

UNDERSTANDING THE POWER OF A QUANTUM ALGORITHM

FROM 0 TO $|\text{HELLO}\rangle + |\text{WORLD}\rangle$

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Quantum Information for Developers, ETH Zurich 2019



TO FEEL

THE POWER OF ONE
QUANTUM ALGORITHM

with (almost) no physics and
no computational complexity



TO PLAY

WITH QUANTUM COMPUTING
BY **EDITING QUANTUM CODE**

with no configuration
from your laptop...
now, yes, right now.

Please open your laptop



SIGN UP QUANTUMCOMPUTING.COM/QUID2019

INTUITIVE INTERFACE

Get up and running with quantum code using our easy to understand interface.

MULTI-VENDOR SUPPORT

Run experiments using IBM Qiskit, Microsoft Q#, Google Cirq, Rigetti Pyquil, DWave LEAP, and others.

BEAUTIFUL RESULTS

Automatically generated graphs bring your work to life.

COLLABORATE

Create private teams and collaborate on projects.

ORGANIZE YOUR WORK

Manage projects across platforms and collaborators.

PROJECT LIBRARY

Create your own projects or start from our library.

FULL QUANTUM IDE/EDITOR

Edit code from any quantum toolkit using our robust IDE.

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Quid1

PLAY WITH ONE QUBIT

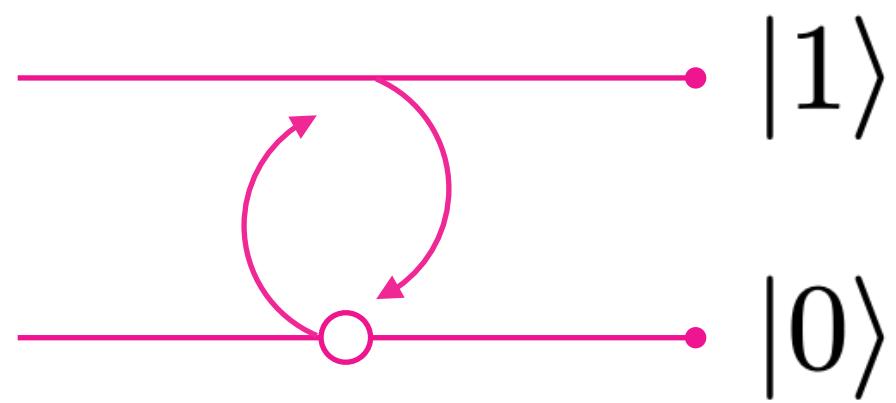
ADD THE PROJECT

app.quantumcomputing.com/library/quid1



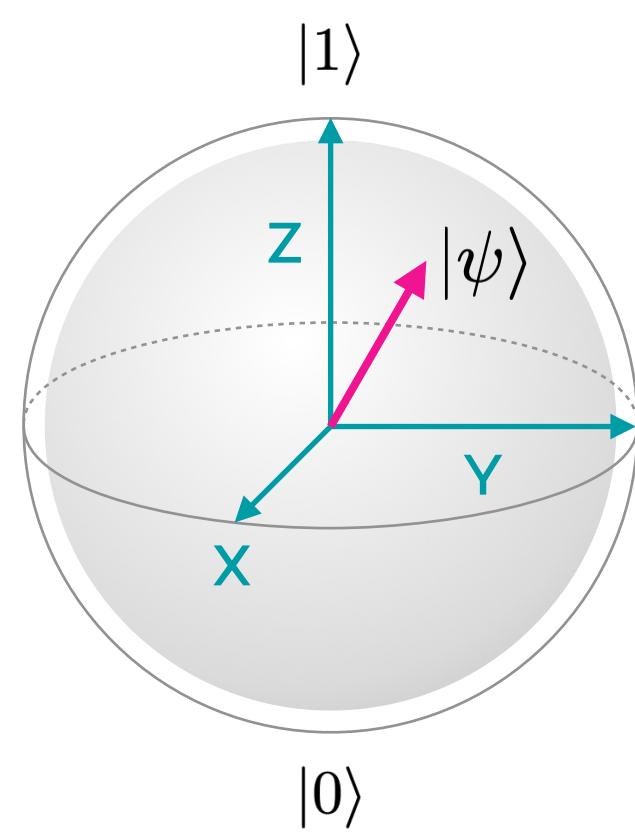
FIRST, PLAY WITH ONE QUBIT

TWO LEVEL QUANTUM MECHANICAL SYSTEM

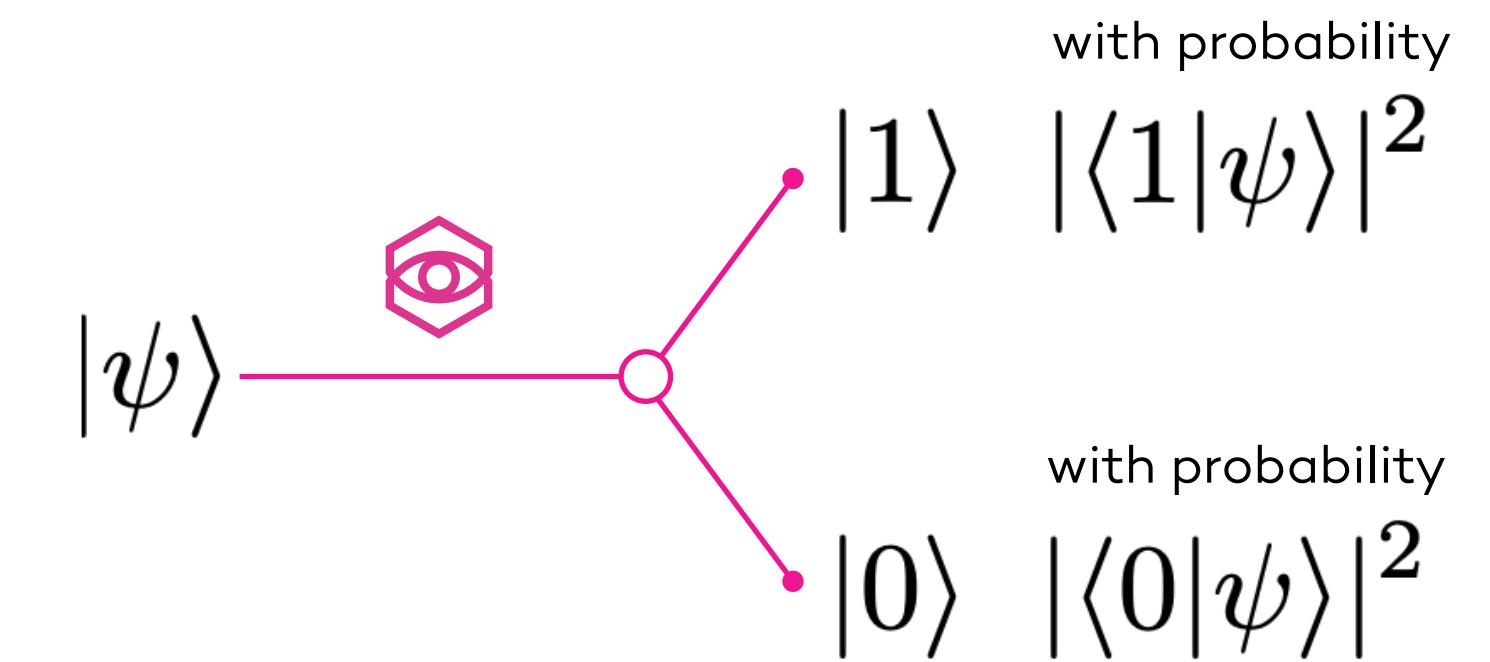


ALLOWS FOR SUPERPOSITIONS

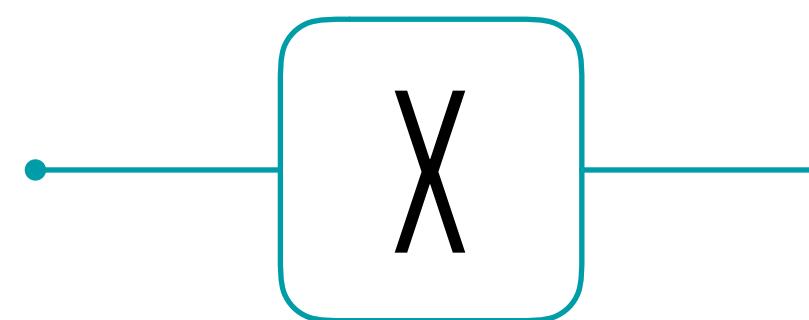
$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$



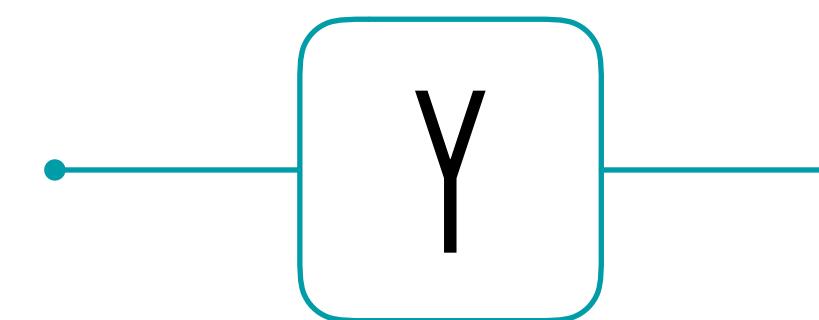
MEASURING SUPERPOSITIONS GIVES PROBABILISTIC OUTCOMES



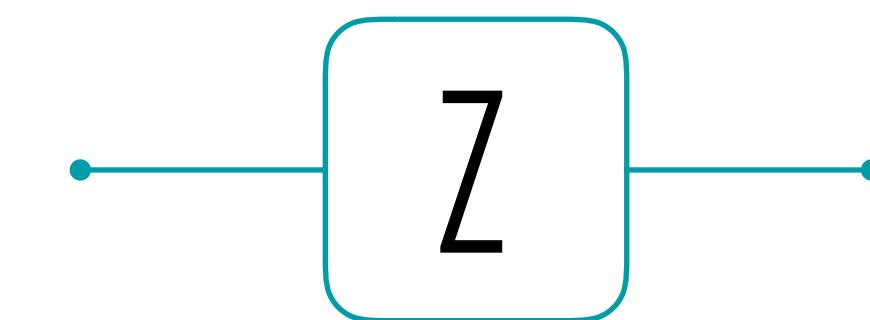
PLAY WITH ONE QUBIT OPERATIONS



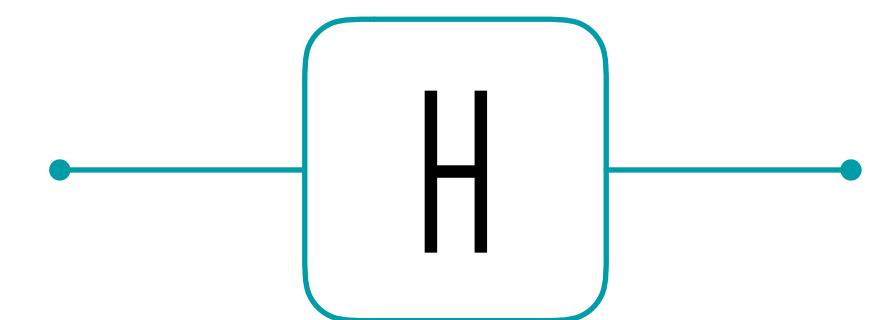
$$\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$$



