STATIC QUANTUM CIRCUITS

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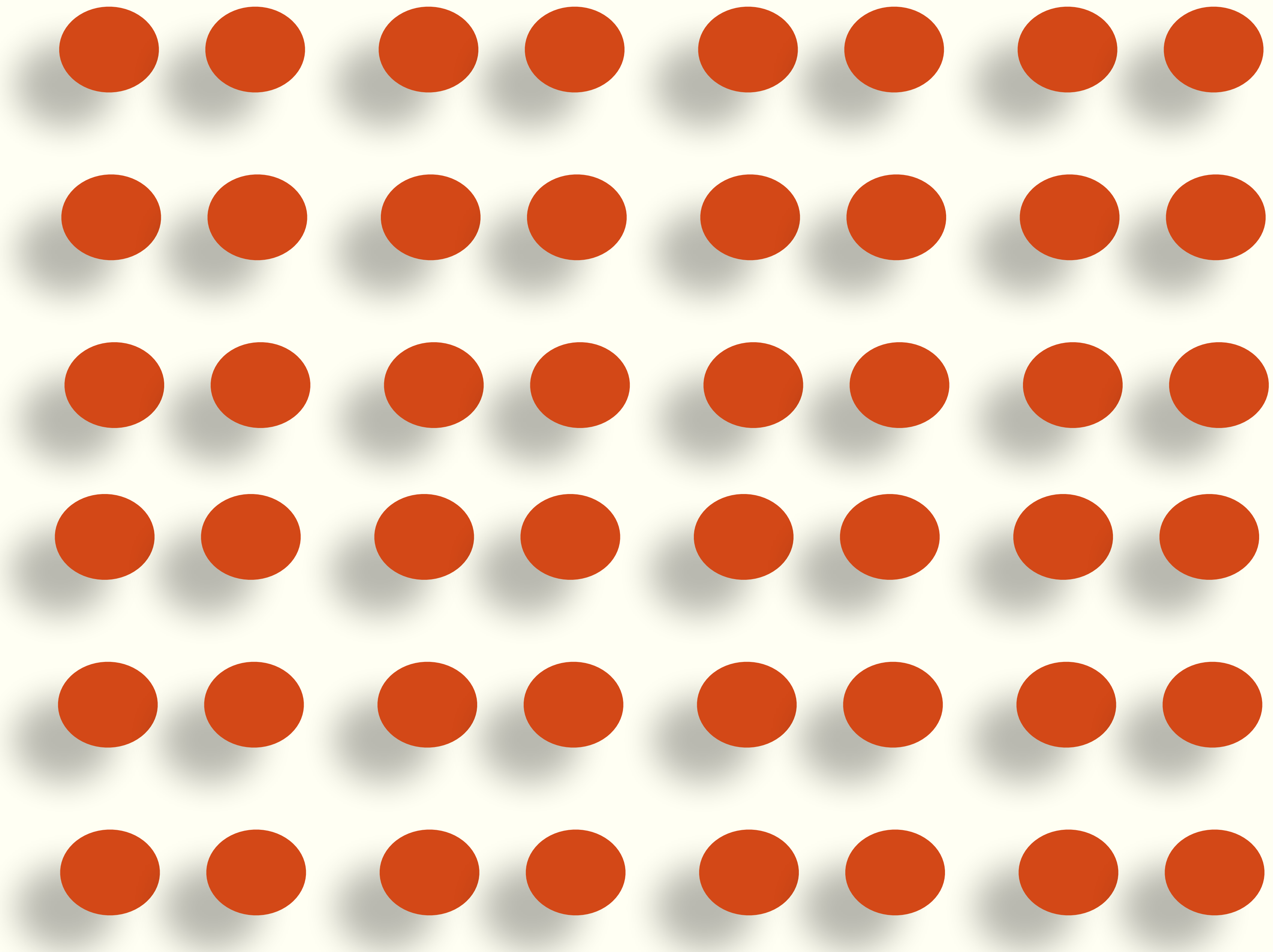
Black Sea
Istanbul
Georgia
Caspian Sea
Azerbaijan
Uzbekistan
Kyrgyzstan
Turkey
Turkmenistan
Tajikistan
Syria
Lebanon
Iraq
Afghanistan
Iran
Israel
Jordan
Pakistan
New Delhi
नई दिल्ली
Egypt
Persian Gulf
Riyadh
الرياض
United Arab Emirates
Saudi Arabia
Mecca
مكة
India
Red Sea
Oman
Map data ©2017 Google, ORION-ME

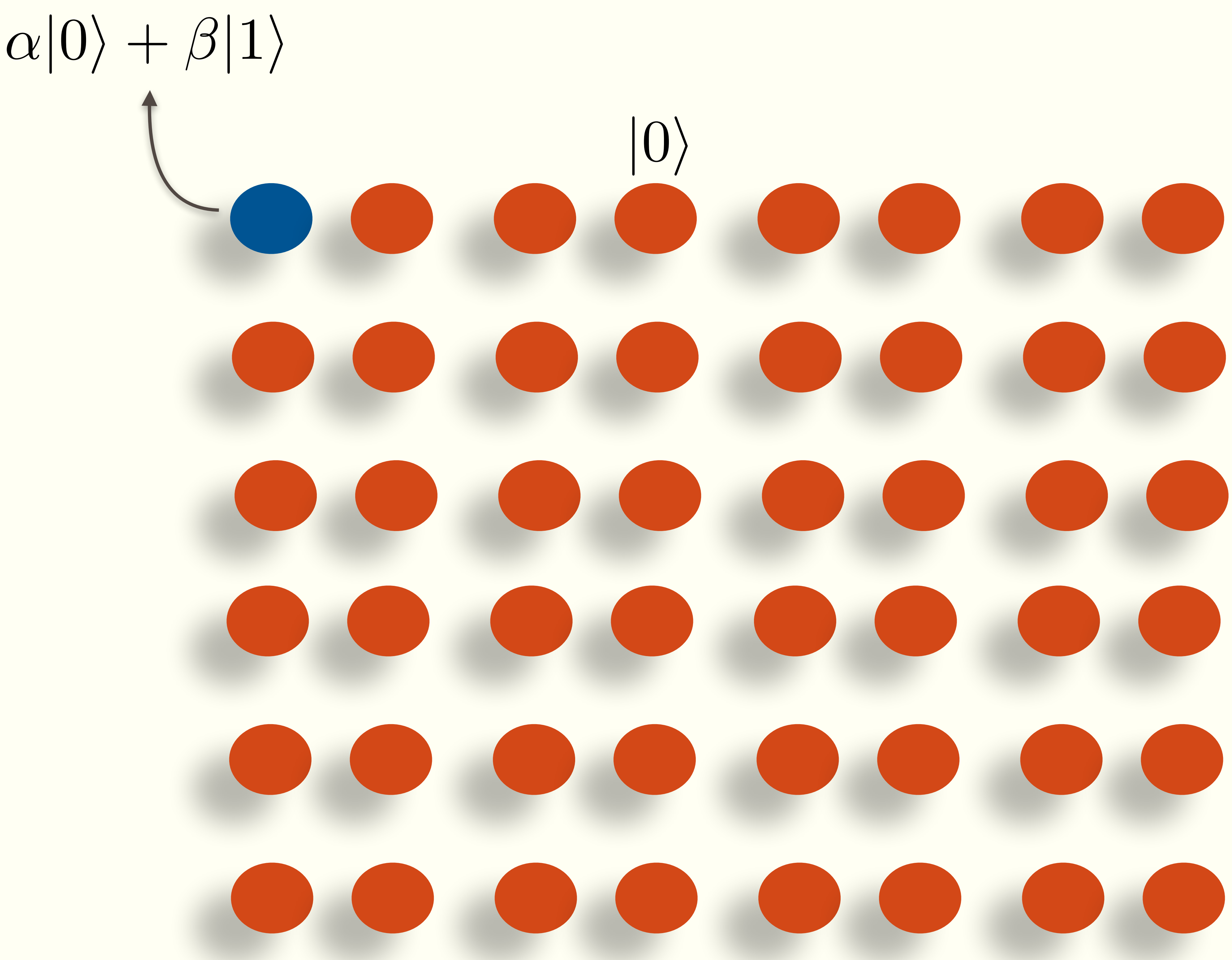

Iran, Iraq, and Kuwait
0 100 200 300 400
Kilometers
© World Sites Atlas (sitesatlas.com)
ARMENIA
Yerevan
AZERBAIJAN
Baku
UZBEKISTAN
TURKMENISTAN
Ashgabat
TURKEY
Araks
Caspian Sea
Tabriz
Ardabil
Lake Urmia
Urmia
Rasht
Atrek
Tigris
Zanjan
Mosul
Irbil
Qazvin
Mashhad
Euphrates
Karaj
Tehran
Kirkuk
As Sulaymaniyah
SYRIA
Sanandaj
Hamadan
Qom
Kermanshah
Samarra'
Lake Tharthar
IRAQ
Arak
Ar Ramadi
Khorramabad
IRAN
Baghdad
AFGHANISTAN
Esfahan
Karbala'
Al Hillah
Al Kut
JORDAN
Ad Diwaniyah
An Najaf
Yazd
Al 'Amarah
Euphrates
Tigris
Ahvaz
An Nasiriyah
Karun
Basra
Kerman
Shiraz
Zahedan
Kuwait City
KUWAIT
PAKISTAN
Bandar-e Abbas
SAUDI ARABIA
Persian Gulf
Qeshm
Strait of Hormuz
Manama
BAHRAIN
QATAR
Doha
UNITED ARAB EMIRATES
Riyadh
Abu Dhabi
OMAN
Arabian Sea
INDIAN OCEAN

Iran

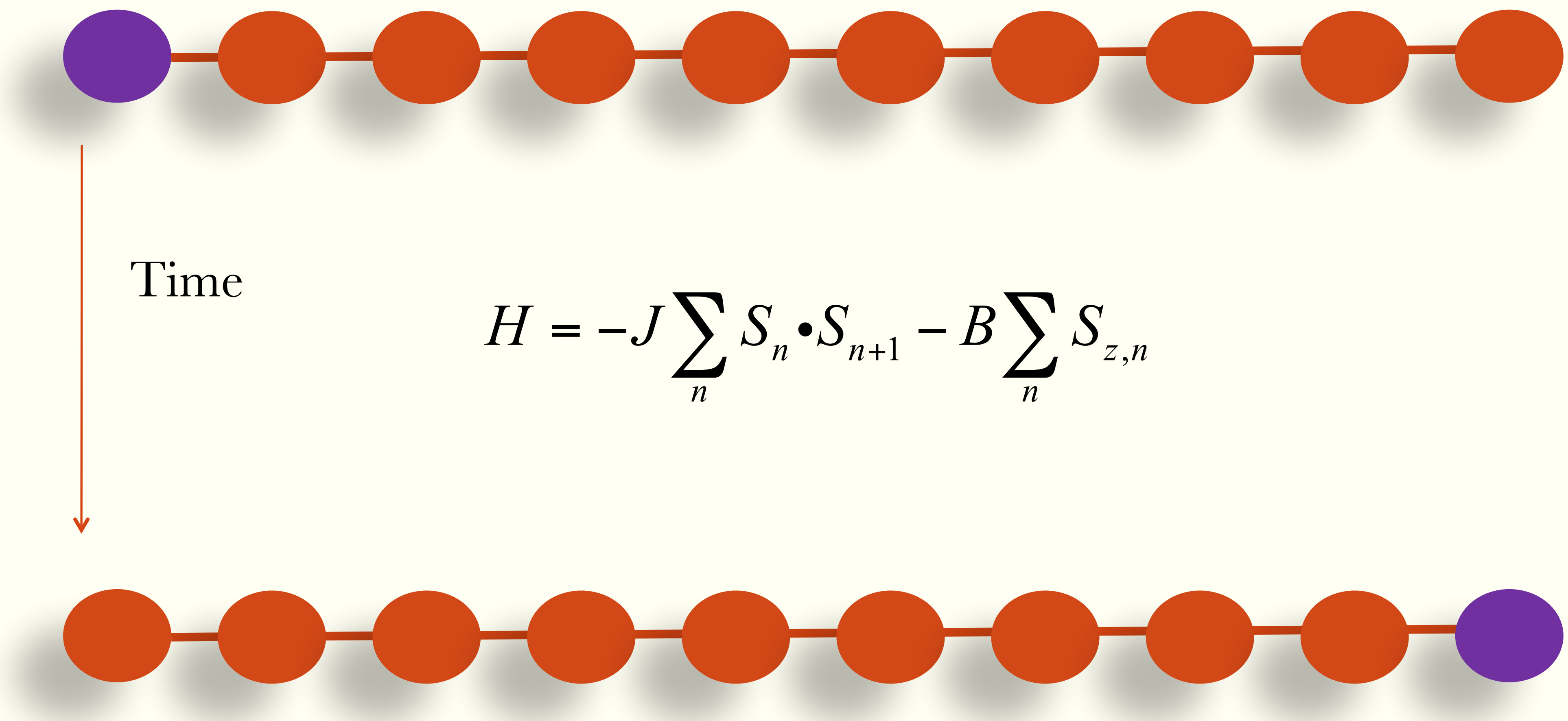
Take it to the bridge: the Tehran architect striking the right chord in Iran and beyond

Leila Araghian was 26 when she came up with Tabiat bridge. Five years on, the 270-metre structure is a reality, despite sanctions, garnering awards and paving the way for a new, more avant garde generation of Iranian designers




$\alpha|0\rangle + \beta|1\rangle$
$|0\rangle$

State Transfer Through Heisenberg Chains



$$H = -J\sum_{n} S_{n} \bullet S_{n+1} - B\sum_{n} S_{z,n}$$

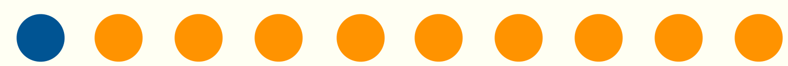
S. Bose, Quantum Communication Through an Unmodulated Spin Chain, Phys. Rev. Lett. **91**, 207901 (2003).

