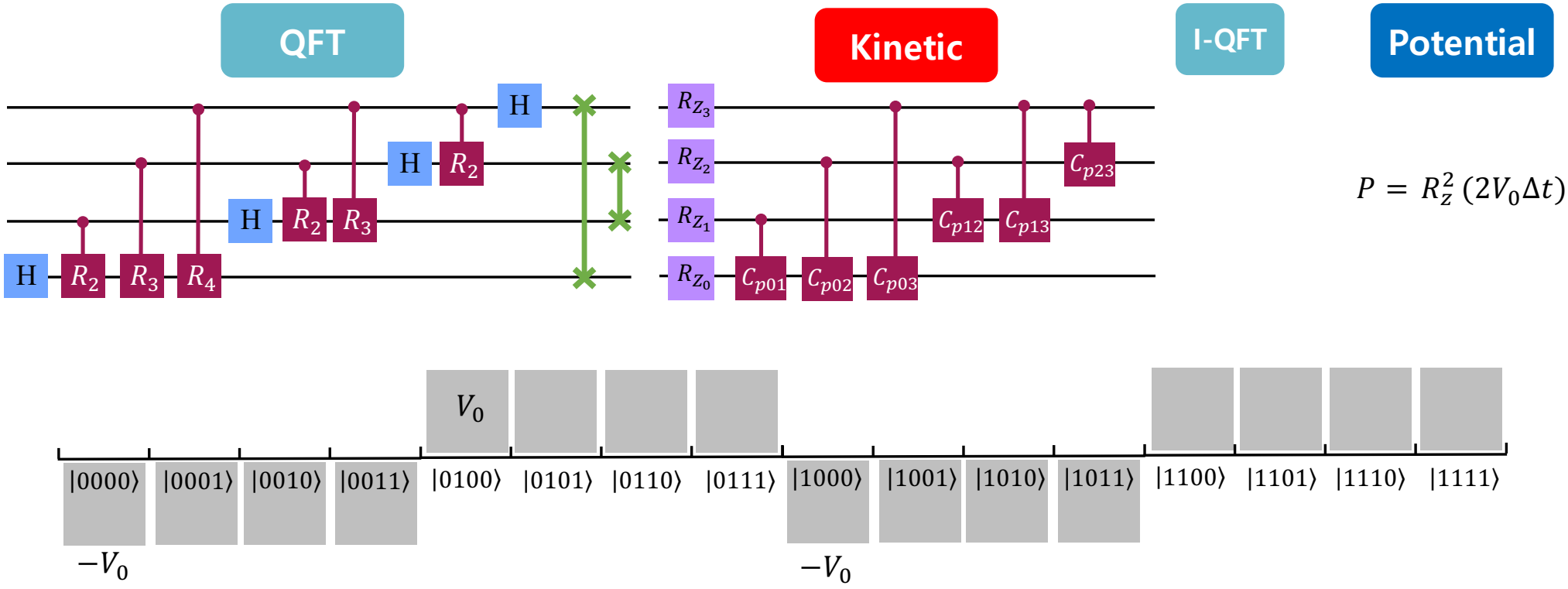
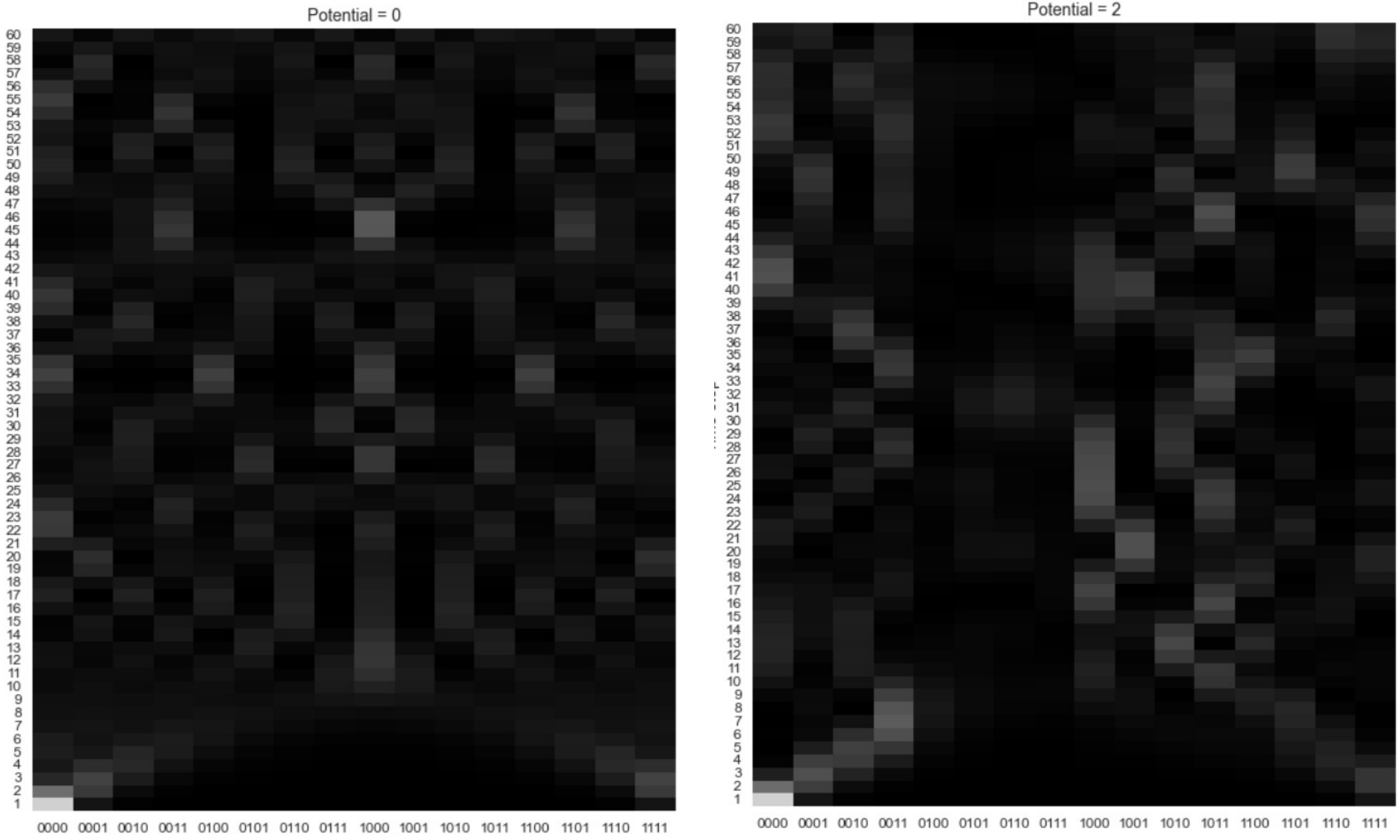
4 qubit

