

Quantum Circuit Wire Cutting: A Tutorial Introduction with Classical Reconstruction Methods

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Abstract: Quantum circuit cutting is an important technique that enables the execution of quantum circuits exceeding the native capabilities of current quantum hardware. By decomposing a large circuit into smaller sub-circuits, the method allows independent execution on devices with limited qubit resources, followed by classical reconstruction of the global output statistics. In this tutorial article, we present a pedagogical introduction to the wire-cutting approach to quantum circuit cutting. The underlying measurement-initialization framework is derived from the Pauli decomposition of quantum states, and the reconstruction procedure is explained step-by-step. A three-qubit example is used to demonstrate the full workflow, including circuit partitioning, sub-circuit execution, and classical recombination of measurement outcomes. Numerical simulations using Qiskit are provided to validate the reconstruction accuracy. This tutorial aims to provide an accessible entry point for researchers and students seeking to understand and implement circuit cutting techniques for near-term quantum computing.

Keywords: Quantum circuit cutting; wire cutting; quantum computing; NISQ devices; classical reconstruction; circuit partitioning; Qiskit simulation.

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1.0 Introduction

Quantum computations are typically represented using quantum circuits, in which

qubits are manipulated through sequences of quantum gates that implement unitary operations, while wires represent the flow of quantum information between these operations. Measurements performed at the end of the circuit convert quantum states into classical outcomes. This circuit model forms the standard framework for describing quantum algorithms and quantum information processing (Nielsen *et al.*, 2010). In principle, executing a quantum circuit requires access to a quantum processor with a sufficient number of high-quality qubits and reliable gate operations. Present-day quantum hardware commonly described as belonging to the noisy intermediate-scale quantum (NISQ) era—faces significant practical limitations (Preskill, 2018). These devices typically provide only a modest number of qubits, exhibit non-negligible gate and measurement errors, and suffer from decoherence that restricts the maximum depth of executable circuits.

To overcome these constraints, several strategies have been proposed to extend the capabilities of near-term quantum hardware. One particularly promising approach is *quantum circuit cutting*, a technique that enables the execution of circuits that exceed the native size or connectivity of a quantum device (Peng *et al.*, 2020 ; Coltler *et al.*, 2020). The fundamental idea behind circuit cutting is to decompose a large quantum circuit into multiple smaller fragments, or sub-circuits, that can be executed independently on available hardware. After running the sub-circuits, their measurement results are combined using classical post-processing to reconstruct the output statistics of the original circuit. In this way, circuit cutting effectively trades additional classical computation for reduced

quantum resource requirements. Among the various circuit cutting approaches that have been proposed, *wire cutting* is one of the most conceptually straightforward and widely studied methods (Mitarai *et al.*, 2021).

In wire cutting, a qubit connection between two regions of a circuit is severed, and the quantum communication across the cut is replaced by a combination of measurement and state preparation operations. The correlations that originally existed between the two parts of the circuit are then recovered through a classical reconstruction procedure based on operator decompositions (Cotler *et al.*, 2020). Because of its clear physical interpretation and relatively simple implementation, wire cutting provides an intuitive framework for understanding the broader family of circuit cutting techniques.

Recent research has explored several aspects of circuit cutting, including optimal circuit partitioning strategies, methods for reducing classical reconstruction overhead, and techniques for mitigating the effects of hardware noise (Tang *et al.*, 2021; Beverland *et al.*, 2022; Perlin *et al.*, 2022). Practical implementations have also been demonstrated on current quantum devices, and software frameworks have been developed to automate the identification of circuit cuts, execution of sub-circuits, and reconstruction of final result (Piveteau *et al.*, 2021; LaRose *et al.*, 2021; Aleksandrowicz *et al.*, 2019). These developments highlight the growing importance of circuit cutting as a tool for extending the capabilities of near-term quantum computers.

In this tutorial, we focus specifically on the *wire cutting approach with classical reconstruction methods*. Our goal is to provide a clear and pedagogical introduction to the fundamental principles underlying quantum circuit wire cutting. We present the theoretical foundations that make circuit cutting possible, describe the reconstruction procedure in a step-

by-step manner, and illustrate the method using a simple three-qubit circuit example. By emphasizing conceptual clarity and practical implementation, this tutorial aims to serve as an accessible guide for researchers and students interested in applying circuit cutting techniques in quantum computing workflows.