$|0\rangle =$ 

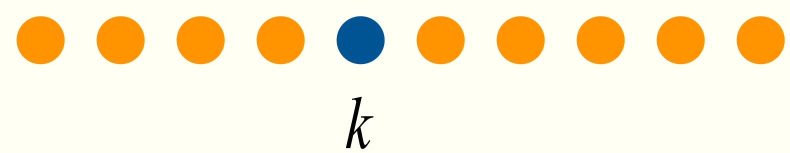
$|g.s.\rangle = |$  $\rangle$

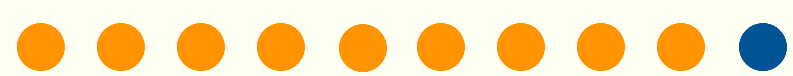
$|1\rangle =$ 

$$H|g.s.\rangle = 0$$

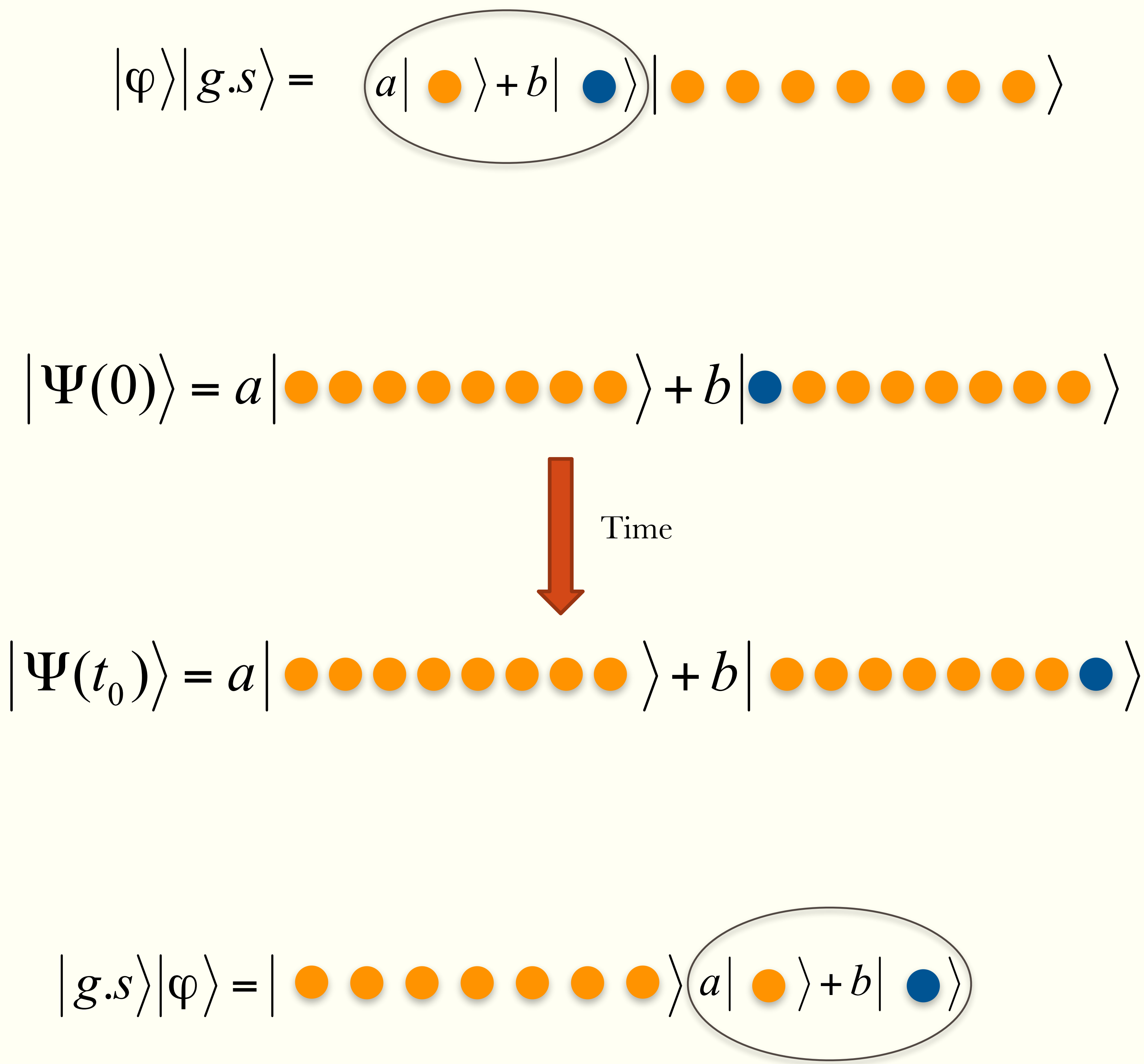
$|1\rangle = |$  $\rangle$

$$[H, S_z] = 0$$

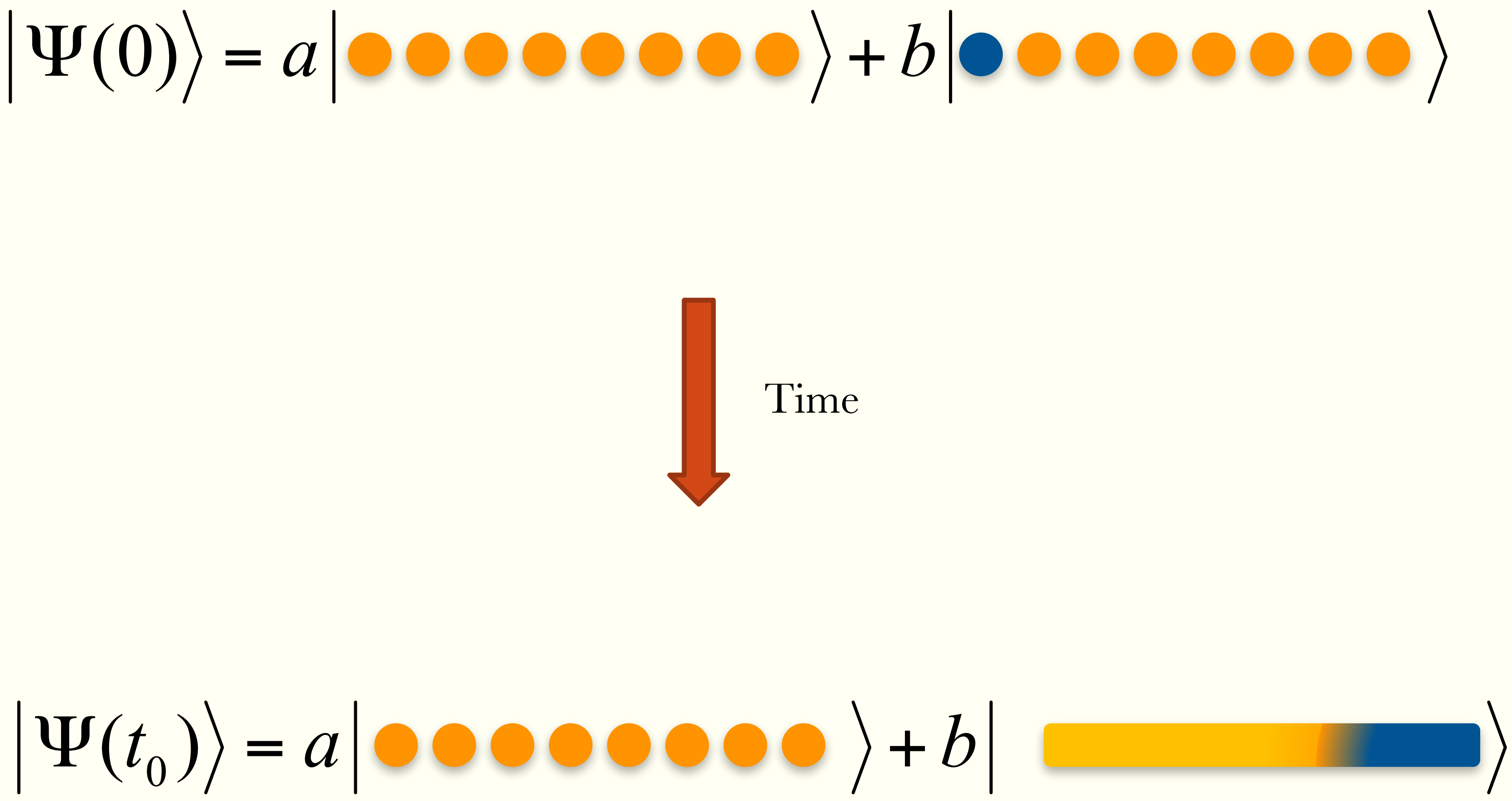
$|k\rangle = |$  $\rangle$

$|N\rangle = |$  $\rangle$

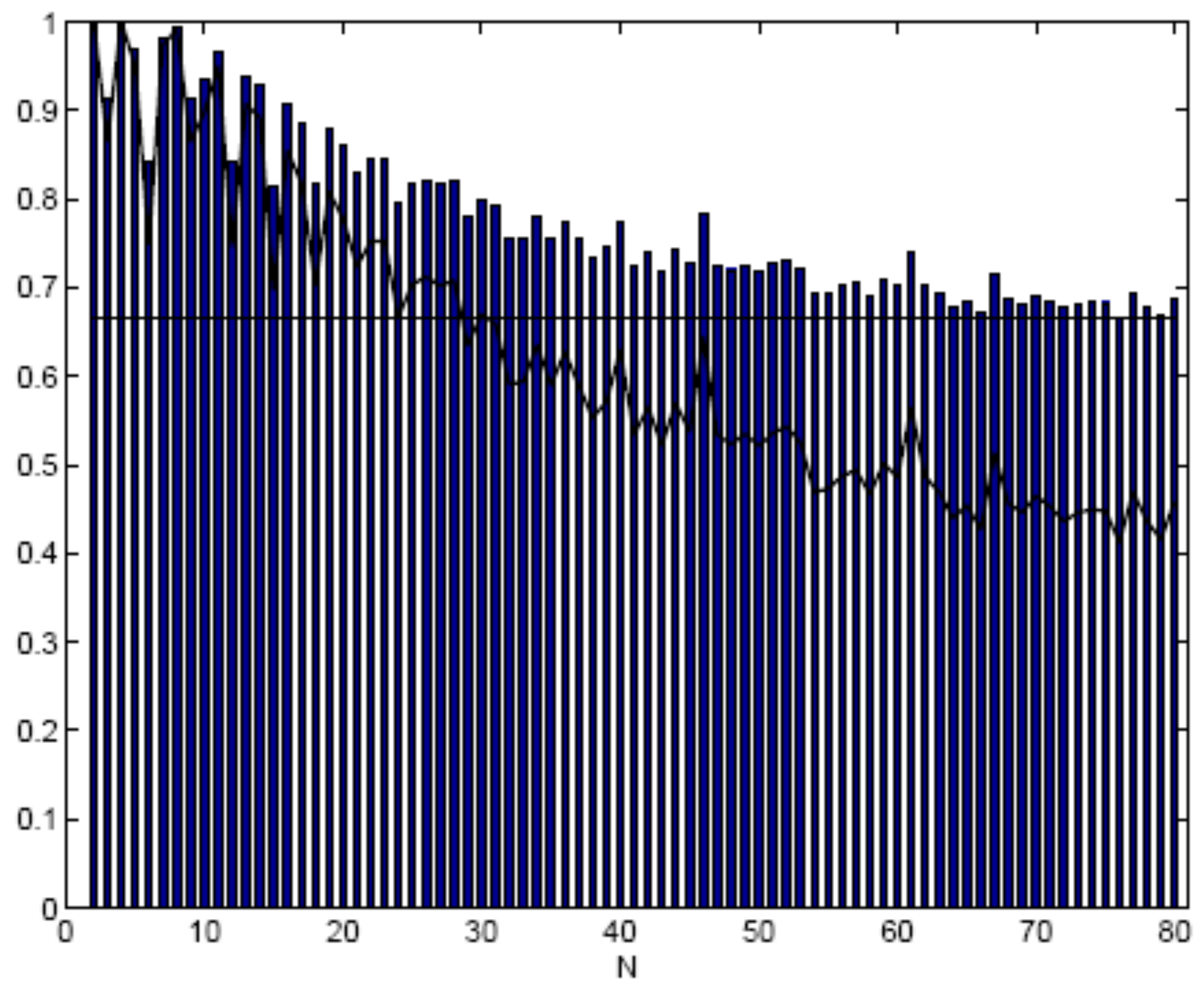
What we like to happen



What actually happens



$$\overline{F(\varphi, \rho_N)} =$$



$$\frac{2}{3}$$

$$H = -J \sum_n x_n x_{n+1} + y_n y_{n+1}$$

$$h_i = \frac{1}{2}(X_i X_{i+1} + Y_i Y_{i+1})$$

$$h|0,0\rangle = 0$$

$$h|0,1\rangle = |1,0\rangle$$

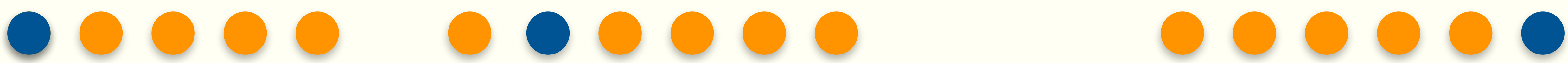
$$h|1,1\rangle = 0$$

$$h|1,0\rangle = |0,1\rangle$$

$$h = |1,0\rangle\langle 0,1| + |0,1\rangle\langle 1,0|$$

Perfect State Transfer

A clever Idea, Rotation in Spin Space



$$\begin{pmatrix}1\\0\\0\\.\\.\\0\end{pmatrix} \qquad \begin{pmatrix}0\\1\\0\\.\\.\\0\end{pmatrix} \qquad \cdots\cdots \qquad \begin{pmatrix}0\\0\\0\\.\\.\\1\end{pmatrix}$$

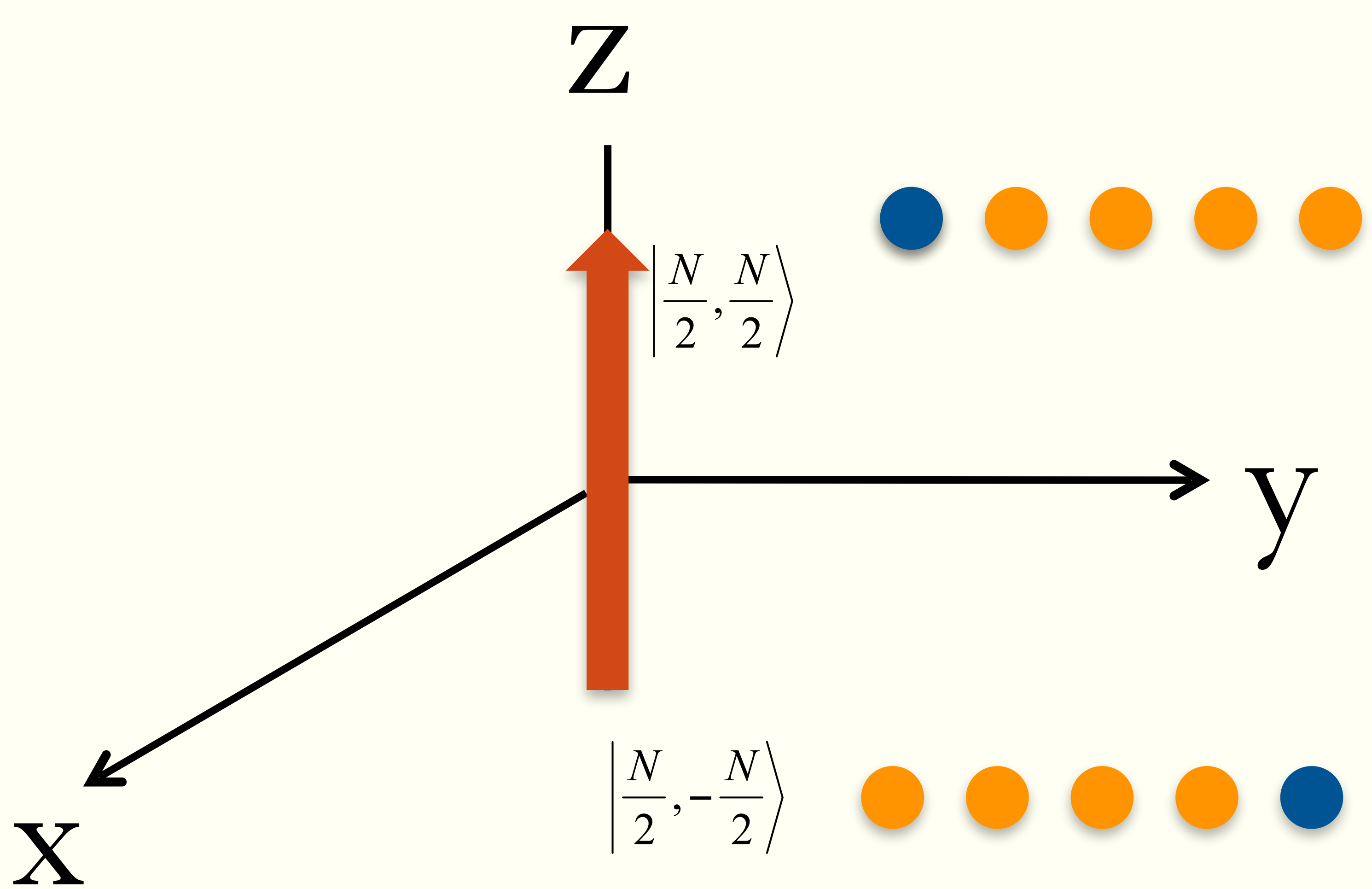
$\left|\frac{N}{2},\frac{N}{2}\right\rangle$ $\qquad$ $|l,m\rangle$ $\qquad$ $\left|\frac{N}{2},-\frac{N}{2}\right\rangle$

- Christandl, Datta, Ekert, Sandahl, Physical Review Letters, 2004.

$$If \quad H = S_x$$

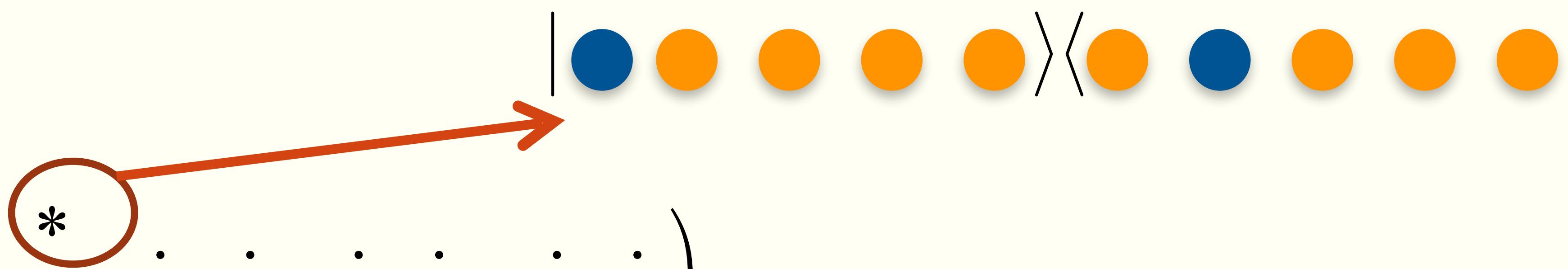
$$and \quad t_0 = \pi$$

$$e^{-iHt_0} = e^{-i\pi S_x}$$



Is the Hamiltonian Local?

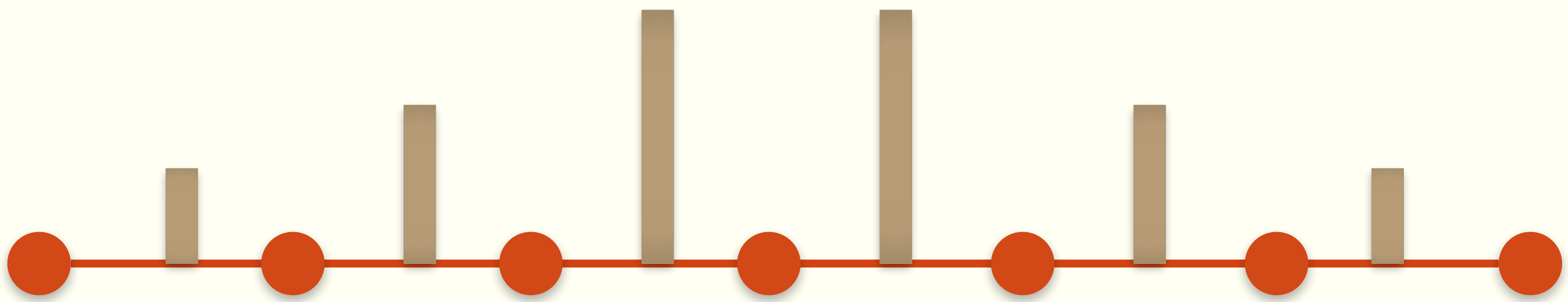
Yes, the Hamiltonian is Local



$$H = S_x = L_+ + L_- = \begin{pmatrix} \cdot & * & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ * & \cdot & * & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & * & \cdot & * & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & * & \cdot & * & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & * & \cdot & * & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & * & \cdot & * & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & * & \cdot & * \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & * & \cdot \end{pmatrix}$$

Perfect State Transfer in long chains

$$H = \frac{1}{2}\sum_{k=1}^{N} J_k(x_k x_{k+1} + y_k y_{k+1})$$



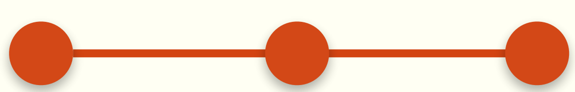
$$J_k = J\sqrt{k(N-k)}$$

- Christandl, Datta, Ekert, Sandahl, Physical Review Letters, 2004.

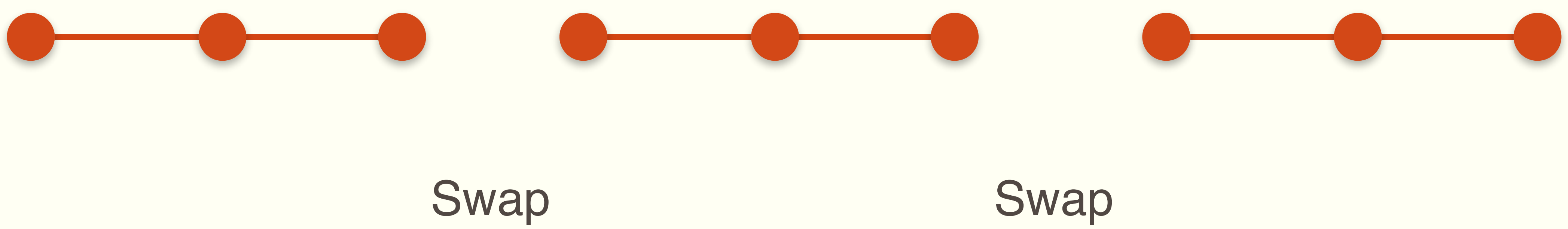
Can we use uniform couplings?

- Perfect state transfer in small chains

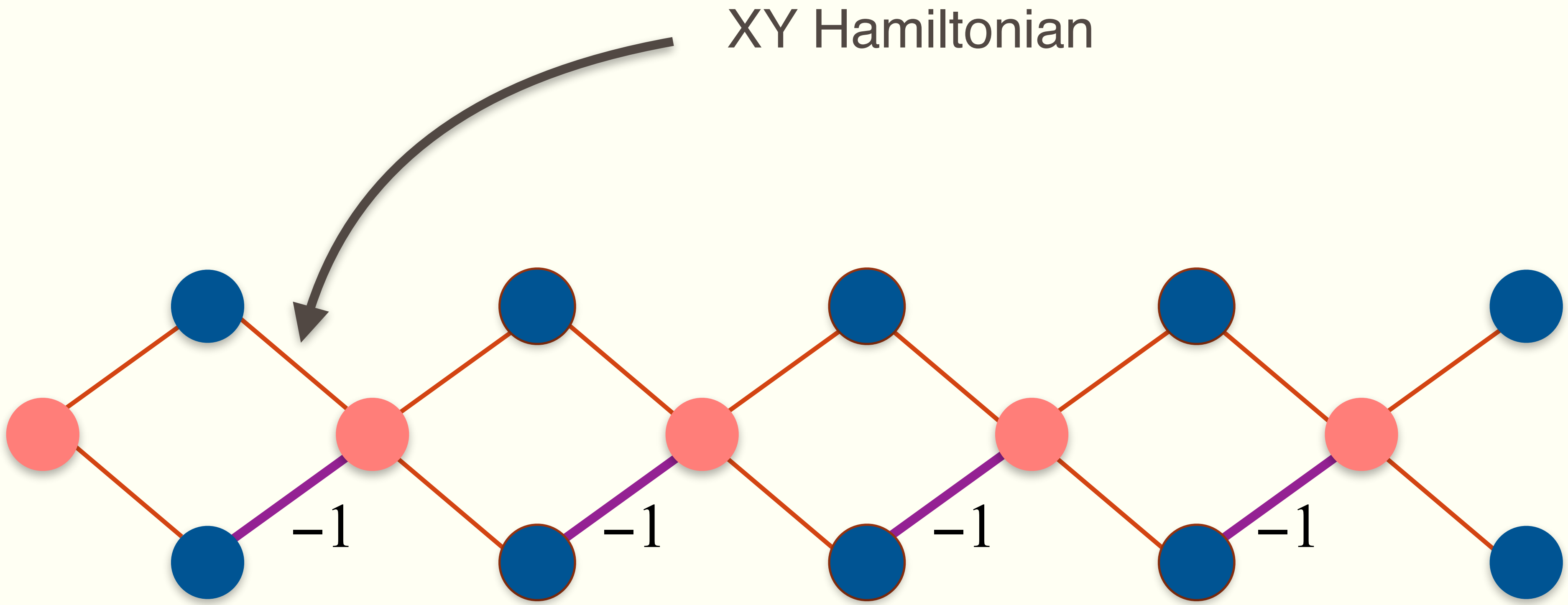
$$S_x = \frac{1}{2}\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$$



$$S_x = \frac{1}{\sqrt{2}}\begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}$$


Swap
Swap

Almost uniform couplings



- Pemberton-Ross and Kay, Physical Review Letters, 2011.

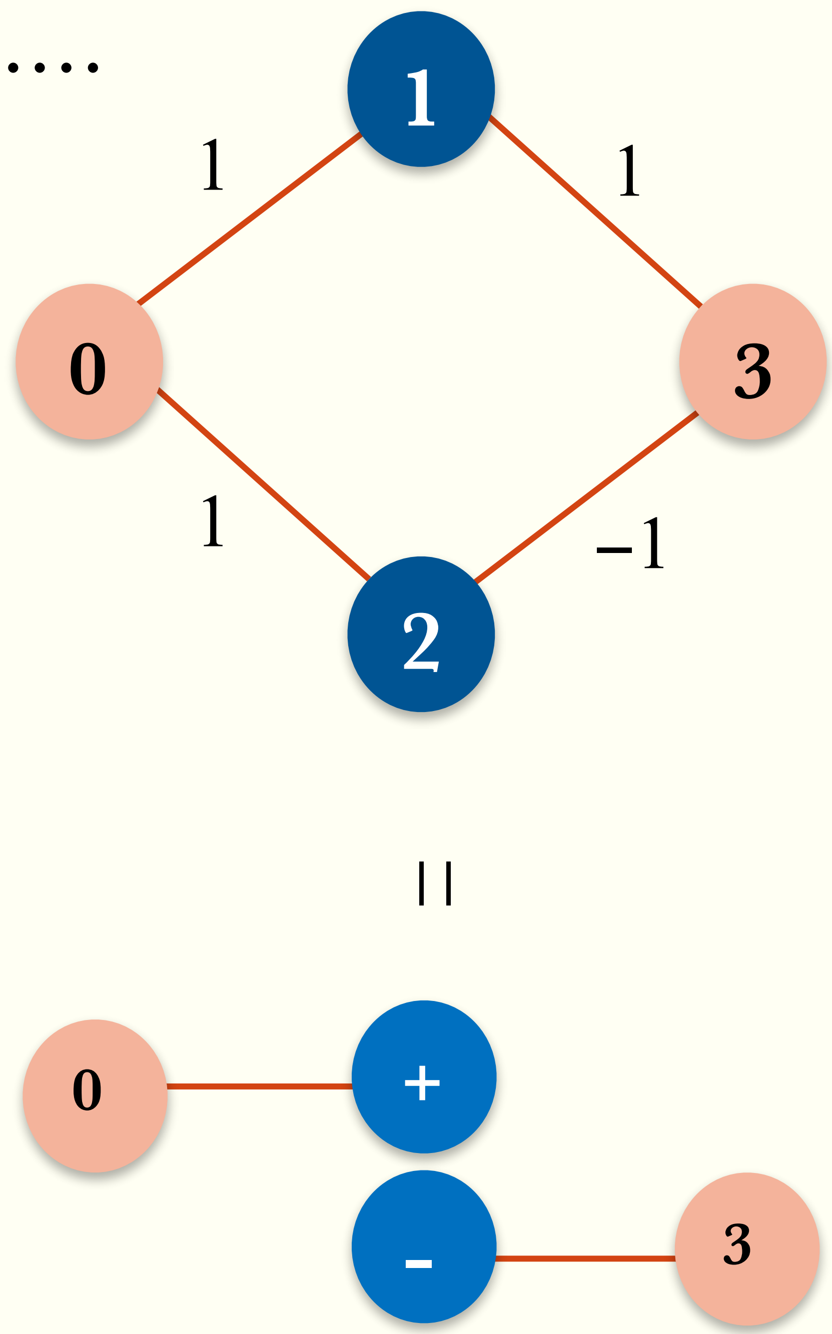
The basic idea

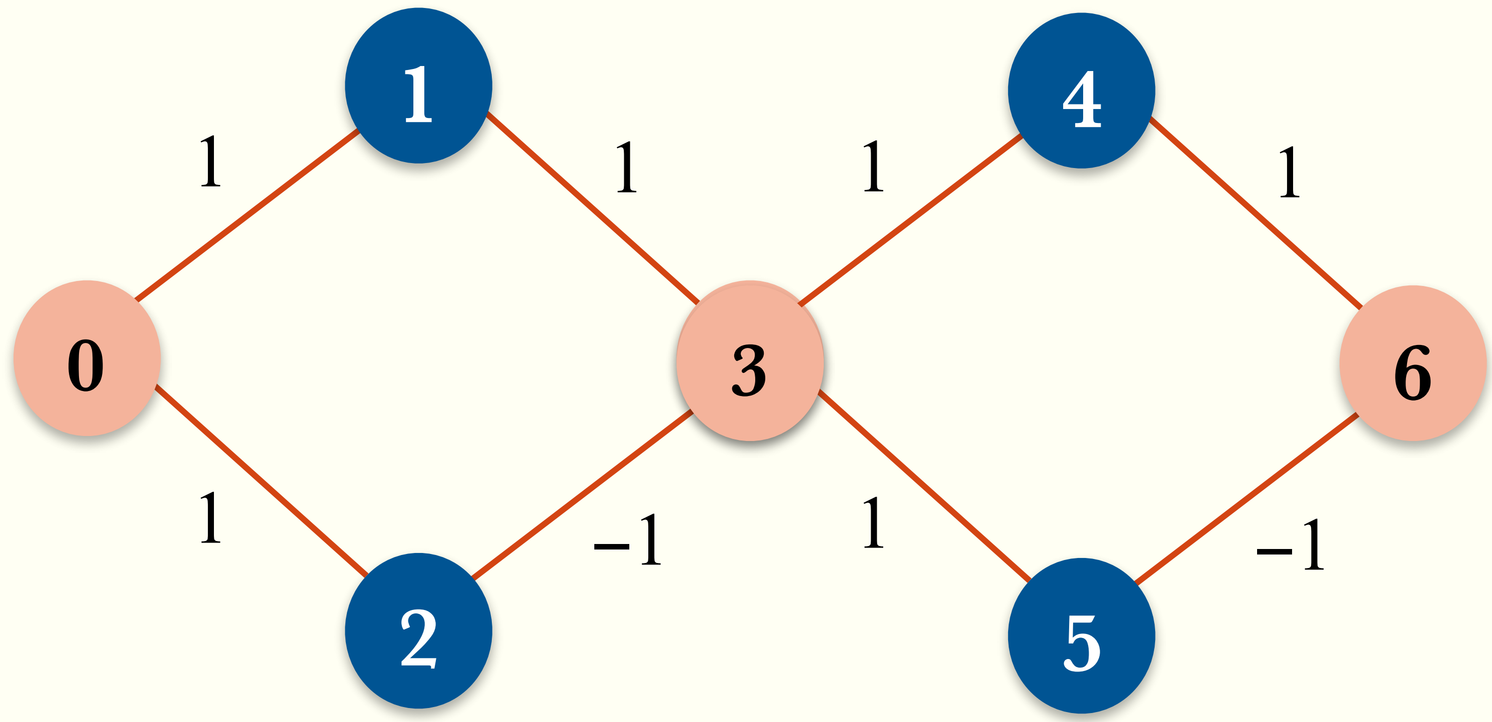
$$h = |0\rangle\langle 1| + |0\rangle\langle 2| + |1\rangle\langle 3| - |2\rangle\langle 3| + \ldots.$$

