SINGLE STEP PARITY CHECK GATE SET for QUANTUM ERROR CORRECTION

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[3] University of Technology Sydney

1. INTRODUCTION - THRESHOLD

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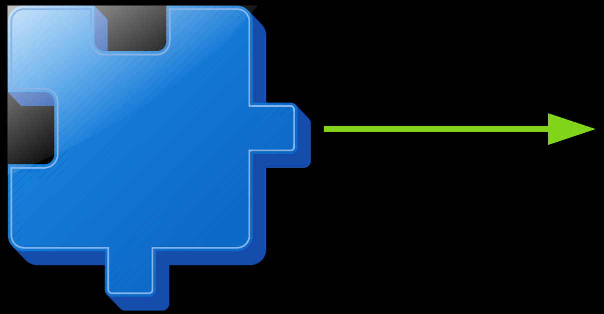

Scalable quantum computer

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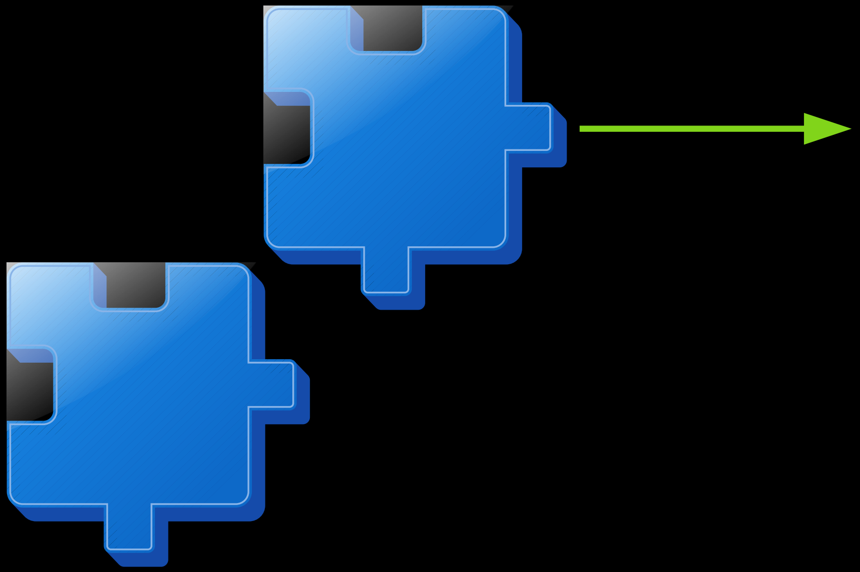

Scalable quantum computer

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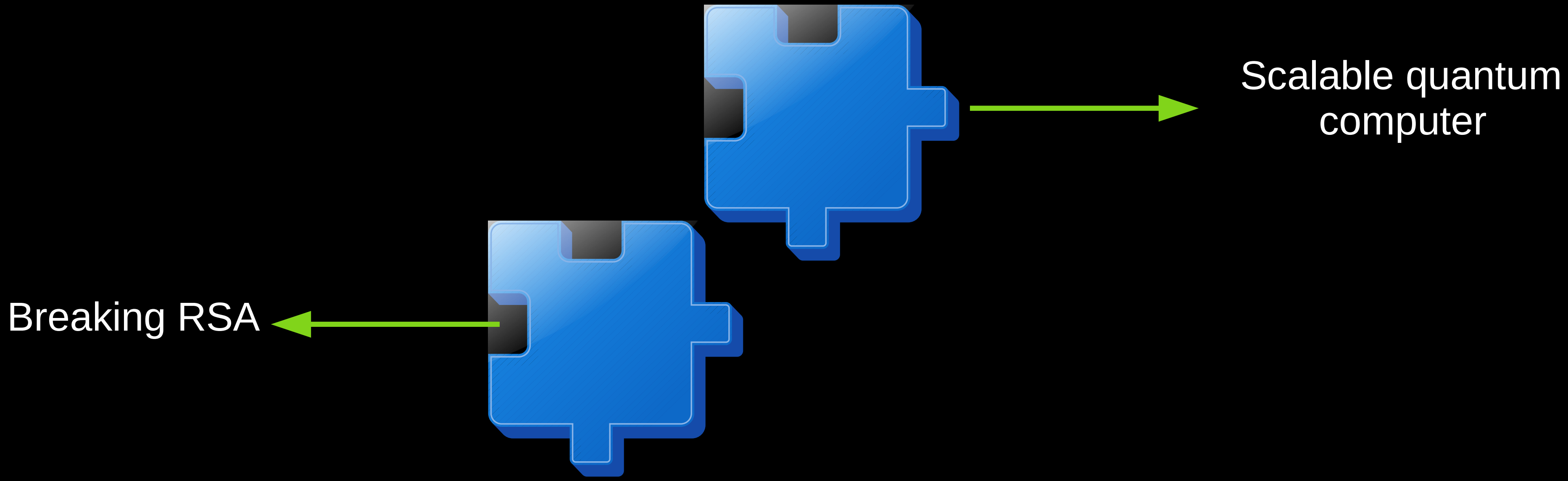

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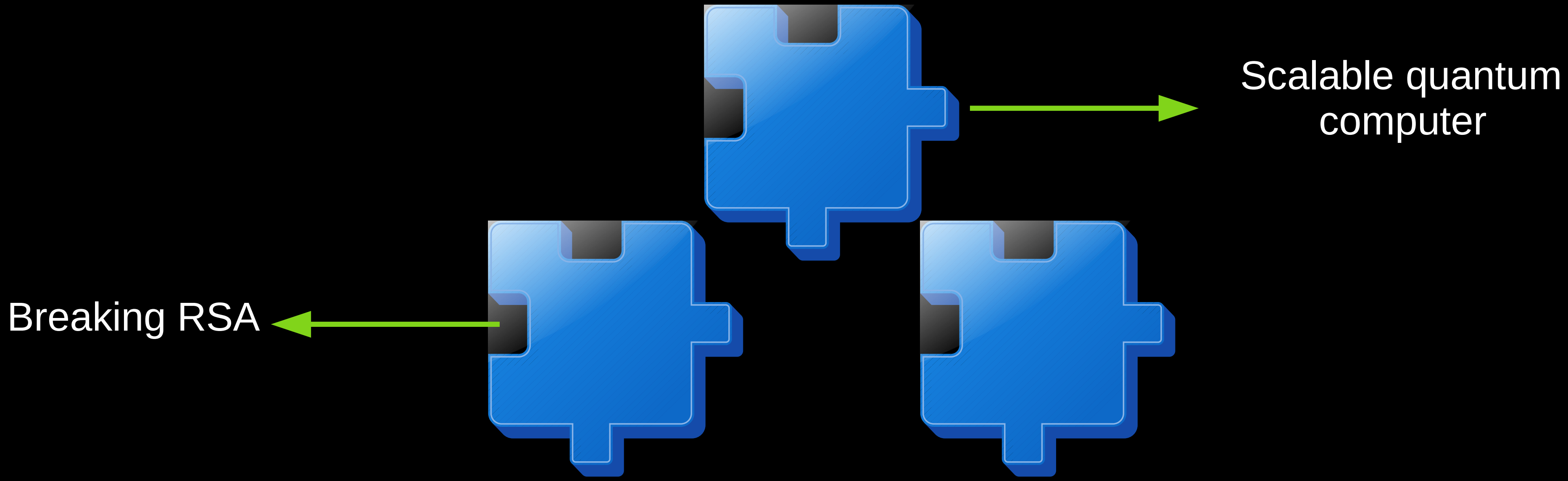

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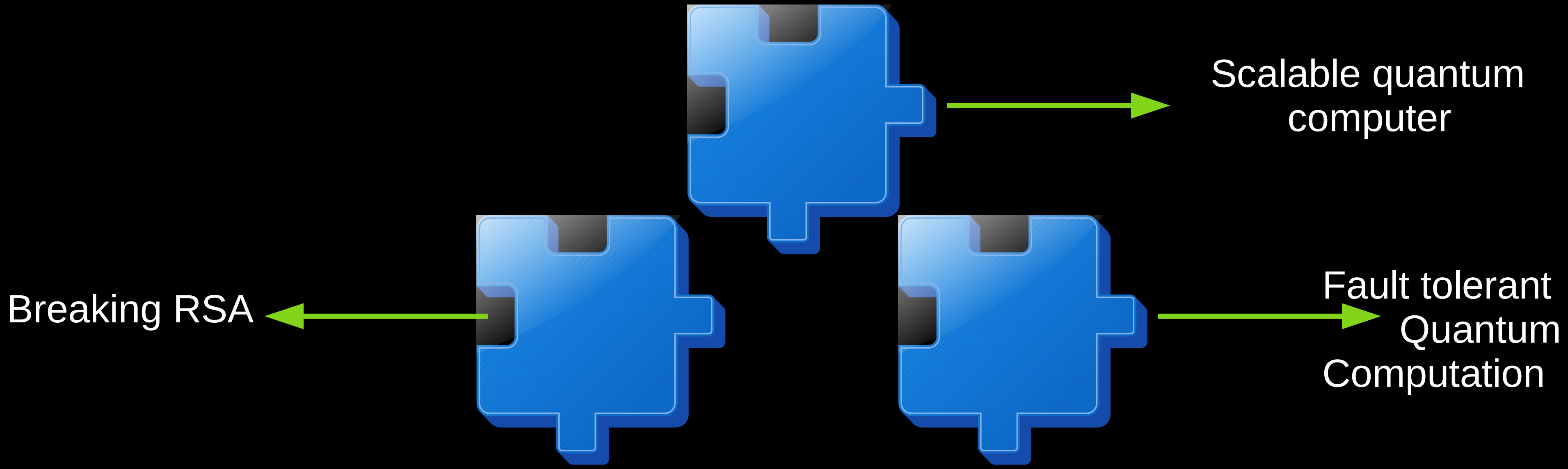

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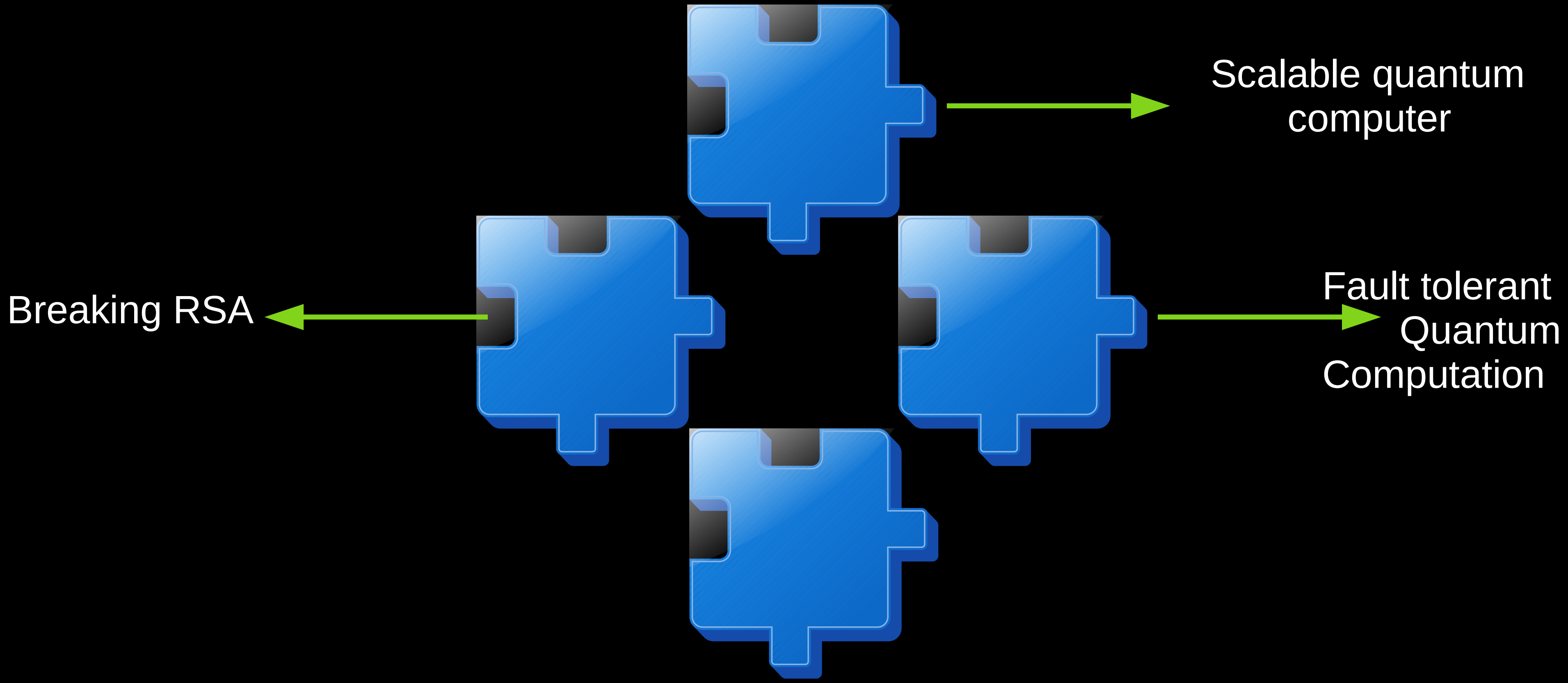

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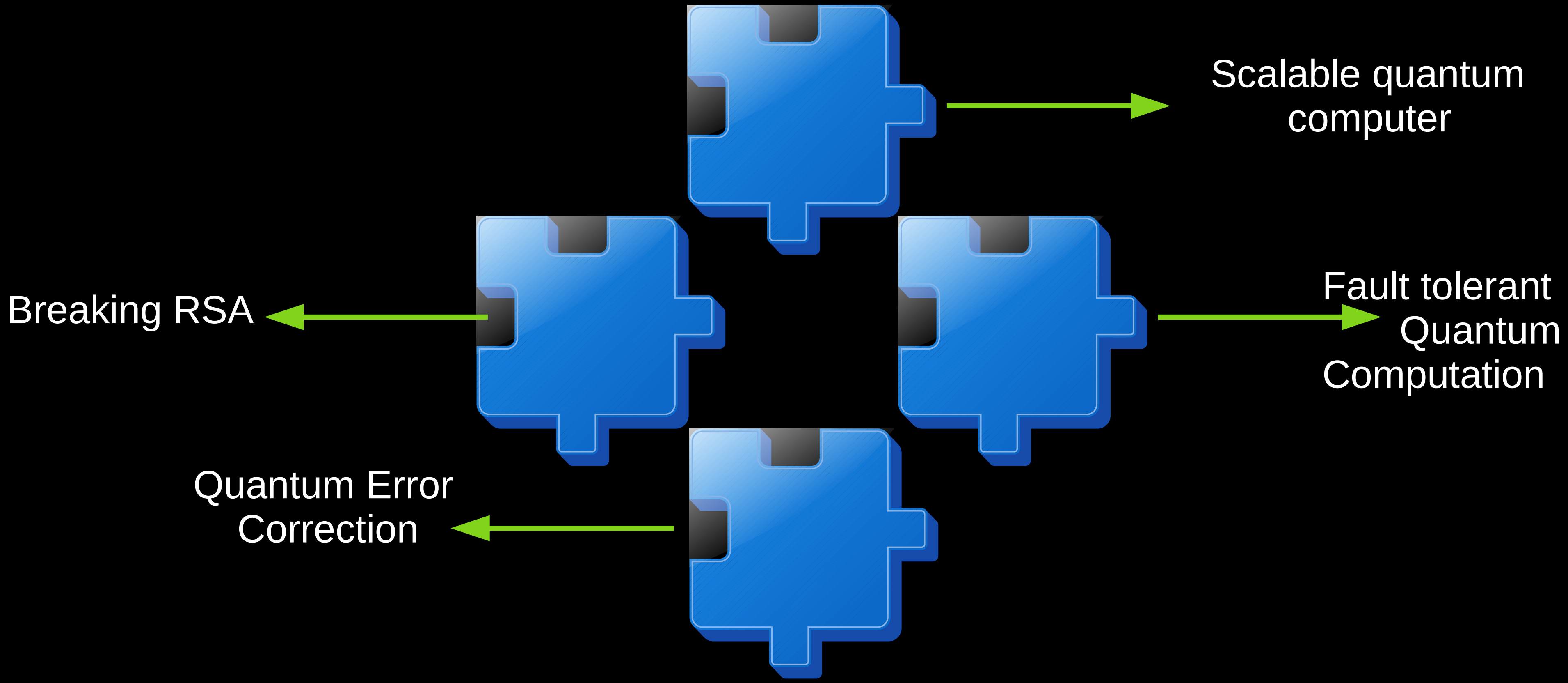

