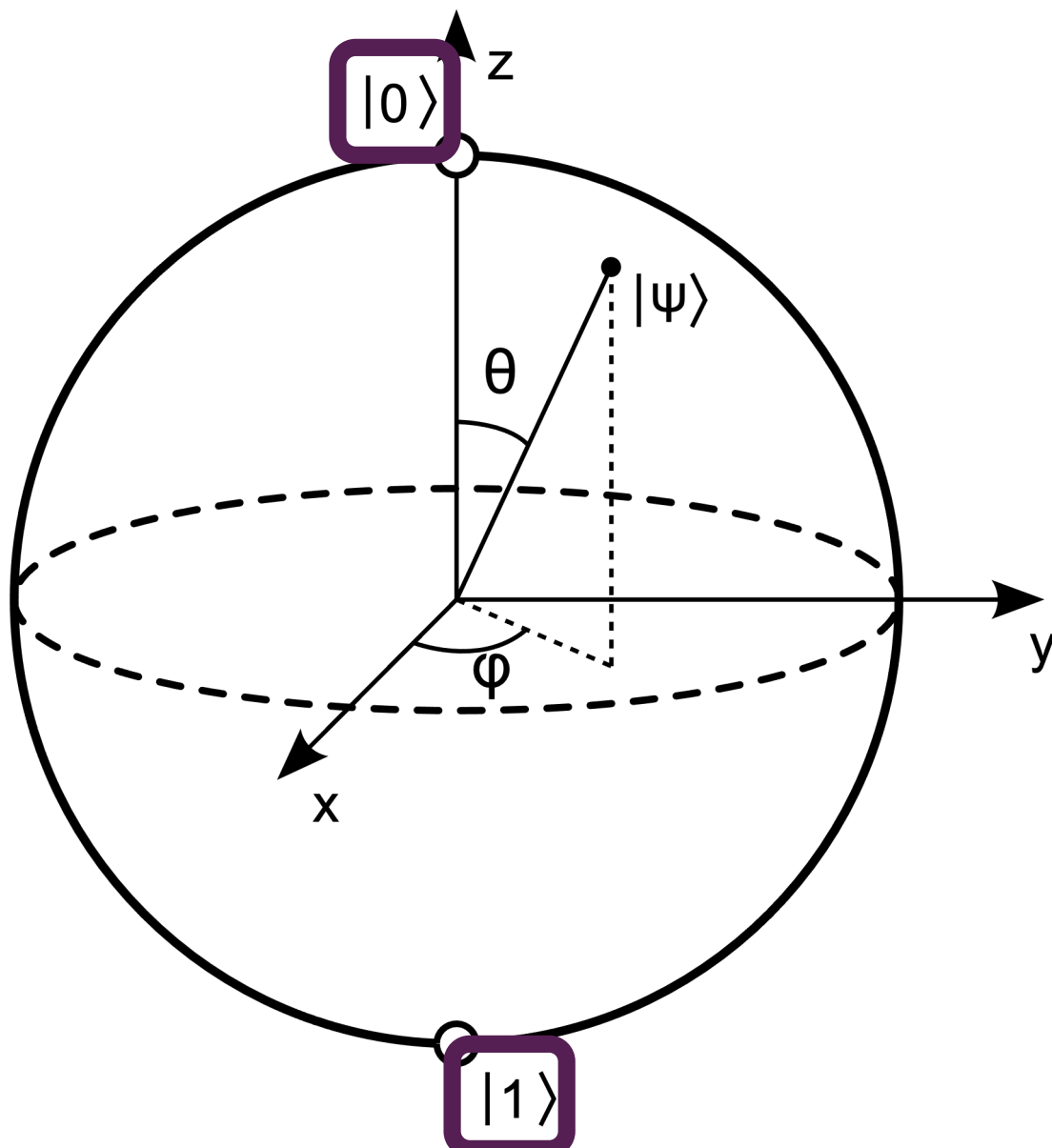


Quantum Circuits Fundamentals

UNIVERSITÀ
degli studi
di BARI
ALDO MORO

Maggio
2024



BLOCH SPHERE

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

$$\alpha^2 + \beta^2 = 1$$

Menu Export Clear Circuit Clear ALL Undo Redo Make Gate Version 2.3

Toolbox

Probes	Displays	Half Turns	Quarter Turns	Eighth Turns	Spinning	Formulaic	Parametrized	Sampling	Parity
$ 0\rangle\langle 0 $ $ 1\rangle\langle 1 $	Density Bloch	Z Swap	S S^{-1}	T T^{-1}	Z^t Z^{-t}	$Z^{f(t)}$ $R_z(f(t))$	$Z^{A/2^n}$ $Z^{-A/2^n}$	Z $Z \otimes 0\rangle$	$[Z]_{\text{par}}$
$ 0\rangle\langle 0 $ $ 1\rangle\langle 1 $	Chance Amps	Y	$Y^{1/2}$ $Y^{-1/2}$	$Y^{1/4}$ $Y^{-1/4}$	Y^t Y^{-t}	$Y^{f(t)}$ $R_y(f(t))$	$Y^{A/2^n}$ $Y^{-A/2^n}$	Y $Y \otimes 0\rangle$	$[Y]_{\text{par}}$
$ 0\rangle\langle 0 $ $ 1\rangle\langle 1 $		\oplus H	$X^{1/2}$ $X^{-1/2}$	$X^{1/4}$ $X^{-1/4}$	X^t X^{-t}	$X^{f(t)}$ $R_x(f(t))$	$X^{A/2^n}$ $X^{-A/2^n}$	X $X \otimes 0\rangle$	$[X]_{\text{par}}$

