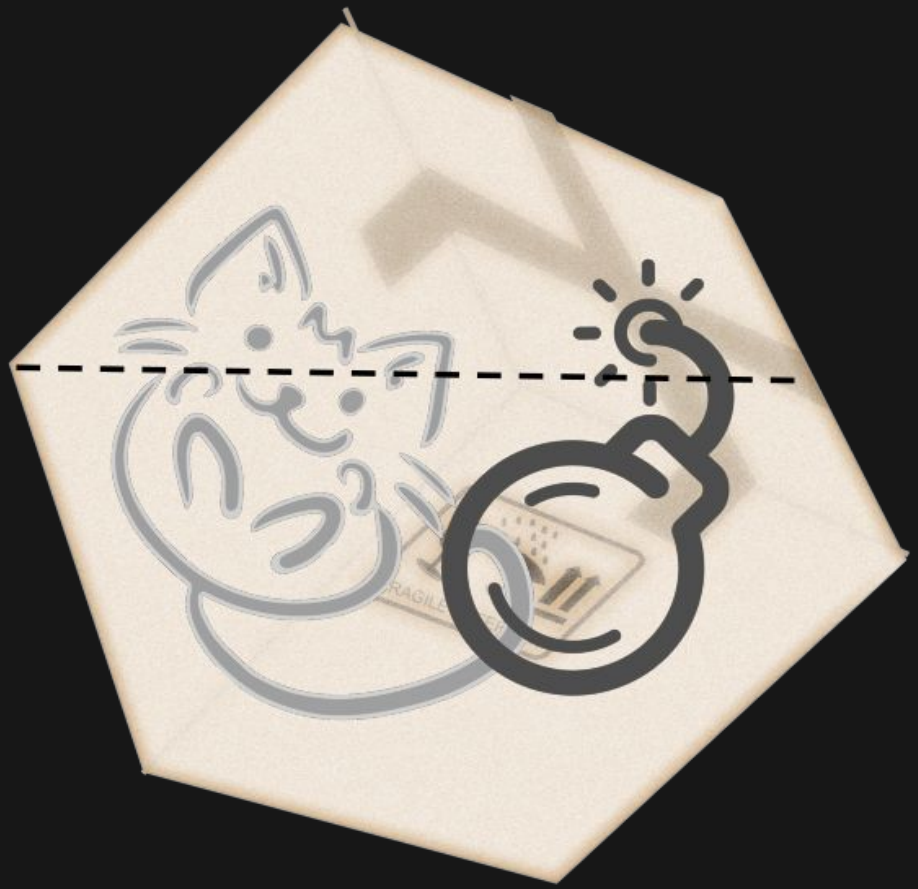
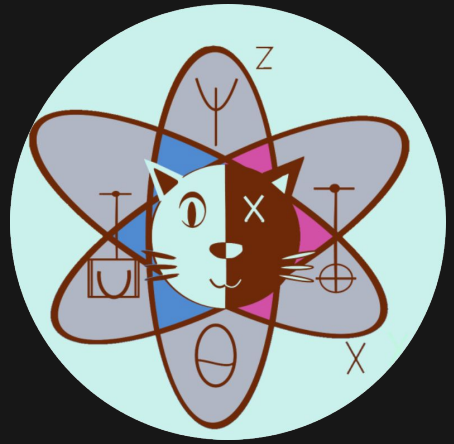
Introduction to Quantum Computing Workshop

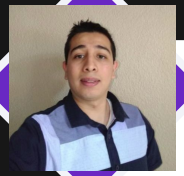


Qiskit

Join!



People Interested in Quantum Universal Education Discord: https://discord.gg/NDm9e9W



Alberto

BS Computing. Studying the MS's in computer science

Lia

CS PhD student at University of Oxford. Qiskit Advocate

Sans

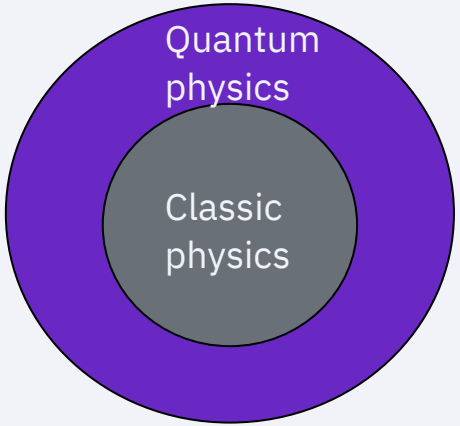
BS Computer Engineering at Clemson University

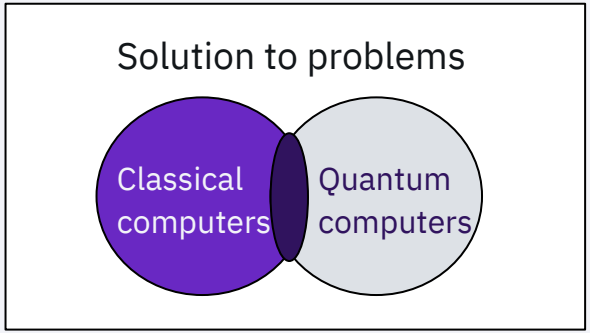
We’re developing community-driven, open-source, accessible quantum education materials: Anyone can contribute and get a free t-shirt!

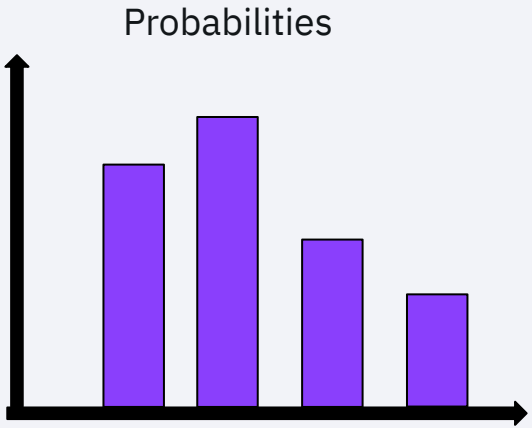
fullstackquantumcomputation.tech/contributing

what is quantum computing?

Quantum computers make direct use of quantum-mechanical phenomena, such as superposition and entanglement, to perform operations on data.

