

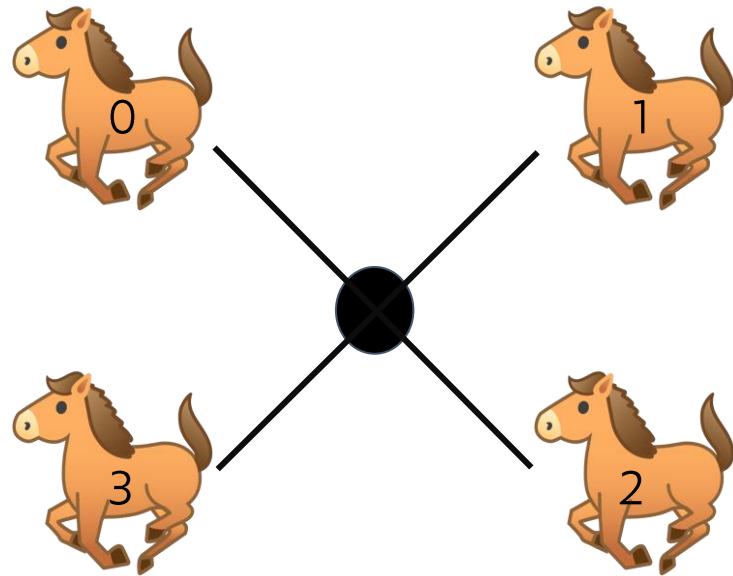
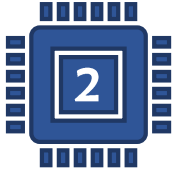


# **SPINNING MUSICAL QUANTUM MEMORY**

**iQuHACK**  
2022

MARCO BALLARIN, ALICE PAGANO, MARCO TRENTI

# IDEA

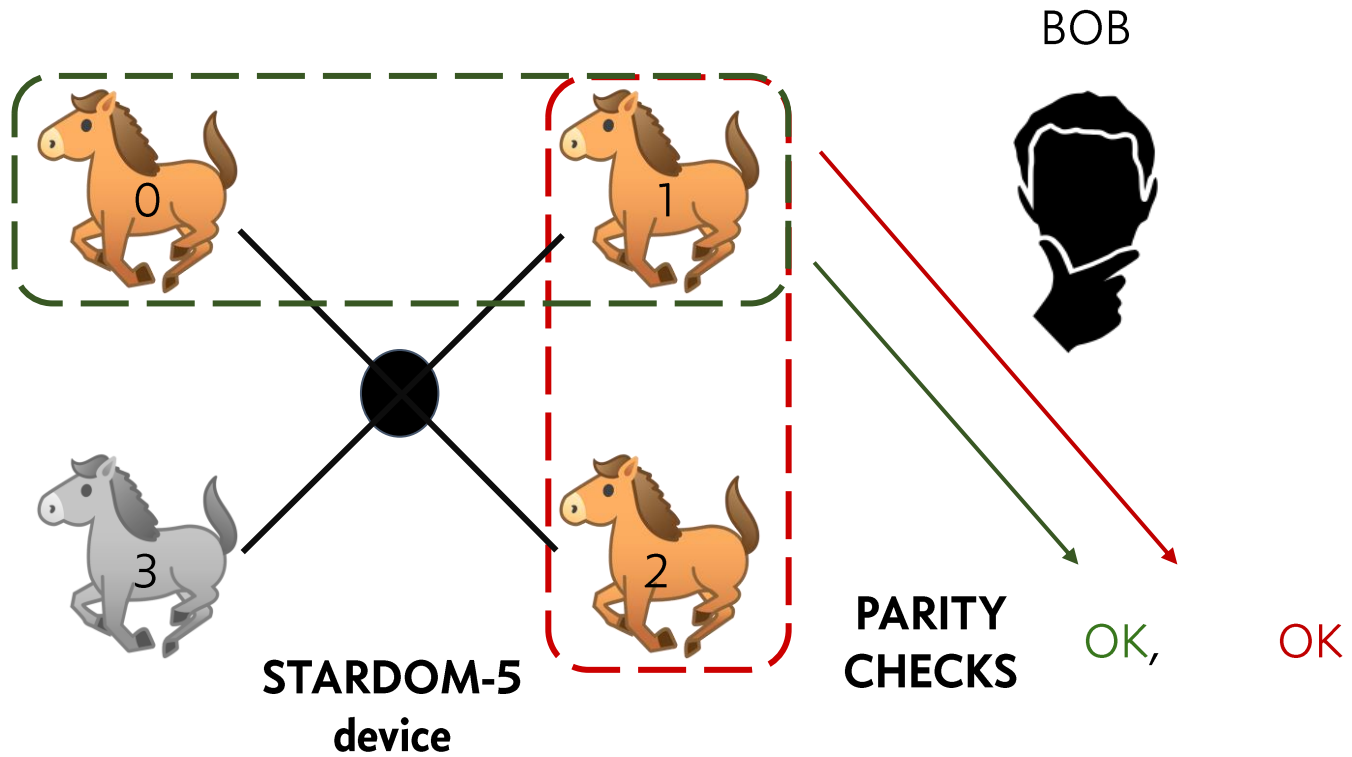
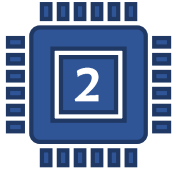


STARDOM-5  
device

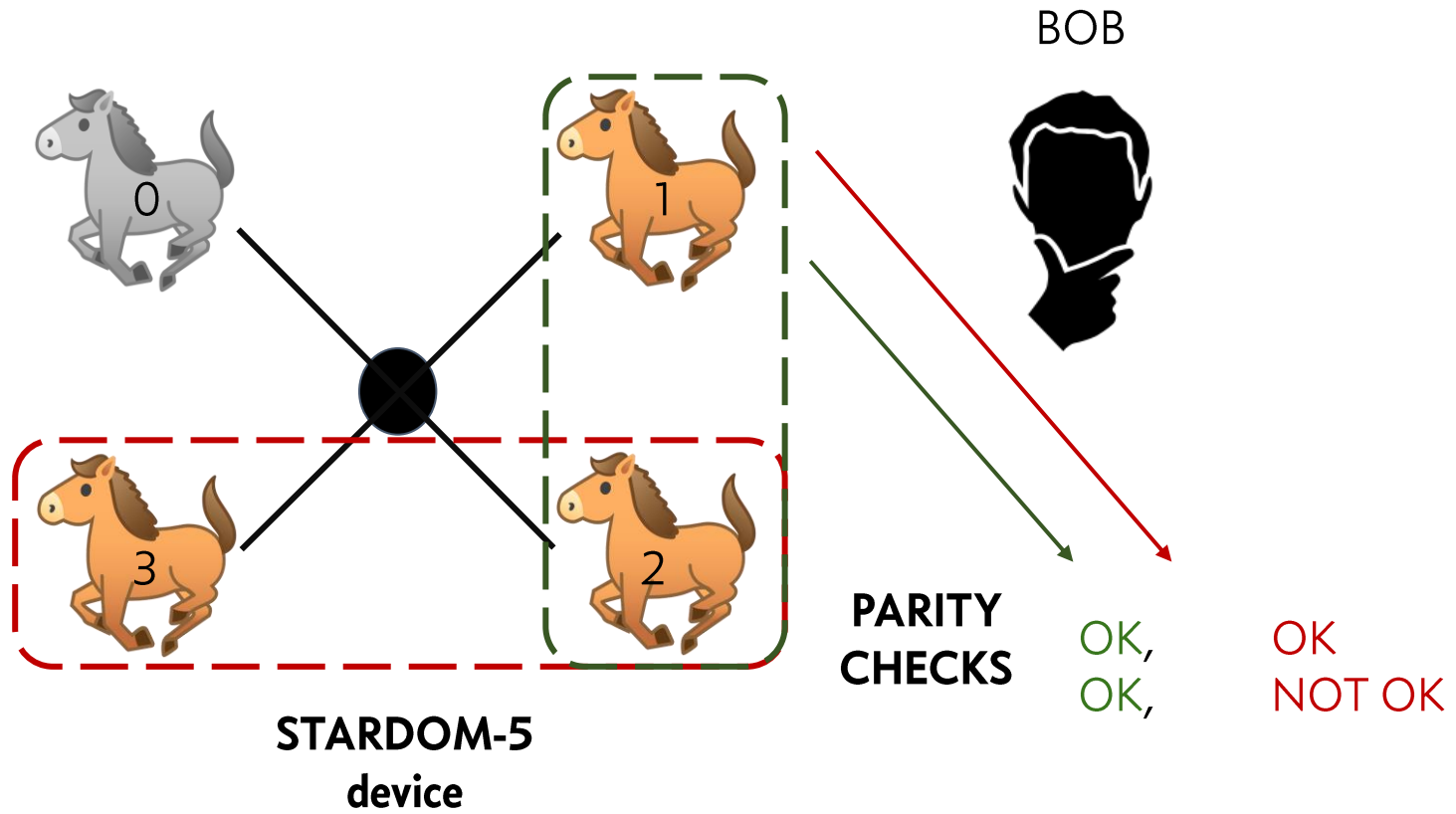
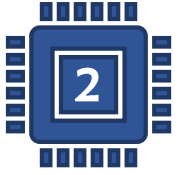
BOB