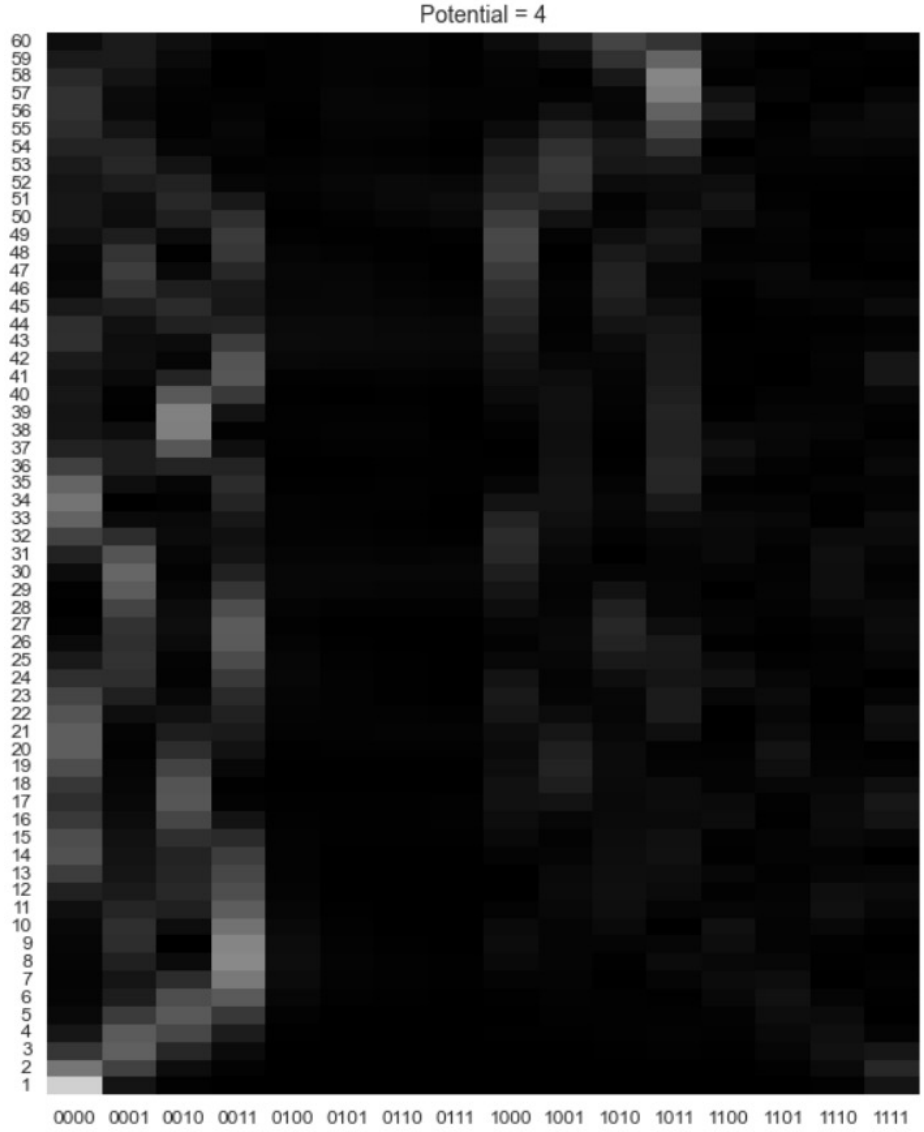
Double potential barrier



$$P = R_z^2\,(2V_0\Delta t)$$

```
# time interval
dt = 0.15
# Number of time step
step = 60
```


Potential = 0
Potential = 2
60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
0000 0001 0010 0011 0100 0101 0110 0111 1000 1001 1010 1011 1100 1101 1110 1111


Potential = 4
60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
0000 0001 0010 0011 0100 0101 0110 0111 1000 1001 1010 1011 1100 1101 1110 1111

