \bar{Z}_4 = S_{(1,3)}$$
$$\bar{X}_5 = X_{(2,2)}, \bar{Z}_5 = S_{(2,3)}$$
$$\bar{X}_6 = X_{(a,2)}, \bar{Z}_6 = S_{(a,1)}$$
$$\bar{X}_7 = X_{(1,1)}X_{(1,3)}, \bar{Z}_7 = S_{(1,4)}$$
$$\bar{X}_8 = X_{(2,1)}X_{(2,3)}, \bar{Z}_8 = S_{(2,4)}$$
$$\bar{X}_9 = X_{(1,2)}X_{(1,4)}, \bar{Z}_9 = S_{(1,5)}$$
$$\bar{X}_{10} = X_{(2,2)}X_{(2,4)}, \bar{Z}_{10} = S_{(2,5)}$$
$$\bar{X}_{11} = X_{(a,4)}, \bar{Z}_{11} = S_{(a,5)}$$
$$\bar{X}_{12} = X_{(a,5)}, \bar{Z}_{12} = S_{(a,4)}$$

$$S_{(i,j)} = [X]_{(i,j)} \prod_{(v,(i,j))\in E} [Z]_v$$



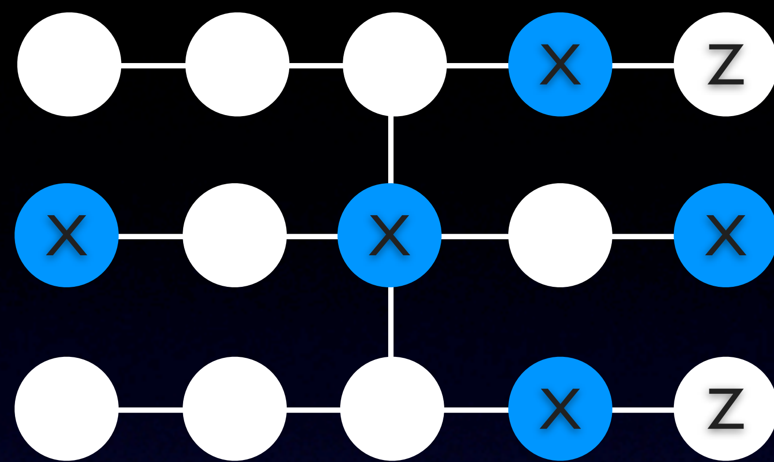
2 Stabilizers

$$S_1 = S_{(1,4)}S_{(2,4)}S_{(a,1)}S_{(a,3)}S_{(a,5)}$$
$$S_2 = X_{(1,2)}X_{(2,2)}X_{(a,1)}X_{(a,3)}X_{(a,5)}.$$

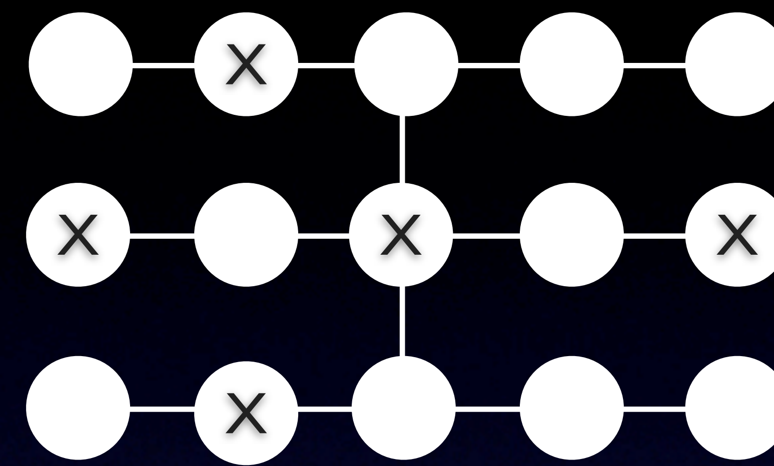
1 Logical Qubit

$$\bar{X}_{L,1} = X_{(1,1)}X_{(1,3)}X_{(1,5)}X_{(2,1)}X_{(2,3)}X_{(2,5)}$$
$$\bar{Z}_{L,1} = X_{(1,2)}X_{(1,4)}Z_{(1,5)}.$$

$S_1 =$

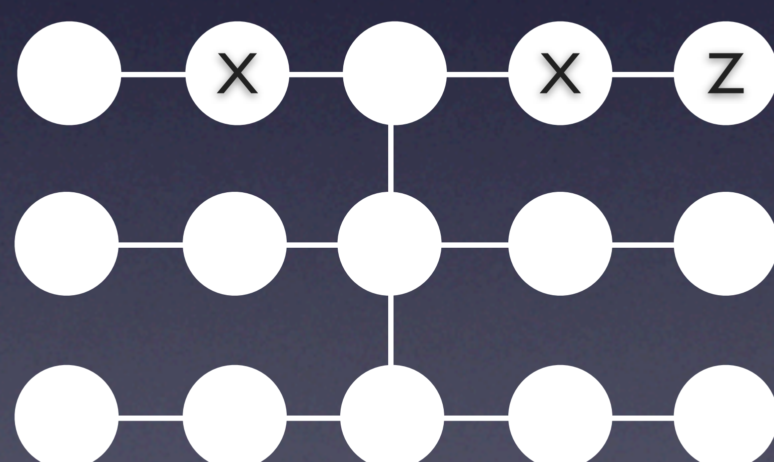


$S_2 =$

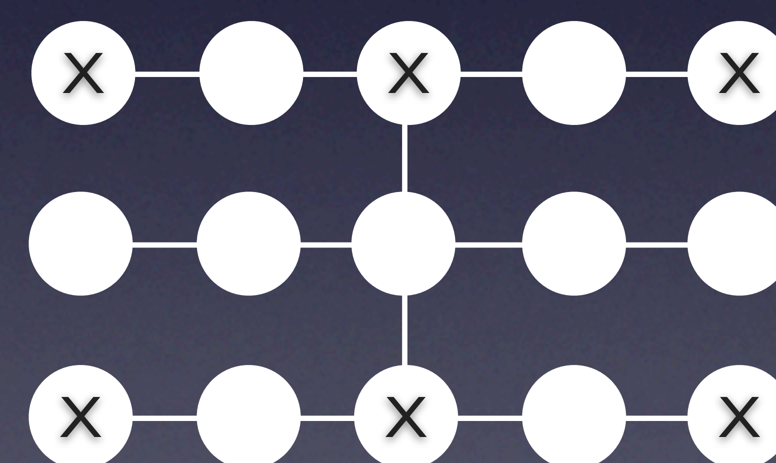


Stabilizers can be measured by low weight measurements

$\bar{Z} =$

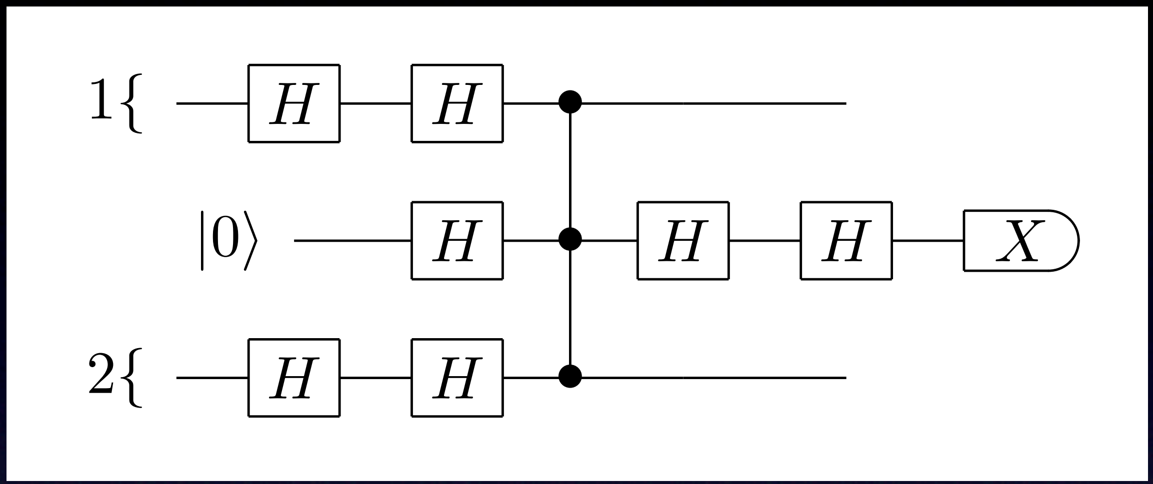


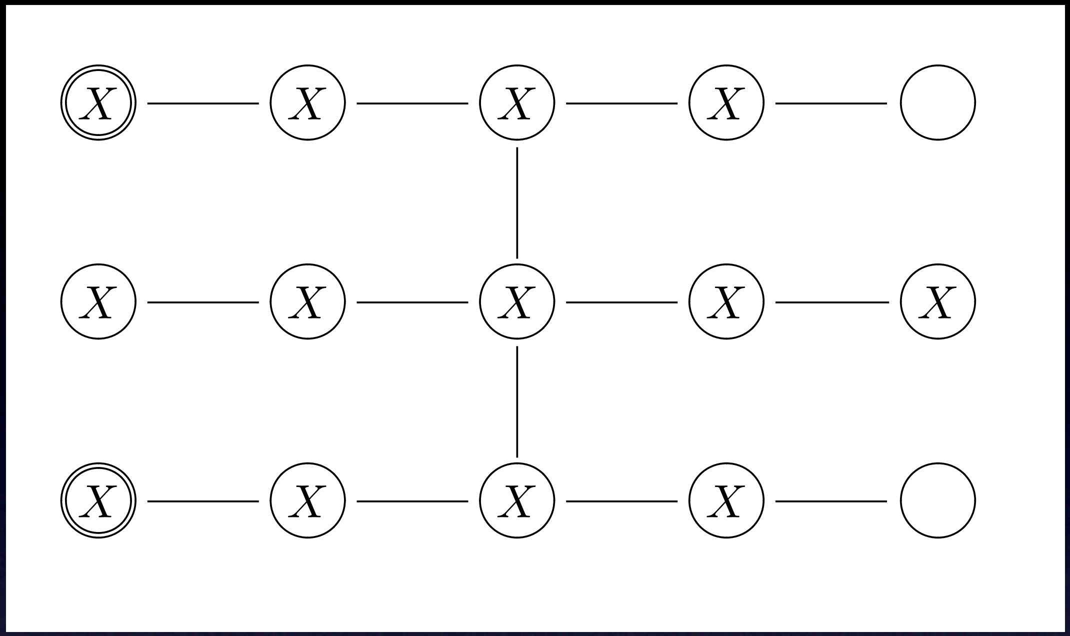
$\bar{X} =$



Modulo gauge and stabilizer group logical Z can be made weight 1, but logical X can only be made weight 2