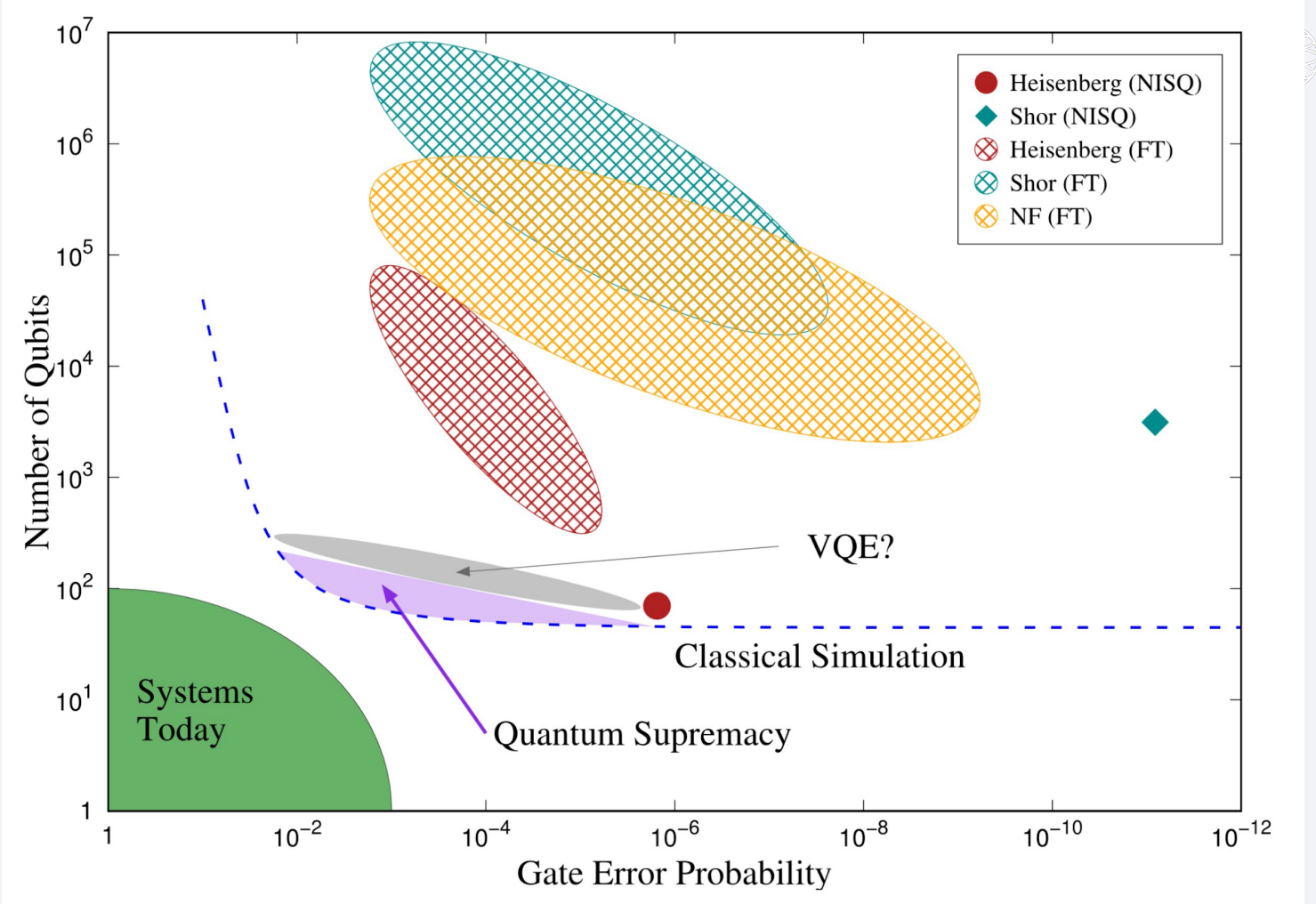




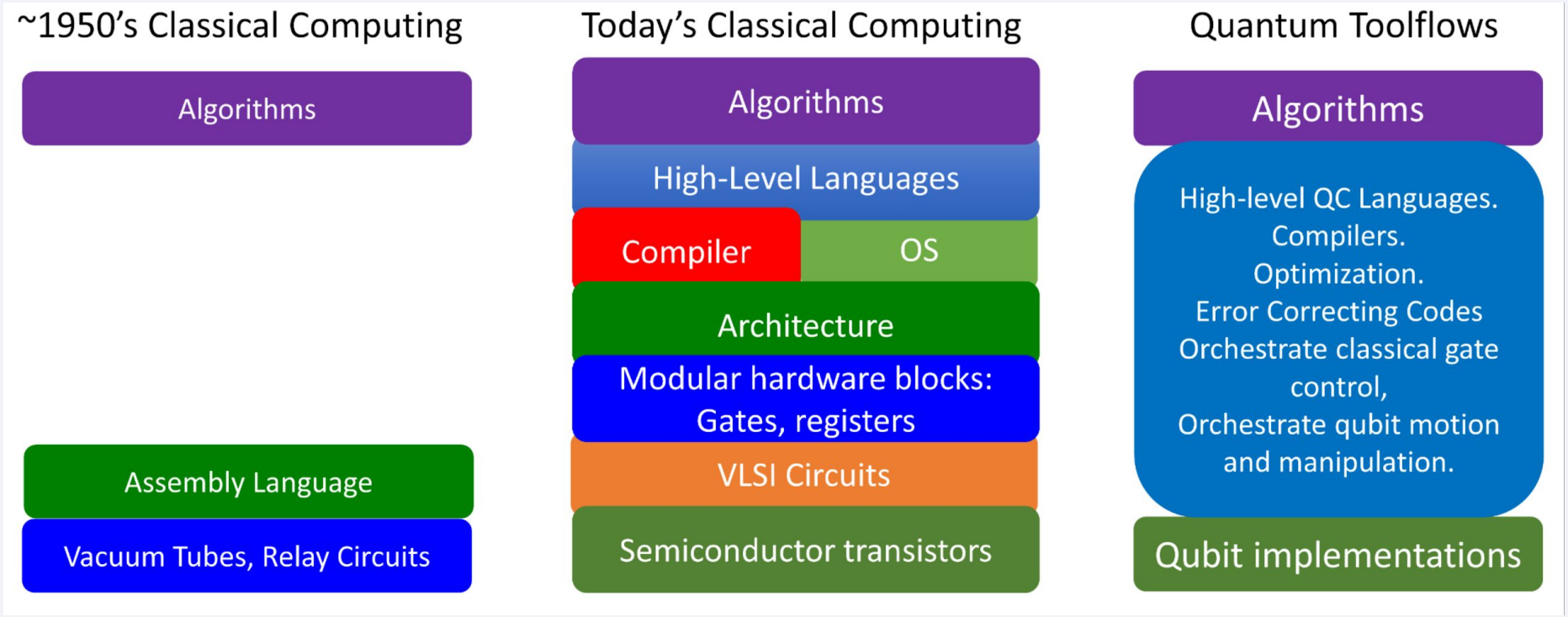


What does the field look like today?

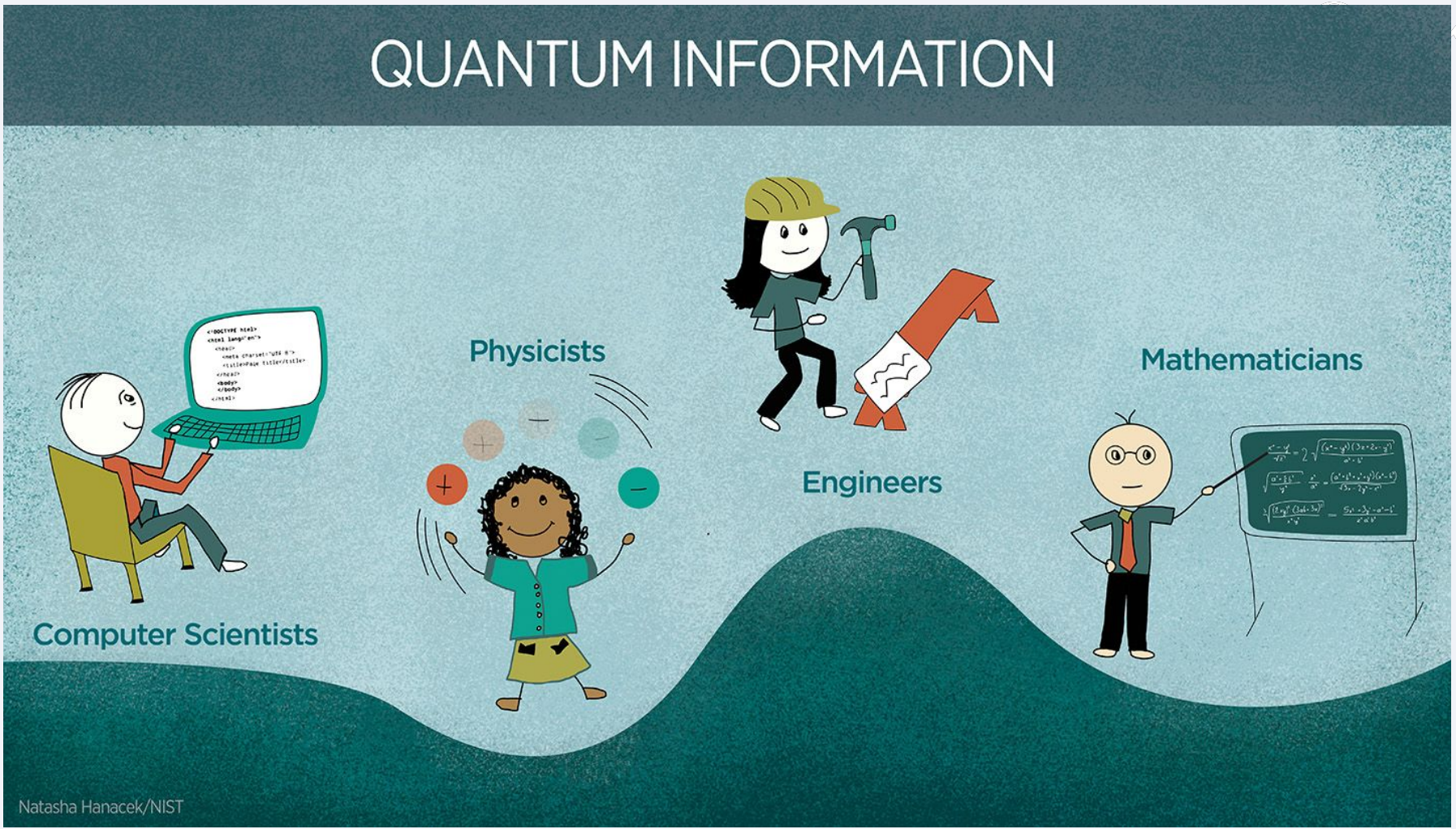
And what might it look like in the coming years?



