Pairs of Quantum Drunkards Walk

Ran-Yu Chang[1], Yu-chao Hsu [1], Tzu-Jui Liu[1]

[1] Ching-Cheng Junior High School, Changhua 50055, Taiwan

leo07010@gmail.com

Abstract

In a recent study, only the Quantum Walk(QW) of a single particle is mentioned, so we want to study the QW of an entangled pair. This corresponds to the interaction of fermions and bosons in the environment. With a view to simulate the particle phenomenon, we use qiskit to construct experiment-requiring circuit. However, before we implement QW in qiskit lab, there is still an important thing that we should make two electrons entangled. On the other hand, it is important that whether two states of photon remain entangled ability after being affected by Electromagnetic storm. In the end, we successfully realized the entangled quantum walk, and got very reasonable results. It can be used as the basic model of the movement of electrons in high-voltage electricity or the entanglement ability of photonic communication after being disturbed by the external environment. The innovation of this project is that we have come up with a way to reasonably describe the interaction of entangled electrons or photons. And try to describe this behavior.

1 Quantum Walk(QW) Introduction

1.1 What is QW?

Quantum walking is a new research topic. Although some authors use the name "quantum random walk" to refer to quantum phenomena, it is generally believed that the first paper on quantum random walks was published in 1993 by Aharonov et al.[1], Quantum random walk is described in terms of the magnitude of probability. By combining each possible step with another degree of freedom (such as spin), the actual detection process is incorporated into the theory, and it can be used as a quantum coin.

The measurement of this observable object will select the actual transition experienced when there is a considerable overlap between the probability amplitudes of moving left or right.

In this case, the average displacement of the particles may far exceed the maximum displacement allowed by the classics. All these concepts can easily be extended to multi-dimensional situations. Therefore, the connection between classical random walk and quantum walk and the use of quantum walk in computer science are two new and open research fields. There is a classic random walk theory on finite graphs, although it is still far from perfection. But it has achieved fruitful results in algorithm development.

1.2 Our QW Circuit

In the process of quantum computing, we learned about the circuit design of circular quantum

The following figure:

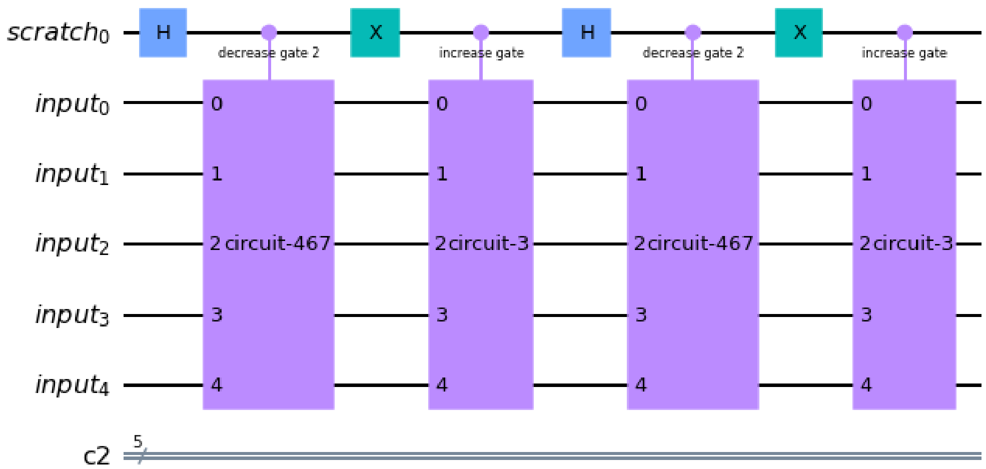


Figure 1: the scratch register is responsible for tossing a coin, and the input register is responsible for accessing the spatial location data. When the coin is rolled to 1, ‘2 circuit-467’ is executed, otherwise, ‘2 circuit-3’ is executed.

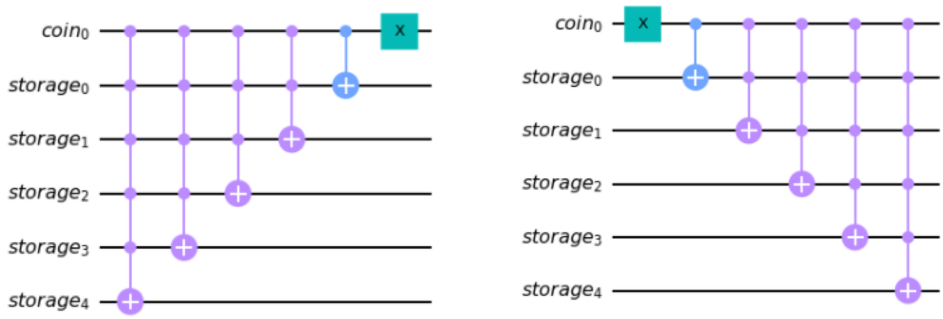


Figure 2: INC (left) and DEC (right) respectively represent 2 circuit-467 and 2 circuit-3 in the above figure

1.3 What’s next?

With this random walking circuit, we began to make quantum walks of entangled particles. This entanglement behavior is divided into two types. The first is that two particles are affected by the environment and start to walk randomly, which corresponds to the change of the entanglement ability of the two electrons in the high-voltage electric transmission line. Another situation is that only one particle is walking due to interference from the environment. This can correspond to the two states of the laser being entangled with each other, one of which is interfered by the outside world, and whether it is subjected to interference will affect the communication.

2 High Voltage Electronics affected by Quantum Walk

2.1 What We Want To Achieve?

The conductor will add very small deviations, and entangled states may be generated in the conduction of high voltages.