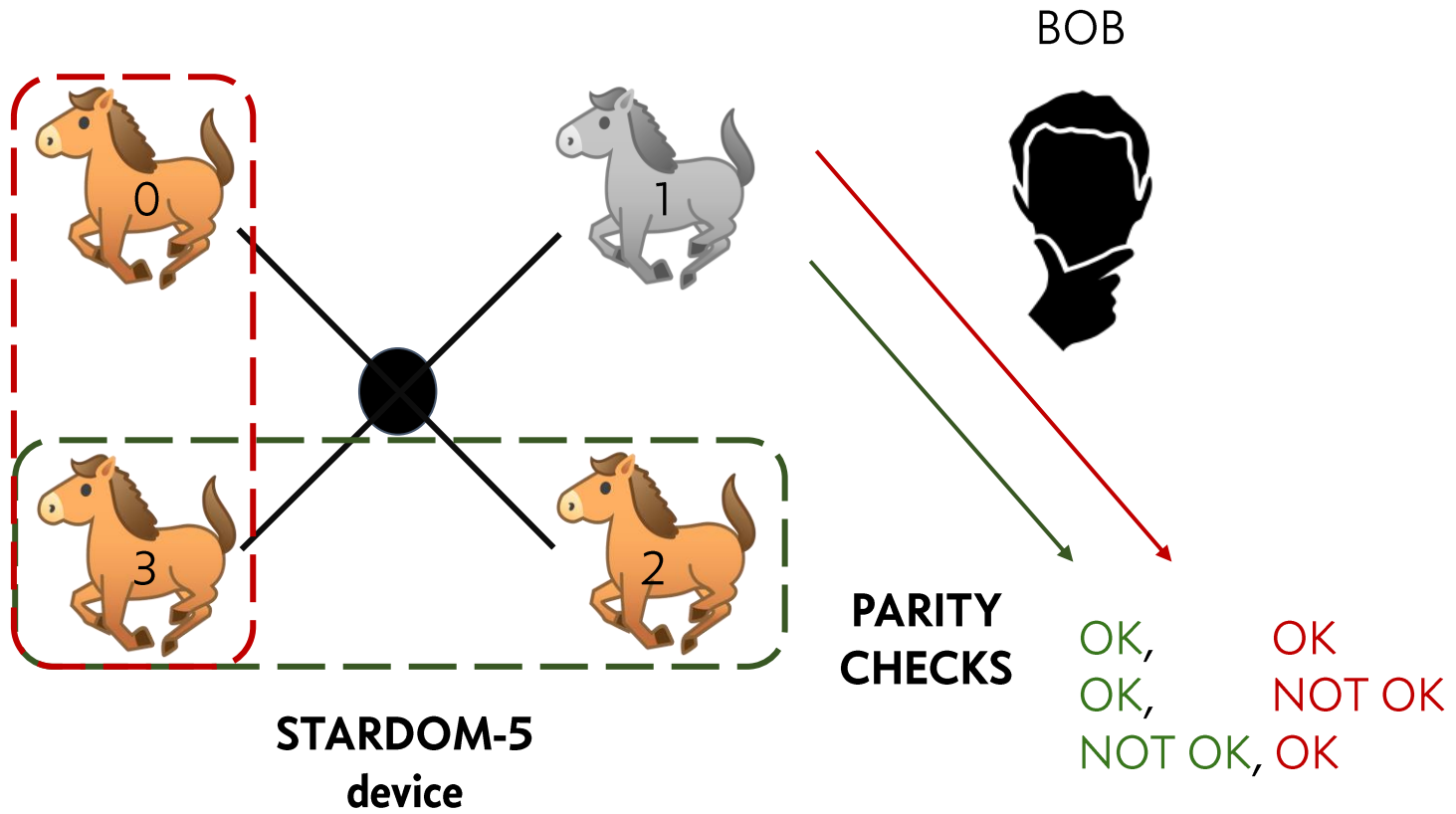
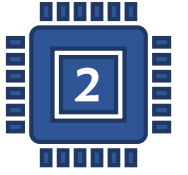
# IDEA