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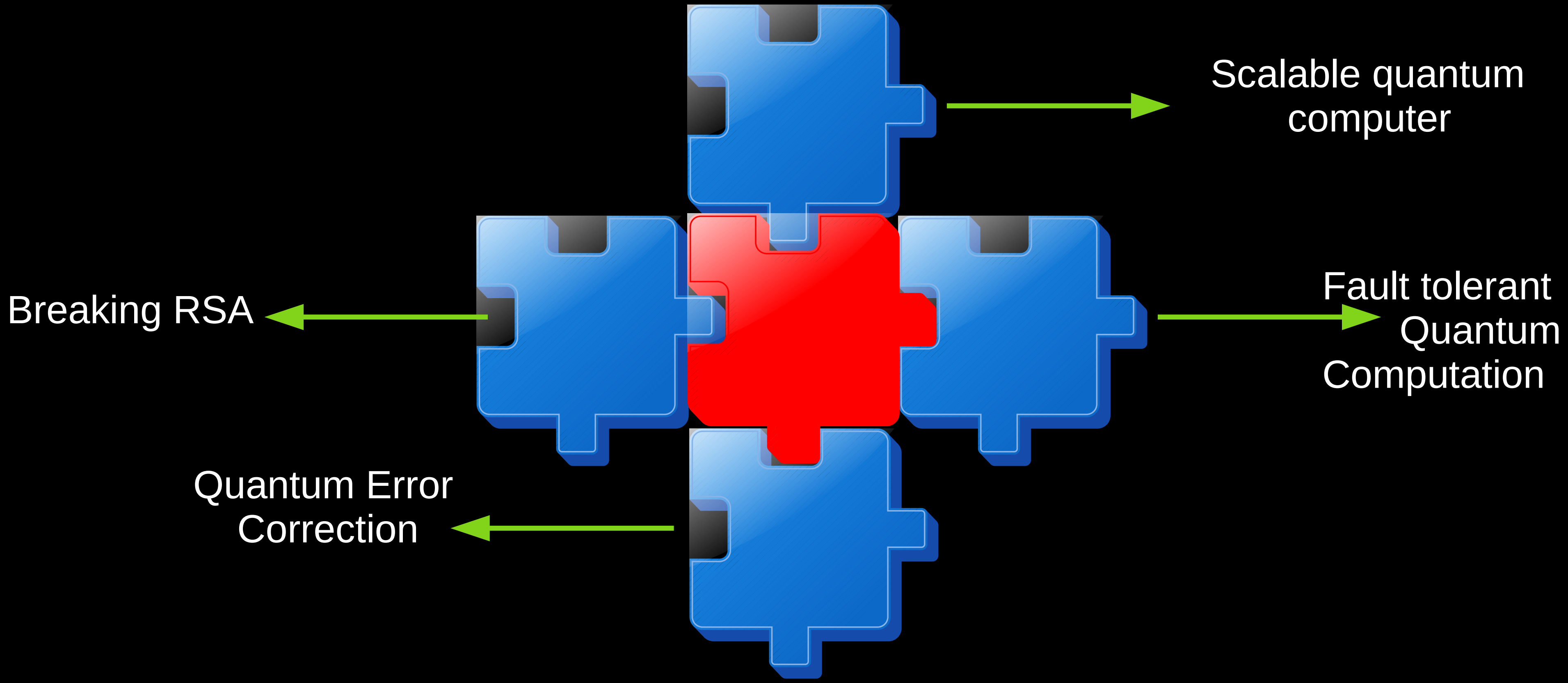

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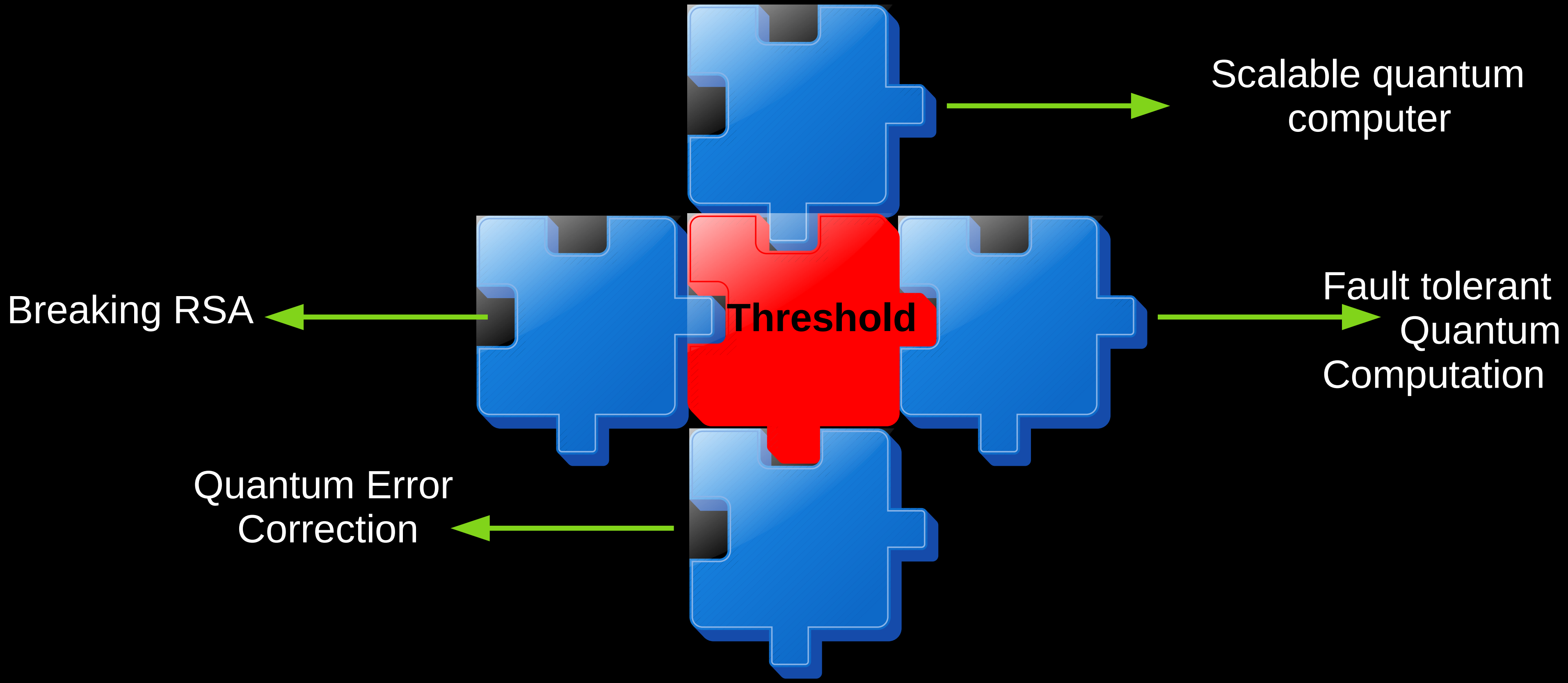

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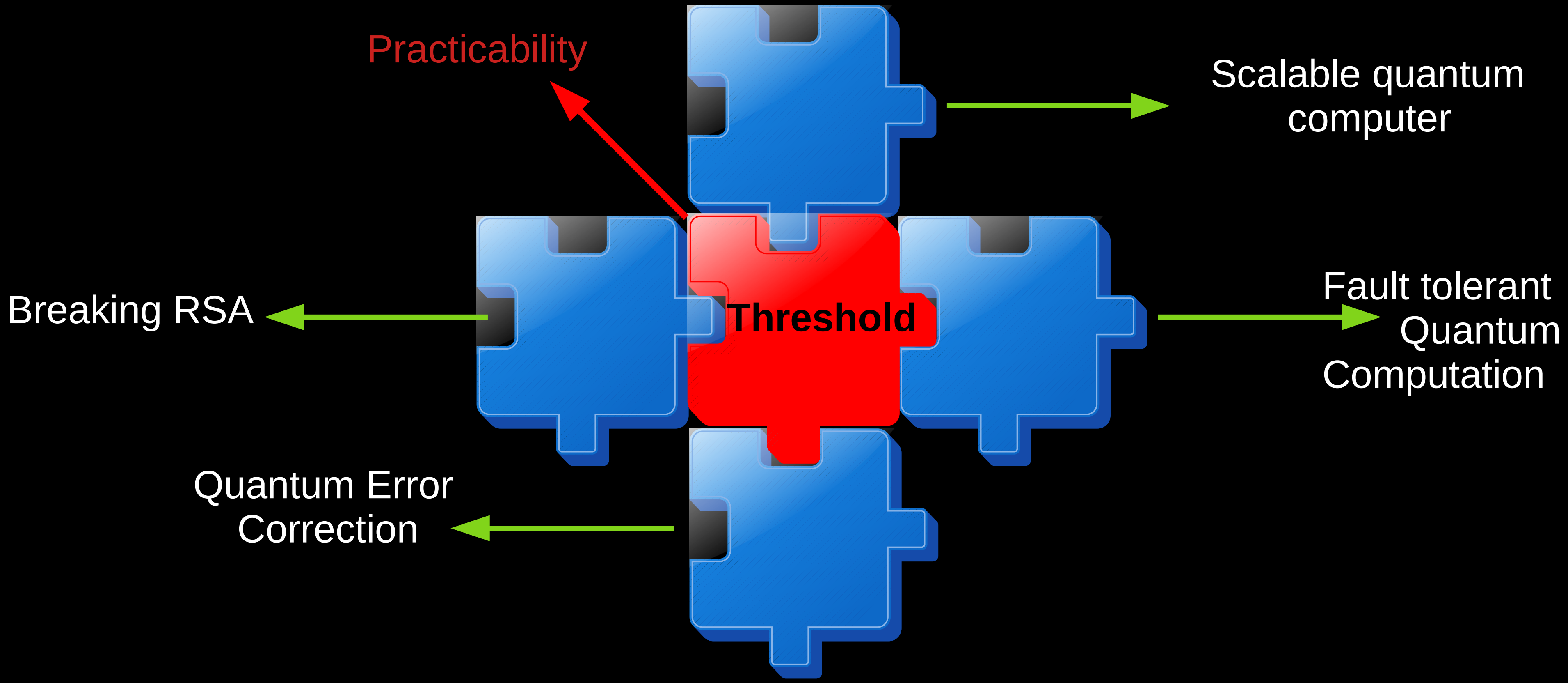

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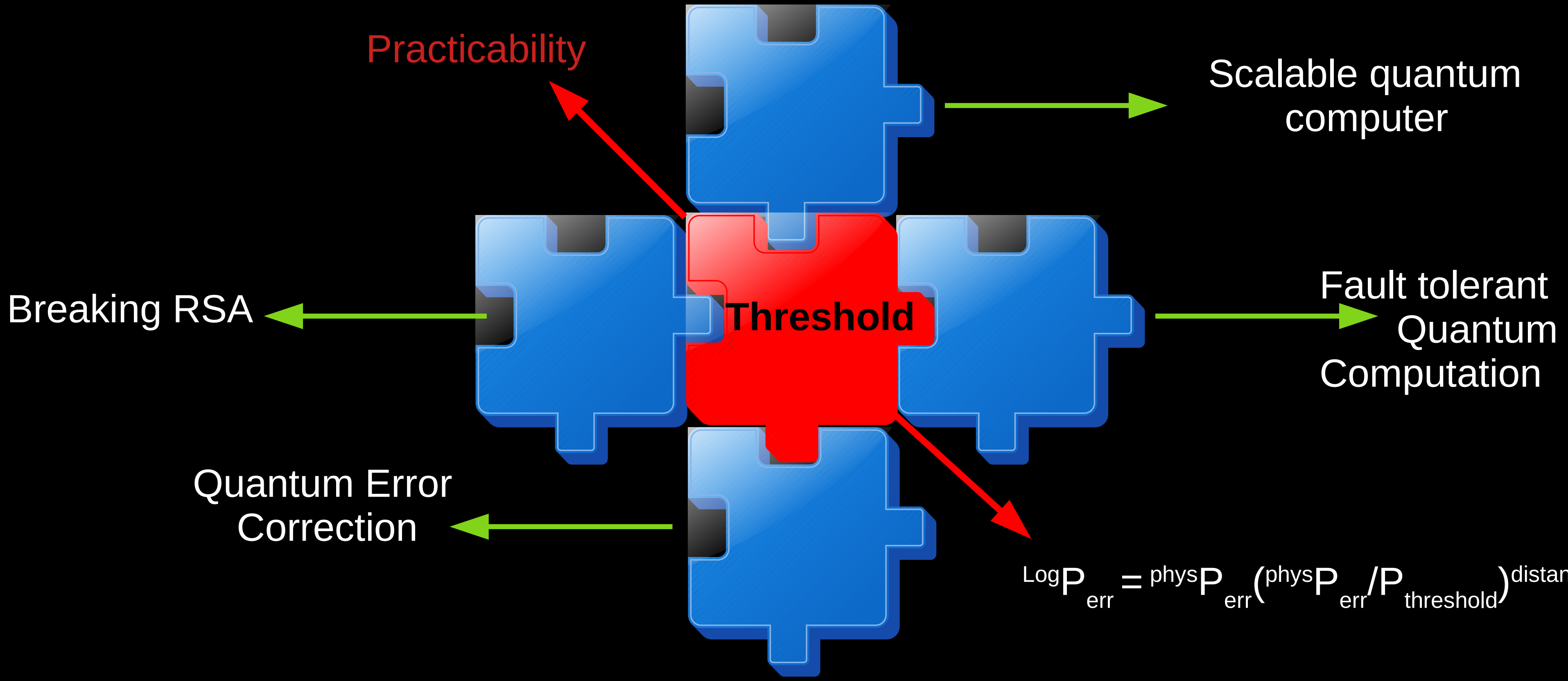

$$^{Log}P_{err} = {}^{phys}P_{err}\left({}^{phys}P_{err}/P_{threshold}\right)^{distance-1}$$

2. WHAT IS THE PROBLEM?

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Building blocks...