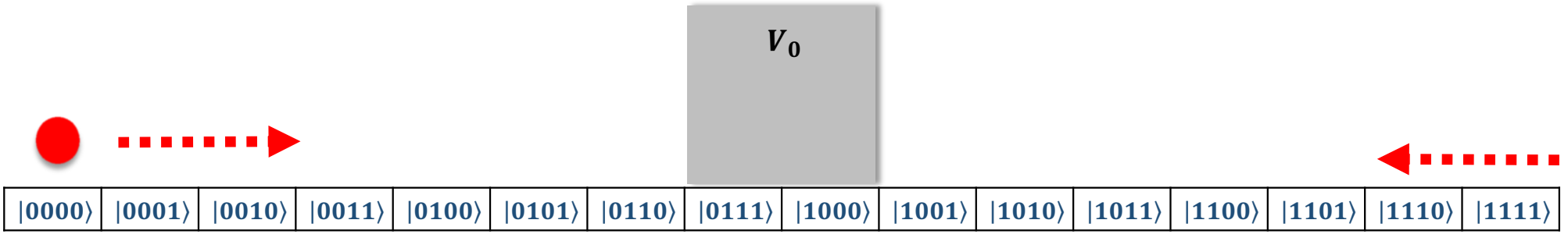

Potential = 6
60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
0000 0001 0010 0011 0100 0101 0110 0111 1000 1001 1010 1011 1100 1101 1110 1111

4 qubit tunneling system은 완성했습니다.

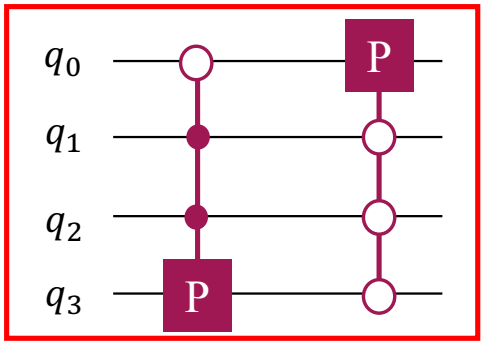
tunneling time을 어떻게 측정할 수 있는지가 문제 일듯 합니다.

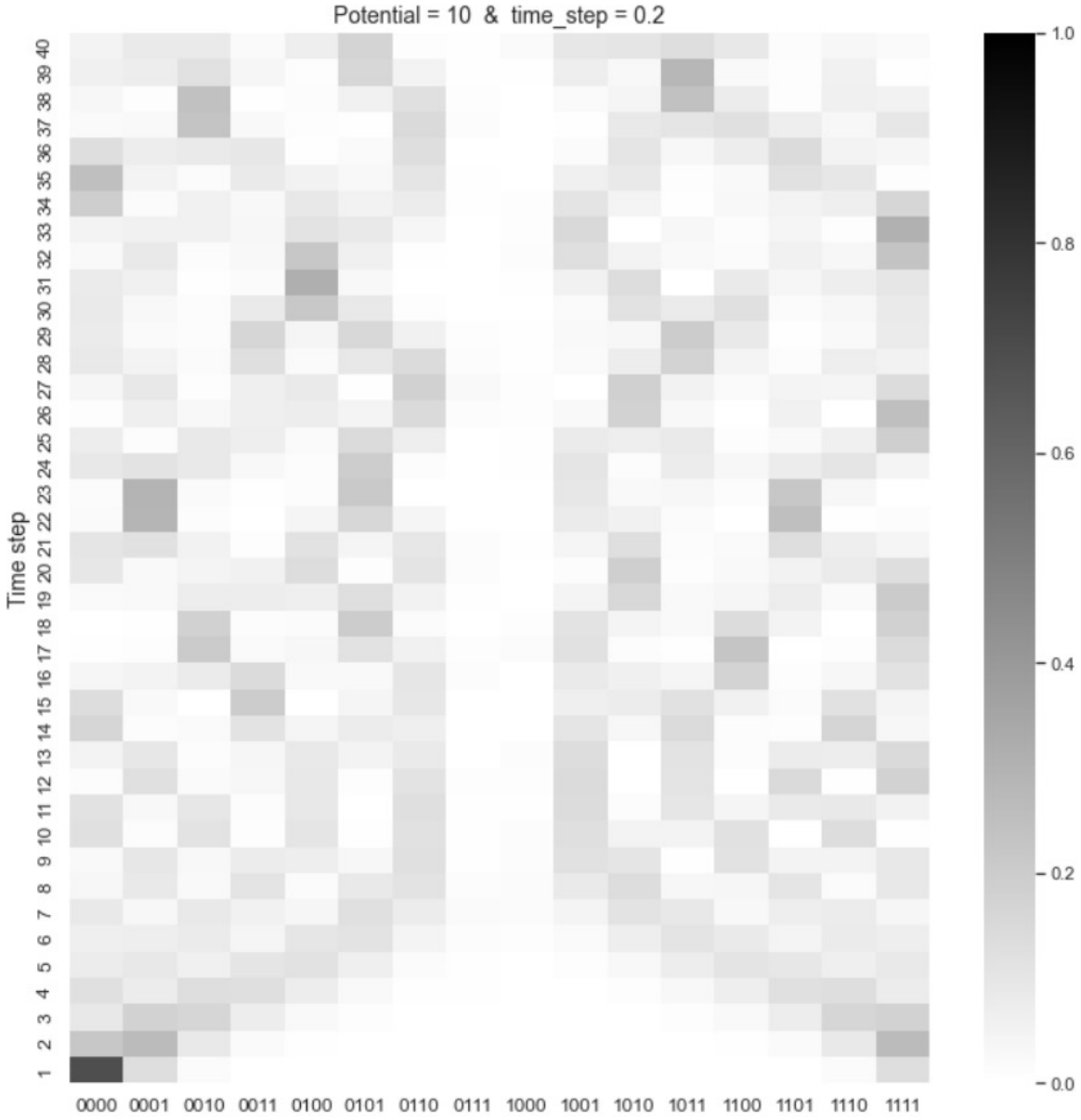
우선은 첫번째로 장벽을 통과한 시점을 관찰해 보겠습니다.