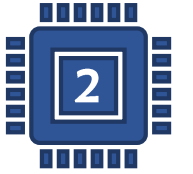
# IDEA



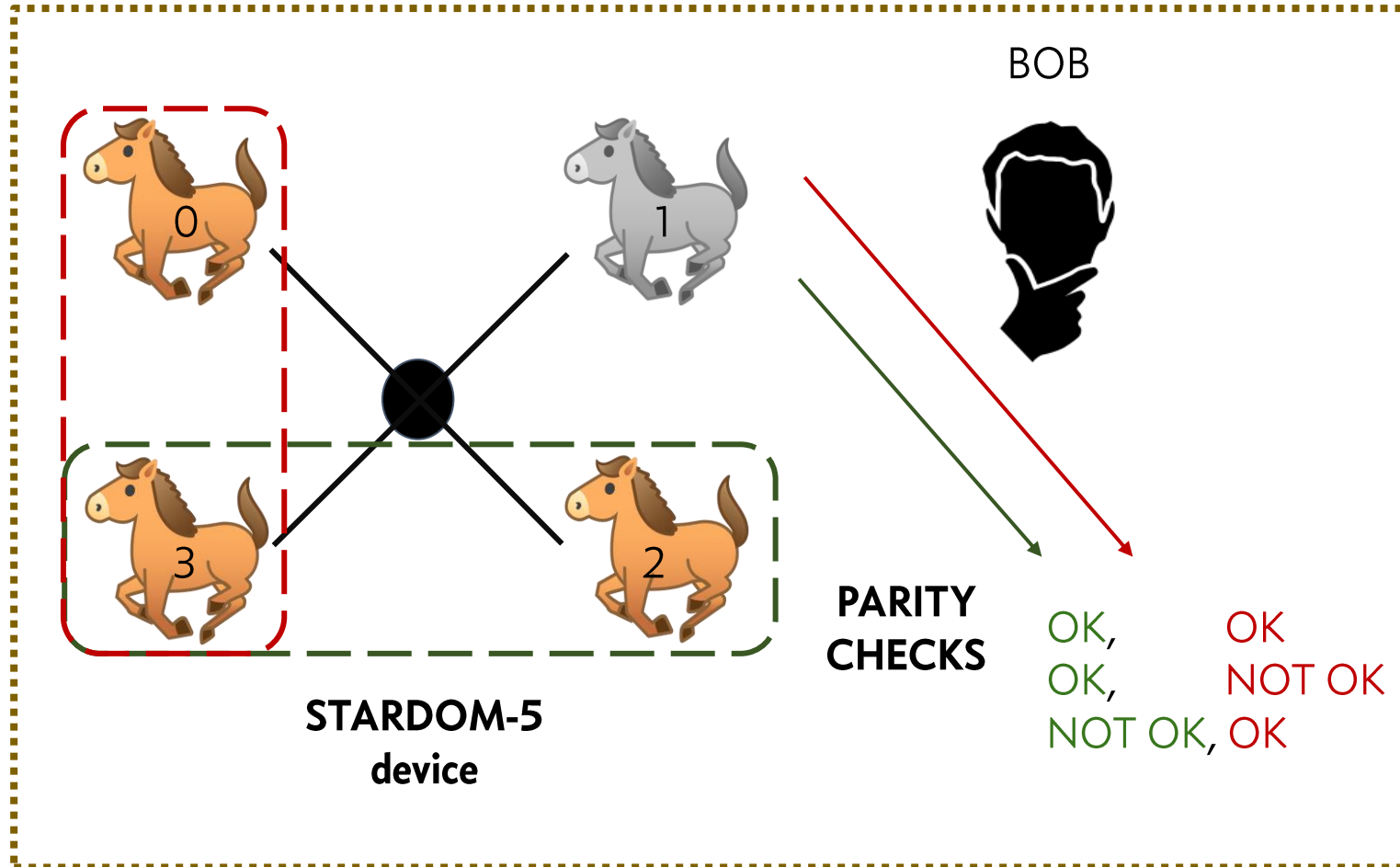
# IDEA



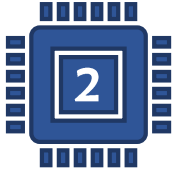
# IDEA



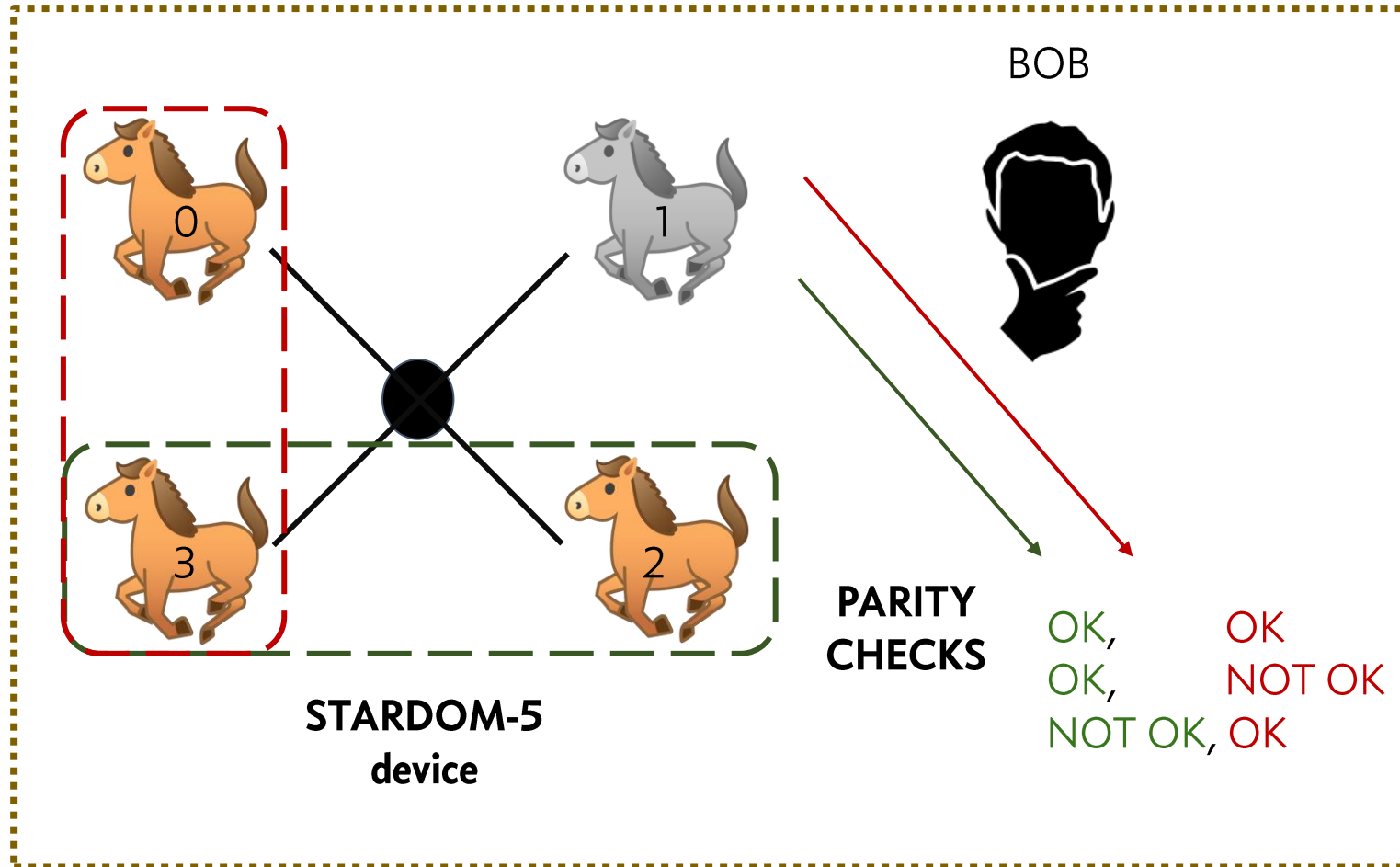
Repeat n times, changing the horse occupancy configuration