General Method



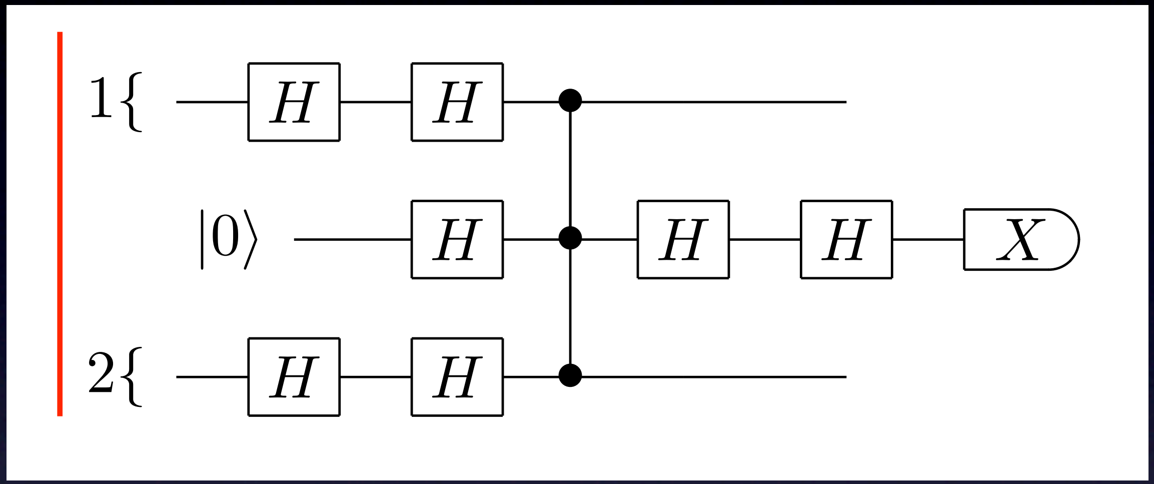


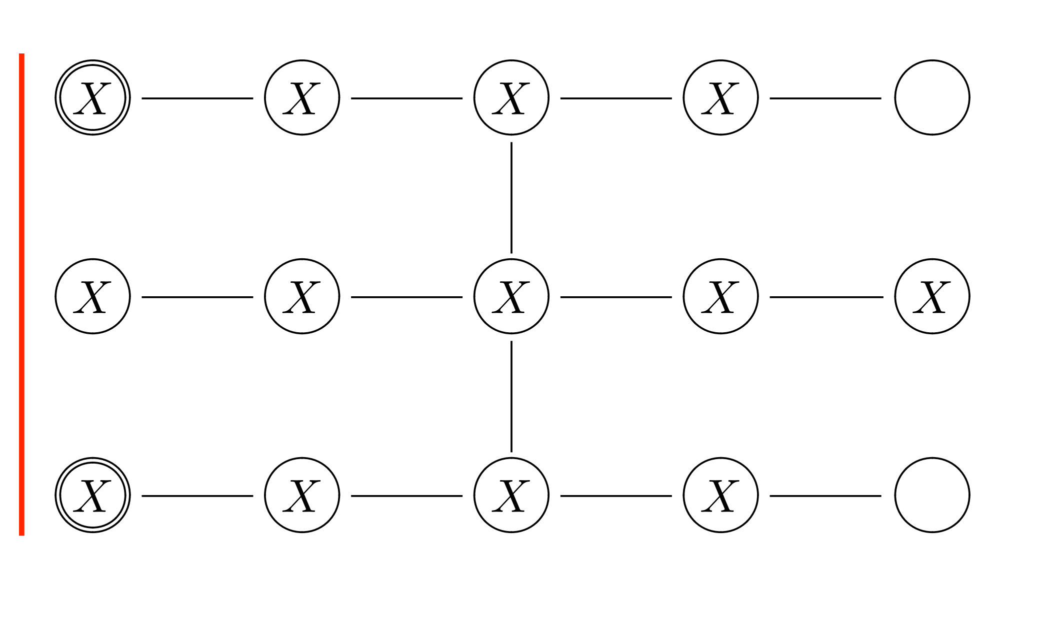
Generalized Heisenberg pict:

- Track X,Y,Z for input qubits
- Track single Pauli for state preps
- Update according to gates
- Update according to measurements

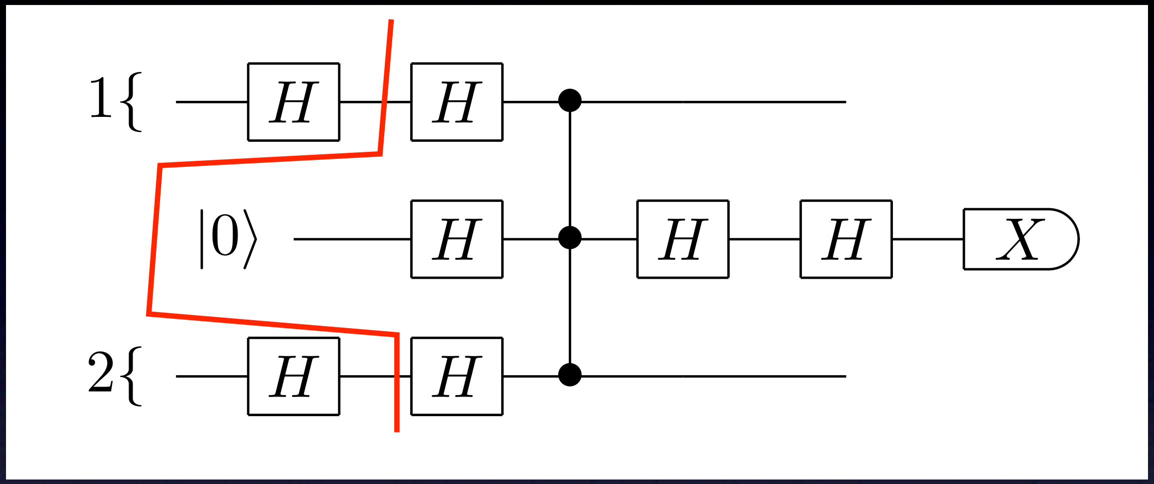
Subsystem code:

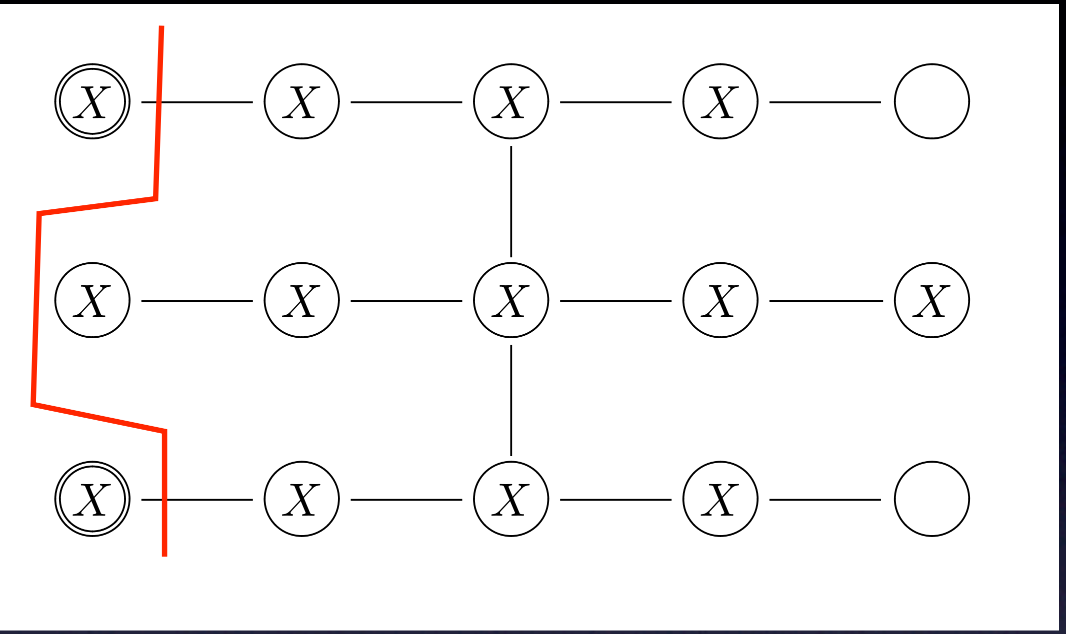
- Track group generated by vertex operators and X operators up to given level
- Group generates gauge and stabilizer group
- Keep track of logical qubits



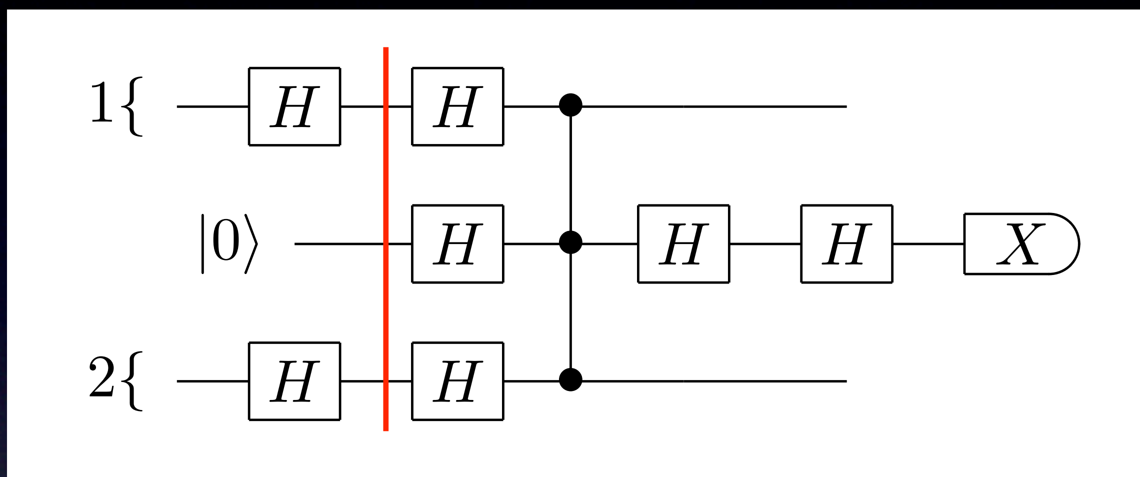


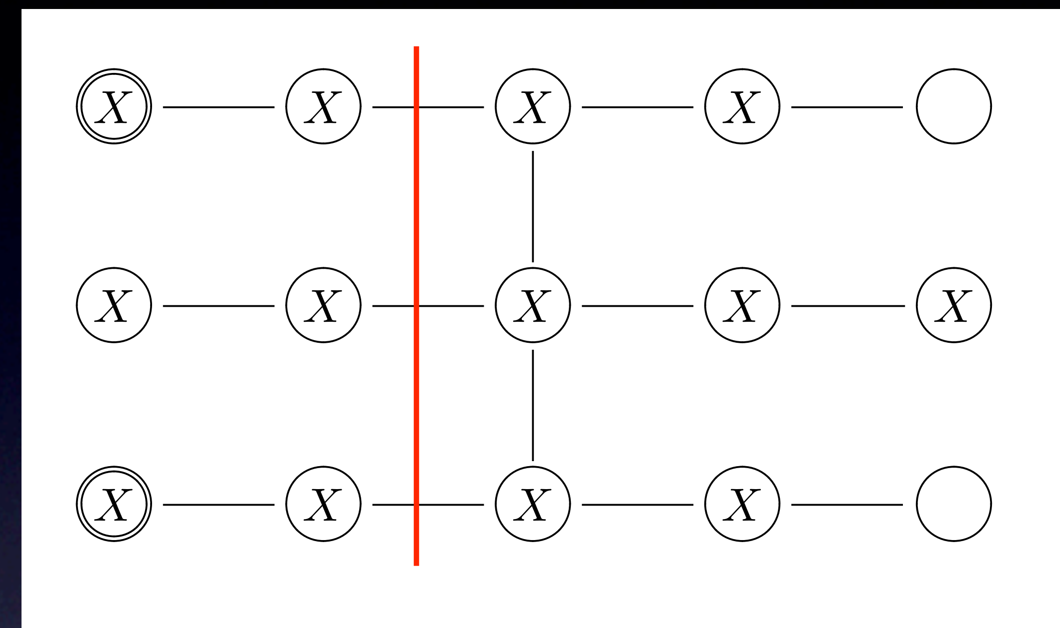
$$\begin{aligned}
\mathcal{S}_0 &= \{S_{(1,2)}, S_{(1,3)}, S_{(1,4)}, S_{(1,5)}, S_{(2,2)}, S_{(2,3)}, S_{(2,4)},\\
&\quad S_{(2,5)}, S_{(a,1)}, S_{(a,2)}, S_{(a,3)}, S_{(a,4)}, S_{(a,5)}\},\\
\mathcal{G}_0 &= \{\}\\
\mathcal{L}_0 &= \{(X_{(1,1)}Z_{(1,2)}, Z_{(1,1)}), (X_{(2,1)}Z_{(2,2)}, Z_{(2,1)})\}
\end{aligned}$$