But we cannot predict the situation of high bias voltage. In the current quantum transmission, energy in the valence band can only be predicted to lose energy in metal conduction, which is more in line with the natural state.

2.2 Method

We have established two steps of entangled electrons in Qiskit, and used straight random walking to simulate the behavior of electrons entangled in the companion space.

The following is the circuit we designed:

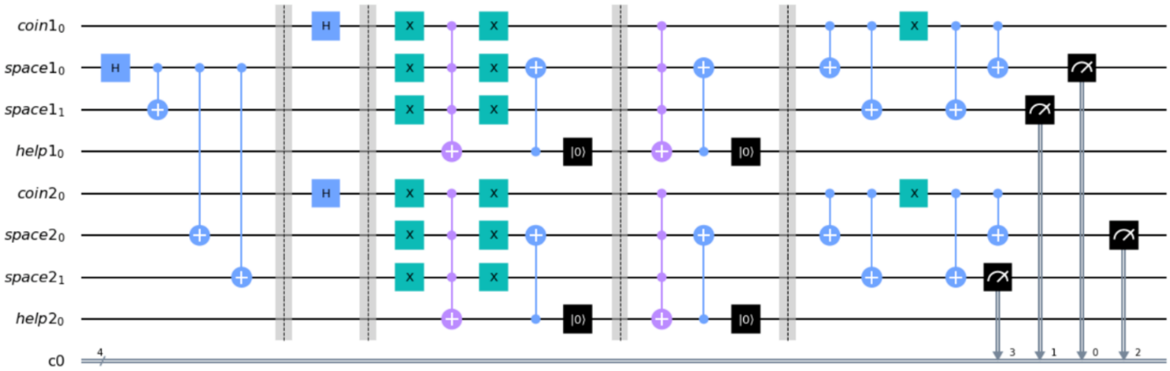
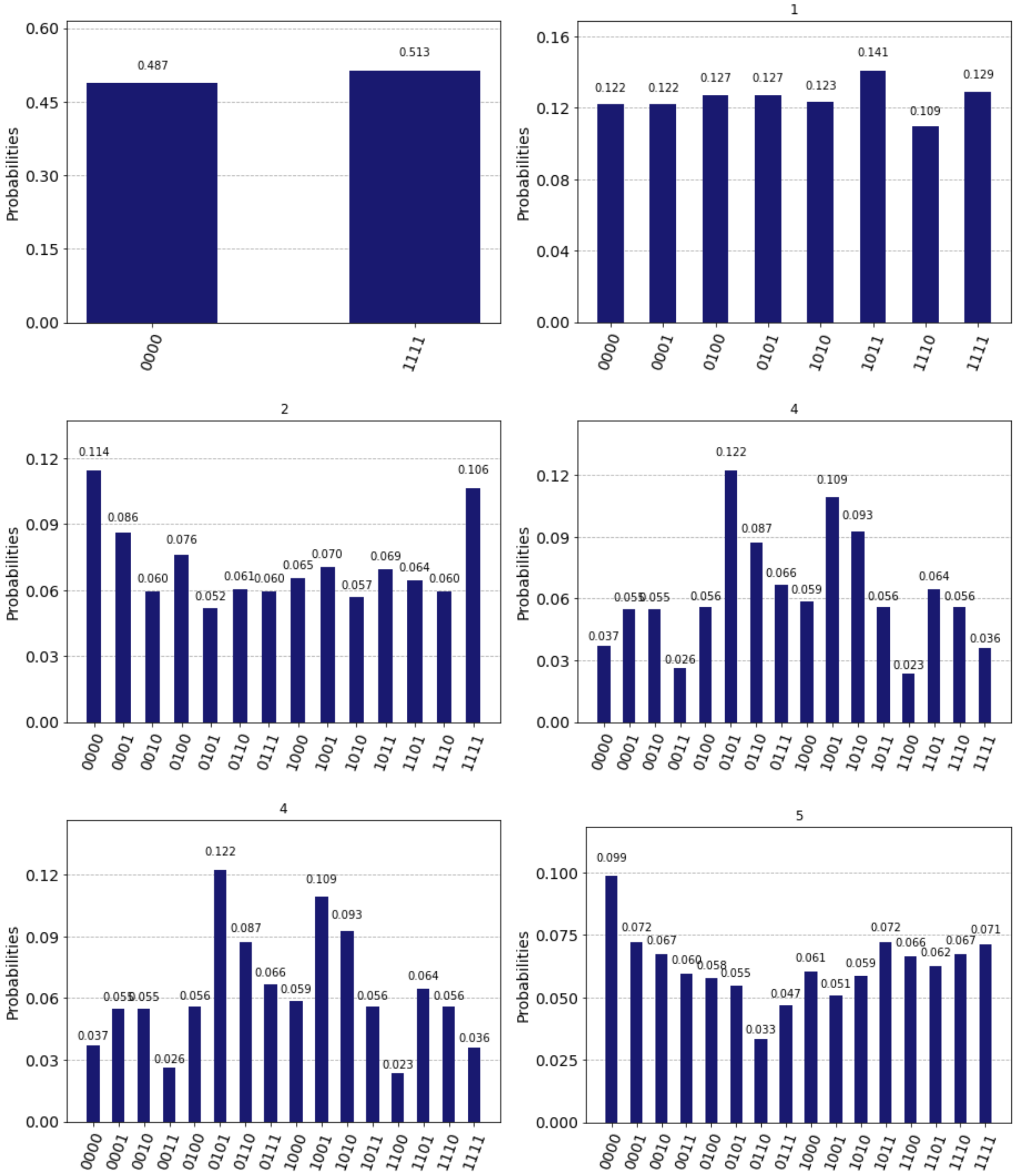


Figure 3:We used four qubits to create two random walking spaces. First, we entangled the two random walking spaces in the first section, and then put the dice we need in the second section. To roll the dice randomly, we designed two dice Hadamard gates with normal and corrected initial phases, and then we enter the judgment of the circuit. In the third section, it is judged that when the states of spacel0 and spacel1 are 00, the dice rolls to 0. Minus one and the fourth block is to add one to 1 when judging that the state of spacel0 and spacel1 is 00. The last section is the instruction to walk, and the final result is the entanglement behavior of electrons in the conductor.