# IDEA



Repeat n times, changing the horse occupancy configuration



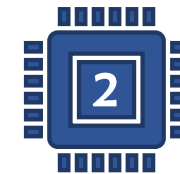
**MACHINE  
LEARNING  
MODEL**

AGENT

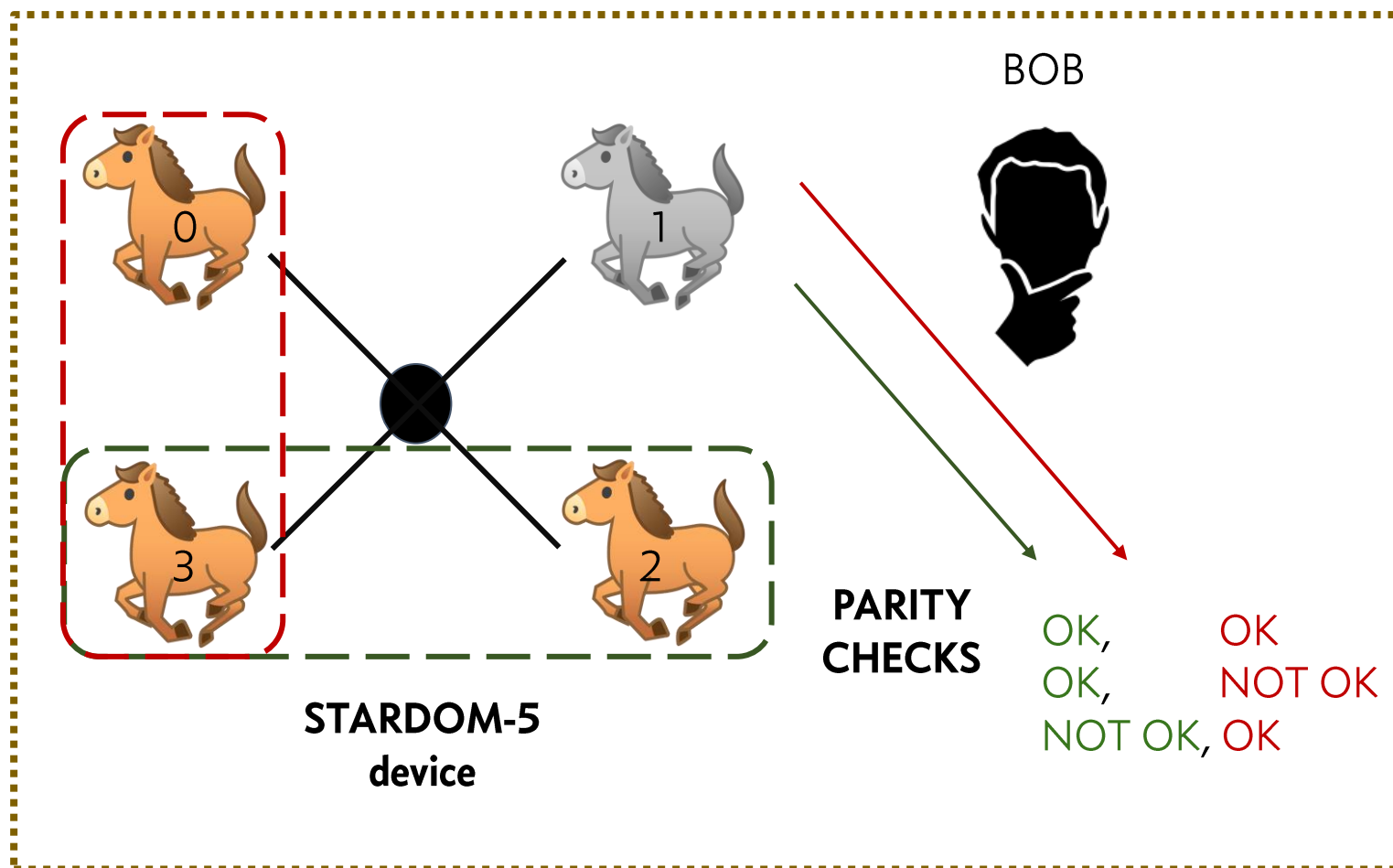


Decode  
OK, NOT OK  
sequence

# IDEA



Repeat n times, changing the horse occupancy configuration



**MACHINE  
LEARNING  
MODEL**

AGENT



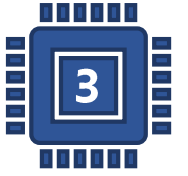
Decode  
OK, NOT OK  
sequence

**POSTPROCESSING**





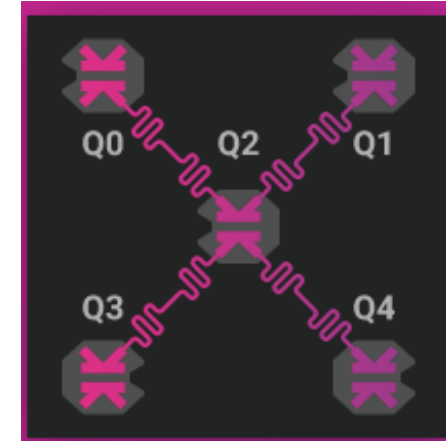
# NOISE MODEL OF STARMON-5: QISKIT DENSITY MATRIX SIMULATOR



We get inspiration from Starmon-5 real hardware to implement a noise model in Qiskit.

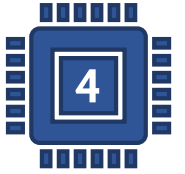
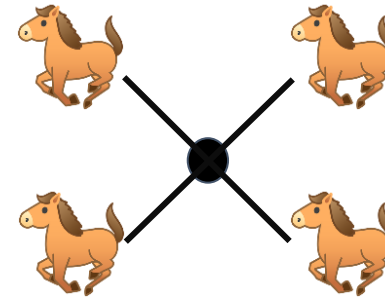
We take into account:

- Coupling map
- Basis set of gates: X, Y, Id, Rx, Ry, Rz, Cz
- Initialization error
- Thermal relaxation error
- Depolarizing error



|    | T1<br>( $\mu$ s) | T2e<br>( $\mu$ s) | F1q<br>(%) | F2q<br>(%) | Finit<br>(%) | FR/<br>O<br>(%) |
|----|------------------|-------------------|------------|------------|--------------|-----------------|
| Q0 | 12.5             | 22.1              | 99.9       | 97.6       | 99.6         | 92.3            |
| Q1 | 12.9             | 22.6              | 99.8       | 97.7       | 99.6         | 94.5            |
| Q2 | 20.4             | 21.7              | 99.8       | n.a.       | 99.0         | 96.8            |
| Q3 | 13.6             | 18.3              | 99.6       | 97.1       | 97.2         | 93.4            |
| Q4 | 13.4             | 19.8              | 99.9       | 97.5       | 90.8         | 96.0            |

# PREPARING THE CAROUSEL: STATE ENCODING



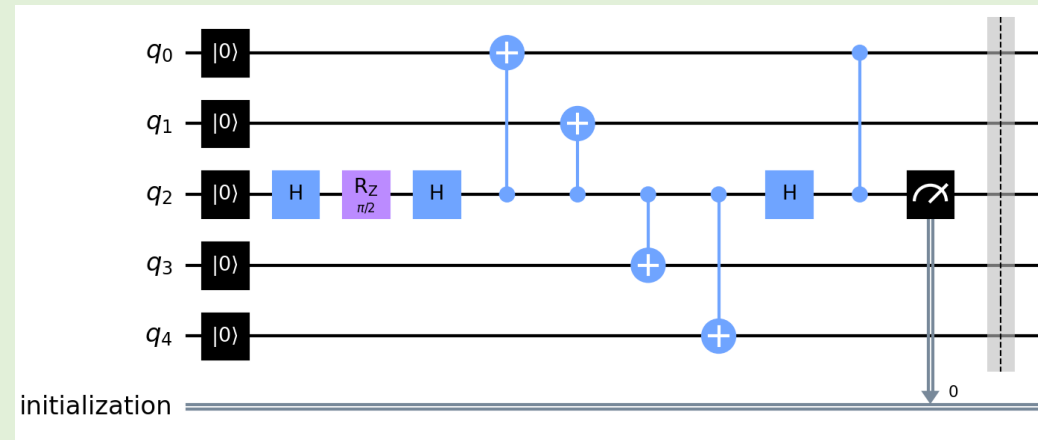
Encode a general state in the device using 4 physical qubits ( $q_0, q_1, q_3, q_4$ ).

## EXAMPLE

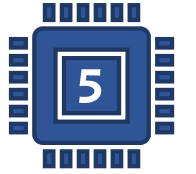
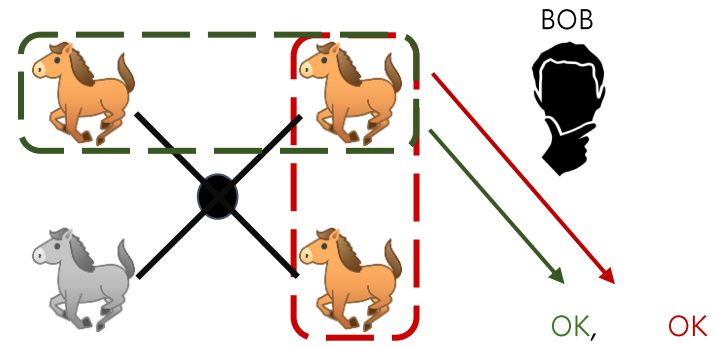
$$|\psi\rangle = \frac{1}{\sqrt{2}} [ |0\rangle - i |1\rangle ]$$



