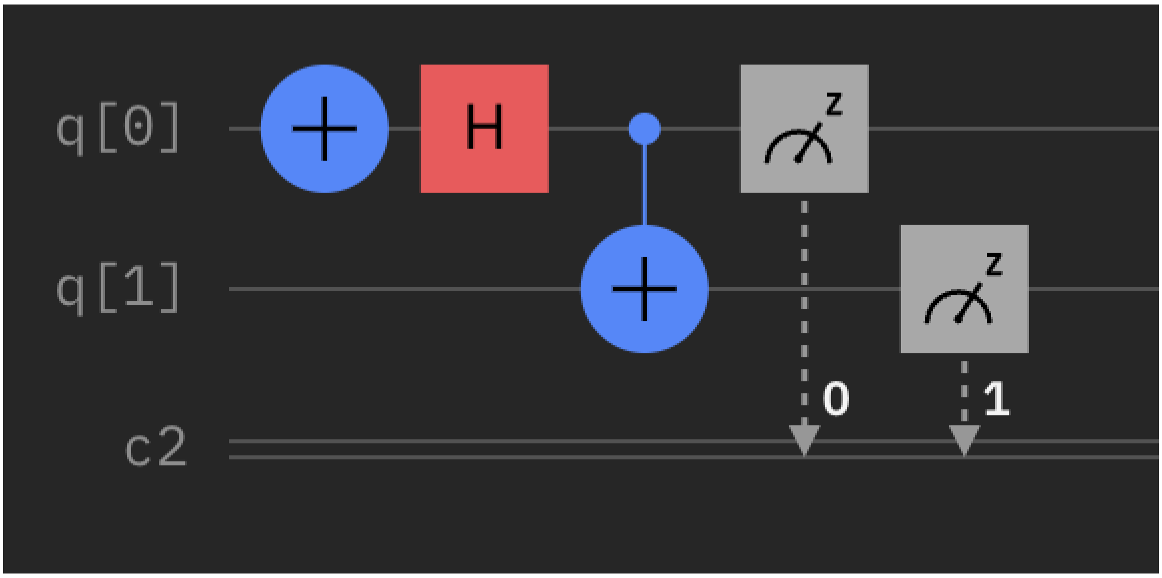
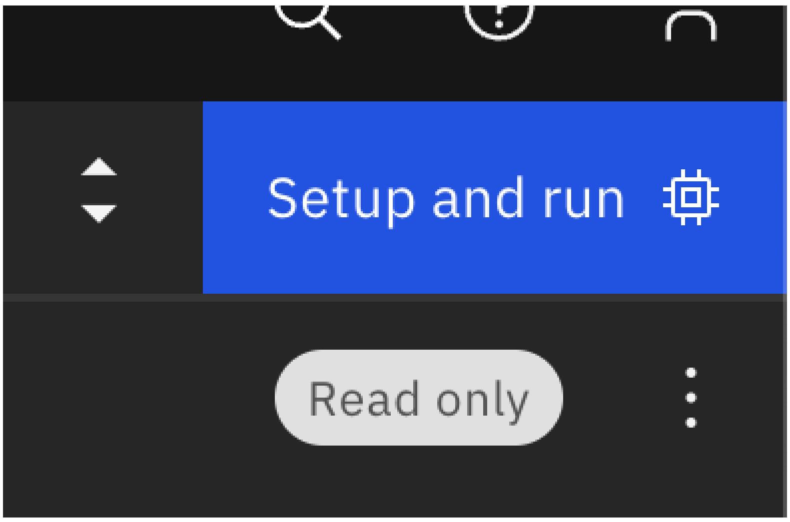
Module 4 Tutorial Solutions