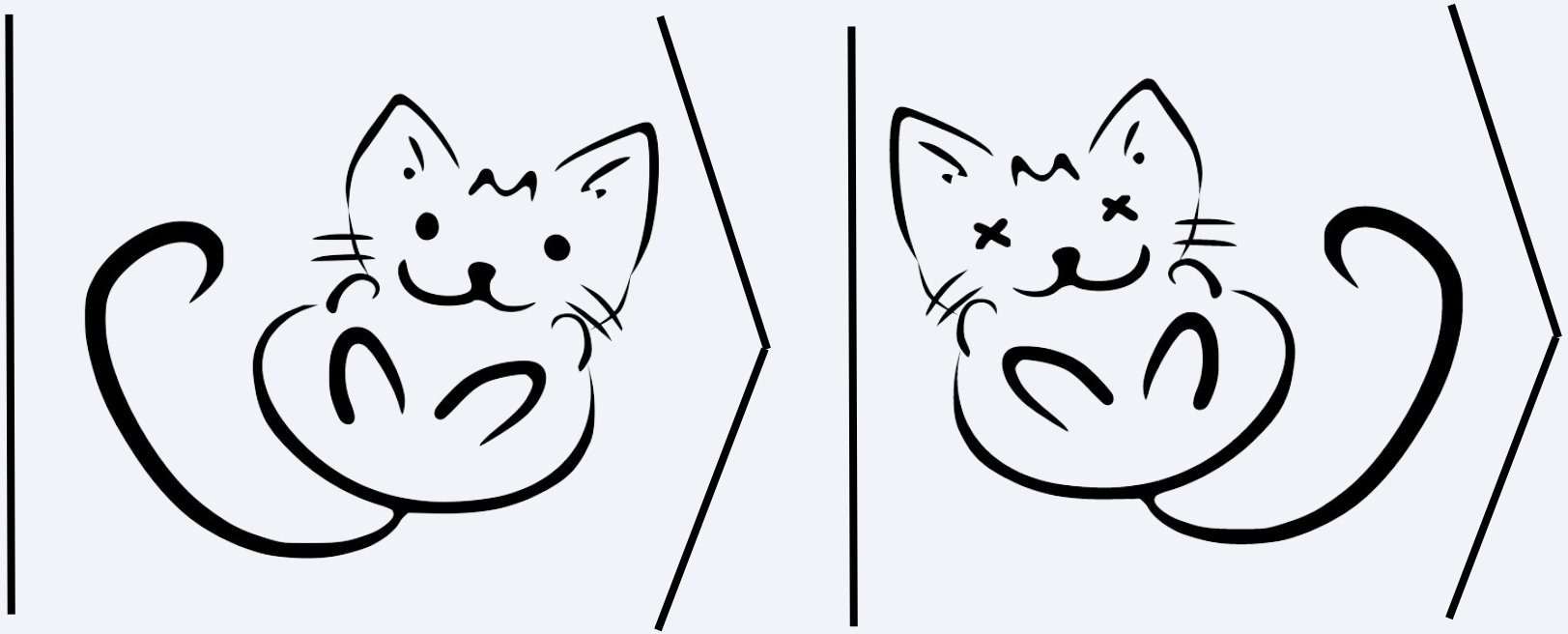
Maslov, Dmitri & Nam, Yunseong & Kim, Jungsang. (2019). An Outlook for Quantum Computing. Proceedings of the IEEE. 107. 5-10. 10.1109/JPROC.2018.2884353.



M. Martonosi and M. Roetteler, "Next steps in quantum computing: Computer science's role,"Computing Research Association CCC Catalyst, Nov 2018.