$$|\psi\rangle = \frac{1}{\sqrt{2}} [ |00s00\rangle - i |11s11\rangle ]$$

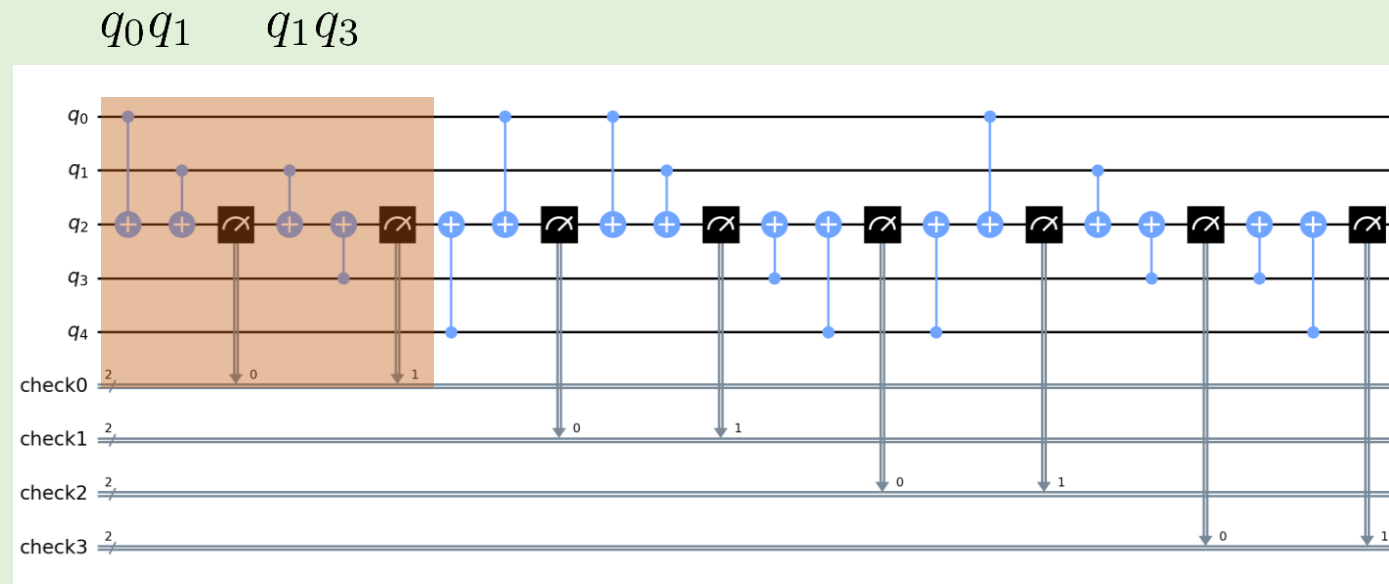


# LISTEN TO THE HORSES: THE PARITY CHECKS

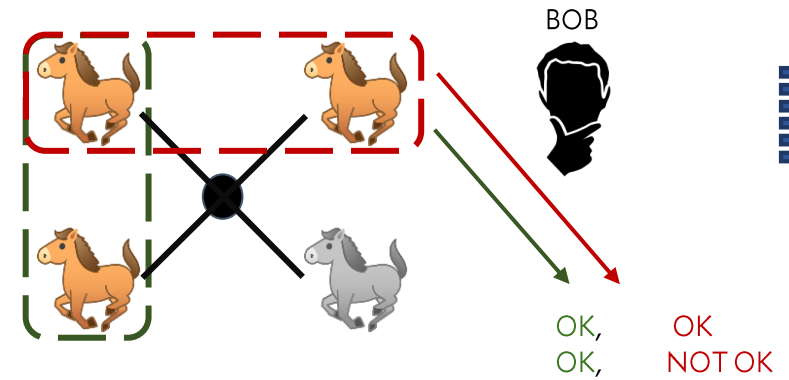


Measure parity of two couples of qubits ( $q_2$  is the ancilla qubit).

## EXAMPLE

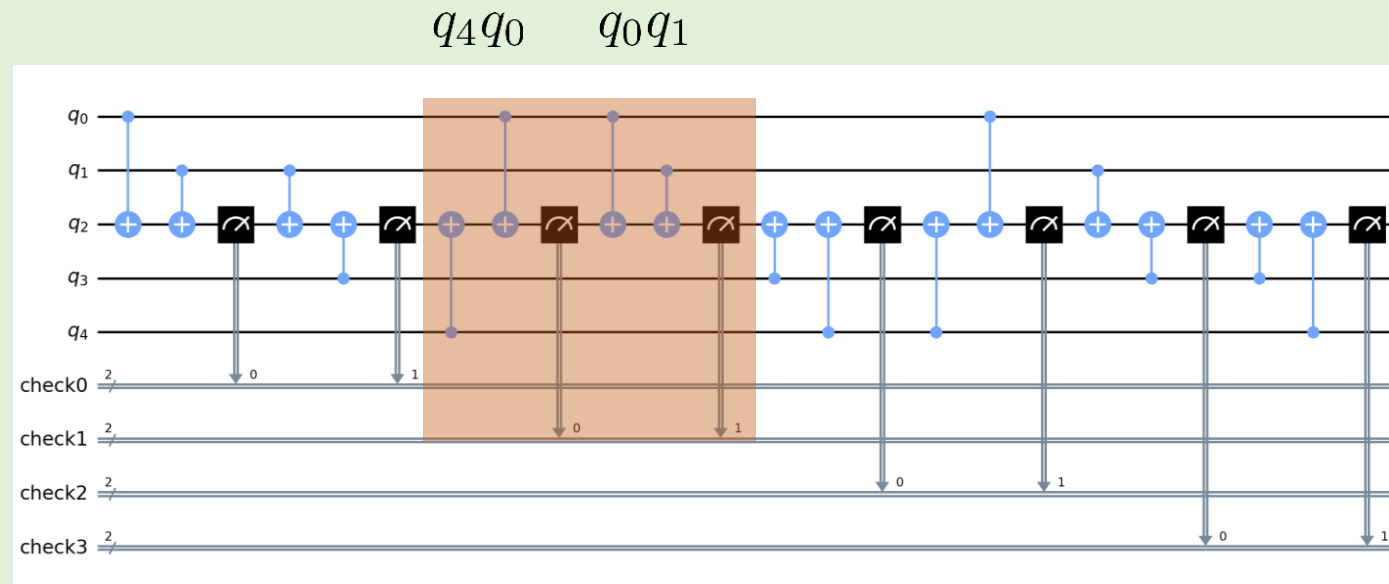


# LISTEN TO THE HORSES: THE PARITY CHECKS



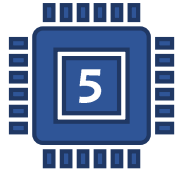
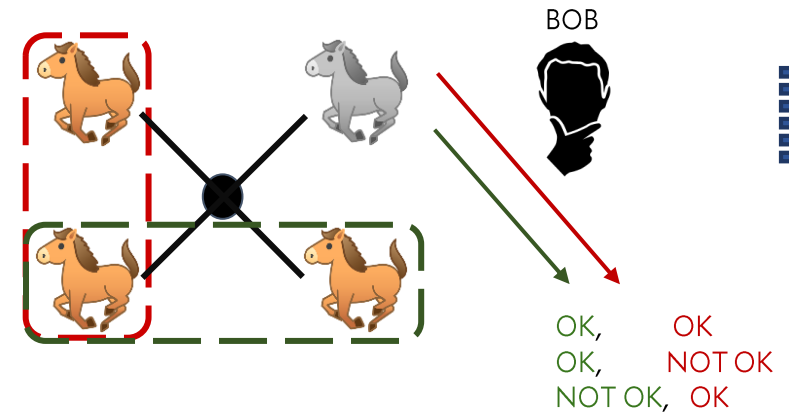
Measure parity of two couples of qubits ( $q_2$  is the ancilla qubit).

## EXAMPLE

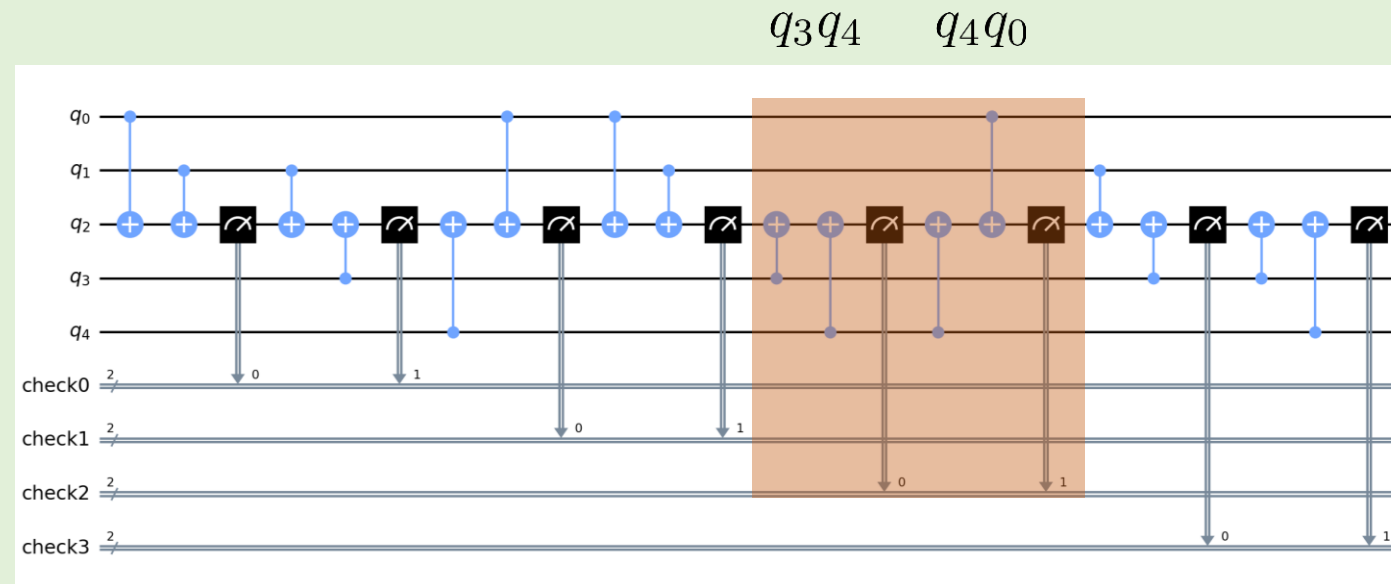


# LISTEN TO THE HORSES: THE PARITY CHECKS

Measure parity of two couples of qubits ( $q_2$  is the ancilla qubit).