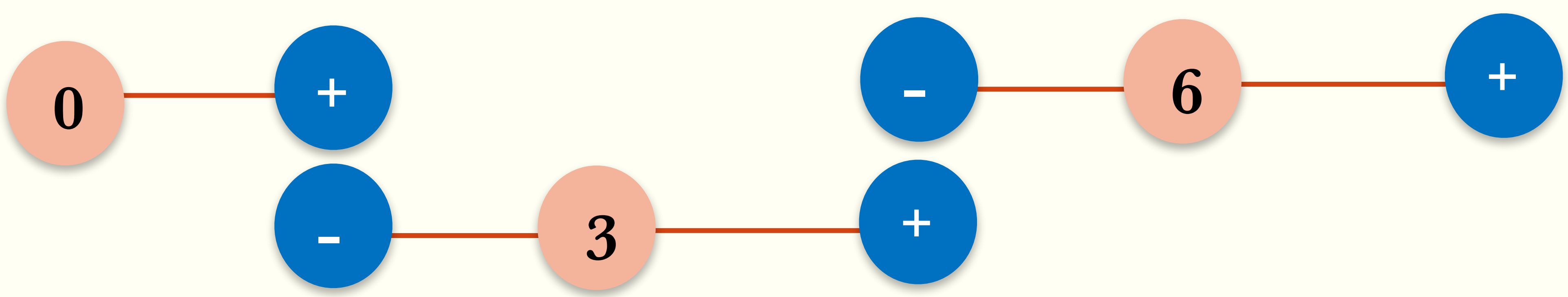
$$|+\rangle = |1\rangle + |2\rangle$$

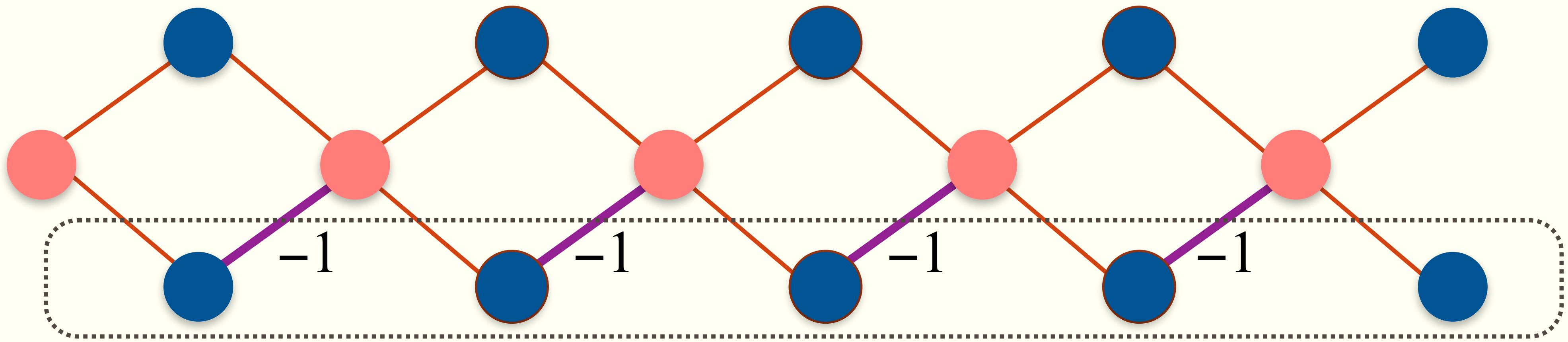
$$|-\rangle = |1\rangle - |2\rangle$$

$$h = |0\rangle\langle +| \quad + \quad |-\rangle\langle 3|$$




0
1
2
3
4
5
6
1
1
1
−1
1
1
1
−1


0
+
-
3
+
-
6
+

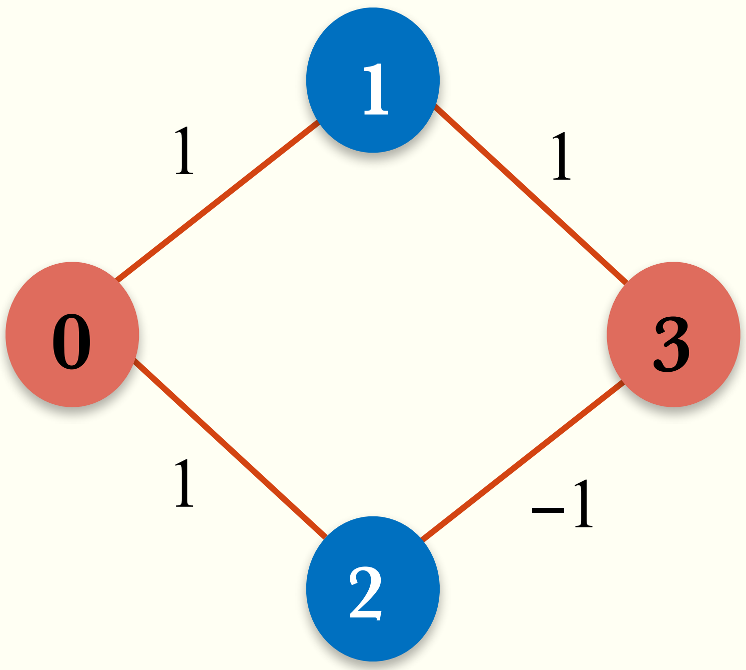


$$z_1 z_2 \cdots z_N |00\cdots1\cdots00\rangle = -|00\cdots1\cdots00\rangle$$

A simple Twist

Karimipour, Sarmadi and Asoudeh, Physical Review (R), 2012.

Hadamard Switch



$$|+\rangle = |1\rangle + |2\rangle$$

$$|-\rangle = |1\rangle - |2\rangle$$

$$H = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$$

The next Hadamard Matrix

$$H = \frac{1}{2}\begin{pmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & 1 & -1 \\ 1 & -1 & -1 & 1 \end{pmatrix}$$

$$|\xi_0\rangle = |0\rangle + |1\rangle + |2\rangle + |3\rangle$$

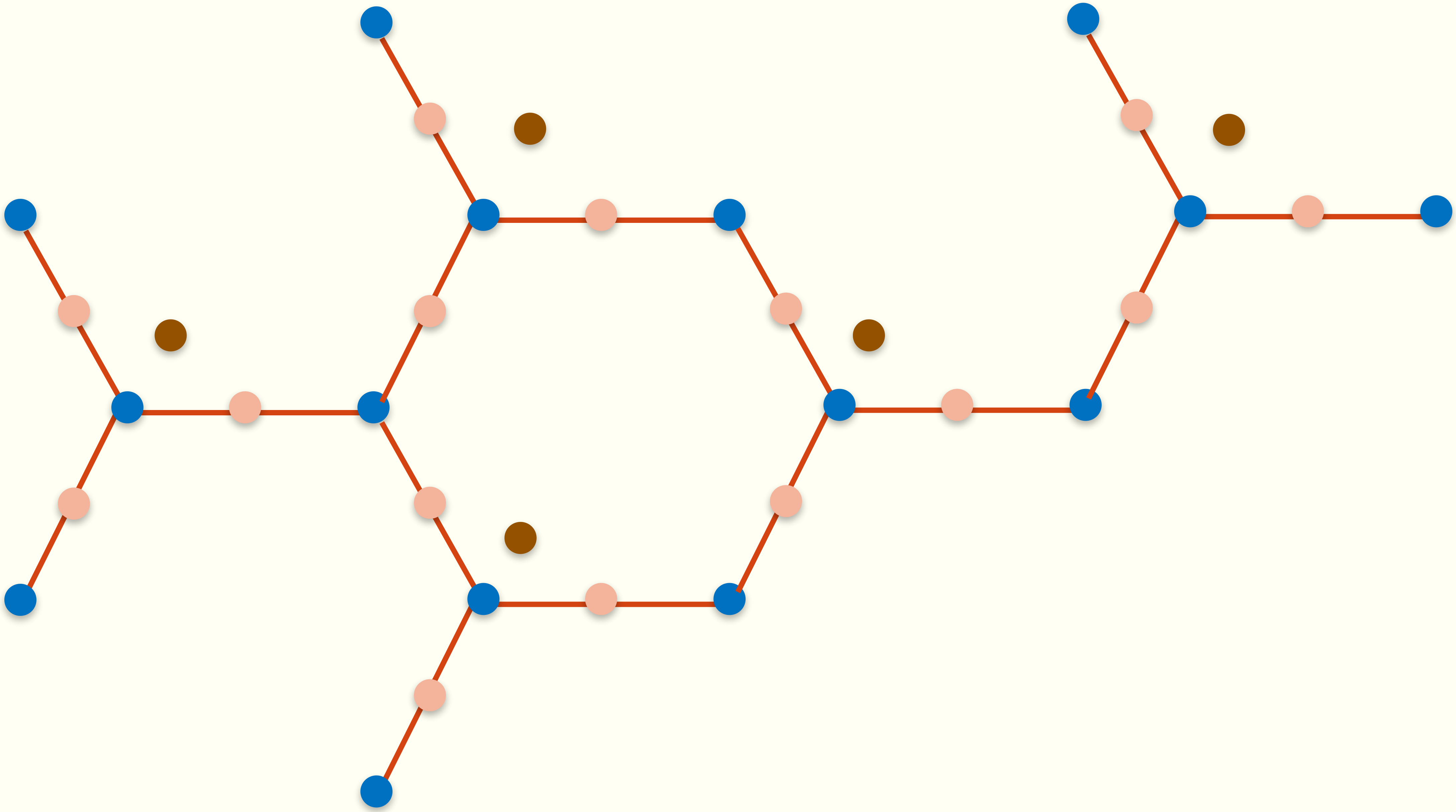
$$|\xi_1\rangle = |0\rangle + |1\rangle - |2\rangle - |3\rangle$$

$$|\xi_2\rangle = |0\rangle - |1\rangle + |2\rangle - |3\rangle$$

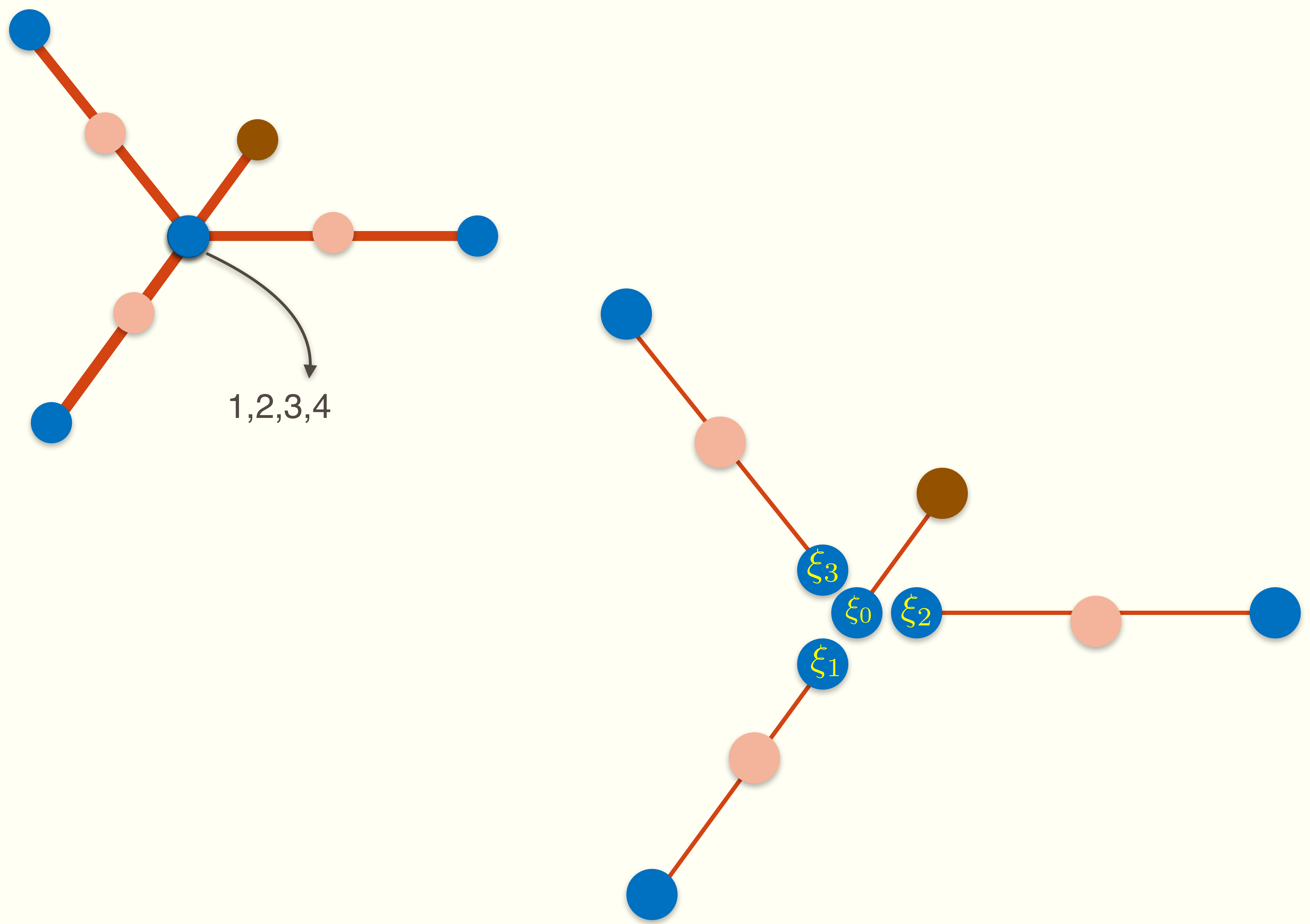
$$|\xi_3\rangle = |0\rangle - |1\rangle - |2\rangle + |3\rangle$$

Karimipour, Sarmadi and Asoudeh, Physical Review (R), 2012.

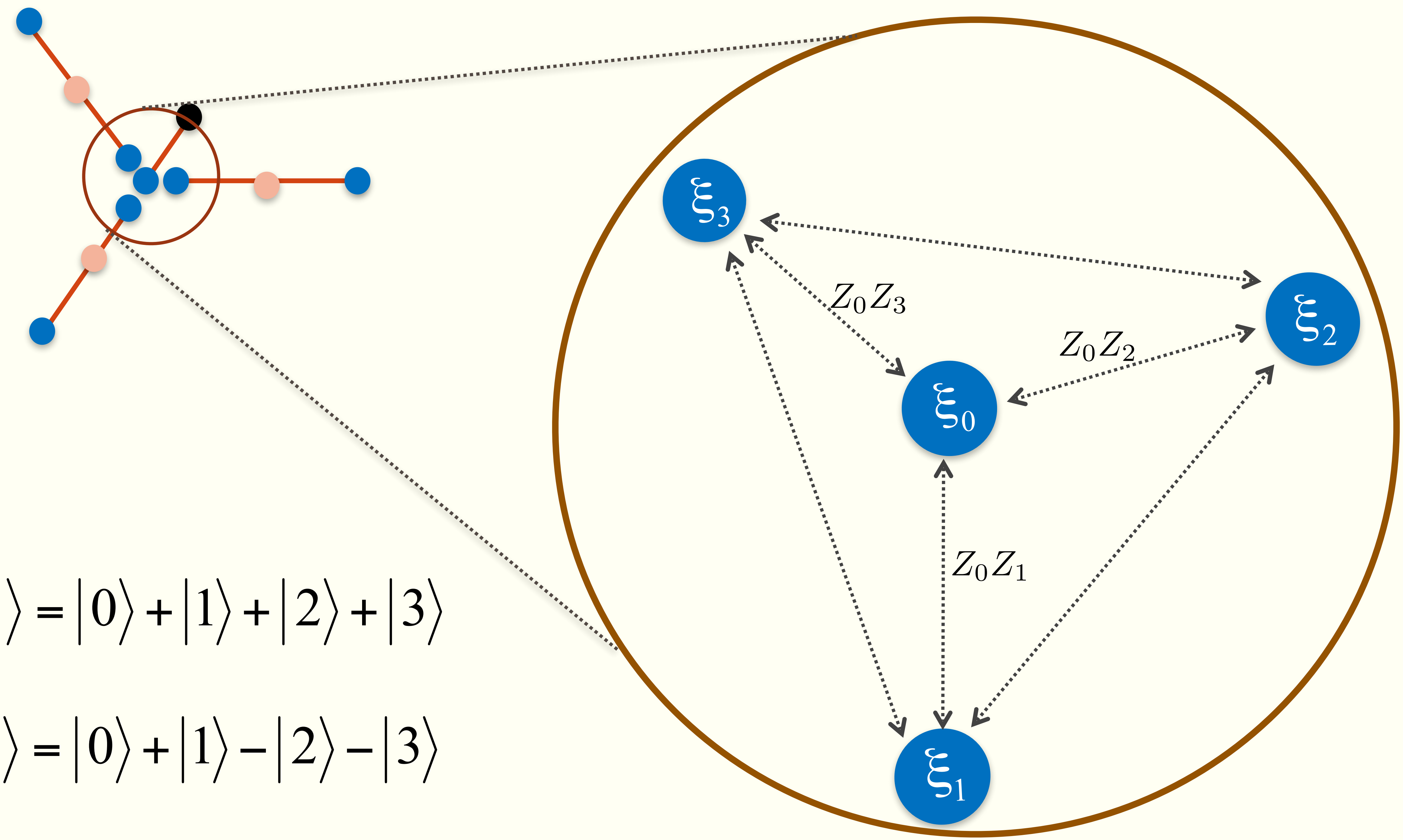
Perfect State Transfer in 2 and 3 dimensional lattices



- Karimipour, Sarmadi and Asoudeh, Physical Review(R), 2012.