2.0 Fundamentals of Quantum Circuit Cutting

Quantum circuits provide a standard framework for implementing quantum algorithms, where qubits are manipulated through a sequence of quantum gates followed by measurement. In principle, executing a quantum algorithm requires a quantum processor with sufficient qubits and connectivity to accommodate the entire circuit. However, current noisy intermediate-scale quantum (NISQ) devices are limited in both the number of available qubits and the circuit depth that can be reliably executed (Preskill, 2018). These constraints pose a significant challenge for implementing large-scale quantum algorithms on present-day hardware.

Quantum circuit cutting has emerged as a promising technique for overcoming these hardware limitations. The central idea of circuit cutting is to partition a large quantum circuit into smaller fragments that can be executed independently on available quantum devices. Each fragment, or *sub-circuit*, is evaluated separately, and the results are combined through classical post-processing to reconstruct the output statistics of the original circuit (Peng *et al.*, 2020; Cotler *et al.*, 2020). The theoretical foundation of circuit cutting relies on expressing quantum states and operations in terms of operator bases. For single-qubit systems, the Pauli operators $\{I, X, Y, Z\}$ form a complete basis for describing arbitrary operators (Nielsen *et al.*, 2010). By inserting measurement and state preparation operations at the points where the circuit is partitioned, the correlations between different sub-circuits can be represented through linear combinations of



these Pauli operators.

Two main approaches to circuit cutting are commonly considered: *wire cutting and gate cutting*. In wire cutting, a qubit connection between two parts of a circuit is severed, and the resulting boundary is replaced by measurement and initialization operations. Gate cutting, on the other hand, decomposes multi-qubit gates that act across different circuit partitions (Beverland *et al.*, 2022; Mitarai *et al.*, 2021). In this tutorial we focus on wire cutting, which provides a clear and intuitive introduction to the general framework of circuit cutting. Fig. 1 shows the workflow of the quantum circuit cutting procedure.

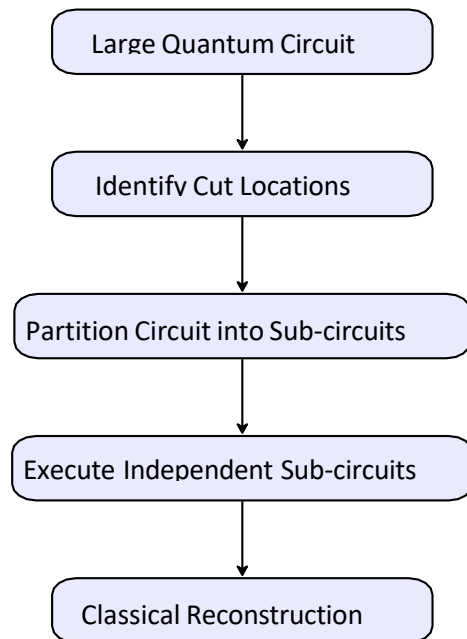


Fig. 1: Workflow of the quantum circuit cutting procedure. Source: Author's illustration based on Peng *et al.* (2020) and Cotler *et al.* (2020).

A large circuit is first analyzed to identify suitable cut locations, then partitioned into smaller sub-circuits that can be executed independently. The results are finally combined through classical reconstruction to recover the statistics of the original circuit.

3.0 Wire Cutting Method

Wire cutting involves partitioning a quantum circuit by severing a qubit wire that connects two regions of the circuit. After the cut, the original circuit is replaced by two independent sub-circuits. The upstream sub-circuit terminates with a measurement on the cut qubit, while the downstream sub-circuit begins with the preparation of a known quantum state. The key challenge is to ensure that the statistical correlations that existed between the two parts of the original circuit are preserved after the cut. This is achieved by expressing the quantum channel associated with the cut wire as a linear combination of Pauli operators. The measurement outcomes obtained from the first sub-circuit and the prepared states used in the second sub-circuit are then combined in a classical reconstruction procedure (Peng *et al.*, 2020; Cotler *et al.*, 2020; Beverland *et al.*, 2022).