use controls
drag gates onto circuit
outputs change

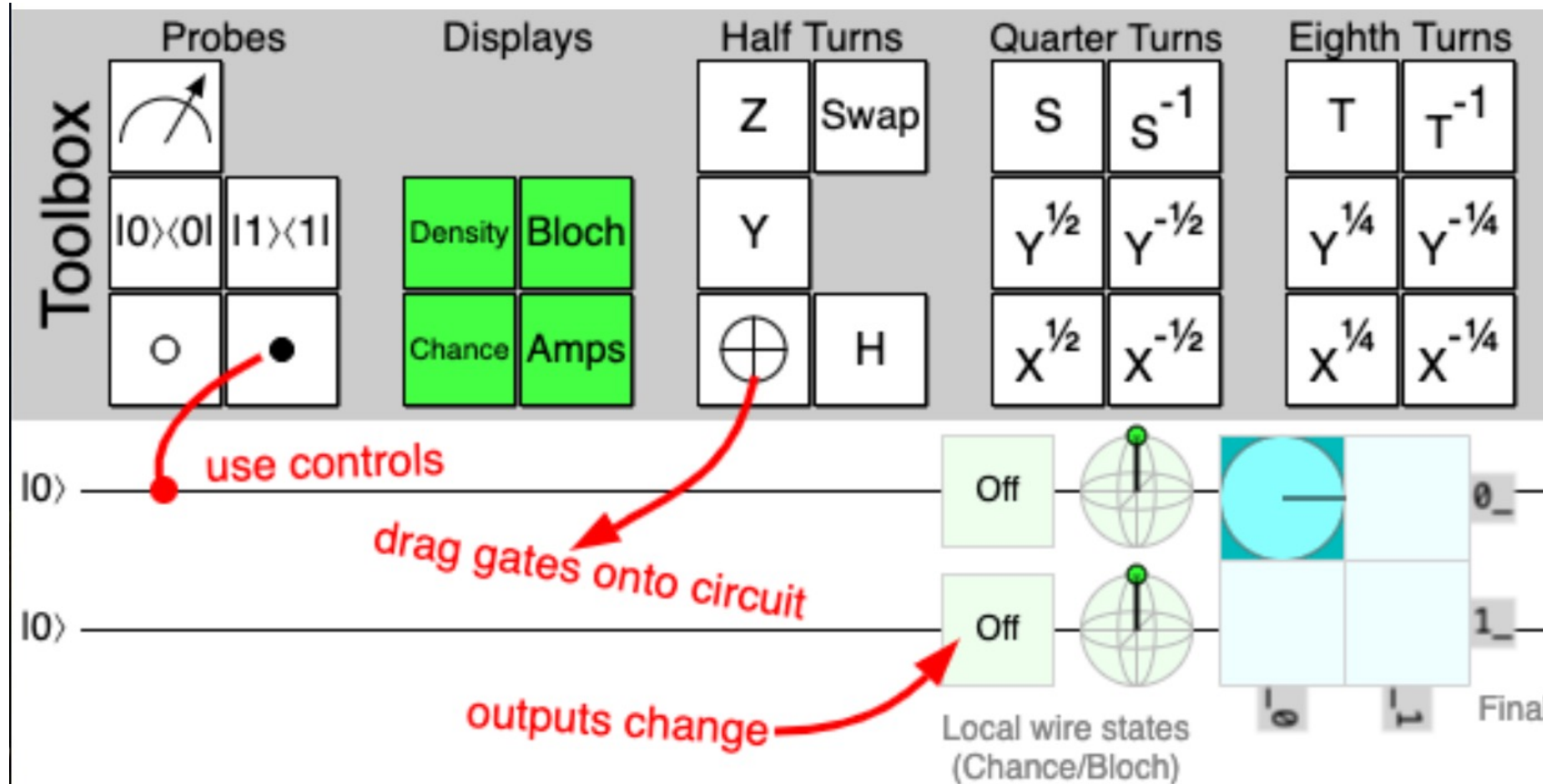
Local wire states (Chance/Bloch) Final amplitudes

Toolbox₂

X/Y Probes	Order	Frequency	Inputs	Arithmetic	Compare	Modular	Scalar	Custom Gates
\ominus \oplus	$+[t]$ $-[t]$	QFT QFT^\dagger	input A $A=\#$ default	$+1$ -1	$\oplus A < B$ $\oplus A > B$	$+1 \text{ mod } R$ $-1 \text{ mod } R$	\dots 0	
\otimes \otimes	Reverse		input B $B=\#$ default	$+A$ $-A$	$\oplus A \leq B$ $\oplus A \geq B$	$+A \text{ mod } R$ $-A \text{ mod } R$	$-$	
$ +\rangle\langle + $ $ -\rangle\langle - $		$\text{Grad}^{1/2}$ $\text{Grad}^{-1/2}$	input R $R=\#$ default	$+AB$ $-AB$	$\oplus A = B$ $\oplus A \neq B$	$\times A \text{ mod } R$ $\times A^{-1} \text{ mod } R$	i $-i$	
$ i\rangle\langle i $ $ -i\rangle\langle -i $		Grad^t Grad^{-t}		$\times A$ $\times A^{-1}$		$\times B^A \text{ mod } R$ $\times B^{-A} \text{ mod } R$	\sqrt{i} $\sqrt{-i}$	