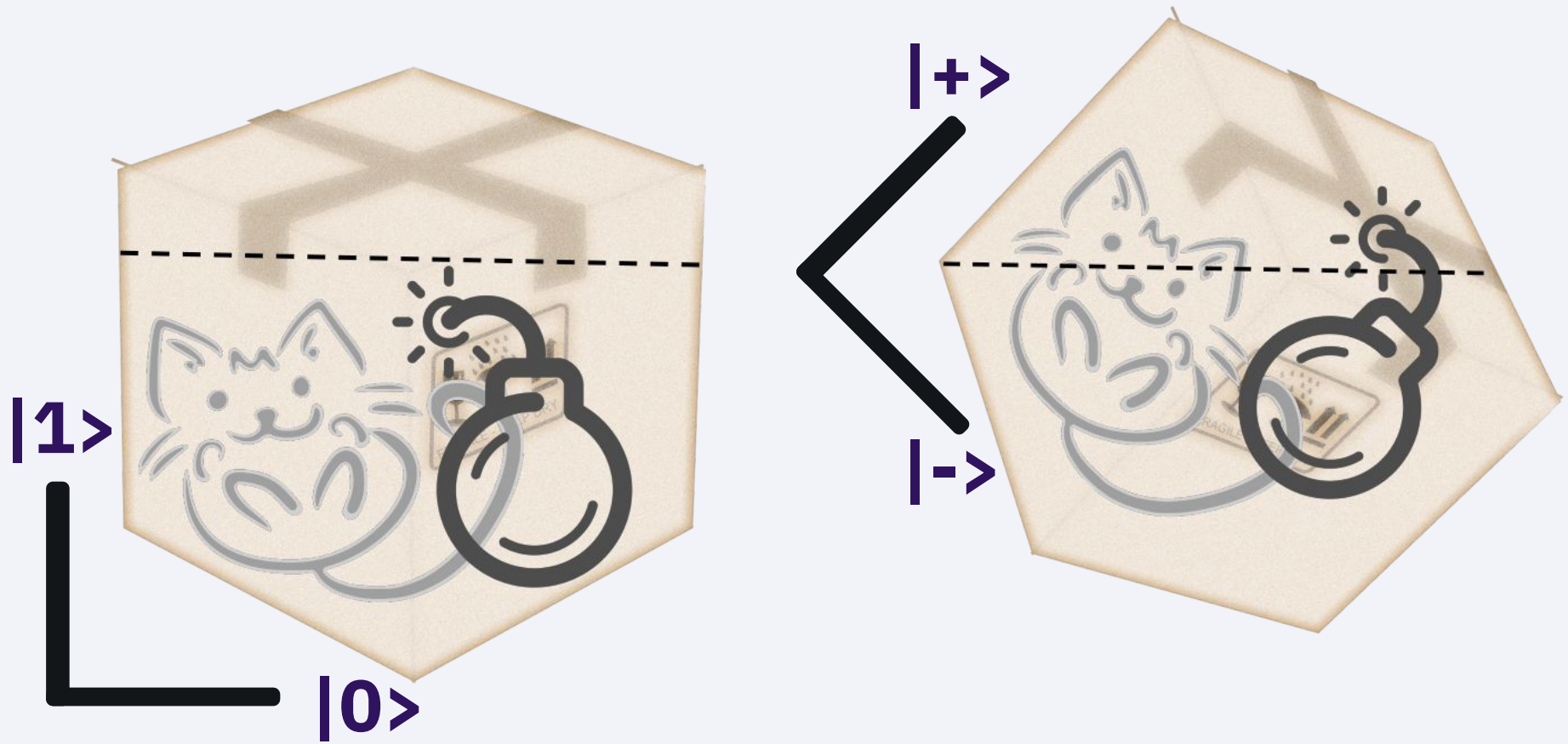
Credit: Natasha Hanacek/NIST




FRAGILE - KEEP DRY


FRAGILE - KEEP DRY


FRAGILE - KEEP DRY


|1>
|0>
|+>
|->
Qiskit

what is a qubit?

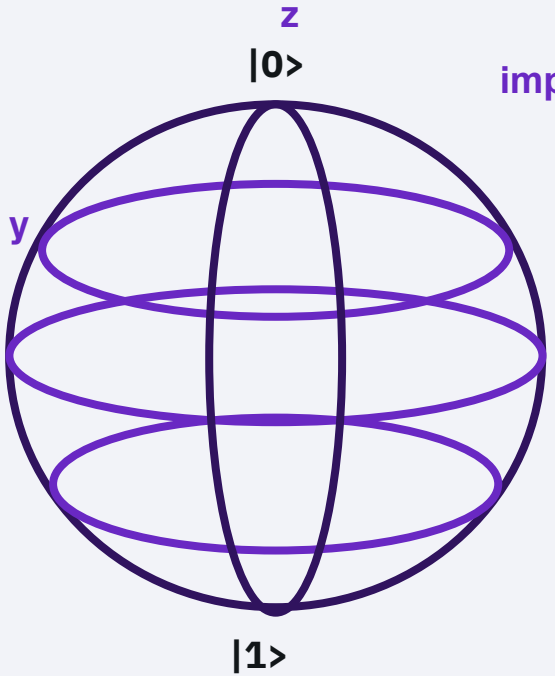
$|\Psi\rangle = \alpha\,|0\rangle + \beta\,|1\rangle$

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

$\alpha, \beta \in \mathbb{C}^2$

$|0\rangle = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$ 

$|-\rangle = \frac{|0\rangle - |1\rangle}{\sqrt{2}}$



$|+\rangle = \frac{|0\rangle + |1\rangle}{\sqrt{2}}$

$|1\rangle = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$ 

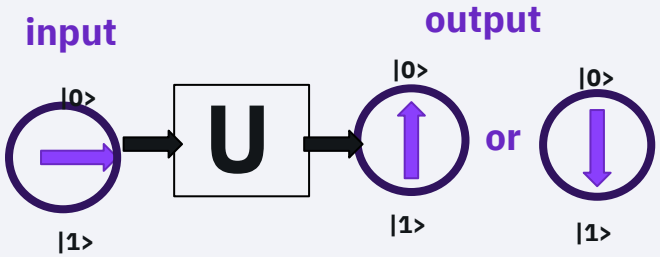
Multiple qubits

If $|\Psi\rangle_{12} = \frac{1}{\sqrt{2}}\,|00\rangle + \frac{1}{\sqrt{2}}|11\rangle$ then it is

impossible to represent $|\Psi\rangle_{12}$ as $|\Psi\rangle_1|\Psi\rangle_2$

qubit vs bit

N qubits = 2^N bits



$U^\dagger U = I$

The probability to obtain a state is equal to

$|\alpha|^2$

$\alpha, \mathbb{C}^2$

Measurement "collapse"

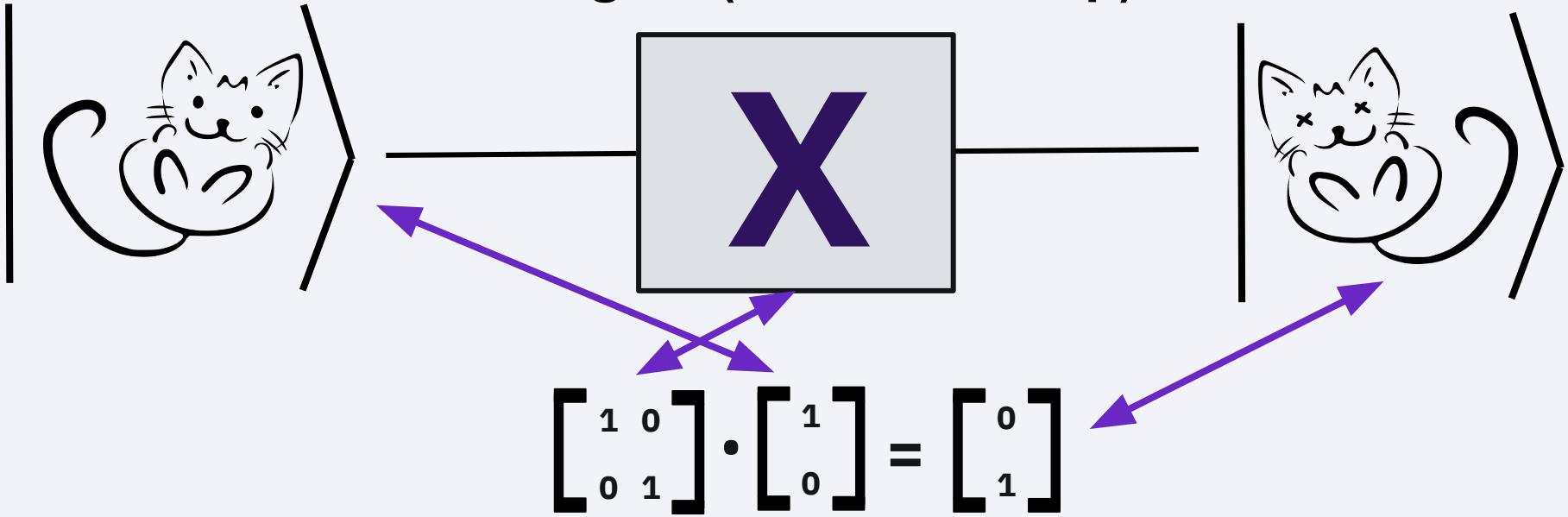
$|outcome\rangle\langle outcome|\Psi\rangle$

$$U = \begin{bmatrix} 1 & 0 & \dots & 0 \\ 0 & 1 & \dots & 0 \\ \vdots & & \ddots & \vdots \\ 0 & 0 & \dots & 1 \end{bmatrix}$$