Single potential barrier



$$e^{-iV(\hat{X})\Delta t} = diag\left(1,1,1,1 \quad 1,1,1,e^{-iV_0\Delta t} \quad ,e^{-iV_0\Delta t},1,1,1 \quad ,1,1,1,1\right)$$

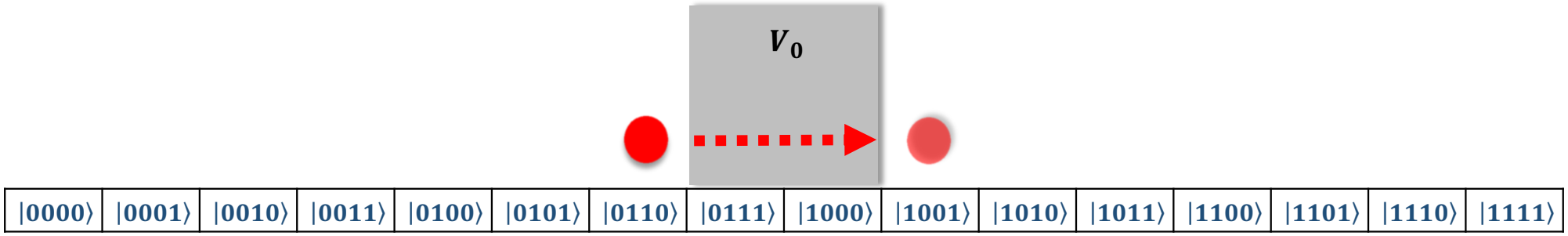


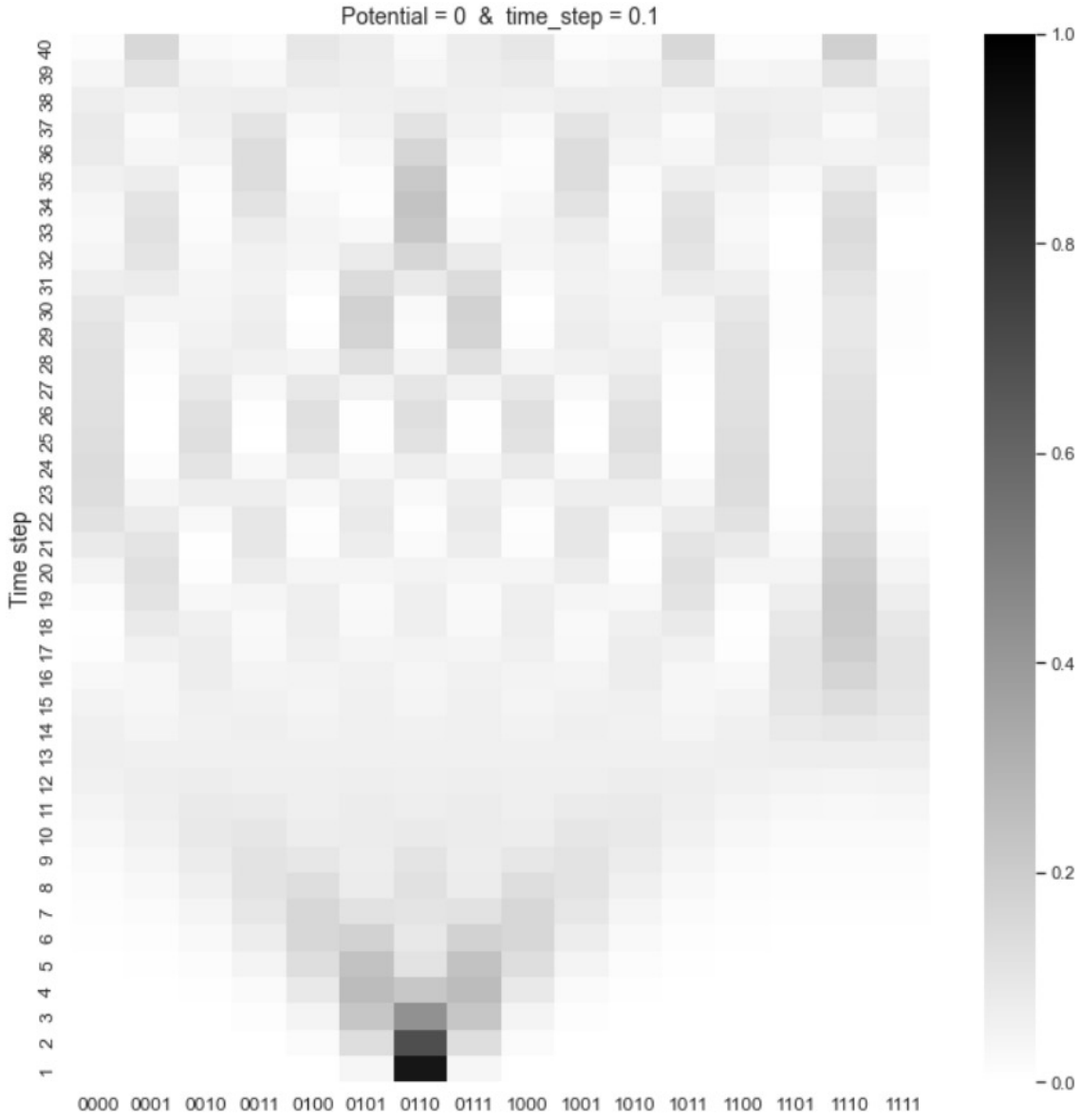