$$
\begin{aligned}
\mathcal{S}_1 &= \{S_{(1,3)}, S_{(1,4)}, S_{(1,5)}, S_{(2,3)}, S_{(2,4)}, S_{(2,5)}, \\
&\quad S_{(a,1)}, S_{(a,2)}, S_{(a,3)}, S_{(a,4)}, S_{(a,5)}\}, \\
\mathcal{G}_1 &= \{(X_{(1,1)}, S_{(1,2)}), (X_{(2,1)}, S_{(2,2)})\} \\
\mathcal{L}_1 &= \{(X_{(1,1)}Z_{(1,2)}, S_{(1,2)}Z_{(1,1)}), \\
&\quad (X_{(2,1)}Z_{(2,2)}, S_{(2,2)}Z_{(2,1)})\}
\end{aligned}
$$

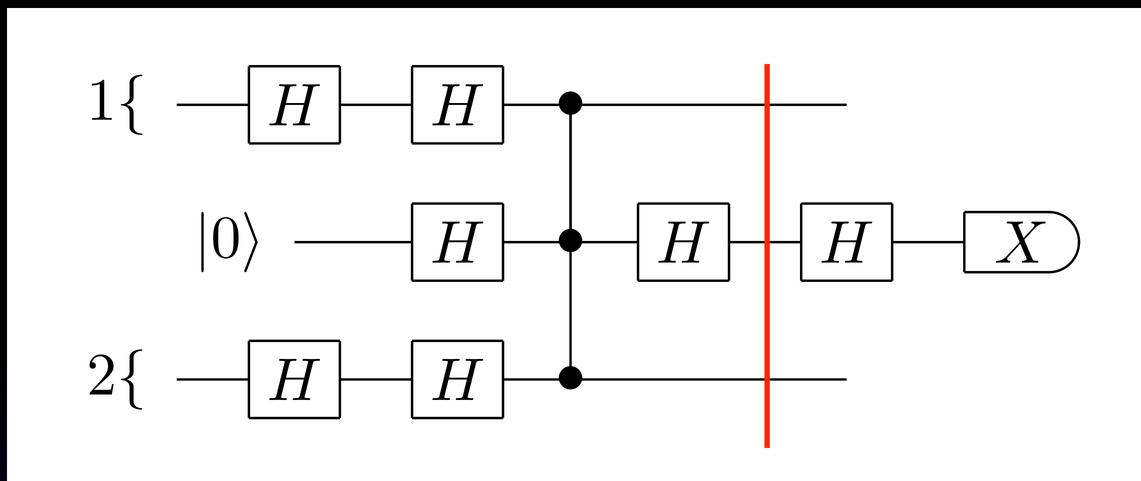


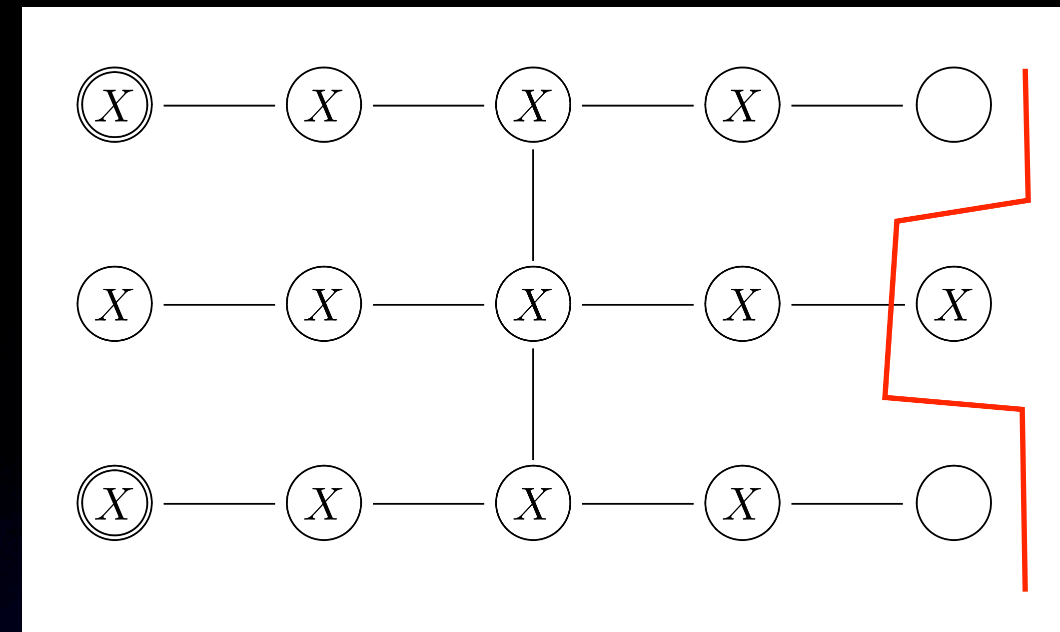


$$\mathcal{S}_2 = \{S_{(1,4)}, S_{(1,5)}, S_{(2,4)}, S_{(2,5)}, \underline{S_{(a,3)}S_{(a,1)}}, S_{(a,4)}, S_{(a,5)}\},$$

$$\mathcal{G}_2 = \{(X_{(1,1)}, S_{(1,2)}), (X_{(2,1)}, S_{(2,2)}), (X_{(1,2)}, S_{(1,3)}), (X_{(2,2)}, S_{(2,3)}), (X_{(a,1)}, S_{(a,2)}), (X_{(a,2)}, S_{(a,1)})\}$$

$$\mathcal{L}_2 = \{(S_{(1,3)}X_{(1,1)}Z_{(1,2)}, S_{(1,2)}Z_{(1,1)}), (S_{(2,3)}X_{(2,1)}Z_{(2,2)}, S_{(2,2)}Z_{(2,1)})\}$$

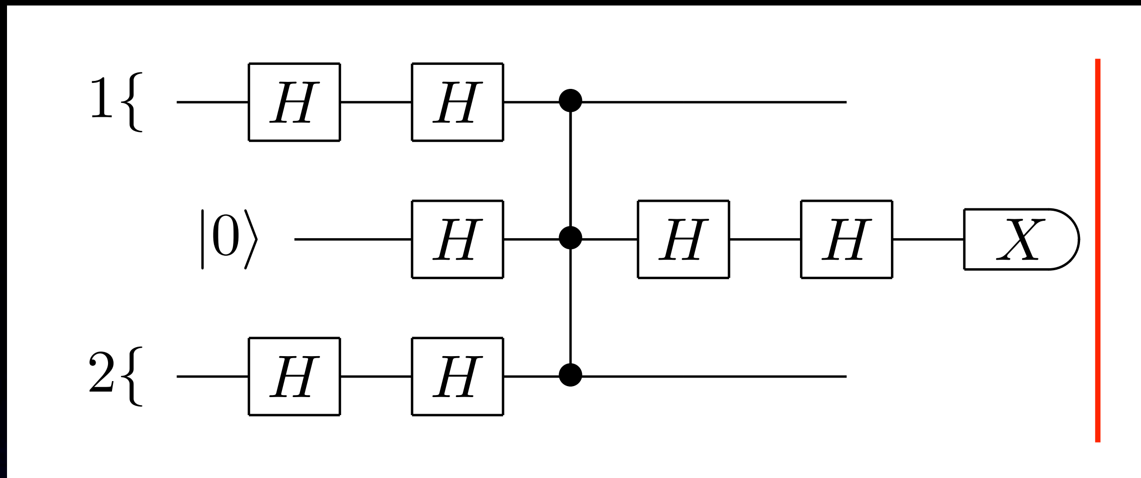


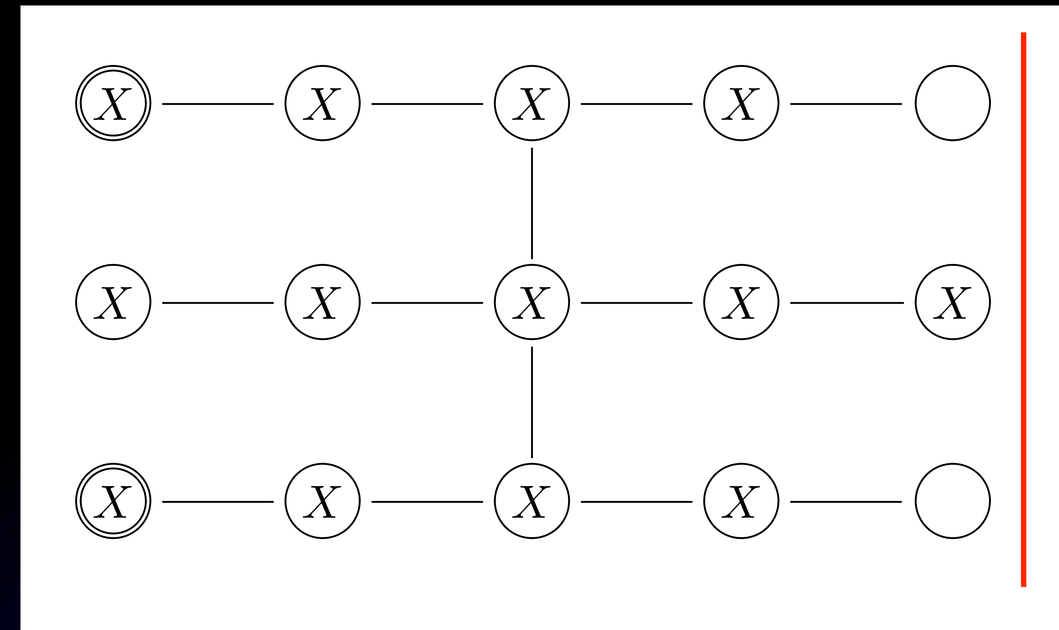


$$\mathcal{S}_4 = \{S_{(a,5)}S_{(a,3)}S_{(a,1)}S_{(1,4)}S_{(2,4)}\}$$

$$\mathcal{G}_4 = \{(X_{(1,1)}, S_{(1,2)}), (X_{(2,1)}, S_{(2,2)}), (X_{(1,2)}, S_{(1,3)}), (X_{(2,2)}, S_{(2,3)}), (X_{(a,1)}, S_{(a,2)}), (X_{(a,2)}, S_{(a,1)}), (X_{(1,1)}X_{(1,3)}, S_{(1,4)}), (X_{(2,1)}X_{(2,3)}, S_{(2,4)}), (X_{(a,1)}X_{(a,3)}X_{(1,2)}X_{(2,2)}, S_{(a,4)}), (X_{(a,4)}, S_{(a,5)}), (X_{(1,2)}X_{(1,4)}, S_{(1,5)}), (X_{(2,2)}X_{(2,4)}, S_{(2,5)})\}$$

$$\mathcal{L}_4 = \{(S_{(1,5)}S_{(1,3)}S_{(a,4)}X_{(1,1)}Z_{(1,2)}, S_{(1,4)}S_{(1,2)}Z_{(1,1)}), (S_{(2,5)}S_{(2,3)}S_{(a,4)}X_{(2,1)}Z_{(2,2)}, S_{(2,4)}S_{(2,2)}Z_{(2,1)})\}$$





