Quantum Toolchains

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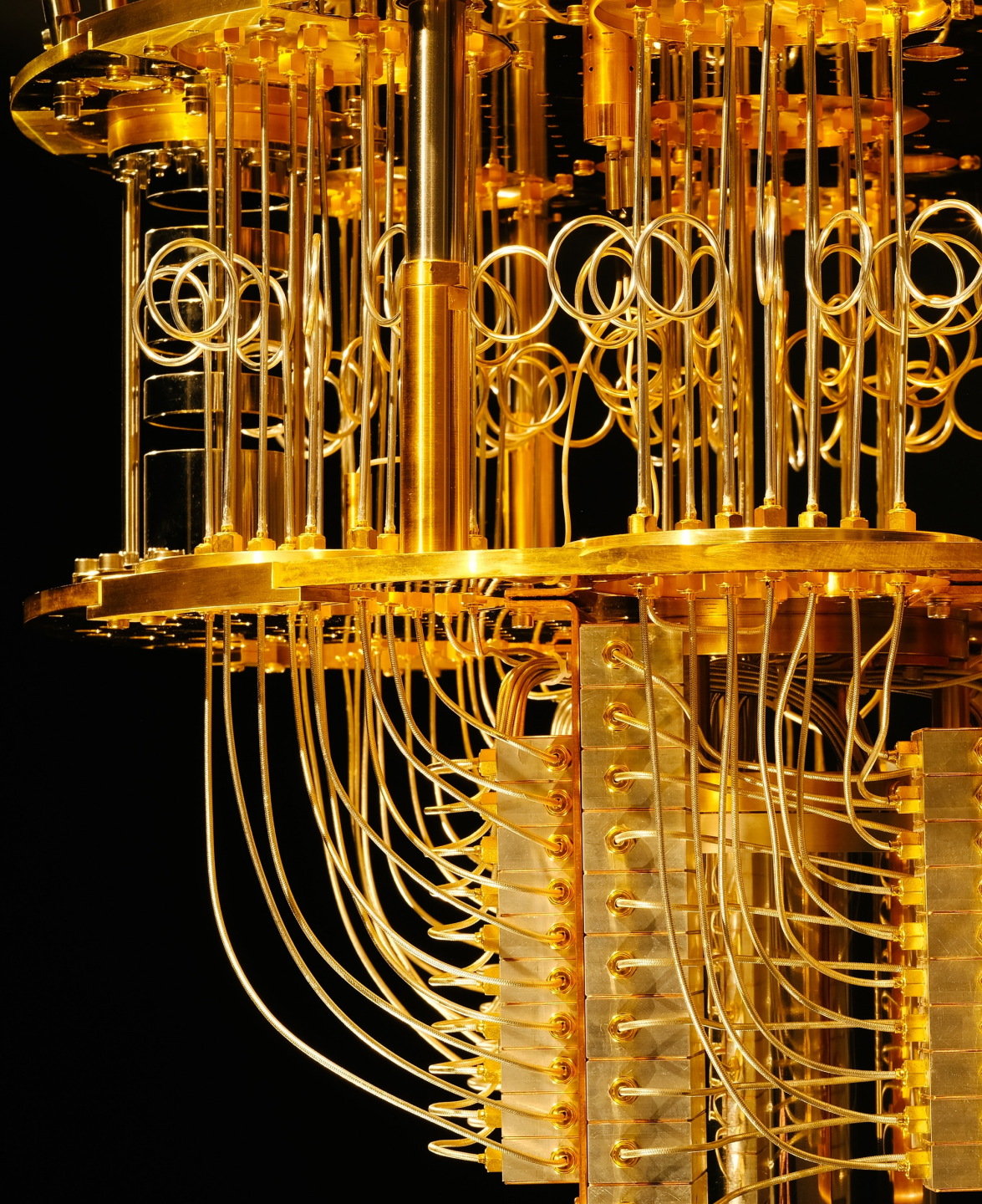
