

Qompress: Efficient Compilation for Ququarts Exploiting Partial and Mixed Radix Operations for Communication Reduction

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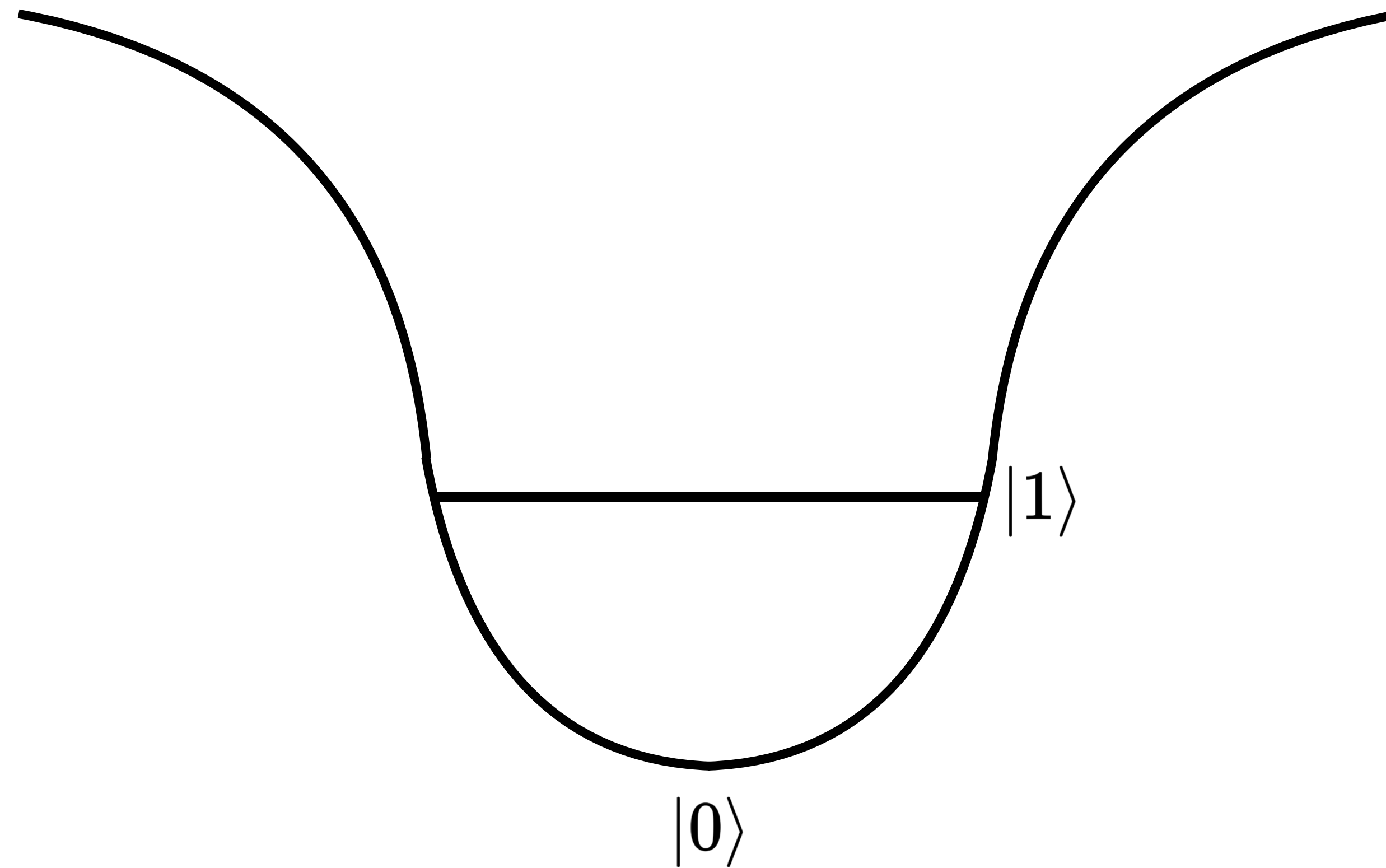
NSF Quantum Leap Challenge Institute for Hybrid Quantum Architectures and Networks (NSF Award 2016136) and in part based upon work supported by the

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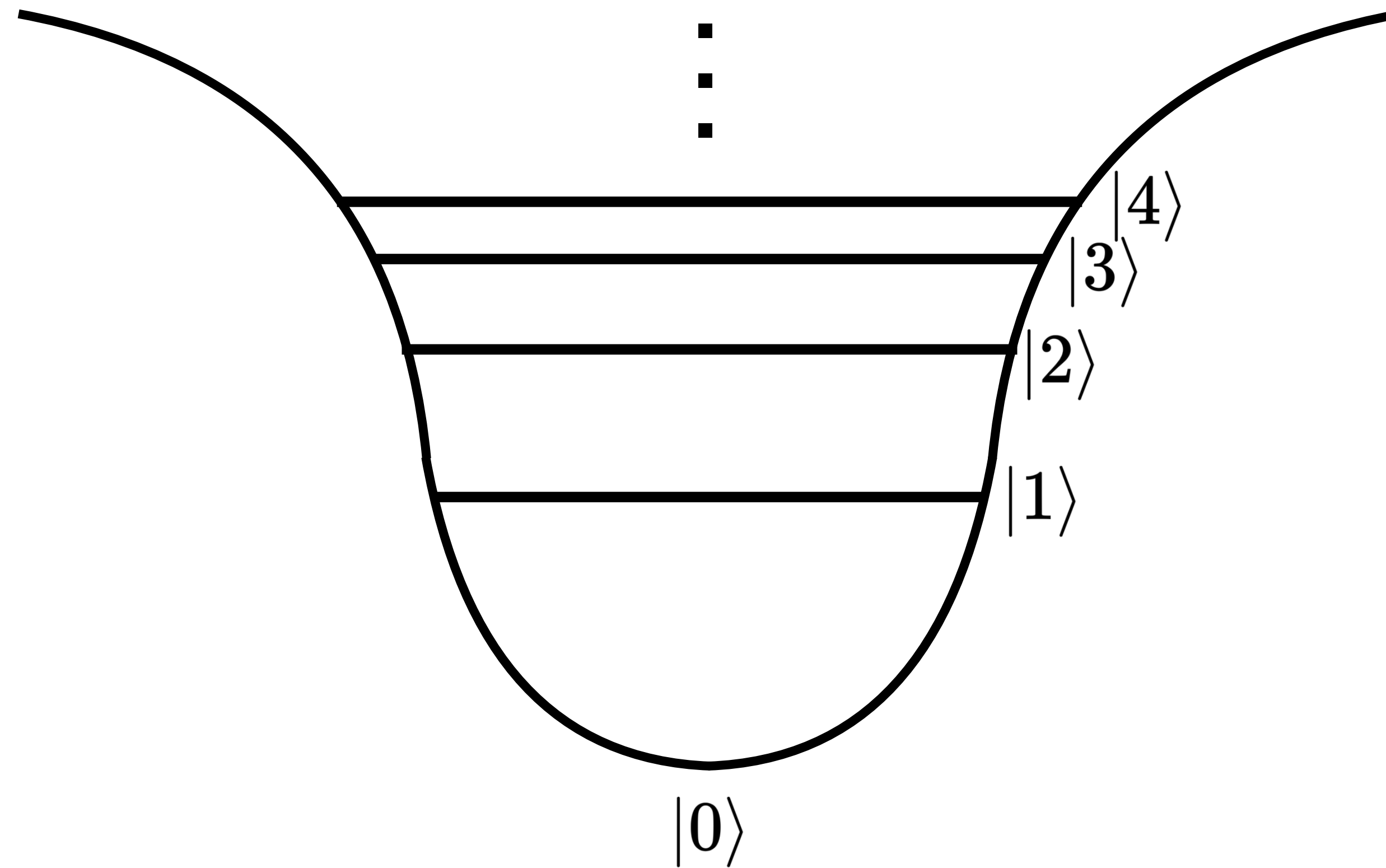
FTC is Chief Scientist for Quantum Software at Inflection and an advisor to Quantum Circuits, Inc.