LET'S SIMULATE

<https://algassert.com/quirk>

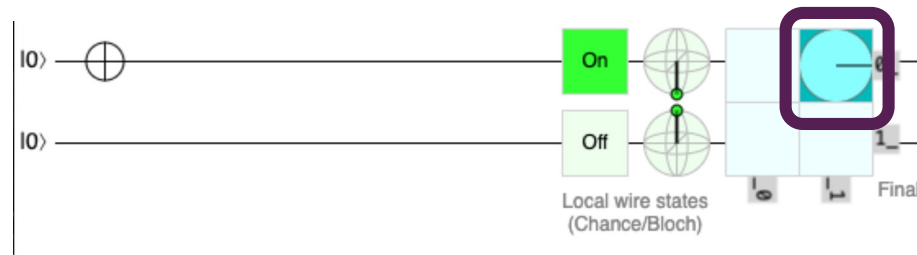


LET'S
SIMULATE

<https://algassert.com/quirk>

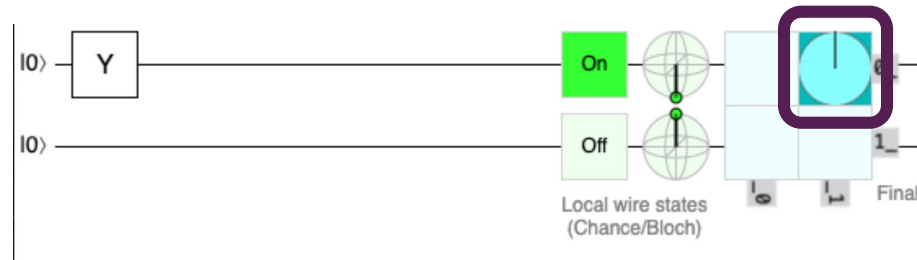
Scenario 1: Pauli Gates

Pauli X



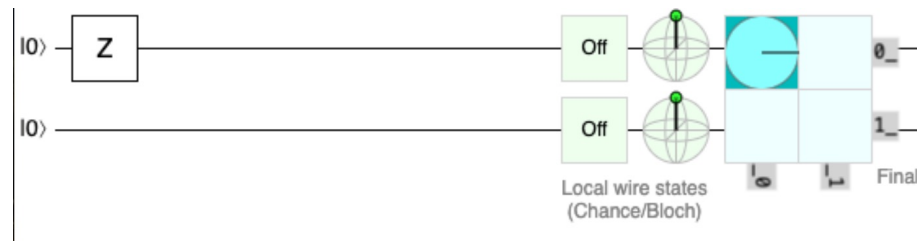
0->1

Pauli Y



0->1

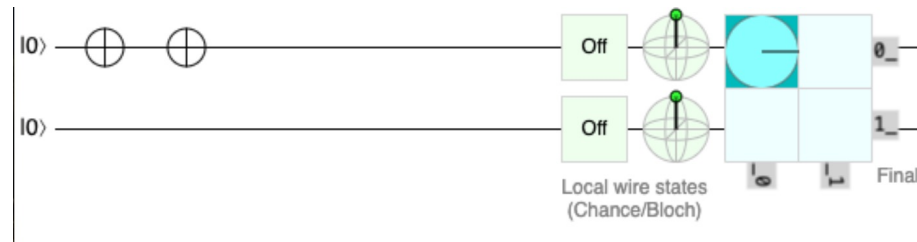
