Dear authors,

Thank you very much for submitting this paper to SciPost. I gave my best to faithfully assess the quality of this paper and hopefully help to improve it with my comments.

This paper studies the fidelity decay in random quantum circuits with focus on swap operations. The considered model interleaves layers of 2-qubit gates with arbitrary permutations. The authors analyze the effect of faulty 2-qubit gates and faulty permutations, implemented through combinations of malfunctioning swap gates. For the ease of the analysis, this model is surrogated with a *solvable* model in which the permutations are substituted with $\Pi \rightarrow R\Pi R$, for R being global unitaries sampled from the Haar-random distribution.

The paper is well explained and written, and it follows a logical line of thought of creating an easyly manageable model to deal with a complicated real scenario. The results are as one could expect from error accumulation in quantum computing: the errors will decay exponentially with the quantum volumen, i. e., LT, implying that errors will take over the computation unless the error rate decays at least at that pace.

I have two main concerns. First, it would be very interesting to have an interpretations on why the solvable model yields accurate results for the original model. From a information-theoretic point of view, one could think that the random gates R scramble the 2-qubit gates and erase all information. Simple 2-qubit gates plus permutations have the same asymptotic effect, but the numerical results show agreement even for low T. In this sense, I miss some interpretation on why the solvable model works so well.

My second concern is about the utility and impact of this research. Precisely because the results are not surprising, I do not see any special novelty in this manuscript, which is not captured by other noise models, such as Pauli depolarization. I am no expert in the field and I do not have a complete overview of the literature. Hence, I would appreciate a section in which the authors clarify what is the relationship of this work with the existing literature in the field.

On the weaknesses side, I miss some clear statement of the motivation and prospects of this research. However, this is a personal opinion, and implementing changes in this direction should be taken only as a suggestion.

Other minor issues:

- In the title of Section 3 there is a typo: *Sovable*
- In Fig. 2, the choices of α seem arbitrary to me, I do not see any particular motivation for those values.
- I have my doubts that Quantum Volume is a well-established measure for complexity.

I hope this report helps to assess the quality of the paper and improve it before publication.

Sincerely,

The referee