시작점 : 0000

potential = 10

time step = 0.2

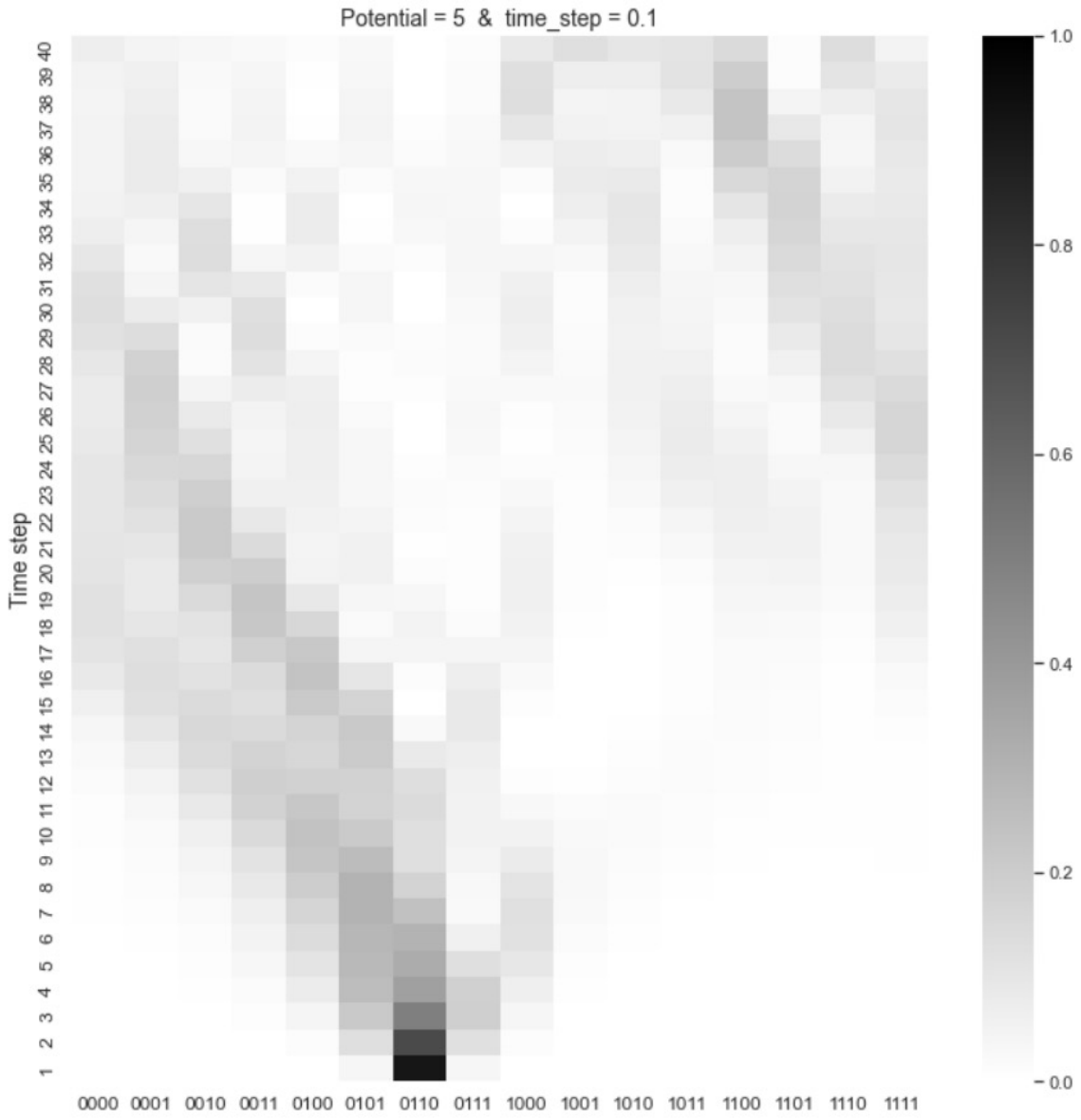

V_0
|0000⟩
|0001⟩
|0010⟩
|0011⟩
|0100⟩
|0101⟩
|0110⟩
|0111⟩
|1000⟩
|1001⟩
|1010⟩
|1011⟩
|1100⟩
|1101⟩
|1110⟩
|1111⟩



시작점 : 0110 (장벽 바로 옆)