Pauli Z



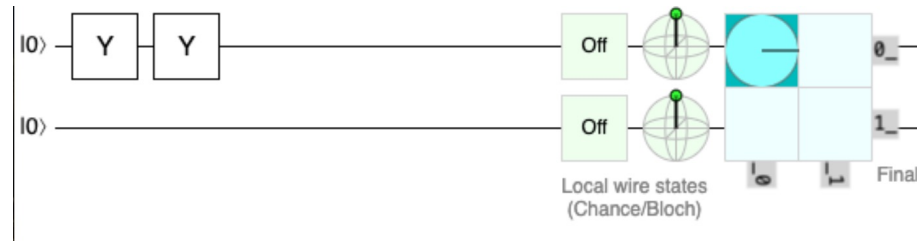
0->0

Scenario 1b: Reversibility

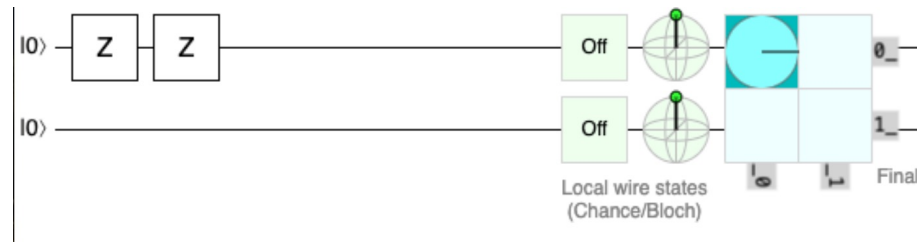
Pauli X



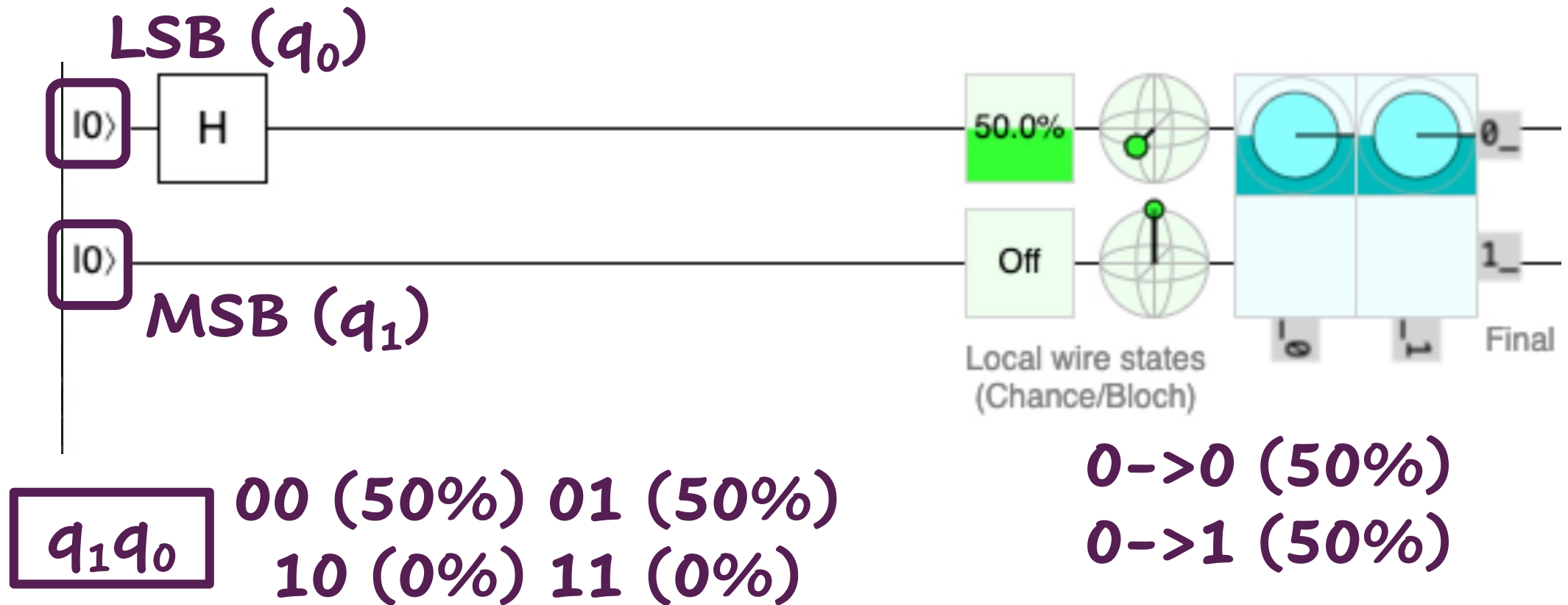
Pauli Y



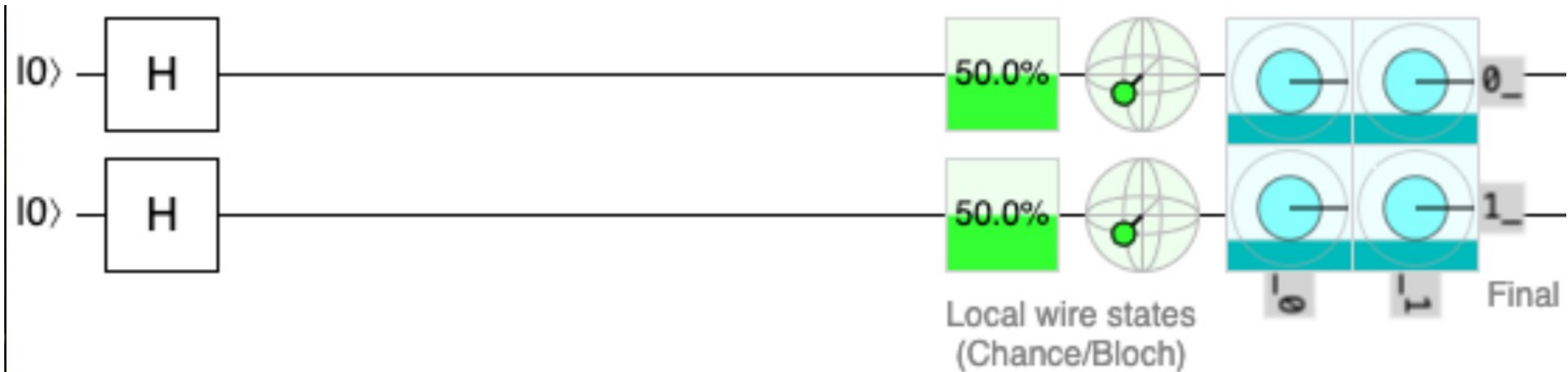
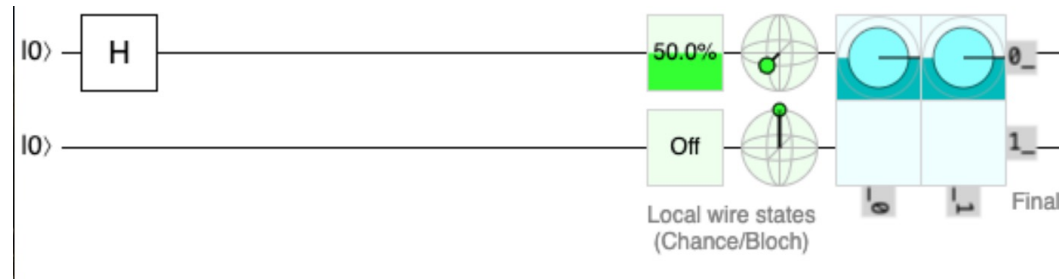
Pauli Z