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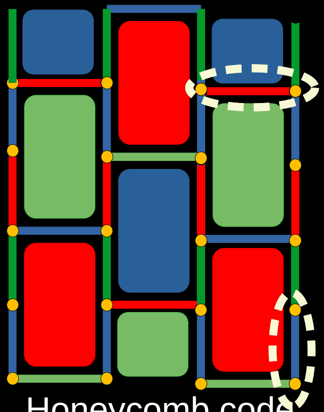

Honeycomb code

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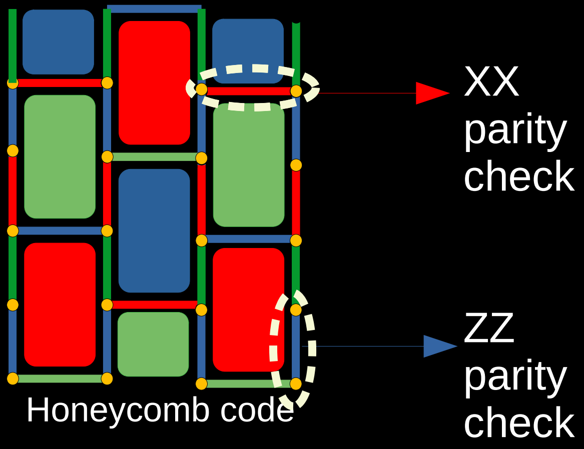

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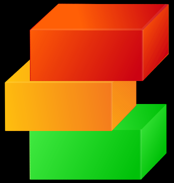

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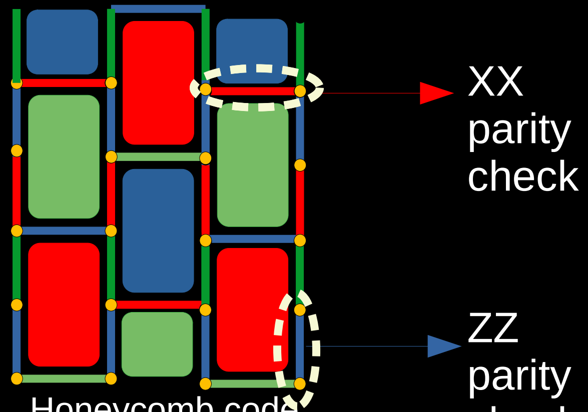

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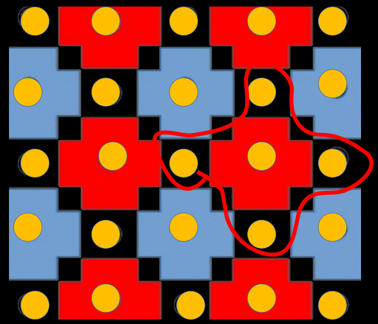

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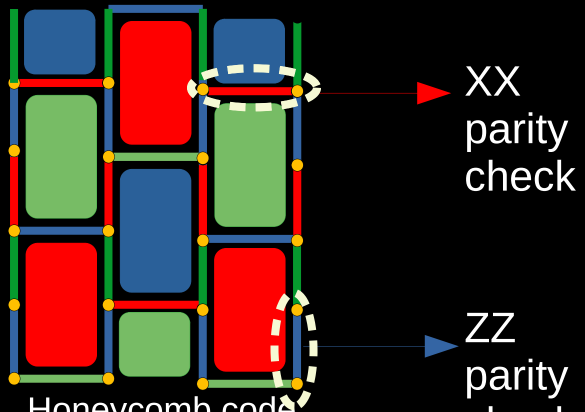

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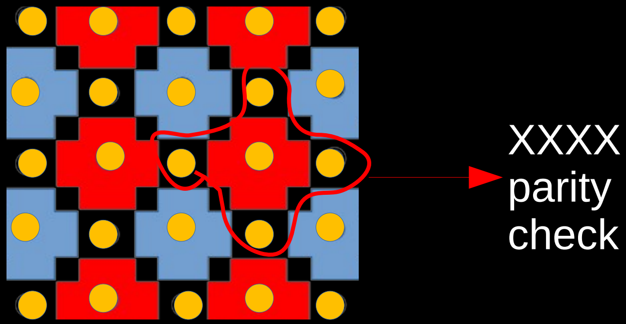

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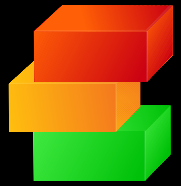

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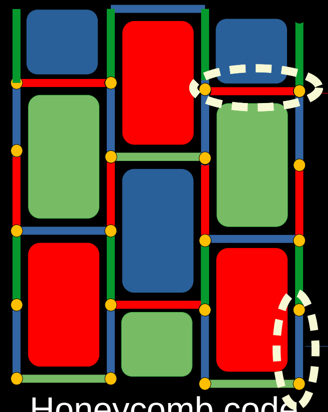

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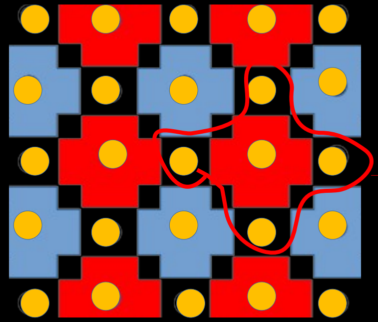
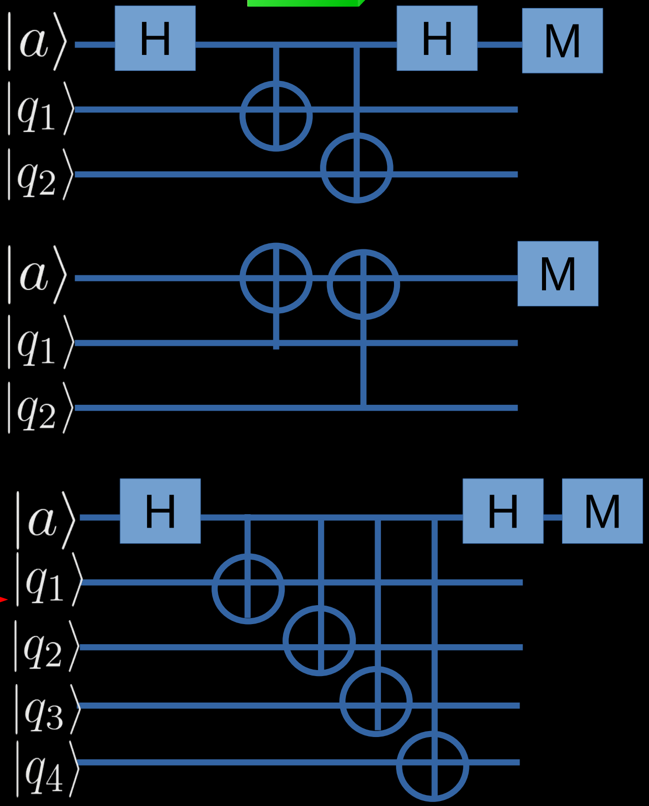


Surface code

XX parity check

ZZ parity check

XXXX parity check



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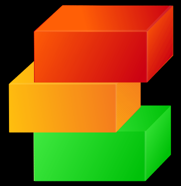

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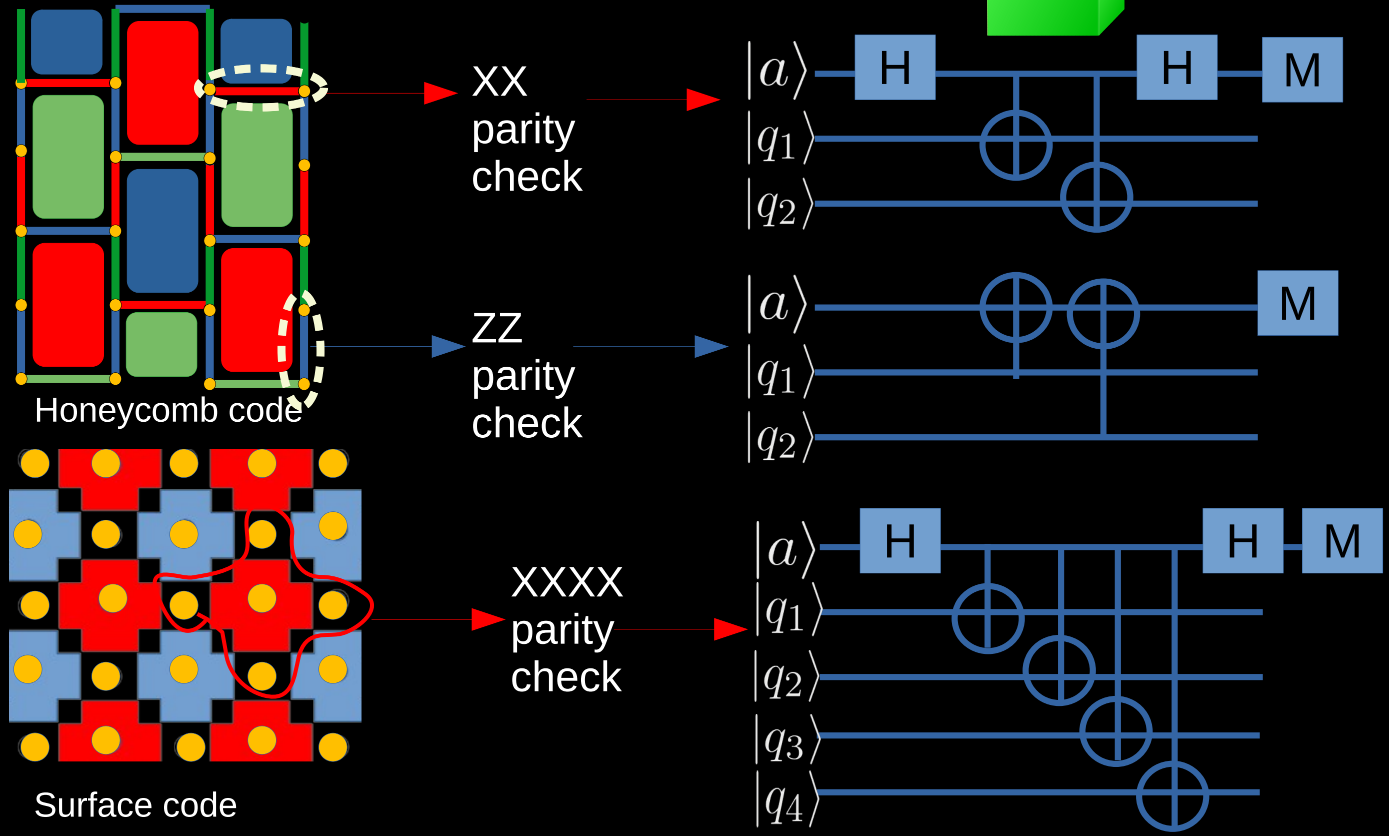

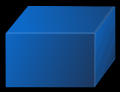

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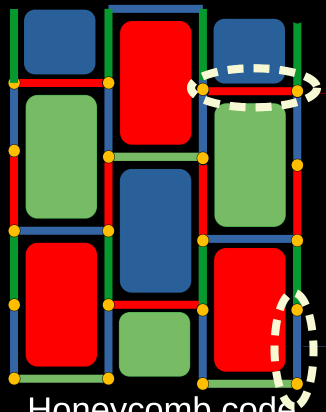

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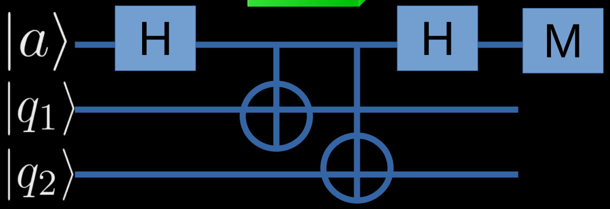

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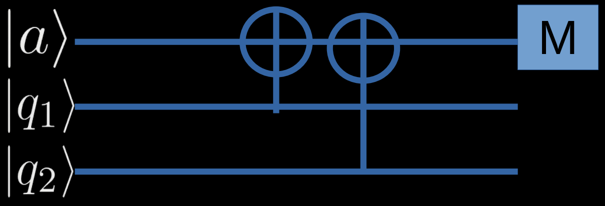

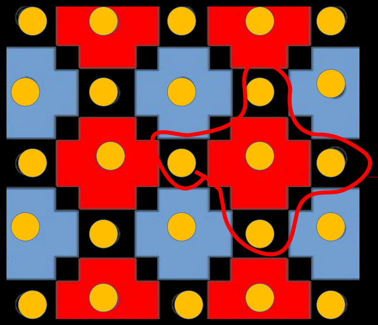

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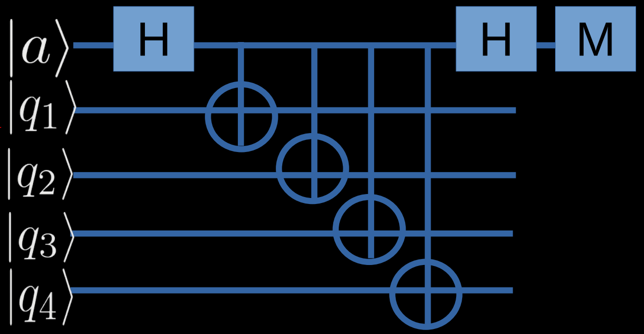

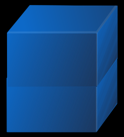

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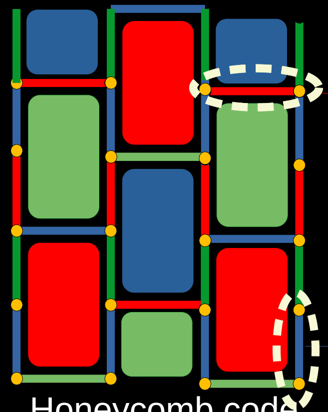

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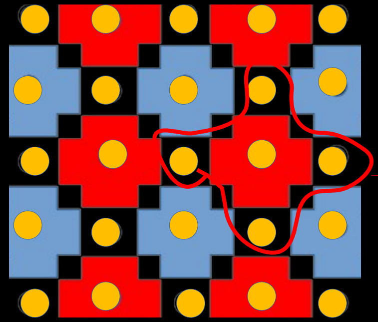

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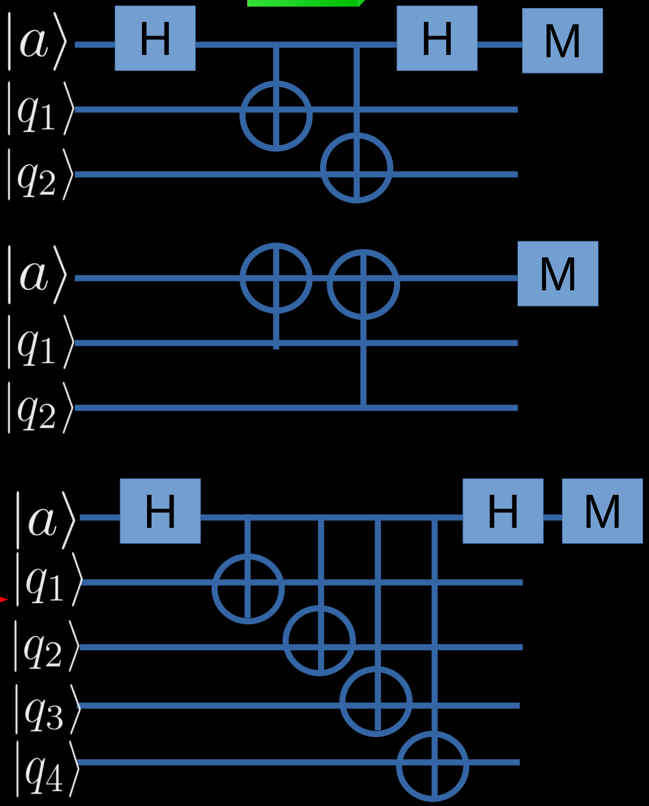

