

Testing dimension by a null witness

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Abstract

Certified qubits are critical for reliable quantum error correction. A diagnostic test of the qubit dimension should be robust against nonideal quantum operations. We developed a dimension witness, a function of measurement probability matrix, which is zero up to statistical error if the tested system is of expected dimension. The witness is tailored to important cases: simple parametric rotation [1]; single qubit and random operations [2,3]; single qubit and a sequence of identical gates [4]; single multi-outcome measurement [5]; entangled qubits [6]. We applied of the test to various IBM Quantum qubits. Collecting large statistics, we conclude that most cases pass the test, which is robust against decoherence and incoherent leakage. However, some cases show failure, Figs. 1,2, with the nonzero witness beyond 5 standard deviations. Our method is therefore a very accurate diagnostic tool to check the extra dimension, invisible for superficial benchmarking. The failures have no simple and consistent causes and need urgent technical or fundamental explanations.

References

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- [3] T. Białeccki, T. Rybotycki, J. Batle, J. Tworzydło, A. Bednorz, arXiv:2301.03296
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- [6] J. Batle, T. Białeccki, T. Rybotycki, J. Tworzydło, A. Bednorz, arXiv:2312.13996

Figures

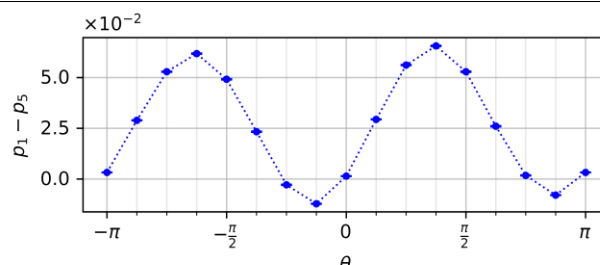


Figure 1: Failure of the rotation test on IBM lagos qubit 0. The difference between probabilities for 1 and 5 gates at the angle θ is not zero [1]

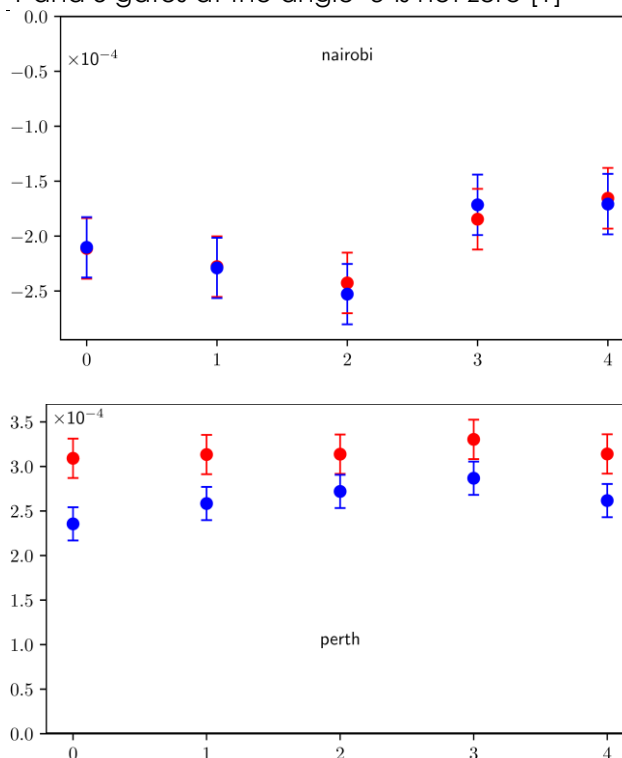


Figure 2: Failure of the parametric random operation test of the qubit dimension on IBM qubits (nairobi 0 and perth 0) [3], with the witness calculated from averaged probabilities (blue) and averaged over individual runs (red)

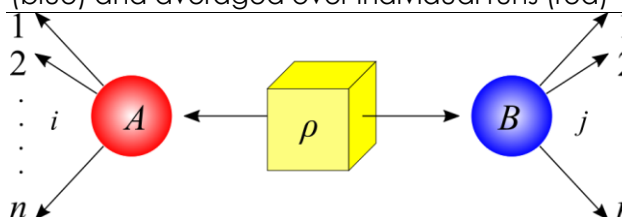


Figure 3: Test of dimension of entangled qubits with n measurements at each party [6]