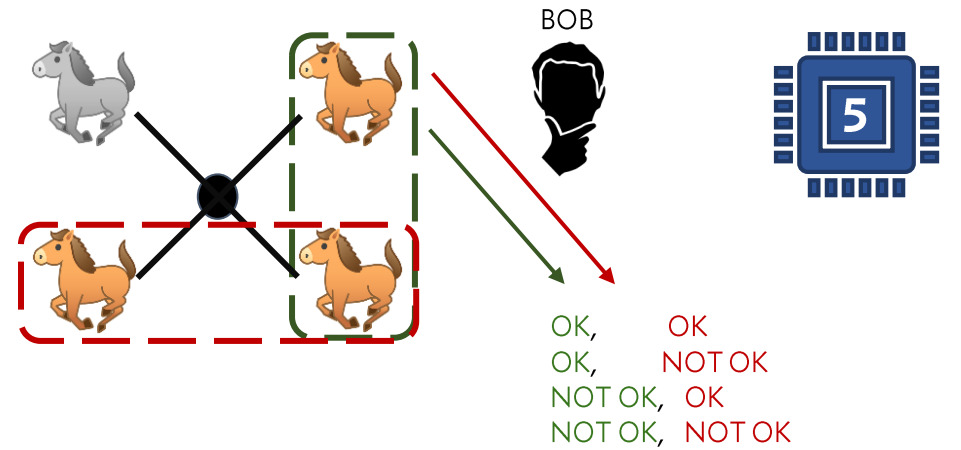


## EXAMPLE

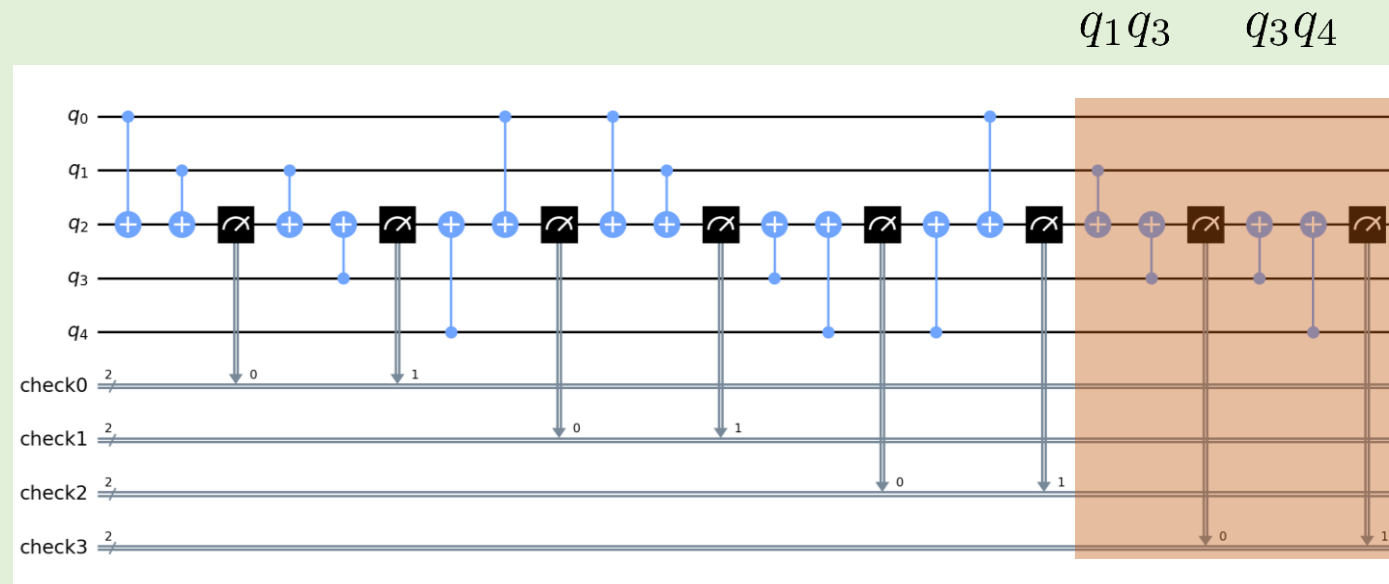


# LISTEN TO THE HORSES: THE PARITY CHECKS

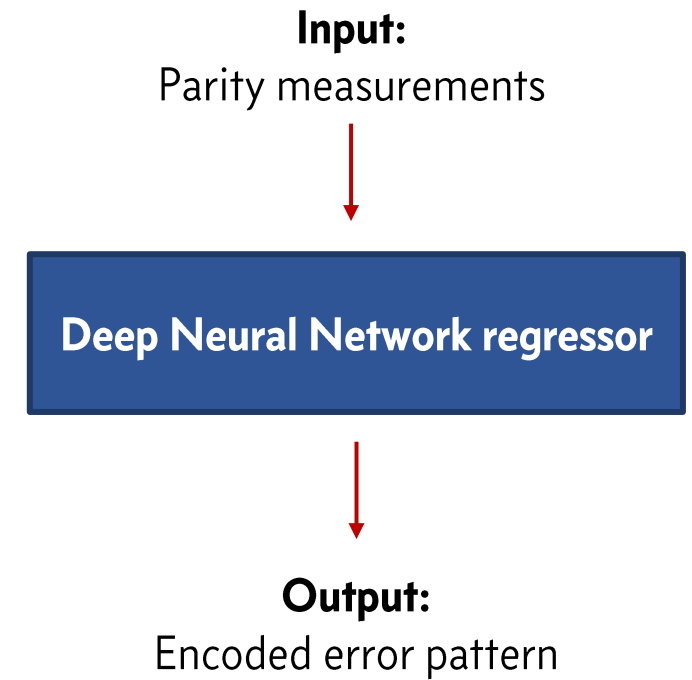
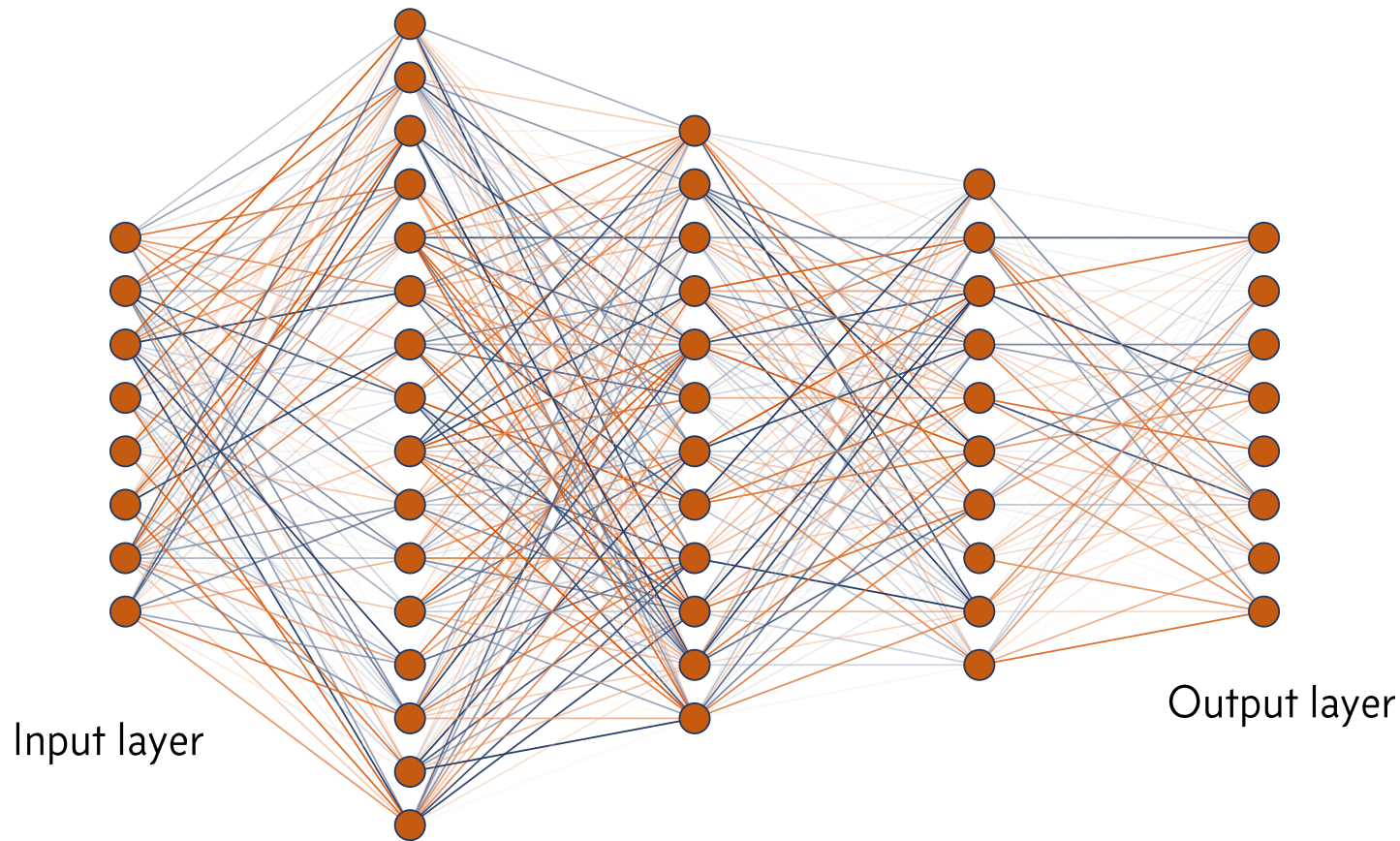