Operationally, the wire cutting protocol consists of the following steps:

1. Identify a qubit wire in the circuit where the cut will be applied.
2. Partition the circuit into two smaller sub-circuits.
3. Replace the cut wire with measurement operations in the first sub-circuit.
4. Initialize the corresponding qubit in the second sub-circuit in specific basis states.
5. Execute the sub-circuits multiple times for different Pauli-basis configurations.
6. Combine the resulting measurement statistics through classical post-processing (Mitarai *et al.*, 2021; Piveteau *et al.*, 2021).

By repeating this process for all required Pauli configurations, it becomes possible to reconstruct the probability distribution or expectation values of the original circuit (Peng *et al.*, 2020).

As illustrated in Fig. 2, the wire cutting procedure partitions the original quantum circuit into two smaller sub-circuits by



severing the connection between circuit components.

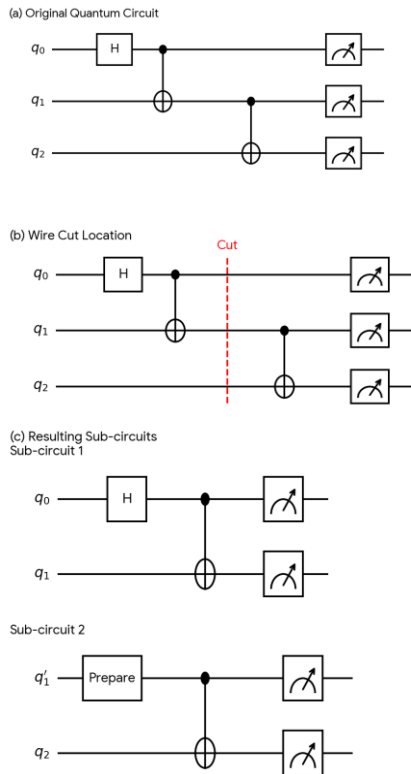


Fig. 2: Illustration of the wire-cutting procedure. (a) Original three-qubit circuit. (b) The location where the circuit is partitioned by cutting the wire. (c) The resulting sub-circuits that can be executed independently. The measurement and state preparation operations enable classical reconstruction of the original circuit results. Source: Author's illustration based on Peng et al. (2020), Cotler et al. (2020), and Beverland et al. (2022).

Measurements and state preparation operations are introduced at the cut location to enable classical reconstruction of the global circuit behavior (Peng et al., 2020; Cotler et al., 2020).

4.0 Mathematical Formulation of Circuit

Cutting

The fundamental idea behind circuit cutting is that the quantum state transmitted through a qubit wire can be expressed in terms of a complete operator basis. For a single qubit, the

Pauli operators $\{I, X, Y, Z\}$ form such a basis. Any single-qubit density matrix ρ can therefore be expanded in the Pauli basis as (Nielsen et al., 2010; Cotler et al., 2020)

$$\rho = \frac{1}{2} \sum_{i \in \{I, X, Y, Z\}} \text{Tr}(M_i \rho) M_i, \quad (1)$$

where ρ is the single-qubit density matrix, M_i denotes the Pauli operators $\{I, X, Y, Z\}$, and $\text{Tr}(\cdot)$ represents the trace operation. The coefficients $\text{Tr}(M_i \rho)$ correspond to expectation values obtained by measuring the qubit in the corresponding Pauli basis.

Eq. (1) provides the theoretical basis for cutting a qubit wire in a quantum circuit. When a wire is cut, the quantum communication between two parts of the circuit is replaced by a classical reconstruction procedure based on Pauli operator decomposition (Peng et al., 2020; Beverland et al., 2022). The first sub-circuit produces measurement results corresponding to $\text{Tr}(M_i \rho)$, while the second sub-circuit prepares the corresponding eigenstates.