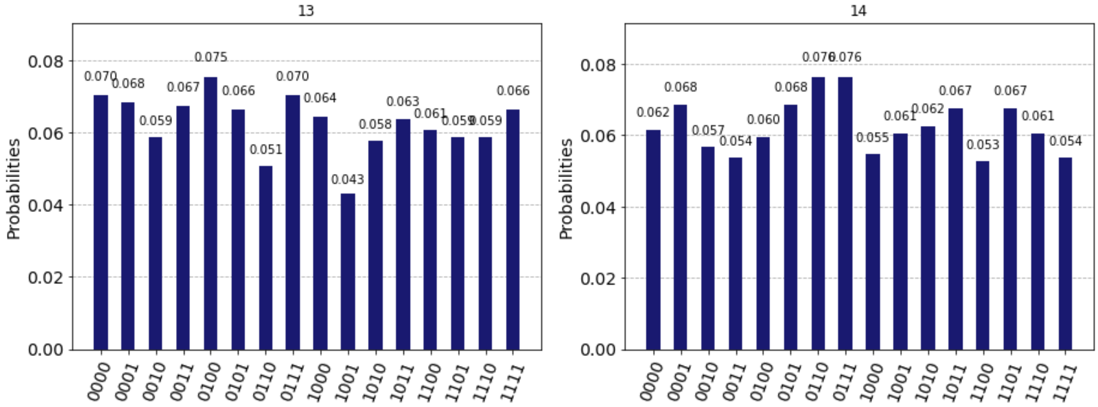
2.3 Result

2.3.1H Coin with initial position 00,11



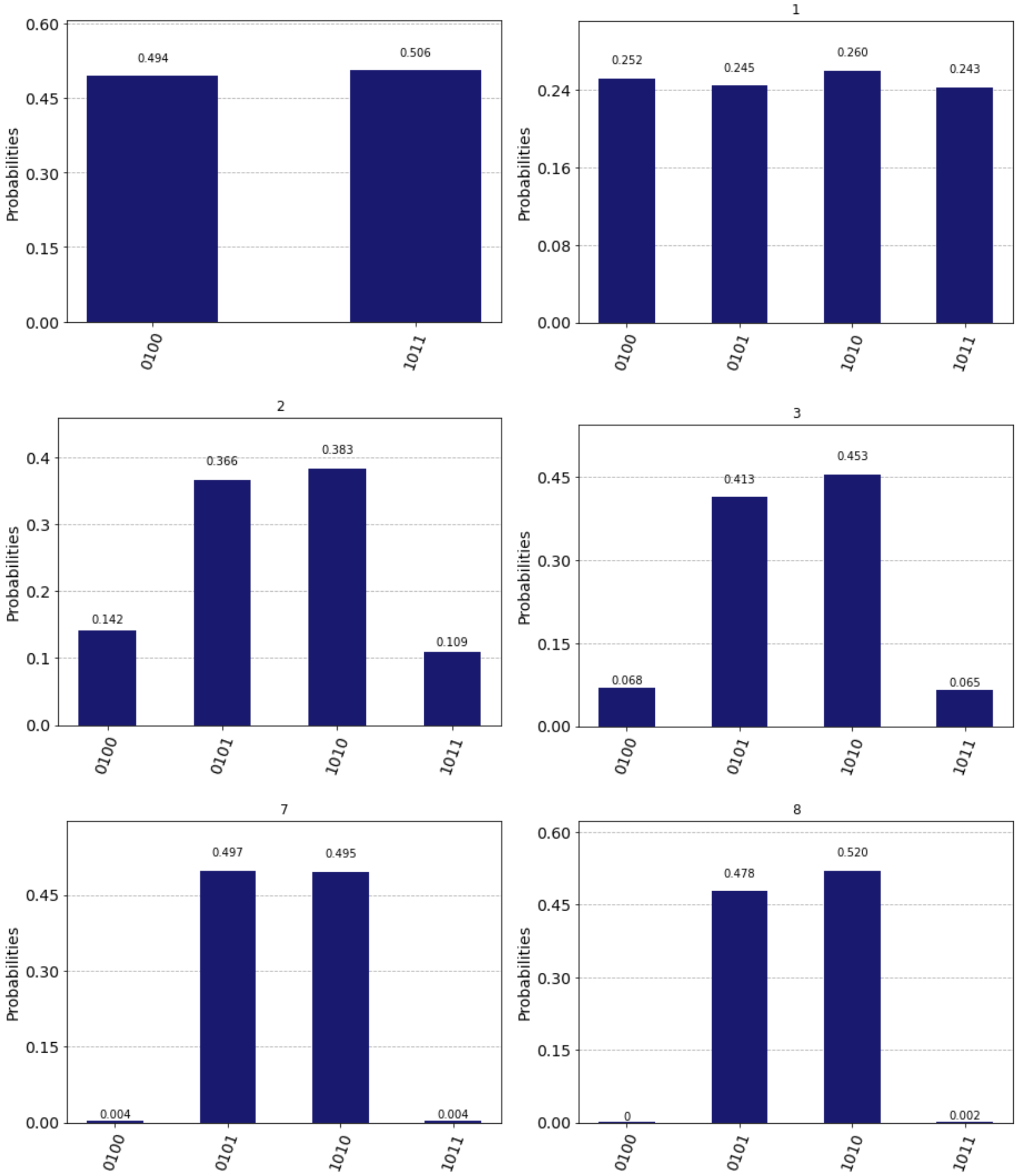
We can see that at the beginning, two particles existed at 00 and 11 at the same time, and then when the particles started walking on the line, eight different states appeared. This is reasonable because, under this position condition, Each particle has two possibilities of walking (stationary or moving to the side). The combination of two particles has eight states. Immediately after the particle took the second step, we can see that there are obvious peaks on the left and right sides, because when the particle is on the most side, such as 00, it will be limited to 00 or advance to 01, so there will be a lot of states appearing in Left and right sides. What's interesting is that when we walk the third and fourth steps, the most likely electronic states are 01, 01 and 10, 01.