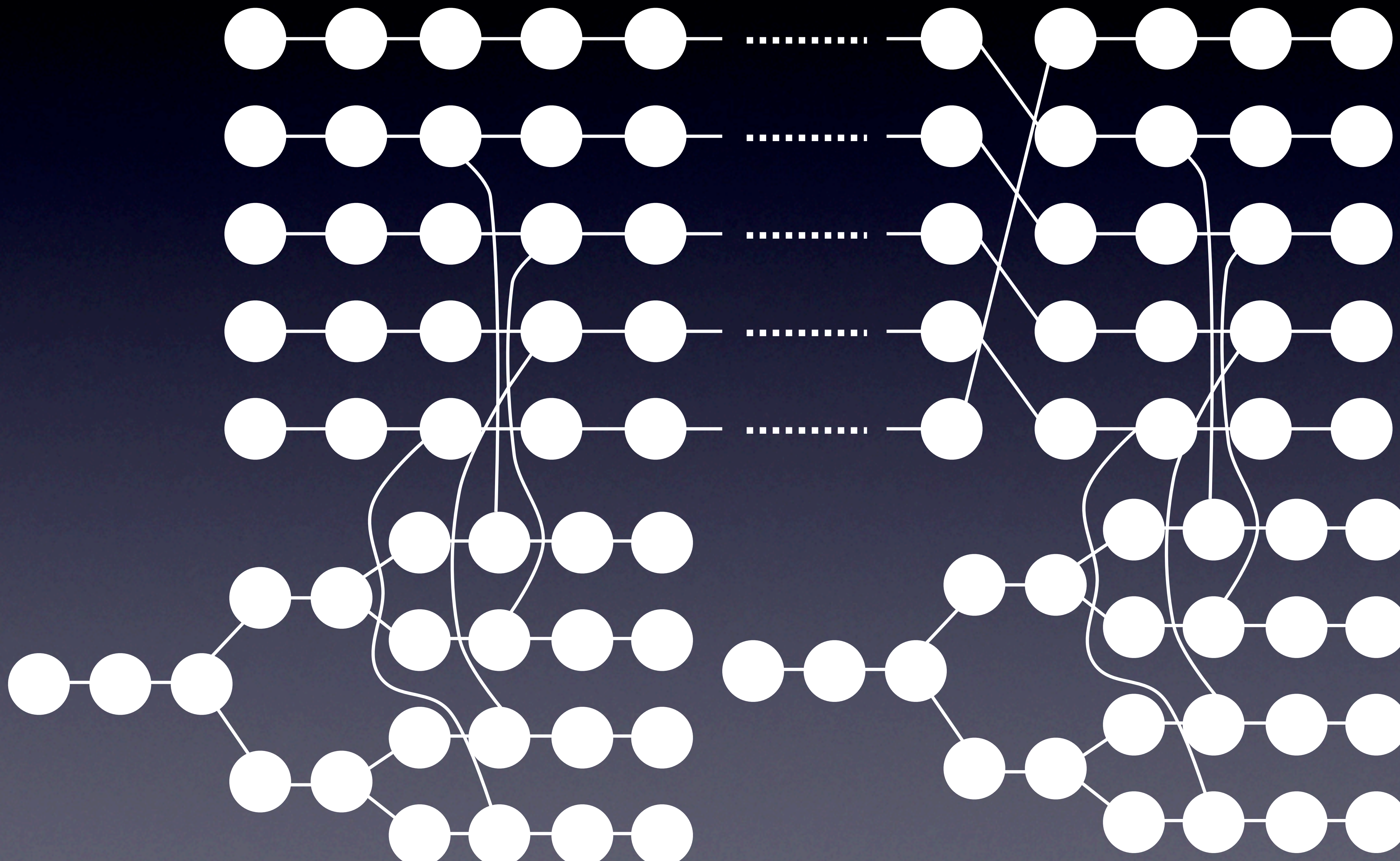
$$
\begin{aligned}
\mathcal{S}_5 &= \{S_{(a,5)}S_{(a,3)}S_{(a,1)}S_{(1,4)}S_{(2,4)}, \\
&\quad X_{(a,5)}X_{(a,3)}X_{(a,1)}X_{(1,2)}X_{(2,2)}\} \\
\mathcal{G}_5 &= \{(X_{(1,1)}, S_{(1,2)}), (X_{(2,1)}, S_{(2,2)}), (X_{(1,2)}, S_{(1,3)}), \\
&\quad (X_{(2,2)}, S_{(2,3)}), (X_{(a,1)}, S_{(a,2)}), (X_{(a,2)}, S_{(a,1)}), \\
&\quad (X_{(1,1)}X_{(1,3)}, S_{(1,4)}), (X_{(2,1)}X_{(2,3)}, S_{(2,4)}), \\
&\quad (X_{(a,1)}X_{(a,3)}X_{(1,2)}X_{(2,2)}, S_{(a,4)}), (X_{(a,4)}, S_{(a,5)}), \\
&\quad (X_{(1,2)}X_{(1,4)}, S_{(1,5)}), (X_{(2,2)}X_{(2,4)}, S_{(2,5)})\} \\
\mathcal{L}_5 &= \{(S_{(1,5)}S_{(1,3)}S_{(2,5)}S_{(2,3)}X_{(1,1)}Z_{(1,2)}X_{(2,1)}Z_{(2,2)}, \\
&\quad S_{(1,4)}S_{(1,2)}Z_{(1,1)})\}
\end{aligned}
$$

Whew

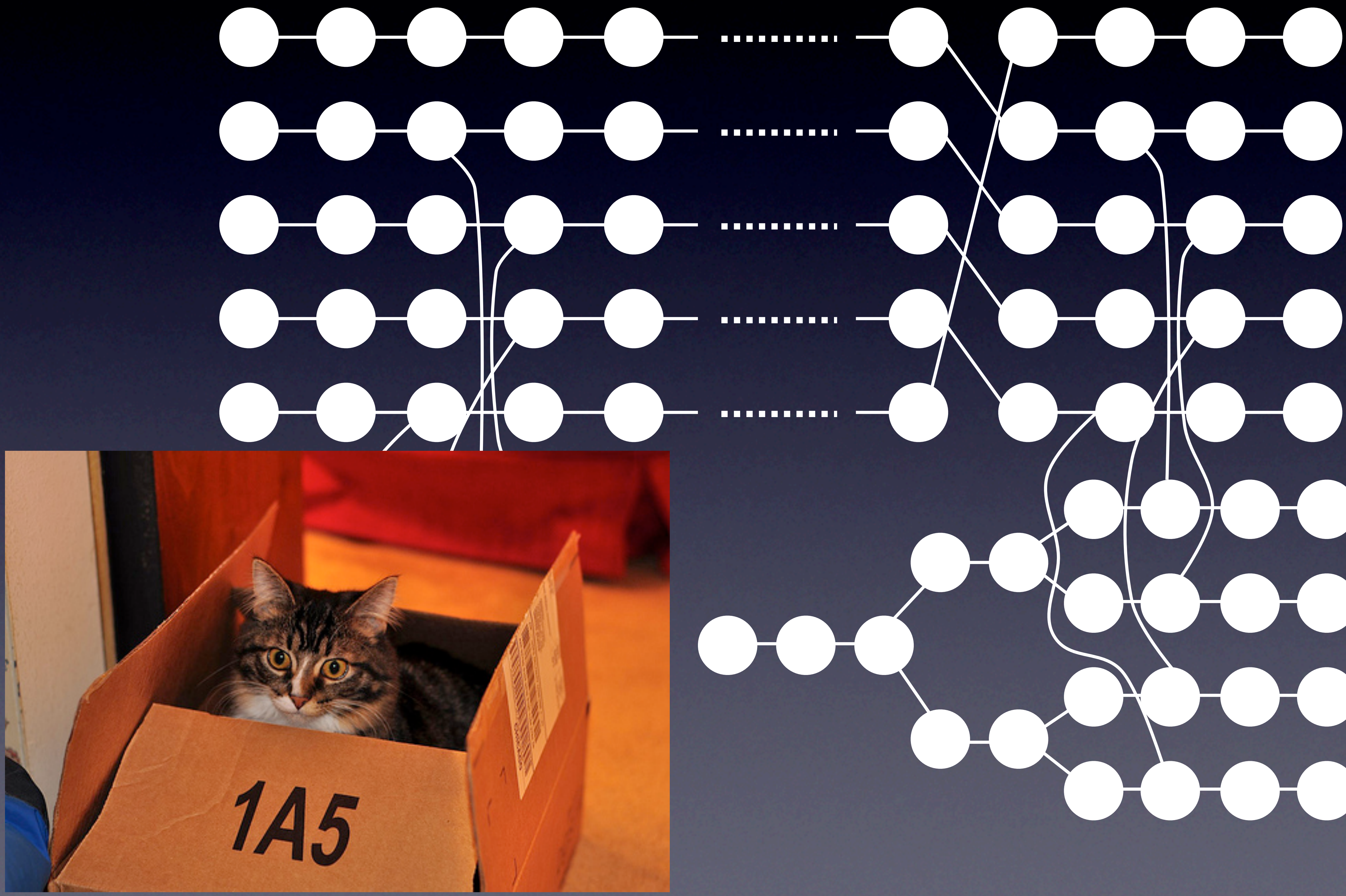
Using this method (track gauge, stabilizer, logical) one can figure out what these operators are for any given circuit.