The Pauli operators can be written in terms of their eigenstate decompositions as

$$I = |0\rangle\langle 0| + |1\rangle\langle 1|, \quad (2)$$

$$Z = |0\rangle\langle 0| - |1\rangle\langle 1|, \quad (3)$$

$$X = |+\rangle\langle +| - |-\rangle\langle -|, \quad (4)$$

$$Y = |i\rangle\langle i| - |-i\rangle\langle -i|, \quad (5)$$

where the eigenstates are defined as

$$|+\rangle = \frac{|0\rangle + |1\rangle}{\sqrt{2}}, \quad |-\rangle = \frac{|0\rangle - |1\rangle}{\sqrt{2}}$$

$$|i\rangle = \frac{|0\rangle + i|1\rangle}{\sqrt{2}}, \quad |-i\rangle = \frac{|0\rangle - i|1\rangle}{\sqrt{2}}$$

Using these decompositions, the reconstruction of the quantum state requires evaluating the expectation values of the four Pauli operators, which can be obtained by measuring the cut qubit in different Pauli bases in the first sub-circuit and preparing the corresponding eigenstates in the second sub-circuit (Peng et al., 2020; Cotler et al., 2020). Consequently, reconstructing the behavior of the original circuit requires executing multiple measurement-preparation configurations. For



a circuit containing u wire cuts, the number of required configurations grows as

$$N_{\text{config}} = 4^u. \quad (6)$$

This exponential scaling represents one of the main practical limitations of circuit cutting. As the number of cuts increases, the amount of classical post-processing and the number of required circuit evaluations also increase significantly. Therefore, minimizing the number of cuts is an important optimization problem in practical implementations of circuit cutting (Beverland *et al.*, 2022; Perlin *et al.*, 2022).

5.0 Classical Reconstruction Procedure

The measurement outcomes of the two subcircuits can be classically recombined to obtain the same outcome as if the original circuit was executed on quantum hardware. Using the Pauli basis expansion, the expectation value of an observable in the original circuit can be reconstructed from sub-circuit measurements according to (Peng *et al.*, 2020; Cotler *et al.*, 2020)

$$\langle R \rangle = \frac{1}{2} \sum_{i \in \{I, X, Y, Z\}} \langle R_{1,i} \rangle \langle R_{2,i} \rangle, \quad (7)$$

Where $\langle R_{1,i} \rangle$ represents the expectation value obtained from the first sub-circuit when the cut qubit is measured in the Pauli basis corresponding to operator i , and $\langle R_{2,i} \rangle$ represents the expectation value obtained from the second sub-circuit when the qubit is initialized in the corresponding eigenstate.

This decomposition effectively replaces direct quantum communication between the two sub-circuits with a classical summation over Pauli configurations. As a result, the global expectation value can be reconstructed from independently executed circuit fragments.

For circuits containing multiple cuts, the reconstruction formula generalizes to a sum over all combinations of Pauli operators associated with each cut (Beverland *et al.*, 2022). While this enables the simulation of larger circuits, the number of required circuit evaluations increases exponentially with the

number of cuts. For practical numerical simulation, we introduce the probability based reconstruction equation by rewriting Eq. (7) in terms of measurement probabilities.

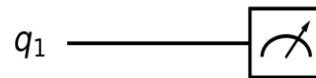
Let $p_i^{(1)}$ denote the probability obtained from the first sub-circuit when the measurement basis corresponds to Pauli operator i , and let $p_i^{(2)}$ denote the corresponding probability obtained from the second sub-circuit under the appropriate initialization. The reconstructed probability of a particular output state can then be written as

$$\langle p \rangle = \frac{1}{2} \sum_{i \in \{I, X, Y, Z\}} p_i^{(1)} p_i^{(2)}, \quad (8)$$

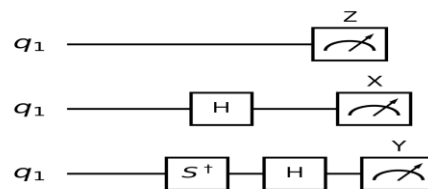
This classical post-processing step combines independently measured statistics from the circuit fragments to approximate the probability distribution of the original circuit (Peng *et al.*, 2020; Cotler *et al.*, 2020).