1. Bell state execution on actual hardware

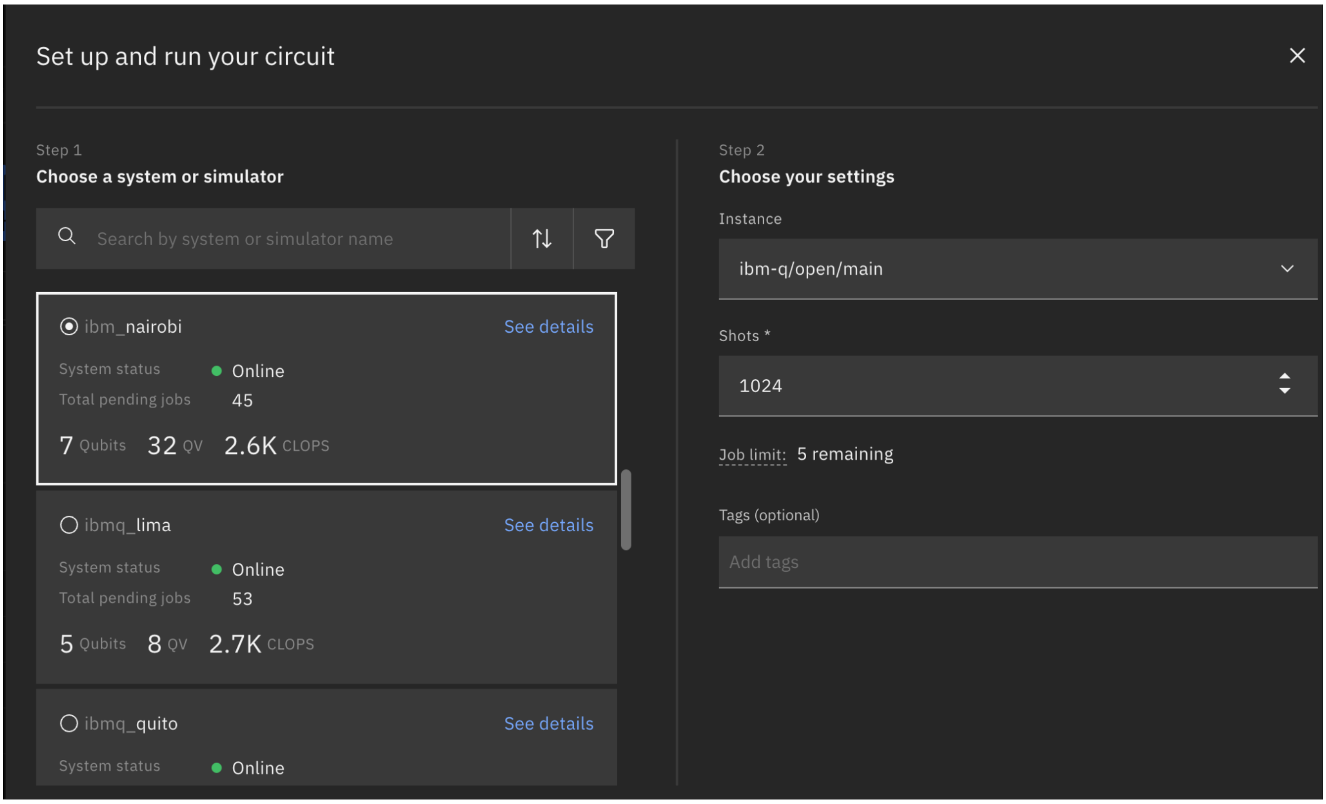


a. Use the same circuit which we used for execution of bellstate on the statevector simulator to run the actual hardware only change takes place in the setup and run part of the job