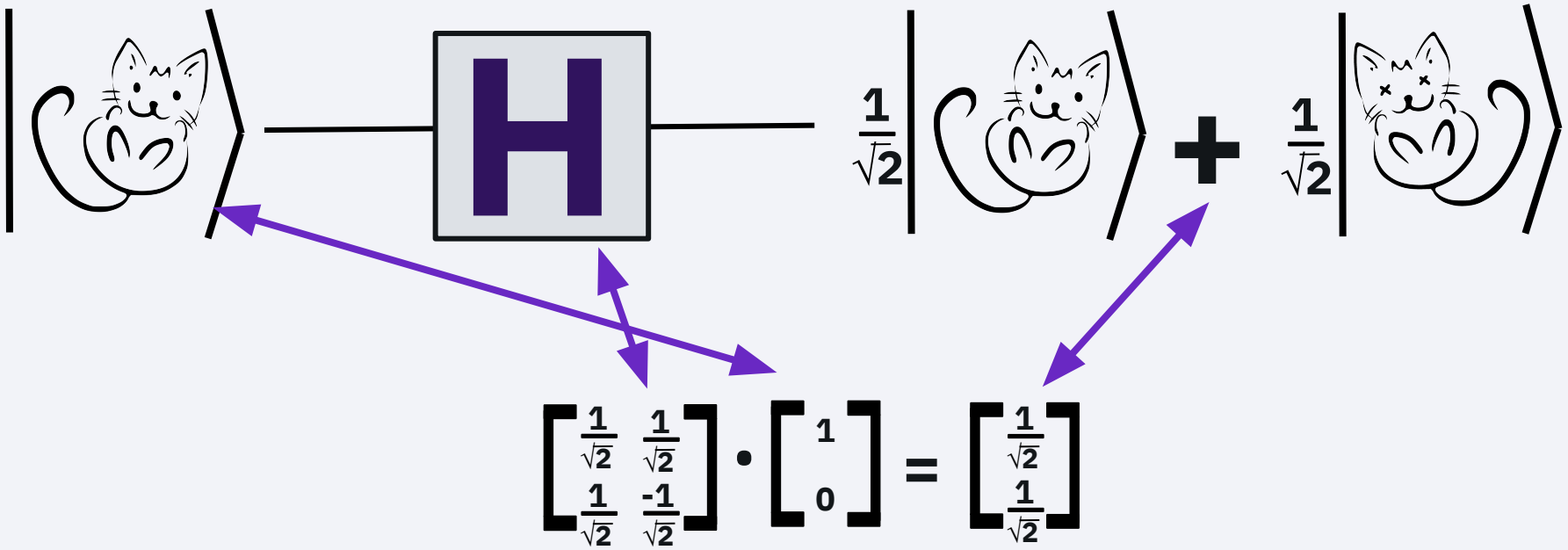
size N

size N

NOT gate (Pauli/X, bit-flip)

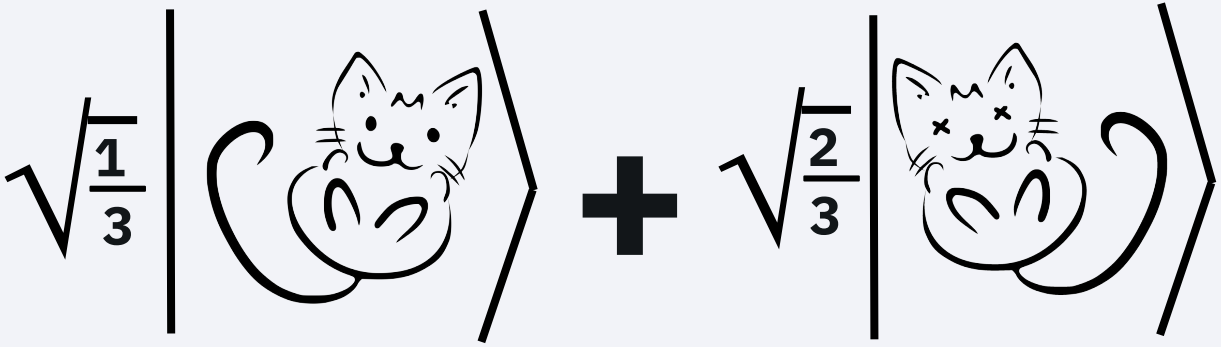


Hadamard gate



Measurement

probability is amplitude squared



When observed there is a:

$\frac{1}{3}$ **probability of** 

$\frac{2}{3}$ **probability of** 

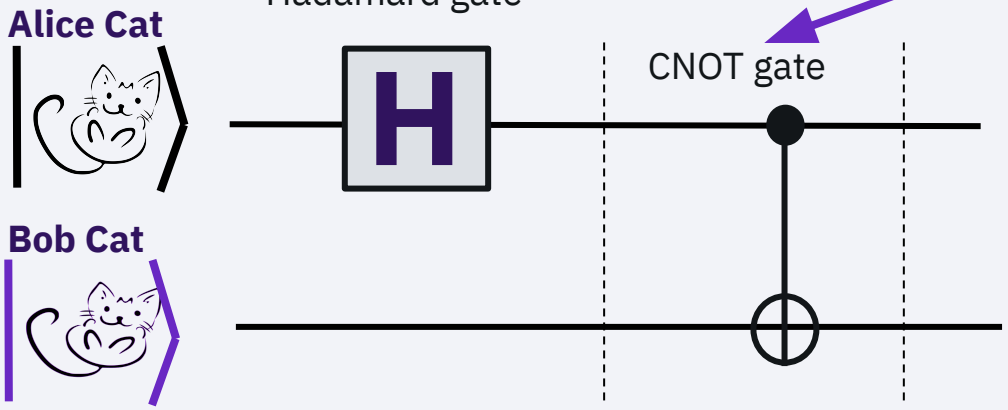
Quantum entanglement

spooky actions at a distance

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

Hadamard gate

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



$$|\text{cat}\rangle = \sqrt{\frac{1}{2}}|\text{cat}\,\text{cat}\rangle + \sqrt{\frac{1}{2}}|\text{cat}\,\text{cat}\rangle$$

$\times m$ and  $\times (p-m)$

Success

f

Balanced

$\times \frac{p}{2}$ and  $\times \frac{p}{2}$

× m and  × $(p-m)$

Failure f Constant

× p or  × p

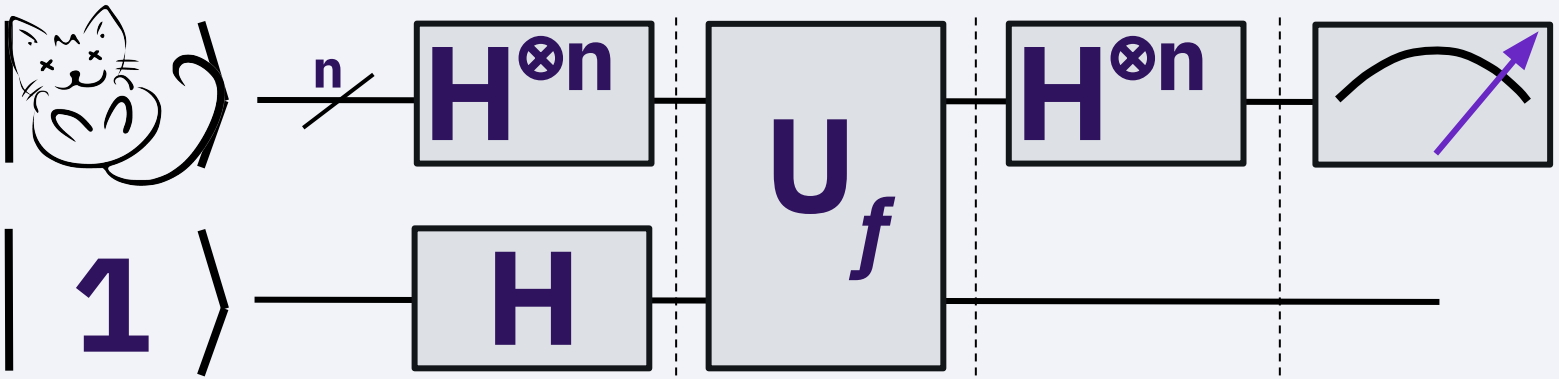
Classical

Test f some number of times exponential in n.

Quantum

Test U_f once.