The classical reconstruction procedure relies on Pauli operator decomposition at the cut location. As illustrated in Fig. 3, the qubit in the first sub-circuit is measured in different Pauli bases, while the second sub-circuit begins with corresponding state preparatio operations. The measurement outcomes obtained

(a) Measurement at the Cut



(b) Pauli-Basis Measurements



(c) State Preparation for Sub-Circuit 2



(c) State Preparation for Sub-circuit 2

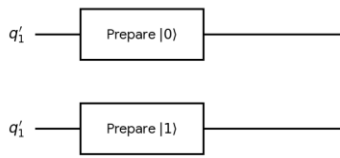


Fig3: Measurement-initialization framework used in classical reconstruction. At the cut location, the qubit in the first sub-circuit is measured in different Pauli bases (X, Y, Z). The second sub-circuit begins with corresponding state preparation. These measurement and preparation operations allow correlations across the cut to be reconstructed using Pauli operator decomposition. Author's illustration based on Peng et al. (2020), Cotler et al. (2020), and Beverland et al. (2022).

From these configurations are then combined using the reconstruction formula to recover the Statistics of the original circuit (Peng et al., 2020; Beverland et al., 2022).

In practical implementations, this reconstruction can be performed using programming languages such as Python in conjunction with quantum software toolkits such as Qiskit (Aleksandrowicz et al., 2019). Numerical simulations are often used to verify that the reconstructed probabilities match those obtained from executing the full circuit without cutting.

6.0 Example: Three-Qubit Circuit

To illustrate the circuit cutting procedure, consider a simple three-qubit circuit consisting of a Hadamard gate applied to the first qubit, followed by controlled-NOT (CNOT) gates that entangle the first and second qubits as well as the second and third qubits. Suppose that the circuit must be executed on hardware that can only support two qubits (Peng et al., 2020; Cotler et al., 2020; Beverland et al., 2022).

A wire cut can be introduced between the second and third qubits, partitioning the circuit into two smaller sub-circuits. The first sub-circuit contains the operations acting on the first two qubits and terminates with a

measurement on the cut wire. The second sub-circuit begins by initializing the corresponding qubit and then applies the remaining gates before performing the final measurement. Each sub-circuit is executed multiple times using different measurement and initialization settings corresponding to the Pauli operators I, X, Y , and Z . The measurement outcomes obtained from these runs provide the statistical data required for the classical reconstruction procedure (Peng et al., 2020; Beverland et al., 2022).

This simple example in Fig. 4 and Fig. 5 demonstrates how circuit cutting enables the evaluation of circuits that would otherwise exceed the qubit capacity of the available Quantum hardware

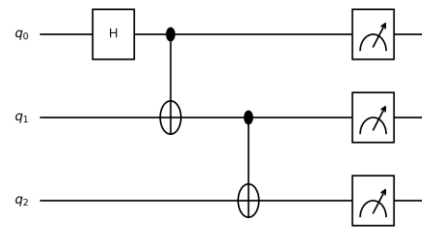


Fig. 4: Example of a three-qubit quantum circuit used to illustrate circuit cutting. The circuit contains entangling CNOT gates and measurements on all qubits (Peng et al., 2020; Cotler et al., 2020). Author's illustration based on Peng et al. (2020) and Cotler et al. (2020).

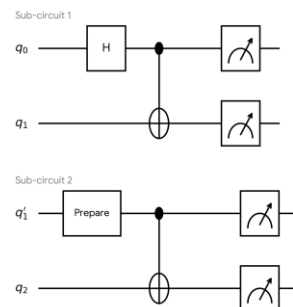


Fig. 5: Illustration of wire cutting. The original circuit is divided into two smaller sub-circuits. The first sub-circuit ends with a measurement on the cut wire, while the



second sub-circuit begins with the preparation of a corresponding quantum state. The measurement and preparation outcomes are later combined using the Pauli-based reconstruction procedure (Peng *et al.*, 2020; Beverland *et al.*, 2022). Source: Author's illustration based on Peng *et al.* (2020) and Beverland *et al.* (2022).

7.0 Numerical Simulation Using Qiskit

To verify the correctness of the classical reconstruction procedure, numerical simulations can be performed using a quantum computing framework such as Qiskit (Aleksandrowicz *et al.*, 2019; IBM, 2023). In this tutorial example, we consider the three-qubit circuit introduced earlier and compare the measurement probabilities obtained from the full circuit with those reconstructed from the cut sub-circuits.