This seems magical. We guess it is because when a large number of probabilities appear on the left and right, If you walk again, there will be a feedback effect, because a large number of 00 and 11 will bounce back at this time, causing the probability to move closer to the middle. It can be seen that in the fifth step, the edge peak appears again, but it is not as high as the previous one, so we infer that with continuous execution, the final state combination probability will be the same.



Something magical happened! ! ! ! ! ! ! The thirteenth and fourteenth steps are correct. Our hypothesis may be that we even expect that when it is a thousand steps, it will be an easy H trigger state, and the entanglement that accompanies the entire quantum system may disappear. .

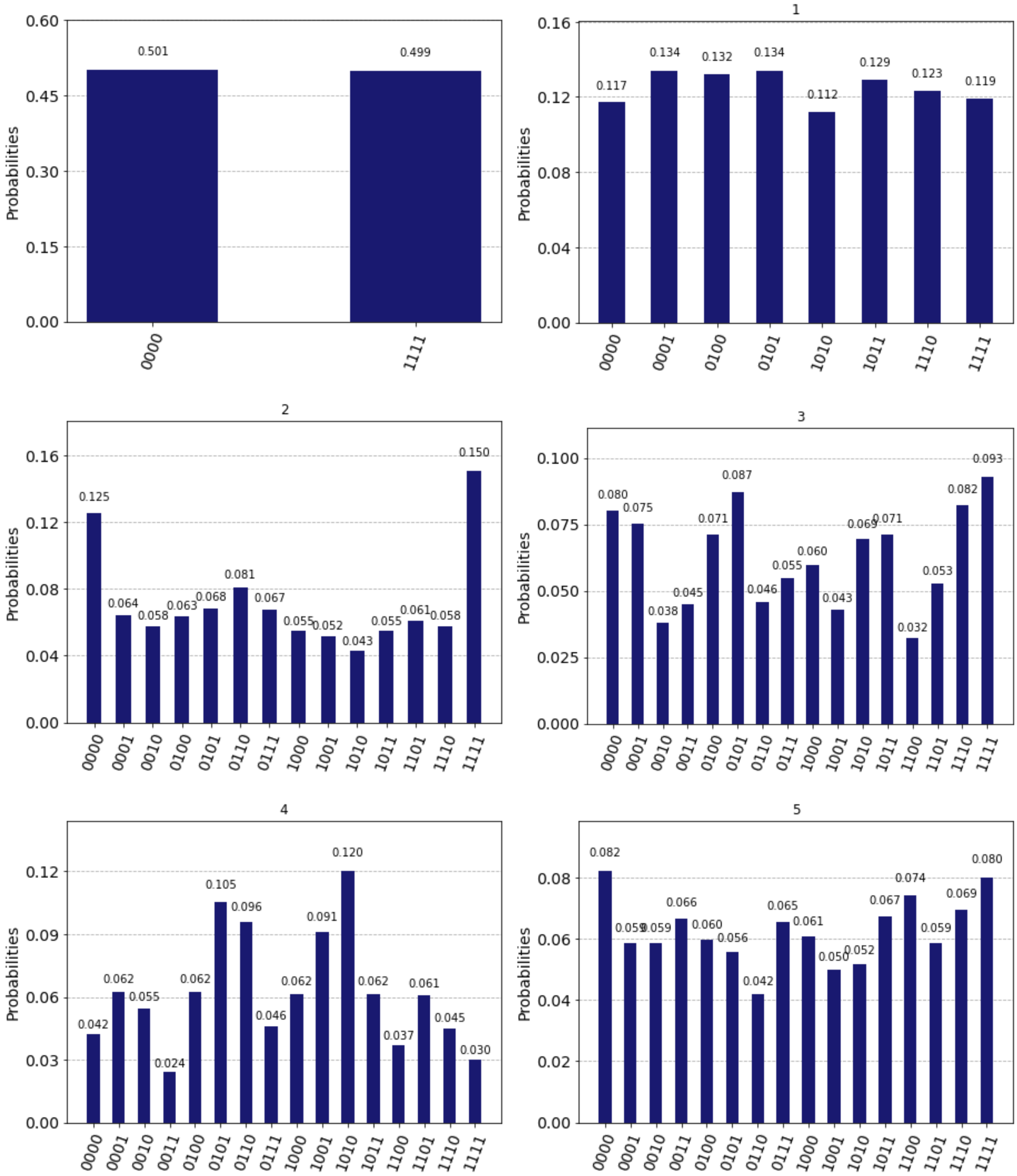
2.3.2Change the walking circuit with Control S