In particular we can work out what the code is when the circuit is a measurement of a syndrome of a [n,k,d] code

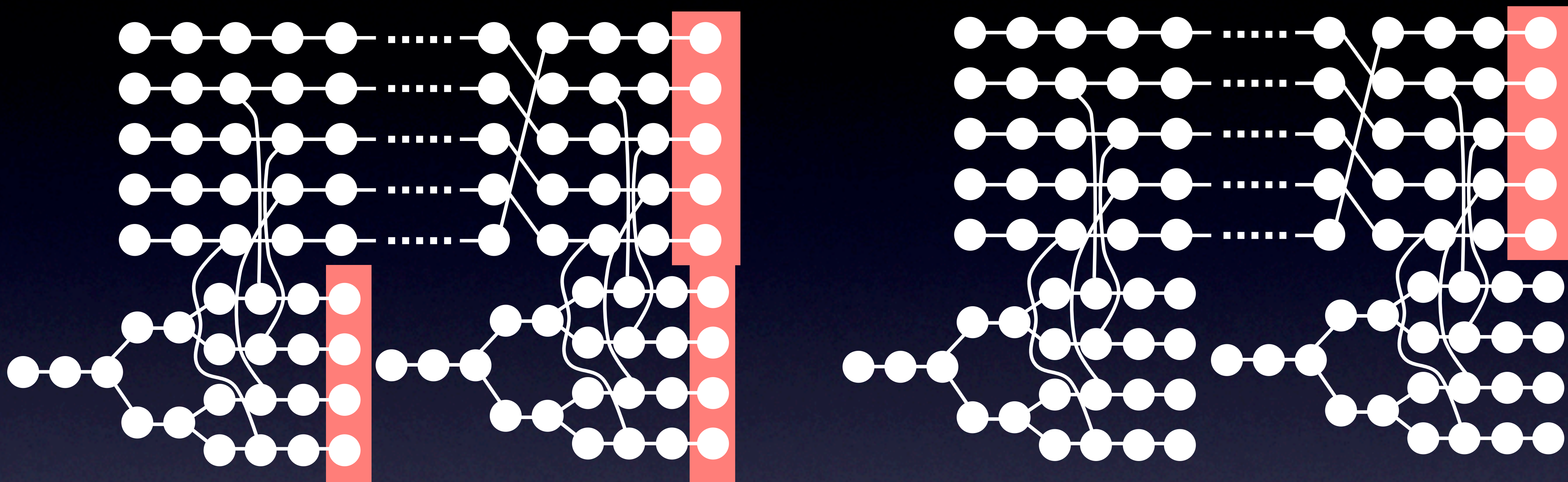
Syndrome Circuit



Syndrome Circuit



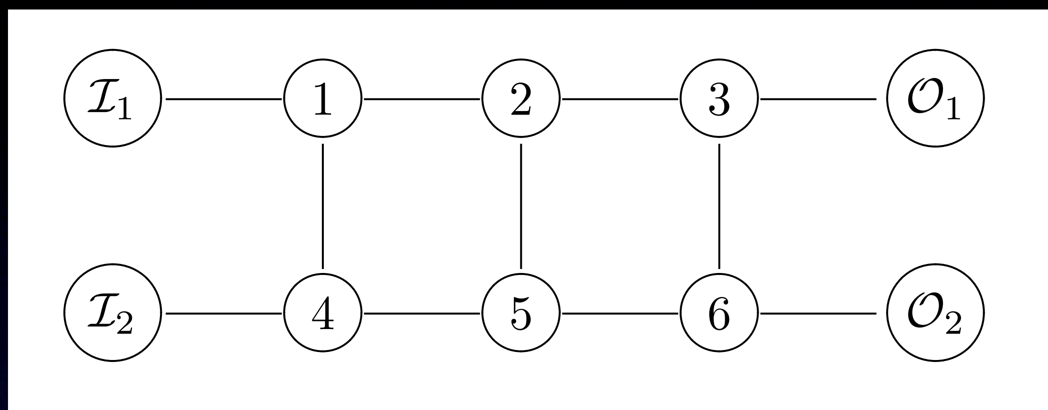
Syndrome Circuit



Modulo gauge operators stabilizers are (a) stabilizer of code with ancillas used to measure then (b) ancillas measurement operators

Modulo gauge/stabilizer operators, logical operators are logical operators for code on output qubits

An Obstacle



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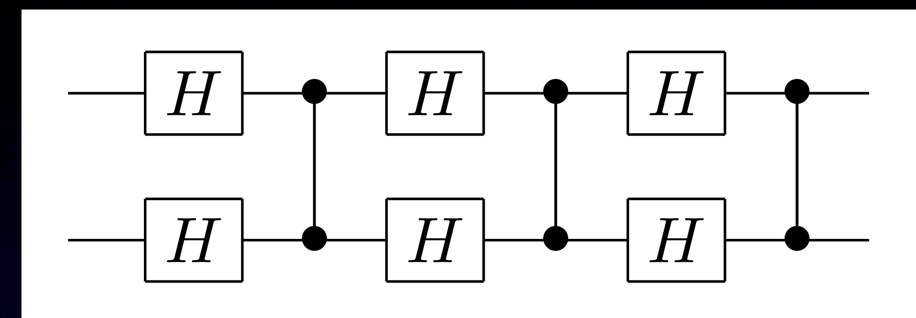
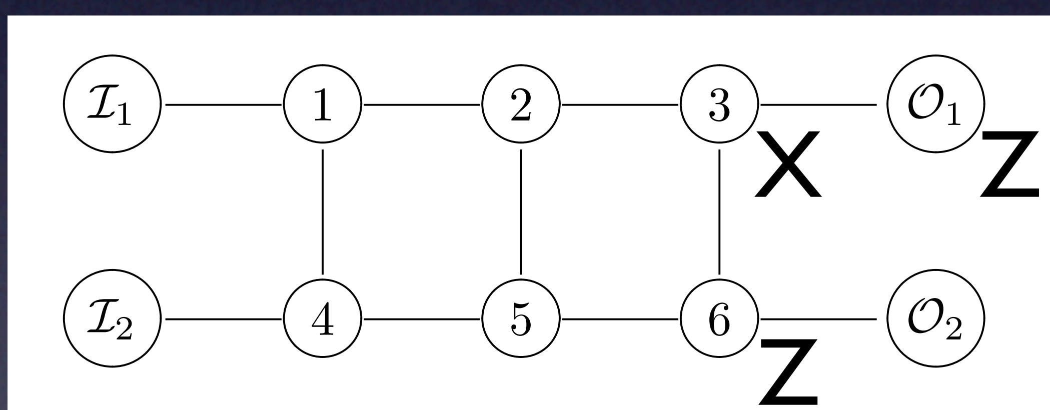
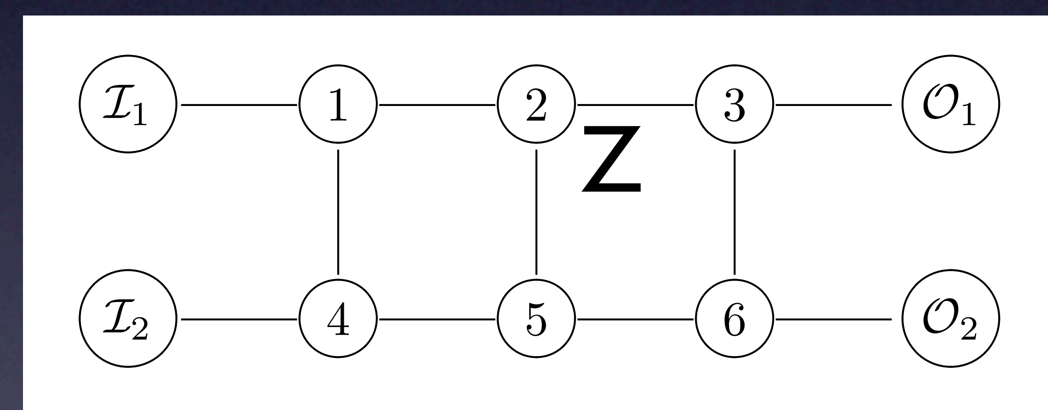
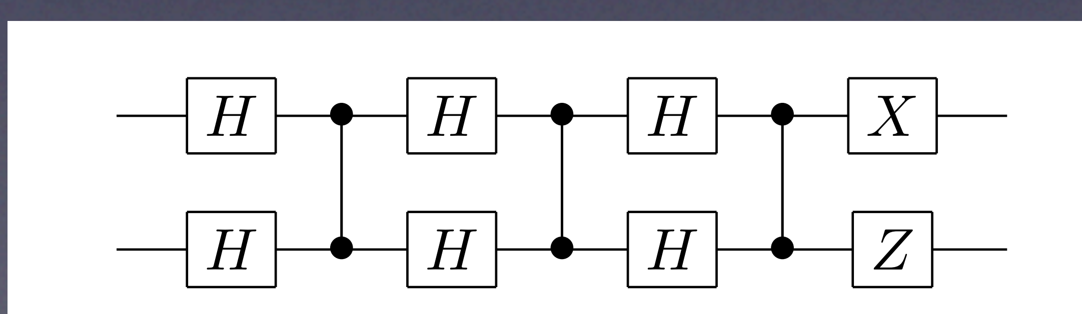