The simulation workflow consists of the following steps:

1. Construct the original three-qubit quantum circuit.
2. Execute the circuit using a quantum simulator to obtain the exact output probabilities.
3. Partition the circuit using the wire cutting procedure (Peng *et al.*, 2020; Cotler *et al.*, 2020).
4. Execute each sub-circuit independently.
5. Apply the classical reconstruction formula to combine the measurement outcomes (Beverland *et al.*, 2022).
6. Compare the reconstructed results with the original circuit output.

The following Python code demonstrates how the full circuit can be simulated using Qiskit.

```
from qiskit import QuantumCircuit from
qiskit_aer import AerSimulator
from qiskit import transpile
# Create a 3-qubit circuit qc =
```

```
QuantumCircuit(3,3)
qc.h(0)
qc.cx(0,1)
qc.cx(1,2)
qc.measure([0,1,2],[0,1,2])
#Simulate the circuit
simulator=AerSimulator()
compiled_circuit=transpile(qc, simulator)
result=simulator.run(compiled_circuit,
shots=1010).result()
counts = result.get_counts()
print(counts)
```

The same procedure can then be applied to the individual sub-circuits obtained after cutting the wire between two qubits. The measurement outcomes from the sub-circuits are combined using the classical reconstruction formula described in the previous section (Peng *et al.*, 2020; Beverland *et al.*, 2022).

Table 1 shows a representative comparison between the measurement probabilities obtained from the full circuit simulation and those reconstructed from the cut circuits.

Table 1: Comparison of measurement probabilities obtained from the full circuit and the reconstructed results from circuit cutting. Source: Authors' Qiskit simulation results.

Measurement Outcome	Full Circuit Probability	Reconstructed Probability
000	0.50	0.49
001	0.00	0.01
010	0.00	0.00
011	0.00	0.00
100	0.00	0.00
101	0.00	0.00
110	0.00	0.00
111	0.50	0.50

The results demonstrate that the reconstructed probabilities closely match those obtained from executing the full circuit. Minor



discrepancies may arise due to finite sampling noise in the simulator. This example illustrates how quantum circuit wire cutting can reproduce the behavior of the original circuit while allowing computations to be performed on smaller sub-circuits. To further illustrate

the agreement between the two approaches, Fig. 6 presents a graphical comparison of the probability distributions obtained from the full circuit simulation and the reconstructed results from circuit cutting (Peng *et al.*, 2020; Cotler *et al.*, 2020).

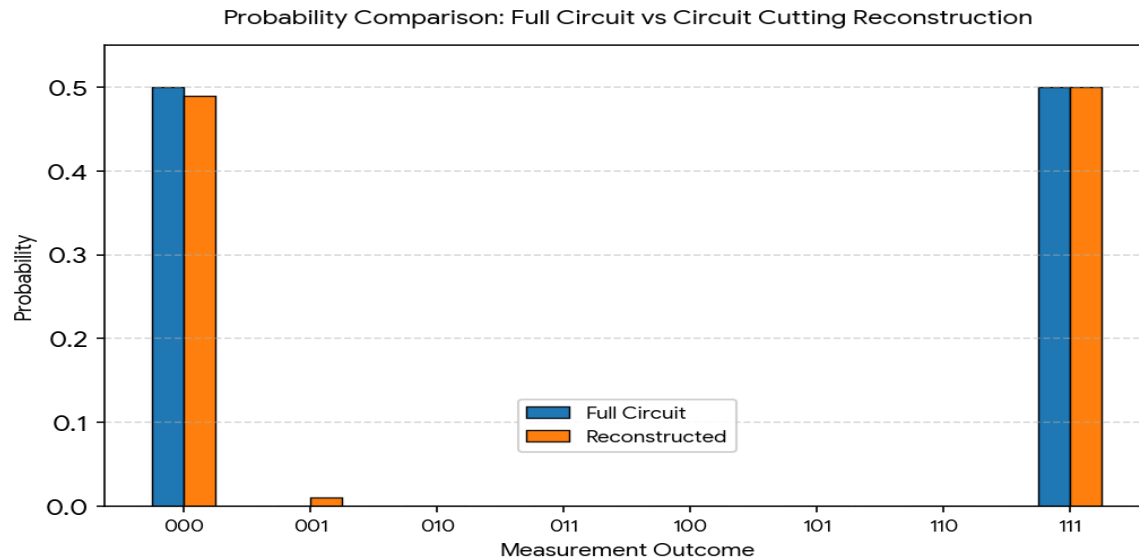


Figure 6: Comparison between measurement probabilities obtained from the full circuit and the reconstructed results from circuit cutting.

