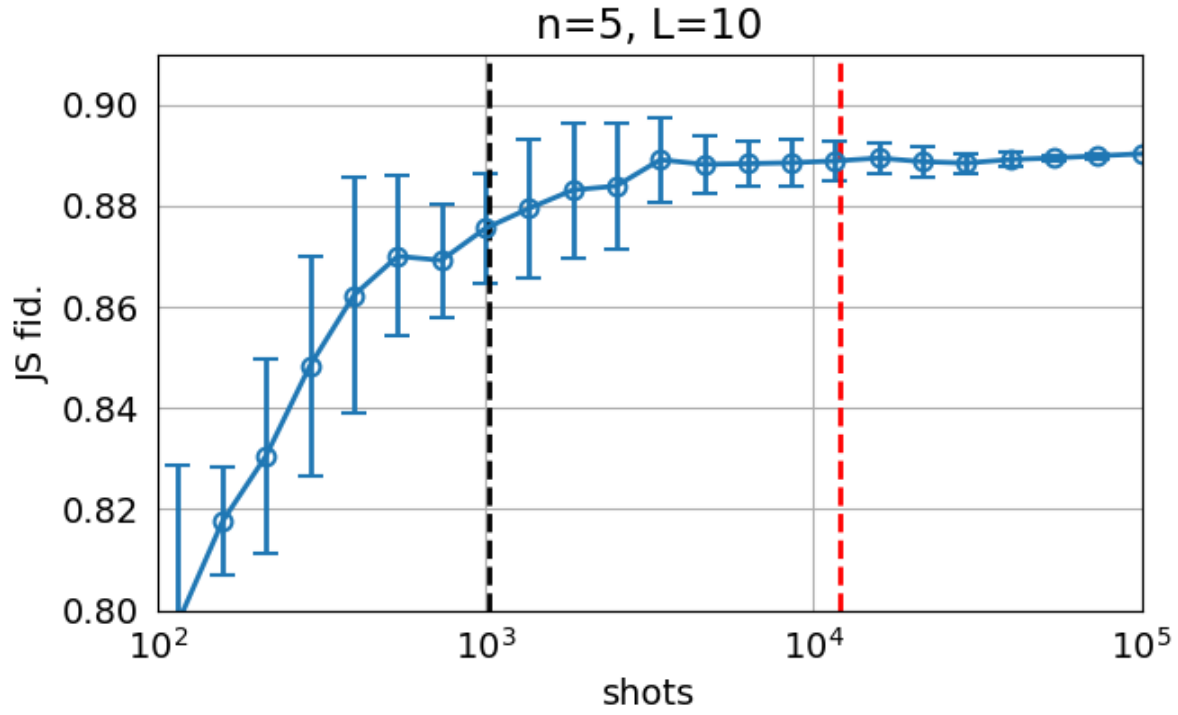
Convergence analysis of shots

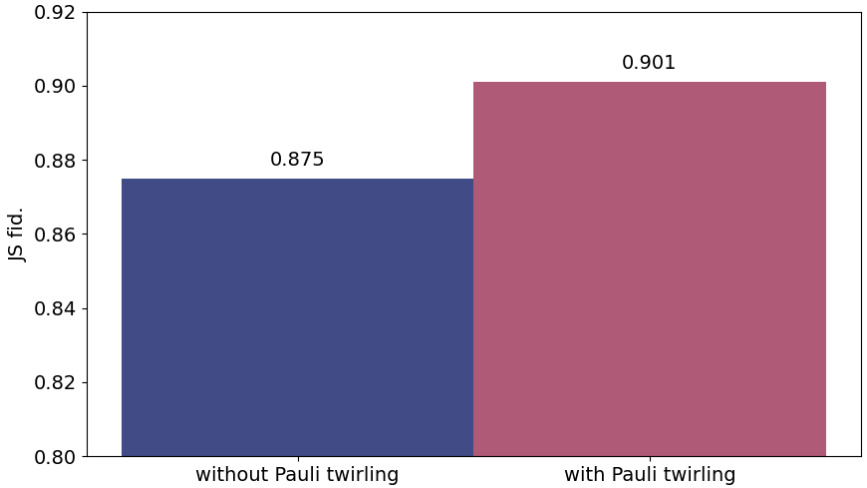
We find that the experimental results are not convergent with only 1024 shots. We increase the number of shots to 12,000 to get more reliable results.

As shown below, we plot the Jensen–Shannon fidelity (see Slide 3 for details) between simulation and experiment as a function of shots. 1024 shots (black dashed line) are obviously not convergent. In the new experiment, we use 12,000 shots (red dashed line) to get better experimental results. These 12,000 shots are divided into 6 groups, and each group corresponds to a realization of random Pauli gates for tailoring the non-stochastic noises (see Slide 2 for more details).

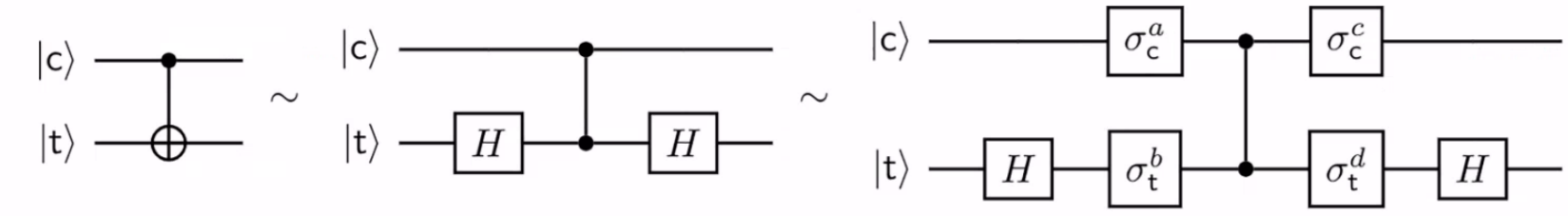


Pauli twirling

We decompose CNOT gates into CZ gates and utilize the twirled CZ gates to improve the results [Phys. Rev. A **94**, 052325 (2016)]. This is possible because there are non-stochastic errors in the circuits, which can be converted into stochastic Pauli errors using some random Pauli gates [Phys. Rev. X **7**, 021050 (2017)]. The effects of Pauli twirling are displayed in the figure below.



More specifically, as depicted below, we can randomly insert four Pauli gates $\{I, X, Y, Z\}$ in front of and behind the CZ gate without changing the unitary. There are 14 combinations of $\sigma_i^j \in \{I, X, Y, Z\}$ that can realize $\sigma_c^c \otimes \sigma_t^d \cdot \mathrm{CZ} \cdot \sigma_c^a \otimes \sigma_t^b = \mathrm{CZ}$. In our experiments, for each CZ gate in the circuit, we randomly choose a combination from them to twirl it. We sampled 6 twirled circuits and measured each of them with 2000 shots.



Appendix: Jensen–Shannon divergence

We use Jensen–Shannon divergence to quantify the similarity between the simulation results and the experimental results.

The fidelity of a circuit is defined as

F = 1 - scipy.spatial.distance.jensenshannon (probs_a, probs_b).

scipy.spatial.distance.jensenshannon computes the Jensen-Shannon distance between two probability arrays. It is the square root of the Jensen-Shannon divergence $\mathrm{JSD}(P||Q)$, where

$$\mathrm{JSD}(P||Q) = \frac{1}{2}\sum_i p_i \log\left(\frac{2p_i}{p_i+q_i}\right) + \frac{1}{2}\sum_i q_i \log\left(\frac{2q_i}{p_i+q_i}\right)$$