swap

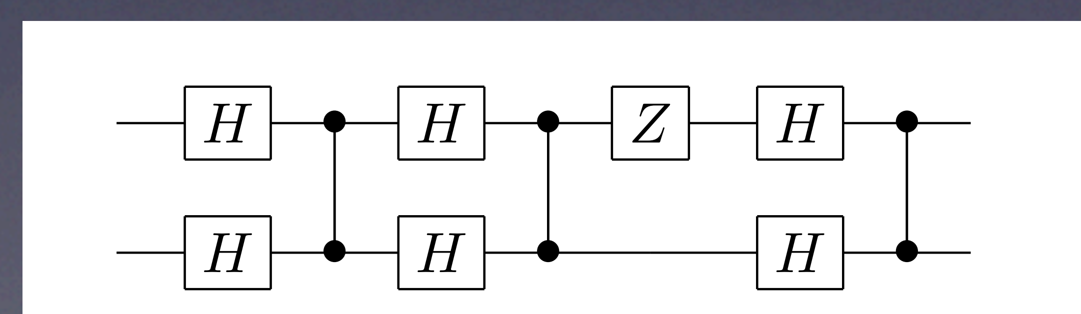


equiv

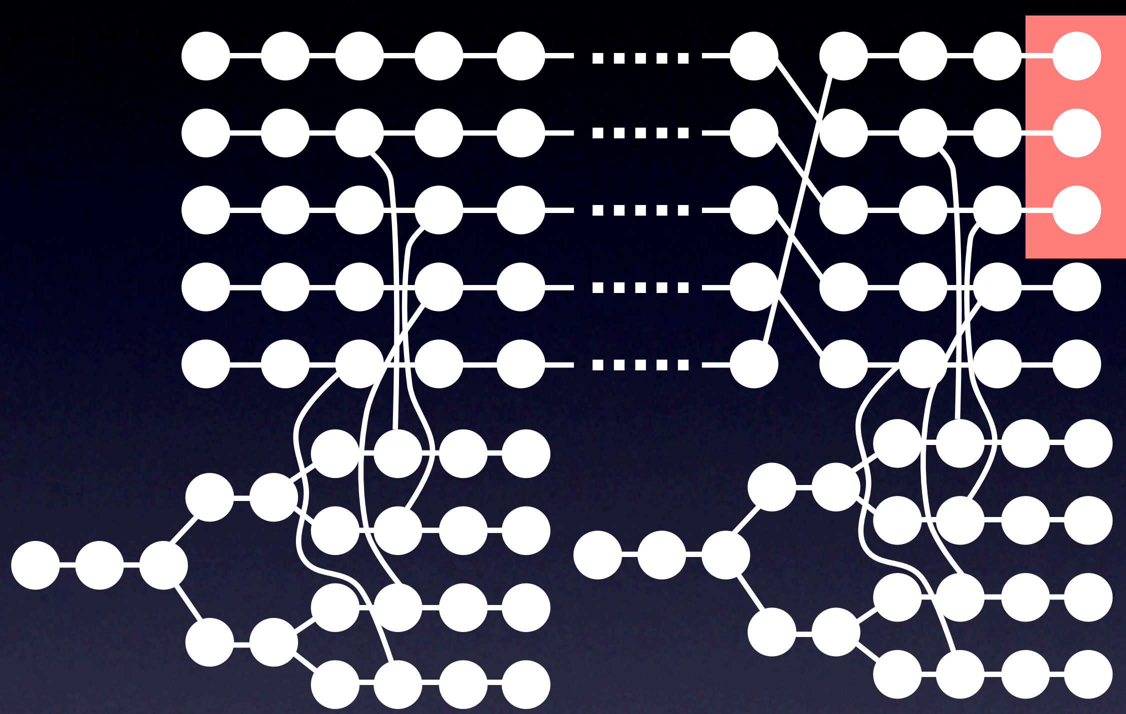




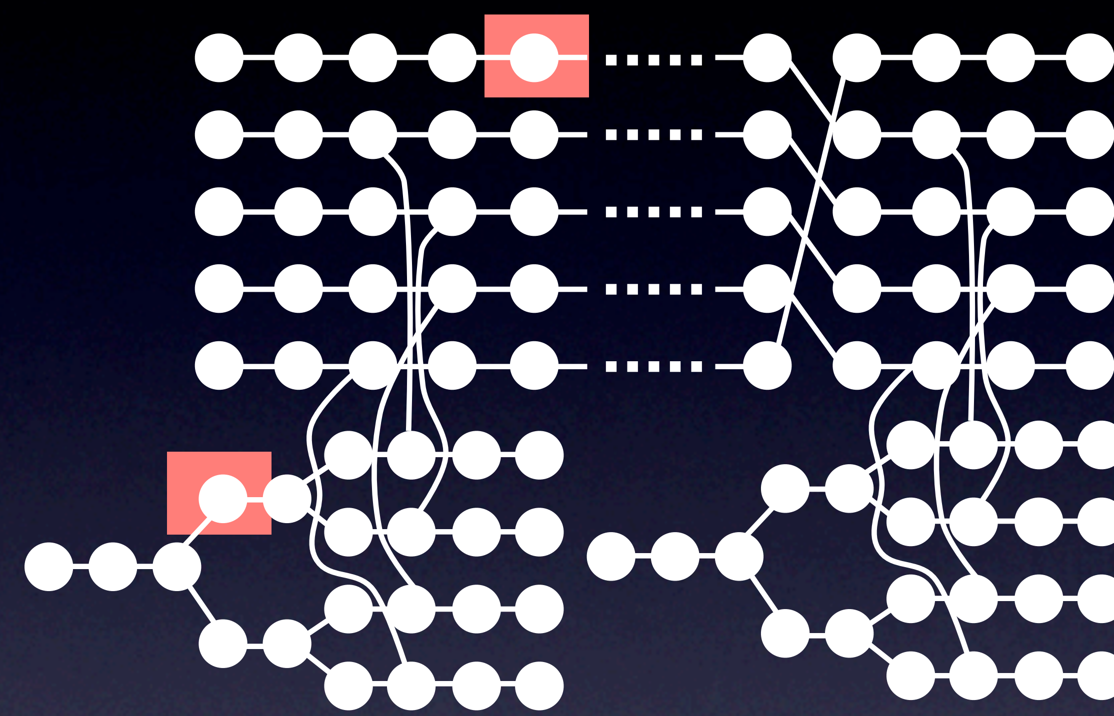
equiv



An Obstacle



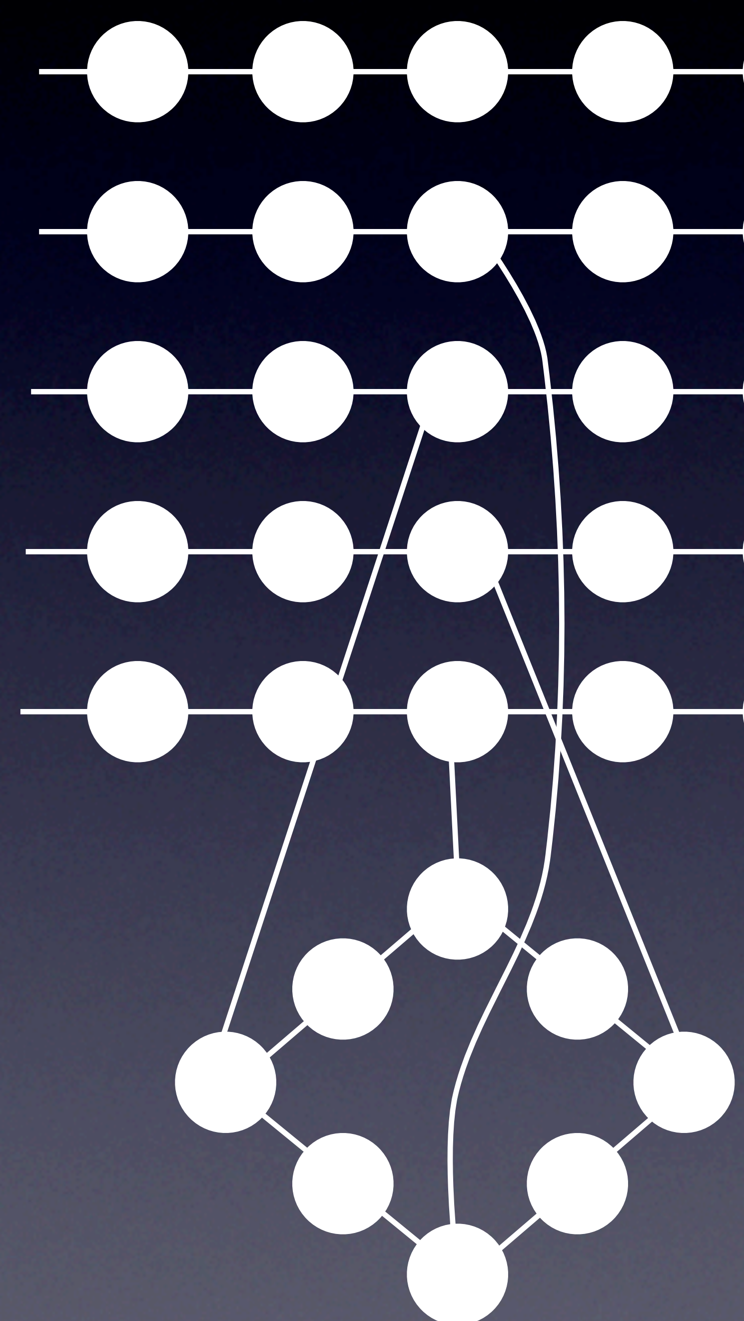
weight d logical



weight <d logical

Need to design circuits that do not lower weight of logicals as they are propagated back through code using gauge operators (FT criteria)

One solution



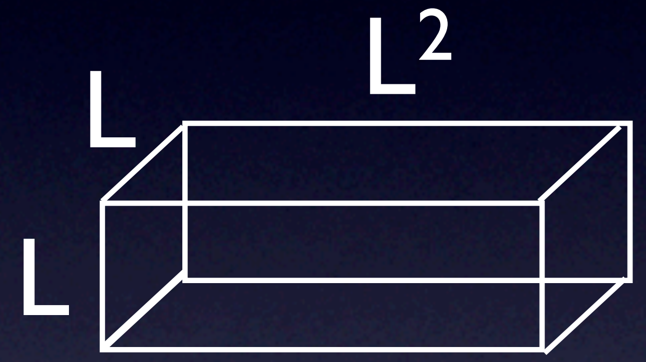
Expander graph
Wire vertices to block
Subdivide
Label all by X

Main Result (AGAIN)

With careful use of syndrome measuring circuits, one can turn any [n,k,d] stabilizer code into a spatially local code with [N,r,k,d] code, where N = O(size of syndrome measuring circuit)

Bravyi-Terhal Bounds

Concatenated code: n^r qubits, distance $d^r = n^{r \log\_n d}$



distance $d = L^{2 \log\_n d}$

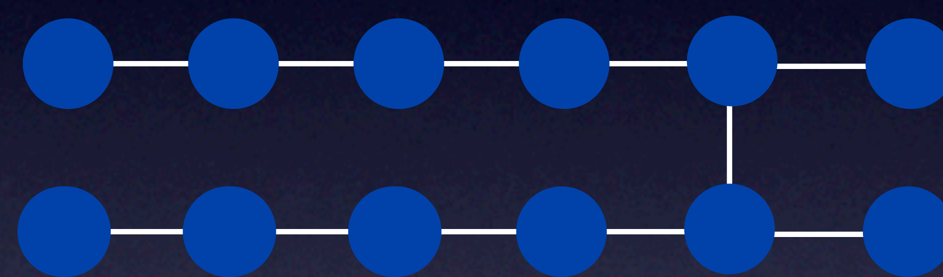
distance $d = L^{1.365}$

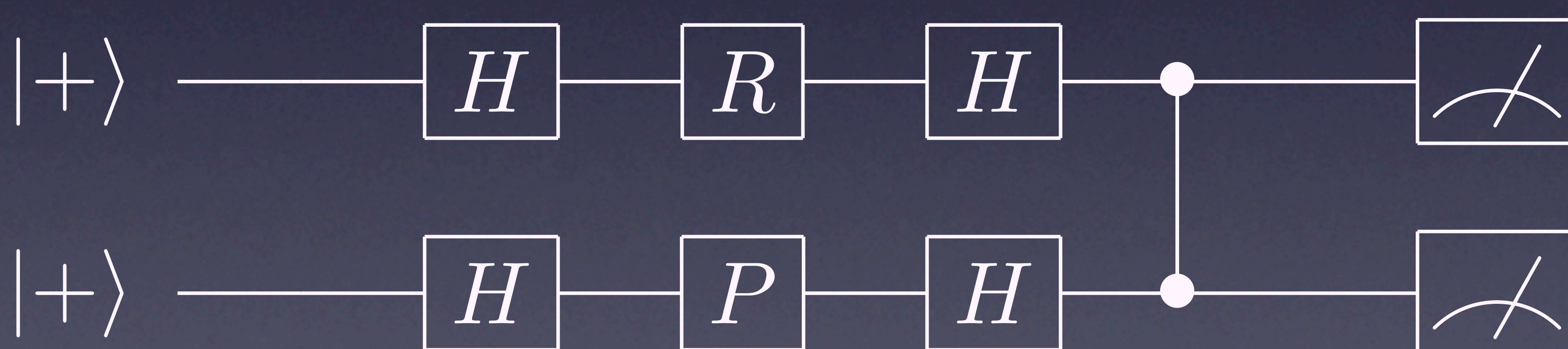
Further, this distance is ONLY in non-“time” direction

If one uses polynomial codes (qudits), one can saturate $d = L^2$

Adiabatic Cluster State QC

By turning on single qubit Hamiltonians while turning off parts of the cluster state Hamiltonian, we can enact a quantum circuit:





[Bacon and Flammia, Phys. Rev. A 82, 030303R (2010)]