Scenario 2: Hadamard Gate



Scenario 2: Hadamard Gate



$0 \rightarrow 0$ (50%)

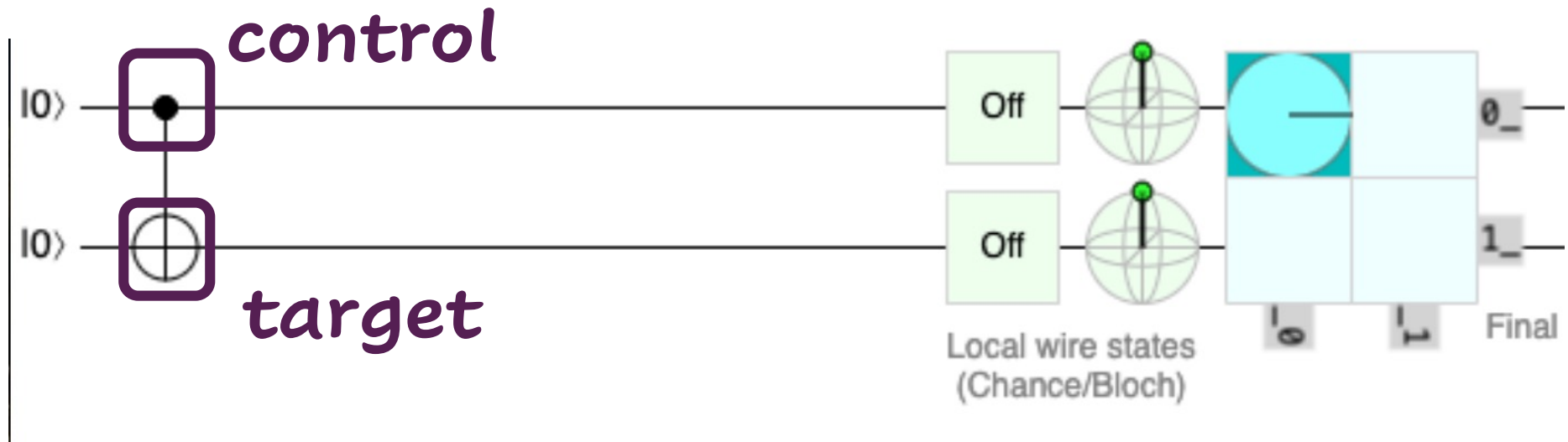
$0 \rightarrow 1$ (50%)

x2 qubits!

00 (25%) 01 (25%)

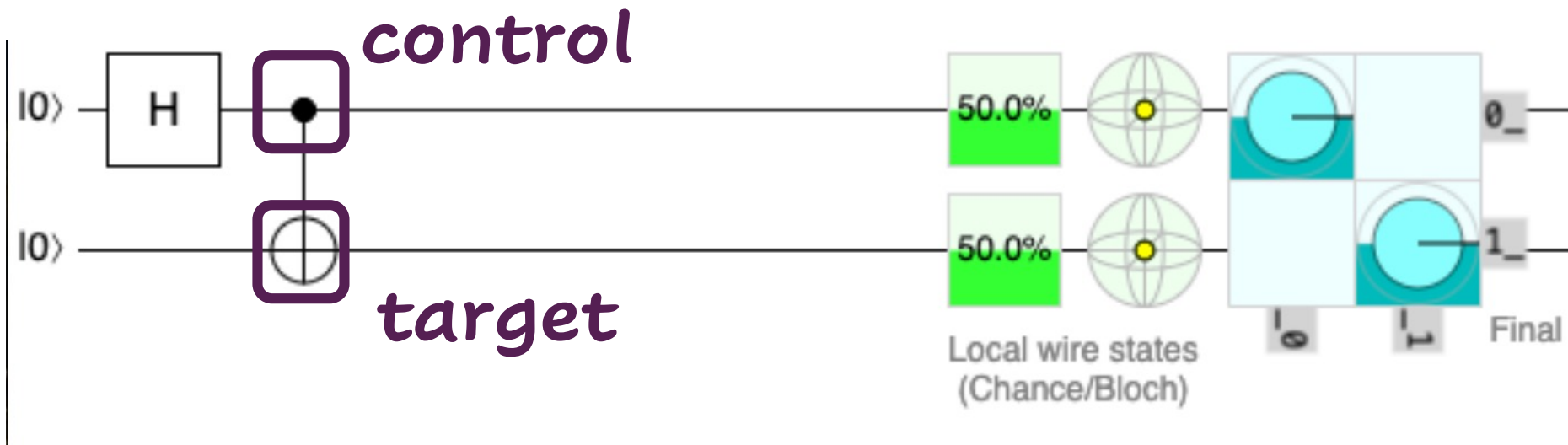
10 (25%) 11 (25%)