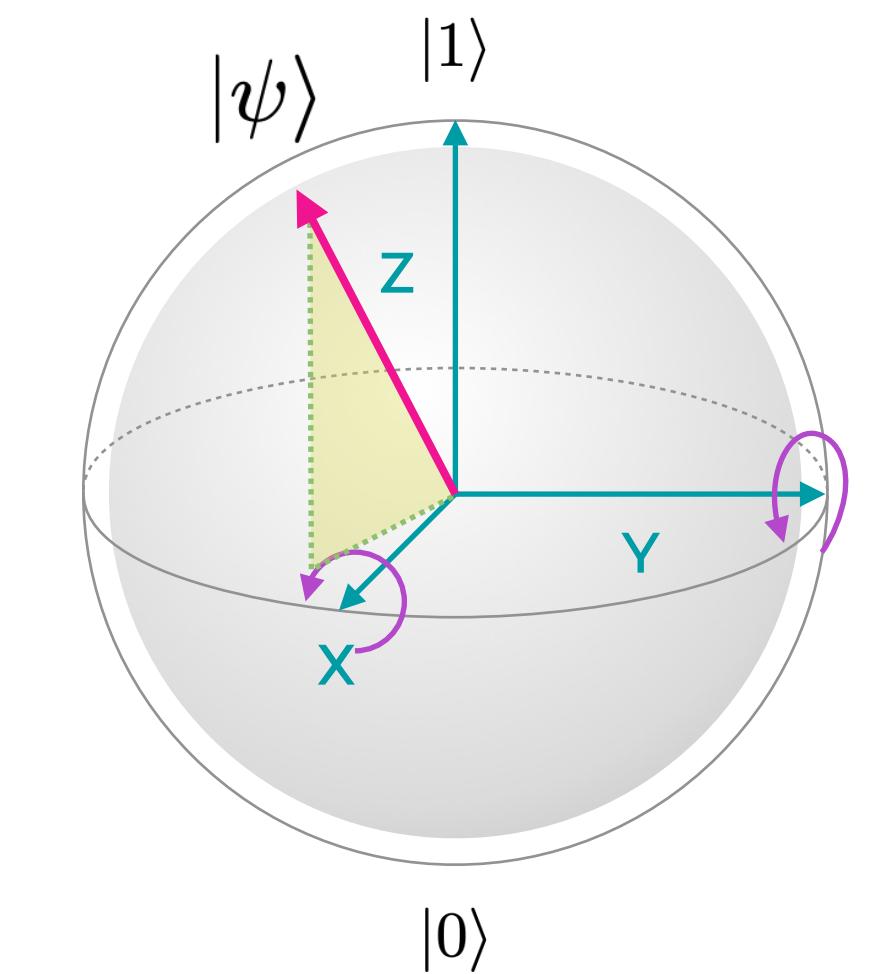
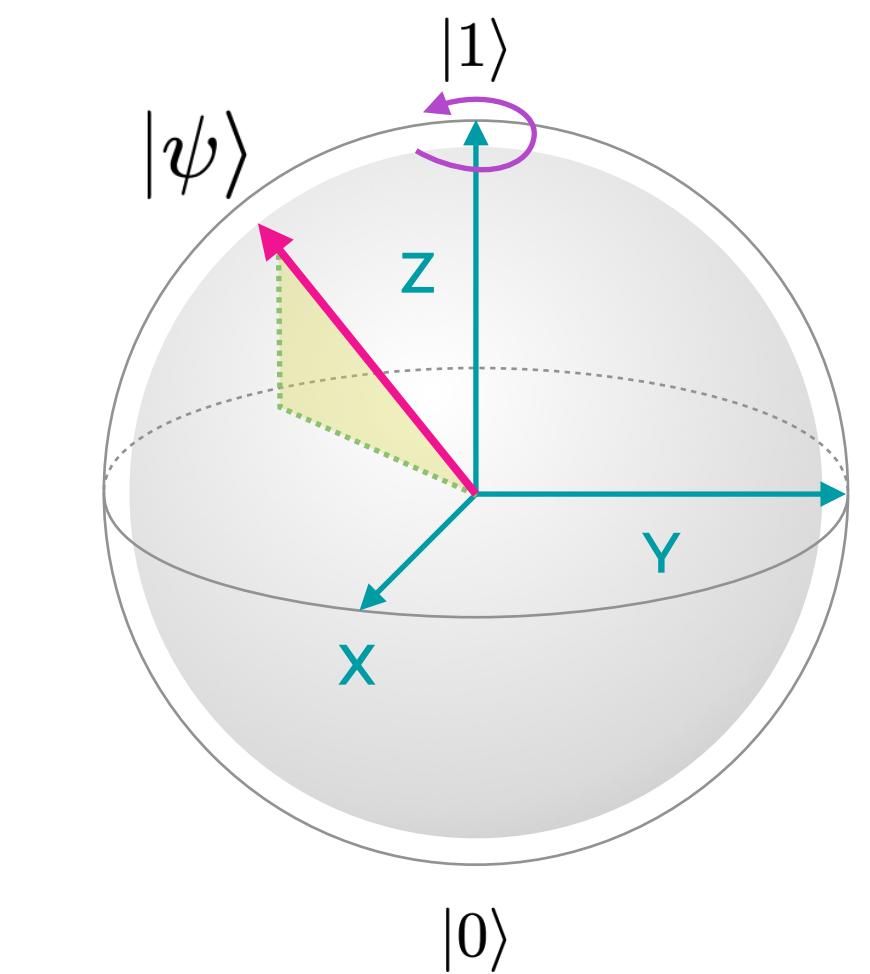
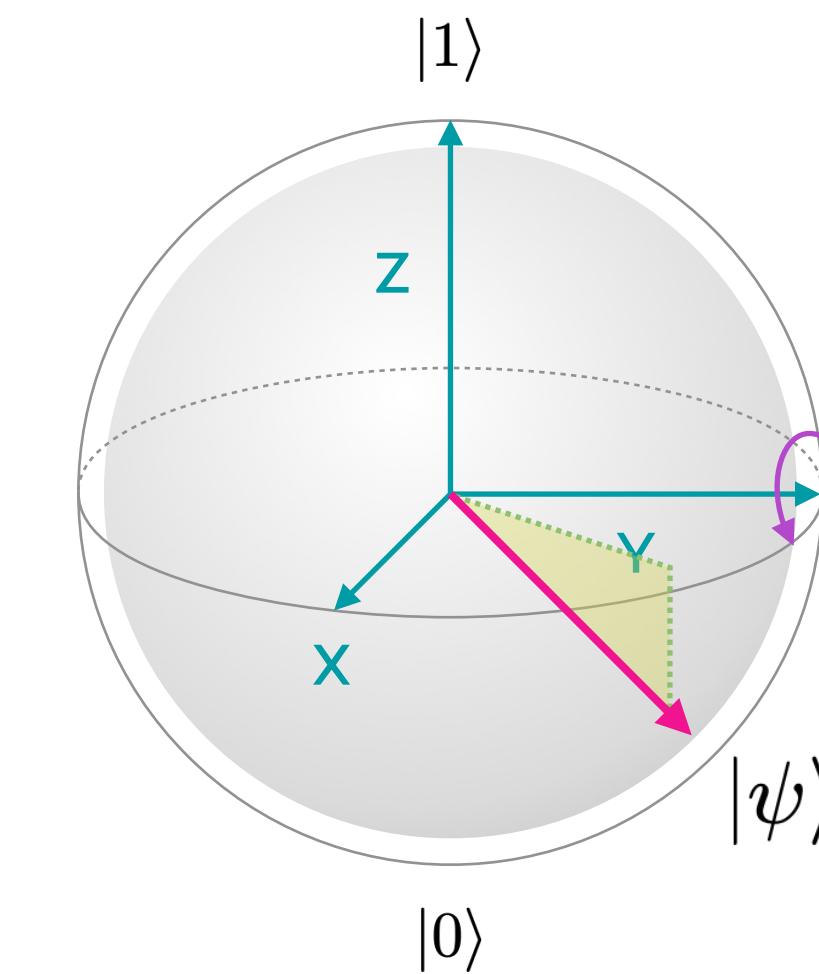
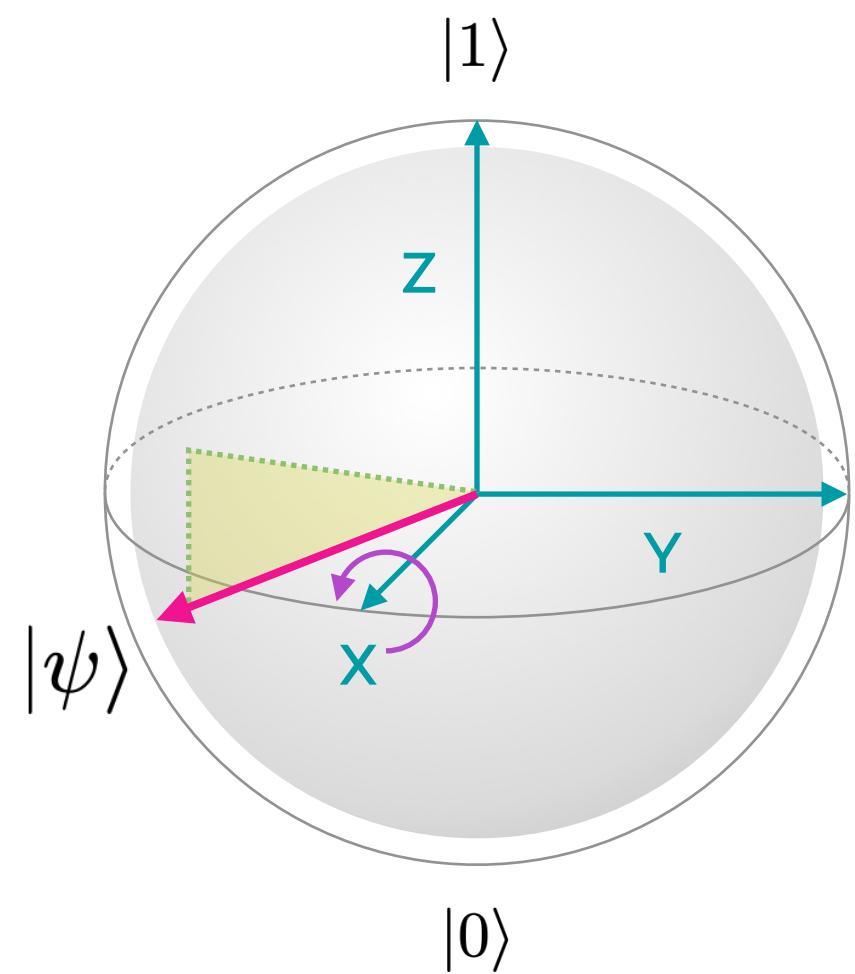
$$\begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix}$$