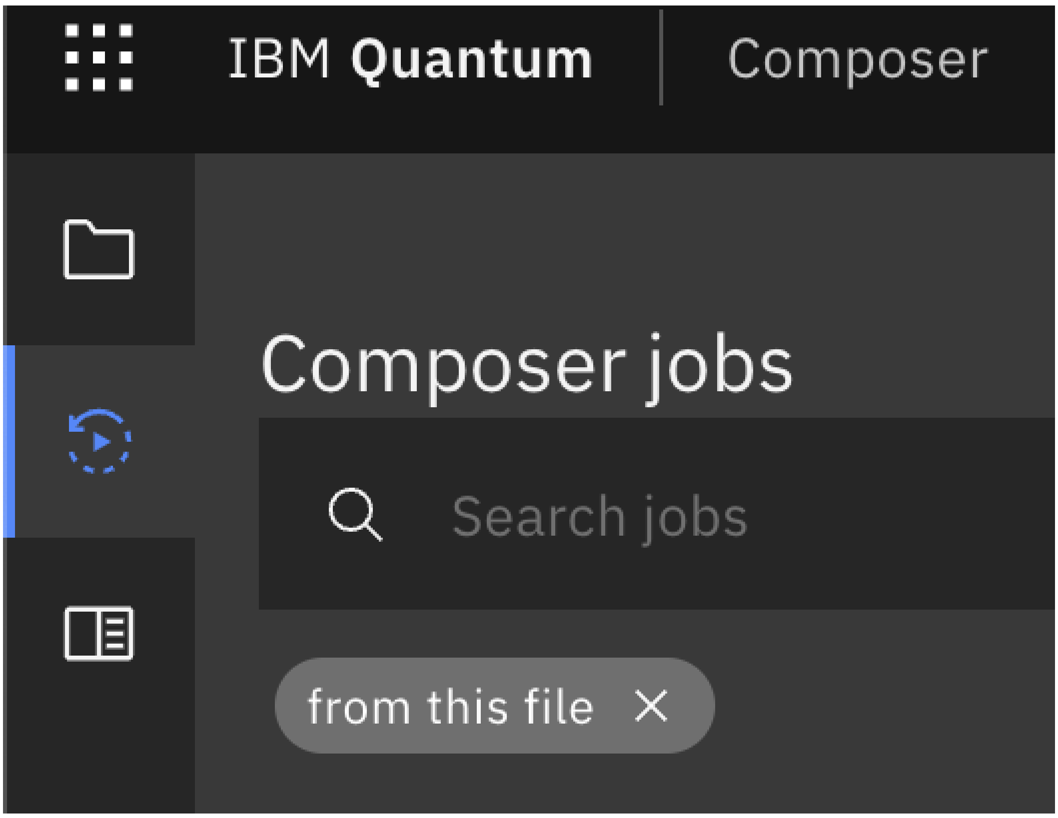
b. Click on the setup and run section on the top right.



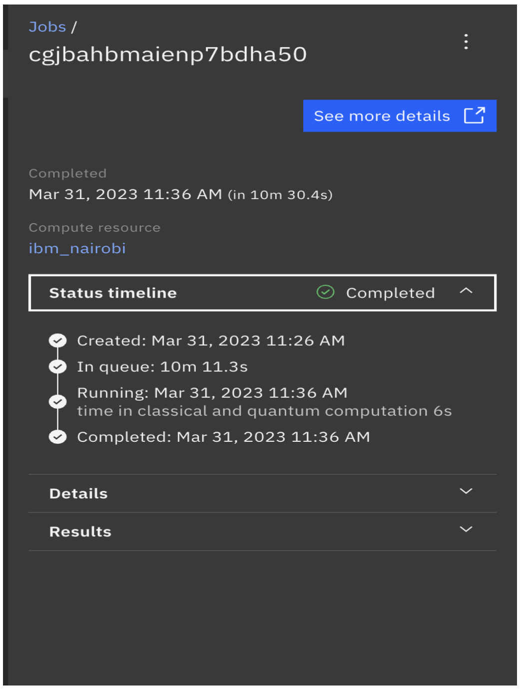
c. Choose a Device from the list of online devices based on the no of qubits required and the no of pending jobs online



d. After running the job, all active jobs appear in the jobs pane on the left of the composer right below the files composer pane.