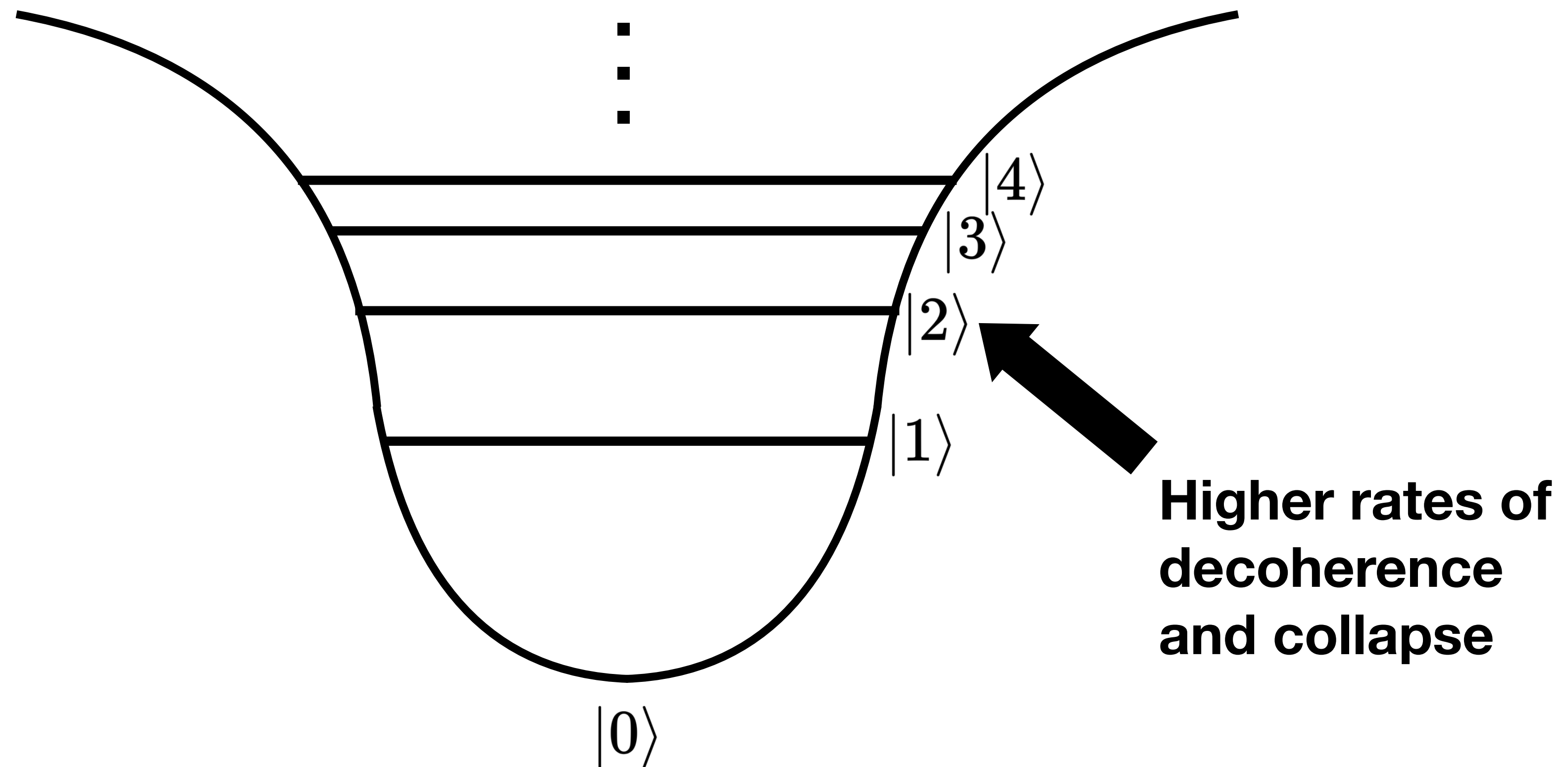
Qubits are Two Level Devices



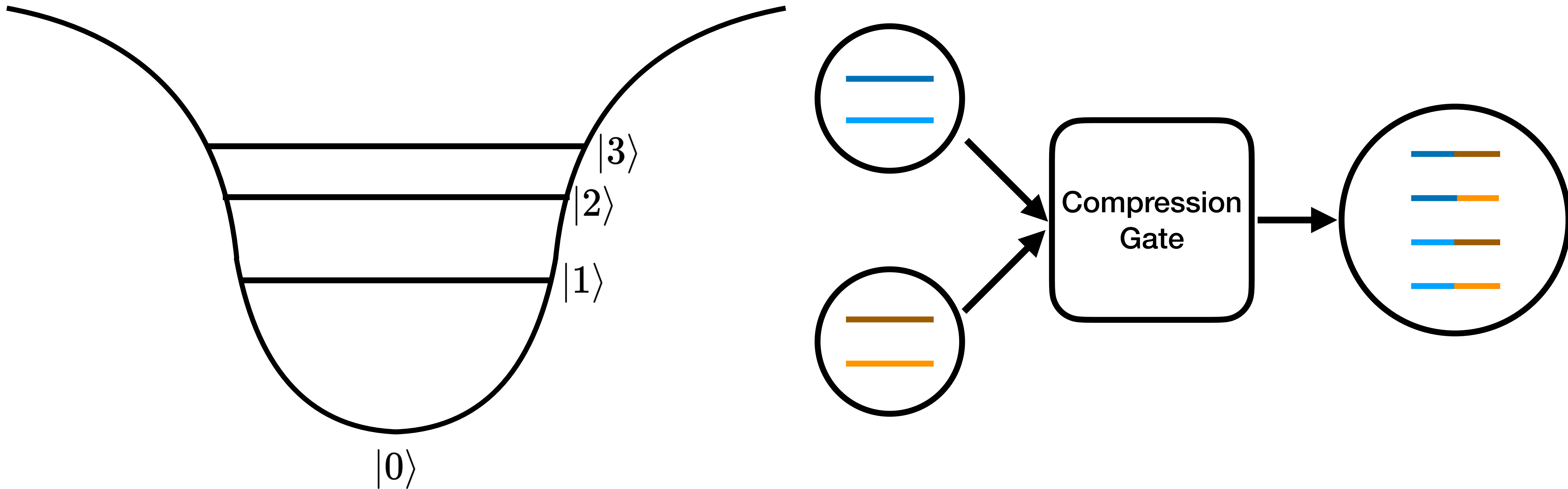
Qubits are Not Just Qubits



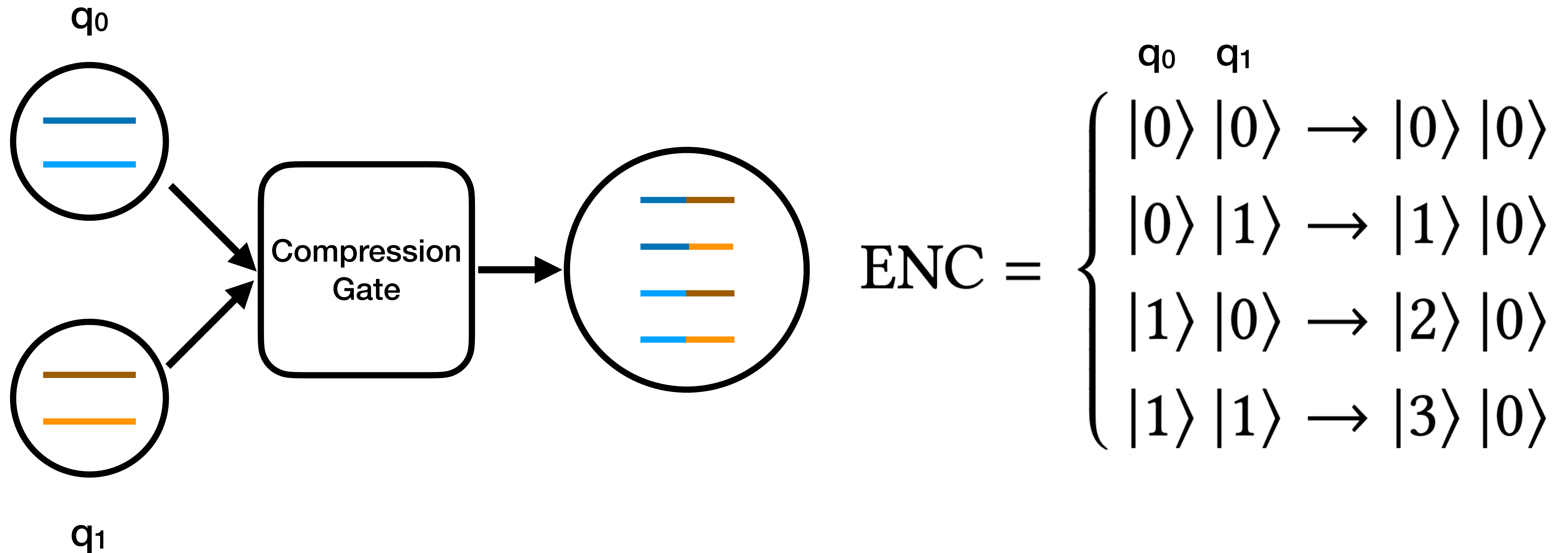
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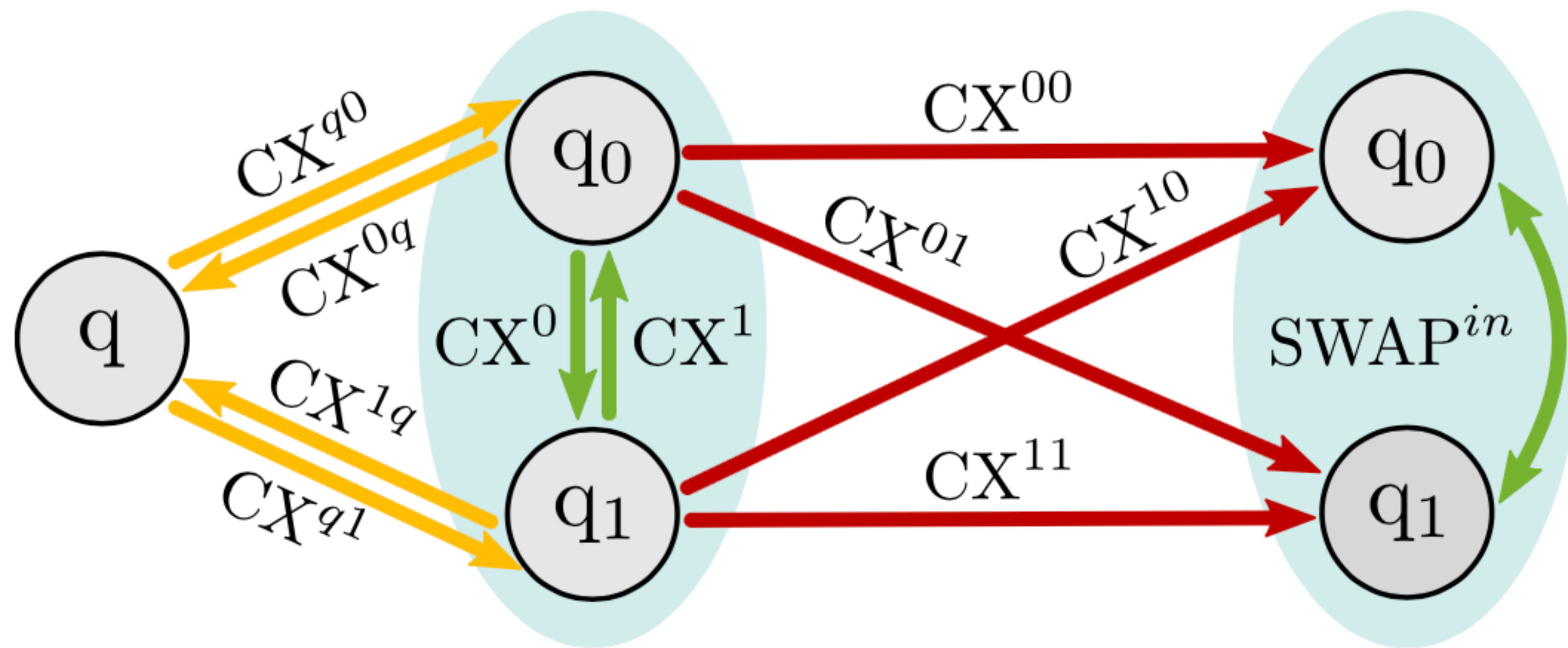
One Ququart Can Be Two Qubits



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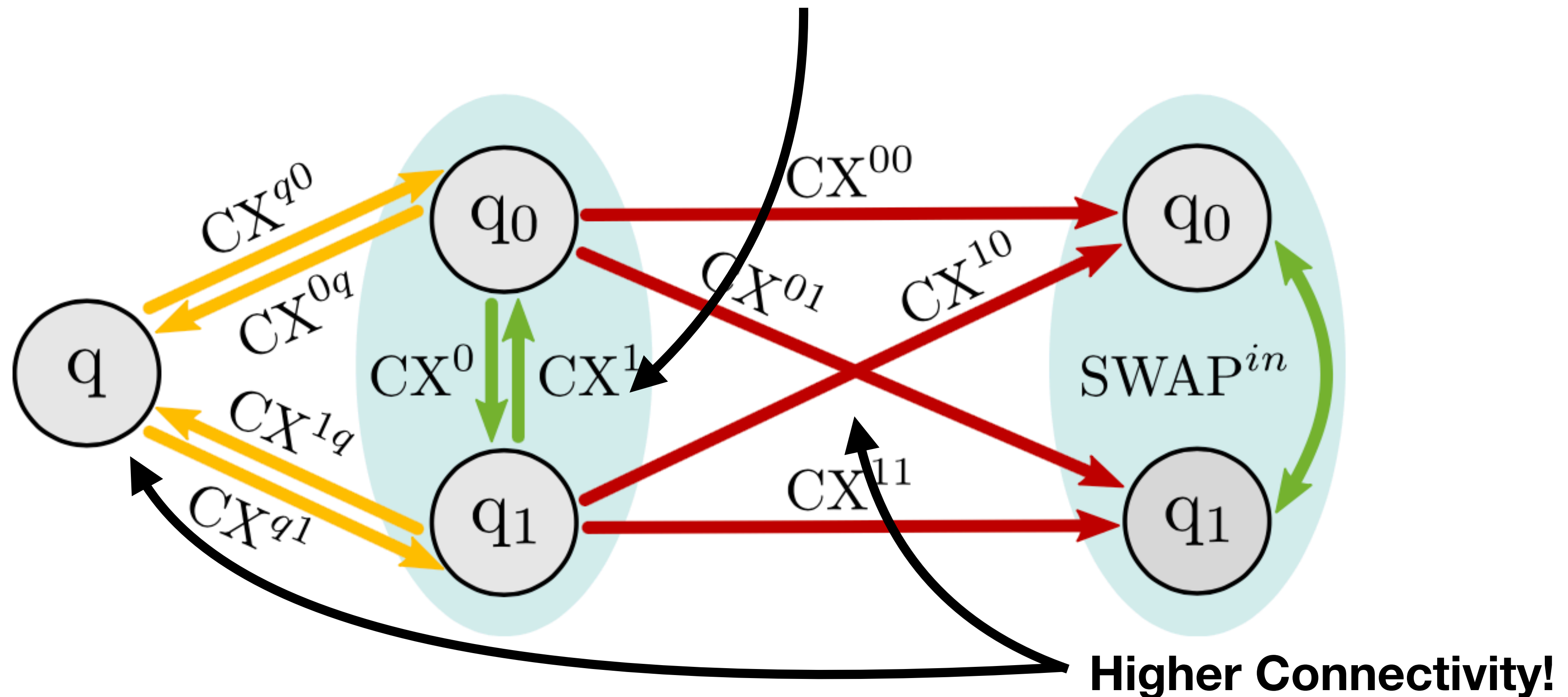


A New-Old Gate Set

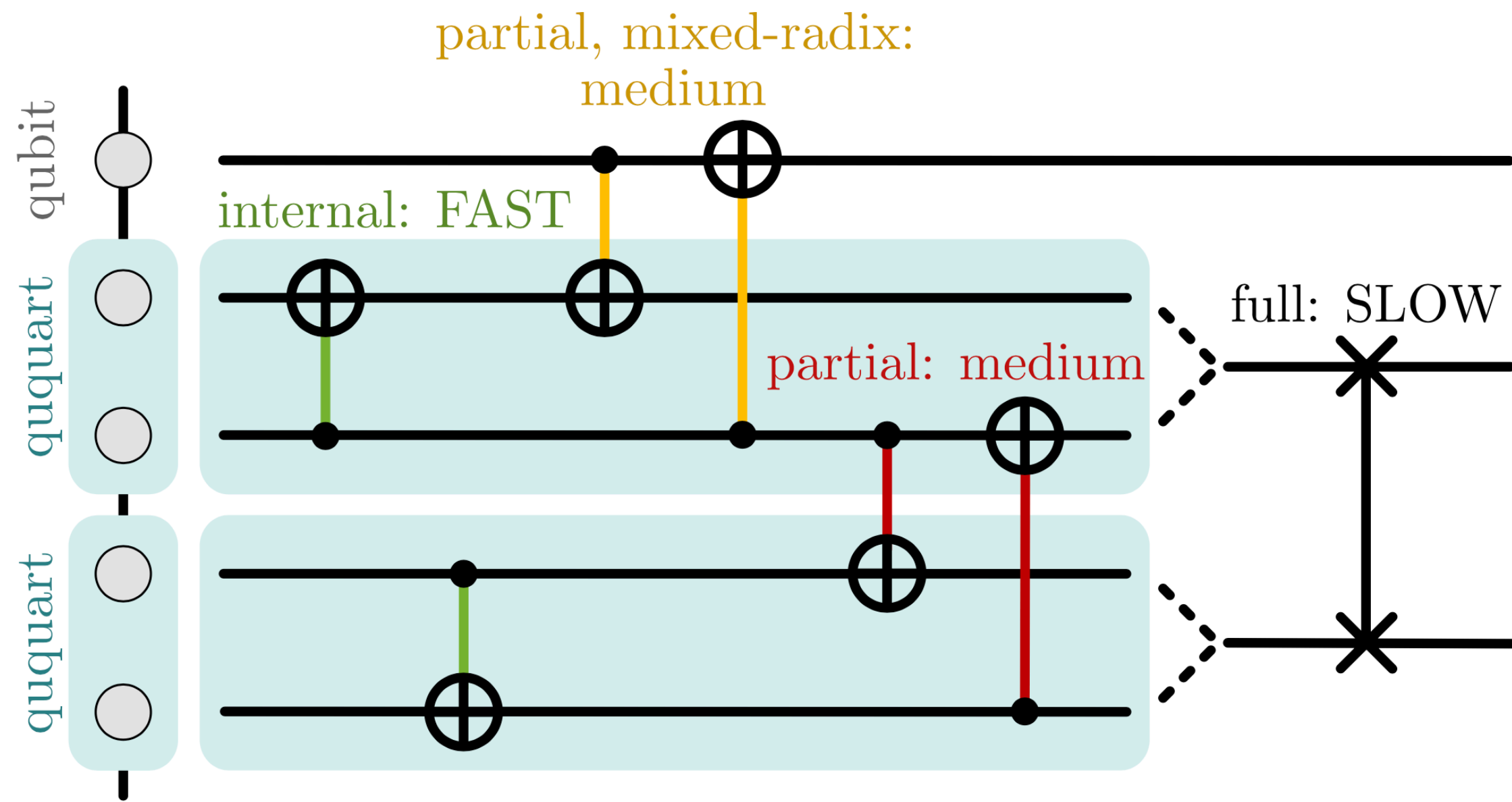


A New-Old Gate Set

10x higher fidelity and 5x faster over traditional qubit-qubit interactions!