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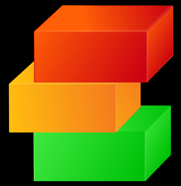

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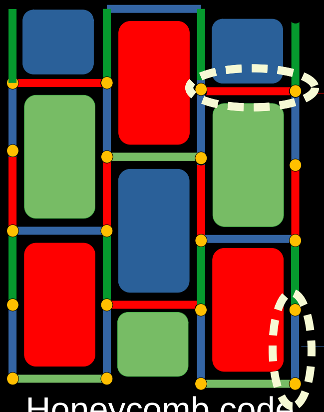

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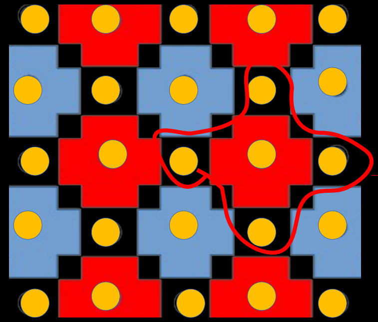

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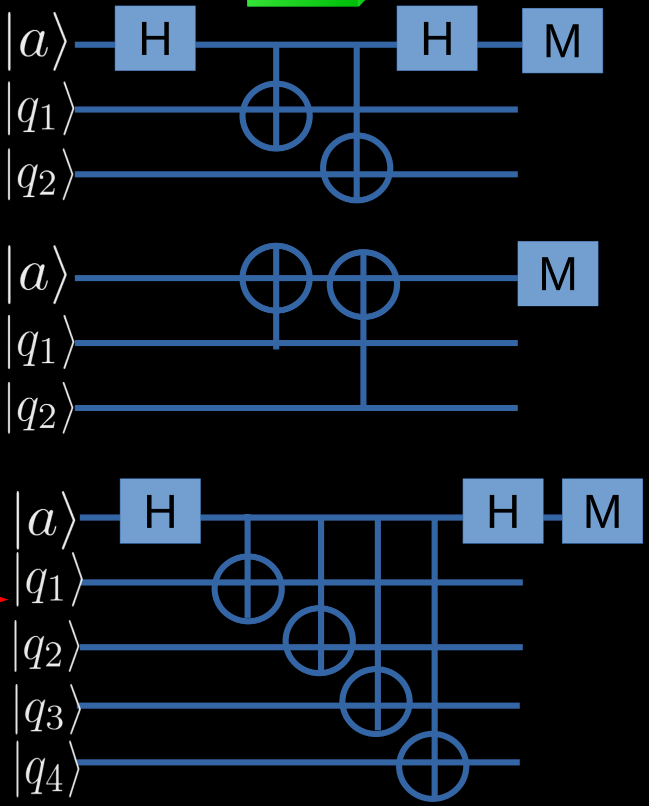
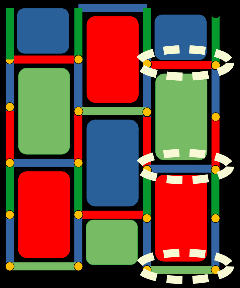
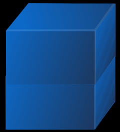




A Fault-Tolerant Honeycomb Memory, Gidney et all,Quantum 5, 605 (2021).



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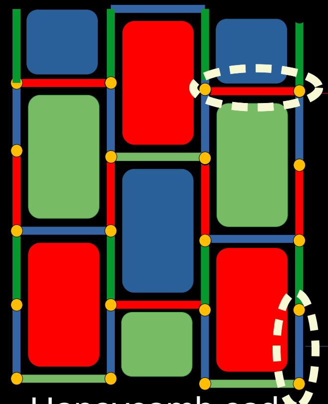

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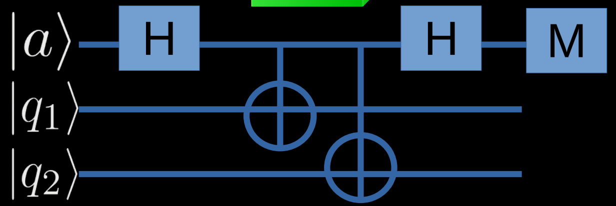

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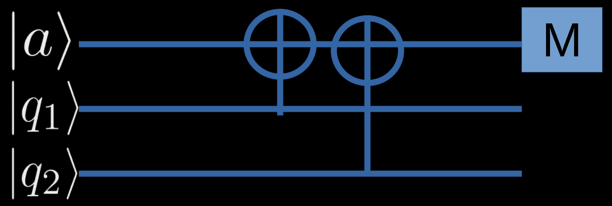

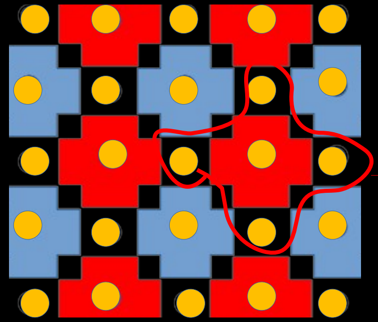

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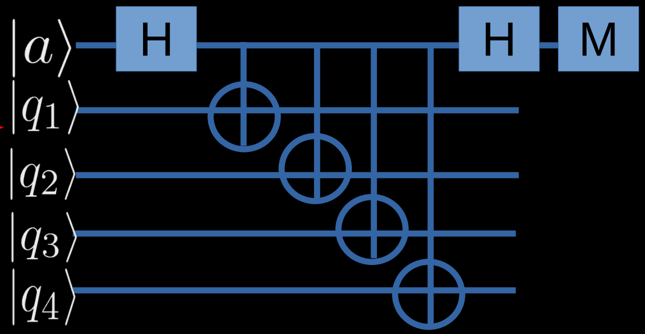

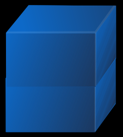

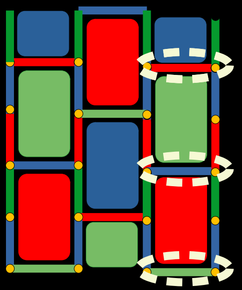

Direct XX parity check

Direct YY parity check

Direct ZZ parity check

A Fault-Tolerant Honeycomb Memory, Gidney et all,Quantum 5, 605 (2021).

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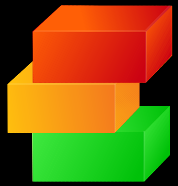

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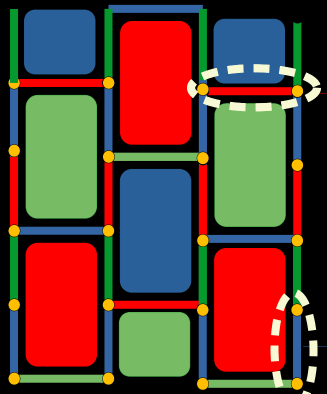
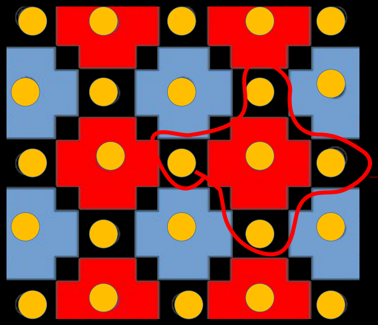


Honeycomb code



Surface code

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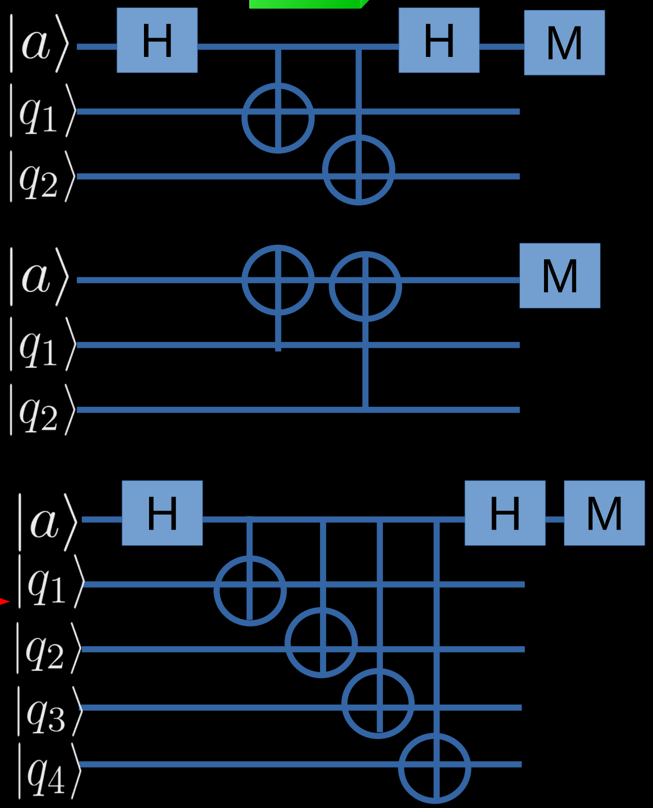

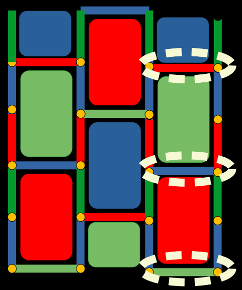

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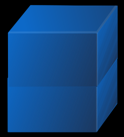
Three times higher threshold than surface code!



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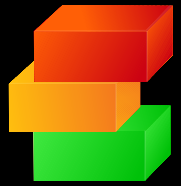

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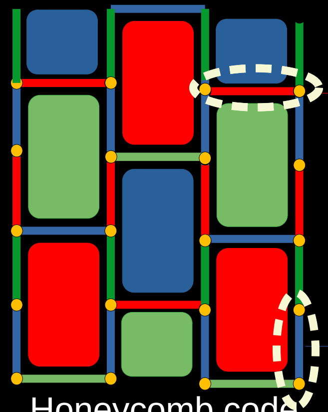

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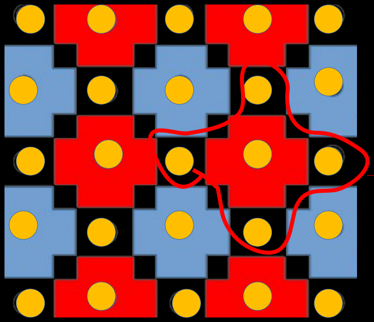

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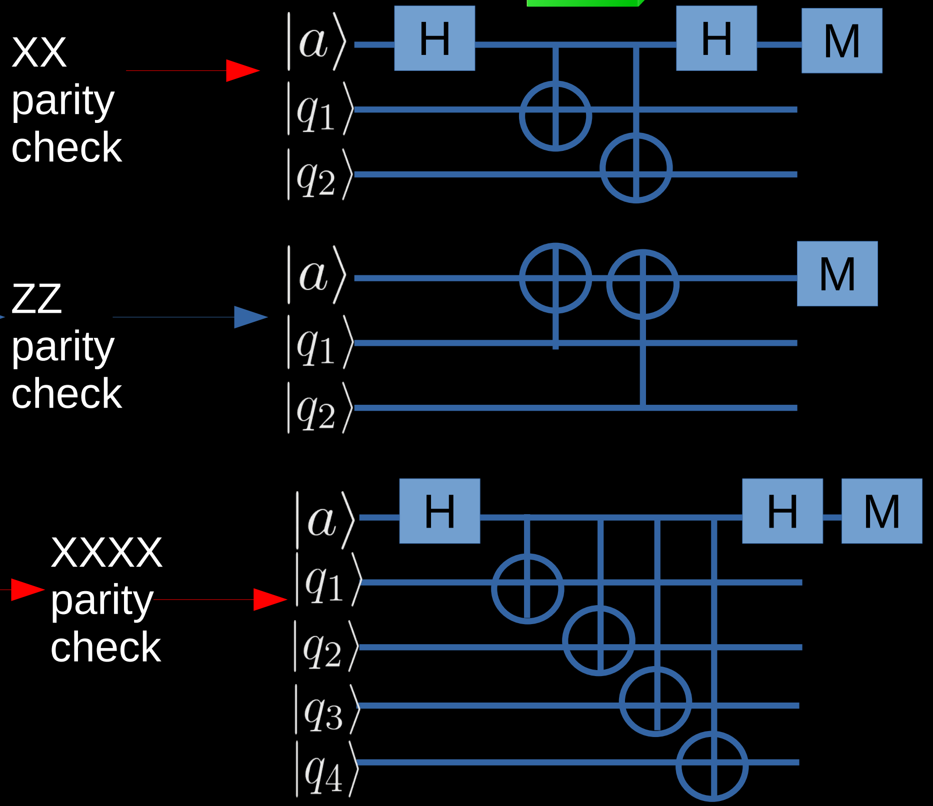

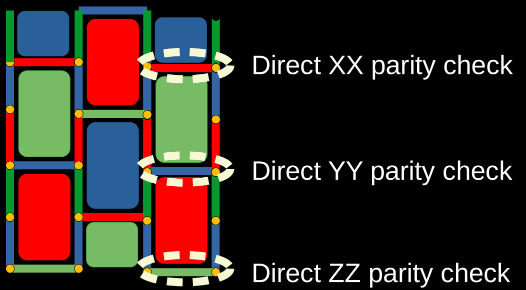

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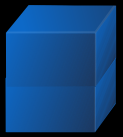
If there is M_{pp2} …???