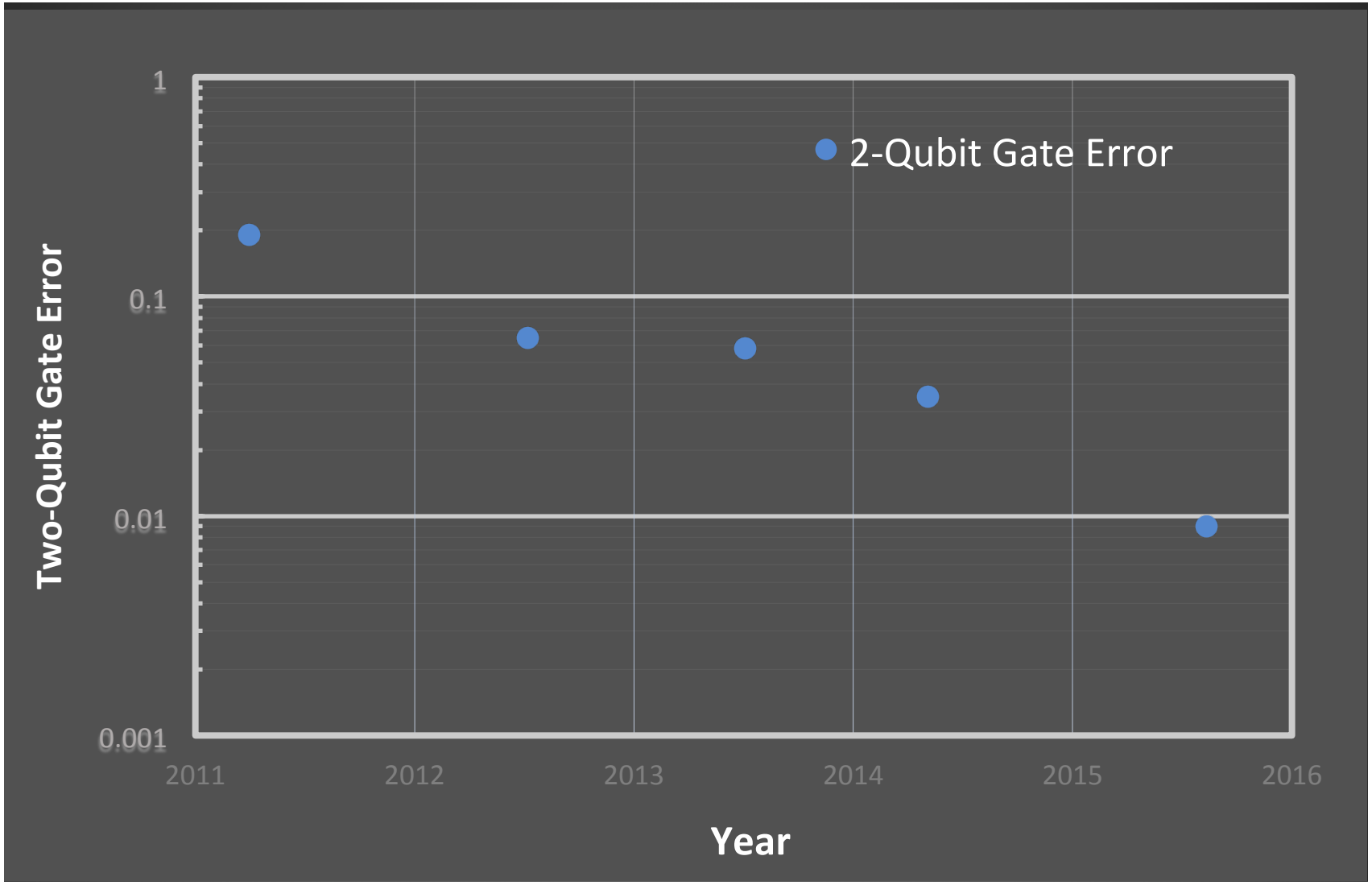
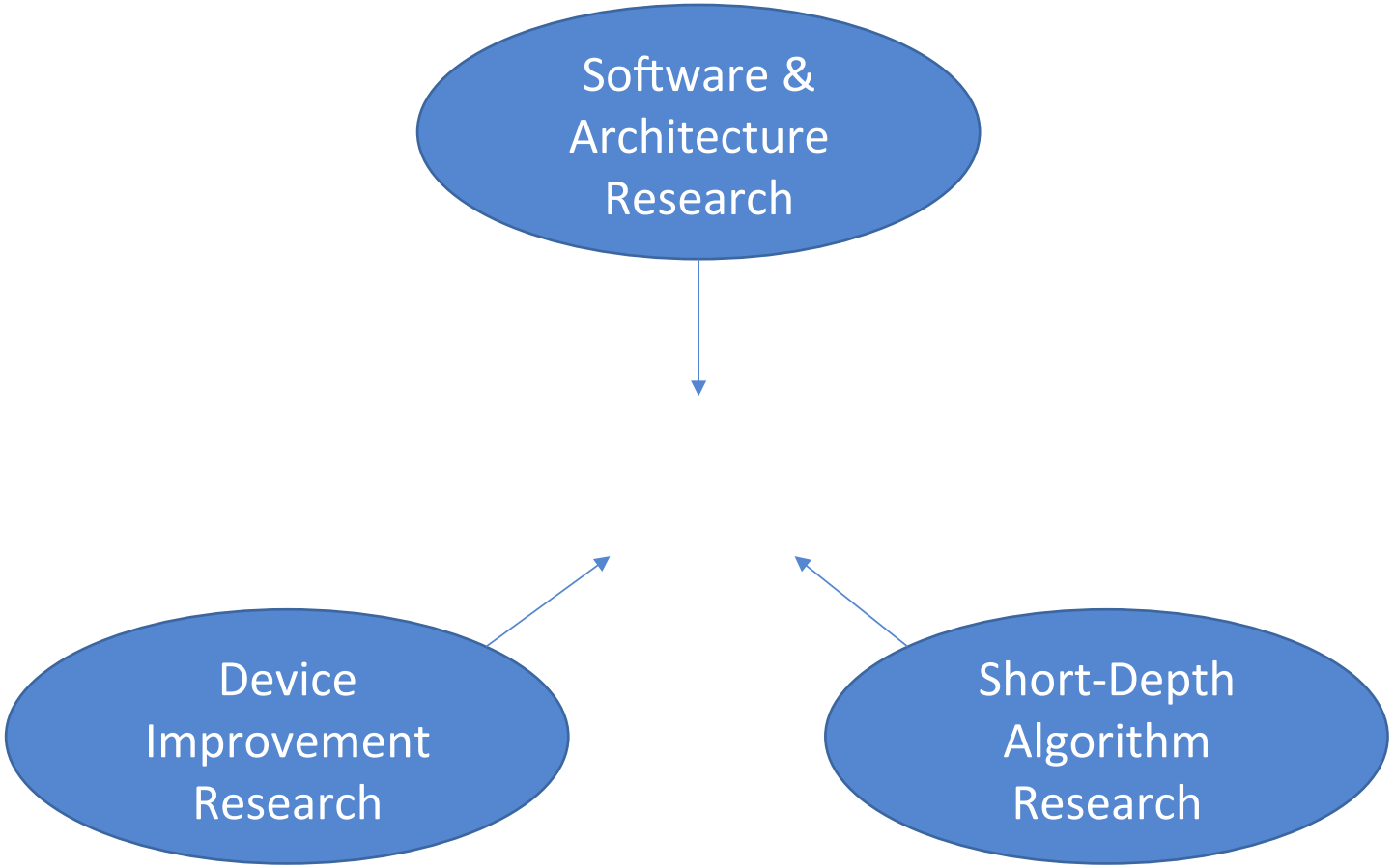