1,2,3,4
ξ_3
ξ_0
ξ_2
ξ_1

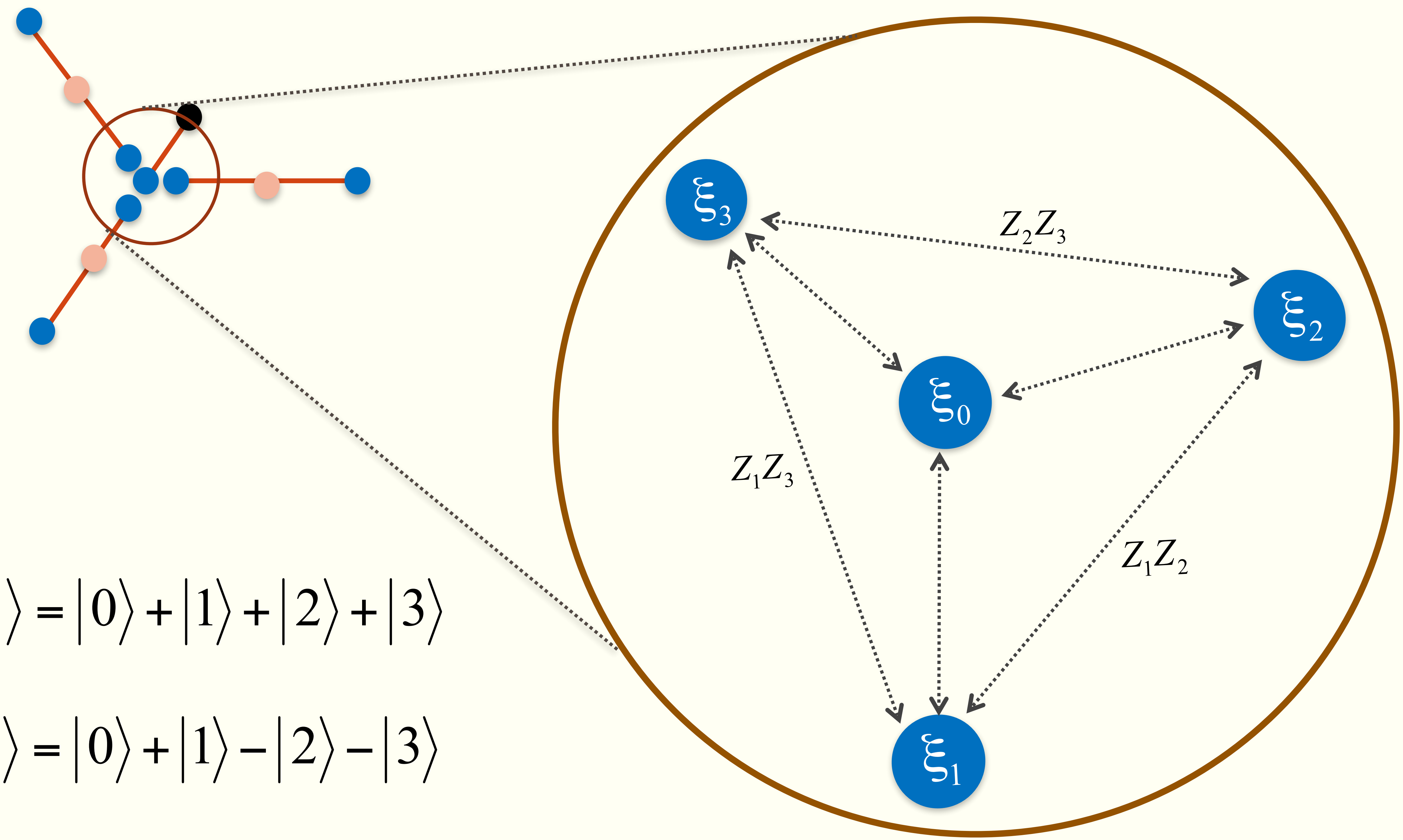


$$|\xi_0\rangle = |0\rangle + |1\rangle + |2\rangle + |3\rangle$$

$$|\xi_1\rangle = |0\rangle + |1\rangle - |2\rangle - |3\rangle$$

$$|\xi_2\rangle = |0\rangle - |1\rangle + |2\rangle - |3\rangle$$

$$|\xi_3\rangle = |0\rangle - |1\rangle - |2\rangle + |3\rangle$$

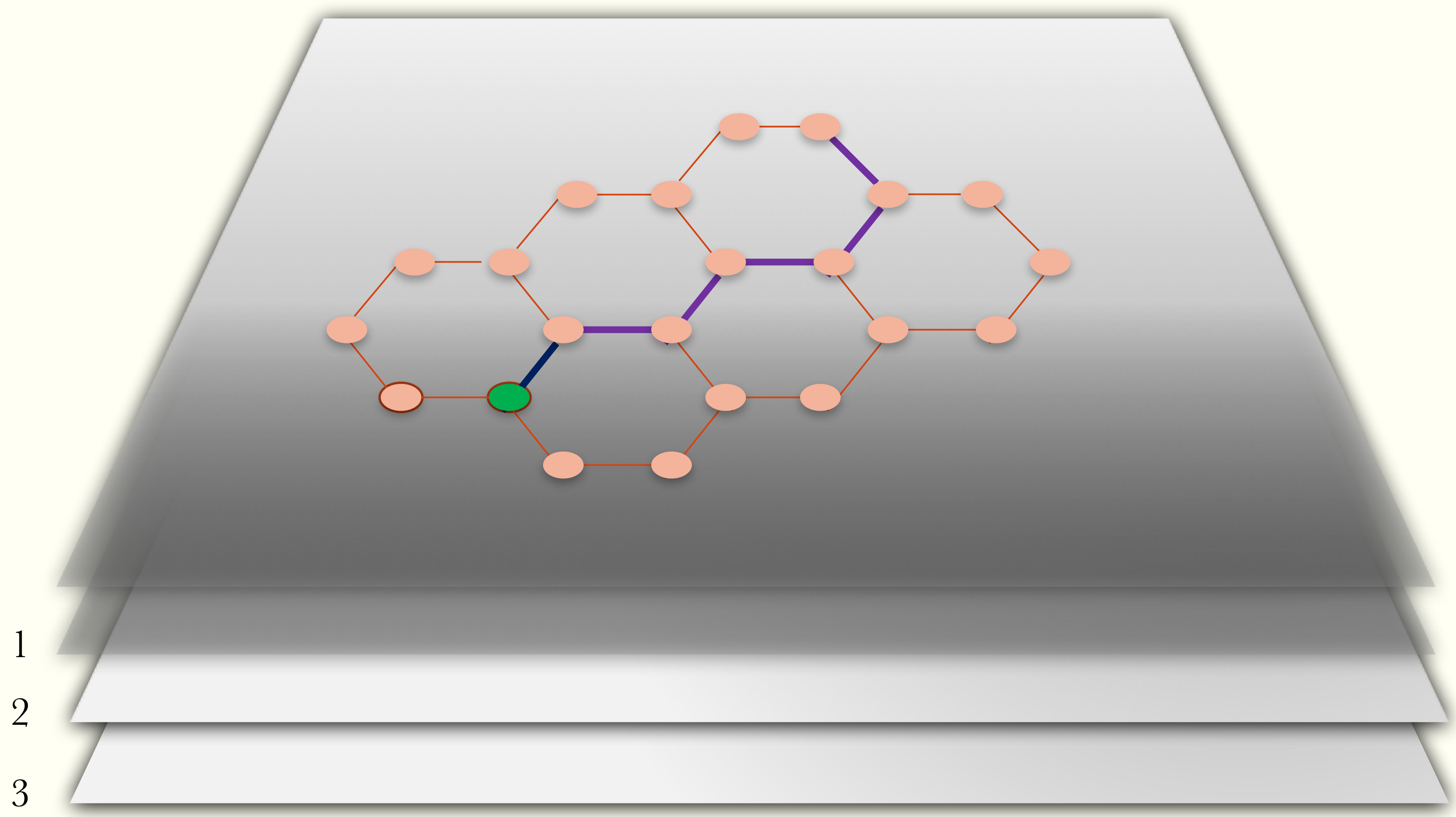


$$|\xi_0\rangle = |0\rangle + |1\rangle + |2\rangle + |3\rangle$$

$$|\xi_1\rangle = |0\rangle + |1\rangle - |2\rangle - |3\rangle$$

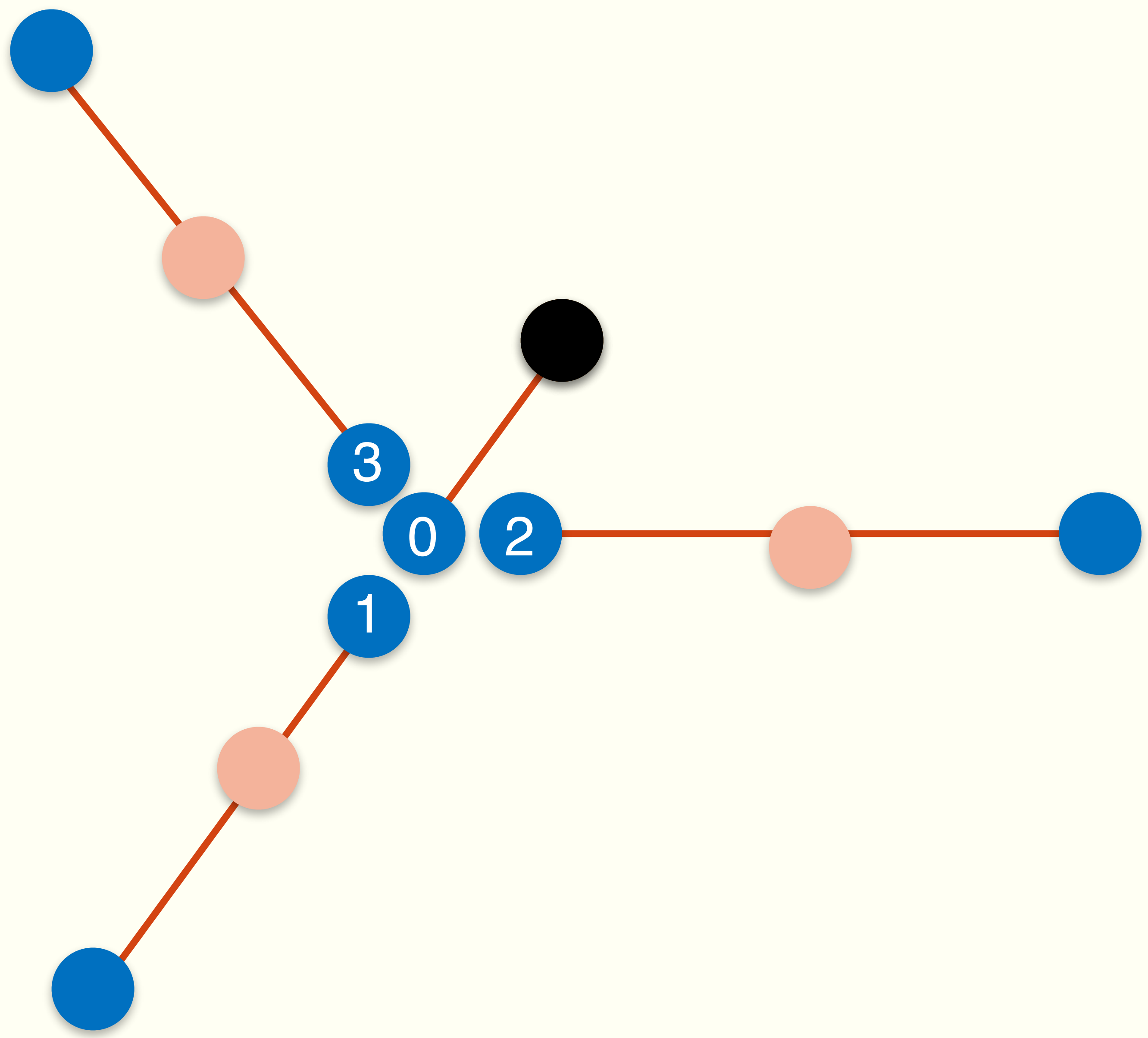
$$|\xi_2\rangle = |0\rangle - |1\rangle + |2\rangle - |3\rangle$$

$$|\xi_3\rangle = |0\rangle - |1\rangle - |2\rangle + |3\rangle$$

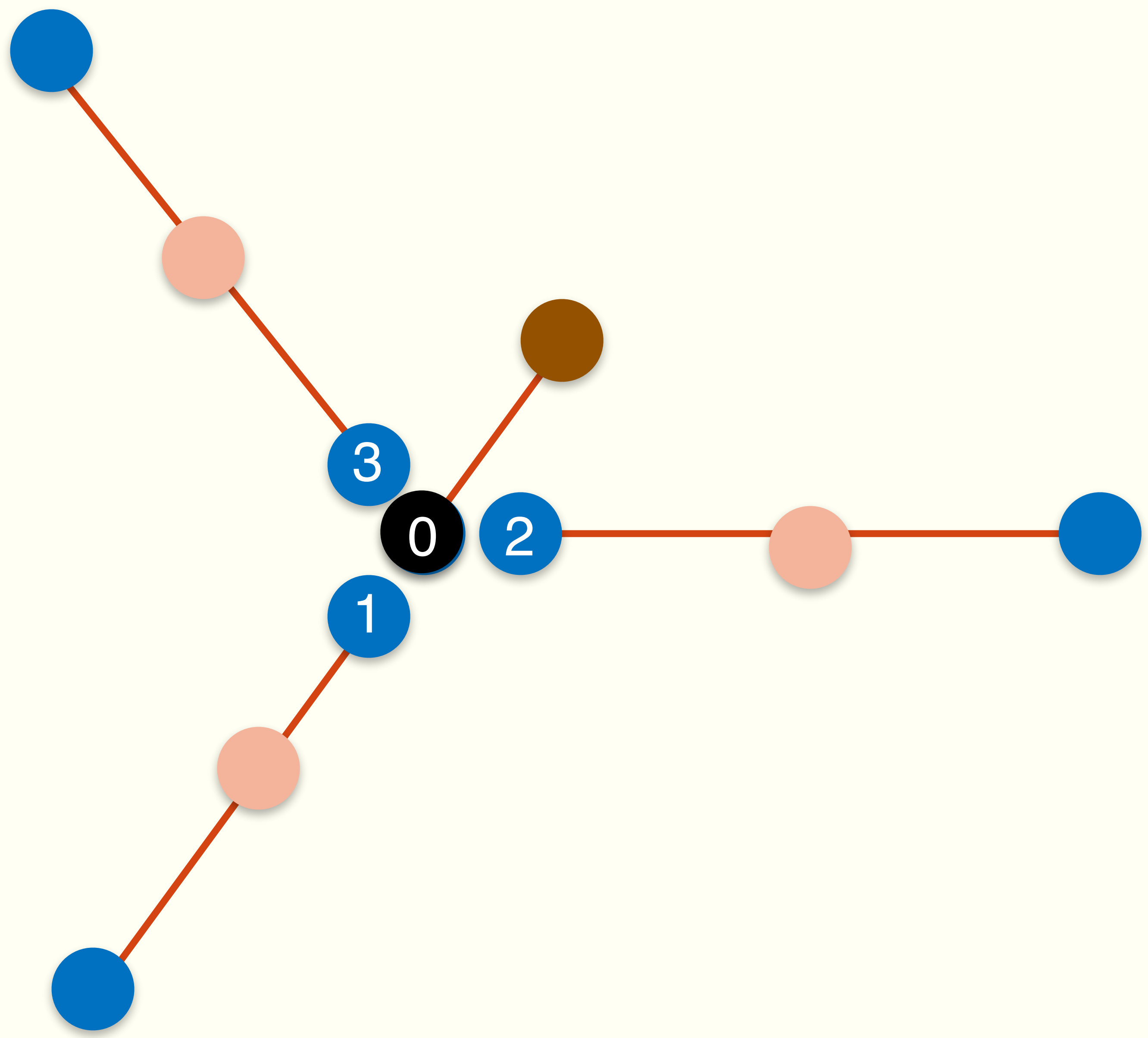


1
2
3

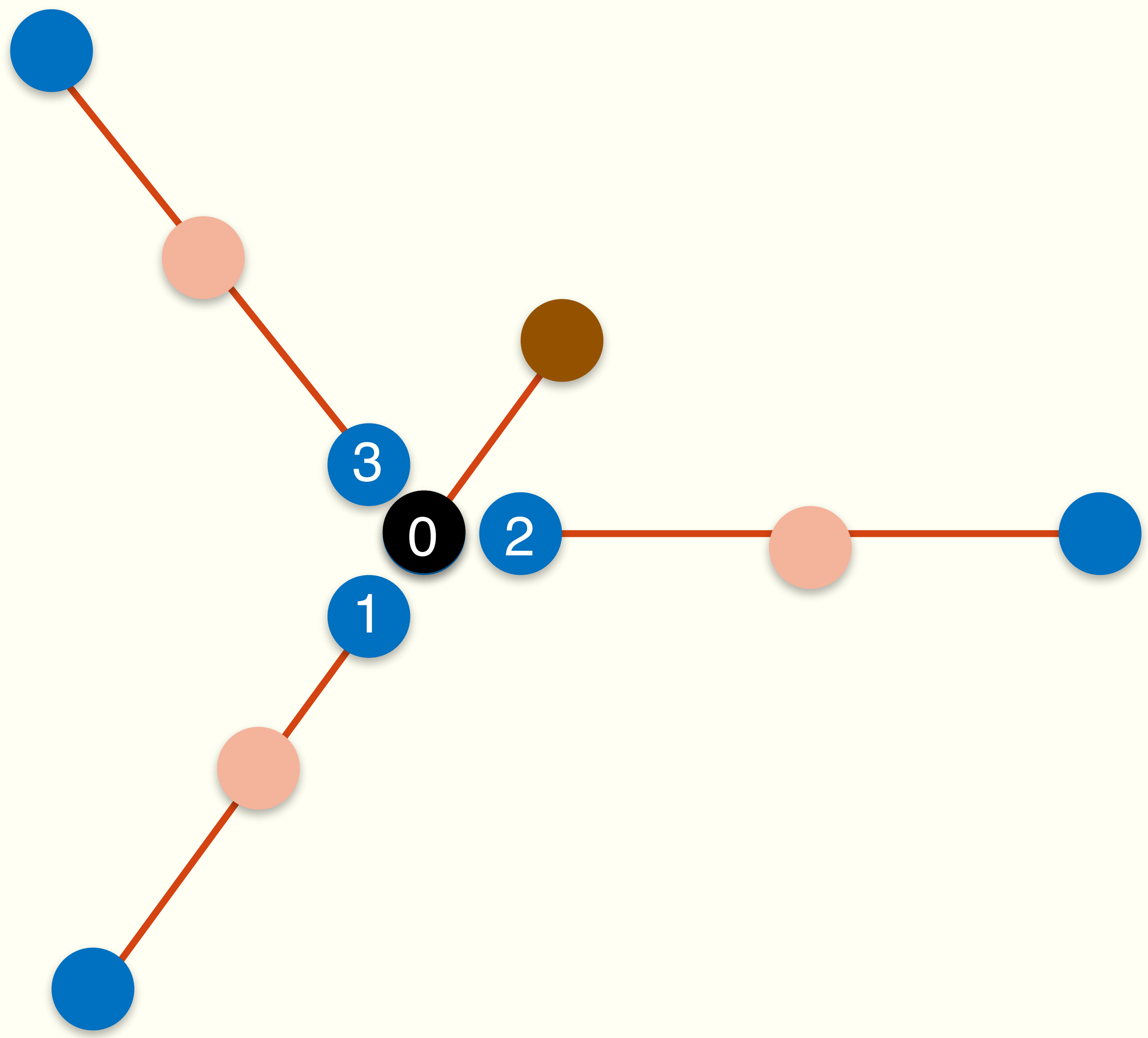
A particle is ready for uploading

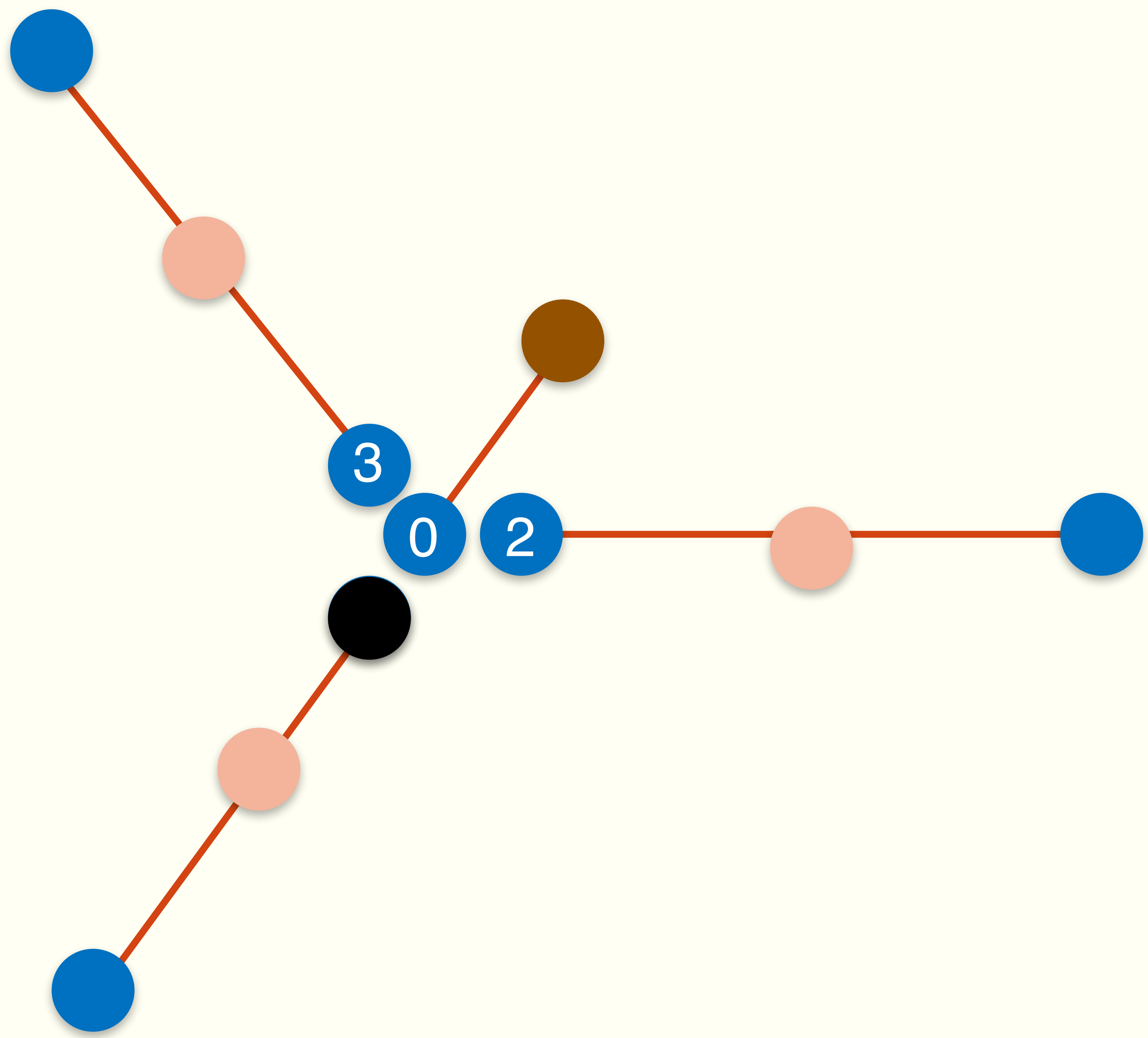


If we do nothing the particle stays there.