3. CURRENT METHODS

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From fidelity to p

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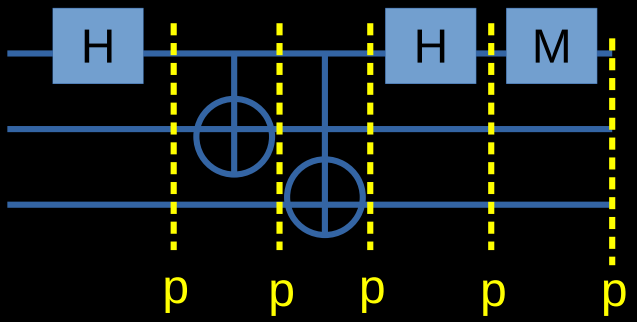

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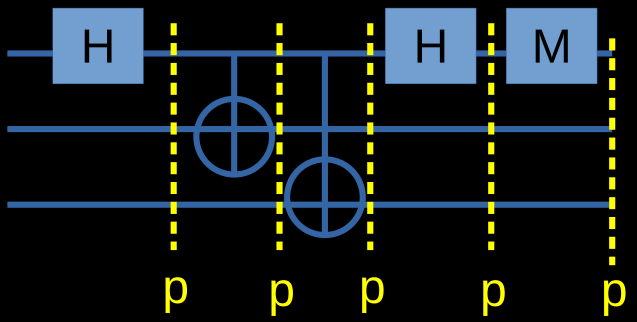
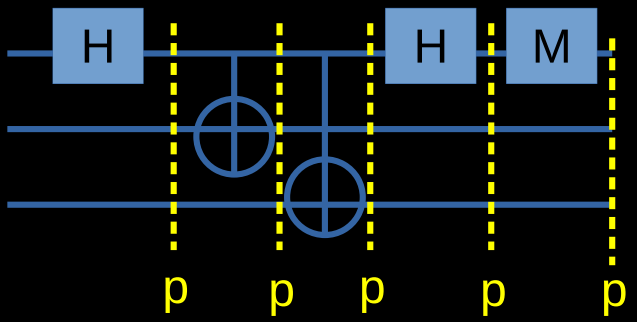


1. Take GST matrices

3. CURRENT METHODS

From fidelity to p



1. Take GST matrices
2. They are actually PTM matrices

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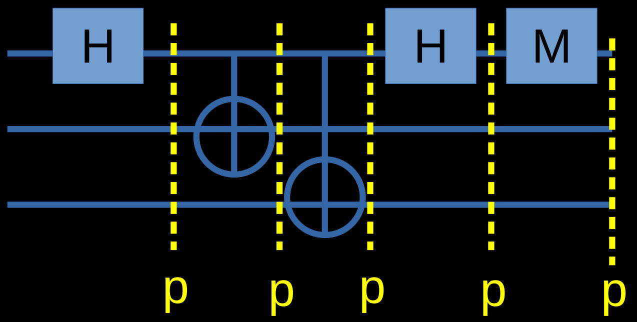

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3. Find Kraus Operators

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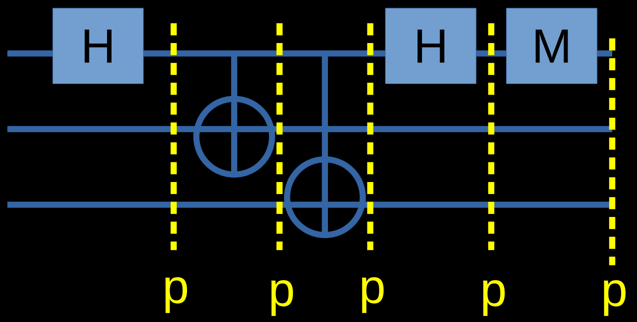

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3. Find Kraus Operators
4. Write Kraus operators in terms of Pauli Matrices

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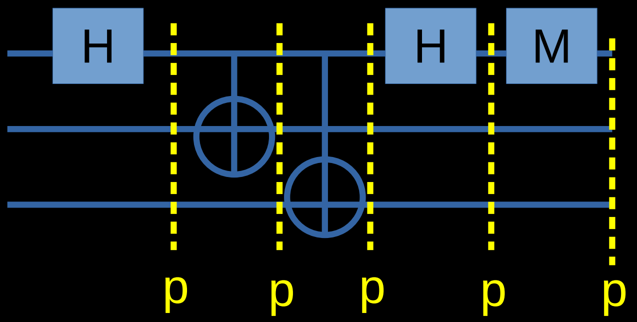

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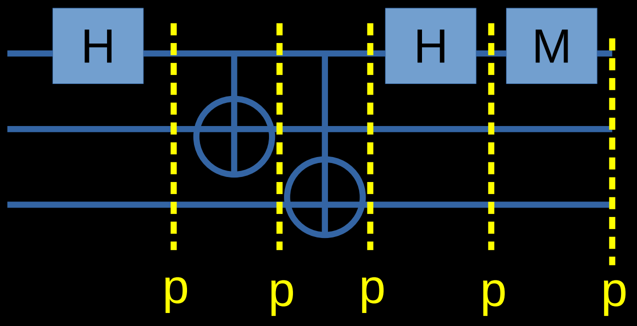

1. Take GST matrices
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5. Write final density matrices

As a result, we analysed the succession/perfection rate in terms of accumulated error in the stochastic Pauli channels

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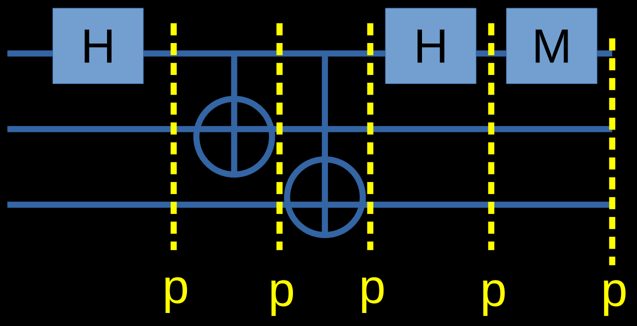

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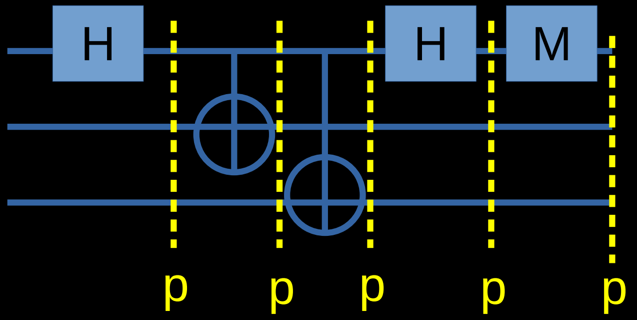
From fidelity to p



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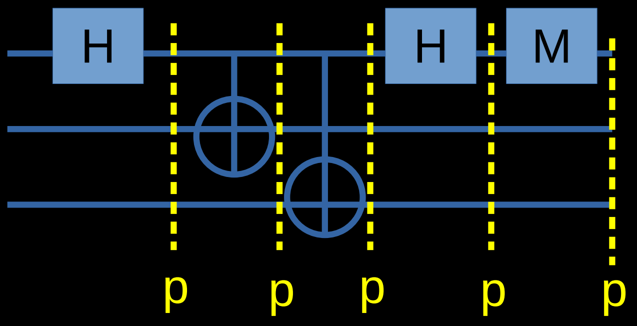

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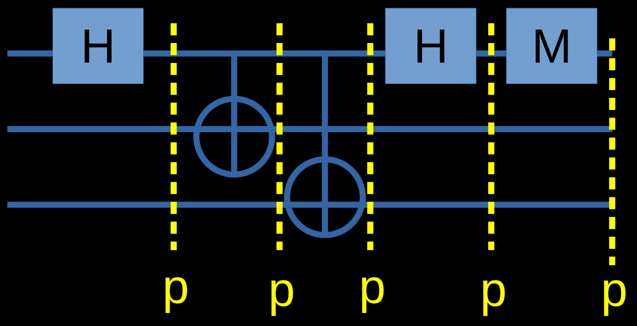

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Surface codes: Towards practical large-scale quantum computation, Fowler et all,Phys. Rev. A 86, 032324

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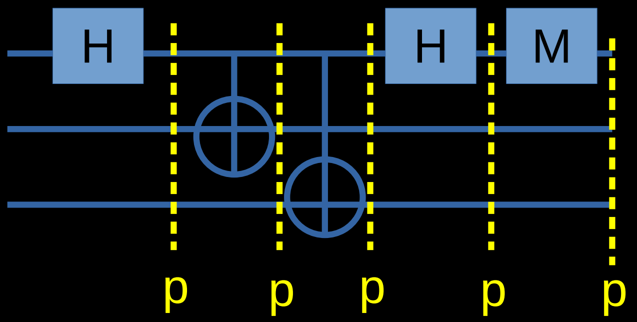

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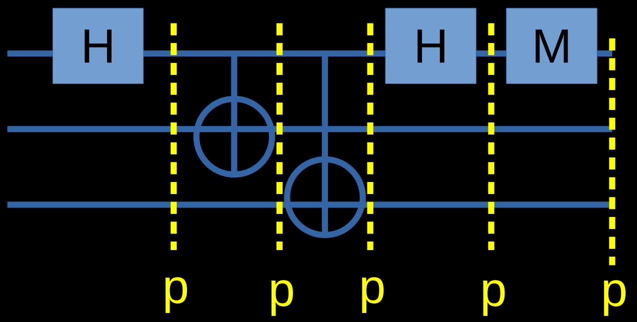

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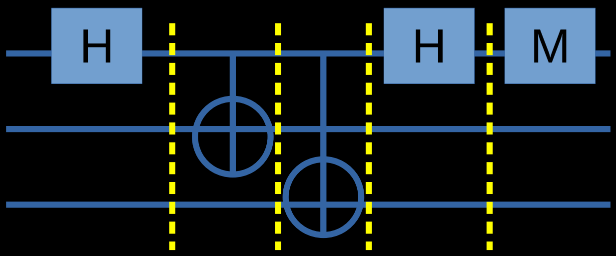

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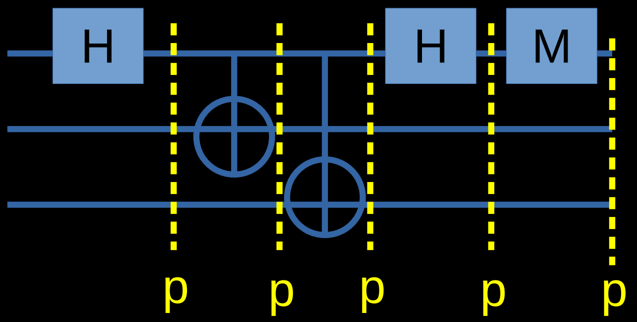

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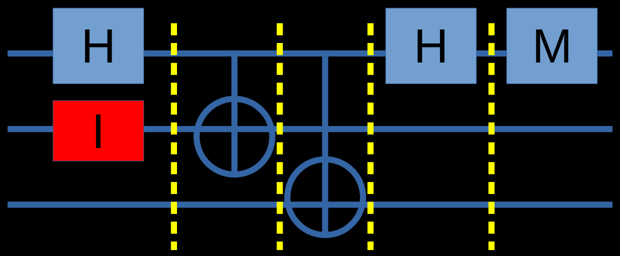

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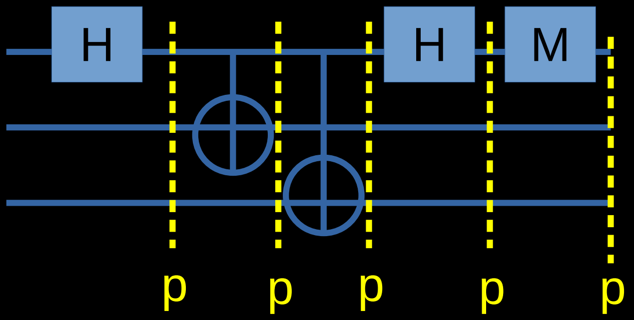

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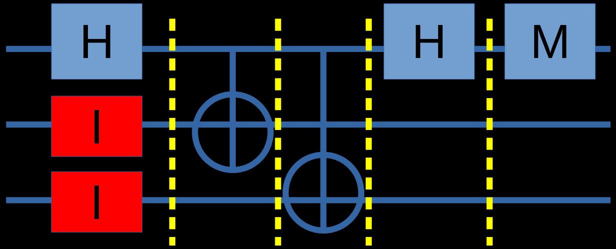

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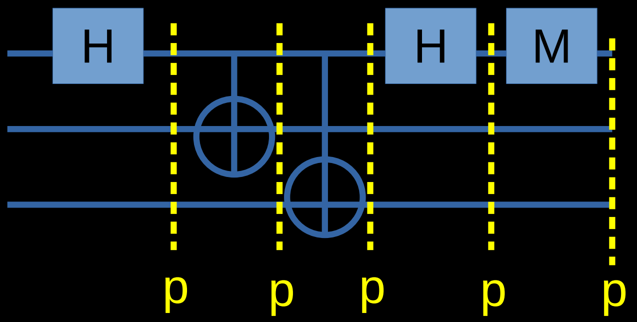

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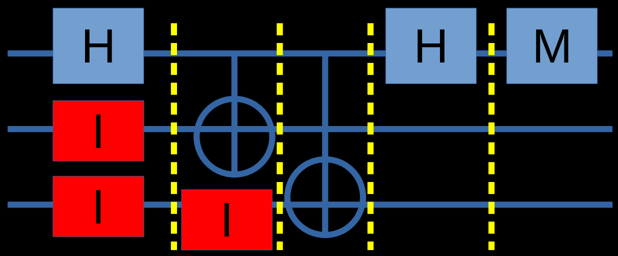

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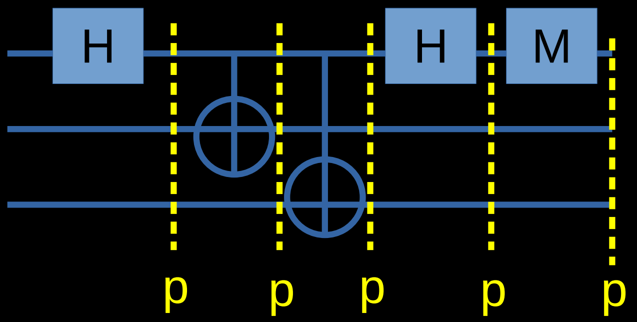

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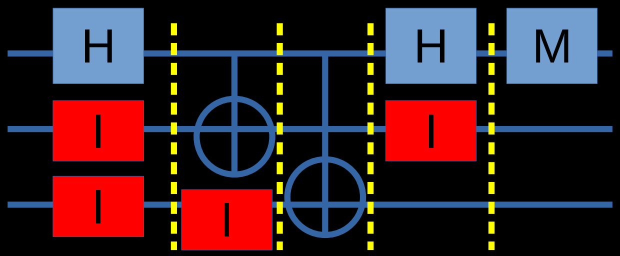

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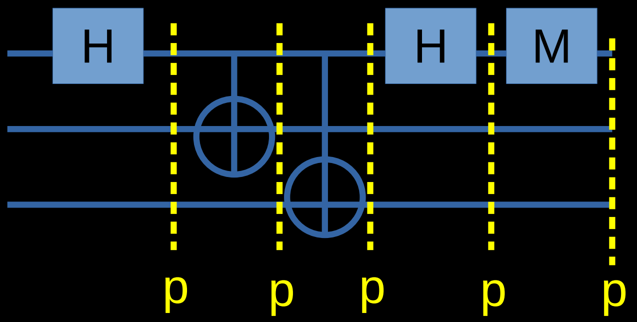

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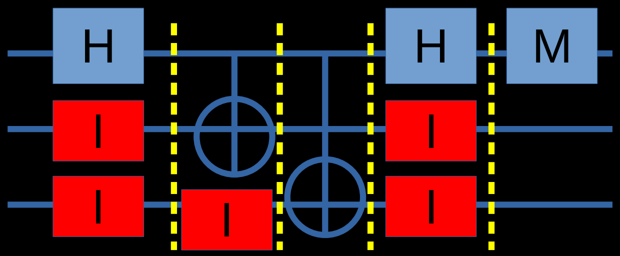

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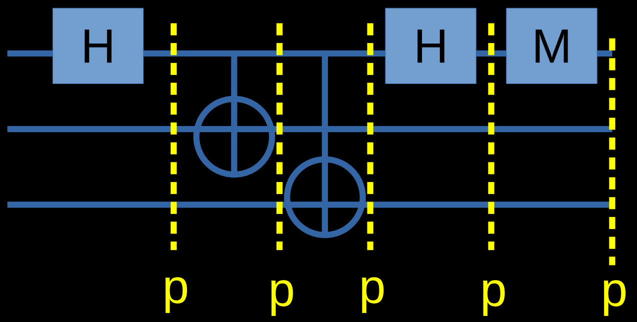