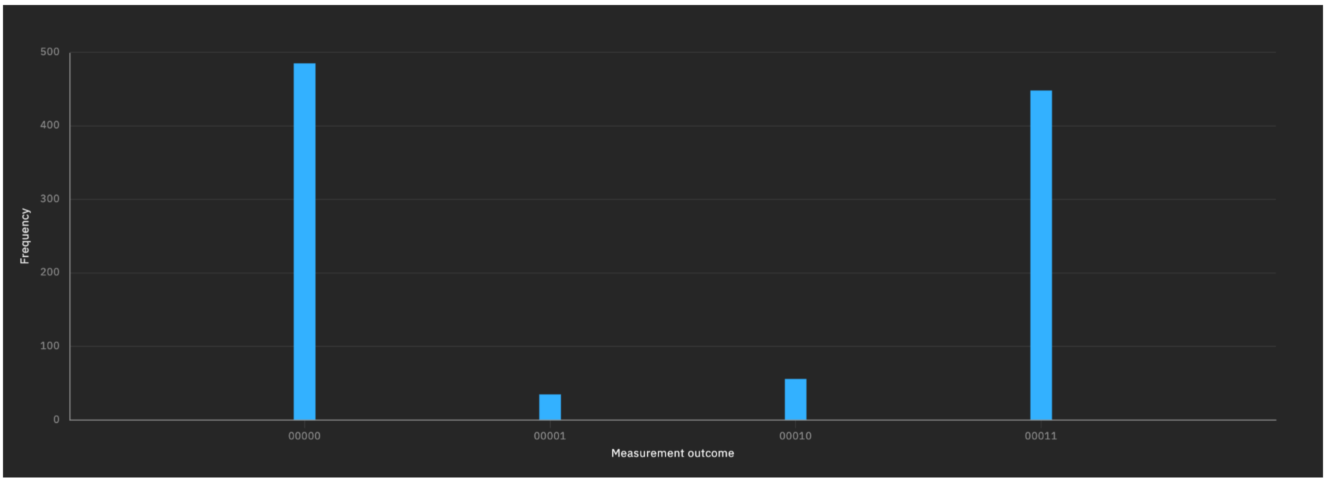


e. Find the active job in the list and wait for it run on the cloud, if the job remains in queue for very long just switch between the jobs window and the composer file pane there seems to be a glitch with IBM at the moment where the job appears in queue for very long



f. After completion of the experiment you can find the histogram of measurement results in the results section of the job and as shown here we will get a plot majorly split between |00⟩ and |11⟩ but there will be other results obtained by virtue of error in the hardware, here we can see the error is almost equally split among |01⟩ and |10⟩.

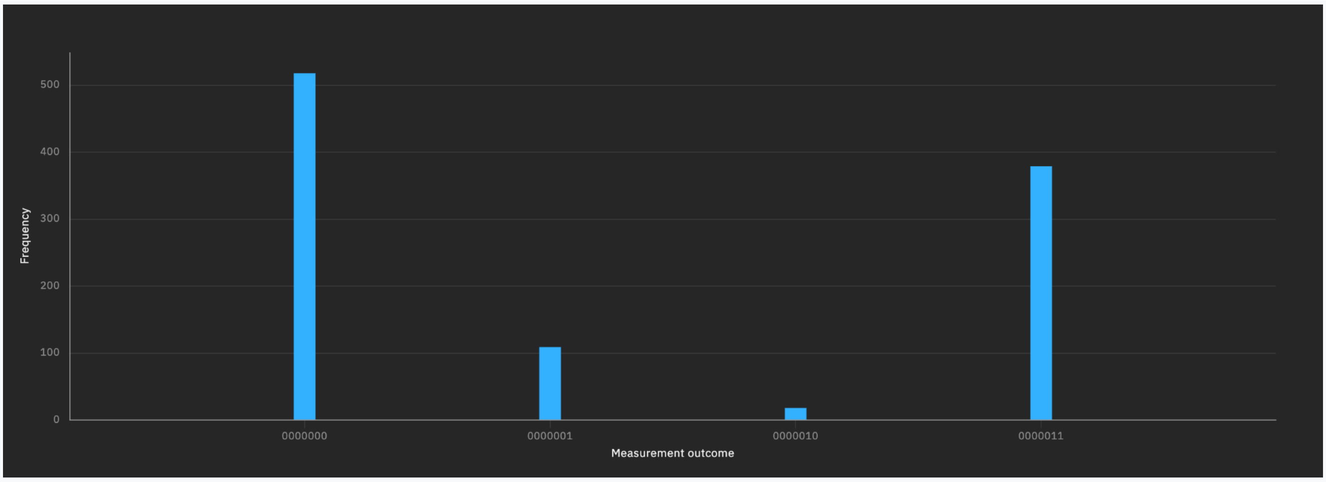
IBM_Nairobi Bell state measurement results



2. Running on backends with different Quantum Volume

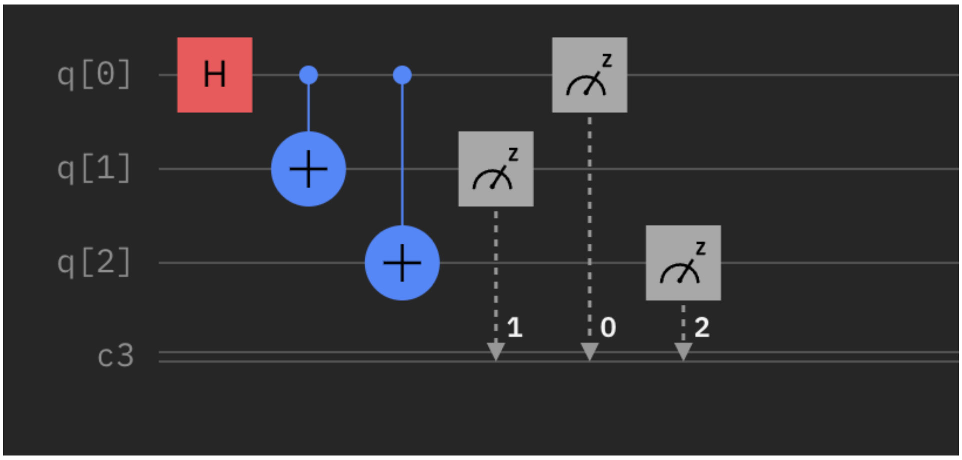
a. Run the same circuit on a backend with different Quantum Volume
b. Compare the results of the outputs
c. In this hardware backend we can see a greater error in the state $|01\rangle$ than $|10\rangle$.