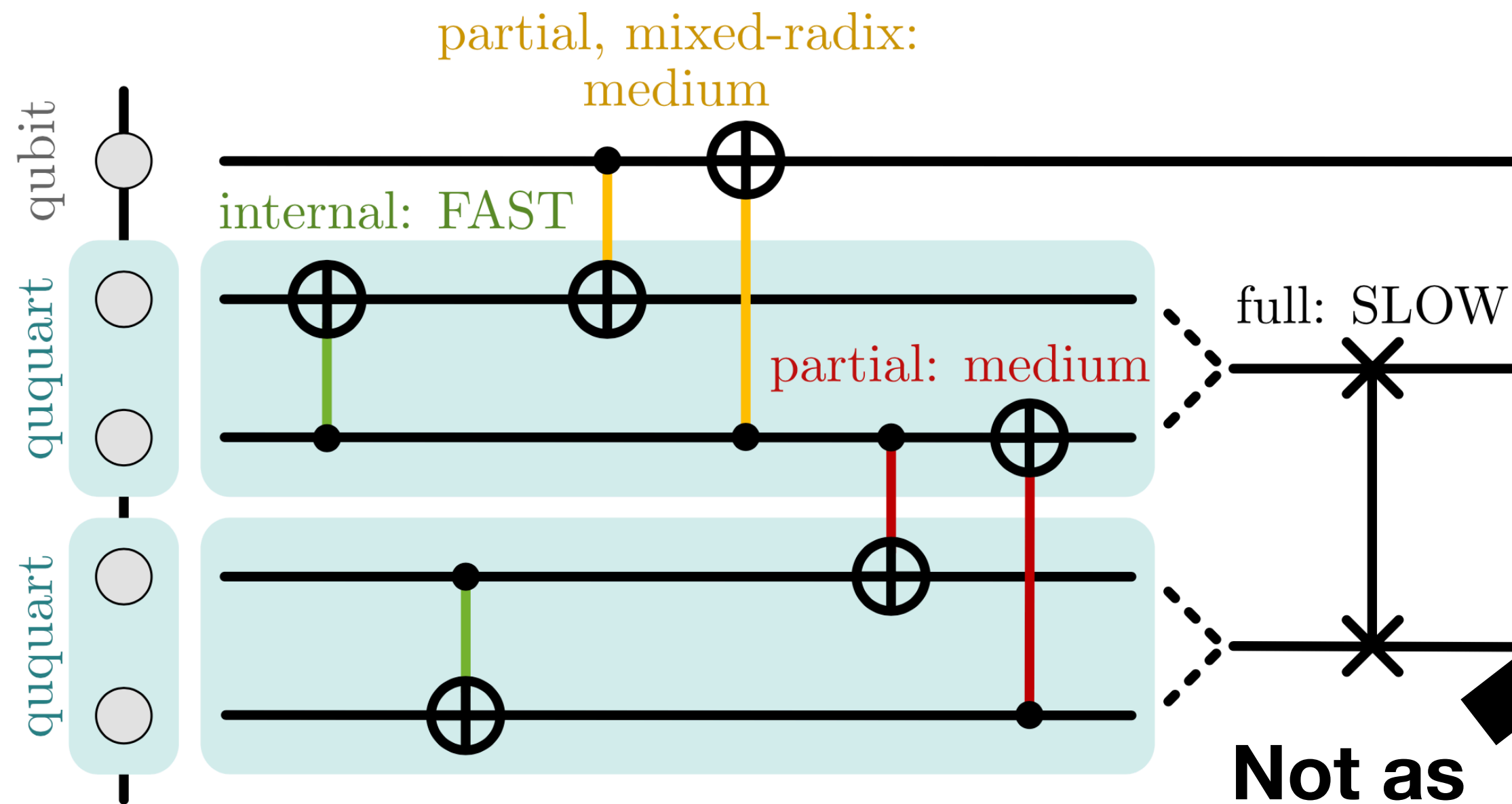


Partial Operations Are Not As Expensive



Selected Gates	Fidelity	Time [ns]
Internal CX	99.9%	85
Qubit CX	99%	251
Qubit SWAP	99%	254
Partial Mixed-Radix CX	99%	632
Partial Mixed-Radix SWAP	99%	680
Partial CX	99%	544
Partial SWAP	99%	916
Full SWAP	99%	1184

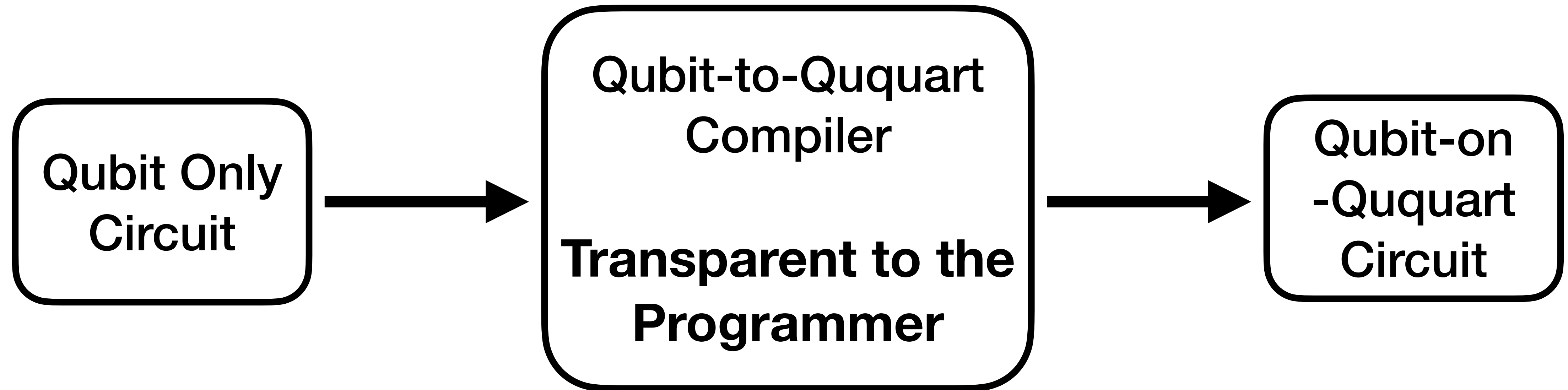
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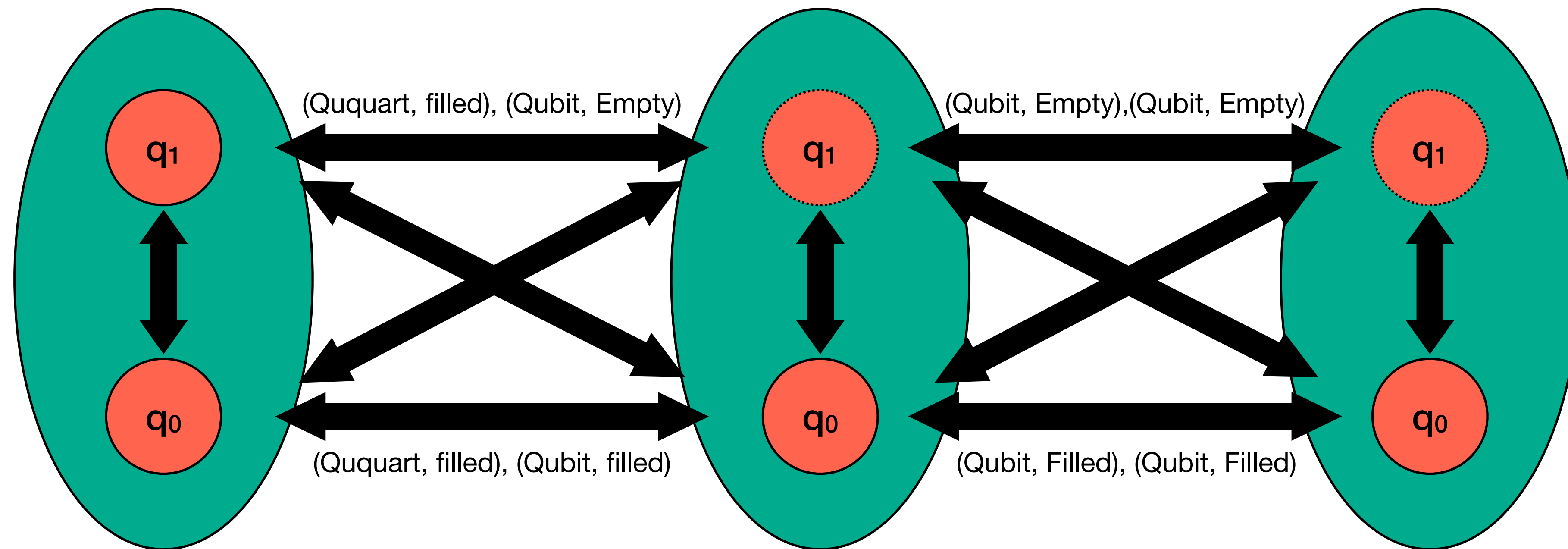
Not as expensive as expected compared to Full-Ququart Operations

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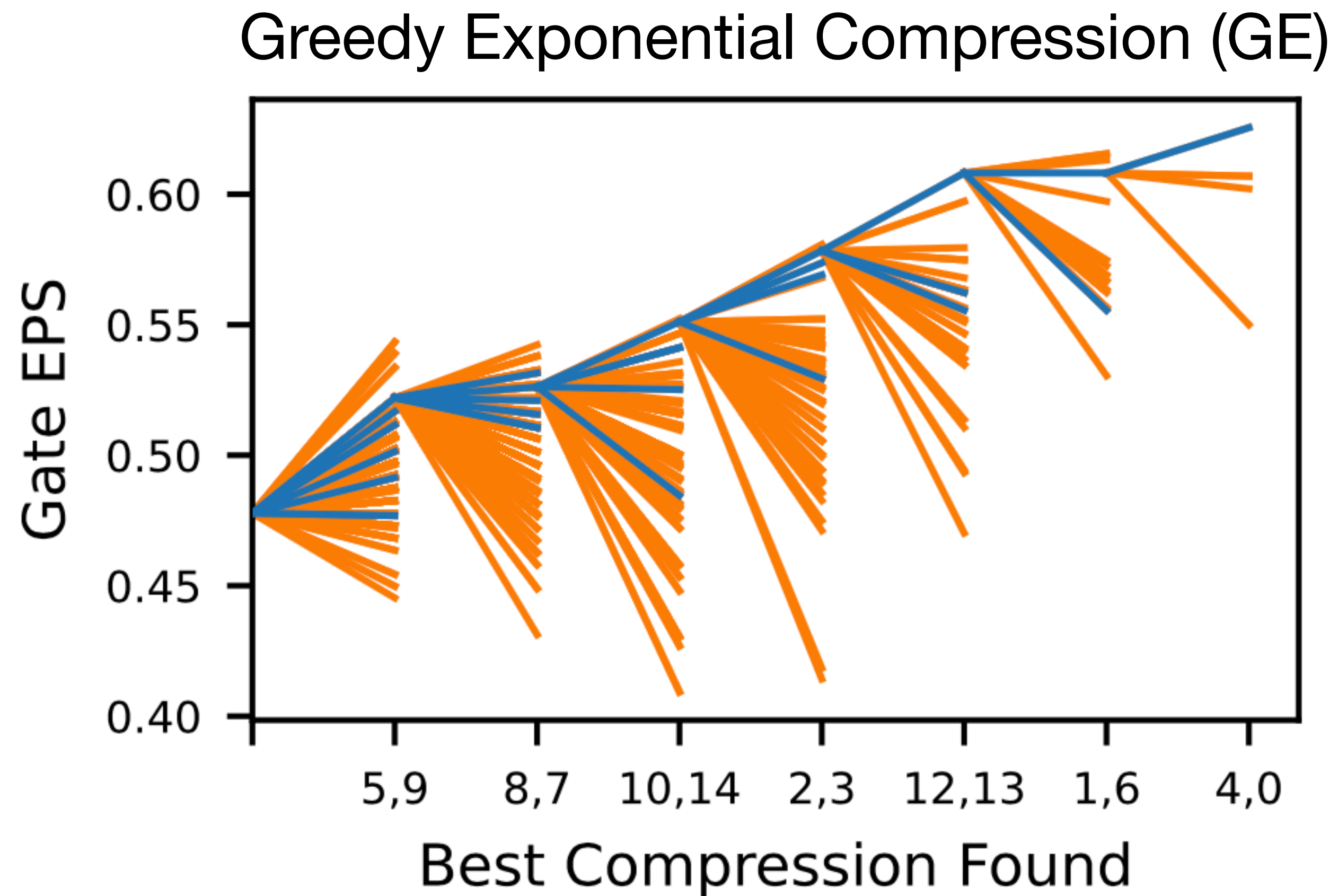
A Compiler For Qubits-on-Ququarts