potential = 0

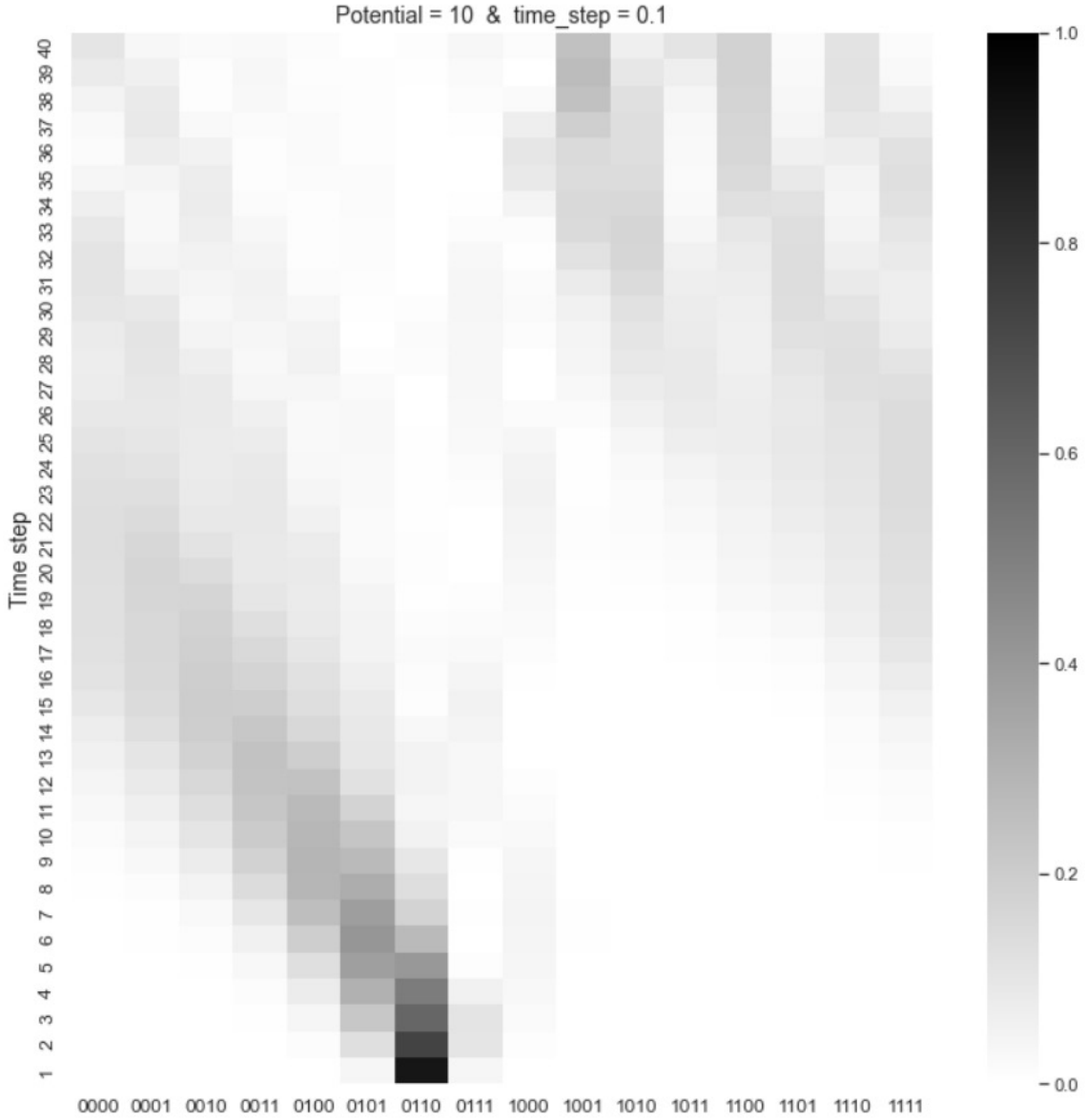
time step = 0.1



시작점 : 0110 (장벽 바로 옆)