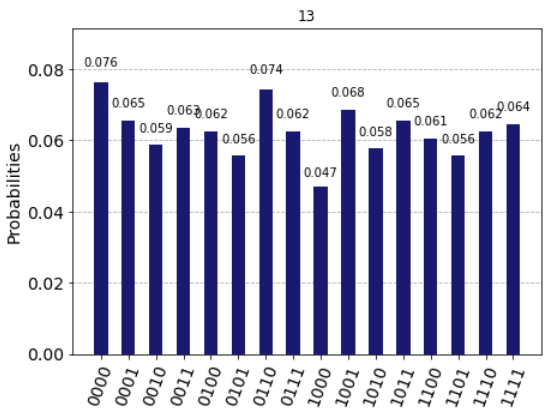
In this simulation, we replaced the CX and CCX Gate in the last block with CCS and CCSdg Gate. Because the S gate is non-Hermitian, we expect the energy loss problem. We want to use this experiment to prove it.

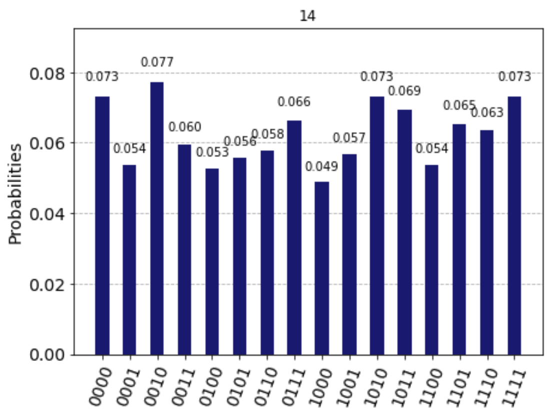
But the final result is that the state will eventually be confined to 01 or 10. We speculate that it is because the part of the initial state is too much 00 to make the phase gate characteristics not appear.

2.3.3Modified H Coin with initial position 00,11



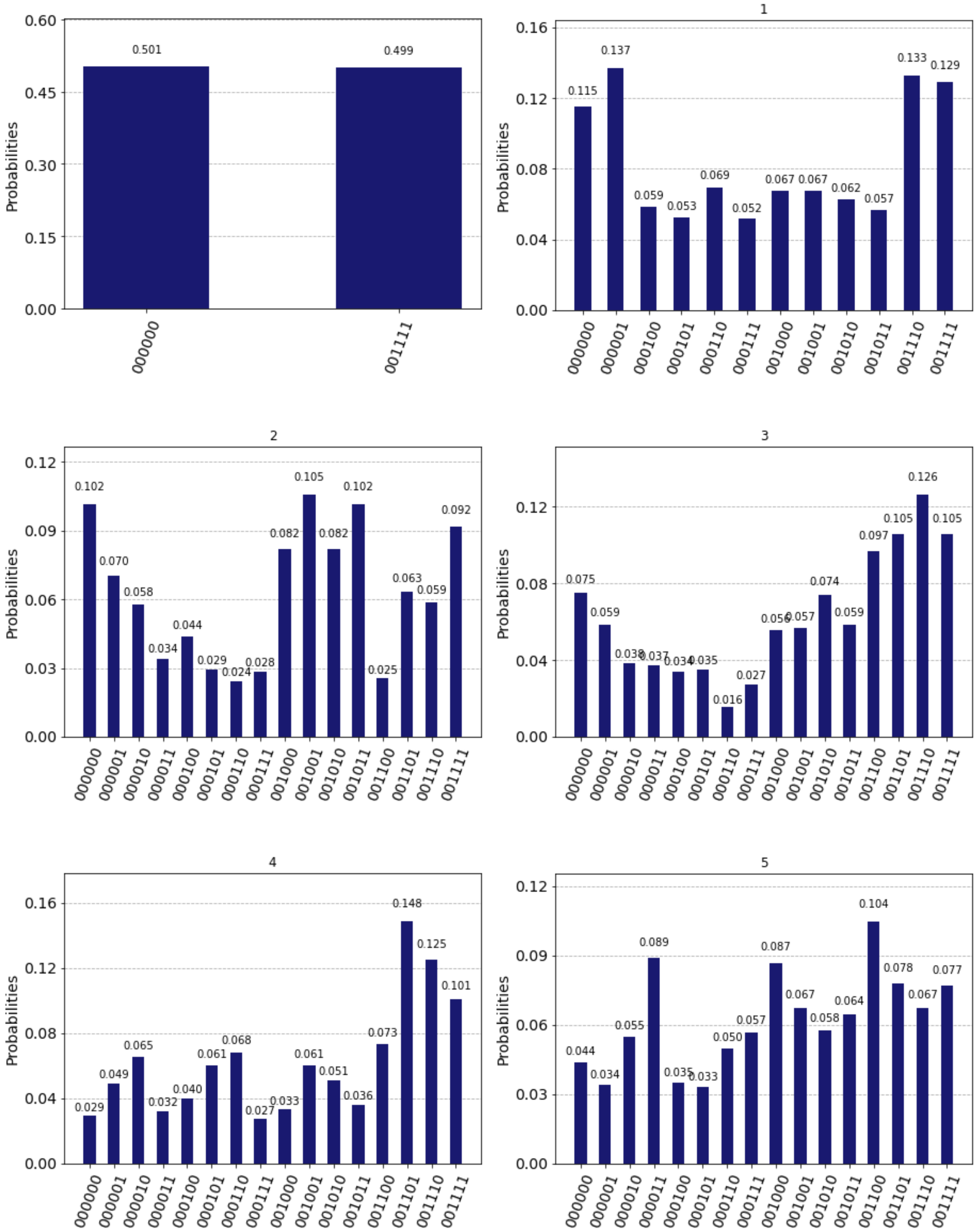
We can see that although we replaced the original H coin with other gates to carry out the experiment, we can see that the experimental results are also very reasonable. In the first step, each particle has two states at the same time. This state combination. In the third step, we found that the state was mostly gathered on both sides. But the magic is that there are four peaks of 0000, 0101, 1011, and 1111 in the third step, which do not appear to be the same as the H coin, but in the fourth step, the left and right peaks disappear again. Until the fifth step, we found that the probability of the state is getting smaller and smaller, and the same situation as the H coin (gradually stabilized) appears.