A Compiler For Qubits-on-Ququarts



Compression Strategies

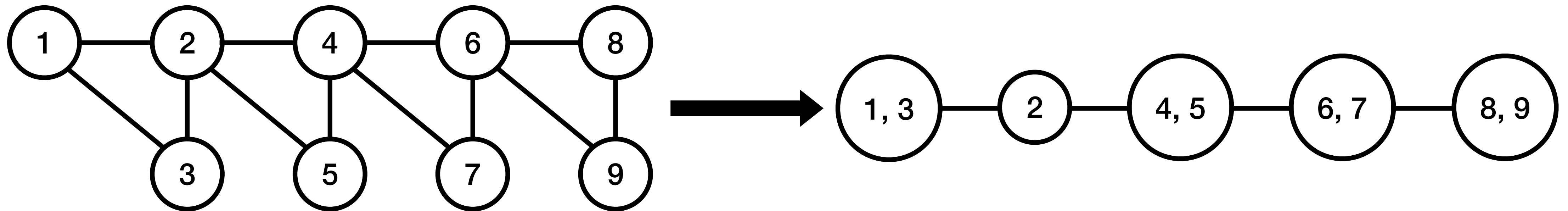


Compression Strategies

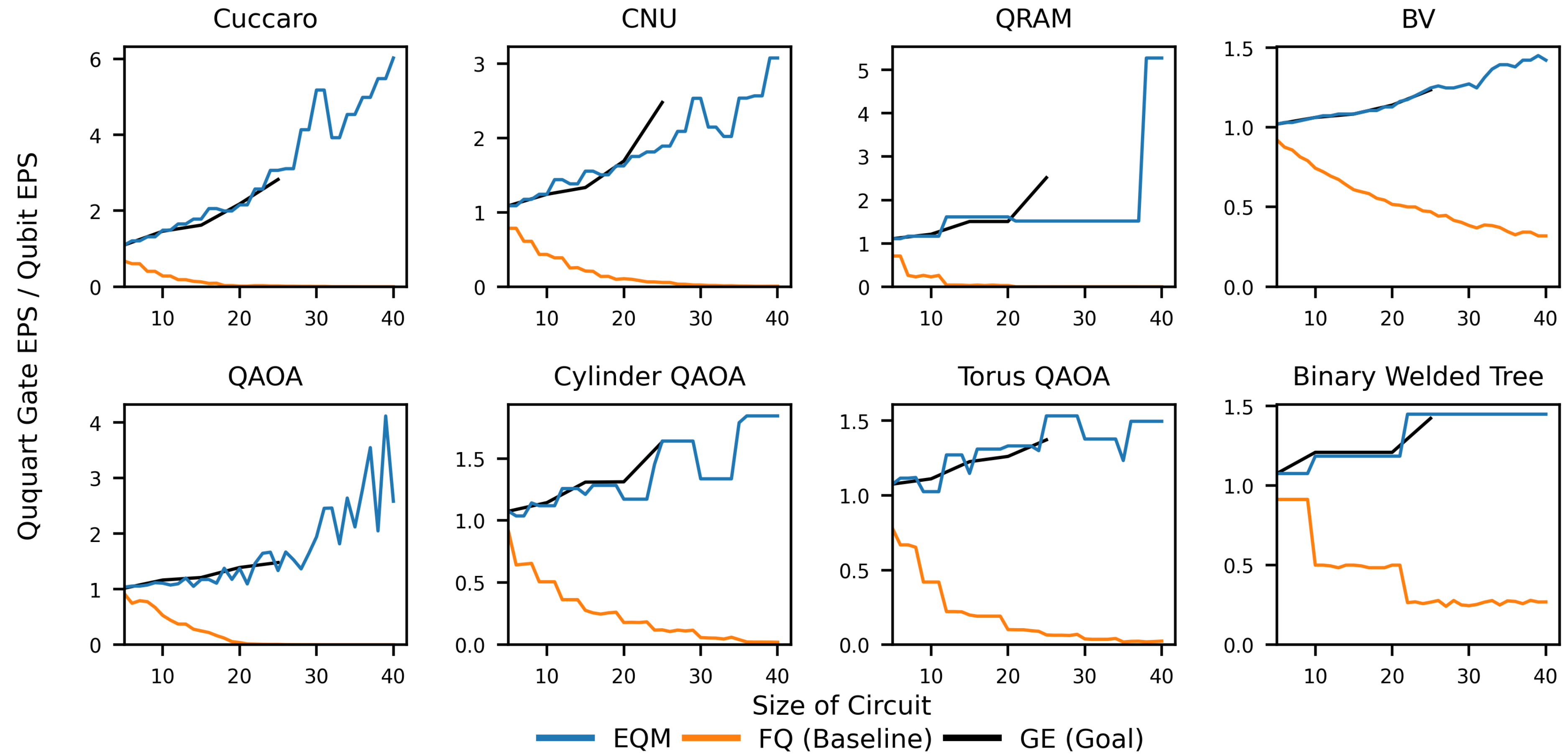
- Greedy Exponential (GE) (Goal)
- Full-Ququart Operations (FQ) (Baseline)
- Extended Qubit Mapping (EQM)

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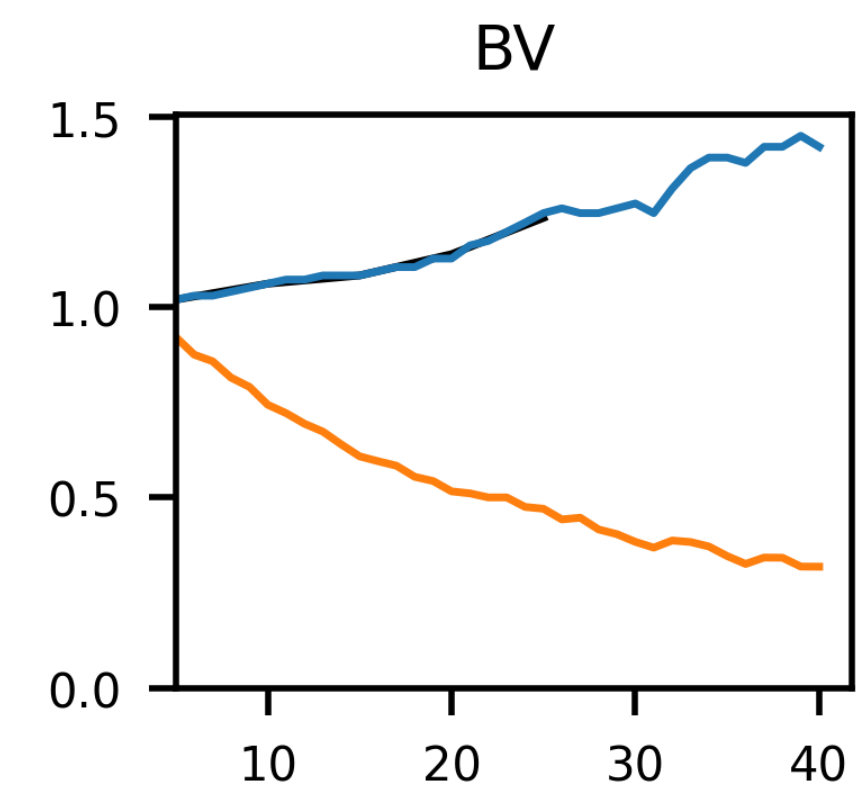
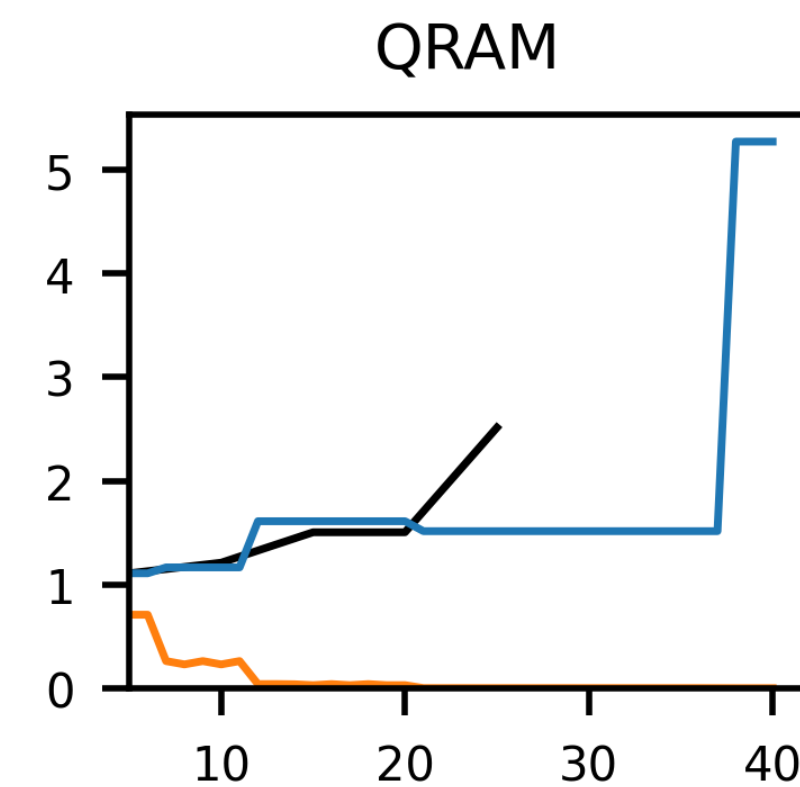
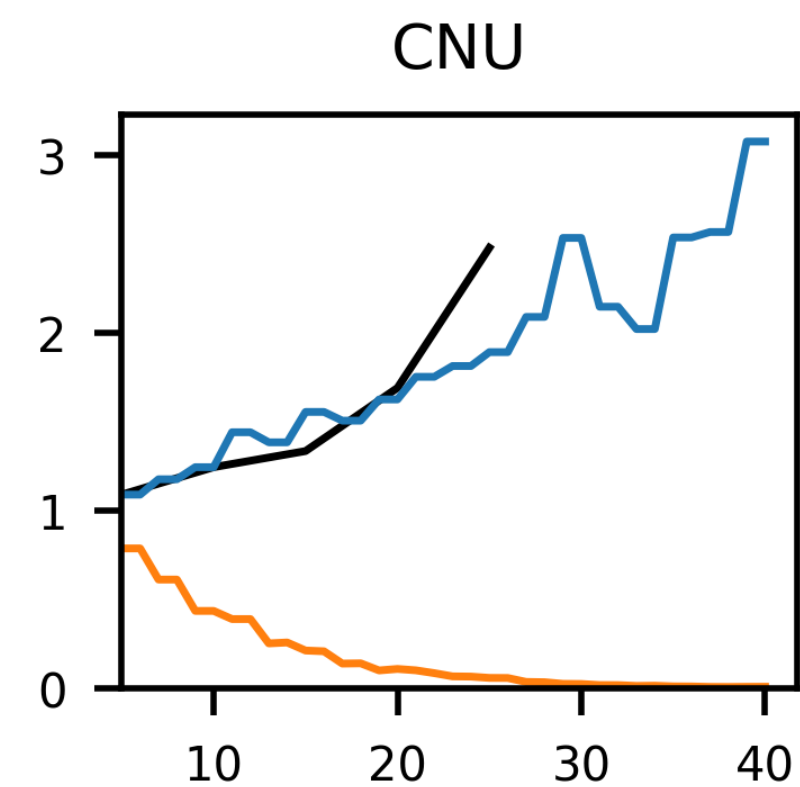
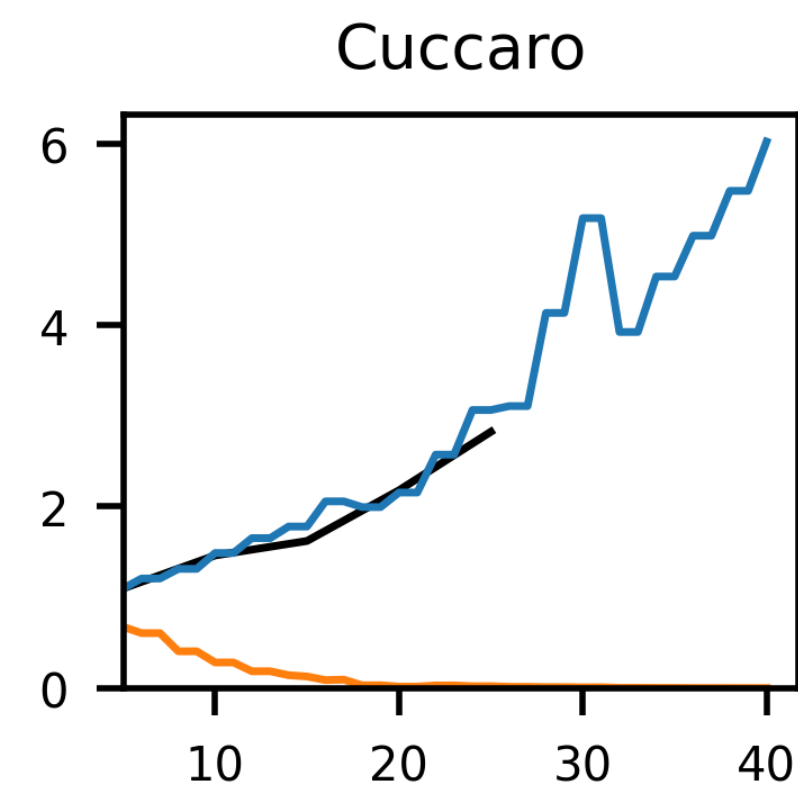