Deutsch-Jozsa algorithm



Failure: **measure all zero's** (Constant)

Success: **measure anything else** (Balanced)

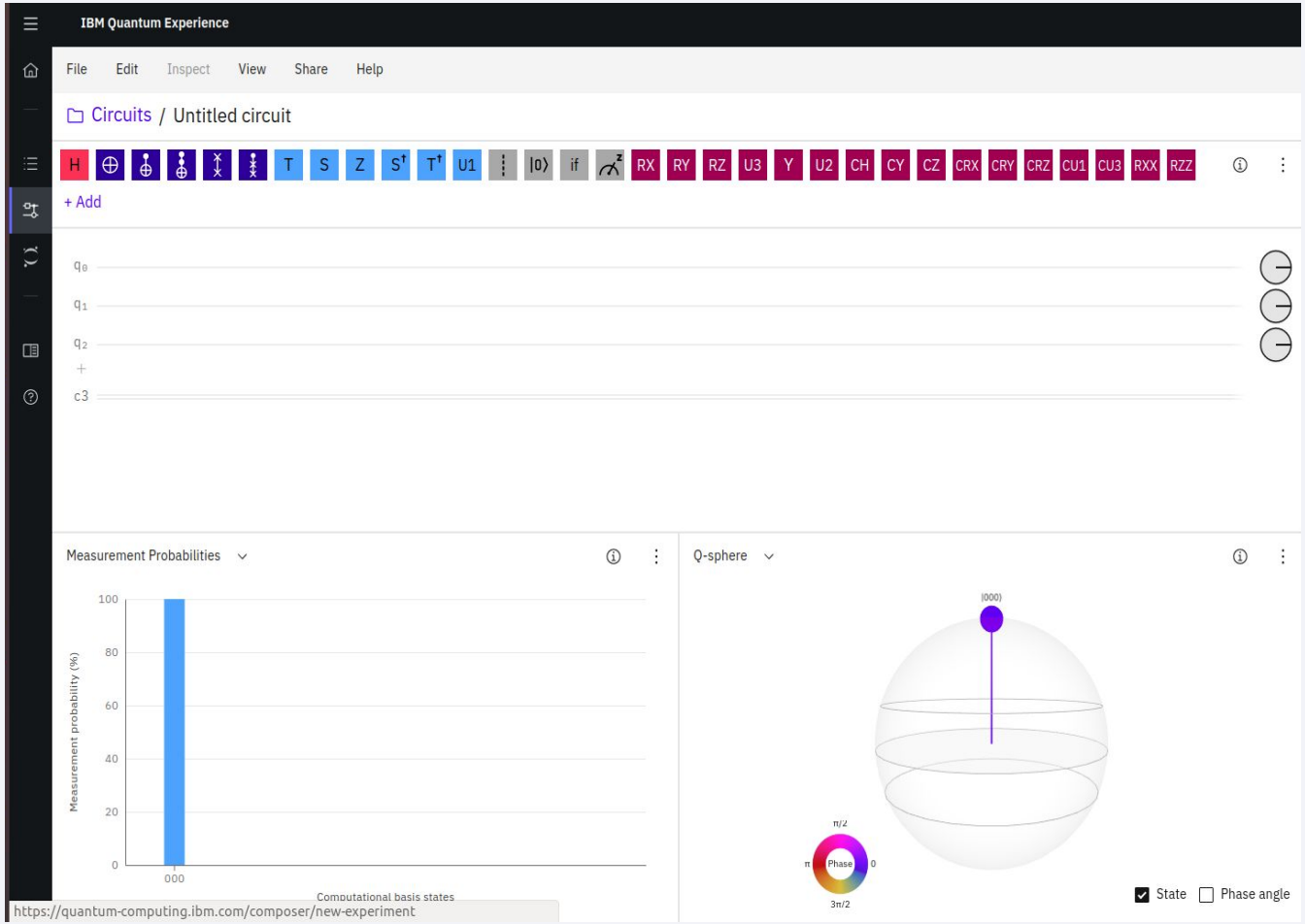
IBM Quantum Experience

Qiskit

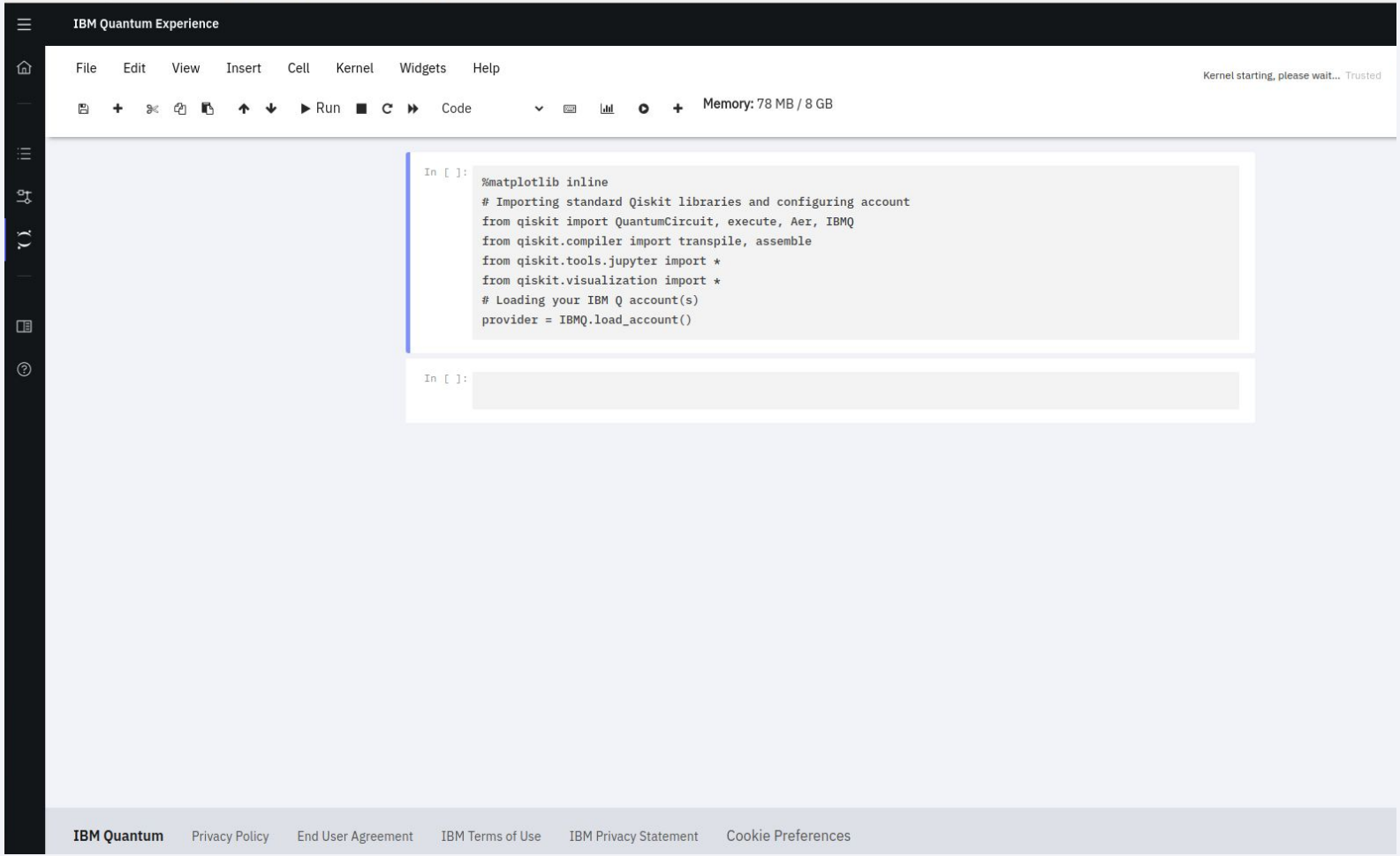
Easiest way to use a quantum computer: drag & drop in-browser!

At https://quantum-computing.ibm.com/ you can make circuits to run on several types of quantum computers around the world!