$$\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$$



$$\frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$





QuID 2

SOLVE THIS RUBIQ'S SPHERE

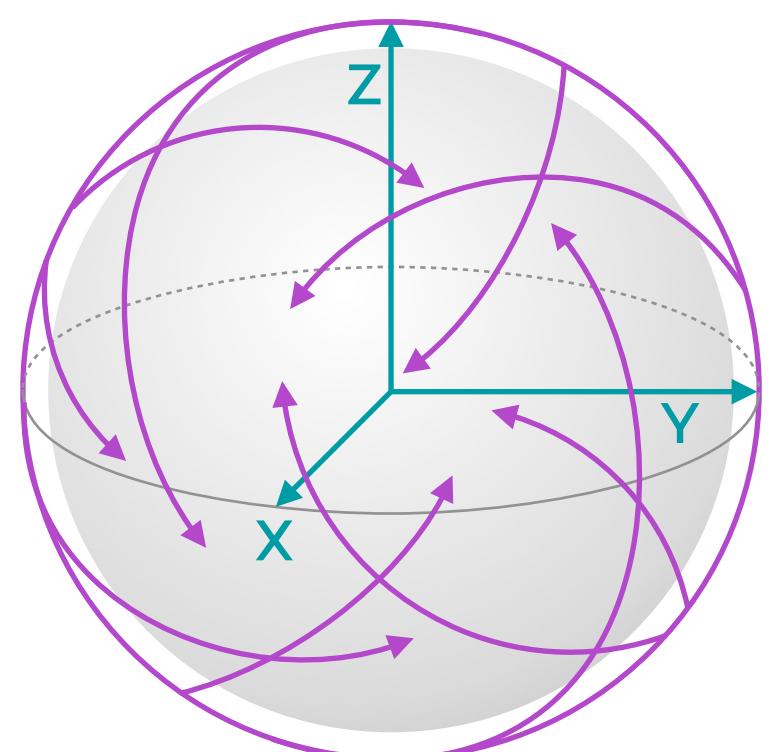
ADD THE PROJECT

app.quantumcomputing.com/library/quid2

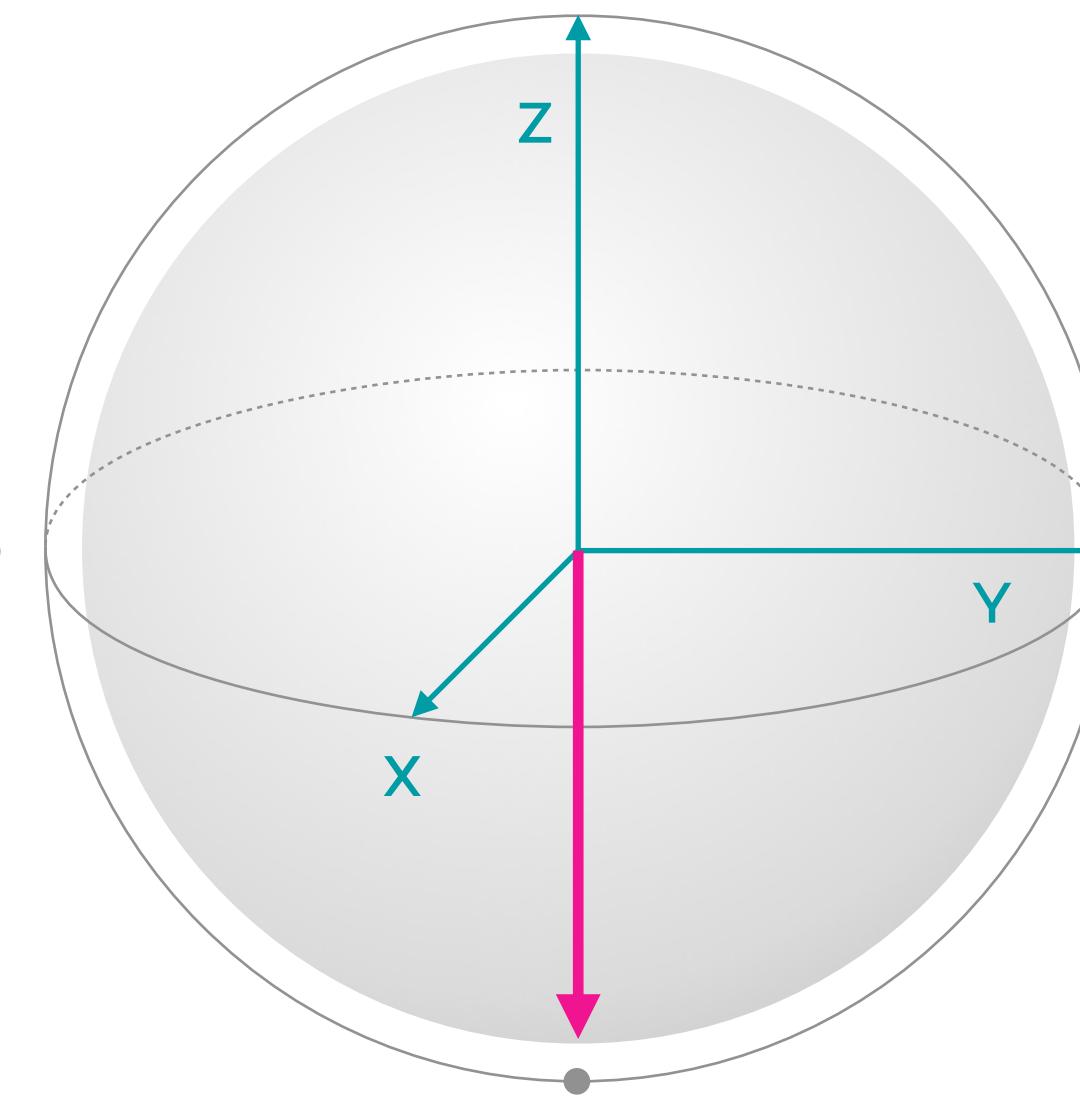


SOLVE RUBIQ'S SPHERE

I SPUN A QUBIT IN ALL DIRECTIONS



YOUR MISSION
MAKE IT POINT TO 0 WITH A PROBABILITY OF 1 ALL THE TIME



$$|\psi\rangle = |0\rangle$$

I HAVE SOME HINTS

- Use at least 10 iterations
- You only need a combination of x, y, z & h gates (Copy and paste them around from the code)
- The order of gates makes a difference
- You can do it with just two gates





PROJECT LIBRARY FOR WHOM THE BELL ENTANGLES

ADD THE PROJECT

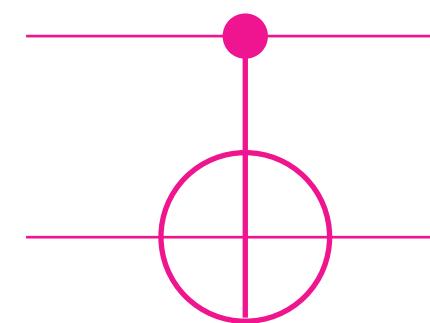
app.quantumcomputing.com/library/for-whom-the-bell-entangles



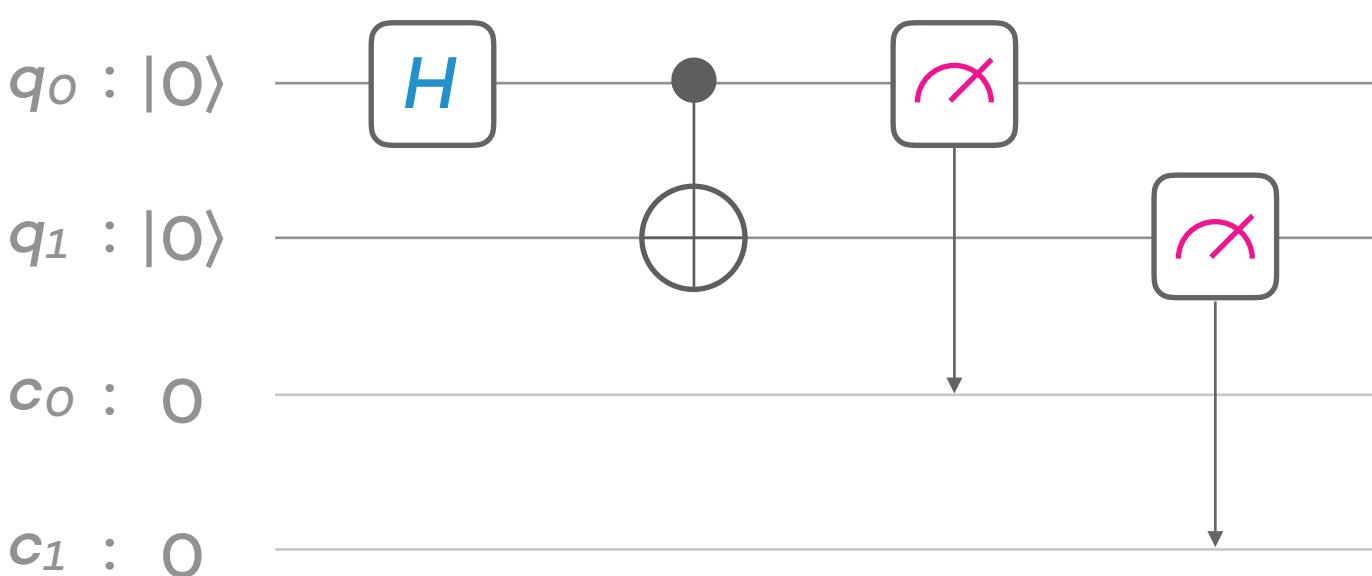
PLAY WITH THE CONTROLLED-NOT GATE

THE CONTROLLED NOT

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$



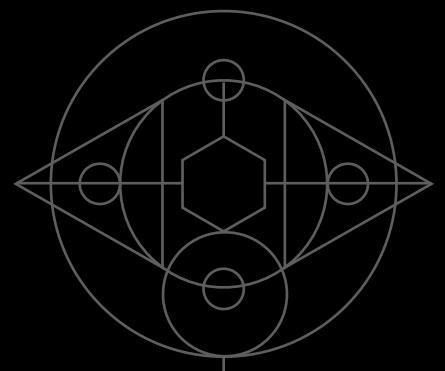
IT'S A CRUCIAL GATE TO
CREATE ENTANGLEMENT



THINGS TO TRY

- Go to the code and change the Hadamard gate for others
- What is the effect of different gates on q_0 and q_1 just before the measurements?