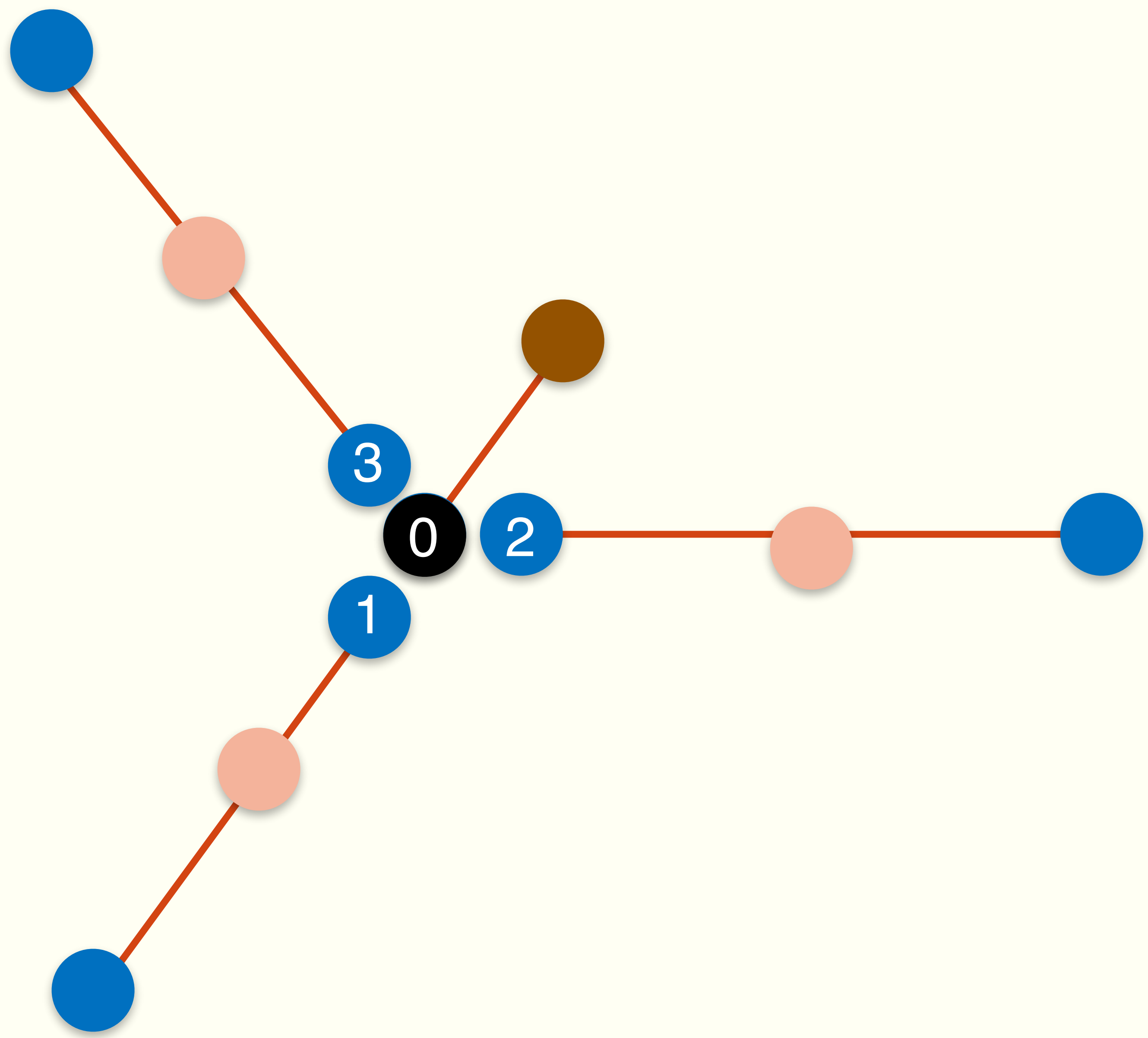


By a 0-1 pulse

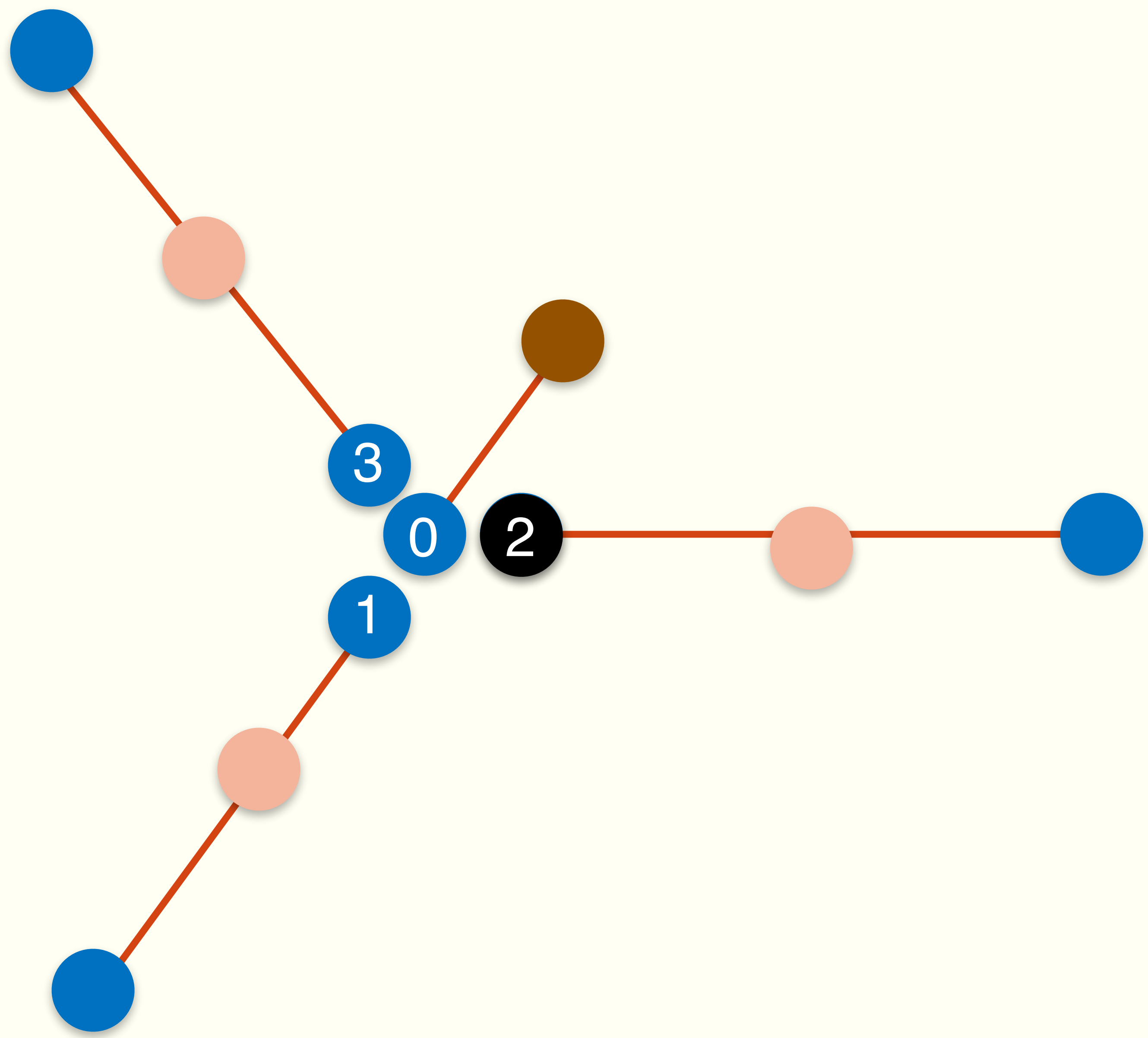


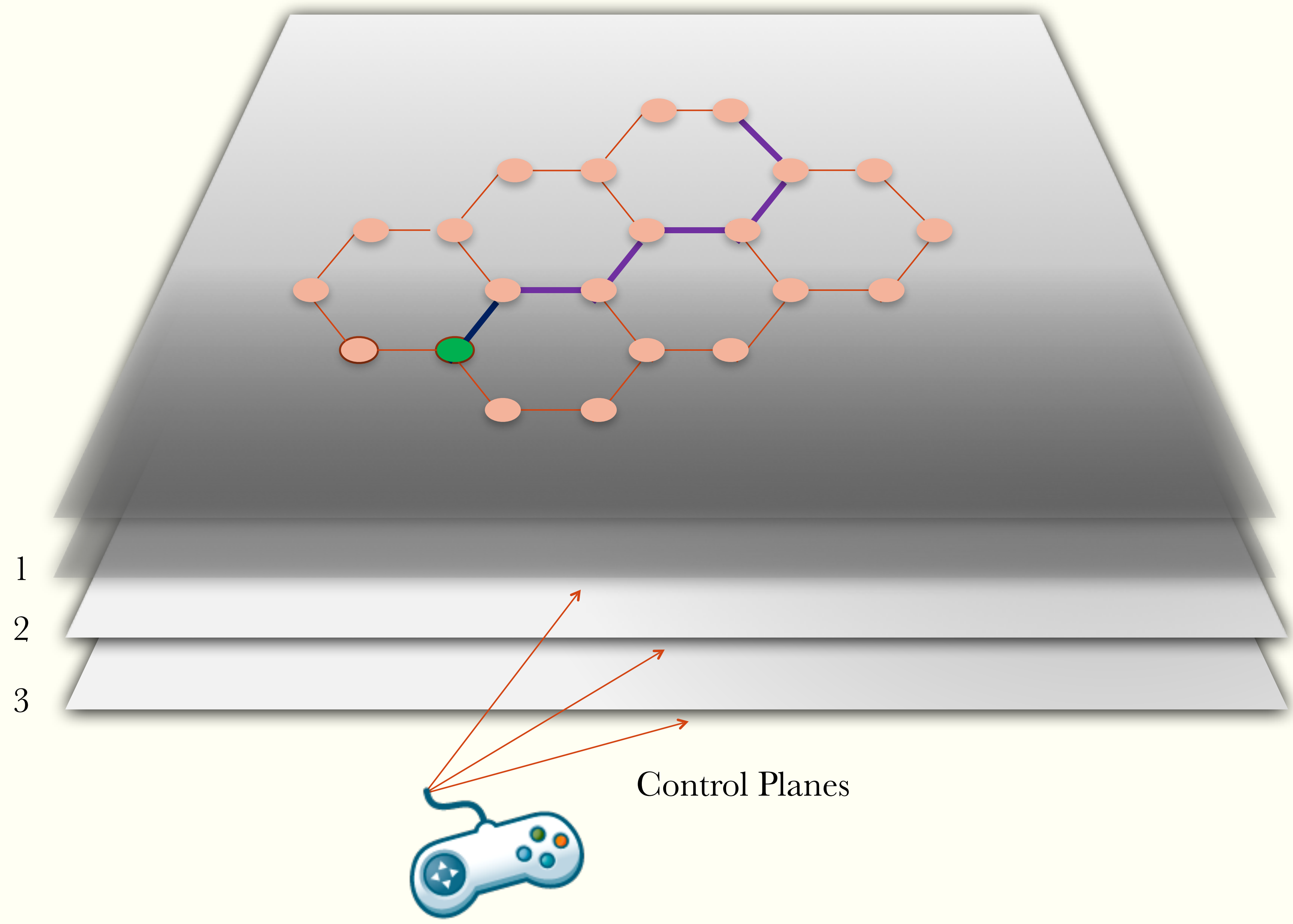

3
0
2

By a 0-2 pulse



By a 0-2 pulse

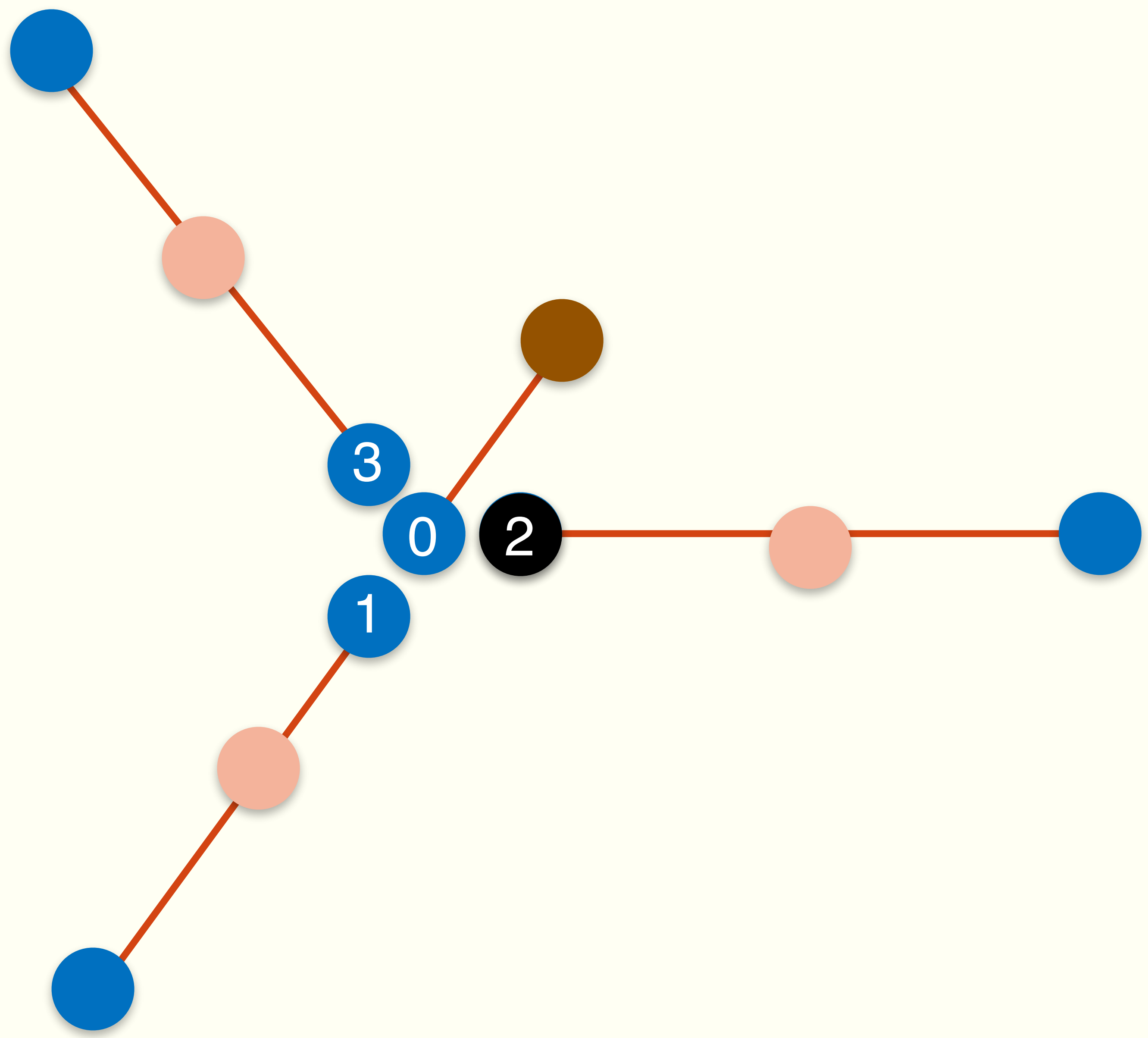


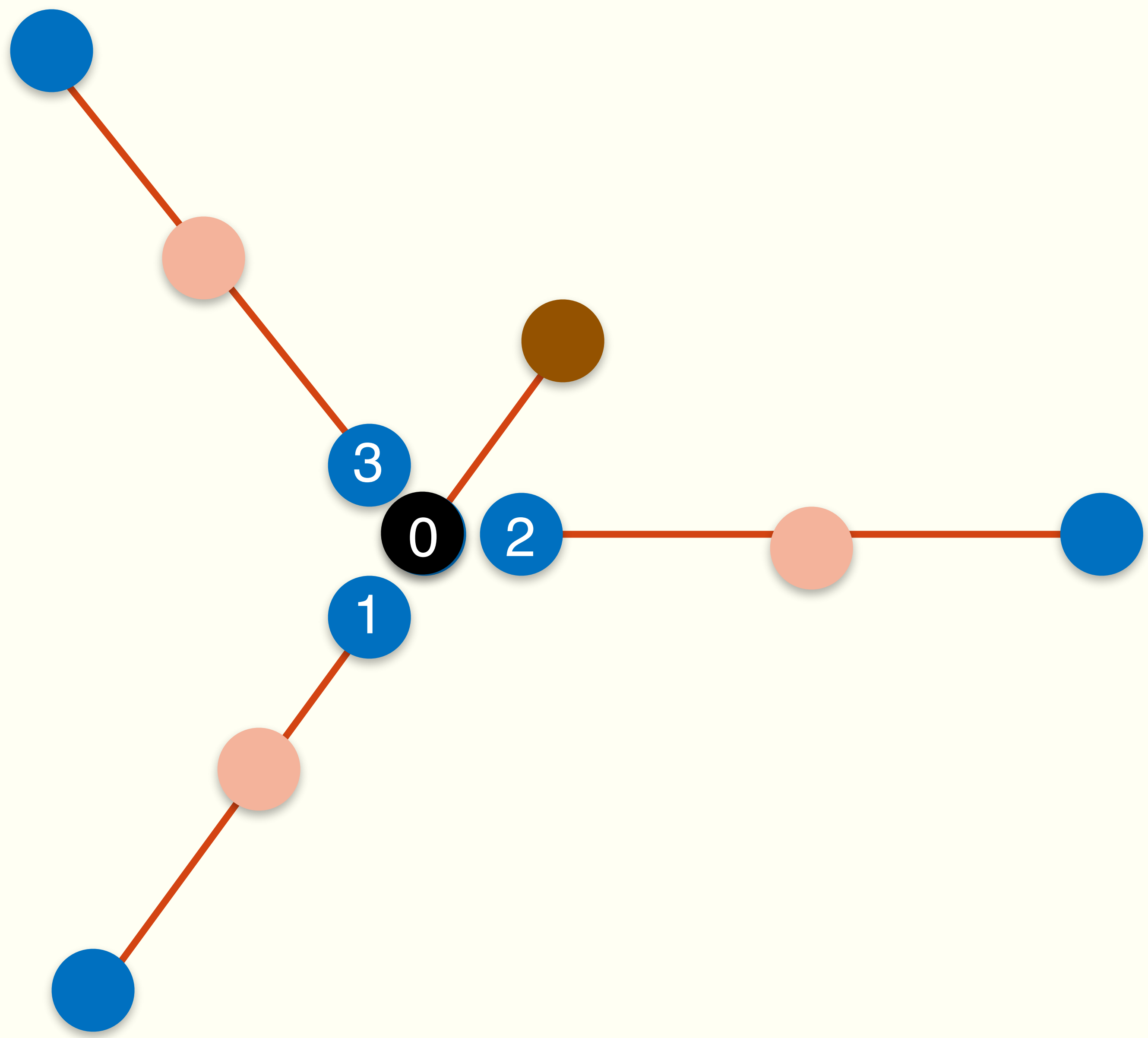


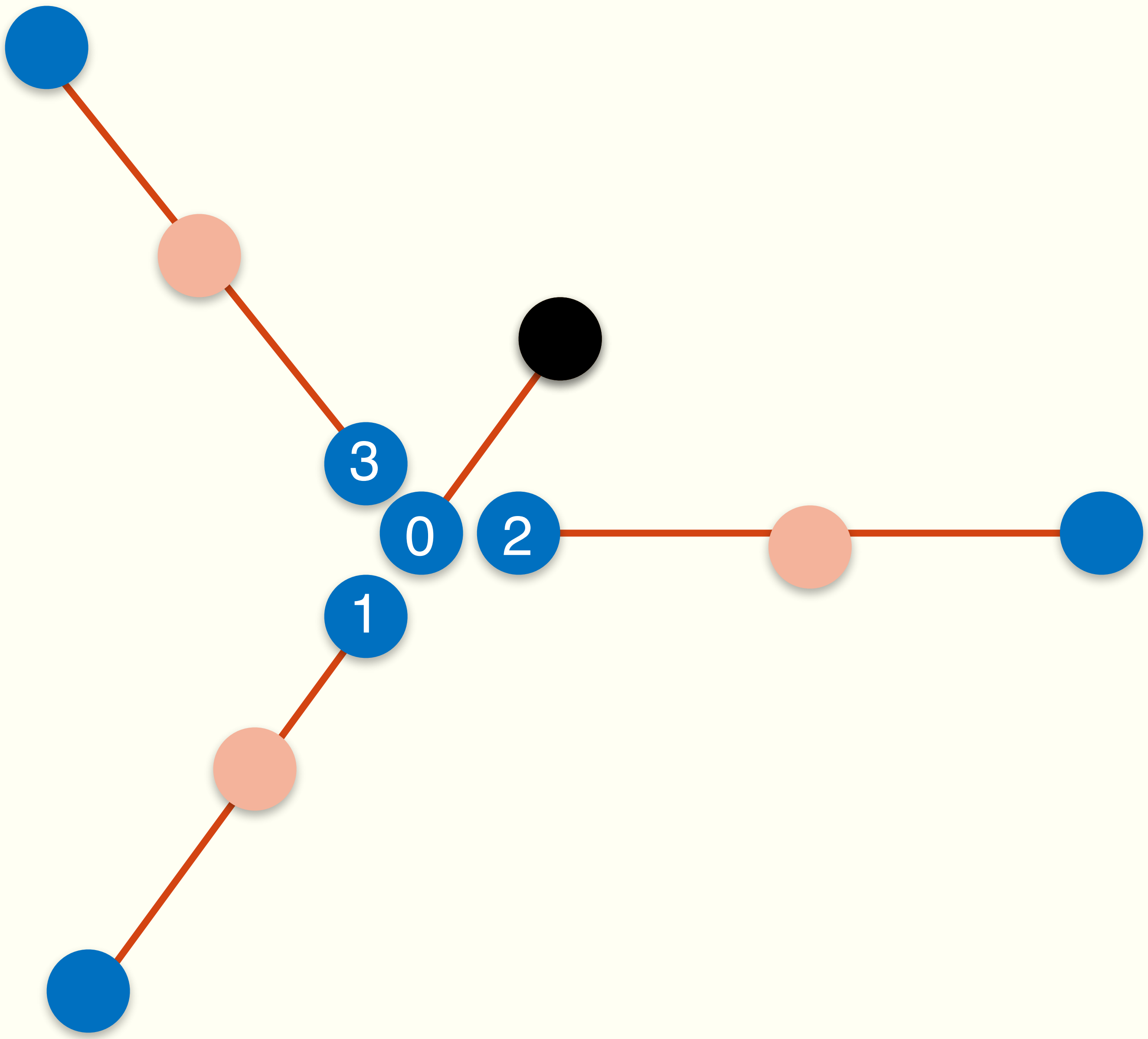
1- You can guide multiple particles at the same time,