In other words, as we perform more steps, the state will become more and more stable. Sure enough, when we performed the 13th and 14th steps of the experiment, we saw an increasingly stable trend. We hope that when the experiment is executed 100 or even 1000 times, the entangled state will not exist.

2.3.4Modified H Coin with initial position 000,111



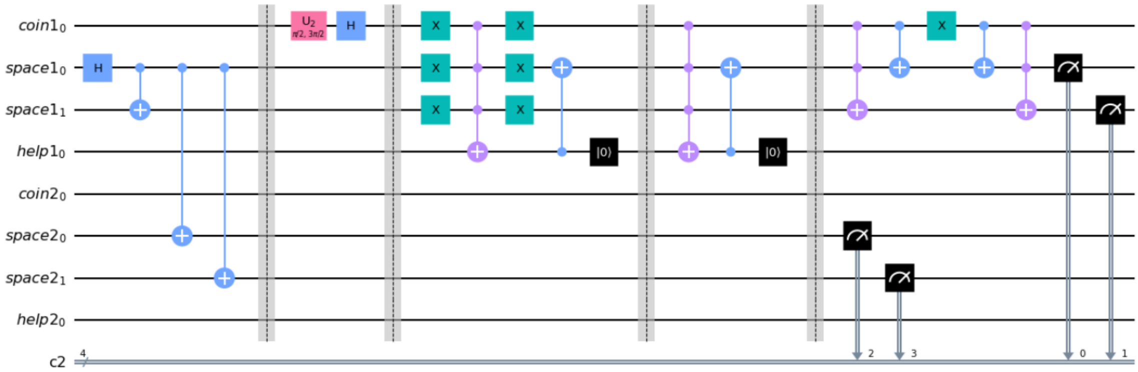
With a simple model, we decided to extend it to a larger space, so I expanded the states that each particle can reach, such as 000 and 111. We expect to see the same trend as the original experiment, but after the experiment It is found that the state does not tend to gradually stabilize. We speculate that it is because the vector space is too large. If you want to reach stability, you must walk more steps.

3 Laser communication affected by Quantum Walk

3.1 What We Want To Achieve?

When we shoot a laser beam on a nonlinear crystal. It will be possible to create a pair of entangled photons. We designed two walking spaces of quantum walk with entanglement which can simulate the interaction betwhen two photon.We execute the walking process on one of the photons . Observe whether the two photons produce error while executing random walk.

3.2 Method



Figure?:We devided our circuit into few part. Simular to the last one. First, we entangled the two space of random in the first section then set the dice we designed in the second section. Due to the phenomenon we want to observe(we mention in 3.1)There is only a coin on coin1 qubit. In third and forth section, we determine the two situation which need to mark the help qubit(while coin is 0 and position is 00 or coin is 1 and position is 11). The last section is the instruction to the fundamental random walk, and the final result is the entanglement behavior of Laser communication conductor.