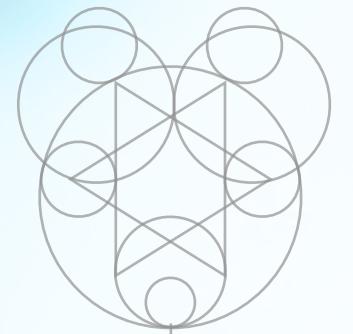
LEARN QUANTUM

BY PROGRAMMING A QUANTUM COMPUTER

COME BACK AND PLAY WITH QUANTUM CODE

Don't worry about the details for now





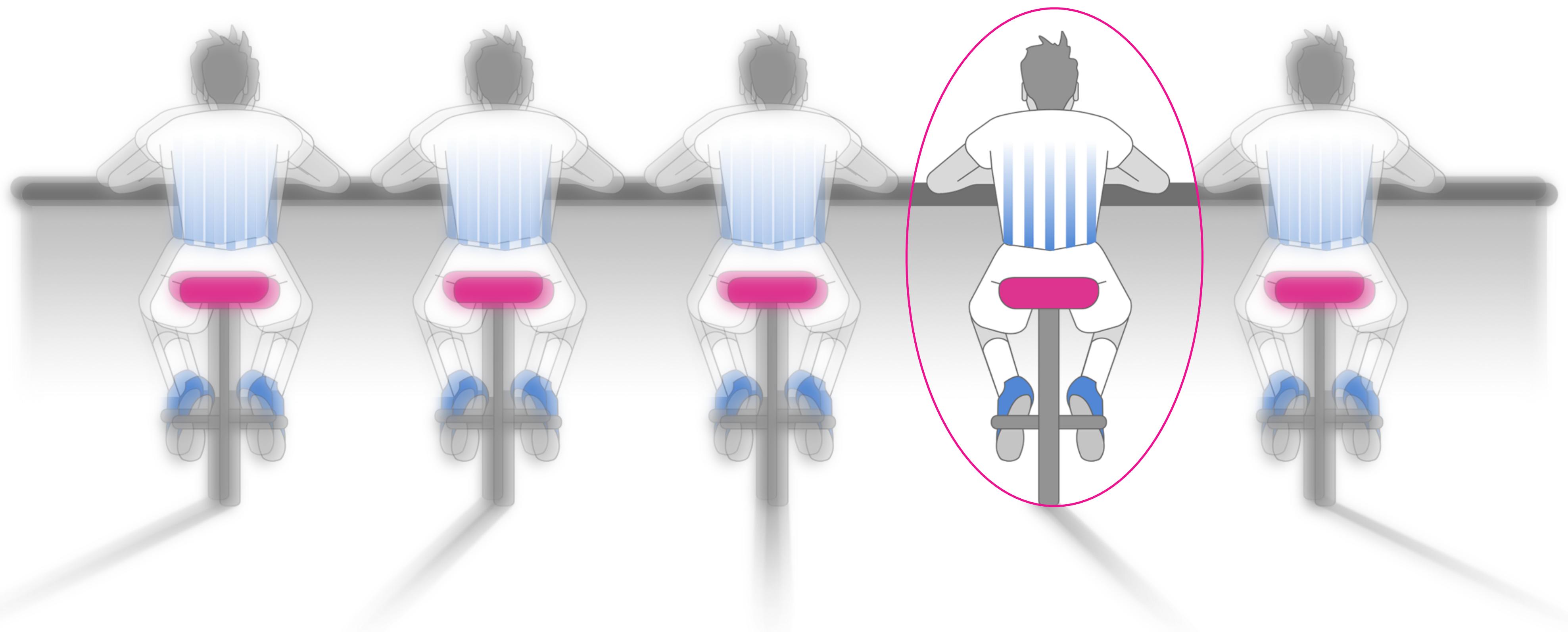
THE POWER OF ONE QUANTUM ALGORITHM

STICK WITH ME

It's about to get strange



CLASSICAL DRUNK



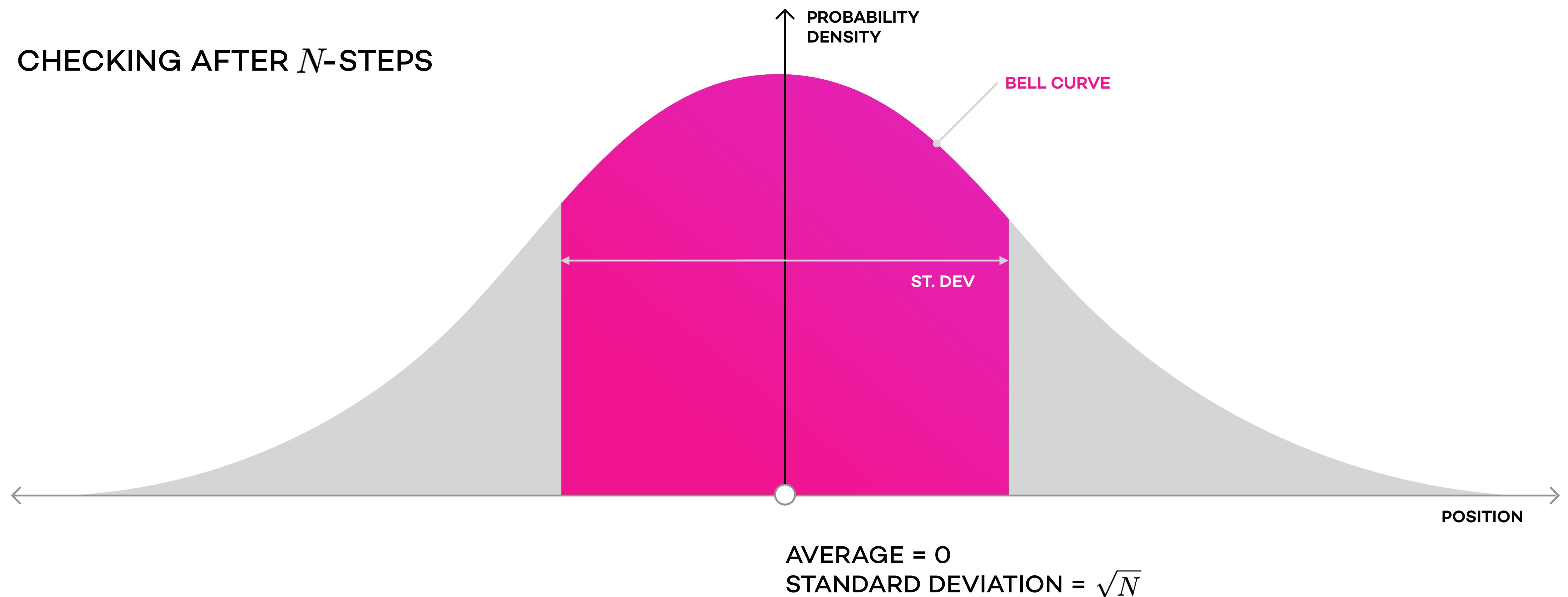
CLASSICAL DRUNK