Scenario 3: Controlled Gates



control + NOT \rightarrow CNOT

Scenario 3: Controlled Gates



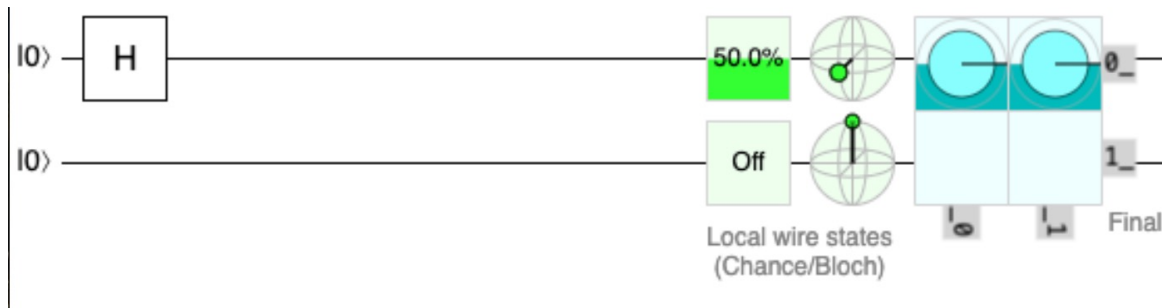
q_0 AND q_1

00 (50%) 01 (0%)
10 (0%) 11 (50%)

Let's play!!



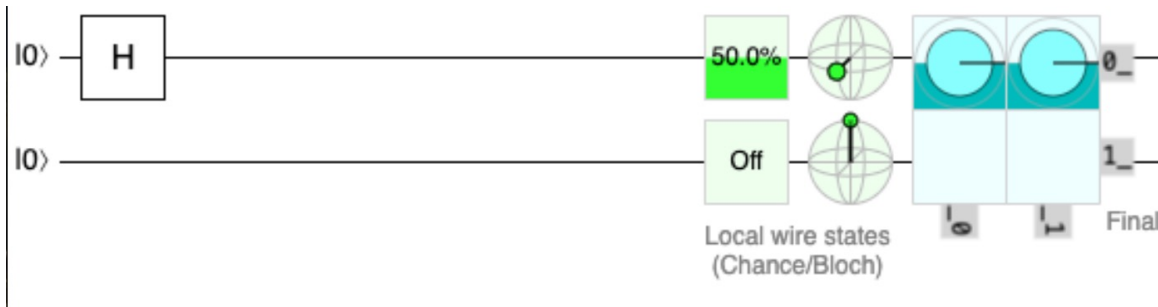
Let's play!!



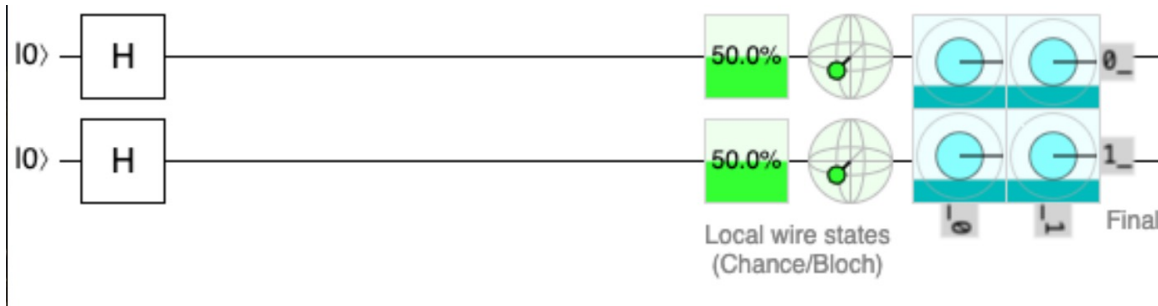
00 (50%) 01 (50%)
10 (0%) 11 (0%)



Let's play!!