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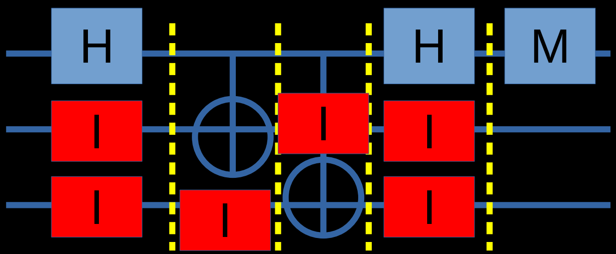

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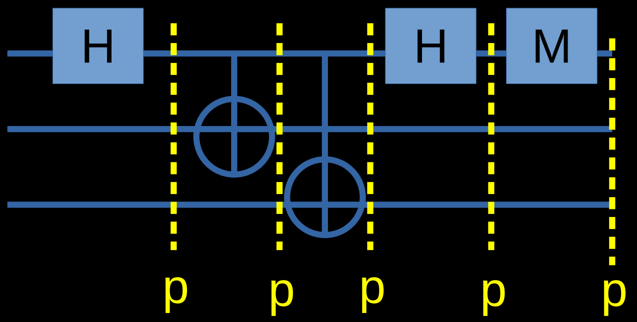

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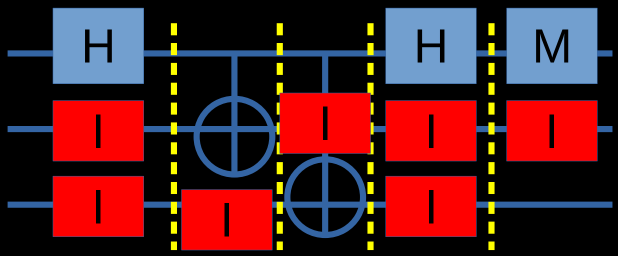

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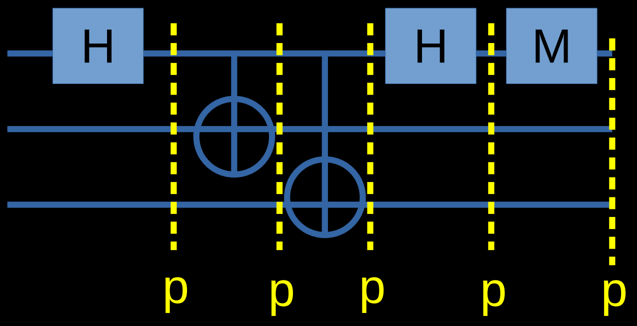

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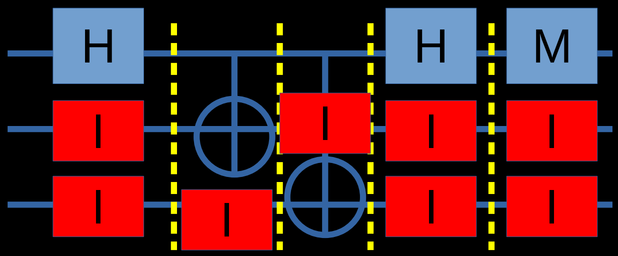

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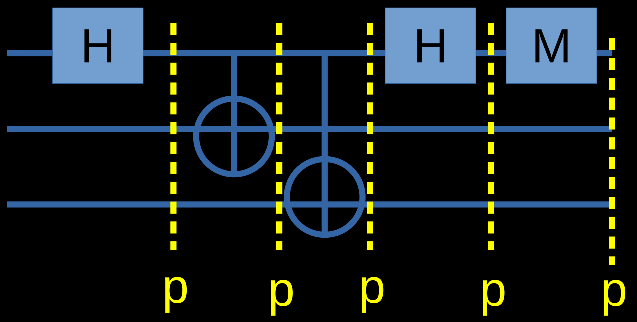

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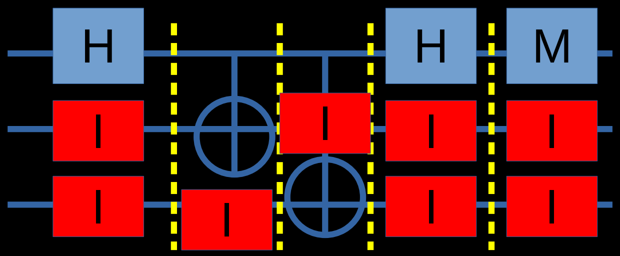

$P_I = 0.974$

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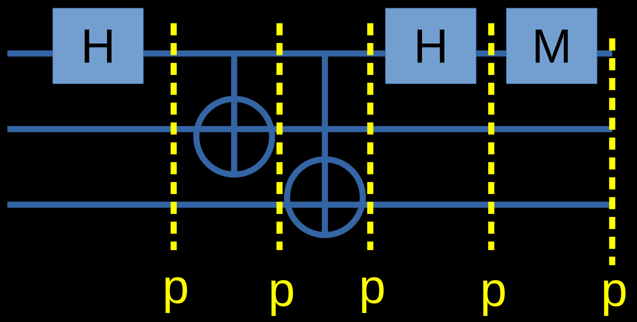

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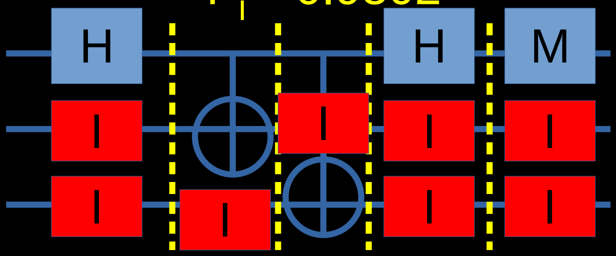

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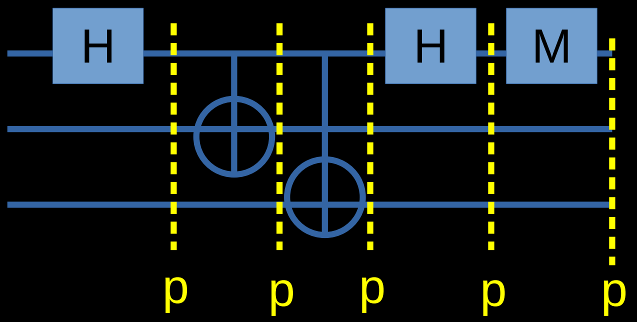

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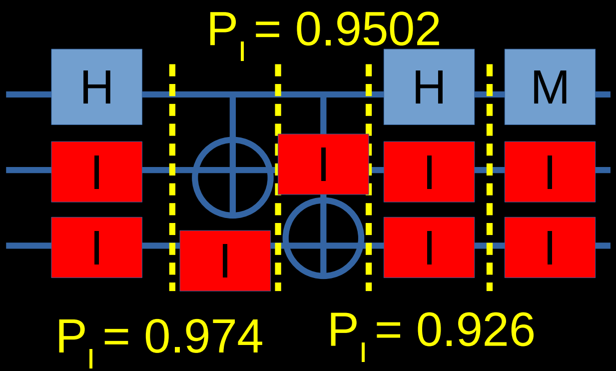

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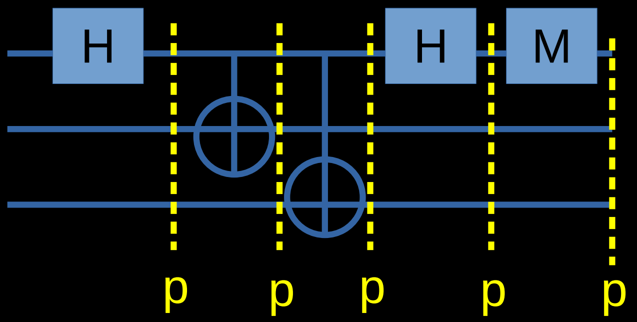

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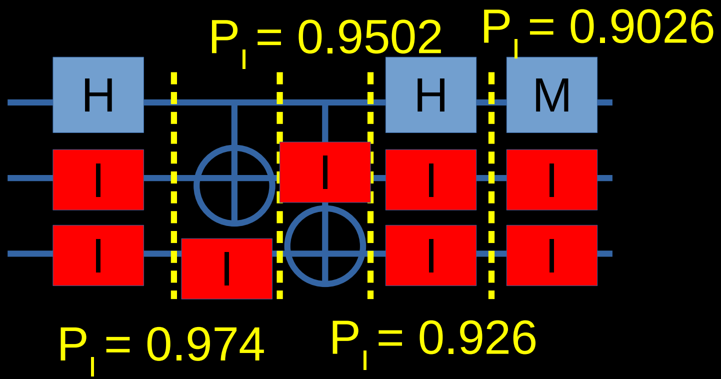

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CAN WE FIND A BETTER WAY?

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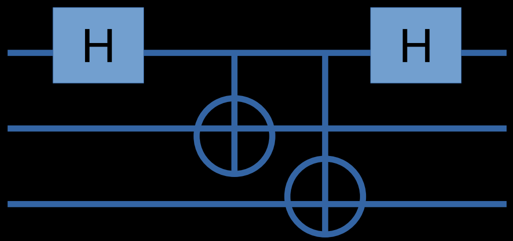

XX parity check circuit

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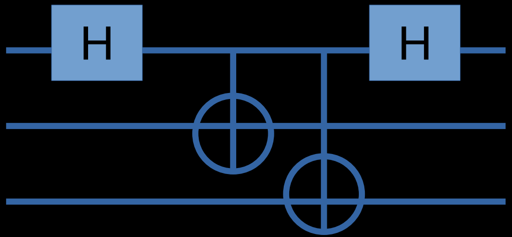

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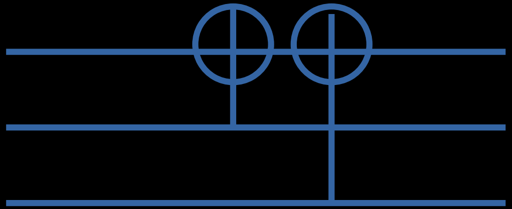

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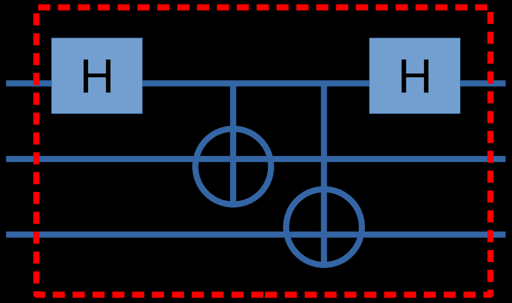

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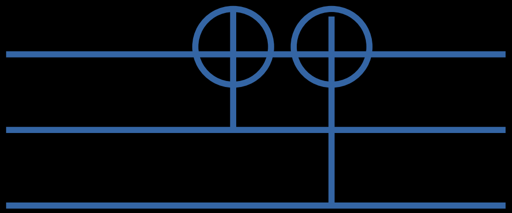

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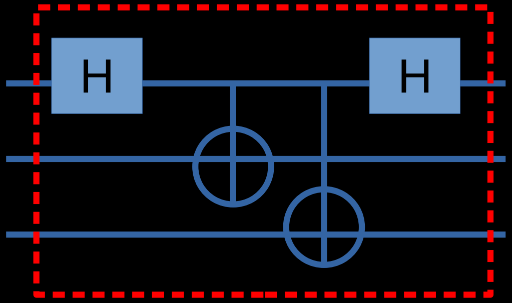

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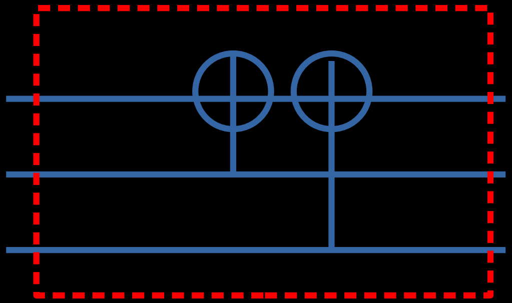

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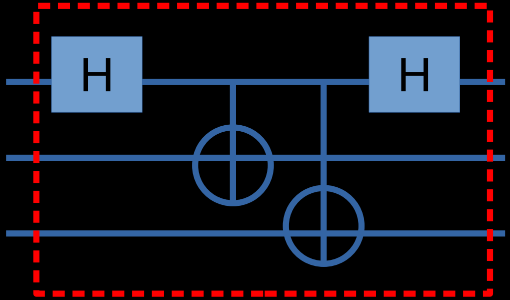

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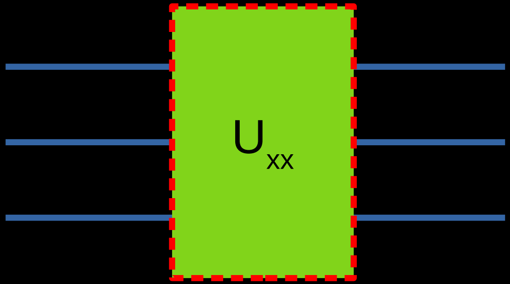

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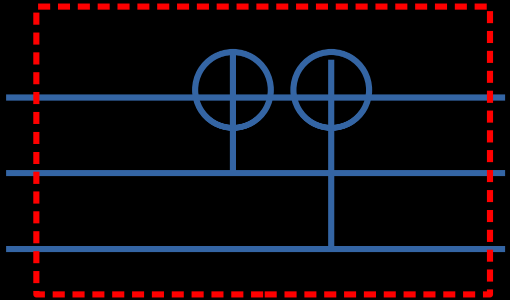

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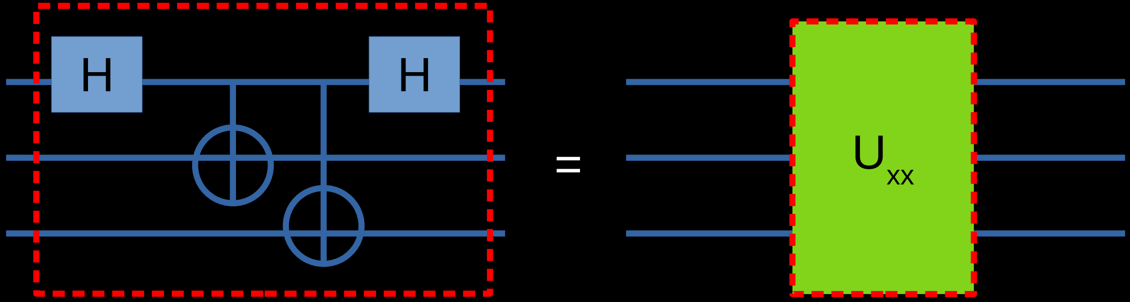

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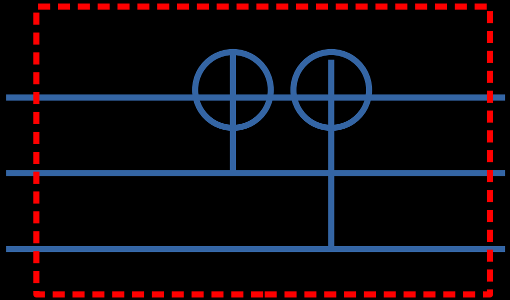