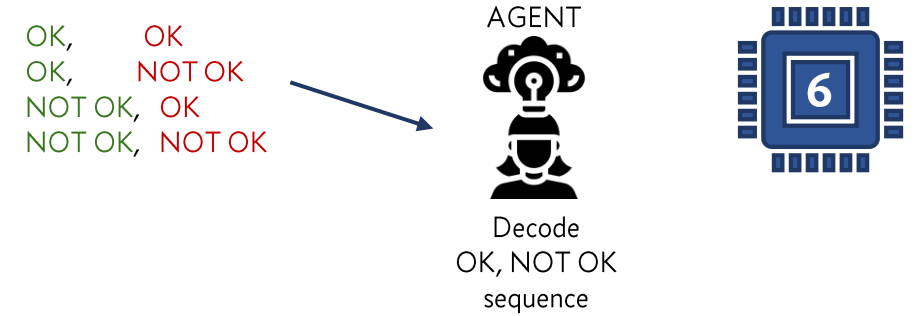
Measure parity of two couples of qubits (q2 is the ancilla qubit).



## EXAMPLE

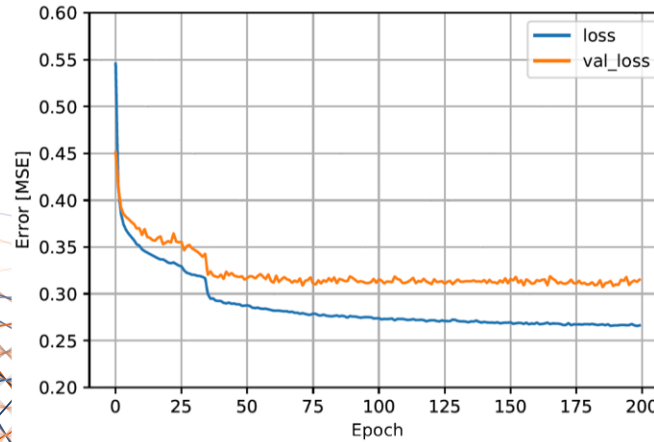
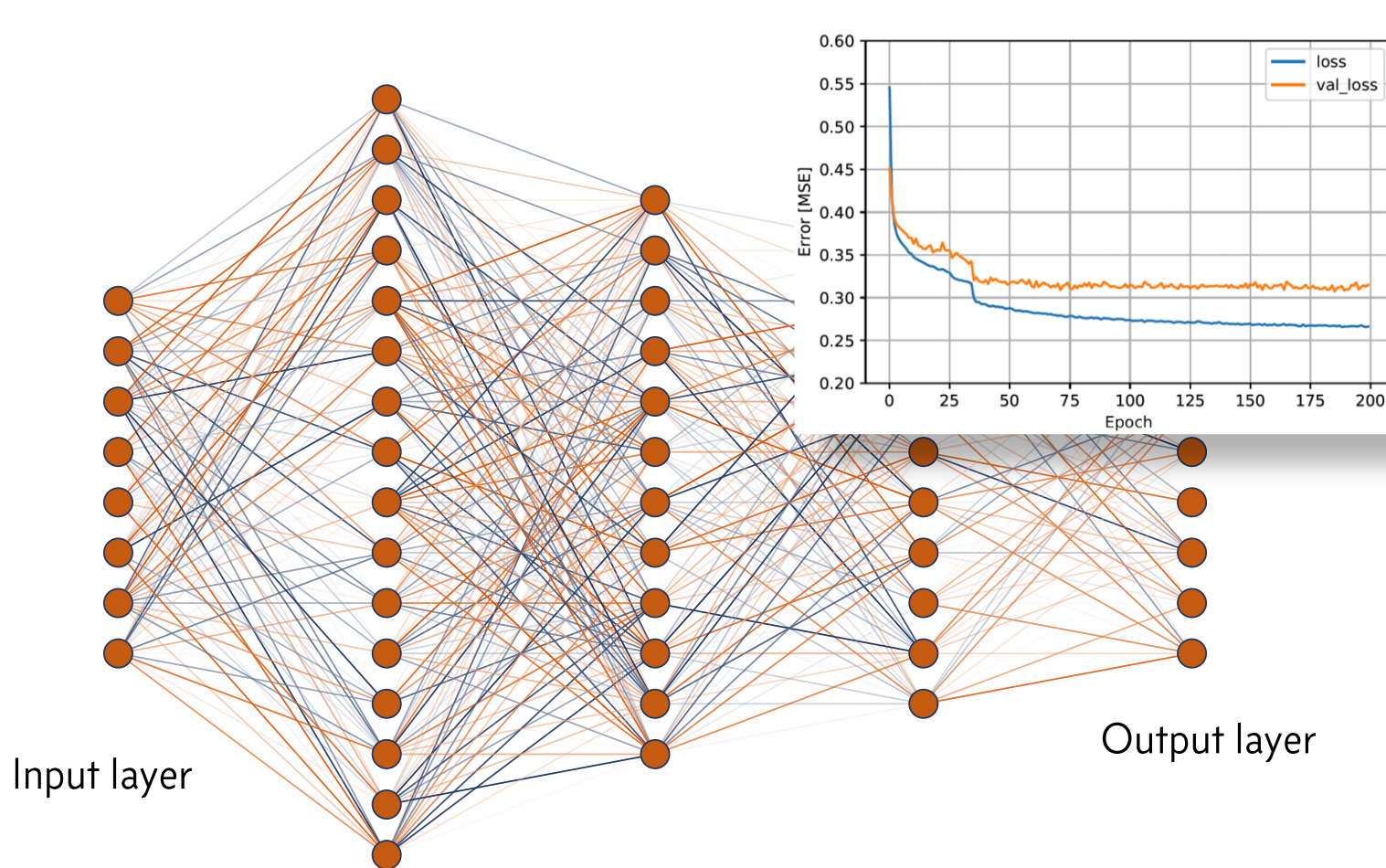
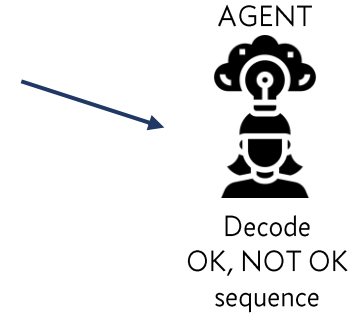