Graphic mode



Code mode


IBM Quantum Experience
File Edit View Insert Cell Kernel Widgets Help
Kernel starting, please wait... Trusted
Run Code Memory: 78 MB / 8 GB
In [ ]:
%matplotlib inline
# Importing standard Qiskit libraries and configuring account
from qiskit import QuantumCircuit, execute, Aer, IBMQ
from qiskit.compiler import transpile, assemble
from qiskit.tools.jupyter import *
from qiskit.visualization import *
# Loading your IBM Q account(s)
provider = IBMQ.load_account()
In [ ]:
IBM Quantum Privacy Policy End User Agreement IBM Terms of Use IBM Privacy Statement Cookie Preferences

IBM Quantum Experience

Qiskit

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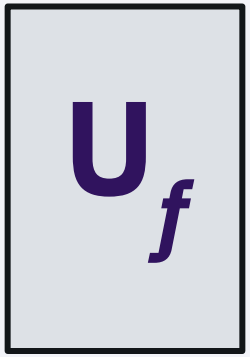
What does U_f look like in the balanced case?



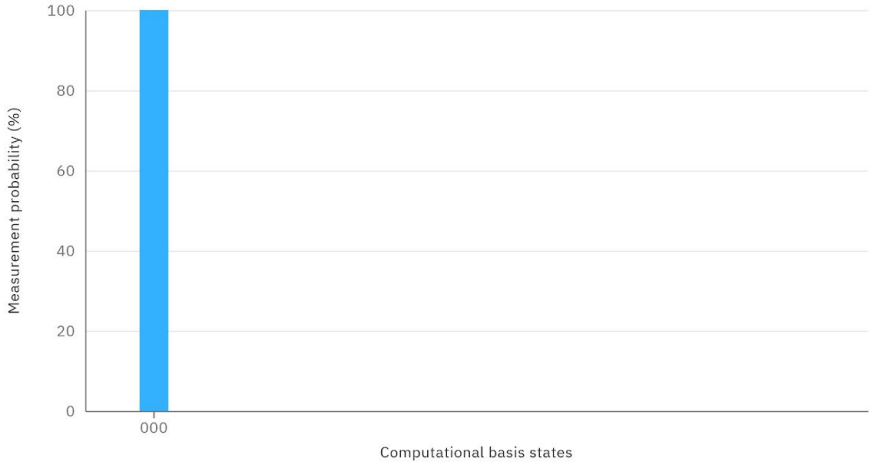
IBM Quantum Experience

File Edit Inspect View Share Help Run Settings Run on ibmq_armonk

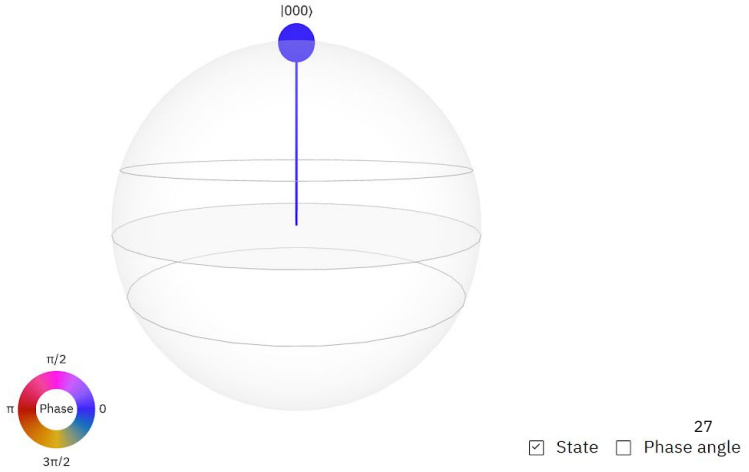
Circuits / U_f for Deutsch-Jozsa Balanced [f succeeds in the analogy], n=2 *Saved* Code Docs Jobs

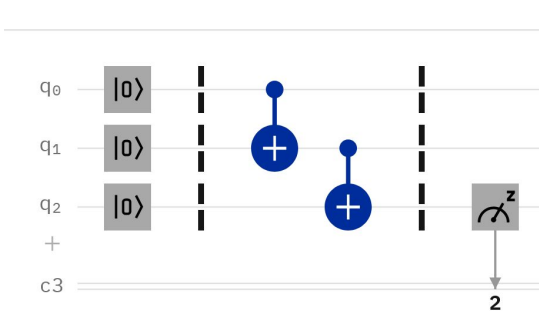
H T S Z S† T† U1 |0⟩ if RX RY RZ U3 Y U2 CH CY CZ CRX CRY CRZ CU1 CU3 RXX RZZ nG0 + Add