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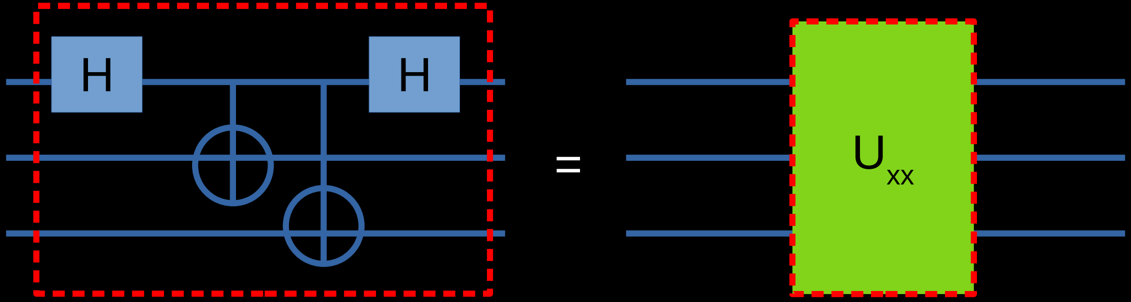

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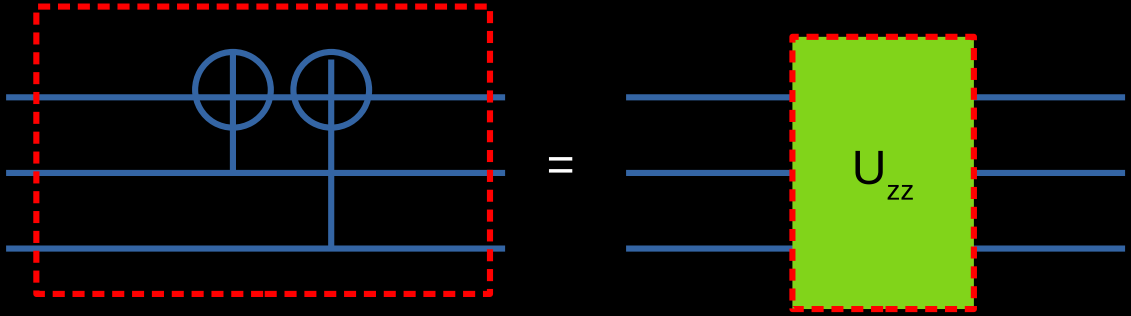

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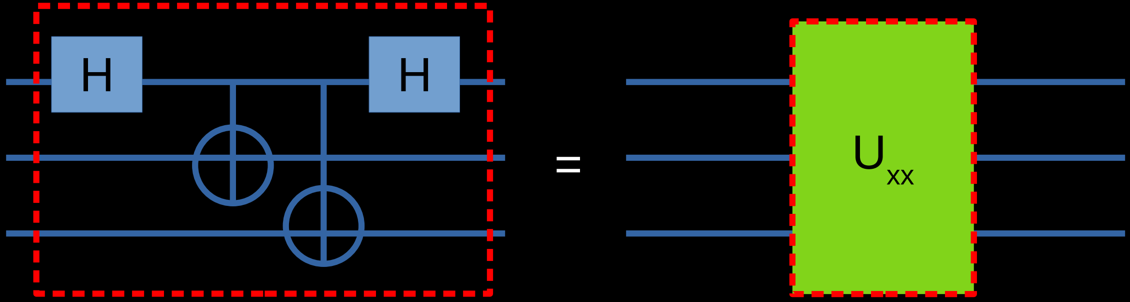

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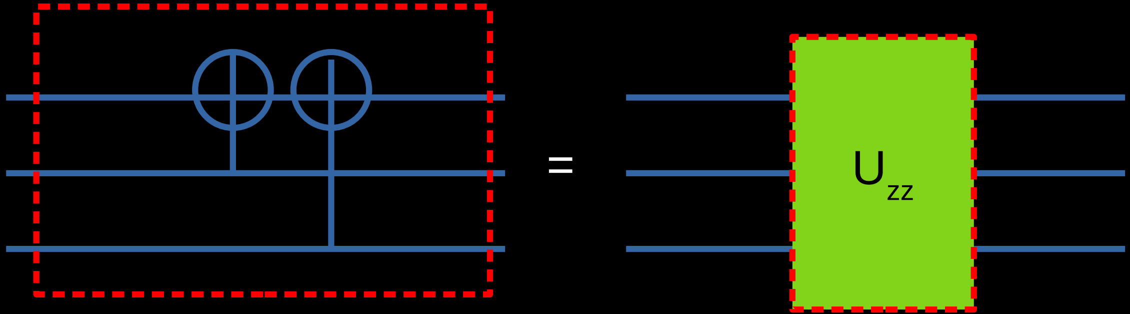

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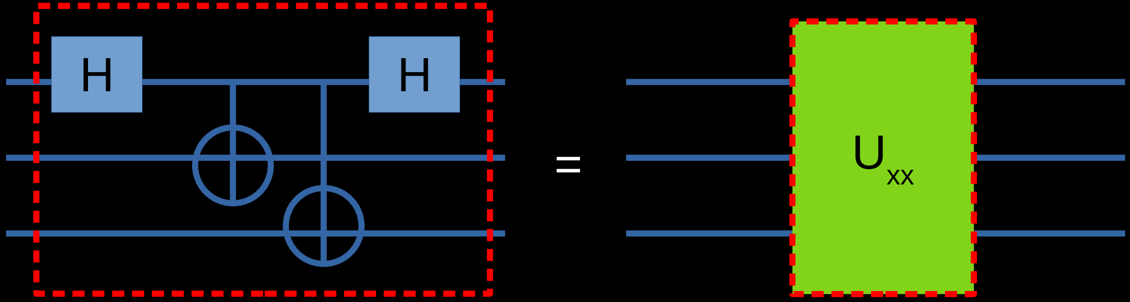

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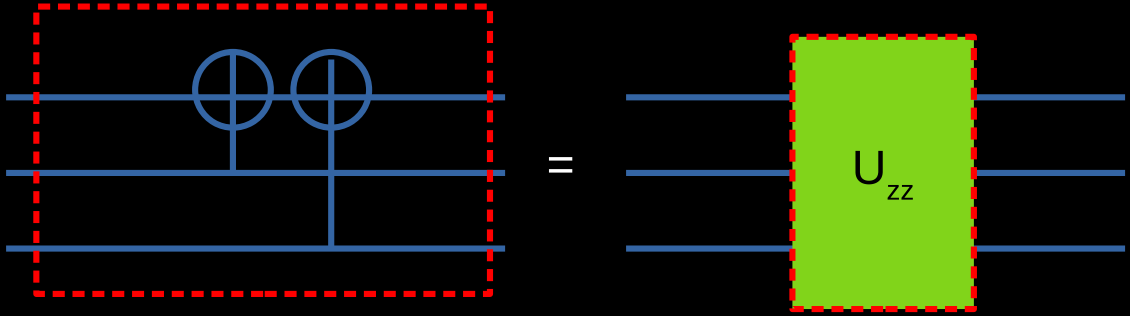

$$= U_{ZZ} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

ZZ parity check circuit

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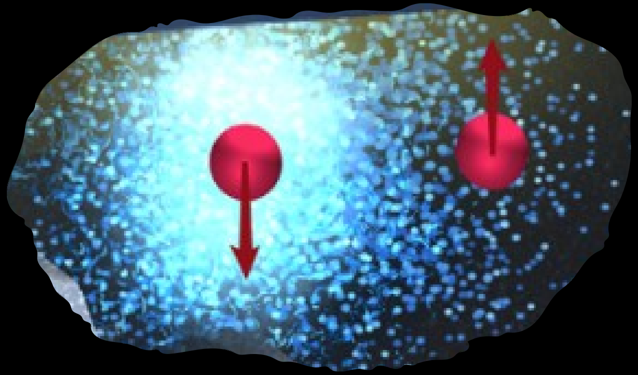

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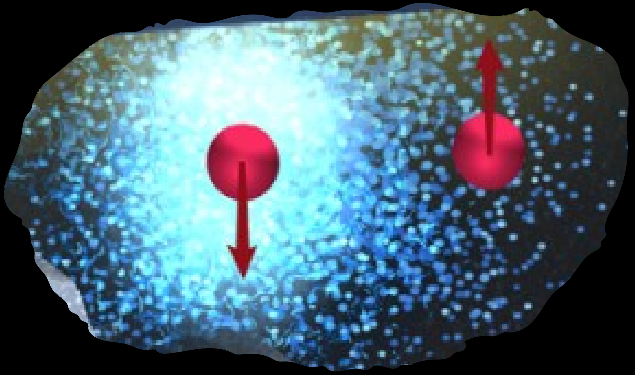

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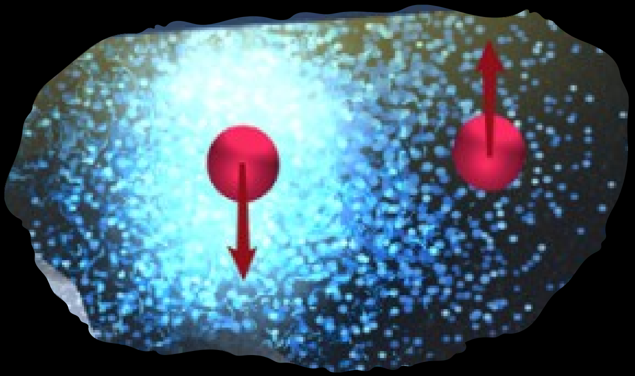

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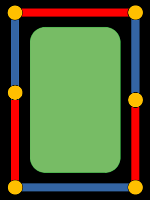

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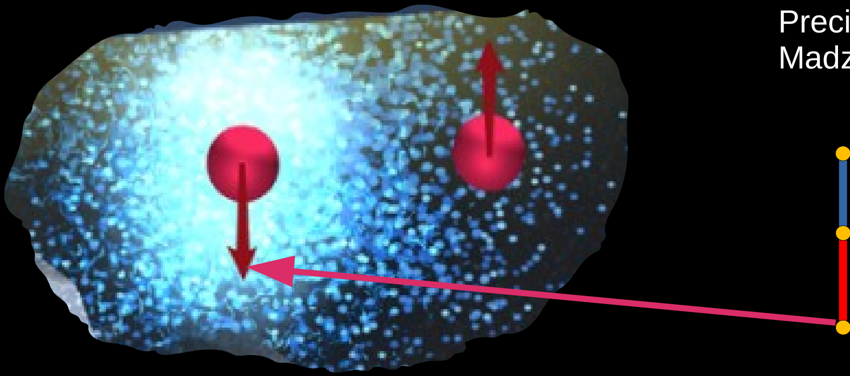

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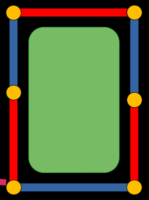

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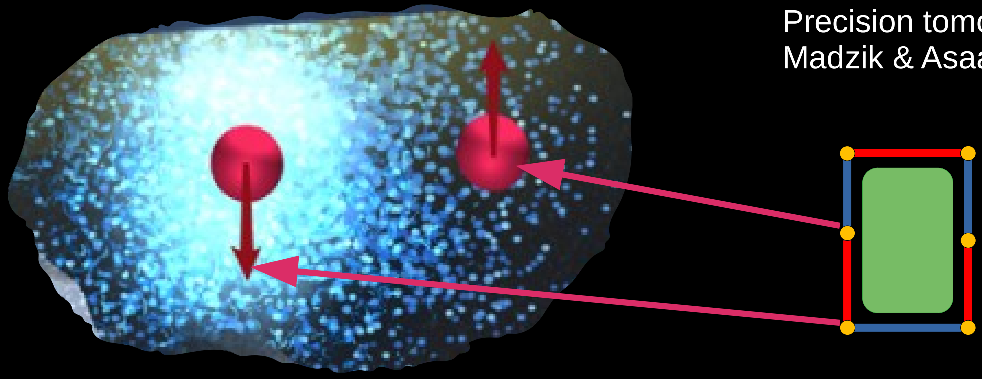

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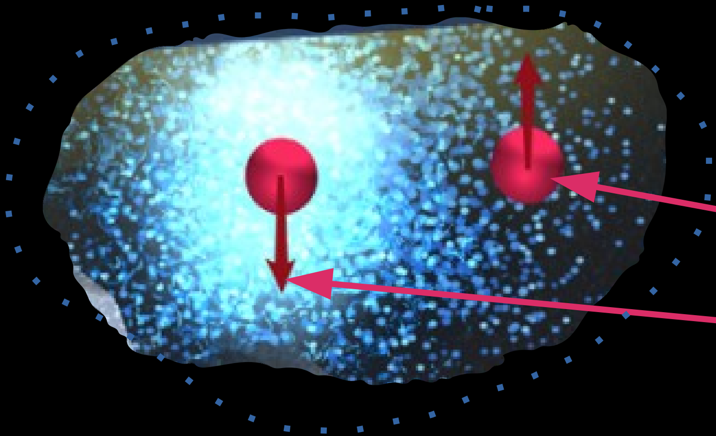

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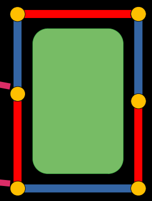

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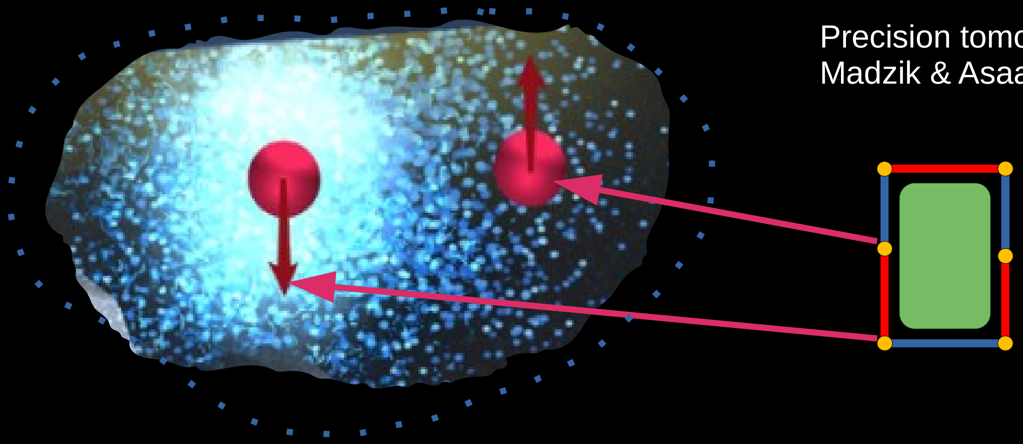

$$\vec{H}_d = -\gamma_e B_0 \hat{S} - \gamma_n B_0 (\hat{I_{z1}} + \hat{I_{z2}}) + A_1 \vec{S}.\vec{I_1} + A_2 \vec{S}.\vec{I_2}$$

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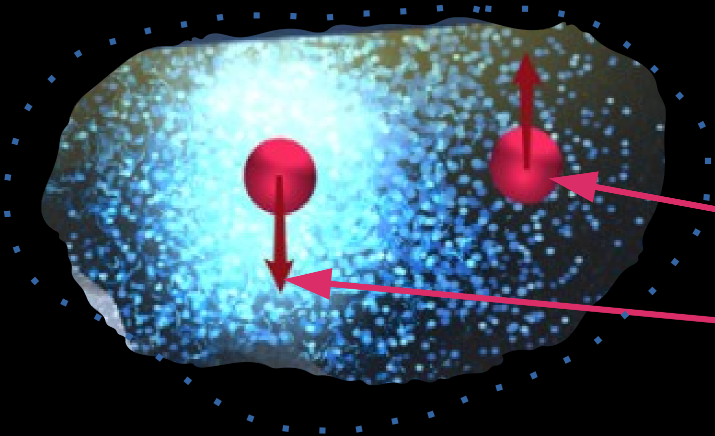