potential = 5

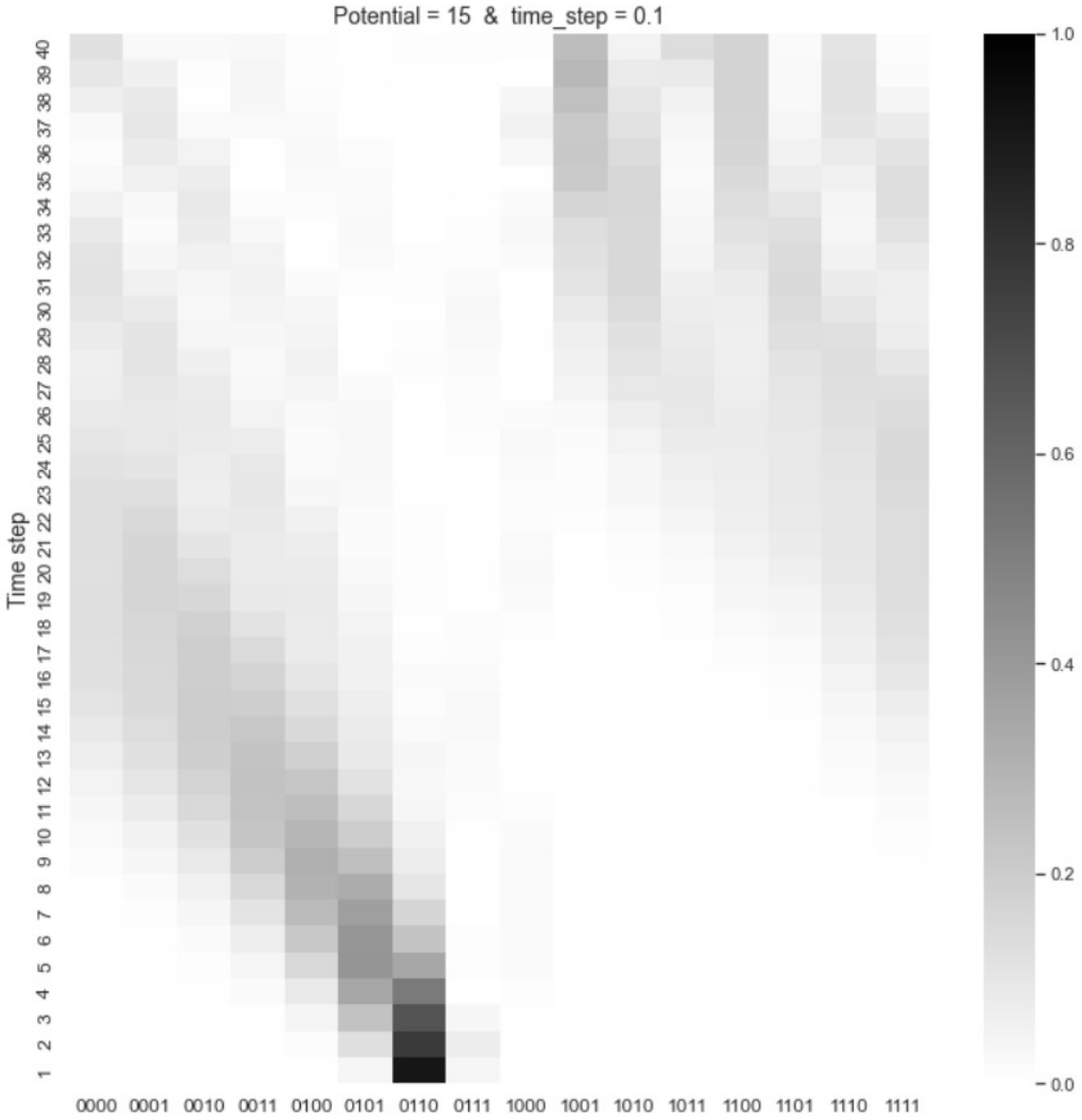
time step = 0.1



시작점 : 0110 (장벽 바로 옆)