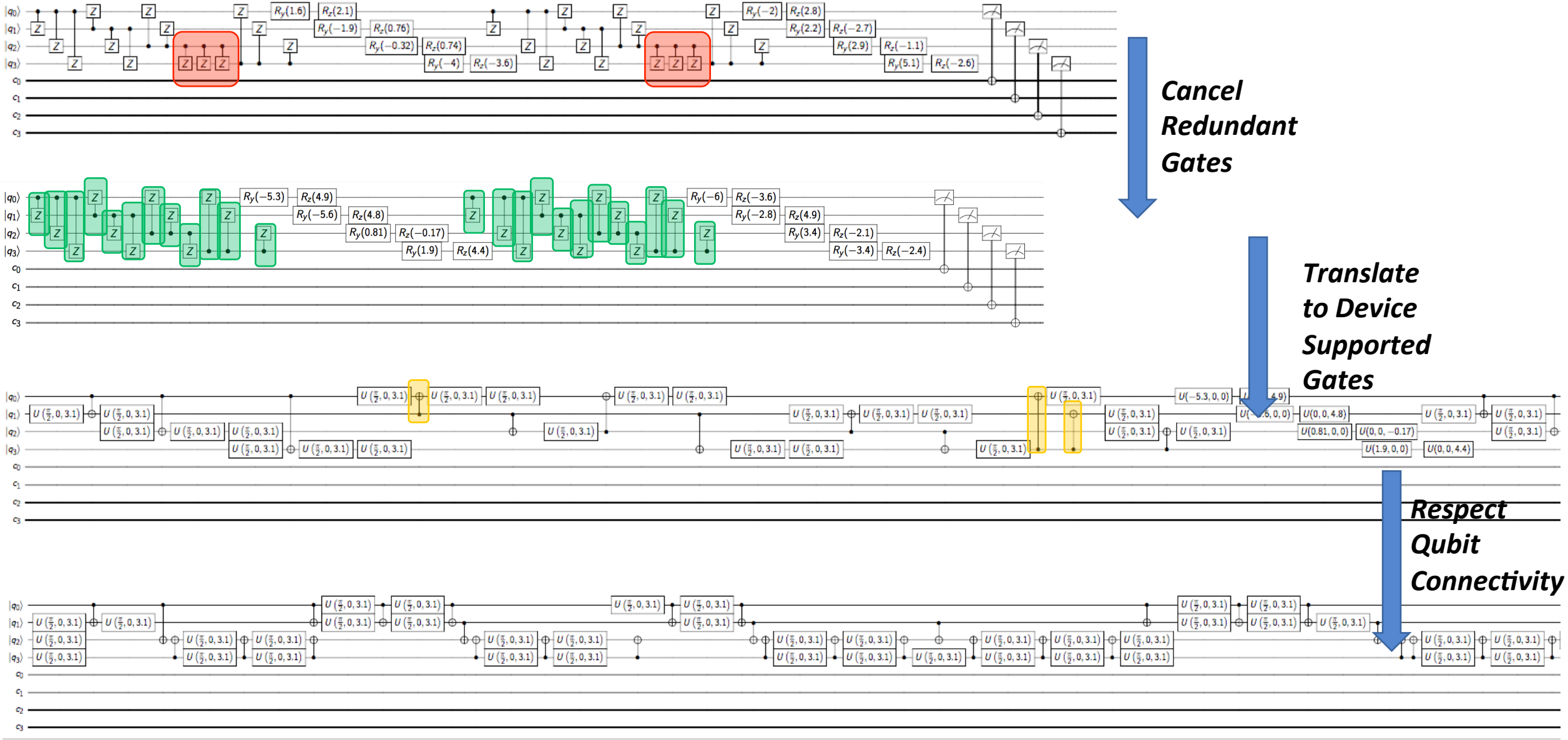
Progress in Superconducting Qubits



Computer Science's Role?