Fig. 6: Comparison between measurement probabilities obtained from the full circuit and the reconstructed results from circuit cutting. Source: Authors' Qiskit simulation results.

8.0 Challenges and Limitations of Circuit Cutting

Although quantum circuit cutting provides a powerful strategy for extending the capabilities of near-term quantum hardware, the technique also introduces several practical challenges and limitations (Cotler *et al.*, 2020; Peng *et al.*, 2020; Beverland *et al.*, 2022). Understanding these issues is essential when applying circuit cutting methods in real quantum computing workflows.

One of the primary challenges is the *classical computational overhead* associated with the reconstruction procedure. When a circuit is partitioned at one or more locations, the quantum correlations between the resulting sub-circuits must be reconstructed using a linear combination of measurement outcomes obtained from different Pauli-basis configurations (Peng *et al.*, 2020). As the

number of cuts increases, the number of required measurement settings grows rapidly. In many implementations, the classical reconstruction cost scales exponentially with the number of cuts, which can significantly increase both the computational time and the amount of data required for accurate reconstruction.

Another important limitation arises from *sampling noise*. Each sub-circuit must be executed multiple times in order to estimate measurement probabilities or expectation values. Because these estimates are obtained from a finite number of measurement shots, statistical fluctuations may lead to inaccuracies in the reconstructed results (Beverland *et al.*, 2022; Cotler *et al.*, 2020). When many measurement configurations are required, these statistical errors can accumulate, potentially reducing the overall



fidelity of the reconstructed output distribution.

The *selection of optimal cut locations* also presents a nontrivial challenge. Ideally, a circuit should be partitioned in a way that minimizes the number of required cuts while preserving the structure of the computation. Poorly chosen cuts can lead to an excessive number of reconstruction terms or create sub-circuits that remain too large to execute efficiently on the target hardware (Peng *et al.*, 2020). Consequently, determining optimal partitioning strategies is an active area of research in the field of quantum circuit cutting.

In addition, circuit cutting introduces a trade-off between *quantum and classical resources*. While the method reduces the number of qubits required to execute individual sub-circuits, it increases the amount of classical processing needed to reconstruct the global result (Cotler *et al.*, 2020; Beverland *et al.*, 2022). For large circuits or circuits with many cuts, the classical processing requirements may become substantial. This trade-off must be carefully considered when deciding whether circuit cutting is advantageous for a given quantum computation.

Finally, practical implementations must also account for *hardware noise*. Although circuit cutting can reduce circuit depth and thereby mitigate certain noise sources, executing multiple sub-circuits and combining their results may still amplify errors arising from imperfect gates and measurements (Peng *et al.*, 2020). Consequently, additional error mitigation techniques may be required to obtain reliable results on real quantum devices.

Despite these challenges, circuit cutting remains a valuable tool for enabling larger quantum computations on limited hardware. Ongoing research continues to explore improved reconstruction algorithms, automated circuit partitioning methods, and

hybrid quantum–classical techniques that reduce the overhead associated with circuit cutting (Cotler *et al.*, 2020; Beverland *et al.*, 2022). These developments are expected to play an important role in extending the practical capabilities of near-term quantum computing systems.

9.0 Applications of Circuit Cutting

Quantum circuit cutting has become an important technique for extending the practical capabilities of near-term quantum computers. By enabling the execution of quantum circuits that exceed the native size and connectivity constraints of available hardware, circuit cutting provides a flexible framework for exploring larger quantum algorithms using existing devices. As a result, the method has found applications in several areas of quantum computing research. One major application of circuit cutting is in *distributed quantum computing* (Nickerson *et al.*, 2014). In this paradigm, a large quantum computation is divided across multiple smaller quantum processors that operate independently. Circuit cutting allows a large circuit to be partitioned into fragments that can be executed on separate devices, while classical communication is used to reconstruct the global result. This approach is conceptually similar to distributed computation in classical computing systems and may play an important role in the development of modular and networked quantum architectures.