Compression Strategies Comparison



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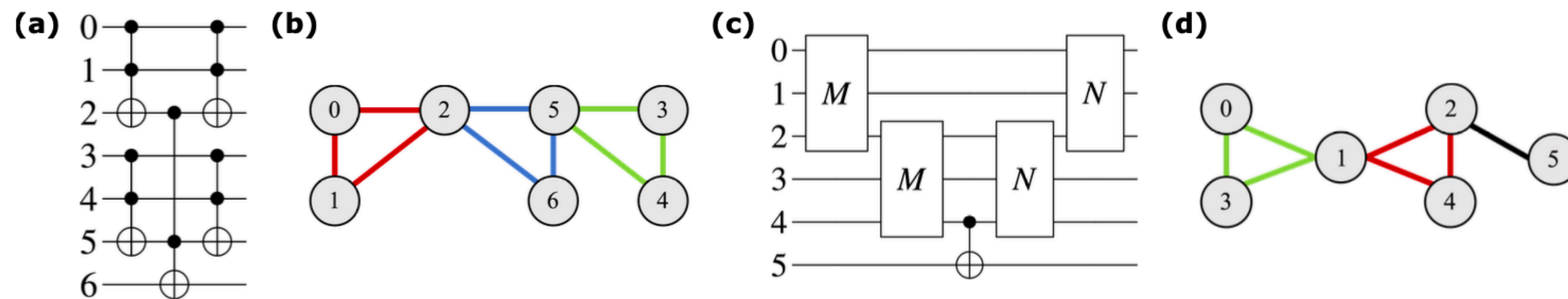
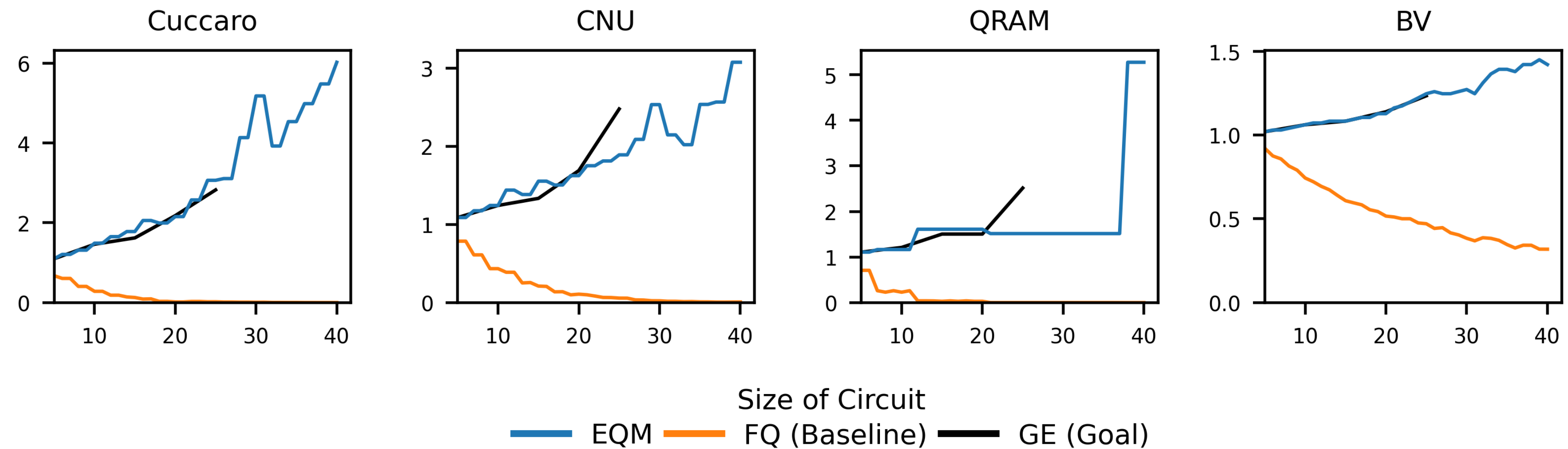
Ququart Gate EPS / Qubit EPS



Size of Circuit
— EQM — FQ (Baseline) — GE (Goal)