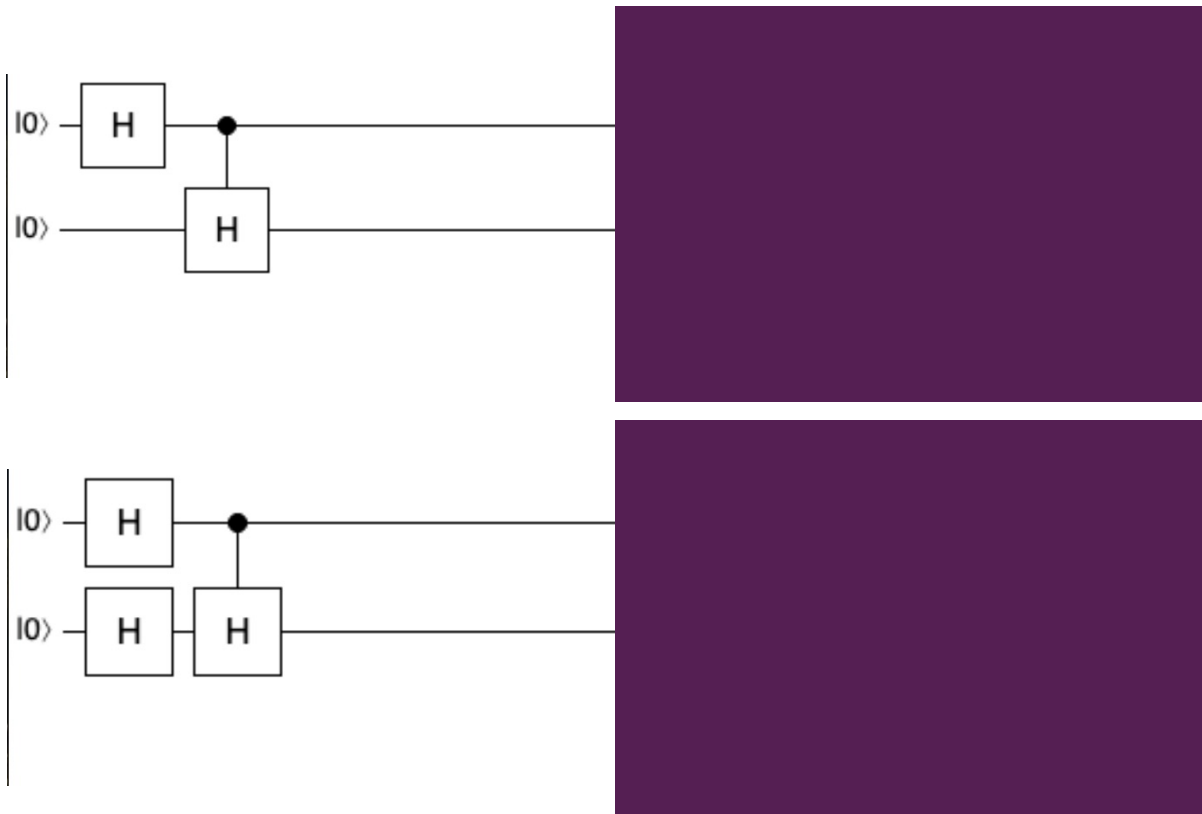


00 (50%) 01 (50%)
10 (0%) 11 (0%)

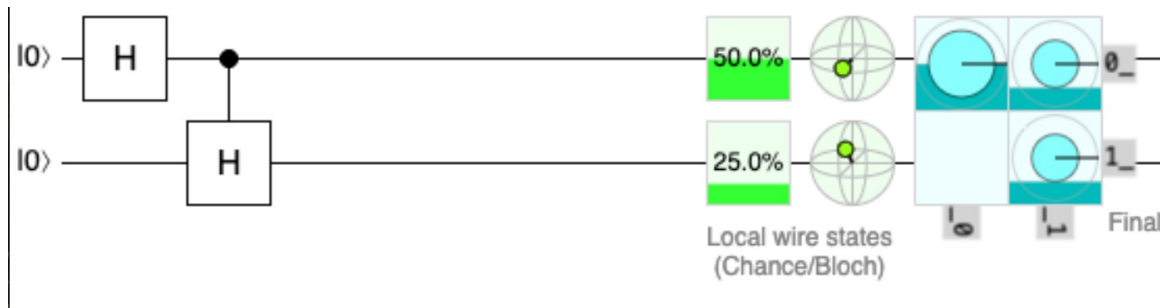


00 (25%) 01 (25%)
10 (25%) 11 (25%)

Let's play (2)!!



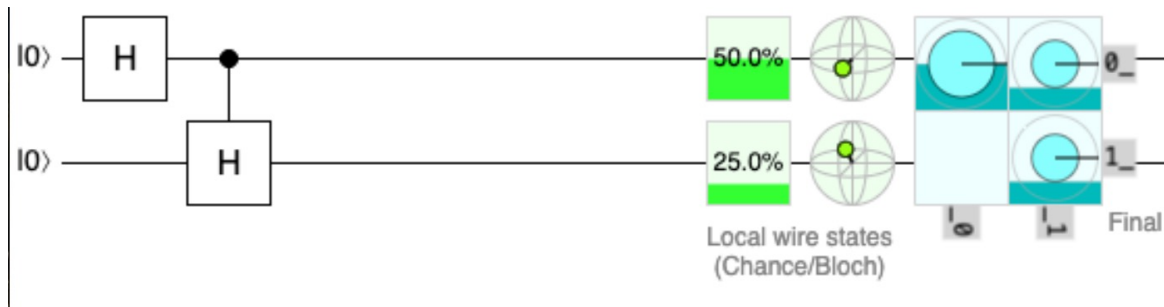
Let's play (2)!!