FLIPPING A COIN TO DECIDE,
EACH STEP OUR DRUNK CAN GO LEFT OR RIGHT

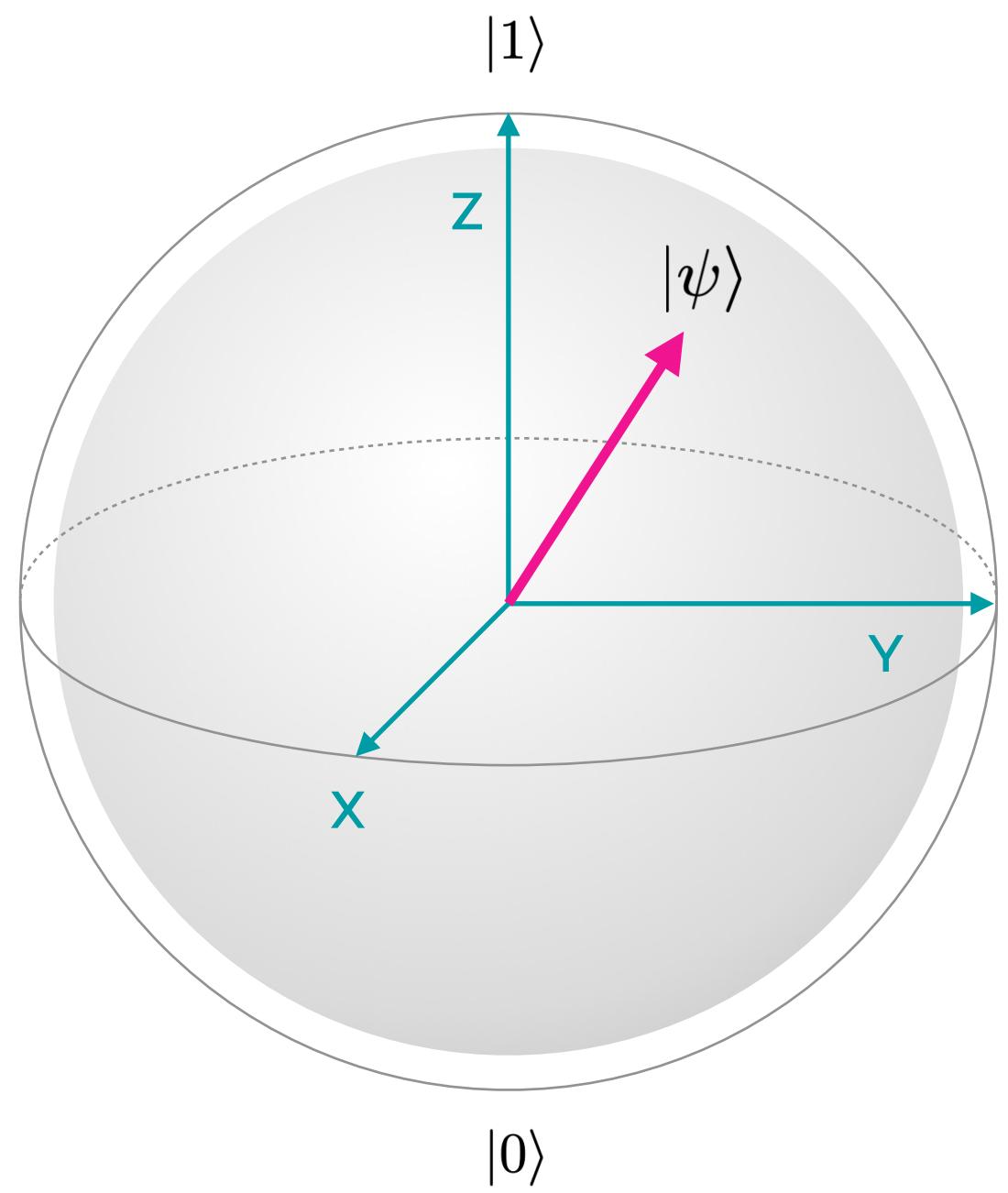


DRUNKEN WALK = BELL CURVE

CHECKING AFTER N -STEPS



QUANTUM SUPERPOSITION

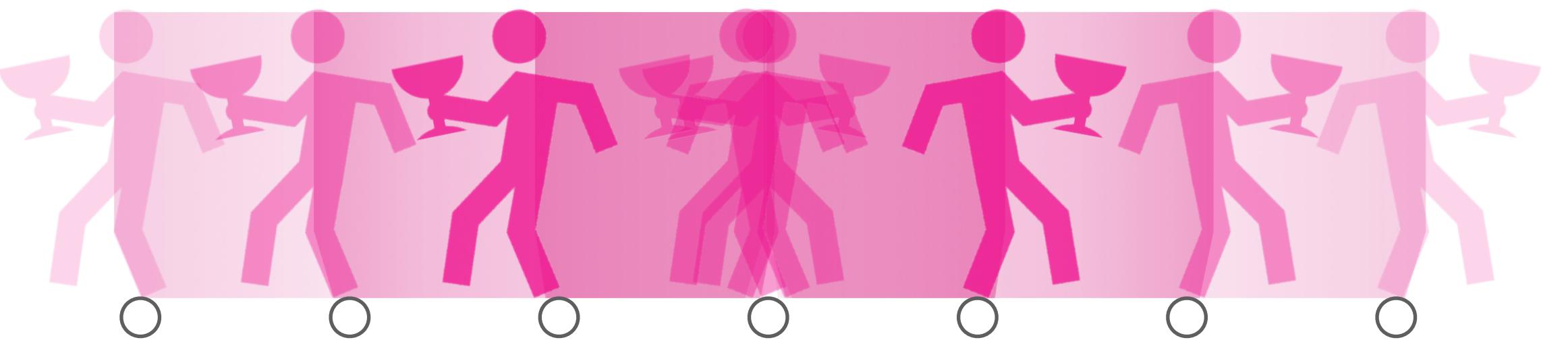
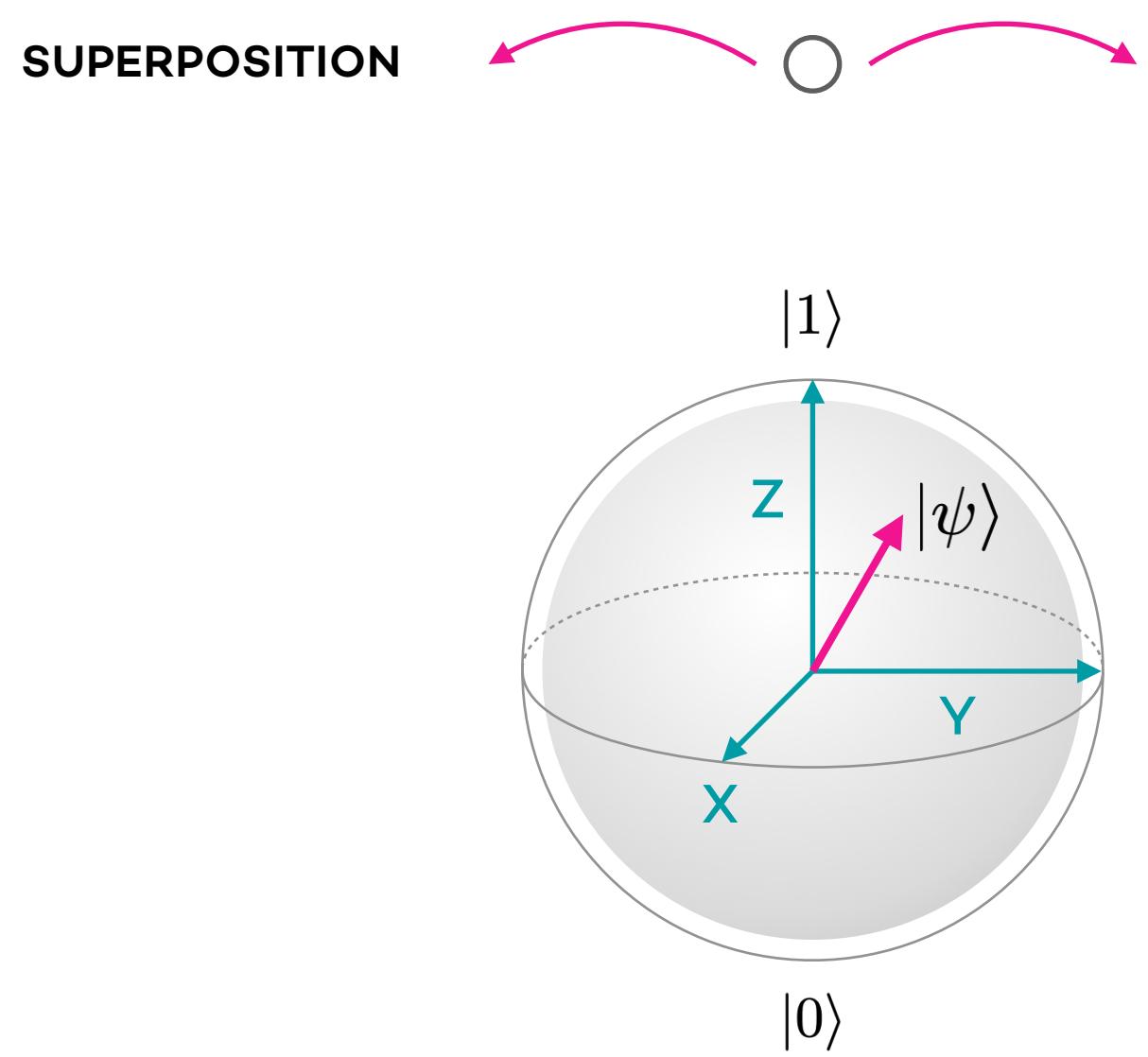


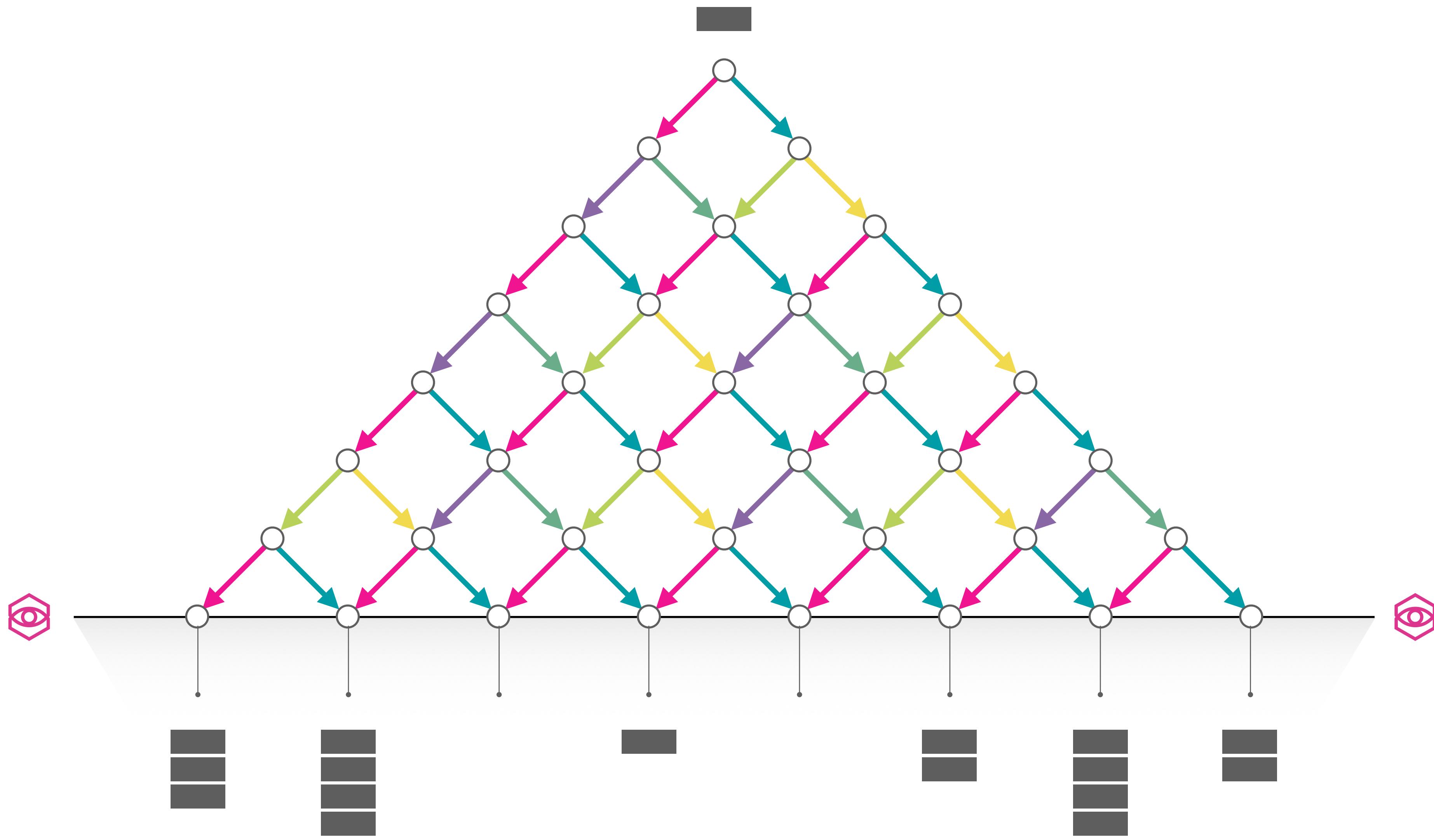
$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$