An Example Use of a Toolchain



Existing Toolchains

Quipper

Liquid/Q#

XACC

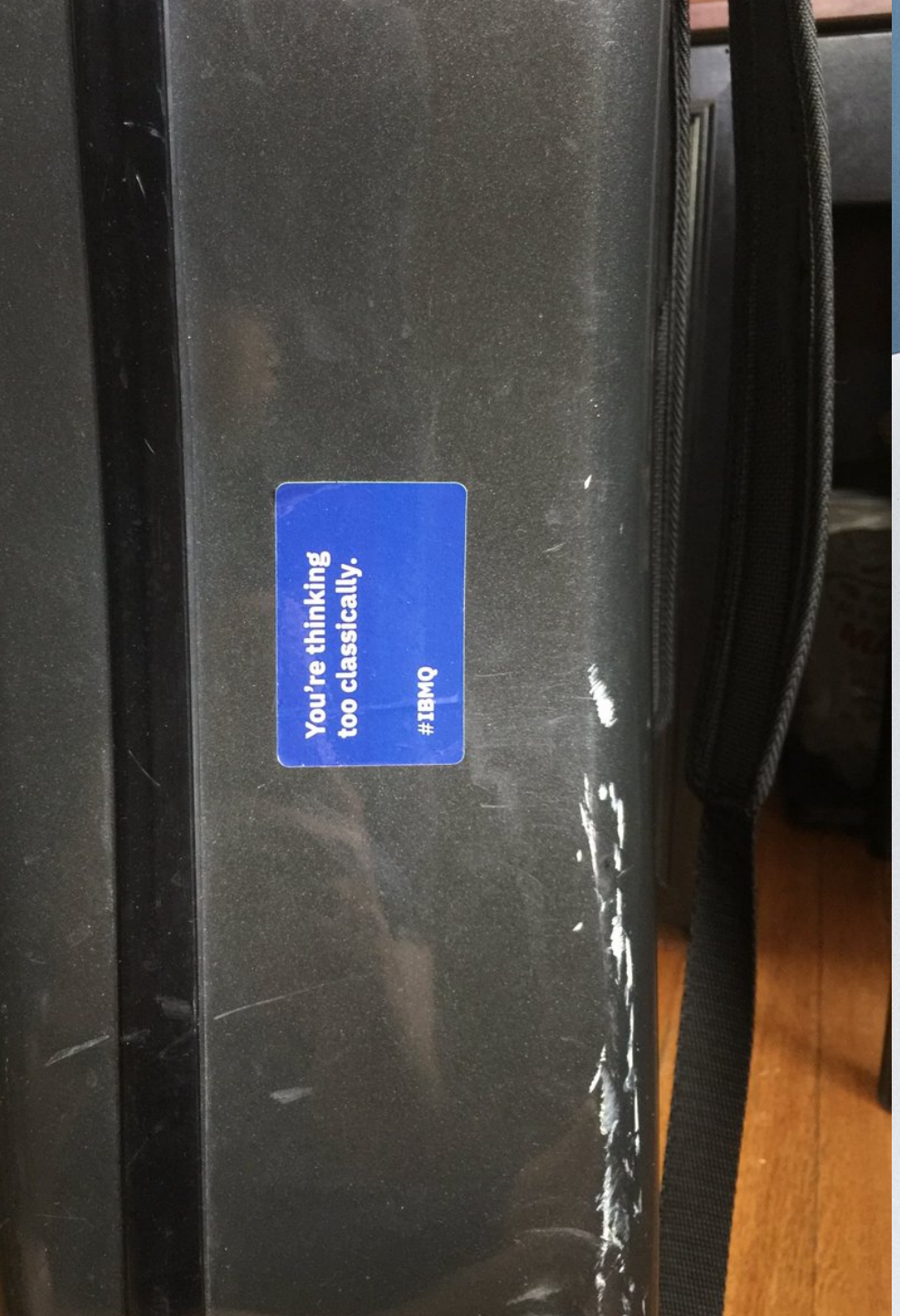
Project Q

Scaffold

Strawberry Fields

Forest

QISKit


You're thinking
too classically.
#IBMQ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#IBMQ