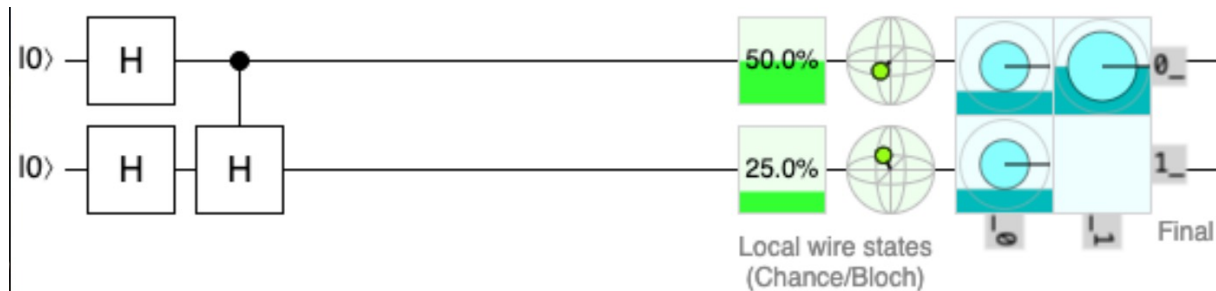
00 (50%) 01 (25%)
10 (0%) 11 (25%)



Let's play (2)!!

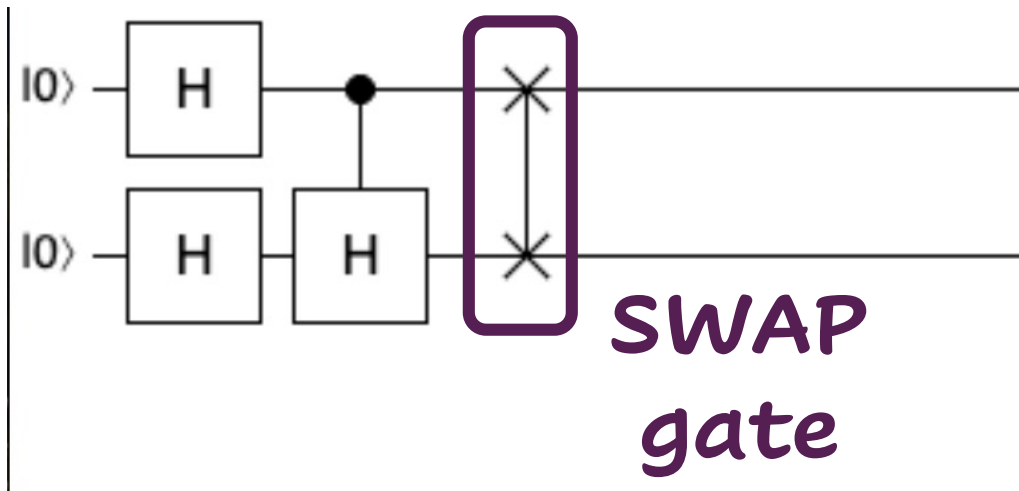


00 (50%) 01 (25%)
10 (0%) 11 (25%)

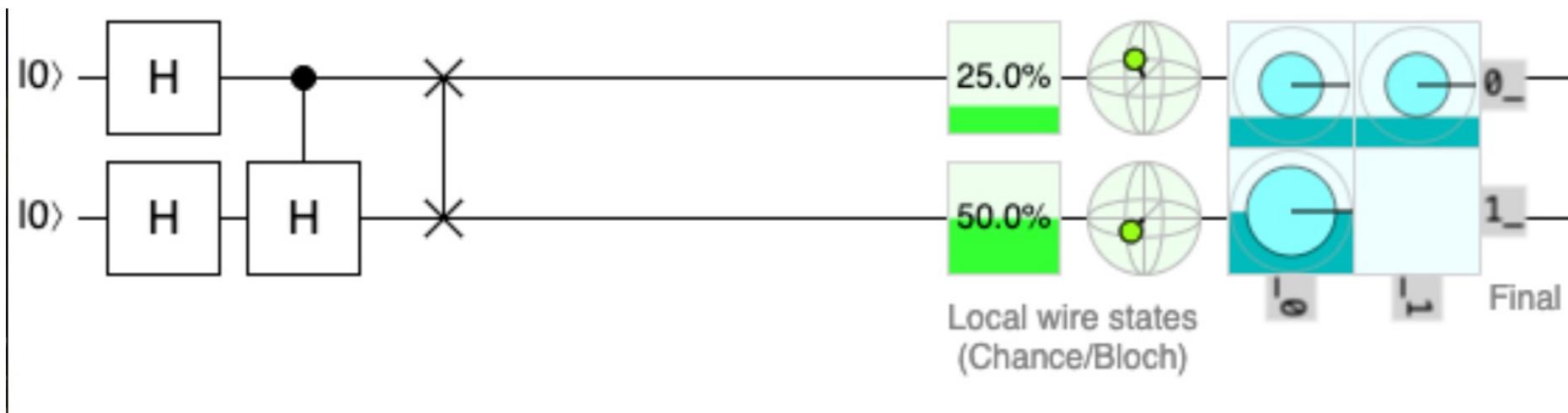


00 (25%) 01 (50%)
10 (25%) 11 (0%)

Let's play (3)!!



Let's play (3)!!



00 (25%) 01 (25%)
10 (50%) 11 (0%)

Grazie!!!

Quantum
Circuits
Fundamentals

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@jjoselemuss