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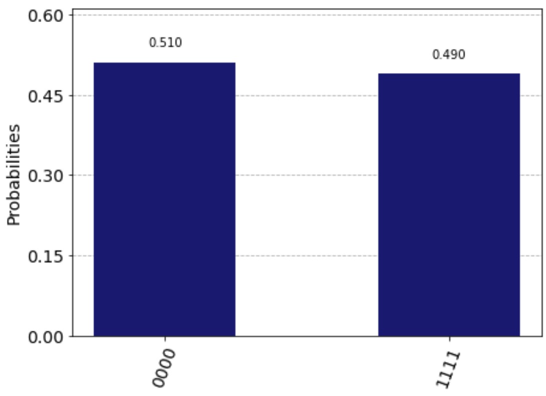
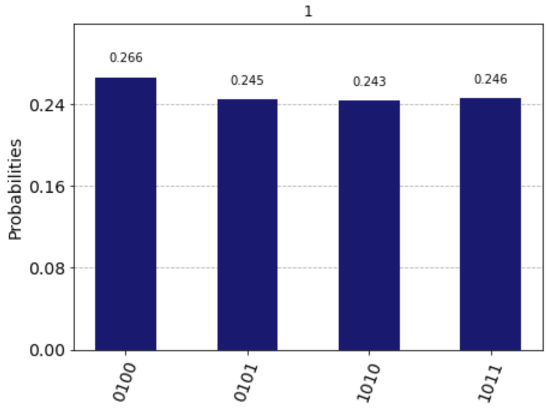
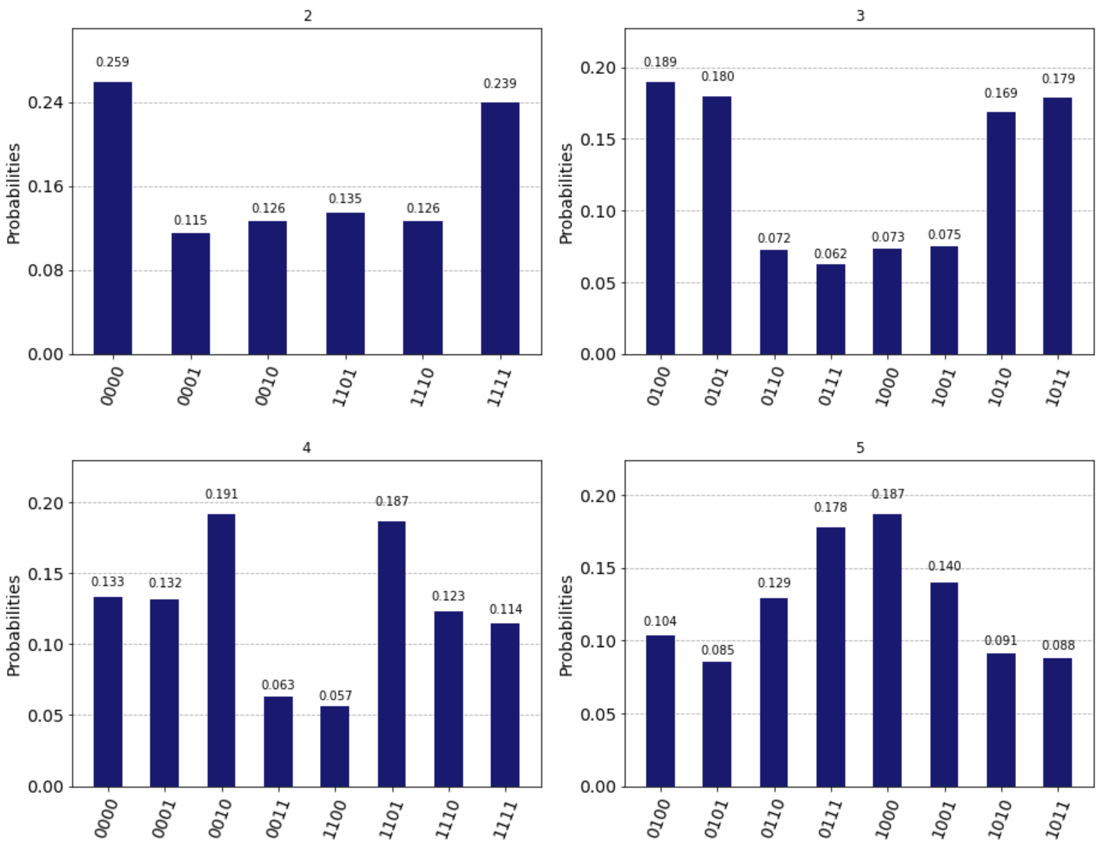
3.3 Result