Adiabatic Cluster State QC

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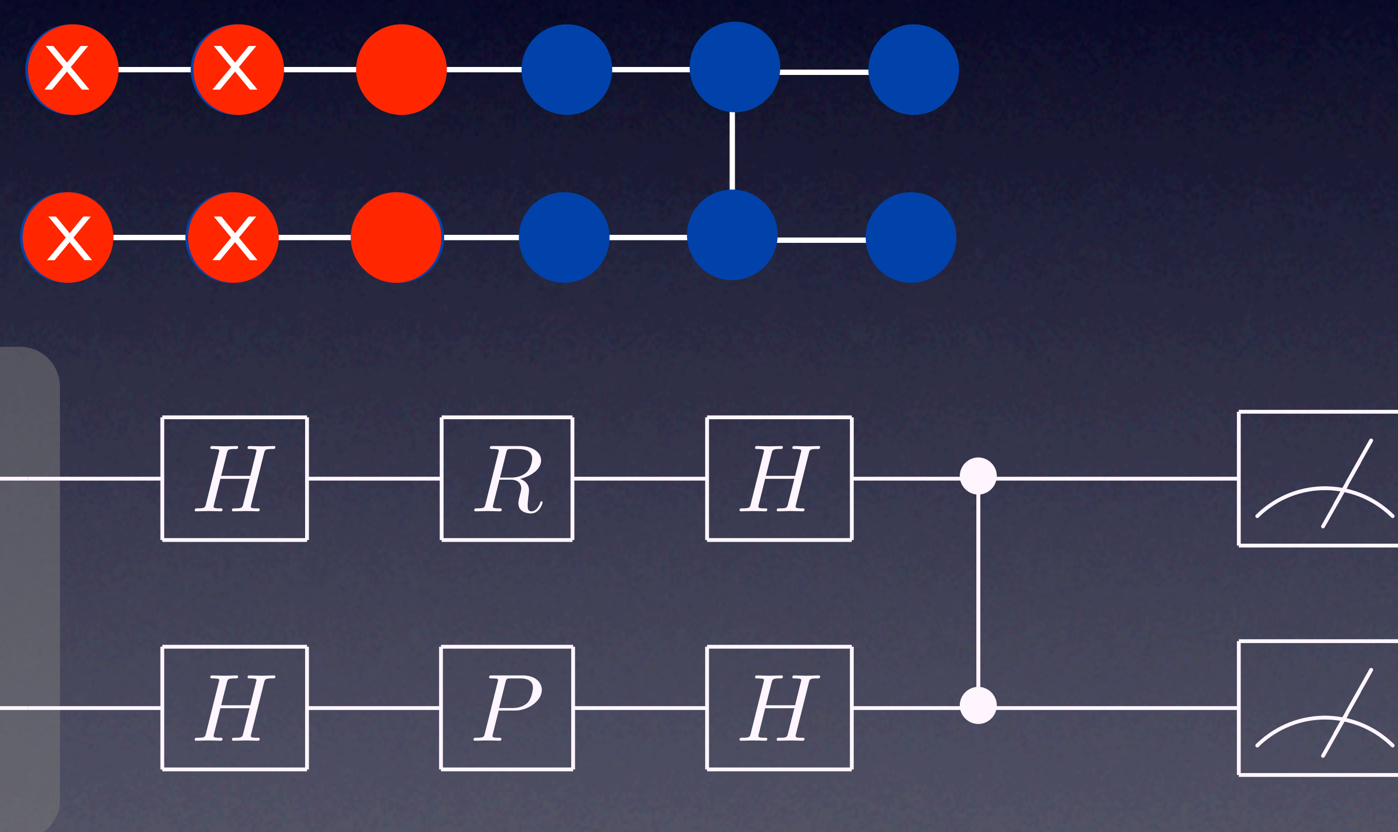

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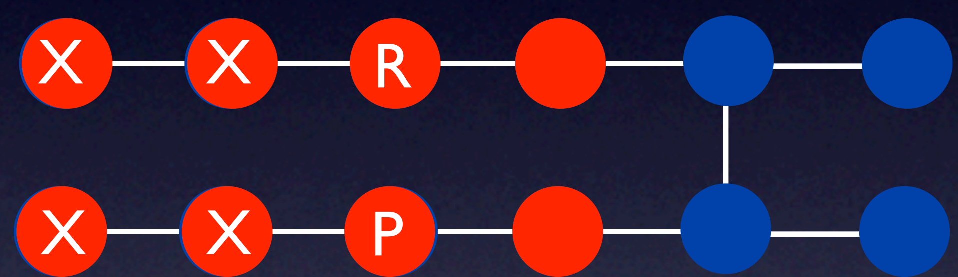

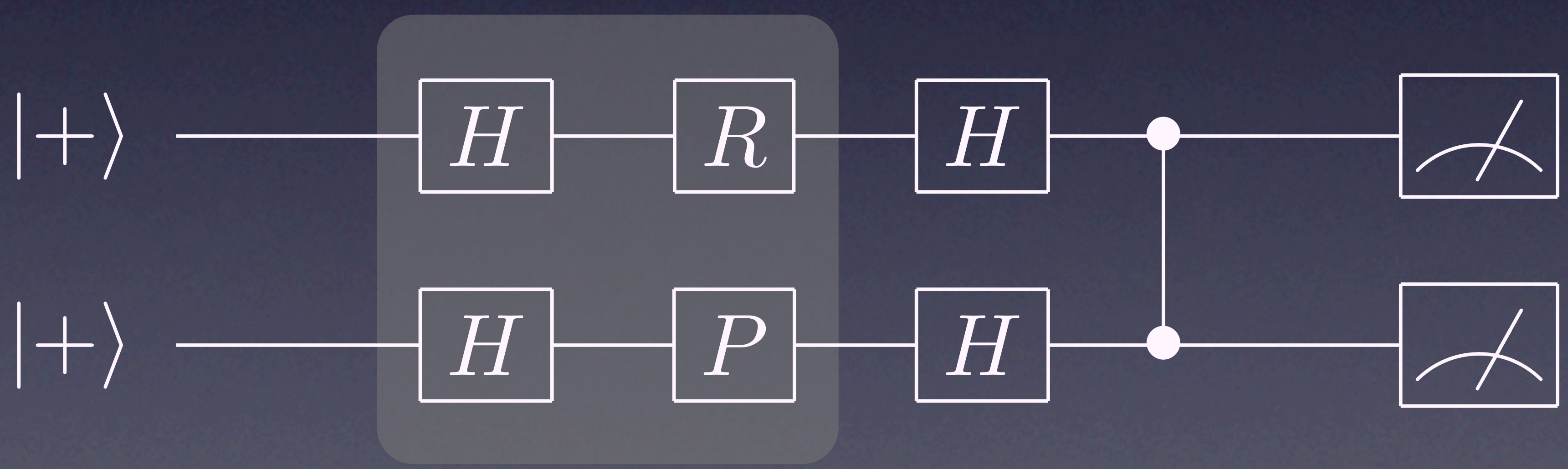

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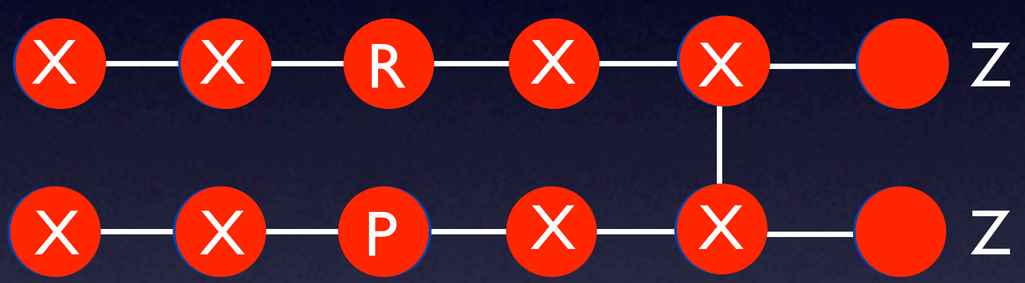

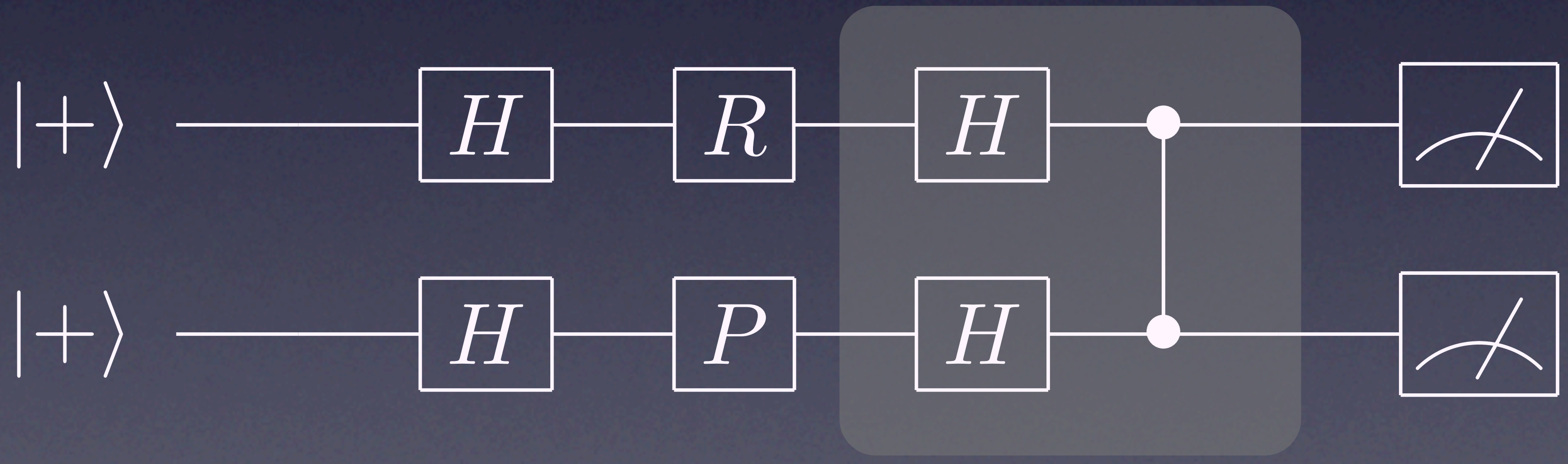

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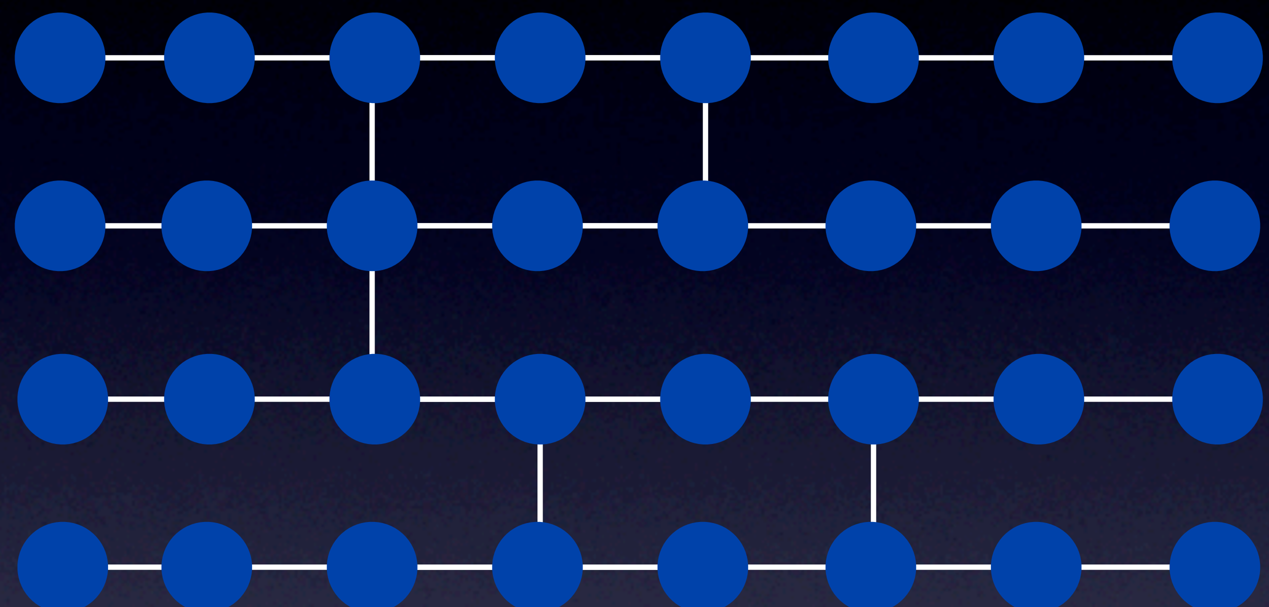
Quantum Transistor