Measurement Probabilities

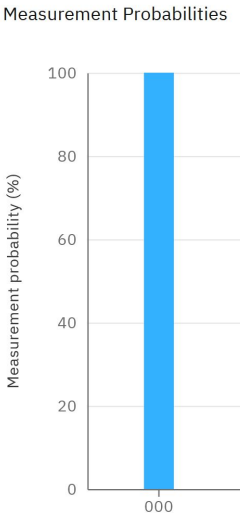


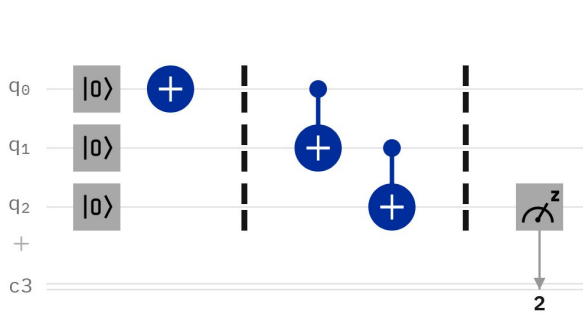
Q-sphere



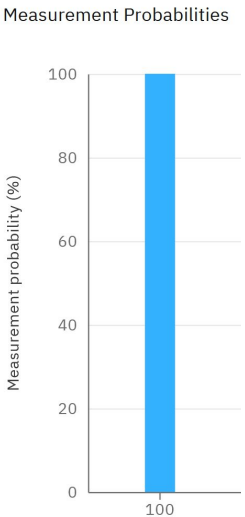


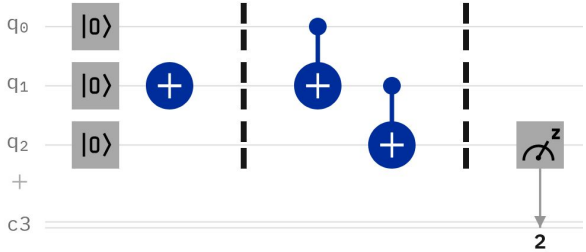
f(00) = 0



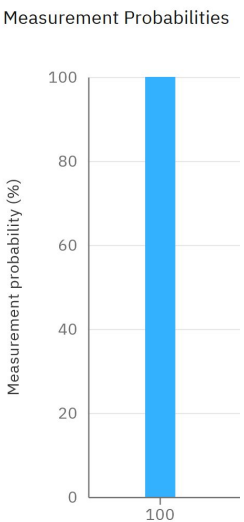


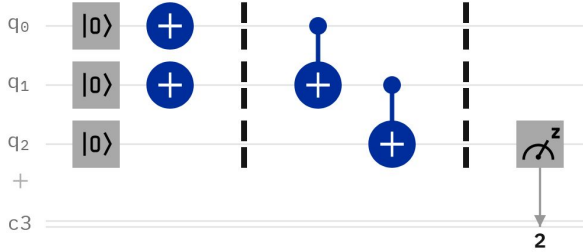
f(01) = 1



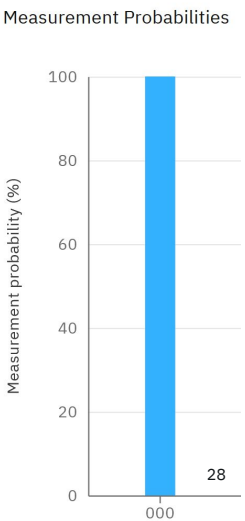


f(10) = 1

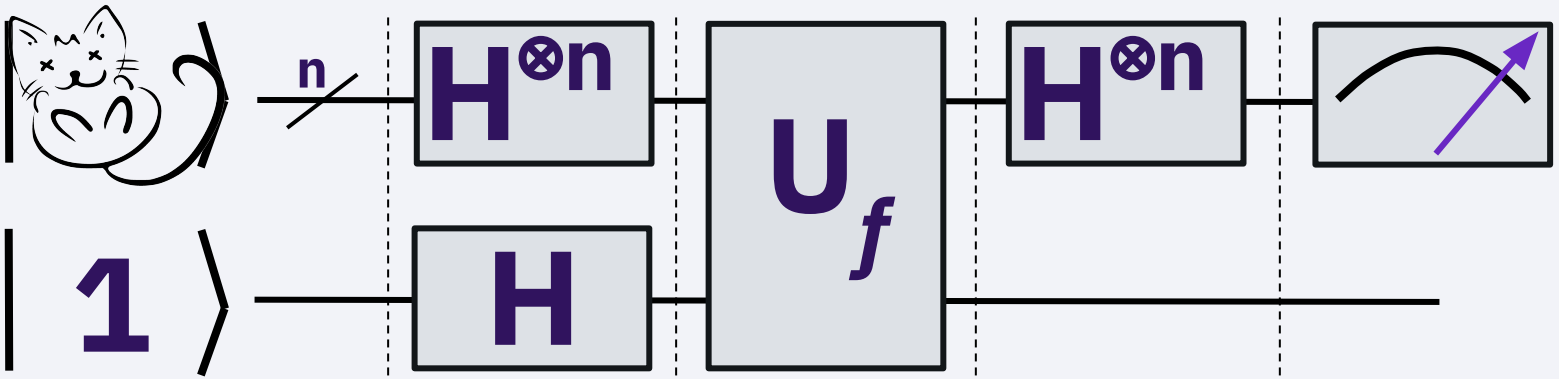


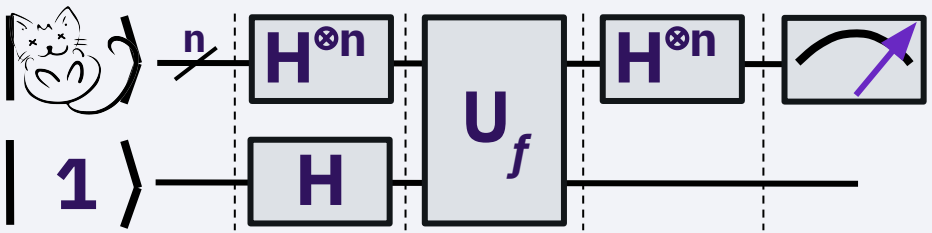


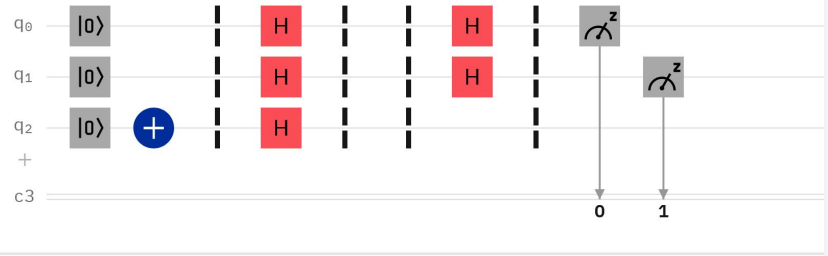
f(11) = 0



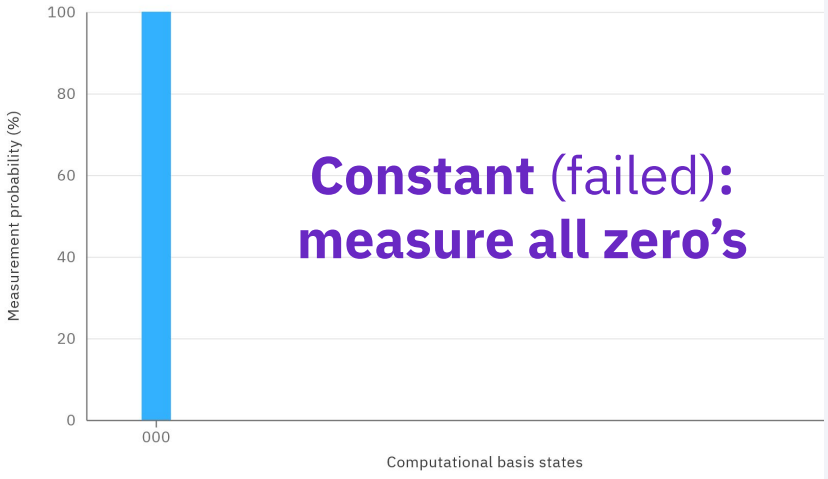
What does the Deutsch-Jozsa algorithm look like for n=2?



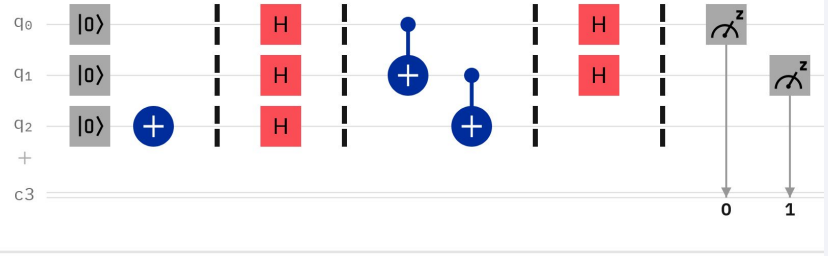




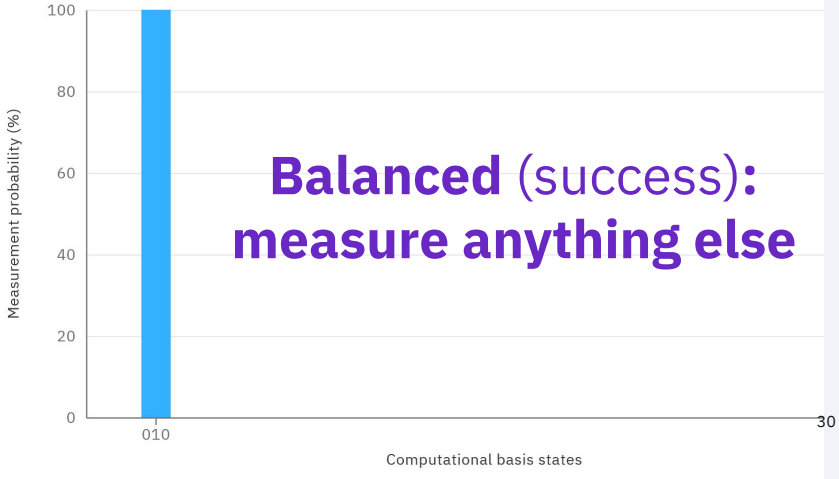
Measurement Probabilities



Constant (failed):
measure all zero's



Measurement Probabilities



Balanced (success):
measure anything else

Installation of Qiskit

Qiskit is tested and supported on the following 64-bit systems:

- ❏ Ubuntu 16.04 or later
- ❏ MacOS 10.12.6 or later
- ❏ Windows 7 or later

The recommendation by the official site, indicate to use a Conda environment (possible in Windows and Linux) that allows to specify a specific version of Python and a set of libraries.

Command line:

```
conda create -n name_of_my_env python=3

conda activate name_of_my_env
```

The following command installs the packages: Terra, Aer, Ignis, and Aqua.

```
pip install qiskit
```

To use visualization functionality or Jupyter notebooks

```
pip install qiskit[visualization]
```

Validate the installation using in a python file the command

```
import qiskit
```