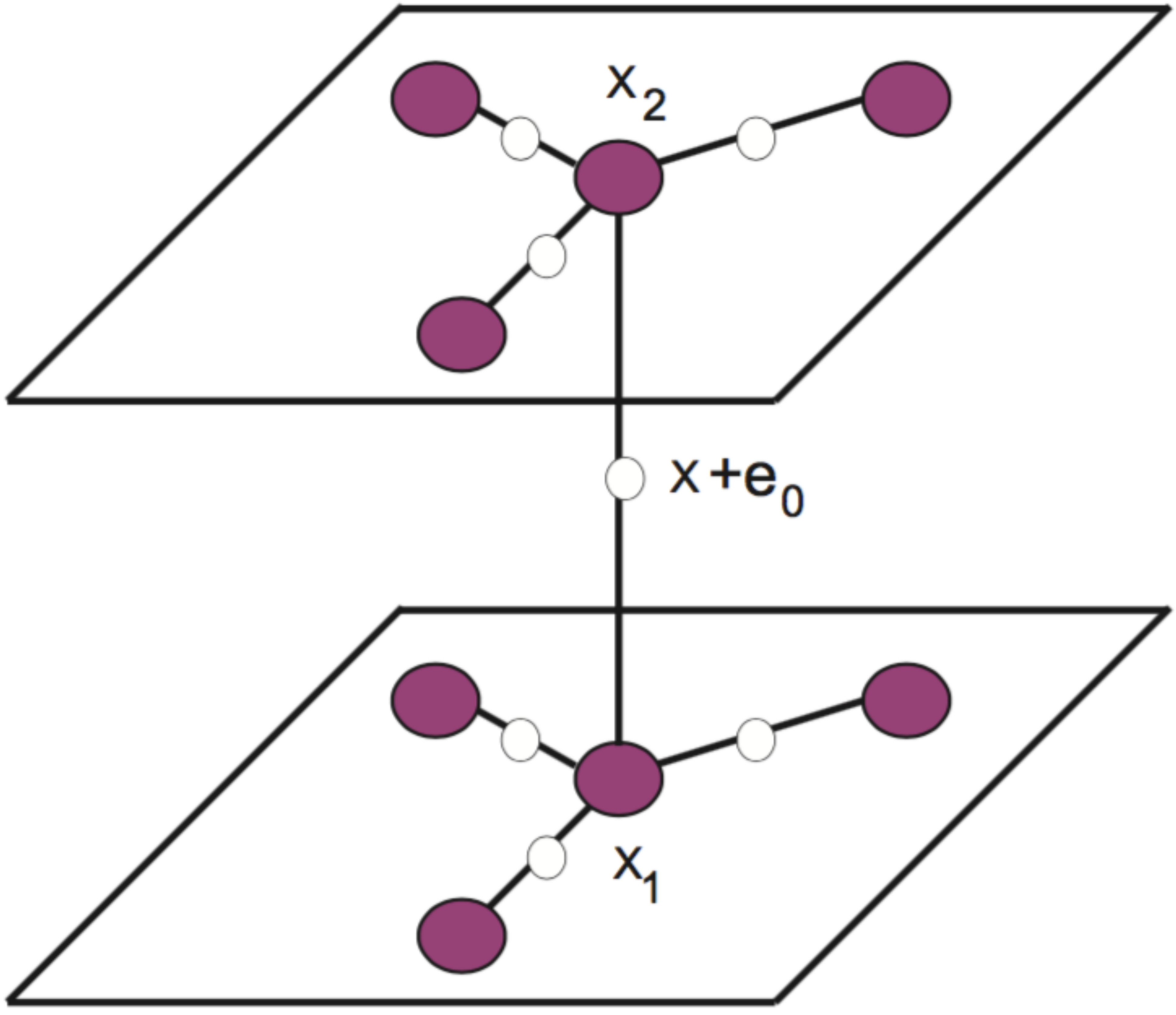
2- You can avoid imperfections and defects in the lattice.

Downloading the particle



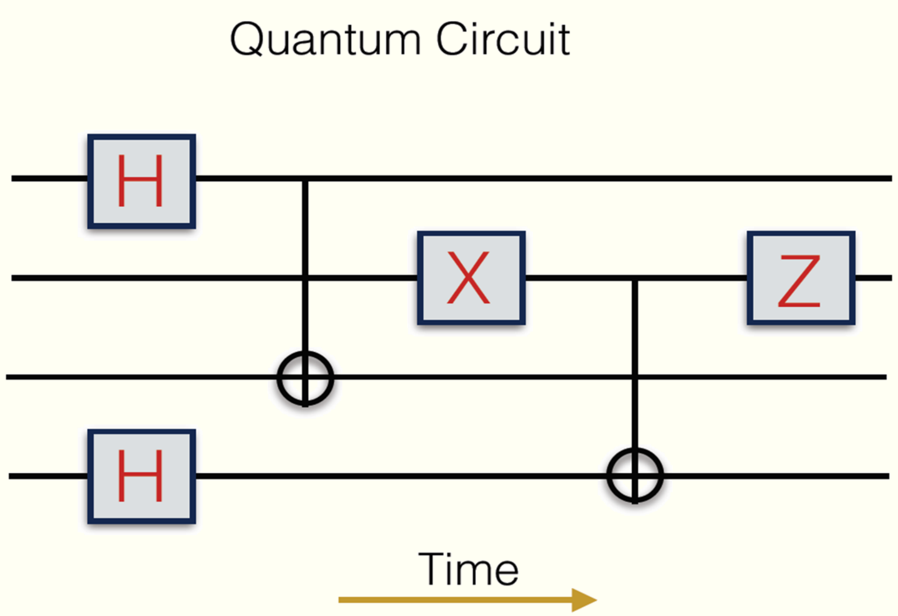

3
0
2
1

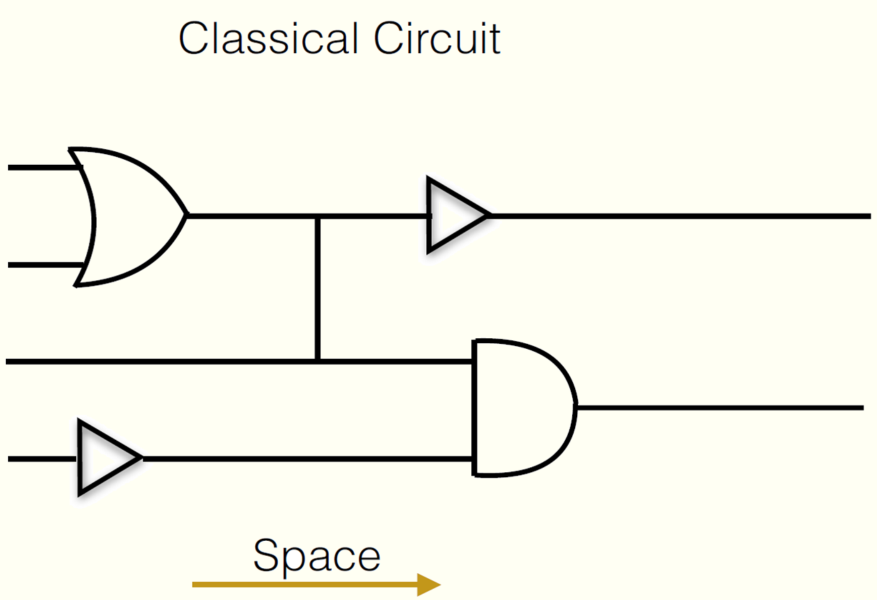

3
0
2
1


x_2
$x+e_0$
x_1

Quantum Circuits

Quantum Computing vs Classical Computing

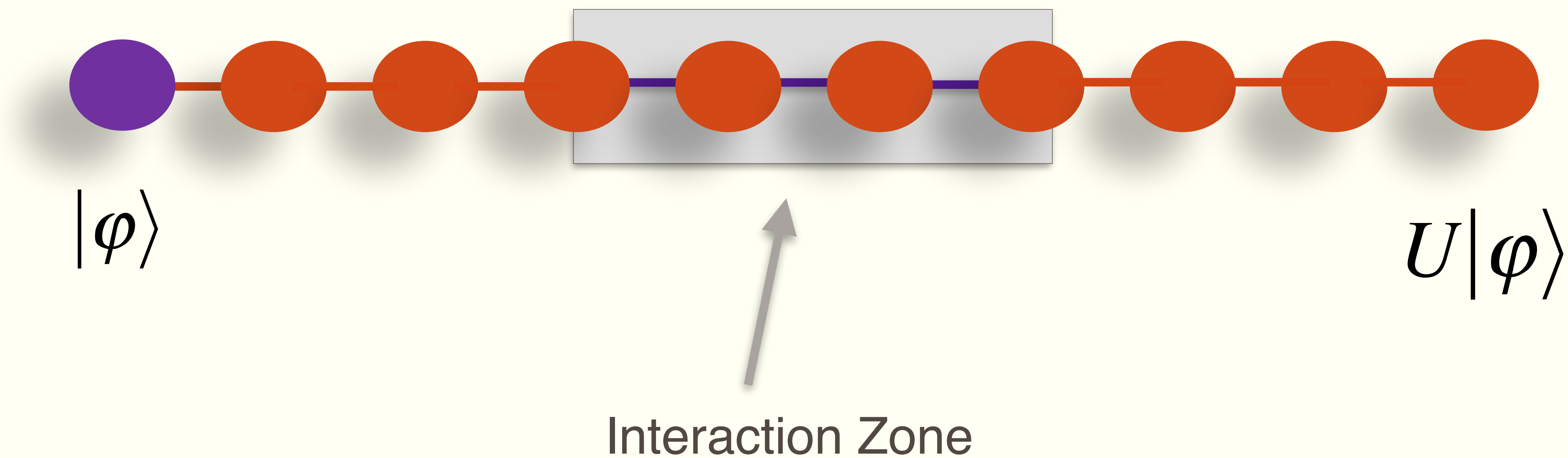




- Horizontal lines represent flow of time
- Gates correspond to localized operations in time
- A great deal of external control is needed

- Horizontal lines represent direction in space
- Gates correspond to localized operations in space
- No external control is needed

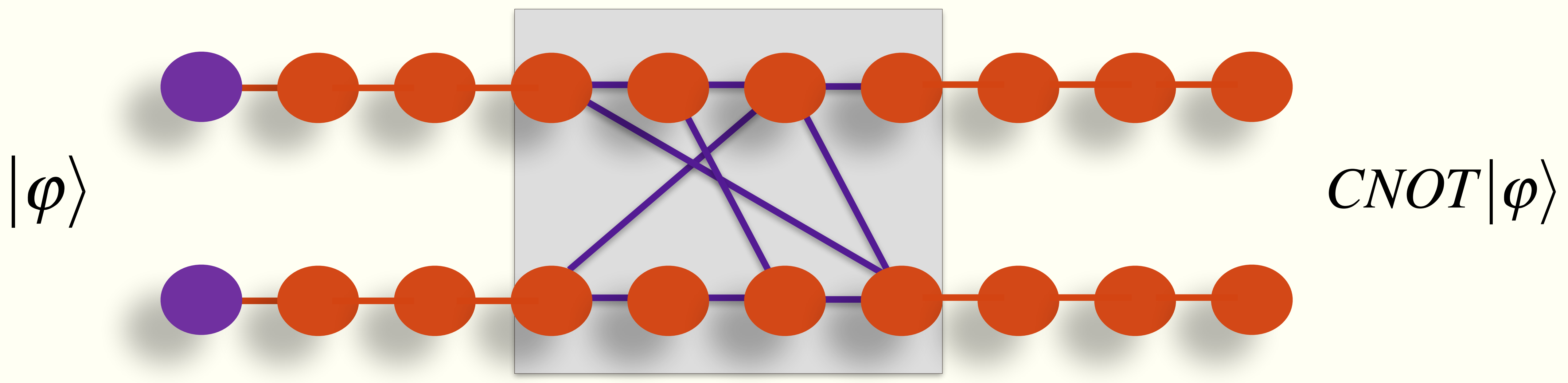
Quantum Gates



Time Independent Universal Computing with Spin Chains: Quantum Plinko Machine

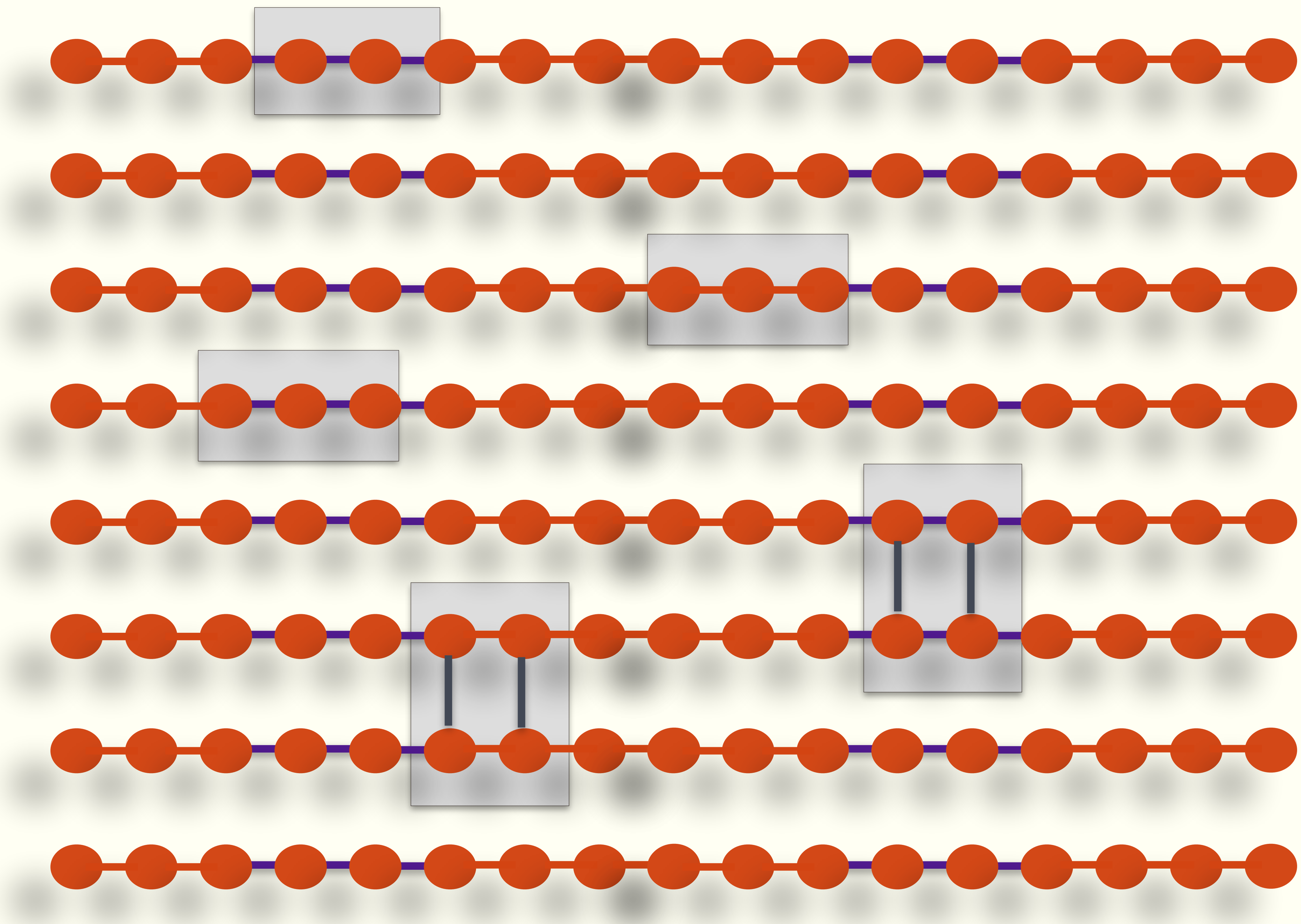
Kevin Thompson, Can Gokler, Seth Lloyd and Peter Shor.

New Journal of Physics (2016)

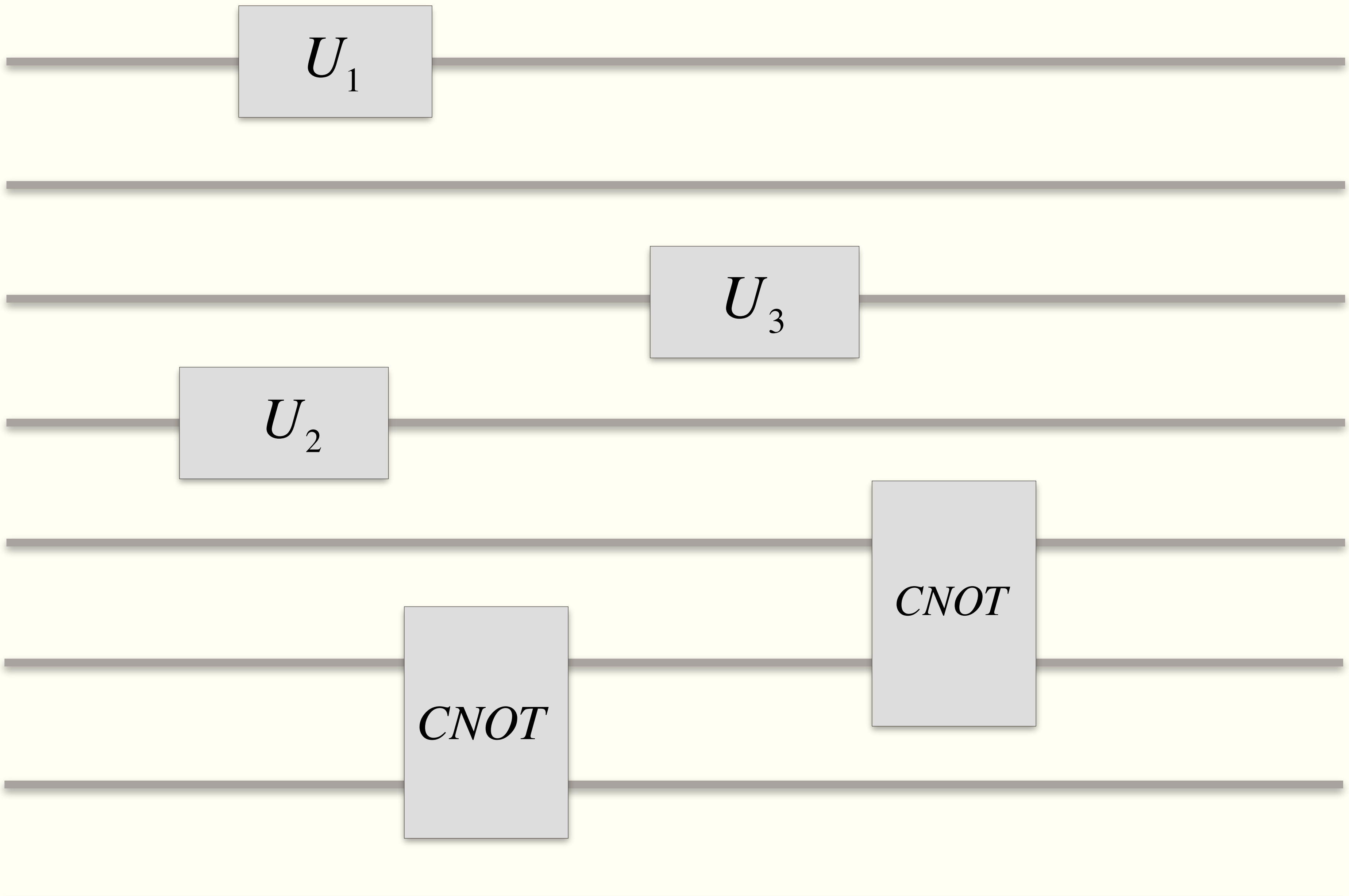


Universal Set of Gates = {Single Qubit Gate, CNOT}

Time independent Quantum Circuit

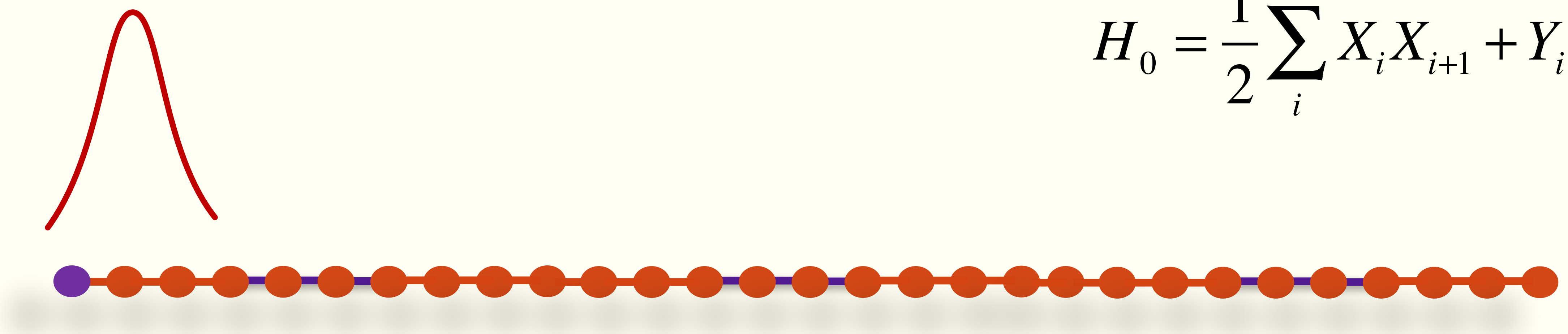


Time independent Quantum Circuit

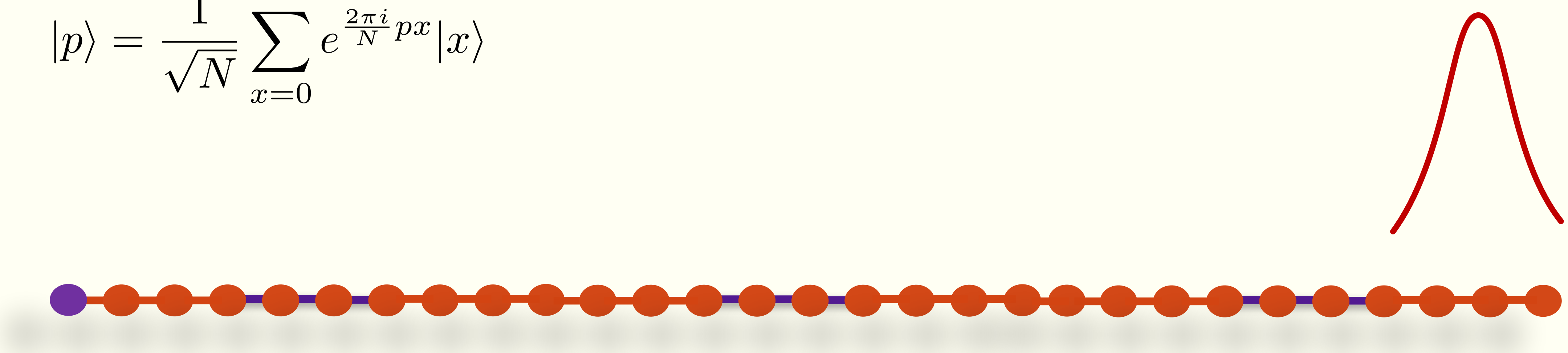


Dispersion-less Gaussian wave-packets

$$H_0 = \frac{1}{2}\sum_i X_i X_{i+1} + Y_i Y_{i+1}$$

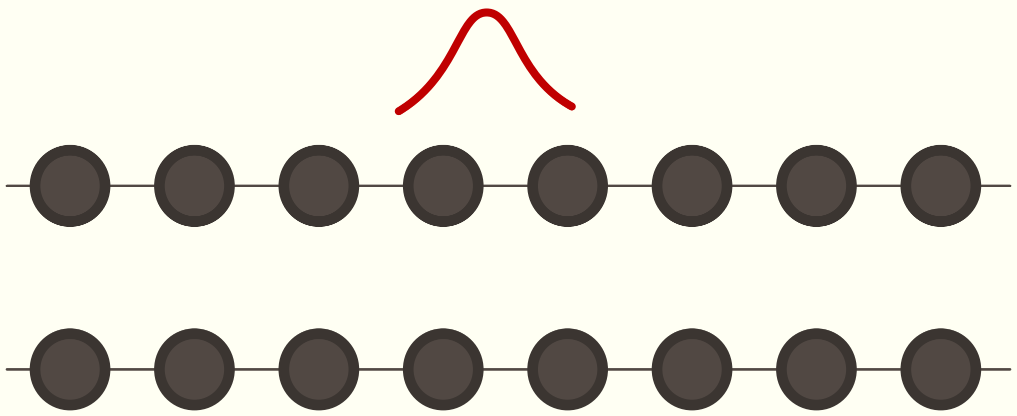


$$|p\rangle = \frac{1}{\sqrt{N}} \sum_{x=0}^{N} e^{\frac{2\pi i}{N} px} |x\rangle$$