Major Focus Areas for Quantum Toolchains

1. Errors

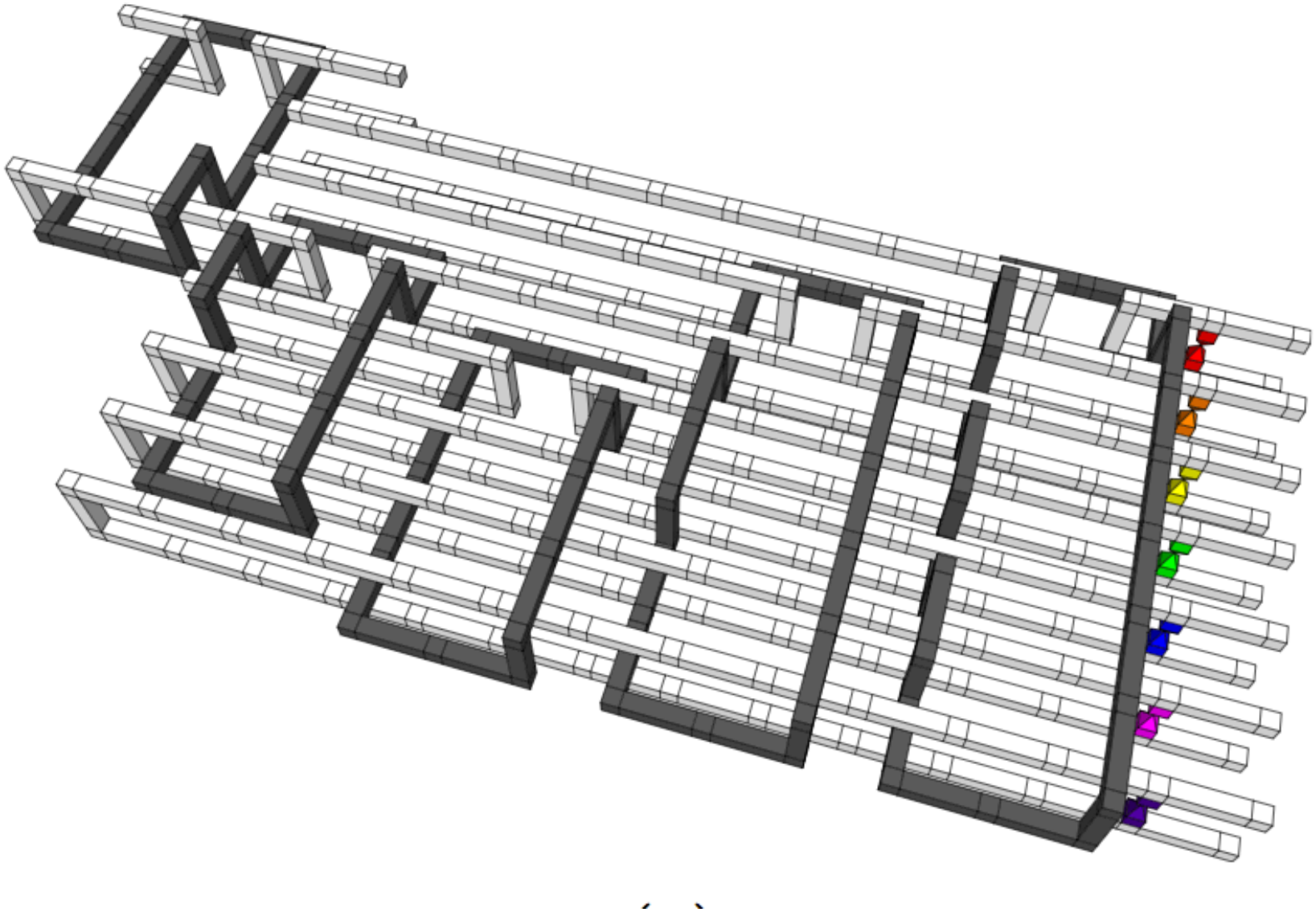
Long term:

- Quantum Error Correction to detect/correct general errors (so expensive that we will basically build an error correcting machine, and computation will be a byproduct)

Near term:

- Heavy circuit optimization to prevent error accumulation
- Error mitigation techniques