QUANTUM DRUNK

FLIPPING A “QUANTUM COIN” TO DECIDE, OUR DRUNK GOES TO SUPERPOSITION OF BOTH SIDES

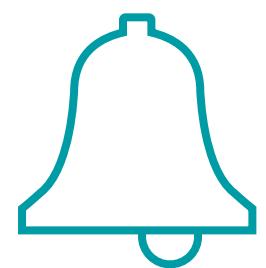
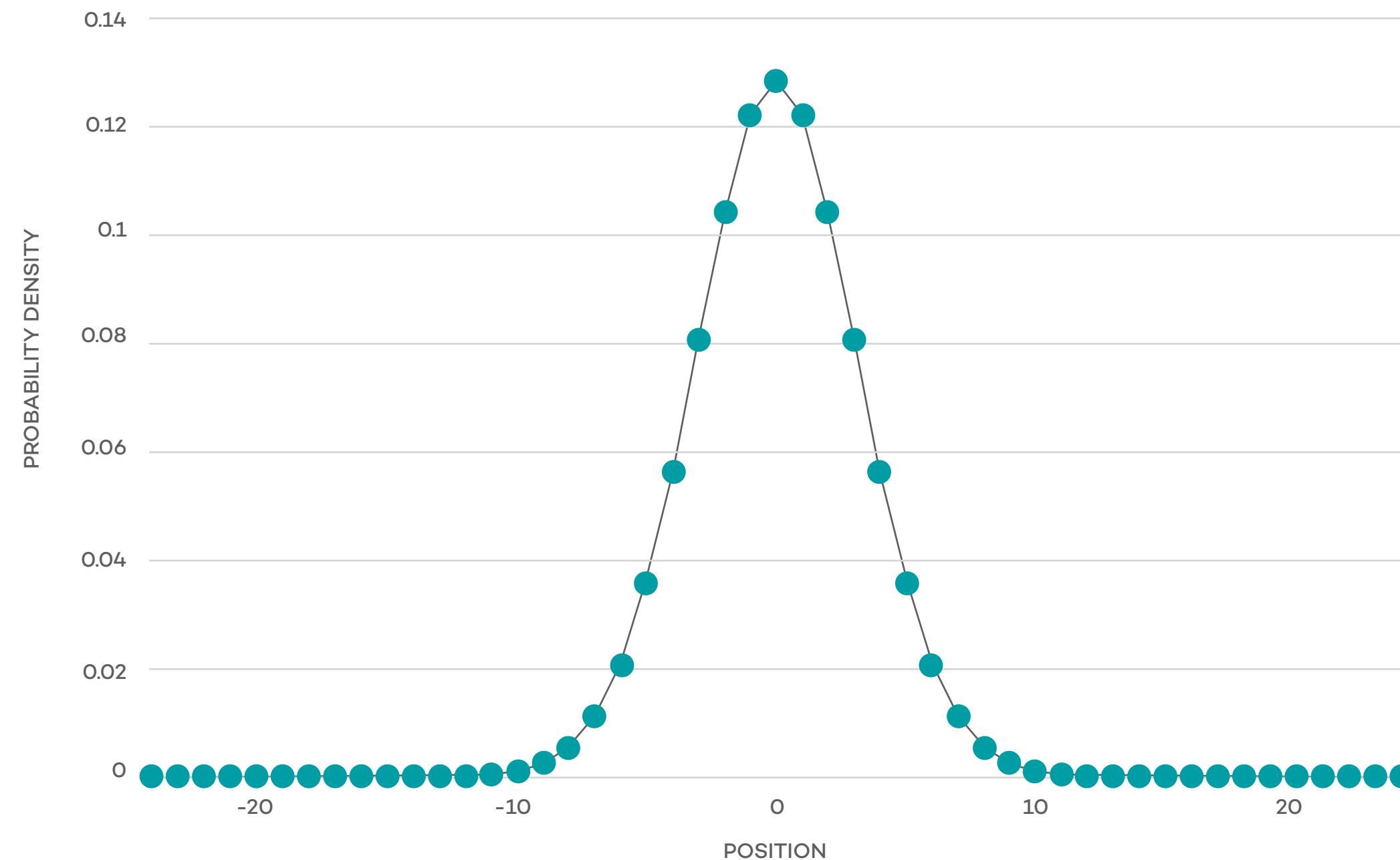




WALK A LINE



CLASSICAL RANDOM WALK

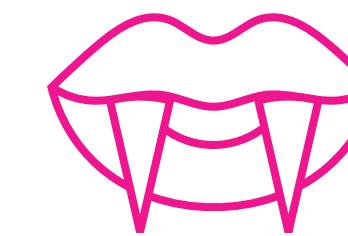
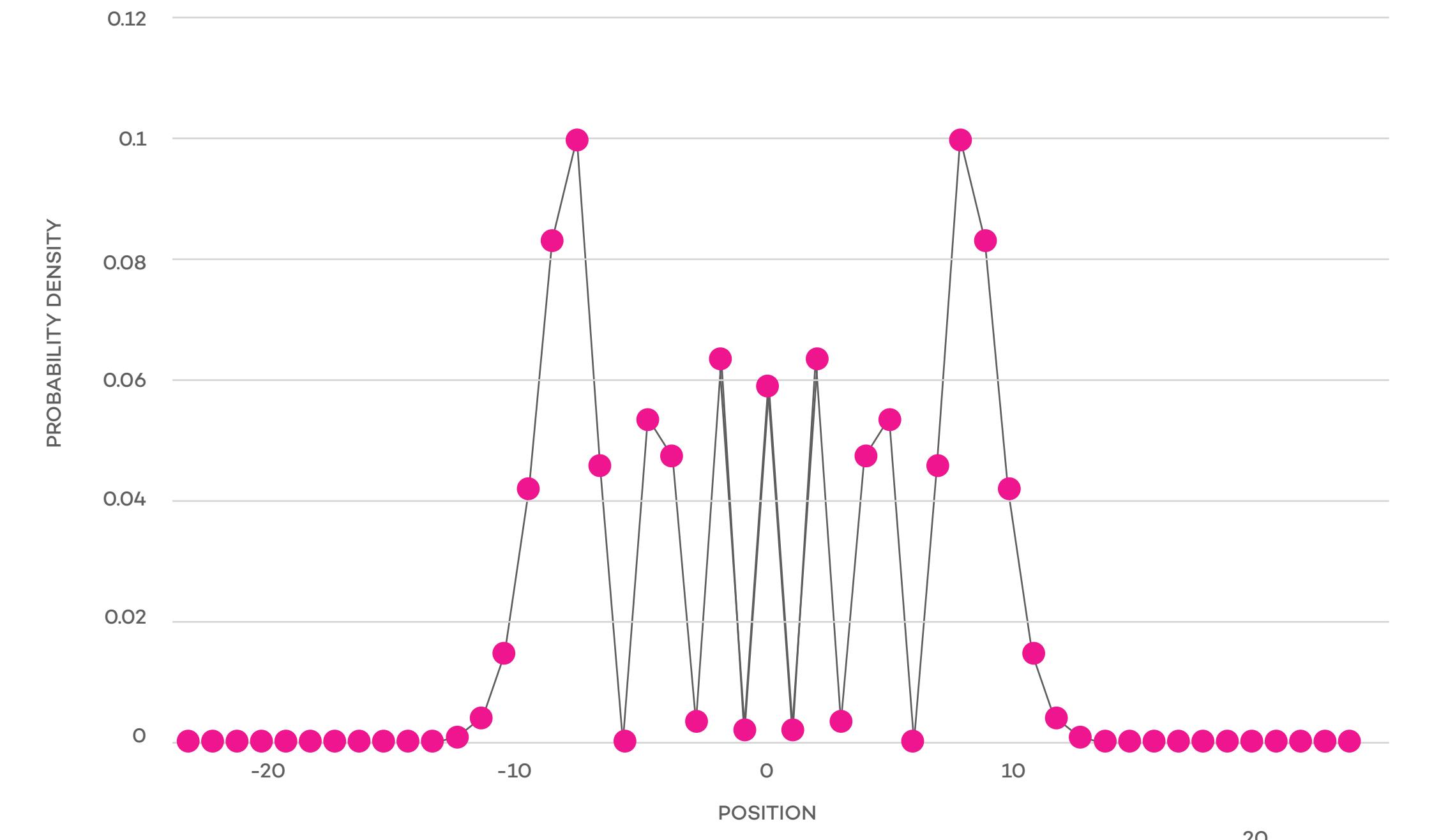