[Bacon, Crosswhite, Flammia “Adiabatic Quantum Transistors” (2010) ask me for a copy]



1. Many-body system in its ground state

Quantum Transistor

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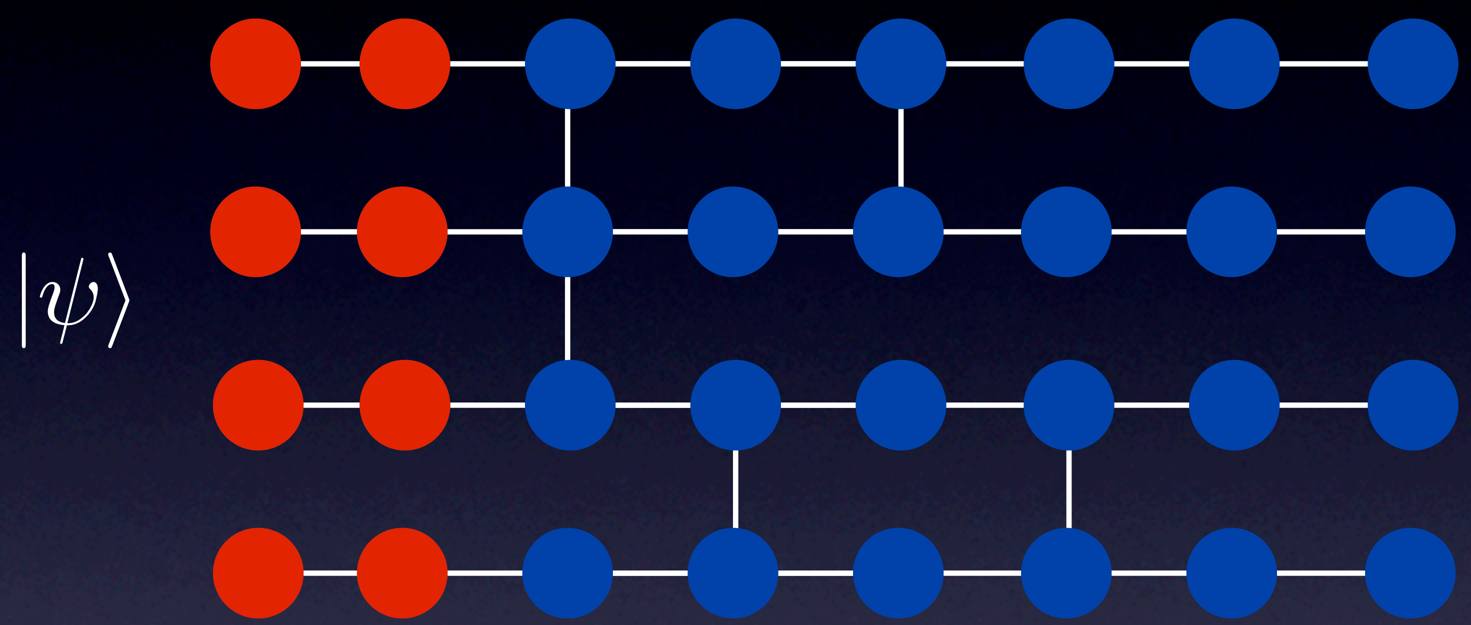

1. Many-body system in its ground state
2. Qubits localized on one side of the device

Quantum Transistor

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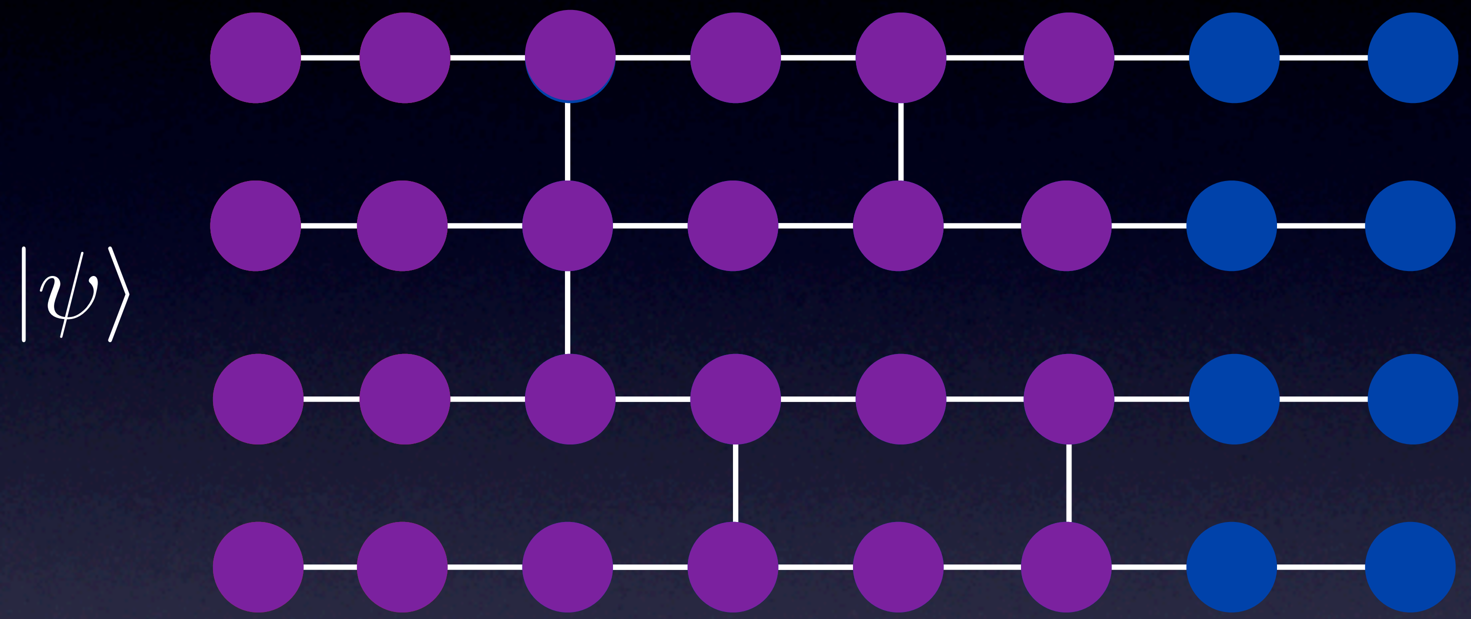

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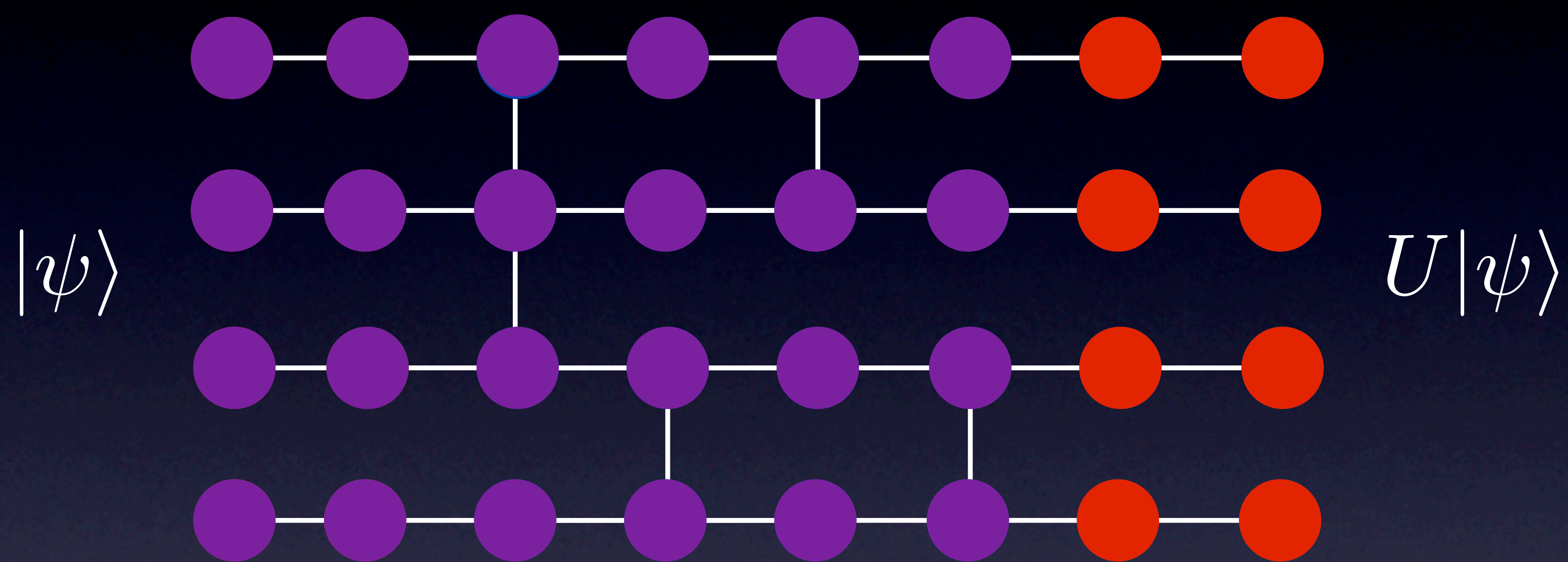

1. Many-body system in its ground state
2. Qubits localized on one side of the device
3. Apply a strong 1-qubit external field to device
4. Qubits now localized on other side of device with a quantum circuit applied to the qubits

Questions

- Threshold?
- Hamiltonian which is sum of generators, is it self-correcting? (Related to questions about "adiabatic quantum transistor.")
- Other methods for not lowering weight of error operators? Do traditional FT methods work?
- Can we reinterpret topological codes using these codes?
- Can we turn any code into 2-local subsystem code?

“Q-Dub” Group

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Isaac Crosson (Physics)
Lukas Svec (Physics)
Jijiang Yan (Physics)
Kamil Michnicki (Physics)
Kevin Zatloukal (CS)
David Rosenbaum (CS)
Paul Pham (CS)

Faculty

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Aram Harrow (Visiting)

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Zakk Webb (Physics)
Kate Liotta (Physics/CS)
Jonathan Shi (Physics/CS)

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