IBM_Quito Bellstate measurement



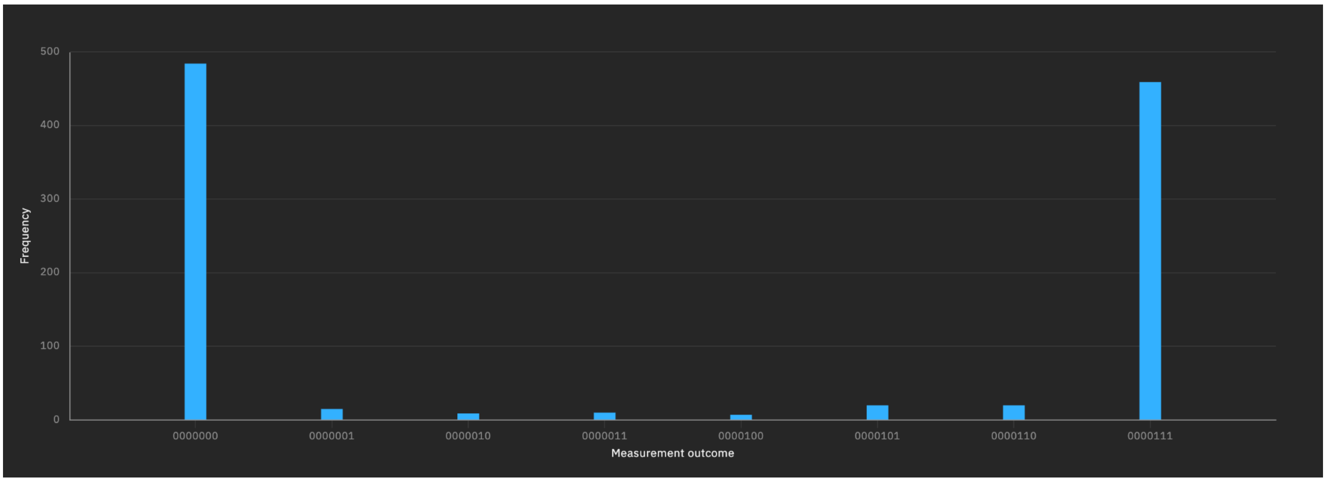
3.GHZ State

a. Prepare the below circuit to build the GHZ state for entanglement between 3 qubits.



b. Send the circuit as a job to the hardware backend of your choice
c. Compare the results received from the hardware to the results from the simulator, in the actual hardware we'll see measurement outcomes apart from the states we expect which are $|000\rangle$ and $|111\rangle$.