CENTERED, SPREADS SLOWLY

average = 0
standard deviation = \sqrt{n}



QUANTUM WALK

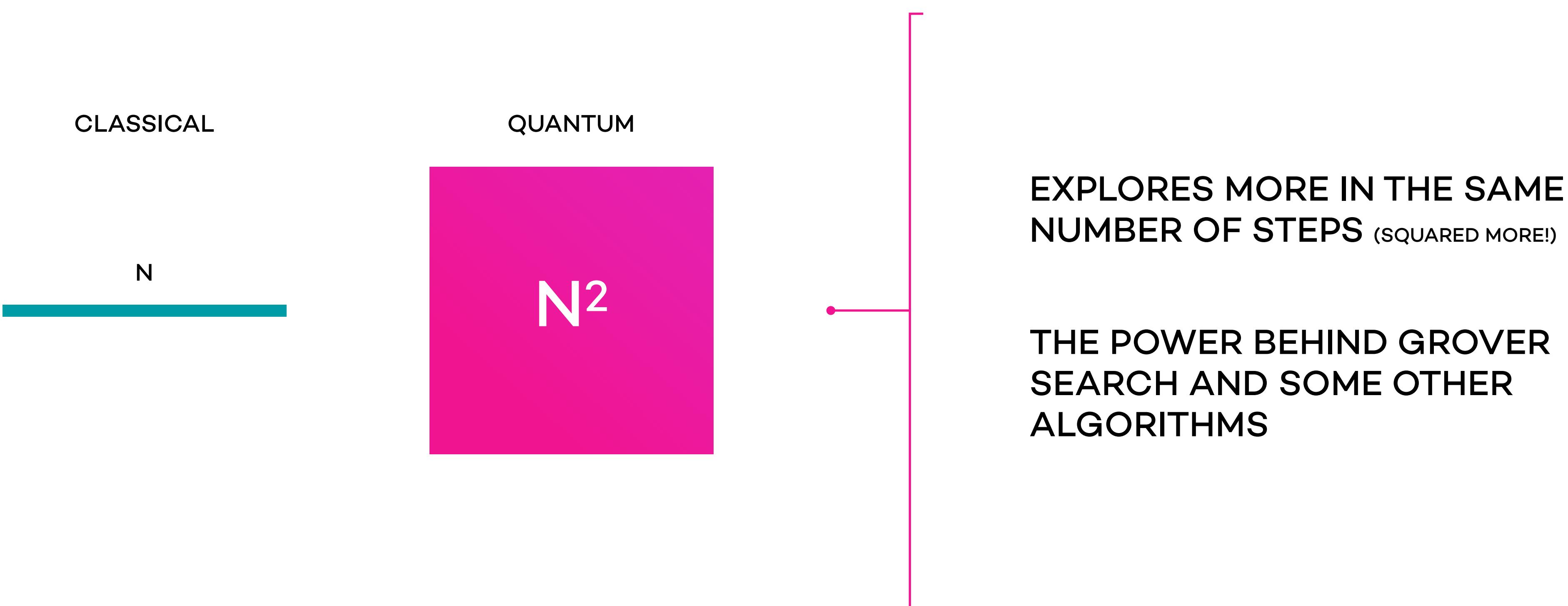


MOSTLY ON THE SIDES

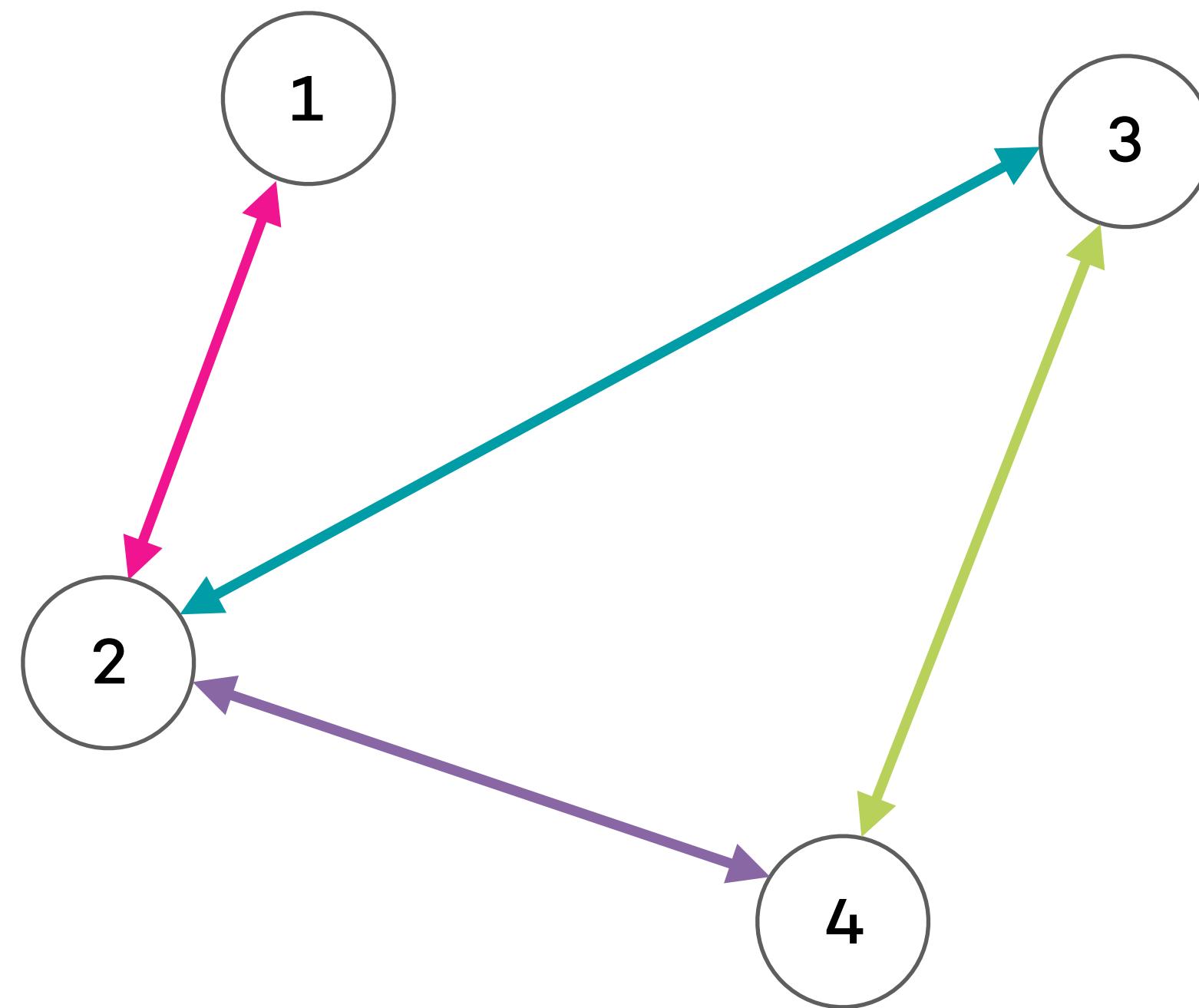
average = 0
standard deviation = n



POWER OF QUANTUM



DRUNKS IN A LABYRINTH

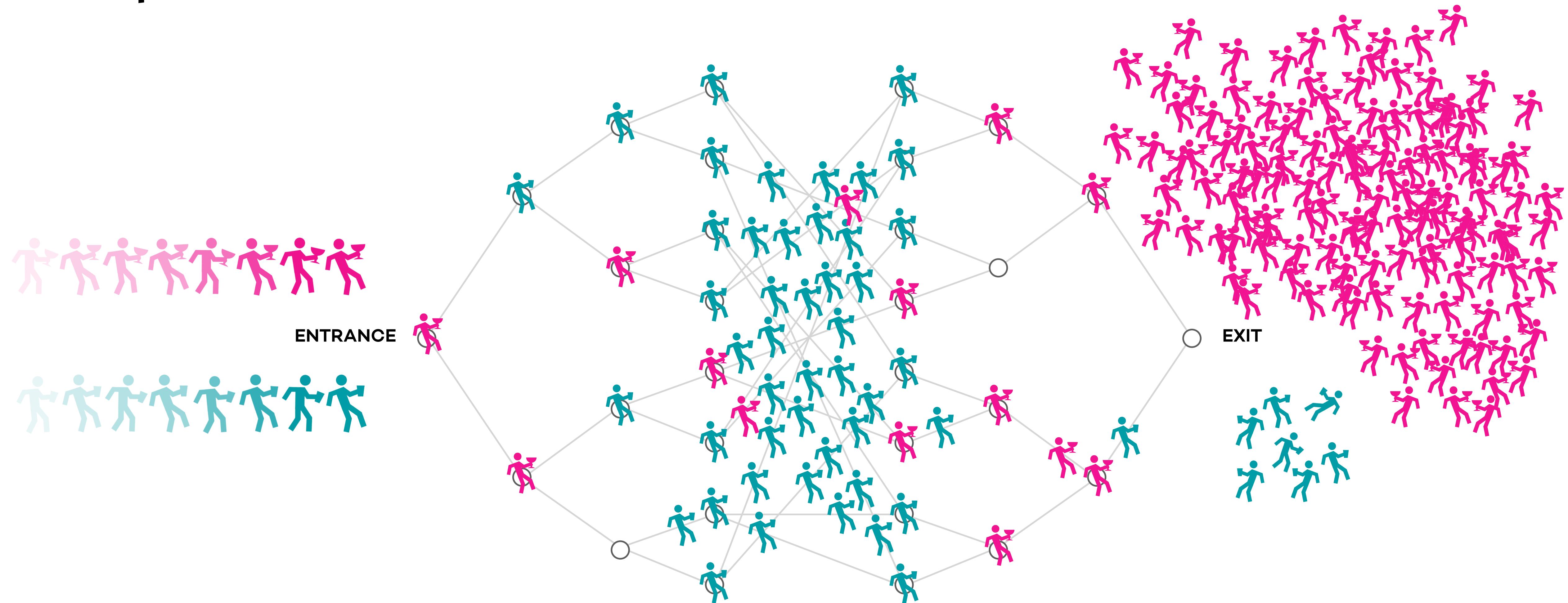


SAME PRINCIPLE
WALK ENCODED AS A NETWORK

$$M = \begin{pmatrix} 1 & -1 & 0 & 0 \\ -1 & 3 & -1 & -1 \\ 0 & -1 & 2 & -1 \\ 0 & -1 & -1 & 3 \end{pmatrix}$$



QUANTUM DRUNK IS EXPONENTIALLY BETTER





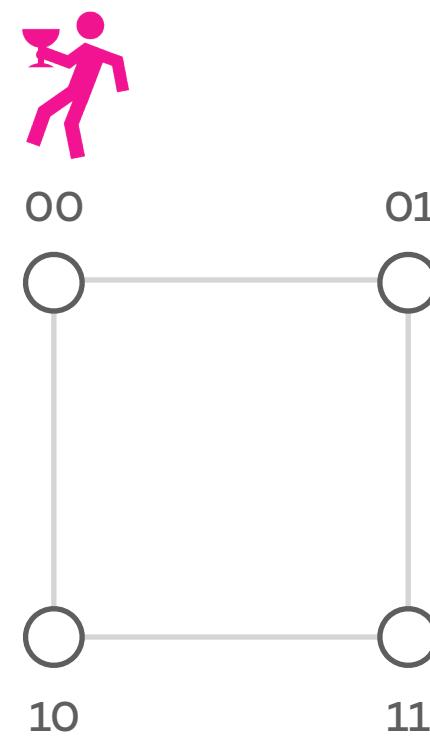
QuID3
QUANTUM WALK, FOUR NODES

ADD THE PROJECT

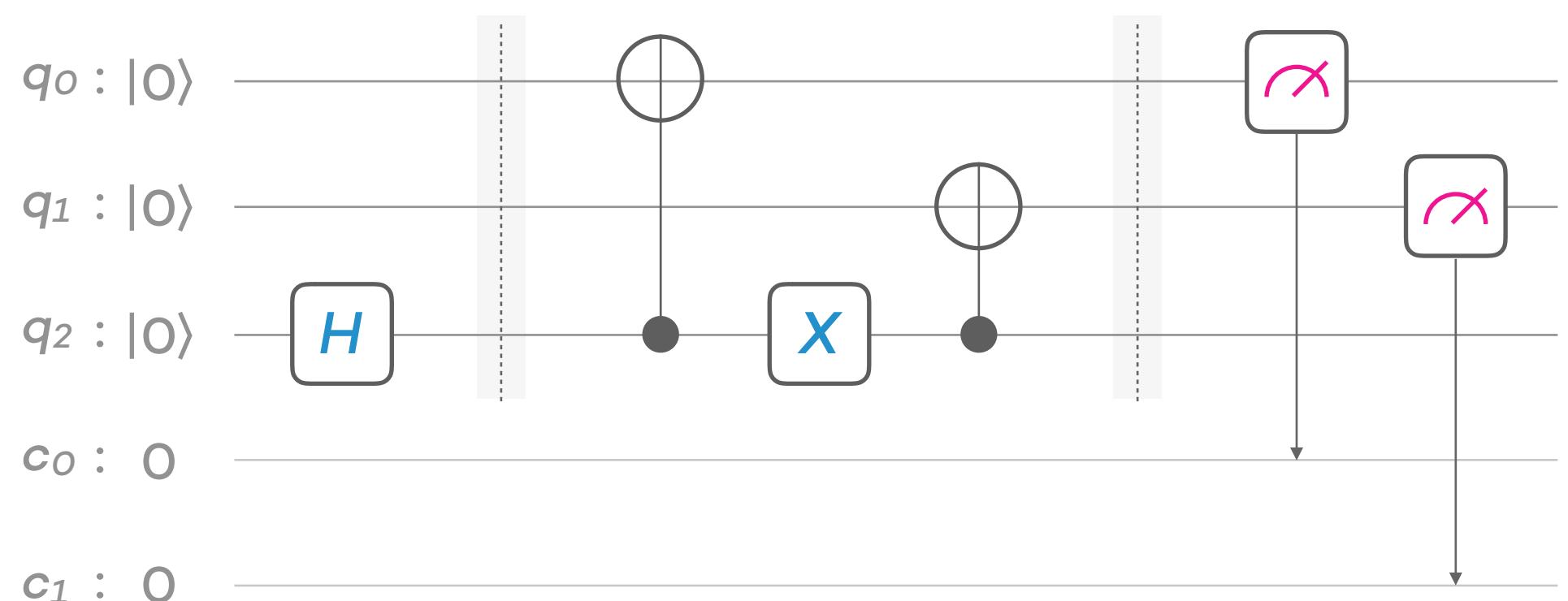
app.quantumcomputing.com/library/quid3



THE QUANTUM WALK



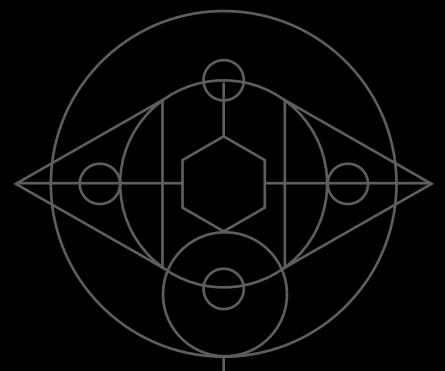
GENERATED QW CIRCUIT



THINGS TO TRY

- Change number of steps 2... then 3... then... 4, 5...any patterns?
- Change initial state
- Change how to prepare the coin