# DECODING THE SEQUENCE: MACHINE LEARNING AGENT



# DECODING THE SEQUENCE: MACHINE LEARNING AGENT

OK, OK, NOT OK, NOT OK,  
OK, NOT OK, NOT OK



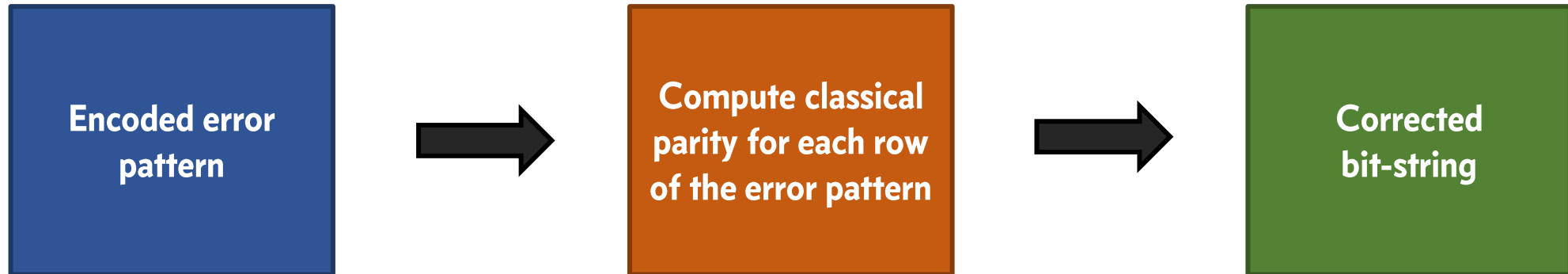
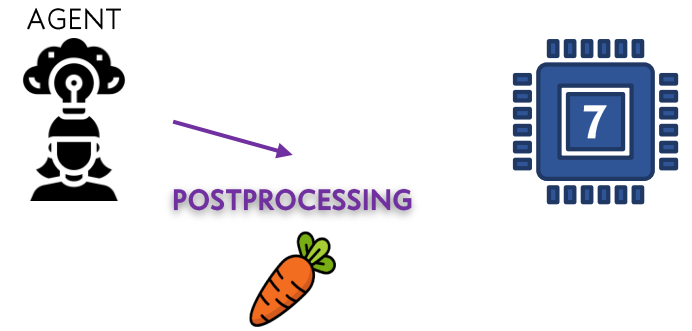
**Input:**  
Parity measurements

**Deep Neural Network regressor**

**Output:**  
Encoded error pattern



# CORRECT NUMBER OF CARROTS: CLASSICAL POSTPROCESSING



Classical parity:

$$\mathcal{P}(\vec{x}) = \left( \sum_i x_i \right) \% 2$$

$$\vec{x} = x_0 x_1 \dots x_n$$

## EXAMPLE

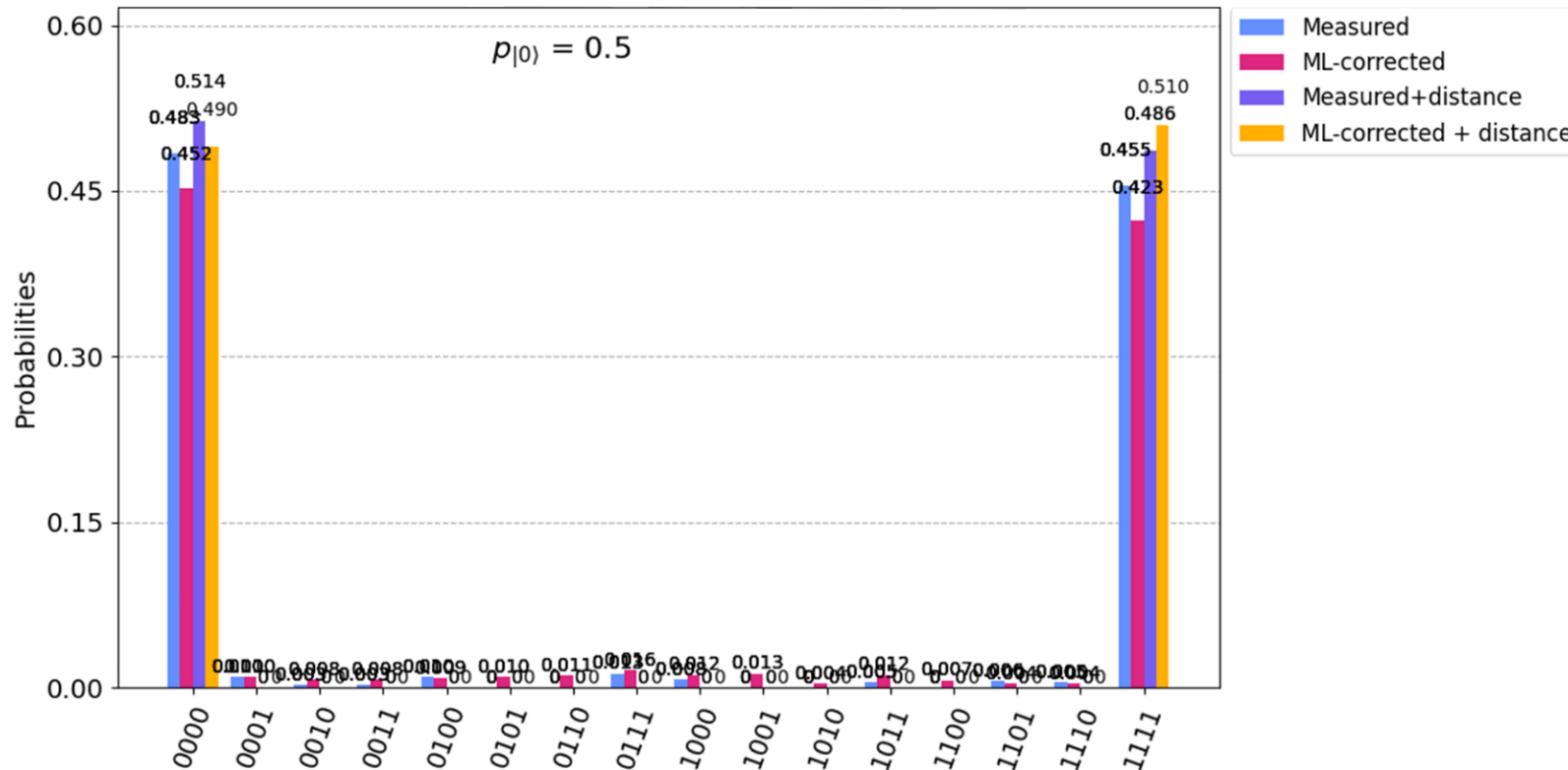
If column 0 has  $\mathcal{P} = 1$ ,  
flip the value of q0.

# CORRECT NUMBER OF CARROTS: CLASSICAL POSTPROCESSING

AGENT



POSTPROCESSING



Corrected  
bit-string

## EXAMPLE

If column 0 has  $\mathcal{P} = 1$ ,  
flip the value of  $q_0$ .

# CONCLUSIONS

- Qiskit noise model for Starmon-5
- 4-qubit stabilizer code implementation
- Machine learning approach to error correction
- Free ticket for a carousel ride!