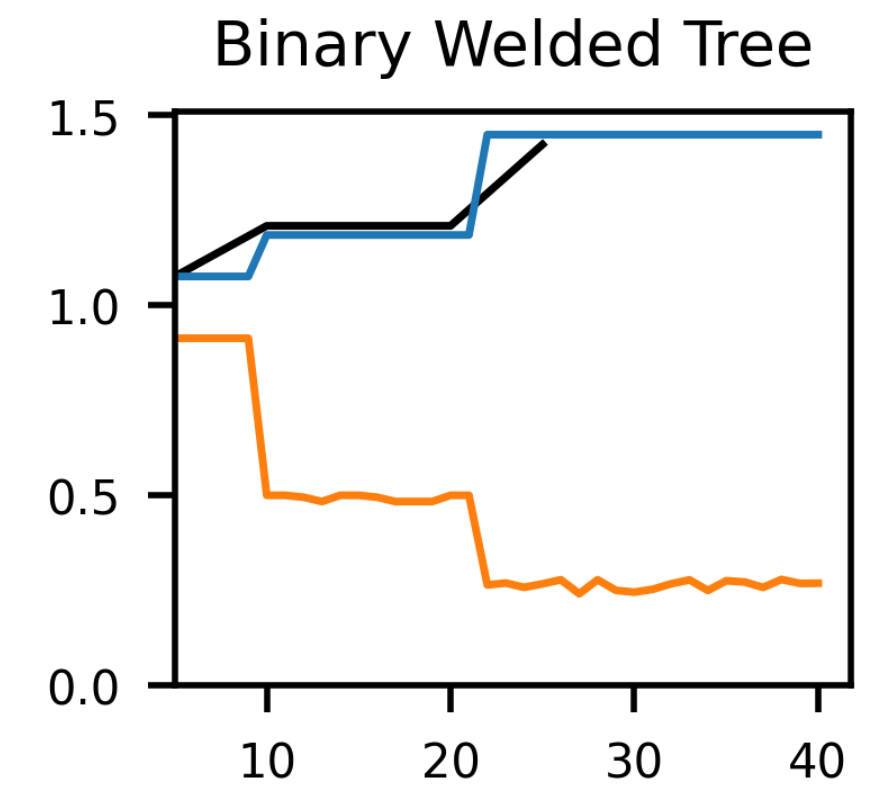
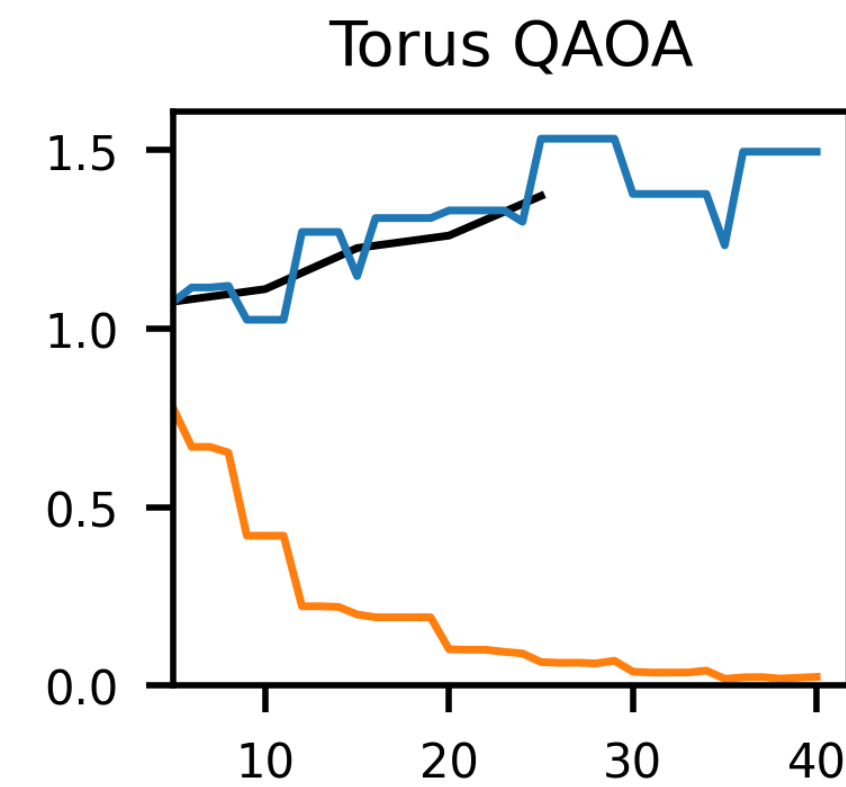
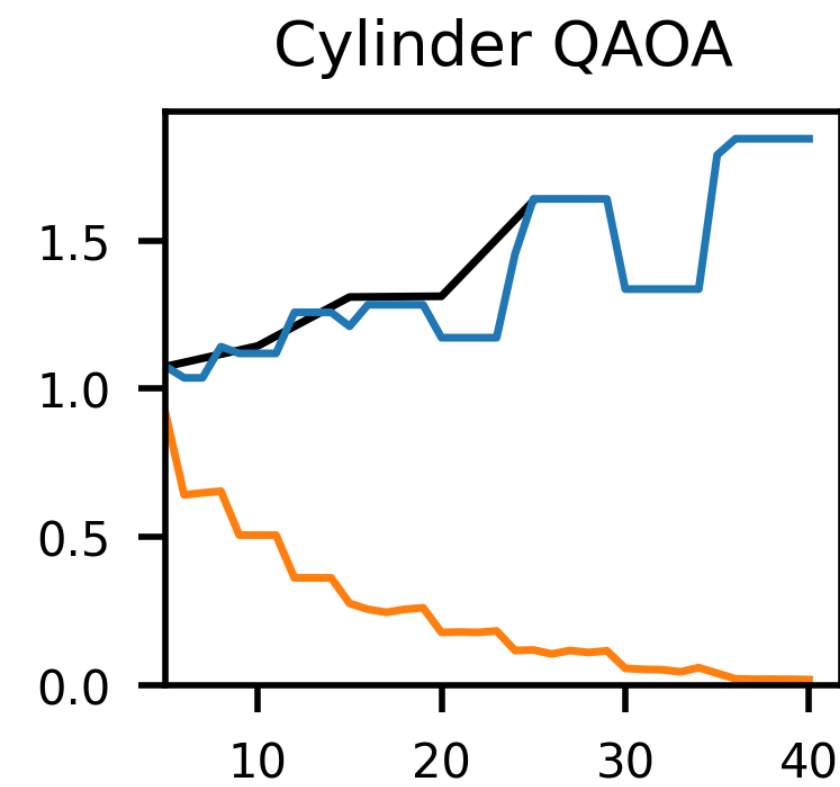
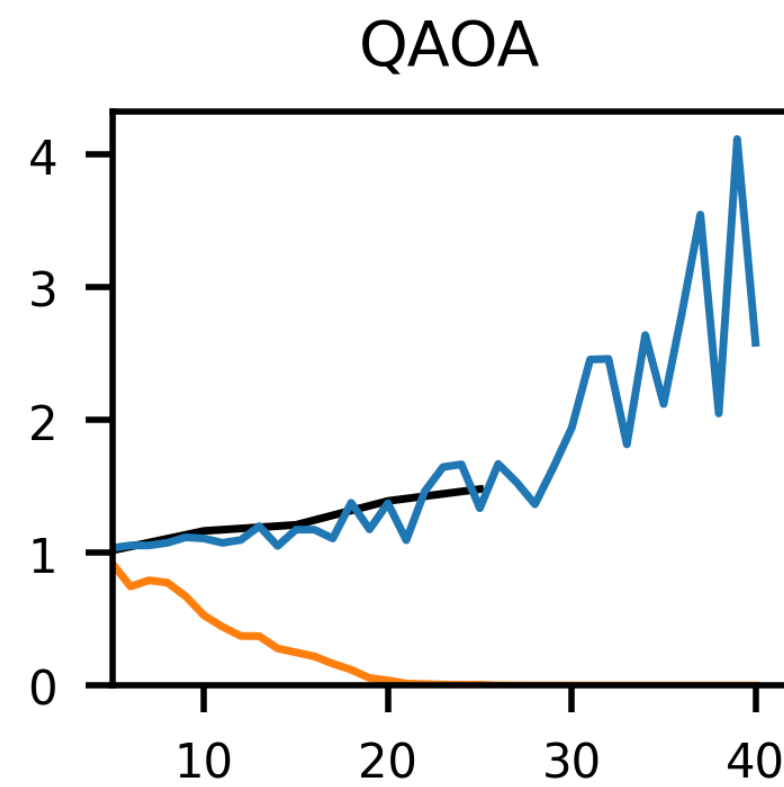
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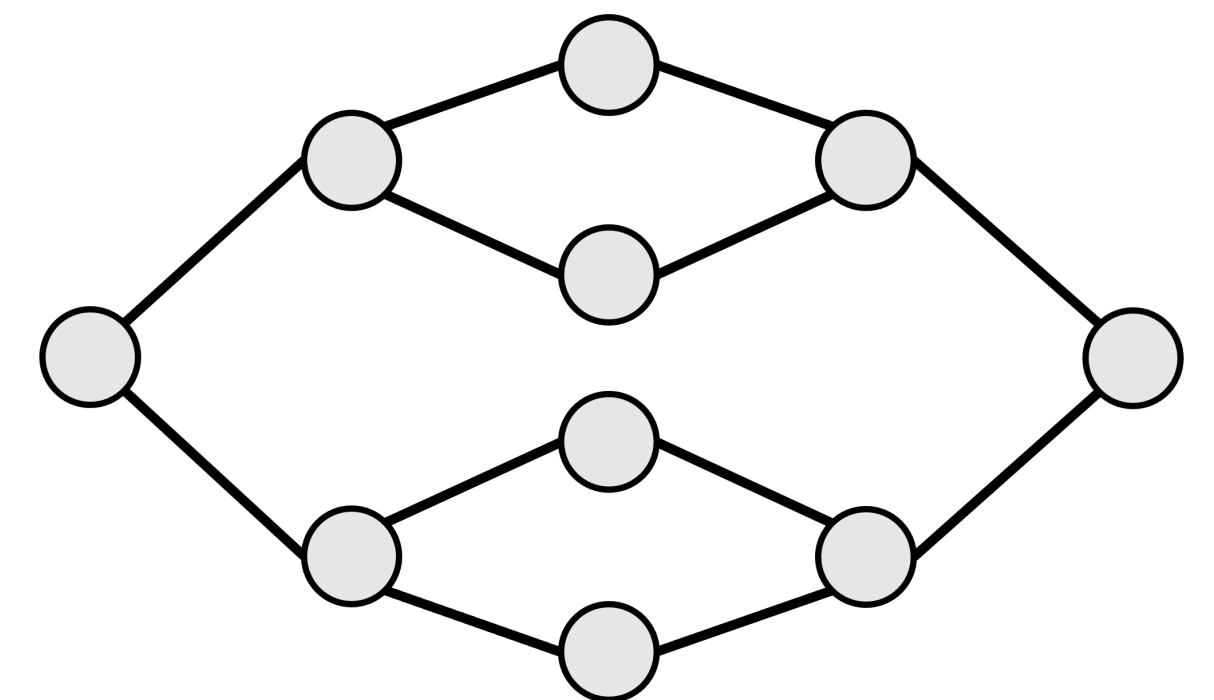
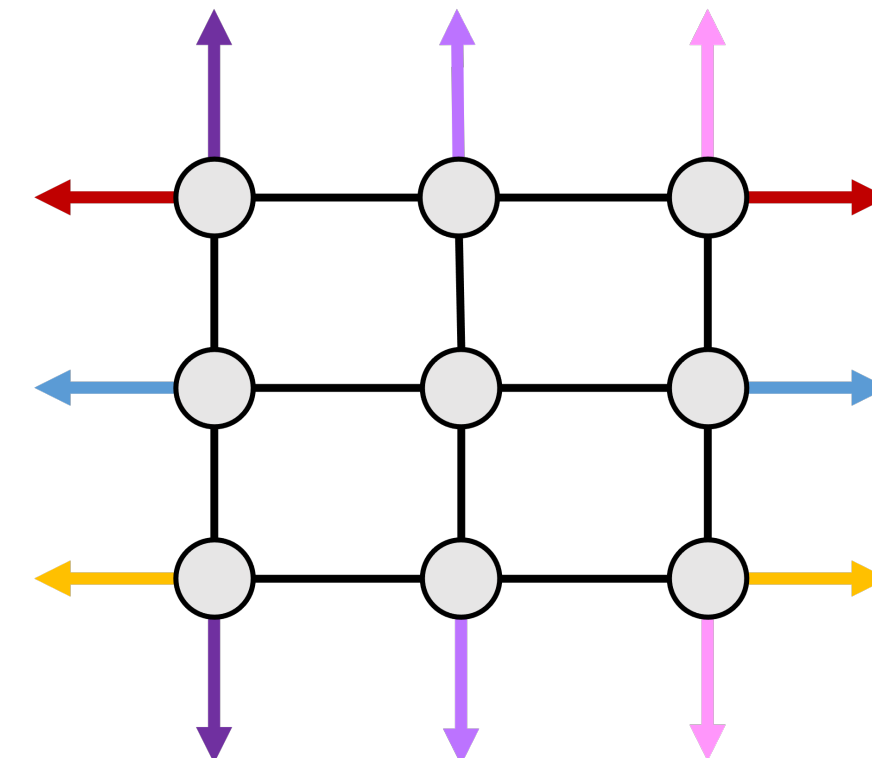
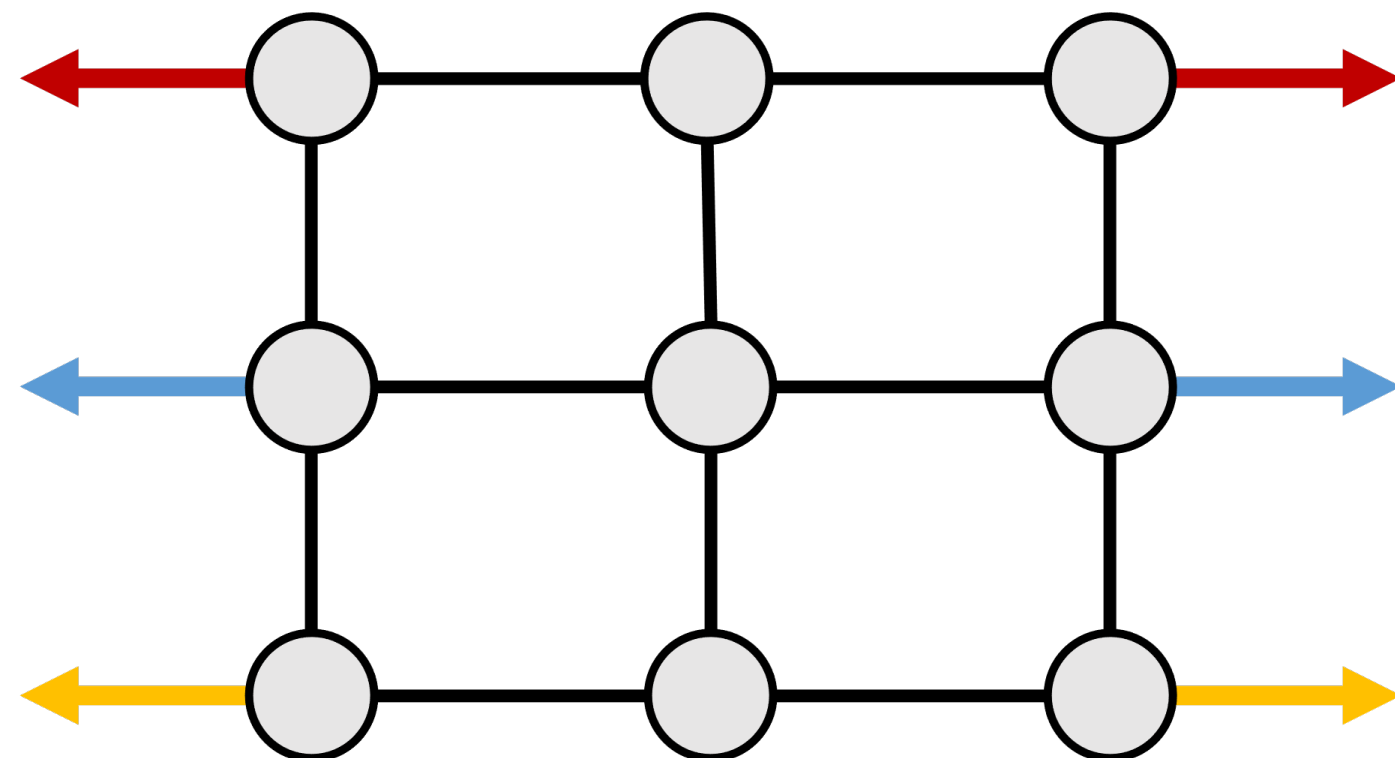


Compression Strategies Comparison

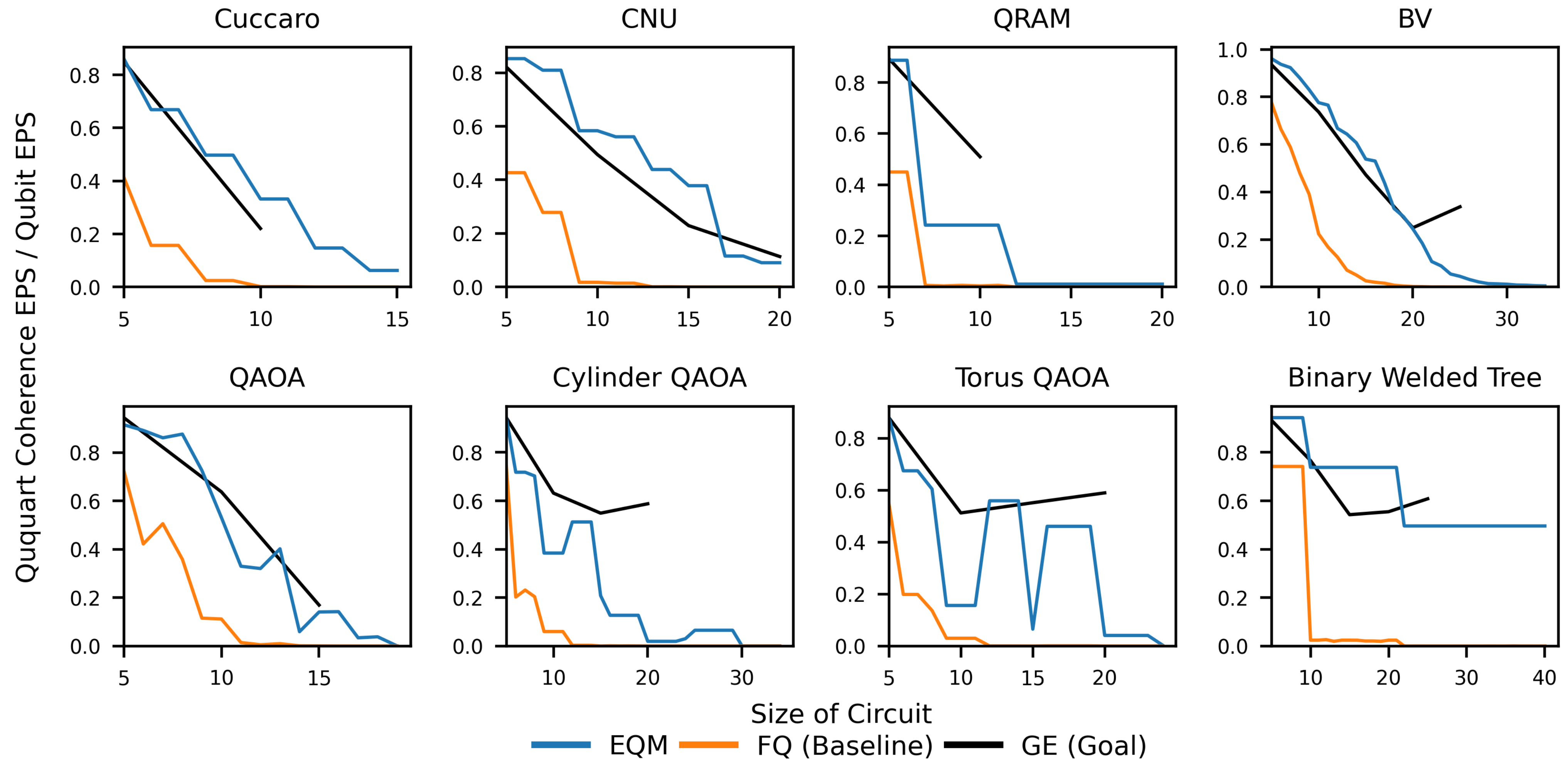
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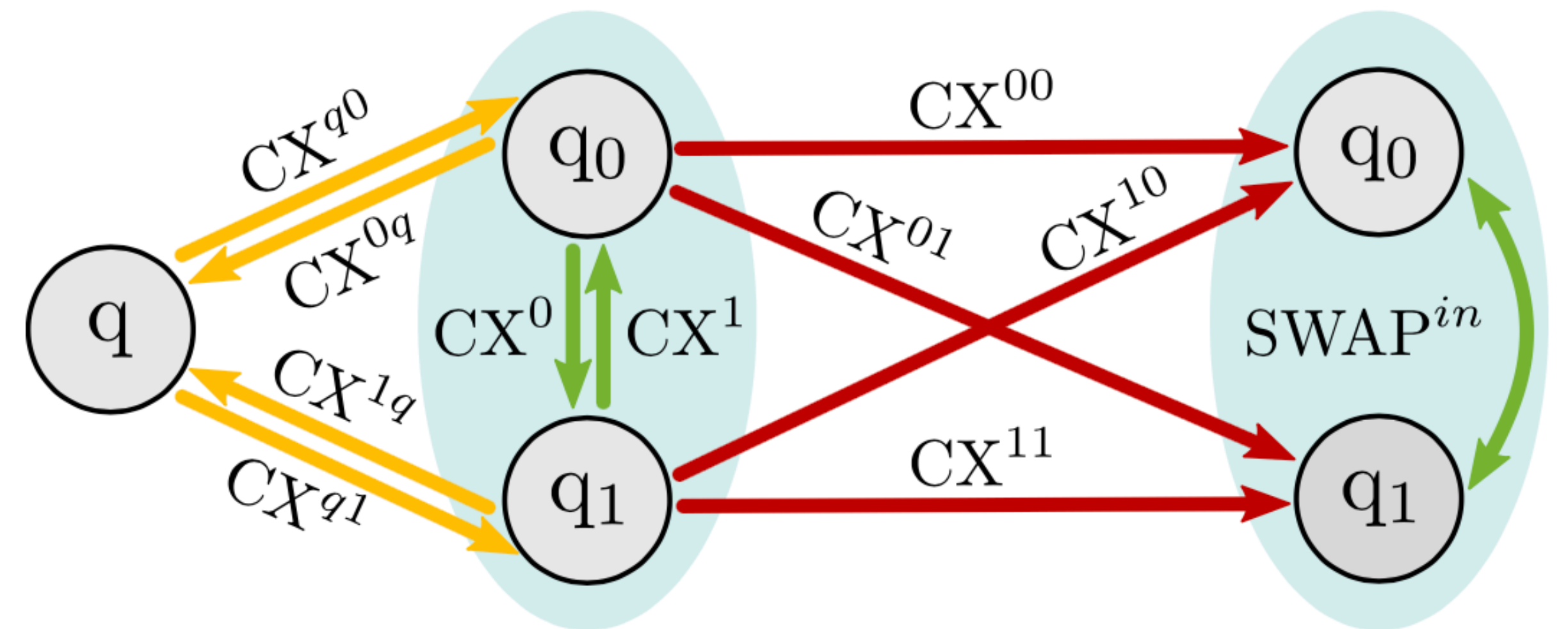