3.3.1H Coin with initial position 00,11

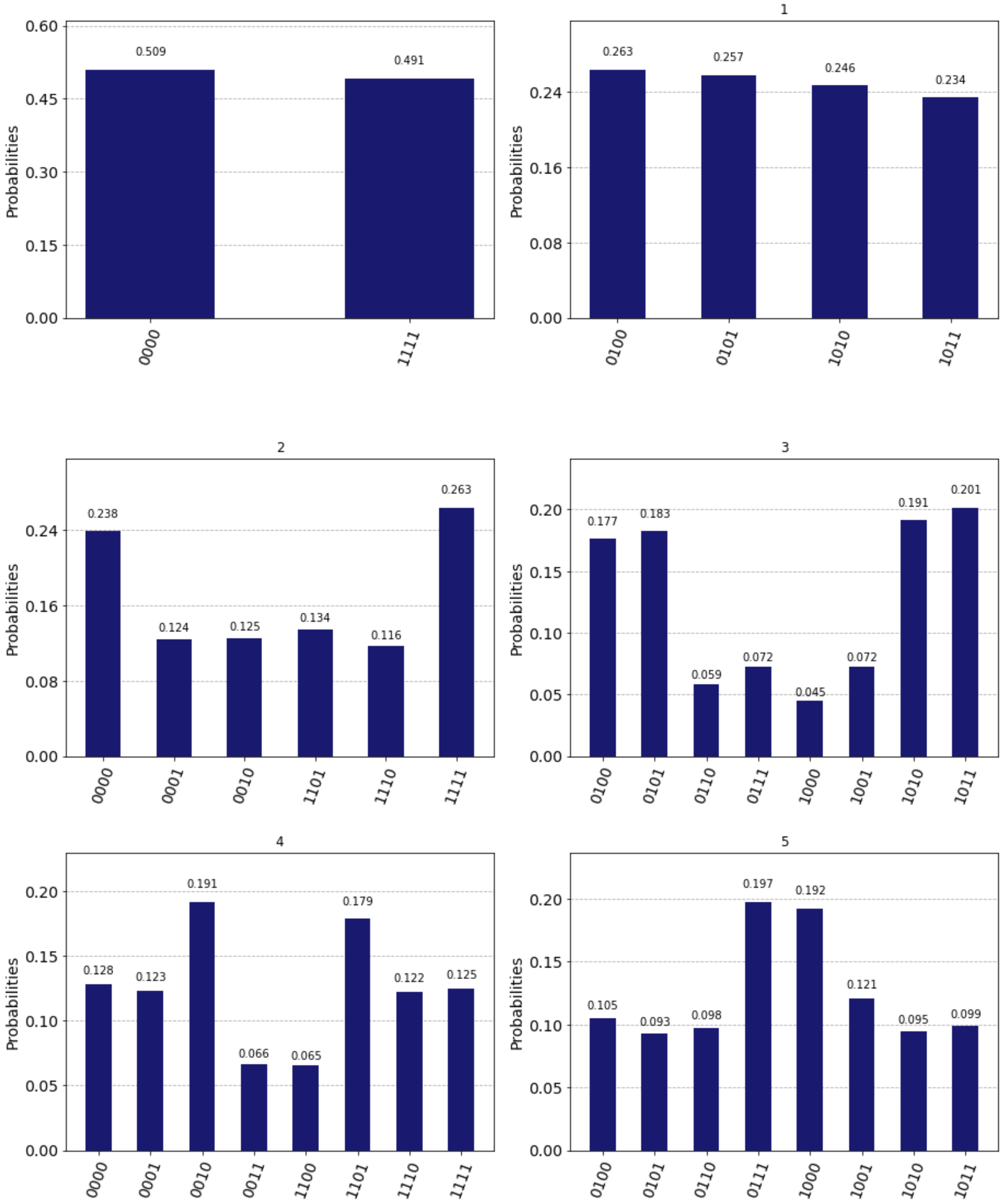




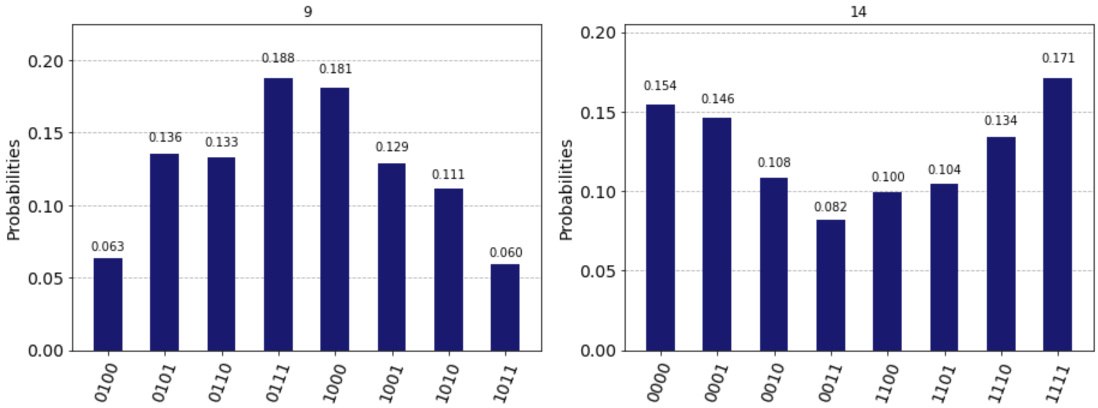


Here we use the H gate, we can see that the state of the entangled photon pair at the beginning is 00 and 11. The difference from the electronic experiment results is that when the entangled photon pair makes the first step of walking in a straight line, four states will be generated. , We think that because the photon is walking at this time, the energy has not yet diffused, only walking to 01, 10, the energy began to diffuse in the second step, the entangled photon pair began to walk in other directions, and finally will produce eight different states, we can In the second step, the energy is mostly concentrated in 00 and 11. The reason is that there are still entangled photon pairs staying in place and have not yet walked. In the third step, these entangled photon pairs begin to spread inward toward 01 and 10 directions. Walking, so the probability will move closer and closer to the middle.

3.3.2Modified H Coin with initial position 00,11



We can see that at the beginning we used the phase-corrected H gate. Two entangled photons existed at 00 and 11 at the same time, and when we walked a step on the line, four states of 00, 11, 10, and 11 were generated. At this time, the energy of the two photons has not been diffused when they are entangled, so the energy is still limited to 00, 11, 10, and 11, but during the second walk, the energy began to diffuse and appeared in six states, which are the same as mentioned before. Similarly, when the entangled photon pair walks at positions 00 and 11, there will be six different states, and at the end there will be eight different states. In the second step, we can clearly see that there are peaks on the left and right sides. The energy of the photon on the side will be limited to 00 or advance to 01, and the entangled photons will shrink in the third and fourth steps because a large number of 00 and 11 will spread out at this time, so we can be in the fourth In the step diagram, you can see that there is a peak at the positions of 10 and 01, and then the probability of rebounding back is closer to the middle, so it is the situation presented in the fifth step.



That is to say, the difference from the electron experiment is that the entangled photon pair will continue to spread and rebound when walking, so it is the case of the ninth and fourteenth steps.

4 Conclusion

4.1 Hydrogen Electrons affected by Quantum Walk

To sum up, from this hackathon, we successfully simulated the random walking behavior of entangled particles and got quite reasonable results. We want to use this experimental result to explain the entanglement behavior of electrons in high-voltage cables. In the results, we found that the state combination of the particles will constantly oscillate between the edges and the center. If the movement time is longer, the entanglement behavior of the particles is likely to eventually cancel out.

4.2 Laser communication affected by Quantum Walk

In the third part, we saw the photon state constantly oscillating. We think that the entanglement ability of photons will also disappear, but it will take longer than the second part of the experiment. But the result also tells us that we successfully simulated the photonic communication

5 Future Works

5.1 We hope to use mathematics to figure out what kind of quantum coin can quickly return two particles to a pure state.

5.2 We hope to be able to define the behavior of these two circuits more rigorously.

5.3 We hope this can be used to describe the motion behavior of entangled particles.