LEARN QUANTUM

BY PROGRAMMING A QUANTUM COMPUTER

COME BACK AND PLAY WITH QUANTUM CODE

Don't worry about the math and physics

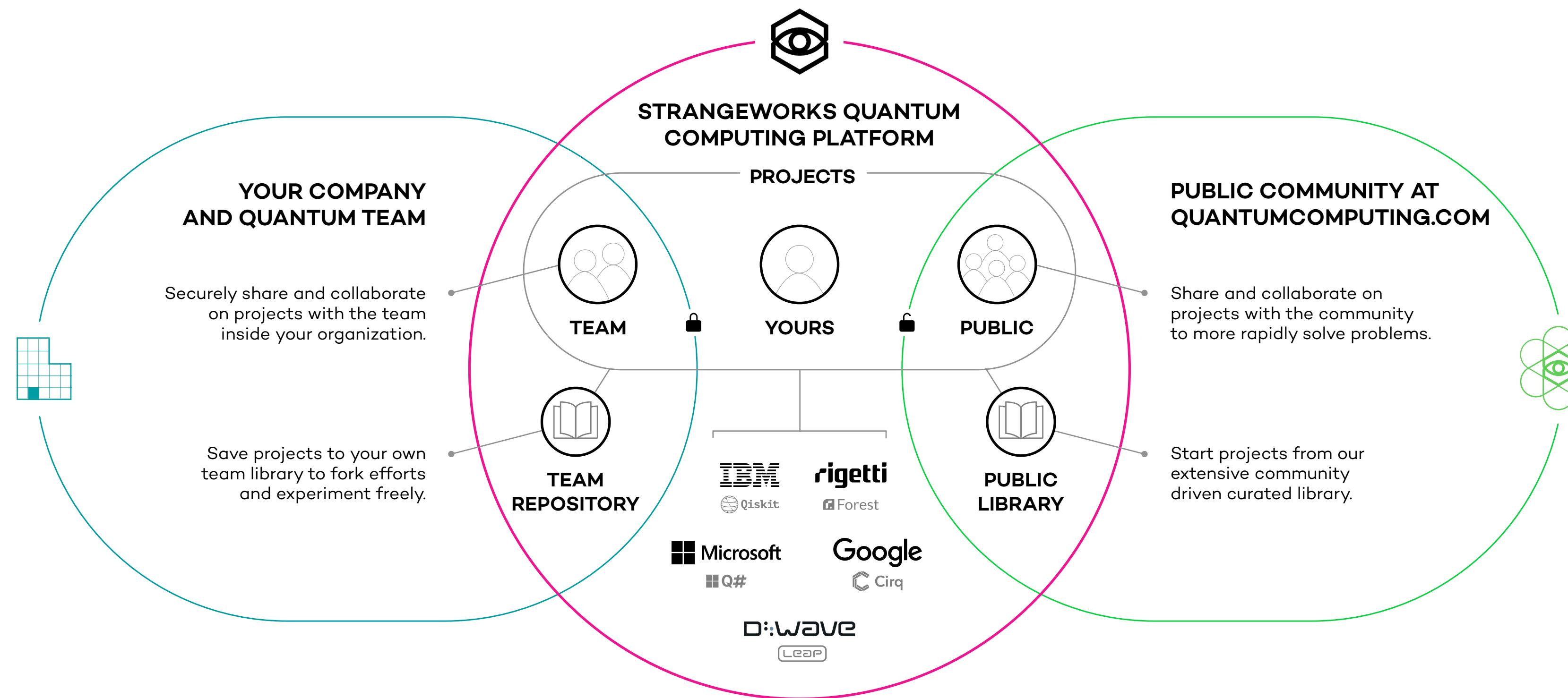
There are more things for you to play with in the library

quantumcomputing.com/quid2019



IT'S FREE, USE IT FOR WORK

IF YOU DO COOL STUFF, WE CAN ADD IT TO THE LIBRARY, YOU GET CREDIT

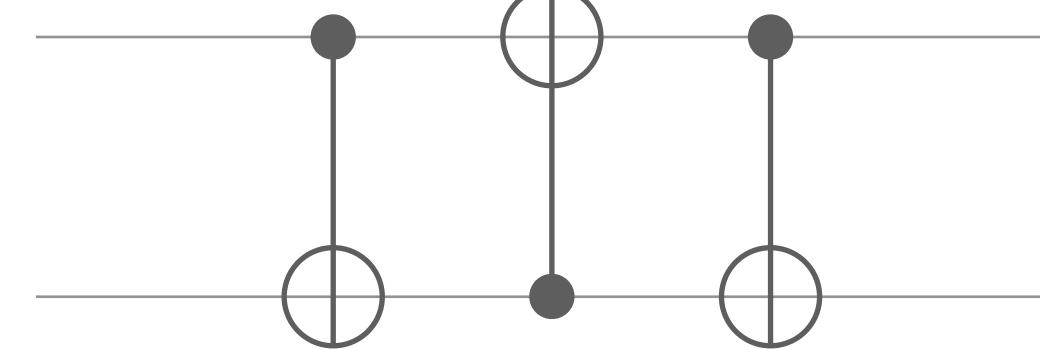


FEEDBACK & FEATURE REQUESTS
feedback.quantumcomputing.com

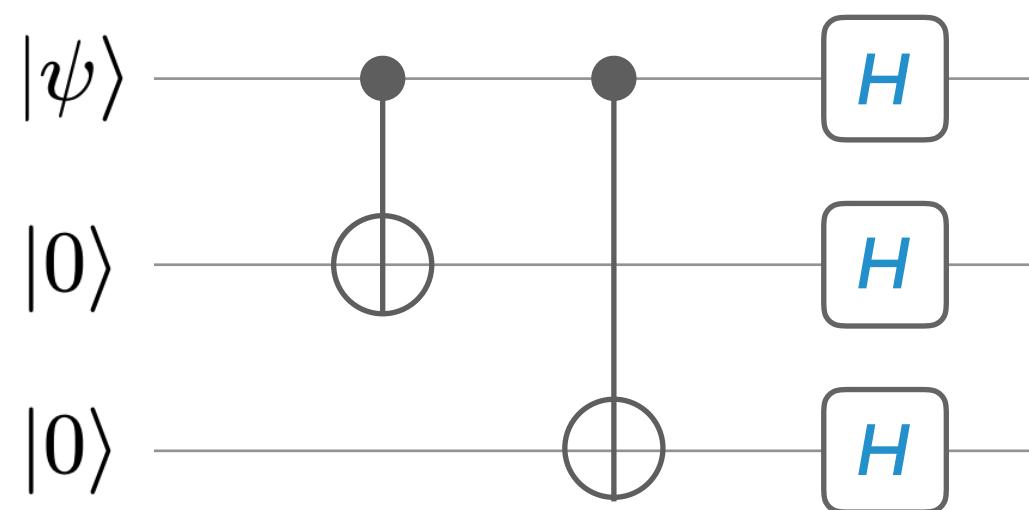


SOME IDEAS TO HACK

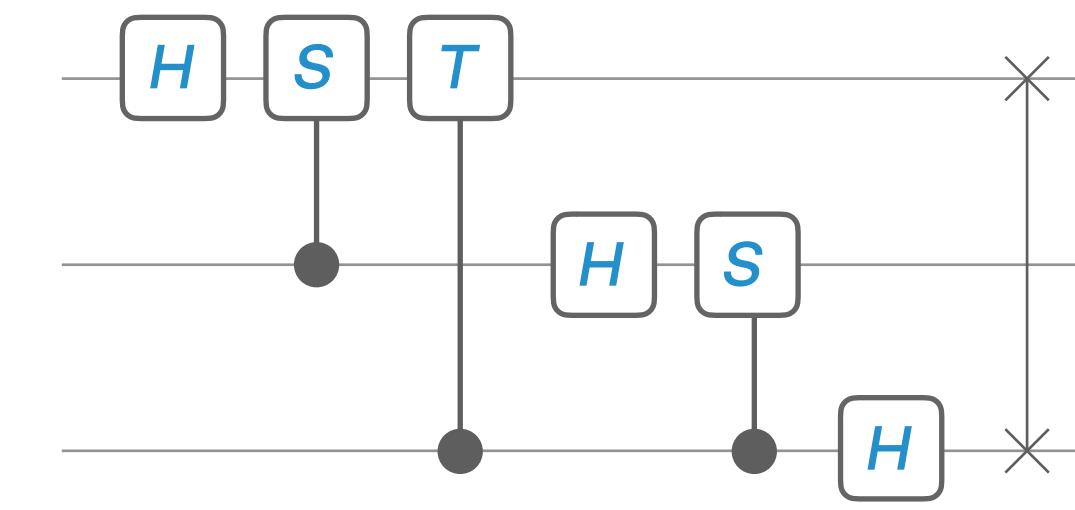
CONVINCE YOURSELF
THAT THIS CIRCUIT
SWAPS TWO QUBITS



CIRCUIT FOR
ERROR-CORRECTION
FOR PHASE-FLIP



CODE THIS
3 QUBIT QUANTUM
FOURIER TRANSFORM



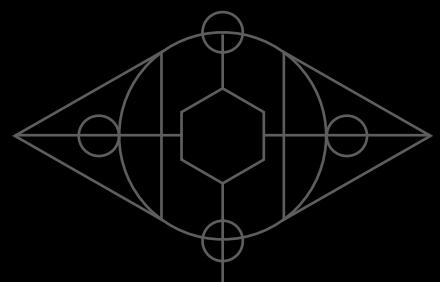
PLAY WITH THE STRANGWORKS LIBRARY

QASM arxiv.org/abs/1707.03429

CIRQ cirq.readthedocs.io/en/stable/tutorial.html

QISKIT arxiv.org/abs/1903.04359 & community.qiskit.org/textbook





THANKS.
NOW, GO HACK!

HUMANIZING QUANTUM™



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[APP.QUANTUMCOMPUTING.COM](https://app.quantumcomputing.com)

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