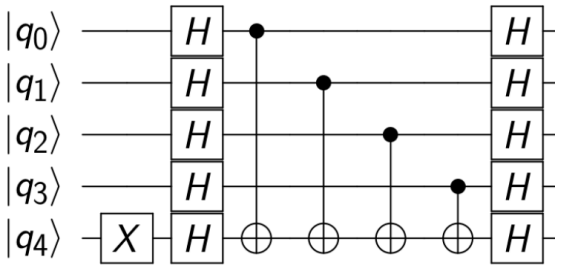
Compiling for Future Machines

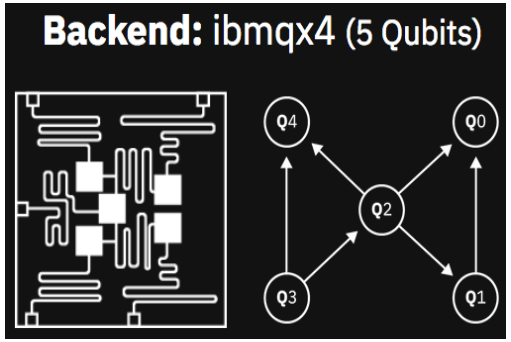


(ref) Paler, Devitt, 2017

Compiling for Near Term Machines

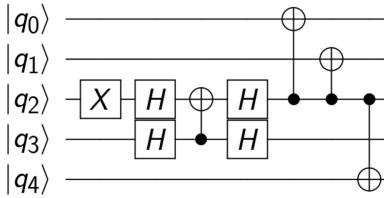
Programmed Circuit

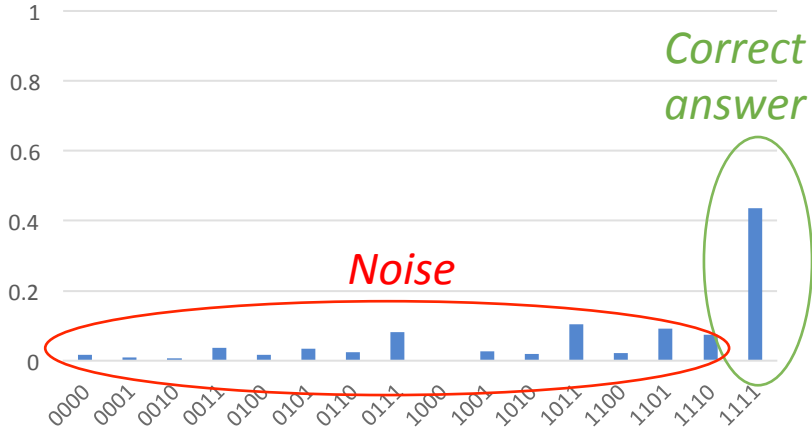




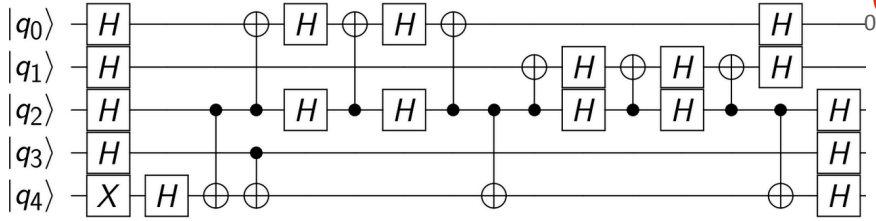
Device

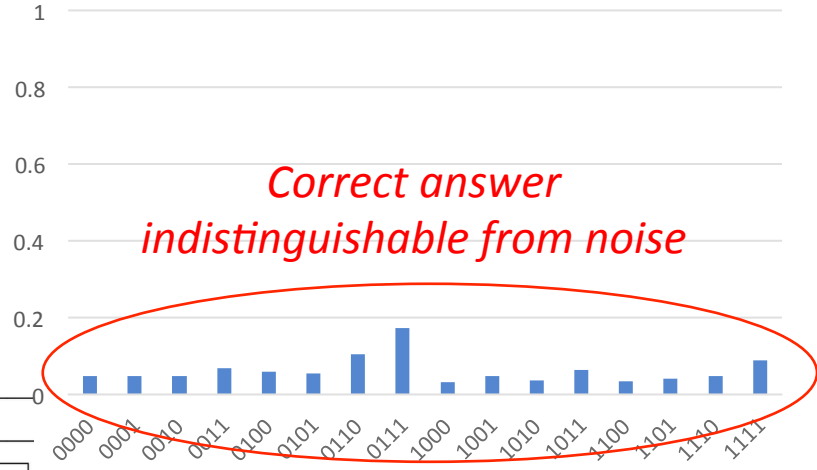
Good Compiled Circuit #1





Bad Compiled Circuit #2

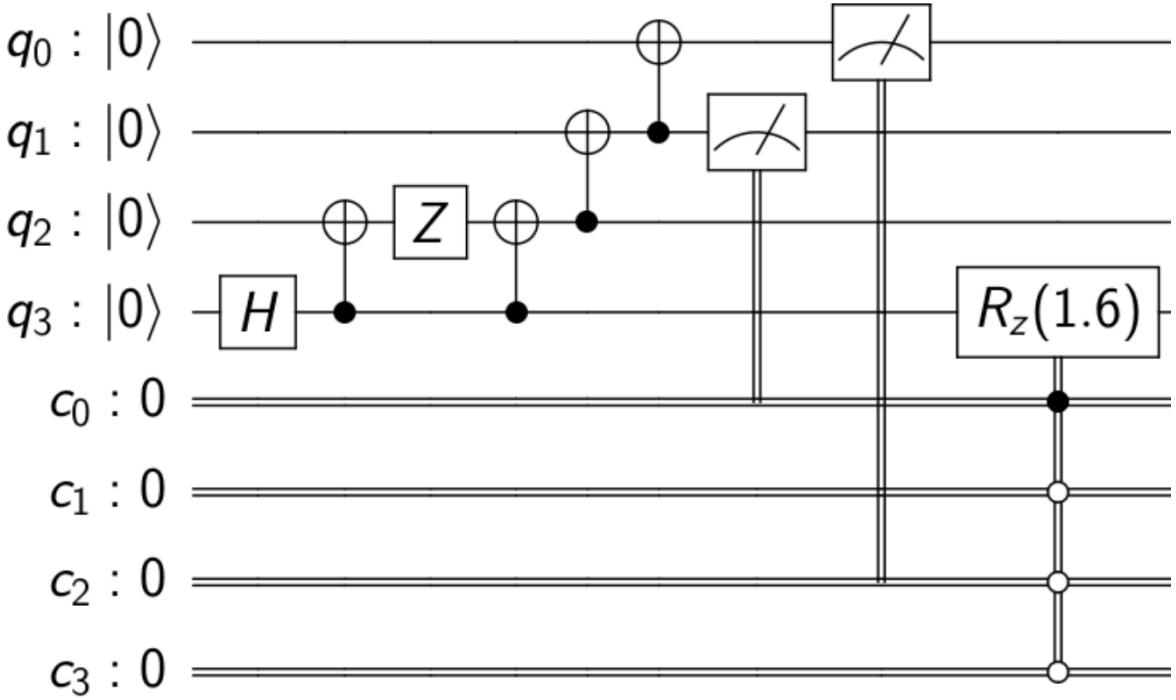




Major Focus Areas for Quantum Toolchains

2. Extreme Latency Sensitivity
Limited coherence:
limits measure + fast feedback

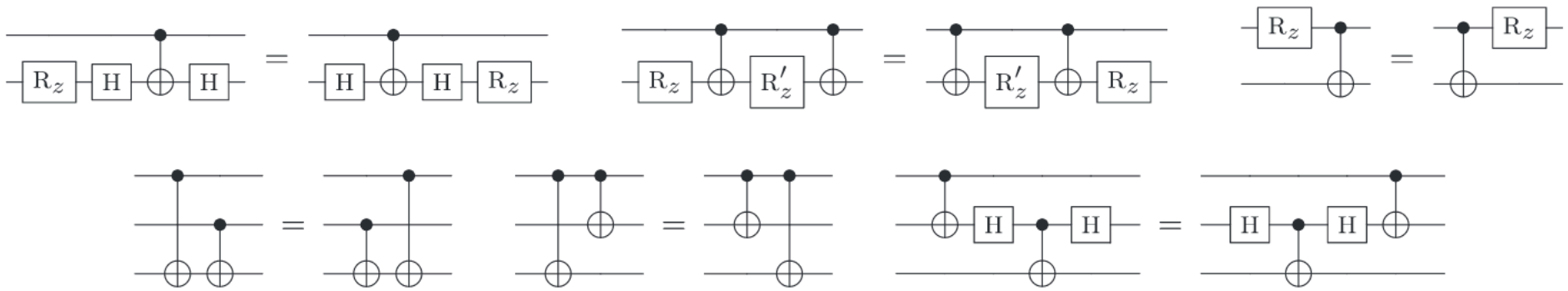
Compilers need to know something about the physical controller layout.



Major Focus Areas for Quantum Toolchains

3. Circuit Synthesis, Optimization, Scheduling

- Automatic synthesis of reversible circuits
- Asymptotically efficient, reduce constant factors
- Gate identity libraries
- Parallelism is affected by gate commutation relations



ref: Nam, Ross, Su, Childs, Maslov

Major Focus Areas for Quantum Toolchains

4. Adaptive Compilation

- Qubit/gate characteristics widely vary over time. Adapt.

	Q0	Q1	Q2	Q3	Q4
Frequency (GHz)	5.24	5.31	5.35	5.41	5.19
T1 (μs)	51.20	54.00	46.80	39.50	52.50
T2 (μs)	14.00	62.50	68.40	18.10	28.20
Gate error (10^{-3})	0.94	2.92	1.46	3.95	1.20
Readout error (10^{-2})	5.00	17.00	6.60	12.70	7.40
MultiQubit gate error (10^{-2})		**CX1_0**	**CX2_0**	**CX3_2**	**CX4_2**
		2.46	3.01	10.14	5.56
			CX2_1	**CX3_4**	
			3.08	8.75	

Major Focus Areas for Quantum Toolchains

5. Limited Power Budgets

Heat dissipation at cryogenic tempratures is a challenge.