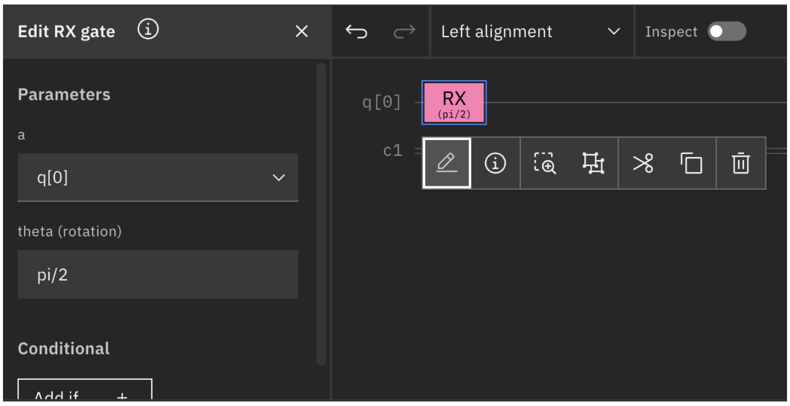
IBM_Nairobi GHZ state Measurement



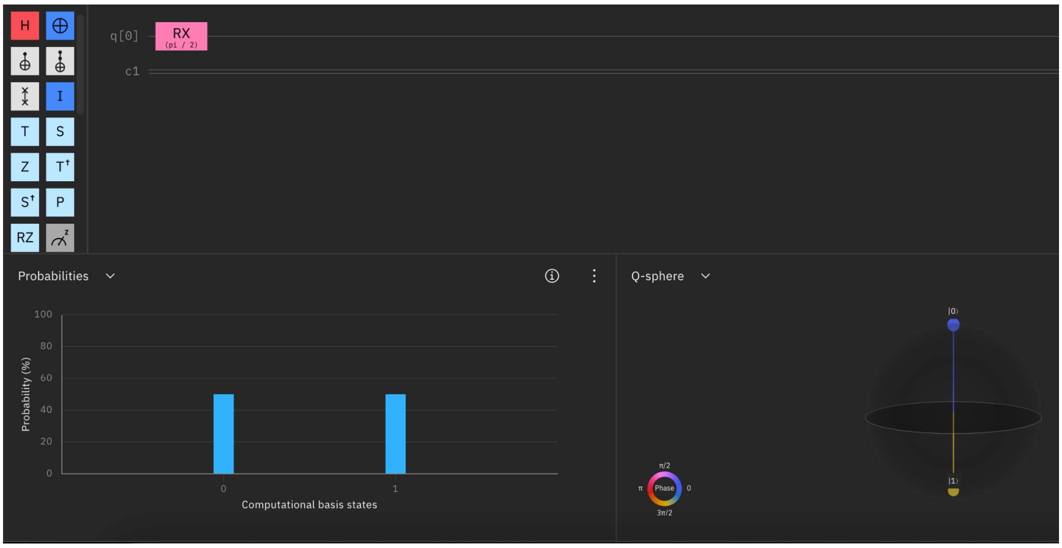
4. Noisy Backend Emulation

Ideal Run

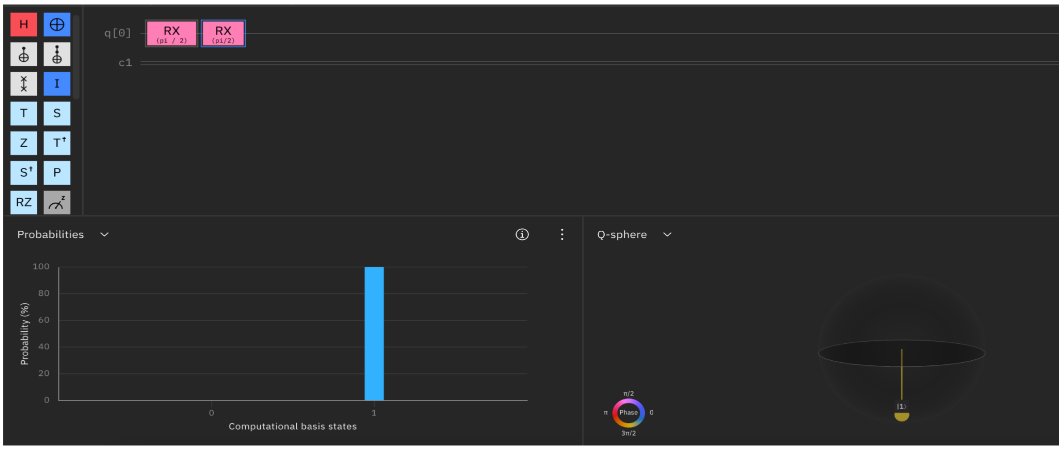
a. The first run of the operations is without any error added to the gates, 4 Rx(pi/2) rotations acting on the state zero, the four diagrams below show the action after application of each gate.
b. You can find the RX gate in the pane on the left the pencil symbol on the gate allows you to input the amount of angle you want to rotate the state by, observe the effect of applying each RX gate on the Q-Sphere and the statevector.