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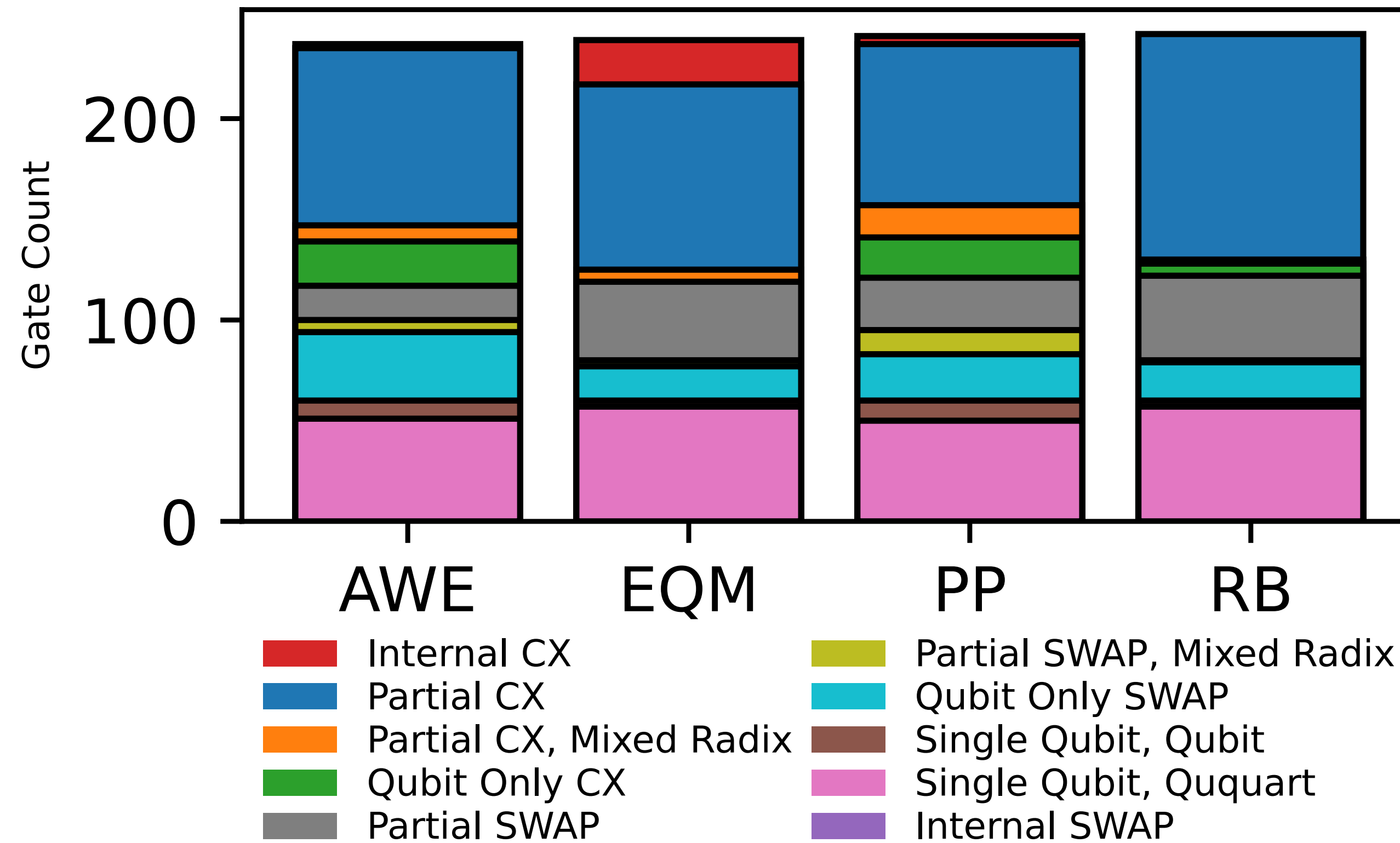
Conclusion

- ~2x more space via compression with similar fidelity
- Enabled by optimized ququart and partial ququart operations designed by quantum optimal control
- Compiler takes advantage of:
 - Higher fidelity two-qubit operations internal to a ququart
 - Higher connectivity
 - Faster than expected partial ququart operations

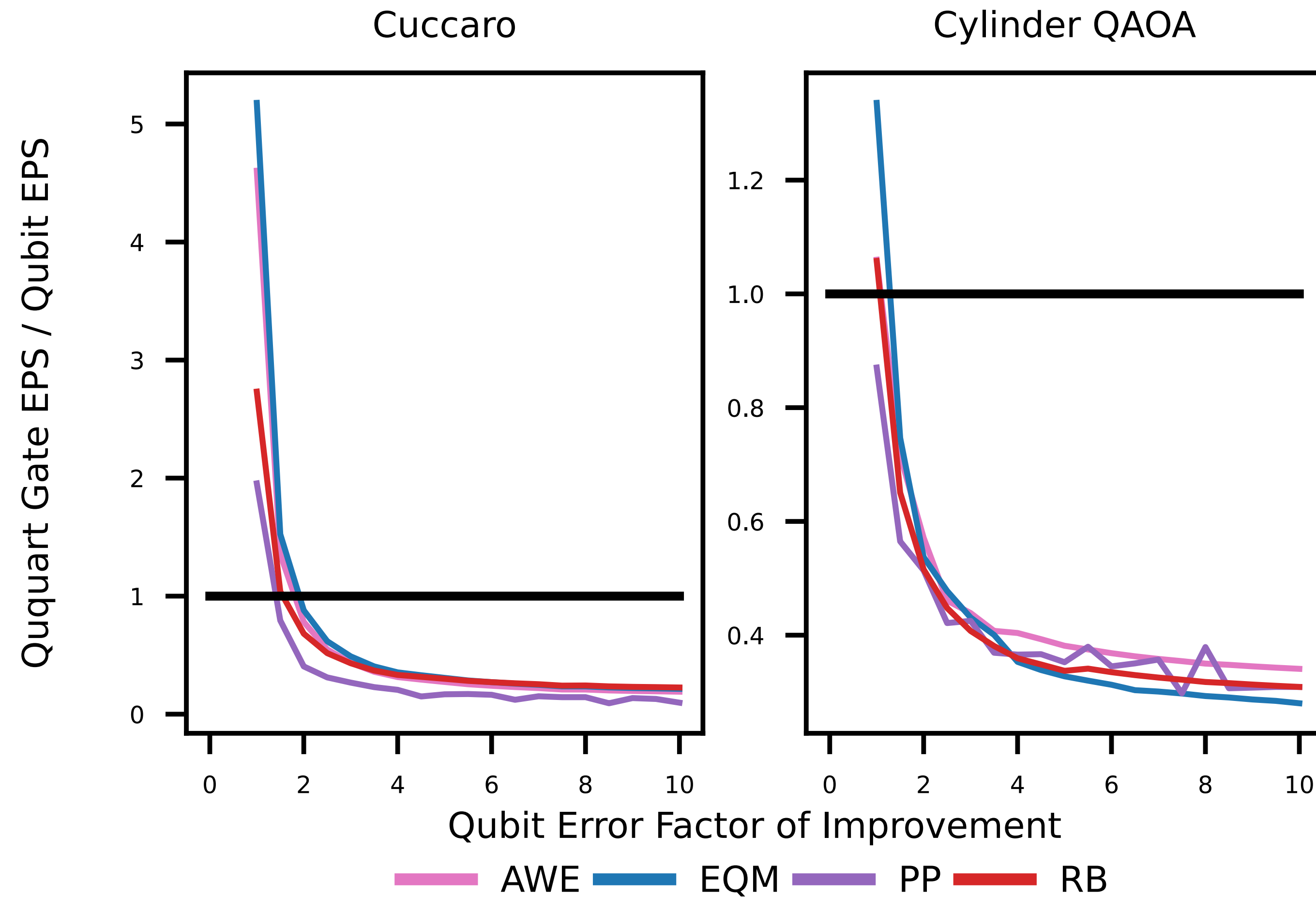


Questions?