Circuit cutting is also useful for *executing large quantum circuits on limited hardware* (Cotler *et al.*, 2020; Peng *et al.*, 2020). Many quantum algorithms require more qubits than are currently available on most quantum processors. By partitioning a large circuit into smaller fragments, circuit cutting allows researchers to simulate or experimentally test portions of these algorithms without requiring a full-scale quantum computer. This capability is particularly valuable for algorithm prototyping and benchmarking on current



noisy intermediate-scale quantum (NISQ) devices.

Another important application is in *quantum circuit simulation* (Beverland *et al.*, 2022). Classical simulation of large quantum circuits is generally computationally expensive due to the exponential growth of the quantum state space. Circuit cutting techniques can reduce the simulation complexity by dividing a large circuit into smaller fragments that can be simulated independently. The results from these simulations can then be combined through classical reconstruction methods, allowing larger circuits to be studied using classical computing resources. Circuit cutting has also been explored as a tool for *error mitigation* (Peng *et al.*, 2020; Beverland *et al.*, 2022). Because cutting reduces the depth and complexity of individual sub-circuits, it can help limit the accumulation of hardware errors that occur during long quantum computations. In some scenarios, executing multiple shorter sub-circuits and reconstructing the final result can produce more reliable outcomes than running a single deep circuit on noisy hardware.

Finally, circuit cutting plays an important role in the development of *hybrid quantum-classical work-flows* (Cotler *et al.*, 2020; Nickerson *et al.*, 2014). Many modern quantum algorithms rely on a combination of quantum circuit execution and classical post-processing. Circuit cutting naturally fits within this paradigm, as it shifts part of the computational workload from quantum hardware to classical processing. This hybrid approach enables more flexible resource allocation and may help bridge the gap between current hardware capabilities and the requirements of larger quantum algorithms.

These applications highlight the versatility of circuit cutting as a tool for extending the reach of near-term quantum computing systems. As research continues to improve reconstruction techniques and optimize circuit partitioning

strategies, circuit cutting is expected to become an increasingly valuable component of practical quantum computing workflows.

10 Conclusion

Quantum circuit cutting has emerged as an important technique for extending the capabilities of near-term quantum hardware. By decomposing a large quantum circuit into smaller sub-circuits, the method enables quantum computations that would otherwise exceed the qubit capacity or connectivity constraints of current devices. The independent execution of these sub-circuits, followed by classical reconstruction of the global output statistics, allows larger quantum algorithms to be explored within the limitations of noisy intermediate-scale quantum (NISQ) systems (Cotler *et al.*, 2020; Peng *et al.*, 2020; Beverland *et al.*, 2022).

In this tutorial, we focused specifically on the wire cutting approach to quantum circuit cutting. The fundamental principles underlying the technique were introduced, including circuit partitioning, the measurement-initialization framework at the cut location, and the classical reconstruction procedure based on Pauli operator decomposition. A three-qubit example was used to illustrate the complete workflow, demonstrating how a circuit can be partitioned into smaller fragments while preserving the ability to reconstruct the behavior of the original circuit. Numerical simulations using Qiskit further validated the reconstruction process by comparing the reconstructed probabilities with those obtained from executing the full circuit (Aleksandrowicz *et al.*, 2019; IBM, 2023; Peng *et al.*, 2020).

Despite its advantages, circuit cutting introduces several challenges, including classical computational overhead, statistical noise from finite sampling, and the difficulty of selecting optimal cut locations (Cotler *et al.*, 2020; Beverland *et al.*, 2022). These limitations highlight the importance of



developing improved partitioning strategies and more efficient reconstruction algorithms. Continued research in this area is expected to reduce the overhead associated with circuit cutting and make the technique more practical for increasingly complex quantum computations. Overall, quantum circuit wire cutting provides a valuable framework for bridging the gap between the theoretical potential of quantum algorithms and the practical constraints of existing quantum hardware. As quantum technologies continue to advance, circuit cutting methods are likely to play an increasingly important role in enabling scalable quantum computations, distributed quantum processing, and hybrid quantum-classical workflows (Nickerson *et al.*, 2014)

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Conflict of interest

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Ethical Consideration

Not applicable

Author Contributions

All components of the work were carried out by the authors