c. 1 RX rotation

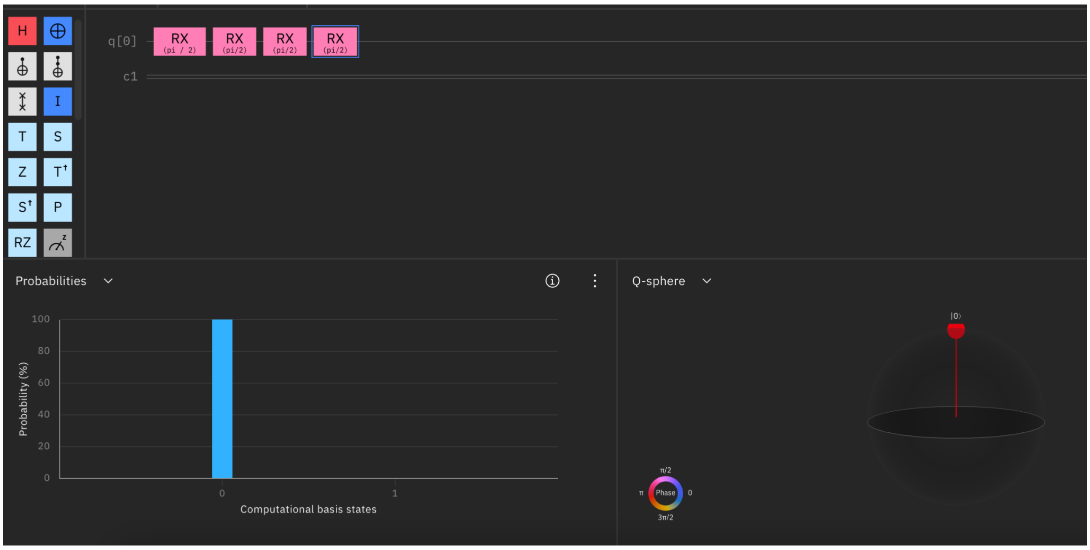


d. 2 RX rotations



e. 3 RX rotations

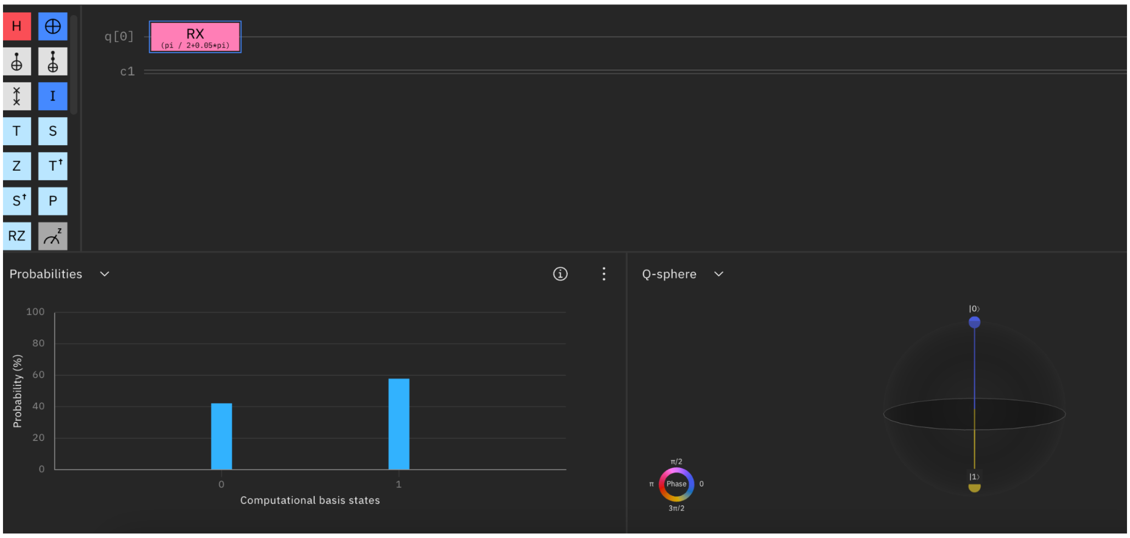
f. 4 RX Rotation



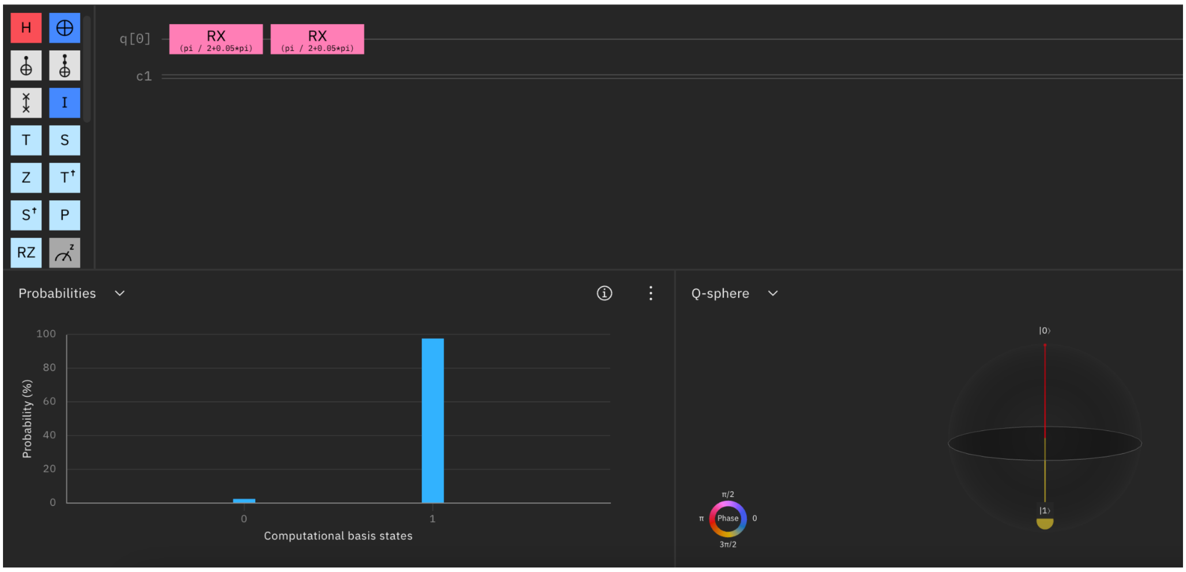
Noisy run

a. Add a small amount of error on each of the gates, in this example 0.05*pi/2 to see the emulated effect of noise on the operations