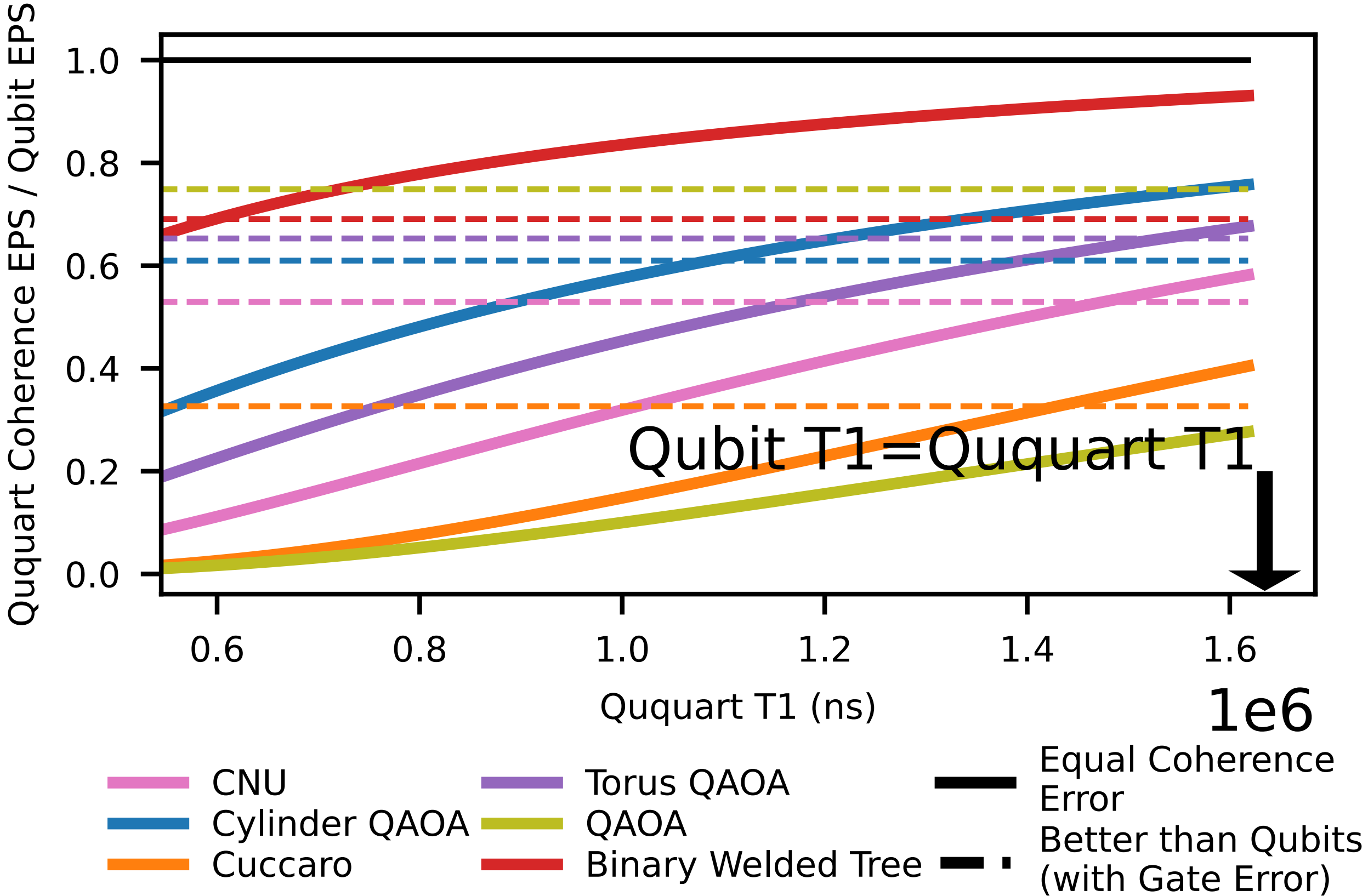
Gate Type Distribution



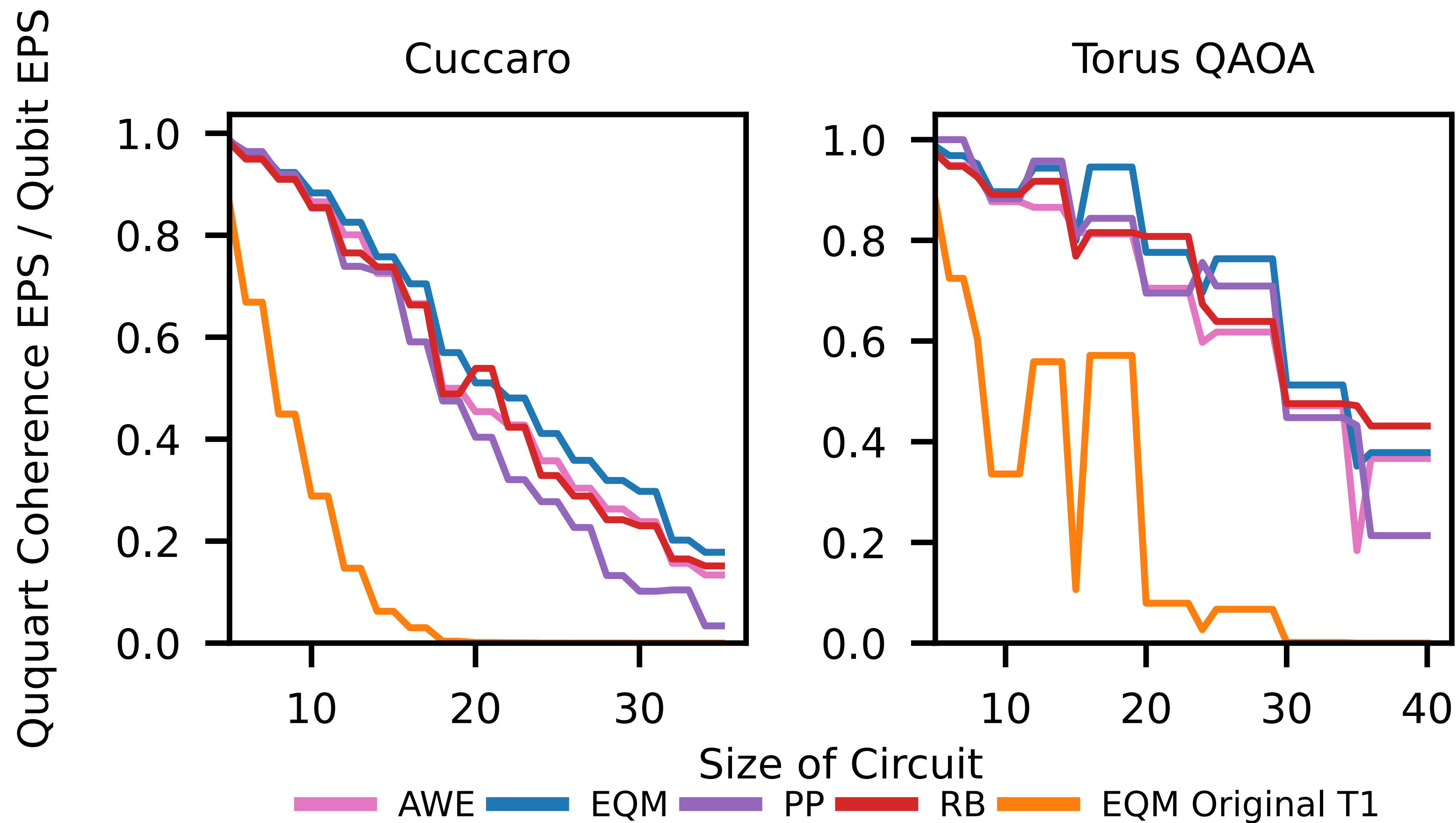
Sensitivity to Higher Ququart Gate Error



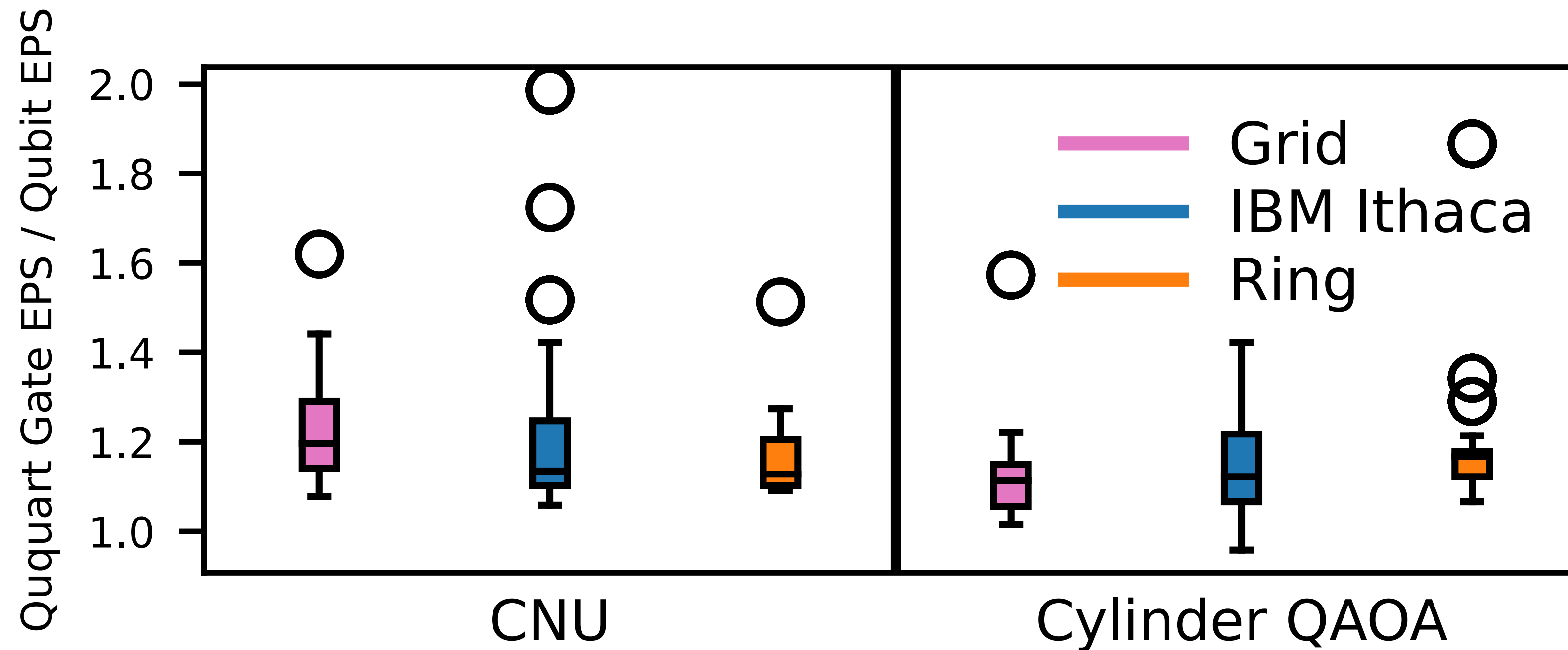
Sensitivity to Ququart Decoherence Error

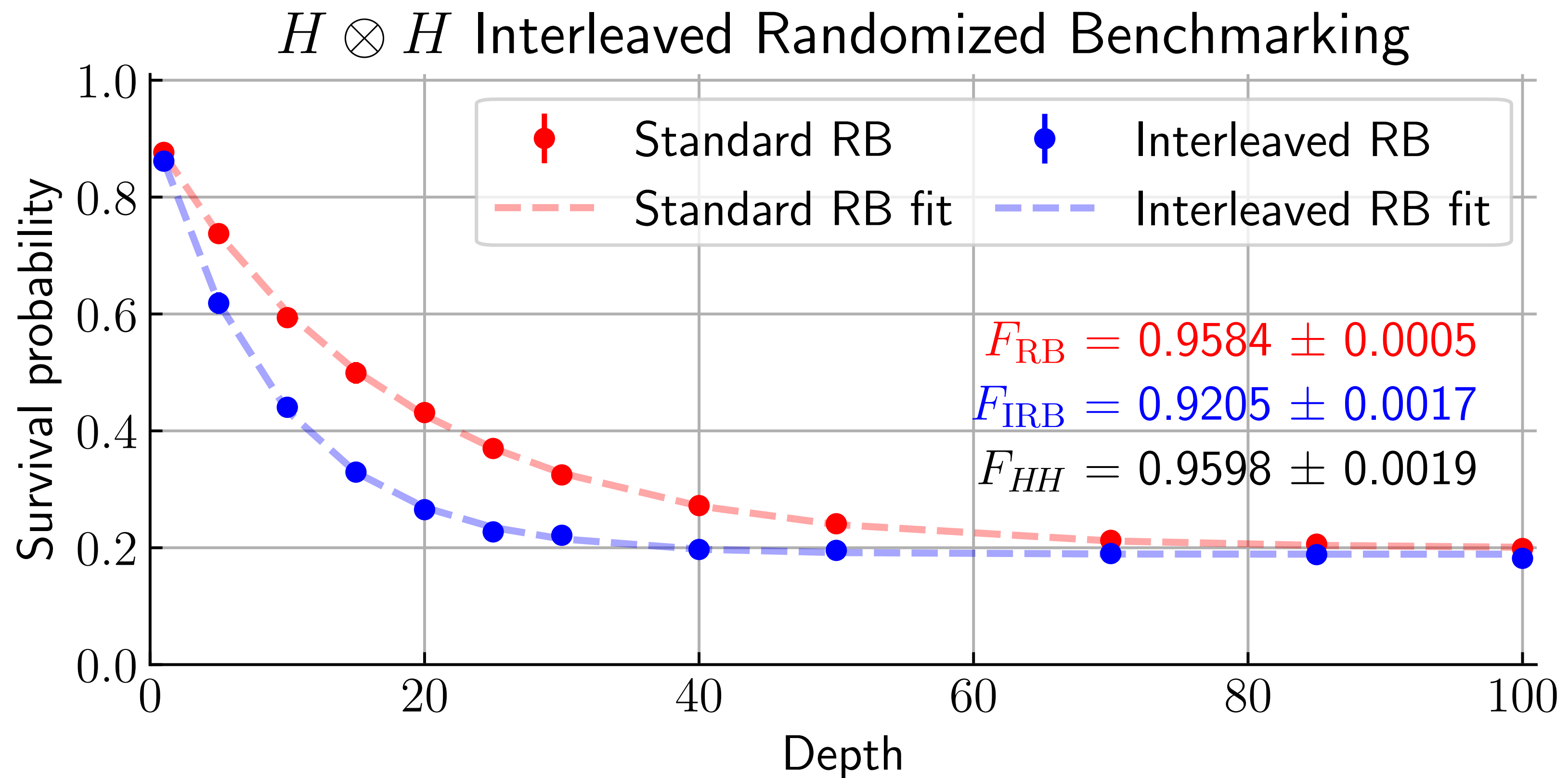


Longer Ququart Coherence Times



Different Architectural Shapes





Dancing the Quantum Waltz: <https://arxiv.org/abs/2303.14069>