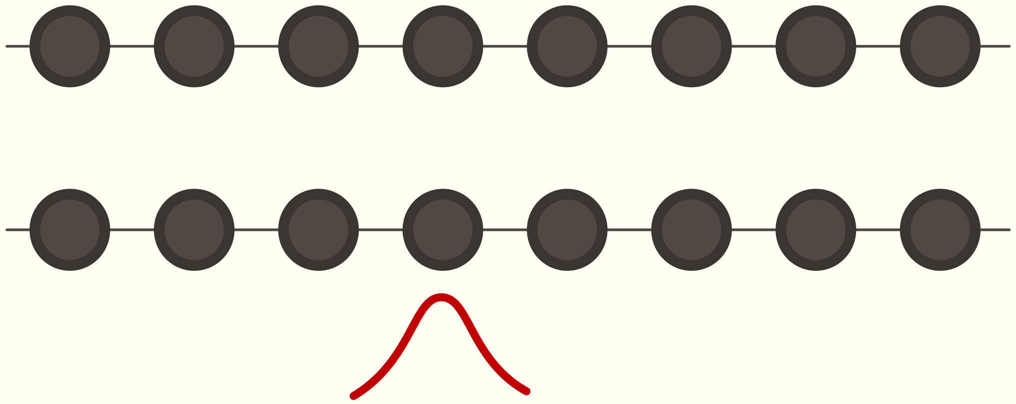


T. J. Osborne and N. Linden, Phys. Rev. A, 2004.

Dual Encoding

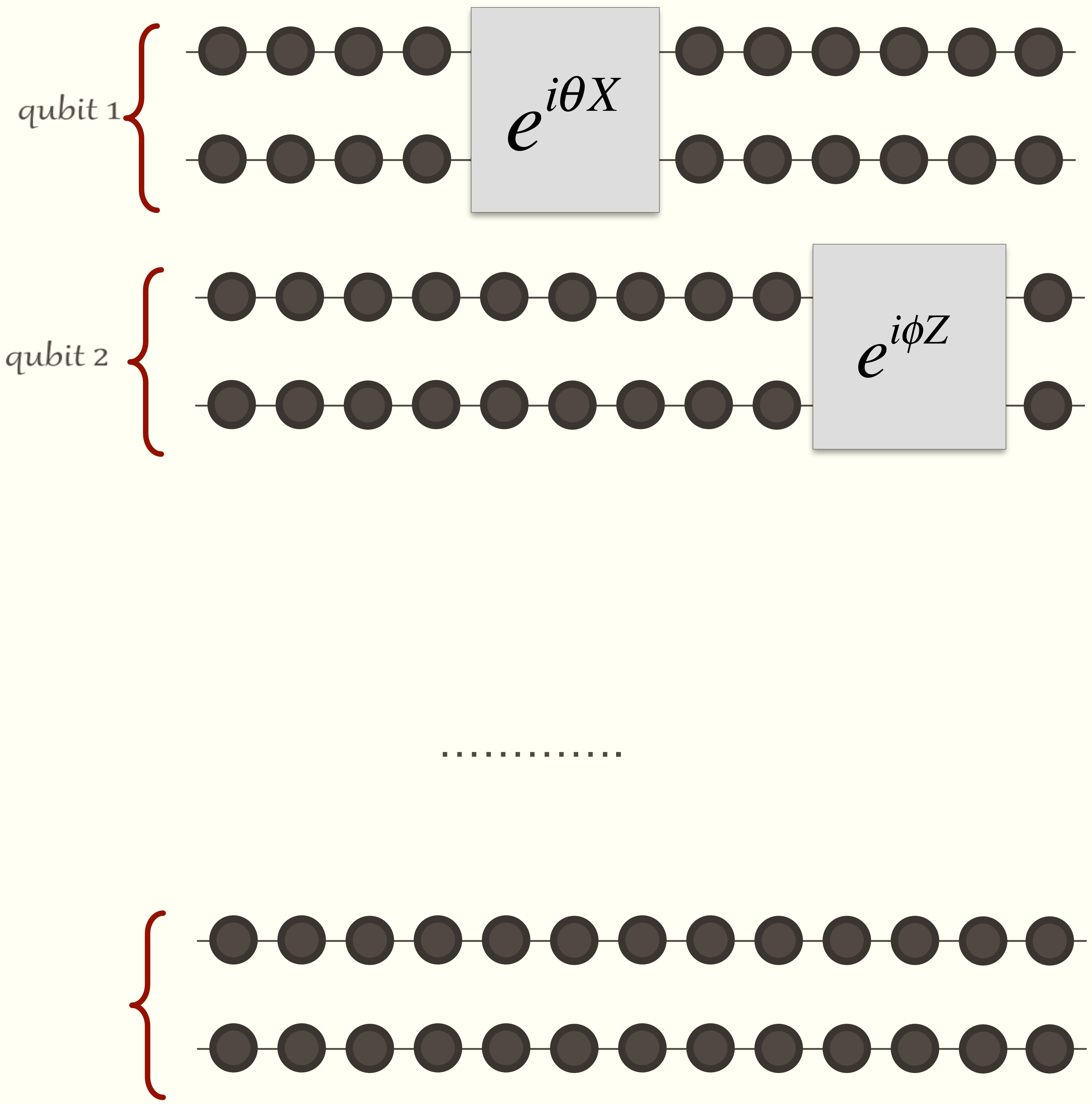


$$|0\rangle_L = |G\rangle \otimes |\Omega\rangle$$

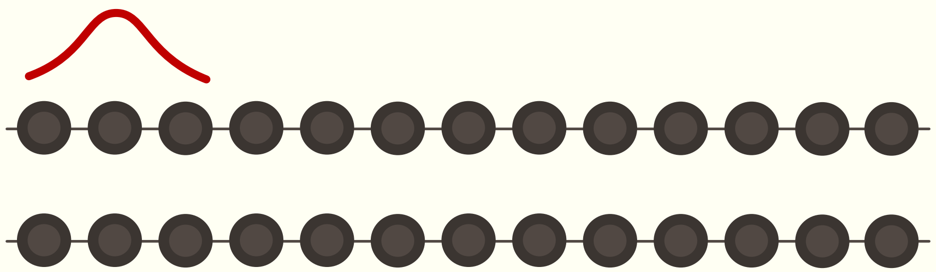


$$|1\rangle_L = |\Omega\rangle \otimes |G\rangle$$

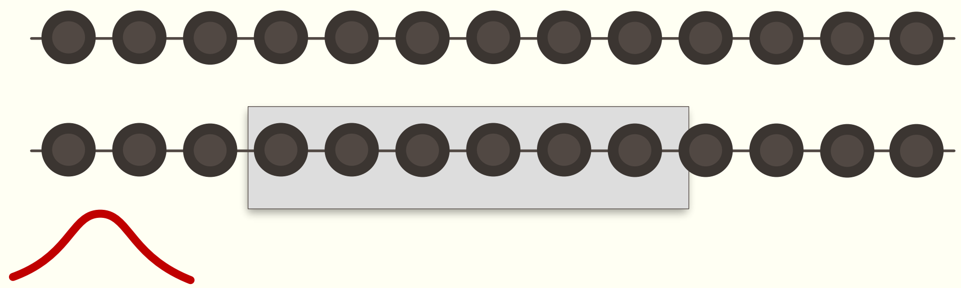
D. Burgarth and S. Bose, Phys. Rev. A **71**, 052315 (2005).


qubit 1
$e^{i\theta X}$
qubit 2
$e^{i\phi Z}$
....

The Gate $e^{i\phi Z} = \begin{pmatrix} 1 & \\ & e^{i\phi} \end{pmatrix}$



$$e^{i\phi Z}|0\rangle_L = |0\rangle_L$$

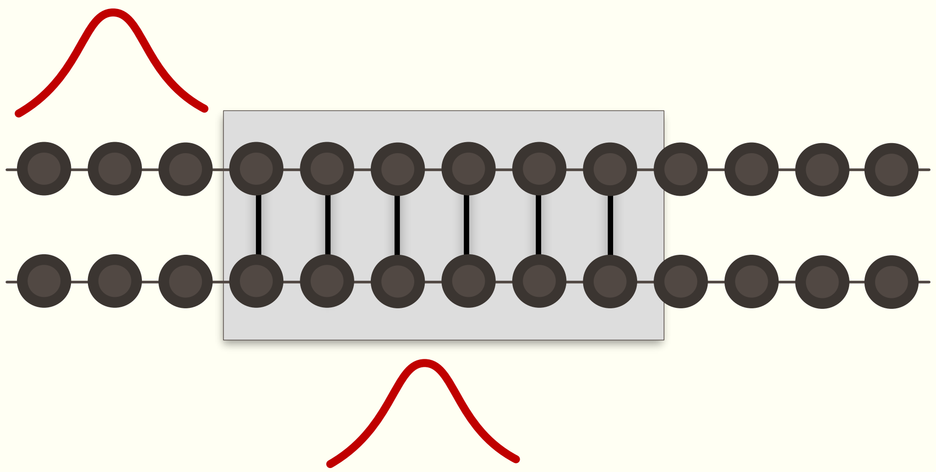


$$e^{i\phi Z}|1\rangle_L = e^{i\phi}|1\rangle_L$$

$$H = H_0 + B$$

$$H = H_0 + \phi \sum_k z_k$$

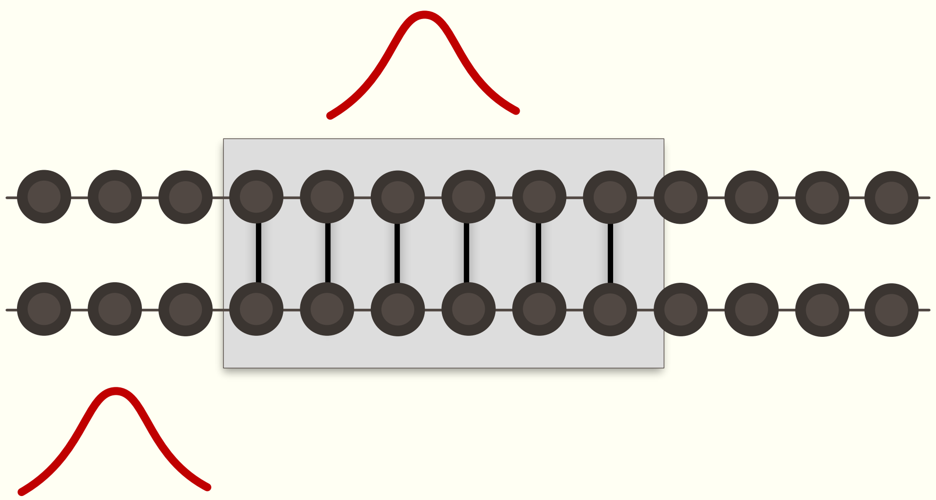
The Gate $e^{i\theta X}$



$$X|0\rangle_L = |1\rangle_L$$

$$X|1\rangle_L = |0\rangle_L$$

The Gate $e^{i\theta X}$



$$X|0\rangle_L = |1\rangle_L$$

$$X|1\rangle_L = |0\rangle_L$$

$$H = H_0 + \theta H_X$$

$$H_X = \frac{1}{2}\sum_i x_i x_{i+1} + y_i y_{i+1}$$

A two qubit gate

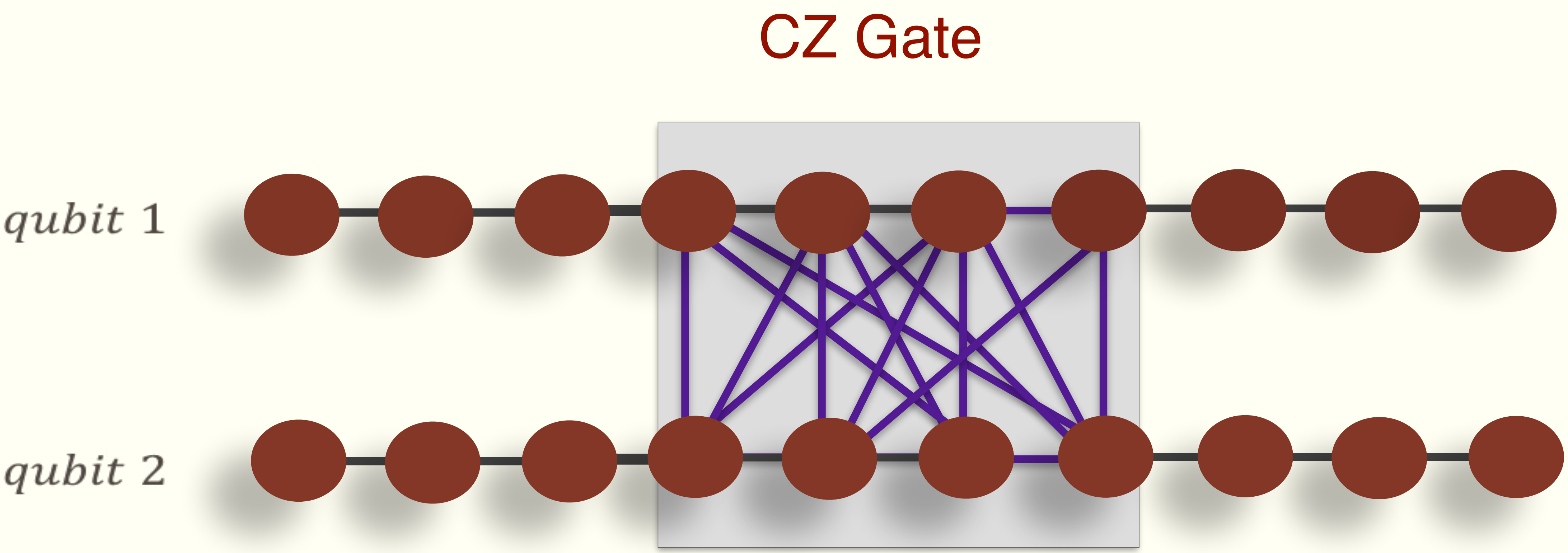
$$CZ = \begin{pmatrix} 1 & & & \\ & 1 & & \\ & & 1 & \\ & & & -1 \end{pmatrix}$$

$$CZ = e^{-i\pi H}$$

$$H = \begin{pmatrix} 0 & & & \\ & 0 & & \\ & & 0 & \\ & & & 1 \end{pmatrix}$$

$$H = \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix} \otimes \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix}$$

$$H = \sum_{i,j} \frac{1-\sigma_{z,i}}{2} \otimes \frac{1-\sigma_{z,j}}{2}$$



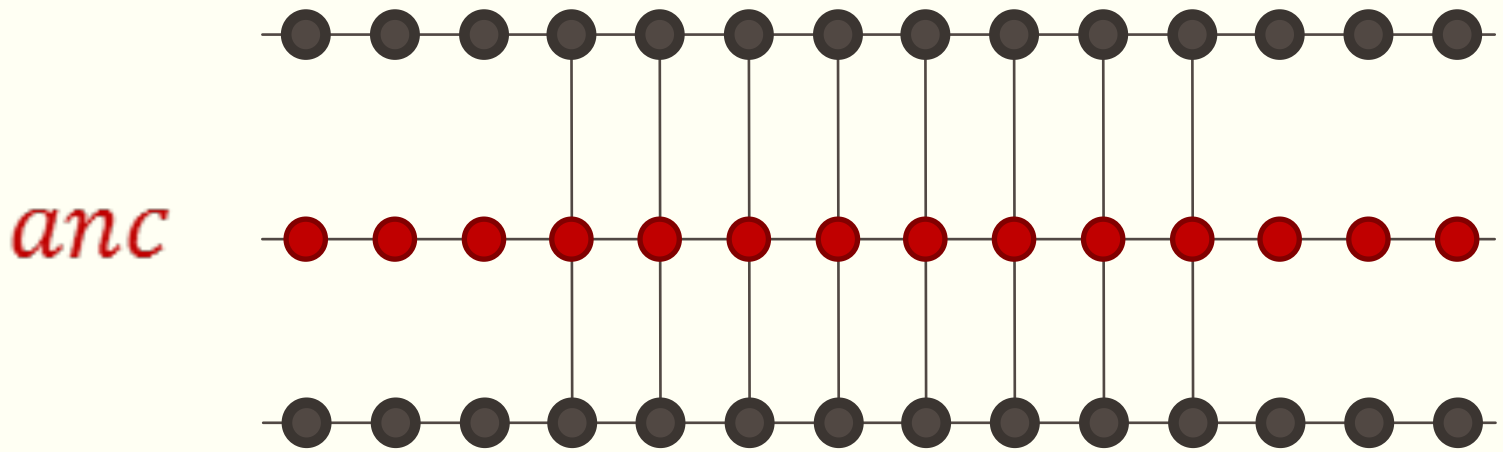
The drawback is long-range interactions

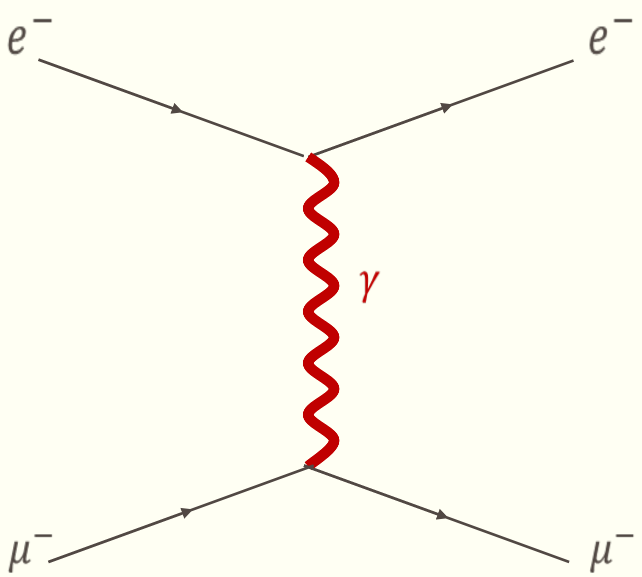
Another Simple Twist

Time independent quantum circuits with local interactions,
Seifnashri, Kianvash, Nobakht and Karimipour,
Phys. Rev. A 93, 062342 (2016)

A lesson from gauge theory

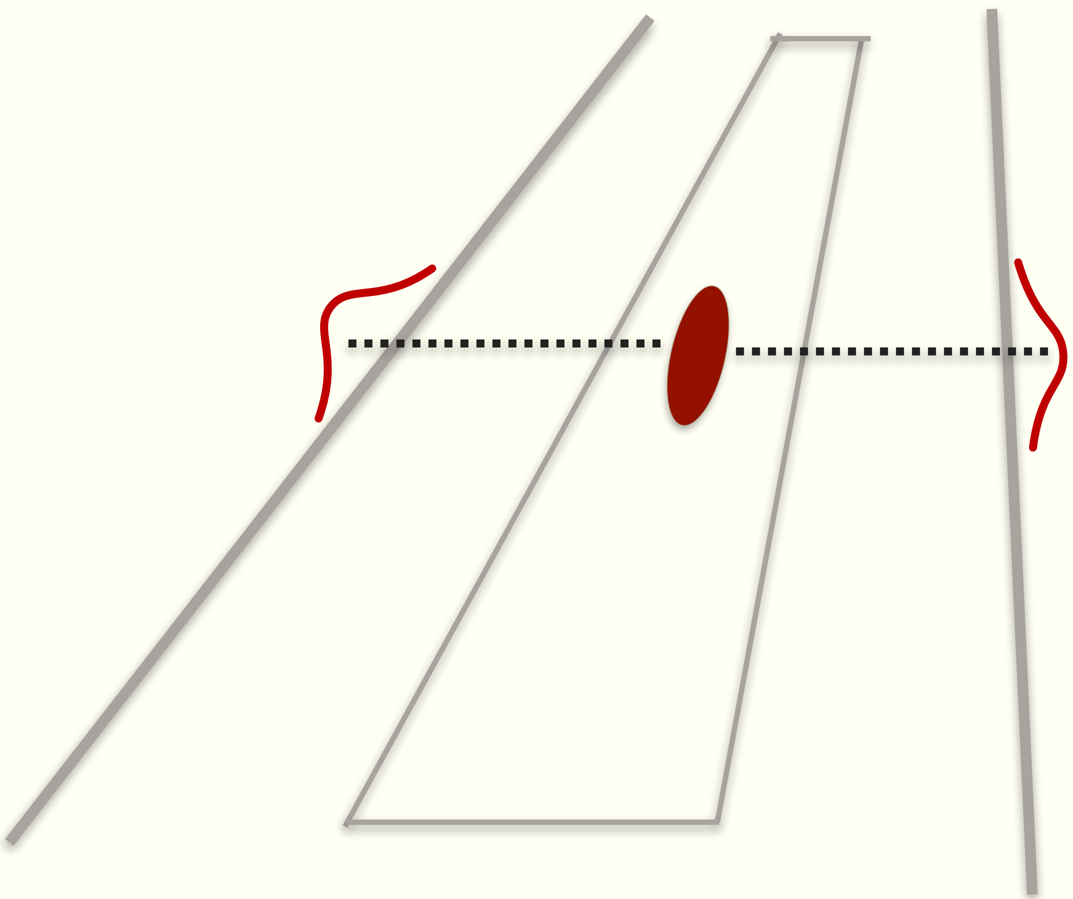
Using gauge particles to mediate long-range interactions