b. The four circuits below show the same 4 operations with small amount of error added to each rotation
c. Each state is slightly deviated from the ideal state received in the previous run

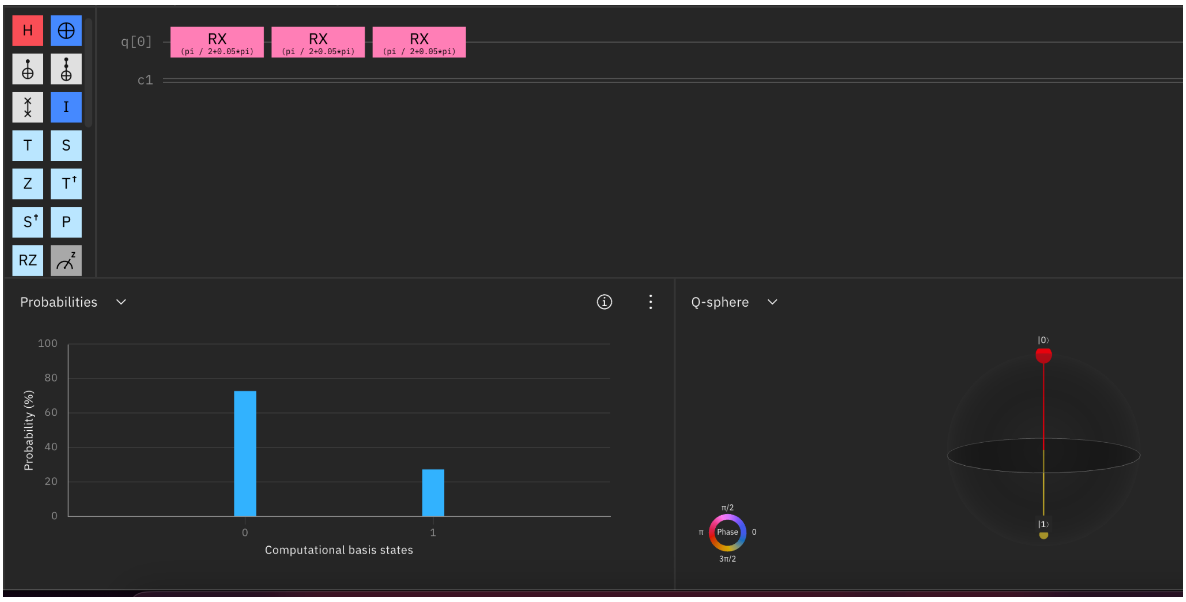
d. 1 Noisy RX rotation



e. 2 Noisy RX rotations



f. 3 Noisy RX rotations



g. 4 Noisy RX rotations