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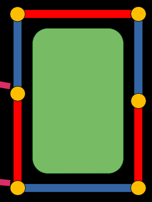

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$$H_{rf}(t) = -\gamma_e \vec{B_1} \vec{S} sin(wt) - \gamma_n \vec{B_1} (\vec{I_1} + \vec{I_2}) sin(wt)$$

Method 2: Analytical Analysis of Hamiltonian + Numerical simulation

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Gate_1 Gate_2 Gate_3 Gate_4 Gate_5

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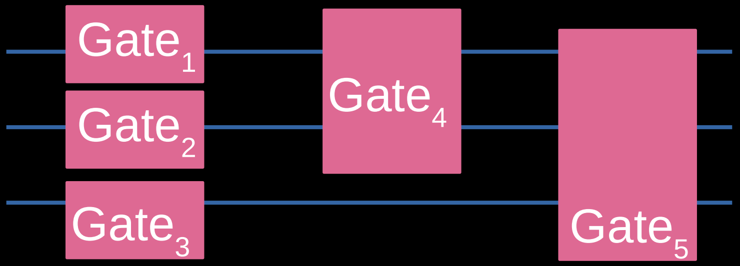

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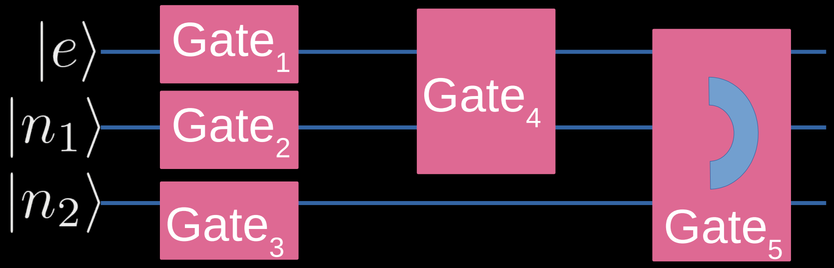

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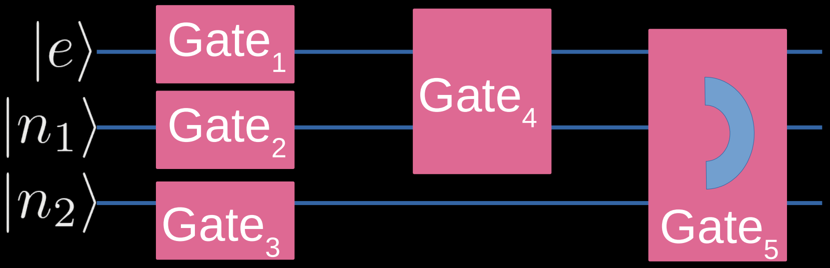

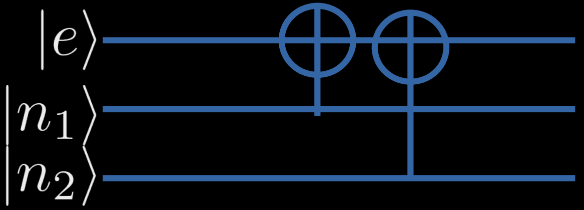

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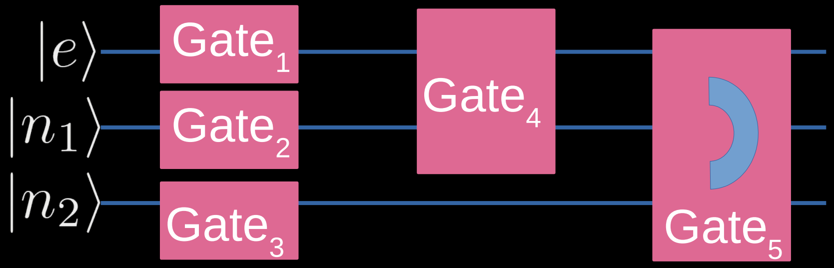

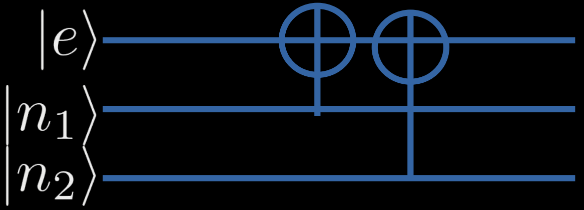

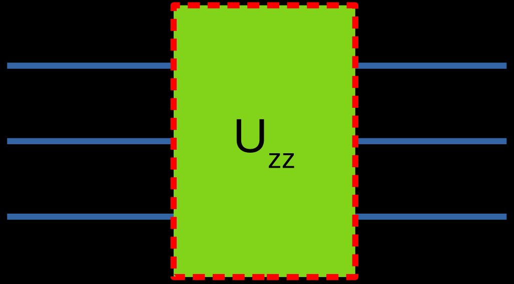

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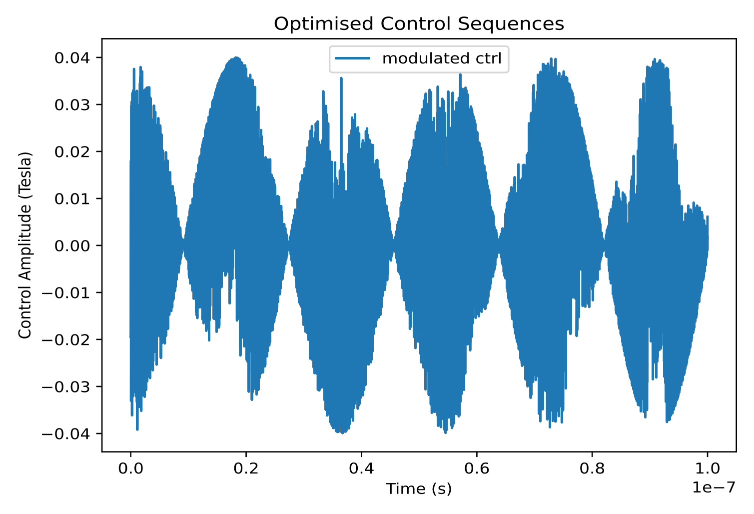

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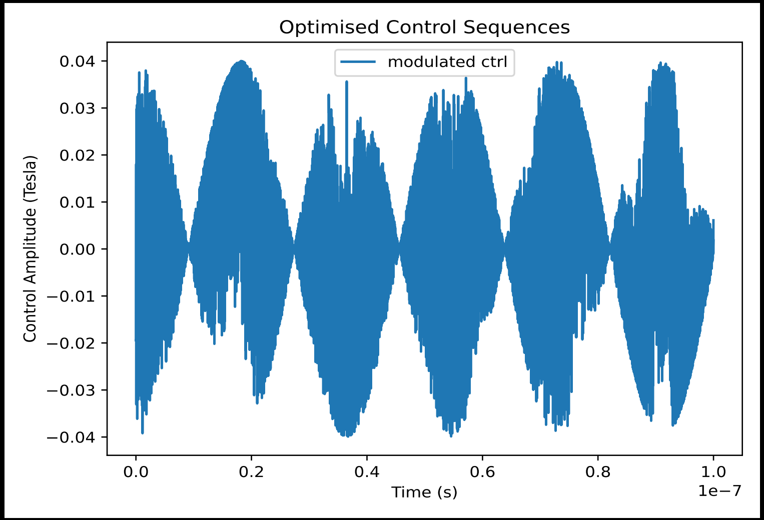

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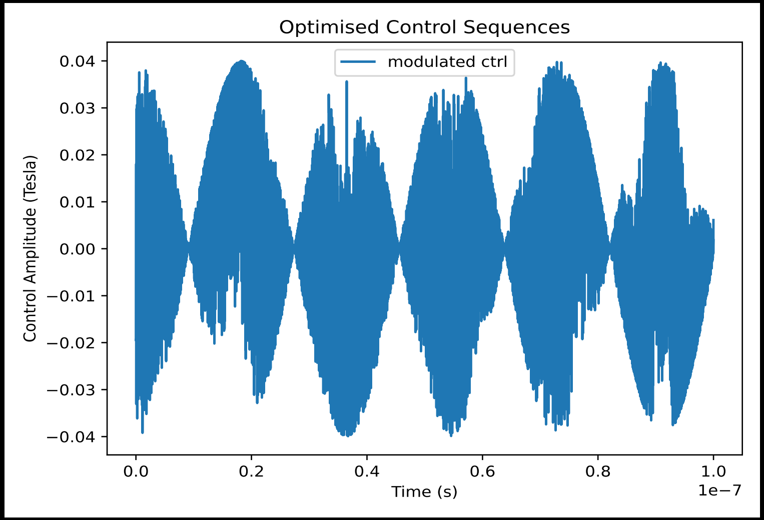

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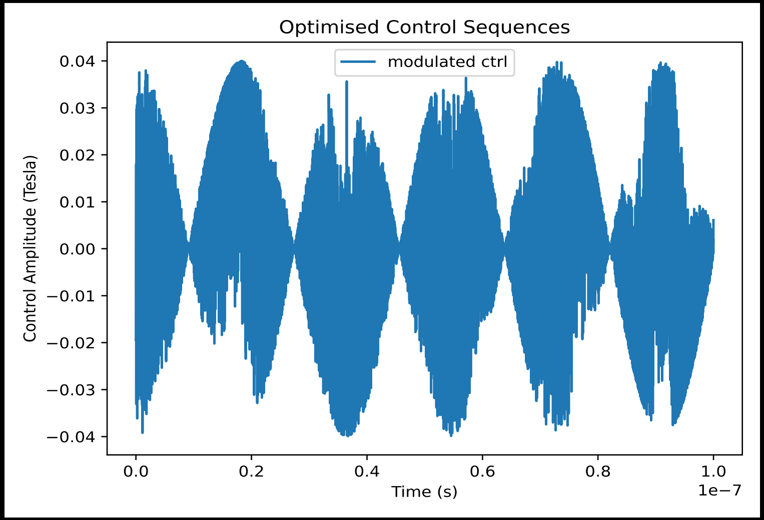

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Hence: M_{pp2} is one of single step parity check gate + a measurement

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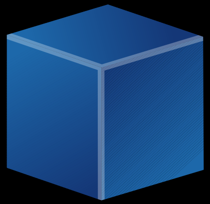

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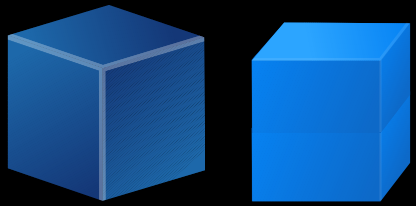

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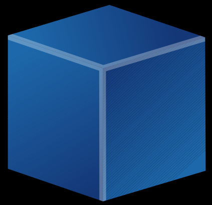


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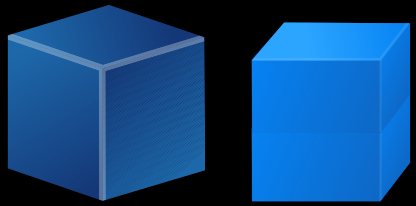

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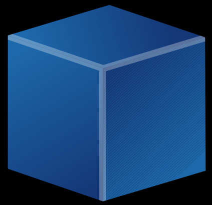

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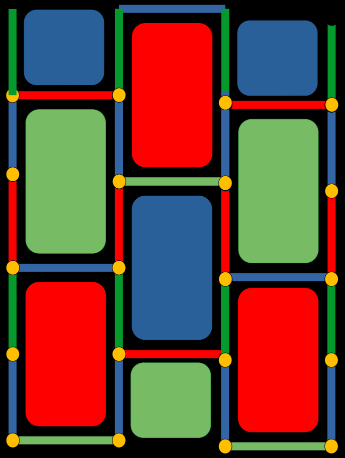

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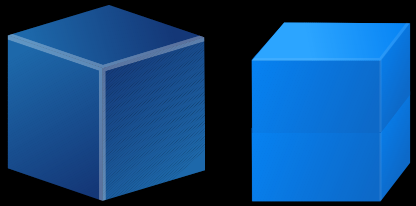

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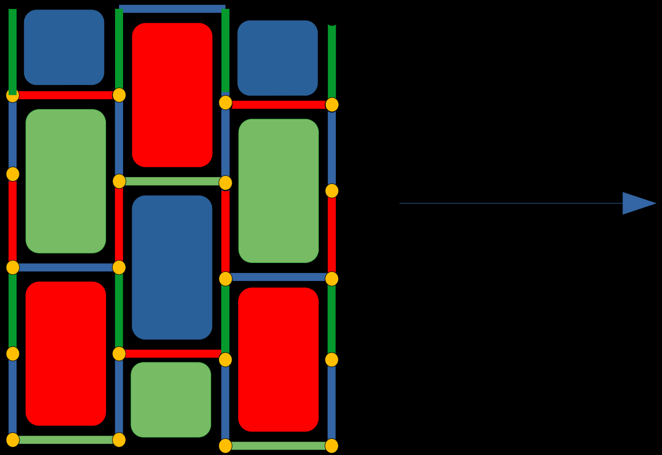

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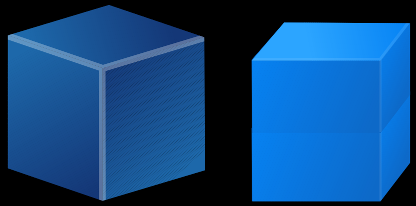

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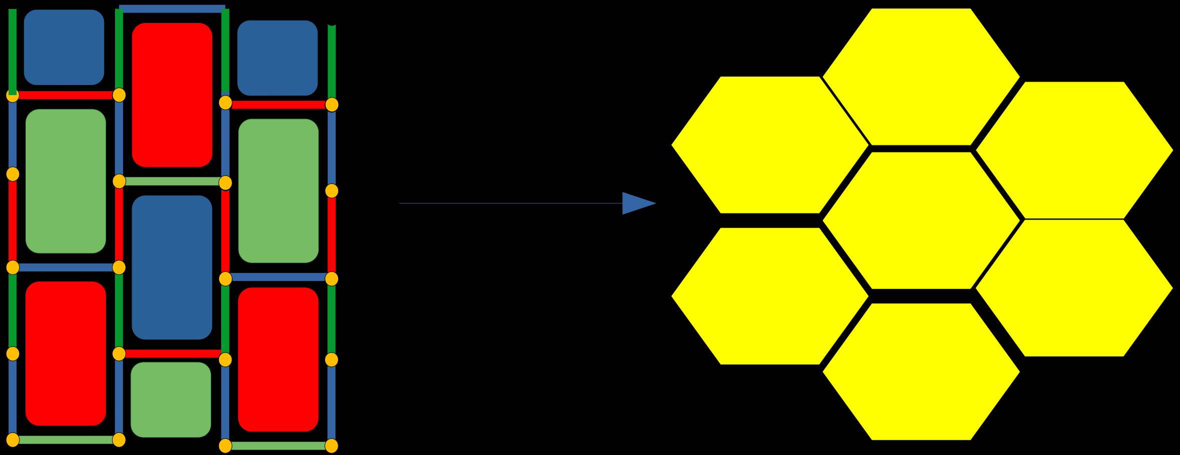

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THANK YOU FOR LISTENING