Time independent quantum circuits with local interactions,
Seifnashri, Kianvash, Nobakht and Karimipour,
Phys. Rev. A 93, 062342 (2016)

The effective interaction



$$CZ = \begin{pmatrix} 1 & & & \\ & 1 & & \\ & & 1 & \\ & & & -1 \end{pmatrix}$$

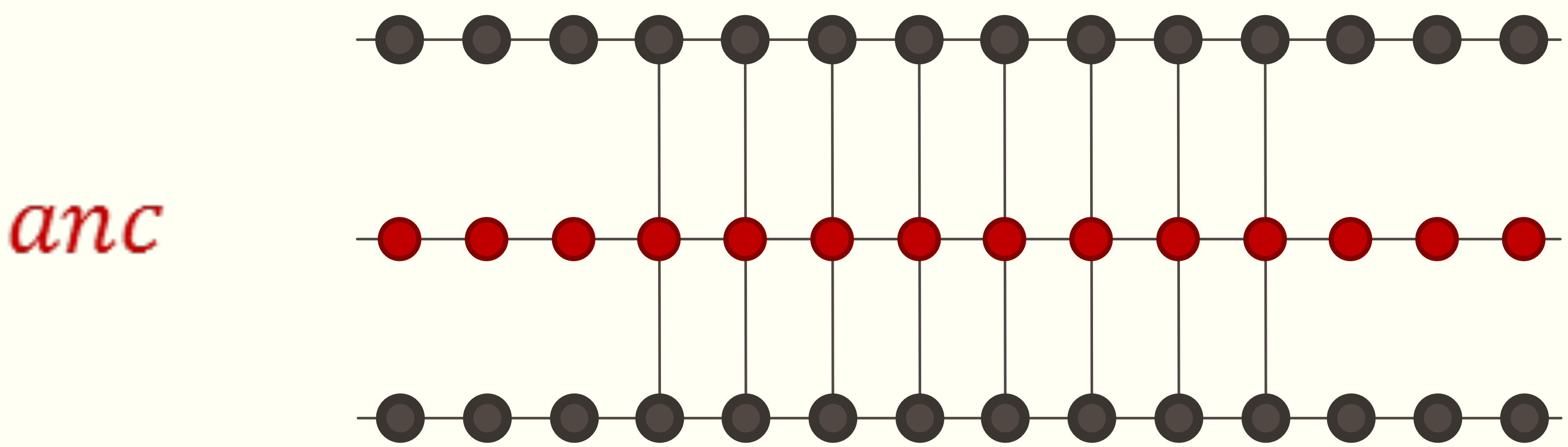
So we need an ancillary chain with

1- Doubly degenerate ground state

2- Large gap

3- an inter-chain Hamiltonian whose effective interaction generates CZ

Photon=Ancillary Rail



$$H^{anc} = \frac{1}{4m}\sum_{i=0}^{N-1}\left(\mathbb{I} - Z_i - \frac{X_iX_{i+1} + Y_iY_{i+1}}{2}\right)$$

The ancillary rail has two degenerate ground states $\left|\Omega\right\rangle$ $\left|\psi\right\rangle$

$$\left|\Omega\right\rangle = \left|0000......0\right\rangle \qquad \left|\psi\right\rangle = \frac{1}{\sqrt{N}}\sum_x \left|000.....1.....000\right\rangle$$

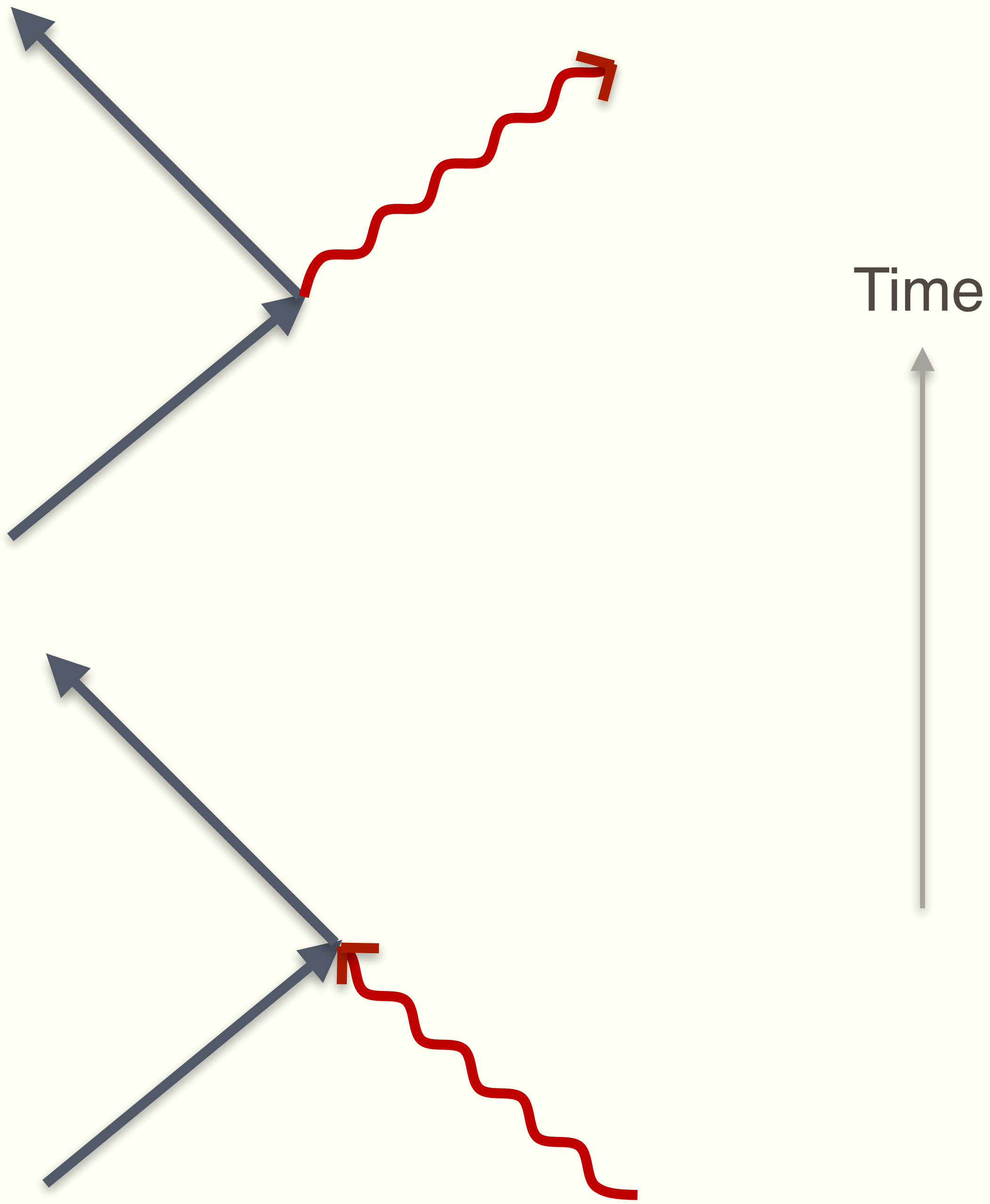
The large gap, allows us to always stay in the ground space

The local interactions

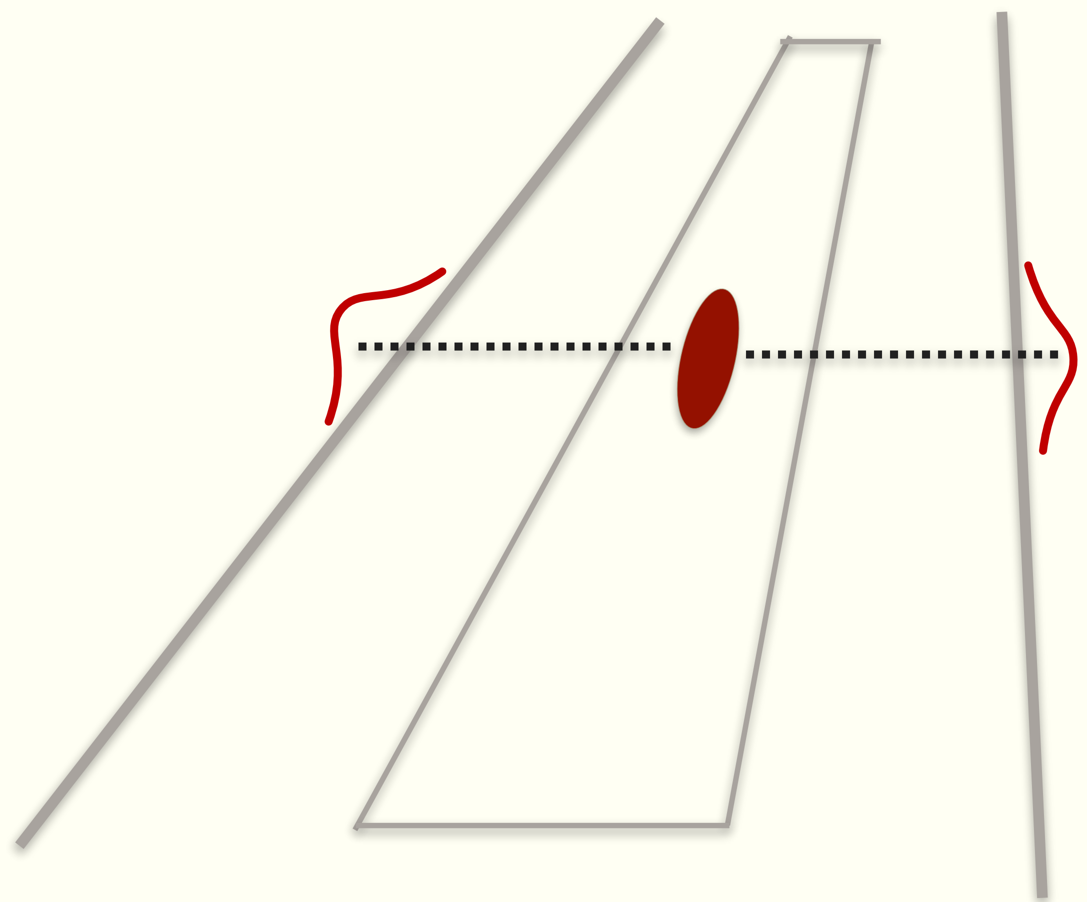
$$V_{eff} = \hat{N} \otimes X$$

$$V_{eff} |1\rangle \otimes |0\rangle = |1\rangle \otimes |1\rangle$$

$$V_{eff} |1\rangle \otimes |1\rangle = |1\rangle \otimes |0\rangle$$



The effective interaction

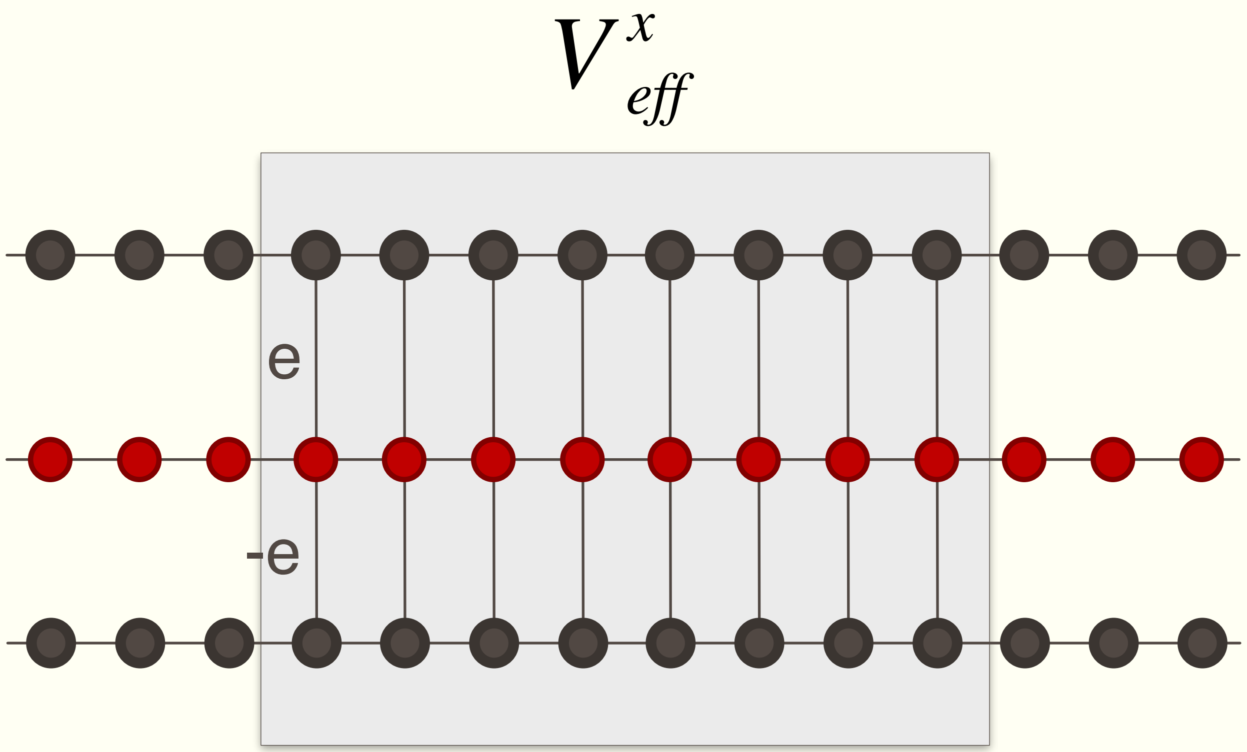


$$V = \sum_j n_j \otimes \sigma_{x,j}$$

$$P = |\Omega\rangle\langle\Omega| + |\psi\rangle\langle\psi|$$

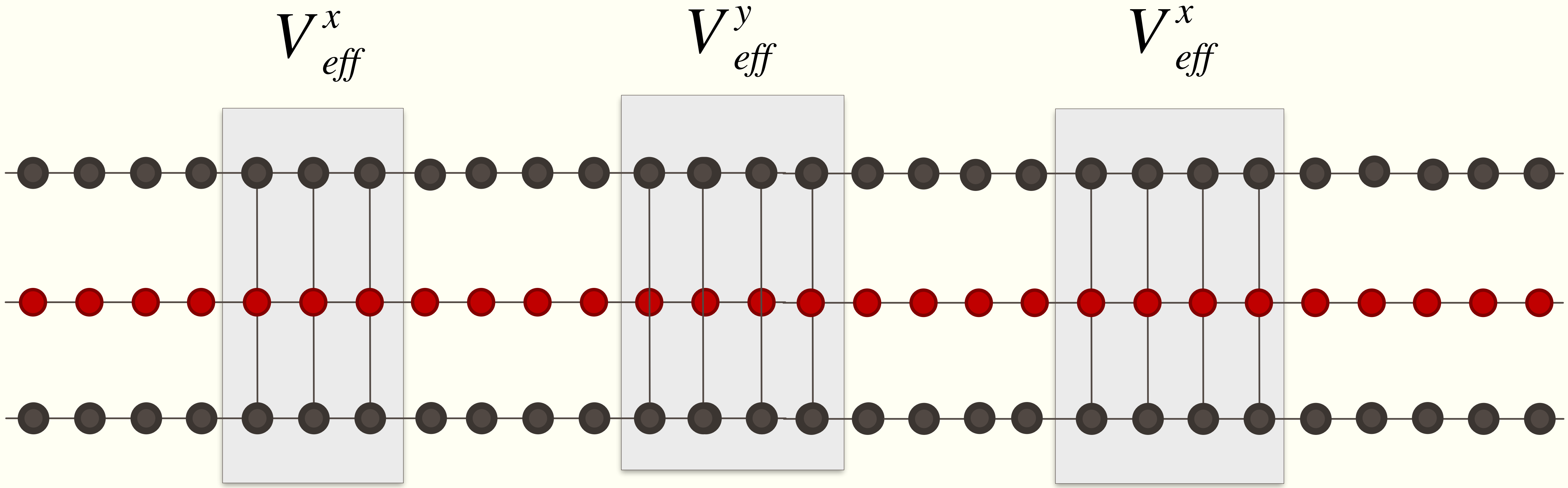
$$V_{eff} = PVP$$

$$V_{eff} = \hat{N} \otimes X$$



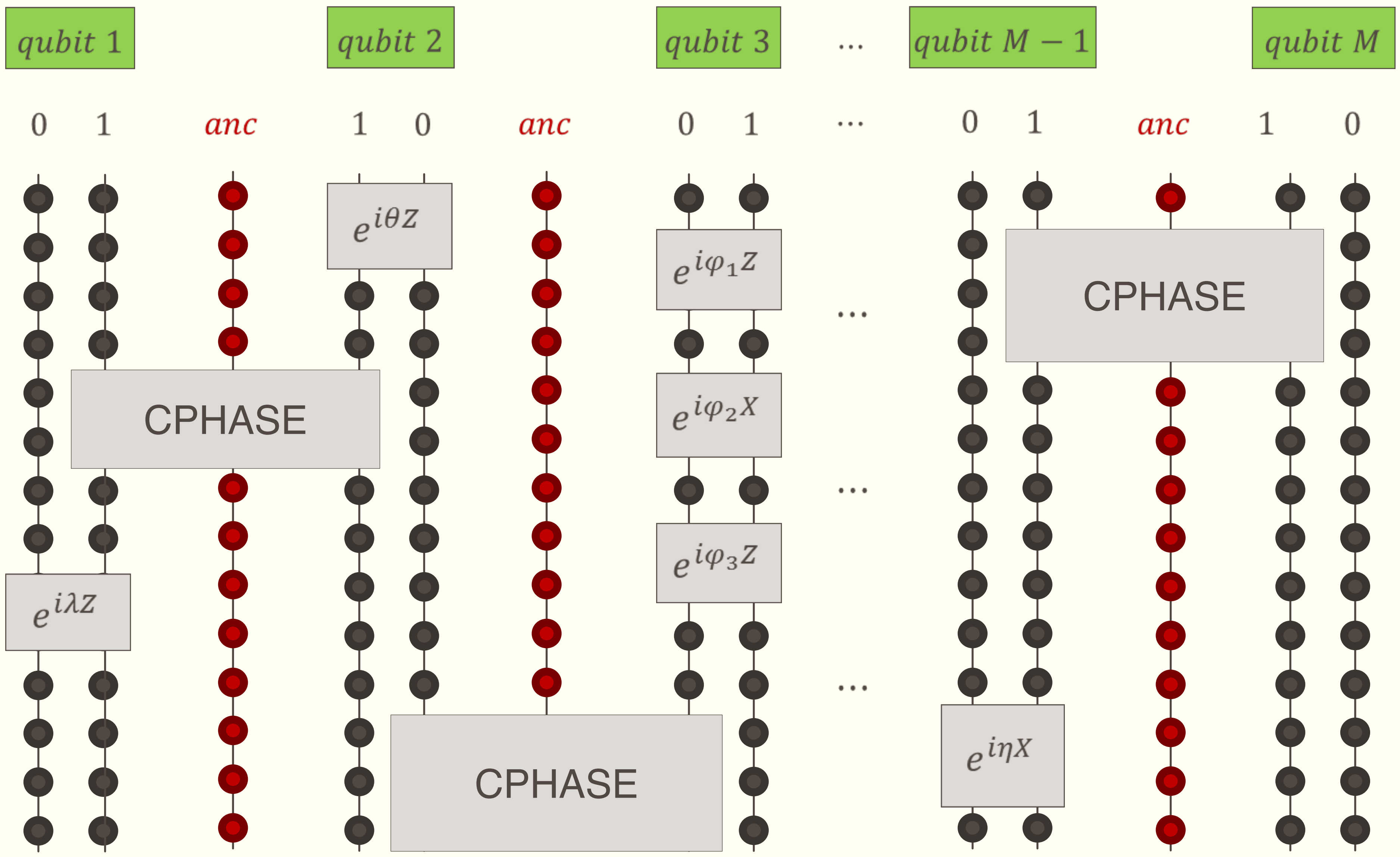
$$V_{eff}^{x} = e(\hat{N}_1 - \hat{N}_2) \otimes X$$

$$V_{eff}^{y} = e(\hat{N}_1 - \hat{N}_2) \otimes Y$$



$$\Lambda_\phi = e^{-i\frac{\pi}{4}V^y_{eff}} e^{i\phi V^y_{eff}} e^{i\frac{\pi}{4}V^y_{eff}} = \begin{pmatrix} 1 & & & \\ & e^{-i\phi} & & \\ & & e^{-i\phi} & \\ & & & 1 \end{pmatrix}$$

Summary



qubit 1
qubit 2
qubit 3
…
qubit M − 1
qubit M
0 1 anc 1 0 anc 0 1 … 0 1 anc 1 0
$e^{i\theta Z}$
$e^{i\varphi_1 Z}$
$e^{i\varphi_2 X}$
$e^{i\varphi_3 Z}$
$e^{i\lambda Z}$
$e^{i\eta X}$
CPHASE
CPHASE
CPHASE

Thank you for your attention