potential = 10

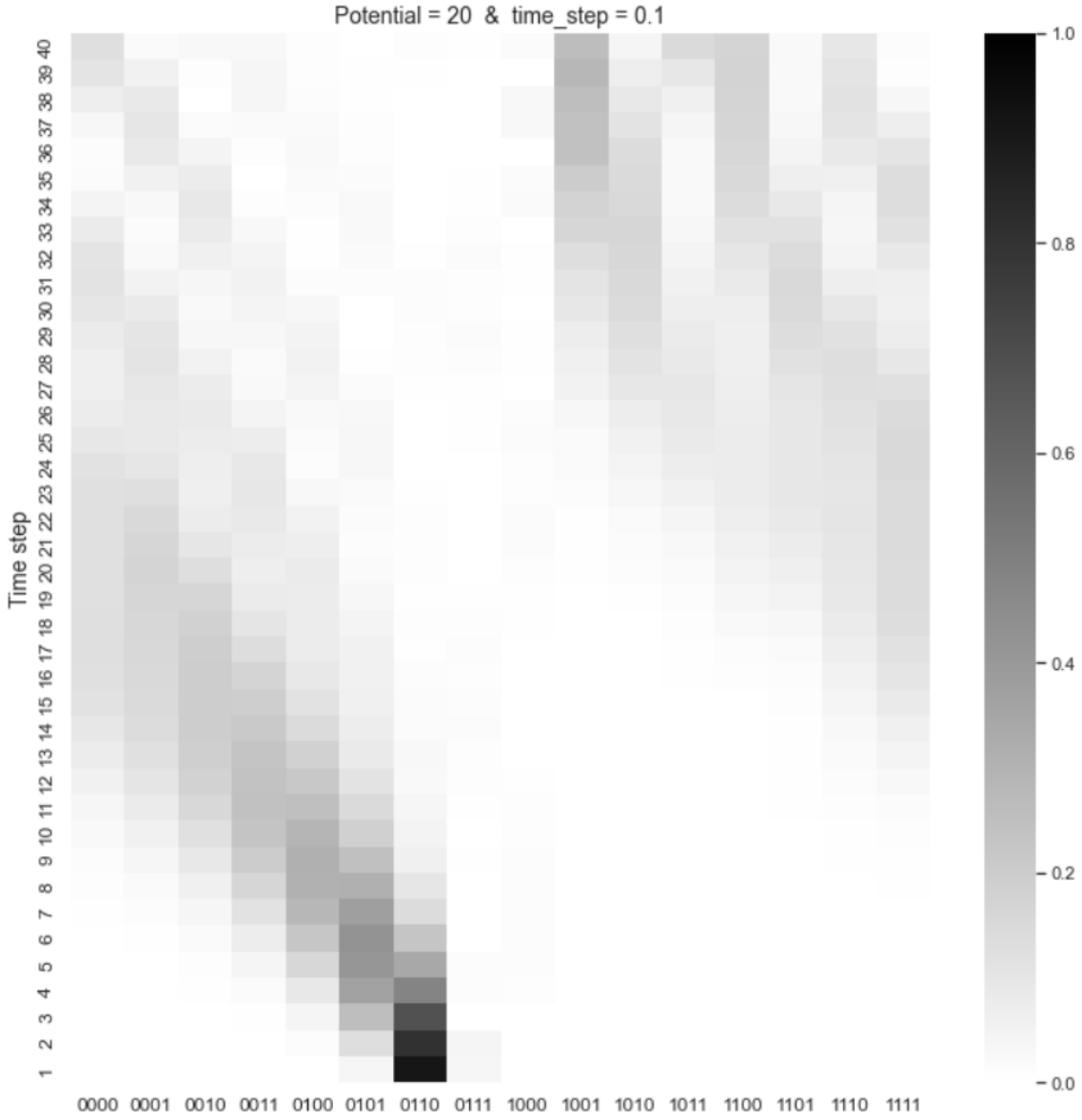
time step = 0.1



시작점 : 0110 (장벽 바로 옆)

potential = 15

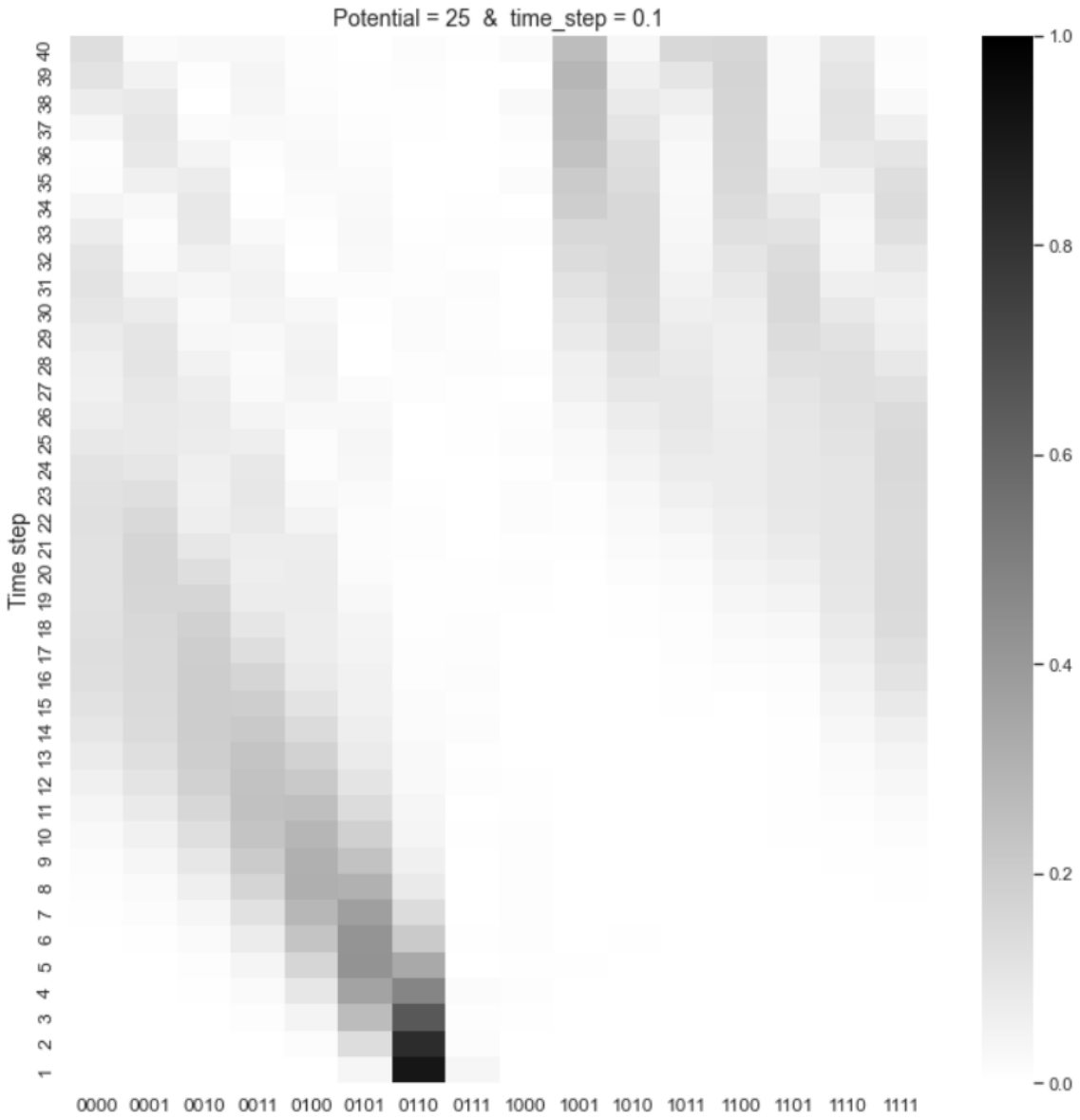
time step = 0.1



시작점 : 0110 (장벽 바로 옆)

potential = 20

time step = 0.1



시작점 : 0110 (장벽 바로 옆)

potential = 25

time step = 0.1

가운데 만들어준 포텐셜이 잘 작동
>> 포텐셜이 커짐에 따라 장벽 내부에 존재할 확률이 낮아짐

작은 타임 스텝에서 엑셀 데이터 파일을 통해 터널링 타임을 정리해보겠습니다.

포텐셜이 커지면